2nd Summer School on INtelligent signal processing for FrontIEr Research and Industry

Monday 14 July 2014 - Friday 25 July

2014 University Paris-Diderot, Paris,

France

Book of Abstracts

Contents

Tuesday, 15 July 2014

- **09:00 - 13:00 First Morning Session**
  - **09:15 - 09:45 Introduction to the Paris-Diderot University, UnivESarth LabEx and APC Lab: Present and future Educational and Research Objectives *30'* (BioPark Auditorium)**

    Campus in the City: Pierre Binetruy, former Director of the APC Laboratory and instrumental to its creation and development over these last 10 years, is currently co-director of the UnivEarthS LabEx and coordinator of the french participation in the LISA gravitational waves project.

    Speaker: Prof. Pierre Binetruy (APC-University Paris-Diderot)

  - **09:45 - 11:00 About a few Challenges for Signal Processing in emission and transmission tomography *1h15'* (BioPark Auditorium)**

    The use of positron emitting radioisotopes for the localization of brain tumours was first proposed by Wrenn et al. in Science in 1951. Since the construction of the “hair dryer” in the 60s in Brookhaven and the development of X-ray CT in the 70s, detector development and signal treatment have achieved continuous progress to improve the quality and accuracy of medical images. Basics of emission and transmission tomography will be presented, from the detection of annihilation photon pairs in coincidence to building the 3D X-Ray Transform of a volume down to its inversion while processing 3D PET reconstruction. Trends and current challenges in detector development and signal treatment will be addressed in the field to positron emission tomography (PET), X-ray CT, and the combination of different modalities to image simultaneously anatomy and metabolic function of living tissues.

    Speaker: Prof. Christian Morel (University of Aix-Marseille/ imXGam-CPPM/CNRS (FR))

  - **11:30 - 13:00 New Challenges for Signal Processing for HEP experiments *1h30'* (BioPark Auditorium)**

    The lecture will reflect on the present situation in particle physics experiments, and how we reached the current state of the art, before attempting to identify the significant areas where progress is expected in the coming years, and the associated challenges to be overcome.

    Speaker: Prof. Geoffrey Hall (Imperial College Sci., Tech. & Med. (GB))

- **14:00 - 16:45 First Labs session *2h45'*(BioPark Auditorium)**

  The first session on July 15 will be devoted to the presentation of all the 11 Computing Labs and 10 Practical Labs by their authors. This will be a plenary session held in the BioPark Auditorium as the other plenary sessions.

The participants will have to choose the “Menu of Labs” they want to perform. Students must choose sessions that do not correspond to their expertise and/or current work.

The organizers will prepare accordingly the overall work plan and schedule for the whole duration of the school. The first parallel sessions will thus start on July 16.

- **17:15 - 18:30 Overview of Cosmology with SKA, the Square Kilometer Array *1h15'* (BioPark Auditorium)**

SKA is a new technology radio-telescope array, about two orders of magnitude more sensitive and rapid in sky surveys than present instruments. It will be able to detect and measure the redshifts of billions of galaxies at the redshifts up to z=2, to probe through baryonic acoustic oscillations the nature of dark energy; it will probe the dark age of the universe, just after recombination, and during the epoch of reionisation (z=6-15); it will be the unique instrument to map the atomic gas in high redshift galaxies, and determine the amount and distribution of dark matter in the early universe. We will discuss these exciting perspectives, which will realize around 2020.

Speaker: Prof. Francoise Combes (Observatoire de Paris & LERMA (FR))

Wednesday, 16 July 2014

- **09:00 - 13:00 Second Morning Session**

  This session is dedicated to a series of lectures on Very Deep SubMicron CMOS Technologies, 3D technologies and New Packaging Technologies

  Location: BioPark Auditorium

  - **09:00 Introduction to Very Deep Sub Micron CMOS technologies: the 65nm CMOS technology for mixed mode analog-digital circuits *1h0'***

    Future upgrades of detector systems for high energy physics experiments at high-luminosity colliders and for photon science at advanced X-ray sources set unprecedented and extremely challenging requirements to the readout electronics. In the case of pixel detectors, current designs of front-end microelectronic systems foresee the integration of very complex analog and digital functions inside small readout cells, and have to ensure the capability of handling huge data rates and of keeping adequate performance at extremely high radiation levels. The progress of industrial microelectronic technologies has to be exploited to the purpose of complying with these aggressive designs ideas for front-end integrated circuits at future experiments. Recently, the community of microelectronic designers has focused its activity on the 65 nm CMOS generation as a promising technology for these applications. This lecture provides a review of the potential advantages and challenges associated to the design of low noise, high speed and rad-hard mixed-signal circuits in such a process for pixel detectors in the fields of high energy physics and photon science.

    Speaker: Prof. Valerio Re (INFN and University of Bergamo (IT))

  - **10:00 Introduction to Very Deep SubMicron CMOS Technologies: FD-SOI technology for digital systems *1h0'***

    FDSOI is now considered as a realistic solution to pursue the device scaling thanks to reduced short channel effects, excellent mismatch properties, simplified planar manufacturing process versus 3D finFet technology, the capitalization of existing design techniques and then power saving. This lecture gives an overview of the FDSOI technology scaling from 28nm platform down to the 10nm node, actually at the research and development step. Performance and technological integration steps are described for each node and the additional boosters added from node to node are highlighted. This work is the results of fruitful collaboration with academic laboratories, industrial alliances, European projects and Phd student's contributions.

    Speaker: Dr. Claire Fenouillet-Beranger (CEA-LETI (FR))

  - **11:30 3D and Novel Packaging technologies *45'***

    Speaker: Dr. Robert Patti (Tezzaron Semiconductor (USA))

- **12:15 3D technologies: new area for packaging and IC development *45'***

  With the today's mass production of 3D image sensors, and the first announcements of high volume production, 3D technologies are definitely entering a new era, moving from technological hype to an applications-pull phase with two paradigms: on one hand, the demand of signal routing will become even stronger with the extreme CMOS nodes while on the other hand the heterogeneous integration of multi-functionalities will require flexibility and specific packaging. This talk will illustrate how 3D integration radically changes the electronics devices packaging with respect to these challenges.

  The first high density interposers (Xilinx, Altera or Shinko/LETI) are now commercially emerging, especially in the high-end segments like data centers and servers. They encompass multi fine pitch wiring and bumps on front side and TSV middle in a 2.5D technology. The key remaining technical challenges are today identified: large module (>30x30mm2) stress management, CTE mismatch, thermal management and test and will be discussed with an inventory of the potentials solutions. Disruptive 3DIC stacking is potentially offering unmatched performances and scalability in both niche and consumers markets but is facing difficult integration challenges in terms of signal integrity, thermal/mechanical managements and reliability. Specific applications oriented technological solutions are today required and will be reviewed in this talk. We will discuss how microelectronic for particle physics and imaging is about to become one of the main driver and recipient of 3D integration.

  Speaker: Dr. Yann Lamy (CEA-LETI (FR))

- **14:00 - 16:45 Labs session**

  The parallel sessions from 2 to 4h45 are divided into three categories: i) the computing Labs, ii) the Practical Labs and iii) the dedicated master-classes. These sessions will be held from July 16 to 25 (included).
  The participants will follow the programme of parallel sessions of their choice (see introductory session on July 15 and the booklet of Computing and Practical Labs posted as "paper" in this INDICO page).
  The dedicated master-classes will allow a Q&A session with the lecturers of the day as a third option.
  The location of rooms and Labs all located in the Physics Department, Building Condorcet, will be specified on July 15.

  Location:Physics Department, Building Condorcet, Universite Paris-Diderot

- **17:15 - 18:30 New Challenges in Signal Processing in Astrophysics: the SKA case *1h15'* (BioPark Auditorium)**

  Signal processing and communications are driving the latest generation of radio telescopes with major developments taking place for use on the Square Kilometre Array, SKA, the next generation low frequency radio telescope. The data rates and processing performance that can be achieved with currently available components means that concepts from the earlier days of radio astronomy, phased arrays, can be used at higher frequencies, larger bandwidths and higher numbers of beams. Indeed it has been argued that the use of dishes as a mechanical beam former only gained strong acceptance to mitigate the processing load from phased

array technology. The balance is changing and benefits in both performance and cost can be realised.

In this talk we will mostly consider the signal processing implementation and control for very large phased arrays consisting of hundreds if thousands of antennas or even millions of antennas. This can use current technology for the initial deployments. These systems are very large extending to hundreds of racks with thousands of signal processing modules that link through high-speed, but commercially available data networking devices. There are major challenges to mitigate power consumption and make the system maintainable.

Speaker: Dr. Andrew Faulkner (Cambridge (UK))

Thursday, 17 July 2014

- **09:00 - 13:00 Third Morning Session**

  This session will be dedicated to a series of lectures on the Front End Signal Processing for the calorimeters (for both Astrophysics experiments and upgrades at LHC for High Luminosity). It will include the Very Front End signal processing, the on-detector real time selection and Level 1 triggering as well as the various overall trigger strategies.

  Location: BioPark Auditorium

  - **09:00 High-level on-detector Signal Processing on Calorimeters in HEP: needs and challenges *1h0'***

    Speaker: Dr. Francesco Lanni (Brookhaven National Laboratory (USA))

  - **10:00 New calorimeters for Space experiments: Physics needs and technological challenges *1h0'***

    Direct measurements of charged cosmic radiation with instruments in Low Earth Orbit (LEO), or flying on balloons above the atmosphere, require the identification of the incident particle, the measurement of its energy and possibly the determination of its sign-of-charge. The latter requires a magnetic spectrometer, also providing an independent measurement of momentum. However, magnetic deflection in space experiments is at present limited to values of the Maximum Detectable Rigidity (MDR) hardly exceeding a few TV. Advanced calorimetric techniques are, at present, the only way to measure charged and neutral radiation at higher energies in the multi-TeV range. Despite their mass limitation, calorimeters may achieve a large geometric factor and provide an adequate proton background rejection factor, taking advantage of advanced imaging capabilities. In this lecture, after a brief introduction on electromagnetic and hadronic calorimetry, the state-of-the-art in the field will be discussed.

    Speakers: Prof. Oscar Adriani (Dipartimento di Fisica Universita di Firenze (IT)), Prof. Pier Simone Marrocchesi (Universita degli studi di Siena (IT))

  - **11:30 New trends and different strategies on Triggering in High Energy Physics *1h30'***

    The lecture will compare the triggering schemes in use in the CMS, ATLAS and LHCb experiments, and their future plans, and discuss the advantages and challenges of the different approaches.

    Speaker: Prof. Geoffrey Hall (Imperial College Sci., Tech. & Med. (GB))

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Towards the next generation Neutrino Observatory: Physics & Technological Challenges**

Convener: TBA

Location: BioPark Auditorium

- **20:00 - 22:00 Public Lecture 1: The Higgs Boson and the Two Infinities -- Le Boson de Higgs et les Deux Infinis *2h0'* (Amphitheater BUFFON (University PARIS-DIDEROT, Paris 13eme))**

  This Public Event will be given in english by Michel SPIRO, Physicist, Conseiller Scientifique au Commissariat a l'Energie Atomique, Former President of CERN Council as well as Professor at the Ecole Polytechnique.
  The Public lecture will be given in the Amphitheater BUFFON in the University PARIS DIDEROT Campus (Paris 13) and will be film recorded.
  Cette Presentation Grand Public sera donne par Michel SPIRO, Physicien, Conseiller Scientifique au Commissariat a l'Energie Atomique, precedent President du Conseil du CERN et Professeur a l'Ecole Polytechnique. Michel Spiro est auteur de plusieurs ouvrages scientifiques accessibles a un large public et a donne de nombreuses conferences ces dernieres annees pour differents publics y inclus large audience.

  Speaker: Prof. Michel Spiro (CEA/IRFU,Centre d'etude de Saclay Gif-sur-Yvette (FR))

Friday, 18 July 2014

- ## 09:00 - 13:00 Fourth Morning Session

  This session will be dedicated to a series of lectures on the intelligent front signal processing of the tracking devices. This will include tracking devices based on Silicon strip detectors and Scintillating Fibers read out by SiPMs as developed for example for High Energy Astrophysics and LHC experiments (for the High Luminosity upgrades) and Astrophysics High Energy experiments.

  Location: BioPark Auditorium

  - ### 09:00 On-detector Signal Processing for Large area tracking system based on Silicon strips *1h15'*

    The lecture will give an overview of Front-end electronics for Silicon Strip detectors, with the following broad-brush program: introduction to Silicon sensors in particle physics; signal shaping and sampling; front-end noise; overview of recent large-scale Silicon strip detectors; challenges and design of future detector.

    Speaker: Dr. Stefano Mersi (CERN (CH))

  - ### 10:15 Real time (Level-1) Track Triggering: Technological challenges *1h0'*

    The lecture will mainly focus on future application of real-time tracking, with the following broad-brush program: introduction to real-time signal processing (applications and techniques); examples of real-time processing in past large-scale HEP experiments; challenges and design of real-time tracking in ATLAS and CMS experiments

    Speaker: Dr. Stefano Mersi (CERN (CH))

  - ### 11:45 Large Area tracking systems based on Scintillating Fibers read out by SiPM's *1h15'*

    This session will cover both the LHCb case in High Energy Physics and the Astrophysics High Energy application. Cintillating plastic fibres have been used for more than 30 years in tracking detectors. The advent of a new type of photodetector, the so-called Silicon Photomultiplier (SiPM), allows for new applications of the elegant and flexible SciFi technology. In the context of a major upgrade program of the LHCb detector, to be operational after the LHC shutdown LS2, R&D is being performed on a large scale SciFi detector. With more than 300 m2 of detector surface, it is conceived to replace the currently installed Inner (Silicon micro-strips) and Outer Trackers (straw tubes) by a single technology. The talk will give a short summary of the scintillating fibre technology and revisit some of the past fibre detectors (UA2, Chorus, D0). It will then discuss the design of the LHCb SciFi tracker and focus on some topics of the current R&D program.

    Speaker: Dr. Christian Joram (CERN (CH))

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Physics Motivations for Level-1 track triggering at LHC and future HEP experiments *1h15'* (BioPark Auditorium)**

  The central mission of the High Luminosity LHC (HL- LHC) physics programme will include measuring the properties of the recently discovered Higgs boson and continued searches for New Physics beyond the Standard Model. Higher luminosity will extend the discovery mass reach, allow more sensitive searches for signatures of new physics, and enable studies of any newly found particles and their interactions.

  The very high luminosity and event pile-up environment of the HL-LHC makes this goal a major challenge for the necessary detector upgrades. Both ATLAS and CMS are pursuing a programme of trigger upgrades aimed at maintaining the present sensitivity for precision measurements of the properties of the new boson, as well as its ability to search for and characterize a broad range of possible new physics phenomena at the TeV scale, up to the highest luminosity of the HL-LHC upgrade. An integral part of this detector upgrade programme in the addition of a tracker trigger at the very early stage of event-selection.
  In this lecture I will outline the general core physics programme of the LHC (past, present, and future) and than discuss how a track trigger can help to successfully execute this ambitious physics programme

  Speaker: Dr. Oliver Buchmueller (Imperial College Sci., Tech. & Med. (GB))

Saturday, 19 July 2014

- ## 09:00 - 13:00 Fifth Morning Session

  This session will be dedicated to the Intelligent Pixels based tracking devices. The way novel semi-conductor technologies and advanced microelectronics allow a high-level of signal processing in pixel based devices both for fundamental research and applied developments will be shown

  Location: BioPark Auditorium

  - ### 09:00 How & why pixels are becoming more & more intelligent (FE & readout electronics): lecture 1 *1h0'*

    These two lectures will give an introduction to micropatterned semiconductors (esp. pixels) in general with the physics basis, charge collection, weighting fields including irradiation and the FE electronics up to CMOS pixels and the FE and R/O electronics.
    Speaker: Prof. Norbert Wermes (Universitaet Bonn (DE))

  - ### 10:00 How & Why Pixels are becoming more & more intelligent (FE & readout electronics): lecture 2 *1h0'*

    The lecture covers "basics" and "advancements" of pixel detectors. It includes the physics of the detection mechanism, sensor properties, signal development, resolution optimisation, bonding, radiation damage effects, sensors and R/O chip features, examples of current pixel detectors, new advances like DEPFET pixels and CMOS pixels and their PROs and CONs.

    Speaker: Prof. Norbert Wermes (Universitaet Bonn (DE))

  - ### 11:30 How and Why Pixels are becoming more and more intelligent (sensors-part1): lecture 3 *45'*

    Semiconductor Detectors have and are playing critical roles in many experiments from particle physics to astrophysics. I will describe how a silicon sensor works and the challenges posed by the high luminosity environment of the LHC and the HL-LHC. I will focus on the impact of pixel detectors and why they are essential for extracting physics and allowing precision measurements both at hadron and lepton colliders.

    Speaker: Prof. Daniela Bortoletto (Purdue University (USA) and Oxford (UK))

  - ### 12:15 Why and How Pixels are becoming more and more intelligent (sensors-Part2): lecture 4 *45'*

    Although most of the pixel intelligence is often found in the electronics, some important progress has been achieved in the sensors themselves, allowing for significant performance improvement.
    This lecture will focus on the most interesting elements of novelty that have characterized pixel sensors in the past few years, with emphasis on the device and technological aspects. In particular, sensors exploiting the third dimension in silicon (i.e., 3D sensors and active edge sensors) and sensors

with intrinsic signal amplification capabilities, based on avalanche multiplication (both in the linear and Geiger modes) will be addressed.

Speaker: Prof. Gian-Franco Dalla Betta (INFN and University of Trento (IT))

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Intelligent Pixels: The SOIPiX R&D programme and applications *1h15'***

Speaker:Prof. Eduardo Cortina Gil (Université catholique de Louvain (BE))

Monday, 21 July 2014

- **09:00 - 13:00 Sixth Morning Session**

  This session will be dedicated to the new technologies for data transmission available or in development in the Industrial Telecom World and of special interest for Fundamental and Applied research

  Location: BioPark Auditorium

  - **09:00 Silicon Photonics: Optical Modulation and Detection Part 1 *1h0'***

    Silicon is the mainstream material in the electronic industry and it is rapidly expanding its dominance into the field of photonics. Indeed, silicon photonics has been the subject of intense research activities in both industry and academia as a compelling technology paving the way for next generation of energy-efficient high-speed computing, information processing and communications systems. The trend is to use optics in intimate proximity to the electronic circuit, which implies a high level of optoelectronic integration. Over the last decade, the field of silicon photonics has advanced at a remarkable pace. Most applicative sectors have now included silicon photonics in their roadmaps as a key technology to be deployed over short, medium or long term horizons. This evolution towards silicon-based technologies is largely based on the vision that silicon provides a mature integration platform supported by the enormous existing CMOS manufacturing infrastructure which can be used to cost-effectively produce integrated optoelectronic circuits for a wide range of applications, including telecommunications, optical interconnects, medical screening, spectroscopy, and biological and chemical sensing…

    This lecture will introduce silicon photonics and the basics and recent results of silicon optical modulators and germanium photodetectors and their integrations in a common photonic/electronic platform. The outline of the talk will be:

    Silicon photonics: Motivation
    Optical modulator
    - Physical effects
    - Figures of merit
    - Experimental results

    Light detection
    - Material choice
    - Properties
    - Experimental results

    Conclusion and perspectives

    Speaker: Dr. Laurent Vivien (Si-Photonics Lab (Paris-Sud University/CNRS) FR)

  - **10:00 Silicon Photonics: Optical Modulation and Detection Part 2 *1h0'***

Speaker: Dr. Laurent Vivien (Si Photonics Lab (Paris-Sud University/CNRS) FR)

- **11:30 Data transmission needs and challenges for Frontier Particle Physics: The versatile link Project for LHC applications *50′***

  I will present the Versatile Link project for phase 1 LHC upgrades. The requirements and what is special about HEP applications will be discussed. The ASICs and the optoelectronics in the system will be described. Measurements of Single Event Upsets (SEU) will be presented as well as error correction schemes. A summary of extensive studies of fibre radiation damage will be given. Some ideas about Future developments for LHC phase 2 upgrade and beyond will be discussed.

  Speaker: Prof. Anthony Weidberg (University of Oxford (GB))

- **12:20 Data transmission Needs and Challenges for Frontier Particle Physics: Radiation Hardness and Longetivity *40′***

  Data transmission with optical links is discussed for applications in radiation hazard environment of hadron collider experiments. The usage of fiber is favorable for low-mass requirements and high bandwidth over long distance without cross-talk. Radiation damages to opto-electronics, including laser diodes, PIN diodes and driver chips are caused by ionizing dose and bulk damages. Passive light-guide and fiber materials may deteriorate with ionizing dose. The assemblies of opto-electronics and designs of light coupling to fibers are described for applications at Tevatron and LHC. Commercial high-speed devices are investigated. Radiation hardness of various types of laser diodes and PIN diodes are presented. Ageing tests and longevity are also discussed.

  Speaker: Prof. Suen Hou (Academia Sinica (TW))

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Overview lecture TBA**

- **20:00 - 22:00 Second Public Lecture**

  Location: Place in Paris to be announced

Tuesday, 22 July 2014

- **08:45 - 13:00 Seventh Morning Session**

  This session will be dedicated to some specific application of the modern data transmission technologies to the SKA case, the high luminosity LHC upgrades (ATLAS, CMS and LHCb) and the Novel Medical Imaging developments.

  Location: BioPark Auditorium

  - **09:00 New Trends in Silicon Photonics and Industrial Perspectives *1h0'***

    Speaker: Dr. Jean Louis Malinge

  - **10:00 Novel Data Transmission wireless based technology for Frontier Applications *1h15'***

    Wireless data transfer has revolutionized the consumer market for the last decade giving products equipped with transmitters and receiver for wireless data transfer. Wireless technology has features attractive for data transfer in future tracking detectors. The removal of wires and connectors for data links is certainly beneficial both for the material budget and the reliability of the system. Other advantages is the freedom of routing signals which today is particularly complicated when bringing the data the first 50 cm outside the tracker. With wireless links intelligence can be built into a tracker by introducing communication between tracking layers within a Region Of Interest which would allow the construction of track primitives in real time. I will in the lecture introduce the principle of wireless radio, the key components for the technology and modulation techniques used for transmitting data. I will give an overview of recent trends and development of wireless technology for transfer of data with high rate. I will then discuss the use of wireless technology for data transfer in tracking detectors in HEP and for applications outside HEP where large data rates are required.

    Speaker: Prof. Richard Brenner (Uppsala University (SE))

  - **11:45 Data transmission challenges and needs for Frontier Astrophysics: the SKA case *1h15'***

    Modern radio telescopes are formed using interconnected arrays of sensors. The networks form the backbone of these systems. This talk will describe the function the network plays in the modern radio telescope. It will outline the performance enhancements in existing telescopes, afforded by modern optical transmission techniques. It will look at the SKA, its networks, the requirements and the design options available for implementation of signal transmission for Frontier AstroPhysics.

    Speaker: Dr. Roshene Mc Cool (SKA Organisation, UK)

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Real time Signal Processing, Data Filtering and High-Degree on-device data processing in Medical Imaging *1h15'* (BioPark Auditorium)**

  Since the first devices with tomographic capabilities where developed in the early 70?s, medical imaging has become a cornerstone of modern medicine in many disciplines: oncology; traumatology, muskoskeletal disorders, etc. Currently imaging is critical for diagnosis and a better evaluation of the treatment effects. Since their conception, the temporal and spatial resolutions of many image modalities have increase to the point where we may state that information is no longer 3D but 4D. This fact has a significant impact on the data size that has to be processed, i.e. a 512x512x512 3D hearth image takes 512 MB of memory while 10.7 GB would be needed to store a full cycle with 20 frames. A 11 x 11 x 11 filter convolution requires ~179 billion multiply add operations in the 3D volume while a 11 x 11 x 11 x 11 filter would requires ~39 trillion multiply add operations in the 4D volume.

  The generation of such datasets has become possible thanks to the development of advanced data acquisition front-ends, incorporating advanced real time signal processing algorithms to transform the raw signal into an image, as well as to the development of new processing programmable architectures , optimized for image processing, which allow the implementation of sophisticated algorithms to reconstruct the image. As 3D and 4D processing is becoming common, the implementation of tasks such as image segmentation, registration, denoising or filtering, with an increasing demand of computational power, is progressively evolving towards the cloud.

  In this session we will evolve from the micro to the macro, starting with the architecture of modern field programmable electronics that have made possible the incorporation of complex real time digital signal processing as part of the acquisition front end, and ending with the architecture of modern computers and the increasing need for parallel programming to maximize the use of existing resources.

  Speaker: Dr. Pedro Guerra (Universidad Politecnica de Madrid (SP))

- **20:00 - 23:50 SCHOOL BANQUET**

  Location: The school banquet will take place in a boat that will be cruising along the Canal St Martin from Bastille till the Bassin de La Villette

Wednesday, 23 July 2014

- **08:45 - 13:00 Eighth Morning Session**

  This session will be dedicated to the Introduction to the most modern Massive Parallel Computing Tools, on both the hardware (Novel Processor Units and related technology challenges) and the software (modelling complex architecture, real time algorithms, optimization software tools etc.)

  Location: BioPark Auditorium

  - **09:00 Massive Parallel Computing: an overview panorama *1h30'***

    Speaker: tba

  - **10:15 Compressed Sensing and Sparsity *1h0'***

    During the last two decades, the concept of sparsity radically changed the way inverse problems are tackled. The first part of this course will introduce the very basics of the sparse modeling of signals and its use to solve standard inverse problems (e.g. denoising, deconvolution, component separation, inpainting, etc.), with a particular focus on imaging problems. Sparsity further gave birth to a revolutionary sampling theory, coined compressed sensing. The second part of this course will focus on the fundamentals of compressed sensing and its applications in various fields of physics: radio-interferometry, medical imaging and optics.

    Speaker: Dr. Julien Bobin (Comostat Group/CEA)

  - **11:30 Radio Aperture synthesis as a practical example of sparse signal reconstruction *50'***

    Interferometry has been widely used, especially at radio wavelengths, to indirectly reconstruct scientifically exploitable images of the sky through a discrete sampling of its Fourier transform. Formulated as an inverse problem, it constitutes a relevant application case for sparse reconstruction. In the first part of this course, we will introduce the basics of radioastronomy, radio interferometry and the classical methods of reconstruction/deconvolution of images from interferometric data.
    In the second part, we will show how sparse reconstruction methods are relevant for radio-interferometry by presenting the current implementations and results obtained (particularly, with inpainting).
    The successful application of these methods is a decisive challenge in the scope of the current and future "new generation" radio interferometers such as LOFAR, SKA or ALMA.

    Speaker: Dr. Julien Girard (CEA-AIM)

  - **12:20 Front-End Multiplexing *40'***

    As we have seen for the digital camera market and a resolution increasing to "megapixels", all the scientific and high-tech imagers (whatever the wave

length - from radio wave to X-ray) tends also to always increases the pixels number. So the constraints on front-end data processing increase too. A quasi-unavoidable solution to simplify integration of large arrays of pixels is the front-end multiplexing. Moreover, the integration of a "simple" and "efficient" multiplexing technique allows its integration on the same substrate of the focal plane array. For instance, CCD (Charge Coupled Device) technology has boost number of pixel in digital camera. Indeed, this is exactly a planar technology which integrates both the sensors and a front-end multiplexed readout. In this context, front-end multiplexing techniques will be reviewed for a better understanding of their advantages and their limits. Finally, the cases of astronomical instruments in the millimeter ranges will be discussed as examples.

Speaker: Dr. Damien Prele (APC Laboratory/CNRS)

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Massive Parallel Computing: The exascale Challenges *1h15'* (BioPark Auditorium)**

  The past few years have seen a growth in supercomputing flops faster than Moore's Law. Technology to increase compute density, ensure interconnect scaling and to improve resiliency have been enabling system designers to take on designs of greater complexity and scale. We are entering a phase in which the heterogeneity of systems and new use cases become strong drive for designing HW and SW architectures to serve the needs at the crossroad between HPC and Big data.

  Speaker: Dr. Marie Christine Sawley (Exascale Lab Center -INTEL)

- **19:30 - 21:00 SCHOOL RACE**

The "traditional INFIERI School race" will take place in Parc Montsouris.

Location: PARC MONTSOURIS in Paris

Thursday, 24 July 2014

- **09:00 - 13:00 Ninth Morning Session**

  This session will be dedicated to lectures on the needs and challenging applications of Massive Parallel Computing tools with some specific examples in Astrophysics, Particle Physics and Medical Imaging

  Location: BioPark Auditorium

  - **09:00 Massive Parallel Computing based on GPU: introductory lecture *1h0'***

    Speaker: Dr. Pierre Kestener (IRFU, CEA/Saclay (SEDI Division), FR)

  - **10:00 MPC needs and challenges in Particle Physics: The High Luminosity LHC case *1h0'***

    Speaker: Prof. Valerie Halyo (Princeton University (US))

  - **11:30 Massive Parallel Computing Needs and Challenges in Astrophysics: the SKA case *1h0'***

    In two previous lectures, the Square Kilometer Array has been described from the receiver and data transmission point of view. In this final SKA presentation, I will concentrate on the processing required once the massive data stream from the SKA receivers has been transported to the Science Data processor. Using experience gained from several of the pathfinder and precursor instruments, we show some of the bottlenecks encountered, and how we avoid these in the SKA. We show the challenges we face in designing a very high performance, extremely scalable system, that is part of an operational instrument, and compare this to conventional high performance computing facilities.

    Speaker: Chris Broekema (Netherlands Institute for Radio Astronomy, ASTRON)

- **14:00 - 16:45 Labs session**

- **17:15 - 18:30 Modelling Sophisticated Signal Processing Architectures in Astrophysics, HEP and Medical Imaging *1h15'* (BioPark Auditorium)**

  Implementing real-time signal processing applications requires a total mastery of the scheduling, the latency and the time spent at run time by any piece of code on the chip. Memory management is also a critical problem, as the amount of memory is always limited and garbage collector mechanisms forbidden, for they would take too much processing time and jeopardize the running applications. While real-time means “being able to compute data at the speed it is received”, this becomes harder to achieve as the throughput of data to be processed or the computing power required to process them increases.

The legacy way to implement these applications is to dedicate one chip to one specific application – or to a part of an application when it is too big to fit on a single chip – and to statically design the scheduling of that application on that particular chip.

As the technology improves, it allows more or larger applications to be executed on the same chip, which leads to new types of problems. On one hand, running several applications on the same chip gives rise to composability problems. On the other hand, as applications become bigger, they also become more complex and increasingly dynamic. With dynamicity, the behaviour of an application depends on the result of some computation performed on the received data. The good old days where we could use static allocation and predictable processing algorithms is over. With many-cores chips and dynamic applications we must think parallel, consider the implications of shared bandwidth, and be flexible with on-chip resources.

Another architectural step forward is the need for dedicated hardware in order to improve the computing power to power consumption ratio. Dedicated hardware means heterogeneous architectures and programming language diversity. Heterogeneity increases the complexity of the architecture which in turn makes the job of the programmer harder.

Another kind of chip is needed, as is a new approach to application design.

Thales has designed innovative heterogeneous architectures such as FlexTiles, containing a new kind of versatile FPGA matrix stacked on top of a many-core chip that has both general-purpose processors and digital signal processors. The architecture supports dynamic resource allocation and offers composability, as well as being self-monitoring. Thanks to our comprehensive toolchain, the FlexTiles architecture is easy to program.

This is an example of the holistic approach that is needed to design architectures, the next step being to use a toolchain to generate from the description of an application both a fine tuned architecture and the best mapping of that application on that particular architecture.

Speaker: Dr. Philippe Millet (THALES Research & Technology (FR))

Friday, 25 July 2014

- **09:00 - 13:00 Tenth Morning Session**

  This session will be dedicated to the specifics and new test bench and evaluation/characterization tools allowing to test the performances of the developed prototypes or instruments in Astrophysics, Medical Physics and Particle Physics.

  Location: BioPark Auditorium

  - **09:00 New Test Infrastructures for Future Particle Physics Experiments and Upgrades *1h0'***

    Speaker: Prof. Matthew Timothy Jones (Purdue University (USA))

  - **10:00 New tools for testing Advanced 3D technology based devices *1h0'***

    Speaker: MENTOR GRAPHICS representative (tba)

  - **11:30 EMBRACE an Ultra Wide Field of View Prototype for the Square Kilometer Array *1h30'***

    A revolution in radio receiving technology is underway with the development of densely packed phased arrays for radio astronomy. This technology can provide an exceptionally large field of view, while at the same time sampling the sky with high angular resolution. Such an instrument, with a field of view of over 100 square degrees, is ideal for performing fast, all-sky, surveys, such as the "intensity mapping" experiment to measure the signature of Baryon Acoustic Oscillations in the HI mass distribution at cosmological redshifts. The SKA, built with this technology, will be able to do a billion galaxy survey.

    The Nancay radio observatory is a major partner in the development of dense phased arrays for radio astronomy, working closely with The Netherlands Foundation for Radio Astronomy (ASTRON). The joint project is called EMBRACE (Electronic MultiBeam Radio Astronomy Concept). With significant funding from European Commission FP6 project SKADS, two EMBRACE prototypes have been built: One at Westerbork in The Netherlands, and one at Nancay. These prototypes are currently being characterized and tested at the two sites. Conclusions from the EMBRACE testing will directly feed into the SKA and will have a decisive impact on whether or not dense array technology is used for the SKA.

    I will present a very brief introduction to radio interferometry and synthesis imaging, as well as an overview of the Square Kilometre Array project. This will be followed by a description of the EMBRACE prototype and a discussion of results and future plans.

    Speaker: Dr. Steve Torchinsky (Observatoire de Paris and Nancay (FR))

- **14:00 - 16:45 Labs session**

- **17:15 - 18:15 Concluding School Session**

  Concluding lecture and Poster Awards

  Location: BioPark Auditorium