Results from XENON100

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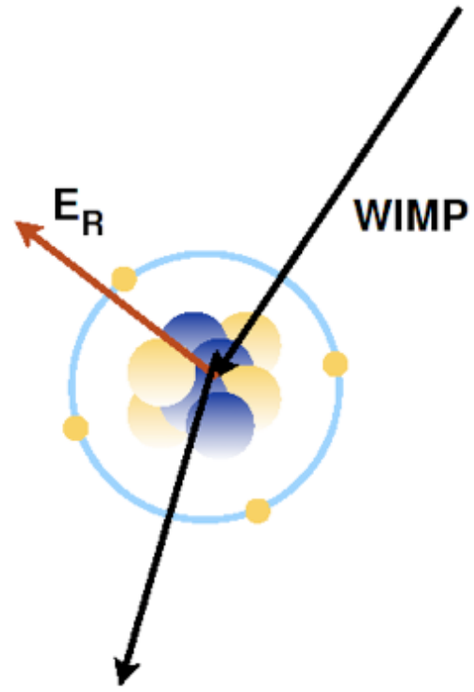
DMUH11
CERN

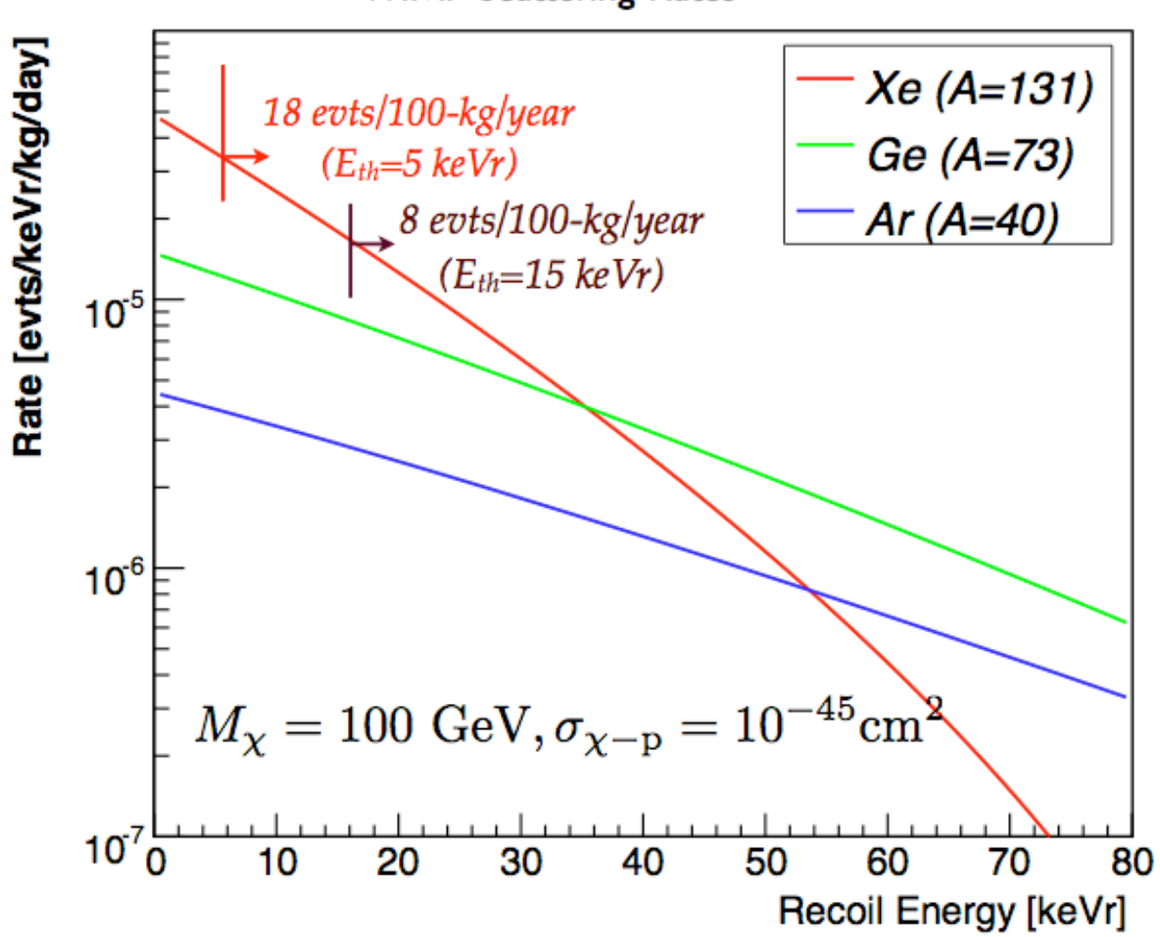
WIMP direct detection with LXe

Detect the dark matter particles (WIMPs) by their elastic scattering on atomic nuclei.

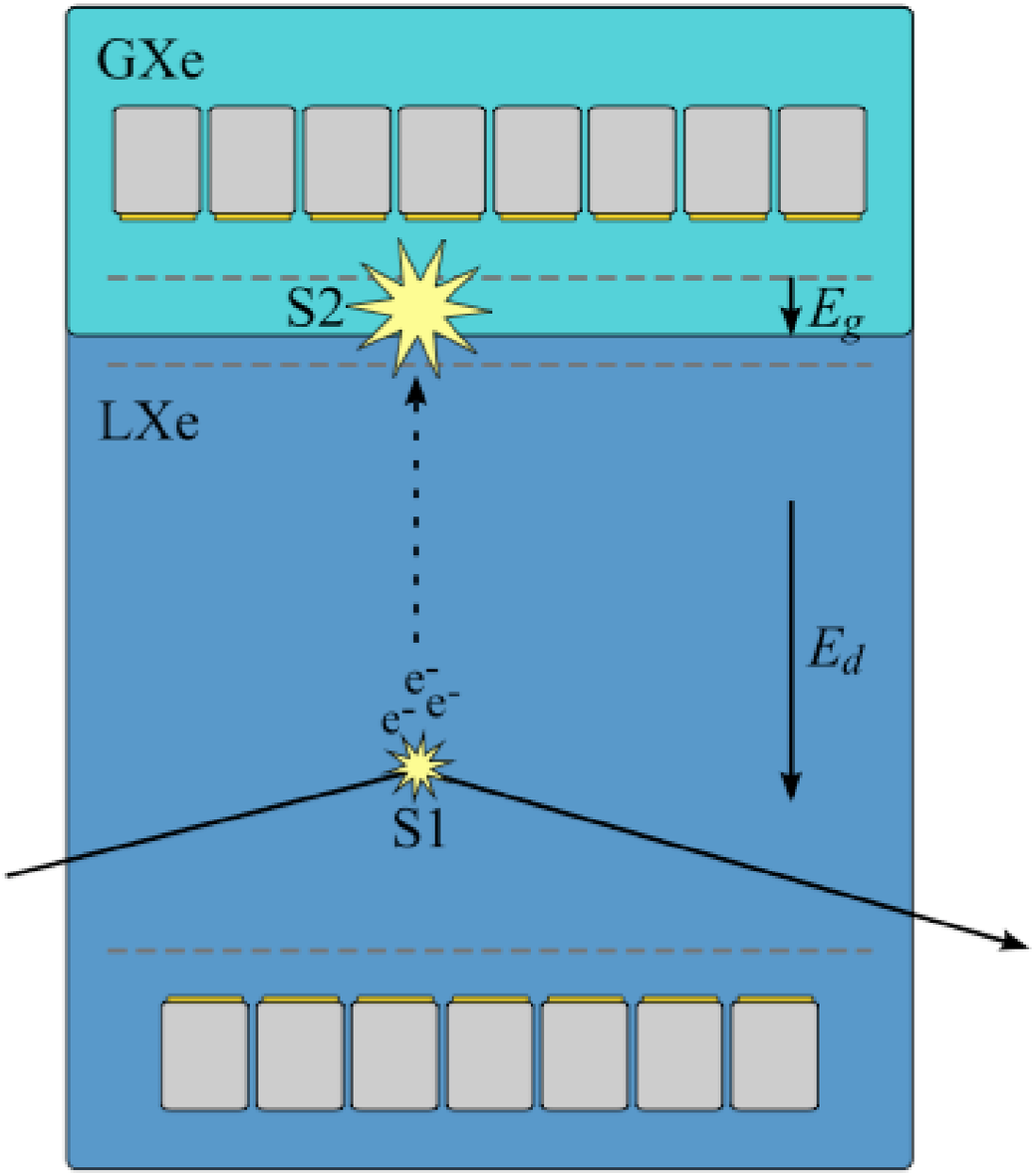


Why Xenon ?

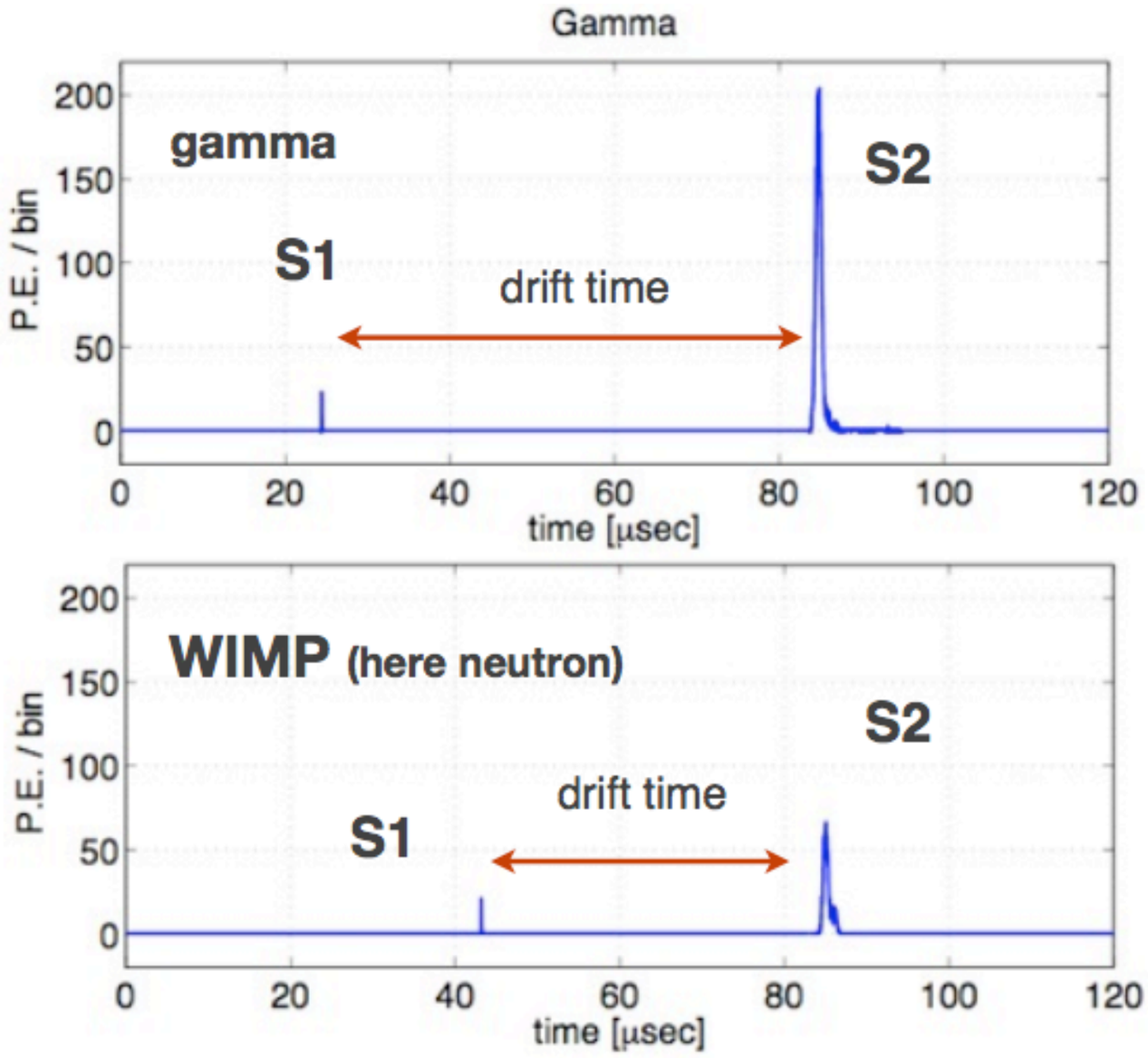
- High mass number, SI cross section scales with A^2
- 50% of odd isotopes → sensitivity to SD coupling
- High Z and density → good selfshielding
- No long lived Radioisotopes
- "High Temperature" cryogenics @ -100°C



Two phase LXe TPC



- Scintillation light signal (S1)
- Charge drift to the liquid-gas interface
- Proportional scintillation light signal (S2)

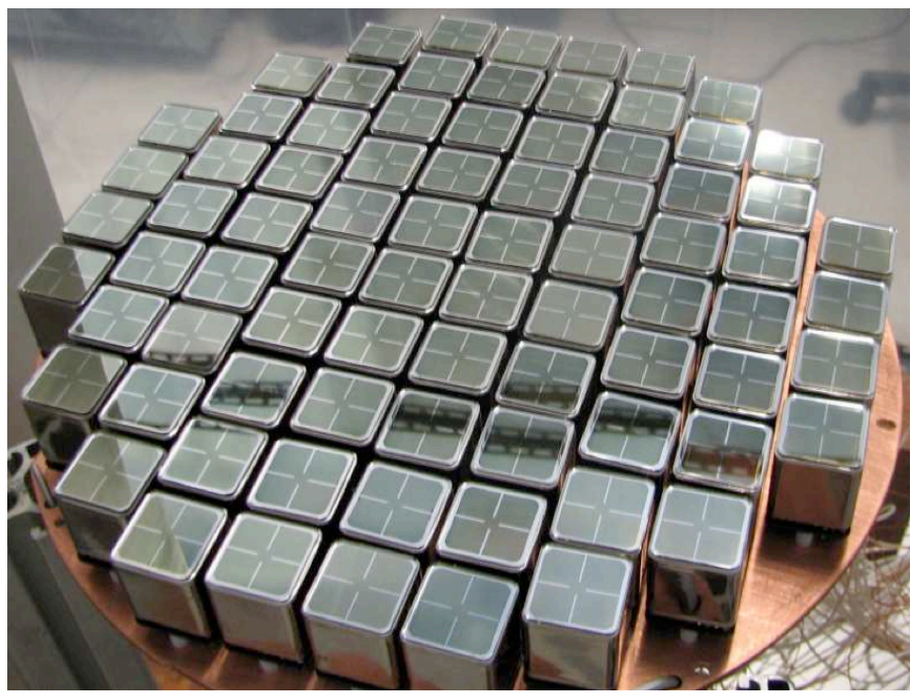


Electron recombination is stronger for nuclear recoils

Discrimination between nuclear and electron recoils

XENON100 detector

- Total of 161 kg LXe (30 - 50 kg fiducial)
- Drift length 30 cm
- 100x background reduction with respect to XENON10
- Active LXe veto
- High QE bottom PMT's (on average > 30% @ 178nm)
- Enclosed by passive shielding (Water, Pb, Poly, Cu)
- Nitrogen Purge

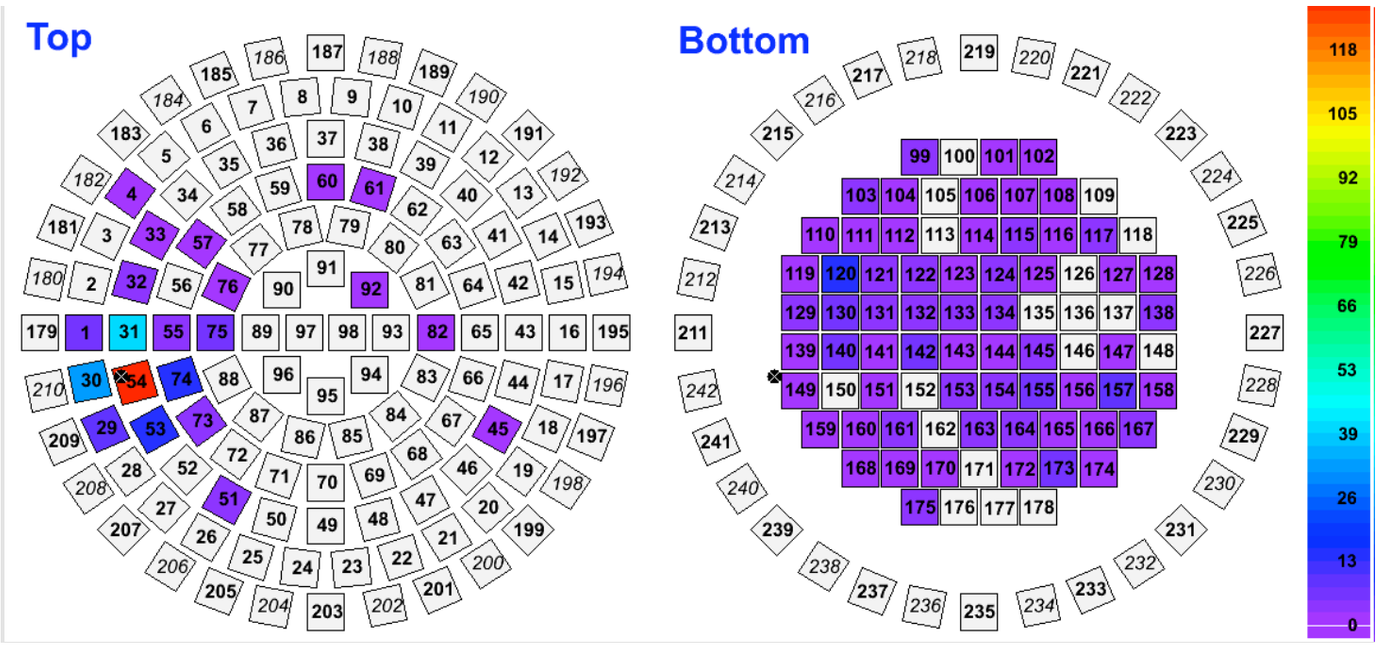


Located at LNGS with a 3700 mwe rock-overburden, shielding against cosmic radiation.

Event localization

Based on the hit pattern in the top PMT array a position reconstruction in the XY-plane is possible

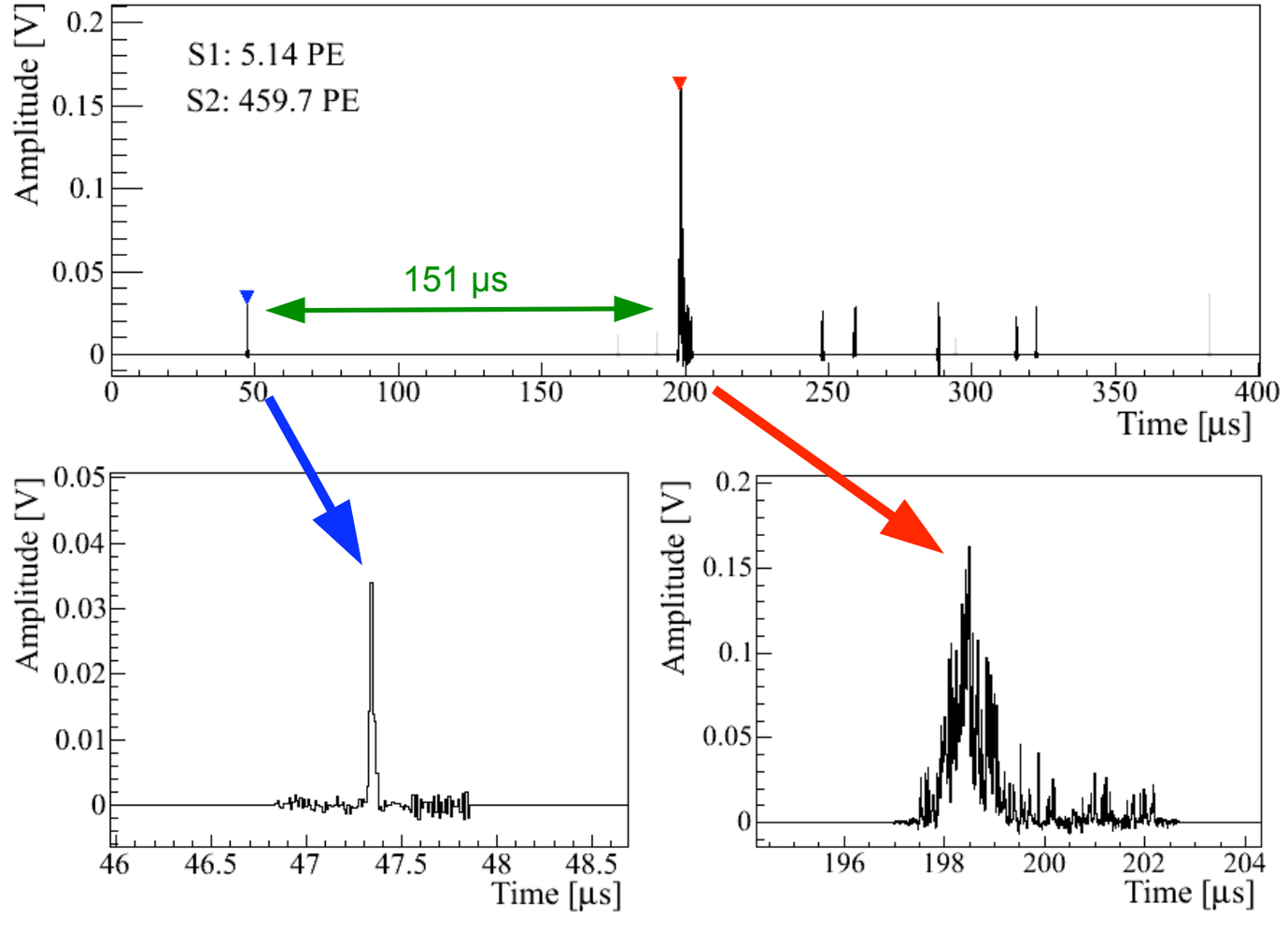
Reconstruction algorithm based on a Neural Network reconstruction with a resolution of < 3mm.



The drift time of the electrons gives information on the z position of the interaction.

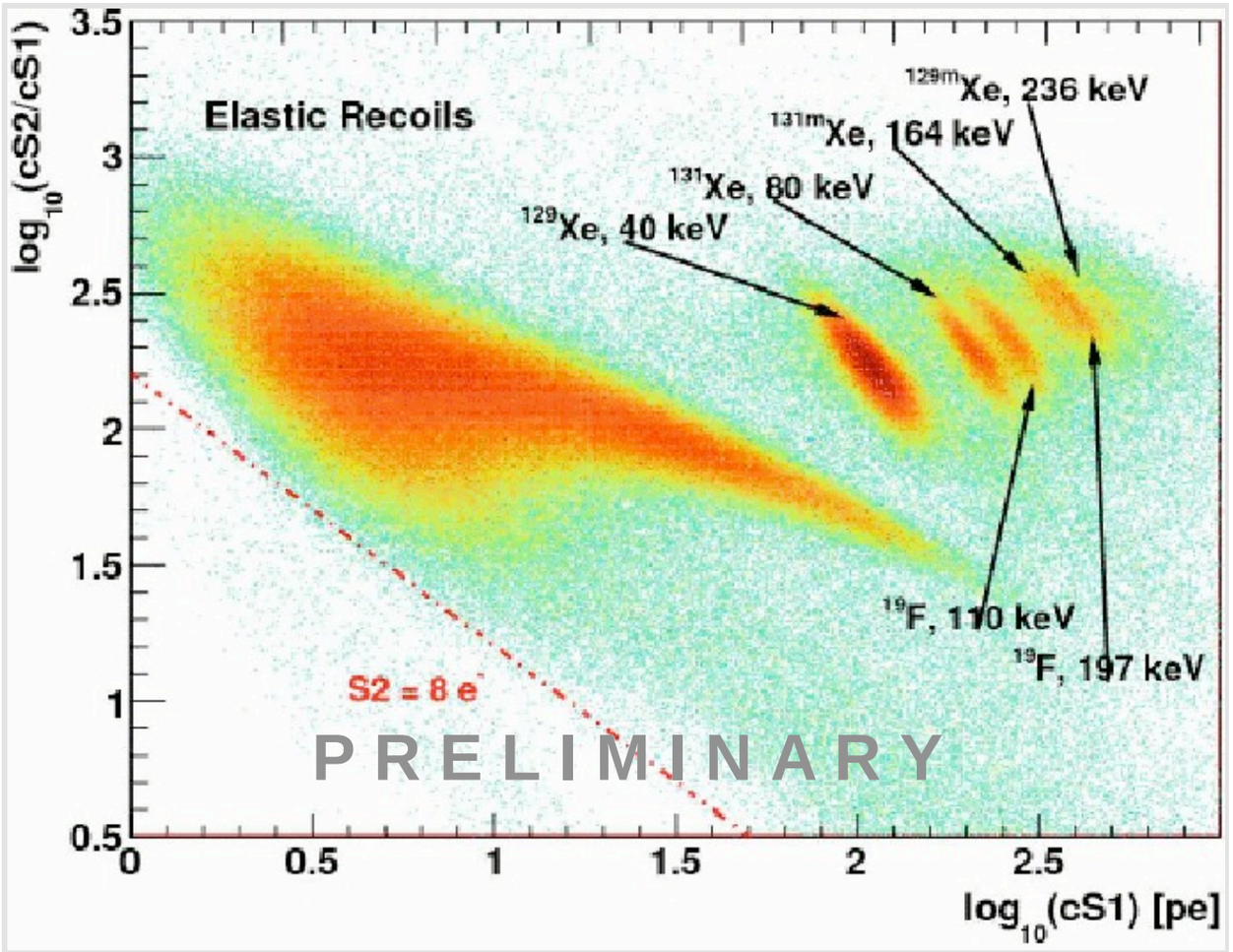
The resolution of the z-coordinate is 0.3 mm

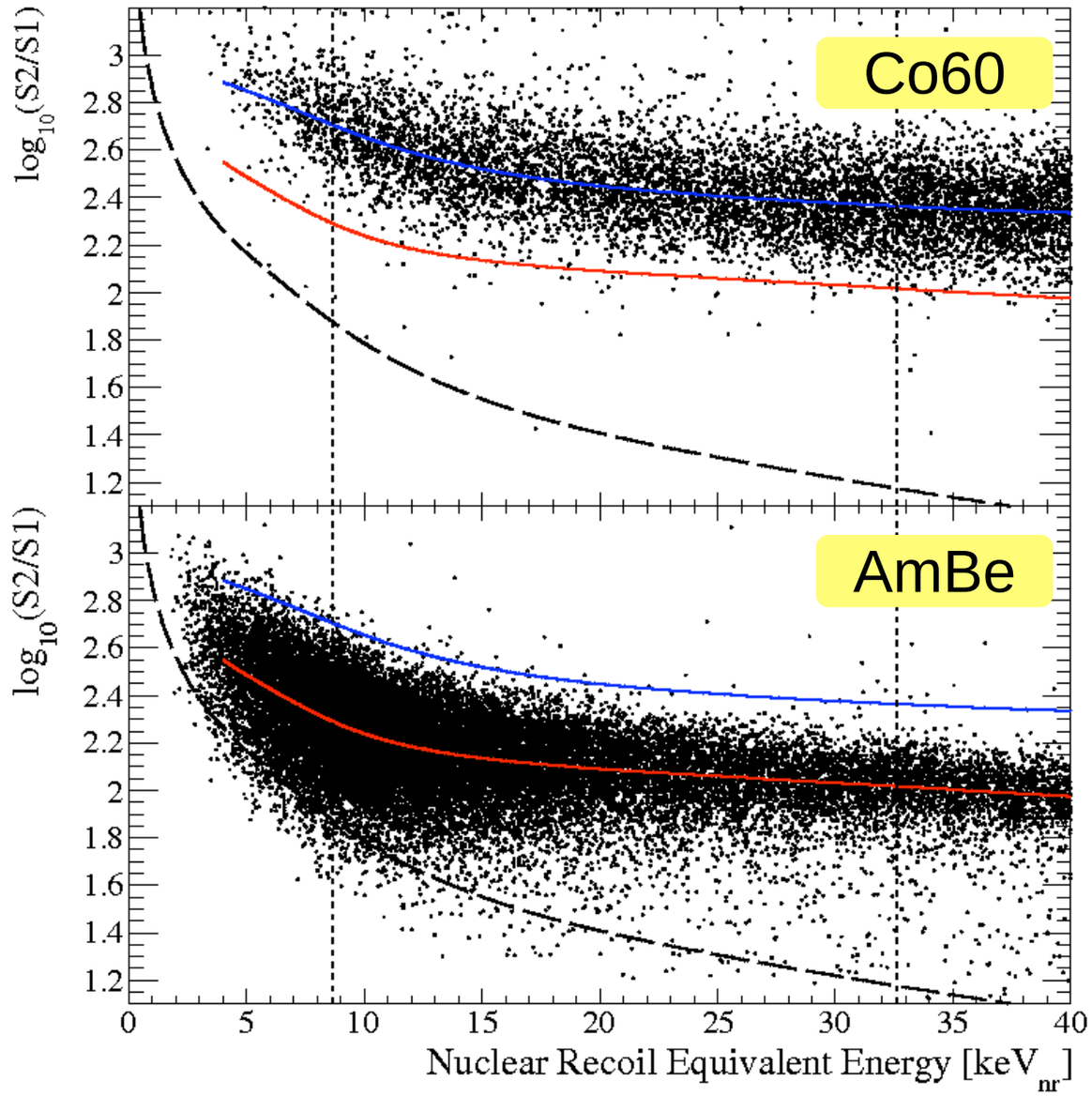
Allows the definition of a 3D fiducial volume



Detector calibration

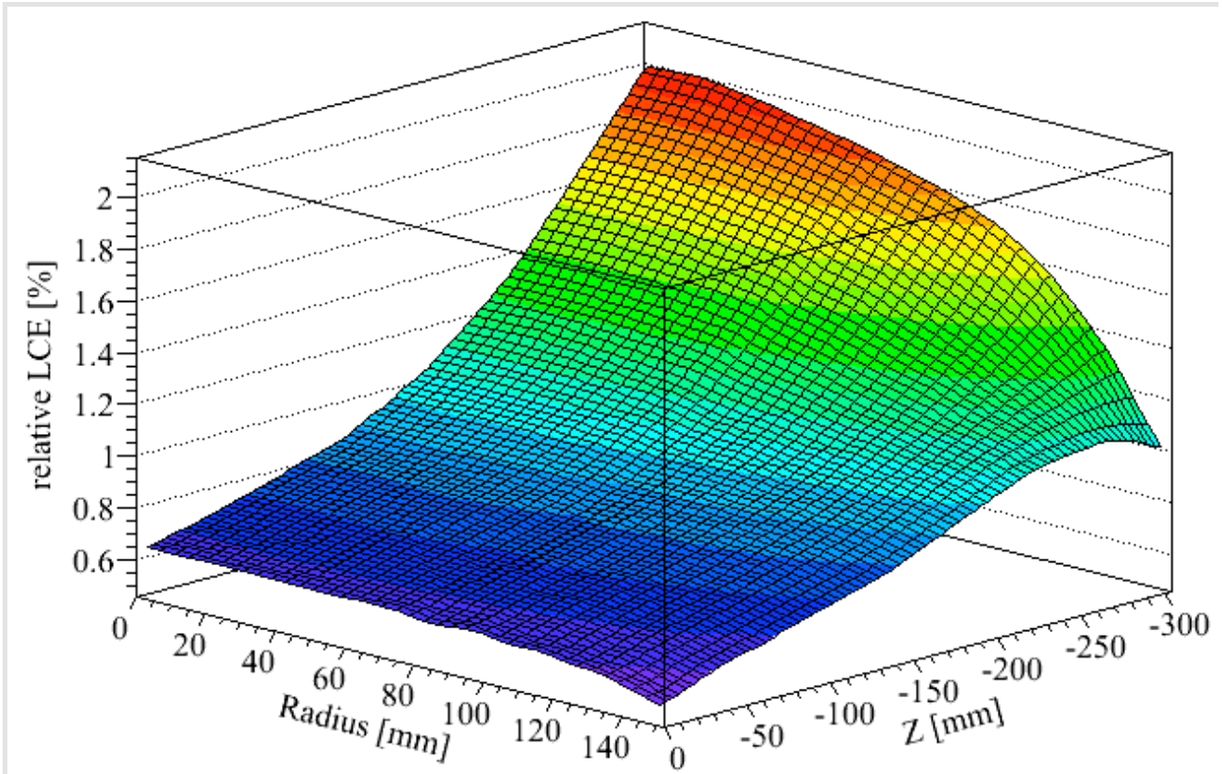
Regular performed ER calibrations with Co60 to calibrate detector's response to ER.





Large statistics NR calibration to calibrate detector's response to NR and define the expected WIMP signal region.

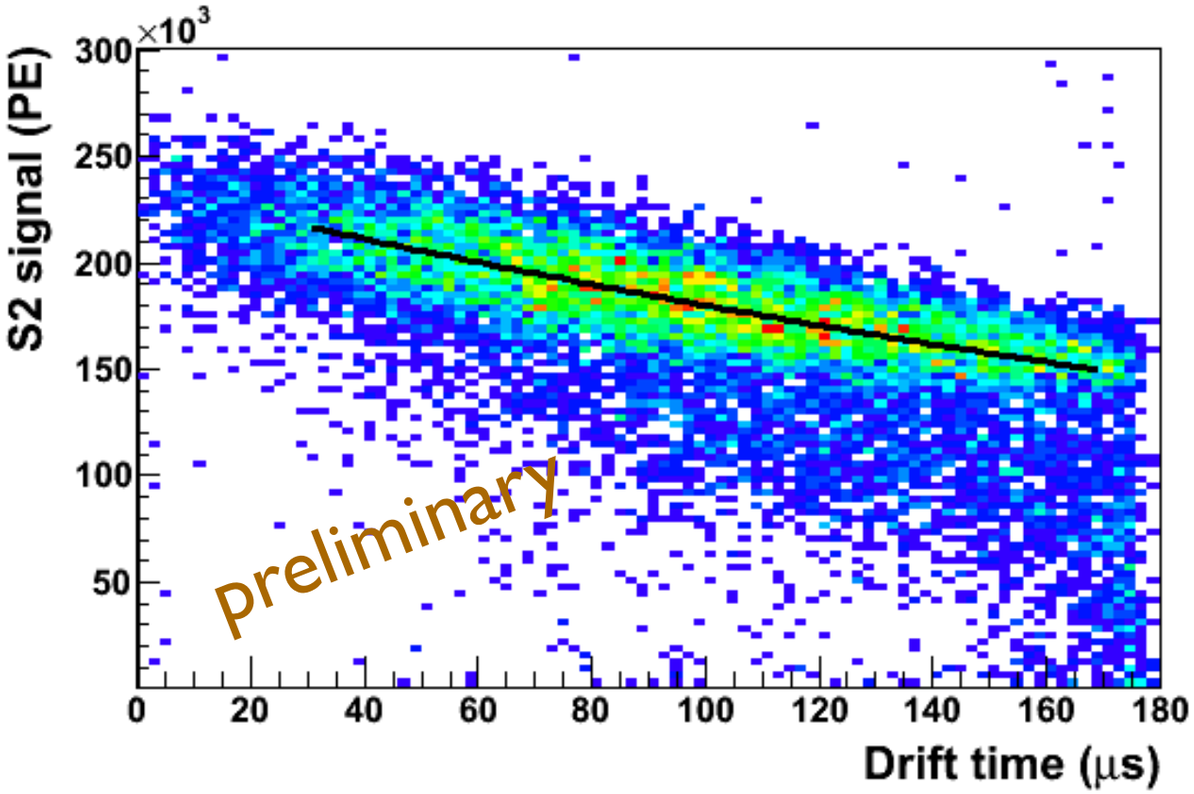
Position dependent corrections

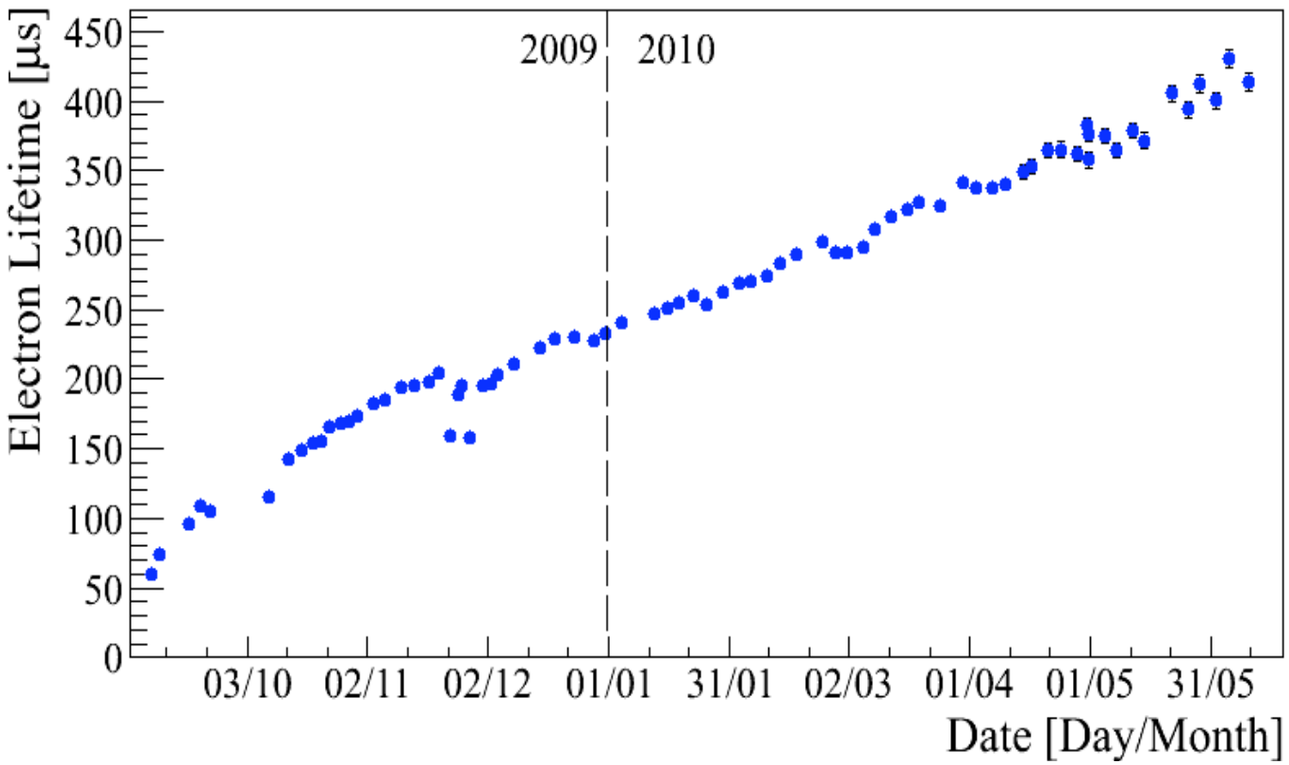


Light collection map used for the correction of the S1 signals

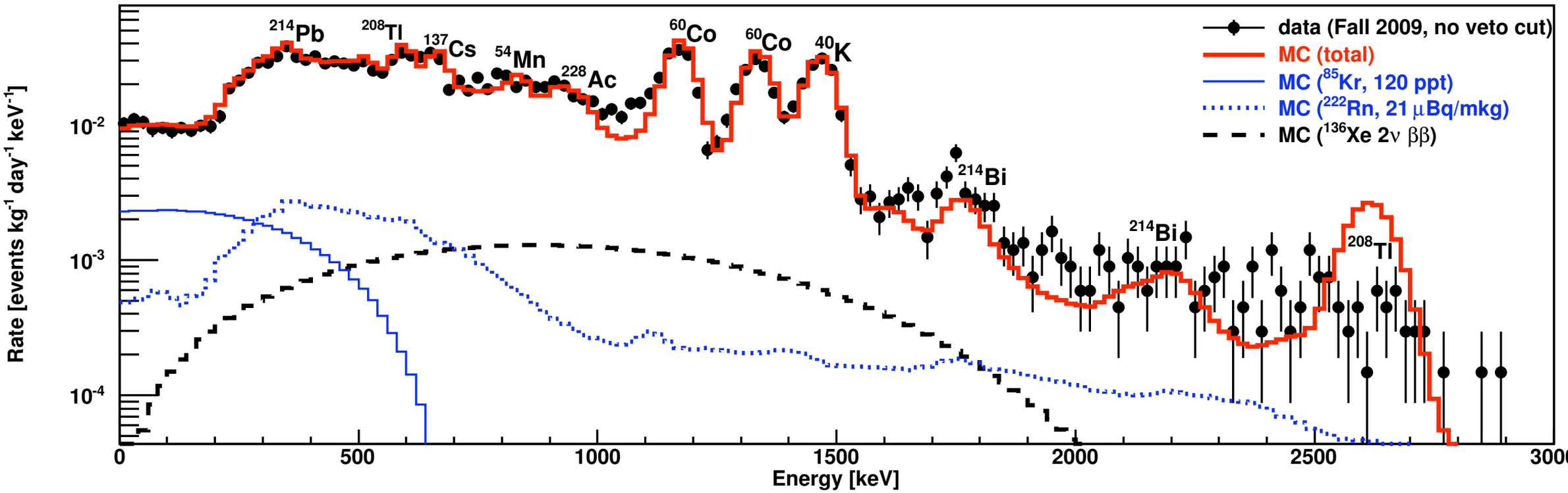
Z-dependence of the S2 signals due to limited electron lifetime.

Electron lifetime increases due to constant reduction of impurities





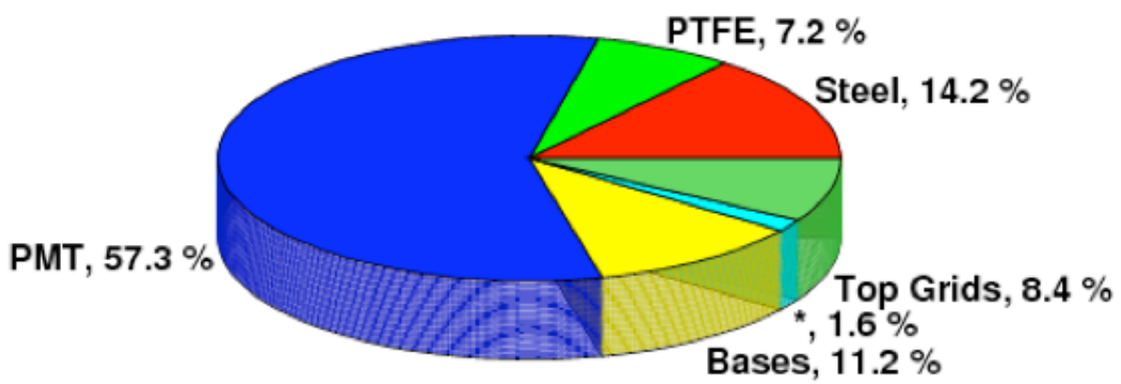
XENON100 background



Very good agreement between the data and Monte Carlo. No tuning of the Monte Carlo, only measured activities of the apparatus components.

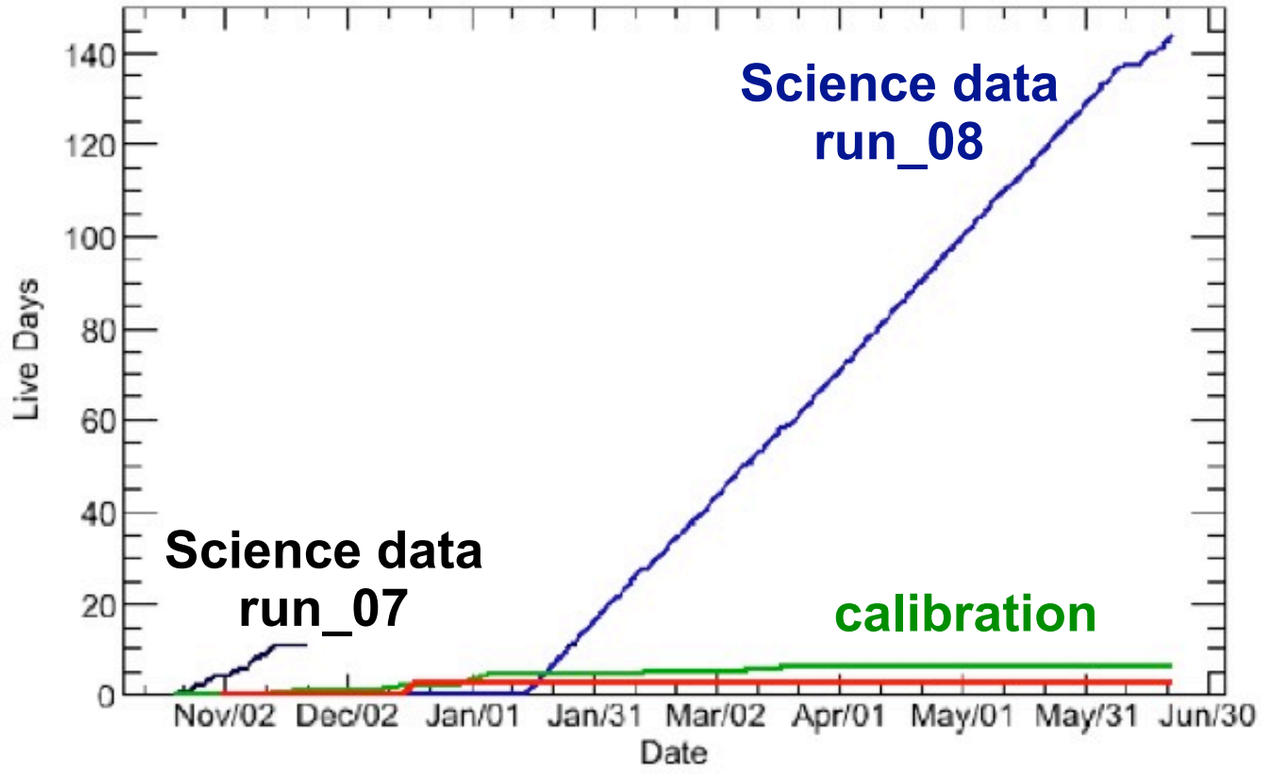
Measured single scatter rate below 100 keV is 5 x 10e-3 evts/kg/d/keV.

Background in the ROI is dominated by the contribution from the PMTs.

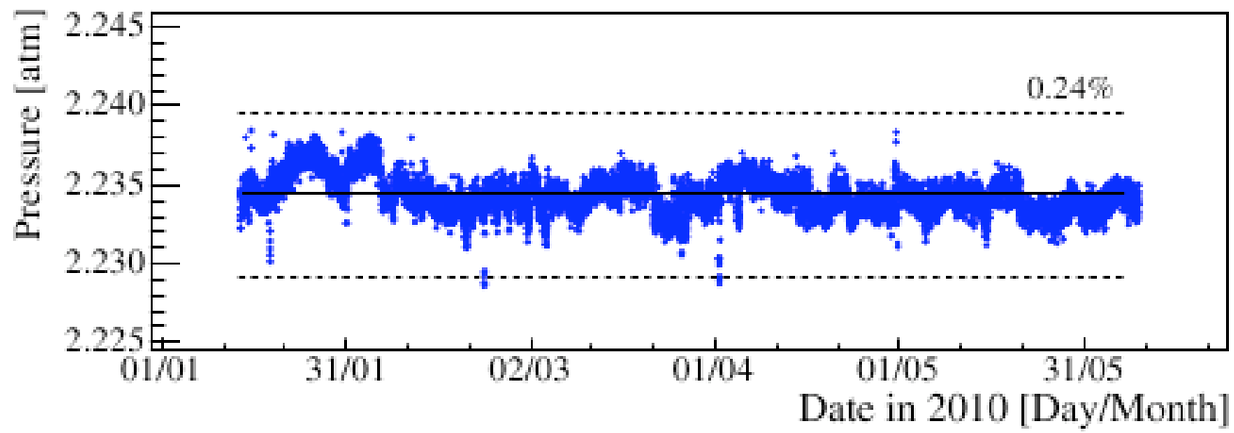


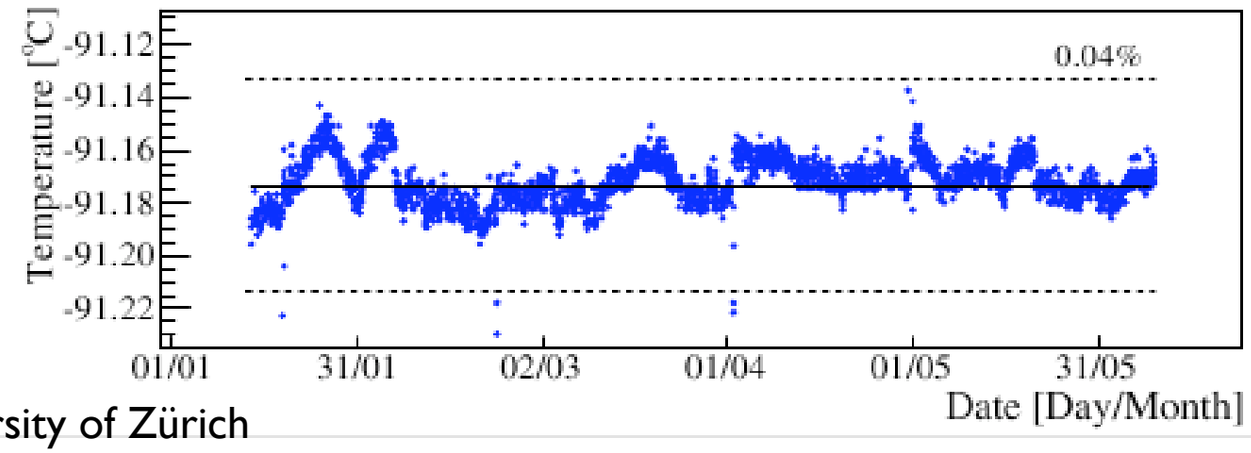
Data taking period

Continuous data taking in 2010, interspersed with regular calibration measurements.

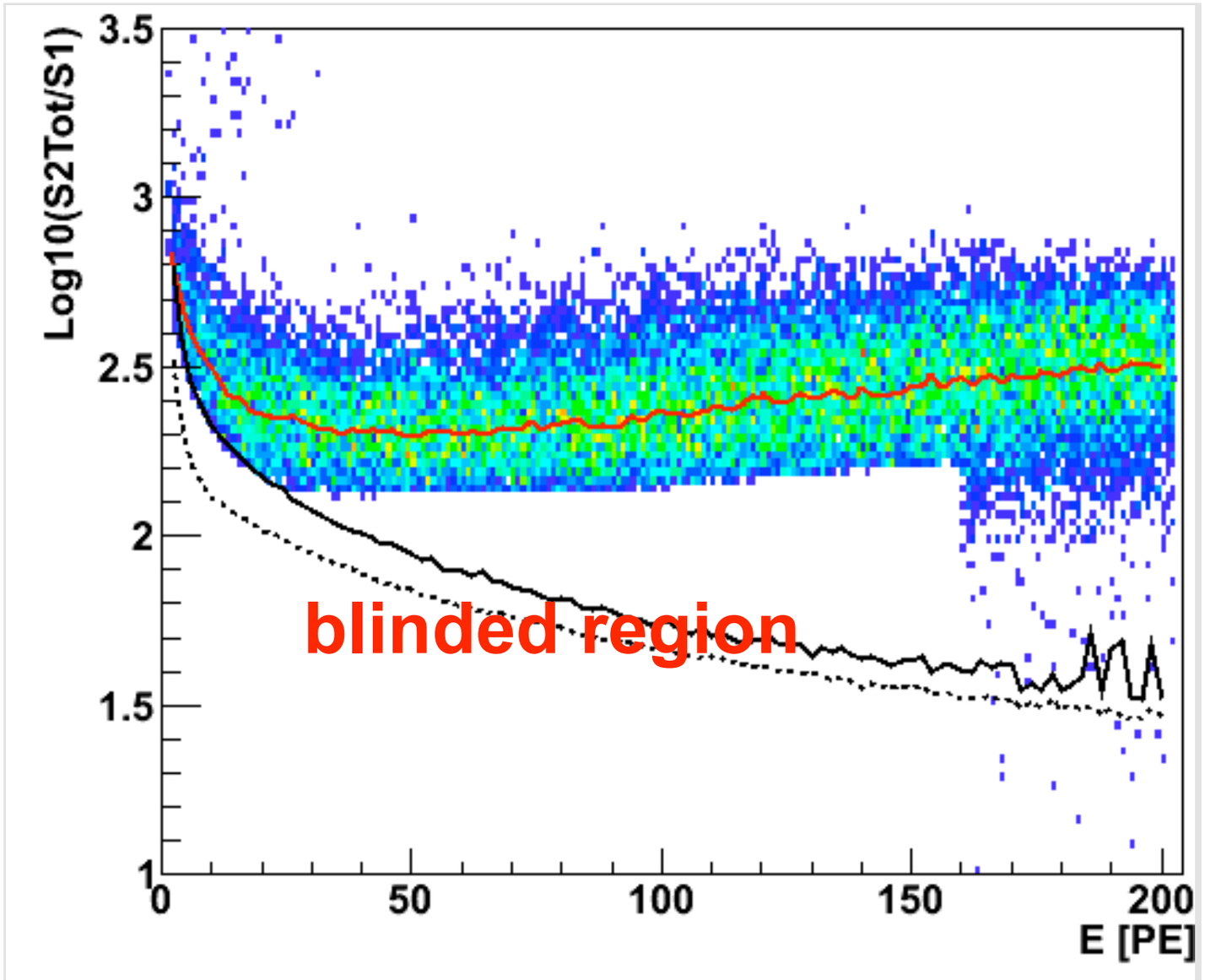


Throughout the data taking period the experimental parameters were monitored and show a great stability in time.





Blinding of the data

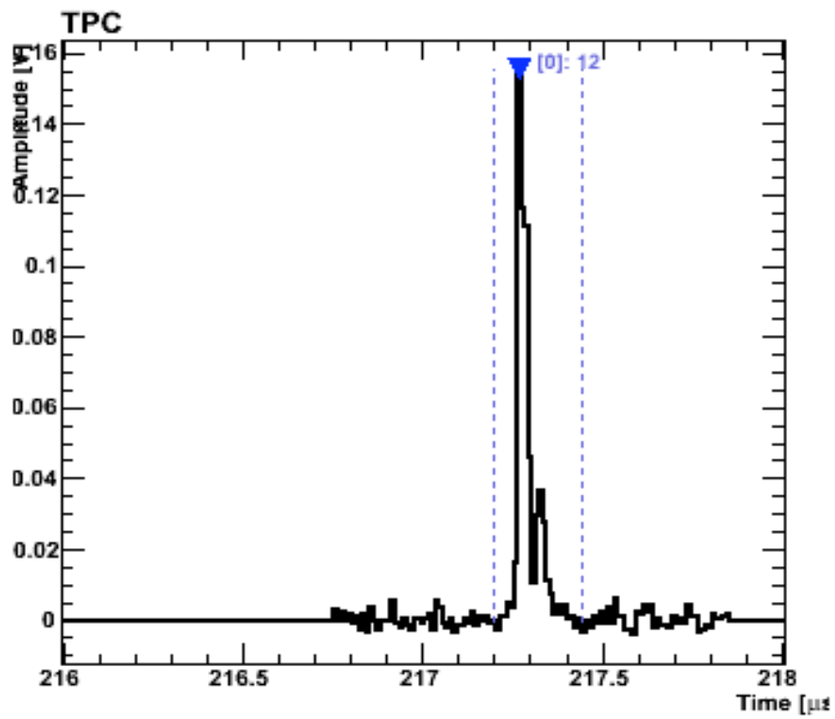


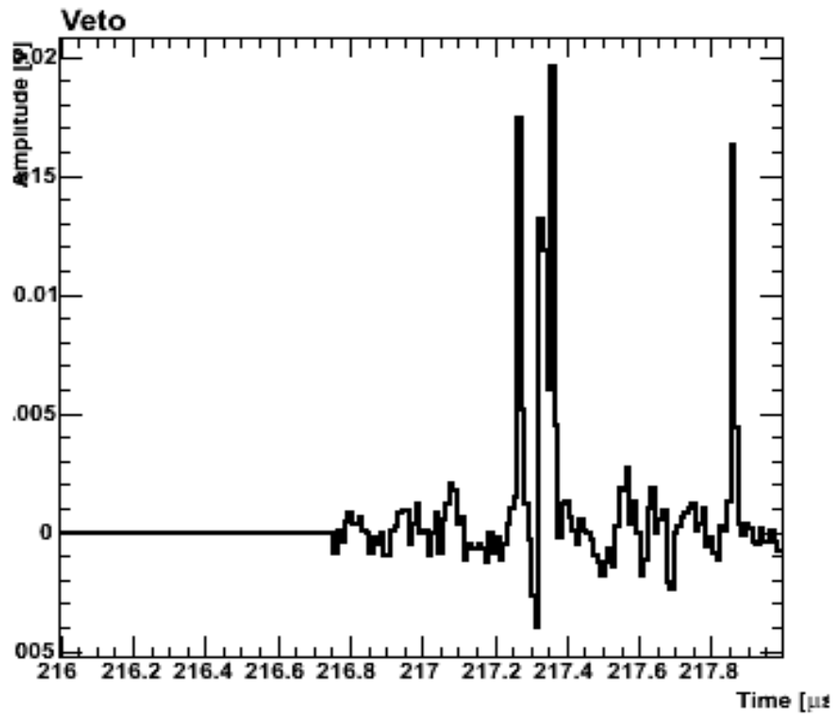
To ensure an unbiased analysis the potential signal region was blinded while selection cuts were defined.

Each event below the 90% quantile of the ER distribution was hided in the analysis.

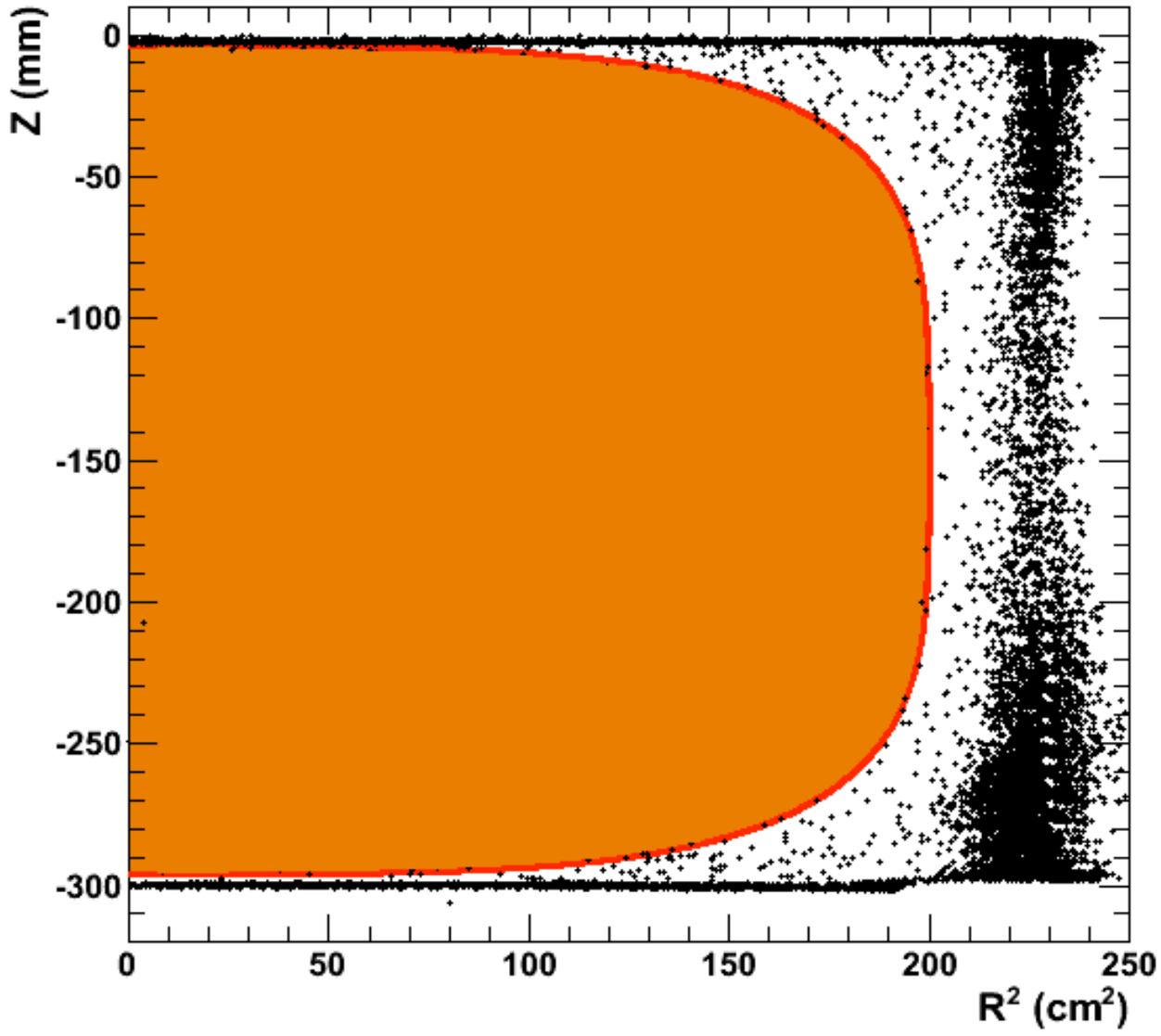
Basic data quality cuts

- ☑ Remove periods of unstable detector performance.
- ☑ Remove hot spots (PMTs wildly firing).
- ☑ Reject noise events.
- ☑ Remove events interacting in the gas phase.
- ☑ Request 2 fold coincidence for S1 signals (remove PMT dark current and noise events).
- ☑ Select events with only a single S1 pulse (noise rejection).
- ☑ Reject events which have a hit in the active LXe veto (see figures)





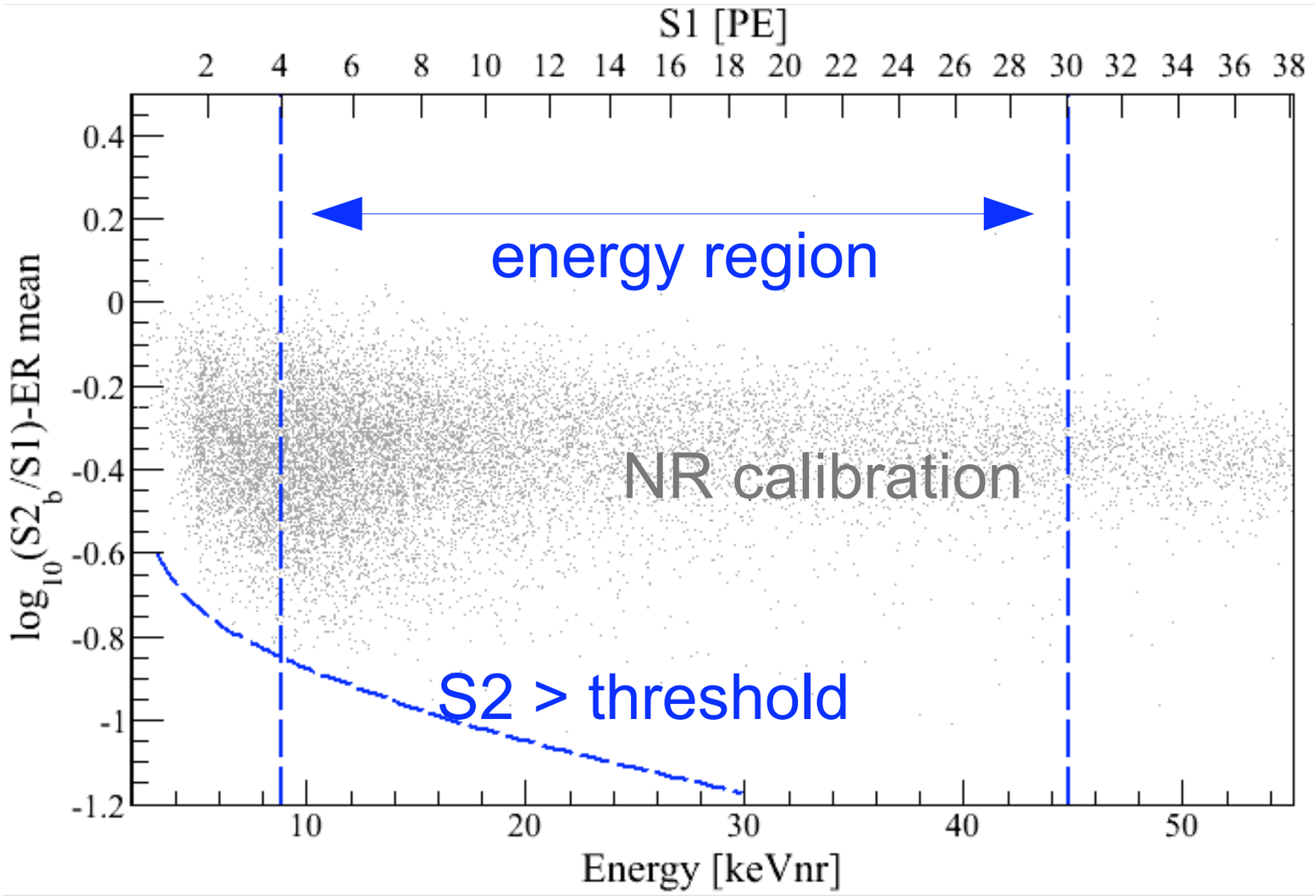
Fiducial volume



Select only events in the inner part of the TPC to exploit self-shielding effect.

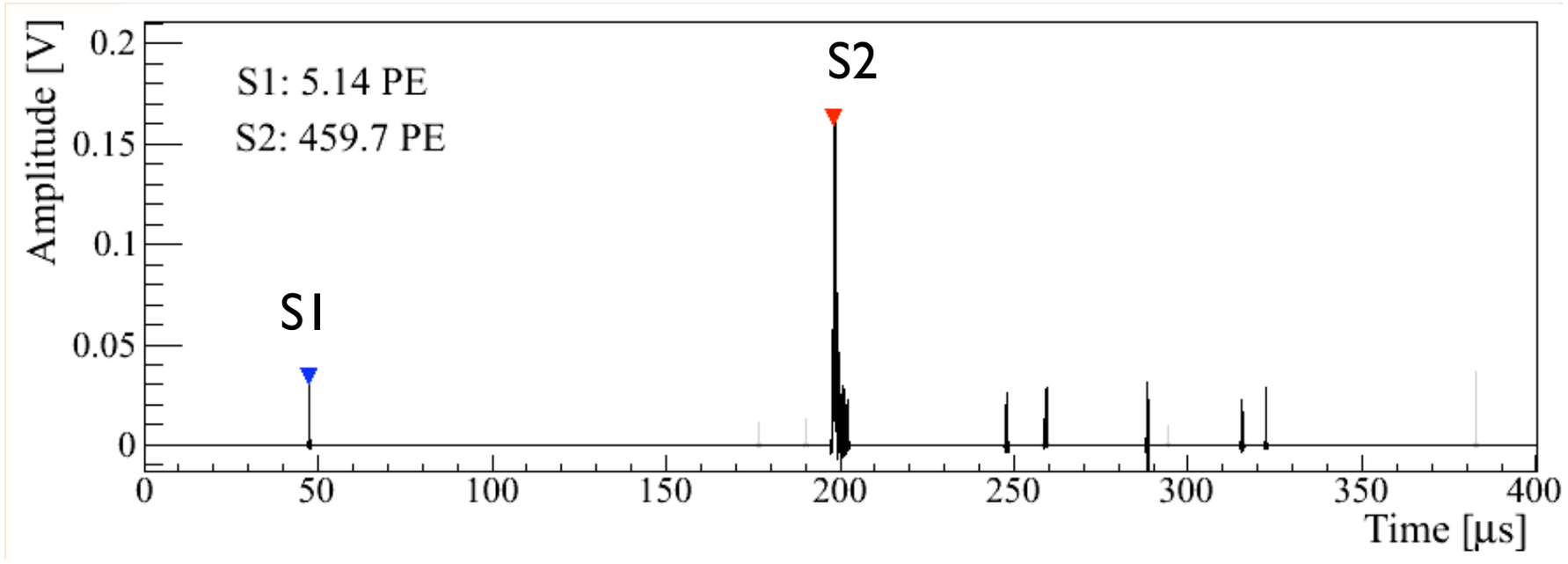
Tunable to reduce background for a chosen mass of xenon used in the WIMP analysis.

Definition of the energy region



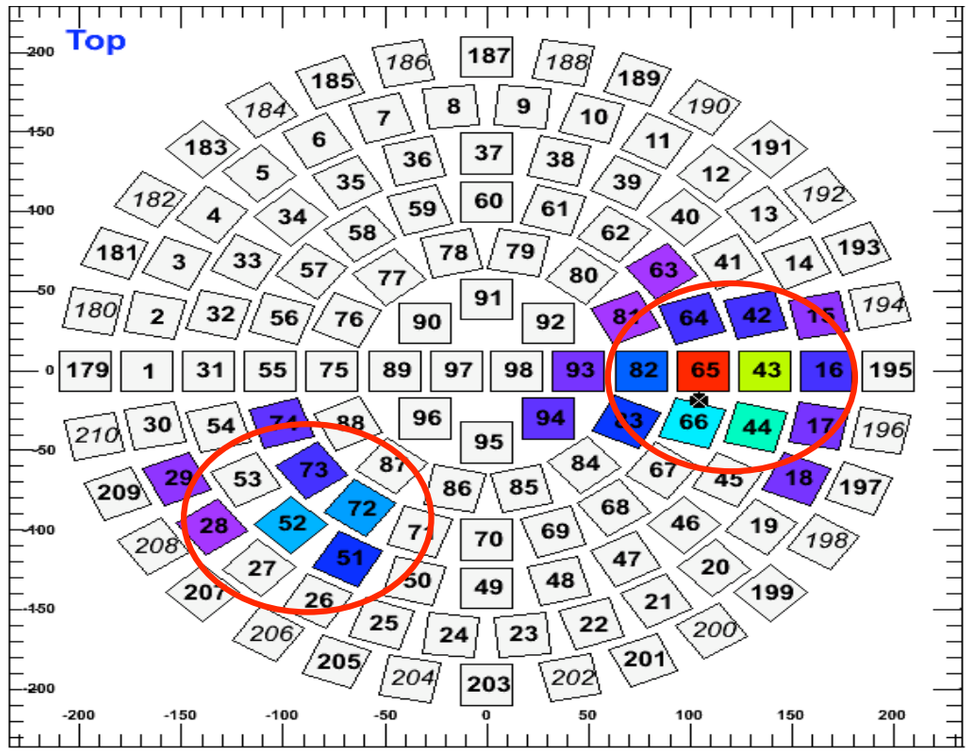
The energy region has been chosen such that it was possible to perform the search for elastic scatters (WIMPs) and inelastic scatters (iDM).

Single scatter selection

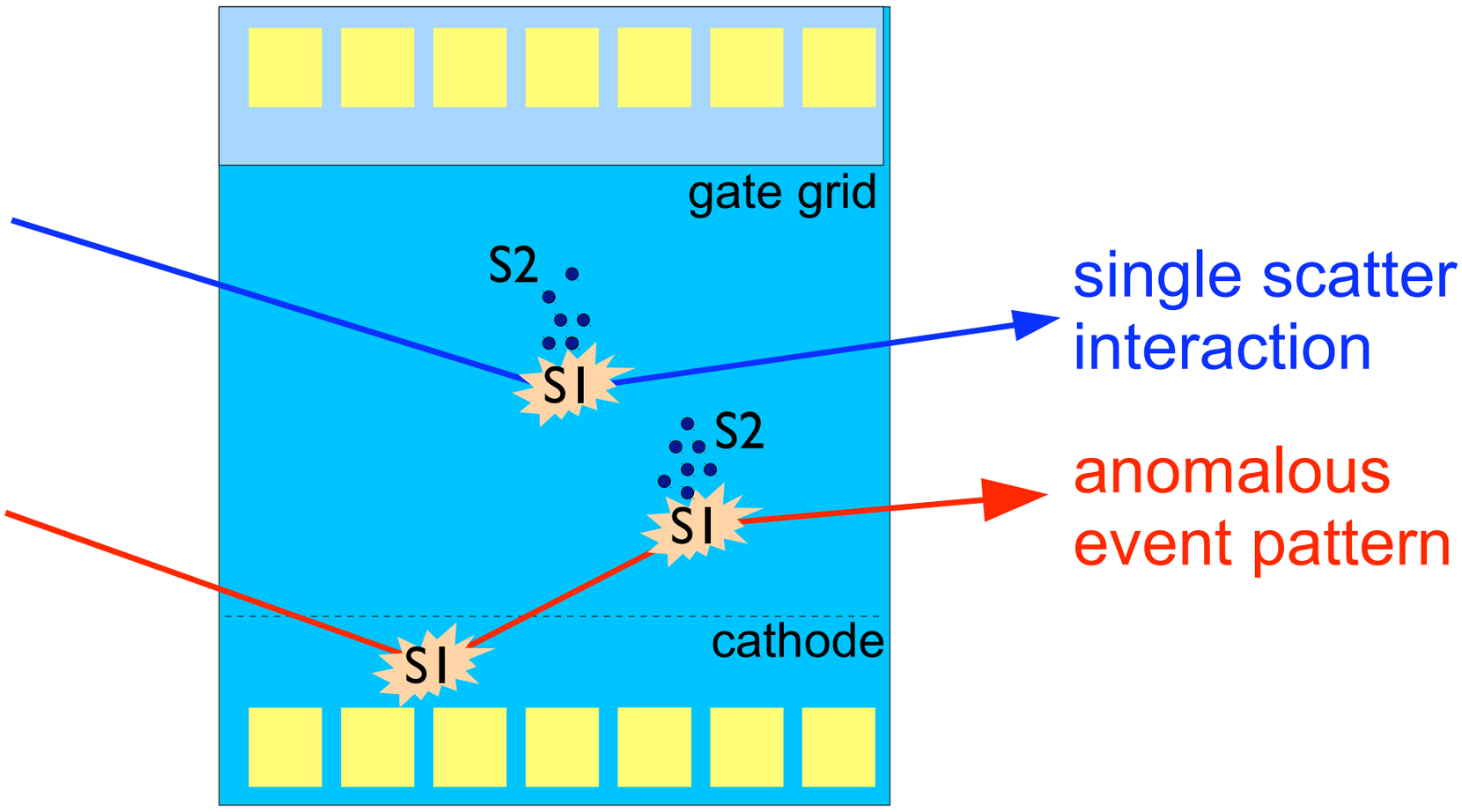


Valid candidate events should have only one S2 signal. (Two S1 signals from the same interaction cannot be resolved).

Single scatter identification possible on the number of detected S2 pulses and also the hit patterns.



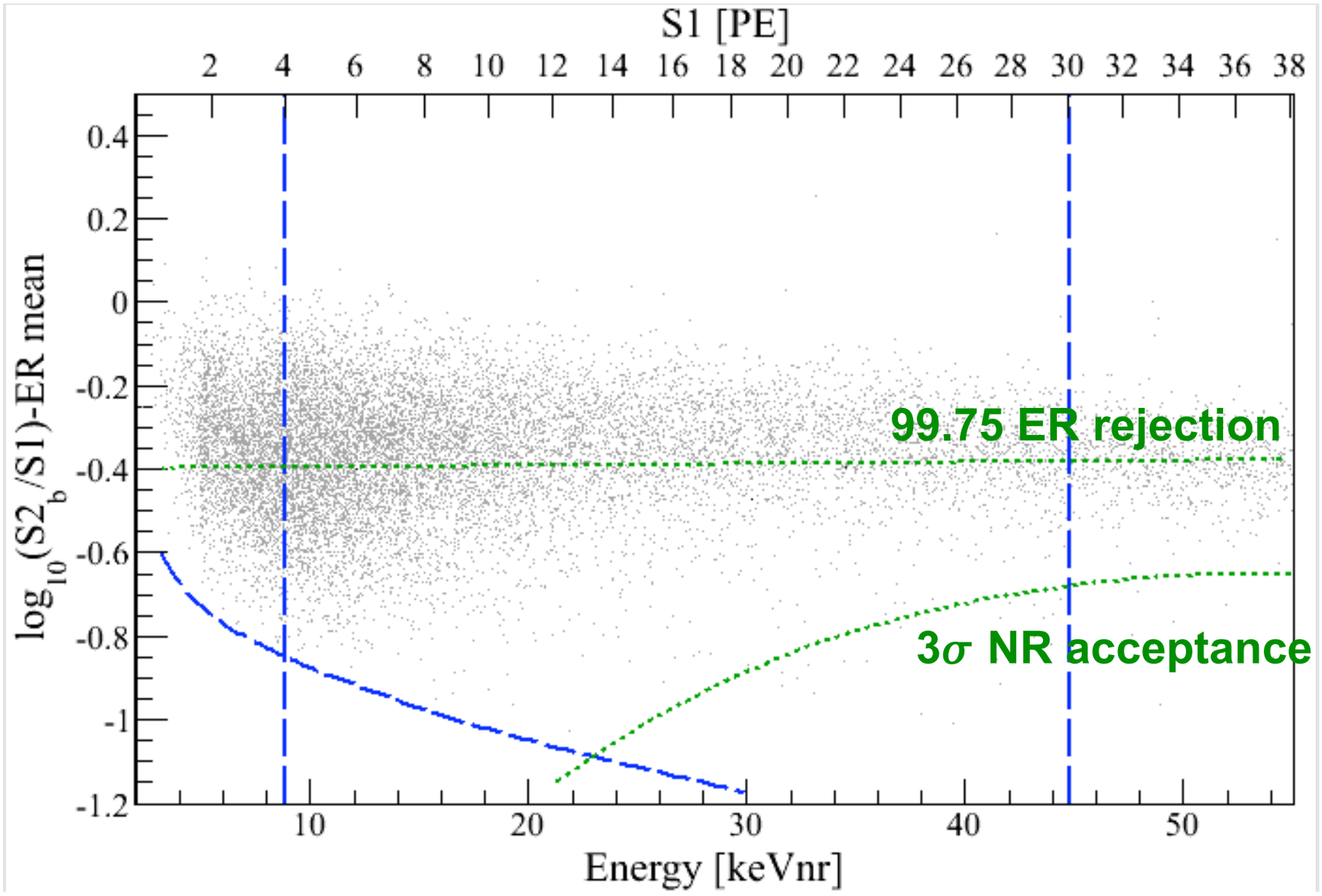
Rejection of anomalous hit patterns



For multiple scatters for which interactions happen below the cathode the corresponding S2 signal is missing.

Such events may mimic nuclear recoils and are rejected based on the S1 hit pattern.

Nuclear recoil acceptance



The nuclear recoil acceptance for a cut based analysis is defined by the 99.75% ER rejection line and the 3 σ NR acceptance.

Choice based on maximizing the expected sensitivity.

Expected background

Statistical ER leakage

(1.14 ± 0.48) events

Determined from non-blinded ER background data. Dominated by ^{85}Kr concentration (~650ppt).

Anomalous events

(0.56 +0.21/-0.27) events

Using data and Monte Carlo from ^{60}Co and Background data.

Neutrons

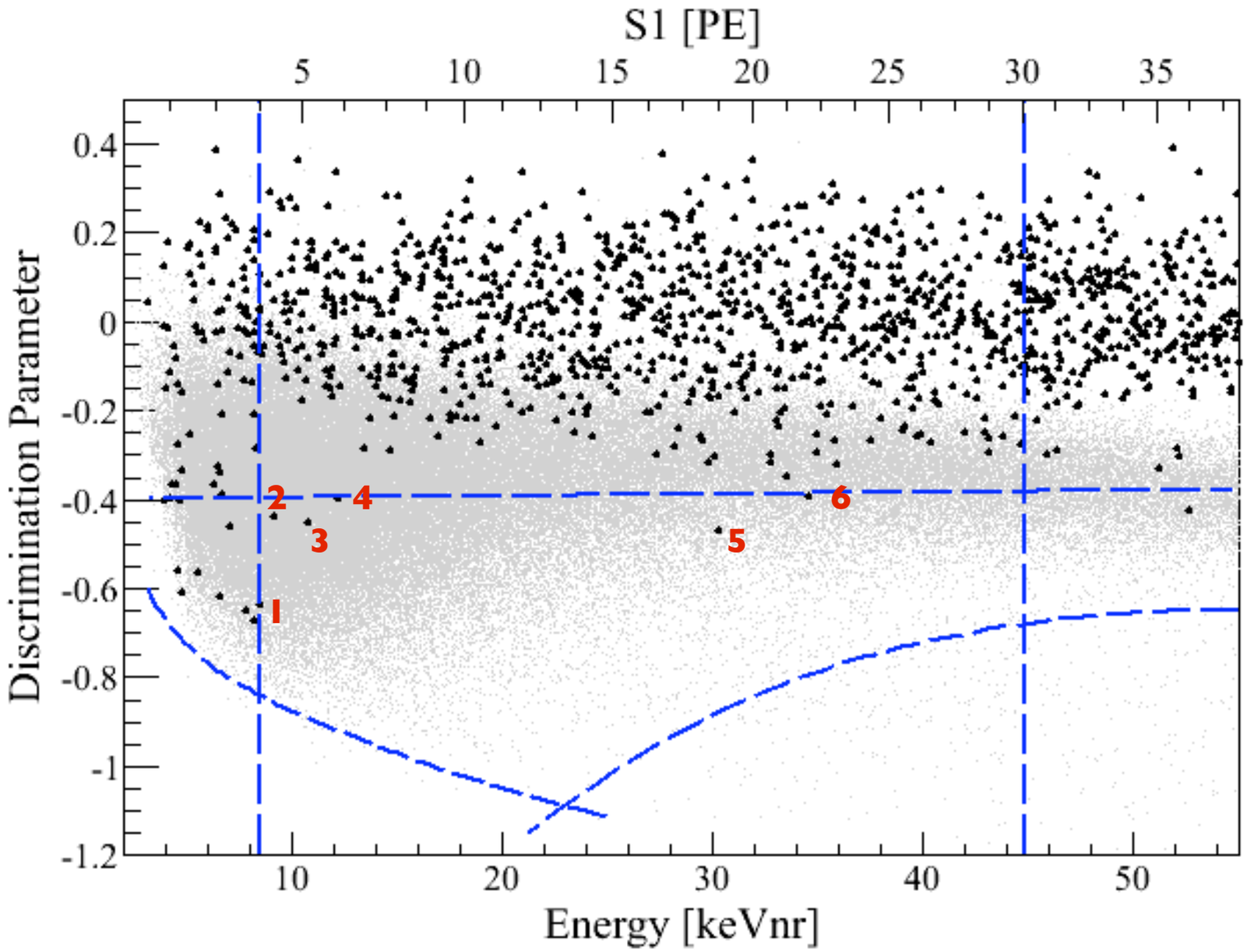
(0.08 +0.08/-0.04) events : Muon induced nuclear recoils

(0.032 ± 0.006) events : α-n reactions and spontaneous fission

Total

(1.8 ± 0.6) events

Unblinding

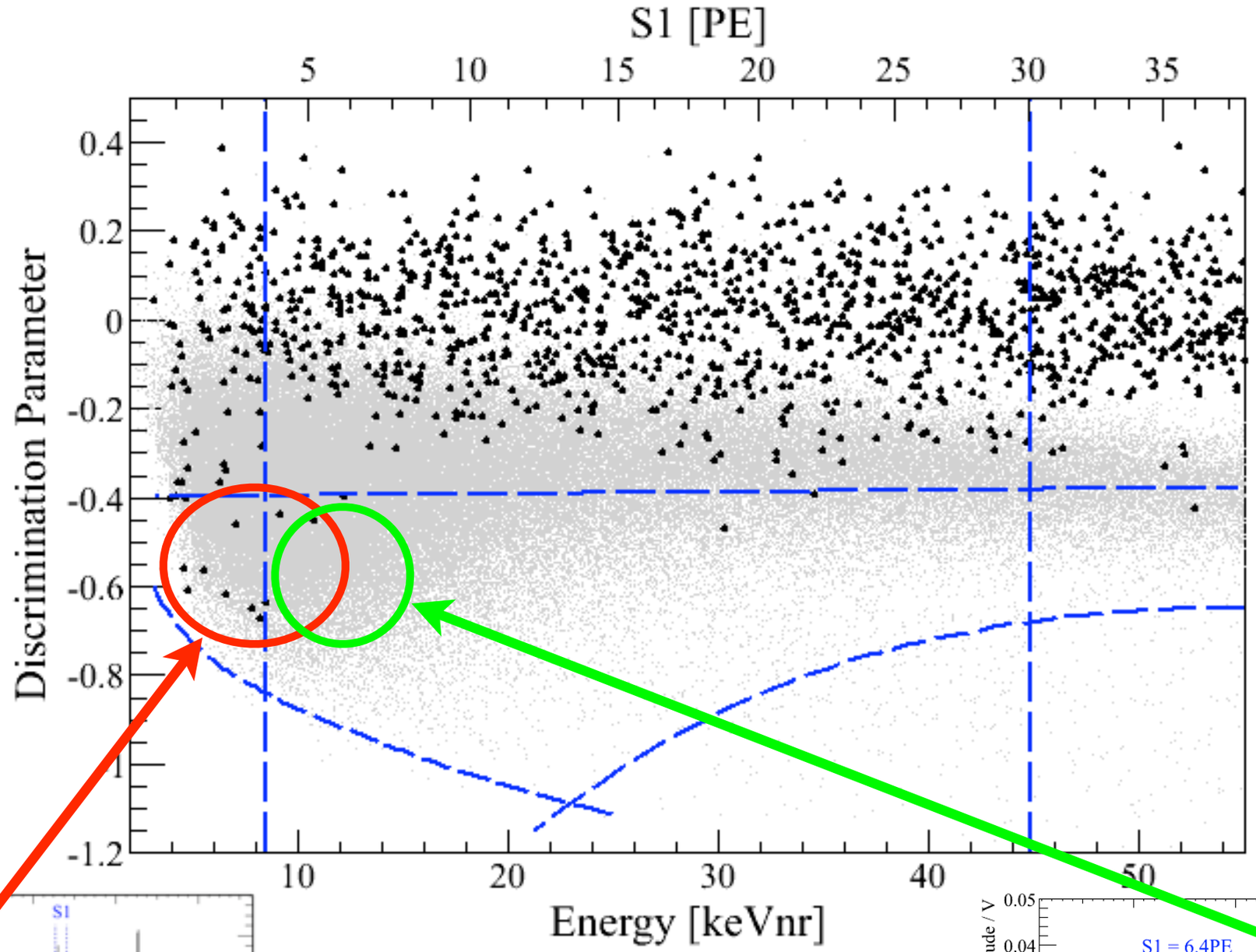


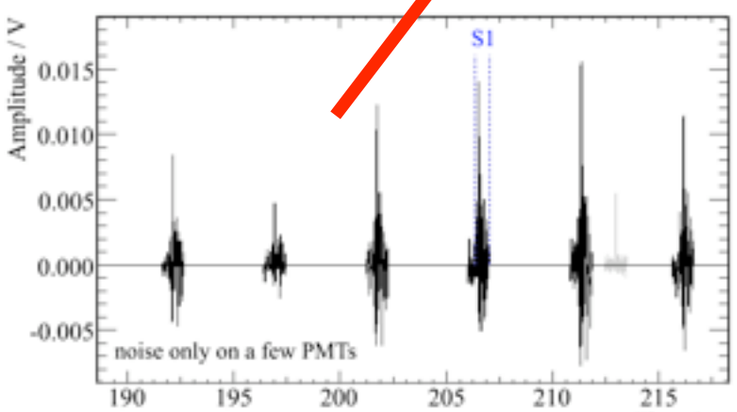
Upon unblinding of the data 6 events were observed in the predefined signal region.

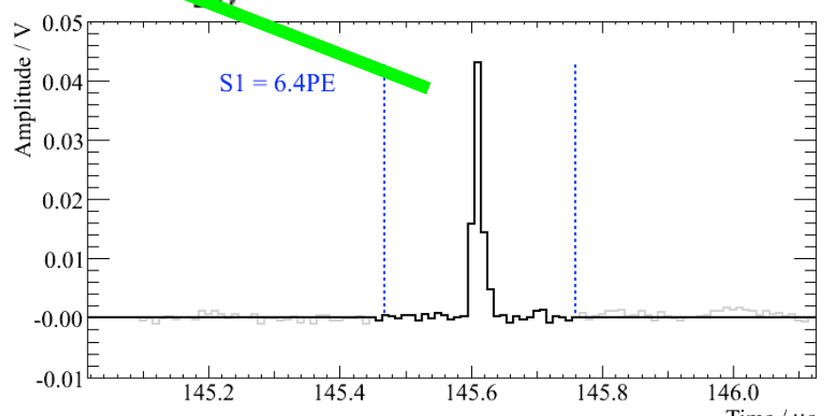
4 events at low recoil energies → large gap with no events → 2 events at high recoil energies.

Noise issue after unblinding

Events at the lowest energies (above and below the analysis threshold) showed an increased noise in the waveforms, unlikely to be real physical events.

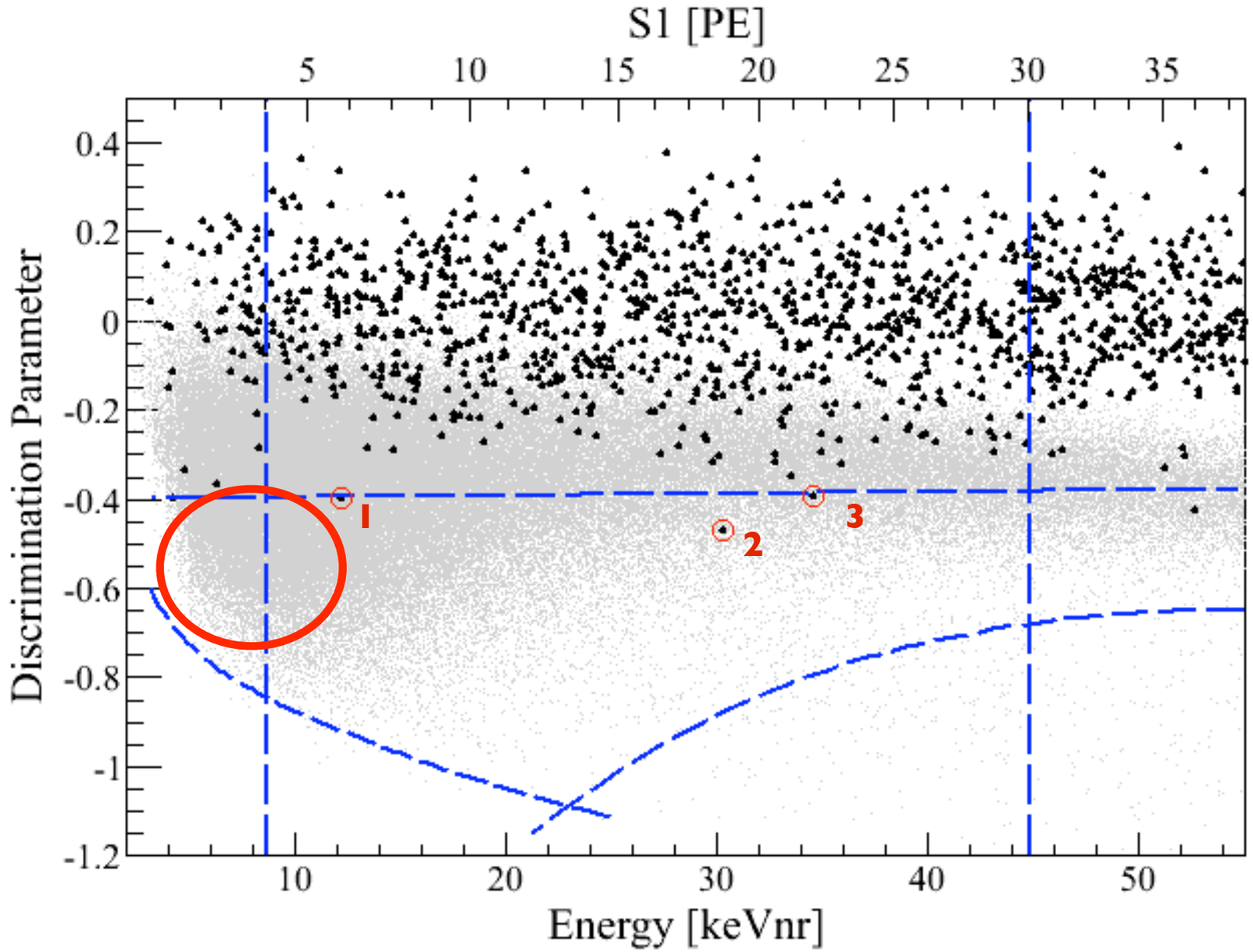






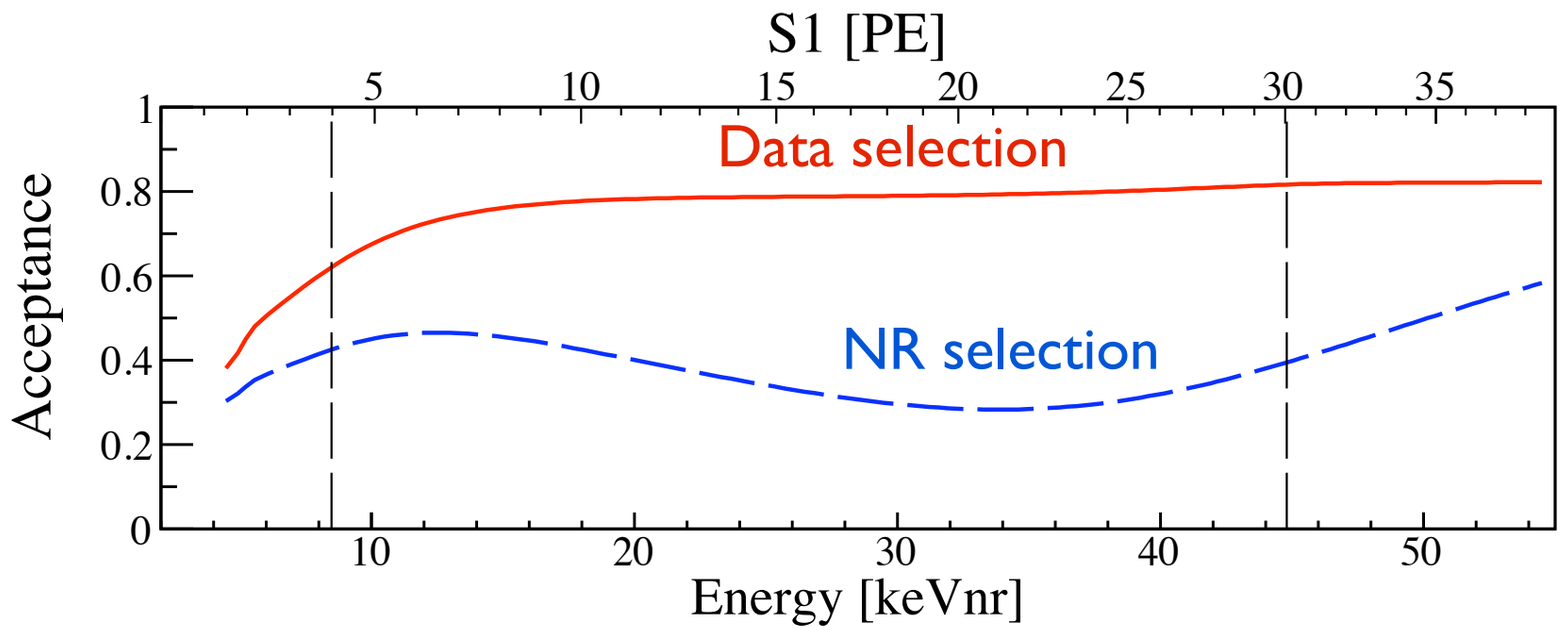
Post-unblinding result

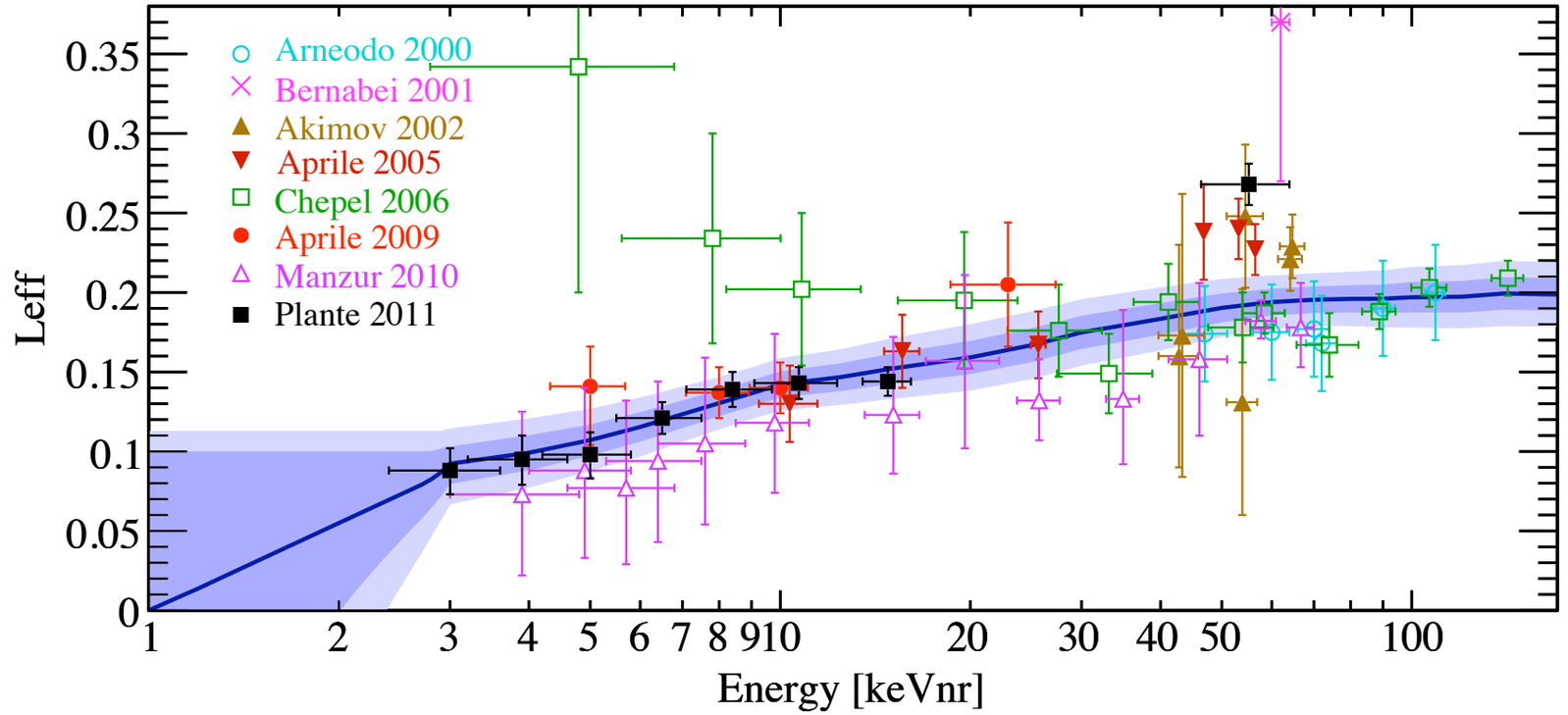
The definition of post-unblinding cuts which reduced the overall signal acceptance (<0.1%), removed this population of noise events (above and below the analysis threshold, no fine-tuning)



The analysis of the first 100 days of XENON100 data resulted in the observation of 3 candidate events in the predefined nuclear recoil acceptance region.

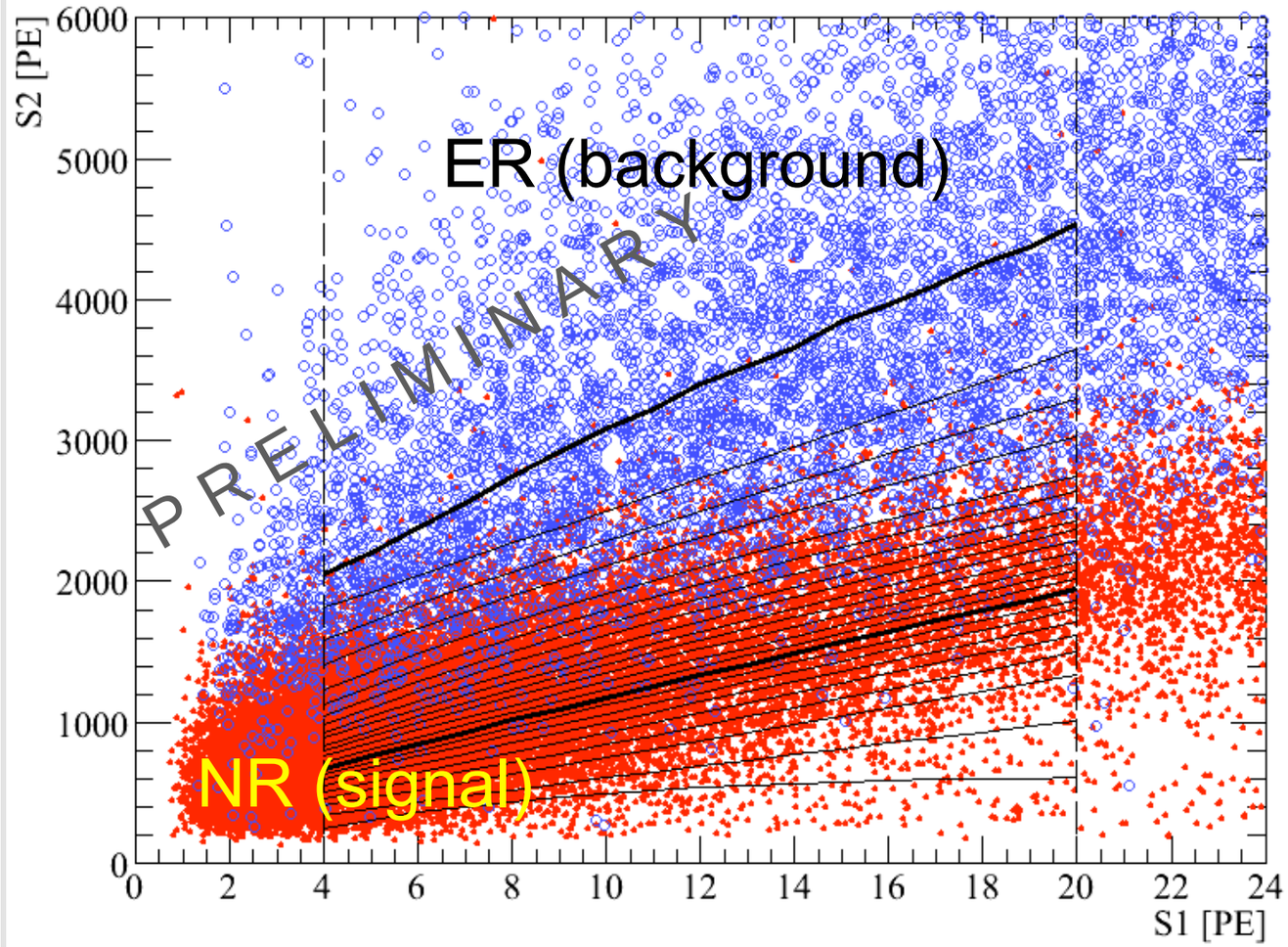
Signal acceptance and energy scale





Energy scale measured down to 3keVnr, uncertainties taken into account when calculating expected WIMP spectrum.

Profile-Likelihood method



$$\mathcal{L} = \mathcal{L}_1(\sigma, N_b, \epsilon_s, \epsilon_b, L_{eff}, v_{esc}; m_\chi) \times \mathcal{L}_2(\epsilon_s) \times \mathcal{L}_3(\epsilon_b) \times \mathcal{L}_4(L_{eff}) \times \mathcal{L}_5(v_{esc})$$

Dark Matter likelihood

NR likelihood

ER likelihood

Uncertainties on the energy scale

Uncertainties on the escape velocity

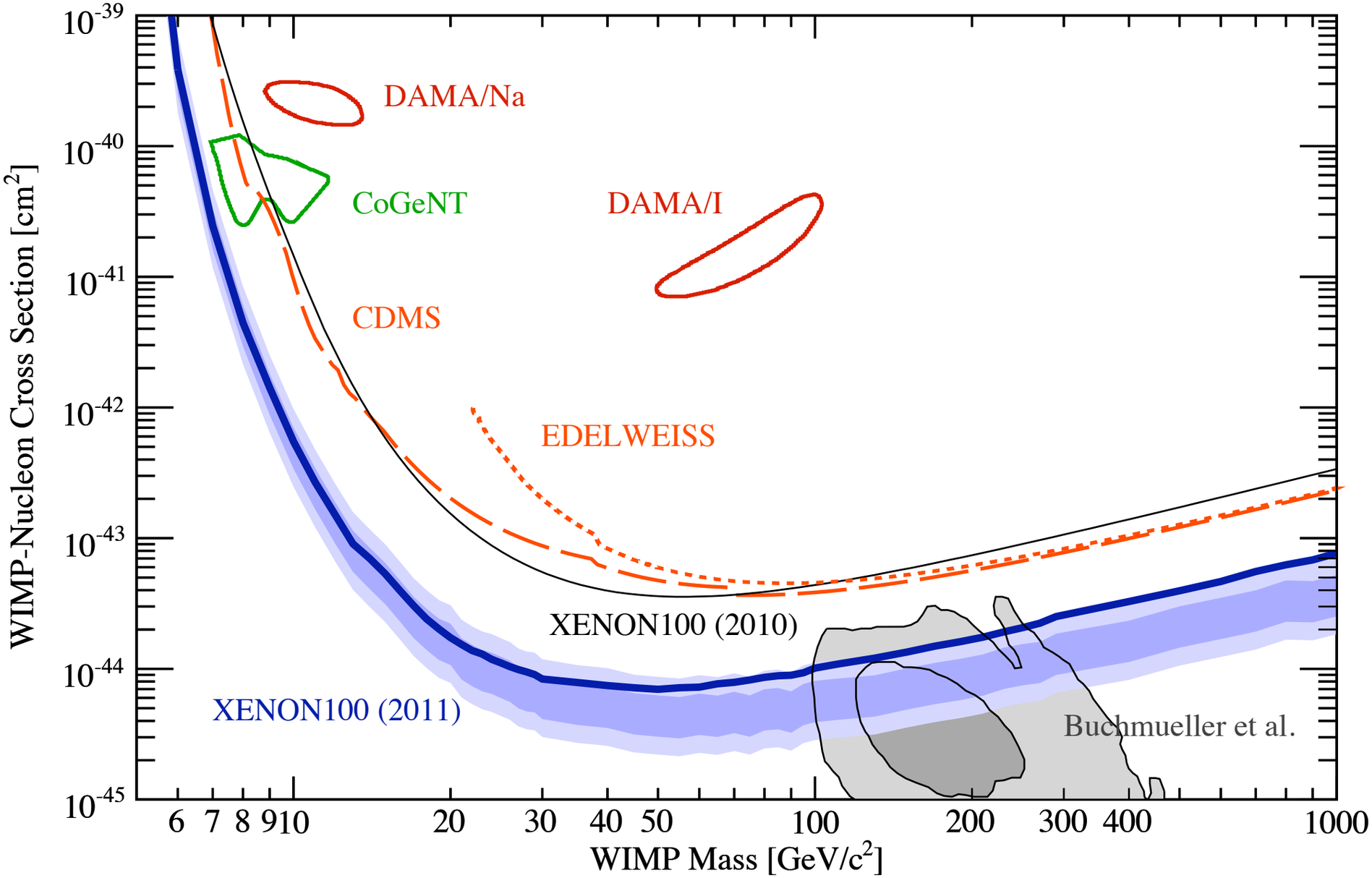
Likelihoodratio test is used in hypothesis testing (signal/background).

Takes care of systematic uncertainties by profiling over the nuisance parameters.

Results from the first 100 days

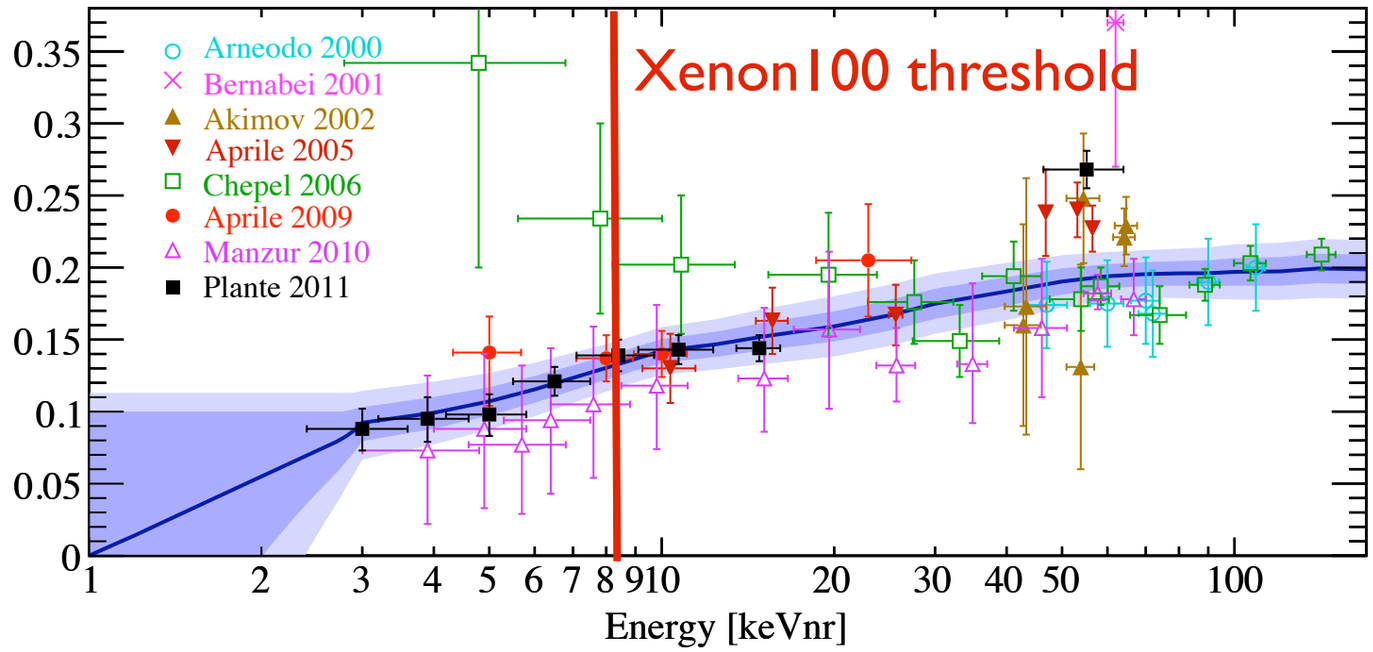
Poisson probability to observe 3 events or more when expecting 1.8 ± 0.6 : 28%.

The PL method did not show a significant signal contribution in the data.



World leading upper limit on the SI WIMP-Nucleon cross section.

Uncertainties at low masses: Leff



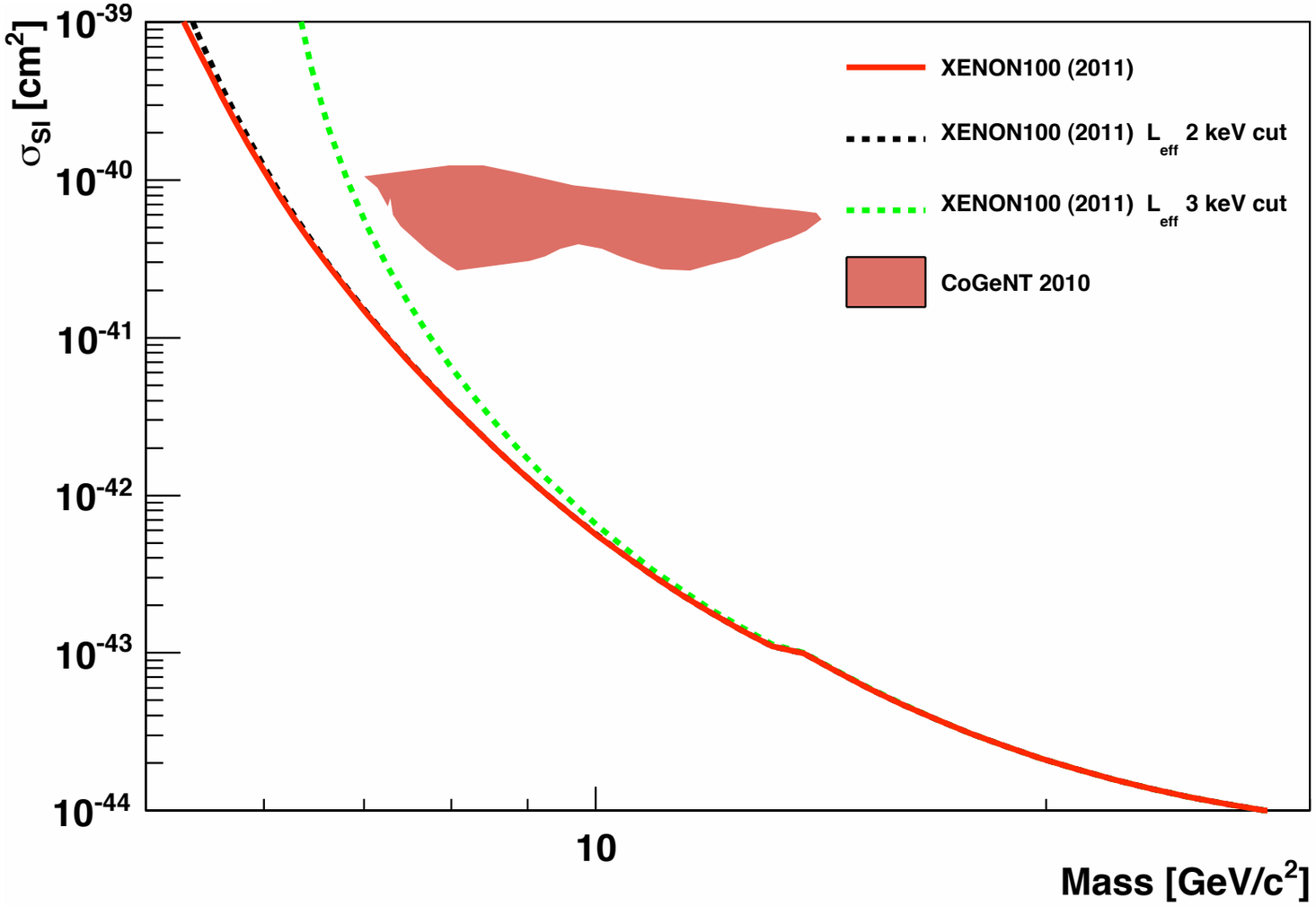
The nuclear recoil energy scale is well determined down to energies of 3keV.

Below 3 keV extrapolation is used.

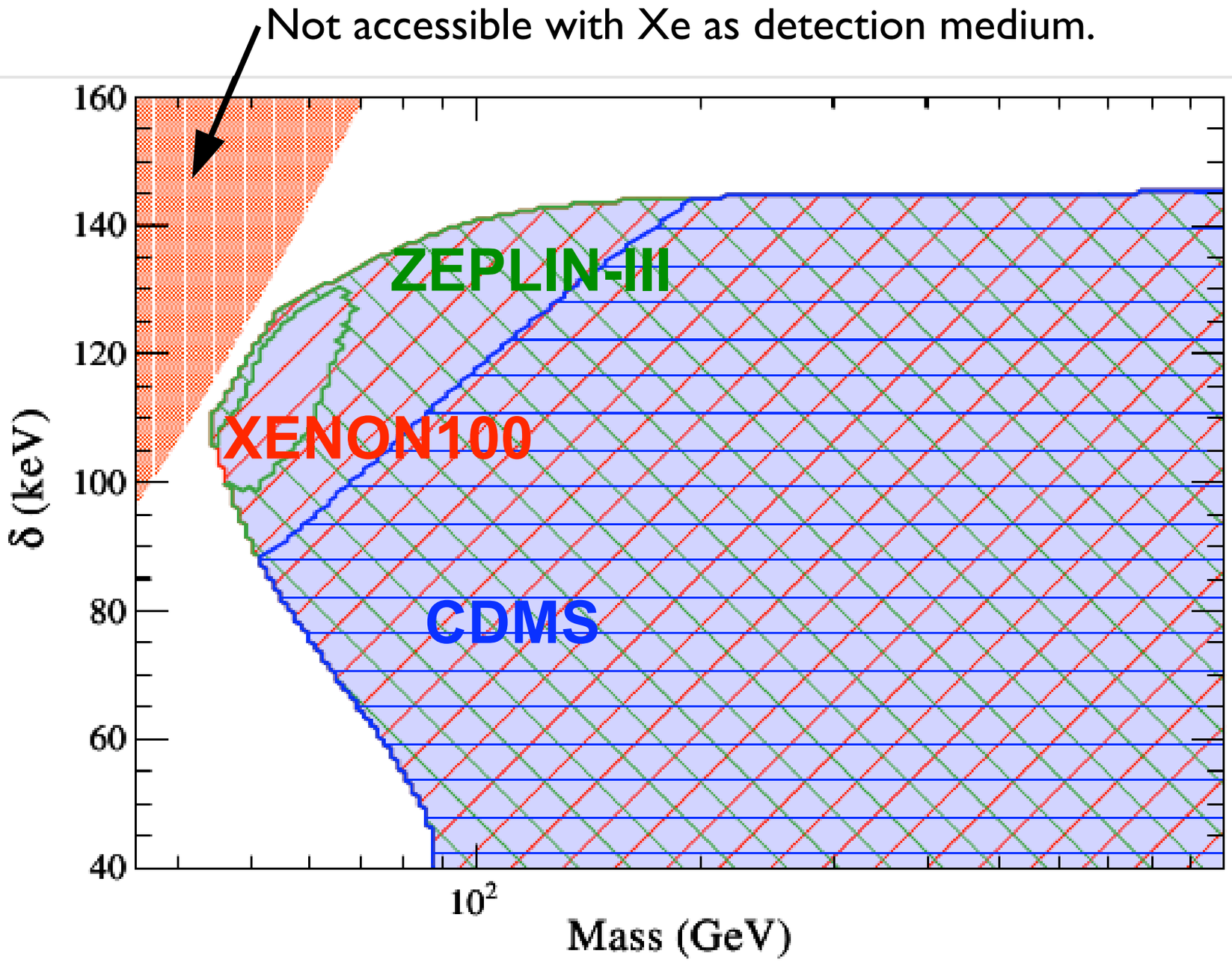
Sensitivity at low masses is only due to the energy resolution of the detector.

Dependence of the sensitivity on the energy scale below threshold of 8.4 keV.

Even when an unphysical cut on the production of scintillation light below measured values is applied, this does not affect the result when compared to the CoGeNT claim.



Inelastic Dark Matter

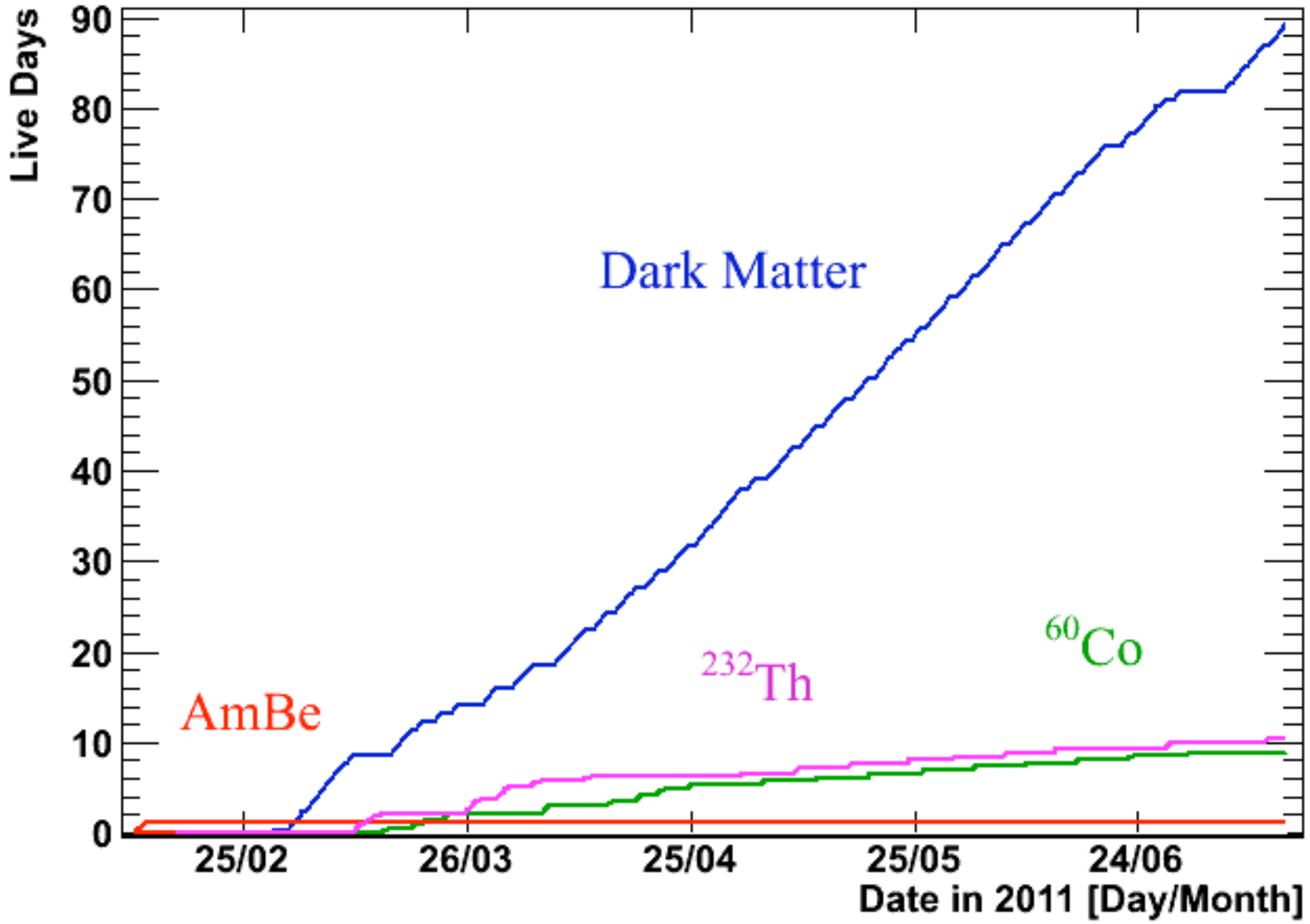


The XENON100 results exclude the whole allowed DAMA/LIBRA allowed region.

Shown are only regions for which XENON100 results are not compatible with DAMA/LIBRA at the 90% CL.

The near future

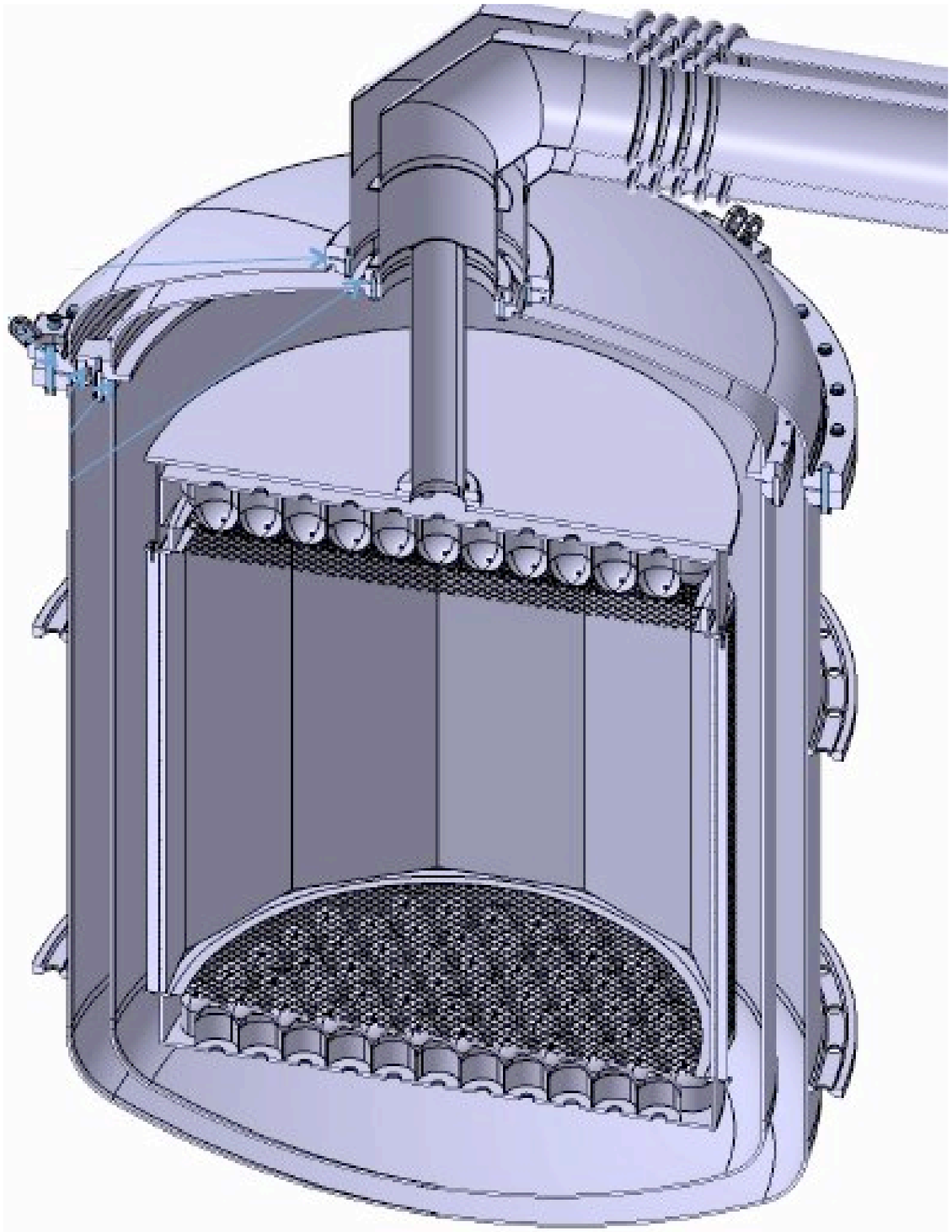
New Dark Matter run started at the beginning of 2011, already ~100 days of exposure.



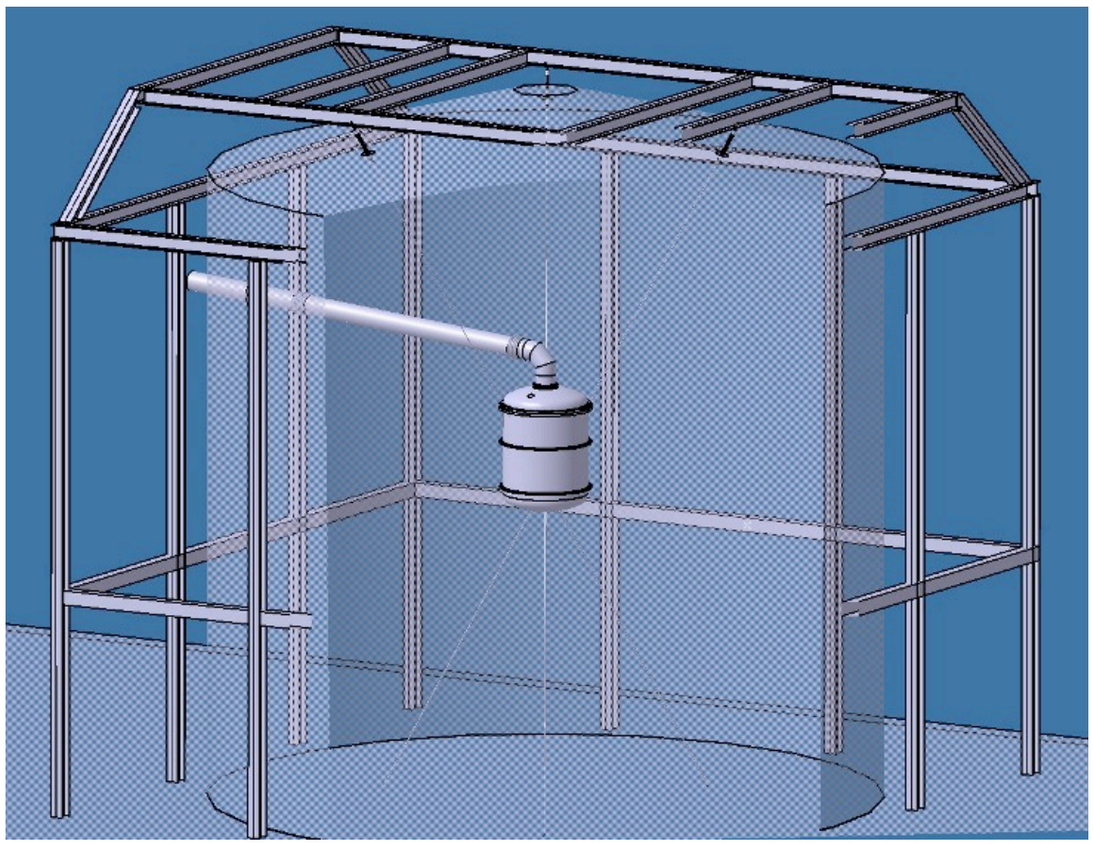
Reduced 85 Kr concentration by a factor of 5 → reduced background from statistical leakage.

Improved purity of the detector and lowered trigger threshold.

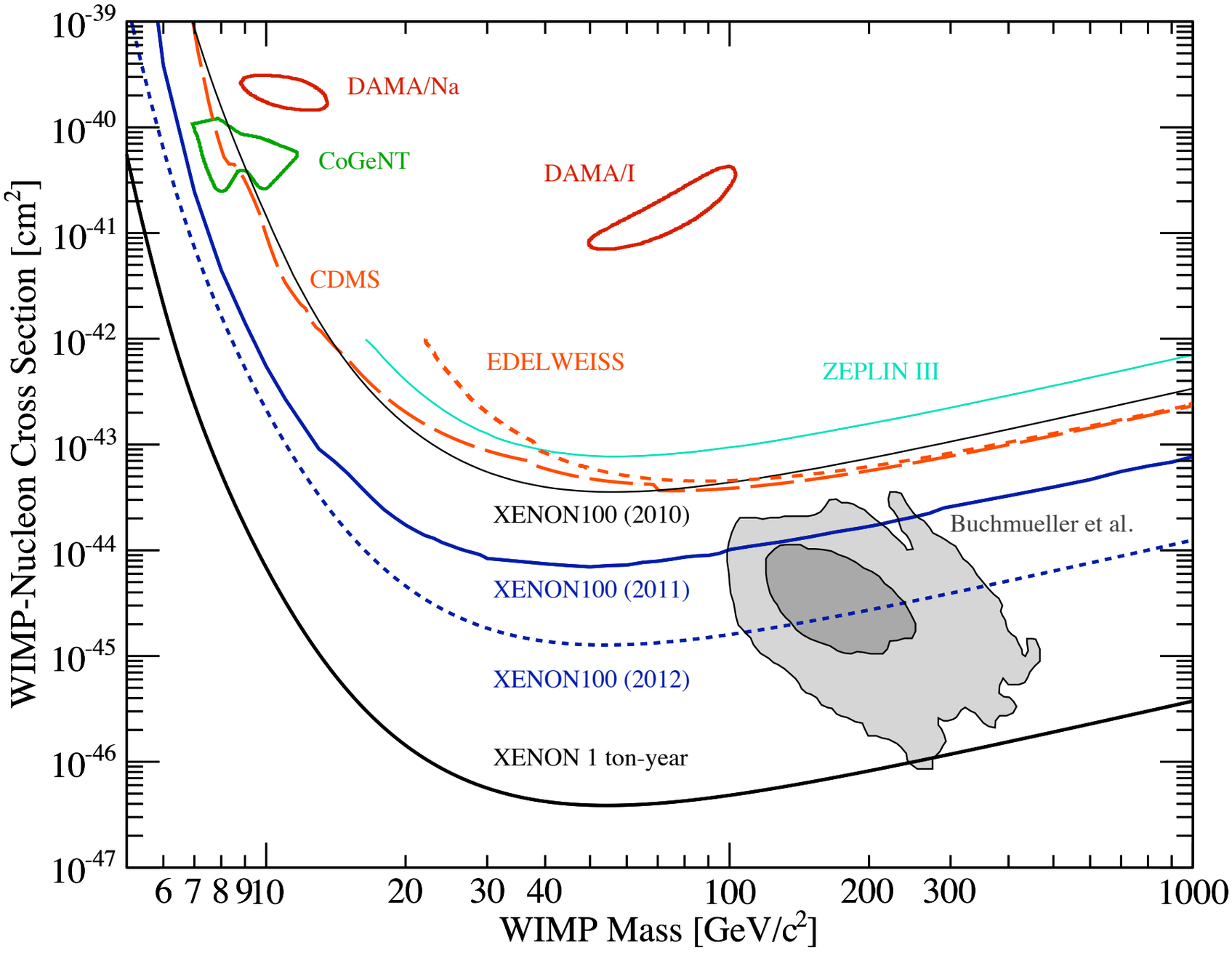
XENON1T



- Total of 2.4 ton LXe (1 ton fiducial)
- Drift length ~1m
- 100x background reduction with respect to XENON100
- Enclosed by a 5m water shield (passive and active muon veto)
- Timeline 2011 - 2015



Expected sensitivities



The XENON program will probe most of today's favored parameter-space in the next years.

So stay tuned!

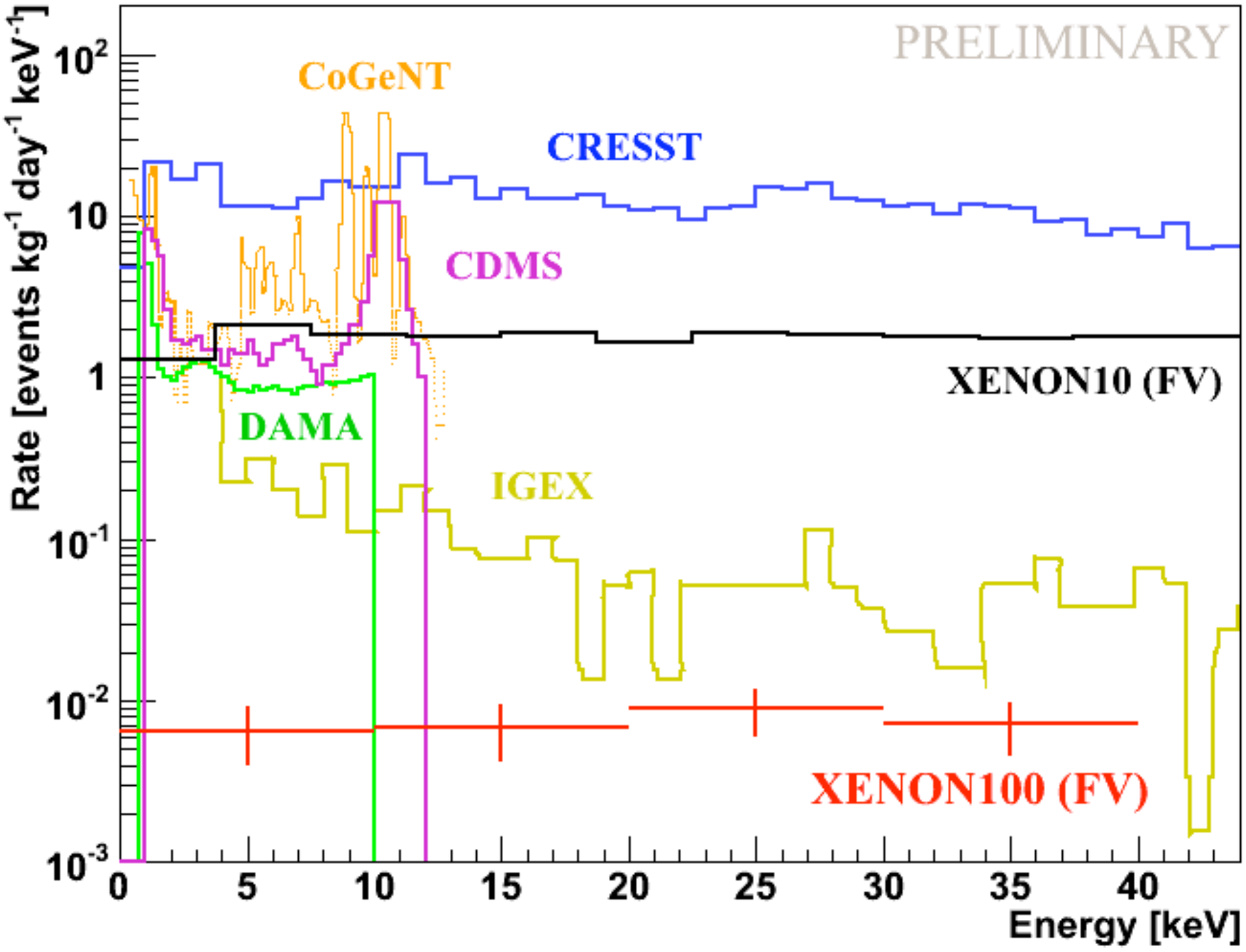
Summary

- Liquid xenon has proven to be a promising target material to detect Dark Matter.
- Anticipated background level has been achieved for XENON100.
- The XENON100 experiment has world leading sensitivity to search for WIMP Dark Matter. So far no significant detection.
- Already another ~100 days of exposure with an decreased background level, lowered energy threshold and improved electron drift at hand.
- XENON1T has been brought on its way to improve the sensitivity by another order of magnitude.

XENON100 Collaboration

Thank you!

Background comparisons



Spatial distribution of candidate events