Industrial Applications of Accelerators: Traditional and new

Accelerators for America's Future
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Ion Beam Applications sa

Defining Industrial Applications of Accelerators?

- Generally, high energy particle beams induce nuclear reactions and activation
- In contrast, in industrial applications, nuclear reactions and activation are undesirable and avoided, but other effects of ionizing radiations are researched
- These desired effects include:
  - Sterilization
  - Cross linking of polymers
  - Curing of composite materials
  - Modification of crystals
  - Doping of semi conductors
  - Beam aided chemical reactions
  - Thermal or mechanical effects of the particle beam

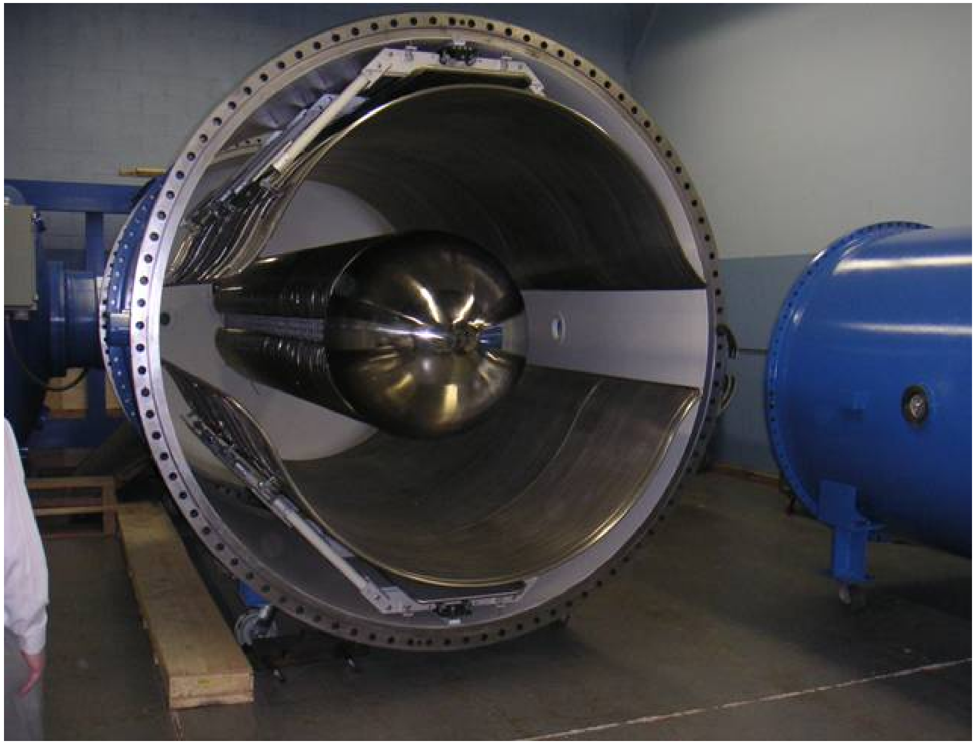
Which beams are used?

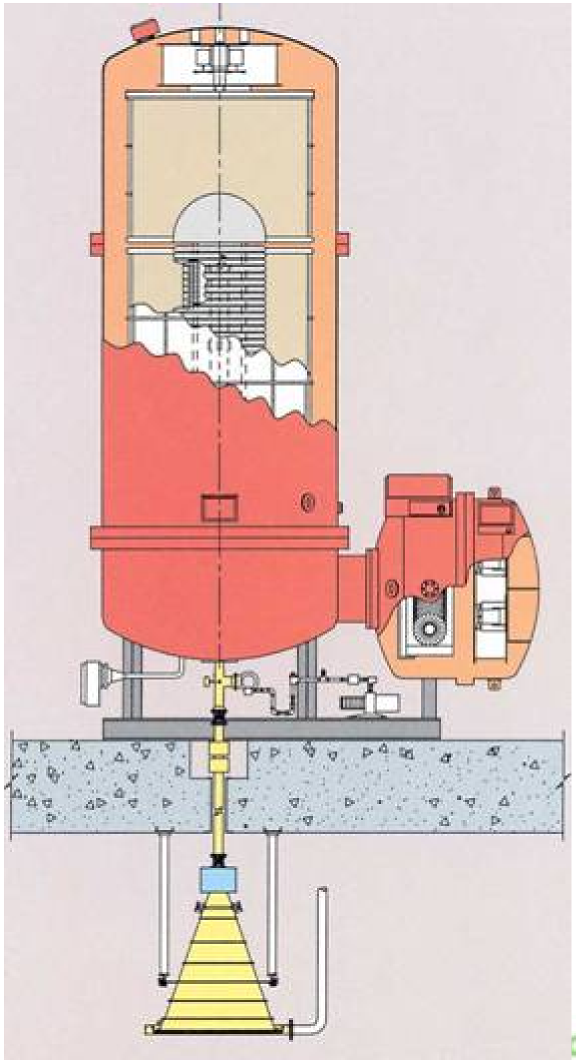
- The choice of particle beams used in industrial application is defined, to a large extent, by the desire to avoid nuclear reactions and activation
- Commonly used beams include
  - Electron beams below 10 MeV
  - X-Rays from e-beams below 7.5 MeV
  - Intense, low energy proton beams
  - Heavy ion beams well below the Coulomb barrier
- Also, for industrial applications, large beam currents/powers are needed to reach industrial scale production rates. Beam powers from 50 kW to 1 MW are common

Key E-beam and X-ray Industrial Applications

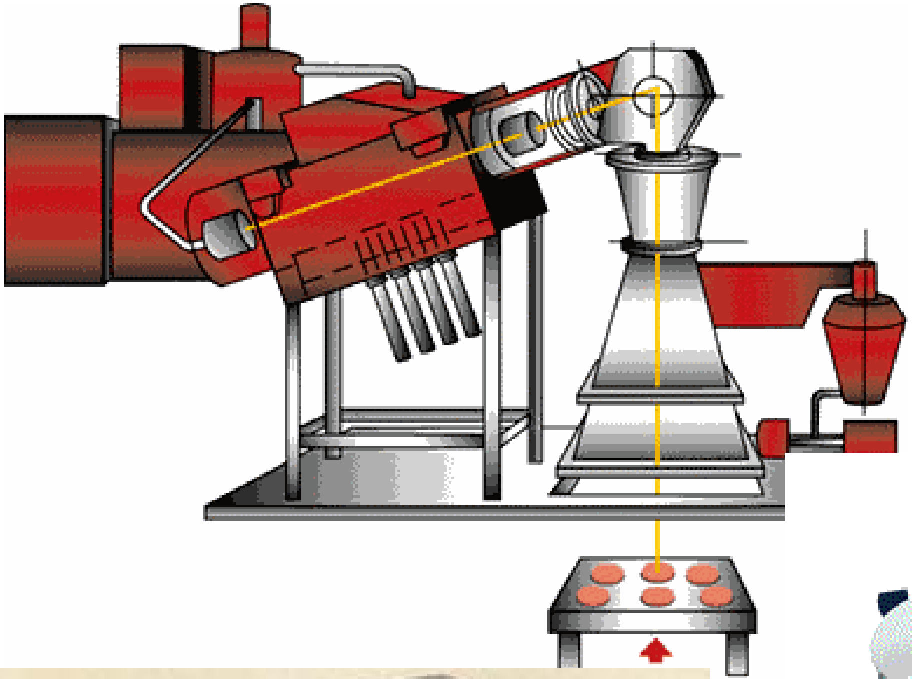
- Sterilization
  - Sterilization of Medical Devices
  - Surface Sterilization
  - Food Pasteurization
- E-beam induced chemistry
  - Reticulation of Polymers
  - Curing of composites
  - Environment remediation
- E-Beam induced crystal defects
  - Modification of Semiconductors
  - Coloring of Gemstones

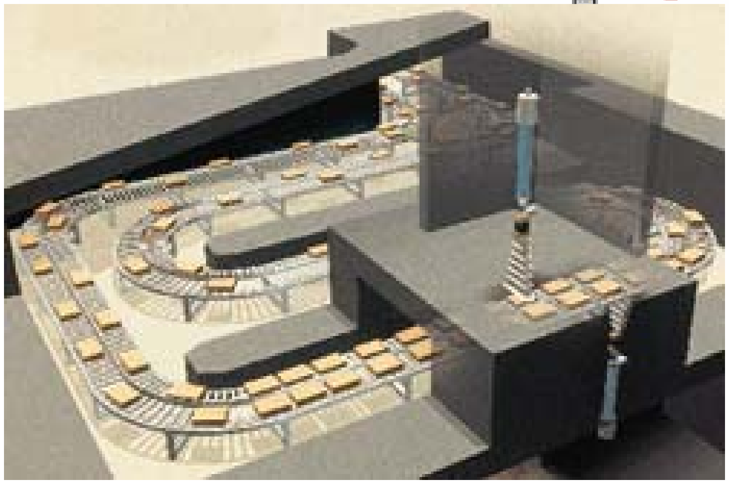
High power E-beam accelerators: 1) the Dynamitron

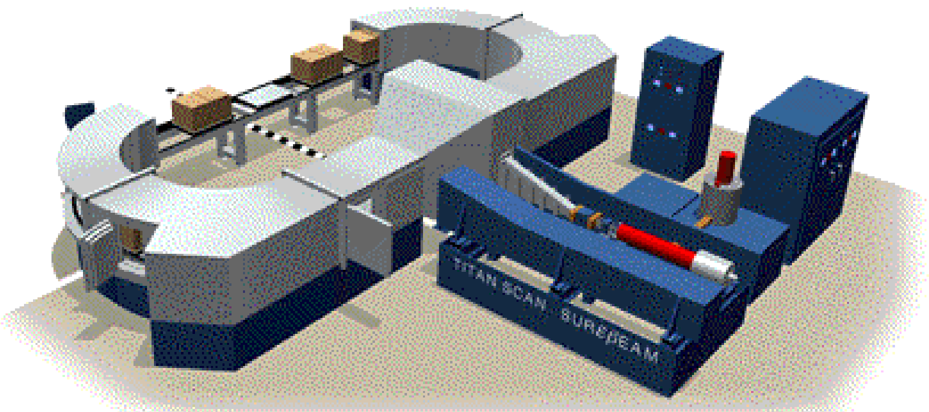




High power E-beam accelerators: 2) the Linacs







On-Site is a complete turn key operating system validated to ISO 11137 and delivered with all required training, documentation, dosimetry system and process certification.

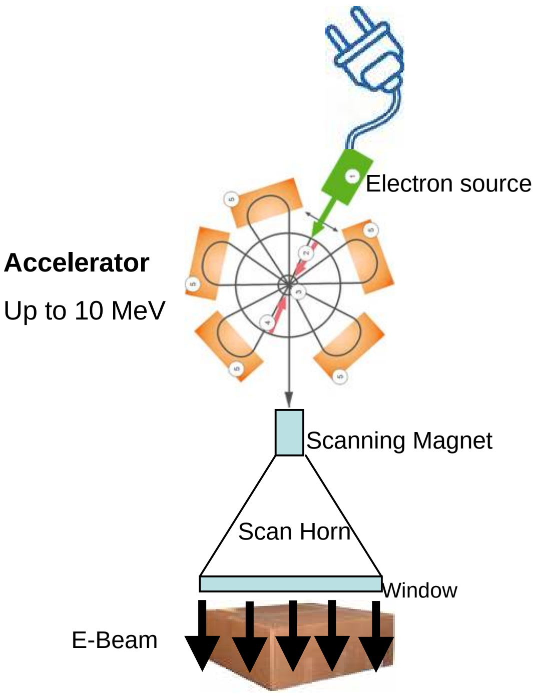
High power E-beam accelerators: 3) the Rhodotron

The options for the sterilization of medical devices

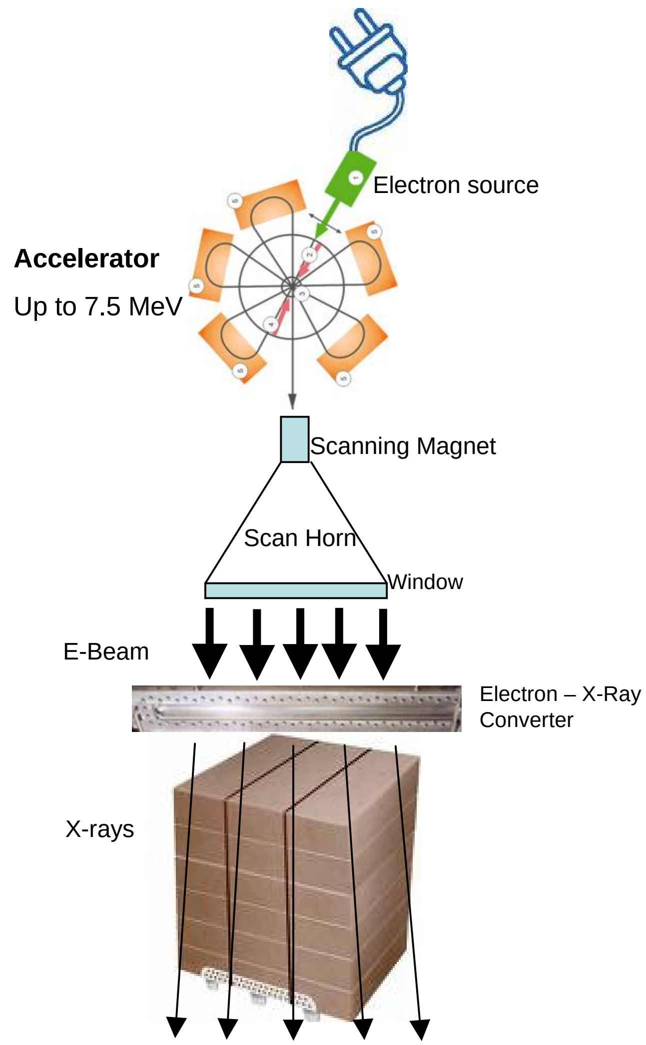
- Steam (incompatible with most polymers)
- Ethylene Oxyde
  - Inexpensive
  - EtO is explosive, toxic and harmful to the environment
  - EtO sterilization may leave harmful residues
- Irradiation
  - Cobalt
  - E-beam
  - X-ray

The options for sterilization by irradiation

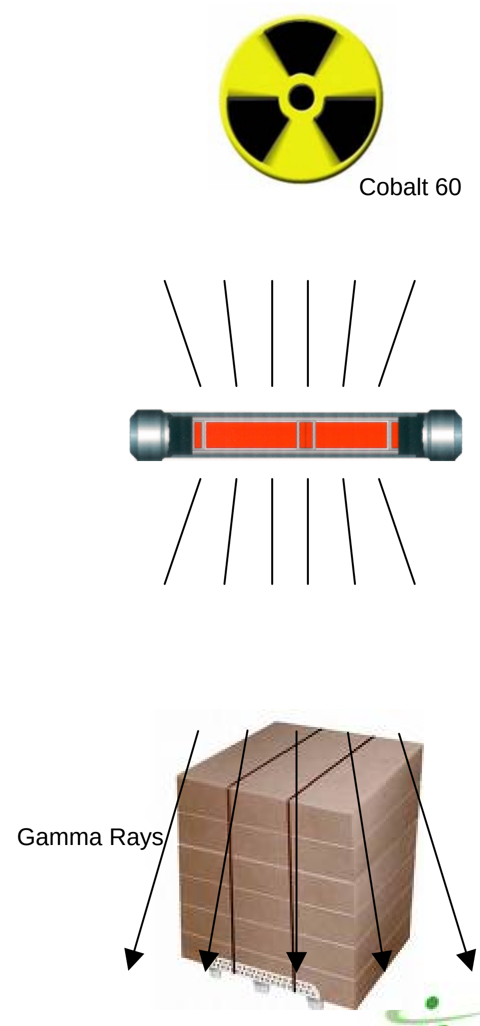
E-beam



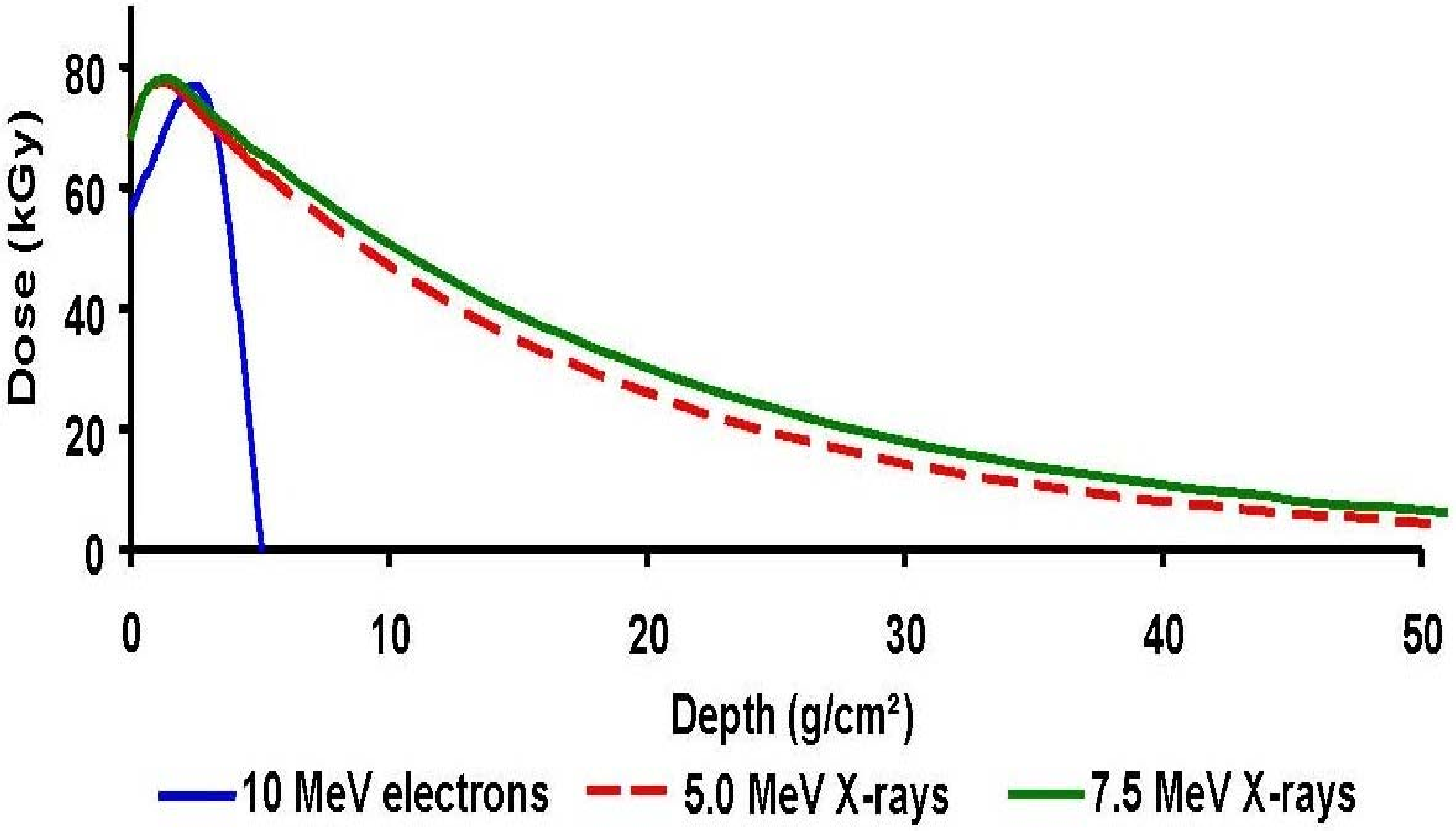
X-ray



Gamma



Depth-Dose Distributions – EB and X-ray



The options for sterilization by irradiation (1)

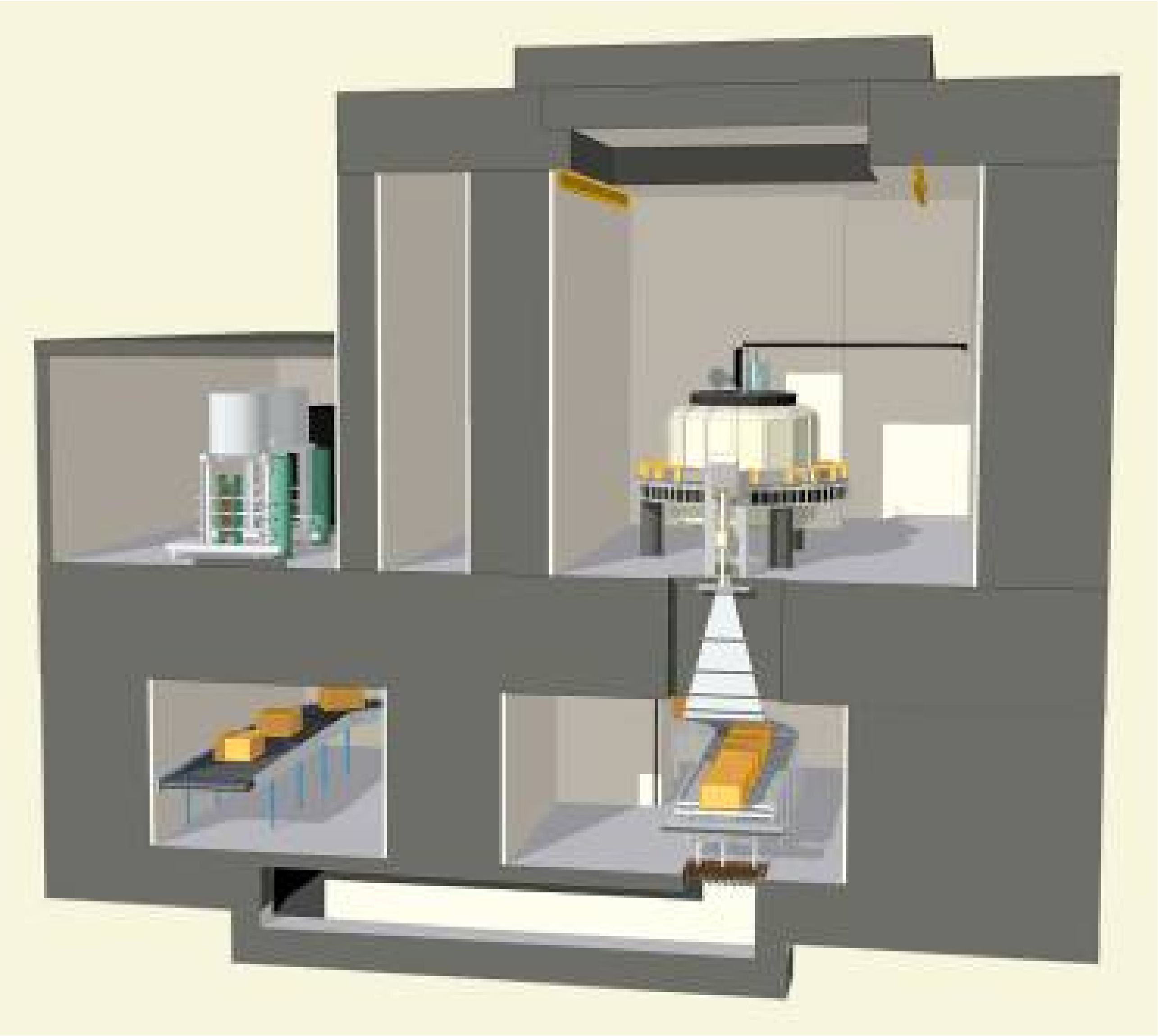
- Gammas from Co60
  - Low investment cost, specially for low capacities
  - Simple and reliable, scalable from 100 kCuries to 6 MCuries
  - Isotropic radiation > inefficiencies in use
  - Pallet irradiation, but low dose rate > slow process
  - Absolutely no activation
  - Cannot be turned OFF > inefficient if not used 24/7
  - Growing security concern: the cobalt from a sterilization plant could be used to make dirty bombs
- Electron beams
  - Directed radiation > Efficient use
  - Lowest cost of sterilization for large capacities
  - Can be turned OFF > safer
  - Short range (4.5 g/cm^2 at 10 MeV) > 2-sided irradiation of boxes
  - More complex dose mapping
  - Minimal, hardly measurable, but non zero activation

The options for sterilization by irradiation (2)

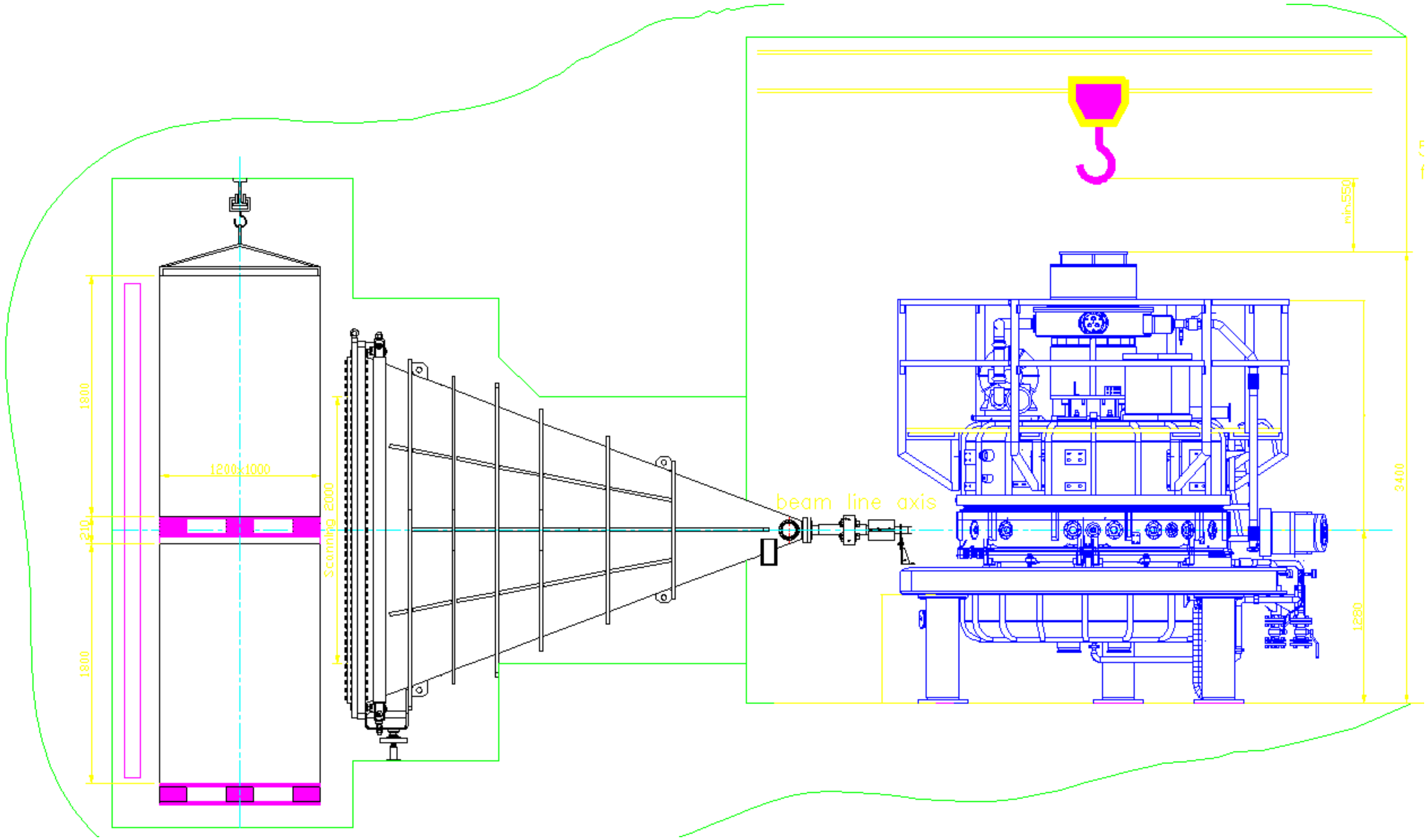
X-Rays from E-beams

- Excellent penetration
- Simple dose mapping
- Pallet irradiation
- Directed radiation > Efficient use
- Loss of a factor 10 in energy when converting e-beams to photons
- Cost of sterilization higher than electrons
- Cost of sterilization is generally higher by X-Rays than Cobalt if used 24/7, excepted for very large capacities
- Can be turned OFF > safer
- Minimal, hardly measurable, but non zero activation

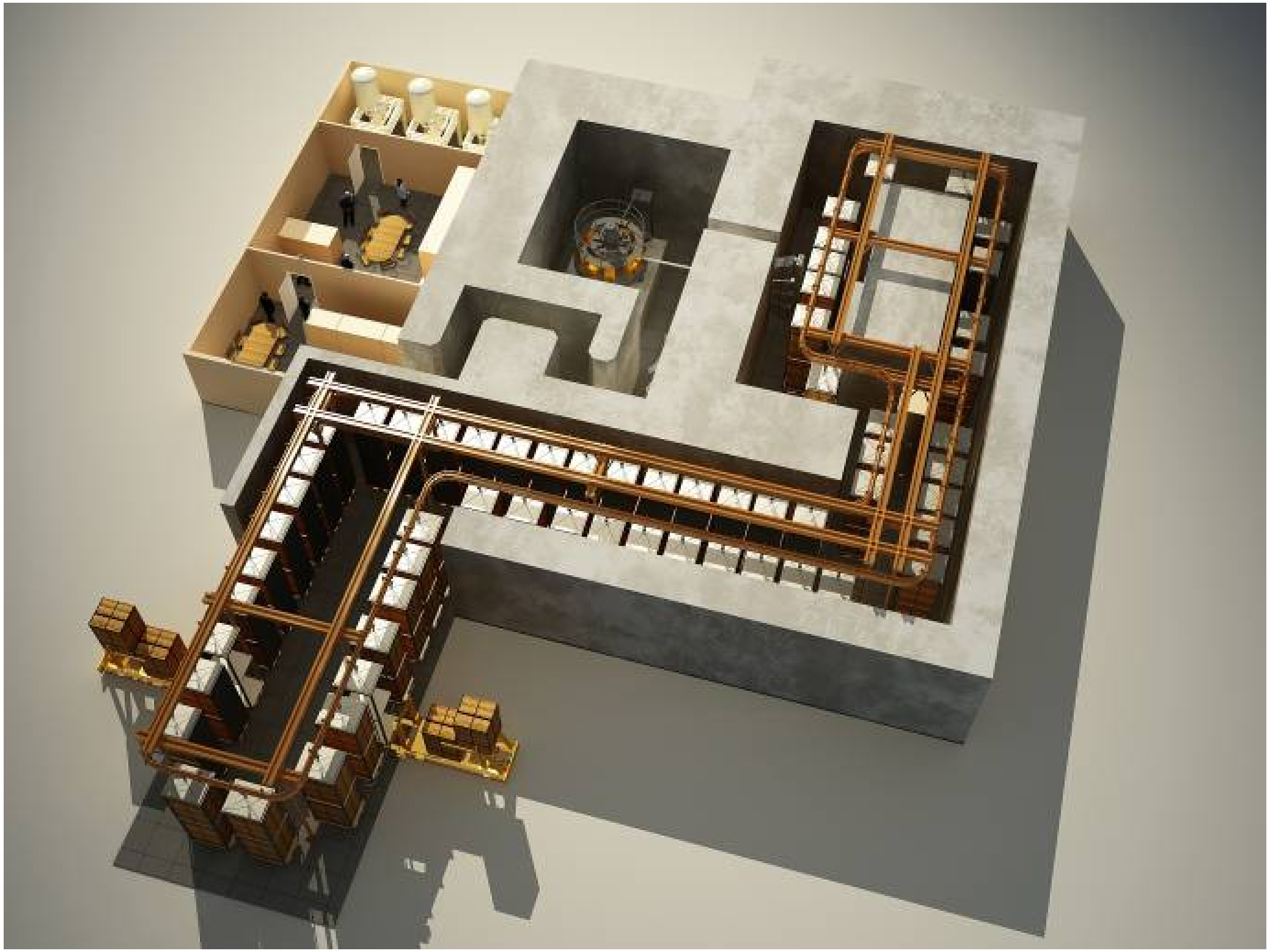
E-Beam medical disposables facility



700 kW Rhodotron with 3m long X-Ray target



X-ray facility layout



Food irradiation applications

- **Low Dose Applications (< 1kGy)**
  - **Phytosanitary** Insect Disinfection for grains, papayas, mangoes, avocados...
  - **Sprouting Inhibition** for potatoes, onions, garlic...
  - **Delaying of Maturation**, parasite disinfection.

- **Medium Dose Applications (1 – 10 kGy)**
  - **Control of Foodborne Pathogens** for beef, eggs, flounder-crab-meat, oysters...
  - **Shelf-life Extension** for chicken and pork, low fat fish, strawberries, carrots, mushrooms, papayas...
  - **Spice Irradiation**

- **High Dose Applications (> 10 kGy)**
  - **Food sterilization** of meat, poultry and some seafood is typically required for hospitalized patients or astronauts.

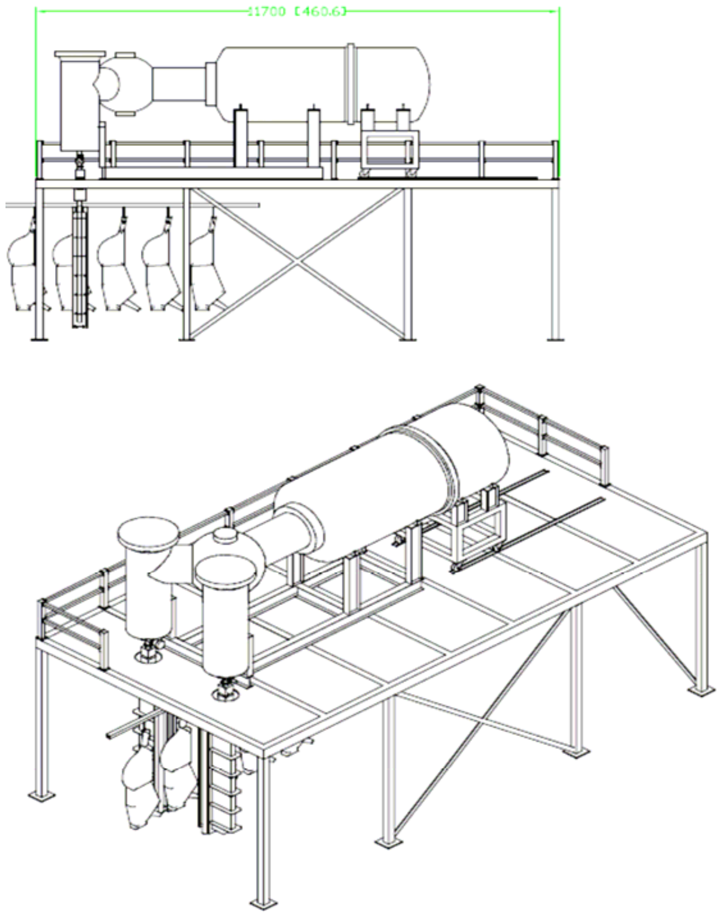
Surface Treatment of Carcasses

Relatively low voltage e-beam

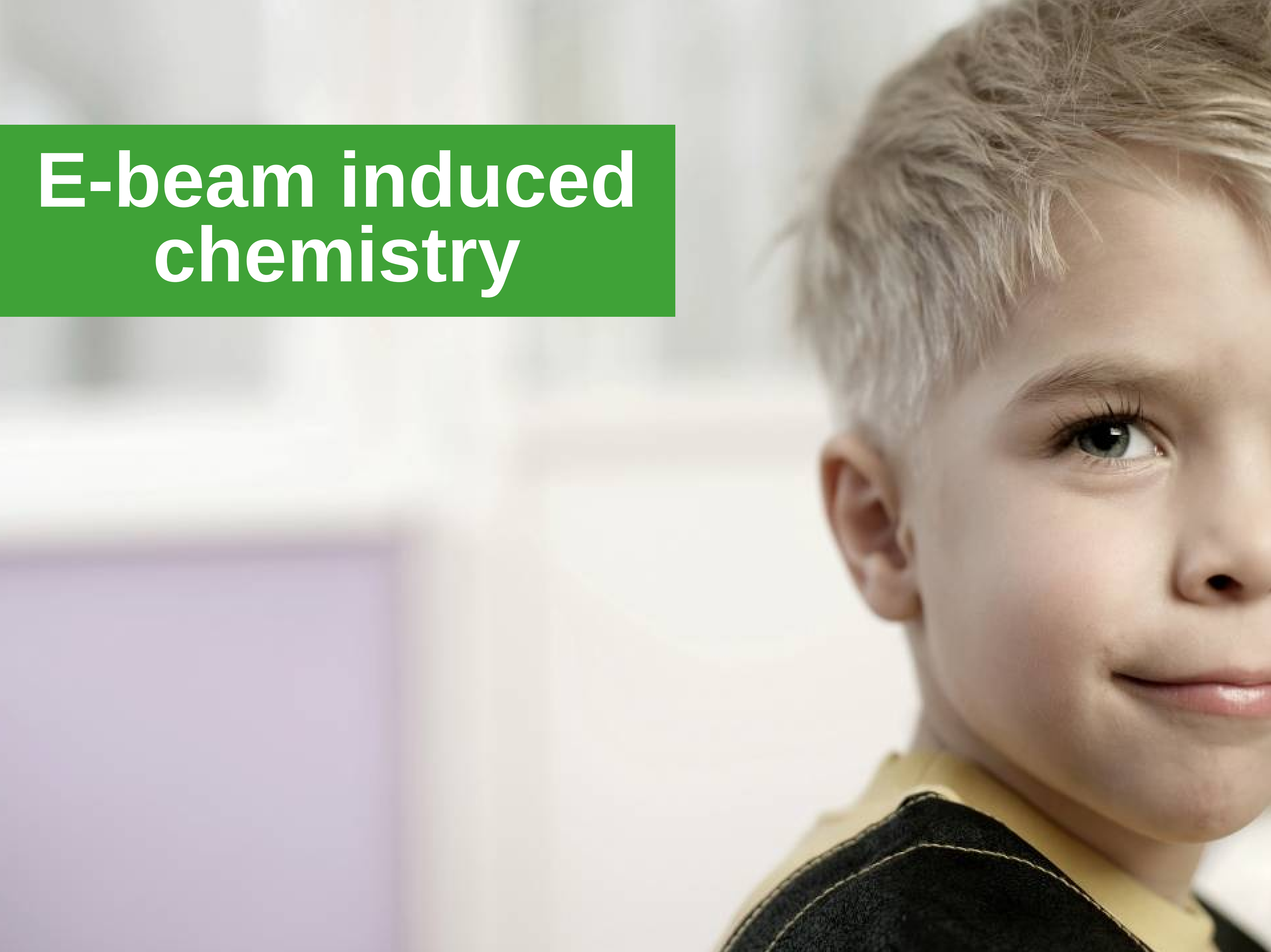
1 to 3 cm treatment depth

Mitigates risk of e-coli entering processing plant.

May be exempt from labeling requirements

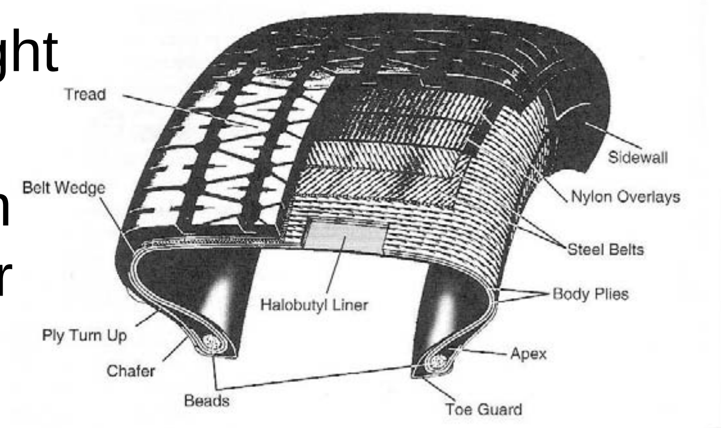


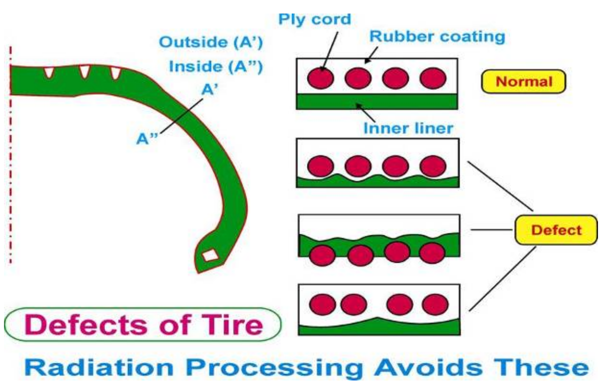
E-beam induced chemistry



E beam treatment of Tires

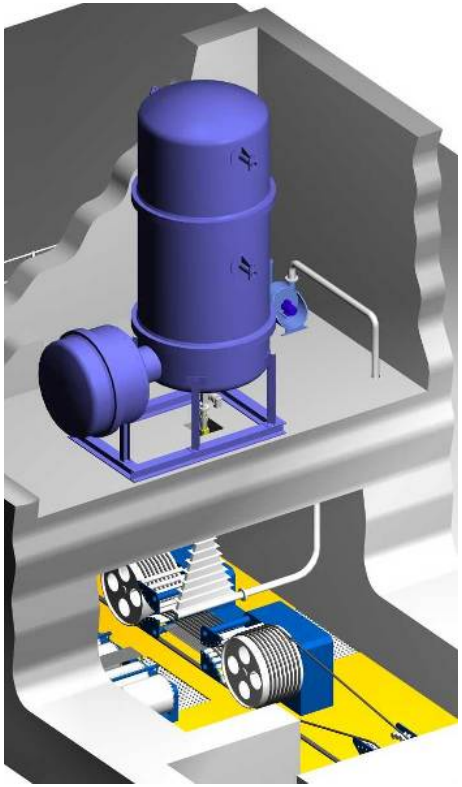
- Reduction in material hence in the weight of the tire
- Relatively low cost synthetic rubber can be used instead of costly natural rubber without a loss in strength
- The radiation pre-vulcanization of body ply is achieved by simply passing the body ply sheet under the scan horn of an electron accelerator to expose the sheet to high-energy electrons
- Higher production rates
- Construction of green tires
- Reduction of production defects



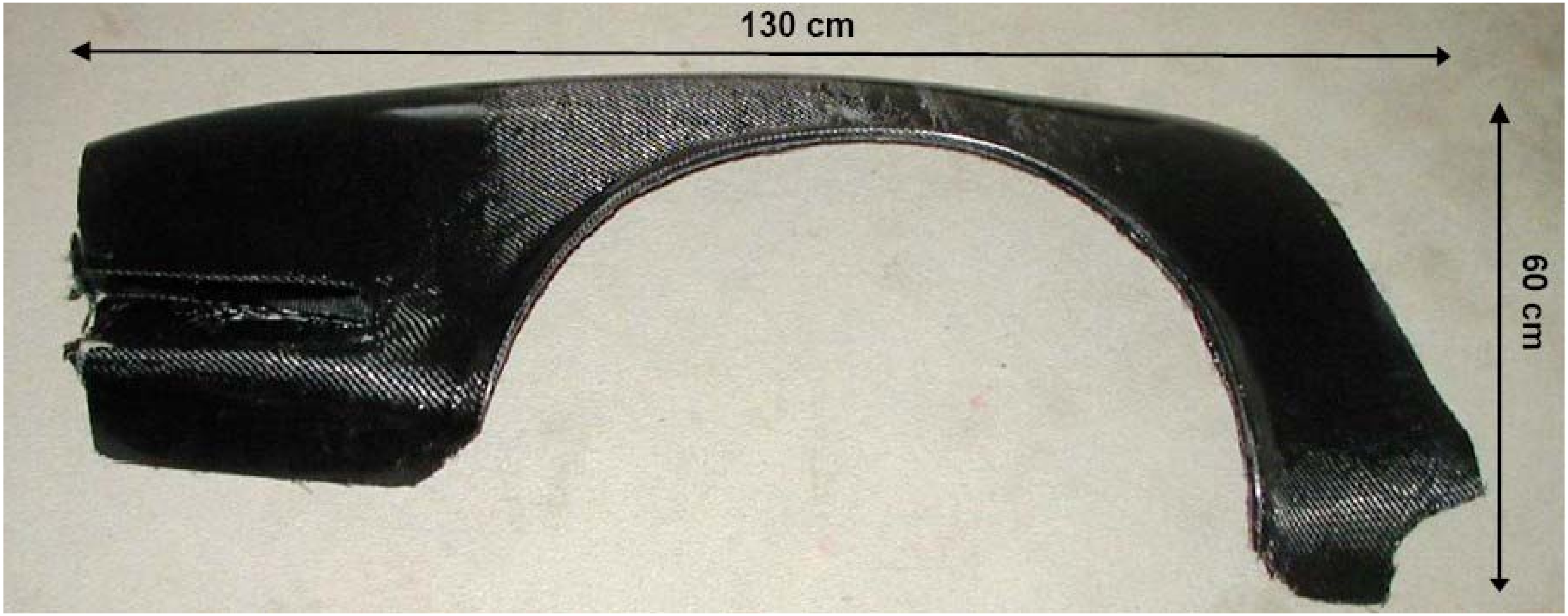


Polymer Cross-Linking

- **Wires** stand higher temperature after irradiation
- **Pipes** for central heating and plumbing
- **Heatshrink elastomers** are given a memory

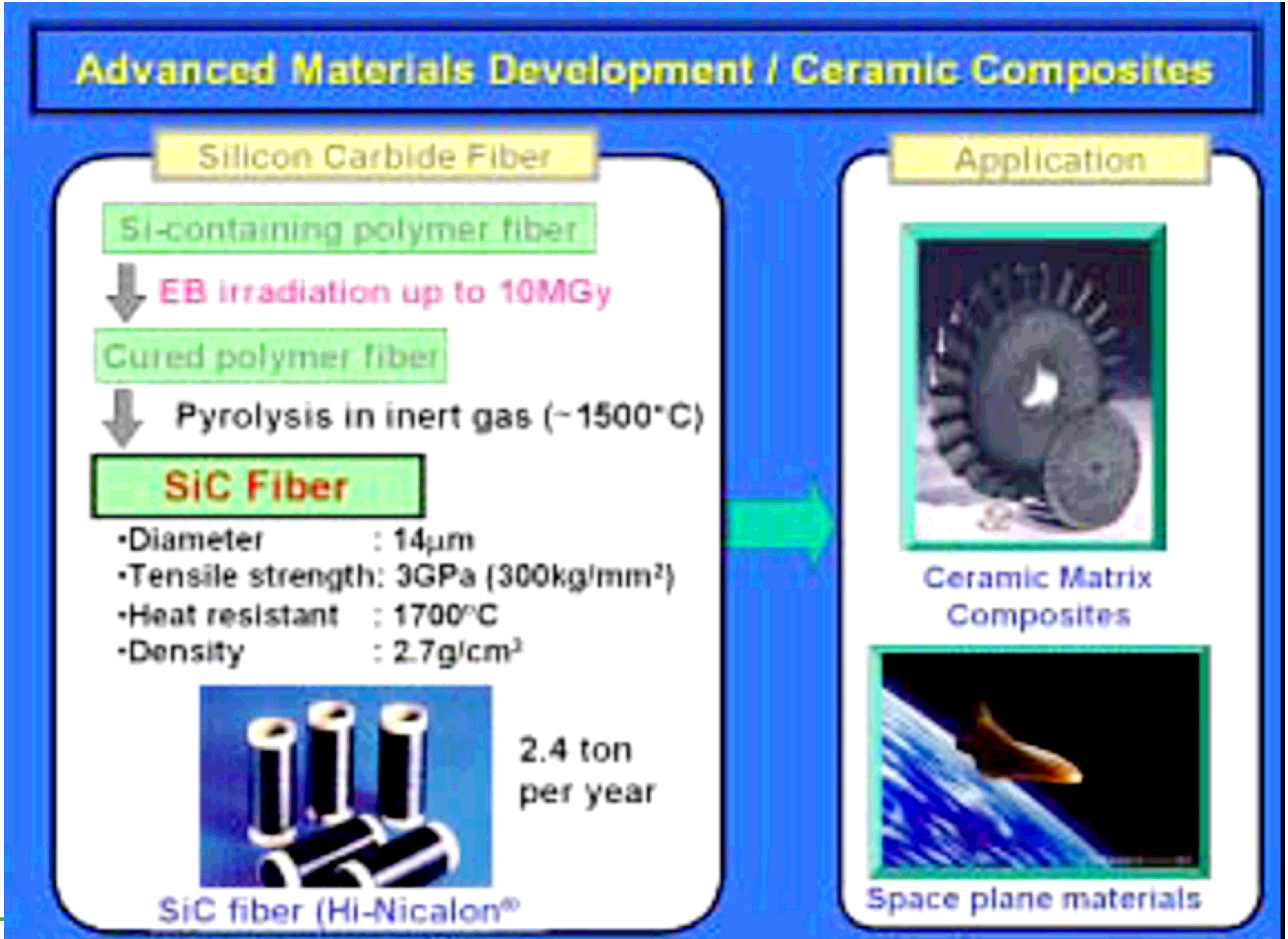


Composite curing: X-ray Cured Carbon Fiber



- Sports Car Fender made light, restistant and requiring less fuel

Production of High Heat Resistant SiC fibers



E-beam applications for the environment

Flue gas treatment

Liquid effluents treatment

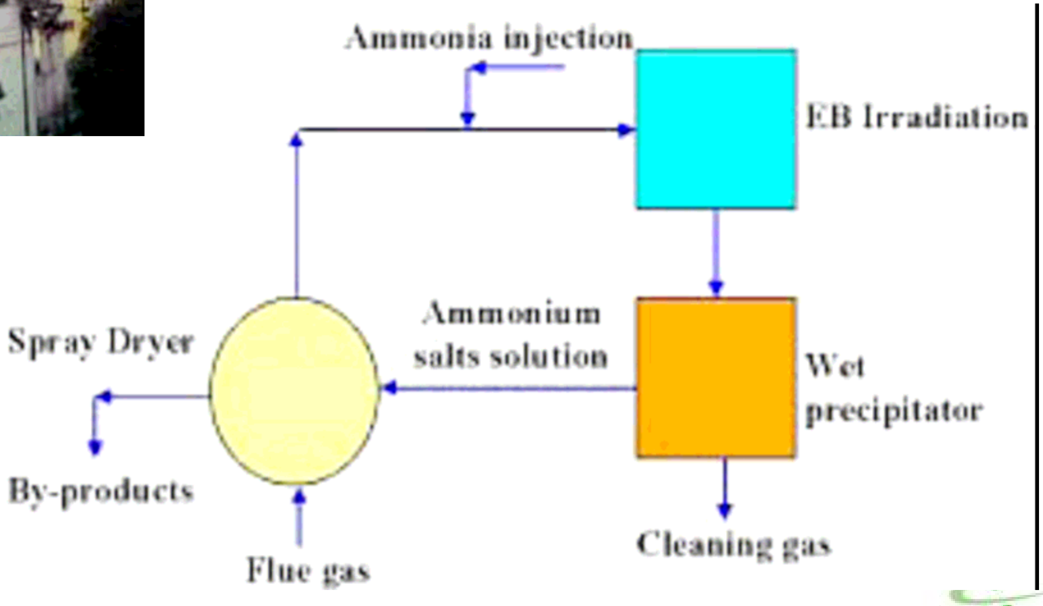
Production of Viscose

EB Based Flue Gas Cleaning

-Removal of SOx and NOx

- Pilot Plants :China, Poland,
-Japan, USA, Malaysia, Germany

-Coal Power Plants &
-Municipal Waste Incinerators

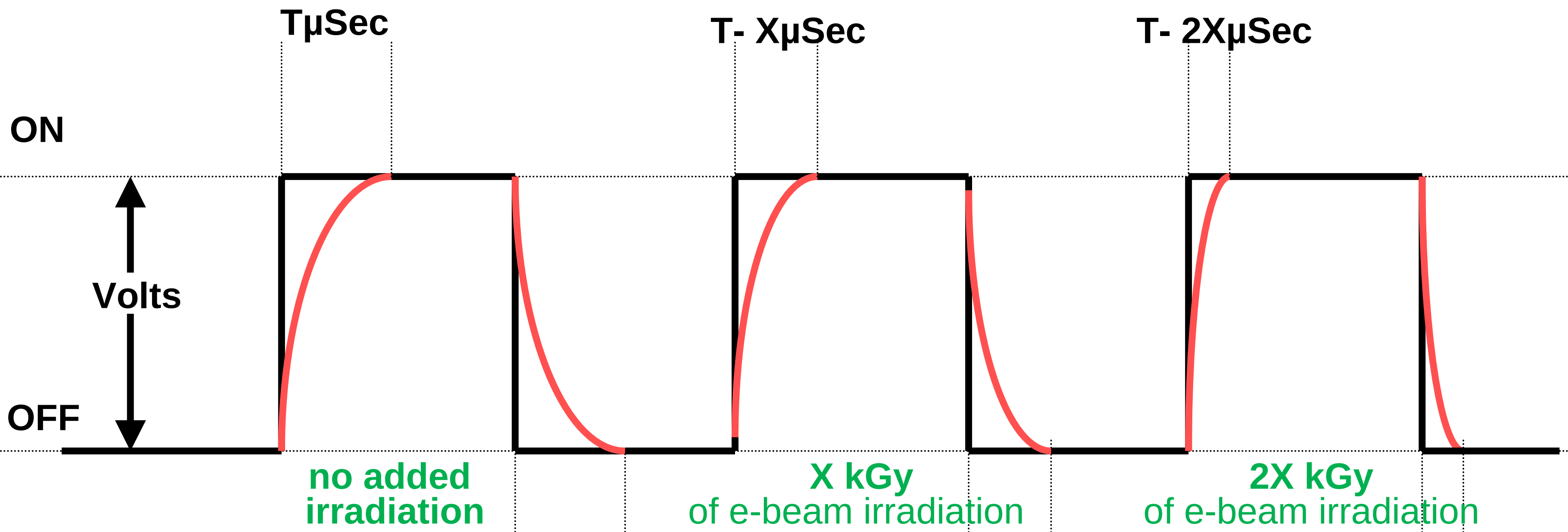


E-beam induced defects in crystals

Gemstones

Improving the color of glass and gemstones

E-beam irradiation improves SC switching speed

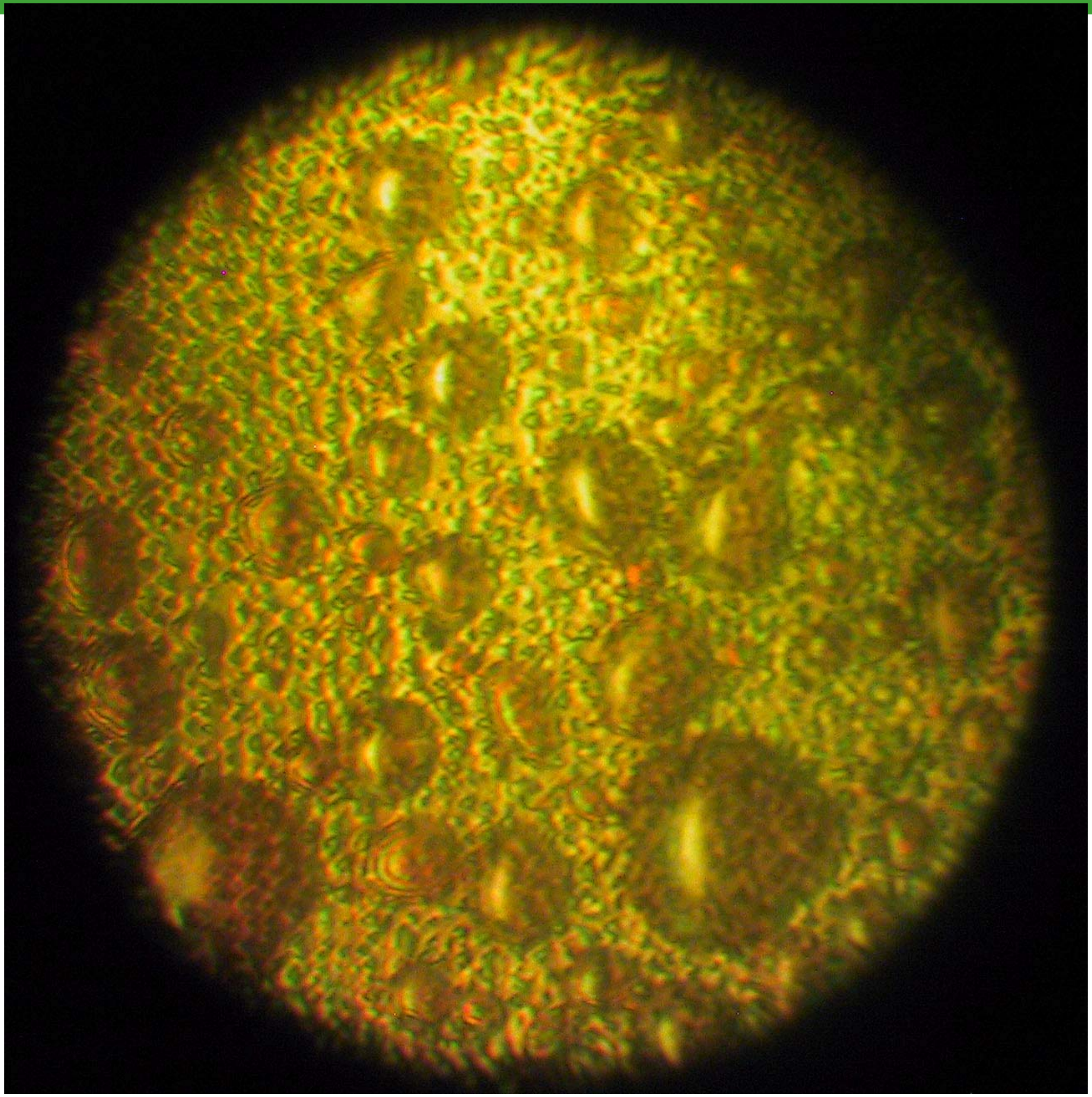


Typical semicondutors:

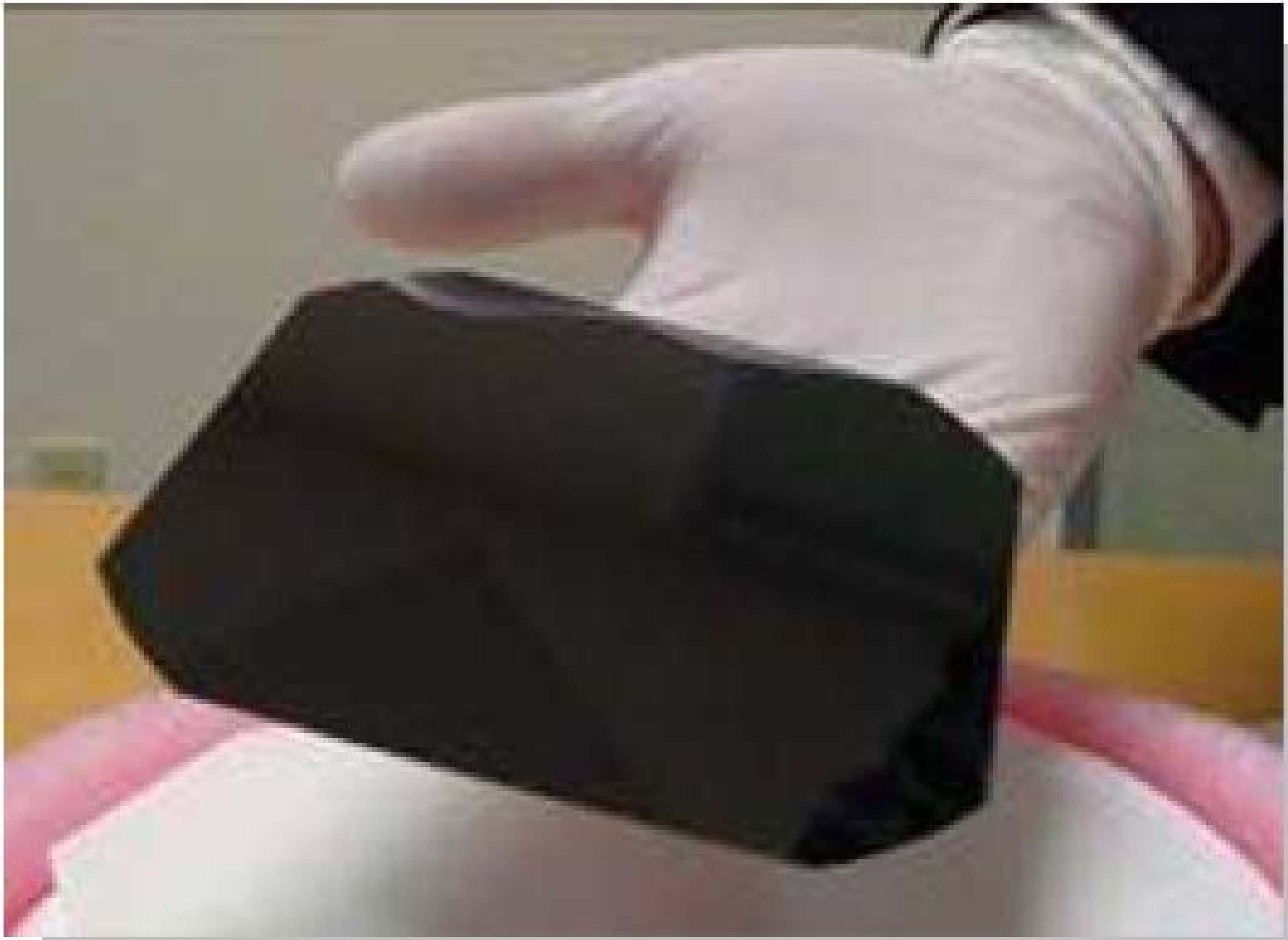
- fast recovery diodes
- power diodes
- Bipolar power transistors
- power MOSFETs
- power rectifiers
- IGBT's
- thyristors
- silicon-controlled rectifiers

Industrial use of low energy proton beams

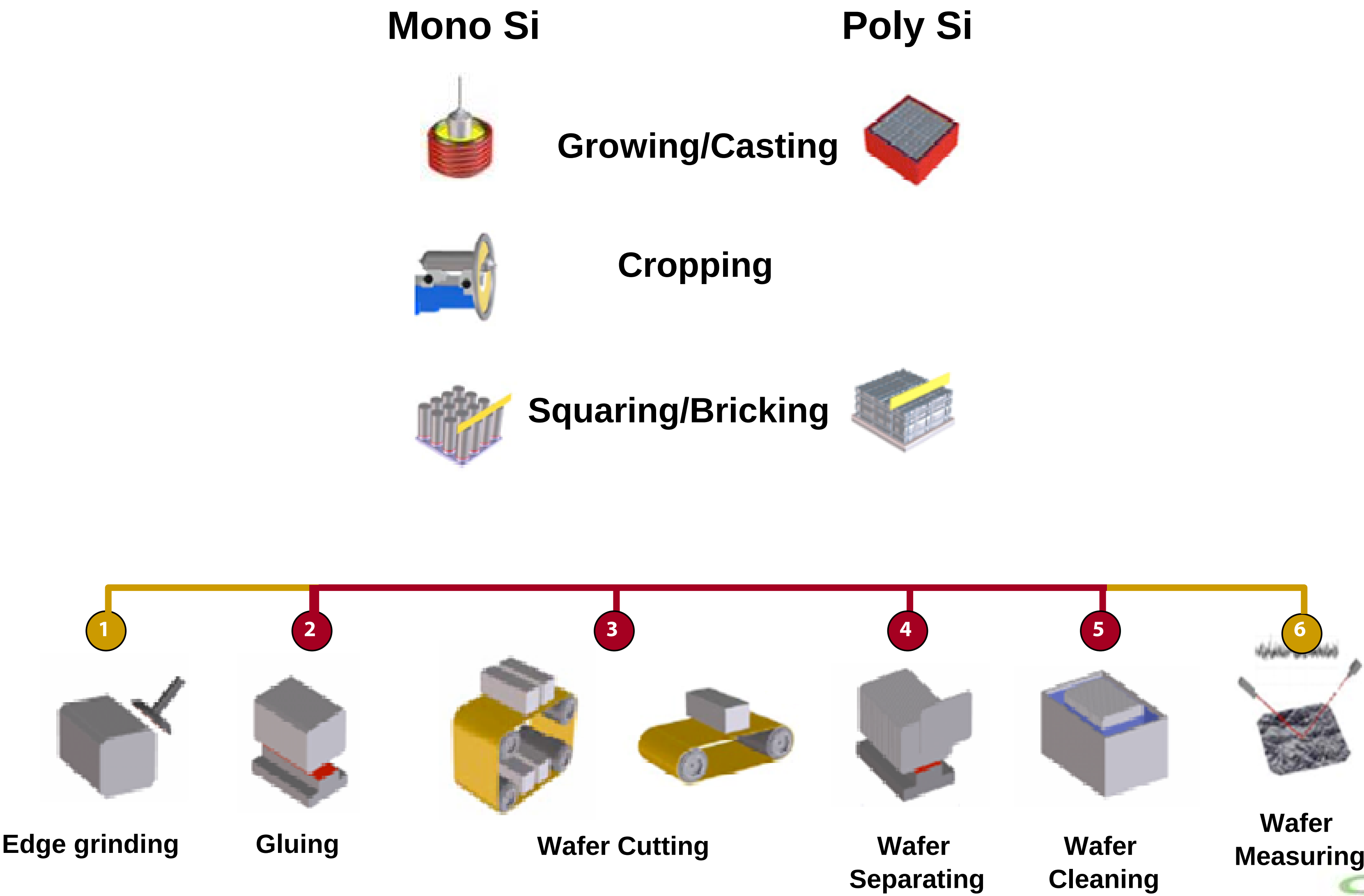
Blistering caused by 300 keV protons on copper



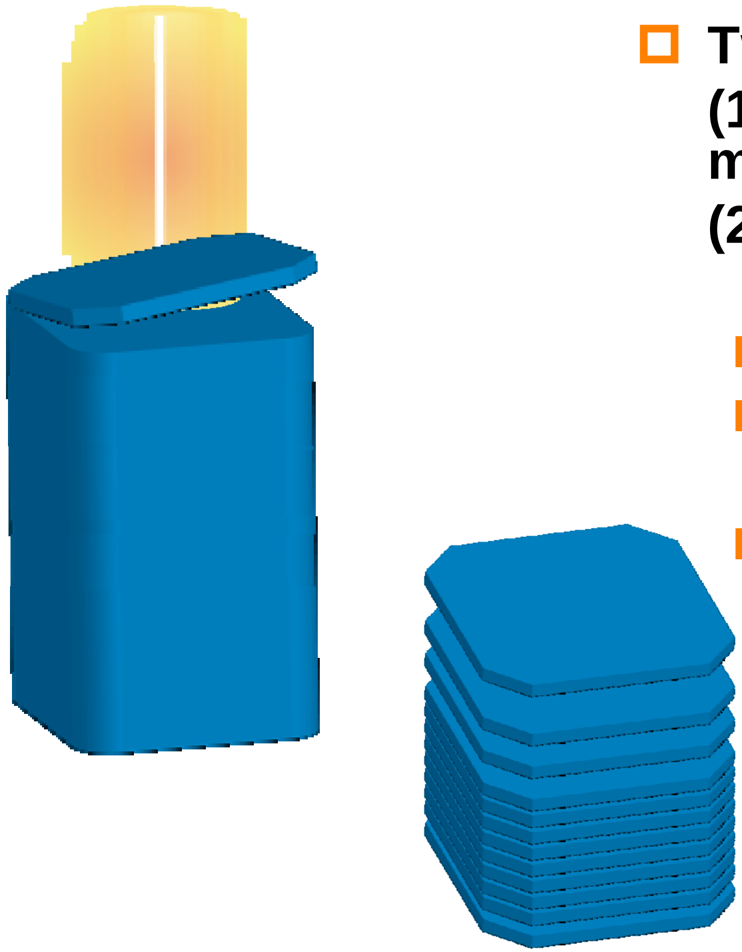
Industrial application of the Bragg Peak



The present process using wire saws



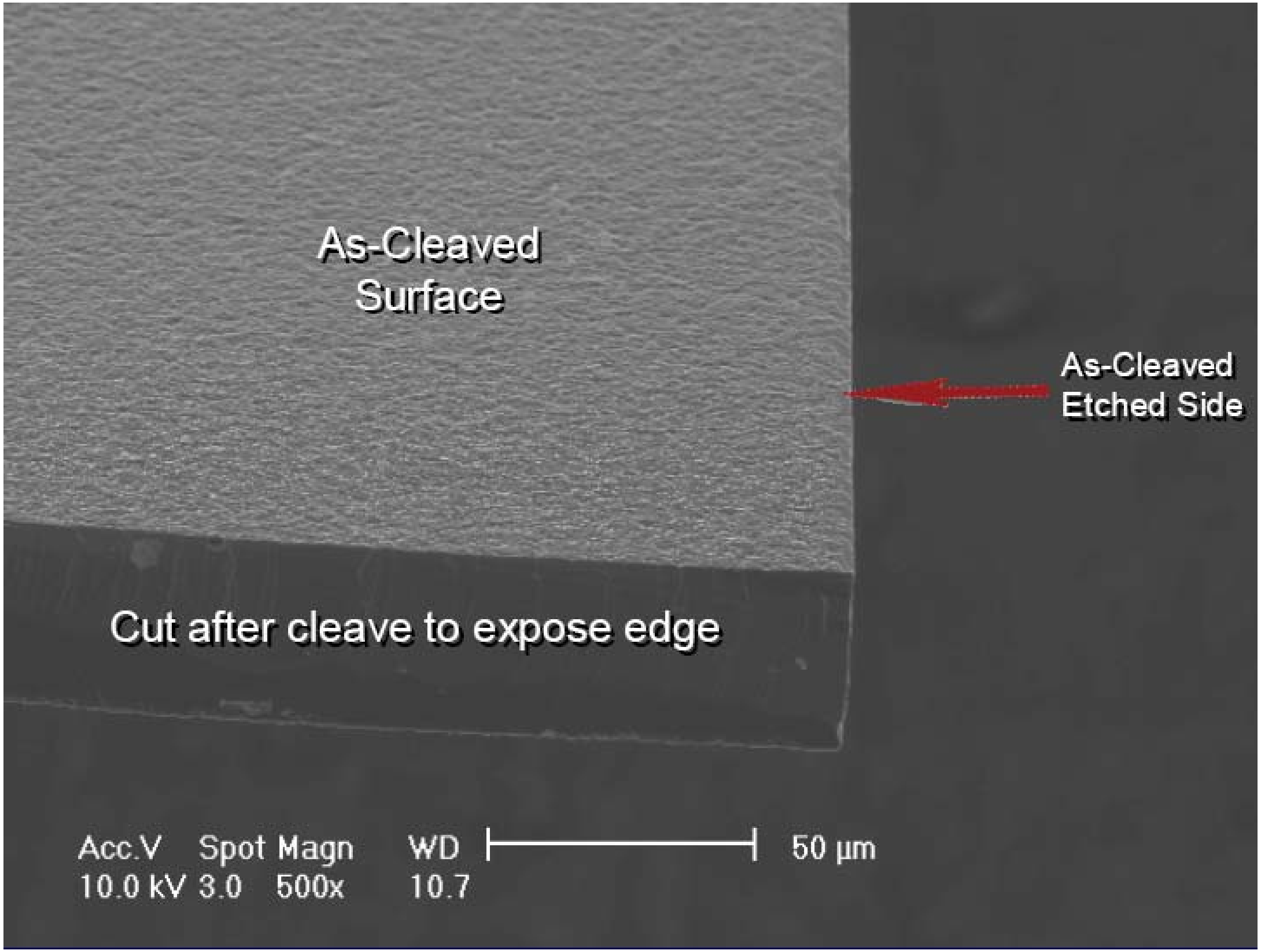
Sigen « Direct Cleave » AKA « Beam Saw » process



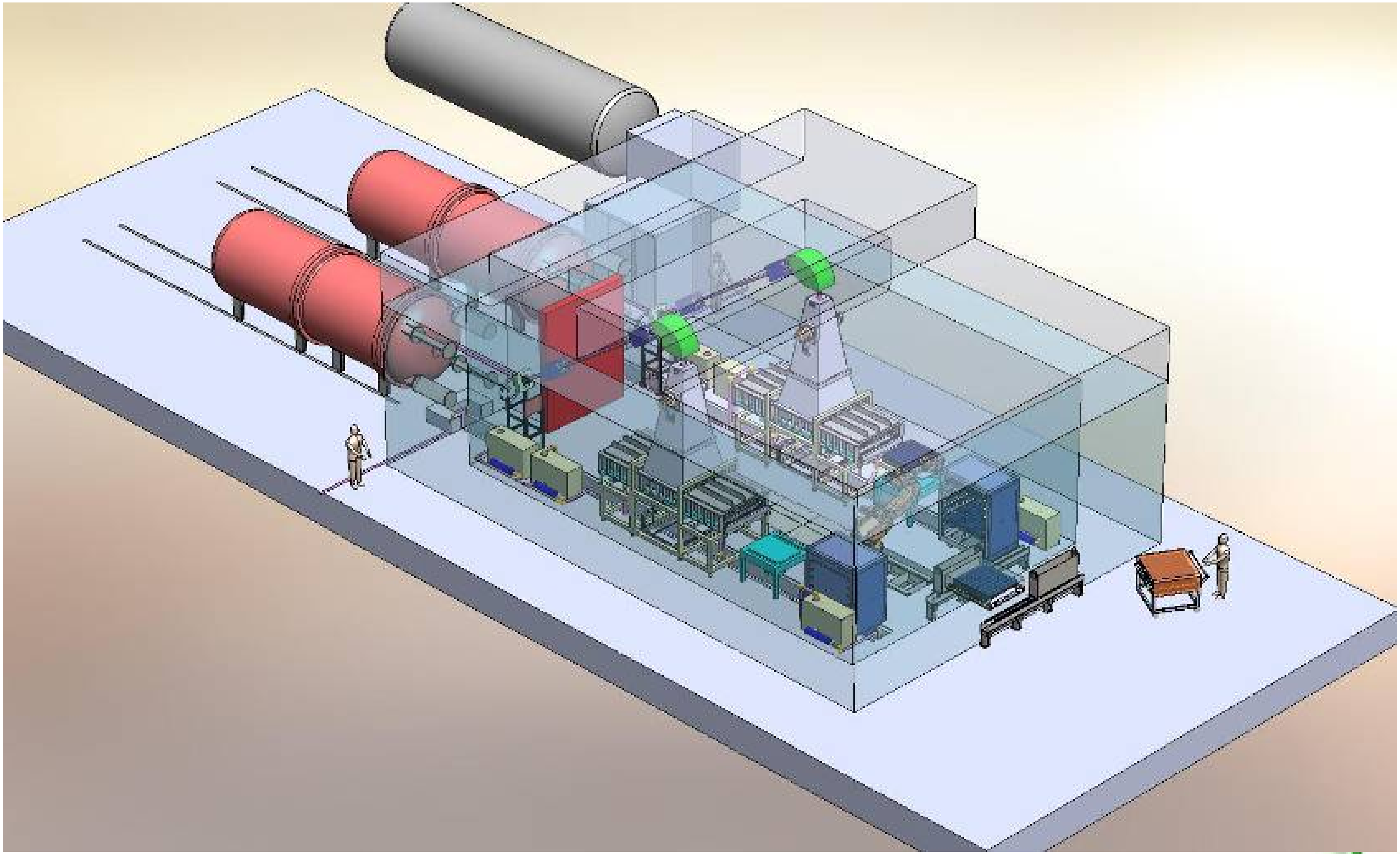
- **Two Step Process**
  (1) Implant 2…4 MeV protons (20 mA)
  (2) Cleave

  - **Eliminates Kerf Loss**
  - **Eliminates Consumables**
    - **SiC, Slurry, Wire**
  - **Eliminates Other Systems**
    - **Gluing**
    - **Singulation**
    - **Cleaning**
    - **Less Damage Etch**

SEMS of the as-cleaved edge

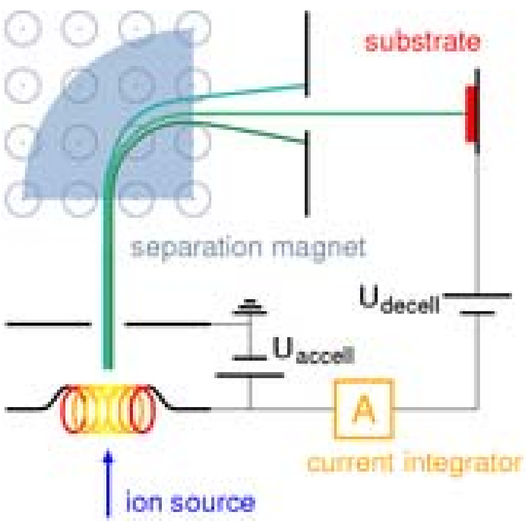


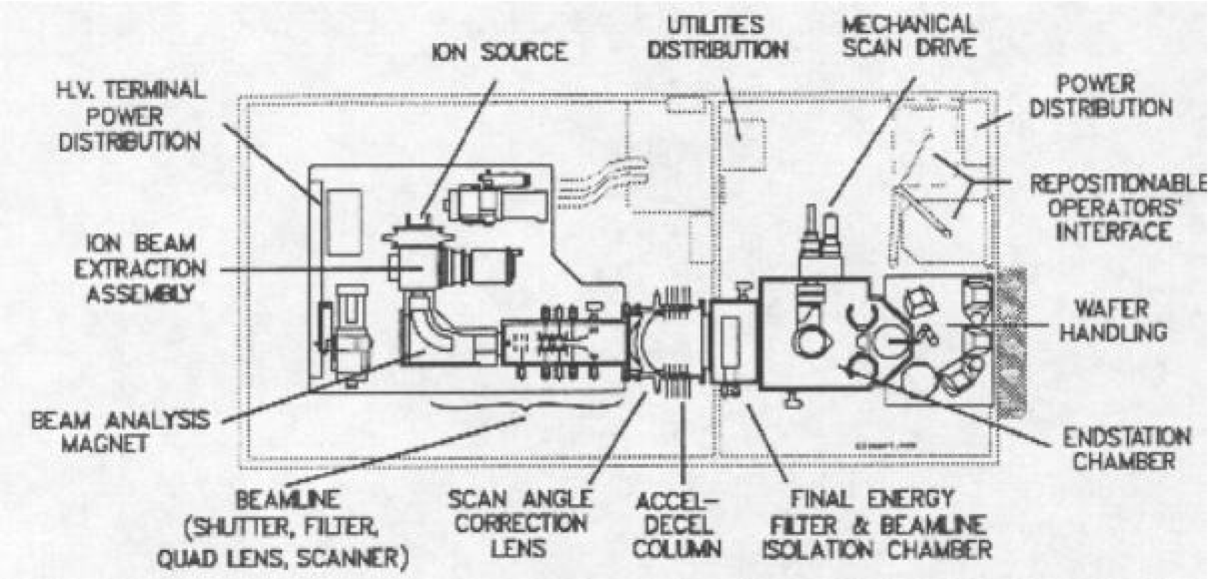
Industrial silicon cleaving equipment “Dynasolar”



Industrial use of low energy heavy ion beams

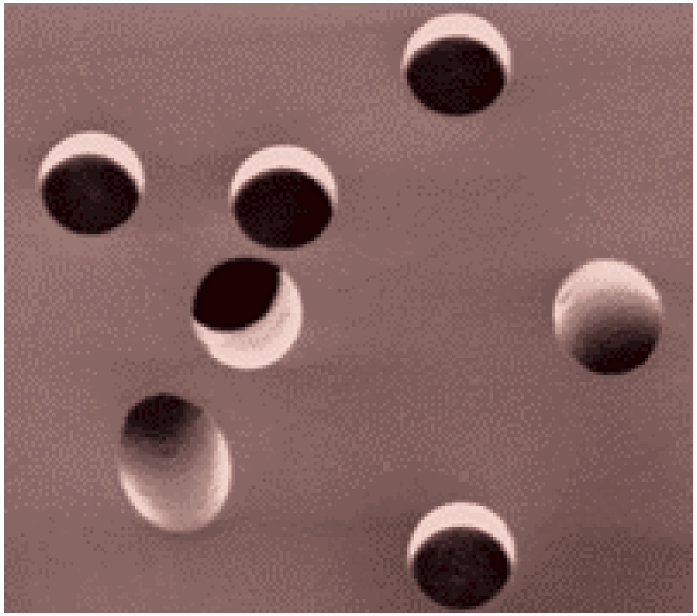
Ion implanters are used for the doping of SC

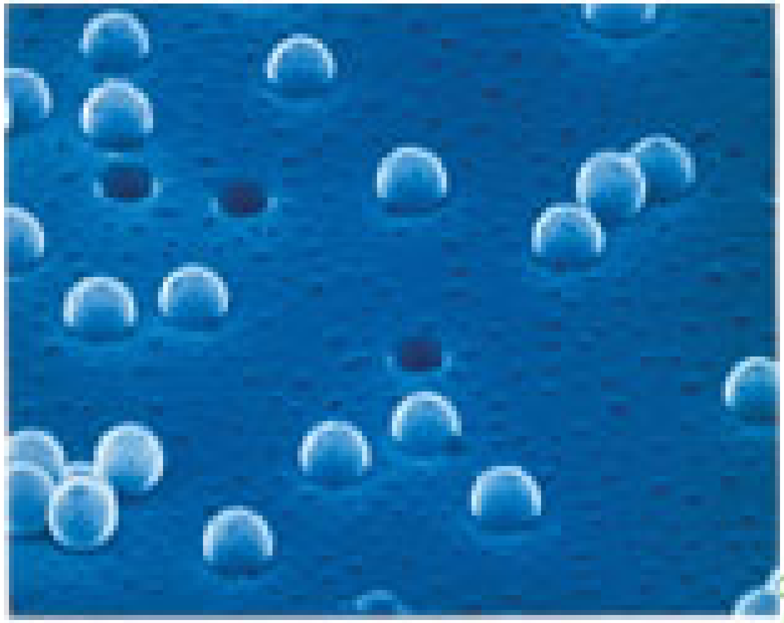




Microfiltration membranes by heavy ions

- Heavy ion beams are used to produce track-etched microfiltration membranes, commercialized i.a. under the brand name “Cyclopore”
- In these membranes, tracks of slow, heavy ions crossing a sheet of polymer are chemically etched, giving cylindrical pores of very accurate diameter






Thank you !