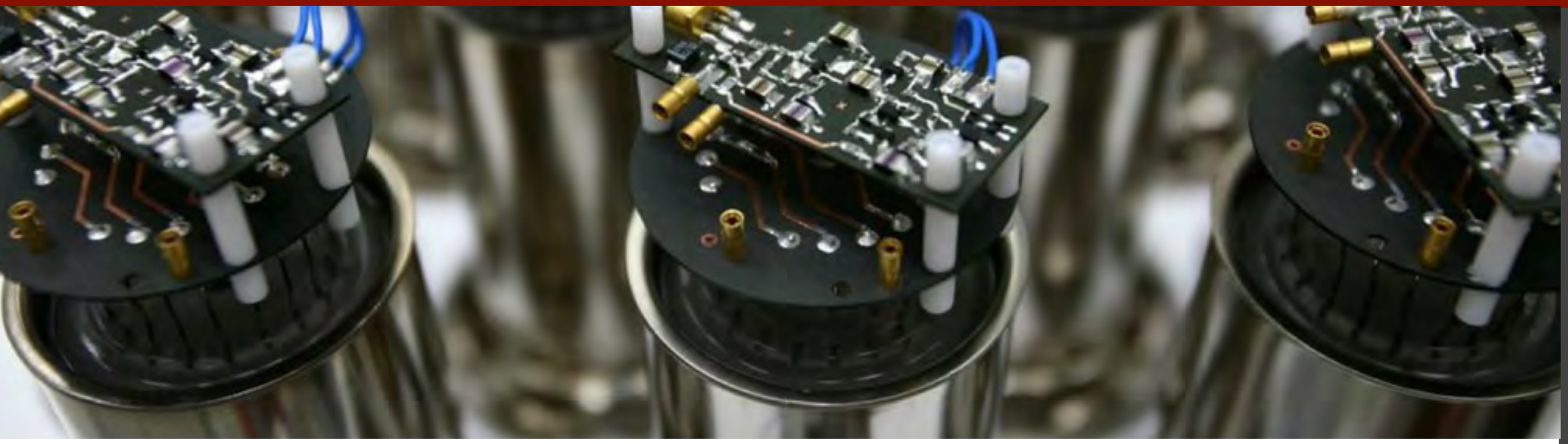


THE DARKSIDE OF DIRECT DARK MATTER SEARCHES

Emilija Pantic
for the DarkSide collaboration

UC DAVIS
UNIVERSITY OF CALIFORNIA

TeVPA 2016, CERN

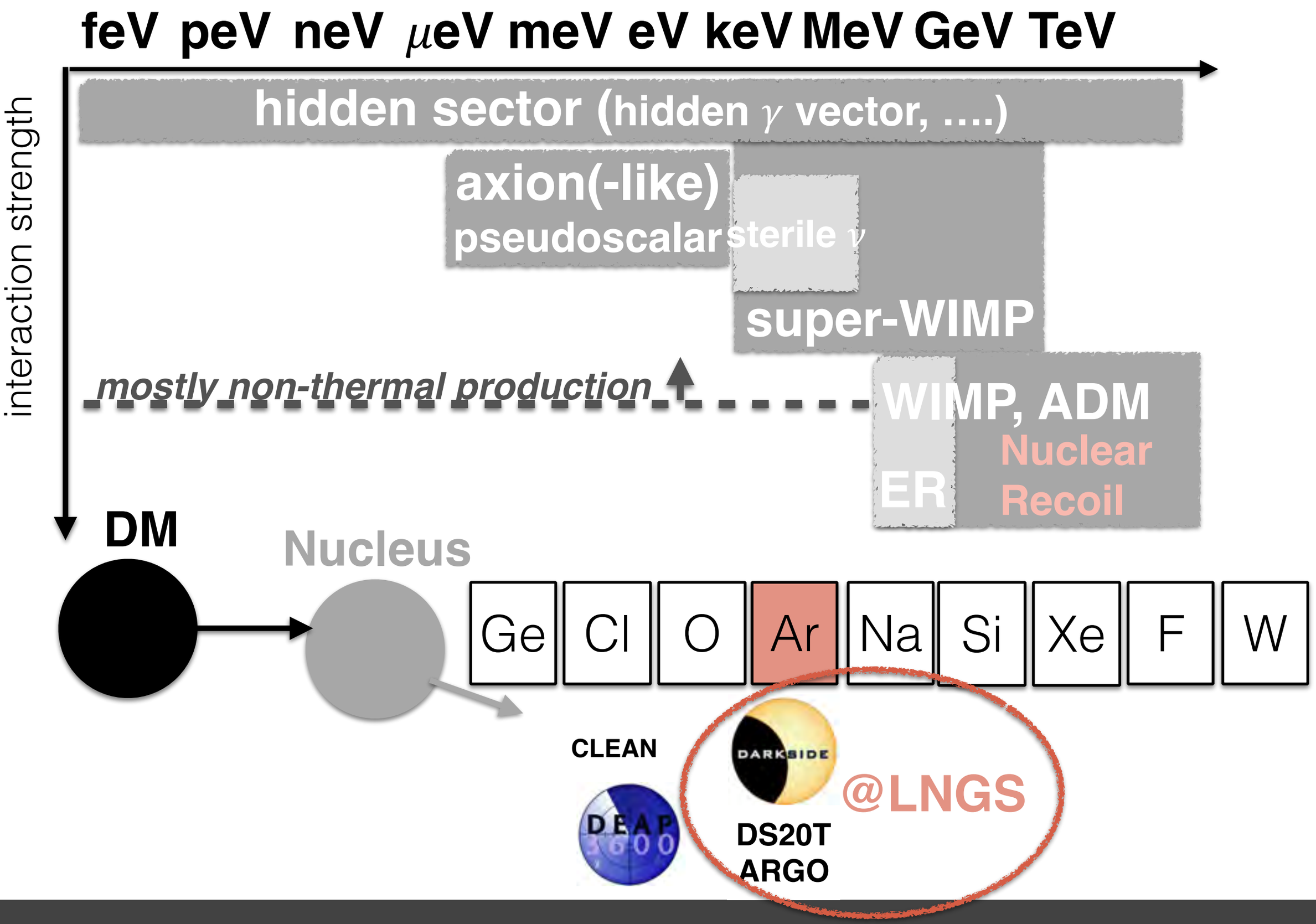
style from F.Tanedo (UCR)

pantic@ucdavis.edu

http://darkside.lngs.infn.it/collaboration

Lets put things in perspective

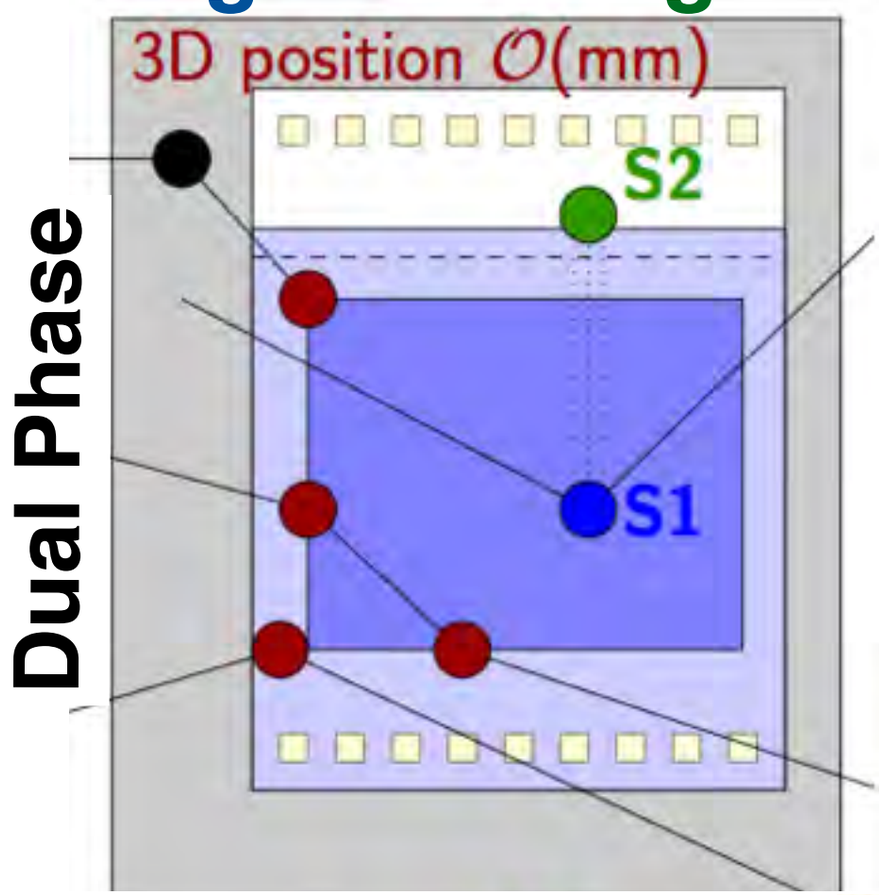
Just a sketch



"50 shades of dark" P.Gondolo

DarkSide LAr dual phase TPC

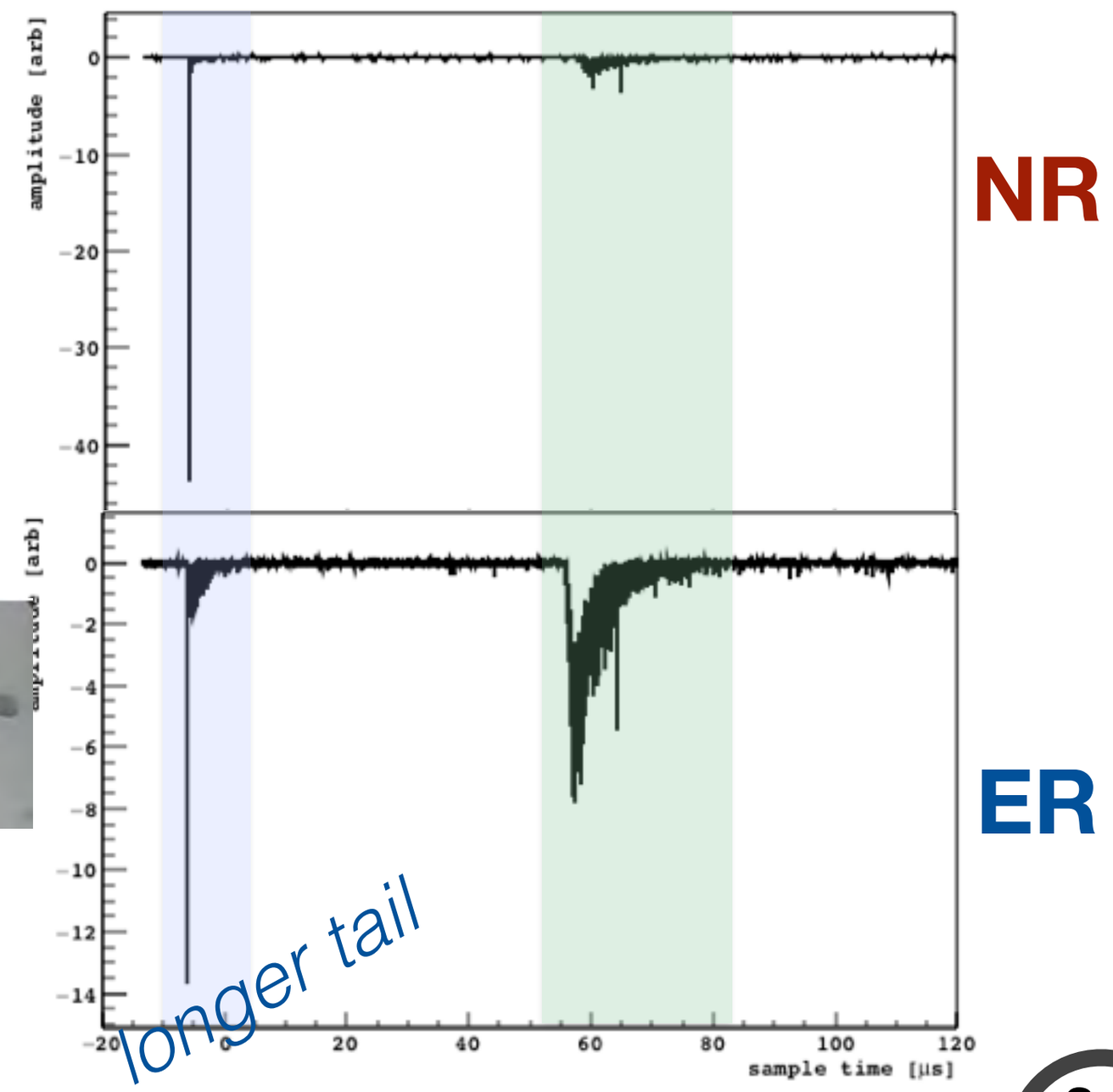
Light + Charge



46kg of LAr
200V/cm drift field
38 3” PMTs
ITO on quartz for electrodes
TPB as wavelength shifter
Teflon as reflector
extraction grid

Pulse shape discrimination of ERs

S2/S1 discrimination of ERs

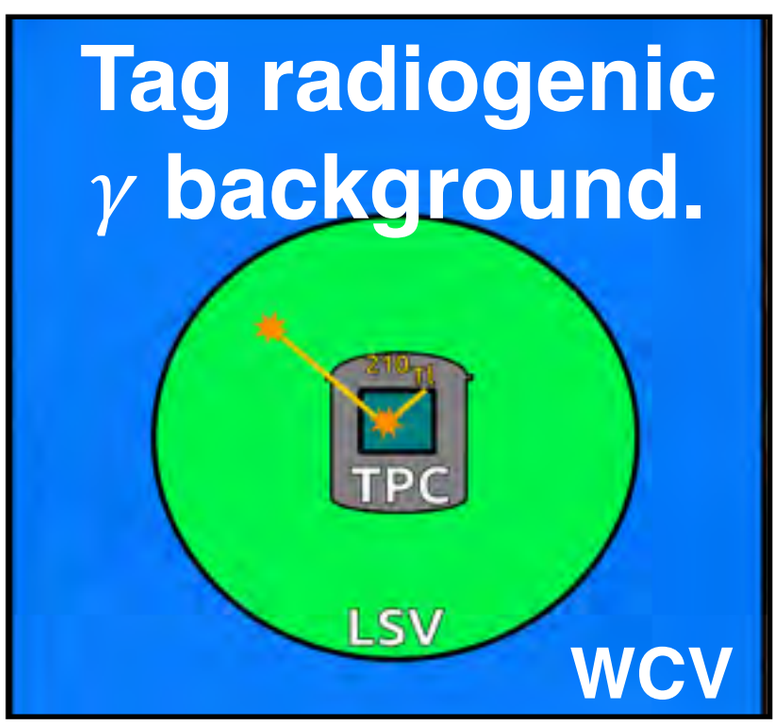


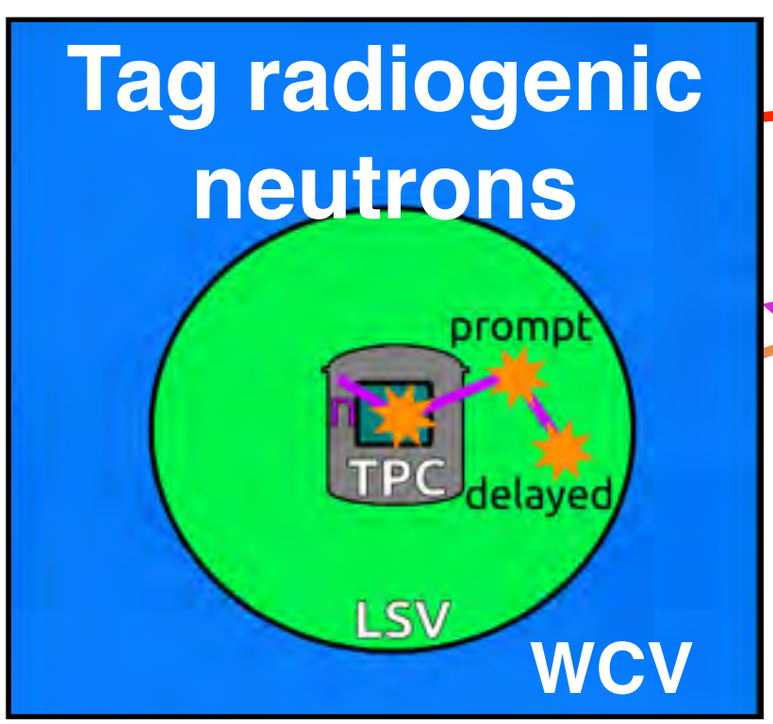
DarkSide-50 Veto Detectors:

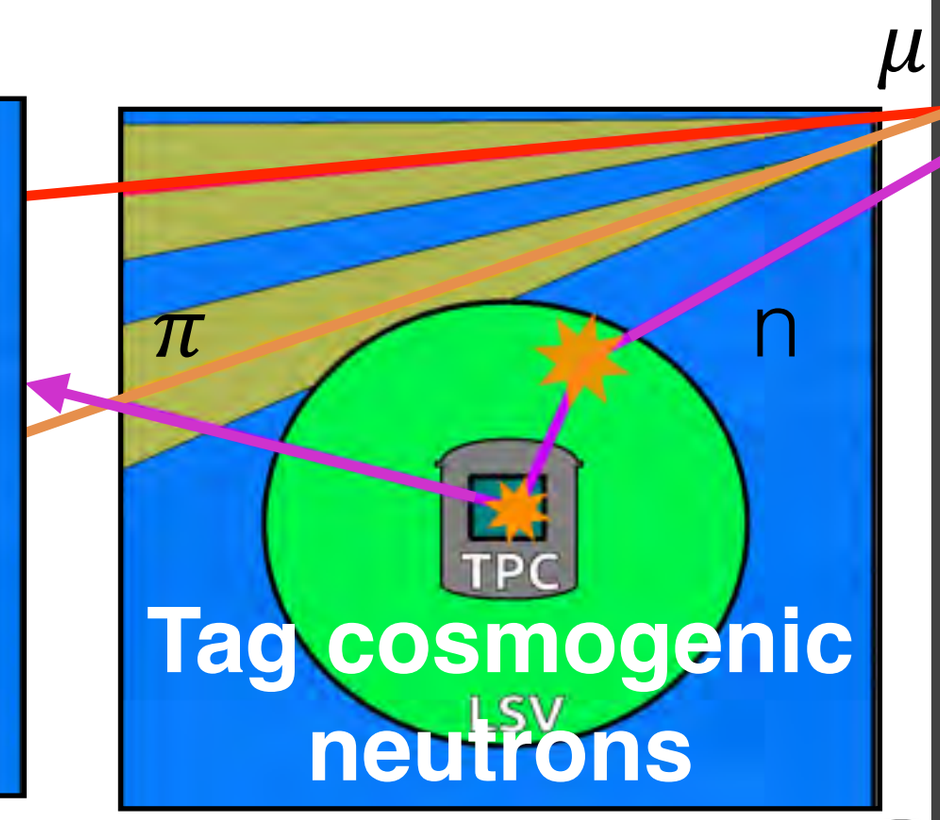
Liquid Scintillator Veto (LSV) = 30 t of TM**B** + PPO + PC

Neutrons that scatter in the TPC can be detected via capture signal on **^{10}B** or thermalization signal in LSV.

Water Cherenkov Veto (WCV), to tag cosmogenic neutrons via muons.

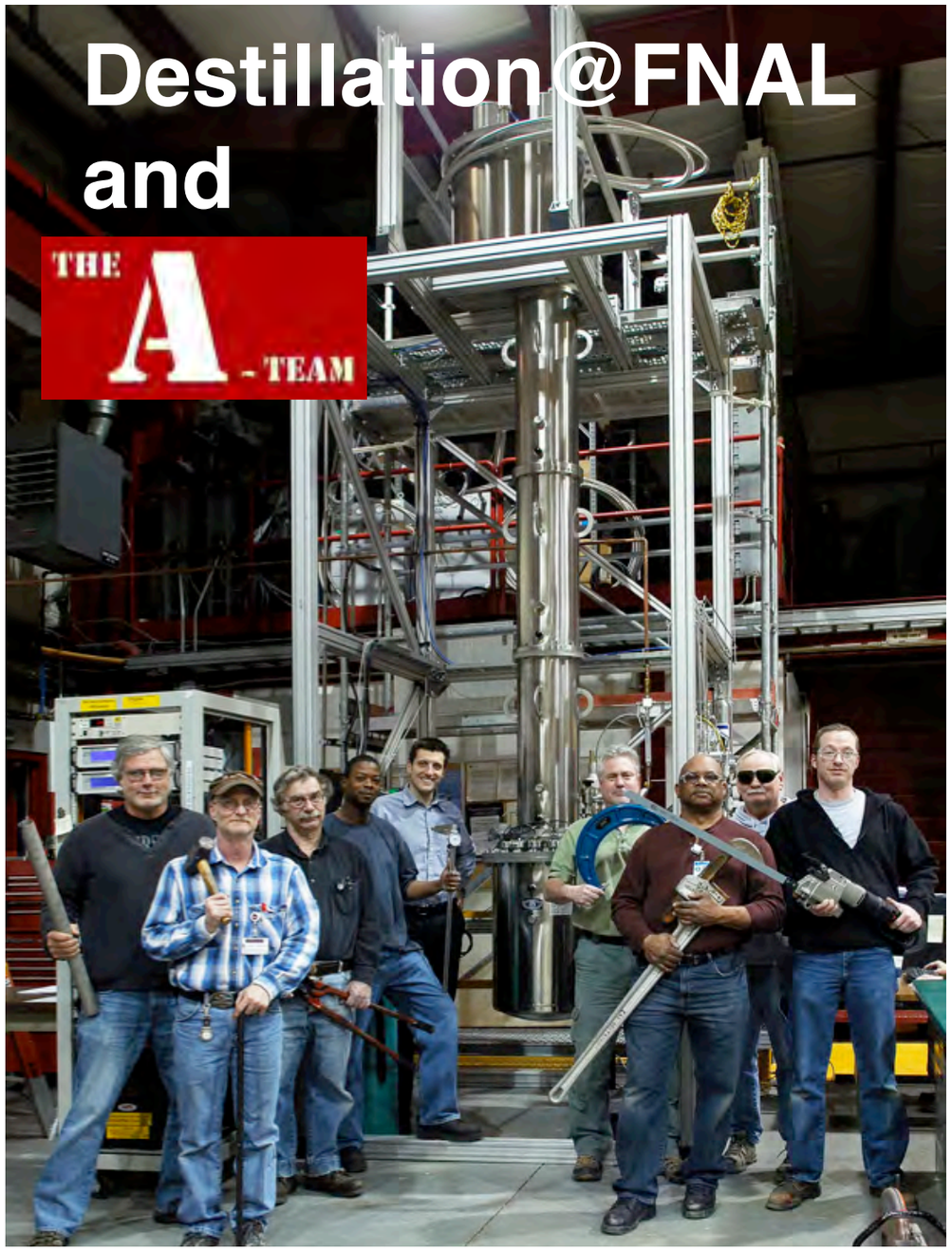


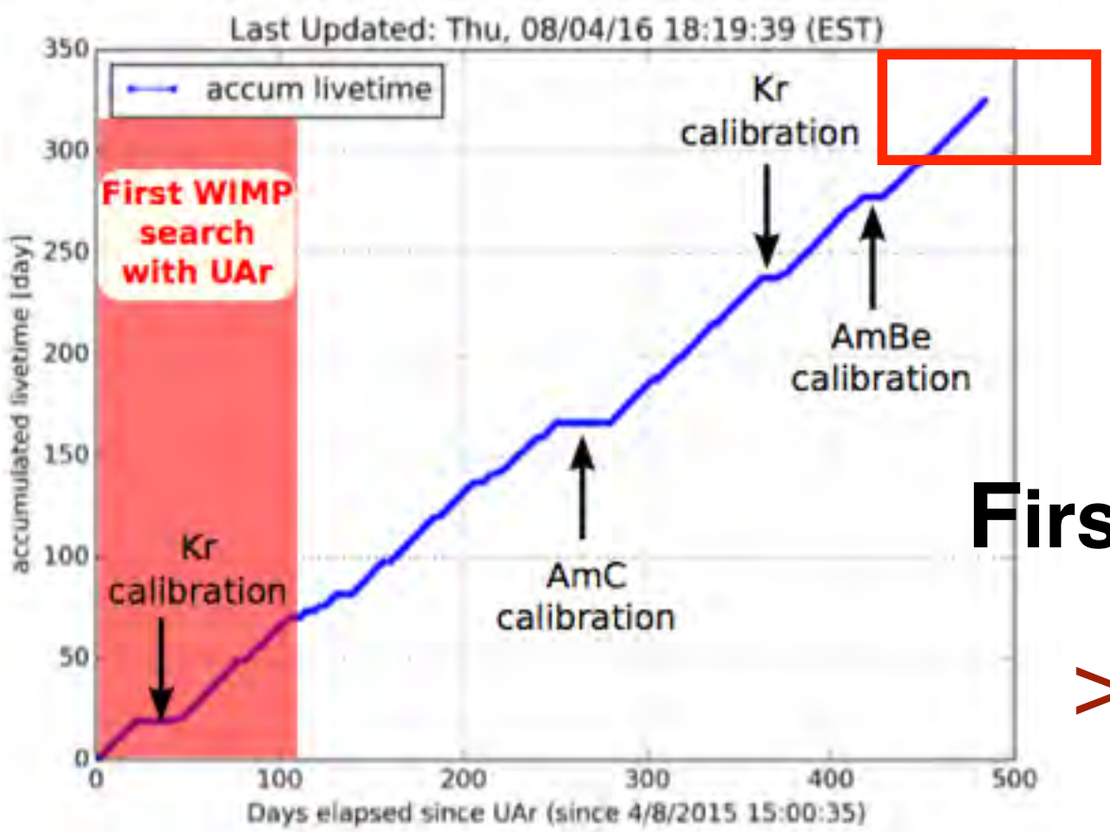




pictures from S.Westerdale

Underground Ar





First run (70days) with 150kg of UAr

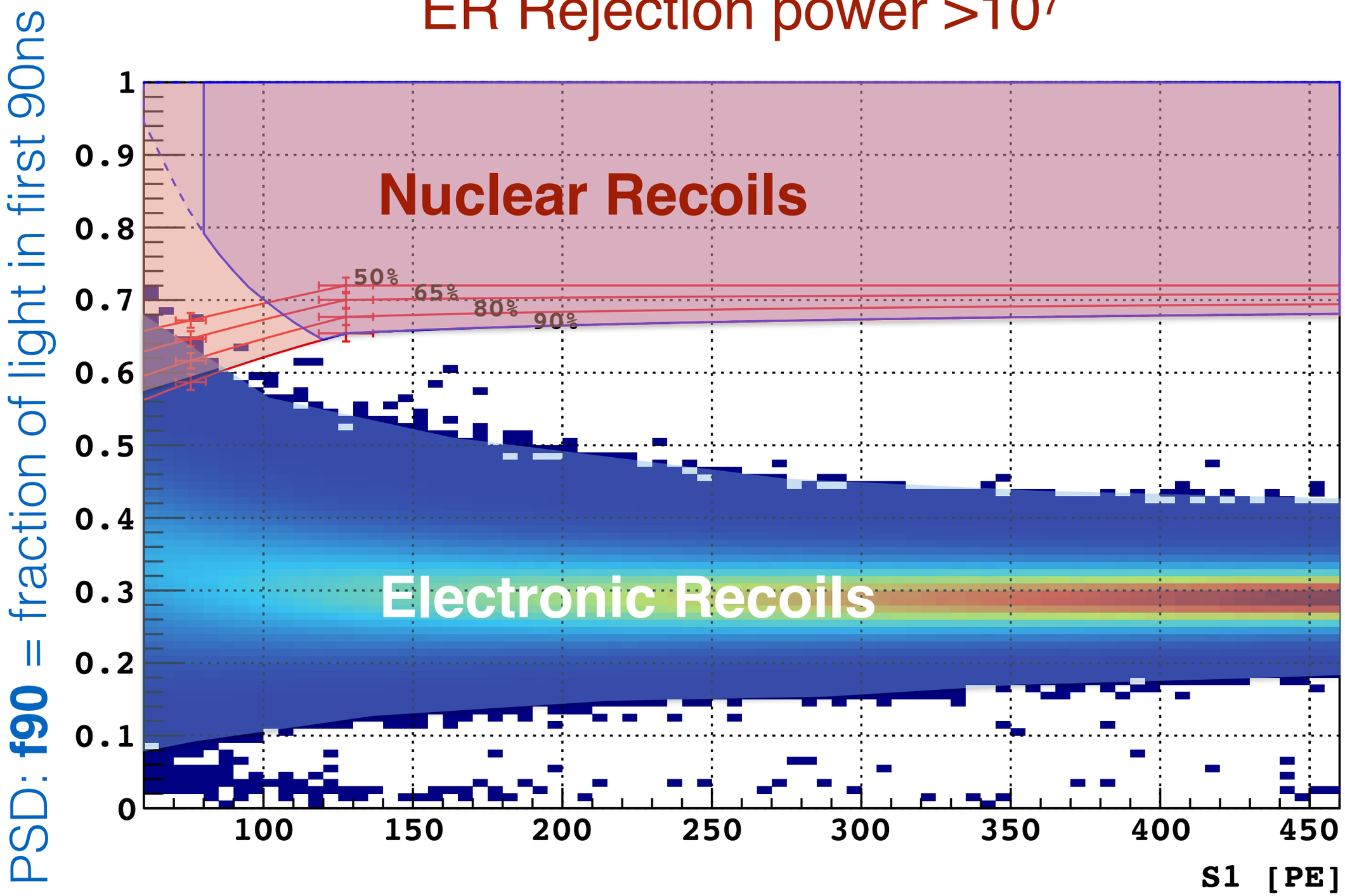
> 260 additional days recorded

A Study of the Residual 39Ar39Ar Content in Argon from Underground Sources Astropart.Phys. 66 (2015)
First Large Scale Production of Low Radioactivity Argon From Underground Sources arXiv:1204.6024

In-situ internal calibrations: TPC

50 days of Atmosph. Ar run is calibration: 1.5 x10^7 ER events

ER Rejection power >10^7



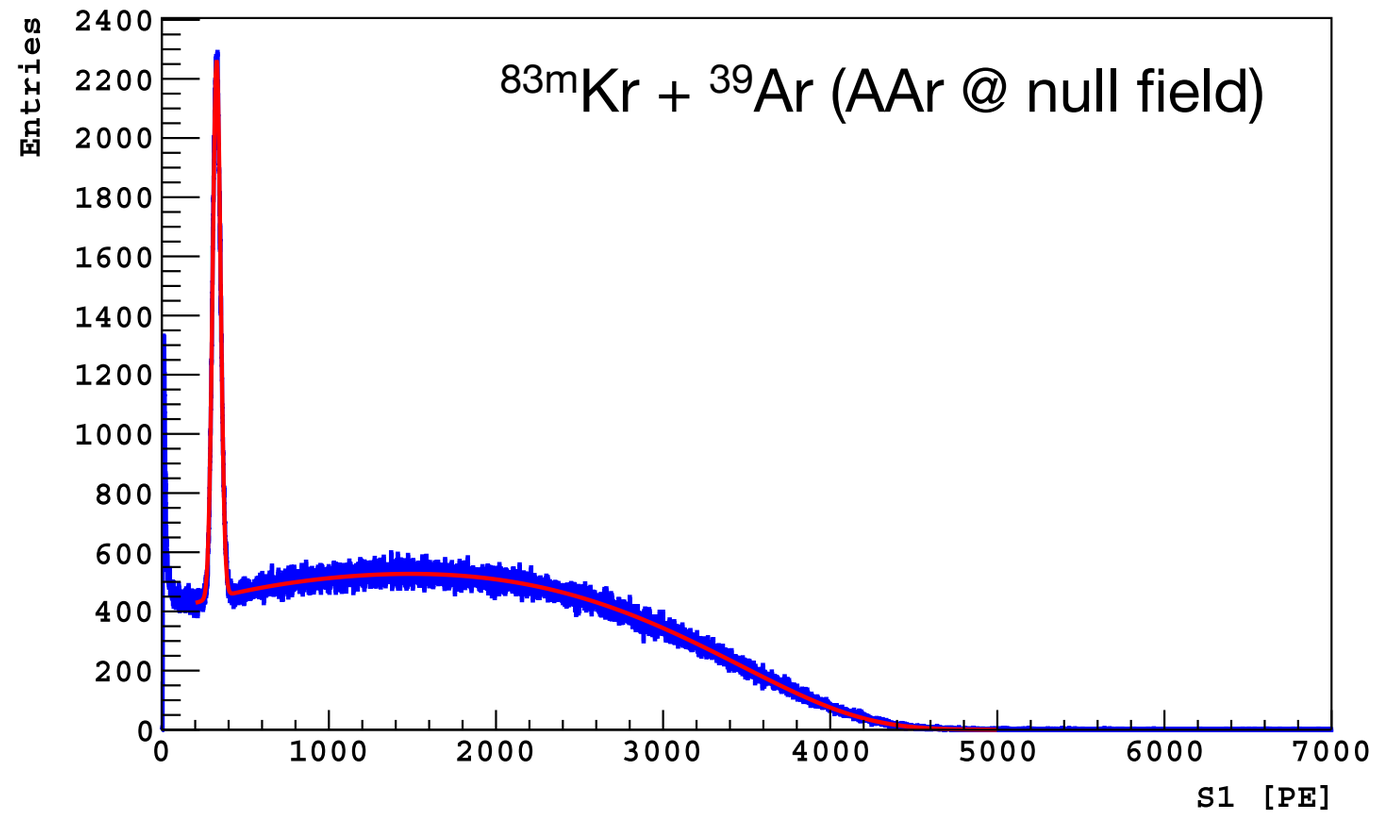
First Results from the DarkSide-50 Dark Matter Experiment at Laboratori Nazionali del Gran Sasso, Phys.Lett. B 743 (2015)

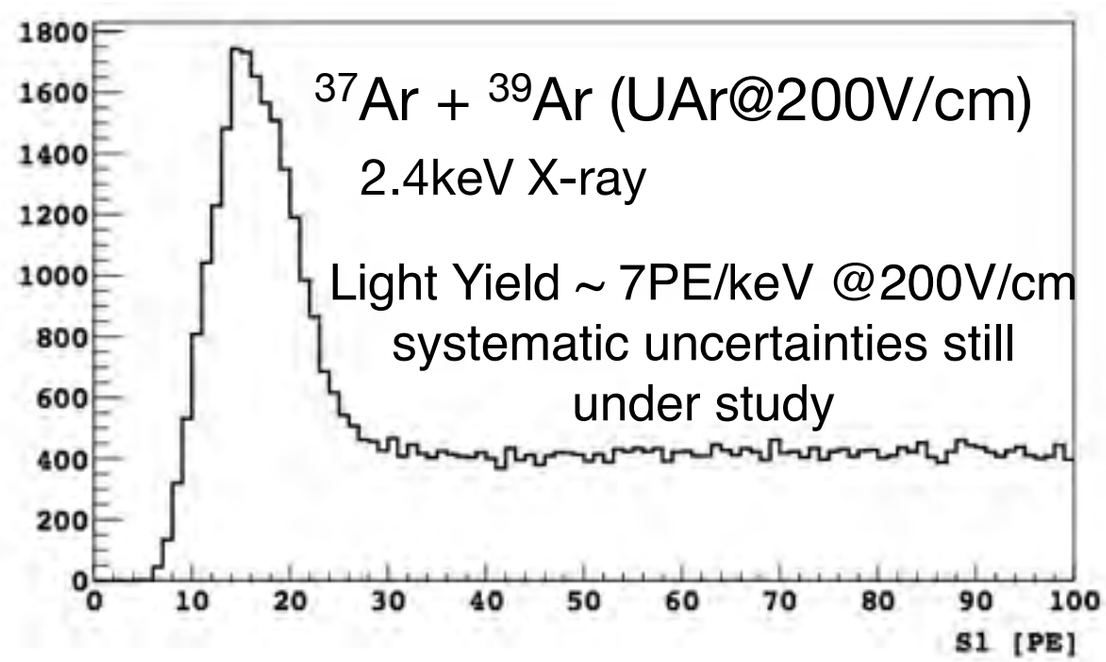
In-situ internal calibrations: TPC

^{83m}Kr Light Yield:
7.9 ± 0.4 PE/keV @ null field
7.0 ± 0.3 PE/keV @ 200 V/cm

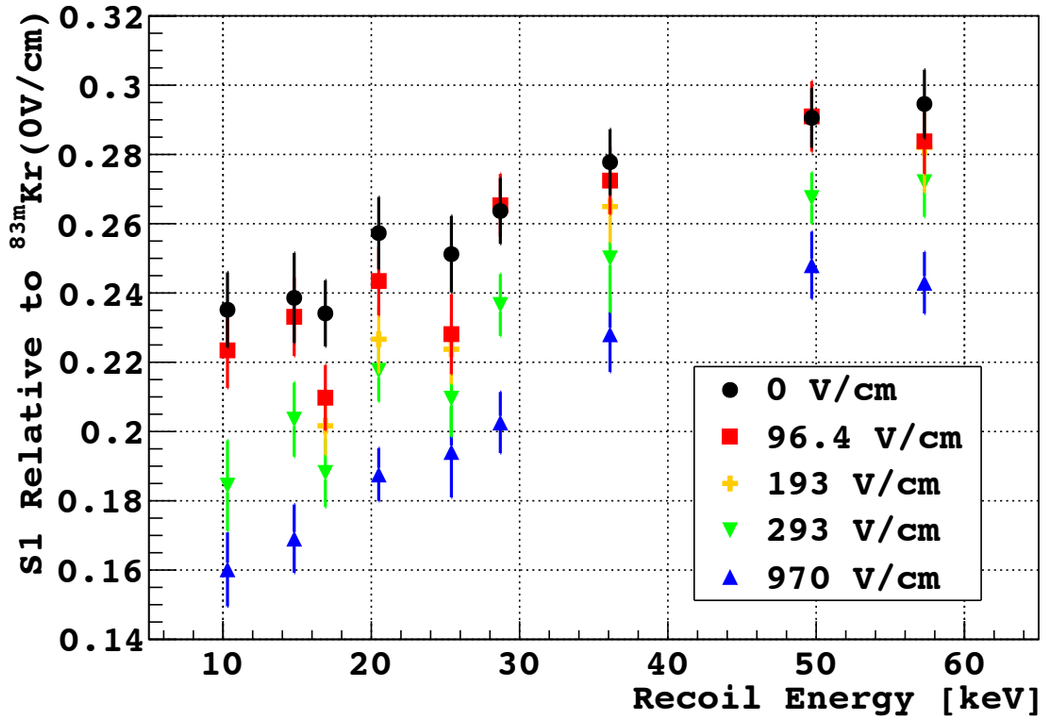
^{83m}Kr used for **light yield map correction** and electron lifetime estimates.

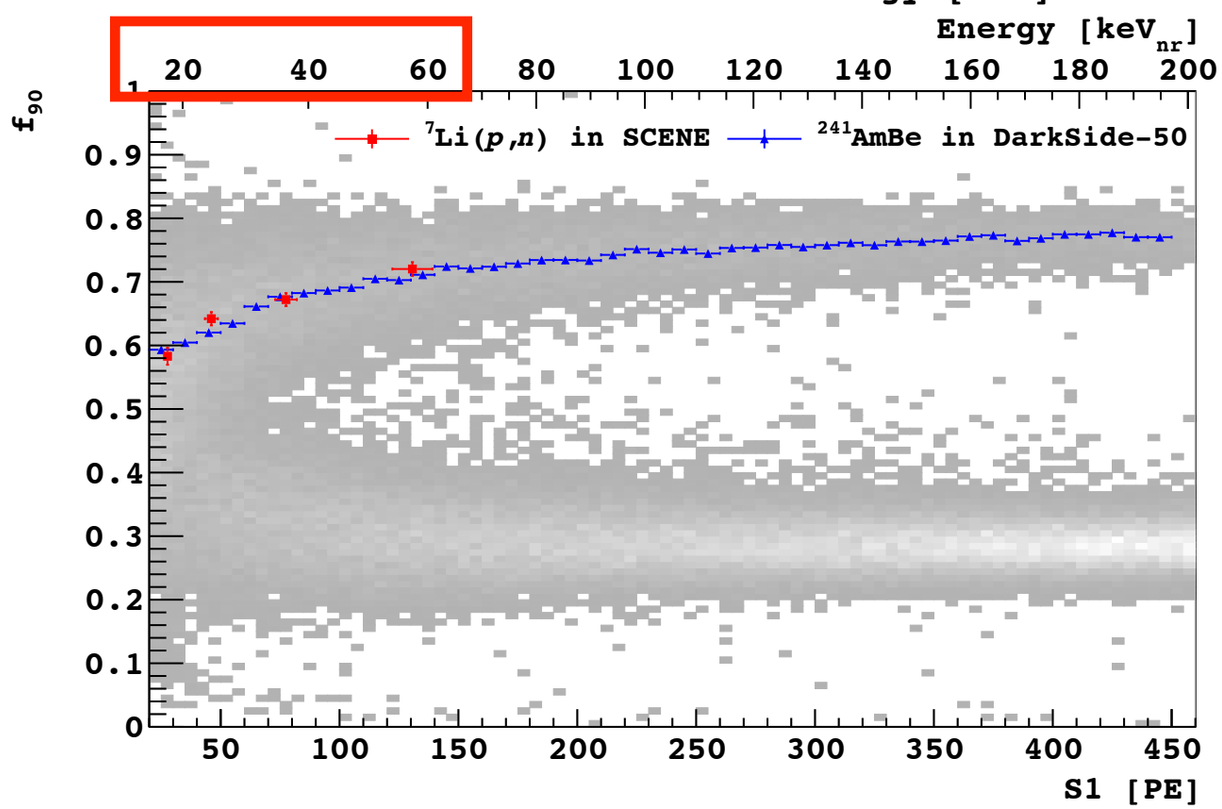
electron lifetime > 5000 μS
(max drift time 375 μs)
No S2 signal correction.





Energy scale calibration



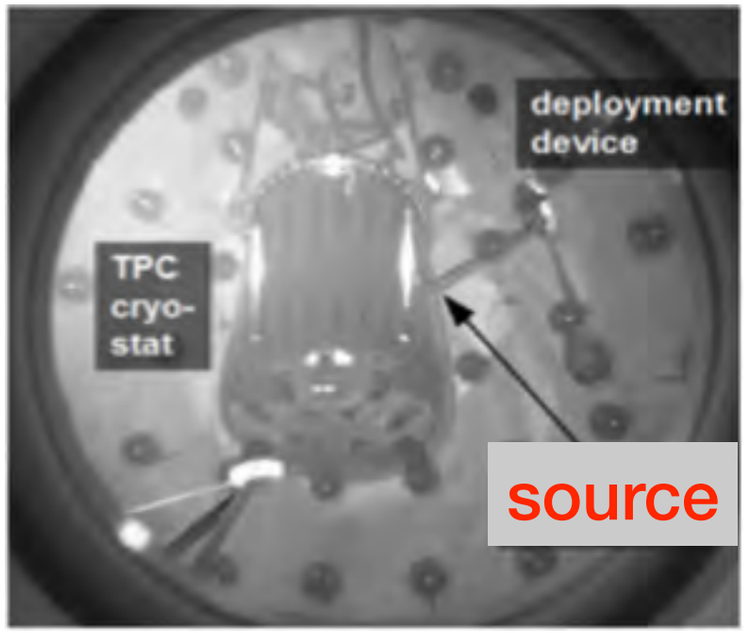


pure sample of single nuclear recoils

Extrapolate NR energy scale and F90 response from SCENE to DS50

Use ^{83m}Kr as cross-calibration point

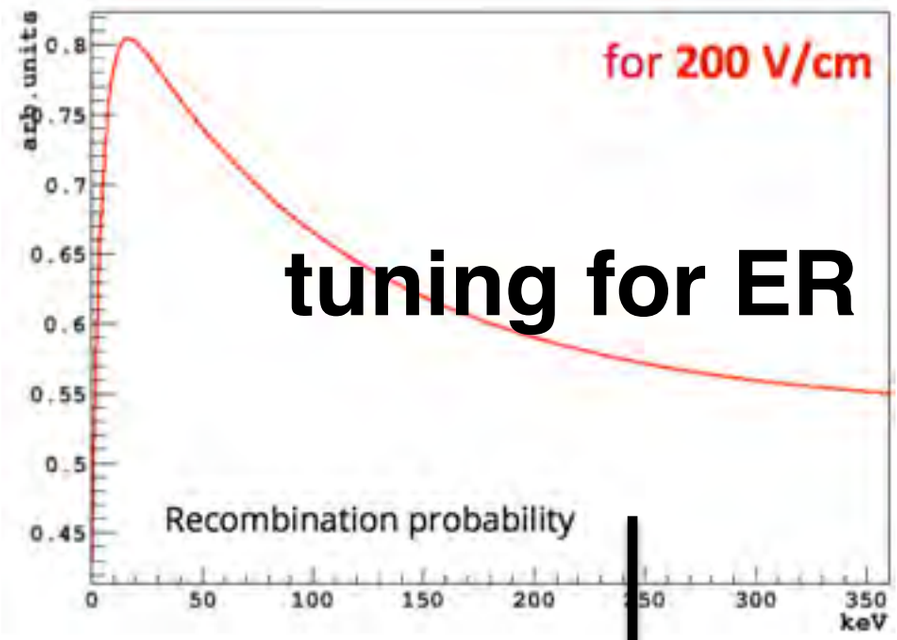
in-situ AmBe calibration to validate extrapolation of SCENE values to DarkSide-50



Measurement of scintillation and ionization yield and scintillation pulse shape from nuclear recoils in liquid argon Phys. Rev. D 91, 092007 (2015)
CALIS - a CALibration Insertion System for the DarkSide-50 dark matter search experiment - Paper in Prep.

Modeling ER and NR response in Ar

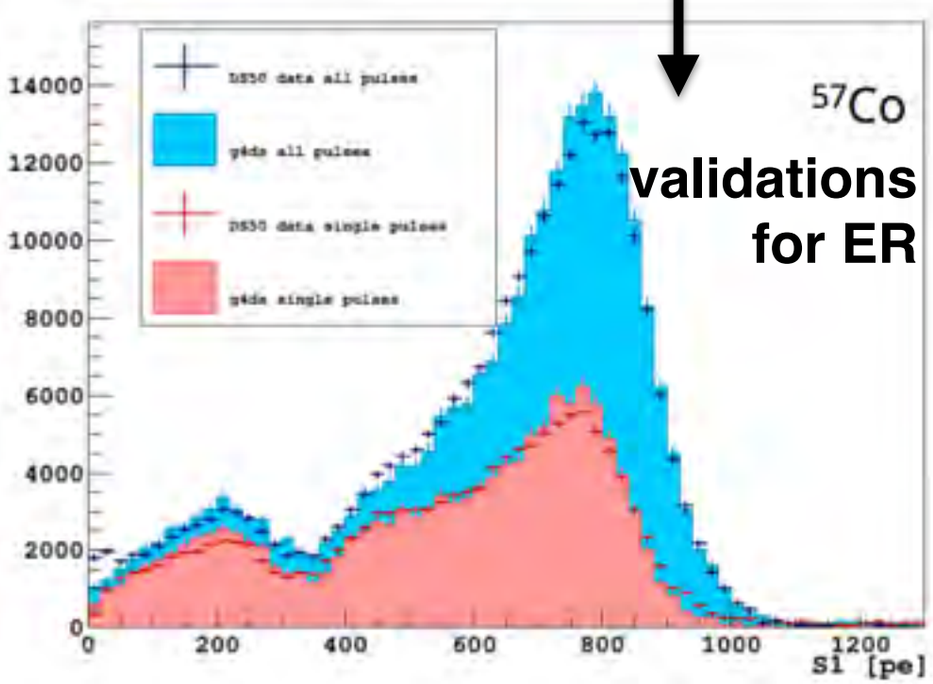
g4ds = geometry, electronics chain, optics, S1 (work ongoing for S2)
Model the recombination probability as a function of recoil energy use data inputs from endpoint of 39Ar, 83mKr summed peak and 37Ar



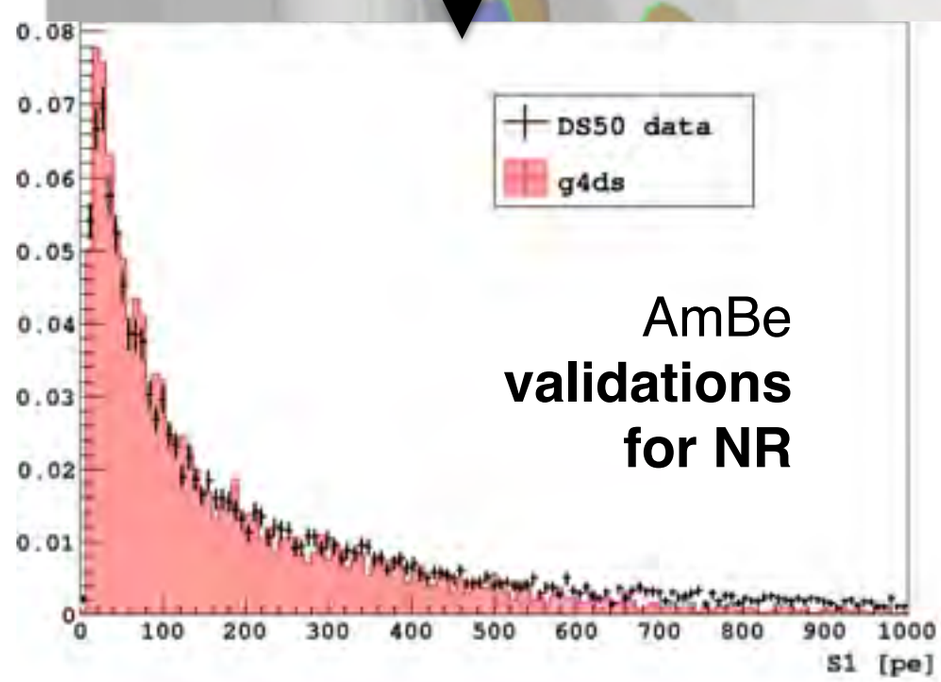
tuning for ER

+

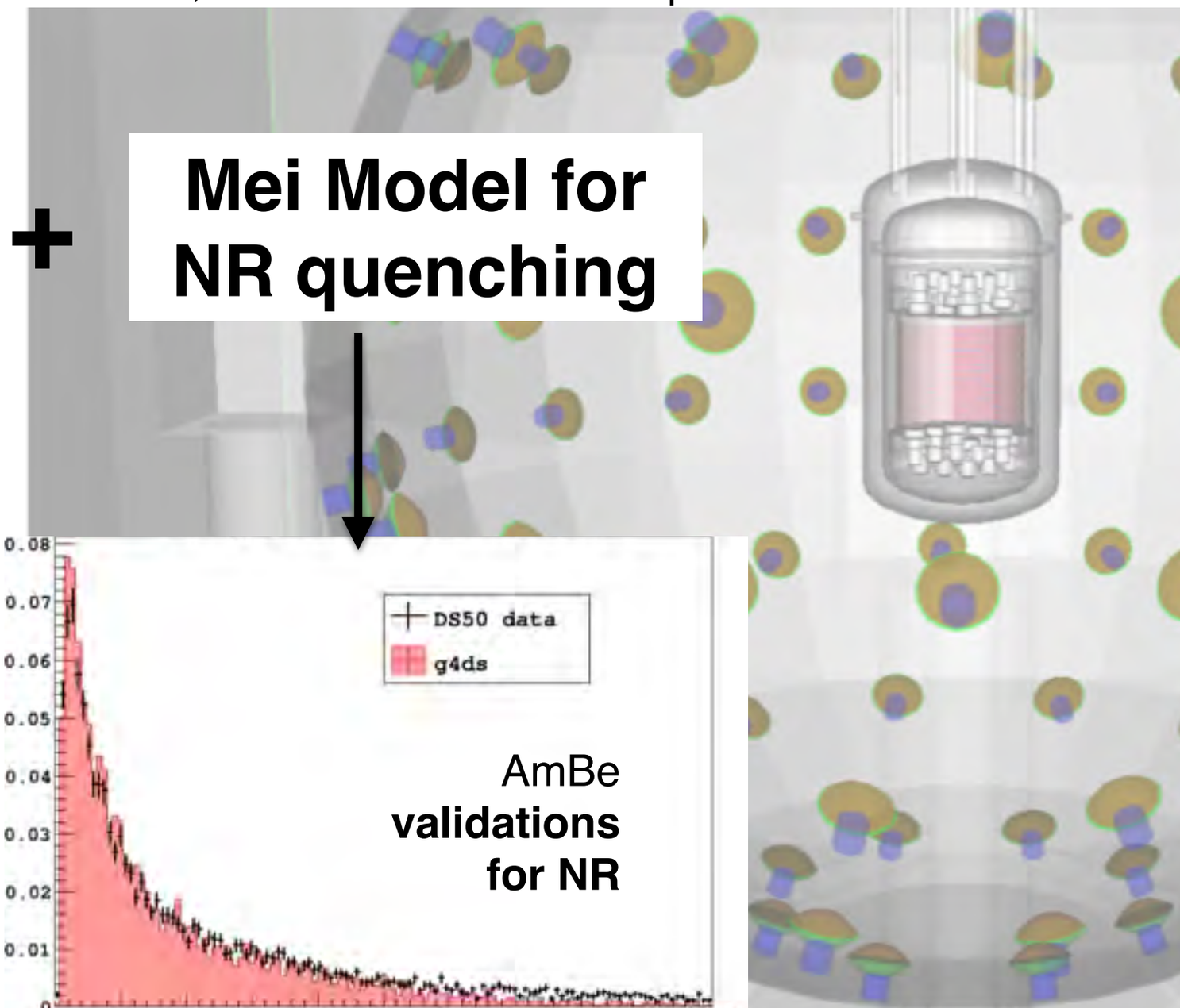
Mei Model for NR quenching



validations for ER



AmBe
validations for NR



See P.Agnes talk "g4ds the DarkSide simulation tool" at UCLA DM 2016

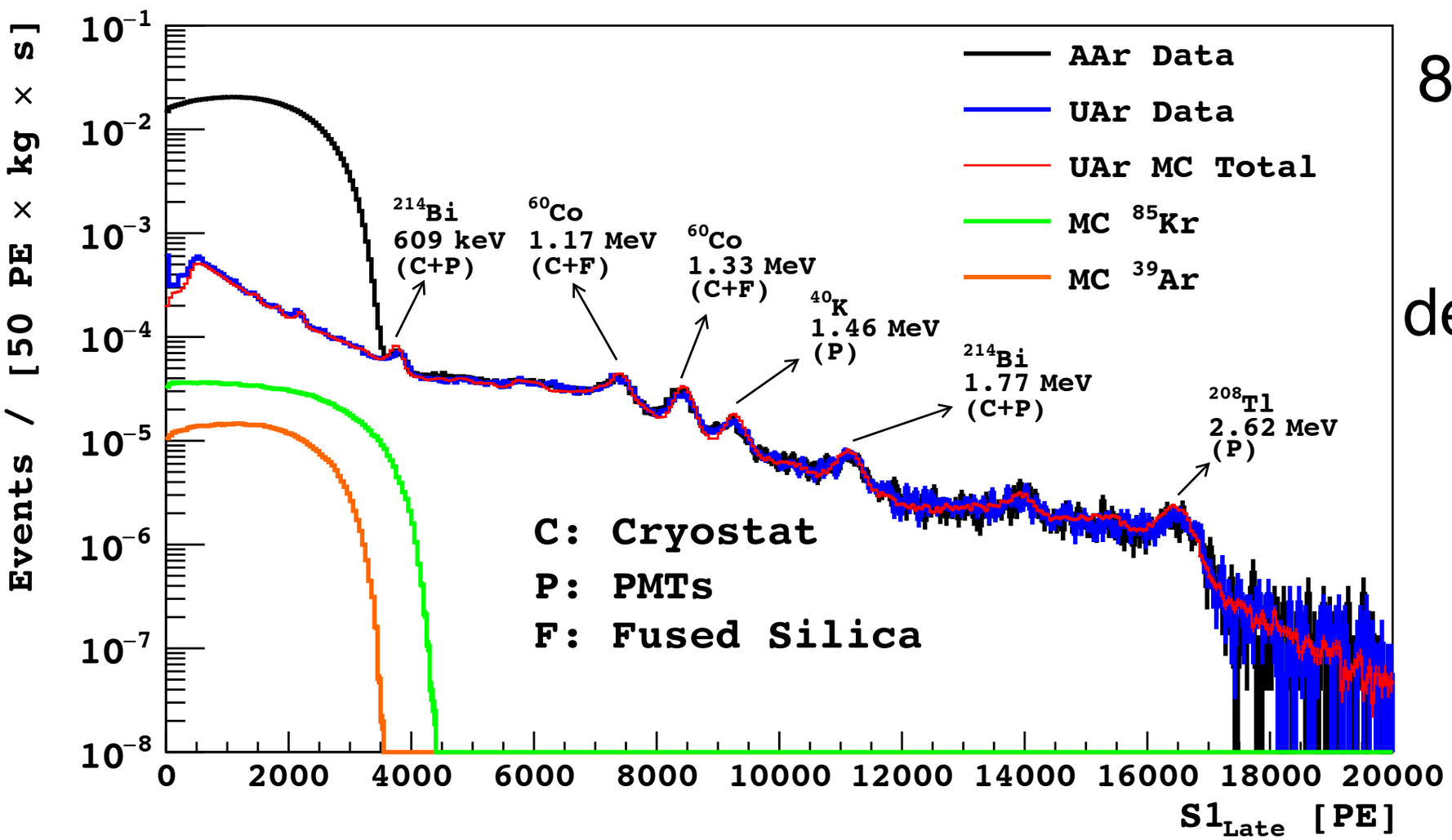
ER backgrounds

Multidimensional spectral fit of MC (g4ds) on AAr data

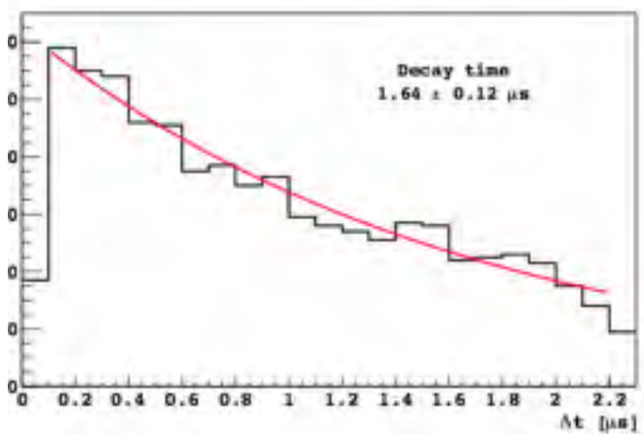
S1 spectrum with field on + S1 spectrum with field off + spatial distribution (z)

Repeat the fit on the UAr data

after subtracting background from radioisotopes in detector material from AAr fit



85Kr contamination found and confirmed via delayed coincidence analysis.



See P.Agnes talk "g4ds the DarkSide simulation tool" at UCLA DM 2016

^{39}Ar and ^{85}Kr background

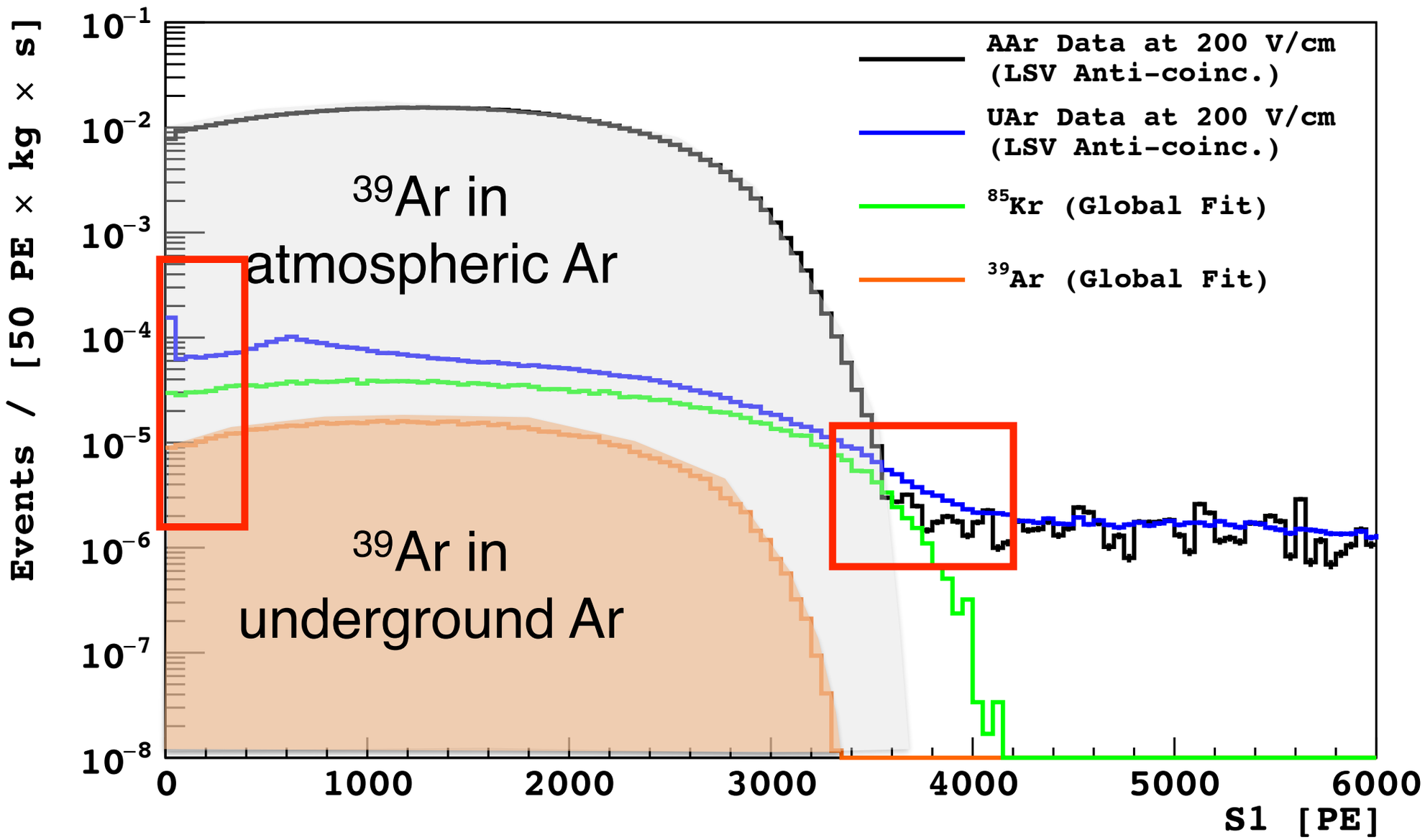
With respect to AAr: **>300 reduction of intrinsic radioactivity in UAr**

~1400 reduction of 39Ar activity

1000 mBq/kg

↓

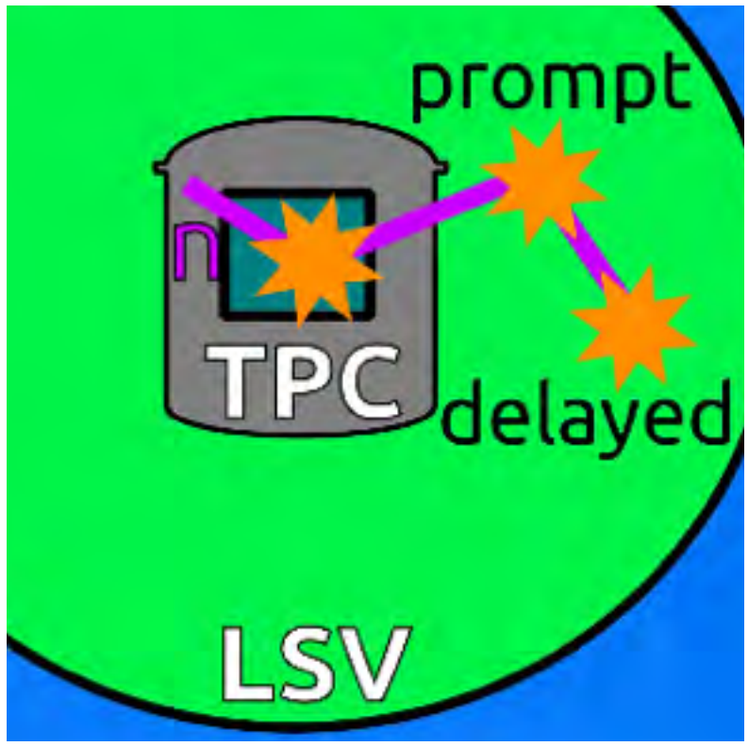
0.73± 0.11 mBq/kg

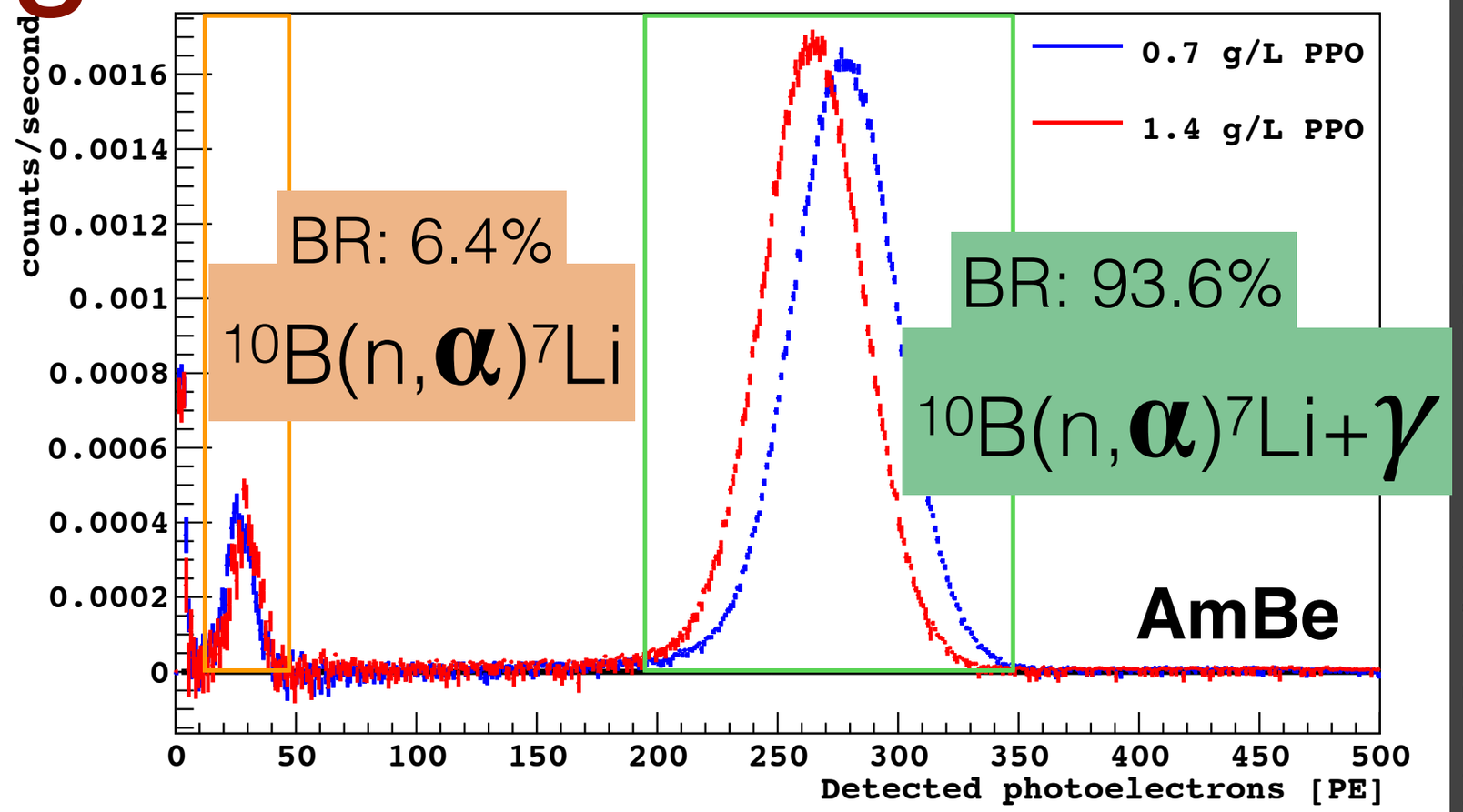


Background in ROI = ~50% β-events + ~50% of γ-events

Results from the first use of low radioactivity argon in a dark matter search, Phys.Rev. D93, no.8, 08110 (2016)

Neutron background in 70d of UAr





>99.1% efficiency to veto neutrons via delayed capture on ^{10}B and ^{1}H (AmBe + MC)

Tagged 2±2 neutron events in combined AAr + UAr data

Predicted <0.02 neutrons after veto cuts

Ongoing study: LSV Efficiency to tag neutron thermalization signal in prompt region using AmC calibration (custom made)

The veto system of the DarkSide-50 experiment, JINST 11, no.03, P03016 (2016)

Unblind analysis for 70d UAr

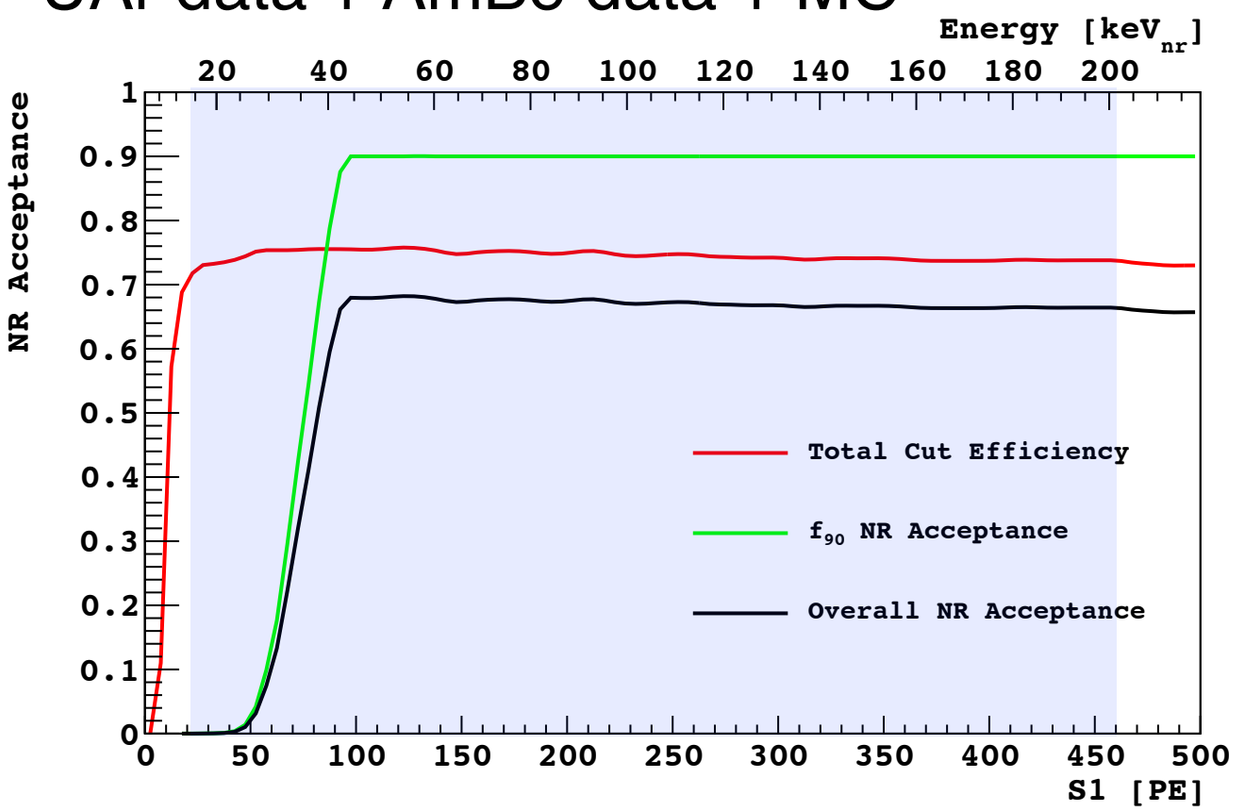
Select single scatters in 36.9 kg fiducial mass with:

no abnormal clustering of S1 signal

no prompt/delayed signal in LSV and no preceding muon-like event in LSV+ WCV (major loss)

Cut efficiencies evaluated using

UAr data + AmBe data + MC



Fiducial volume cut only in z

no evidence of side surface backgrounds in or near ROI after all cuts in 70d exposure -> ongoing analysis

Results from the first use of low radioactivity argon in a dark matter search, Phys.Rev. D93, no.8, 08110 (2016)

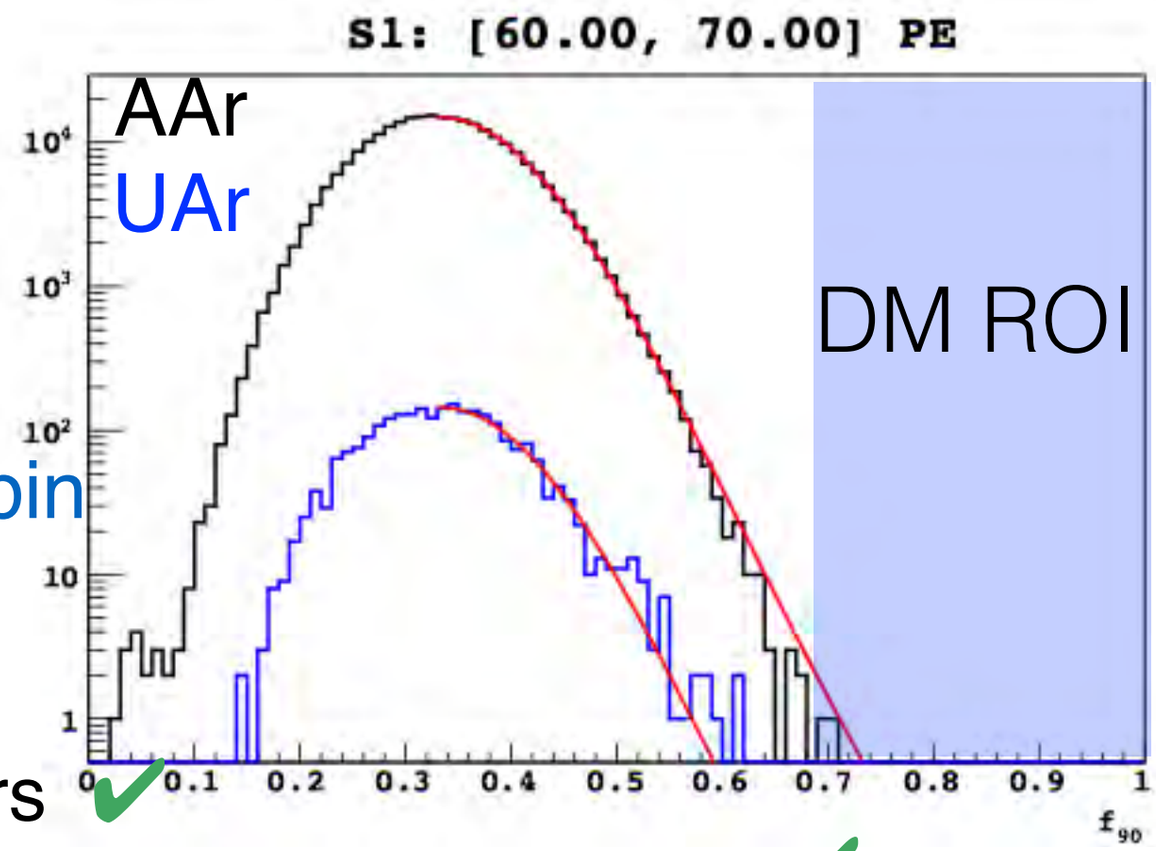
Pulse shape discrimination (f90) model

Use Hinkley analytic model for single scatters ERs

Fit to high statistics AAr data

Scale to UAr data

Derive 0.01 ER leakage events / S1 bin



For 70days of UAr:

Dominant background are single scatters ✔

Unresolved multiple scatters have no visible impact (via MC) ✔

Hints of other spurious backgrounds but so low in statistics (they do not leak into ROI)

Hinkley model as implemented overestimates the tails

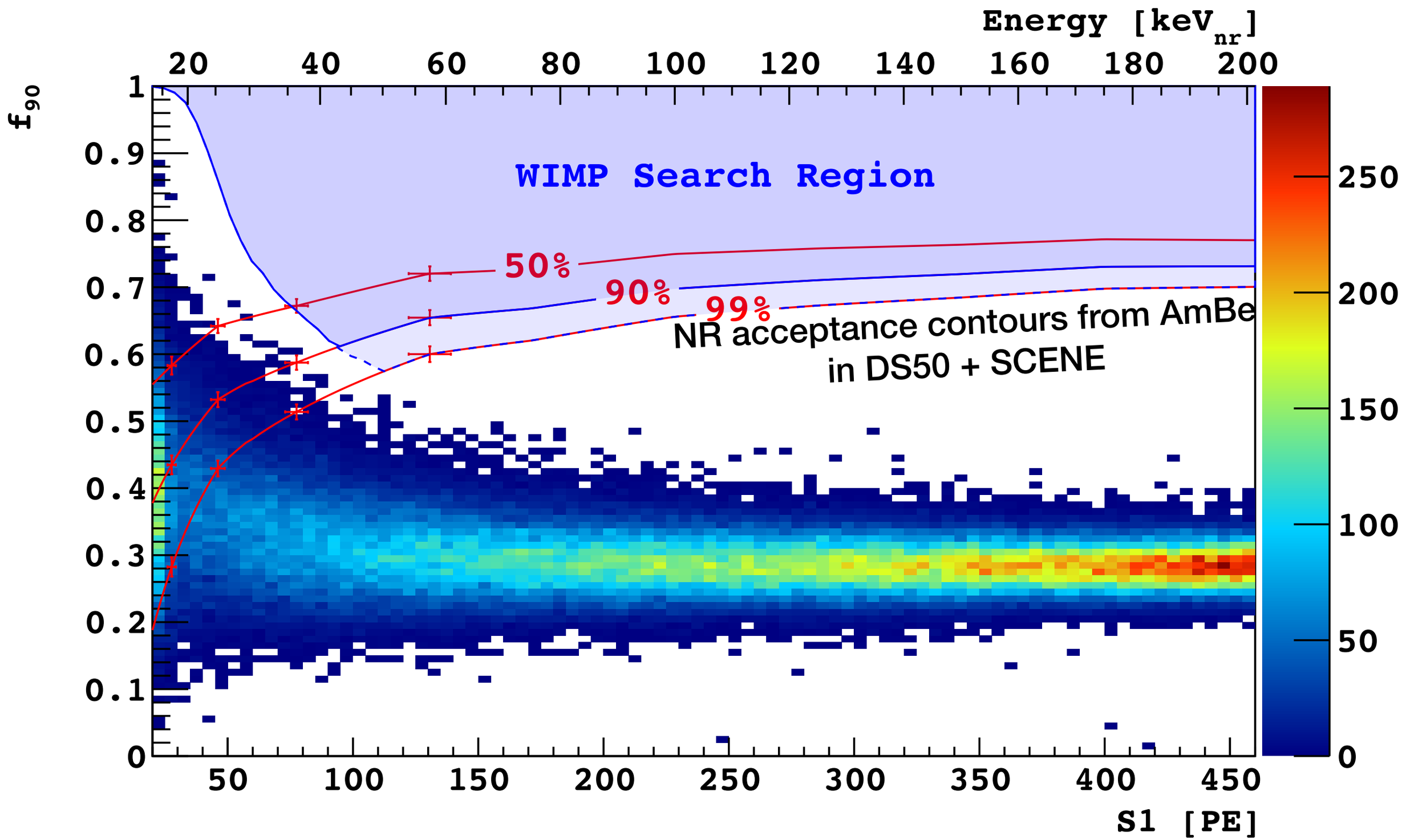
Ongoing work:

implement analytic models with improved statistics treatment

develop f90 models for other rare backgrounds

See talk of G.Koh at APS 2016;

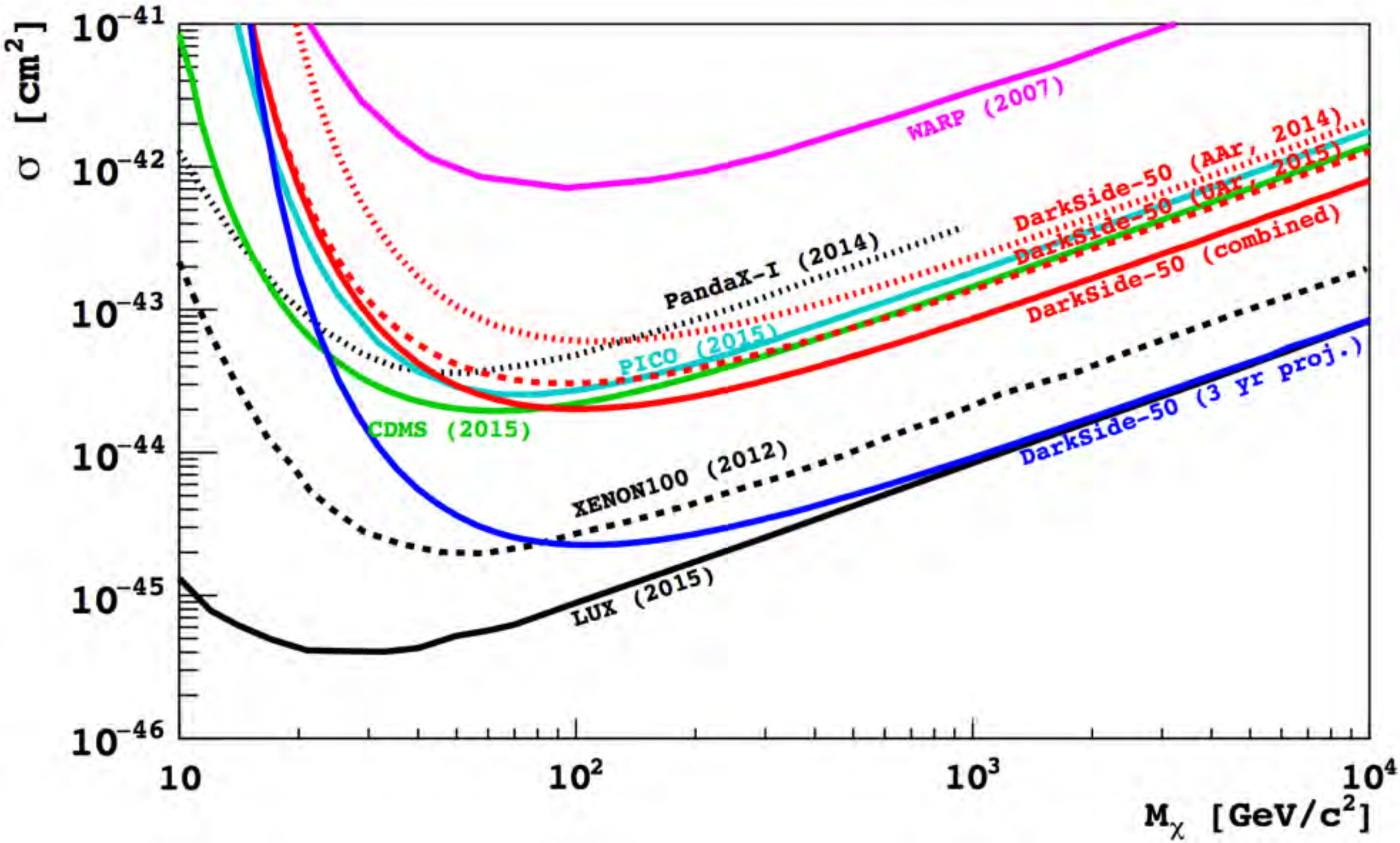
Dark Matter search data



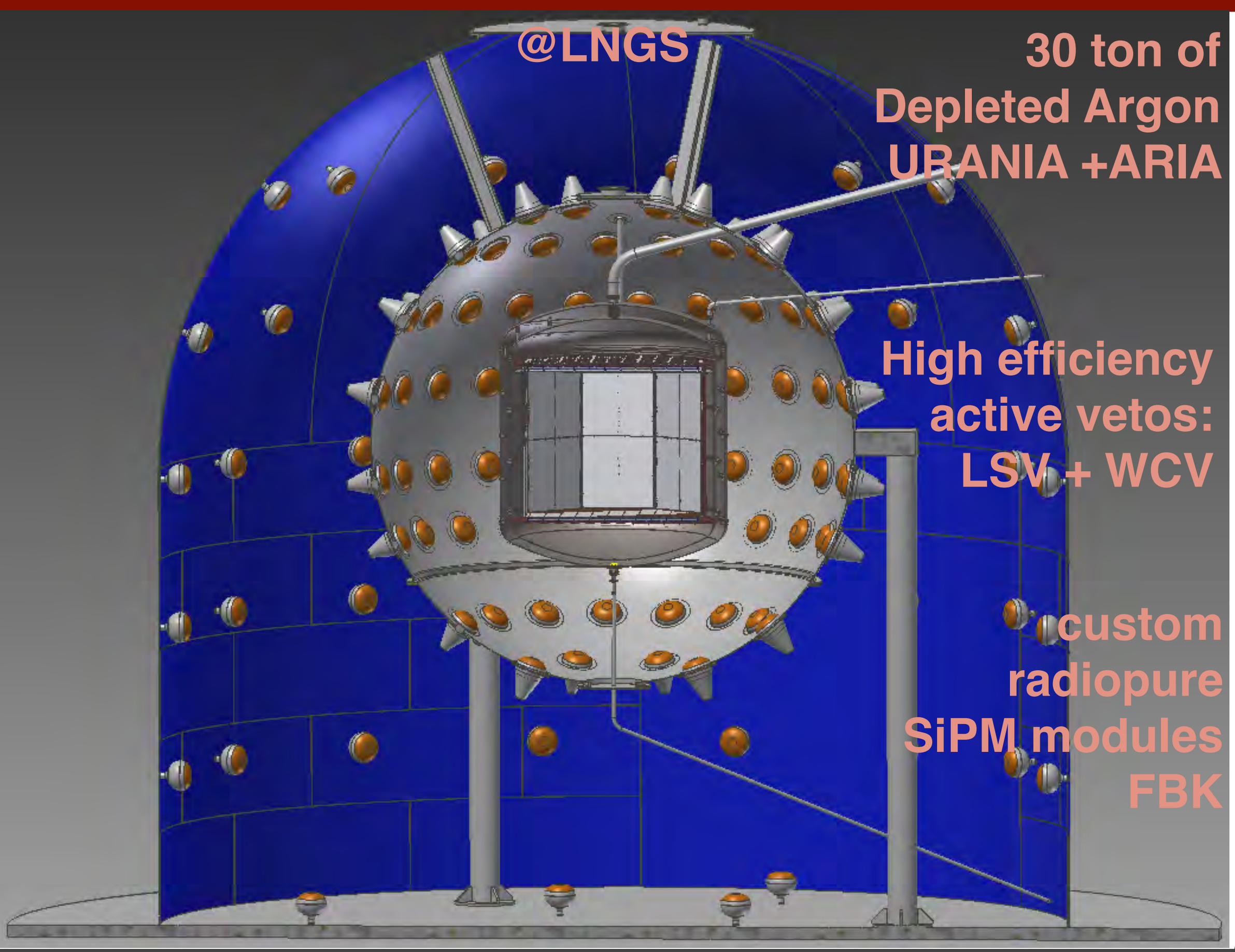
No events in the WIMP search region.

Results from the first use of low radioactivity argon in a dark matter search, Phys.Rev. D93, no.8, 08110 (2016)

Dark Matter search result and projection



Results from the first use of low radioactivity argon in a dark matter search, Phys.Rev. D93, no.8, 08110 (2016)



DarkSide-20k key points

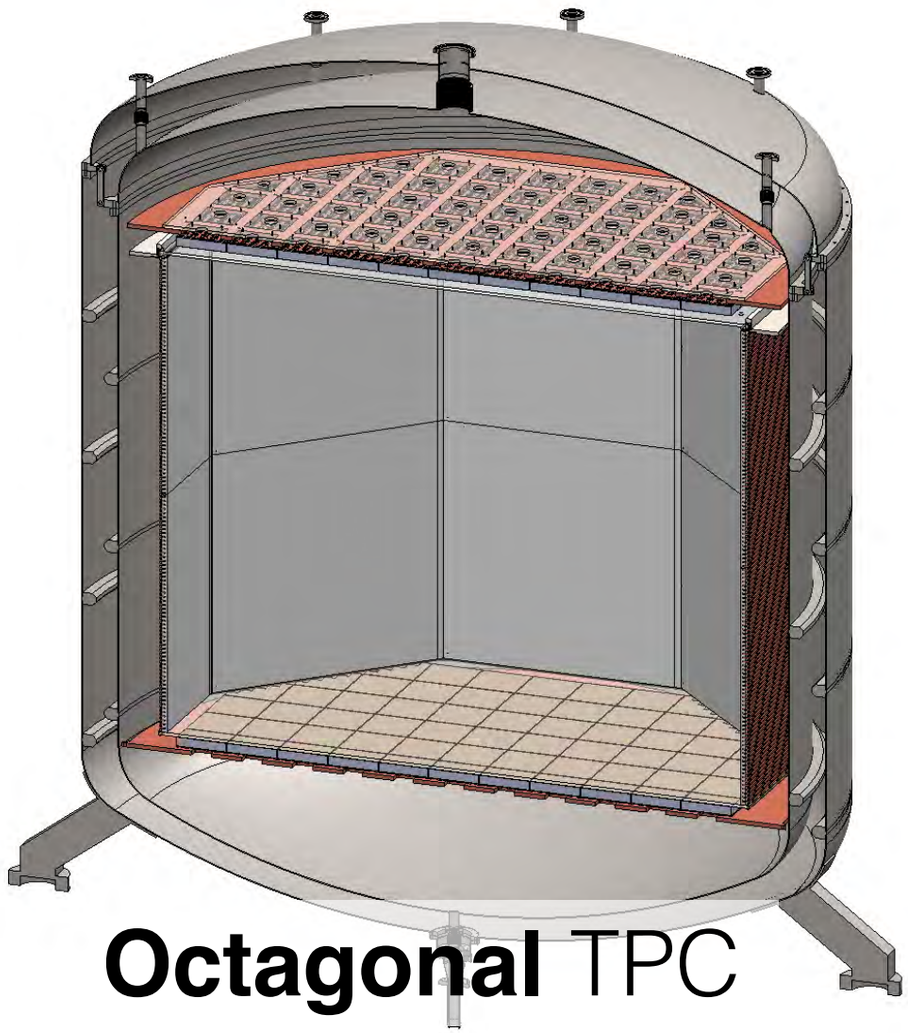
see G.Fiorillo talk at IDM2016

URANIA and ARIA

Urania= expansion of existing Colorado facility to reach 100 kg/d
for UAr extraction and purification at 100kg/d
in cooperation with Kinder Morgan
Argon extraction expected to start in 2017 to reach 50tons by 2020.

Aria facility = **350m** tall distillation column in Seruci mine in Sardinia for **isotopic separation of Ar-39 and UAr purification at 150kg/d**
in cooperation with Regione Sardegna (production of other isotopes of interest for medical application)
Depletion factor goals:
10-100 for Ar-39 and >1000 for N2,02,Kr per pass

DarkSide-20k and Prototype



Octagonal TPC

200V/cm drift field

5210 **SiPMs-based** modules

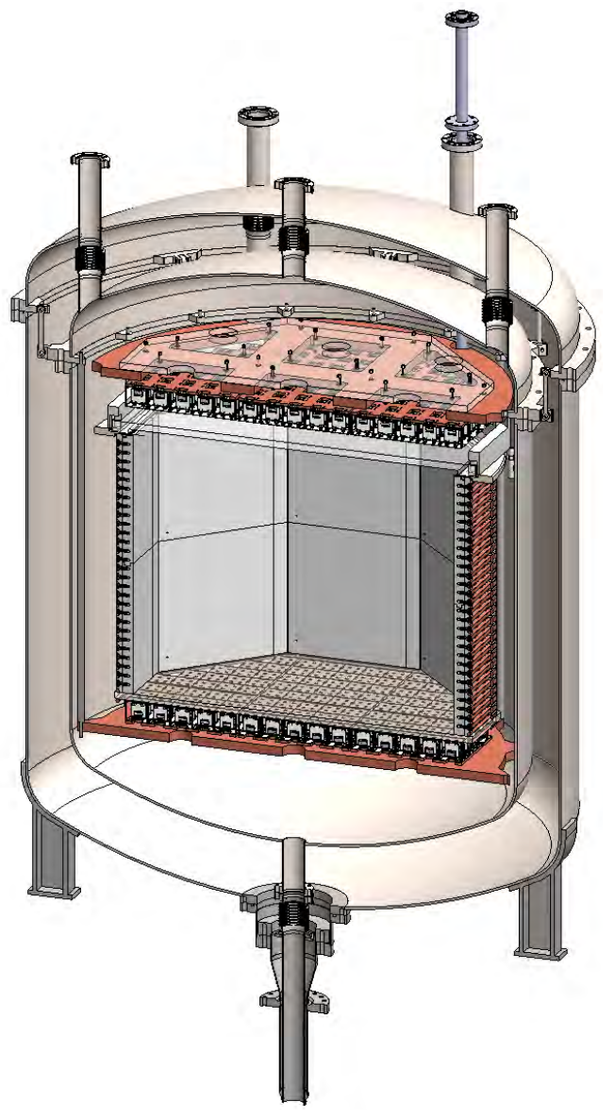
ITO on **acrylic** for electrodes

TPB as wavelength shifter

Teflon as reflector

extraction **linear** grid

Full size components in scaled down (1t) prototype @CERN in 2017



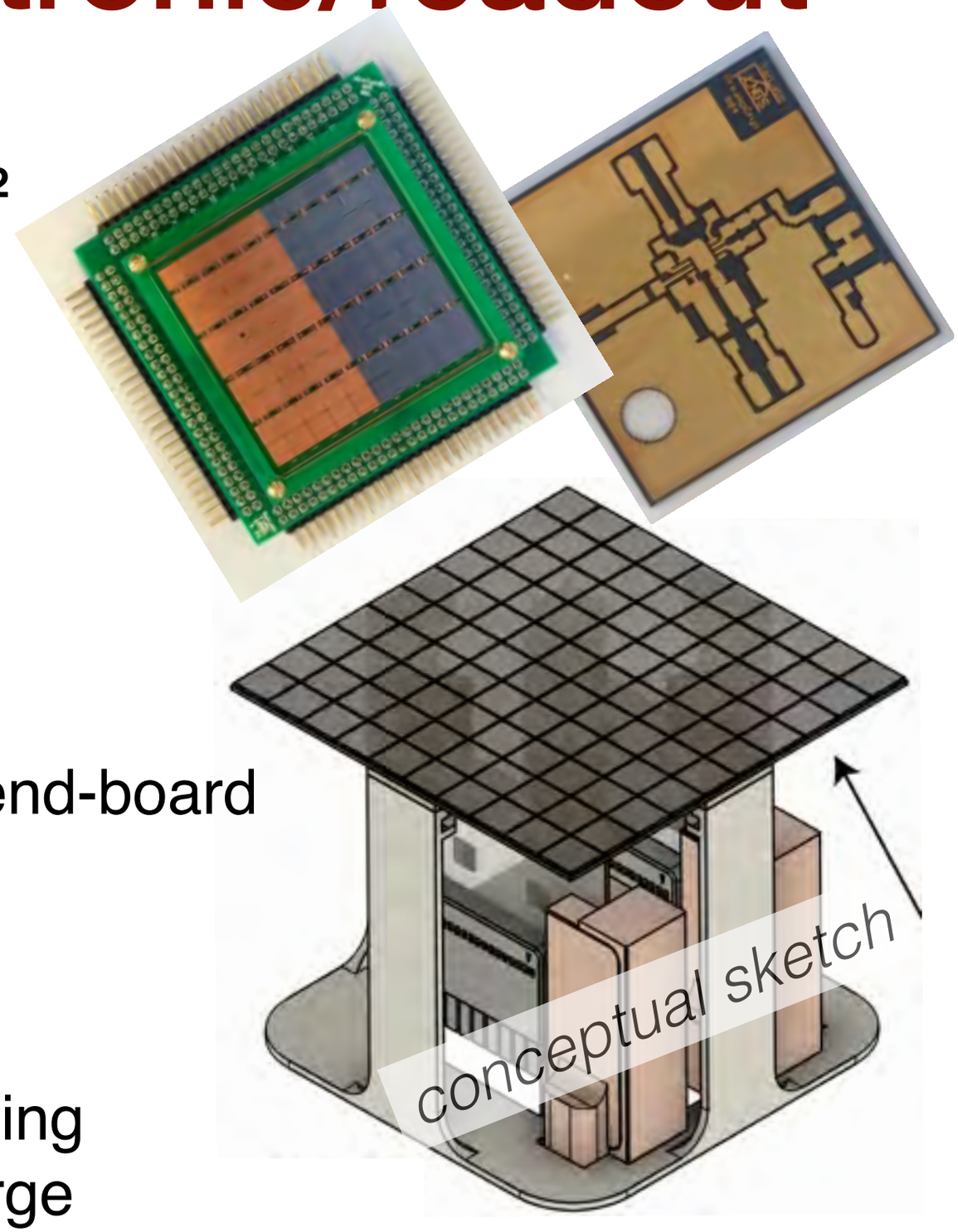
thing in bold differs from DS-50

Photosensors/electronic/readout

5210 photodetector modules 5x5cm²

SiMP (5x5mm²) arrays forming tile
PDE >40% @420nm fill factor > 92%
dark current <0.1Hz/mm²
+
cryogenic trans-impedance amplifier
+
patterned sapphire for mating to front-end-board
+
signal transmitter

Count individual hits and track their timing for S1 and down-sample integrate charge for S2



FBK development with INFN

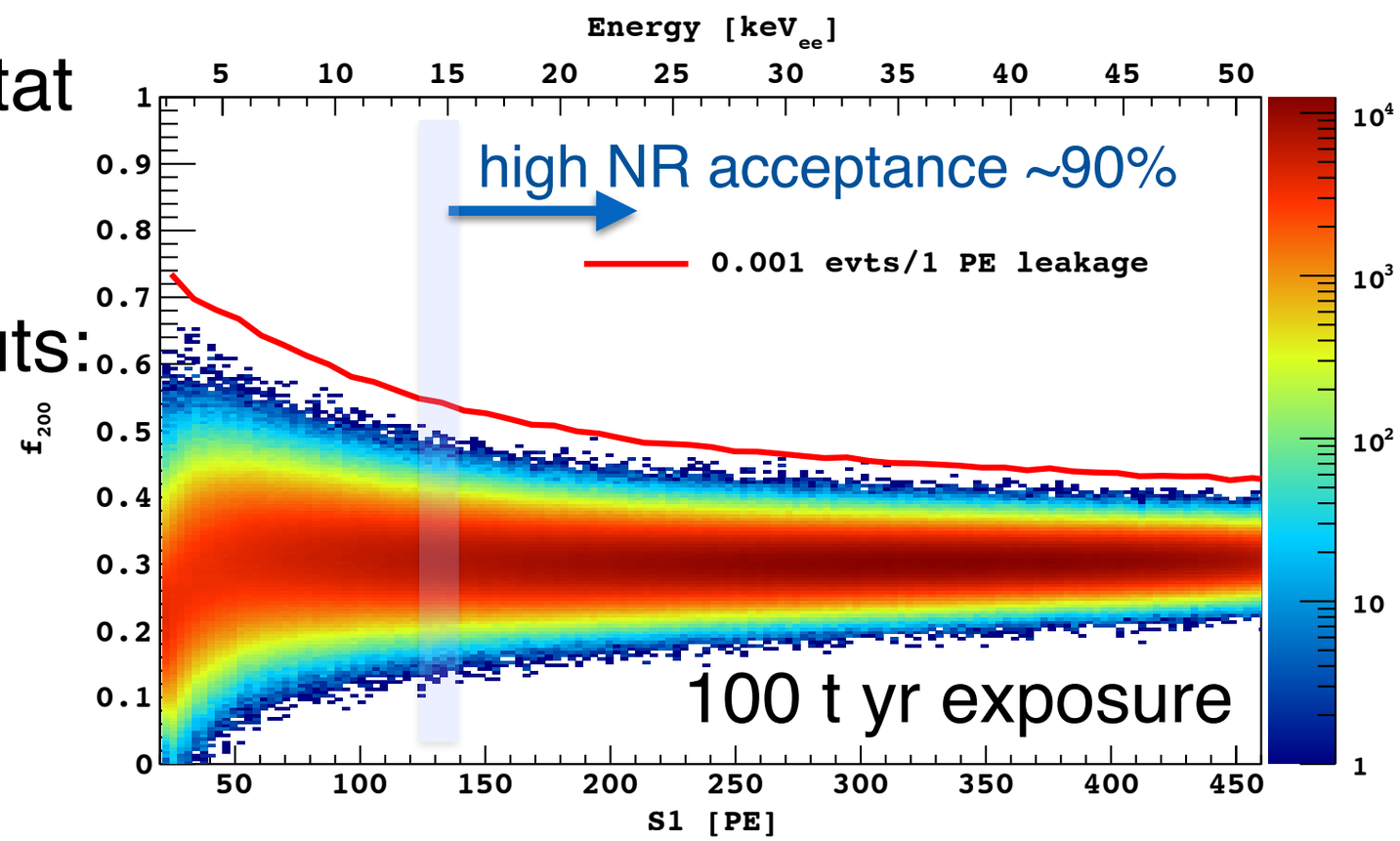
Expected performance for 100t yr

use full g4ds simulation package
S1 light yield = 9PE/keV @200V/cm
PSD: f200 = fraction of light in the first 200ns

ER Background assumption:

internal β/γ ^{39}Ar as in DS-50, ^{85}Kr is negligible
ν induced ER @200 t yr
external β/γ from TPC/cryostat

NR Background after veto cuts:
radiogenic neutron <0.12 *
cosmogenic NR <0.1
ν induced NR <<

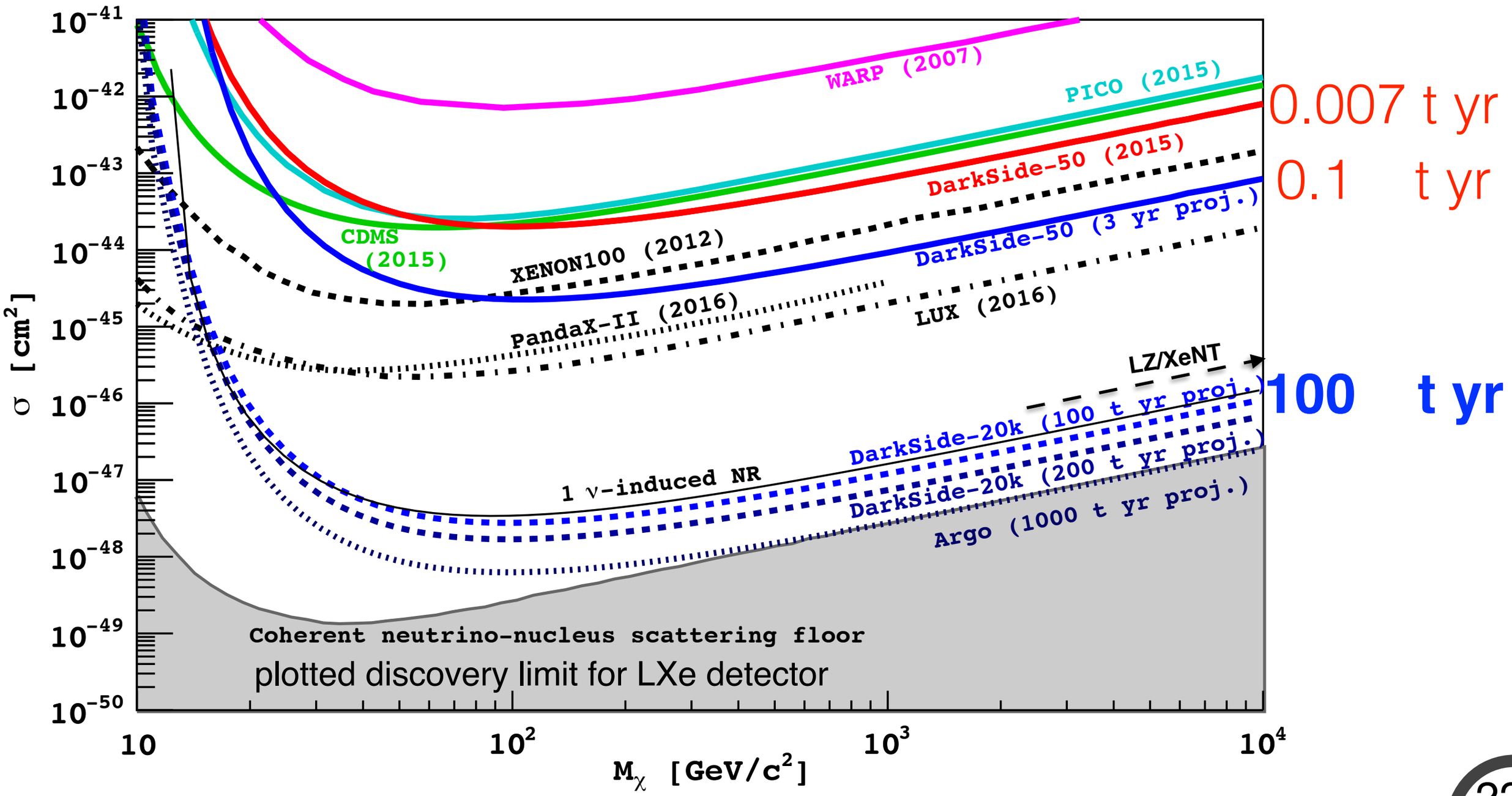


* dominant component from PTFE when using achieved upper limits -> more sensitive screening is underway

Sensitivity of DarkSide-20k

Background-free exposure of 100 t yr
reaching 1.2 x10-47cm^2 at DM mass of 1TeV/c^2

(with ^{39}Ar level as in DS-50)



Summary

DarkSide-50

Measured ^{39}Ar level in UAr to be factor 1400 smaller than in AAr.

Efficiency of the Neutron Veto via delayed capture is >99.1%.

More data for new DM search and investigation of rare backgrounds.
(Cherenkov events in coincidence with ER event)

DarkSide-20k

Critical R&D facilities: URANIA, ARIS and SiPM modules, photo-electronics and prototype development are already underway.

Feasible to explore DM up to neutrino floor for M_{DM}>100GeV in background-free mode thanks to PSD against ν induced ERs and intrinsic/dissolved radioactive nuclei inducing ERs.

ARGO

300 t LAr TPC conceived to reach 1000 t yr exposure for precision measurement of cosmic neutrinos and expanded reach of DM search

EXTRA SLIDES