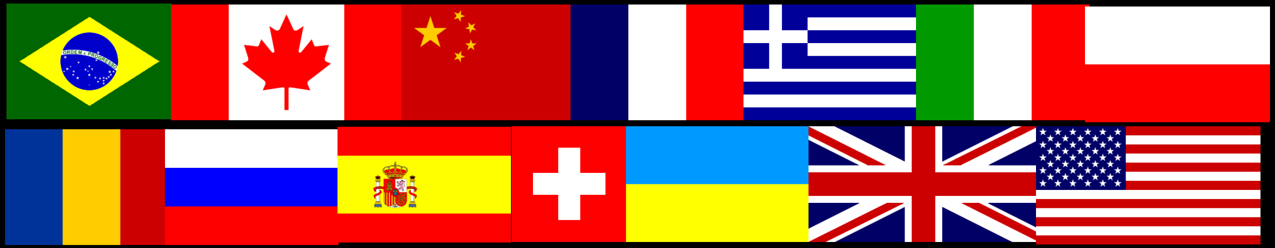
DarkSide: a program of direct WIMP searches with two-phase argon TPCs

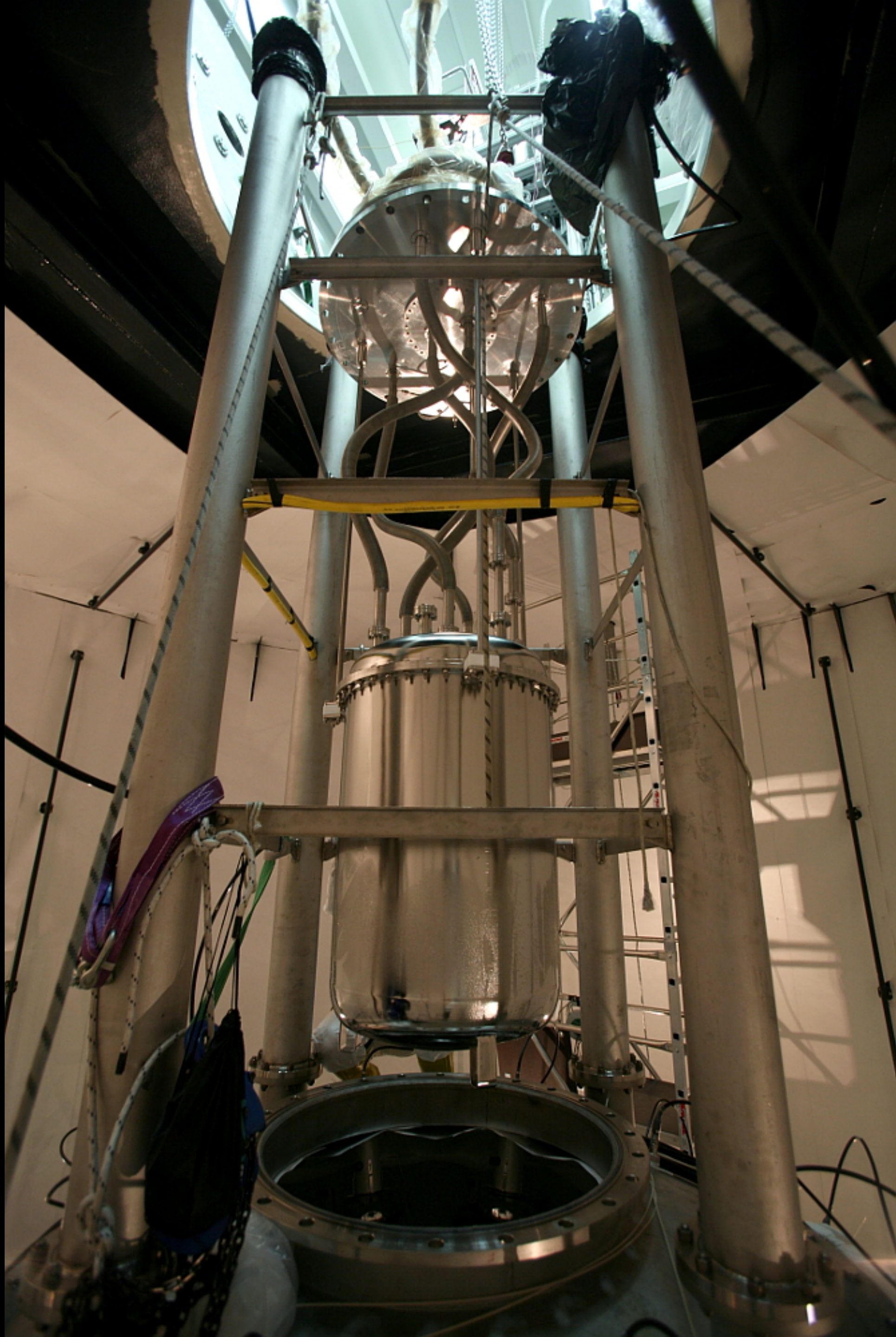
P. Meyers – Princeton

TAUP 2017

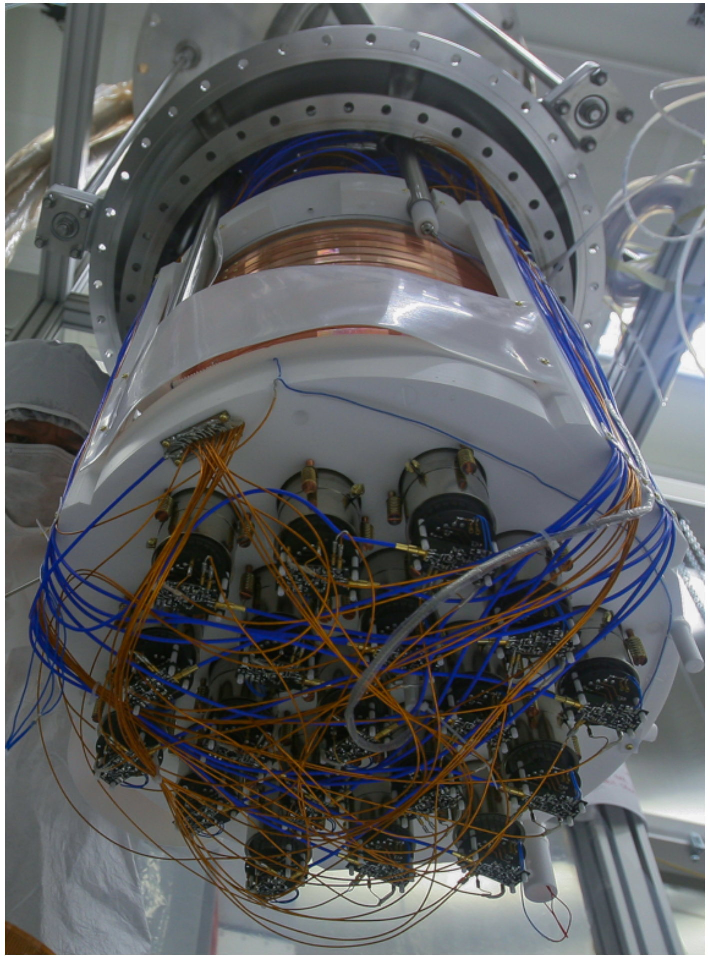


$$\int \text{DarkSide}\, dt$$

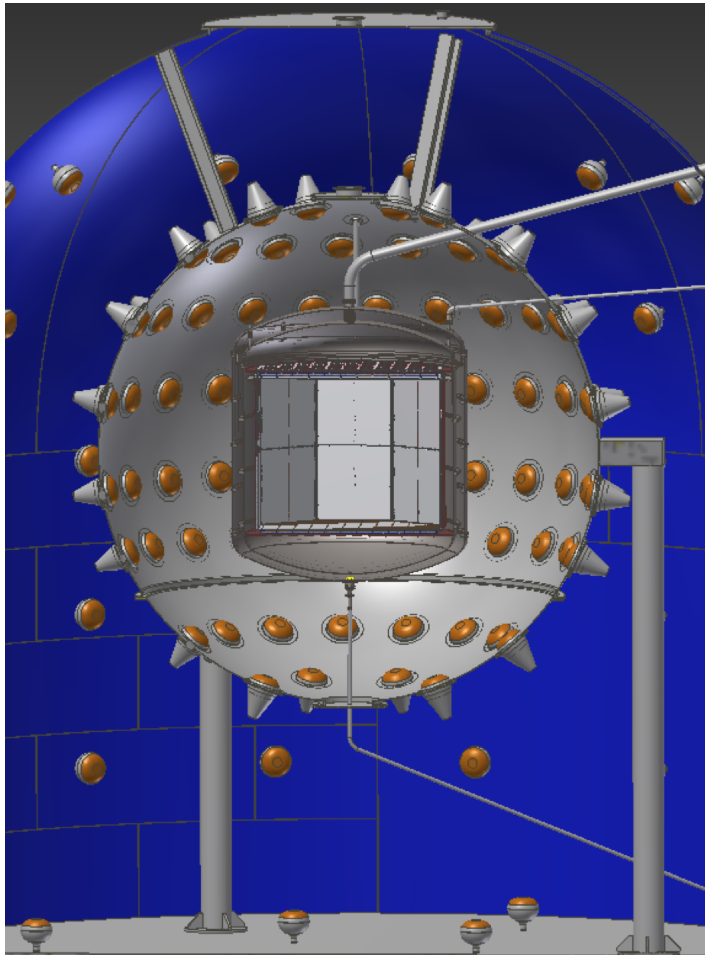
DarkSide-50 TPC cryostat above liquid scintillator neutron veto in water tank



The DarkSide Program at Gran Sasso Lab



DarkSide-50
150/50/30 kg total/active/fiducial
Sensitivity<10^{-44} cm^2
Data: 2013-present

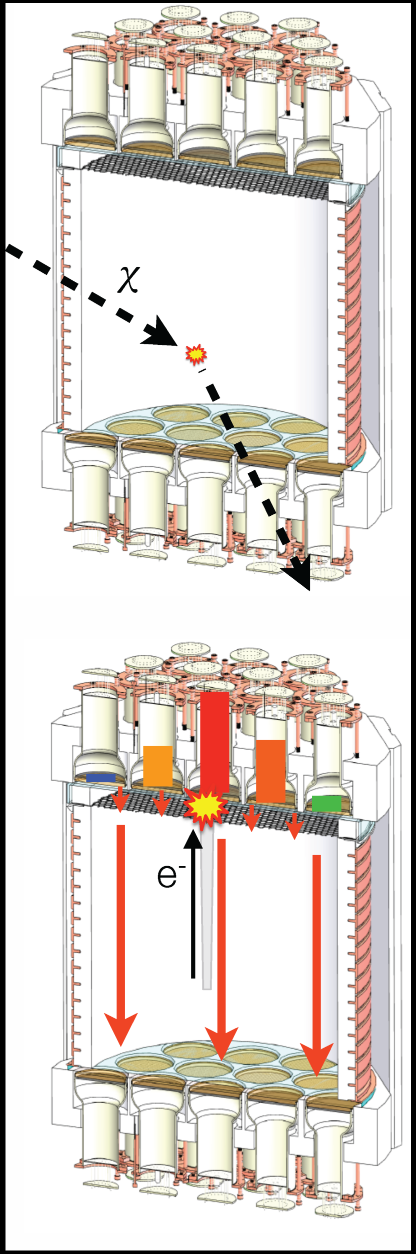


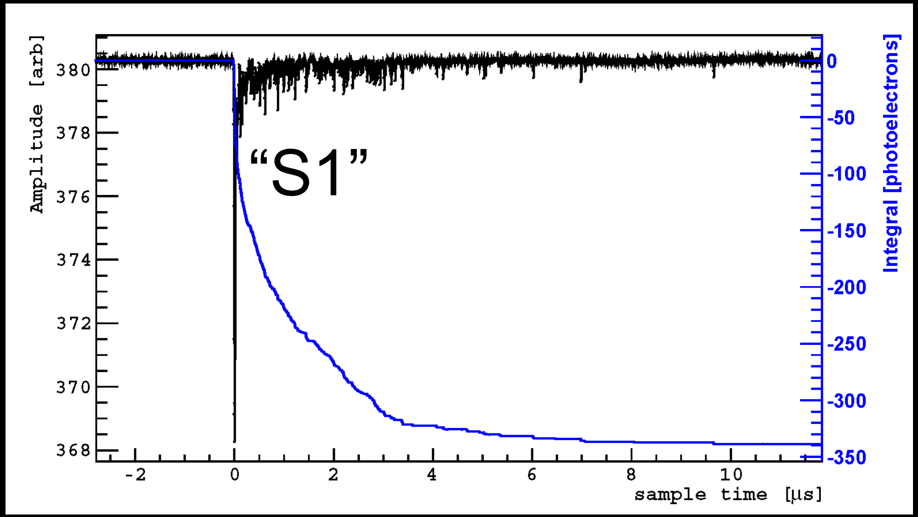
DarkSide-20k
30/23/20 T tot/act/fiducial
Sensitivity<10^{-47} cm^2
Data: ~2021

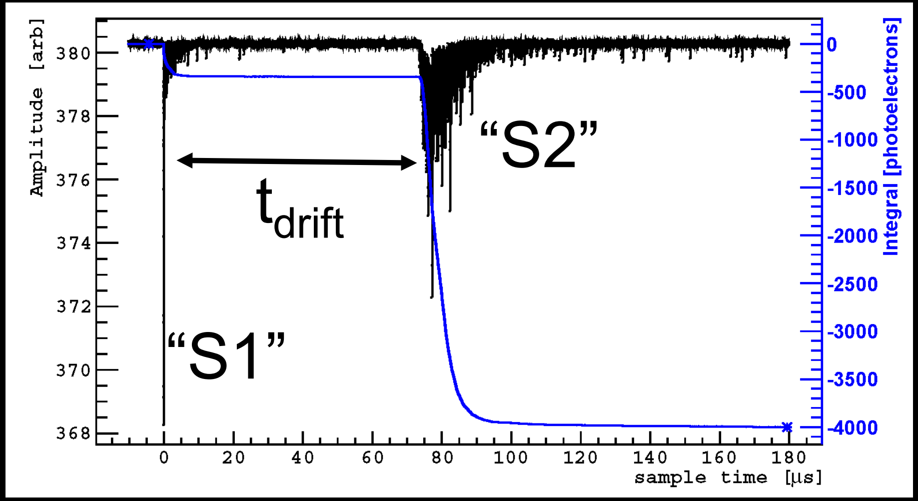
Features

- High light yield: LAr Pulse Shape Discrimination >10^7
- Underground Argon: low ^{39}Ar
- TPC 3D event reconstruction
- High-efficiency neutron vetoing

Two-phase Argon (or Xenon) Time Projection Chamber

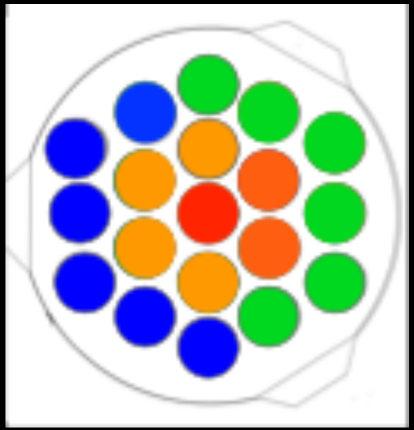






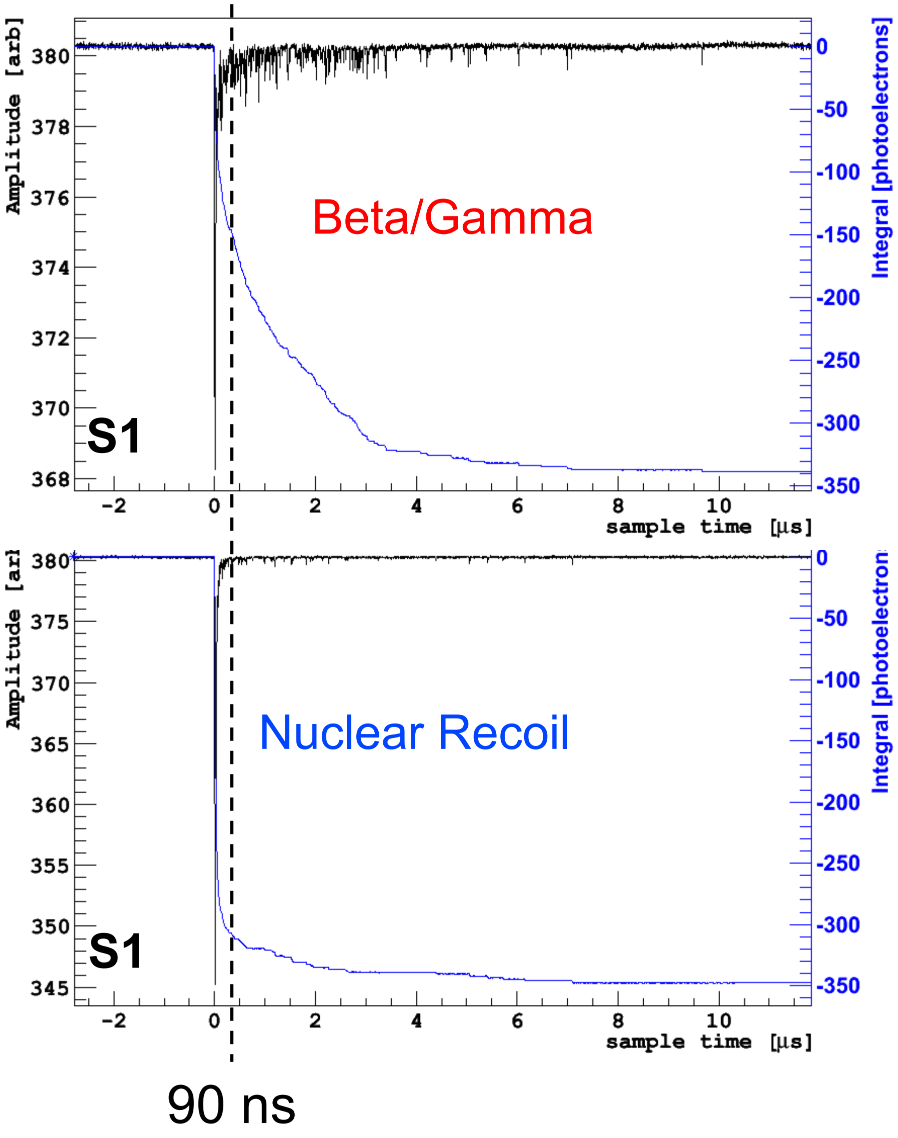
S1 (scintillation signal) and S2 (ionization signal) give

- Energy
- 3D position
- Discrimination between
  - Nuclear recoil (NR) WIMP or neutron
  - Electron recoil (ER) beta or gamma



S2 pattern on top PMTs

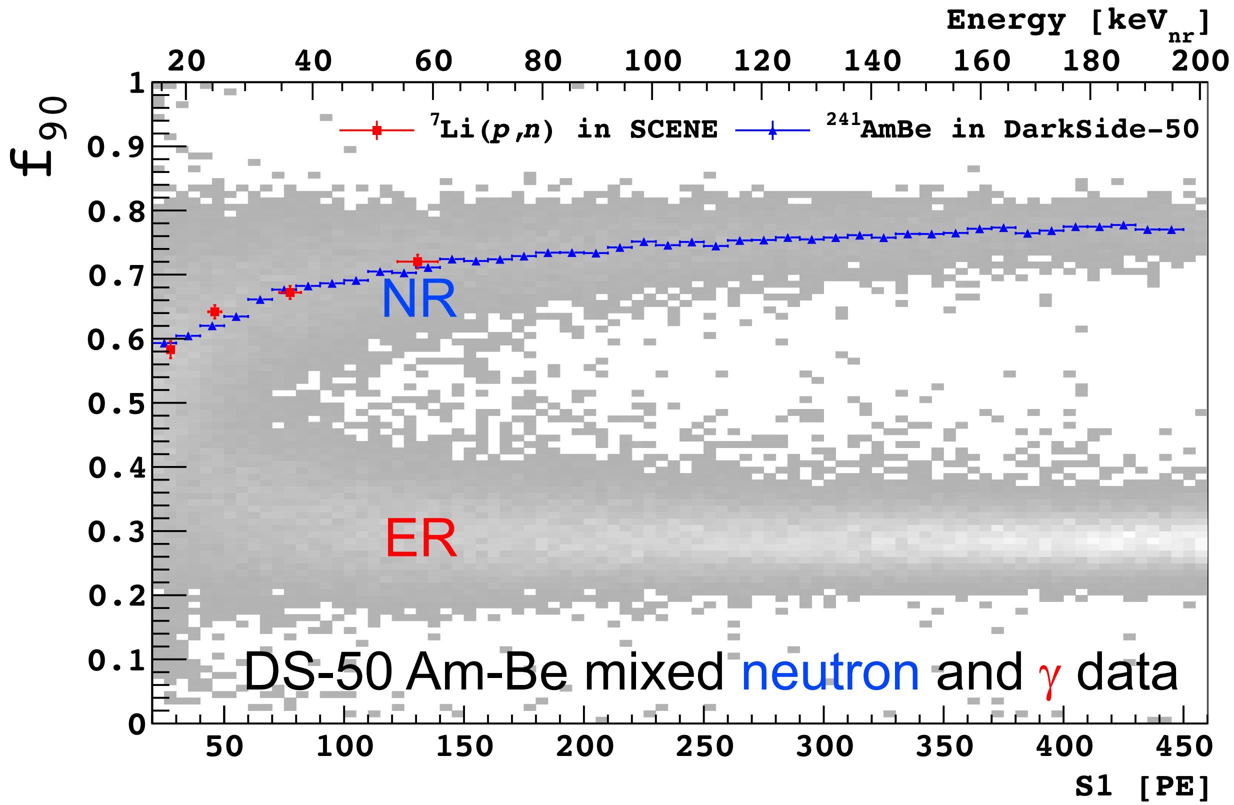
Pulse Shape Discrimination (PSD) in Liquid Argon



Two events with ~the same integrated S1 signal.

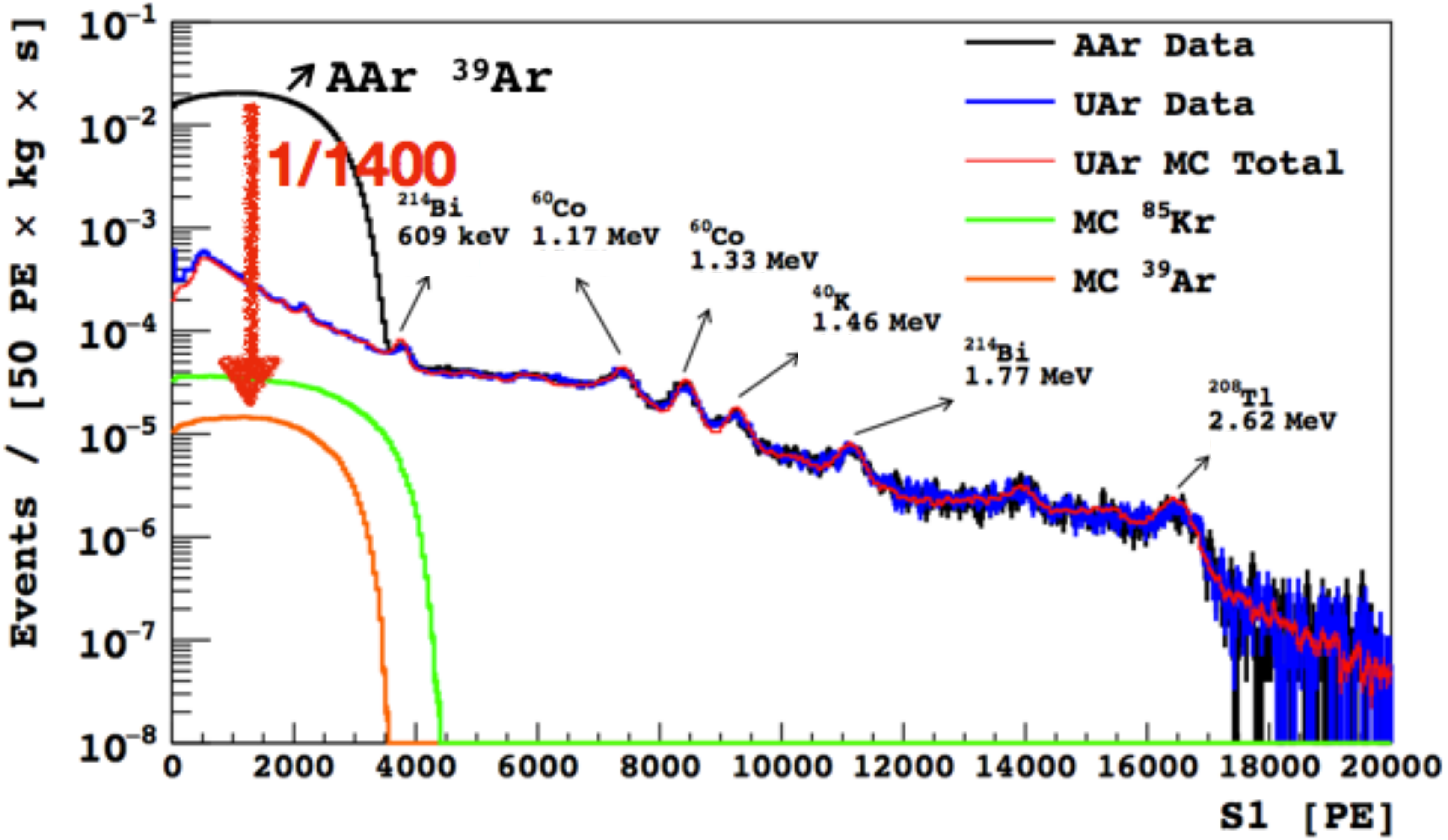
Simple discriminant: f_{90} = S1 fraction in first 90 ns.

- $f_{90} \approx 0.3$ for electron recoils (ER)
- $f_{90} \approx 0.75$ for nuclear recoils (NR)
- Electron rejection as high as 10^8 with sufficient p.e. statistics

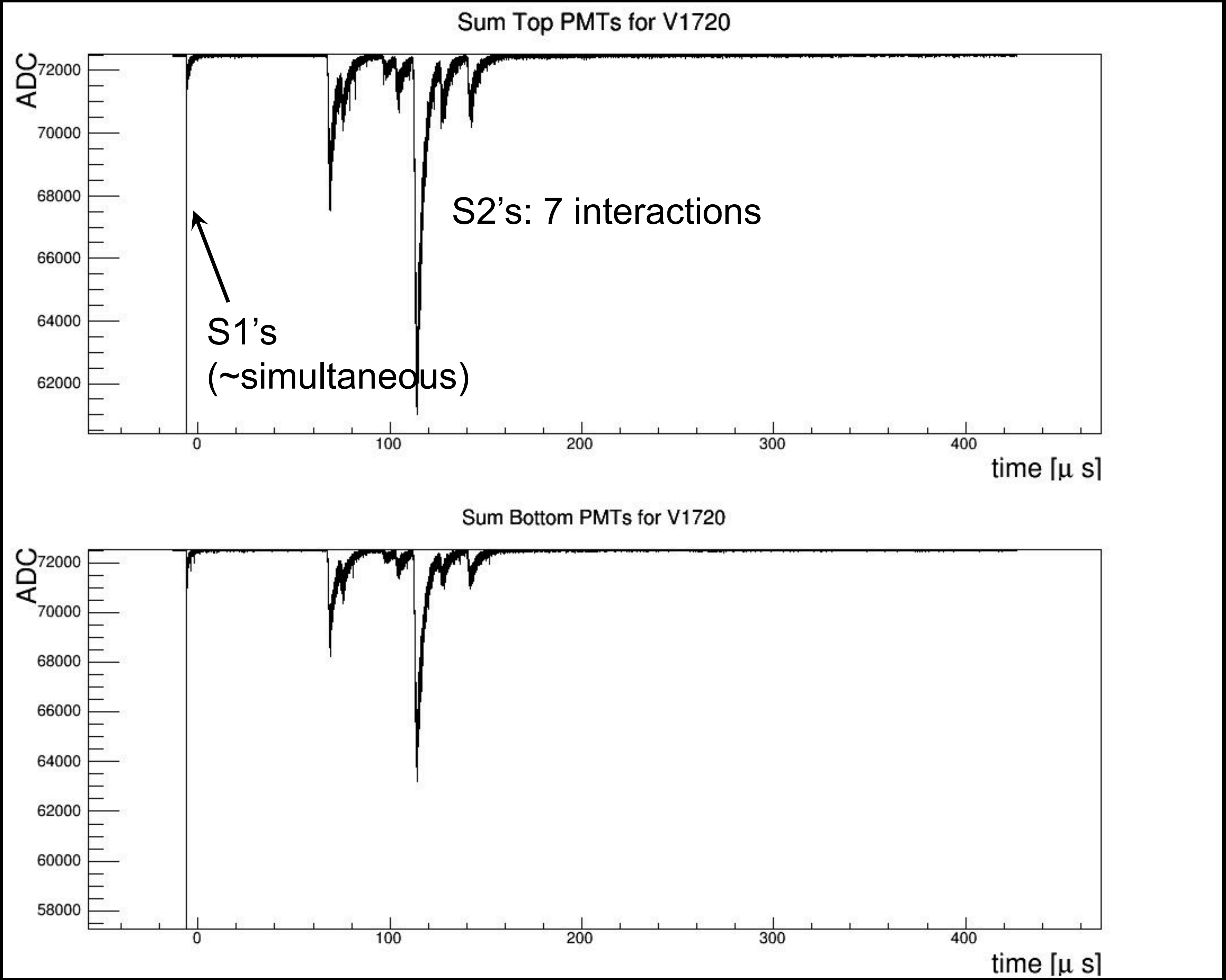


Underground Argon (UAr)

- Atmospheric argon (AAr) has 1 Bq/kg of β-emitting ^{39}Ar (τ = 388 y, Q = 565 keV)
- We extracted 156 kg of UAr from CO_2 wells in Colorado for the 2nd run of DarkSide-50

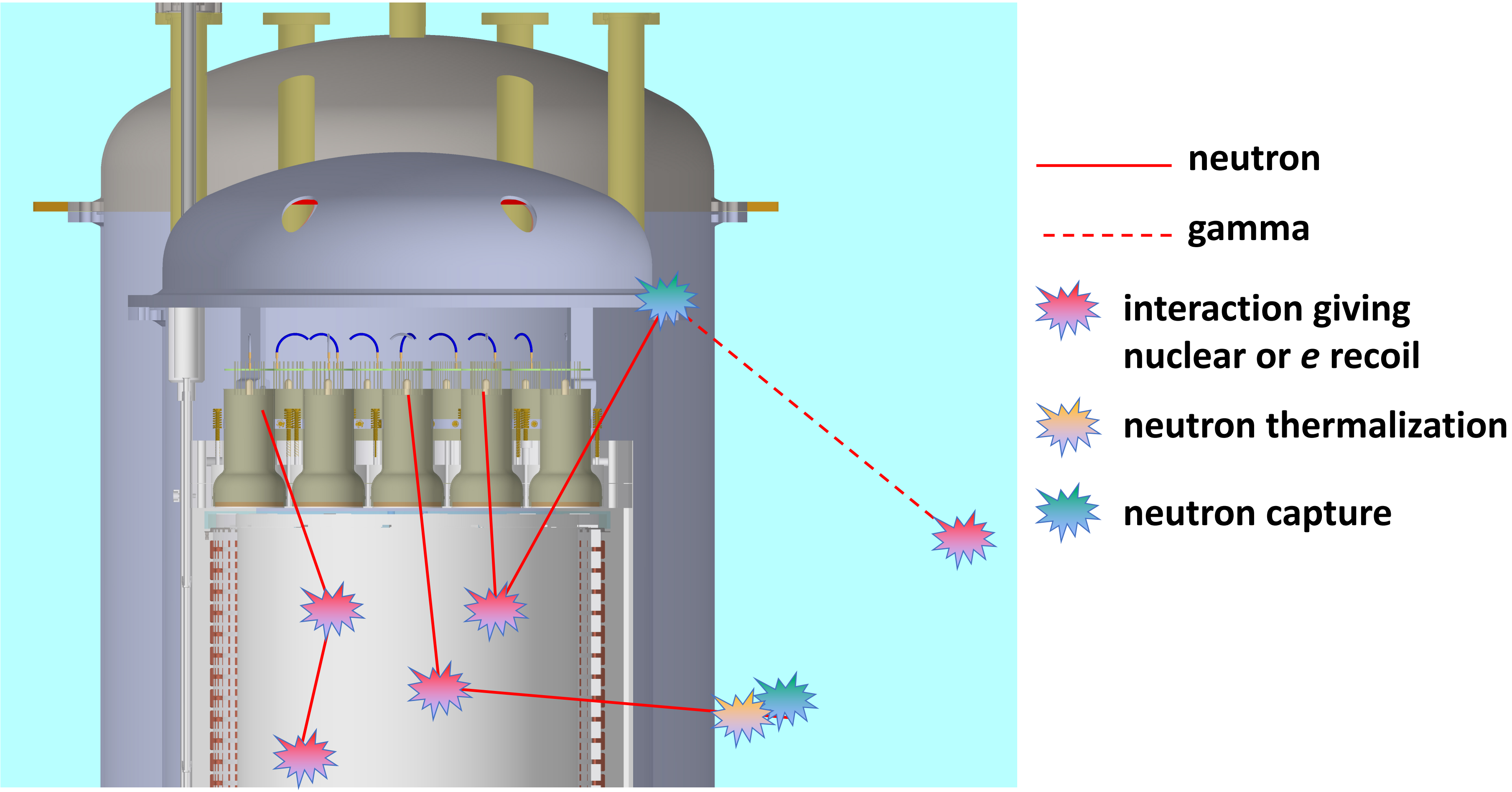


With ^{39}Ar β's suppressed, γ's from the PMTs are dominant background. They often multi-scatter and can give signals in the neutron veto.



Borated-liquid-scintillator neutron veto

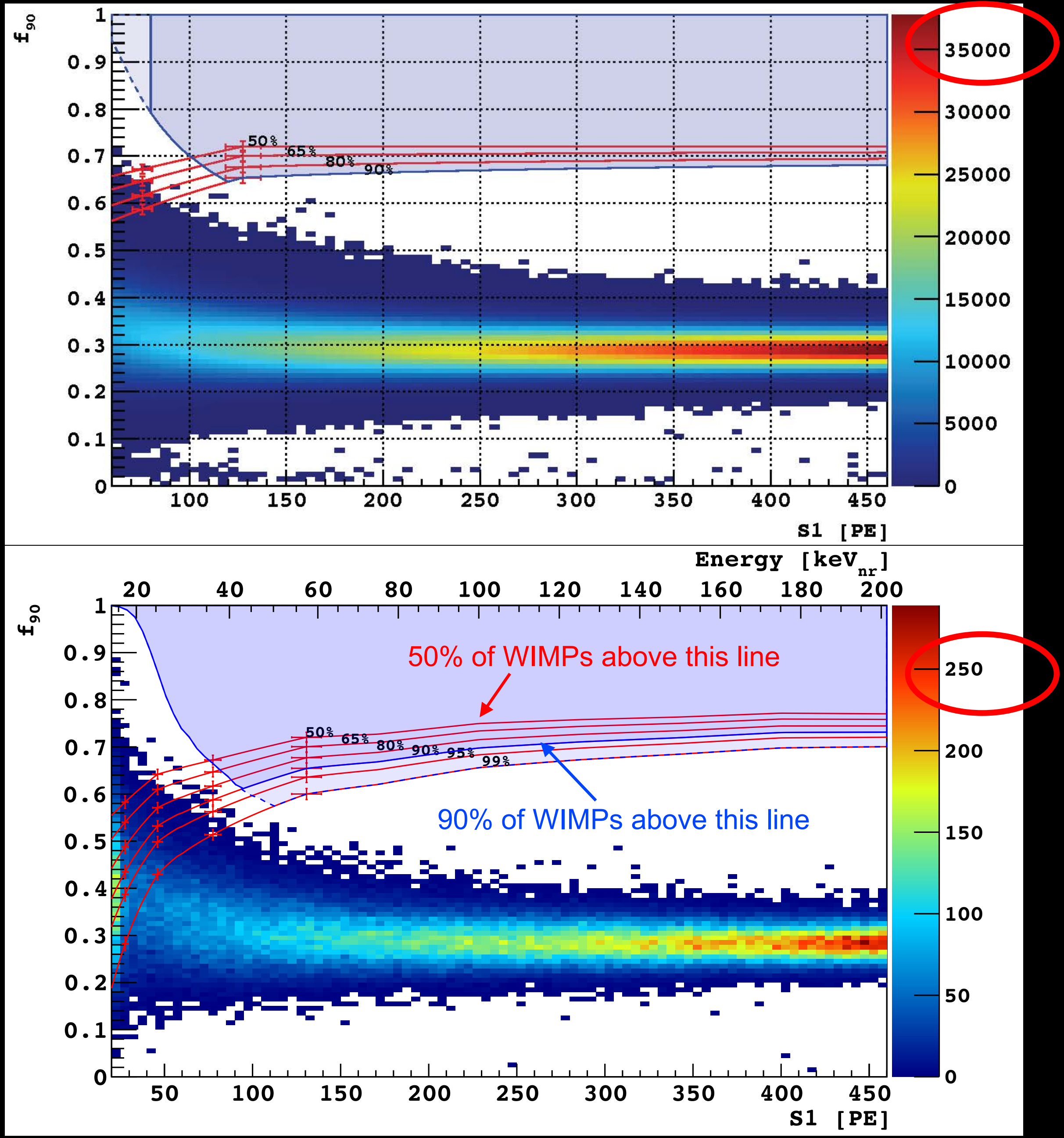
- (α,n) from PMT U and Th are the dominant neutron source.
- Separately detect both thermalization and capture signals from neutron.
- Rejection **measured** with AmC neutrons giving WIMP-like TPC signature.
- Rejection for radiogenic neutrons **~500**.
- Also effective for cosmogenic neutrons.

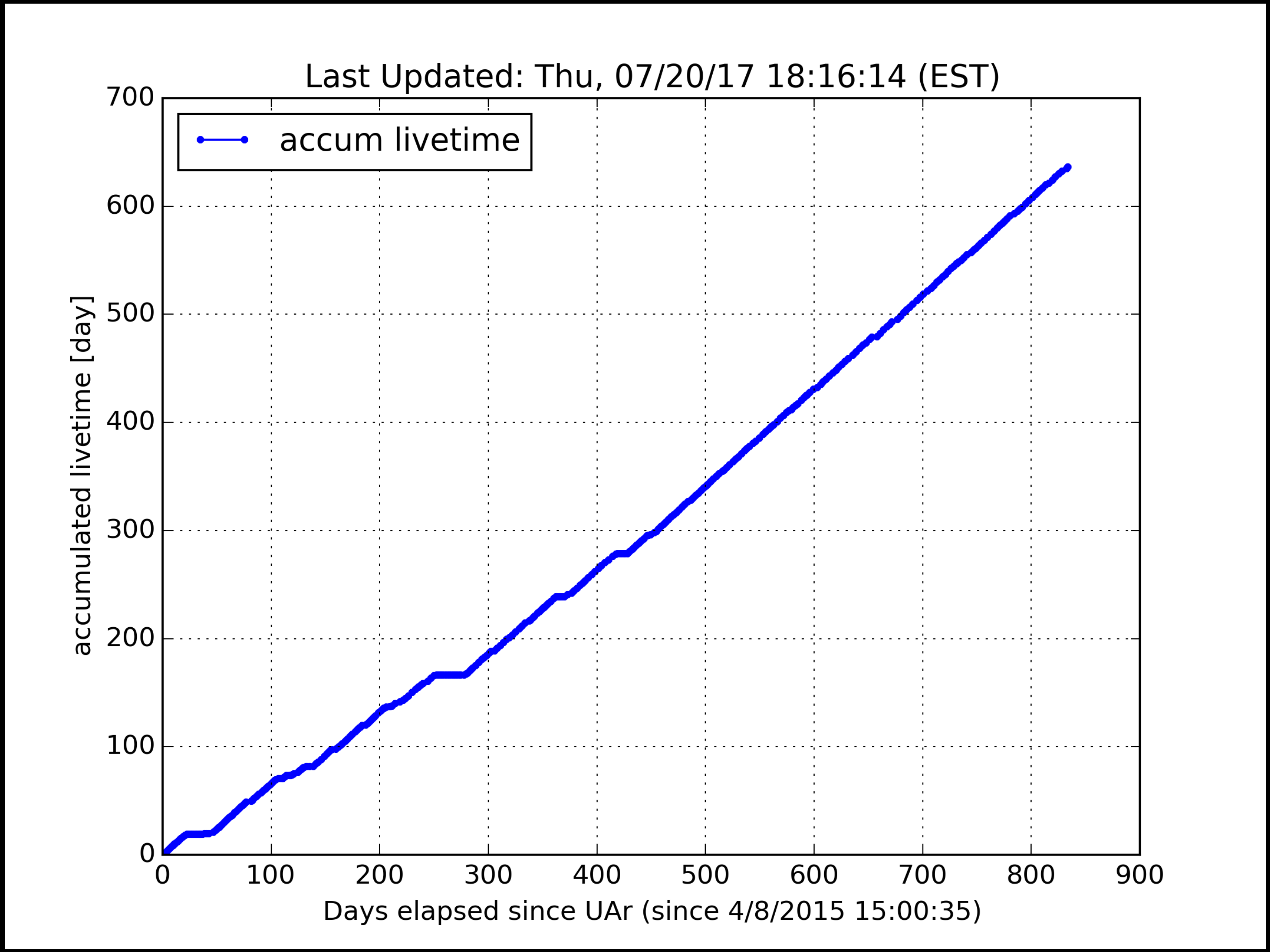


DarkSide-50: Published WIMP searches

50 days of Atmospheric Argon

70 days of Underground Argon

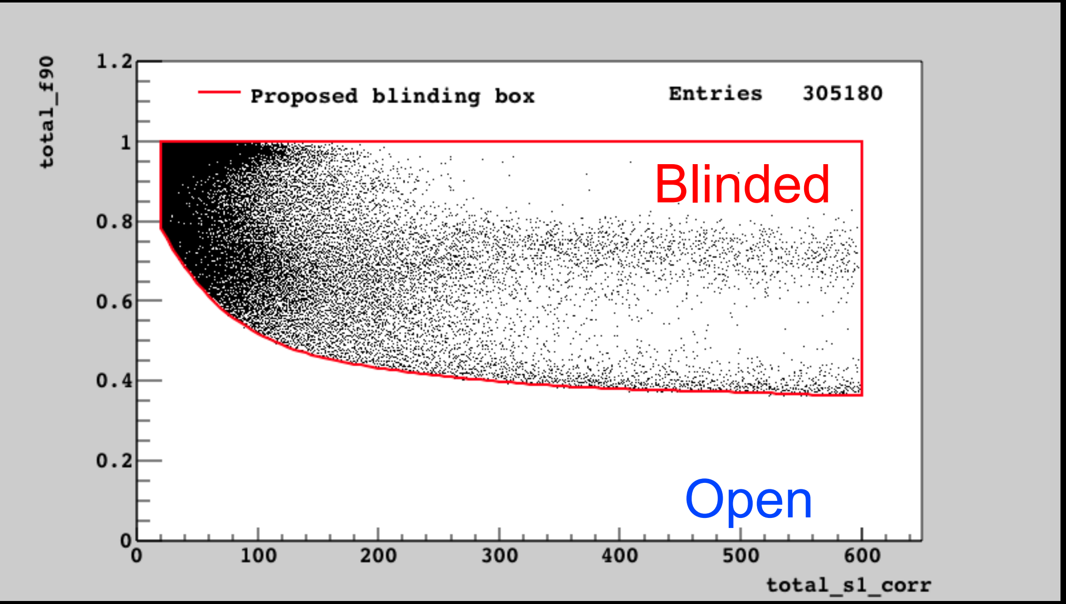


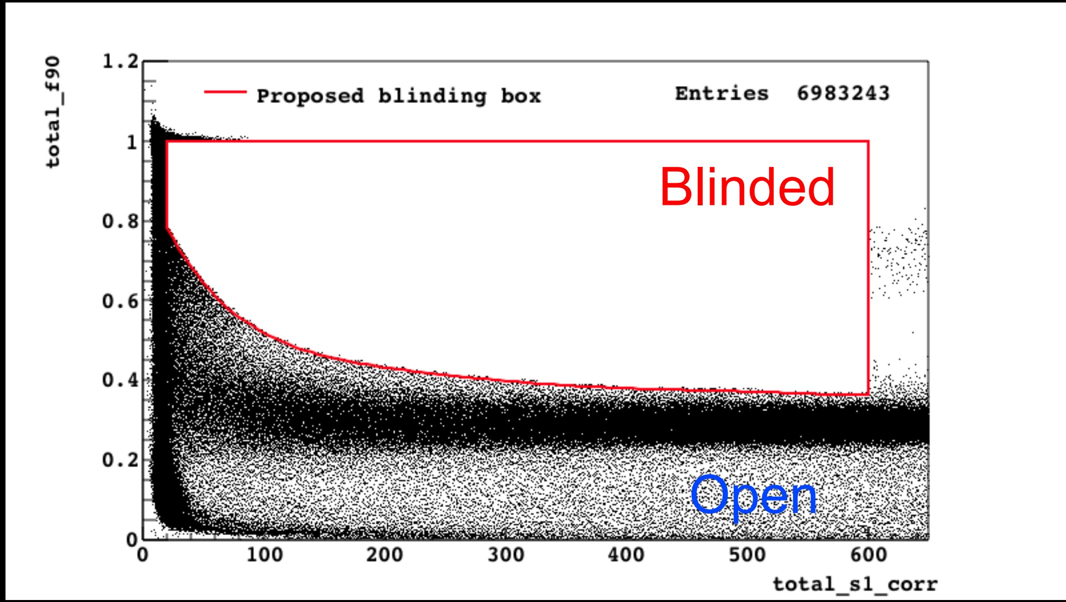


~500 live-days of usable post-70-day UAr data – Signal region hidden for our first **Blind Analysis**

Blind analysis procedure

- Process raw data hiding events in Blinding Box (>> 70-day WIMP box) + a tiny random fraction.
- AAr, 70-day UAr, and calibration-source data all open.
- Develop cuts and predict background using open data.
- Choose cuts and final search box to give <0.1 event of predicted background after all cuts.



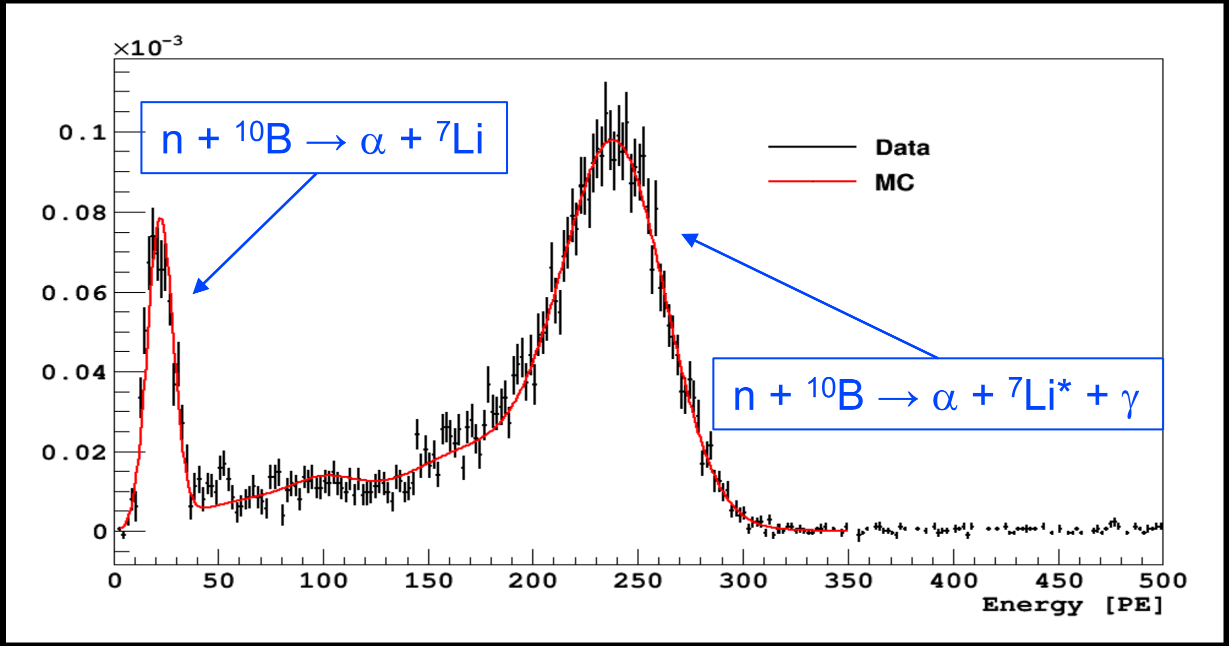


(70-day UAr raw data – actually all open)

Example background study: Radiogenic neutrons

Step 1: measure efficiency for rejecting neutrons

- ^{241}Am-^{13}C neutron source
- Select neutron events using standard TPC WIMP analysis
- Apply veto cuts
  - ~99.3% veto efficiency for Am-C neutrons
- MC-based corrections (origin and spectrum) from Am-C to internal radiogenic sources
- Final efficiency ~99.8% → neutron rejection factor ~500



DarkSide-50 Am-C neutron capture spectrum on ^{10}B

Example background study: Radiogenic neutrons

Step 2: measure neutron rate passing TPC WIMP selection

- Unblind events with neutron-veto signal.
- Select neutron events using standard TPC WIMP analysis
  - Veto tags ~99% of radiogenic neutrons passing TPC cuts
  - Negligible ER background (and WIMPs)
- Just count! (We are about to do this…)

… for now, estimate with Monte Carlo

- Use NeuCBot for (α,n) yield and spectrum (arXiv:1702.02465 and S. Westerdale talk tomorrow).
- MC gives ~25 neutron events passing TPC cuts in 500 live-days $\Rightarrow$ 25% stat error.
- The measurement will be an interesting test of (α,n) predictions.

- Prediction using Step 1 and rate from MC gives 0.04 radiogenic neutron background events in the 500-day WIMP search.

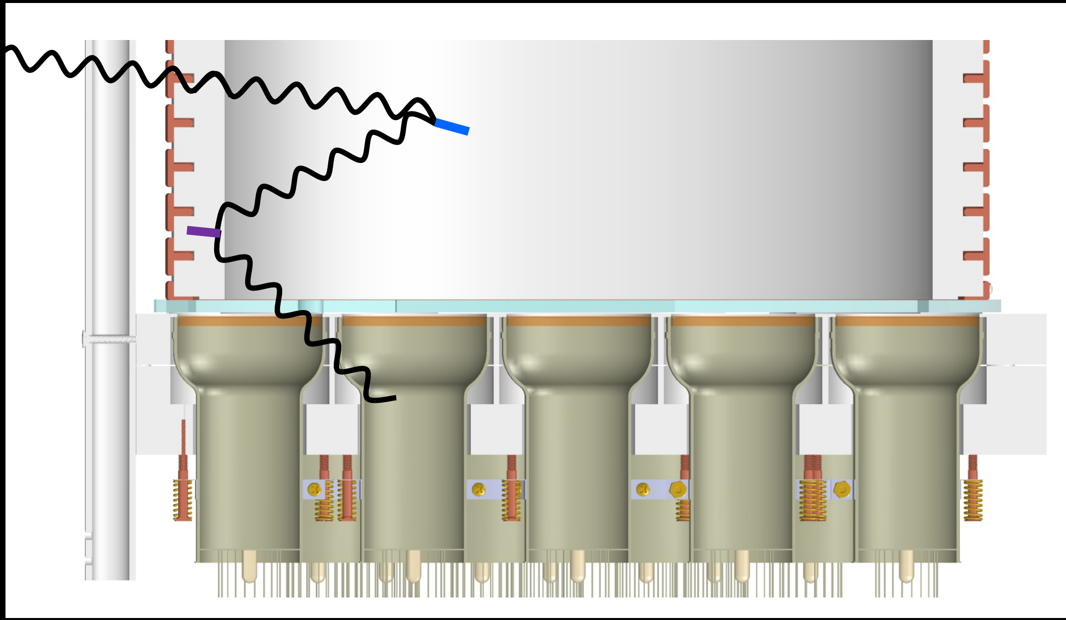
Blind Analysis Status

Most backgrounds estimated and under control:

- Radiogenic neutrons
- Cosmogenic neutrons
- Single and multiple ERs in LAr
- Surface backgrounds (see C. Stanford talk)

Still working on one background:

- Multiple-Compton scatter of gamma
- All-prompt Cherenkov signal in Teflon reflector boosts f90



Now preparing final tests before box opening…

Next Step – DarkSide-20k: 20 ton (fiducial) two-phase TPC

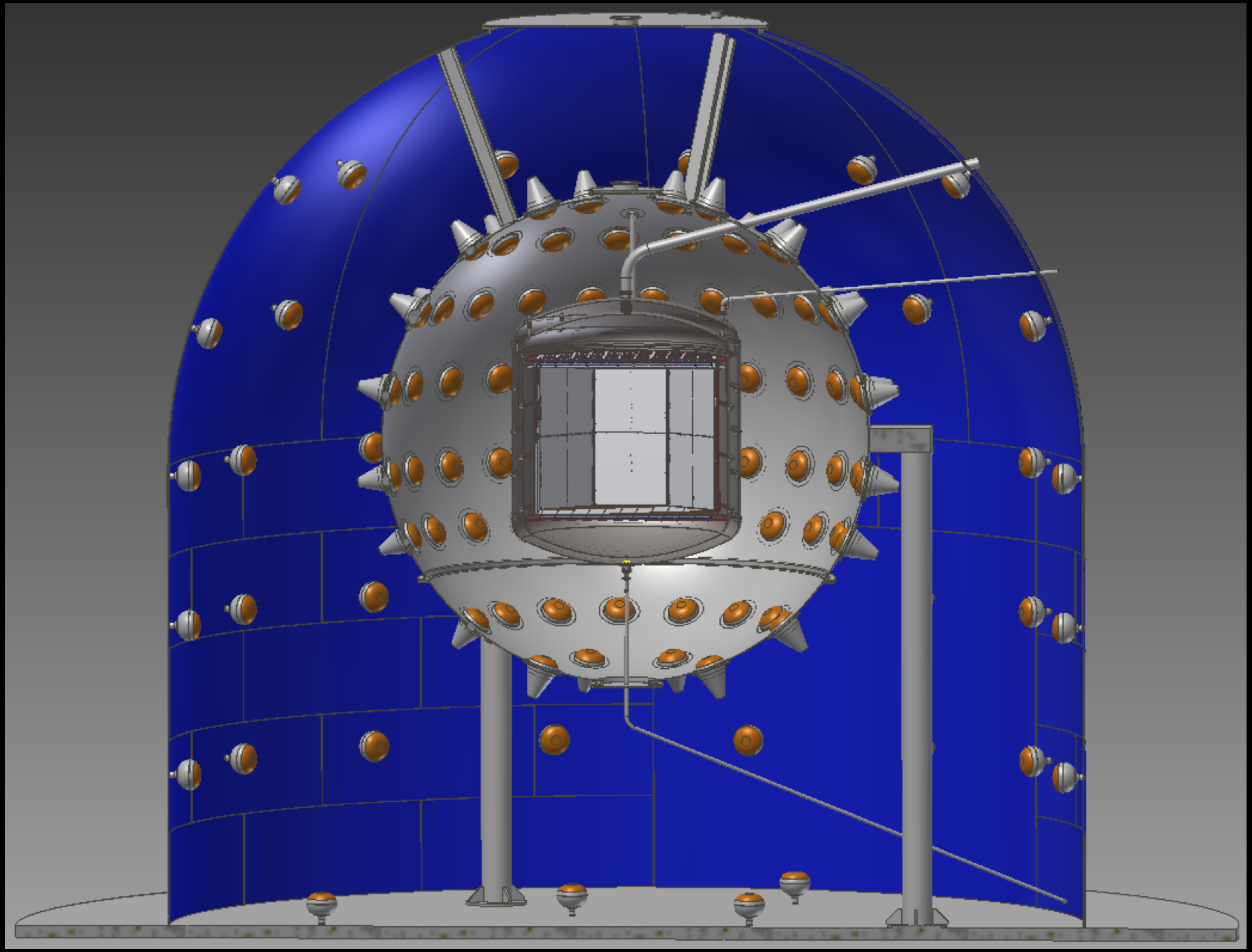
New argon collaboration formed – the groups finish their current experiments (DarkSide-50, DEAP-3600,…) and

DarkSide
DEAP
MiniCLEAN
ArDM

} DarkSide-20k ⟶ Multi-100 ton*

DS-20k approved by INFN and LNGS, NSF decision soon.

* Site and technology TBD



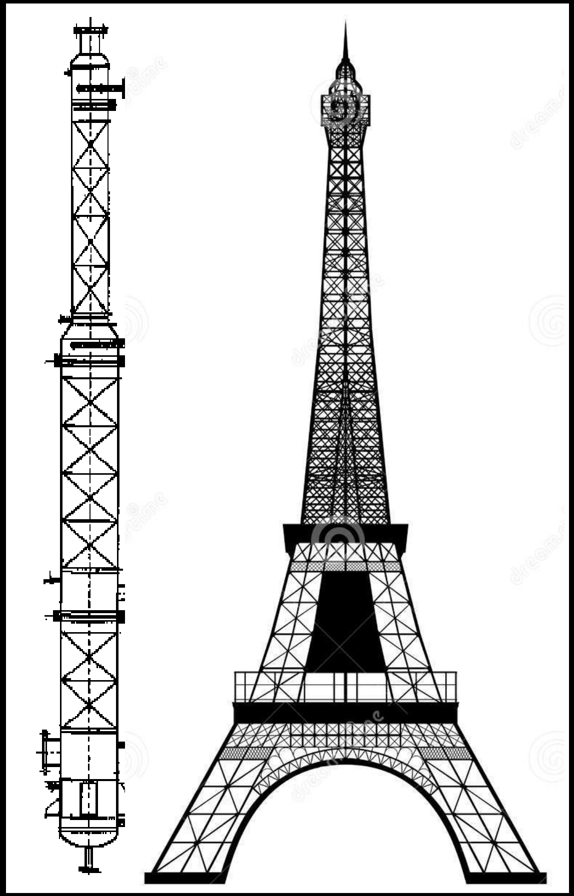
DarkSide-20k

DarkSide-20k New Technology

30 tonnes of UAr

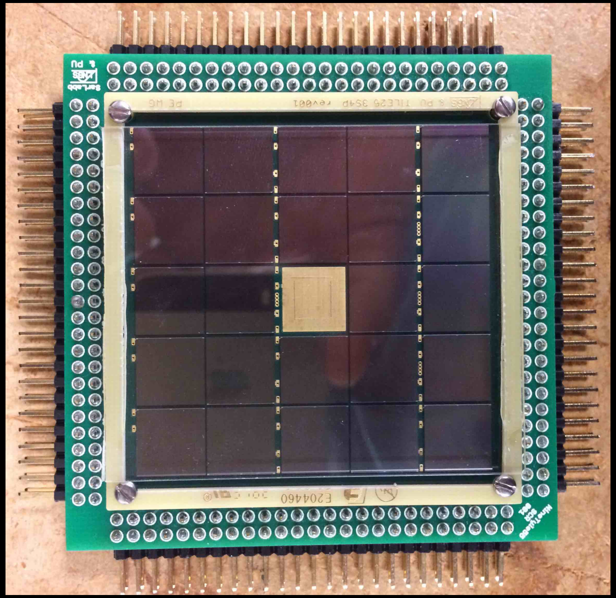
…possibly with further depletion.

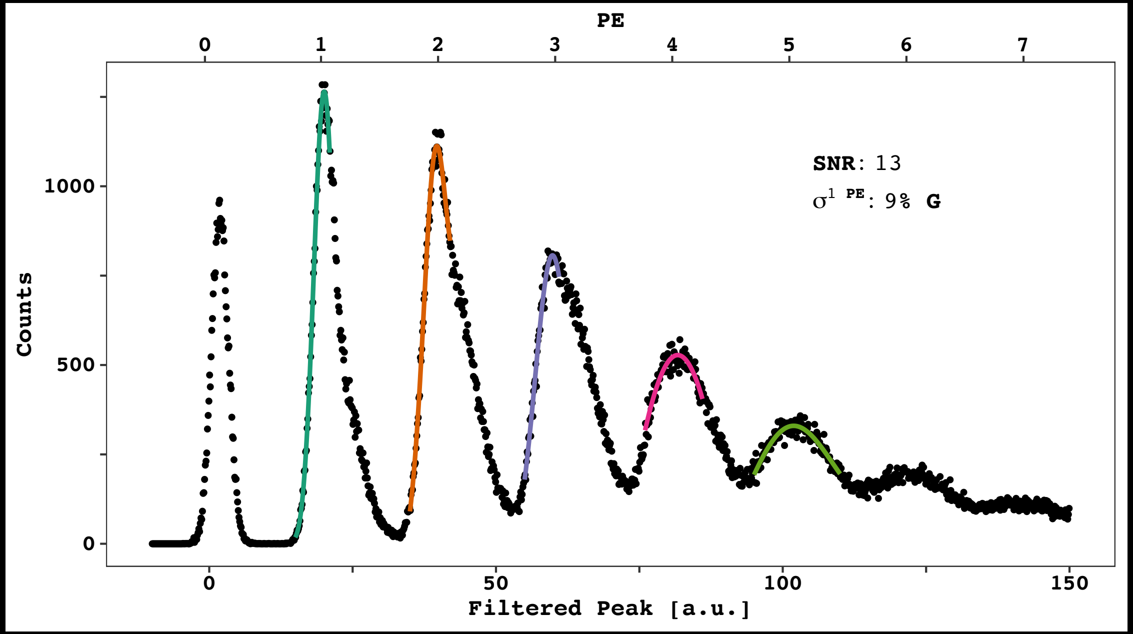
See A. Renshaw talk Wednesday.

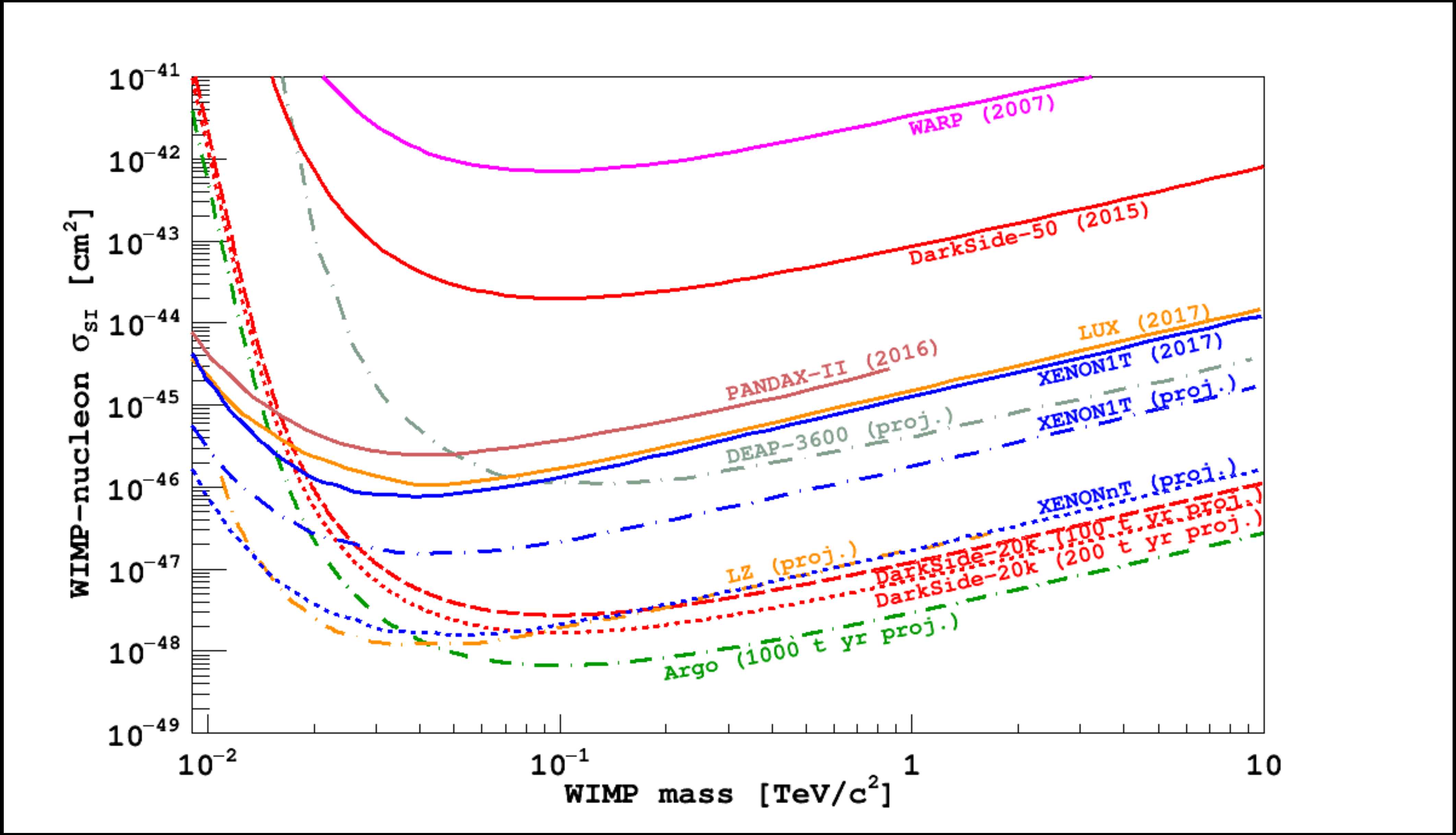


Replaces PMTs with ~13 m^2 of SiPM.

See G. Giovanetti talk Wednesday







WARP (2007)
DarkSide-50 (2015)
LUX (2017)
XENON1T (2017)
PANDAX-II (2016)
DEAP-3600 (proj.)
XENON1T (proj.)
XENONnT (proj.)
LZ (proj.)
DarkSide-20k (100 t yr proj.)
DarkSide-20k (200 t yr proj.)
Argo (1000 t yr proj.)
WIMP-nucleon σ_SI [cm²]
WIMP mass [TeV/c²]