Current Status and Prospects for the XENON Dark Matter Search Experiment

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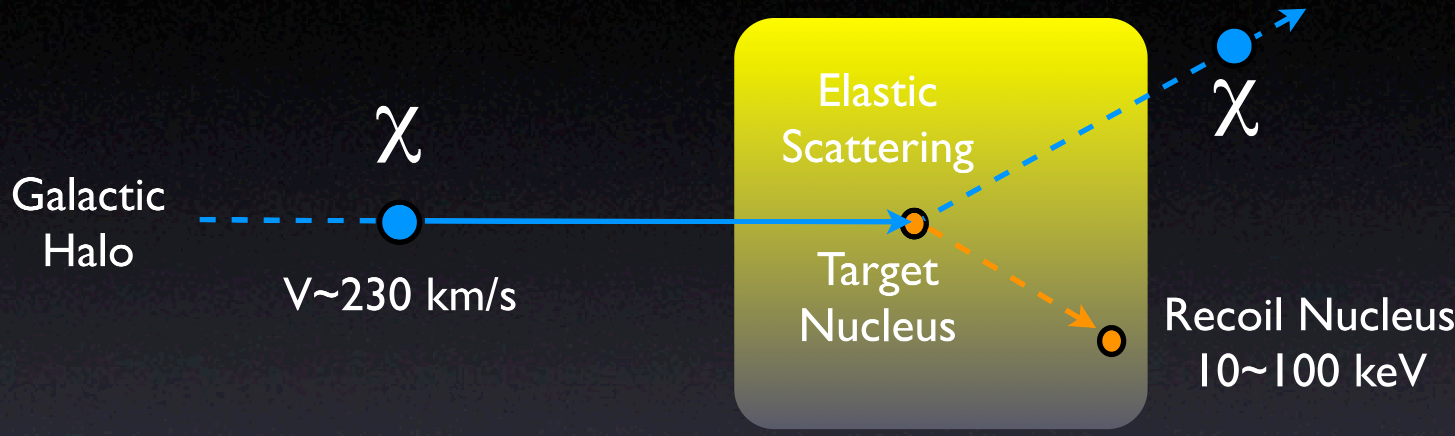
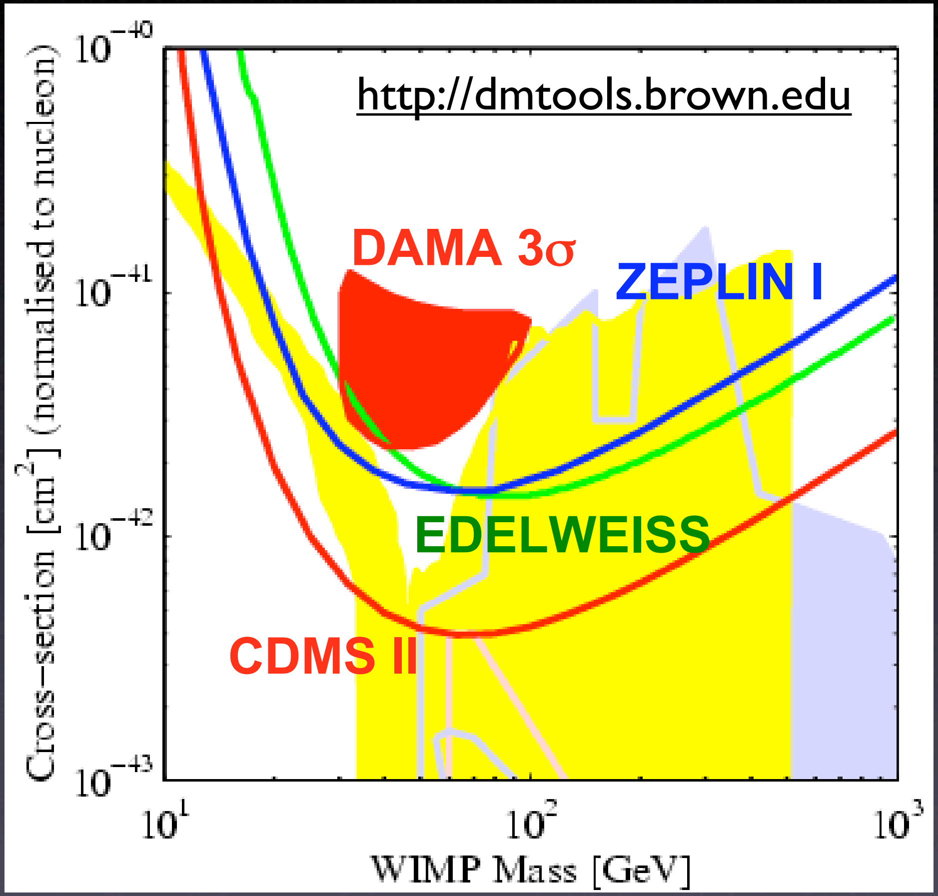
(on behalf of the XENON Collaboration)
TeV Particle Astrophysics, Fermilab, July 14, 2005
http://www.astro.columbia.edu/~lxe/XENON/

Direct detection of dark matter



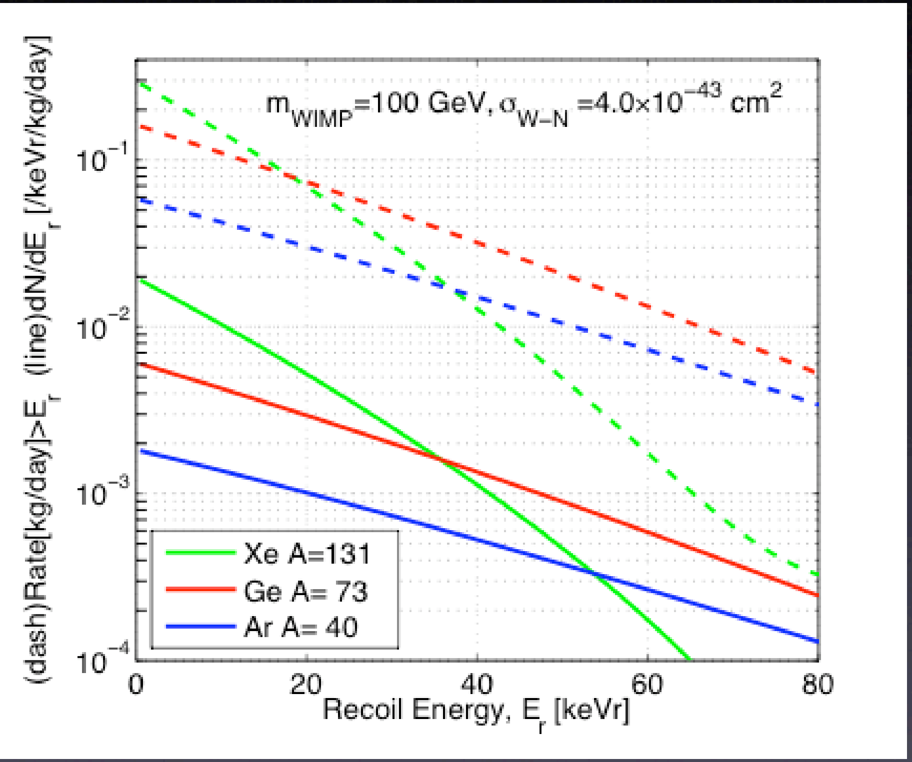
- Neutralino: the lightest super-particle from supersymmetry is a major candidate for dark matter
- Neutralino makes elastic scattering off the target (NaI, Ge, Xe, etc.) nucleus with a recoil energy of 10~100 keV
- Main task: discriminate these events from backgrounds

Neutralino has been discovered?



- The DAMA 3 sigma detection region are excluded by all of the latest experiments (CDMS, EDELWEISS, CRESST)
- Future dark matter direct detection needs large mass (~ ton scale) to probe the lower SUSY parameter space

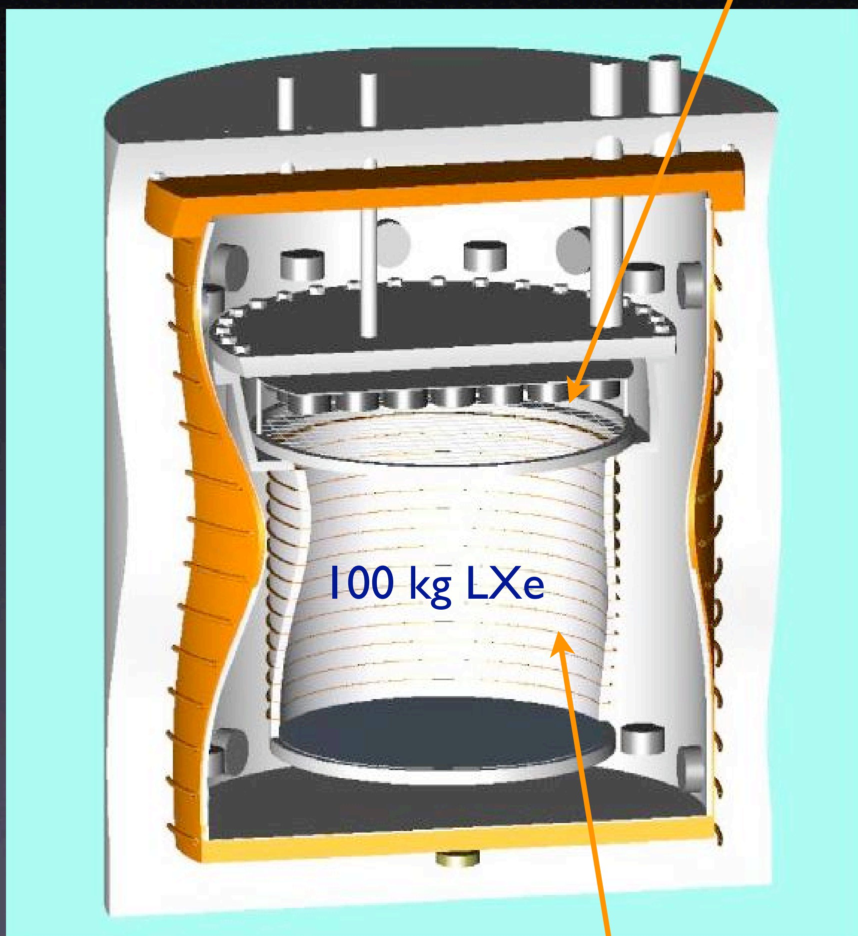
Xenon as a dark matter target ...



- High atomic mass (A~131) gives higher cross-section for Spin-Independent interaction. Total event rate in a Xe detector with 16 keVr threshold is identical to that of a Ge detector with a 10 keVr threshold.
- Odd spin component (Xe-129, Xe-131): also sensitive to spin-dependent interaction
- Xenon is available in large quantity, and is well suited for large mass detectors
- No long-lived radioactive component: internal background free.

XENON Project Overview

PMT array to detect scintillation light



Electric field to drift ionization charge

- The goal is to have mass of 1 tonne, distributed in 10 independent XeTPCs with a WIMP-nucleon cross-secion sensitivity to 10^(-46) cm^2
- Ionization and scintillation of liquid xenon (LXe) provides electron/ nuclear recoils discrimination (99.5% above threshold of 16 keVr)
- 3D position sensitivity TPC, an active veto shield and passive Pb/Poly shieldinig for additional background suppresion
- The project is supported by NSF and DOE

The XENON Collaboration

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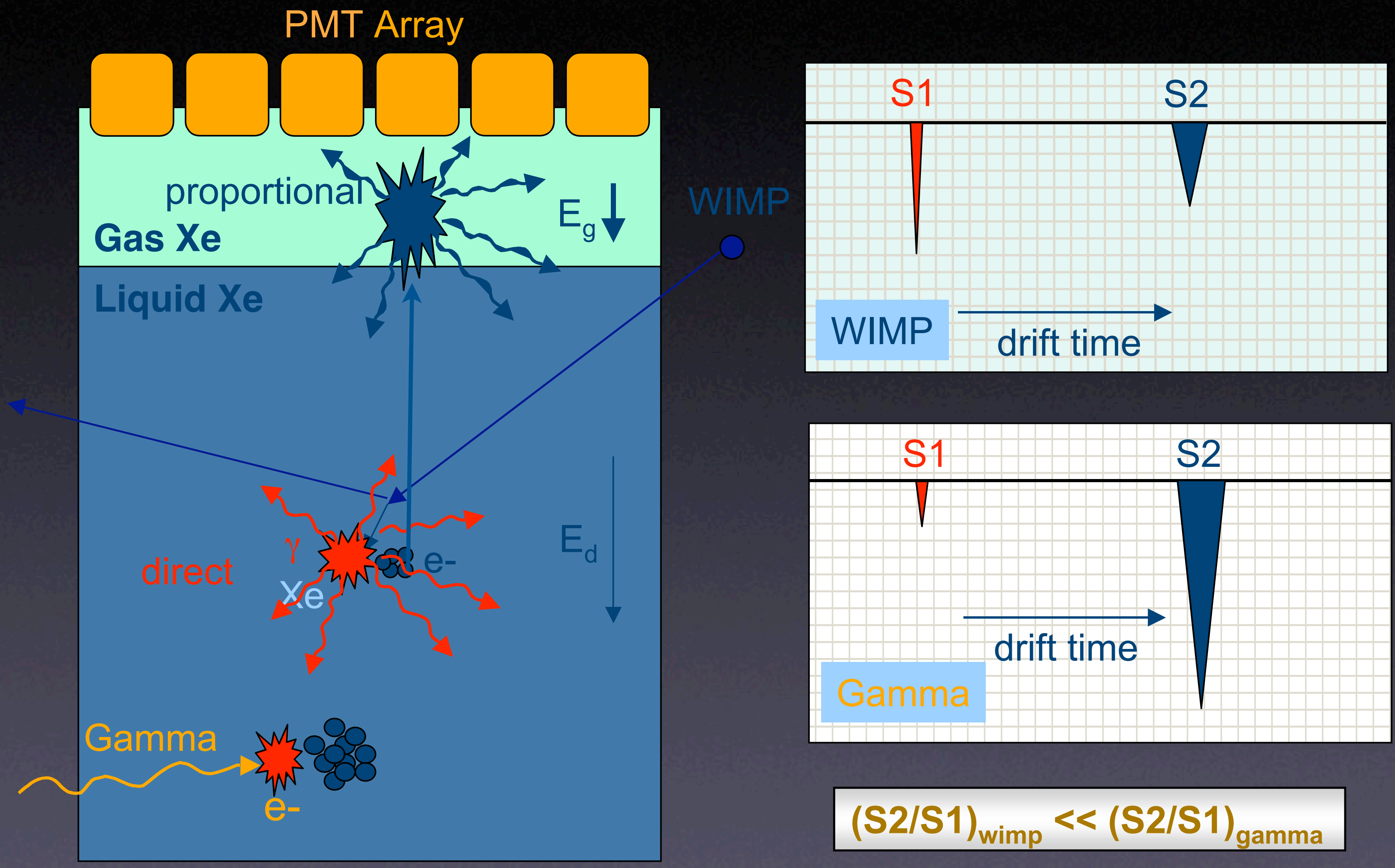
Principle of Operation



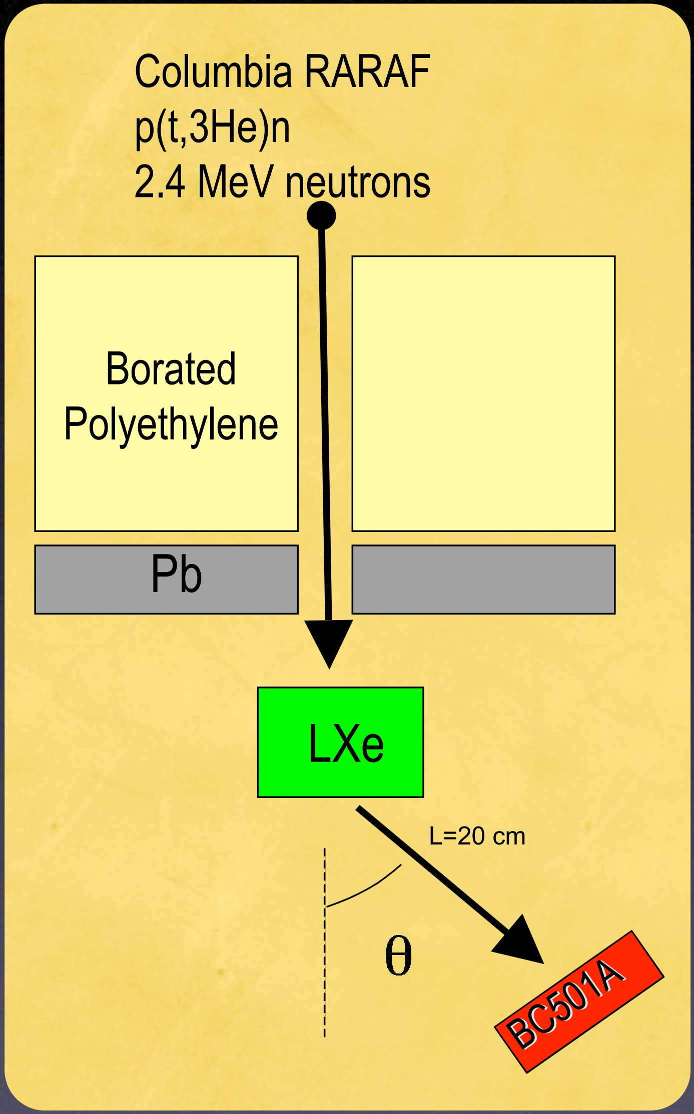
$(S2/S1)_{wimp} << (S2/S1)_{gamma}$

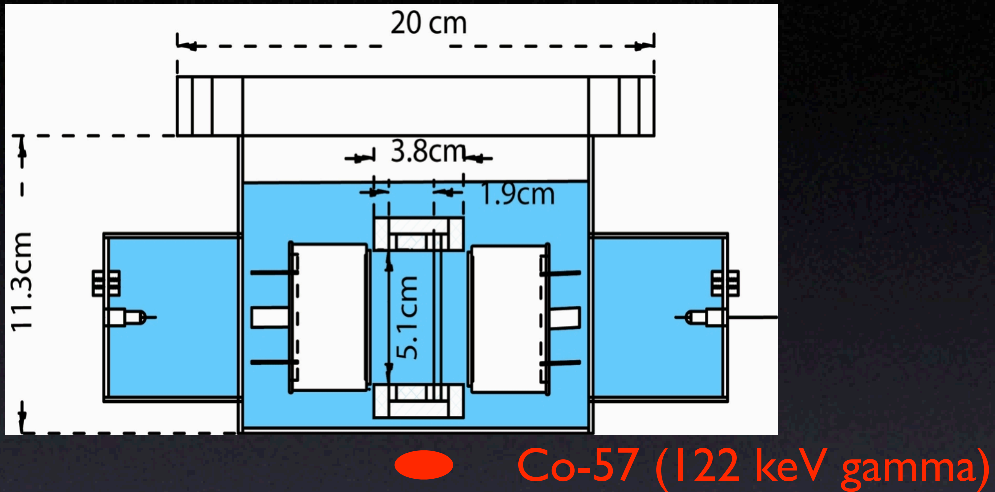
Study of scintillation and ionization in LXe by low energy nuclear recoils

The R&D phase of XENON project recently has focused on the study of the two most important properties for Dark Matter Searches using LXe

- LXe Scintillation Efficiency for Nuclear Recoils
  - WIMP recoil energy can be properly calculated based on this parameter
  - Existing data inconsistent, no measurement below ~40 keVr
- LXe Ionization Yield for Nuclear Recoils
  - Electron/Nuclear recoil identification and background discrimination depend on this parameter
  - No prior measurement available

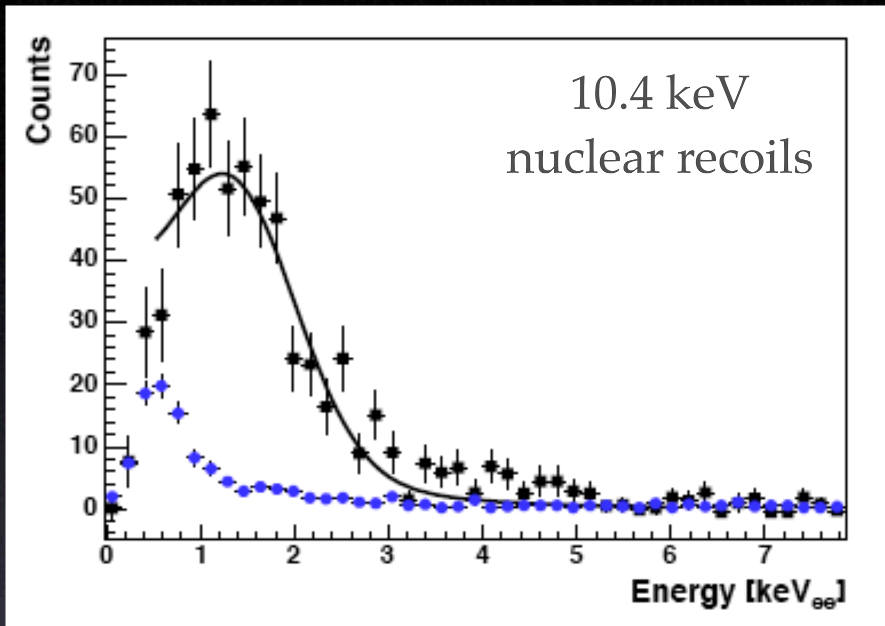
Nuclear Recoil Scintillation Efficiency Measurement

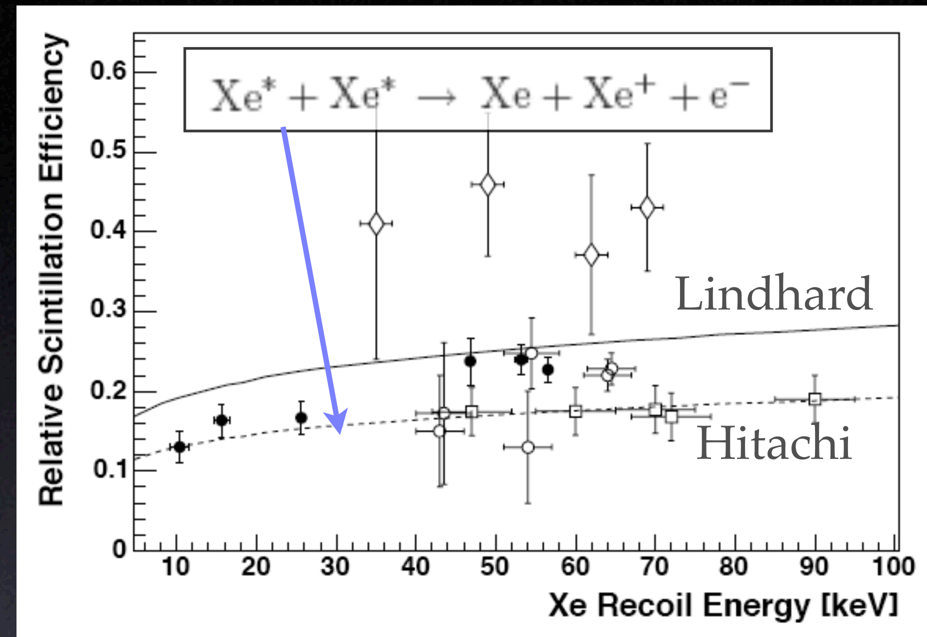


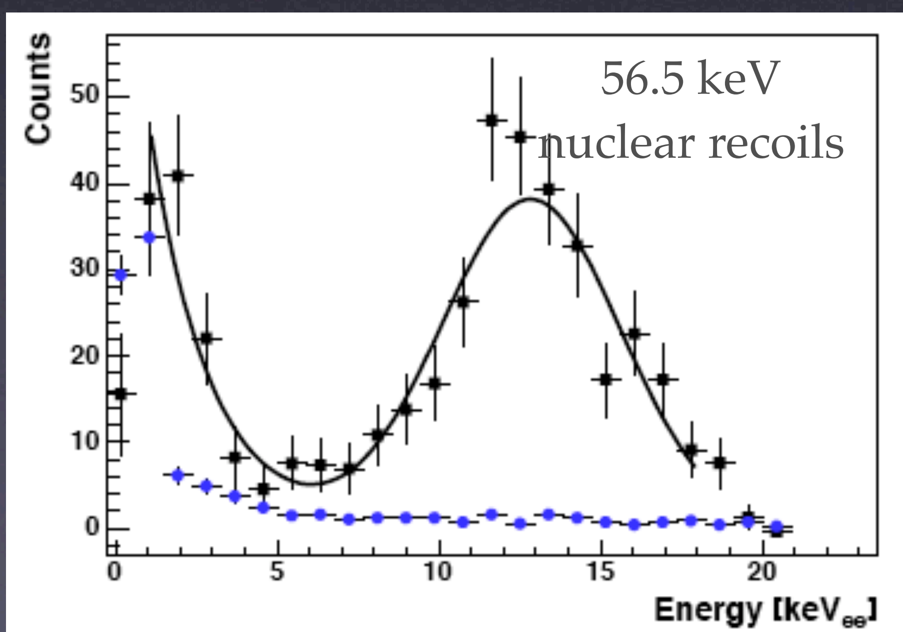


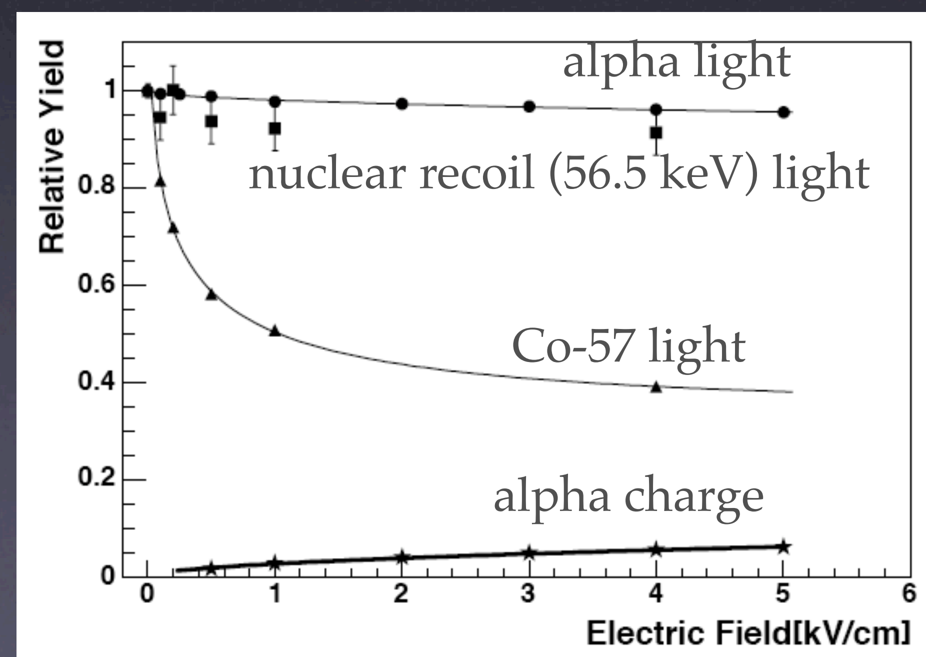
- 2.4 MeV neutrons were scattered in LXe to produce 10~50 keV nuclear recoils
- External gamma source (122 keV) was used to calibrate the detector

Nuclear Recoil Scintillation Efficiency

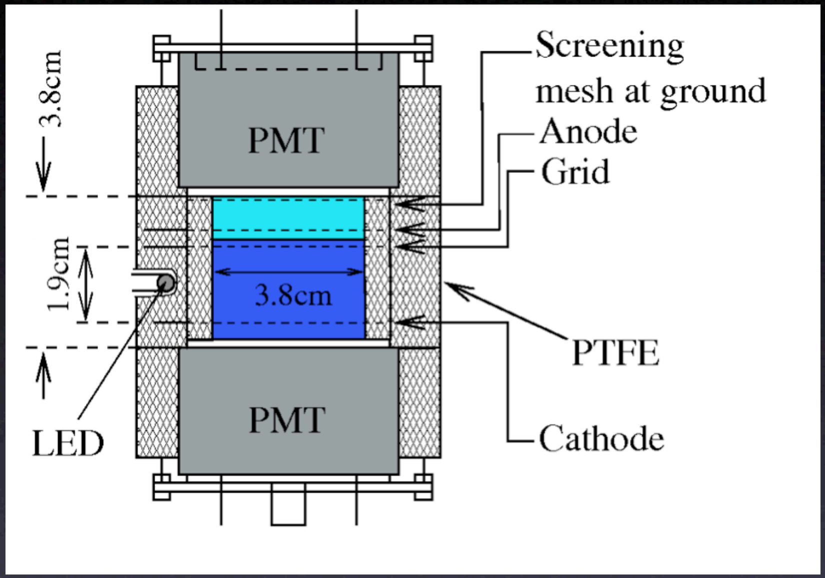


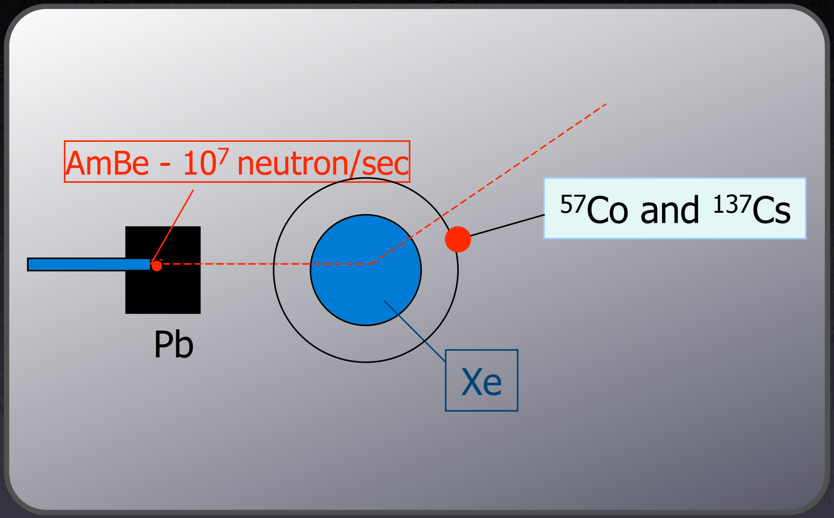






Nuclear Recoil Ionization Measurement

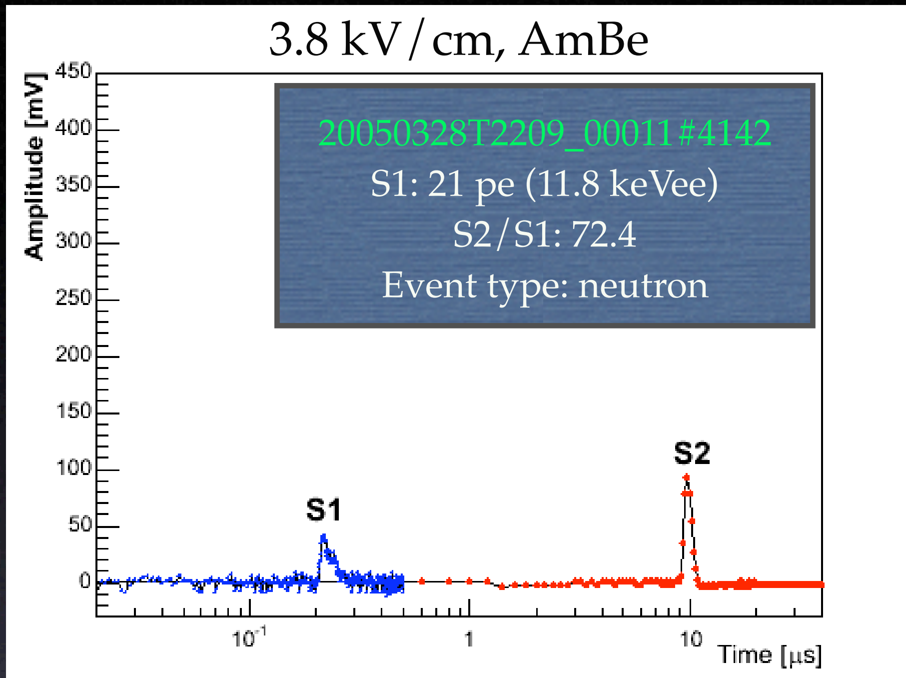


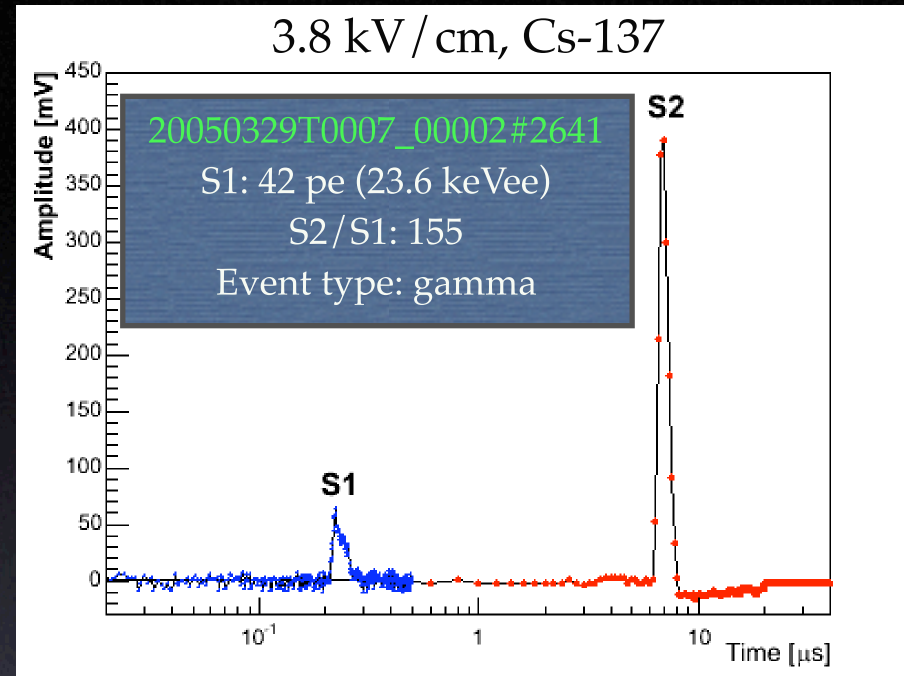


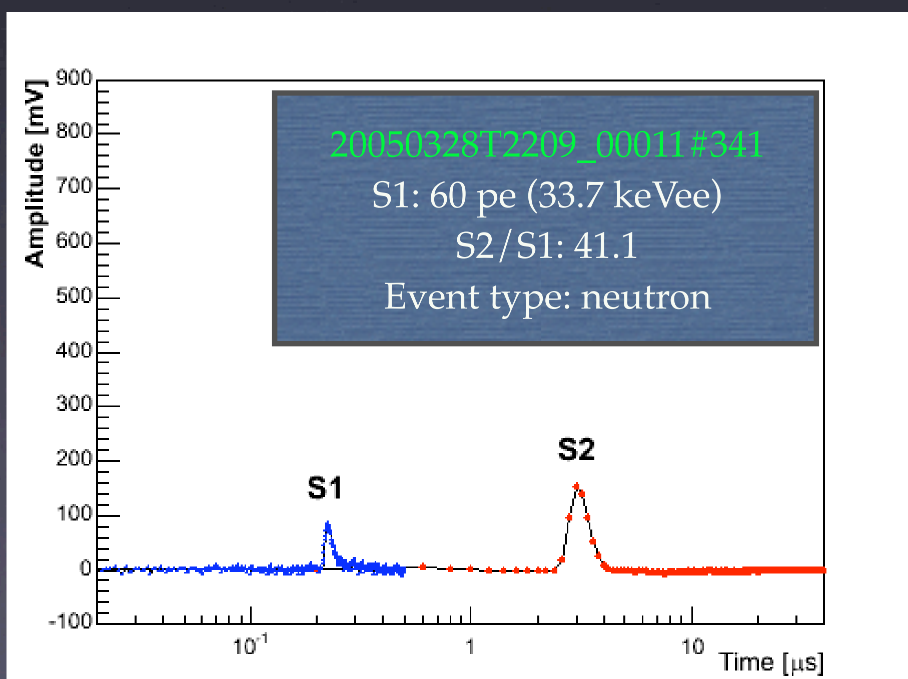
Energy threshold: 10 keVr

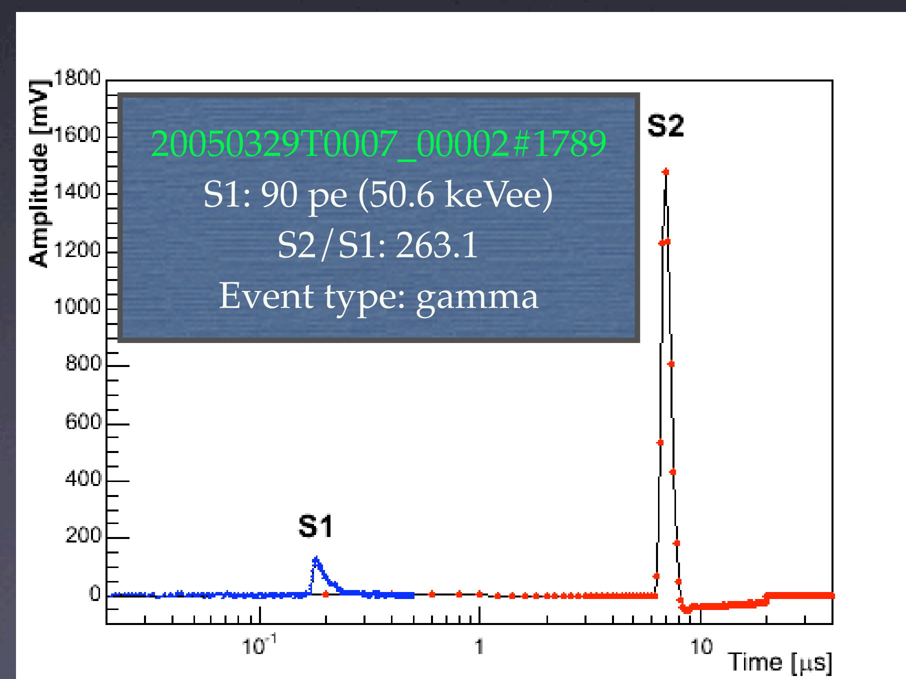
- Neutrons (similar to WIMPs) from AmBe make elastic scattering off LXe target
- 122 keV gamma ray from Co-57 used for energy calibration
- Low energy gamma ray from Cs-137 662 keV gamma Compton scattering as background source

Event by event discrimination

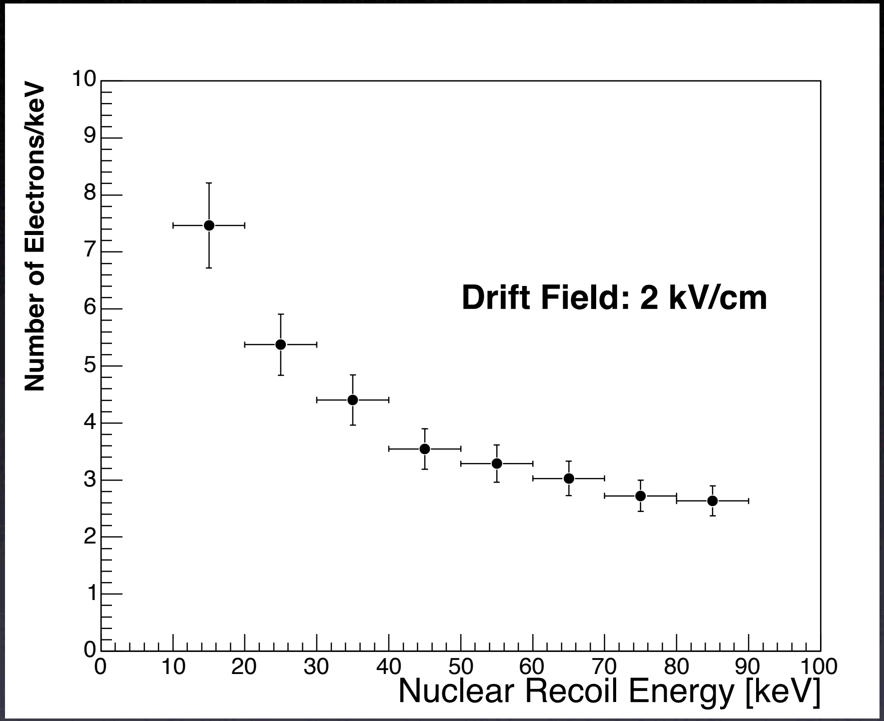


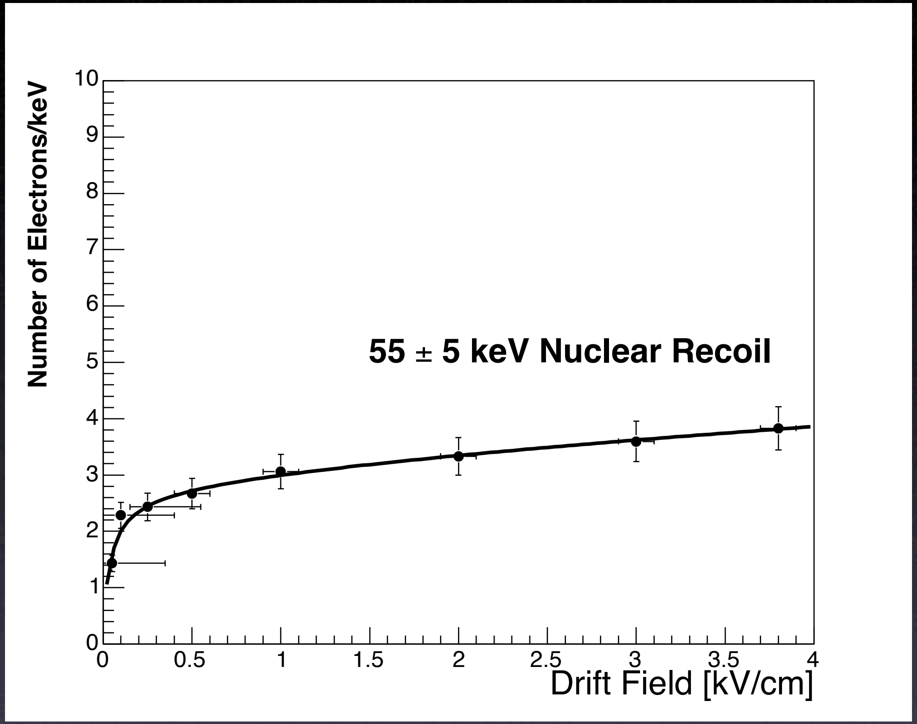






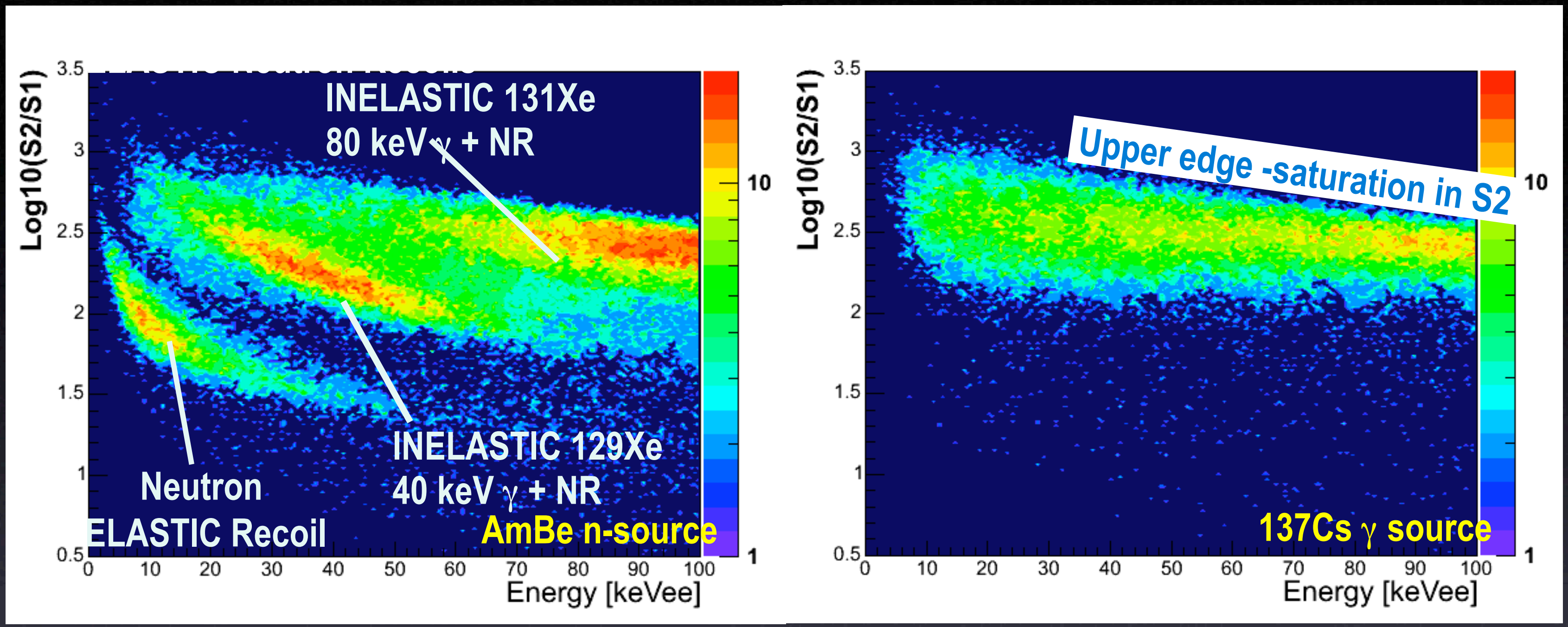
Nuclear recoil ionization yield in LXe



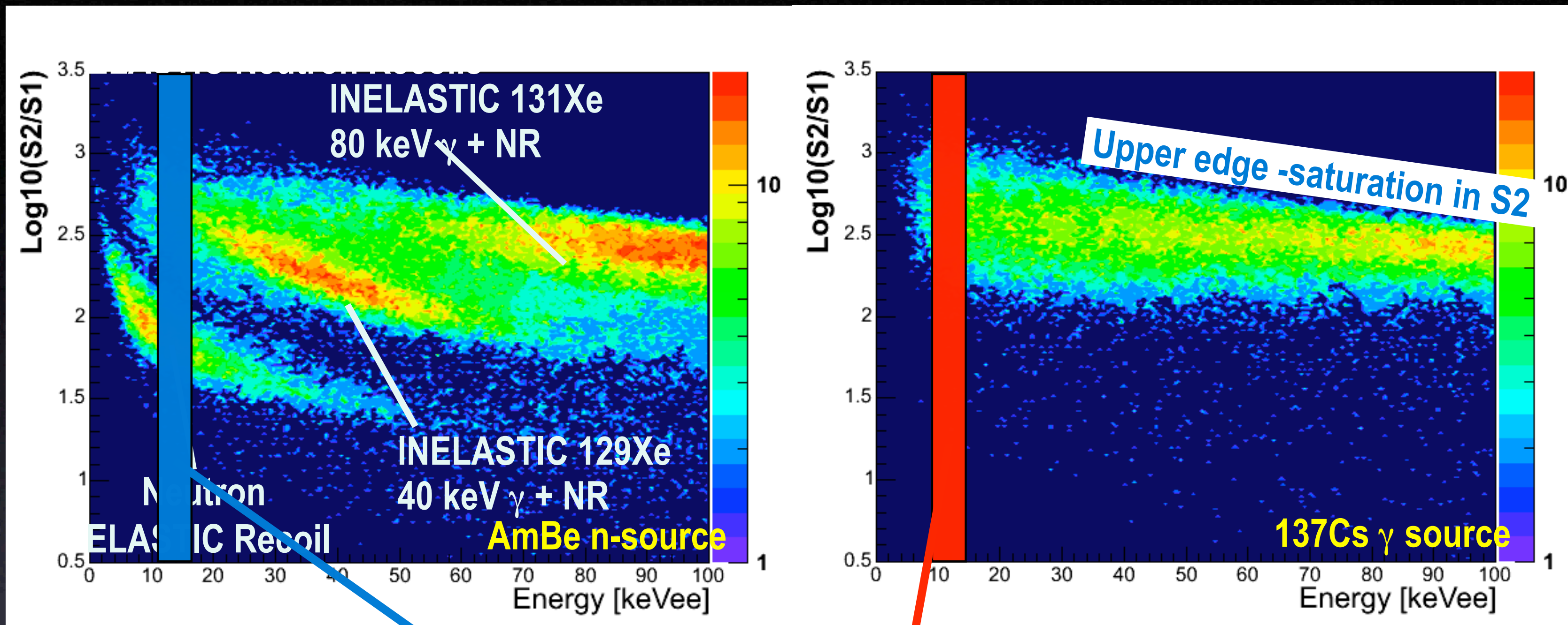


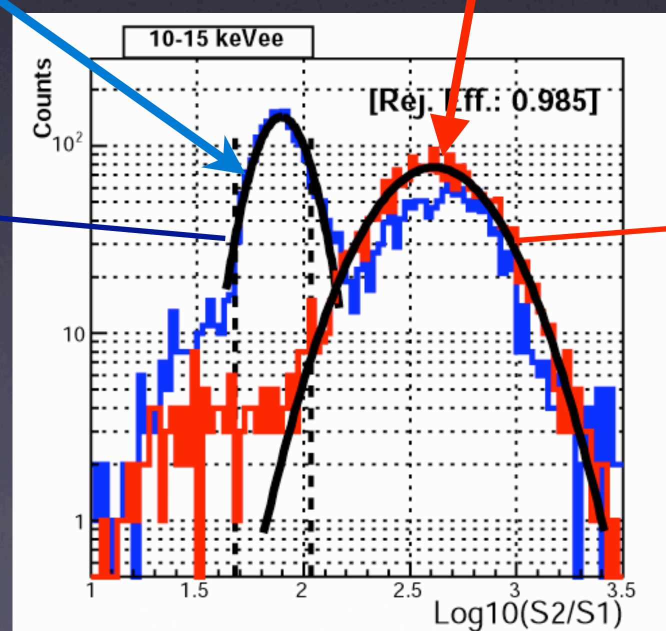
- Energy dependence was measured down to 10 keV recoil energy
- NR ionization yield is higher than expected (from alpha ionization)

Background discrimination capability



Background discrimination capability





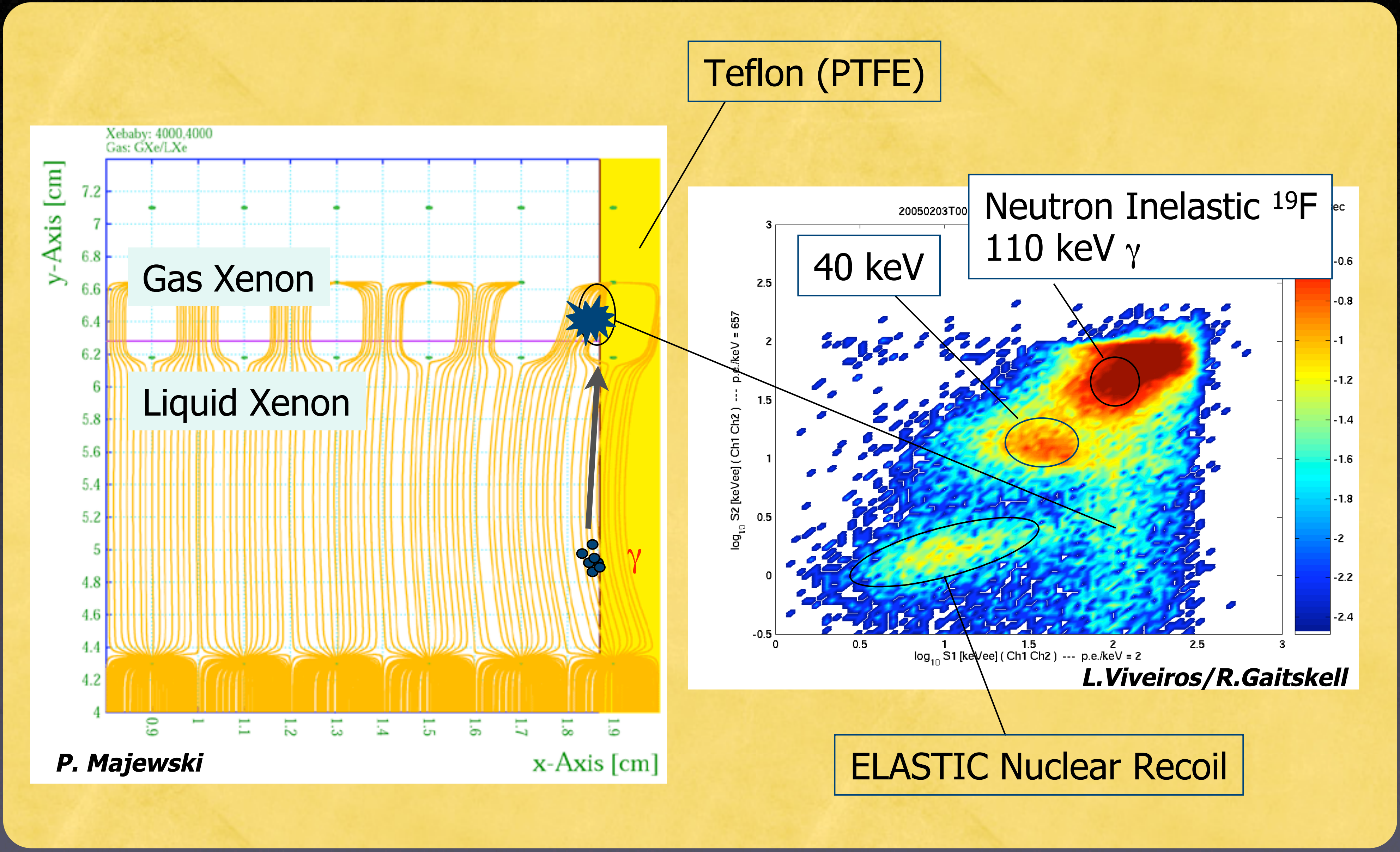
nuclear recoils

gamma rays/
electron recoils

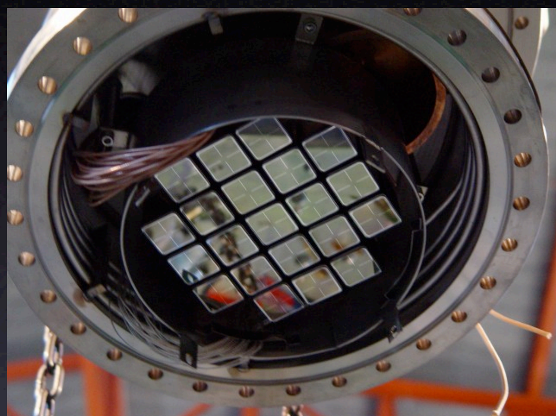
First demonstration of electron/nuclear recoil discrimination at this energy level for a dual phase xenon detector

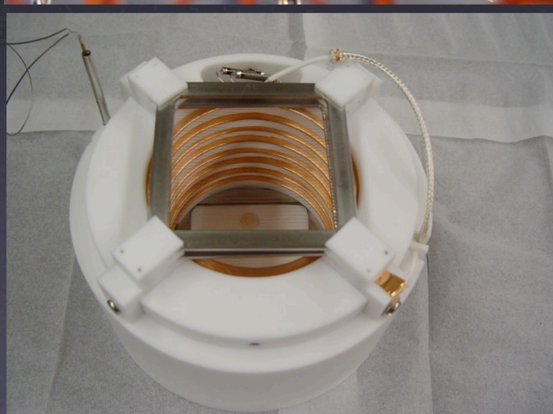
Discrimination potential can be further improved with the 3D sensitive detector and optimized field configuration

3D sensitivity required for better gamma rejection near the edge

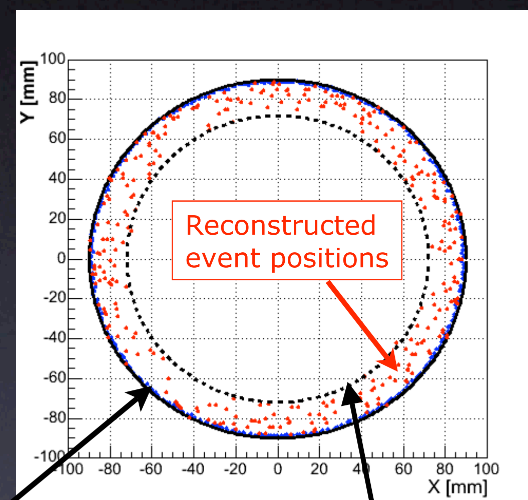


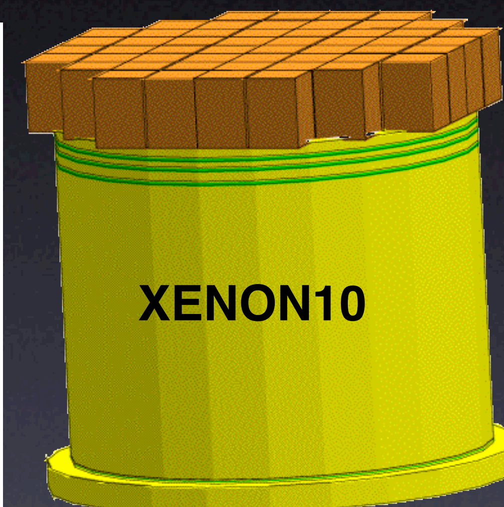
Progress to the XENON10 dark matter detector





Geant4 Simulation



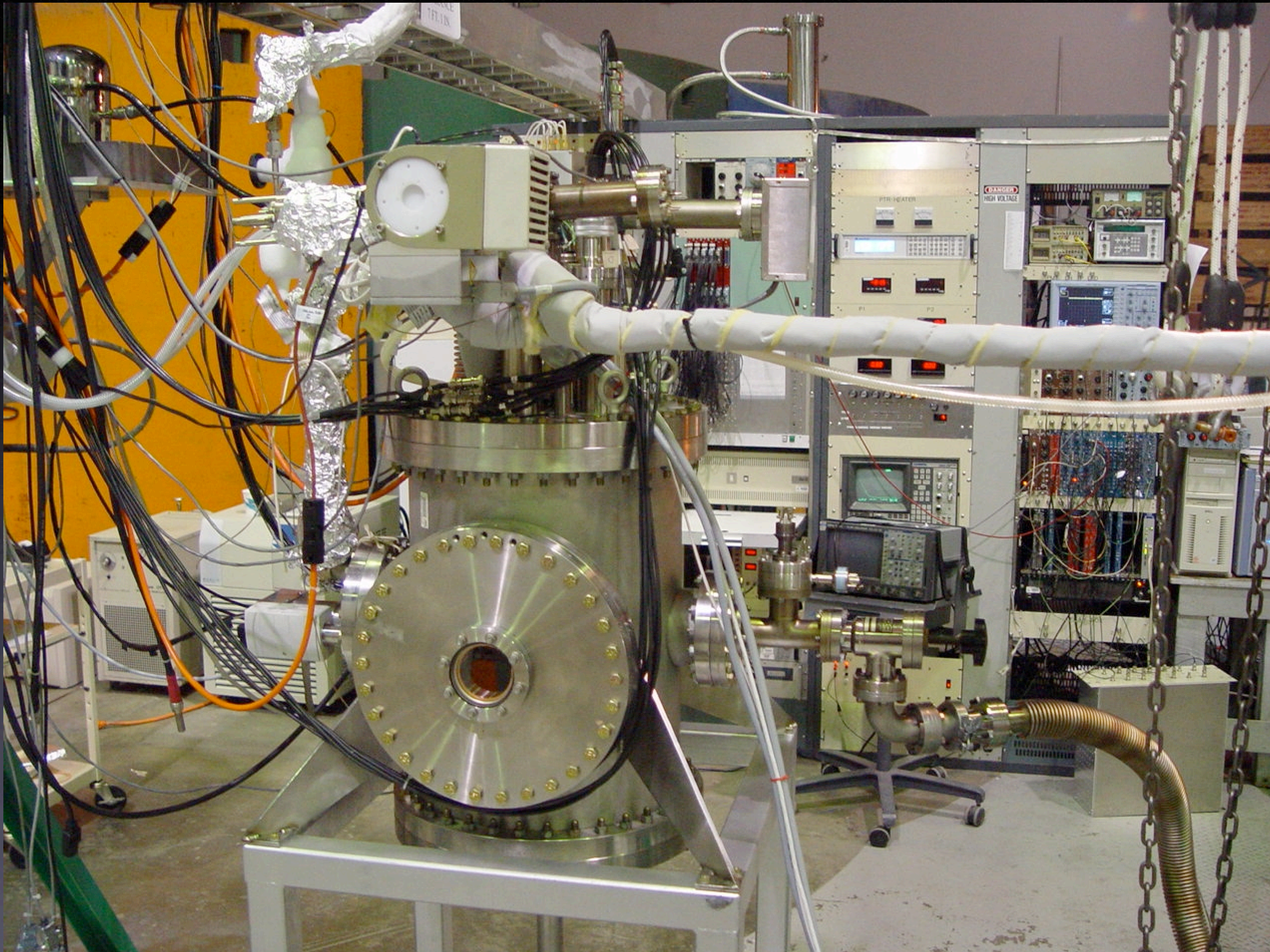


10 keVr equivalent events near the edge

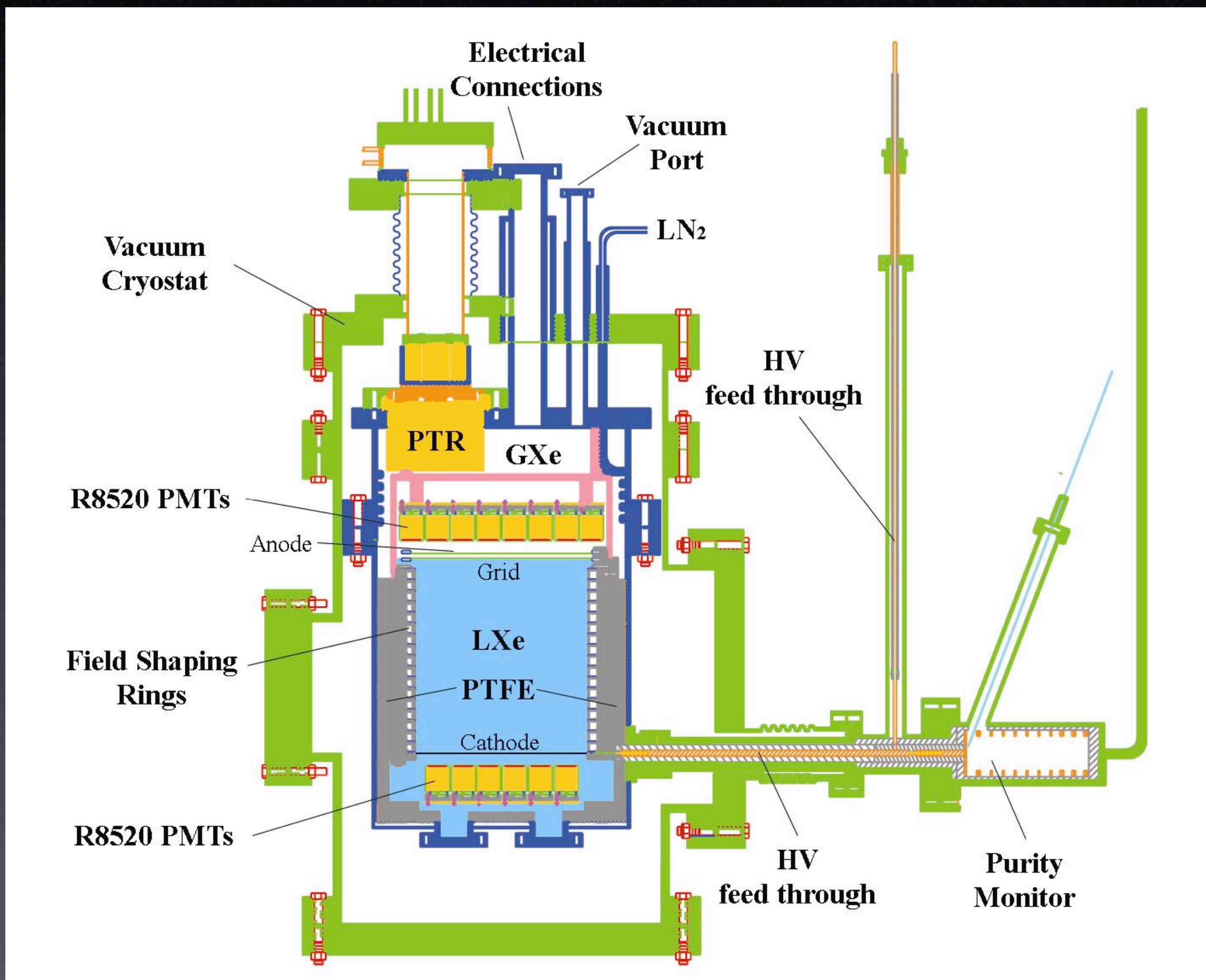
Edge events can be rejected based on reconstructed positions

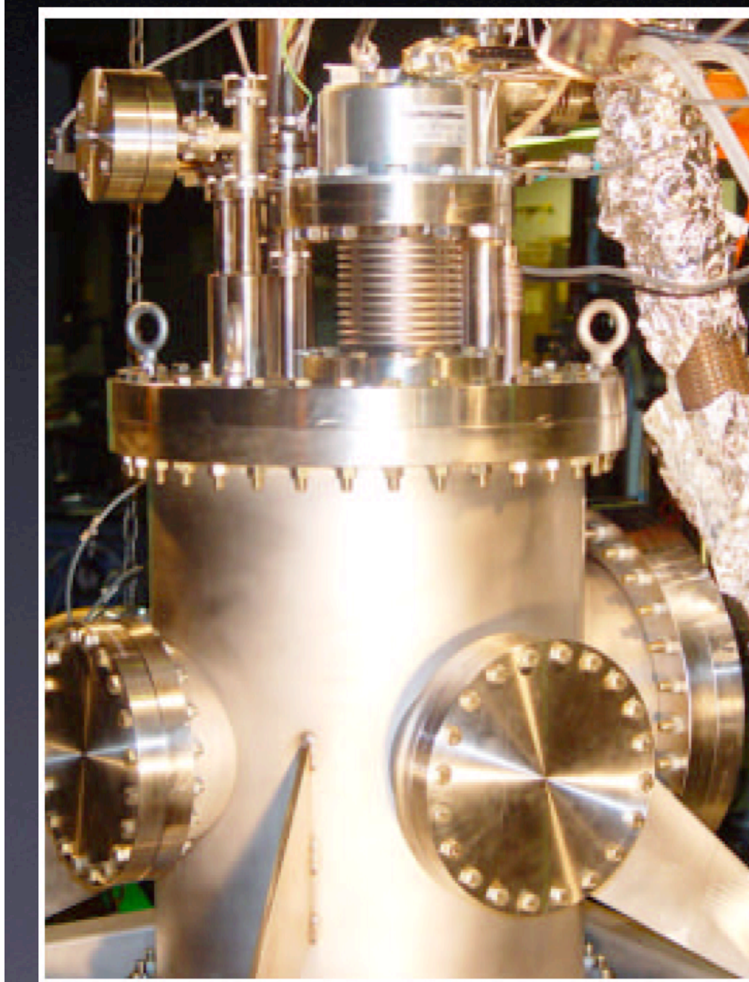
a 3kg prototype with 21 PMTS is running to confirm the XY position sensitivity

XENON10: finish construction, start underground deployment within 2005

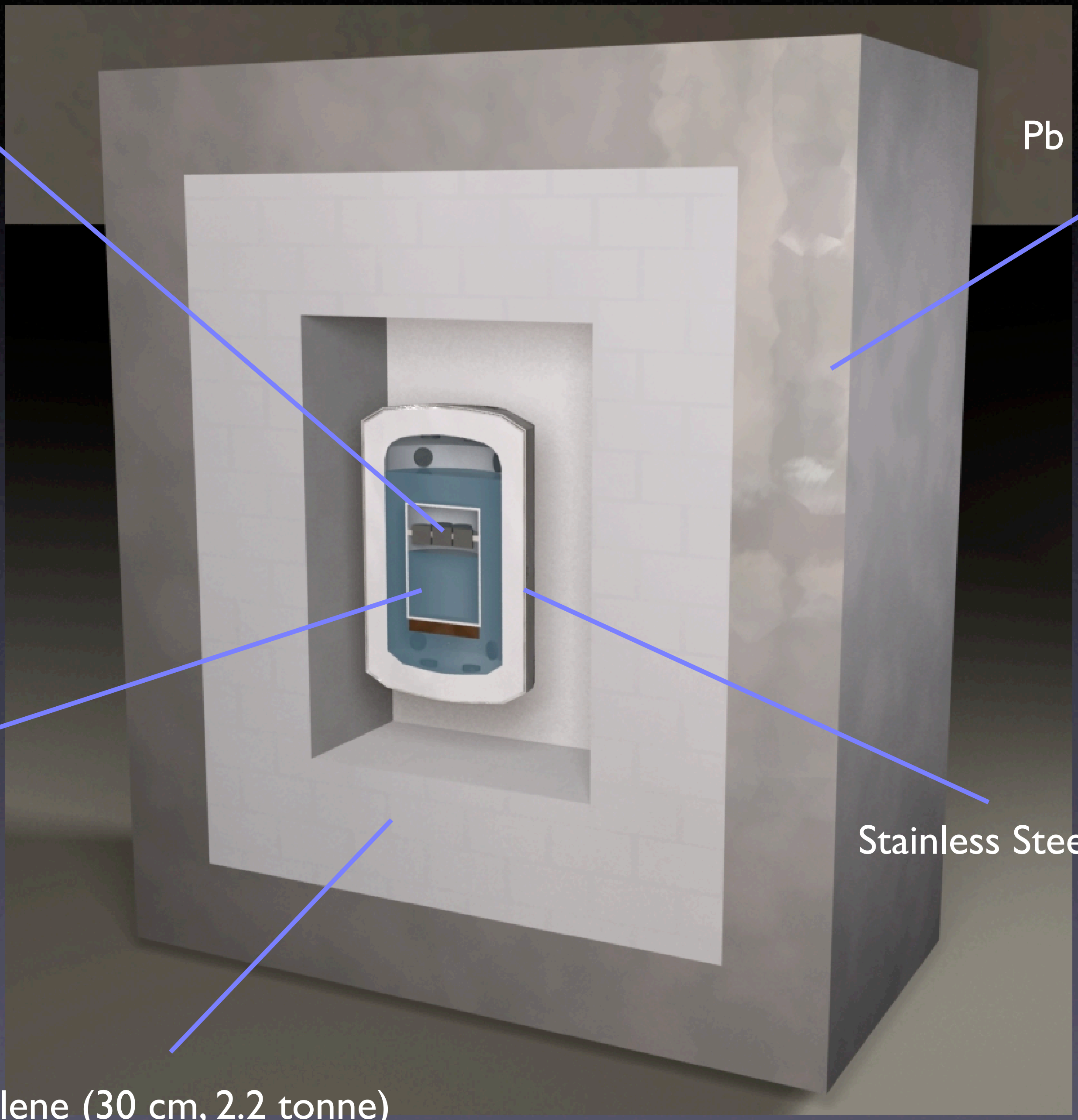

PTR HEATER
P1
P2
DANGER
HIGH VOLTAGE

XENON10 Detector Design





XENON10 Shield Design



XENON10: Background considerations

Gamma/Electron Background

Source	Event Rate (8<E<16 keVee) [mdruee]
PMTs	9
Shaping Ring Resistors	1.6
Stainless Steel Cryostat	12
Polyethylene Shield	9
External Pb Shield	<5
Teflon Walls	<1
Kr-85 (<0.1 ppb)	<6
Pb-210 Brem (Pb shield	<5
Tritium	(Removed by Gas
Total	<40 mdru

Neutron Background

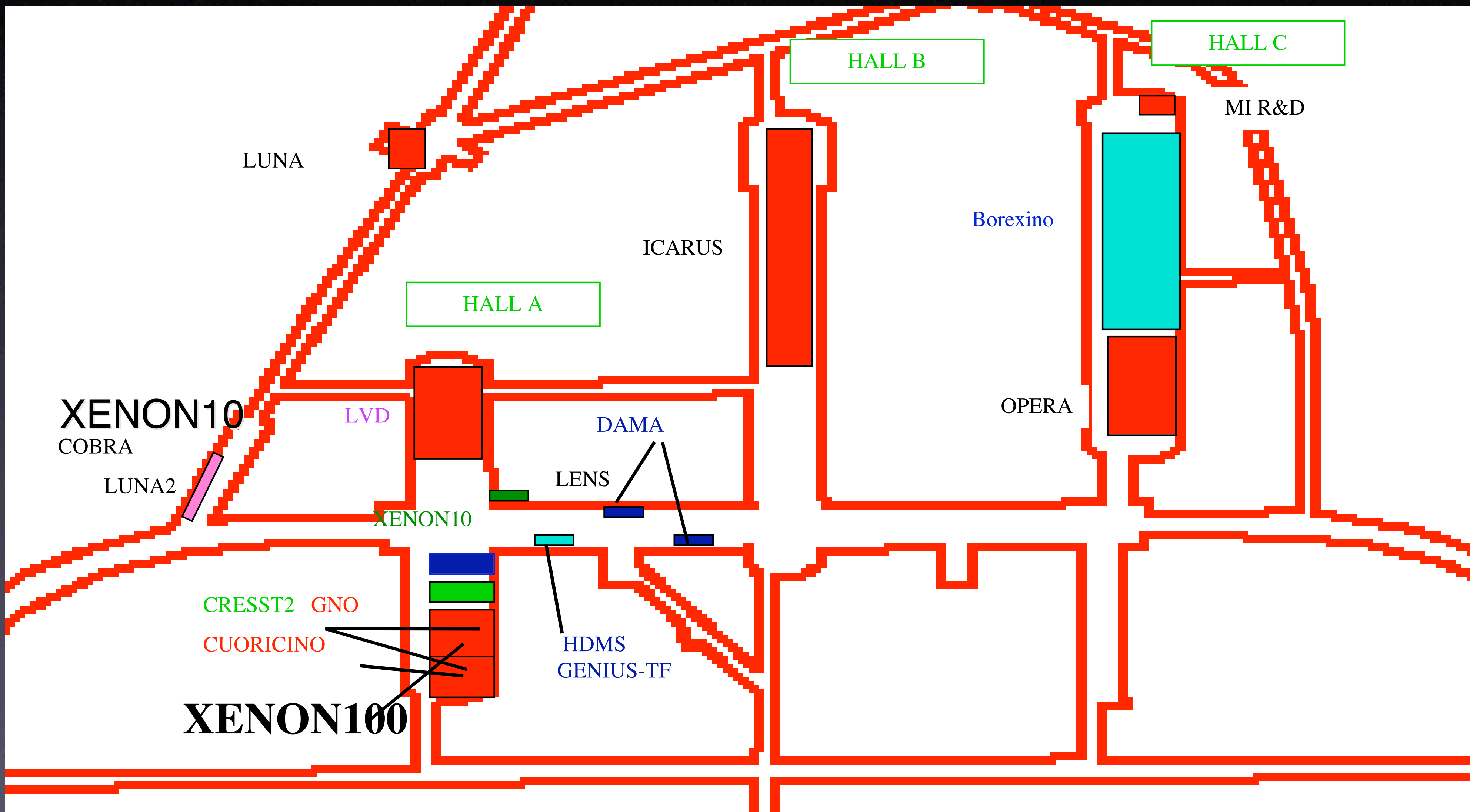
Source	Event Rate (no cuts) (@ 2 keVr) [μdrur]
PMT/Stainless Internal (alpha,n) Neutrons	0.01
(alpha,n) Fission Neutrons from cavern	15
Muon-Induced Neutrons from Pb Shield	10
Muon-Induced Neutrons from Poly Shield	6
High energy Muon-Induced Neutrons from Rock	3
Total	34 μdrur

Requirements to achieve XENON10 projected sensitivity:
Gamma background < 140 mdru; Neutron background < 360 μdrur

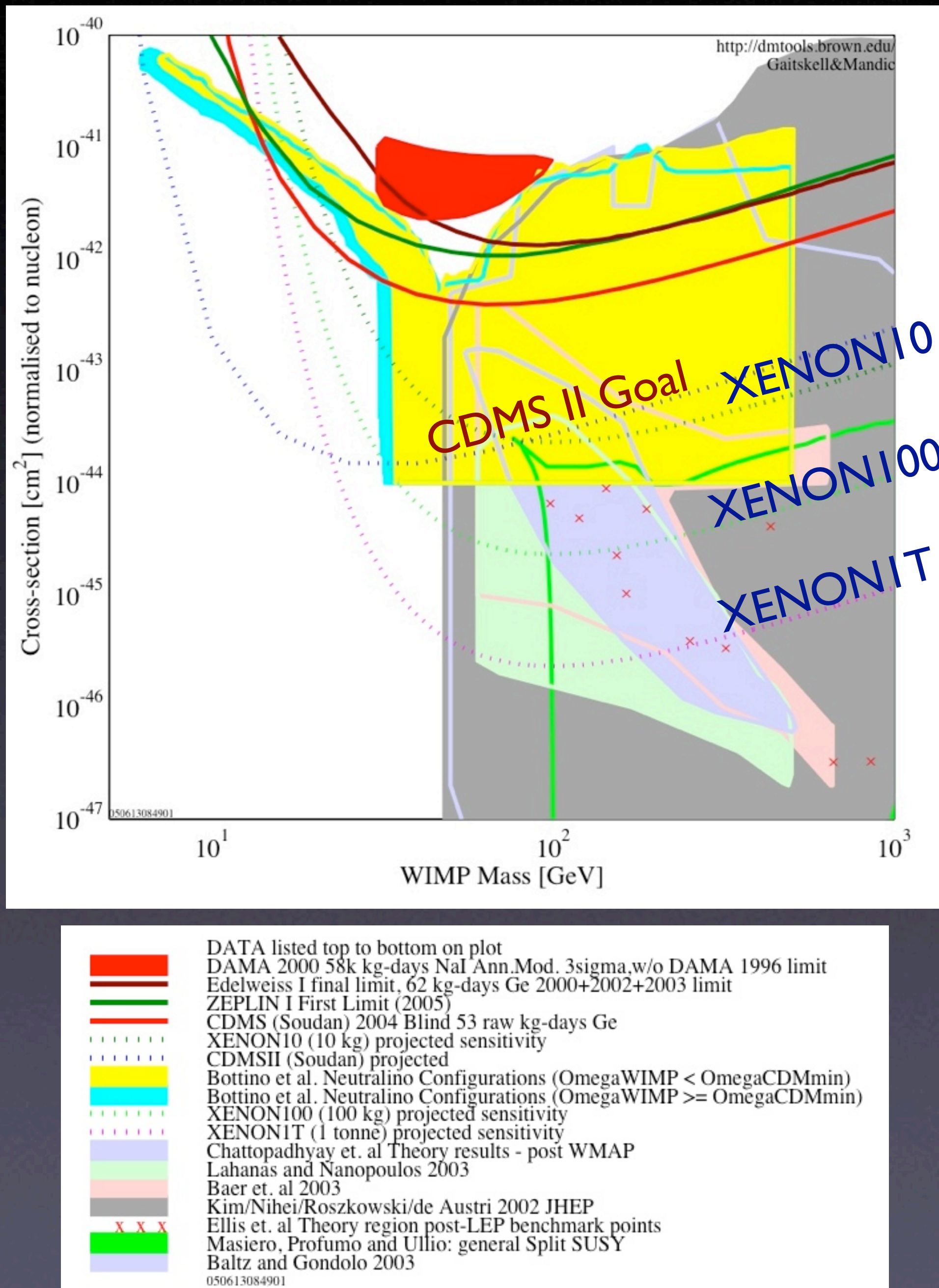
XENON R&D Milestone: Summary

+ PMTs operation in LXe		Achieved
+ > 1 meter λ_e in LXe		Achieved
+ CsI photocathode in LXe w/o Feedback	astro-ph/0407575	Achieved
+ Operating ~few kV/cm electric field	astro-ph/0502279	Achieved
+ Electron extraction to gas phase		Achieved
+ Efficient & Reliable Cryogenic System		Achieved
+ Electron/Alpha recoil discrimination		Achieved
+ Nuclear recoil Scintillation Efficiency (10-55 keVr)	astro-ph/0503621	Achieved
+ Nuclear recoil Ionization Yield and Field Dependence		Achieved
+ Electron/Nuclear recoil discrimination		Achieved
+ Kr removal for XENON10		In progress
+ Electric Field / Light Collection Simulations		In progress for XENON10
+ Background Simulations		In progress for XENON10
+ Materials Screening for XENON10		In progress (SOLO Facility)
+ Design of XENON10 System		In Progress
+ Low Activity PMTs		Achieved

XENON10 at Gran Sasso National Lab



Summary



- Two important properties (scintillation and ionization) measured for the dual phase xenon dark matter detector; Background discrimination capability demonstrated with a small prototype
- Design/Fab/Calibration of XENON10 will complete in 2005; Move/Install underground (Gran Sasso) in the end of this year
- Physics run start in 2006, XENON10 sensitivity curve corresponding to 2 dm-evts/10kg/month
- Design XENON100 in 2006, based on performance of XENON10. Complete XENON100 in 2007