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DarkSide 50kg latest results
(and future prospects)

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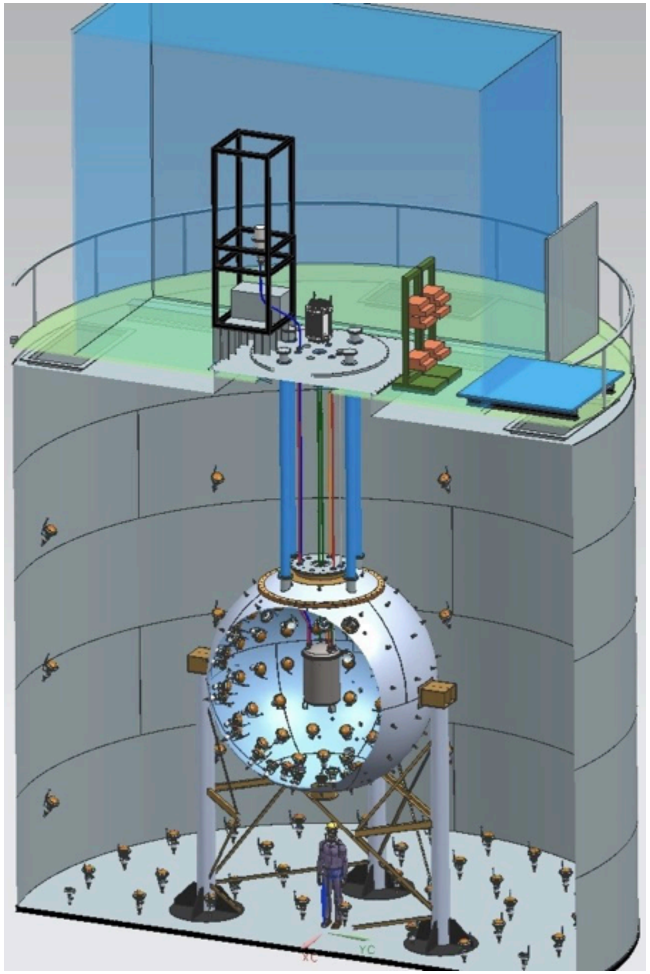
on behalf of the DarkSide Collaboration

The DarkSide 50kg experiment at Laboratori Nazionali del GranSasso underground site (Italy)

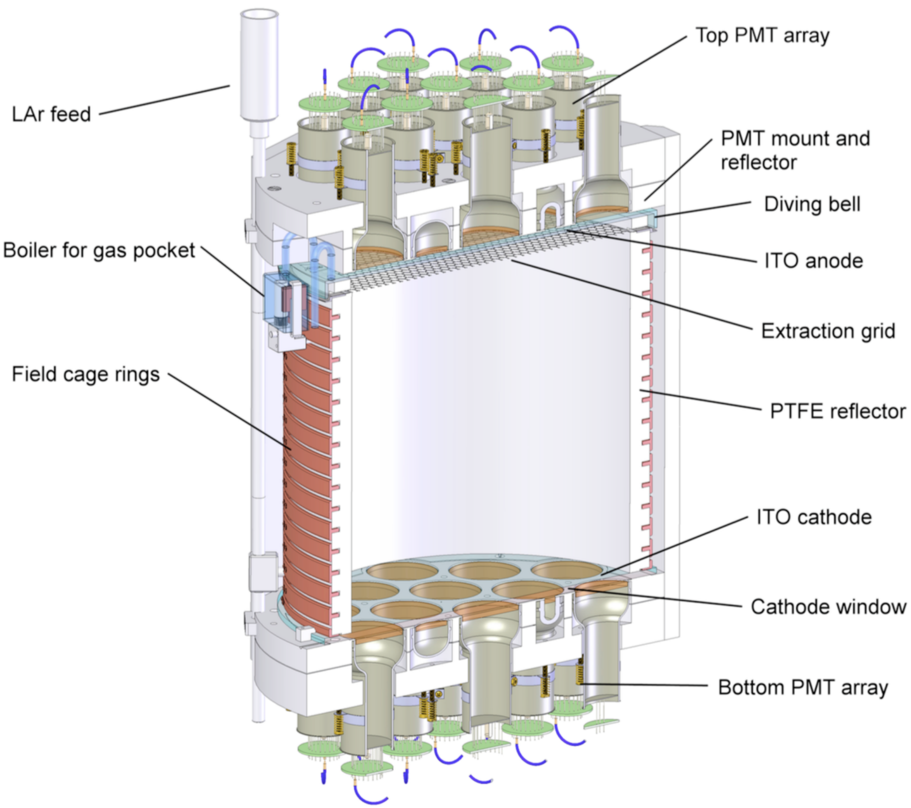
Liquid Argon double phase TPC
for WIMP Dark Matter search

Liquid scintillator inner VETO
for neutrons and gammas
(30 tons of PC+PPO+TMB)

Water Cherenkov outer VETO
to reduce external radiation and tag muons that may produce spallation neutrons
(1000 ton of ultra pure water)



DarkSide 50kg TPC



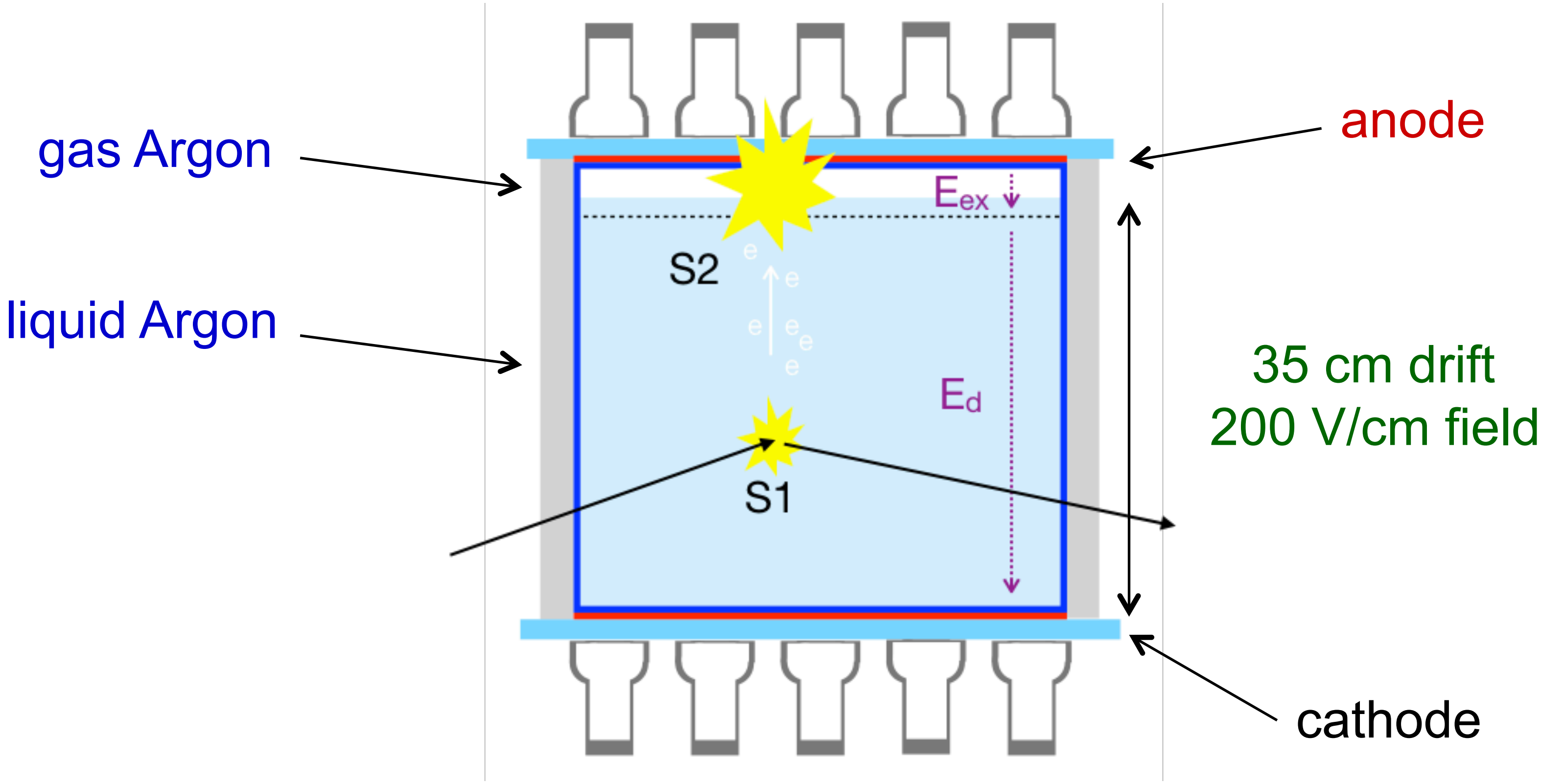
35.6 cm (diameter) x 35.6 cm (height) TPC

Low Radioactivity Argon
(150 Kg total – 46.4 inner volume)

Viewed by 19 (top) + 19 (bottom)
Hamamatsu R11065 PMTs (35% QE)

DarkSide double phase TPC

Prompt light signal (S1) followed by scintillation in gas (S2)



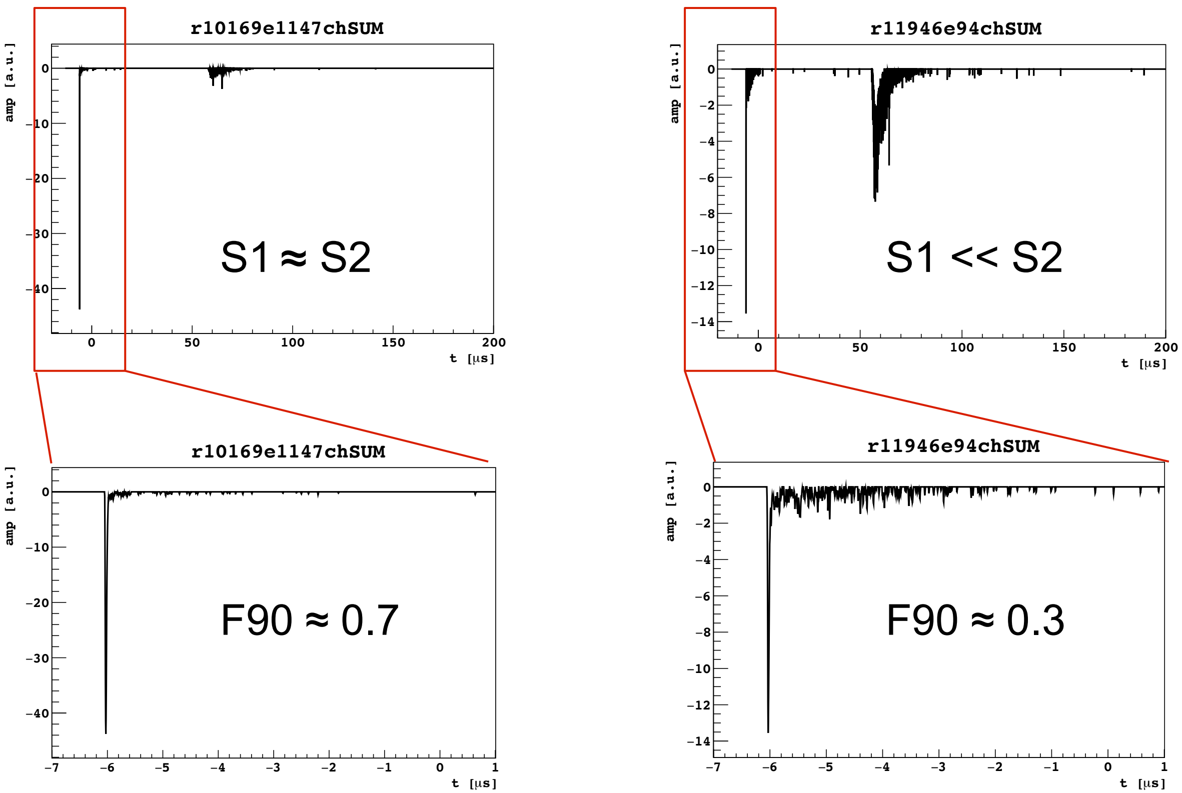
Light yield of 7 phe/keV (^{83m}Kr @ null field)

Scintillation/ionization yield in Liquid Argon

Pulse Shape Discrimination (PSD)

Neutron induced nuclear recoil

e-like induced signal

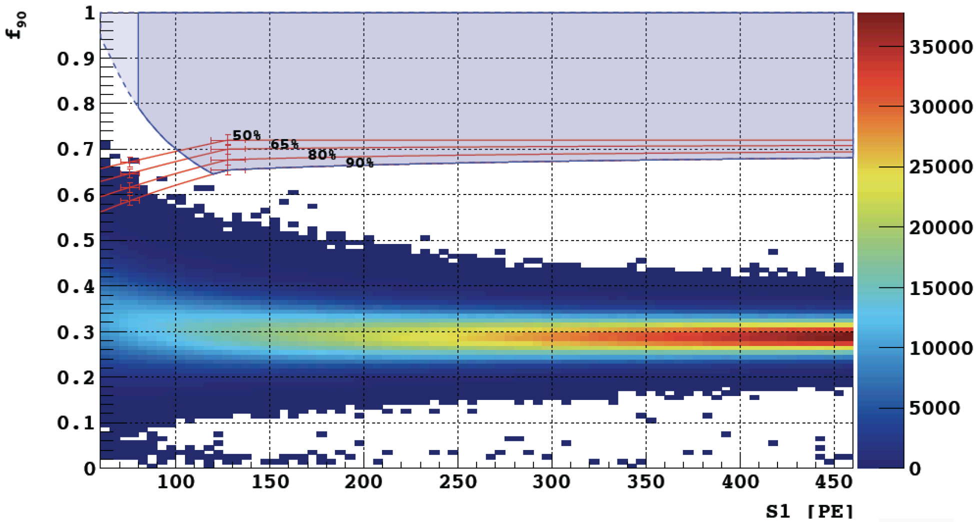


S1 light signal time profile allow primary particle identification by using the f90 parameter

$$f90 = \frac{S1\ [0;\ 90]\ \text{ns}}{S1\ [0;\ 7]\ \mu\text{s}}$$

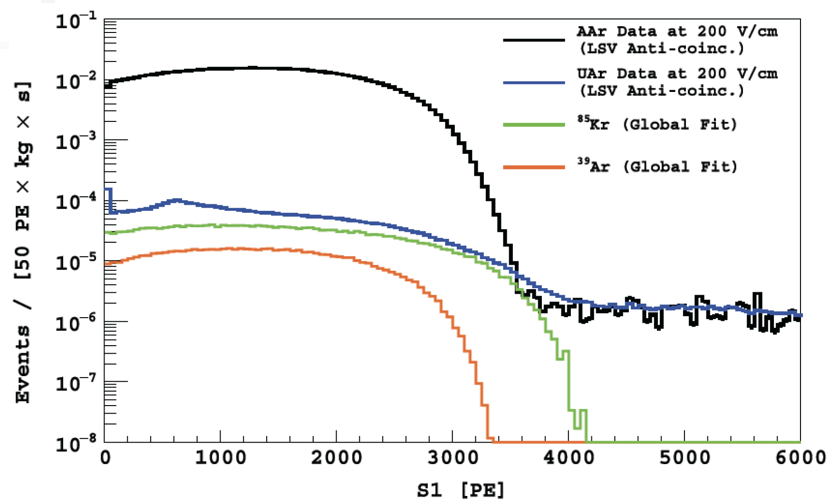
Ratio of singlet ($\tau \approx 6$ ns) to triplet ($\tau \approx 1.6$ µs) Ar^{2+} dimer excitation and amount of free electrons that can drift towards the liquid–gas interface depend on ionization density and applied electric field

Electron-like induced event rejection power and ^{39}Ar depleted Argon



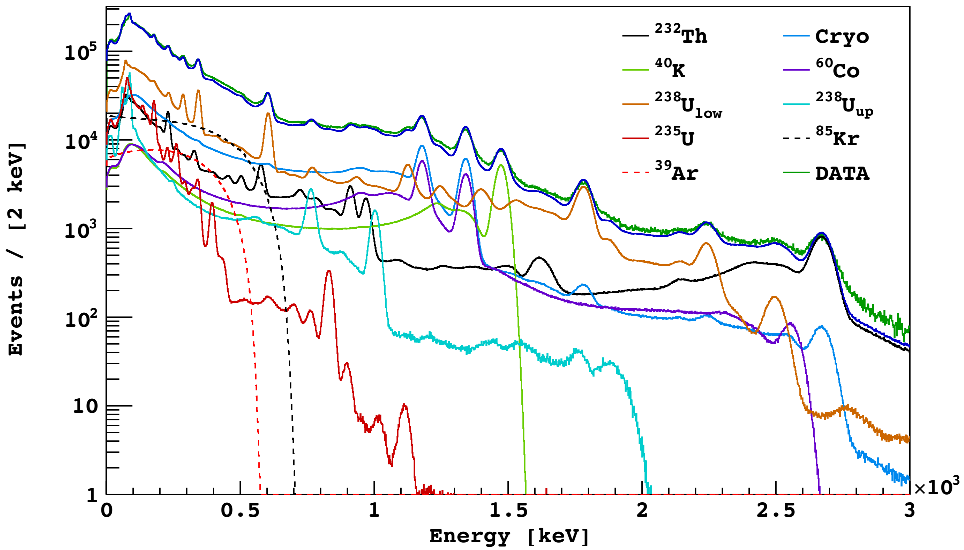
f90 rejection power better than 10^7 as measured in DS 50kg using atmospheric Argon (1 Bq/kg of ^{39}Ar)

Argon extracted from underground wells contains very small amount of ^{39}Ar (better than 10^3 reduction factor)



These are the key ingredients to the high mass and background free detector aimed at very high sensitivity WIMP search (see next talk)

Background modeling



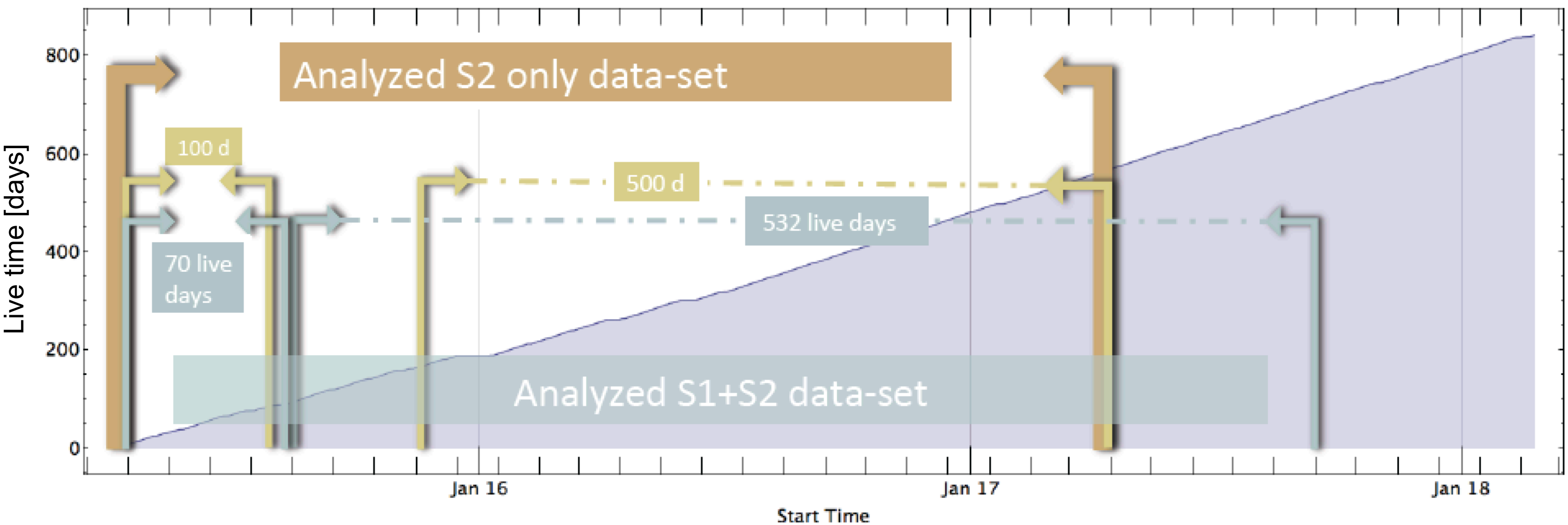
Source	Activity [Bq]	Source	Activity [Bq]
$^{232}Th_p$	0.277 ± 0.005	$^{232}Th_c$	0.19 ± 0.04
$^{40}K_p$	2.74 ± 0.06	$^{40}K_c$	$0.16^{+0.02}_{-0.05}$
$^{60}Co_p$	0.15 ± 0.02	$^{60}Co_c$	1.4 ± 0.1
$^{238}U_p^{low}$	0.84 ± 0.03	$^{238}U_c^{low}$	$0.378^{+0.04}_{-0.1}$
$^{238}U_p^{up}$	4.2 ± 0.6	$^{238}U_c^{up}$	$1.3^{+0.2}_{-0.6}$
$^{235}U_p$	0.19 ± 0.02	$^{235}U_c$	$0.045^{+0.007}_{-0.02}$
^{85}Kr	1.9 ± 0.1 mBq/kg	^{39}Ar	0.7 ± 0.1 mBq/kg

Proper materials selection and precise MC modeling are crucial in order to control events that may mimic a genuine WIMP interaction

G4DS (Geant 4 based simulation) shows a very good agreement with data

DS 50kg Underground Argon data set

(more than 800 days livetime)



PRD 93, 081101(R) (2016)

arxiv:1802.06994

arxiv:1802.06998

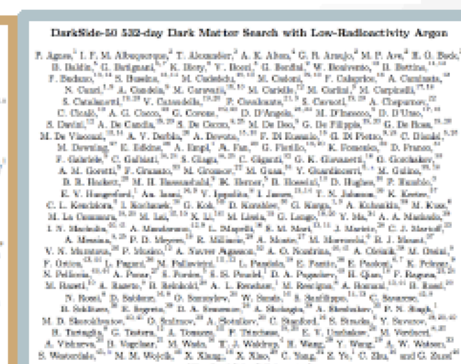
arxiv:1802.07198

PHYSICAL REVIEW D 93, 081101(R) (2016)

Results from the first use of low radioactivity argon in a dark matter search

Low-mass Dark Matter Search with the DarkSide-50 Experiment

Constraints on Sub-GeV Dark Matter-Electron Scattering from the DarkSide-50 Experiment

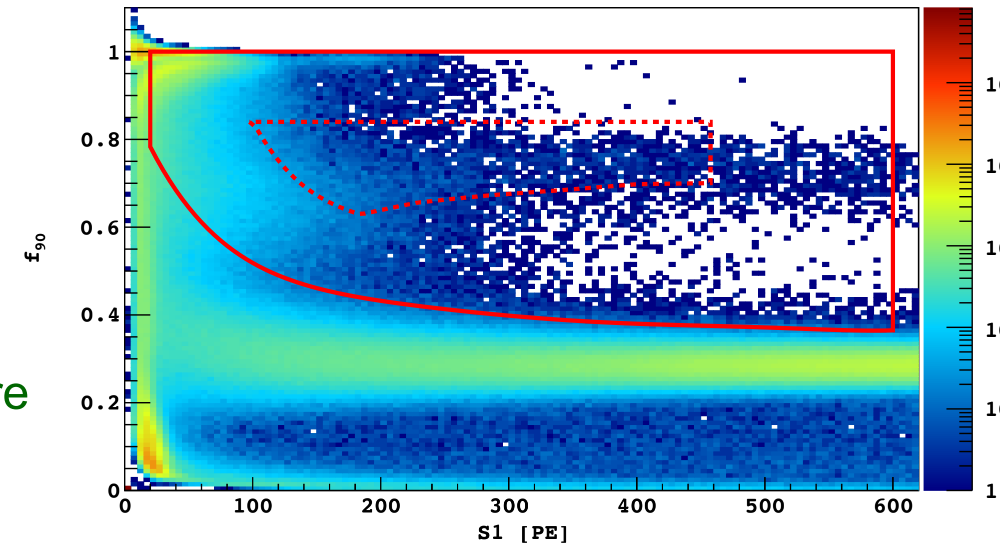


DarkSide-50 532-day Dark Matter Search with Low-Radioactivity Argon

First blind analysis of UAr data

534 live days blind analysis:
solid red shows the region used to design the box to blind (dashed) having expected background below 0.1 event

Data shown is the control set before blinding (PRD 93 081101(R) 2016)



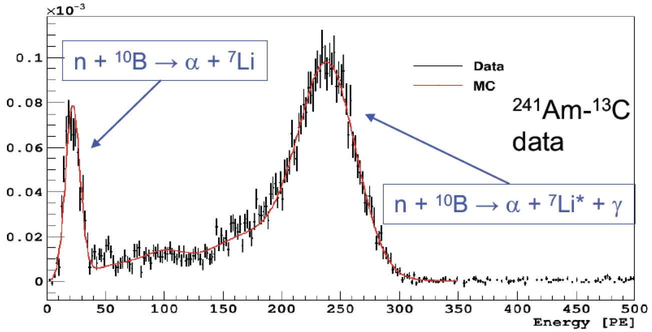
Use data driven measurement and methods to identify and model background source

Extensive calibration source campaign to characterize detector performance and efficiencies

Blind analysis: neutron calibration

Neutron veto tag in liquid scintillator

Evaluation of veto efficiency using Am-C and Am-Be sources



Prompt tag : >1 PE in [-50; 250] ns

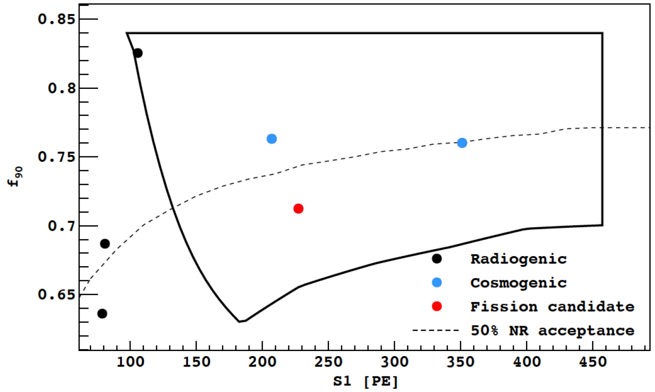
Delayed tag: >6 PE in 500 ns sliding window

[0; 185] μs of the TPC trigger

Efficiency:

Prompt cut only	Delayed cut only	Combined
0.9927 ± 0.0005	0.9958 ± 0.0004	0.9964 ± 0.0004

Use events having the Prompt tag to evaluate background in the blinded sample



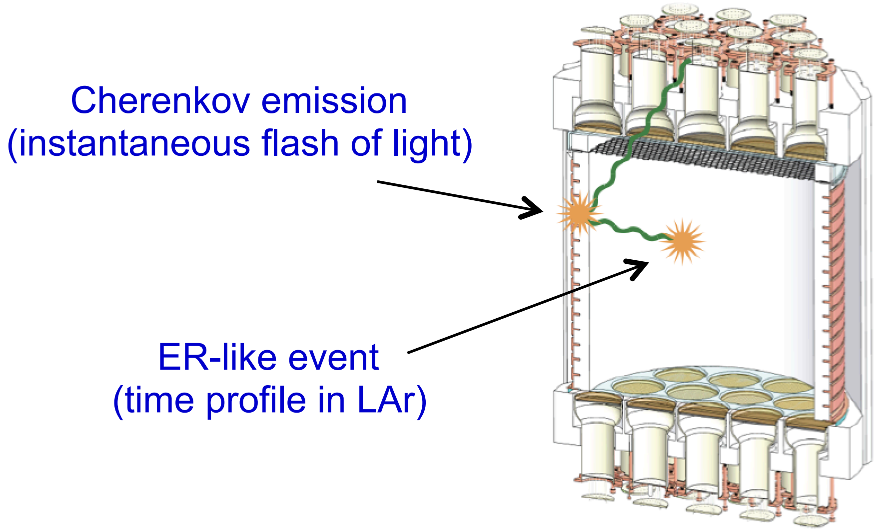
Radiogenic: 1 event found in the signal region scales to less than 0.005 events expected

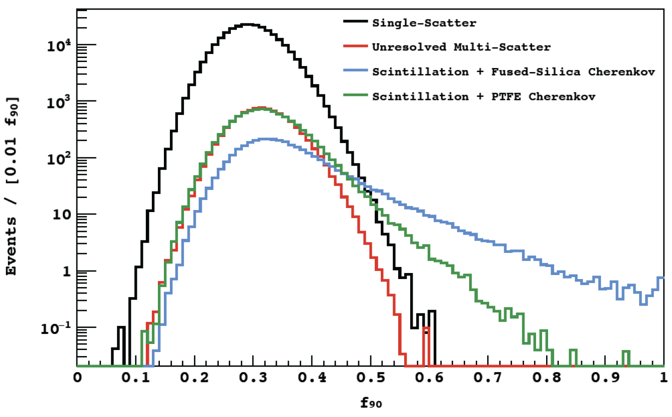
Cosmogenic: FLUKA based simulation predicts 2 induced neutrons/year when removing the Water VETO cut (2 found)

Blind analysis: Cherenkov events

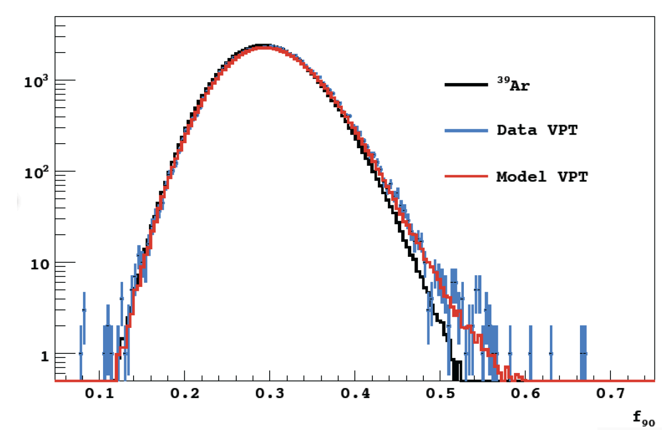
Compton scattered e^- in the PTFE or fused silica may produce Cherenkov light

These "fast" photons add to the ER light and may mimic a NR-like signal (high f90)





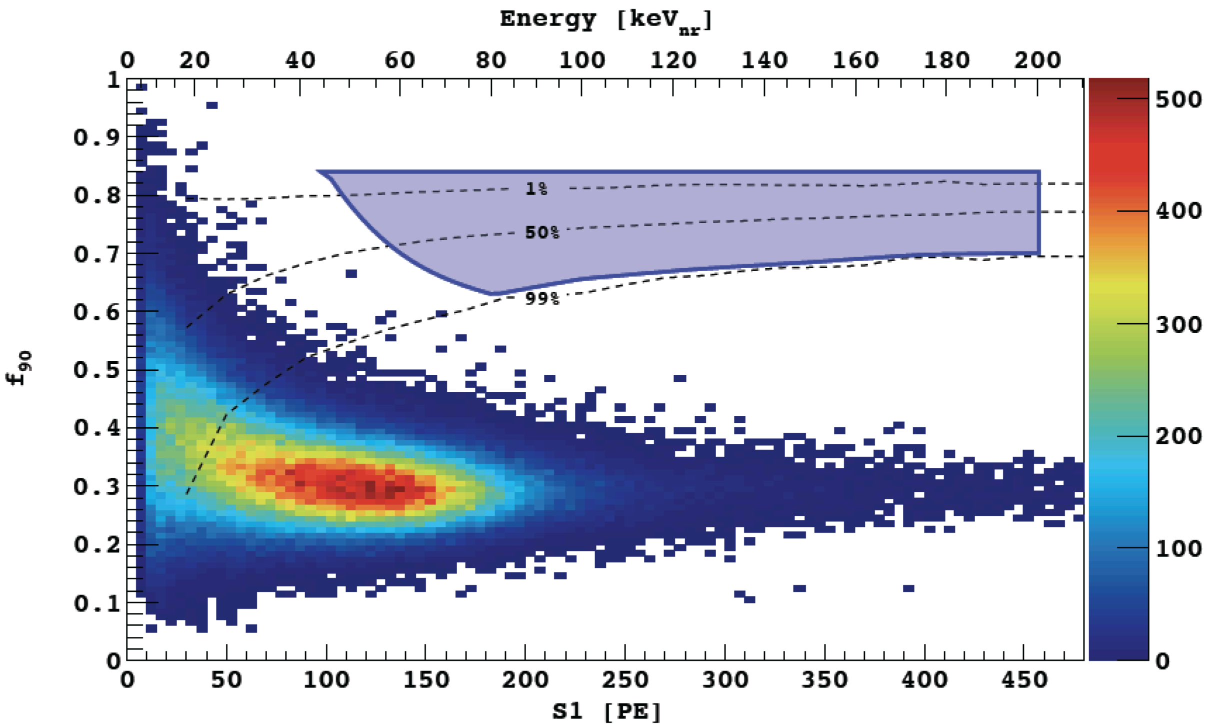
Geant4 based simulation in order to model these events



Use of a dedicated ^{22}Na calibration source

Final check and normalization using the "Veto Prompt Tag" sample

Blind analysis: unblind data

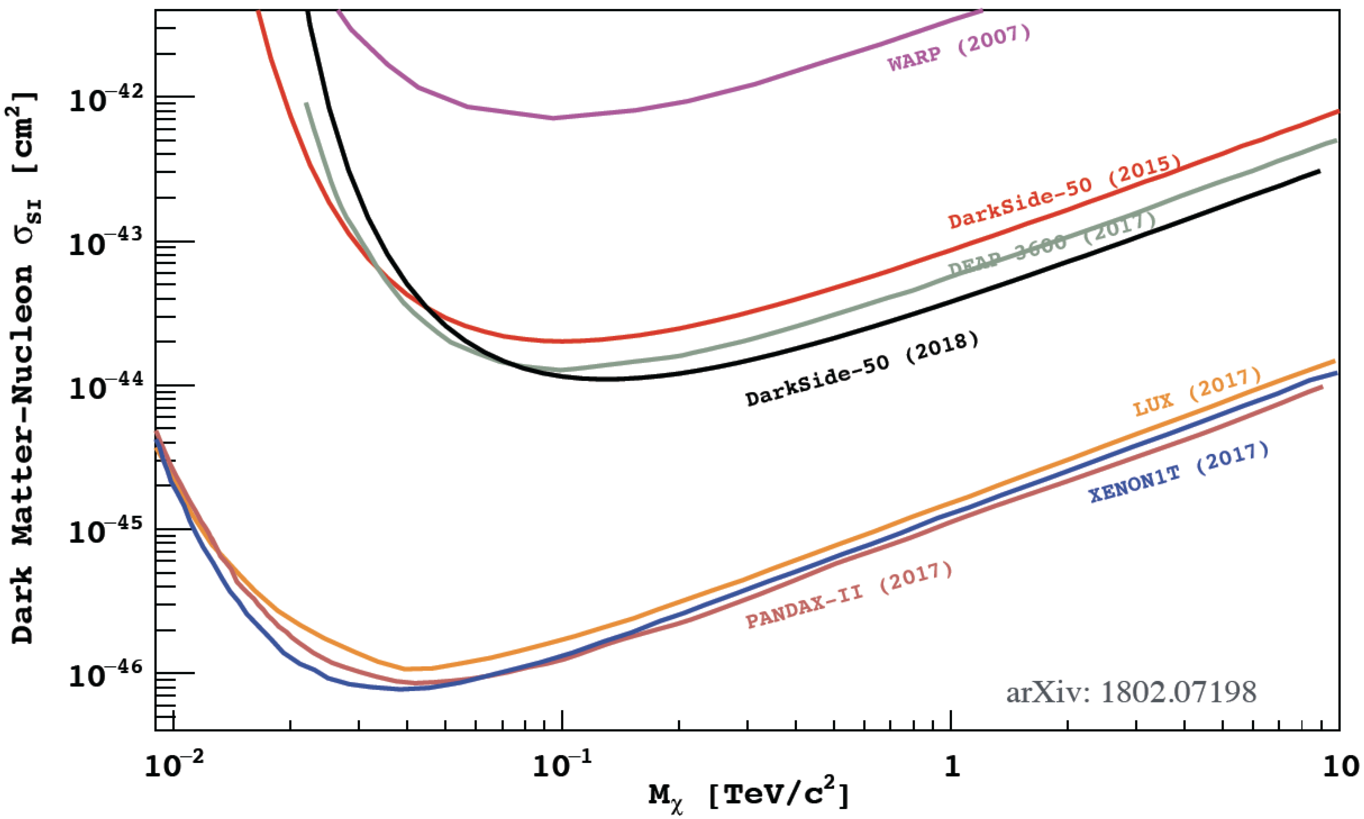


No events are found in the signal region

Also shown are the 1% 50% and 99% f90 acceptance contour for nuclear recoils

Details in arxiv:1802.07198

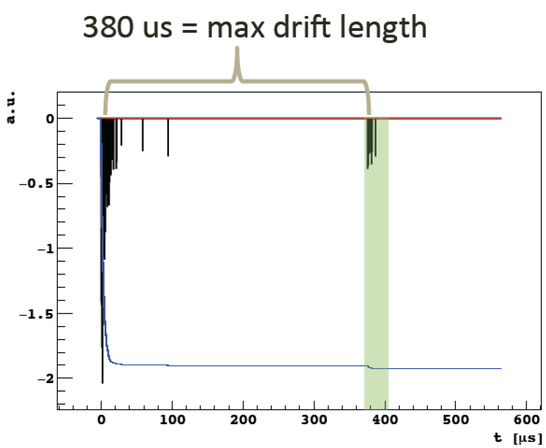
Blind analysis: result



S2-only analysis

DarkSide TPC may be used to investigate very low energy events whose primary scintillation light (S1) is below trigger threshold

Single ionization electrons are studied using a sample of events having an “S2 echo”

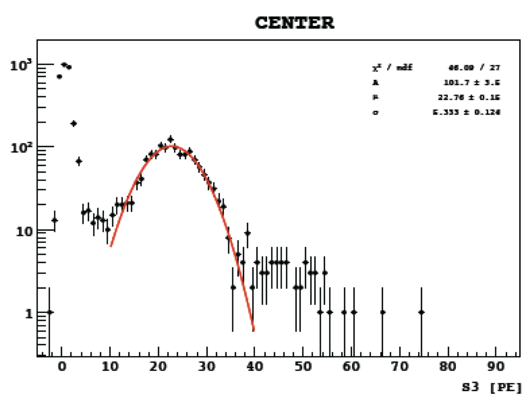


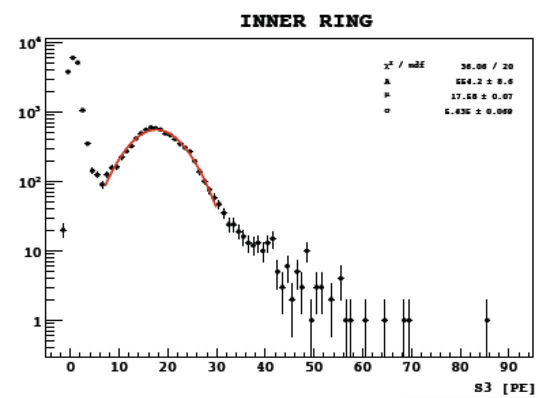
S2 VUV light may extract electrons from the cathode

23 PE per single electron in the central PMT

Det. zone	ε_2^{1e} [PE/e]	$\langle\kappa\rangle$	ε_2^{1e} (corr) [PE/e]
CENTER	22.76 ± 0.15	0.94	24.2 ± 0.2
INNER RING	15.58 ± 0.07	0.70	25.2 ± 0.1

Only the 7 central PMTs are used in the analysis

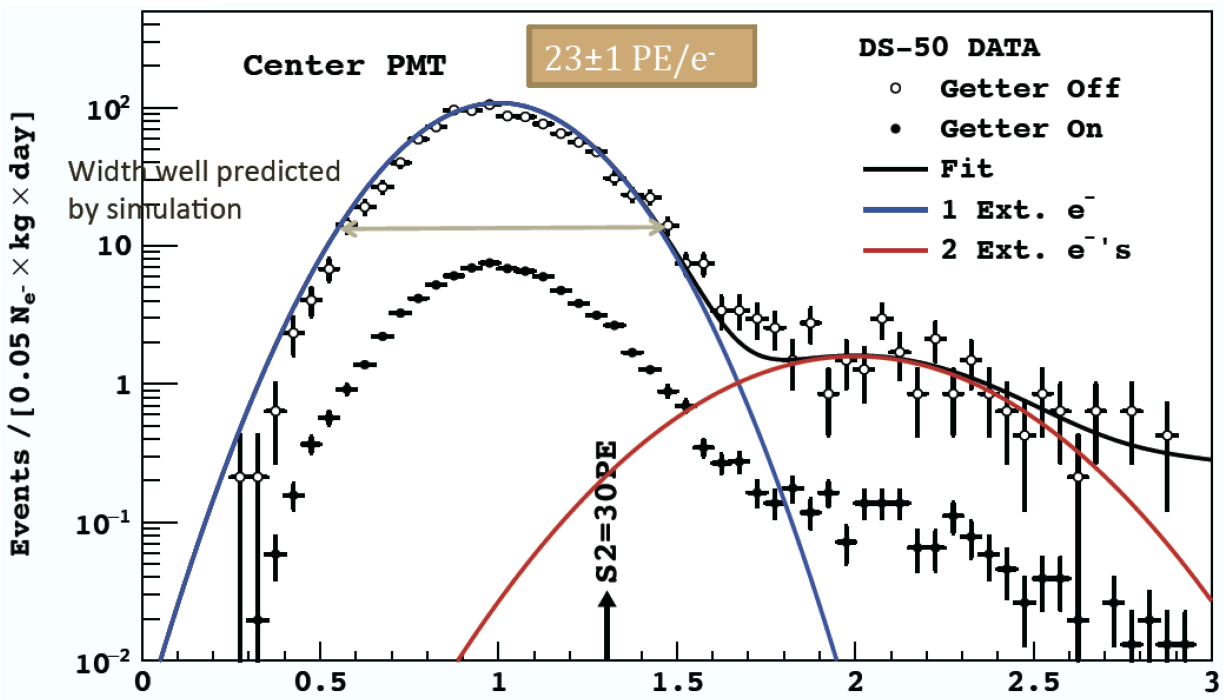




S2-only analysis
single electrons form impurities

Drifting electrons may be trapped by impurities (O_2, H_2O) and released after O(ms)

Rate increase when getters are excluded from the Argon recirculation circuit



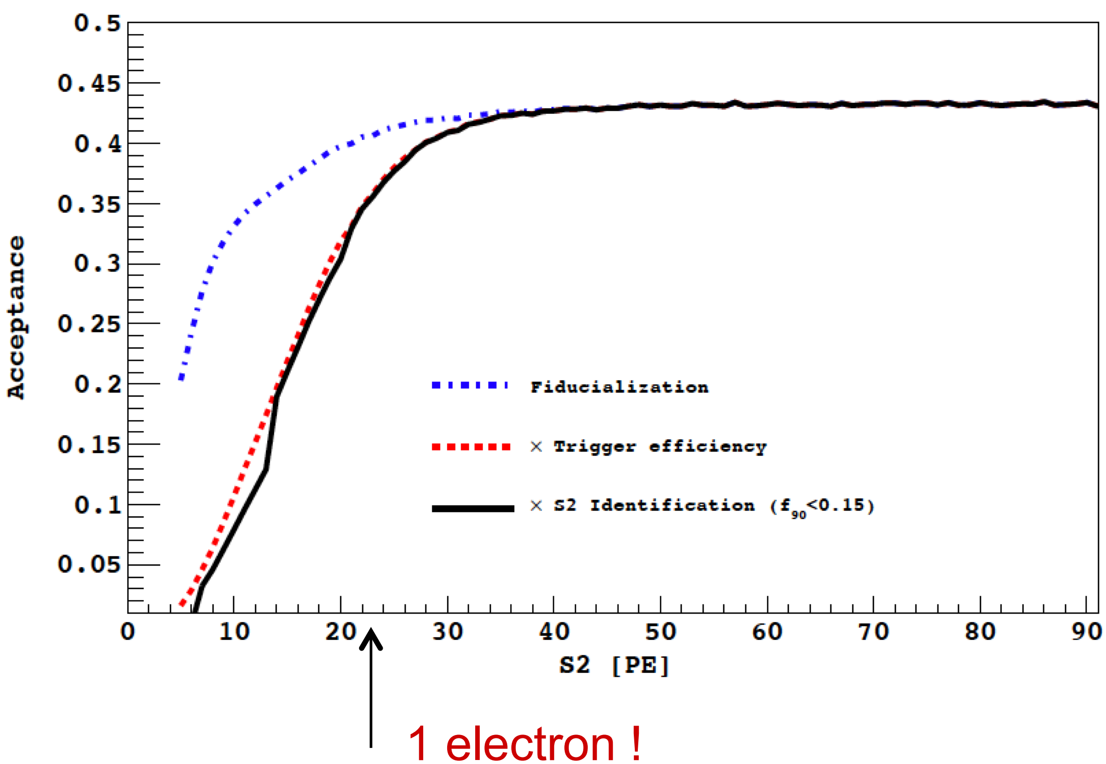
Rate during normal data taking is (0.5 ± 0.1) x 10^{-5} e-/ionization e-

S2-only analysis
detection efficiency

Only 7 PMTs out of 19 are taken to avoid events near the edge (about 20 Kg fiducial)

Trigger (2 hits in 100 ns) reach 100% efficiency for 30 PE (50% @ 15 PE)

Offline pulse finding algorithm fully efficient above 30 PE



S2-only analysis
ER energy scale

Analysis of ^{37}Ar decay events in the first period of UAr data taking

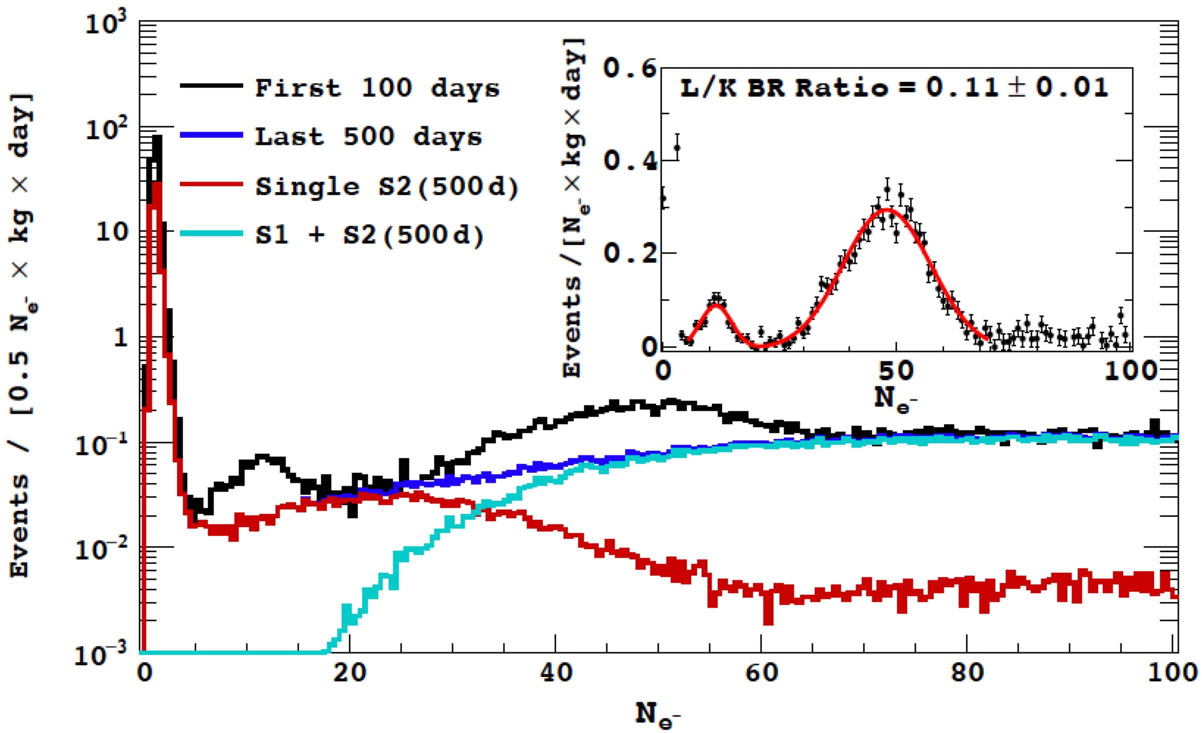
^{37}Ar produced by cosmic ray activation during transport of UAr from US to Italy

$^{37}Ar \longrightarrow {}^{37}Cl + \nu_e$ + auger

2.82 keV (K capture)

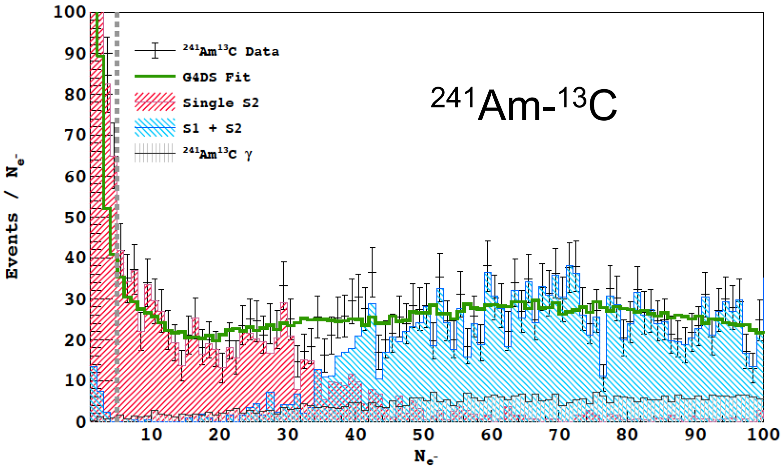
0.27 keV (L capture)

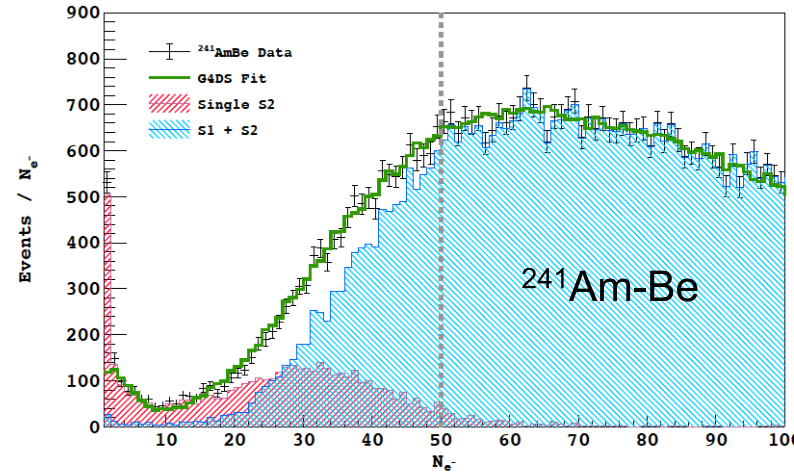
$\tau_{1/2}$ = 35 days



S2-only analysis
NR energy scale

Calibration with neutron sources deployed in liquid scintillator VETO:





Low rate (a few n/s)

Little gamma ray activity

Allow measurement down to 4 Ne

High rate (160 n/s)

4.4 MeV gamma tag

Low LSV efficiency for S2-only

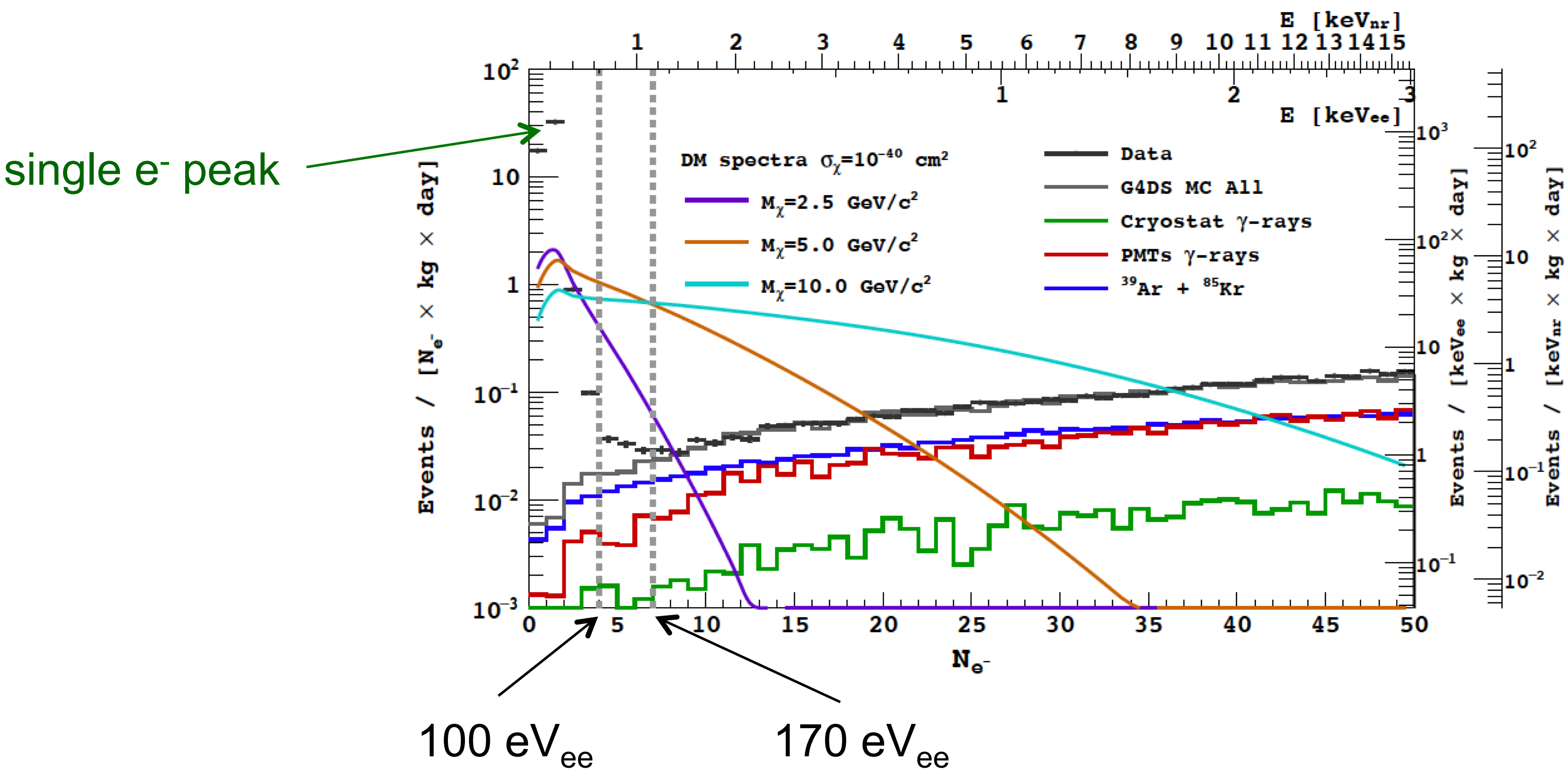
Common fit performed above 50 N_e

S2-only analysis
data – MC comparison

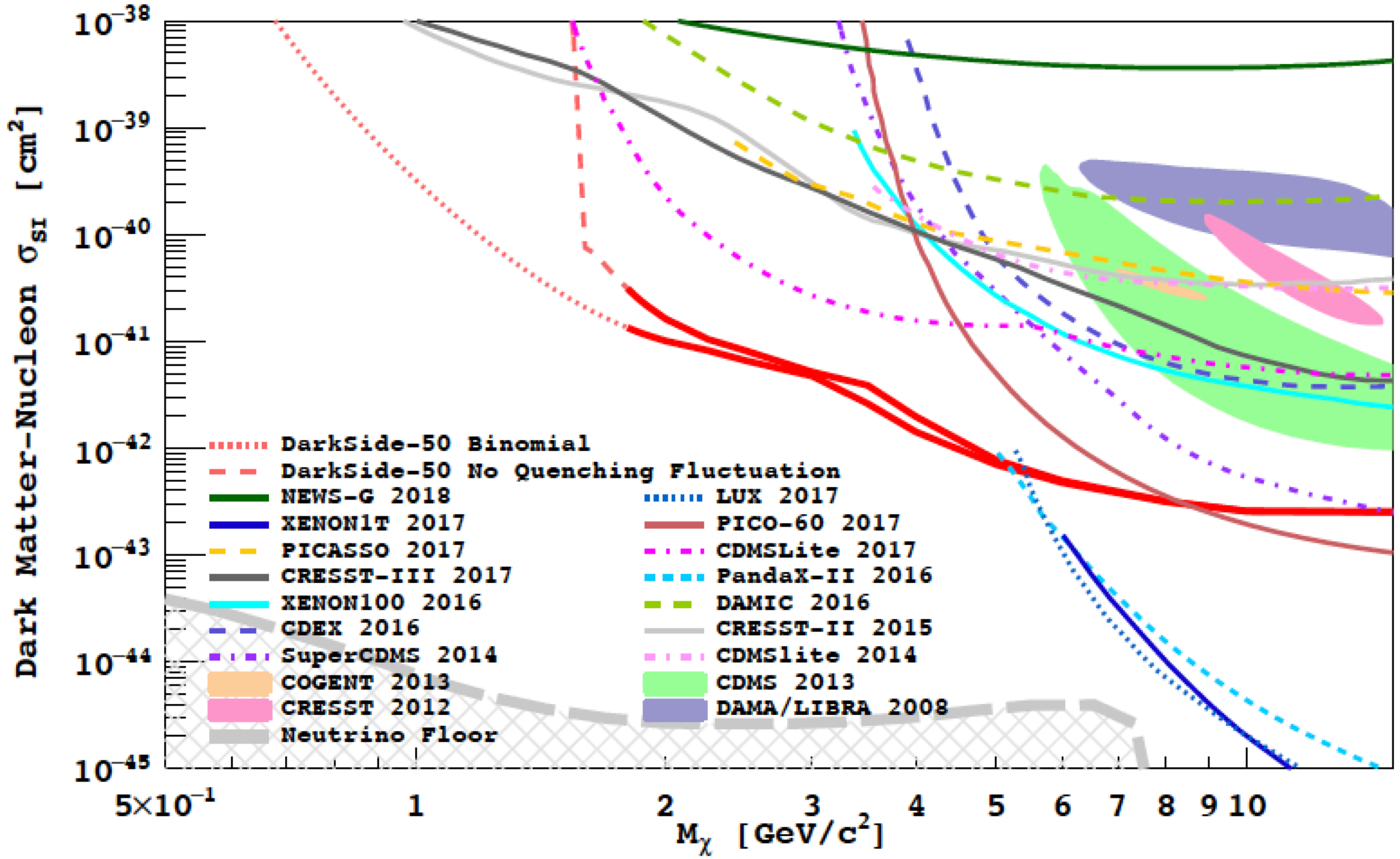
500 days exposure

No excess found above N_e=7 (conservative analysis threshold)

Unknown component in the region N_e=[4; 7]



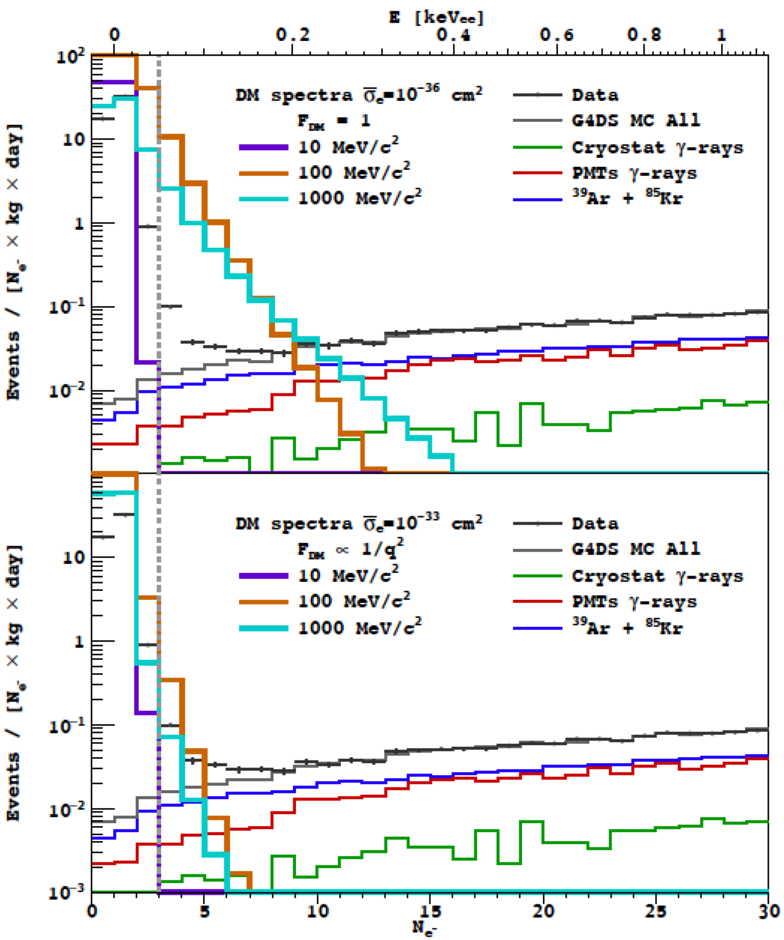
S2-only analysis
WIMP search results

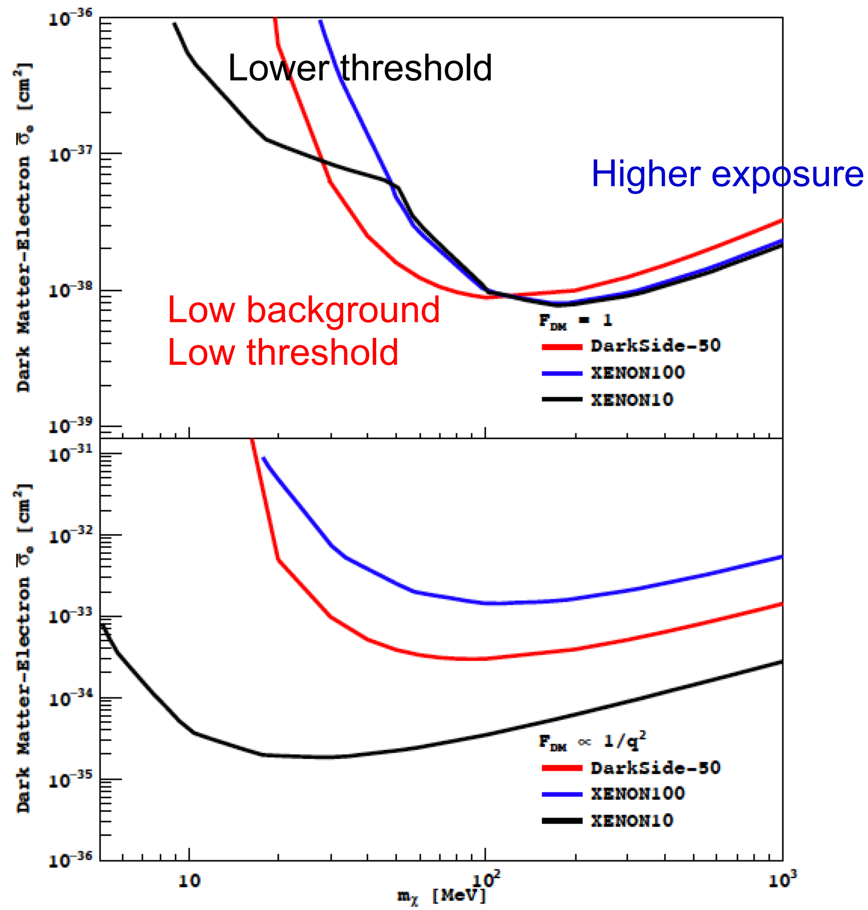


More details in arxiv:1802.06994

S2-only analysis

WIMP interaction with e^-





More details in arxiv:1802.06998

Conclusions

DS 50kg detector is still taking good data

DS 50kg S2-only analysis: a new opportunity

almost 3 annual cycles available to analyze

combined analysis + annual modulation

Manpower needed to continue to take and analyze data

(however, joint effort on Liquid Argon is ongoing)

Next generation of Liquid Argon experiments will approach neutrino floor for both high and low mass WIMP search

Thank you