

R&D towards a
Liquid Xenon
Advanced Compton Telescope
for MeV Gamma-Ray Astrophysics

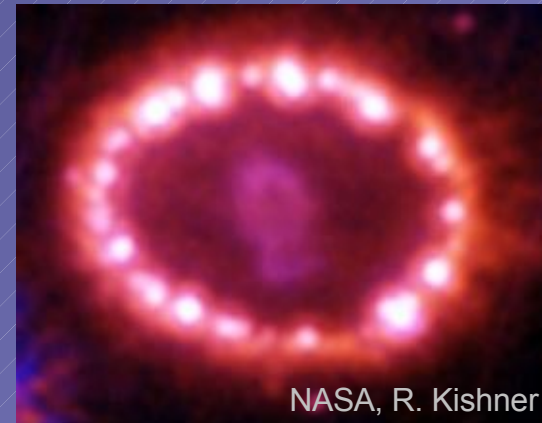
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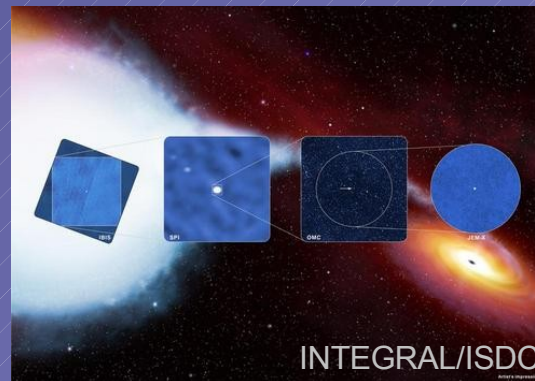
APS Meeting @ Jacksonville, FL
Apr 14, 2007

MeV Gamma-Ray Astrophysics

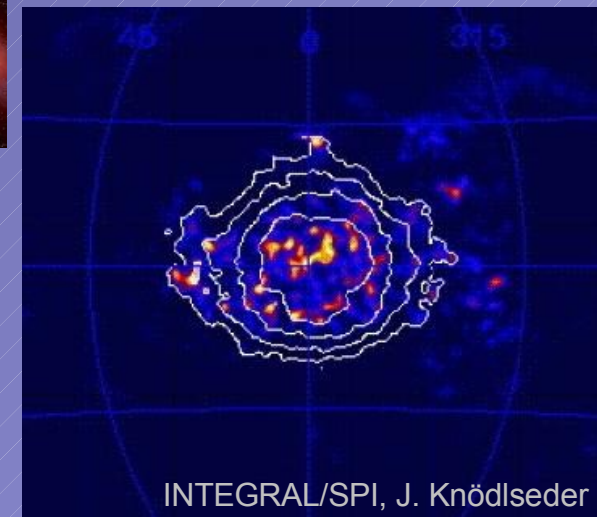
- Life Cycles of Matter
 - ▶ Supernovae, stellar evolution, nucleosynthesis
 - ▶ Supernova remnants & interstellar medium
 - ▶ Neutron stars, pulsars
 - ▶ Novae



- Black Holes
 - ▶ Creation & evolution
 - ▶ Lepton vs. hadron jets
 - ▶ Deeply buried sources



- Fundamental Physics & Cosmology
 - ▶ Gamma-ray bursts & first stars
 - ▶ History of star formation
 - ▶ MeV dark matter ?



The Liquid Xenon TPC as a Compton Telescope



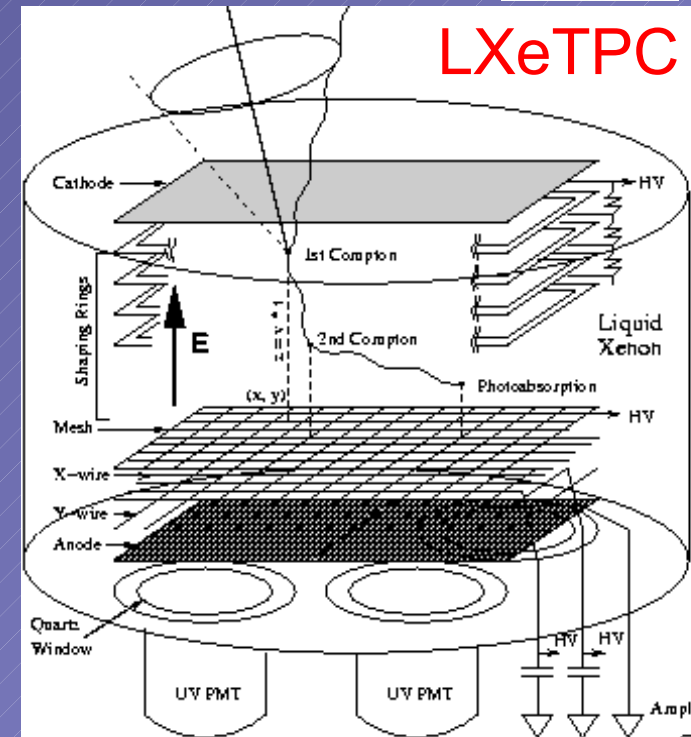
UV scintillation light:

- Energy measurement #1
- Fast time response for time of flight (ToF) measurement.
- Trigger

Ionization Charge:

- Energy Measurement #2
- X-Y- sensitive readout
- Large drift distance (~ 7 cm)
- Z-coordinate from drift time
- Sub-mm 3D position resolution

CT: Identify 1st & 2nd interaction!



Advantages:

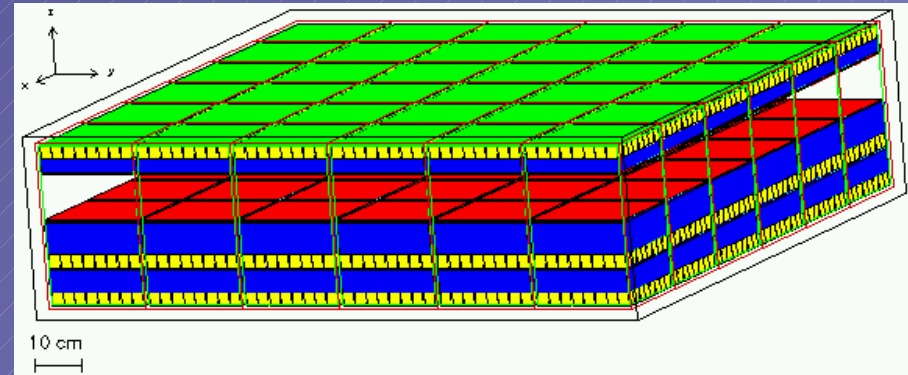
- Compact homogeneous modules.
- Scalable to large area.
- Radiation-hard.

The LXeACT Concept with Time-of-Flight and Enhanced Spectroscopy



Multiple LXeTPC modules in compact configuration

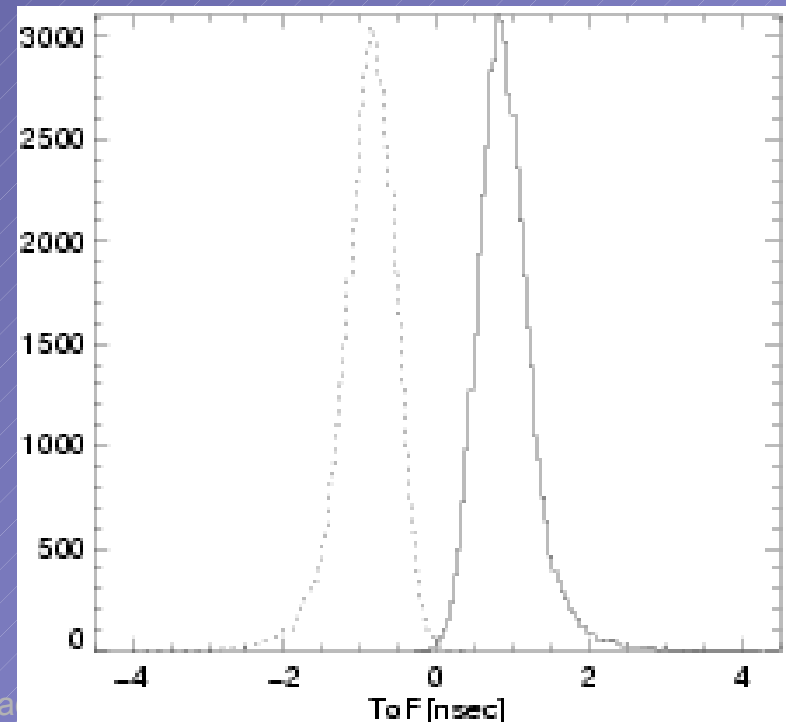
- Module area:
 - ▶ Converter: $\sim 22 \times 22 \times 3 \text{ cm}^3$
 - ▶ Calorimeter: $\sim 22 \times 22 \times 7 \text{ cm}^3$
- Total area: $\sim 4 \text{ m}^2$ (shown: 2 m^2)
- Separation: 10 cm



Time-of-Flight

- Enhanced efficiency
- Background reduction at trigger level

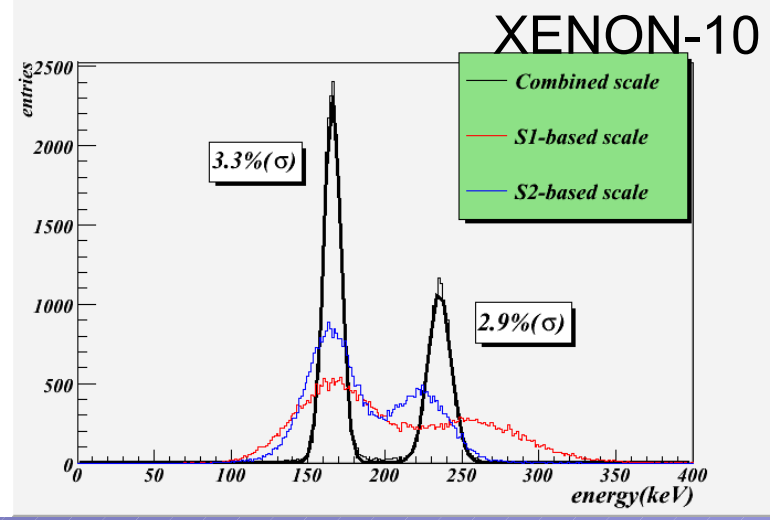
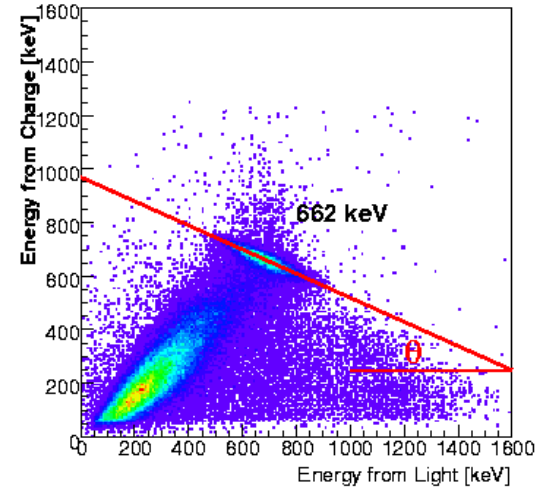
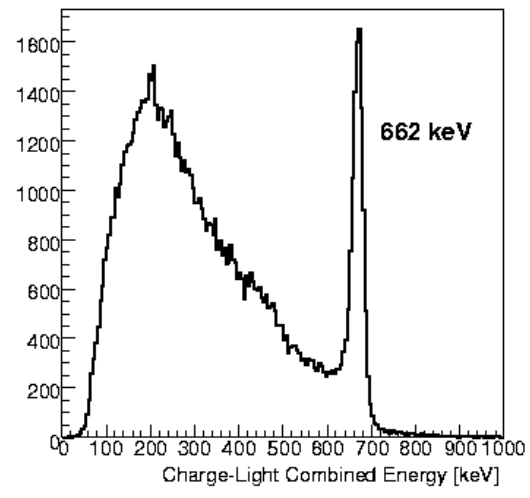
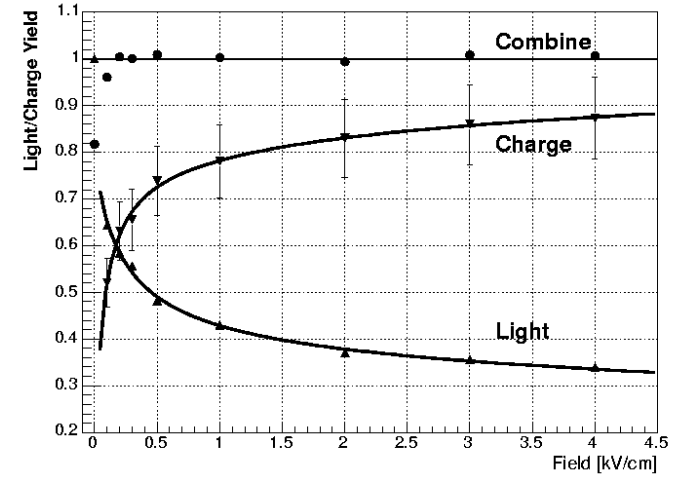
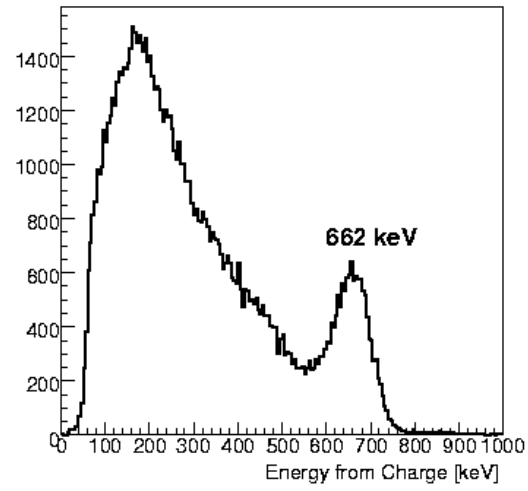
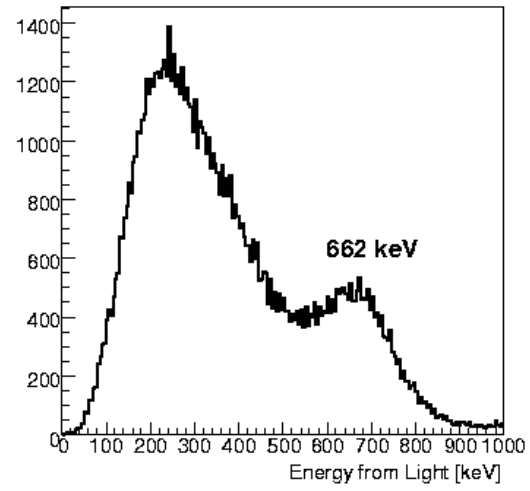
Enhanced Spectroscopy from Light & Charge Measurement



Charge-Light Anti-Correlation in LXe

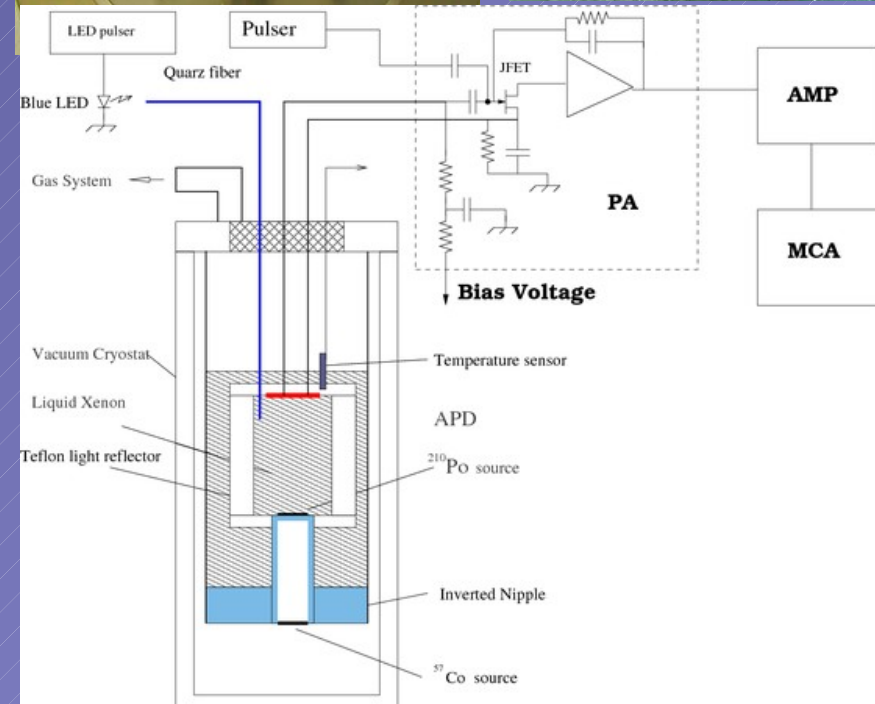
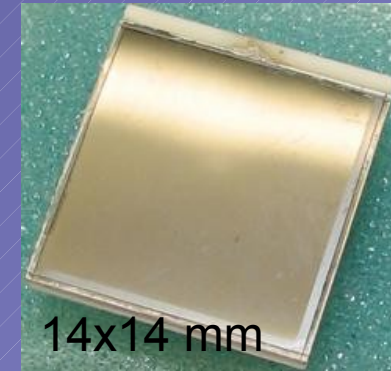
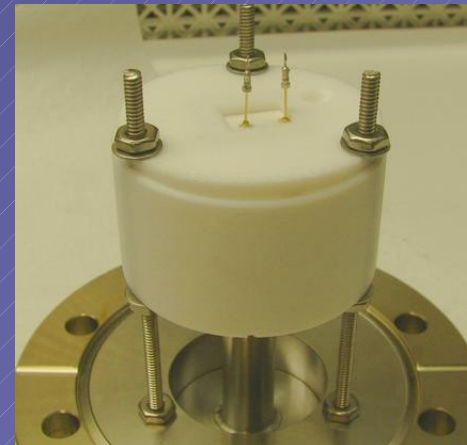


E. Aprile et al., NIMA, 2007

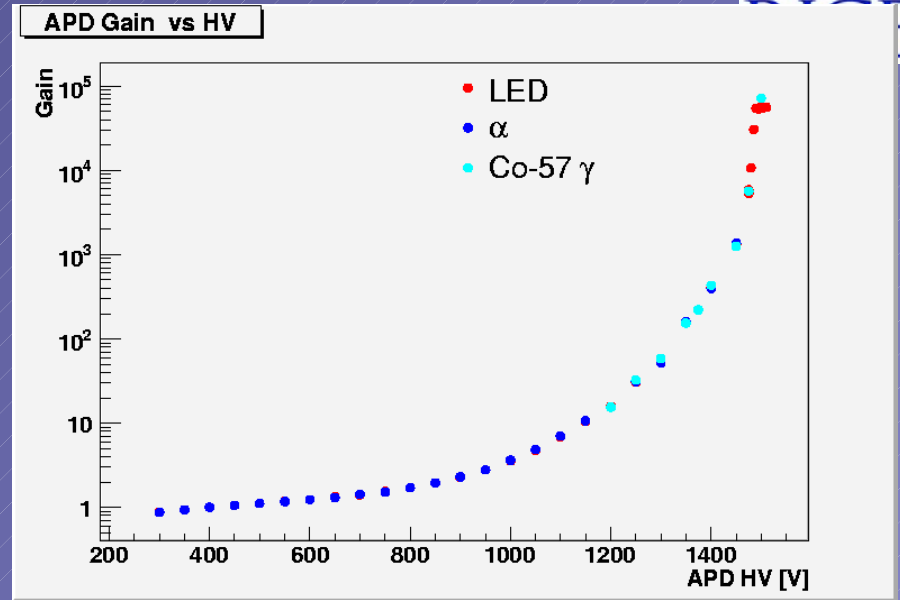
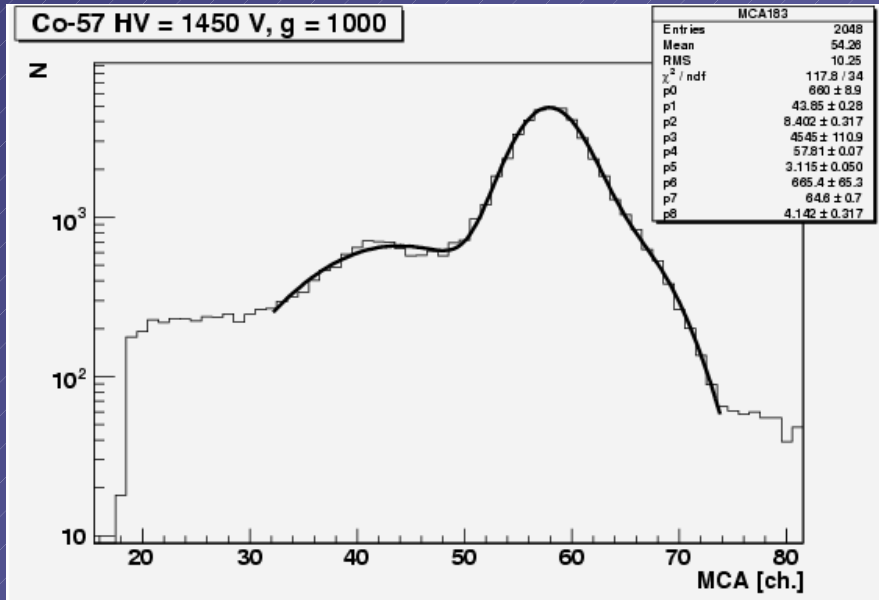


Avalanche Photodiodes in LXe

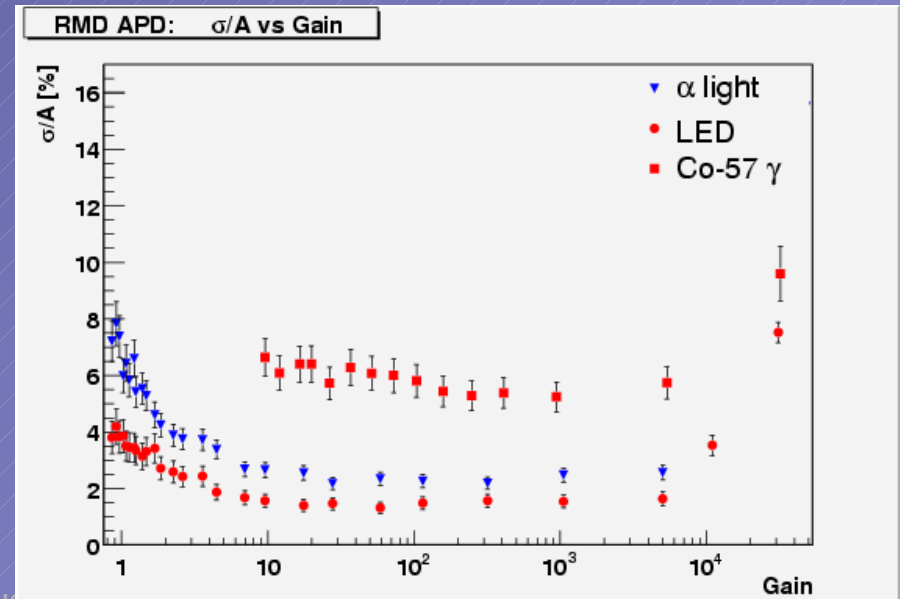
- UV-enhanced APD by RMD, Inc.
- Large area APD 14x14 mm
- Favorable ratio of active to passive sensor area
- Square format – good tiling for efficient large area detector coverage
- Possible substitute for standard Photomultiplier Tubes



APDs in LXe - Results

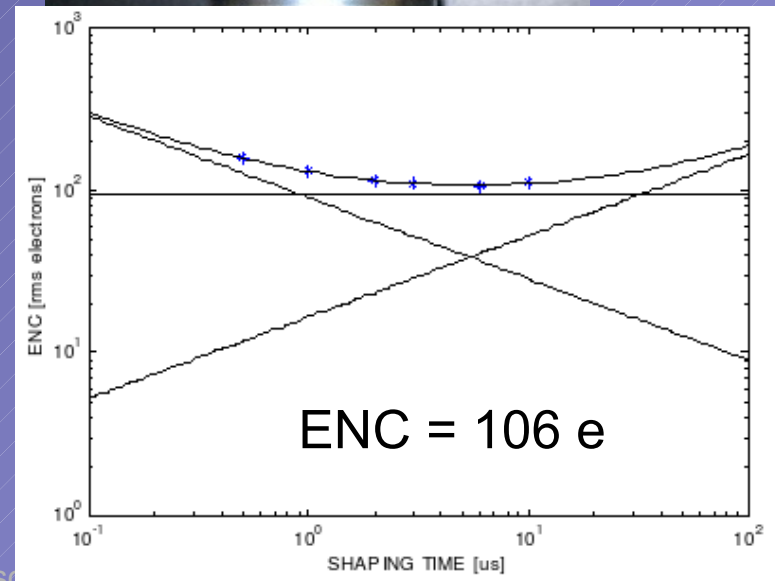
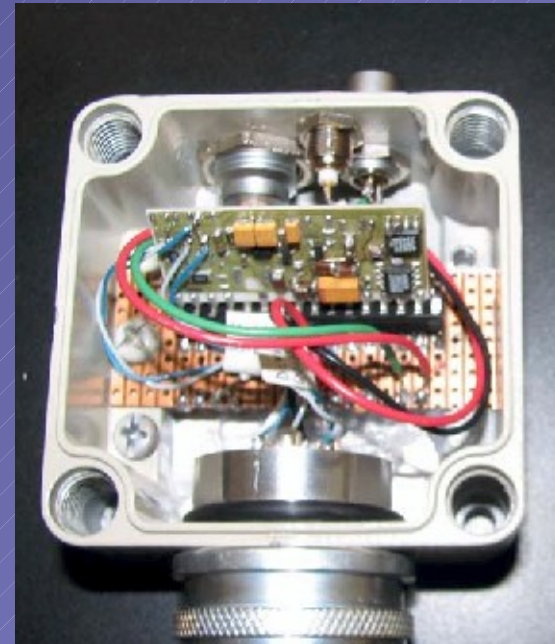


- Measurement with α -source Po-210 and γ -source Co-57
- Calibration with blue LED
- Maximum gain: 2.5×10^4
- Good energy resolution
- APD works very well at LXe temp.!
- Low noise: ~ 2 electrons @ input



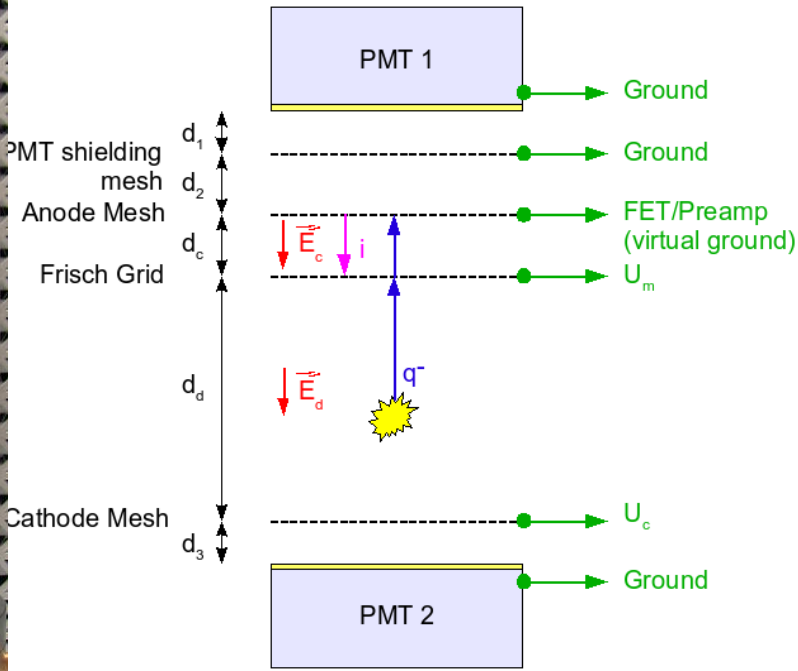
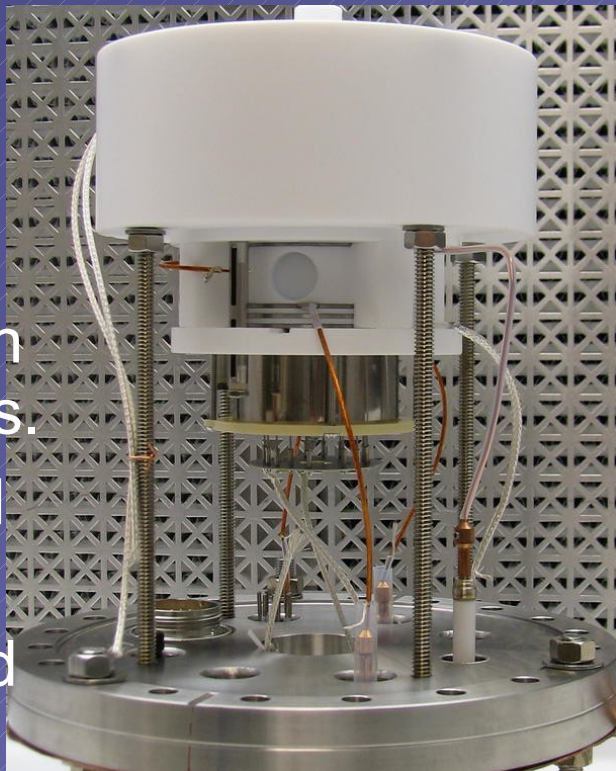
Cold Charge Preamplifiers in LXe

- Good energy resolution desired, small charge signals available
→ need very low noise preamplifier.
- Cryogenic setup usually requires significant cable length between electrodes and external preamp: capacitance, noise pick-up.
- Put the front-end JFET with feedback-loop into the liquid.
- Twisted pair connection to remaining low-noise preamp outside the feed-through.
- First results on test bench very promising!
- Collaboration with A. Pullia, F. Zocca @ Univ. of Milan

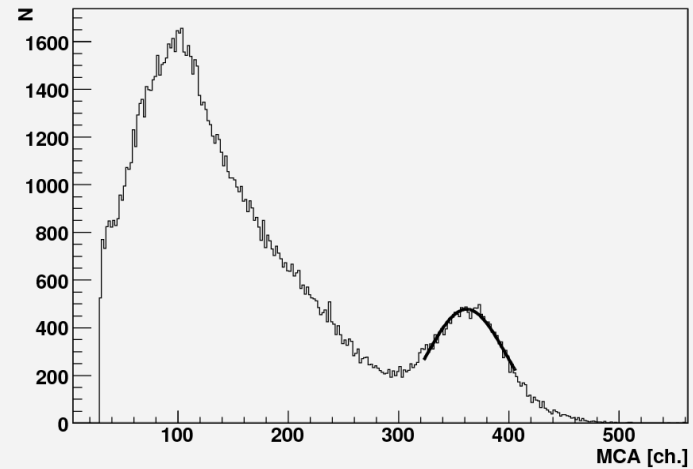


Study of Charge / Light in LXe @ Rice

- XeSpec chamber for light/charge anti-correlation measurements.
- Cold front-end preamp.
- High light yield (PTFE, 95% transparent meshes)
- Full waveform sampling.
- Ready soon.



PMT spectrum Cs137 source



Outlook

- Push the limit of energy resolution in LXe using combined charge/light readout.
- Test low-noise charge amplification inside LXe.
- Study timing resolution of SiPMs & APDs in LXe.
- Design 2D readout for a single LXeTPC module with cold front-end.
- Design & build a mini Compton telescope to test ToF, energy resolution, and imaging.
- Implement scalable readout system.
- ... scale it up and put it on a long-duration balloon!

