The DarkSide WIMP Search Program

Ben Loer

8th Patras Workshop on Axions, WIMPs and WISPs

July 18, 2012

Outline

- Argon as a dark matter target
- The DarkSide dual phase argon TPC design
- Low radioactivity argon
- Recent results from the DarkSide-10 prototype
- DarkSide-50 Schedule and outlook

The DarkSide Collaboration

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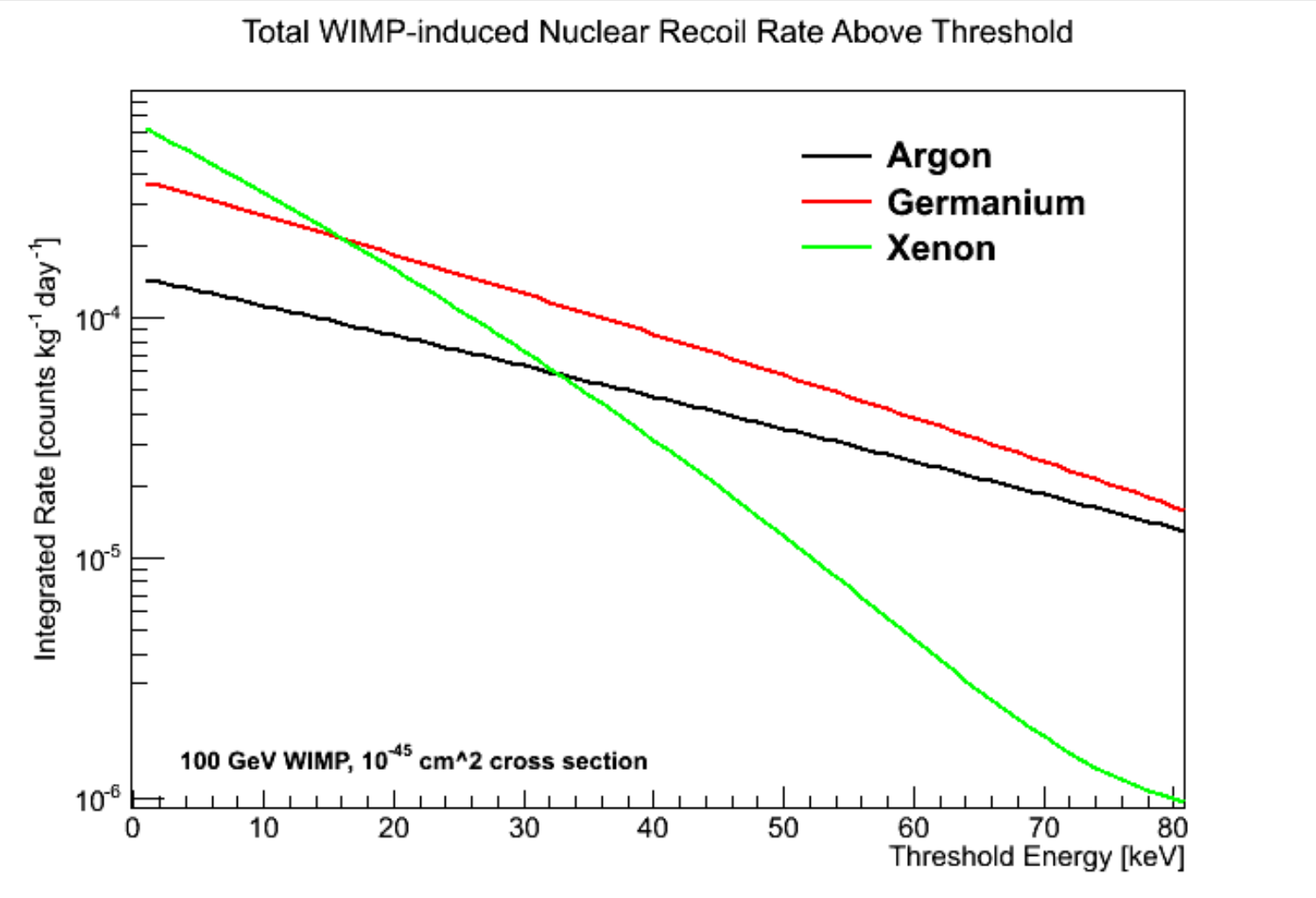
Why argon?

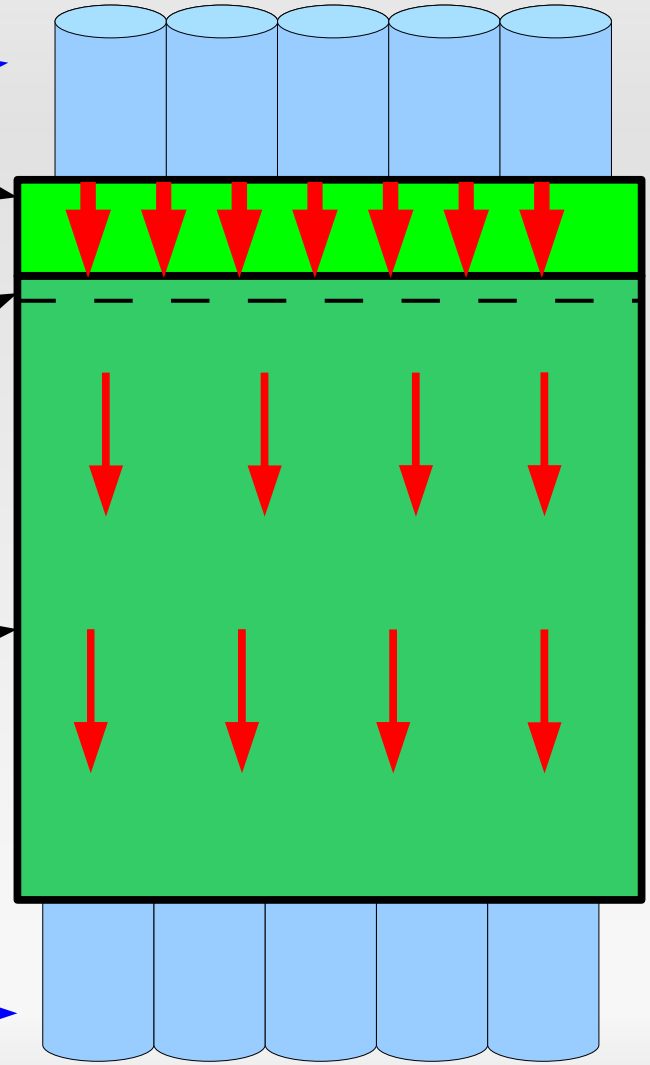

Total WIMP-induced Nuclear Recoil Rate Above Threshold
Argon
Germanium
Xenon
Integrated Rate [counts kg^{-1} day^{-1}]
10^{-4}
10^{-5}
10^{-6}
100 GeV WIMP, 10^{-45} cm^2 cross section
0
10
20
30
40
50
60
70
80
Threshold Energy [keV]

Argon as a Dark Matter target

- Why an argon TPC?
  - Very efficient scintillator (40 photons/keVee, long absorption length, can be purified easily)
  - Only moderate cryogenic requirements (87 K)
  - Pulse shape and scintillation/ionization ratio give 2 independent background rejection handles
  - TPC gives accurate 3D position reconstruction to reject surface events

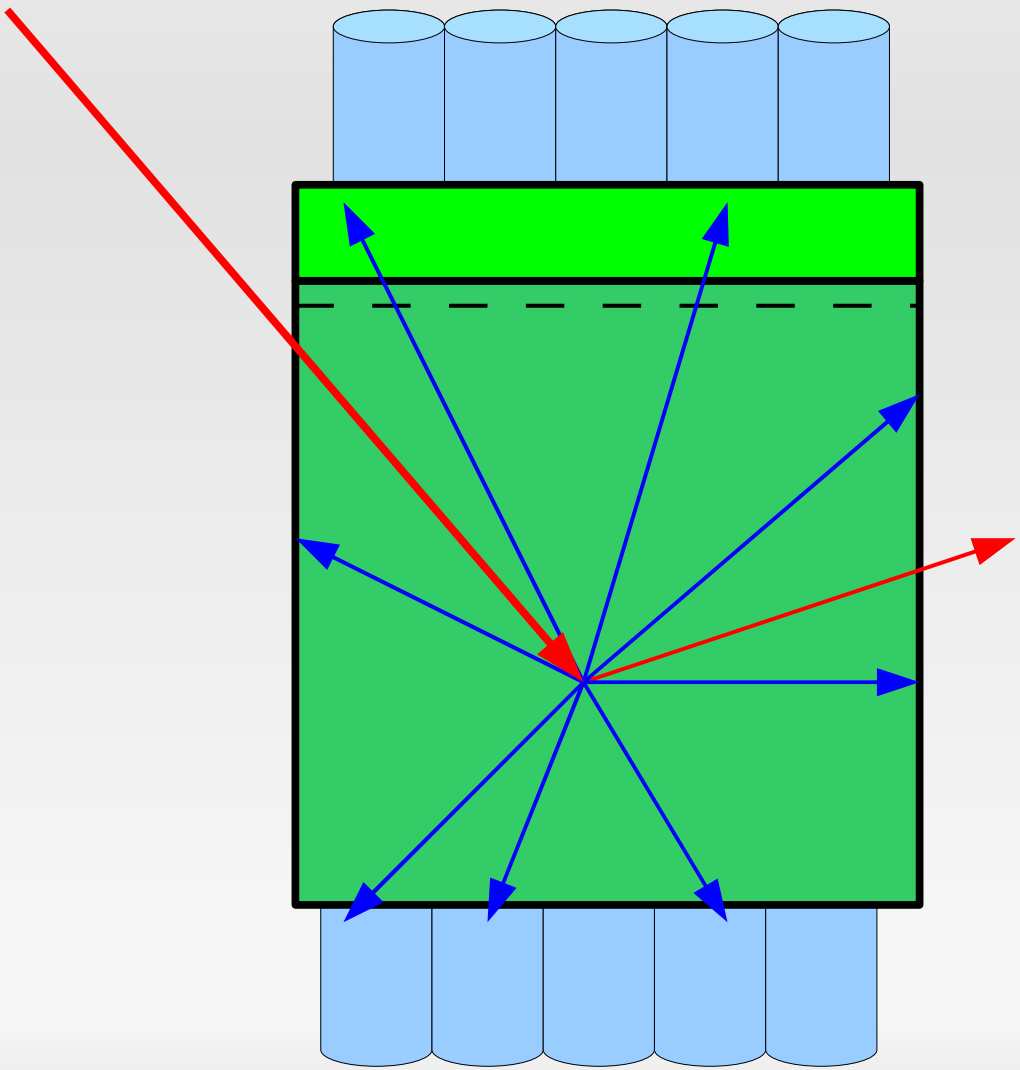
Dual-Phase Argon Time Projection Chamber

- Gaseous argon volume with multiplication field ~3-6 kV/cm
- Grid plane allows for discontinuity in field
- Liquid argon active volume with drift field ~1 kV/cm
- Photodetectors



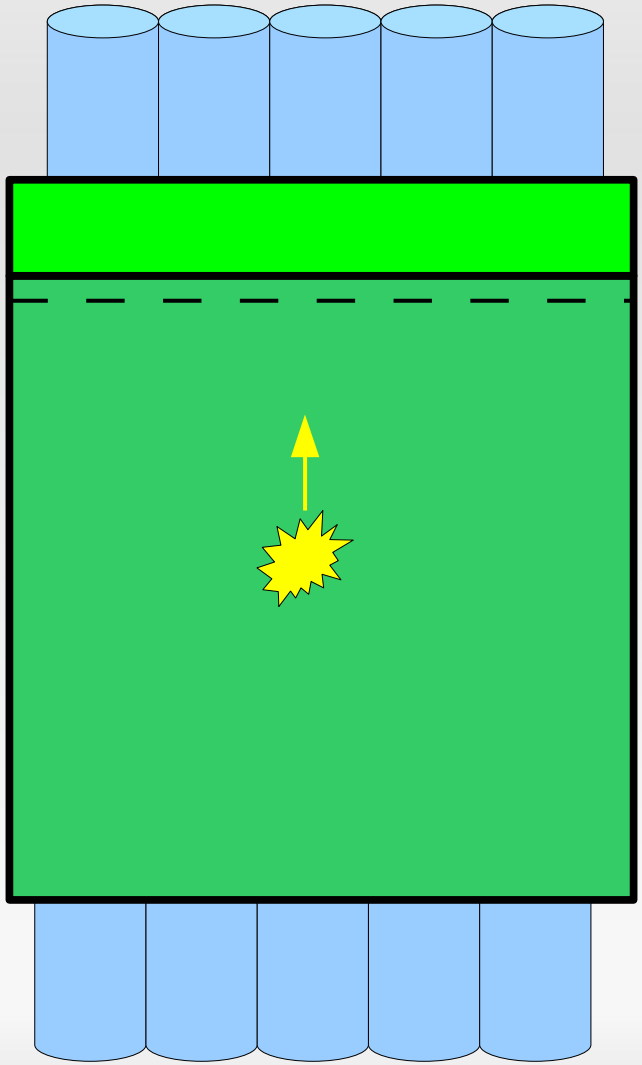
Dual-Phase Argon Time Projection Chamber

- An energetic particle (WIMP, gamma, etc) interacts in the liquid volume
- Prompt scintillation light (S1) is emitted from the point of interaction
- Gives time and energy of the event



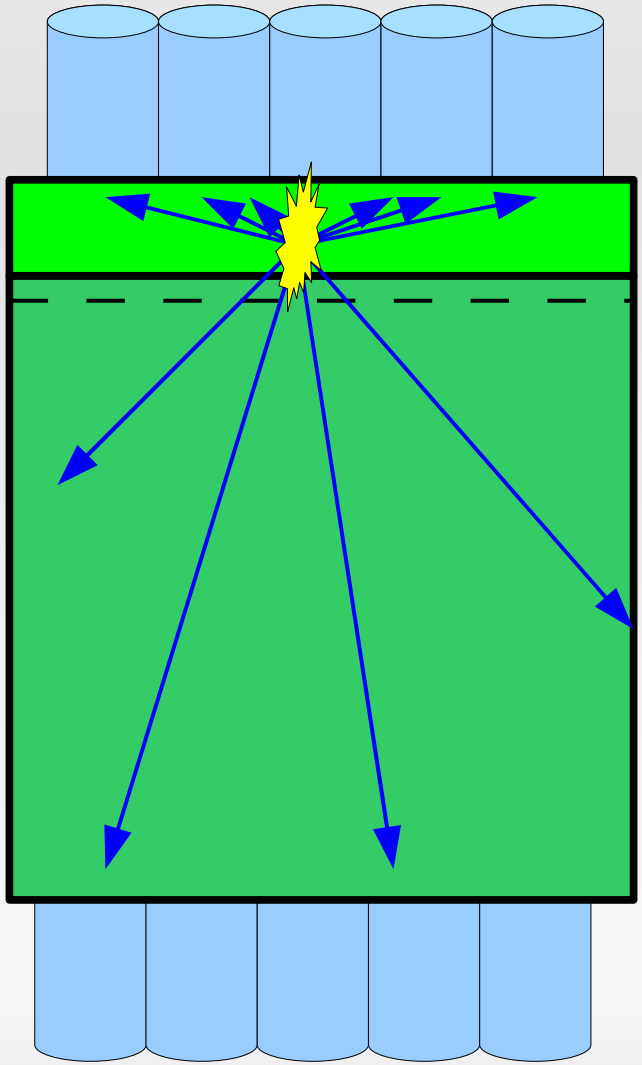
Dual-Phase Argon Time Projection Chamber

- Interaction also produces free electrons from ionization
- Electric field causes them to drift upward at ~1mm/microsec

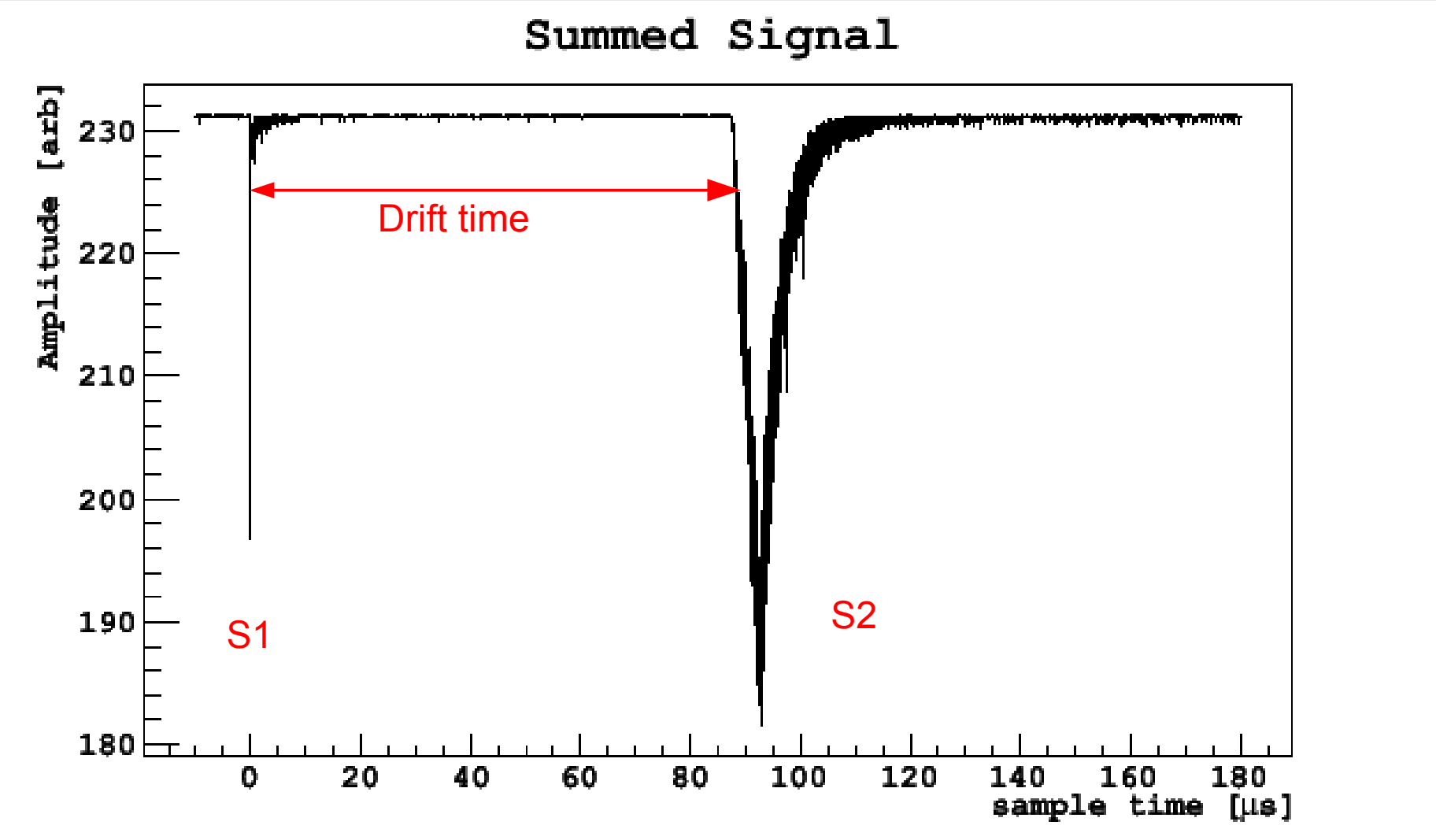


Dual-Phase Argon Time Projection Chamber

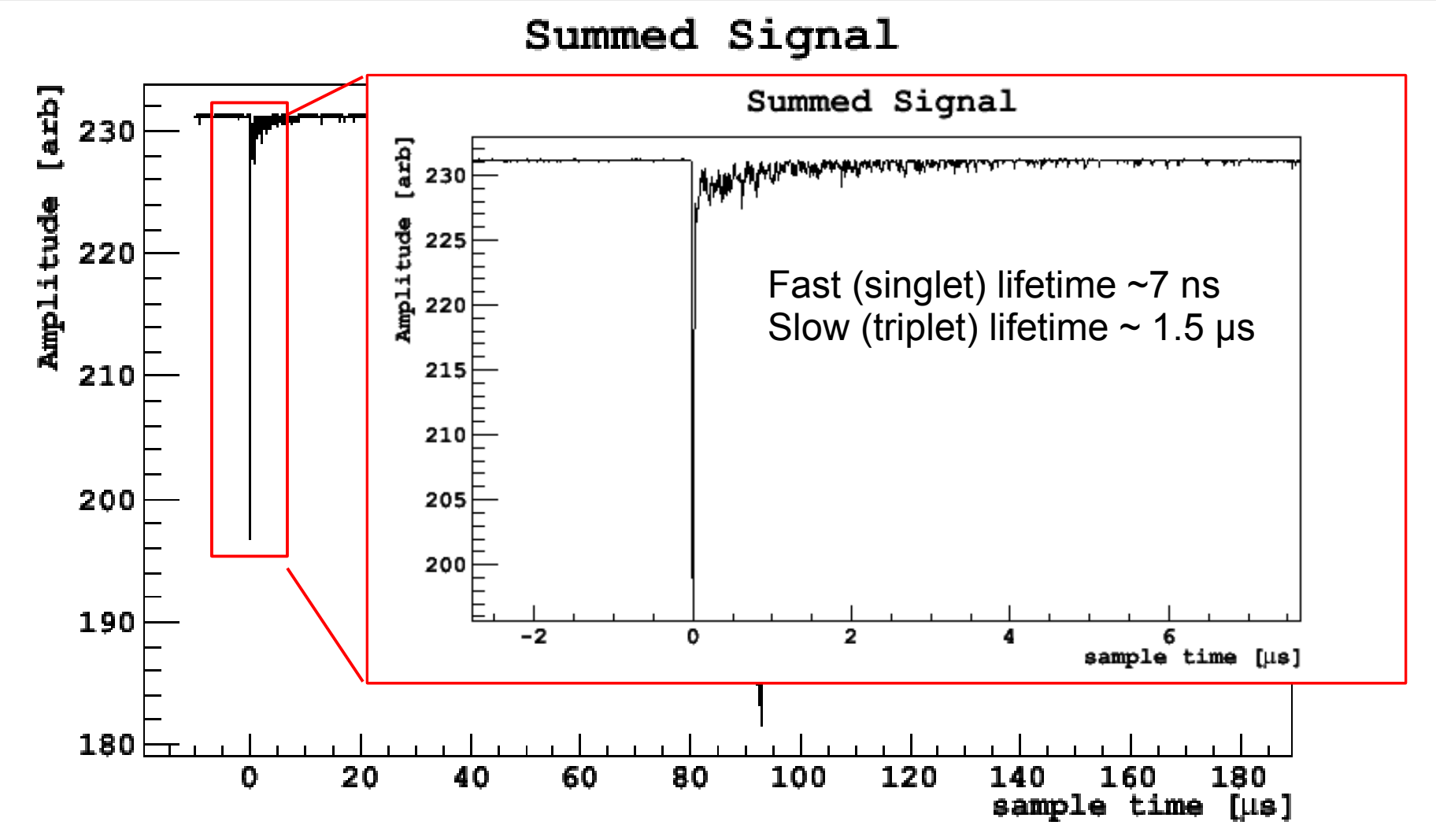
- High electric field in the gas region gives electrons energy to excite secondary scintillation (S2)
- Size of S2 gives amount of ionization
- Light collection ratio in PMTs gives x-y position
- Time between S1 and S2 gives z position



Typical Event

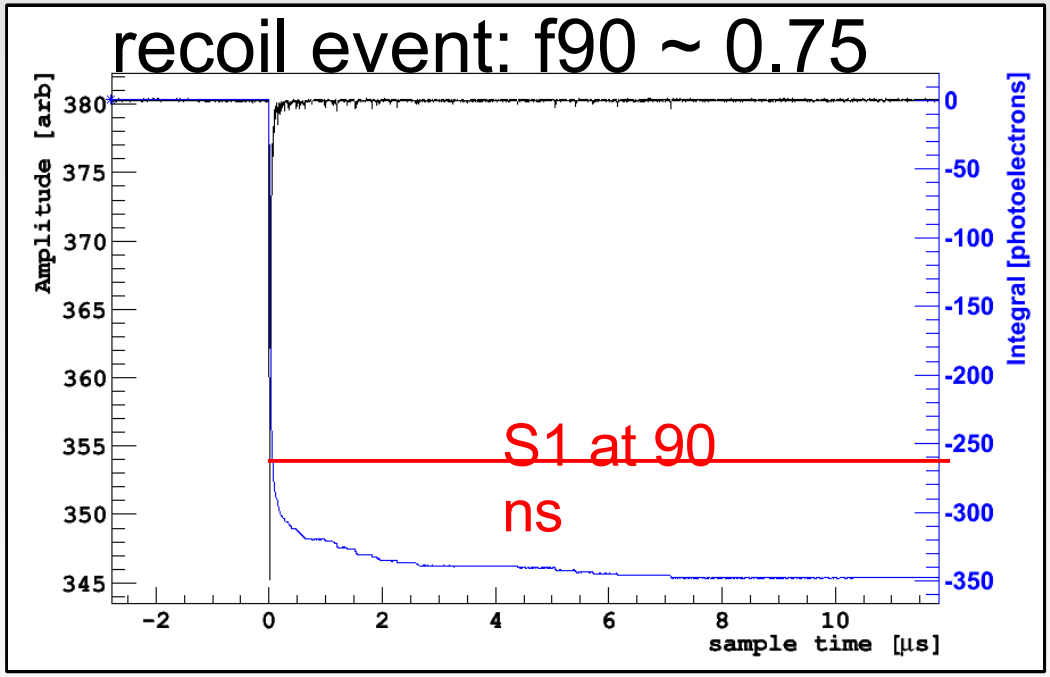


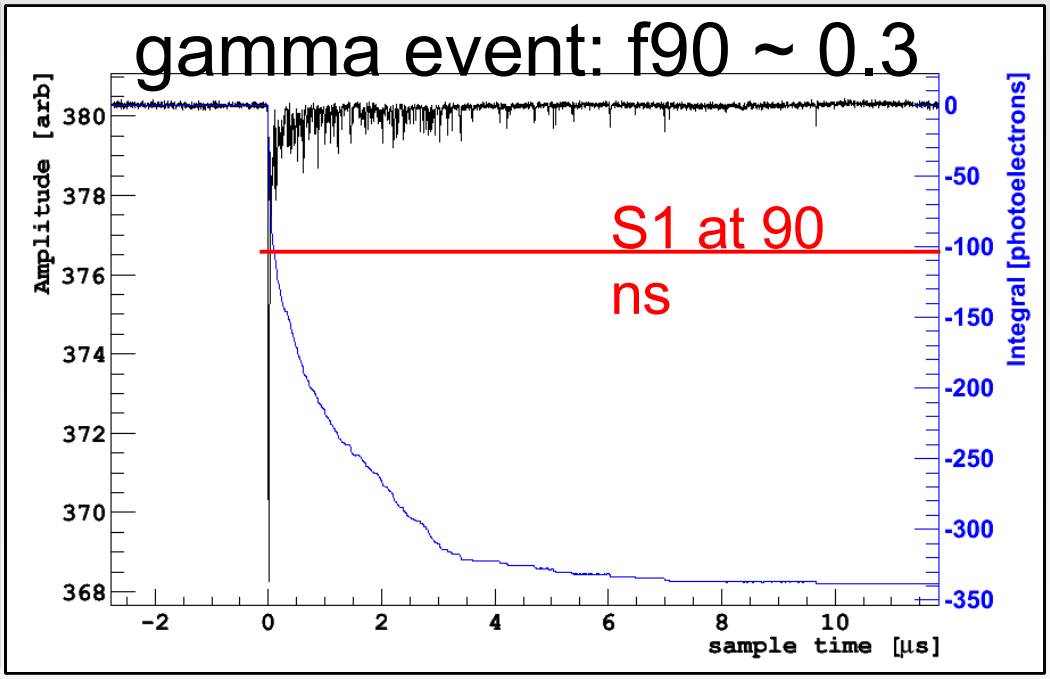
Typical Event



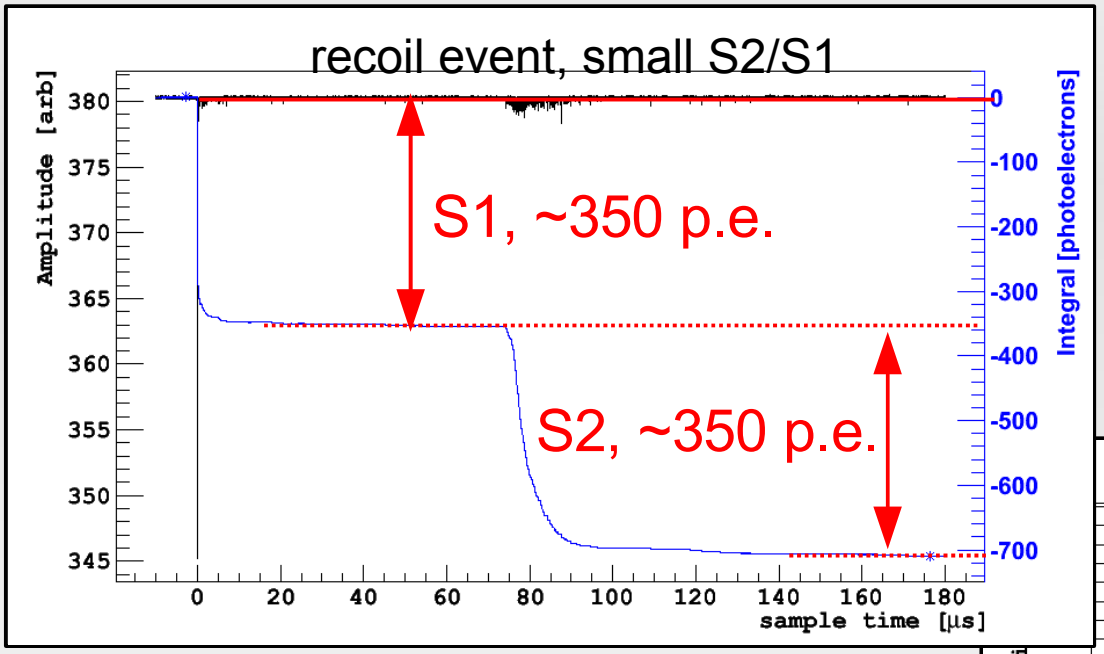
Pulse Shape Discrimination

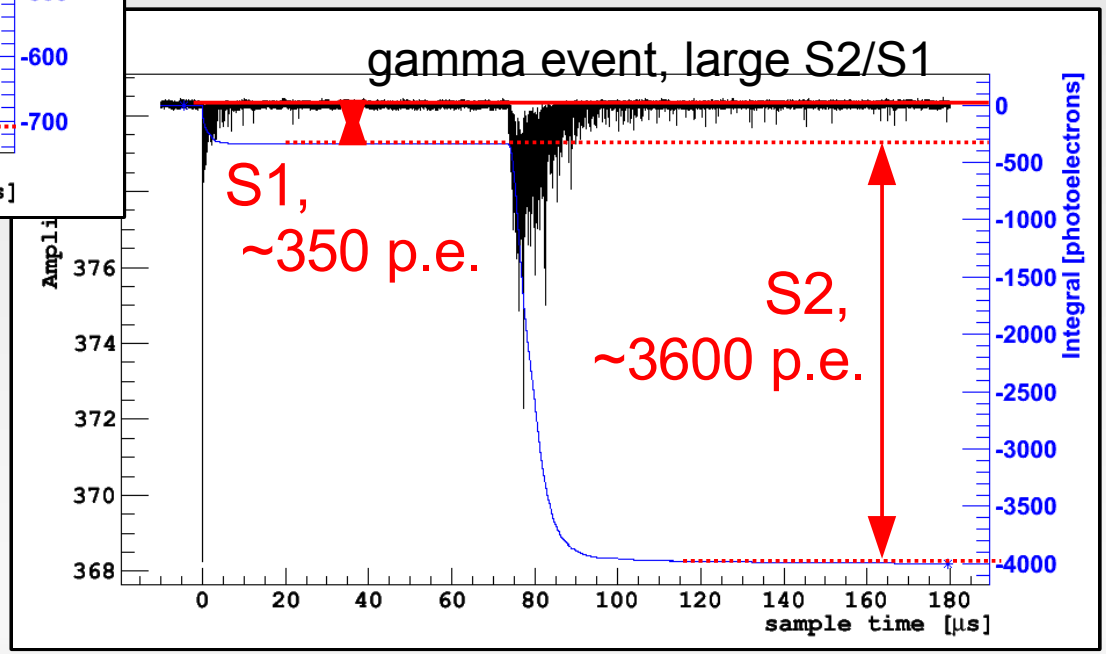
- f90: the fraction of S1 light that arrives within the first 90 ns



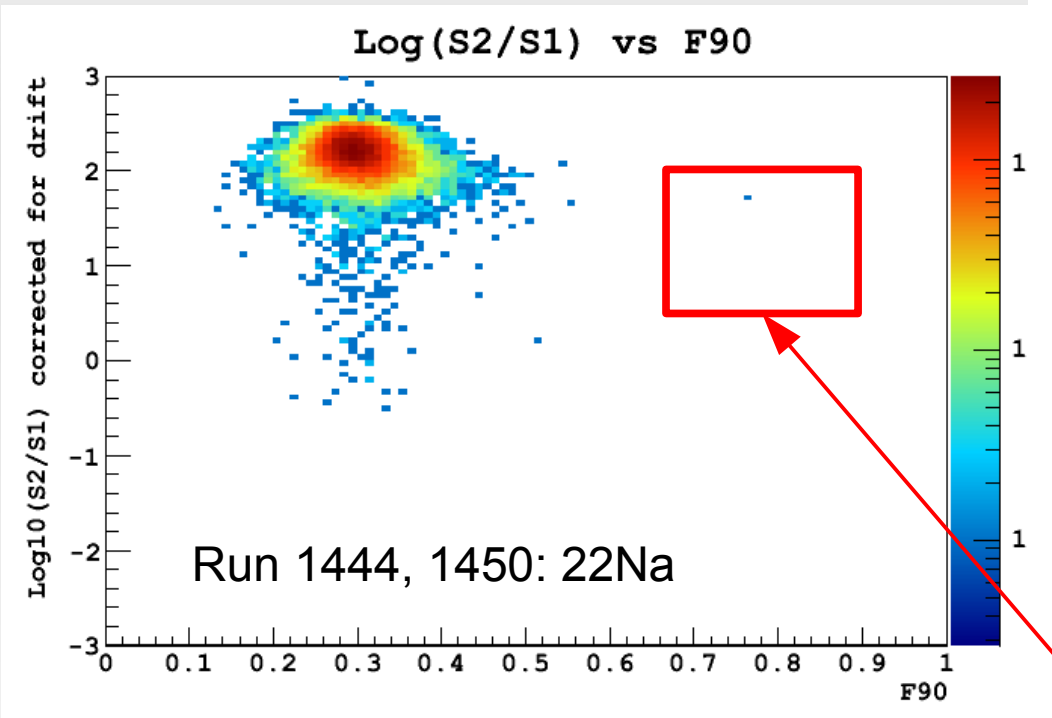


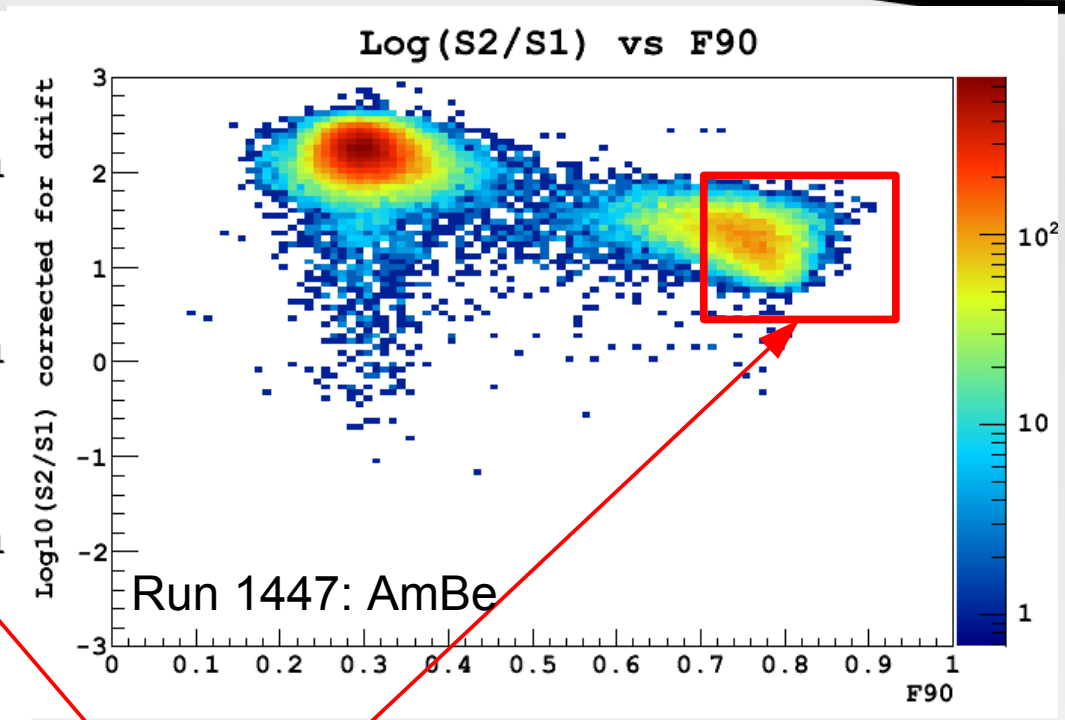
Scintillation/Ionization Ratio





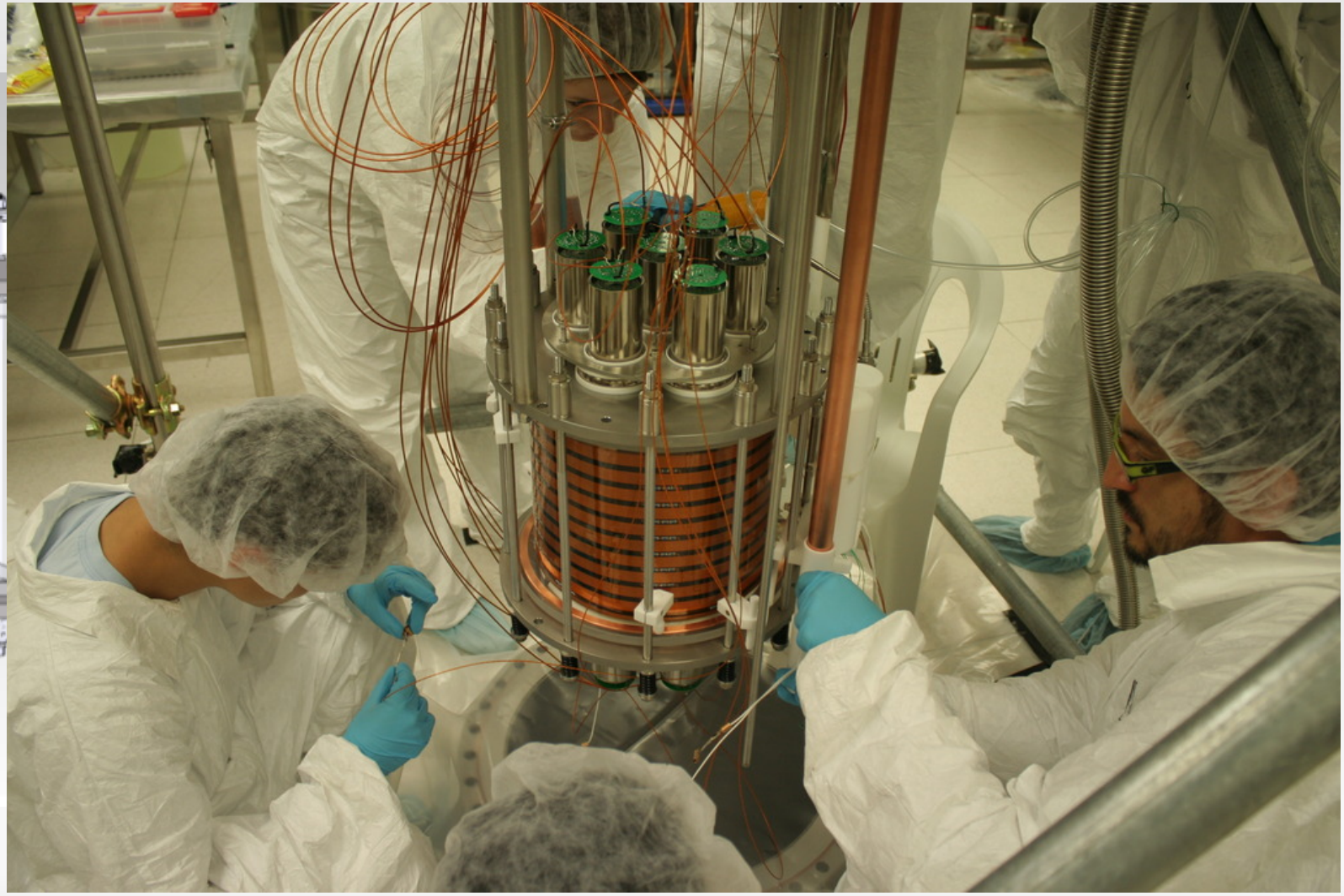
DarkSide-10 Analysis: Combined Background Rejection





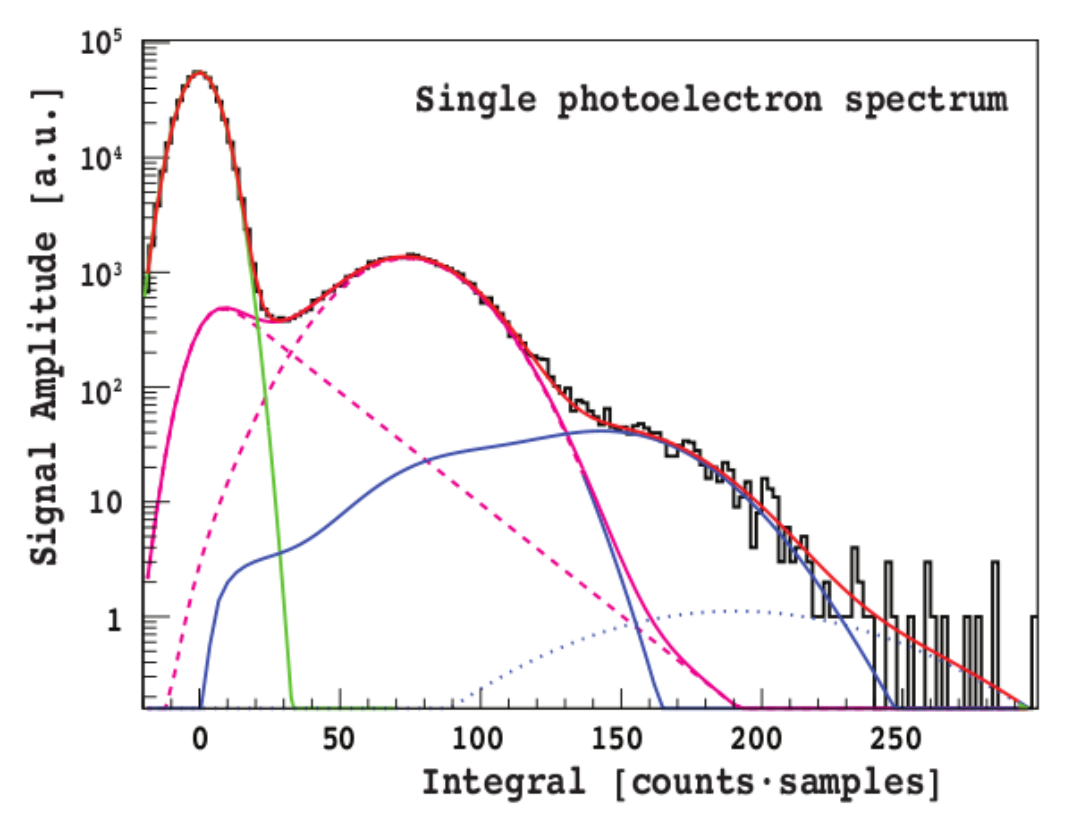
Example nuclear recoil acceptance bounds

DarkSide-10



Photomultiplier Calibration

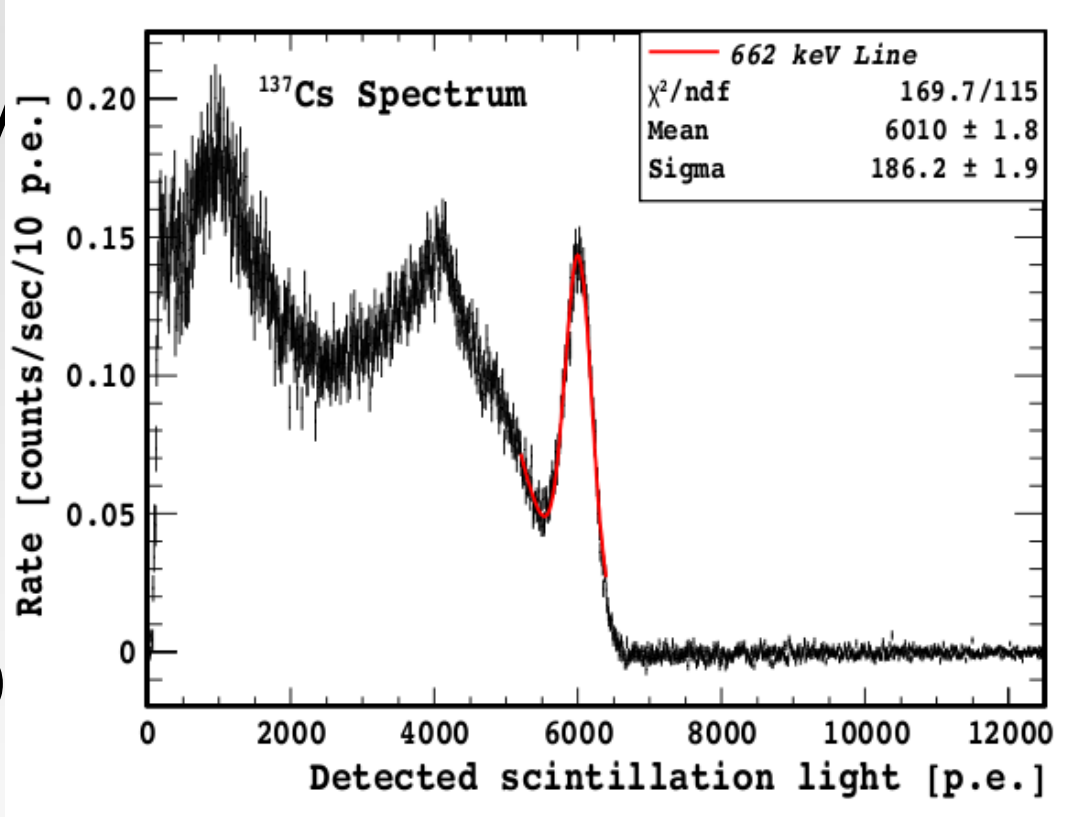
- New to market Hamamatsu 11065 PMTs
- Cryogenic capable
- High quantum efficiency (~35%!)
- Single p.e. spectrum seems to contain exponential component



arxiv:1204.6218

DarkSide-10 Light yield

- Measured ~9 p.e./keV light yield, ~4% resolution at 662 keV
- Best reported from liquid argon detector
- More light means lower energy threshold, better PSD

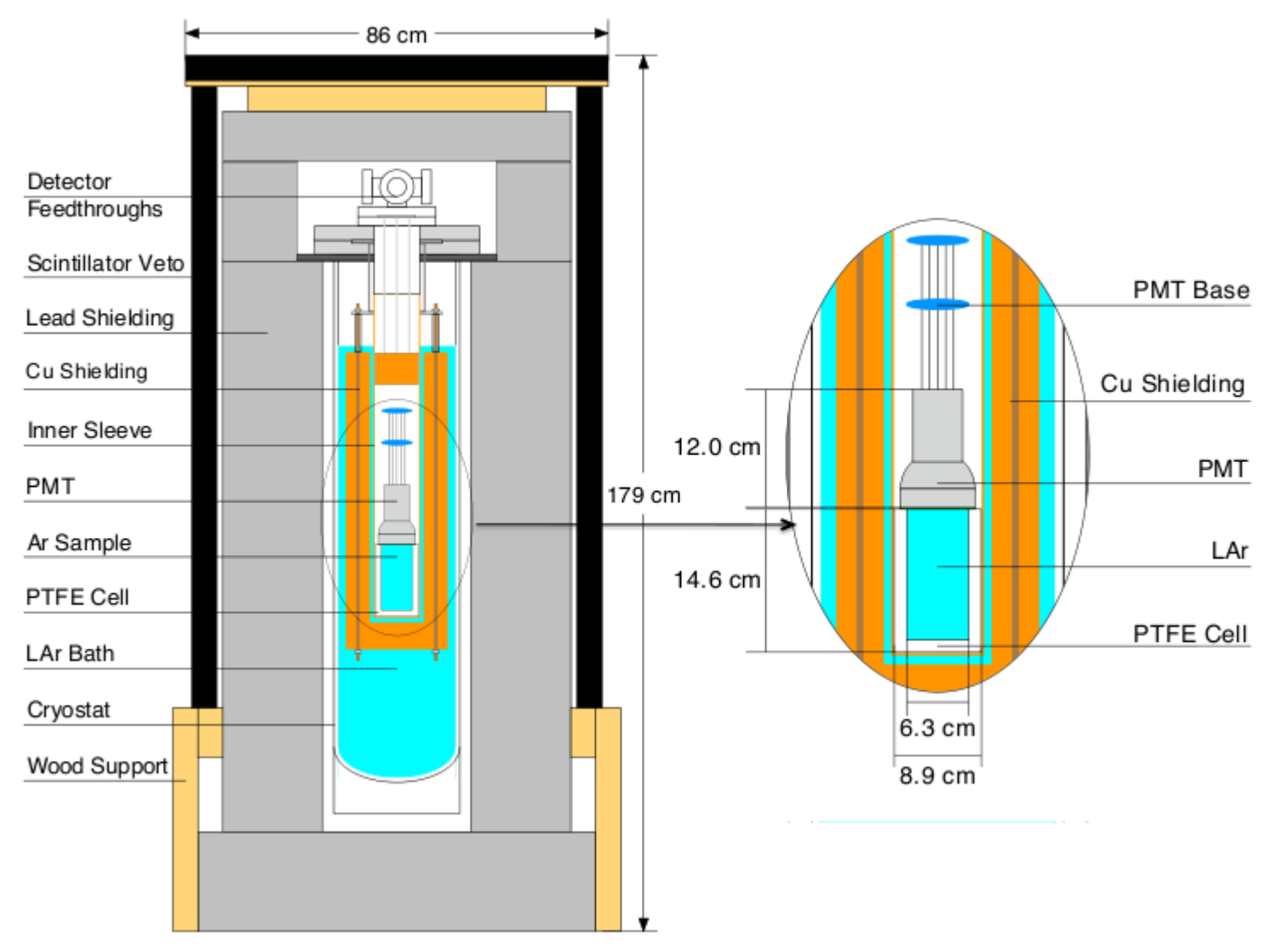


arxiv:1204.6218

Underground argon

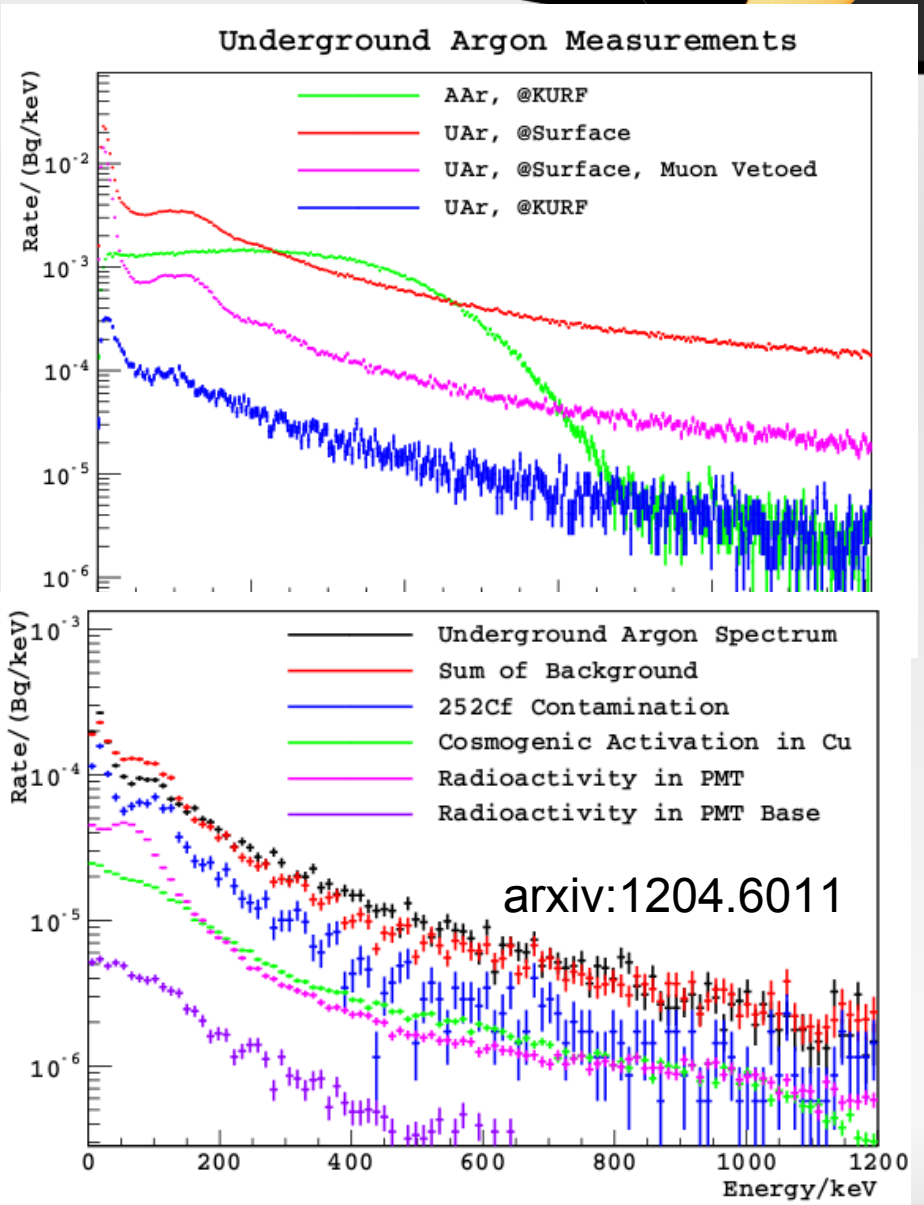
- Atmoshperic argon contains Ar-39, which undergoes beta decay with Q=565 keV, half-life 269 y, at ~1 Bq/kg natural argon
- TPCs limited at ton scale by pileup
- Ar-39 is produced by cosmic rays in the upper atmosphere, so underground argon might have reduced Ar-39 content
- But it can be produced by n,p reactions on K-40, so different sites must be tested

Underground argon measurement



Underground argon decay rate

- Detector operated at Kimbalton Underground Research Facility (KURF)
- Ar-39 rate < 0.65% of atmospheric rate
- Suitable for multi ton-scale TPCs



Underground argon extraction

- Stage 1 is pressure swing adsorption
- Boosts few hundred ppm of argon in stream to few percent
- Producing ~0.5 kg/day,
- ~100 kg produced so far

arxiv:1204.6024

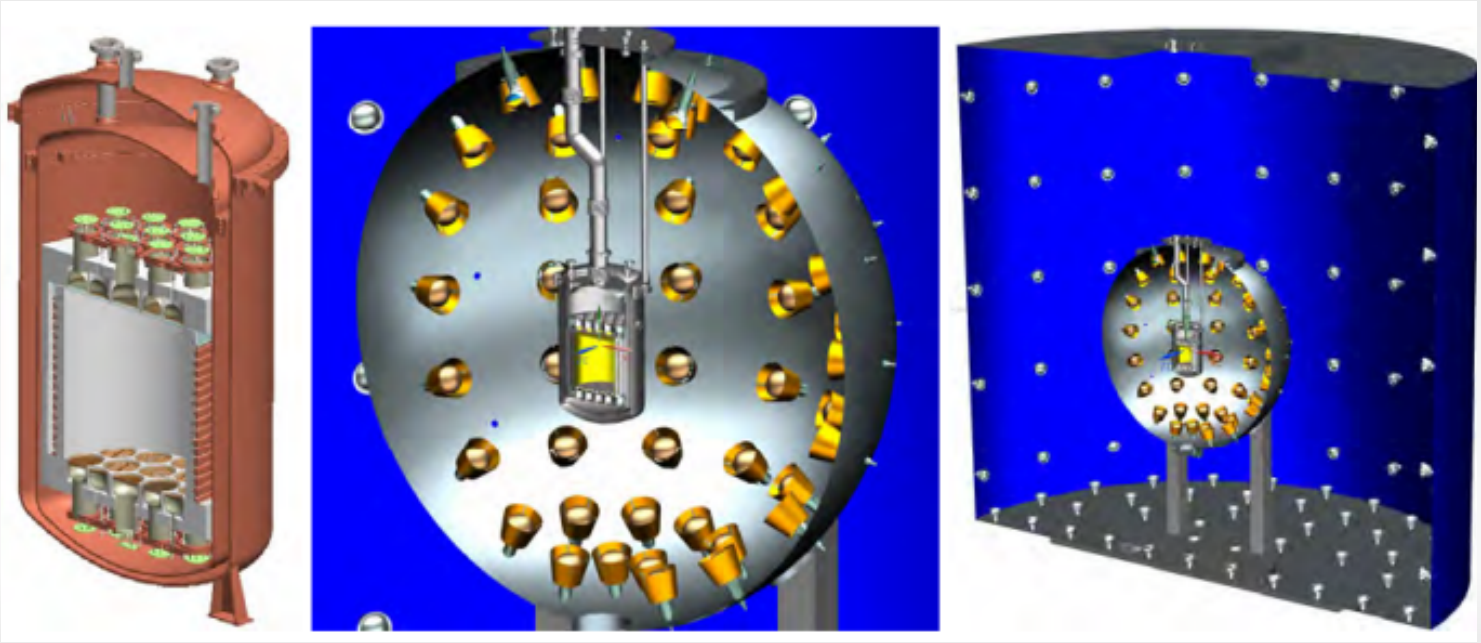
Underground argon extraction

- Stage 2 is a cryogenic distillation column
- Purifies PSA output to <0.05% impurities at ~1 kg/day (limit of RGA, not distillation)
- Plans to upgrade both stages to produce 50 kg/day

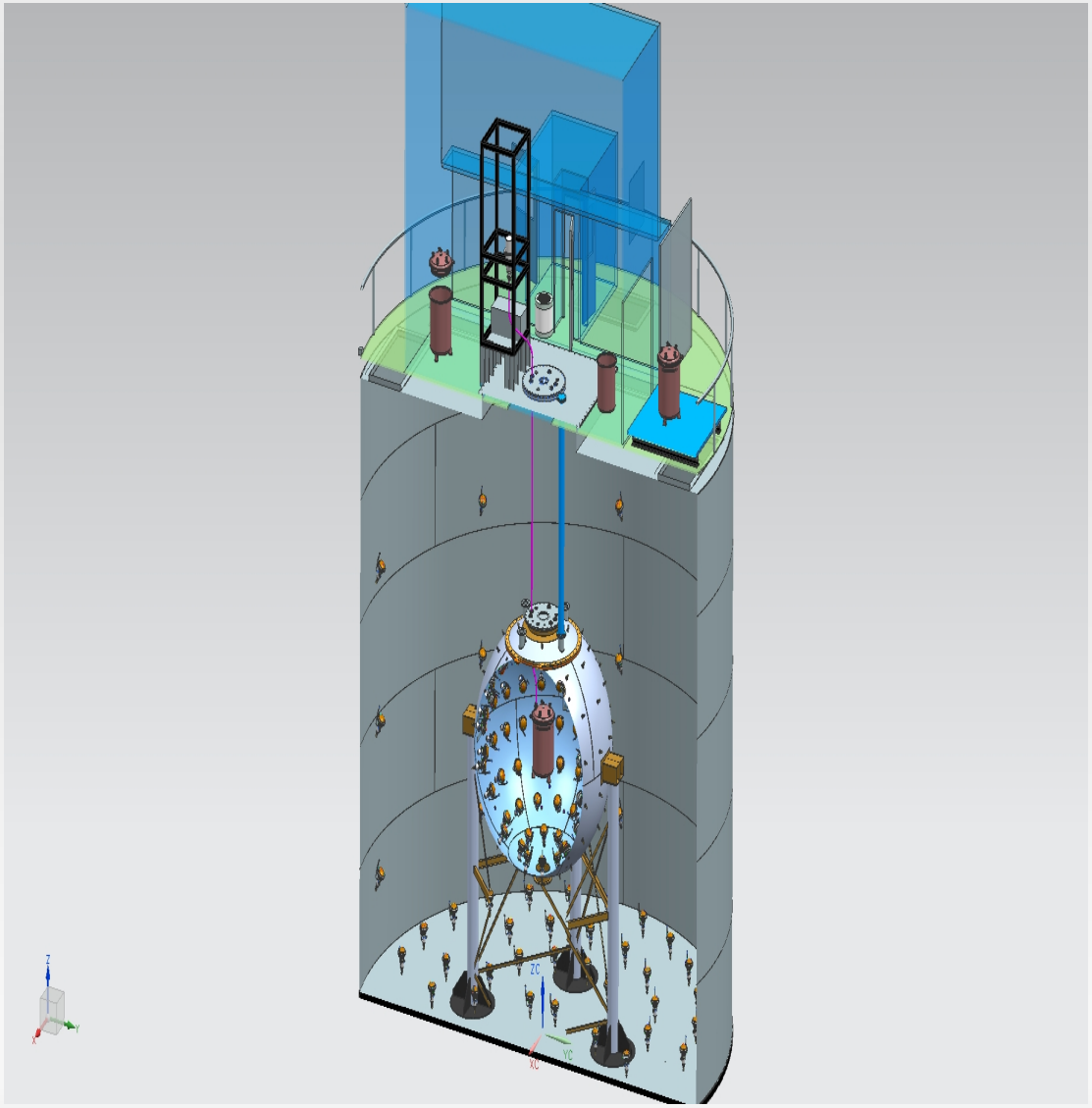
arxiv:1204.6061

DarkSide-50: Coming soon to LNGS

- 50 kg underground argon (~33kg fiducial)
- 4m diameter boron-loaded liquid scintillator neutron veto (estimated >99.5% veto efficiency for radiogenic neutrons)
- 11m diameter water shield/muon veto

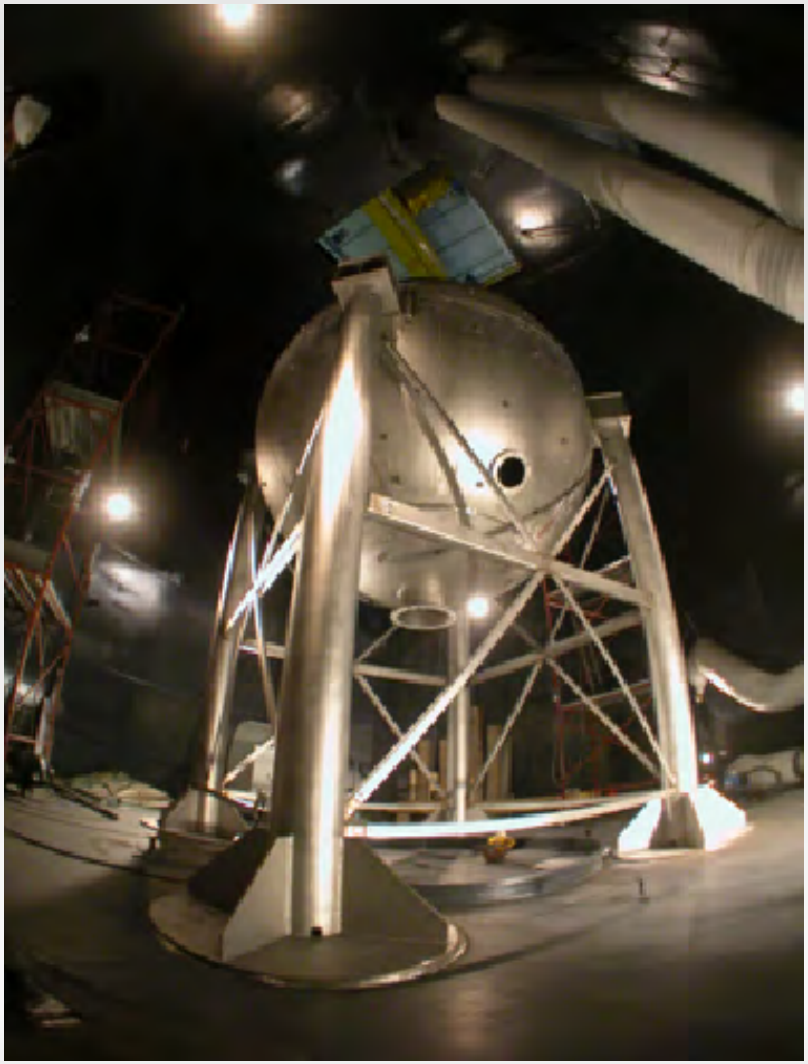


DarkSide-50 : Coming soon to LNGS

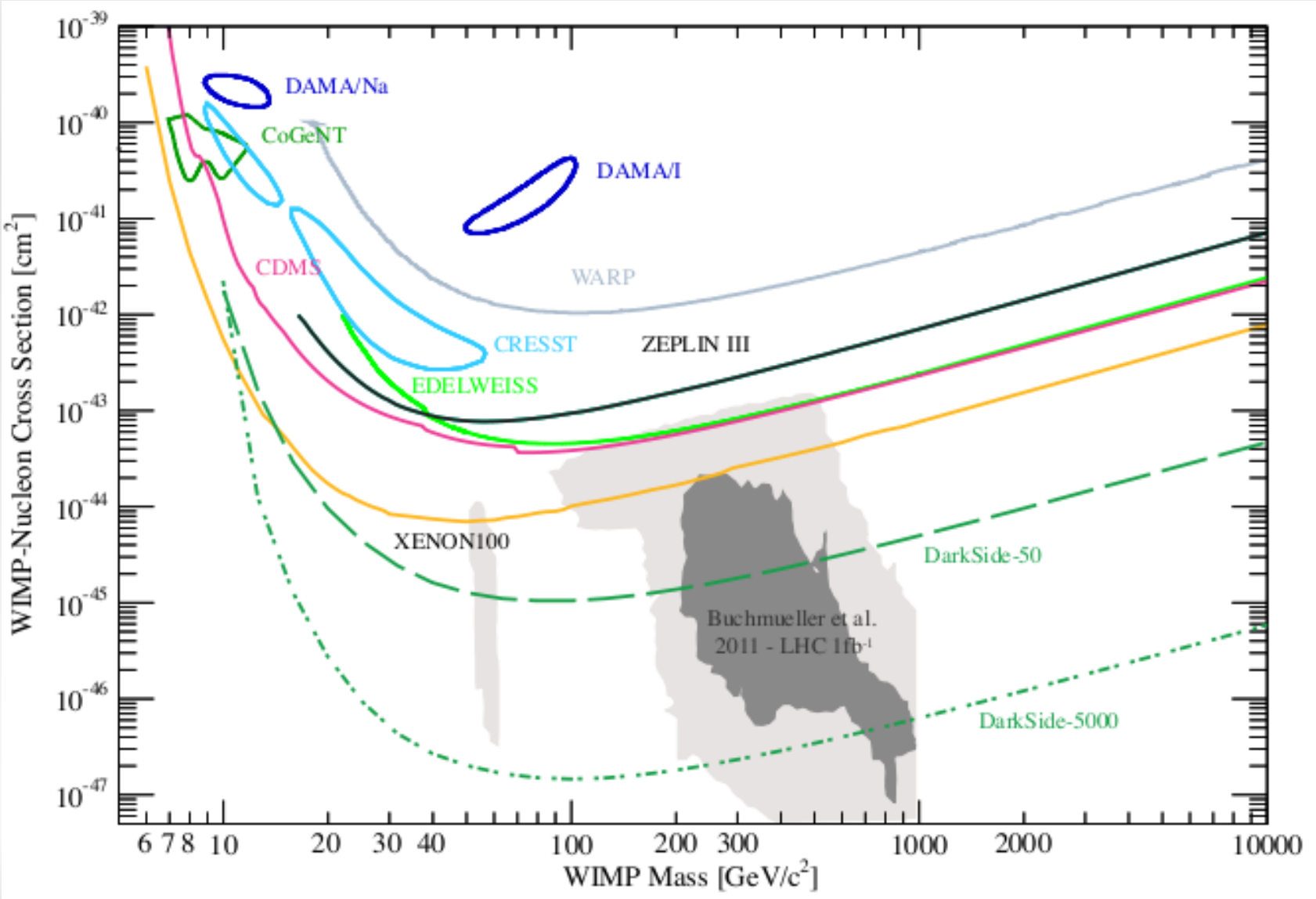


DarkSide-50 Schedule

- Neutron veto tank is installed, expect first data early 2013
- Plan to run for three years
- Best estimates are for <0.5 total background events
- Vetos are already sized to hold a ~3 ton cryostat for the next generation



DarkSide-50 Predicted Sensitivity



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