ZEPLIN III
FIRST SCIENCE RUN

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On behalf of the ZEPLIN III collaboration
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Imperial College London (UK)
ITEP-Moscow (Russia)
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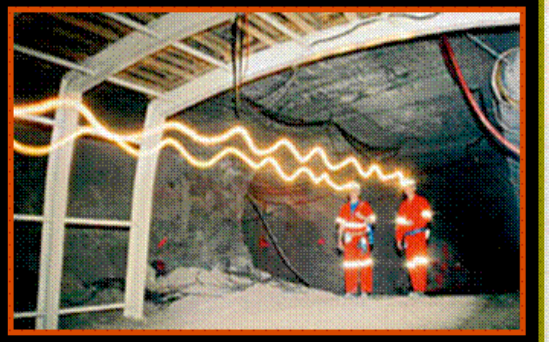
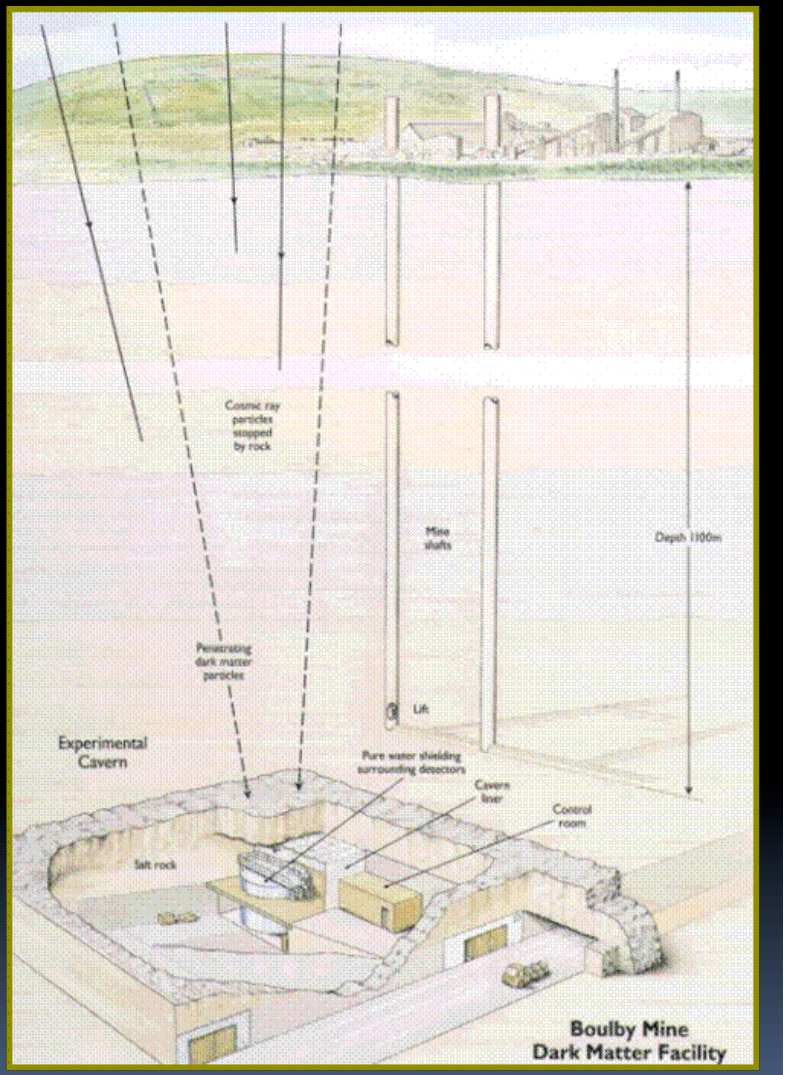
In Memoriam Vadim Nikolaevitch Lebedenko 1939-2008

TeV Particle Astrophysics , September 24th 2008, IHEP, Beijing, China

ZEPLIN III at the Boulby mine

- Location: Boulby, North Yorkshire (UK)
- Vertical Depth : 1070 m (meters of water equivalent) : 2850
- Muon flux:
  ~ $4*10^{-8}$ cm^{-2} s^{-1}
- Other experiments:
  ZEPLIN II
  DRIFT II
  SKY





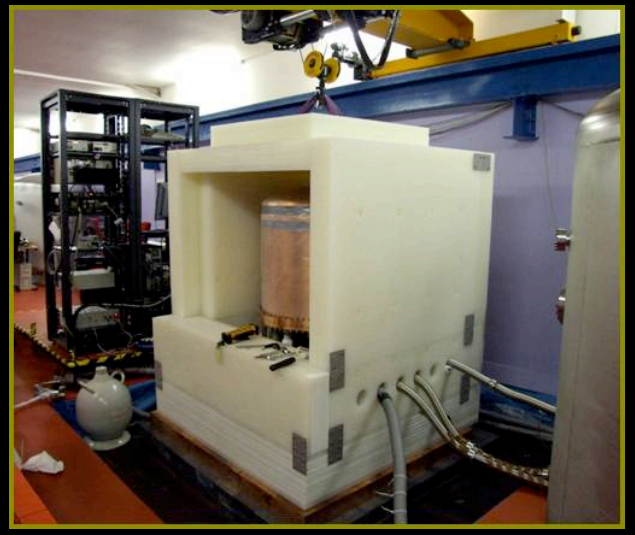
ZEPLIN III at the Boulby mine

DAQ and Slow Control

ZEPLIN III Detector

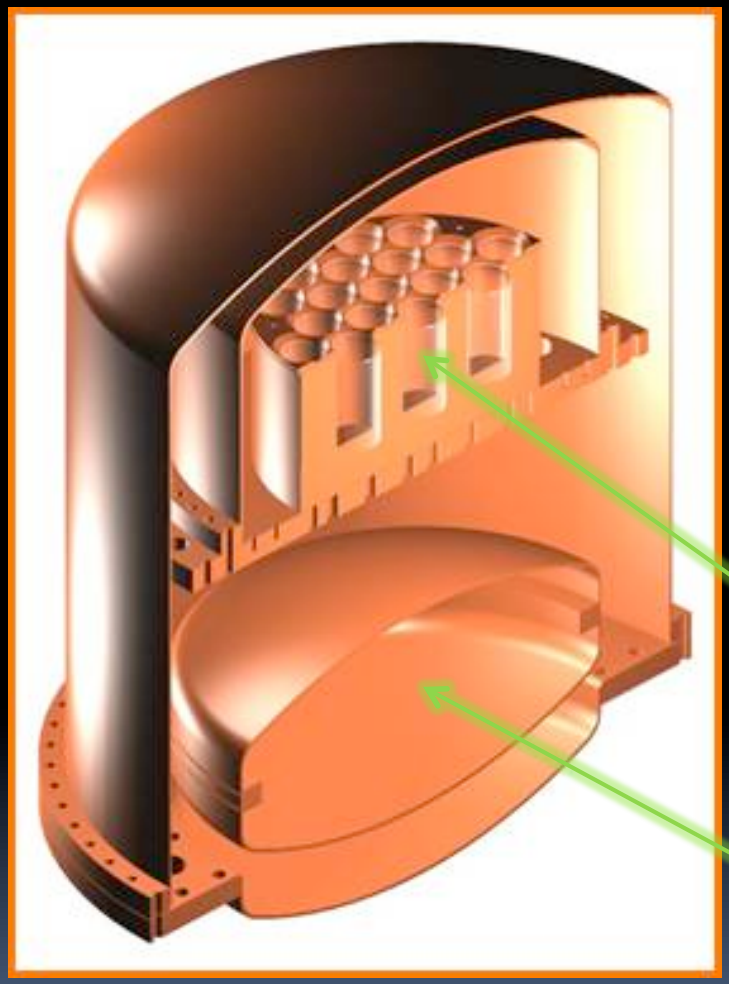
Xenon safety dumps

Neutron shield – 30 cm of hydrocarbon



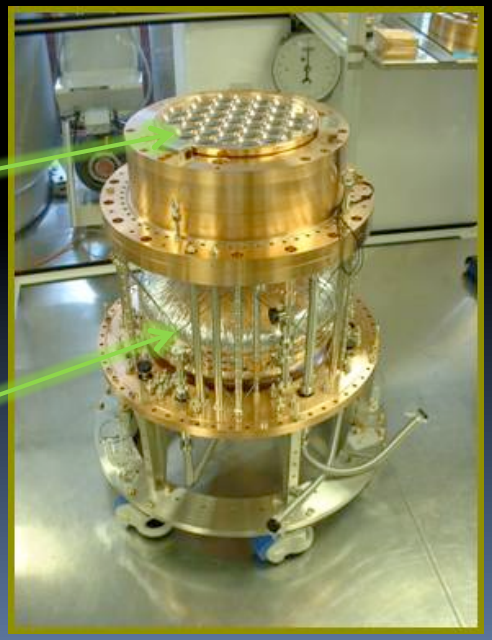
Gamma shield – 20 cm lead

ZEPLIN III detector structure



16 plates for internal PMT dynode Interconnections

PMTs array



LN2 vessel (36 litres)

Operational temperature is -100C and the heat load is ~40 W

ZEPLIN III
Double-phase LXe detector

- Scintillation light collection
  - 31 2" PMTs with high quantum efficiency (~ 30 %) immersed in liquid
  - 36 mm drift height
  - 400 mm diameter
  - 4 mm gas gap with 1.6 atm operating pressure
  - no PTFE reflector

- Electric field operation
  - 4 kV/cm in liquid and 8 kV/cm in gas
  - no extraction grids

- Light yield at 4 kV/cm
  - S1 ~ 2.5 pe/keV
  - S2 ~ 11 pe/keV

- Event 3D position reconstruction

ZEPLIN III detector structure and operation principles

Radiation interaction with LXe creates scintillation signal : S1

Ionization charge extracted into gas phase creates electroluminescence signal : S2

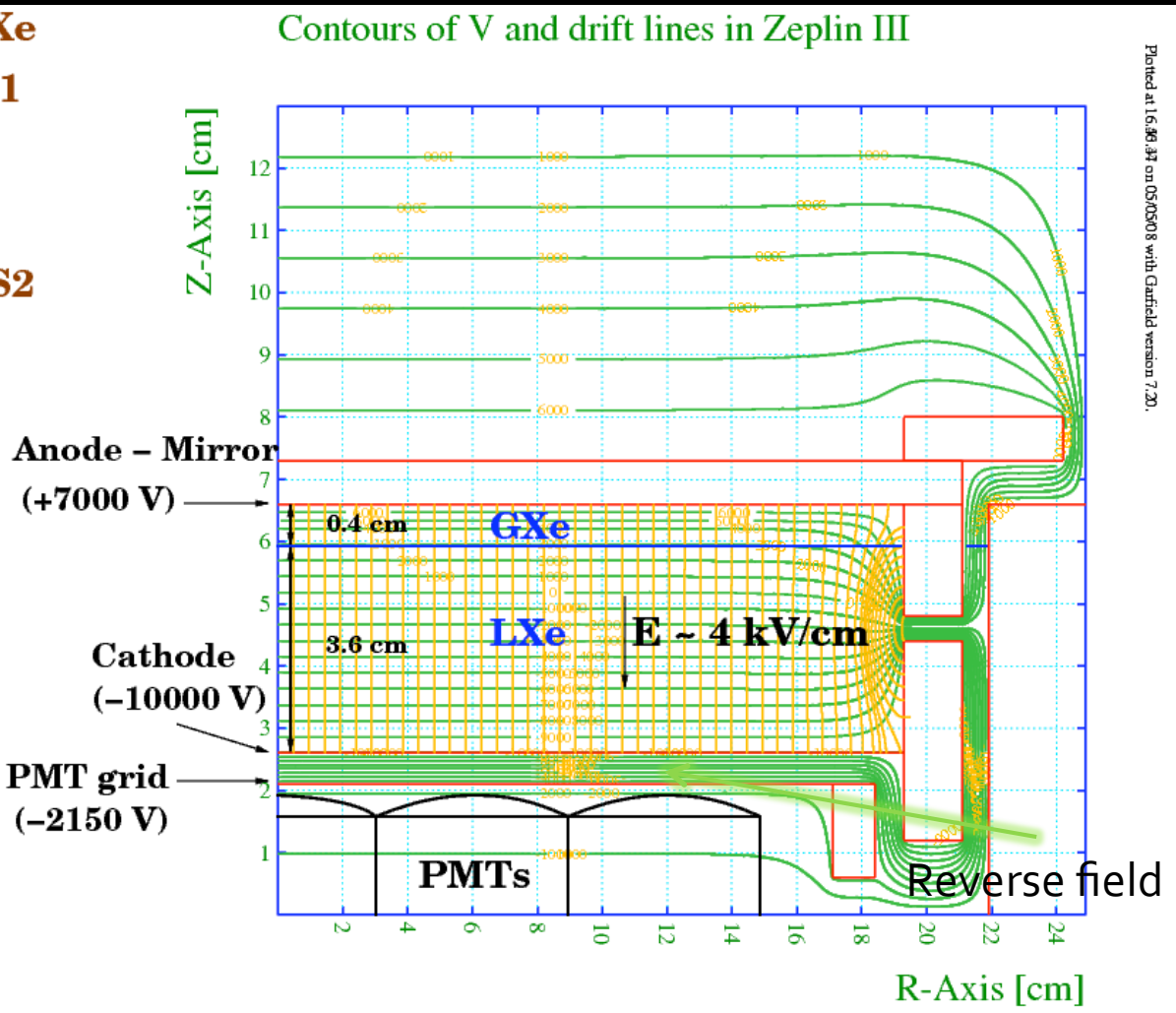
For electron recoils :

S2>>S1

For nuclear recoils:

S1>>S2

Both S1 and S2 are detected by PMTs facing upwards



ZEPLIN III First Science Run (FSR)
- summary -

- Mid-February 2008 : commissioning complete

  Engineering run: Detector calibration with ^{137}Cs and AmBe sources

- 27th February : Start of FSR

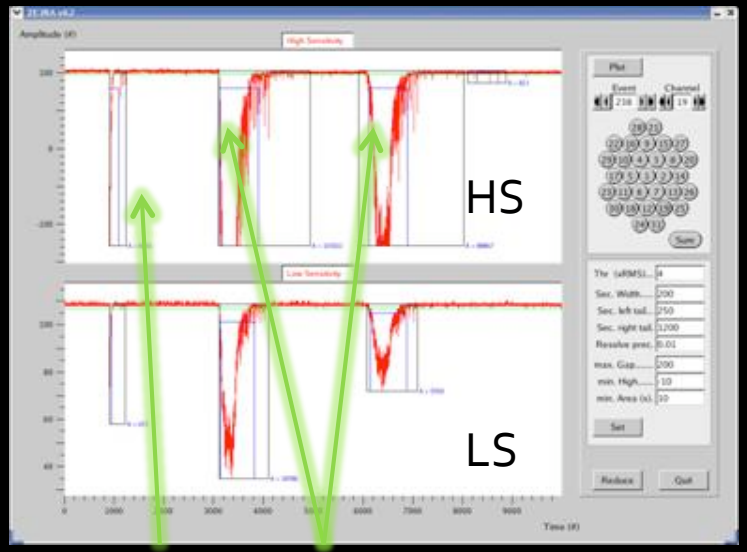
  Detector daily calibration using ^{57}Co source
  Continuous detector operation at high field without a single HV trip
  Occasional PMT HV trip (in average 1 .6 trip /day)
  Achieved electron lifetime > 20 μs

- 18th May : End of FSR

  Engineering run: Detector calibrations with ^{137}Cs and AmBe sources

  Stable pressure throughout entire FSR period
  Low LN2 consumption ~20 litres/day
  800 kg*days of raw data accumulated (12 kg Lxe)

Data Acquisition and Processing



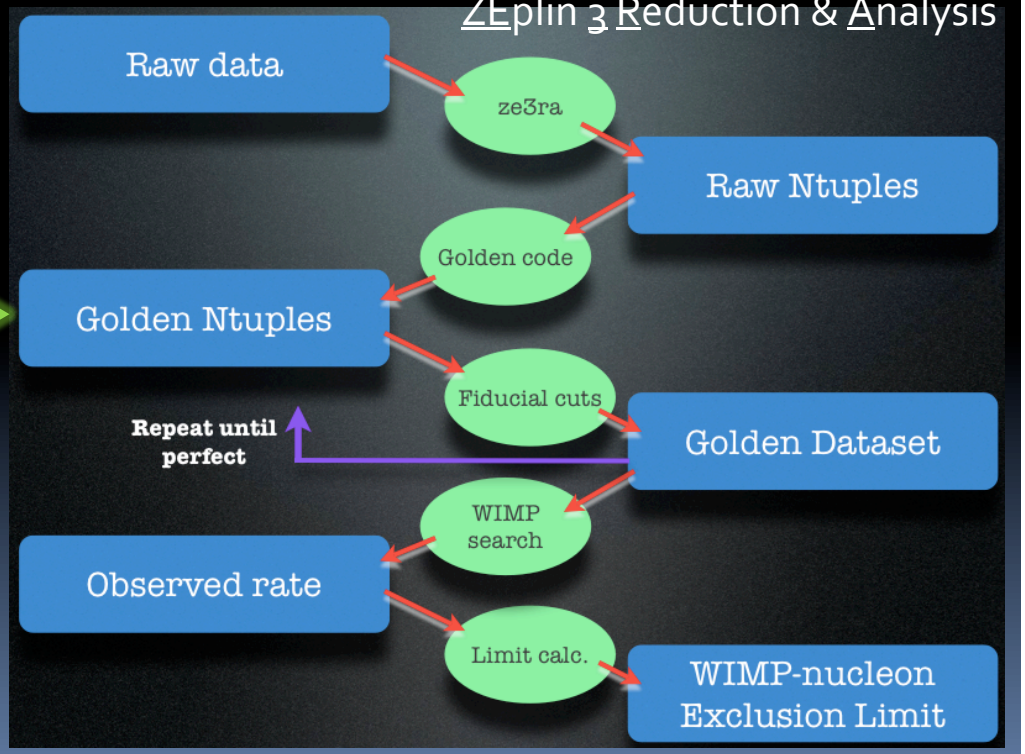
Waveforms from PMTs are acquired using 8-bit dual-range Acqiris system (64 channels) with 2ns sampling rate. Maximum acquisition speed : 100 events/s.

Example of double Compton event registered fully with low sensitive readout channel.

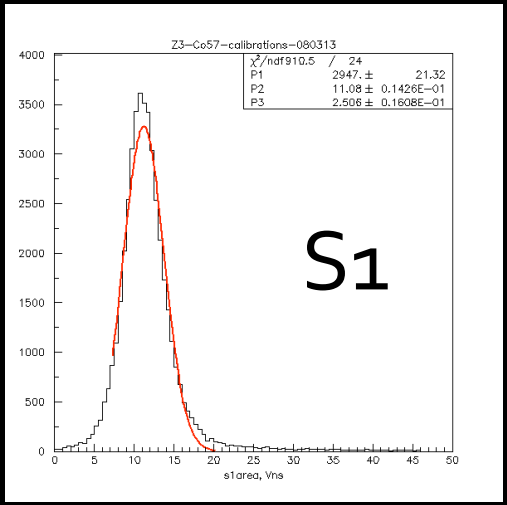
Analysis cuts select events with only one S1 and one S2

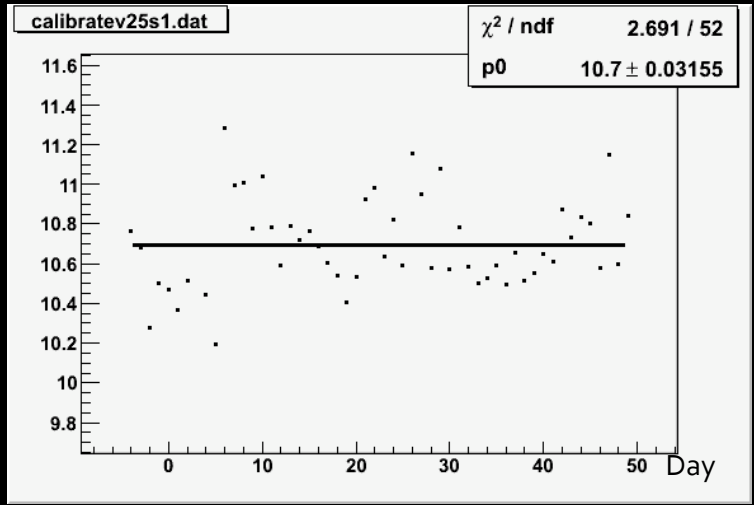
Event energy and position using S1 and S2 signals are reconstructed using Least Square algorithm.

ZEplin 3 Reduction & Analysis

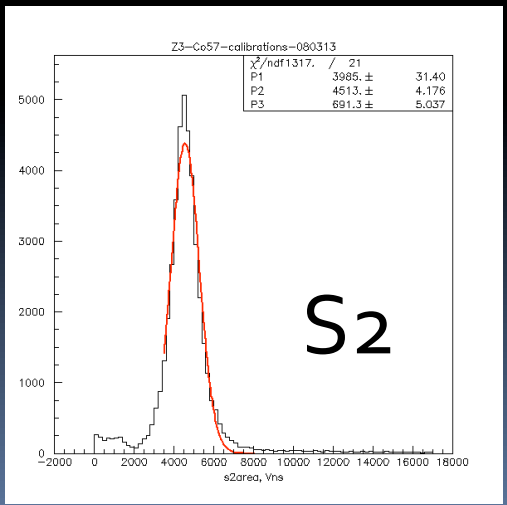


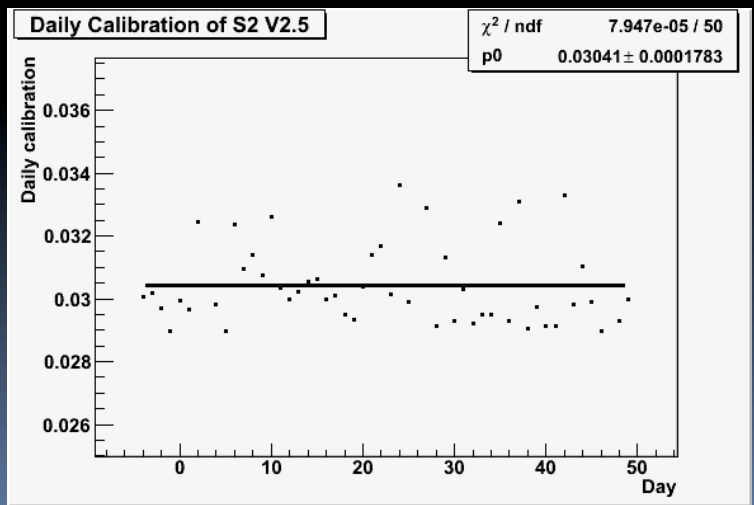
S1 and S2 signal stability during FSR using ^{57}Co 122 keV gammas



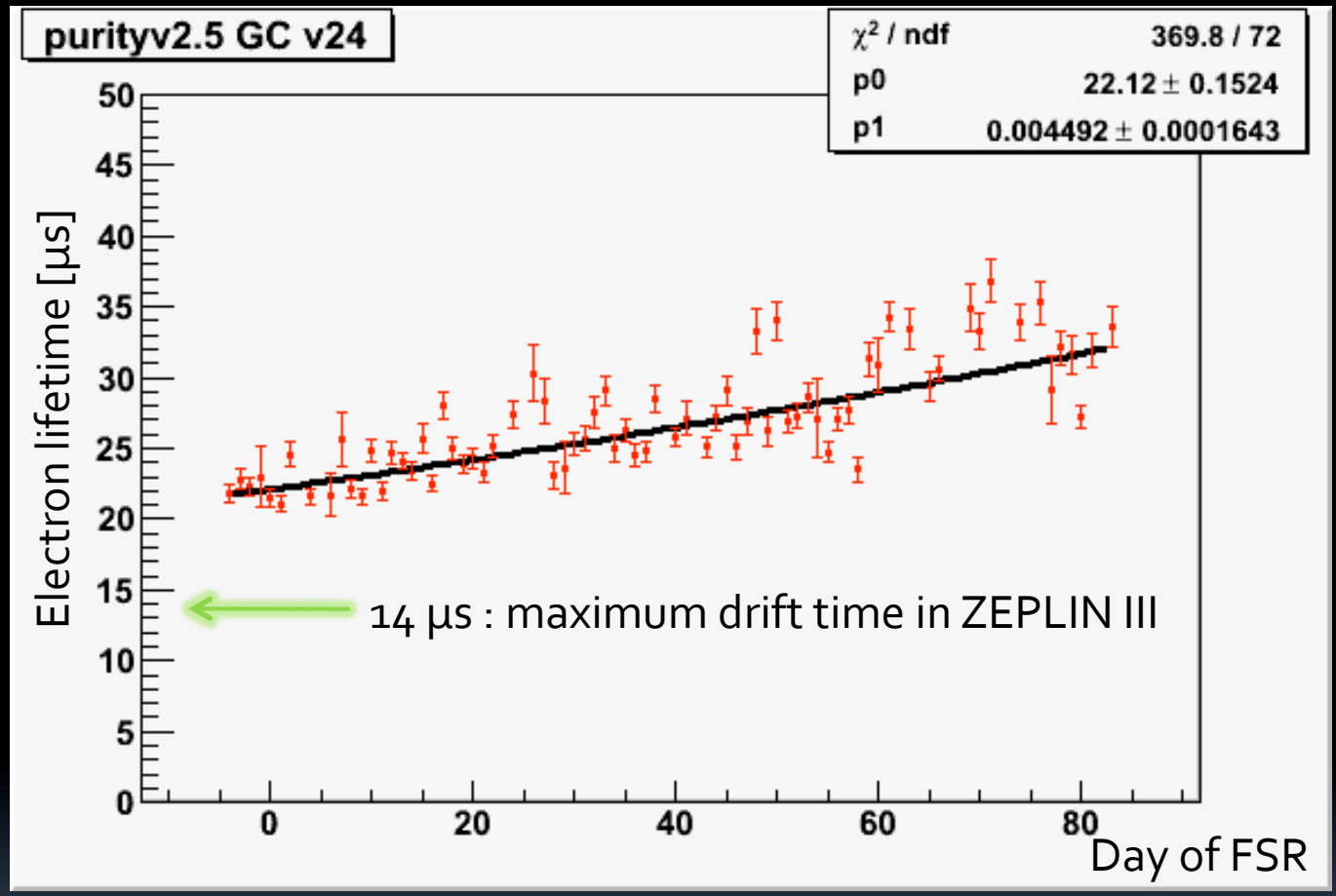


Average excess from the fit for S1 and S2 is at the level of 2-3%



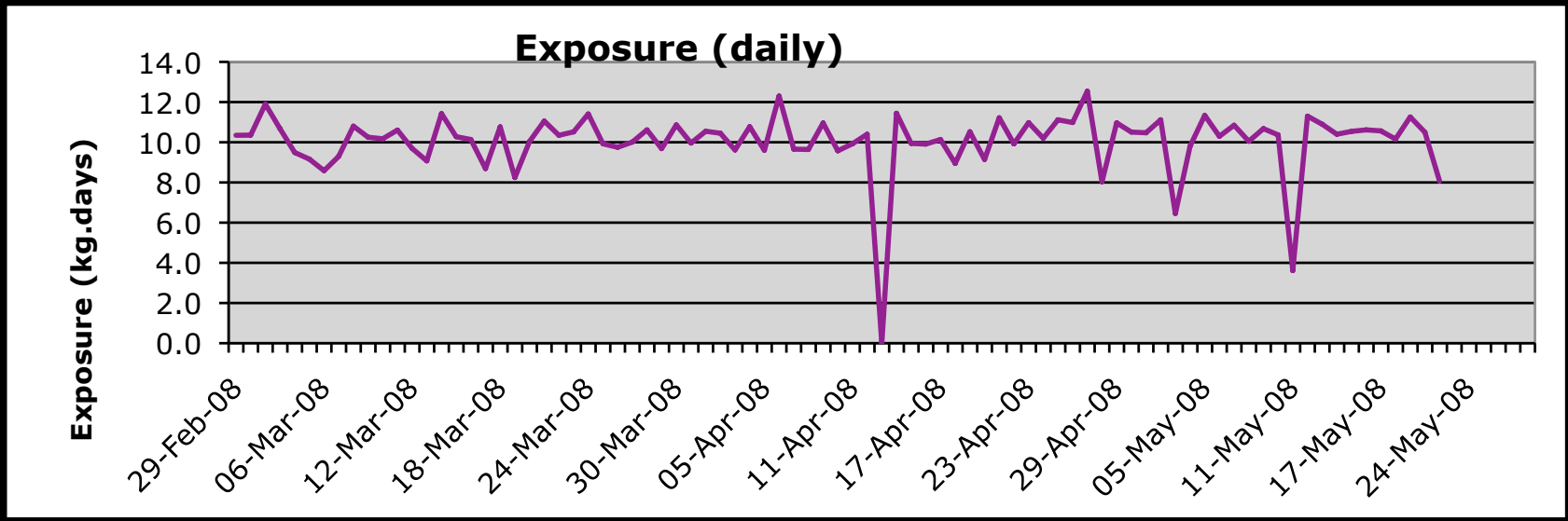


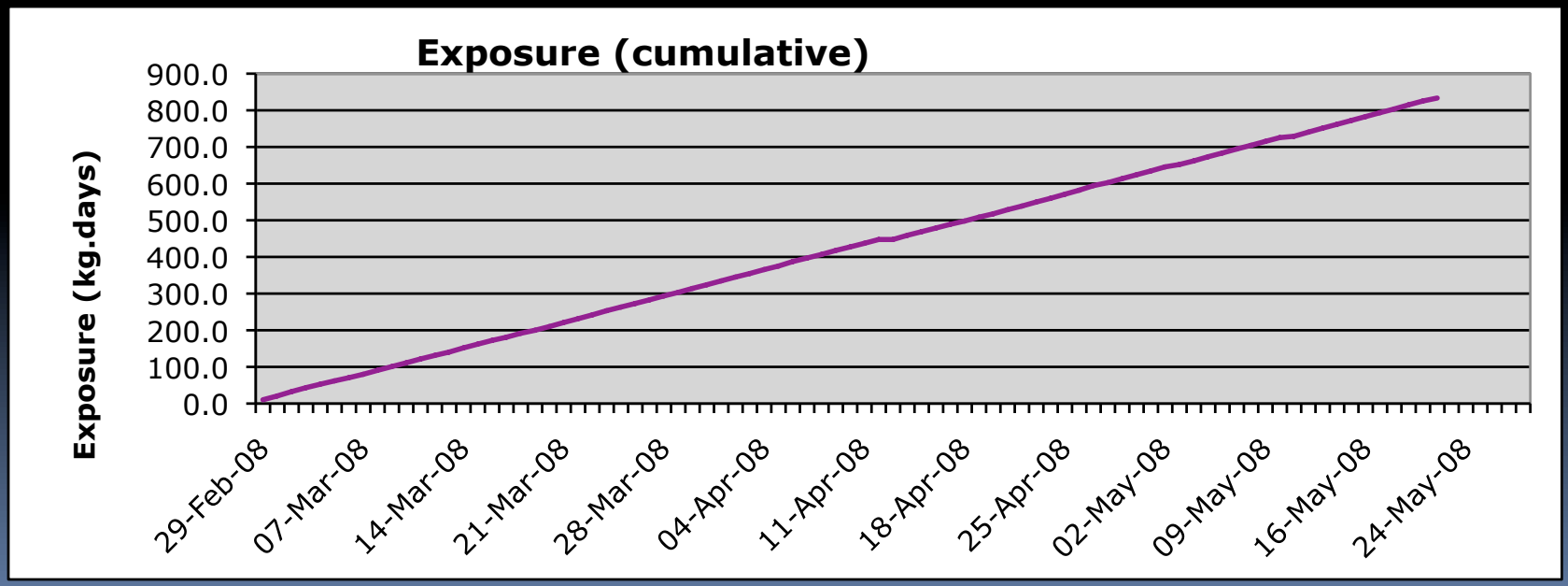
LXe purity stability



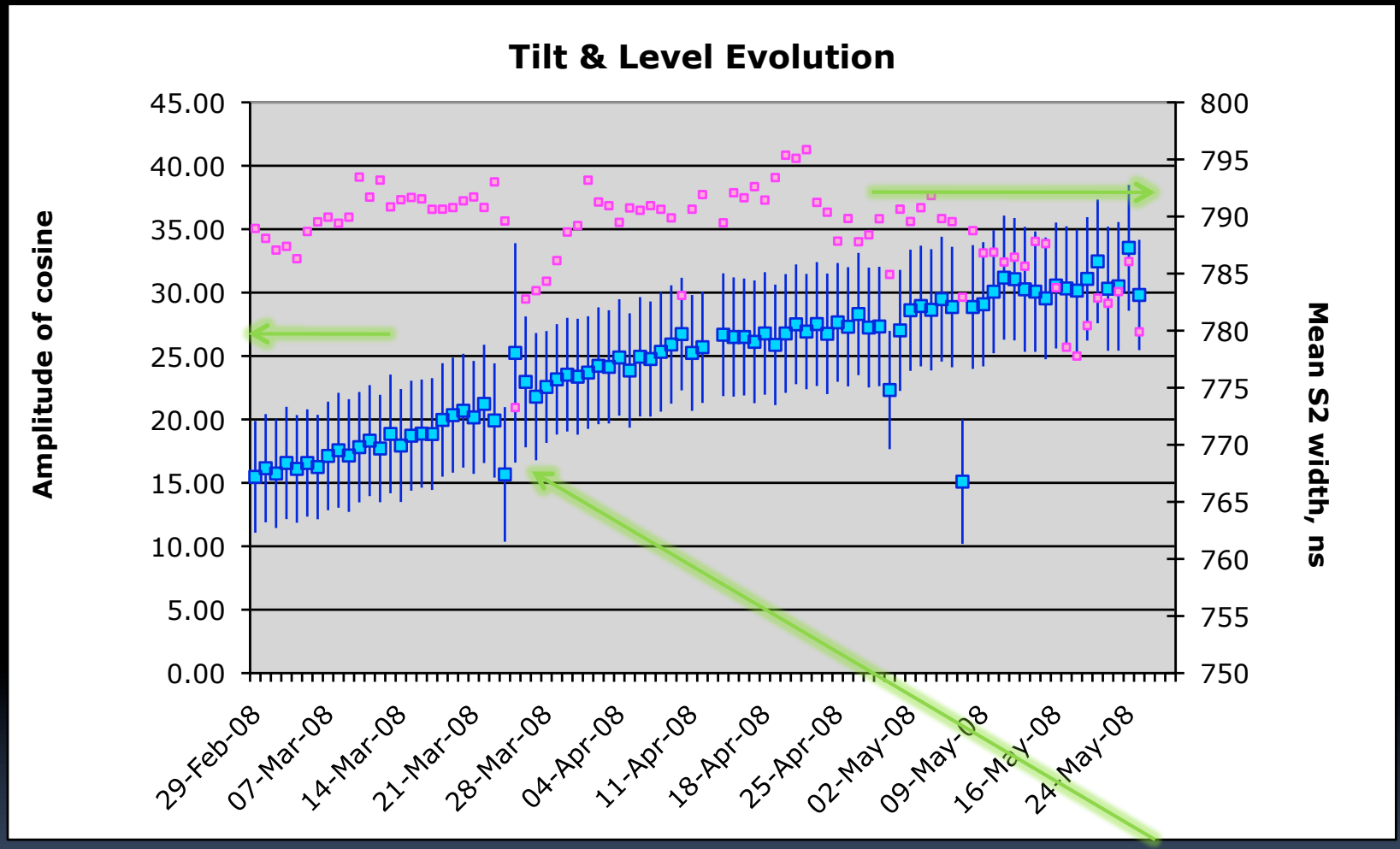
- High LXe purity achieved in high electric field
- No external recirculation system

ZEPLIN III FSR stability





ZEPLIN III FSR stability

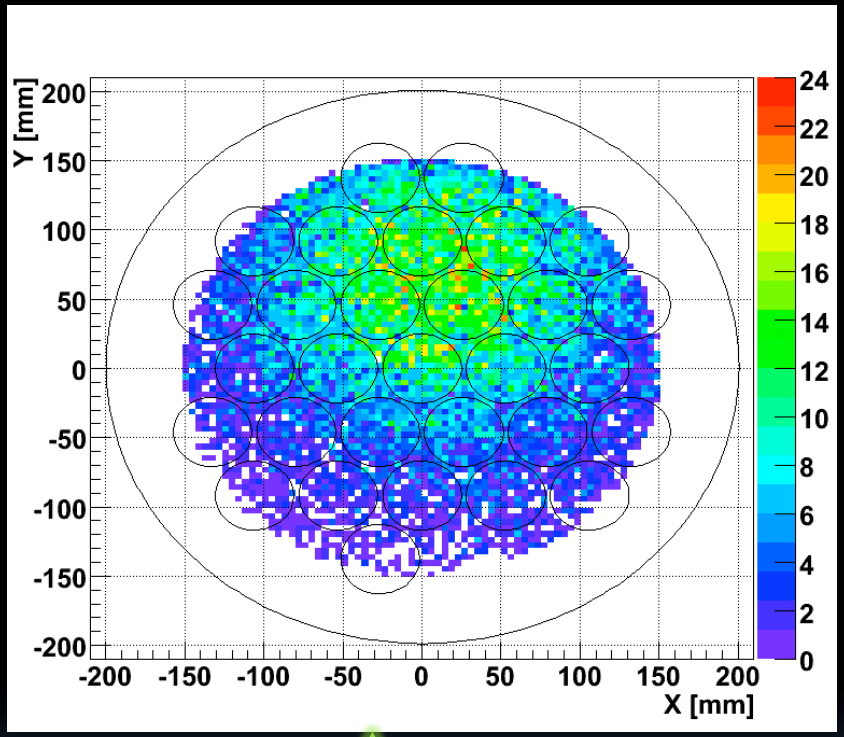


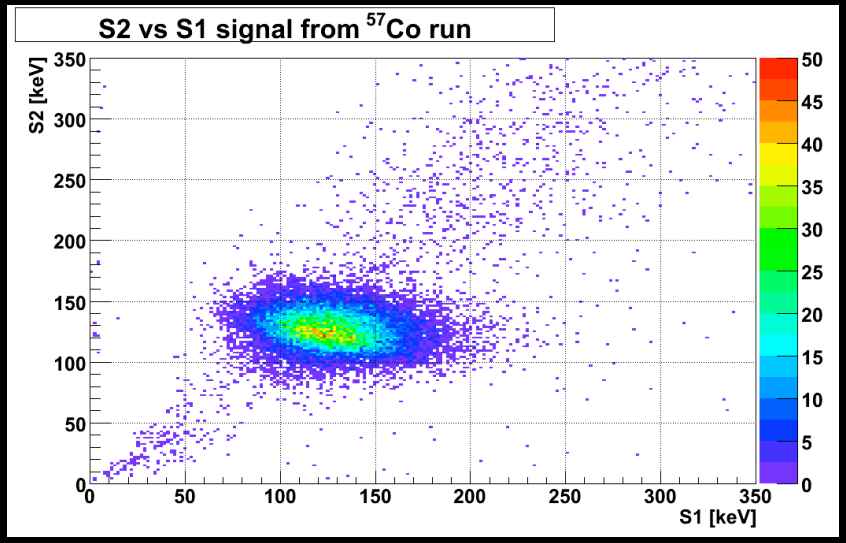
In total 4 days were excluded from FSR due to underground ventilation system failure

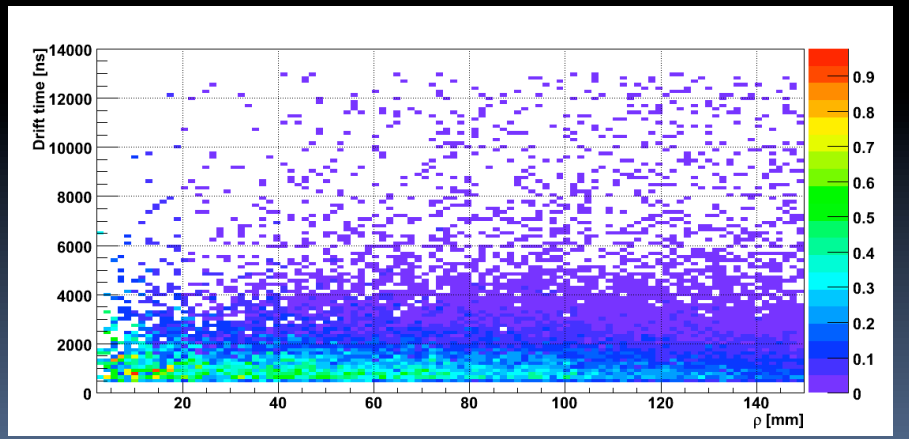
Underground ventilation system failure

Detector calibration with ^{57}Co placed on top of the detector

S1 and S2 signal energy reconstruction





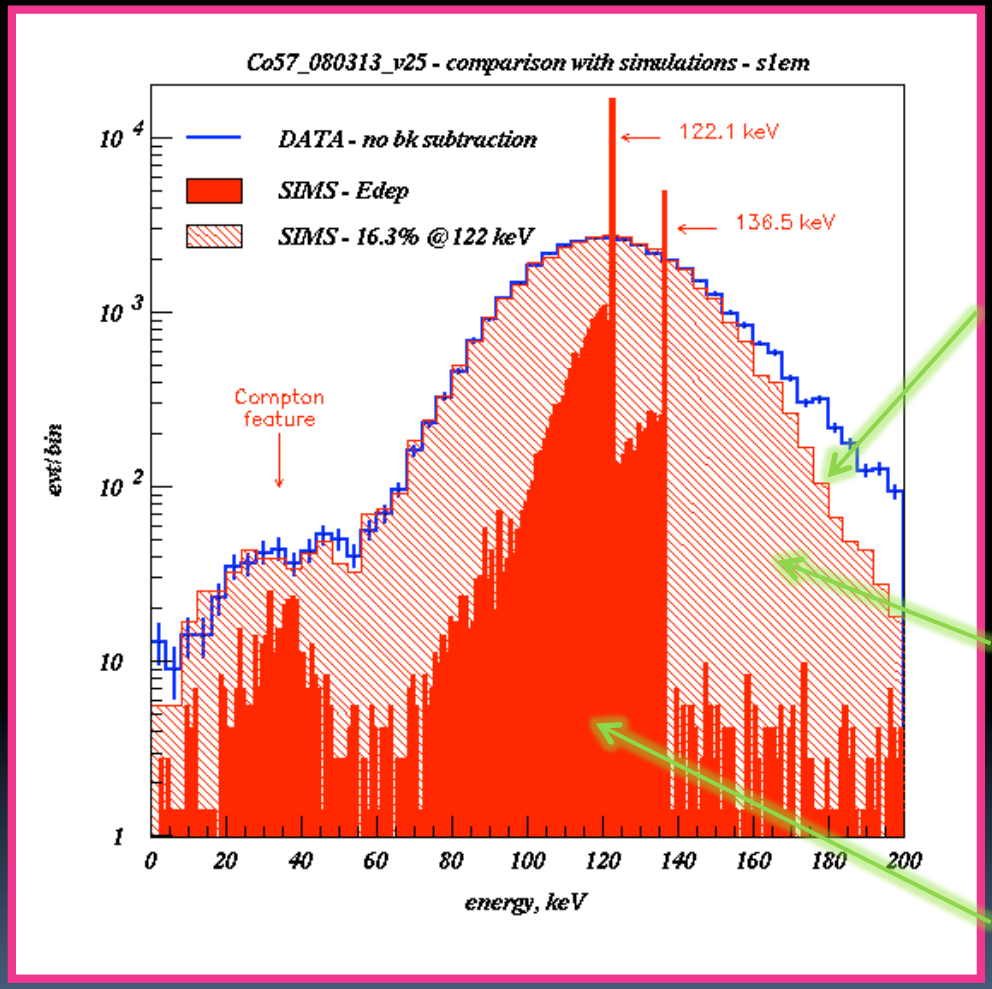


Events position reconstruction in X and Y showing off centre source position

Drift time (interactions close to LXe surface)

2000 ns ~ 5 mm

Detector calibration with ^{57}Co - simulation -



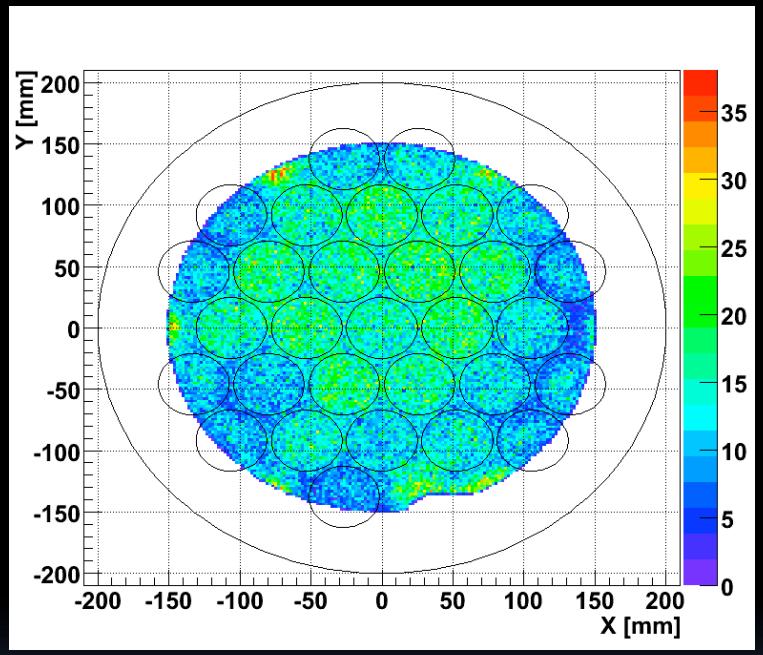
Difference at energies >160 keV due to
- no background subtraction
- single scatter event selection in data

Smeared simulated energy depostion

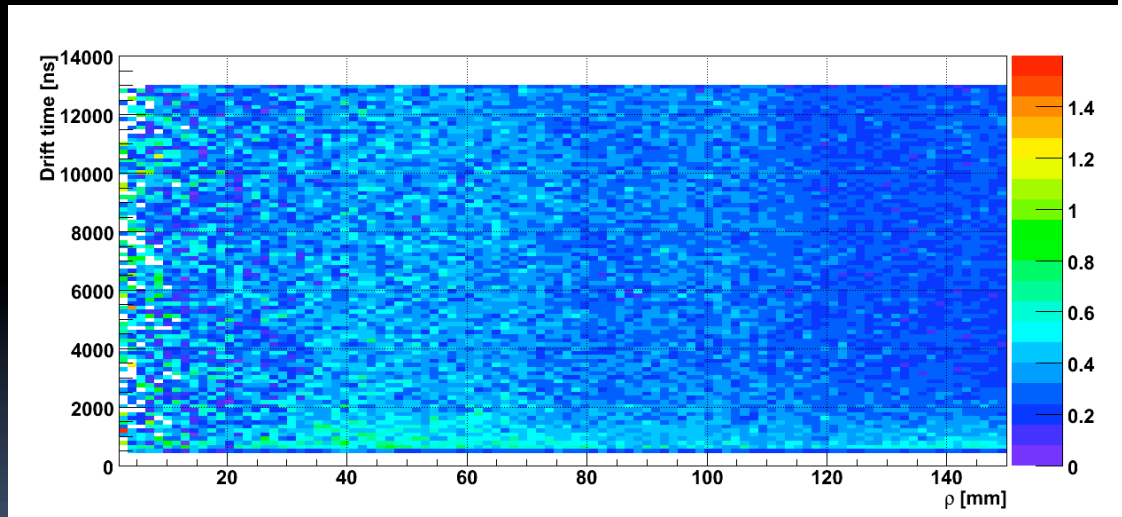
Simulated energy deposition

Detector calibration with ^{137}Cs placed on top of the detector

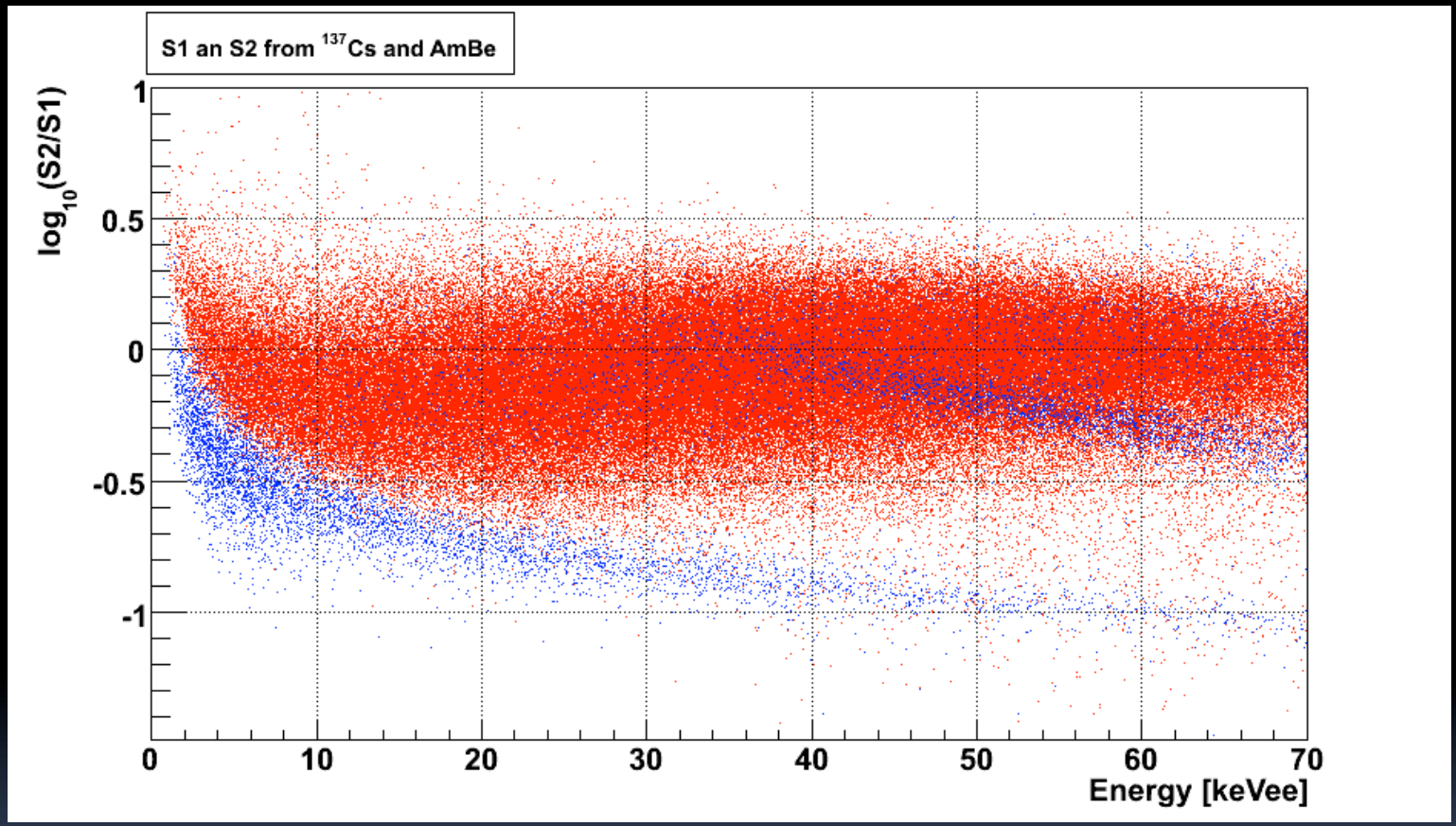
/calibration run with hardware cut on high pulses' amplitudes /



Events position reconstruction in X and Y and their vertical distribution with 1/r correction



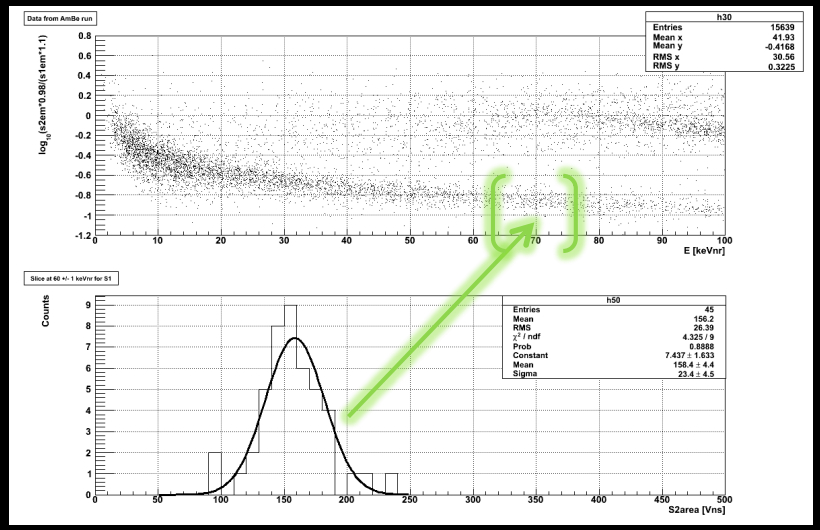
Detector calibration with neutrons from AmBe source



Combined data from runs with ^{137}Cs (red) and AmBe (blue) sources. Separation of NR and ER bands is very clear. 40 keV line from neutron inelastic scattering is clearly visible on the ER band.

Measurement of the Nuclear Recoil Ionization Charge Yield

S2 area distribution for points from NR band and energy E_{nr}=60+/-1 keVnr



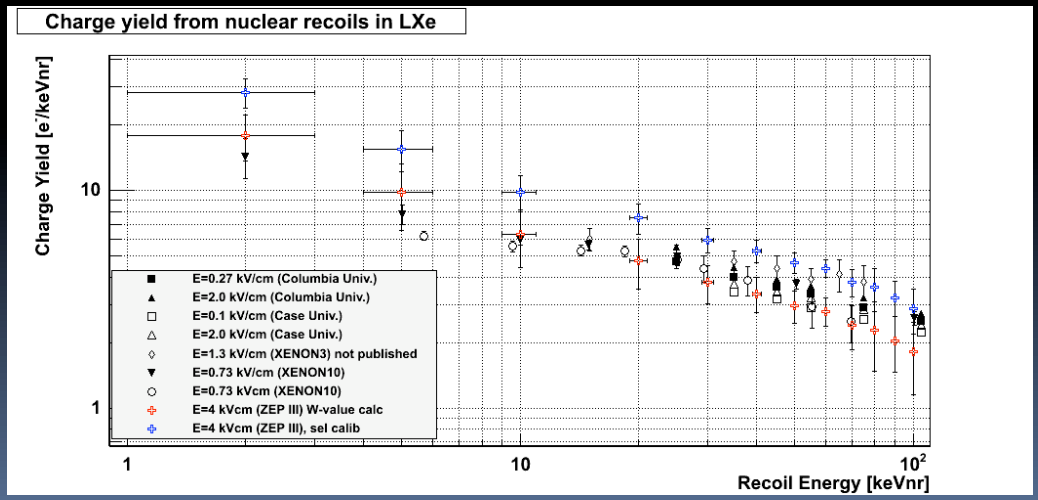
Scaling energy :

$$E_{nr} = \frac{E_{ee}}{q_f}\frac{S_{ee}}{S_{nr}}$$

Where S_{ee} = 0.36
S_{nr} = 0.9*
q_f = 0.19

Red crosses – using W=15.6 eV, S_q=0.78*, infinite electron lifetime and efficiency of the charge extraction into gas =0.8

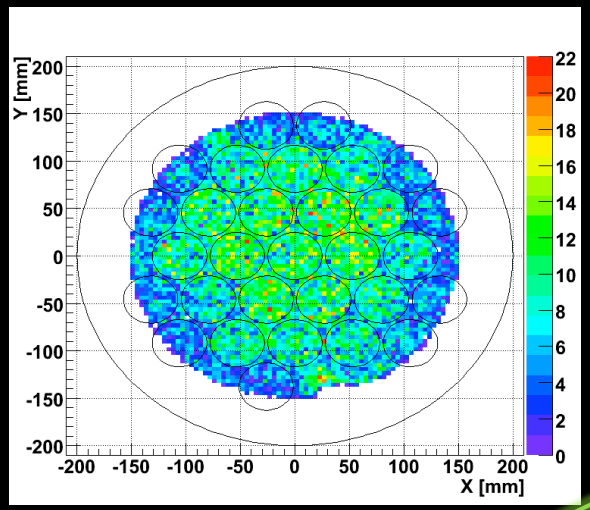
Blue crosses – from sel area estimation ~0.6 Vns

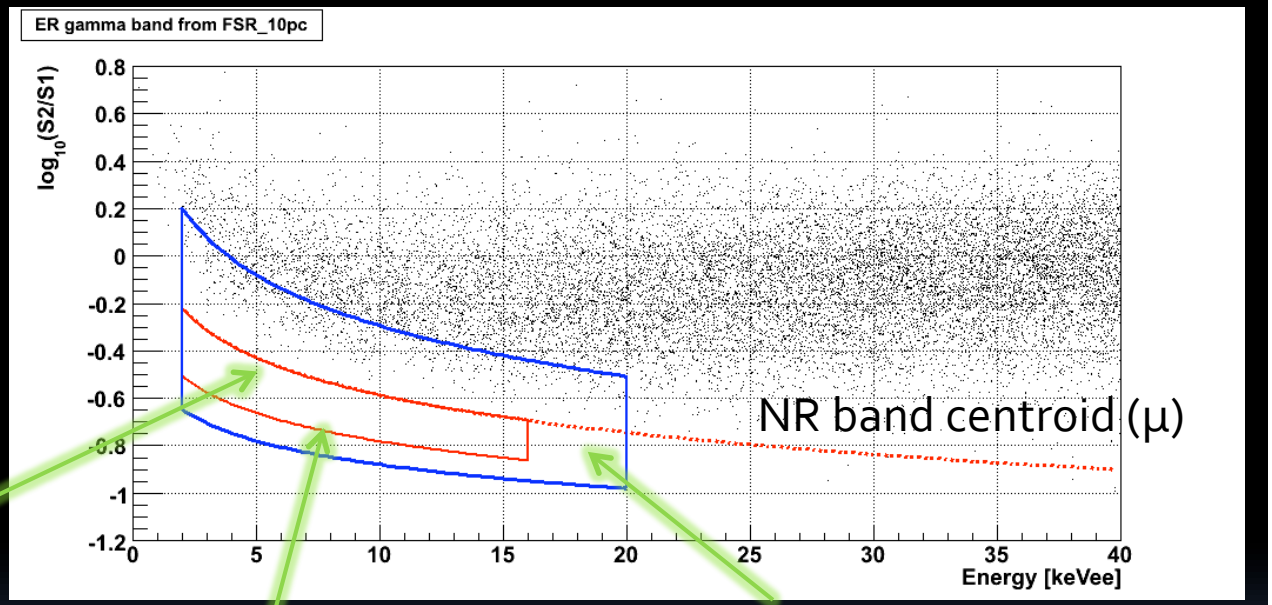


* From E. Aprile et. al PRL 97 2006
Data compilation from P.Sorensen et. al arXiv 0807.0459

First Science Run: 10 % and 20 % of Data

X-Y events distribution



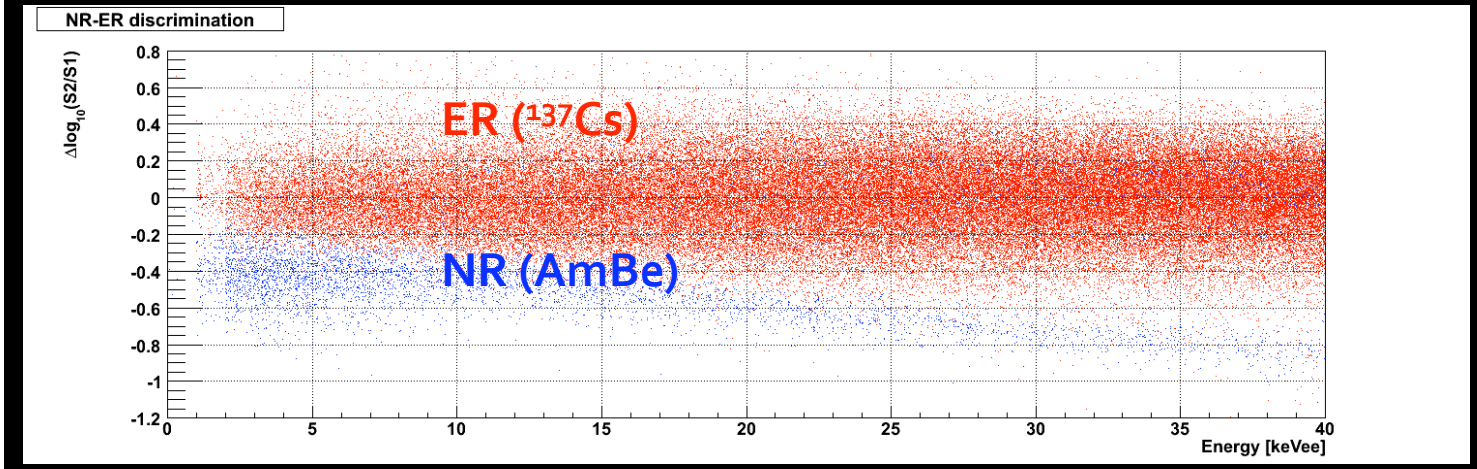


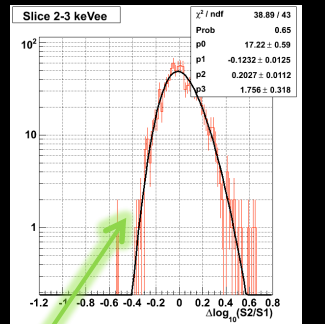
Acceptance box:
- 2-16 keVee
- μ-2σ<log10(S2/s1)<μ

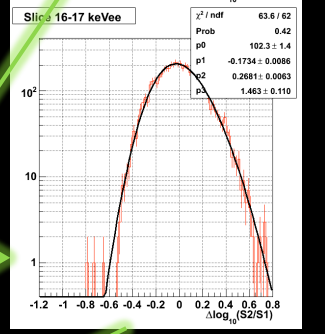
0 Events (10 %)
0 Events (20 %)

195 Events (10%)
352 Events (20 %)

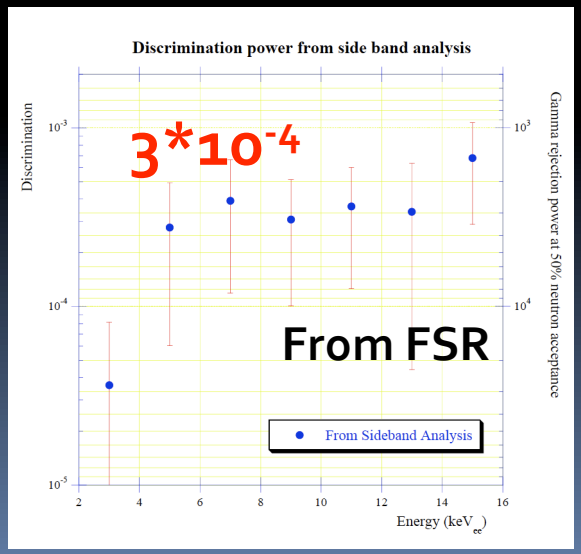
Discrimination Power /preliminary,analysis still in progress/

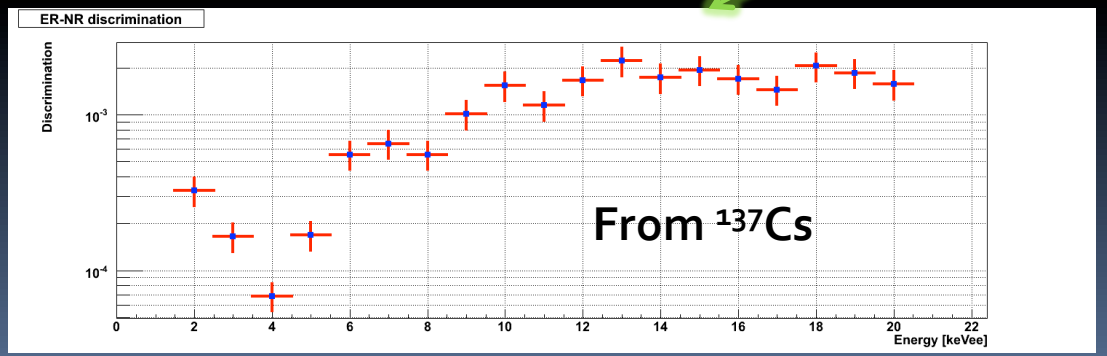






Slicing with 1 keV bin and fitting with skew-normal function:





Data Analysis Status

- 10 % of data unblinded : full FSR and calibration data analysis
  - establishing cuts
  - establishing acceptance box

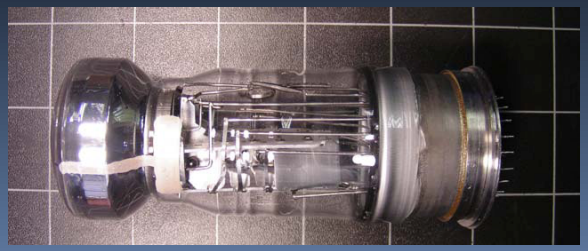
- Opening 90% of FSR data outside of the acceptance box
  (no change to cuts and box), sideband analysis
  comparison with Cs data

- 20 % of data unblinded (confirming the gamma leakage)
(no change to cuts and box)

- 70 % of FSR data unblinded – analysis in progress

Second Science Run Preparations: ZEPLIN III Detector Upgrade

Ultra Low-Background PMTs upgrade (reduction in radioactivity 30 times)



Active Veto System : 20 (roof) and 32 (barrel) plastic slabs equipped with 52 PMTs surrounding Gd-loaded hydrocarbon