DEAP-3600
Dark Matter Experiment

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on behalf of

the DEAP-3600 collaboration

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Sudbury, Ontario, Canada

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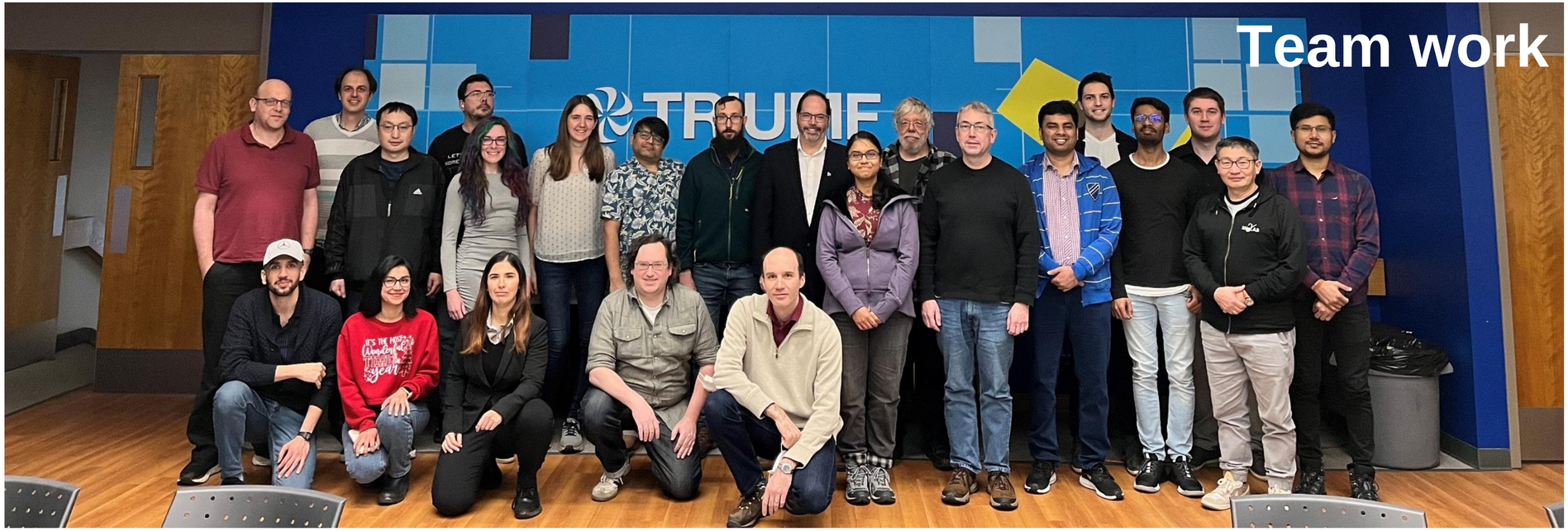
Lake Louise Winter Institute

DEAP Collaboration

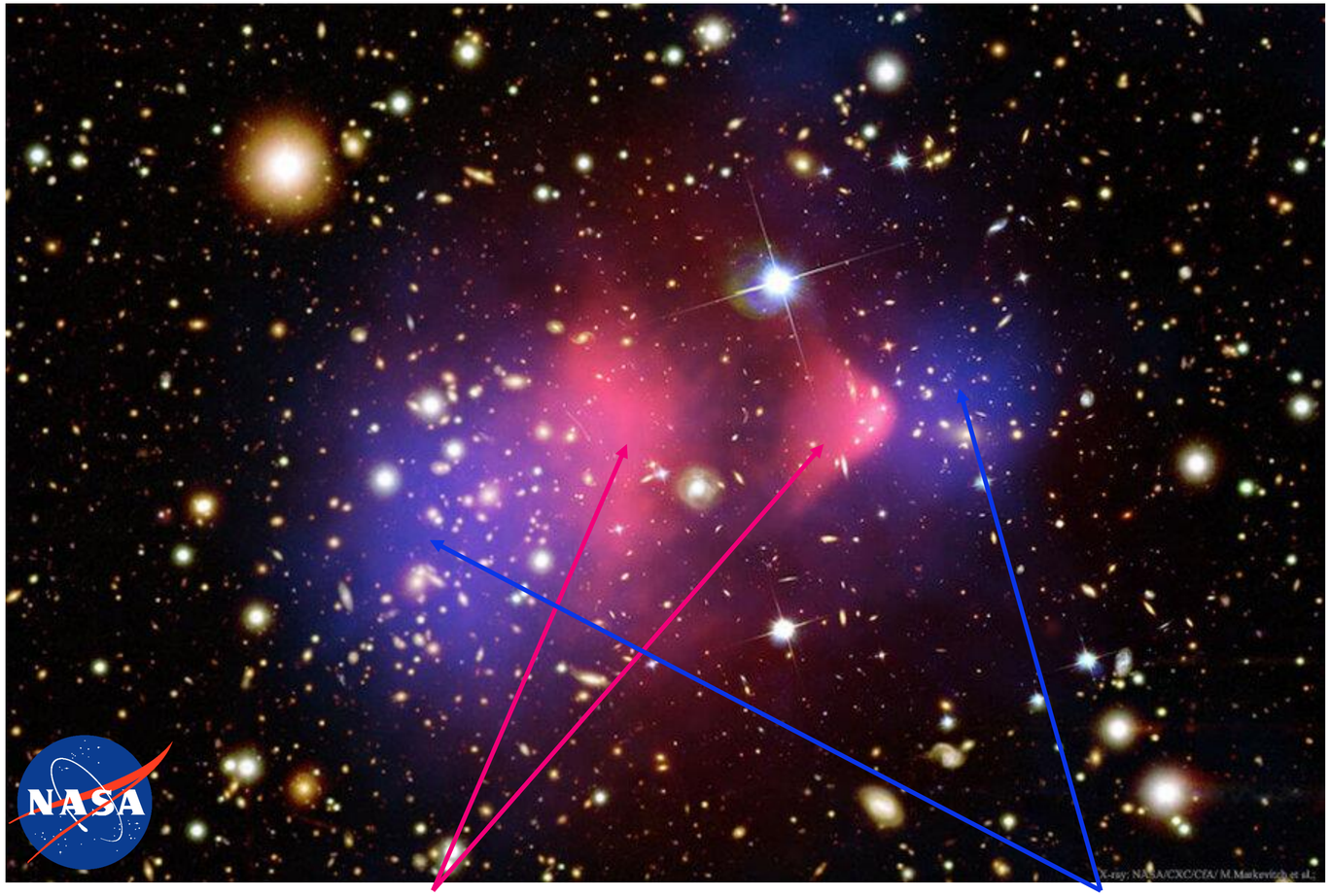


~ 100 researchers in Canada, Germany, Italy, Mexico, Poland, Russia, Spain, UK, USA

Why do we search for DARK matter?

One of the pieces of evidence for the existence of DARK matter:

A collision between galaxies: formed Bullet Cluster



Matter we know (hot gas) traced by X-ray detector

Matter we don't know observed by gravitational lensing

Most of the Bullet Cluster's total mass was in a different place than most of the 'normal' mass

Therefore, most of the total mass causing the gravitational lensing must be dark matter.

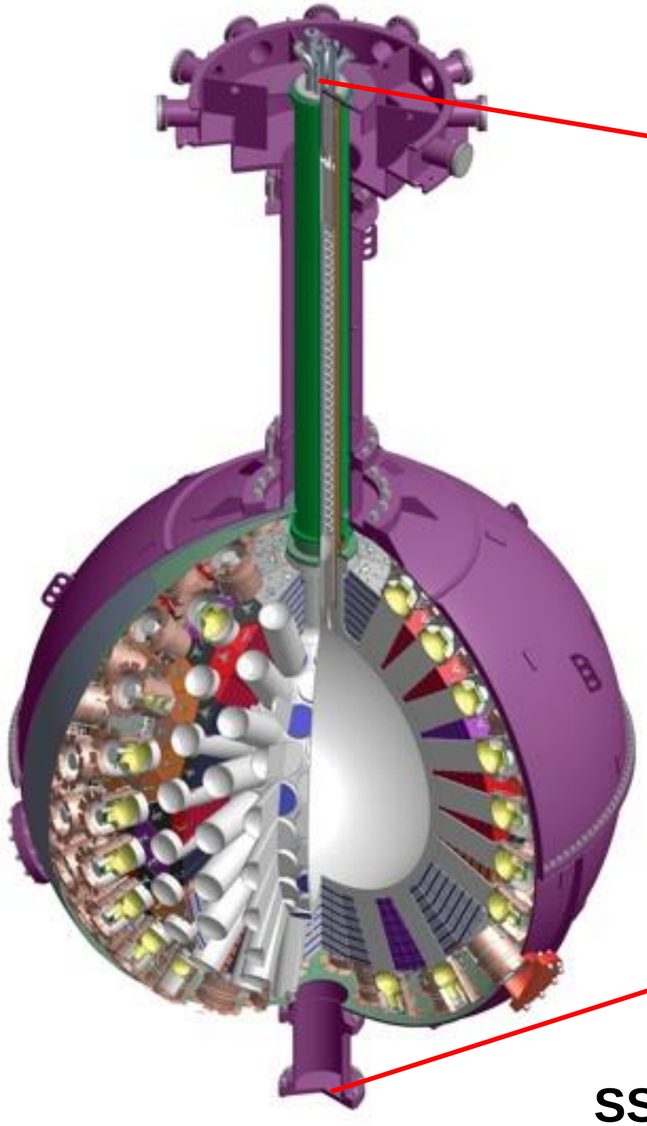
Matter we know slowed down but matter we don't know not slowed down.

Therefore, unknown matter is neither collisional nor interactive with the ordinary matter.

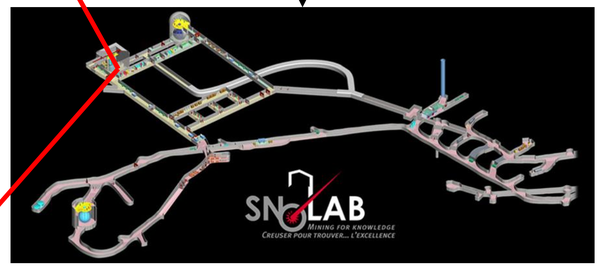
DEAP-3600

≈ 14,000,000 muons/m^2 per day

The Dark matter Experiment using Argon Pulse-shape discrimination 3600 – proposed mass of liquid argon in kg.



2 km rock | ≈ 6 km water



Underground lab

≈ 0.27 muons/m^2 per day

Worth hiding underground!!!

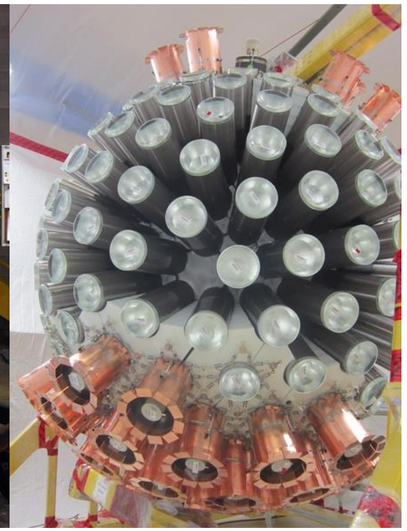
SSS submerged into 300 tons ultra-pure water

DEAP-3600

The Dark matter Experiment using Argon Pulse-shape discrimination 3600 – proposed mass of liquid argon in kg.

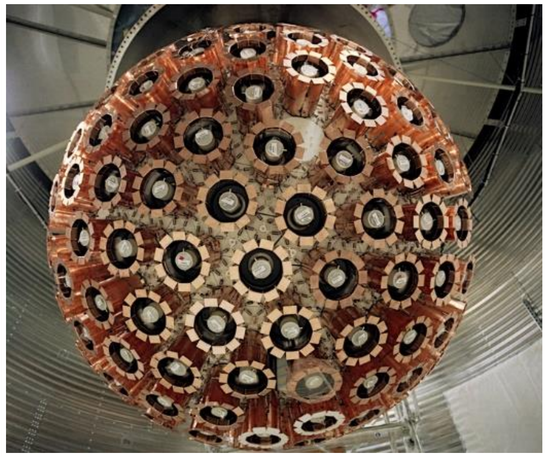
Acrylic Vessel

PMT installation



Getting ready to bond the shoulder onto the sphere

All PMTs installed

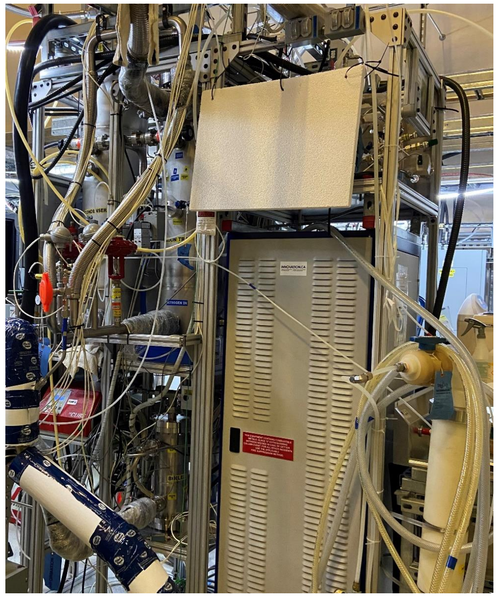


Steel Shell and Muon Veto PMTs

DAQ

Nitrogen Dewar and Cryo coolers

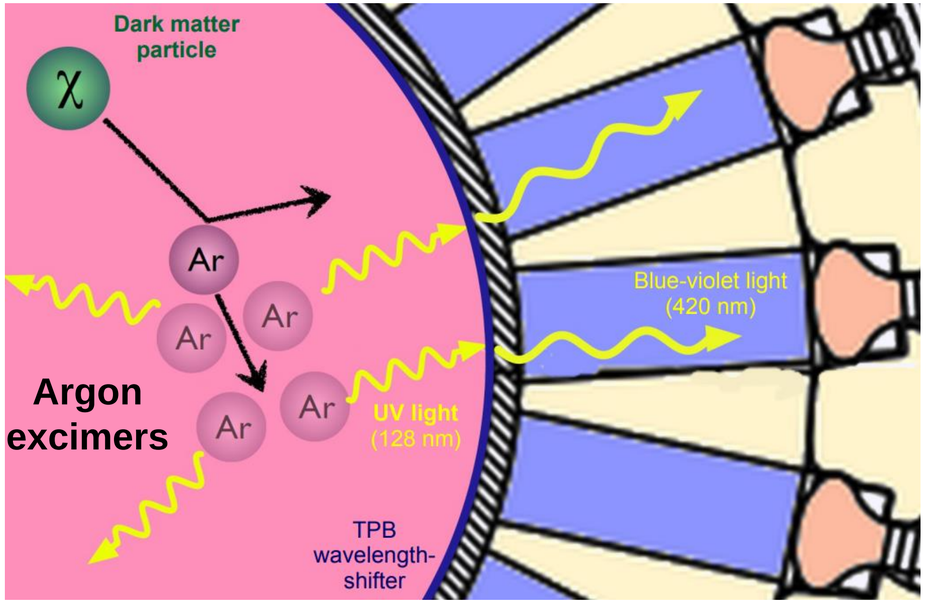
Argon gas process system



Argon gas purifier

Some parameters for the DEAP-3600 detector

Target: Single phase liquid argon (mass 3279 kg).

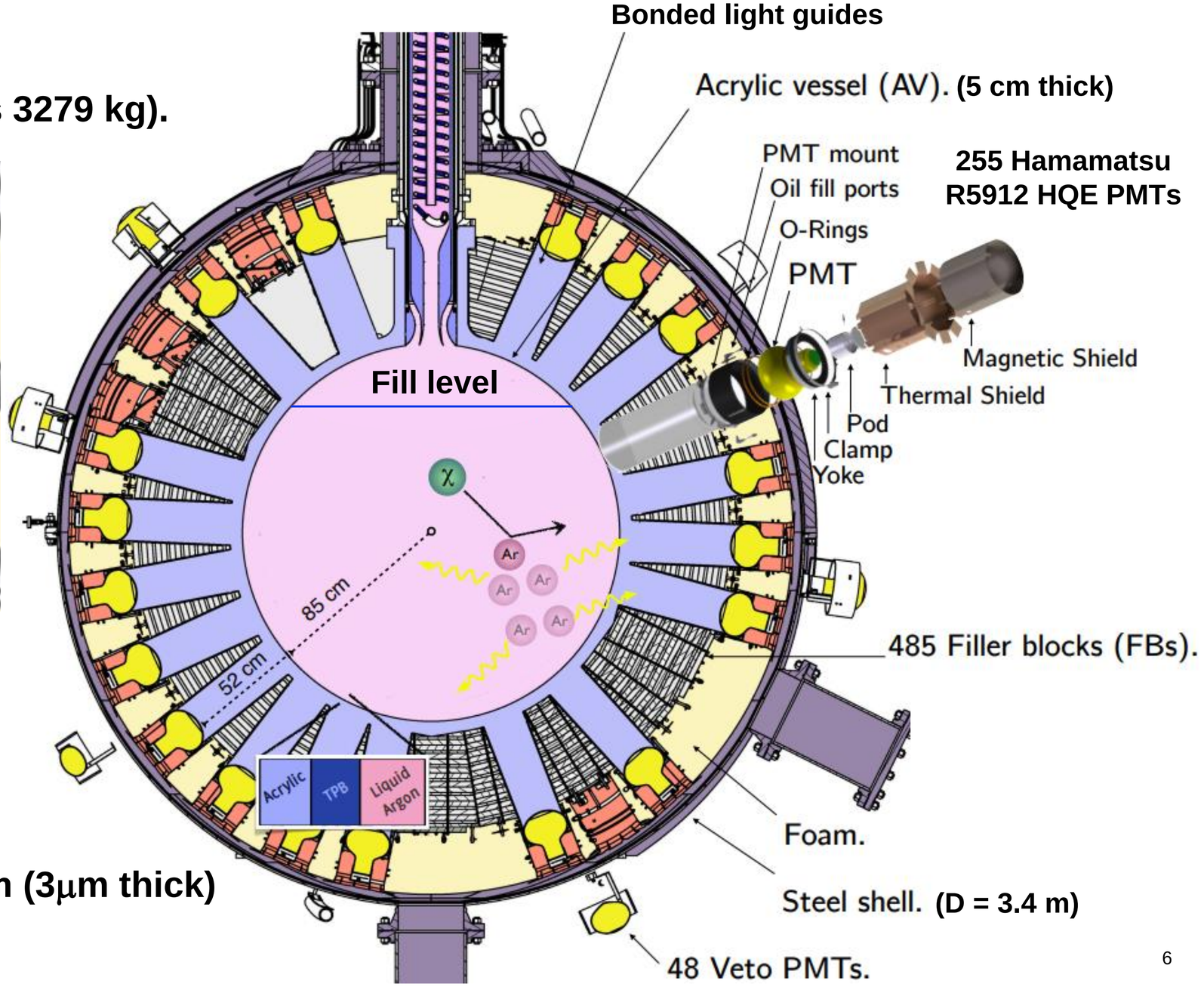


PMT Quantum efficiency 32%

Detector geometrical efficiency 75%

TPB wavelength shifter 128 nm → 420 nm (3μm thick)

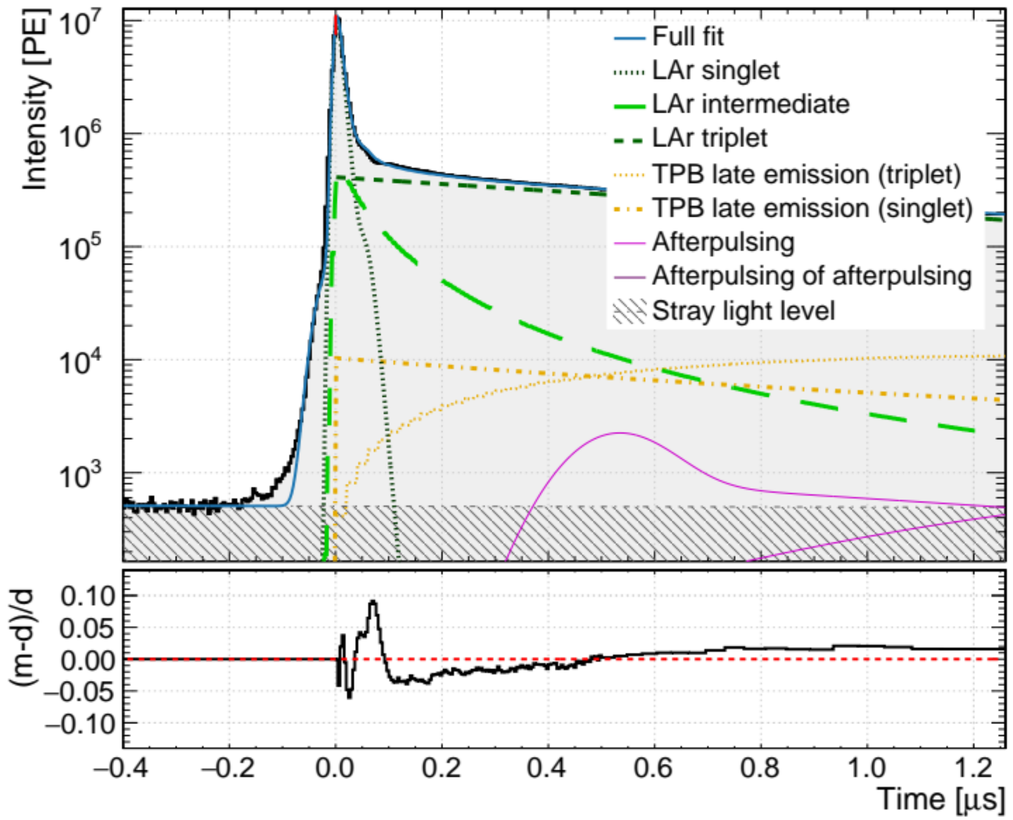
[Astropart. Phys. 108 (2019) 1-23](#)

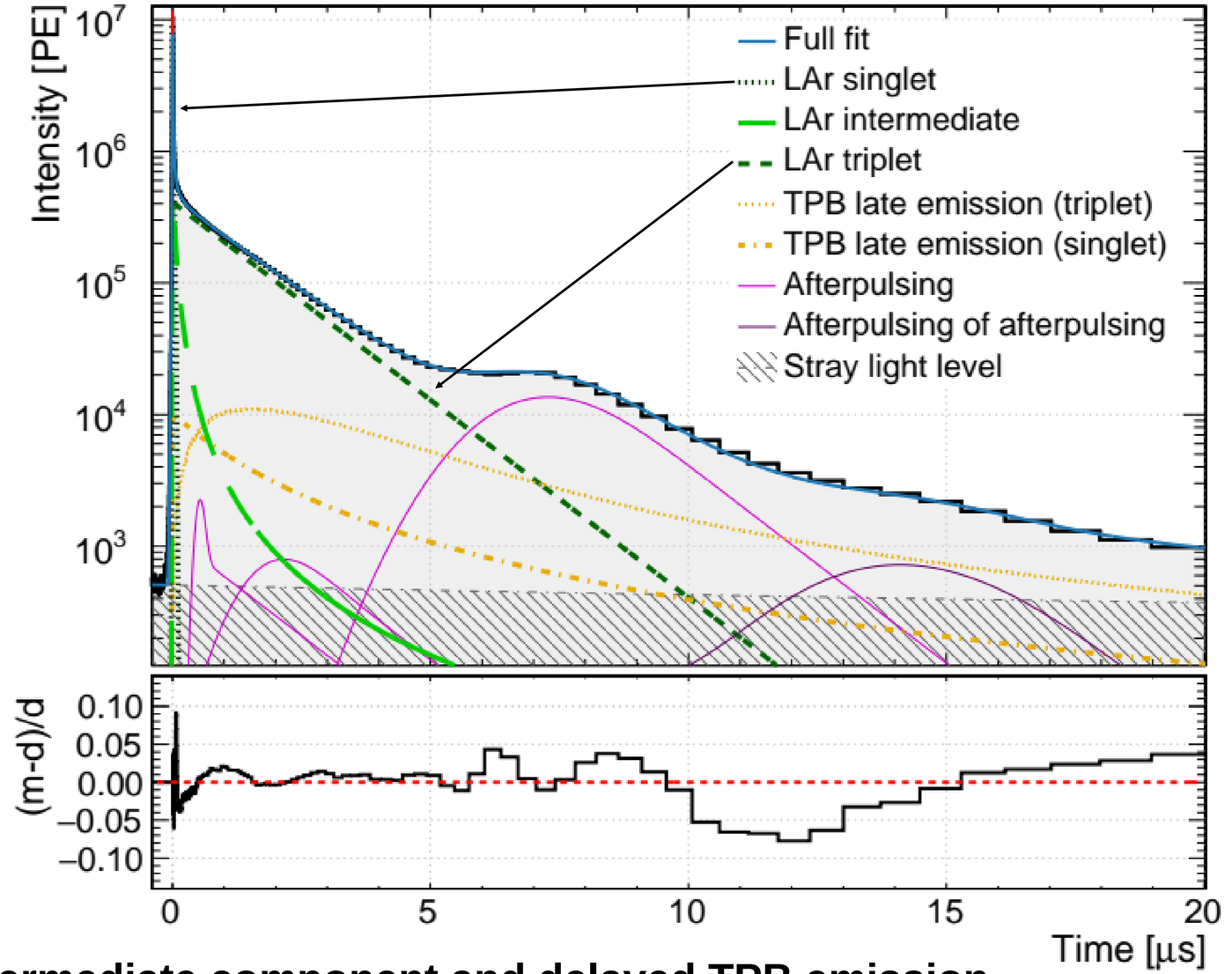


Fully modelled liquid argon scintillation pulse shape

Argon excimers have two excited states

- **Singlet decays with lifetime of 8.2ns**
- **Triplet decays with lifetime of 1445 ns**

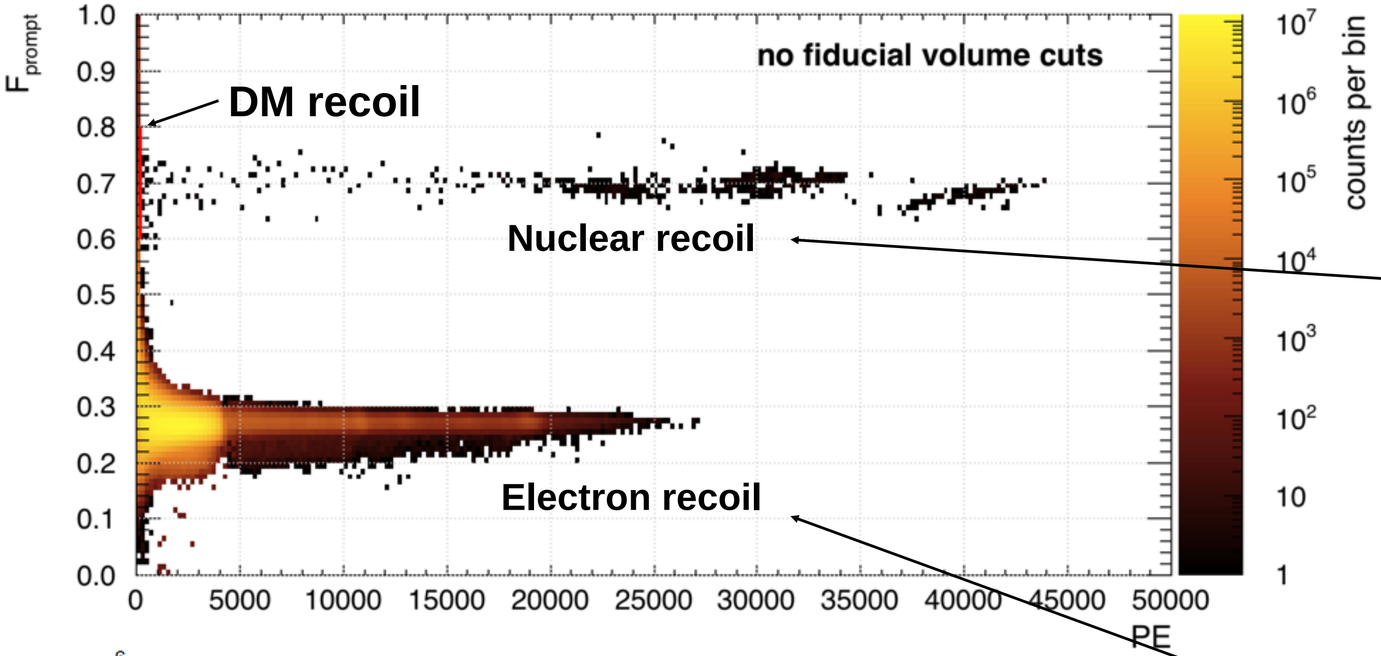


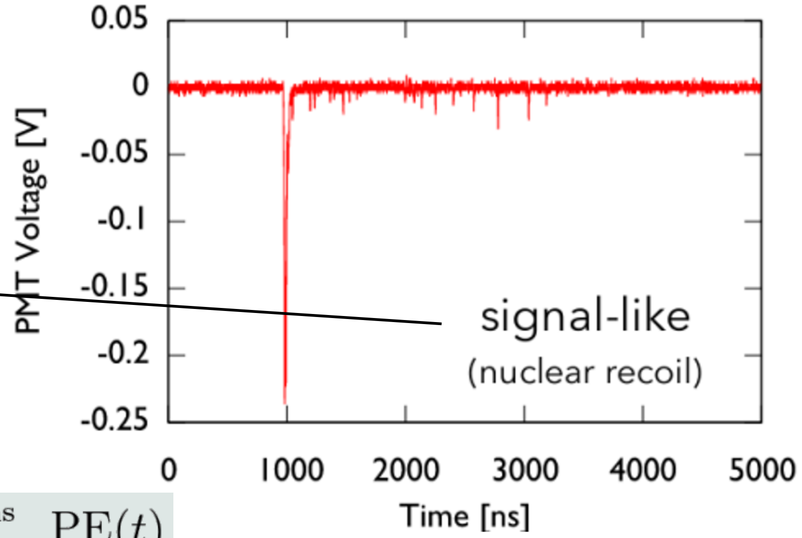


The model accounts for the LAr intermediate component and delayed TPB emission.

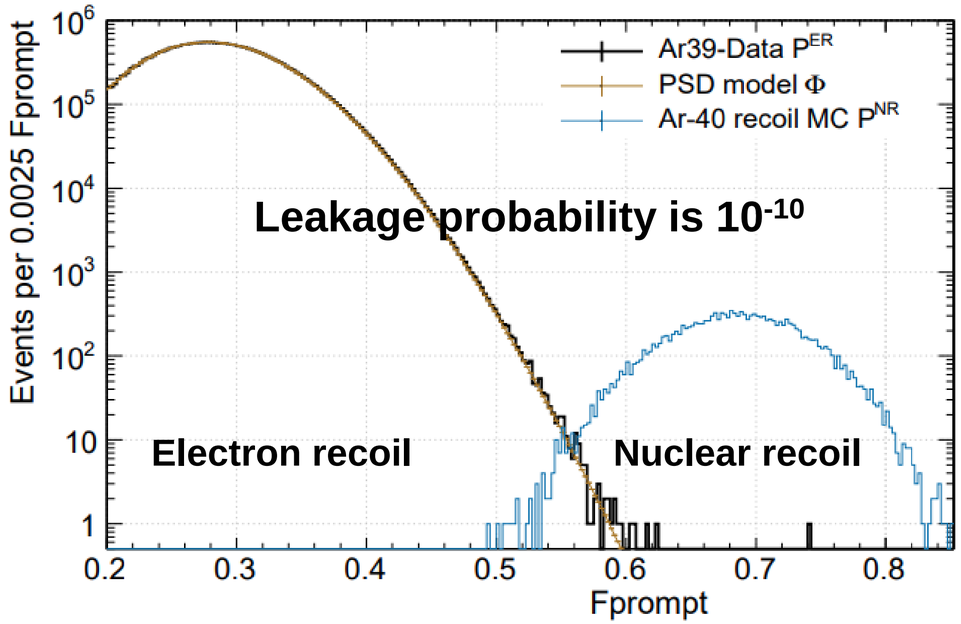
Eur. Phys. J. C 80, 303 (2020)

Excellent Pulseshape Discrimination (PSD) performance



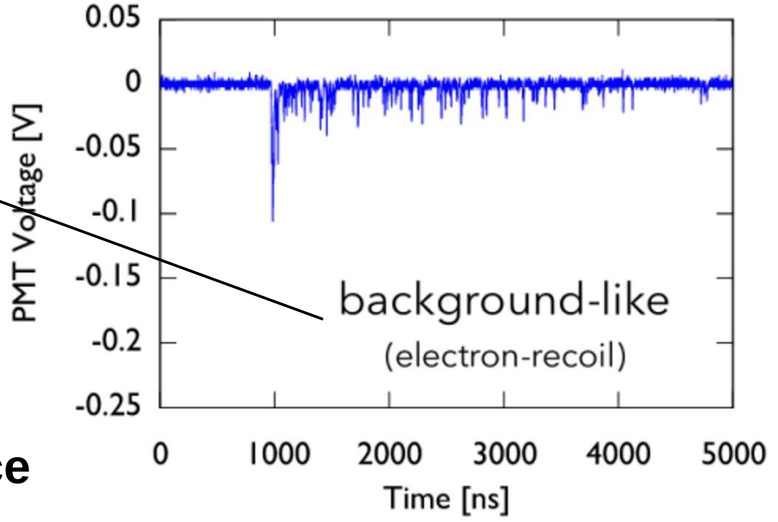


$$\mathrm{F_{prompt}} = \frac{\sum_{-28\ \mathrm{ns}}^{60\ \mathrm{ns}} \mathrm{PE}(t)}{\sum_{-28\ \mathrm{ns}}^{10\ \mu\mathrm{s}} \mathrm{PE}(t)}$$



at 50% NR acceptance
at 110 PE (~ 17.5 keVee)

World-leading PSD performance

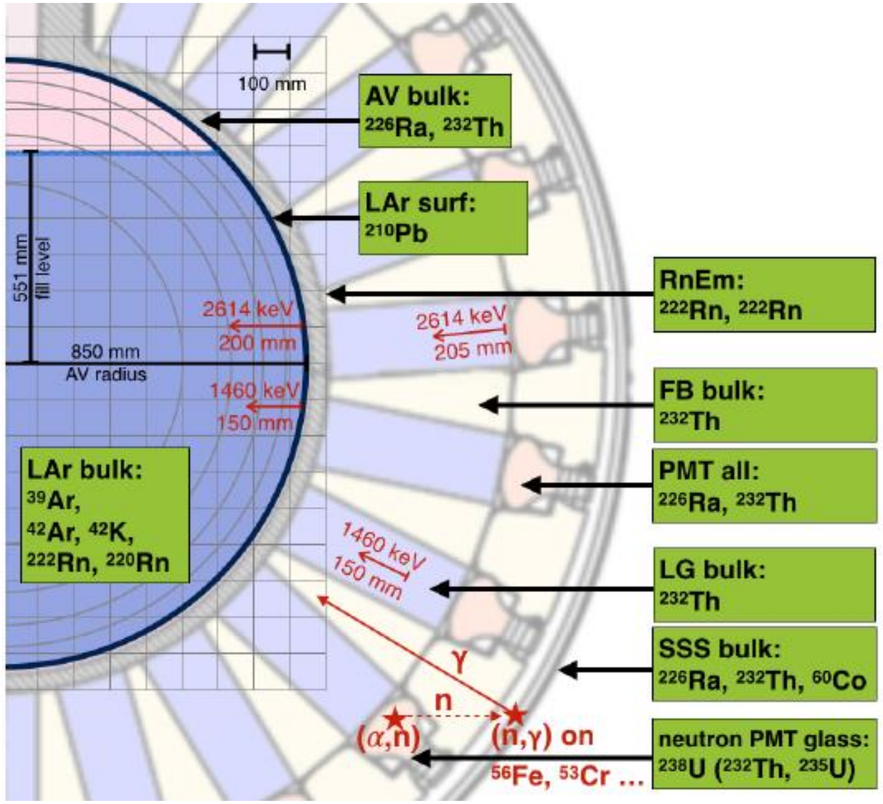


Eur. Phys. J. C 81, 823 (2021)

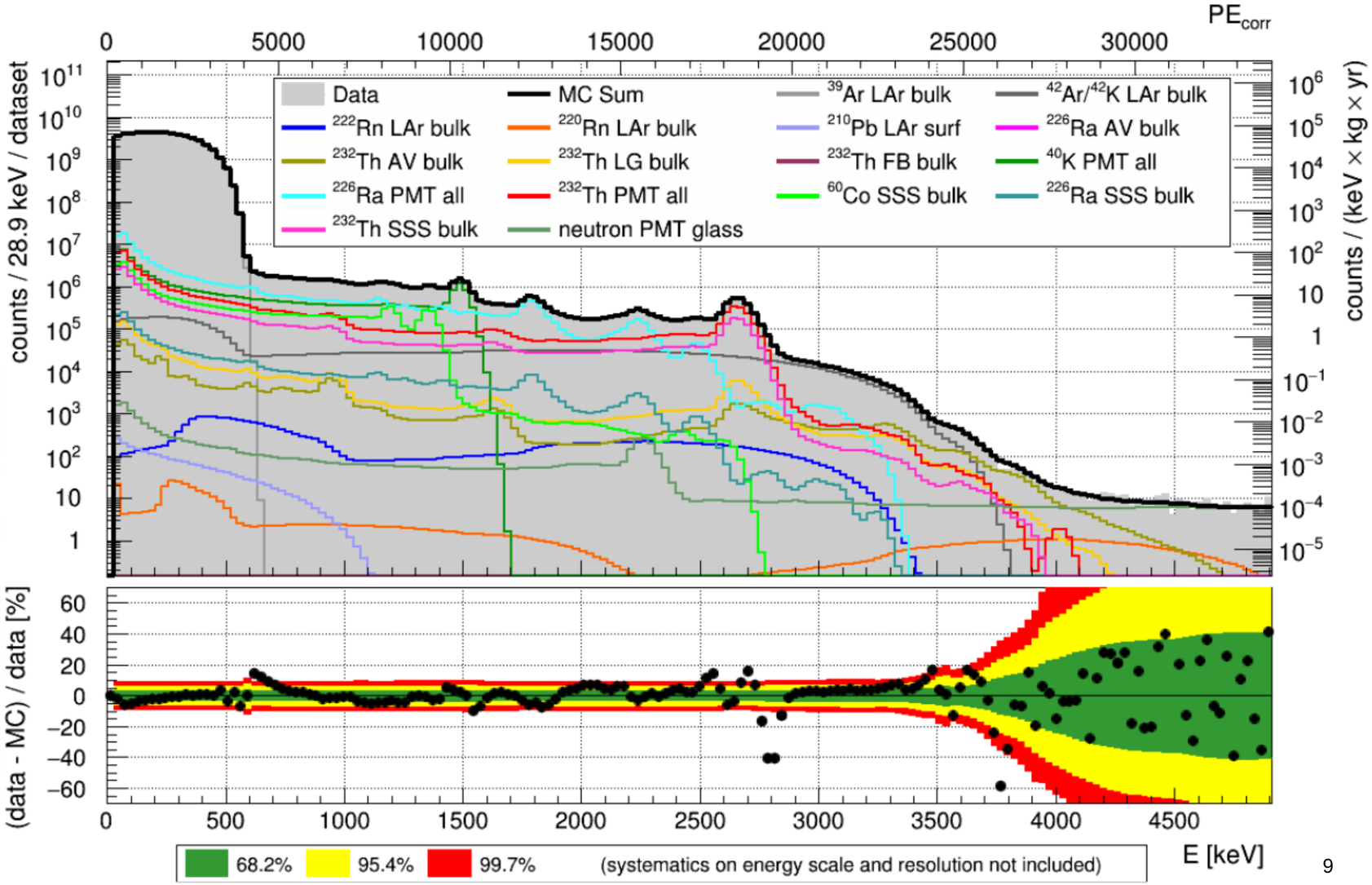
Fully modelled electromagnetic backgrounds

Surrounding radioactivity was shielded by water, SSS, filler blocks, light guide, acrylic vessel.

These contaminants are very low
- **Material choice**
- **Cleanness**



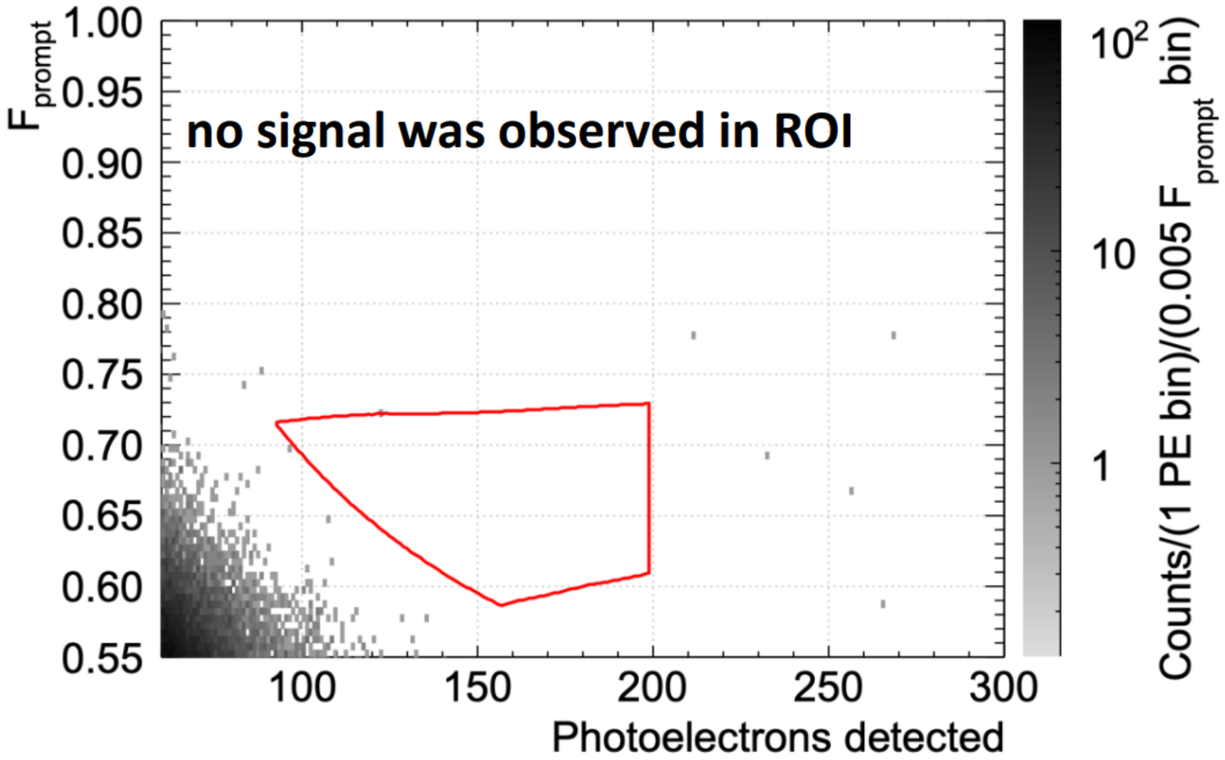
The energy spectrum of the ER band



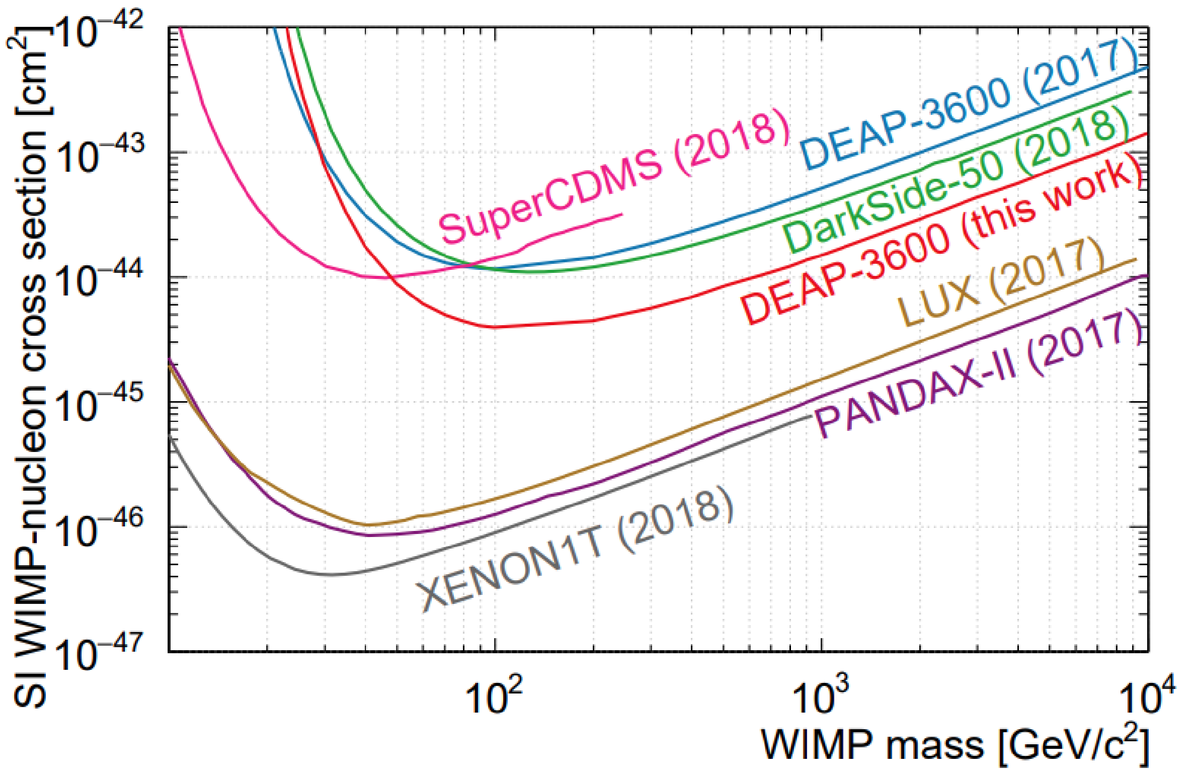
Phys. Rev. D 100, 072009 (2019)

First year WIMP dark matter search

First year dataset (Nov 2016 – Oct 2017)



90% confidence upper limits



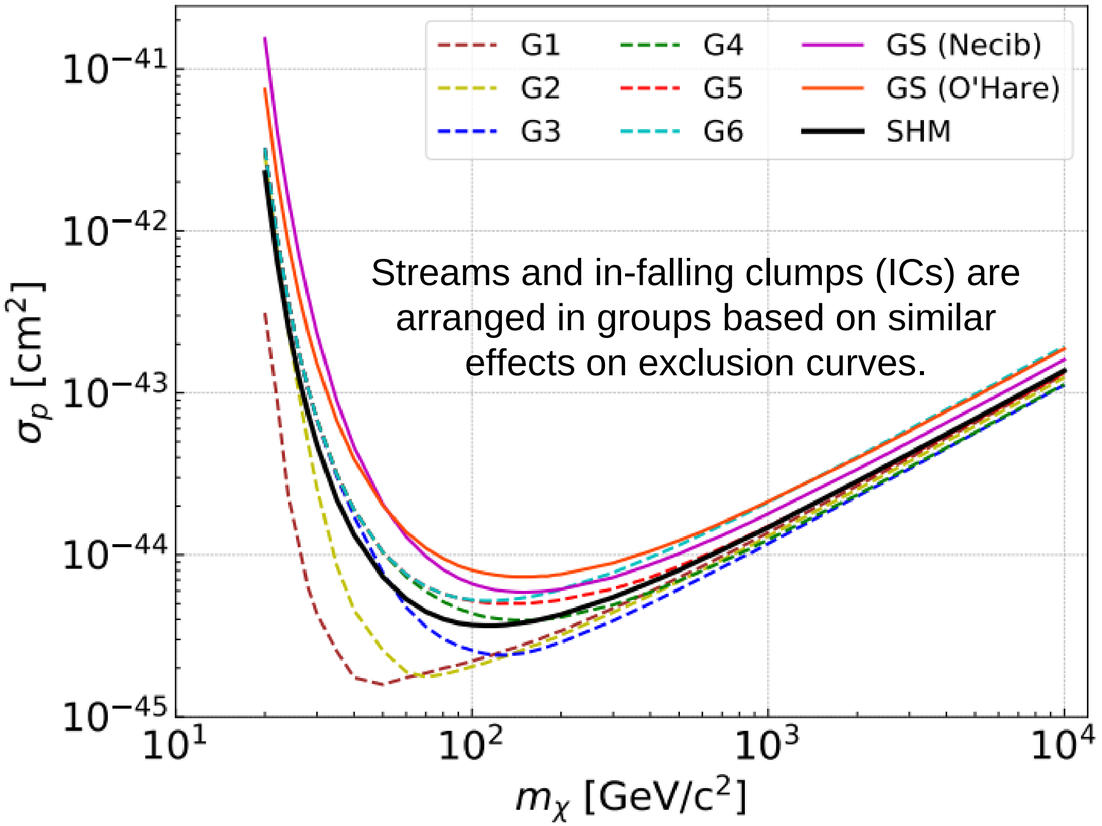
The WIMP ROI is a region designed for sensitivity to low energy nuclear recoils where we expect WIMP signal and expected background is less than 1 event per year.

These upper limits are calculated accounting for the systematic uncertainties in the detector response function.
Most sensitive limit with a liquid argon

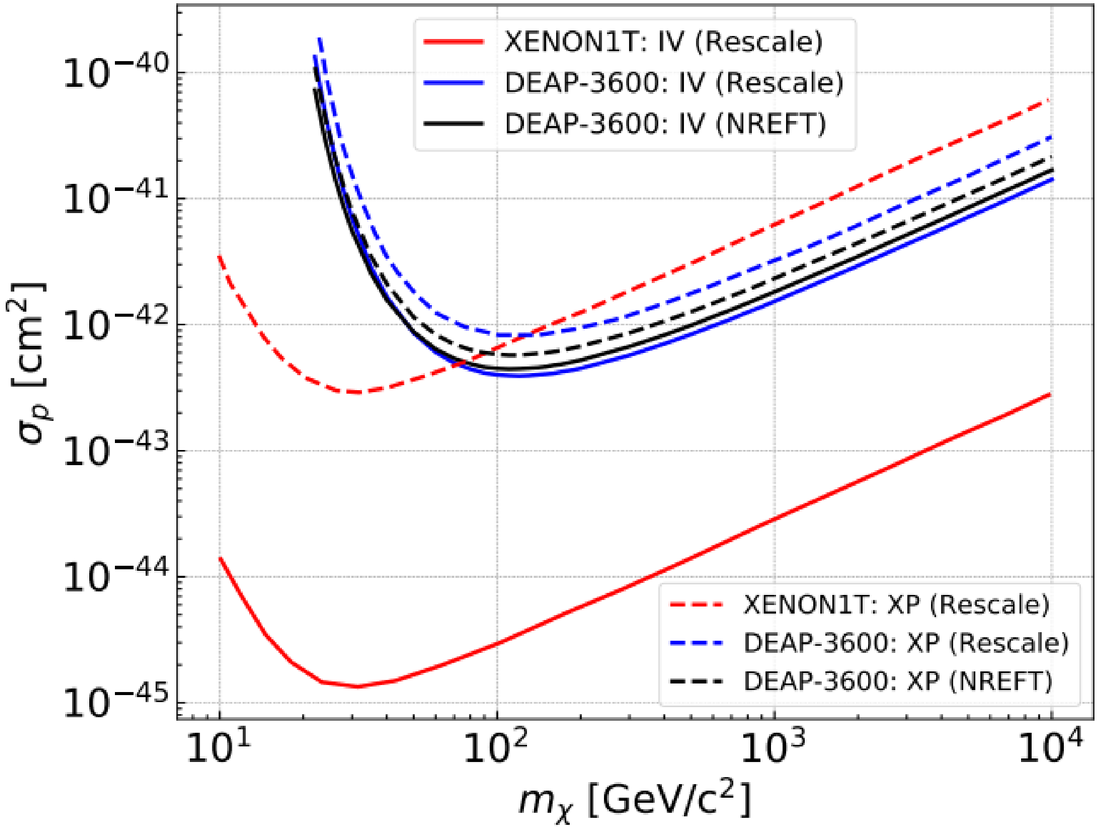
Phys. Rev. D 100, 022004 (2019)

Constraints on dark matter-nucleon effective couplings

- **Results are interpreted with a Non-Relativistic Effective Field Theory framework.**
- **Examines how various substructures in the local dark matter halo may affect these constraints.**



Upper limits (90 % C.L.) on the effective operator Q1 for substructures.

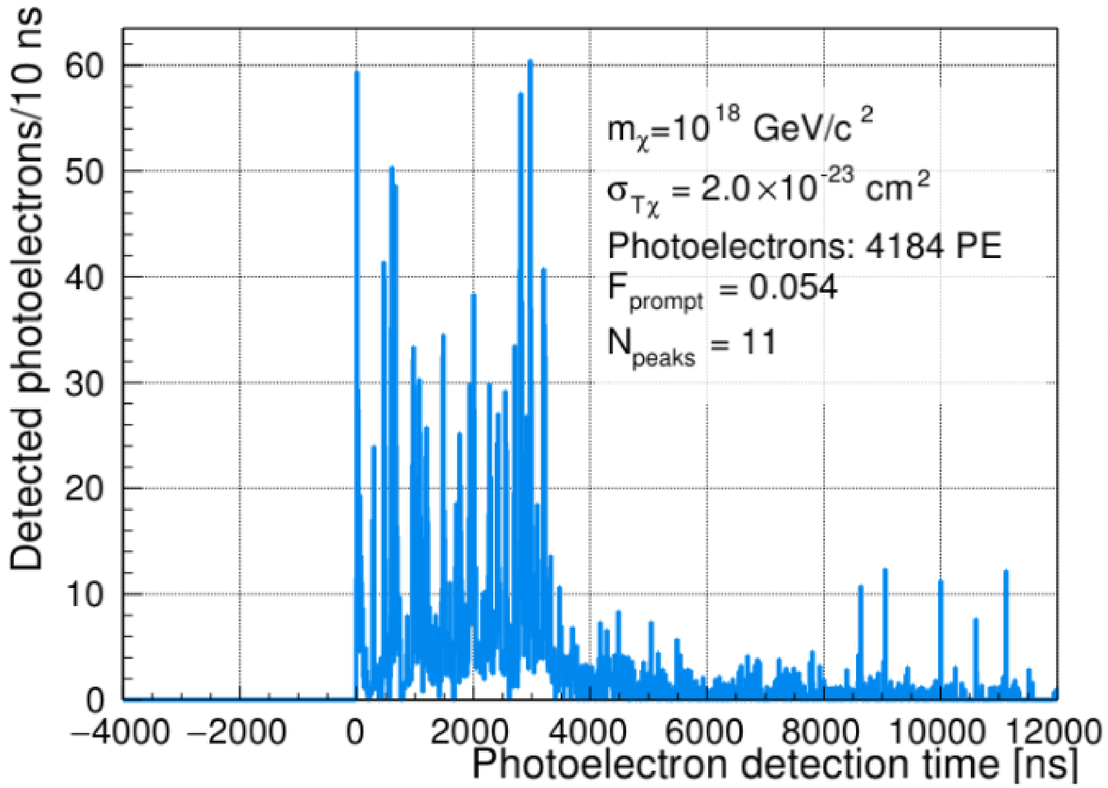


Constraints on the Q1 interaction, for IV (isovector; solid) and XP (xenonphobic; dashed) scenarios. Limits labeled “Rescale” were obtained following published work “NREFT” used the present approach.

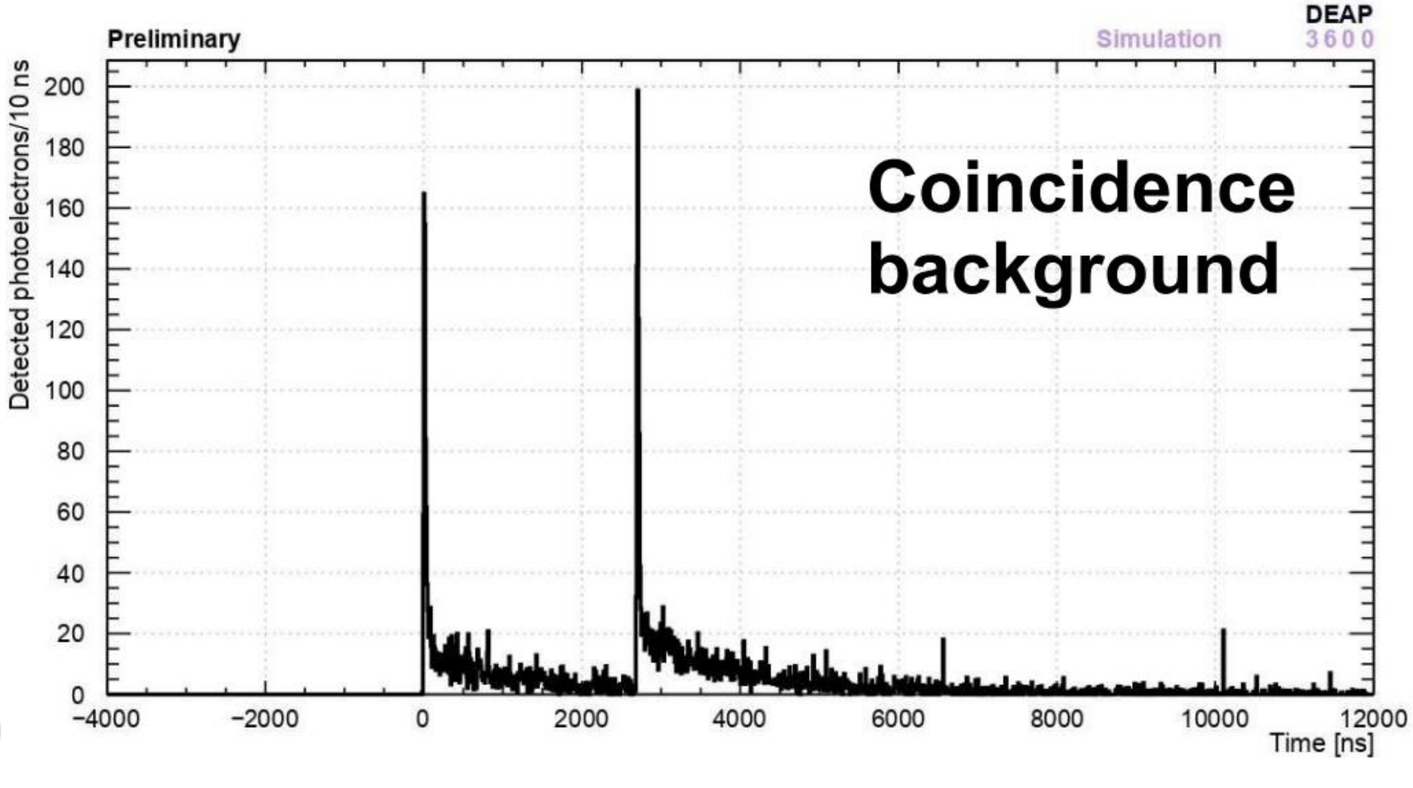
Phys. Rev. D 102, 082001 (2020)

Constraints on Planck-scale mass dark matter

A search for multi-scatter signals from supermassive dark matter was performed with a blind analysis of data collected over a 813 d live time with DEAP-3600.



Simulated PE time distributions for DM with $m_\chi = 10^{18}$ GeV/c^2 with low $\sigma_{T\chi}$



Expected signal pulse-shape is inconsistent with coincidence backgrounds

Phys. Rev. Lett. 128, 011801 (2022)

Constraints on Planck-scale mass dark matter

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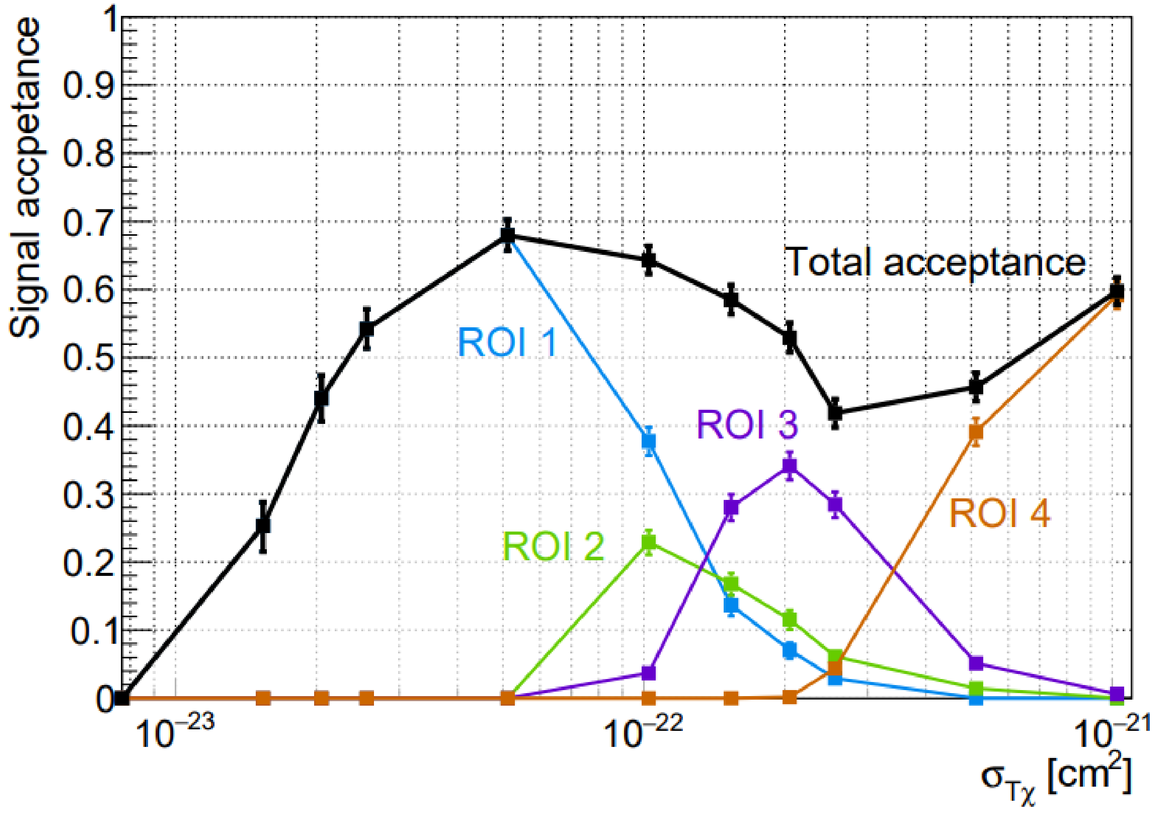
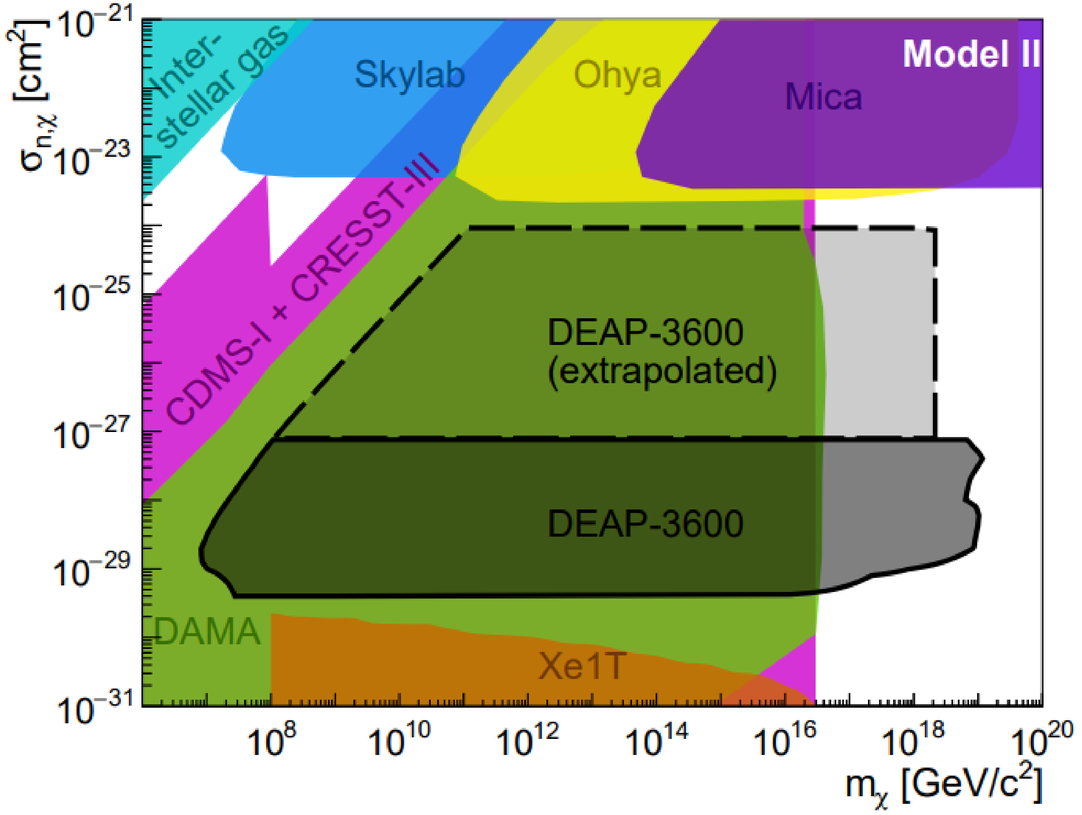


Probability of DM with $m_\chi = 10^{18}$ GeV/c^2 populating each ROI.



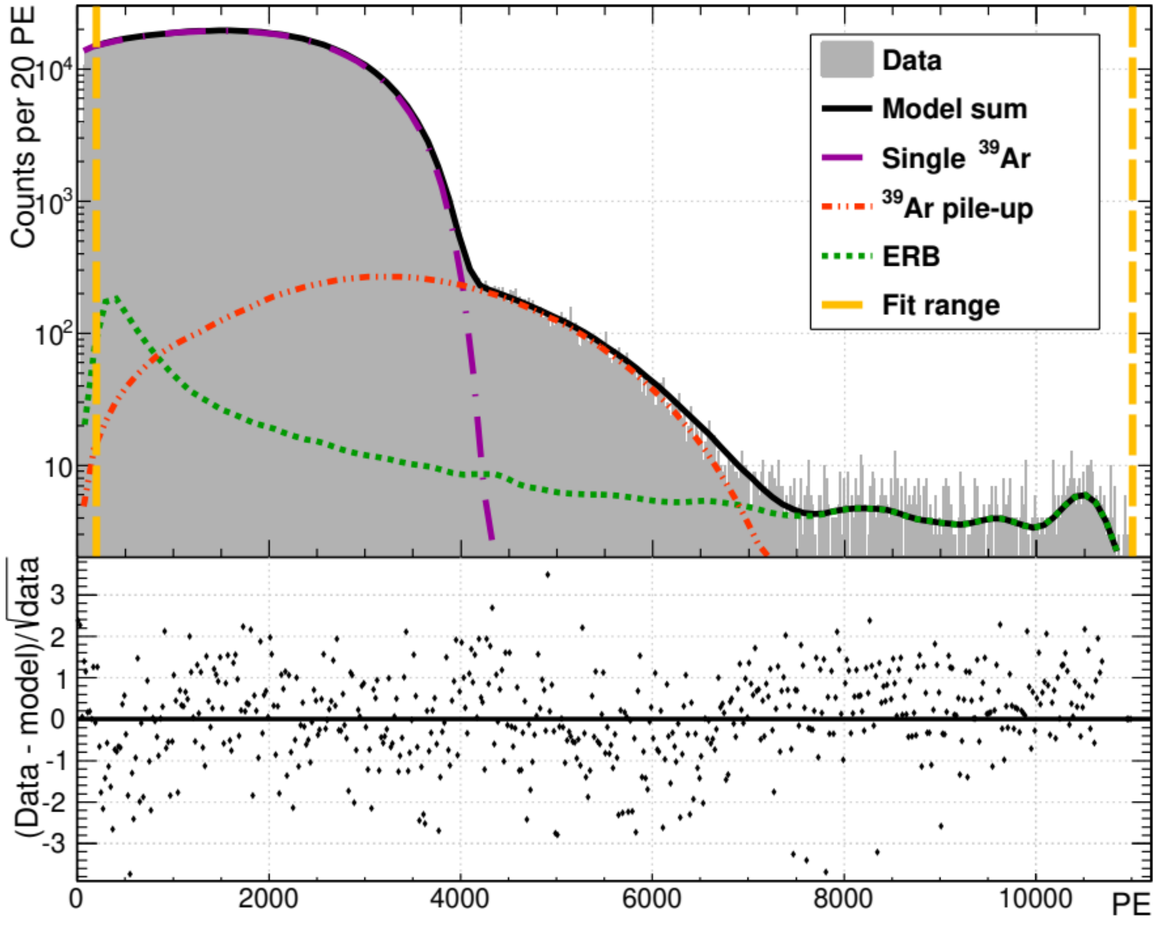
World-leading sensitivity to Planck-scale mass dark matter!

No event was found in the region of interest for this search

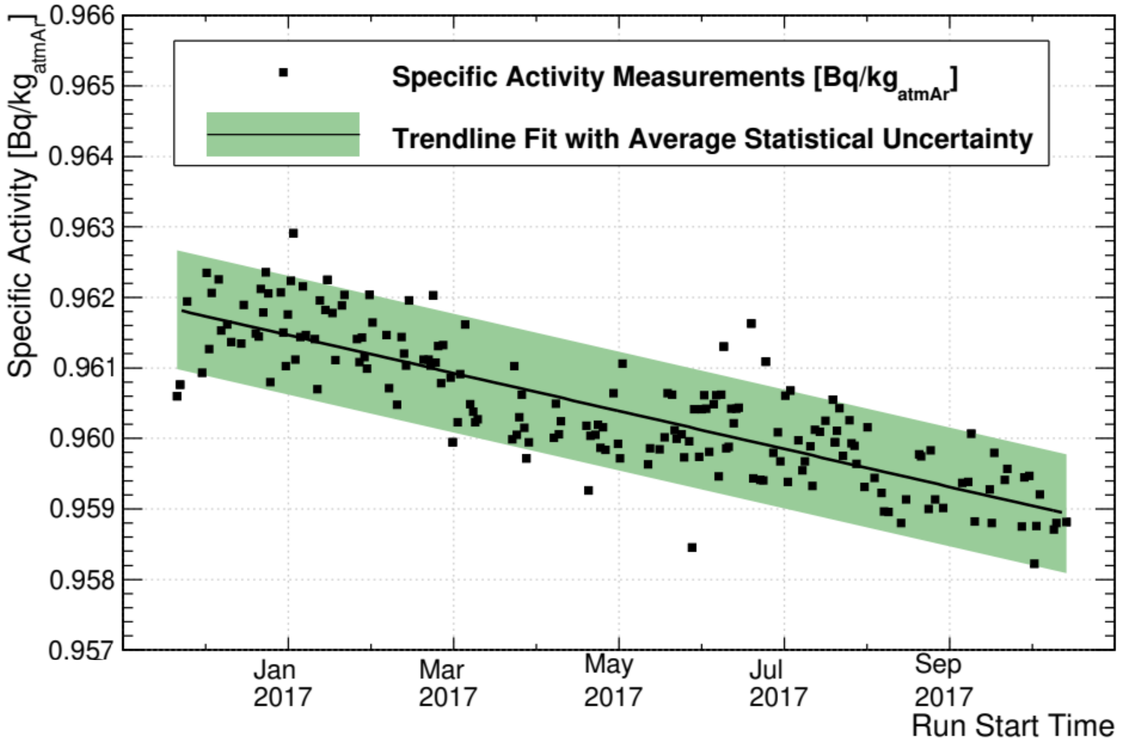
Phys. Rev. Lett. 128, 011801 (2022)

Measurement of the Specific Activity of ^{39}Ar

This result is the most precise measurement of the specific activity of ^{39}Ar in atmospheric argon to date and agrees with existing measurements.



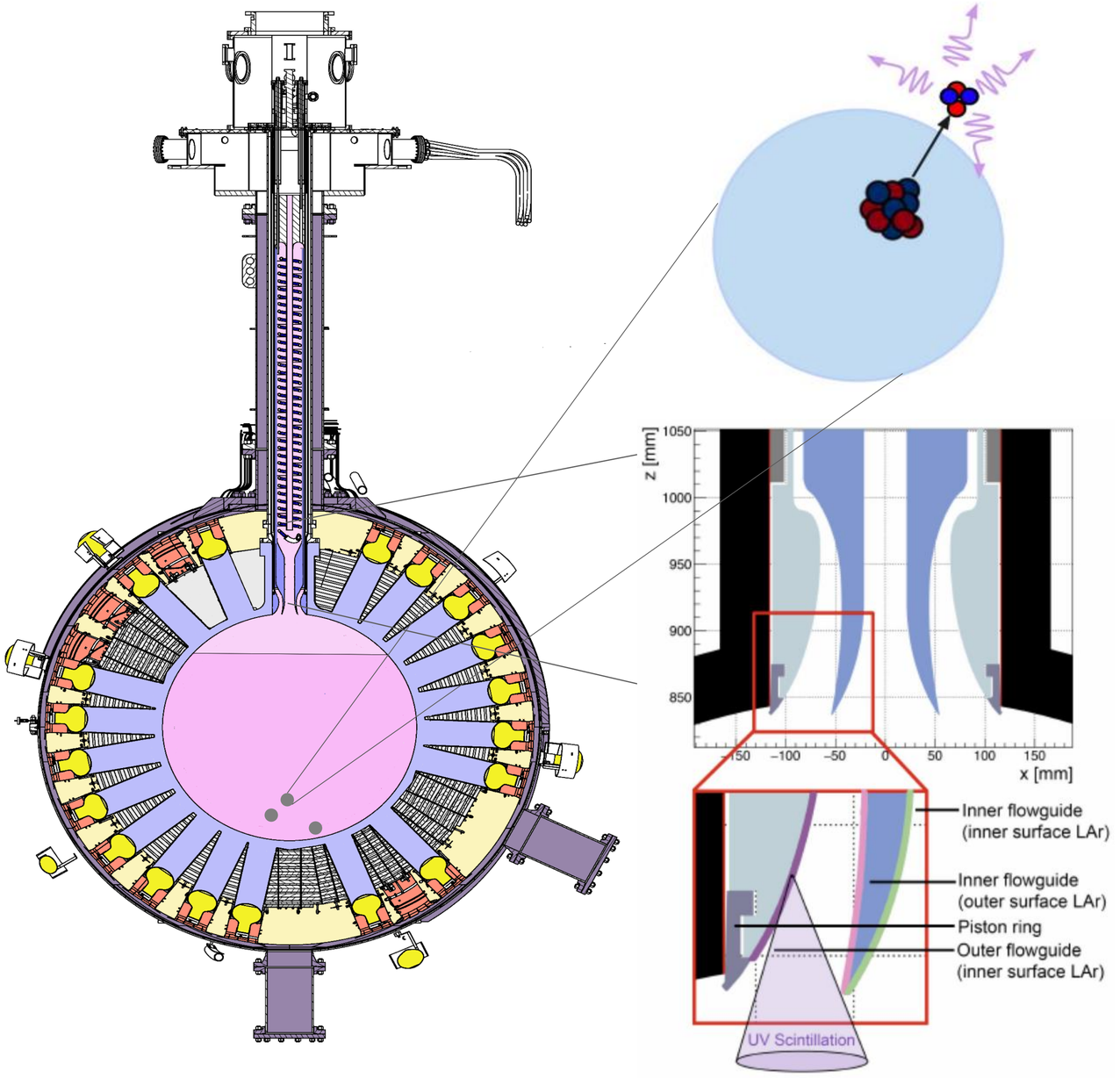
An example fit on one run including the ^{39}Ar, electron recoil backgrounds (ERB), and ^{39}Ar pile-up components.



Measurement	Specific activity [Bq/kg$_{atmAr}$]
WARP [15]	$1.01 \pm 0.02_{stat} \pm 0.08_{sys}$
ArDM [16]	0.95 ± 0.05
DEAP-3600 (this work)	$0.964 \pm 0.001_{stat} \pm 0.024_{sys}$

Eur. Phys. J. C 83, 642 (2023)

Currently DEAP-3600 detector under hardware upgrade



Dust alphas

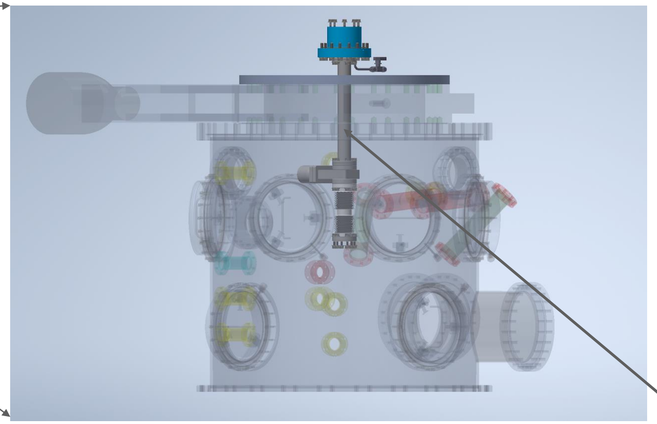
Evidence for presence of dust in LAr in the detector. Alpha decays embedded in dust lose energy before reaching LAr and pushes event to low E region (ROI) !!!

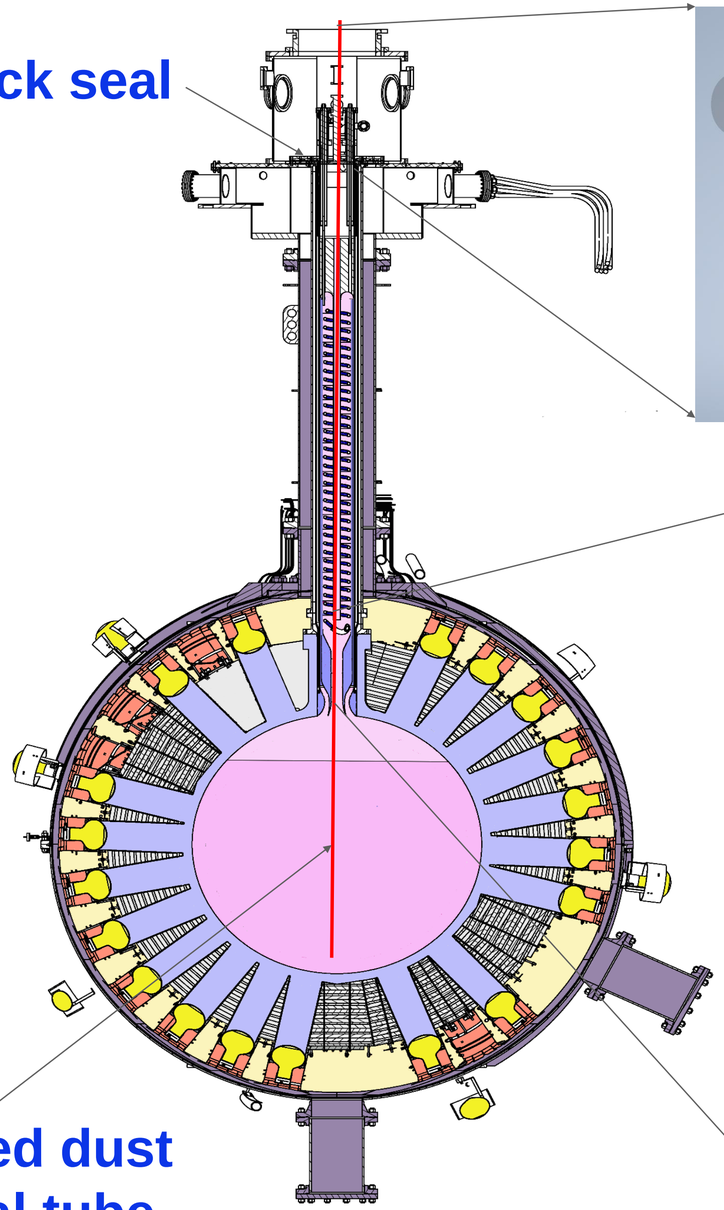
Shadowed alphas

Alpha from flow-guide material (acrylic) scintillate in LAr film/mist covering the flow-guide. A fraction of light enters to the detector and pushes event to low E region (ROI) !!!

Hardware upgrade mitigates all of the issues

New neck seal





Deployed dust removal tube

Dust alphas

Evidence for presence of dust in LAr in the detector. Alpha decays embedded in dust lose energy before reaching LAr and pushes event to low E region (ROI) !!!

An alternate cooling system filtering out dust particulates from LAr.

Shadowed alphas

Alpha from flow-guide material (acrylic) scintillate in LAr film/mist covering the flow-guide. A fraction of light enters to the detector and pushes event to low E region (ROI) !!!

Replacement acrylic flow-guide coated with slow WLS (Pyrene).

Summary

- DEAP-3600 is a single-phase dark matter detector distinguished by its use of the largest volume of liquid argon medium in the field.
- The experiment has demonstrated world-leading performance in PSD using liquid argon.
- A sophisticated background model has been developed to enhance signal detection.
- The experiment benefits from a well-described and fully simulated pulse-shape model.
- It serves as a multidisciplinary platform for low-background research.

Next

- Complete hardware upgrade 2024 and start a new data taking campaign with third fill.
- Search WIMP DM using profile-likelihood ratio (PLR) method.
- 388 live-days of DEAP-3600 detector data will be used.

Thanks for your attention!