The 50th Rencontres de Moriond:

ELECTROWEAK INTERACTIONS AND UNIFIED THEORIES

La Thuile 15/03/2015

First Results from DarkSide-50

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on behalf of the DarkSide Collaboration

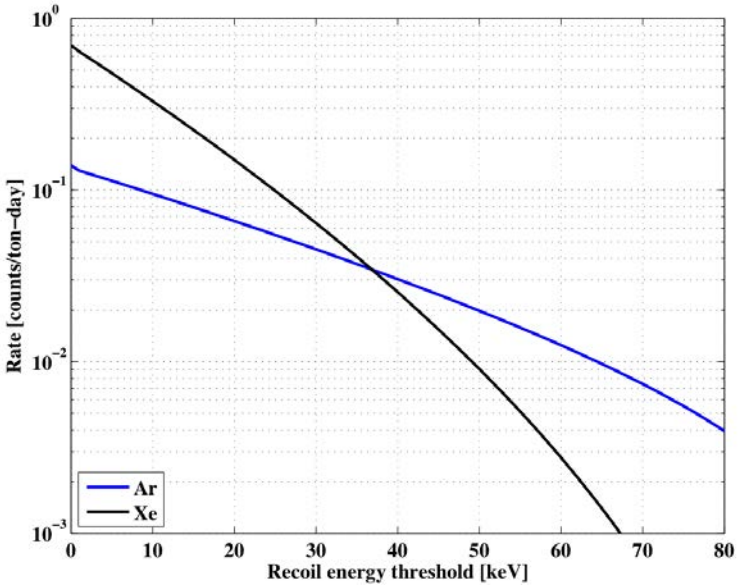
The DarkSide Project

- 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 vetoes
  - in situ background measurement
- Powerful background rejection
  - Pulse shape discrimination (PSD)
  - Ionization to scintillation ratio (S2/S1)
  - Surface rejection using 3D position reconstruction

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 (WLAr = 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:
^{39}Ar contamination

^{39}Ar Depleted LAr

Atmospheric Ar:

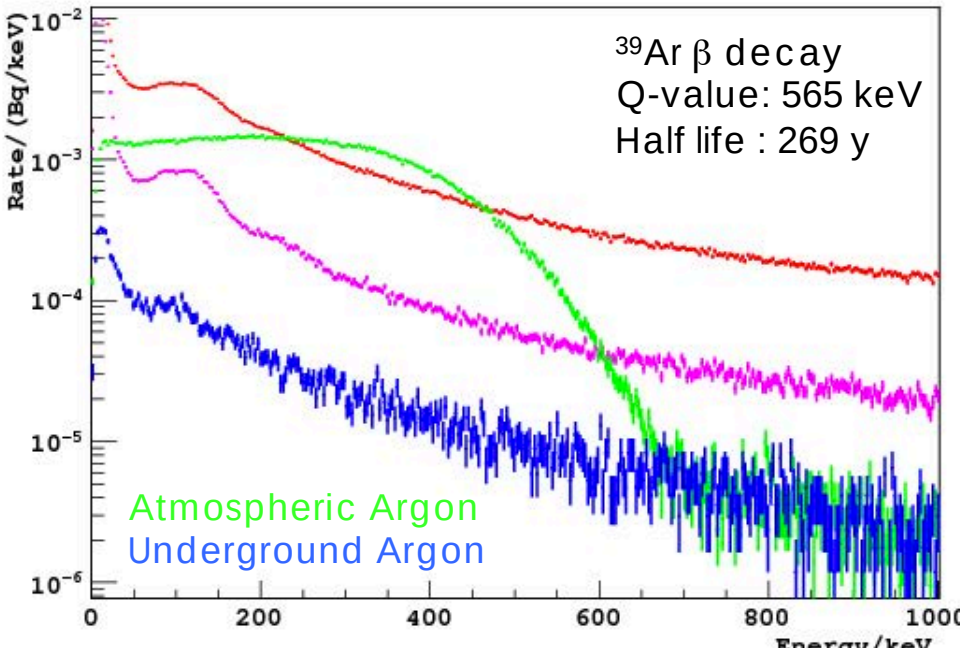
$^{39}Ar/^{40}Ar = 8 \times 10^{-16}$

Rate ~ 1 Bq/kg

Underground Ar:

^{39}Ar < 6.5 mBq/kg

(arXiv:1204.6011)

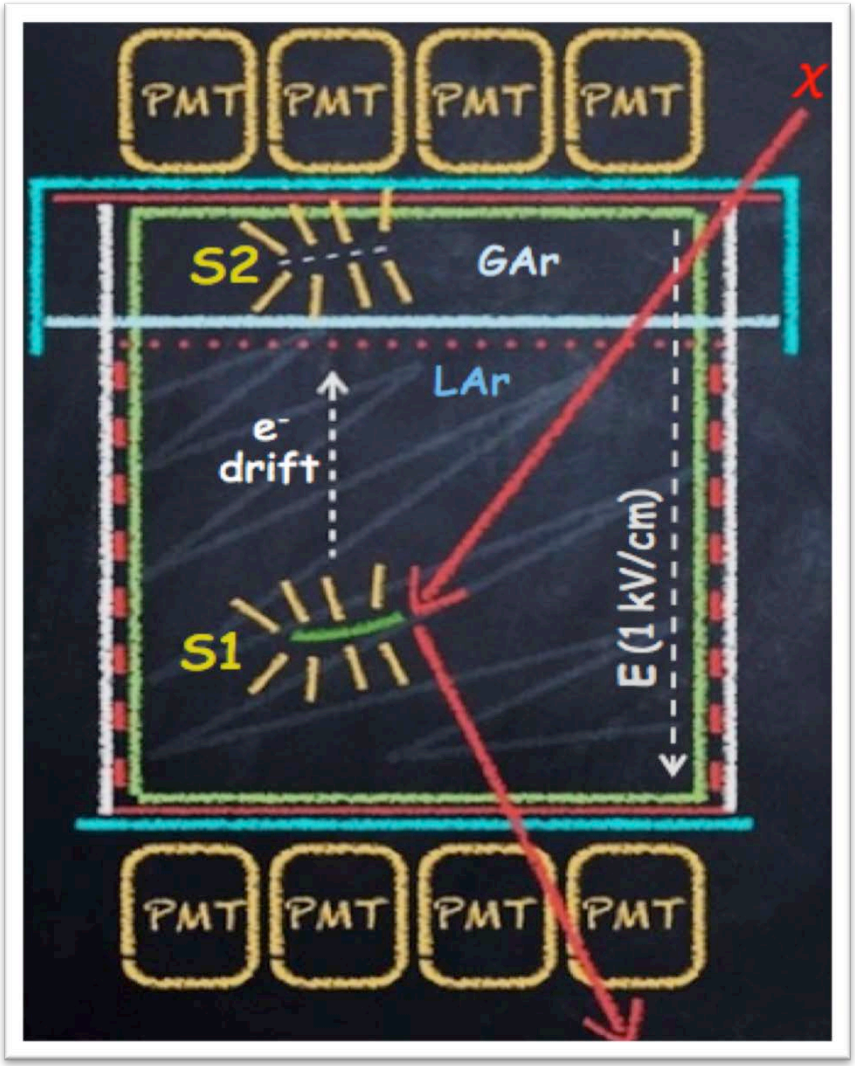


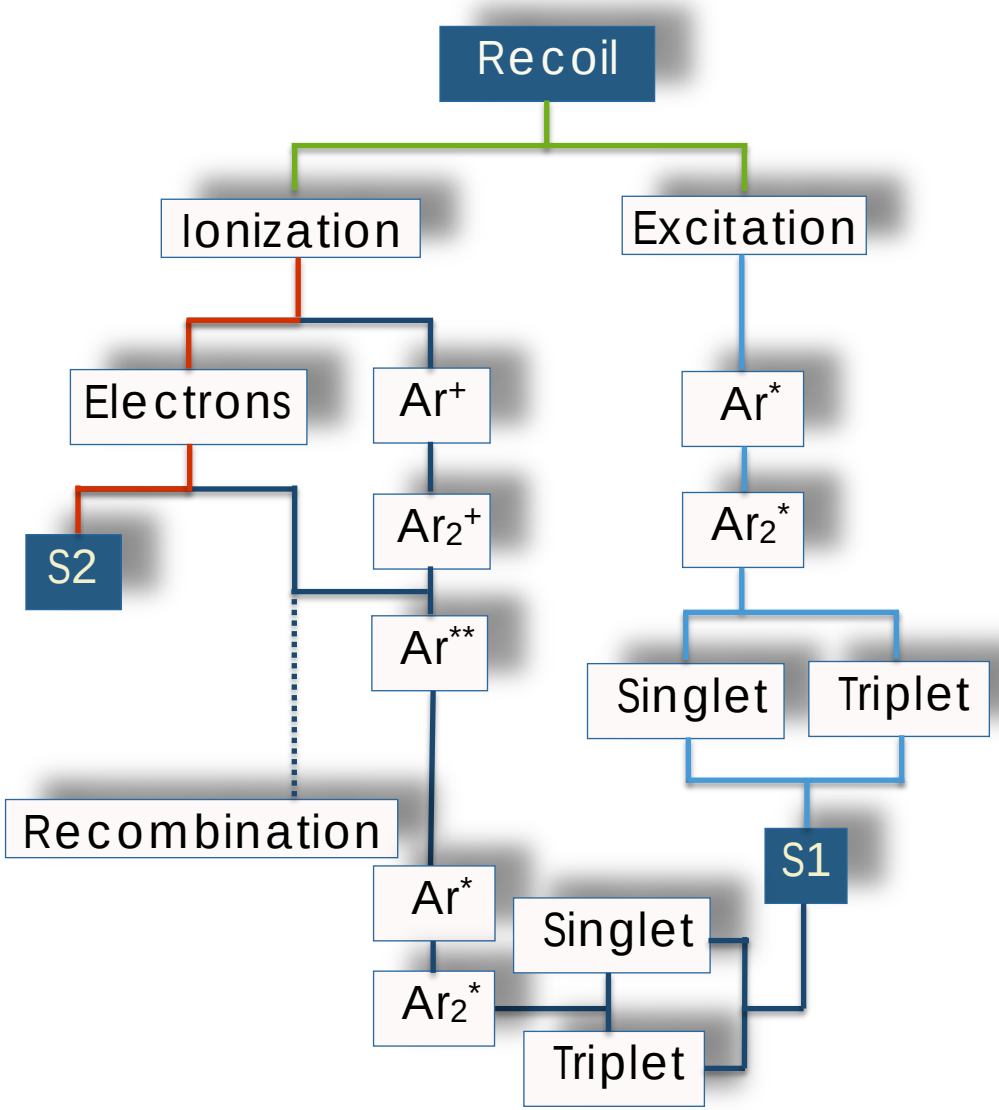
	Total Rate [mBq /100 keV]	Estimated BG Rate [mBq/100keV]	BG Subtracted Rate [mBq/100keV]
Atmospheric Argon	108.8 ± 0.4	1.5 ± 0.2	107.2 ± 1.9
Underground Argon	1.87 ± 0.06	1.5 ± 0.2	0.32 ± 0.23
^{39}Ar Suppression Factor	58.2 ± 1.9		> 153 (95%)

arXiv:1204.60111

Depletion Factor > 150

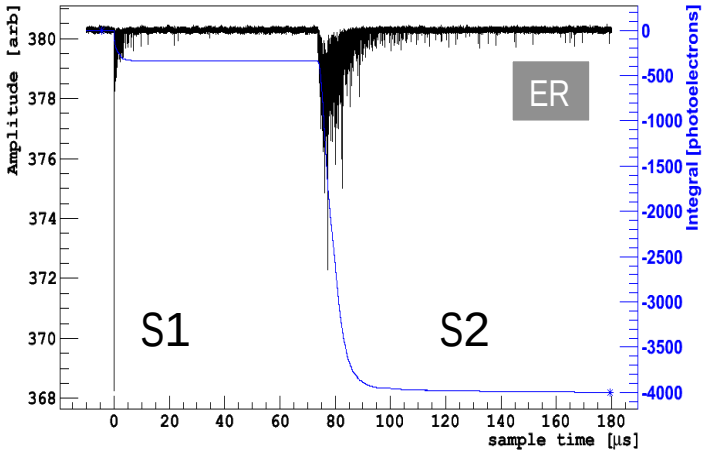
Dual Phase Liquid Argon TPC



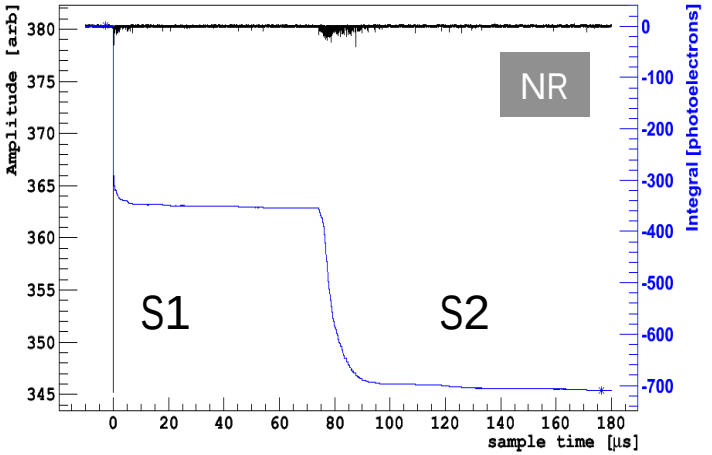


Discrimination Power

S1/S2



µs



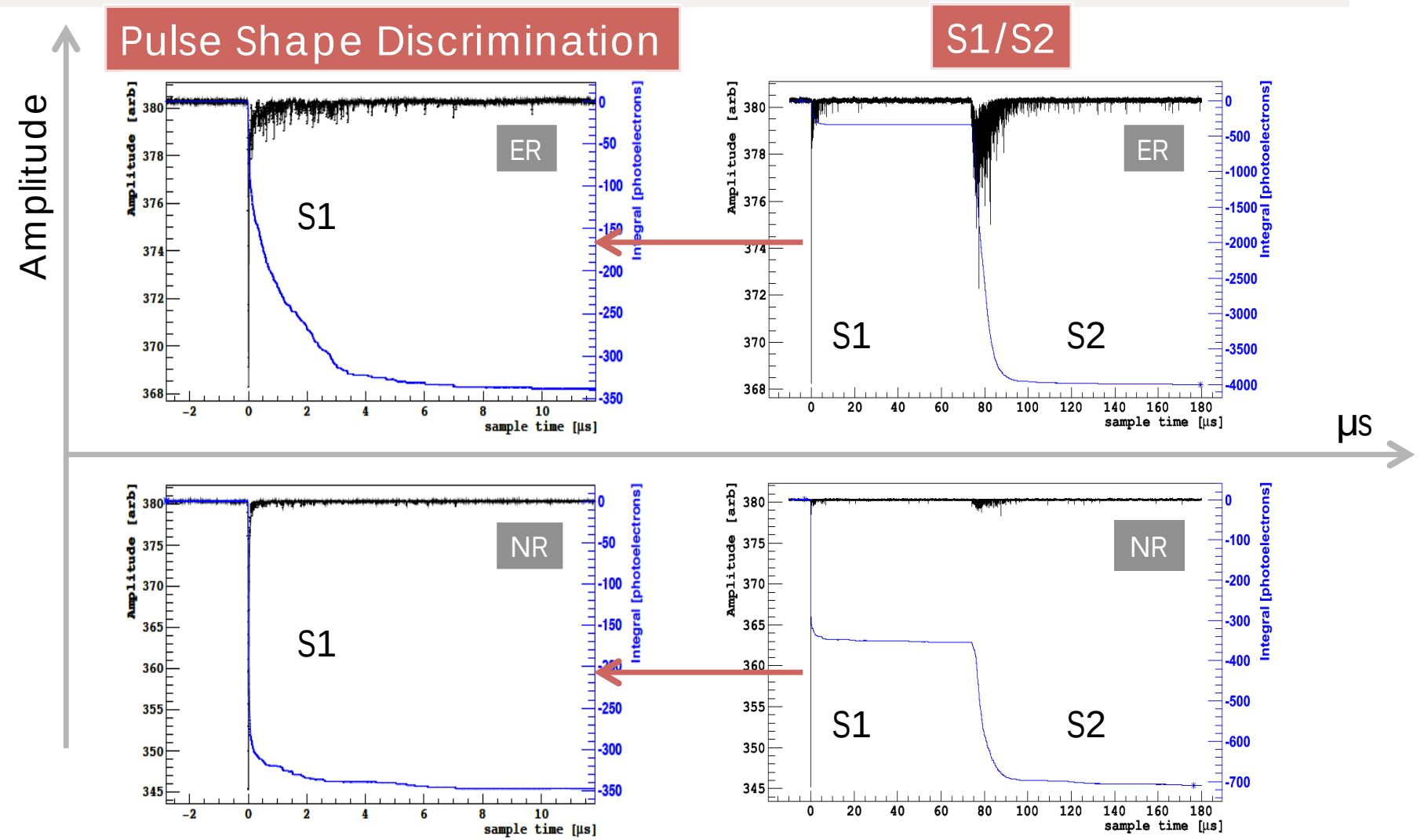
Amplitude

Rejection Factors

10^2-10^3

Benetti et al. (WARP) 2006

Discrimination Power



WARP Astr. Phys 28, 495 (2008)

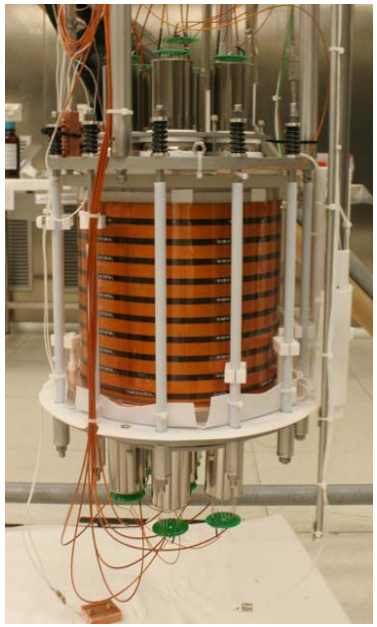
Benetti et al. (WARP) 2006

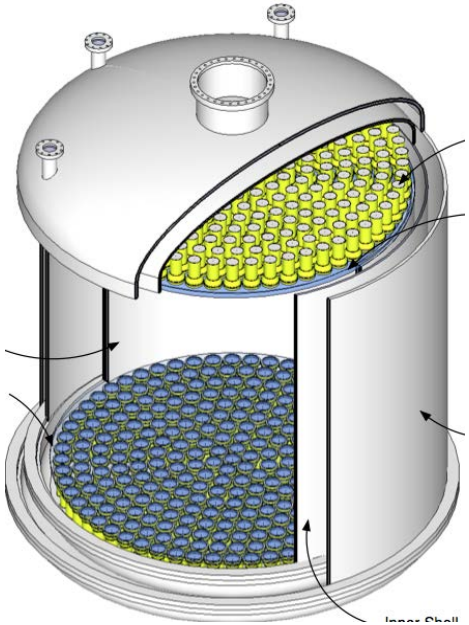
The DarkSide Program

DarkSide-10
2011-2013

DarkSide-50
2013-2016

10 kg → 50 kg → 5 ton → 100 ton





~10^{-45} cm^2

~10^{-47} cm^2

"neutrino floor"
~10^{-48} cm^2

The DarkSide Collaboration

ITALY

INFN Laboratori Nazionali del Gran Sasso – Assergi
Università degli Studi and INFN – Cagliari
Università degli Studi and INFN – Genova
Università degli Studi and INFN – Milano
Università degli Studi Federico II and INFN – Napoli
Università degli Studi and INFN – Perugia
Università degli Studi Roma Tre and INFN – Roma

USA

Augustana College – SD
Black Hills State University – SD
Fermilab – IL
Princeton University – NJ
SLAC National Accelerator Center – CA
Temple University – PA
University of Arkansas – AR
University of California – Los Angeles, CA
University of California – Davis, CA
University of Chicago – IL
University of Hawaii – HI
University of Houston – TX
University of Massachusetts – MA
Virginia Tech – VA

FRANCE

APC – Paris
LPNHE – Paris
IPHC - Strasbourg

CHINA

IHEP – Beijing

POLAND

Jagiellonian University – Krakow

Ukraine

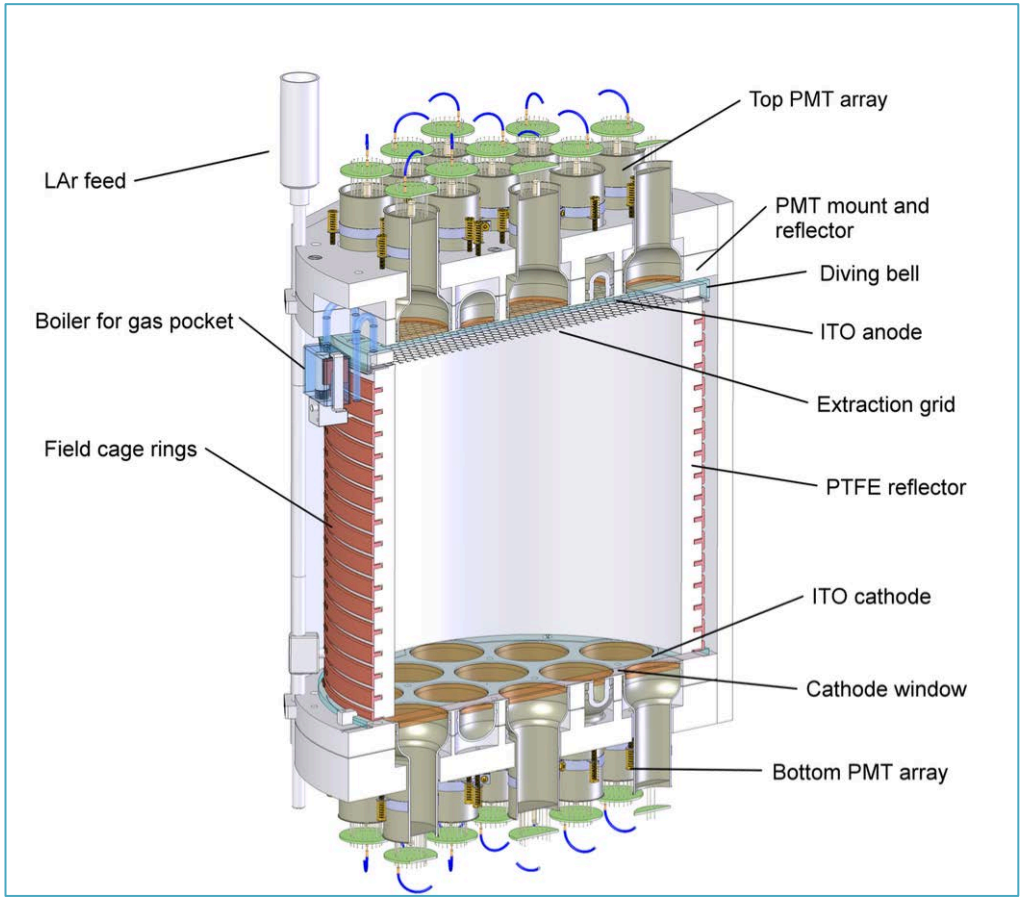
KINR, NAS Ukraine – Kiev

RUSSIA

Joint Institute for Nuclear Research – Dubna
Lomonosov Moscow State University – Moscow
National Research Centre Kurchatov Institute – Moscow
Saint Petersburg Nuclear Physics Institute – Gatchina

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
- Cold pre-amps
- Low field of 0.2 kV/cm drift
- 2.8 kV extraction field



Low field to maximize the S1 light yield

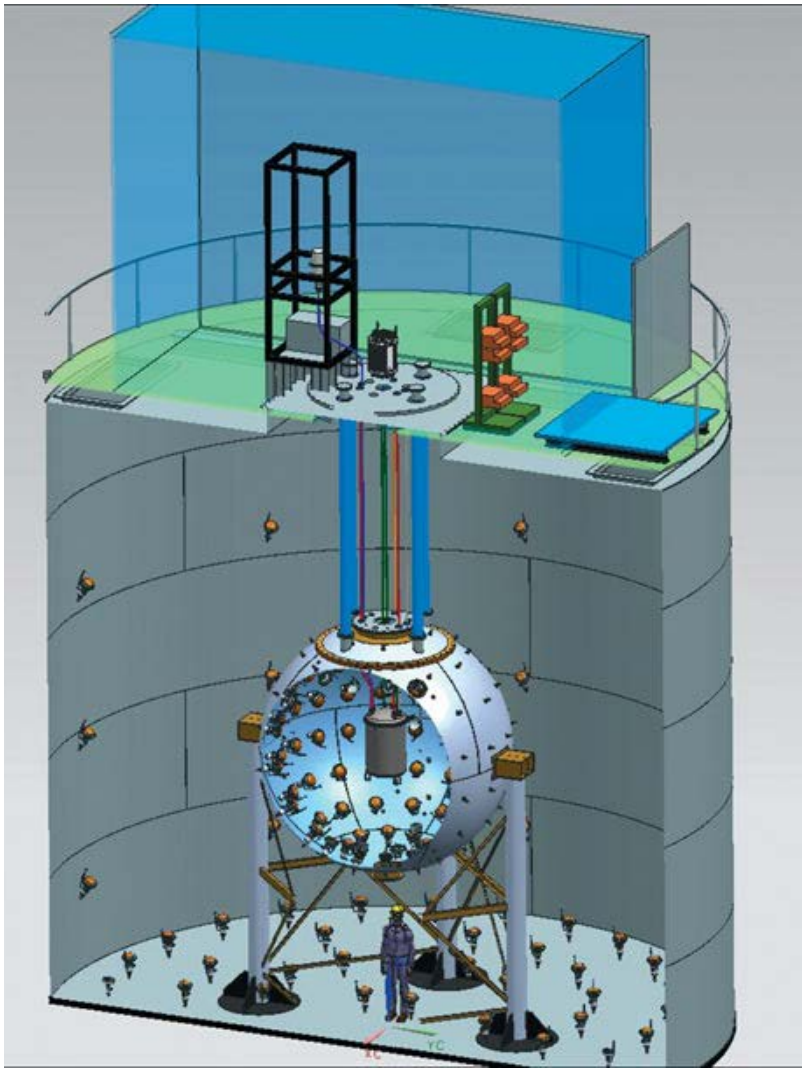
The Vetoes

Neutrons: Liquid Scintillator Veto

- 4 m diameter sphere
- Boron-loaded: 1:1 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 ~ 500 pe/MeV

Muons: Cherenkov Water Detector

- 11 m diam. x 10 m
- 80 PMTs
- Active muon veto
  - tag cosmic muons



Ready for G2!

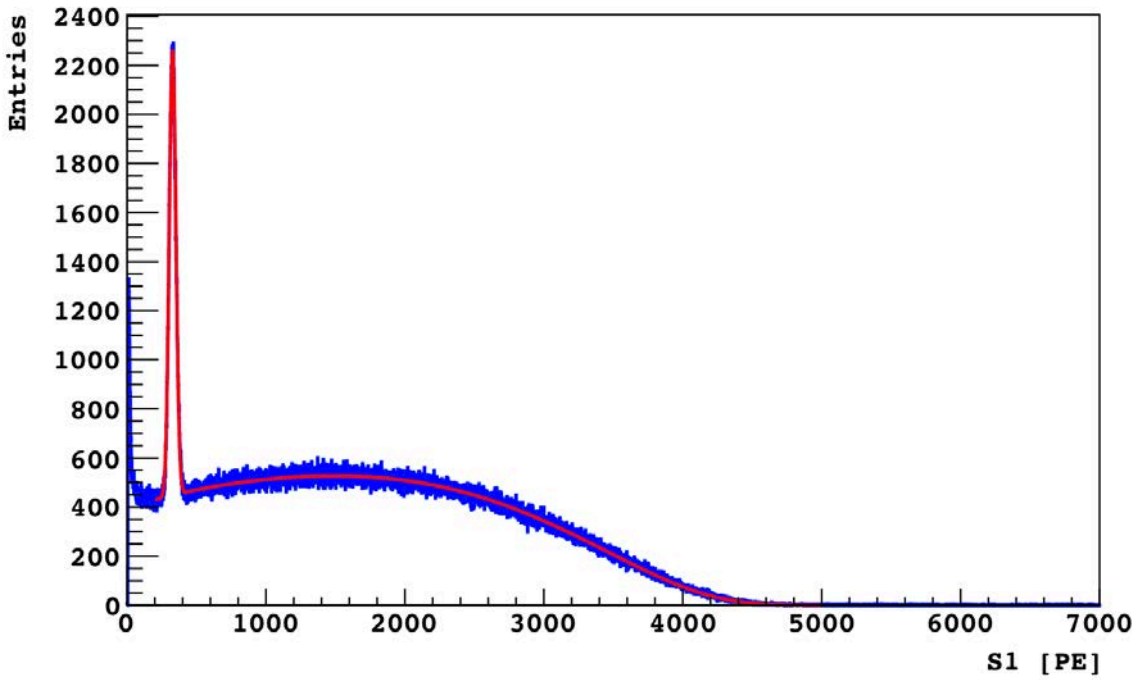
The Detectors

Calibrations

Atmospheric argon:
~1 Bq / kg of ^{39}Ar
1.5 x 10^7 events in 47.1 days
Q-value = 565 keV

Injected gaseous ^{83m}Kr
E = 41.5 keV

Average Light Yield:
~7.9 pe/keV at null field
~7.0 pe/keV at 200 V/cm



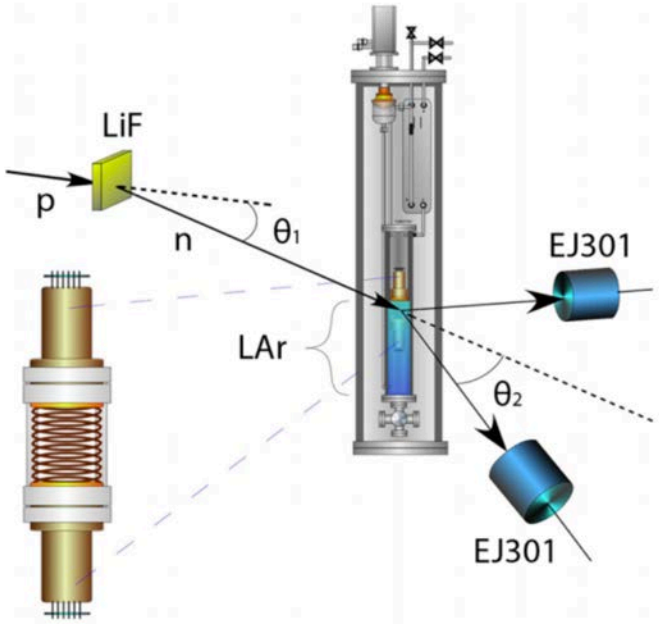
Electron lifetime: ~10 ms
Maximum drift time in the TPC: 375 µs at 200 V/cm
Drift velocity 0.93 mm/µs

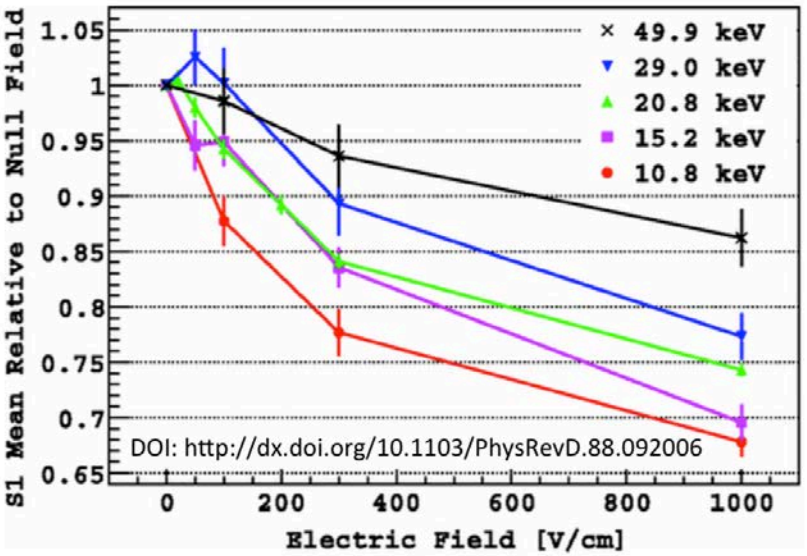
Calibration campaign with neutrons (AmBe) and gammas (^{57}Co and ^{133}Ba) just completed

Nuclear Recoil Energy Scale

SCENE

Scintillation Efficiency of Nuclear Recoils in Noble Elements



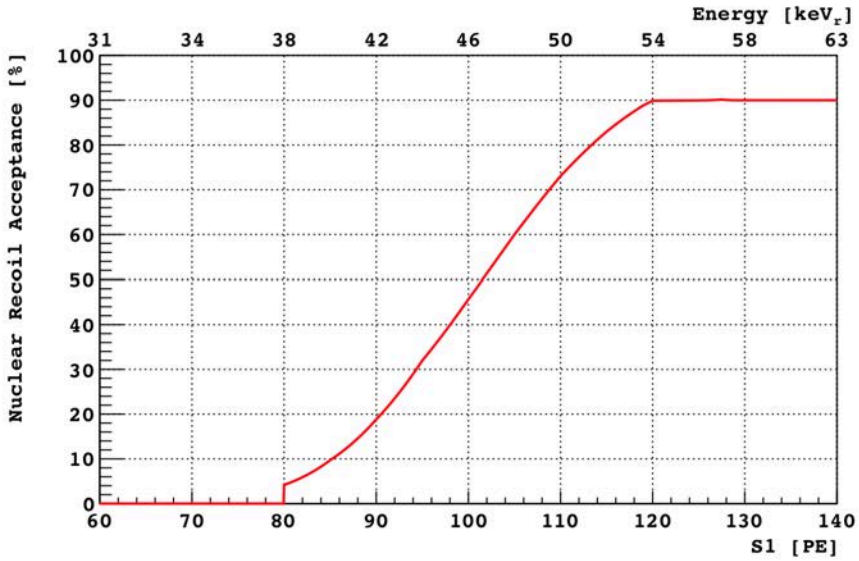


Neutron calibration in large detectors affected by neutron multiple scatterings

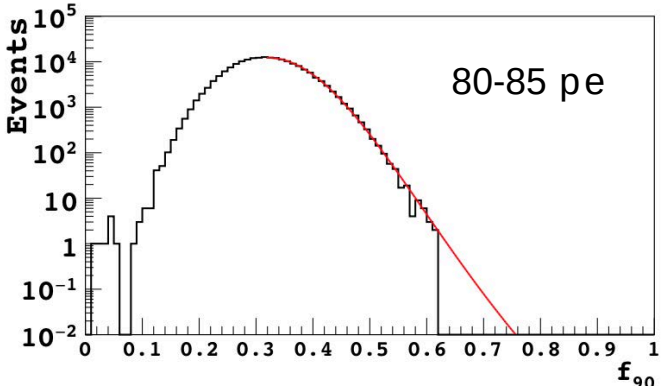
SCENE has collected extremely pure samples of single nuclear recoils in a small scale TPC

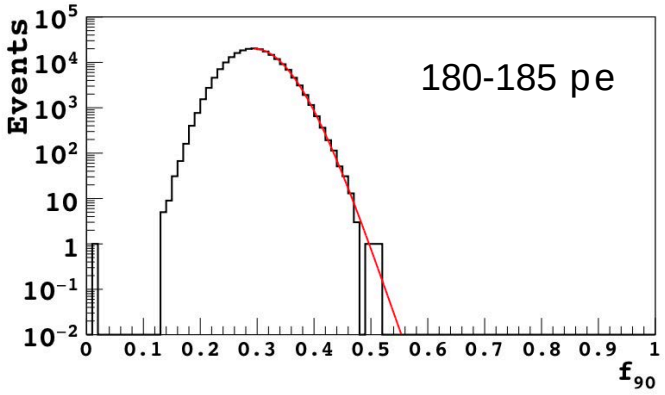
WIMP Acceptance Band

Nuclear recoil acceptance



Electron leakage fitted with the Two Gaussian Ratio Model

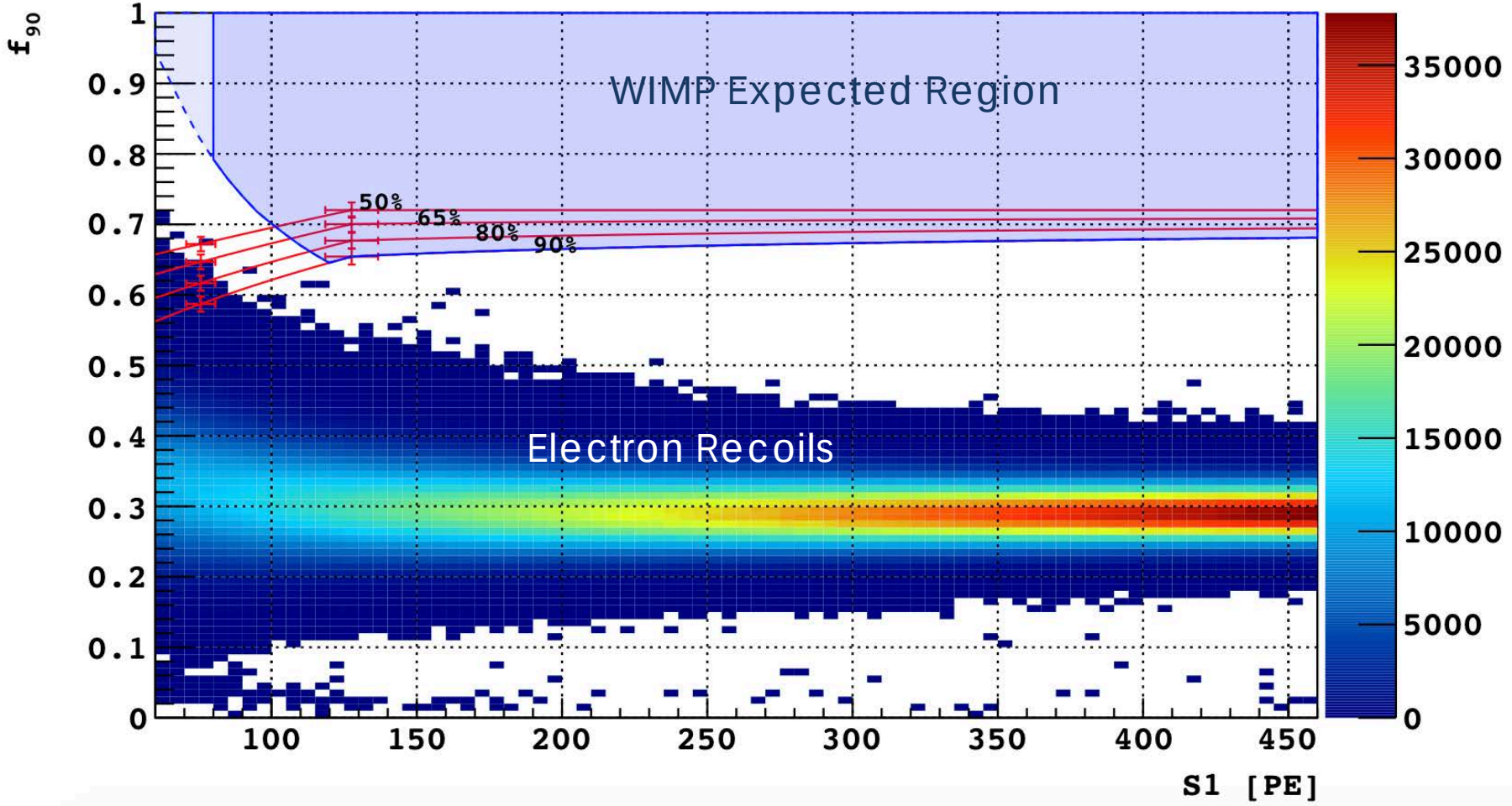




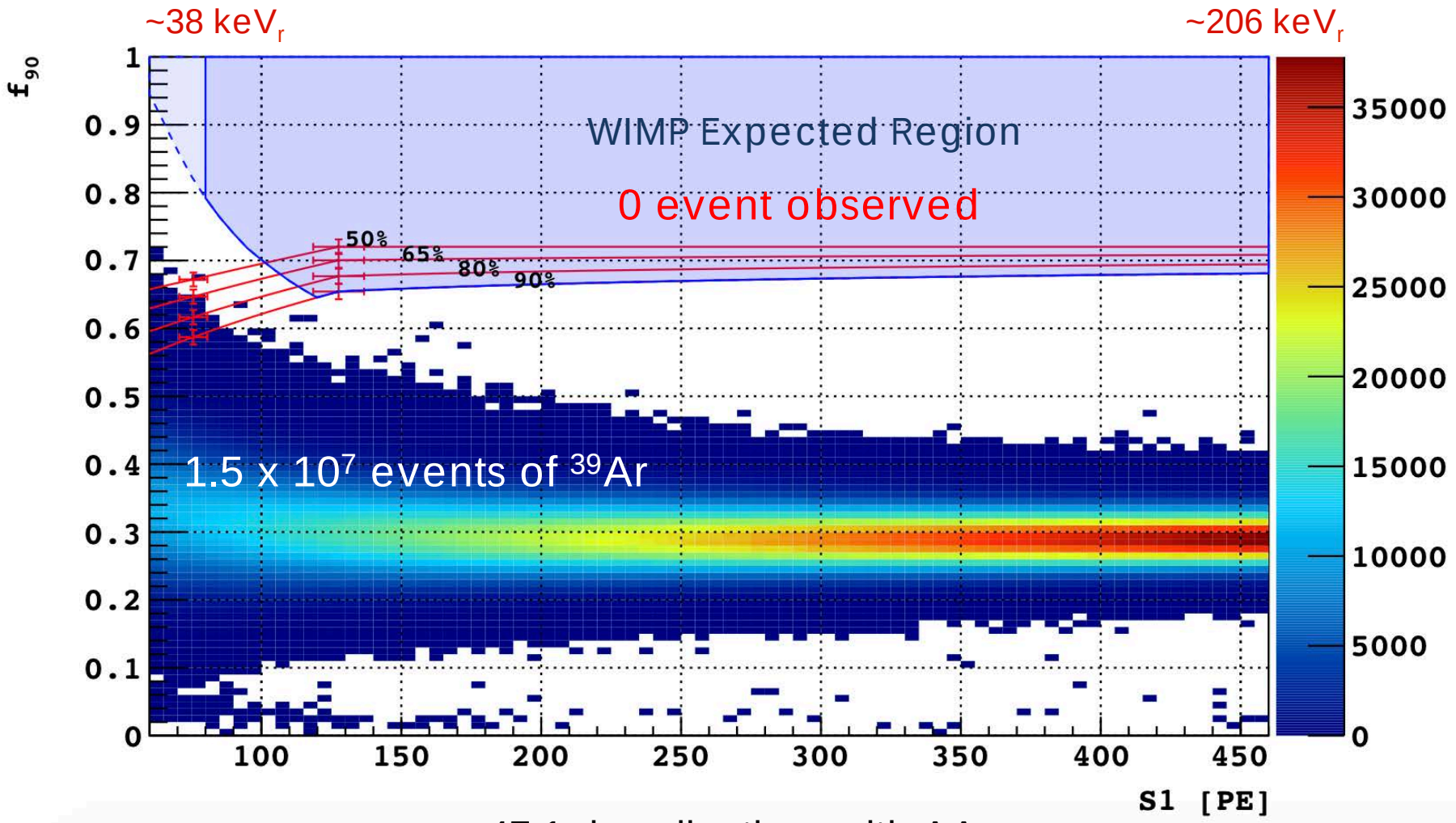
F90: fraction of pe in the first 90 ns of the pulse

The first results (with atmospheric argon)

Exposure: 1422 ± 67 kg x days (47.1 days)



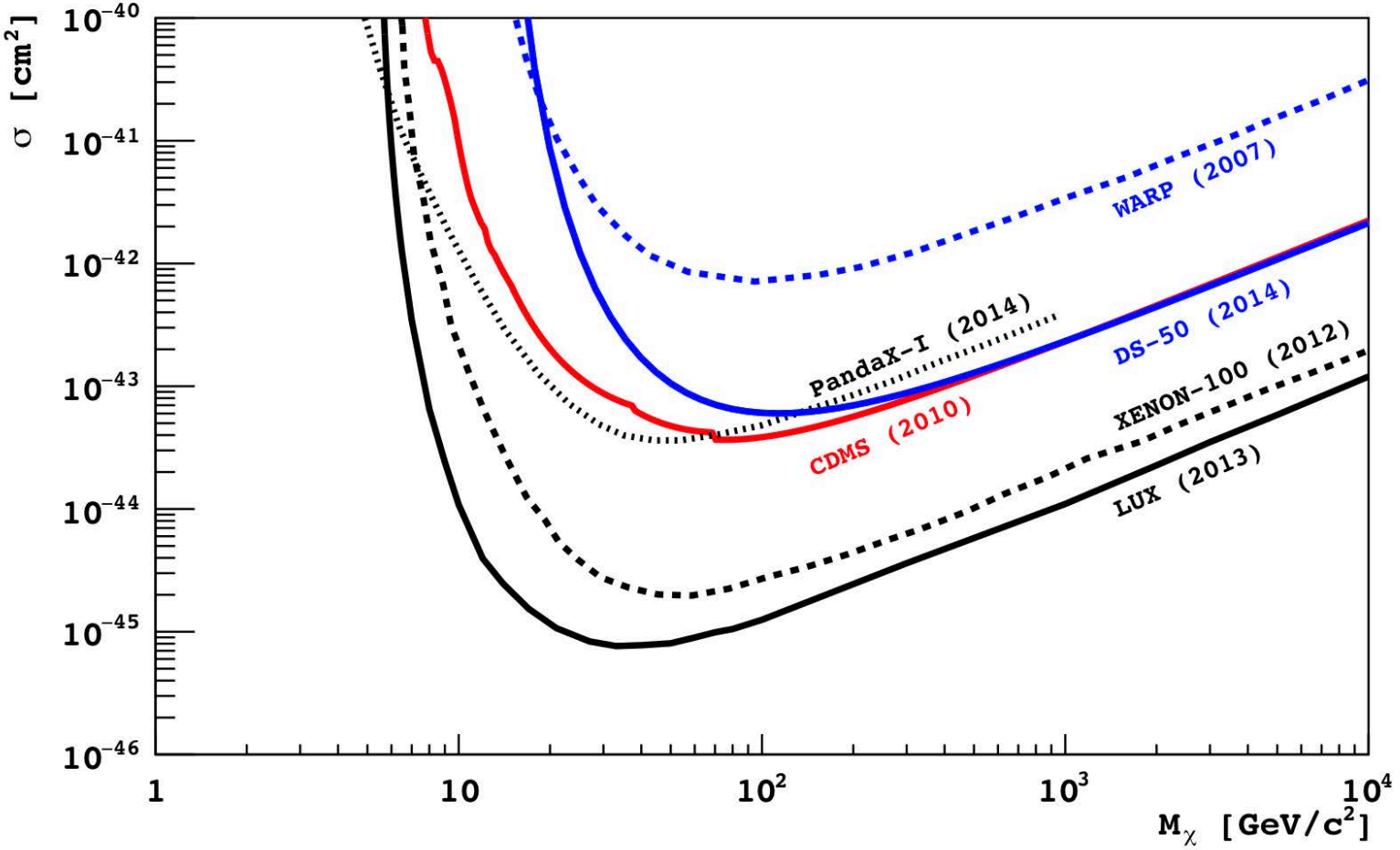
The first results (with atmospheric argon)



47.1 days livetime with AAr

Corresponding to 20 years of DS-50 with Underground Argon

WIMP Limit



$\sigma < 6.1 \times 10^{-44}$ cm^2 for 100 GeV WIMP mass

Conclusions

DS-50 taking data since Oct 2013

First physics results in arXiv:1410.0653 (accepted by PLB)

PSD: excellent background rejection technique

Calibration campaign with gammas and neutrons concluded. Data analysis ongoing

Underground Argon delivered to LNGS: results on ^{39}Ar contamination in underground argon in the next weeks

Design study for the 5 ton detector on going