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Title: Measuring x-ray spectra of flash radiographic sources

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Measuring x-ray spectra of flash radiographic sources

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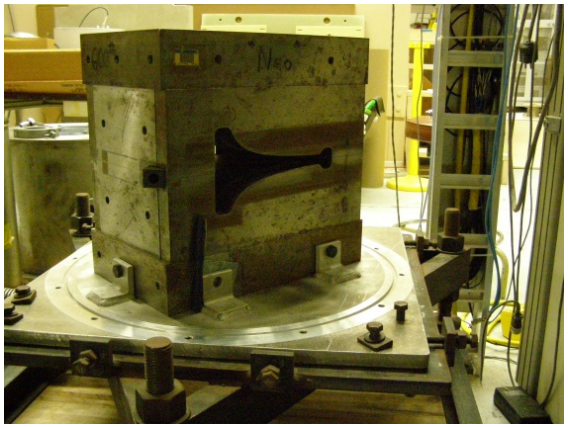


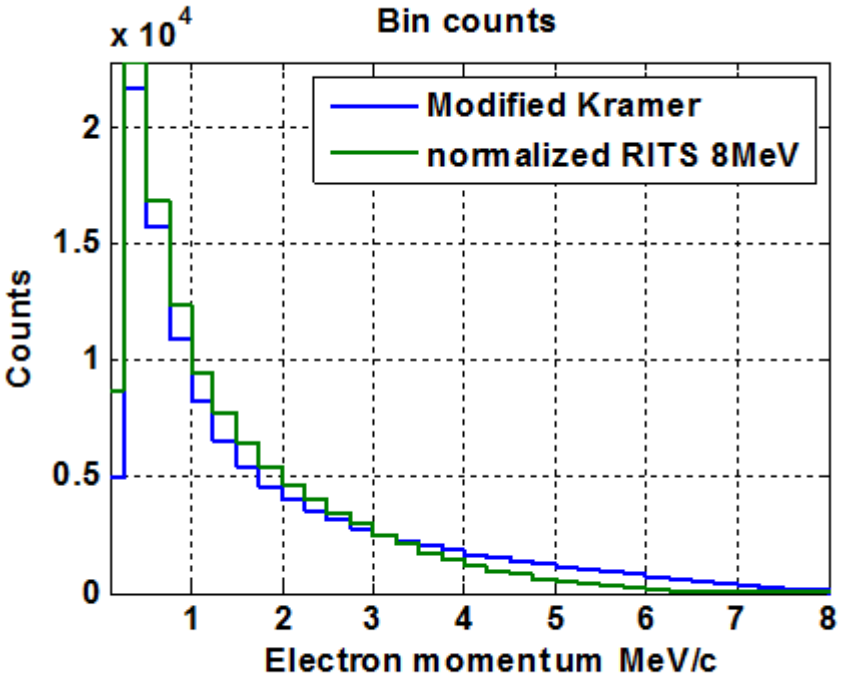
Acknowledgements

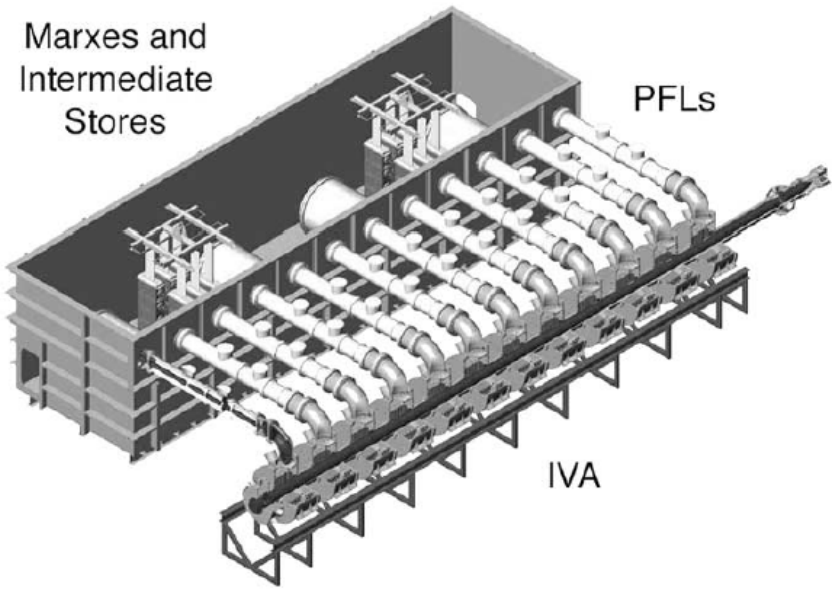
- Michelle Espy
- Todd Haines
- Robert Sedillo
- Petr Volegov
- DARHT: Dave Moir, Jacob Mendez, Roger Shurter, and J-5
- RITS: Tim Webb and many others!

The x-ray spectra of flash radiographic sources is difficult to measure

Radiographic Integrated Test Stand-6

370 rad at 1 m; 50 ns pulse

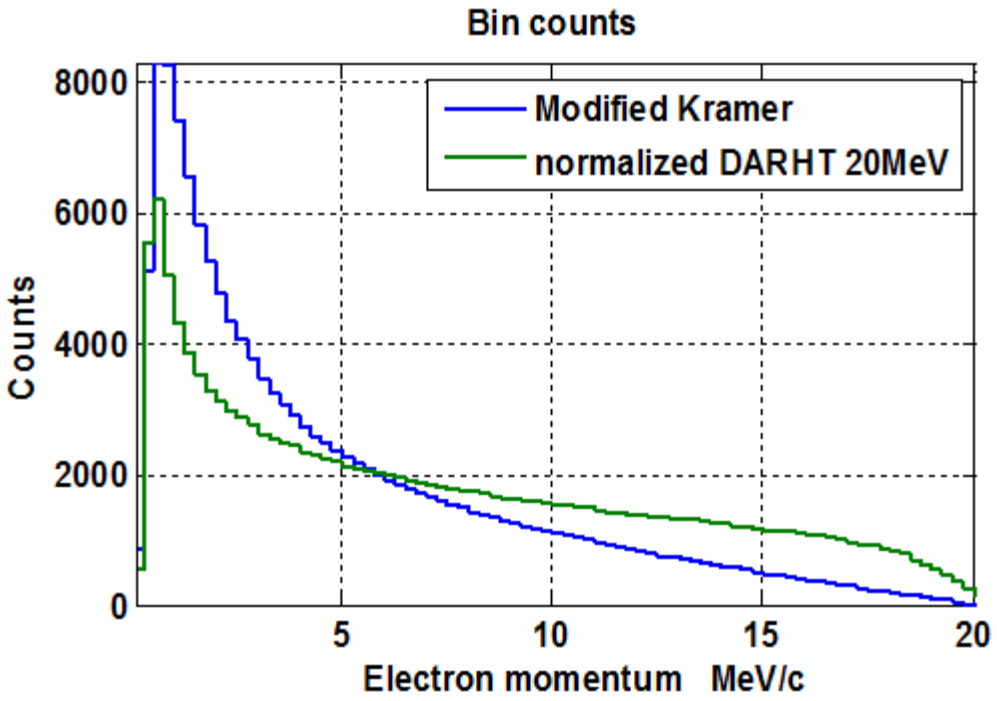




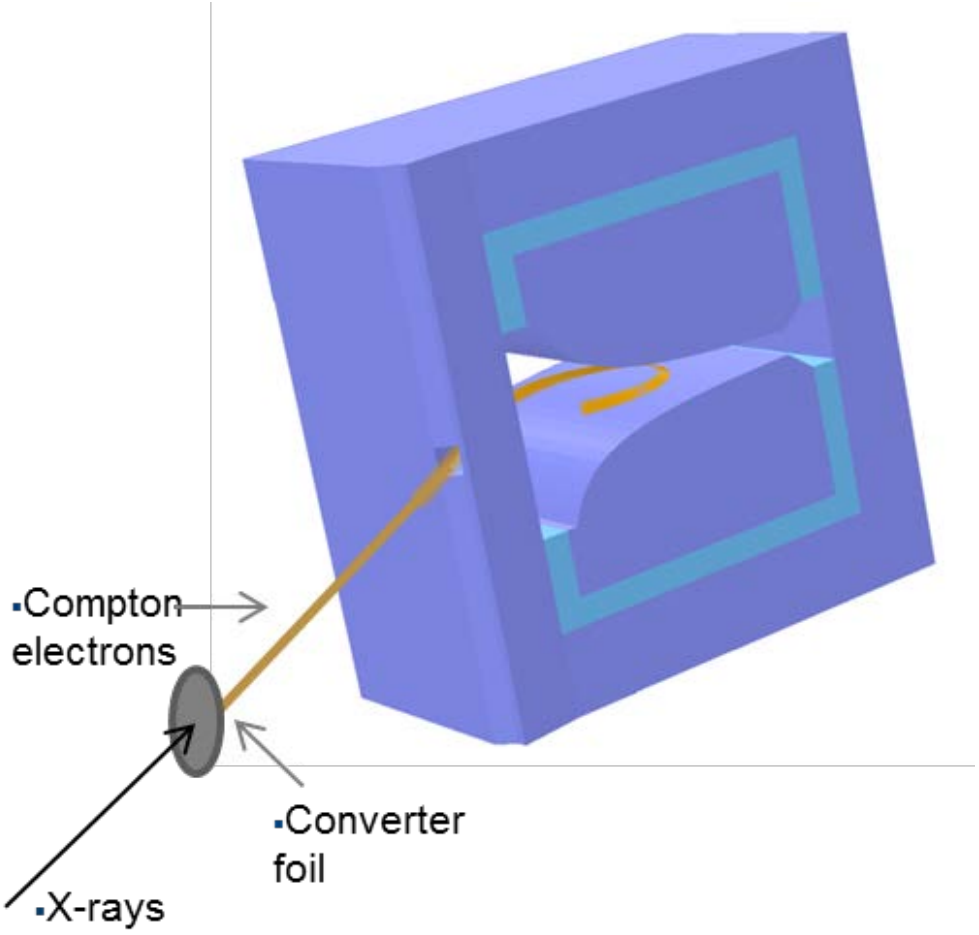
The x-ray spectra of flash radiographic sources is difficult to measure

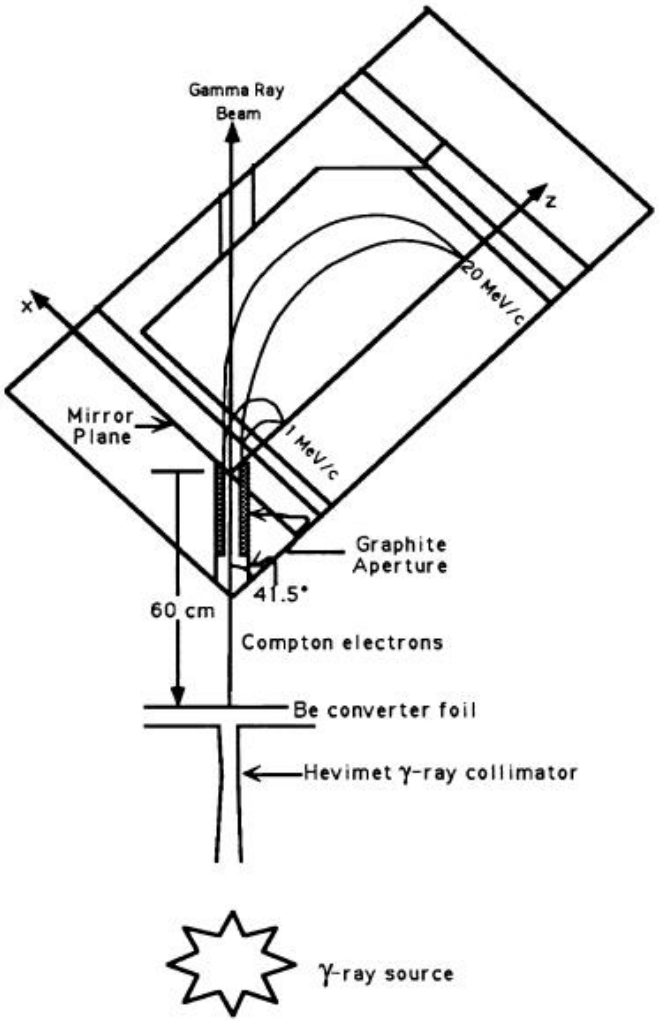
Dual Axis Radiographic Hydrodynamic Test Facility (DARHT)

550 rad at 1 m; 50 ns pulse



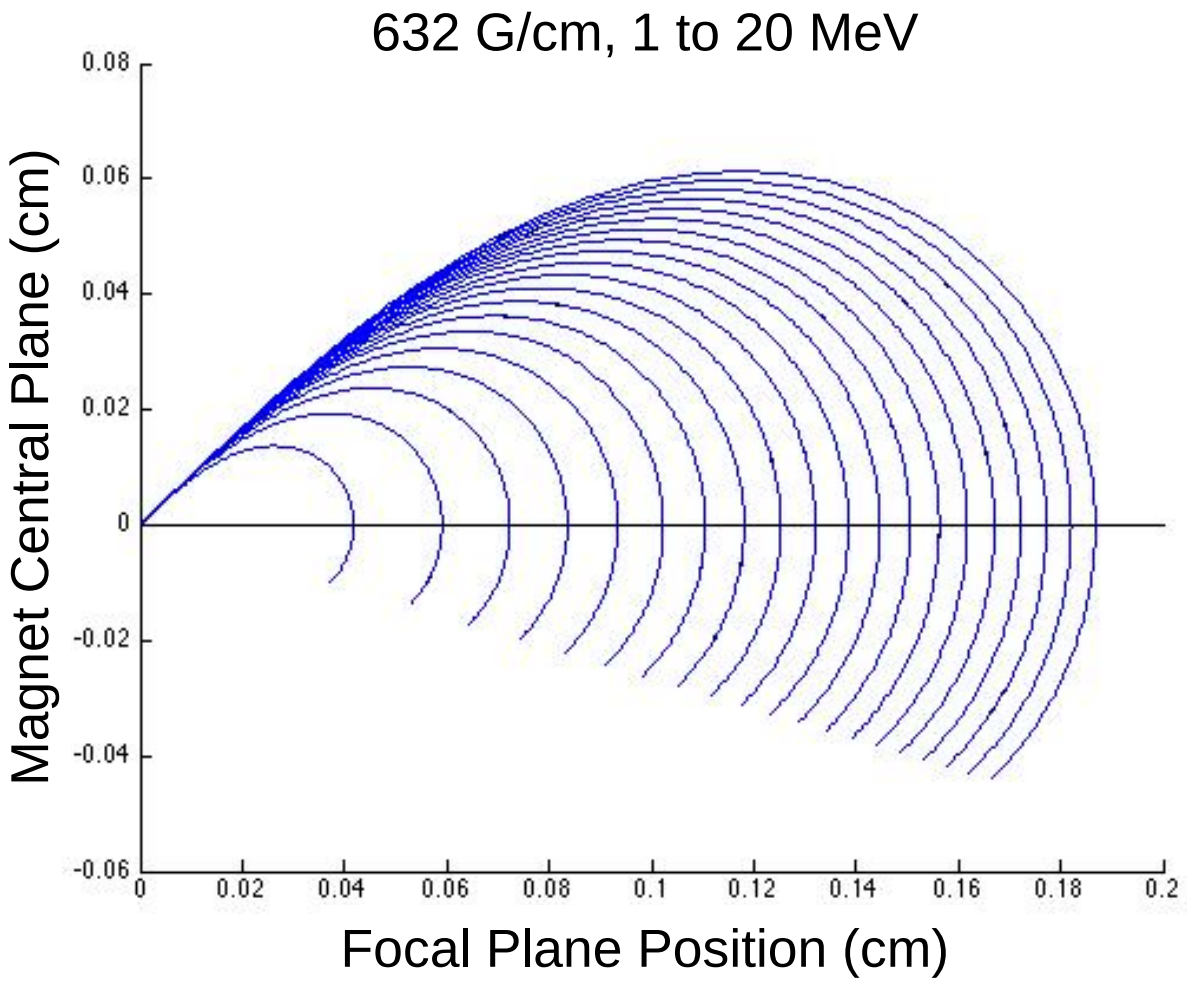
Our Compton spectrometer



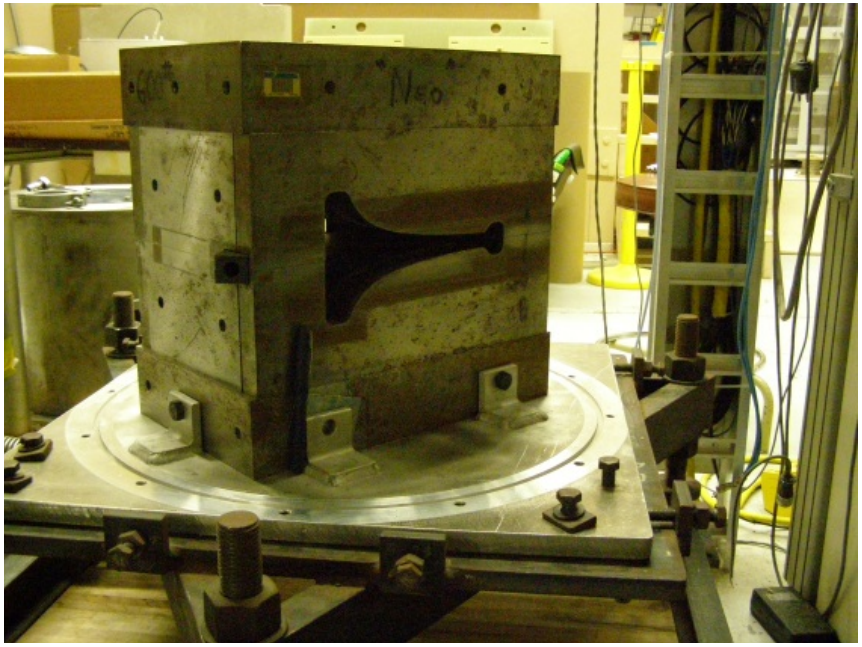


Morgan et al., Nucl. Instr. And Meth. A308 (1991) 544

Electron Trajectories



Our Compton spectrometer



Our Compton spectrometer

Interesting features:

- 300 kg neodymium-iron magnet
- 632 G/cm field gradient; maximum field of 12 kG
- Distance electron crosses focal plane proportional to square root of electron momentum.
- Design accommodates a broad range of energies (from ~ 1 MeV/c up to 20 MeV/c)
- Reported electron momentum resolution is the larger of 0.1 MeV/c or 1% of momentum

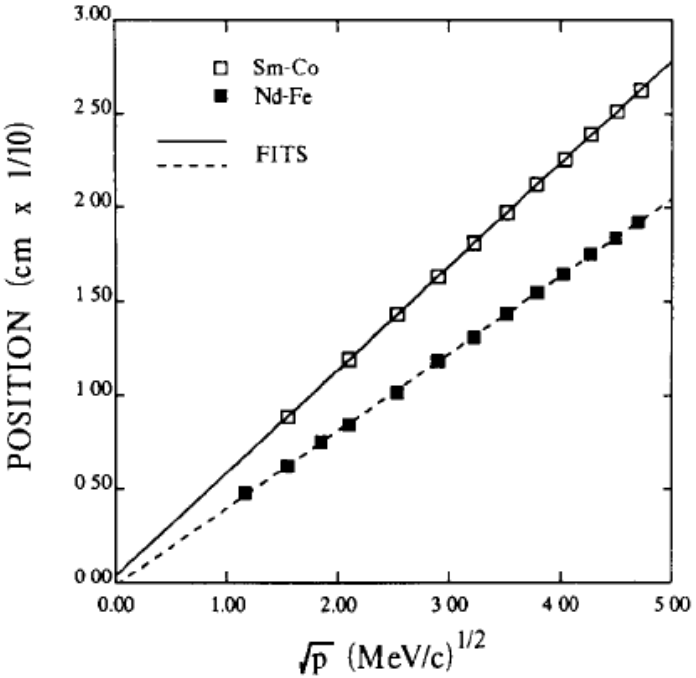
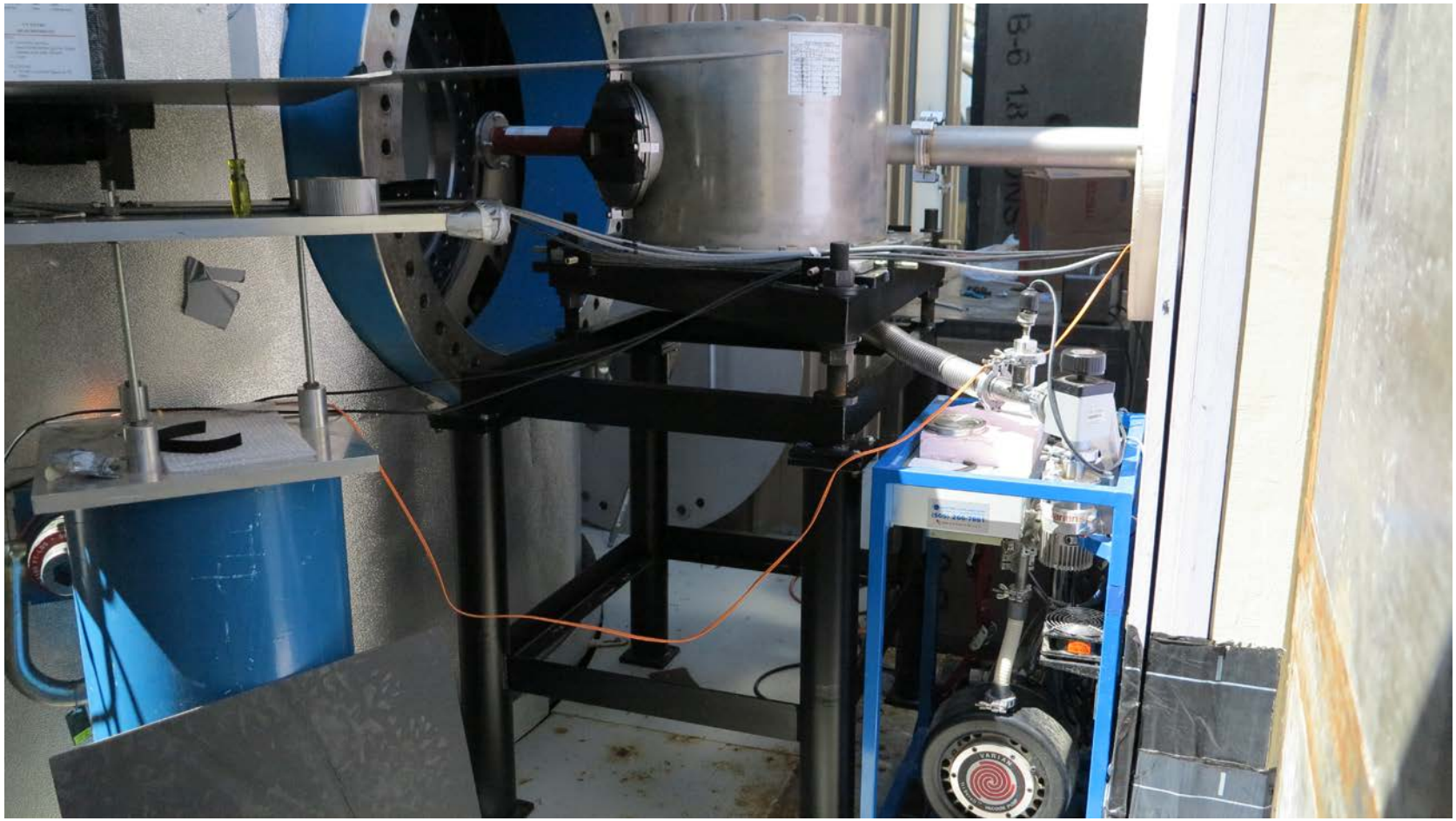


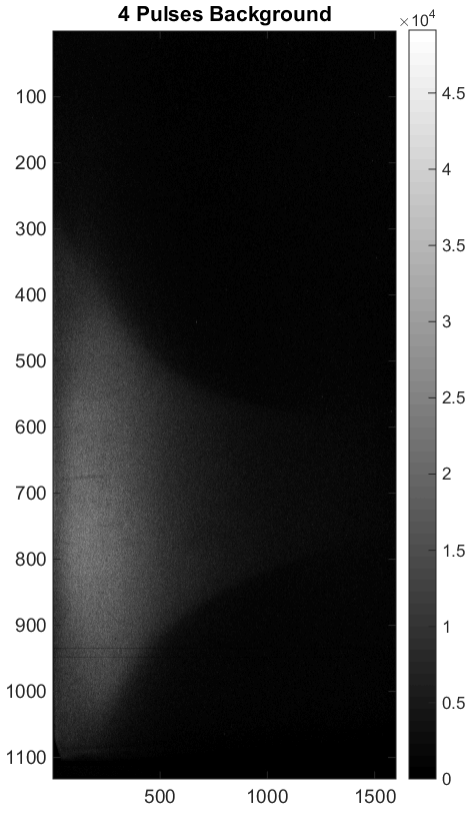
Fig. 13. Measured positions along the focal plane in the two spectrometers versus the square root of momentum. The error bars on the data are smaller than the symbol size. The solid curve is a fit to the data.

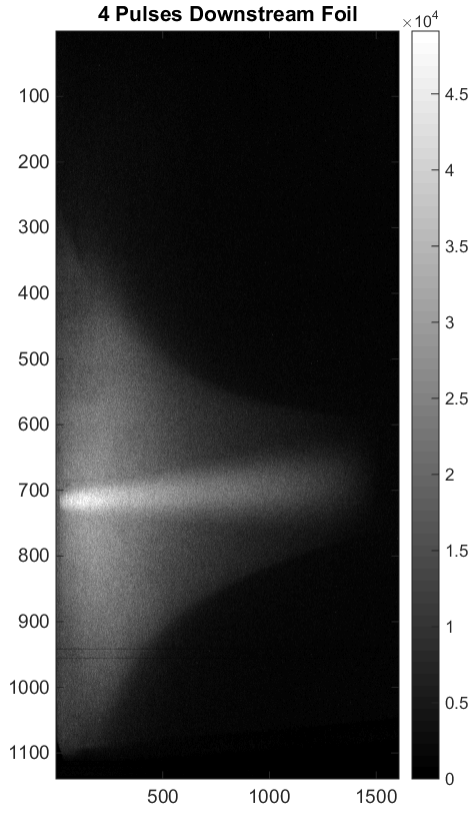
Morgan et al., Nucl. Instr. And Meth. A308 (1991) 544

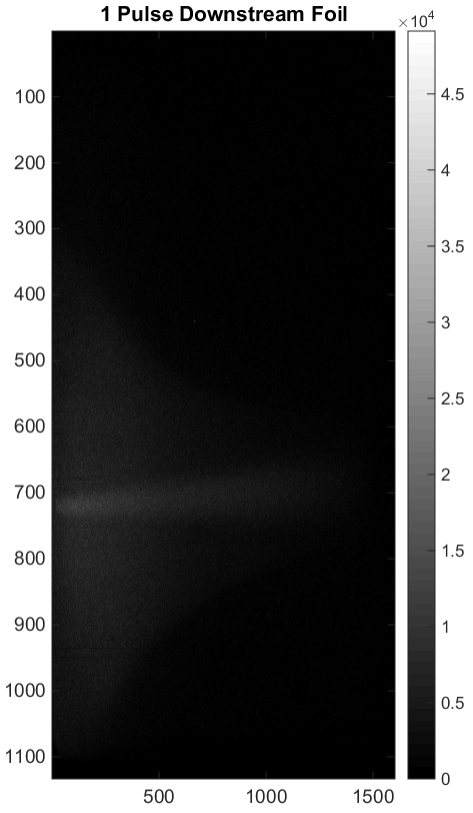
DARHT Measurement



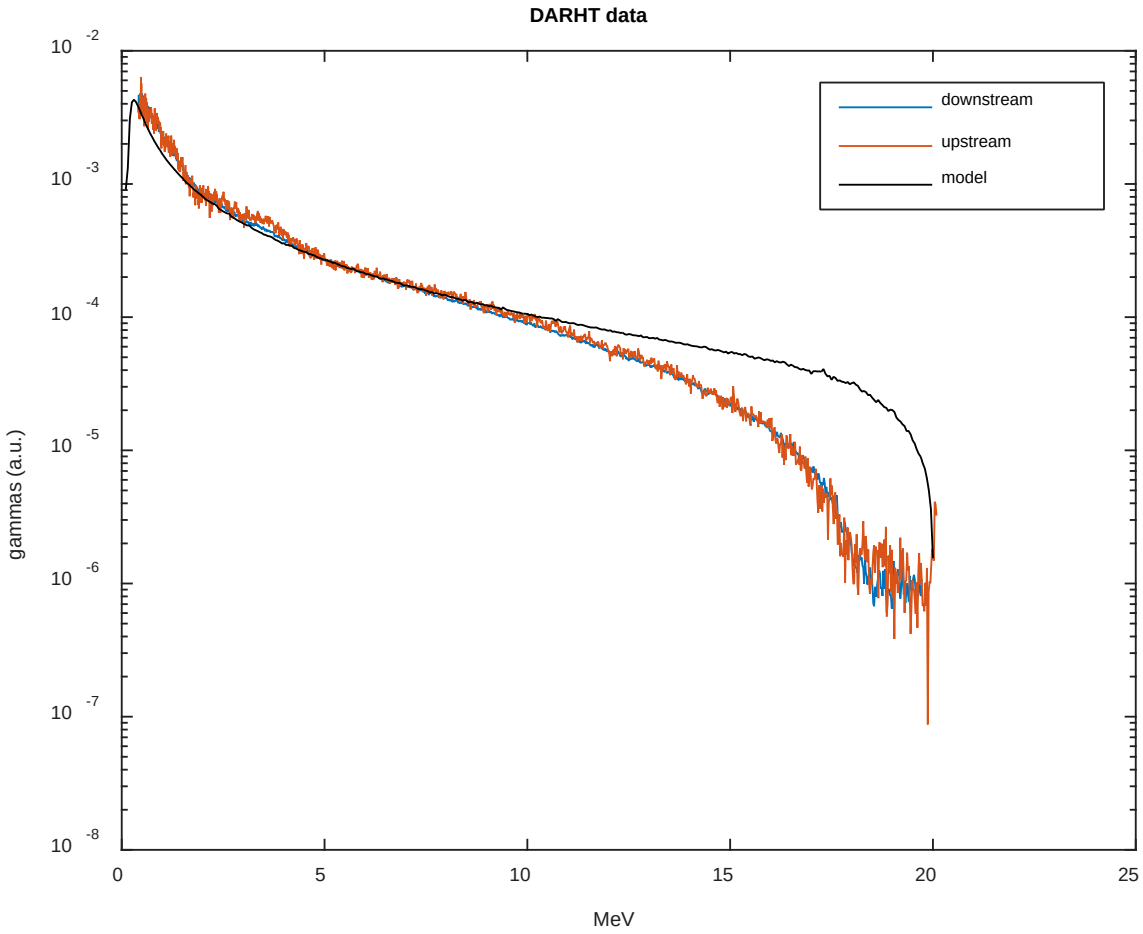
DARHT – Image Plates







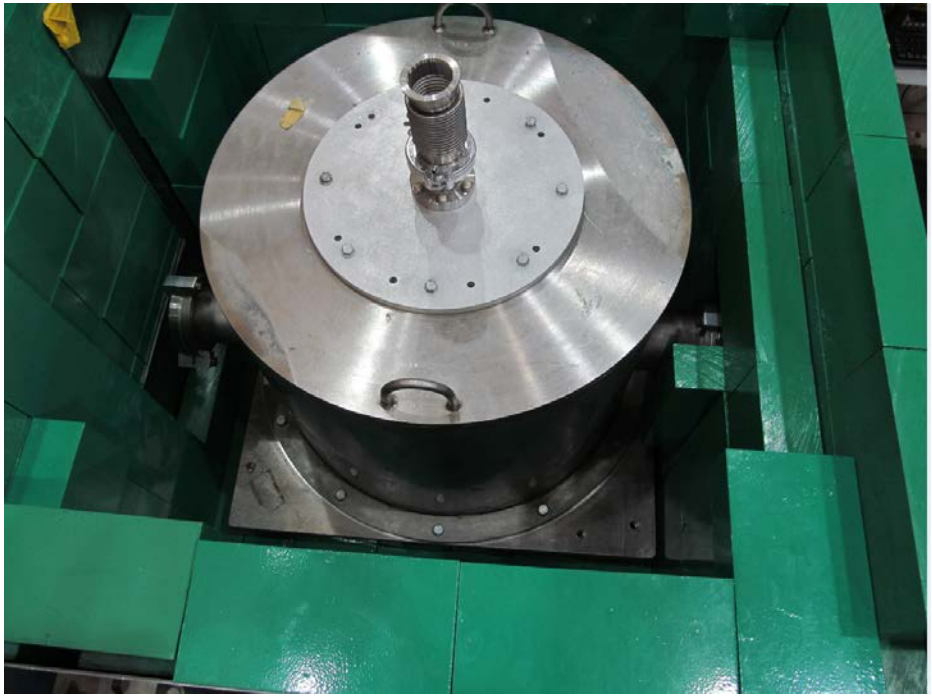
Comparison to model

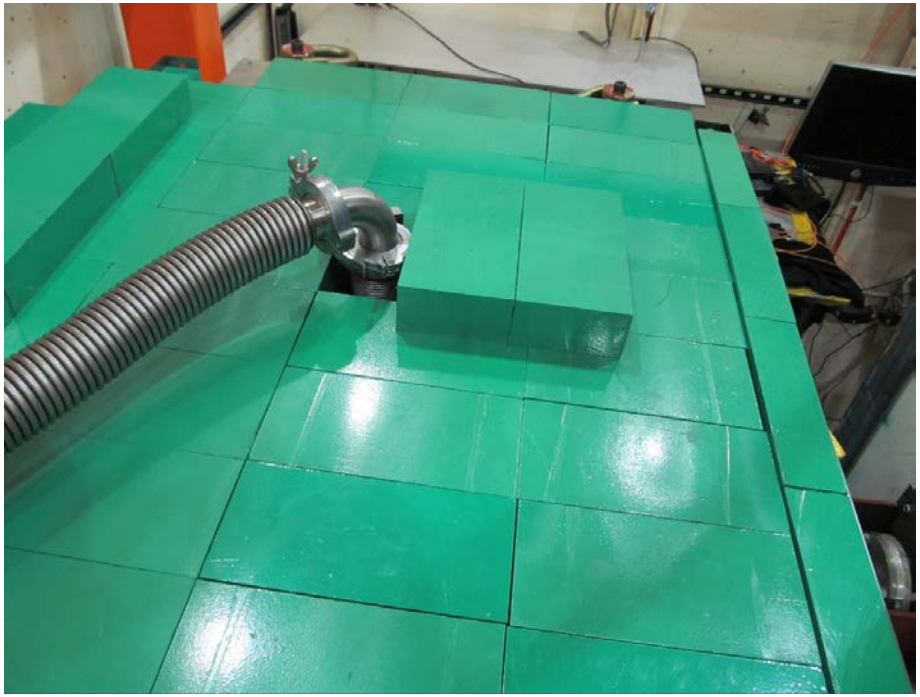


* Model provided by Chris Tomkins, analysis by Espy

RITS Measurement

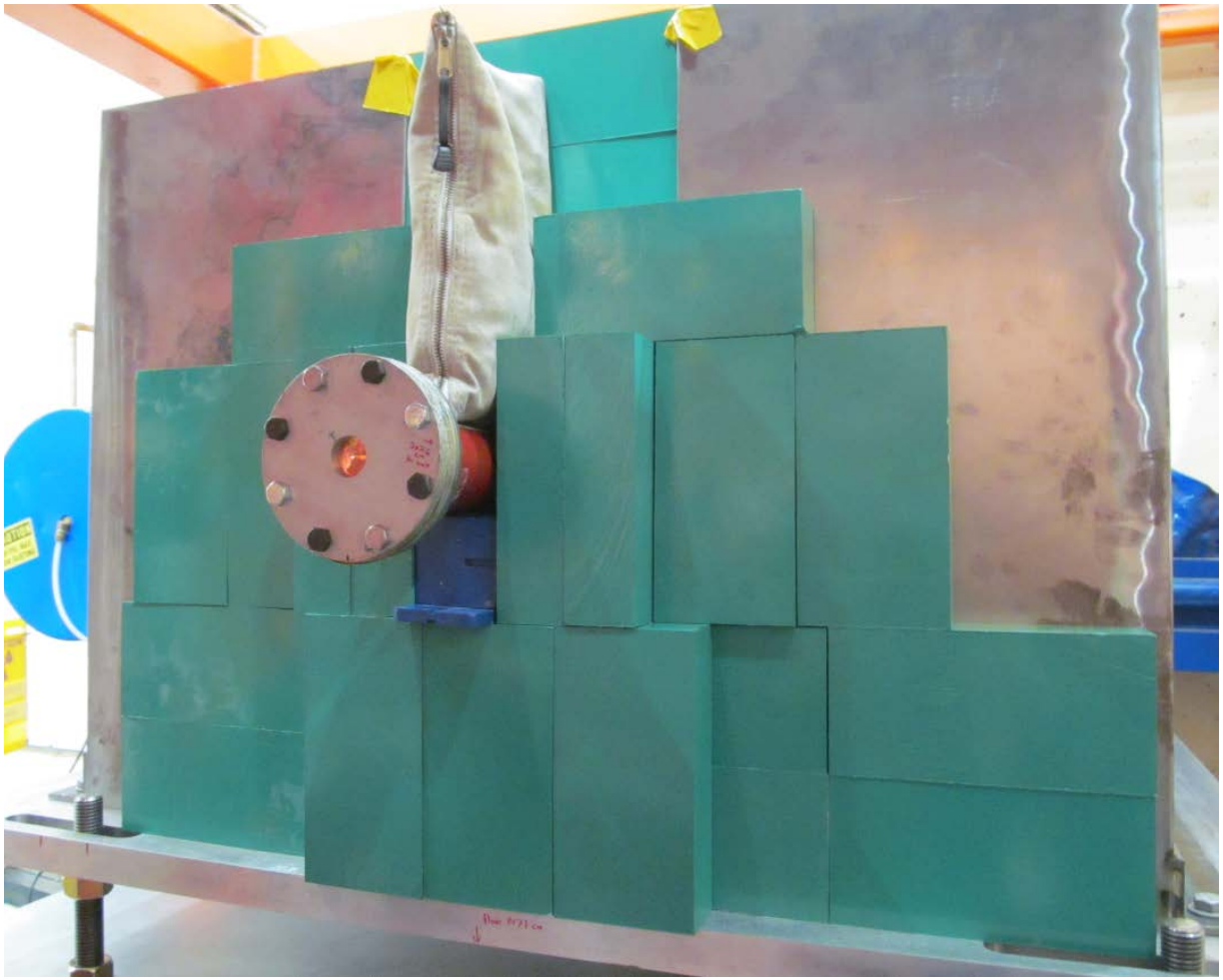
RITS Measurement



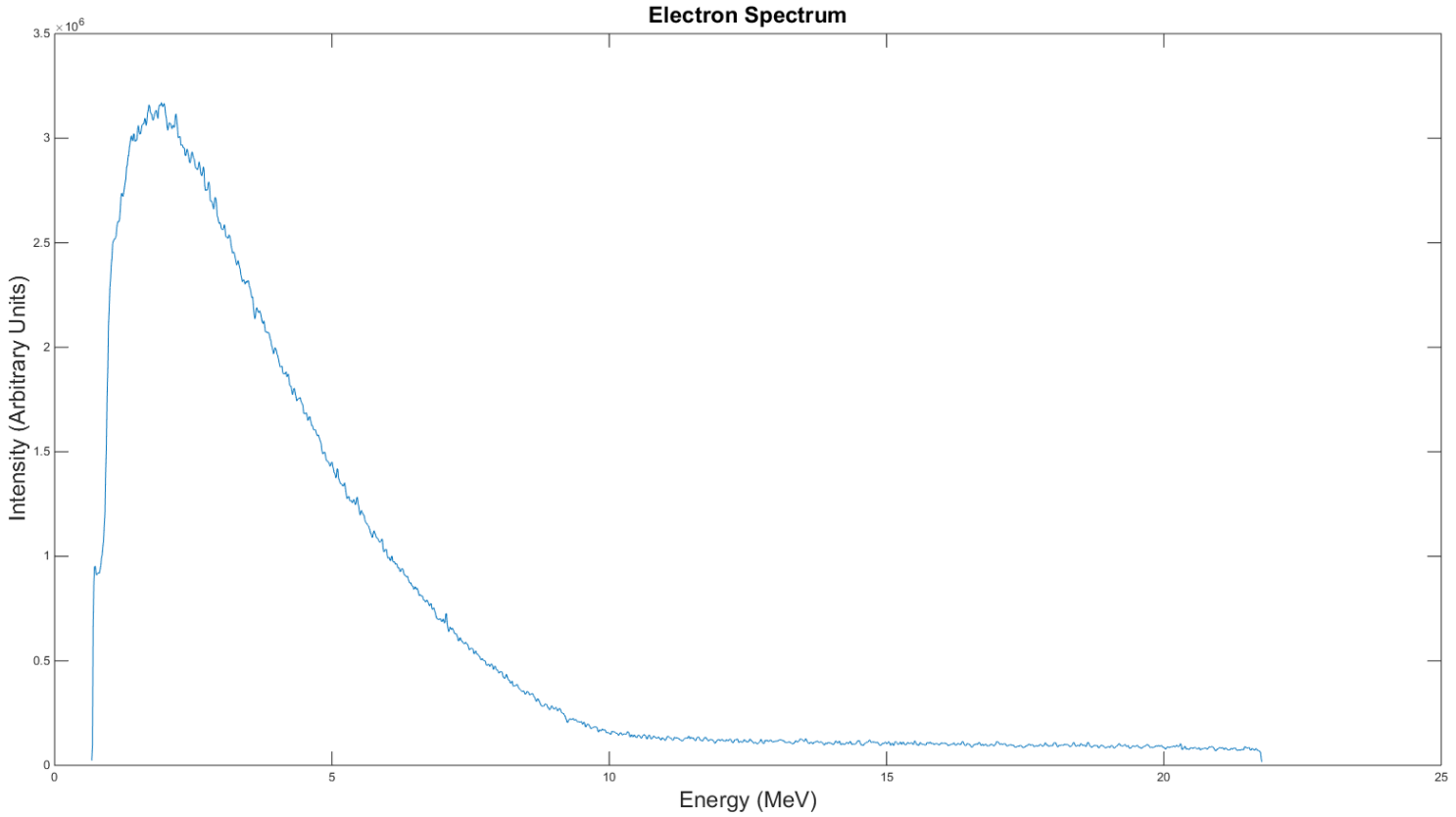


RITS Measurement

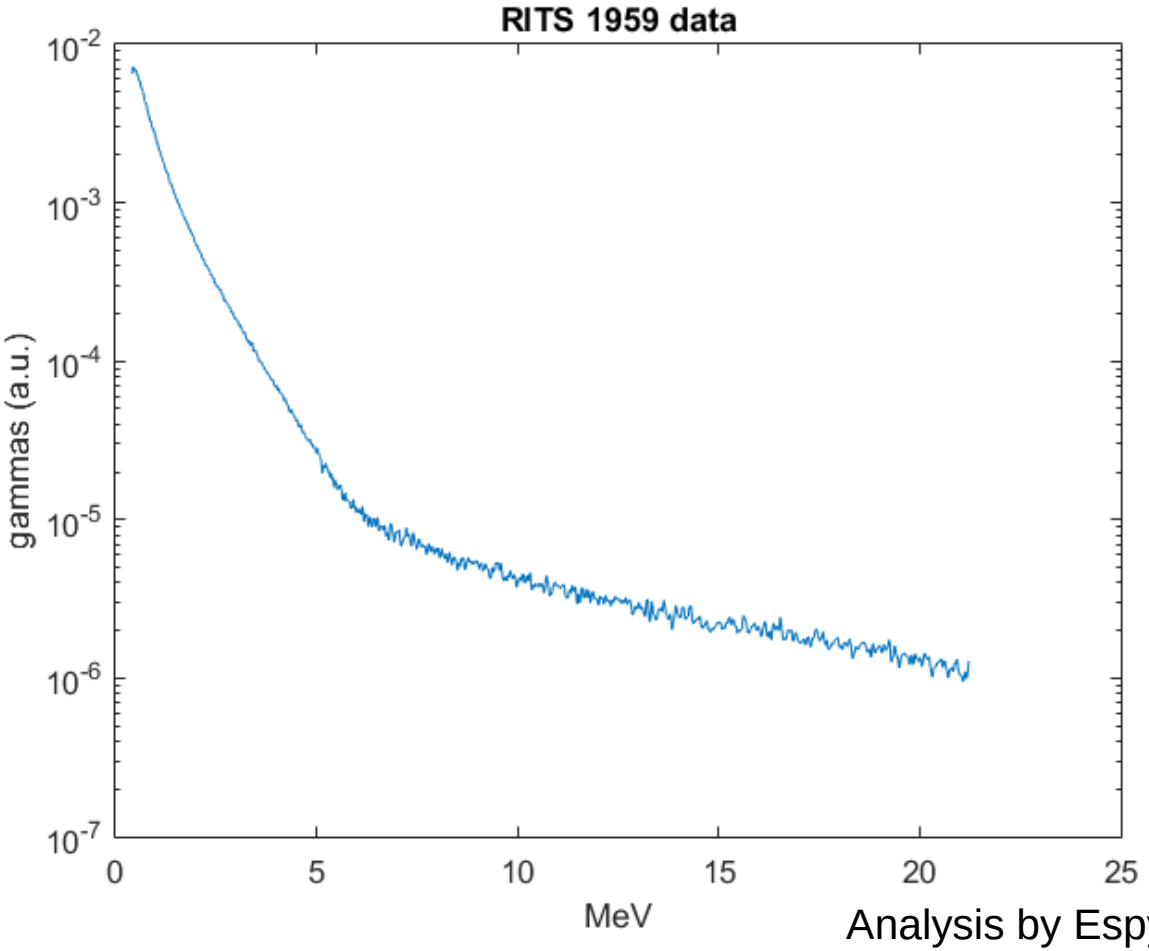
RITS Measurement



RITS Measurement – PRELIMINARY ELECTRON SPECTRUM



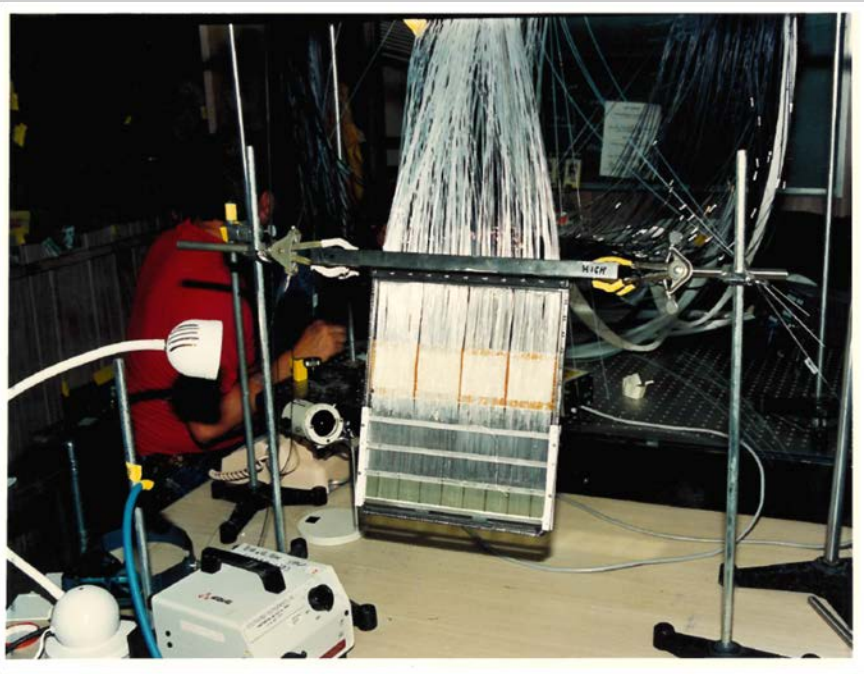
RITS Measurement– PRELIMINARY GAMMA SPECTRUM

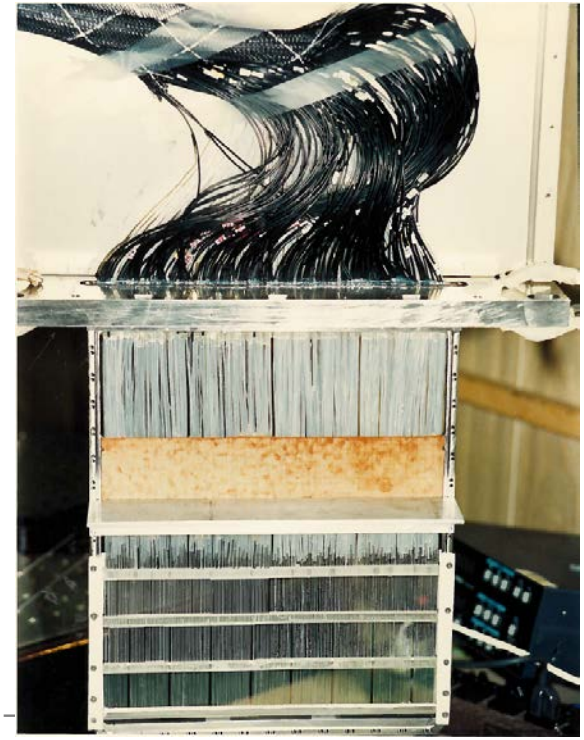


Analysis by Espy

Future development of detector system

- Time-integrated detector system will be an array of plastic scintillators
- Time-resolved system is being developed
  - Goals: Bin size ≤ 0.25 MeV and ~1 ns time resolution





Summary

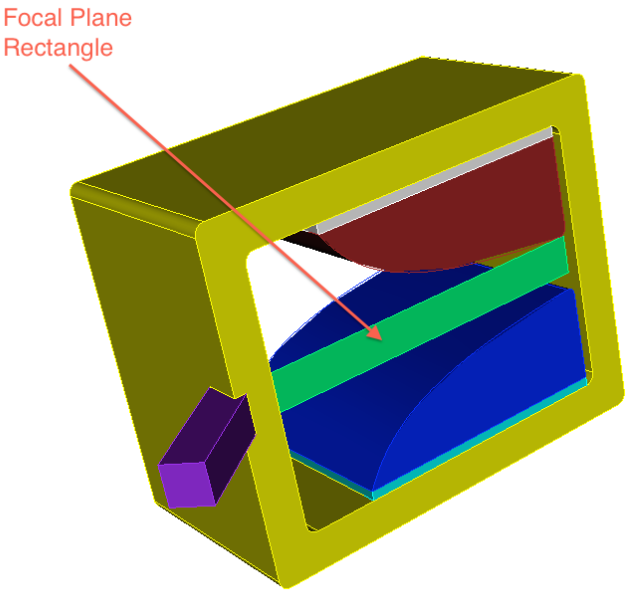
- Successful measurement of the DARHT x-ray spectrum
- Successful measurement of the RITS-6 x-ray spectrum
- **First measurements of pulsed sources have been completed!**

Work in progress

- Final analysis of previous experiments
- RITS-6 experiment and initial DARHT analysis
- Detector system development

Path forward

- Idaho Accelerator Center experiments September 2015
- Build, test, and calibrate time-integrated detector system
  - Final design and procurement in process
- Received quote for low energy CS; fabrication and assembly timeline is ~3 months
- Procure and field new low energy CS by end of calendar year

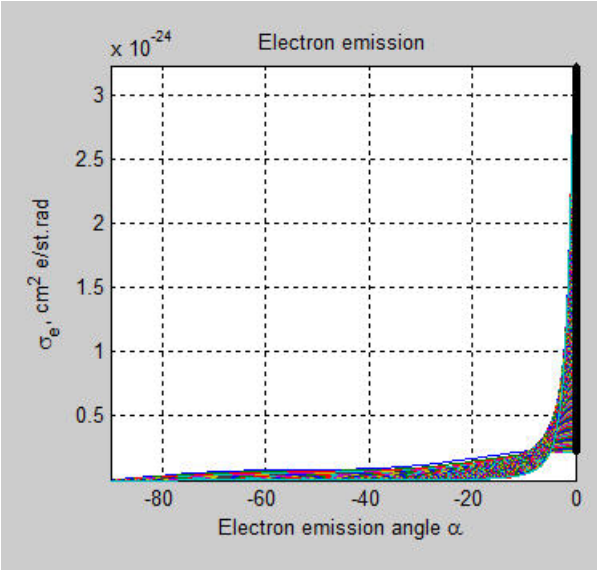


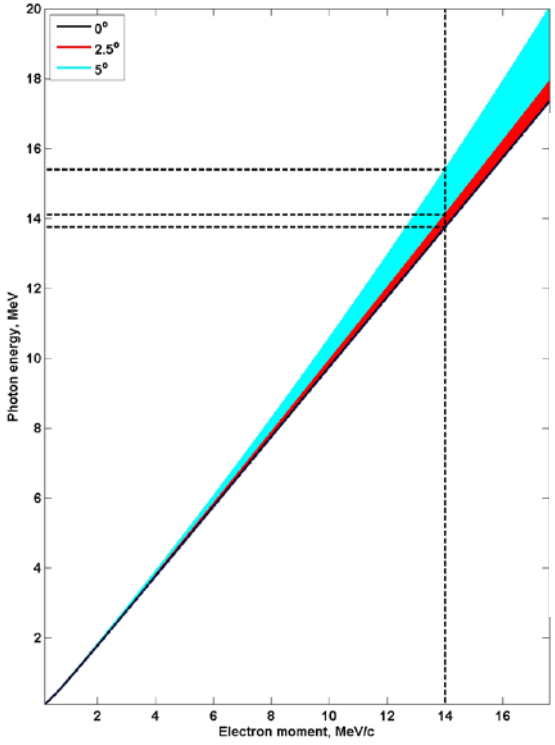
New Compton Spectrometer

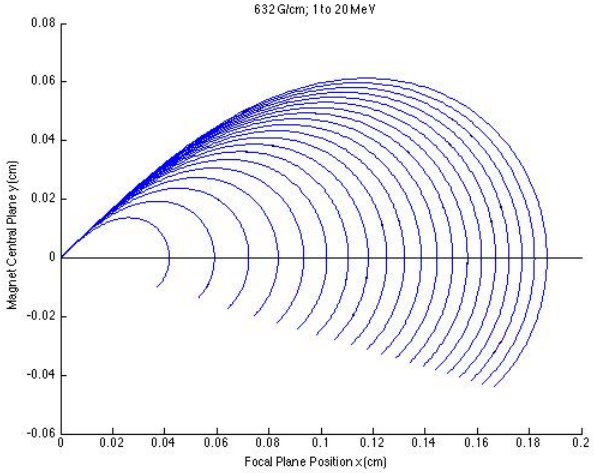
Questions?

X-rays Compton scatter into easier-to-detect electrons

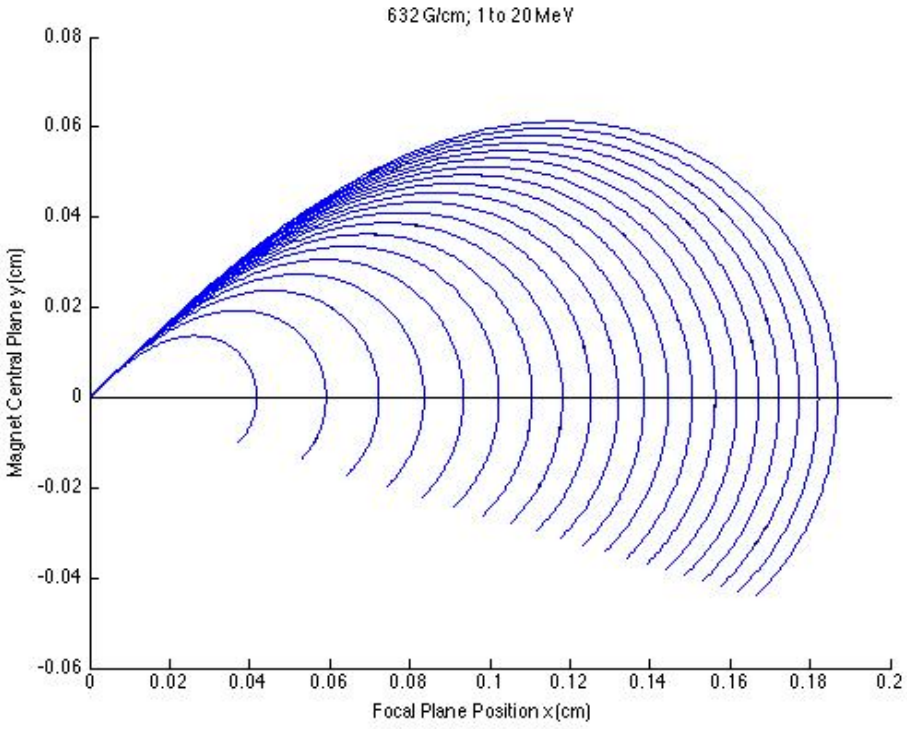
- Most electrons are forward
- Restricting angular acceptance of Compton electrons, incoming gamma energies & ejected electron momenta are simply related
- Magnet relates energy to position

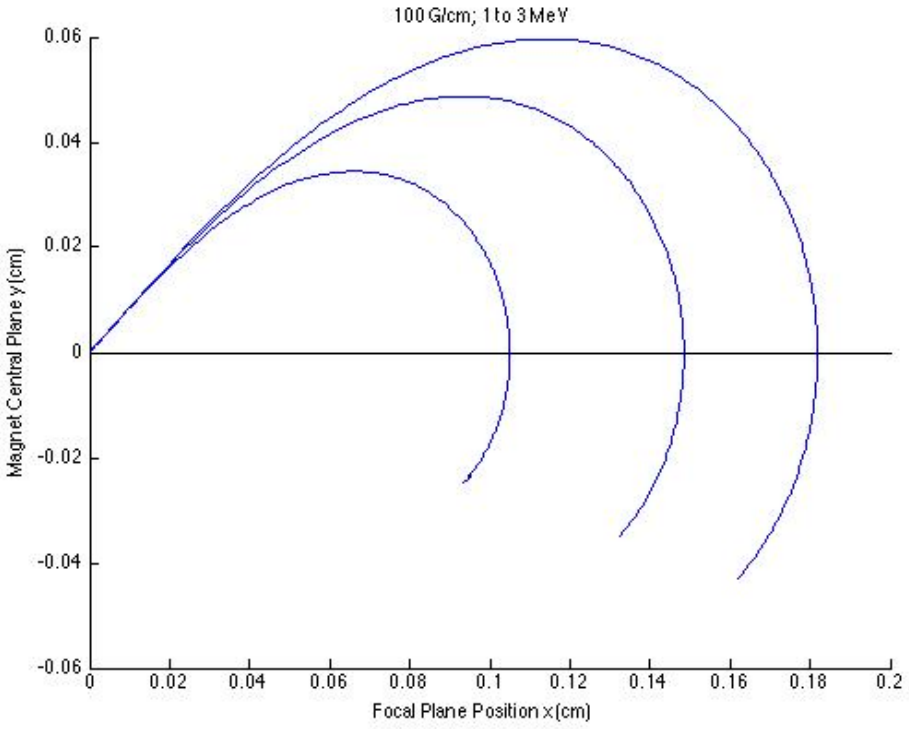






Electron Trajectories





Energy Calibration

- ^{60}Co source at NSTec Source Range – resolve 1.17 and 1.33 MeV lines?
- Will need to shield spectrometer for the first time

- 20 MeV High Repetition-Rate LINAC

at Idaho Accelerator Center

- Will potentially measure 0.5-20 MeV

electrons, 0.5 MeV step

Morgan et. al.

- Focus on alignment issues

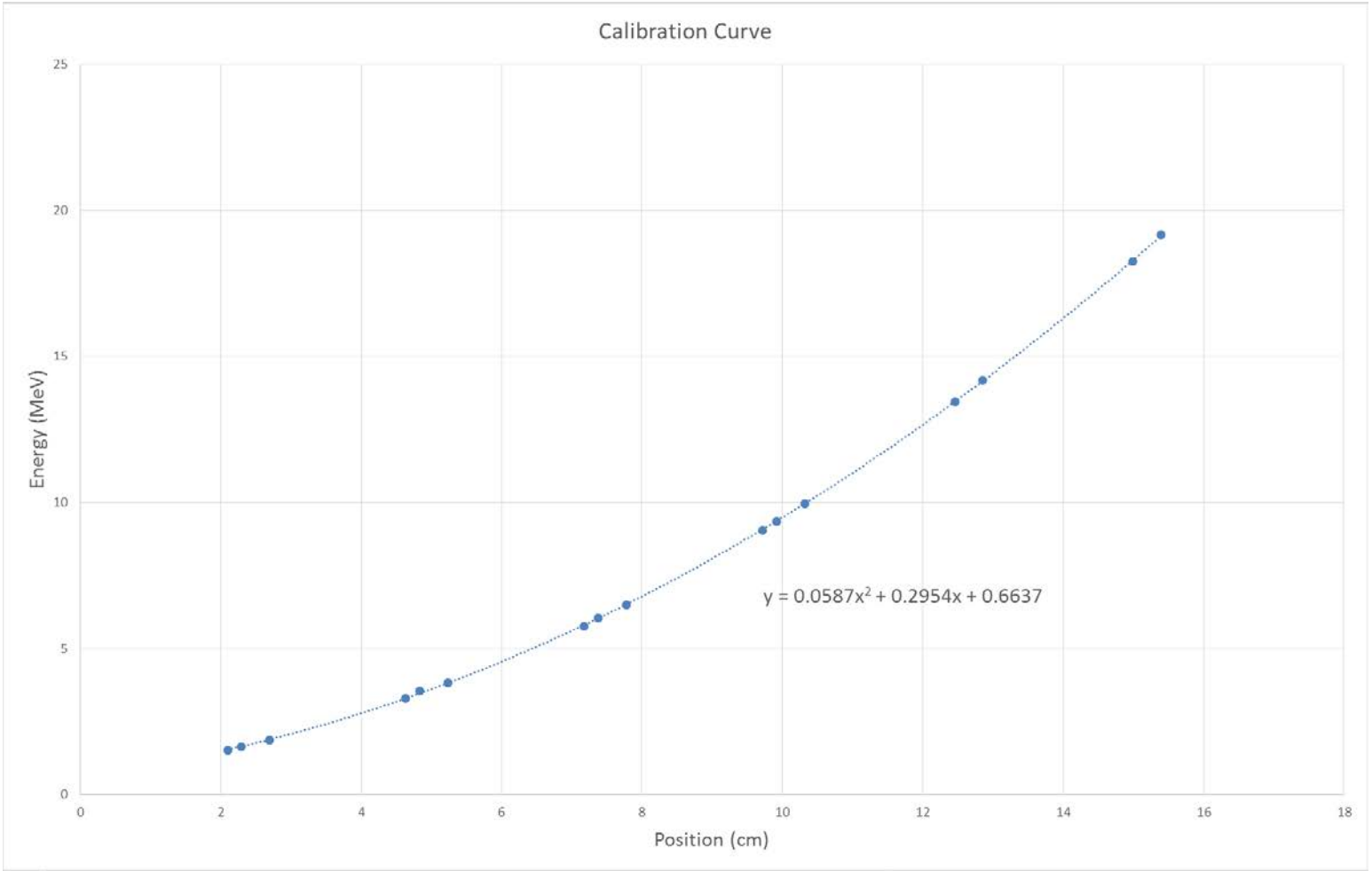
Calibration experiment

- Conducted July 2014 at the Special Technology Laboratory of National Security Technologies, LLC with a continuous ion beam
- H^- and OH^- accelerated to known energies (1-45 kV)
- 6 brass “button” detectors along focal plane, connected to ammeters
- 2 masks in front of detectors, 16 known positions
- Altered beam energy by varying acceleration voltage
- Relationship between ion momentum and position by design:

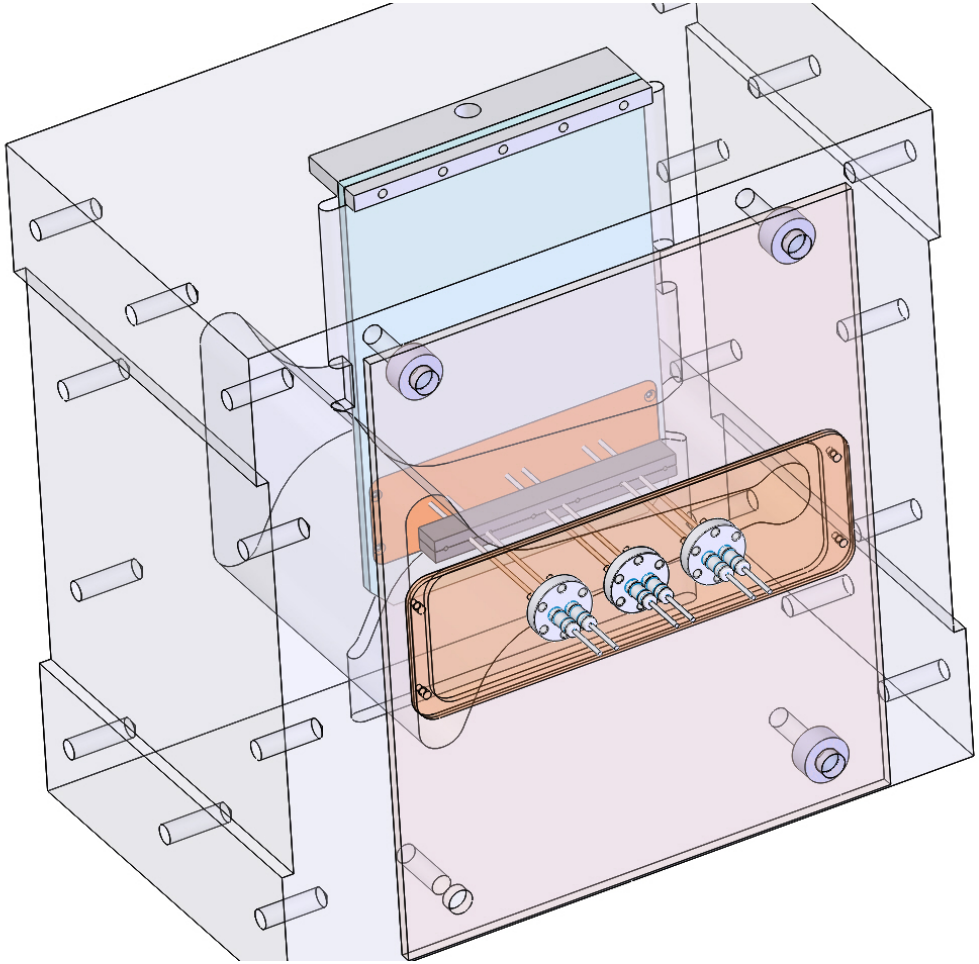
$$p\ (\text{MeV/cm}) = \frac{Gx^2(cm)}{2*3.3356(1+\sin A)}$$

G = magnetic field gradient in kG/cm
A = entrance angle with respect to focal plane

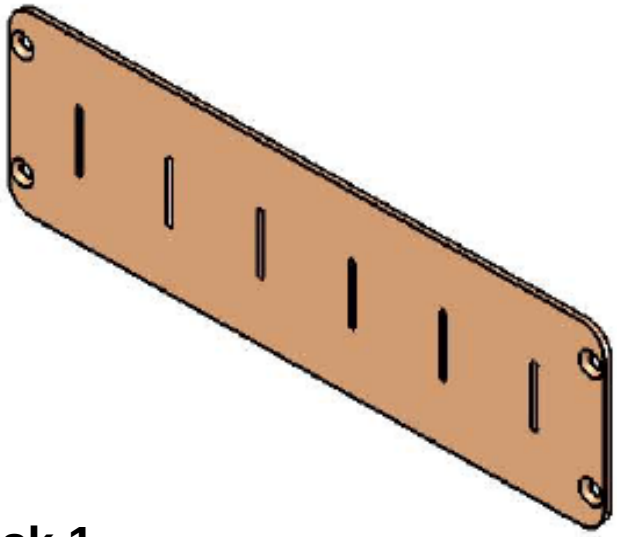
Calibration results



Detection hardware and new configuration for calibration experiment



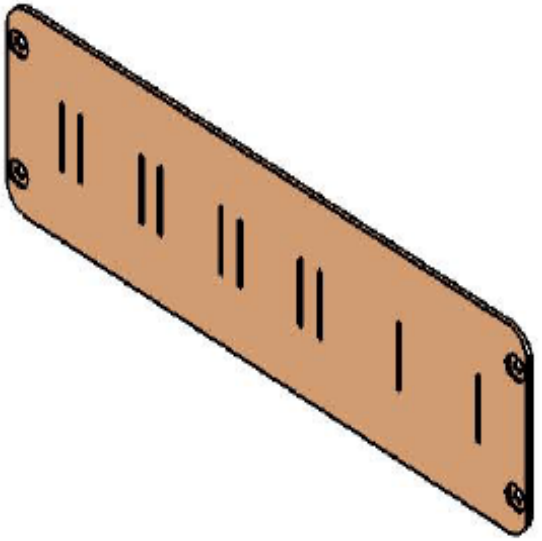
Masks



Mask 1

Slit are centered over the brass detectors

All slits 1.5 mm wide

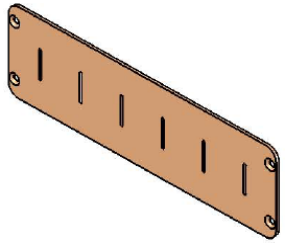


Mask 2

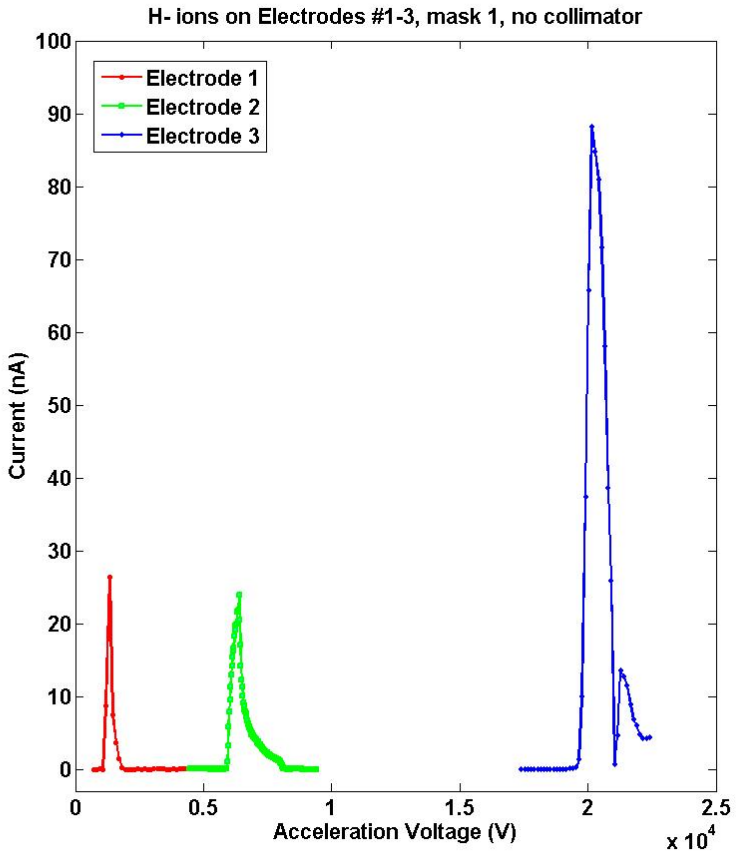
Paired slits -2 mm and +4 mm relative to the central slit of mask 1

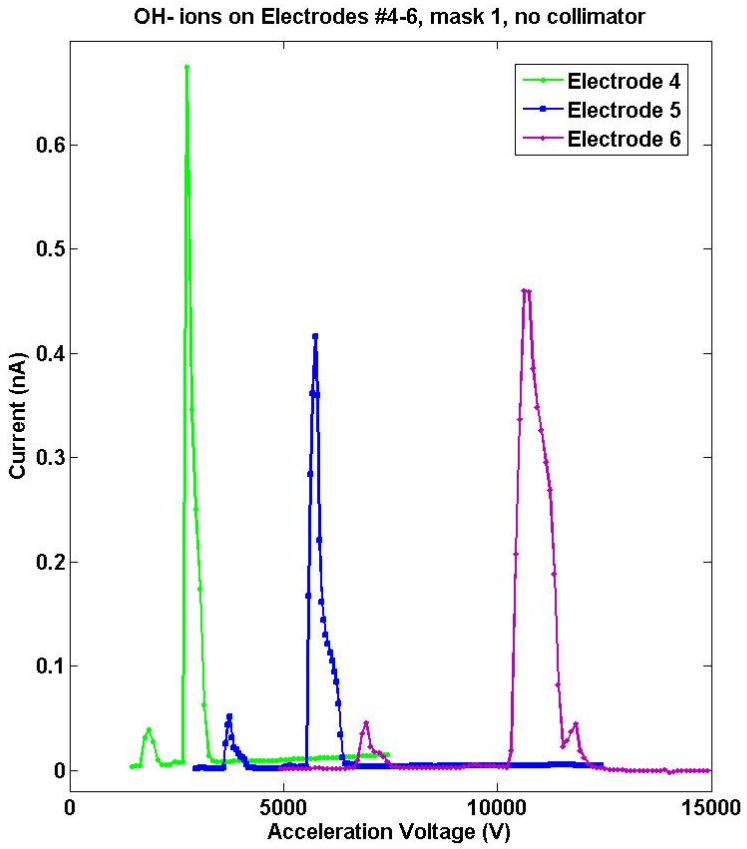
Single slits +4 mm as relative to the central slits of mask 1

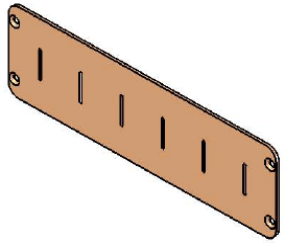
All slits 1 mm wide



Calibration data – mask 1







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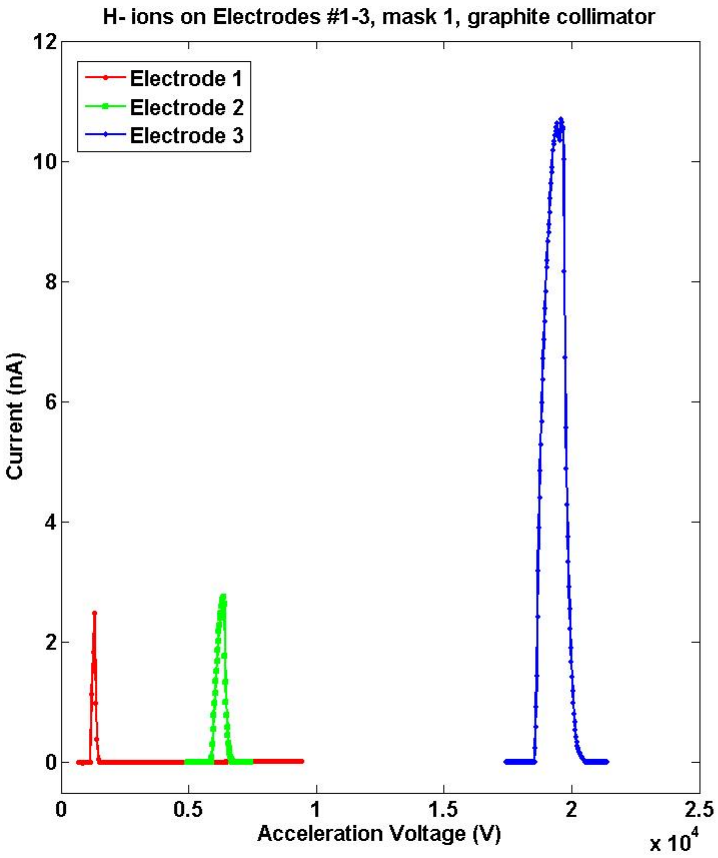

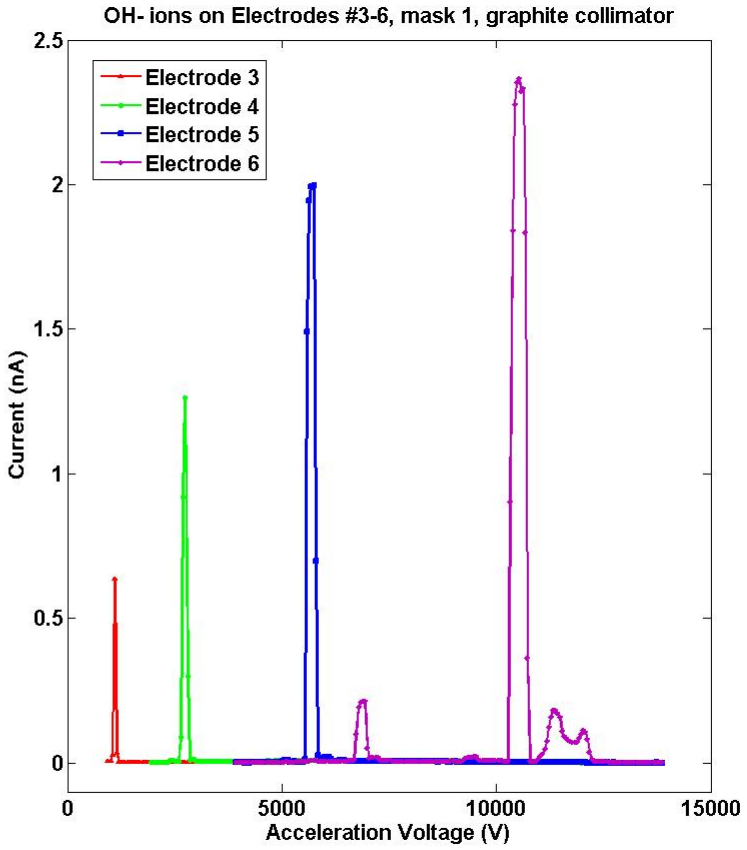

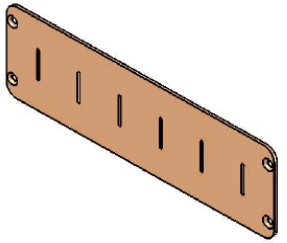

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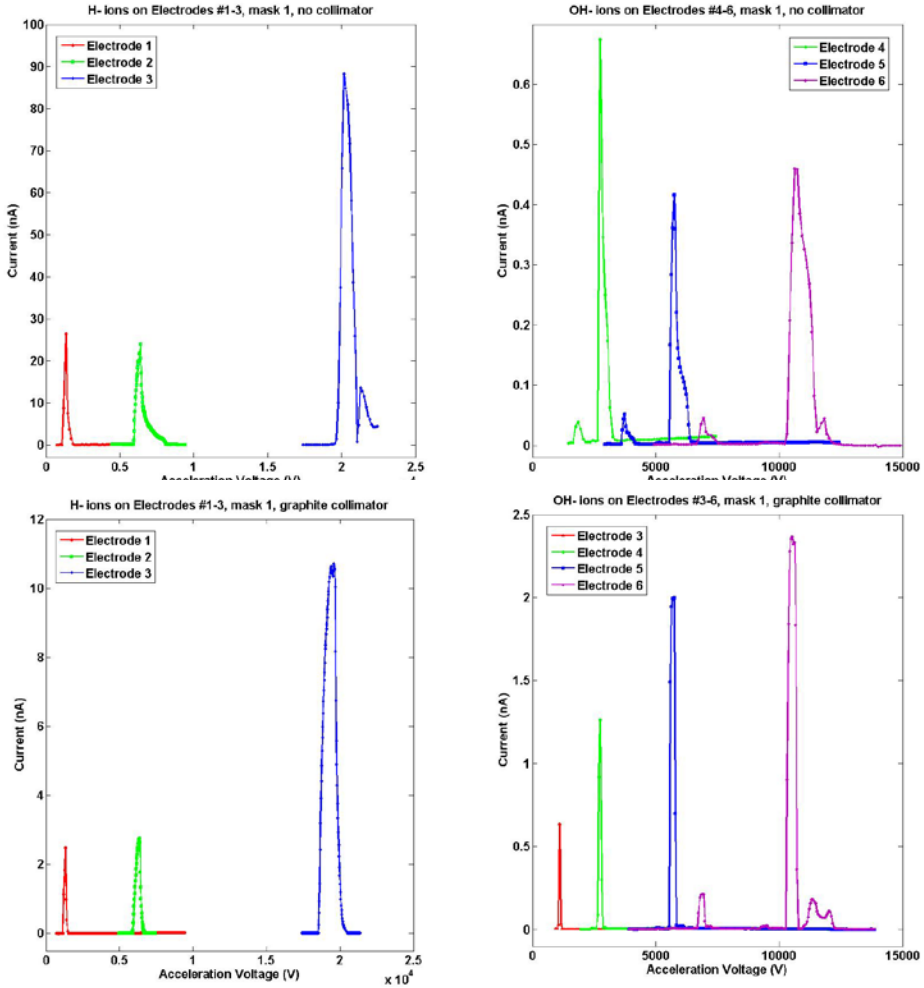

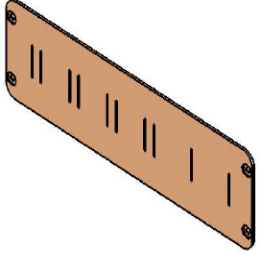

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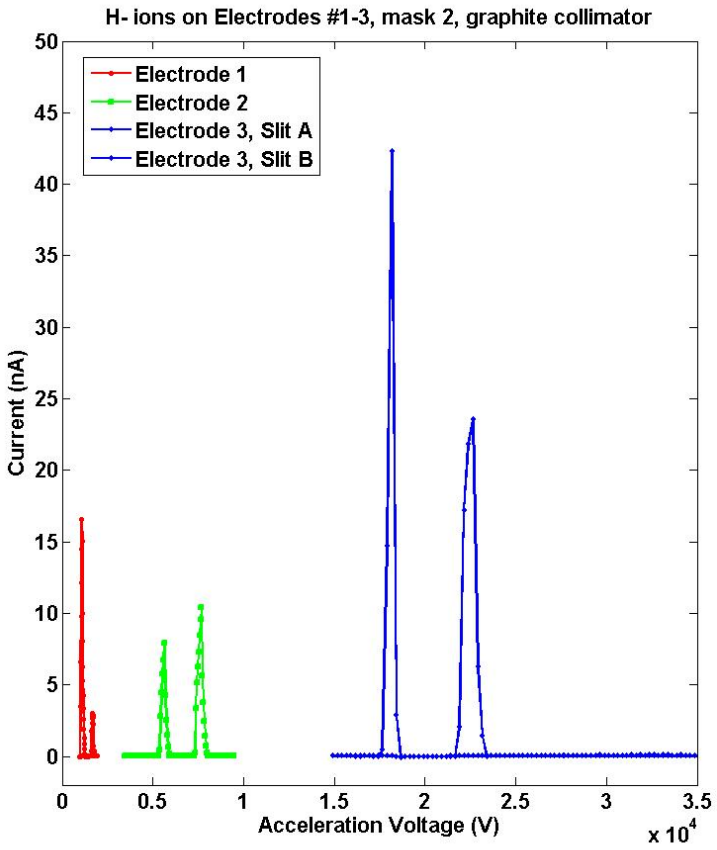

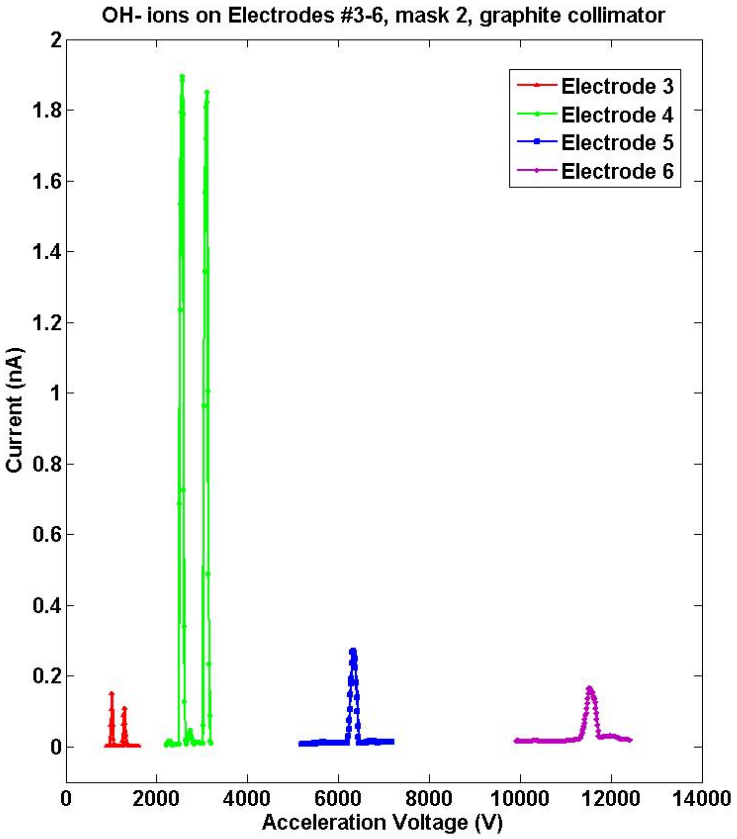

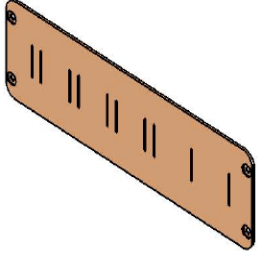

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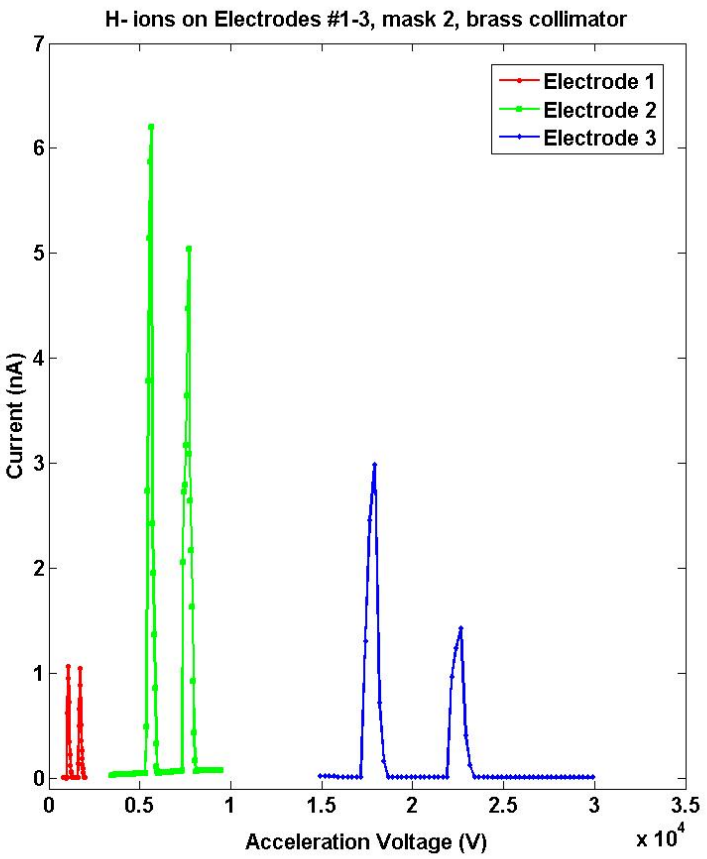

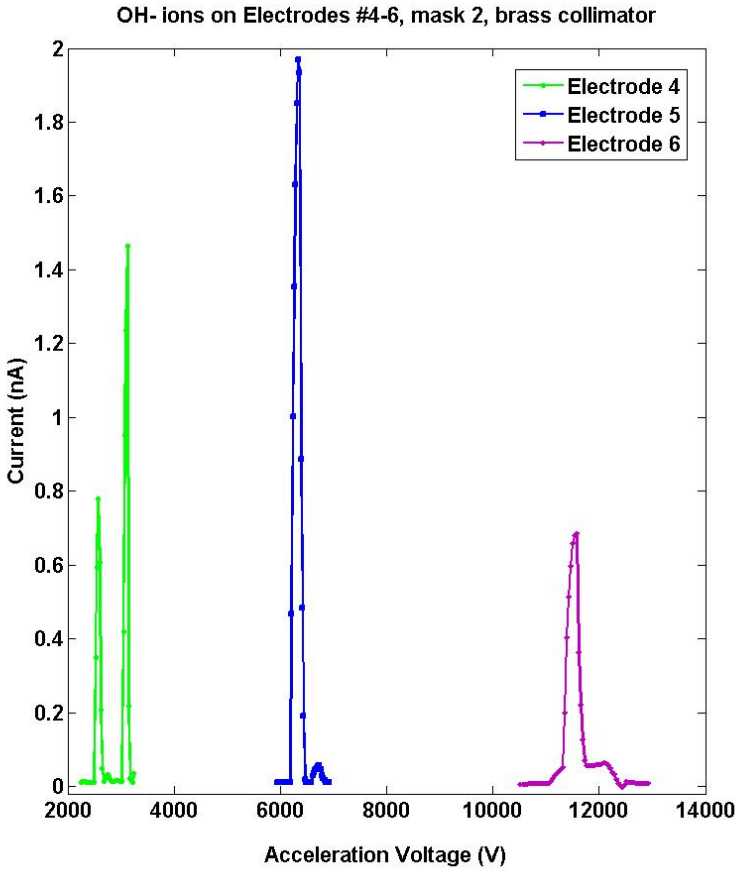

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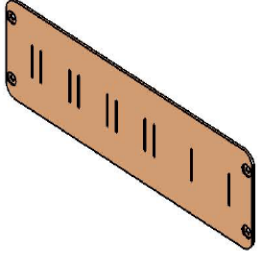
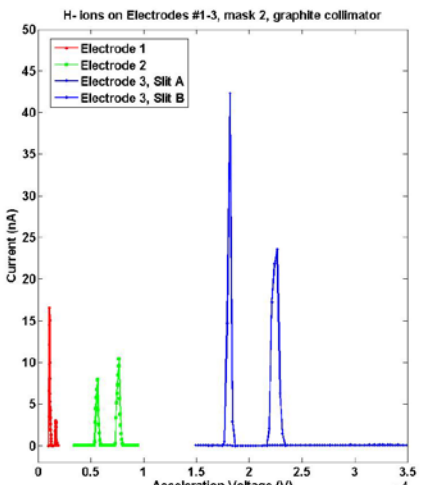
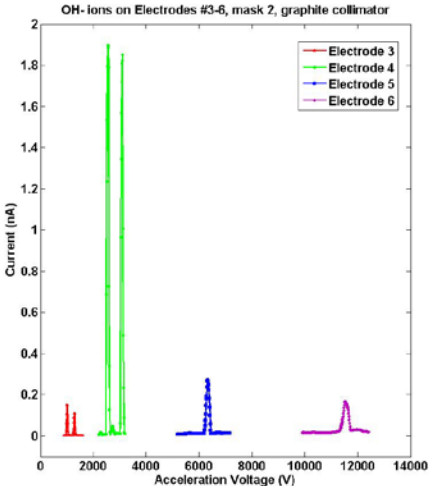
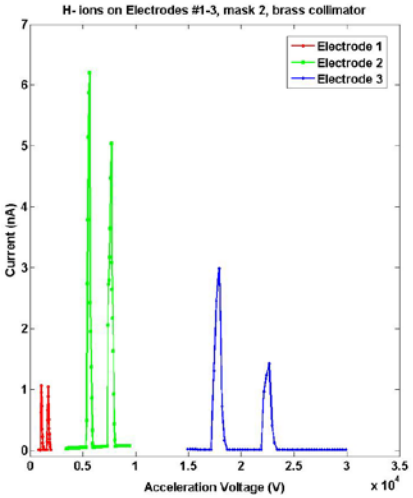
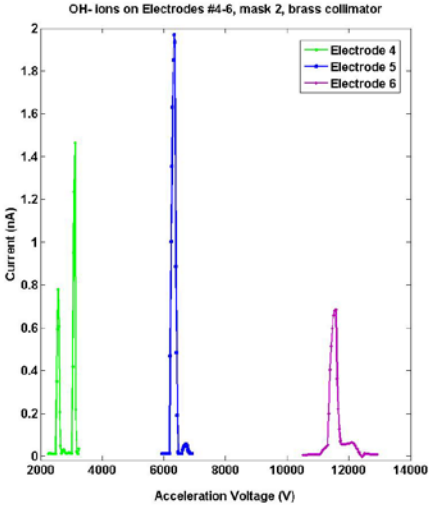


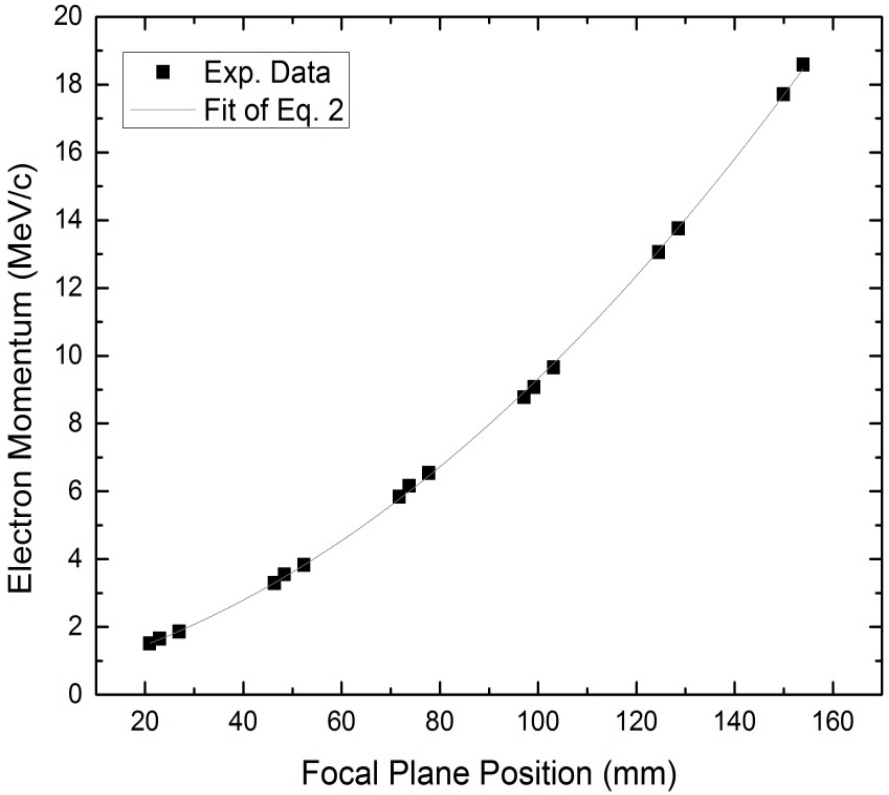








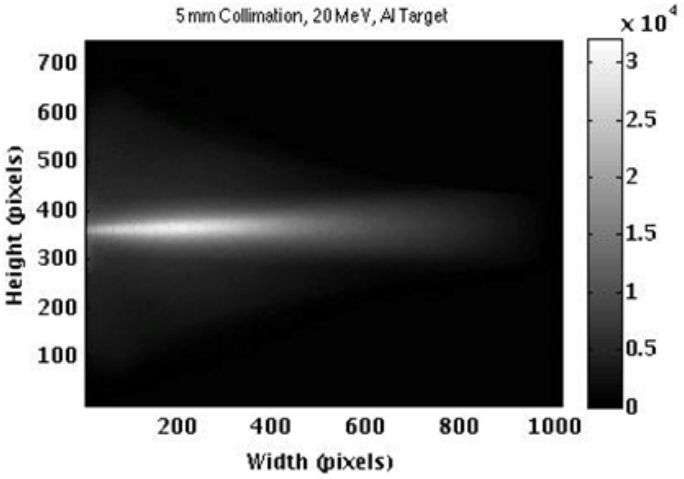
Calibration results

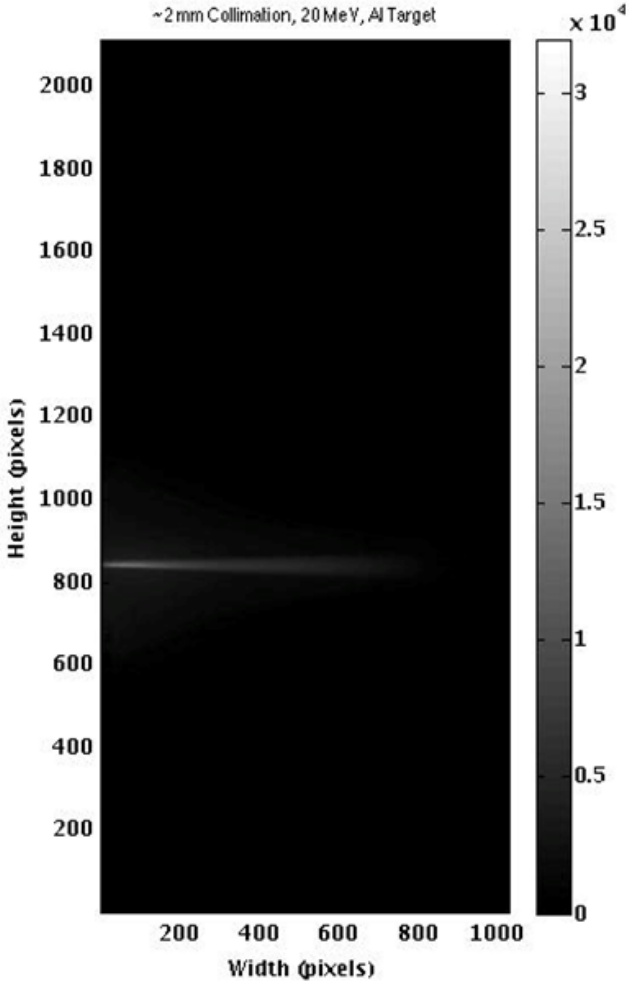


Measurements at the microtron

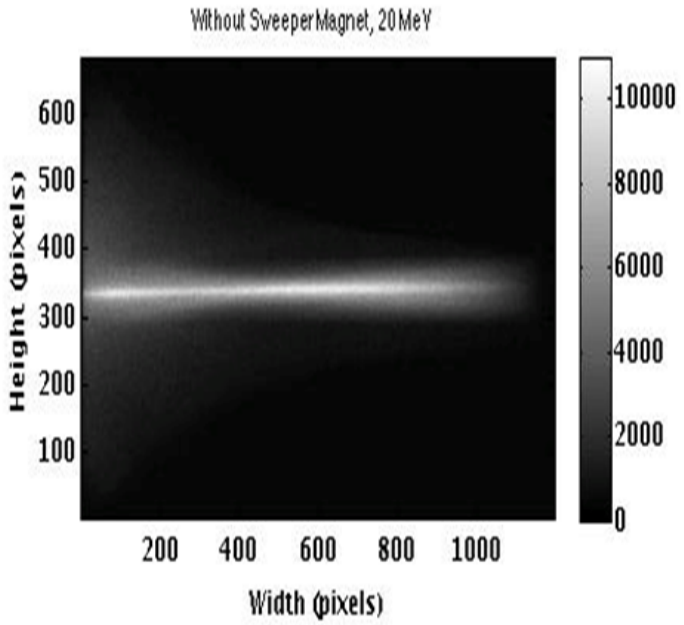
- Bremsstrahlung X-ray source with electron endpoint energies 6, 10, 15, 20 MeV
- 5 mm tungsten collimator, reduced further to ~2 mm
- Sweeper magnet
- Electrons detected with storage phosphor
  - Drop vacuum every energy change
- Graphite collimator for ~ 1° angular acceptance
- Excellent agreement w/ predicted energy endpoints

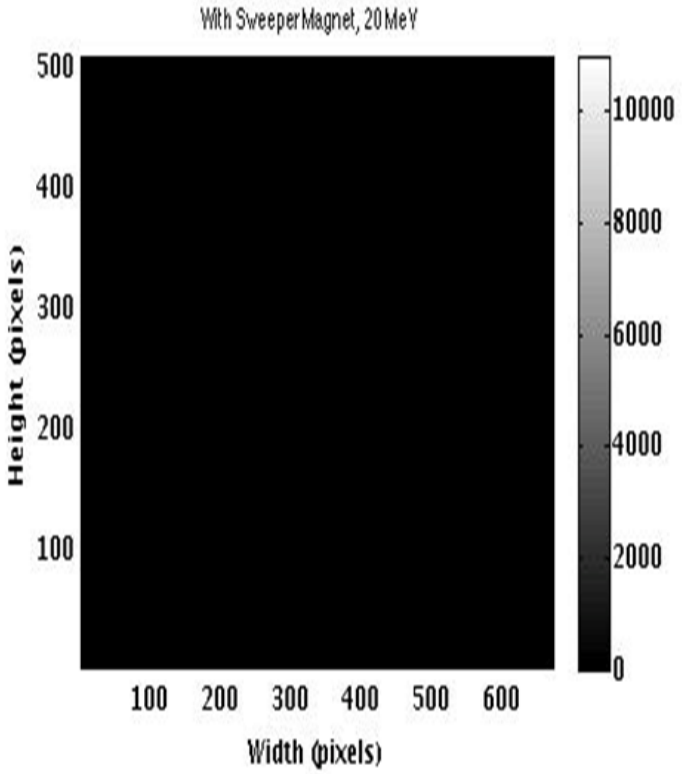
Improved collimation



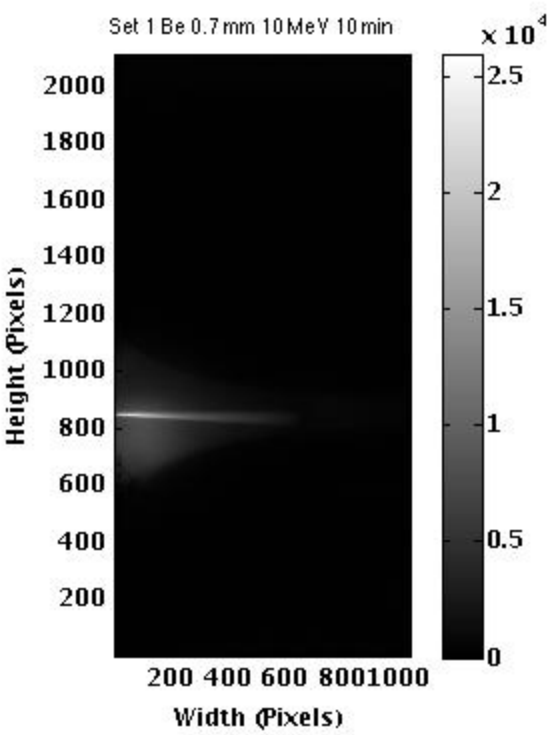


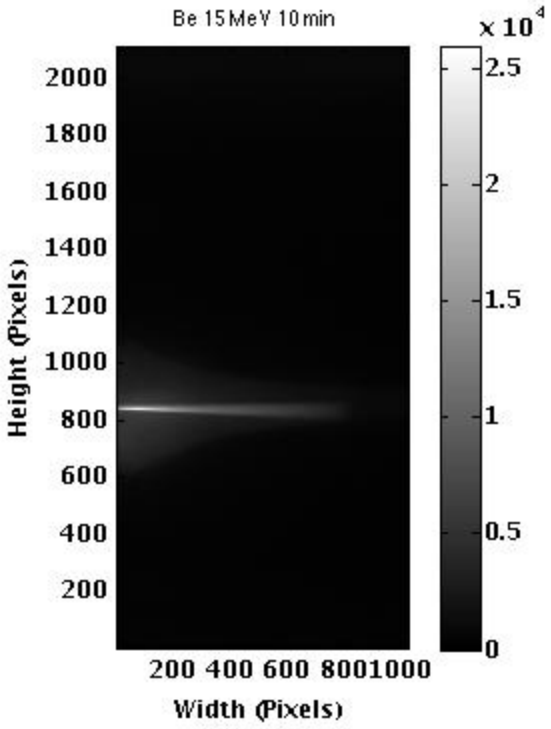
Addition of sweeper magnet

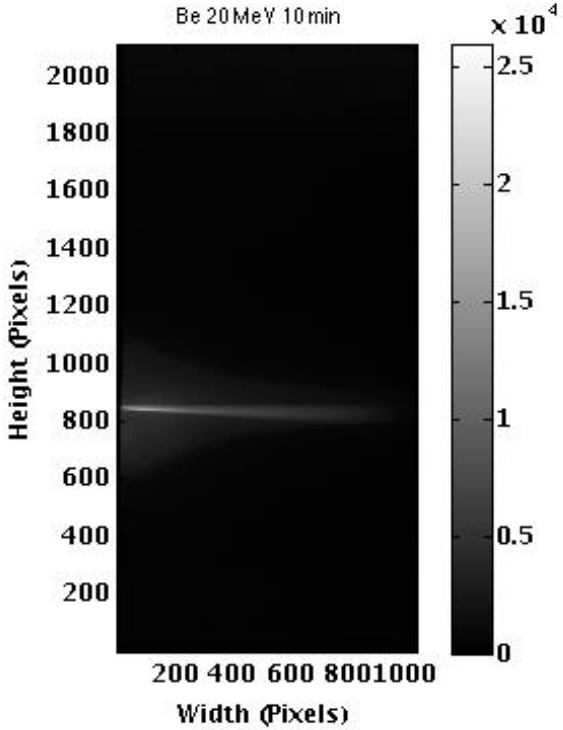




Storage phosphor images

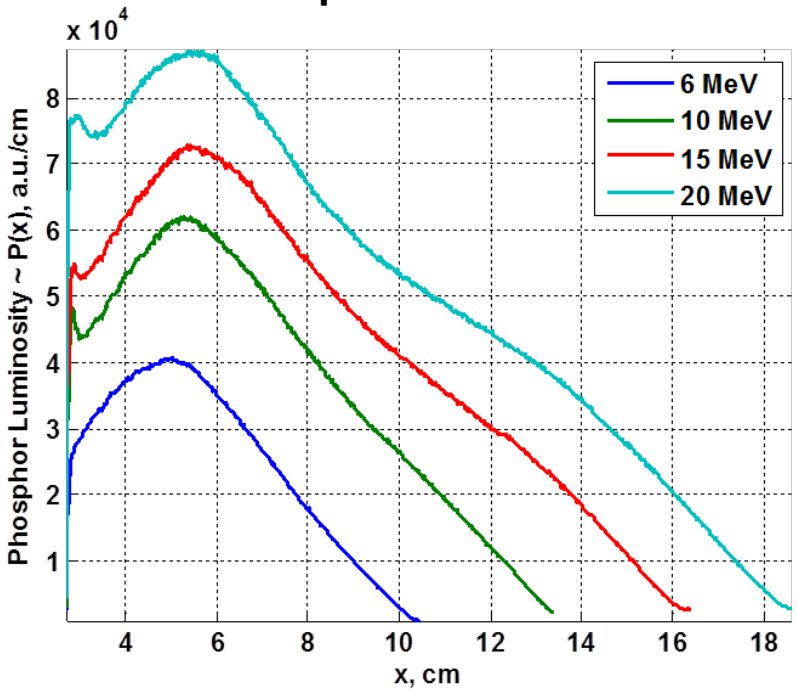




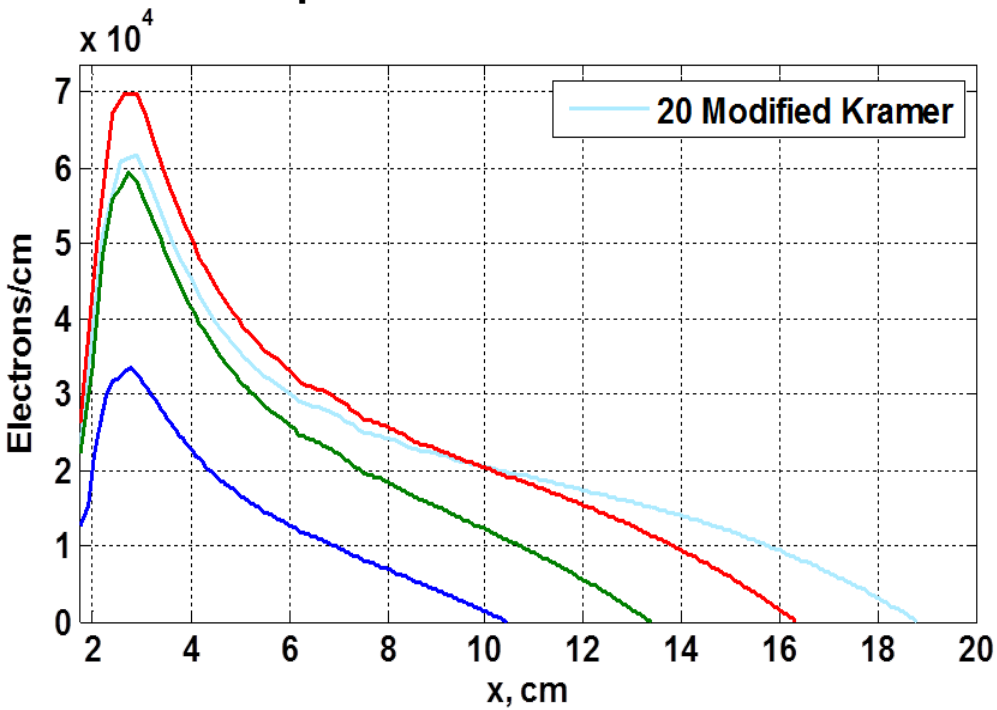


Reconstructed spectra

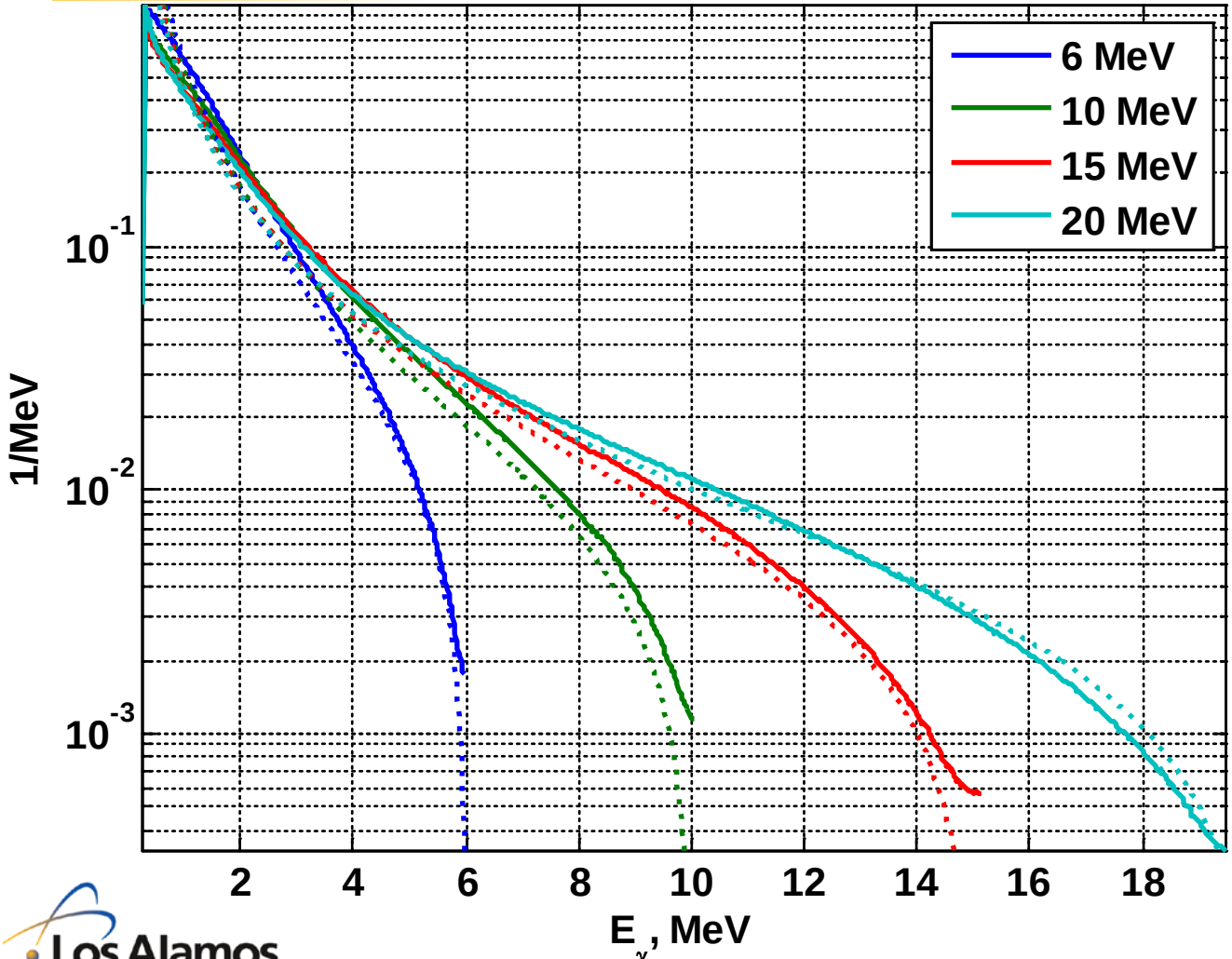
Experimental Data



Model of Expected Electrons/cm vs Position



Reconstructed x-ray spectra

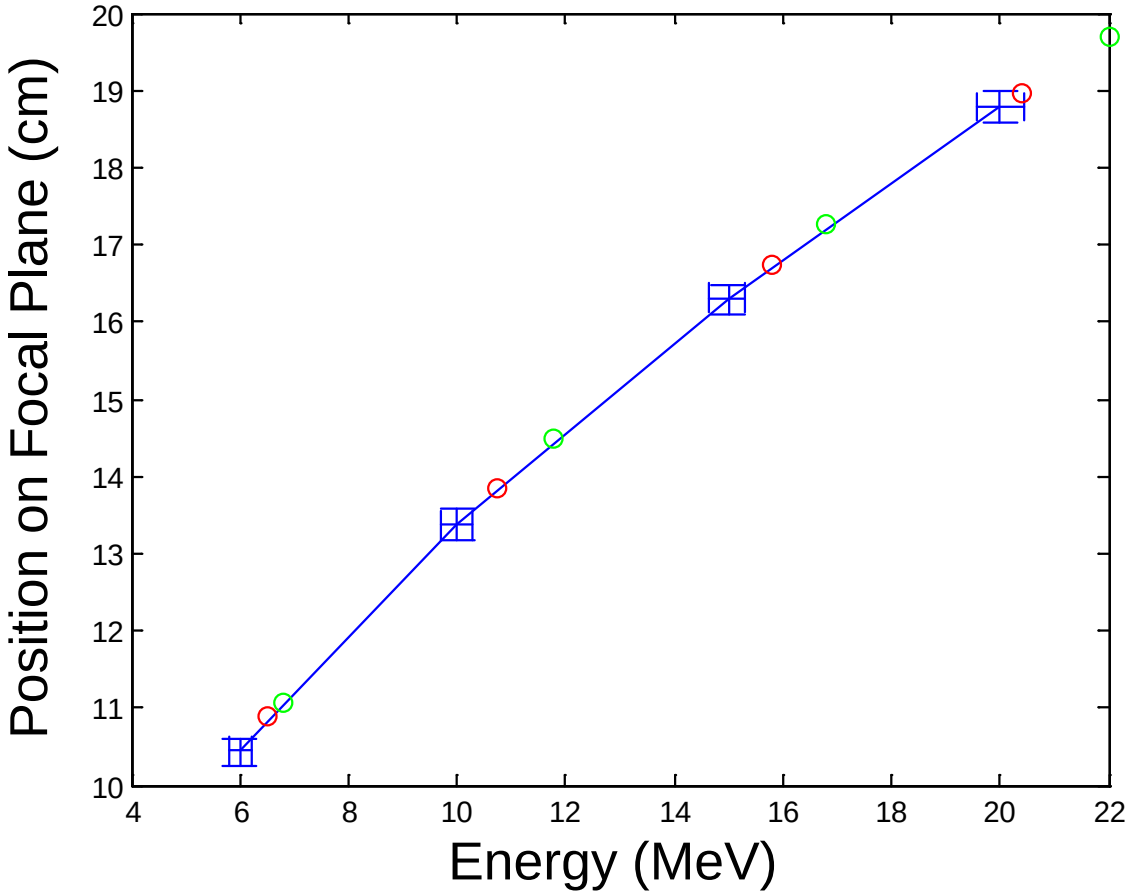


Solid = measured data reconverted to gamma position;

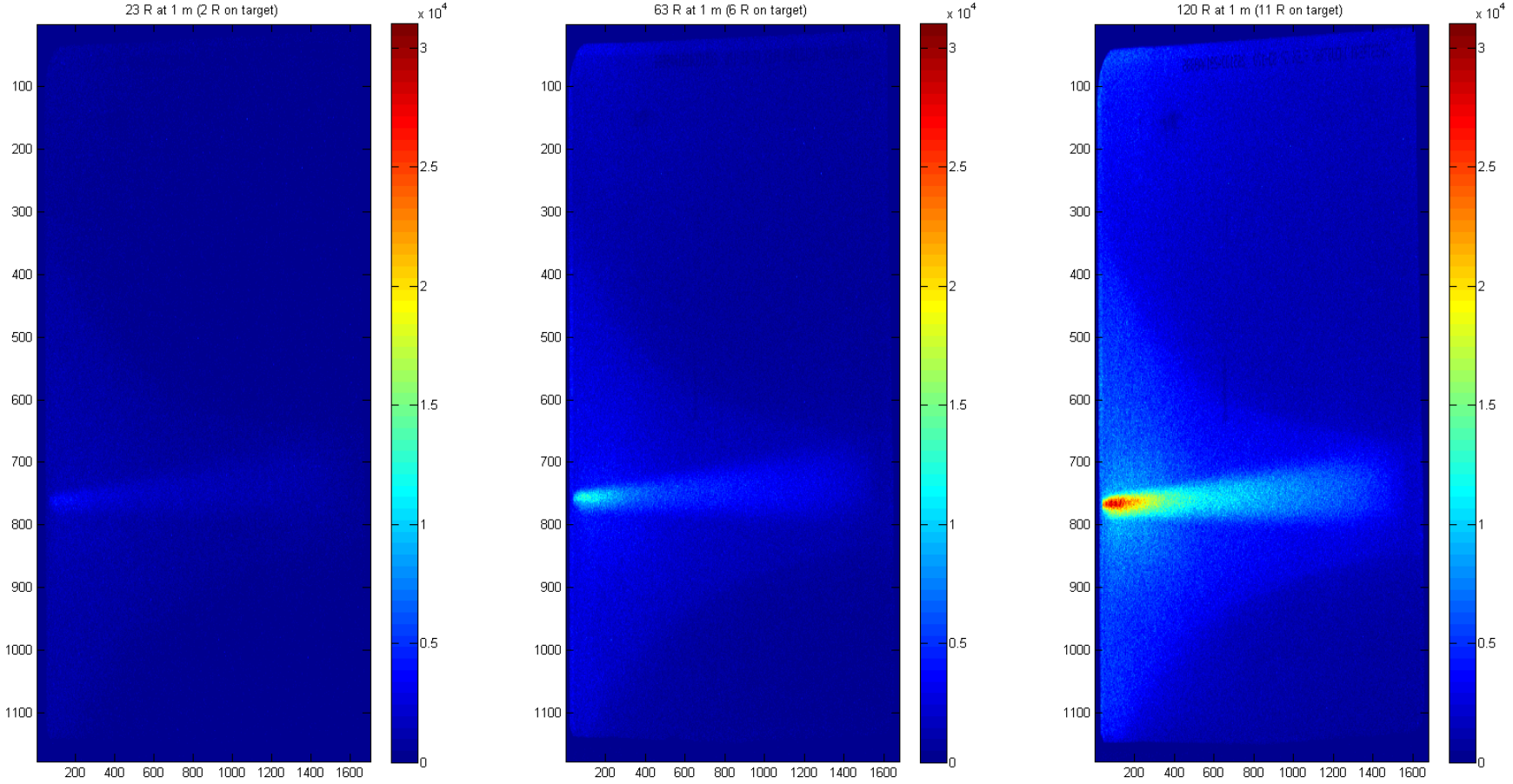
Dashed = Bremsstrahlung model; no correction for background, assumes energy independent response of phosphor

Microtron endpoint energies

Gehring et al., SPIE Proc (2014) and Rev. Sci. Inst. in progress



20 MeV Spectra at Various Dose



20 MeV Spectra at Various Dose