The DarkSide program at LNGS: update and outlook

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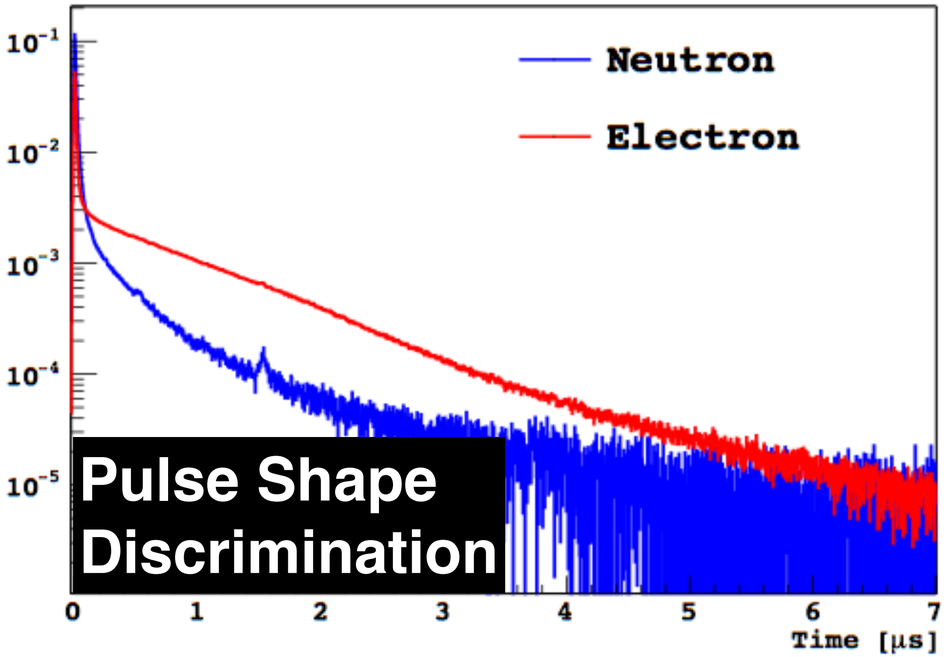
Gran Sasso Science Institute
Torino - September 7th, 2015

DarkSide

Direct search for **WIMP** dark matter

using a **L**iquid **Ar**gon **T**ime **P**rojection **C**hamber

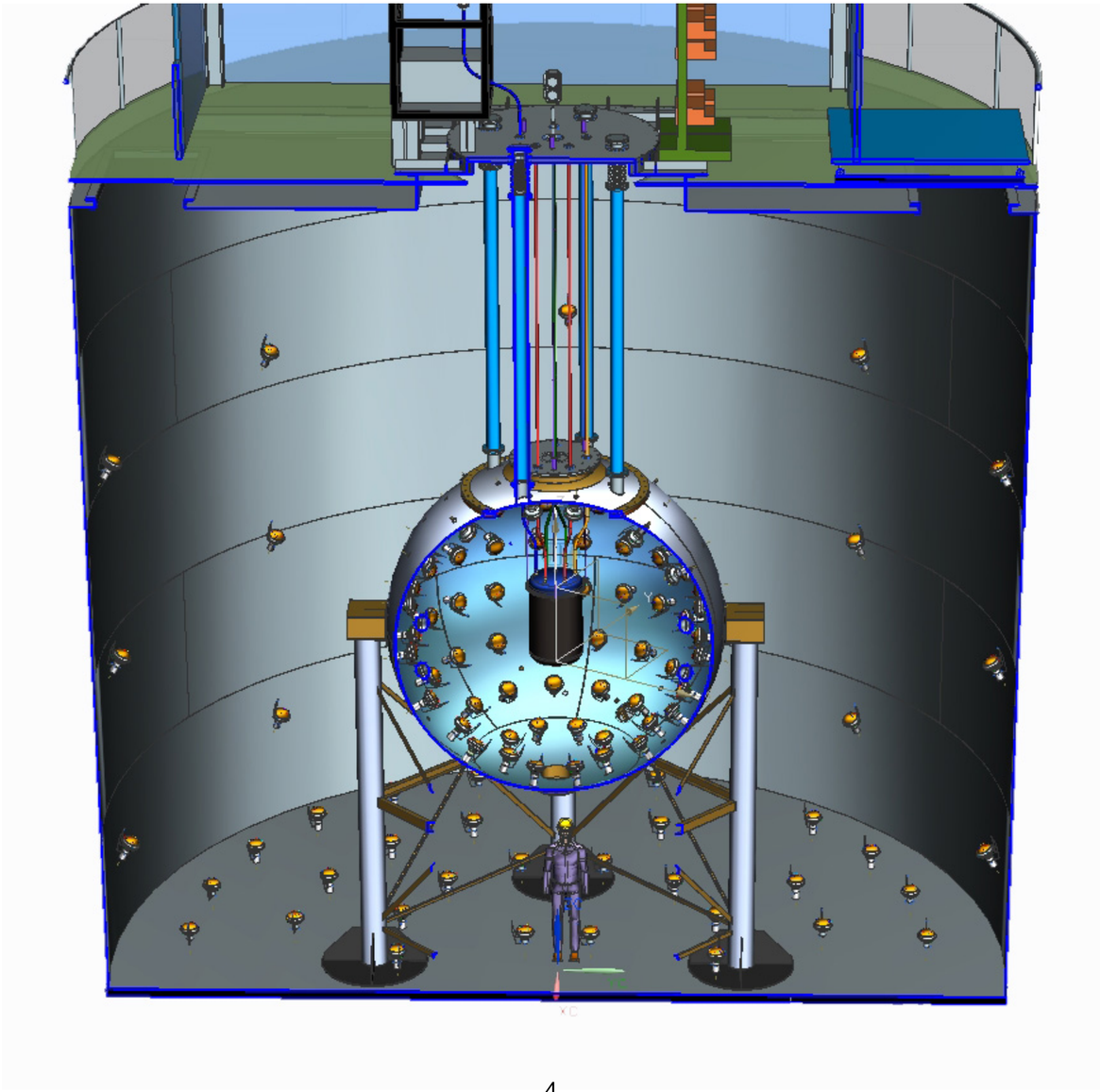
at **L**aboratori **N**azionali del **G**ran **S**asso



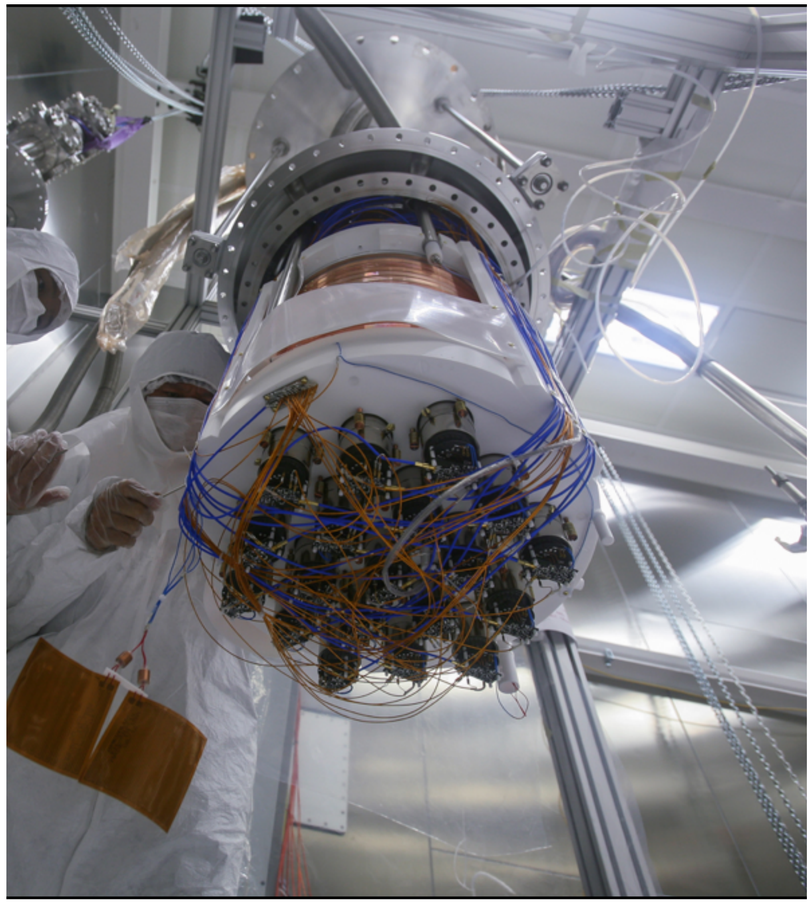
Plan of Talk

- Updates on DS-50 (15’)
  - Calibrations, Underground Argon Run
- DS-20k, ARGO (5’)
  - Urania, Aria

The DarkSide-50 detectors at LNGS



The DarkSide-50 LAr-TPC



Target

filled with **U**nderground **Ar**gon

active mass 46 kg *total mass 153 kg*

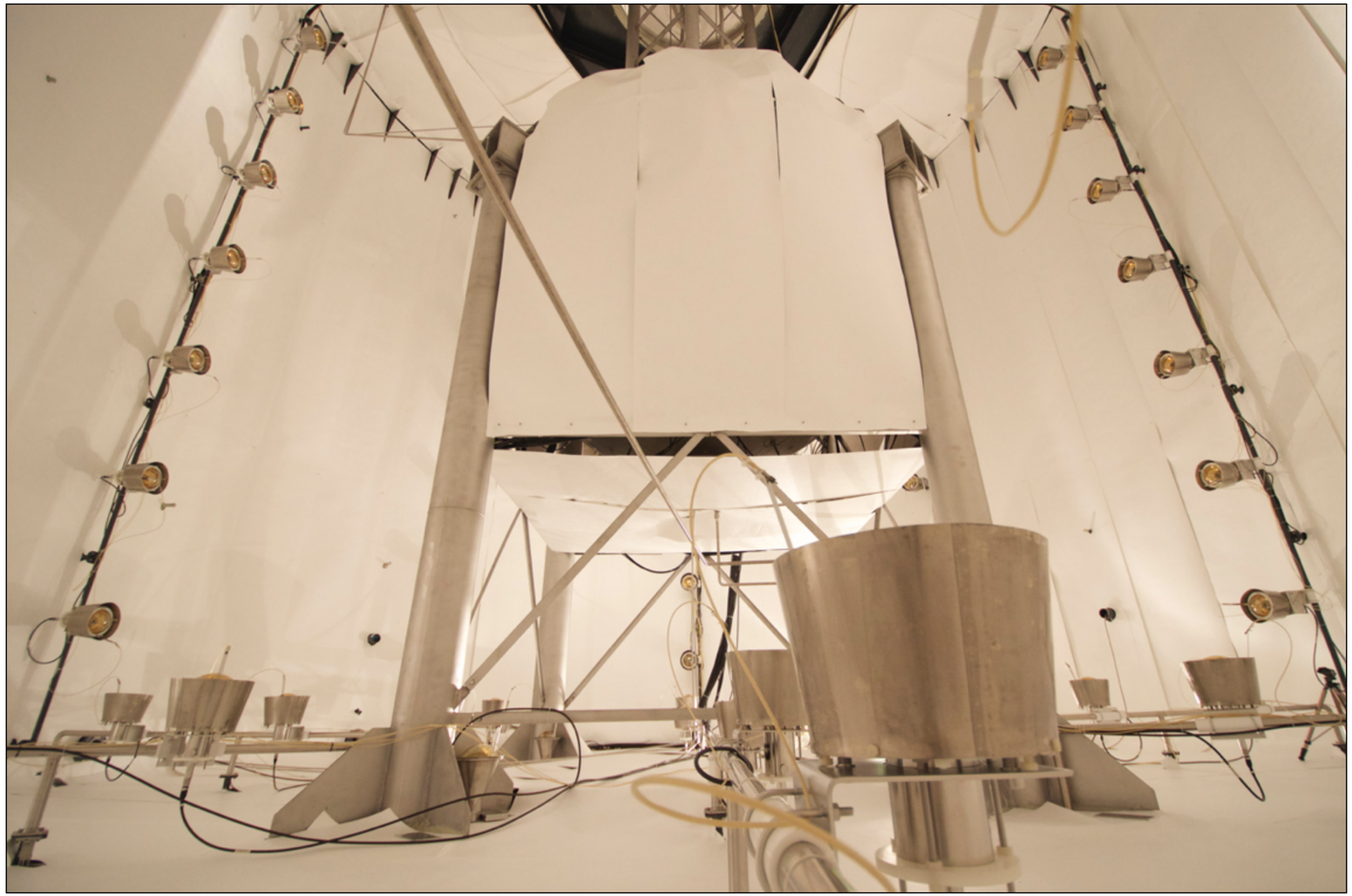
The DarkSide-50 borated Liquid Scintillator Veto

Anti-coincidence detector for neutrons

$^{10}\mathbf{B}$ + n —> ^{7}Li + **α** (*1775 keV*) *6.4%*

$^{10}\mathbf{B}$ + n —> ^{7}Li* + **α**, ^{7}Li* —> ^{7}Li + **γ** (*478 keV*) *93.6%*

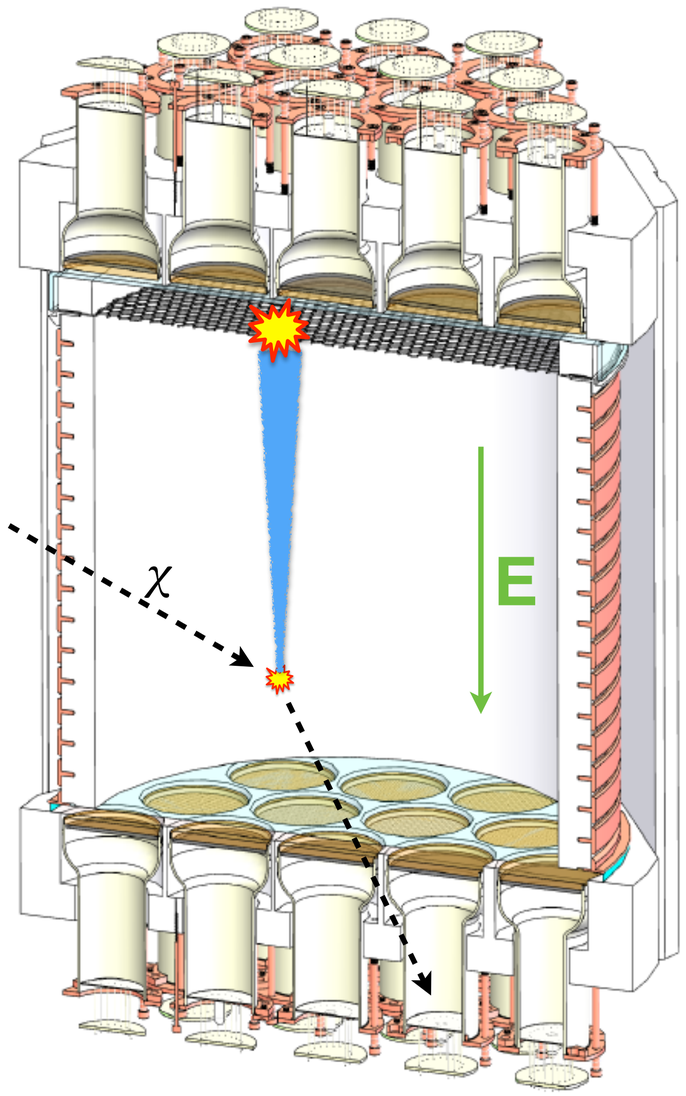
The DarkSide-50 Water Cherenkov Detector



Anti-coincidence detector for muons

Two phase LAr-TPC

19 PMTs on top



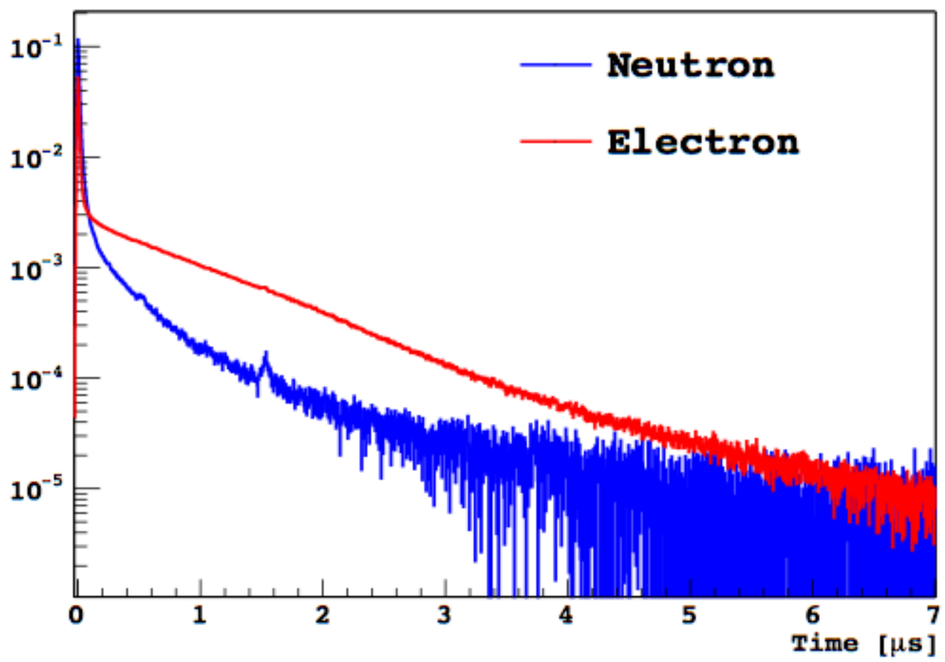
S2 - ionization

Drift field - 200 V/cm
Extraction field - 2.8 kV/cm

S1 - scintillation
light yield (β) - 7.0 PE/keV
light yield (n) - 2.0 PE/keV

19 PMTs on bottom

Pulse Shape Discrimination

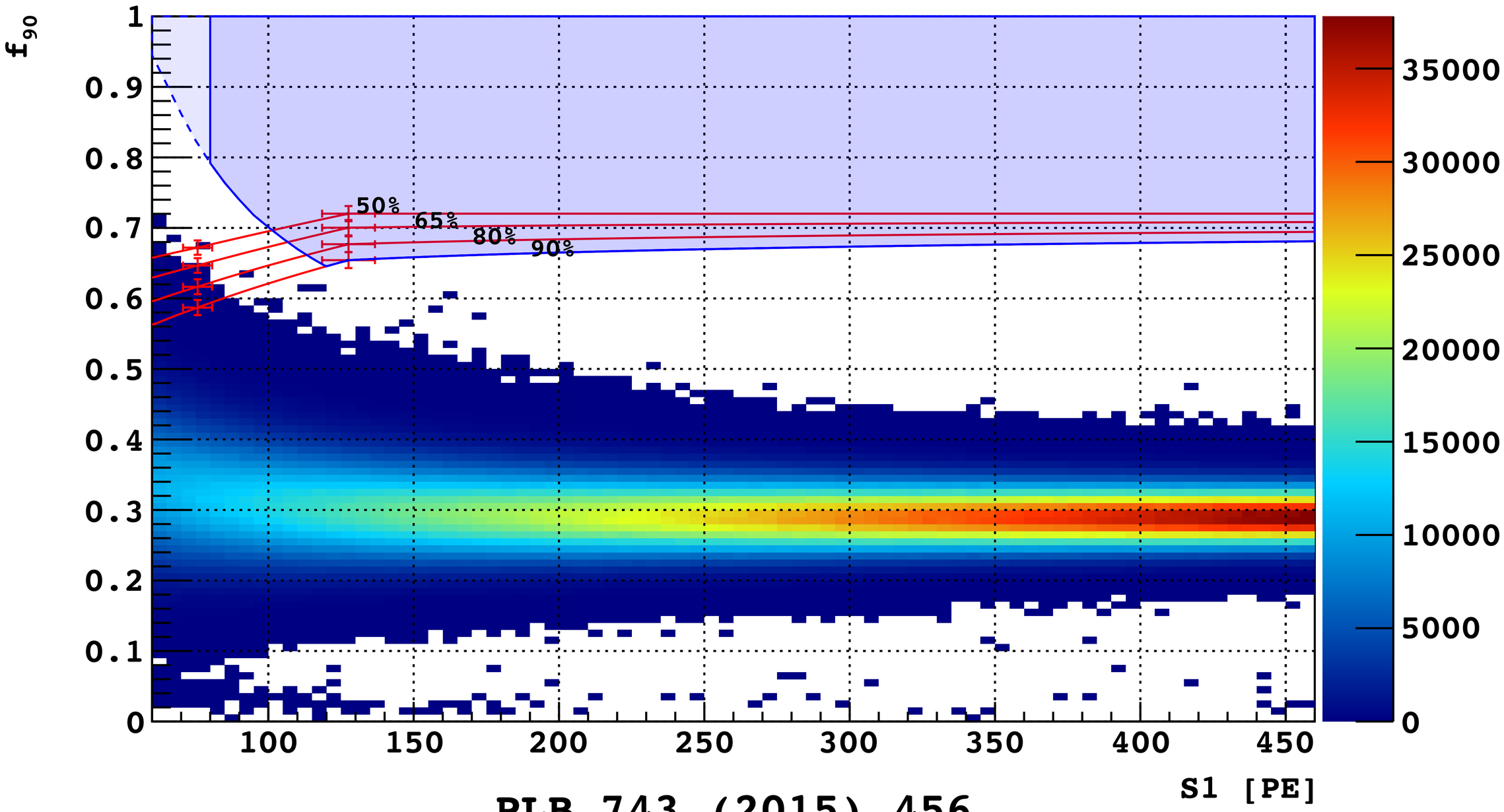


electron - nuclear recoil discrimination

PSD parameter $\mathbf{f_{90}}$: fraction of S1 in the first 90 ns

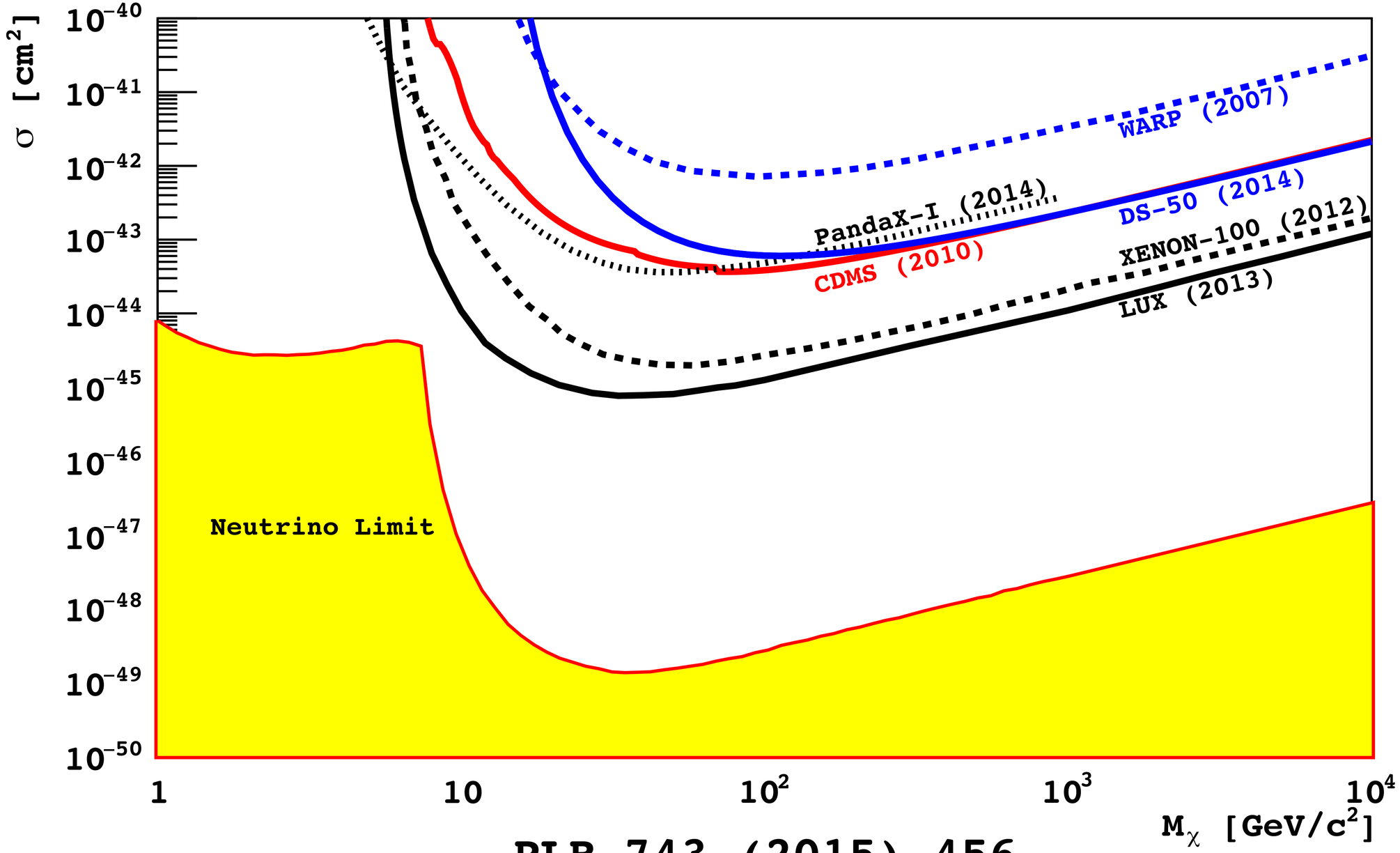
DarkSide-50 First result
Atmospheric Argon run
(2014)

1,422 kg×day - zero background



PLB 743 (2015) 456

Third best dark matter limit at high masses



PLB 743 (2015) 456

Atmospheric Argon run

Background free
PSD electron background discrimination **> 15 10^6**

PLB 743 (2015) 456

Major activities in DarkSide-50 (late 2014 and 2015)

Reconstitution of the **Liquid Scintillator**

Calibration Measurements with Radioactive Sources

Running of LAr-TPC with low-^{39}Ar **UAr**

Full detector system functioning in low background mode
appropriate for extended dark matter search

DarkSide-50
Calibration Campaigns

Gamma sources: **^{57}Co**, **^{133}Ba**, **^{137}Cs**

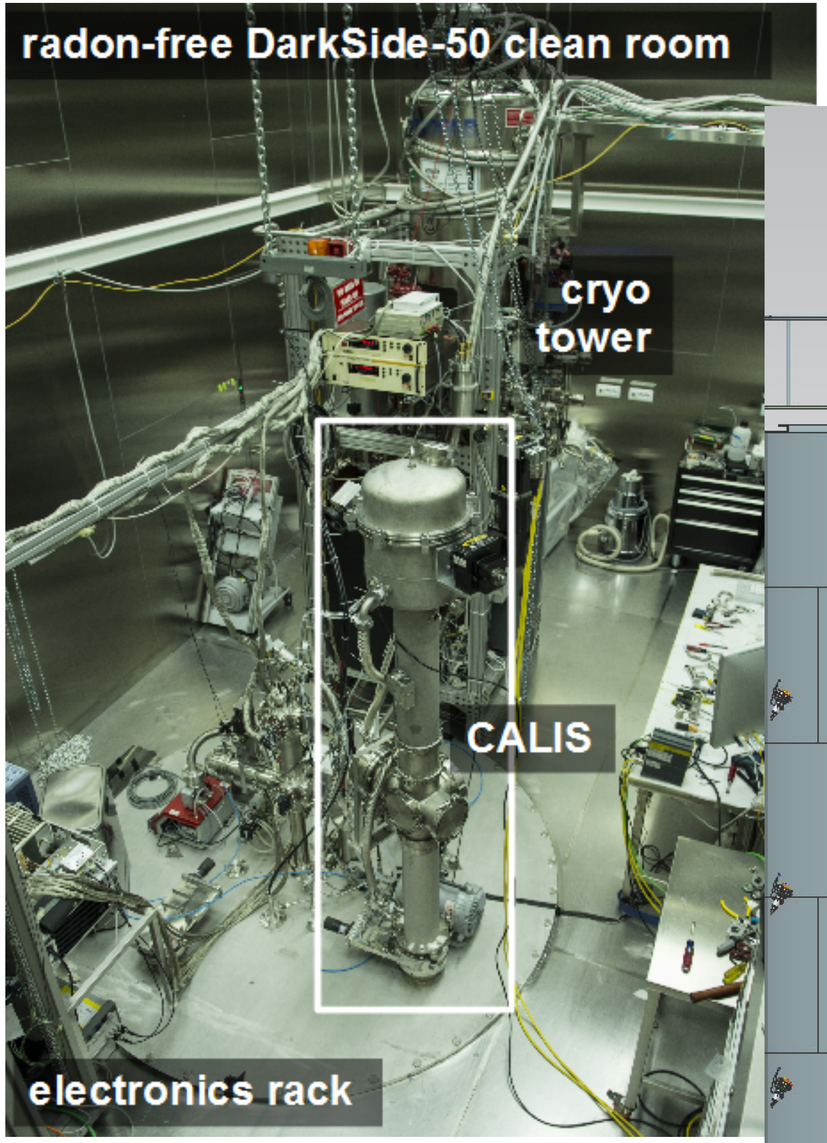
Neutron sources: **^{241}AmBe**

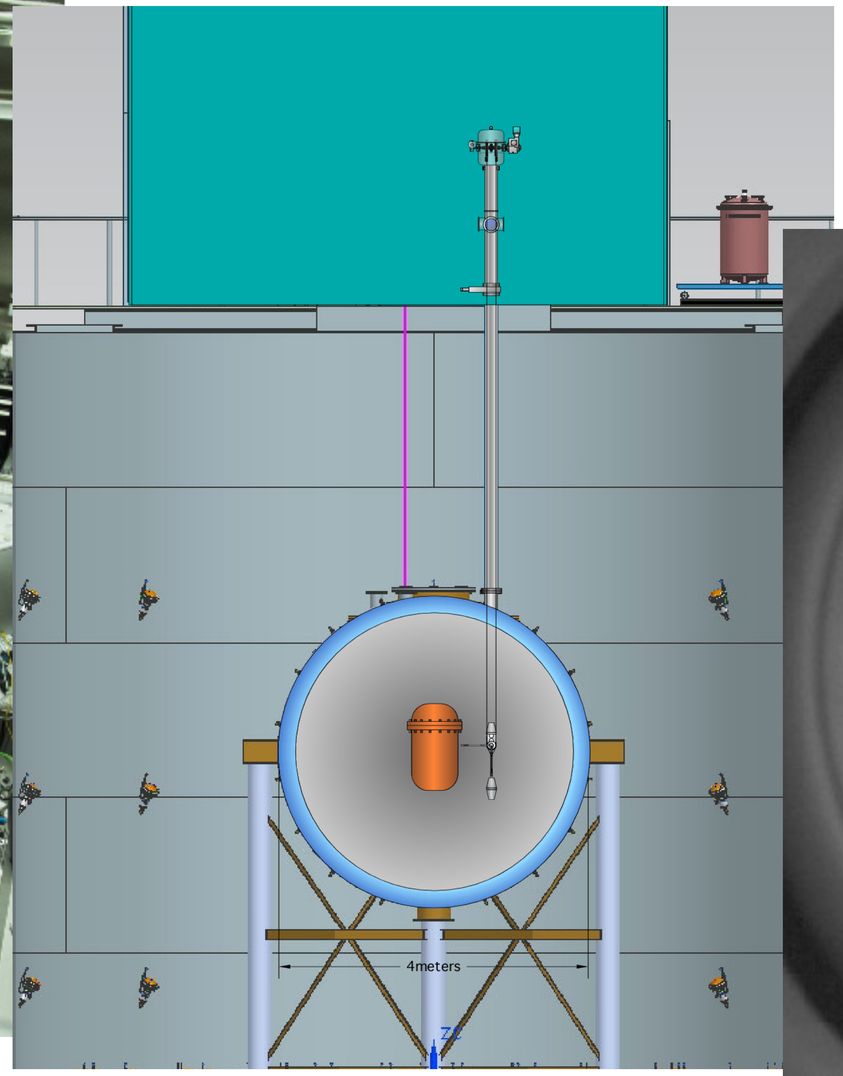
Detector response at different drift fields

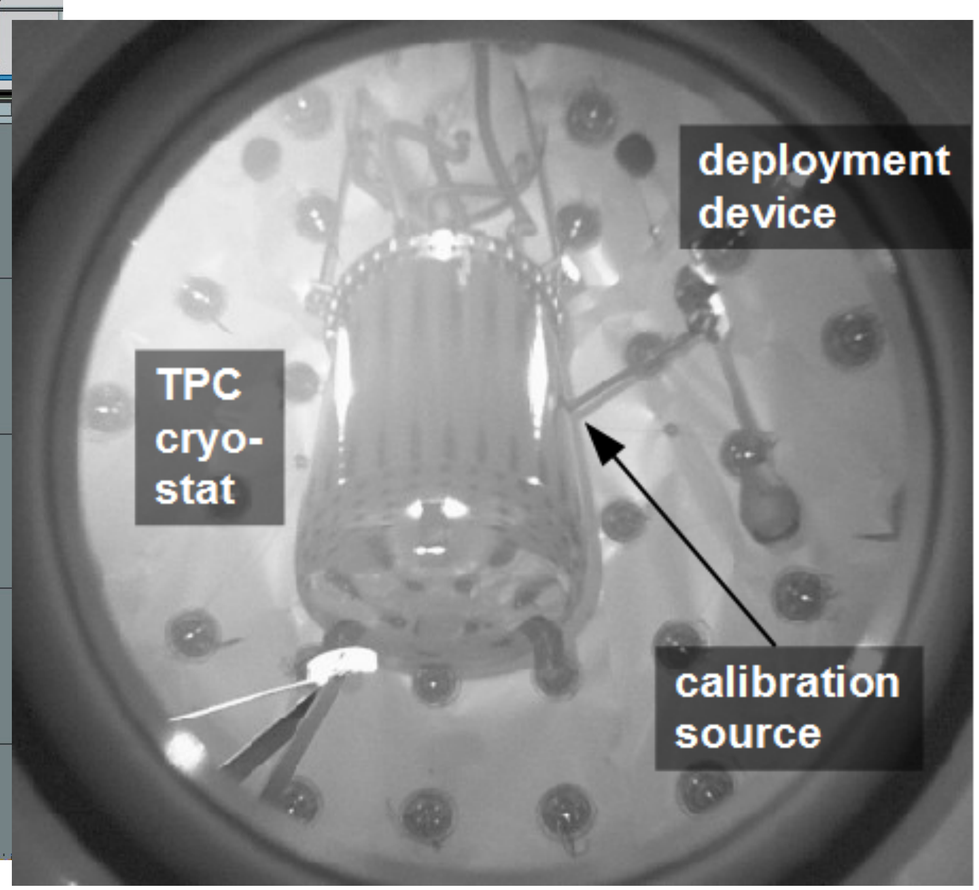
Understanding TPC and LSV, tuning of Monte Carlo

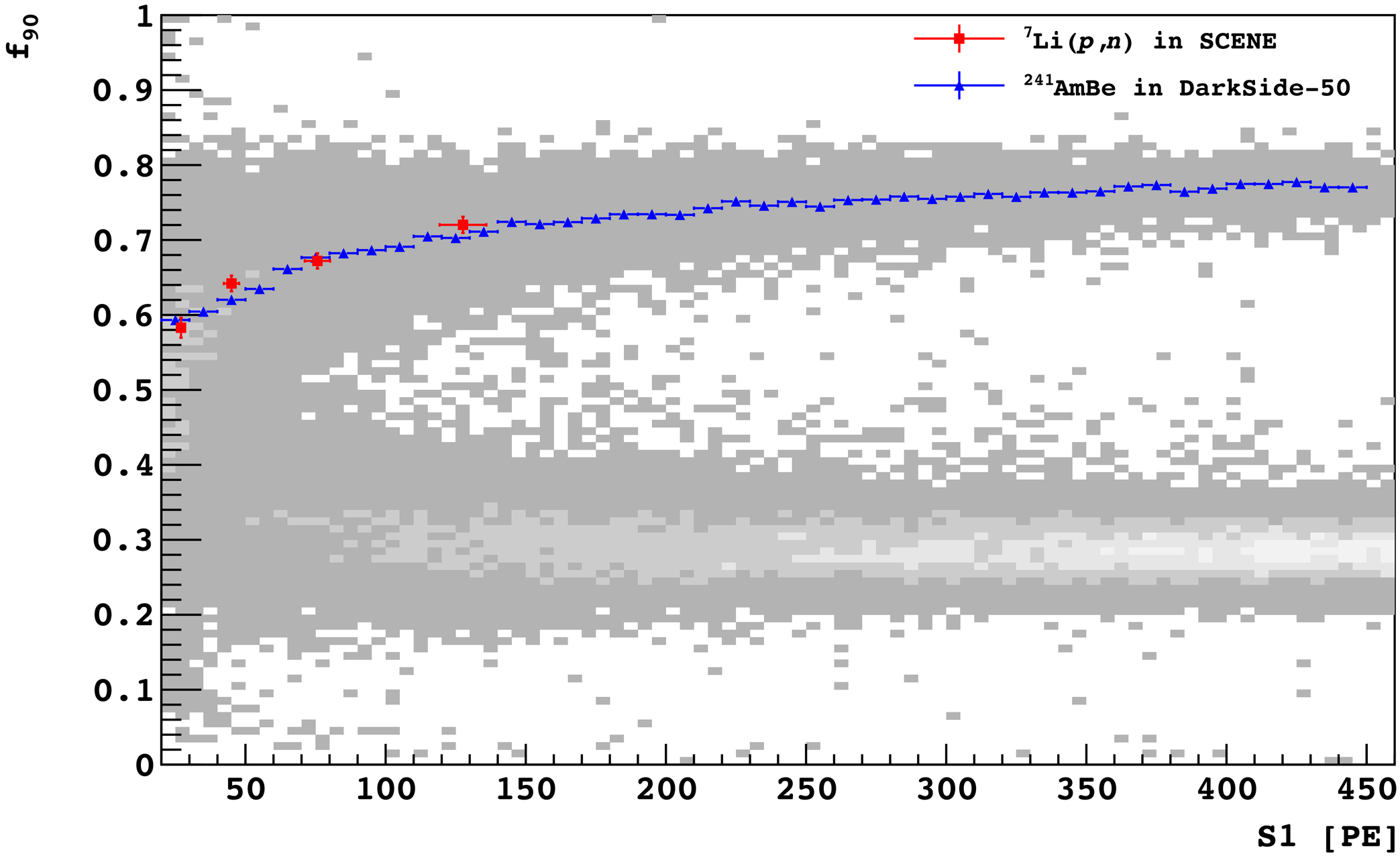
Agreement between DS-50 and extrapolated SCENE acceptance curves

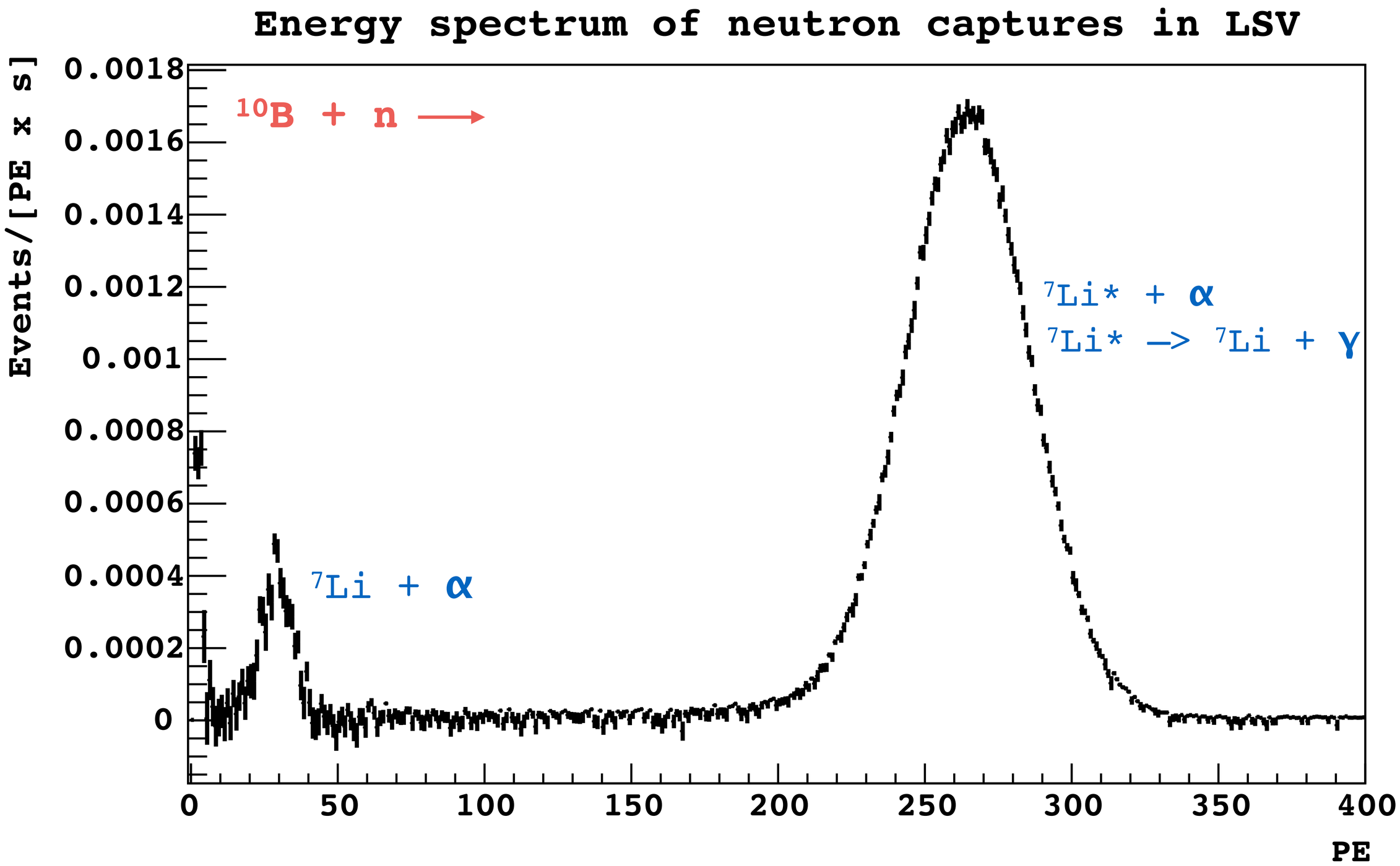
CALIS - CALibration Insertion System



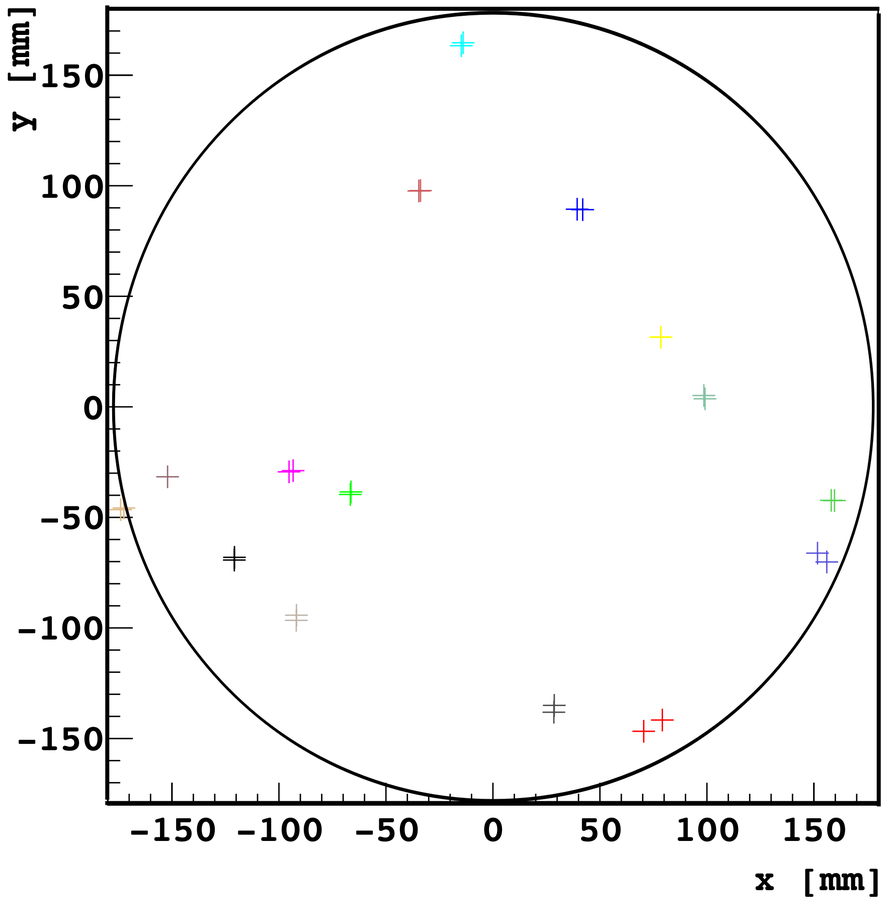





f_{90}
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50
100
150
200
250
300
350
400
450
S1 [PE]
^{7}Li(p,n) in SCENE
^{241}AmBe in DarkSide-50

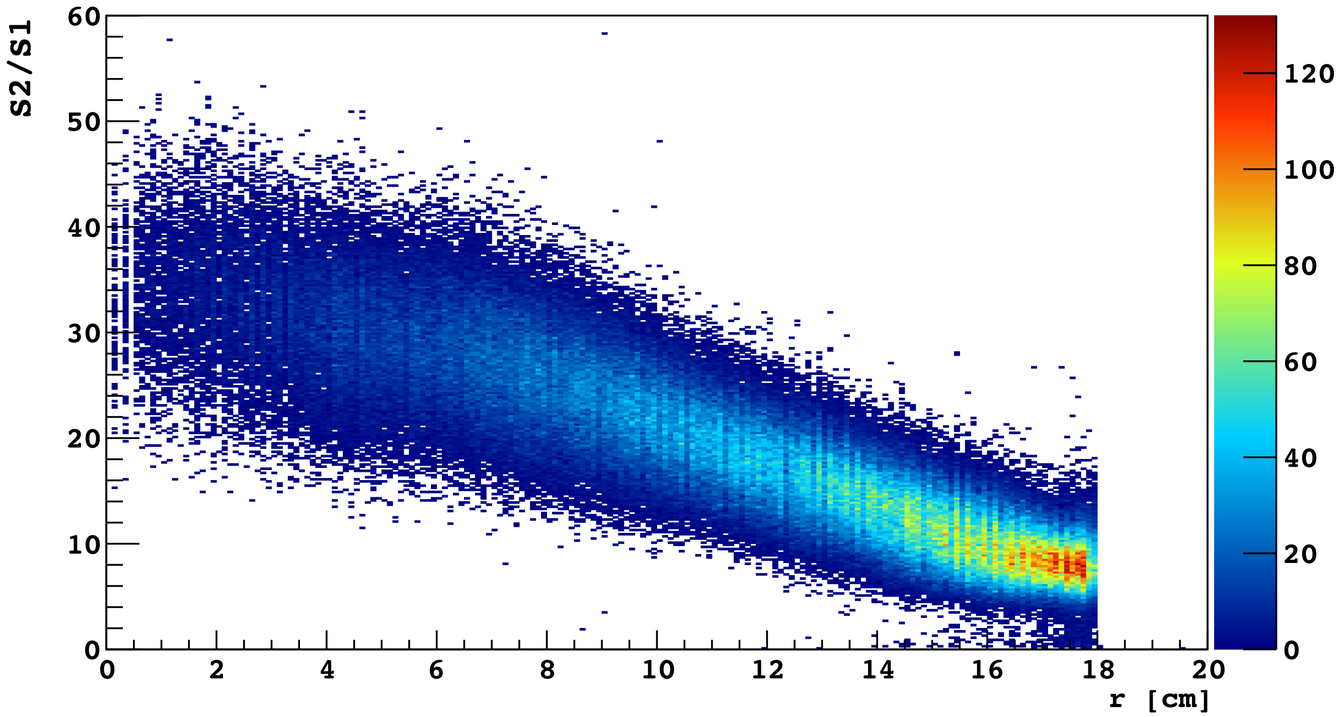

Energy spectrum of neutron captures in LSV
Events/[PE x s]
0.0018
0.0016
0.0014
0.0012
0.001
0.0008
0.0006
0.0004
0.0002
0
0
50
100
150
200
250
300
350
400
PE
$^{10}B + n \longrightarrow$
$^{7}Li + \alpha$
$^{7}Li^{*} + \alpha$
$^{7}Li^{*} \rightarrow {}^{7}Li + \gamma$

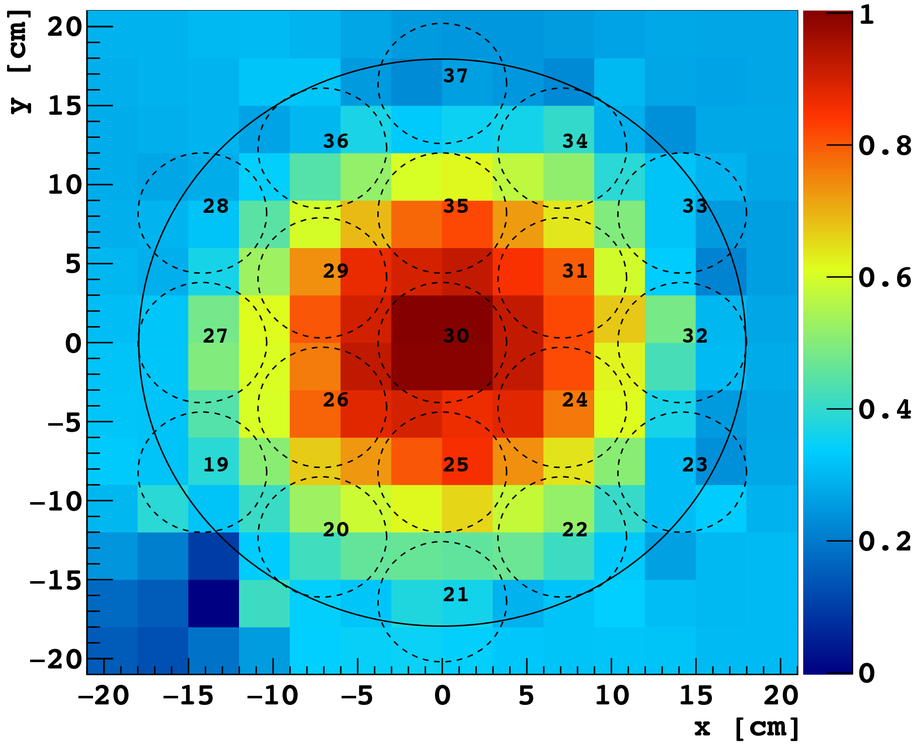
X-Y position reconstruction



Developed x-y reconstruction algorithms
Check in data using ^{214}BiPo coincidences

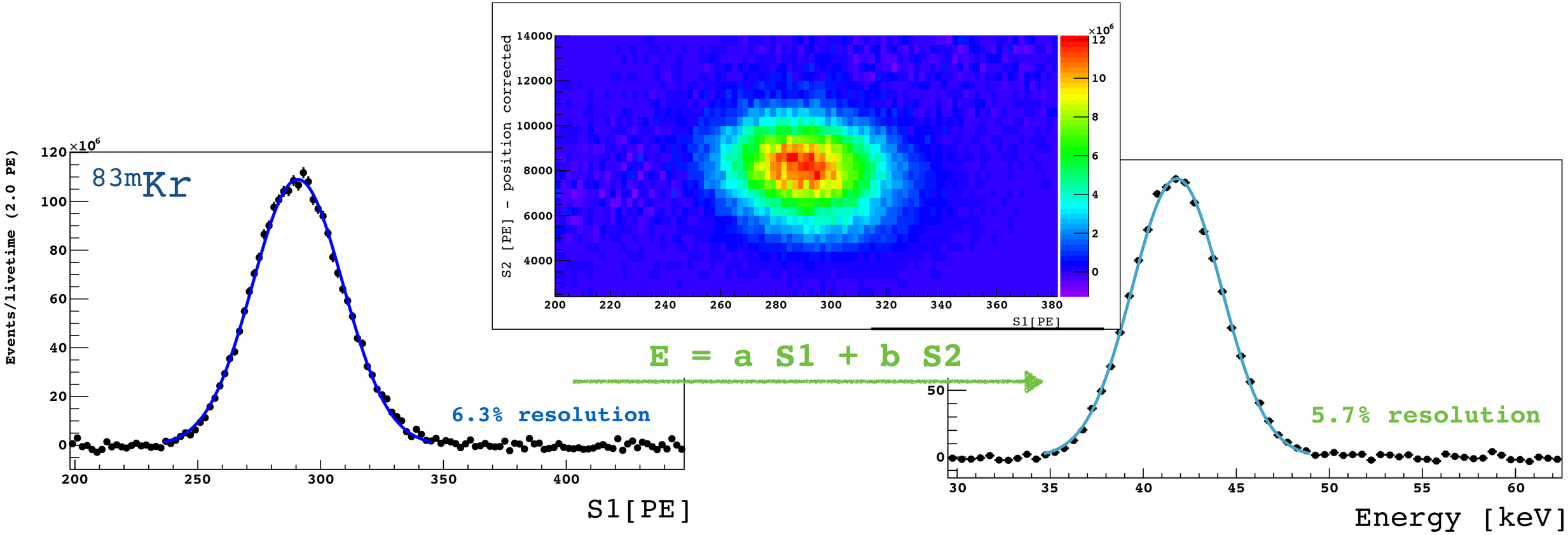
Understanding S2





Measured radial dependence of S2
Evaluated x-y correction map using ^{83m}Kr data

Energy variable



Anti-correlation between S1 and S2 (recombination)
Energy variable (linear combination) with slightly improved resolution

Underground Argon

Extraction in Colorado

Purification at FNAL

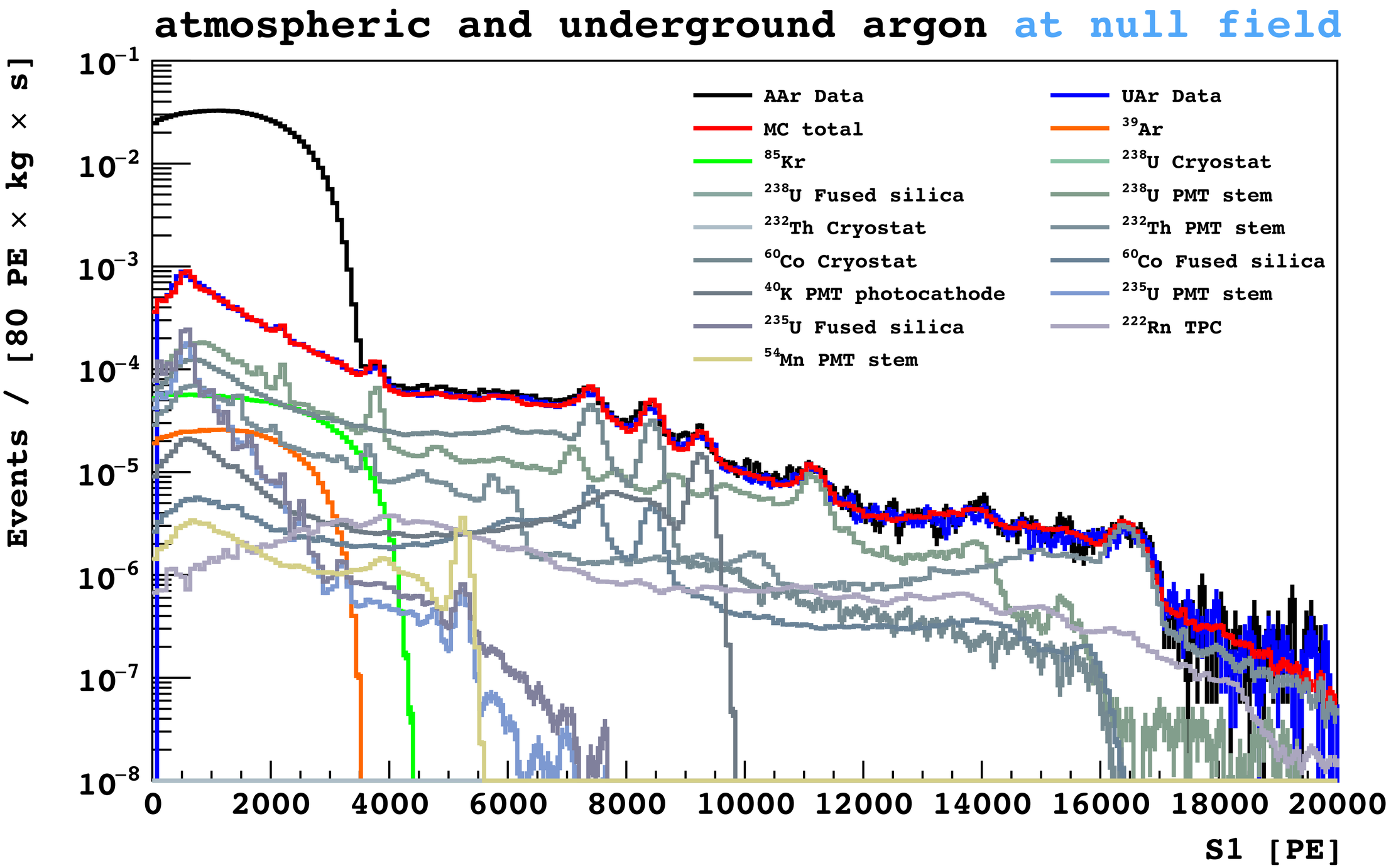
Shipping to LNGS

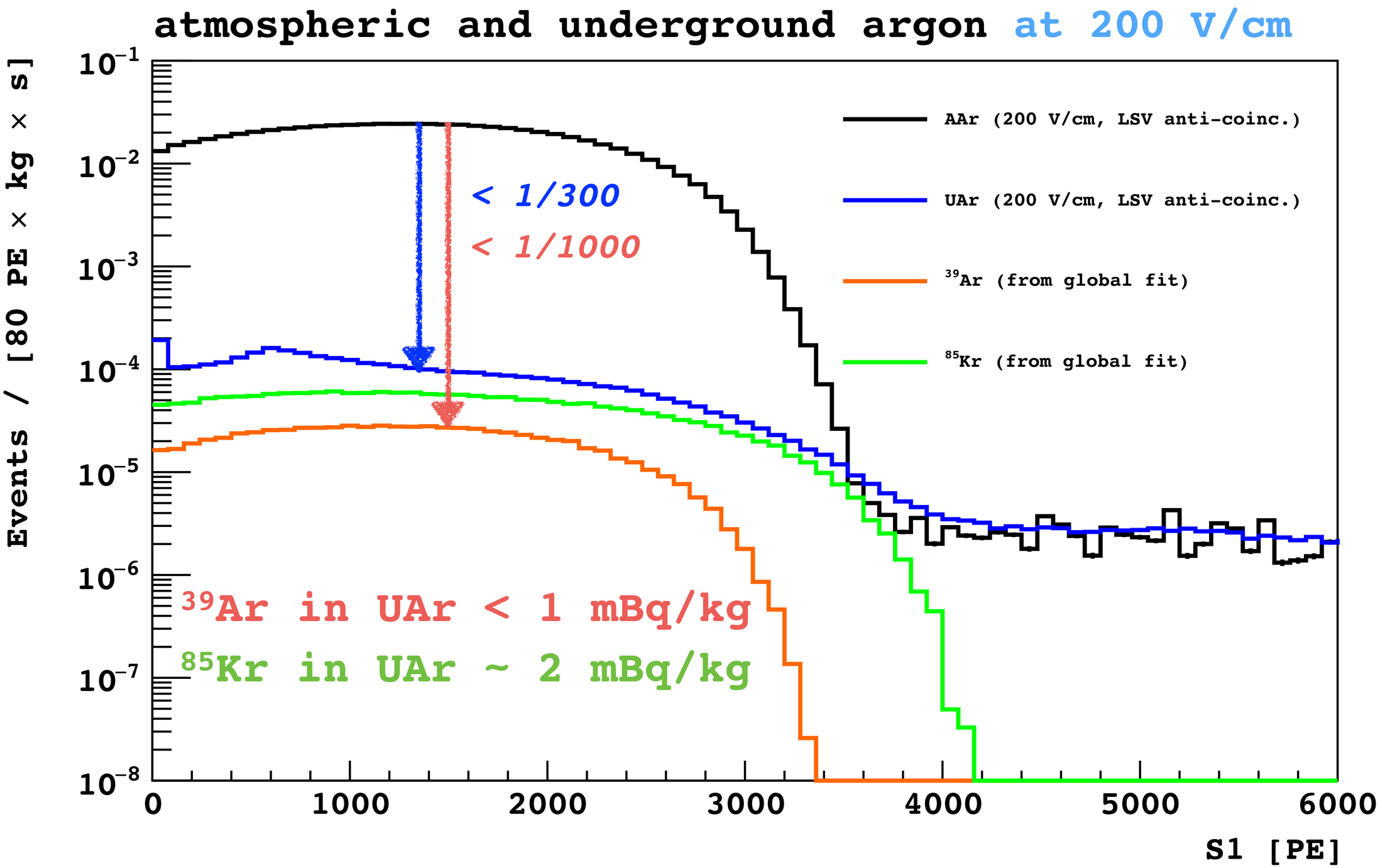
LAr-TPC operations with UAr

AAr draining (Mar 18 - 22, 2015)

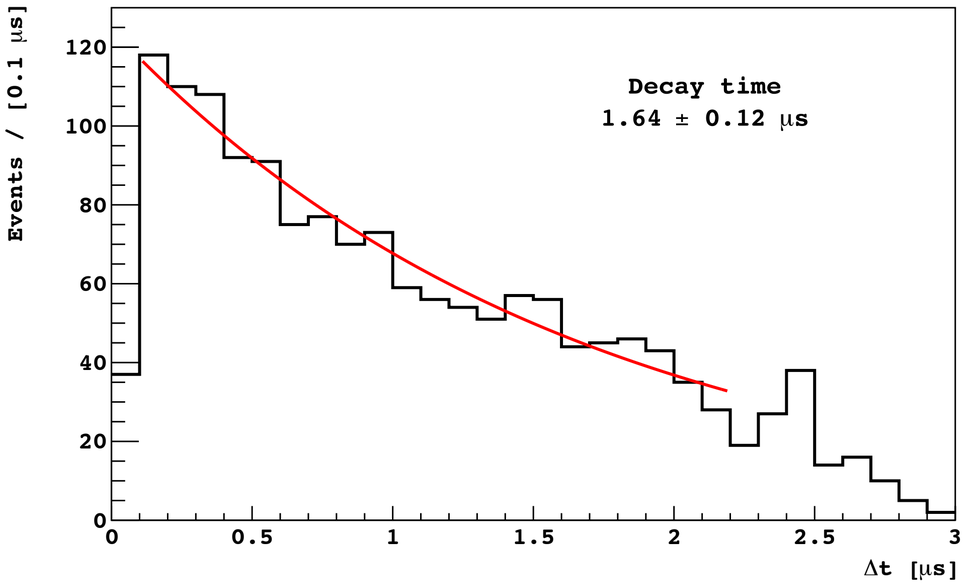
UAr filling (Mar 25 - Apr 1, 2015)

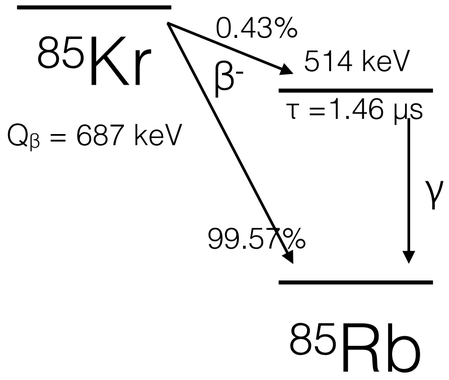
Re-commissioning of the detector: ^{39}**Ar**, light yield…

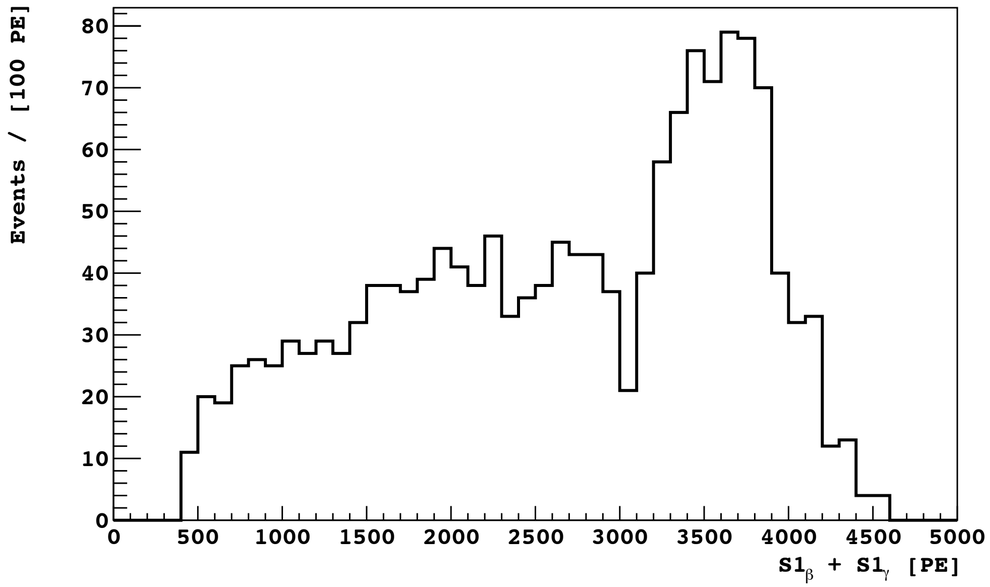

atmospheric and underground argon at null field
Events / [80 PE × kg × s]
S1 [PE]
AAr Data
MC total
85Kr
238U Fused silica
232Th Cryostat
60Co Cryostat
40K PMT photocathode
235U Fused silica
54Mn PMT stem
UAr Data
39Ar
238U Cryostat
238U PMT stem
232Th PMT stem
60Co Fused silica
235U PMT stem
222Rn TPC


atmospheric and underground argon at 200 V/cm
Events / [80 PE × kg × s]
S1 [PE]
AAr (200 V/cm, LSV anti-coinc.)
UAr (200 V/cm, LSV anti-coinc.)
39Ar (from global fit)
85Kr (from global fit)
< 1/300
< 1/1000
39Ar in UAr < 1 mBq/kg
85Kr in UAr ~ 2 mBq/kg

^{85}Kr in UAr with coincident γ search





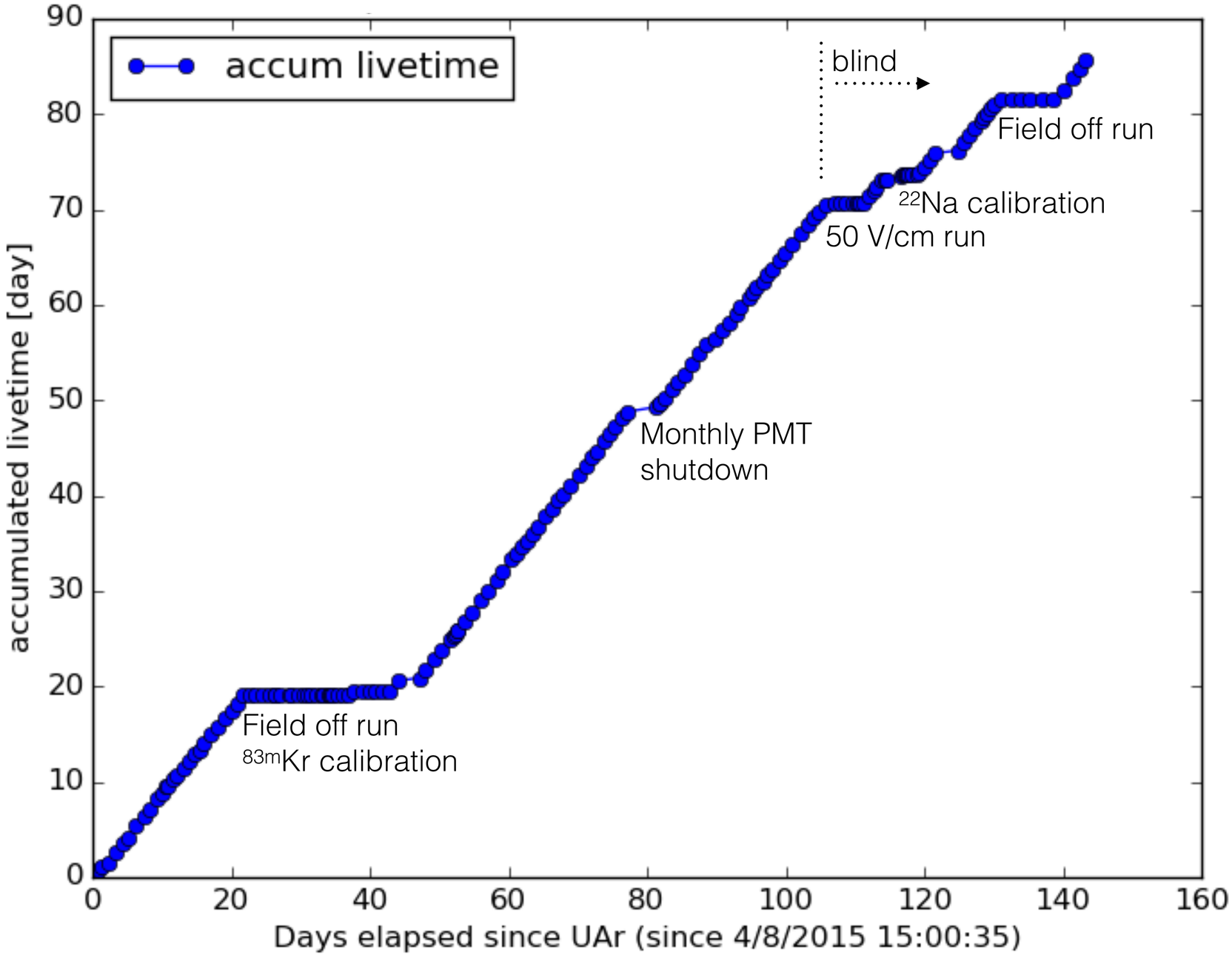


Check spectral evidence using rare ^{85m}Rb branch with coincident γ

Agreement between coincidence search (33.1 ± 0.9 cpd of ^{85}Kr in ^{85m}Rb) and expected from spectral fit (34.9 ± 1.0 cpd of ^{85}Kr in ^{85m}Rb)

Dark matter search with UAr

started on April 8, 2015


accum livetime
blind
Field off run
^{22}Na calibration
50 V/cm run
Monthly PMT
shutdown
Field off run
^{83m}Kr calibration
accumulated livetime [day]
Days elapsed since UAr (since 4/8/2015 15:00:35)
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160

Dark matter search with UAr

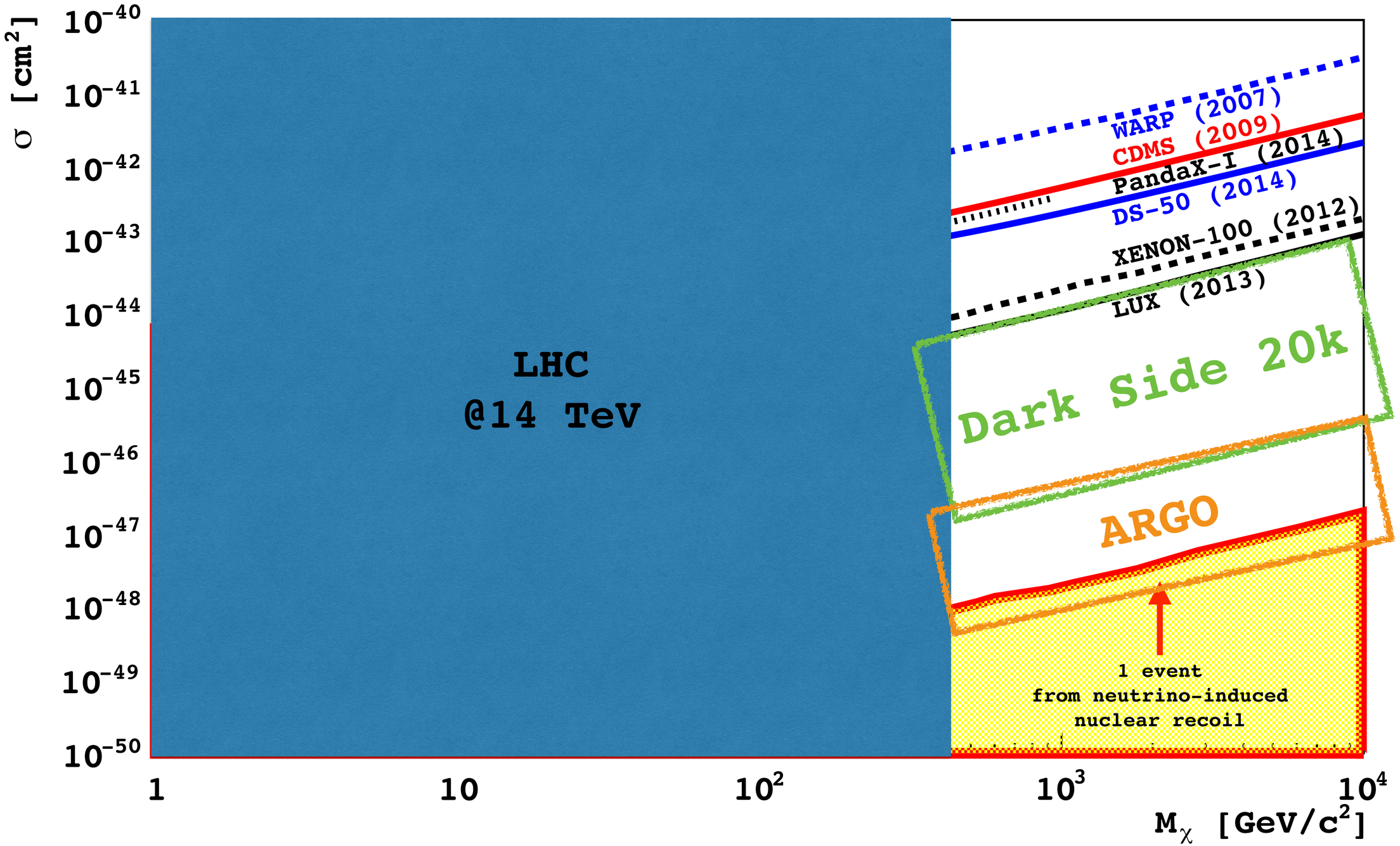
Non-blind analysis on first 70 days of UAr

TPC cuts as close as possible to AAr search

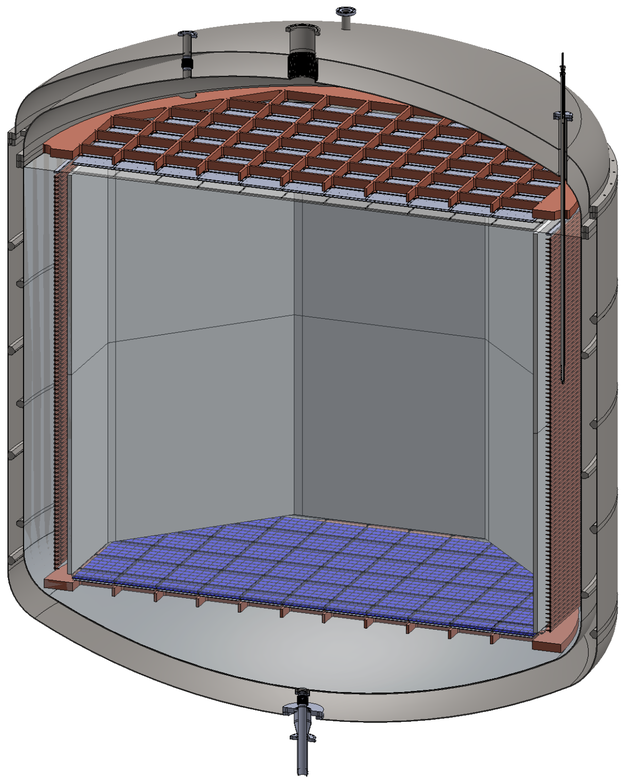
LSV efficiency increased (see S. Westerdale's presentation)

Will be public in few weeks

DarkSide 20k and Argo

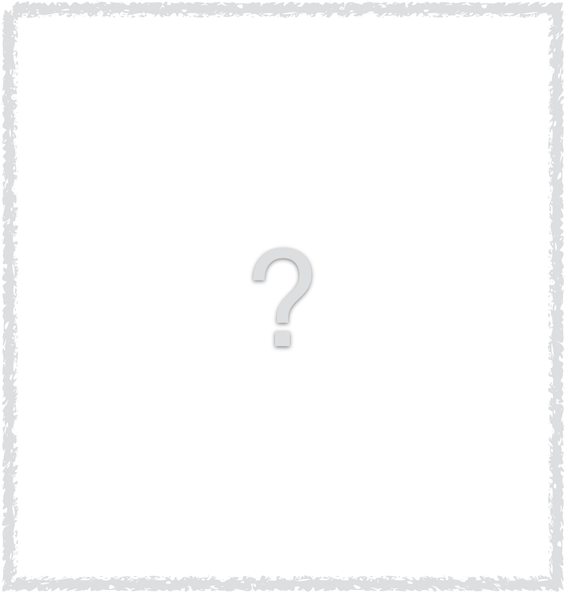

σ [cm²]
10⁻⁴⁰
10⁻⁴¹
10⁻⁴²
10⁻⁴³
10⁻⁴⁴
10⁻⁴⁵
10⁻⁴⁶
10⁻⁴⁷
10⁻⁴⁸
10⁻⁴⁹
10⁻⁵⁰
1
10
10²
10³
10⁴
M_χ [GeV/c²]
LHC
@14 TeV
WARP (2007)
CDMS (2009)
PandaX-I (2014)
DS-50 (2014)
XENON-100 (2012)
LUX (2013)
Dark Side 20k
ARGO
1 event
from neutrino-induced
nuclear recoil

Future DarkSide detectors



DS-20k

30 tonne (20 tonne fiducial) detector



ARGO

300 tonne (200 tonne fiducial) detector

DarkSide 20k LAr-TPC

15 m^2 of **SiPM's**

reduced radioactivity
improved photon detection yield

Low-radioactivity titanium cryostat from Russia

Further depletion of ^{39}Ar

Urania

Replacement of the Ar extraction plant in Colorado

Reach capacity of **100 kg/day** of UAr

MIUR/INFN funds from Progetto Premiale 2013

Aria

350 m tall distillation column in the Seruci mine in Sardinia, Italy

Chemical and isotopic purification of Underground Argon

Exploits finite vapor pressure difference between $^{39}Ar/^{40}Ar$

Protocollo di Intesa between INFN and Regione Sardegna

DarkSide-20k and ARGO

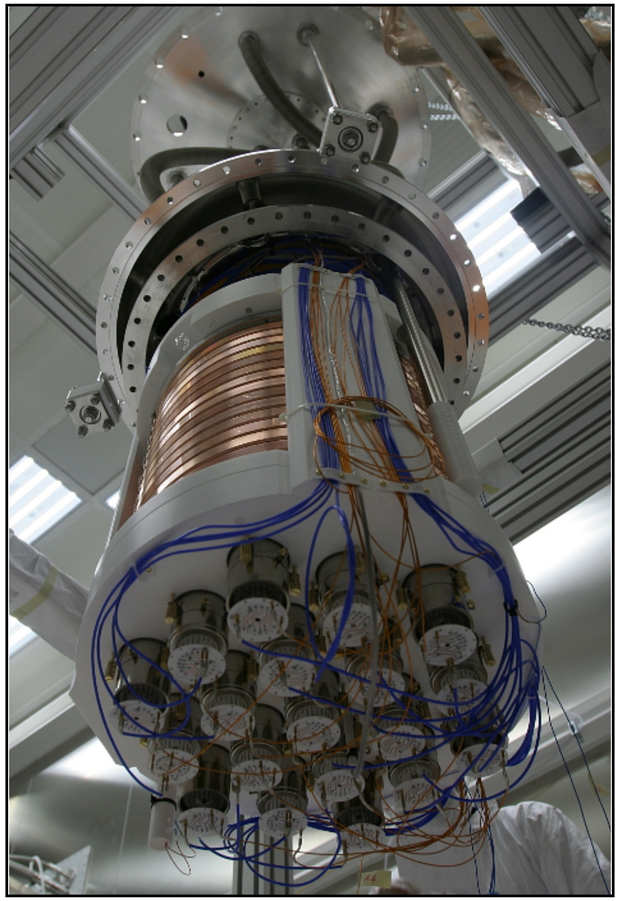
DarkSide status and outlook

- **DS-50** running in background free mode
- **U**nderground **Ar**gon, ^{39}Ar isotopic depletion **< 1/1000**
- **Dark matter search** with UAr, results are imminent
- **DS-20k** and **Argo** ambitious programs

The End

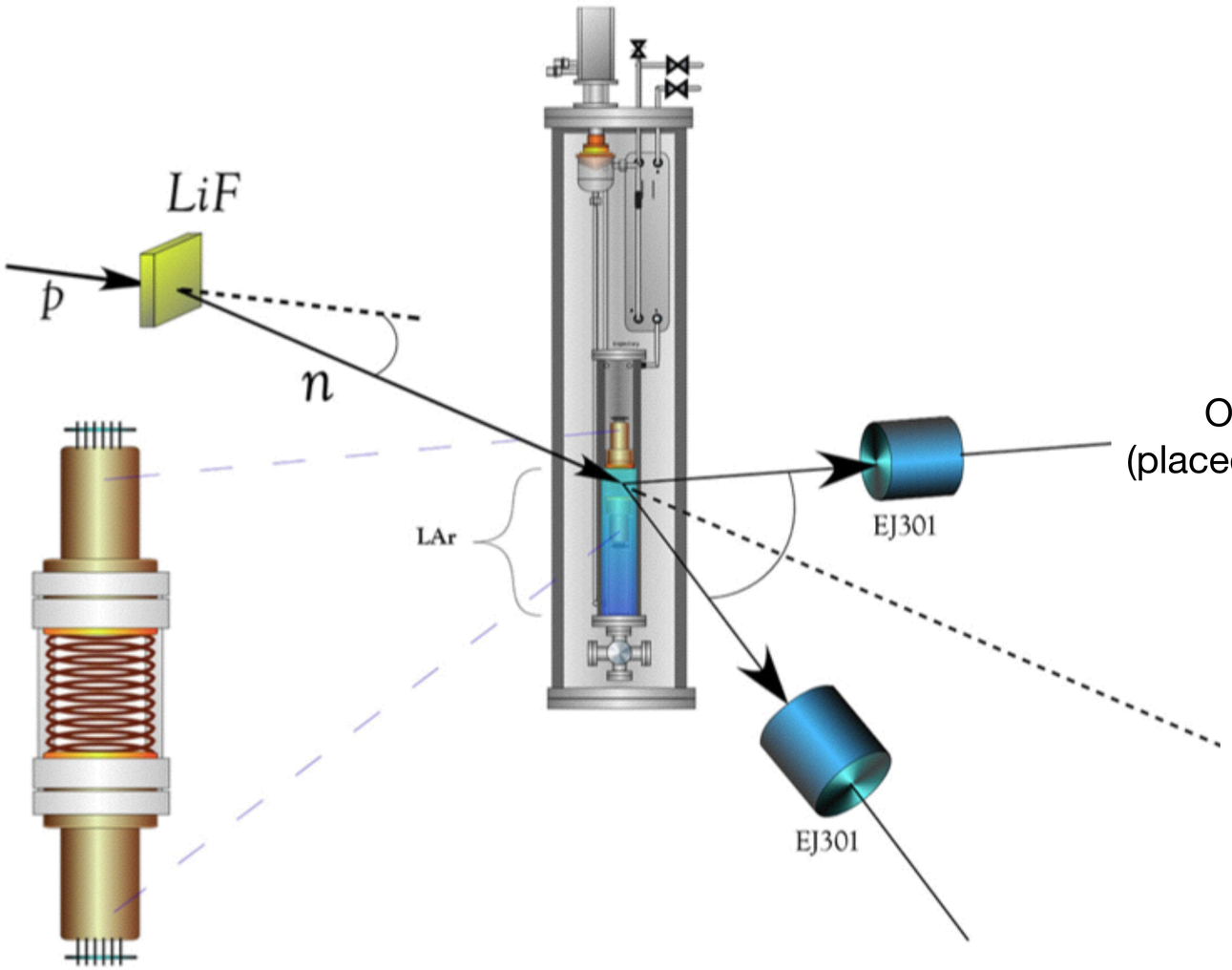
Backup

The DarkSide-50 LAr-TPC



SCENE

Proton Beam
at University of Notre Dame



Organic Liquid Scintillators
(placed at precise deflection angles)

LAr-TPC
(based on DarkSide
design)

$^{7}Li(p, n)^{7}Be$ reaction produces low energy monoenergetic neutrons
TOF measurement between target, LAr and organic scintillators allows
clean identification of elastic neutron interactions of known energy

Liquid Scintillator Veto reconstitution

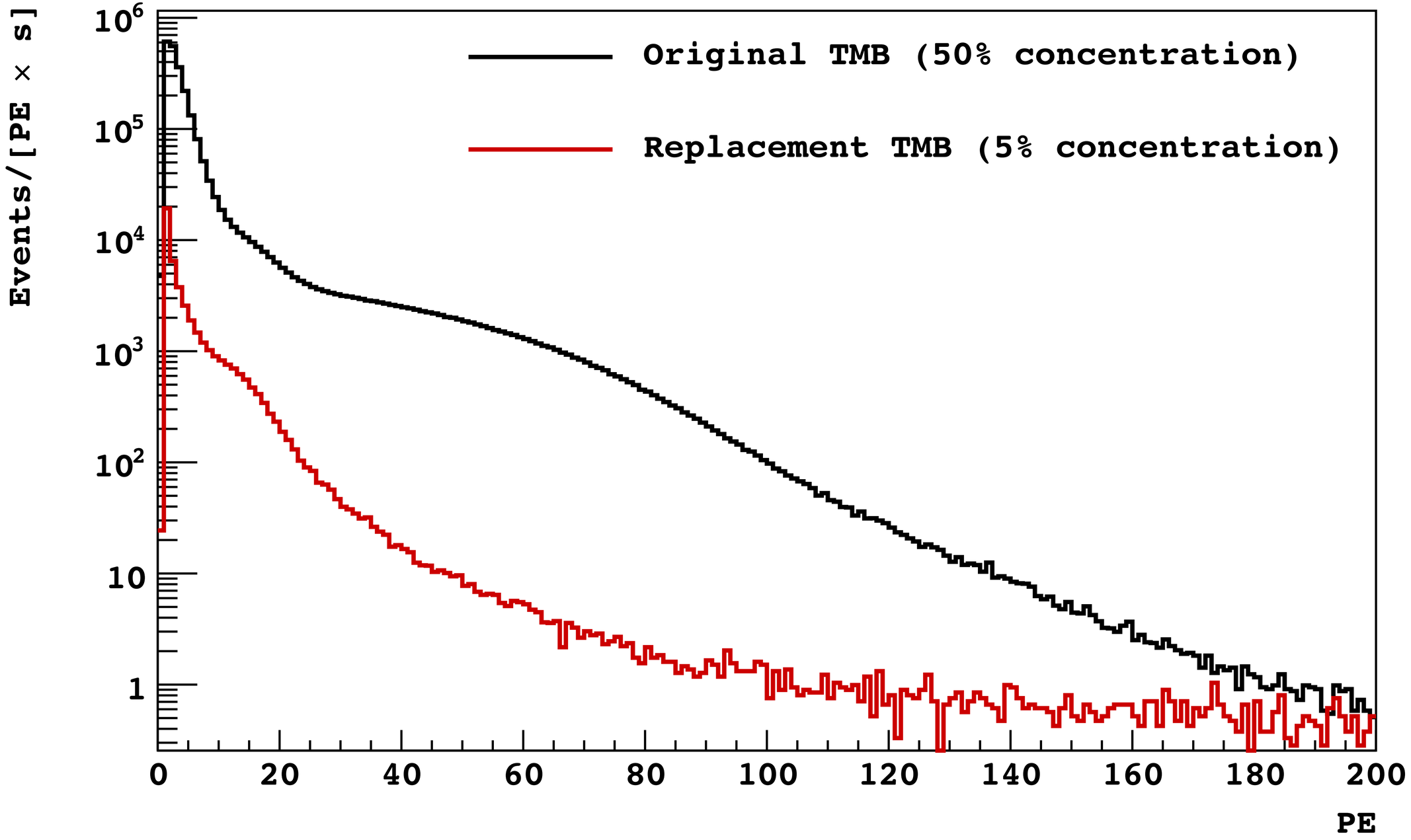
Removing high-^{14}C TMB (June, 2014)

Add radiopure TMB at 5% concentration (Jan 2015)

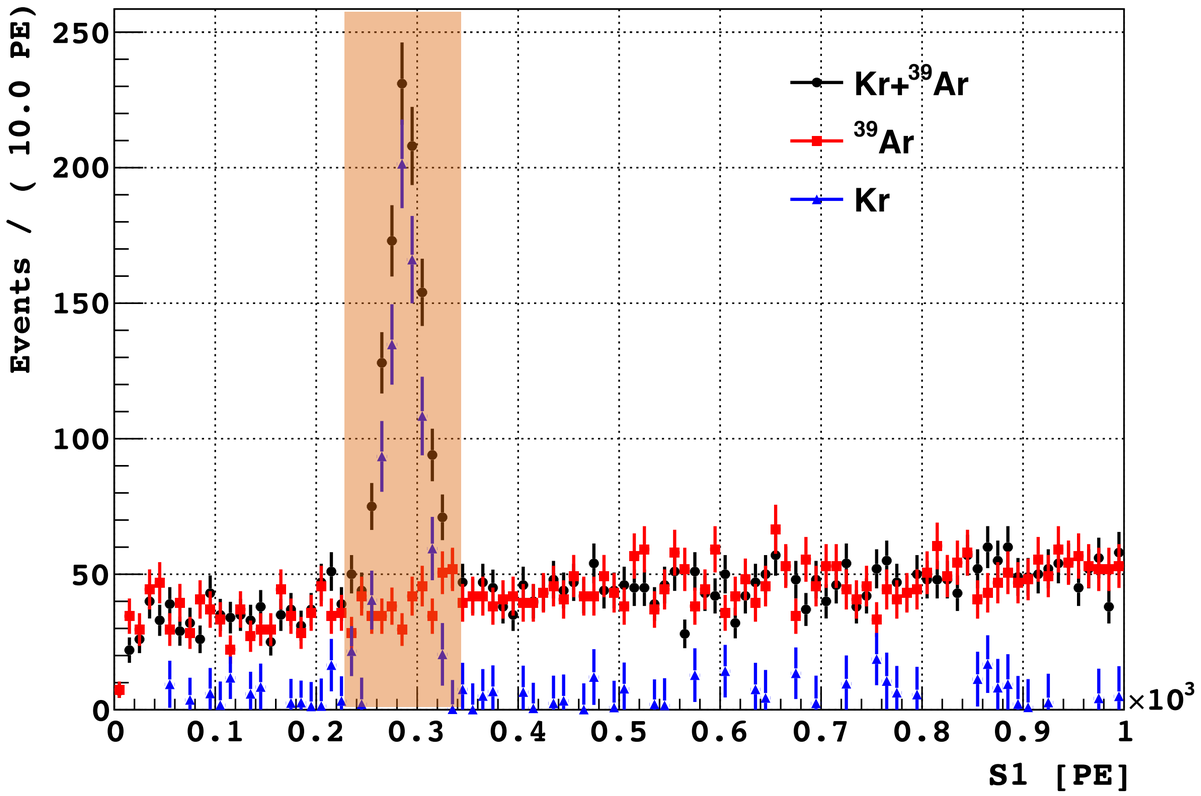
^{14}C activity decreased from 150 kBq to 0.3 kBq

More efficiency neutron veto cuts than in AAr campaign

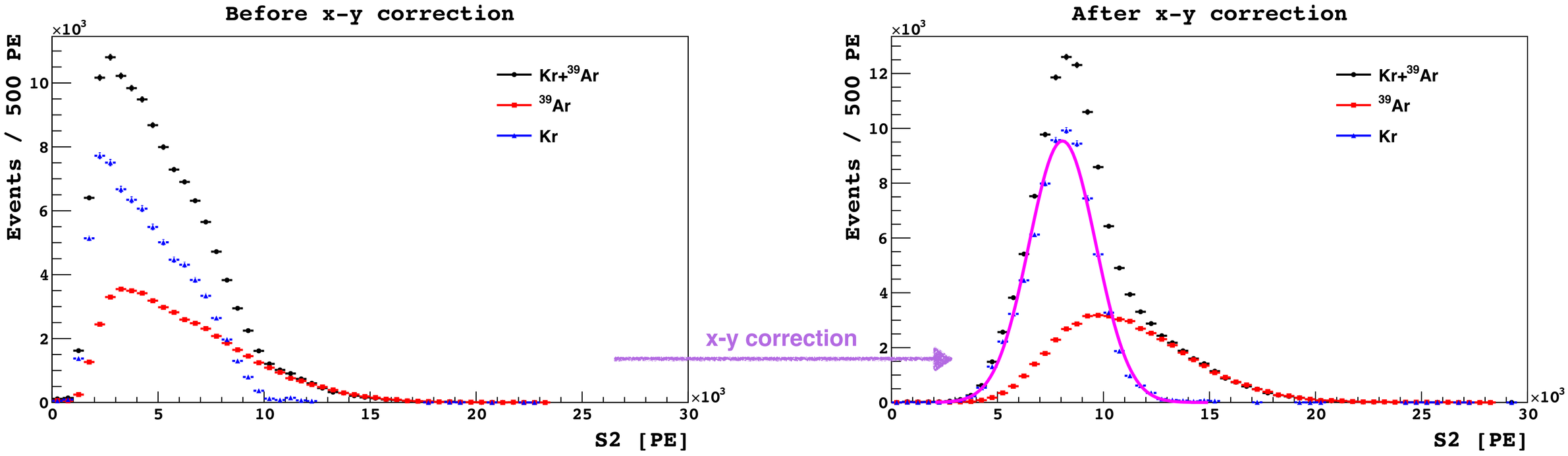
LSV energy spectrum



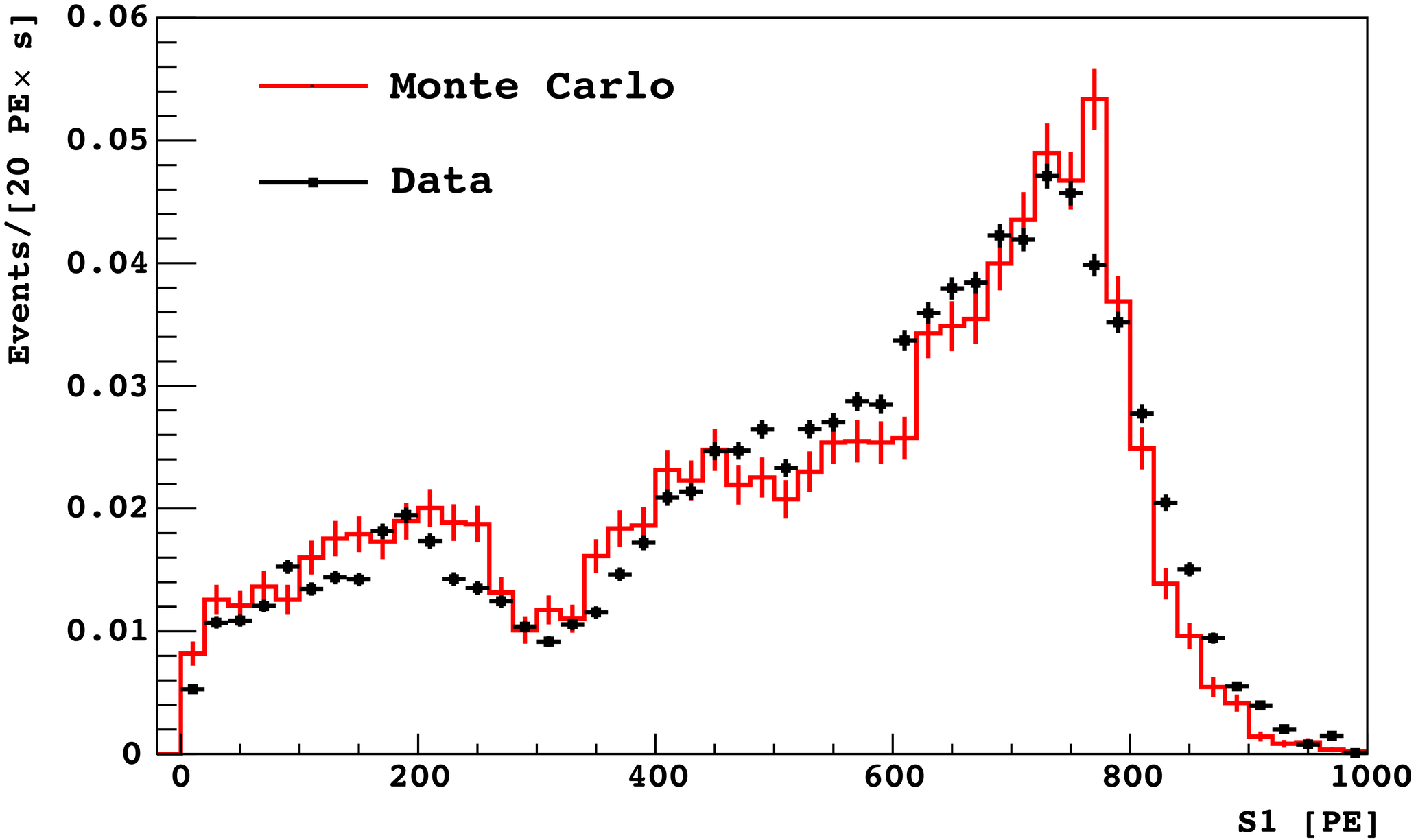
Calibration with ^{83m}Kr

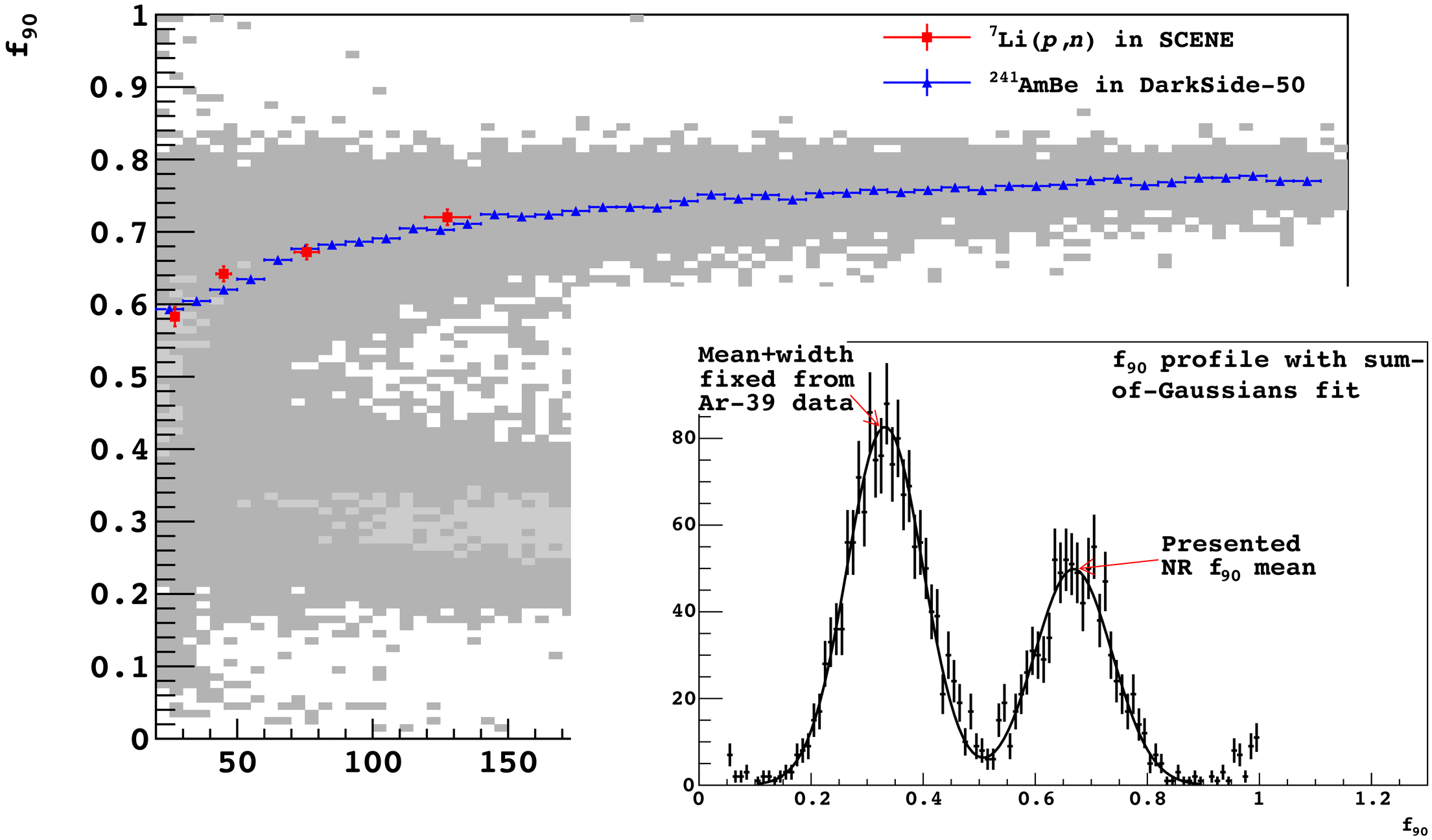


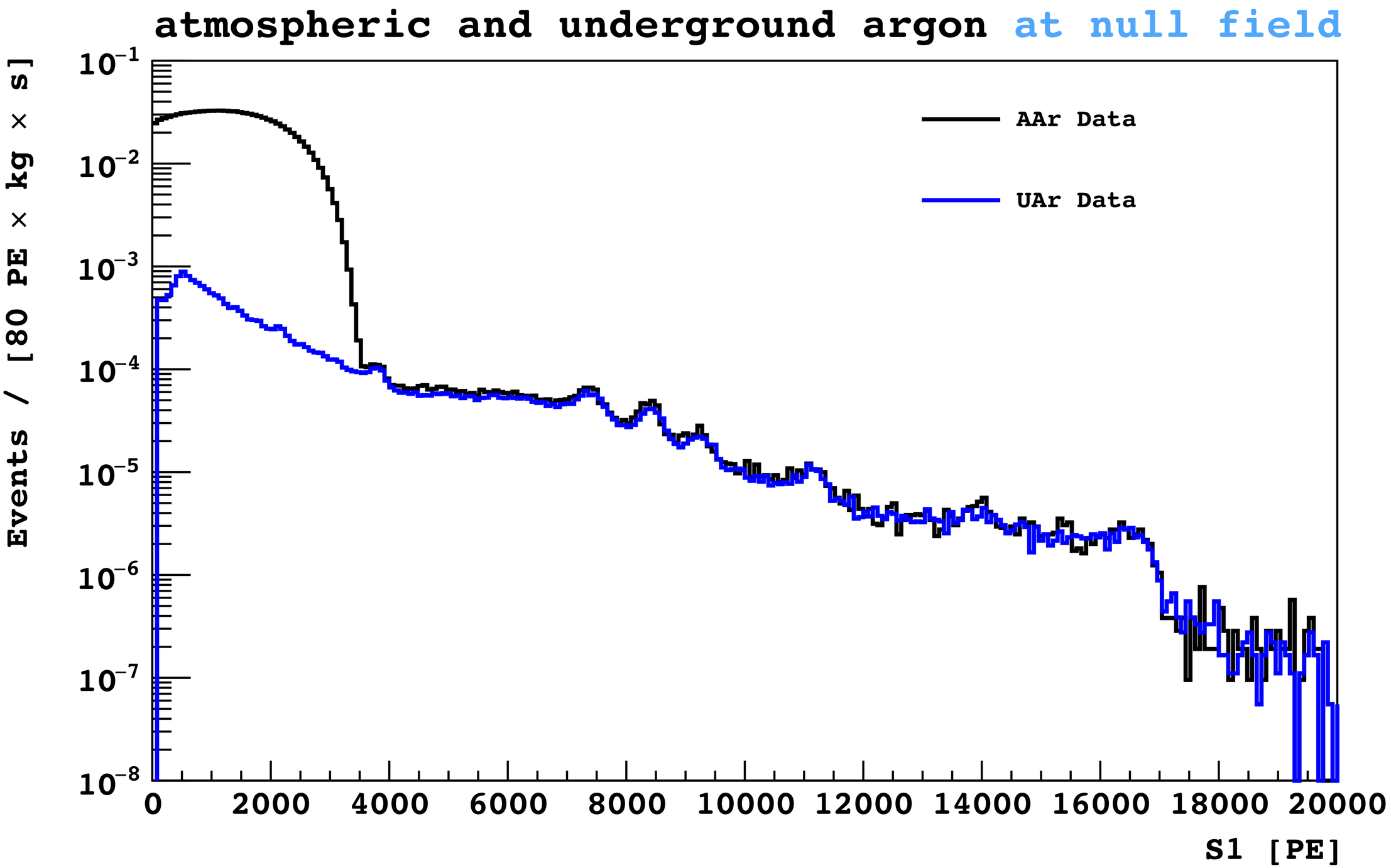
Understanding S2

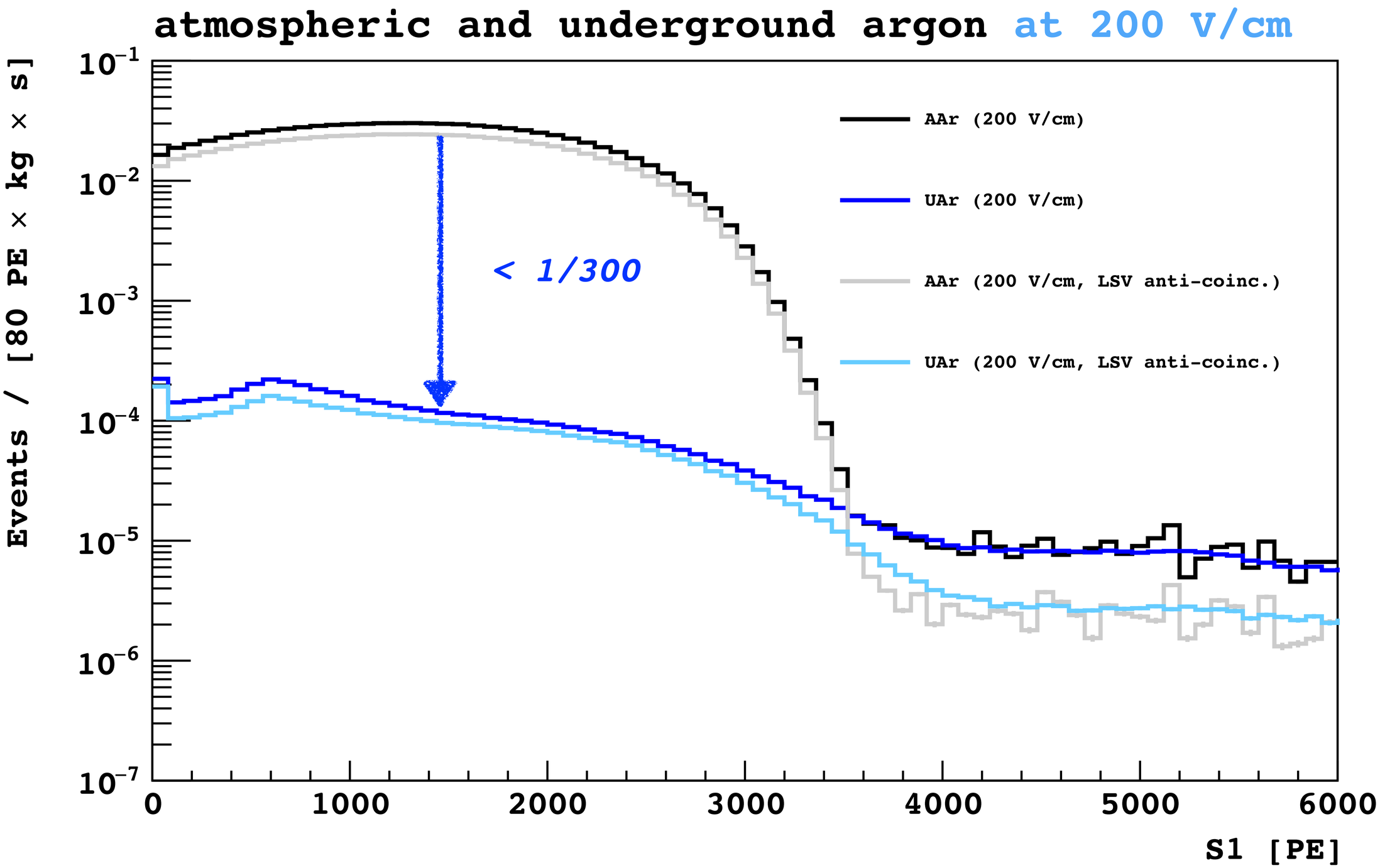


DATA-MC comparison: ^{57}Co source next to the cryostat




f_{90}
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
50
100
150
^{7}Li(p,n) in SCENE
^{241}AmBe in DarkSide-50
Mean+width fixed from Ar-39 data
f_{90} profile with sum-of-Gaussians fit
Presented NR f_{90} mean
80
60
40
20
0
0.2
0.4
0.6
0.8
1
1.2
f_{90}


atmospheric and underground argon at null field
AAr Data
UAr Data
Events / [80 PE × kg × s]
S1 [PE]
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000


atmospheric and underground argon at 200 V/cm
Events / [80 PE × kg × s]
S1 [PE]
AAr (200 V/cm)
UAr (200 V/cm)
AAr (200 V/cm, LSV anti-coinc.)
UAr (200 V/cm, LSV anti-coinc.)
< 1/300
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0
1000
2000
3000
4000
5000
6000

Experiment	σ [cm²] @1 TeV/c²	σ [cm²] @10 TeV/c²
LUX [10k kg×day Xe]	1.1×10^{-44}	1.2×10^{-43}
XENON [7.6k kg×day Xe]	1.9×10^{-44}	1.9×10^{-43}
DS-50 [1.4k kg×day Ar]	2.3×10^{-43}	2.1×10^{-42}
ArDM [1.5 tonne×yr Ar]	8×10^{-45}	7×10^{-44}
DEAP-3600 [3.0 tonne×yr Ar]	5×10^{-46}	5×10^{-45}
XENON-1ton [2.7 tonne×yr Xe]	3×10^{-46}	3×10^{-45}
LZ [15 tonne×yr Xe]	5×10^{-47}	5×10^{-46}
DS-20k [100 tonne×yr]	9×10^{-48}	9×10^{-47}
1 Neutrino Event [400 tonne×yr Ar or 300 tonne×yr Xe]	2×10^{-48}	2×10^{-47}
ARGO [1,000 tonne×yr]	9×10^{-49}	9×10^{-48}