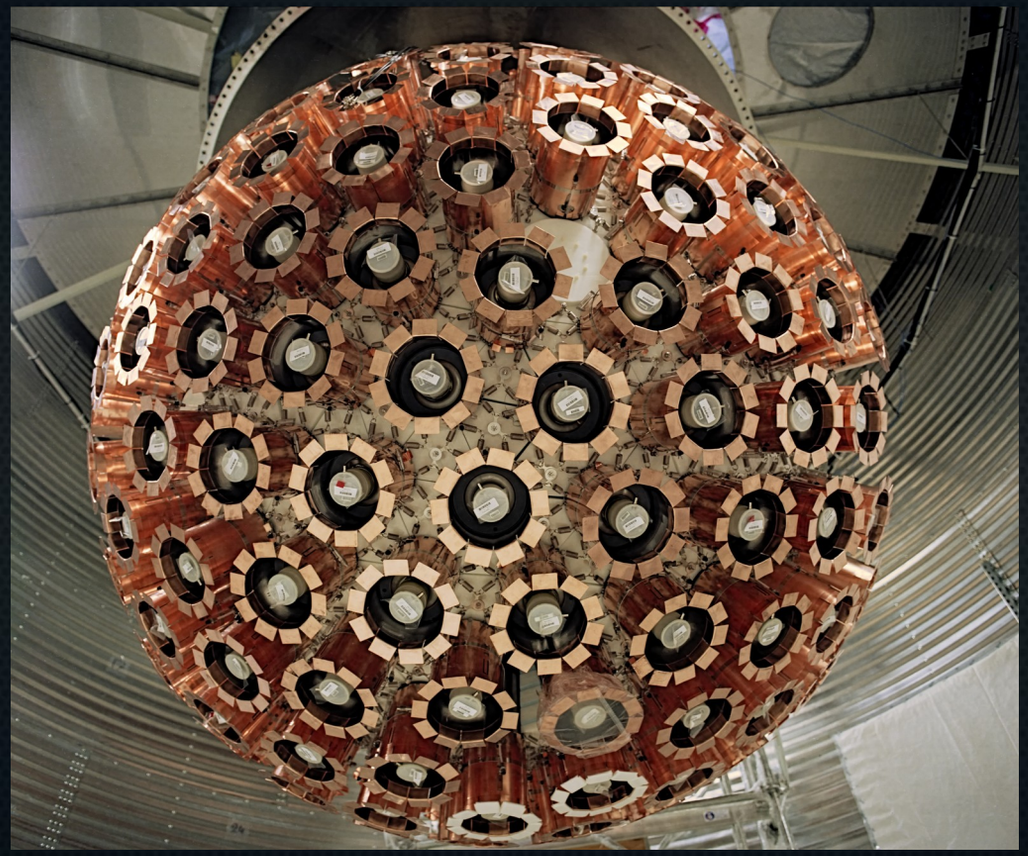
Latest Results from the DEAP-3600 Dark Matter Search Experiment



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ICNFP 2019

UNIVERSITY OF ALBERTA

Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens

Carleton UNIVERSITY

GOBIERNO DE ESPAÑA
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NATIONAL RESEARCH CENTER "KURCHATOV INSTITUTE"

Laurentian University
Université Laurentienne

IF
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POR MI RAZA HABLARÁ EL ESPÍRITU

PRINCETON UNIVERSITY

Queen's UNIVERSITY

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Particle Physics
Rutherford Appleton Laboratory

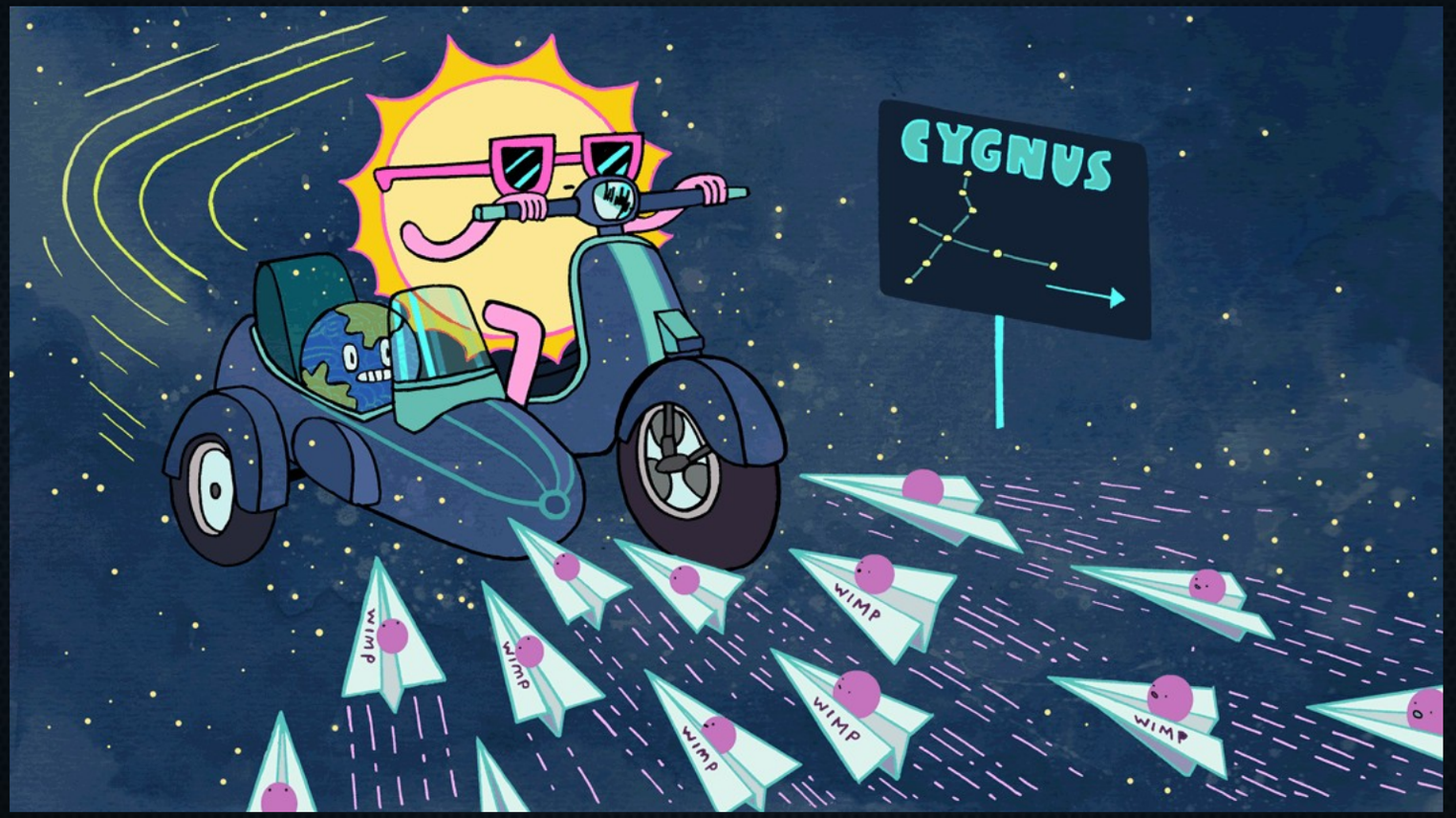
SNOLAB

University of Sussex

Technical University of Munich

TRIUMF

The dark matter wind



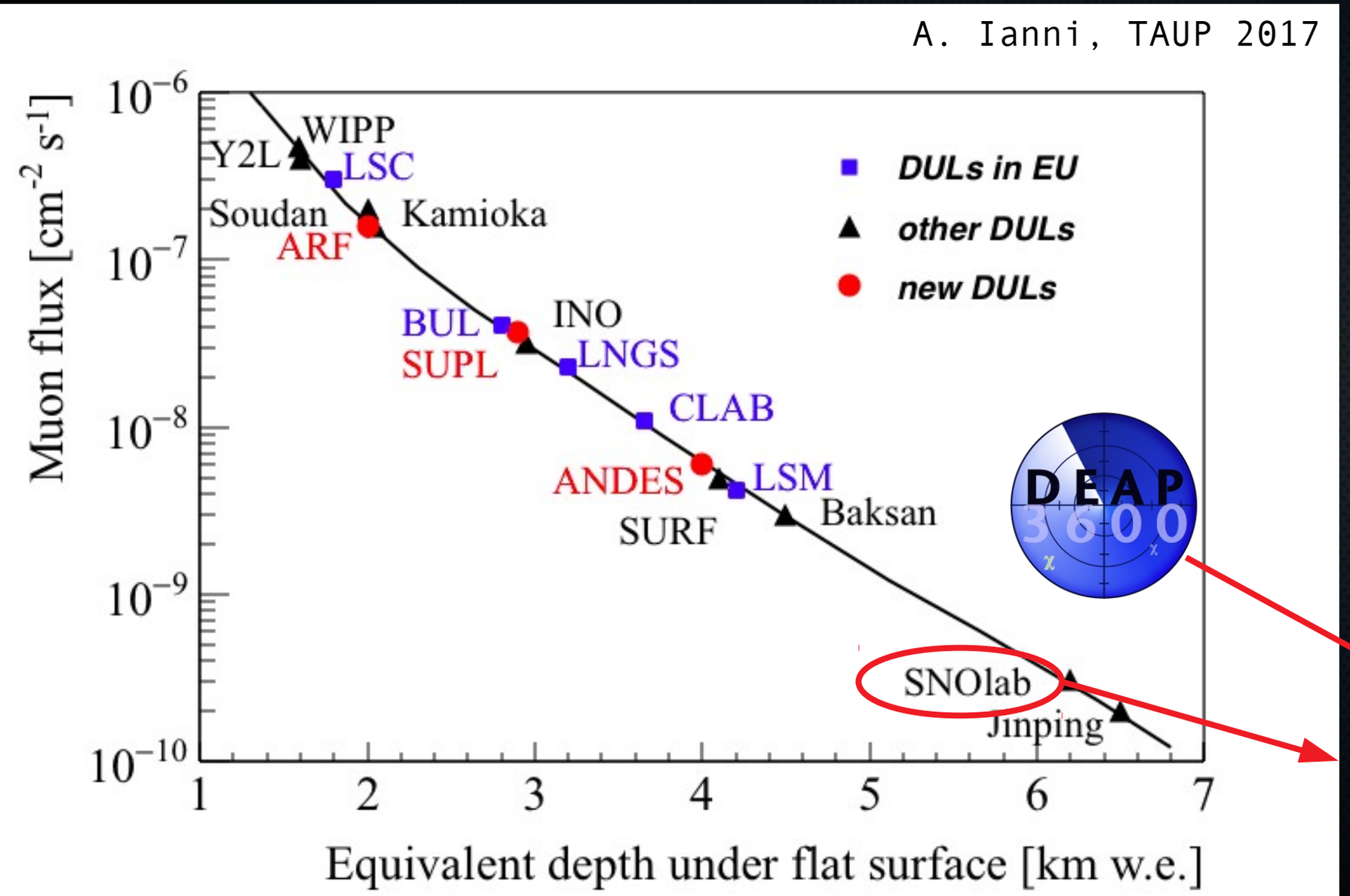
symmetry magazine, Artwork by Sandbox Studio, Chicago with Corinne Mucha

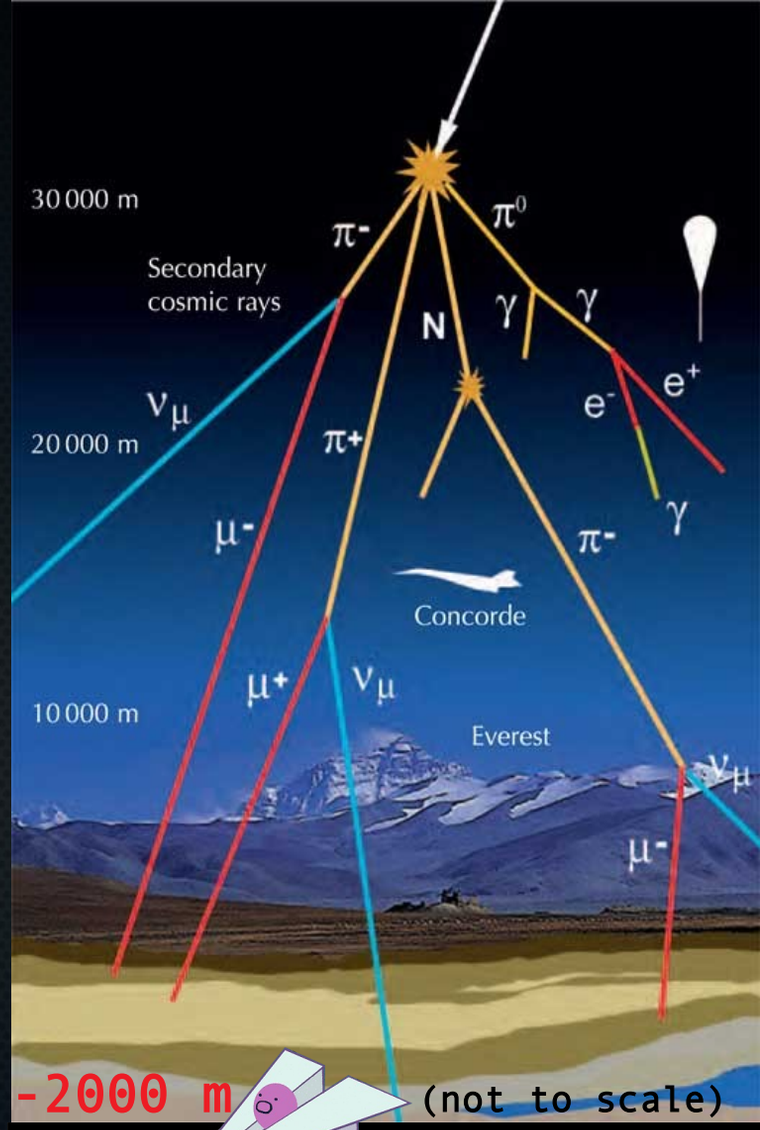
Catching paper planes sounds easy...

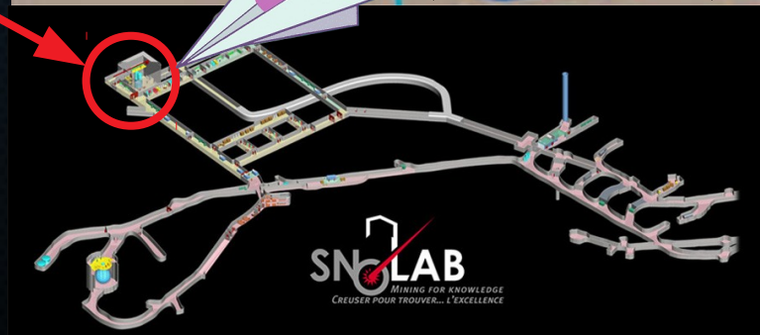
symmetry magazine, Artwork by Sandbox Studio, Chicago with Corinne Mucha

Going underground

A. Ianni, TAUP 2017

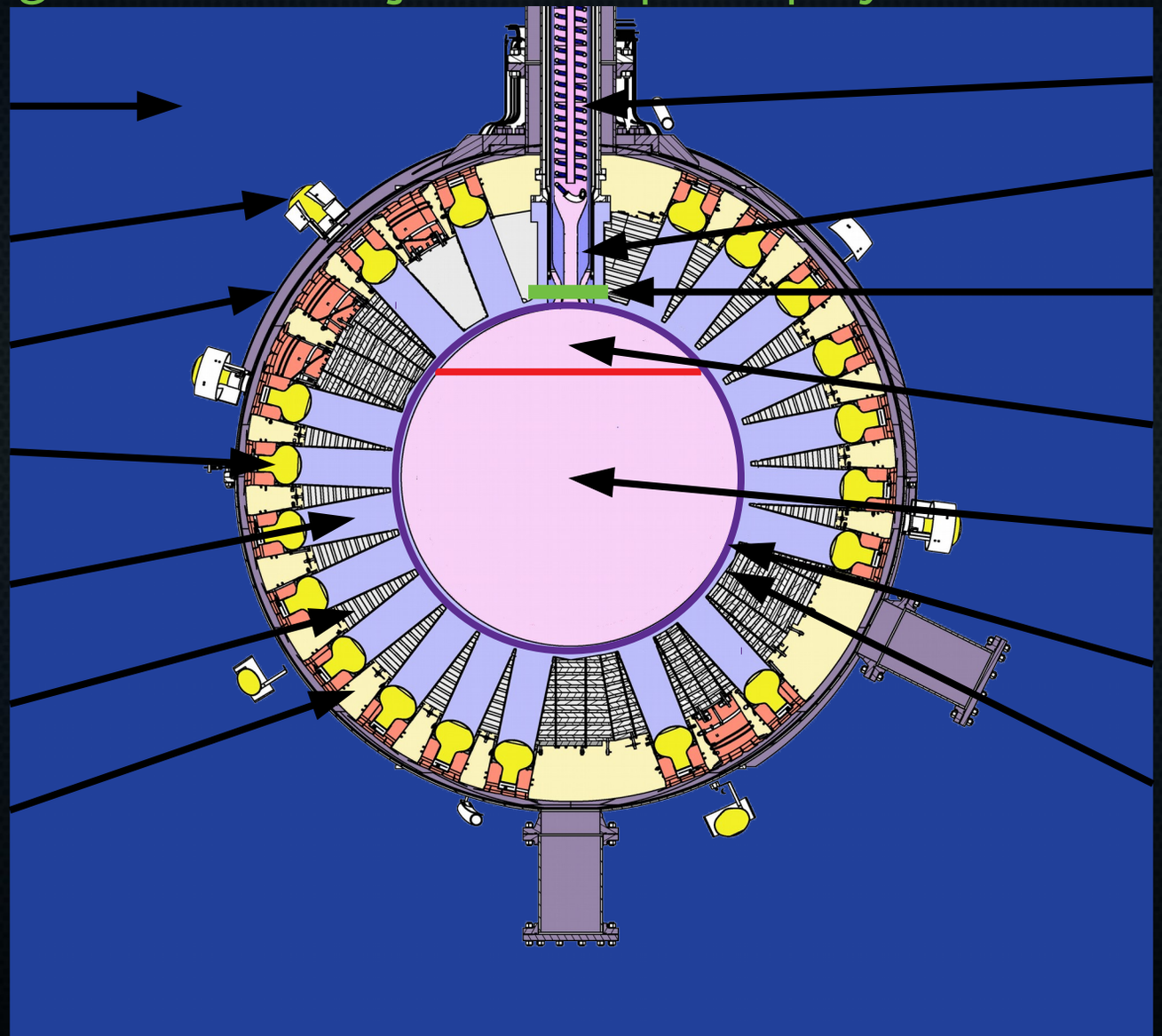






Dark matter Experiment using Argon Pulse-shape discrimination 3600 (3279)

doi.org/10.1016/j.astropartphys.2018.09.006



~300t water Cherenkov muon veto

48 8“ muon veto PMTs

steel shell

255 8“ signal PMTs

45cm acrylic light guides

filler blocks

filler foam

cooling coil

acrylic flow guides

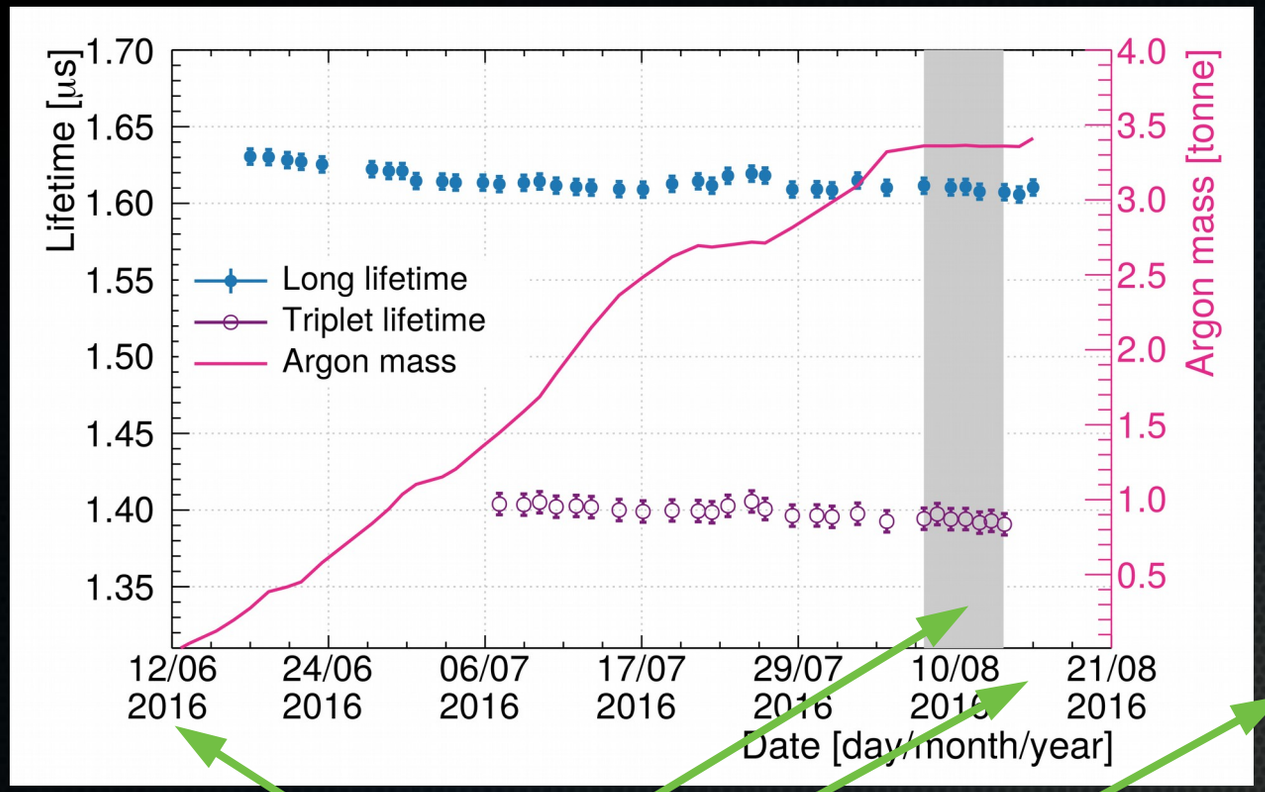
10cm wide WLS fiber neck veto

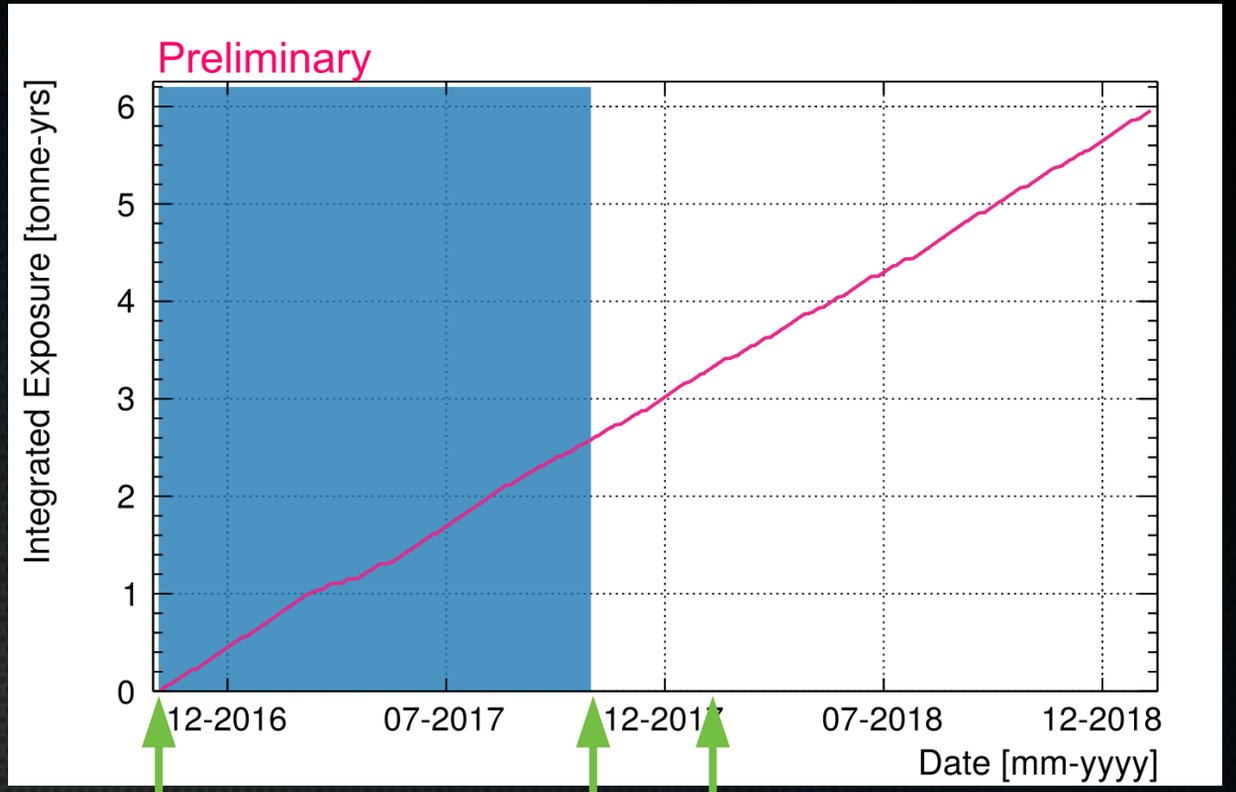
~30cm gaseous argon

~3.3t liquid argon

3µm TPB wavelength shifter (WLS)

5cm acrylic vessel





2012

Start of construction

Start of 1st fill

1st paper dataset
doi.org/10.1103/PhysRevLett.121.071801

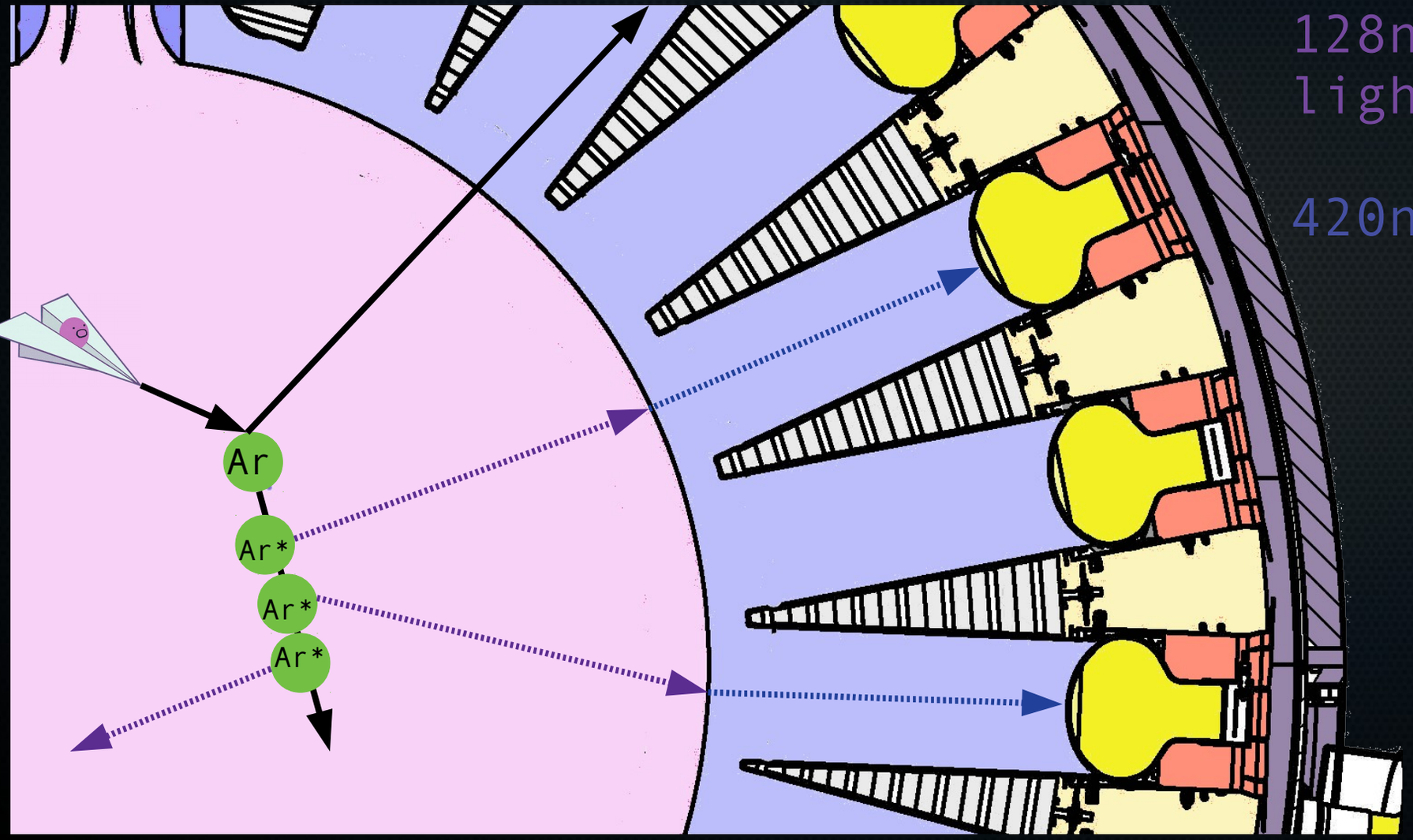
- Neck seal failure
- Poison Ar scintillation with Rn-scrubbed N2

Drain and refill Ar

2nd paper dataset (open)
doi.org/10.1103/PhysRevD.100.022004

- Blinded dataset
- Analysis currently under development

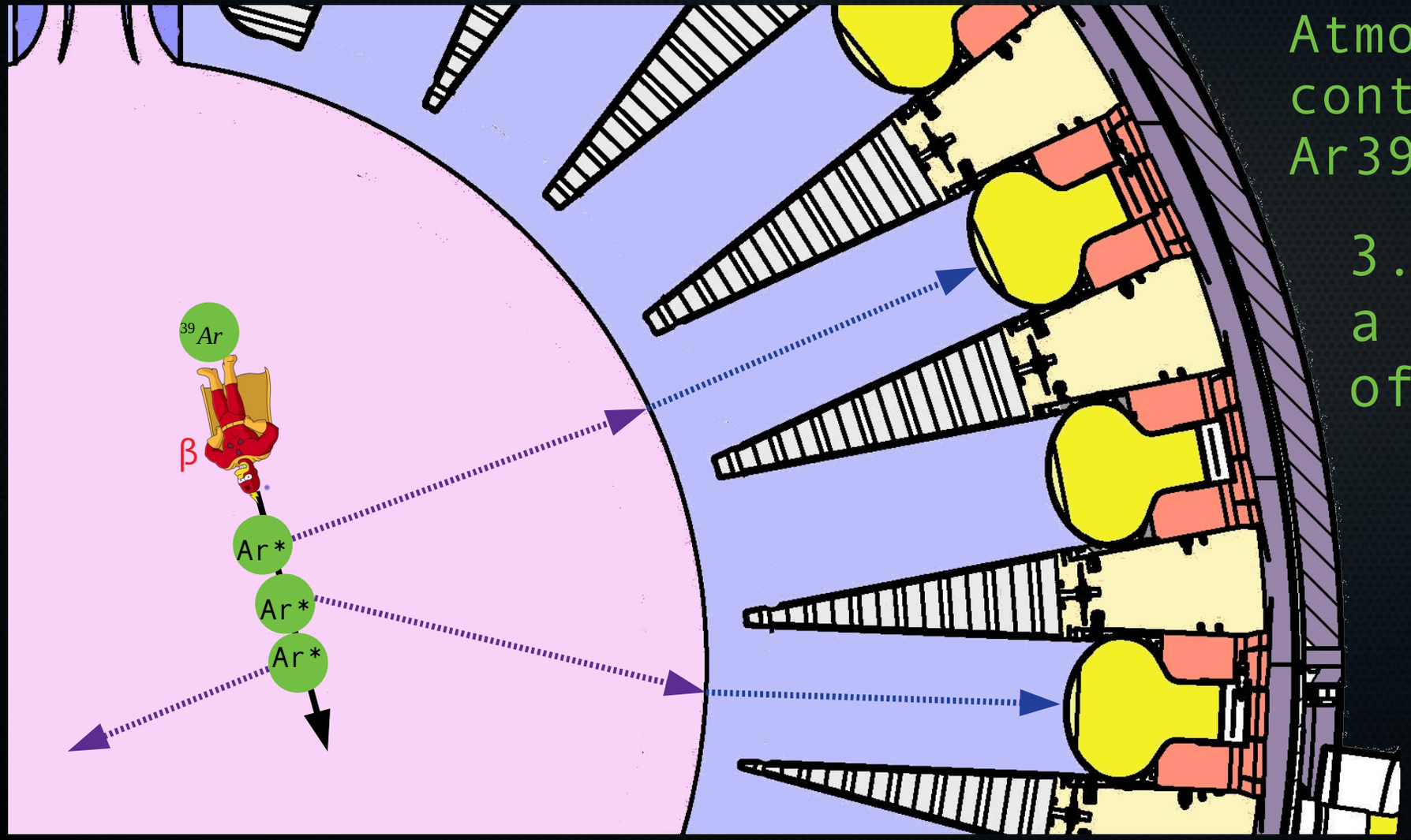
WIMP detection: nuclear recoil (NR)



128nm scintillation light

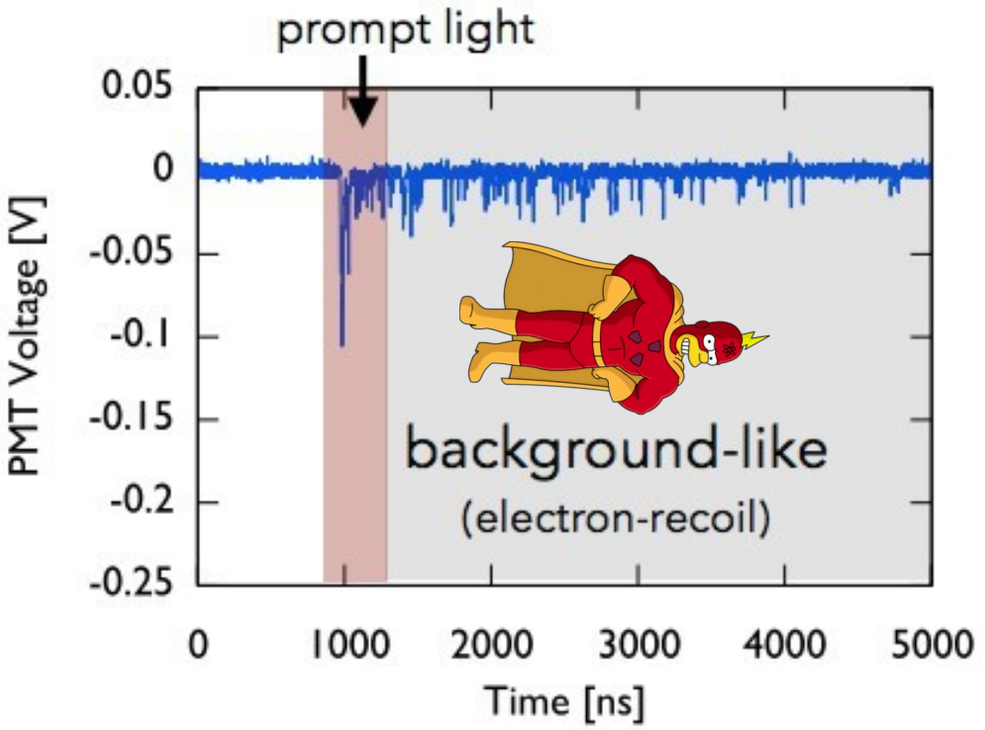
420nm shifted light

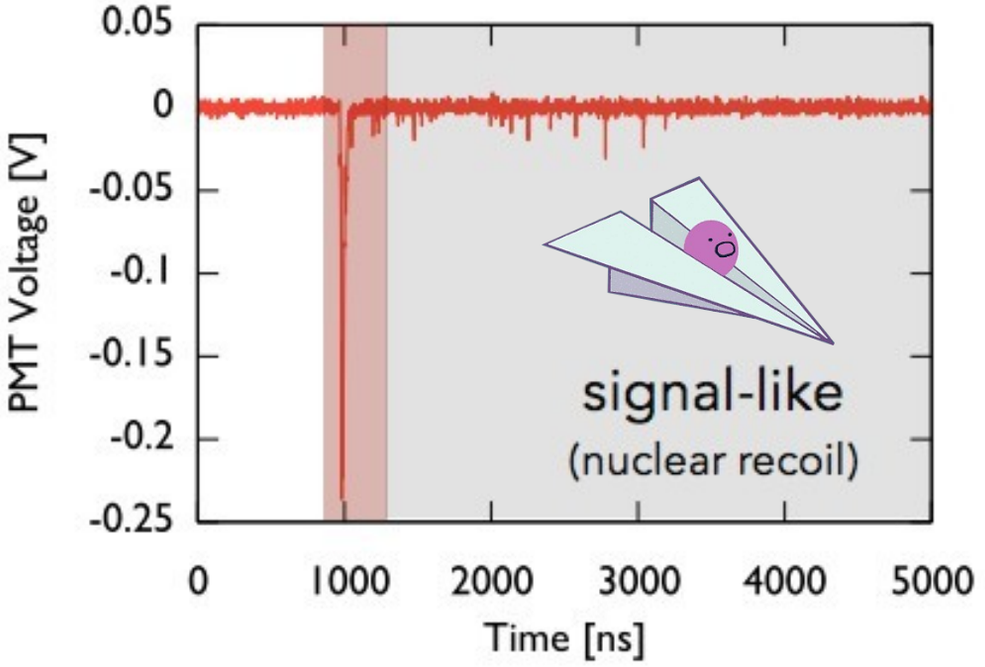
Ar39 background: electron recoil (ER)



Atmospheric argon contains ~1Bq/kg of Ar39

- 3.3t Ar produces a background rate of ~3.3kHz

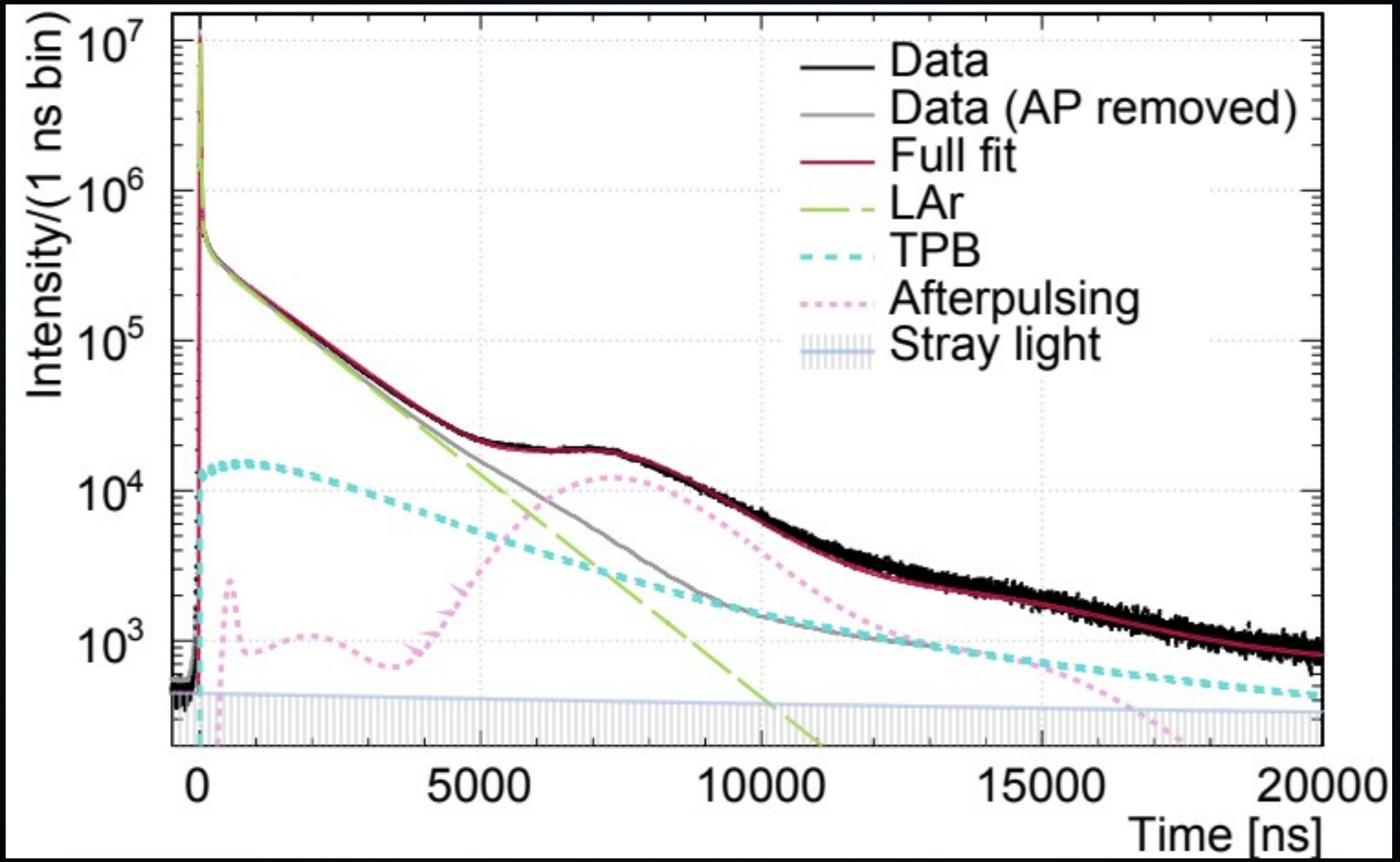




Pulse-shape discrimination (PSD)

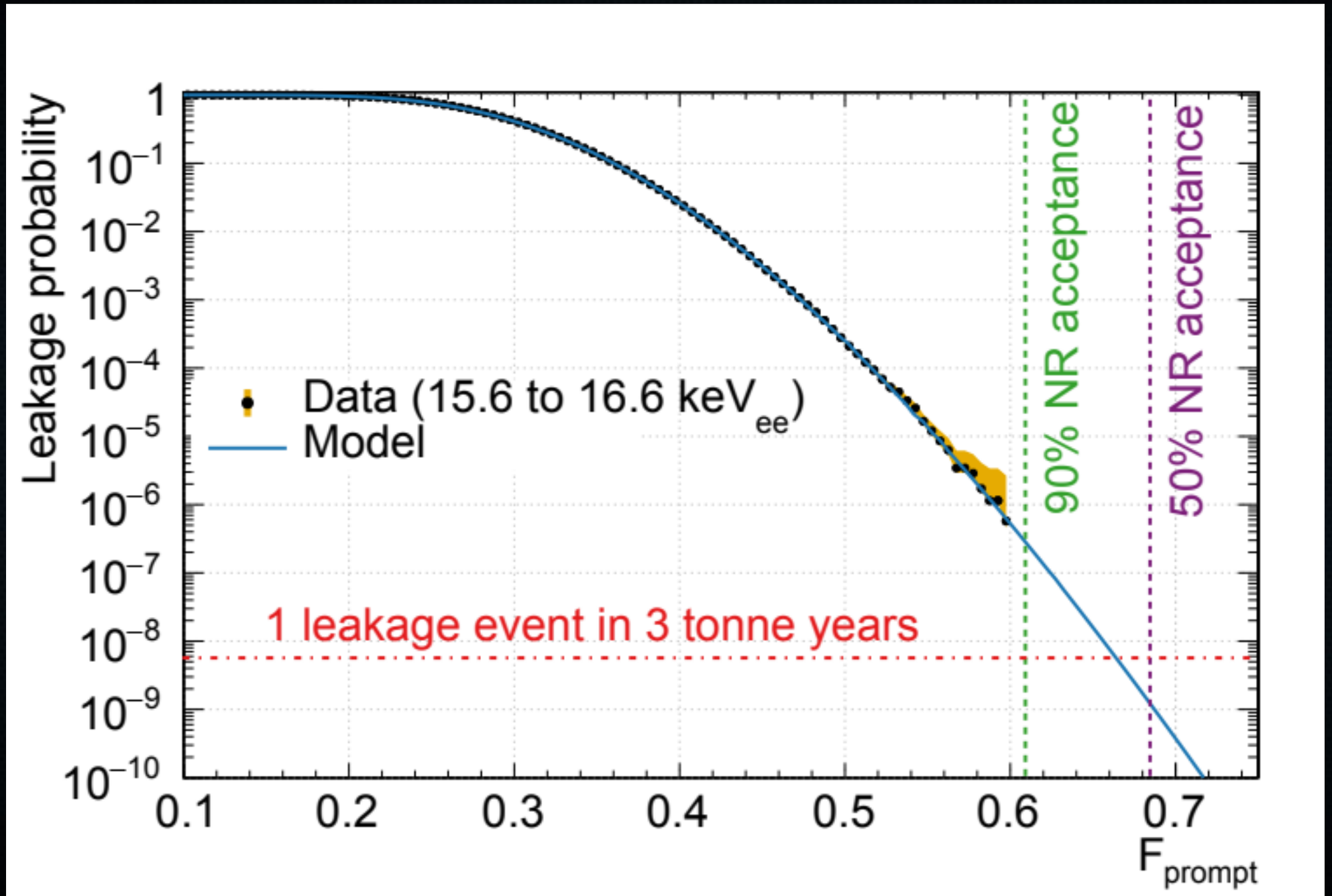
- Excited Ar produced in singlets and triplets
- Triplets live much longer (1.3μs) than singlets (6ns)
- Use ratio of prompt light (Fprompt) to discriminate ER backgrounds

Afterpulse removal using a Bayesian photoelectron (PE) counting algorithm

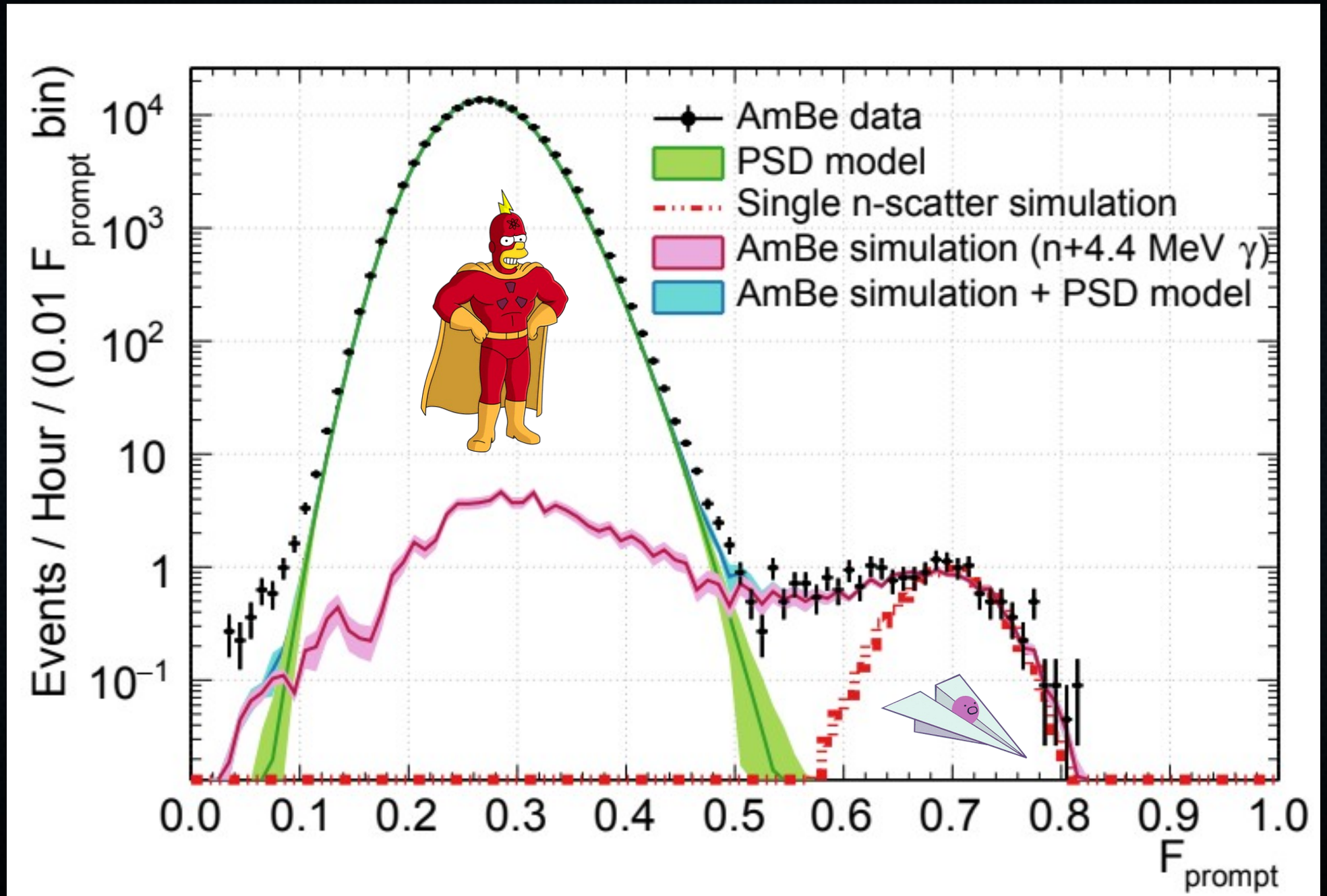


Improved PSD, energy and position reconstruction

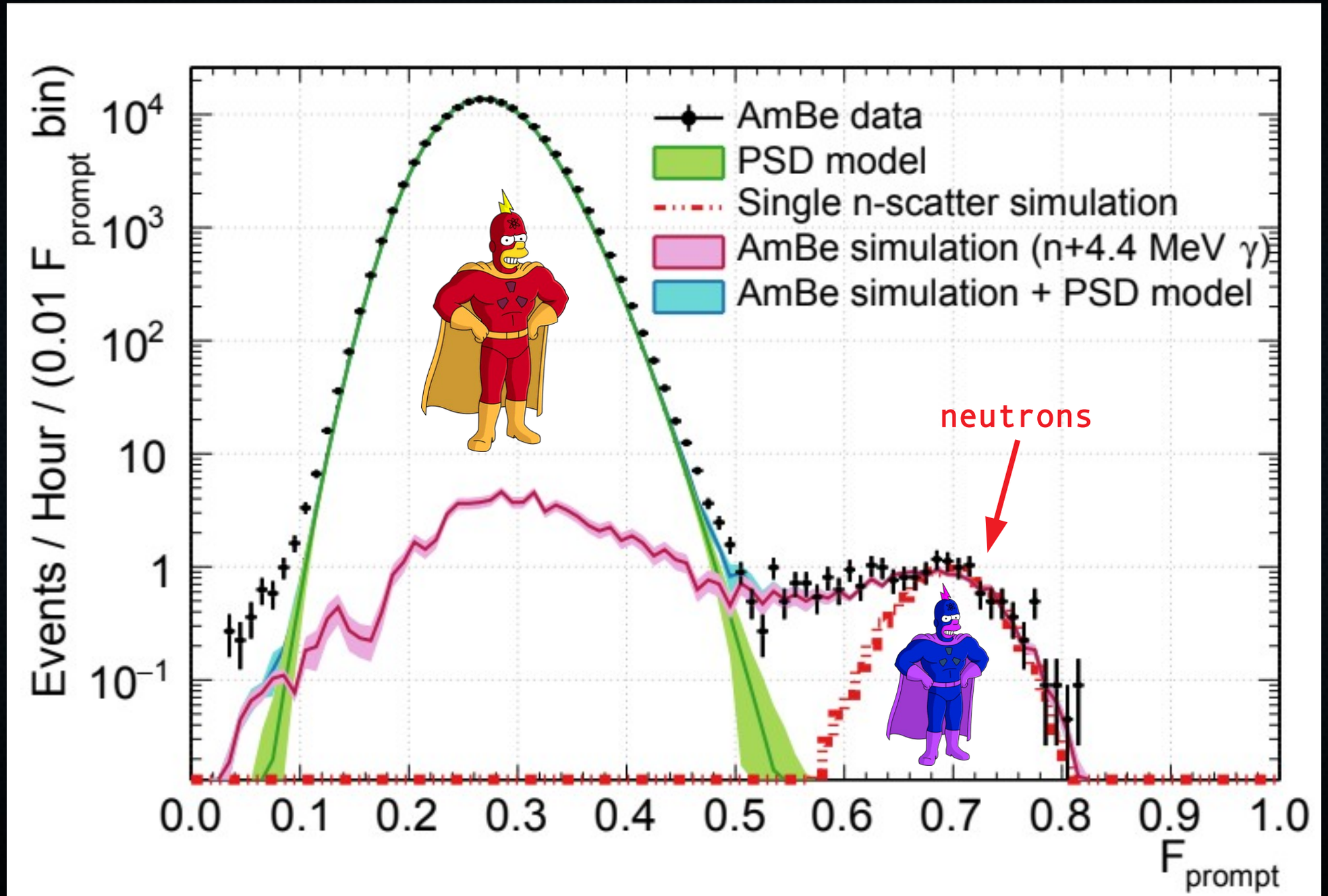
Best PSD on the market



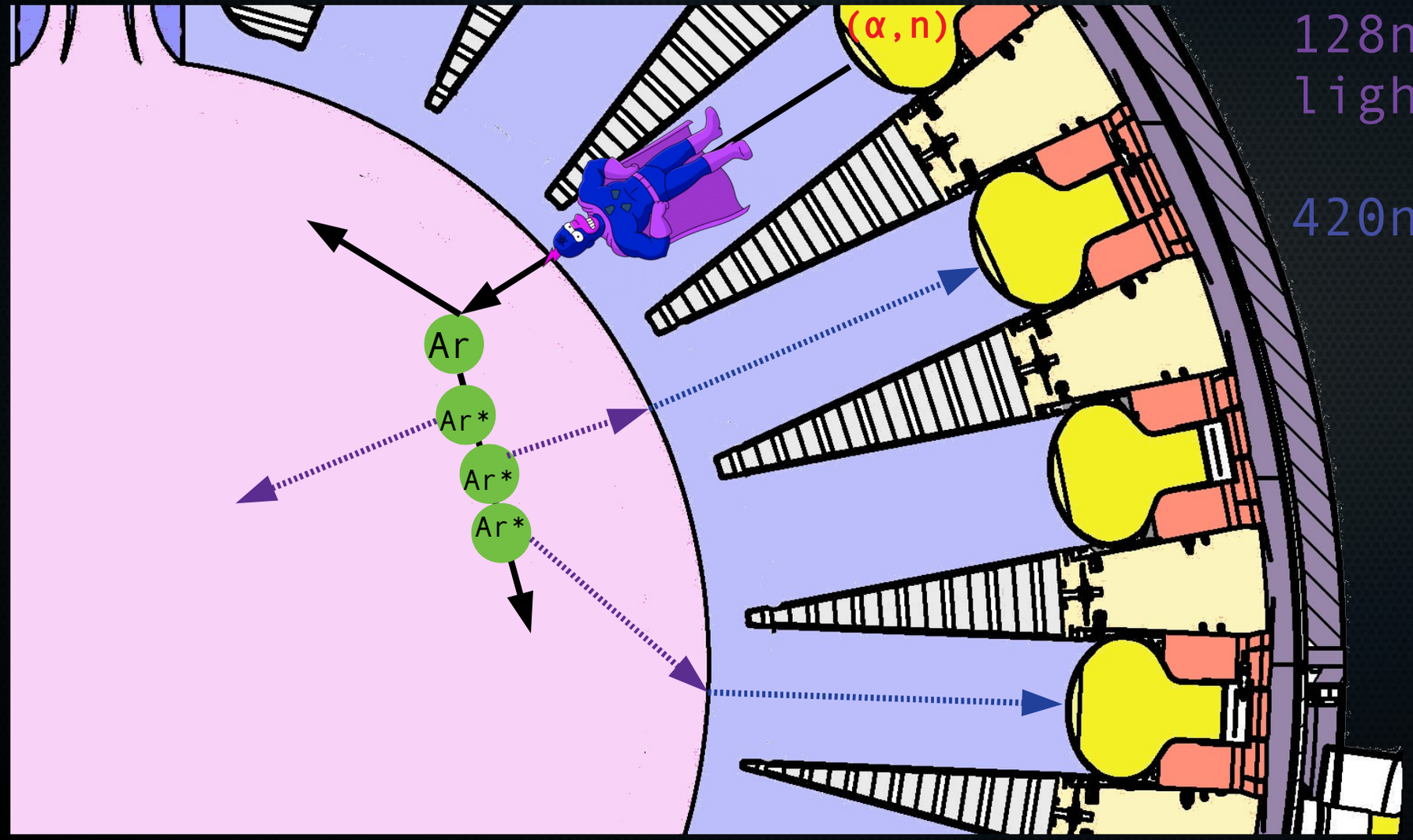
AmBe neutron source calibration



Neutrons cannot be rejected using PSD



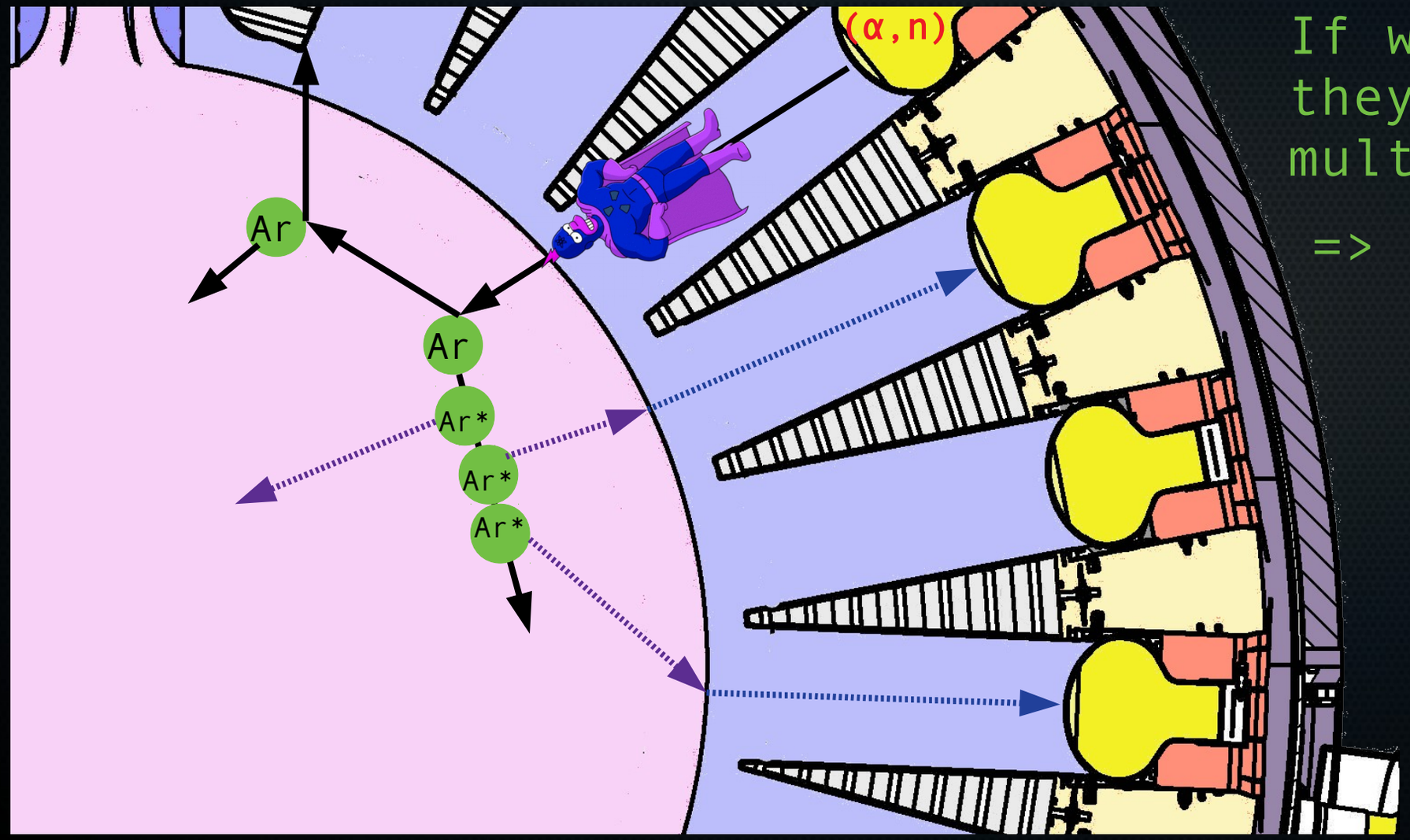
Neutrons from (α,n) in PMTs



128nm scintillation light

420nm shifted light

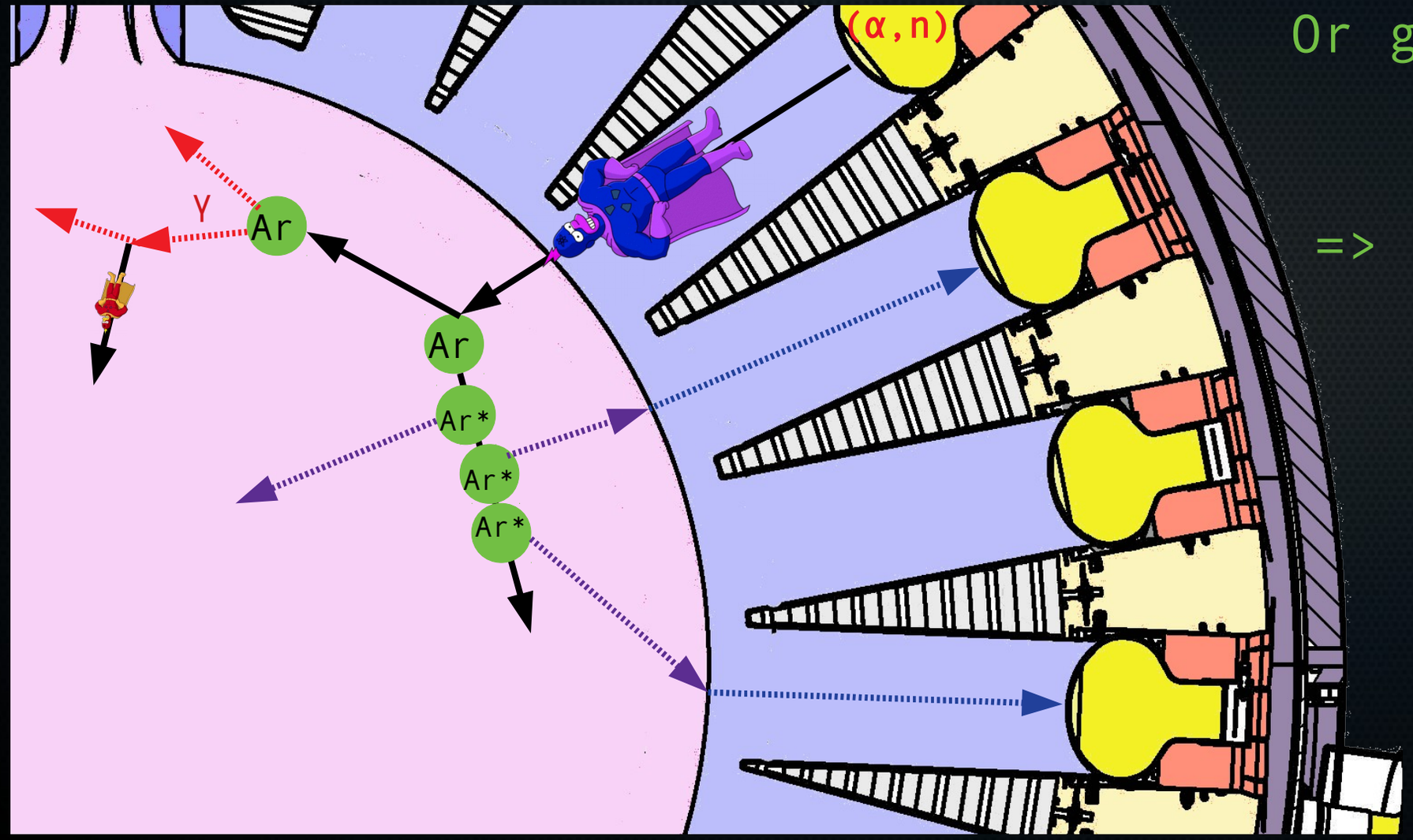
Neutrons from (α,n) in PMTs



If we‘re lucky, they scatter multiple times.

=> Reject multiple scatters

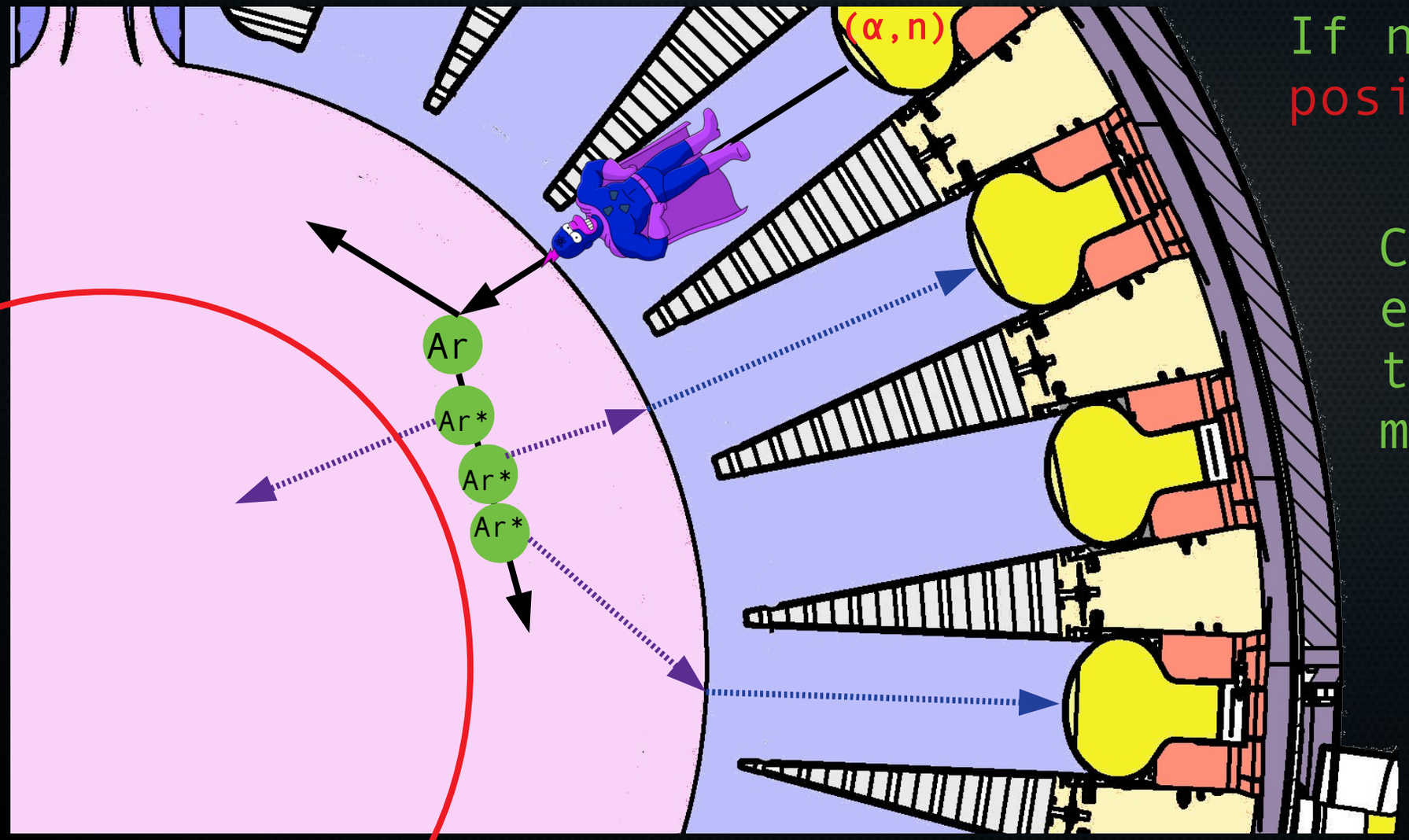
Neutrons from (α,n) in PMTs



Or get captured.

=> Reject events followed by capture gammas

Neutrons from (α,n) in PMTs

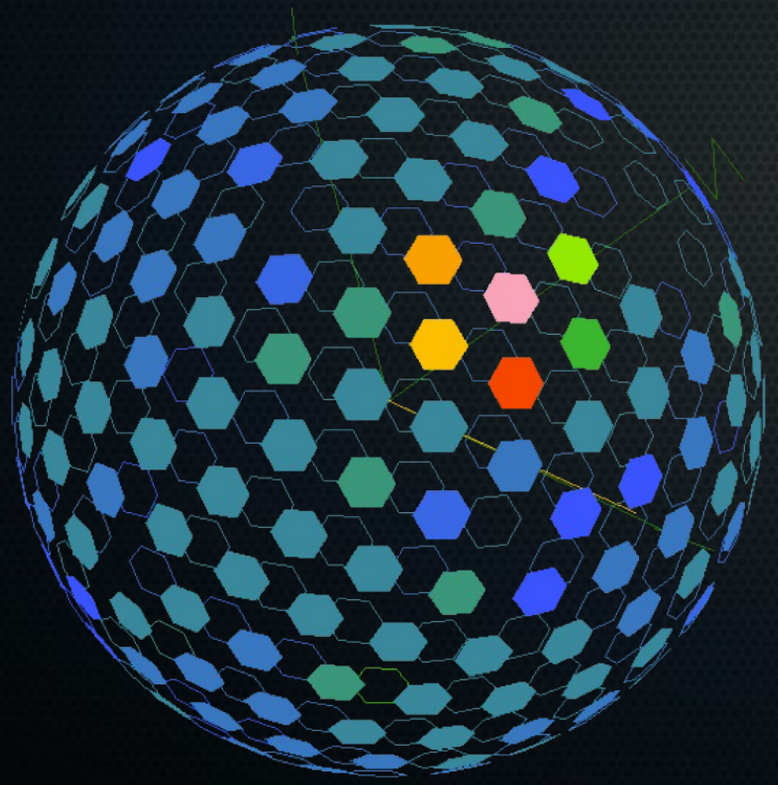


If not, reject by position.

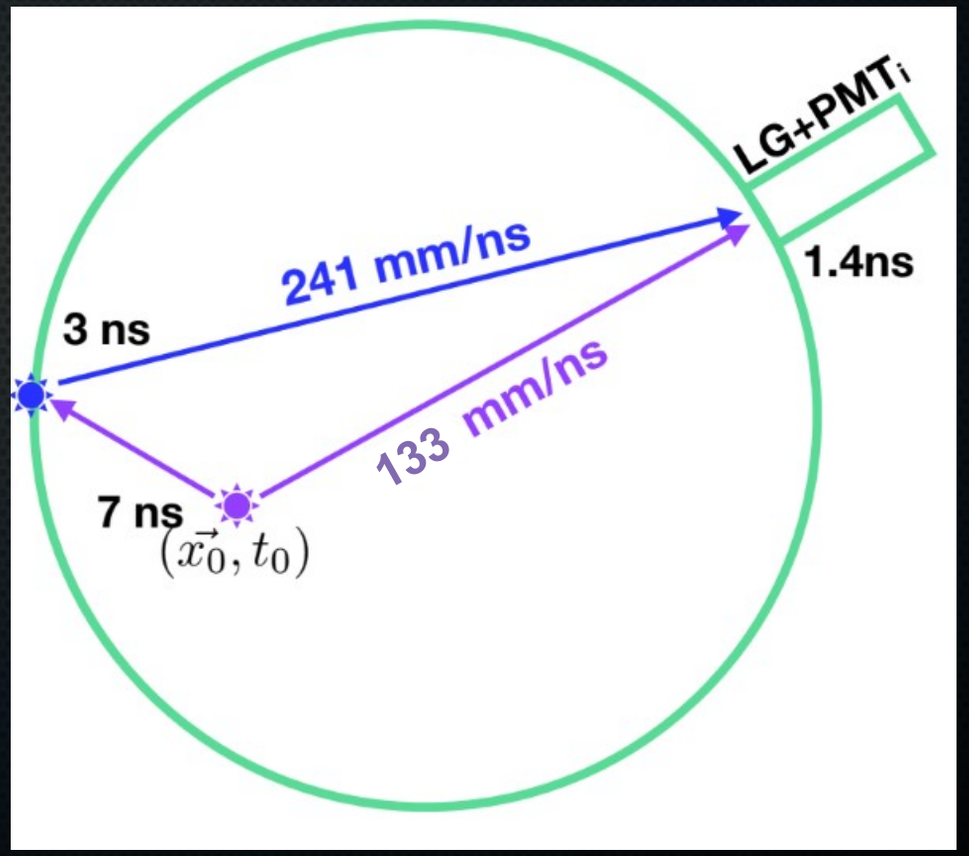
Current analysis employs only this rejection mechanism.

Position reconstruction

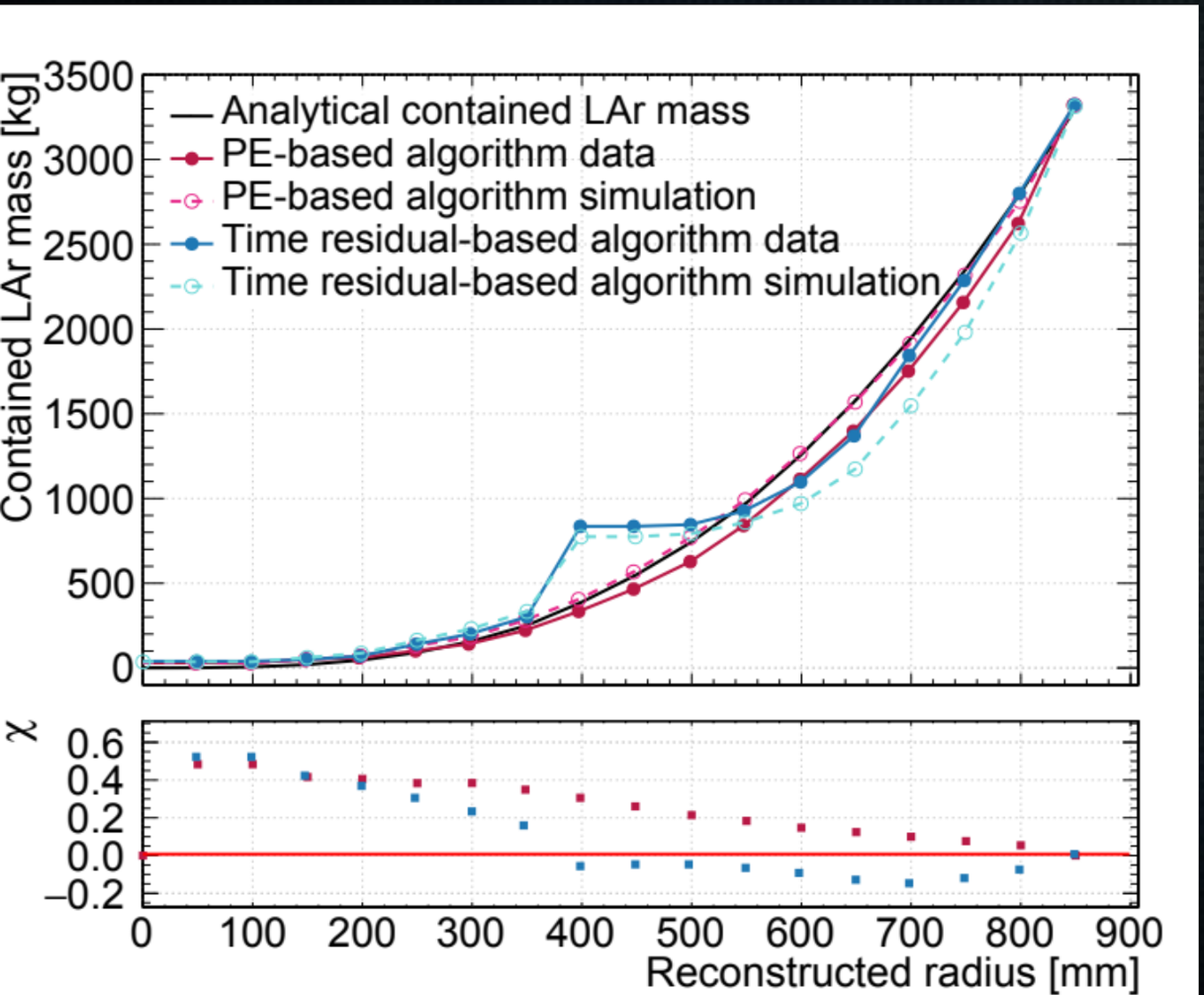
1. Based on PE distribution



2. Based on time of flight

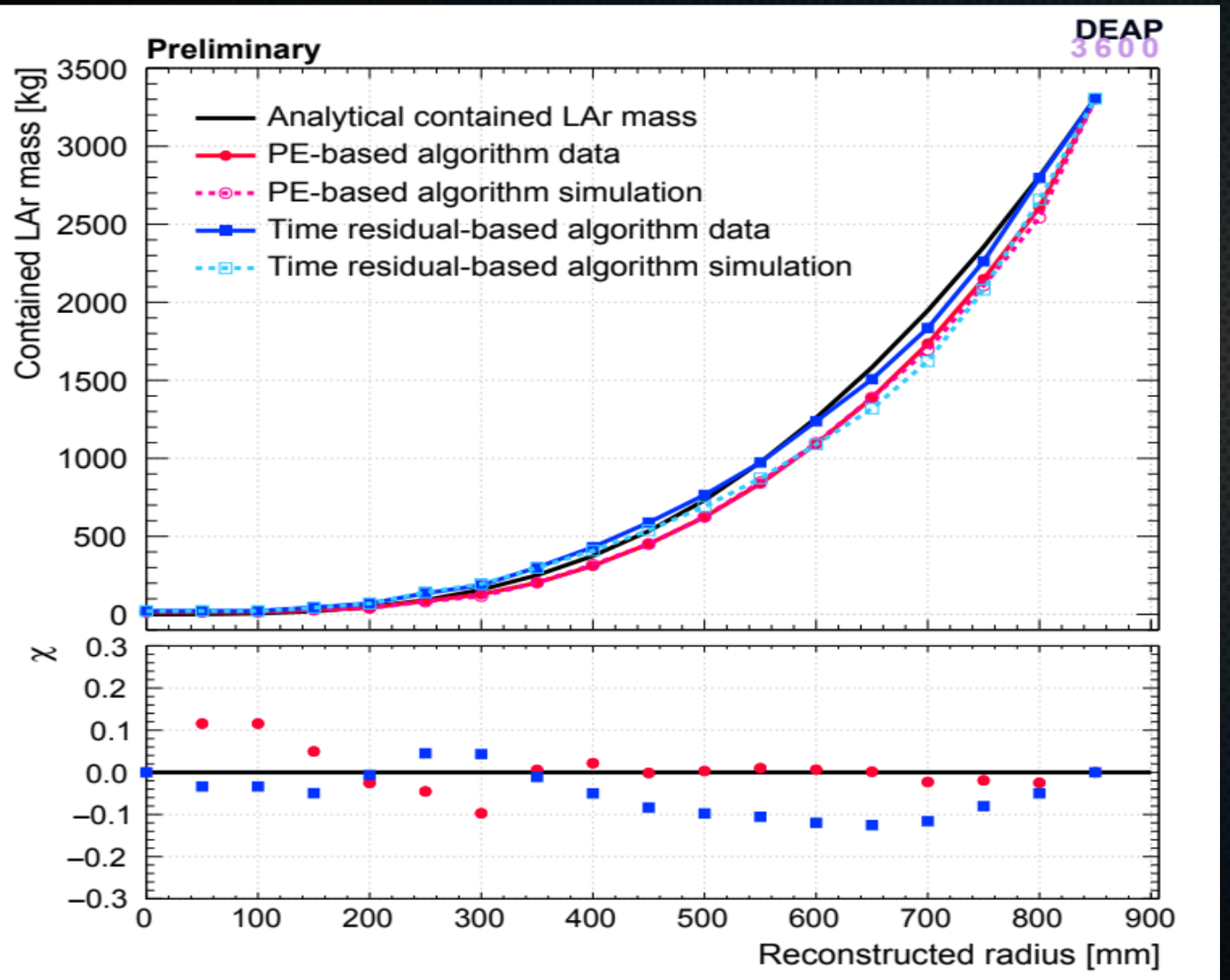


Position reconstruction validation



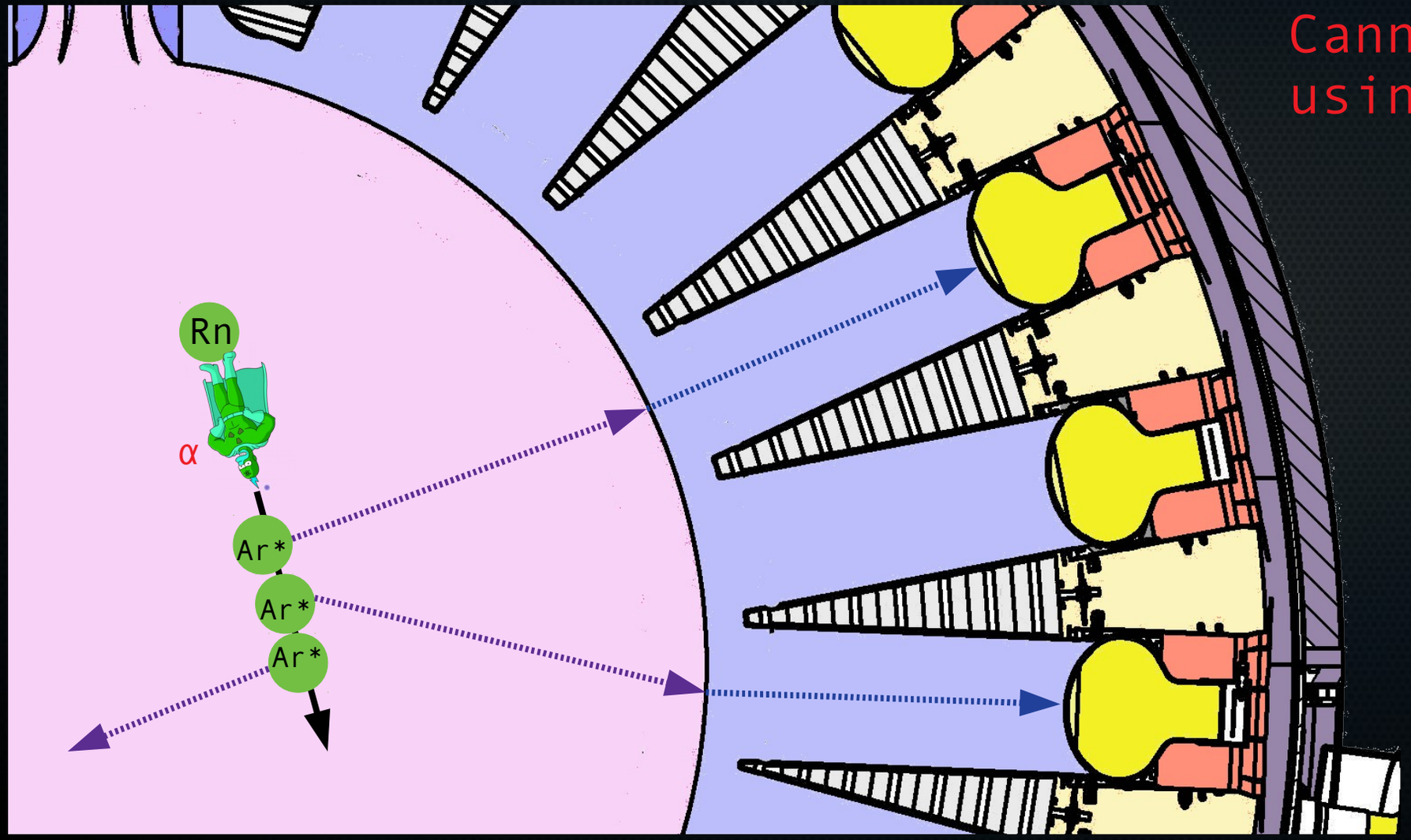
- Reconstruct contained LAr mass using Ar39 events
- Kink is an artifact of time-residual calculation
- Will be tuned in future analyses

Position reconstruction validation



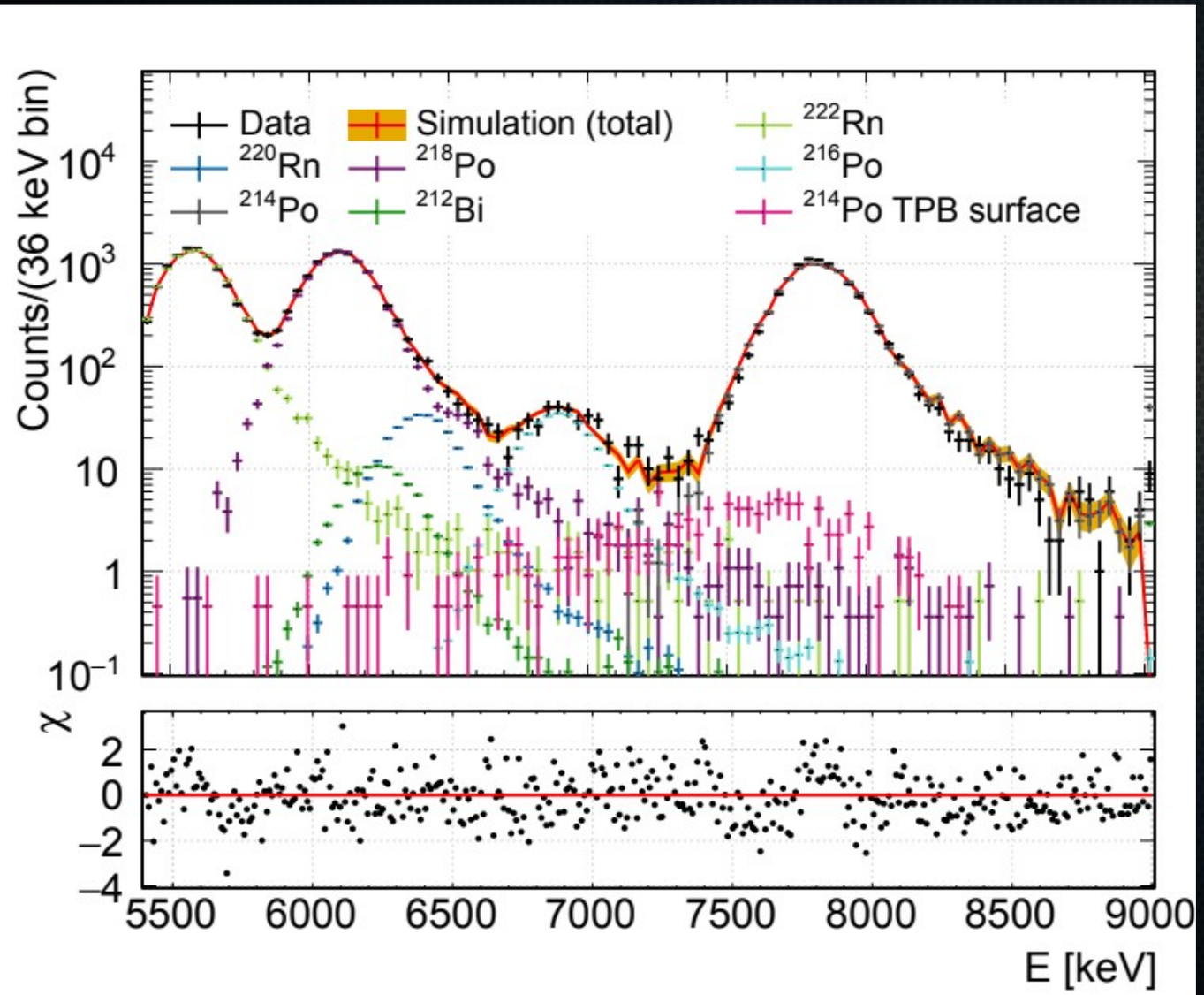
- Reconstruct contained LAr mass using Ar39 events
- ~~Kink is an artifact of time-residual calculation~~
- ~~Will be tuned in future analyses~~

More backgrounds: α



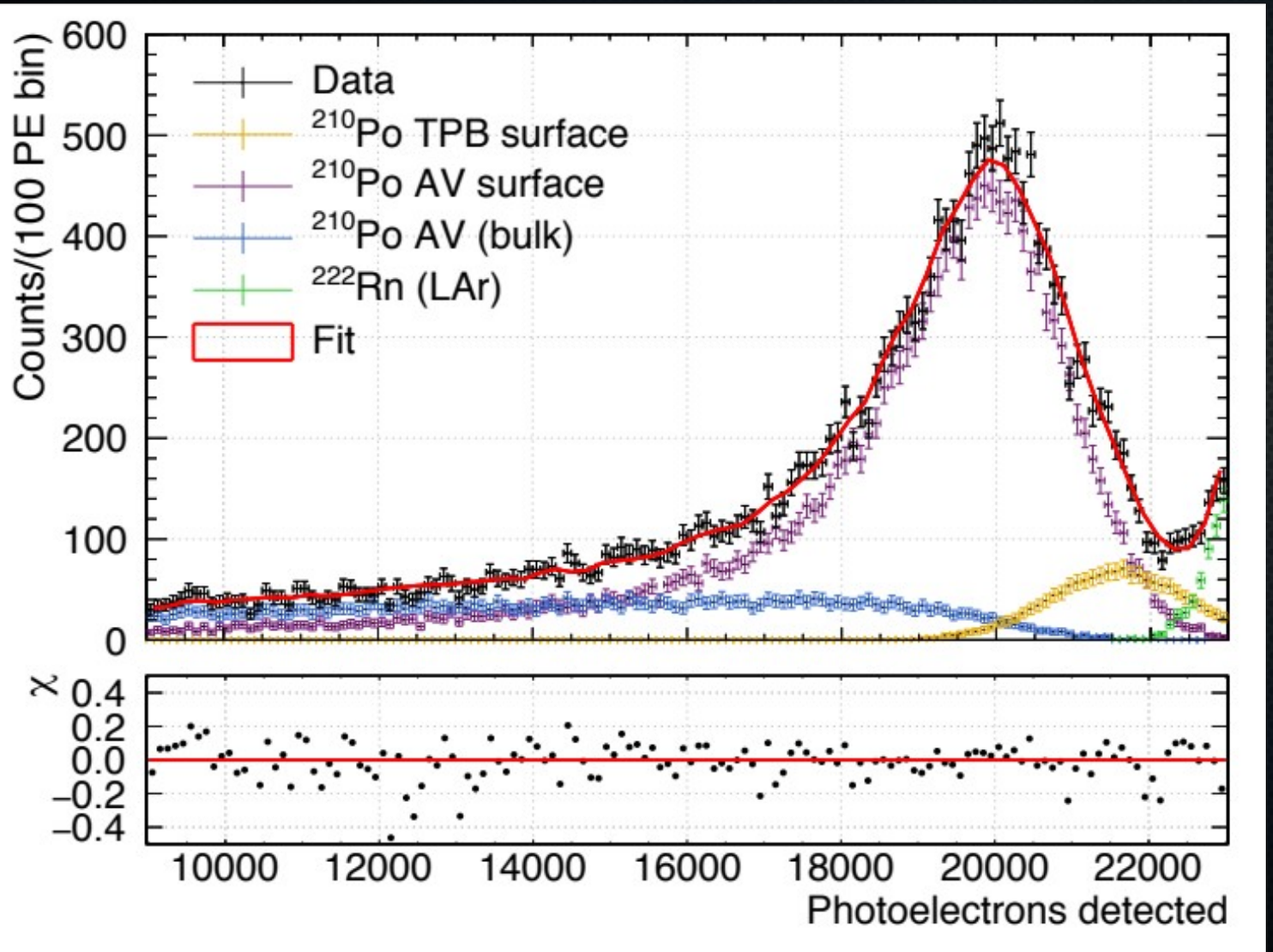
Cannot be rejected using PSD

Rejecting LAr bulk α backgrounds

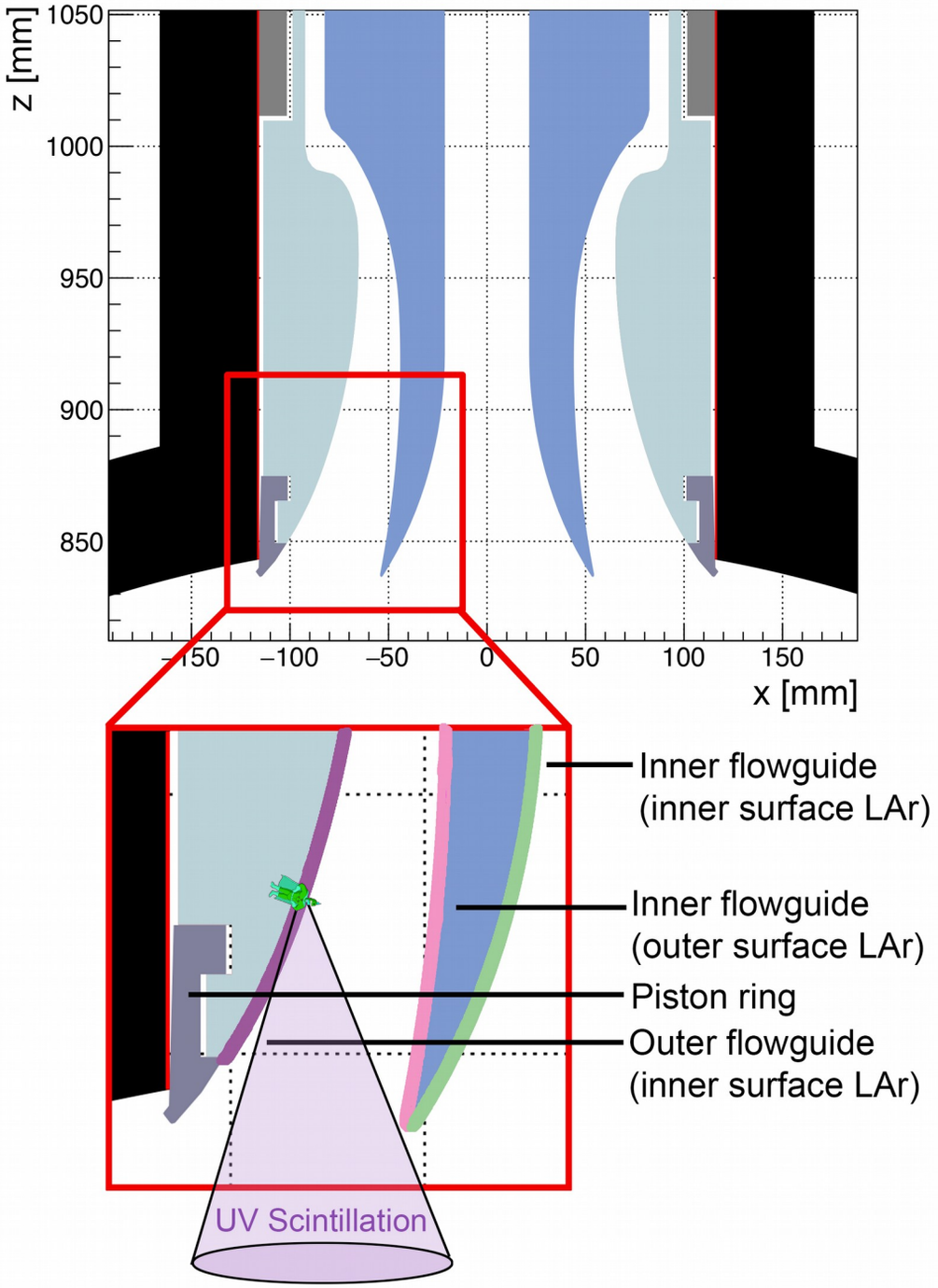


- Energy well beyond WIMP region of interest (ROI)
- Well explained by background model
- Easy to reject

Rejecting AV surface α backgrounds

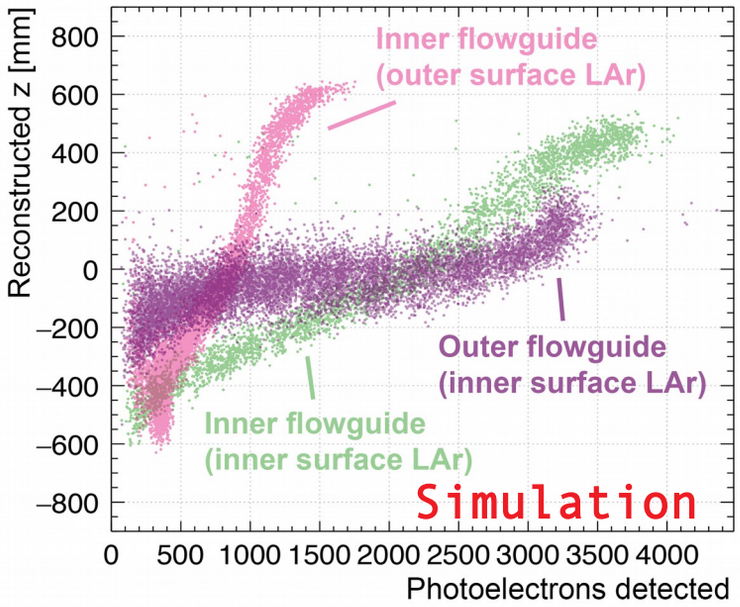


- Emitted from the acrylic vessel (AV) surface
- Only partial energy deposition in LAr
- Can leak into WIMP ROI
- Reject using position reconstruction

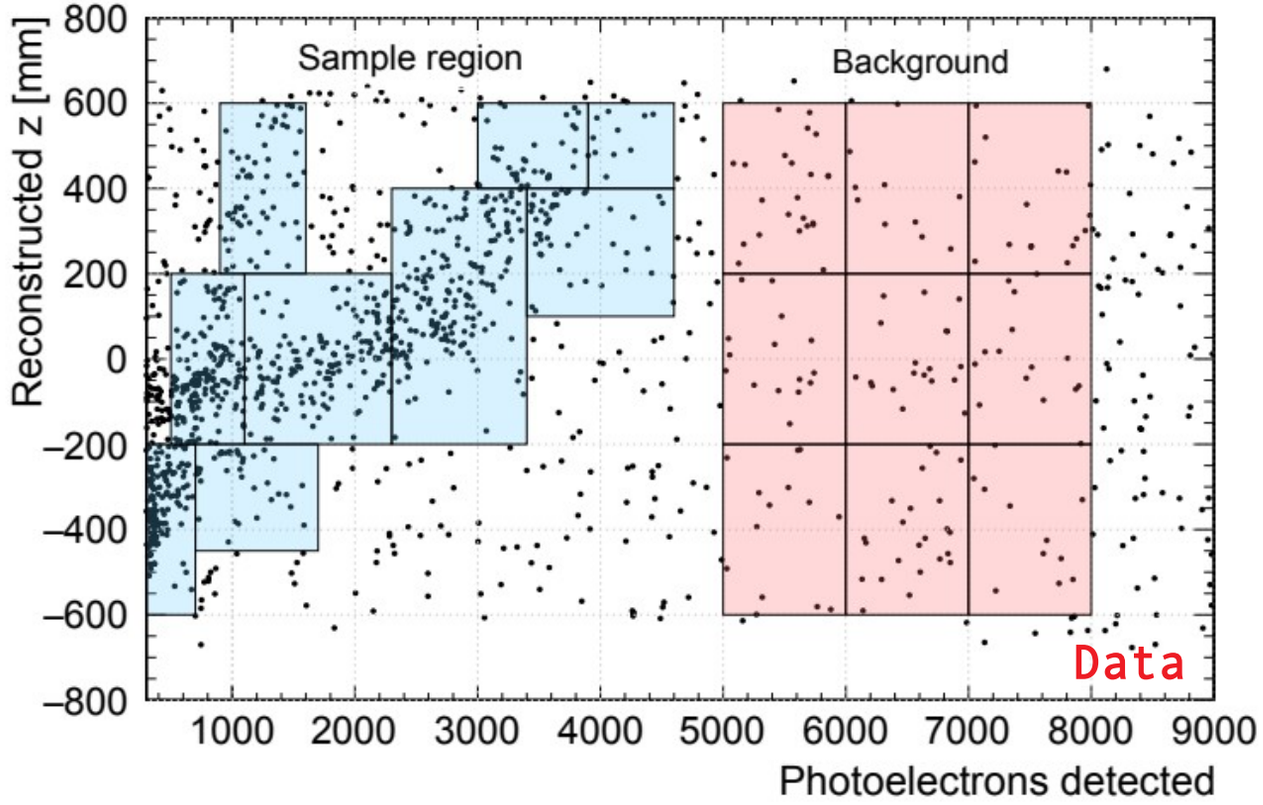


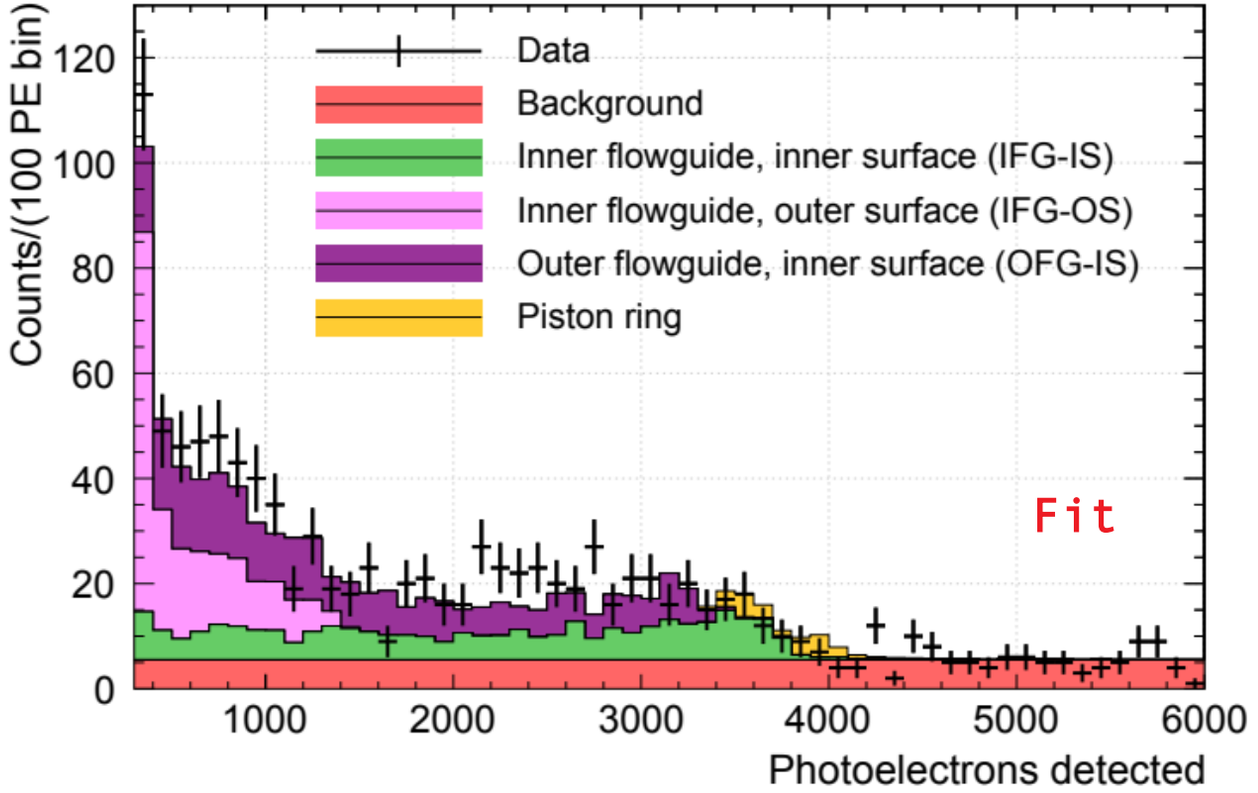
Neck α backgrounds

- α emitted from acrylic flowguide surfaces
- Scintillate in LAr film covering surfaces
- Scintillation light collimated by neck
- Majority lost because neck has no TPB
- Significant ROI leakage

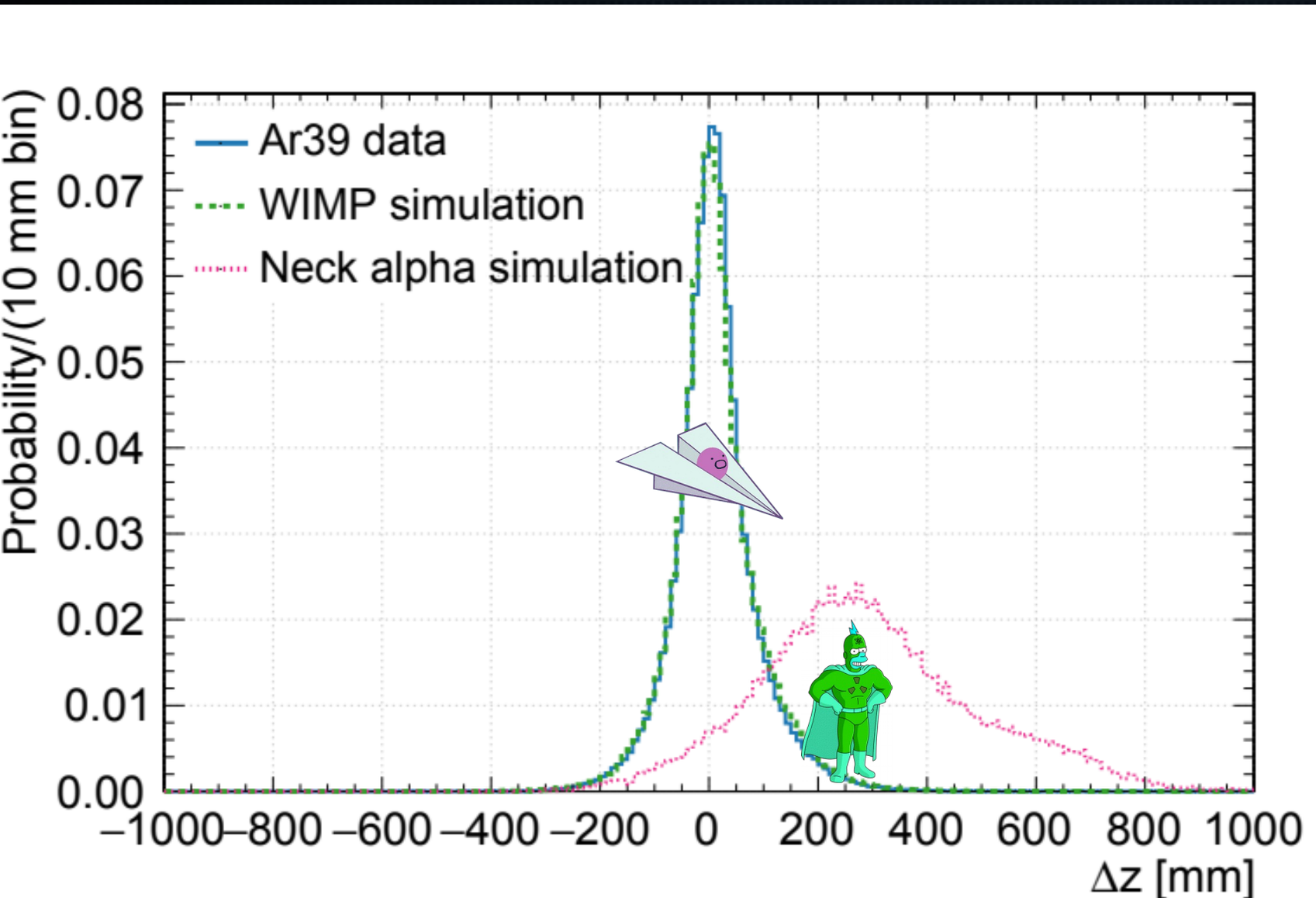


- Distinct features in reconstructed energy and position
- Allows to break the degeneracy between flowguide surfaces
- Estimate rates from fit to data

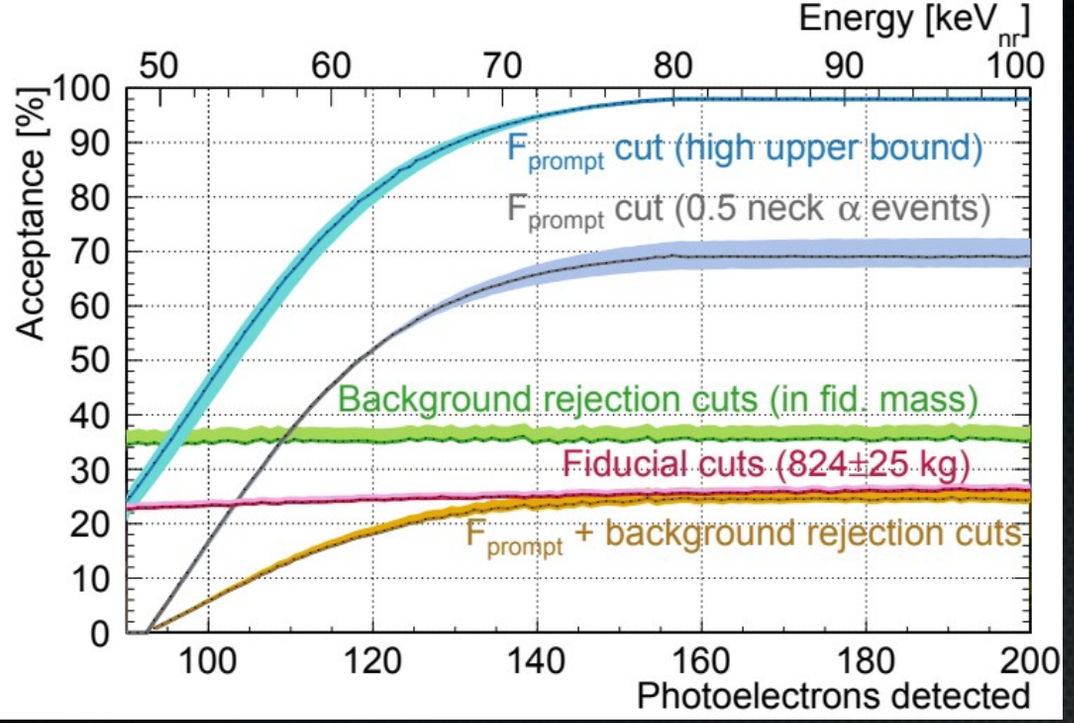


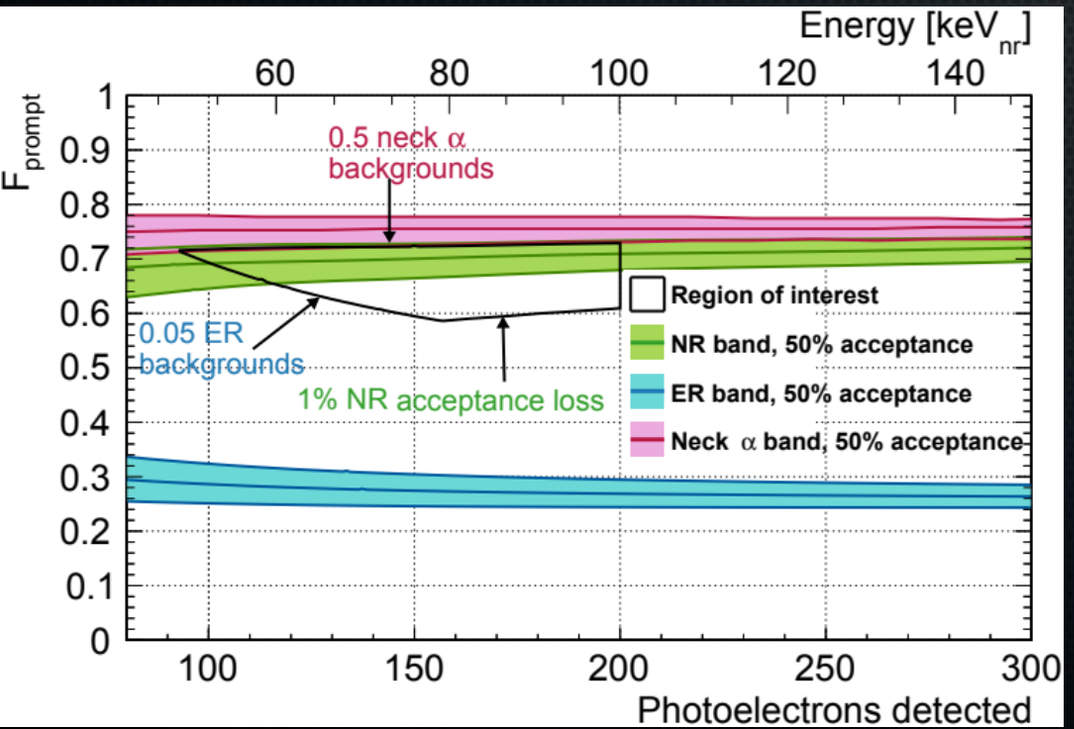


Rejecting neck α backgrounds



- Exploit discrepancy between two position fitters
- Caused by collimated light from neck





Backgrounds summary

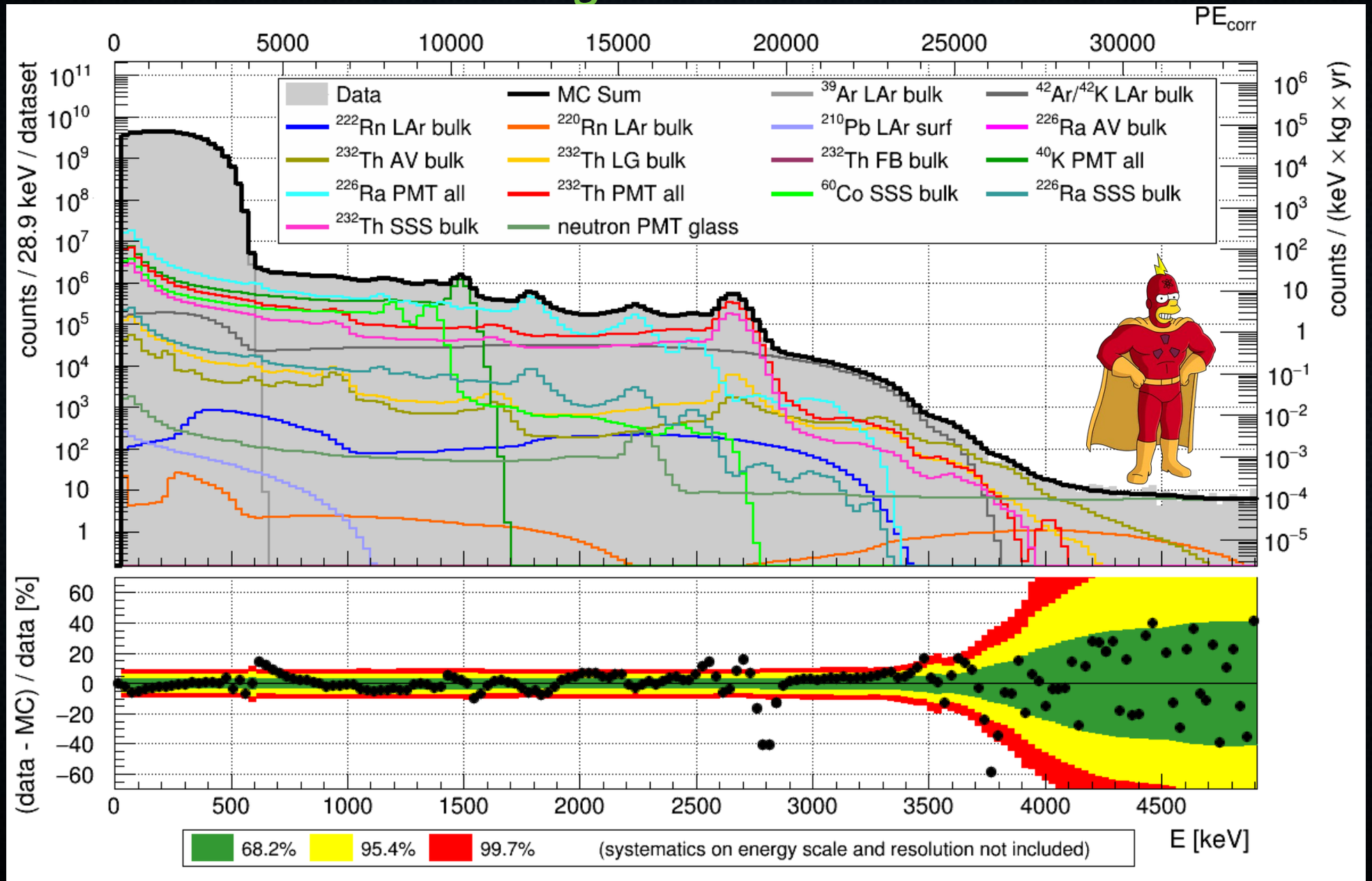
Final PE and Fprompt cuts chosen such that total background expectation:

< 1 event in 758 tonne days

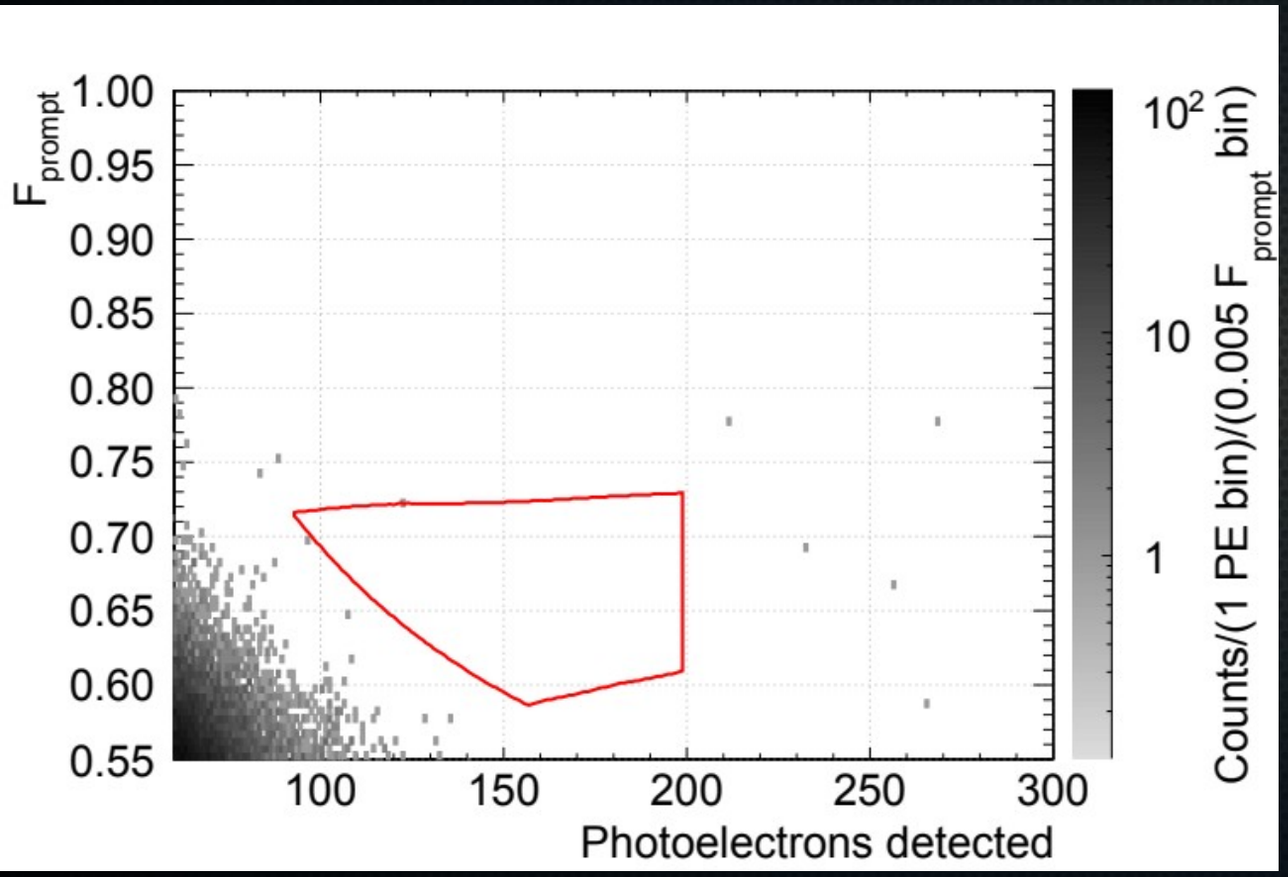
	Source	N^{ROI}
β/γ's	ERs	0.03 ± 0.01
	Cherenkov	< 0.14
n's	Radiogenic	$0.10^{+0.10}_{-0.09}$
	Cosmogenic	< 0.11
α's	AV surface	< 0.08
	AV Neck FG	$0.49^{+0.27}_{-0.26}$
	Total	$0.62^{+0.31}_{-0.28}$

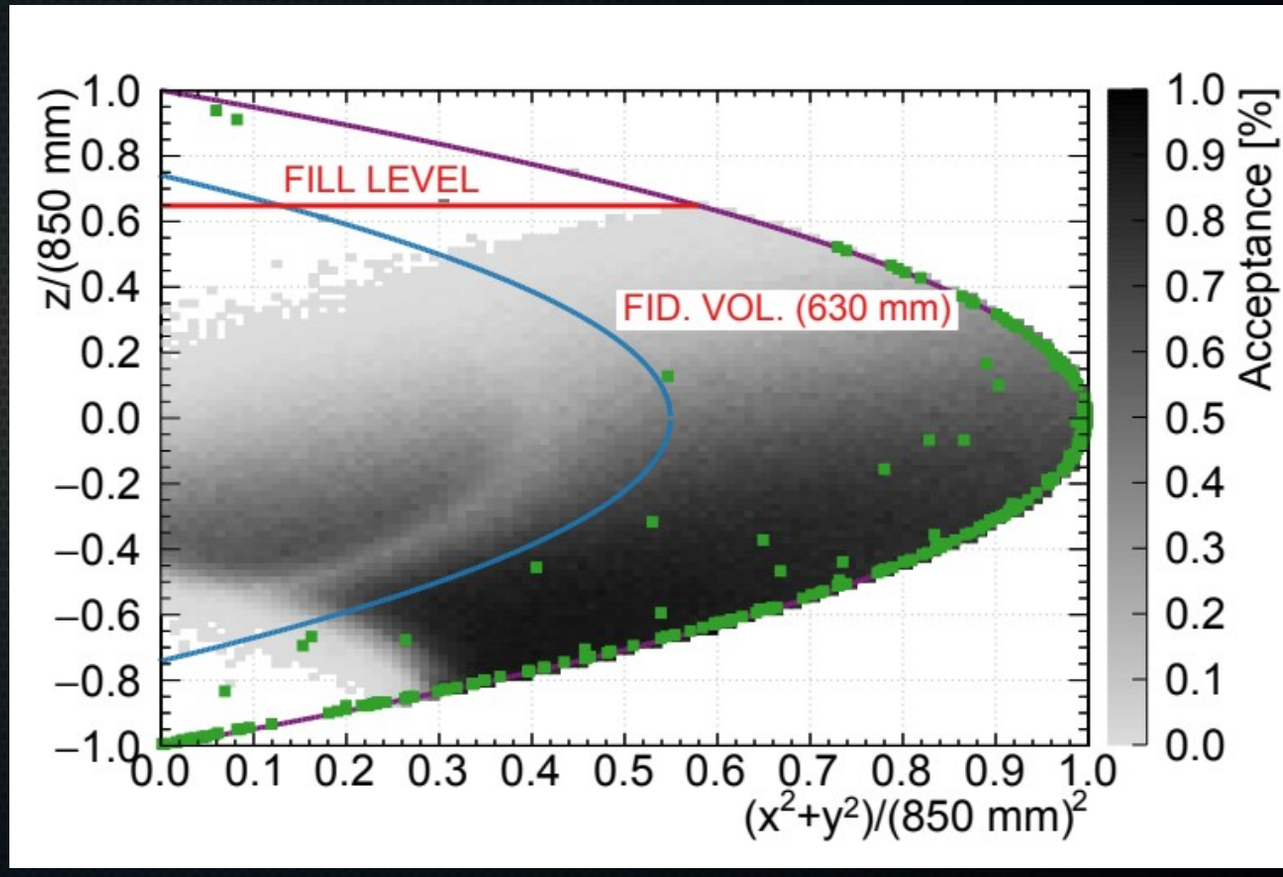
Combined ER background model

arxiv.org/abs/1905.05811

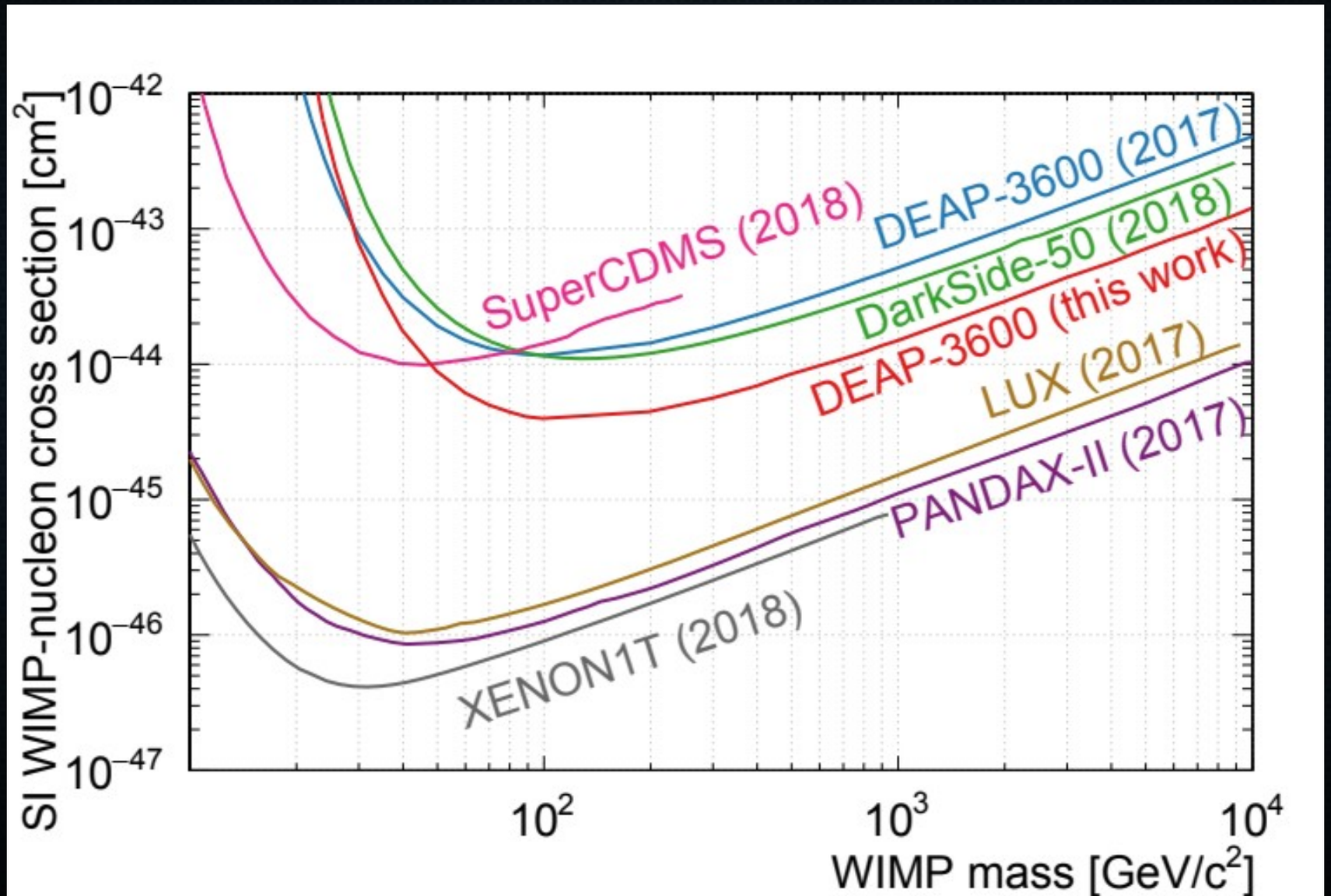


WIMP ROI: 0 events in 758 tonne days





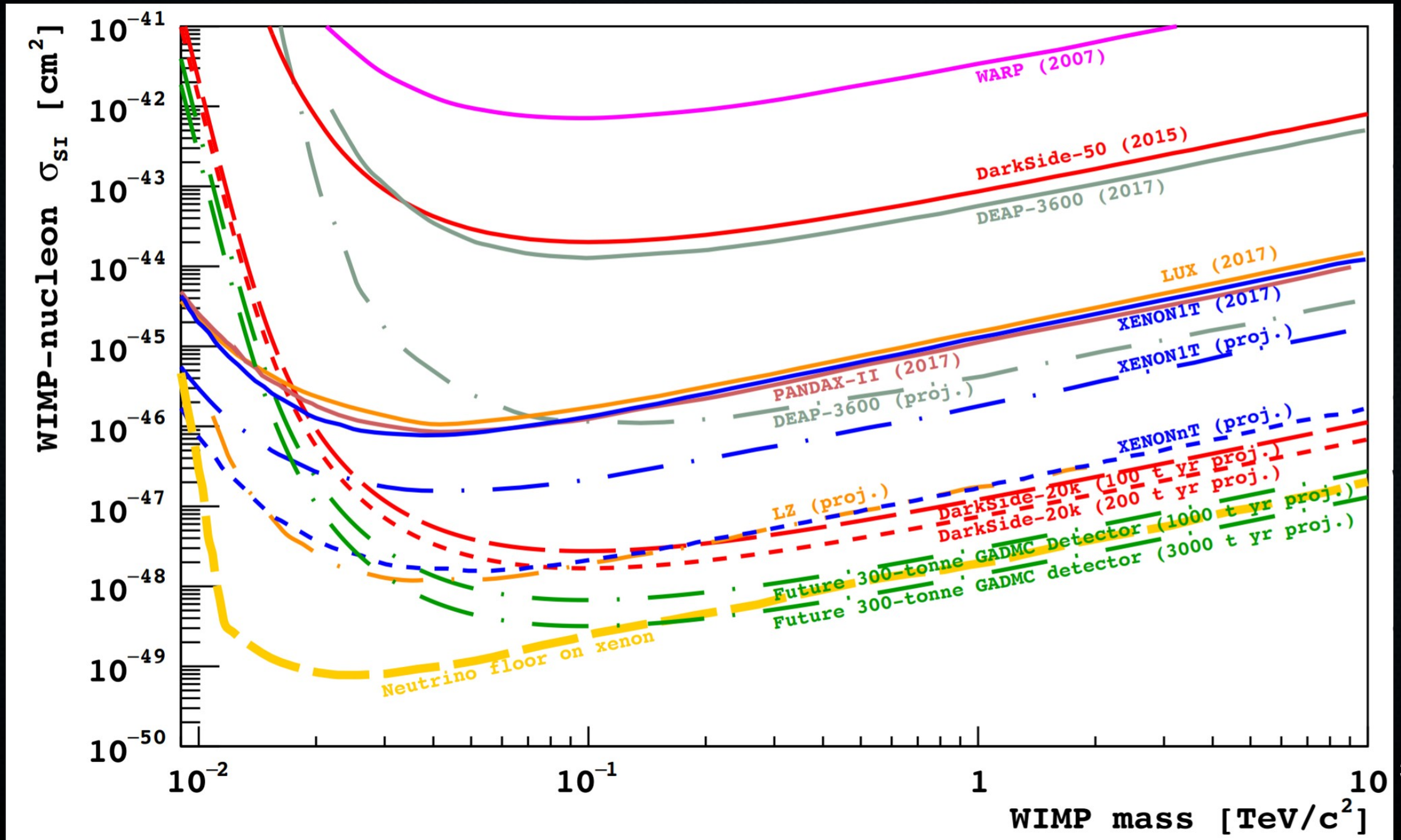
Leading limit on the WIMP-nucleon spin-independent cross section on a LAr target of 3.9E−45cm² for a 100 GeV WIMP mass at 90% C.L.



Conclusion

- World-leading PSD performance:
  2.8E-7 @ 90% NR acceptance
- Combined fit of ER background simulation to data over 9 orders of magnitude
- Two position reconstruction algorithms:
  PE-based and TOF-based
- Background expectation < 1 event in 758 tonne days
- Observed no events
- Leading limit on the WIMP-nucleon spin-independent cross section on a LAr target of 3.9E−45cm² for a 100 GeV WIMP mass at 90% C.L.
- Developing analysis for current blind dataset

Future


WIMP-nucleon σ_{SI} [cm^2]
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-2}
10^{-1}
1
10
WIMP mass [TeV/c^2]
WARP (2007)
DarkSide-50 (2015)
DEAP-3600 (2017)
LUX (2017)
PANDAX-II (2017)
XENON1T (2017)
DEAP-3600 (proj.)
XENON1T (proj.)
XENONnT (proj.)
LZ (proj.)
DarkSide-20k (100 t yr proj.)
DarkSide-20k (200 t yr proj.)
Future 300-tonne GADMC Detector (1000 t yr proj.)
Future 300-tonne GADMC detector (3000 t yr proj.)
Neutrino floor on xenon