DARKSIDE: CHALLENGES, PERSPECTIVES AND PLANS

Emilija Pantic
for the DarkSide collaboration

UC DAVIS
UNIVERSITY OF CALIFORNIA

- **DarkSide-50 brief intro and status**
- **DarkSide-20k CPP**

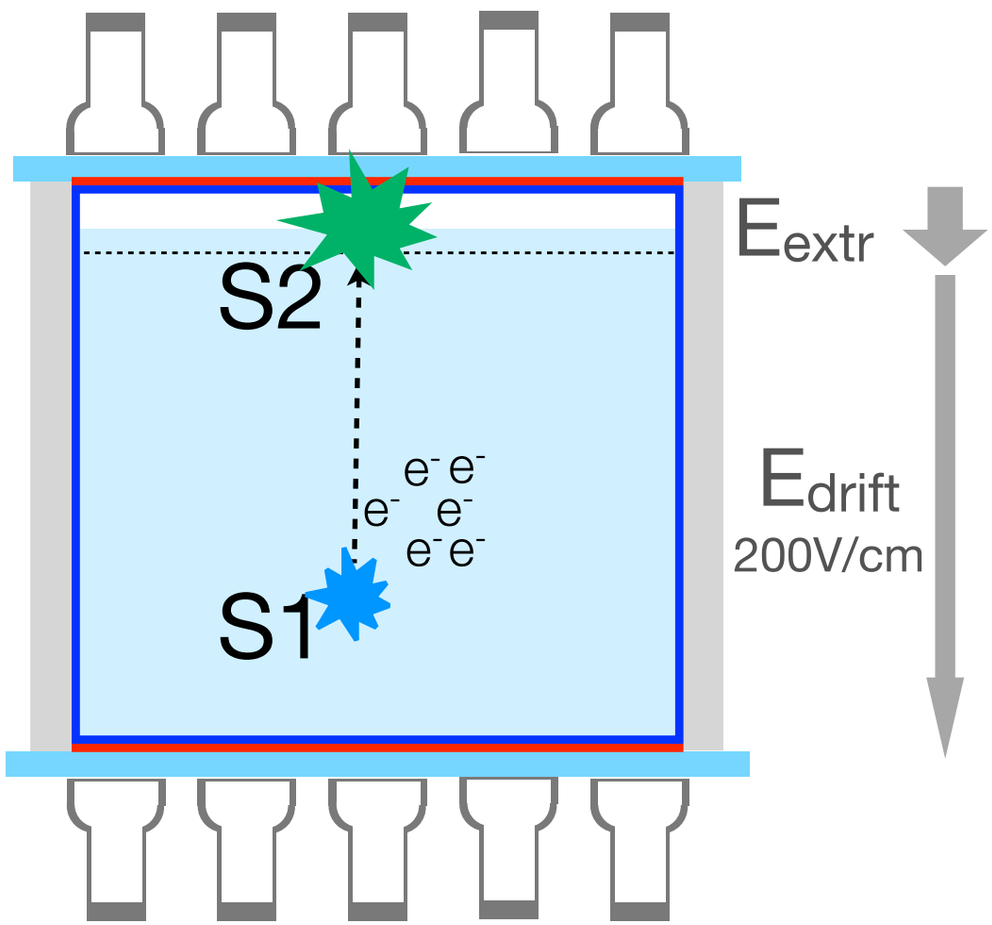
Look for references here

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

pantic@ucdavis.edu

DarkSide-50 LAr dual phase TPC

Light + Charge

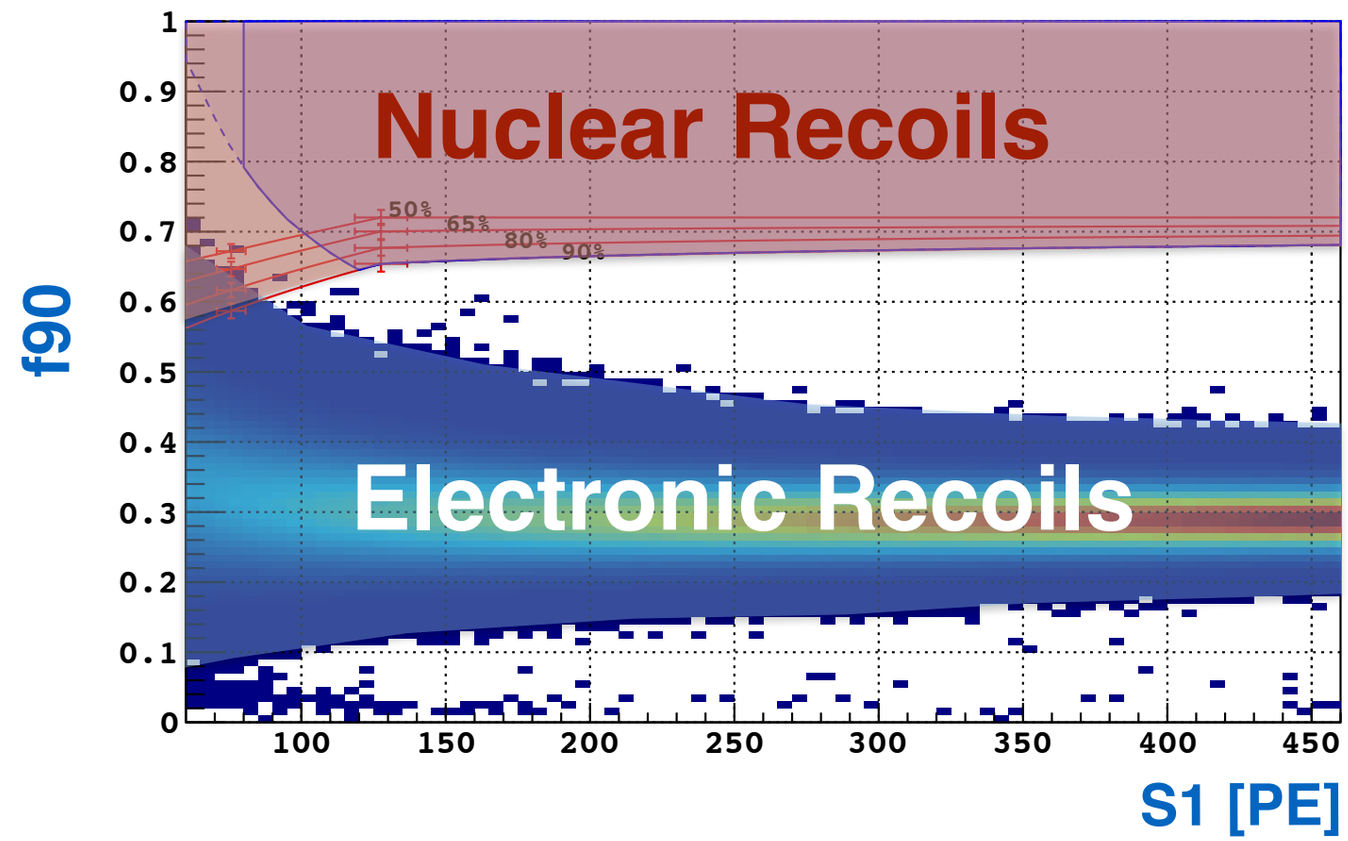


3D positioning ⌚ (few mm)

S2/S1 discrimination of ERs

Pulse shape discrimination of ERs

f90 = fraction of S1 in the first 90ns



46kg of LAr
38 3” PMTs
TPB as wavelength shifter
cathode/anode = **ITO** on **fused silica**
Teflon as reflector
extraction grid

ER Rejection power >10^7

^{83m}Kr S1 Light Yield:

7.0 ± 0.3 PE/keV @ 200 V/cm

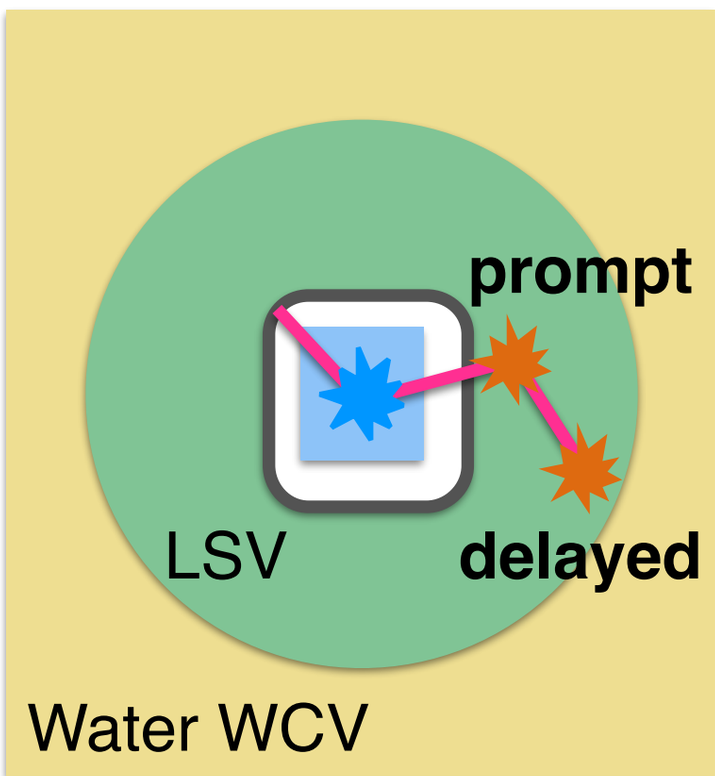
DarkSide-50 Veto Detectors:

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

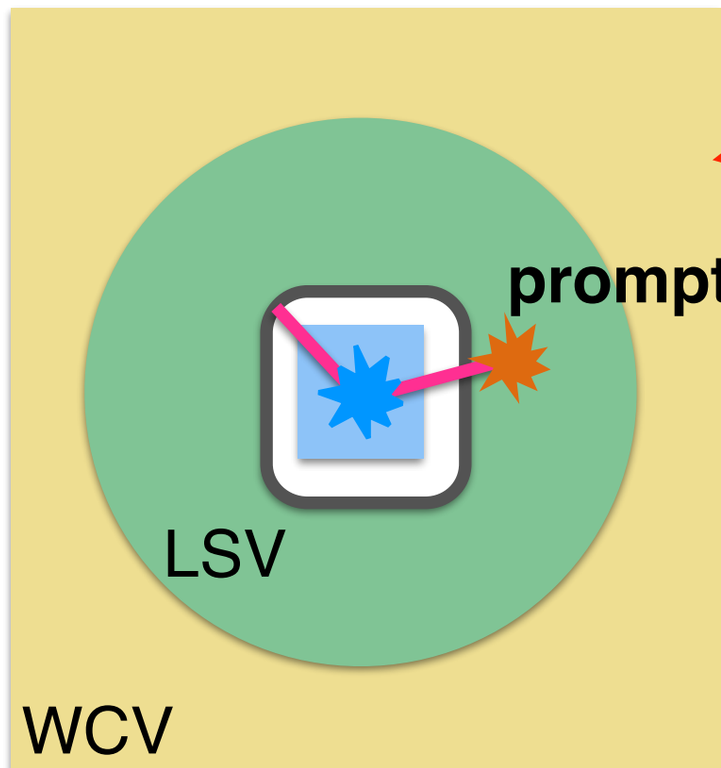
1000t Water Cherenkov Veto (WCV)

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

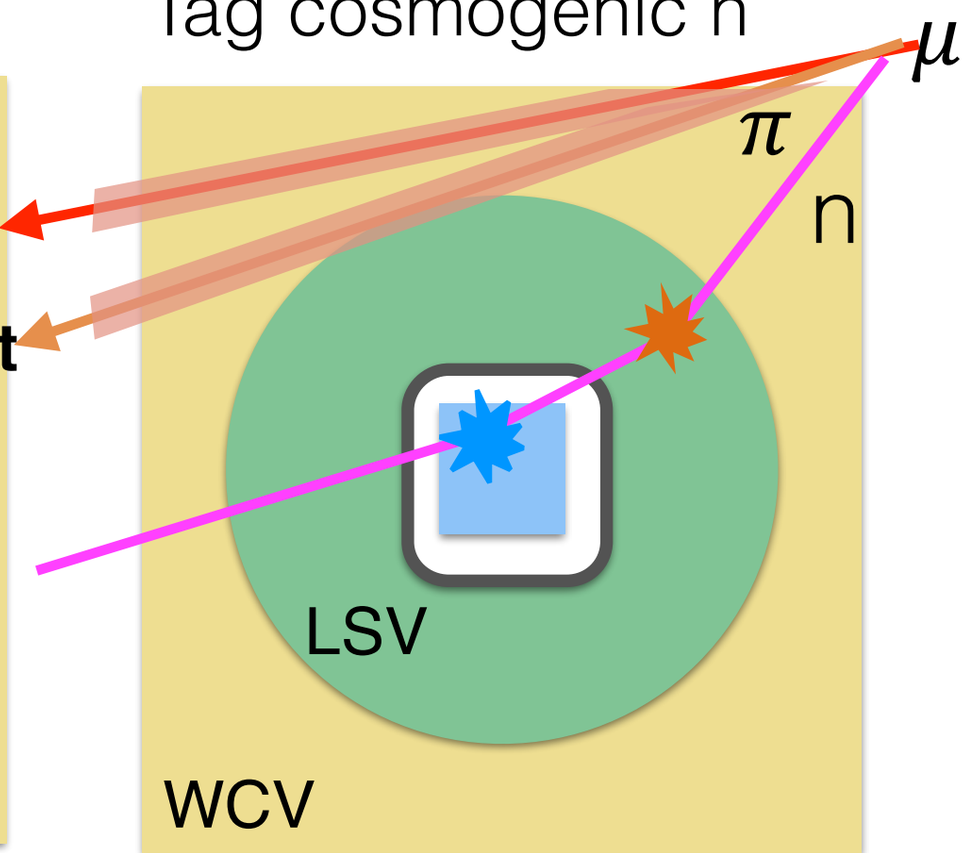
Tag radiogenic n



Tag radiogenic γ



Tag cosmogenic n



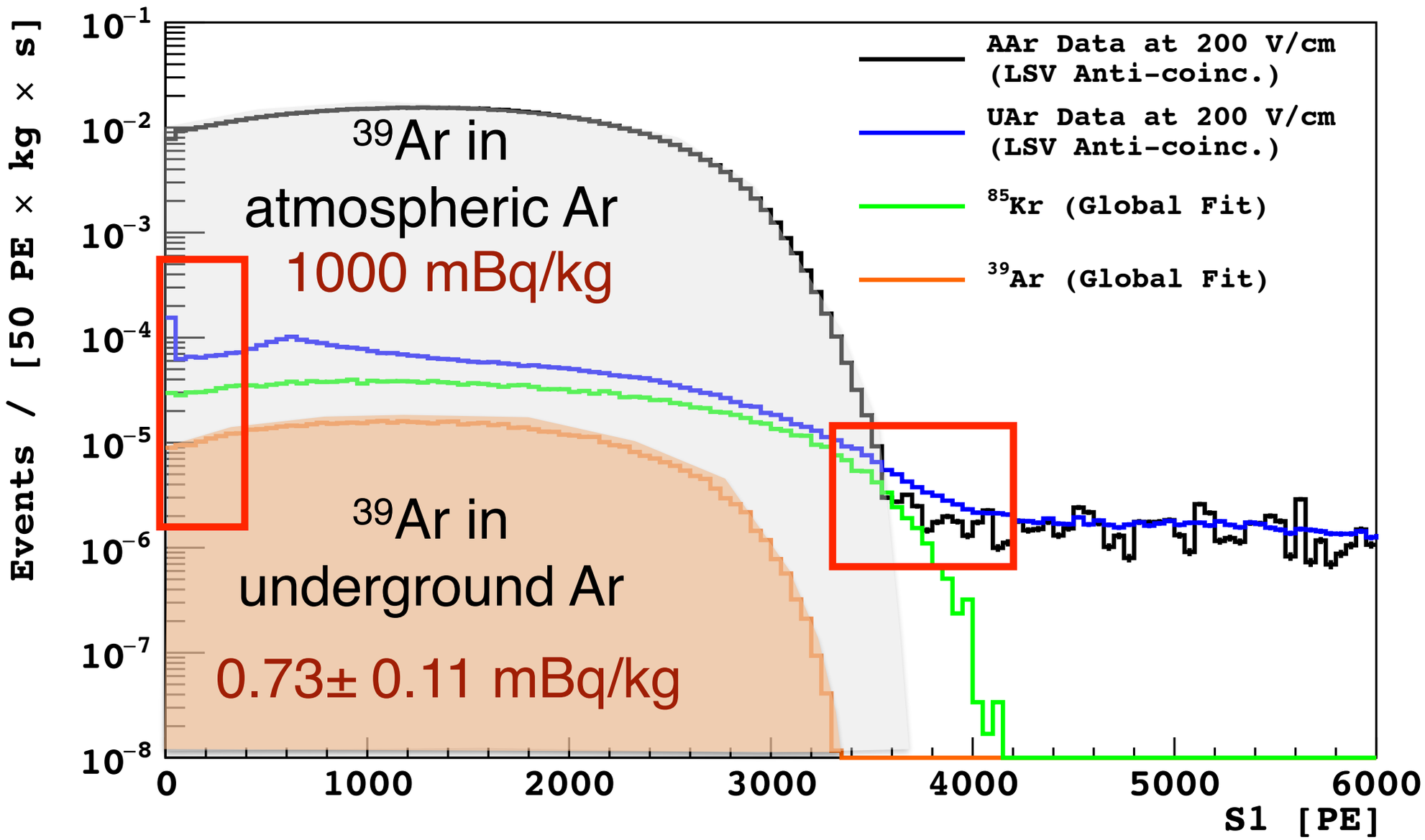
>99.1% efficiency to veto radiogenic neutrons via delayed capture on ^{10}B and ^{1}H (AmBe + MC)

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

Intrinsic background of Underground Argon

With respect to Atmospheric Ar:
> factor of **300** reduction of intrinsic radioactivity in UAr
~ factor of **1400** reduction of ^{39}Ar activity

Multidim. spectral fit of MC (g4ds) on AAr/UAr plus delayed coincidence tagging



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)

Dark Matter search data for 70d UAr

Reject:

~~abnormal clustering of S1 signal~~

~~prompt/delayed signal in LSV~~

~~preceding μ-like event in vetoes~~

~~top and bottom of TPC in drift~~

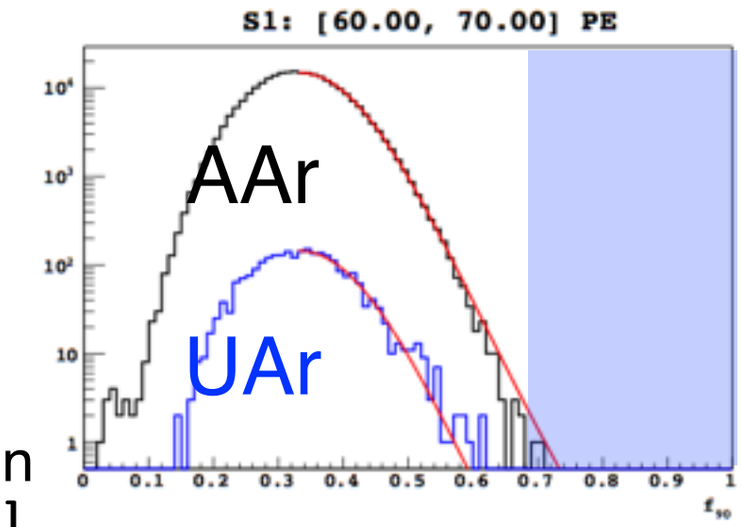
Select

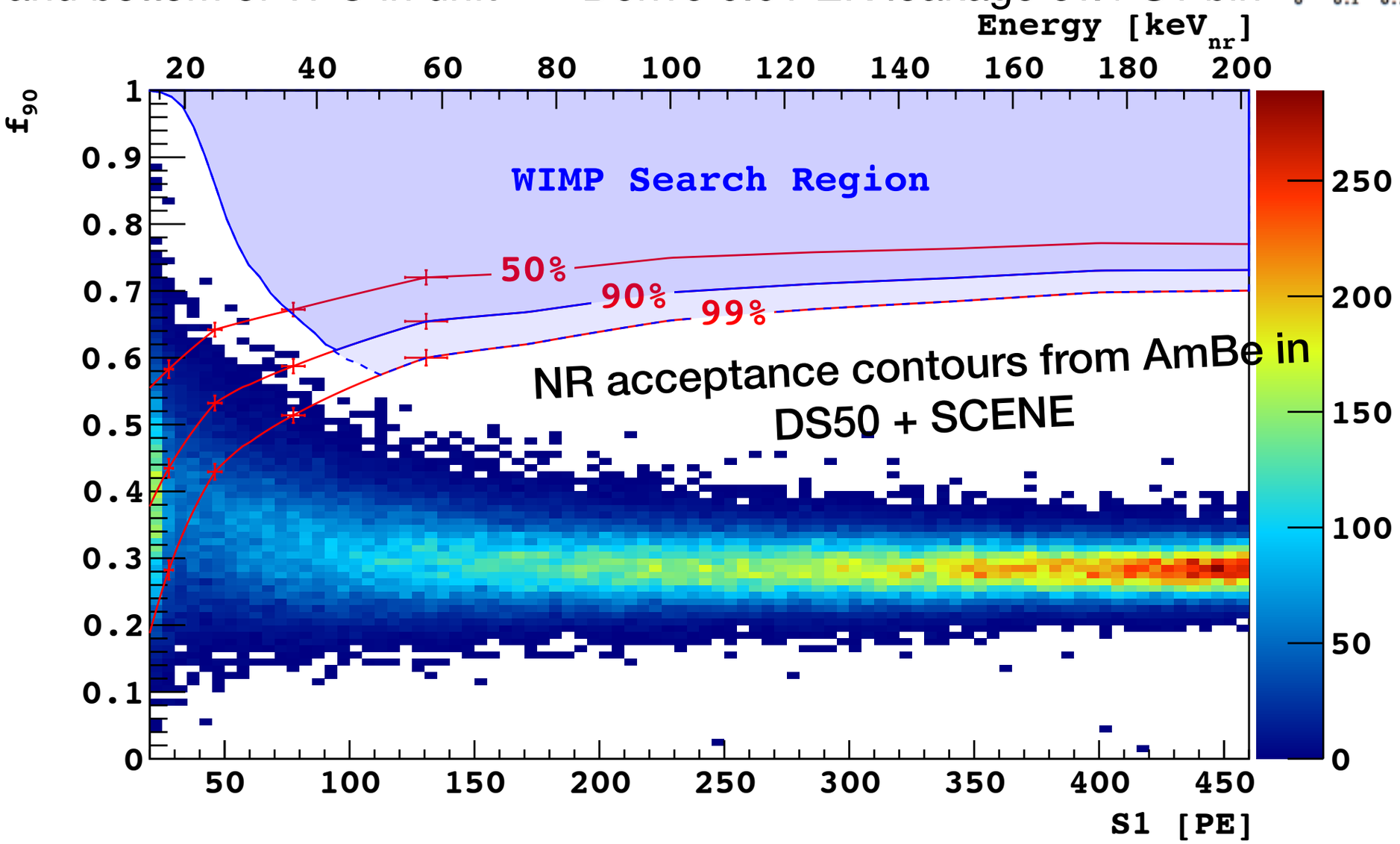
Single scatters

Use Hinkley f90 model

Fit to AAr data Scale to UAr data

Derive 0.01 ER leakage ev. / S1 bin

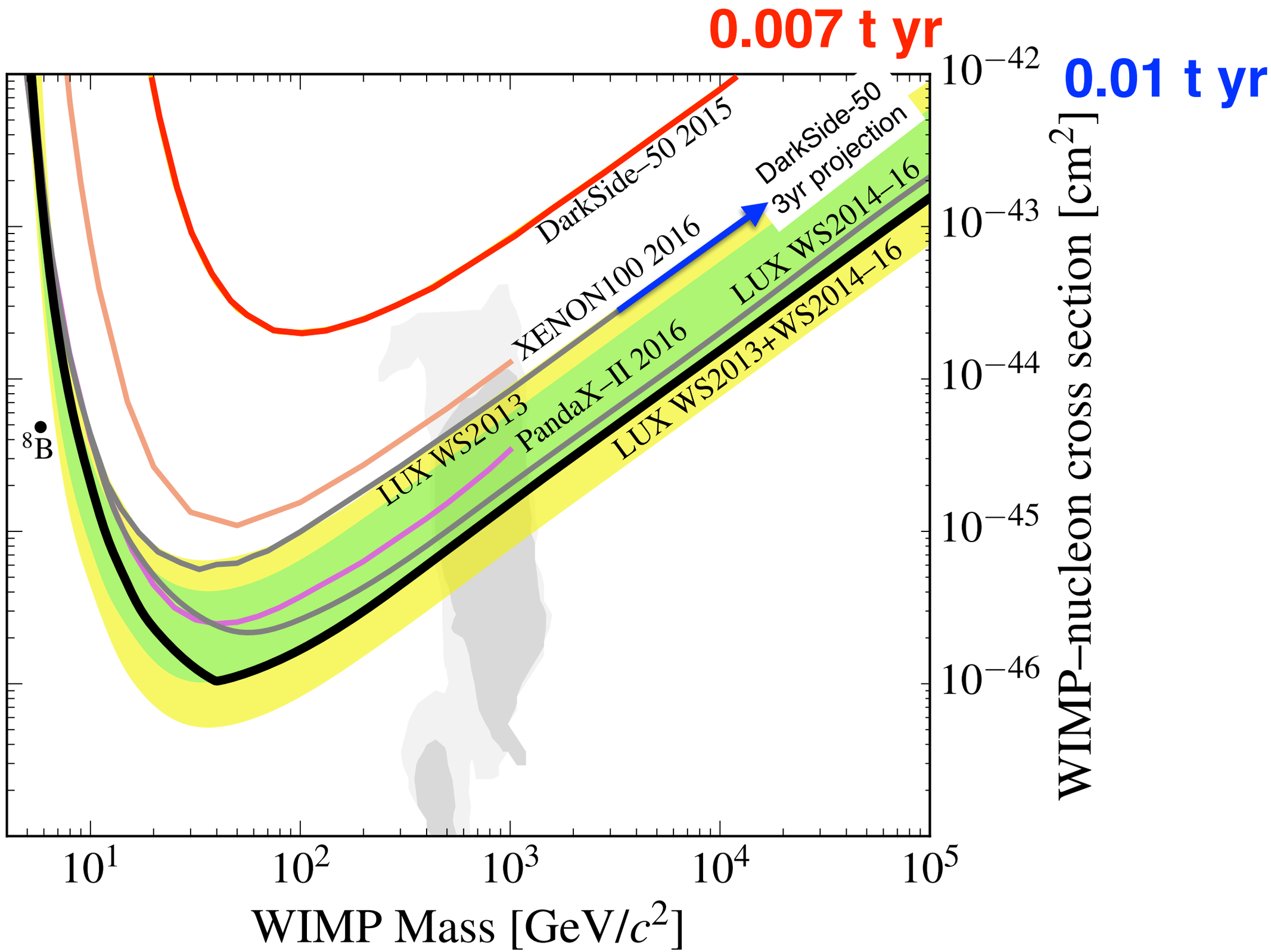




No events in the WIMP search region.

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

Latest DarkSide-50 Dark Matter search result

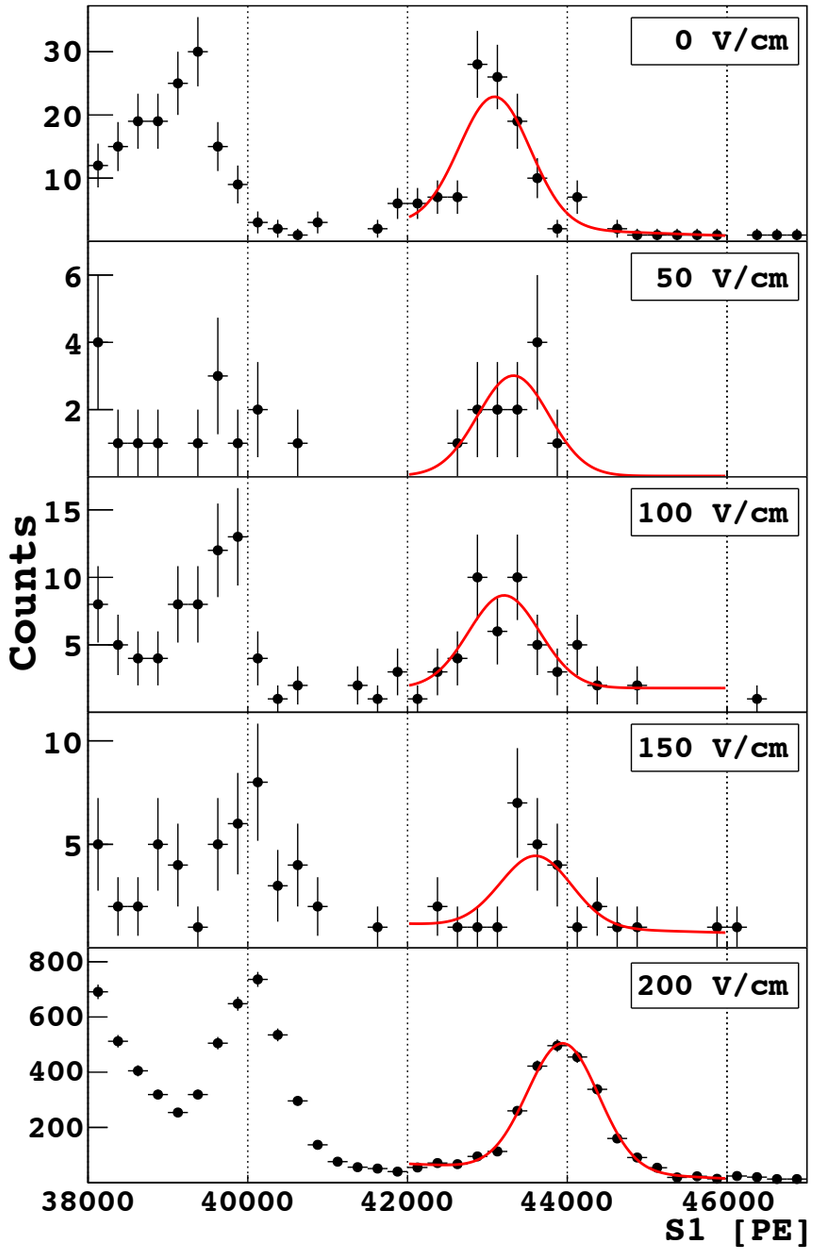


Results from the first use of low radioactivity argon in a dark matter search, Phys.Rev. D93, no.8, 08110 (2016)
PLOT adapted from Results from a search for dark matter in the complete LUX exposure arXiv:1608.07648 (2016)

DarkSide-50 Short Term Plan

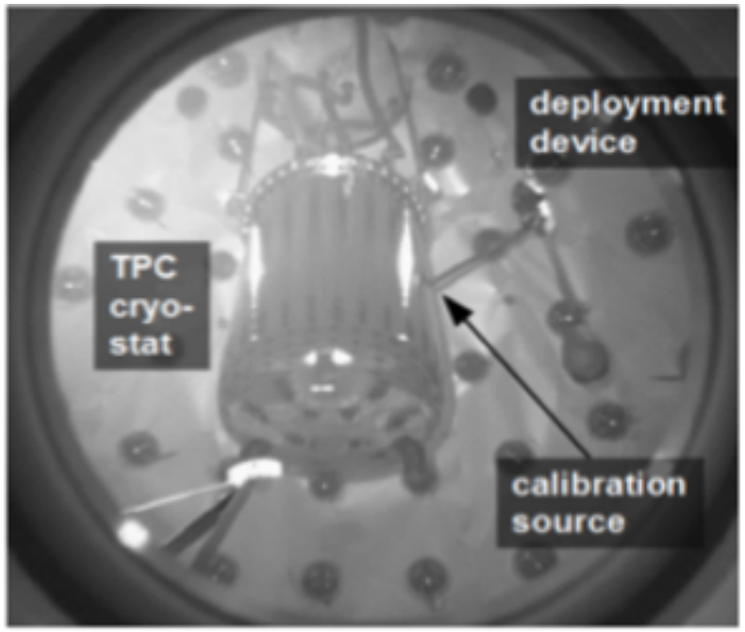
New data **almost one full year**:

-test and utilize blind analysis in steps
-re-optimize full analysis chain
-implement improved background model for ERs
-finalize background model for “Cherenkov plus ER” events



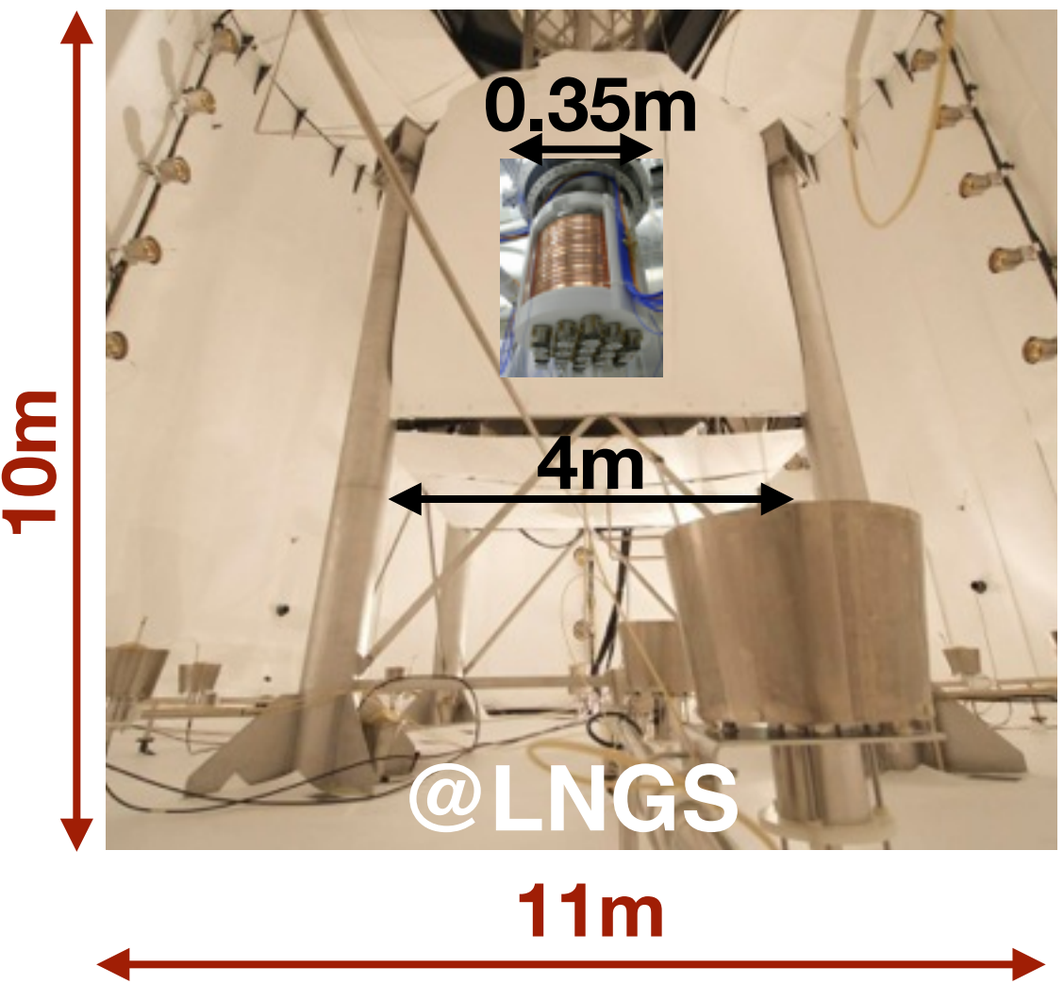
Other studies/publications:

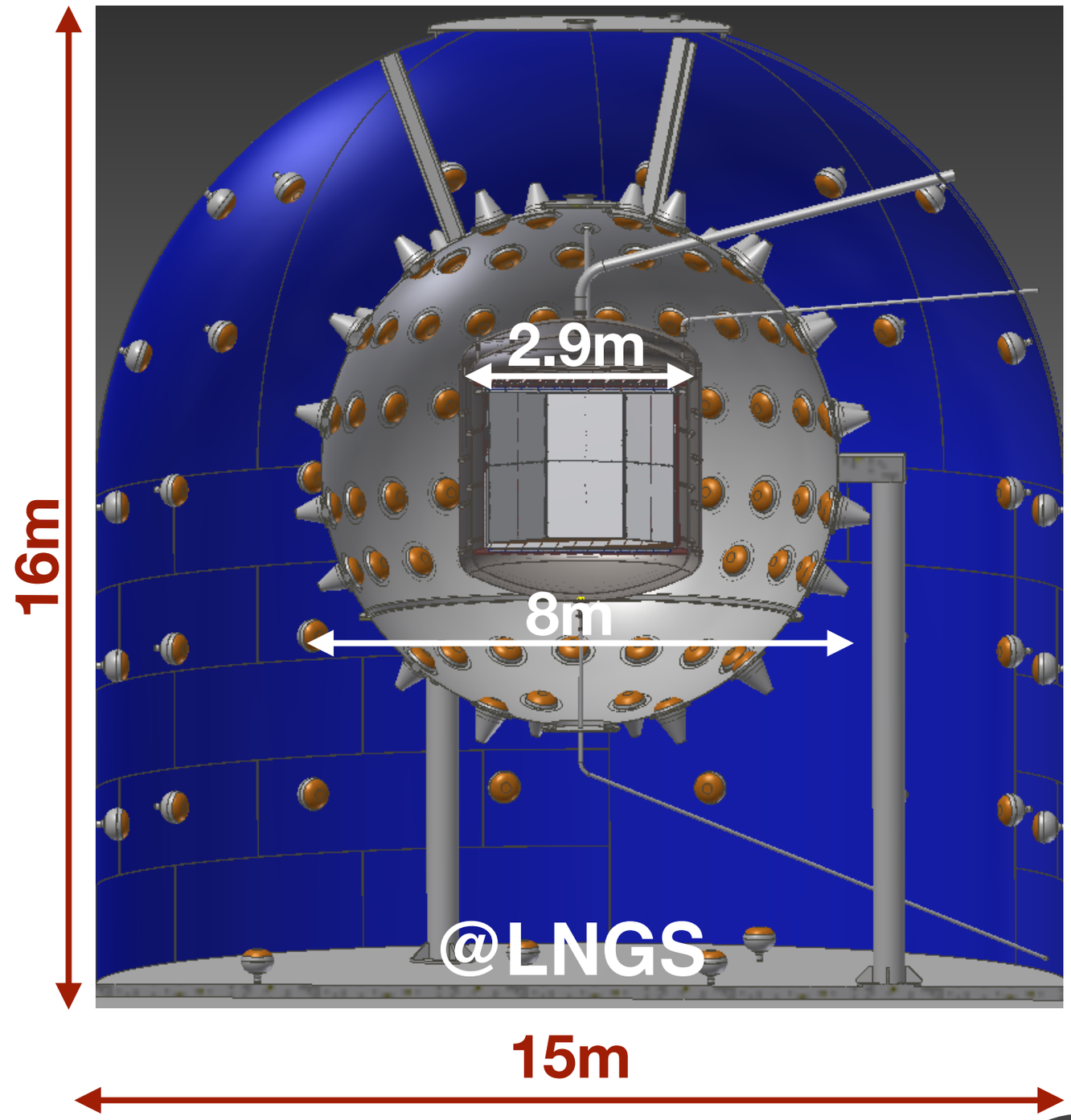
-G4DS simulation framework
-G4DS recombination model
-ER background spectrum
-f90 model
-alpha background
*-alpha yield***
-combined energy scale
-detector performance
*-CALIS**
-S2/S1
-Effective field theory



**CALIS - a CALibration Insertion System for the DarkSide-50 dark matter search experiment - Paper submitted*
***Effect of Low Electric Fields on Alpha Scintillation Light Yield in Liquid Argon - Paper submitted*

DarkSide-20k challenges and status





How to collect 50 000 kg of underground argon and then purify and distill to arrive to 30 000 kg by 2020 ?

Each purification or distillation step introduces a loss.

URANIA and ARIA

Urania
UAr extraction/ purification@100kg/d
Ar extraction expected to start in 2017.

Aria
Seruci1 - purification of UAr
Seruci2- isotopic separation of Ar-39
Rate @150kg/d
Depletion factor goals:
~10 for Ar-39 and >1000 for N2,02,Kr per pass

Pantic (UC Davis) on DarkSide @ Berkeley Workshop 2016

Urania in cooperation with Kinder Morgan
ARIA in cooperation with Regione Sardegna (production of other isotopes of interest for medical application)

How to provide 14 m^2 of single-photon sensitive and radiopure surface with < 10 000 number of readout channels?

DarkSide-20k Photodetector module

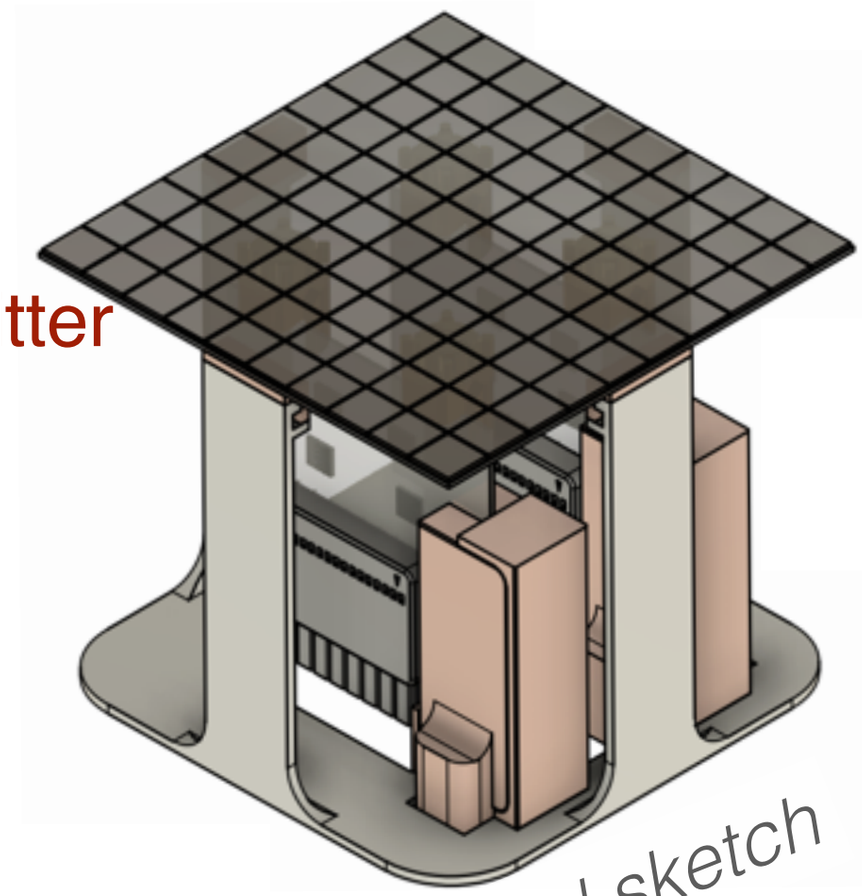
KEY GOALS

50x50mm² SiPM tile

FEB
with Cryo-TIA, transmitter
at Sapphire PCB
SNR>6
bandwidth>20MHz

Sapphire substrate

Power <250mW



conceptual sketch

ACHIEVED IN R&D

20x20mm² SiPM tile

FEB
with Cryo-TIA,
transmitter at FR4 PCB
SNR>6
bandwidth>20MHz

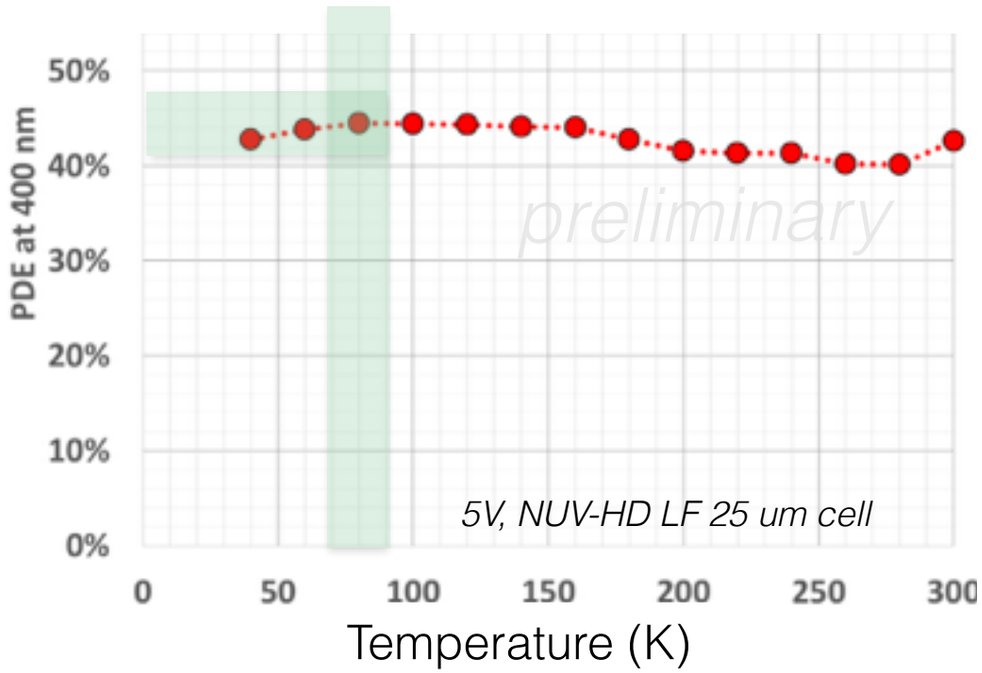
FR4 PCB substrate

Power <250mW

SiPM development by FBK/TIFPA. TIA=Trans-Impedance Amplifier. SNR=Signal to Noise Ratio

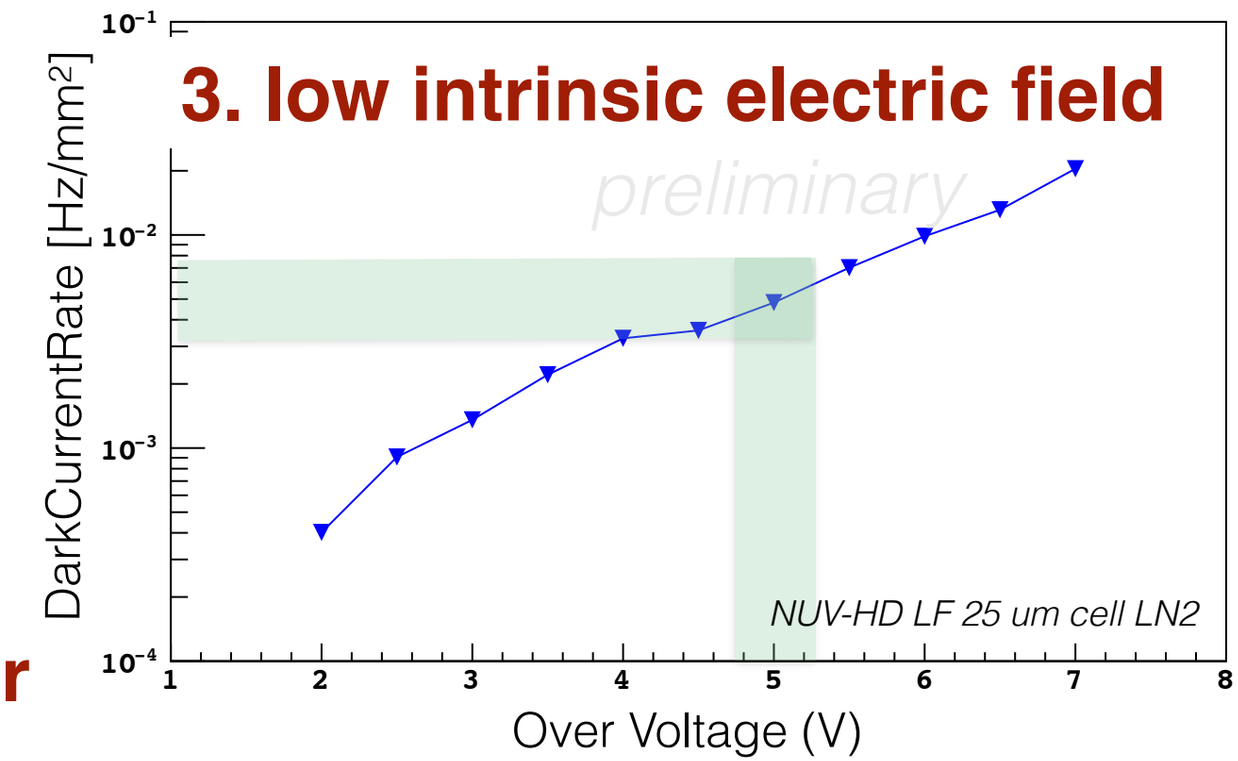
FBK NUV-HD-LF-HRq SiPM technology

1. peak efficiency in NUV

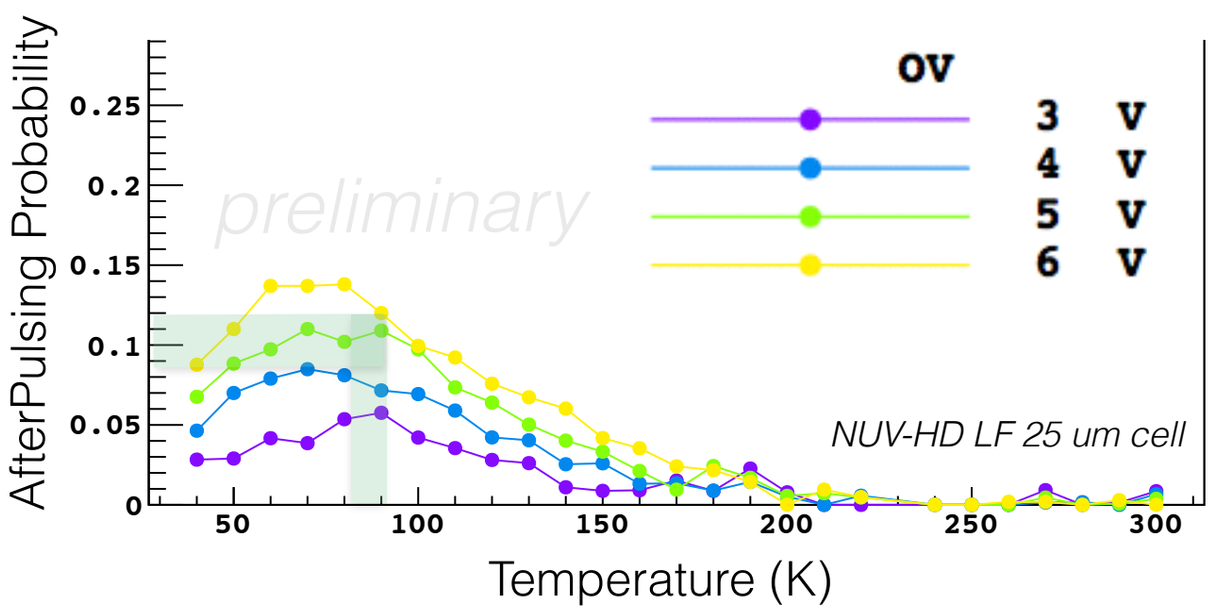


2. high dynamic range

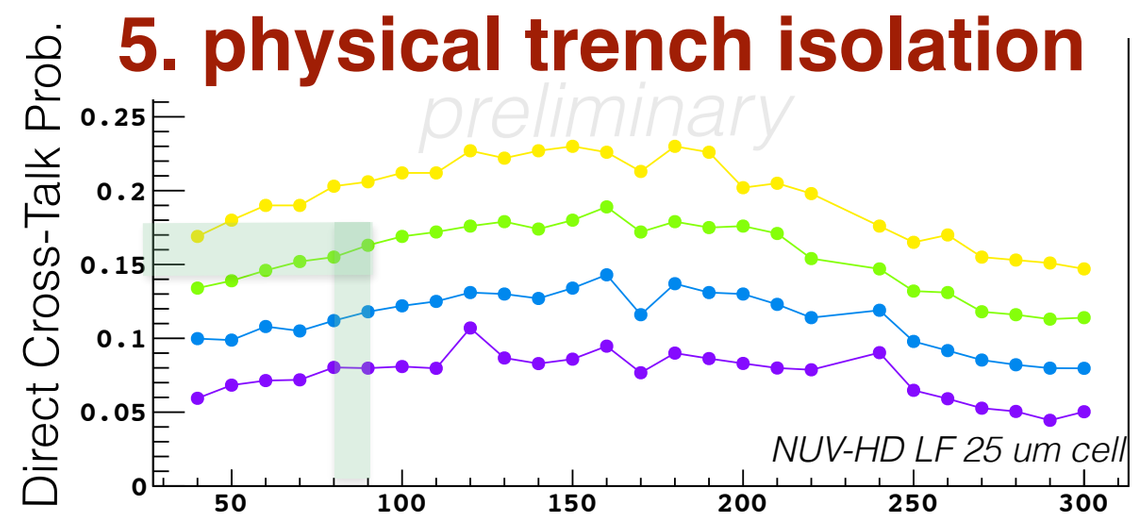
via (25-35 μm) cell size



4. high value of quenching resistor

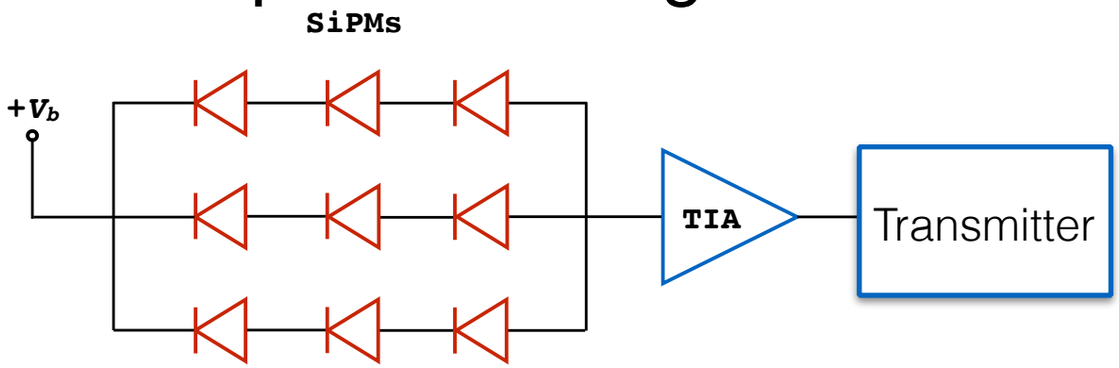


5. physical trench isolation

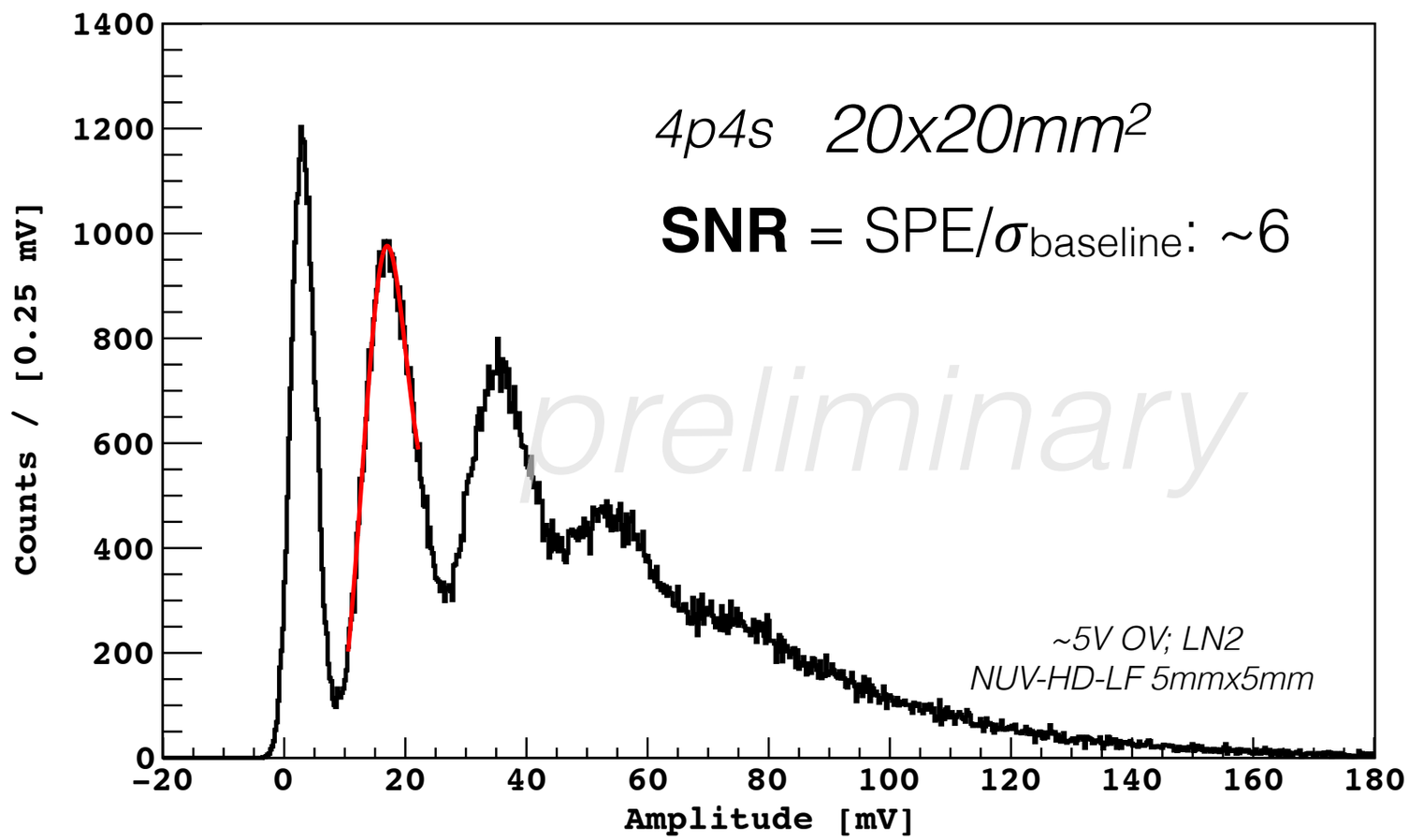


Hybrid scheme for SiPMs summing

Maintain SNR>6 for high threshold efficiency at SPE and photon timing ~10ns for Pulse Shape Discrimination



Optimization of summed capacitance and signal input to Cryogenic Trans-Impedance Amplifier and differential (optical) transmitter.

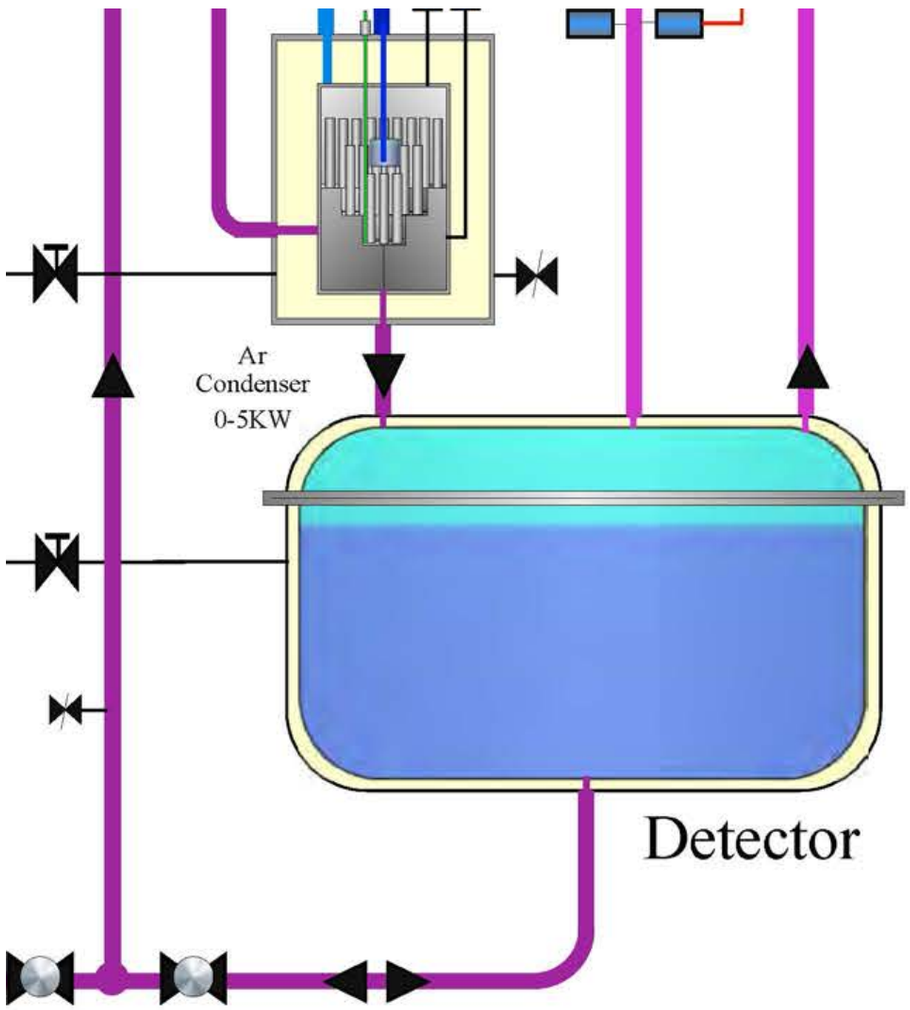


Cryogenic system

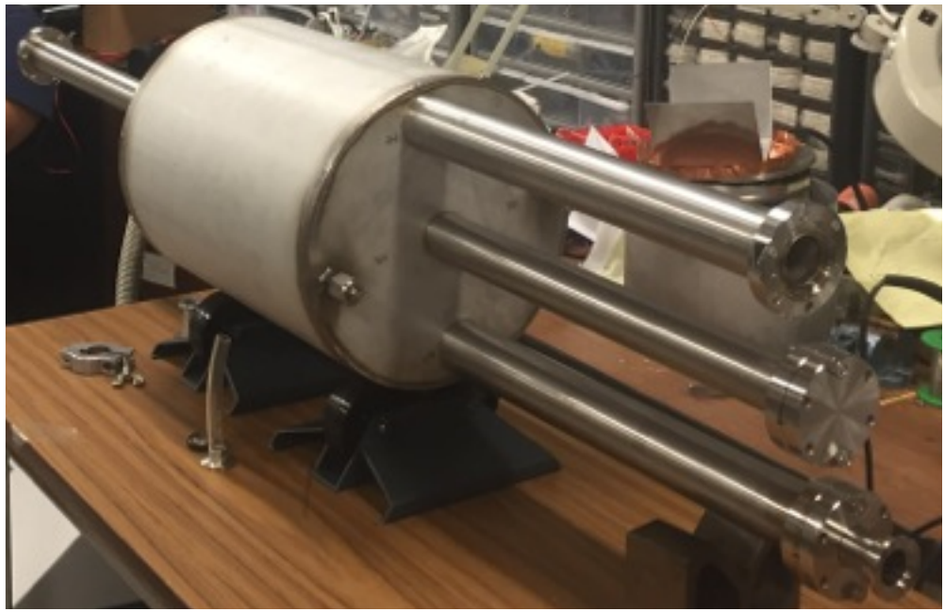
LAr from heat exchanger, radon trap and purification

LN2 powered LAr condenser

LAr to heat exchanger and purification



GAr to heat exchanger and purification system

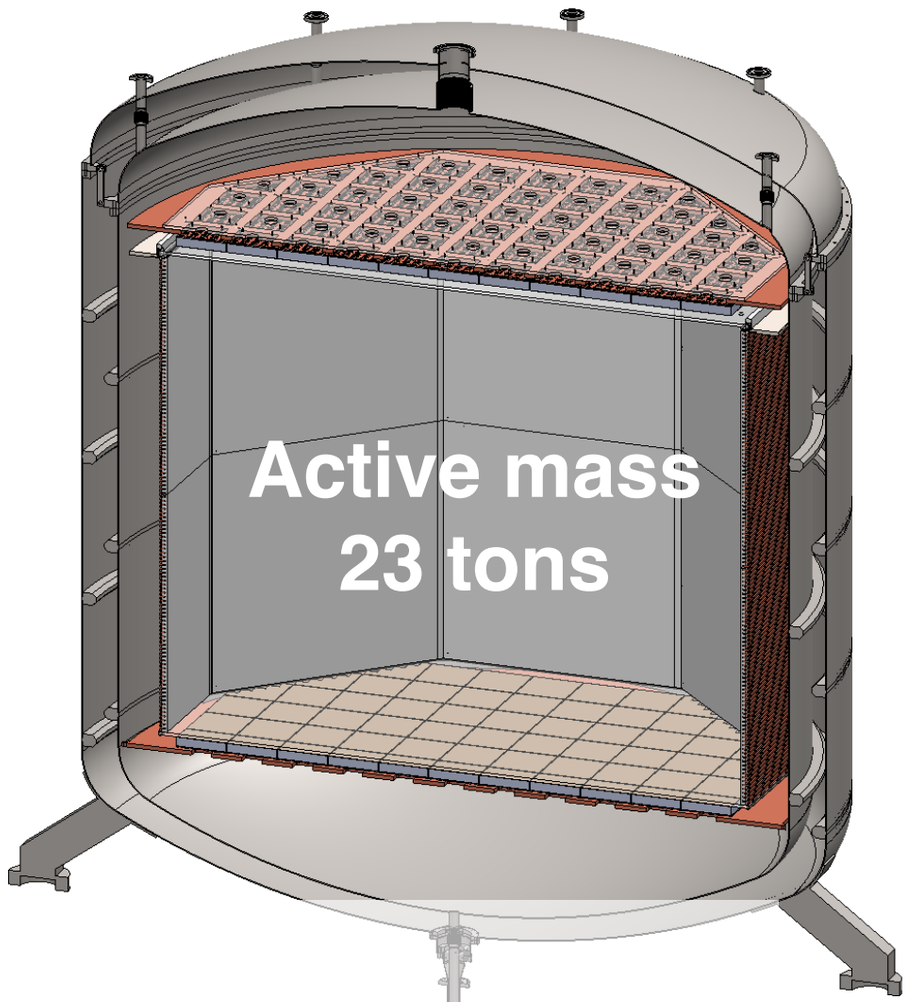


LAr to recovery

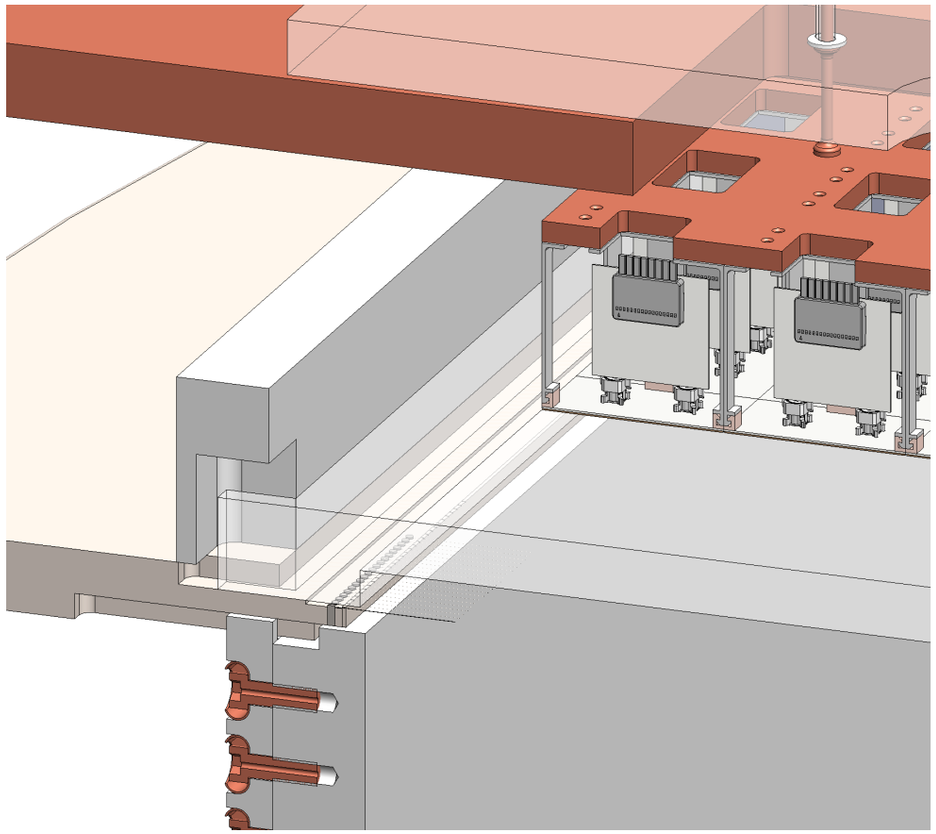
bi-directional **LAr** line

based on DarkSide-50 cryogenic system

Dual-phase octagonal TPC



liquid level control via diving bell
5210 **SiPMs-based** PDM modules
Cu motherboard holds 25 PDM
extraction **linear** grid



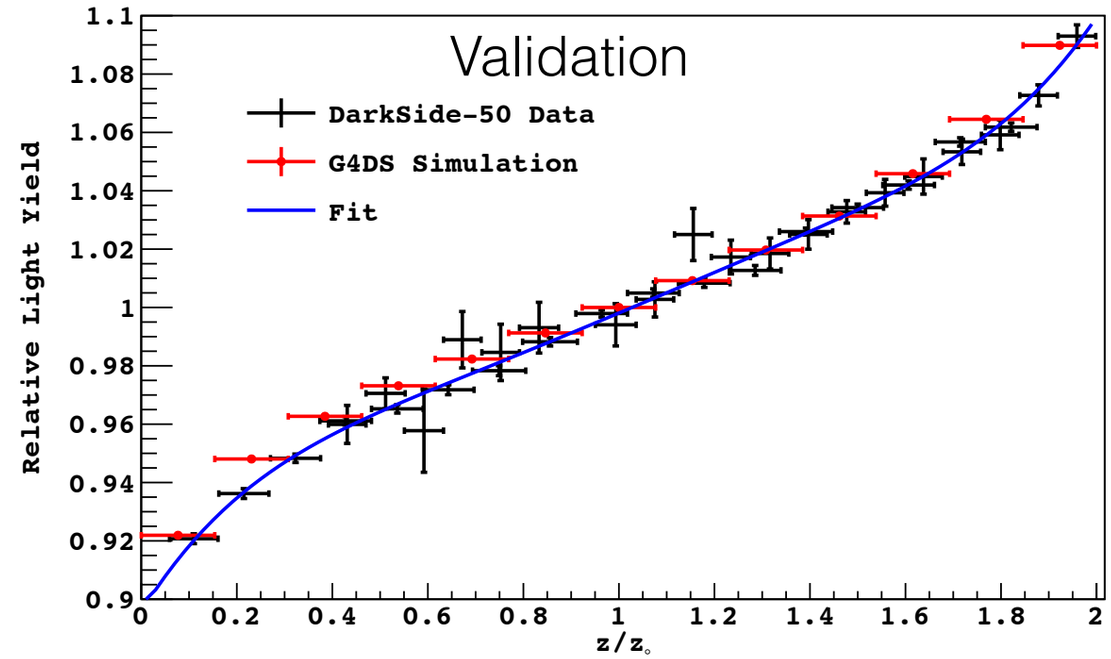
ITO on **bonded acrylic** for electrodes
Cu field cage shrinks with reflector
200V/cm drift field
Teflon as reflector
TPB as wavelength shifter
stainless steel (titanium) cryostat

Full size components scaled down (1ton) prototype in 2017. Things in bold differ from DarkSide-50

What is the perspective of DarkSide-20k?

DarkSide-20k light yield via G4DS

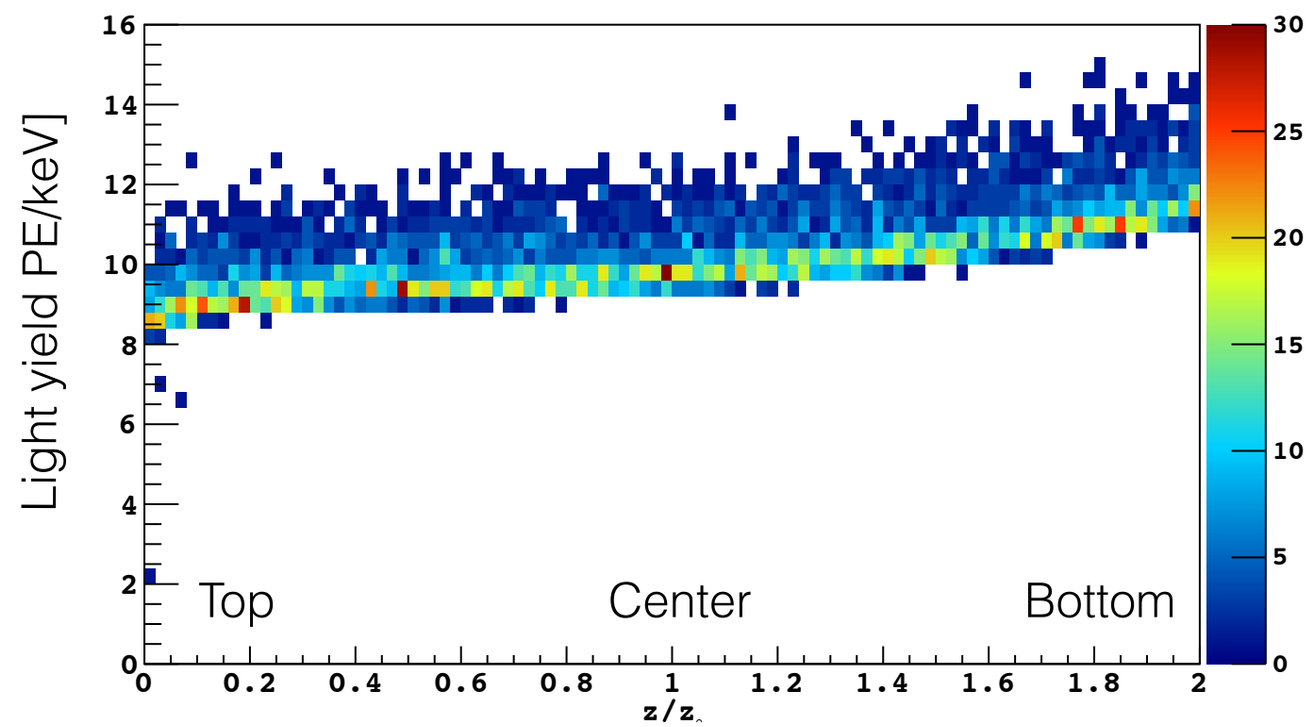
G4DS = Monte Carlo simulation with detailed geometry, electronics chain, tuned and validated optics parameters for S1 on various DarkSide-50 data.



Light yield for ^{39}Ar with an electric field of 200 V/cm

~ 9 PE/keV

assuming 40% PDE of PDM

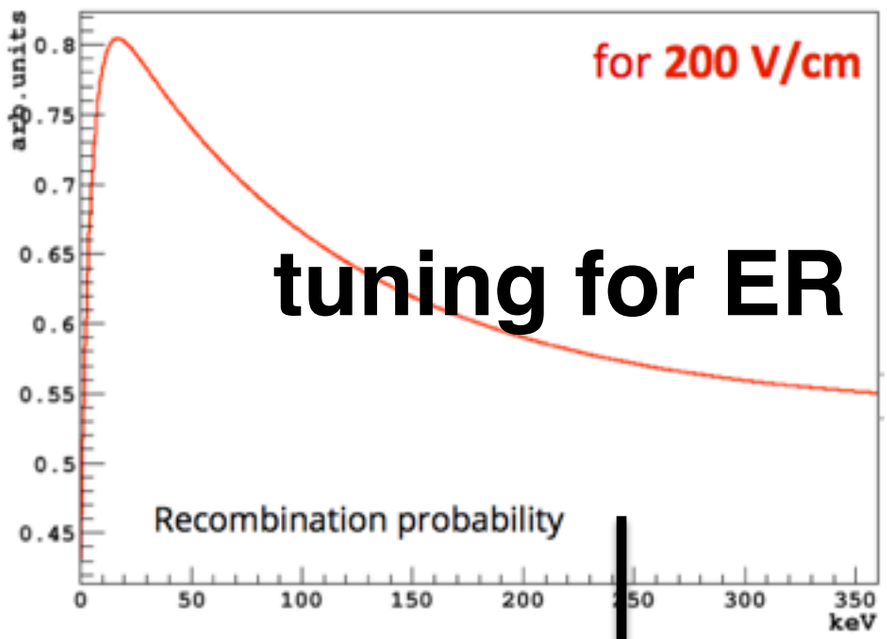


Normalized vertical coordinate.

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

Modeling ER and NR response in LAr

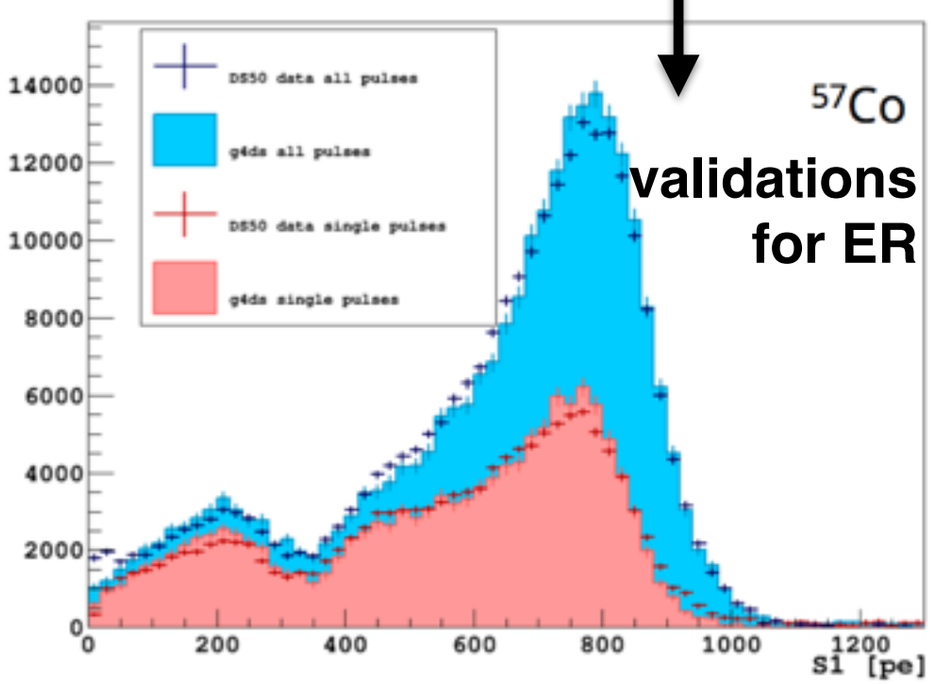
G4DS = also models the recombination probability as a function of recoil energy using DarkSide-50 data inputs from endpoint of ^{39}Ar, ^{83m}Kr summed peak and ^{37}Ar.



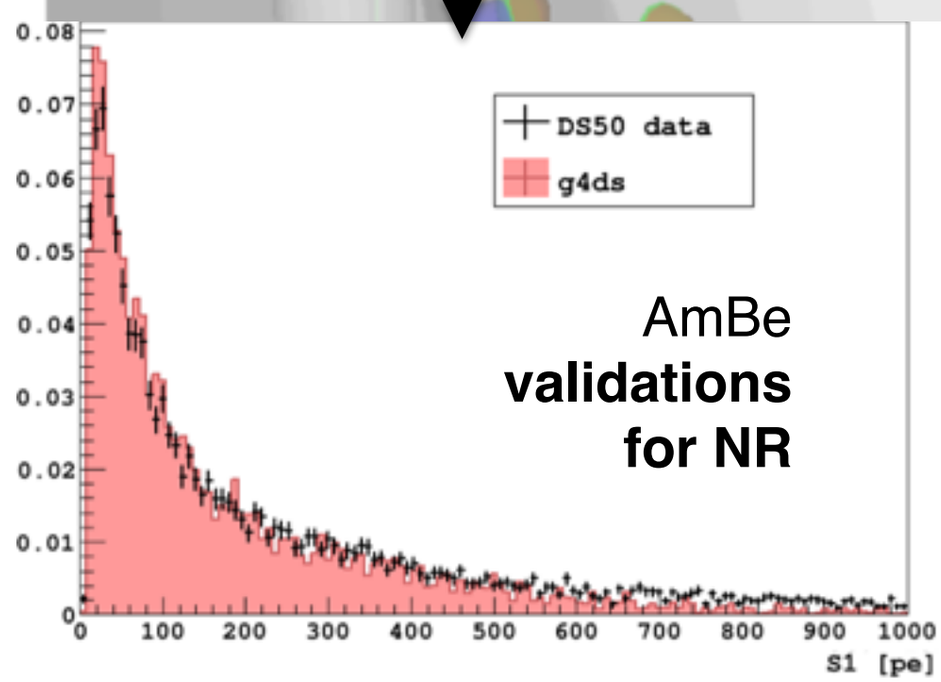
tuning for ER

+

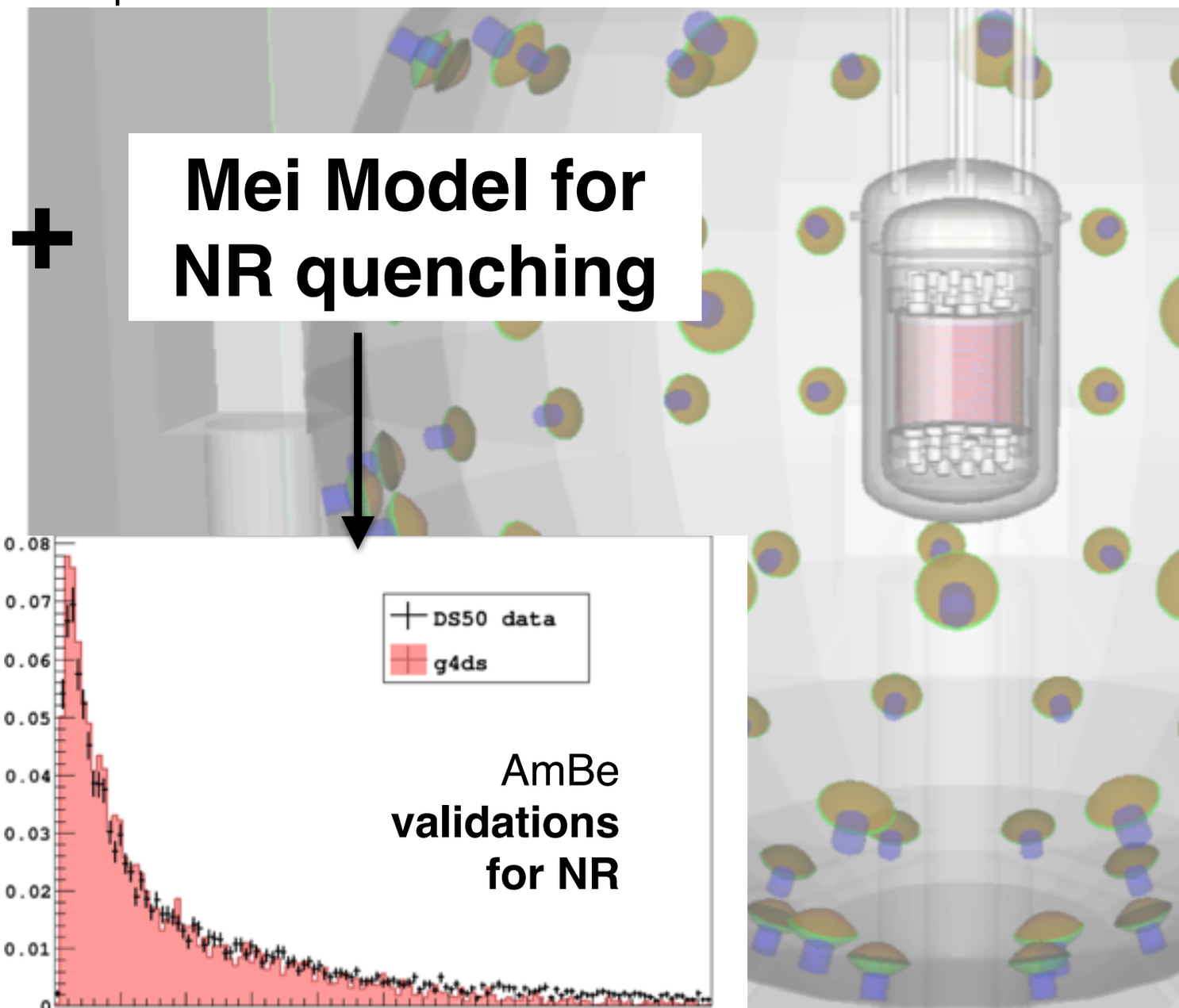
Mei Model for NR quenching



^{57}Co **validations for ER**



AmBe **validations for NR**



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

DarkSide-20k Background budget

^{39}Ar = DS-50

^{85}Kr, ^{222}Rn = <<

surface is active

~200ev/ty

PTFE/SS

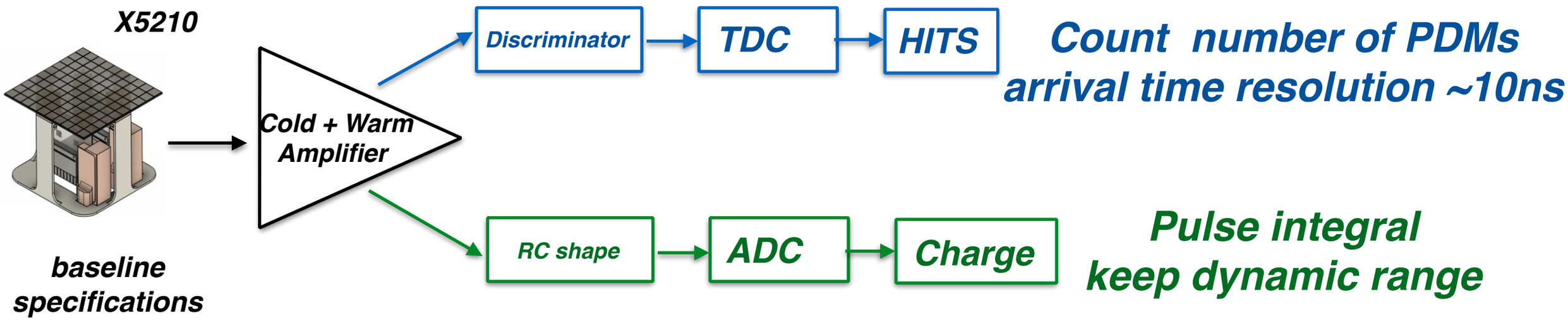
Background	Events in ROI / [100t yr]		Background / [100t yr]
Internal β/γ	**1.8 x 10^8**	*g4ds PSD sim* →	**0.06**
Internal NRs	<<<		<<<
e -ν_{pp} scatters	2 x 10^4		<<<
External NRs	<154	*g4ds Veto sim* →	<0.12
Cosmogenic β/γ	3 x 10^5	*g4ds Veto sim* →	<<0.01
Cosmogenic NRs		*g4ds Veto sim* →	<0.1
ν-induced NRs	1.6		

"What if?" ^{222}Rn = DS50 1 x 10^5 <<<

"What with?" Cherenkov + β/γ ongoing analysis, it is rare, pattern and fiducial cuts are effective

ROI= 30-200keVr. Events in ROI have no veto, no fiducial, no PSD cut. 222Rn level in DS50 is <2μBq/kg

DarkSide-20k PSD simulation

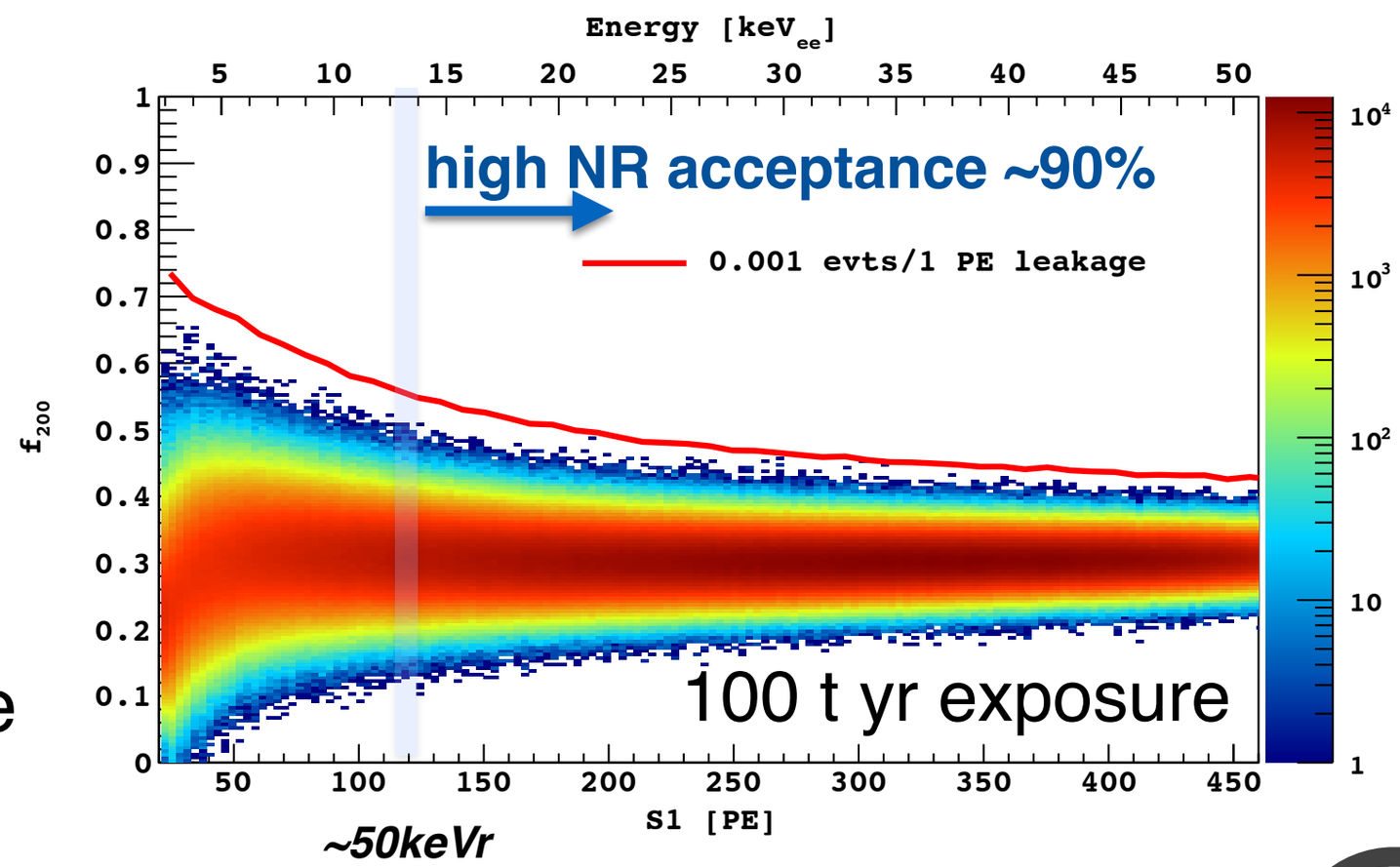


G4DS ERs simulation:

S1 light yield = 9PE/keV @200V/cm

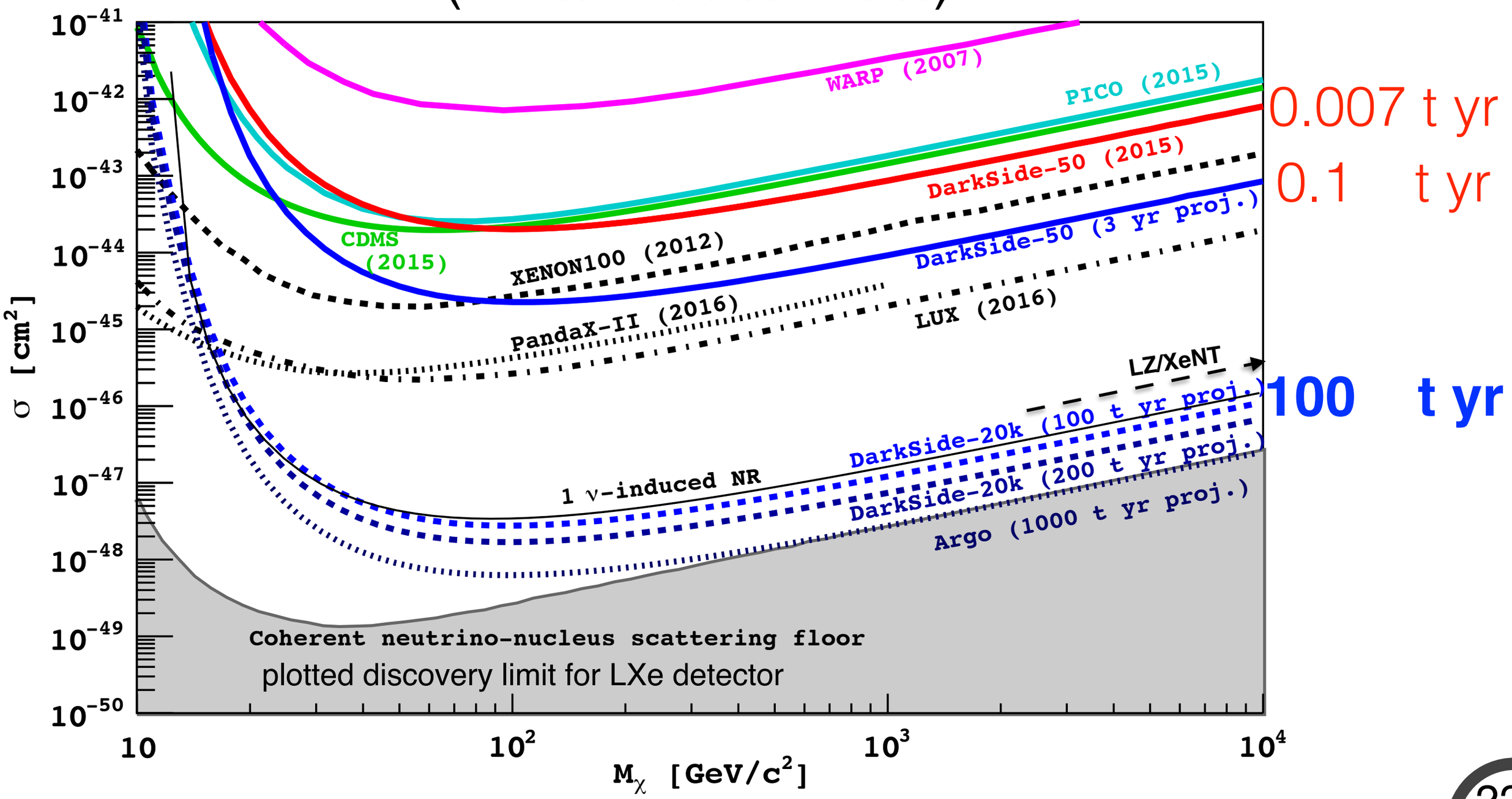
^{39}Ar as in DS-50

f200 = fraction of light in the first 200ns



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)



DarkSide-20k Plans

Proposal is submitted to NSF and INFN.

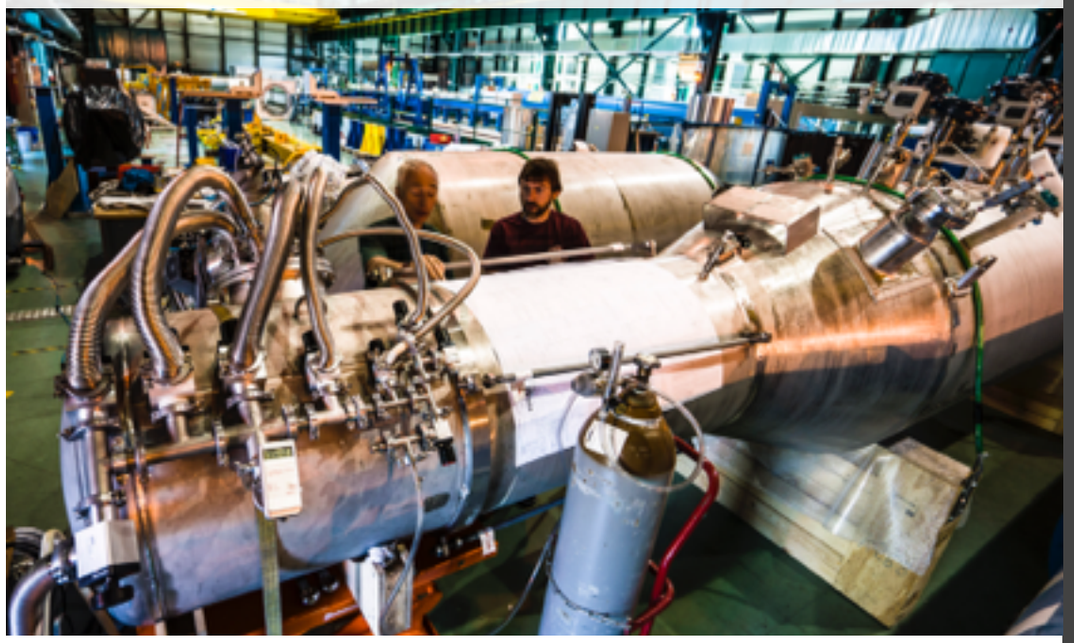
Continue with photodector modules R&D to optimize performance.
Start setting up facilities for mass production and testing.

Continue with production of ARIA modules and testing.

Full size components scaled down (1ton) TPC prototype including is planned for 2017.

Material Screening Strategy is being finalized.

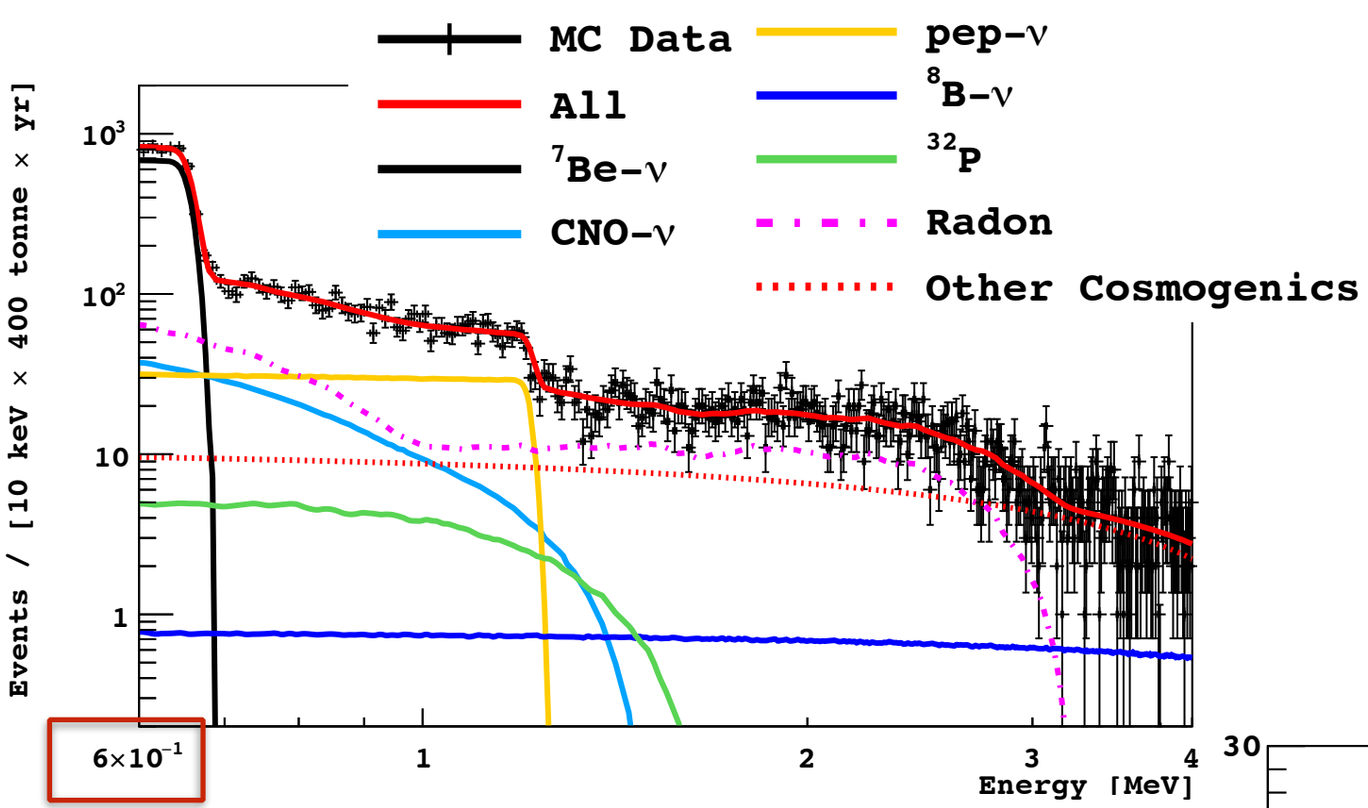
ARIA module testing



20–	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
DS–20k																		

Number of collaborating institutions is growing.

Solar ν detection in dual-phase LAr TPC



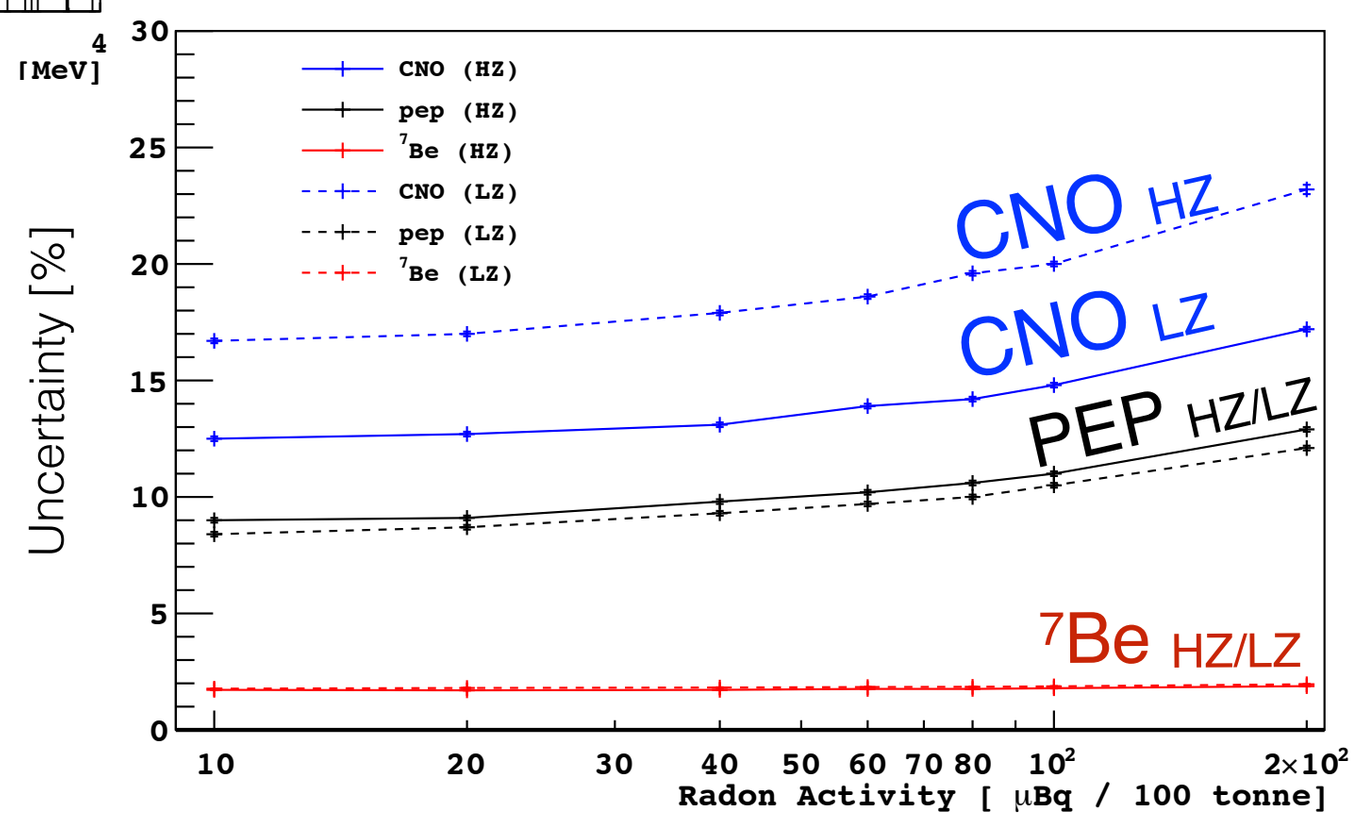
Toy MC study for 300t (100t fiducial) LAr TPC@LNGS. 400tyr exposure

"Conservative" scenario: ^{222}Rn @100μBq/100t

directly measure CNO νs

improve precision on ^{7}Be/pep νs

discriminate between two solar metallically models



8cpd/100t is approx.100μBq/100t; Borexino Rn level < 0.57cpd/100t

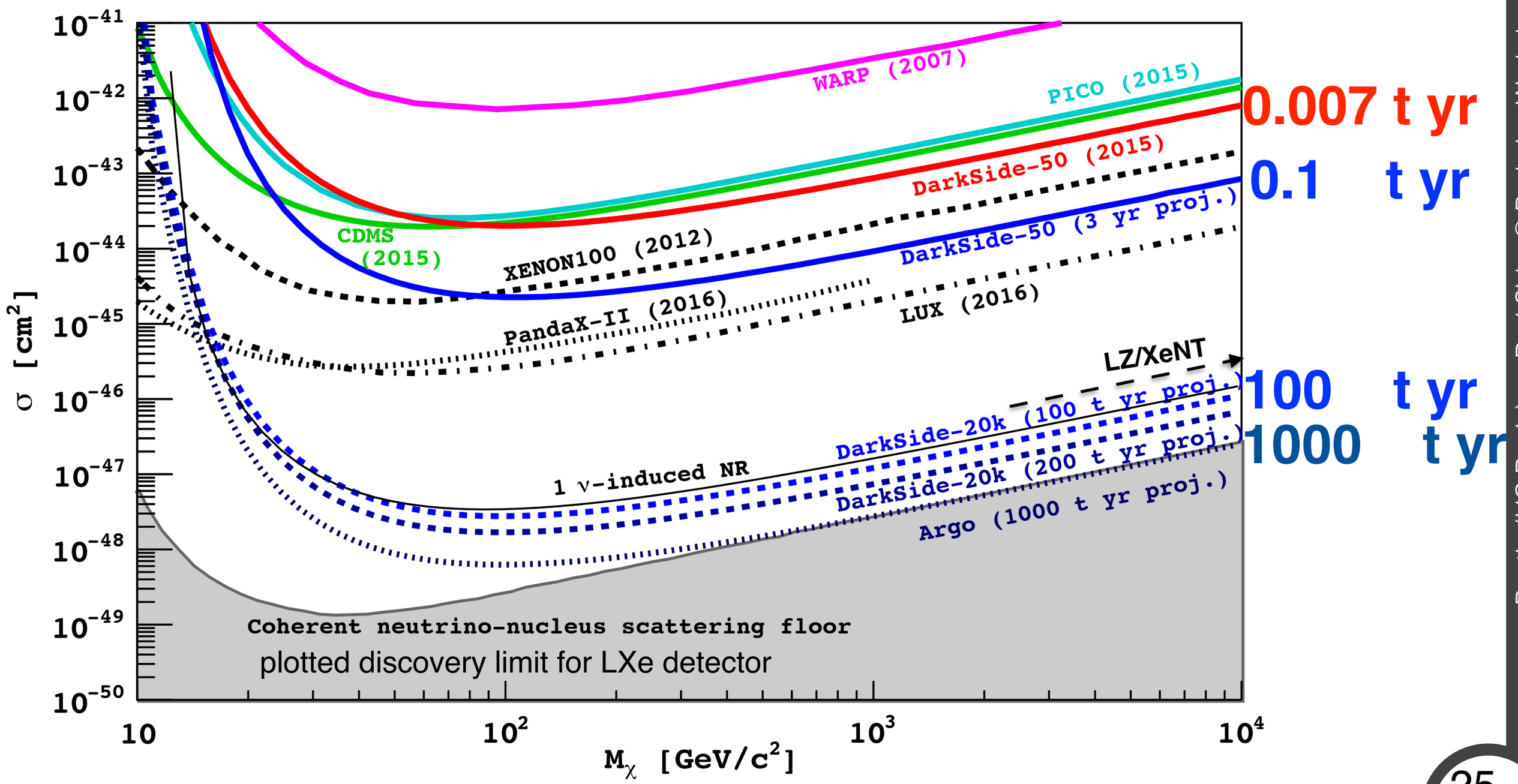
Solar neutrino detection in a large volume double-phase liquid argon experiment, JCAP 08 (2016

Argo = concept for 300 t LAr TPC

precision measurements on low energy solar νs

extend dark matter sensitivity for higher masses via bck. subtraction

*explore 1D Directionality via columnar recombination



*R&D efforts ongoing; see ReD experiment@Naples and Measurement of scintill.and ionization yield and scintill. pulse shape from NRs in LAr Phys. Rev. D 91, (2015)

Summary

collaboration:

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)

Critical R&D facilities: URANIA, ARIA and prototype development are already underway.

A SiPM based, large-area photo-detection module @ LAr temperature has been demonstrated

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.

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

DarkSide-50 DarkSide-20k ARGO

Work supported by NSF, INFN, DOE, NCN and others. LNGS and FNAL lab support.