APPLICATIONS OF PARTICLE ACCELERATORS IN EUROPE

A. Faus-Golfe

on behalf of APAE committee

Outlook

- APAE Project and Objectives
- APAE working group
  - APAE International Committee
  - Areas, Conveners and Roles
- Kick-off meeting
  - Objectives
  - Health Area: First Conclusions
- Future work

EuCARD²

WP4 Accelerator applications

Key question: what does the man in the street need?

More and better science – we all agree!
More and better life – we all agree, too…

People in the street need the LHC (and now the FCC…) but need as well more and better medical isotopes, better materials, better semiconductors, improved security, etc.

From M.Vretenar Eucard2 coordinator

Originally developed to investigate the fundamental laws of nature, today, accelerators are far more than a tool for fundamental research and their significant role in industry and society means that they have a very important, but often unseen, impact on our everyday lives.

Over 30,000 particle accelerators are in use all over the world. In fact, until recently, most people had one in their sitting room. They allow beams of particles to be produced and used for a range of applications in a number of different areas, including health, industry, energy production, security and the environment.

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Objectives

The aim of the project is to create a European document equivalent of the "Accelerators for America's Future" document (US focus, 5 years old)

The focus will be on **applications** of interest in **Europe** and for which technology developed for research can have an impact. The document will be entitled **"The Applications of Particle Accelerators in Europe"**

Objectives

It is intended for policy makers, as a result, it will be in two parts:

- Executive summary, focussing on the main issues for each country and in the correct language (International Committee)
- Supporting document in English (Conveners)

It is being organized by Work Package 4 of EuCARD²

Avoiding duplications with others existing docs in Europe such: the Nupecc report, but exploiting the complementarity and synergies on work already done in Europe:

- TIARA, Accelerators for Society
- CERN document
- Documents from various countries

Report will be finished by end of EUCARD2 April 2017

The Working Group

WP4: Application of Accelerators

- ✓ Rob Edgecock (WP4 coordinator)
- ✓ Agnes Szeberenyi (outreach&communication)

International Organizing Committee:

- ✓ Roy Aleksan
- ✓ Oliver Boine-Frankenheim
- ✓ Phil Burrows
- ✓ Angeles Faus-Golfe
- ✓ Steve Myers
- ✓ Andrea Pisent

International Committee and Roles

International Committee charge is:

- Identify the areas and the conveners ✓
- Coordinate and support the different areas and conveners ✓
- Meeting organization: kick-off ✓
  mid-term and next
- Responsible for writing of the Executive summary, focussing on the main issues for each country and in the correct language
- Ensure Main doc (English) is well balanced

Areas, Conveners and Roles

Energy	**Fission:** E. Mund **Fusion:** A. Mosnier **Accelerators:** J.L. Biarrott
Health	**Radiation Therapy:** M. Dosanjh **Radionuclides**: O. Lebeda **Accelerators:** H. Owen
Industry & Environment	**Ion implantation**: R. Webb **Ion beam analysis**: M. Chiari **e^- beam treatment and uses**: A. Chmielewski **e^- accelerators:** F. Roegner
Security	G. Burt
Photonics	L. Rivkin
Neutronics	M. Lindroos

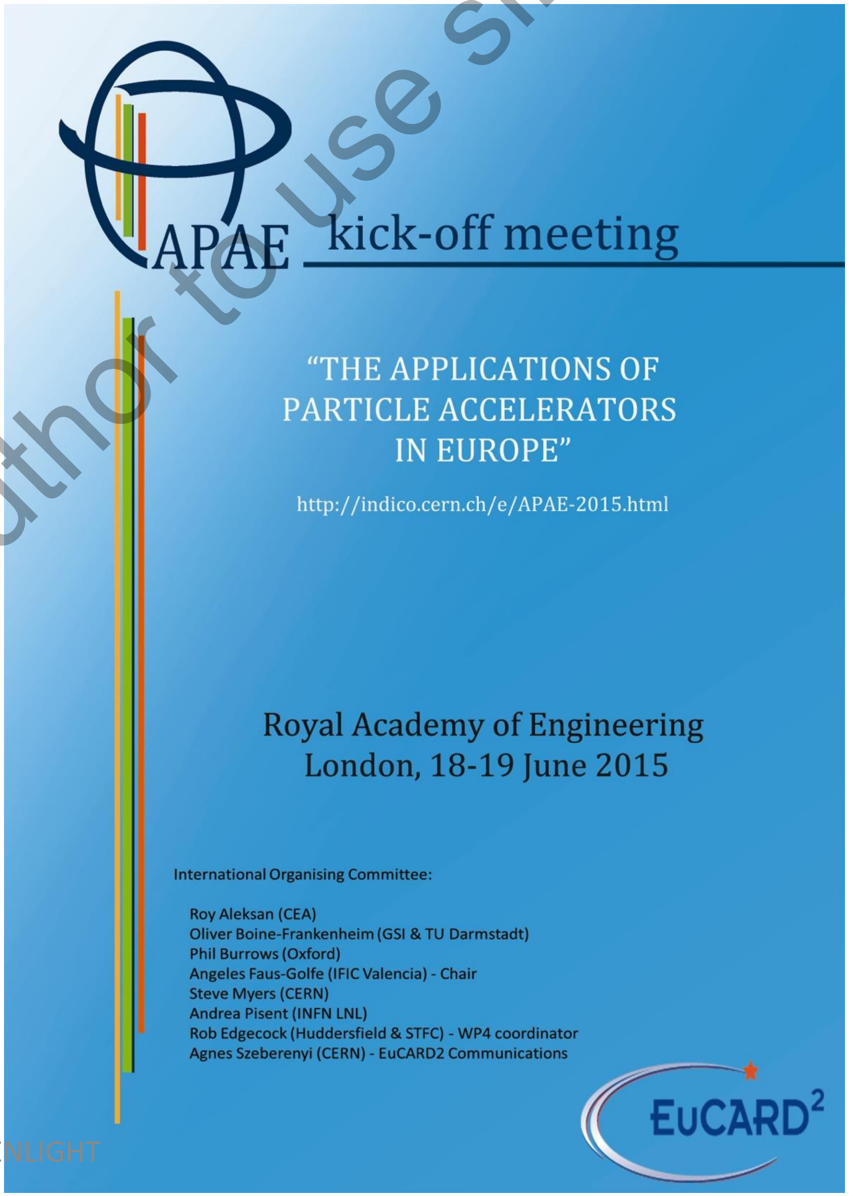
Areas, Conveners and Roles

Conveners charge will be to:

- Identify the agenda and speakers for the appropriate session at the kick-off meeting ✓
- Invite participants to the meeting ✓
- Create a working group to deliver a chapter for the application area ✓
- Ensure that this chapter is written

Kick-off meeting: the objective

- Starting the APAE process
- Bring together people interested in the different application areas
- Initial discussion of what to include
- Existing and possible new applications
- Identification of the next steps



Kick–off meeting: the programme

APAE kick-off meeting:

"The Applications of Particle Accelerators in Europe"
Royal Academy of Engineering
London, 18-19 June 2015

Thursday 18 June 2015

09:00 09:30	**Registration and Coffee**	
09:30 10:00	**Welcome and Opening**	
10:00 11:15	**Security** G. Burt	
	Imran Tahir, Rapiscan Systems	Application of Accelerators in borders and homeland security
	Philippe Dethier, IBA	The Rhodotron used as an X-ray generator for next generation automated 3D Cargo Inspection System
	John O'Malley, AWE	Opportunities for accelerator driven radiation sources to support the detection of radiological and nuclear materials
	Slawomir Wronka	- Security applications development at NCBJ
	Discussion session animated by G. Burt: Present challenges for accelerators for Security, future needs in the next decades....	
11:15 11:30	**Coffee**	
11:30 13:00	**Industry and Environment: Ions** Roger Webb, Massimo Chiari	
	Russell Gwilliam	Ion implantation
	Franco Lucarelli	Ion beam analysis
	Graeme Taylor	Metrology and accelerator applications
	Discussion session animated by Franco Lucarelli: Present challenges for accelerators for Industry and Environment: Ions, future needs in the next decades....	
13:00 14:00	**Lunch**	
14:00 15:00	**Industry and Environment: Electrons** Andrzej Chmielewski, Frank-Holm Roegner	
	A. G. Chmielewski	Developments in the electron beam accelerators and e/X systems engineering. Industrial applications of electron beams – materials processing, sterilization, food irradiation and environment
	M. Fulop	Multipurpose irradiation facility equipped in electron accelerator
	M. Demsky	Linear electron accelerators for radiation processing
15:30 16:00	**Tea**	
16:00 17:00	**Industry and Environment: Electrons**	
	Frank-Holm Roegner	A wide sprayed field of application for low energy electron irradiation in European Industries
	Ian Bland	e-beam Goes Viral: "the pipeline of applications for compact, sealed, low-energy EB accelerators"
	Discussion session animated by F.H. Roegner: Present challenges for accelerators for Industry and Environment: Electrons, future needs in the next decades....	

APAE kick-off meeting:

"The Applications of Particle Accelerators in Europe"

Friday 19 June 2015

09:00 10:30	**Health** M. Dosanjh, O. Lebeda, H. Owen	
	Bleddyn Jones	Radiation Treatment
	Ulli Koester	Isotopes
	Tim Antaya	Accelerators
10:30 11:00	**Coffee**	
11:00 11:30	**Discussion** session animated by Manjit Dosanjh: Present challenges for accelerators for Health, future needs in the next decades....	
11:30 12:15	**Photonics** L. Rivkin	
	Gabriel Aeppli	Photonics applications: from beamline to industry
	Ian Robinson	Use of beam brilliance in imaging nanomaterials
	Discussion session animated by Leonid Rivkin: Present challenges for Photonics, future needs in the next decades....	
12:15 13:00	**Neutronics** M. Lindroos	
	John Thomason, ISIS	ISIS and future short pulse spallation sources in Europe
	Eugene Tanke, ESS	The first long spallation source (ESS) and continuous sources spallation sources (PSI
	Pierfrancesco Mastinu, LNL-	Compact neutron sources
	Discussion session animated by Eugene Tanke: Present challenges for Netronics, future needs in the next decades....	
13:00 14:00	**Lunch**	
14:00 15:30	**Energy** E. Mund, A. Mosnier, J.L. Biarrott	
	Alban Mosnier	FUSION: overview talk (fusion energy, ITER, IFMIF, accelerators status & challenges)
	Gert Van den Eynde	- FISSION: Transmutation issue, the GEN IV scenarios and the MYRRHA project
	Dirk Vandeplassche	- FISSION: ADS accelerator developments presently on-going for MYRRHA and possibly for the Chinese-ADS
	Discussion session animated by Jean Luc Biarrott: present challenges for accelerators for energy, future needs in the next decades....	
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Present challenges for accelerators in: Energy, Health, Industry& Environment, Security, Neutronics and Photonics, future needs in the next decades....

The document

- One chapter per application area, with an extension of around 20 pages, responsibility of the convenors

- The contents of the doc:
  - State of the art: technology and applications
  - Issues and present Challenges, which technology developments are needed to overcome it?
  - New possible applications, how technology could help to developed these new Applications?

- Executive summary, recommendations and summary chart table with particles/characteristics/applications/numbers responsibility of the International Committee

- Format to use: a template will be provided

- Final professional formatting at the end

The APAE web page

The APAE web page http://apae.ific.uv.es/apae/ is under construction, with the help of IFIC computer service.

Conveners has to provide :

- Short text to be added in each of the areas and nice pictures if you have for the public area
- Suggestions for the useful links

APPLICATIONS OF ACCELERATORS IN EUROPE: HEALTH

Manjit Dosanjh
Ondrej Lebeda
Hywel Owen

APAE

ENLIGHT

Radiation therapy

1. State of the art IMRT conventional treatment is doing an excellent job but one cannot change physics, so what next?
2. High energy electrons… Immunotherapy…
3. Protons are here and from the physics they are better so which are the problems and challenges before they can become widely adopted and accepted?
4. Is there room for other ions such as helium and carbons which are more conformal and have higher radiobiological effects?
5. What is the future for alpha emitters in treatment?
6. Can advances in nanoparticle delivery offer future scope for improved brachytherapy?
7. Stereotactic radiotherapy/theragnostics?

Radionuclides – 1

1. Nuclear medicine is today dominated by imaging applications, although the role of radionuclide targeted therapy slowly increases.
2. SPECT procedures (dominated by ^{99m}Tc) still significantly outnumber PET imaging (dominated by ^{18}F).
3. In principle replacements exist for many ^{99m}Tc-based radiopharmaceuticals. Cyclotron production of ^{99m}Tc in Europe.
4. Will ^{18}F replace ^{99m}Tc if supplies of ^{99m}Tc fall?
5. Neutron-rich radionuclides are produced by research reactors and neutron-deficient ones by accelerators (mainly cyclotrons). Some radionuclides can be produced by either facility.
6. Research reactors will not die out!

Radionuclides – 2

6. Future is open for emerging positron emitters, frequently prepared from generators like $^{68}Ge/^{68}Ga$, $^{82}Sr/^{82}Rb$, etc. Direct production of ^{68}Ga – an alternative to $^{68}Ge/^{68}Ga$ generators, interesting for the existing PET centres
7. Targeted radionuclide therapy are on the rise: ^{177}Lu and ^{90}Y are the gold standards for β^- therapy, but new therapeutic or theranostic (e.g. ^{64}Cu, ^{67}Cu, ^{186}Re) radionuclides continue to appear; Auger emitters
8. Alpha emitters provide more targeted irradiation but are still in short supply: ^{149}Tb (GeV p beams), ^{211}At (29 MeV α beams), ^{213}Bi (decay of ^{225}Ac that is obtained either from $^{233}U/^{229}Th$, or via $^{226}Ra(p,2n)$ reaction), ^{223}Ra – cyclotron production of alpha emitters or their parent nuclides
9. New non-conventional positron emitters for PET (^{44}Sc, ^{52}Mn, ^{64}Cu, ^{86}Y, ^{124}I etc.)

Accelerators

1. Proton therapy – how do alternative technologies compete with established cyclotron technology – FFAGs, laser acceleration, linacs etc.
2. What are the next steps in carbon therapy?
3. What is the role of He and ^{11}C in particle therapy in the next 5 years?
4. Other ions?

Next steps – Strategy

- Need a list of topics and the people to be involved for each topic
- Put forward ideas and get a community response
- Separate the document into near-term and mid-term needs
- Get contributions from experts in the field in Europe and beyond
- Currently – Manjit, Hywel and Ondrej but looking for help
- To be discussed: need broad endorsement from institutes - how

Purpose of the document

- Why is it being written?
- How will it help?
  - Funding?
  - Awareness?
- Impact
  - How will we measure it?
  - Need to start today

Next steps

- Periodic Meetings: once per month, first in July 2015. ✓
- If the conveners have some names to add as co-conveners or collaborators in the working group please let know us to be added in the list or in the web page.
- Mid-term meeting 16-17 December 2015 in Paris: outline of the chapter
- Meeting in the framework of 3rd EUCARD2 meeting: draft of the chapter
- Meeting End 2016 : final version chapter
- Printing the document End 2016
- Document presented on April 2017 in EUCARD2 meeting

THANK YOU

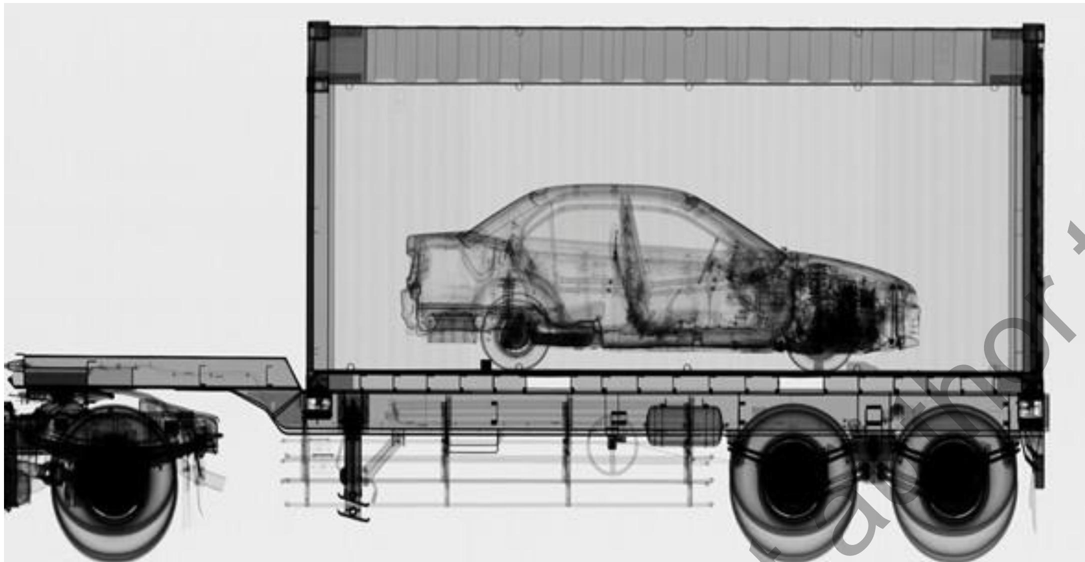
Security Applications of Accelerators

Dr G Burt
Lancaster University, Cockcroft Institute

Security Applications of Accelerators

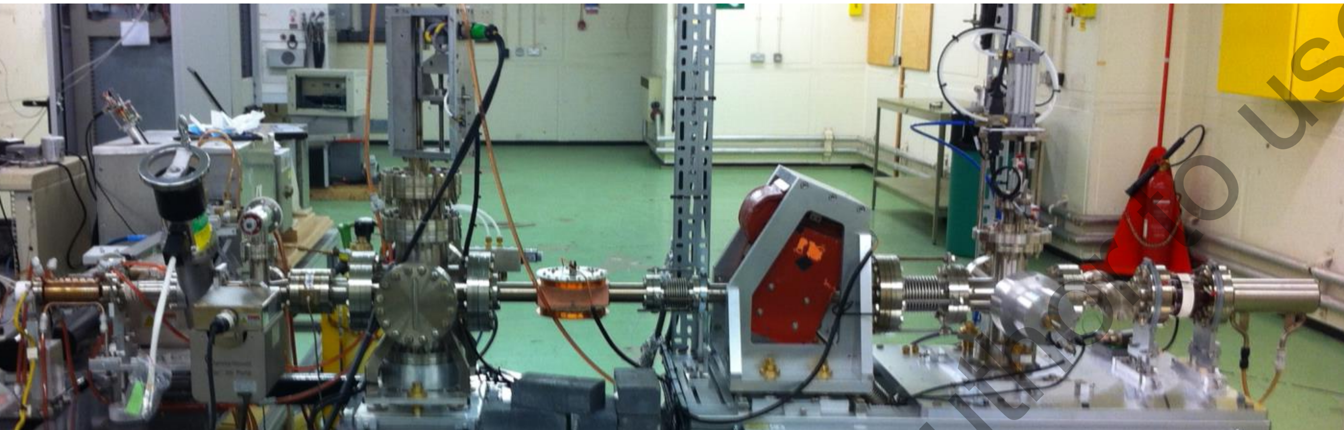
- X-ray cargo imaging (1-10 MeV electrons via linac or Rhodotron)
- Gamma's (10-20 MV) inducing resonances in nitrogen for explosives detection.
- Neutron cargo imaging for material discrimination (sometimes combined with photons)
- Active special nuclear material detection (neutrons or photons possible, some 10 MeV photons some 5 MeV D+ from RFQ to obtain gamma and neutrons)
- Flash radiography of Nuclear equipment (Electrostatic 10 MeV, ~kA ions)

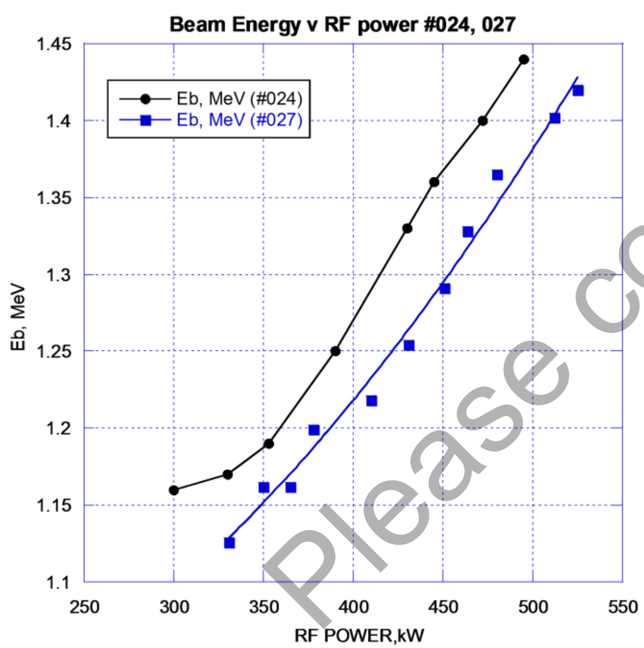
Cargo screening

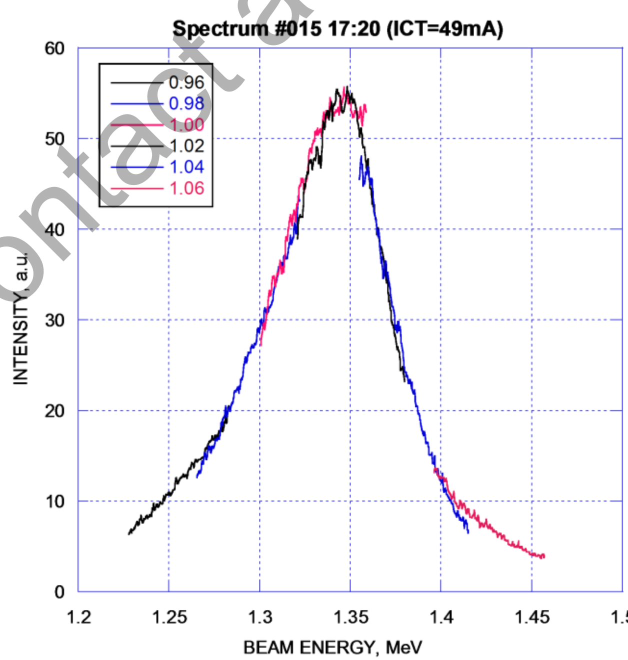


- A major use is in cargo screening to ensure that what is in a shipping container is what is in the manifest and not cash, drugs, gold, uranium, cigarettes or cars.

1-3 MeV compact linac development with image driven optimisation







Science & Technology Facilities Council

Lancaster University

Neutrons

- Neutrons can also be used for cargo scanning.
- A pulse of neutron particles, for example, would illuminate the items inside the cargo and react with the nuclei, which then emit gamma rays. A particle detector would identify the type of gamma ray and reveal what is inside the box.
- As such neutrons can also be used for material discrimination but the variation in neutron energy from most sources is a real challenge.
- Better discrimination is obtained by combining a neutron source with an X-ray or gamma source.
- The neutrons can come from sealed sources, reactors or in our case an accelerator (typically an RFQ)

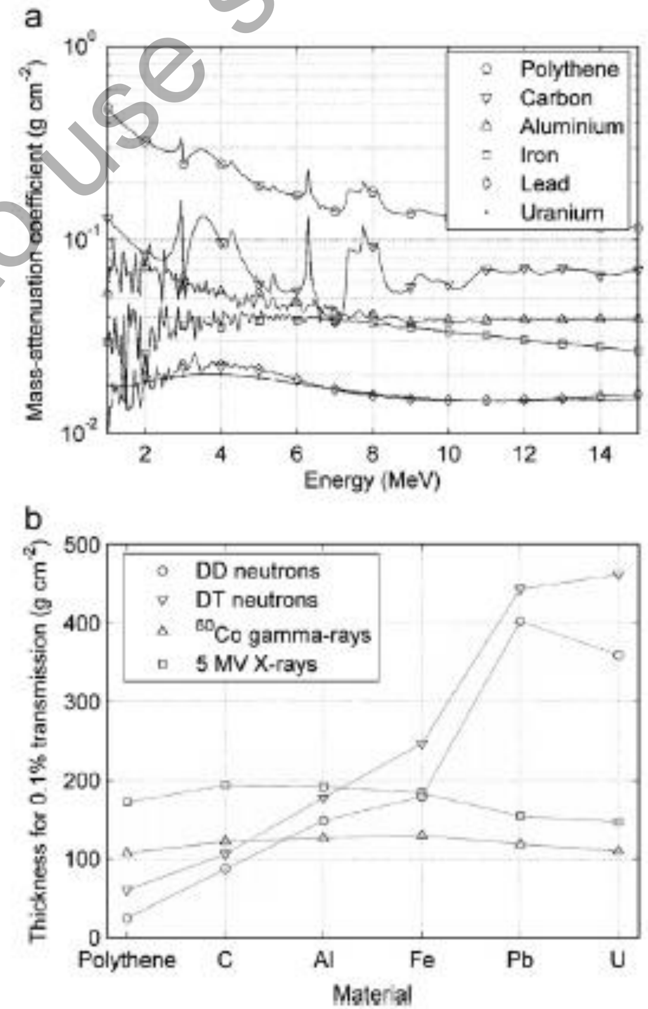


Fig. 6. (a) Neutron mass-attenuation coefficients versus energy for various materials. (b) Thicknesses of the same materials through which 0.1% of DD neutrons, or DT neutrons, ^{60}Co gamma-rays (1.17 and 1.32 MeV) and X-rays from a 5 MV Bremsstrahlung source are transmitted.

Automatic Cargo-Container Inspection System (ACCIS)

research instruments

$^{11}B(d,n+\gamma)^{12}C$ – Deuteron Energy 3-8 MeV

4.43, 15.09 MeV γ-rays
Dual Discrete Energy
Gamma Radiografie
=> SNM detection

0-17 MeV neutron spectrum
Fast Neutron
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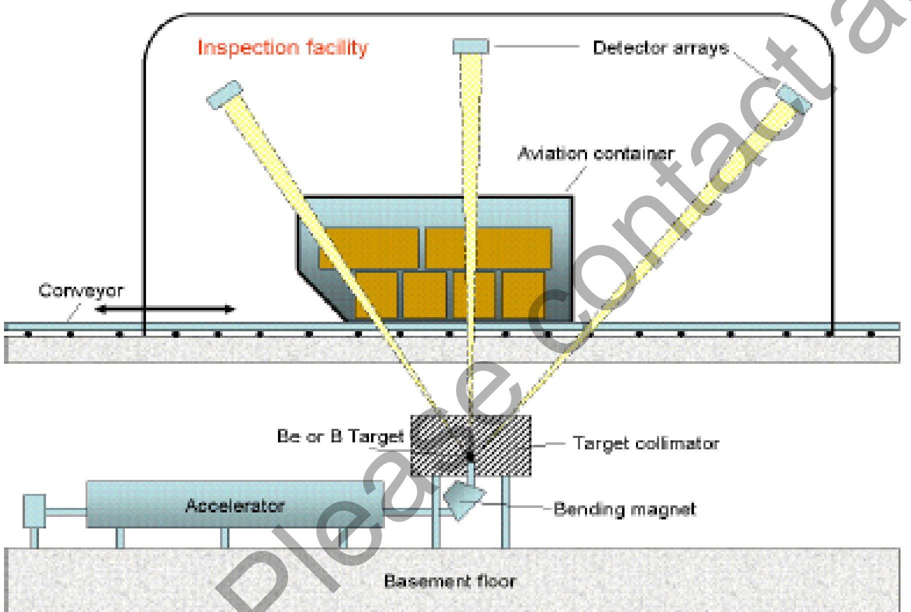
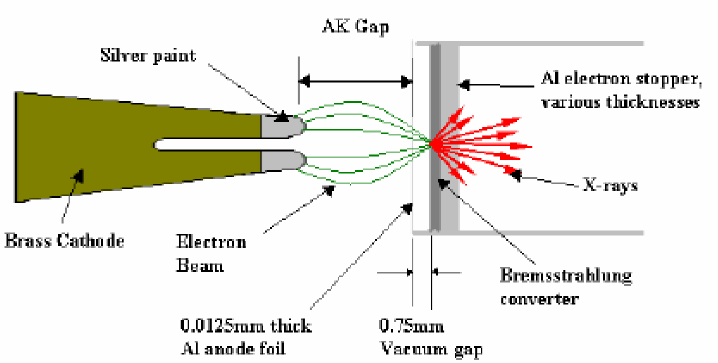


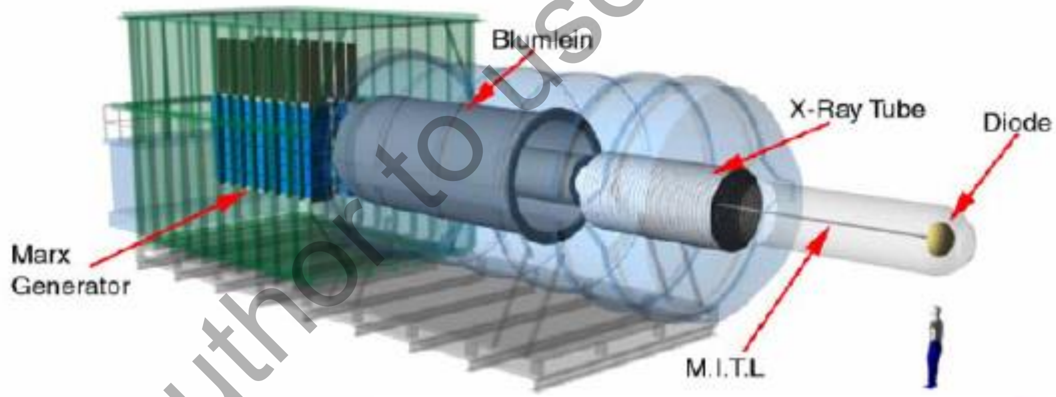
- (Semi-) Automatic Inspection
- Isotope specific Detection
- Combined Explosives & SNM Detection

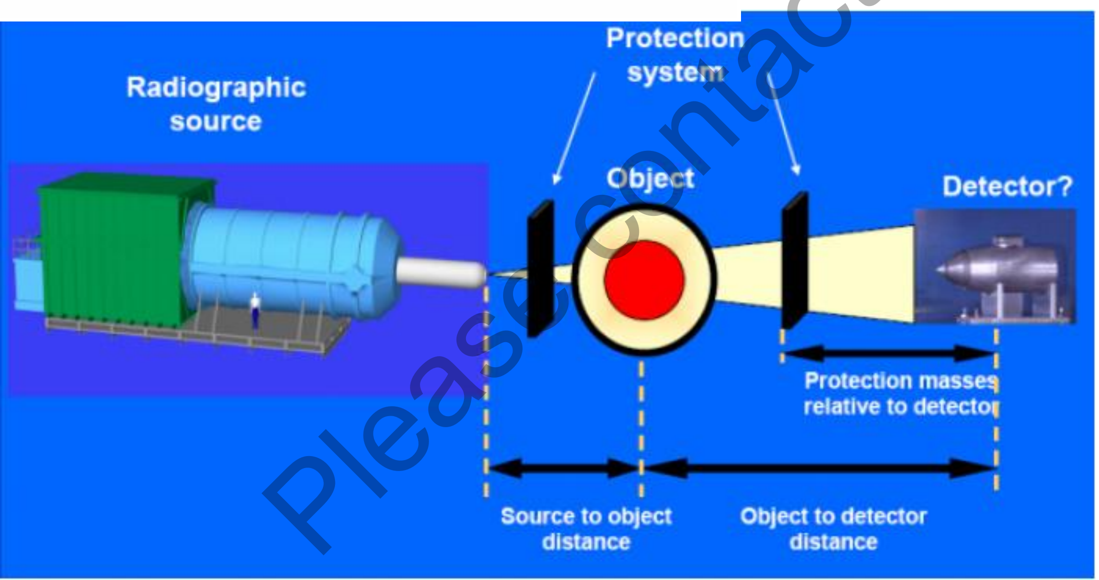
Images from AWE, PAC05

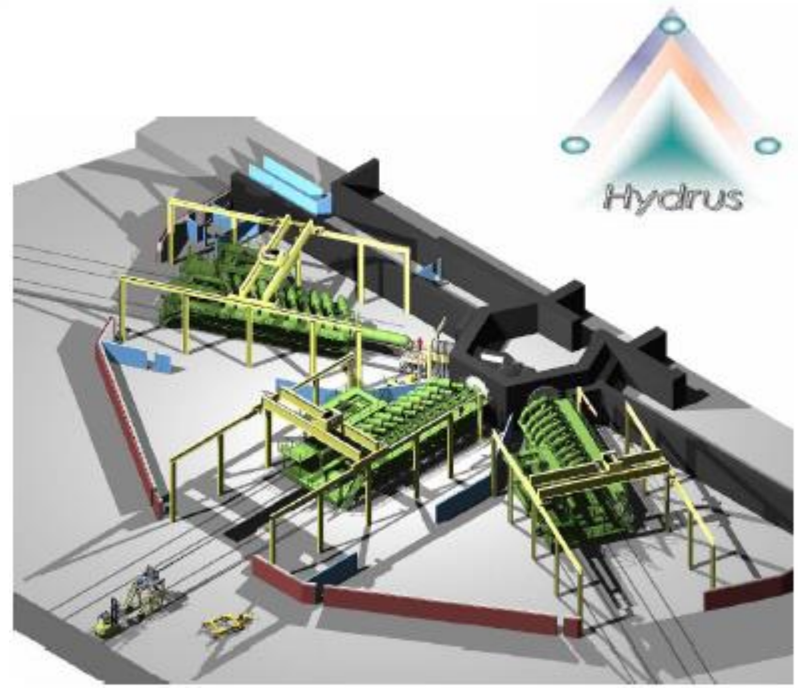
Flash Radiography

- 1-10 MV
- 10’s kA for under 100 ns









European Activities

- Cargo scanning – X-ray: Rapiscan is an industry leader based in the UK. Smiths also have a smaller presence. Research on the linacs at Cockcroft Institute, UK, AWE, UK, NCBJ, Poland. Rhodotron research at IBA, .
- Neutron and/or Gamma cargo scanning for explosives and special nuclear materials (SNM) at AWE, UK and PTB, Humbold Uni & Research Instruments, Germany.
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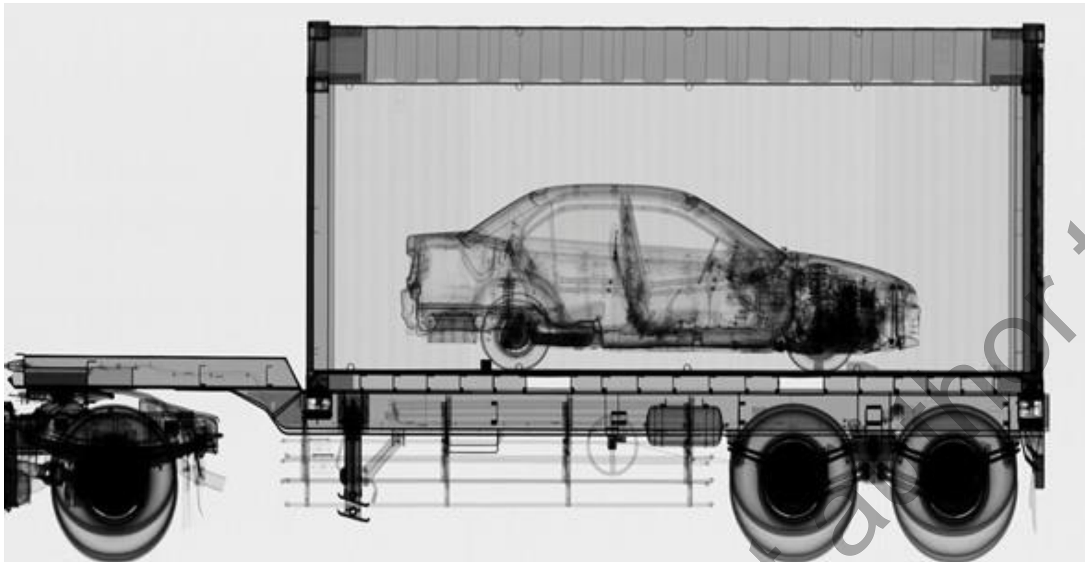

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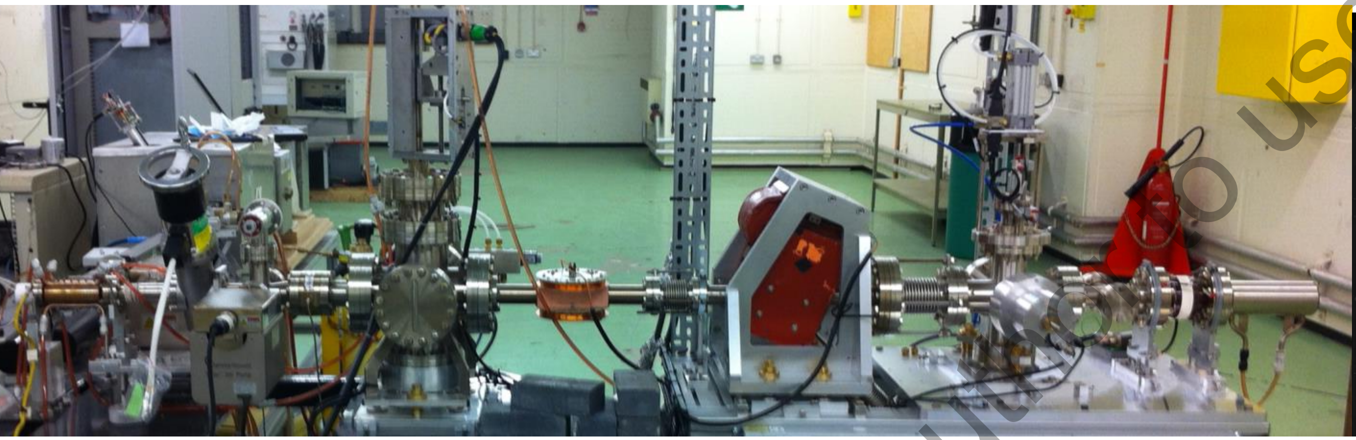

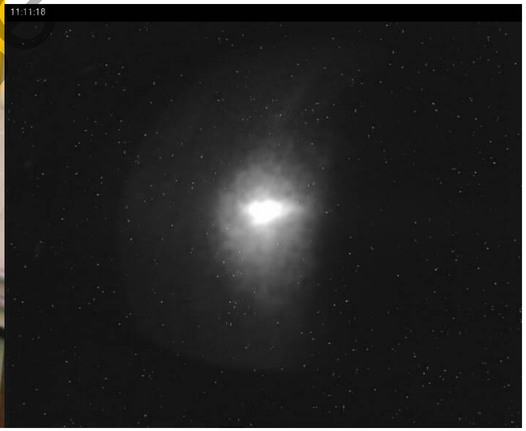

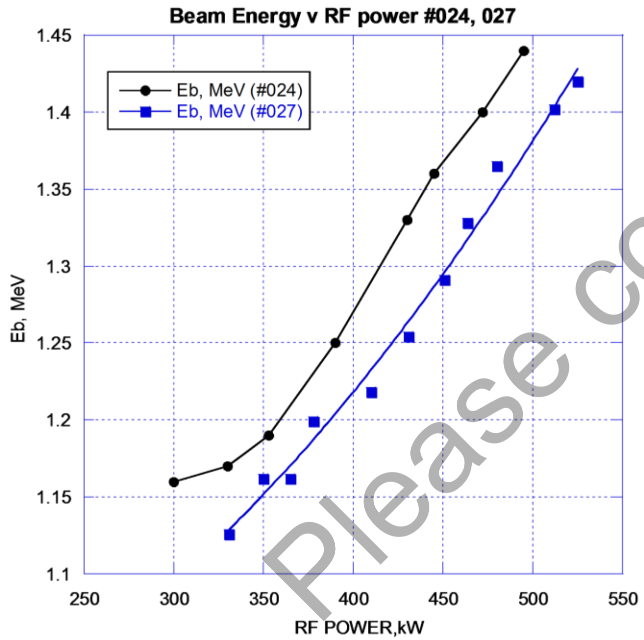

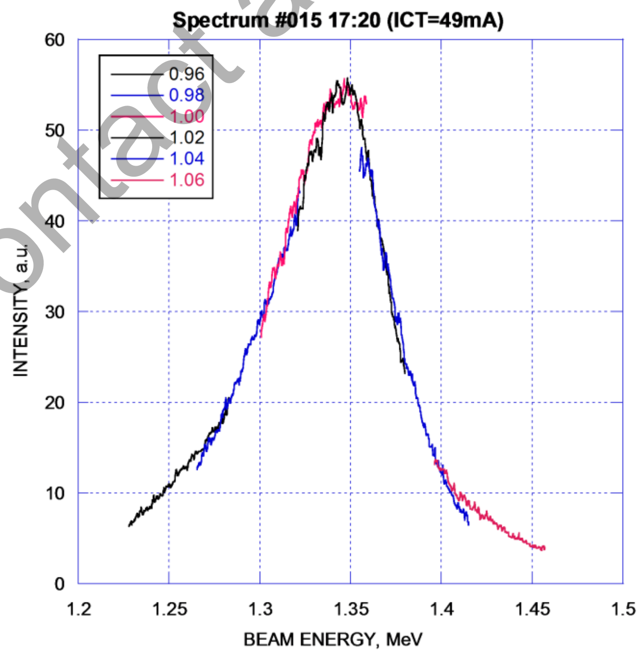

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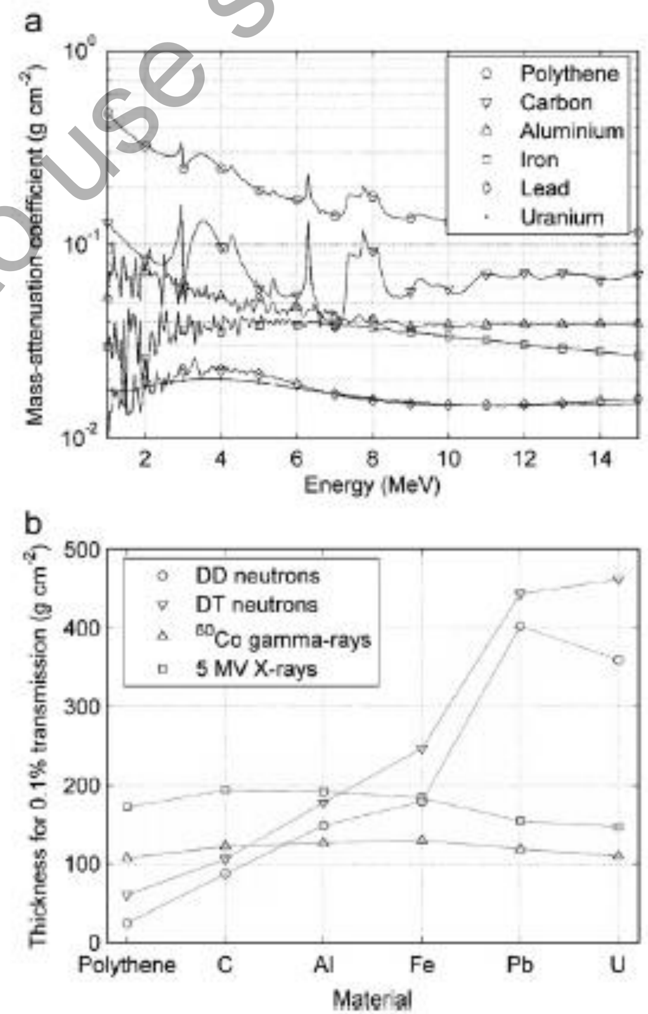

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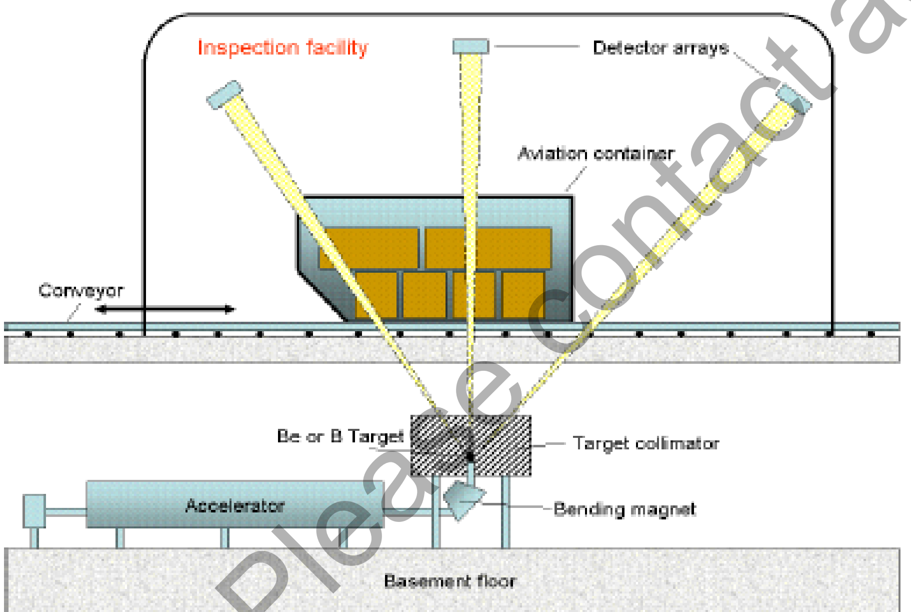

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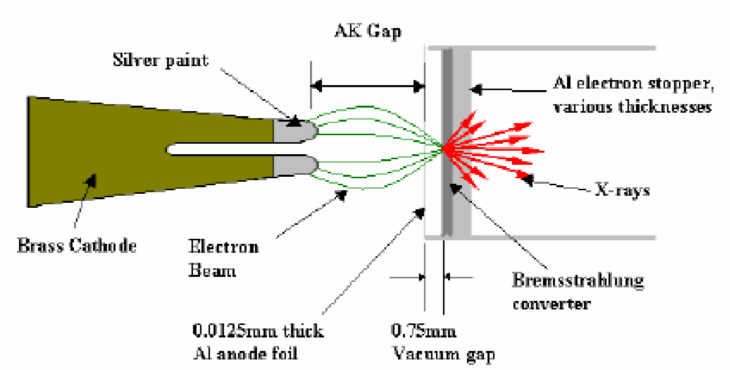

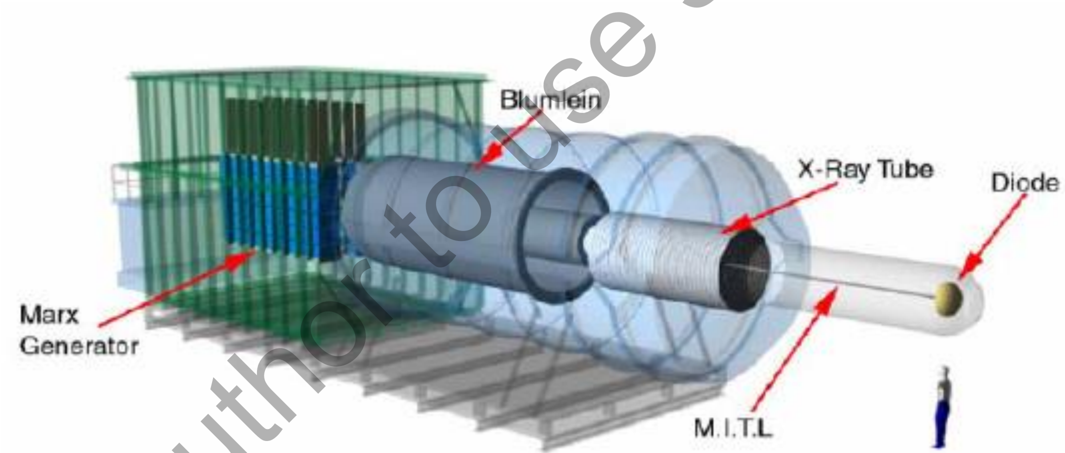

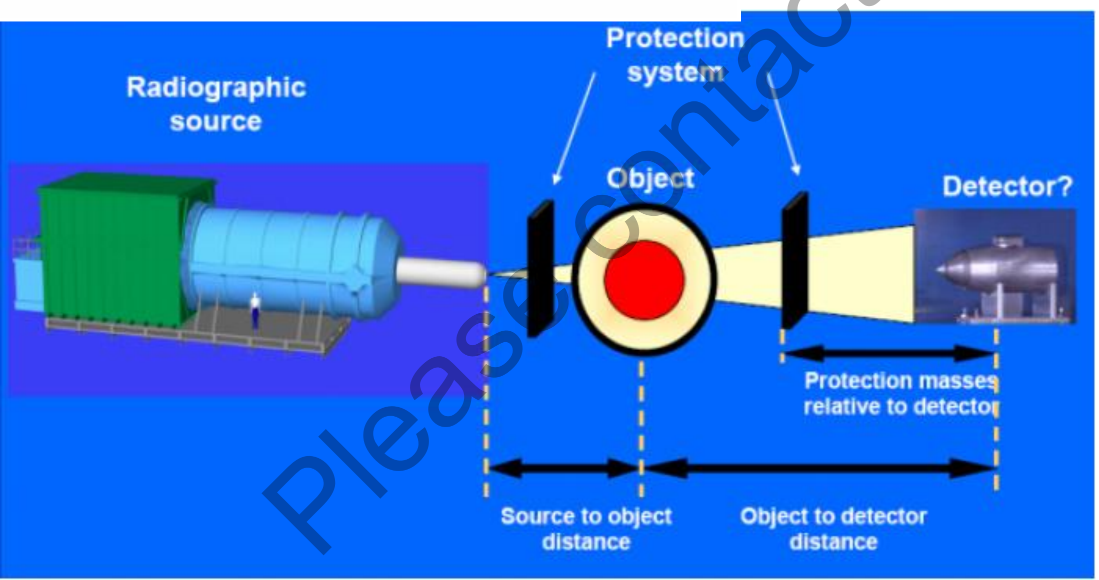

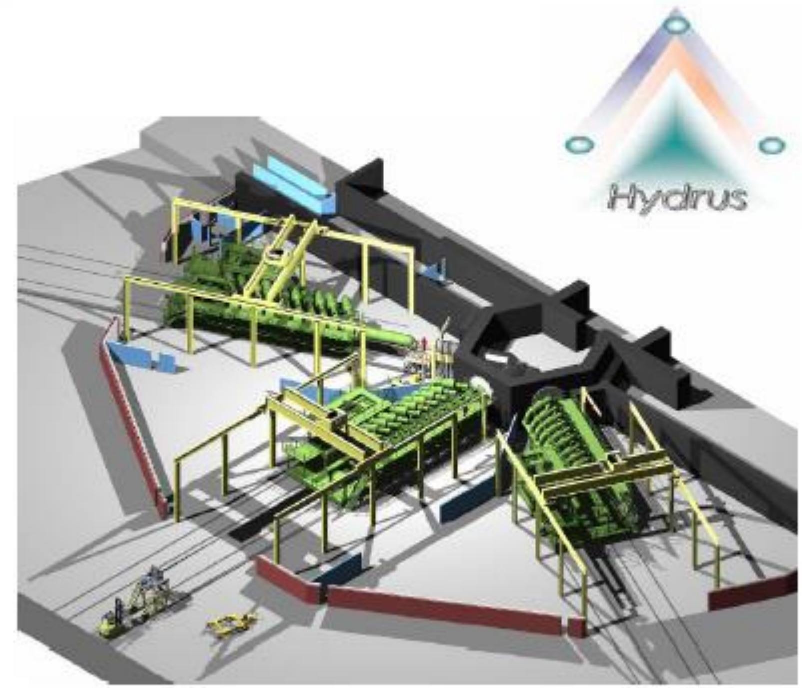

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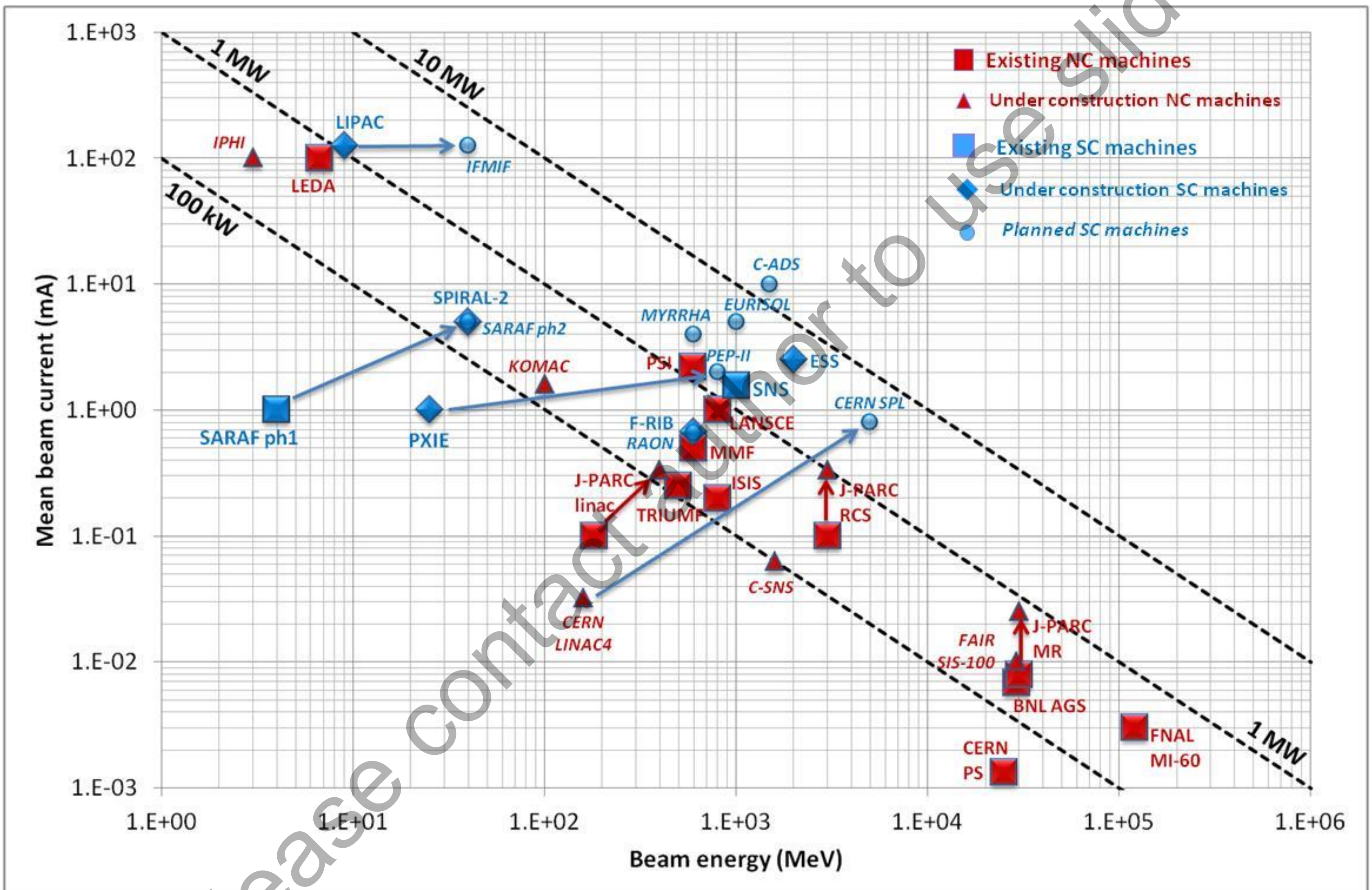
Energy session: discussion topics

Main challenges

- Beam power levels
- Accelerator reliability requirements
- More generally, lack of clear view on the future of nuclear energy (at least in Europe…)

Beam power levels

- Multi-MW hadron beams
  - Demo LIPAC: 1.1 MW
  - IFMIF: 5 MW
  - MYRRHA: 2.4 MW
- State of the art is 1.3MW (PSI, SNS)
- Adequate present technology for HP proton linac is SRF
  - ESS is now under construction @5MW
- Main challenges
  - High beam current production/transport
  - Low-loss machine operation (low activation for maintenance)
  - High Power components (RF, beam instrumentation…)
  - Machine protection
  - Energy efficiency
- Up to which power level in the future using these technologies ?
- What will the future needs? 10-100 MW for ADS?

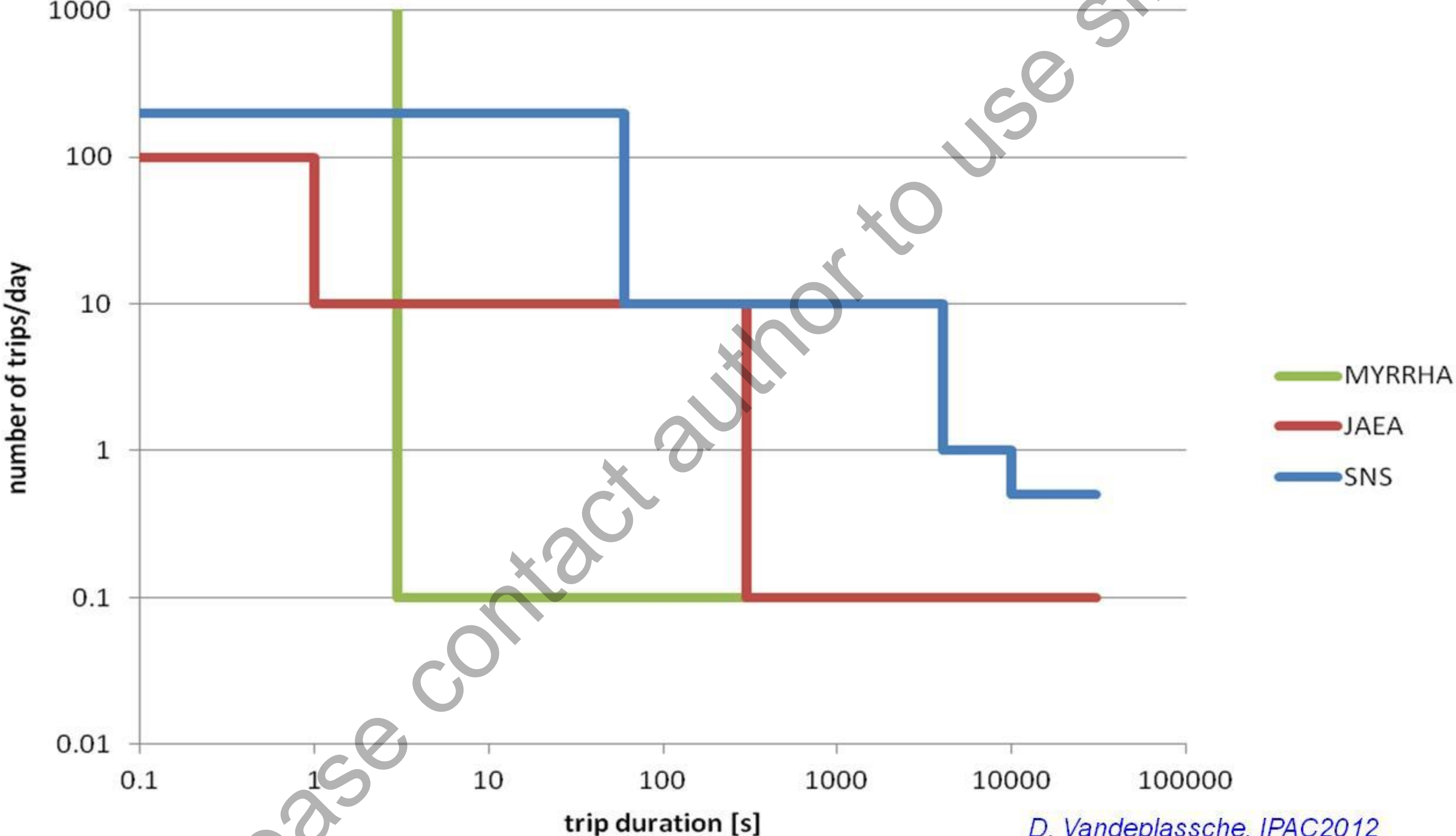


Non exhaustive plot !

J-Luc Biarrotte, SLHIPP-4, CERN, 15-16 May 2014

Reliability requirement

- 250h MTBF for Myrrha
  - 2/3 orders of magnitude higher than state-of-the-art
- Induced extra-cost & extra-complexity is high
  - Redundant systems
  - New generation innovative control systems
  - A lot of additional R&D is needed in general
- Justification for such a requirement is tb reinforced
  - Could this requirement be relaxed? Cf Chines-ADS
  - What to expect for industrial ADS?


1000
100
10
1
0.1
0.01
number of trips/day
0.1
1
10
100
1000
10000
100000
trip duration [s]
MYRRHA
JAEA
SNS
D. Vandeplassche, IPAC2012

Future of nuclear energy

- Fusion
  - ITER
  - DEMO, Post DEMO ???
- Fusion
  - Gen IV
  - Transmutation & ADS??
- Politics/support
  - Euratom is (one of the only?) clear support
  - Several different national policies/flavours on these issues… NO CONSENSUS presently

Industry and Environment: ions

What is Ion Implantation?

Ion Implantation refers to an energetic process by which impurity atoms are introduced into the *near surface* of a material to change its *electrical, optical or materials* properties:

Doping in semiconductors

Device isolation in integrated circuits

Compound synthesis

Defect Engineering

Waveguides and optical devices

Anti-fouling

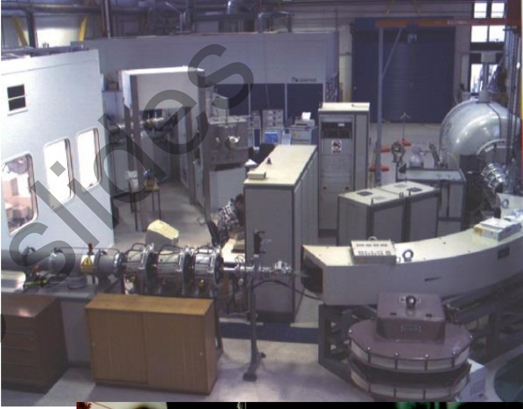
Wear resistance in metals - hip replacement

Tumour therapy

Etc, etc, etc,……………………….

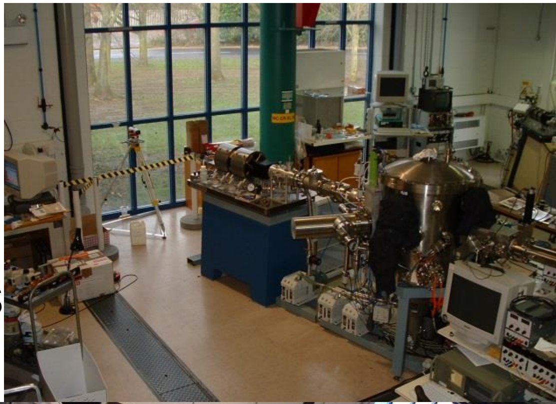
Surrey Ion Beam Centre

- **Controllable Materials Modification**
  - **Facilities**
    - 0.2-2MV HVEE High Energy Implanter (1991)
    - 2-200kV Danfysik High Current Implanter (1997)
    - Implantation 2keV $\Rightarrow$ 4MeV (up to 10mA)
    - Sample size ¼mm² to ¼m²
    - Hot (1000°C) or cold (~LN & 20K)
    - Sample chambers in class 100 clean room
  - **Applications**
    - Ion Implantation
    - Defect Engineering
    - Single ion implantation with high spatial resolution
      - **Bio clean room with targeting facility**
    - Proton beam lithography (using Tandem)
      - **potentially nm resolution to 10μm depths**
    - Ion Beam Synthesis
      - **Buried and surface oxides, silicides etc**



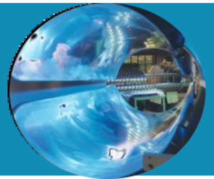
Surrey Ion Beam Centre

- **Advanced Materials Analysis**
  - **Facilities**
    - 2MV Tandem (commissioned 2002)
    - Techniques include RBS, EBS, ERD, PIXE, NRA
    - Sub micron size micro-beam with full scanning
    - Channelling spectroscopy for damage analysis
    - Automated collection and analysis
    - External Beam for vacuum sensitive samples
  - **Applications**
    - Thin Film Depth Profiling
    - Compositional Analysis
    - Disorder Profiling of Crystals
    - 3-D elemental composition and mapping

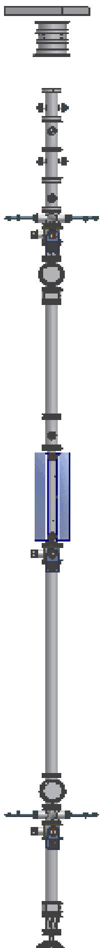


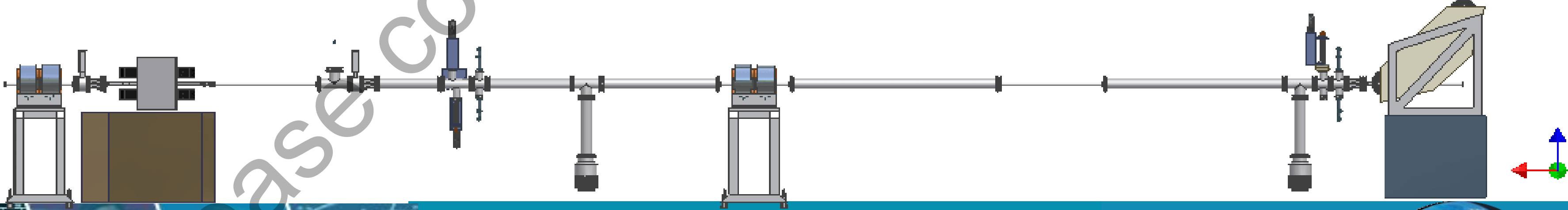
Conclusions

- Implant is versatile and can bring positive benefits to many material systems
- The implant hardware is well understood and characterised however the target behaviour requires careful thought in some materials
- Emerging tools require development for specific applications – this requires knowledgeable companies and is very leading edge (SIMPLE!!!)
- Funding is tough, trust is expensive. Keep your customers.



- **Bio-medical Irradiation Facility**
  - **Facilities**
    - Targeted (~30nm) single ion irradiation
    - End Station in Cat 2 biological clean room
    - Vertical Arrangement to allow irradiation of living cells in liquid cultural
    - Looking for 10,000 cell irradiations per hour
    - Ions up to Ca from 2MVTandem
    - Environmental chamber, incubators etc.
  - **Applications**
    - Cell Irradiation
    - Proton/hadron therapy research
    - Continuous mode for in-situ analysis



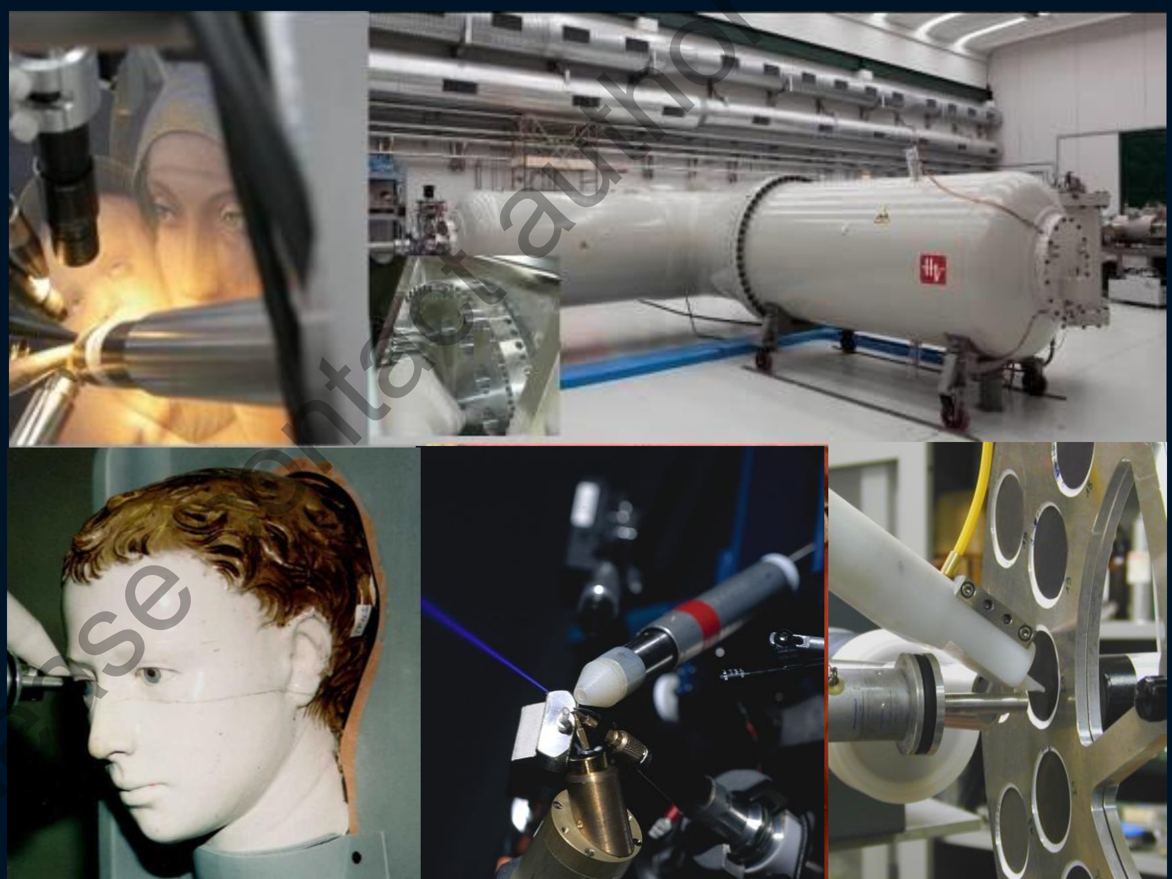


INFN LABEC
Laboratorio di Tecniche Nucleari per i Beni Culturali - Firenze

Ion Beam Analysis for Environmental and Cultural Heritage studies

Franco Lucarelli

Department of Physics and Astronomy, University of Florence and I.N.F.N. - Florence

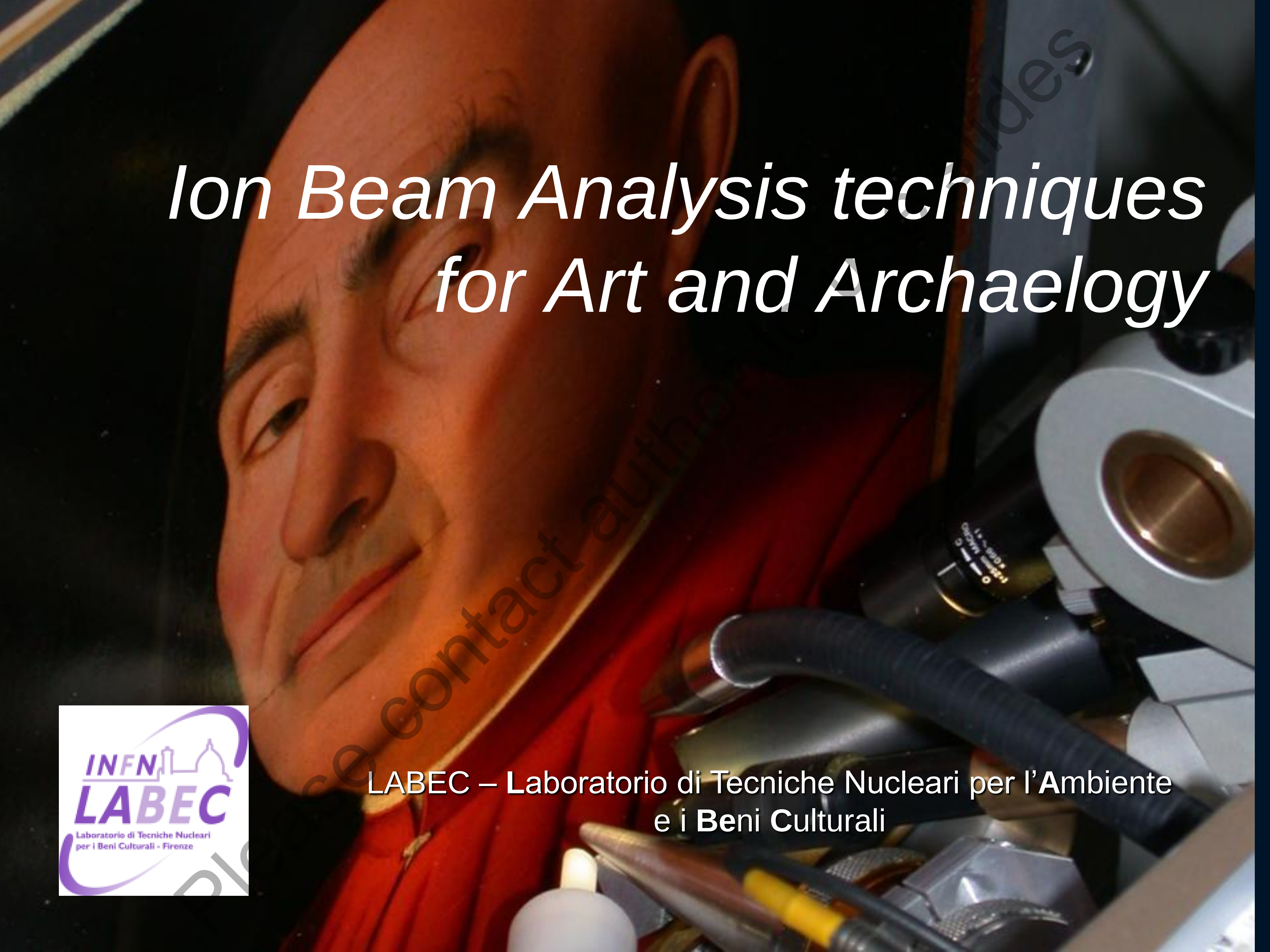


PIXE technique for aerosol pollution studies

Conclusions (I)

- The use of a proper experimental set-up is a prerequisite for a rational application of PIXE for aerosol analysis
- The high sensitivity-rapidity of PIXE makes the use of this technique a feasible approach to study the impact of desert dust over representative long periods and for extended monitoring networks
- The use of a streaker sampler followed by PIXE analysis produces elemental concentrations with 1-h resolution which help to identify the aerosol sources in urban or industrial areas
- The possibility to analyze by PIXE samples with very low mass :without any samples preparation is useful for the analysis of the aerosol collected in remote areas

- ✓ **It is mandatory to collaborate with other groups (chemists, geologists, physicists….)**
- ✓ **Partecipate to aerosol conferences and publish on "non nuclear physics" journals**
- ✓ **Partecipate to all the steps of the study, not only to the measurements**



Ion Beam Analysis techniques for Art and Archaelogy

LABEC – **L**aboratorio di Tecniche Nucleari per l'**A**mbiente e i **Be**ni **C**ulturali

Which IBA techniques to use in archaeology ?

Materials identification

- *analysis of major elements by PIXE and PIGE*

Materials provenance

(sources of raw materials and trade routes)

- *analysis of trace elements by PIXE*

Manufacture technology

- *High spatial resolution required: lateral by μ-PIXE, in depth by RBS*

Which IBA techniques to use conservation science ?

Evaluation of the state of conservation of museum objects
study of alteration of the surface

- *depth profiling by RBS, ERDA and NRA*

Preventive conservation
monitoring the museum environment (air)

- *analysis of aerosols collected on filters in museums by PIXE*

Conclusions

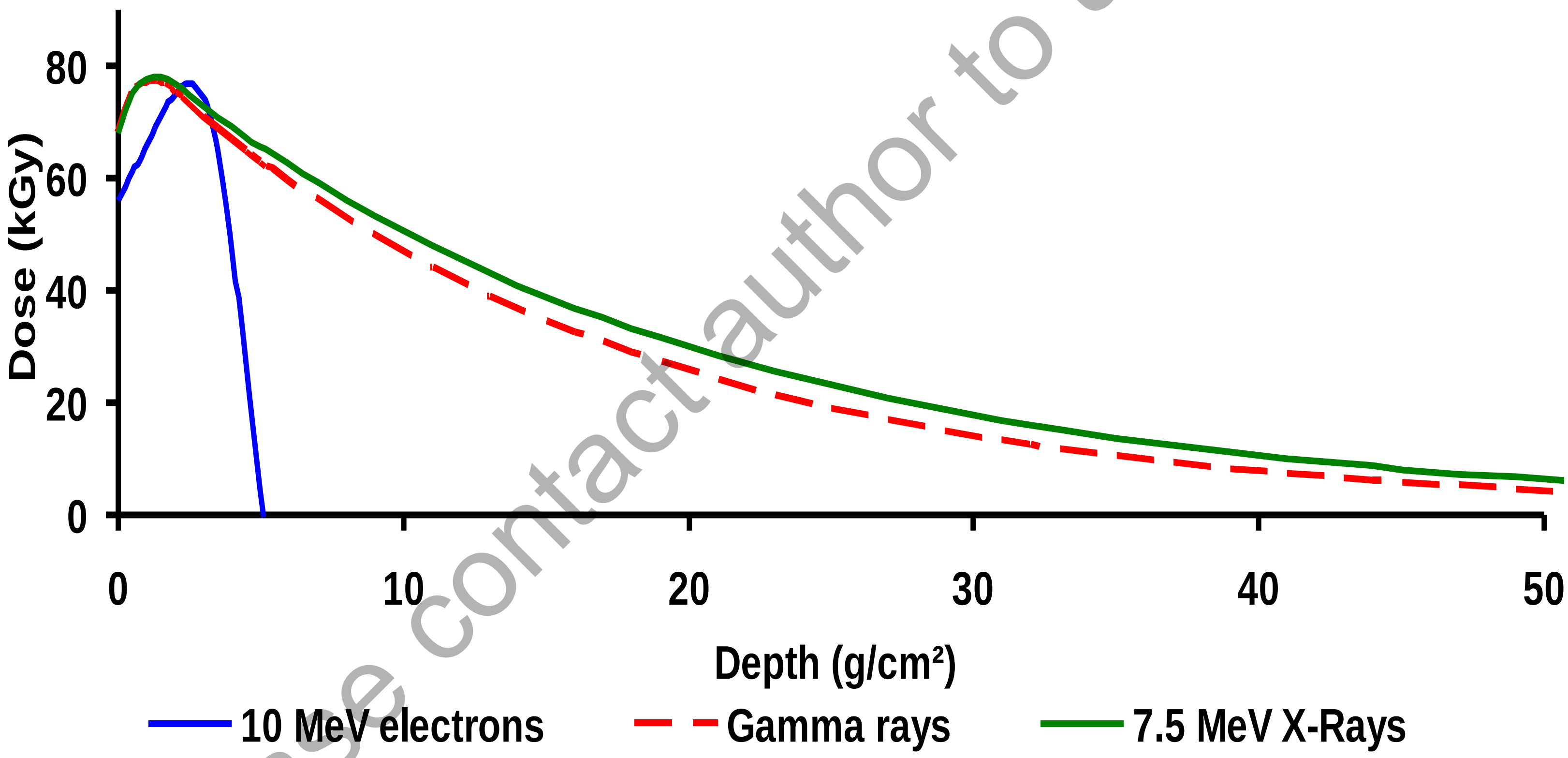
•Also for cultural heritage applications a proper experimental set-up is mandatory

•A strong collaboration with restorators, art historians, ….. is necessary

•IBA must be used when portable techniques cannot give equivalent information

Industry and Environment:
e- beams

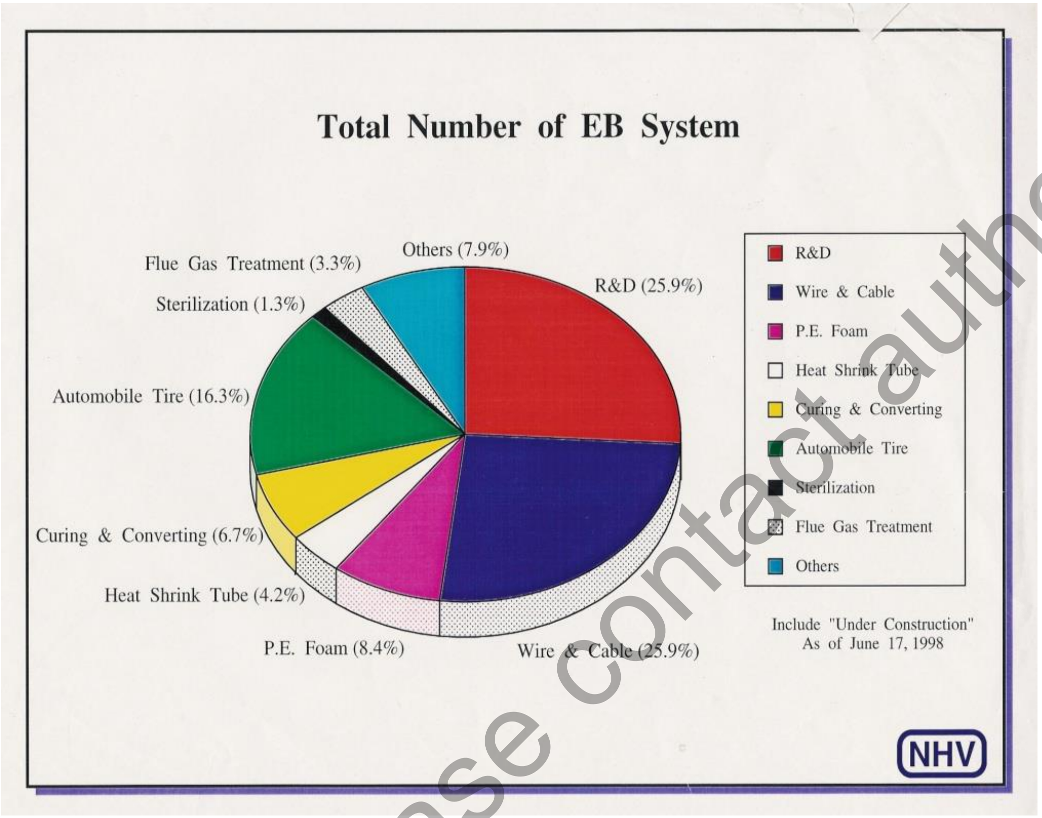
Gamma Ray and X-ray Penetration

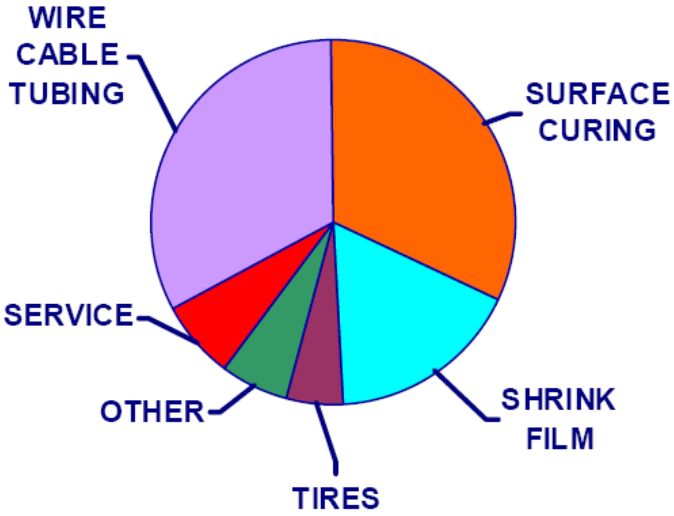


Accelerators for different applications

Market segment	Typical energy	Electron penetration
Surface curing	80 – 300 keV	0.4 mm
Shrink film	300-800 keV	2 mm
Wire & Cable	0.4 – 3 MeV	11 mm
Sterilization	4 – 10 MeV	38 mm
Food	4 – 10 MeV	38 mm
Composites (carbon fiber)	10 MeV	24 mm or less
Flue gas	300 – 1000keV	120cm do 3m
Wastewater	1MeV	2mm
Biological sludge	1 – 10 MeV	2mm do 30mm

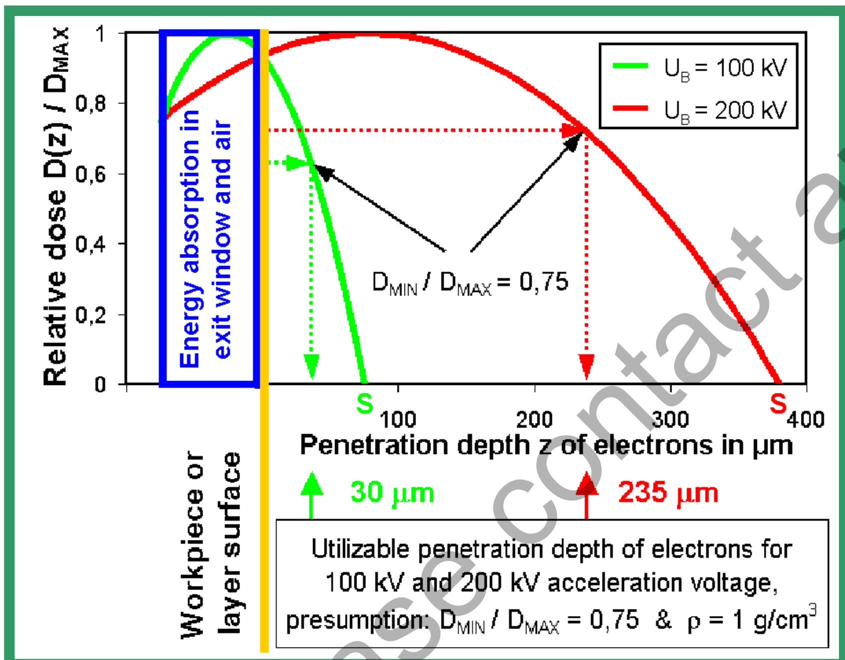
Industries using electron accelerators

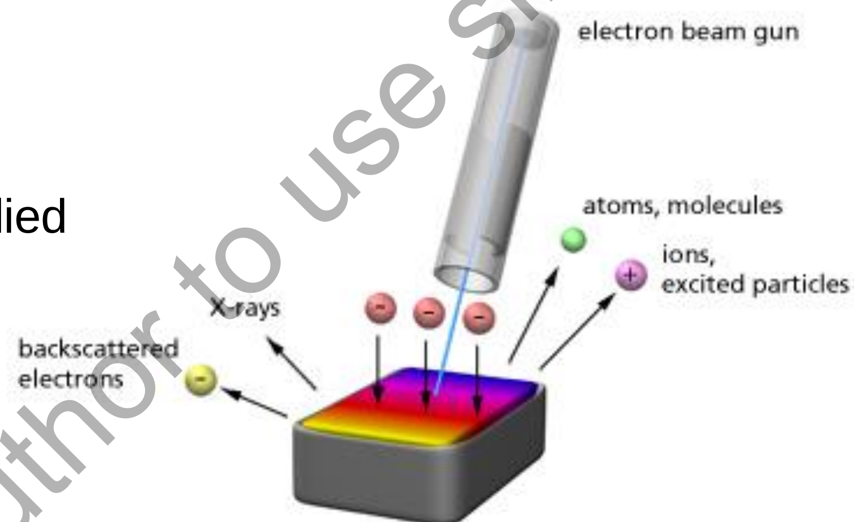


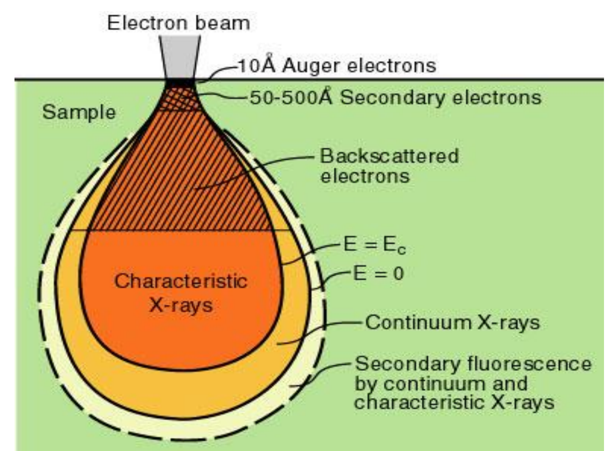


Electron Beam Processing - General

- Different interactions of accelerated electrons with matter
- Each interaction is technological applied







Fraunhofer FEP

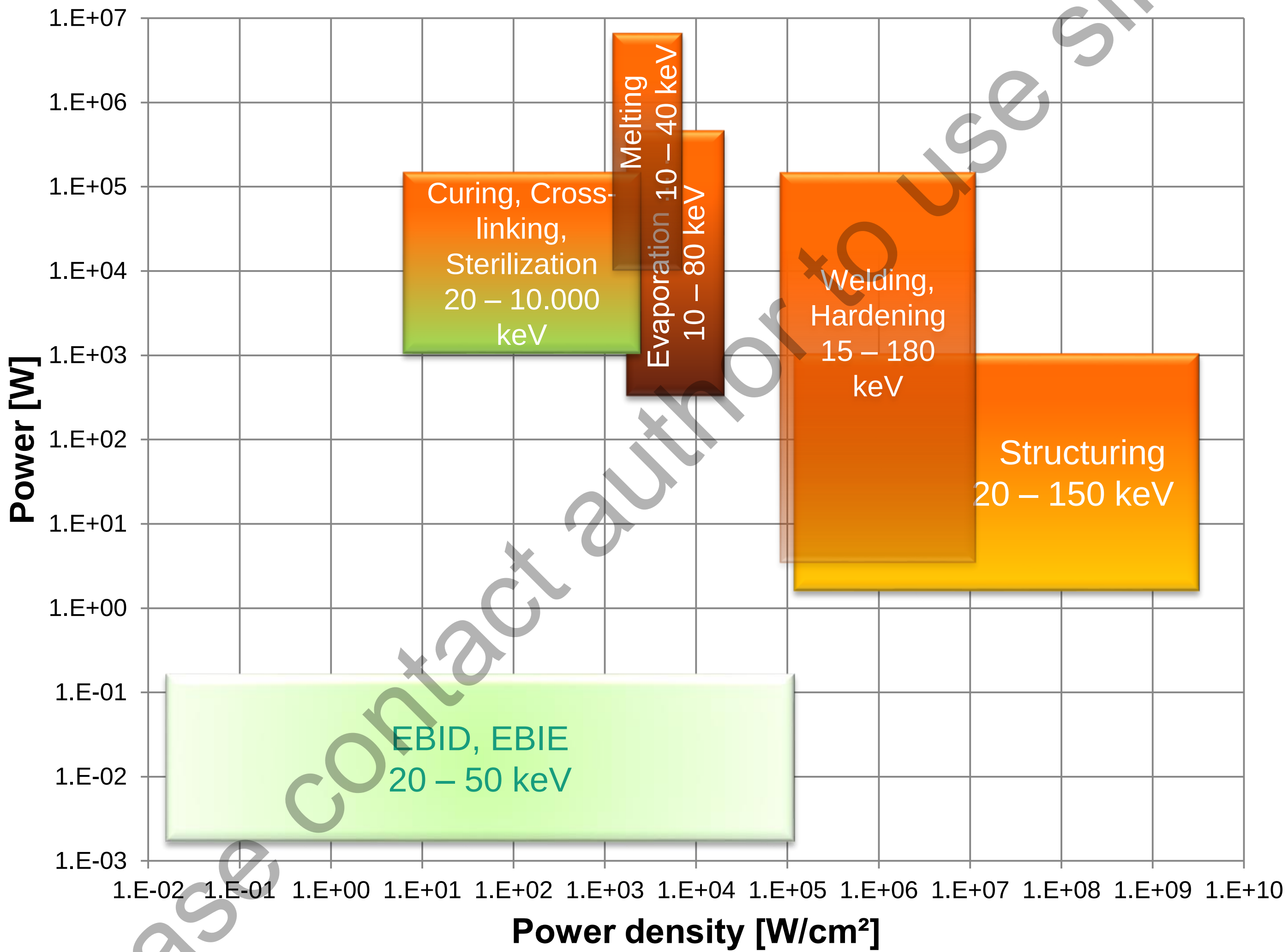
Electron Beam Processing - General

Effects of Electron Beam Interaction

Thermal Processes	Non-thermal Processes	
Heat Production	Chemical Reactions	Biocidal Effects
Vacuum	Atmosphere	Atmosphere
- Evaporation - Melting - Welding / Joining - Hardening - Micro- structuring	- Curing - Crosslinking - Drying print-inks - Surface modification (Grafting)	- Disinfection of animal feed - Seed treatment - Sterilisation of products - Sterile packaging - Inactivation of pharma waste

Fraunhofer FEP

Electron Beam Processing - General



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4. “Hot Spots/Highlights” of Low-Energy EB-Applications

(Examples)

- **4.1. Sterilization Lines of Pharmaceutical Syringe Filling Tubs**
- Linac-Getinge
- Metall + Plastic
- IBA Industrial Inc.

- **4.2. Sterilization of Bottles**
- Krones AG, Neutraubling/Germany
- Hitachi Zosen (No Europe)

- **4.3. Sterilization of Water**
- 4.3.1. Krones AG, Neutraubling/Germany

4. “Hot Spots/Highlights” of Low-Energy EB-Applications
(Examples)

- **4.4. Cleaning of Gases**
- IOM Leipzig/Germany and FZK Karlsruhe/Germany

.

- **4.5. Disinfection of Seeds**
- Fraunhofer FEP Dresden/Germany

.

- **4.6. Crosslinking of Polymers**
- CFS Kempten – Schur Flexibles Dixie GmbH Kempten – ConFlex Packaging GmbH Kempten/Germany
- DTS-Systemoberflächen GmbH – Oberhausen/Germany DTS-Systemoberflächen GmbH, D-39291 Möckern/Germany

4. “Hot Spots/Highlights” of Low-Energy EB-Applications

(Examples)

4.7. Coating/Printing of Decor Foils

.

- FEP Dresden/Germany in Coop with MEC Alsdorf/Germany (in 1995)
- Fachhochschule München/Germany, (Experimental Pilot Plant)
- DTS-Systemoberflächen GmbH, D-39291 Möckern/Germany
- SURTECO-Süddekor GmbH, Laichingen/Germany

4.8. Lacquer Curing on Furnitures

.

- FEP Dresden/Germany in Coop with MZI, Kraft and Kampmeier (in 2000)
- Scannery Holztechnik GmbH, Falkenhagen/Germany

Fraunhofer FEP

Summary

- Electron beam technology is an all-round tool for application in different industries
- Processing by electron beam means:
  - energy efficiency
  - very high processing speed
  - environmental friendly
  - long term stability
  - Vacuum or non-vac processing

Summary

- Actually market trends
  - Rising EB-technology implemention driven by energy, environment, throughput, quality arguments
  - Online dosimetry will become a key part of quality ensurance
  - Need of compact design for production line implementation
  - Thermal application have a markable part of industrial application
  - Food safety and plant protection will become more importance

Metrology

Neutron

Metrology and Accelerator Applications

Graeme Taylor

Neutron Metrology Group
National Physical Laboratory, Teddington, UK

Applications of Particle Accelerators in Europe
18-19 June 2015
Royal Academy of Engineering

Aims and capabilities

Role: Ensure measurements in the UK are consistent and to the required accuracy

The Neutron Metrology Group, NMG, provides:

- Characterised neutron fields
- Traceable calibrations
- Type test facilities
- Neutron spectrometry capabilities (field mmts)
- Research into dosimetry techniques

Proton and ion beam dosimetry at NPL

- development of a primary standard for protons and ions based on a portable graphite calorimeter
- improved measurements of the mean energy required to produce an ion pair in air for ionisation chamber dosimetry in proton and ion beams
- improved measurement and simulation using Monte Carlo methods of ionisation chamber perturbation factors;
- characterisation of energy dependent absorbed dose response of relative dosimeters: alanine, radiochromic film
- Improved dose conversion from different materials to water
- develop SQUID-based micro-calorimeter to measure ion beam microdosimetric spectra to underpin the definition of more biologically relevant quantity for radiotherapy.

Looking to the future

(accelerator-based neutron metrology in Europe)

- PTB Germany
  - Approval for new Tandetron 2 MV accelerator granted
  - Under construction by HVEE in Amersfoort/Netherlands
  - Expected delivery Q2-Q3 2016
- IRSN France
  - Already have a 2 MV Tandetron from HVEE
  - Off-line 2014 – 2016 for installation of 2nd beam line for microbeam facility
- NPL
  - Discussions re: accelerator replacement at early stage

2011 EMRP bid for HE Neutron Reference Fields (Fai

- Secondary radiation produced during ion (proton / carbon) therapy consists primarily of high-energy neutrons
- Characterization and calibration of dosemeters used in such fields require traceable neutron reference fields in the energy ranges under consideration (up to “a few 100 MeV”)
- No metrological facilities for this purpose in Europe
- Several proton / carbon ion therapy centres already in operation and more will start treatment in next few years
- There is a need to provide metrological infrastructure for such reference fields and provide them to stakeholders
- Proposed to develop such reference fields at existing proton therapy facilities.