Latest results from DarkSide experiment

Quentin Riffard on behalf the DarkSide collaboration

2016/11/24

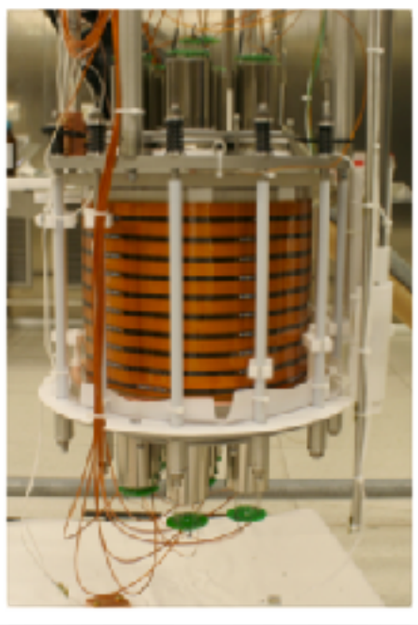
GDR TeraScale 2016

DarkSide program

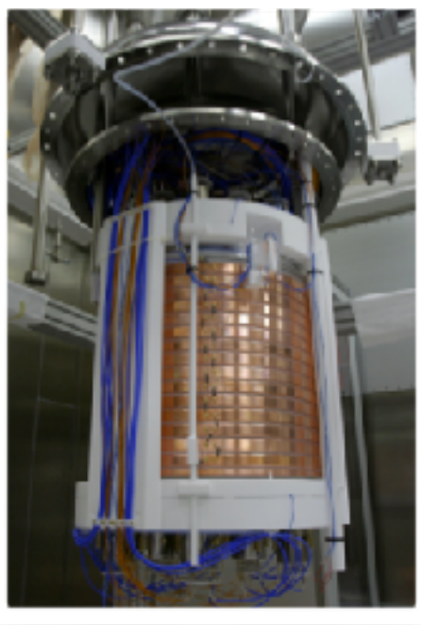
- Direct detection search for **WIMP dark matter**

- **Low background level**:
  - Suppression (ultra-low background materials)
  - Active shield (Vetos)
  - Identification (ER/NR dicrimination, fiducialisation)

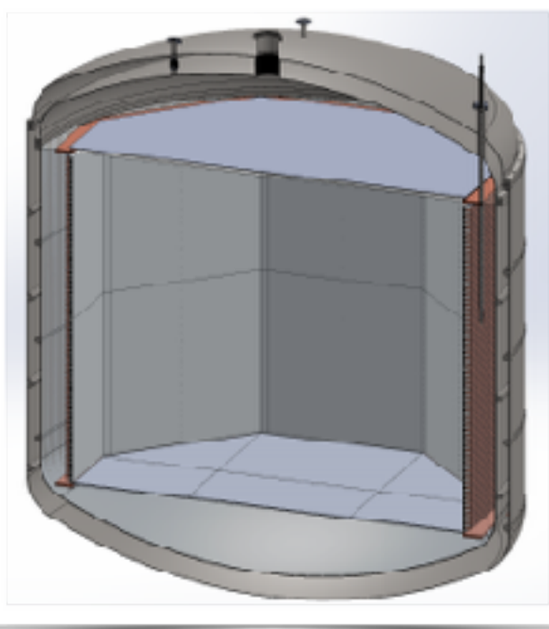
DarkSide-10
2011-2013



DarkSide-50
2013-201x



DarkSide-20k
2017-2020



ARGO

?

300 tonne
(200 tonne fiducial)

Location: Laboratori Nationali del Gran Sasso (LNGS)

DarkSide program

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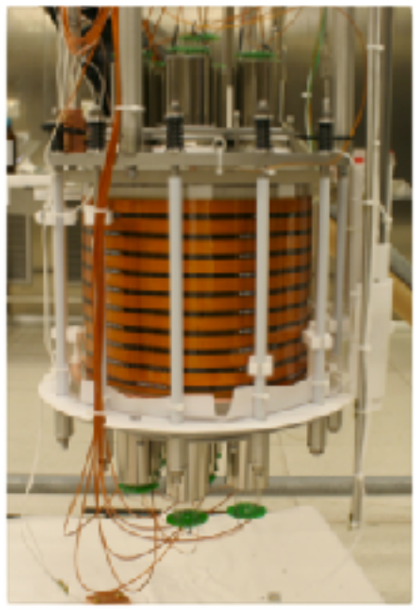

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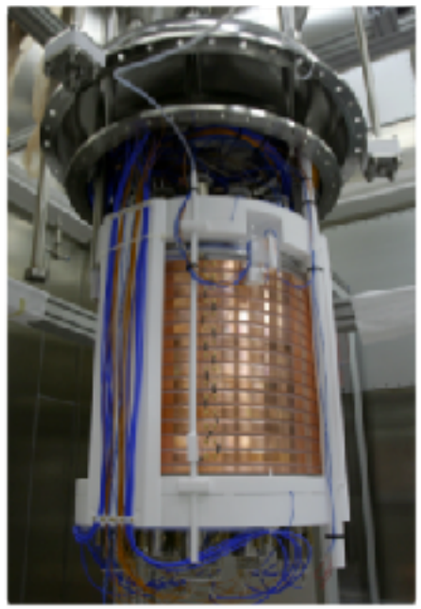

DarkSide-20k
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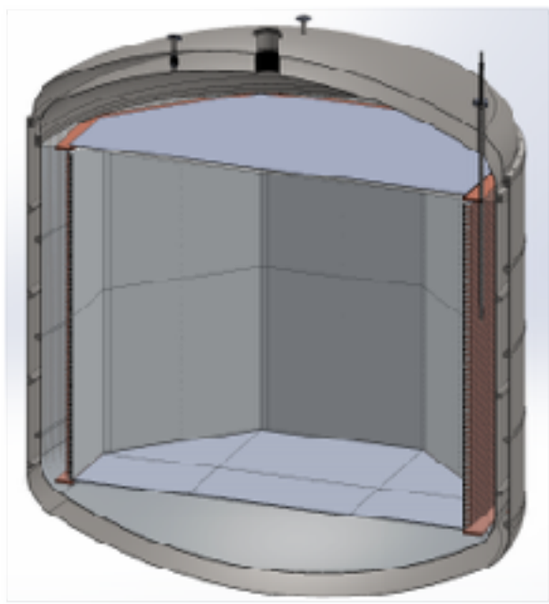

ARGO

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300 tonne
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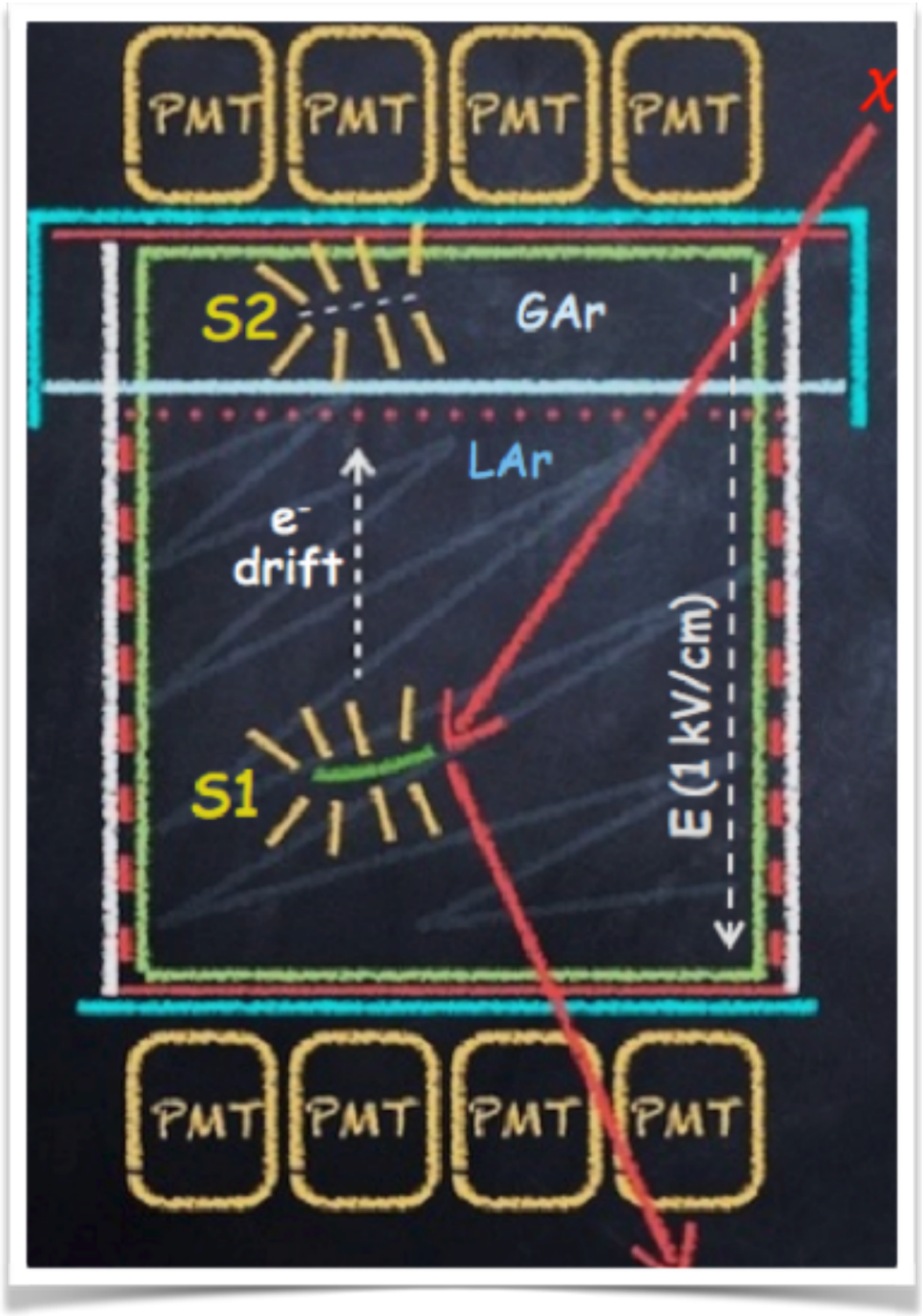
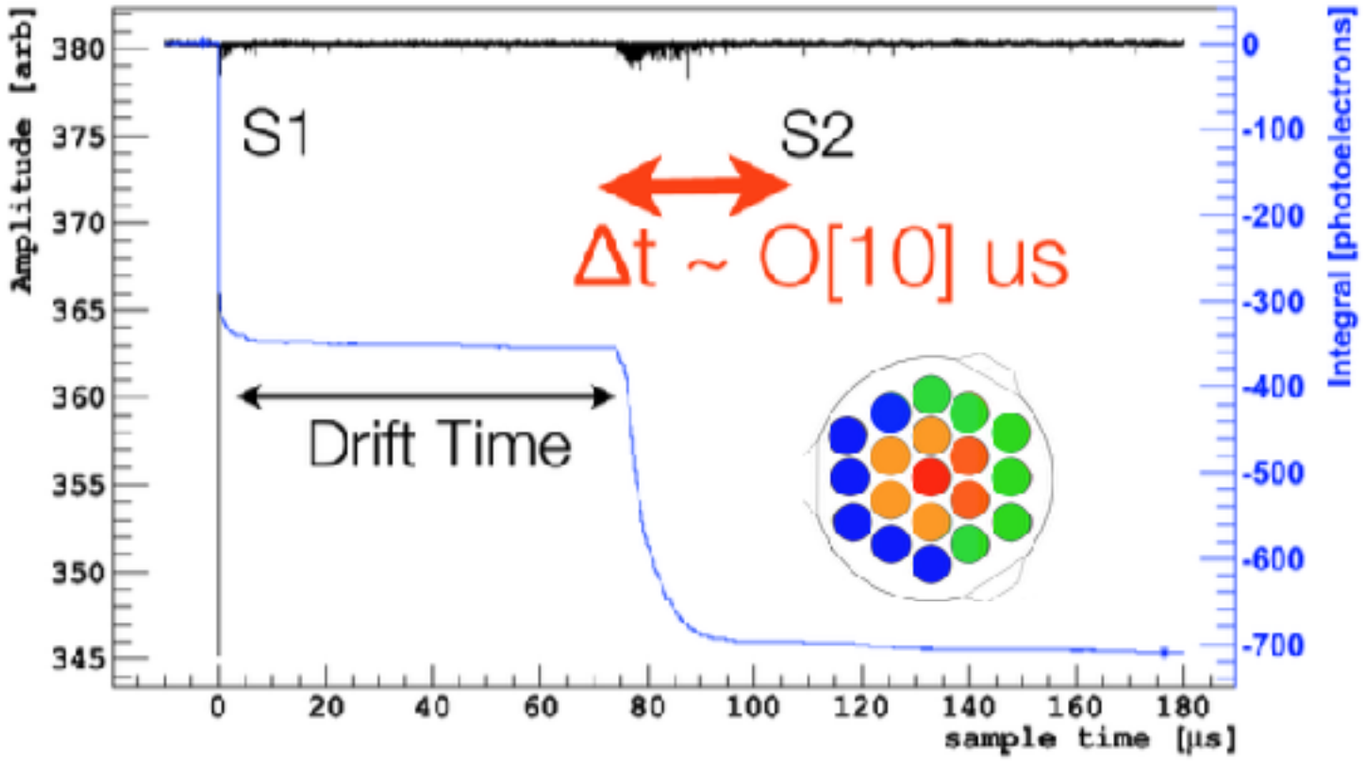
Location: Laboratori Nationali del Gran Sasso (LNGS)

DS50: dual phase liquid argon TPC



Particle discrimination through:

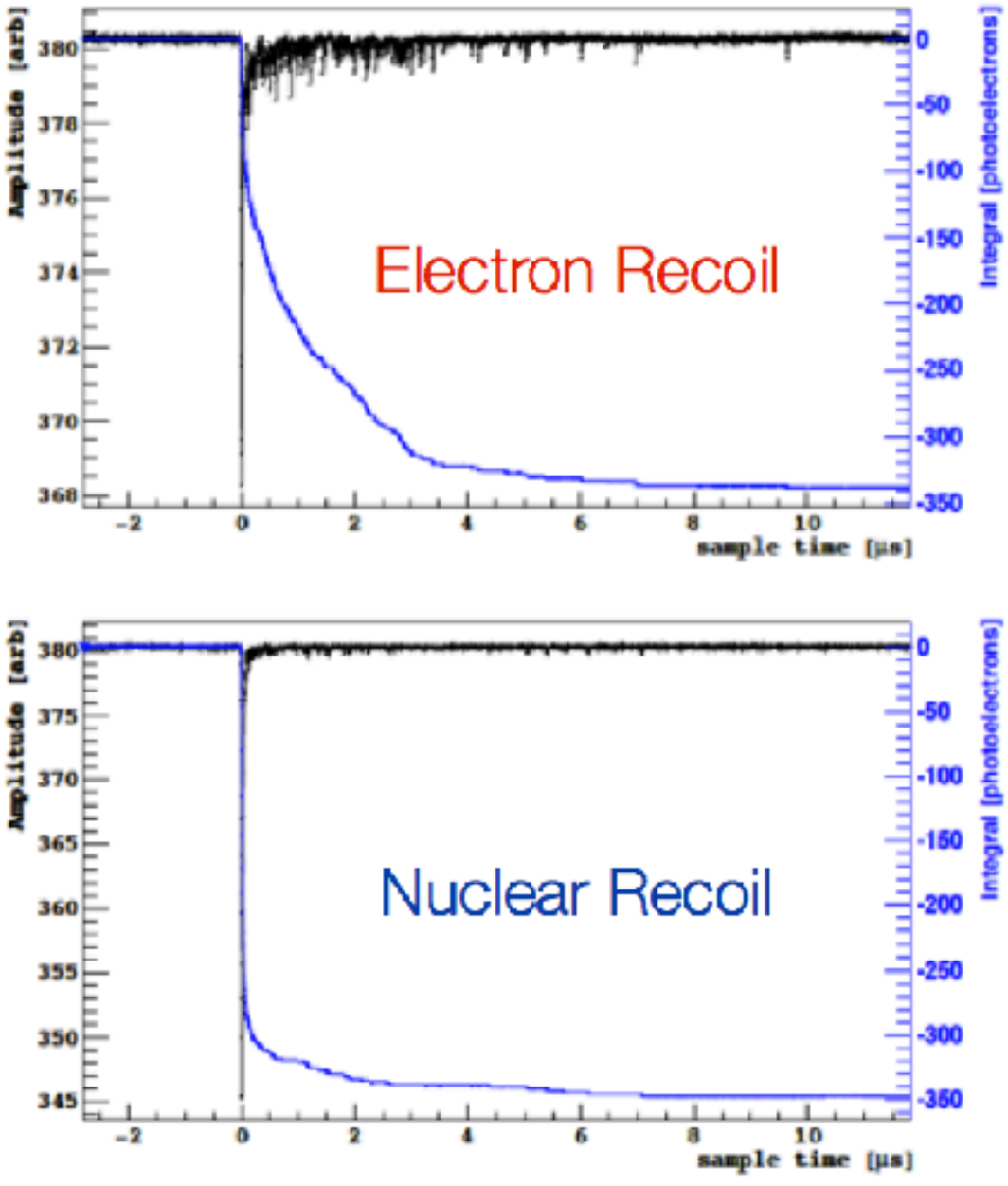
- Accurate 3D position identification
- Multiple-scattering rejection
- **S2/S1** ratio
- S1 **PSD** (if available)



Electron recoils rejection

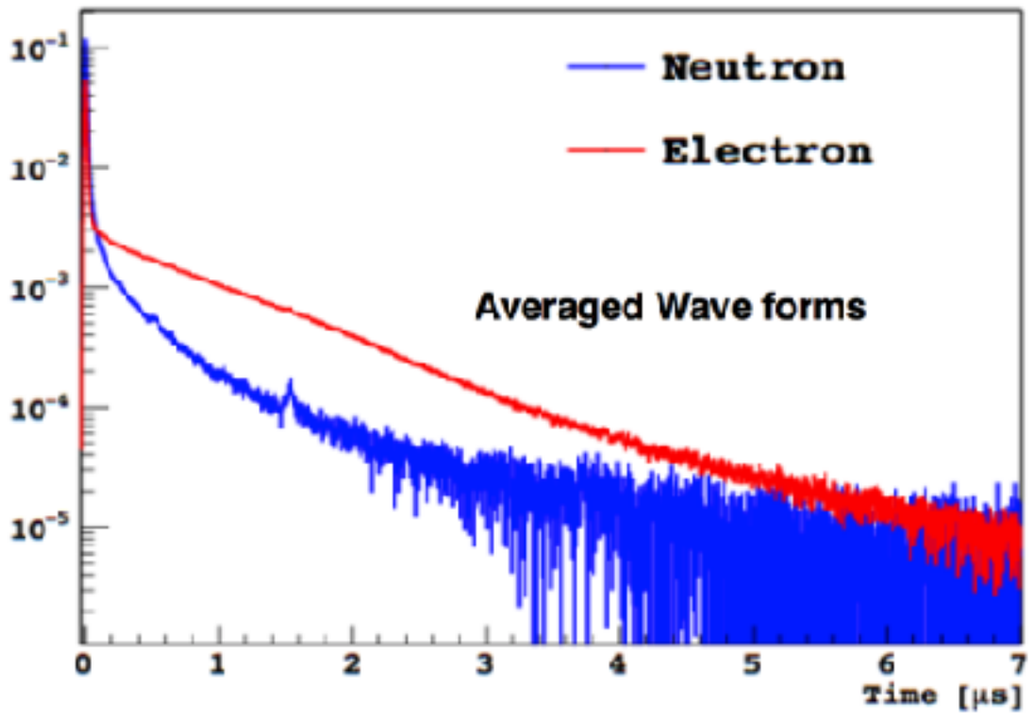
Pulse-shape discrimination (S1)

Electron and nuclear recoils produce different excitation densities in the argon, leading to different **ratios of singlet** (~7 ns) and **triplet** (~1500 ns) excitation states



Pulse-shape parameter f90:

Fraction of light seen in the first 90 ns



ER Rejection factor: ~10^8

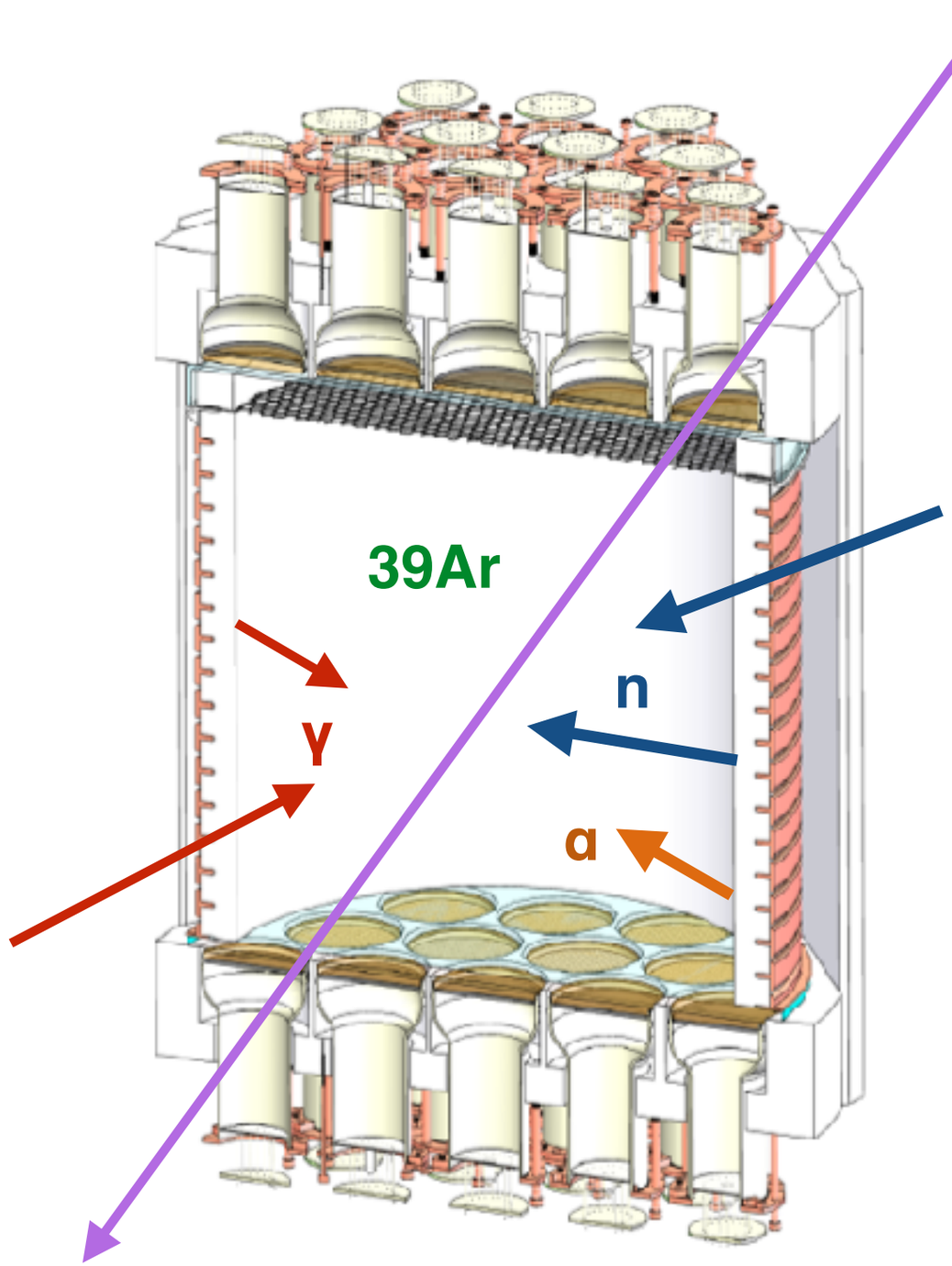
WARP Astr. Phys 28, 495 (2008)

Dark matter searches backgrounds

Electron recoils

^{39}Ar
~9x10^{4} evt/kg/day

γ
~1x10^{2} evt/kg/day



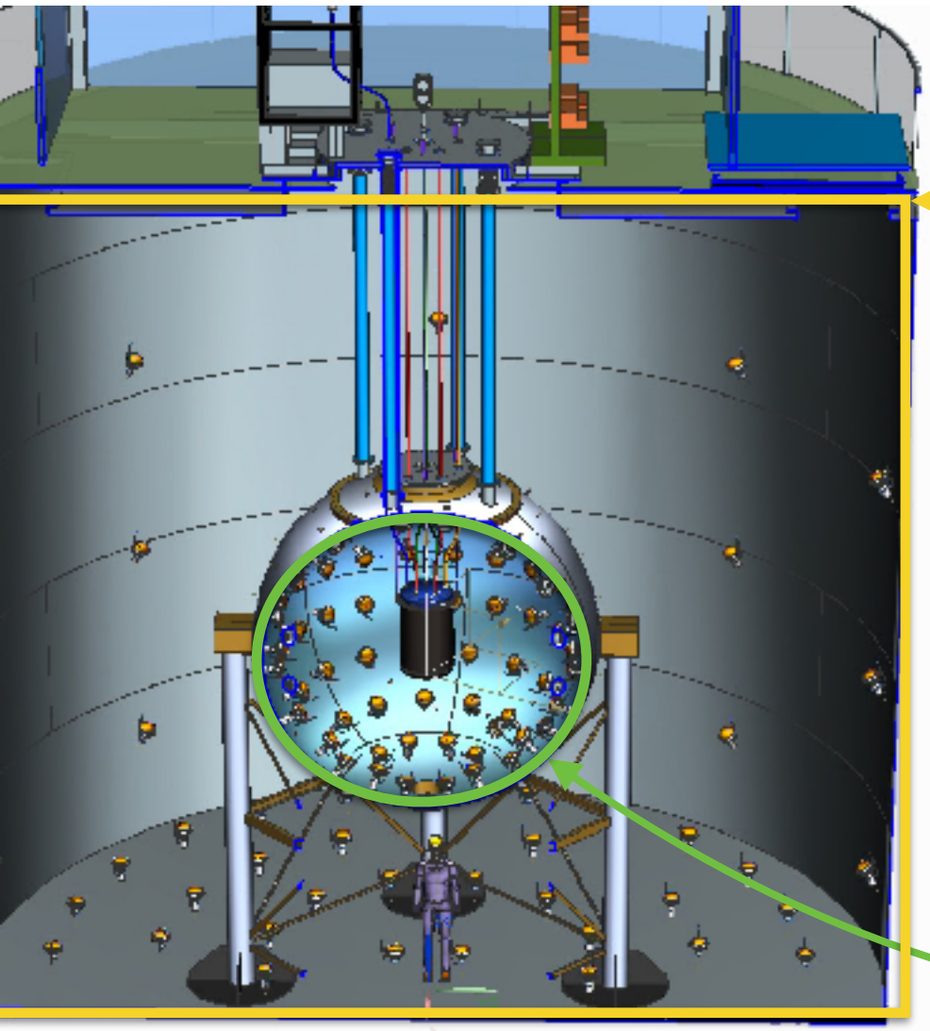
Nuclear recoils

Radiogenic n
~6x10^{-4} evt/kg/day

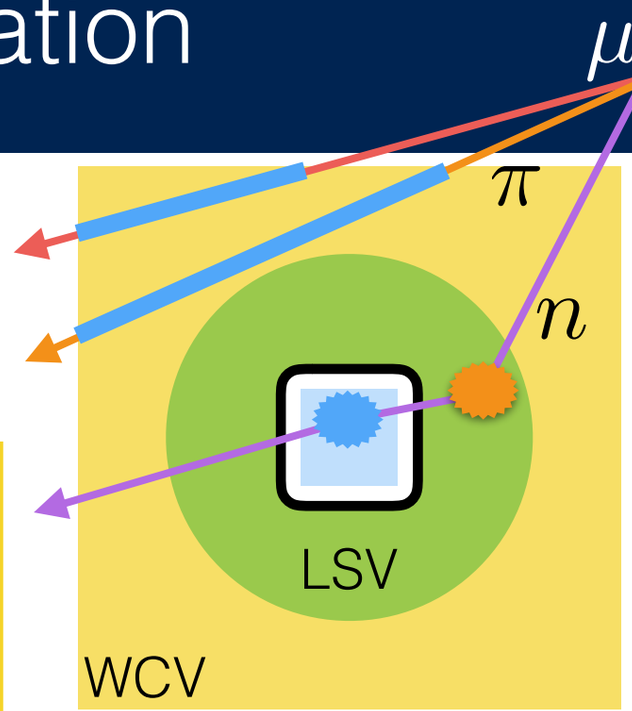
α
~10 evt/m^{2}/day

100 GeV, 10^{-45}cm^{2} WIMP Rate ~ 10^{-4} evt/kg/day

Radiogenic and neutron identification

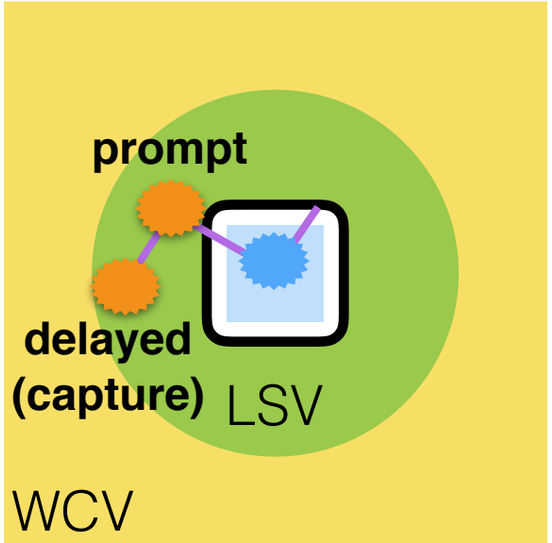


Water Cherenkov Veto:
1,000-tonne
tag cosmogenic neutrons via muons



Tag cosmogenic n

Liquid Scintillator Veto:
30-tonne
Liquid scintillator: TMB + PC



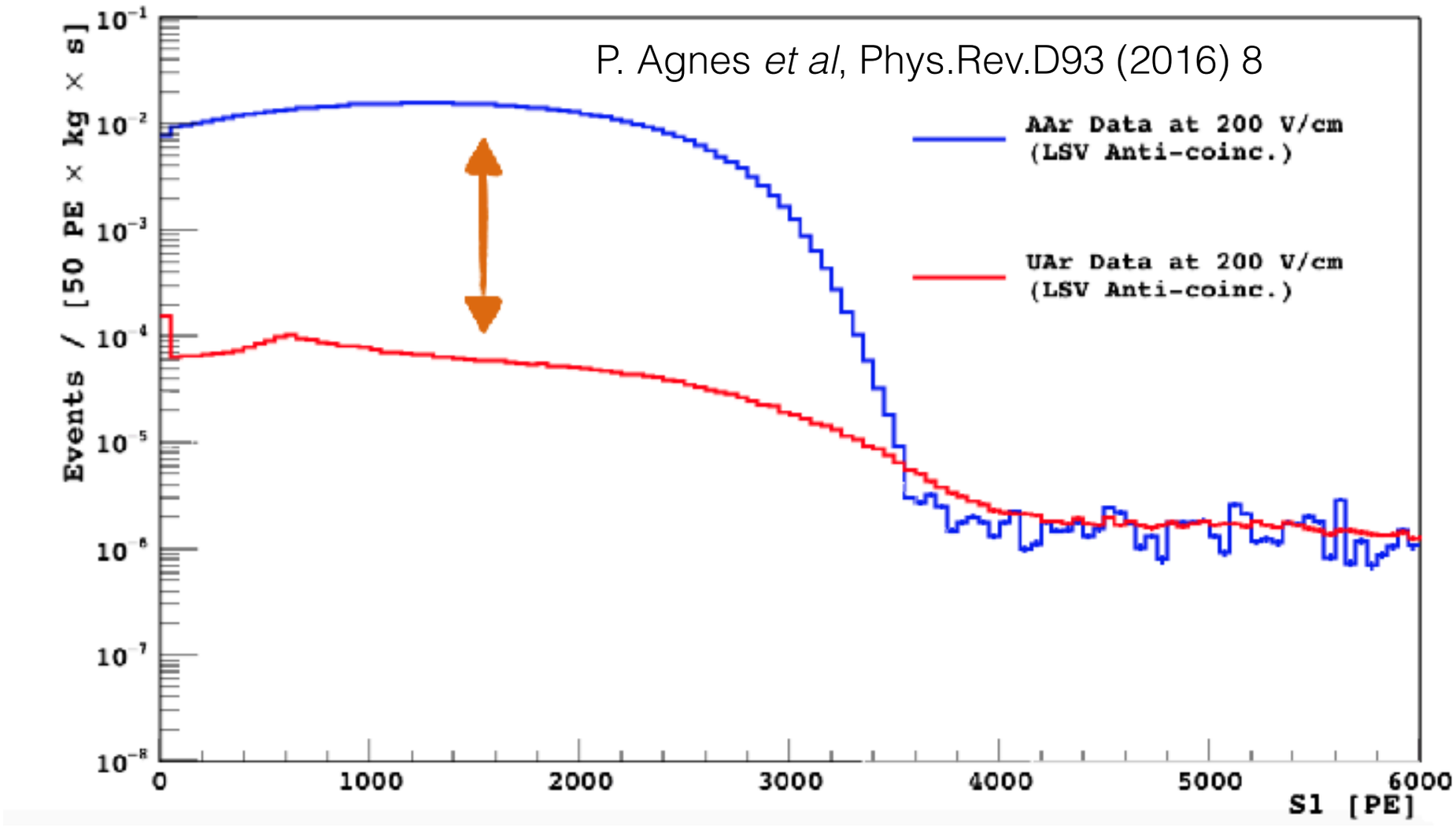
Tag radiogenic n

Veto's Rejection Efficiencies (AmBe measurement + Monte-Carlo):
> 99.5% against Radiogenic neutrons & > 95% against Cosmogenic neutrons

Underground Argon

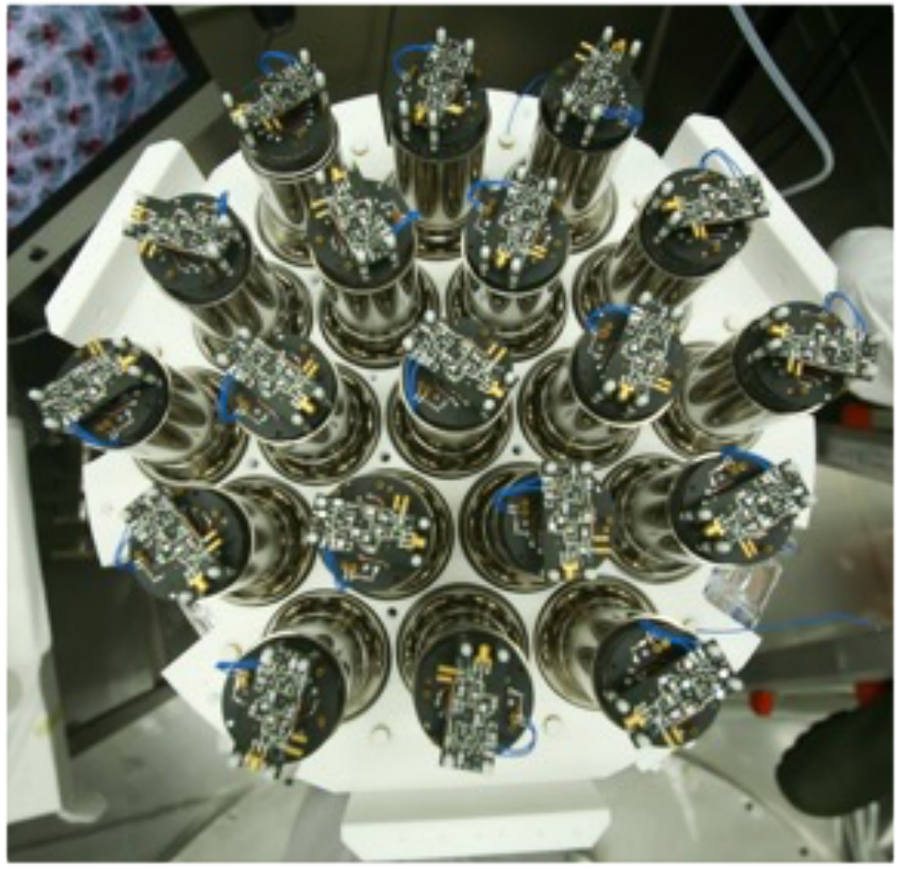
39Ar:

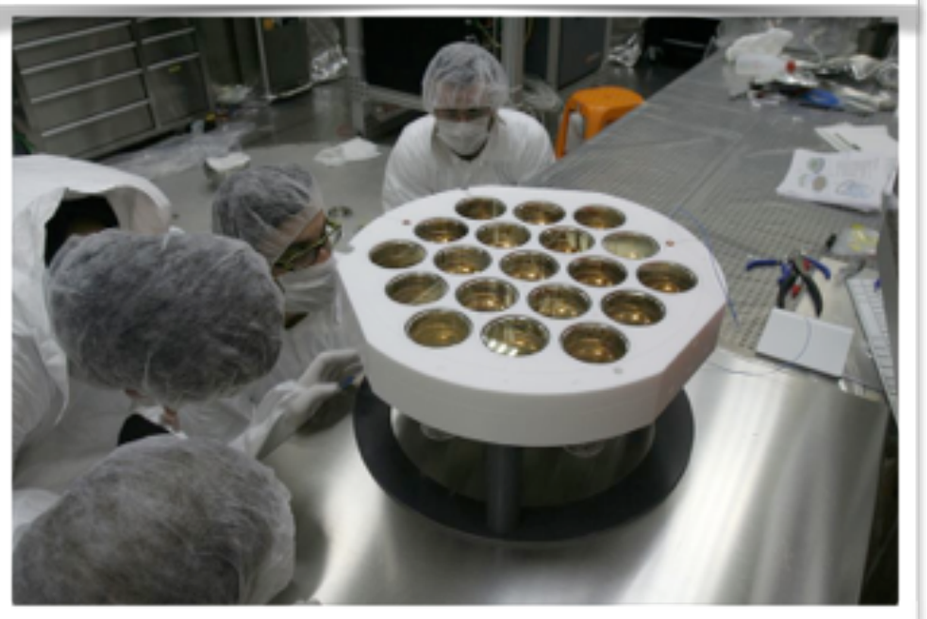
- ^{39}Ar is **cosmogenic** produced by ^{40}Ar(n,2n) interactions in the atmosphere
- **Beta emitter** with endpoint at **565 keV** and **half-life of 269 y**
- Nominal activity of atmospheric argon: ~ 1 Bq/kg.



→ Solution: **underground argon**

DS50 detector commissioning





Commissioning: October 2013

UAr deployement: March 2015

External calibration

Two fondamental parameters for LAr target:

1. Scintillation efficiency of NR (quenching)
2. Characterisation of the PSD estimator for NR

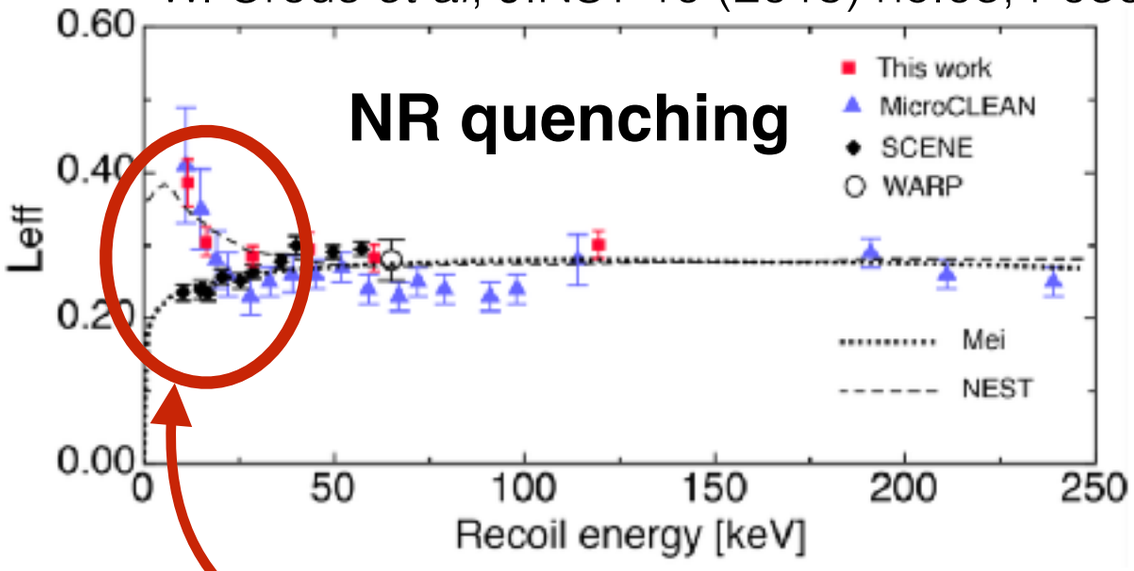
} **Need to be measured**

SCENE experiment:

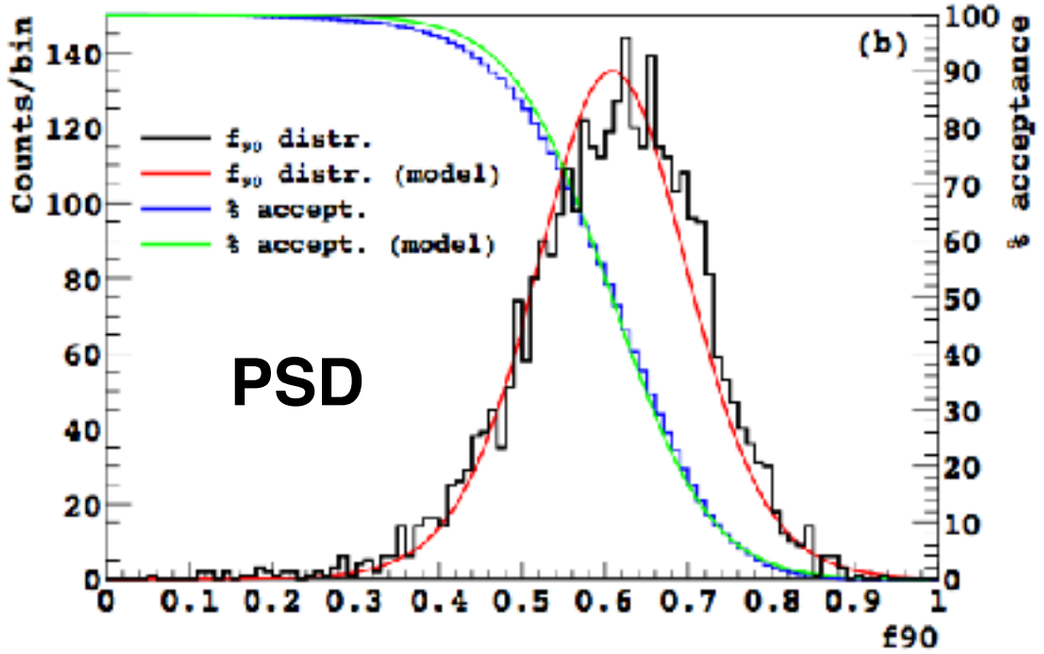
Measurement of NR using neutrons from $^{7}Li(p,n)^{7}Be$ reaction

H.Cao *et al*, Phys.Rev. D91 (2015) 092007

W. Creus *et al*, JINST 10 (2015) no.08, P08002



Discrepancy below 25-30 keVnr



Low statistics for PSD characterisation

Need to improve statistics and resolution!!

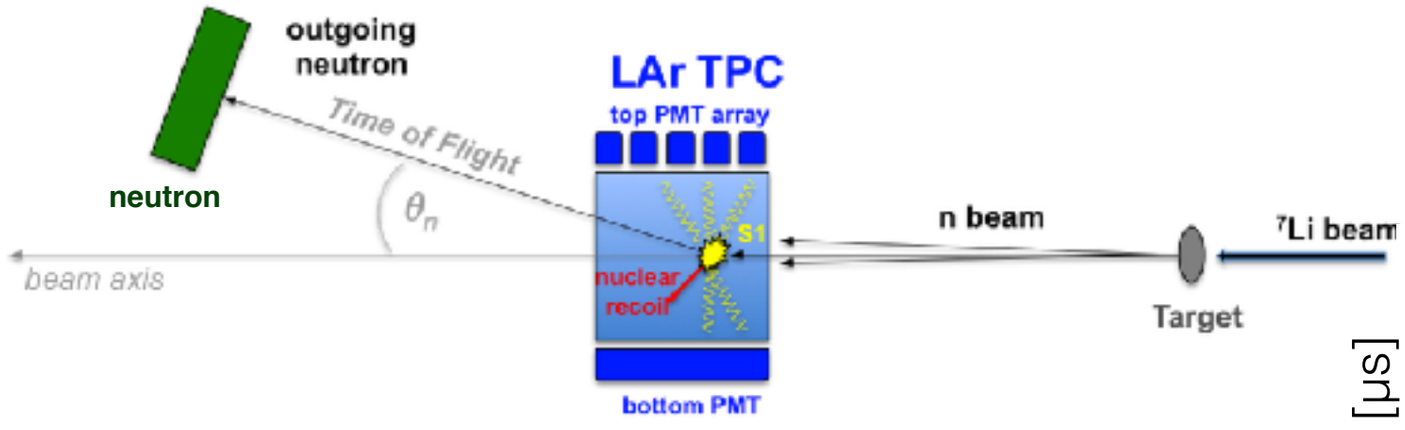
External calibration: ARIS

ARIS international collaboration
France, USA, ITALY

Neutron production: inverse $^{7}\mathrm{Li}(p.n)^{7}\mathrm{Be}$

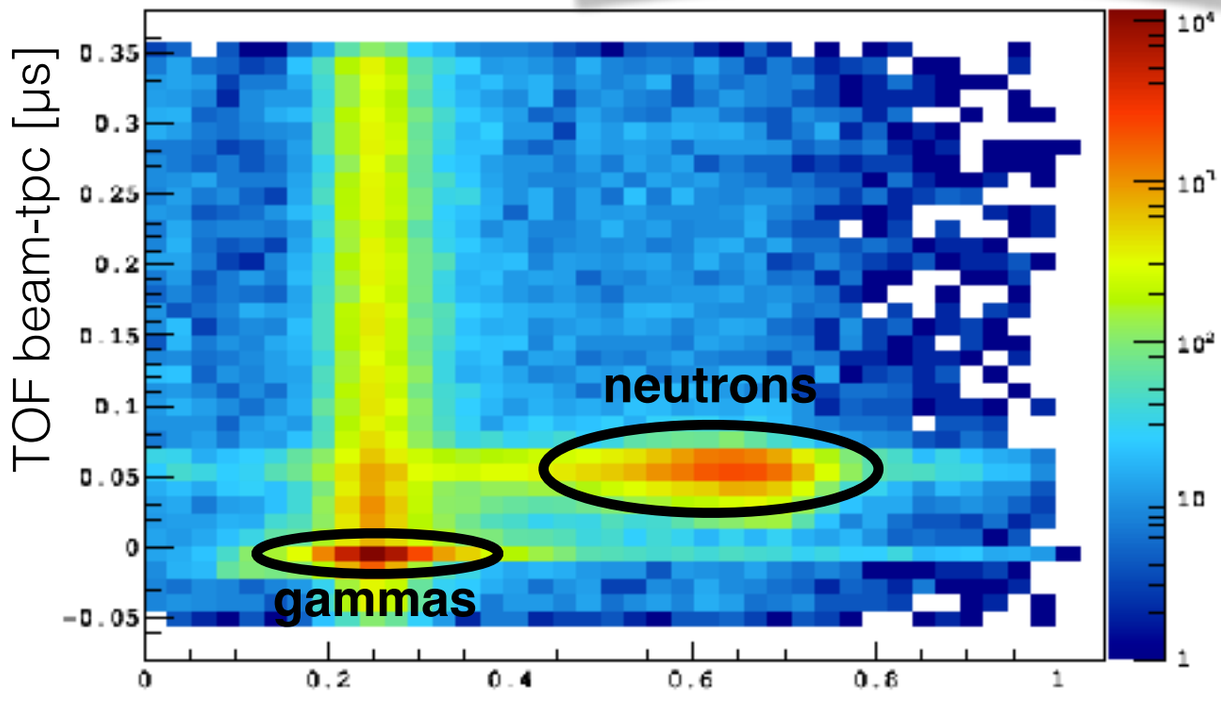
- ➡ Monochromatic
- ➡ Collimated beam
- ➡ Neutron energy ~1.3-1.4 MeV

http://aris.in2p3.fr



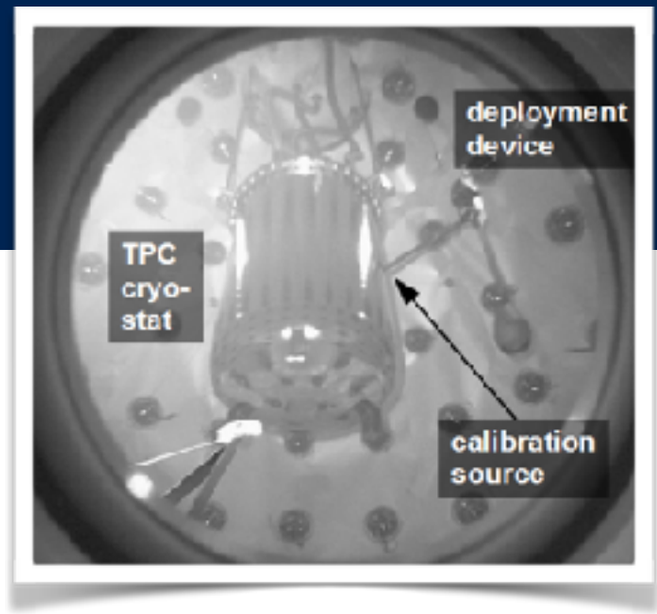
Data taking completed in late October at LICORNE (IPNO/France)

Data analysis in progress



f90

In-situ calibration

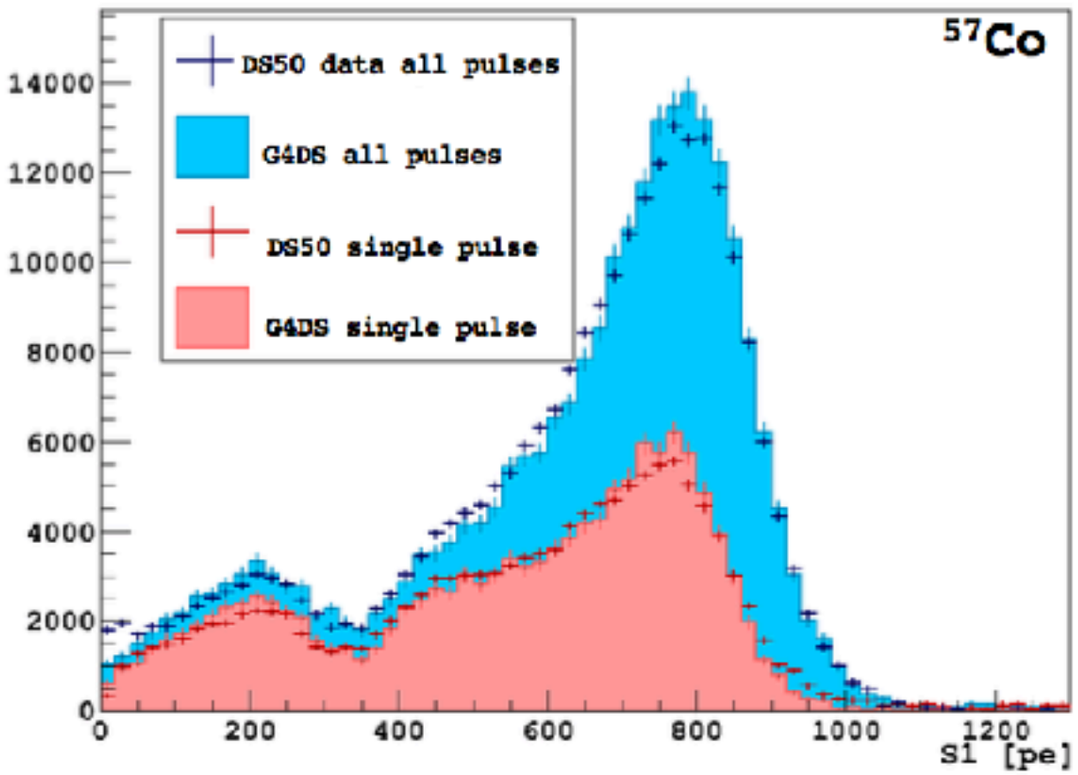


CALibration Insertion System (CALIS)

P. Agnes, arXiv:1611.02750

Gamma sources:

^{57}Co (122 keV), ^{133}Ba (356 keV),
^{137}Cs (663 keV)

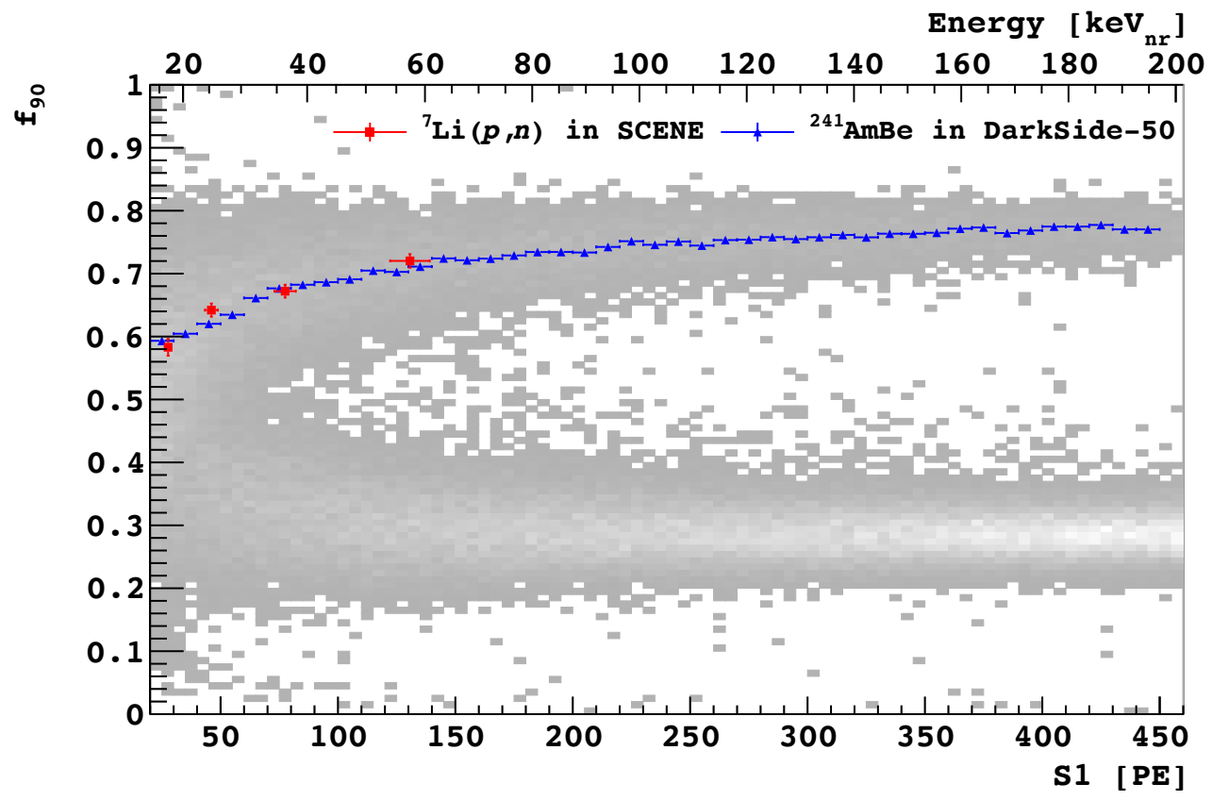


Objectives:

Monte-Carlo (g4ds) tuning cross check
LY measurement and monitoring
Monitoring of detector stability

Neutron source:

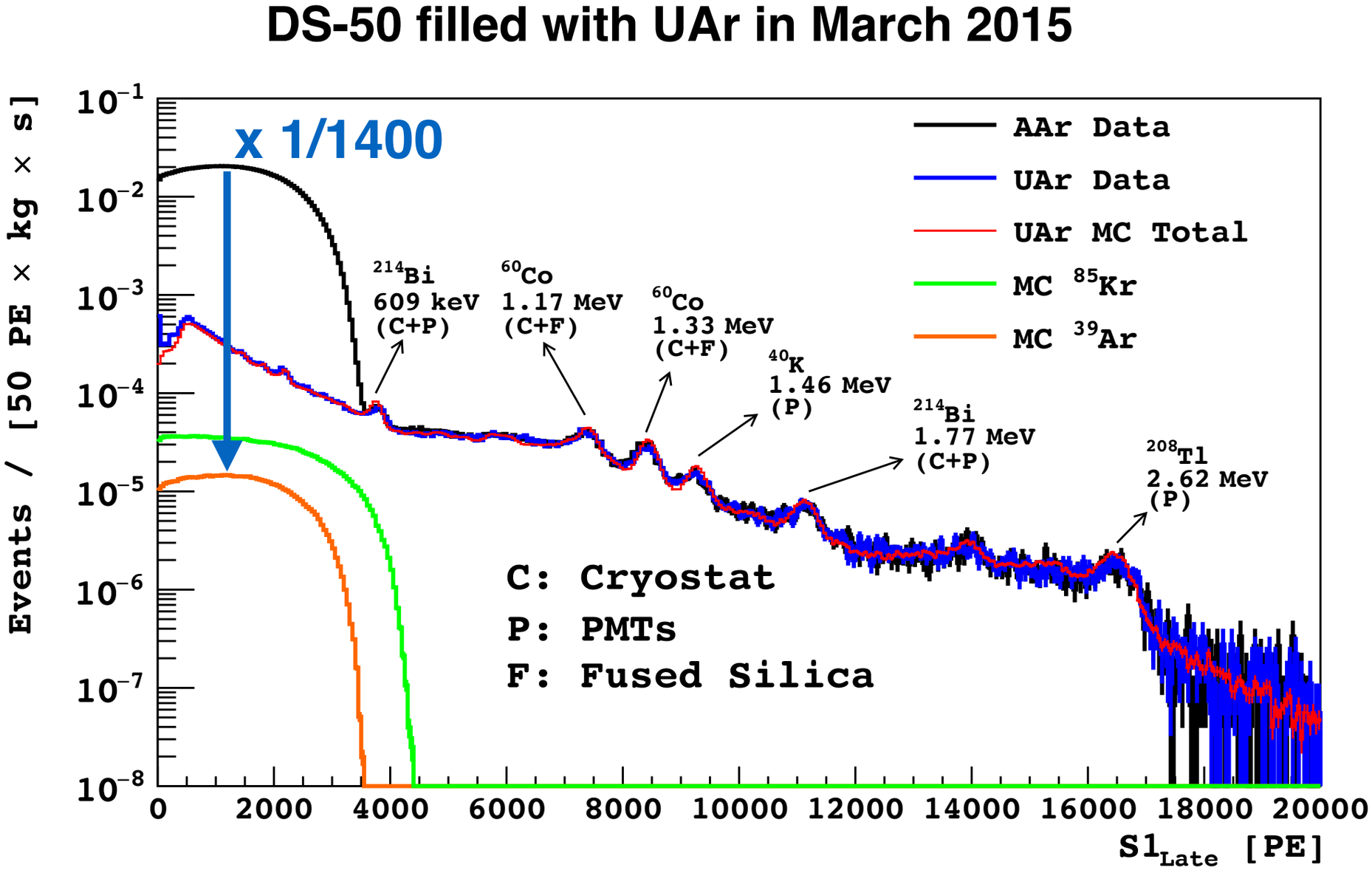
AmBe w/ and w/o collimator



Objectives:

NR study
Cross check external calibrations

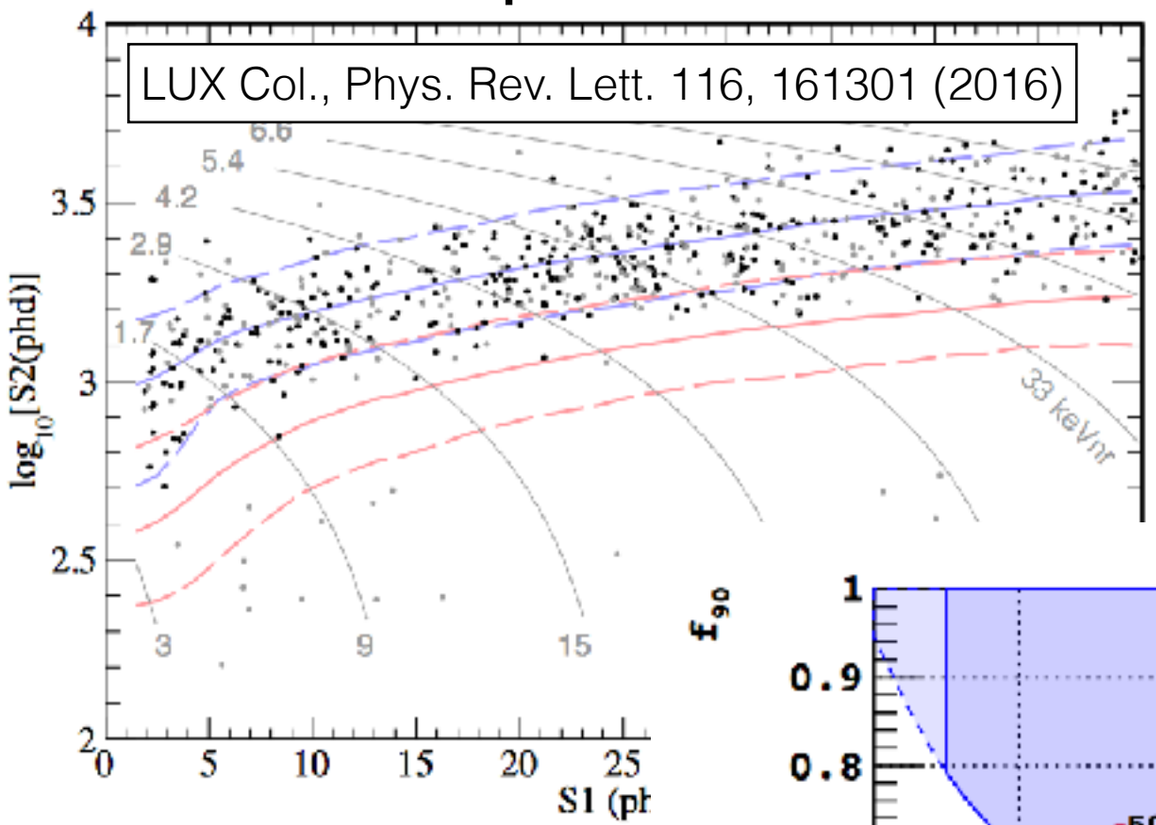
Underground Argon



- Fitted ^{85}Kr activity in UAr: 2.05 ± 0.13 mBq/kg
- Fitted ^{39}Ar activity in UAr: 0.73 ± 0.11 mBq/kg
- ^{39}Ar activity in AAr: 1000 mBq/kg

The PSD power in liquid Ar

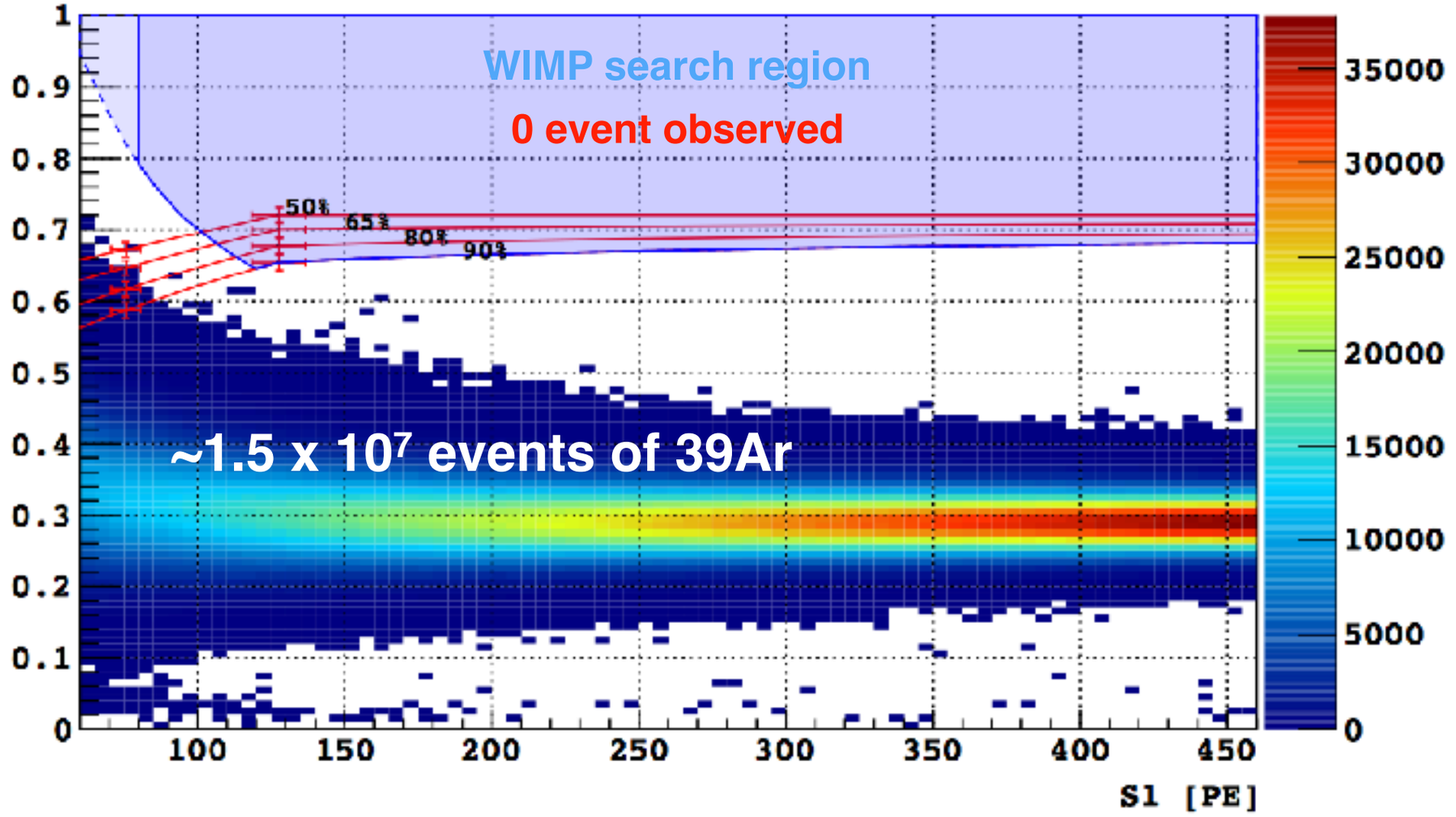
Liquid Xenon



Excellent Pulse Shape Discrimination:
ER Rejection factor ~ 10^8

WARP, Astr. Phys 28, 495 (2008)

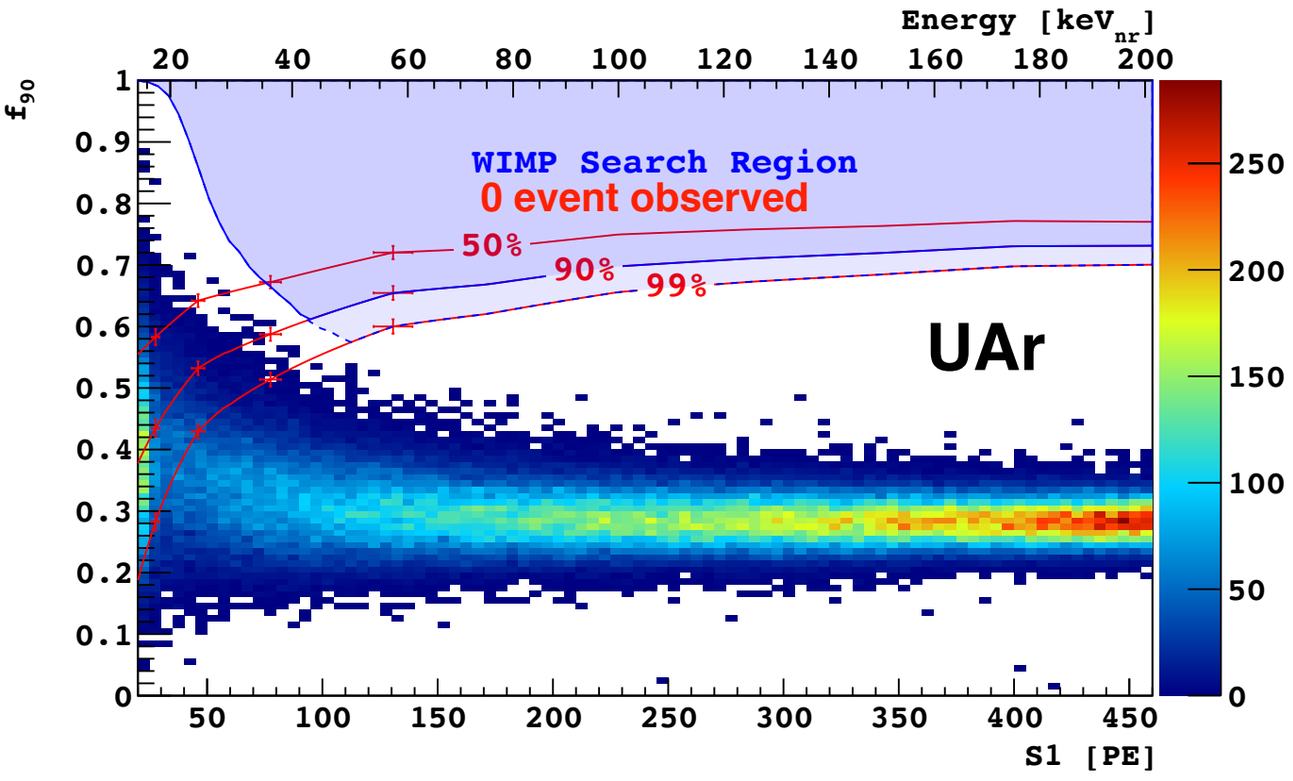
Atmospheric Liquid Argon

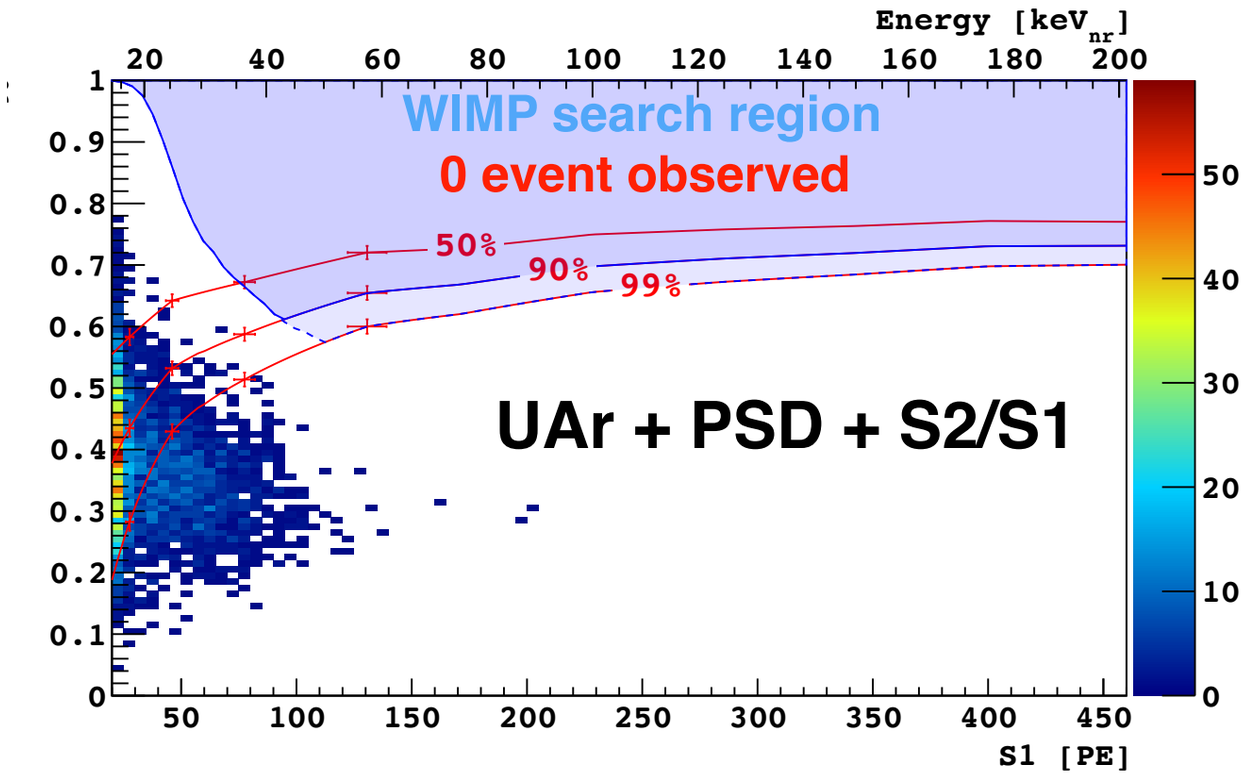


Underground argon

Requirements:

- No multiple interactions (one S1)
- No energy deposition in the vetoes





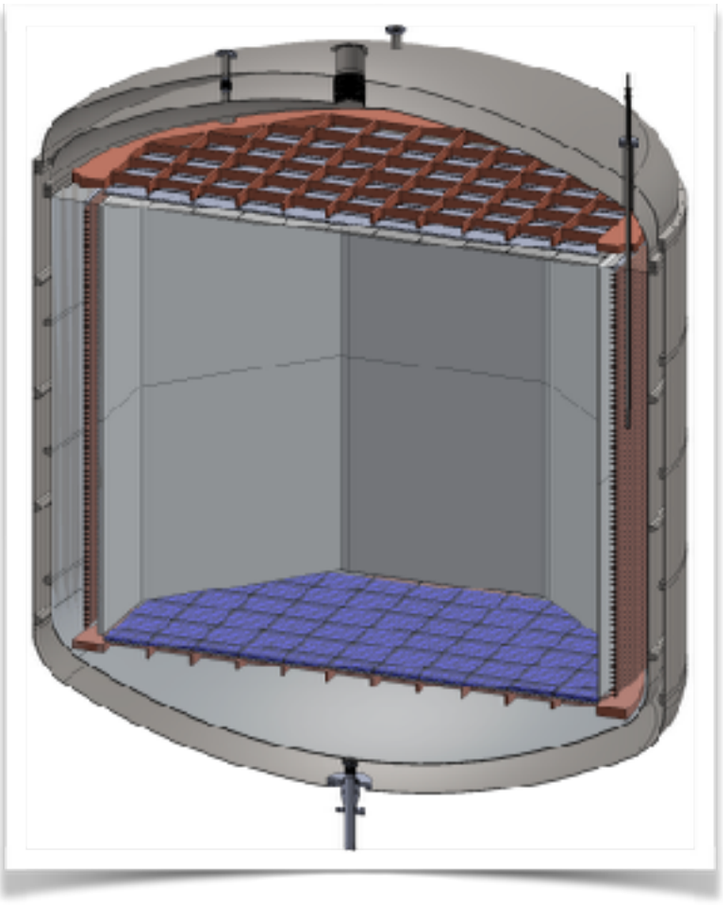
· **70.9 live-days** · **36.9 kg fiducial mass**

Background free measurement

DarkSide-20k

DarkSide-20k:

- 30 tonne of LAr —> ~20 tonne fiducial
- Underground & depleted argon (URANIA+ARIA)
- High efficiency active vetoes (LSV + WCV)
- Photosensor: SiPM

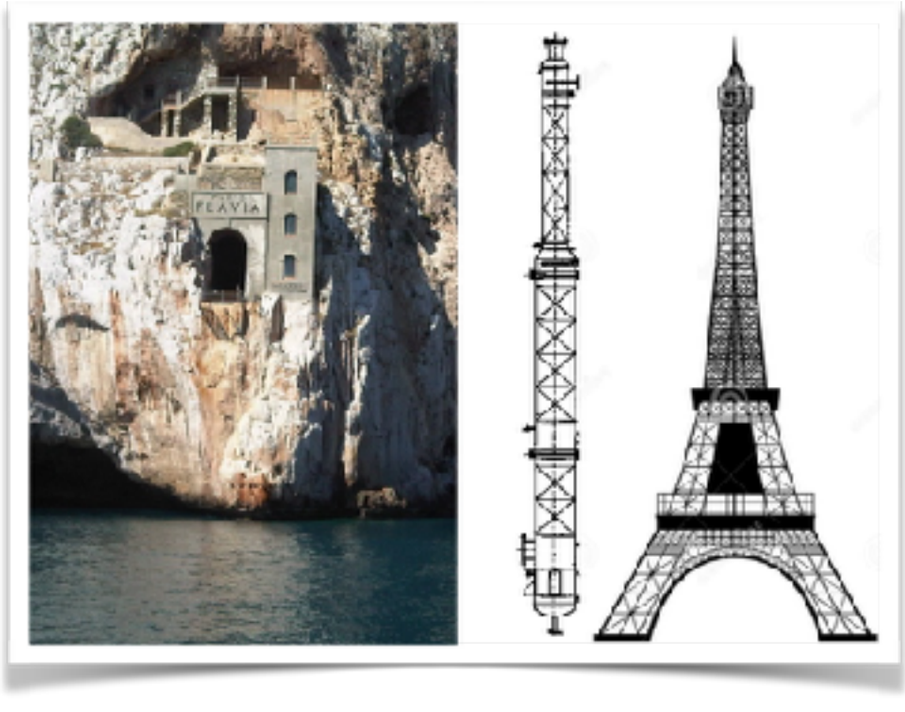


Requirements:

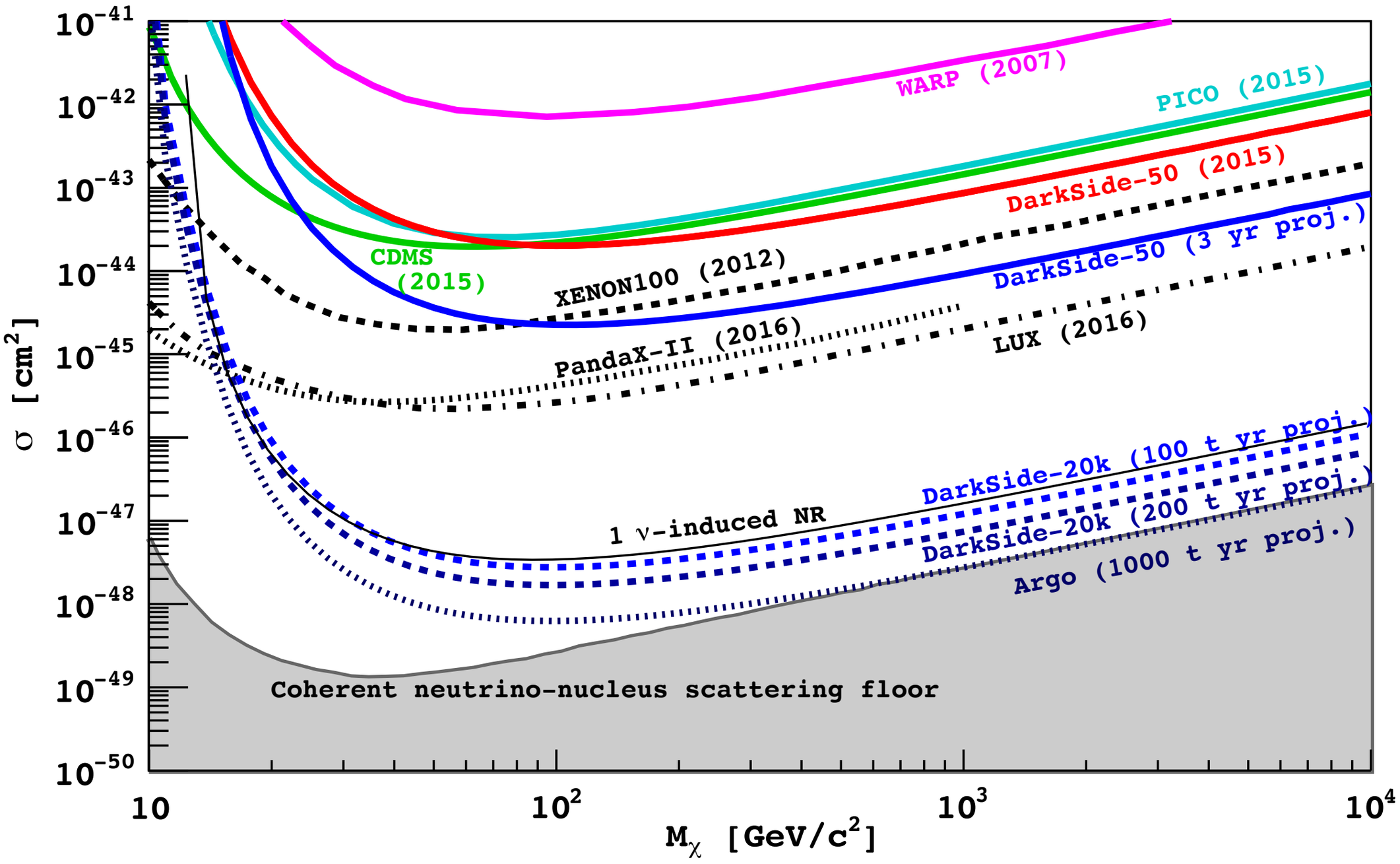
Radiogenic neutron background must be **lower than 0.1 evts / 100 t.y**

ARIA (UAr purification):

Very tall column in the Seruci mine in Sardinia (Italy) for high-volume **chemical and isotopic purification** of **underground argon**



DarkSide-20k: expected sensitivity



Conclusion

DarkSide-50:

- Concentration of ^{39}Ar in UAr is **1400 times lower** than in AAr.
- **G4DS**: Complete understanding of our data and background
- **Background free experiments** thanks to several discrimination techniques (PSD, S2/S1, Multiple scatter cut, fiducial volume cut, active vetos)
- DarkSide-50 has the strongest WIMP limit among Ar target experiments.
- **Currently in stable** WIMP search mode.

DarkSide-20k:

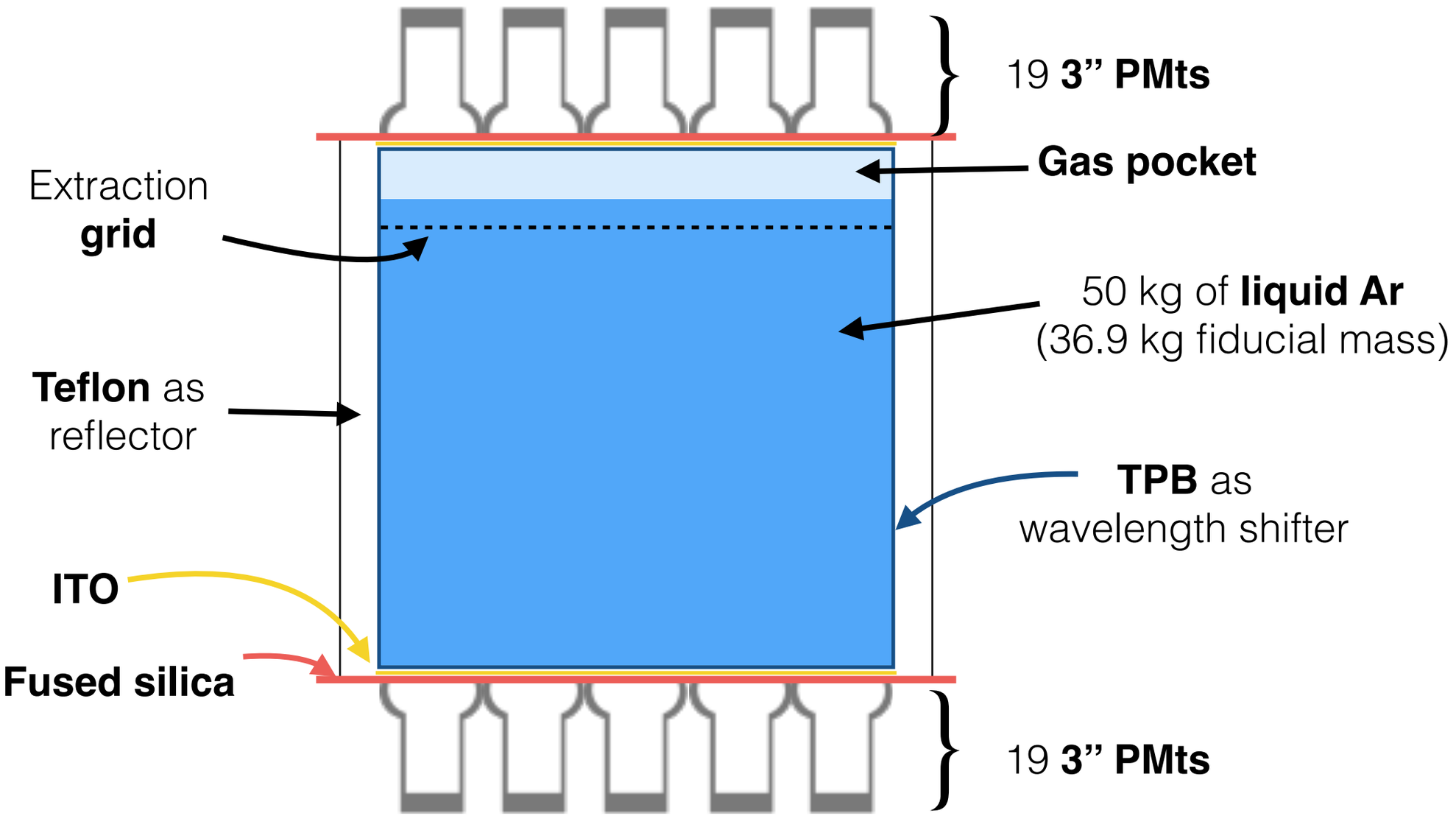
- Future detectors are planned and active R&D's are underway.

BACKUP

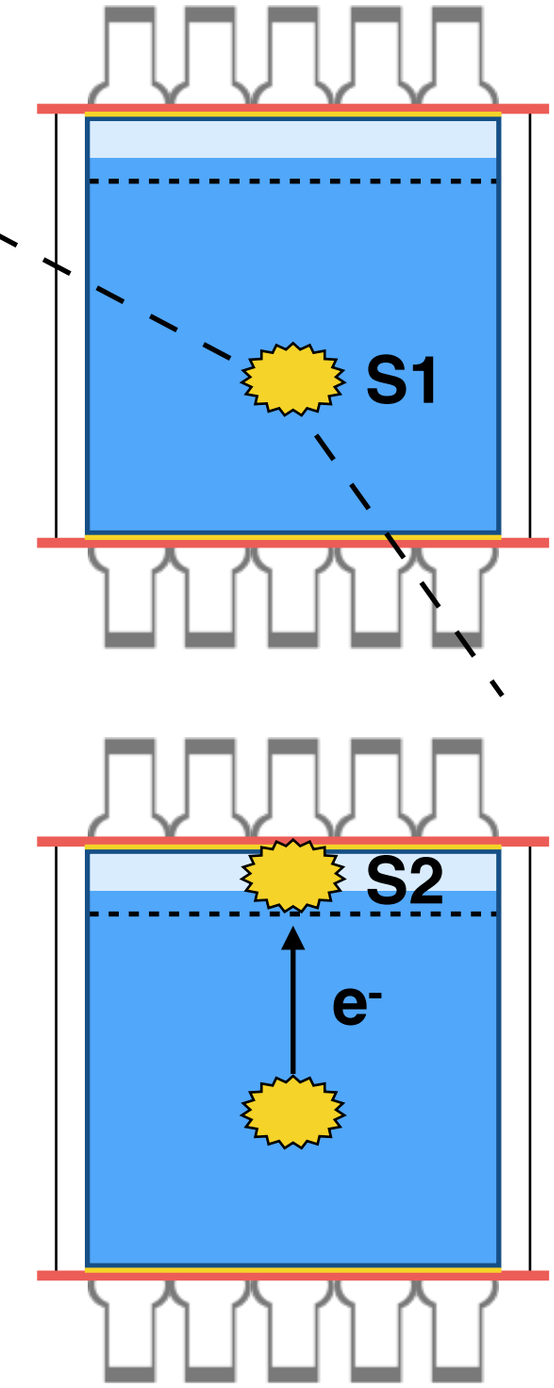
DS50: dual phase liquid argon TPC

Liquid Argon

- relatively **dense** and easy to purify (chemically)
- allowing to **scale the experiment to large volume**
- good scintillator: **transparent to its own light**
- has **exceptional discrimination pow**



TPC Read-out



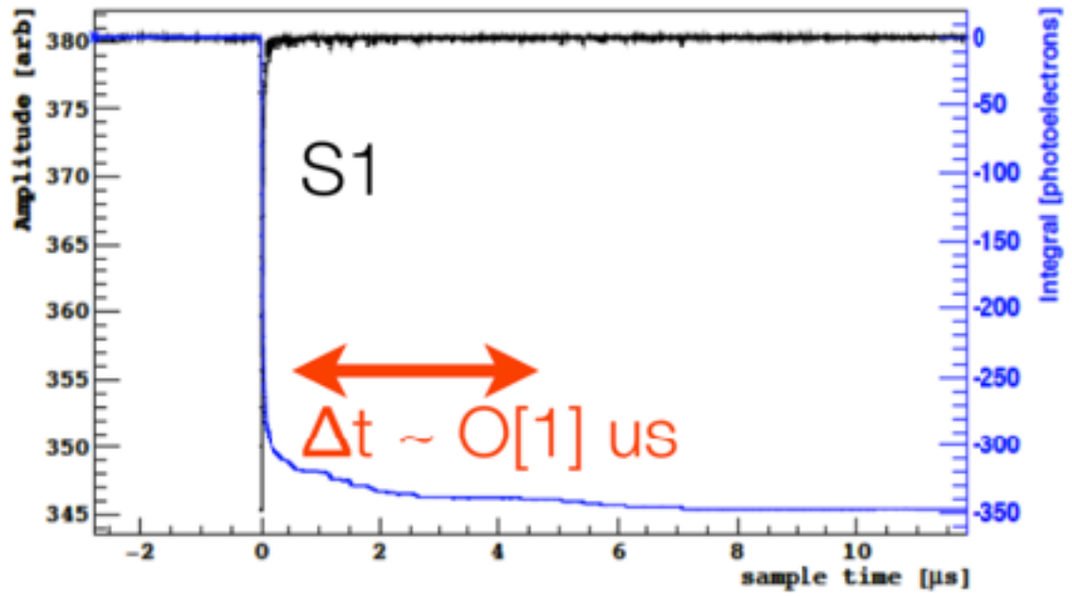
Nuclear recoil **excites** and **ionizes** liquid argon

↓

Scintillation light emission

↓

S1



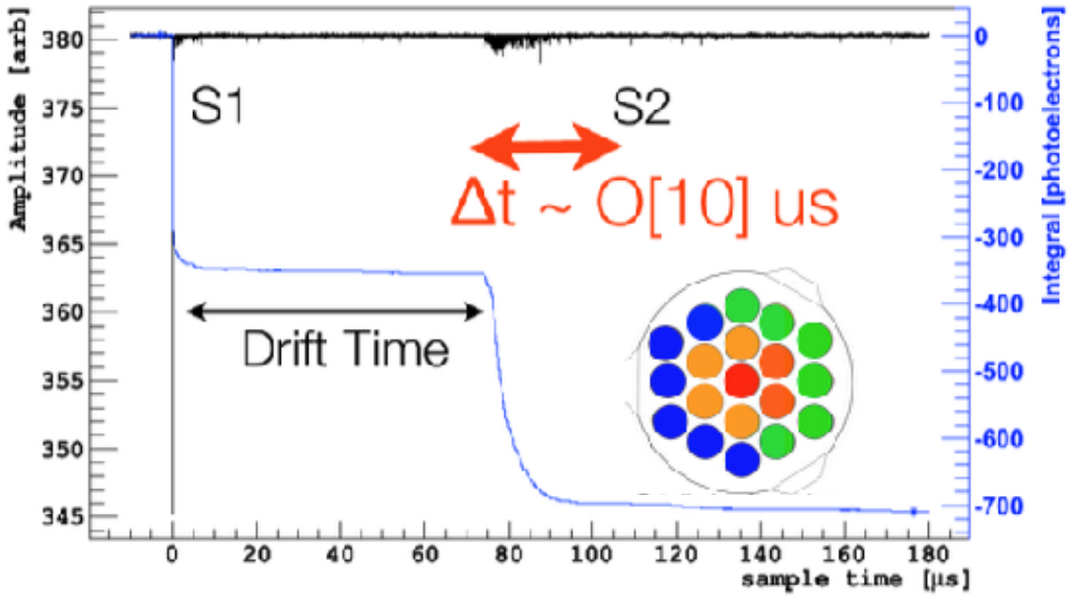
Electric field:
electron collection

↓

Gas pocket:
electroluminescence

↓

S2



3D positioning { (X,Y) position reconstruction: S2 light fraction in each PMT

Z coordinate given by drift time

Monte-Carlo: G4DS

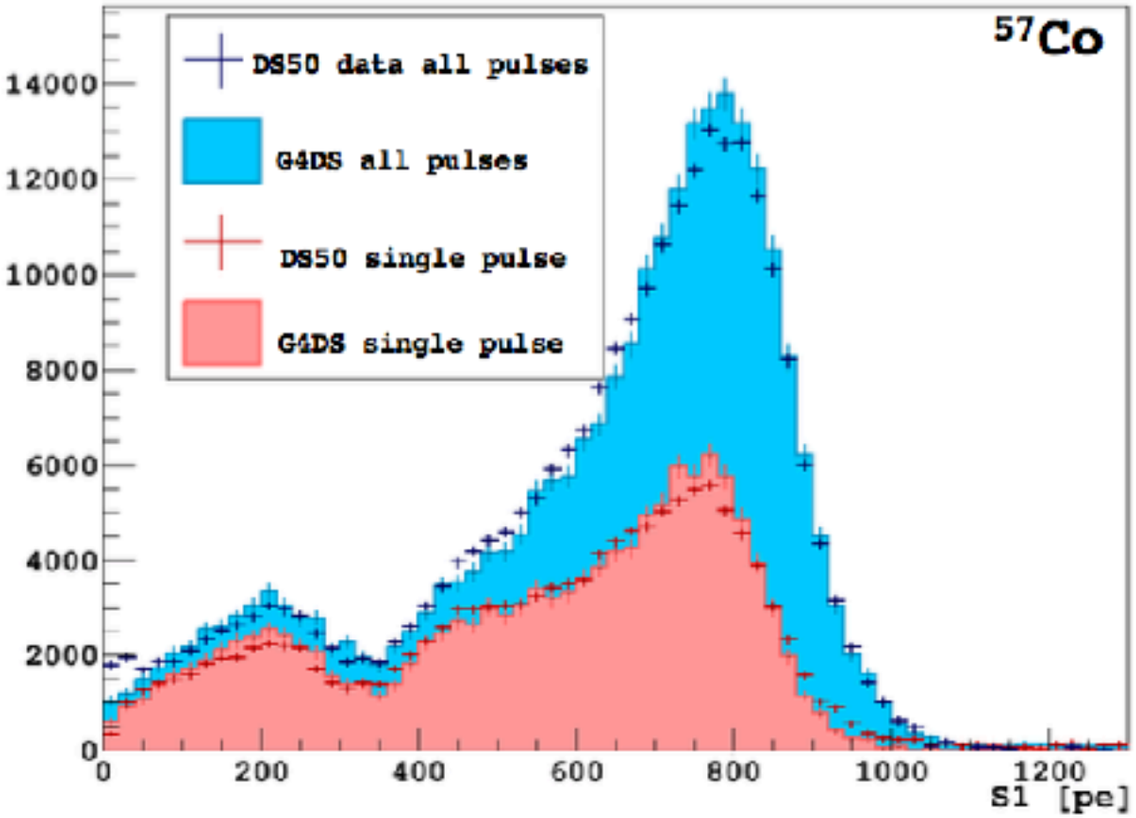
G4DS: GEANT-4 based simulation (developed from scratch in Paris)

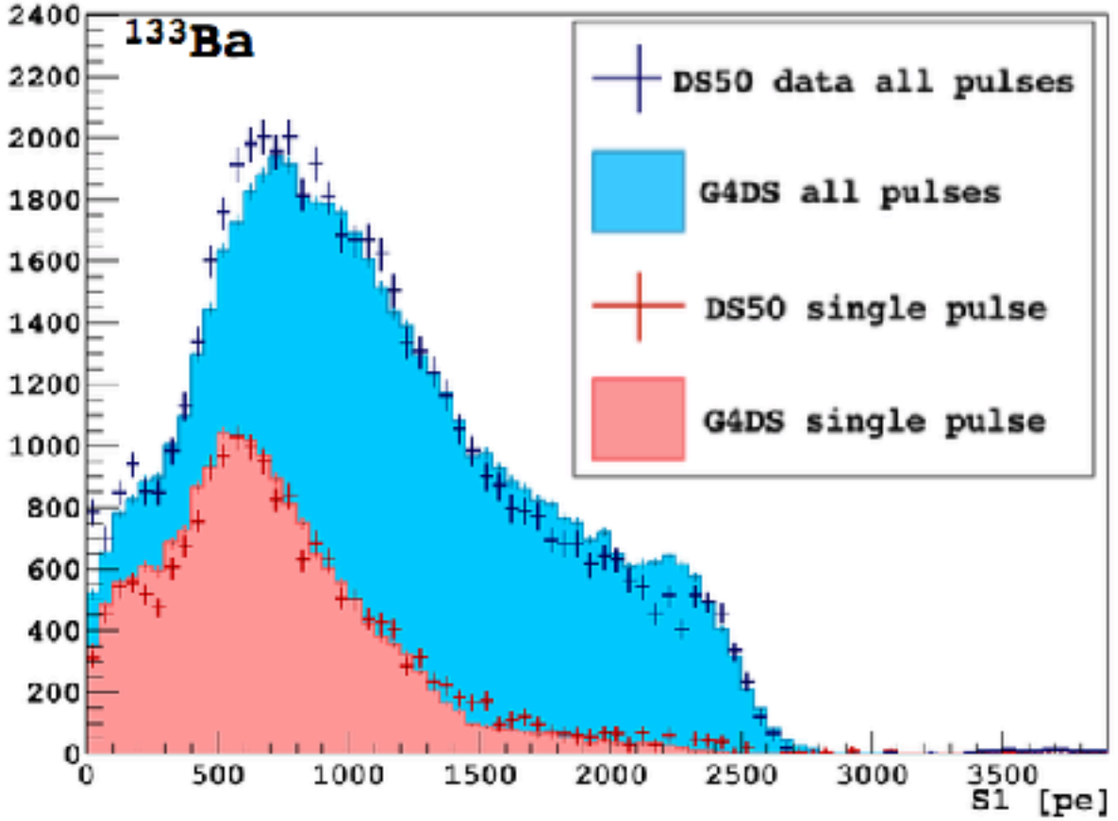
Features:

1. Electronics simulation
2. Full optics description
3. TPC energy scale (S1 and S2) with dedicated model
4. Calibration of the vetoes
5. Pulse shape discrimination parameter (f90)

Monte-Carlo parameters tuned on AAr data —> Good agreement

MC tuning cross check using calibration sources:





Same agreement for number of pulses, tdrift vs x-y distribution