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

D. Akimov[k], T. Alexander[d], D. Alton[a], K. Arisaka[v], H.O. Back[m], P. Beltrame[v], J. Benziger[l], A. Bolozdynya[k], G. Bonfini[i], A. Brigatti[r], J. Brodsky[m], L. Cadonati[x], F. Calaprice[m], A. Candela[i], H. Cao[m], P. Cavalcante[i], A. Chavarria[m], A. Chepurnov[j], S. Chidzik[m], D. Cline[v], A.G. Cocco[s], C. Condon[m], D. DAngelo[r], S. Davini[w], E. De Haas[m], A. Derbin[n], G. Di Pietro[r], I. Dratchnev[n], D. Durben[b], A. Empl[w], A. Etenko[k], A. Fan[v], G. Fiorillo[s], K. Fomenko[i], G. Forster[x], F. Gabriele[m], C. Galbiati[m], S. Gazzana[i], C. Ghag[p], C. Ghiano[i], A. Goretti[m], L. Grandi[m], M. Gromov[l], M. Guan[e], C. Guo[e], G. Guray[m], E. V. Hungerford[w], Al. Ianni[i], An. Ianni[m], A. Kayunov[n], K. Keeter[b], C. Kendziora[d], S. Kidner[y], R. Klemmer[m], V. Kobychev[f], G. Koh[m], M. Komor[m], D. Korablev[h], G. Korga[w], E. Shields[m], P. Li[e], B. Loer[d], P. Lombardi[r], C. Love[o], L. Ludhova[r], L. Lukyanchenko[l], A. Lund[x], K. Lung[v], Y. Ma[e], I. Machulin[k], J. Maricic[c], C.J. Martoff[o], Y. Meng[v], E. Meroni[r], P. Meyers[m], T. Mohayai[m], D. Montanari[d], M. Montuschi[i], P. Mosteiro[m], B. Mount[b], V. Muratova[n], A. Nelson[m], A. Nemtzow[x], N. Nurakhov[k], M. Orsini[i], F. Ortica[t], M. Pallavicini[q], E. Pantic[v], S. Parmeggiano[r], R. Parsells[m], N. Pelliccia[t], L. Perasso[q], F. Perfetto[s], L. Pinsky[w], A. Pocar[x], S. Pordes[d], K. Randle[x], G. Ranucci[r], A. Razeto[i], A. Romani[t], B. Rossi[m,s], N. Rossi[i,m], S.D. Rountree[y], P. Saggese[i], R. Saldanha[i], C. Salvo[q], W. Sands[m], M. Seigar[u], D. Semenov[n], M. Skorokhvatov[k], O. Smirnov[h], A. Sotnikov[h], S. Sukhotin[k], Y. Suvarov[v], R. Tartaglia[i], J. Tatarowicz[o], G. Testera[q], A. Teymourian[v], J. Thompson[b], E. Unzhakov[n], R.B. Vogelaar[y], H. Wang[v], S. Westerdale[m], M. Wojcik[g], A. Wright[m], J. Xu[m], C. Yang[e], S. Zavatarelli[q], M. Zehfus[b], W. Zhong[e], G. Zuzel[g]

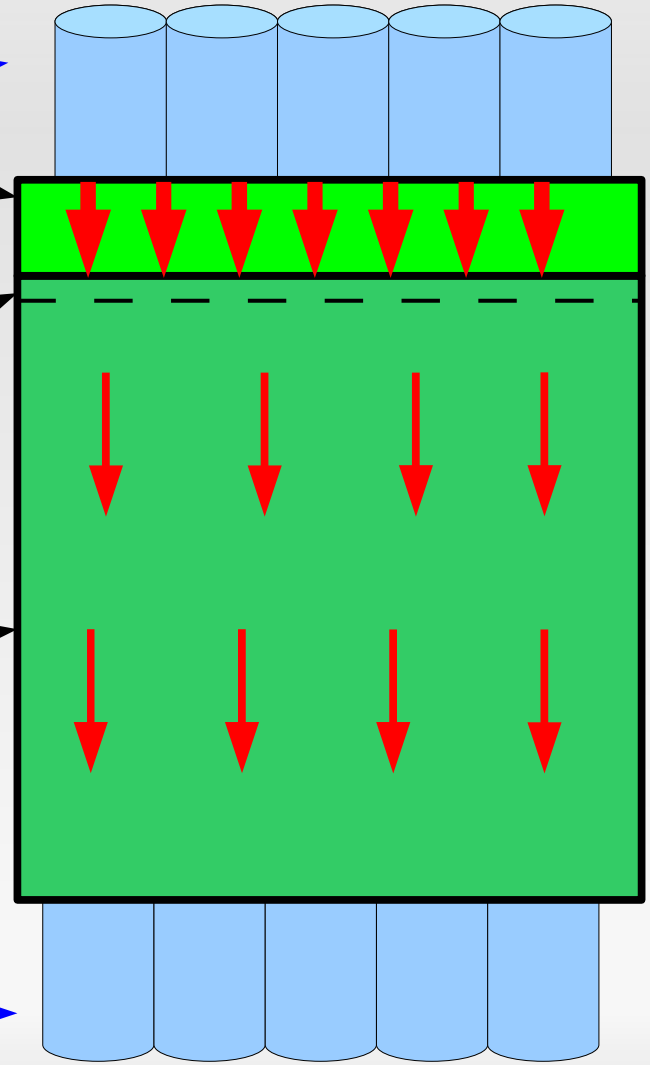
[a] *Physics and Astronomy Department, Augustana College, Sioux Falls, SD 57197, USA*
[b] *School of Natural Sciences, Black Hills State University, Spearfish, SD 57799, USA*
[c] *Department of Physics, Drexel University, Philadelphia, PA 19104, USA*
[d] *Fermi National Accelerator Laboratory, Batavia, IL 60510, USA*
[e] *Institute of High Energy Physics, Beijing 100049, China*
[f] *Institute for Nuclear Research, National Academy of Sciences of Ukraine, Kiev 03680, Ukraine*
[g] *Smoluchowski Institute of Physics, Jagellonian University, Krakow 30059, Poland*
[h] *Joint Institute for Nuclear Research, Dubna 141980, Russia*
[i] *Laboratori Nazionali del Gran Sasso, SS 17 bis Km 18+910, Assergi (AQ) 67010, Italy*
[j] *Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow 119991, Russia*
[k] *National Research Centre Kurchatov Institute, Moscow 123182, Russia*
[l] *Chemical Engineering Department, Princeton University, Princeton, NJ 08544, USA*
[m] *Physics Department, Princeton University, Princeton, NJ 08544, USA*
[n] *St. Petersburg Nuclear Physics Institute, Gatchina 188350, Russia*
[o] *Physics Department, Temple University, Philadelphia, PA 19122, USA*
[p] *Department of Physics and Astronomy, University College London, London WC1E 6BT, United Kingdom*
[q] *Physics Department, Università degli Studi and INFN, Genova 16146, Italy*
[r] *Physics Department, Università degli Studi and INFN, Milano 20133, Italy*
[s] *Physics Department, Università degli Studi Federico II and INFN, Napoli 80126, Italy*
[t] *Chemistry Department, Università degli Studi and INFN, Perugia 06123, Italy*
[u] *Department of Physics and Astronomy, University of Arkansas, Little Rock, AR 72204, USA*
[v] *Physics and Astronomy Department, University of California, Los Angeles, CA 90095, USA*
[w] *Department of Physics, University of Houston, Houston, TX 77204, USA*
[x] *Physics Department, University of Massachusetts, Amherst, MA 01003, USA*
[y] *Physics Department, Virginia Tech, Blacksburg, VA 24061, USA*

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

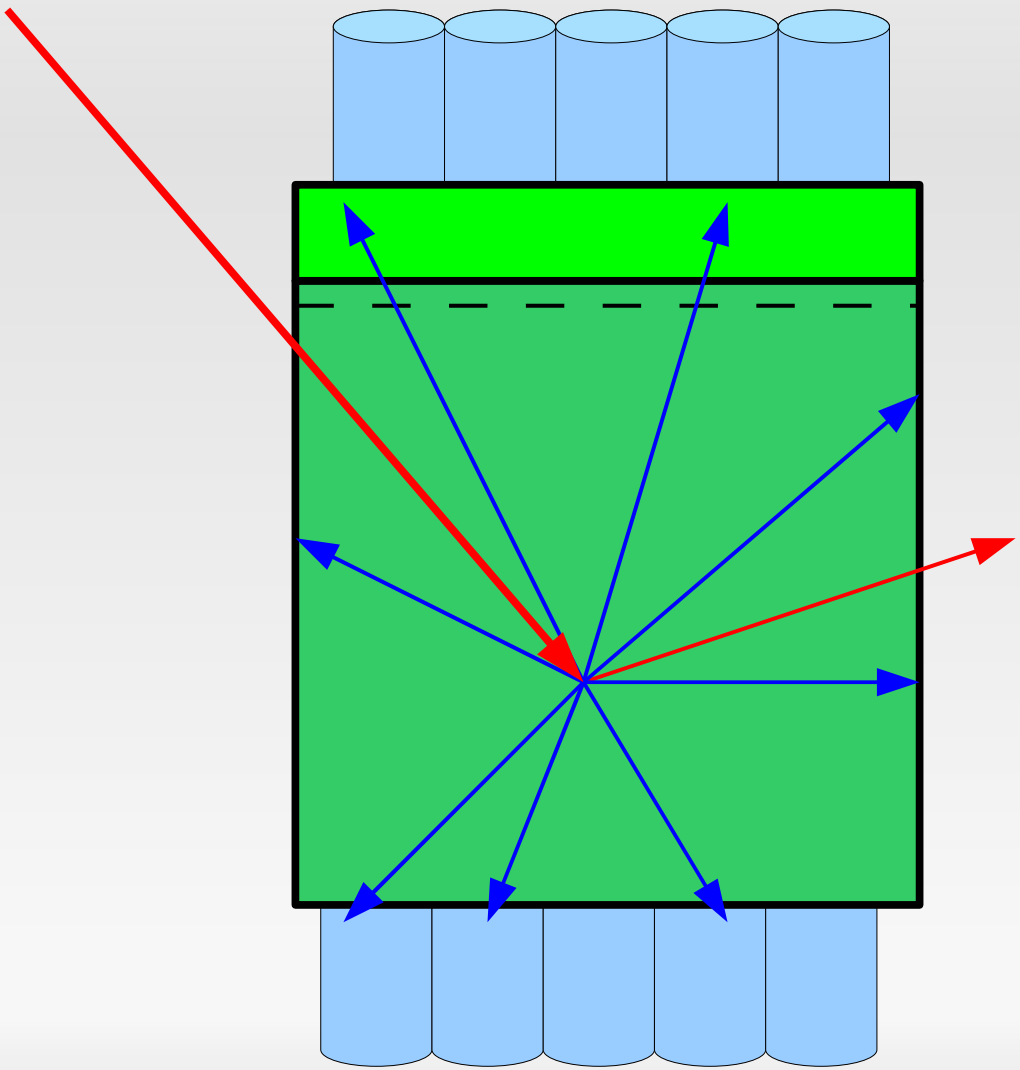
Dual-Phase Argon Time Projection Chamber

- 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



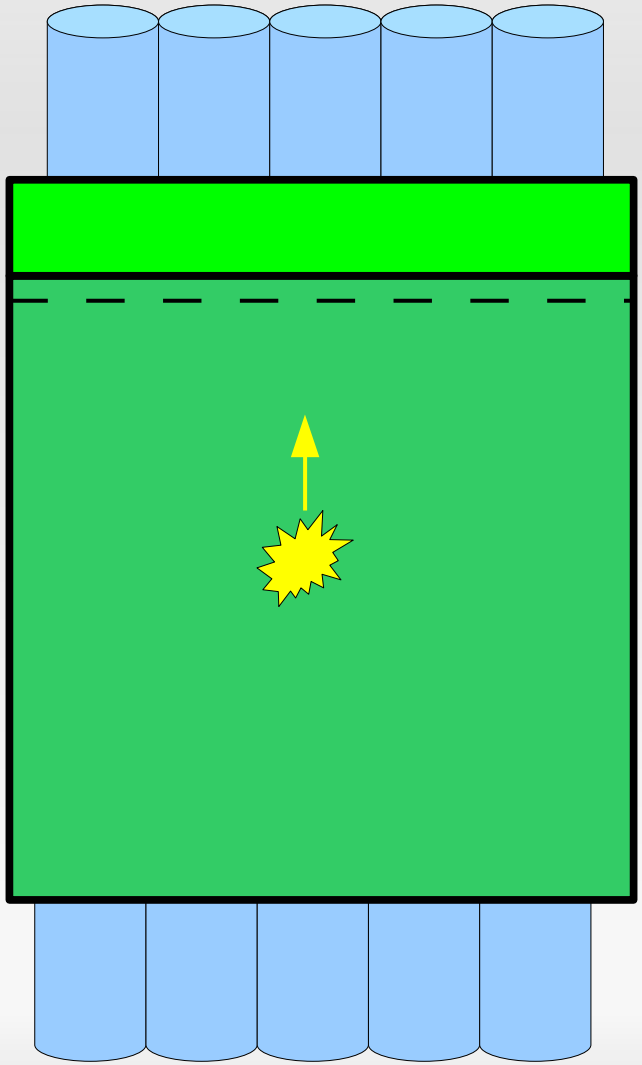
Dual-Phase Argon Time Projection Chamber

- 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



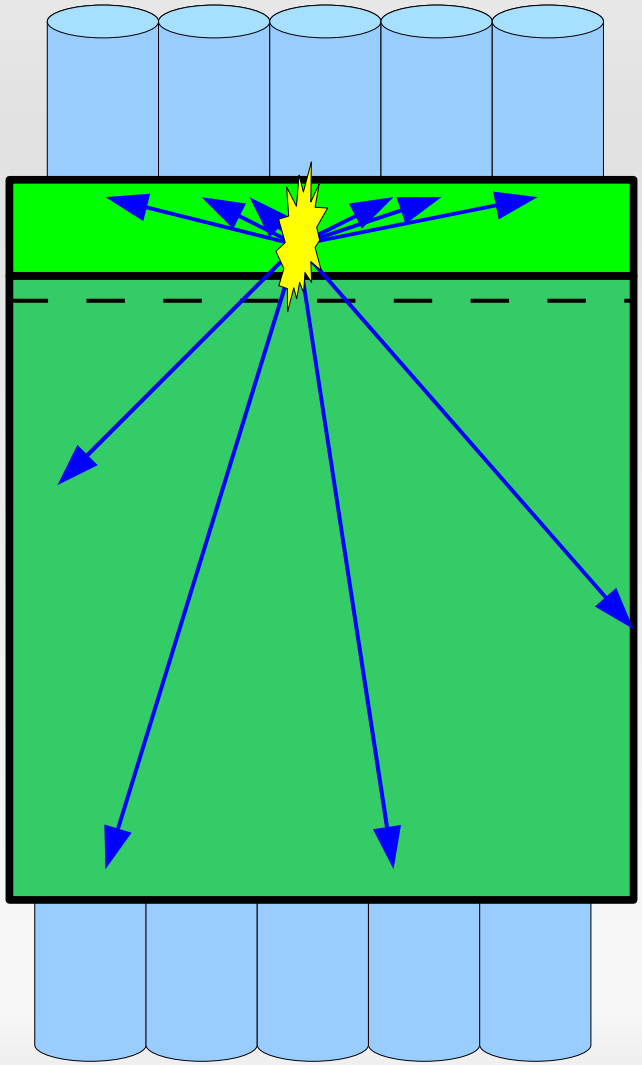
Dual-Phase Argon Time Projection Chamber

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

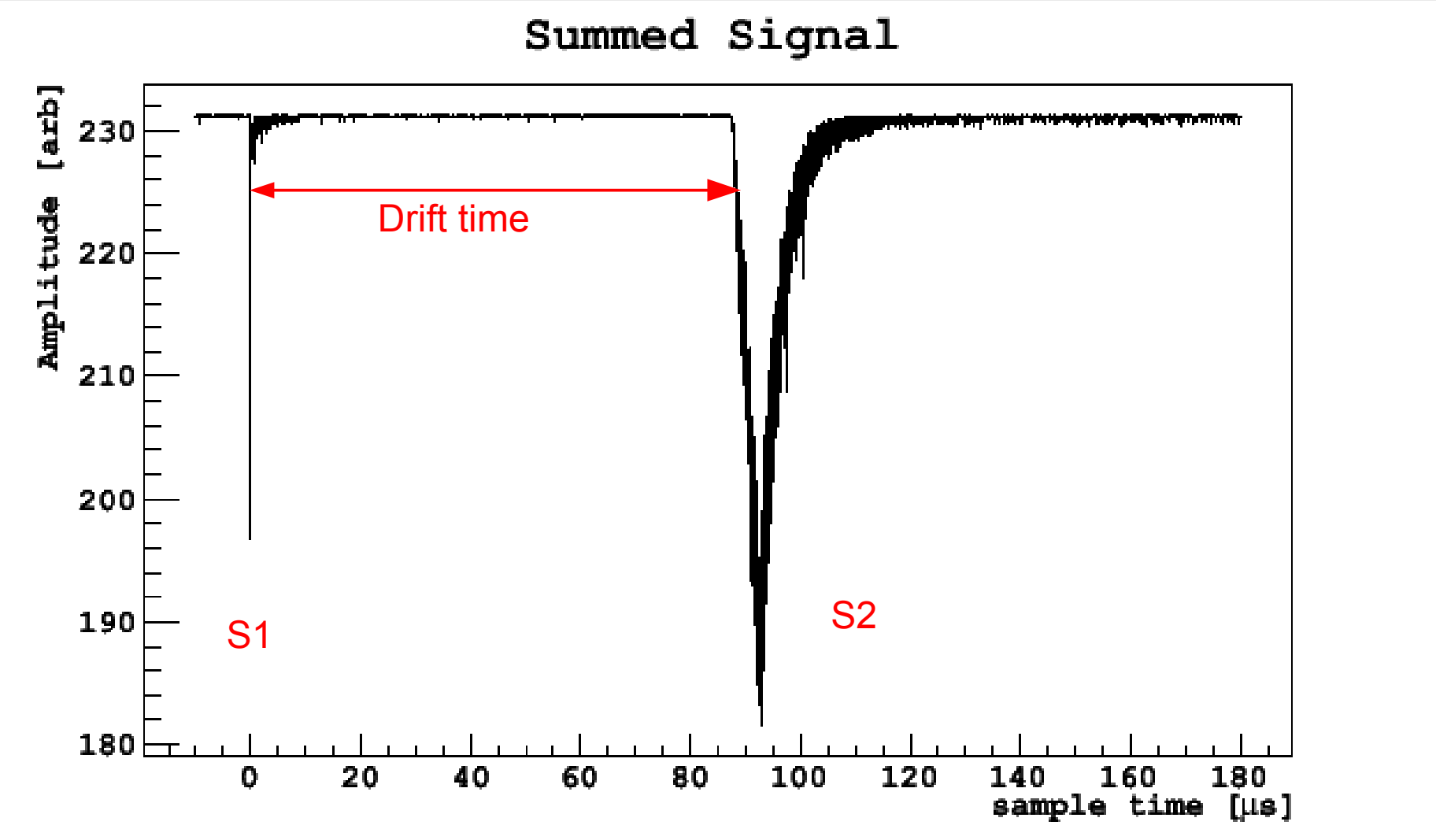


Dual-Phase Argon Time Projection Chamber

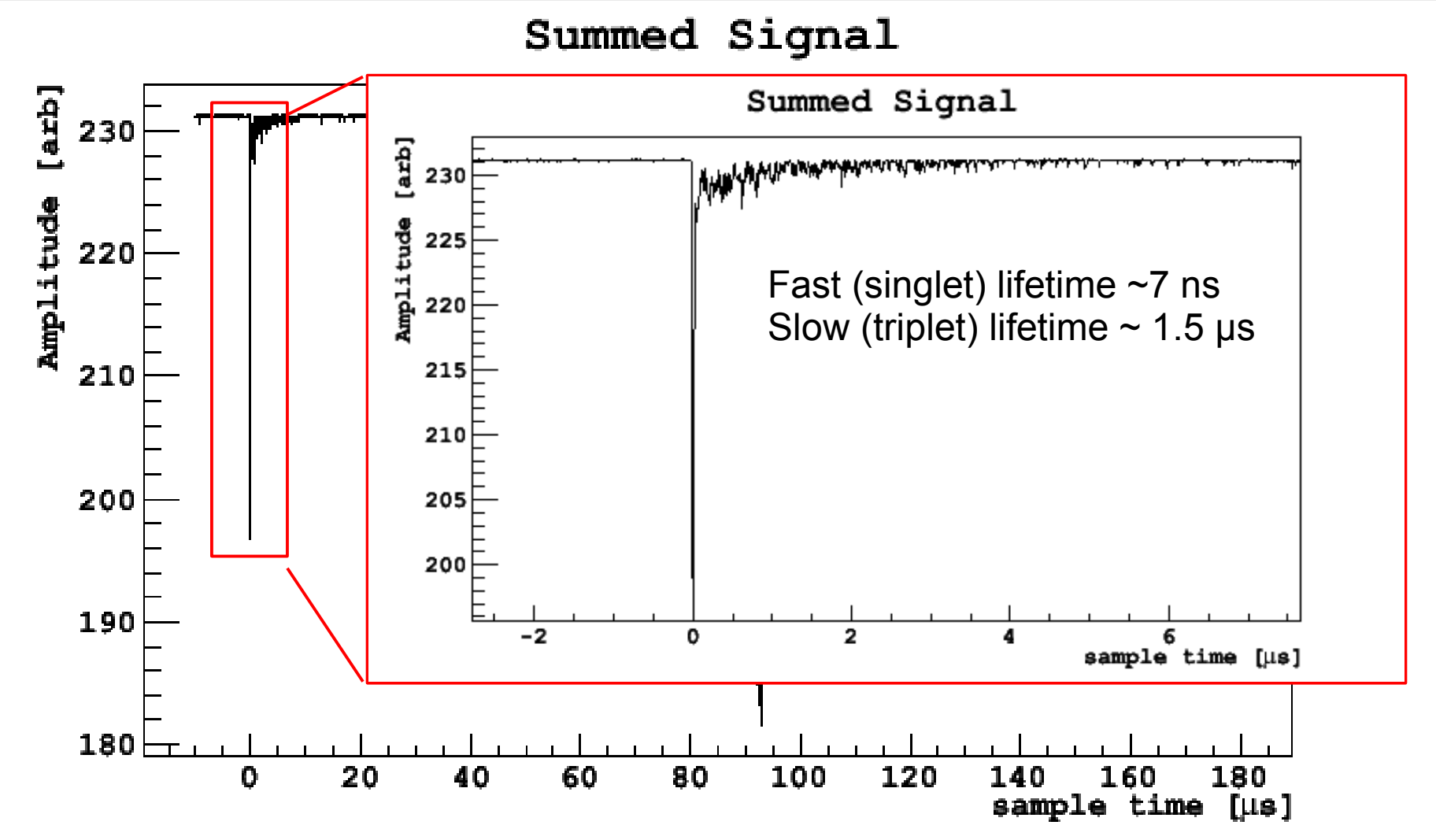
- High electric field in the gas region gives electrons energy to excite secondary scintillation (S2)
- Size of S2 gives amount of ionization
- Light collection ratio in PMTs gives x-y position
- Time between S1 and S2 gives z position



Typical Event

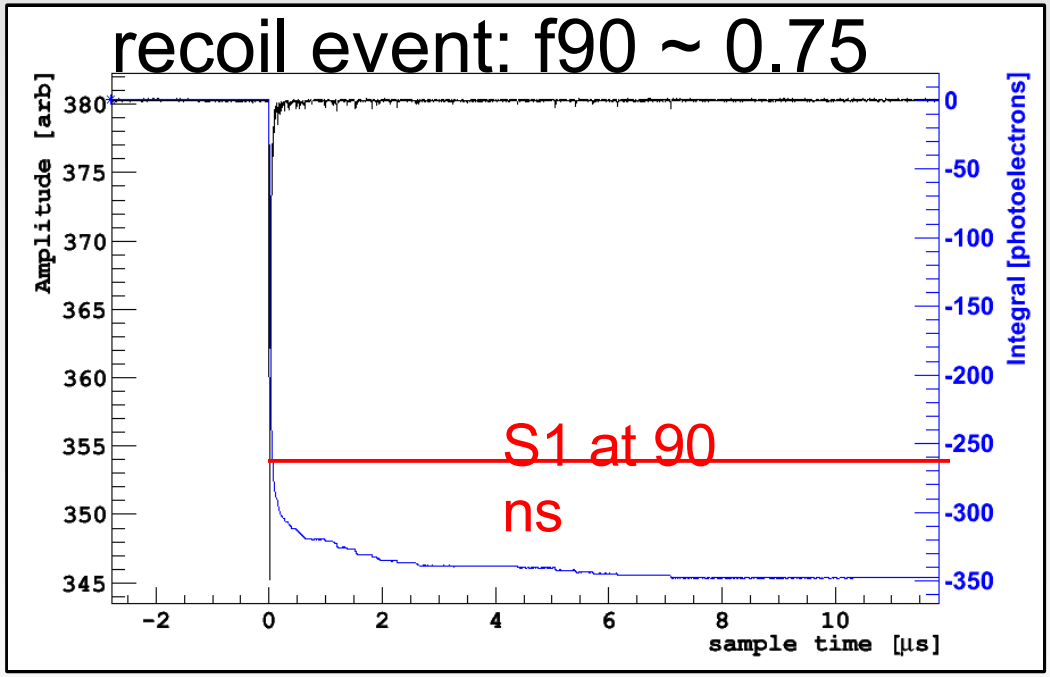


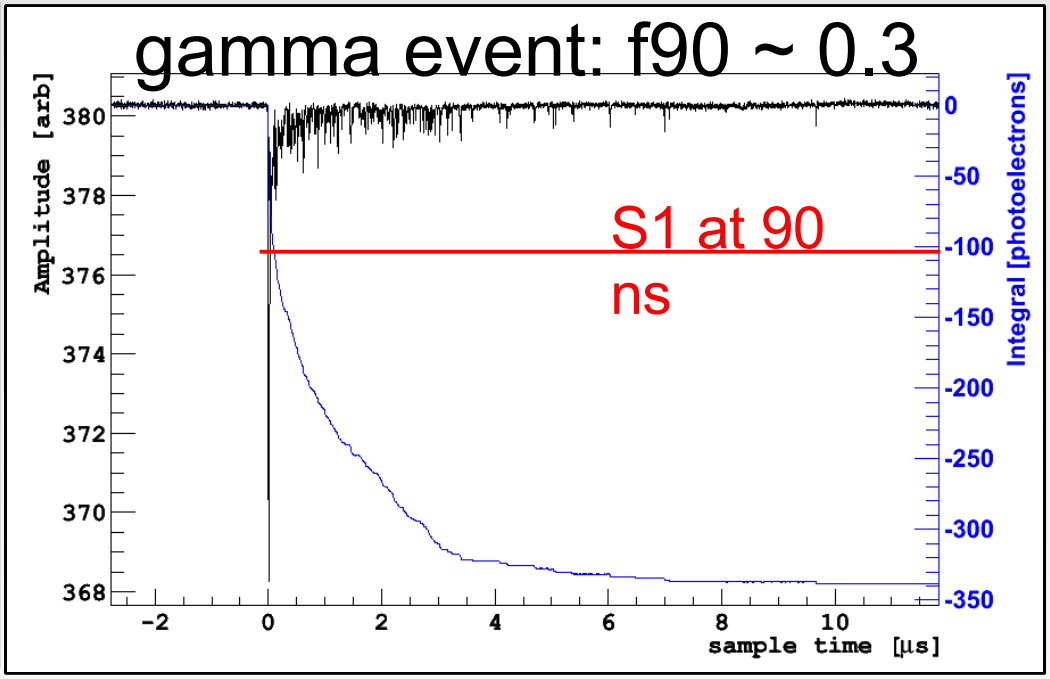
Typical Event



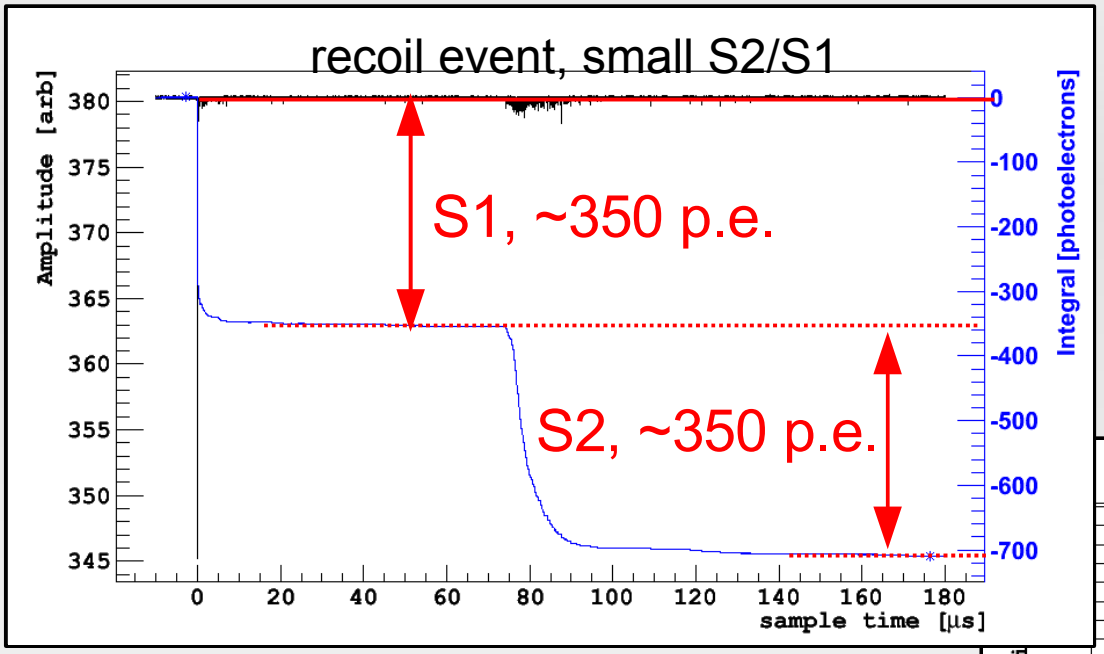
Pulse Shape Discrimination

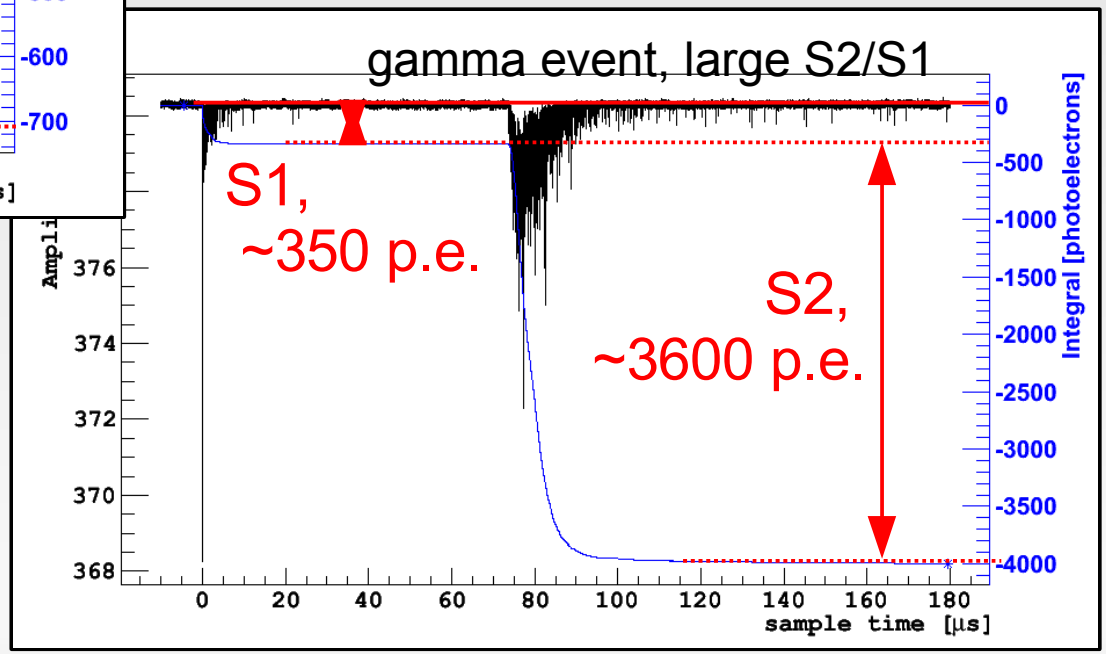
- f90: the fraction of S1 light that arrives within the first 90 ns



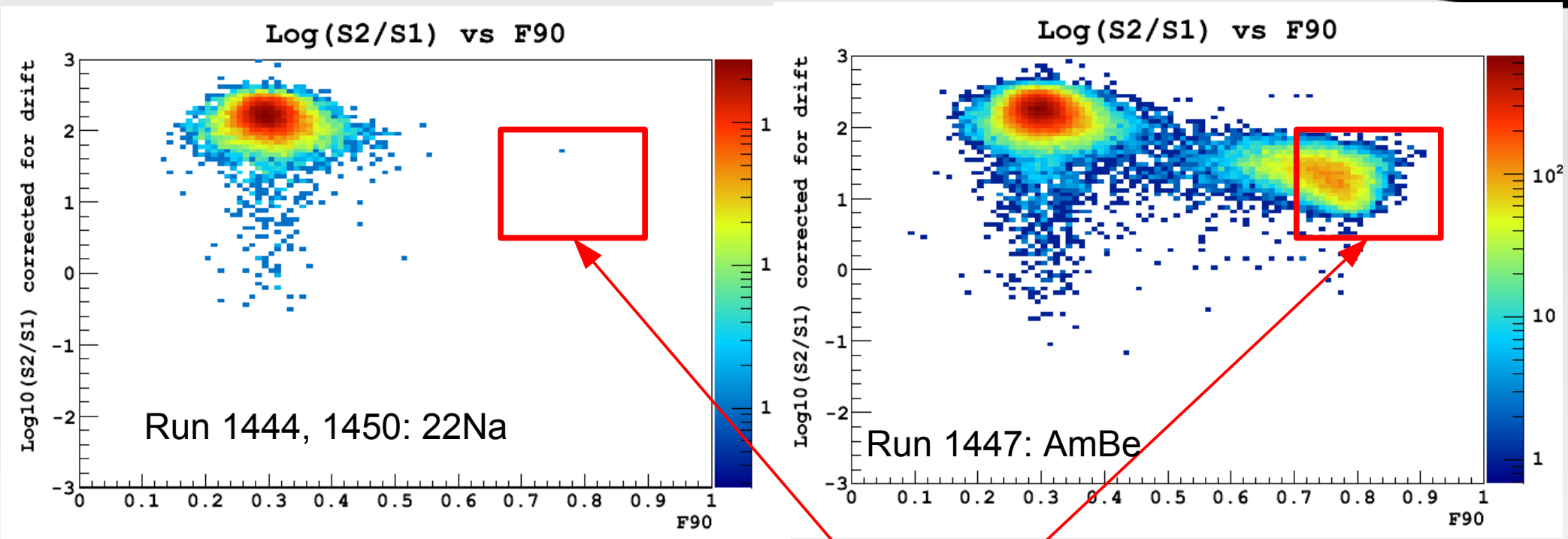


Scintillation/Ionization Ratio



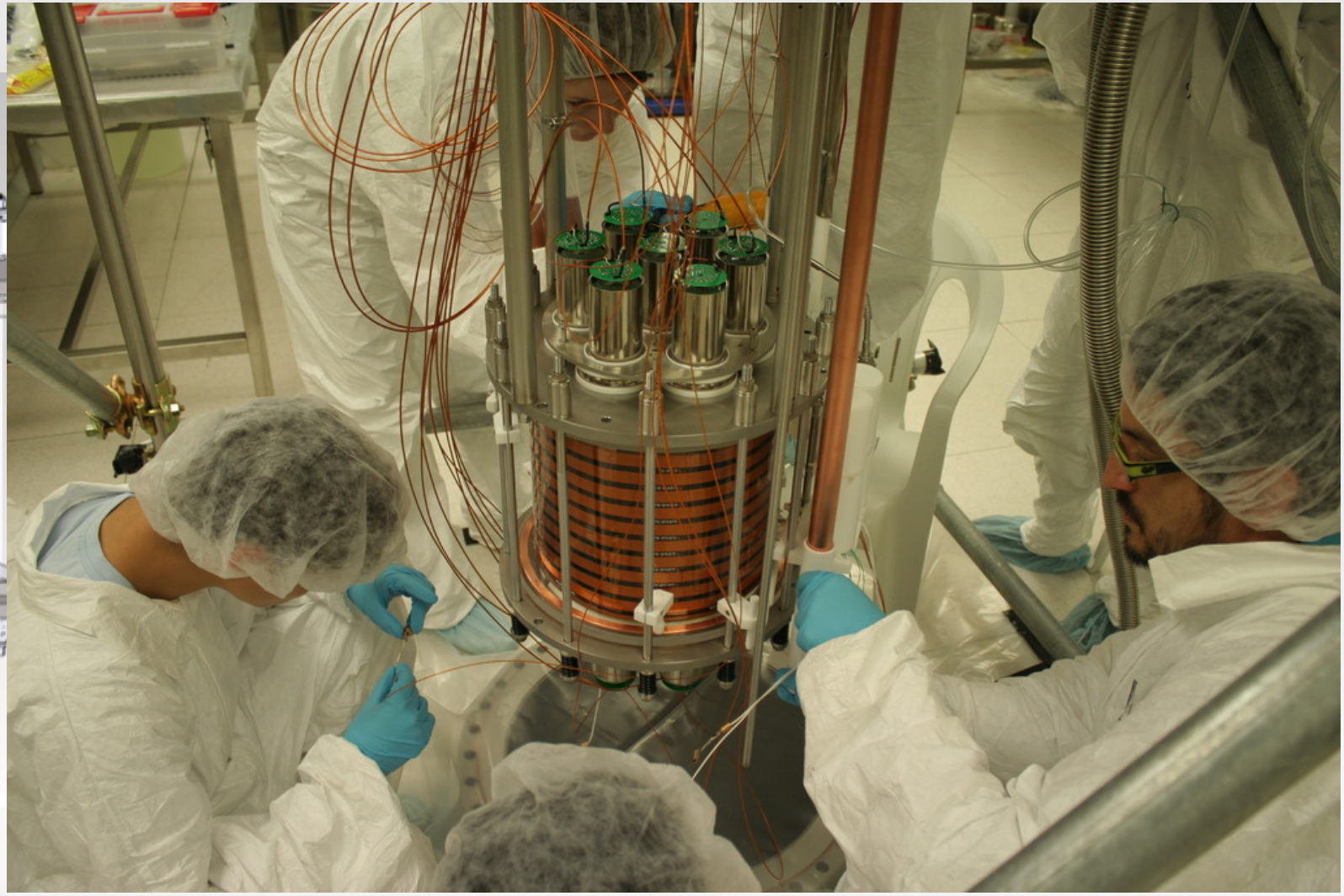


DarkSide-10 Analysis: Combined Background Rejection



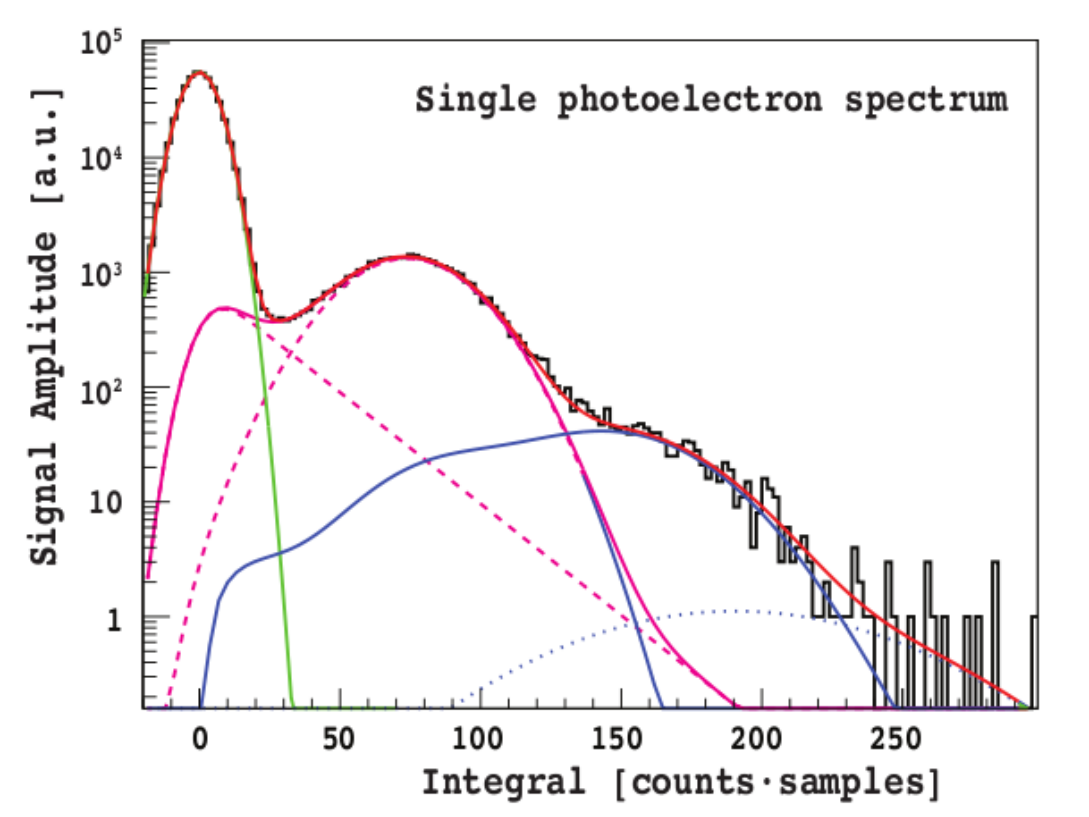
Example nuclear recoil acceptance bounds

DarkSide-10



Photomultiplier Calibration

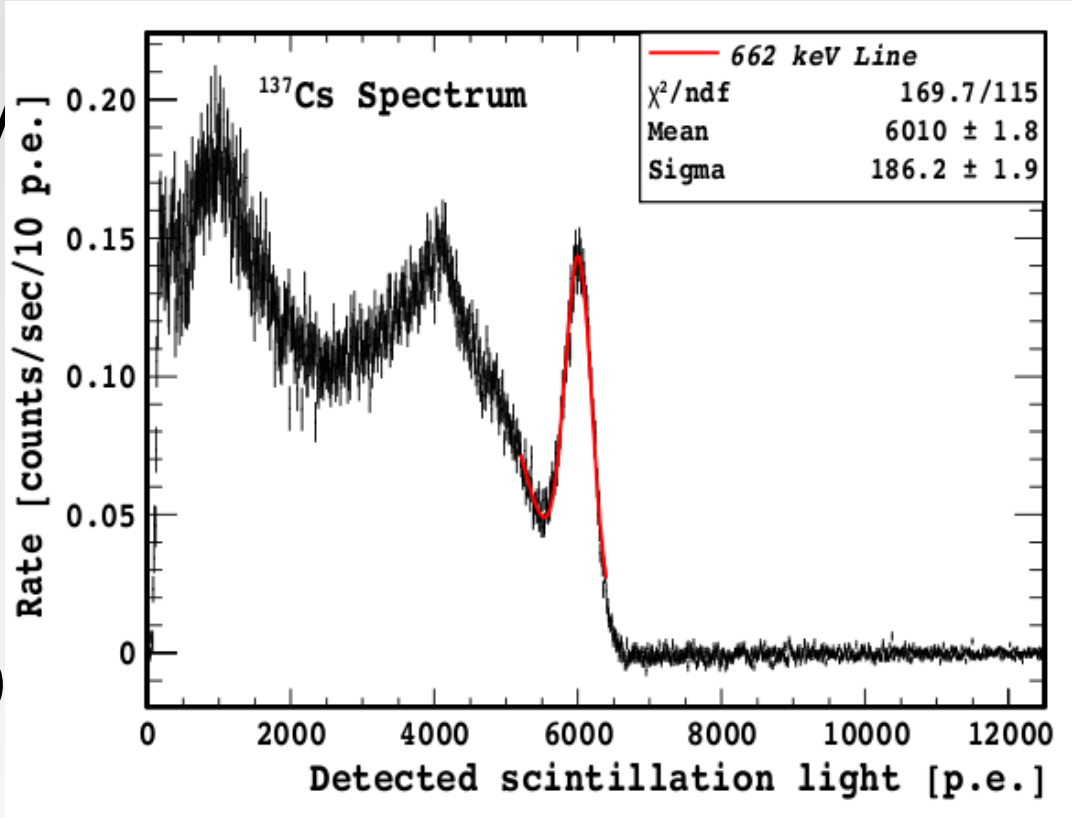
- New to market Hamamatsu 11065 PMTs
- Cryogenic capable
- High quantum efficiency (~35%!)
- Single p.e. spectrum seems to contain exponential component



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

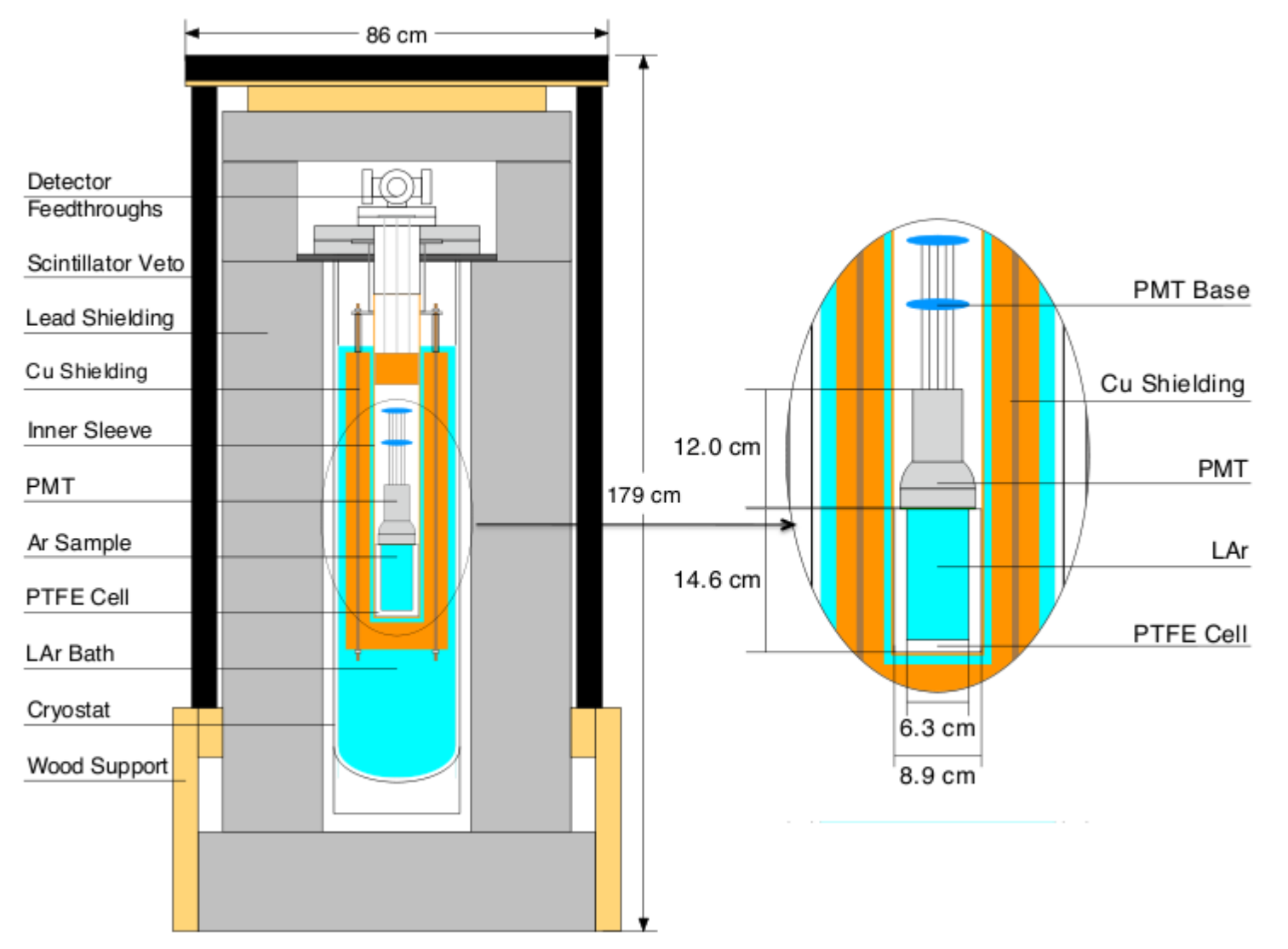


arxiv:1204.6218

Underground argon

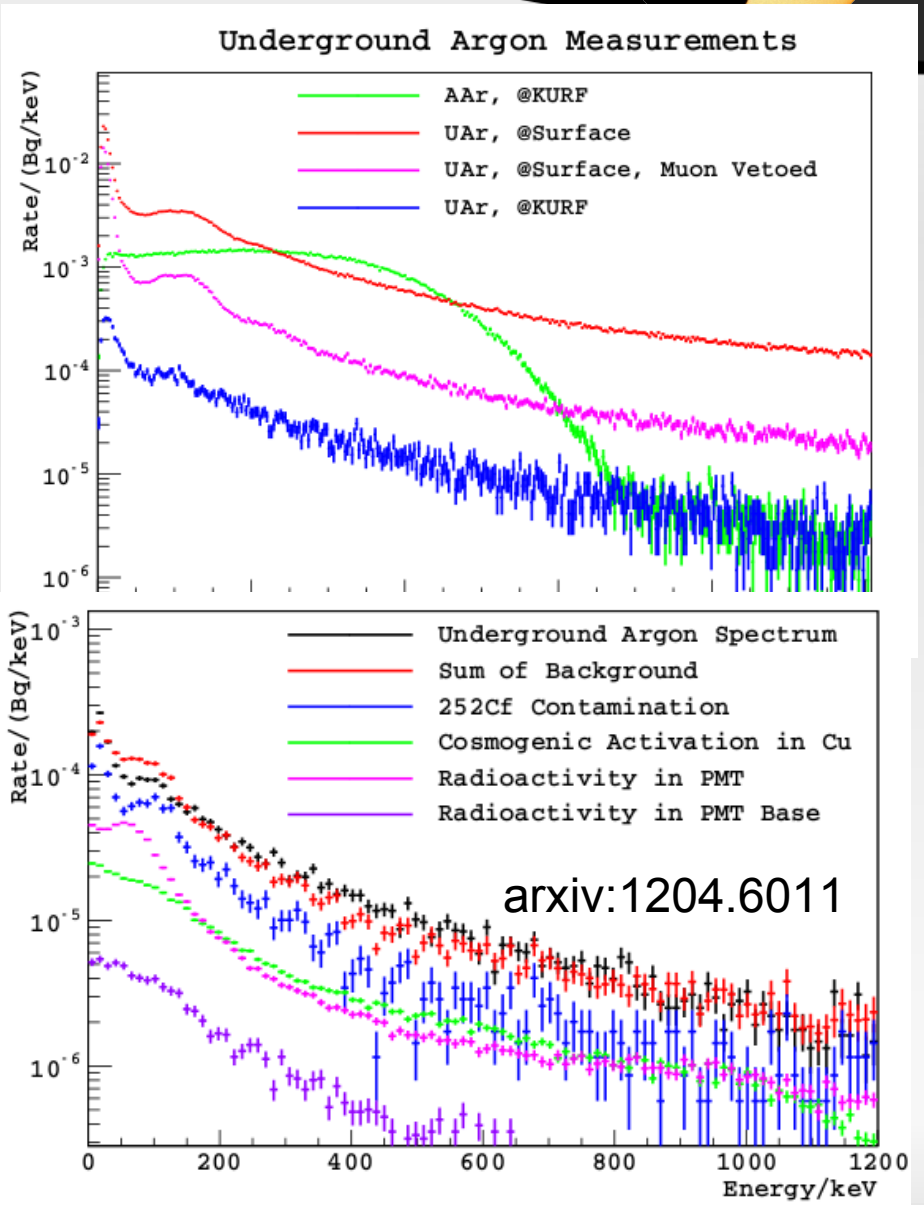
- Atmoshperic argon contains Ar-39, which undergoes beta decay with Q=565 keV, half-life 269 y, at ~1 Bq/kg natural argon
- TPCs limited at ton scale by pileup
- Ar-39 is produced by cosmic rays in the upper atmosphere, so underground argon might have reduced Ar-39 content
- But it can be produced by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

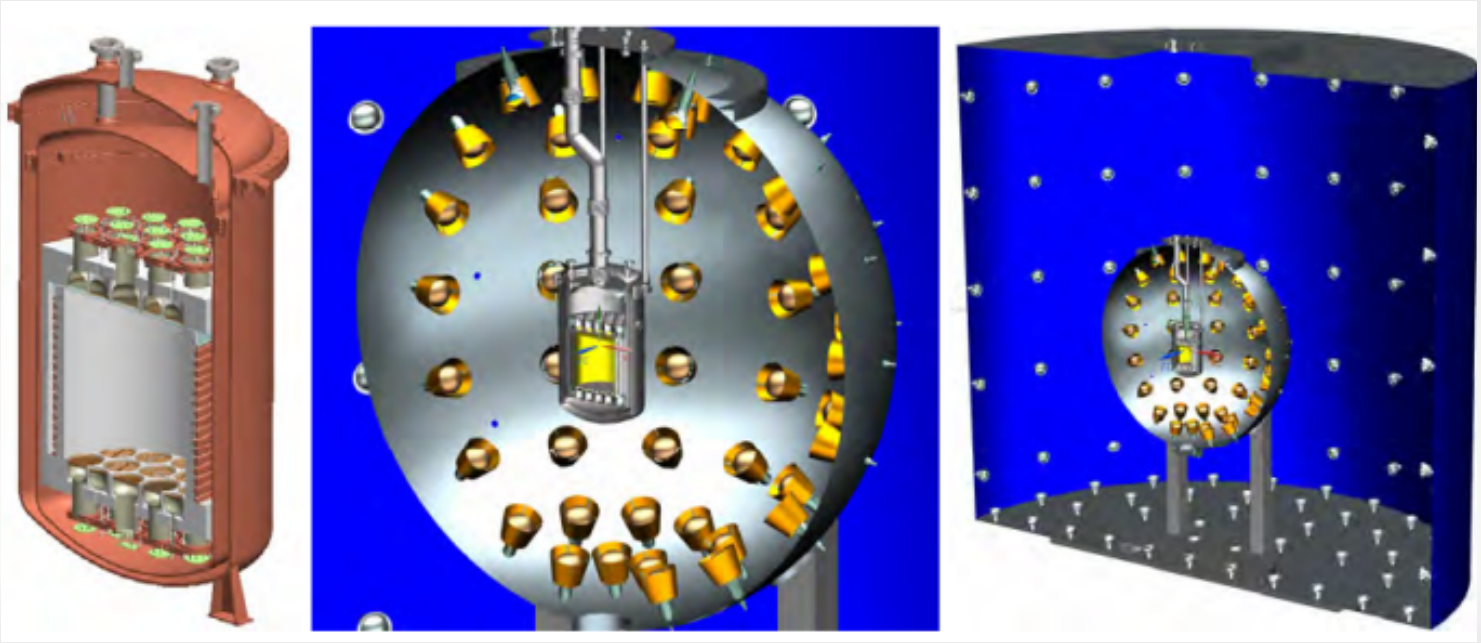
Underground argon extraction

- 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

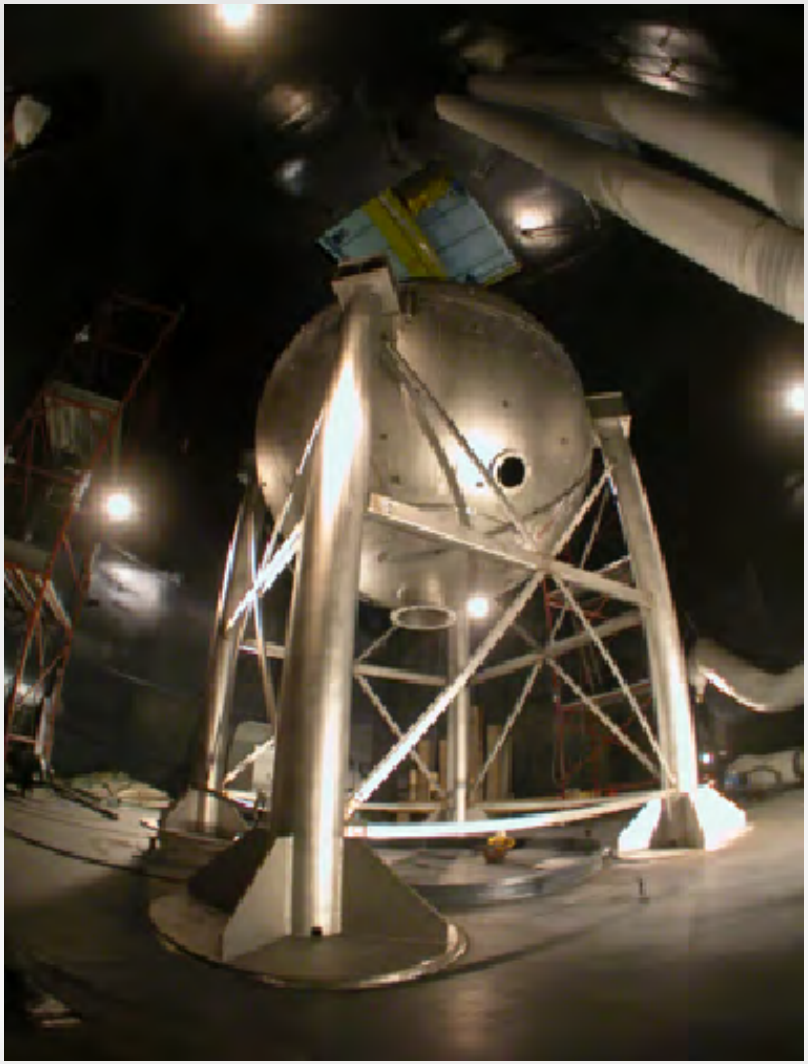
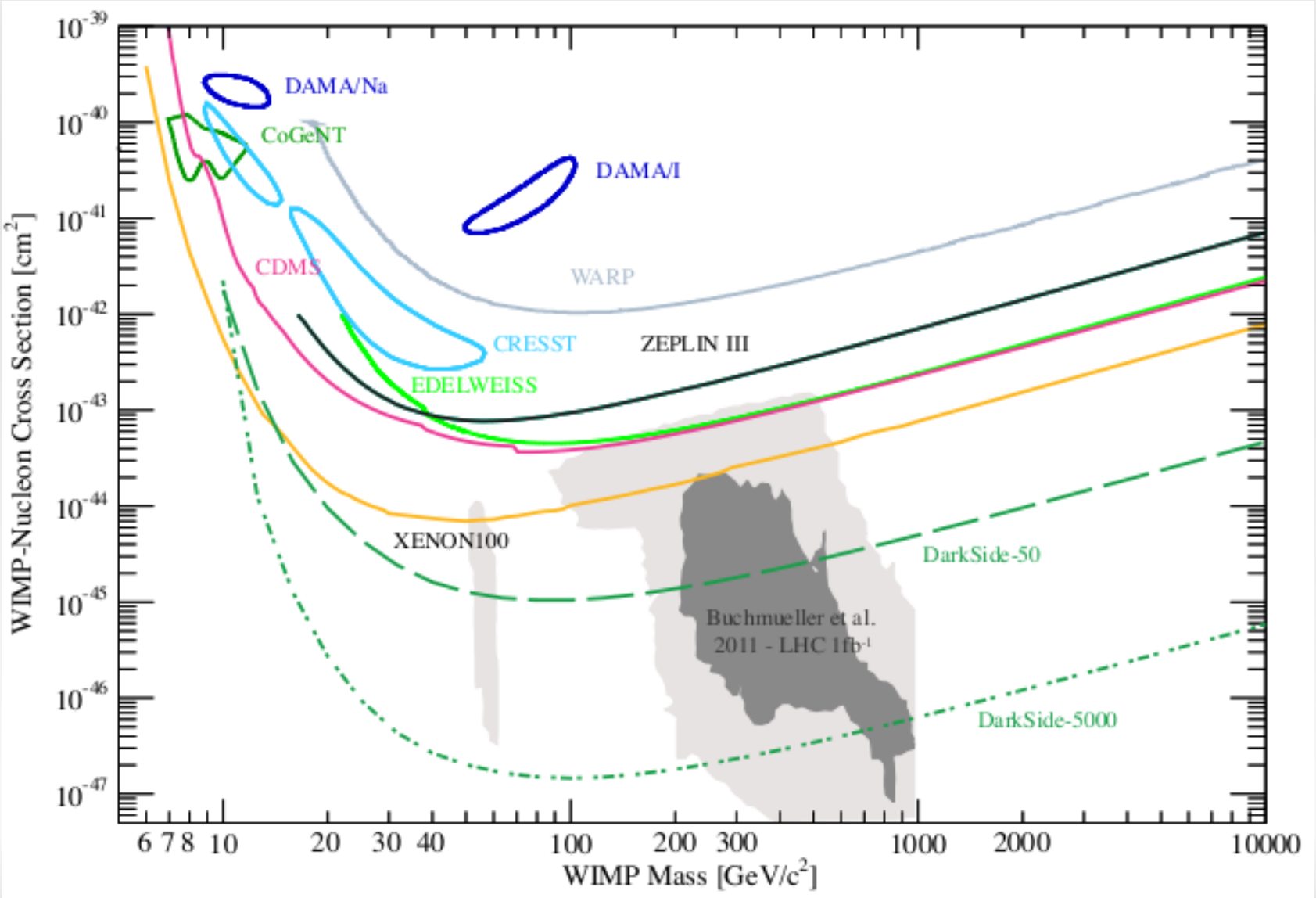
DarkSide-50: Coming soon to LNGS

- 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 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