

The DarkSide WIMP Search Program



Ben Loer

8th Patras Workshop on Axions, WIMPs and WISPs
July 18, 2012



- 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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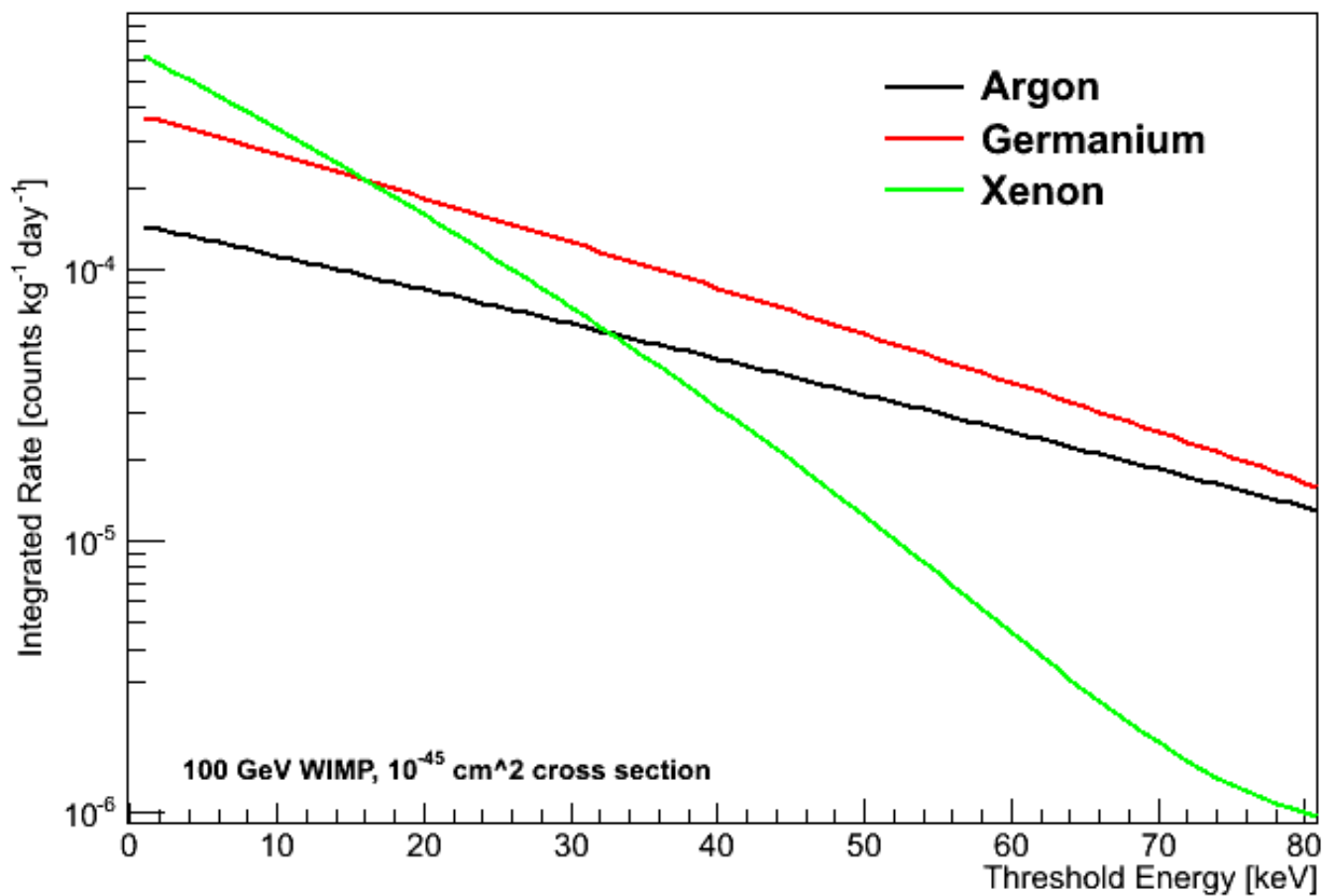
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Why argon?



Total WIMP-induced Nuclear Recoil Rate Above Threshold



Argon as a Dark Matter target

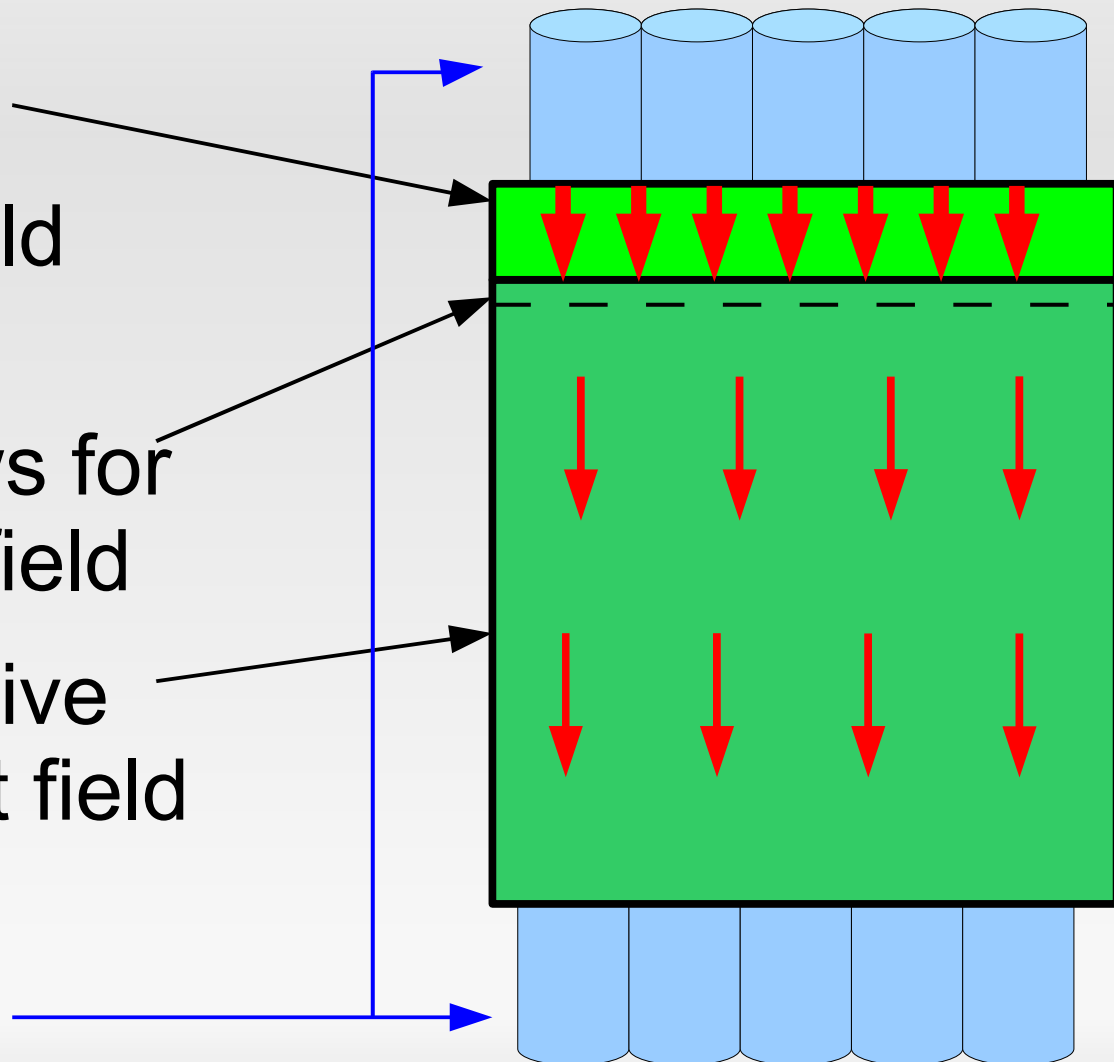


- Why an argon TPC?
 - Very efficient scintillator (40 photons/keVee, long absorption length, can be purified easily)
 - Only moderate cryogenic requirements (87 K)
 - Pulse shape and scintillation/ionization ratio give 2 independent background rejection handles
 - TPC gives accurate 3D position reconstruction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

Dual-Phase Argon Time Projection Chamber

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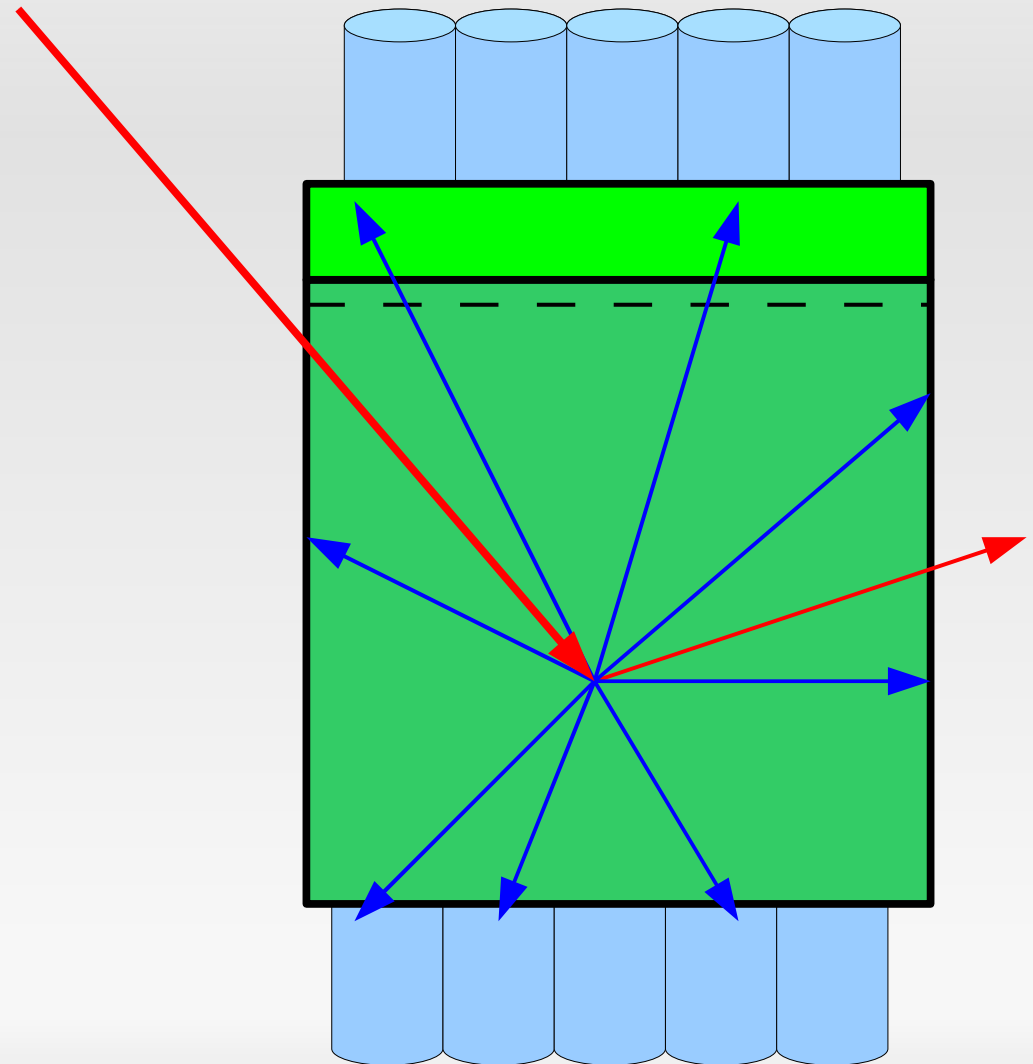
- Gaseous argon volume with multiplication field $\sim 3-6$ kV/cm
- Grid plane allows for discontinuity in field
- Liquid argon active volume with drift field ~ 1 kV/cm
- Photodetectors



Dual-Phase Argon Time Projection Chamber

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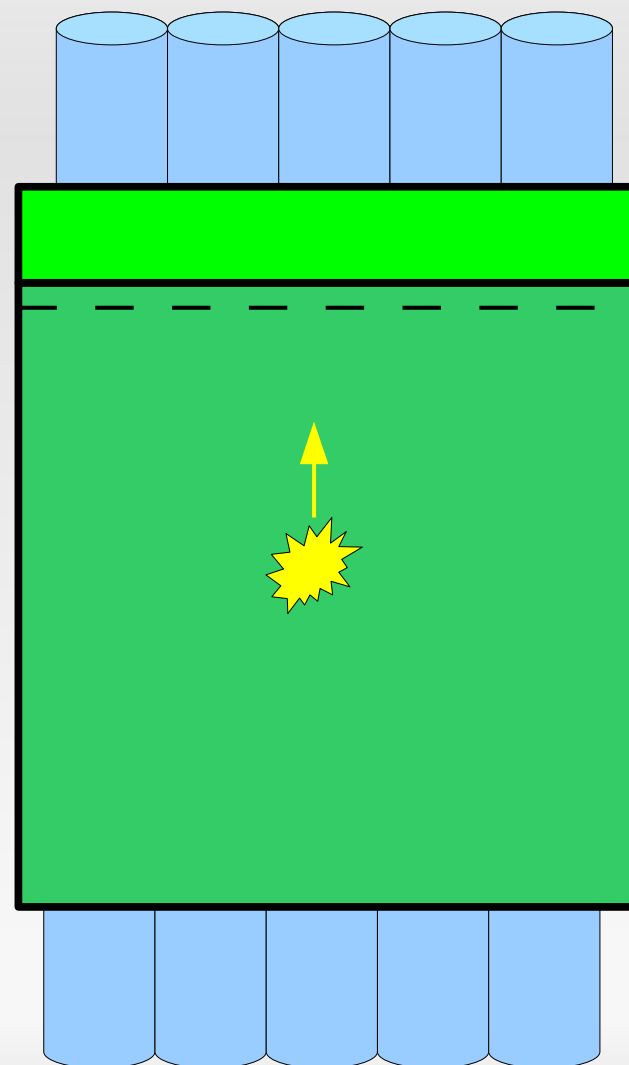
- An energetic particle (WIMP, gamma, etc) interacts in the liquid volume
- Prompt scintillation light (S1) is emitted from the point of interaction
- Gives time and energy of the event



Dual-Phase Argon Time Projection Chamber



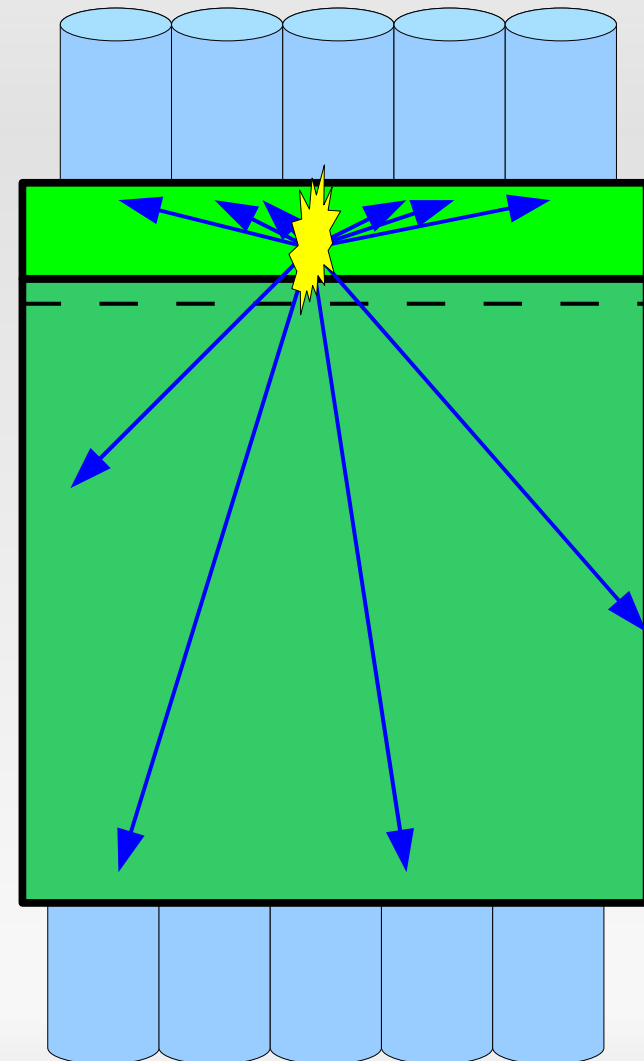
- Interaction also produces free electrons from ionization
- Electric field causes them to drift upward at $\sim 1\text{mm}/\text{microsec}$



Dual-Phase Argon Time Projection Chamber

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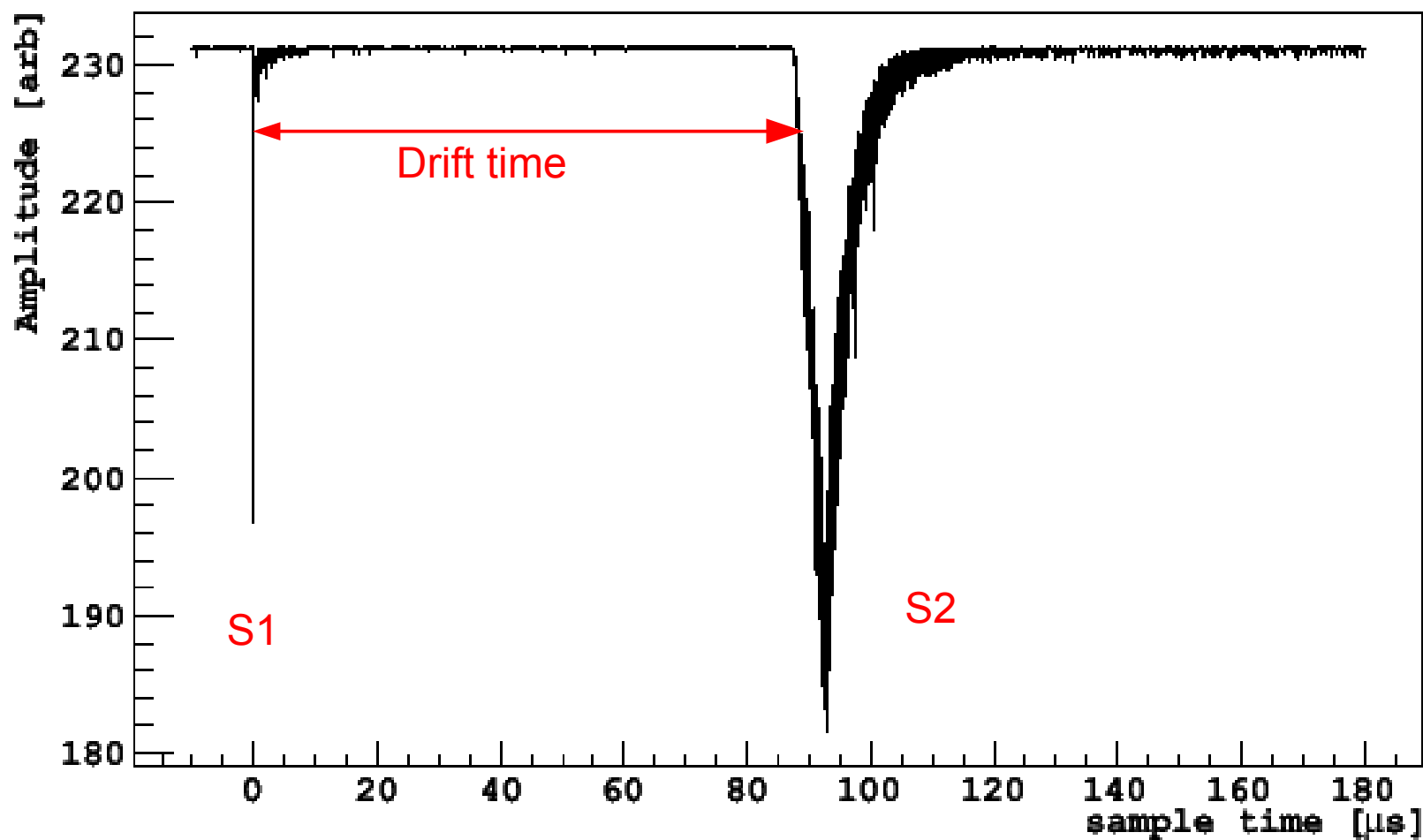
- High electric field in the gas region gives electrons energy to excite secondary scintillation (S2)
- Size of S2 gives amount of ionization
- Light collection ratio in PMTs gives x-y position
- Time between S1 and S2 gives z position



Typical Event



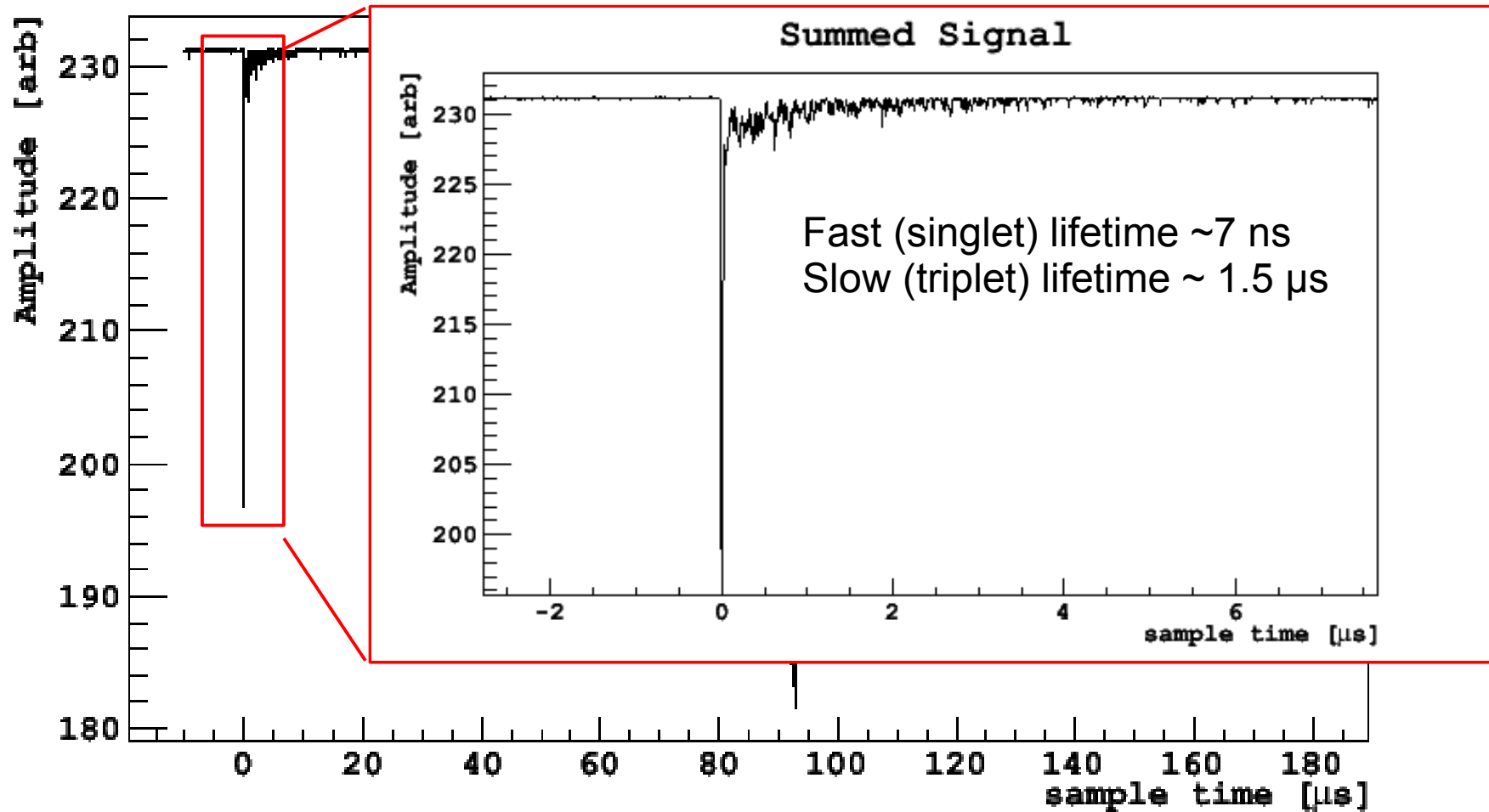
Summed Signal



Typical Event



Summed Signal

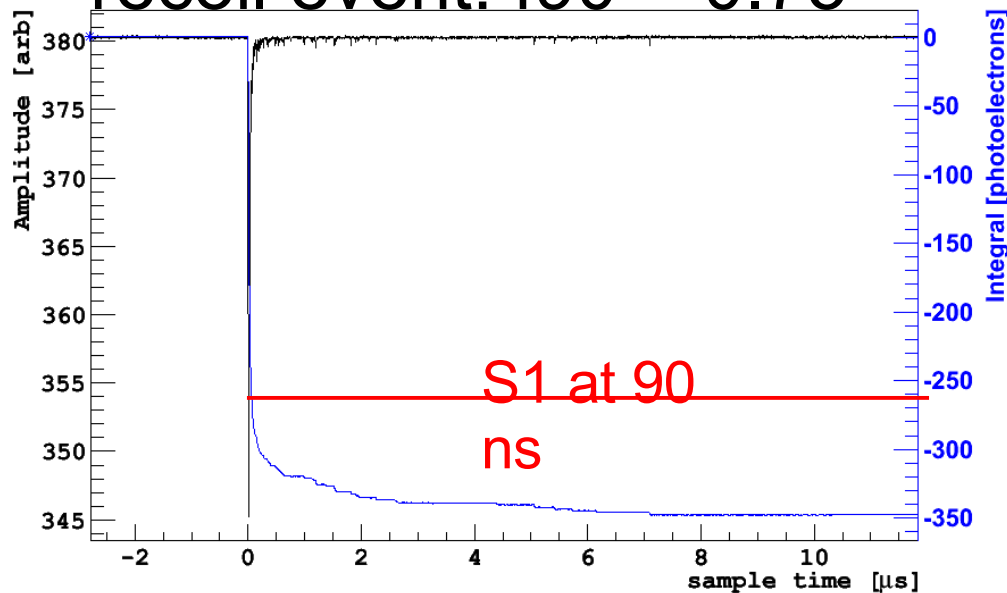


Pulse Shape Discrimination

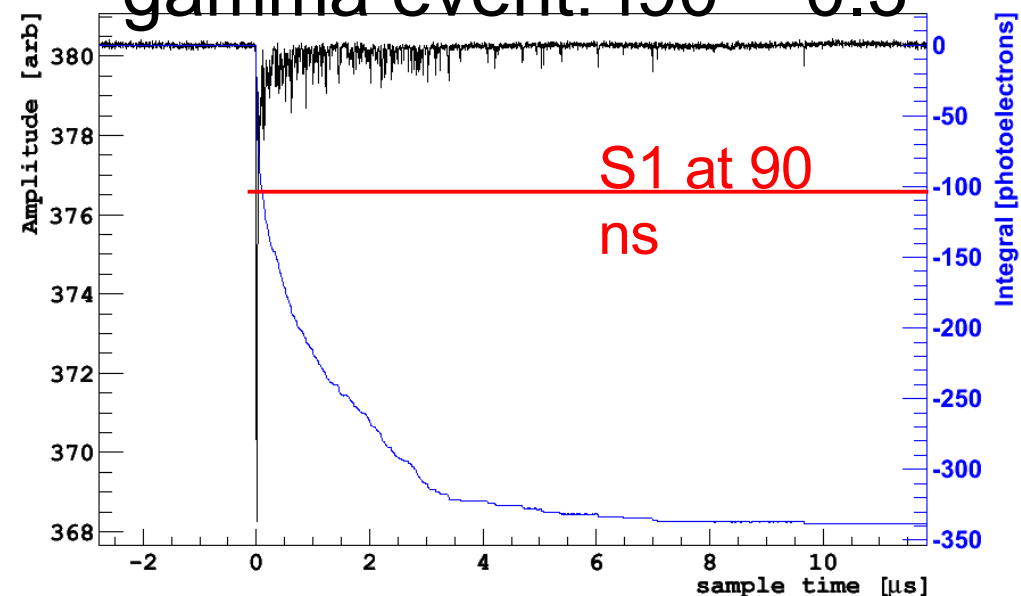
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- f_{90} : the fraction of S1 light that arrives within the first 90 ns

recoil event: $f_{90} \sim 0.75$



gamma event: $f_{90} \sim 0.3$

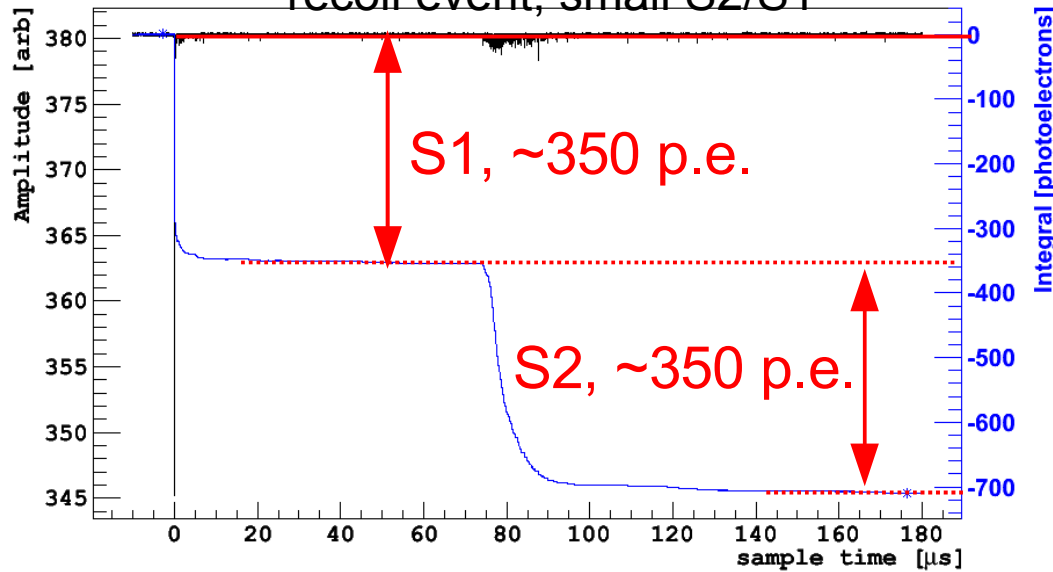


Scintillation/Ionization Ratio

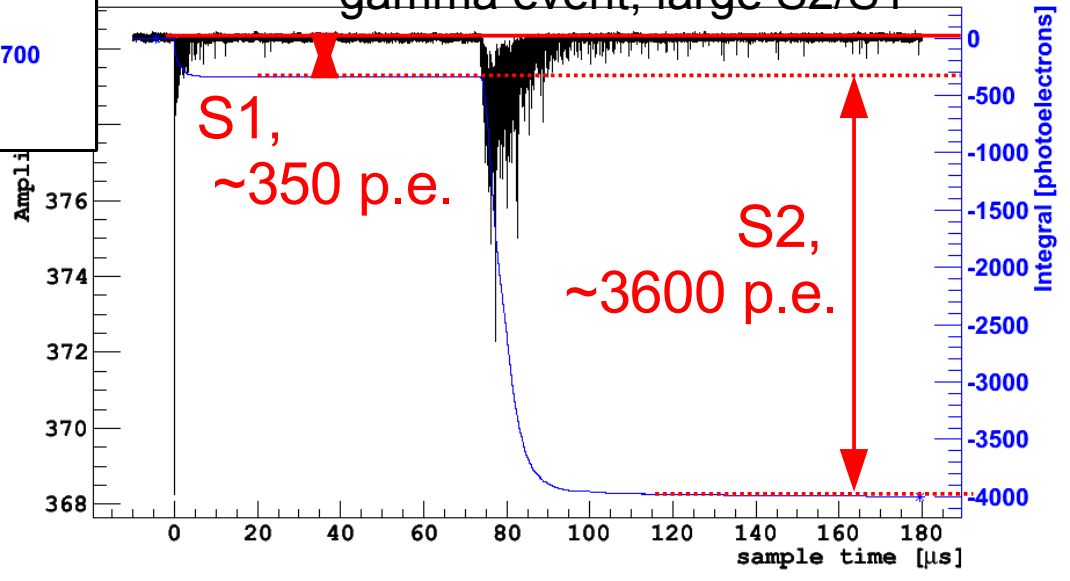
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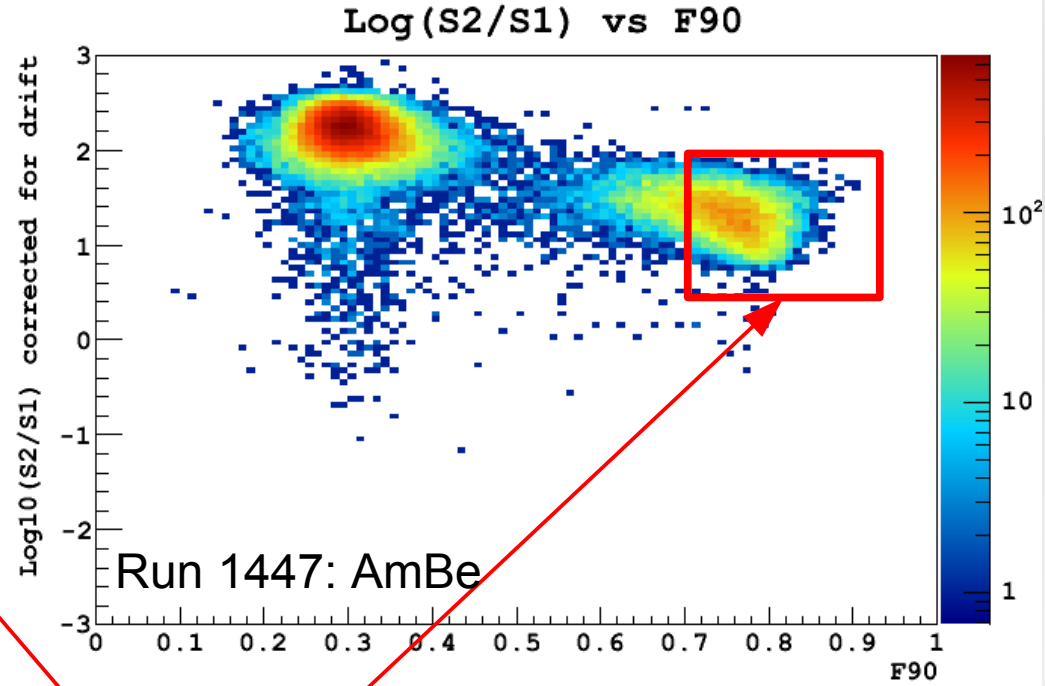
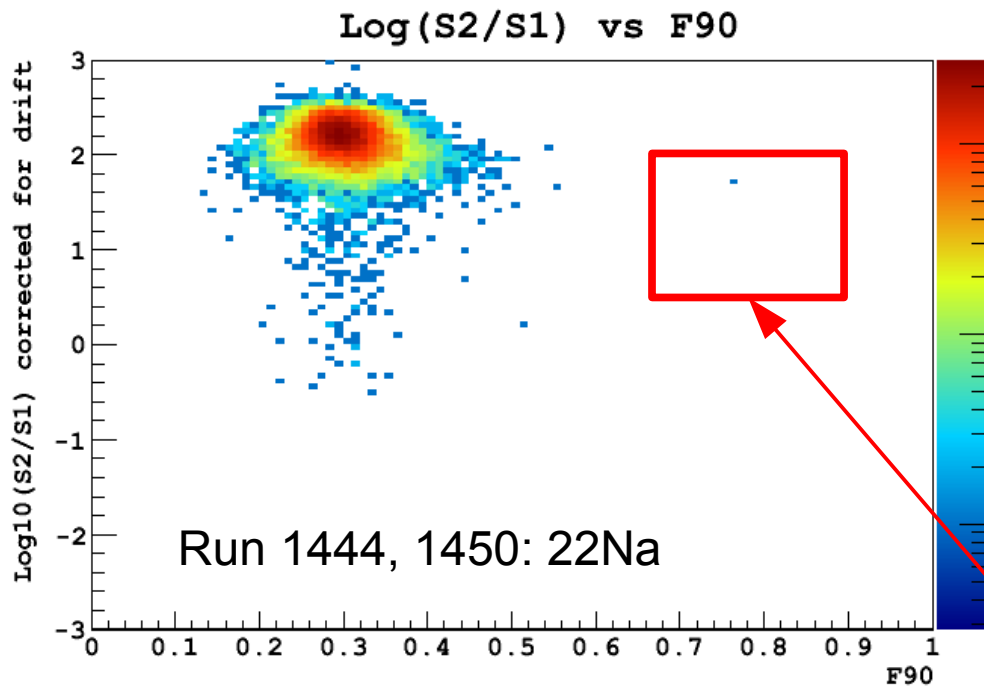
recoil event, small S2/S1



gamma event, large S2/S1



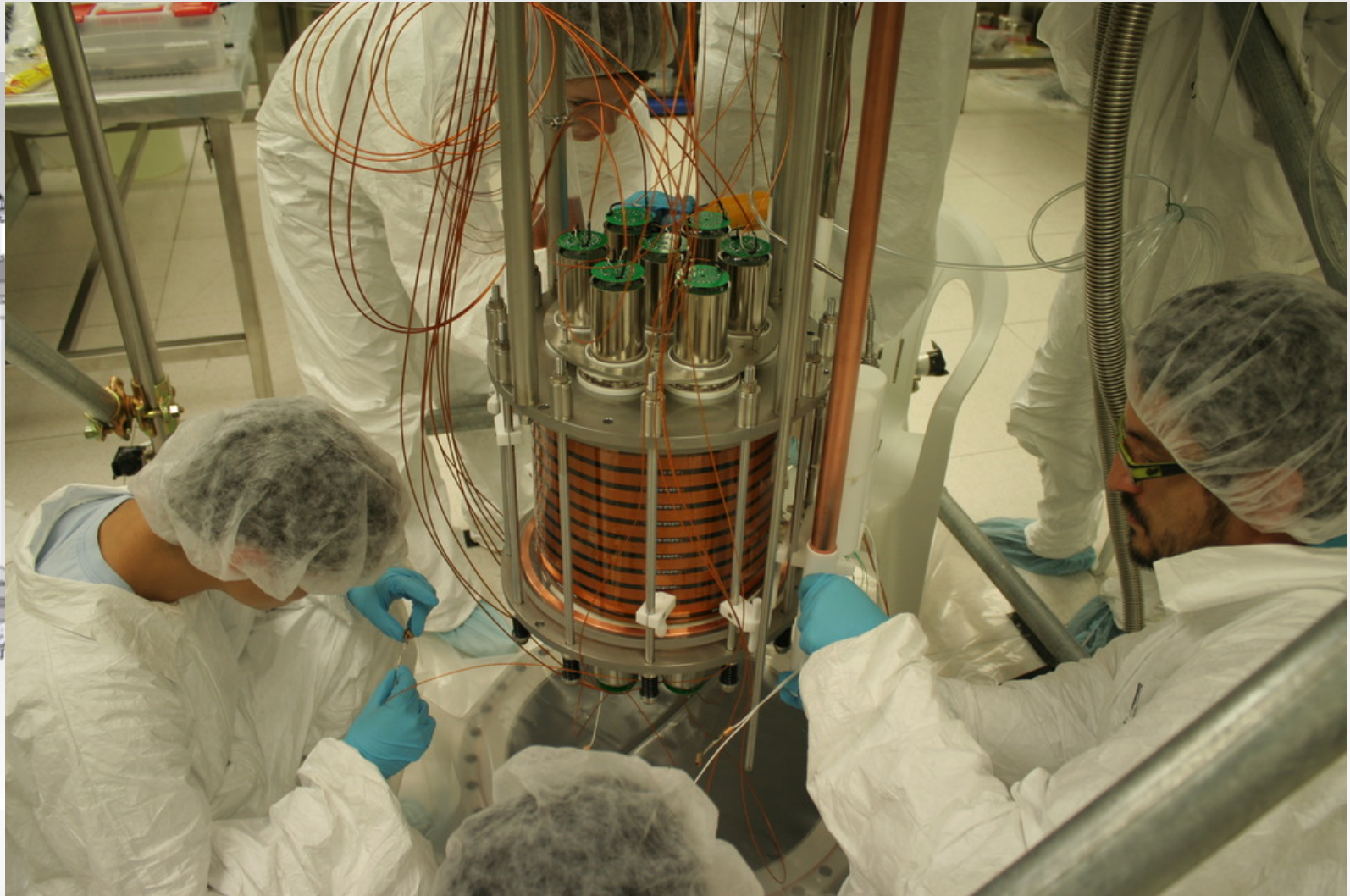
DarkSide-10 Analysis: Combined Background Rejection



Example nuclear recoil acceptance bounds

DarkSide-10

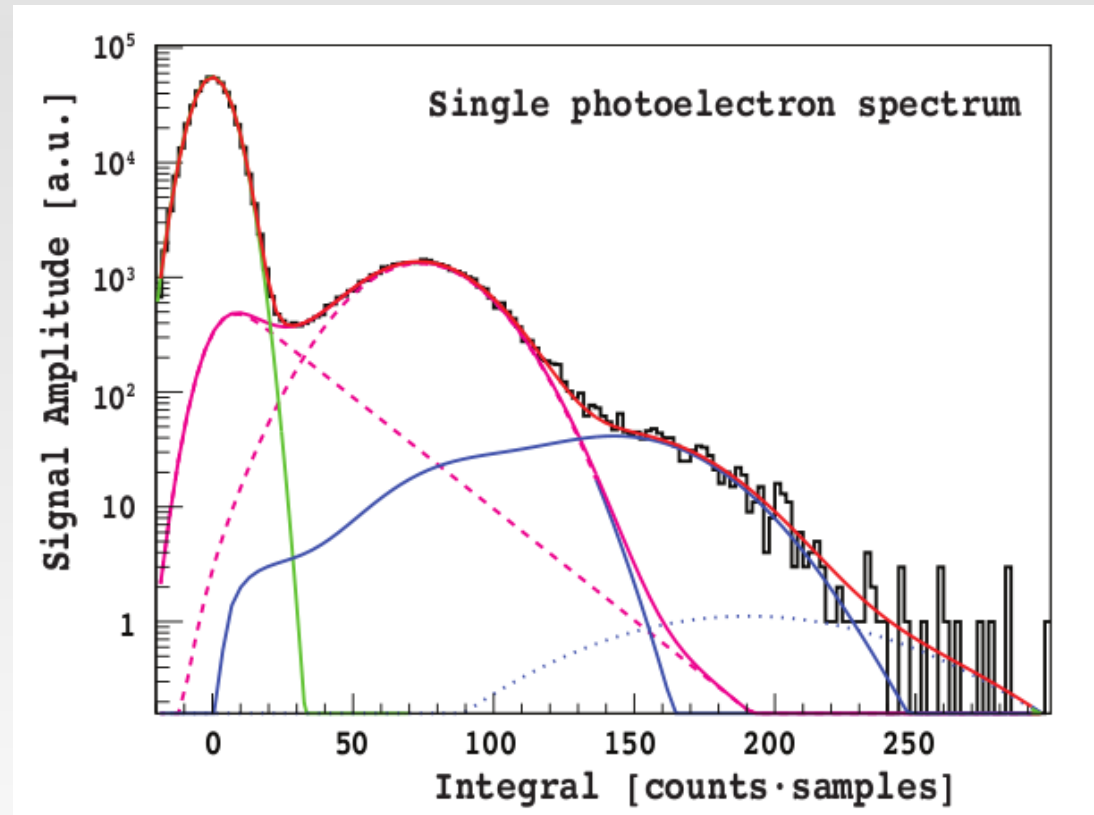
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Photomultiplier Calibration



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

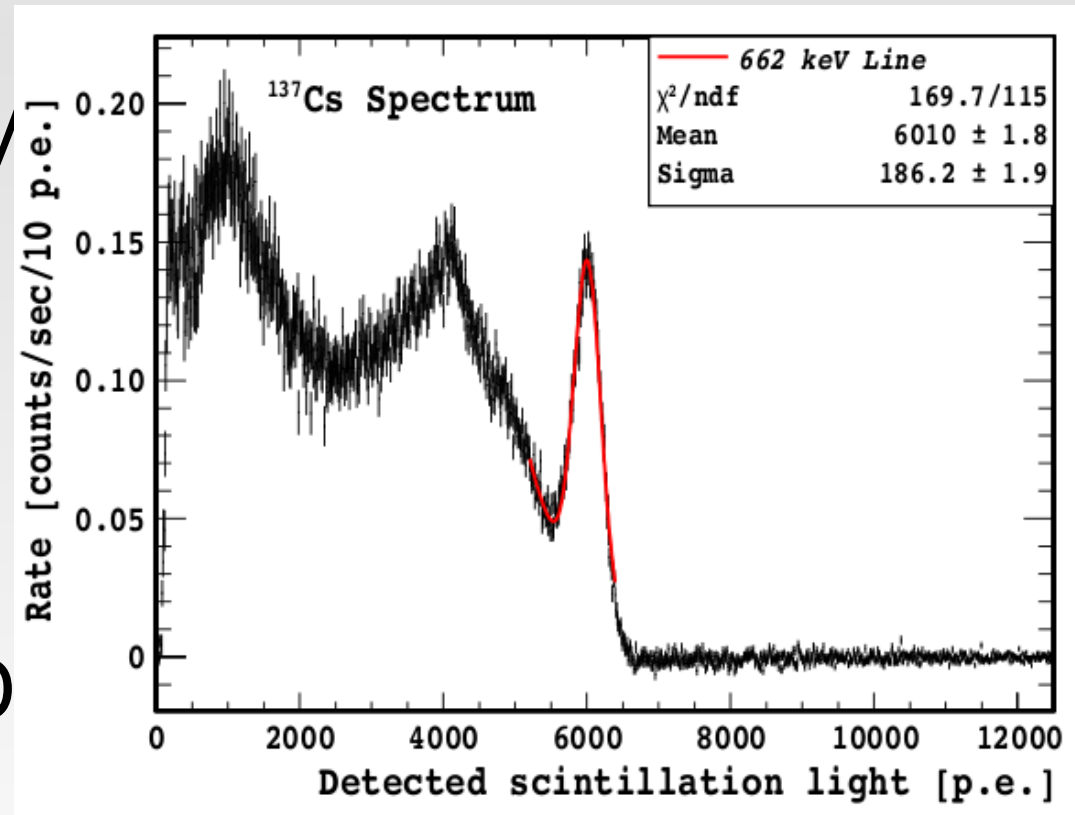


arxiv:1204.6218

DarkSide-10 Light yield



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



arxiv:1204.6218

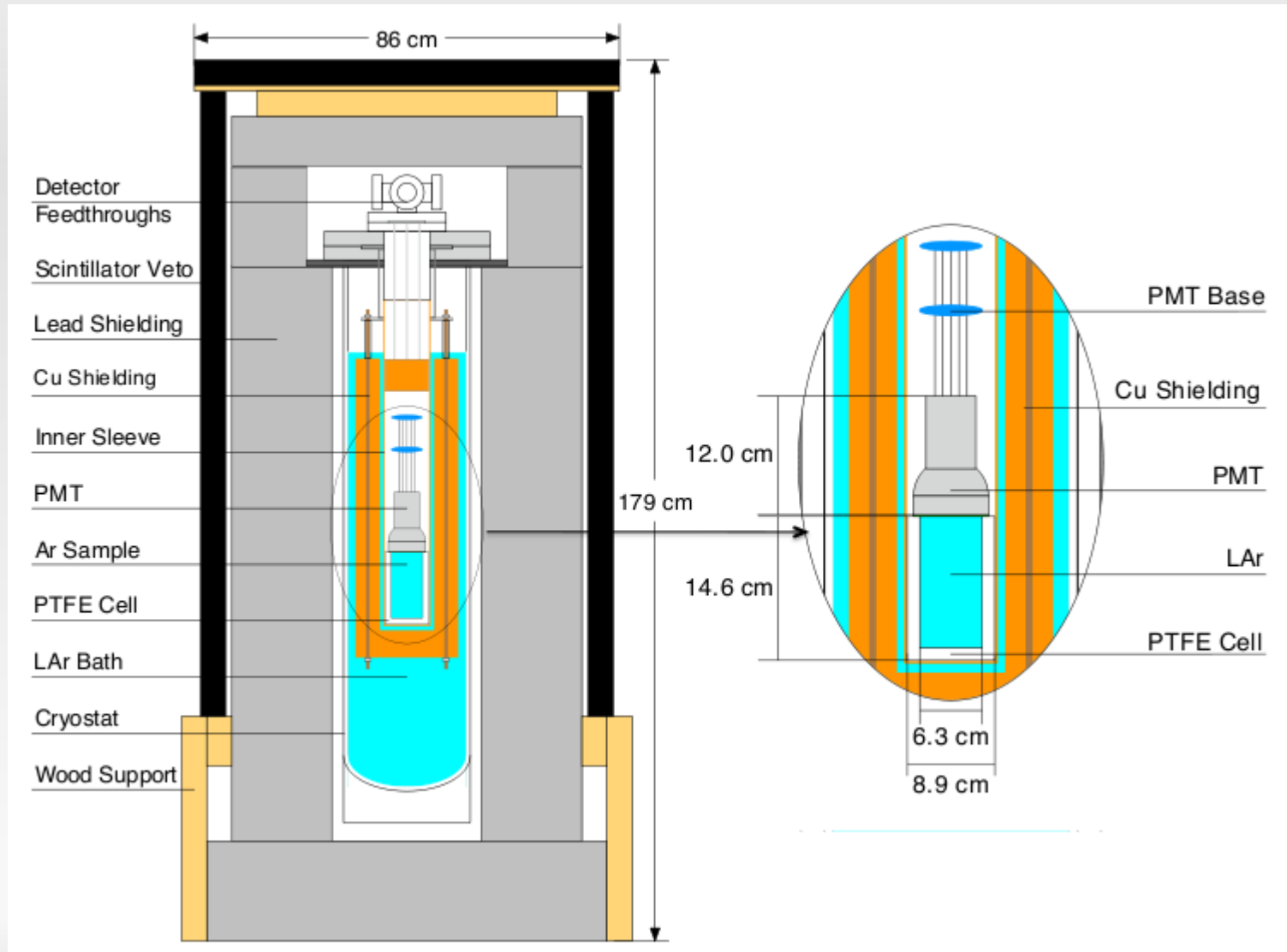
Underground argon



- Atmospheric 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

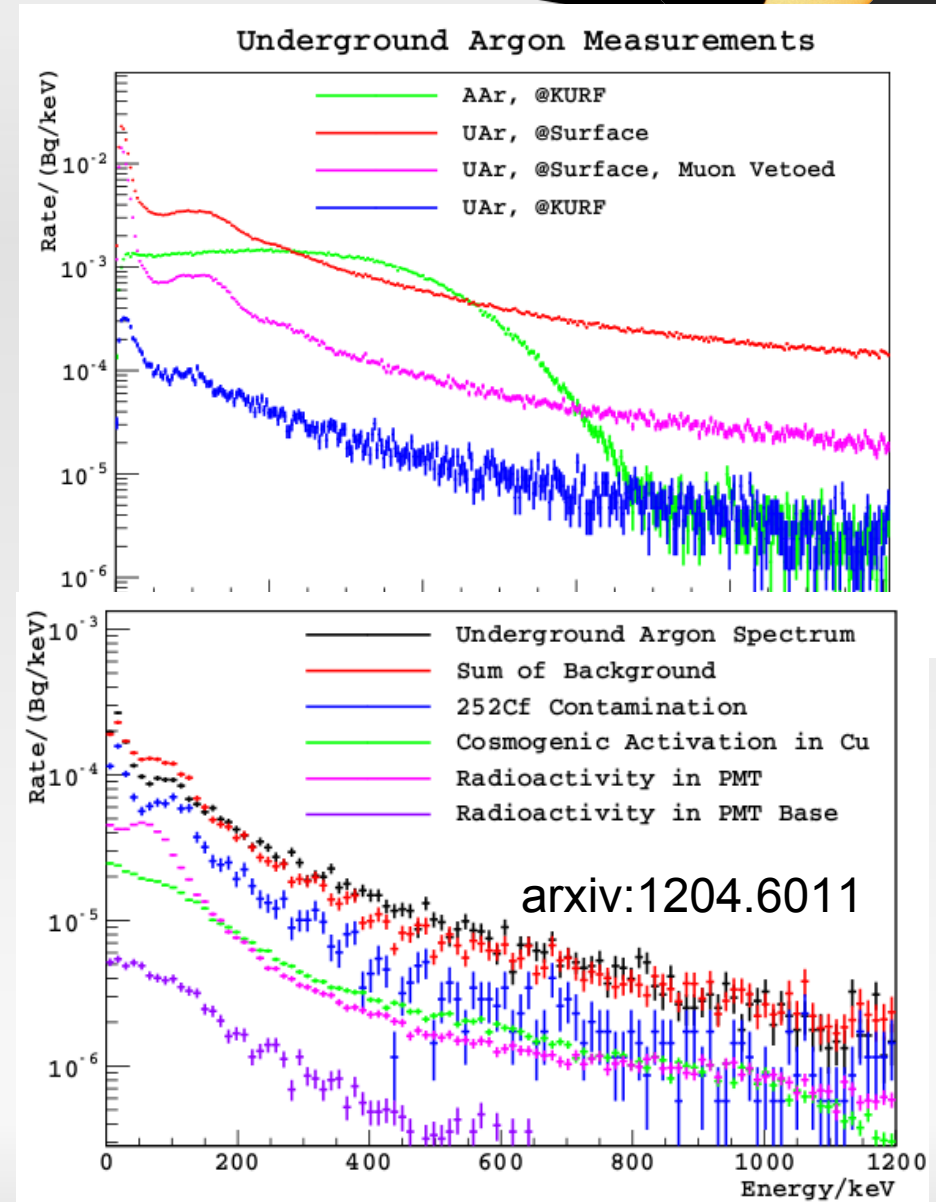
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Underground argon decay rate

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- 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



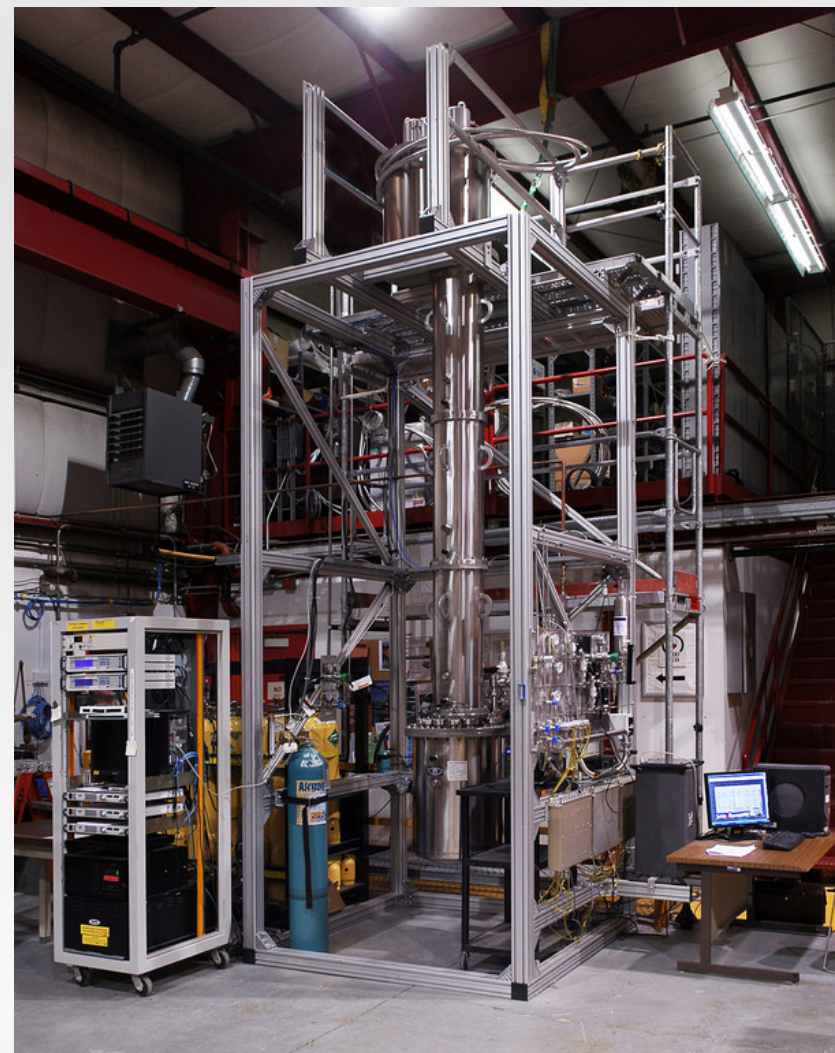
arxiv:1204.6024

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

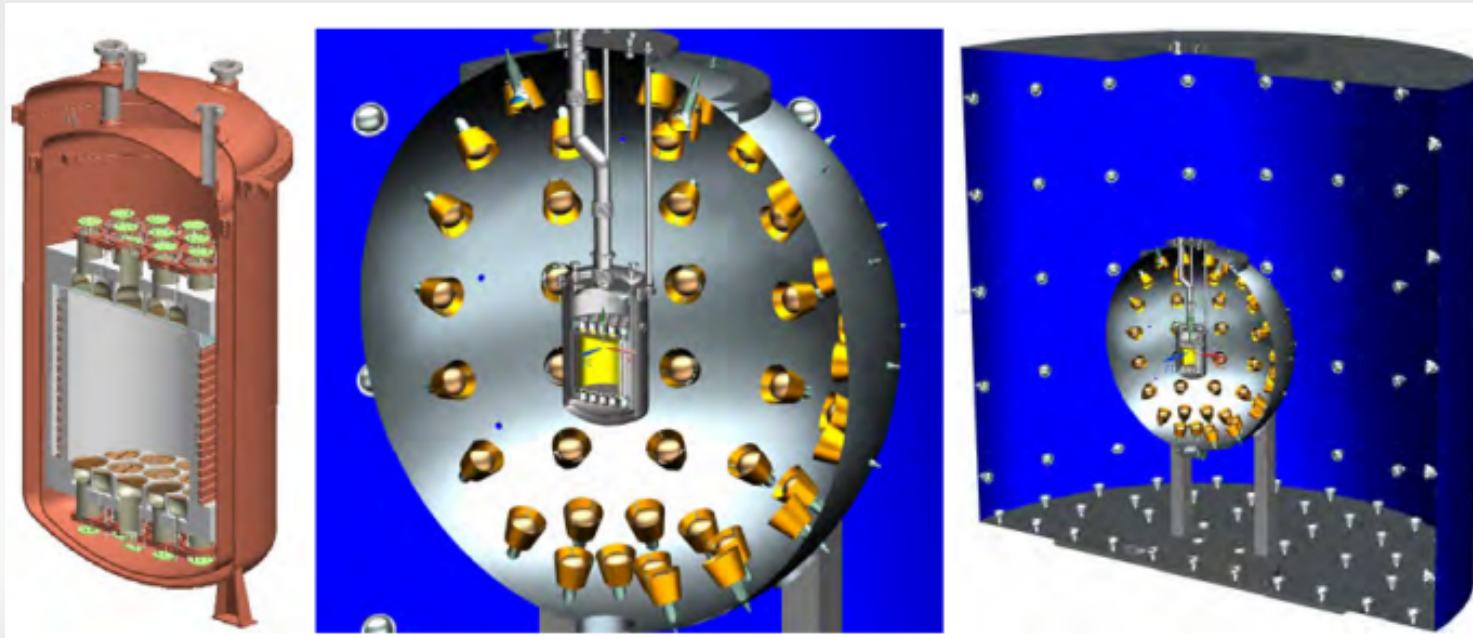
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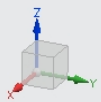
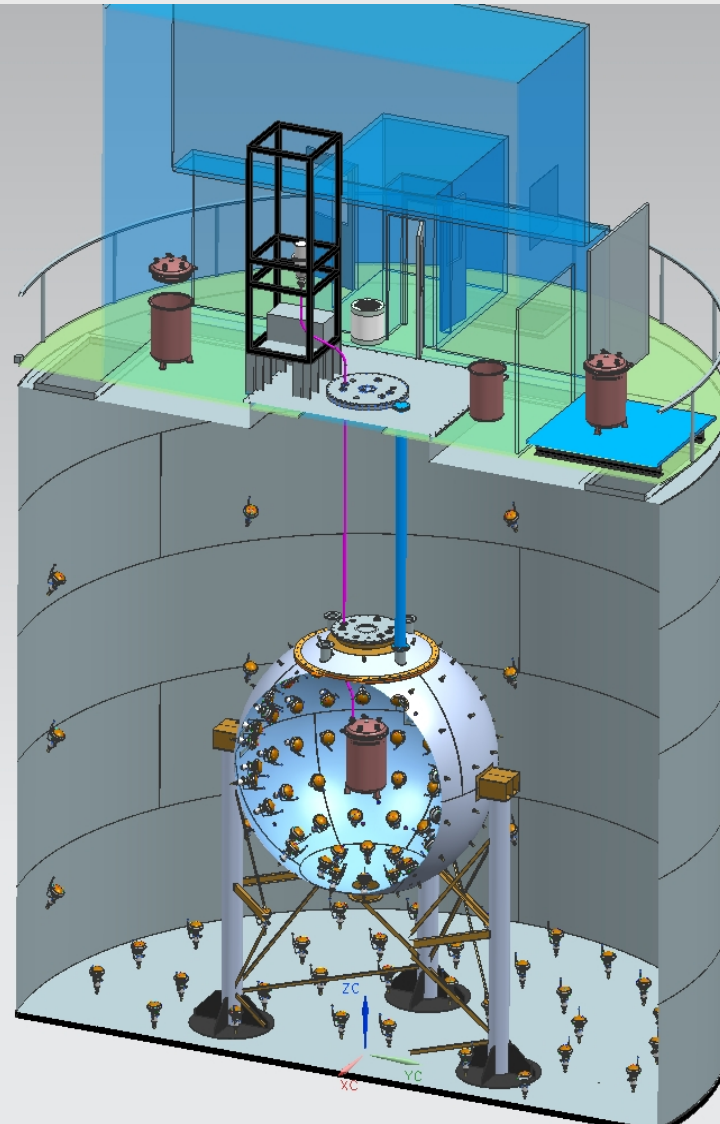
DarkSide-50: Coming soon to LNGS



- 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



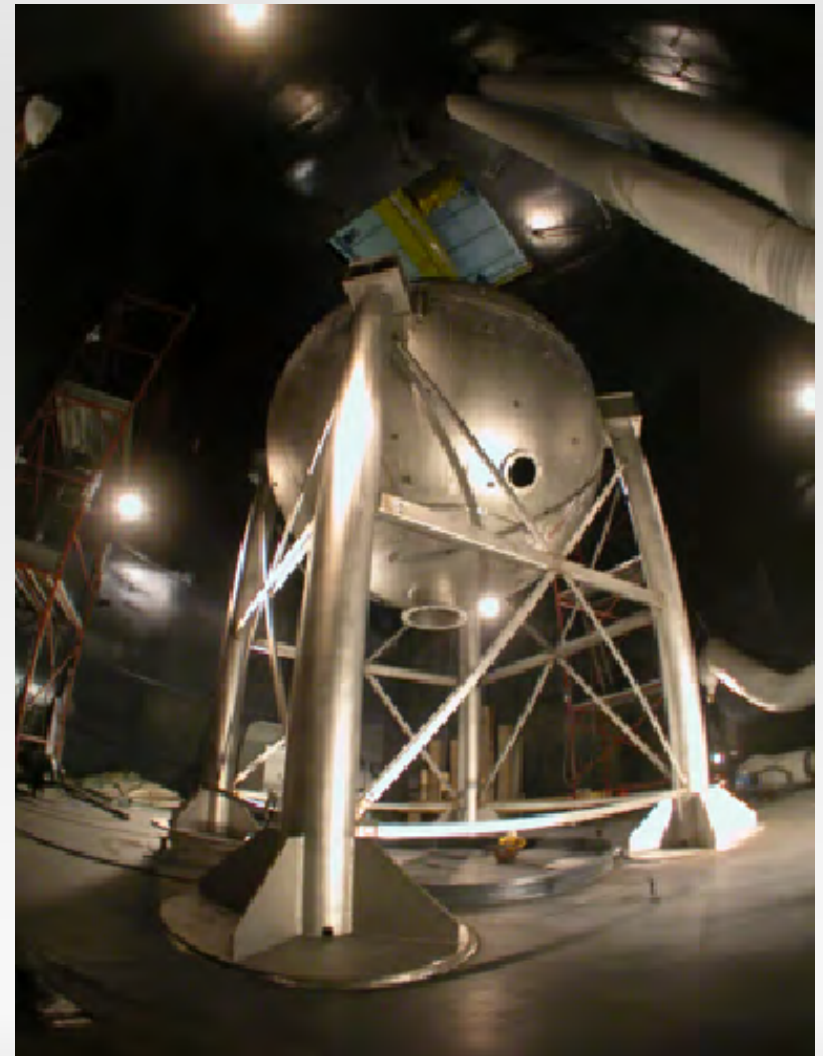
DarkSide-50 : Coming soon to LNGS



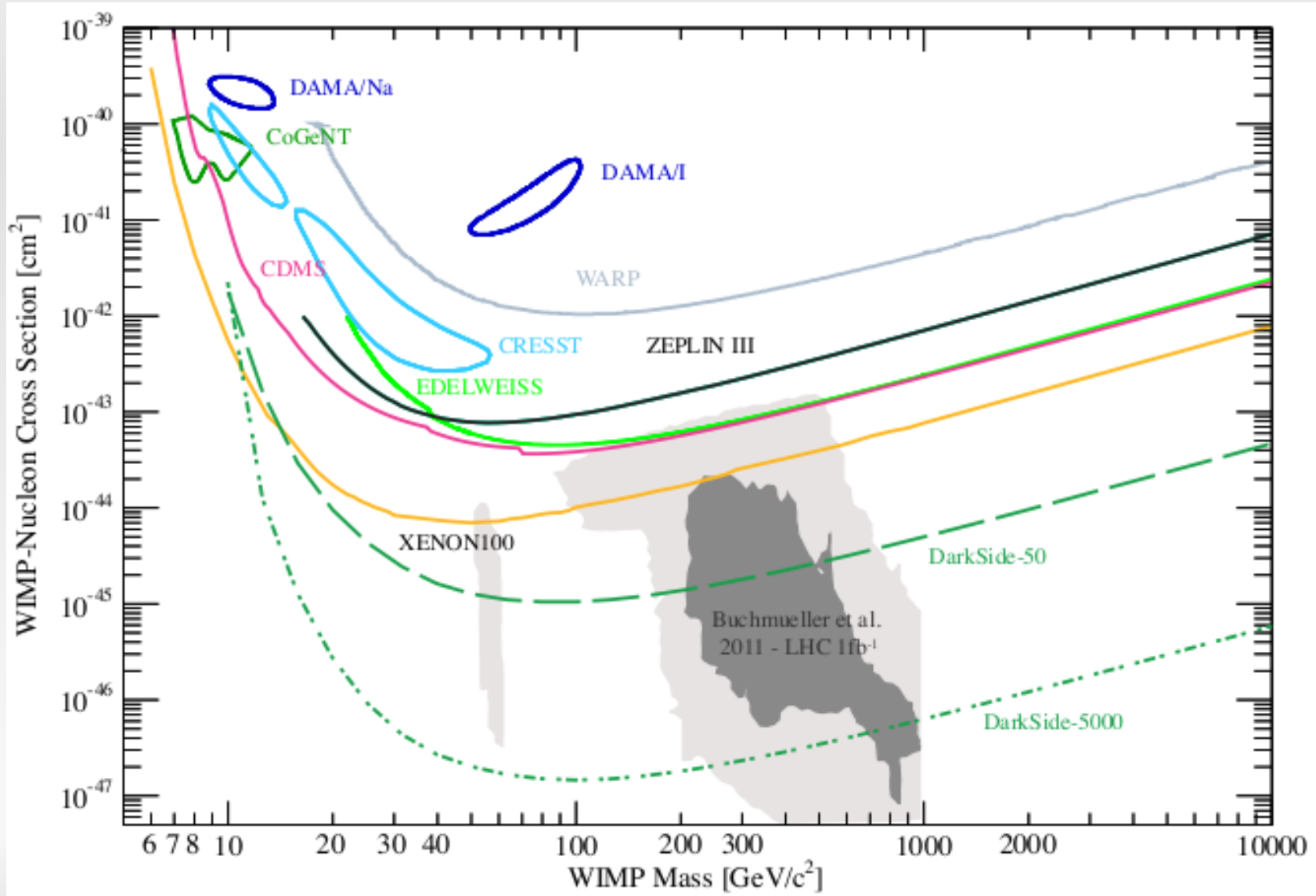
DarkSide-50 Schedule



- 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



Google image search delivers

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lifeisaroad.com