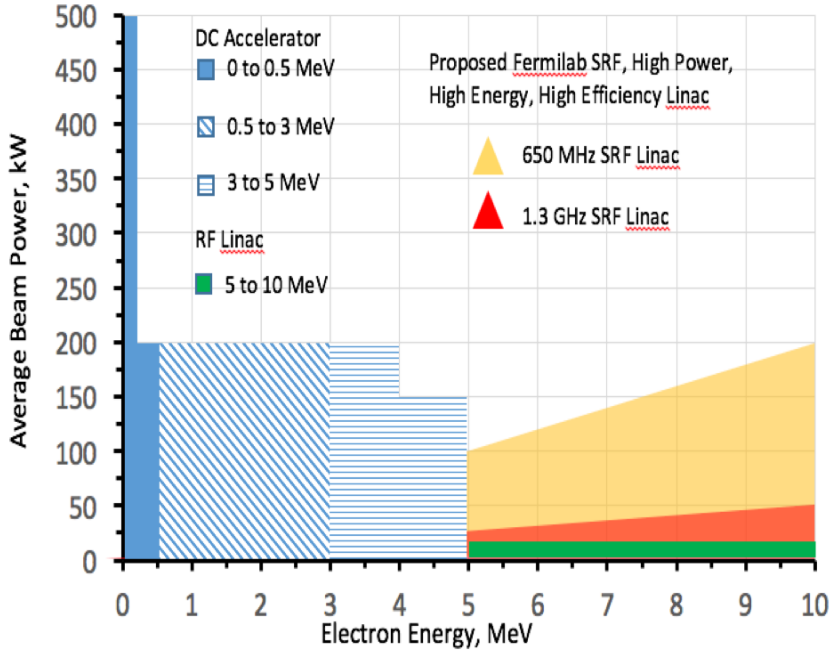
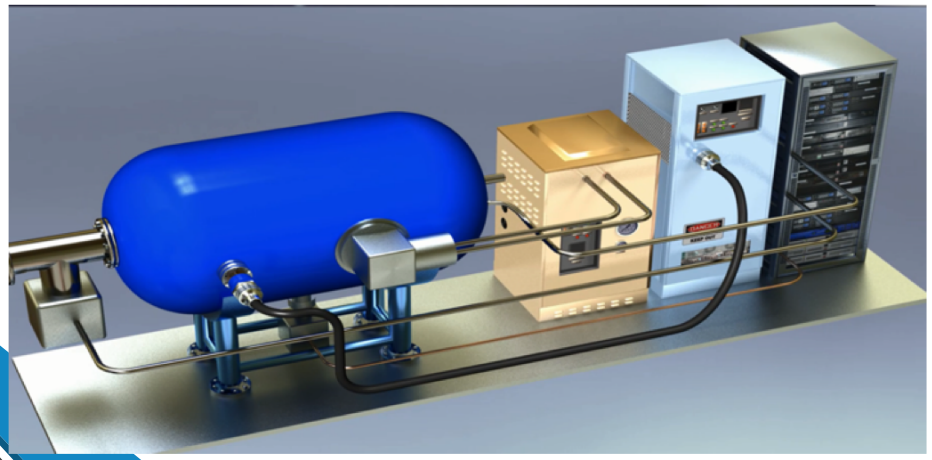
Technology Maturation

Compact Accelerator Platform Technology



- Currently we are integrating multiple new technologies to create a compact, portable, high power, high reliability electron beam platform accelerator.
- We are concurrently developing applications for this compact accelerator.



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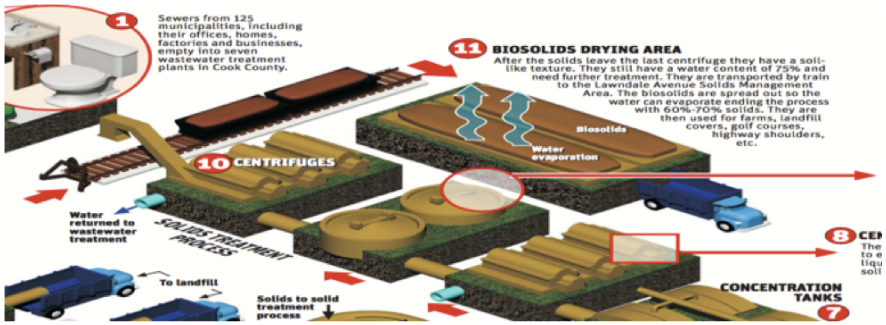
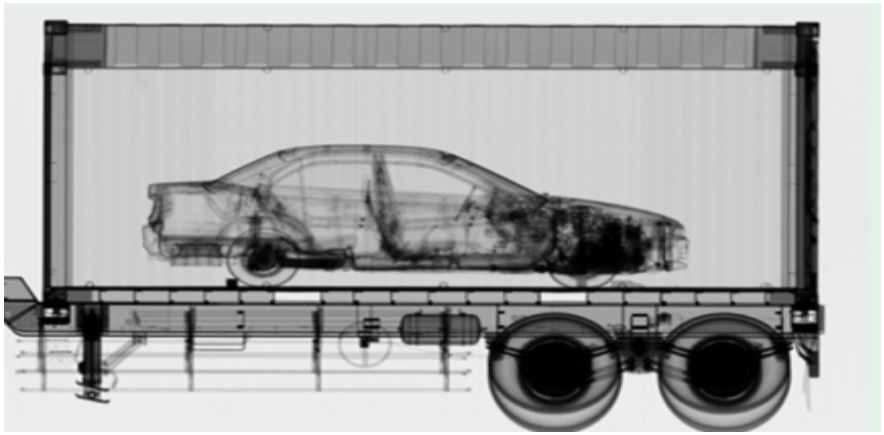
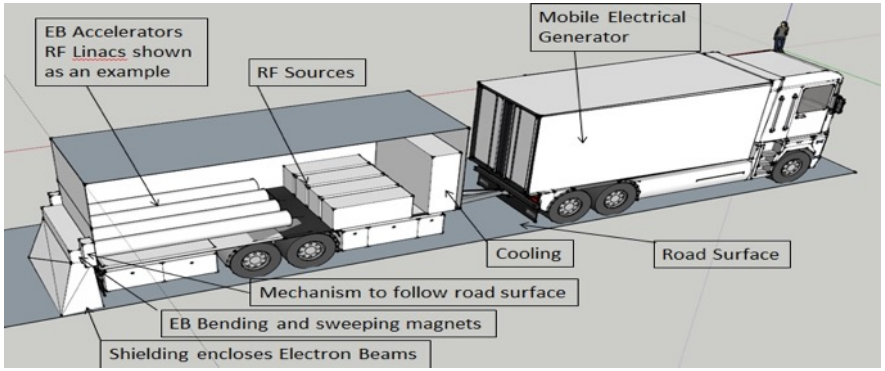
Application Areas

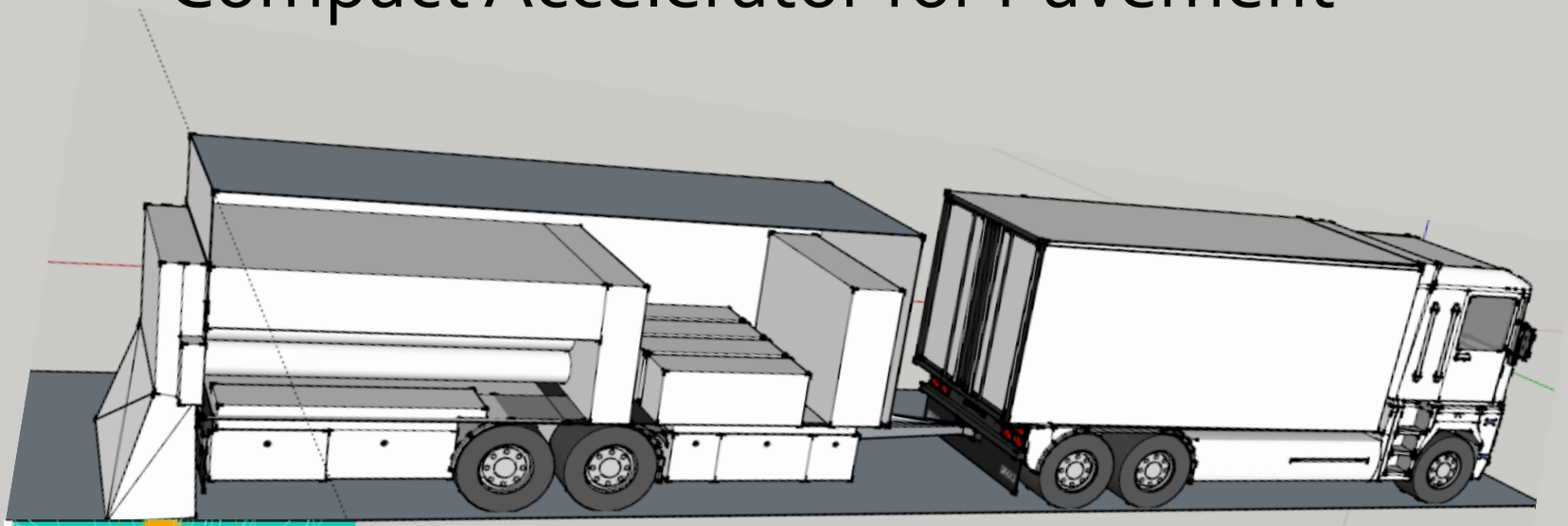
- Water/Biosolids
- Cargo Scanning (DNDO)
- Modification of Materials (like pavement - ERDC)
- Medical Sterilization(NNSA)
- Driving various industrial chemistries
  - GTL of flare gas
  - Rubber
- Environmental remediation, Advanced Mnfg, food treatment, surface hardening, digital electronics, mining

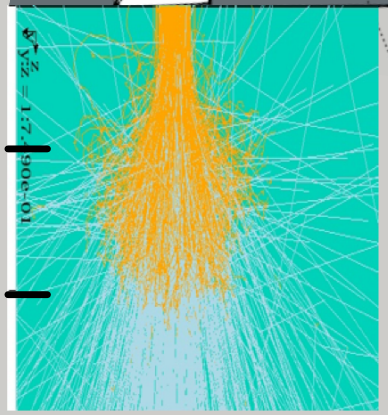






Compact Accelerator for Pavement





- High power and good penetration depth allow for rapid deployment of new pavement
- Enables use of new types of pavement materials that are more resilient to wear than asphalt
- Can be used for applications like military runways, specialty coatings, and normal roadways
- Penetration depth allows for cold repairs
- U.S. Patent #9,186,645 & 9,340,931

Compact Accelerator for Environmental Remediation

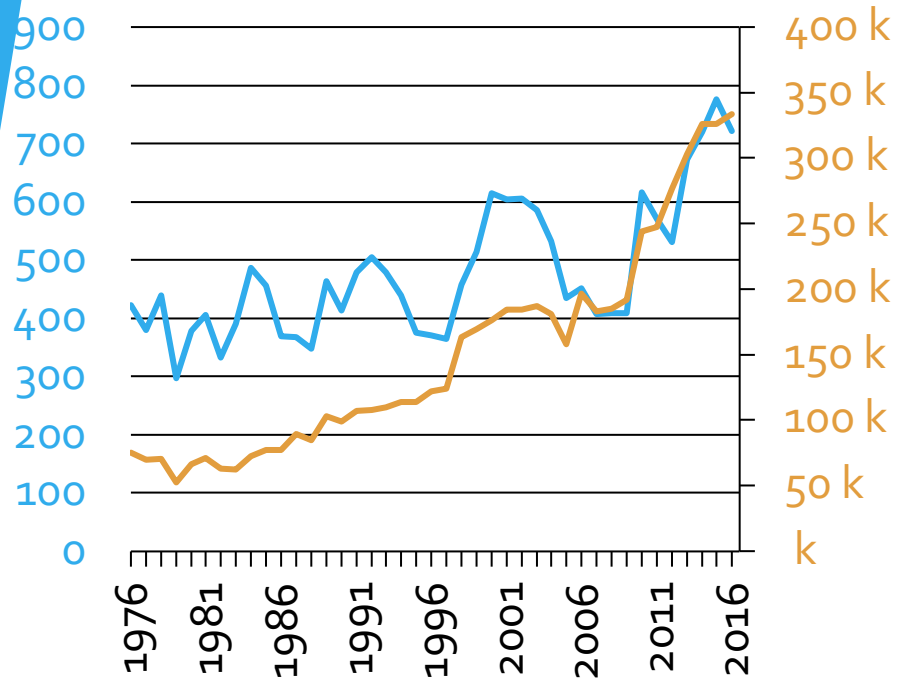
- In several pilot programs electron accelerators have be proven to be effective at destroying toxic organic contaminates in water and soil
- Typically large volumes of material are removed from contaminated areas creating a concern of secondary contamination
- Key to deployment at large scale is development of high power (100's of KW to MW class) industrial electron accelerators that are cost effective and reliable
- Compact Accelerator could enable new in-situ environmental remediation or decontamination processes

Compact Accelerator for Crops

- E-Beam treatment can improve shelf life, destroy disease causing bacteria and be used for pest control
- A portable high power accelerator has the potential for saving crops in quarantined areas
- Potential for large cost saving as quarantined crops are often destroyed

Compact Accelerator for Driving Chemistry

- In the U.S. Industry consumes ~32% of end use sector
  - 27% of that is used in the Chemical Sector (www.eia.gov)



Total # US Original Catalyst Patents

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patft.uspto.gov

- Demonstrated industrial effort to develop catalyst to increase efficiency
- Electron Beam Driven Chemistry largely unexplored
- More efficient that direct heating
  - Rubber Industry
- Can remove need for some toxic initiators, cross linkers

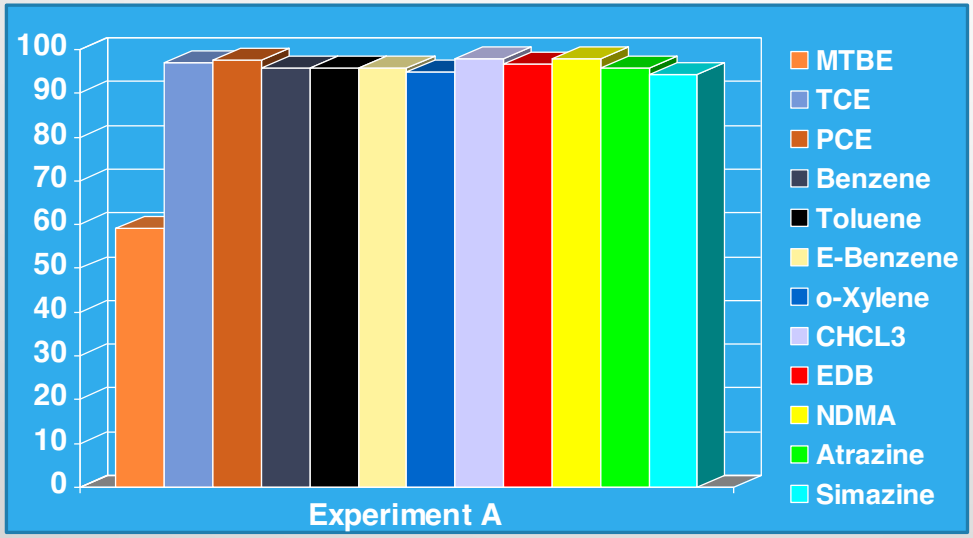
US E-beam Treatment of Wastewater

- *CN Kurucz et al., "The Miami electron beam research facility: a large scale waste water treatment application", Radiat. Phys. Chem. Vol. 45, pp299-308 (1995)
- High Voltage Environmental Applications, Inc., Electron Beam Technology Innovative Technology Evaluation Report - August 1997 – EPA, NRMRL
- Workshop on Energy and Environmental Applications of Accelerators at ANL in June of 2015 developed language that was used in 2016 Accelerator Stewardship program.
  - Design 1 MW accelerator for waste water treatment

Why Use E-Beam for Water Treatment?

$$H_2O \xrightarrow{\text{Electron Beam}} OH^-, H^+, e^-_{aq}, H_2, H_2O_2$$

- Primarily works by generating oxidizing and reducing radicals from the water
  - But can directly decompose contaminants as well
  - Removal of toxic chemicals not removed in conventional domestic water treatment
    - Pharmaceuticals
    - Agricultural run off
    - Fuel additives (MTBE)
    - PCBs
    - Explosives
  - No toxic residuals (no secondary waste generation)



*William J. Cooper, Dept. of Civil and Env. Engineering, UC, Irvine

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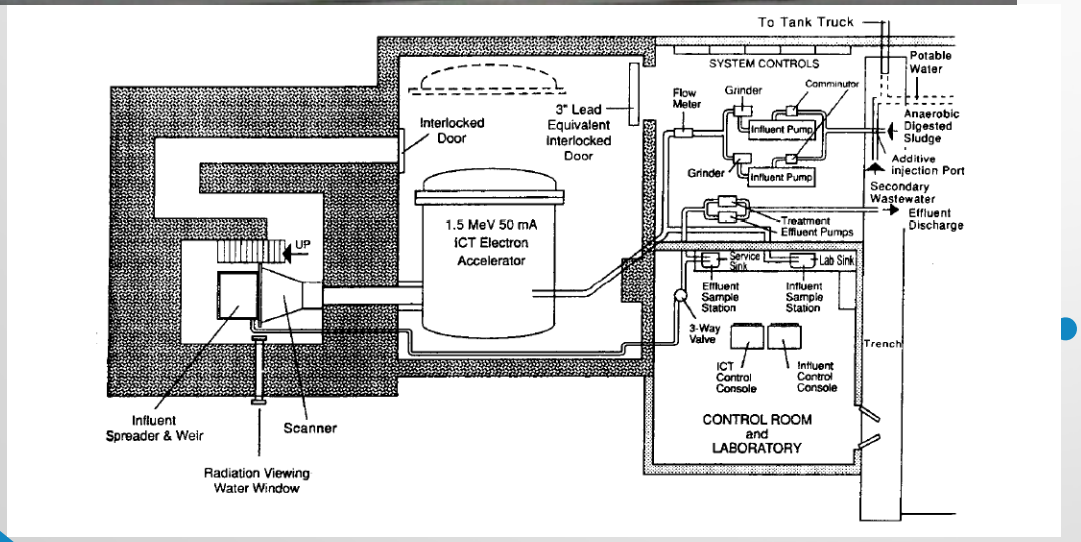
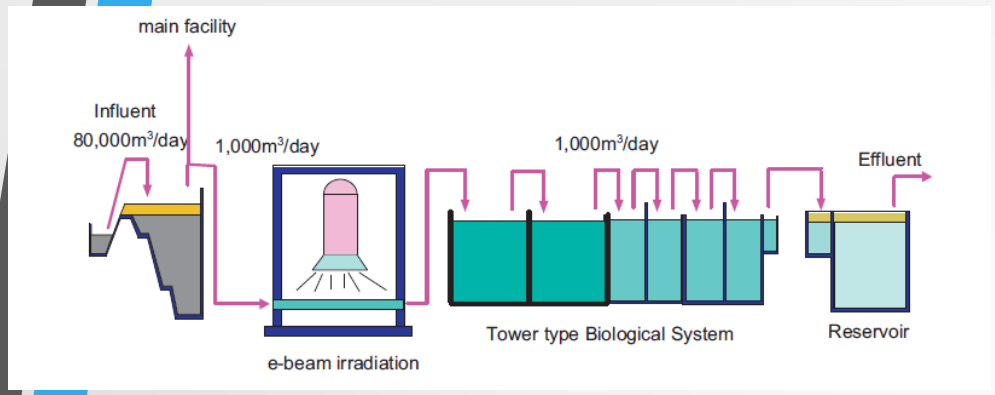
Demonstration: Municipal Waste Water

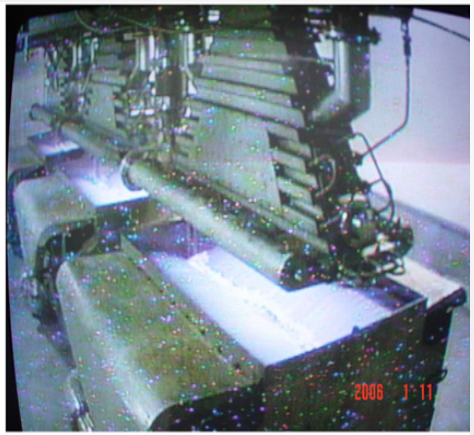


- Miami, Florida treatment facility
- 150 GPM
- Effective in disinfecting and removing organic waste from municipal waste water
- Treatment cost estimated at 1.5-2 cents/gal in 1995

*CN Kurucz et al., "The Miami electron beam research facility: a large scale waste water treatment application", Radiat. Phys. Chem. Vol. 45, pp299-308 (1995)

Demonstration: Textile Wastewater Treatment





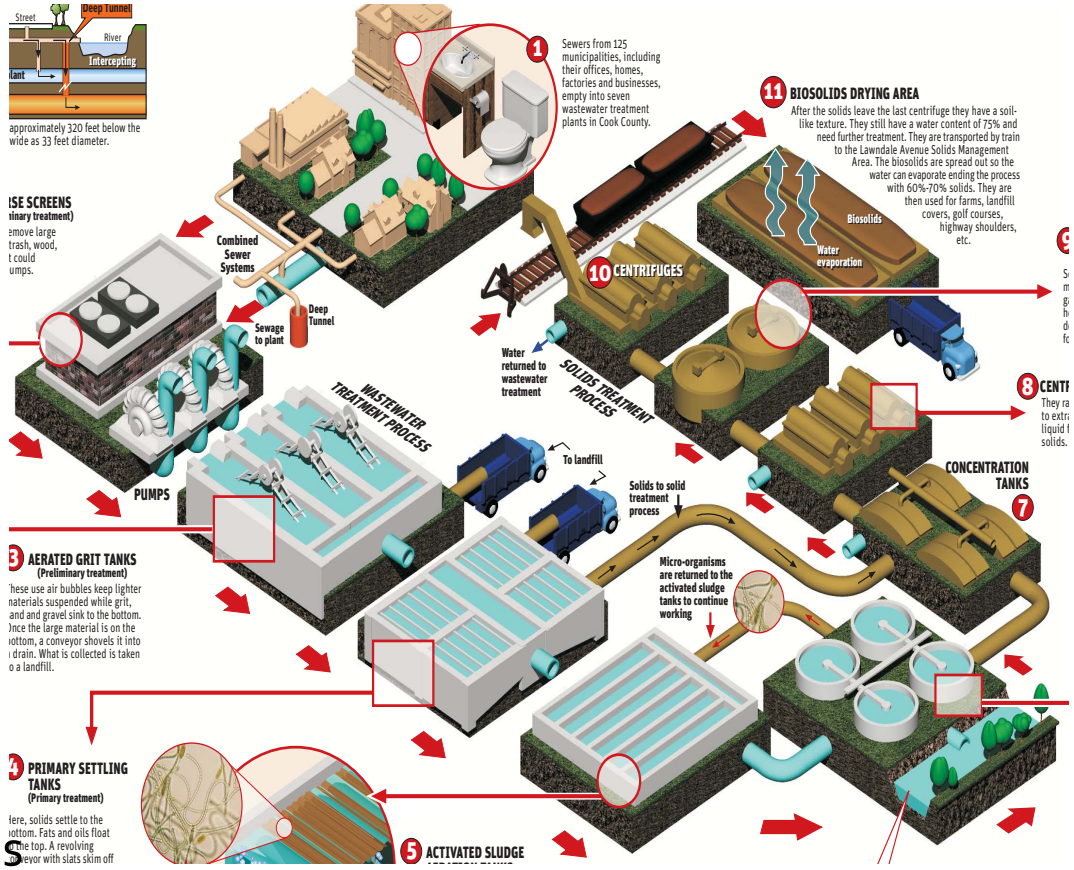
Interaction area of water and beam (beam on to the right)

- Treatment of 1000 m^3/day (180 gpm) of water from textile dyeing process
- Showed significant decrease in TOC, COD_{Cr} and BOD_5(30-40% increased removal eff.)
- Based of earlier success 10,000 m^3/day plant constructed for $4M US in 2005
- Operational cost measured to be 0.11 cents/gal.

B Han et al., "Operation of industrial-scale electron beam wastewater treatment plant", Rad. Phy. Chem. 81, p1475-1478 (2012)

Municipal Water Treatment via Compact Accelerator

- Currently partnered with Metropolitan Water Reclamation District of Chicago
- Stickney plant, largest in the world (1.2 Billion gal/day)
- Incoming water is a fuel source not just waste
- Goal of net zero energy operation
- Desire to recover nitrates and phosphates



- Biosolids can be sold as fertilizer
- Treat 2MGD with 1 MW of total power , treat at Thickened WAS stage (5% solids before anaerobic digester)

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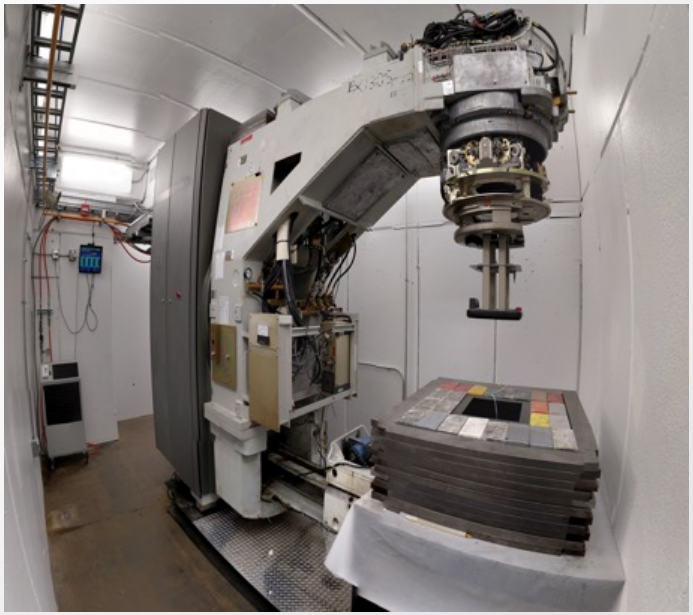
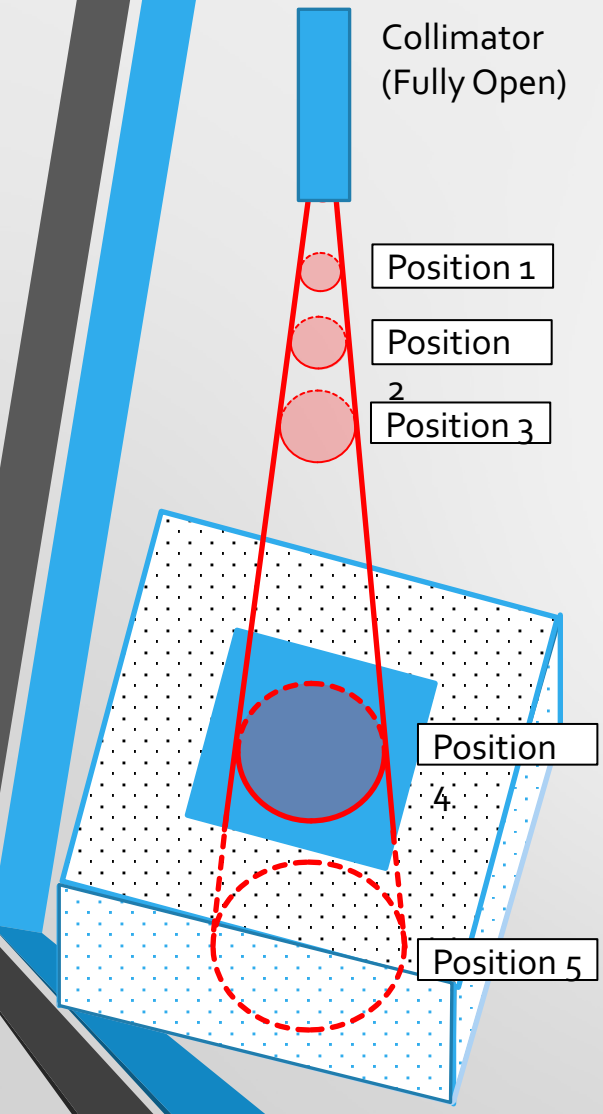
and Demonstration (A2D2) - Accelerator for Application Development

- We are integrating multiple new technologies to create a compact, portable, high-power electron beam platform accelerator.
- Electron-beam application development must be done because of the new application areas that the Compact Accelerator enables



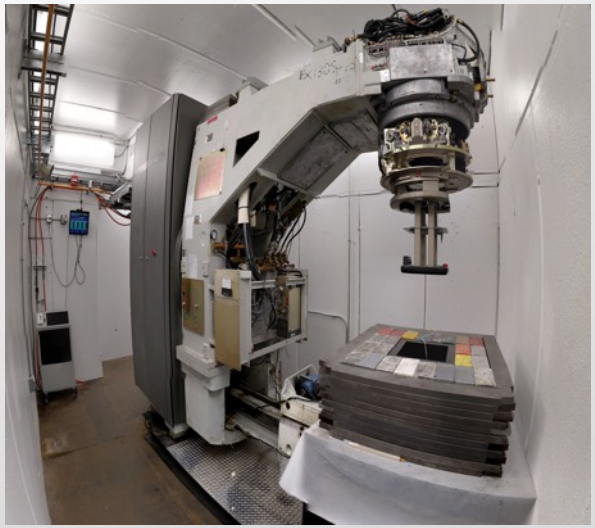
- A2D2 allows for precise control of development work so that the beam, beam sample interaction and analytical data taken can be changed as needed

A2D2 Beam Info

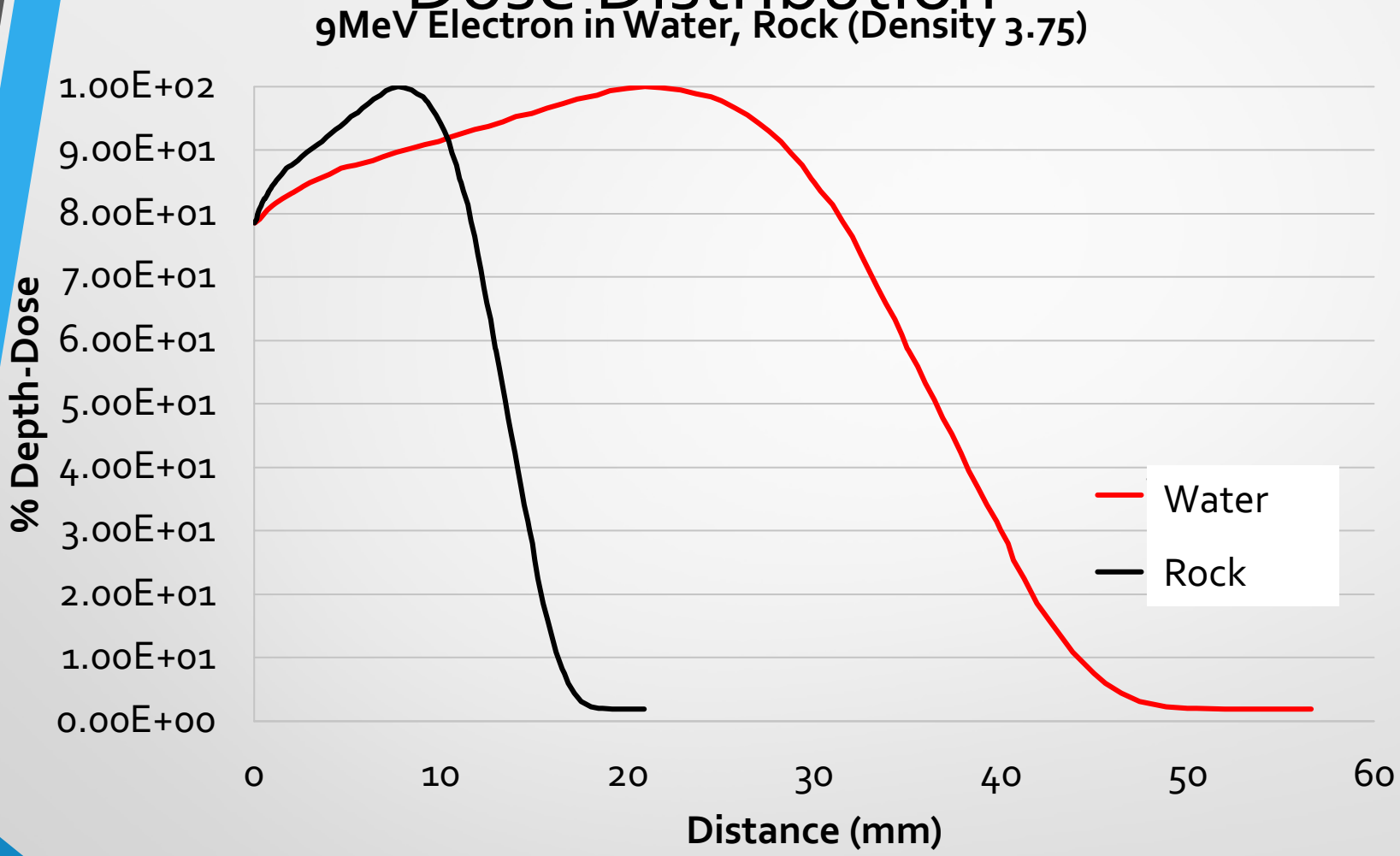


Position	Beam Diameter, cm	Distance from Collimator, cm
1	4.8	63
2	5.7	75
3	7.1	93
4	10.3	135
5	12.6	165

Setting	Power, kW	Dose Rate, kGy/kg-s
1	0.22	0.22
2	0.43	0.43
3	0.65	0.65
4	0.87	0.87
5	1.08	1.08
6	1.3	1.3



Dose Distribution



Title:
Workshop on Application of Electron Beam (EB) Technology on Wastewater and Biosolids Treatment

Purpose:
- Promote use of e-beam technology for wastewater treatment
- Inform water treatment professionals about e-beam technology and opportunities
- Provide feedback to NSF that opens future funding opportunities

Format:
This two-day workshop will include expert speakers on the current state of wastewater treatment, a summary of the science of using e-beam technology for treatment of waste, the current state of e-beam accelerator technology, a tour of Fermilab National Accelerator Lab, panel discussions with water treatment experts, breakout discussions and a summary close-out session.
Post conference a report will be issued with findings and recommendations.

Where:
Illinois Accelerator Research Center, Fermi National Accelerator Lab

When:
May 10-11, 2018 (Thursday-Half Day Friday)

Who: By invitation only: Water treatment professionals, e-beam researchers, industrial accelerator experts, industry and utilities partners, regulatory personnel, NSF and Federal and State government officials