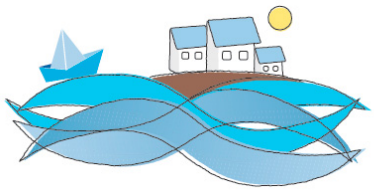
MEDAMI 2016 - IV Mediterranean Thematic Workshop in Advanced Molecular Imaging



Mediterranean
Thematic Workshops
in Advanced Molecular Imaging

Report of Contributions

https://indico.cern.ch/e/446975

Contribution ID: **1** Type: **Oral**

Precision Surgery with a novel radio-guided surgery

INTRODUCTION: Radio-guided surgery(RGS) is a technique that helps the surgeon to perform a complete lesion resection. Currently, RGS uses γ emitting tracers, to mark the cancerous tissue form the healthy organs, and a γ radiation detection probe. To overcome the limitations due to the high penetration of γ radiation, a novel approach based on β- radiation has been developed(Camillocci, Sci Rep.2014;4:4401), allowing to include cases with high uptake of nearby healthy organs, and to benefit of a low medical team exposure.

MATERIAL AND METHODS: Feasibility studies for meningioma, glioma and NETs were performed assuming administration of 90Y-DOTATOC, utilizing a simulation code based on the biodistribution estimated in 68Ga-DOTATOC-PET scans (Collamati. JNuclMed. 2015;56(1):3-8). Experimental phantoms have been prepared to tune the simulations and finally ex-vivo tests on patient specimens after surgery of meningioma have been performed to validate in clinical setting the features of the probe.

RESULTS: Considering typical tumor uptakes ranging 0.1%-1% of the injected activity, preclinical tests and simulations estimated that about 3MBq/kg administered to the patient is enough to identify in 1s a tumor volume <0.1ml. The exposure of surgeon was estimated to be 0.04μSv/h on the whole body, 0.35μSv/h on the hands. Phantom measurements confirmed the simulations. Ex-vivo tests showed excellent agreement between experimental and expected rates for lesions and healthy tissues: e.g. the bulk tumor showed signals of ˜100cps, 0.2 ml residuals signals of ˜40cps and healthy tissues of less than 1cps. Furthermore, exposure measurements confirmed the low level of radioactivity in the surgical environment (<1μSv/h at 10cm from patient abdomen).

CONCLUSIONS: The proposed RGS using β− radiation has a wide range of applications and succeeded in the first clinical test. The future goal is to study the efficiency of the probe to other radio-tracers to further extend applicability.

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Track Classification: Personalized/Precision medicine: Imaging technologies

Contribution ID: **2** Type: **Oral**

Final design and initial results of the first MINDView brain PET insert prototype

Monday, 2 May 2016 17:20 (20 minutes)

The first prototype of the MINDView project, a brain PET insert MR compatible, is currently being assembled. The scanner is composed of 3 rings of 20 detector blocks each. The detector block includes a monolithic LYSO crystal with 50x50x20 mm3 and a custom 12x12 SiPM array (TSV-type). The system defines an axial and transaxial field of view (FOV) of about 150 mm and 240 mm, respectively. Detector blocks are kept at a stable temperature in the range of 20-25ºC using controlled temperature air cooling.

The X and Y light projections of each detector are measured and from them the planar and depth of interaction (DOI) positions deduced. Here, several methods have been studied namely traditional Center of Gravity (CoG), Rise to Power (RTP), Fitting profiles to the light distribution but also Neuronal Networks. Using the standard approaches (CoG and RTP) it has been possible to characterize the DOI with a resolution of about 5 mm. This makes it possible to reach an average detector spatial resolution (without source finite size corrections) of about 2.6 mm for the whole crystal volume, improving to 1.7 mm, at DOI's values closer to the photosensor. Average energy resolution ranging from 17% at the crystal entrance down to 16% near the photosensor, is obtained.

Parts of the detector ring have been successfully tested for RF shielding and eddy currents. This was carried out by using a Radio frequency (RF) screen structure based on carbon fiber composites with specific thickness and orientations.

Summary

Aim

To show the latest performance of the detector blocks building up the first prototype of the brain PET insert under the MINDView project. The mechanical design, including final detector geometry, cooling system and the RF shielding method is also presented. Currently, the first ring is being built with the aim to run experiments in Spring 2016 at the TUM-MED in Munich inside the Siemens mMR. These results will additionally be reported.

Material and methods

One of the objectives of the MINDView project is to develop a brain PET insert compatible with most of the already installed clinical MR based systems (3 Tesla). The main components of the first prototype have already being defined and the system is currently being commissioned. The PET is composed of 3 rings of 20 detector blocks each. The system has an aperture of about 330 mm to allocate a brain dedicated birdcage RF coil. This defines a geometry with an axial FOV of roughly 150 mm and a transaxial FOV of about 240 mm, see Figure 1.

The detector block uses a rectangular monolithic 50x50x20 mm3 LYSO crystal [1]. Using 20 mm thick crystals without trapezoidal shape [2][3] challenges an accurate 3D determination of the 511 keV photon impact. To solve this, arrays of 12x12 SiPMs have been custom designed at i3M. In contrast to the pitch distance of standard arrays built by the partner organization SensL of 4.2 mm, the MINDView arrays have a slightly larger pitch of 4.36 mm, with an active area of 51x51 mm2 reducing border effects in the crystal, see Figure 2. The SiPM package is TSV (through silicon vias) and they were already successfully tested in magnetic field environments [1].

SiPM arrays are readout through 40 cm long flexible PCBs avoiding connectors (typically containing Nickel) in the useable PET-MR FOV region. Each row and column of the SiPM array is digitized.

Characterizing the X and Y projections of the light distribution allow us to accurately determine the planar and depth of interaction (DOI) photon impact position [4]. The DOI is obtained through fits to the measured light distributions [5] or estimated by calculating the ratio of the energy to the maximum SiPM row or column [1][4]. The preferred crystal surface treatment is all faces black painted except the one in contact to the photosensors array.

A new data acquisition system has been developed, including an ADC board allocating up to 66 channels with 12 bit precision each. This permits to fed 2 detector modules (12+12 channels each) to every ADC board. The photon impact coordinates XY and DOI are calculated in the ADCs using FPGA processing and then are transfered to the workstation using 10 GB Ethernet [5]. Currently, planar coordinates are obtained using Rise To the Power (RTP) calculation with powers 1 (Center of Gravity) or 2 [4].

Towards simultaneous PET-MR imaging both PET and MR systems should not affect or be affected by the other imaging modality. To shield the PET electronics from the Radiofrequency (RF) field without generating eddy currents, we surrounded the PET by a Carbon Fiber (CF) structure, see Figure 1. The CF screens are made by three unidirectional CF layers of 200 um each. The CF layers are always at 90º one to each other. Two sets of CF orientations were tests. The first had the exterior CF layers aligned to the axial axis of the PET and MR. The second had the exterior CF layers at 45ºC, middle layer at -45ºC.

Results

Using the black painted LYSO block, we obtained a DOI resolution ranging from 3.5 to 6.5 mm FWHM, at the crystal center and at the crystal border, respectively. This allows us to efficiently separate photon impacts in at least four DOI regions. The DOI has been characterized for 3 main XY planar regions (see Figure 4) as a consequence of the light truncation, namely center, corners and laterals. As depicted in Figure 3 for a centered ROI, the distribution of light widths follows the exponential attenuation and the impacts can be accurately assigned to the proper crystal DOI (left). On the right side, we depicted the estimated DOI resolution FWHM for the three XY planar regions of interest in the crystal volume.

We irradiated the crystal block with 9x9 Tungsten collimated 22Na sources. The detector spatial resolution was evaluated at four DOI layers. Region 1 and 2, 20-15.5 mm (photosensor=0 mm) and 15.4-11 mm, respectively, showed a slight image compression. However, regions 3 and 4, 10.9-6.4 mm and 6.3-2.1 mm, respectively, showed an almost linear dependence of the measured and real coordinates. A detector spatial resolution FWHM at the crystal center, without correction for the 1 mm source size (collimator diameter 1.2 mm), of 2.6 mm, 2.4 mm, 2.0 mm and 1.7 mm (± 0.3 mm) was determined for DOI layers 1, 2, 3 and 4, respectively. An energy resolution for a centered ROI (15x15 mm2), was determined to be 17%, 16.7%, 16.7% and 16.1%, for DOI regions 1, 2, 3 and 4, respectively. Figure 4 depicts the flood maps for the 9x9 sources as a function of the DOI region.

Concerning the RF field shielding, tests were carried out using a network analyzer. The RF shielding based of CF tubes with orientations of the exterior layers aligned to the axial MR axis showed to be sufficient for the use in PET/MR systems. When EPIs (Echo Planar Imaging) have been acquired, only small ghosting effects were observed. The appearance of eddy currents has also been inspected by PRESS (Position Resolve Spectroscopy) tests.

Discussion and conclusion

This work summarizes the final design of the first prototype of the MINDView project composed of 3 rings of 20 detector blocks each (5x5 cm2) with rectangular monolithic LYSO crystals of 20 mm thickness.
Average DOI resolution nearing 5 mm is reached when the crystal is black painted. In this configuration, an average detector spatial resolution FWHM well below 2.6 mm (σ=0.3 mm) for the whole crystal volume (50x50x20 mm3) is obtained. This improves to 1.7 mm (σ=0.2 mm) close to the photosensor detector, without correction for the 1 mm source size.

Currently, the first ring is being assembled and initial tests inside the mMR PET-MR system at the TUM-MED are planned for Spring 2016. To avoid noise to the PET electronics, a novel RF

shielding based on carbon fiber structures has been developed and already successfully tested, also mitigating eddy currents.

References

[1] A.J. Gonzalez, et al., IEEE Medical Imaging Conference M11-81-1374, Seattle, USA, 2014.

[2] L. Moliner, et al., Medical Physics 39, 5393, 2012.

[3] A.J. Gonzalez, et al., Transaction on Nuclear Science, in press, DOI: 10.1109/TNS.2016.2522179, 2016.

[4] R. Pani, et al., Journal of Instrumentation 10, C06006, 2015.

[5] P. Conde, et al., IEEE Medical Imaging Conference M11-9-1422, Seattle, USA, 2014.

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Session Classification: Brain (including open MINDVIEW session)

Contribution ID: **3** Type: **Oral**

PET/MR as translational tool in cardiology

Tuesday, 3 May 2016 10:30 (30 minutes)

Multimodality imaging has become an attractive tool of cardiovascular imaging, delineating cardiac structures with high spatial resolution combined with specific metabolic and molecular information provided by tracer techniques. PET/CT offers the opportunity of non-invasive coronary angiography and myocardial perfusion imaging, linking anatomic definition of coronary stenosis with the functional consequences of reduced regional myocardial perfusion reserve. In addition, marker of perfusion and viability can be combined to delineate not only perfusion but also the metabolic activity as a biomarker for tissue viability in patients with advanced left ventricular dysfunction. More recently, new specific tracers have emerged to visualize autonomic innervation as a prognostic marker in patients with heart failure as well as to identify inflammatory changes occurring in the vascular tree. Especially, the use of F-18 fluoride has gained acceptance as a specific marker of early plaque development. The increasing number of molecular tracers targeting specific biological processes will help to promote multimodal imaging as an important translational tool not only to describe early changes occurring in cardiovascular disease but also to monitor therapeutic interventions.

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Session Classification: Dedicated & Hybrid imaging

Contribution ID: **4** Type: **Oral**

Low dose small animal 3γ imaging with the XEMIS2 liquid xenon Compton telescope

Tuesday, 3 May 2016 16:10 (20 minutes)

The goal of the innovative 3γ medical imaging modality is to reduce significantly the dose administered to the patient. Based both on new detection technologies involving liquid xenon and on a specific 3γ emitter radionuclide, ^{44}Sc produced by the ARRONAX cyclotron, the 3γ imaging has a very high potential from small animal imaging acceptances to whole body clinical applications. Following a conclusive R&D program around the XEMIS1 prototype (XEnon Medical Imaging System), a second phase dedicated to small animal imaging, XEMIS2, is now under qualification. This new prototype is a monolithic liquid xenon cylindrical camera, which totally surrounds the small animal thanks to its 24 cm axial field of view.
XEMIS2 hold around 200kg of liquid xenon. The active volume of the detector is covered by Hamamatsu PMTs to detect VUV scintillation photons generated by liquid xenon, and the ionization signals are collected by two end plates with segmented anodes and a total number of 20000 pixels. XEMIS2 has been designed for preclinical applications in hospital centers; it includes a very compact liquid xenon cryogenics workshop and a fast DAQ with new electronics.
In parallel, a full simulation of the camera has been performed and a complete reconstruction algorithm has been developed to triangulate the position of the source from the interactions of the 3 γ. Absolute sensitivity of 7% should be reached for a small animal. An image of the whole field of view is obtained using an ML-EM iterative deconvolution algorithm. Detectability and contrast are very promising with 20 kBq of injected activity in the phantom with only 20 mn of exposure time. This is typically 100 times less activity than that used for conventional PET small animal imaging.
The XEMIS2 camera should be completely qualified this year. From 2017, it would be operational and available for preclinical research at the CIMA center of the Nantes Hospital.

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Session Classification: New Technologies

Contribution ID: **5** Type: **Oral**

Quantification of CaLIPSO PET scanner potential for personalized medicine in oncology and neurology

Tuesday, 3 May 2016 16:50 (20 minutes)

Positron emission tomography (PET) is a powerful molecular imaging method that plays an increasing role in personalized medicine. Brain PET is especially useful for investigating the molecular dysfunctions associated with neurodegenerative diseases (ND). It contributes to the diagnosis of ND and to the monitoring of the functional changes over the course of ND. For such studies it is important to have a PET scanner with high detection efficiency, high spatial resolution and high time resolution simultaneously. The aim of the CaLIPSO project (French acronym for Liquid Ionization Calorimeter, Scintillation Position Organometallic) is to fulfill these requirements. We aim to develop the proof of concept for a new PET detector dedicated to human brain imaging. The objective is to achieve a spatial resolution of about 1 mm3 with an efficiency of about 7% similar to that of conventional PET scanner or HRRT scanner. Moreover, an excellent time resolution (˜150 ps FWHM) is also needed for time of flight measurements (TOF). The CaLIPSO scanner is thus intended to be the first scanner for brain studies including TOF. A high image resolution, about 1 mm, and contrast are targeted, which might be a definite assess for neurological studies. Such performances will also be helpful in personalized neuro-oncology. It makes possible to extensively assess the tumor heterogeneity and tune the therapeutic approach accordingly.

The high CaLIPSO PET scanner performance is possible thanks to the double detection of the incident 511 keV-gamma though photoelectron conversion in trimethyl bismuth, an innovative liquid filling a PET cell. Created photoelectron emits Cherenkov photons and ionizes the medium. Both light and free charges are collected and used for the reconstruction of the time, 3D position of the interaction and for the estimation of the deposited energy.

We have developed a GATE simulation model to design a full PET scanner and to compare our simulation results with the performance of other high resolution PET systems such as the HRRT by Siemens that is currently the brain PET scanner with the performance of reference. The geometry of the CaLIPSO scanner is cubical with ˜30 cm inner diameter. Such geometry is non-standard and possible in case of the CaLIPSO prototype thanks to the reconstruction of the depth of interaction point in the detection module with high precision. The comparison of the main parameters (Noise Equivalent Count Rate and image resolution) for CaLIPSO and HRRT shows the higher performance of foreseen CaLIPSO scanner. For example, the image resolution is about 1.2 mm for CaLIPSO, but 2.2-2.5 mm for HRRT. We also started development of the reconstruction algorithms on simulated brain images. The first reconstructed images of a brain with different tracers distributions demonstrated the ability of the CaLIPSO PET scanner to be a key tool to study neurodegenerative and brain diseases.

The CaLIPSO is promising ongoing project for a PET scanner with a high potential for brain imaging.

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Session Classification: New Technologies

Contribution ID: **6** Type: **Oral**

Efficient, fast 511-keV γ detection through Cherenkov radiation and ionization: the CaLIPSO detector for PET imaging.

Tuesday, 3 May 2016 16:30 (20 minutes)

Xavier Mancardi1, Olga Kochebina1,2, Emilie Ramos1, Patrice Verrecchia1, Gérard Tauzin1, Viatcheslav Sharyy1, Clotilde Canot1 and Dominique Yvon1,*
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Positron emission tomography (PET) is a powerful molecular imaging method that plays an increasing role in personalized medicine. Brain PET is especially useful for investigating the molecular dysfunctions associated with neurodegenerative diseases (ND). It contributes to the diagnosis of ND and to the monitoring of the functional changes over the course of ND. For such studies it is important to have a PET scanner with high detection efficiency, high spatial resolution and high time resolution simultaneously. The aim of the CaLIPSO project (French acronym for Liquid Ionization Calorimeter, Scintillation Position Organometallic) is to fulfill these requirements.
Our short term goal is to develop a new efficient and accurate gamma detector optimized for brain PET imaging. We target to achieve an imaging accuracy of 1 mm (FWHM). In order to use this detector in a PET-Scan device, we need to increase at the same time the "imaging efficiency"by a factor 10 compared to HRRT so as to preserve the signal to noise contrast in images*. Excellent time resolution is welcomed as Time Of Flight information leads to very significant gain in image contrast in the image reconstruction.
The 511-keV photon converts in liquid TMBi, by producing a relativistic "primary"electron.
This electron propagates and induces Cherenkov light production. The same primary electron ionizes the detection medium. Both signals will be measured by the CaLIPSO detector.
Achieving an efficient detection and an accurate timing on the low-flux Cherenkov light is a challenge common to all Cherenkov PET detector projects. In this paper, we will present our tests results on the CaLIPSO optical detector prototype. We will show that we achieved efficient detection of the Cherenkov light produced by the 511-keV photo-electron conversion in our detector. In addition, we will present the potential of the technology, for high-resolution timing and thus Time Of Flight imaging using our detailed Monté-Carlo simulation.
Building the prototype of a densely pixelated ionization chamber using liquid TMBi, ie the CaLIPSO ionization detector, is now the priority of the group. The main remaining issue is our ability to reliably purify the liquid from electronegative impurities that trap drifting free electrons. We are now testing several purifying technologies (molecular sieves and getters) in parallel. We will present our latest results.

- See Olga Kochebina abstract.

Summary

For convenience, the summary is enclosed in the pdf attached file.

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Session Classification: New Technologies

Contribution ID: **7** Type: **Oral**

Past, Present and Future of Positron Emission Tomography

Tuesday, 3 May 2016 08:30 (30 minutes)

Positron Emission Tomography (PET) is a well established imaging technique for in vivo molecular imaging. After a brief history of PET, the physical principles and the main performance parameters are presented. The evolution of the technology that has brought PET from a bench experiment to a clinical indispensable instrument is fully illustrated. In particular, the present limitations and the expected future performance of the PET tomographs are discussed, both as for the hardware and software aspects. The status of art of clinical, preclinical and hybrid scanners (i.e., PET/CT and PET/MR) is shown. Finally the recent and future technological developments are presented. As a specific example, the current applications of PET to range monitoring in particle therapy are discussed.

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Session Classification: Overview Molecular Imaging Technologies

Contribution ID: **8** Type: **Oral**

The TRIMAGE project: A Trimodality brain scanner for early diagnosis of schizophrenia

Monday, 2 May 2016 16:40 (20 minutes)

TRIMAGE is an interdisciplinary FP7-funded European collaboration aimed at developing a cost-effective dedicated brain PET/MR/EEG brain scanner for early diagnosis of schizophrenia. The brain activity measured with fMRI, combined with the highly sensitive molecular information provided by PET, and the highly sensitive temporal information from EEG converge into a new imaging tool for diagnosing, monitoring and follow-up of mental disorders.

As for the clinical aspects we are interested in the multimodal assessment of response inhibition. The Loudness Dependence of Auditory Evoked Potential (LDAEP) is a suitable biomarker of inhibitory action in signal processing. Patients with schizophrenia may exhibit alterations in the responsiveness to sensory stimuli (i.e., stronger LDAEP values). We aim to further elucidate the relationship between multimodal neuroimaging methods and dimensions of symptoms, observable behavior, personality traits and general psychopathological dysfunction.
A sample of 20 healthy controls and 20 patients with manifest schizophrenia will be initially examined with the LDAEP paradigm in a trimodal approach with the available 3T MR-PET scanners in Munich and Jülich. In Munich, FDOPA will be used and static and dynamic analyses will be compared with fMRI data; in Jülich, PET measurements with the radiotracer [11C]-flumazenil will assess the binding potentials of GABA-A receptors. MRS will provide data about GABA concentrations. At the end of this first clinical evaluation a set of suitable biomarkers will be proposed.

The MR magnet will be cryogen-free with main B0 field of 1.5 T. Magnet warm bore is 720 mm with a field uniformity of ±1 ppm and a field stability <0.1 ppm/hour. The 5 gauss line fringe field will be < 2.8 m axially. The gradient coil has a maximum strength of 42 mT/m (X,Y) and 41.2 mT/m (Z) with a slew rate of 123 T/m/s (X,Y) and 127 T/m/s (Z). The typical MR sequences to be uses will be: UTE (for attenuation correction), MPRAGE and FLAIR (for anatomical information) EPIK (for High resolution functional information)

The PET component is designed to provide performance beyond the state of the art for clinical PET systems with an expected spatial resolution of about 2 mm FWHM. The PET field-of-view will be 162 mm axially and 240 mm diameter with an open bore of 308 mm diameter. The PET detector comprises 216 tiles featuring two layers of LYSO crystal matrices (3.4 mm pitch) with half pitch staggering. SiPM matrices will be used as photodetectors, and a DAQ based on the TRIROC ASIC and FPGAs will take data in list mode.

A state-of-the-art MR-compatible EEG cap with 32 channels will be simultaneously used with the PET/MR scan.

The results of the first clinical results, of the simulations and of the experimental tests will be presented

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Session Classification: Brain (including open MINDVIEW session)

Contribution ID: **9** Type: **Oral**

Dose Profiler: development of a device for online beam range monitoring in charged particle therapy treatments

Tuesday, 3 May 2016 14:20 (20 minutes)

In Charged Particle Therapy (CPT) beams of protons or carbon ions are used for treatment of tumors. The higher precision in dose deposition achieved by charged ions with respect to X-Rays, used in conventional radiotherapy, allows to reduce the undesired dose released to the healthy tissues surrounding the cancer region. This makes the CPT particularly suitable for deep situated tumors close to organs at risk. A strong control on the ion beam delivery is required in order to reduce the impact of patient mispositioning or anatomical changes, that cause an over-dosage to healthy tissues avoiding to fully profit from the CPT precision: the development of an on-line range monitor represents a crucial issue for the quality assurance of the CPT treatments.

The strong interaction between the beam particles and the patient tissues produces secondary particles, whose emission spatial coordinate is correlated to the released dose distribution. Such particles can be exploited for beam range monitoring purpose as mentioned in [1],[2],[3]. The after-treatment measurement with PET-scanners of the β^+ emitters activity is a technique already tested in clinical environment, but suffer for the metabolic washout. Prompt photons measurement, thanks to their high production yield, seems to be a promising method. Finally the detection at large angle with respect to the beam direction of secondary charged particles, easy to backtrack, could represent a good approach especially for carbon ions beams treatments in which the production yield is higher compared to protons beams.

We propose a detector, *Dose Profiler* (DP), designed for the measurement of the secondary charged particles with the aim of performing on-line beam range monitoring. The device is currently under development in the frame of the INSIDE collaborations (Innovative Solutions for In-beam Dosimetry in hadrontherapy) and is going to be tested at CNAO (Centro Nazionale di Adroterapia Oncologica) within 2016. The DP is composed by a tracker, that provides the information of the particles position for the back-tracking, and by a calorimeter, that performs the measurement of the energy. The tracker is built out by six layers (20×20 cm^2) of square scintillating fibers (500×500 μm^2) coupled to Silicon Photo-Multipliers (SiPMs), the calorimeter by a set of 16 pixellated LFS crystals ($5 \times 5 \times 2$cm^3) coupled to multi-anode PMTs; in order to increase the efficiency of the track reconstruction process a plastic scintillator absorber is inserted between the two devices to stop the back-scattered electrons. The read-out electronics, composed of more than 4000 channels, is performed by ASICs specifically designed for SiPM read-out applications. The data acquisition and the trigger system are realized by a set of FPGAs.

In this contribution the design and the expected performances of the DP, evaluated by Monte Carlo simulations based on experimental data, will be presented.

References:

[1] L.Piersanti et al., PMB, 59 (2014), 1857

[2] I.Mattei et al., JINST 10 (2015), P010034

[3] K.Parodi et al., PMB, 47 (2002), 21

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Session Classification: Hadrontherapy

Contribution ID: **10** Type: **Oral**

SPM-guided PET analysis for the evaluation of non-lesional epilepsy.

Monday, 2 May 2016 17:00 (20 minutes)

Multi-modal preoperative evaluation with advanced structural, functional, and metabolic neuroimaging techniques is essential in the pre-surgical evaluation of refractory epilepsy for the delineation of the epileptogenic zone to be resected. In latter years, PET has gained a leading role in this evaluation since it has demonstrated to be simpler and more sensitive than ictal SPECT in certain situations. Furthermore, the availability of co-registered PET/MRI images has improved the interpretation of images of both modalities and enabled a more straightforward use of PET information on MRI-guided surgery. In this regard, MRI findings have demonstrated to be extremely useful for assisting PET analysis, since the location of anatomic anomalies related with epilepsy can focus the PET analysis on a reduced area, making possible to detect small focal hypometabolisms that might be dismissed on a simple visual inspection. Nevertheless, 35% of epilepsy patients show no lesions on the MRI, which are related with an earlier stage of the disease, and resective epilepsy surgery in non-lesional epilepsy is commonly associated with less favourable outcome. For these patients, PET is of particular importance, but its performance is reduced due to the lack of the aforementioned MRI guiding. In this context, the use of PET quantification techniques, such as Atlas-based Asymmetry Indices (AI) and especially Statistical Parametric Mapping (SPM) has improved the localization of the epileptogenic focus. In particular, SPM has potential for being a suitable substitute of MRI guiding the PET analysis when no anatomical lesions are found. On this work we evaluated the correlation between anatomical findings and SPM results on 24 patients with different types of epilepsy-related MRI lesions (12 cortical focal dysplasia, 12 mesial temporal sclerosis) and 5 patients with non-lesional MRI. PET images were processed with iSFS-RR resolution recovery algorithms and SPM maps were obtained by an unpaired t-test voxel-by-boxel comparison between the patient and the database of 97 healthy patients. Patients were evaluated by using PET, PET/MR and PET/SPM images, trying to reproduce a clinical scenario. On lesional epilepsy patients, SPM provided better sensitivity (91.6%) than PET only images (70.8%), and SPM findings showed high correlation with MRI anatomical findings. When applied to non-lesional epilepsy patients, PET/SPM also offered better sensitivity (80%) than simple PET visual analysis (40%). Thus, the purposed SPM-guided PET visual analysis demonstrated to be more effective than the routine visual inspection, showing potential for improving focus location on non-lesional epilepsy.

Summary

Introduction

Multi-modal preoperative evaluation with advanced structural, functional, and metabolic neuroimaging techniques is essential in the pre-surgical evaluation of refractory epilepsy for the delineation of the epileptogenic zone to be resected (Brázdil et al, Epileptic Disord 2006). In latter years, PET has gained a leading role in this evaluation since it has demonstrated to be simpler than ictal SPECT and more sensitive than MRI in certain scenarios (Ramey et al. Clin Neurol Neurosurg 2013). Furthermore, the availability of co-registered PET/MRI images has improved the interpretation of images of both modalities and enabled a more straightforward use of PET information on MRI-guided surgery (Shin et al, Neurology 2015). In this regard, MRI findings have demonstrated to be extremely useful for assisting PET analysis, since the location of anatomic anomalies related with epilepsy can focus the PET analysis on a reduced area, making possible to detect small fo-

cal hypometabolisms that might be dismissed on a simple visual inspection. Nevertheless, 35% of epilepsy patients show no lesions on the MRI, usually meaning that the lesion is so subtle that the scanner is not sensitive enough to discriminate between the lesion and surrounding healthy brain tissue, which might be related with an earlier stage of the disease (Pardoe et al, Epilepsy Curr 2014). Resective epilepsy surgery in non-lesional epilepsy is commonly associated with less favourable outcome. For these patients, PET is of particular importance, but its performance is reduced due to the lack of the aforementioned MRI support (Hammers et al, Cambridge University Press 2015). On this context, the use of PET quantification techniques, such as Atlas-based Asymmetry Indices (AI) and especially Statistical Parametric Mapping (SPM) has improved the localization of the epileptogenic focus (Kyeong Kim et al, J Nucl Med 2016). In particular, SPM is an objective tool for the analysis of FDG-PET images and a useful complement for visual analysis (Archambaud et al, EJNMMI Res 2013). Due to this, it has potential for being a suitable substitute of MRI for the guidance of the PET analysis when no anatomical lesions are found. This combined with advanced resolution recovery techniques that help to increase PET image contrast and thus detect smaller pathological areas could severely increase PET performance for this particular application (Silva-Rodríguez et al, EJNMMI Physics 2015, Silva-Rodriguez et al, IEEE Trans Nucl Sci 2016, In press). On this work, we are aimed at evaluating the correlation between MRI anatomical findings and SPM results. Afterwards, we applied the evaluated methodology to non-lesional epilepsy patients.

Methods

Patients

This study was performed on 29 patients previously diagnosed and operated by the Refractory Epilepsy Surgery Unit at the University Hospital of Santiago de Compostela in the period 2012-2013. All patients underwent the presurgical evaluation by routine at our centre, which includes FDG-PET, SISCOM SPECT, 3T-MRI, video electro-encephalography and a wide range of neurological and neuropsychological tests. Positive epilepsy diagnosis and focus localization were obtained by evaluating the results coming from the whole group of tests included in our protocol. Patients were categorized between temporal lobe epilepsy (16 patients, 55.2%) and extra-temporal lobe epilepsy (13 patients, 44.8%). Along the temporal epilepsy group, most common MRI finding was hippocampal atrophy due to mesial temporal sclerosis (12 patients, 75.0%) followed by focal cortical dysplasia (2 patients, 12.5%) and non-lesional MRI (2 patients, 12.5%). On the extratemporal epilepsy group, most common MRI finding was focal cortical dysplasia of the frontal lobe (8 patients, 61.5%), followed by focal cortical dysplasia of the occipital lobe (2 patients, 15.4%) and non-lesional MRI (3 patients, 23.1%). Patients were also categorized in lesional (24 patients, 82.7%) and non-lesional (5 patients, 17.3%). A summary of this classification is shown in Table 1.

We also used images from 97 control subjects. These images were obtained from pre-treatment oncologic patients that underwent FDG-PET after signed consent. All of the control subjects were examined for ensuring that there are no signs of a neurologic or psychiatric disease and the obtained images were evaluated by two experienced nuclear medicine physicians and were considered normal. All the images were acquired following the protocols detailed below.

Imaging protocols
3T-MRI: structural imaging was performed with an Achieva 3.0T X-series MR imaging scanner (Philips Healthcare, Best, The Netherlands) using a head coil. The MRI protocol consisted of the acquisition of T1-weighted 3D TFE, FLAIR and T2-weighted sequences. The different sequences were visually evaluated for diagnosis following the protocols of the Refractory Epilepsy Surgery Unit.

FDG-PET: all patients underwent the routine neuroimaging protocol at our institution. Starting 45 min after after intravenous injection of 370 MBq of 18F-FDG, the patients were scanned during 30 min for emission data and 15 min for transmission data, required for attenuation correction. The imaging device was a GE Advance NXi PET scanner (General Electrics Healthcare, Little Chalfont, Buckinghamshire, United Kingdom). Following the default protocols of the GE Advance, scatter, randoms, attenuation and normalization corrections were applied before the reconstruction. PSF modeling and motion correction were not included. The images were reconstructed using 3D

ordered subsets expectation maximization (3D-OSEM), with 4 subsets and 16 iterations. The size of the reconstructed image is 128x128x35, with a voxel size of 2×2×4.25 mm3. No smoothing was applied during or after the reconstruction. Prior to evaluation, PET images were corrected using Iterative Structural-Functional Sinergy Resolution Recovery (iSFS-RR) (Silva-Rodríguez et al, EJNMMI Physics 2015, Silva-Rodriguez et al, IEEE Trans Nucl Sci 2016, In press), an image-based PVC algorithm incorporating anatomical information provided by accurately co-registered and segmented T1-MRI into the PET image, thus enhancing resolution and image contrast.

Image Evaluation

MRI and PET images were co-registered for all patients by using SPM12 software package (Wellcome Trust Centre for Neuroimaging, University College London, United Kingdom). The co-registered PET has the same matrix and pixel size of the MRI image. Co-registered images were normalized to the MNI space using SPM12 via a segmentation routine. SPM voxel-by-voxel comparison was performed by an unpaired t-test between the patient and the database of 97 healthy patients. The results of this comparison were evaluated and only pixels with significant differences ($p<0.05$) were included in the final SPM map (Kyeong Kim et al, J Nucl Med 2016). The matrix obtained from the normalization process was inverted and applied to the SPM map, obtaining co-registered PET/MRI/SPM images on the patient space.
The sensitivity of the purposed PET/SPM methodology was assessed and compared with PET only and PET/MRI co-registered images trying to reproduce a clinical scenario:

Visual assessment of 18F-FDG PET: An experienced nuclear physician assessed the images looking for hypometabolisms compatible with the epileptogenic process. Prior information of the clinical findings from V-EGG and previous neurological tests was given to the physician.

Visual assessment of PET/MRI: An experienced nuclear physician evaluated the PET/MRI images looking for hypometabolisms related with the MRI findings. Aforementioned information, along with the findings report from an experienced radiologist about the MRI images was given to the physician.

Visual assessment of PET/SPM: An experienced nuclear physician assessed the co-registered PET/SPM images looking for hypometabolisms compatible with the epileptogenic process. Prior information of the clinical findings from V-EGG and previous neurological tests was given to the physician.

After the validation, the purposed protocol was applied to non-lesional epilepsy. The sensitivity was compared with PET only images. The final diagnosis based on the complete bunch of tests (MRI, PET, SPECT, V-EGG and neurological and neuropsychological tests) and the clinical outcome of the surgery after a year of follow-up (when possible) were used as gold standards along the experiment.

Results and discussion

Following the image evaluation procedures described in the previous, the sensitivity of a simple PET visual inspection, PET/MRI visual inspection and SPM-guided PET visual inspection were assessed for lesional patients in order to validate the methodology and the correlation of MRI and SPM findings. Figures 1 and 2 show examples of PET/SPM results correlation with MRI findings.

Table 2 shows the results obtained on the 24 positive-MRI patients. PET/MRI was more sensitive that PET alone (100% and 70.8%), in good agreement with previous studies (Yu-Shin Ding, Am J Nucl Med Mol Imaging 2014). SPM provided useful information for re-evaluating PET images in five patients, providing better sensitivity than PET only images (91.6% and 70.8%).

After this validation, the proposed PET/SPM methodology was applied on the 5 negative MRI patients and compared to PET visual analysis. On this group, PET visual analysis located lesions compatible with the epileptic process and in good agreement with V-EGG and neurological tests in 2 patients (40%), while PET/SPM located lesions in 4 patients (80%). In one case, PET/SPM helped the re-evaluation of the patient MRI (see Figure 3), locating a subtle lesion missed on the previous analysis.

Conclusions

SPM demonstrated to be a useful technique providing additional information to the physician in the evaluation of PET images in refractory epilepsy. In lesional patients, SPM findings showed high correlation with MRI anatomical findings, pointing to the fact that SPM could be used for guiding the visual interpretation of PET images. In a limited group of non-lesional epilepsy patients, SPM-guided PET analysis demonstrated to be more effective than the routine visual inspection, showing potential for improving focus location on non-lesional epilepsy.

*This is an on-going project. Work to be presented on MEDAMI 2016 shall include results of a bigger number of patients.

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Session Classification: Brain (including open MINDVIEW session)

Contribution ID: **11** Type: **Oral**

Prostate cancer (PCa) : A Theragnostic evaluation of radioisotope methods

Monday, 2 May 2016 09:00 (20 minutes)

Prostate cancer is the most common malignancy among males of developed countries. Several methods of diagnosis, staging and therapy have been recently studied : among them radio isotope methods are growing and probably are helping personalization and tailoring of treatment.
Tailoring is important in PCa because High and low risk, neuroebdocrine or glandular, hormone therapy responsive or castration resistant (CR) PCa need different cure and also different attention and management. New specific pharmaceuticals as well as therapeutic radio-pharmaceuticals, e.g. the bone seeking alpha emitters such as the relatively new 223RaCl2 , or also some beta emitter agents, can prolong the survival of patients by curing a selected type or site of lesion, e.g. only bone metastases from castration resistant PCa. We need accurate methods of Node (N) / Distant metastases (M) staging and of biological characterization to select the patients and plan the exact therapy.
Non invasive imaging methods include contrast enhanced CT and NMR, diffusion NMR and echography. These imaging methods are of great help in the management of patients with PCa, but echography has a very limited field of view and despite substantial technological progress , CT and NMR are not enough sensitive nor specific to become reliable standard methods to detect nodes and to guide surgical or radiotherapic cure . 18F/11C Choline (FCH) PET is specific but not highly sensitive for Tumor(T) and N staging, the accuracy of FCH for early bone metastases is controversial.
Experiences conducted by our group showed high accuracy of 99mTc Bombesin SPECT for N staging. Our data have recently been confirmed by Mistakis et al, who detected higher uptake of 68Ga MJ9 - a bombesin analogue- than FCH in PCa invaded nodes. Bombesin is a growth factor for androgen dependent and also androgen independent PCa, because it can be secreted also by PCa cells that underwent neuroendocrine shift. Our group was able to demonstrate this circumstance in some- though few- patients by using neuroendocrine seeking and glandular PCa seeking radiopharmaceuticals, such as 111In somatostatin and99mTc bombesin or 18F FCH and 68Ga DOTANOC. In these patients the PCa specific therapy can be integrated.
HPED-CC, a PSMA inhibitor, will also play an important role in a near future as a PCa seeking agent and can be used for diagnostic use when labeled with 68Ga and for therapy when labeled with 177Lu. Early diagnostic trials with 68Ga HPED-CC have recently shown accuracy as high as 95% in detecting relapsed nodes.
Theragnostics means coordinated procedures closely linking diagnostic and therapeutic methods in order to selectively cure the patients, in other words to personalize the patients' management.
As a conclusion we can observe that new radiopharmaceuticals, though at the moment still used for clinical research or very recently become costumer available can give a substantial contribution to personalize/tailor the therapy of PCa patients as theragnostic novel procedures .

Aknowledgements: We are indebted with John Prior and the team of Lausanne CHUF for their help on 68Ga MJ9

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Session Classification: Theranostics

Contribution ID: **12** Type: **Oral**

Tumor heterogeneity characterization in a dedicated breast PET scanner: a feasibility study based on patient and phantom data

Tuesday, 3 May 2016 11:00 (20 minutes)

Introduction: different quantitative parameters estimated from PET and dedicated breast PET images have been proposed in order to describe heterogeneity in tumors, which could have predictive value in breast cancer. However, existing studies have not reached agreement on the predictive performance, in particular for textural features and other heterogeneity-related parameters. We have carried out a standardized study based on comparisons between patient and phantom data in order to reveal for why existing studies have not reached agreement on the predictive value. Our aim was to compare texture features and heterogeneity-related parameters derived from phantom and patient studies measured in a dedicated breast PET scanner (MAMMI PET).

Material and Methods: we have carried out multiple acquisitions of a phantom specifically developed for dedicated breast PET scanners, simulating homogeneous spherical tumors of different sizes with different activities. In addition, 52 patients with invasive breast cancer, prior neoadjuvant chemotherapy, underwent dedicated breast PET study (MAMMI PET) in prone position. Low Gray-Level Run Emphasis (LGRE) and Cumulative SUV-volume histograms (CHAUC) were obtained from phantom and patient data.

Results: CHAUC analysis provided similar values from phantom and patient data. This might be explained by the fact that some factors not necessarily related to the tumor heterogeneity could be significantly affecting the measure of CHAUC. Similar findings were found for LGRE analysis, although some tumors provided LGRE values significantly higher than those obtained from phantoms. In these cases, LGRE could be interpreted as a suitable measure of heterogeneity.

Conclusions: our findings showed that comparisons between patient and phantom data are strictly required before considering studies about the predictive value of the existing textural features and heterogeneity-related parameters.

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Session Classification: Dedicated & Hybrid imaging

Contribution ID: **13** Type: **Oral**

On the role of imaging and data analytics in personalized medicine and population health: a view from Philips

Monday, 2 May 2016 14:00 (30 minutes)

Healthcare around the world is undergoing dramatic transformations, due primarily to the unsustainable rate of growth in the cost of care. In response, the community must provide better care at a lower cost. Personalized medicine plays an integral part in that.

At Philips we are pursuing a strategy in precision health, which links across the entire care continuum from monitoring of healthy living, to early and definitive diagnosis and prevention, to more precisely therapies, to enabling safer transitions from hospital to home-based care, and ultimately to healthy living again.

Imaging plays a central role in rendering definitive diagnosis and therapy selection. As a biomarker, imaging is needed for localization and staging of many diseases; it can be used to effectively segregate cohorts of patients by prognosis, and it can help select therapies, guide interventions, and monitor the effectiveness of therapies. Significantly, imaging –with its tissue-level view of the patient –wields even greater diagnostic power when combined with cellular-level views of the patient through histopathology, as well as the molecular level view through genomics, molecular pathology, and other ‘omics. To succeed, we need to apply analytics techniques to both extract greater information from each modality, as well as to establish causality between modalities operating at different scales.

The potential to extract greater information content is perhaps more pronounced with PET than any other imaging modality. Introduction of the digital PET (dPET) provides us with unprecedented resolution and CNR, which will likely translate into earlier diagnosis and greater quantification of disease. Yet evidence for improved diagnostic and prognostic value derived from these improvements are still accrued at present, especially in the context of oncology, neurology, and cardiac patients. The use of PET during interventional therapies remains largely unexplored at this time. PET can likely also play a greater role in producing dose maps of chemoembolization therapies. Additionally, the ability of PET to offer physiological and metabolic insights will likely be an important complement to cellular and molecular characterizations of disease.

In short, we believe that imaging in general, and molecular imaging in particular, needs to heed the call for value-based transformation of healthcare. The implication is that, we, as a community, needs to focus on providing greater clinical value in our imaging studies, and developing techniques which are easier to use, protocols which are more repeatable, and findings which are more quantitative and more indicative of pathological or physiological changes in patients.

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Session Classification: Industry

Contribution ID: **14** Type: **Oral**

Enabling new trends in molecular imaging

Monday, 2 May 2016 14:30 (30 minutes)

We will review the new trends and the exciting future developments of molecular imaging, and relate them to how the industry can enable and strengthen these new directions.

1)Enabling new trends:

i)Theranostics and its role in personalized medicine, and the associated requirements on present and future generations of PET scanners

ii)Beyond "generic"FDG imaging, new specific tracers and some examples: prostate cancer, Alzheimer.

iii)Beyond "static"SUV imaging, dynamic imaging, parametric imaging

2) Enabling promising applications: Prostate cancer, Lung cancer, Breast, pancreas, and Screening of genetically high risk patients

3) Enabling better workflow and patient comfort: faster scans, patient comfort, continuous bed motion, computer guided/assisted scans, dosimetry

4) Enabling better image quality and image reconstruction: Motion correction, Low dose, TOF reconstruction

5) Envisioning technological innovation: Dedicated scanners for cardiac, brain, surgical probes; improve TOF performance and PET sensitivity

6) Enabling clinical research: Easier access to data via listmode and dynamic imaging

Summary

We will review the new trends and the exciting future developments of molecular imaging, and relate them to how the industry can enable and strengthen these new directions.

1)Enabling new trends:

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5) Envisioning technological innovation: Dedicated scanners for cardiac, brain, surgical probes; improve TOF performance and PET sensitivity

6) Enabling clinical research: Easier access to data via listmode and dynamic imaging

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Session Classification: Industry

Contribution ID: **15** Type: **Oral**

ClearPEM an example of a collaborative project to develop a dedicated PET for breast imaging

Tuesday, 3 May 2016 11:20 (20 minutes)

In 2001, crystal clear launched a program to develop a dedicated breast positron tomograph. We will present the results of the first prototypes and the recent development of new crystal modules.

Summary

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Session Classification: Dedicated & Hybrid imaging

Contribution ID: **16** Type: **Oral**

Nuclear and CT imaging: what drives it ?

Tuesday, 3 May 2016 09:00 (30 minutes)

Since the invention of the CAT scan by Hounsfield in the early 1970s, transmission and emission imaging modalities used in radiology and nuclear medicine have continually benefit from improvements in detection technology, signal treatment and applied mathematics. The development of 3D PET in the late 1980s, and of positron rotating partial-ring tomographs leaving potentially enough void between arrays of detectors to insert an X-ray tube and X-ray detectors, led to the invention of PET/CT in the early 1990s. Although the original concept of PET/CT could not be implemented as envisaged, the advent of the first PET/CT prototype in the late 1990s, which provided native fusion of anatomical and functional images, revolutionized rapidly both the practice and the market of nuclear medical imaging.

Riding the wave of PET/CT that was claimed to be the invention of the year 2000 by the Time Magazine, and thanks the development of solid-state photodetector devices insensitive to magnetic fields, industry majors have made recently a determined effort to bring PET/MR devices to the market. Although the pertinence of this new evolution of the imaging discipline remains to be assessed, it is nevertheless obvious that every technological breakthrough that would bring better insight and quantification of the metabolic function, or of several molecular pathways at a time, together with precise anatomical information, possibly at a reduced absorbed dose, constitutes a genetic trend for the development of future hybrid nuclear and CT imaging modalities.

In this regard, the invention of massively parallel hybrid pixel detectors for charged particle trajectography in high energy physics, once applied to the detection of X-rays for photon counting CT, paves the way to the development of spectral CT that will potentially provide the first ever intrinsically anatomo-functional medical imaging device, which could be used to image several functionalized contrast agents made of nanoparticles. In a similar line, improvements of scintillation spectrometry implementing photonic devices and novel compact and fast photodetectors such as SiPMs permits to improve dramatically signal-to-noise ratio of medical images by exploiting TOF information in the image reconstruction process. Hence, extrapolating this trend may possibly foreshadow the advent of reconstructionless positron tomography in some unknown but brilliant future of nuclear and CT imaging.

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Session Classification: Overview Molecular Imaging Technologies

Contribution ID: **17** Type: **Oral**

EndoTOFPET-US: A multi-modal endoscope for Ultrasound and Time-of-Flight PET

Tuesday, 3 May 2016 11:40 (20 minutes)

The EndoTOFPET-US collaboration is developing a multi-modal imaging tool combining Ultrasound with Time-Of-Flight Positron Emission Tomography into an endoscopic imaging device. The objective of the project is to obtain a coincidence time resolution of about 200ps FWHM and to achieve ˜1mm spatial resolution for the PET head, while integrating all the components in a very compact detector suitable for endoscopic use. This scanner aims to be exploited for diagnostic and surgical oncology, as well as being instrumental in the clinical test of new biomarkers especially targeted for prostate and pancreatic cancer.

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Session Classification: Dedicated & Hybrid imaging

Contribution ID: **18** Type: **Oral**

Compton Telescope for hadron therapy range monitoring: update on characterization results and beam tests.

Tuesday, 3 May 2016 14:00 (20 minutes)

The detection of prompt gammas to assess range variations in real time during hadron therapy is being investigated as an alternative to PET techniques. The use of prompt gammas can be advantageous given the larger amount produced as compared to positron emitters and the fact that they are produced within nanoseconds after irradiation. However, their detection is challenging due to the continuous emission spectrum at high energies (useful up to about 10 MeV).

The IRIS group of the Instituto de Fisica Corpuscular (IFIC-CSIC/UVEG, Valencia) has developed a three-layer Compton telescope based on LaBr3 scintillator crystals and Silicon photomultipliers for this purpose. The system aims at combining two- and three-layer events. For the latter, the energy is determined by event kinematics and thus they provide high precision. Two-layer events without requiring absorption of the photons provide high efficiency. In order to use both types of events, an image reconstruction code capable of estimating the energy of the incoming gamma ray has been developed.

The telescope is made of LaBr3 continuous crystals coupled to MPPC arrays in order to obtain high spatial resolution and fast timing response, together with compactness and operation simplicity. The VATA64HDR16 ASIC is employed in the front-end readout. A custom-made data acquisition system drives the ASIC and controls the acquisition. A programmable coincidences board makes it possible to acquire data with any two or three planes simultaneously.

The system has been characterized in the laboratory with radioactive sources of different energies (Na-22, Y-88). Data have been acquired in several geometrical configurations with two and three planes. With the Y-88 source, a preliminary spatial resolution of 3.1 mm FWHM has been obtained with two planes, and of 5.2 mm FWHM with three planes.

The system has also been tested in beam facilities. At KVI-CART (Groningen), data were taken with a 150 MeV proton beam with an intensity of about 1E8 protons/s and a lateral beam spread of 5.3 mm impinging on a PMMA phantom. The PMMA target was placed in two different positions along the beam separated by 10 mm. A shift in the Bragg peak consistent with the phantom position was observed. At HZDR (Dresden) the system was placed in different positions to image 4.4 MeV photons. The distance between the centers of the reconstructed images corresponds to the telescope shift.

The telescope shows promising results both in laboratory and in beam tests. Further optimization of the device is ongoing in order to achieve the specifications necessary for the application.

Summary

Hadron therapy is a promising radiotherapy technique for certain types of cancer, in particular for ocular tumours, radioresistant tumours, paediatric patients, or tumours close to critical organs. The benefits of sparing healthy tissue from irradiation have been demonstrated[1,2]. However, the lack of precise methods to monitor the treatment online is hindering its further application. PET techniques currently applied have strong limitations, such as low efficiency, late emission of positrons and biological washout, complicating its use for real time monitoring.

The detection of prompt gammas to assess range variations in real time during hadron therapy is being investigated as an alternative to PET techniques. The use of prompt gammas can be

advantageous given the larger amount produced as compared to positron emitters and the fact that they are produced within nanoseconds after irradiation. However, their detection is challenging due to the continuous emission spectrum at high energies (useful up to about 10 MeV).

Collimated and Compton Cameras with different configurations and materials are being employed for this purpose. The IRIS group of the Instituto de Física Corpuscular (IFIC-CSIC/UVEG, Valencia) has developed a three-layer Compton telescope based on LaBr3 scintillator crystals and Silicon photomultipliers[3]. The system aims at combining two- and three-layer events. For the latter, the energy is determined by event kinematics and thus they provide high precision. Two-layer events without requiring absorption of the photons provide high efficiency. In order to use both types of events, an image reconstruction code capable of estimating the energy of the incoming gamma ray has been developed[4].

The telescope is made of LaBr3 continuous crystals coupled to MPPC arrays in order to obtain high spatial resolution and fast timing response, together with compactness and simplified operation. Each crystal is coupled to four arrays with 4x4 pixels of 3 mm x 3 mm size. The first layer is made of a 27.2 mm × 26.8 mm × 5 mm crystal coupled to four Hamamatsu MPPC S11830-3340MF monolithic arrays. The arrays are biased individually. The second and third layers are composed of crystals of size 32 mm × 36 mm and thickness of 5 and 10 mm, respectively, coupled to four S11064-050P(X1) arrays (an older version with larger gaps between the pixels), with a common bias for all of them.

The ASIC VATA64HDR16 is employed in the front-end readout to process the signals of the 64 channels and provide the detector trigger. The trigger signals are fed to a programmable coincidences board which makes it possible to acquire data with any two or the three planes simultaneously. Custom-made data acquisition system and software are employed to drive the ASIC and control the acquisition.

The system has been characterized in the laboratory with radioactive sources of different energies (Na-22, Y-88). The uniformity of the channel response is within 5% for the first detector and the energy resolution around 7% FWHM at 511 keV. For the second and third detectors, the uniformity is about 10% and the energy resolution 7.5% FWHM at 511 keV. Coincidence data have been acquired in several geometrical configurations with two and three planes and with the two radioactive sources in different positions. With the Y-88 source, a preliminary spatial resolution of 3.1 mm FWHM has been obtained with two planes, and of 5.2 mm FWHM with three planes.

The system has also been tested in beam facilities. At KVI-CART (Groningen), data were taken with a 150 MeV proton beam with an intensity of about 1E8 protons/s and a lateral beam spread of 5.3 mm impinging on a PMMA phantom. The PMMA target was placed in two different positions along the beam separated by 10 mm. A shift in the Bragg peak consistent with the phantom position was observed[5].
At HZDR (Dresden) the system was placed in different position to image 4.4 MeV photons. The distance between the centers of the reconstructed images corresponds to the telescope shift.

The telescope shows promising results both in laboratory and in beam tests. Further optimization of the device is ongoing in order to achieve the specifications necessary for the application.

[1] A. D. Jensen, M.W. Munter and J. Debus, Review of clinical experience with ion beam radiotherapy. The British Journal of Radiology, 84 (2011), S35–S47.

[2] M. Uhl et al. High Control Rate in Patients With Chondrosarcoma of the Skull Base After Carbon Ion Therapy. Cancer 2014;120:1579–1585.

[3] G. Llosá et al. First Images of a Three-layer Compton Telescope prototype for Treatment Monitoring in hadron Therapy. Front. Oncol., 2016, volume 6: 14.

[4] J. Gillam et al. Simulated one pass listmode for fully 3D image reconstruction of compton camera data. 2012 IEEE Nuclear Science symposium and Medical Imaging Conference record (NSS/MIC), 2012, pages 3298–3305.

[5] P. Solevi et al. Submitted to Phys. Med. Biol. 2016.

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Co-authors: Ms ETXEBESTE, Ane (Instituto de Física Corpuscular); SOLAZ CONTELL, Carles (Instituto de Fisica Corpuscular (ES)); LACASTA LLACER, Carlos (IFIC-Valencia); Mr MUÑOZ, Enrique (IFIC-Valencia); Mr BARRIO, John (Instituto de Física Corpuscular); OLIVER GUILLEN, Jose Francisco (Instituto de Fisica Corpuscular (ES)); GARCIA ORTEGA, Pablo (IFIC- Valencia and CERN); SOLEVI, Paola (IFIC (CSIC/UV))

Presenter: G. LLOSA LLACER, IFIC - VALENCIA (IFIC - Valencia)

Session Classification: Hadrontherapy

Contribution ID: **19** Type: **Oral**

Prostate-Checker: Prostate cancer assessment by multi-parametric MRI studies

Monday, 2 May 2016 10:30 (20 minutes)

Prostate cancer (PC) is the second most diagnosed type of cancer and the fifth leading cause of cancer-related death in men worldwide (most frequent cause of cancer death in men in developed countries).
Guidelines about prostate magnetic resonance (MR) imaging published by the European Society of Urogenital Radiology (ESUR) in 2012 recommended a multi-parametric approach for a better characterization of PC. Available sequences that allow the acquisition of anatomical and functional studies have led MRI to be the modality of choice in PC evaluation and during follow-up studies.
Anatomic T2-weighted (T2W) images, diffusion-weighted (DW) images and dynamic contrast enhanced (DCE) series allow the assessment of interstitial edema, cellularity and micro-vascularity of the gland respectively. MR imaging derived biomarkers provide quantitative information to objectively characterize a pathological process or a therapeutic action.
A software prototype (Prostate Checker Ltd, UK http://prostatechecker.co.uk) is presented (Figure 1). The tool is capable of performing voxelwise multi-parametric analysis from T2W, DW and DCE MR images to extract several imaging biomarkers related to PC detection and grading. Imaging biomarkers and their multi-variate combination are displayed in the form of parametric maps (Figure 2).
As images have different spatial resolutions and space orientation, and the prostate may slightly change in position, the software performs a re-slicing and elastic co-registration, driving all images to a common reference space and resolution.
Once the spatial coherence is achieved, the user manually segments the prostate or any PI-RADS region, launching the complementary multi-parametric analyses based on T2W, DW and DCE images.
First module of the prototype applies advanced TexRAD texture analysis (licenced by TexRAD Ltd www.texrad.com, part of Feedback Plc) to T2W images to quantify tissue heterogeneity through a filtration-histogram technique. First step uses a band-pass Laplacian of Gaussian (Mexican hat shaped filter similar to a non-orthogonal Wavelet approach) to extracts and enhances texture features of different sizes corresponding to spatial scale filter (SSF). Second step performs histogram-analysis to describe the shape of the histogram e.g. mean intensity/mean of positive pixels, standard-deviation, entropy, kurtosis and skewness. Diverse published literature states the use of filtration-histogram texture analysis technique to assist in risk-stratification.
A second module applies pharmacokinetic models to the DCE series to characterize tissue microcapillarity. This module extracts and displays parameters such as the transfer constant (Ktrans), the reverse transfer constant (κep) and the extracellular space fractional volume (⊠e), widely reported in literature to have a high sensitivity in cancer detection. The third module exploits DW images computing and displaying apparent diffusion (ADC) maps and intra-voxel incoherent motion (IVIM) parameters when several b-values are acquired. PC shows a lower ADC and D properties, with higher D* and f properties.
Nosologic images from the combination of the different extracted biomarkers are created by their combination through the application of multivariate analysis, providing closer information to the clinical endpoints.

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Session Classification: Theranostics

Contribution ID: **20** Type: **Oral**

Personalised production of medical radioisotopes with laser-accelerated protons

Monday, 2 May 2016 09:40 (20 minutes)

Many diagnostic methods are based on the use of tracers labelled with radioactive isotopes. Their production in centralised facilities and delivery to local health centres imply strong constraints to the isotope half lives. For this reason, more than 90% of all PET interventions are based on F-18 at present. The on-site synthesis of short-lived tracers containing C-11, O-15, or N-13 would allow for a wealth of drugs with ideal characteristics for each patient and pathology.

The production of radioisotopes requires beams of accelerated protons or deuterons with energies around 15-20 MeV/u. A novel acceleration technique based on highly intense, pulsed lasers has the potential to provide such beams at much lower cost than classical synchrotrons. We present the development of a dedicated setup aiming at the production of PET isotopes, comprising a table-top, terawatt laser with high repetition rate. With this setup we have recently achieved the first demonstration of laser-proton acceleration in Spain. In addition, we have calculated the requirements for the synthesis of useful quantities of different isotopes in various reaction channels.

Primary author: M. SEIMETZ, I3M VALENCIA (Instituto de Instrumentación para Imagen Molecular (I3M))

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Session Classification: Theranostics

Contribution ID: **21** Type: **Oral**

Imaging the continuous spectrum of therapeutic radionuclides with detectors and pinholes suited for high energy

Monday, 2 May 2016 10:50 (20 minutes)

Targeted radionuclide therapy (TRT) is an established cancer treatment modality. It relies on cancer specific agents that are labeled with radionuclides for internal radiotherapy. The biological effect to tissues is generated by the energy absorbed from the radiation (typically beta-emittors) emitted by the radionuclide, TRT can result in substantial sparing of uninvolved tissue and organs and therefore avoid adverse events compared to conventional external beam therapy. Current PET or SPECT systems are suboptimal for imaging isotopes used in radionuclide therapy. SPECT (developed for single gamma photons with mono-energetic low-energy emission) has been used as imaging that has very limited use in the specific domain of radionuclide therapy due to poor quantification. PET can only be used for Y-90, which has a small fraction of positron emission. The main limitations of current SPECT systems for these isotopes are related to the high penetration in the collimator and low detection efficiency of the used detectors. Secondary bremsstrahlung photons, characterised by a continuous energy spectrum, up to the maximum energy of the emitted electron, need a collimator with minimal penetration similar to high-energy pinhole SPECT. To efficiently detect incoming photons, dense high-energy detectors similar to those used in PET should be used.

The conventional 3/8 inch NaI works well at low energies but has only very limited stopping power at 1 MeV. The currrent standard PET scintillator L(Y)SO is not suited for this task due to its high intrinsic activity (which cannot be removed when acquiring in singles mode). BGO is more suited, the main advantage of BGO comes from the high amount of direct photo-electric interactions and resulting smaller amount of Compton interactions arriving in the lower energy window. A disadvantage of BGO is the smaller amount of scintillation light resulting in reduced energy resolution at lower energies (>30% at 100 keV and 15 % at 1 Mev), but given the continuous spectrum this is less important. As the spectrum from a typical therapeutic radionuclide will be mostly composed of low energies, a relatively thin detector can be considered (about 1 cm was selected from simulation study). Based on the expected resolution of these detectors a stationary system can be designed with 1 cm spatial resolution in the cFOV.

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Session Classification: Theranostics

Contribution ID: **22** Type: **Oral**

Molecularly targeted therapy and radiogenomic imaging in glioblastoma

Monday, 2 May 2016 16:10 (30 minutes)

Glioblastoma (WHO grade IV) is the most common malignant primary brain tumor in adults with a dismal median overall survival of 16 months, despite intensive radio-chemotherapy. In recent years, the advent of high-throughput genomic analyses has helped us to better understand the biology underlying this disease. These advances translate in two ways "from bench to bedside": First, tumors now can robustly be grouped in molecularly defined subgroups, which increasingly complement the WHO classification, and even prove to be prognostically superior to it. Secondly, key molecular "driver"alterations and biomarkers predictive of therapy response have been identified and caused a great interest in the development of molecularly targeted therapies in these highly treatment-resistant tumors. Today, treatment decisions are increasingly based on defined molecular biomarkers, most prominently the methylation status of O6-methylguanine-DNA methyltransferase (MGMT) promoter or combined deletion of the short arm of chromosome 1 and the long arm of chromosome 19 (1p/19q codeletion), a hallmark of oligodendroglial tumors. Furthermore, several actionable alterations have been identified which are recurrently found in these tumors, such as isocitrate dehydrogenase (IDH) mutations, epidermal growth factor reception (EGFR) amplifications or FGFR-TACC fusions. In parallel, fostered by advancements in MR and PET imaging and post-processing, the field of radiogenomics, investigating how genomics are reflected in the imaging phenotype, has received increasing attention. These developments have been met with great enthusiasm, as drugs targeting defined genomic alterations promised to improve therapeutic options for this disastrous disease, while hopefully reducing side effects compared to conventional chemotherapeutic agents.

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Session Classification: Brain (including open MINDVIEW session)

Contribution ID: **23** Type: **Oral**

Scintillators: a new way to fast emission

Wednesday, 4 May 2016 10:40 (20 minutes)

Scintillating crystals performance in terms of light output and timing are key parameters in order to achieve ultimate time resolution in radiation detector systems, particularly in the low energy regime of medical imaging. State-of-the-art Time of Flight measurements present Coincidence Time Resolution (CTR) values on the order of 140 picoseconds for 20 mm long LYSO:Ca crystals using 511 keV, which translate into a background rejection area on the order of few centimeters. Reaching the milimeter level on vertex identification means lowering CTR values down to 10 ps. From the scintillator point of view and in strong correlation with the photodetector time performance, lowering CTR values implies increasing photostatistics, shortening scintillating signal rise and decay times or introducing a prompt signal. Measurements of the intrinsic light yield for LYSO crystals done using electron excitation conclude on 40 000 Ph/MeV $\pm$ 10\% (syst) $\pm$ 3\% (stat). This values sets a limit on the improvement that photostatistics could bring to the CTR measurements and new ways to fast prompt emission are being explored looking at new materials: nanocrystal.

Nanocrystals are semiconductors grown at different levels of confinement, which define its optoelectronic properties and band gap structure in the visible range. They usually present high quantum efficiency (QE) and fast recombination times on the order of few hundreds of picoseconds under laser excitation, in comparison with bulk scintillators (τd_LYSO ˜ 40 ns). Under ionising radiation of few tents of keV, Auger recombination is responsible for weakly emissive multiexciton population, which among other effects, degenerate the high QE. A new generation of Auger suppressed materials have been tested using a Hamamatsu streak camera and a picosecond pulsed X-ray tube up to 40 keV. The materials are CdSe nanoplatelets and CdSe/CdS giant shell quantum dots. Measurements under single photon counting mode and instrumental response function of 70 ps, show near zero rise time, resolution limited first decay component and a second component between 200-400 ps for both materials. The small time differences between laser and x-ray irradiation for CdSe nanoplatelets point towards a high suppression of the non-radiative channels. First deposition of nanocrystals on conventional scintillators has been also characterized showing a long third decay coming from absorption and remission of scintillating light by the nano-materials. However, spectrally resolved information show comparable light yield between nano-materials and scintillators when integrating over the firsts nanoseconds.

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Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **24** Type: **Oral**

Fast Advanced Scintillator Timing - COST Action TD1401

Wednesday, 4 May 2016 09:30 (20 minutes)

Scintillator-based detectors have been very successful in high energy physics (HEP) calorimetry, medical imaging, and many other applications. In particular, the potential of such detectors to achieve precise timing information is of increasing importance for those applications. Already today, scintillator-based detectors coupled to high bandwidth amplifiers are capable of producing a timing precision of better than 200ps in coincidence time resolution (CTR). The demand to discriminate between closely spaced bunch trains in future highest luminosity accelerators and to deliver space points in addition to the traditional back-to-back line of response reconstruction algorithms of positron emission tomograph (PET), requires a further quantum step in time resolution, i.e. below 100ps. The implications of such a radical improvement in time resolution come with dramatic benefits in many domains. HEP will profit from a significant increase in detection efficiency and the health sector from an unprecedented improvement in imaging quality and image reconstruction time. Such a 'paradigm'change, however, must go hand-in-hand with a similar break in the interdisciplinary domain of photon detection. Therefore, new expertise must be gained in the fields of scintillators, photodetectors, as well as electronics to develop ultrafast timing scintillator-based detectors.

This Trans Domain COST Action (FAST, Fast Advanced Scintillator Timing) aims to establish a multidisciplinary network that brings together European experts from academia and industry to ultimately achieve scintillator-based detectors with time precision better than 100ps and provides an excellent training opportunity for researchers interested in this domain. The FAST COST (Action TD1401) started on November 20 2014 and will end on November 19 2018.

Summary

Scintillator-based detectors have been very successful in high energy physics (HEP) calorimetry, medical imaging, and many other applications. In particular, the potential of such detectors to achieve precise timing information is of increasing importance for those applications. Already today, scintillator-based detectors coupled to high bandwidth amplifiers are capable of producing a timing precision of better than 200ps in coincidence time resolution (CTR). The demand to discriminate between closely spaced bunch trains in future highest luminosity accelerators and to deliver space points in addition to the traditional back-to-back line of response reconstruction algorithms of positron emission tomograph (PET), requires a further quantum step in time resolution, i.e. below 100ps. The implications of such a radical improvement in time resolution come with dramatic benefits in many domains. HEP will profit from a significant increase in detection efficiency and the health sector from an unprecedented improvement in imaging quality and image reconstruction time. Such a 'paradigm'change, however, must go hand-in-hand with a similar break in the interdisciplinary domain of photon detection. Therefore, new expertise must be gained in the fields of scintillators, photodetectors, as well as electronics to develop ultrafast timing scintillator-based detectors.

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Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **25** Type: **Oral**

Fast SiPM readout for PET

Wednesday, 4 May 2016 11:00 (20 minutes)

Medical imaging devices have historically been based on scintillator crystals coupled to photomultipliers tubes, PMTs. The problems to combine PMTs with high electromagnetic fields and the relatively high cost per unit surface, opens new opportunities on the field for a different type of photodetector named silicon photomultiplier.

SiPM or Multipixel Photon Counter, MPPCs, offer an alternative combining the high gain of the photomultipliers tubes, and the insensitiveness to the magnetic field, high quantum efficiency and compact structure of the avalanche photodiodes. This allows an increasing quality of medical imaging technics, such as positron emission tomography, allowing a better and early detection of different diseases.

A front end application specific integrated circuit (ASIC) for the readout of common cathode Silicon Photo-Multipliers arrays is presented with the following features: less than 10 ps RMS of timing resolution, wide dynamic range, high speed, multi-channel, low input impedance current amplifier, low power (≈10mW per channel), common cathode connection, directly coupled input with common mode voltage control and separated timing and charge signal output.
The low jitter current mode processing together with a configurable differential current mode logic (CML) output provides a timing signal suitable for Time of Flight (ToF) measurements. This low jitter allows coincidence time resolution (CTR) measurements close to 100 ps using 2x2x5 mmˆ3 LYSO crystals. Each channel delivers a digital output of a Time over Threshold (ToT) type with a pulse width proportional to peak current (charge) input.

The results show that the FlexToT v2 ASIC is a flexible solution for the front-end readout of different designs of SiPM-based scintillator detectors in TOF-PET applications.

A new version of the ASIC is under development in a 180 nm CMOS technology, with 3.5 mW/ch power consumption and similar or better timing performances. Inclusion of digitization and back-end and implementation of individual time-stamps per channel will be considered as well.

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Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **26** Type: **Oral**

Radioisotope production and the Arronax Facility

Monday, 2 May 2016 09:20 (20 minutes)

Radioisotopes can be used in different field of medicine like oncology, neurology and cardiology. Different types of applications are possible thanks to the different kind of radiation available through the radioactive decay of nucleus. Gammas which are penetrating radiation are used for imaging to help diagnosis whereas charged radiations are used for therapy to destroy cells.
Only few radionuclides can be used directly (I131 for thyroid cancer is one example). In most cases, these radionuclides must be coupled to a carrier molecule (a vector) to target the cells of interest. This labelled vector forms a radiopharmaceutical. A vector can be a chemical molecule, a peptide or an antibody and its distribution time in the body is dependent on its size. Peptide can distribute within hours whereas antibodies need days.
Currently, only few isotopes are used in clinical practice (Tc99m, F18 for imaging and I131 and Y90 for therapy). However, many others may be of medical interest due to their emitted radiations (alpha emitters, Auger emitters) and / or their half-lives that can be adapted to the carrier molecule transit time and to the pathology.
Recently, with the recent technological advances, it is possible to combine imaging information and therapeutic use of radionuclides which is called the theranostic approach. This approach allows personalizing the treatment to each patient. The diagnosis test done prior to the treatment allows following and controlling the patient response to the injected radiopharmaceutical. It allows a better control of the targeting and increases the benefit/toxicity ratio as useless treatments on patients with no response to the diagnosis test are avoided. For the theranostic approach, it is preferable to use pairs of radioisotopes of the same element like (I124/131I, Cu64/Cu67,).
All these points lead to a renewal interest on isotope production and the necessity to have dedicated facilities like the Arronax facility in France which is devoted to the production of innovative radionuclides for medical applications.

Primary author: F. HADDAD, SUBATECH & ARRONAX (Subatech and GIP ARRONAx)

Presenter: F. HADDAD, SUBATECH & ARRONAX (Subatech and GIP ARRONAx)

Session Classification: Theranostics

Contribution ID: **27** Type: **Oral**

Nuclear Medicine and Molecular Imaging for Minimizing Medical and Surgical Interventions

Sunday, 1 May 2016 17:20 (30 minutes)

This presentation will show actual and upcoming applications of nuclear medicine and molecular imaging for minimizing medical and surgical interventions. There are several ways nuclear medicine and molecular imaging can do this: (1) early detection of potentially lesion (rule-in/rule-out); (2) easier targeting of biopsies; (3) better detection of micro-metastases and tumor margins during oncological surgery; (4) help in deciding minimal invasive, standard surgical, or watch-and wait approaches; and (5) early detection of residual disease or recurrence, among others.

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Presenter: J. PRIOR, CHUV LAUSANNE (CHUV University Hospital)

Session Classification: Imaging for minimizing interventions

Contribution ID: **28** Type: **Oral**

Recent progress in Cherenkov based TOF PET

Tuesday, 3 May 2016 15:50 (20 minutes)

We will report on the development of a novel PET scanner concept which is potentially cost-effective, could have a higher patient throughput, and would also allow for a construction of a full-body PET apparatus. The resulting detection system would provide the basis for increased sensitivity in cancer detection, providing a more robust diagnosis for an early therapy selection in an individual patient. The scanner will be based on the detection of annihilation gammas by using Cherenkov-light, thus translating basic physics experiments to clinical PET. We will report on a series of experimental and simulation studies that have shown that with this detection concept TOF resolutions below 100ps are possible, that SiPMs present a very promising device for Cherenkov light detection in TOF PET, and that such an apparatus offers a very interesting cheaper alternative to scintillating crystal based scanners.

Summary

The information on flight time difference of the two gamma rays emitted simultaneously during positron annihilation can be incorporated in the image reconstruction algorithm in the time-of-flight positron emission tomography (TOF PET), resulting in a lower image noise. The reduction depends on the TOF resolution, which is in the range of 500 ps in current clinical scanners, and reaches 300 ps in prototype developments. Gain in variance is around 3 in this case. It has been shown [1] that a TOF resolution of 100 ps would reduce variance by a factor up to 18.

In positron emission tomography the annihilation gammas are traditionally detected using scintillation crystals. Gamma interactions in the crystal produce thousands to tens of thousands of optical photons, a large fraction of which can be detected with a photodetector. As better scintillators and faster photodetectors became available, the main limiting factor for the resolution of time measurement in time-of-flight (TOF) PET became the time constants characteristic for the production and decay of scintillation light. This limitation can be avoided by basing the method on detection of Cherenkov photons, which are produced by a passage of fast charged particle (i.e. an electron resulting from gamma interactions) through suitable material. The Cherenkov photons are emitted instantaneously, however only about 10 are produced by a 511 keV gamma, meaning that the method must be based on detection of single photons.

The proposed scanner concept has a number of advantages. The cost of a Cherenkov based scanner will be significantly lower than that of a scintillator based apparatus since the contribution of the sensitive detector material, which typically amounts to one half of the system cost, will be reduced by about a factor of three. In addition, for a whole-body PET with 100 ps TOF information a significant increase of signal-to-noise ratio is expected if compared to the currently available TOF PET systems. This improvement could be used in a number of ways, by shortening the acquisition time and thus increasing throughput, by reducing the radiation exposure, or by allowing for an individually measured bio-kinetics of tracers in an effort towards an individualized diagnosis and therapy.

Using 25×25×15 mm3 lead fluoride (PbF2) crystals as Cherenkov radiators and microchannel plate photomultipliers (MCP PMTs) as photodetectors, a coincidence timing of 87 ps FWHM has already been experimentally demonstrated [2]. With only a couple of photons available for detection, the photon detection efficiency (PDE) of the light sensor becomes the limiting factor for the efficiency of the method. To improve the relatively low PDE of original sensors, silicon photomultipliers (SiPMs) were used to improve the efficiency of the method [3]. The SiPMs can have a very high peak PDE and also have other desirable properties: they operate at low voltages, are insensitive to

high magnetic fields, could be more cost effective than other photodetectors and are suitable for a 1:1 coupling with crystals used in TOF PET.

The high photon detection efficiency (PDE) of SiPMs led to a large improvement in detection efficiency in the first set of tests [3]. On the other hand, the time response of available SiPMs was not as good as that of MCP PMTs, and further detailed studies of timing properties of several recently developed SiPMs produced by four different manufacturers were carried out with single photon level picosecond laser illumination.

Simulations were performed in order to estimate the performance of TOF PET scanner based on the Cherenkov method of gamma detection. The main building block of the simulated scanner was a gamma detector composed of a PbF2 crystal and a SiPM. The performance of a single gamma detector was explored in depth using GEANT4. The simulation was then transferred to GATE [5] and a full body scanner was simulated, and the performance of the scanner based on the Cherenkov method was compared to that of a state-of-the-art LSO scanner. First preliminary Monte Carlo simulation studies have shown that a Cherenkov-PET scanner using Lead fluoride with the same size of detector elements and the same ring geometry as a state-of-the-art PET scanner will have a 20% improved spatial resolution, as is now achieved using one-to-one coupling. Sensitivity will be about one half, but noise equivalent count rate can be expected to be as good as or better than the standard PET scanner, if TOF resolution is 200 ps or better.

We will report on a series of experimental and simulation studies that have shown that with this detection concept TOF resolutions below 100ps are possible, that SiPMs present a very promising device for Cherenkov light detection, and that such an apparatus offers a very interesting cheaper alternative to scintillating crystal based scanners.

[1] K. Vunckx et al.: IEEE Trans Med Imaging 29 (2010) 311-321

[2] S. Korpar et al., Nucl. Instr. and Meth. A 654 (2011) p. 532; S. Korpar et al., Physics Procedia, 37 (2012) p. 1531.

[3] R. Dolenec et al., Nucl. Instr. and Meth. A 804 (2015) 127.

[4] S. Jan, et al., Phys. Med. Biol. 49 (2004) 4543.

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Presenter: S. KORPAR, LJUBLJANA UNIV.

Session Classification: New Technologies

Contribution ID: **29** Type: **Oral**

Feasibility of in-beam time-of-flight SPECT/PET gamma imaging based on Silicon Photomultipliers for high precision hadrontherapy

Tuesday, 3 May 2016 14:40 (20 minutes)

Hadrontherapy is an emerging technology toward personalized high precision medicine, a vital instrumentation, especially in a cancer treatment. Success in the treatment critically depends on the precision of gamma imaging in general and absorbed dose profile monitoring in particular. PET and SPECT are well-established modalities of gamma imaging, and both of them have specific advantages and specific drawbacks with respect to hadrontherapy applications. Therefore, EU R&D activities in this area (ENLIGHT network, ENVISION project, INSIDE collaboration) are mostly focused on in-beam imaging, and a necessity to combine PET and prompt gamma imaging (in fact, SPECT) is already foreseen as the next major step in hadrontherapy improvements. However, this combination hardly could rely on conventional approaches to PET and SPECT, first of all, because slit-based SPECT contradicts with PET imaging technology.

Authors consider another approach in a development of in-beam in-vivo bimodal imaging for high precision hadrontherapy –a combination of time-of-flight (TOF) PET and recently proposed Prompt Gamma-Ray Timing (PGT, in fact, TOF SPECT). In contrast with slit-based SPECT, TOF SPECT allows encoding information on a hadron absorption spatial profile by the hadron transit time and the prompt gamma transit time using a reference time signal of a beam monitoring system without any collimation and compatible with TOF PET modality. To uncover its full potential, the combined TOF SPECT/PET imaging should utilize cutting-edge advances in accelerator beam monitoring, profiling and timing and in fast scintillation detectors with Silicon Photomultipliers (SiPM). Feasibility, benefits, challenges, and possible implementation of the TOF SPECT/PET approach to be considered and discussed.

Summary

Hadrontherapy is an emerging technology toward personalized high precision medicine, a vital instrumentation for a cancer treatment. Success in the treatment critically depends on the precision of gamma imaging in general and absorbed dose profile monitoring in particular. PET and SPECT are well-established modalities of gamma imaging, and both of them have specific advantages and specific drawbacks with respect to hadrontherapy applications. Therefore, EU R&D activities in this area (ENLIGHT network [1], ENVISION project[2], INSIDE collaboration [3], [4]) are mostly focused on advances in in-beam gamma imaging.

PET still is the only technically feasible and clinically proven method for a volumetric non-invasive verification of the ion treatment during or shortly after daily dose delivery [5]. However, with respect to conventional PET, in-beam PET imaging in hadrontherapy has specific features and limitations [6]:
Typically, the activity induced by the nuclear reactions between the incident beam and the patient tissues is 3 orders of magnitude less than those injected in a conventional clinical PET scan;
The created isotopes during the irradiation are short-lived isotopes and these isotopes diffuse inside the patient tissues because of the human metabolism;
There is a large amount of background because of the other secondary particles, particularly the gamma-prompts also produced by the nuclear reactions and affecting the 511 KeV measurements;
The geometry of the detector is also specific, as it cannot be a complete ring-like conventional clinical PET.

In a hadrontherapy, prompt gammas are a more intense source of information on absorbed irradiation then inter-spill or delayed positron annihilation gammas of PET imaging, it yields 22% of secondary radiation vs. 0.02% for positrons [4]. In spite of higher intensity, an in-spill prompt gamma imaging (PGI) has large spatial spread around the primary particle deposition point while for an inter-spill acquisition, the spread is much smaller [4].

Passively collimated gamma camera is a conventional approach for a PGI. However, it has low efficiency because most of the gammas are absorbed or scattered in a collimating grid. Electronically collimated systems such as Compton cameras require a tremendous electronic expense and still lack in the low efficiency of useable events. Overall, the PGI has not yet been demonstrated to be successful in clinical environments, there are still unsolved technical challenges [7], [8].

A necessity to combine PET and PGI (in fact, SPECT) is already foreseen as the next major step for the best estimations of dose placement in hadrontherapy [8], [9]. However, this combination hardly could rely on conventional approaches to PET and SPECT, first of all, because a passively collimated (slit-based) SPECT contradicts with non-slit PET imaging technology.

Authors consider another approach in a development of in-beam in-vivo bimodal imaging for high precision hadrontherapy –a combination of time-of-flight (TOF) PET and recently proposed Prompt Gamma-Ray Timing (PGT, in fact, TOF SPECT) [7] –to resolve the contradiction pointed above. In contrast with a slit-based SPECT, the TOF SPECT allows encoding information on a hadron absorption spatial profile by the hadron transit time and the prompt gamma transit time using a reference time signal of a beam monitoring system without any collimation and compatible with TOF PET modality.

Silicon Photomultipliers (SiPMs) are widely recognized as the most appropriate detectors for various TOF applications, especially for TOF PET, due to their unique performance in photon number and time resolution [10], [11], [12]. Recently SiPM-based TOF PET scanners have been successfully developed by Philips and General Electric, and very active ongoing R&D on SiPM development and applications provide sustainable competitiveness of this emerging technology and further advances in SIPM performance.

Therefore, the universal non-collimated scintillator-SiPM-based detector system for TOF SPECT/PET imaging is assumed to operate as follows:

1. Advanced beam monitoring provides reference time for TOF SPECT as well as a spatial distribution of hadrons in the beam [13], [14];
2. TOF SPECT modality provides distribution of detection events (typically 4.3 –4.5 MeV) accumulated during beam-on time. Improvement in precision of a dose profile monitoring is expected to be good enough because time resolution of 4.5 MeV gammas with SiPM could be about 3 times better than that for 511 KeV gammas (˜ 150 ps for LSO/LYSO-SiPM detectors) just because of ˜ 9 times higher number of scintillation photons for 4.5 MeV gammas;
3. TOF PET modality operates during beam-off time in a time coincidence window and in an energy window around 511 KeV (conventional way);
4. Scintillator–SIPM block detector should be optimized for both modalities, and it could be rather challenging task;
5. TOF SPECT/PET detector design is assumed to be a monolithic scintillator block for higher efficiency and faster timing of photon detections as considered in [11];
6. Absorbed dose profile reconstruction is to be based on utilization of temporal and spatial distribution of the hadrons for TOF SPECT/PET image post-processing (deconvolution of output time distribution with measured beam spatial profile).

To reveal its full potential, the combined TOF SPECT/PET imaging should utilize cutting-edge advances in accelerator beam monitoring, profiling and timing on-the-fly and in fast scintillation detectors with advanced SiPMs.

Challenges to be evaluated and resolved for TOF SPECT/PET imaging:
1. Implementation of precision beam profile and beam time monitoring;
2. Development of TOF SPECT modality for high time resolution PET-compatible detection;
3. Optimisation of TOF PET modality for low-dose high-sensitivity SPECT-compatible detection;
4. Development of advanced fast timing SiPMs;
5. Optimisation of monolithic scintillator block detector performance;
6. Development of processing/modelling algorithms for precise dose profile reconstruction.
Feasibility, benefits, challenges, and possible implementation of the TOF SPECT/PET approach to be considered and discussed.
References

[1]. ENLIGHT network: http://enlight.web.cern.ch/
[2]. European NoVel Imaging Systems for ION therapy: http://cern.ch/envision
[3]. J. Krimmer et al., "Collimated prompt gamma TOF measurements with multi-slit multi-detector configurations", JINST 10 P0101, 2015: http://dx.doi.org/10.1088/1748-0221/10/01/P01011
[4]. F. Pennazio et al., "A Study of Monitoring Performances with the INSIDE System", Acta Physica Polonica A, V. 127, 5, 2015.
[5]. K. Parodi, "PET monitoring of hadrontherapy", Nuclear Medicine Review 2012, Vol. 15, Suppl. C, C37-C42.
[6]. G. Montarou, "In-beam ballistic control for hadrontherapy", http://ppse.in2p3.fr/PET%20imaging
[7]. C. Golnik et al. "Range assessment in particle therapy based on prompt ɣ-ray timing measurements", Phys. Med. Biol. 59 5399, 2014: http://dx.doi.org/10.1088/0031-9155/59/18/5399
[8]. A. del Guerra, "The current status and challenges of detection and imaging in radiation therapy", in ENLIGHT Meeting, Kraków 18-20 September 2015.
[9]. M. Dosanjh, "ENLIGHT Highlights December 2015": http://enlight.web.cern.ch/sites/enlight.web.cern.ch/files/media/d
[10]. P. Buzhan et al., "Silicon photomultiplier and its possible applications", NIMA 504, 48–52, 2003: http://dx.doi.org/10.1016/S0168-9002(03)00749-6
[11]. D. Schaart, "Prospects for sub-100 picosecond TOF-PET", in Fast Timing Workshop, LPC Clermont-Ferrand, 12-Mar-2014: http://indico.cern.ch/event/306859/session/2/contribution/7/attachments/584419/804472/S
[12]. S. Vinogradov, "Performance of Silicon Photomultipliers in photon number and time resolution"in Int. Conf. on New Photo-Detectors (PhotoDet15), Moscow, Russia, 6-9 Jul. 2015: https://indico.inr.ru/event/4/session/1/contribution/51
[13]. R Fiorito, "Optical Transition and Diffraction Radiation Diagnostics for Relativistic Charged Particle Beams"in "Electron-Photon Interaction in Dense Media"Chapter VI, Volume 49, NATO Science Series, pp 91-107, 2002.
[14]. R Fiorito, C.P. Welsch, H.D. Zhang, and A. Shkvarunets, "Novel Single Shot Bunch Length Diagnostic using Coherent Diffraction Radiation"Proc. IPAC'15, Richmond, VA, USA: https://jacowfs.jlab.org/conf/y15/ipac15/

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Presenter: S. VINOGRADOV, LEBEDEV PHYSICAL INSTITUTE, MOSCOW (Lebedev Physical Institute)

Session Classification: Hadrontherapy

Contribution ID: **30** Type: **Oral**

Form High-energy physics to medical applications.

Monday, 2 May 2016 15:00 (20 minutes)

CERN is one of the world's best centres for fundamental research. However, the economic return has been disappointingly low. I have been active in the field of technology transfer from fundamental research in high-energy physics to other fields during the last 20 years, and this activity culminated in the creation of a spin-off company a few years sago.
I will analyse the reason for the low economic return of such fundamental research, on the basis of my personal experience over the last 20 years.

Primary author: S. TAVERNIER, PETSYS (Vrije Universiteit Brussel (BE))

Presenter: S. TAVERNIER, PETSYS (Vrije Universiteit Brussel (BE))

Session Classification: Industry

Contribution ID: **31** Type: **Oral**

Development of a highly integrated PET readout system scalable to several 10'000 channels.

Tuesday, 3 May 2016 17:10 (20 minutes)

We have developed a 64 channel ASIC for reading out thousands of SiPM channels for PET applications.
A readout electronics based on this ASIC will be described, and we will present the performance of the readout in a test PET scanner setup with 2'048 channels. We will also present a comparison of the performance of our ASIC with SiPMs form different manufacturers
First results with a new version of he ASIC will also be presented.

Summary

SiPMs allow a dramatically improvement of PET performance because SiPMs are intrinsically faster than PMTs and because SiPMs can easily be subdivided in a large number of small independent photodetector pixels. The good timing performance of SiPMs will result in better effective sensitivity. The small and independent photodetector pixels allow using one-to-one coupling between a SiPM pixls and a LYSO crystals. This will result in significant improvement of the spatial resolution compared to PMT base systems, where some form of crystal encoding must be used to identify the LYSO crystal where the interaction occurred. Furthermore SiPMs are fundamentally low cost devices. and eventually their price will be lower than the price of PMTs.
A whole body PET scanner will typically have 30'000 LYSO crystals measuring 4x4x20mm. To take advantage of SiPMs in PET applications, it is mandatory to have highly integrated electronics readout. We have developed the 64 channel TOFPET1 ASIC for this purpose. It has 64 independent readout cannels without multiplexing. The output is only digital, 80 bits per event. The rest of the electronics only has to transfer the data to the computer. The coincidence sorting is done in firmware. The readout electronics will scale to many tens of thousands of channels.
The electronics will be described, and we will present the performance of the readout in a test PET scanner setup with 2'048 channels. We will also present a comparison of the performance of our ASIC with SiPMs form different manufacturers
First results with a new version of he ASIC will also be presented.

Primary author: S. TAVERNIER, VRIJE UNIVERSITEIT BRUSSEL (BE) (Vrije Universiteit Brussel (BE))

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Presenter: S. TAVERNIER, VRIJE UNIVERSITEIT BRUSSEL (BE) (Vrije Universiteit Brussel (BE))

Session Classification: New Technologies

Contribution ID: **32** Type: **not specified**

Welcome and introduction

Sunday, 1 May 2016 14:00 (15 minutes)

Presenter: P. LECOQ, CERN (CERN)

Session Classification: Precision Medicine –vision, concept, stakeholders and plans for implementation

Contribution ID: **33** Type: **Oral**

A Flagship project for Europe? Towards 10ps Time-of-Flight PET for a 10-fold sensitivity increase and equivalent dose reduction

Wednesday, 4 May 2016 09:00 (30 minutes)

Results achieved by European researchers in recent years make it likely that the 100 ps TOFPET resolution barrier can be broken. Research to reach the 10ps limit is already supported by EU funded projects (ERC Advanced grant #338953 to one member of the consortium, COST action FAST #TD1401). On the same line another member of the consortium has been recently awarded an ERC Advanced grant to improve PET sensitivity, benefiting from this ultimate TOF performance to reconstruct the Compton event, otherwise discarded in the reconstruction algorithms. Moreover, new data processing and image reconstruction algorithms are required to optimally exploit the additional information acquired with such systems.

Summary

In the USA, the Explorer project by UC Davis, Berkeley Lab, and U Penn, funded by a $15.5 million, 5-year NIH Transformative Research Award, aims at the world's first total-body PET/CT scanner with a 2 m long axial length, so as to demonstrate the clinical value of a ˜40-fold improved system sensitivity, which can in particular be used to reduce radiotracer dose and scan times. However, the system concept is intrinsically expensive as it is based on a multiplication of existing scintillation detector technology (in particular a 10-fold increase in the total detector area by extending the scanner length by the same factor).

A different way to achieve the same improvement in effective sensitivity is to push time-of-flight (TOF) resolution to the ˜10 ps level, representing a ˜40-fold improvement over the current state-of-the-art. In fact, this would cause a paradigm shift in in vivo molecular imaging by enabling direct 3D event localization, eliminating the need for statistical image reconstruction. Another approach is to not restrict the PET reconstruction to photoelectric events but to use also the information carried out by Compton events.

Results achieved by European researchers in recent years make it likely that the 100 ps time resolution barrier can be broken. Research to reach the 10ps limit is already supported by EU funded projects (ERC Advanced grant #338953 to one member of the consortium, COST action FAST #TD1401). On the same line another member of the consortium has been recently awarded an ERC Advanced grant to improve PET sensitivity, benefiting from this ultimate TOF performance to reconstruct the Compton event, otherwise discarded in the reconstruction algorithms. Moreover, new data processing and image reconstruction algorithms are required to optimally exploit the additional information acquired with such systems.

Primary author: P. LECOQ, CERN (Lecoq)

Presenter: P. LECOQ, CERN (Lecoq)

Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **34** Type: **not specified**

Personalised Medicine in EU

Sunday, 1 May 2016 14:15 (45 minutes)

Presenter: R. DRAGHIA-AKLI, EU-DG RESEARCH (EU-DG Research)

Session Classification: Precision Medicine –vision, concept, stakeholders and plans for implementation

Contribution ID: **35** Type: **not specified**

Precision Medicine and Advanced Imaging

Sunday, 1 May 2016 15:00 (45 minutes)

Presenter: R. PETTIGREW, NIBIB-NIH, USA

Session Classification: Precision Medicine –vision, concept, stakeholders and plans for implementation

Contribution ID: **36** Type: **not specified**

Joining forces for personalised medicine - Innovative Medicines Initiative, a safe harbour for cross-sector collaboration

Sunday, 1 May 2016 16:15 (45 minutes)

Presenter: M. CHLEBUS, EFPIA BRUSSELS

Session Classification: Precision Medicine –vision, concept, stakeholders and plans for implementation

Contribution ID: **37** Type: **not specified**

Precision Surgery with a novel radio-guided surgery

Sunday, 1 May 2016 17:50 (20 minutes)

Presenter: G. TRAINI, SAPIENZA UNIV. ROMA

Session Classification: Imaging for minimizing interventions

Contribution ID: **38** Type: **not specified**

Robotics and Augmented Reality for Patient and Process Specific Imaging and Visualization

Sunday, 1 May 2016 18:10 (20 minutes)

Presenter: N. NAVAB, TU MÜNICH

Session Classification: Imaging for minimizing interventions

Contribution ID: **39** Type: **not specified**

Theranostics: a key component of personalised medicine

Monday, 2 May 2016 08:30 (30 minutes)

Presenter: O. RATIB, HUGE, GENEVA

Session Classification: Theranostics

Contribution ID: **40** Type: **not specified**

Machine Learning: recent developments and future impact on medical science and technology

Monday, 2 May 2016 11:20 (30 minutes)

Presenter: N. NAVAB, TU MÜNICH

Session Classification: Data Mining

Contribution ID: **42** Type: **not specified**

Multi-parametric multi-modality imaging for prognostic and predictive modeling in oncology

Monday, 2 May 2016 12:10 (20 minutes)

Presenter: D. VISVIKIS, INSERM FRANCE

Session Classification: Data Mining

Contribution ID: **43** Type: **not specified**

MINDVIEW open session, ctn'd

Monday, 2 May 2016 17:40 (1 hour)

Presenter: J.M. BENLLOCH, I3M VALENCIA

Session Classification: Brain (including open MINDVIEW session)

Contribution ID: **44** Type: **not specified**

Trends in clinical hybrid imaging and impact on precision medicine

Tuesday, 3 May 2016 09:30 (30 minutes)

Presenter: C. LEVIN, STANFORD, USA

Session Classification: Overview Molecular Imaging Technologies

Contribution ID: **45** Type: **not specified**

The EXPLORER Total-Body PET Project

Wednesday, 4 May 2016 08:30 (30 minutes)

Presenter: W.W. MOSES, LBNL, BERKELEY, USA

Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **46** Type: **not specified**

Routes towards 10ps in time-of-flight PET

Wednesday, 4 May 2016 10:20 (20 minutes)

Presenter: S. GUNDACKER, CERN

Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **47** Type: **Oral**

A cost-effective, scalable approach to high-resolution, sub-100 ps TOF-PET

Wednesday, 4 May 2016 11:20 (20 minutes)

There remains huge untapped potential for PET in the research, diagnosis and treatment of oncological, neurological, cardiovascular, infectious, and inflammatory diseases. However, to transform PET into a cost-effective tool for personalized medicine in a wide range of clinical applications, we must reduce the radiation dose (currently 5-25 mSv), scan time (currently > 10 minutes), and costs per patient (currently > 1000 €), all by an order of magnitude, as well as improve the compatibility with other modalities to enable multi-parametric data acquisition. Technologically, this translates into a need for more than 10-fold increased sensitivity, without sacrificing other crucial system parameters such as spatial and energy resolution.

In the US, the $15.5 million Explorer project aims at the world's first total-body PET/CT scanner with a 2 m long axial length, to demonstrate the clinical value of a ˜40-fold improved system sensitivity. While major scientific breakthrough are expected from this project, the system concept is intrinsically expensive as it is based on multiplication of existing detector technology.

A different way to improve effective sensitivity is to push time-of-flight (TOF) resolution to less than ˜100 picoseconds, ultimately to ˜10 ps. Results achieved by European researchers in recent years make it likely that high-resolution TOF-PET imaging with sub-100 ps time resolution can be demonstrated within the coming years [1-3]. In particular, the so-called monolithic scintillator concept shows how timing information can be extracted optimally from the spatio-temporal distribution of the optical signal produced upon the interaction of a gamma photon inside a transparent material [4,5].

Sub-150 ps timing in combination with near-1 mm spatial resolution has already been demonstrated in a simple, scalable, and cost-effective monolithic scintillator detector based on the widely available scintillator LYSO:Ce and digital silicon photomultipliers. Experimental evidence of the clinical imaging performance of this detector as well as further steps towards sub-100 ps clinical TOF-PET imaging will be discussed at the conference.

References

[1] DR Schaart et al, LaBr3:Ce and SiPMs for time-of-flight PET: achieving 100 ps coincidence resolving time, Phys Med Biol 55 (2010) N179

[2] S Seifert et al, A Comprehensive Model to Predict the Timing Resolution of SiPM-Based Scintillation Detectors: Theory and Experimental Validation, Ieee T Nucl Sci 59 (2012) 190

[3] MV Nemallapudi, S Gundacker, P Lecoq, E Auffray, A Ferri, A Gola, C Piemonte, Sub-100 ps coincidence time resolution for positron emission tomography with LSO:Ce codoped with Ca, Phys Med Biol 60 (2015) 4635

[4] S Seifert, G van der Lei, HT van Dam, DR Schaart, First characterization of a digital SiPM based time-of-flight PET detector with 1 mm spatial resolution, Phys Med Biol 58 (2013) 3061

[5] HT van Dam, G Borghi, S Seifert, DR Schaart, Sub-200 ps CRT in monolithic scintillator PET detectors using digital SiPM arrays and maximum likelihood interaction time estimation, Phys Med Biol 58 (2013) 3243

Summary

Presenter: D. SCHAART, TUDELFT

Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **48** Type: **Oral**

Theranostics: a key component of personalized medicine

The development of new techniques combining molecular imaging with targeted therapies contributed to the emergence of the concept of "theranostics" in clinical applications. Such an approach used for example in the diagnosis and treatment of neuroendocrine tumors with a molecule (or edotreotide DOTATOC) allows to specifically label the tumor cells for imaging by labeling 68Ga followed by targeted therapy by the same molecule labeled 177Lu transmitter of alpha particles for the destruction of targeted cells. This technique led to the release on the market of a commercial product in record time thanks to the exceptional results of clinical studies that showed a highly significant superiority of this technique over conventional treatments.

Several similar approaches are being validated in other oncological applications. A peptide specific surface antigen of prostate cells (PSMA) identifies the tumor foci and metastasis of prostate carcinomas and potentially destroy by marking of the same molecule of 177Lu. Currently clinically validated this technique can dramatically change treatment approaches for prostate cancer.

With the combination of therapy and imaging, it becomes possible to accurately target patient's markers prdicting the response to treatment. This is the mind-founded principle of personalized medicine. This personalized approach is more expensive than conventional treatments, it is necessary to point with certainty which patients are likely to benefit and show a significant response. This is what constitutes what is referred now as high-precision medicine.

The development of molecular imaging services to the concept of personalized medicine based on highly specialized technical diagnostics and molecular therapy represents one of the priorities of our vision for the future of molecular imaging.

Primary author: Prof. RATIB, Osman (University Hospital of Geneva)

Presenter: Prof. RATIB, Osman (University Hospital of Geneva)

Contribution ID: **50** Type: **not specified**

New approaches to boost PET sytem photon sensitivity

Tuesday, 3 May 2016 17:30 (20 minutes)

Presenter: C. LEVIN, STANFORD, USA

Session Classification: New Technologies

Contribution ID: **51** Type: **Oral**

Routes towards 10ps in time-of-flight PET

Time-of-flight (TOF) is able to improve the noise equivalent count rate (NEC) of positron emission tomography (PET) drastically. For instance a TOF resolution of 100ps would represent a NEC improvement of about a factor 25 for a whole body PET system. With the image signal to noise ratio remaining constant, this already would lead to the possibility of a 5 times faster scanning time or 5 times less dose applied to the patient. Ultimately a TOF resolution of 10ps would not only improve the NEC by a further order of magnitude but would also allow for direct image reconstruction without computation delays. Furthermore, the standard circular PET geometry would not be a necessity anymore, allowing for efficient endoscopic PET probes. These examples show how 10ps in TOF-PET, very likely, will lead to a paradigm shift in PET examination routines. In this contribution state-of-the-art time resolutions achievable with current lab-systems will be shown and their limits in terms of resolving time explicitly discussed. Further, it will be shown how 10ps in TOF-PET can be achieved and practical examples of new materials and techniques allowing for this ambitious goal are given.

Primary author: GUNDACKER, Stefan (CERN)

Co-authors: AUFFRAY HILLEMANNS, Etiennette (CERN); LECOQ, Paul Rene Michel

Presenter: GUNDACKER, Stefan (CERN)

Contribution ID: **52** Type: **Oral**

Big data management - From CERN/LHC to personalised medicine

Monday, 2 May 2016 11:50 (20 minutes)

The transformations that have taken place in Information and Communication Technology in the past 20 years have given rise to a new form of scientific research paradigm where data-intensive, large-scale projects combine experiment, theory and computing to address fundamental questions about ourselves and our universe. The large-scale computing and data analysis infrastructure set up by the High Energy Physics community to support the research of the LHC Experiments at CERN and in the hundreds of collaborating facilities worldwide is one of the foremost examples of this paradigm.

Today the HEP community is not anymore the only place where increasingly large amounts of data are produced. Biomedical and healthcare research and practice could benefit from a broader use of big data analysis and simulation platforms. However, the biomedical domain requires a new focus on careful governance and use of data and information in the respect of the social and human value of such data and the design and deployment of collaborative frameworks where medical research, clinical practice and modern information technologies can constructively interact with each other to deliver personalized care.

This talk briefly describes the state of the art of large-scale data analytics platforms as used in the HEP community and the ongoing work to adapt and extend such platforms for the benefit of medical applications.

Primary author: DI MEGLIO, Alberto (CERN)

Presenter: DI MEGLIO, Alberto (CERN)

Session Classification: Data Mining

Contribution ID: **53** Type: **not specified**

Medical Applications at CERN

Sunday, 1 May 2016 17:00 (20 minutes)

Presenter: M. CIRILLI, CERN

Session Classification: Precision Medicine –vision, concept, stakeholders and plans for implementation

Contribution ID: **56** Type: **not specified**

Technology Transfer at CERN

Monday, 2 May 2016 15:20 (20 minutes)

Presenter: M. CIRILLI, CERN

Session Classification: Industry

Contribution ID: **61** Type: **Oral**

Nanotechnologies in diagnostic and theranostic applications

Monday, 2 May 2016 11:10 (10 minutes)

Nanomaterials based mainly on polymer nanostructures, magnetic nanoparticles and carbon nanoallotropes represent challenging solution in various diagnostic, therapeutic and theranostic applications [1-6]. The present contribution explores the use of superparamagnetic nanoparticles as contrast agents in MRI diagnostics and theranostics involving the results of clinical trials. Various types of polymer and magnetic carriers used in targeted drug delivery are compared in terms of the drug loading and drug release mechanisms. The possibilities of carbon nanostructures (nanodiamonds, carbon nanotubes, graphene derivatives, carbon dots) and their hybrids in photoluminescent imaging, combined magneto-fluorescent imaging and drug delivery are also summarized. The specific attention is focused on photoluminescent carbon dots, control of their optical properties, toxicity and biodistribution. Their use for selective cell labeling, photoacoustic imaging, photodynamic therapy and targeted drug delivery is analyzed taking into account their emission characteristics, surface chemistry and structural properties.

Summary

Nanomaterials based mainly on polymer nanostructures, magnetic nanoparticles and carbon nanoallotropes represent challenging solution in various diagnostic, therapeutic and theranostic applications [1-6]. The present contribution explores the use of superparamagnetic nanoparticles as contrast agents in MRI diagnostics and theranostics involving the results of clinical trials. Various types of polymer and magnetic carriers used in targeted drug delivery are compared in terms of the drug loading and drug release mechanisms. The possibilities of carbon nanostructures (nanodiamonds, carbon nanotubes, graphene derivatives, carbon dots) and their hybrids in photoluminescent imaging, combined magneto-fluorescent imaging and drug delivery are also summarized. The specific attention is focused on photoluminescent carbon dots, control of their optical properties, toxicity and biodistribution. Their use for selective cell labeling, photoacoustic imaging, photodynamic therapy and targeted drug delivery is analyzed taking into account their emission characteristics, surface chemistry and structural properties.

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Session Classification: Theranostics

Contribution ID: **63** Type: **not specified**

The EXPLORER Total-Body PET Project

Positron emission tomography (PET) is the highest sensitivity technique available for imaging the entire human body. Because the axial field-of-view of state-of-the-art clinical scanners is ˜25 cm, they surround only 2% solid angle of an object in the camera's field of view (on average) and so are far from the full sensitivity potential. The goal of the EXPLORER project is to develop a total-body PET scanner for biomedical research whose 2 meter axial field-of-view pushes the limits of sensitivity and opens up a wealth of new possibilities for using PET to study health and disease. In addition to the geometric increase, another 2x effective sensitivity gain will be obtained by adding time-of-flight capability. The project is a multi-institutional collaboration funded by a NIH Transformative Research Award, and is intended to develop a unique and high performance research instrument for the entire nuclear medical imaging community.

The detector design is based on off-the-shelf, conventional LSO/LYSO- based block detectors used in high-performance commercial PET systems. Design goals include <4 mm spatial resolution, <400 ps timing resolution, <12% energy resolution, 76 cm ring diameter, and 200 cm axial field of view. GATE Monte Carlo simulations suggest noise-equivalent count improvements of ˜40x for total- body imaging and 10x for single organ imaging, compared with current clinical PET scanners. The high efficiency along with the desire to image injected doses up to 30 mCi (1100 MBq) place challenging throughput requirements on the electronics. Thus, while real-time coincidence processing will be supported for lower injected doses, the system will also support singles mode data collection using a parallel architecture with coincidences formed offline in software.

We believe that the ˜40x improvement in sensitivity of this camera, along with its ability to image the entire body simultaneously, will enable biomedical applications that are currently impossible. With the same PET protocols currently used (i.e., same radiotracer, injected dose, and imaging time), the signal to noise ratio in the reconstructed images should improve by a factor of >6. This improved SNR could be used to reconstruct images at higher resolution, enabling detection of smaller lesions / lower grade disease, and to reduce the statistical errors to enable more accurate kinetic modeling. Obtaining good quality images with 40x less activity would enable protocols that extend five additional half lives post-injection—3 additional hours for ^{11}C imaging and 16 additional hours for ^{18}F imaging. Much shorter scans also become possible—a full body scan that presently takes ˜20 minutes (8 bed positions at 2–3 minutes per position) could be done in <30 seconds. Finally, the injected dose could be reduced 40x, yielding a radiation exposure similar to a round-trip trans-oceanic airline flight. This would enable longitudinal studies and possibly expand the use of PET into more radiation-sensitive populations.

Summary

Primary author: MOSES, William (LBNL)

Co-authors: Prof. KARP, Joel (U Pennsylvania); Dr PRICE, Patricia (Imperial College, London); Prof. BADAWI, Ramsey (UC Davis); Prof. CHERRY, Simon (UC Davis); Dr JONES, Terry (UC Davis)

Presenter: MOSES, William (LBNL)

Session Classification: New challenges (in collaboration with ERC Advanced Grant TICAL #338953 and COST Action Fast TD1401)

Contribution ID: **64** Type: **Oral**

Full-beam PET monitoring in particle therapy with the INSIDE scanner: first measurements

Tuesday, 3 May 2016 15:00 (20 minutes)

In-beam PET is one of the options for real-time monitoring of the Bragg peak depth in hadron-therapy sessions, which would allow hypofractionation and the treatment of multiple lesions.
The INSIDE collaboration has recently completed the building of a PET scanner, featuring two 10x25 cm2 planar heads at a default distance of 25 cm from the iso-centre, that will soon be complemented by a tracker for prompt charged particles and will operate at the CNAO synchrotron facility (Pavia, Italy).
Testing with monoenergetic proton beams of 68, 72, 77 and 105 MeV targeted to PMMA phantoms placed inside the FOV was performed at the CNAO synchrotron, in order to fine-tune the detector performance in controlled conditions.
Data acquisition was successful in both in-spill (1s) and inter-spill (4s) modality, with a Coincidence Time Resolution (CTR), measured without a fine time calibration, of about 480 ps.
The inter-spill image profiles along the beam axis for the 68 and 72 MeV beams show the characteristic distal activity fall-off, with a measured proton range difference in PMMA (3.6+-0.3 mm) that is compatible with the expected value (3.64 mm) within few hundred microns. Similarly, for 77 and 105 MeV beams delivered sequentially on the same phantom, the measured distance is (30.2+-0.3) mm, to be compared to an expected value of 31.2 mm. Submillimetric bias induced by disuniformity in the detector efficiency, geometrical acceptance or reconstruction software the are being investigated with simulated data.
When comparing inter-spill and in-spill data, it is observed that the fall-off slope is steeper (as expected) and shorter (about 2 mm) for inter-spill data,.
The effect, likely caused by pair production far from the target followed by annihilation, is being investigated, since its contribution is relevant when an absolute measurement is required. In order to reject the neutron-induced contribution, a filter that exploits the 700 μs bunch structure during the beam delivery was developed.
Data acquisition with carbon beam on PMMA was successfully tested at the beginning of April 2016.
Standard proton-based treatment plans were also delivered on PMMA phantoms, reconstructed and successfully compared to previously simulated data.
In order to start testing with patients, the integration of CT and PET data is being completed, so as to be able to generate simulated profiles, which will be compared to data in real-time, during the treatment delivery.

Summary

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