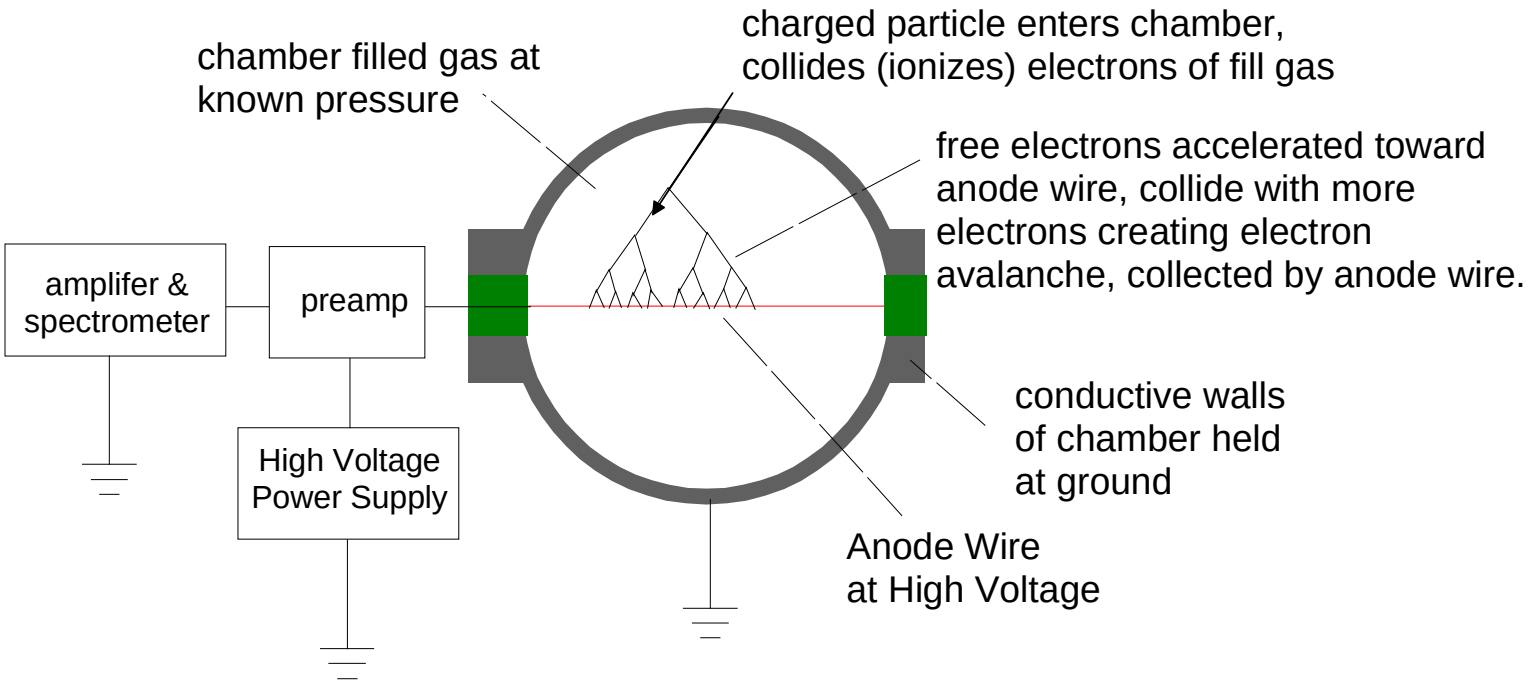
Portable, Low-cost Proportional Counters for Space, Atmospheric and Ground based Applications

E. R. Benton[1], A. C. Lucas[1], O. I. Causey[1],
S. Kodaira[2] and H. Kitamura[2]
[1]*E. V. Benton Radiation Physics Laboratory, Oklahoma State University, USA*
[2]*National Institute of Radiological Sciences, Chiba, Japan*

22nd Workshop on Radiation Monitoring for the ISS
5-7 September 2017, Torino, Italy

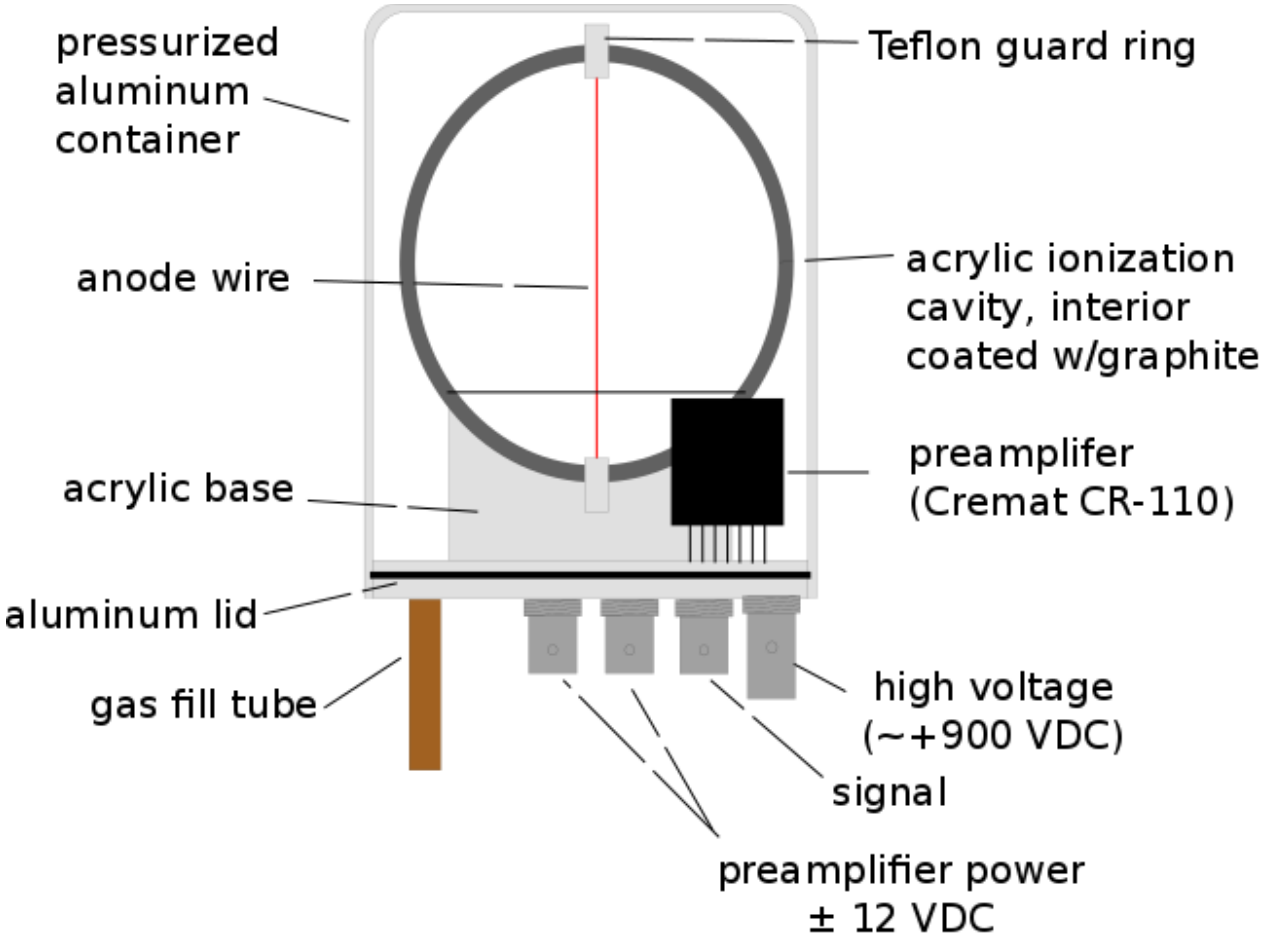
OSU EVB RPL

Operation of a Proportional Counter



OSU EVB RPL

ATED Detector Head



OSU EVB RPL

Active Tissue Equivalent Dosimeter Scientific Objectives

- Continuously measure the Linear Energy Transfer (LET) spectra, absorbed dose and dose equivalent as functions of time with ~1 second resolution for a total duration of 6 months.
- Demonstrate the operational capability of the Active Tissue Equivalent Dosimeter
- Correlate time resolved data with ISS orbital position, altitude and orientation.
- Determine average dose and dose equivalent rates from galactic cosmic rays, trapped protons in the South Atlantic Anomaly, and trapped electrons at high latitudes.
- Compare results with measurements made using other radiation detectors deployed throughout ISS (IV-TEPC, REMs, RAMs, Liulin-4, etc.).
- Compare results with model calculations (HZETRN/OLTARIS).
- Analyze operational performance of instrument and identify problems and lessons learned for improvement in next generation.

OSU
EVB
RPL

Active Tissue Equivalent Dosimeter
Physical Specifications

- Dimensions: 25.5 cm × 15.8 cm × 13.0 cm
- Mass: 3.25 kg (2.25 kg w/o power cable)
- Power: <10 Watts
- Power Source: 120 Vac from ISS inverter
- Maximum internal voltage: +900 Vdc
- Operational Period: Continuous for 6 months, with short interruption for sample data download to ground via ISS laptop
- Data: 32 Gbyte SDRAM card, compatible with ISS laptop

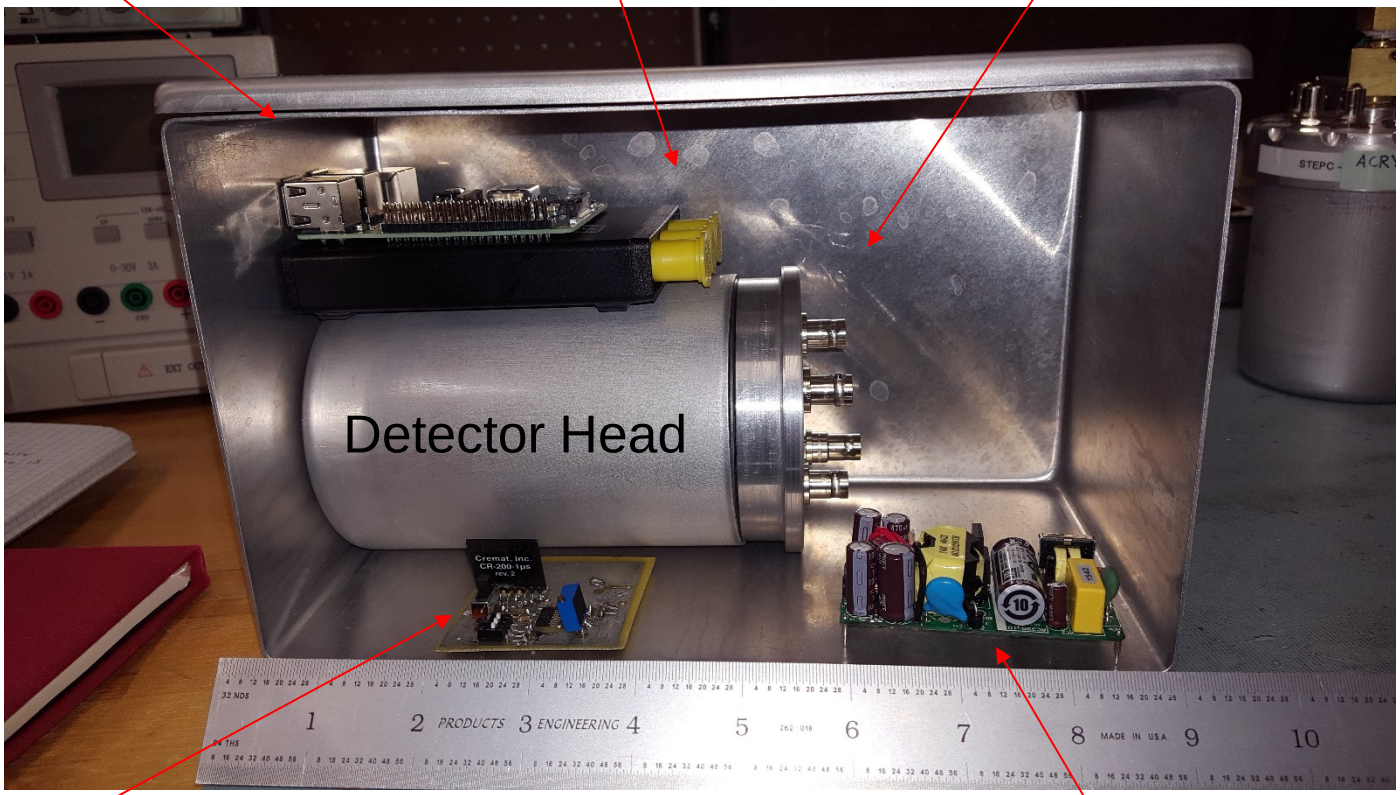
OSU
EVB
RPL

Active Tissue Equivalent Dosimeter Flight Unit

CPU & Data Storage

Spectrometer

Detector head lid w/connectors



Pulse Shaping Amplifier Module

Not Shown: HPVS, Power connector & cable, internal wiring and mounting hardware

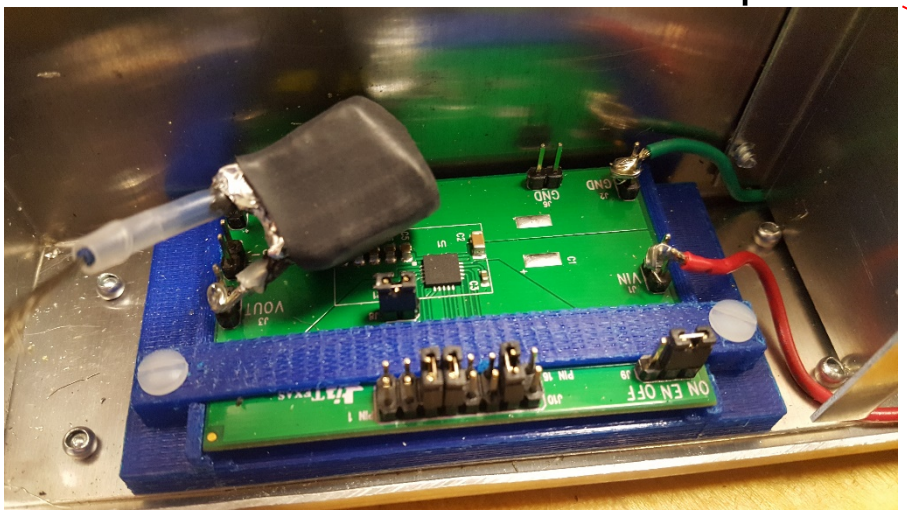
Power Supply

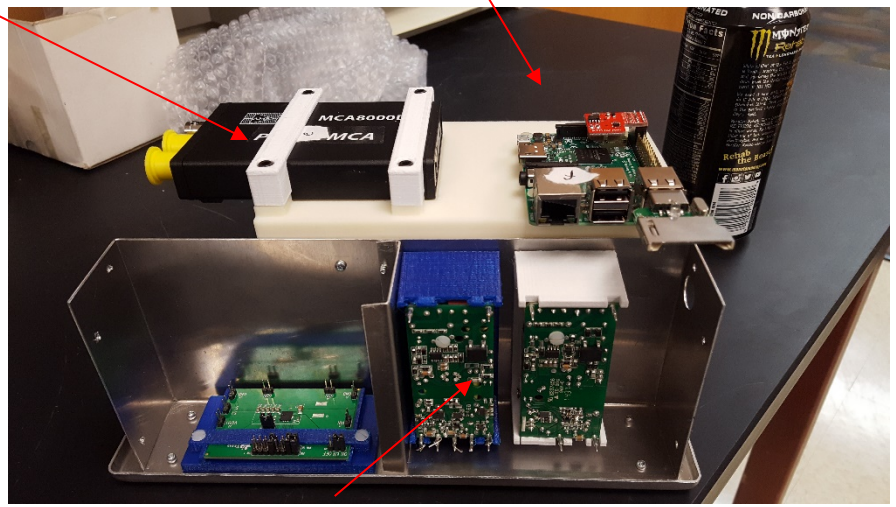
OSU EVB RPL

Active Tissue Equivalent Dosimeter Flight Unit

Spectrometer

CPU & Data Storage

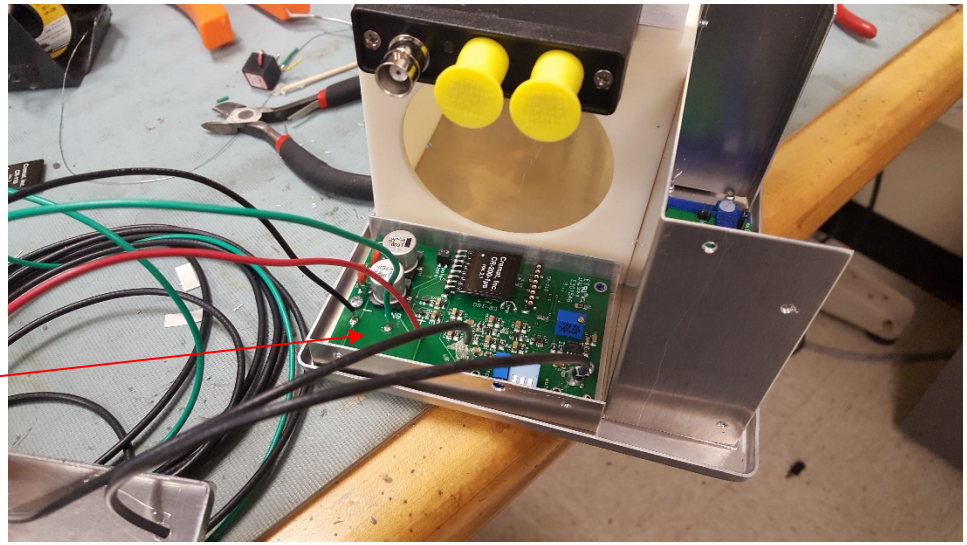




High Voltage Power Supply

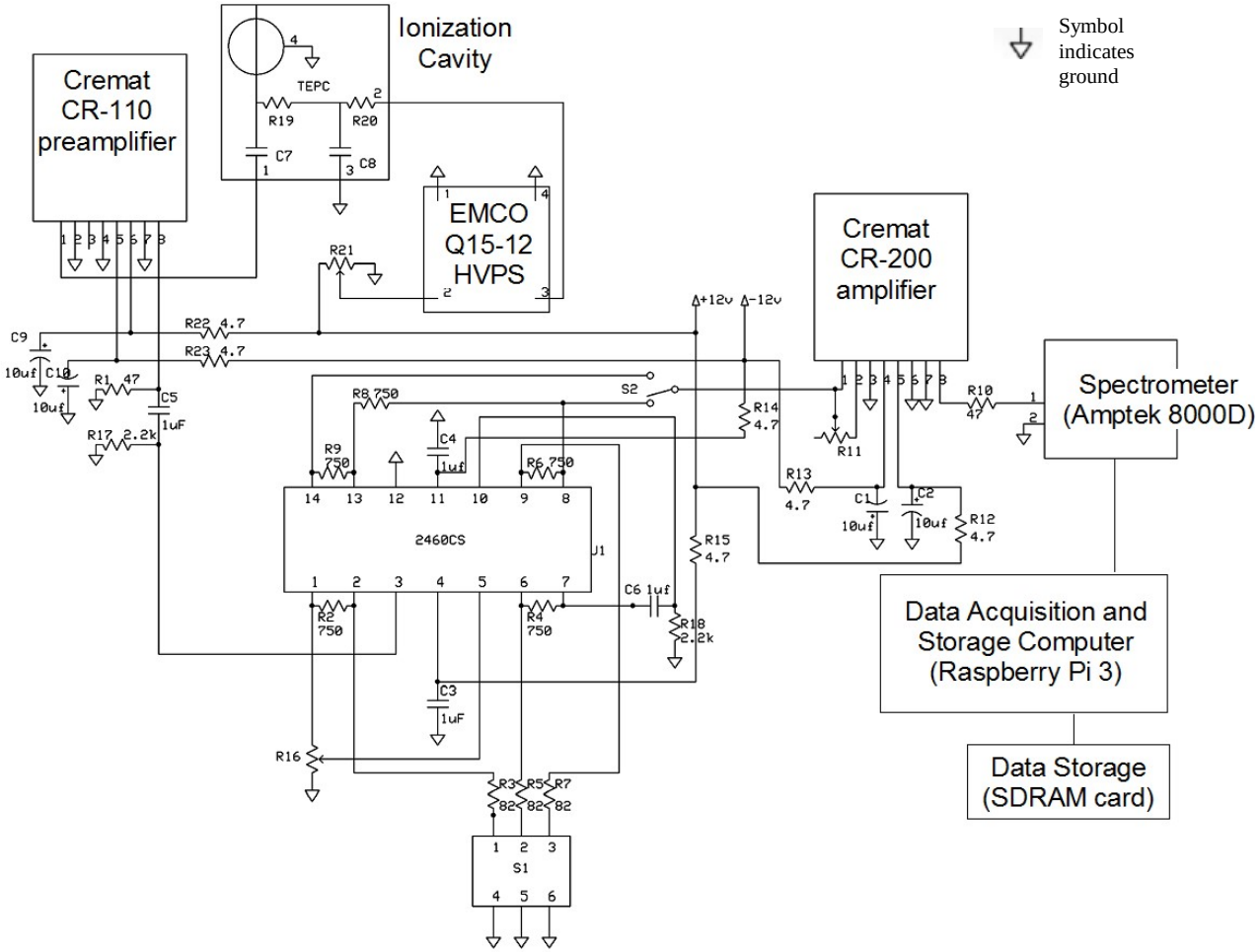
AC to DC Power Supplies

Pulse Shaping Amplifier Module

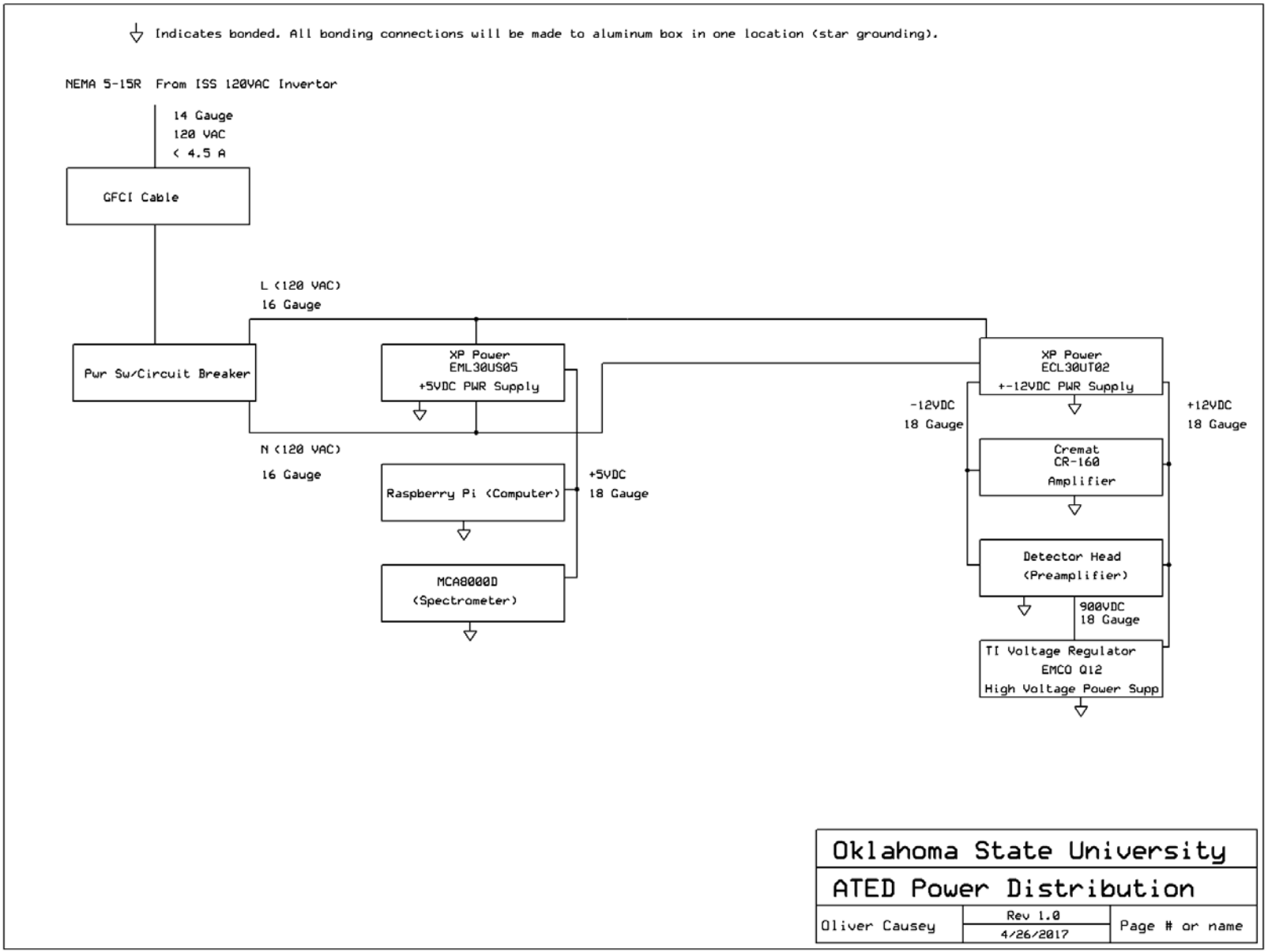


OSU EVB RPL

ATED Block Diagram



ATED Power Distribution Diagram



Active Tissue Equivalent Detector Experiment Chronology

- November 2017: Handover ATED flight unit to NASA
- January 2018: Launch to ISS on SpaceX-14
- Delivery to ISS
- ATED Deployment
  - remove ATED from soft stowage and transfer to ISS Node 3
  - placement of ATED in aisle in Node 3 near IV-TEPC
  - connect ATED to ISS power, 120 Vac via ISS AC power inverter
  - switch on ATED
- Continuous Operation for 1 month intervals
- Transfer sample data at 1 month intervals
  - switch off ATED
  - remove SDRAM card and insert in ISS laptop
  - transfer selected data files to ISS laptop then transmit to ground
  - remove SDRAM card for ISS laptop and insert in ATED
  - switch on ATED

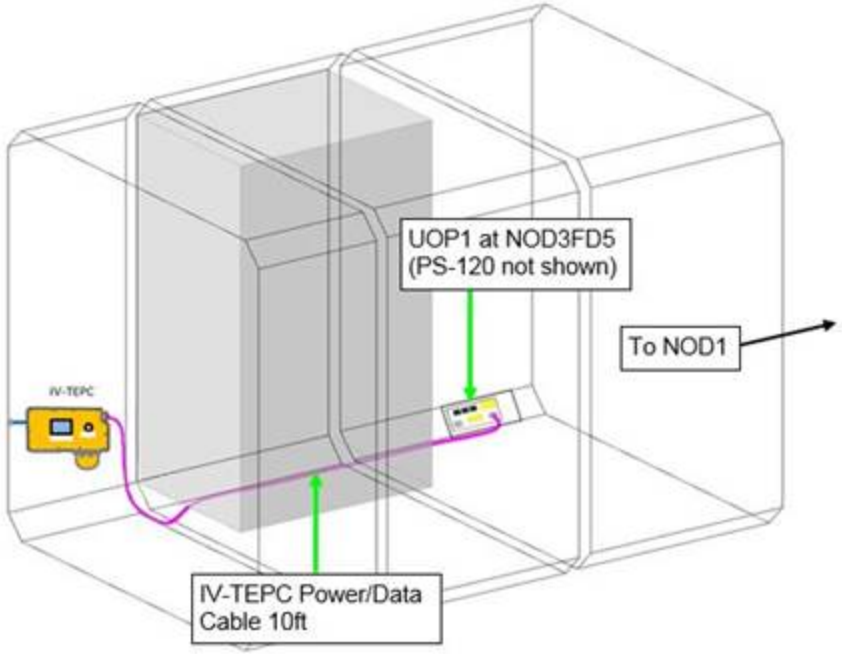
OSU EVB RPL

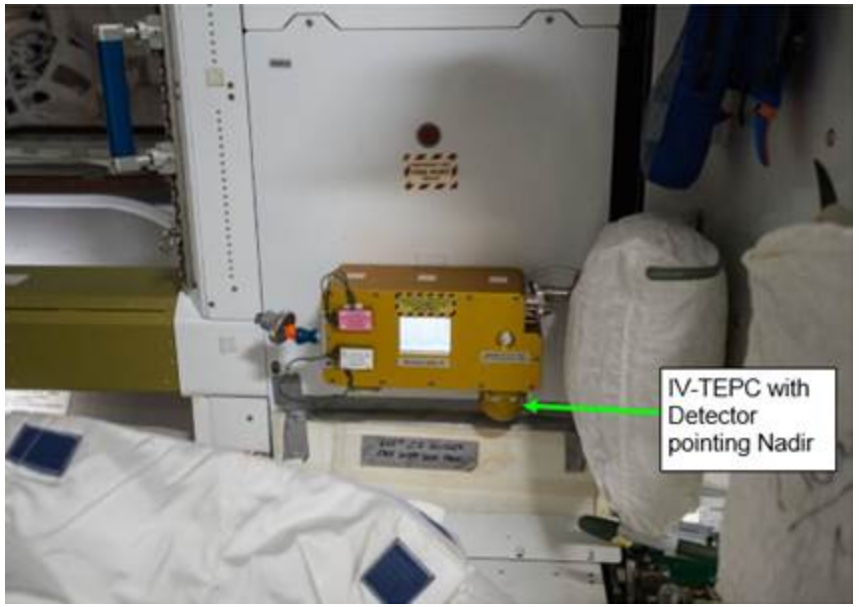
Active Tissue Equivalent Detector Experiment Chronology (cont.)

- End of Experiment after 6 months deployment and transfer of ATED to SRAG
  - switch off ATED
  - remove SDRAM card and place in soft stowage for return to ground.
  - insert new SDRAM card in ATED
  - transfer ownership of ATED to SRAG

OSU EVB RPL

Deployment near SRAG IV-TEPC in Node 3





The Active Tissue Equivalent Detector will be deployed in Node 3 near the IV-TEPC.

Images courtesy of Kerry Lee, NASA SRAG

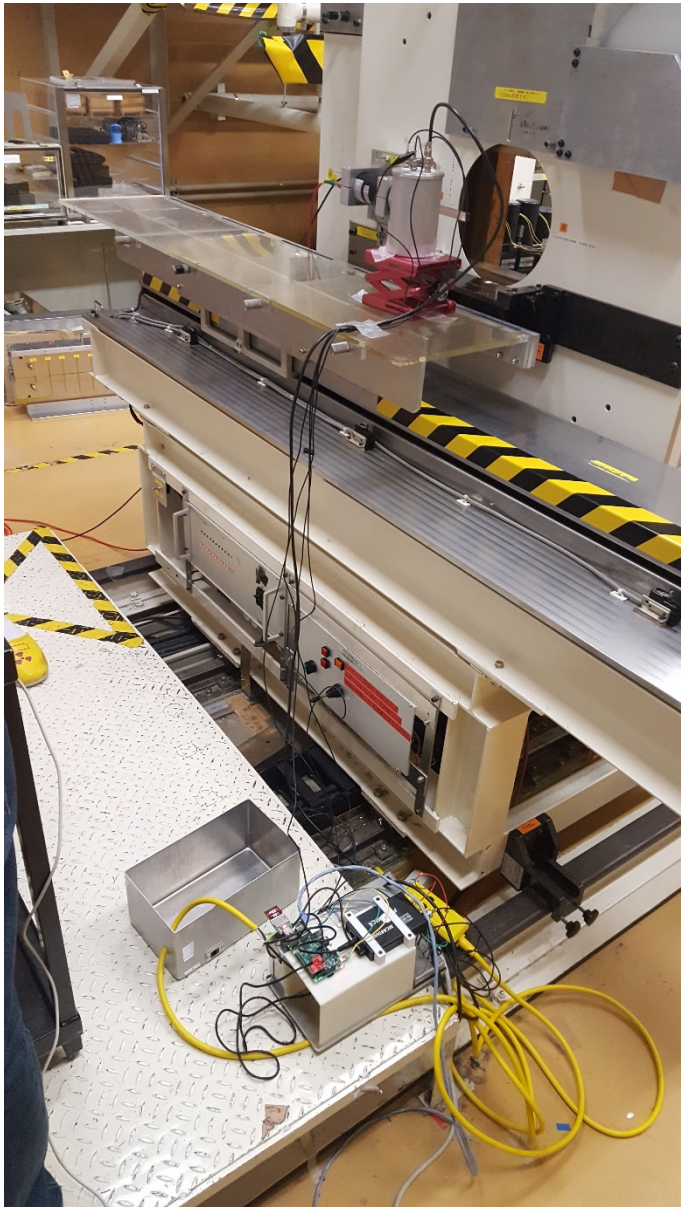
OSU EVB RPL

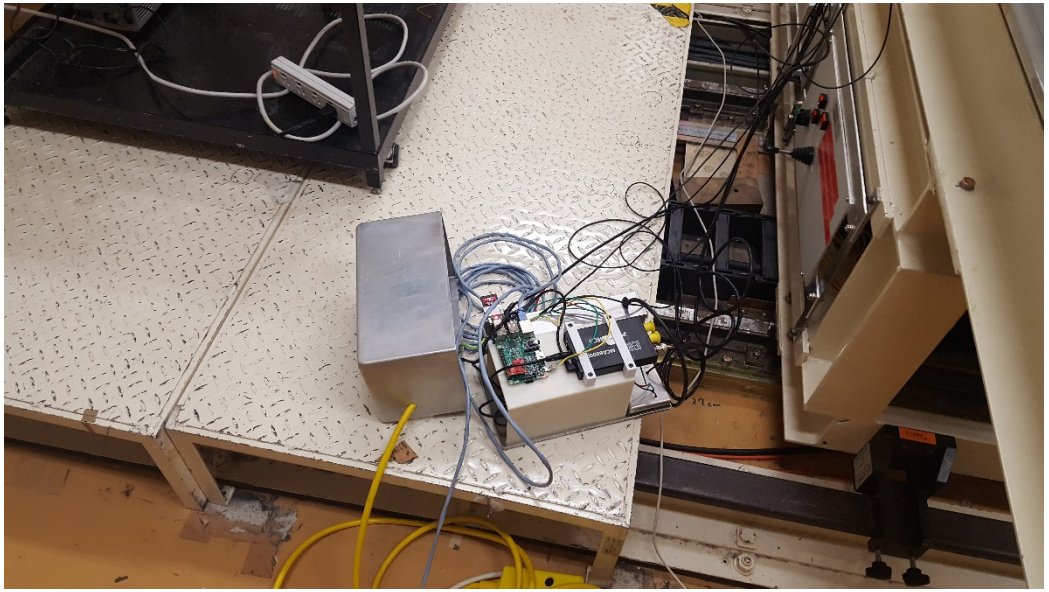
ATED Hardware Update

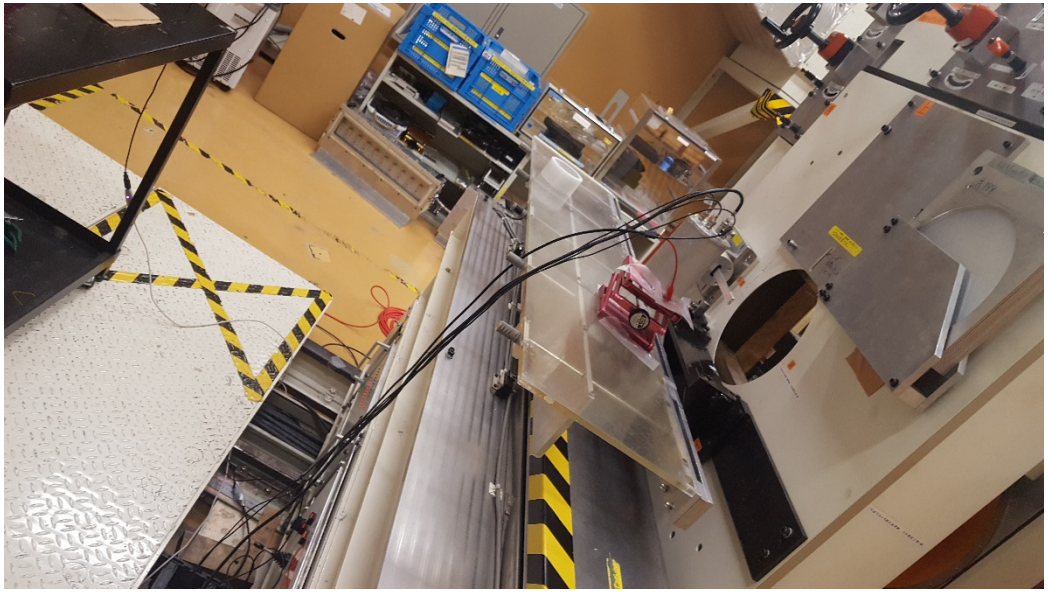
- In June 2017, ATED flight unit was tested in heavy ion beams at the HIMAC heavy ion accelerator in Chiba Japan:
  - 150 MeV/n He, 250 MeV/n C, 490 MeV/n Si, 500 MeV/n Fe,
  - Beams represent important components of space radiation environment in LEO.
  - Calibration of ATED as function of lineal energy
- ATED EMI testing carried out at JSC, 26 June 2017
- ATED electrical compatibility testing carried out at JSC, 27 June 2017

OSU EVB RPL

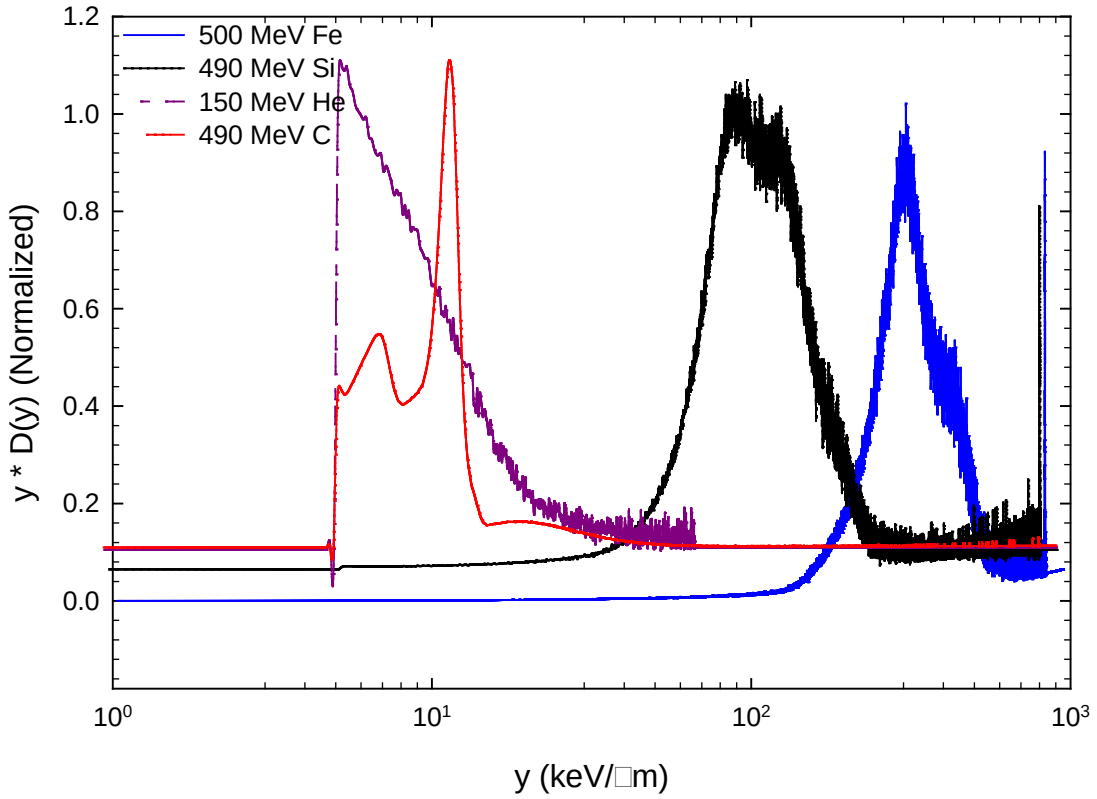
ATED during HIMAC Testing/Calibration







Lineal Energy Fluence Spectrum from HIMAC Exposures



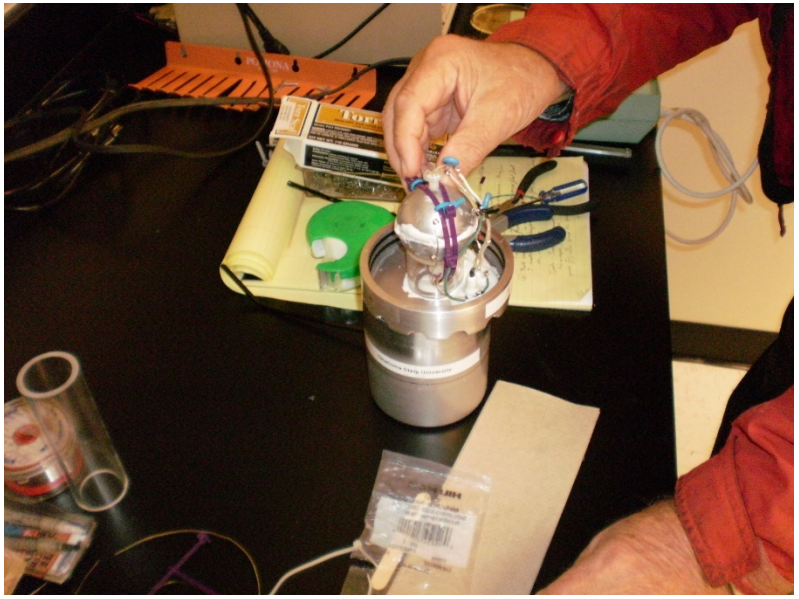
OSU EVB RPL

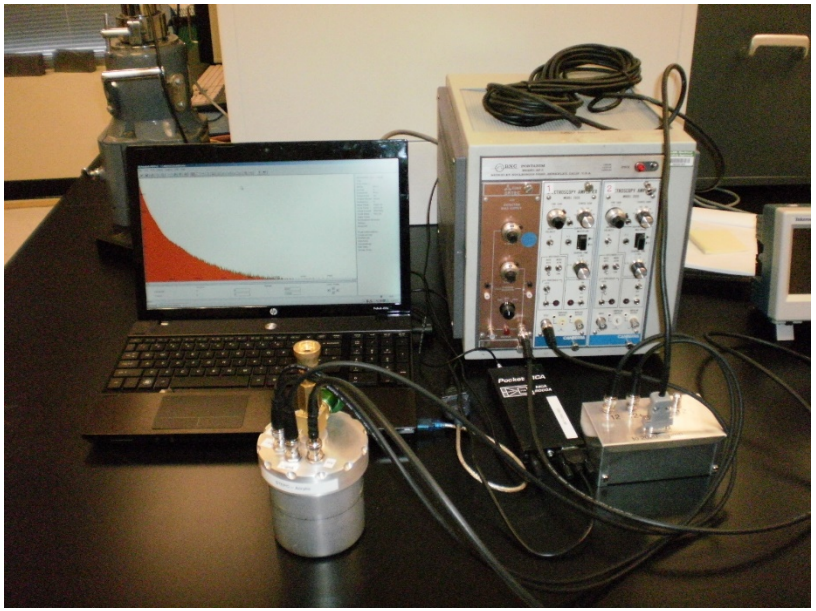
Proportional Counters for use aboard Aircraft

- Access to the atmosphere, especially aviation altitudes, is orders of magnitude cheaper and more common that axis to space
- Dosimetric data available from space is far more abundant and of better quality than dosimetric data from aircraft
- Debate about the risks for ionizing radiation exposure to aircrew and frequent flyers, as well as to avionics, remains controversial and has not been adequately addressed
  ...in part due to a lack of systematic, high quality measurements
- Planning to flight test current version on NASA DC-8, UAVs, and other aircraft starting in March 2018.
- Target markets: Commercial jetliners, business jets (routinely fly at higher altitudes than commercial jetliners), high altitude balloon missions.

OSU
EVB
RPL

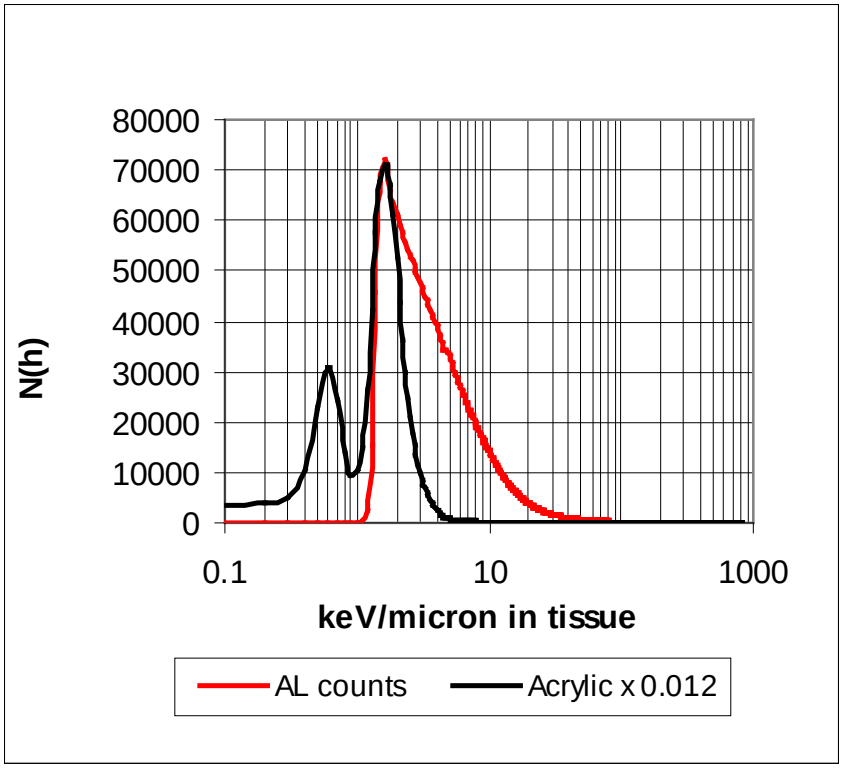
Neutron Field/Aviation Applications
Proportional Counter with
Aluminum and Higher Z Ionization Cavities

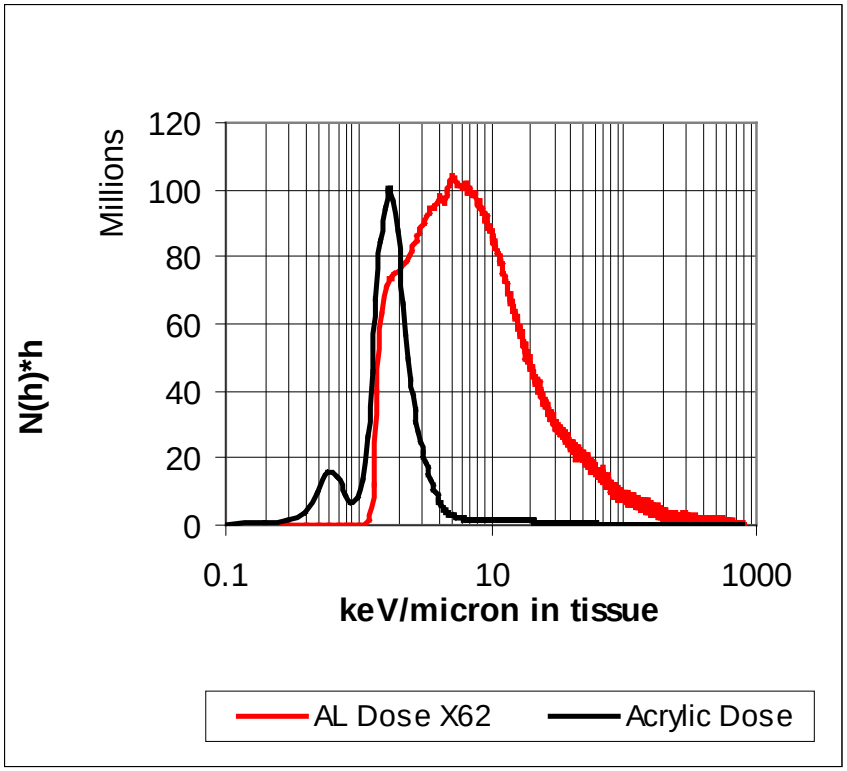




OSU
EVB
RPL

Normalized Count and Dose Spectra from Tissue Equivalent and Aluminum Proportional Counters exposed at LANSCE



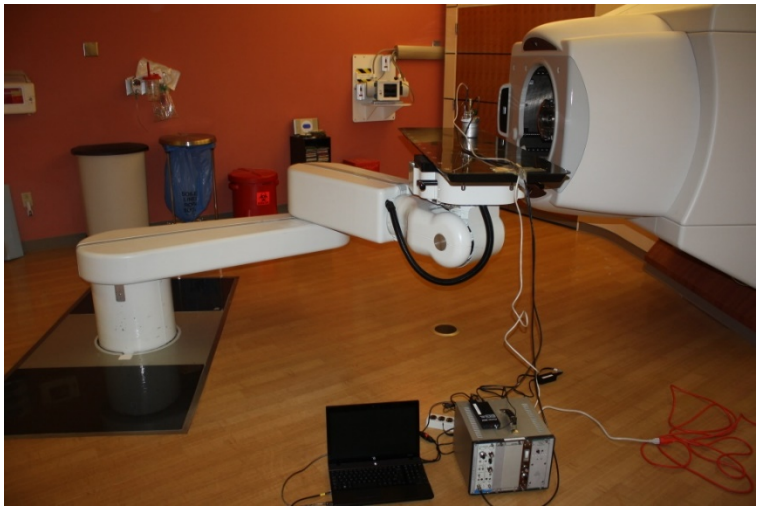


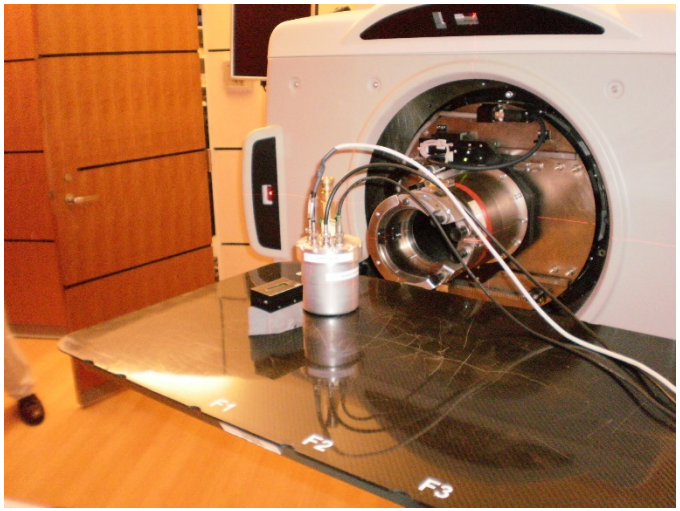
Greater number of counts in Acrylic vs. Al cavities

Higher LET in Al vs. Acrylic cavities

OSU EVB RPL

TEPCs for use in Proton and Carbon Beam Therapy





Proton and Carbon Radiotherapy beams possess higher LET and RBE than do x-ray and electron radiotherapy beams...yet ionization chambers are still used in calibration for all of them.

Microdosimeters such as Tissue Equivalent Proportional Counters are an alternative that provides LET and thus RBE information in addition to absorbed dose.

OSU
EVB
RPL

Conclusions and Future Work

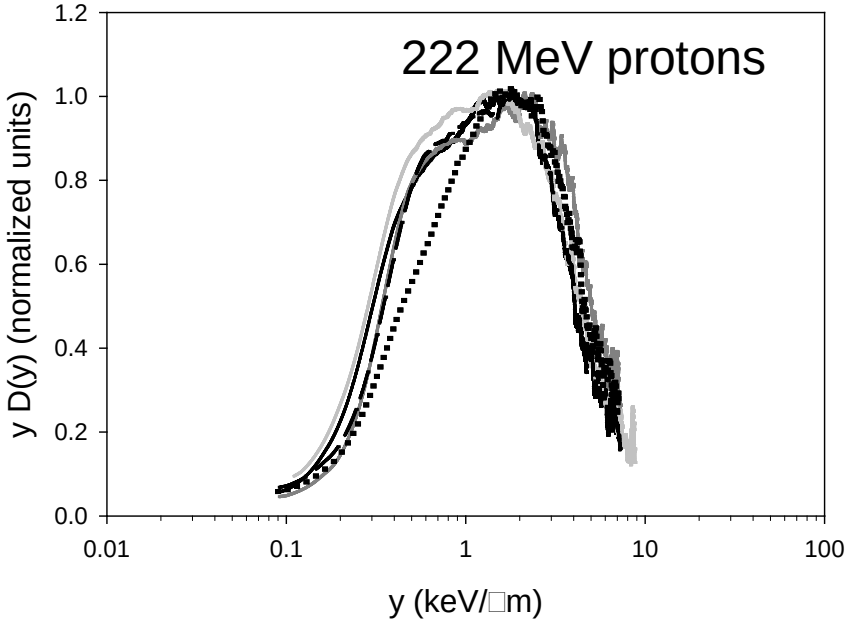
- Using acrylic ionization cavity since more practical than A-150 tissue equivalent plastic
- Initial application will likely be in aviation/air crew monitoring
  - lighter weight (semi-permanent pressurization)
  - lower power ARM microcontroller-based spectrometer
- Continuing development optimized for neutron monitoring
  - multiple ionization cavities of different Z materials
  - charged particle/neutron discrimination by surrounding cavity with anticoincidence plastic scintillator layers
- Developing parallel plate/end-on cylindrical version for use in proton and heavy ion cancer therapy applications
- Make available commercially at reasonable cost

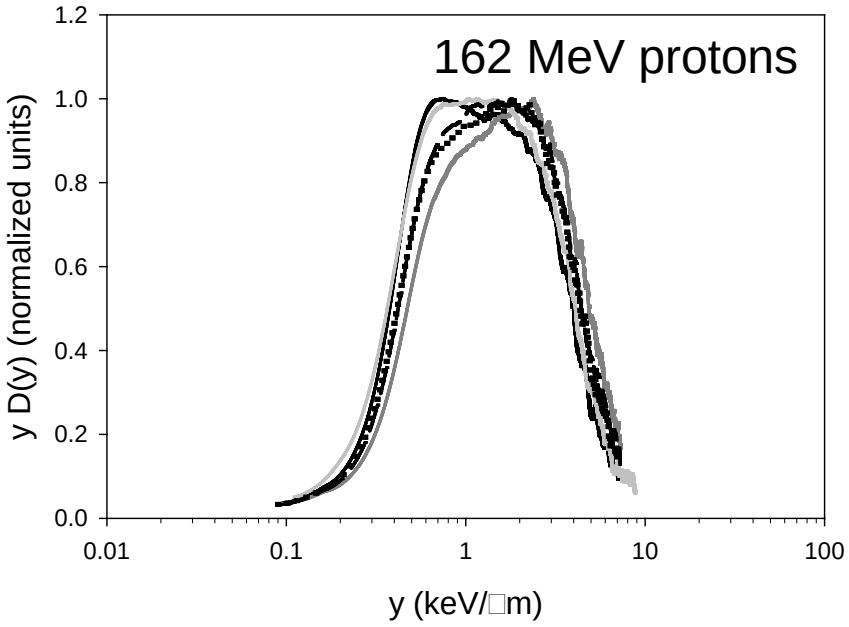
OSU
EVB
RPL

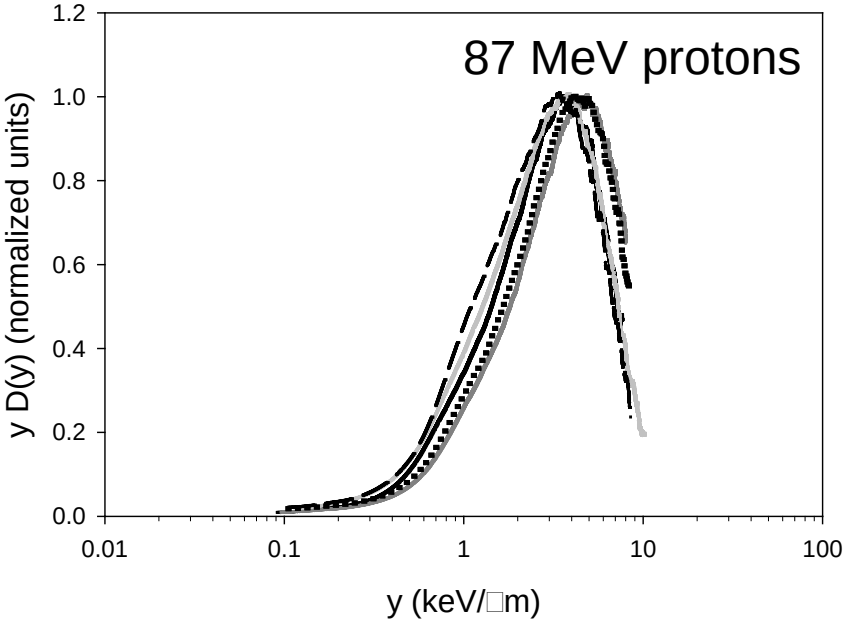
Thank you for your Attention

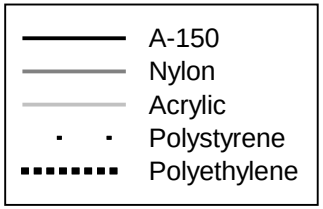
OSU
EVB
RPL

TEPC Response to Energetic Protons



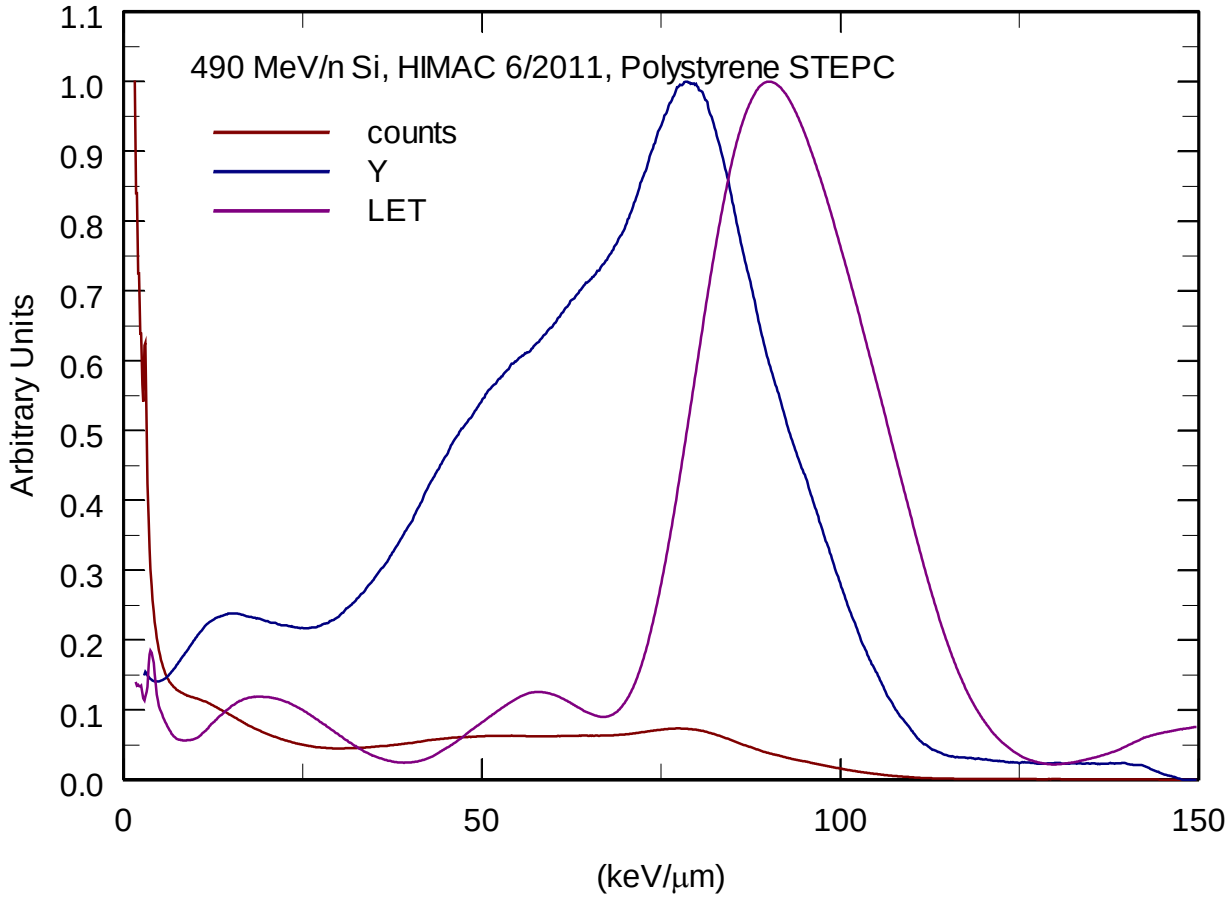






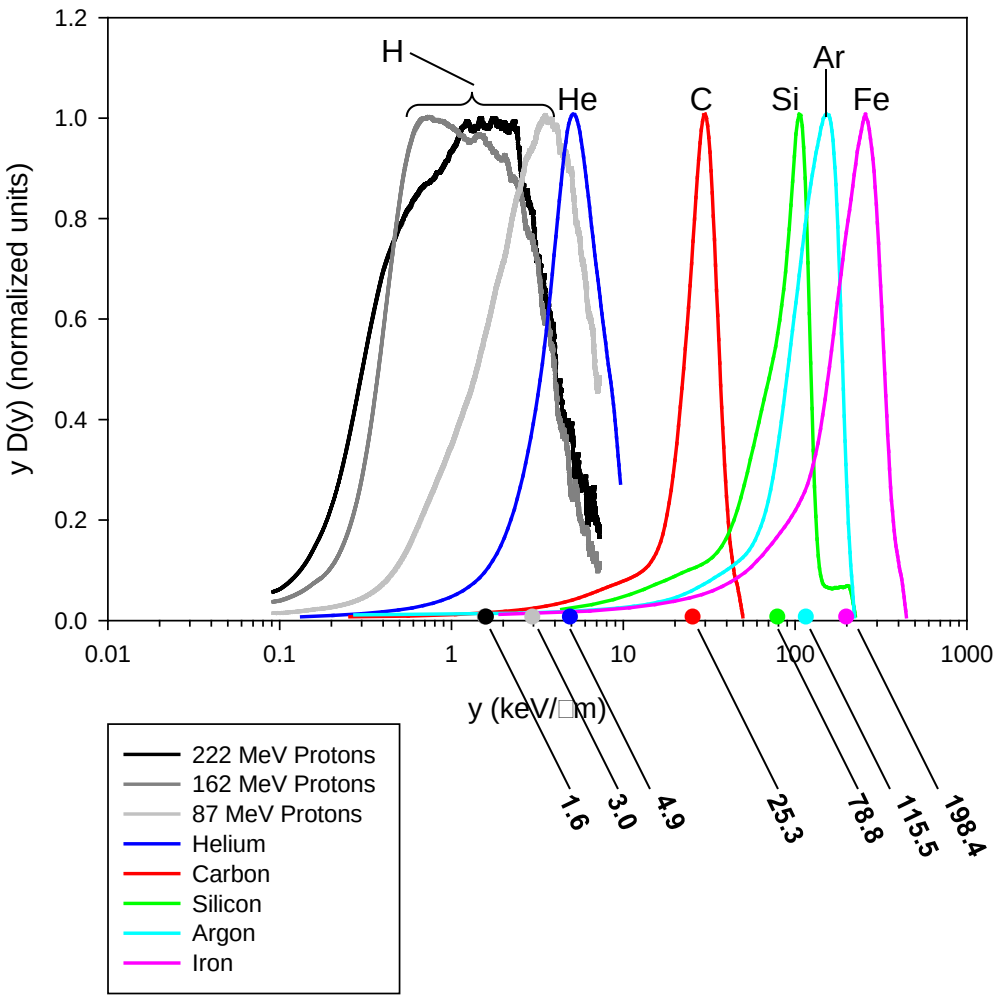
OSU EVB RPL

Exposures of Polystyrene STEPC to 490 MeV/n ^{28}Si beams at HIMAC: Raw, Lineal Energy (y), and LET Spectra



OSU EVB RPL

Average Lineal Energy



Frequency Averaged

Lineal Energy

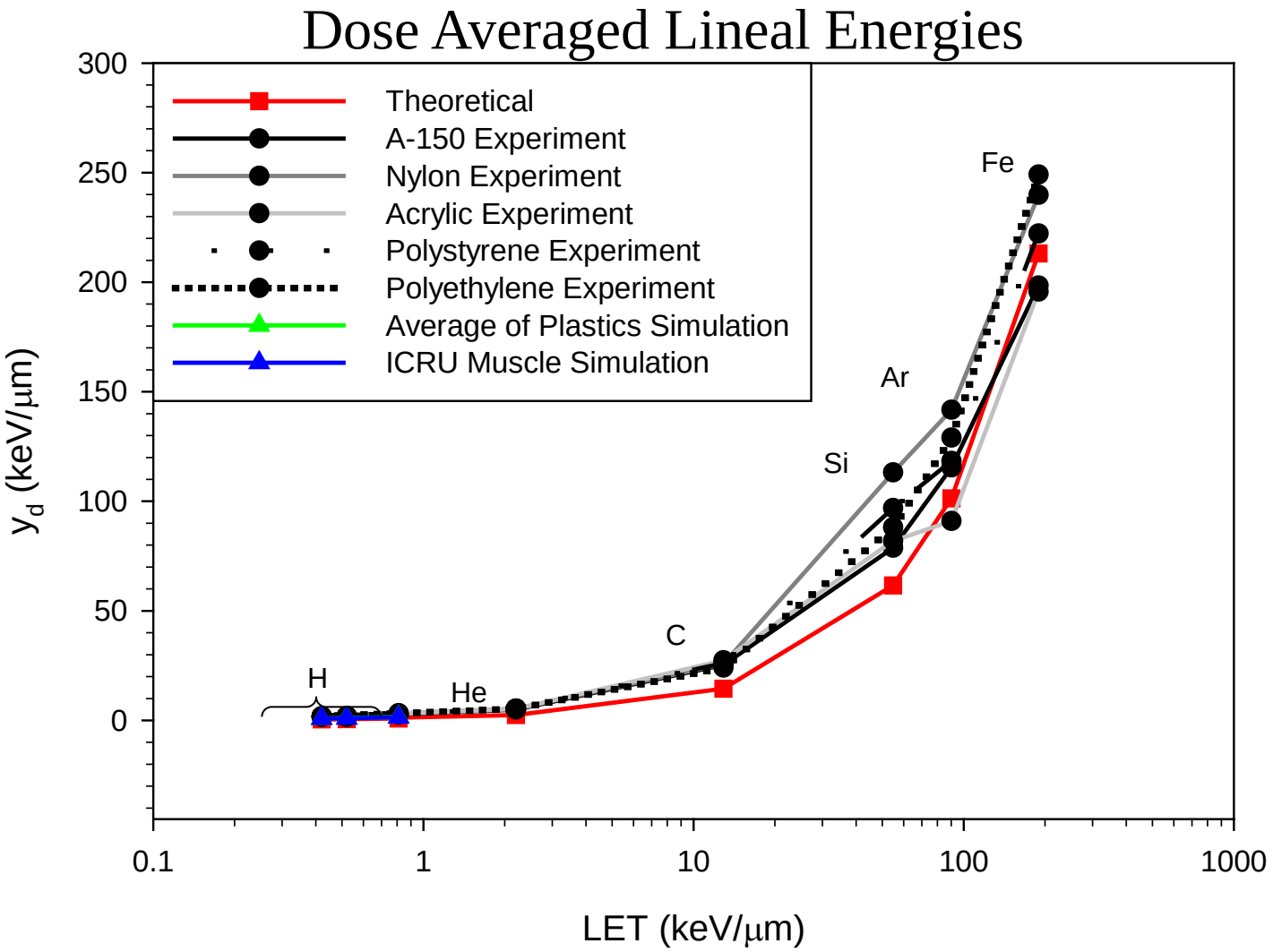
$$\bar{y}_F = \int_0^\infty y\, f(y)\, dy \qquad \bar{y}_F = \frac{\sum_{y=0}^{y=y_{max}} y\, f(y)}{\sum_{y=0}^{y=y_{max}} f(y)}$$

Dose Averaged

Lineal Energy

$$\bar{y}_D = \frac{1}{\bar{y}_F} \int_0^\infty y^2\, f(y)\, dy \qquad \bar{y}_D = \frac{\sum_{y=0}^{y=y_{max}} y^2\, f(y)}{\sum_{y=0}^{y=y_{max}} y\, f(y)}$$

OSU EVB RPL



- No appreciable difference between different plastics and tissue
- Collums et al., *NIM B* **333** 69-72.

OSU EVB RPL