Xenon Detector Development with Germanium-like Energy Resolution

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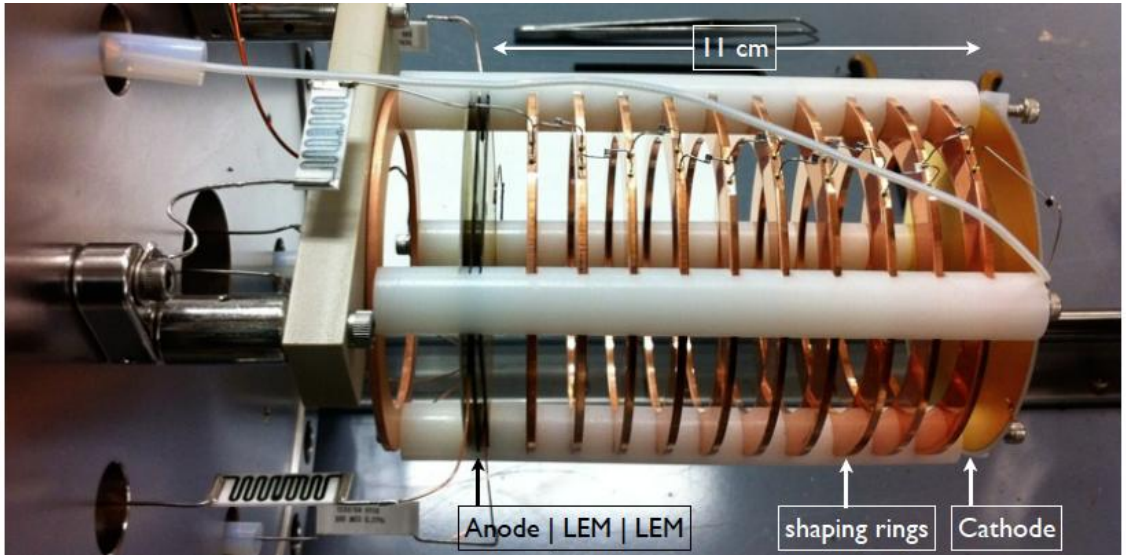

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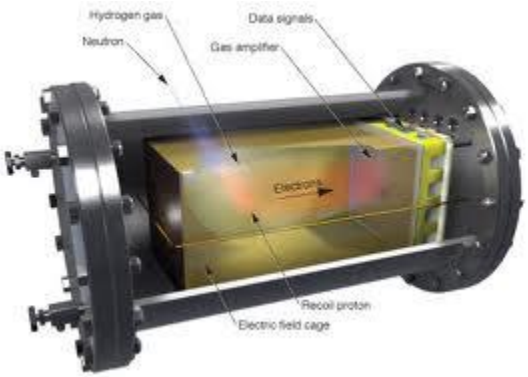
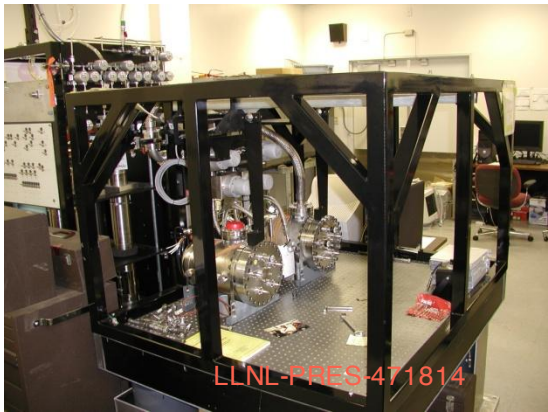
Project Summary

- Goal: Develop High Energy Resolution Xenon Detector – Leading to a proposal for large scale $0\nu2\beta$ experiment
- Significant progress: Observation of **at least 50%** O^-_2 ion stripping in Argon
- FY10 $100k
- FY11 (Aug27th 2010) $150k, Current Balance $69k
- 2 Staff Members, 1 Postdoc, 1 Graduate Student
- Highly leveraged by other TPC projects, Nonproliferation work, LDRD and LLNL infrastructure

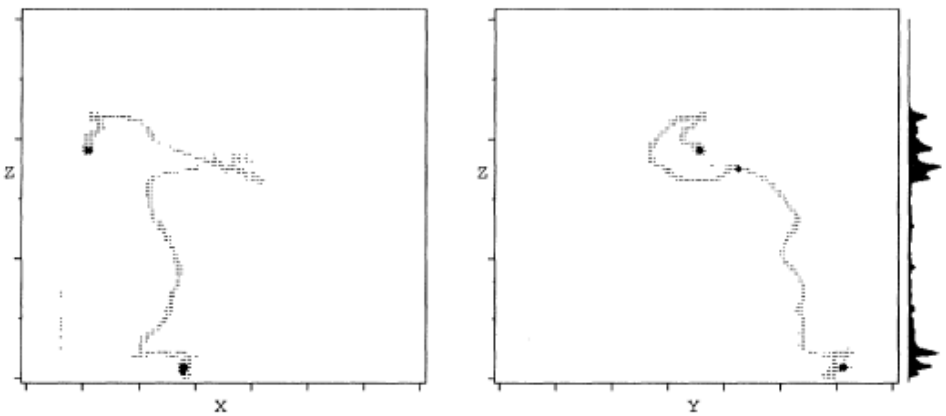


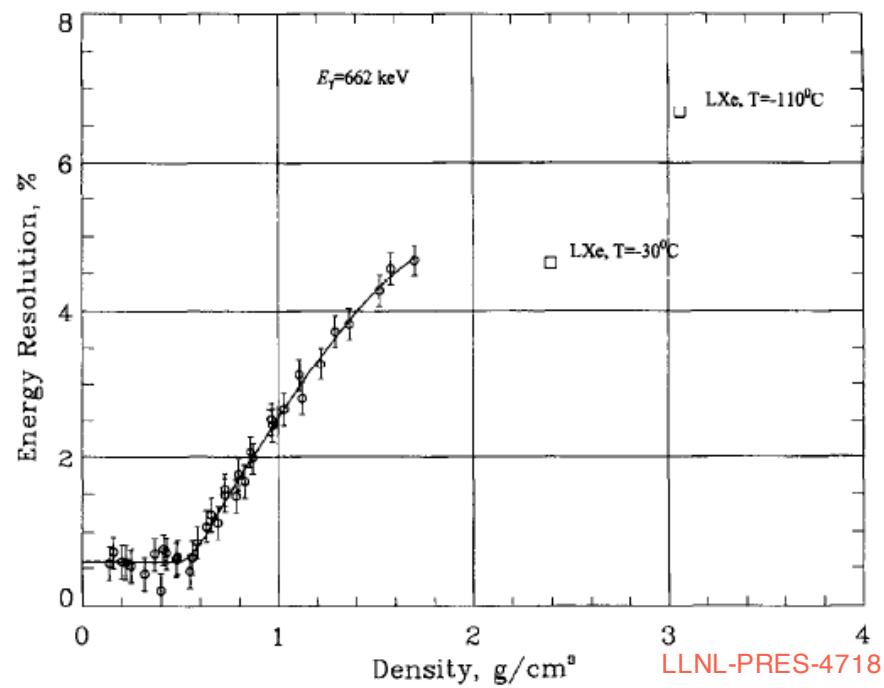


Why Gaseous Xenon?

Gaseous Xenon

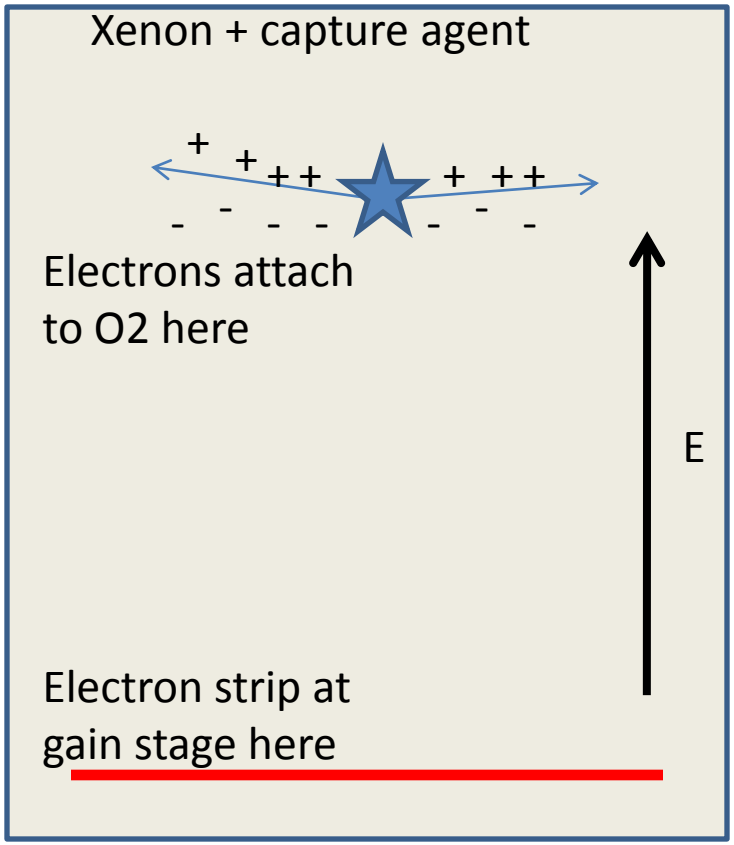
- ^{136}Xe is a $0\nu2\beta$ candidate and is a good drift gas
- Intrinsic energy resolution is quite good, 0.6% FWHM at 662keV
- Tracking provides additional background rejection
- The next generation experiment will require multi-ton active mass and xenon scales well





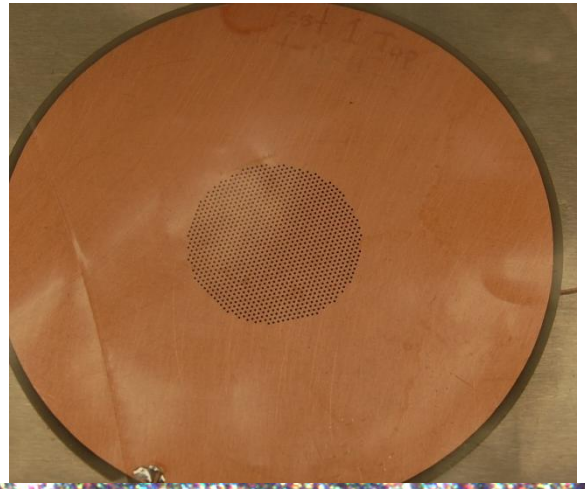
Why Negative Ions?

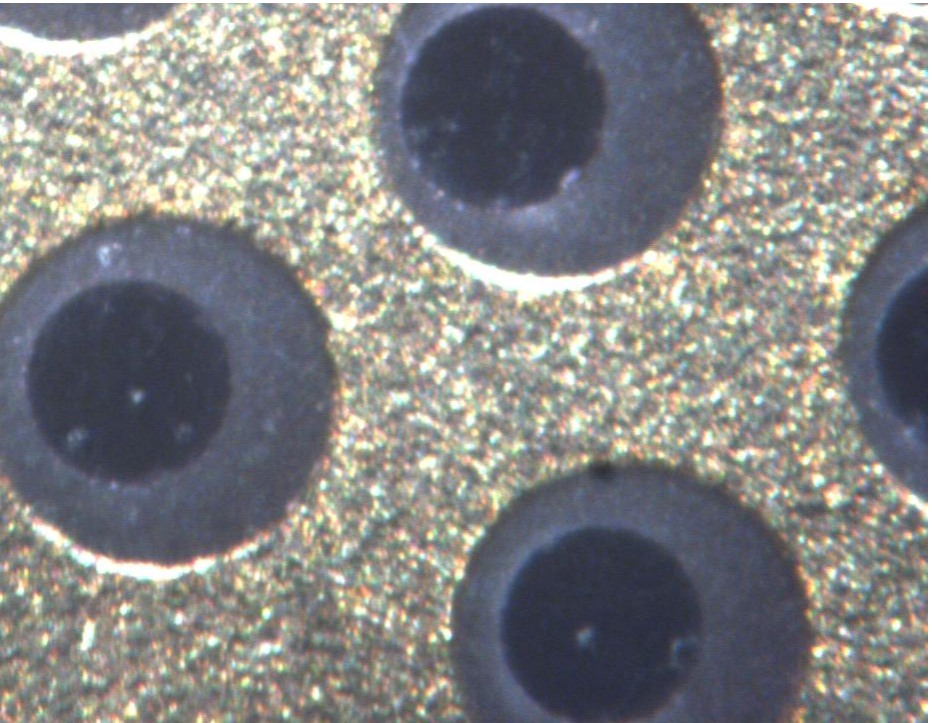
- **<u>Negative Ions</u>**
- Primary electrons generated by the DBD attach to negative ions which act as a conveyer belt, picking up electrons and transporting them to the readout
- NI can be individually counted with ,we believe, high efficiency returning the best possible energy resolution limited only by intrinsic fluctuations
- $\delta E/E = 2.35\ \mathrm{sqrt}(F/N_e)$
- Energy resolution in xenon if all charges could be collected is ~0.6% at 662keV

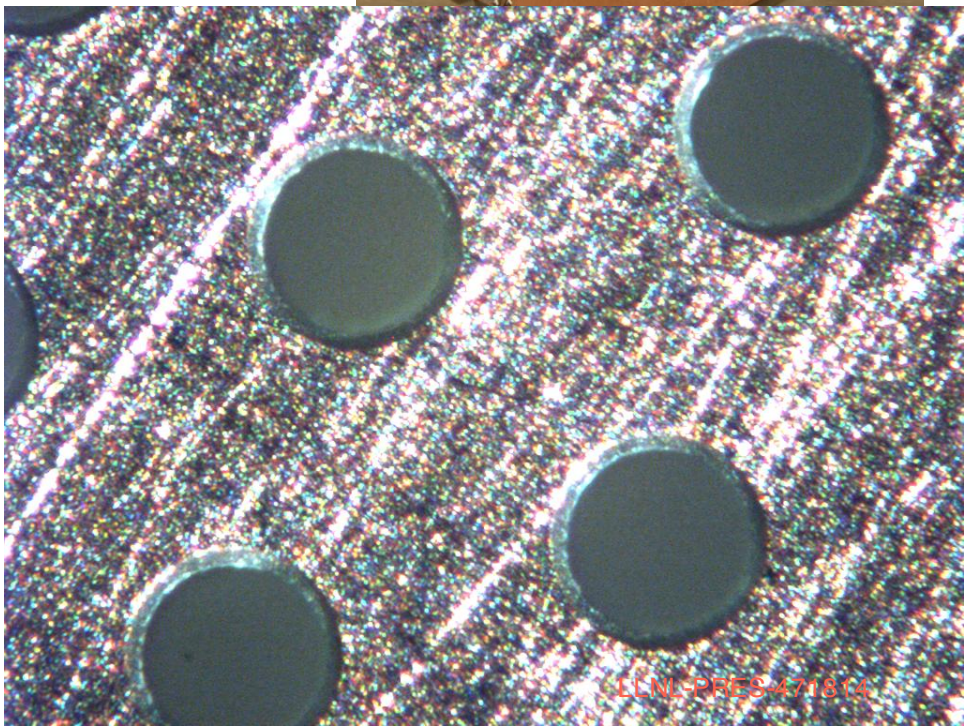


Large Electron Multiplier (LEM)

- The LEM has high electric field that strips electron from ion
- Electron undergoes Townsend avalanche (gas gain)
- LLNL has significant infrastructure to build LEMs that work in this application
- LLNL produced LEMs have led to big improvements in the observed ion stripping







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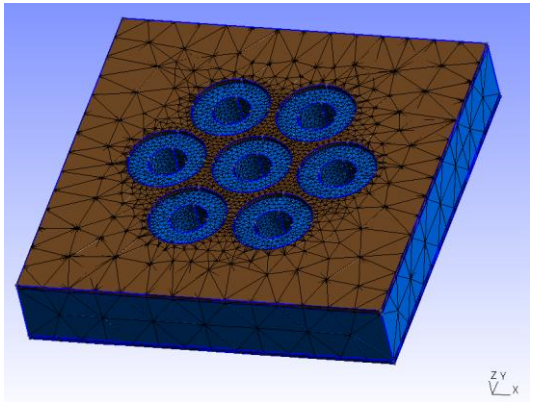
Electrostatic and Monte Carlo Models

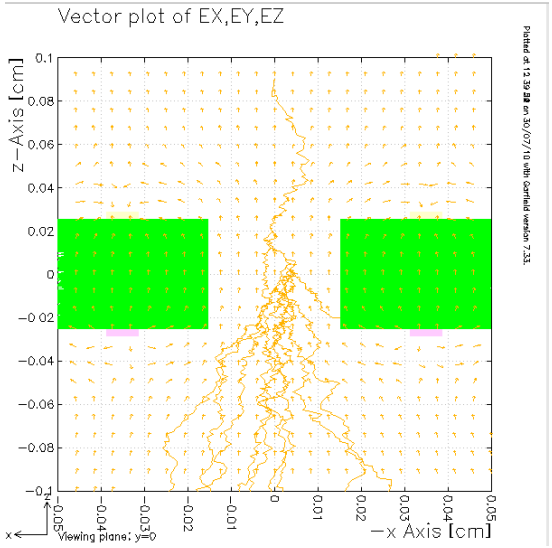
Josh Renner (LBNL)

Model of a LEM gas amplifier

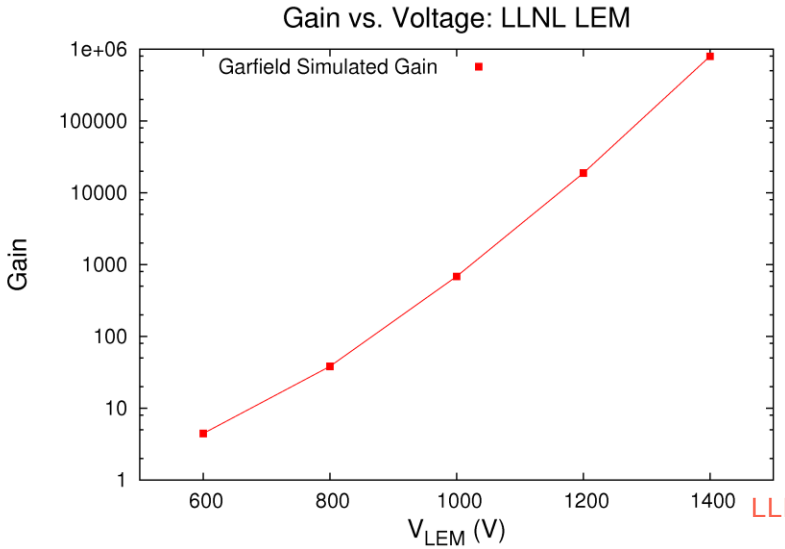


- Full simulation of electrostatics and Monte Carlo of ions done
- Initial results close to experiment
- Will be used to optimize a large experiment

Field map and Townsend avalanche



LEM gain from FEA/Garfiled simulation



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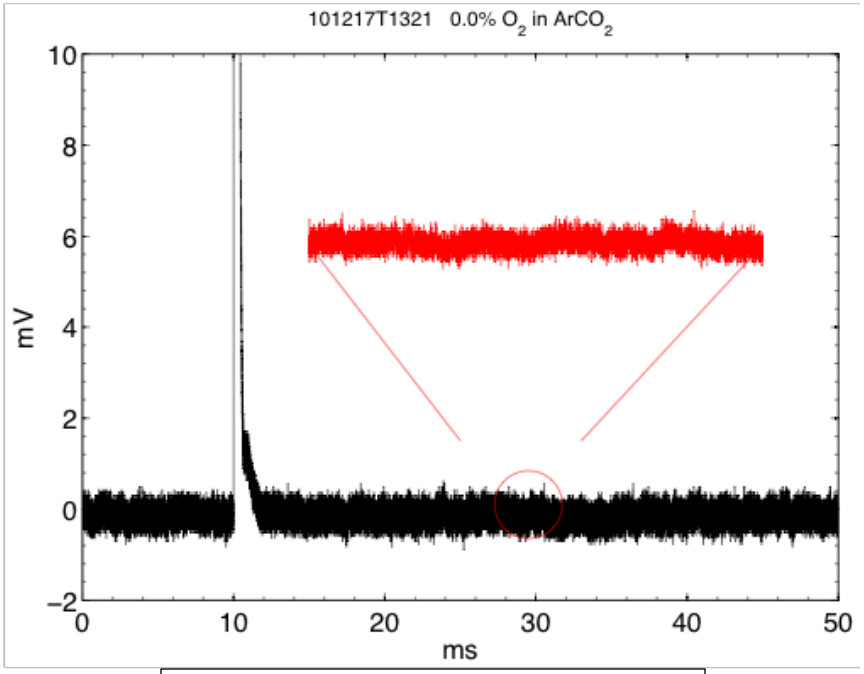
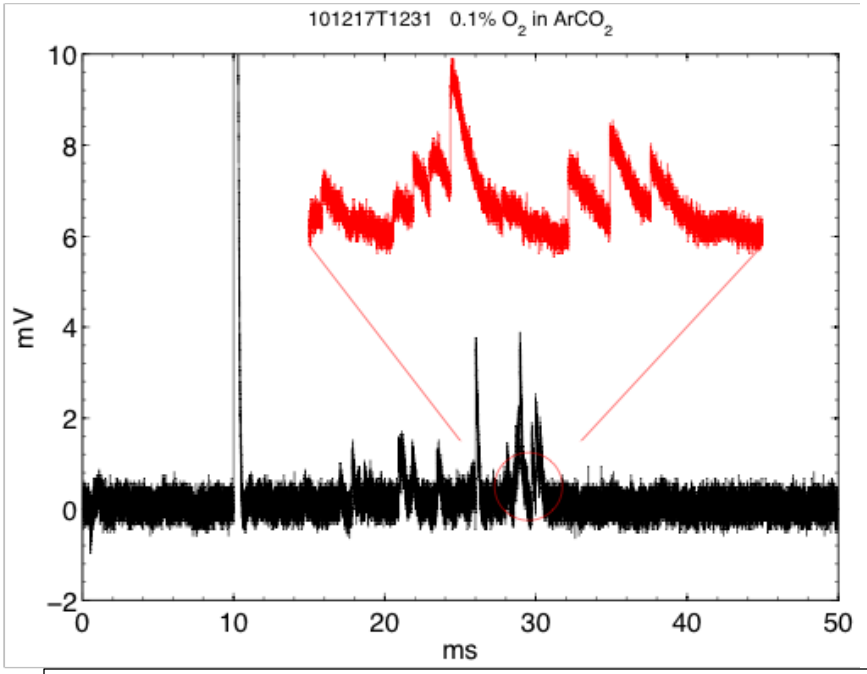
Recent data: electron capture and release by negative ions

Electron drift (no O_2)



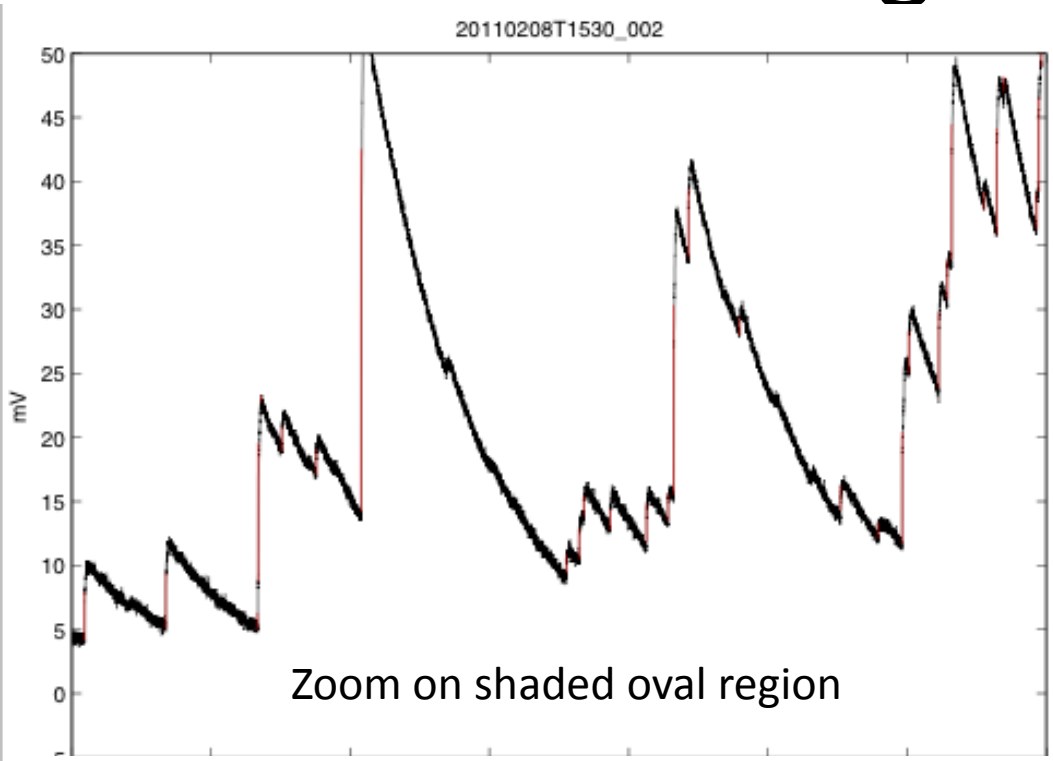
Inset (red): no evidence for late arriving signals in electron drift mode

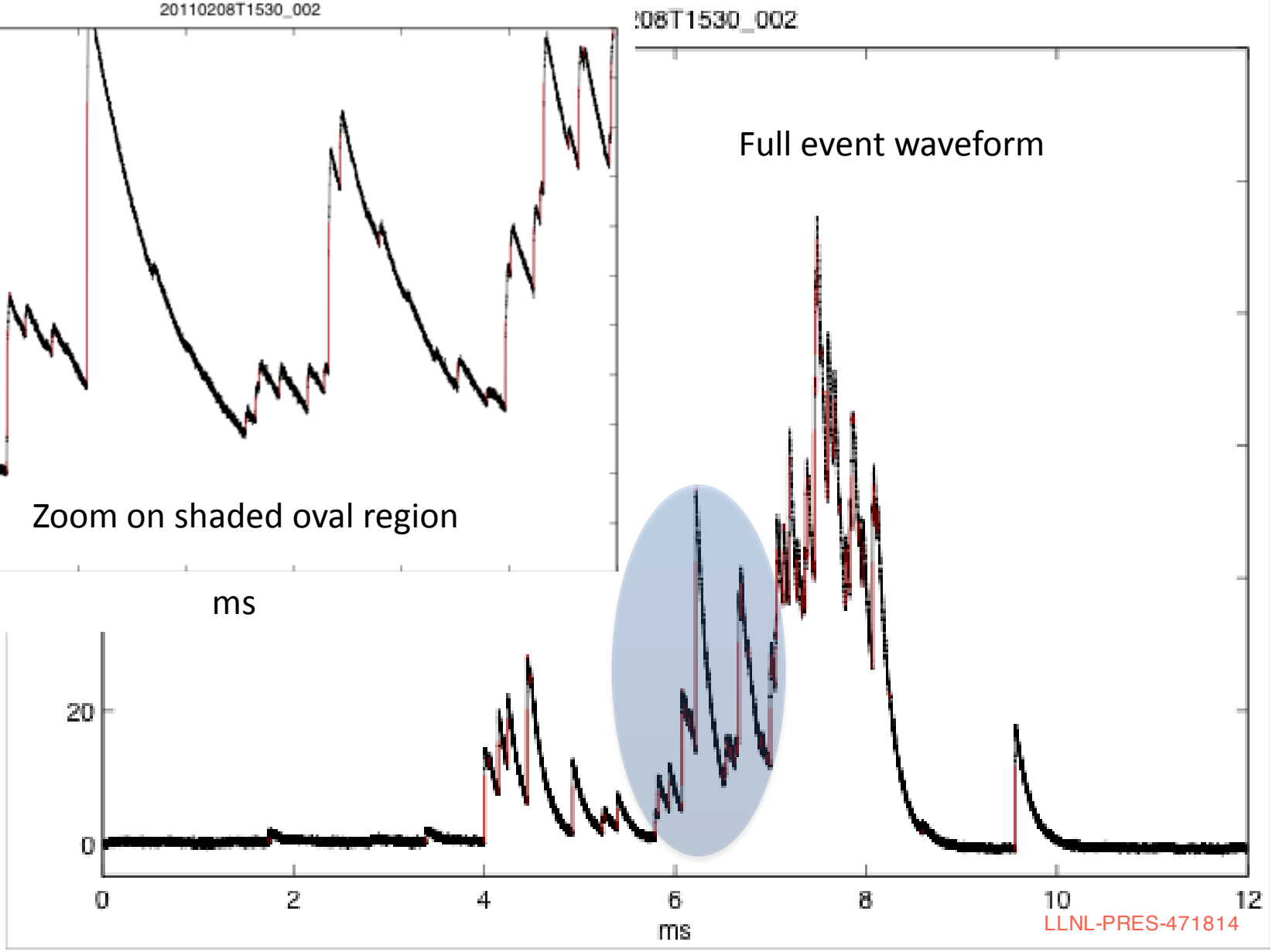
Negative Ion drift



Inset (red): with oxygen present, electrons stripped from ions create individual countable pulses on the readout

A 5.9 keV negative ion event

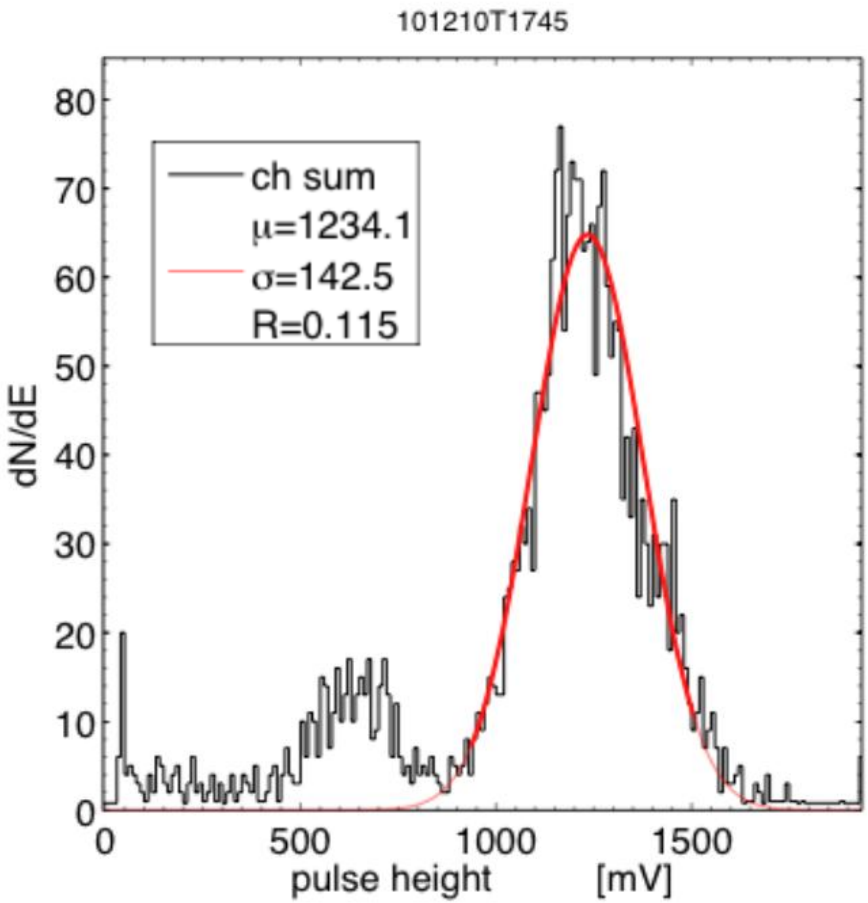




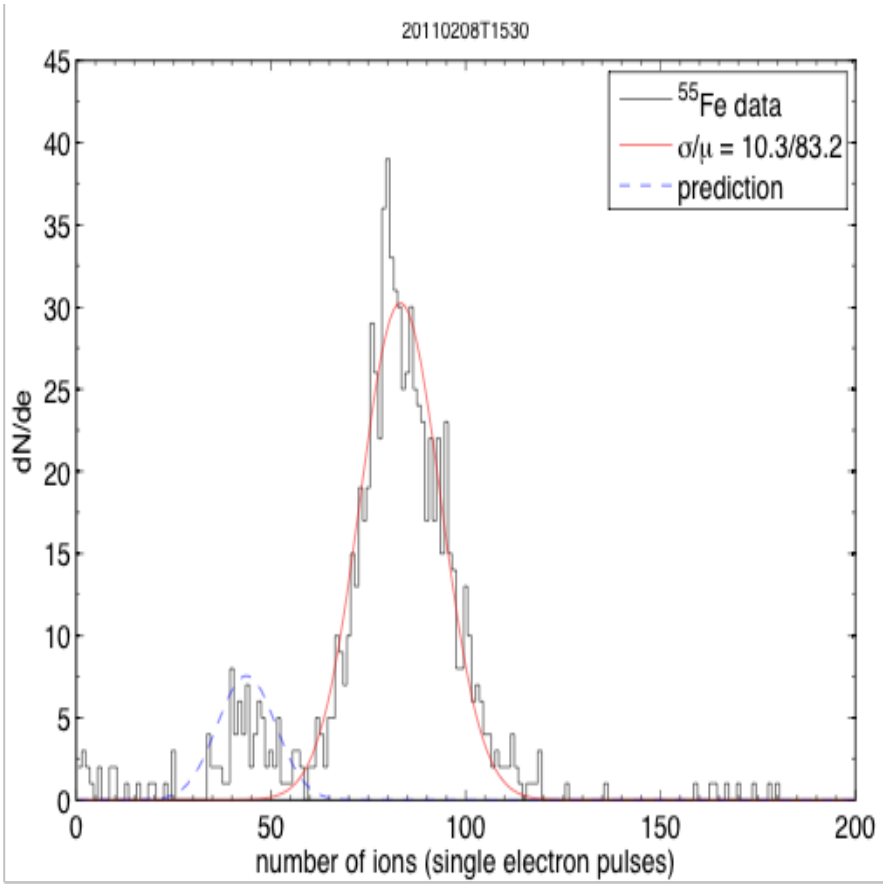
5.8 ms
7.2

Recent data: energy reconstruction from negative ions!

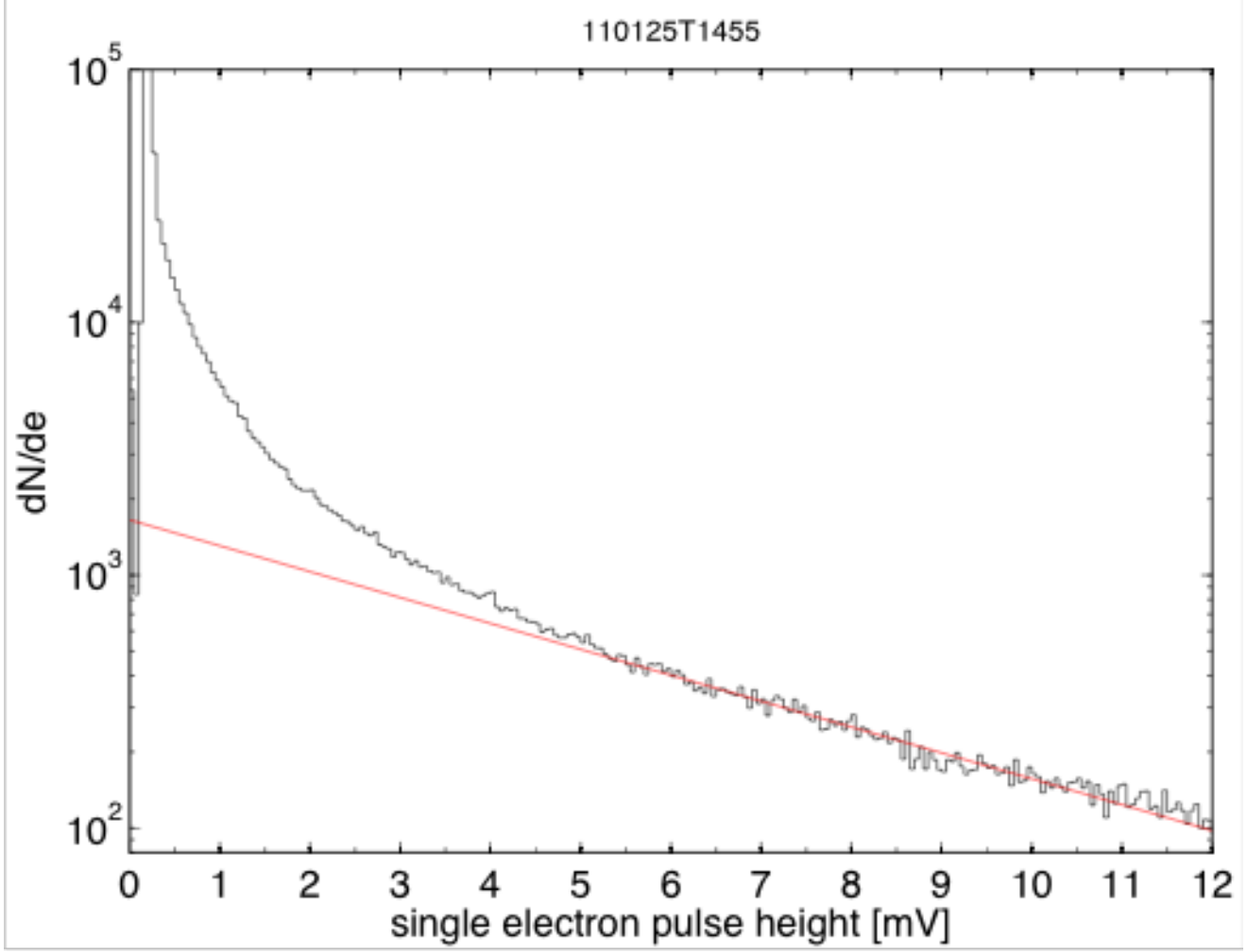
Electron drift (no O_2)



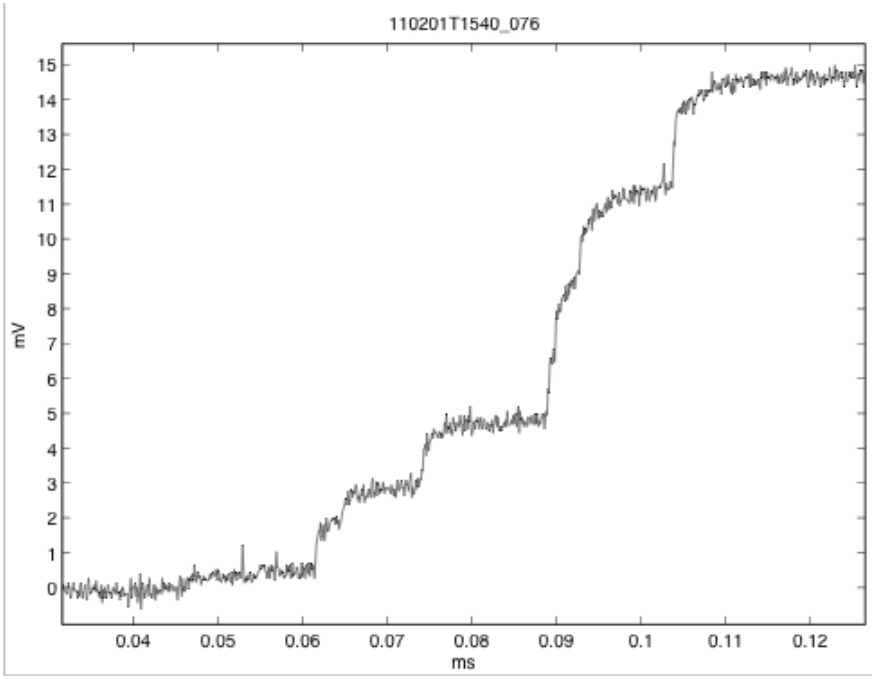
Negative Ion drift

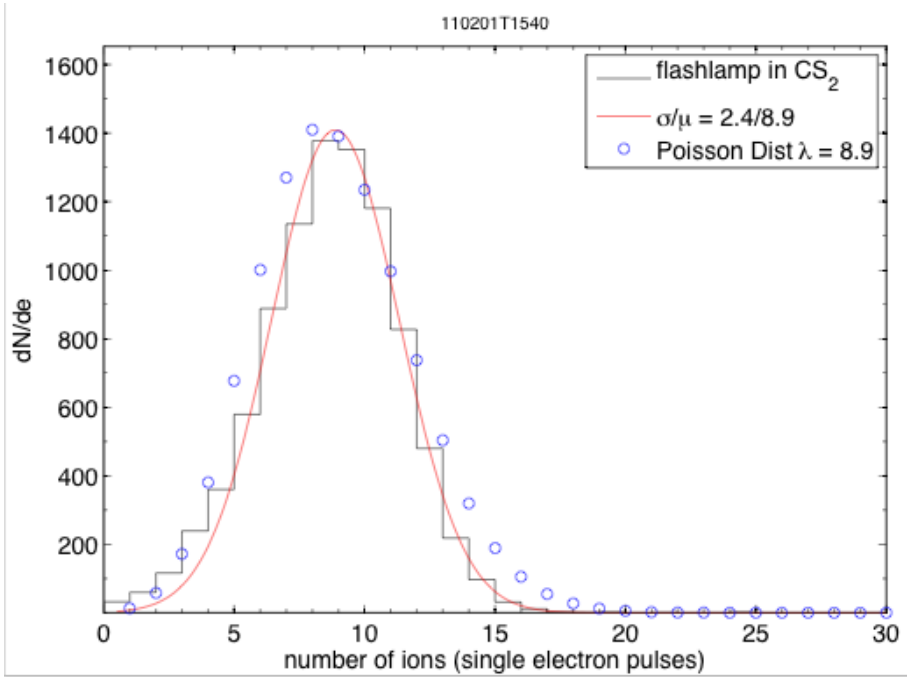


Single electron spectrum as expected



Exploring CS_2 capture agent – also looks promising





Path Forward

- Use models and experiments to improve gas gain structure for better conversion
- Once significant (~80%) numbers of electrons are collected, **write paper**
- Study other capture agents, in xenon and at pressure, **write paper(s)**
- FY2012-13: Proposal to Build small ~$300k per year over two years, segmented detector demonstration, **write paper**
- FY2014-15:Develop and **write proposal** for the next generation neutrinoless double beta experiment