

DarkSide-50



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Plank 2014

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The DarkSide Project

- WIMP dark matter search using **direct detection**
- **Dual-phase Liquid Argon** Time Projection Chamber (LAr TPC)
- Ultra low **background**
 - Deep underground
 - Low-background materials, including Ar target
- Active neutron and muon **veto**s
 - in situ background measurement
- Powerful **background rejection**
 - Pulse shape discrimination (PSD)
 - Ionization to scintillation ratio (S2/S1)
 - Surface rejection using 3D position reconstruction
- **Multi-stage** approach

Why Liquid Argon?

Relatively **inexpensive** and **dense**

Easy to **purify**

- most impurities freeze out
- low surface binding
- purification easiest for colder liquids

Ionization electrons:

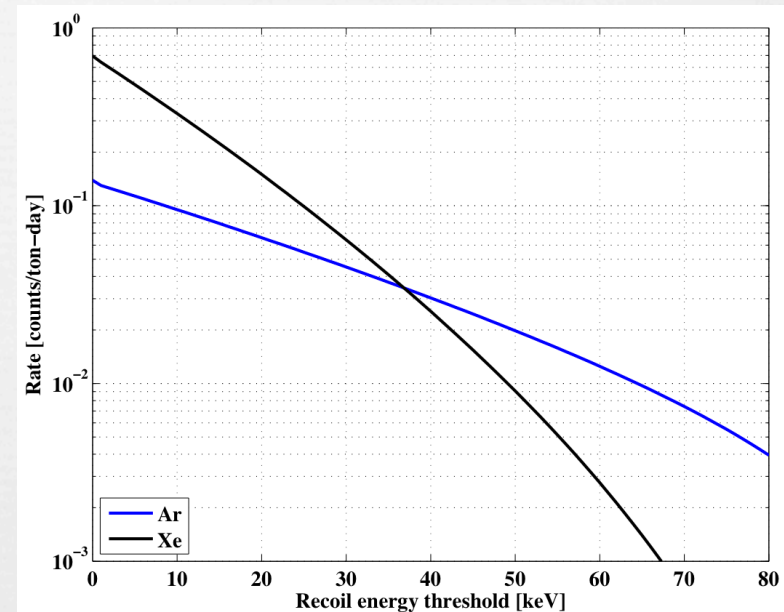
- High ionization (W_LAr = 21.5 eV)
- High electron mobility and low electron diffusion

Scintillation photons:

- Very high scintillation yield (~40,000 ph/MeV)
- Transparent to its own scintillation

Exceptional discrimination power:

- S1/S2
- PSD



One problem:

39Ar contamination

^{39}Ar Depleted LAr

Atmospheric Ar:

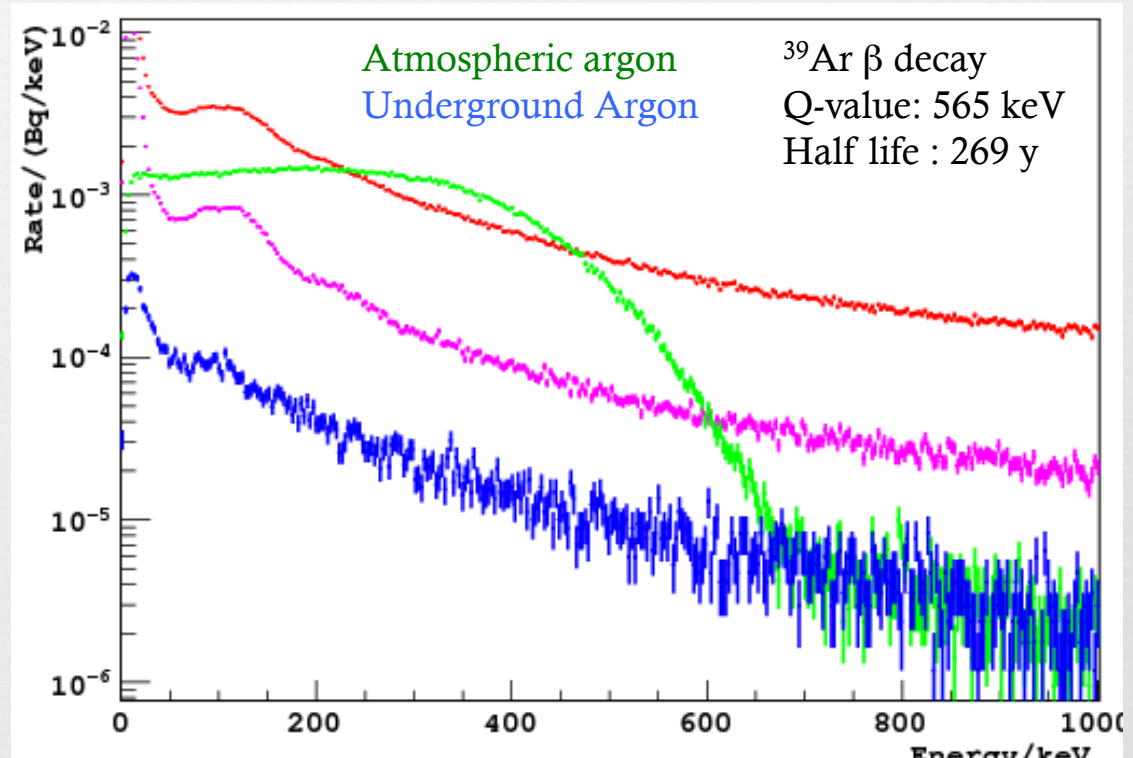
$$^{39}\text{Ar}/^{40}\text{Ar} = 8 \times 10^{-16}$$

Rate \sim **1 Hz/kg**

Underground Argon:

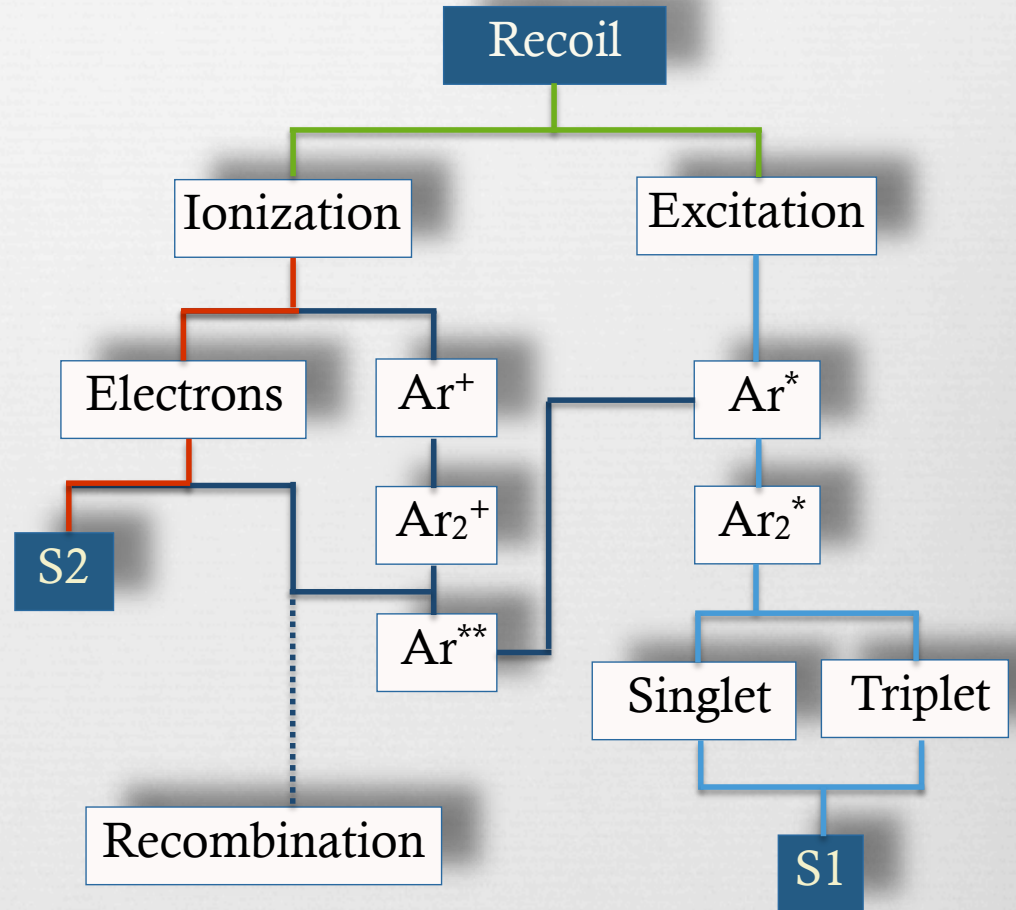
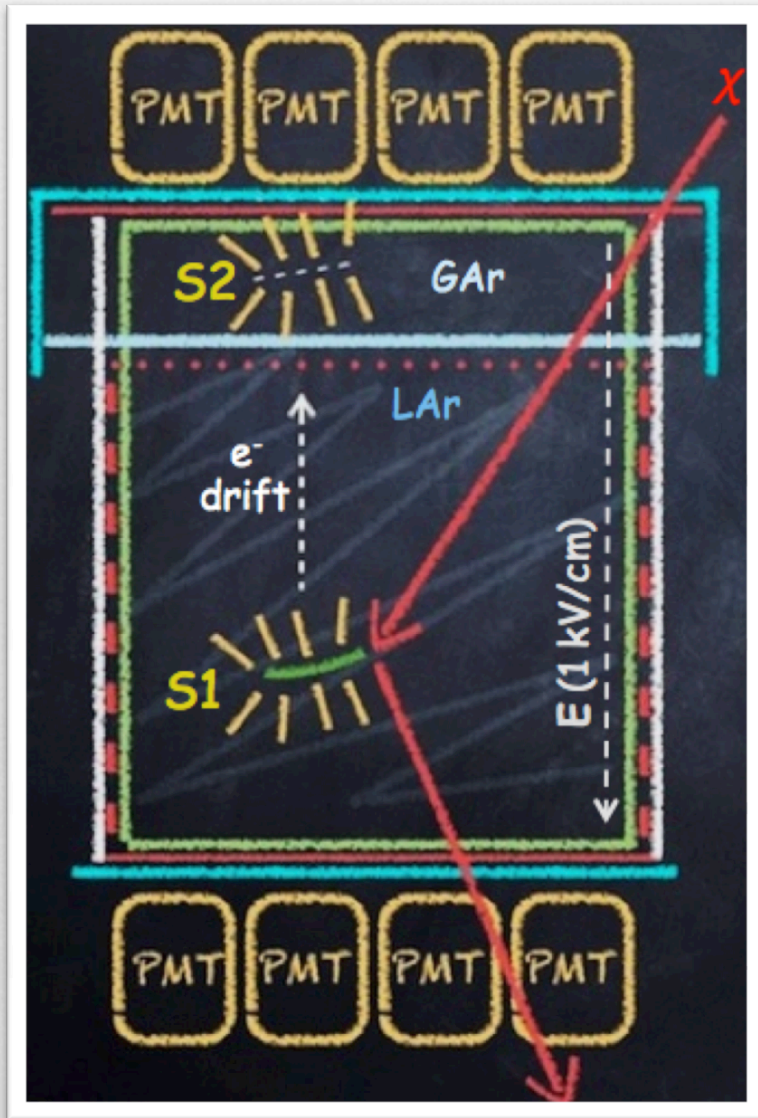
$$^{39}\text{Ar} < \mathbf{6.5 \text{ mBq/kg}}$$

(arXiv:1204.6011)

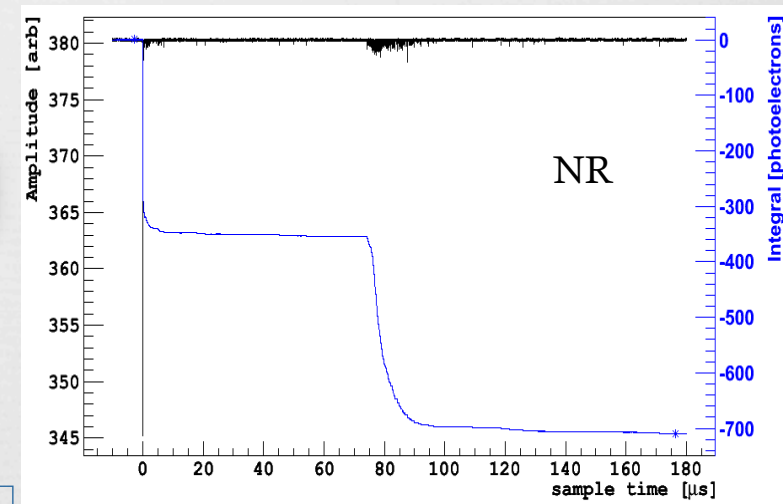
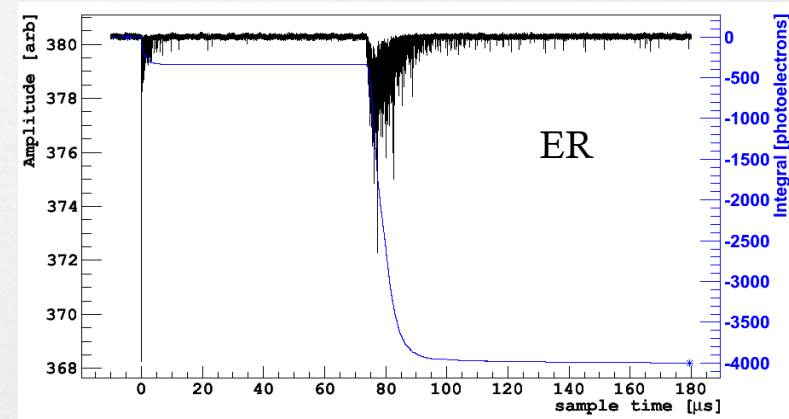
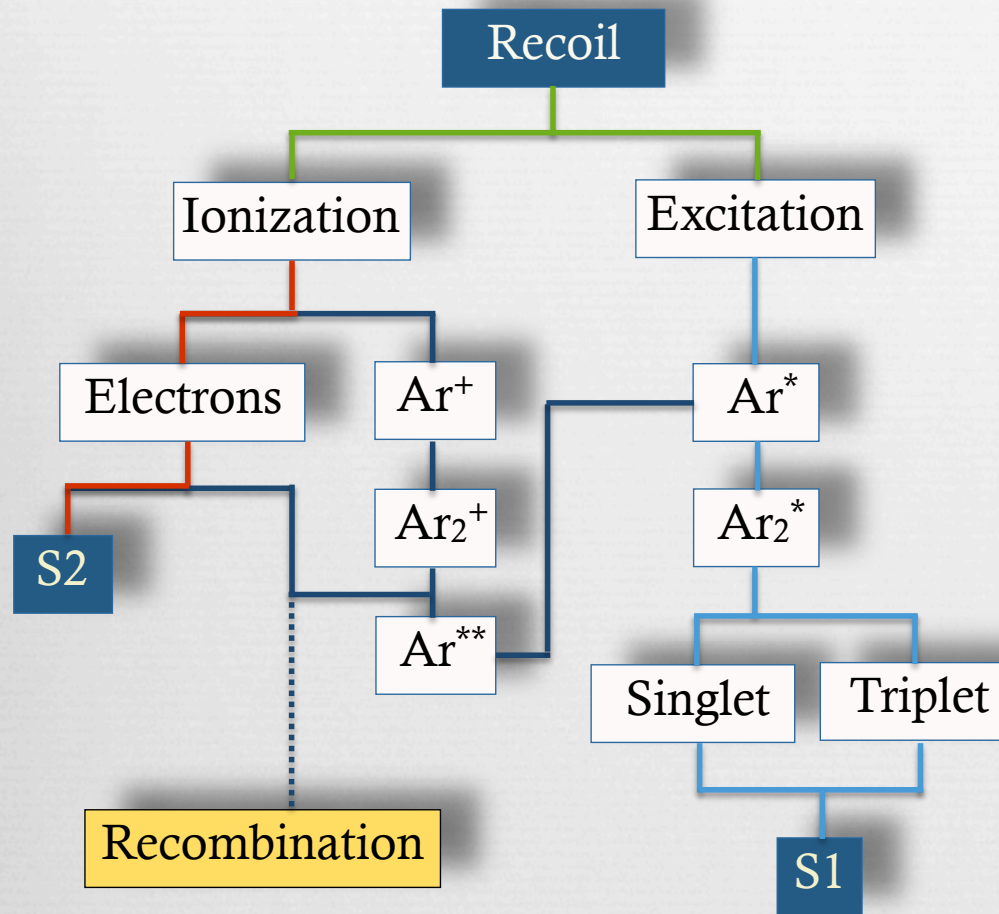


Depletion Factor $>$ 150

Dual Phase Liquid Argon TPC



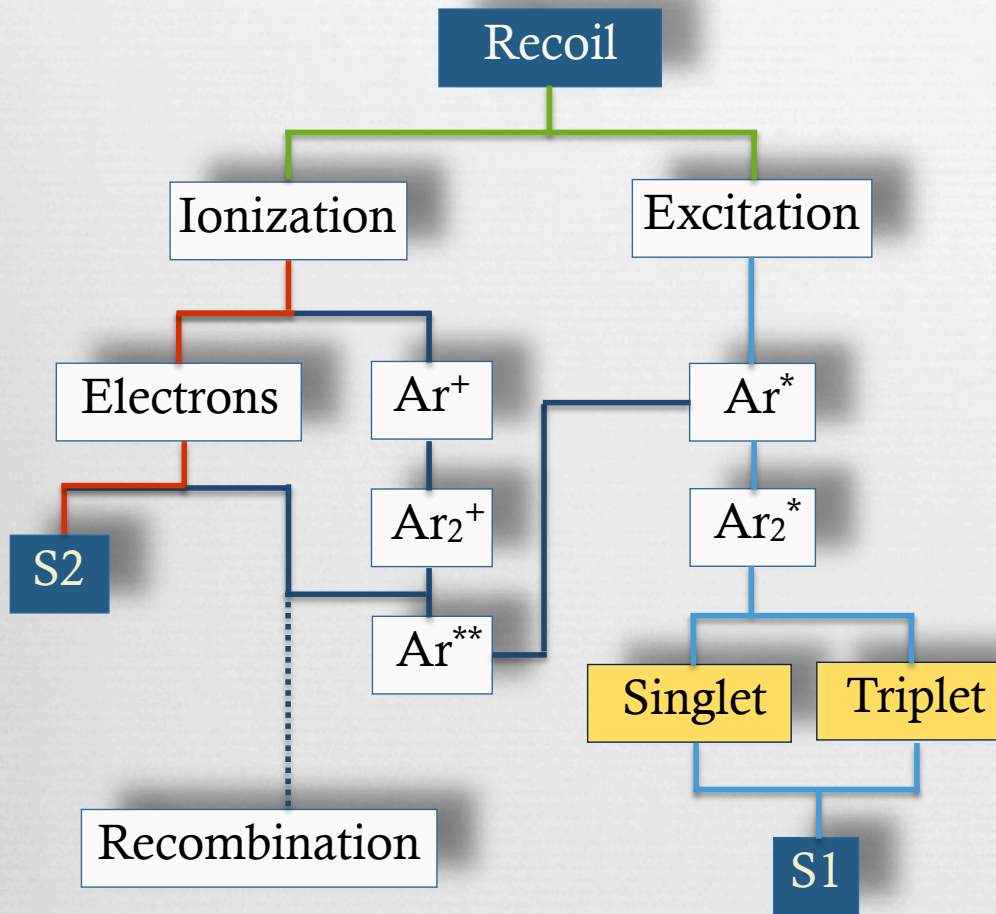
S1/S2 Discrimination Power



Rejection Factor: 10^2-10^3

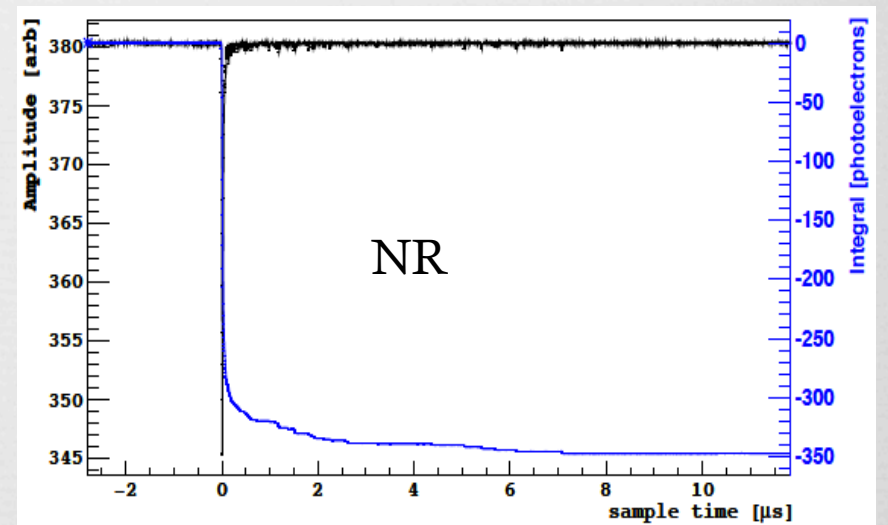
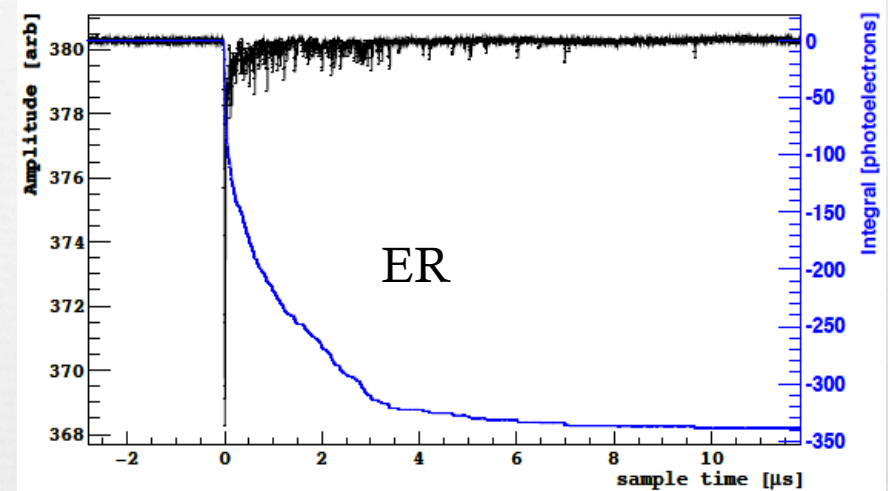
Benetti et al. (ICARUS) 1993; Benetti et al. (WARP) 2006

PSD Discrimination Power



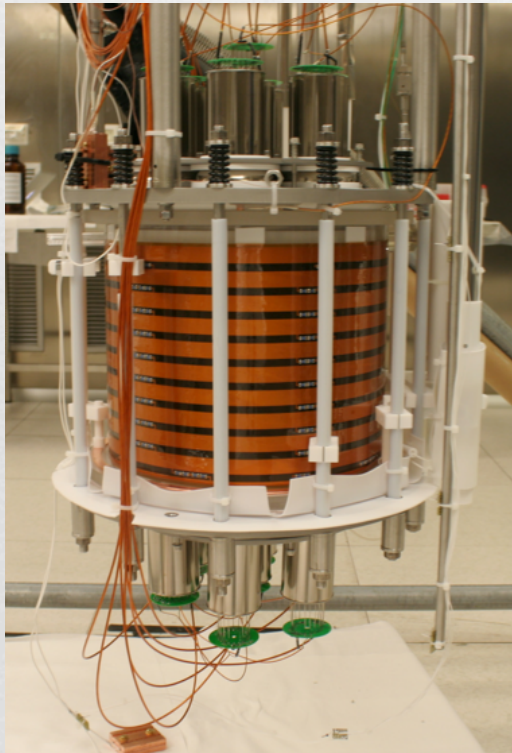
Rejection Factor: 10⁸

WARP Astr. Phys 28, 495 (2008)



The DarkSide Project

DarkSide-10
2011-2013

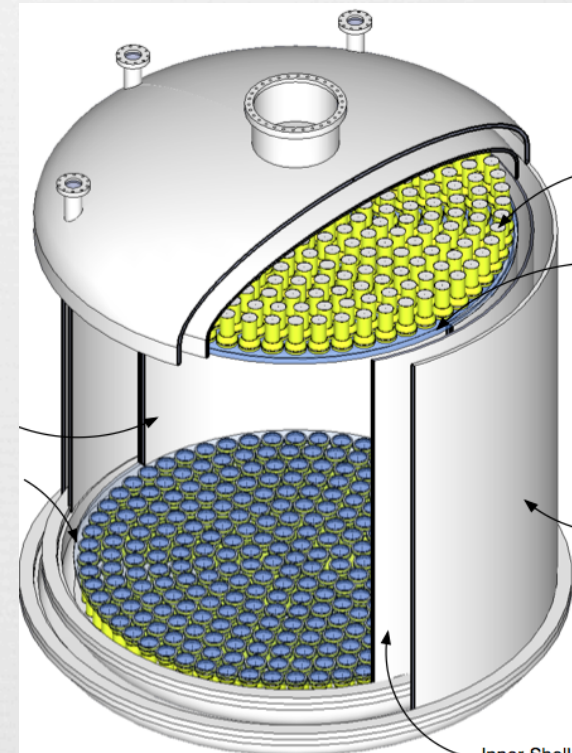


DarkSide-50
2013-201x



$\sim 10^{-45} \text{ cm}^2$

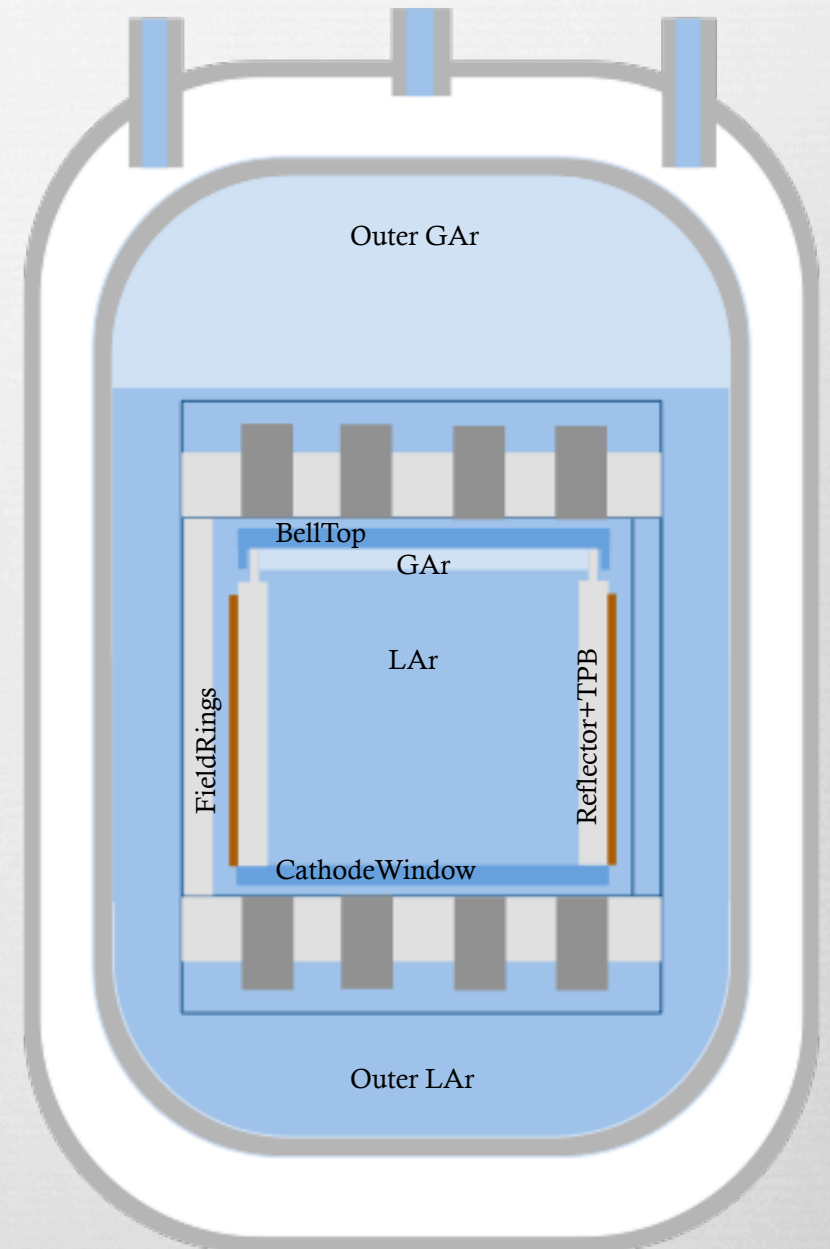
DarkSide-G2
2016-2020



$\sim 10^{-47} \text{ cm}^2$

DarkSide-50 TPC

- **50 kg** active mass of **UAr**
- 19 top + 19 bottom R11065 HQE 3'' PMTs
- 36 cm height, 36 cm diameter
- Lateral walls covered by **high reflectivity** polycrystalline PTFE
- All inner surfaces coated with **TPB**
- Fused silica diving bell (top) and windows (bottom) in front of the PMT arrays, coated with ITO
- **0.2 kV/cm drift**, 2.8 kV extraction



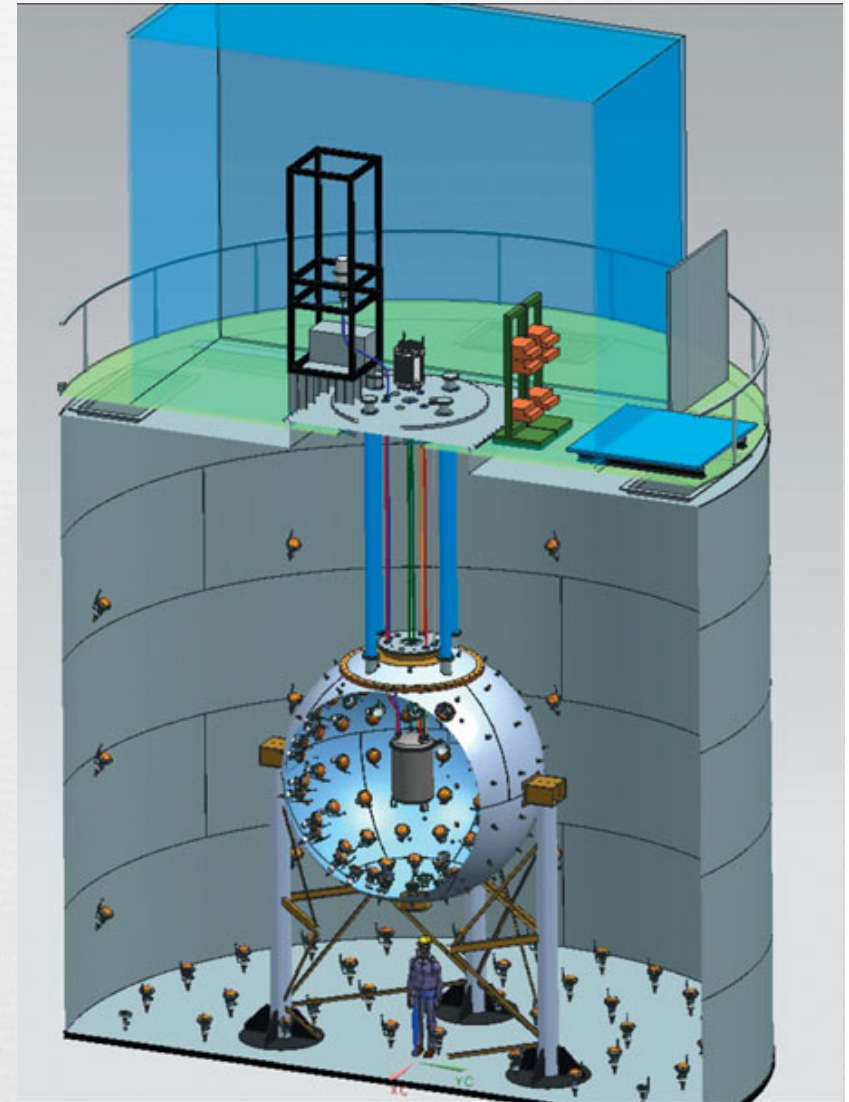
The Vetoes

LSV

- 4 m diameter sphere
- Boron-loaded: 50/50 PC and TMB
- 110 8" PMTs
- Active neutron veto
 - tag neutrons from the TPC
 - in situ measurement of neutron rate
- Neutron and gamma shielding
- LY \sim 500 pe/MeV

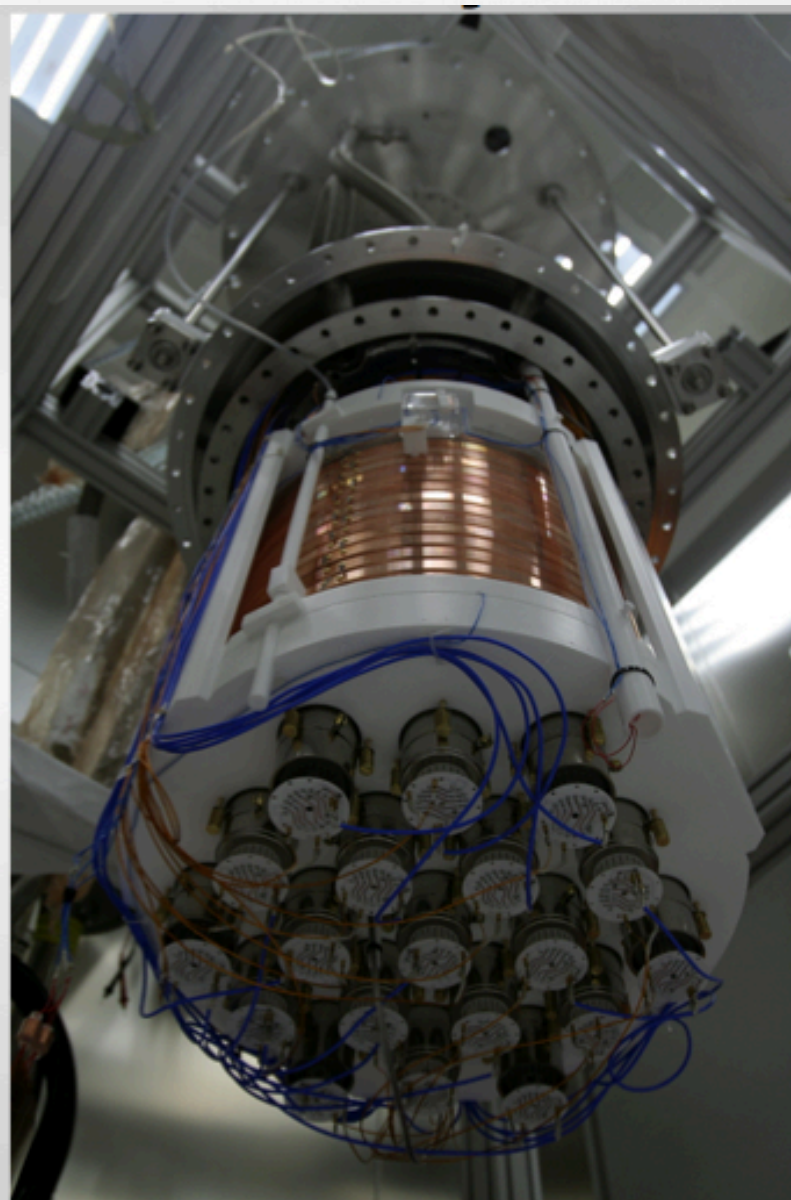
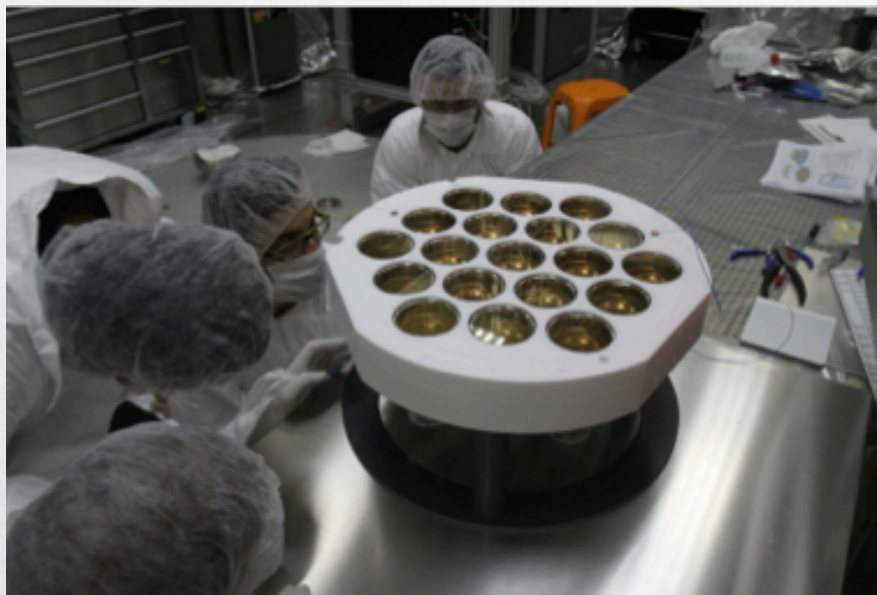
WT

- 11 m diam. x 10 m
- 80 PMTs
- Active muon veto
 - tag cosmogenic neutron events

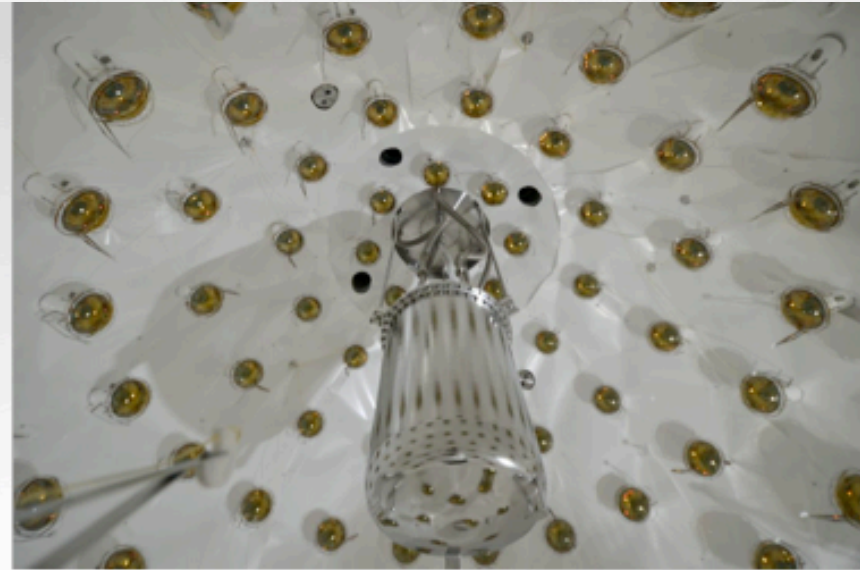


DESIGNED FOR G2!

DarkSide-50 Assembly



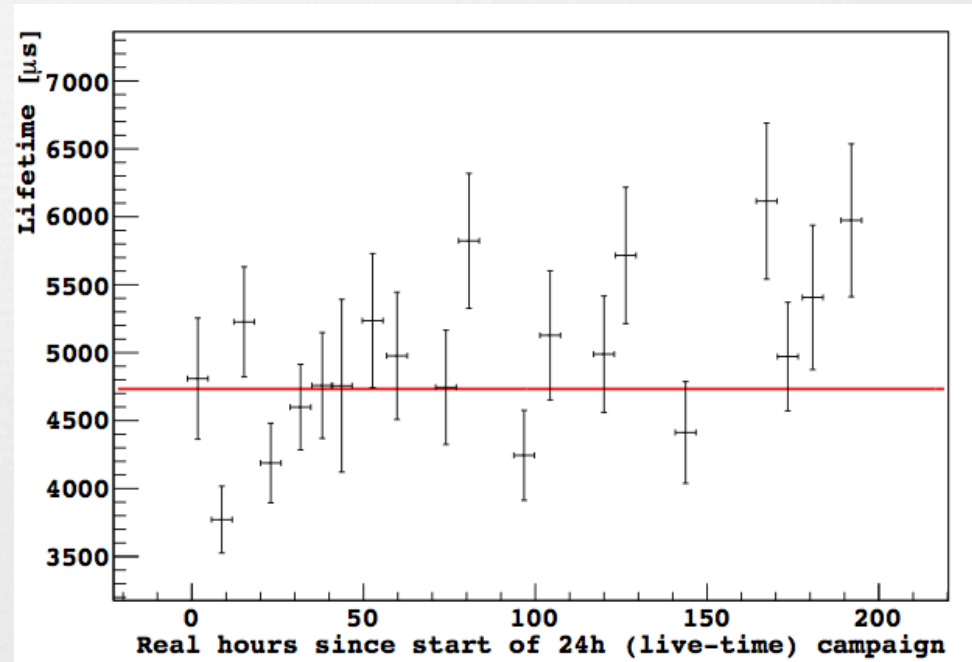
DarkSide-50 Assembly



Electron lifetime

Achieved drift lifetime of
4733 +/- 90 μ s

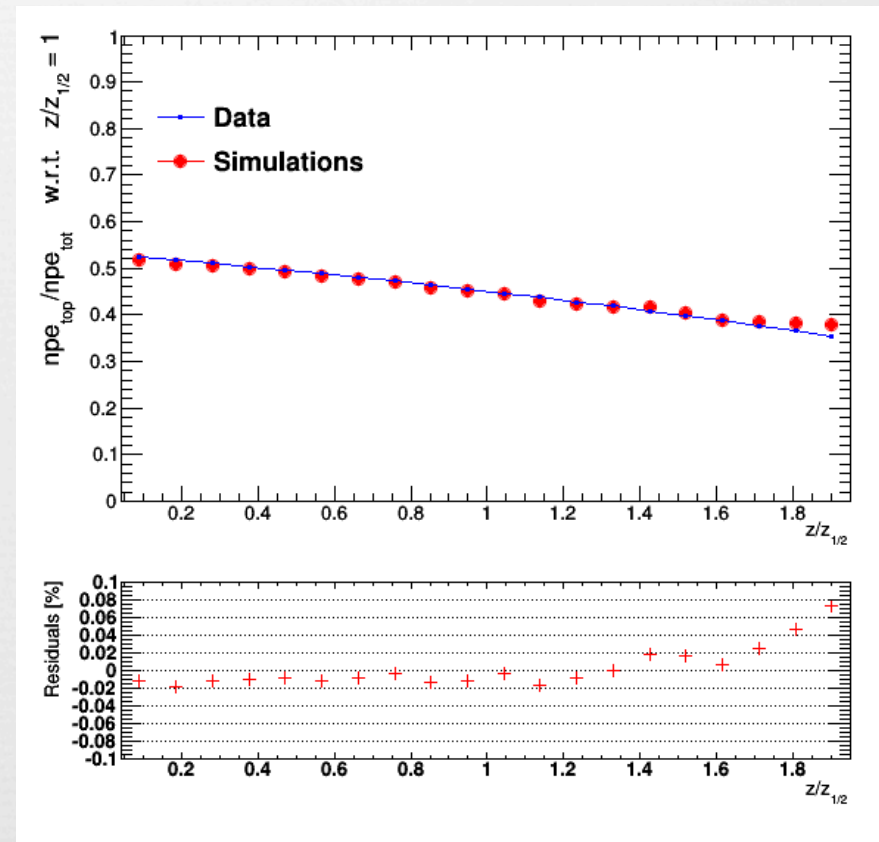
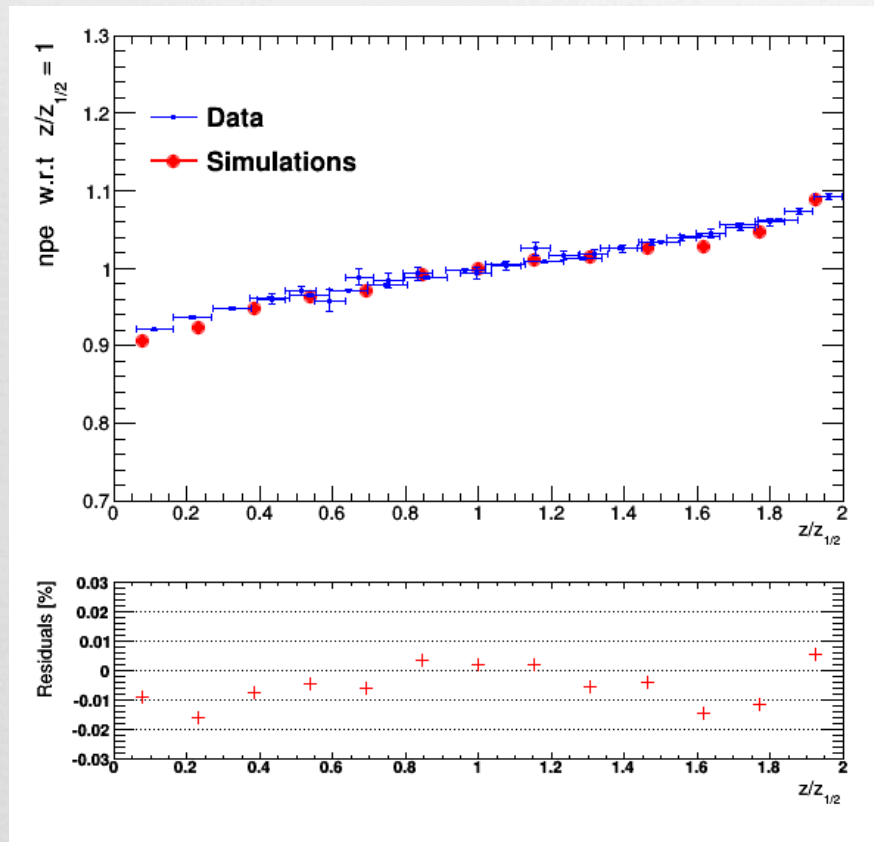
Maximum drift time of the
TPC is $\sim 370 \mu$ s at 200 V/
cm drift field.



Demonstrates high purity of argon
Stable operation of electric fields

TPC Optics: MC-Data comparison

Tuning of the main 36 optical parameters



Few percent accuracy

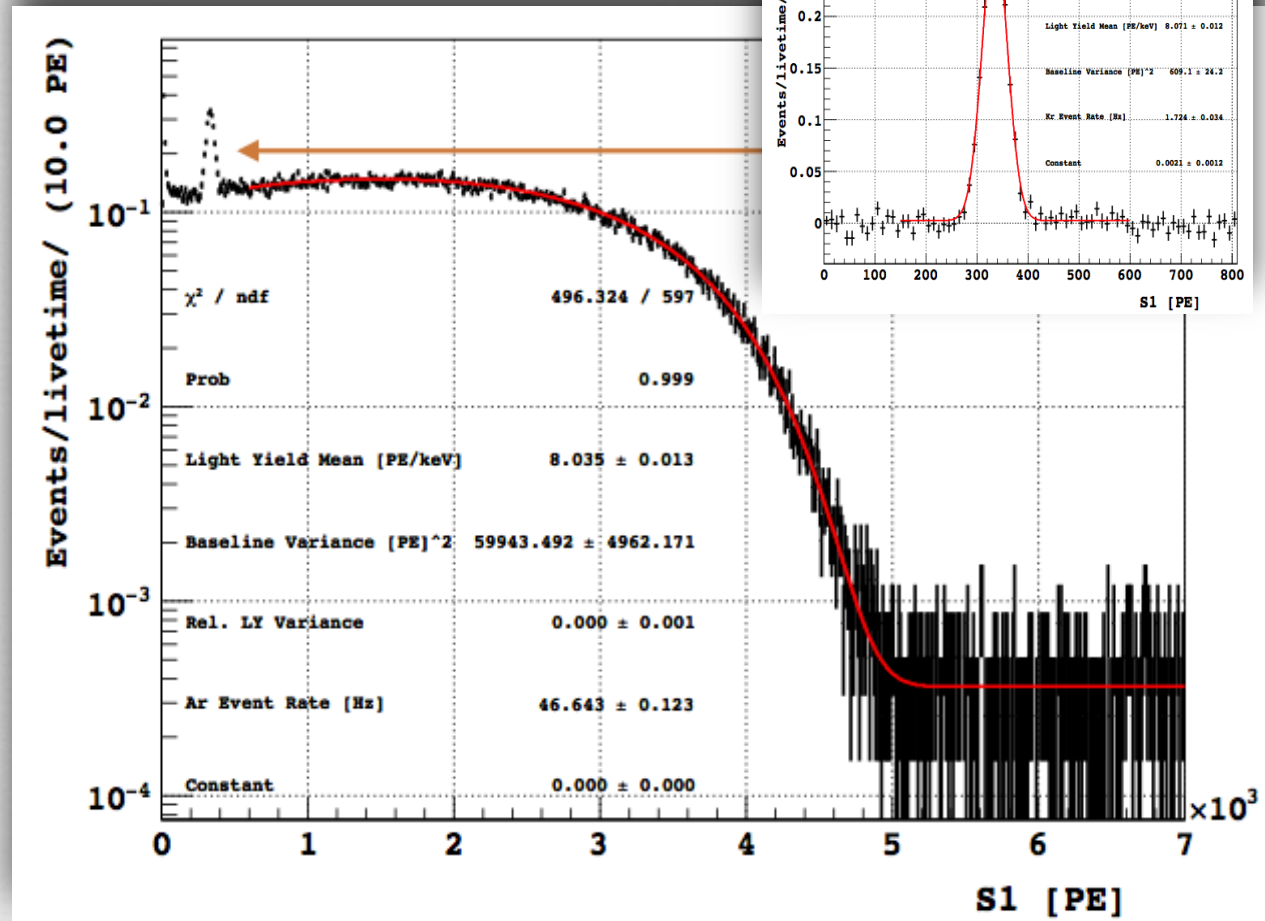
Electron Energy Scale

Calibration with:

^{39}Ar – 565 keV endpoint

Injected gaseous $^{83\text{m}}\text{Kr}$

Total gamma $E = 41.5$ keV

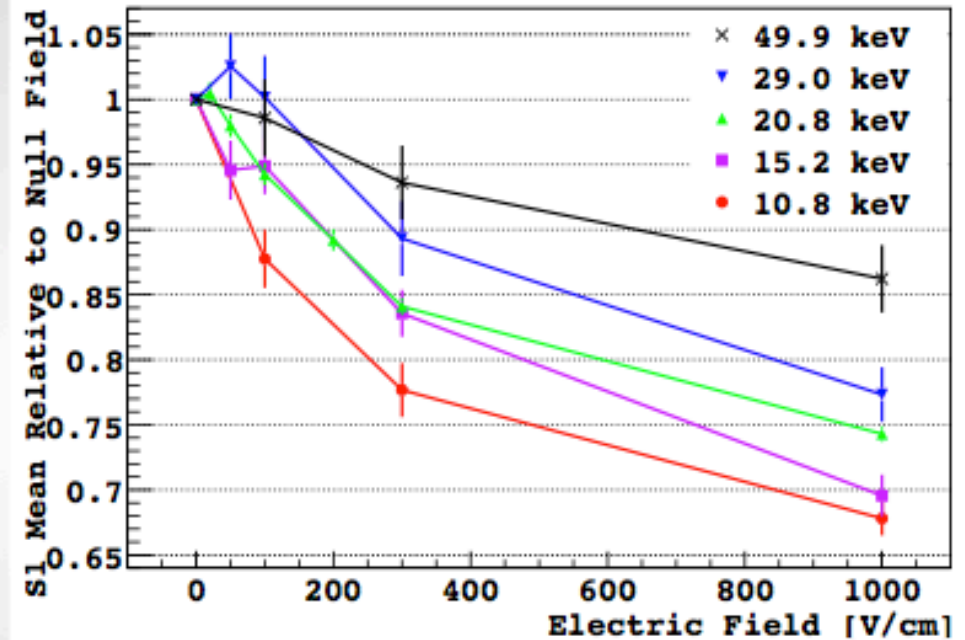
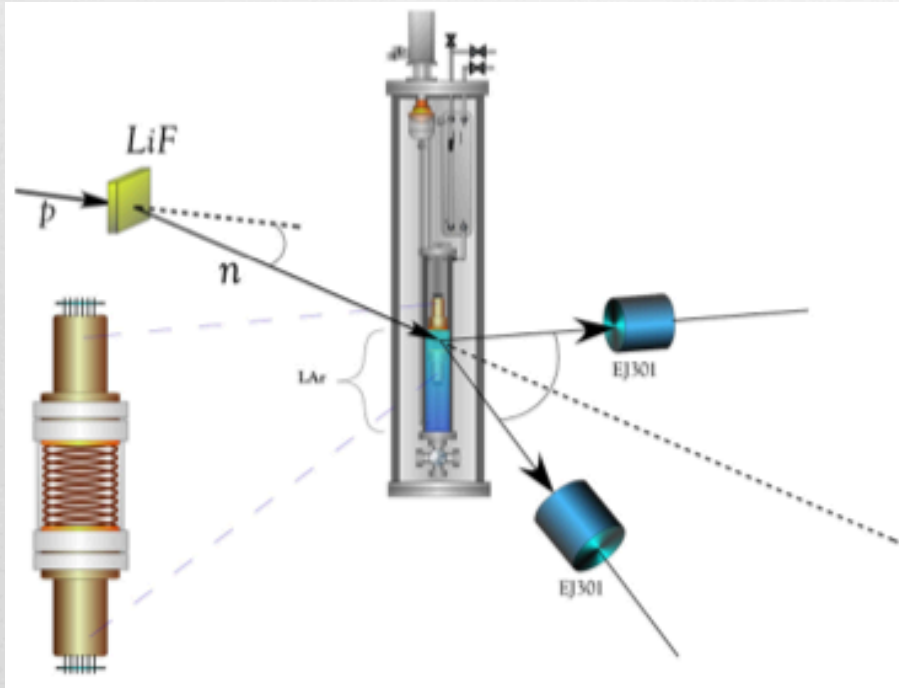


Average Light Yield: **8.040 ± 0.006** (stat) pe / keVee at null field
 (~**7.1** at 200 V/cm)

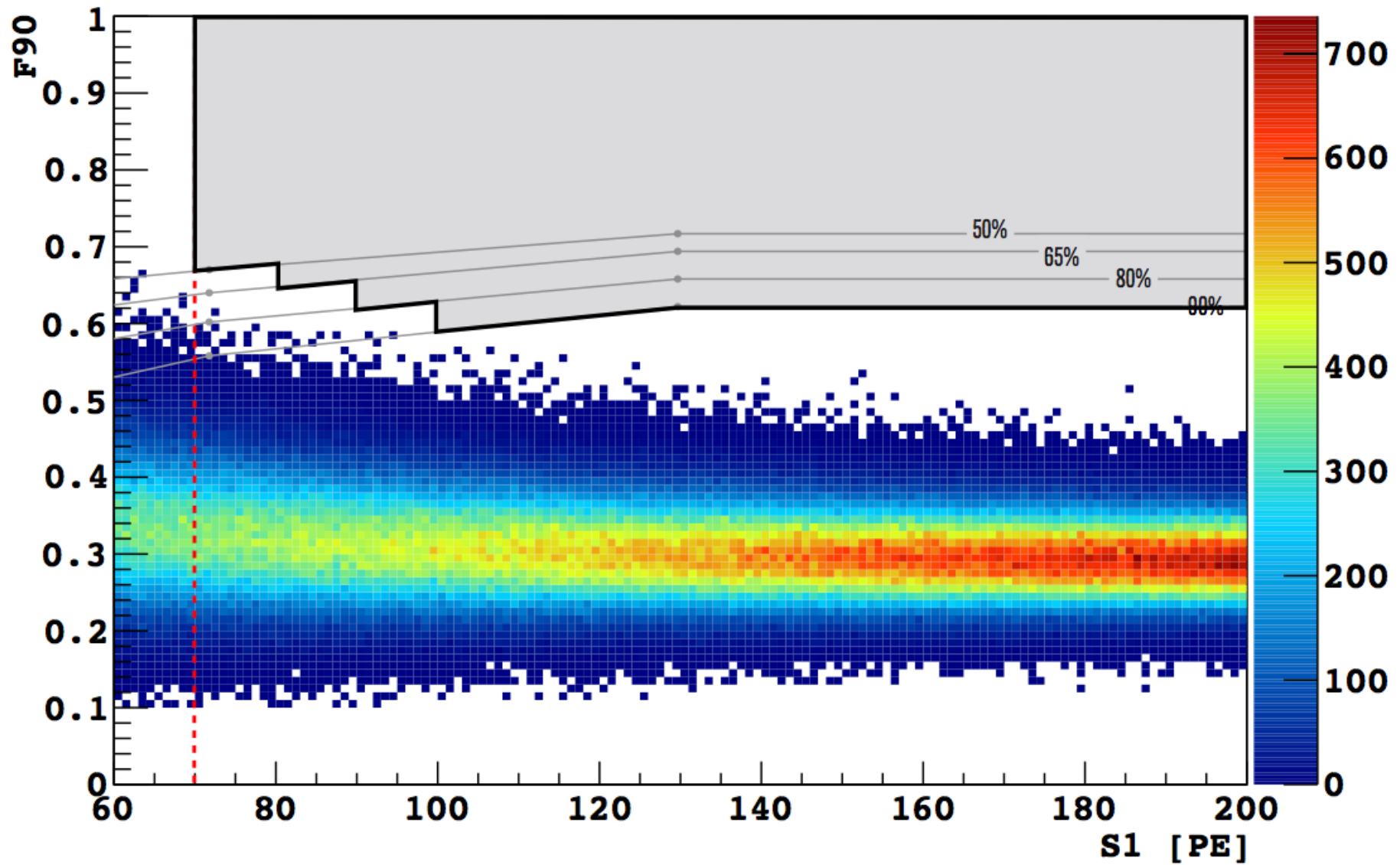
Nuclear Recoil Energy Scale

SCENE

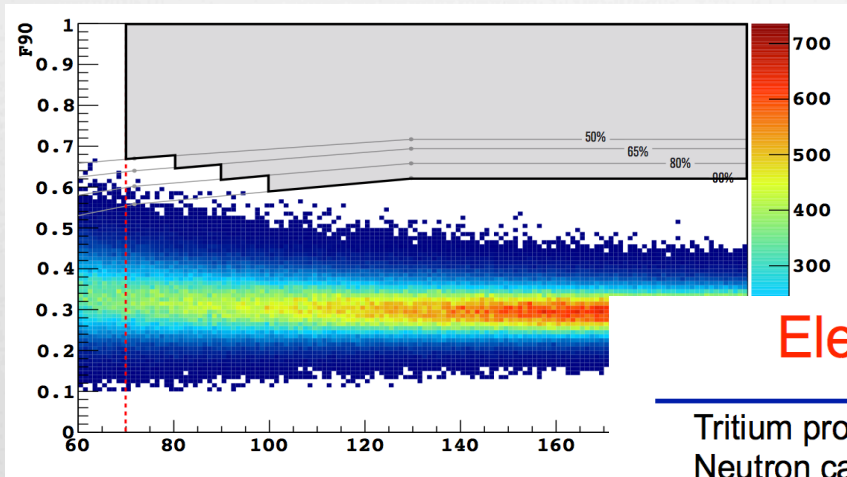
Scintillation Efficiency of Nuclear Recoils in Noble Elements



BG equivalent to 2.6 y with UAr

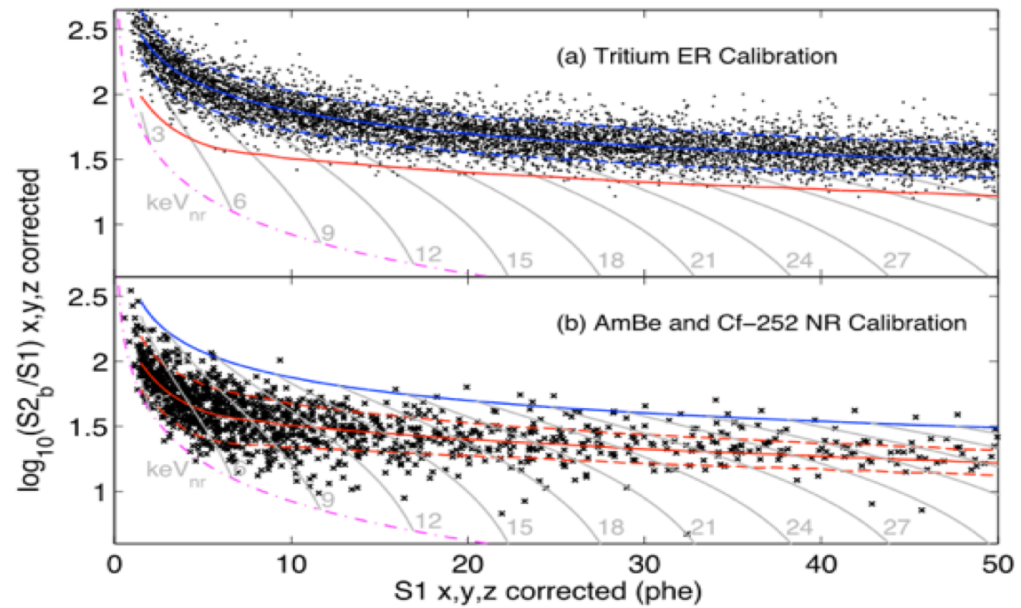


Discrimination Power Comparison



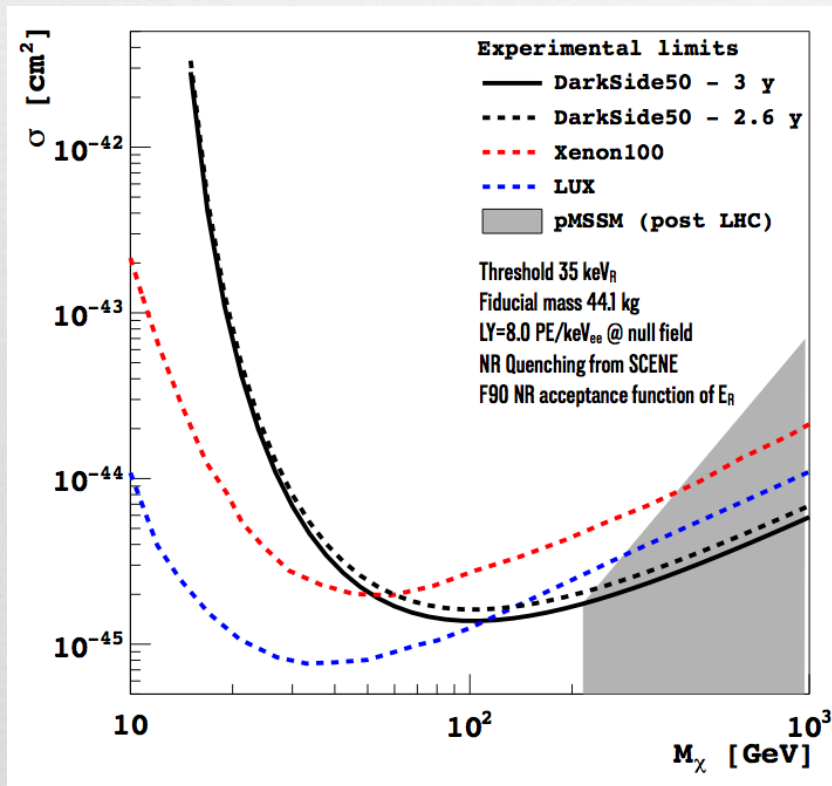
Electron Recoil and Nuclear Recoil Bands

Tritium provides very high statistics electron recoil calibration (200 events/phe)
 Neutron calibration is consistent with NEST + simulations



Gray contours indicate constant energies using a S1-S2 combined energy scale

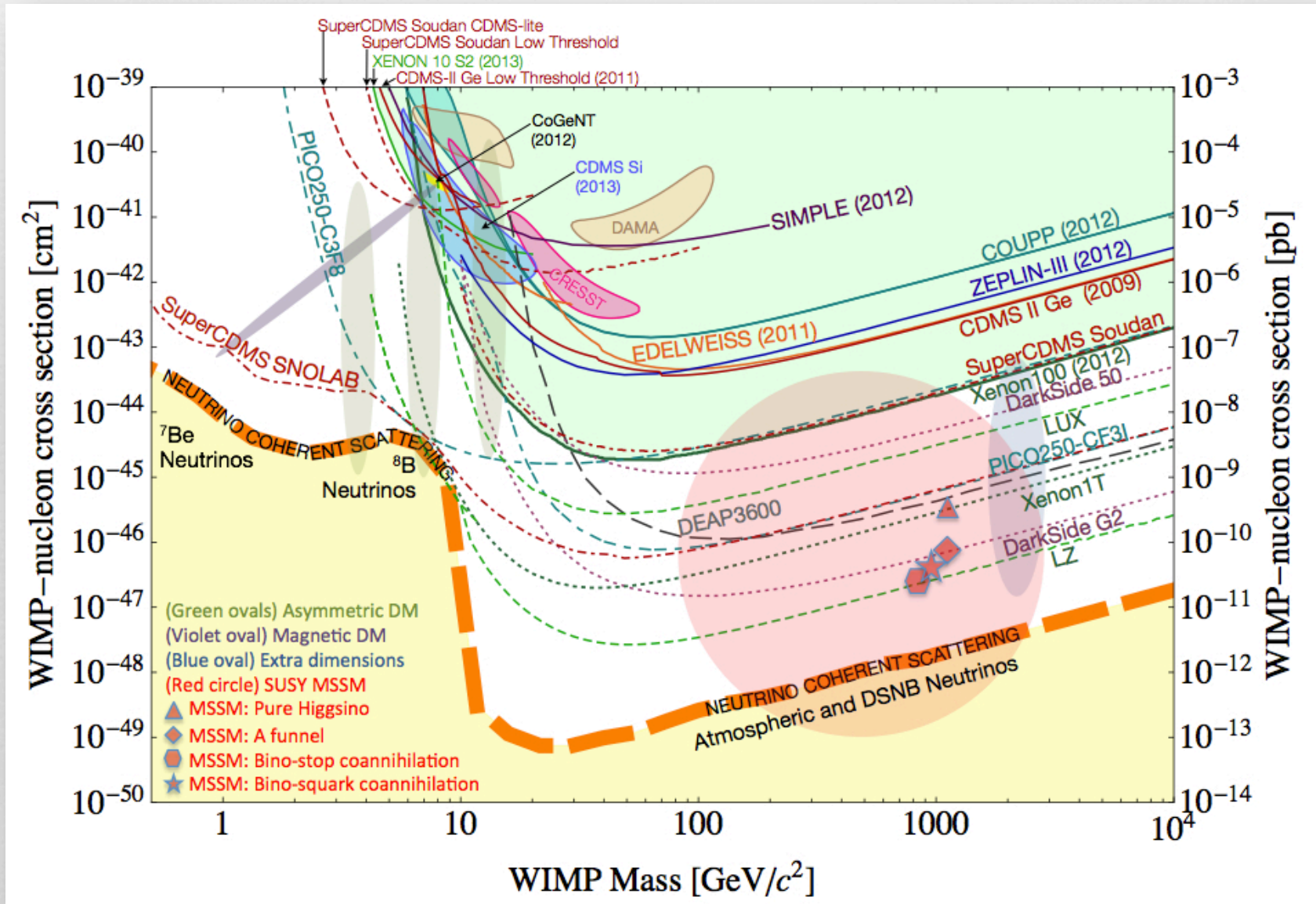
DarkSide-50 Projected Sensitivity



Projected sensitivity evaluated assuming:

- the measured PSD performance;
 - no rejection from S2/S1;
 - fiducial volume along z axis-only;
 - zero neutron-induced events;
 - NR quenching and F90 acceptance curves from SCENE @ 200V/cm
-
- Present systematics on NR Quenching and F90 NR acceptance curves responsible of ~10% variation of the projected sensitivity around 100 GeV/c².

DarkSide-G2 Sensitivity



Summary

DarkSide-50 TPC and vetoes are **operational** at LNGS

Long electron drift **lifetime** achieved

Exceeded desired **light yield**

Early running using atmospheric argon

Excellent **discrimination**

Ready to the depleted LAr phase!