ZEPLIN: Current Results & Future Plans

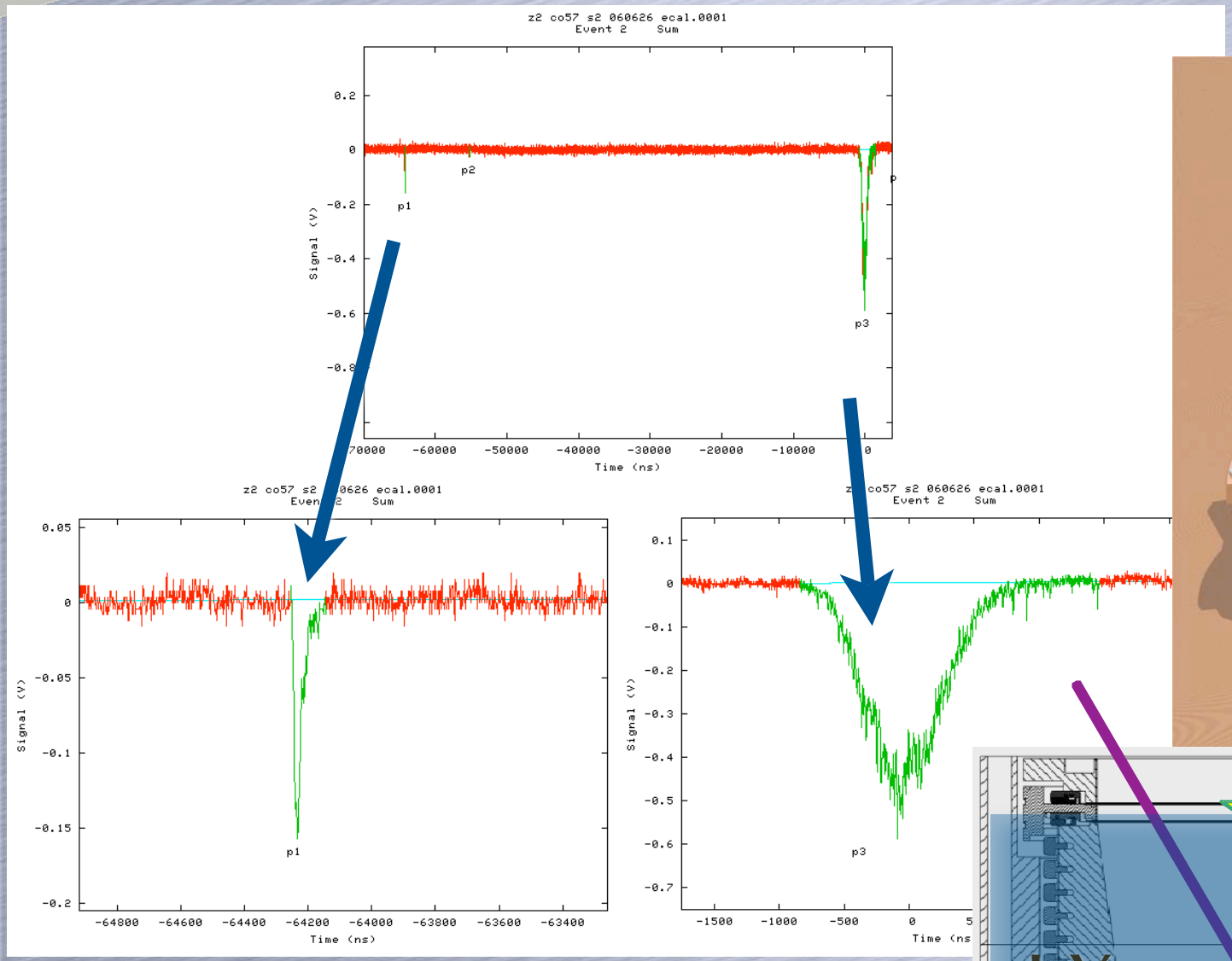
University of Edinburgh, STFC Rutherford Appleton Laboratory, Imperial College London,

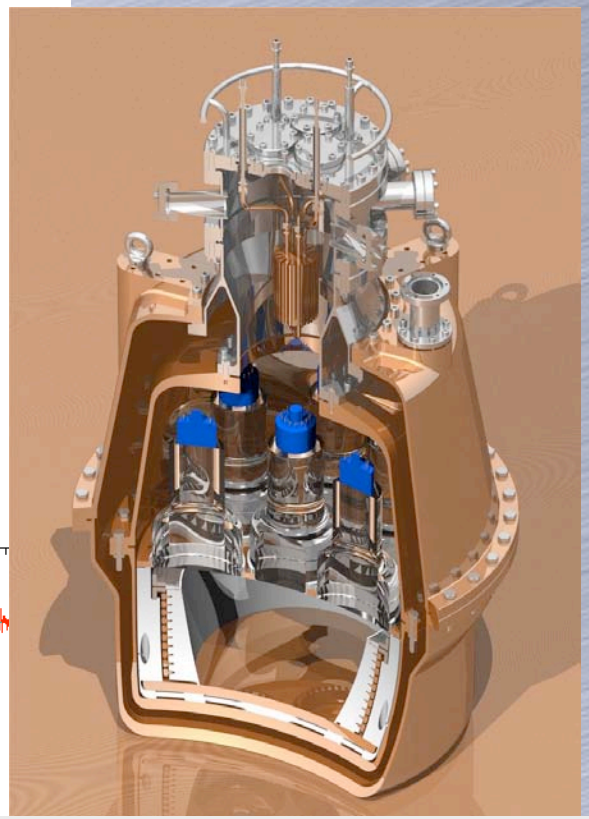
University of Sheffield,

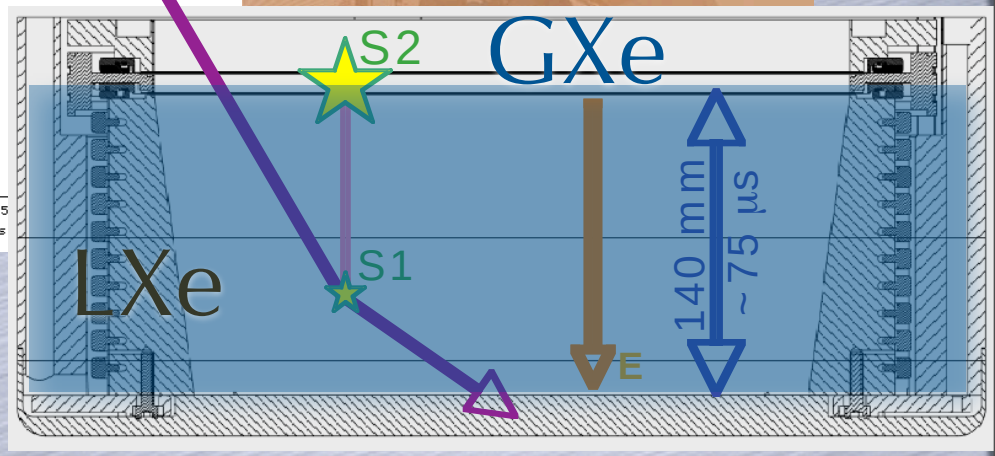
LIP Coimbra, ITEP Moscow,

UCLA, Texas A&M University, Rochester University

ZEPLIN-II Detector

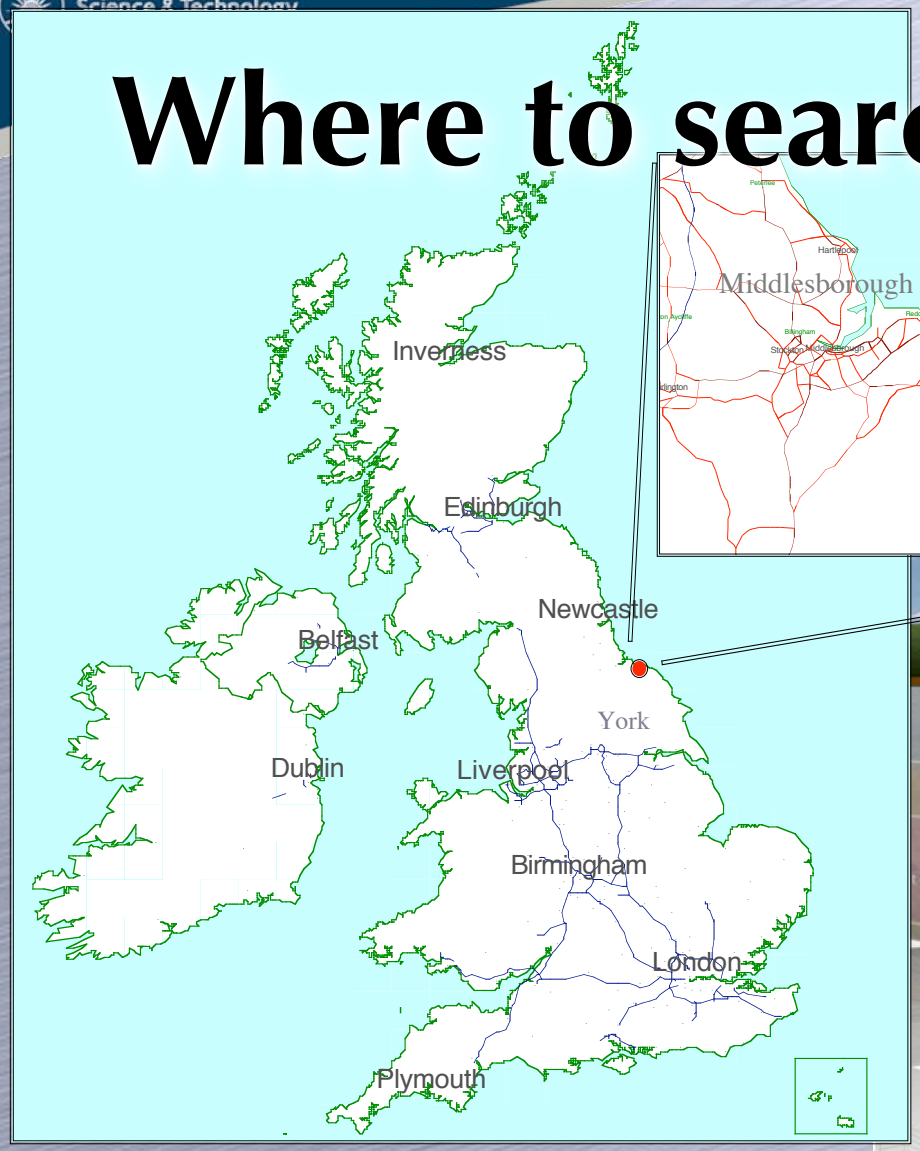


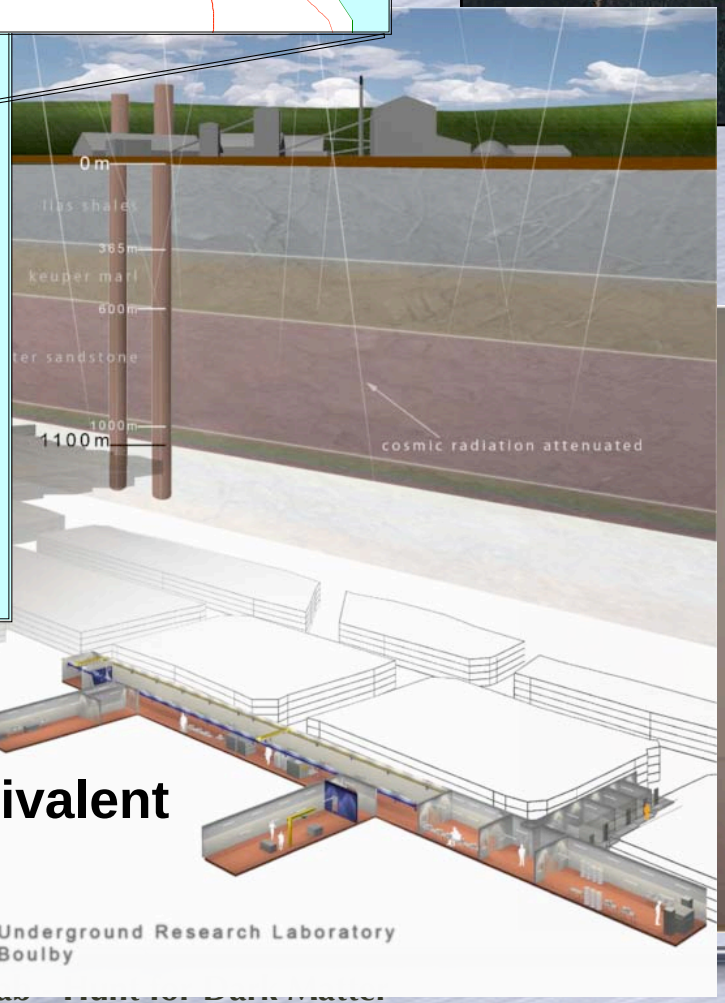




- 5 months continuous operation
- 1.0t*day of raw DM data

Where to search for dark matter?

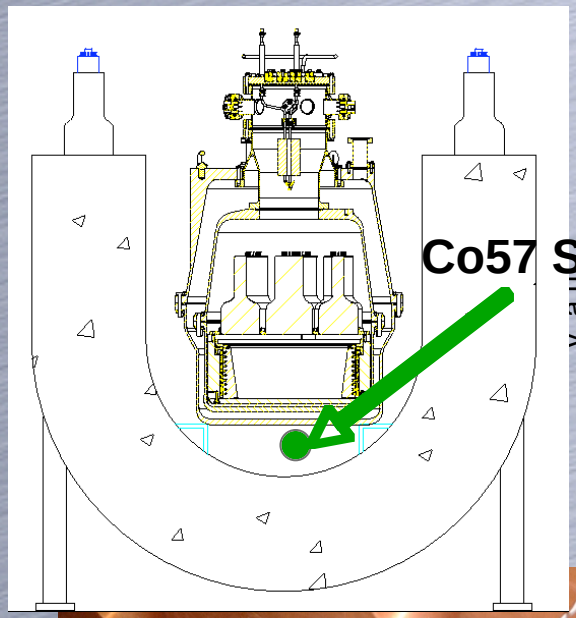


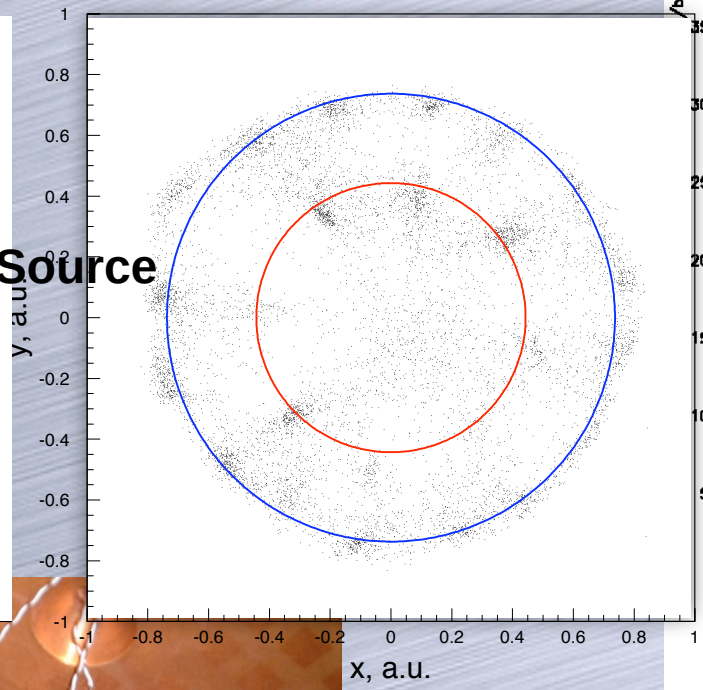


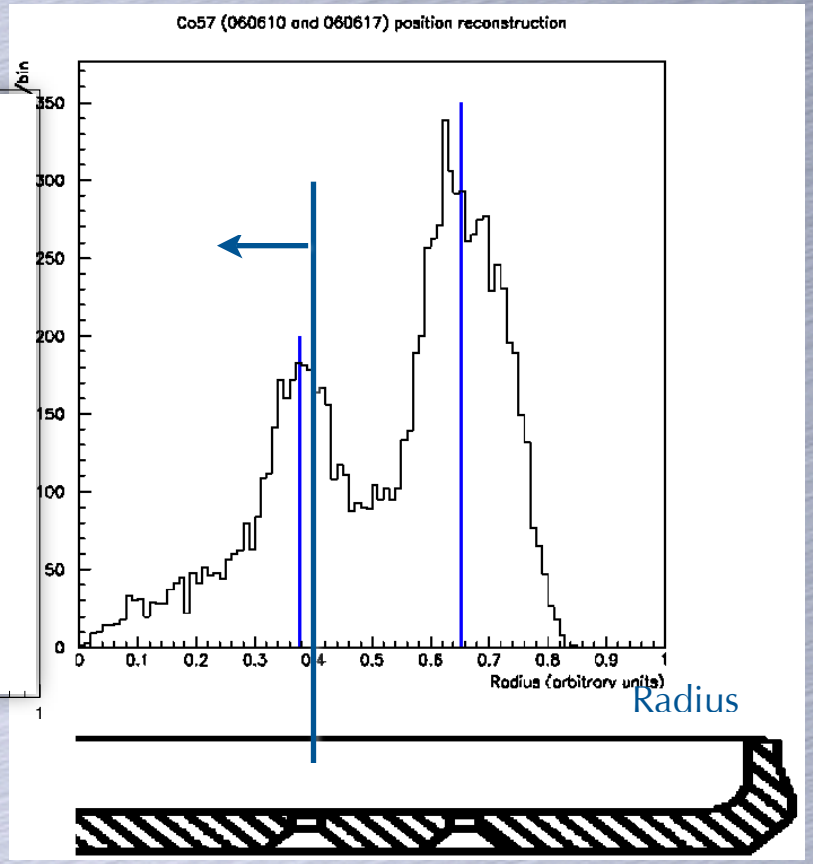
Depth 1100 m, 2.8 km water equivalent

Veto system (Gd loaded)

Detector response: ^{57}Co calibration



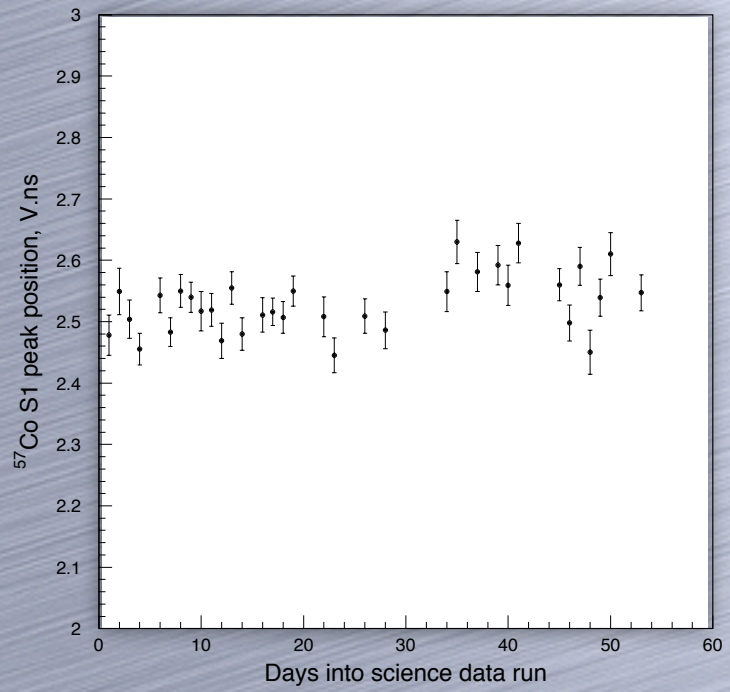


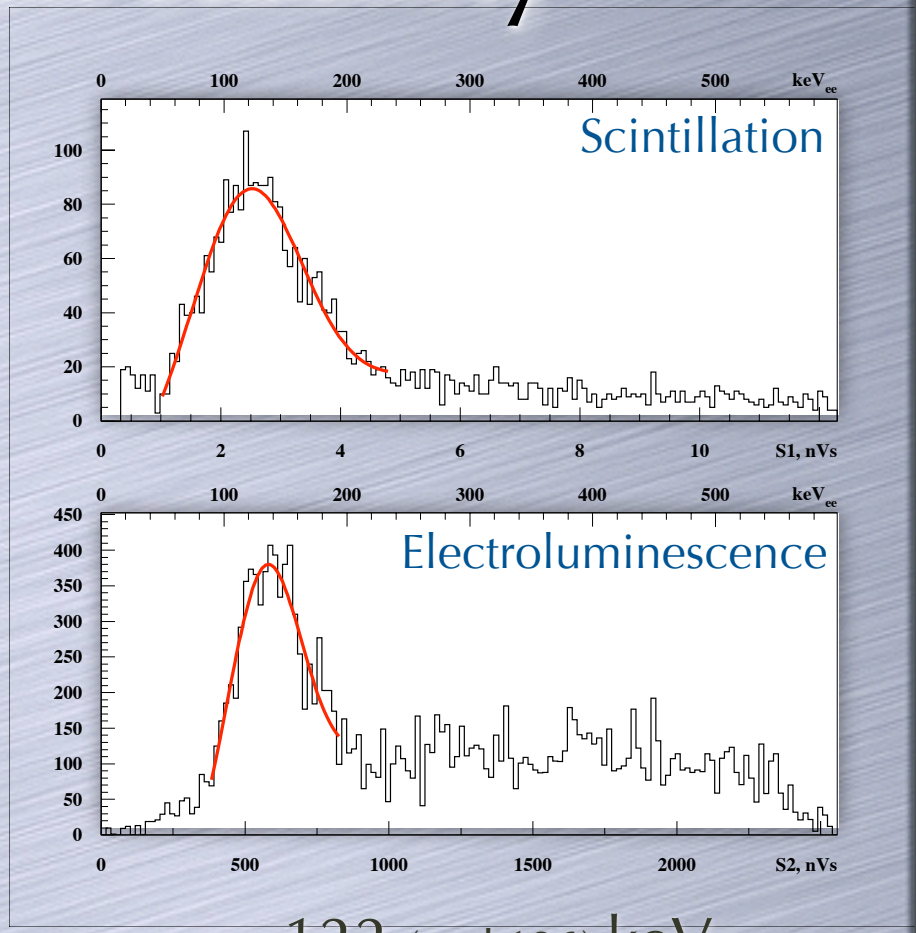


- 0.55 p.e./keV (with field)
- Spatial resolution ~1cm
- Fiducial volume 7.2kg

Co-57 Calibration stability

- S1 peak stability from Co-57
- S2 shows expected improvement in E-resolution
- S1 and S2 anti-correlated
  - not used as no gain in discrimination

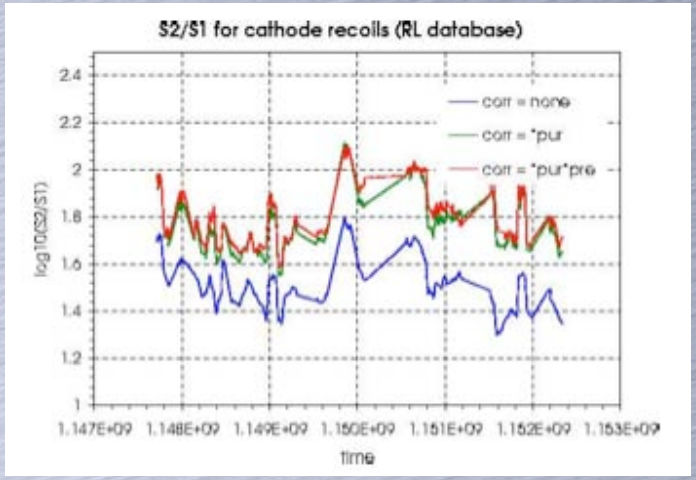


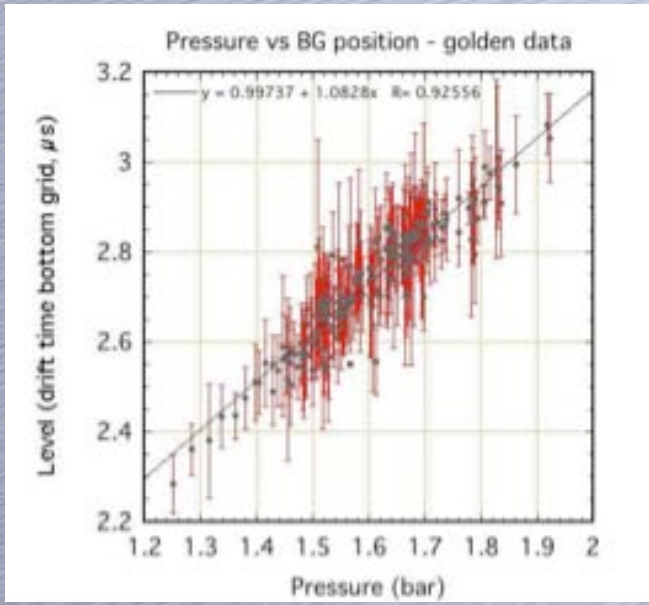


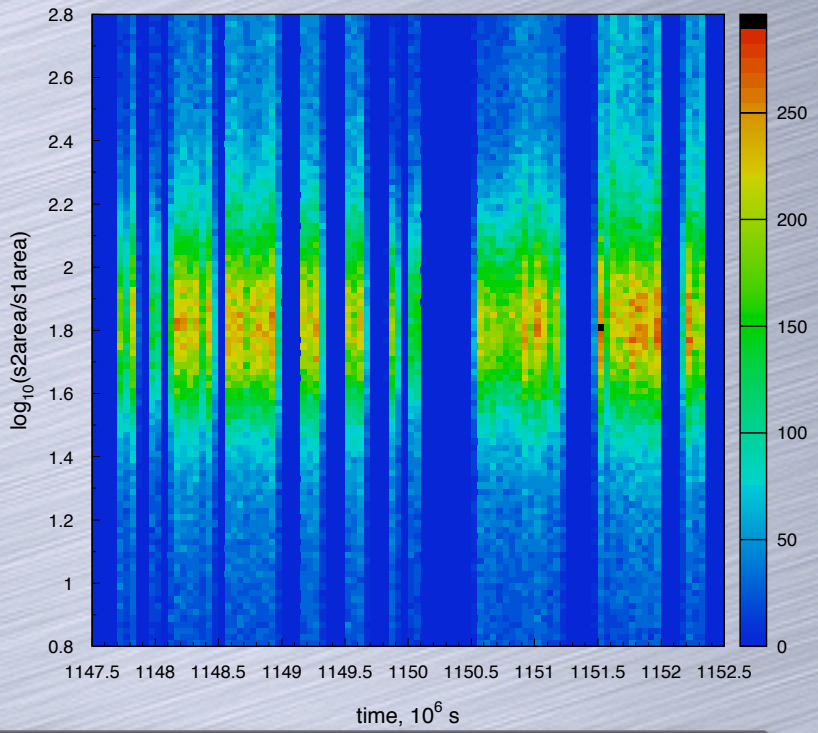
122 (and 136) keV

S2 corrections

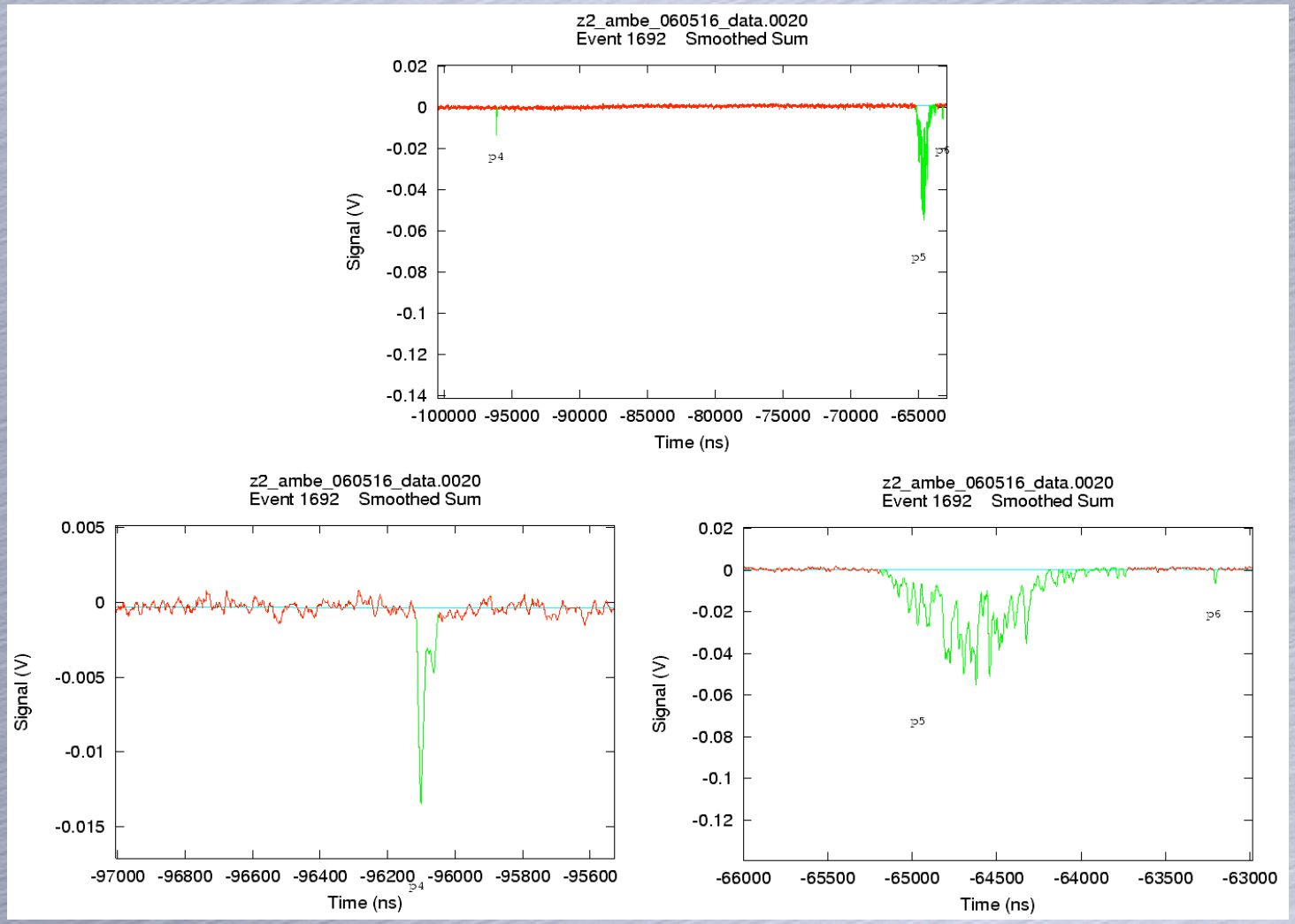
- Corrections to S2 size needed for
  - purity (function of depth)
  - pressure (scaled to 1.5 bar)
    - ... and liquid depth between grids
  - liquid surface charging
    - ... using cathode recoil events





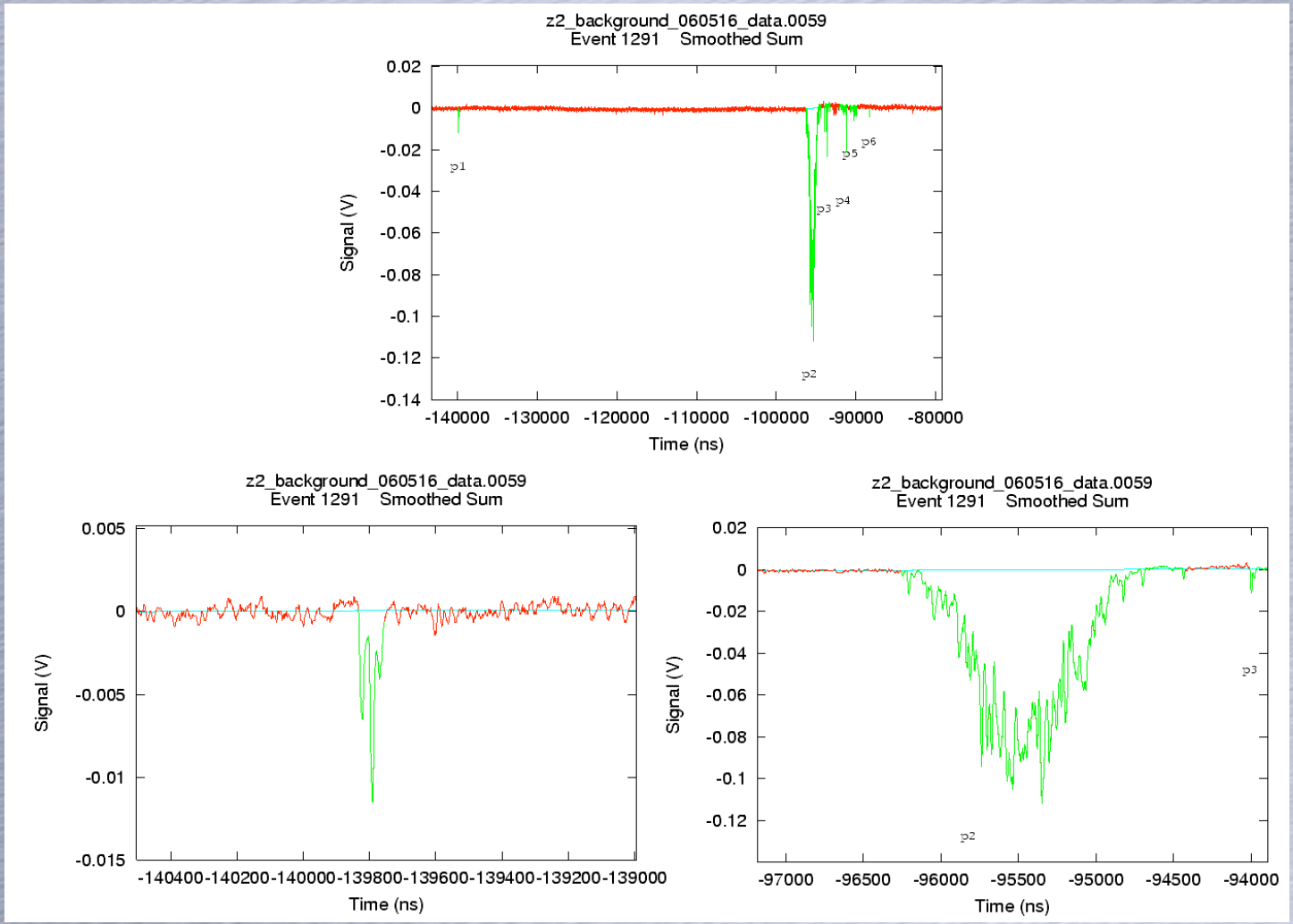


Neutron/Gamma pulses



Neutron pulse

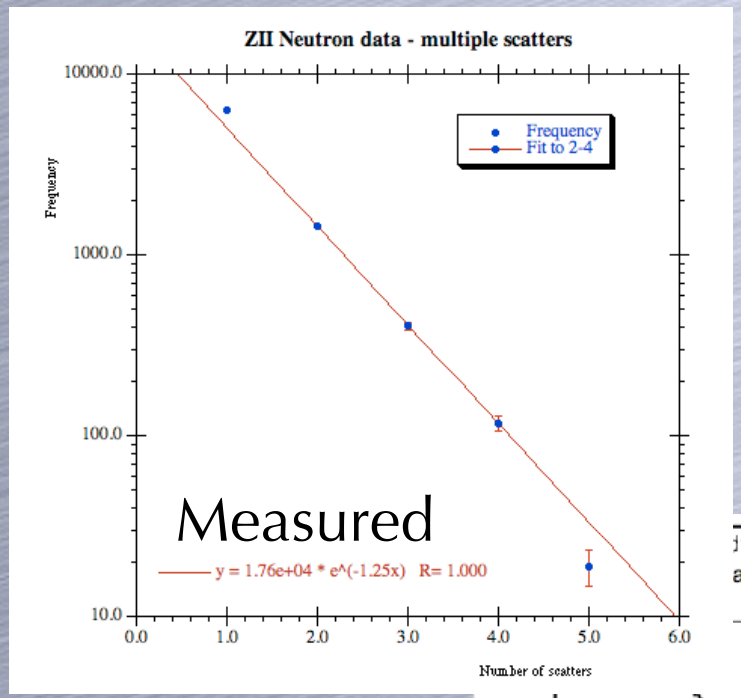
Neutron/Gamma pulses

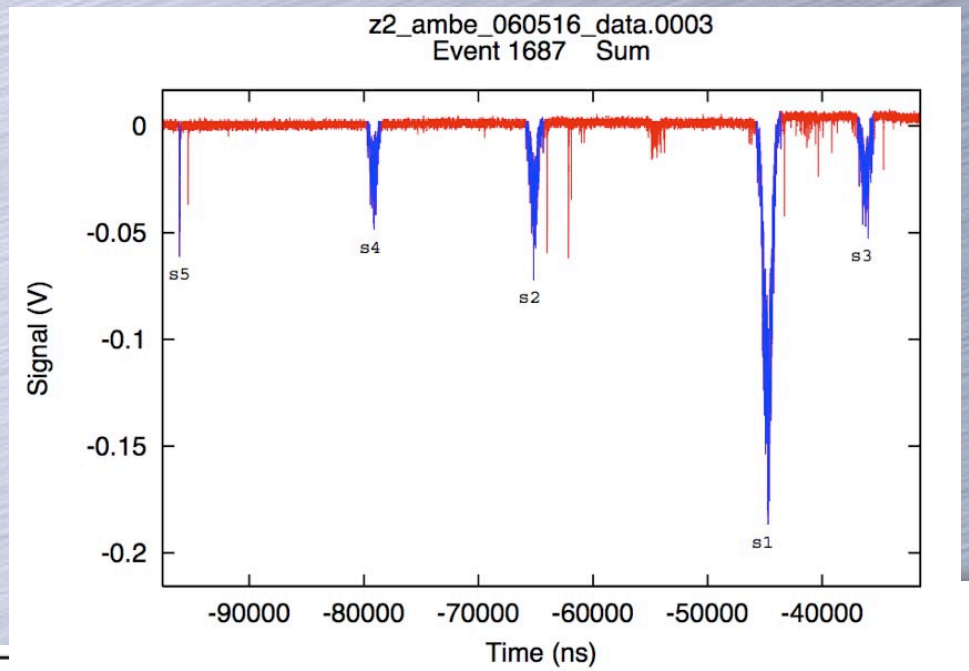


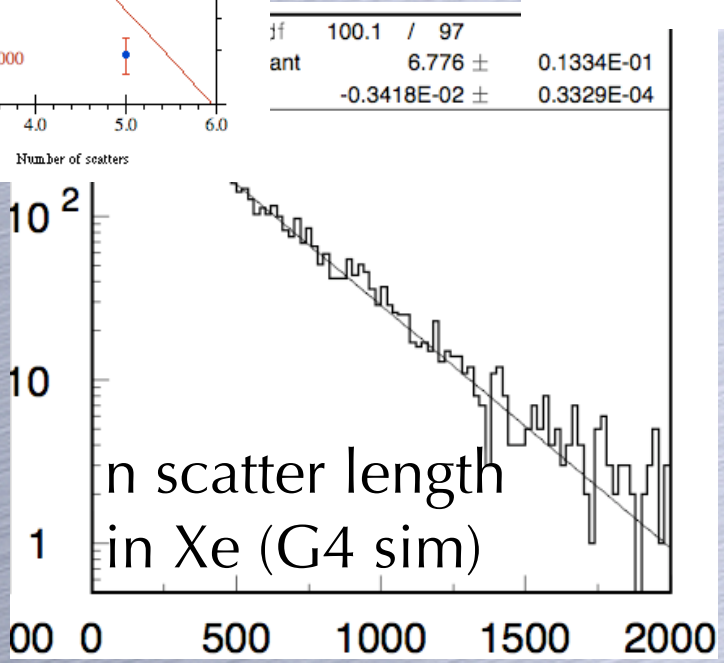
Gamma pulse

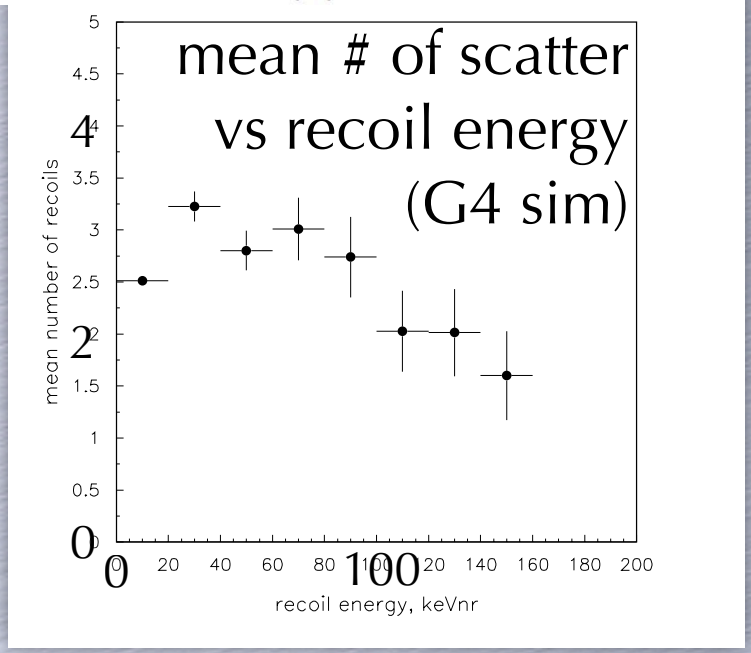
n - Calibration (AmBe or 252-CF)

- Multiple scattering of neutrons

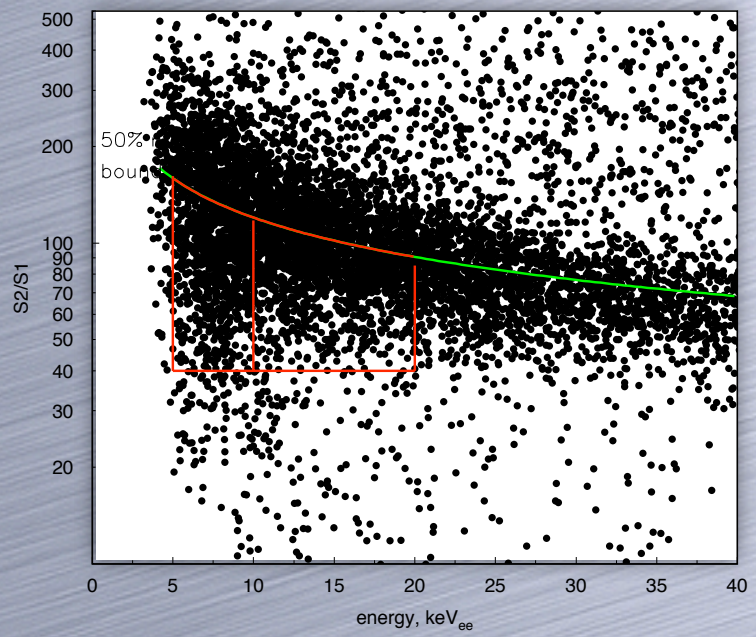


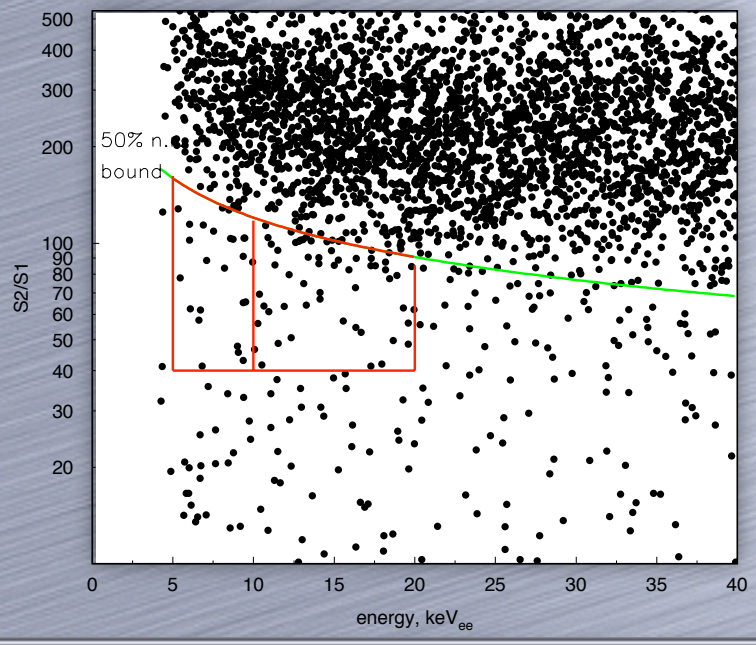






Discrimination Power

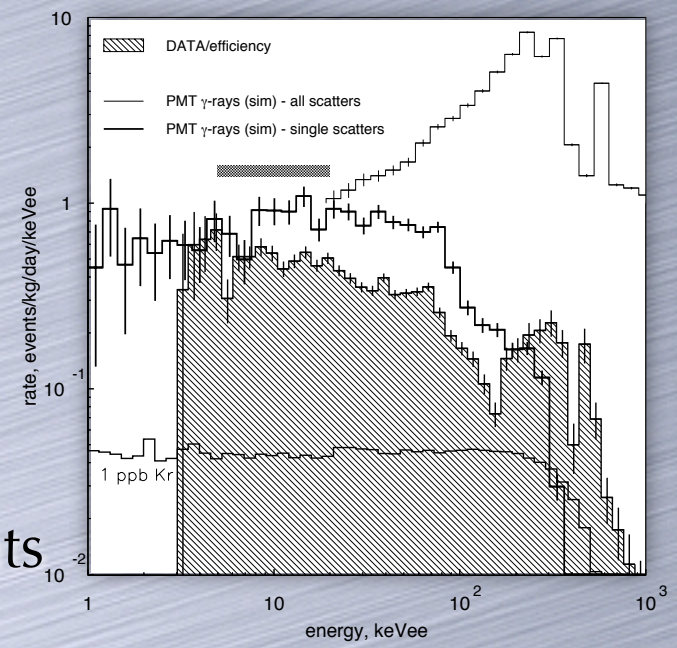




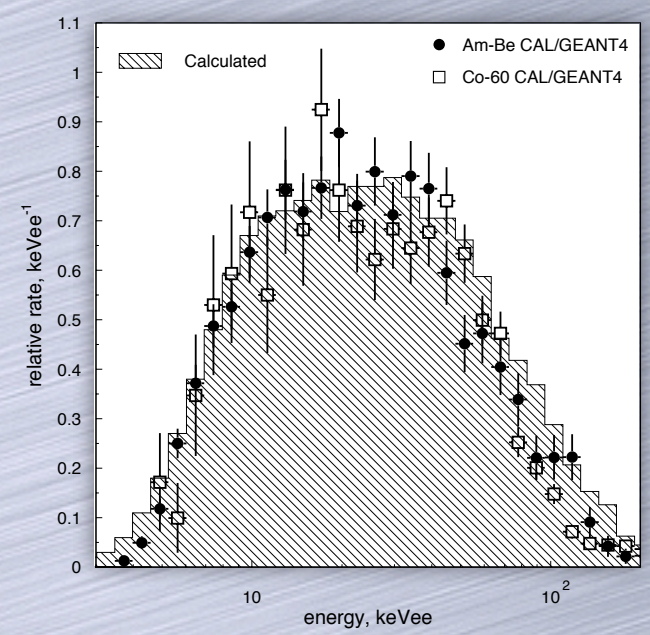
- AmBe calibration (upper)
- Co-60 Calibration (lower)
  - Used to define acceptance window
  - 50% n.r. acceptance shown
  - lower S2/S1=40 bound fixed
  - Box defined 5-20keVee
- Uniform population across plots
  - high rate calibrations (esp Co-60)
  - coincidences between events and 'dead-region' events
- 98.5% γ discrimination at 50% n.r. acceptance

Detector Efficiencies

- Efficiencies calculated for all event selection, algorithm, DAQ, etc.
  - Compared to calibration data
- Observed background consistent with PMT simulations
  - ... but spatial distribution shows cathode events

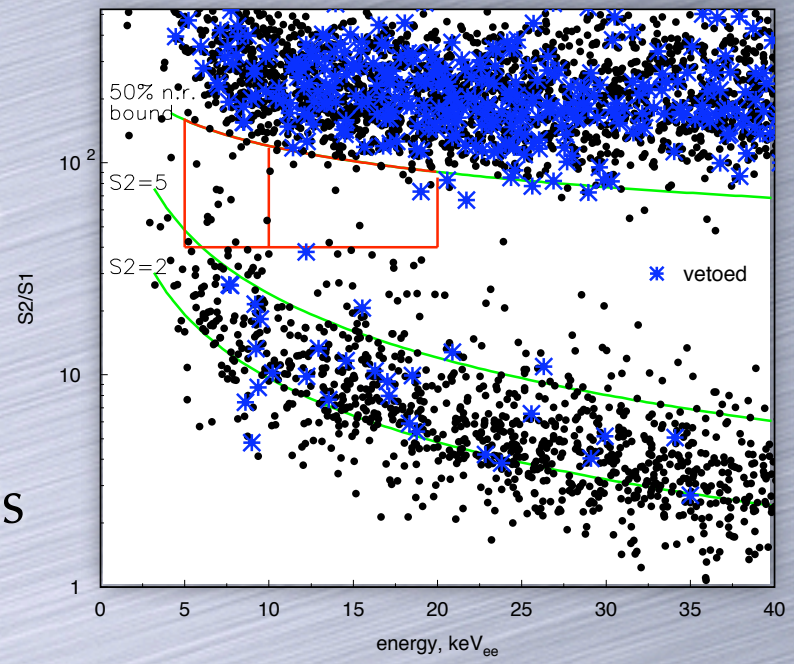


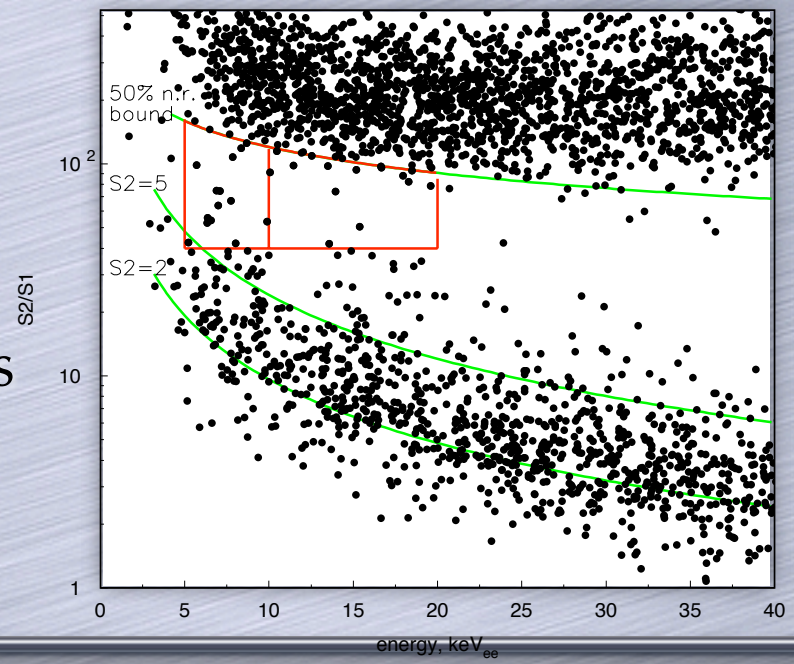
Selection cut	Efficiency	Description
S2 Cut-0	≈100% (exp)	Requirement that a WIMP-like event has one and only one primary and secondary
S2 Cut-1	f(E): 100% >10 keV	Selection of S2 candidates with area>1 Vns
		(smaller pulses due to extraneous single electron extraction are ignored)
S2 Cut-2	90.2%	Removal of events by S2 pulse shape cut (photon mean arrival time)
S2 Cut-3	≈100%	Removal of events with non-physical S2 arrival times relative to trigger
S2 Cut-4	≈100%	Removal of events with multiple S2 candidates (multiple scattering)
S1 Cut-1	f(E): 100%	Selection of S1 candidates with ≥3-fold coincidence at 2/5 photoelectron amplitude
	(5 keV:43% 10 keV:92%)	
S1 Cut-2	≈100%	Removal of events with non-physical drift times relative to S2
S1 Cut-3	≈100%	Removal of events by S1 pulse shape cut (photon arrival time distribution)
S1 Cut-4	98.7%	Removal of events with multiple S1 candidates
S1 Cut-5	99.7%	Tagging of <3-fold S1 signals with cathode drift time (event removed by S1-4)
DAQ Cut-1	f(E): 100% <30 keV	Digitiser saturation cut
DAQ Cut-2	90%	DAQ dead-time correction for science run (trigger rate dependent)
DAQ Cut-3	99.2%	Coincidental events in veto (trigger rate dependent)
DAQ Cut-4	99.7%	Requirement that a valid S1 or S2 trigger the DAQ



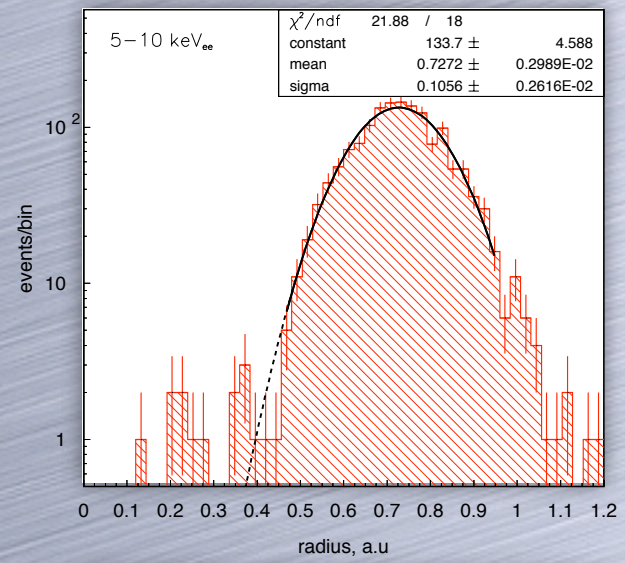
Science runs

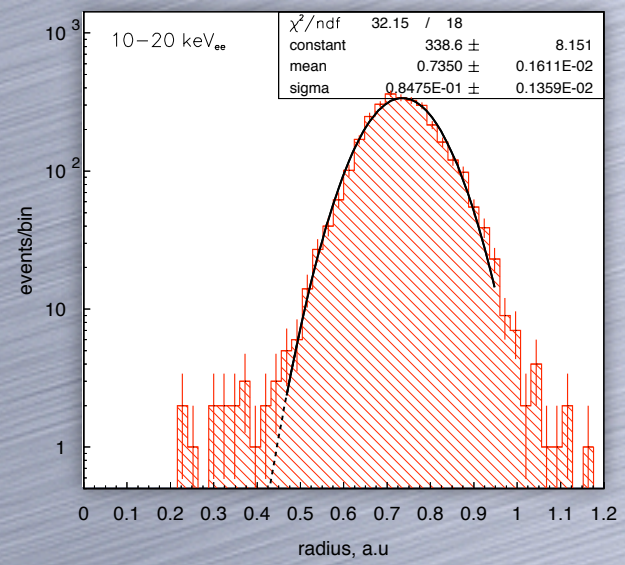
- Top plot shows events with veto
- Lower plot has them removed
  - Second population seen
  - Due to radon-progeny events on walls
  - Acceptance window as before
  - Also shown constant S2 contours
- Second run in preparation
  - Remove radon events to remove second population
  - Emission confirmed from SAES getters
  - Expected sensitivity -> 2e-7pb

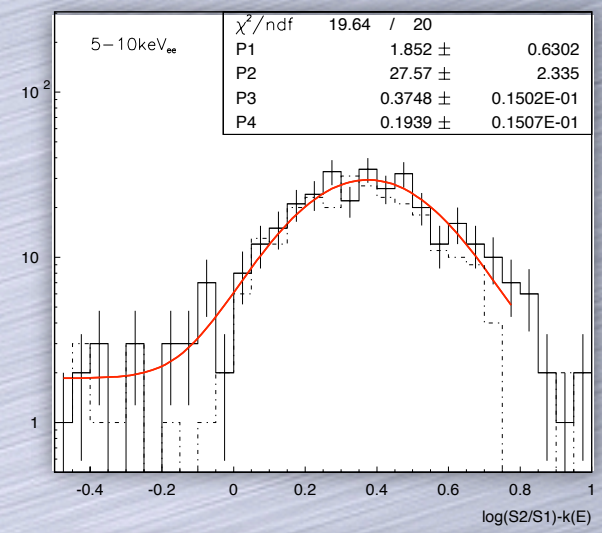


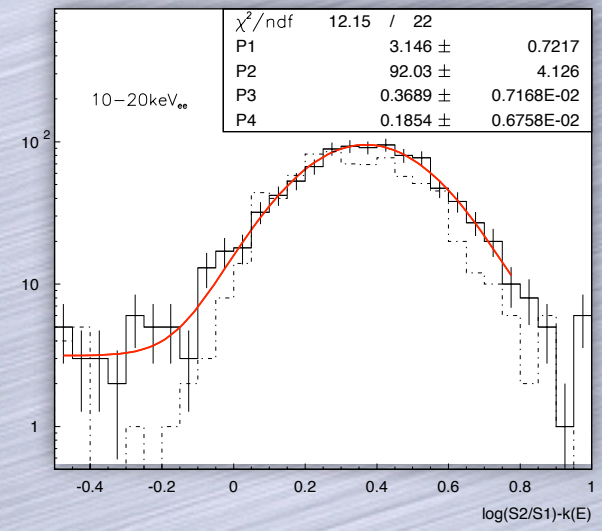


Expectation Analysis









Gamma from Co-60

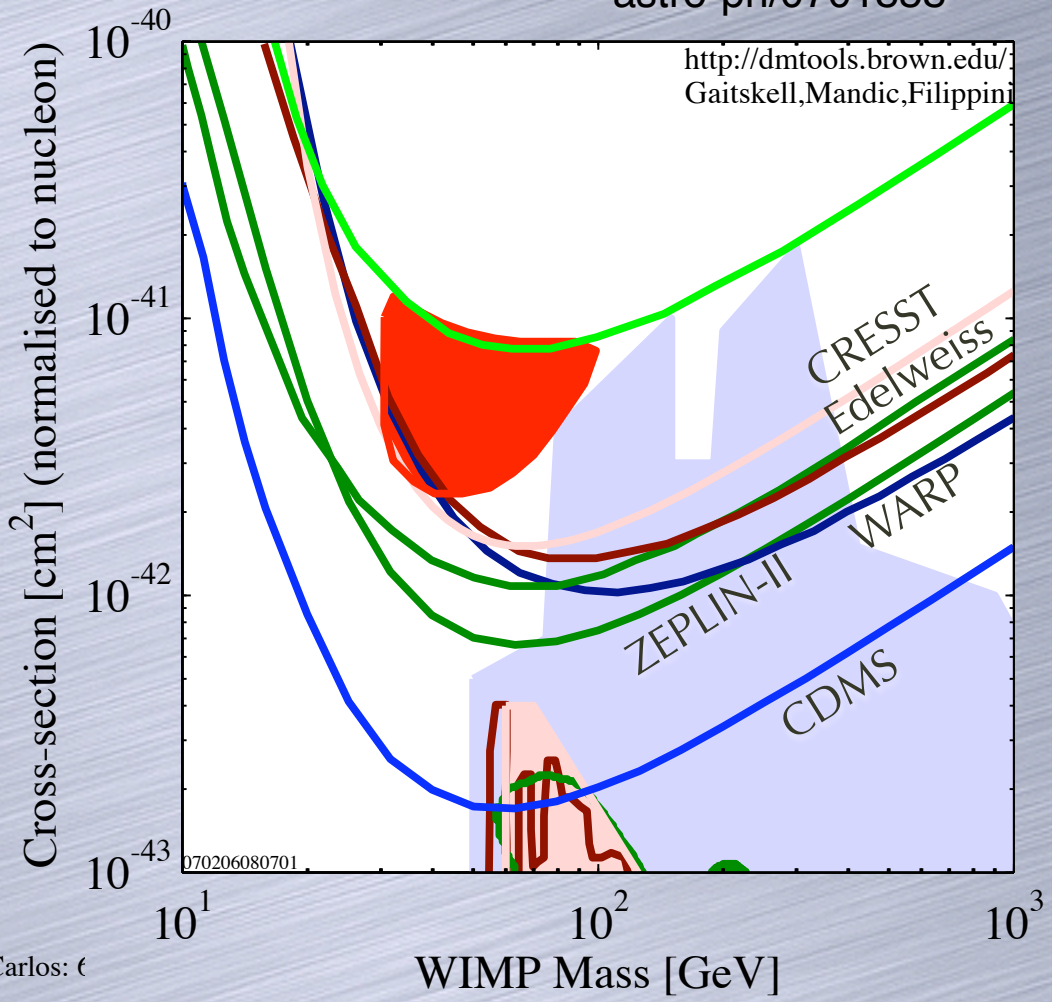
Radon-progeny

Cross-section result, first run

In review with Astropart. Phys.

- 29 events seen in box
- 28.6±4.3 expected (total)
- 10.4 upper limit to n.r
- Translates to limit shown
  - 'canonical' halo model
  - constant q.f of 0.19 used

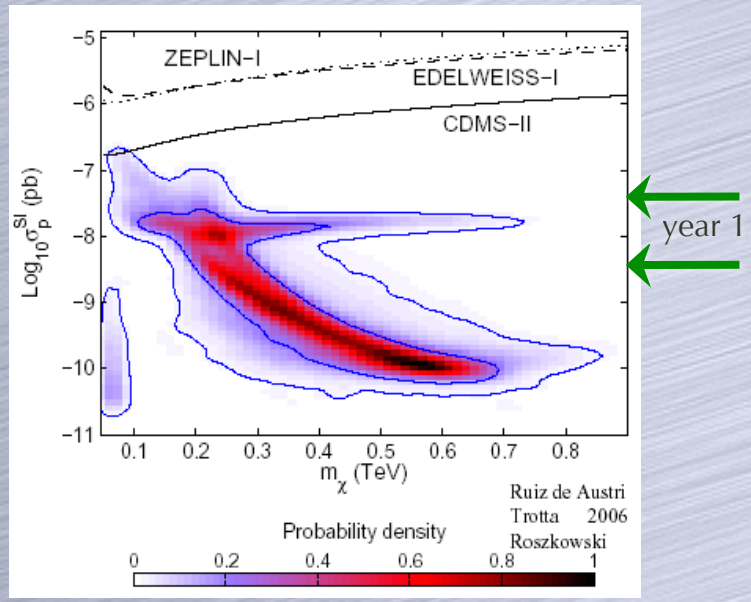
astro-ph/0701858



DATA listed top to bottom on plot
KIMS 2005 - 237 kg-days CsI
DAMA 2000 58k kg-days NaI Ann.Mod. 3sigma,w/o DAMA 1996 limit
CRESST 2004 10.7 kg-day CaWO4
Edelweiss I final limit, 62 kg-days Ge 2000+2002+2003 limit
ZEPLIN I First Limit (2005)
WARP 2.3L, 96.5 kg-days 55 keV threshold
ZEPLIN II (Jan 2007) result
CDMS (Soudan) 2004 + 2005 Ge (7 keV threshold)
Ruiz de Austri/Trotta/Roszkowski 2006, CMSSM Markov Chain Monte Carlos: 6
Baer et. al 2003
Ruiz de Austri/Trotta/Roszkowski 2006, CMSSM Markov Chain Monte Carlos: 9
Ellis et. al Theory region post-LEP benchmark points
Baltz and Gondolo 2003
Baltz and Gondolo, 2004, Markov Chain Monte Carlos
070206080701

Next stage: ZEPLIN-III

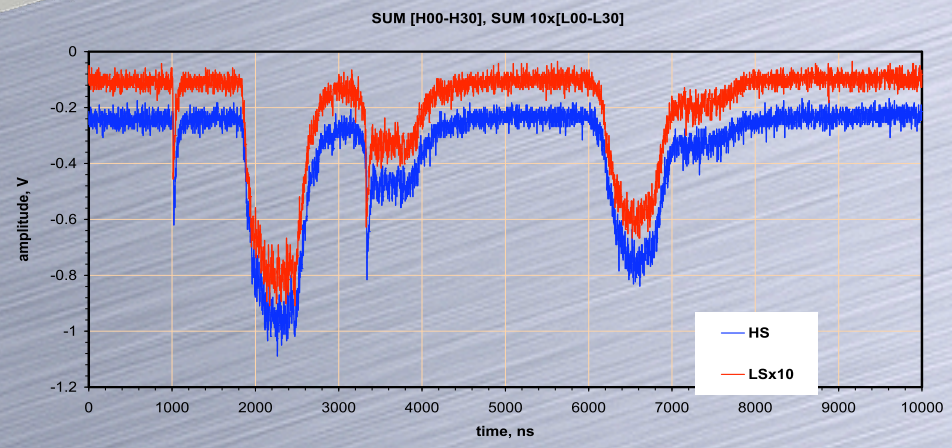
- ZEPLIN-III constructed
- Surface calibrations completed
  - Performance as expected
  - some indication of higher then expected light yield
- Deployment at Boulby in progress
- Operations for next two years approved

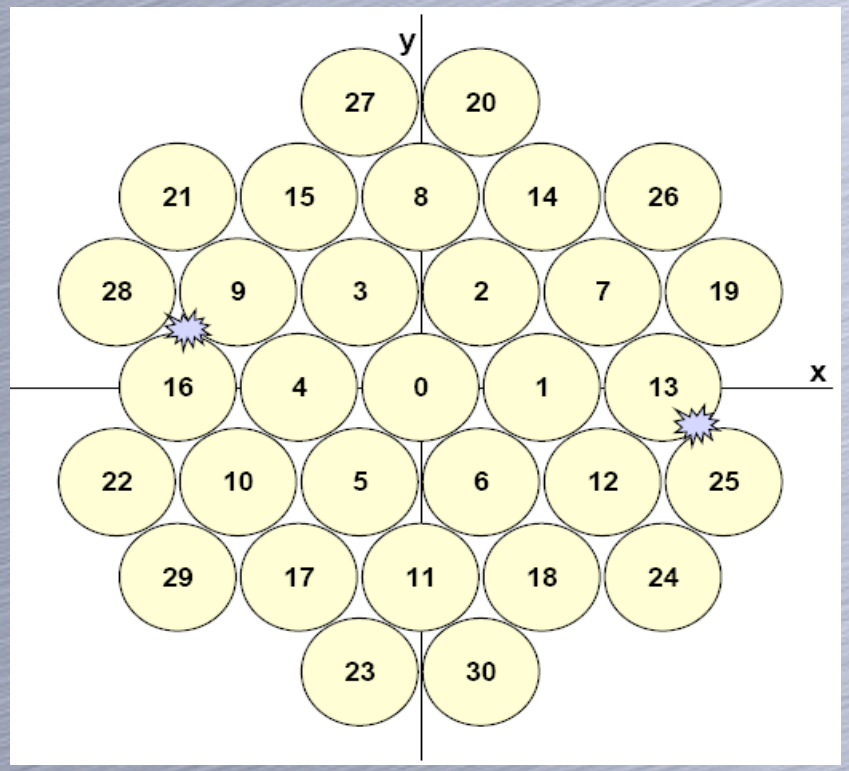


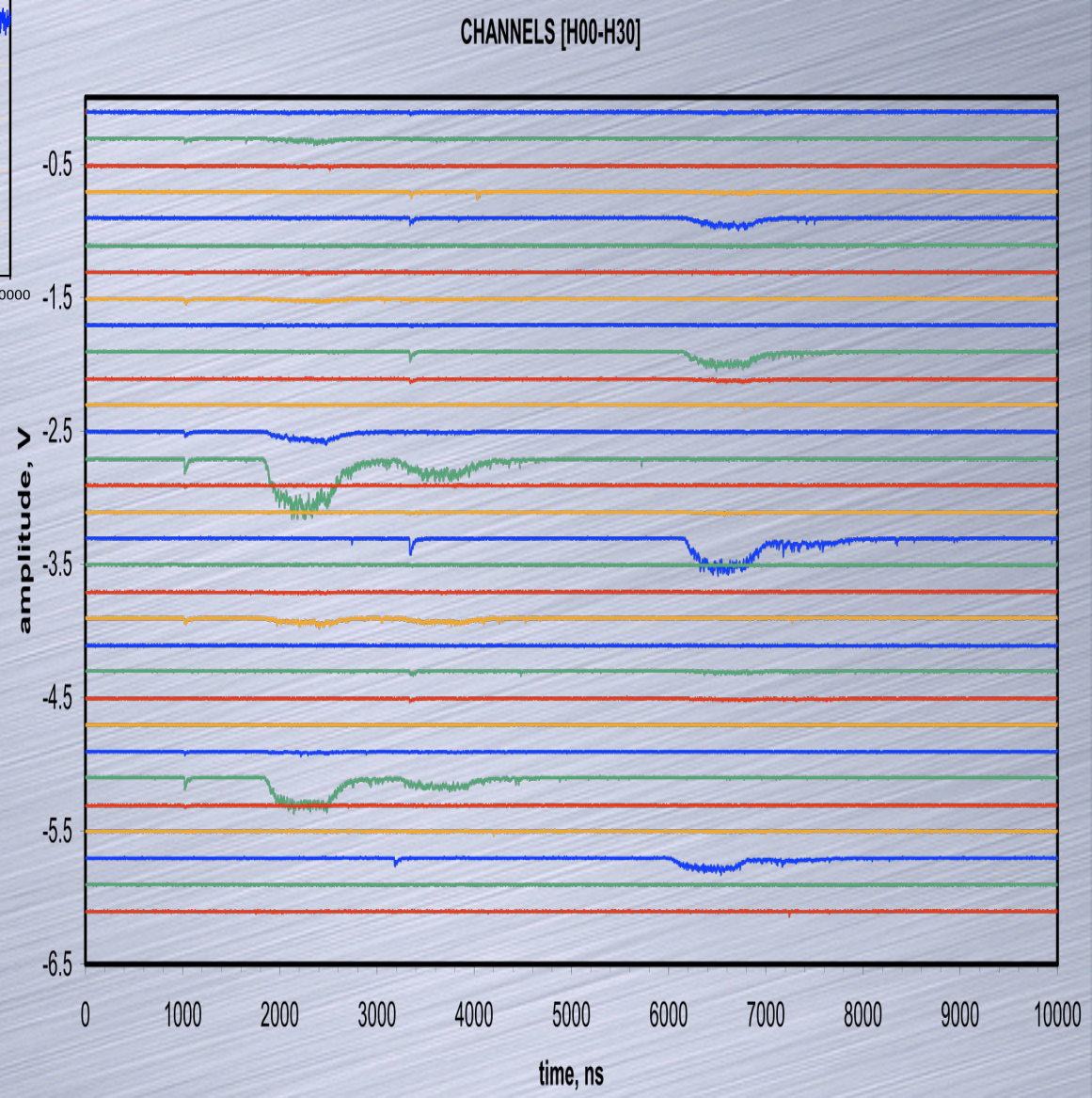
ZEPLIN III Features

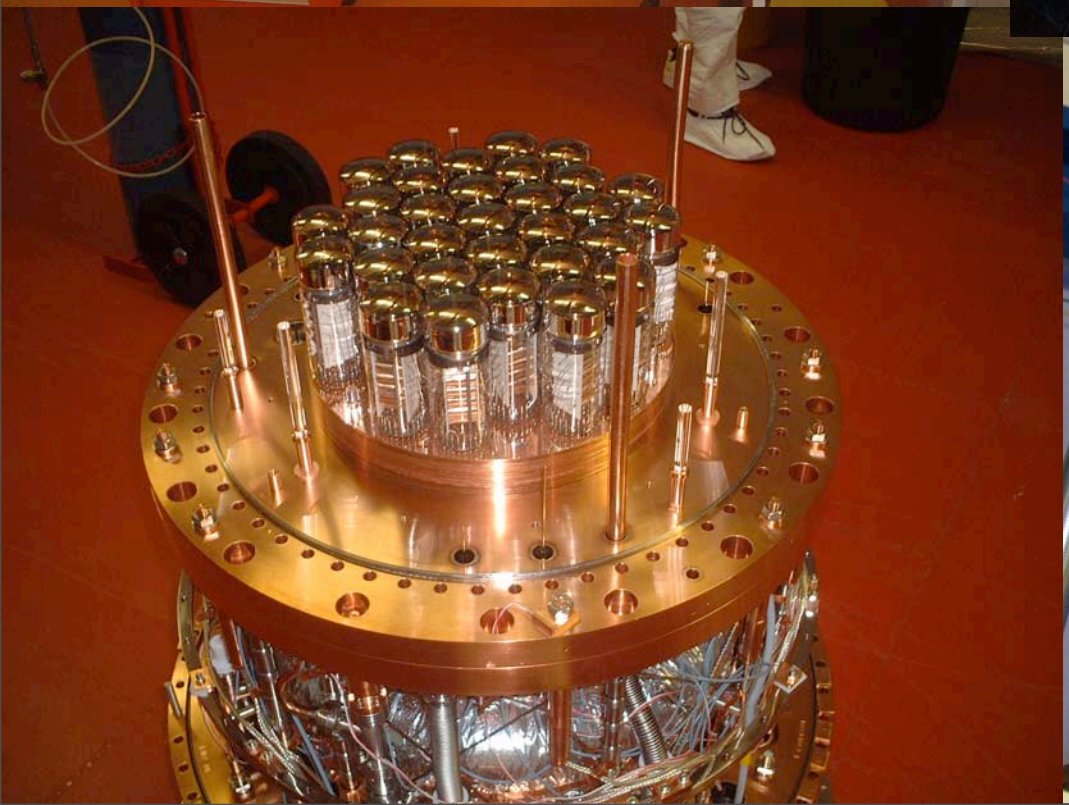
- 8kg fiducial mass
- PMTs in liquid to improve light collection
- 3.5 cm drift depth – higher E-field
- 0.5 cm electroluminescent gap
- 31 small PMTs for fine position sensitivity
- open plan – no surfaces - reduced feedback
- Lower-background PMTs available
- Copper construction
- Low-background xenon (from ITEP)

Position recovery









Summary

- ZEPLIN-II First run completed underground
  - Submitted first results
    - 29 events seen, 28.6±4.3 expected
    - 10.4 n.r 90%c.l. upper limit -> 6.6e-7pb
  - Second run in preparation
    - remove radon events from SAES getters
    - improved stability of cooling systems
    - expected sensitivity -> 2e-7pb
- ZEPLIN-III Construction completed
  - Deployment at Boulby underway
  - Operations for next 2.5 years approved
  - Additional lab tests to confirm/explore xenon physics