



# NICSTAR 2015



## Session -III

# The growth of EB and X Ray technologies

Electron Beam and X Ray equipment;

State of the Art

Francis MARTIN

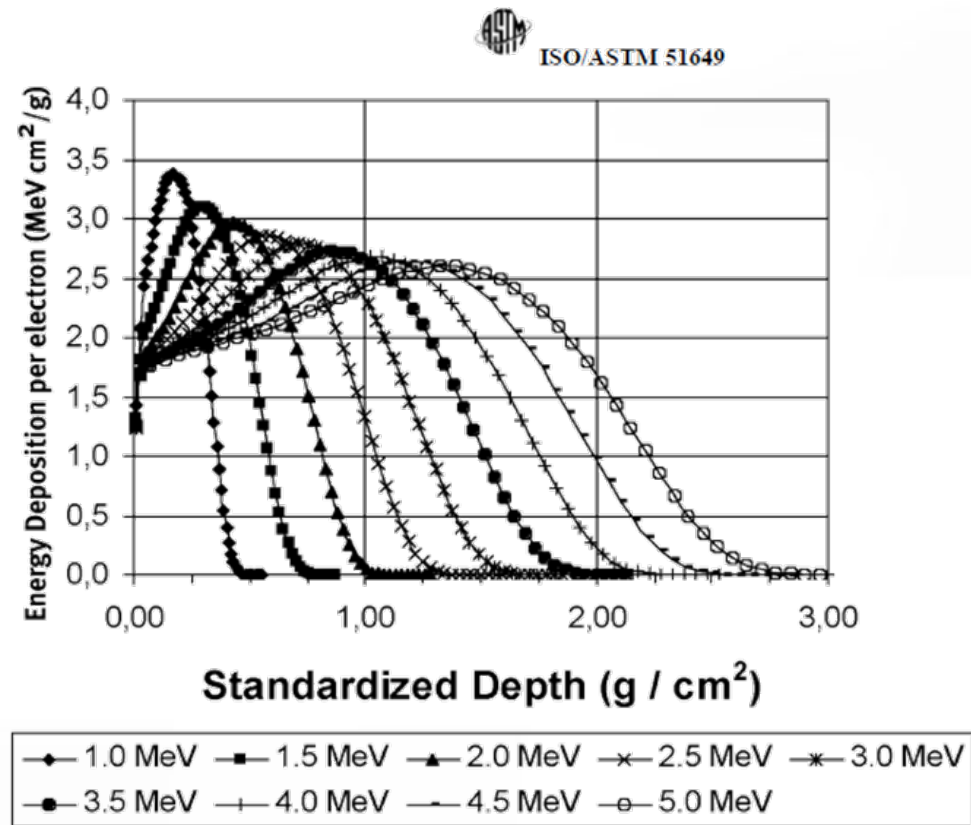
NACRE

# Summary

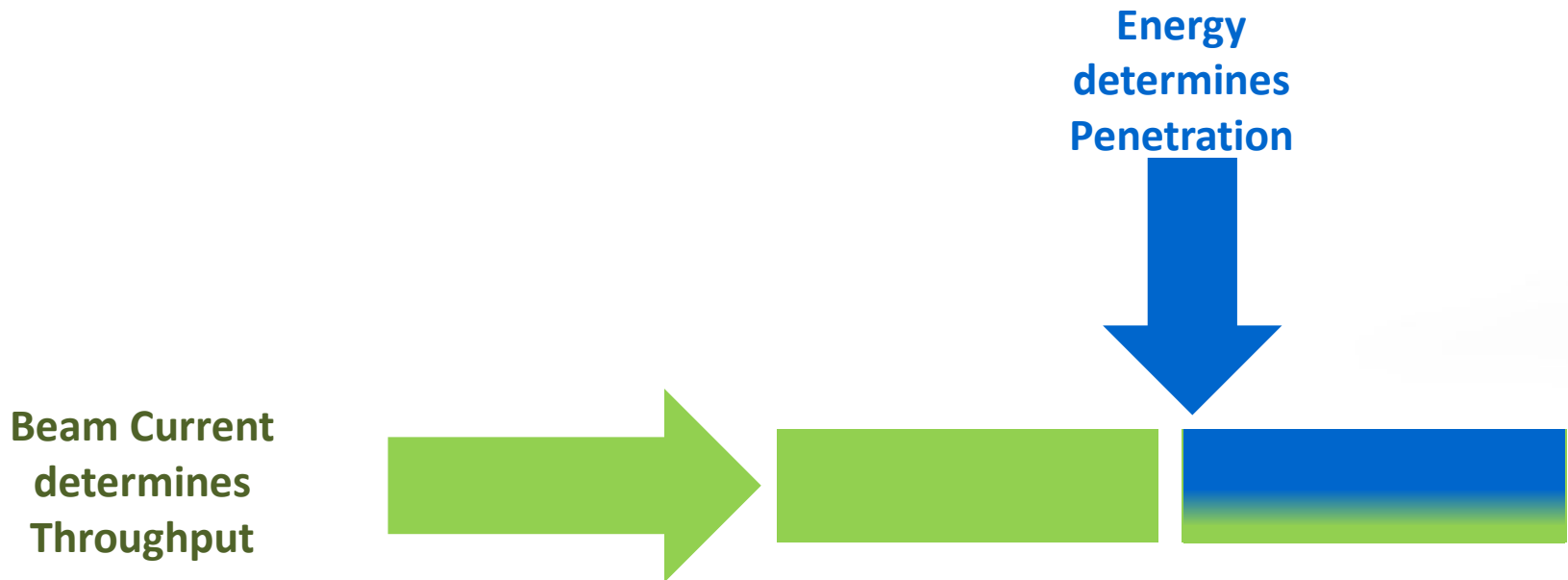
- Back to basic
- Machines and Applications
  - Low Energy (80keV to 300keV)
  - Medium (up to 5MeV)
  - High (up to 10MeV)
- Latest developments
  - Machines
  - R & D
- Some ideas for future...

# Electron Beam Processing

- Low mass charged particles explaining penetration curves
- **Energy = penetration**
- Up to 10MeV
  - No radioactivity induced
  - Penetration less than 6 cm in water



# Electron Beam Processing



**Current = Electrons Flow  $\approx$  Dose  $\approx$   
Treatment Speed**

**Energy = Penetration**

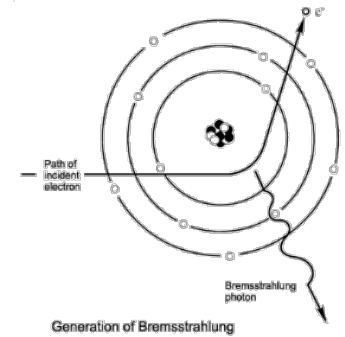
$$P \text{ (kW)} = E \text{ (MeV)} \times I \text{ (mA)}$$

$$1 \text{ Gy} = 1 \text{ J/ kg} = 1 \text{ W.s / kg}$$

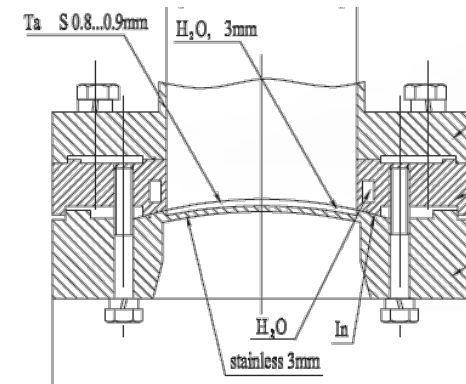
# Electron Beam Processing

- Beam directed toward products
- Finite product penetration
- Controlled treatment zones (scanning)
- High dose delivery (kGy/s) giving very short treatment time
- Wide range of energy and power ratings
- Parameters are electrically controlled
  - Dose =  $k \cdot \text{beam current} / \text{scan} \cdot \text{product speed}$   
(at given energy)
- Equipment can be switched on and off

# X-Rays Converter

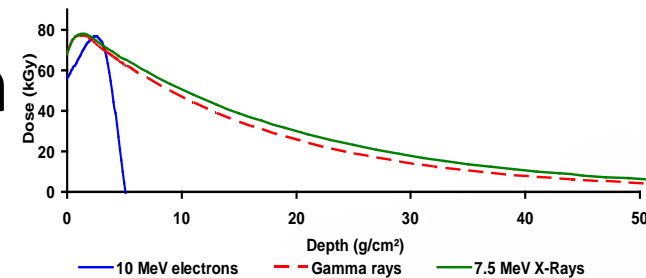


- Generated by electrons decelerated (bremsstrahlung) in high atomic number material (generally Tantalum),
- From EB up to 7,5MeV maximum,
- EB @150kW  $\approx$  12kW X-rays  $\approx$  1MCi,
- Need high power EB to compete with large gamma centers,
- Dose can be adjusted (rotation, speed and scan adjustment,...),
- Nearly all manufacturers of EB supply converters.



# X-Rays Processing

- Rays mainly emitted toward products
- Exponential product penetration
- Dose delivery of kGy/min
- Better Dose Uniformity than electron and improved compare to gamma
- Equipment can be switched on and off
- No decay / time
- Competes with gamma rather than electrons



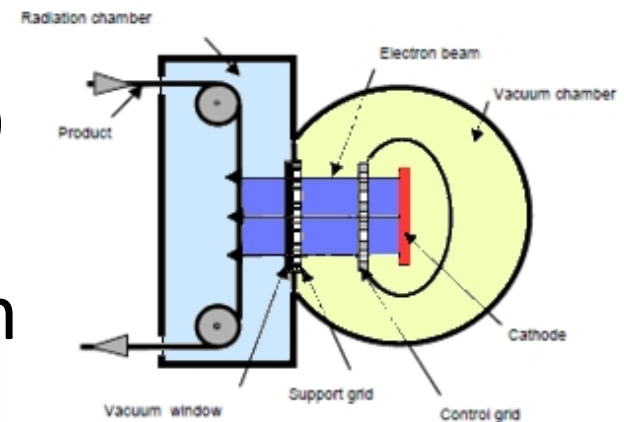
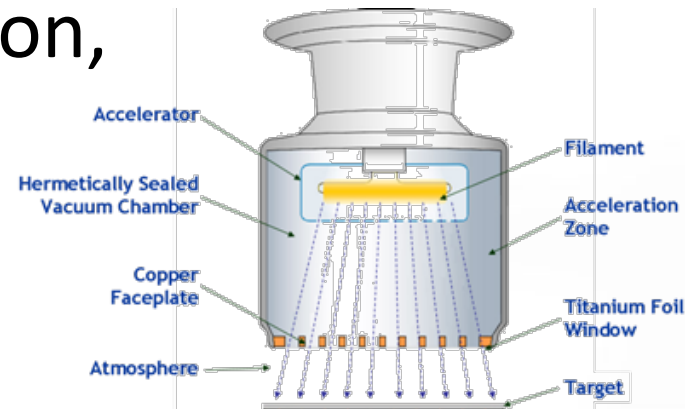
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# Low Energy Machines

- High voltage DC power supply, up to 300keV, single gap acceleration, long or multiple filaments, so called "curtain beam"
- 2 types:
  - Low power (generally sealed vacuum tube) at max around 30mA (several 1000 kGy m/min)
  - Industrial machines up to 1A (15000 kGy m/min)
- Low penetration (less than 1mm in water)



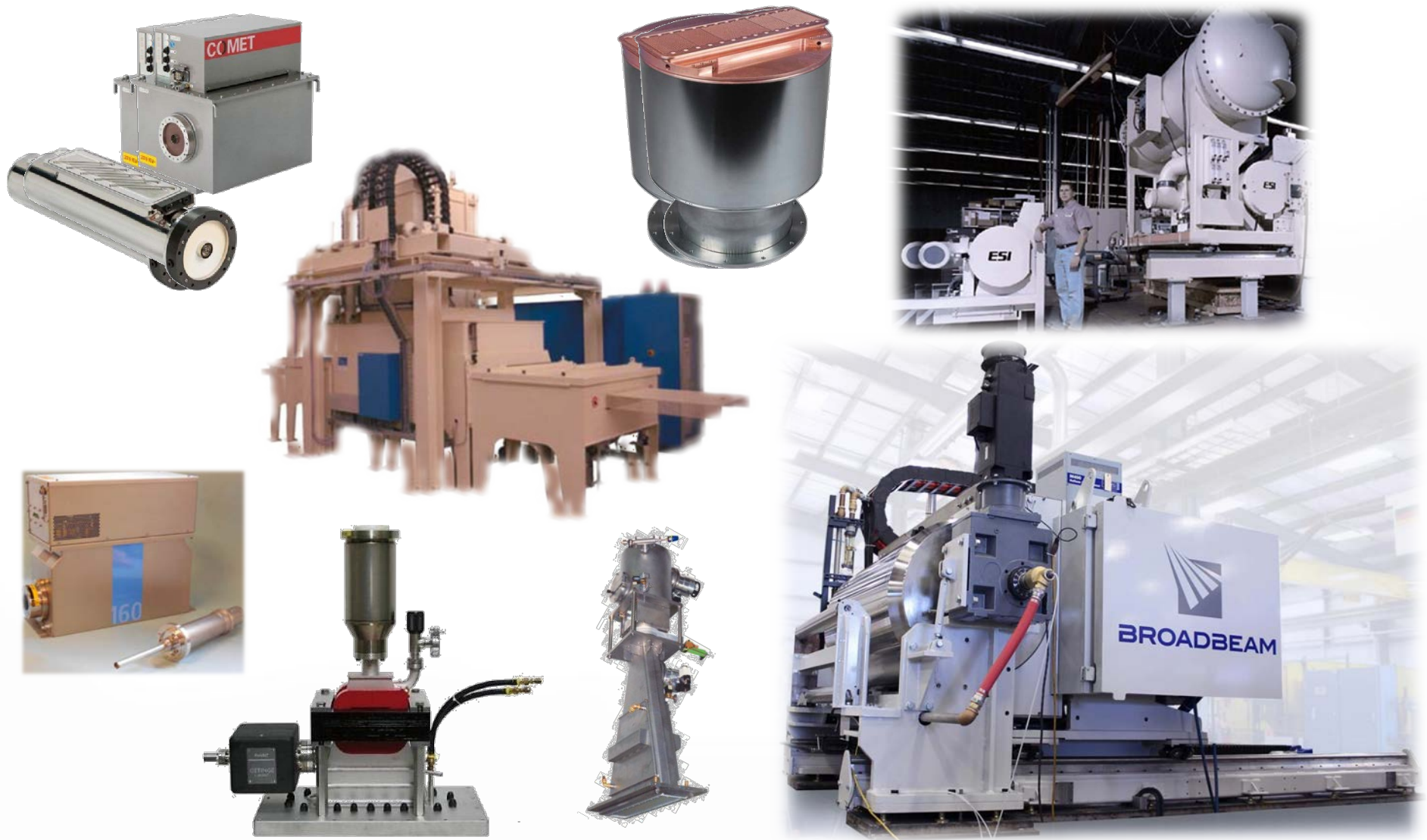
# Low Energy Machines Suppliers

- Crosslinking AB
- ebeam (Comet)
- Energy Science Inc. (EZCure<sup>®</sup>)
- Getinge
- Hitachi Zosen
- Istok (Russia)
- Nissin High Voltage (Curetron<sup>®</sup>)
- PCT Engineered System (BroadBeam<sup>®</sup>)



ANALOG ELECTRONIC SYSTEMS, INC.

# Low Energy Machines Examples



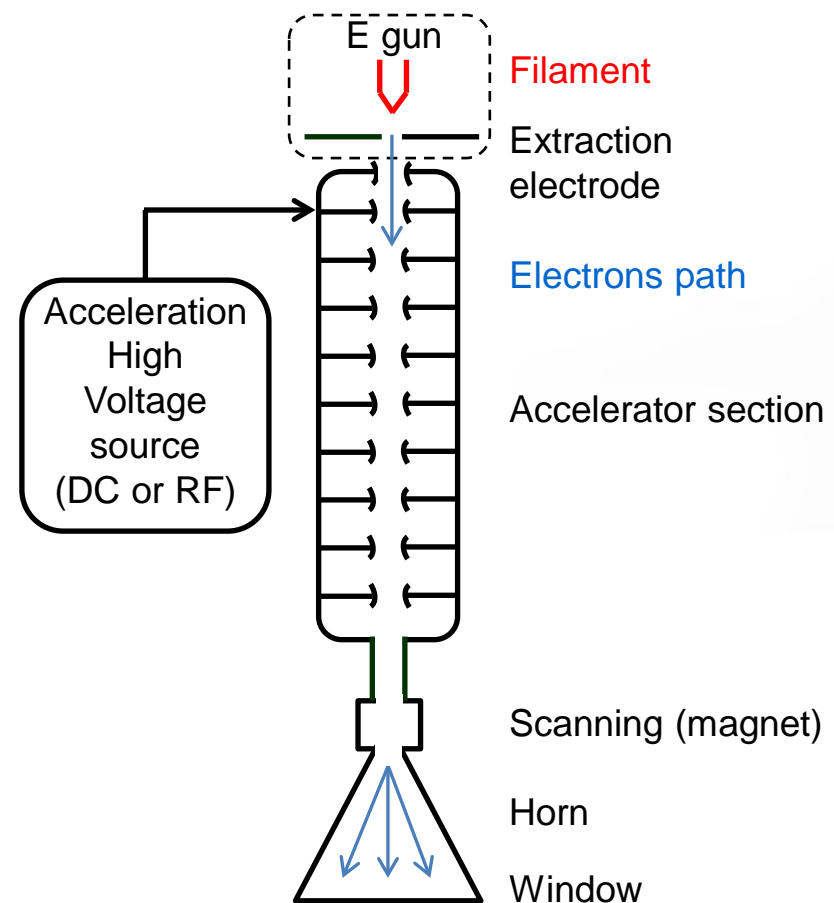
# Low Energy Machines Applications

- Printing & Converting, Press, Flexo, Offset, ...
- Curing Ink, Paint, Coil Coating,...
- Composites, foams, ...
- Food (especially with X-Ray),
- Decontamination and Aseptic Filling; food packaging films, containers (bottle, can, ...)
- Adhesives and PSA (temporary protection film),
- Pharmaceutical industry (drug treatment, insulators,...)



# Medium Energy Machines

- DC Electron beams
  - Van de Graaff
  - Voltage multipliers type, the "Dynamitron" family
  - Transformer type ICT
- Energy up to 5MeV
- Power up to 500kW
- Few cm penetration



# Medium Energy Machines Suppliers

- Budker (ELV) & EB-Tech
- Dasheng Electron Accelerator
- El Pont
- High Voltage Eng.
- Hi-Wits Tech
- IBA Industrial (previously RDI)
- Nissin High Voltage Corp.
- Vivirad
- Wasik



EL PONT



VIVIRAD S.A

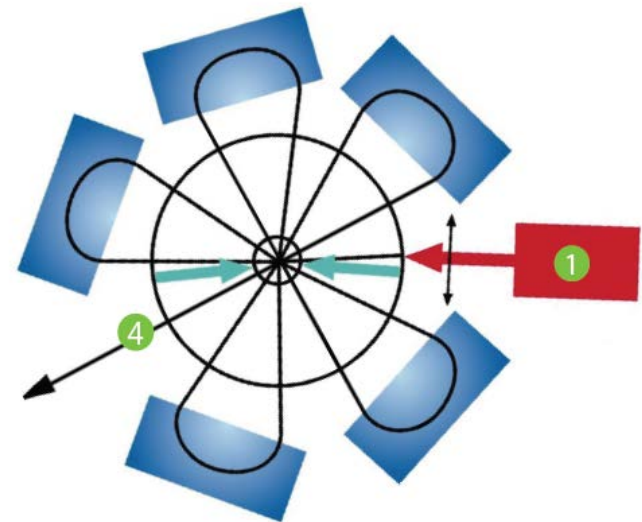
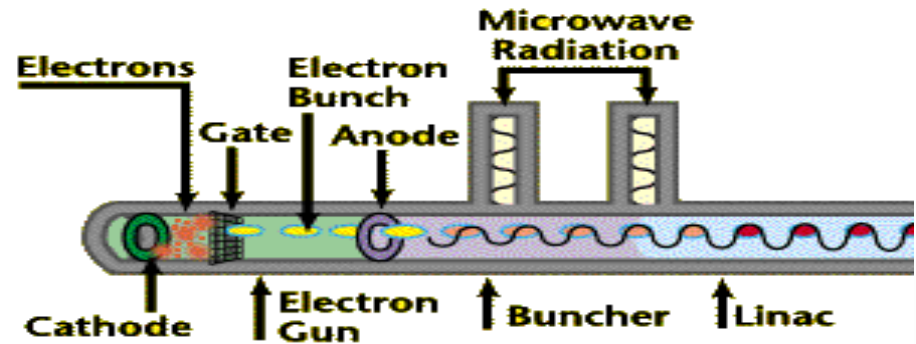


# Medium Energy Machines Examples



# High Energy Machines

- High Frequency type acceleration
  - Linac (few GHz)
  - Rhodotron (100MHz)
  - Others (ILU, FFAG,...)
- Energy up to 10MeV (by regulation)
- Power up to 30kW (linac) and 700kW (Rhodotron)





# High Energy Machines Suppliers

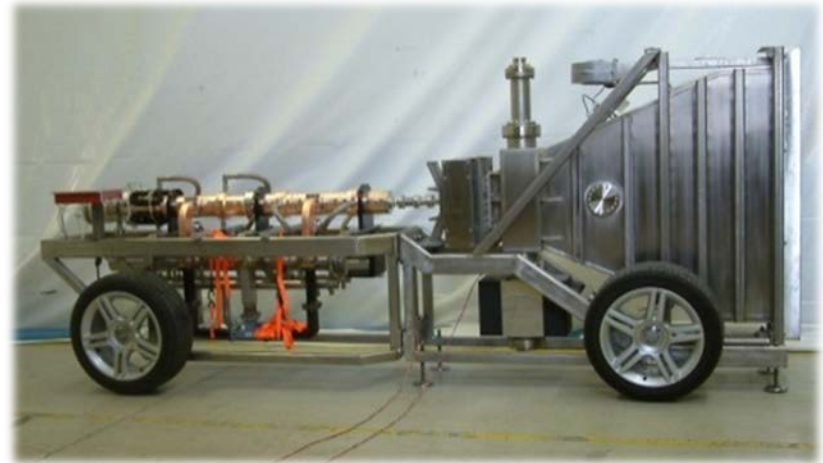
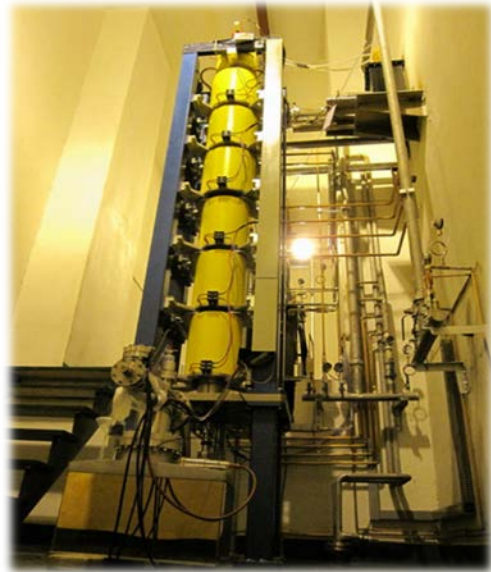
- Budker (ILU)
- El Pont
- Hi-Wits Tech
- Ion Beam Applications
- L3 Applied Technologies
- Nuctech
- Mevex
- RadiaBeam



EL PONT



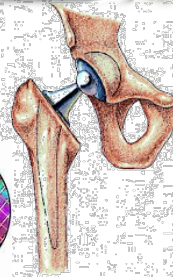
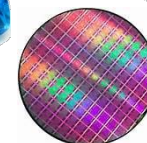
# High Energy Machines Examples



# Medium & High Energy Machines

## Applications

- Medical devices sterilization,
- Polymer crosslink, wires & cables,
- Tires,
- Food (direct Electron or X-Ray),
- Environmental Applications, Water & Flue Gaz treatment, Recycling,
- Medical implant, hydrogel,
- Gemstones, semiconductors,...

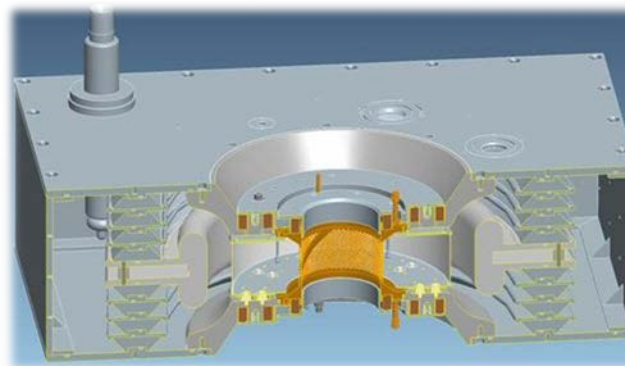


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# Latest Industry Developments

- Security issues, concern on supply and price of Cobalt-60 make X-Ray even more relevant
- IBA Modular Machines and dual technology EB & X-Ray
- Circular machine in Fraunhofer Germany

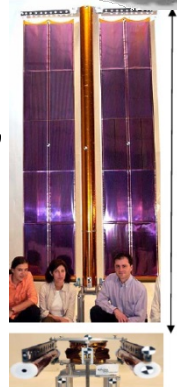
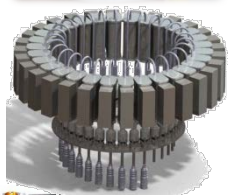


# Latest R&D Works

- Food in USA & South America
  - Chapman University, Texas University, Michigan State University, Hawaii Research Center, Iowa State Univ, Brazil (IPEN), Mexico,...
- "Soft beam" (<300keV EB) in Japan
- Fraunhofer institut (develop machine and market opportunities)
- Korea with EB-Tech works on environmental
- Composites in France (Reims Univ. and EADS)
- And many others...

# Emerging applications

- Food industry
  - Early 80's applications
  - Treatment on site of products; beef paddies, fresh salads, spices, seeds, fruits, ...
  - Decontamination & treatment of packaging,
  - Aseptic filling markets (Tetra Pak, Hitachi, Krönes, Serac, Shibuya,...)
- Treatment of composites (car, aerospace, civil engineering, ...)



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# Conclusions

- EB & X-Ray adaptable to customer needs (energy, power, scan, ...)
- Green technology:
  - no/less solvent, photo-initiator, additive, preservative, energy saving, ...
- Large offer, lot of suppliers
- No decay of X-Ray / time ---> low maintenance cost
- High treatment speed compare to Cobalt (kGy/second or /min)
- But not as developed as it should be...

# Conclusions

- CAPEX for a high power X-Ray unit is still too high and limits the technology. By aiming at high margins, manufacturers deprive themselves of the economy of scales that there would be when selling more machines.
- The price issue complicates what could / should be an obvious choice especially for niche and small businesses.
- All players (academic, consultant, manufacturer, users) should promote this technology proliferation

# Thank you for attention

**NACRE** 

Industrial Irradiation Consulting

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Be Positive  Loose Electrons !

## Questions ?