



DEAP3600-status update

Sumanta Pal

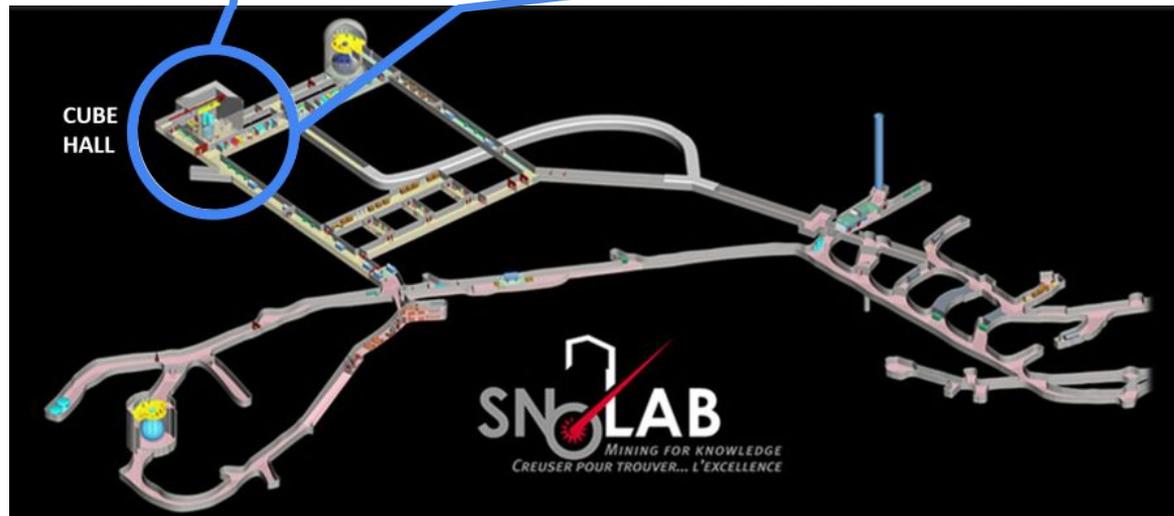
Univ. of Alberta/McDonald Institute

On behalf of the DEAP3600 collaboration

DEAP3600 at SNOLAB

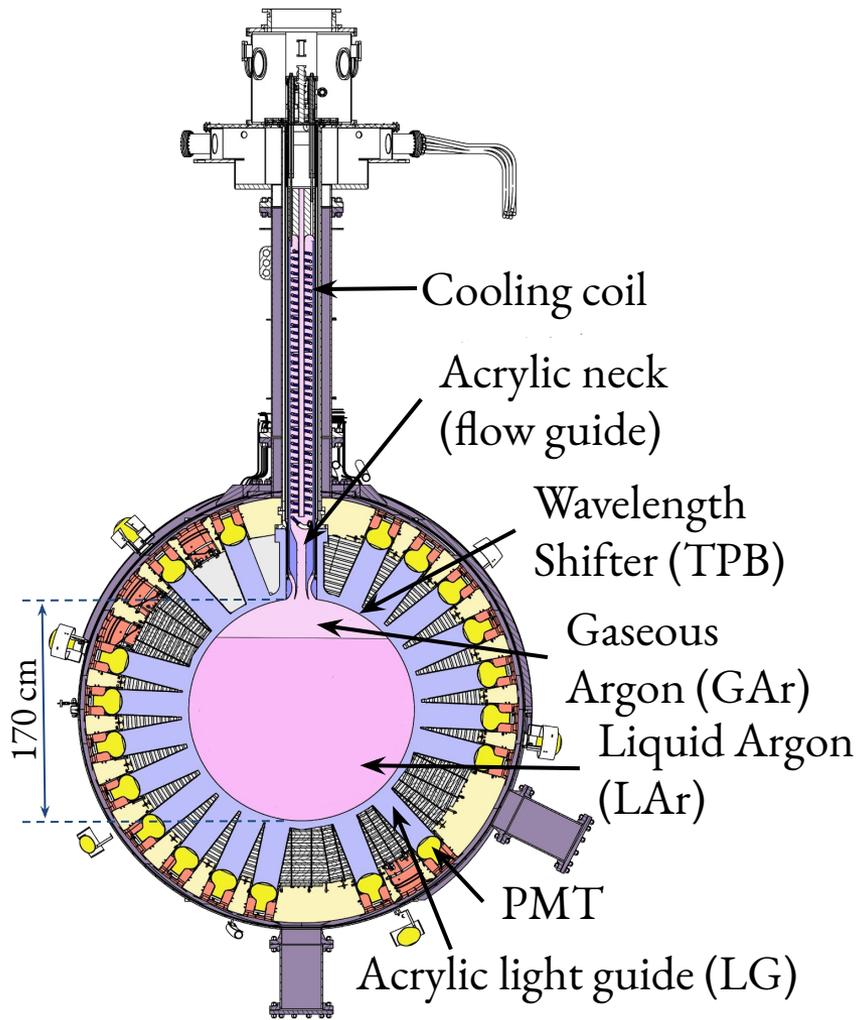


- **D**ark Matter **E**xperiment using Liquid **A**rgon **P**ulse-shape Discrimination
- Designed target mass 3600 kg of liquid argon
- Detect elastic scattering of WIMPs with argon nuclei
- Located 2 km underground in Cube Hall at SNOLAB



- 95 Researchers across Canada, Germany, Italy, Mexico, Poland, Russia, Spain, UK, USA
- WIMP search data collected from Oct 2016 - April 2020

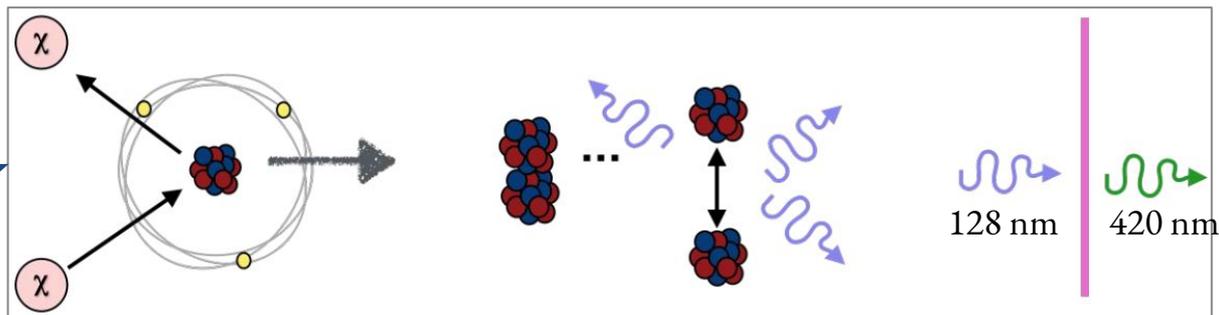
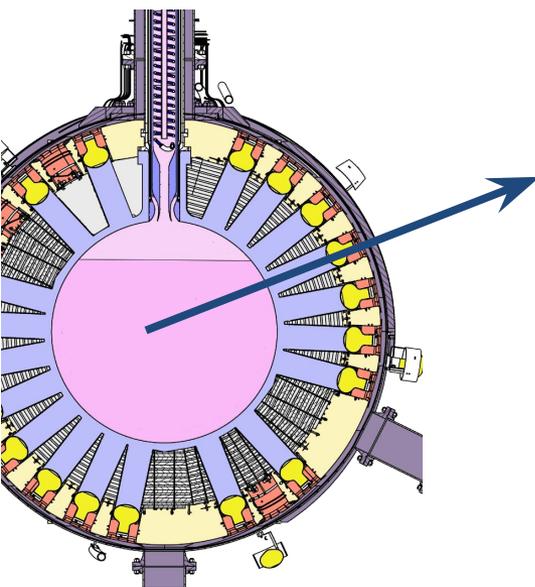
Brief description of the DEAP3600 detector



- **Single phase** liquid argon detector
- So far ~3.3 tonne liquid argon (partial filled) as target material contained in a sealed, ultraclean acrylic vessel (AV)
- Pulse Shape Discrimination (PSD) to identify signal over the background

A cross-sectional view of the DEAP3600 detector

Pulse Shape Discrimination



DM vs argon elastic scattering

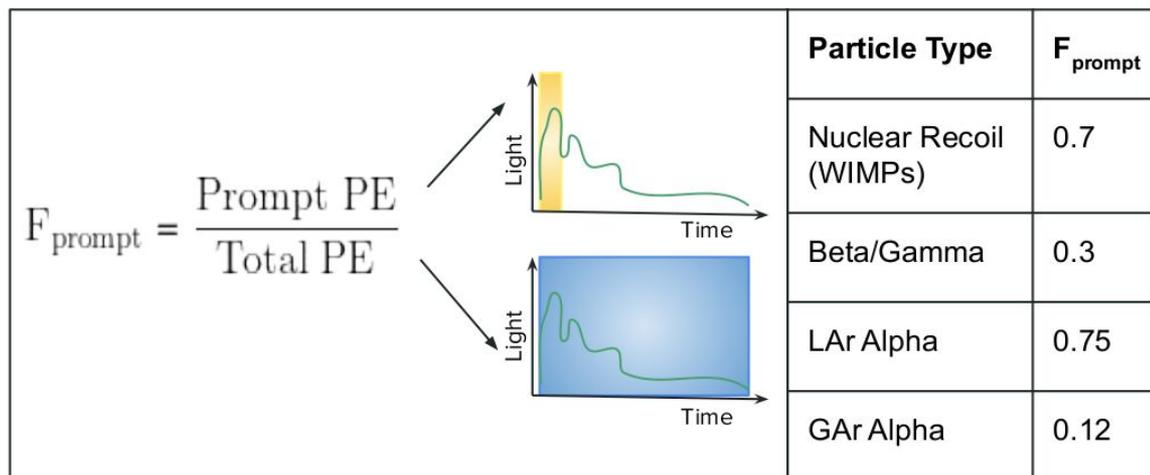
Excitation, ionisation of Ar nucleus, dimer formation, UV light scintillation

Wavelength shifting by TPB at the AV surface

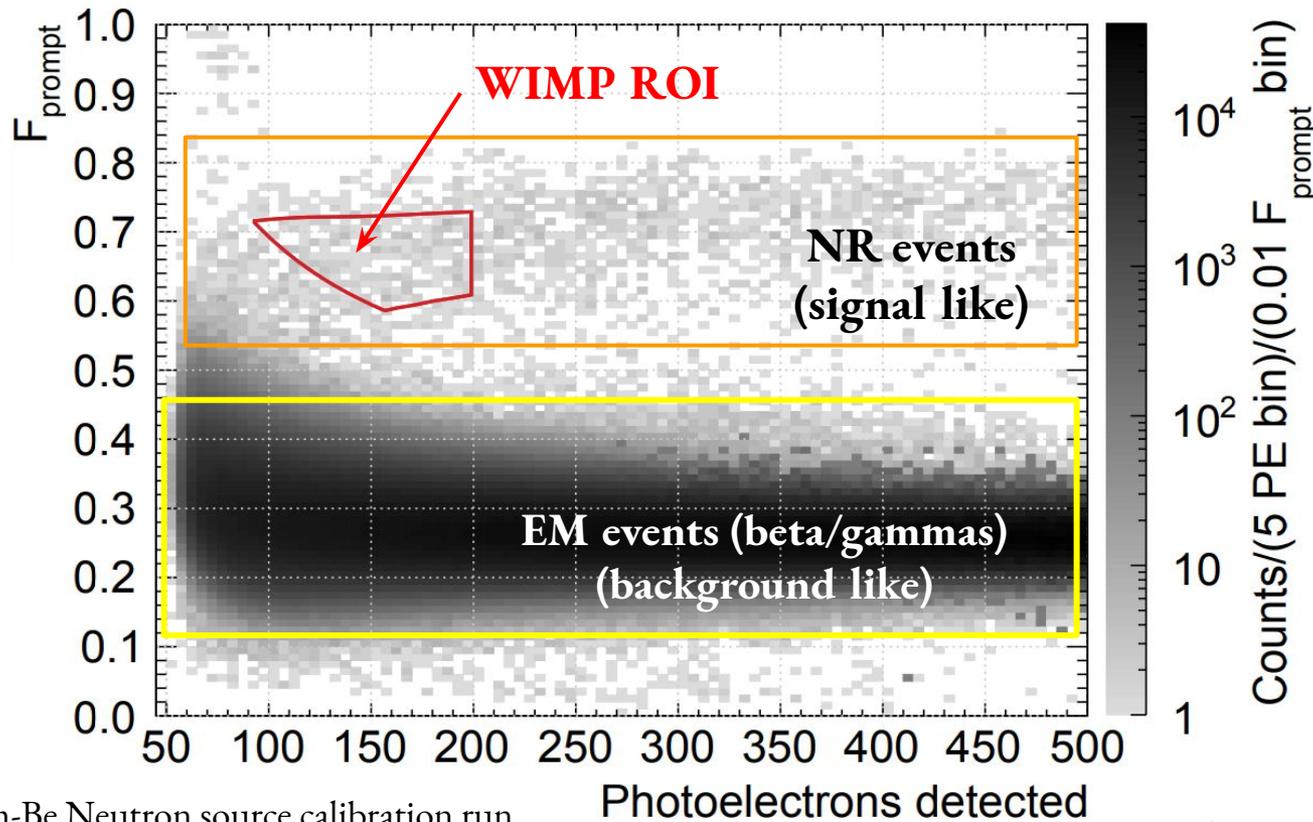
PE : number of reconstructed photoelectrons

No of PE = total charge/charge of a SPE

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



Pulse Shape Discrimination



*Am-Be Neutron source calibration run

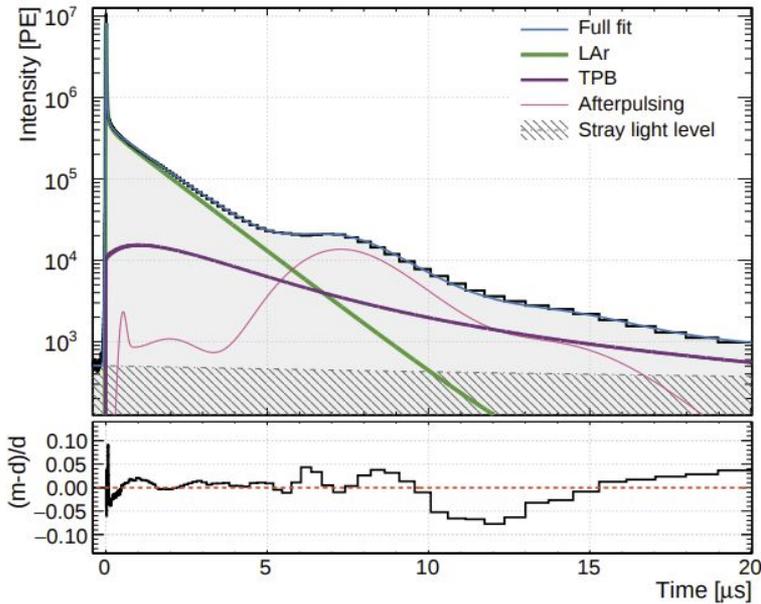
Phy. Rev. D, 100, 022004 (2019)

Light yield: $6 \text{ PE/keV}_{\text{ee}}$

We use a Bayesian PE counting algorithm for energy reconstruction, which removes effects of afterpulsing.

Improvement of the PSD model

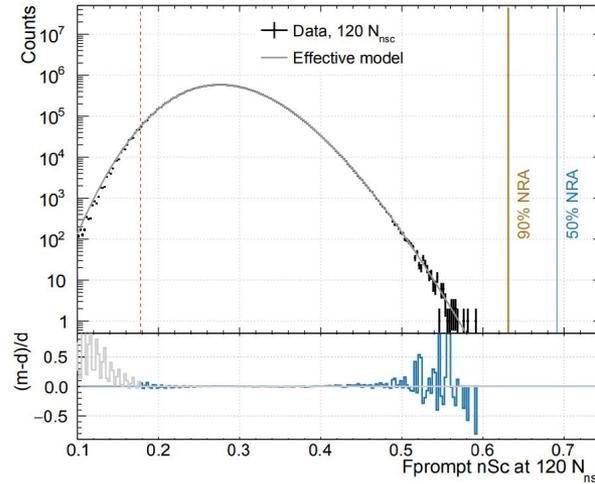
Liquid argon pulse shape



European Phys. J. C 80 (303) 2020

- LAr scintillation physics
- Detector response

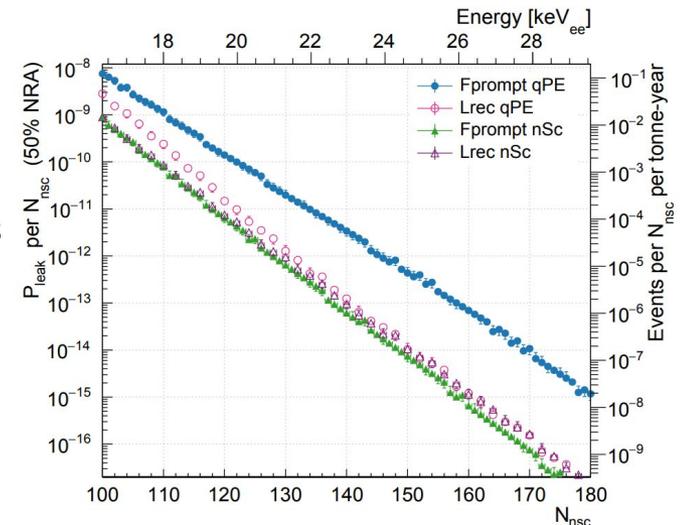
An effective PSD model



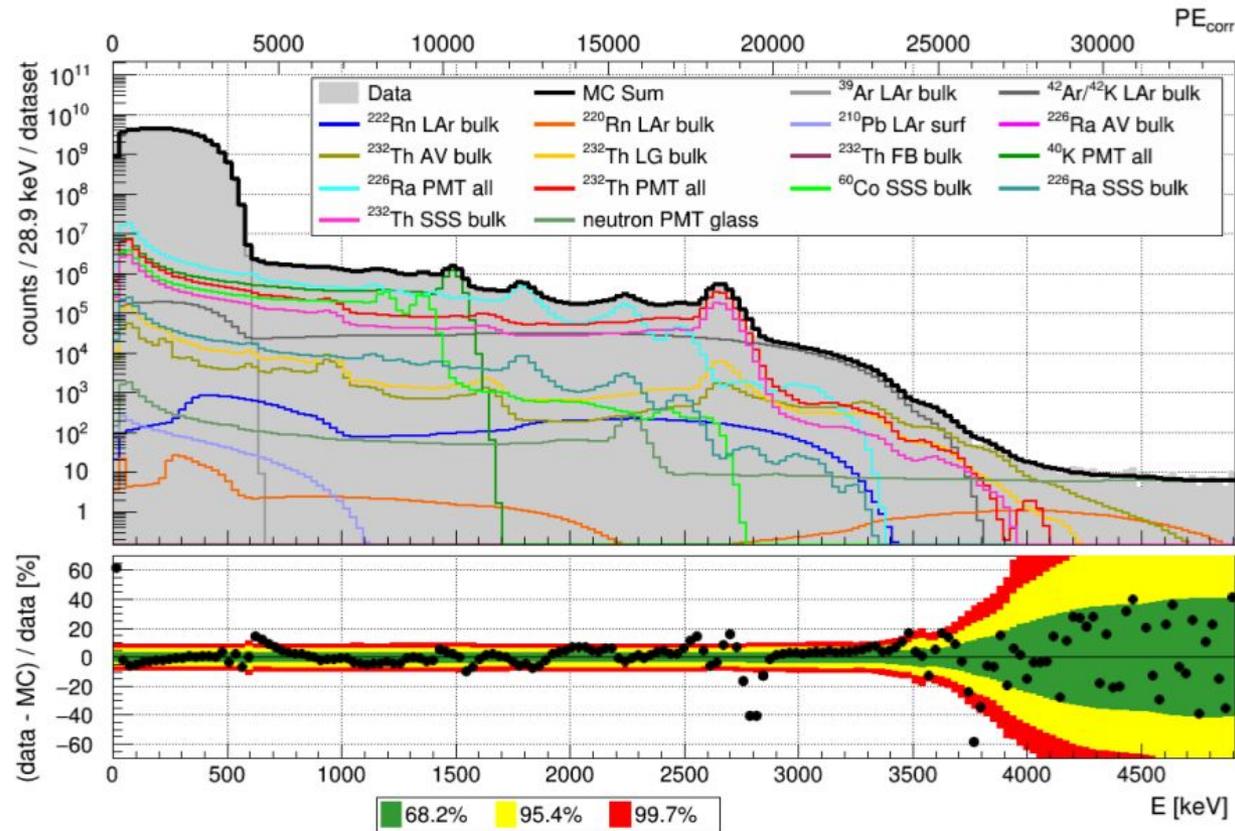
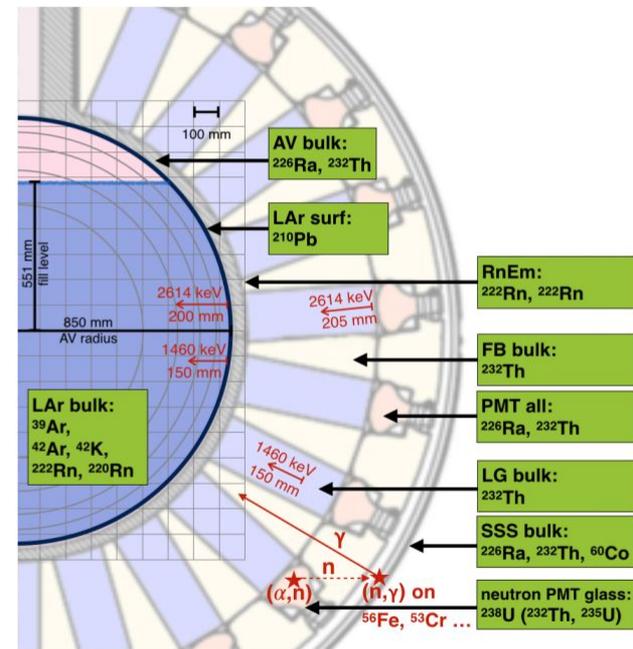
- 4 different PSD methods
- Predict leakage probability into nuclear recoil region as a fn. of energy

- Tested over Ar-39 beta decays
- 4.5 tonne-years of data

arXiv: 2103.12202v2



Understanding of the Electromagnetic (EM) backgrounds and a measurement of ^{42}Ar activity



Backgrounds from ^{39}Ar beta decays, gamma (γ, n) interactions.

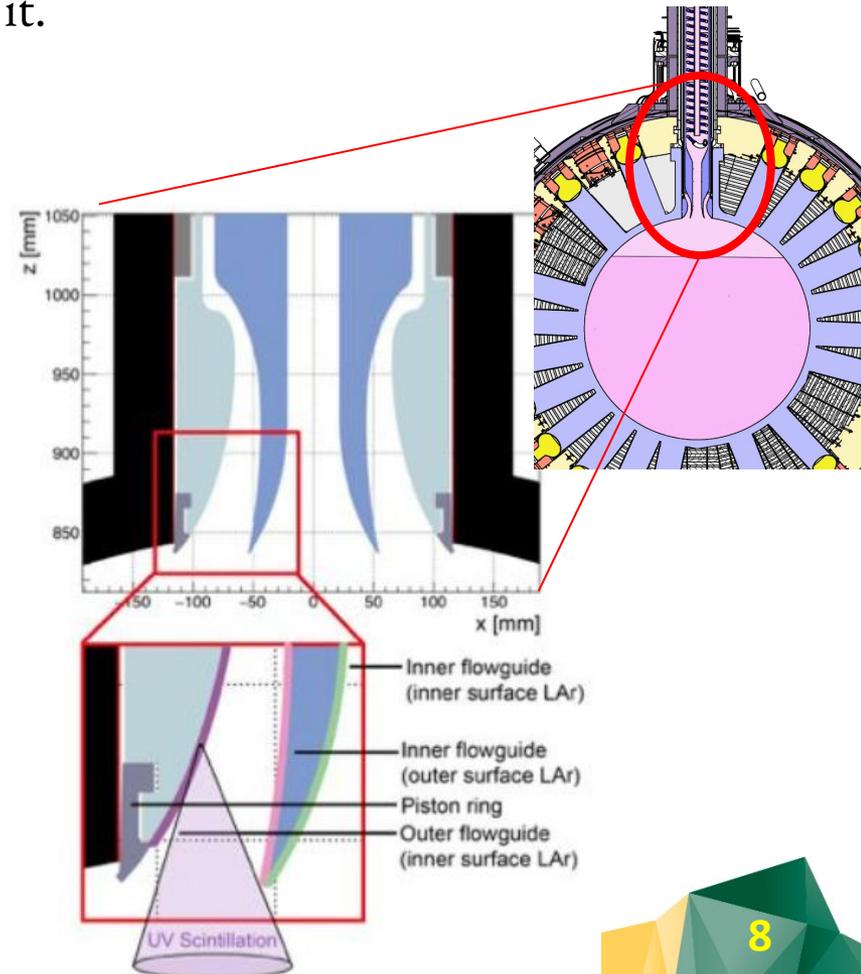
$^{42}\text{Ar}/^{42}\text{K}$ activity: $(40.4 \pm 5.9) \mu\text{Bq}/\text{kg}$

Phy. Rev. D, 100, 072009 (2019)



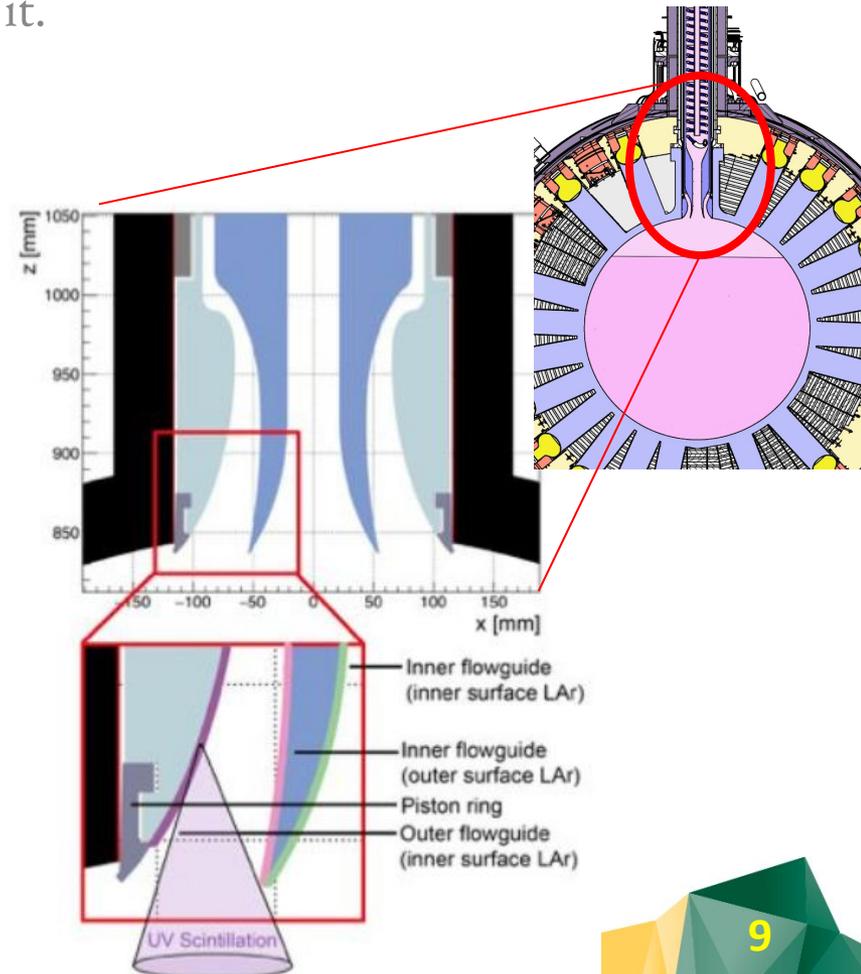
Alpha backgrounds: LAr bulk + AV surface + AV Neck

- Signal like events can be produced by alpha decays in the LAr region
- Alphas in LAr bulk deposits much more energy than DM interactions; no impact on DM search.
- Alphas from the AV surface may be attenuated and reconstructed at intermediate energy. Fiducial volume selection can remove it.
- Alphas from the detector neck acrylic can result in shadowing of scintillation light, i.e., only a small fraction of photons reach PMTs.
 - Low number of photons \rightarrow Signal-like!
 - It is challenging to remove it



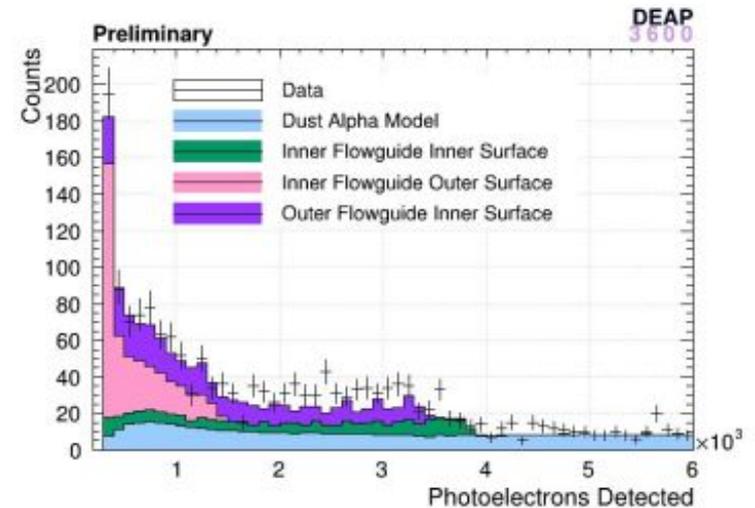
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 - LAr condenses 4.9 g/s in the neck region
 - A 50 micron layer of LAr is thus considered in simulation on the surface of flow guide
 - An alternate LAr droplet model is under study



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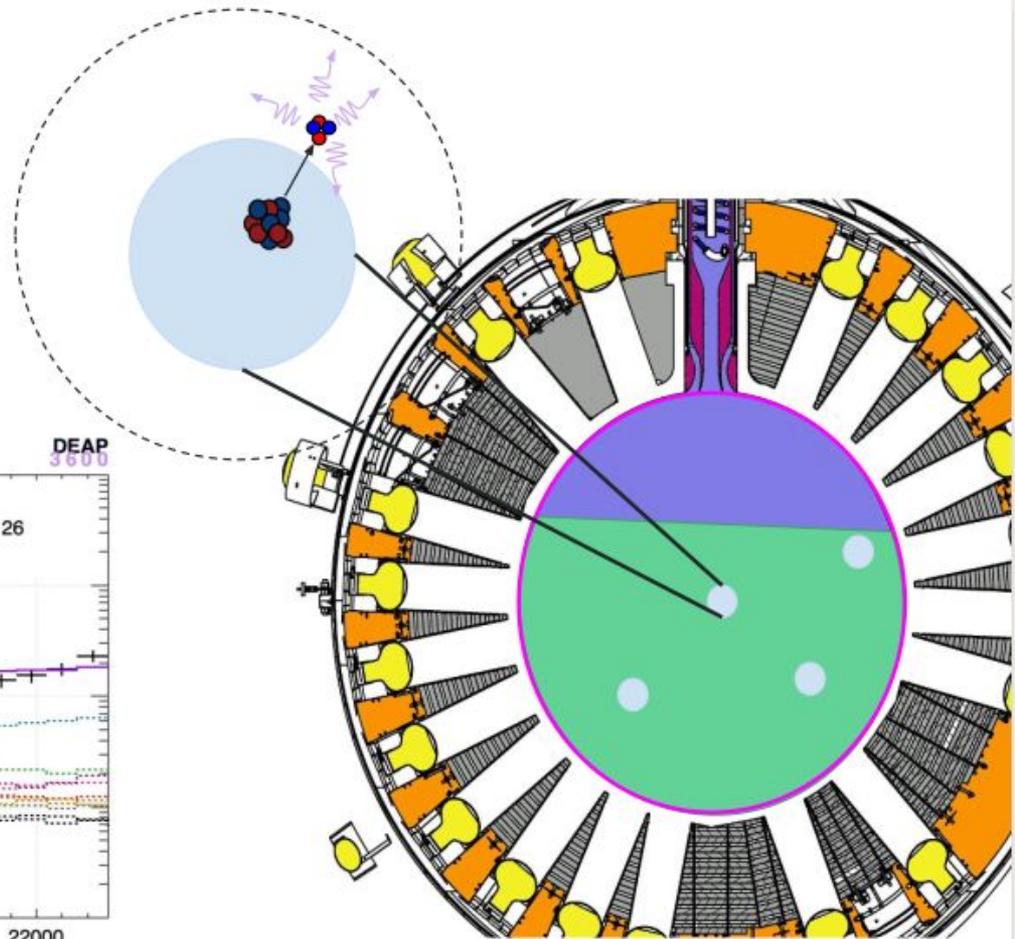
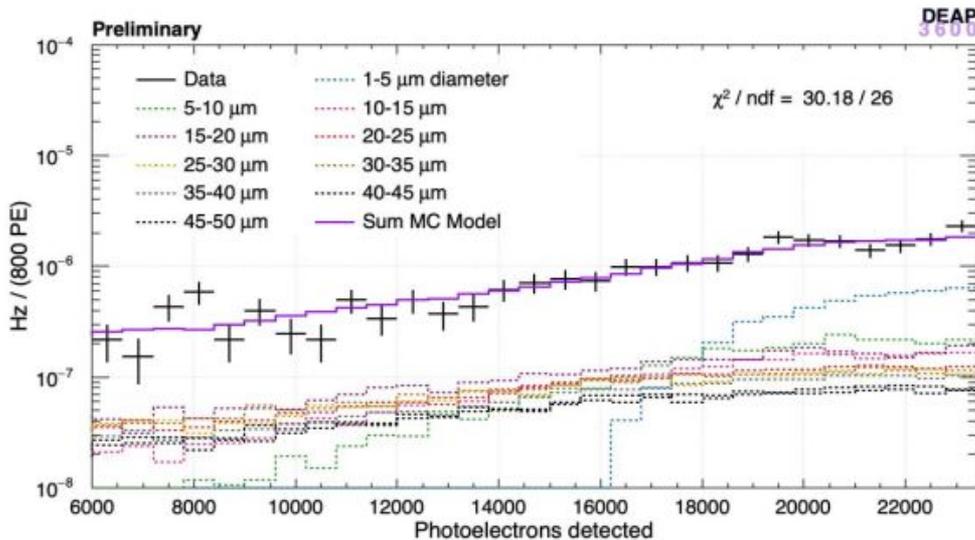
Component	Activity/Rate
^{210}Po inner FG, IS	$(12.5 \pm 1.1) \mu\text{Hz}$
^{210}Po , inner FG, OS	$(18.9 \pm 1.2) \mu\text{Hz}$
^{210}Po , outer FG, IS	$(22.1 \pm 1.3) \mu\text{Hz}$

Long lived α decays

Alpha backgrounds: LAr dust

Dust Alpha Backgrounds

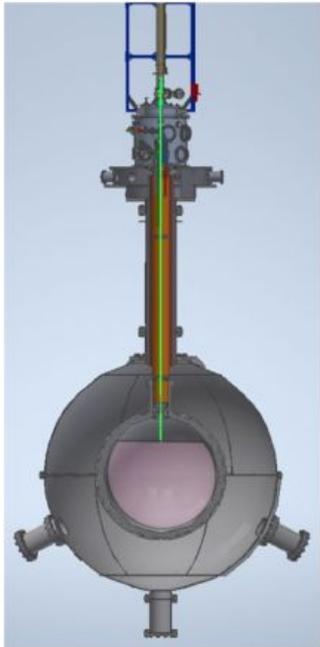
- Alpha decay embedded in dust particulate will have reduced energy deposition in LAr and isotropic photon emission



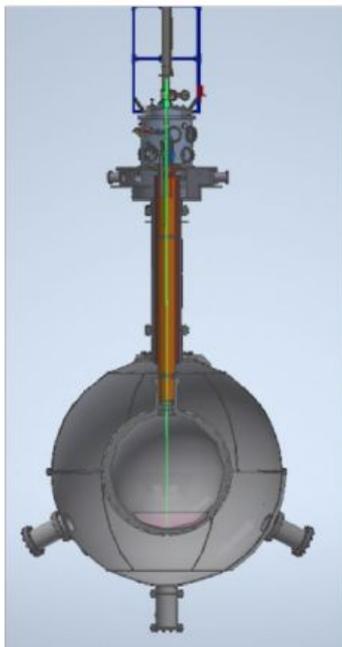
Hardware upgrade

- Fix the seal at the neck (reason for partial fill run)
- Modify the detector characteristics in the neck region
 - Coat the flowguide surface with a “slow” WLS; results VUV photons to visible light
 - Warming the neck region to remove possibility of liquid film or droplets forming
- Remove and filter argon in a liquid state
 - Designed to deploy SS tubes through the neck of the existing detector
 - Deployment will be done under vacuum and through the existing DEAP glovebox to prevent radon from entering the detector

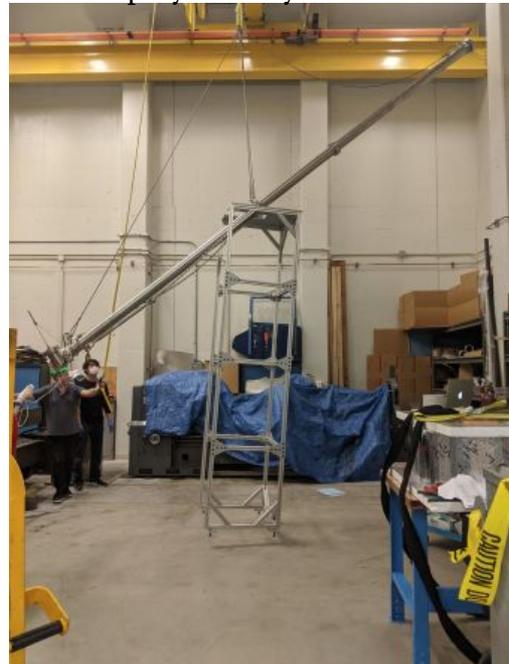
Fill tube



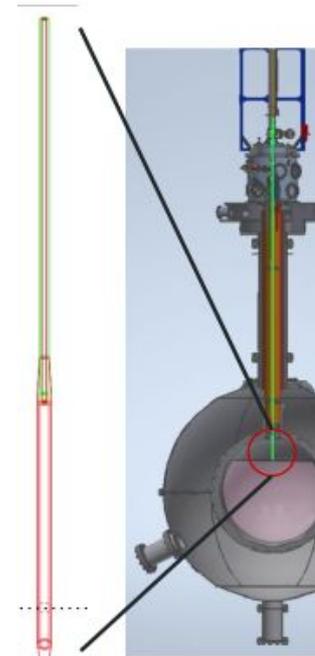
Dust tube



Deployment system

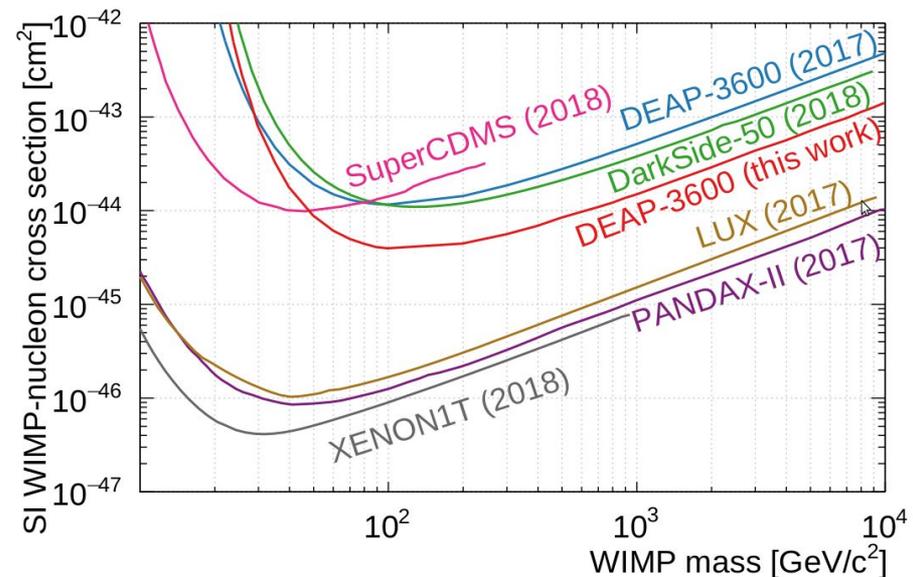
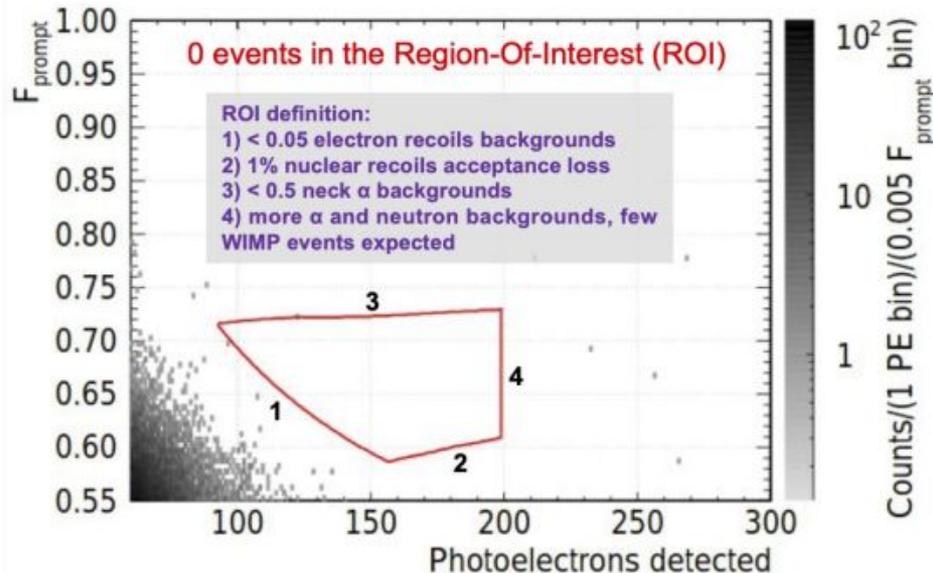


LAr fill tube



WIMP search with 231 days exposure of DEAP3600

No candidate signal events are observed in the WIMP-search region of interest, which results in the leading limit on the WIMP-nucleon spin independent cross section on a LAr target of $3.9 \times 10^{-45} \text{ cm}^2$ for a $100 \text{ GeV}/c^2$ WIMP mass at 90% C.L.



Phy. Rev. D, 100, 022004 (2019)

Timeline and summary

- LAr fill pipe and dust pipe is going to be shipped to site soon
- New acrylic flow guides sanded and coated at Carleton
- Fill with LAr in upgrade configuration in **Fall 2021**
- Comparison and verification of backgrounds post dust filtration and with new neck configuration
 - Quantification of neck alpha background using PSD based variables
- Are there backgrounds that persist in the upgraded configuration?

Papers published/under review

1. Constraints on dark matter-nucleon effective couplings in the presence of kinematically distinct halo substructures using the DEAP-3600 detector (*Phy. Rev. D*, 102, 082001 (2020))
2. Pulse-shape discrimination against low-energy Ar-39 beta decays in liquid argon with 4.5 tonne-years of DEAP-3600 data (review under *Eur. Phys. J. C*)
3. Precision Measurement of the Specific Activity of ^{39}Ar in Atmospheric Argon with the DEAP-3600 Detector (collaboration review)
4. First direct detection constraints on Planck mass scale dark matter with multiple-scatter signatures using the DEAP-3600 detector (collaboration review)