DPF2015

Ann Arbor, MI

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Status and Results of DarkSide-50

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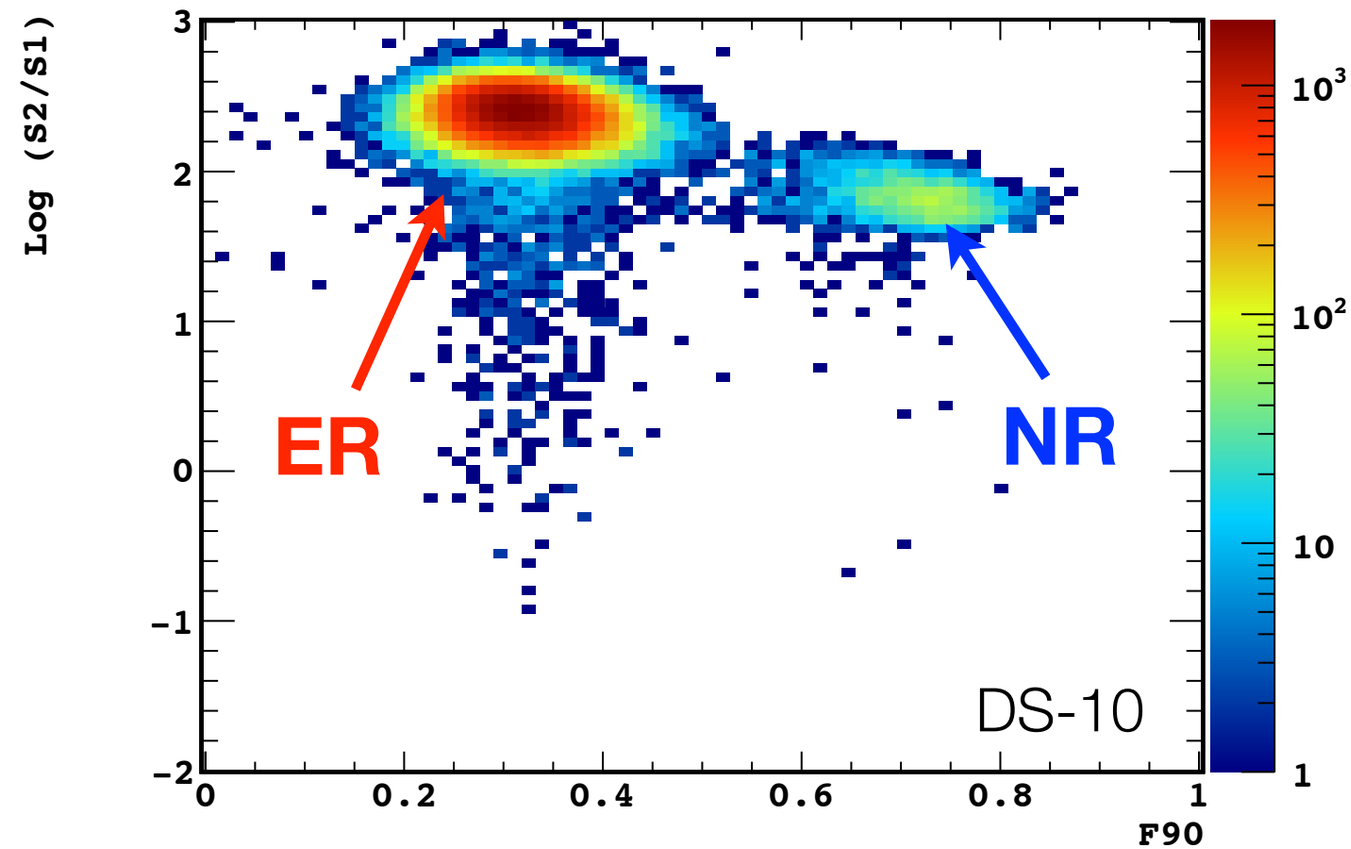
(for the DarkSide collaboration)

The DarkSide Program

- WIMP dark matter search using **direct detection**
- Dual-phase **Liquid Argon** Time Projection Chamber (LArTPC)
- Multi-stage approach
- Ultra **low background**
  - Deep underground at LNGS
  - Low-background materials, including Ar target
- Powerful **background rejection**
  - Pulse Shape Discrimination (PSD)
  - Ionization/Scintillation ratio (S2/S1)
  - Surface rejection using 3D position reconstruction
- Active neutron and muon **vetoes**
  - In situ background measurement

Why Argon?

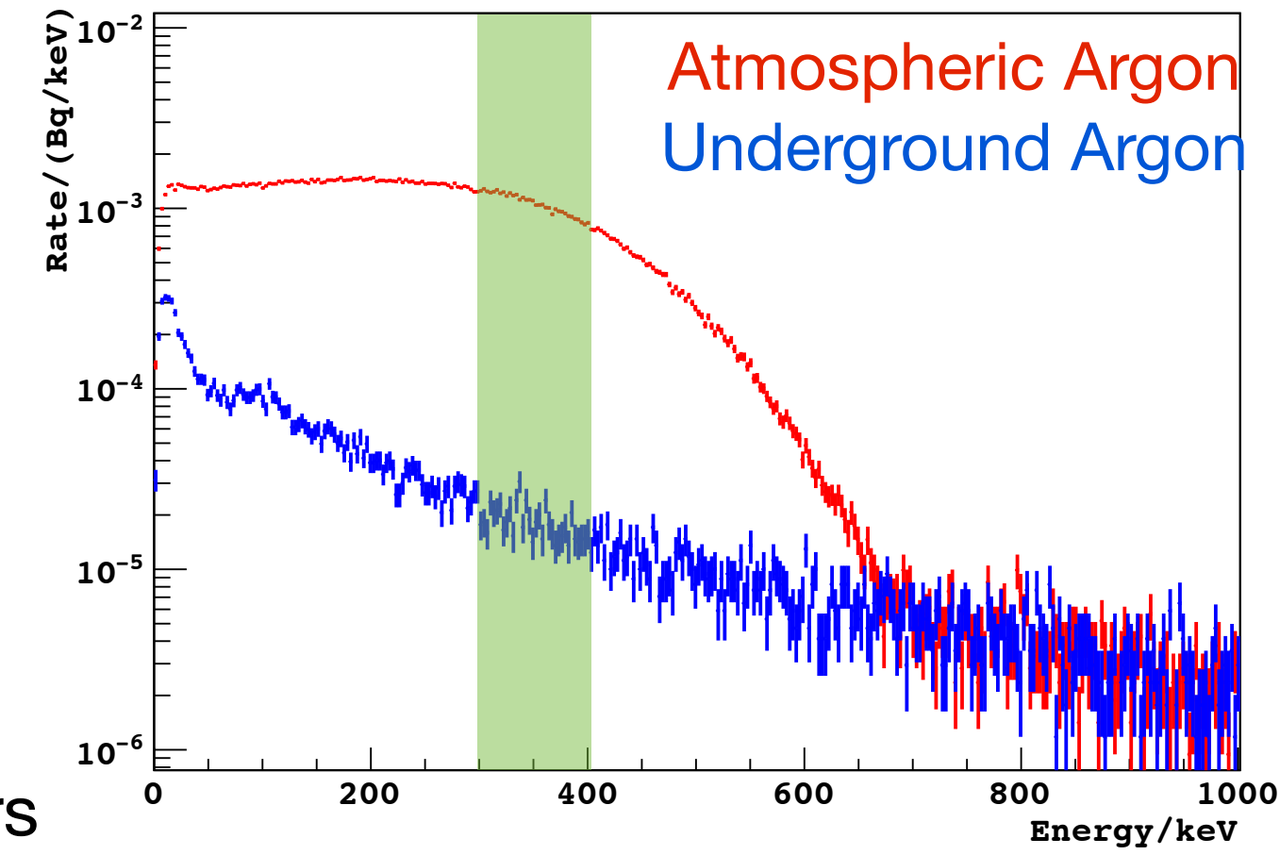
- Relatively **dense**
- Easy to **purify**
- High **ionization**
  - High electron mobility
  - Low diffusion
- High **scintillation** yield
  - ~40k photons/MeV
  - Transparent to its own scintillation light
- Exceptional **discrimination power**
  - PSD
  - S2/S1



Main challenge:
^{39}Ar contamination

Underground Argon

- **Atmospheric argon:**
  high concentration of ^{39}Ar
  - beta decay (269 yr half life)
  - cosmogenically activated
  - 565 keV endpoint
- **Underground argon:**
  significantly reduced ^{39}Ar activity
  - allows to scale to large detectors



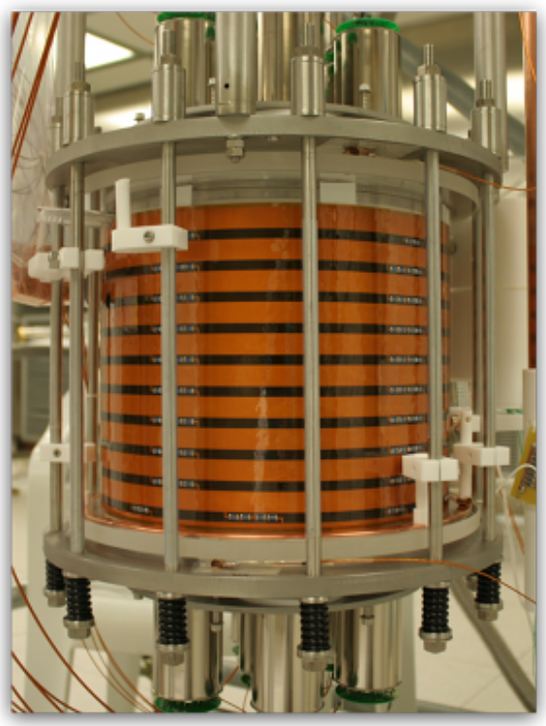
First limit on UAr activity measured in small TPC underground at KURF in 2009

	Total rate (mBq/100keV)	Background rate (mBq/100keV)	BG-subtracted rate (mBq/100keV)
Atmospheric Ar	108.8 +/- 0.4	1.54 +/- 0.22	107.2 +/- 1.9
Underground Ar	1.87 +/- 0.06		0.32 +/- 0.23
Overall reduction	1.71 +/- 0.05 %		<0.65% (95% CL)

J. Xu, et al., Astropart. Phys. 66 (2015) 53.

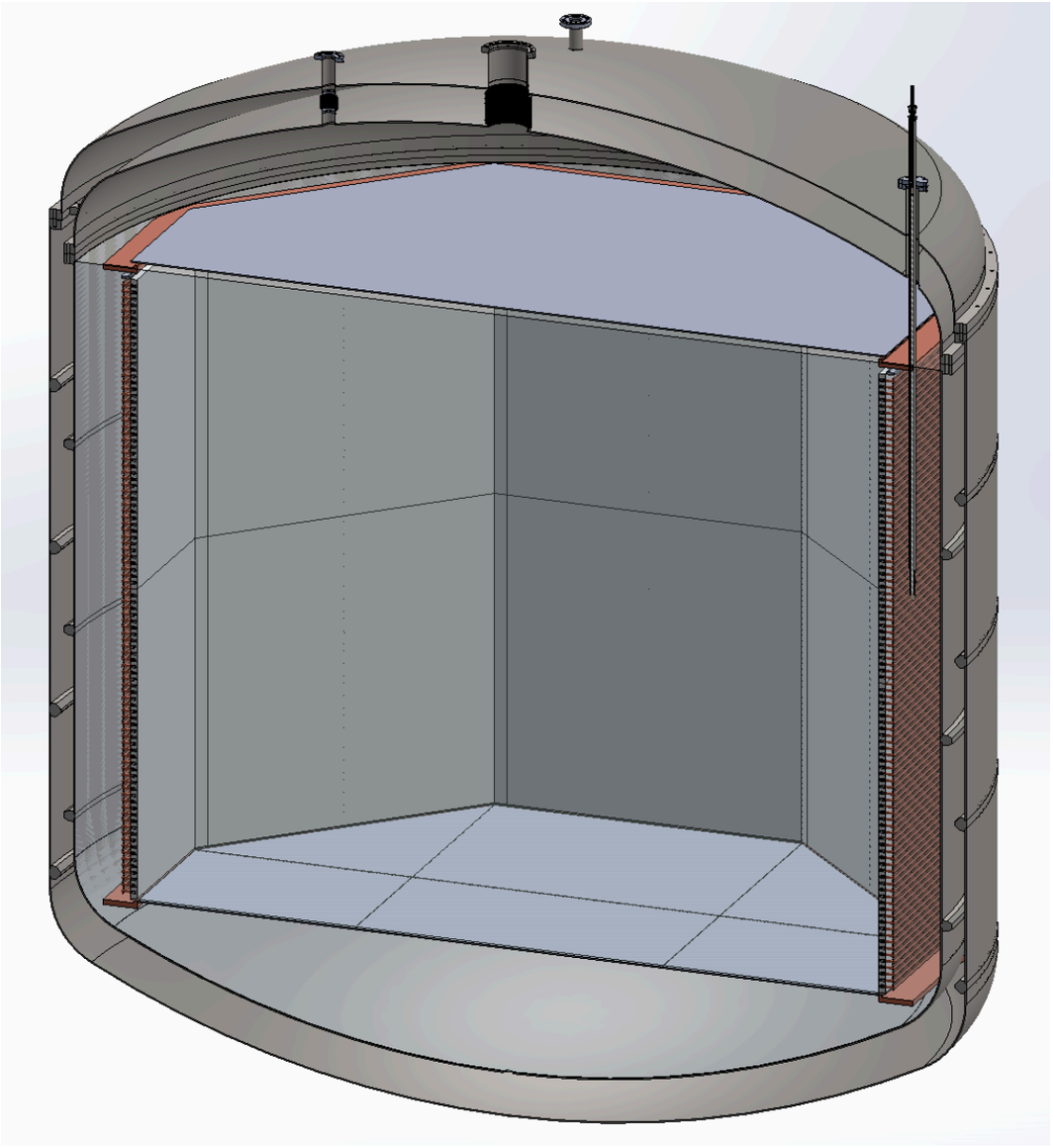
Multi-stage DarkSide program

DarkSide-10
2011-2013

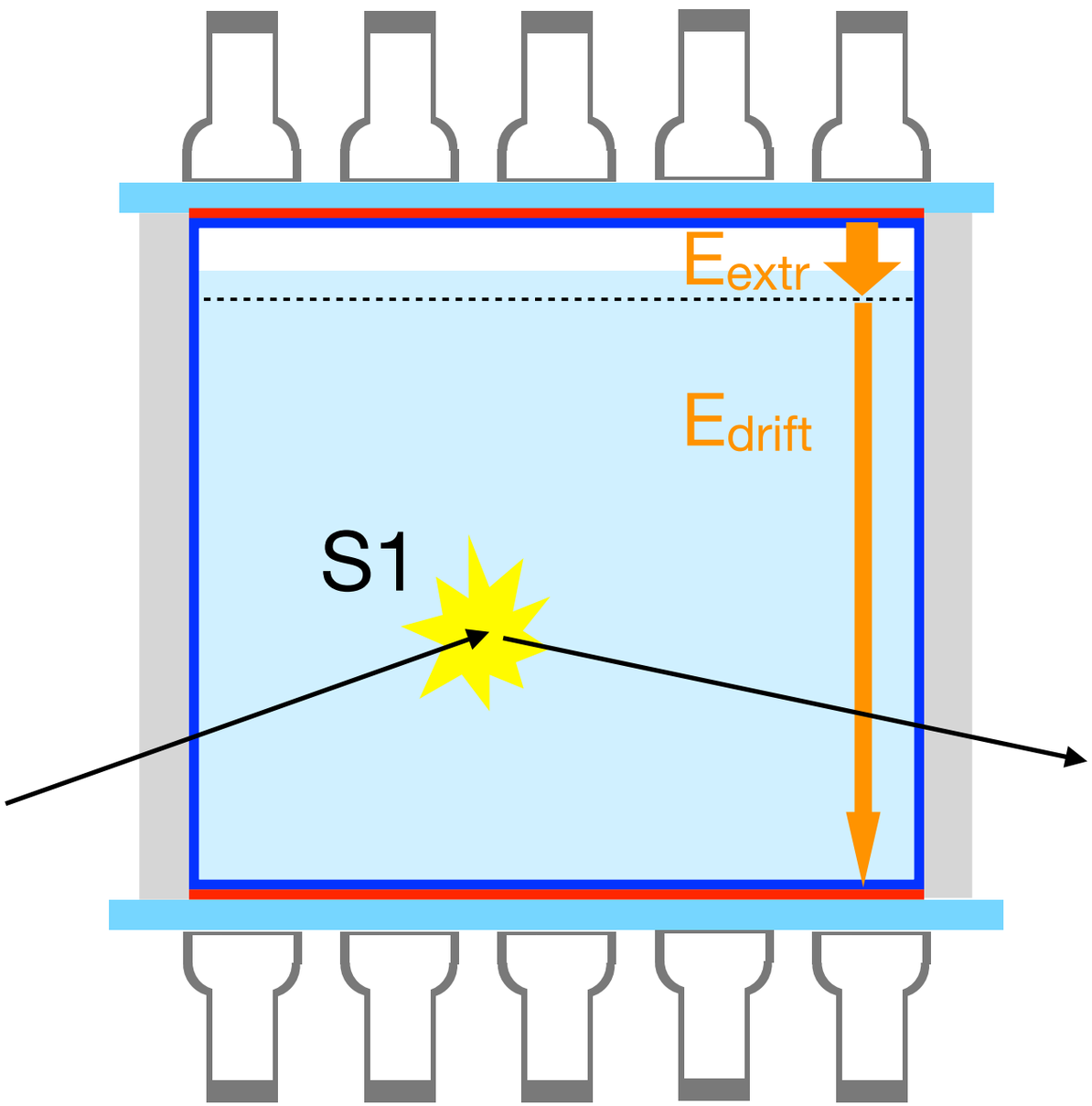


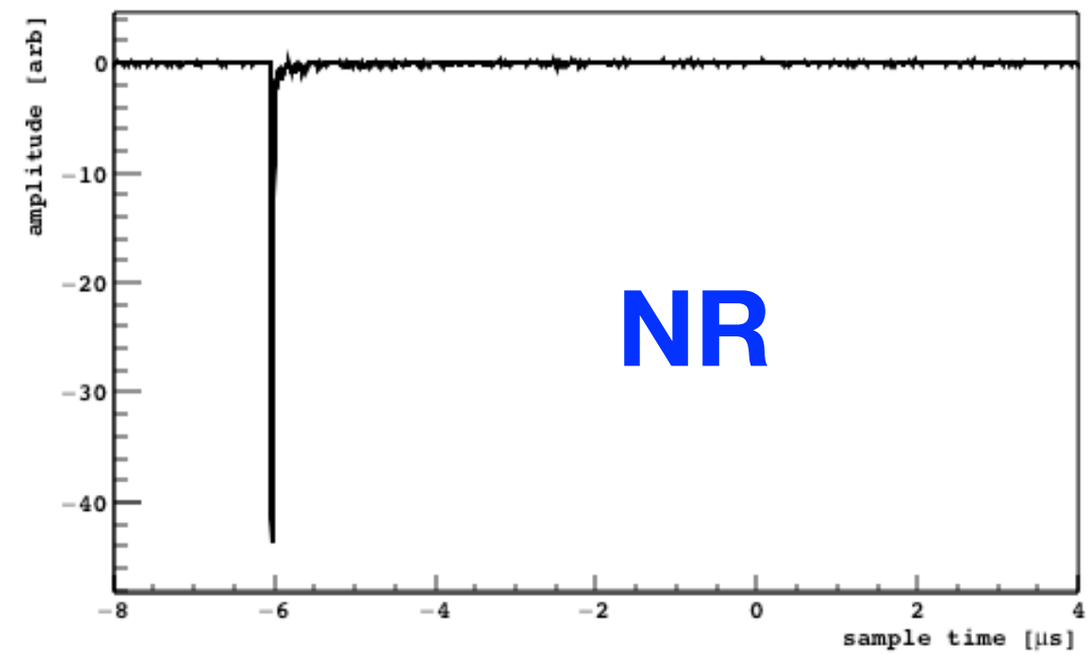
DarkSide-50
2013-201x

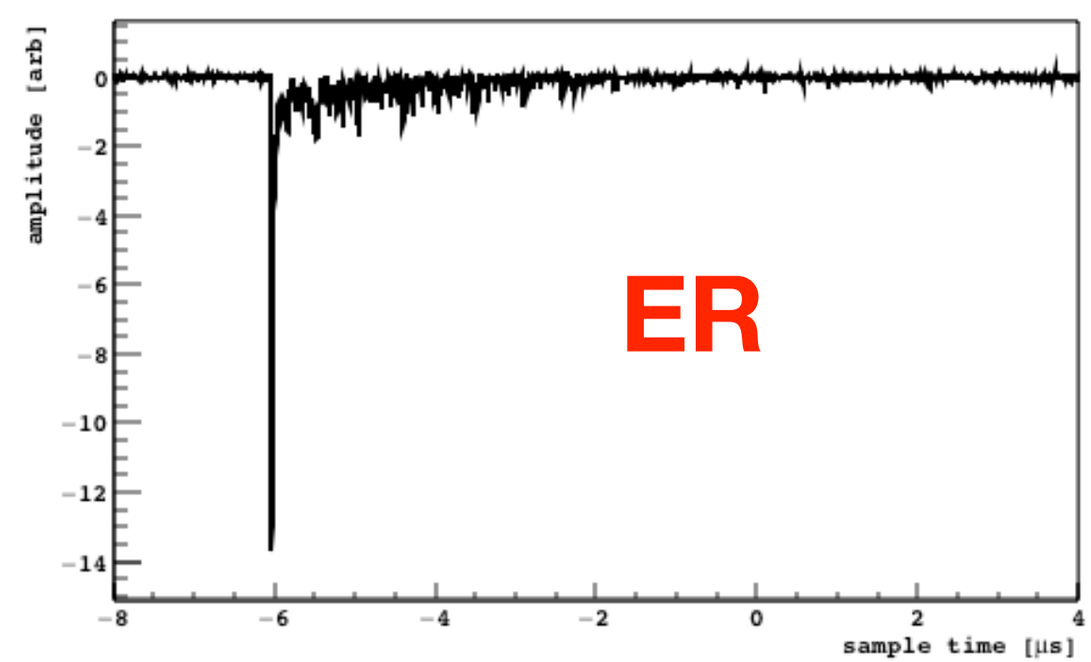
DarkSide multi-ton
201?-20??



Dual-phase LArTPC

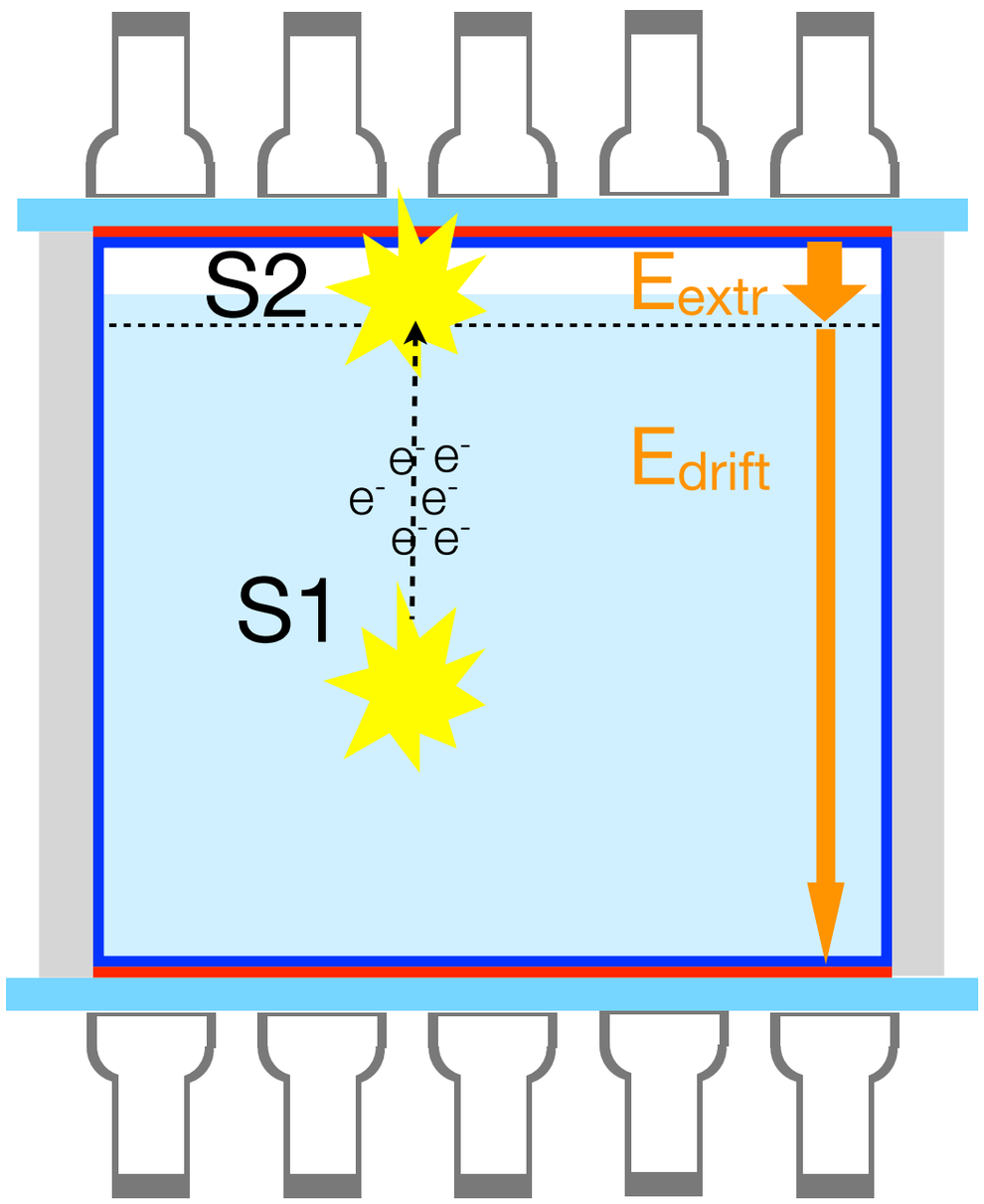


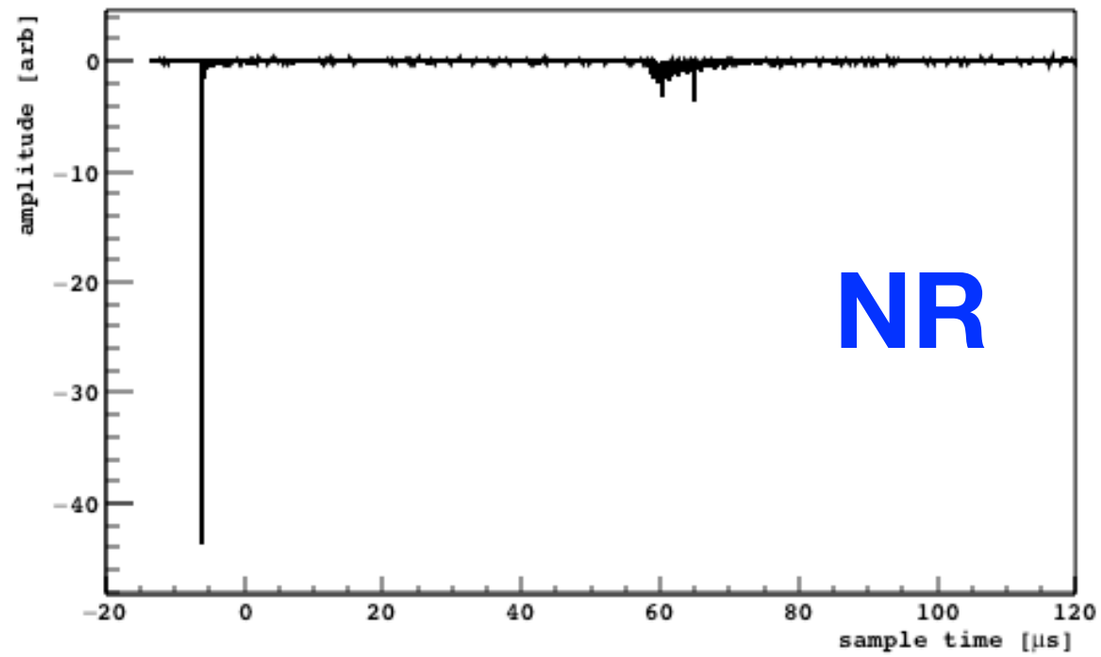


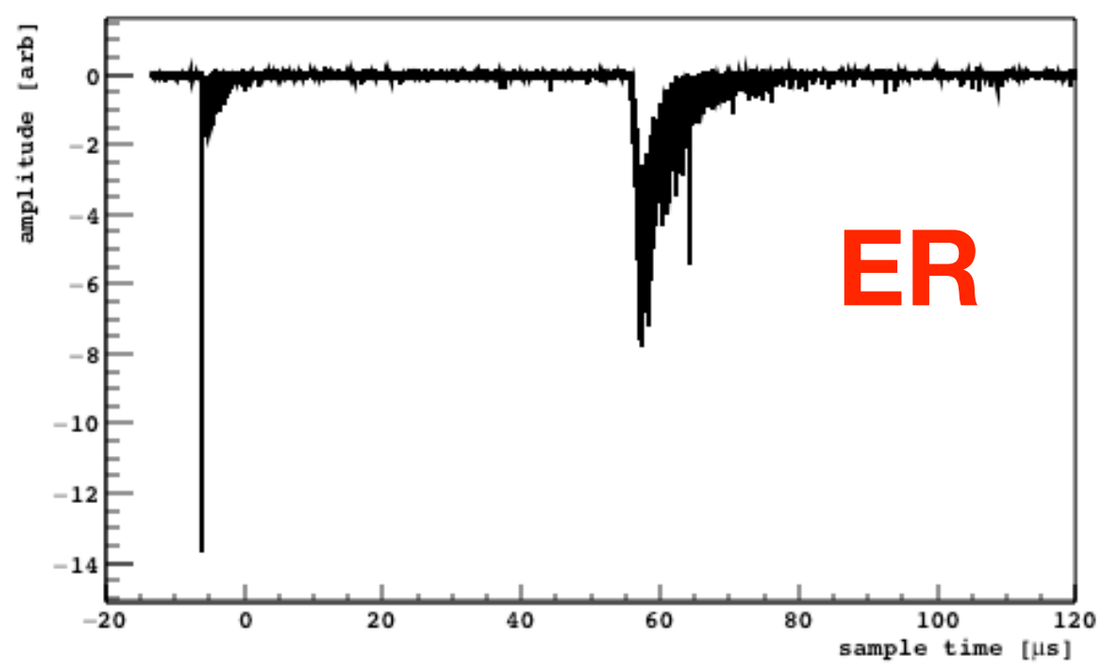


PSD parameter: **F90** = fraction of light in first 90 ns

Dual-phase LArTPC

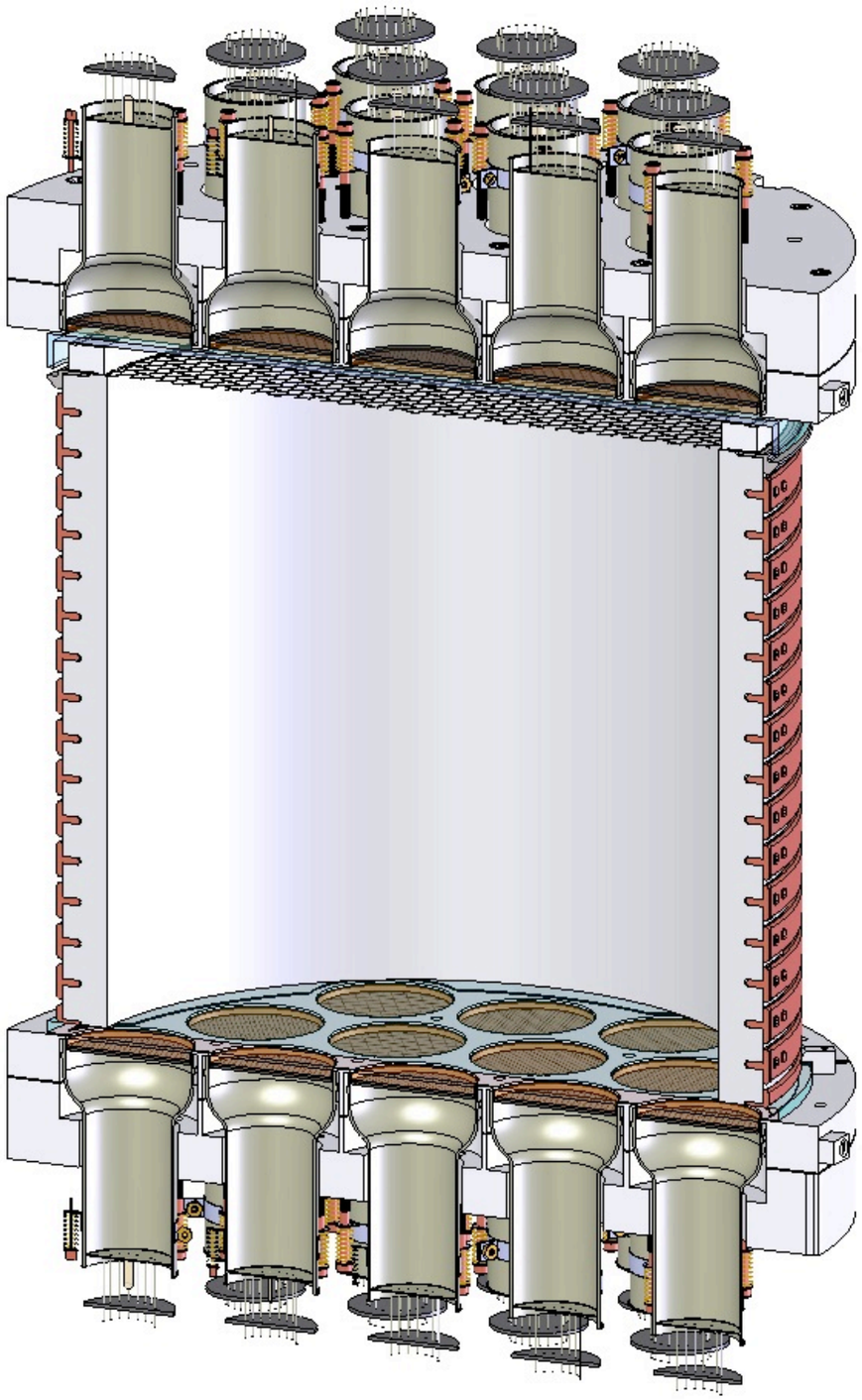






TPC

- **46 kg active** volume
- 36 cm diameter, 36 cm height
- 38 R11065 3” PMTs
- **Cold pre-amps**
- High **reflectivity** PTFE walls
- Fused silica anode and cathode windows
  - Coated with **ITO**
- All inner surfaces coated with **TPB**
- 0.2 kV/cm drift, 2.8 kV/cm extraction



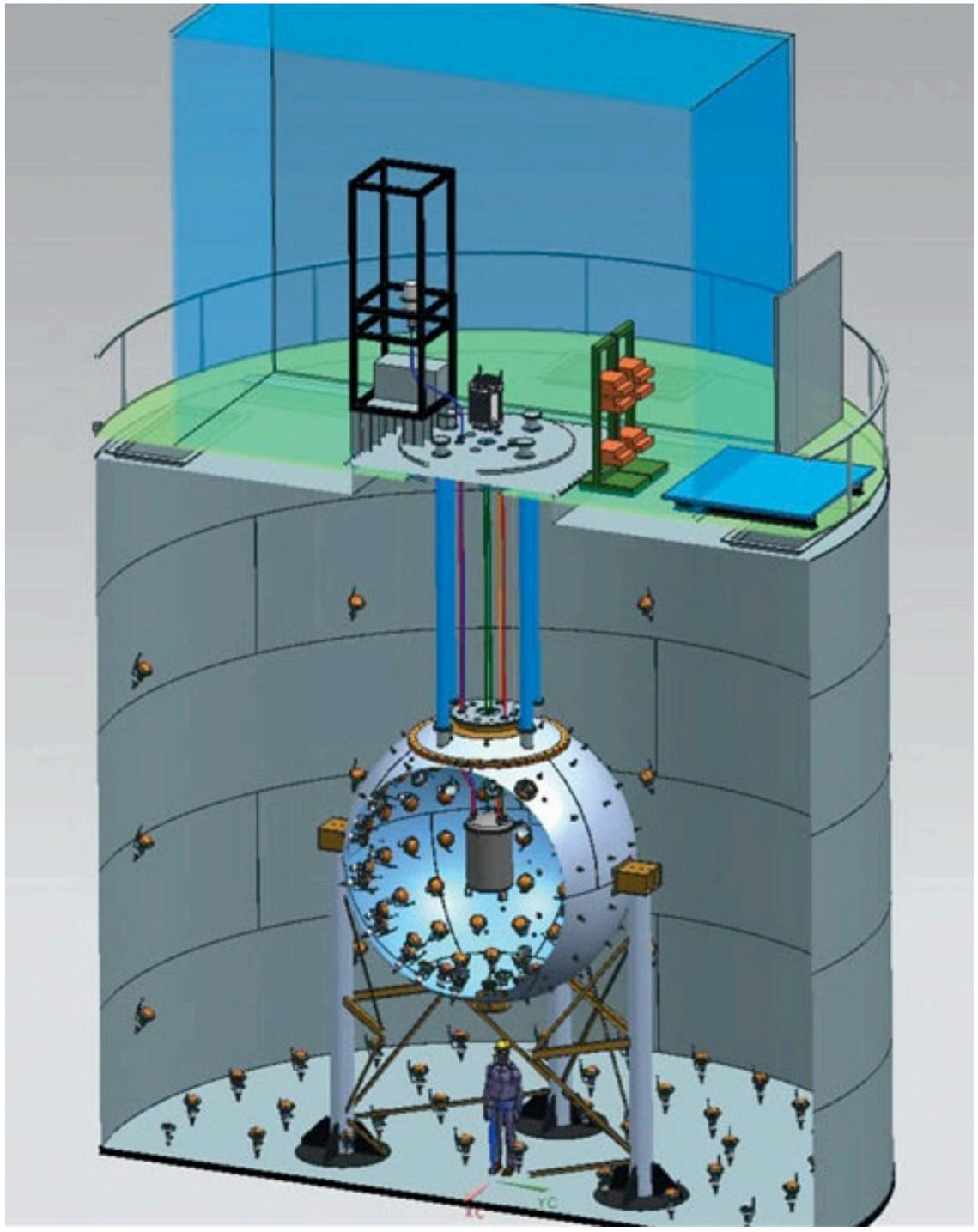
Vetoes

Liquid Scintillator Veto

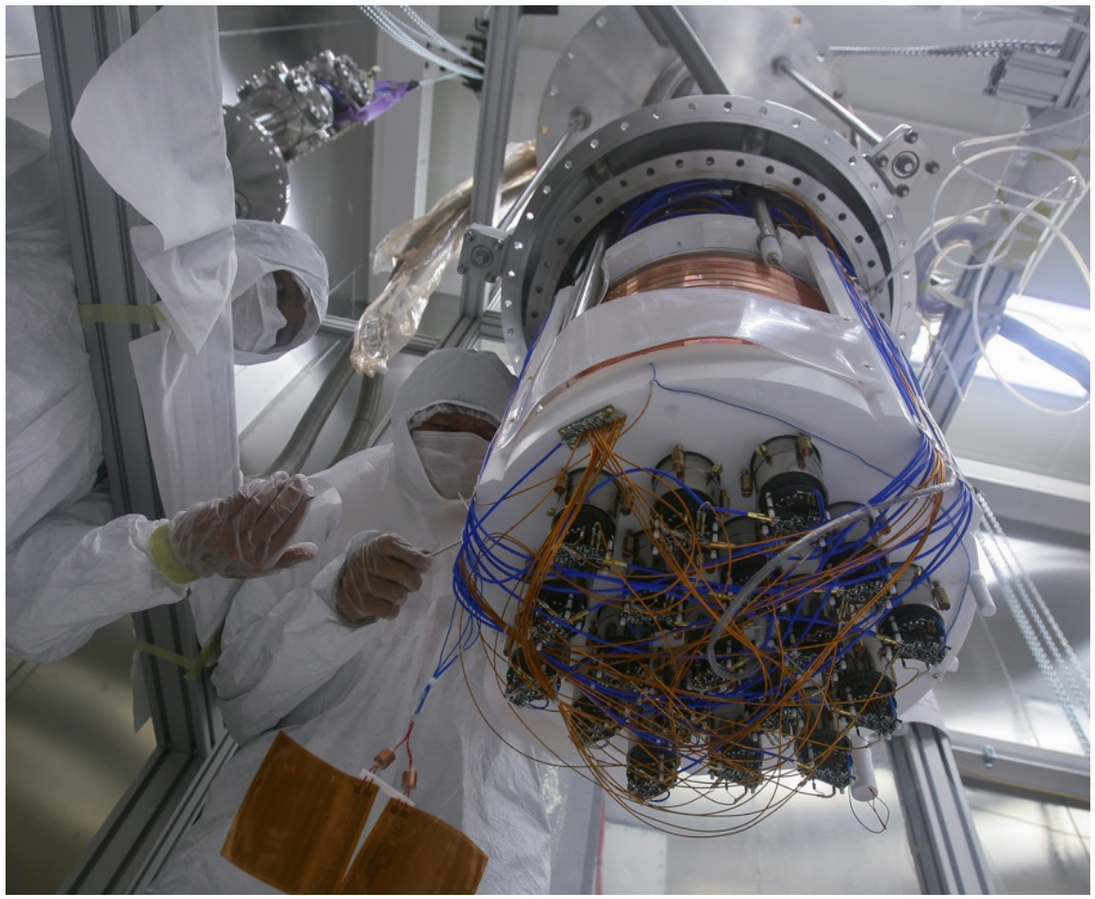
- 4 m diameter sphere
- Boron-loaded: PC + TMB
- 110 8” PMTs
- Active neutron veto
  - tag neutrons in TPC
  - in situ measurement of neutron BG
- Neutron and gamma shielding

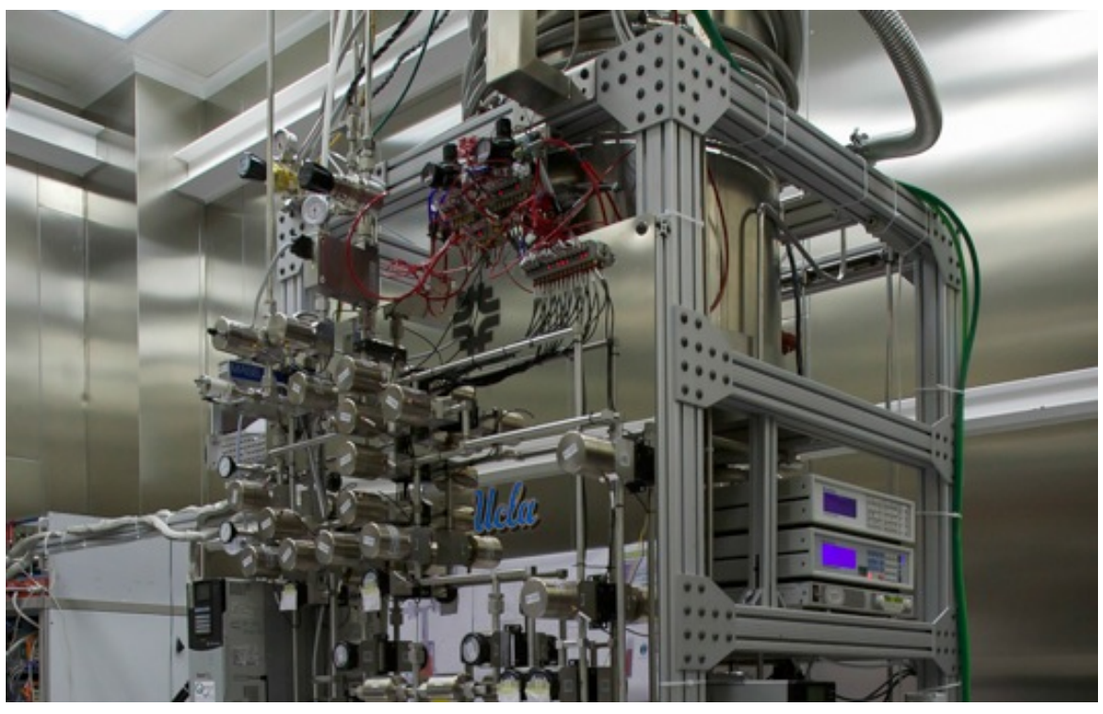
Water Tank

- 11 m diameter x 10 m high
- Existing Borexino CTF tank
- 80 PMTs
- Active muon veto
  - tag cosmogenic neutrons
- Neutron and gamma shielding



DarkSide-50



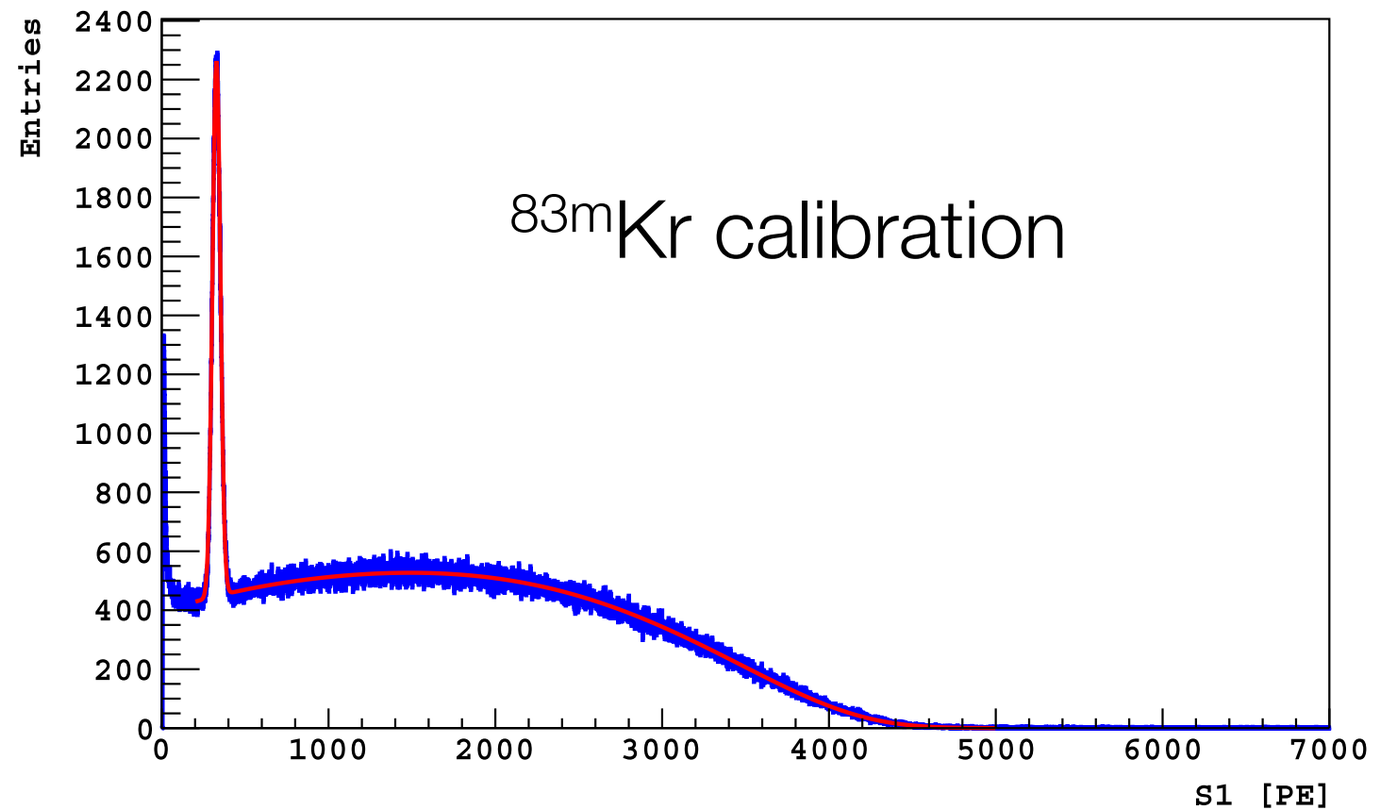


Atmospheric argon campaign

- **47.1 live-days** with AAr

- **~1 Bq/kg of ^{39}Ar**
  1.5 x 10^7 events

- Light yield:
  ~7.9 PE/keV at null field,
  ~7.0 PE/keV at 200 V/cm



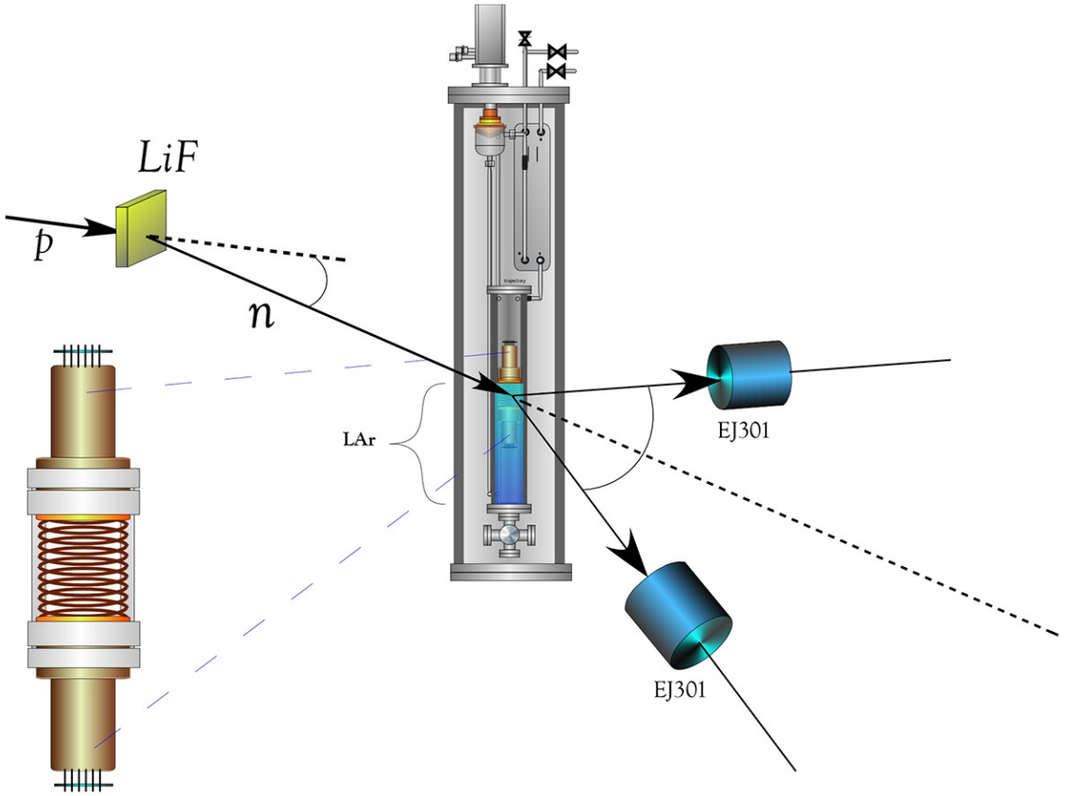
- **Electron drift lifetime >5000 μs**
  Compare to 375 μs max. drift time

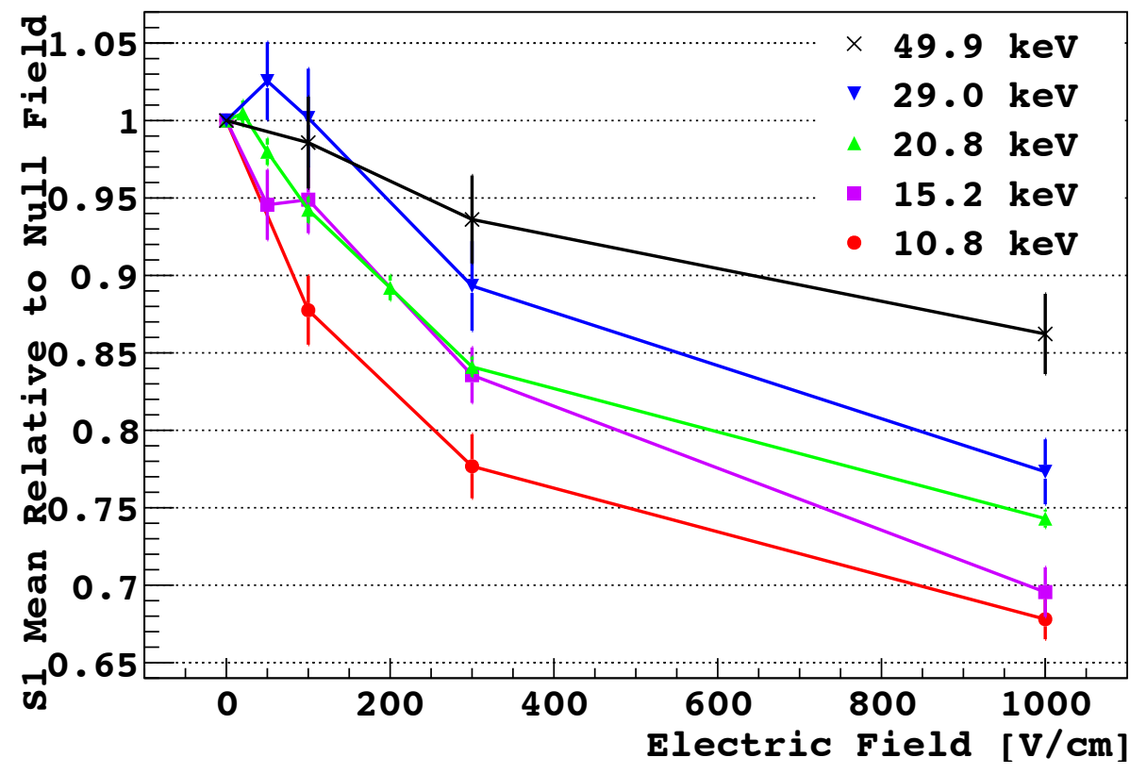
- Reduced veto performance due to high ^{14}C content in TMB
  Have since replaced with far cleaner TMB

Nuclear recoil calibration

SCENE

Scintillation Efficiency of Nuclear Recoils in Noble Elements





LArTPC exposed to bunched **low energy neutron beam**

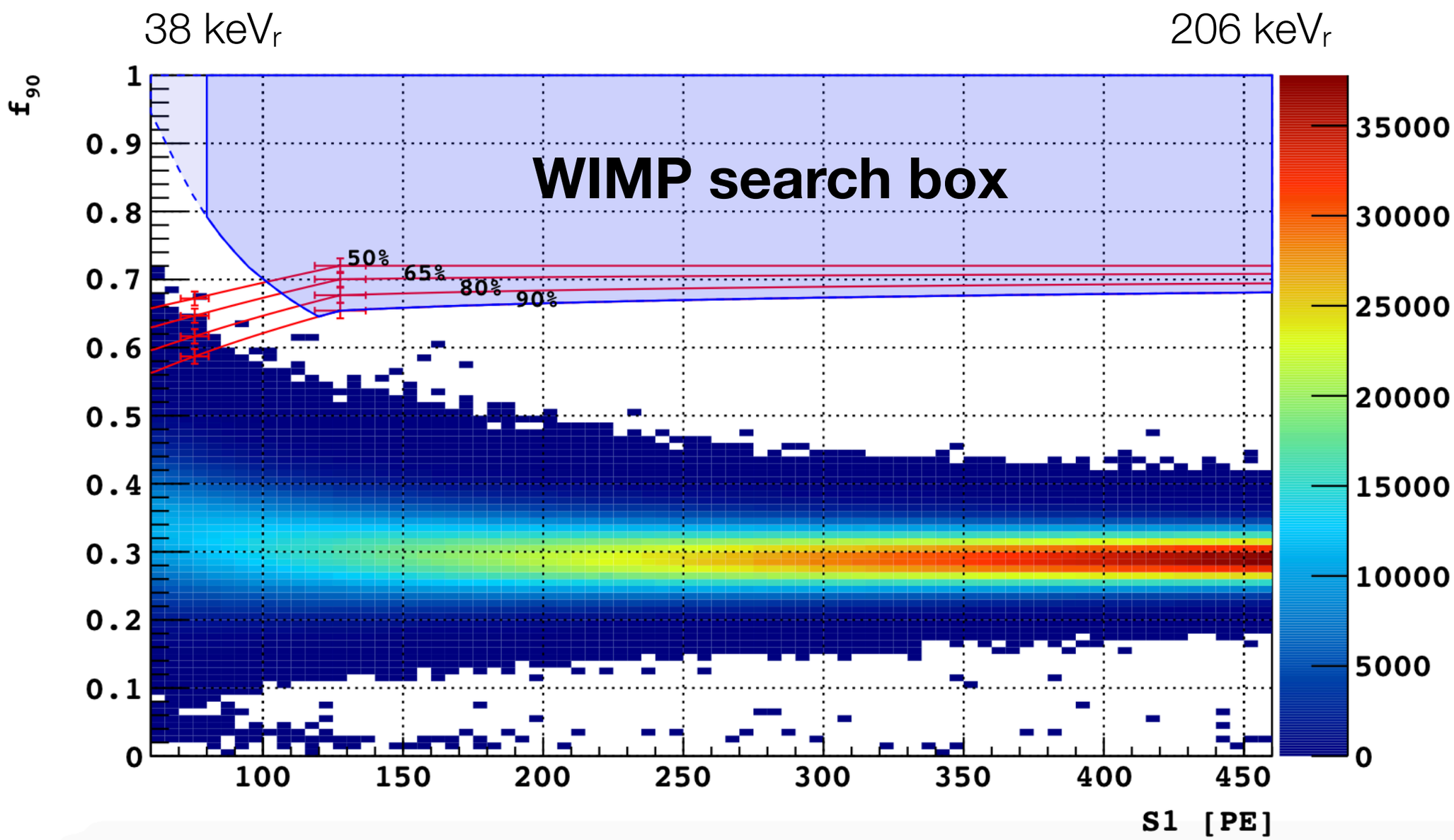
Extremely **pure sample of single nuclear recoils**

Extrapolate NR energy scale and F90 response from SCENE to DS50

First results (using atmospheric argon)

1422 ± 67 kg-day exposure

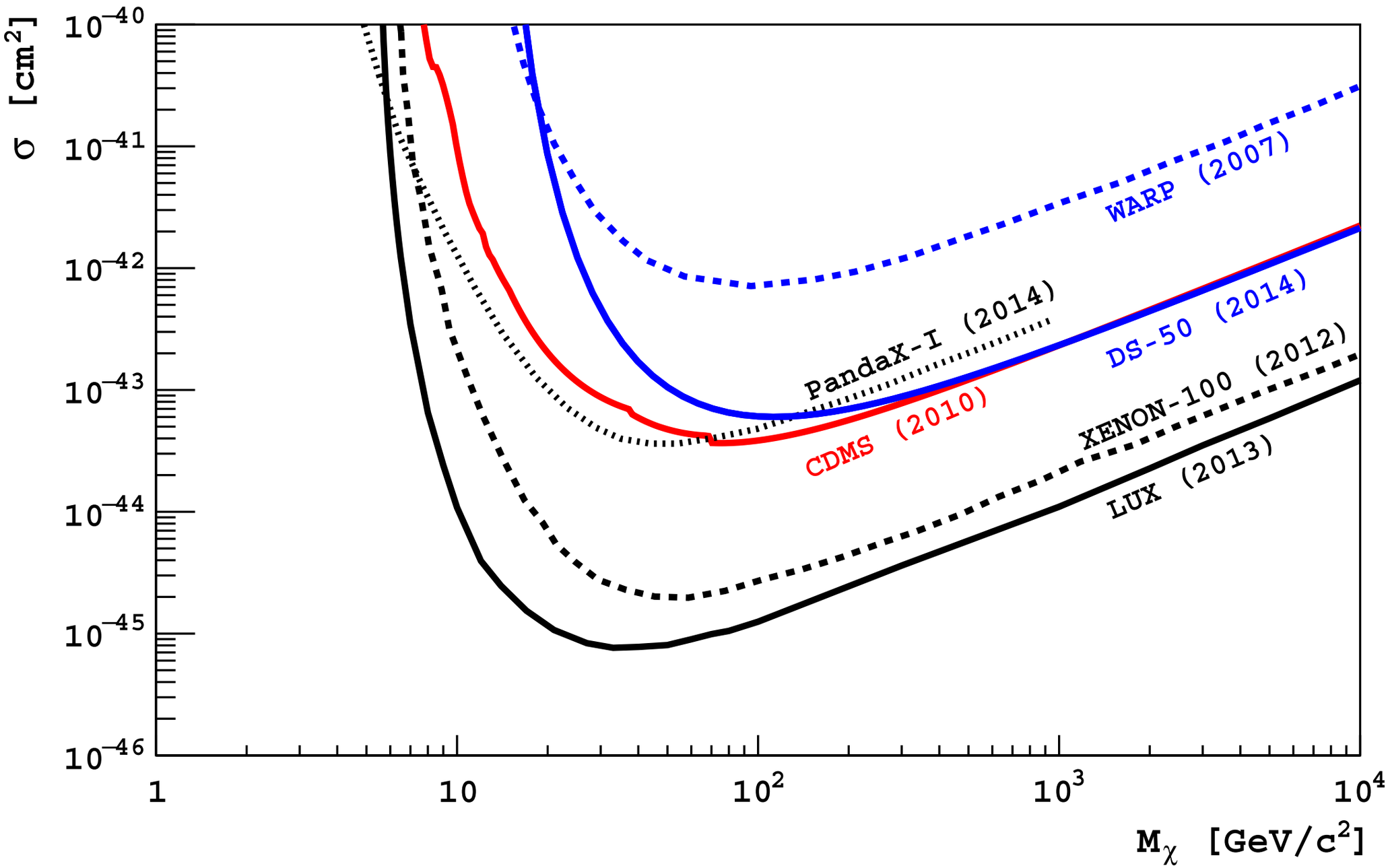
Expected ^{39}Ar leakage: <0.1 evt



Corresponds to > ~20 yr exposure of DS50 with UAr

WIMP limit

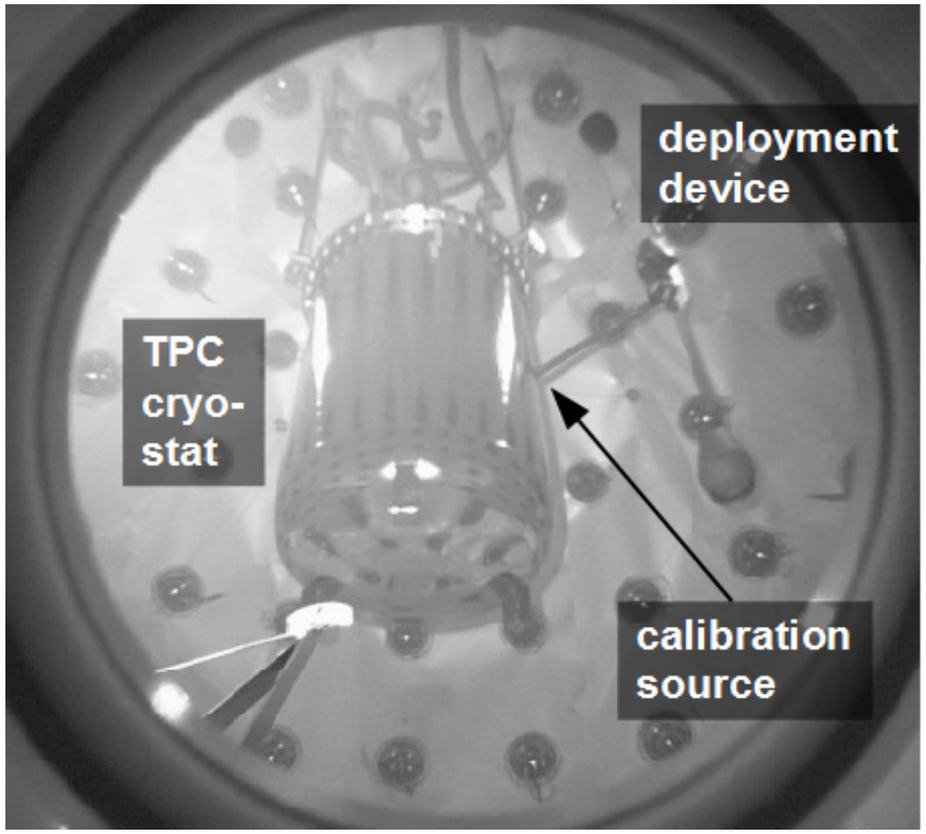
Limit @ 100 GeV/c^2: 6.1 x 10^{-44} cm^2

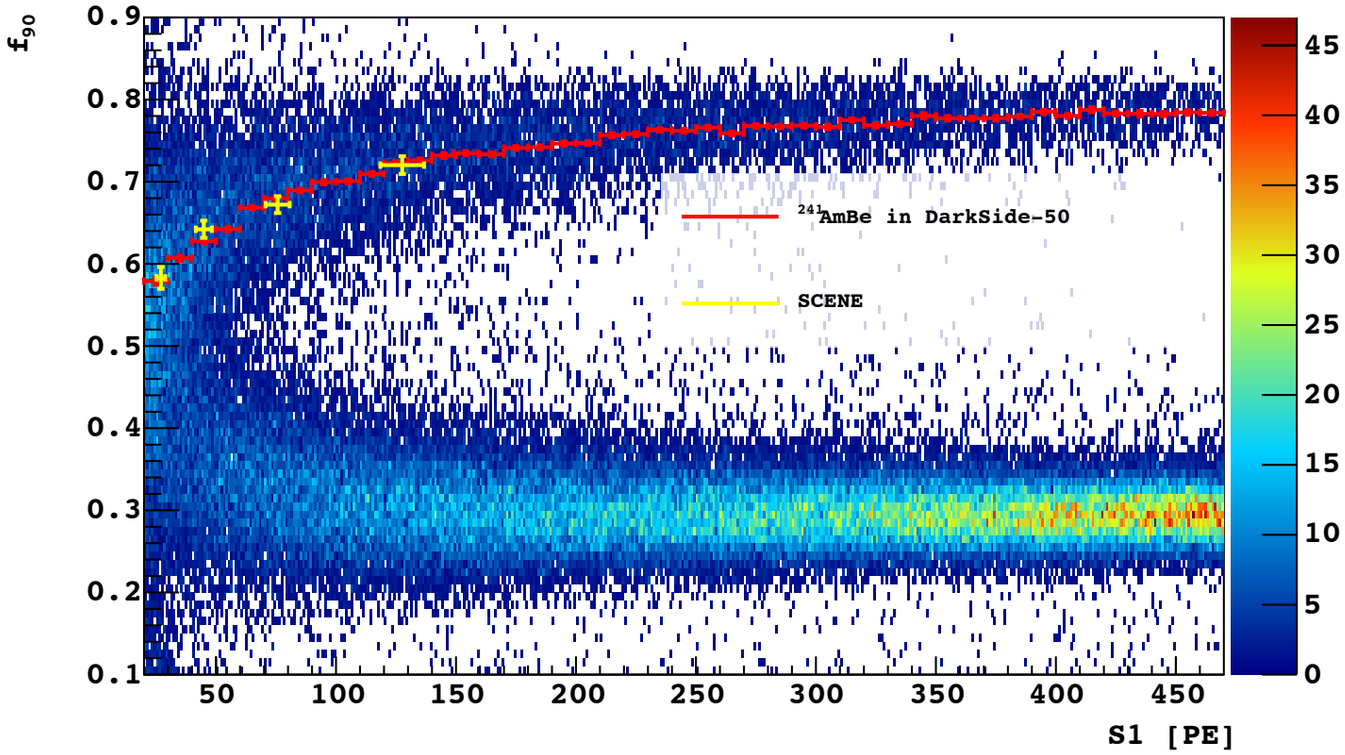


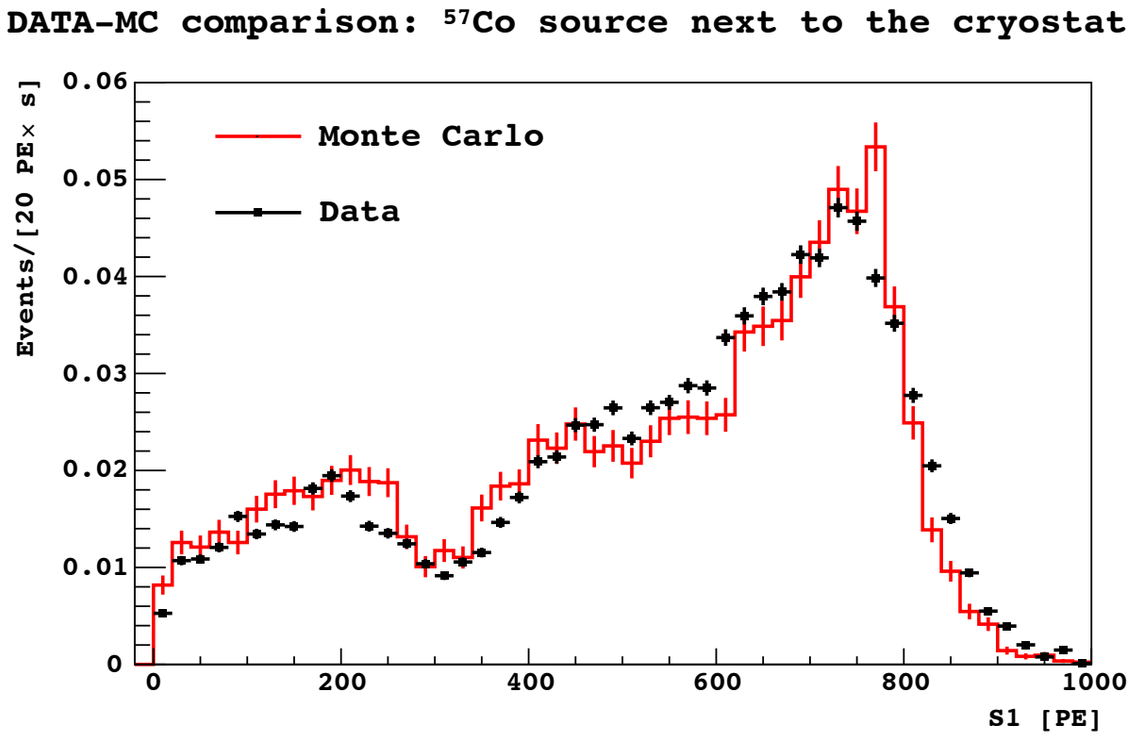
Published: Physics Letters B 743, 456 (2015)

Calibrations

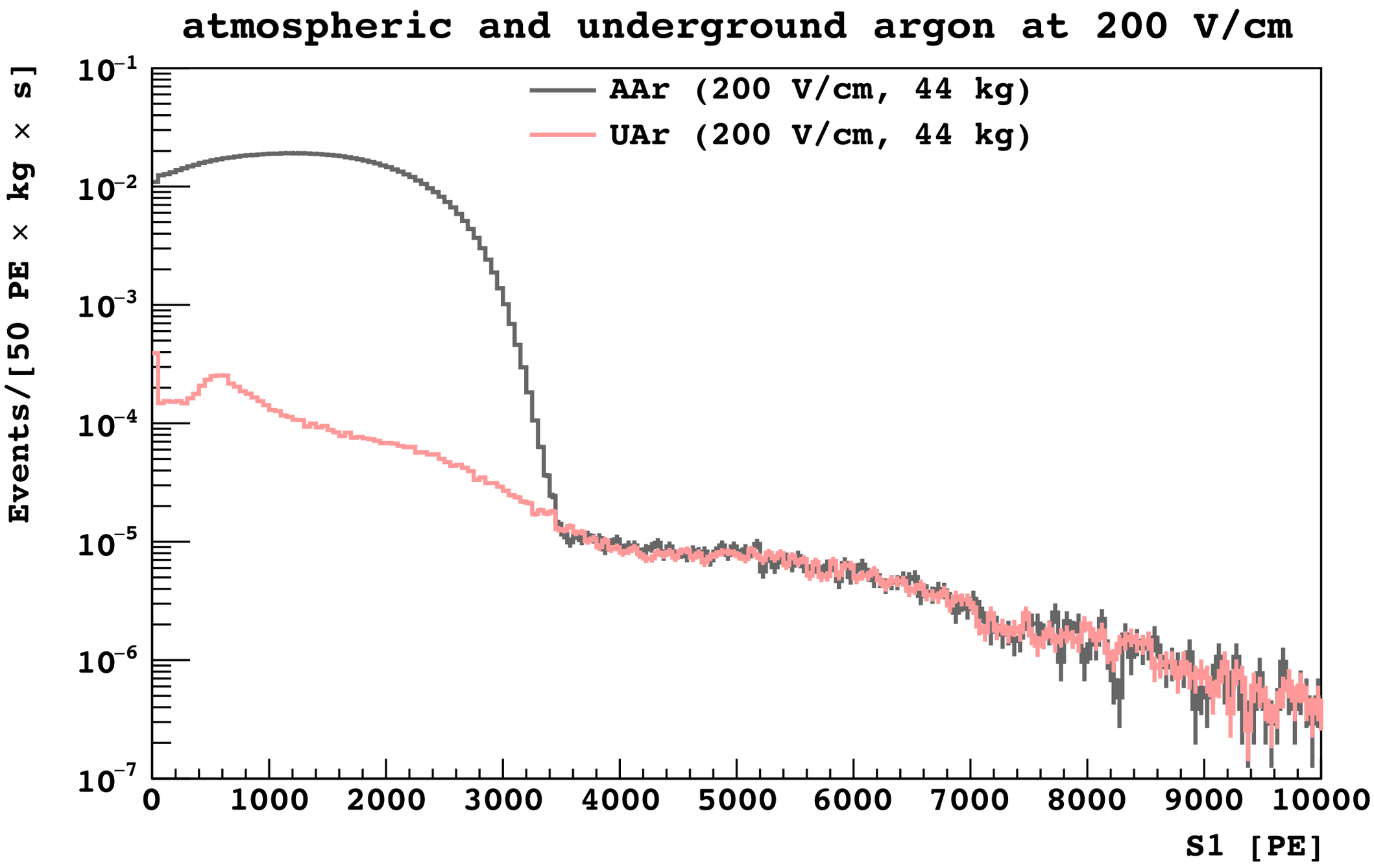
- CALIS deployed Sept 2014
- Calibration campaigns
  Oct - Dec 2014 and Jan - Feb 2015
- **Validate NR band** extrapolated from SCENE for first paper
- **Tuned MC**





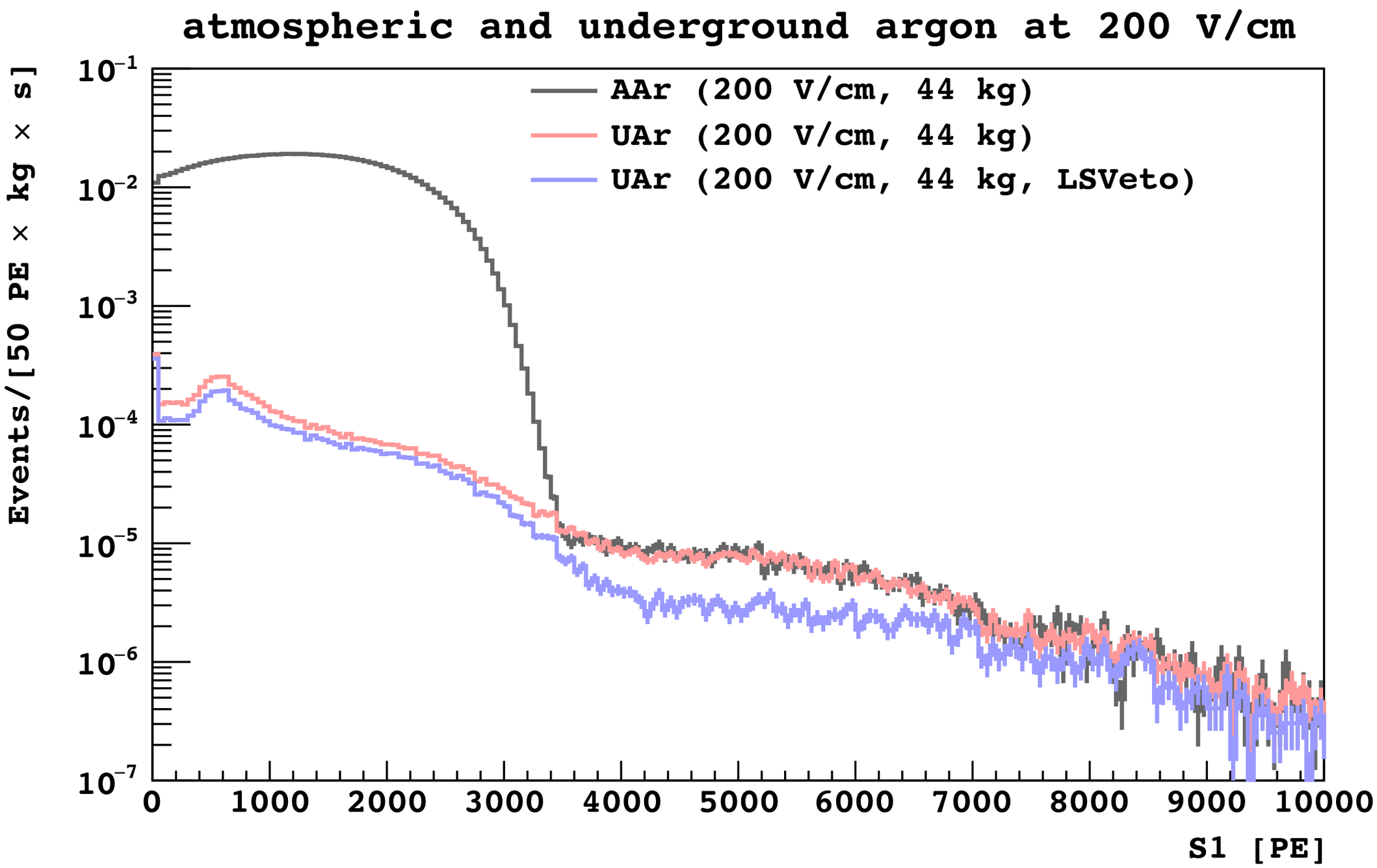


Underground argon



Normalized by live time

Underground argon



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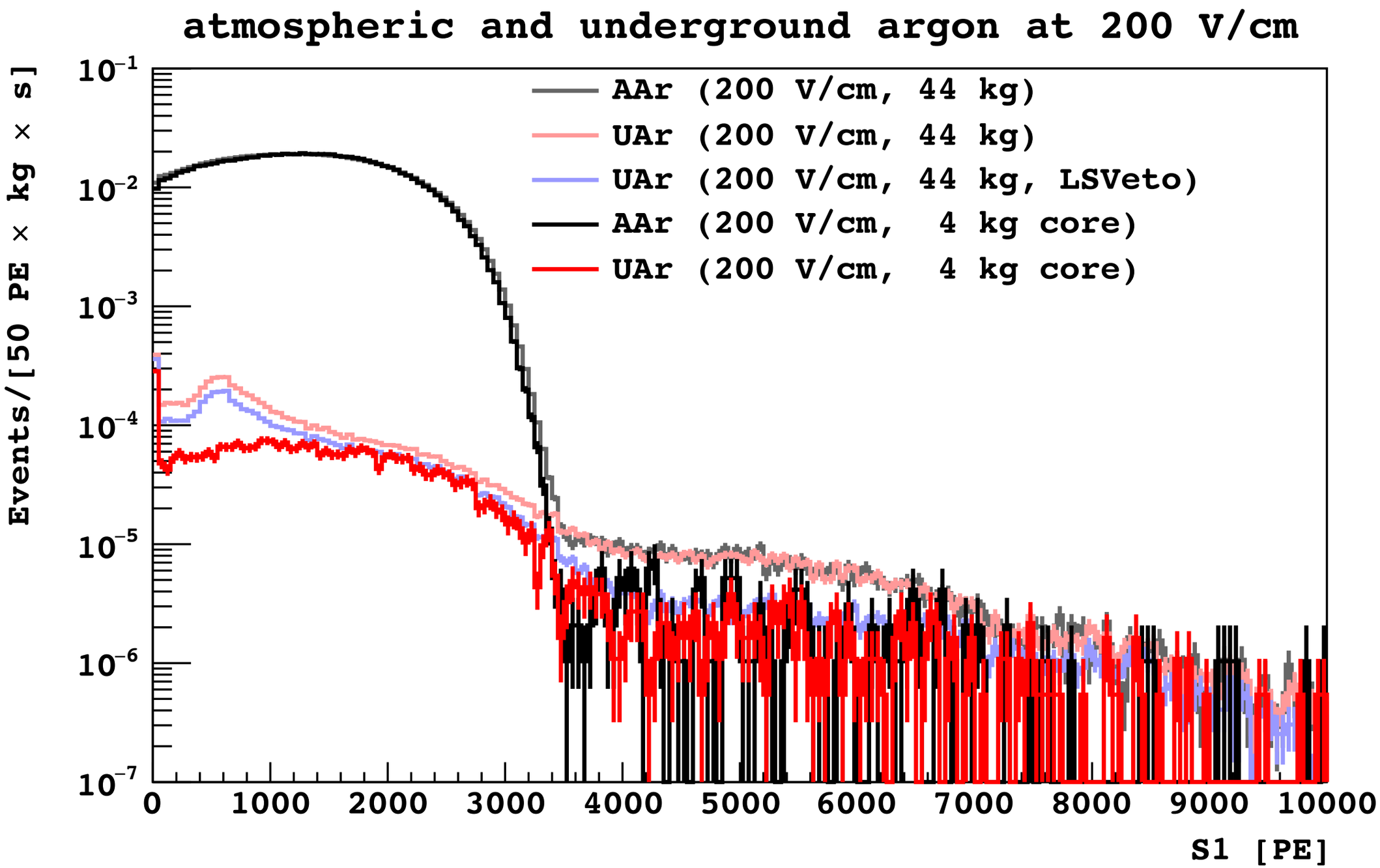

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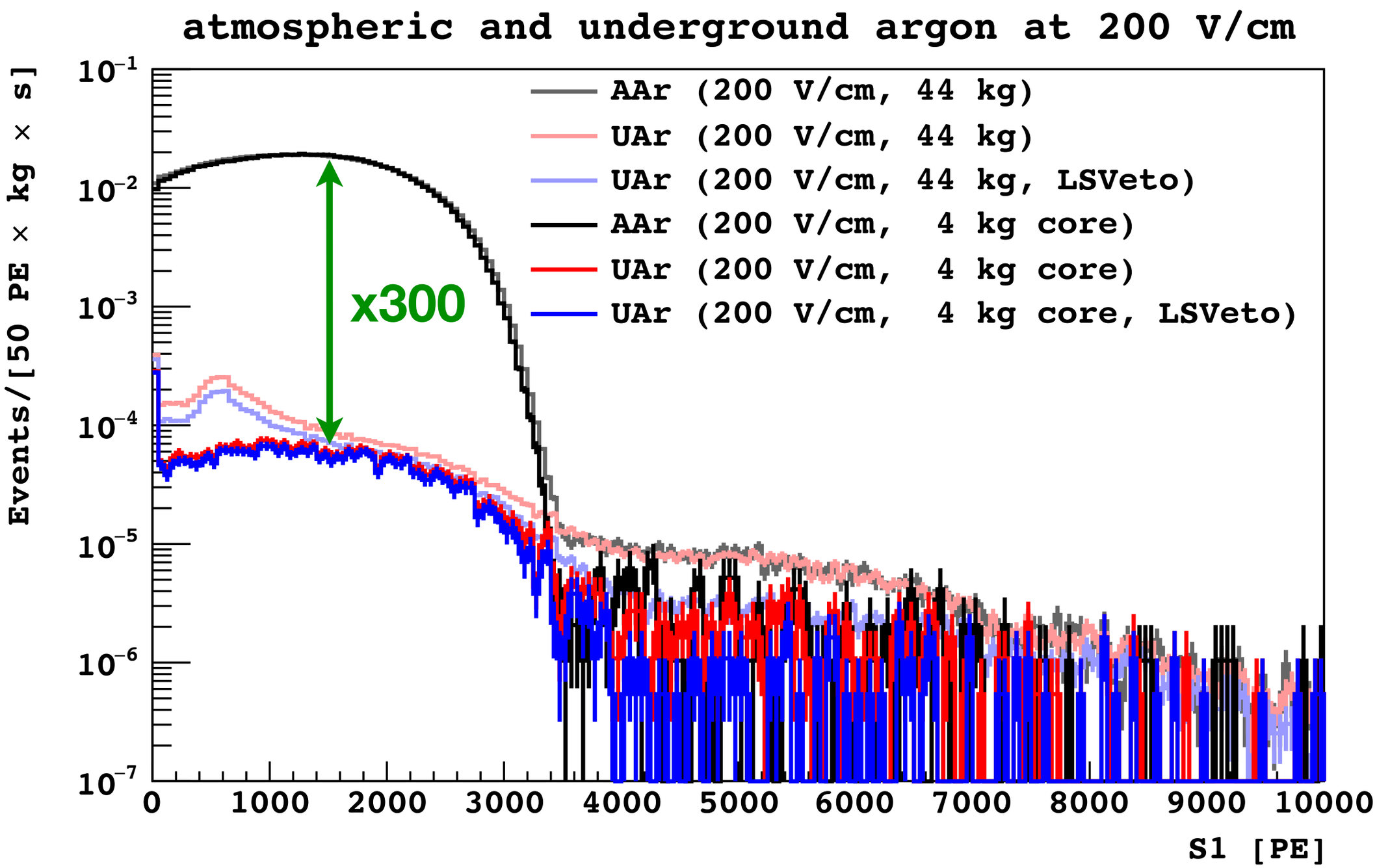

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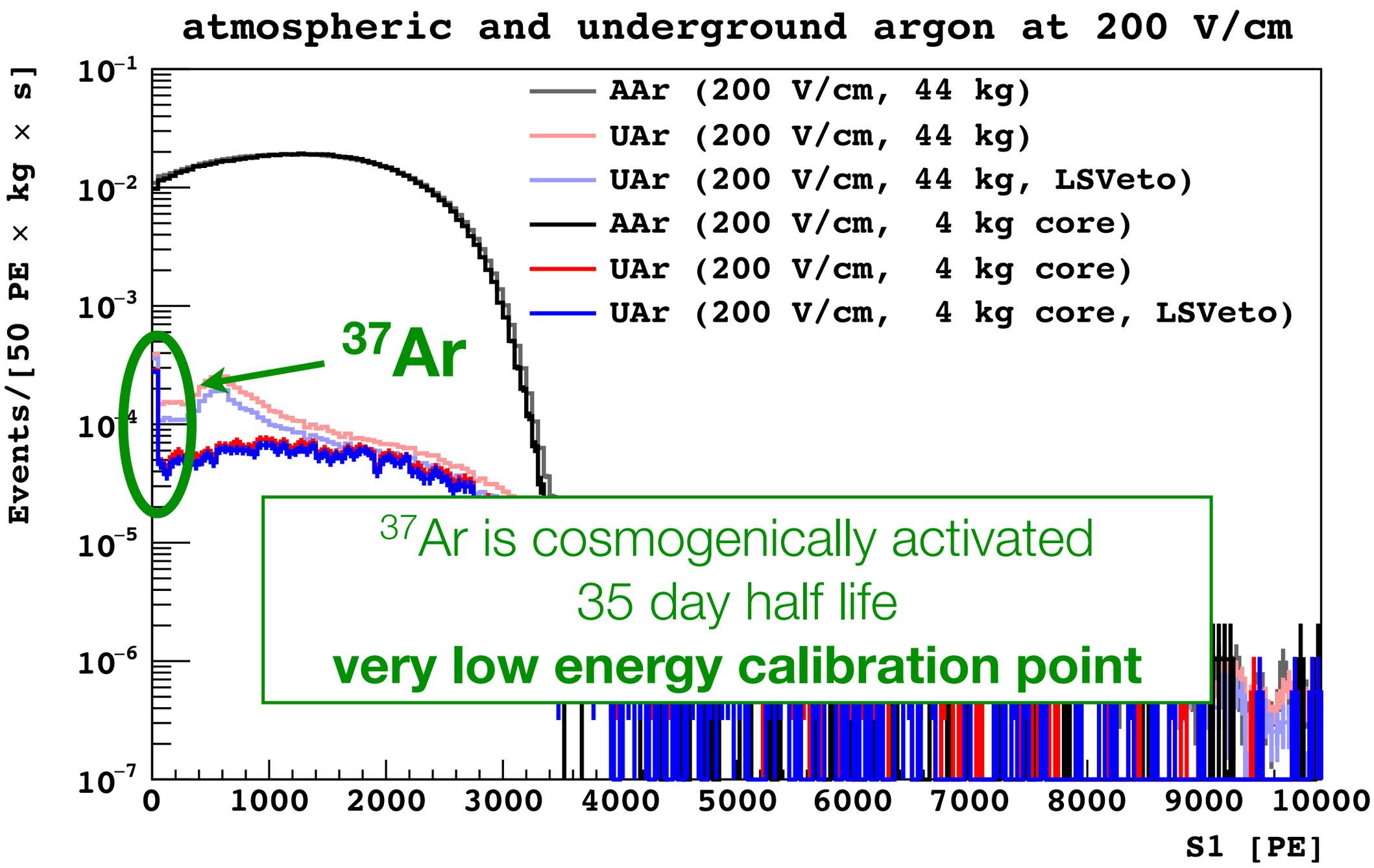
Underground argon

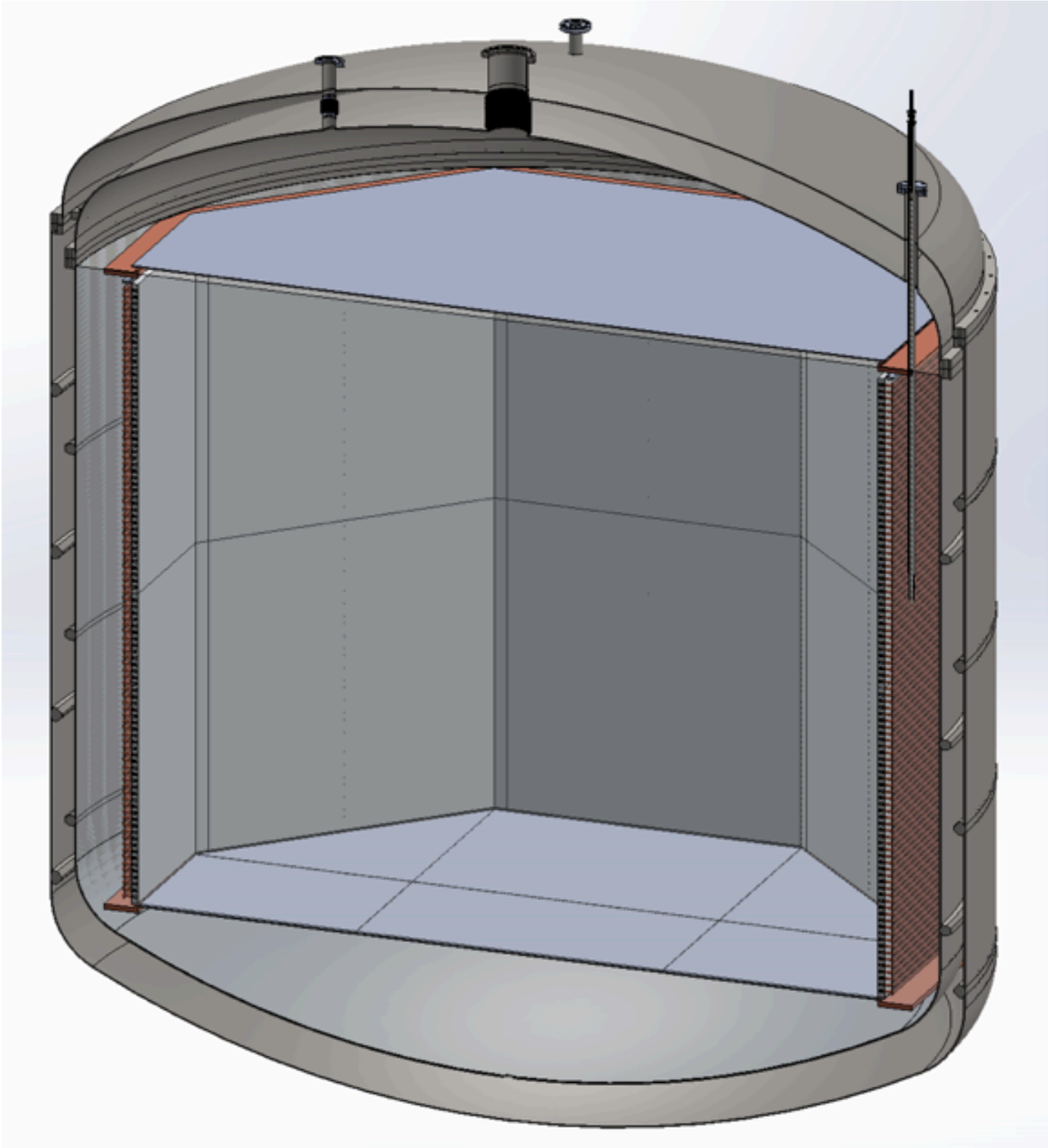


Normalized by live time

Future

DS-20k

- Large TPC
- SIPMs (no PMTs)
- 30 ton detector
  (20 ton fiducial)
- 100 t-yr BG-free exposure
- Projected sensitivity:
  9×10^{-48} cm^2 @ 1 TeV/c^2



Summary

- **First results published** with atmospheric argon in DS-50
- **Calibration campaigns** with gammas and neutrons
- Running with **underground argon** since Apr 2015
- **^{39}Ar depletion factor >300** in underground argon
- DS-20k development underway

Backup

3D position reconstruction