DSU 2016
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Direct dark matter detection with the DarkSide experiment

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On behalf of the DarkSide Collaboration

What’s DarkSide?

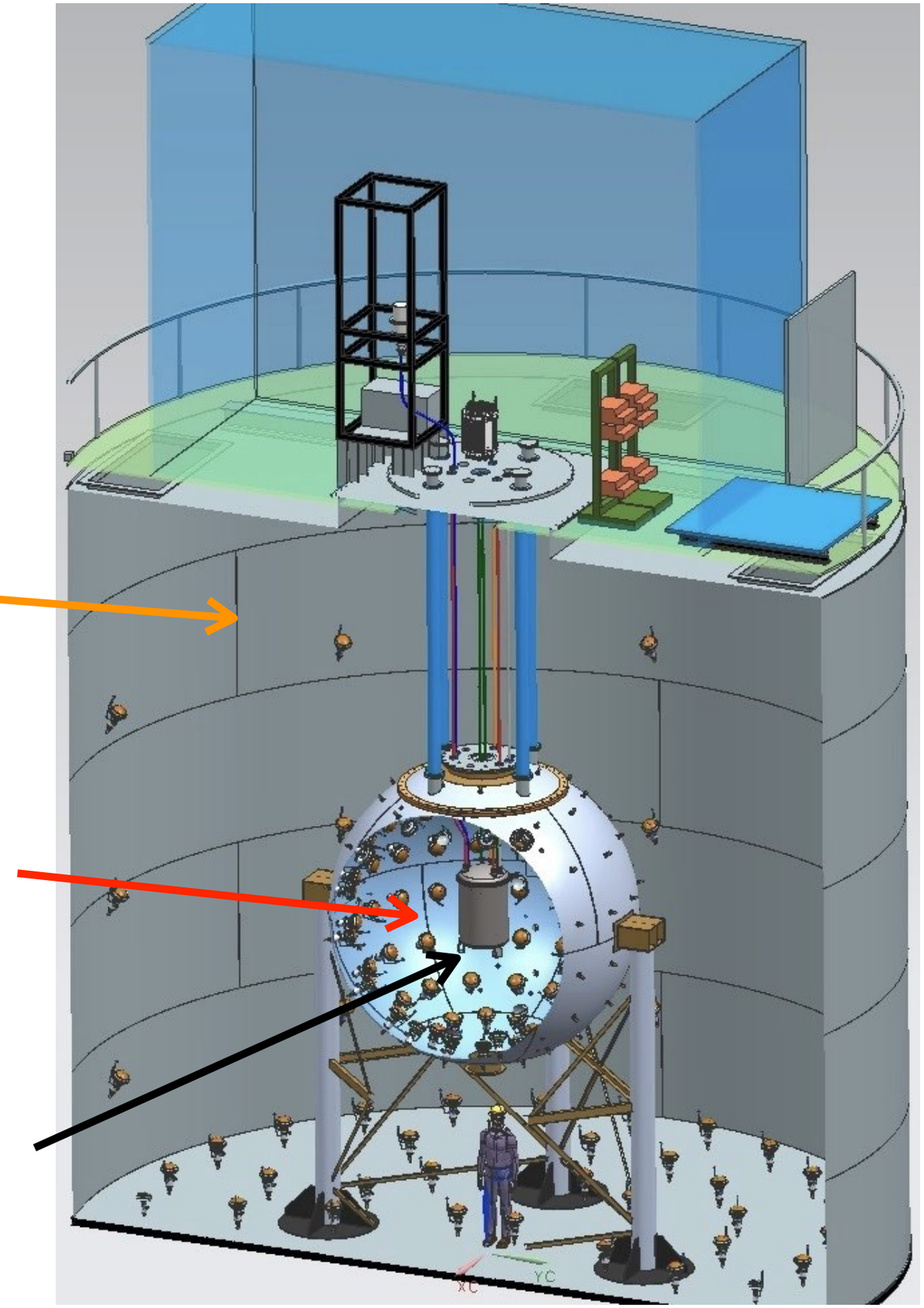
- *Aim*: direct dark matter detection looking for nuclear recoils possibly induced by WIMPs
- *How*: usage of liquid argon (Ar) as detector media in a dual-phase TPC which
  - has **very low background** thanks to be housed in **underground laboratory** at LNGS (Italy) and usage of **low-background materials,** including the target itself
  - has **powerful background rejection** thanks to **effective PSD, ionisation** to **scintillation ratio** and **3d position reconstruction** (surface events rejection)
    - has an **active neutron** and **muon** veto allowing *in situ* background measurement

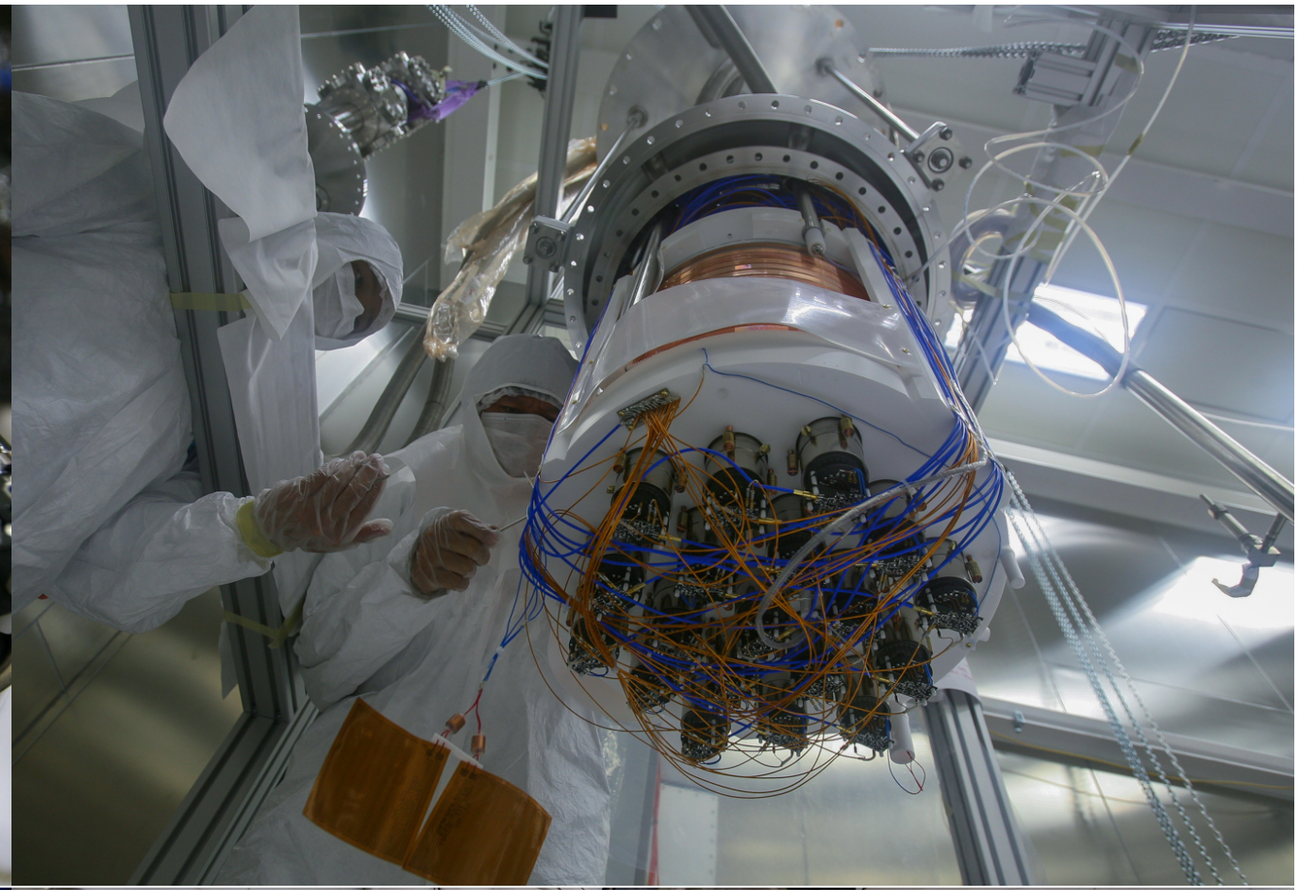
What's DarkSide?

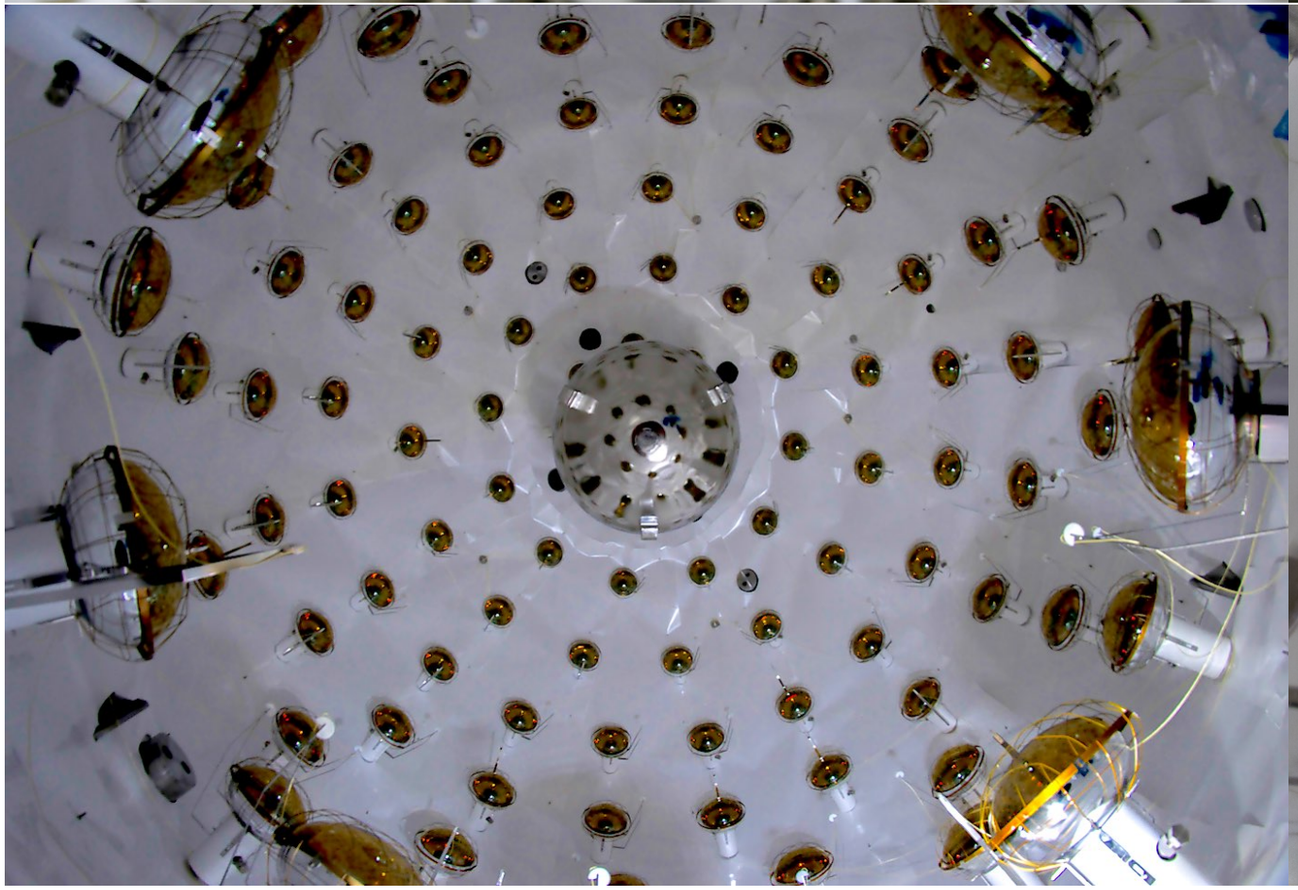
- **Water Cherenkov** detector (1,000 tons of ultra pure water): active veto for μ and as passive shield for external radiation

- **Liquid scintillator** detector (30 tons of PC+PPO +TMB): active γs and neutron detector thank to boron loading

- **LAr TPC** detector (in the current phase ~50 kg of argon in the fiducial volume): inner detector for WIMP







atmospheric nucleus
p,α
π
ν
cosmic ray
μ
μ
μ
Gran Sasso mountains act as natural filter (3,600 w.e.m) suppressing μ rate (~10⁶ times less than surface)
DarkSide experiment

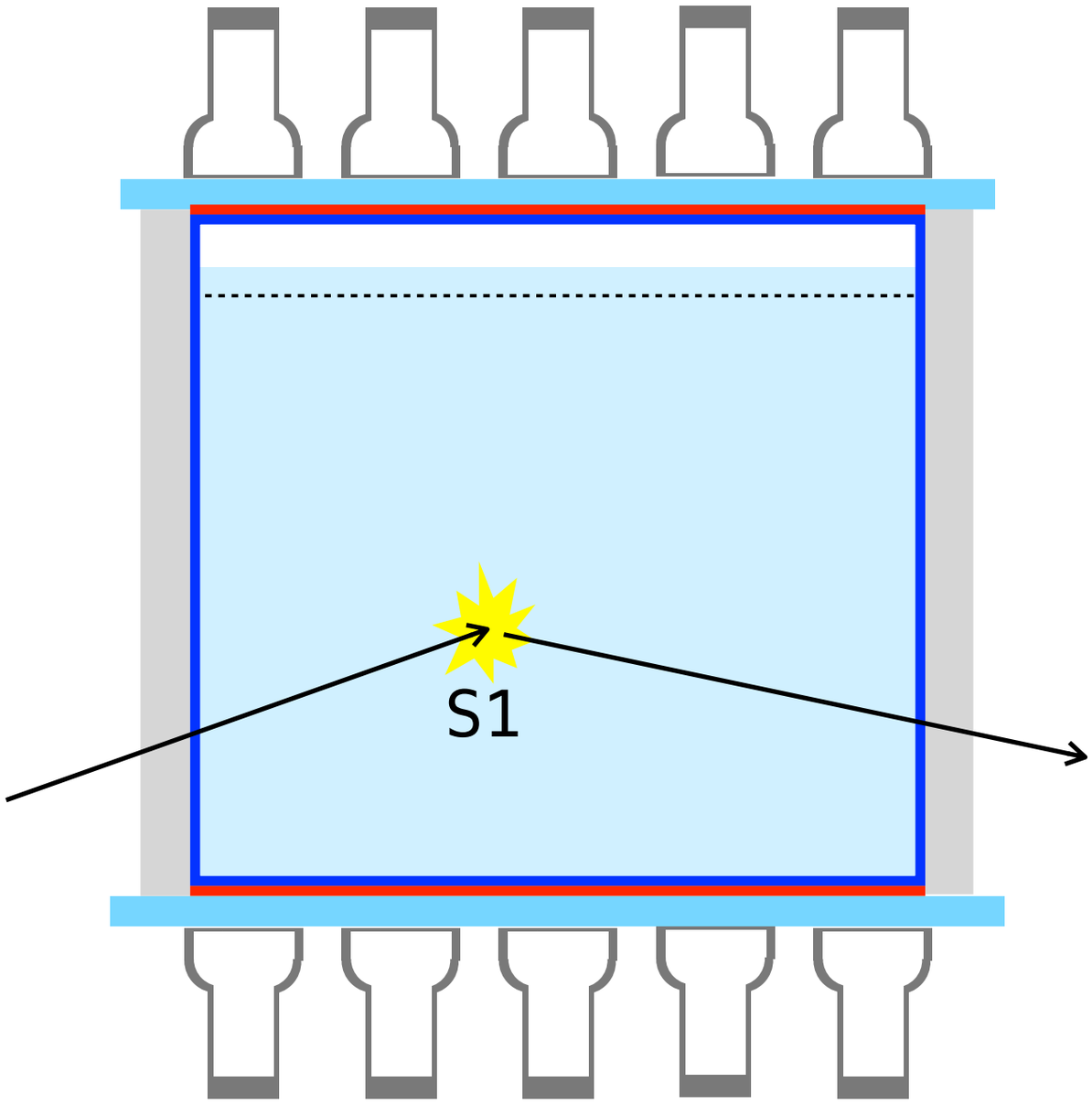
Argon as dark matter target

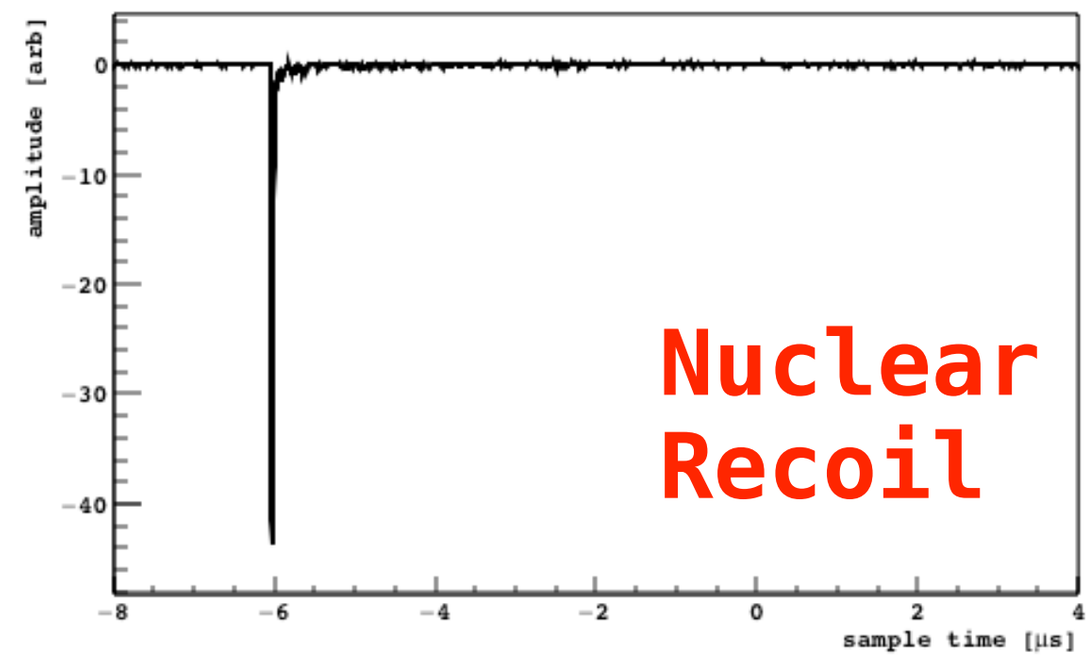
- *Why*: good dark matter target material because
  - is relatively **dense** and **easy to purify** (chemically) allowing to scale the experiment to **large volume**
  - is a **good scintillator** (transparent to its own light)
  - has **exceptional discrimination power**
- *but ..*
  - atmospheric Ar (AAr) contains ^{39}Ar (β decay τ~269 yr and Q~565 keV), a cosmogenically activated isotope, with activity ~1 Bq/kg
  - ***Solution***: use of Ar from underground reservoir (UAr)

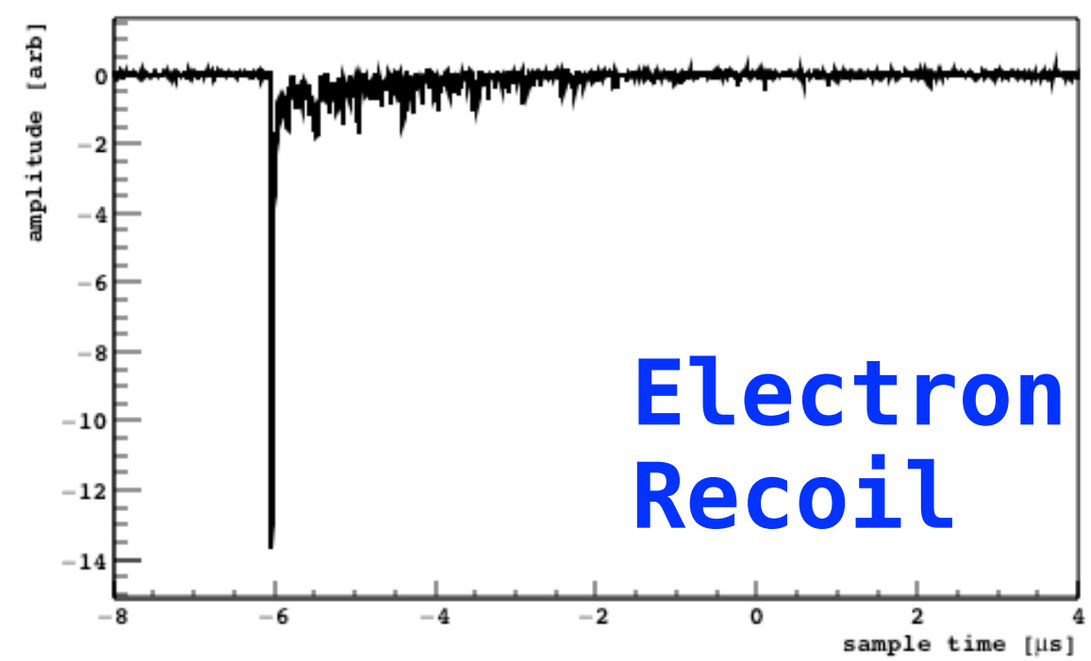
UAr production

- 6 yr effort to collect and purify ~155 kg of UAr
- Ar extracted from CO_2 Doe Canyon (CO) wells
- Distilled with *ad hoc* column at FNAL
- Shipped to LNGS by sea

PSD and 3d reconstruction

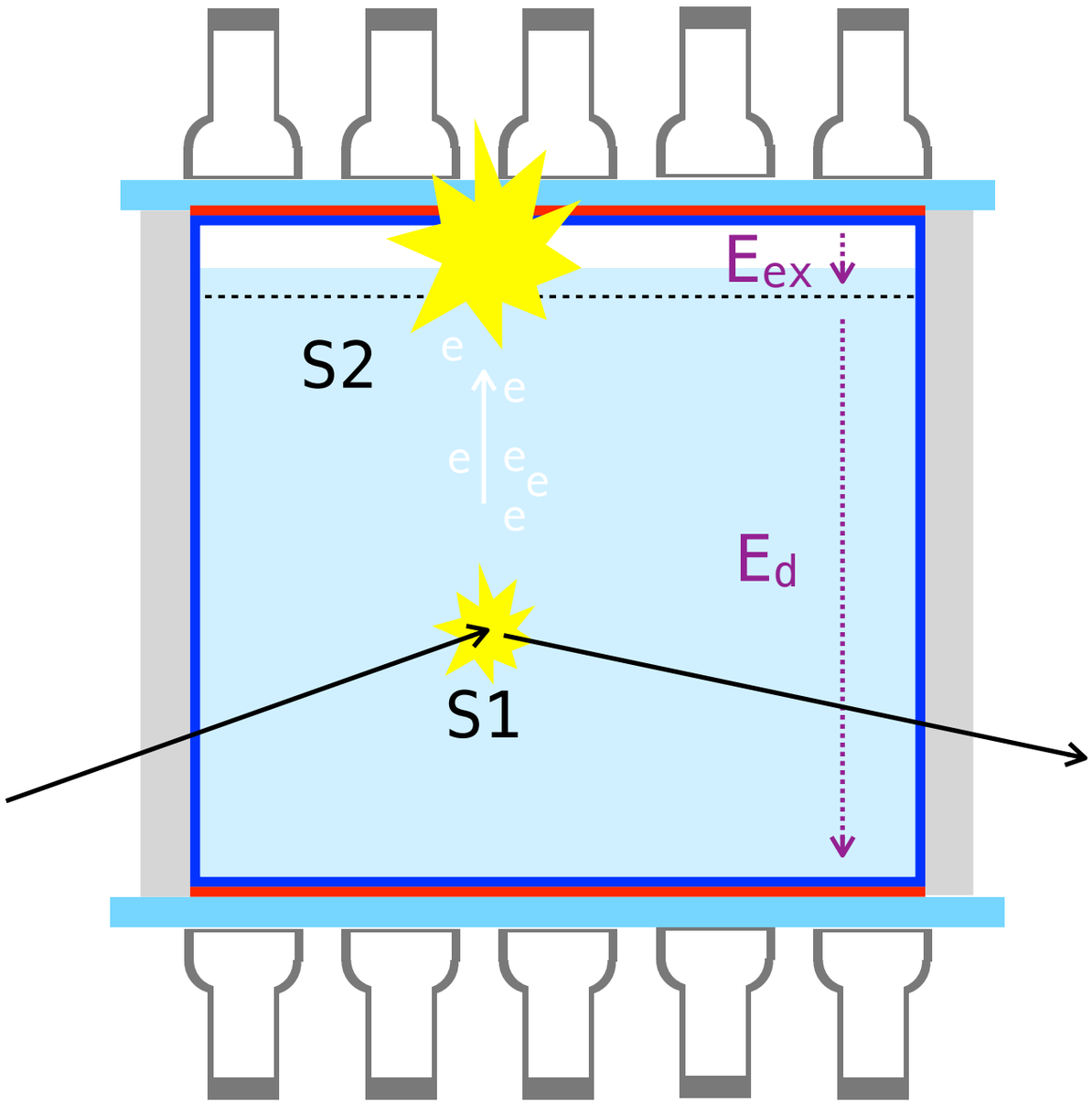


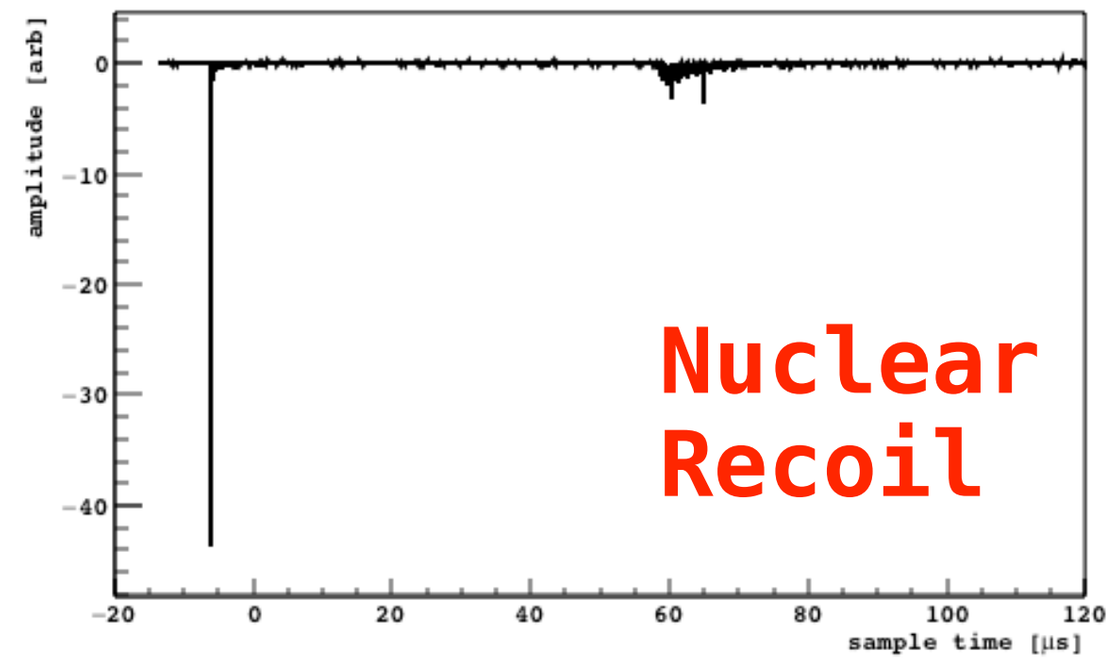


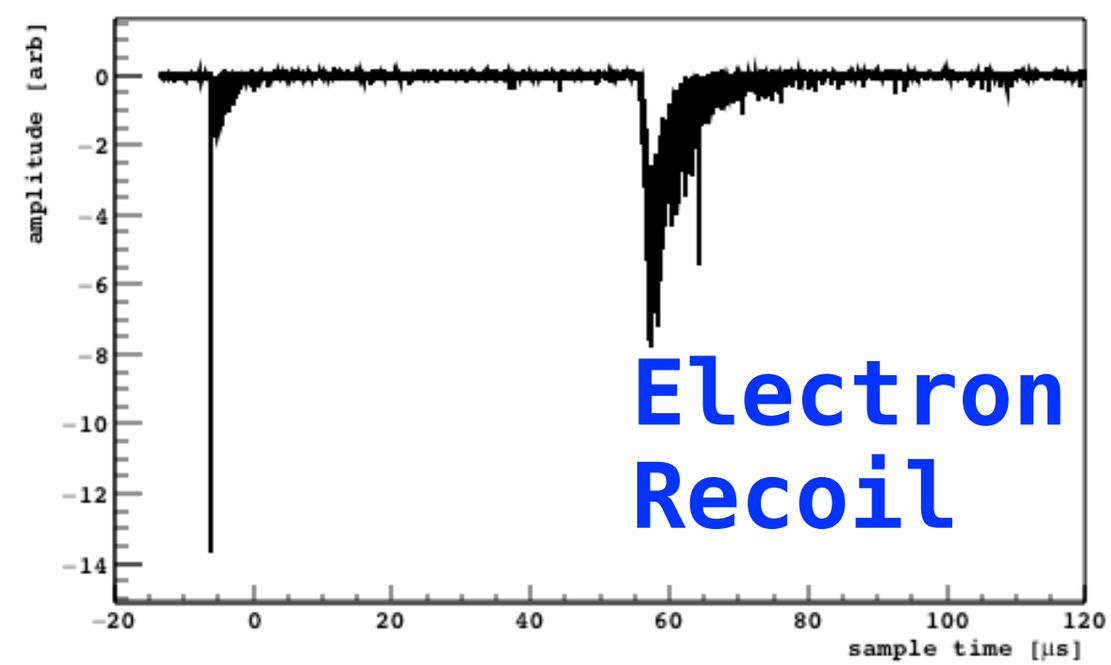


- PSD parameter **f90:** fraction of light in the first 90 ns

PSD and 3d reconstruction



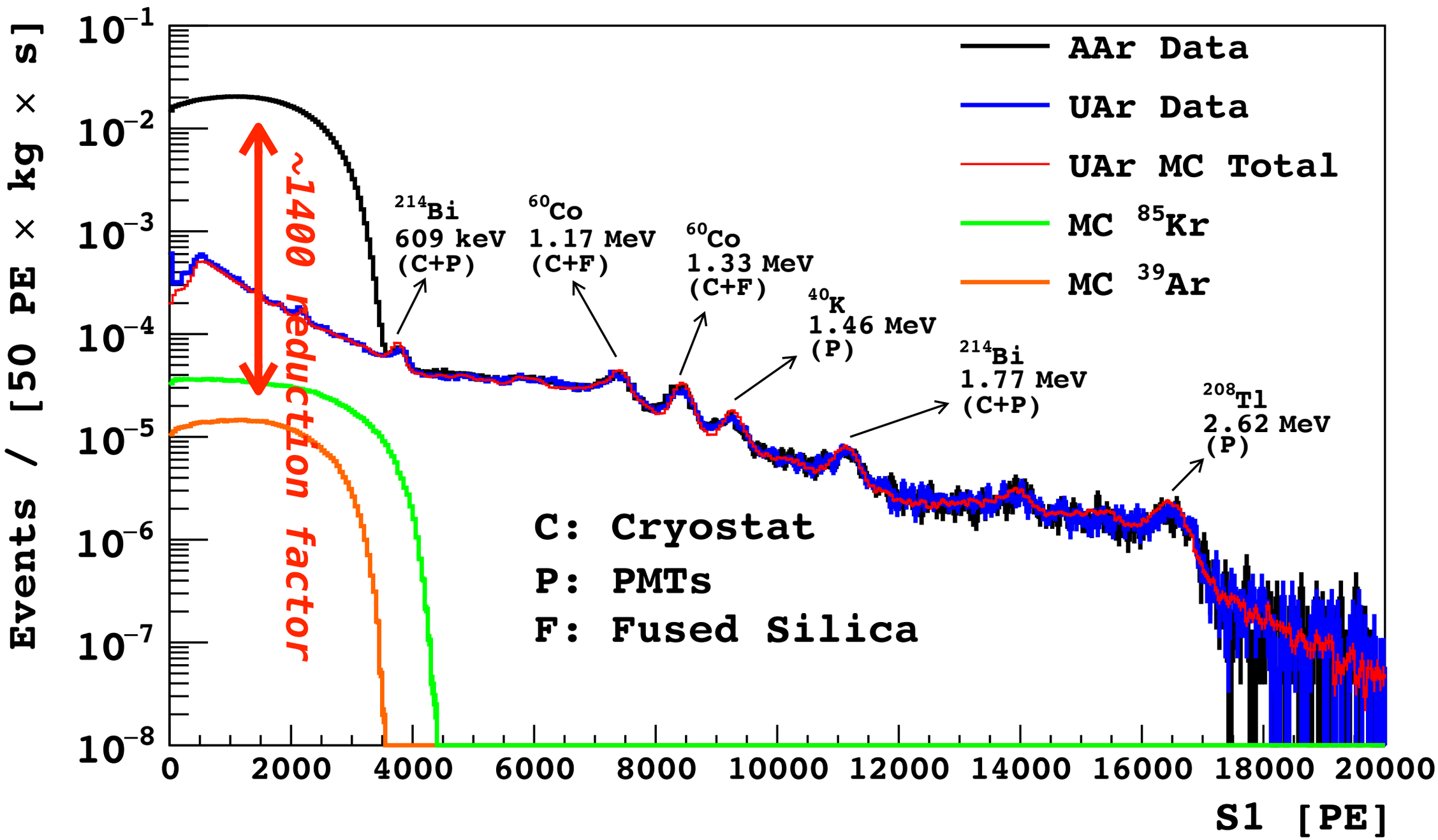




- Charge signal (S2) allows **3d position reconstruction** and additional discrimination (S2/S1)

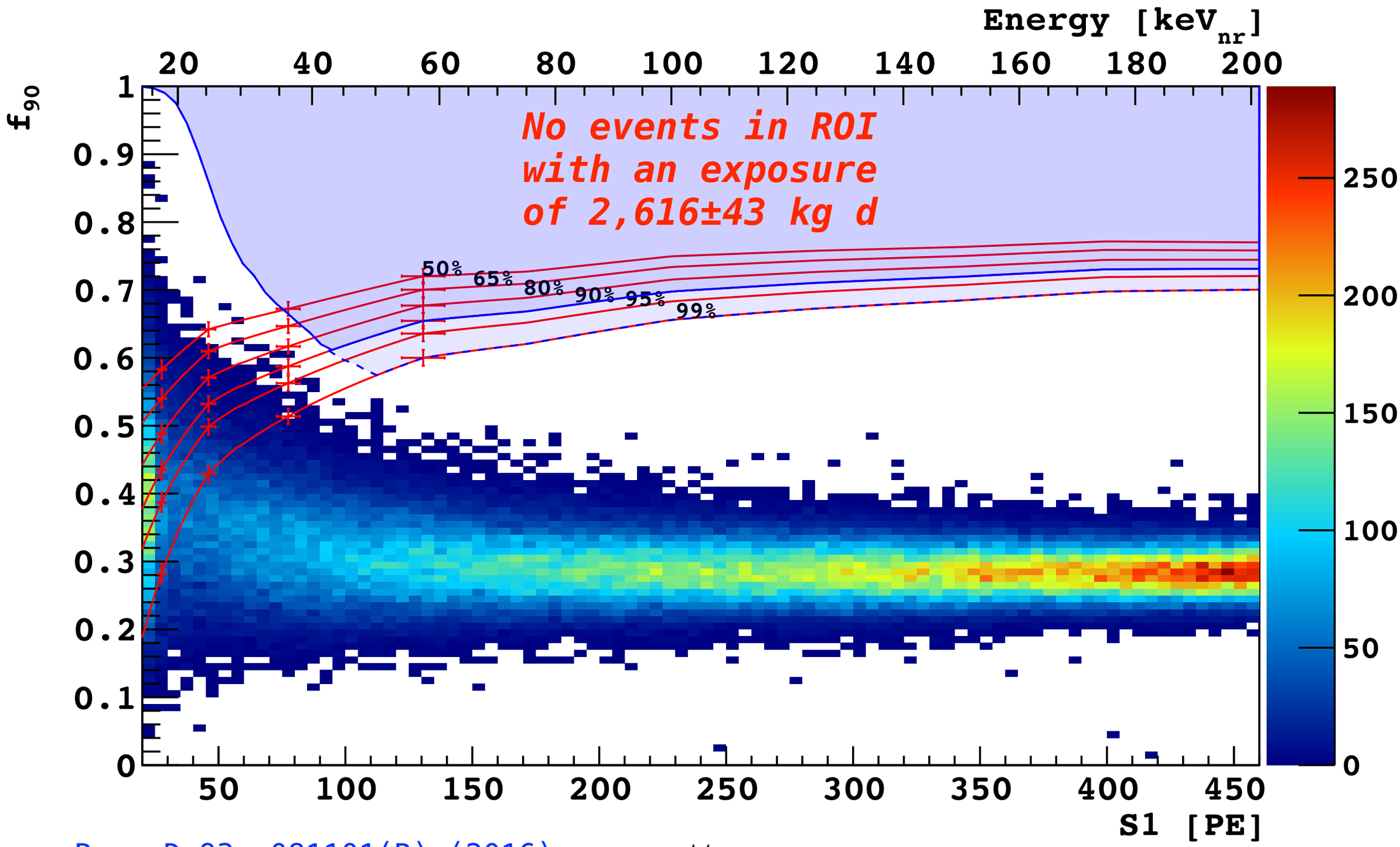
DS-50 results: UAr vs. AAr

Fitted ^{39}Ar in UAr: 0.73 ± 0.11 mBq/kg vs. AAr: 1000 mBq/kg



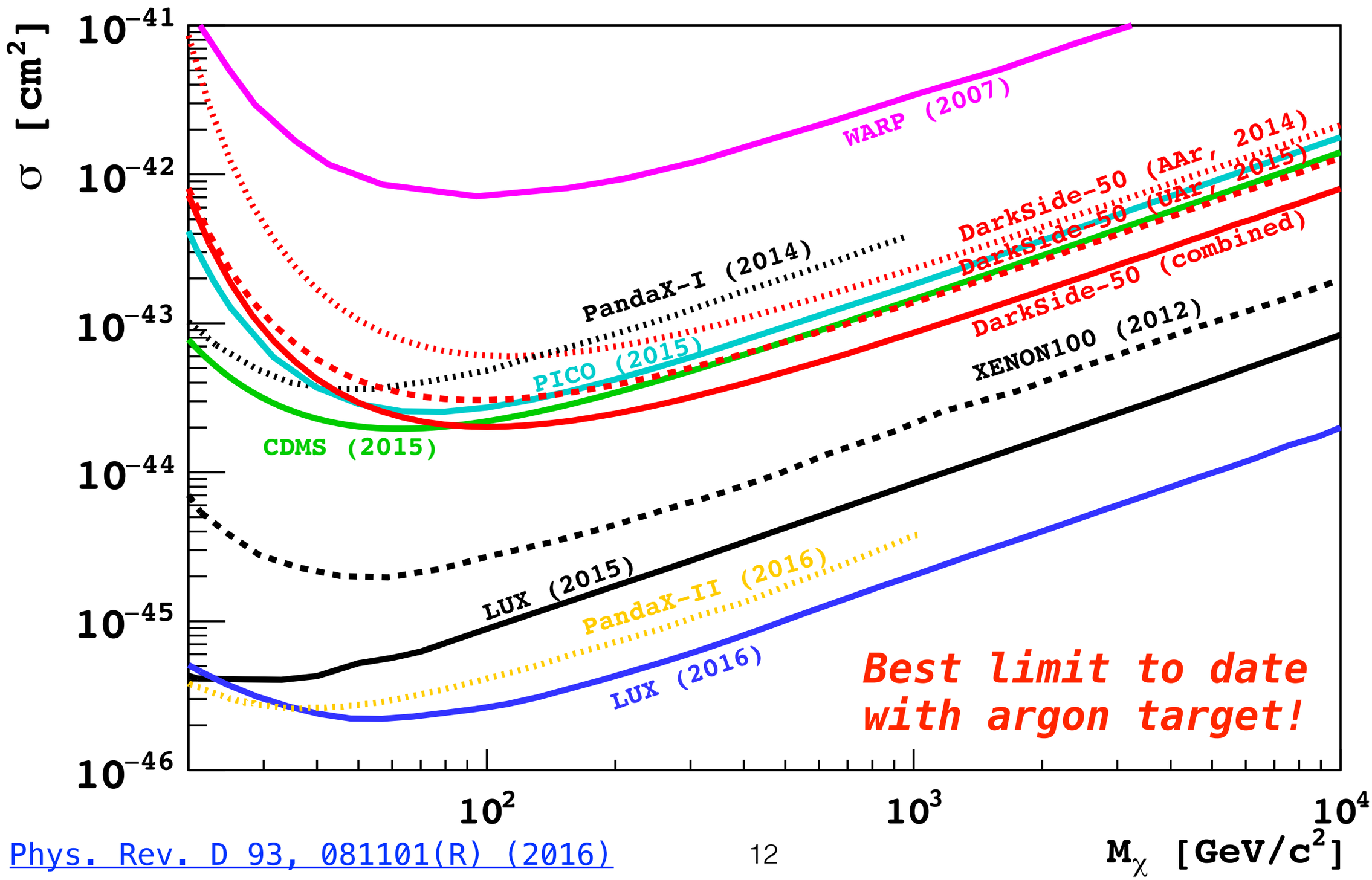
Phys. Rev. D 93, 081101(R) (2016)

DS-50 results: UAr



Phys. Rev. D 93, 081101(R) (2016)

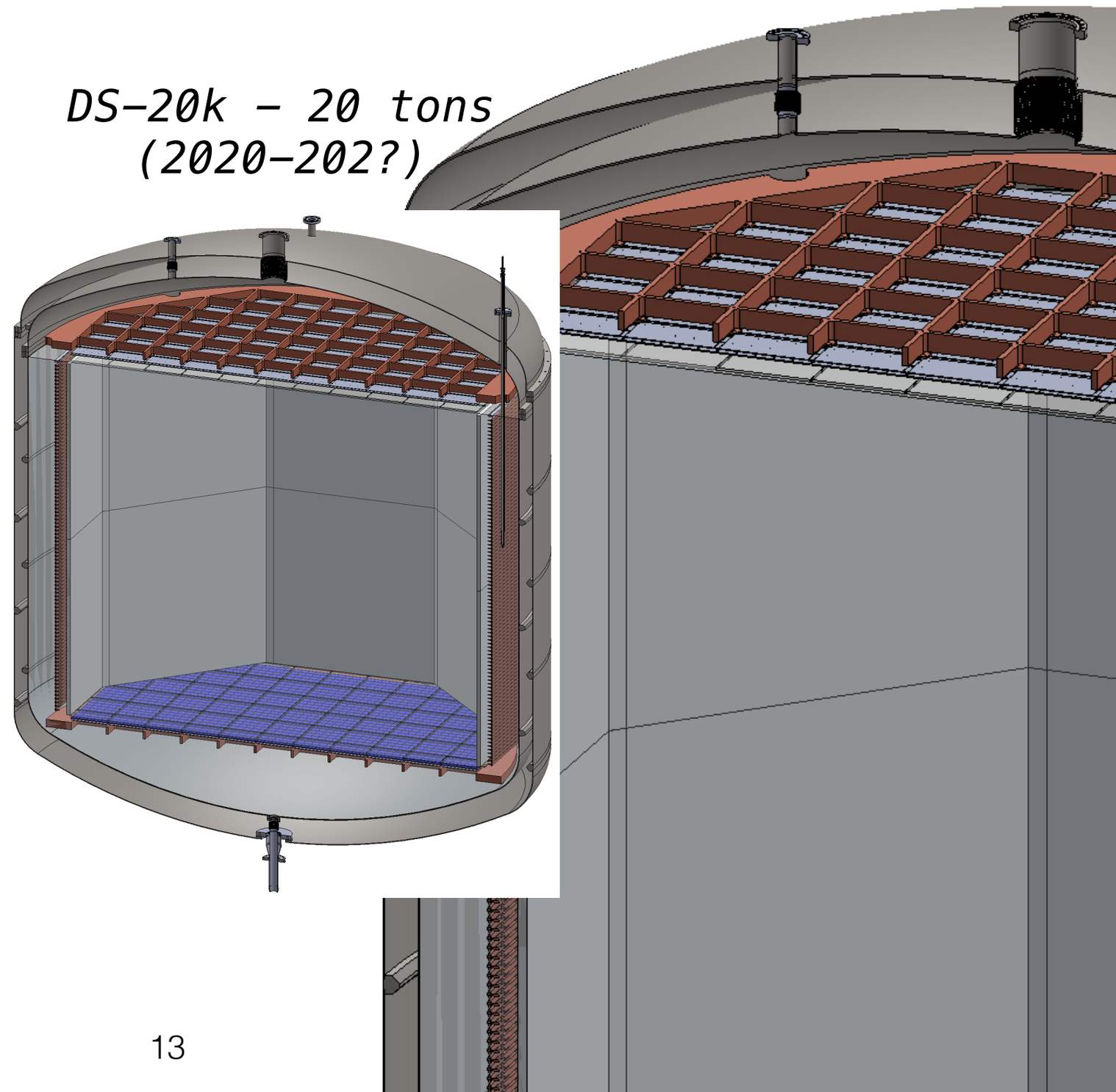
DS-50 results: UAr dark matter limit



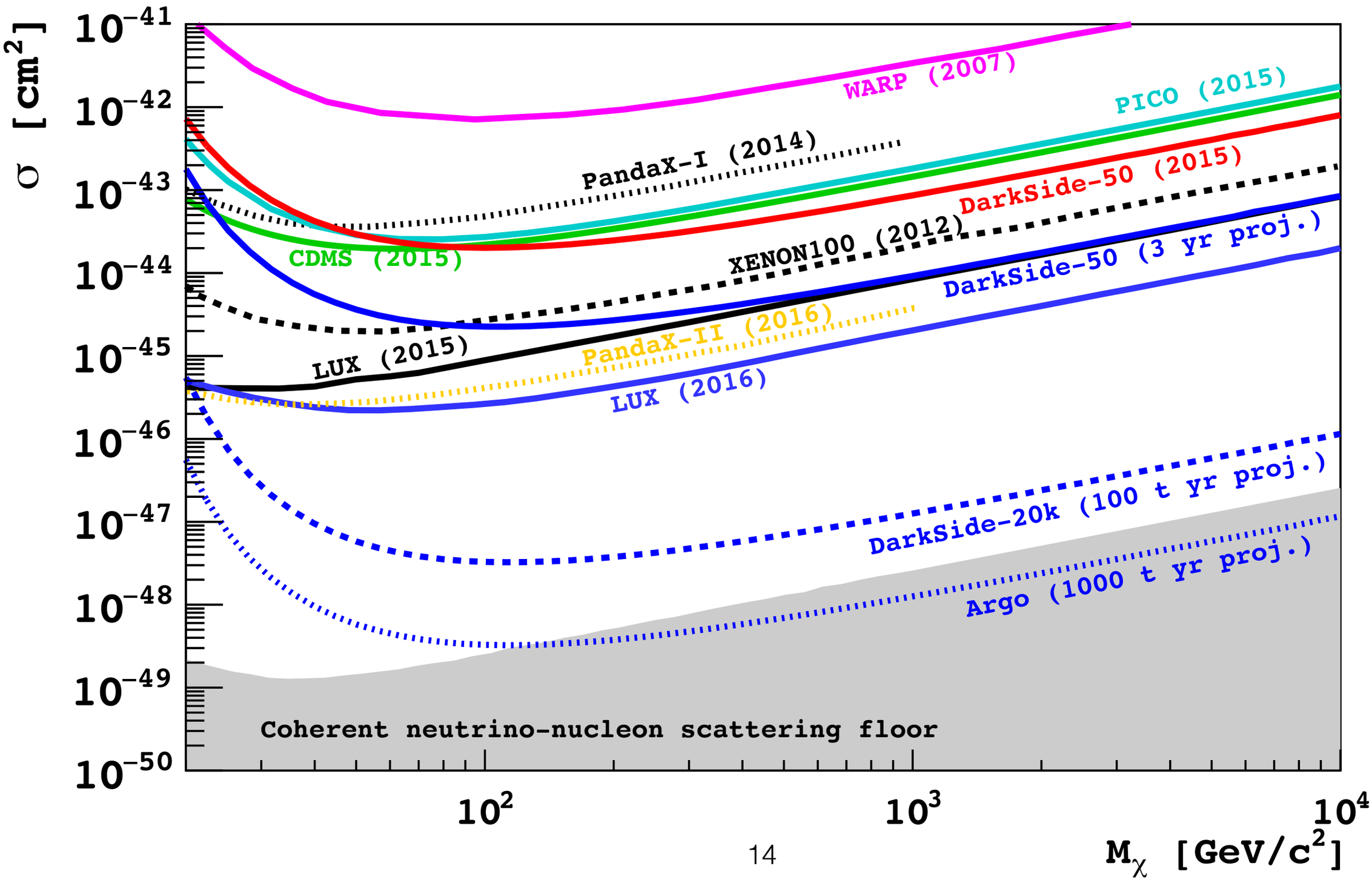
Phys. Rev. D 93, 081101(R) (2016)

What next?

- Collaboration planned to build big volume detector (≥ 20 tons)
- *News*:
  - R&D on going to produce radio pure SiPM
  - Plans for **massive UAr production** (**Urania** project: ~100 kg/d) and **purification** (**Aria** project: ~300 m tall column for isotope separation)

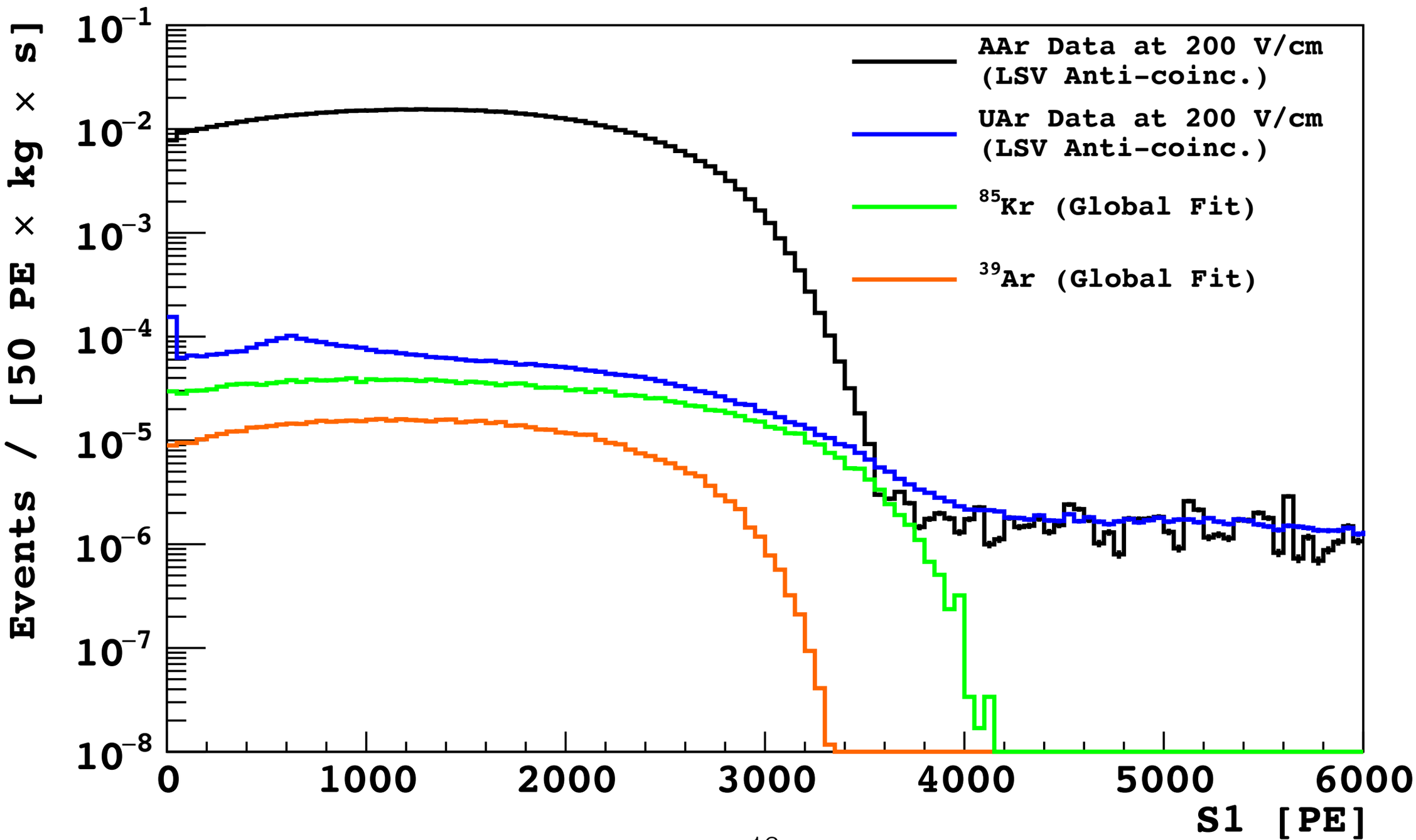


What next? Sensitivity

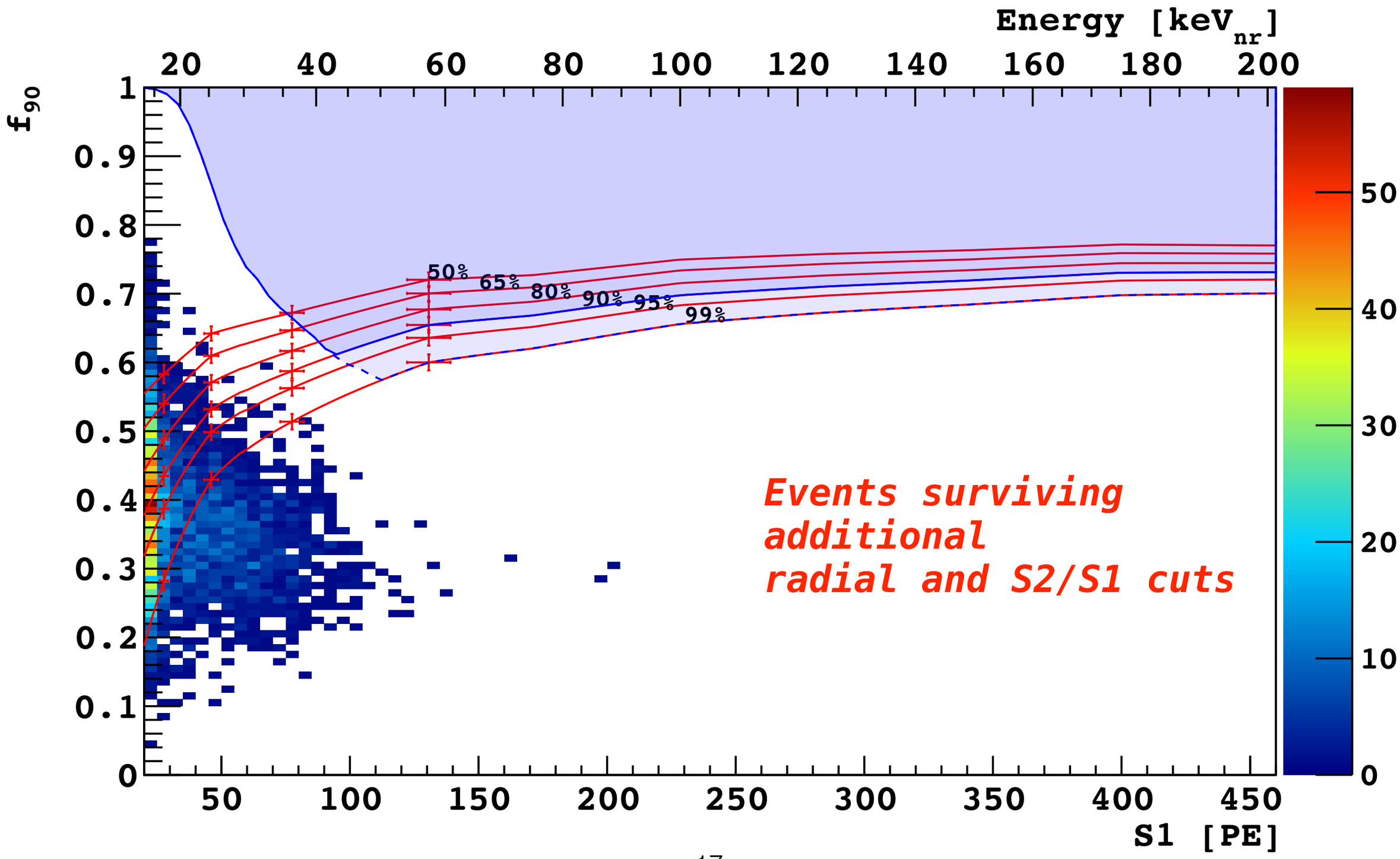


Backups

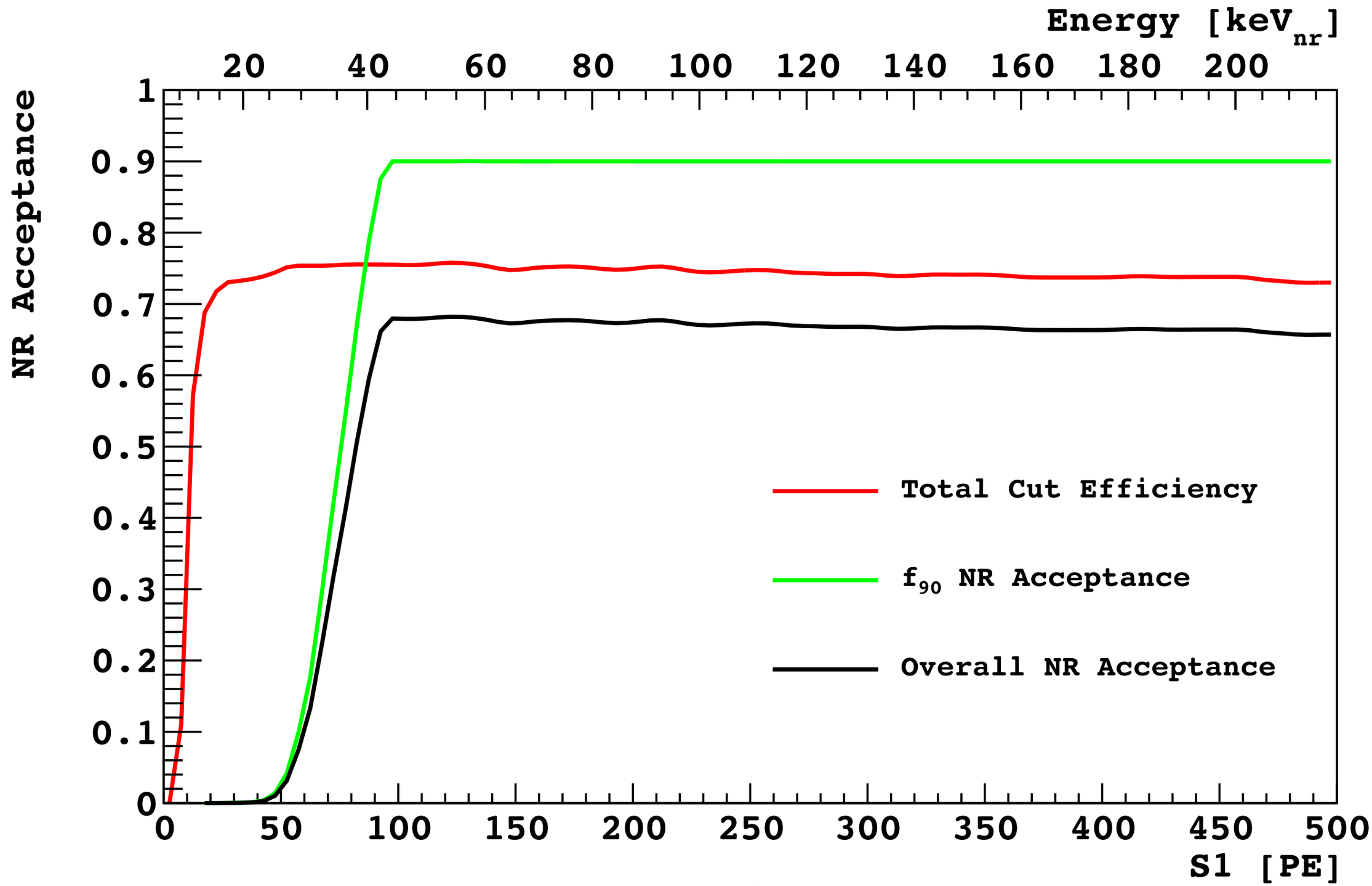
DS-50 results: UAr vs. AAr



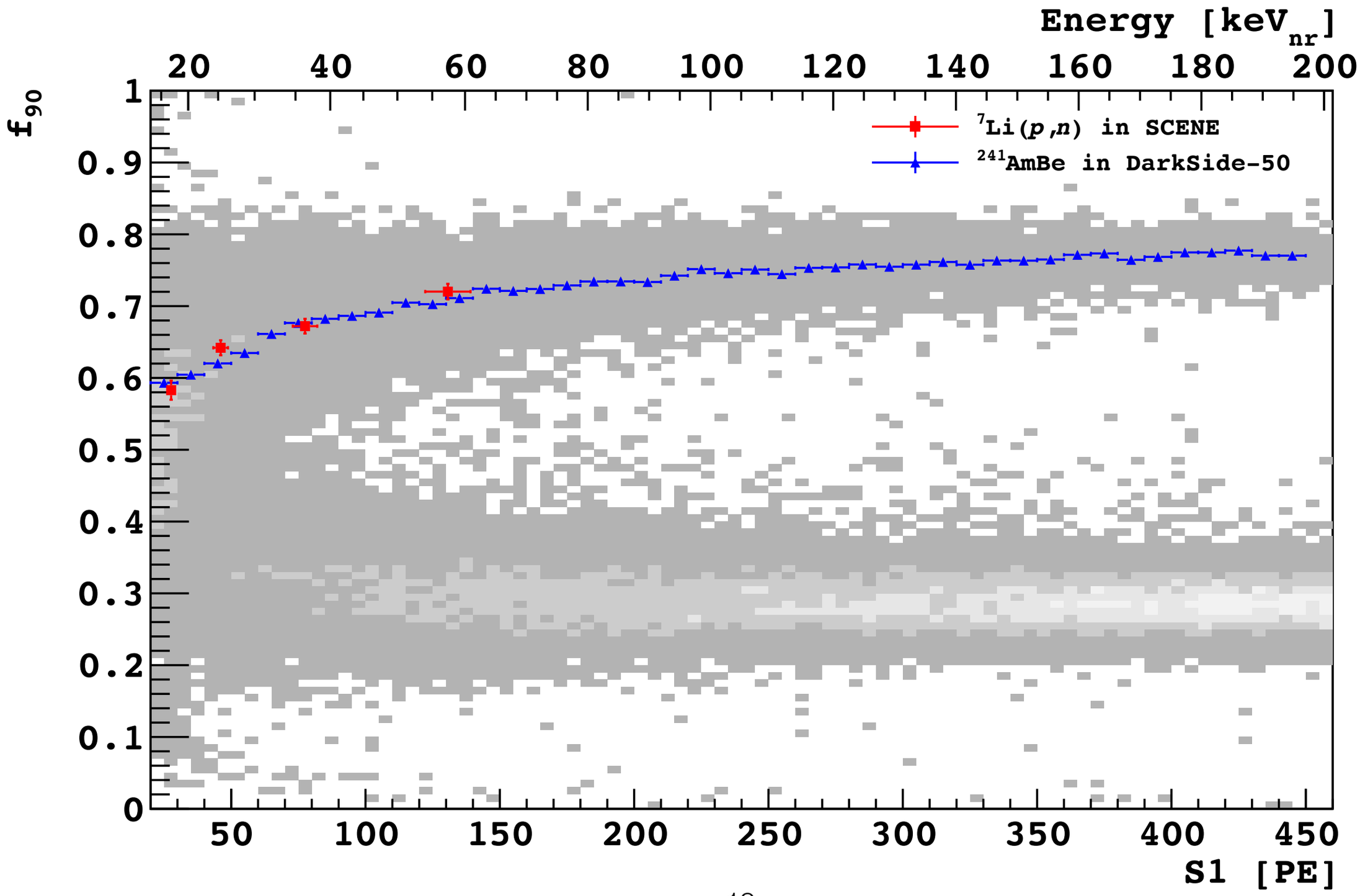
DS-50 results: UAr



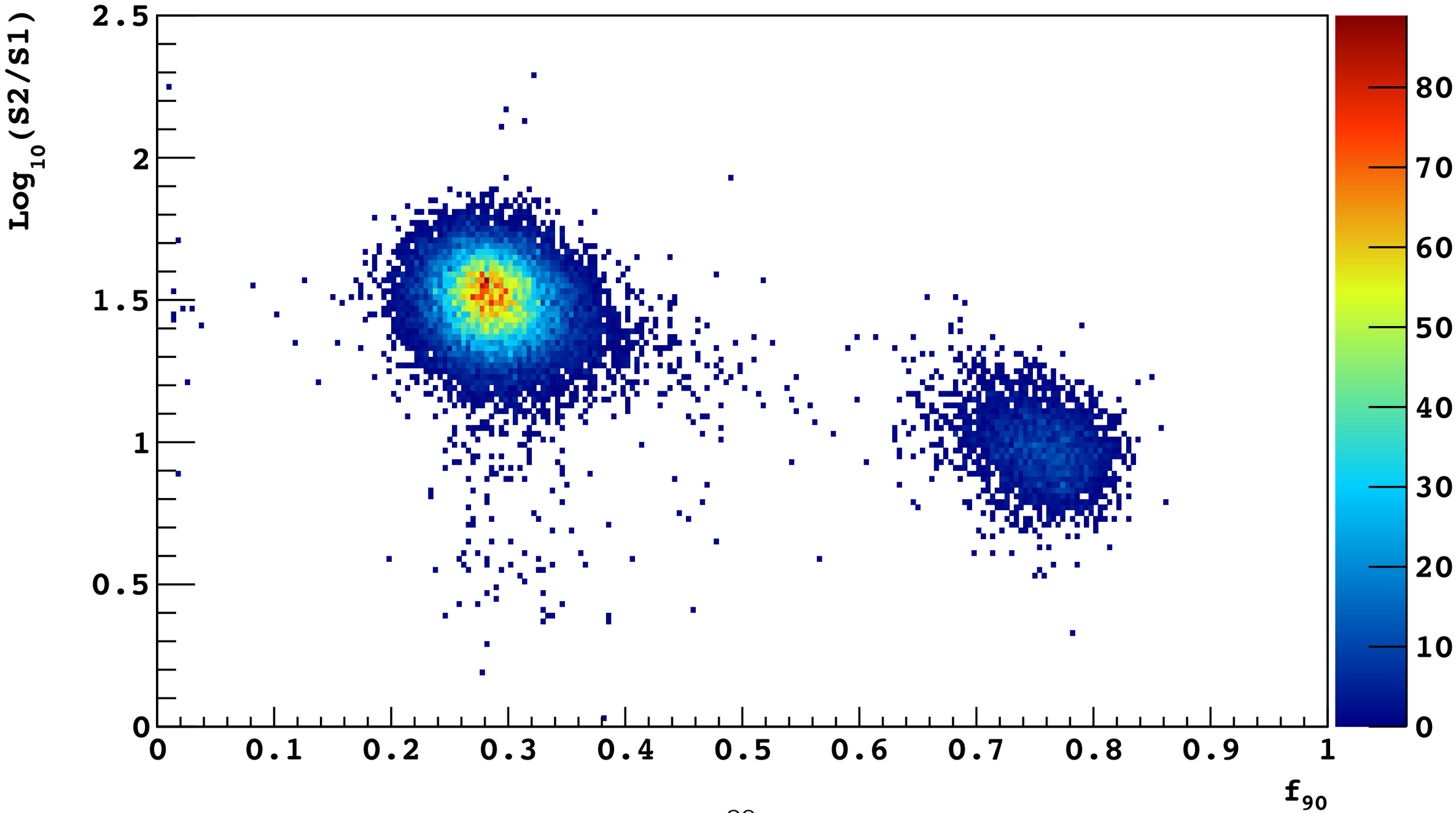
DS-50 results: cut efficiencies



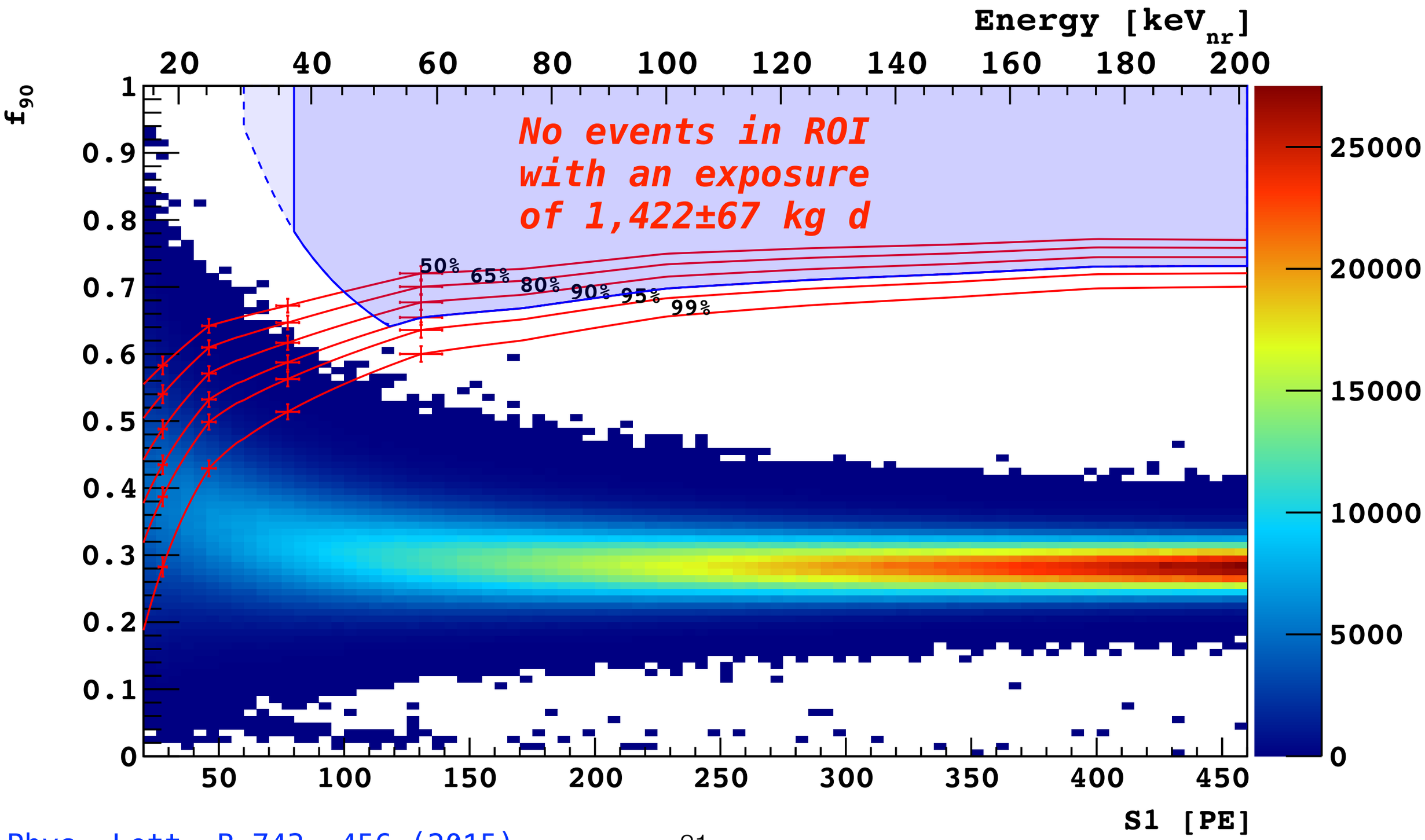
DS-50 results: NR calibration



DS-50 results: NR calibration



DS-50 results: AAr



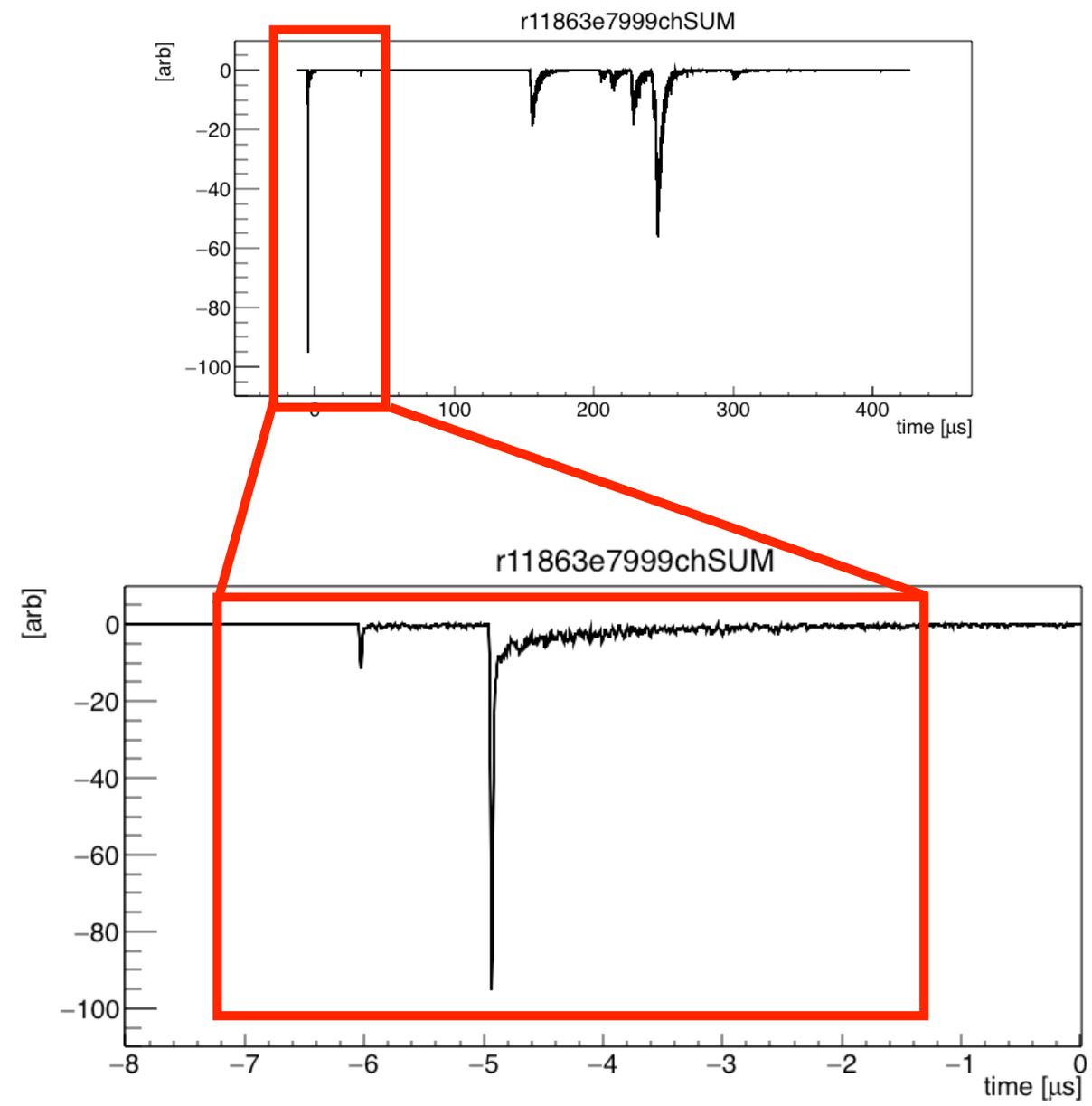
Phys. Lett. B 743, 456 (2015)

^{85}Kr in UAr

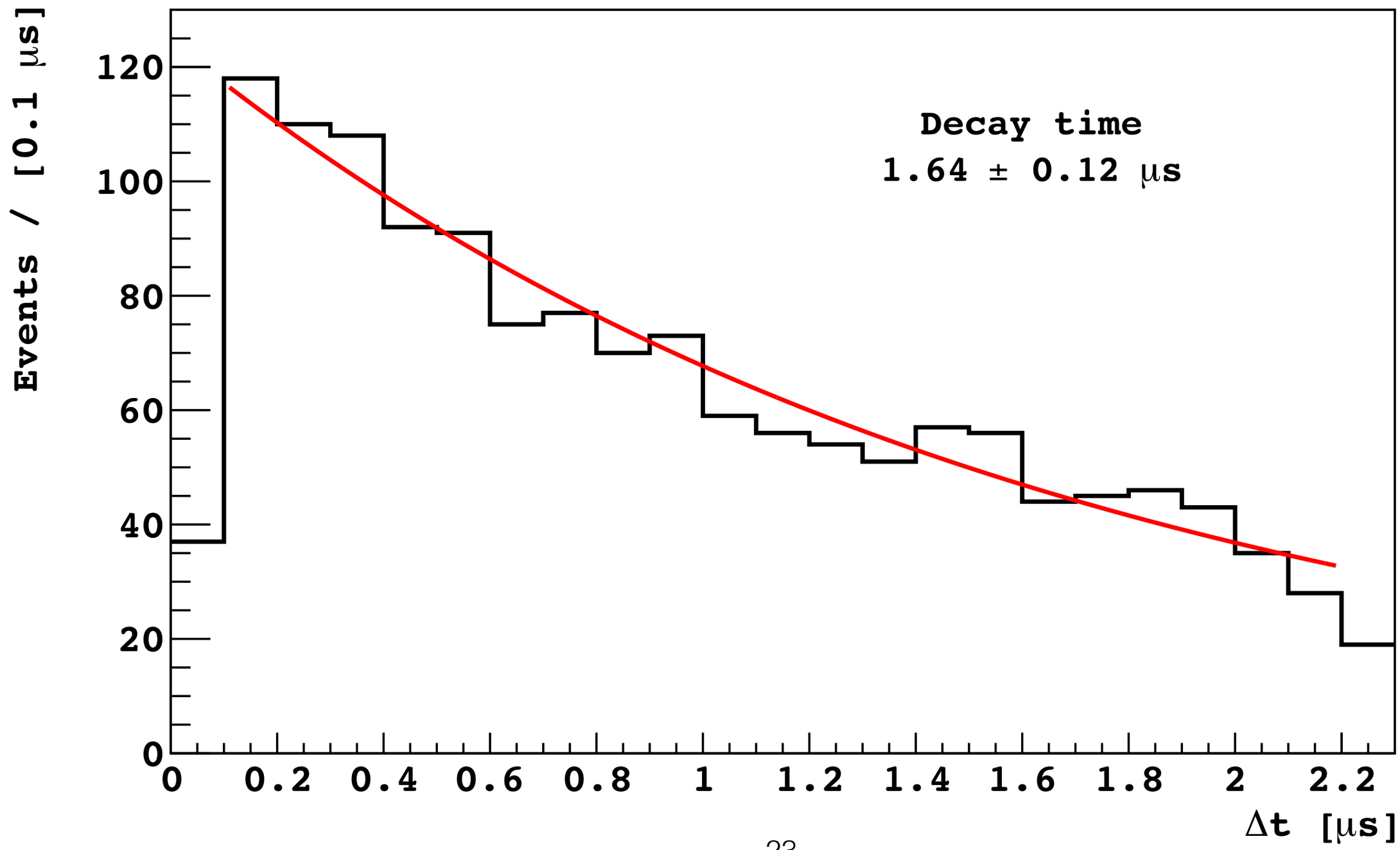
- **Decay:** $^{85}Kr \rightarrow ^{85m}Rb$ BR=0.4% ($\tau_{1/2}$~1 μs, E_{γ}~514 keV)

- **Signature:** 2 S1s (β+γ) in delayed coincidence

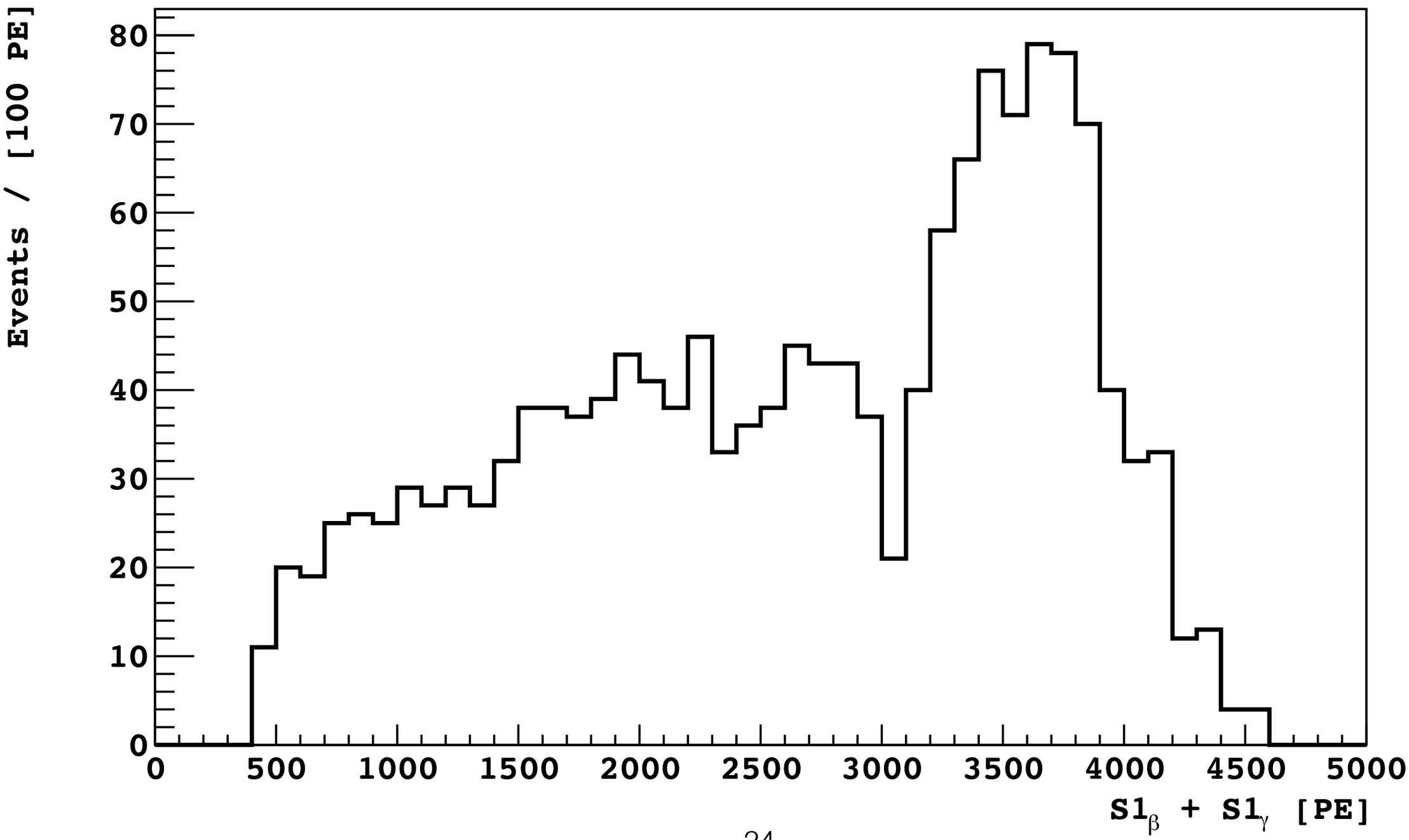
- **Rate:** *observe* 33.1 ± 0.9 events/d vs. *spectral fit* 35.3 ± 2.2 events/d



^{85}Kr in UAr

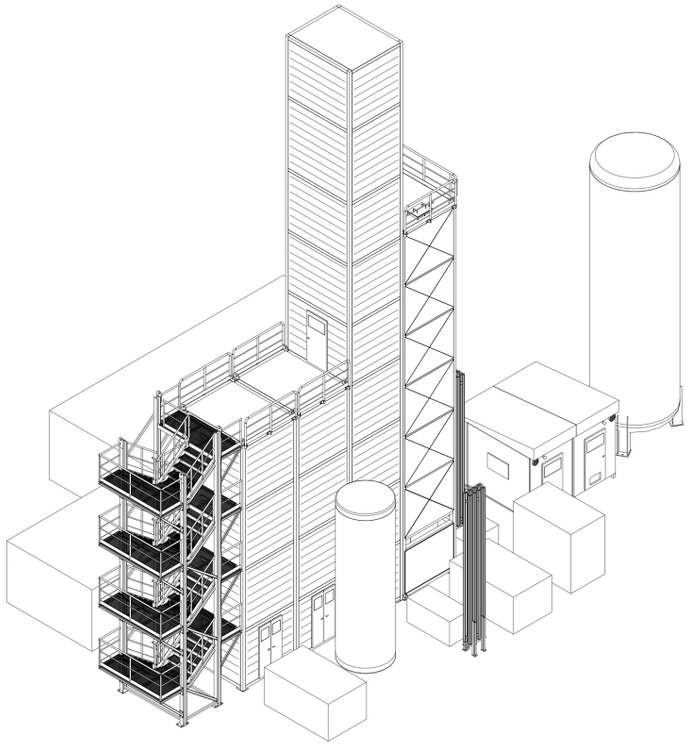
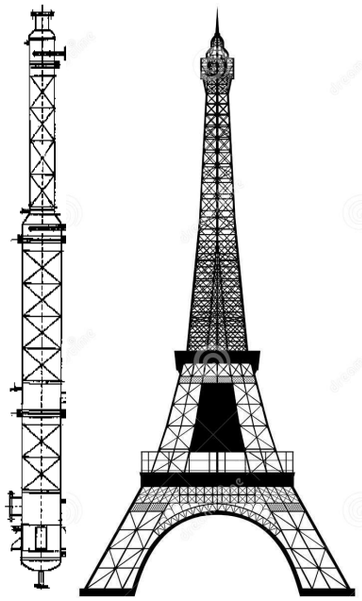

Events / [0.1 μs]
120
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
2.2
Δt [μs]
Decay time
1.64 ± 0.12 μs

^{85}Kr in UAr


Events / [100 PE]
0
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
S1β + S1γ [PE]

UAr production

- **Urania:** expansion of the Ar extraction plants in Cortez, Colorado (USA), to reach production of 100kg/day of UAr



- **Aria:** tall column (~300m) in Seruci mine, Sardinia (Italy), for high-volume chemical and isotopic purification of UAr