XENON
Dark Matter Project

XENON

First Results from the XENON10 Experiment at Gran Sasso

Elena Aprile
Columbia University
http://xenon.astro.columbia.edu

The XENON Project: Overview

Goal: detection of WIMPs via elastic scattering on Xe nuclei. Phased program to reach sensitivity to $\sigma \sim 10^{-46}$ cm^2 with a 1 ton scale low background detector (XENON1T). The proposed next phase is at the 100 kg scale to allow us to probe $\sigma \sim 10^{-45}$ cm^2 before 2009. Current XENON10 limit is 8.8×10^{-44} cm^2 for 100 GeV WIMPs.

Method: two- phase (liquid/gas) Time Projection Chamber (TPC) to simultaneously measure the ionization and scintillation produced by low energy recoils in pure LXe (threshold < 10 keVr) and to reject >99.5% of gamma/beta induced background. Additional background rejection provided by 3D event localization, LXe self-shielding, multiple scatter signature, plus external shielding.

Project History:

2002: R&D for XENON funded by NSF

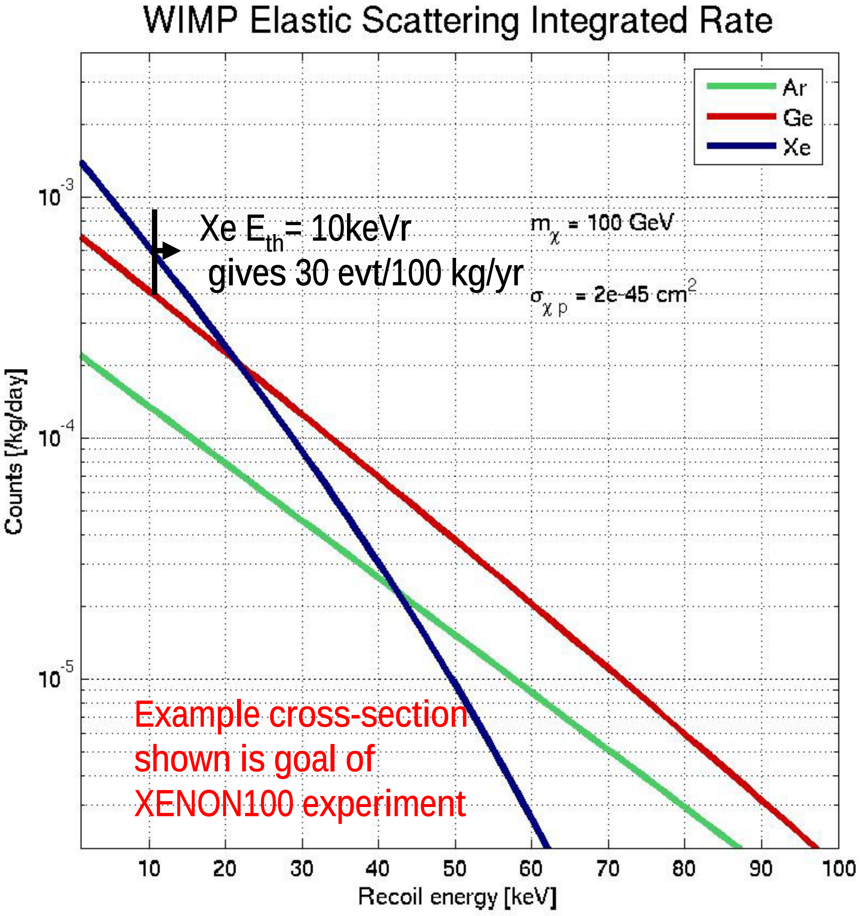
2003: two-phase TPC demonstrated. *Aprile et al.IEEE Trans. Nucl. Sci., vol.51, no.5 (2004) 1986.*

2004: scintillation response of LXe to neutrons measured. *Aprile et al. Phys. Rev. D, 72, 072006 (2005)*

2005: ionization yield of neutron recoils in LXE measured. *Aprile et al. Phys.Rev.Lett. 97 081302 (2006)*

2006-2007: 15 kg detector (XENON10) developed and installed underground at LNGS (NSF and DOE support). WIMP search data taken from Sep 2006 to Feb 2007. Results reported at the APS April meeting this year. *Angle et al. astro-ph/0706.0039*

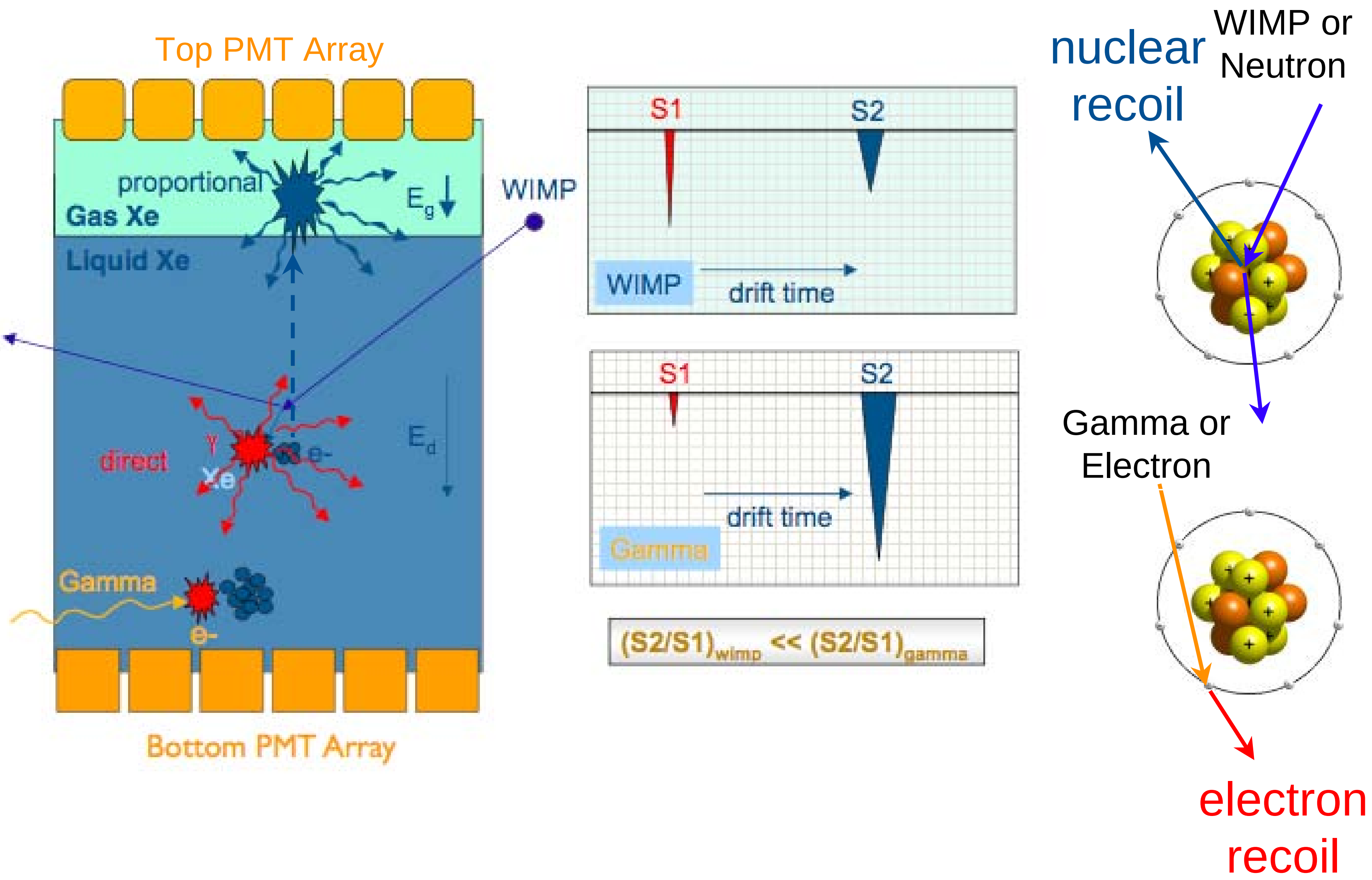
Liquid Xenon for Dark Matter Detection



- Large A (~ 131) good for SI $\sigma \sim A^2$ but need low threshold to avoid Form Factor suppression
- ^{129}Xe **(26.4%)** and ^{131}Xe **(21.2%)** good for SD σ
- No radioactive isotopes - Kr85 can be reduced to ppt
- LXe high stopping power (Z=54, ρ=3 g/cc) for compact, self-shielding geometry
- LXe efficient and fast scintillator (yield ~ 80% of NaI)
- LXe good ionization yield (W=15.6 eV); high e-mobility and saturated e-drift velocity
- Modest quenching factor for NR (~0.2)
- Background Rejection: Simultaneous Charge and Light detection (> 99.5%) plus 3D event localization and LXe self-shielding
- 'Easy' cryogenics at ~165K
- Inert, not flammable, very good dielectric
- Modest cost for large mass detector

The XENON Detector Concept

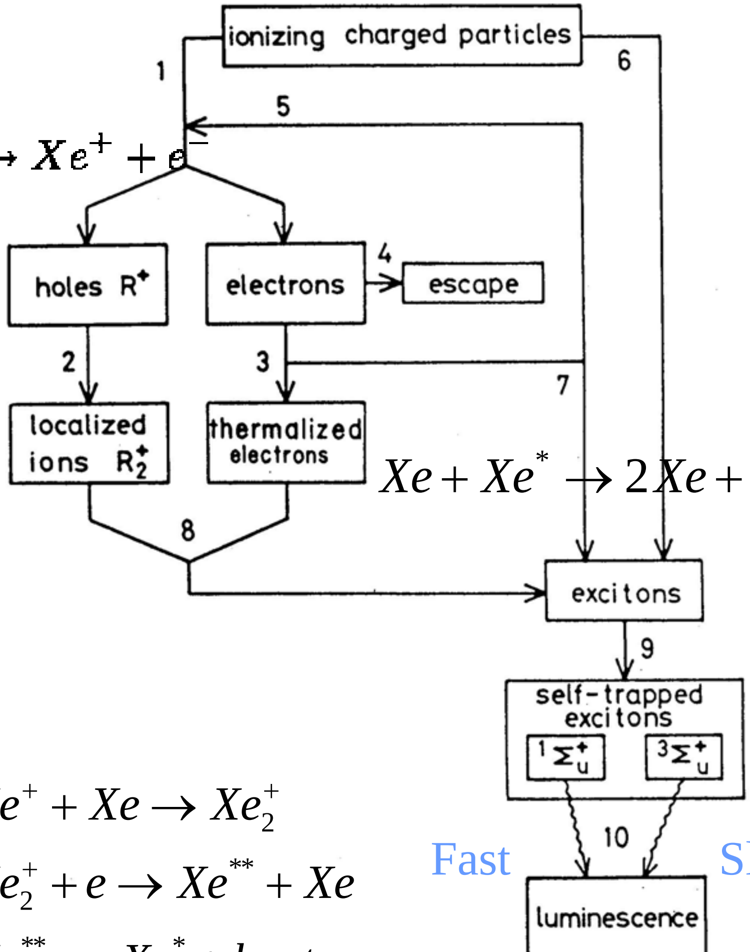
A two-phase Time Projection Chamber with 3-D Event Imaging



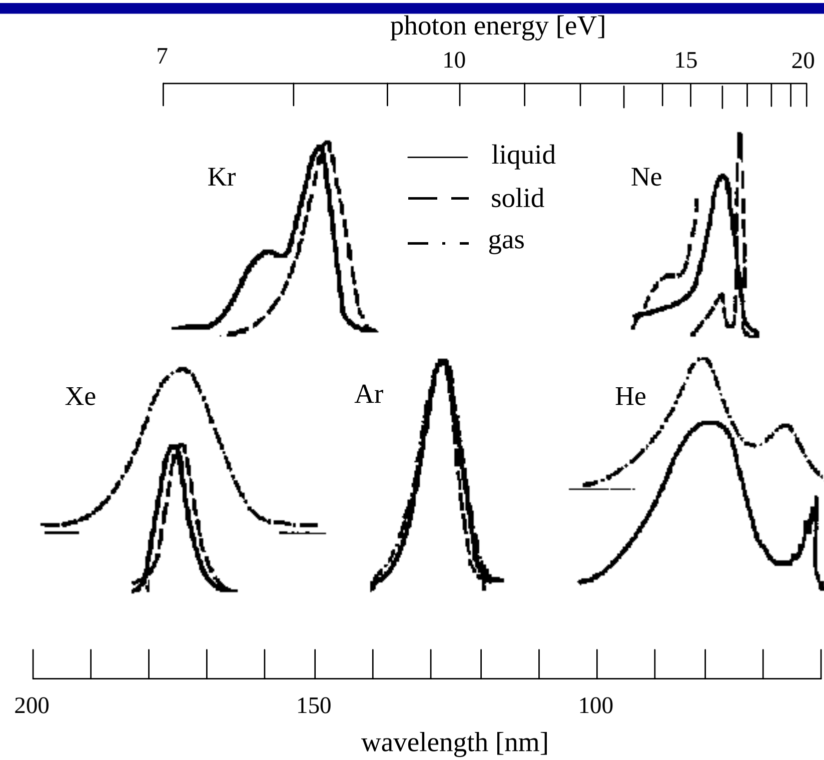
Ionization/Scintillation Mechanism in Noble Liquids

Kubota et al. 1979, Phys. Rev.B

$$Xe \rightarrow Xe^{+} + e^{-}$$



$$Xe + Xe^{*} \rightarrow 2Xe + h\nu$$



$$Xe^{+} + Xe \rightarrow Xe_2^{+}$$

$$Xe_2^{+} + e \rightarrow Xe^{**} + Xe$$

$$Xe^{**} \rightarrow Xe^{*} + heat$$

$$Xe + Xe^{*} \rightarrow Xe_2^{*} \rightarrow 2Xe + h\nu$$

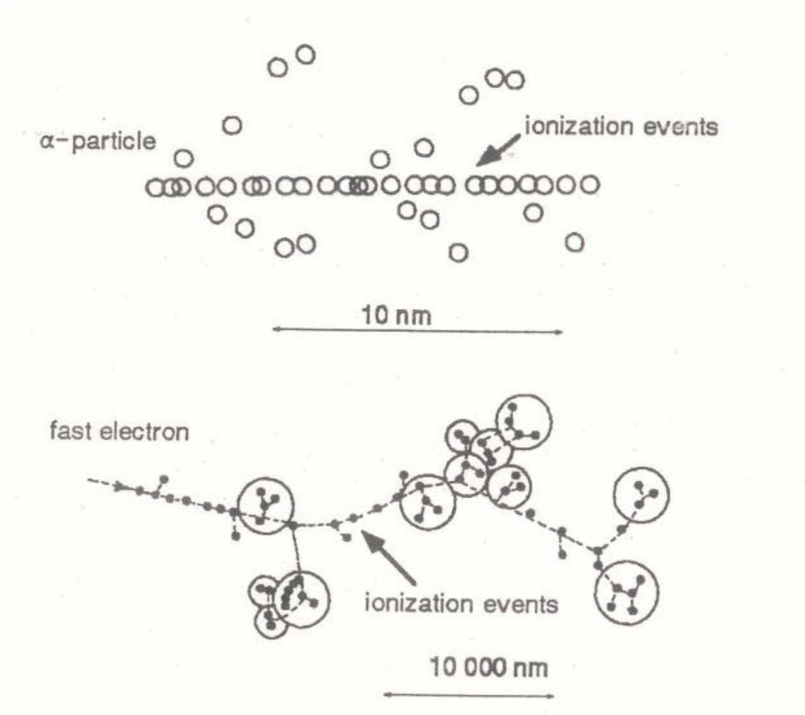
$$\lambda \sim 128_{LAr}$$

$$\lambda \sim 175_{LXe}$$

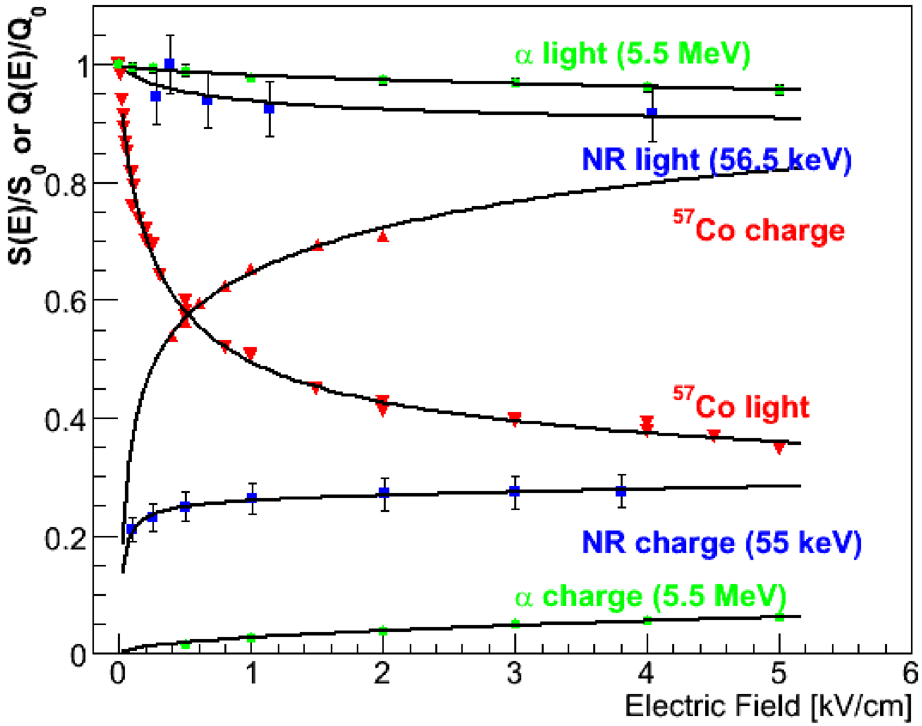
$$\lambda \sim 77.5_{LNe}$$

Charge and Light response of different particles in LXe

Charge/Light (electron) >> Charge/Light (non relativistic particle)



Distribution of ionization around the track of a high energy a-particle or electron



Aprile et al., Phys. Rev. D 72 (2005) 072006

The XENON10 Collaboration

Columbia University

Elena Aprile (Spokesperson), Karl-Ludwig Giboni, Maria Elena Monzani, Guillaume Plante, Roberto Santorelli and Masaki Yamashita

Brown University

Richard Gaitskell, Simon Fiorucci, Peter Sorensen, Luiz DeViveiros

Case Western Reserve University

Tom Shutt, Eric Dahl, John Kwong, and Alexander Bolozdynya

Lawrence Livermore National Laboratory

Adam Bernstein, Norm Madden and Celeste Winant

Rice University

Uwe Oberlack , Roman Gomez and Peter Shagin

Yale University

Daniel McKinsey, Richard Hasty, Angel Manzur, Kaixuan Ni

RWTH Aachen University, Germany

Laura Baudis, Jesse Angle, Joerg Orboeck, Aaron Manalaysay

Laboratori Nazionali del Gran Sasso, Italy

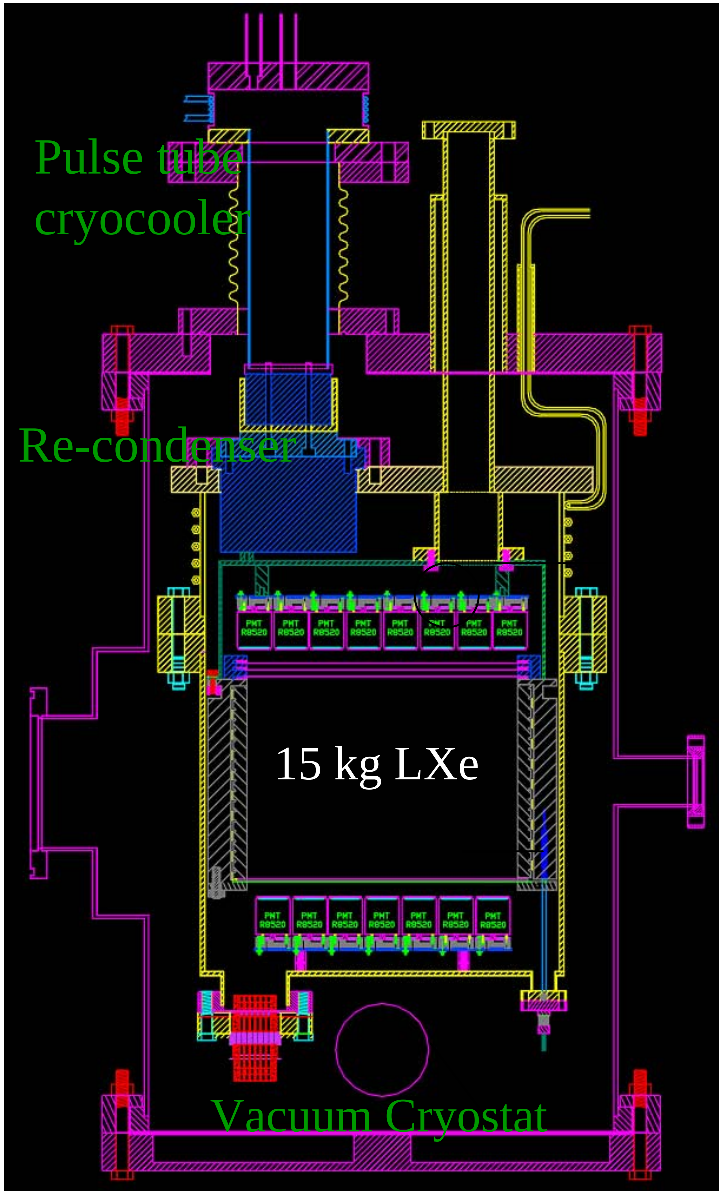
Francesco Arneodo, Alfredo Ferella*

University of Coimbra, Portugal

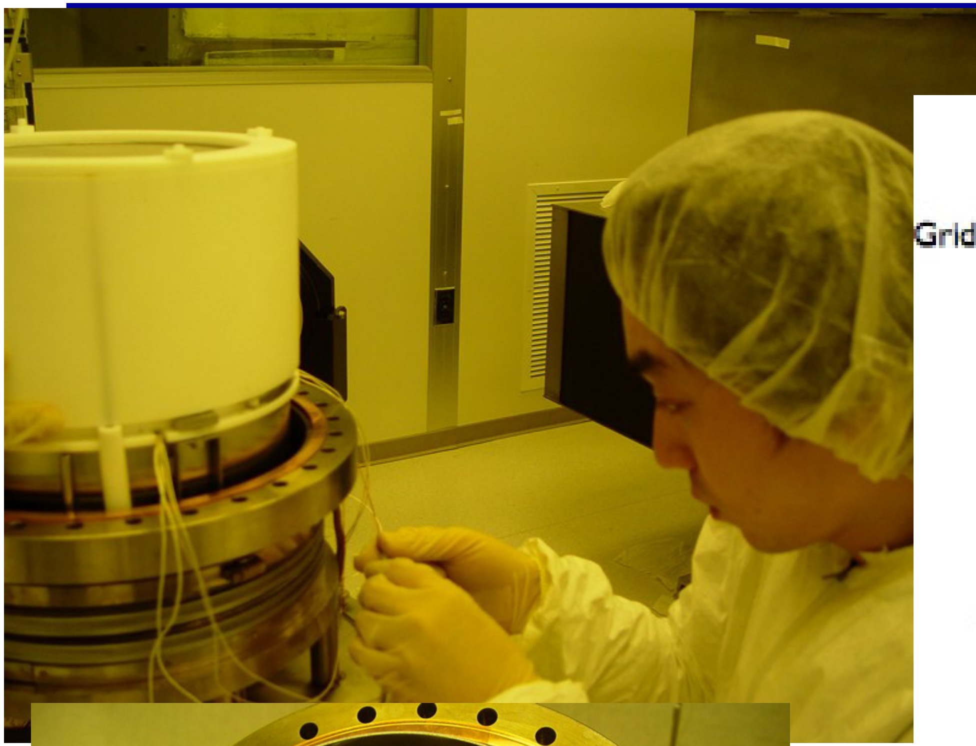
Jose Matias Lopes, Luis Coelho, Luis Fernandes, Joaquim Santos

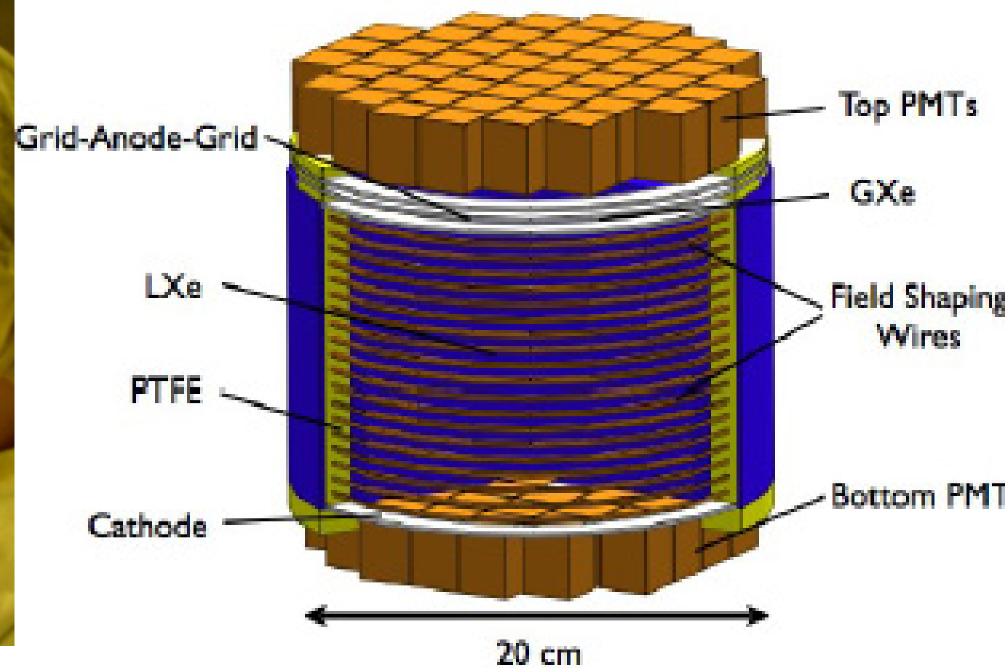

Gran Sasso Lab – June 2006

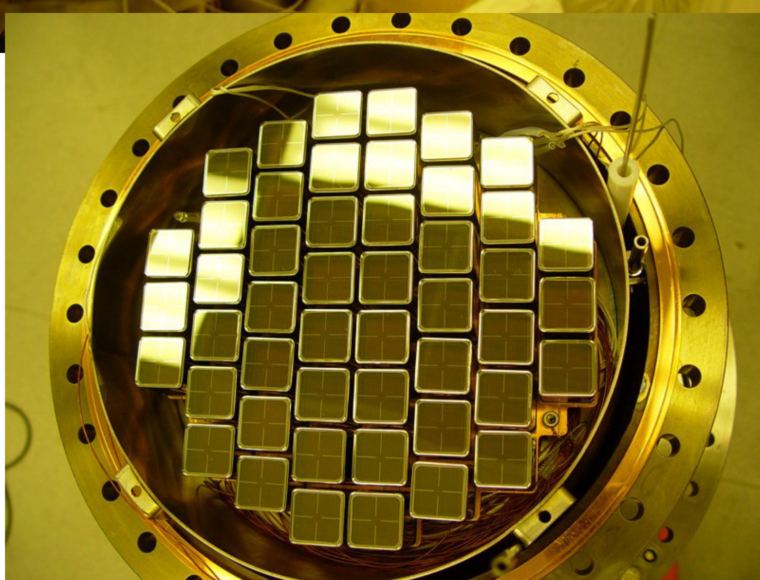
The XENON10 Detector

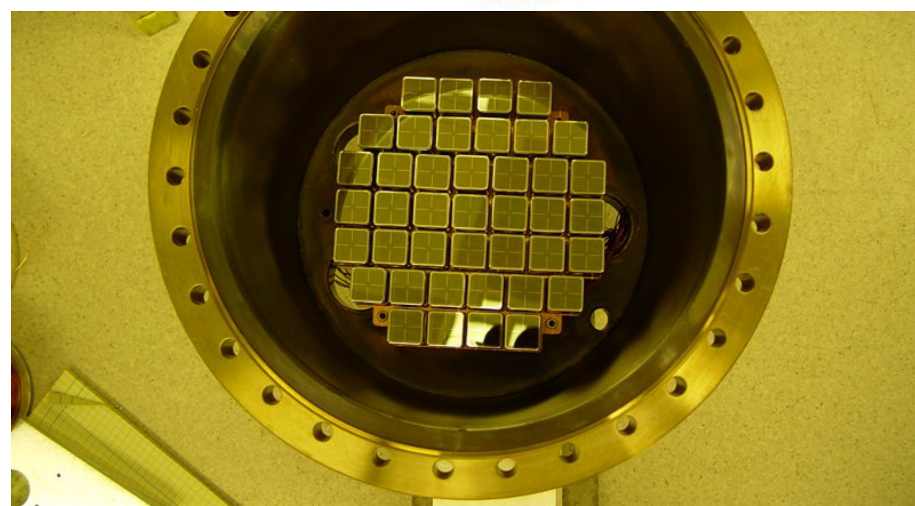


XENON10: some details



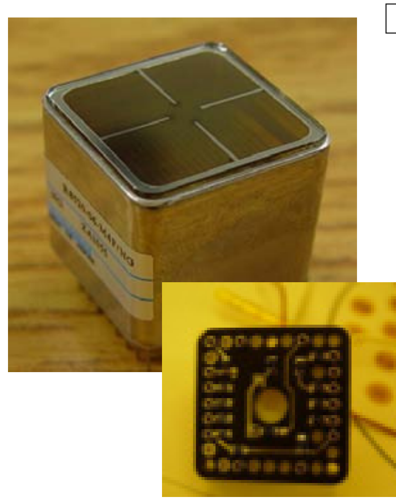


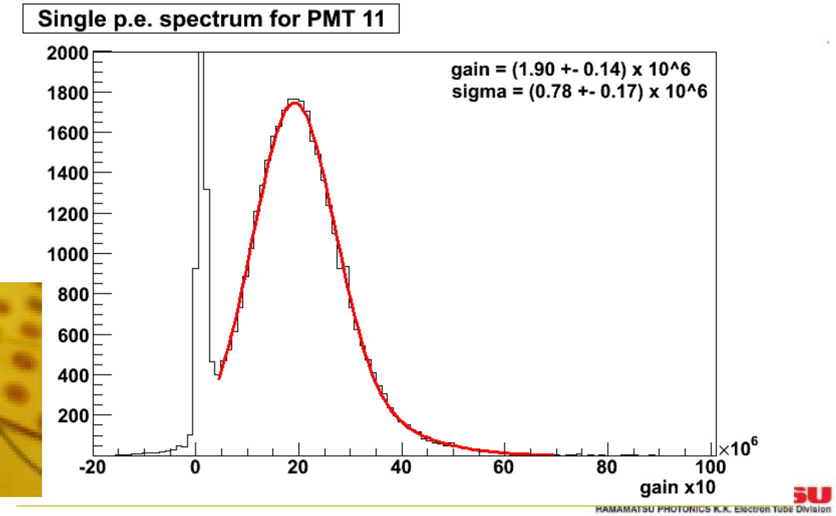


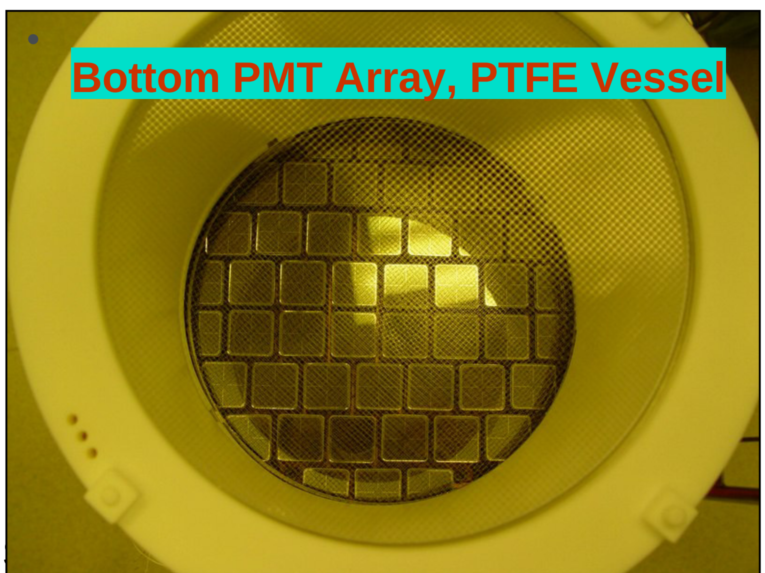


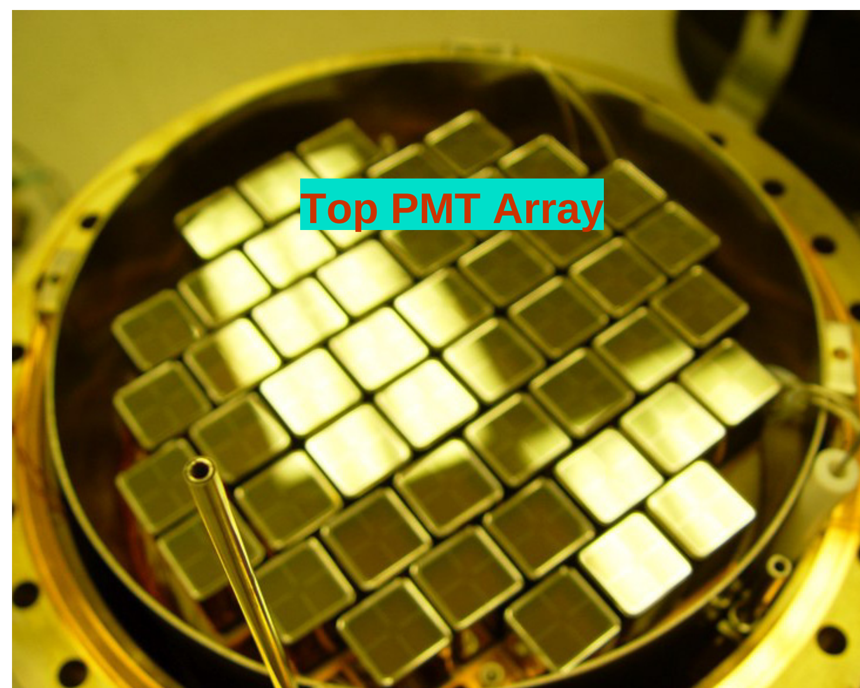
The XENON10 Photomultipliers

- Hamamatsu R8520 1’’×3.5 cm
- bialkali-photocathode Rb-Cs-Sb,
- Metal Channel; 10 dynodes
- Quartz window; at -100ºC and 5 bar
- Quantum efficiency > 20% @ 178 nm
- Custom HV divider on Cirlex base



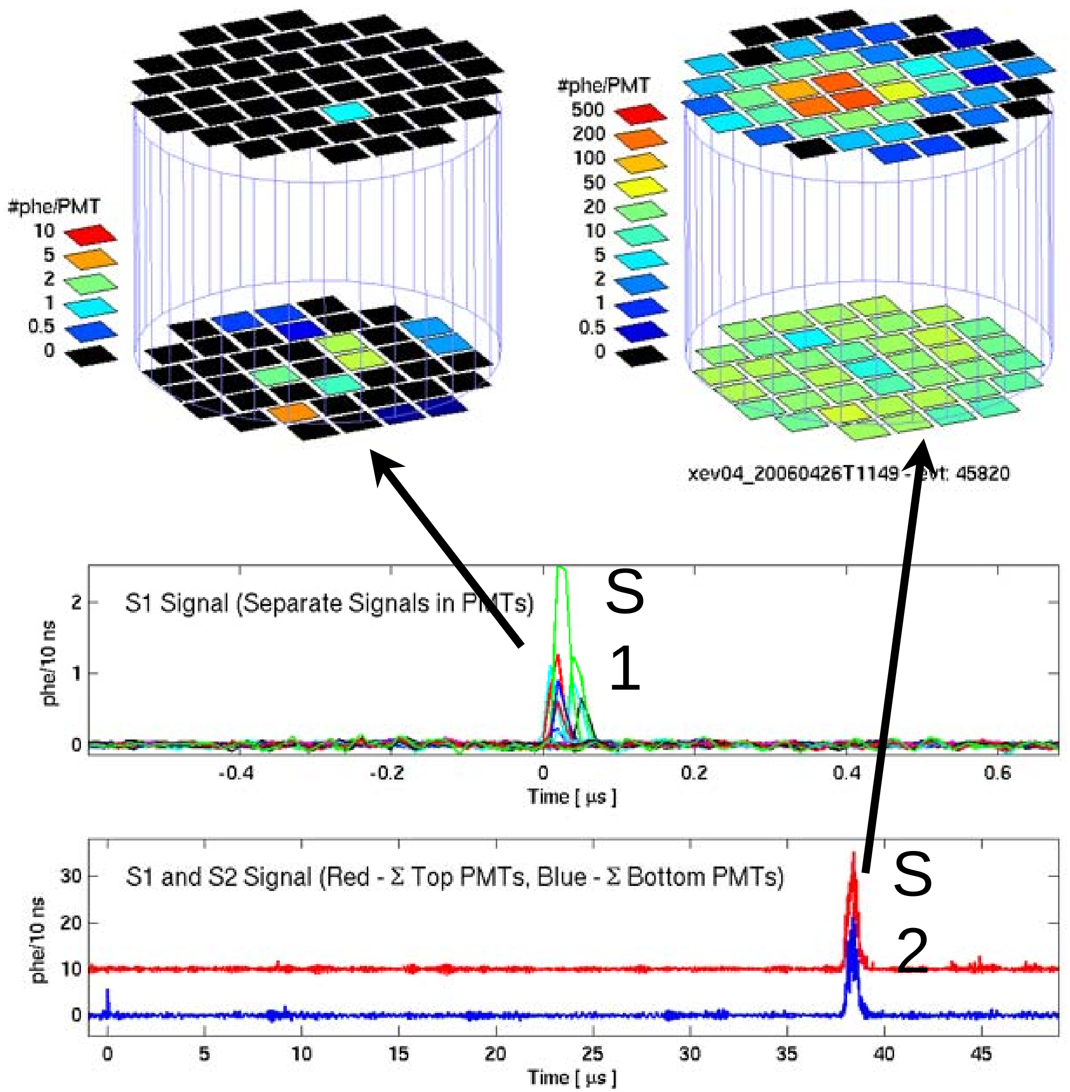




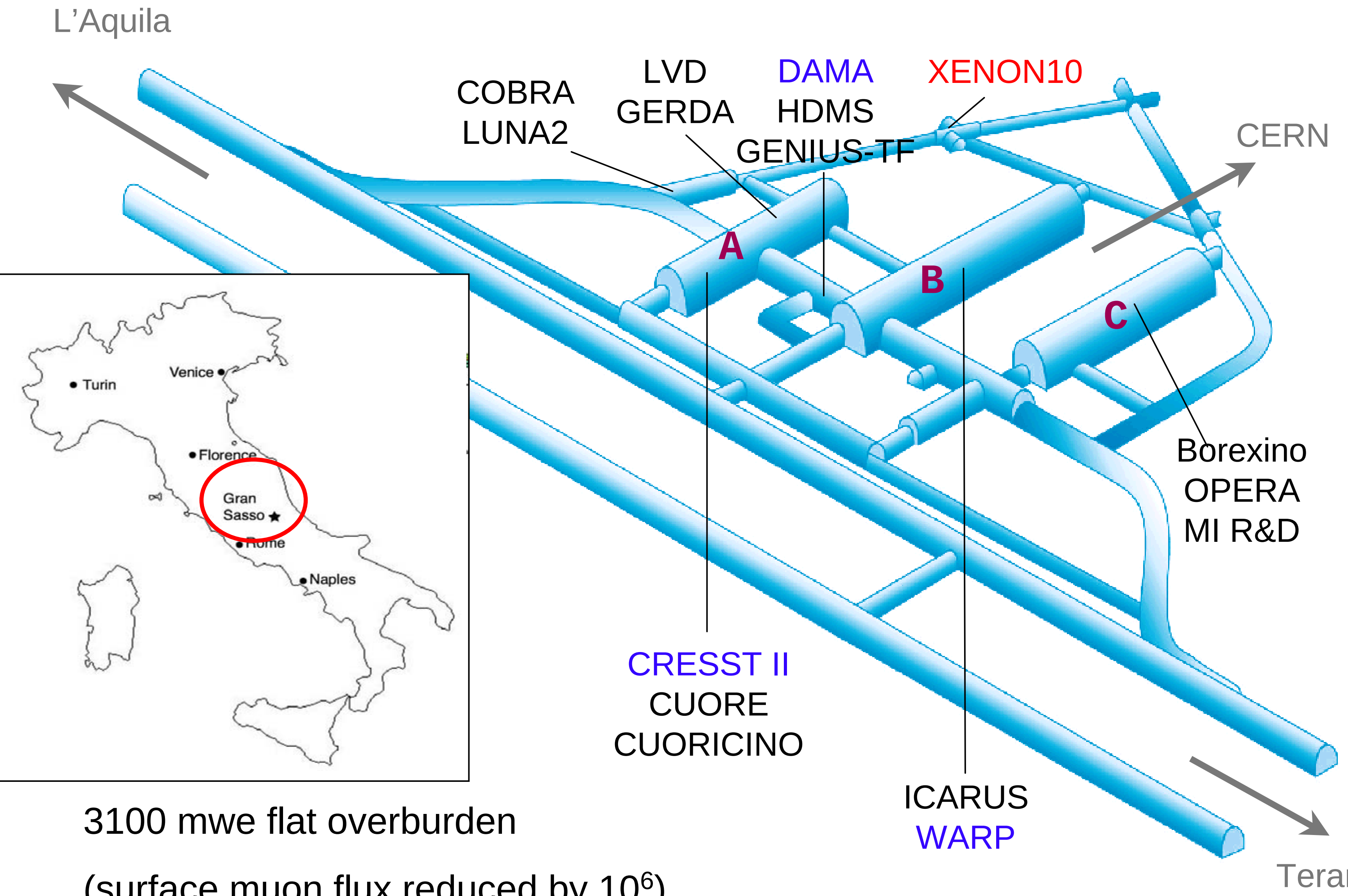


Signals from XENON10

S1 S2



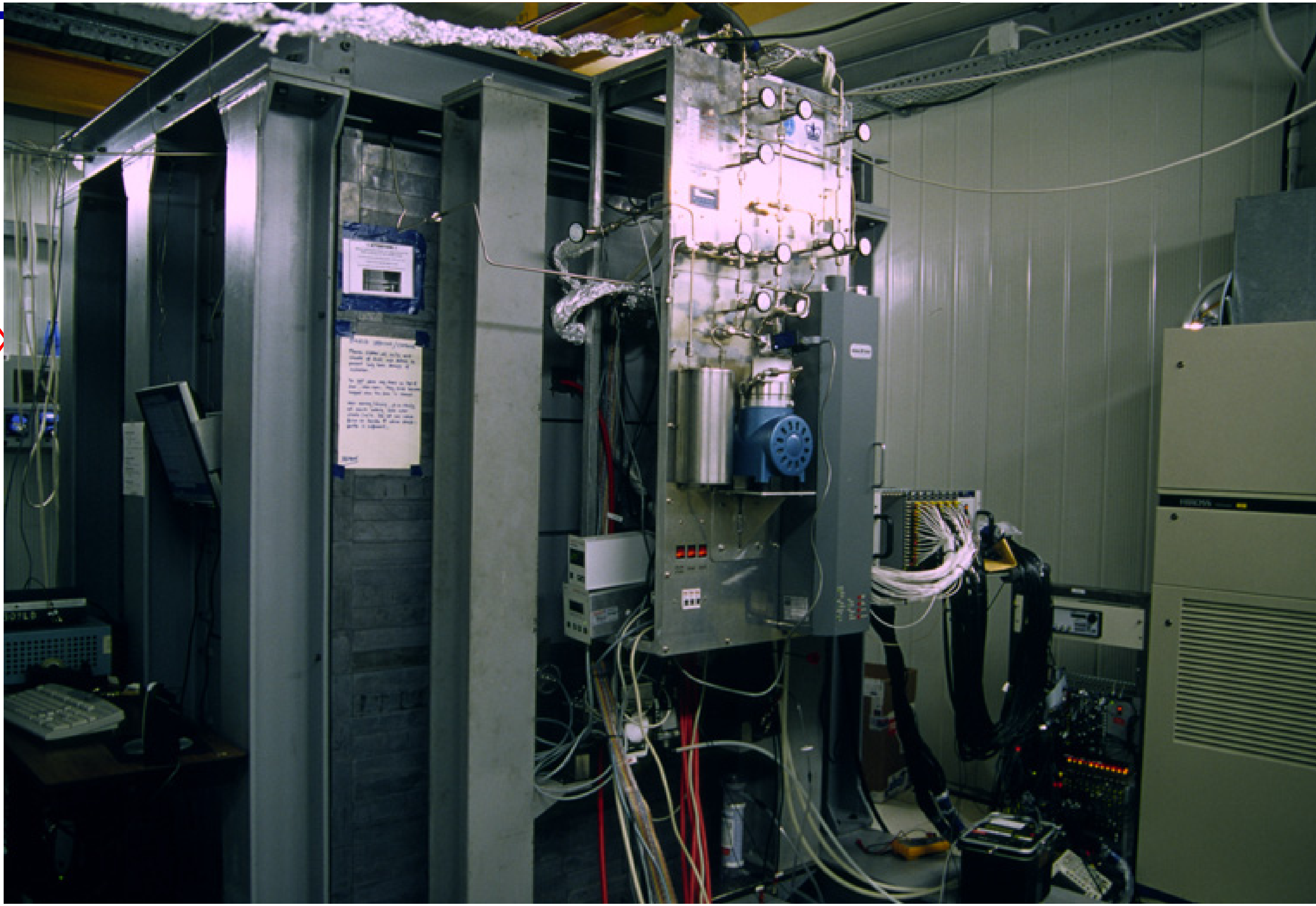
XENON10 @ LNGS



3100 mwe flat overburden

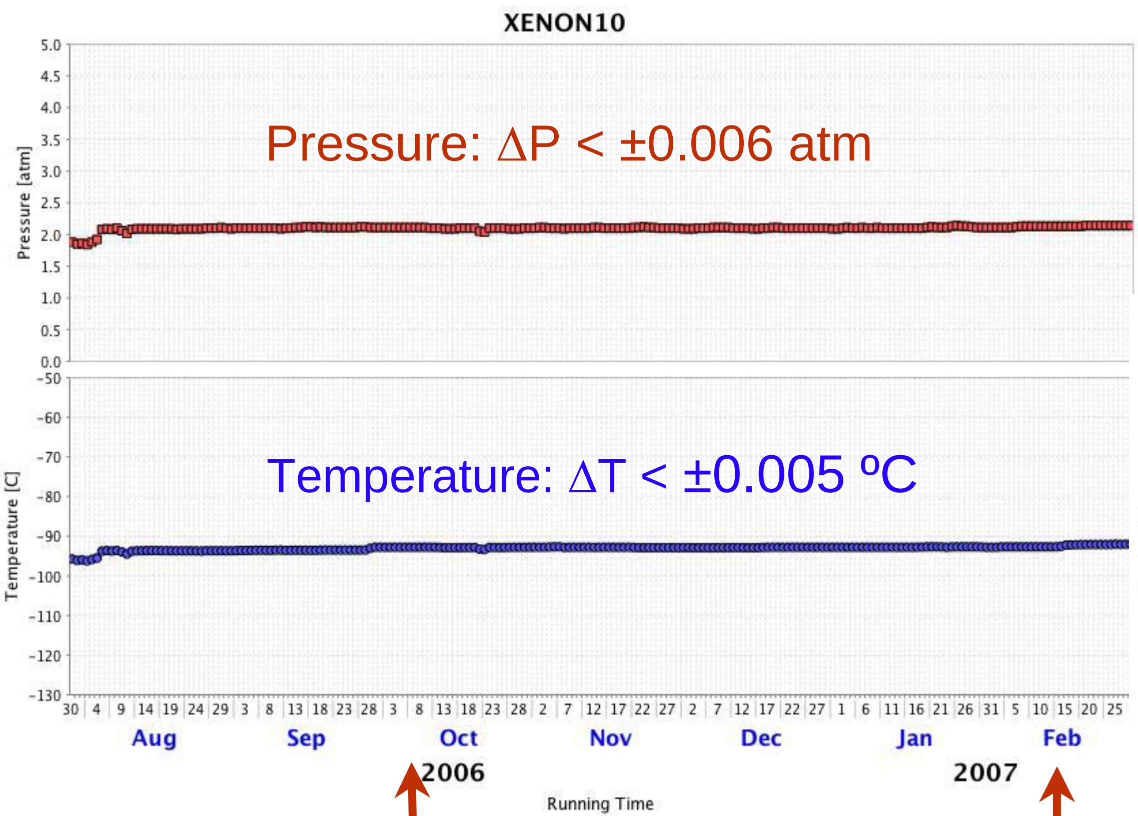
(surface muon flux reduced by 10^6)

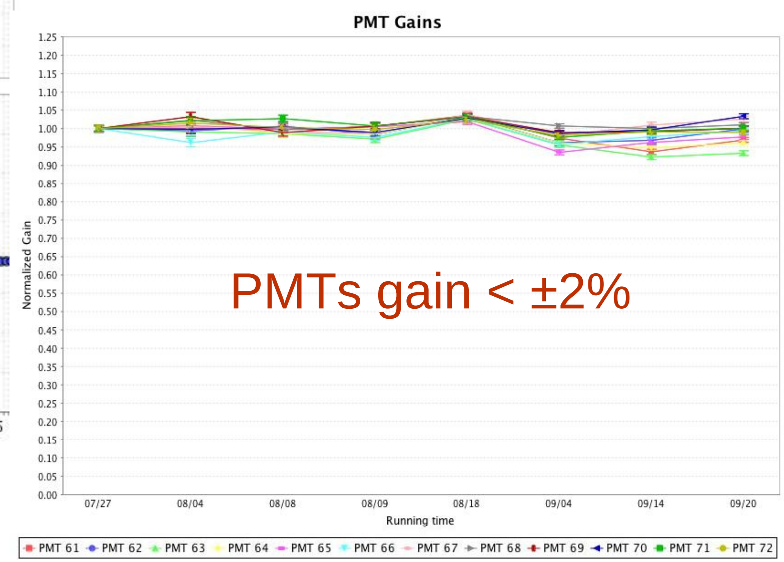
The XENON10 Shield



XENON10 Operating Underground

Detector operation and performance shows excellent stability over 10 months



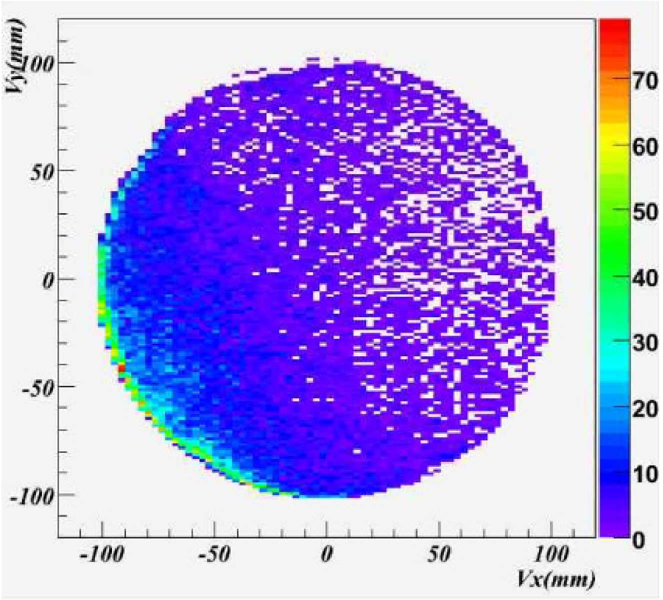


Start of Blind WIMP Search **End of Blind WIMP Search**

XENON10 Gamma Calibration with Radioactive Sources

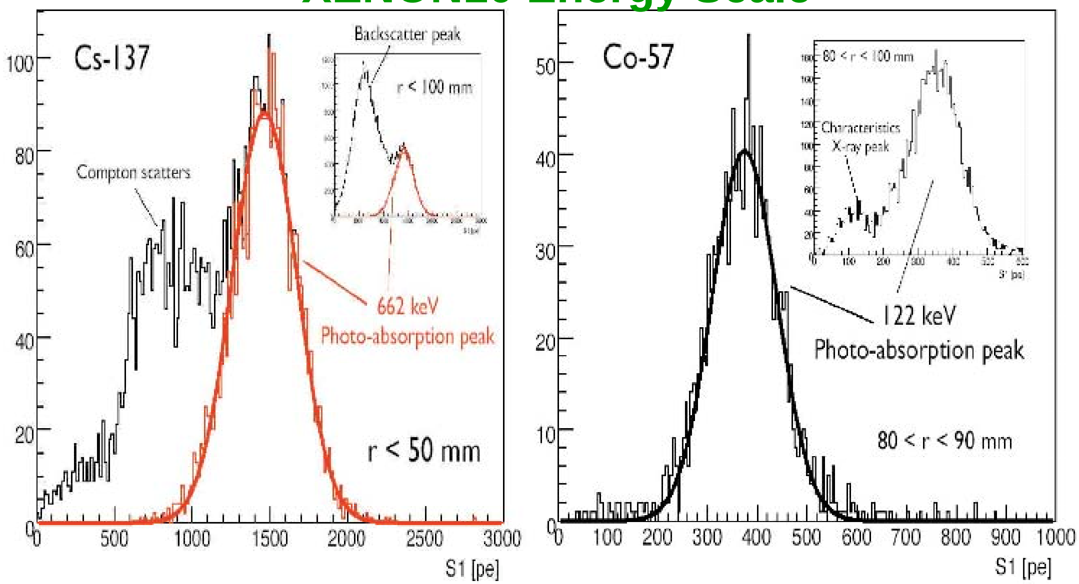
[57]Co, [137]Cs Gamma Sources introduced in shield

- Determine electron lifetime: (1.8±0.4) ms => << 1ppb (O_2 equiv.) purity
- Determine energy scale from primary light: 2.25 p.e./keV at 662 keV and 3.0 p.e./keV
- Test XY position reconstruction algorithms and vertex resolution:
- Determine (μ , σ) of Electron Recoil band→ Background Rejection

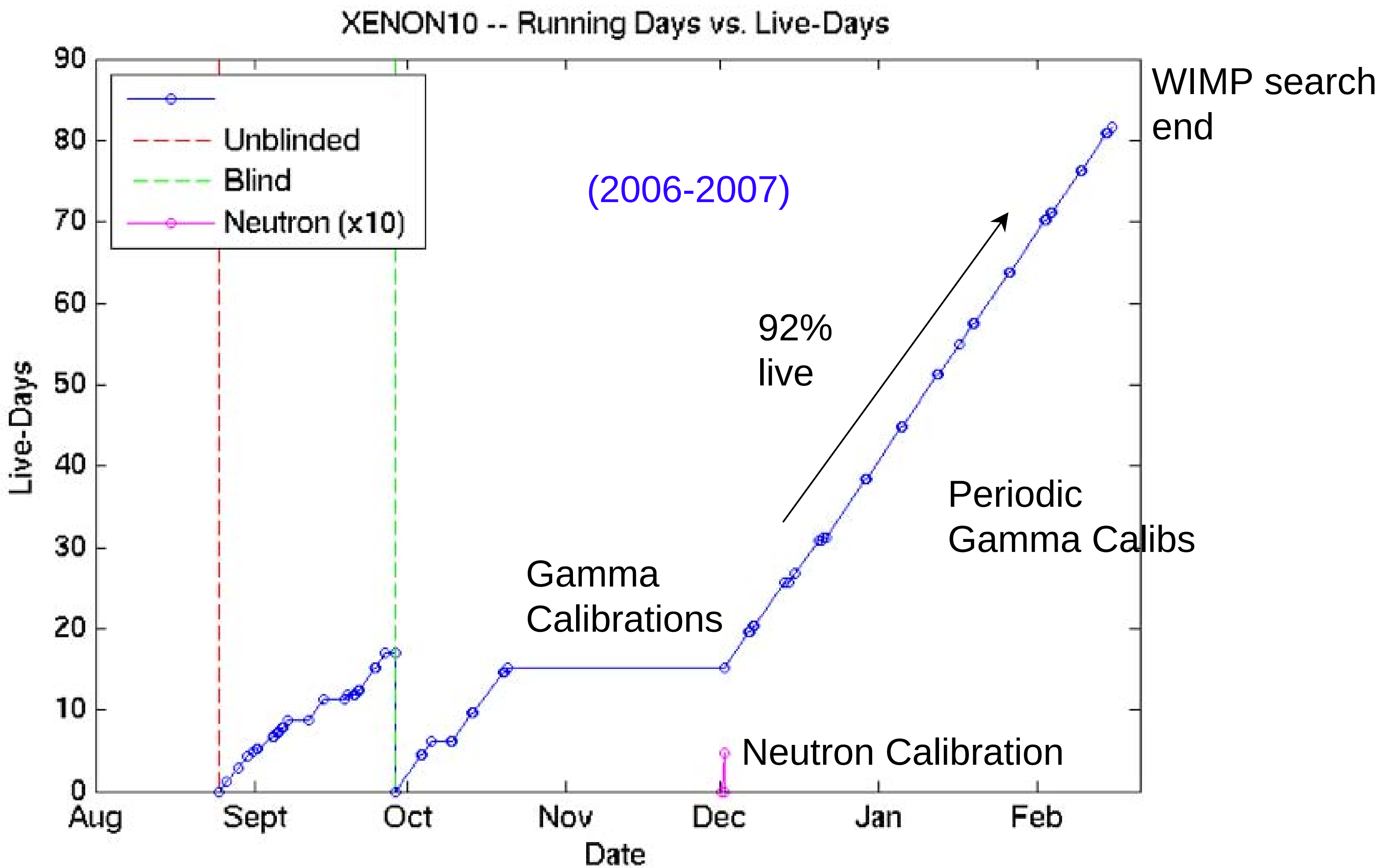


reconstructed source position ([137]Cs)

XENON10 Energy Scale



XENON10 Live-Time / Dark Matter Run Stability



High Statistics Gamma Calibrations + Neutron Calibration

NON BLIND WIMP search data ~20 live days (Sept) + 20 live days (Oct-Feb)

BLIND Analysis of 60 live-day (Oct-Feb) of WIMP Search data

Energy Scale Calibration

energy of nuclear recoils (NRs)

measured signal in # of pe

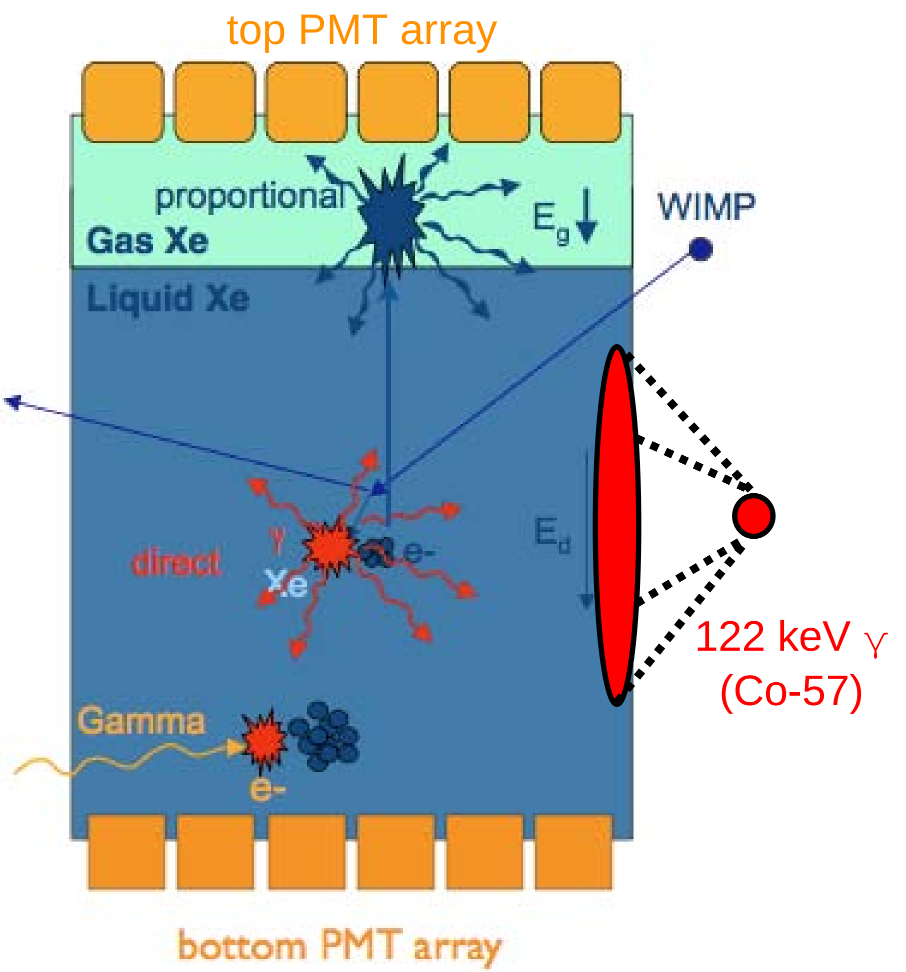
light yield for 122 keV γ in pe/keVee

$$E_{nr} = S1/L_y/\mathcal{L}_{eff} \cdot S_{er}/S_{nr}$$

relative scintillation efficiency of NRs to 122 keV γ's at zero field (~0.19)

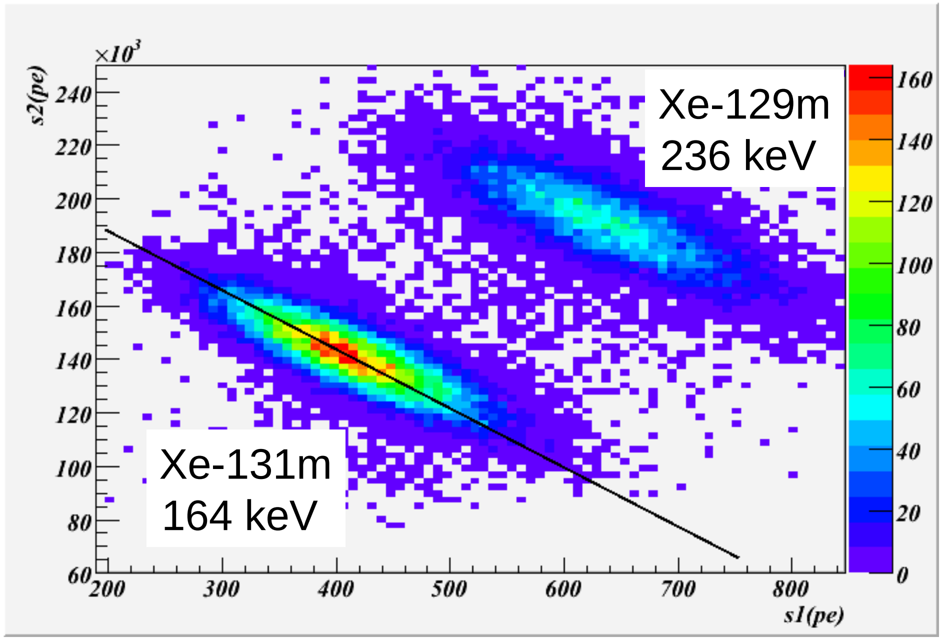
quenching of scintillation yield for 122 keV γ's due to drift field (0.54)

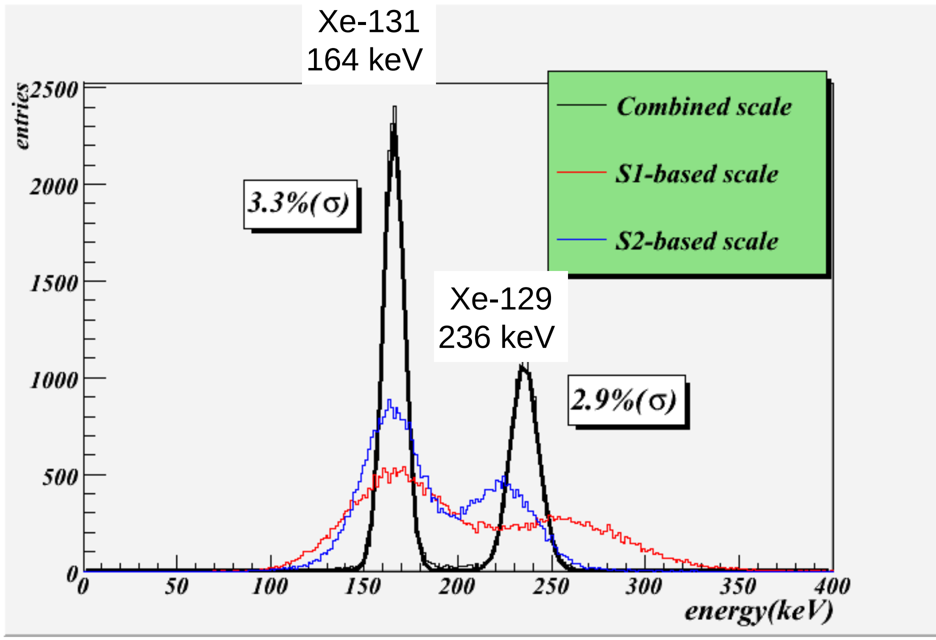
quenching of scintillation yield for NRs due to drift field (0.93)



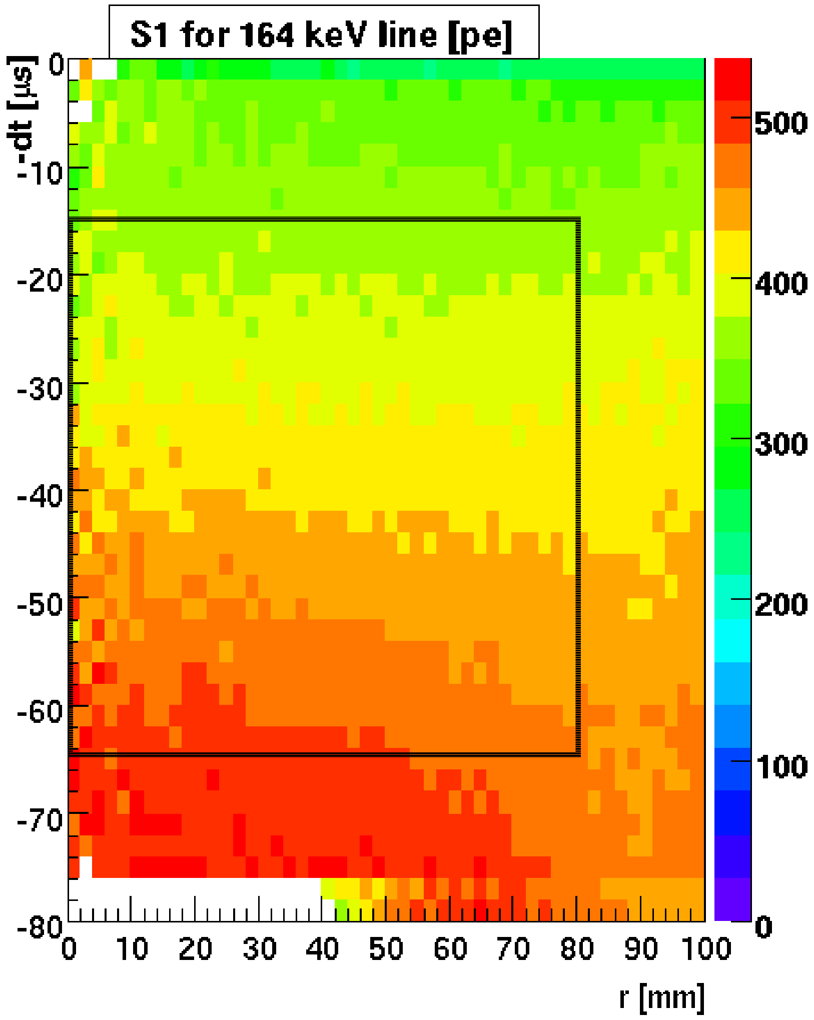
Calibration with n-activated Xe

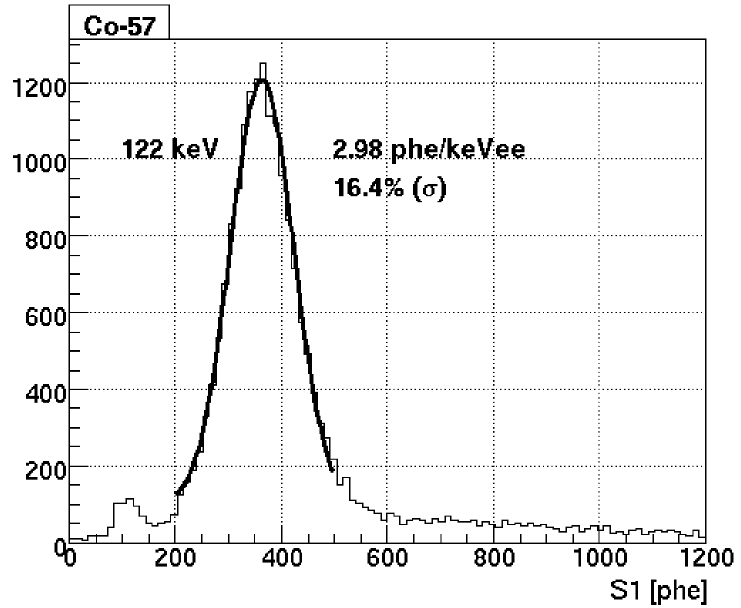
For uniform gamma irradiation we used a small amount of neutron activated Xe into the XENON10 detector in late Feb., after WIMP search data was finished





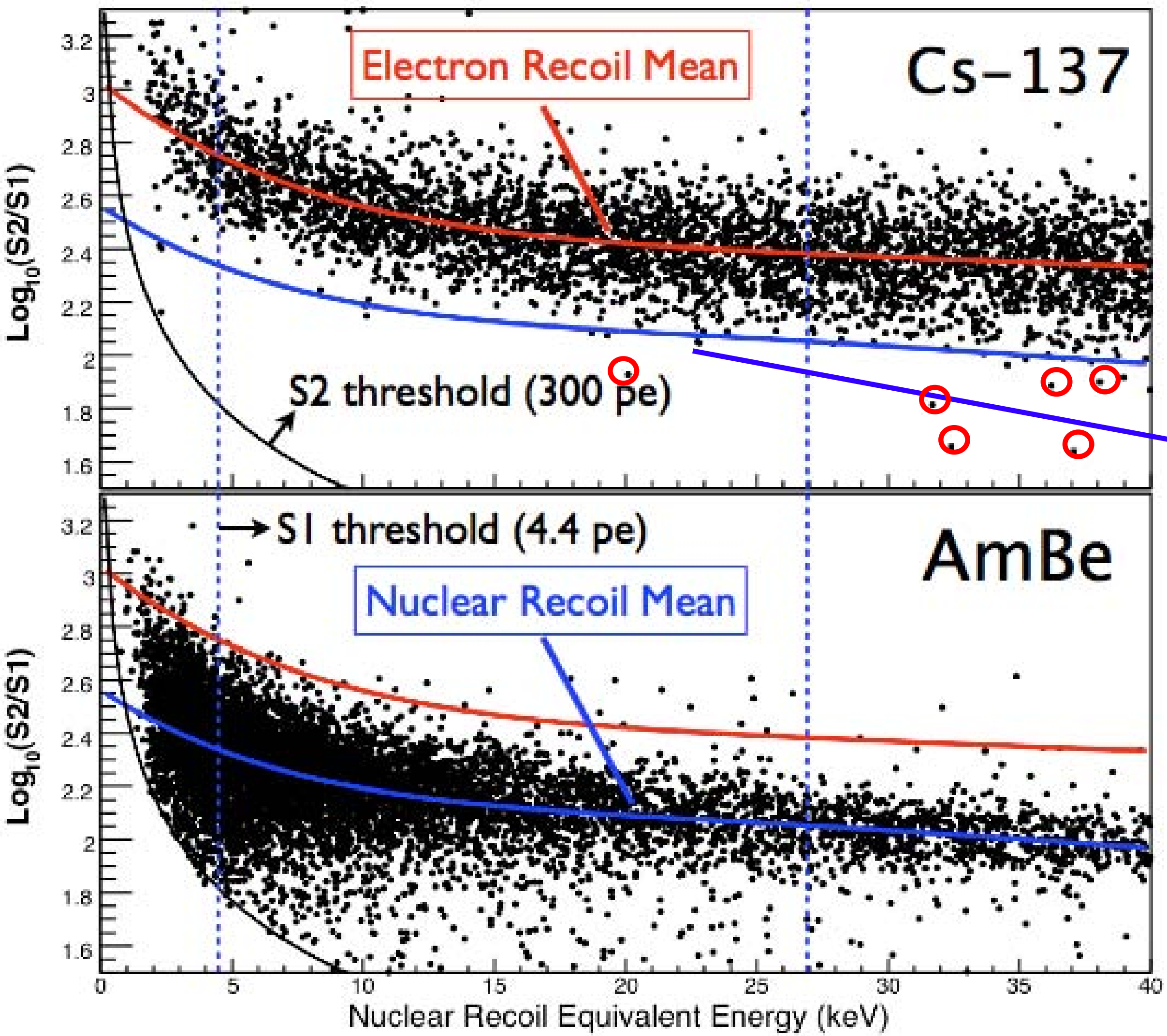
Position dependence of S1 signals in XENON10





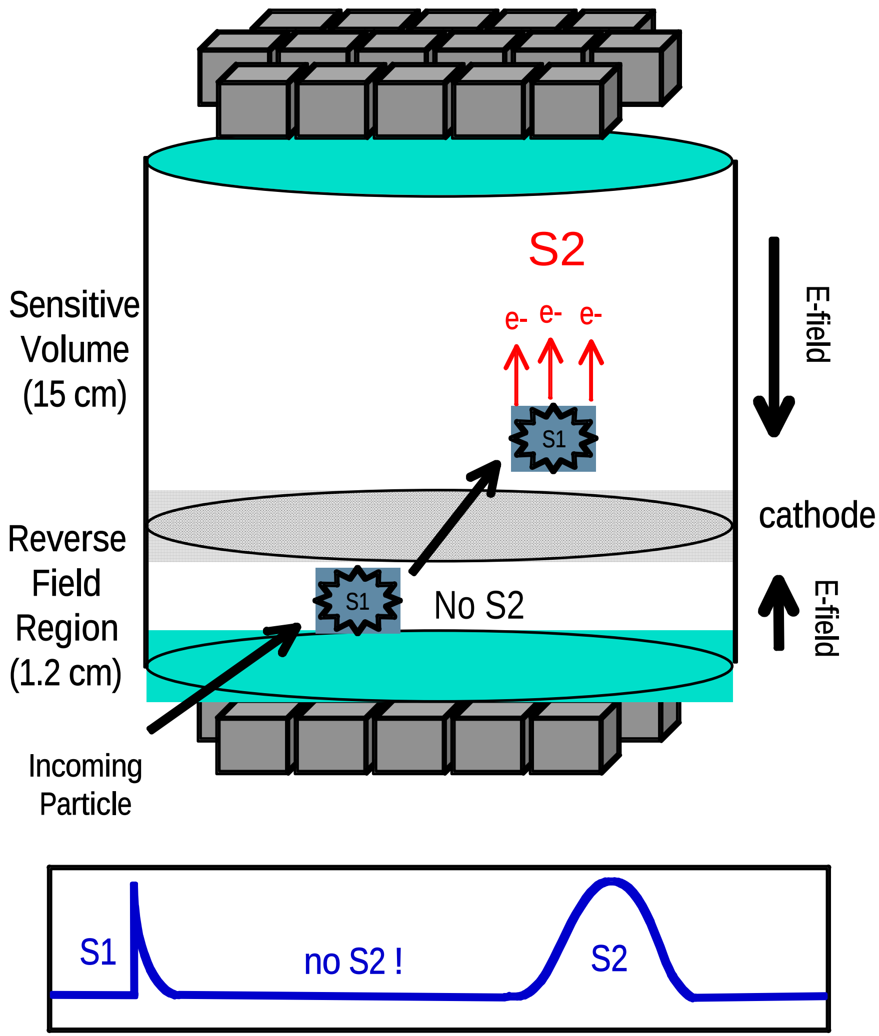
after position-dependent corrections

XENON10 Gamma/Neutron calibration



~ 99.5 % gamma events are rejected below nuclear recoil mean

Anomalous Leakage Events due to non-active LXe



Use S1 hit patten to reject these anomalous events

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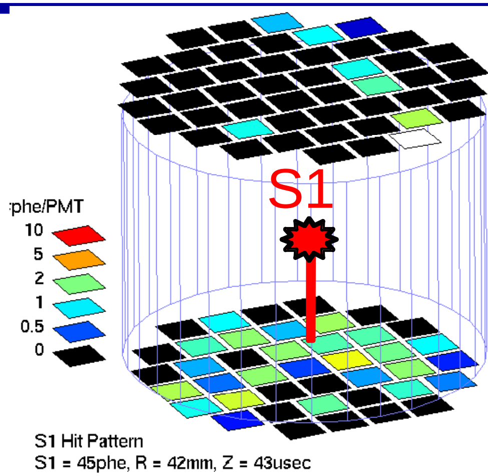
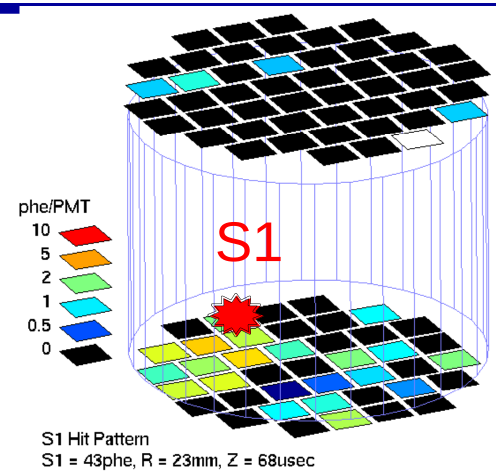
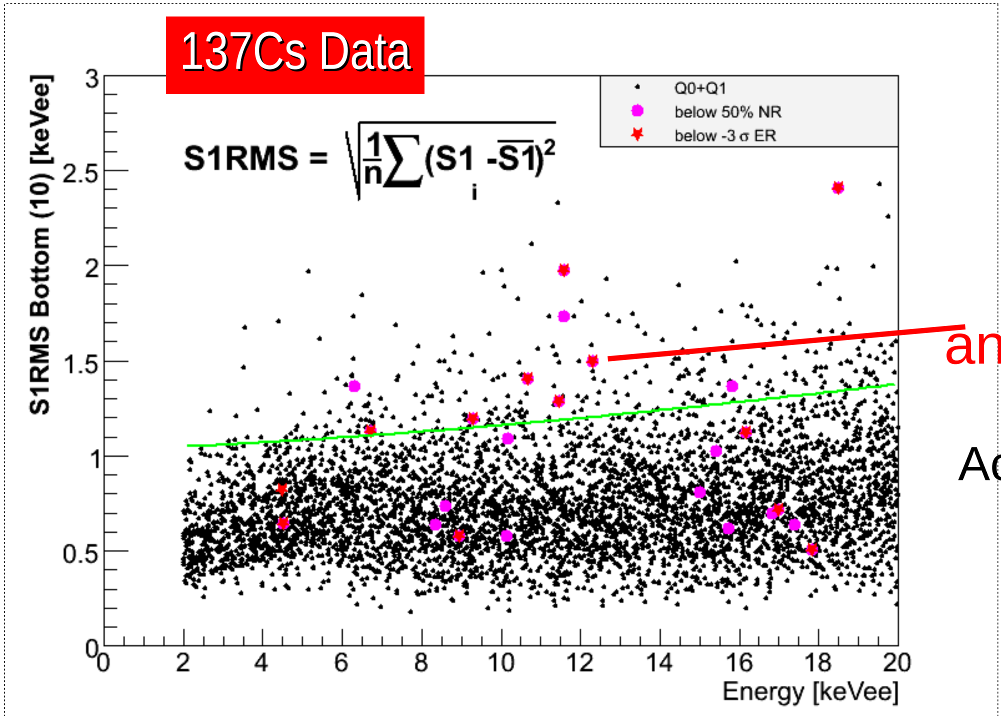
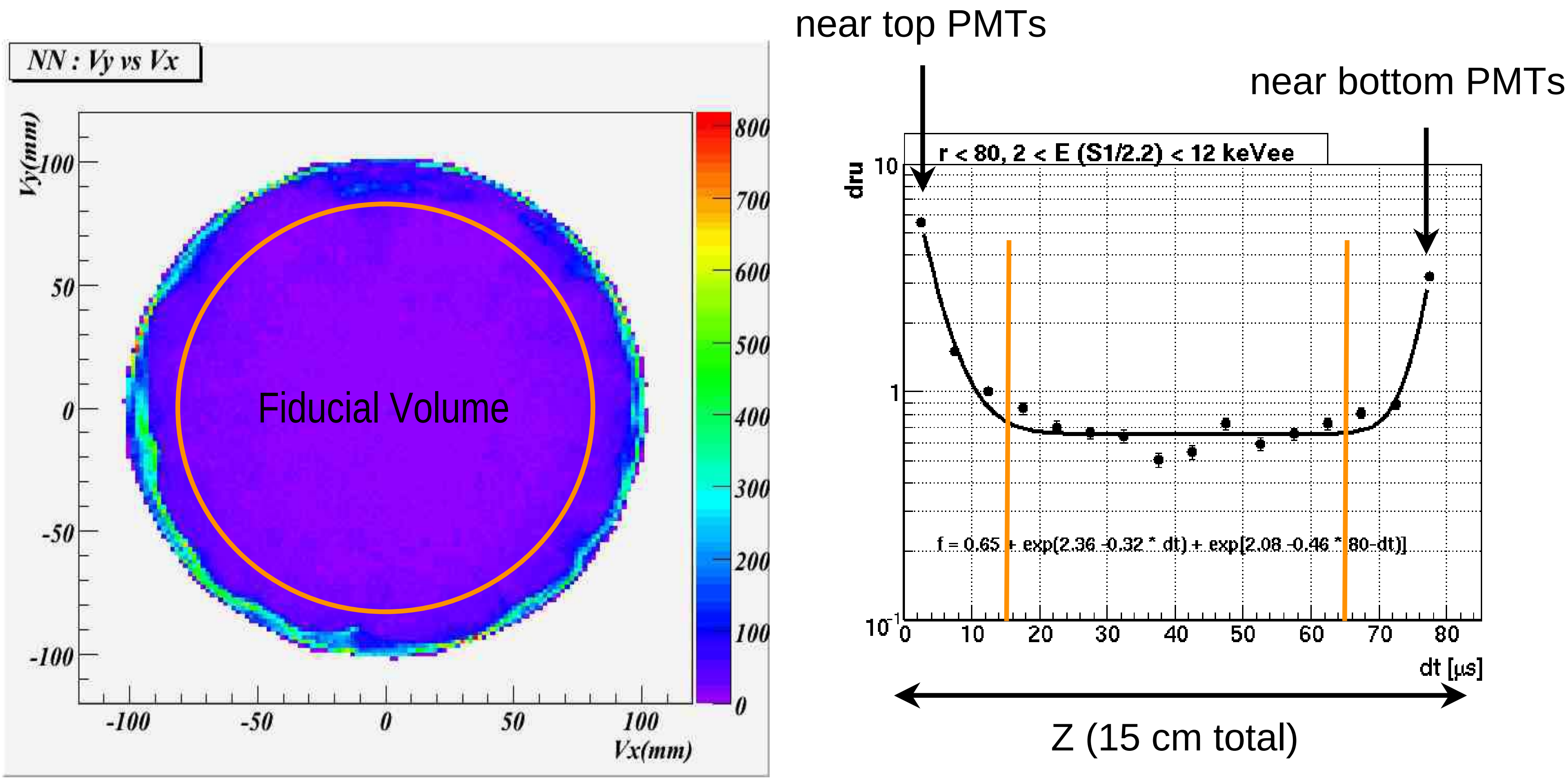






Acceptance of good events: 86%

Self-shielding XENON10 Detector



15 < drift time < 65 μs, r < 80 mm (5.4 kg fiducial mass out of 15 kg)

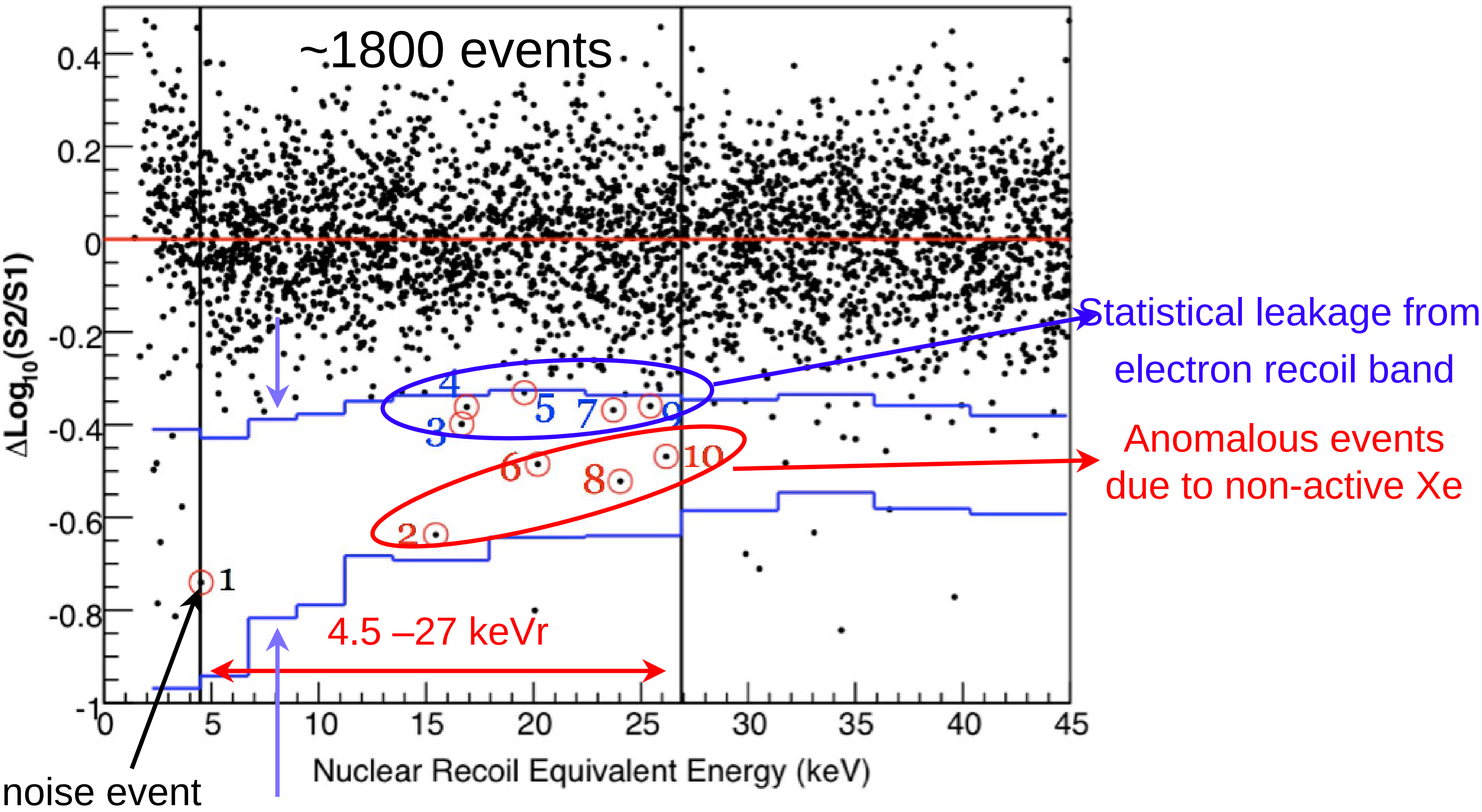
Overall Background in Fiducial Volume ~0.6 event/(kg day keVee)

LXe Stopping Power→Effective Background Reduction by volume cuts

XENON10 WIMP Search Data

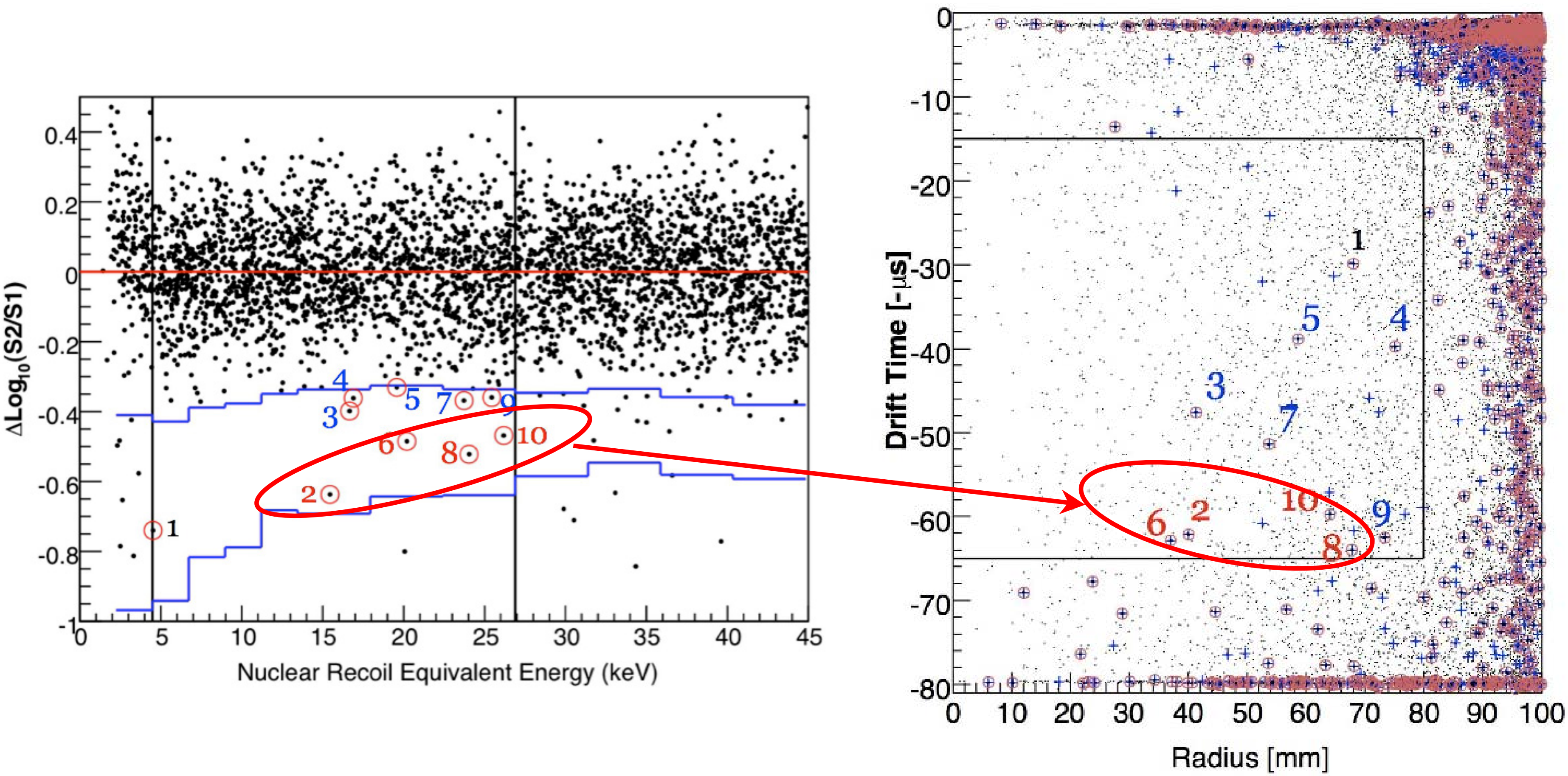
Blind Analysis

136 kg-days Exposure= 58.6 live days x 5.4 kg x 0.86 (∑) x 0.50 (50% NR)

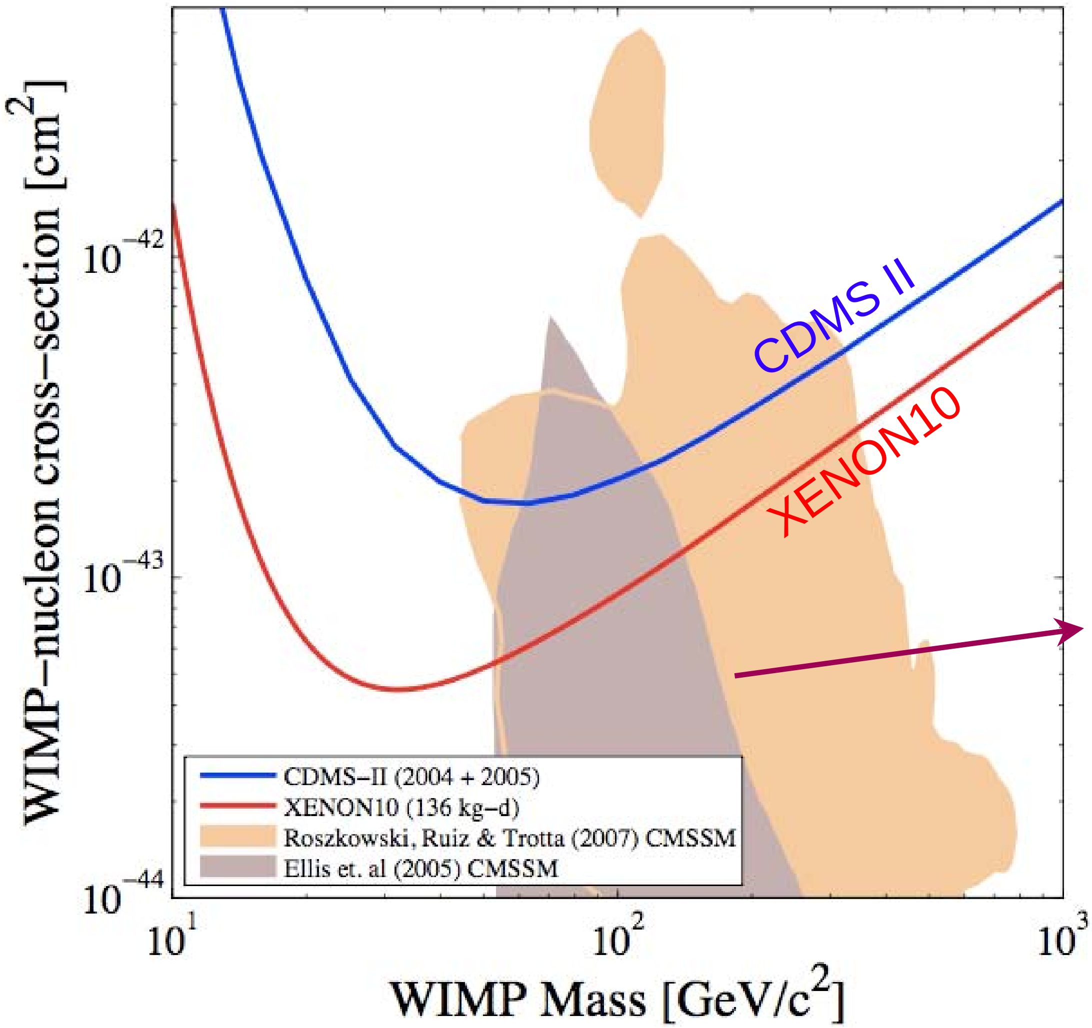


WIMP Search Window defined at ~50% acceptance of Nuclear Recoils (blue lines): [Mean, -3σ]

The “anomalous events”



WIMP-Nucleon Cross-Section Upper Limits (90% CL)



current results based on Yellin Maximal Gap Analysis of 10 events

(NO BKG SUBTRACTION)

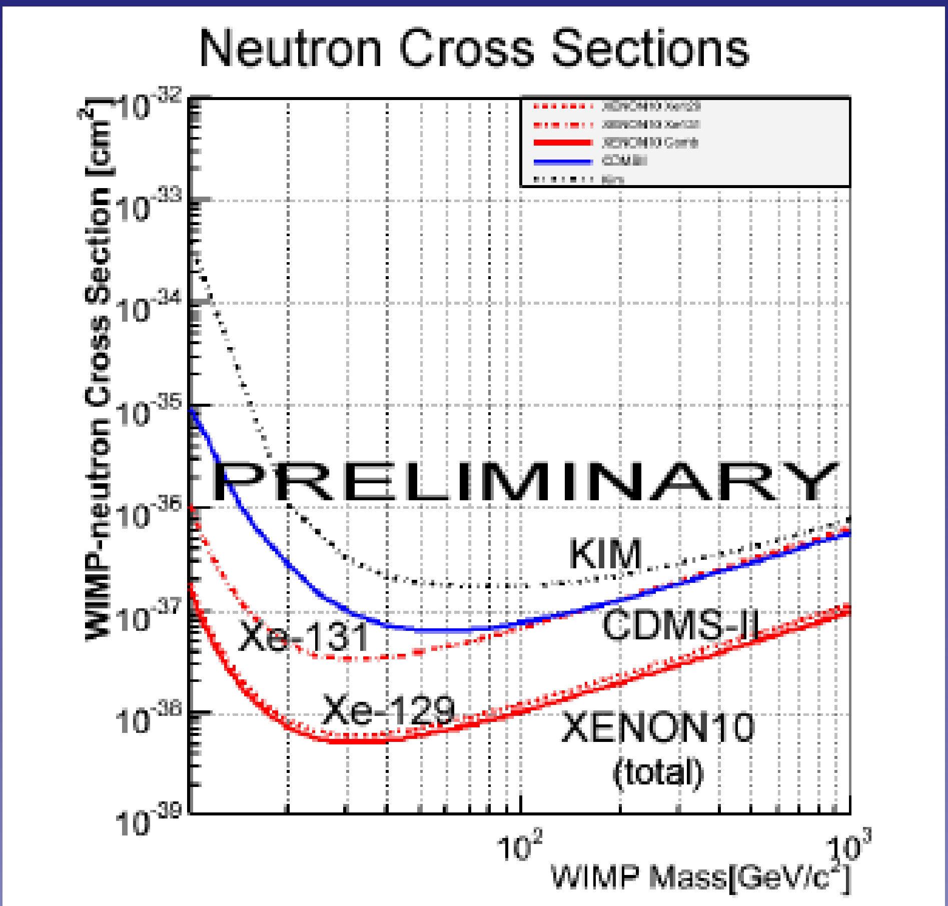
8.8×10^{-44} cm^2 at 100 GeV

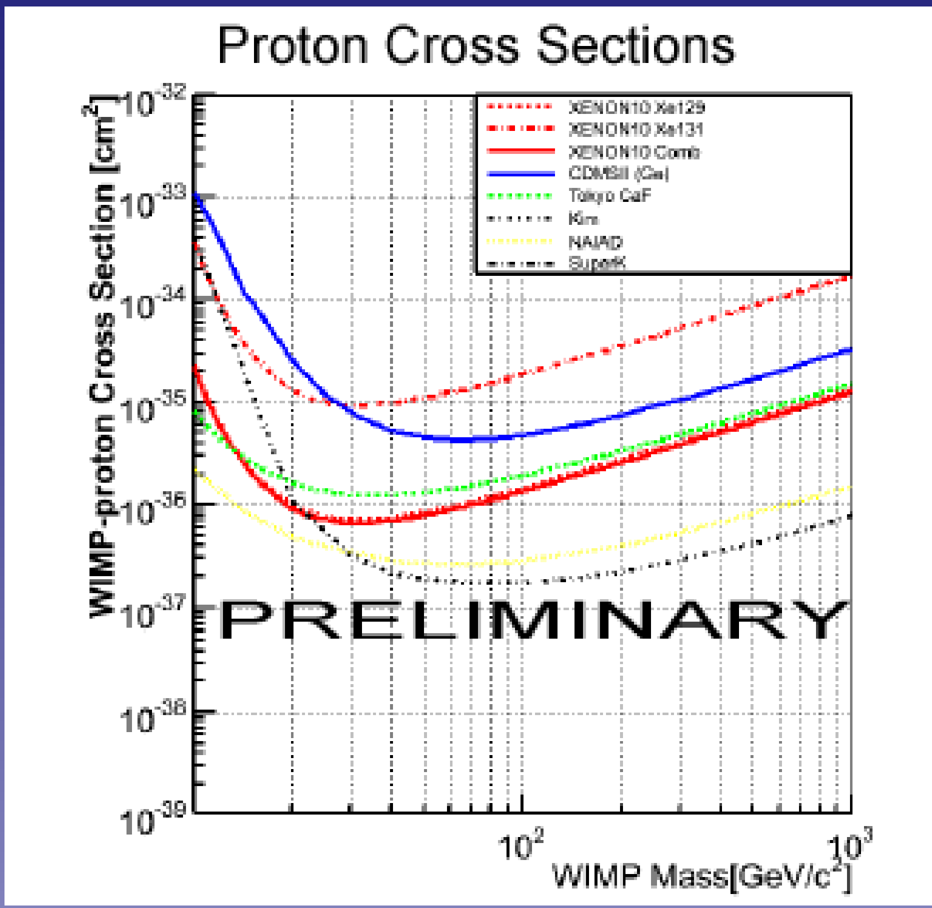
4.5×10^{-44} cm^2 at 30 GeV

supersymmetry models

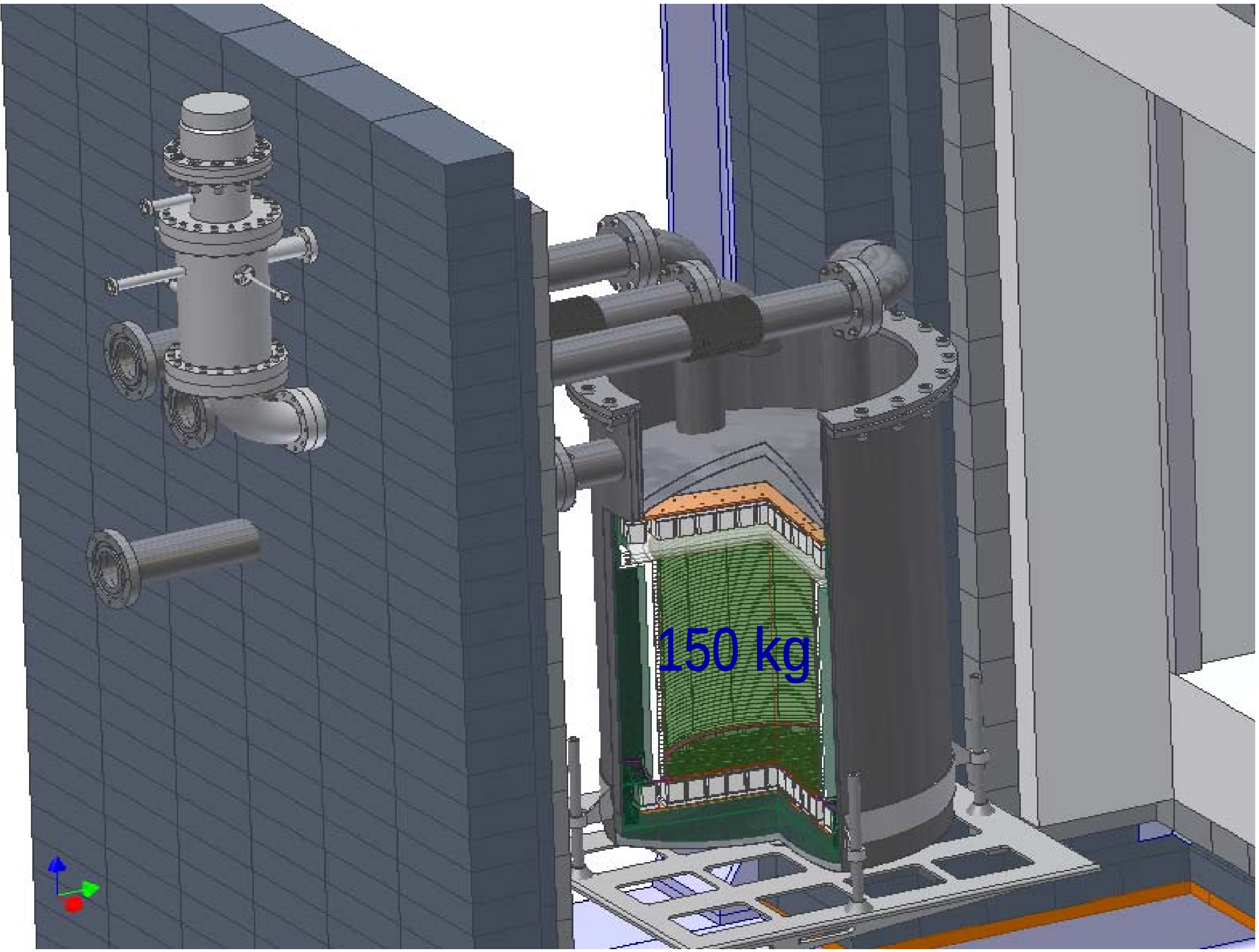
arXiv: 0706:0039 [astro-ph]

XENON10 WIMP Search Results for SD Interactions



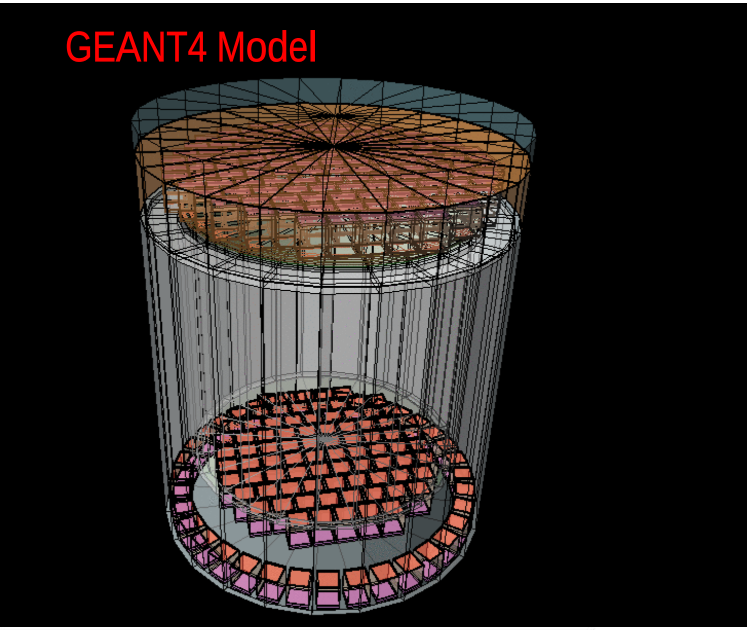


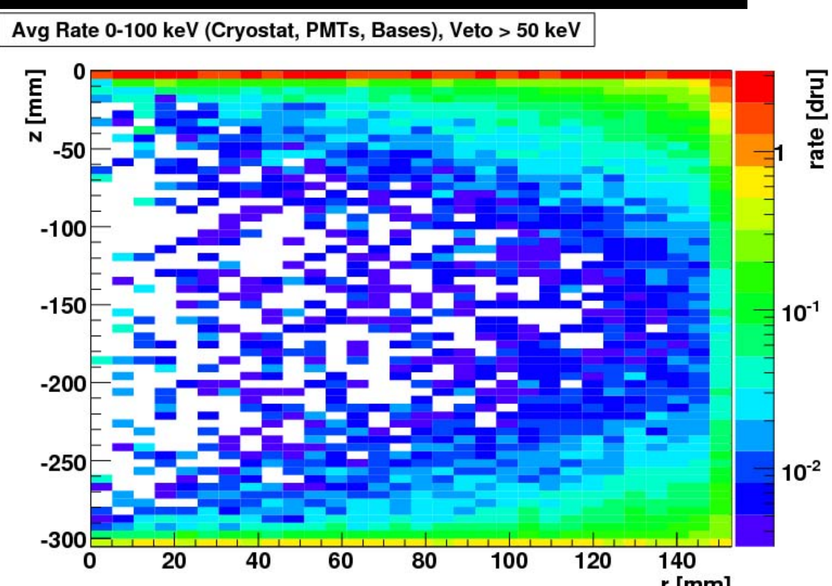
XENON Program : 2007-2008

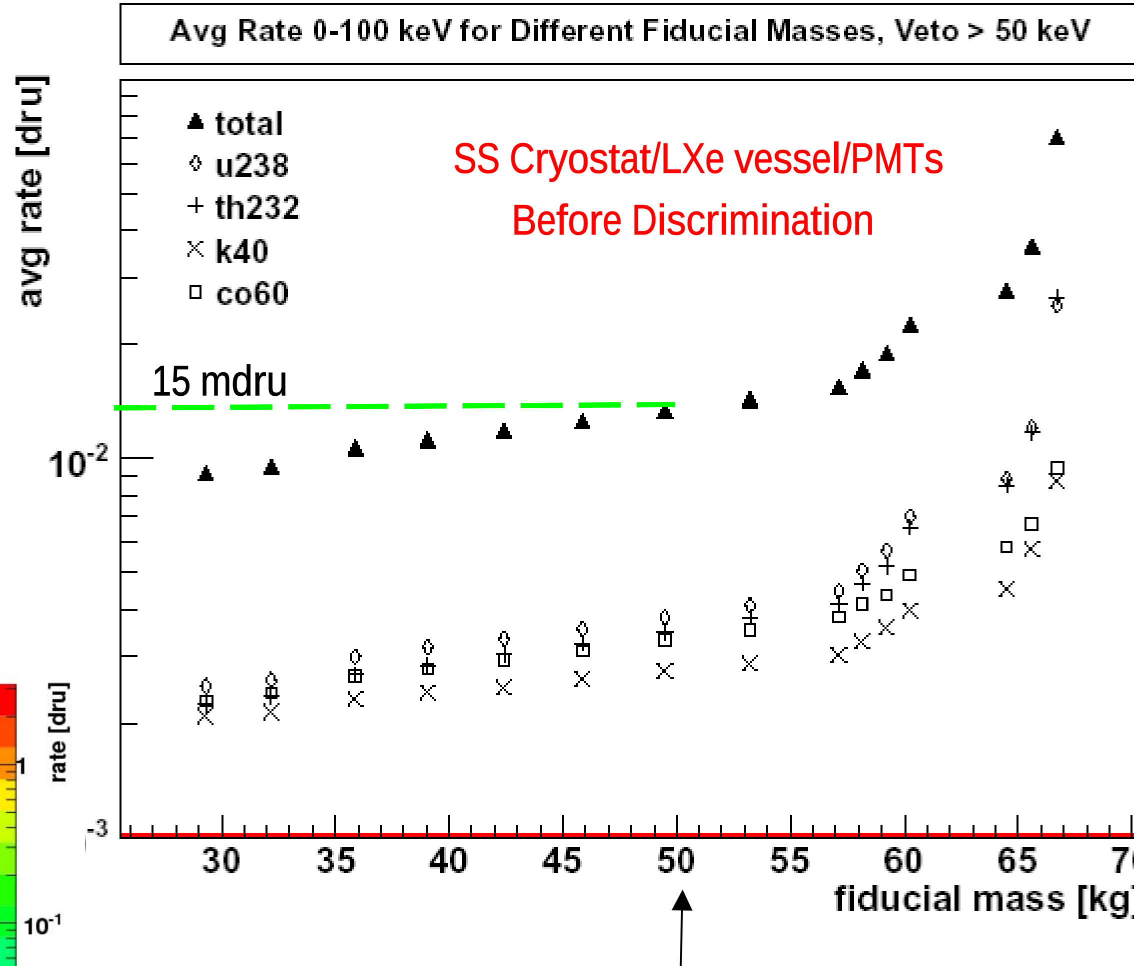


- New detector to replace XENON10 in current shield at LNGS is under construction
- 150 kg total (70 kg in target)
- Low activity PMTs and cryostat, active LXe veto, cryocooler and feed-throughs outside shield → large reduction in total gamma background compared to XENON10
- Systematic screening of components at LNGS
- Optimized light detection for <10 keVr threshold
- New measurements of QF below 10 keVr ongoing

Monte Carlo Simulations of Next XENON Detector Gamma Background



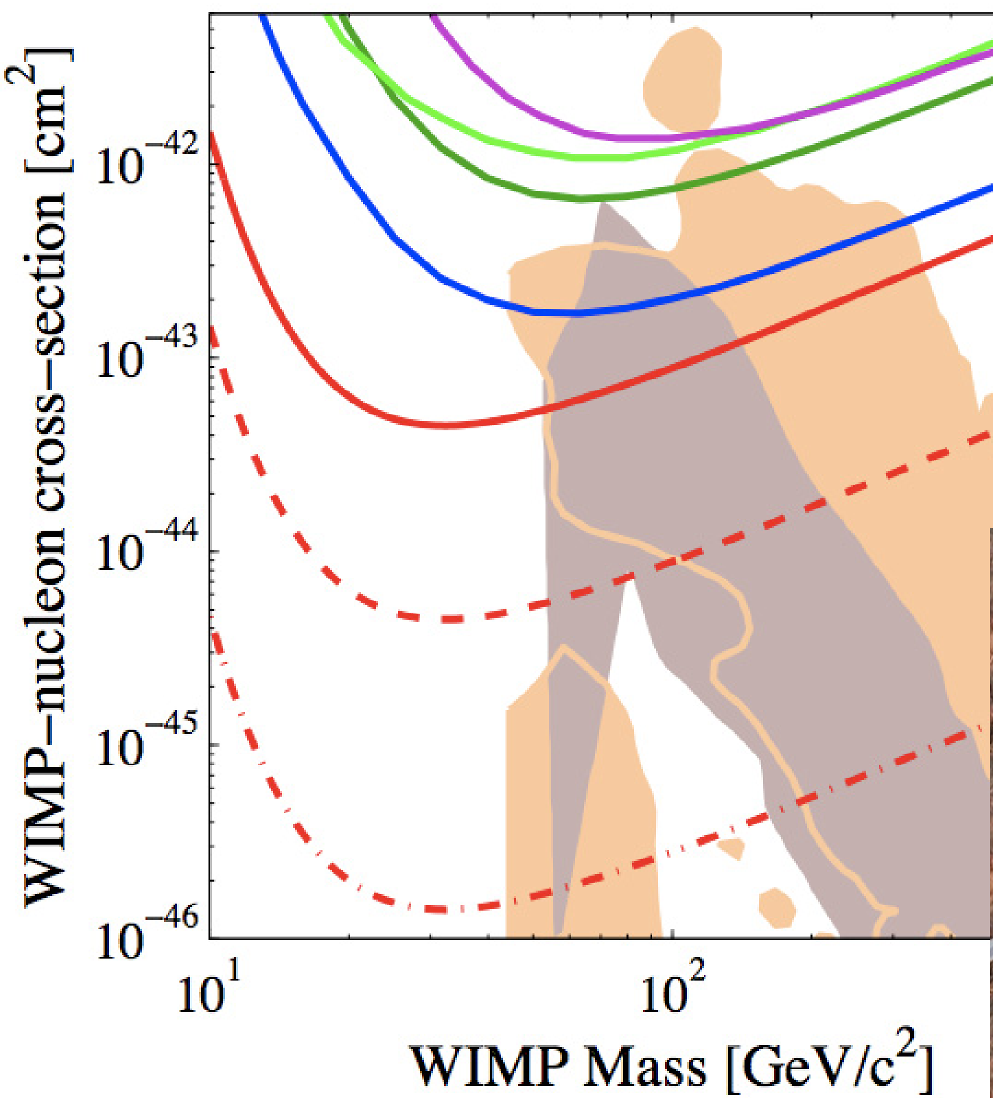


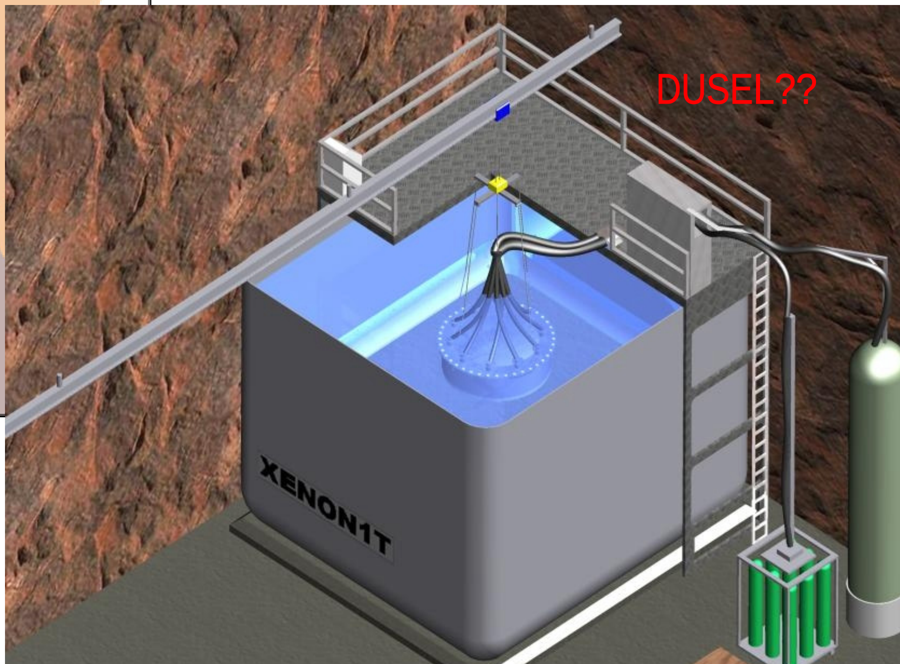


XENON50

Elena Aprile

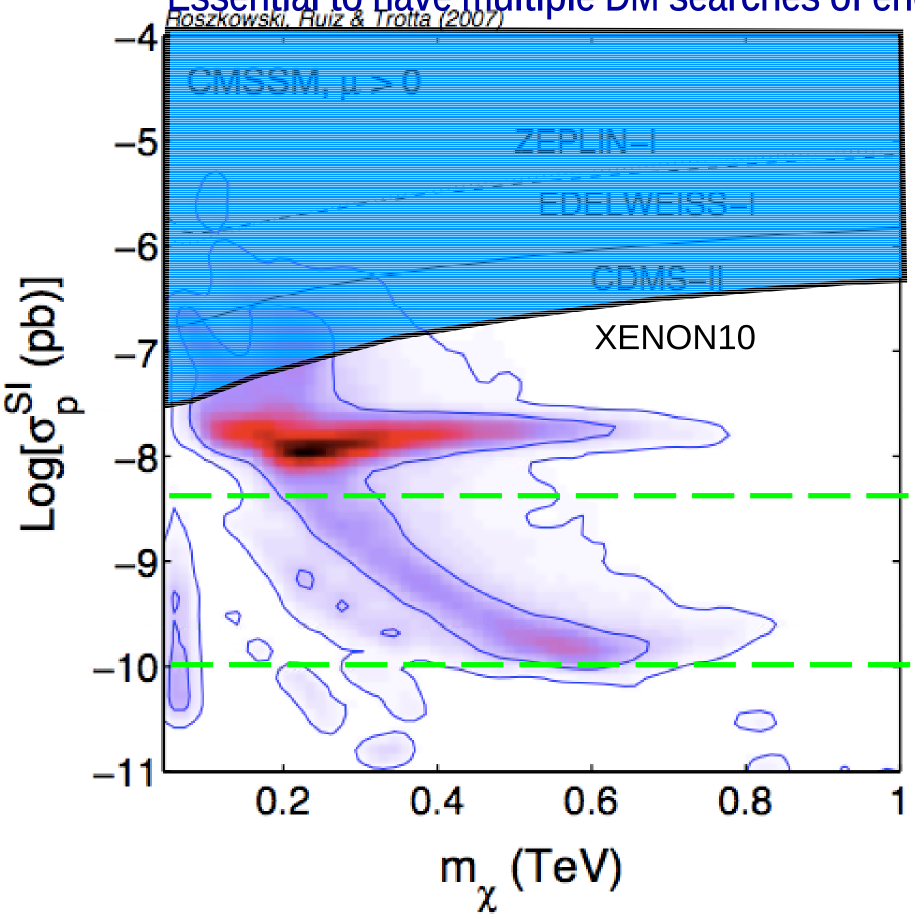
XENON Projected Sensitivity





Summary

- The XENON approach to DM search has made rapid progress
- XENON10 has placed the most stringent DM limits
- Next phase (XENON50) aims at a factor 10 improvement in sensitivity by 2008
- A ton scale experiment is clearly within reach before end of decade.
- Essential to have multiple DM searches of enough sensitivity at the same time as LHC



excluded by XENON10
(2007)

CDMS-II, XENON50, COUPP,
CRESST-II, EDELWEISS-II,ZEPLIN III..

XENON1T, SuperCDMS1T, WARP1T, ArDM..

CMSSM in 2007
http://xxx.lanl.gov/abs/0705.2012

Elena Aprile