

# The ZEPLIN programme: Current results & future plans

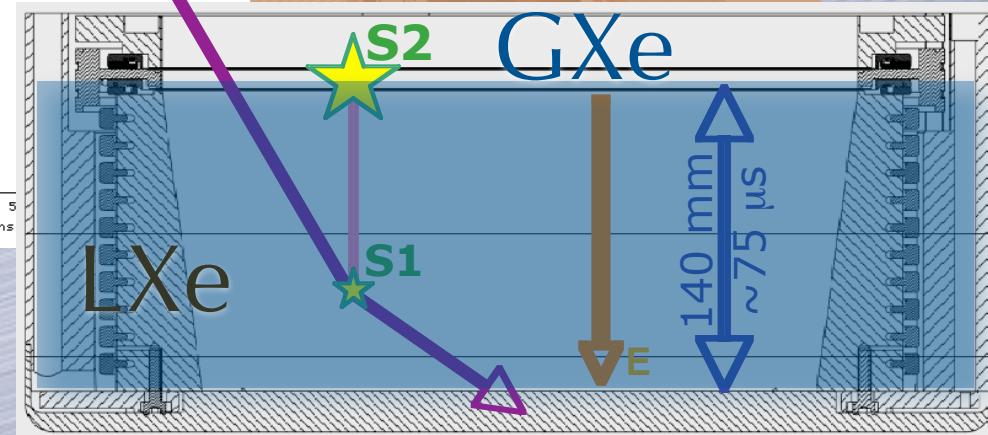
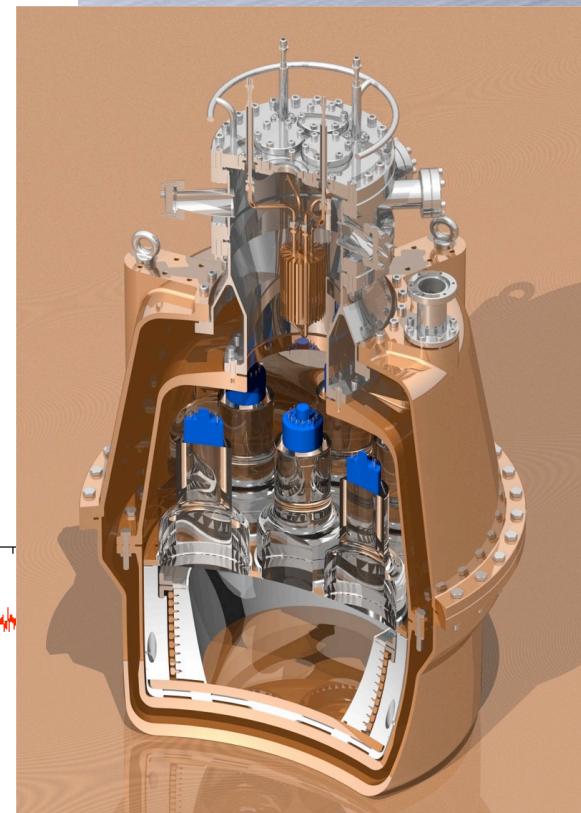
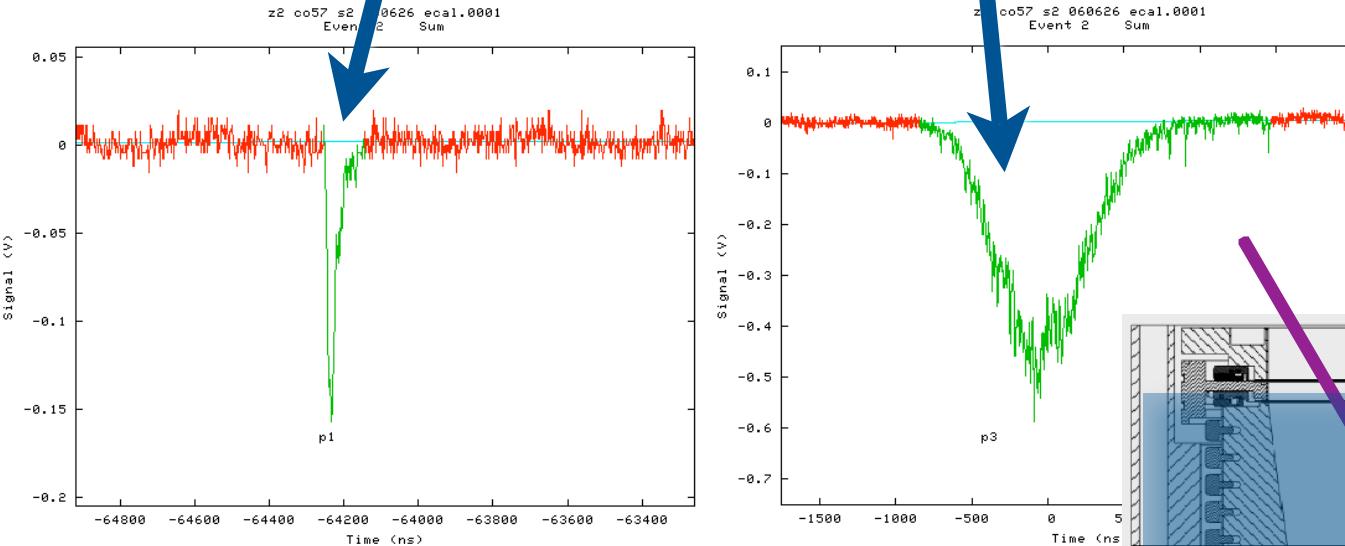
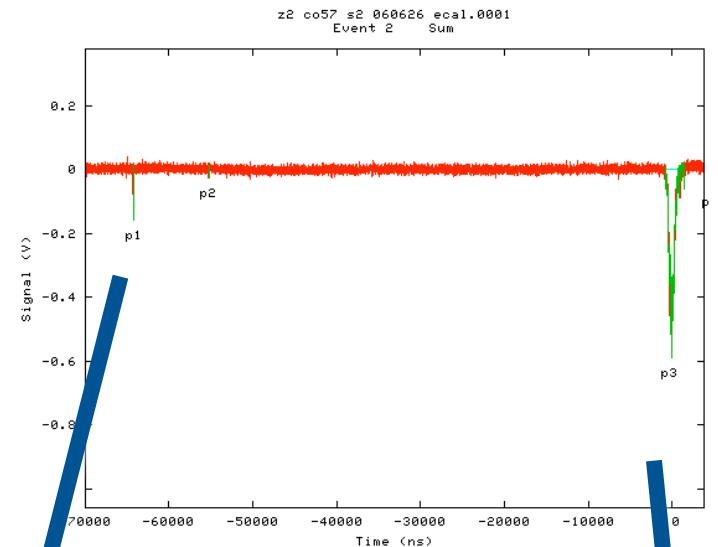
**University of Edinburgh, STFC Rutherford  
Appleton Laboratory, Imperial College London,**

**University of Sheffield,**

**LIP Coimbra, ITEP Moscow,**

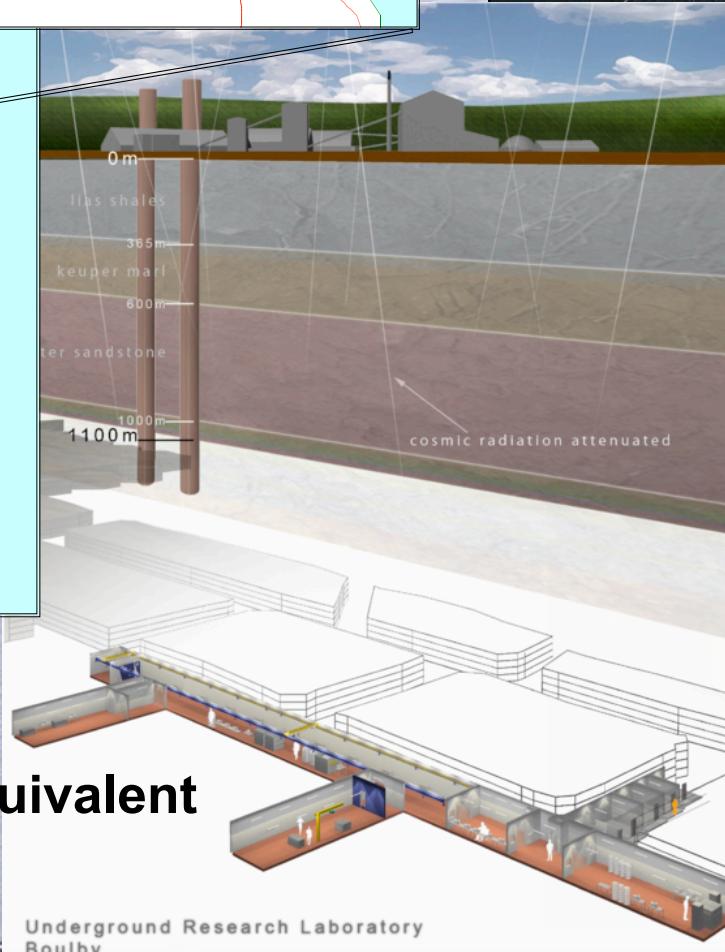
**UCLA, Texas A&M University, Rochester University**

# ZEPLIN-II Detector



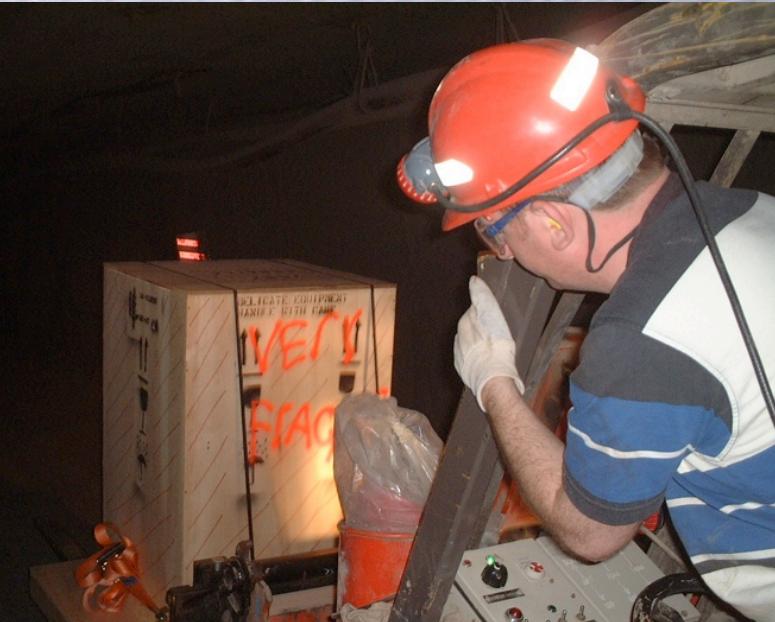
- 5 months continuous operation
- $1.0 \text{ t}^* \text{day}$  of raw DM data

# Where to search for dark matter?



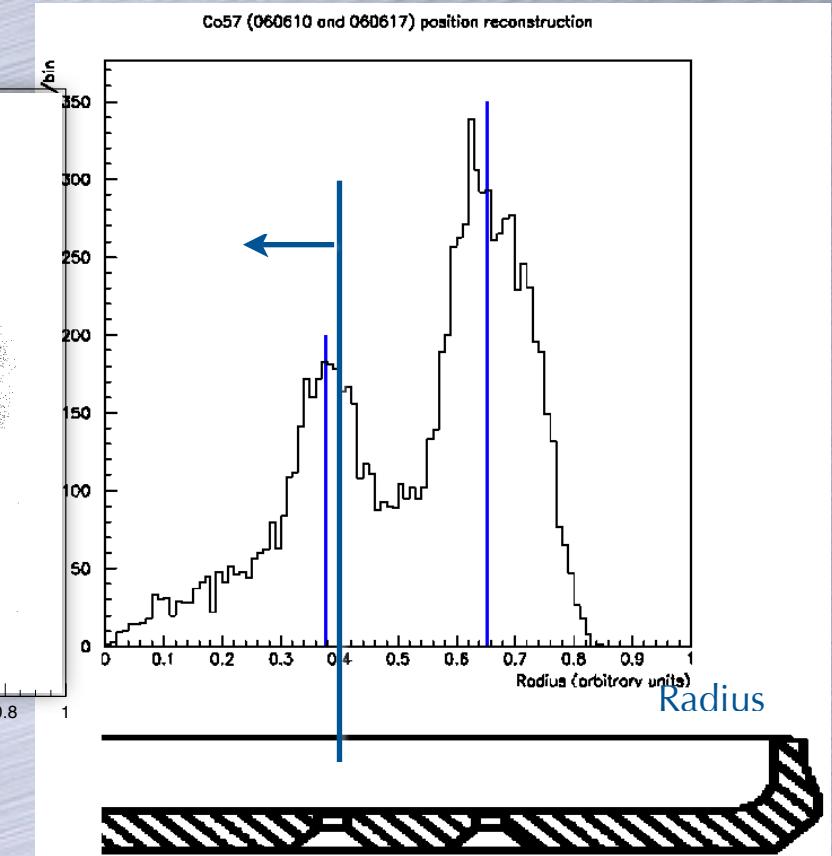
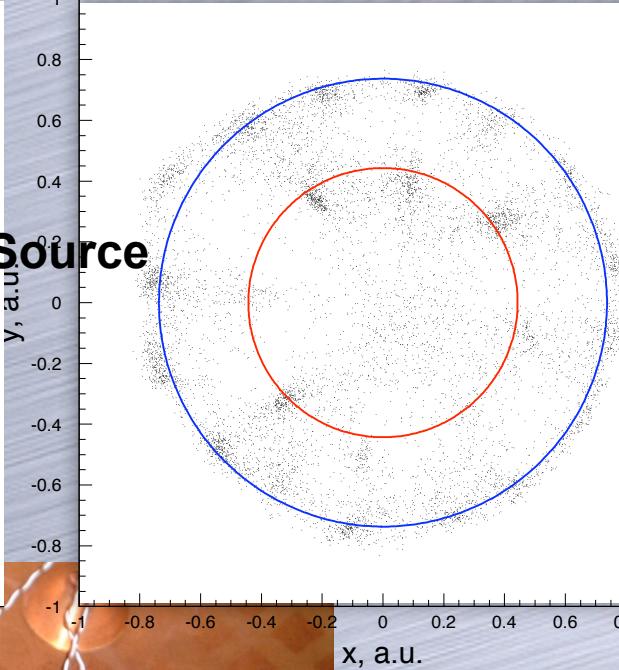
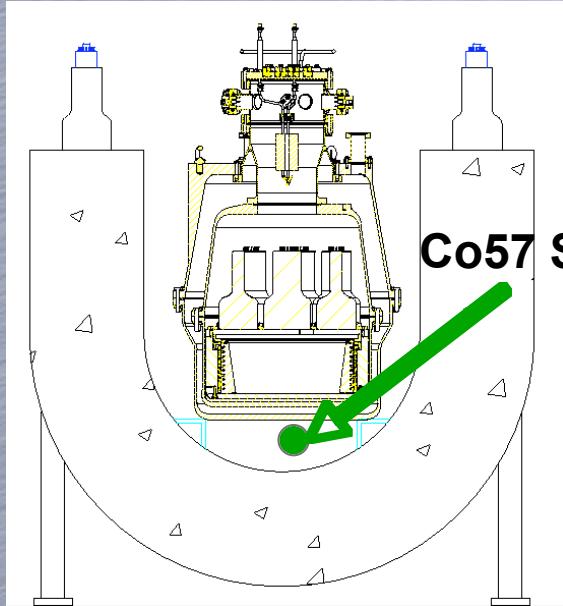
Depth 1100 m, 2.8 km water equivalent





Veto system (Gd loaded)

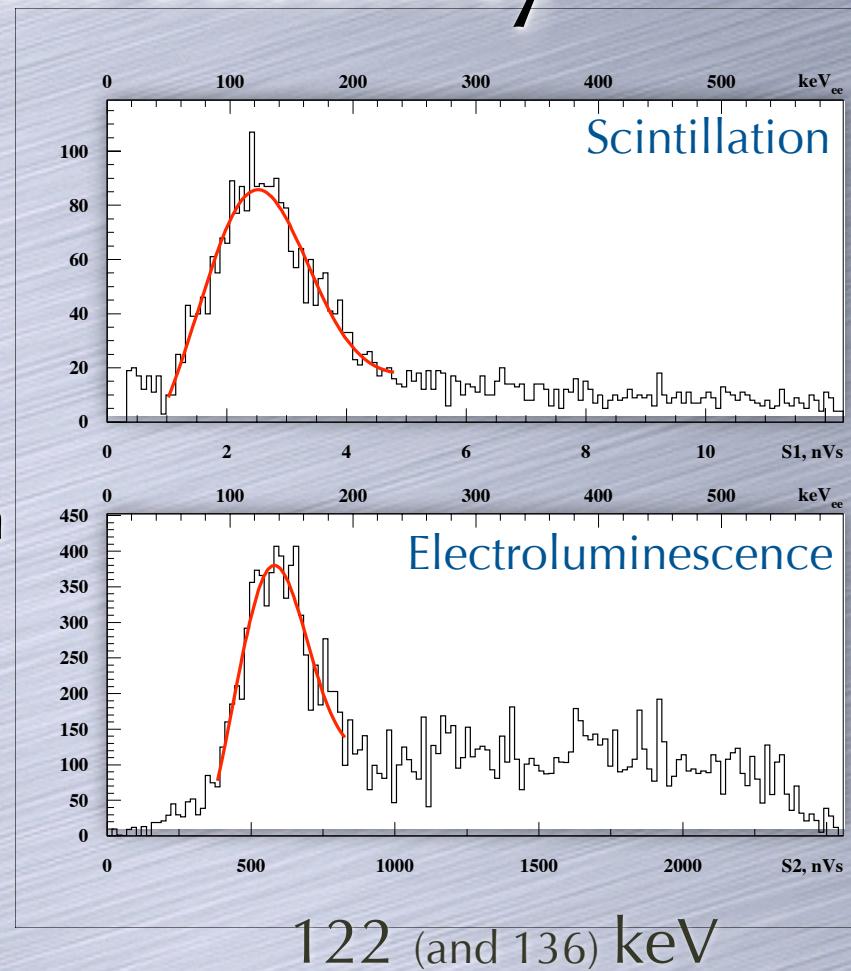
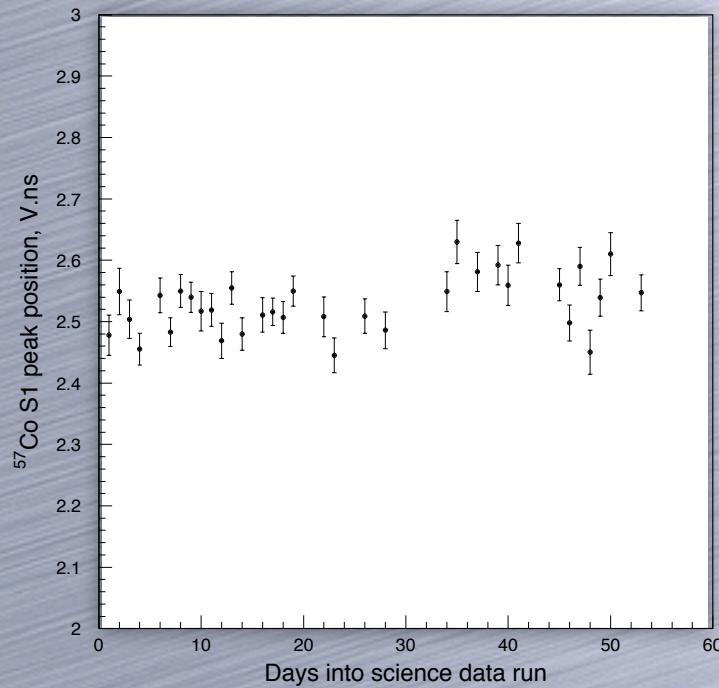
# Detector response: $^{57}\text{Co}$ calibration



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

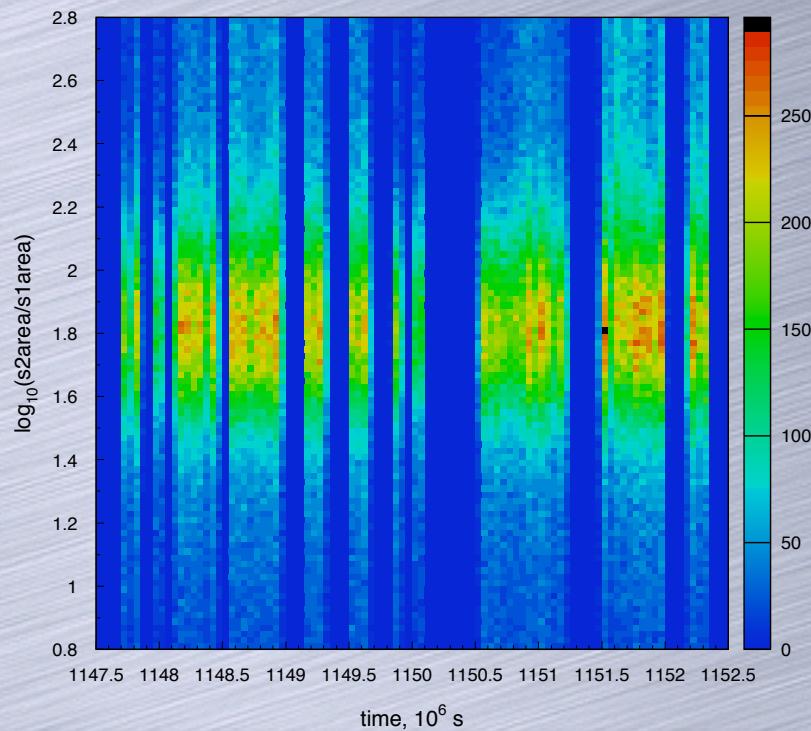
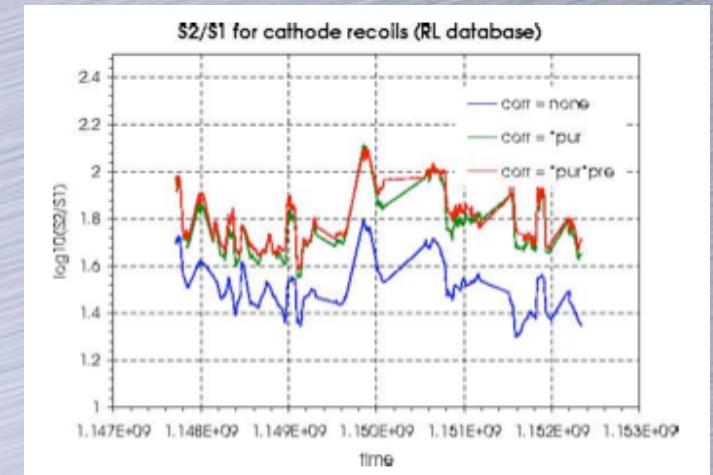
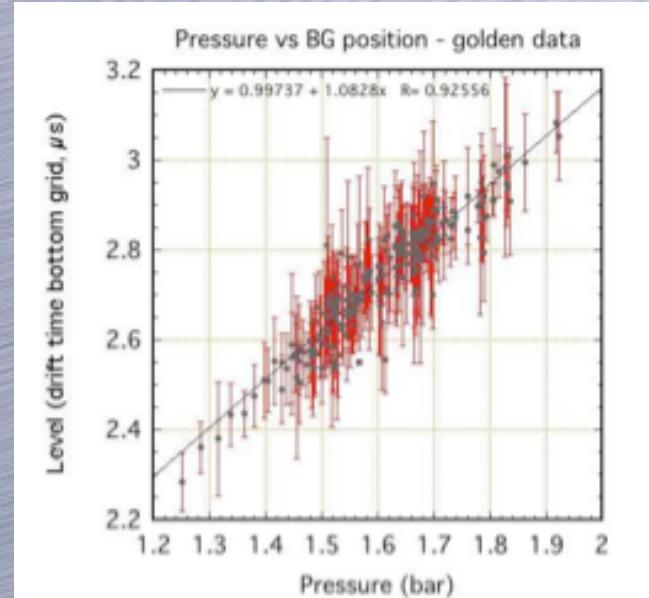
# Co-57 Calibration stability

- 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

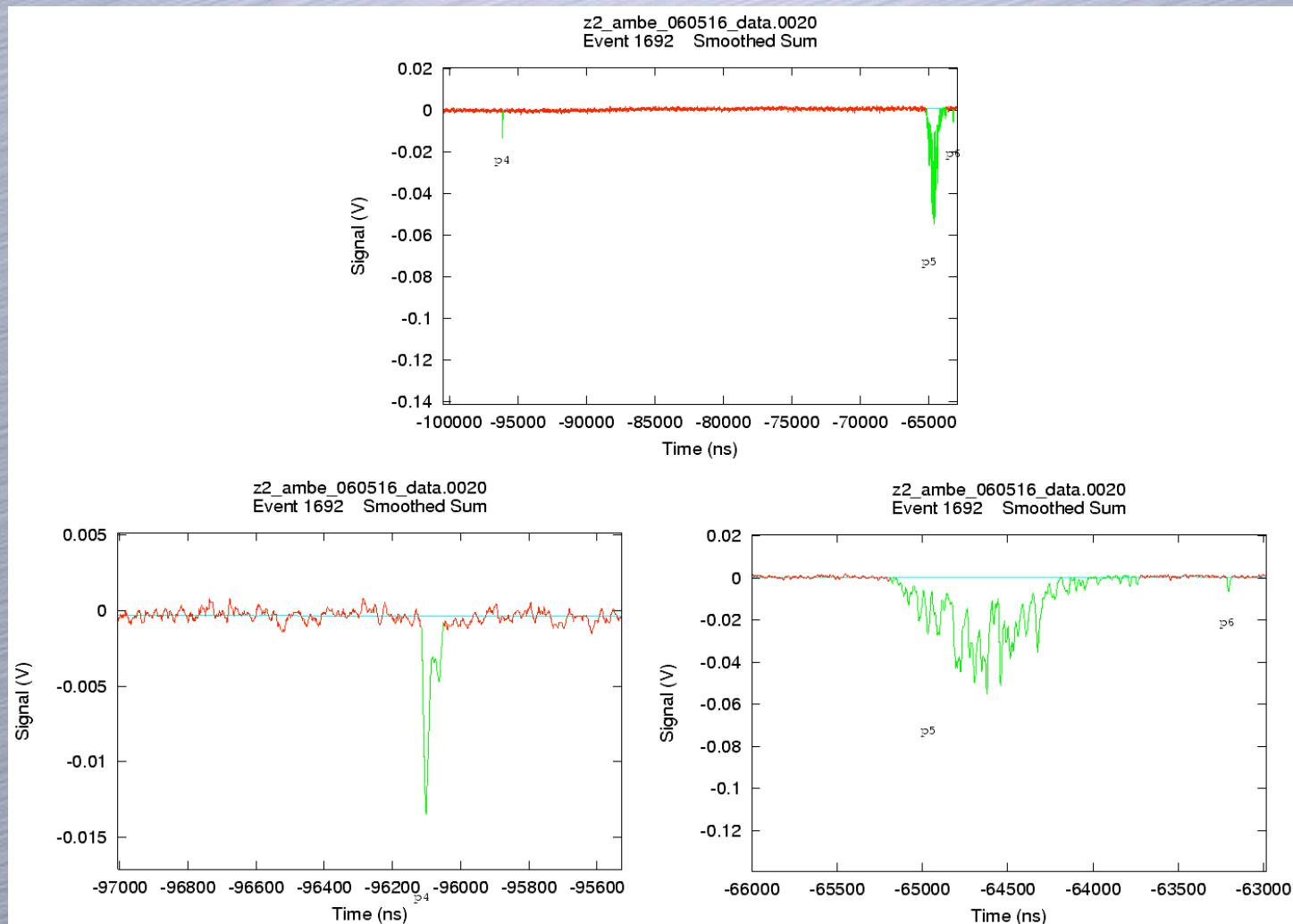


# S2 corrections

- 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

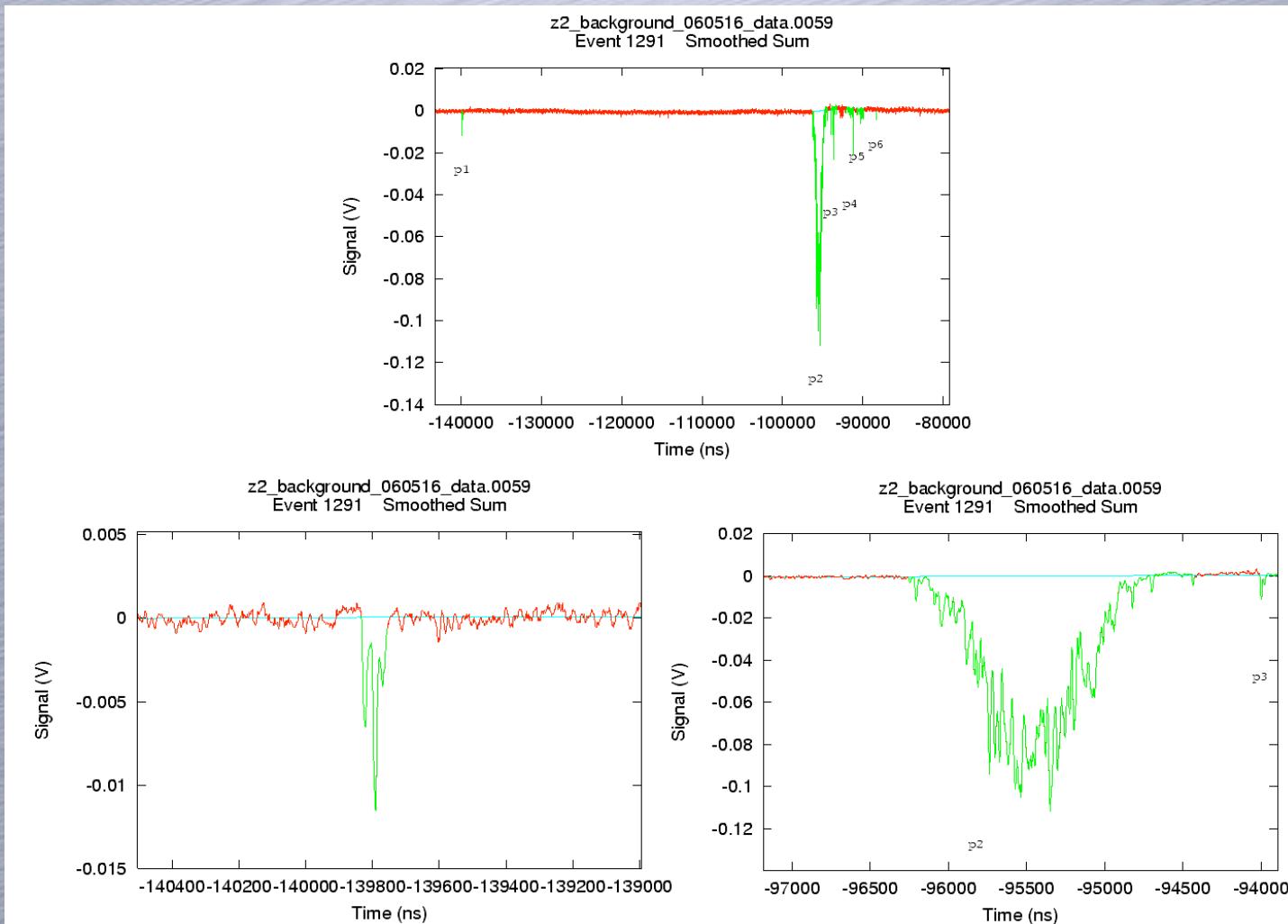


# Neutron/Gamma pulses



Neutron pulse

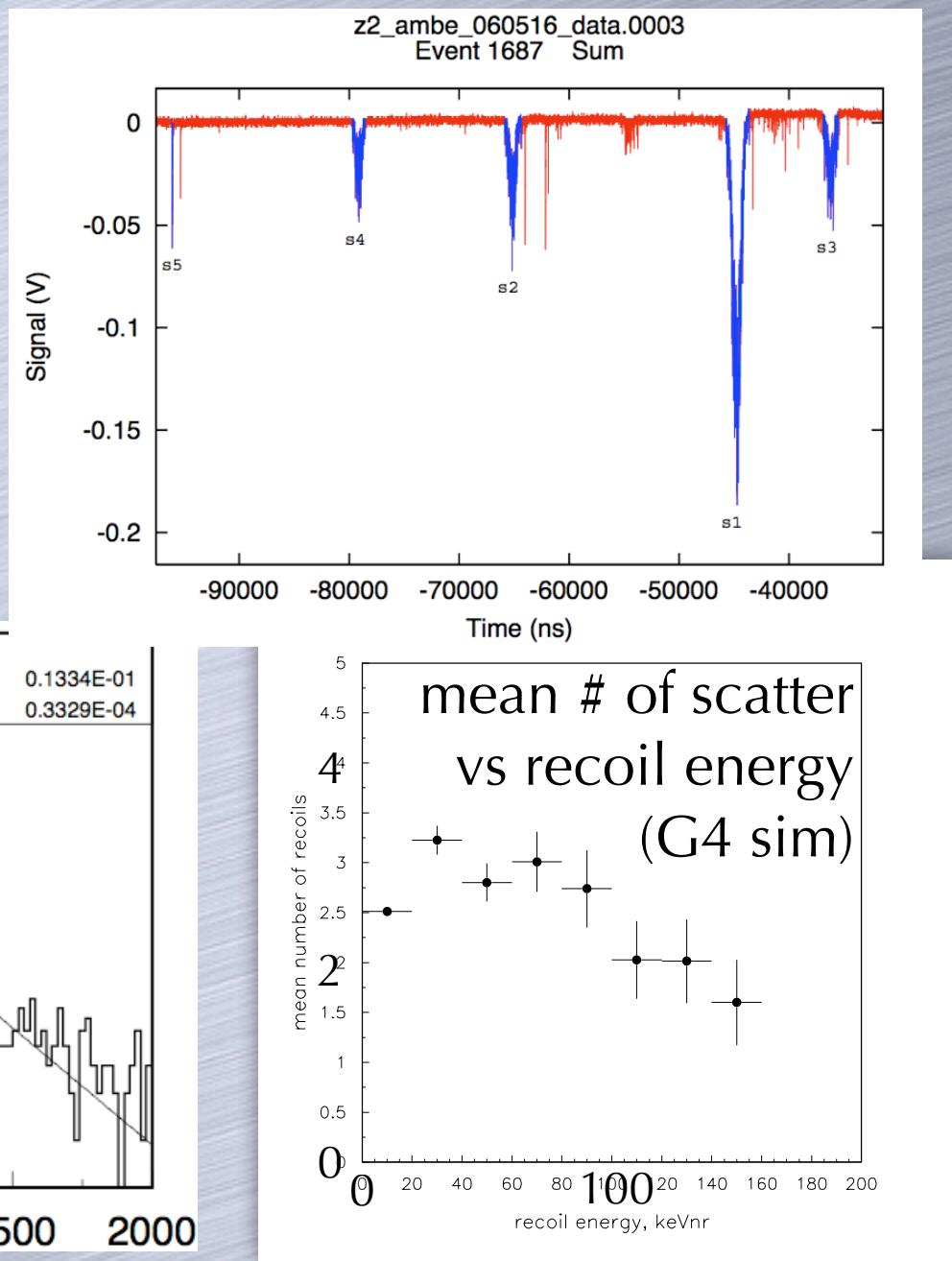
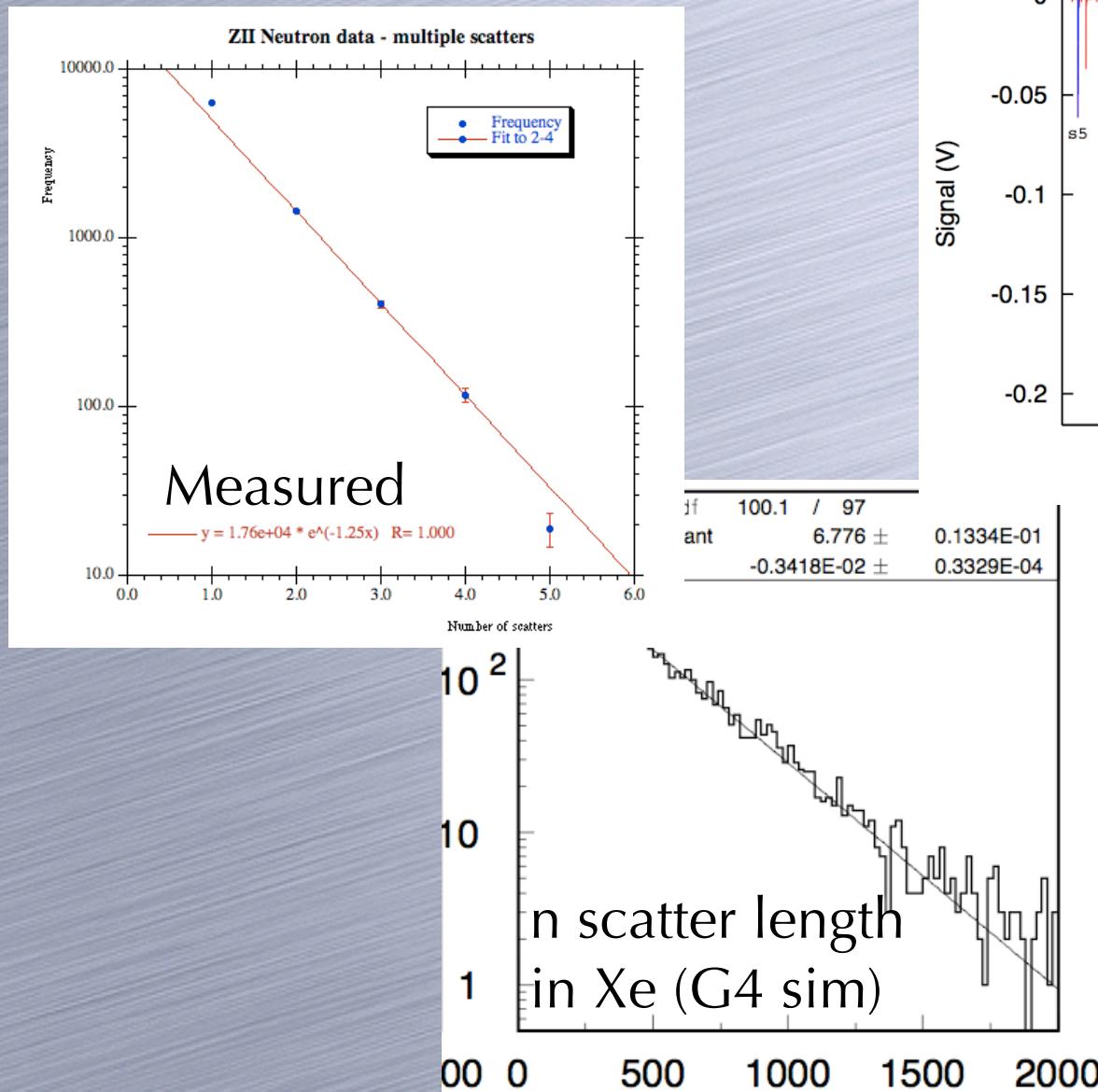
# Neutron/Gamma pulses



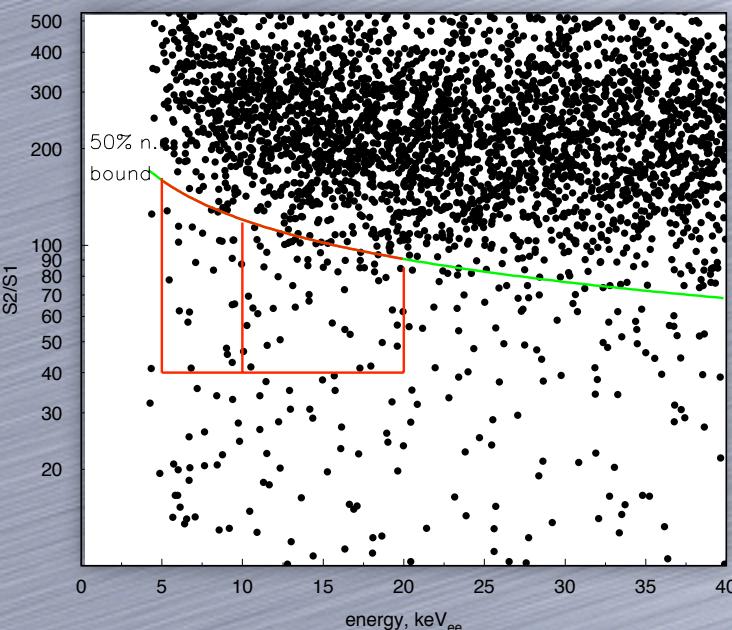
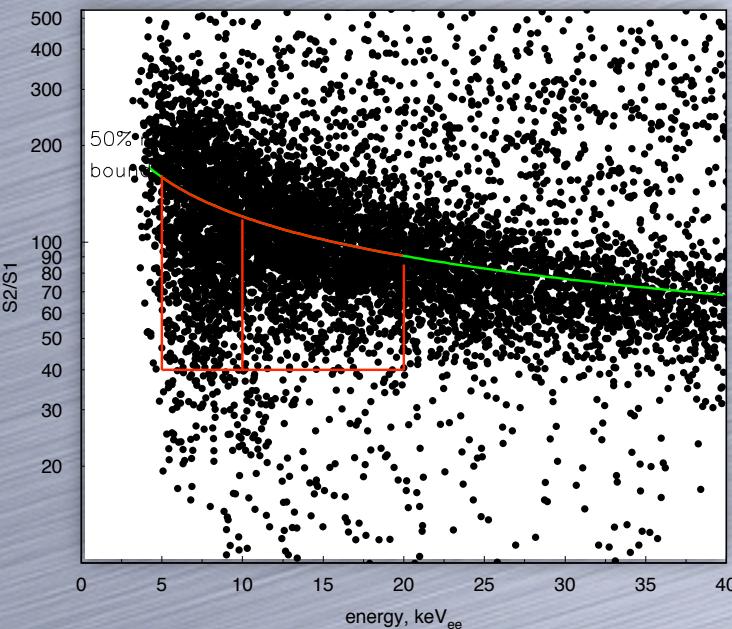
Gamma pulse

# n - Calibration (AmBe or 252-CF)

- Multiple scattering of neutrons



# Discrimination Power

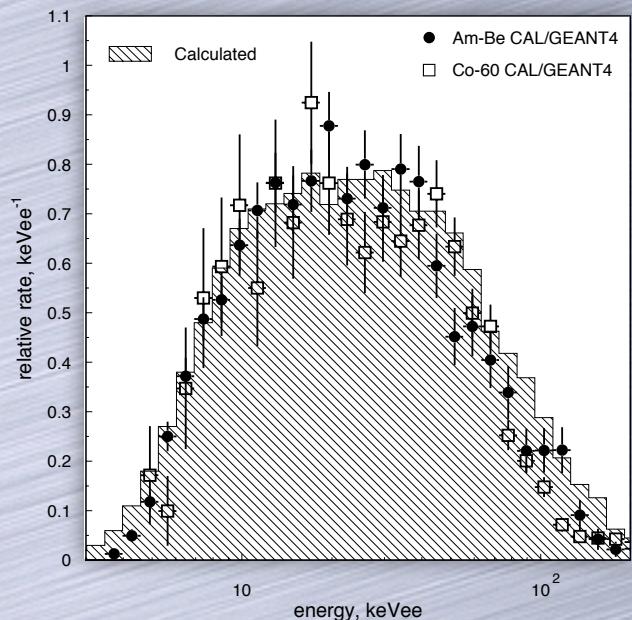
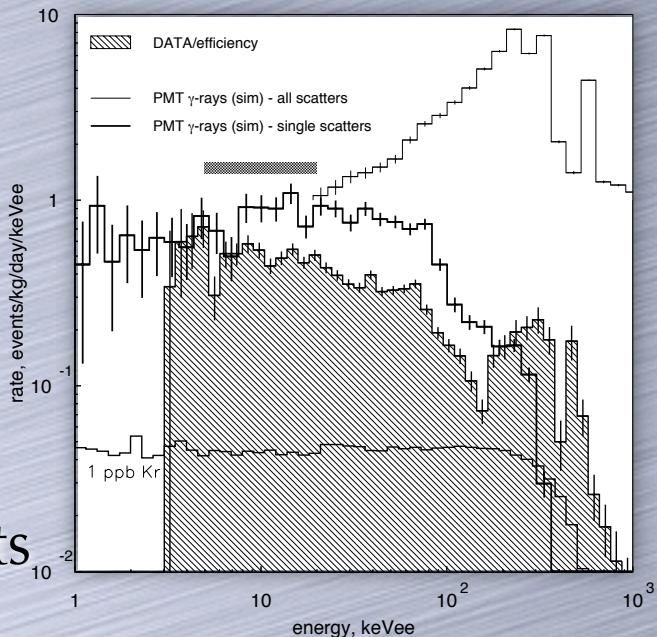


- AmBe calibration (upper)
- Co-60 Calibration (lower)
  - Used to define acceptance window
  - 50% n.r. acceptance shown
  - lower  $S_2/S_1=40$  bound fixed
  - Box defined 5-20 keV<sub>ee</sub>
- Uniform population across plots
  - high rate calibrations (esp Co-60)
  - coincidences between events and 'dead-region' events
- 98.5%  $\gamma$  discrimination at 50% n.r. acceptance

# Detector Efficiencies

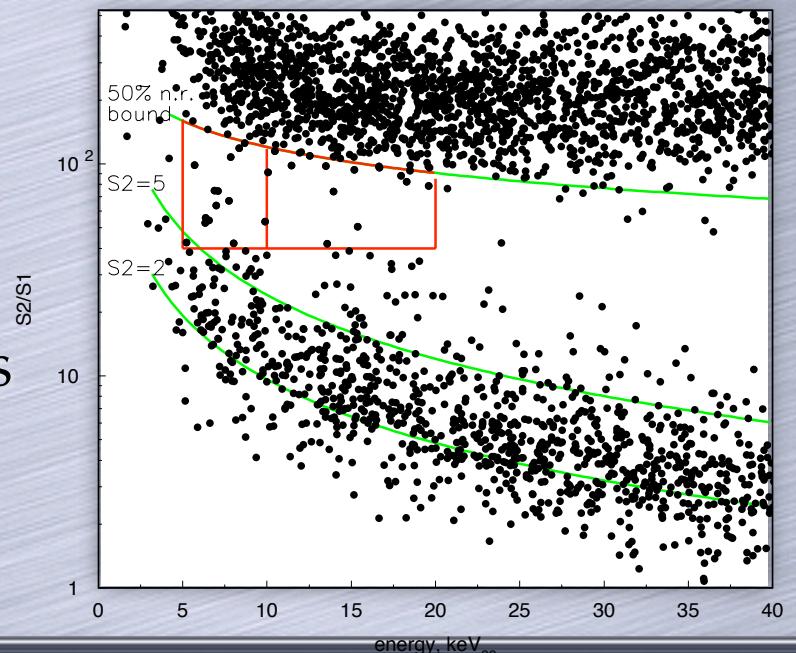
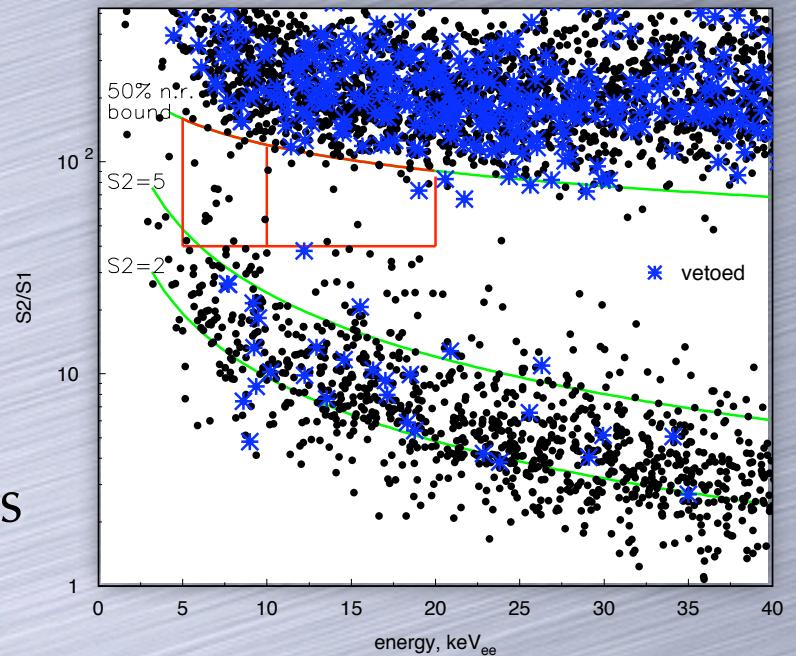
- Efficiencies calculated for all event selection, algorithm, DAQ, etc.
  - Compared to calibration data
- Observed background consistent with PMT simulations
  - ... but spatial distribution shows cathode events

Selection cut	Efficiency	Description
S2 Cut-0	$\approx 100\%$ (exp)	Requirement that a WIMP-like event has one and only one primary and secondary
S2 Cut-1	$f(E) : 100\% > 10 \text{ keV}$	Selection of S2 candidates with area $>1 \text{ Vns}$ (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	$\approx 100\%$	Removal of events with non-physical S2 arrival times relative to trigger
S2 Cut-4	$\approx 100\%$	Removal of events with multiple S2 candidates (multiple scattering)
S1 Cut-1	$f(E) : 100\%$ (5 keV:43% 10 keV:92%)	Selection of S1 candidates with $\geq 3$ -fold coincidence at 2/5 photoelectron amplitude
S1 Cut-2	$\approx 100\%$	Removal of events with non-physical drift times relative to S2
S1 Cut-3	$\approx 100\%$	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	$f(E) : 100\% < 30 \text{ keV}$	Digitiser saturation cut
DAQ Cut-2	90%	DAQ dead-time correction for science run (trigger rate dependent)
DAQ Cut-3	99.2%	Coincidential events in veto (trigger rate dependent)
DAQ Cut-4	99.7%	Requirement that a valid S1 or S2 trigger the DAQ

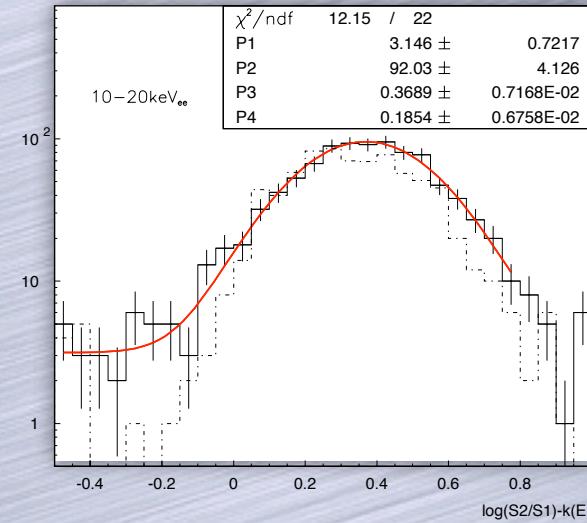
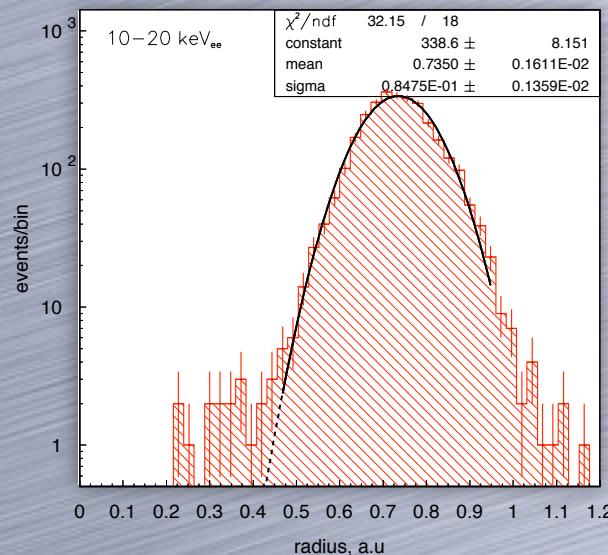
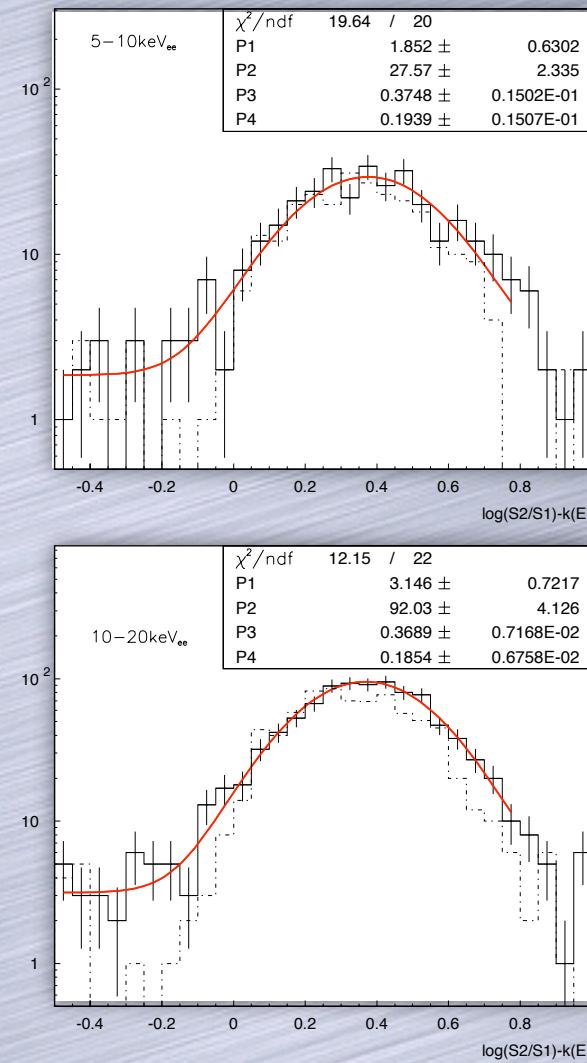
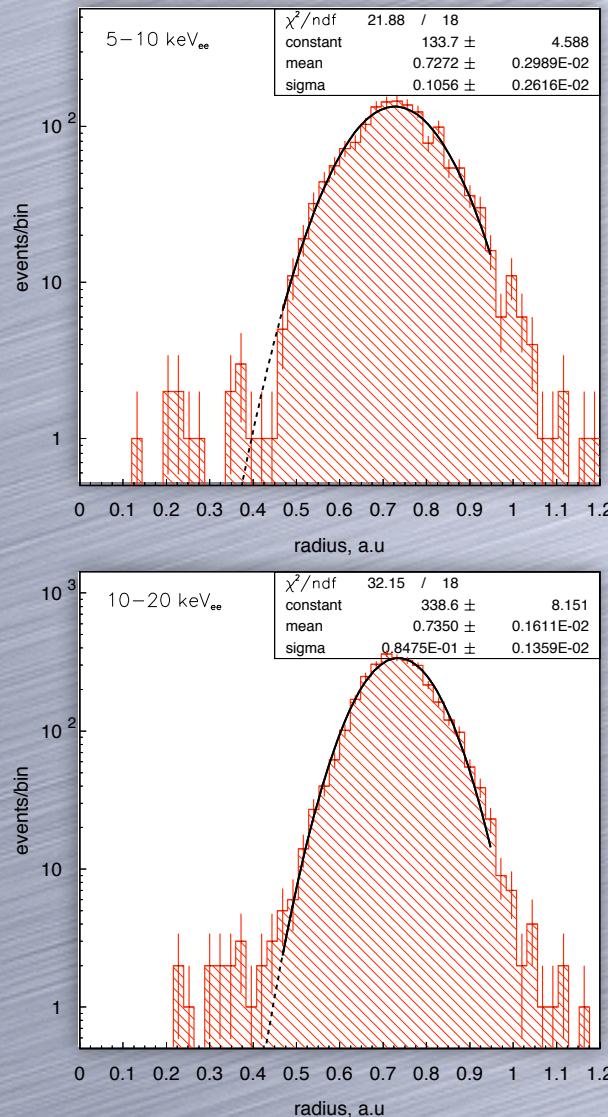


# Science runs

- 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 ->  $2 \times 10^{-7}$  pb



# Expectation Analysis



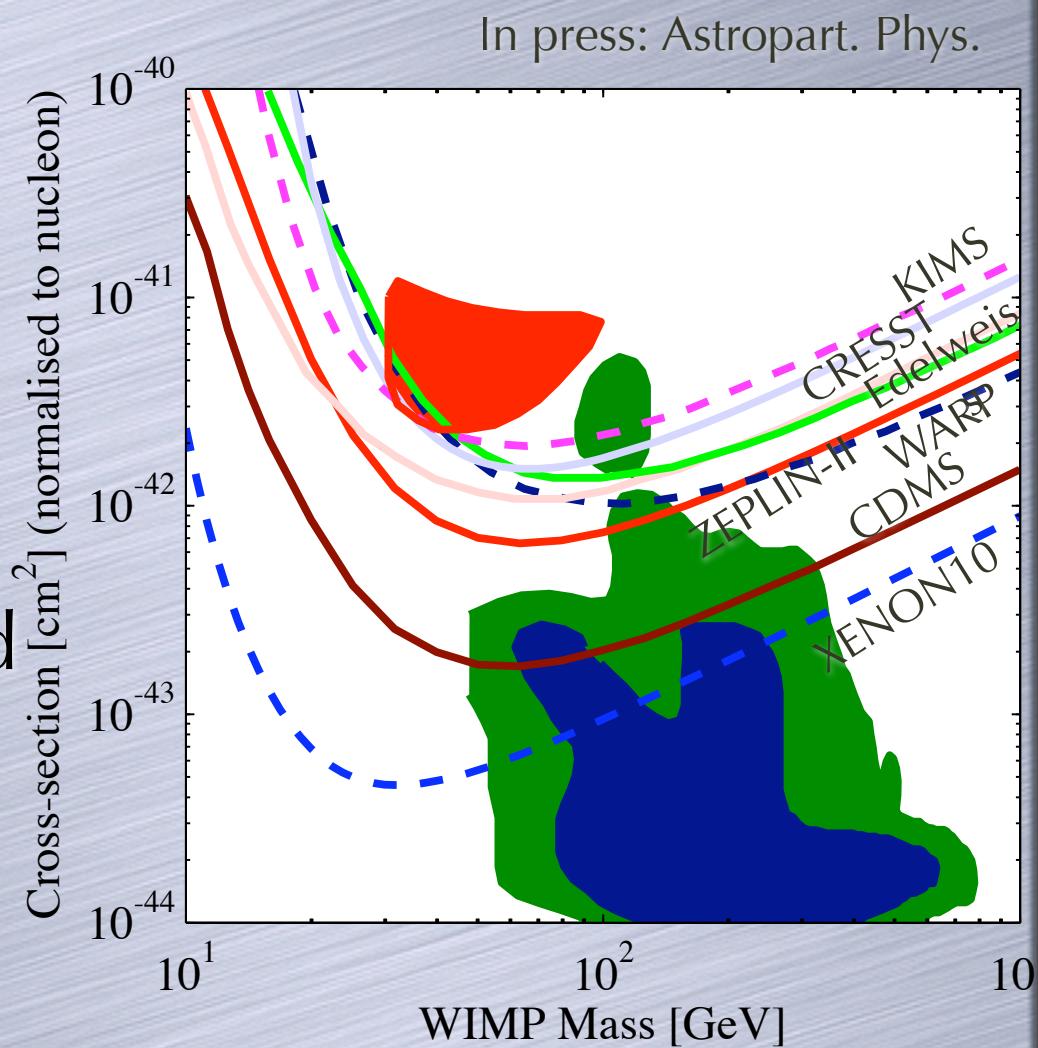
Gamma from Co-60

Radon-progeny

# Cross-section result, first run

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

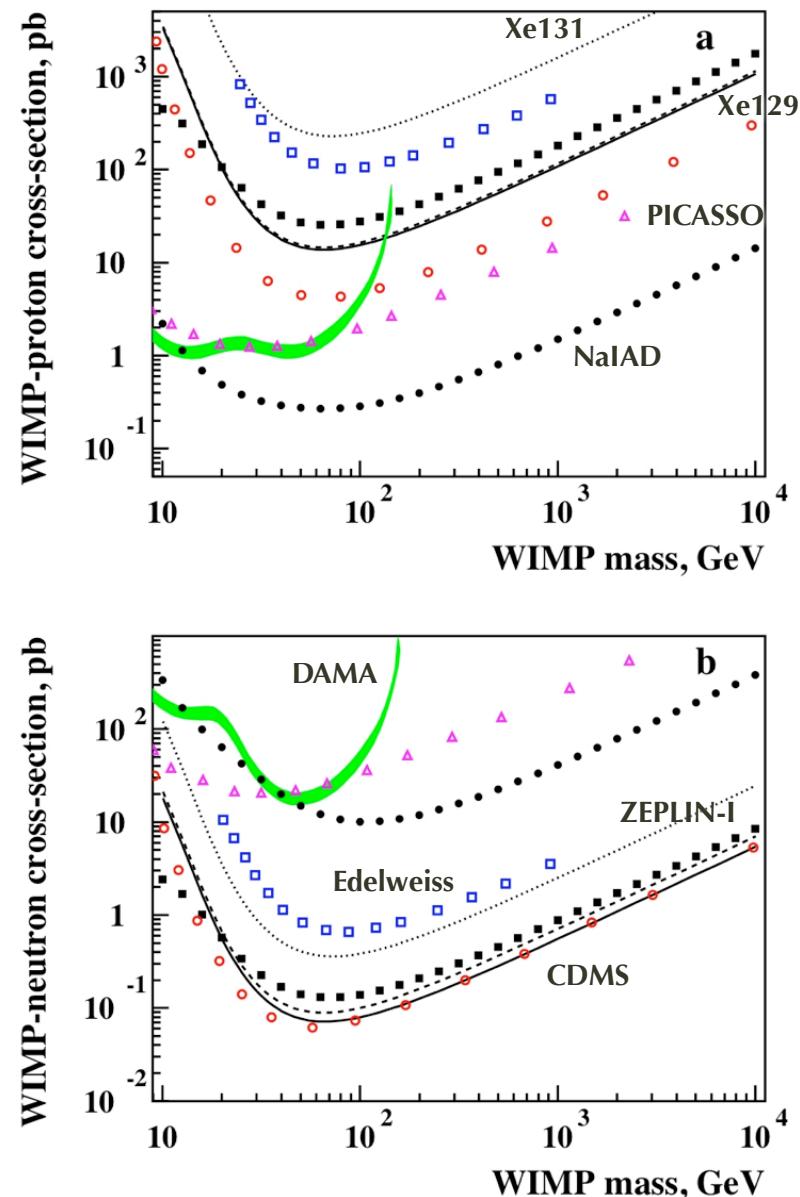
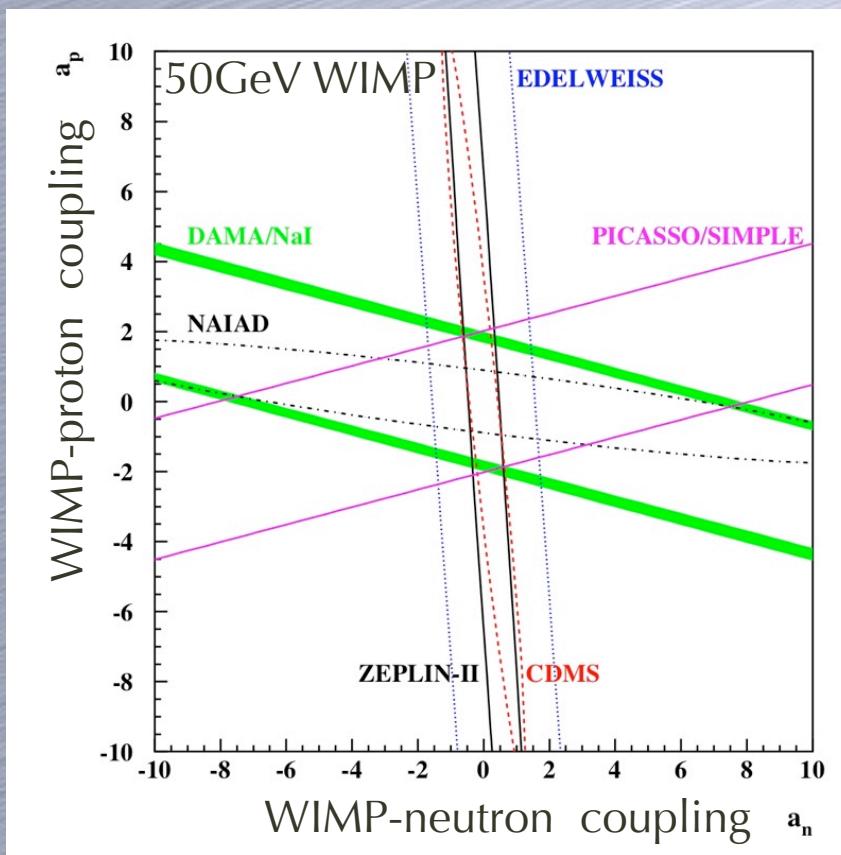
DATA listed top to bottom on plot  
 DAMA 2000 58k kg-days NaI Ann.Mod. 3sigma,w/o DAMA 1996 limit  
 KIMS 2007 - 3409 kg-days CsI  
 CRESST 2004 10.7 kg-day CaWO4  
 Edelweiss I final limit, 62 kg-days Ge 2000+2002+2003 limit  
 ZEPLIN I First Limit (2005)  
 WARP 2.3L, 96.5 kg-days 55 keV threshold  
 ZEPLIN II (Jan 2007) result  
 CDMS (Soudan) 2004 + 2005 Ge (7 keV threshold)  
 XENON10 2007 (Net 136 kg-d)  
 Ruiz de Austri/Trotta/Roszkowski 2007, CMSSM Markov Chain Monte Carlos (1)  
 Ruiz de Austri/Trotta/Roszkowski 2007, CMSSM Markov Chain Monte Carlos (1)  
 Ellis et. al Theory region post-LEP benchmark points



# Spin dependent results

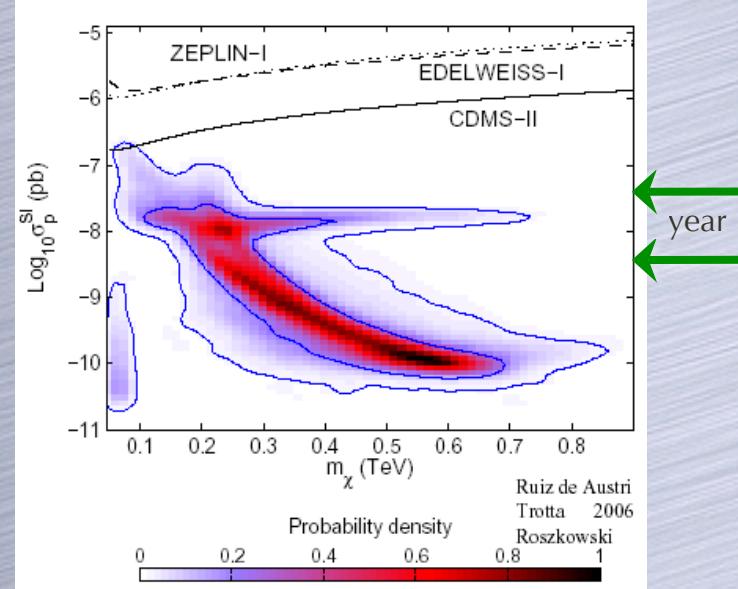
Accepted for publication: Physics Letters B

- Conversion of nuclear recoil limits to SD couplings
- (Published limits plotted)



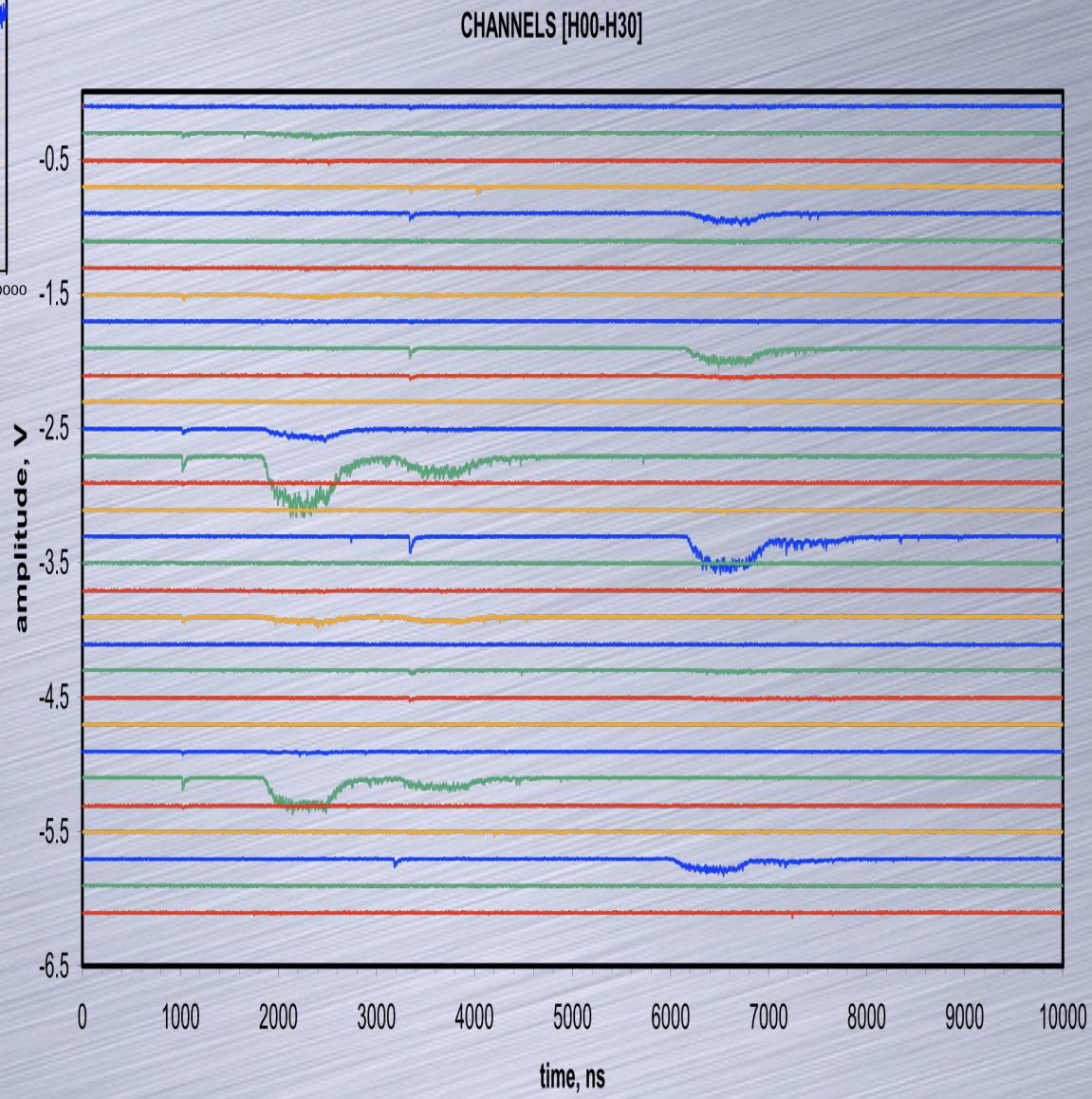
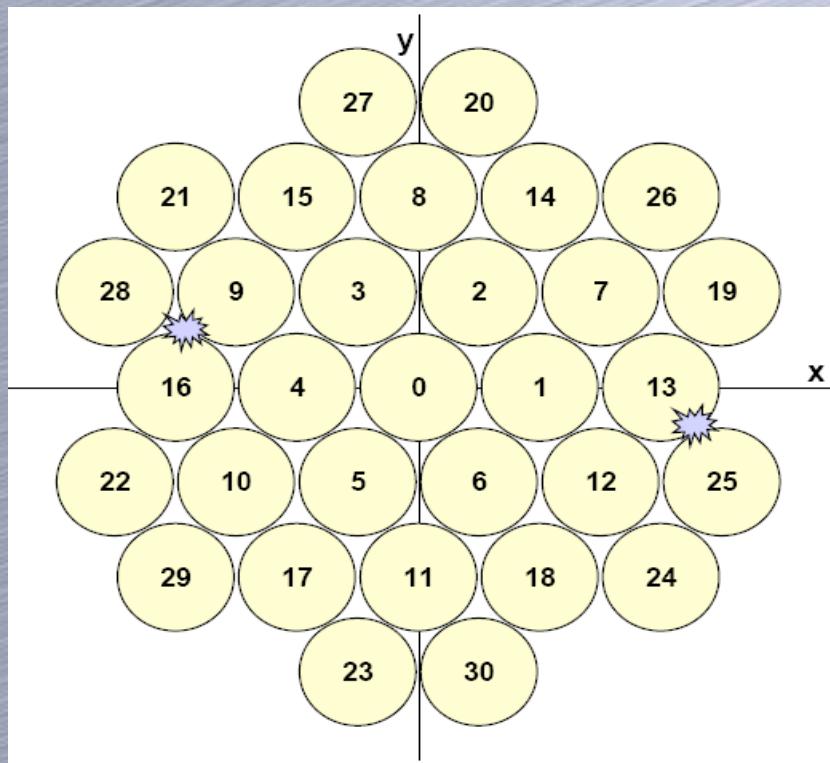
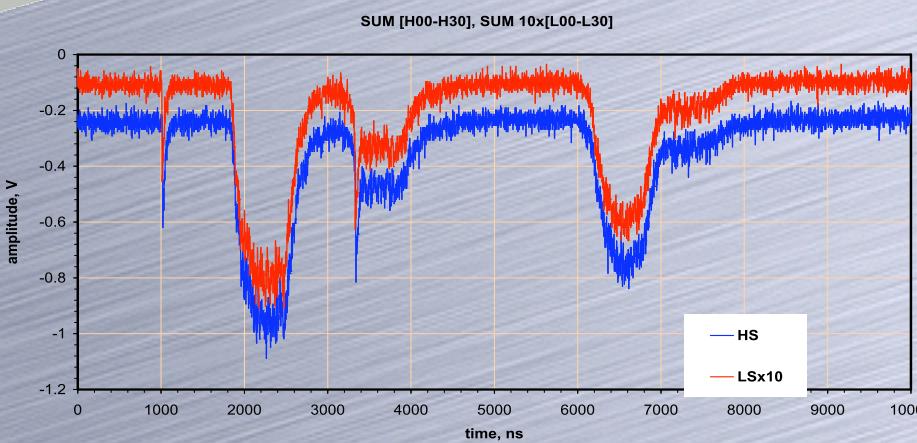
# Next stage: ZEPLIN-III

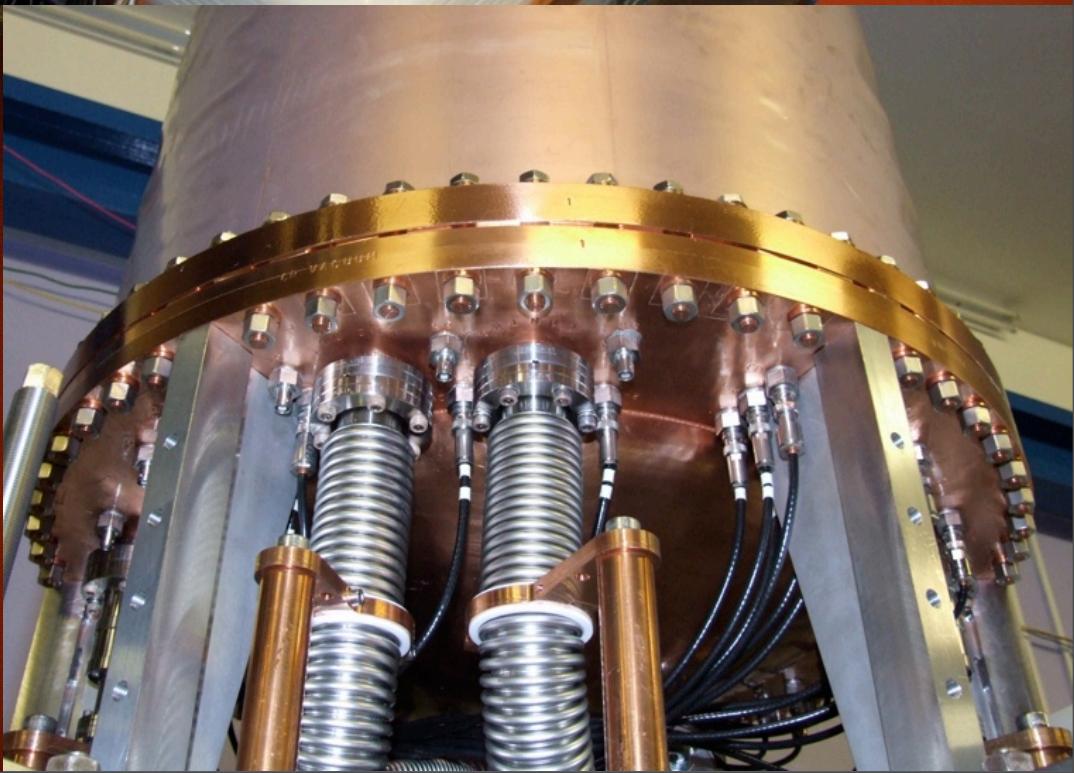
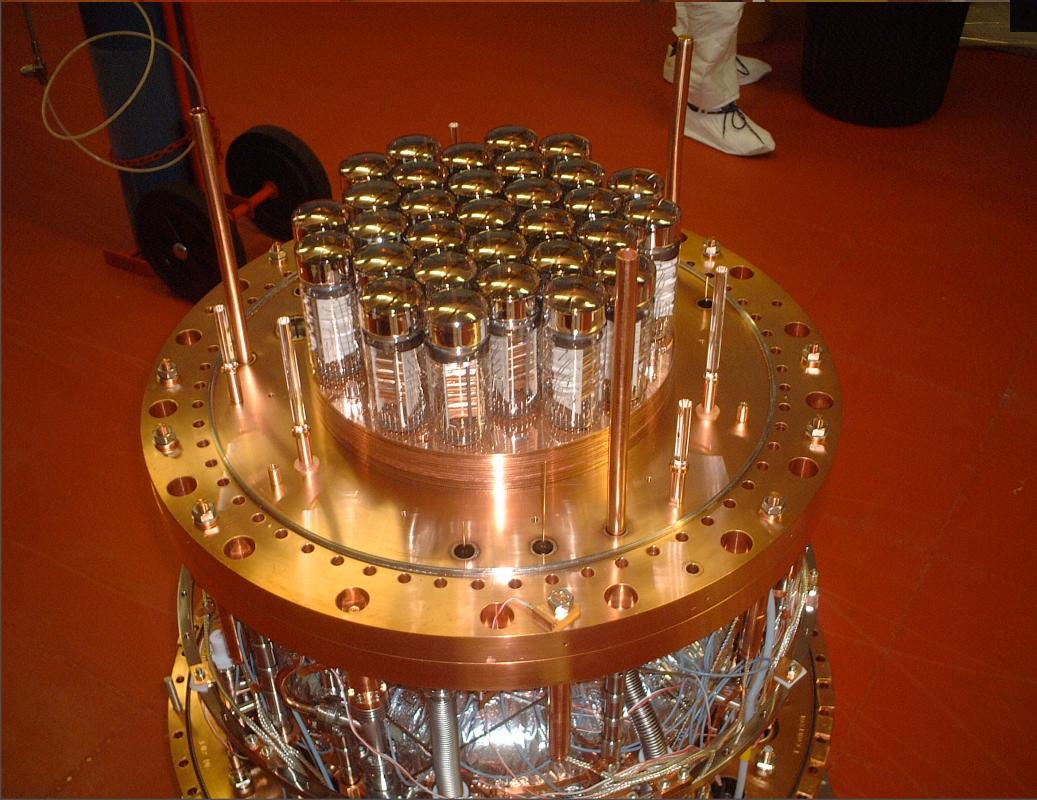
- ZEPLIN-III constructed
- Surface calibrations completed
  - Performance as expected
  - some indication of higher than expected light yield
- Target deployment at Boulby completed
- Operations for next two years approved



# ZEPLIN III Features

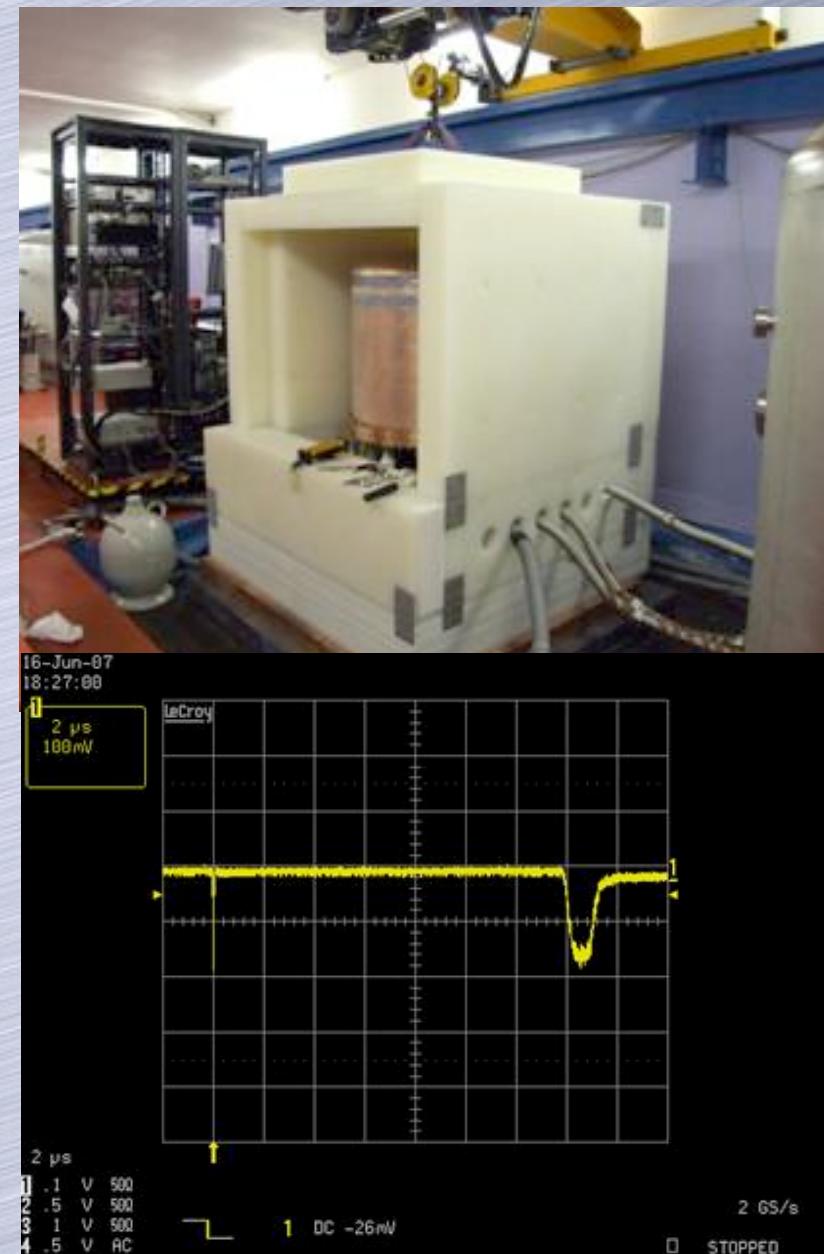
- 8kg fiducial mass
- PMTs **in liquid** to improve light collection
- 3.5 cm drift depth – **higher E-field**
- 0.5 cm electroluminescent gap
- **31 small** PMTs for **fine** position sensitivity
- open plan – no surfaces - reduced feedback
- Lower-background PMTs available
- Copper construction
- Low-background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





# “First dark” pulses

- Neutron shielding in place
- Full gas system operation
- Full PMT/DAQ operations
- Slow control operations
- Commissioning underway
  - light yield
  - purity
  - veto
  - gamma shielding
- Expected full operations by end-October



# Summary

- ZEPLIN-II First run completed underground
  - First results in press
    - 29 events seen,  $28.6 \pm 4.3$  expected
    - 10.4 n.r 90% c.l. upper limit
      - $6.6 \times 10^{-7}$  pb SI,  $7 \times 10^{-2}$  pb SD W-n
  - Second run in preparation
    - remove radon events from SAES getters
    - expected sensitivity  $\rightarrow 2 \times 10^{-7}$  pb
- ZEPLIN-III Construction completed
  - Deployment of target at Boulby complete
    - commissioning underway
  - Operations for next 2.0 years approved
  - Additional lab tests to confirm/explore xenon physics