DEAP-3600 Hardware Upgrades

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On Behalf of the DEAP-3600 Collaboration

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SNOLAB

DEAP 3600

Carleton University

Laurentian University
Université Laurentienne

DEAP-3600 Detector

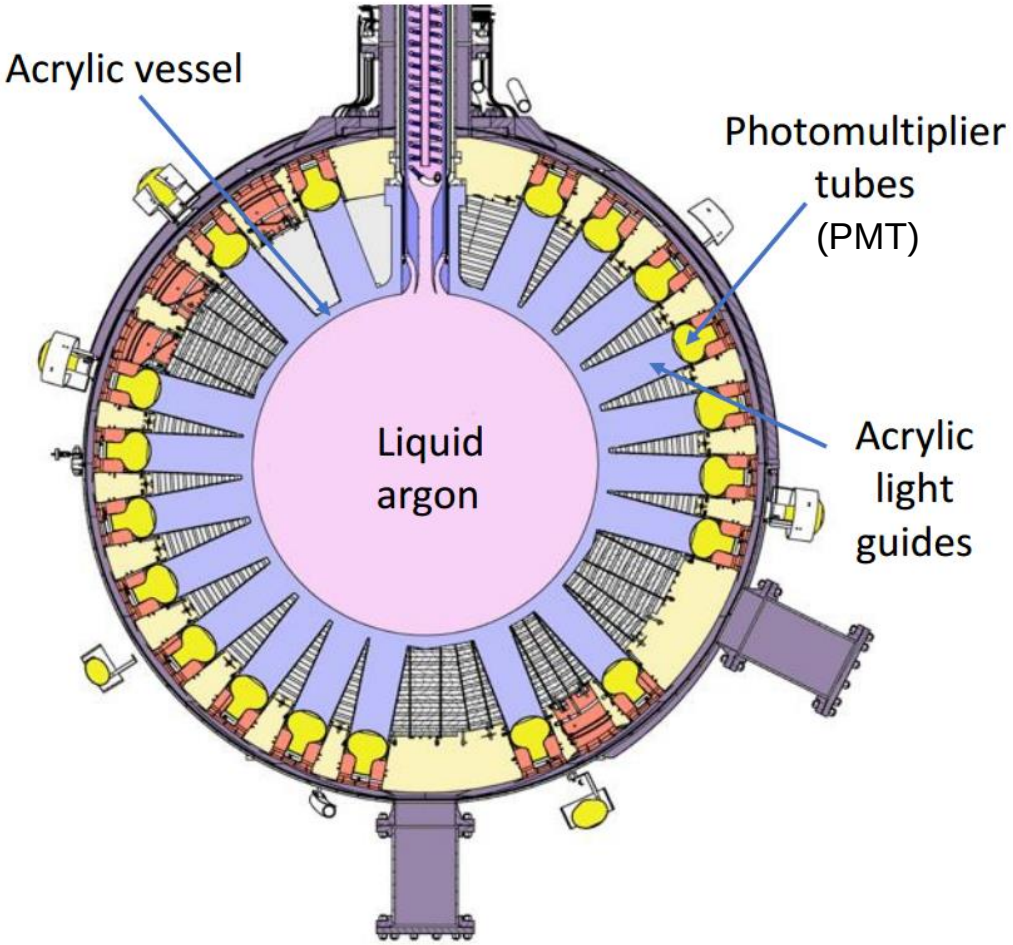
Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination (PSD)

- Design mass of **3600** kg of Liquid Argon (LAr)

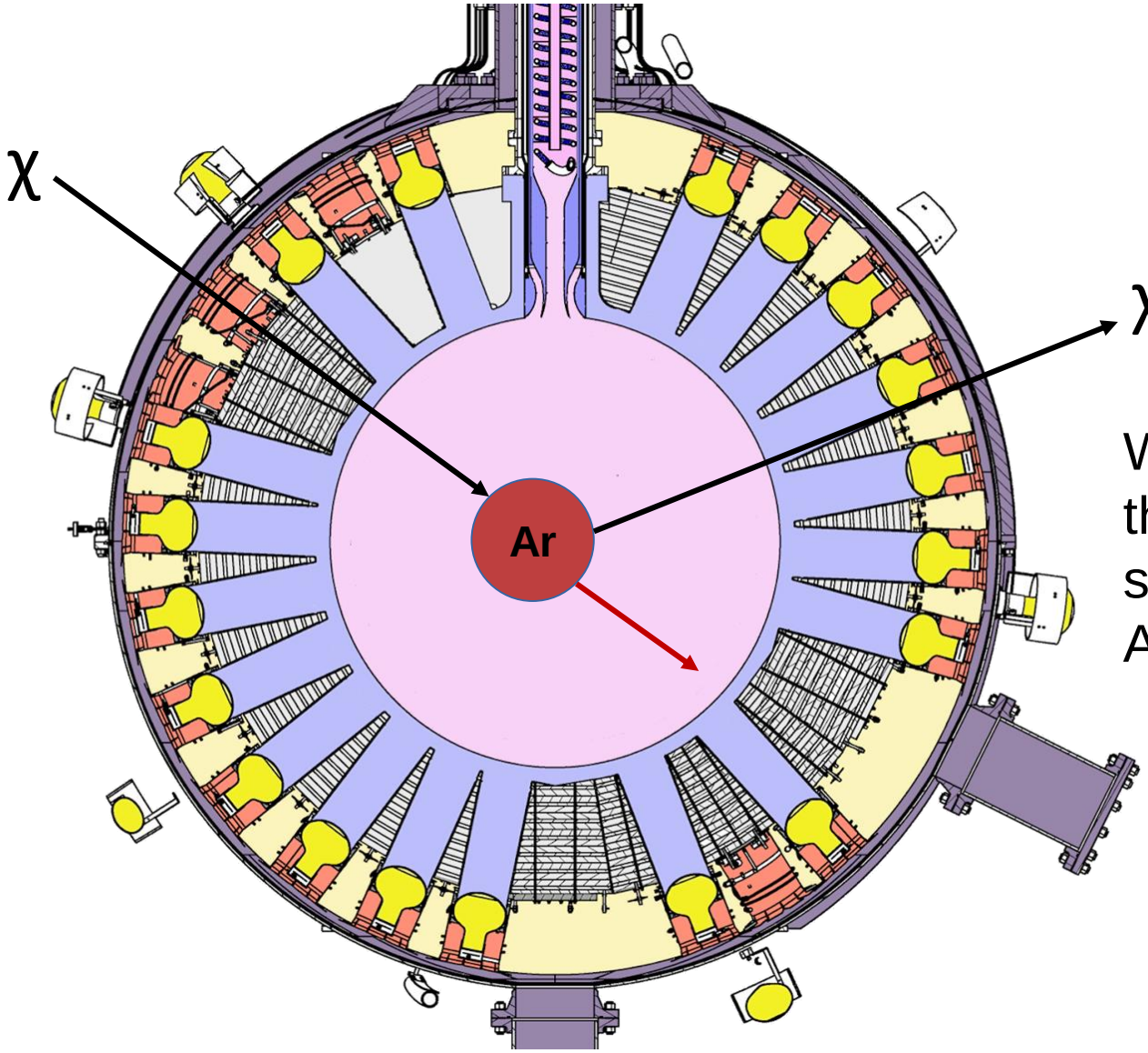
Single phase, LAr scintillation light detector

Nuclear recoils in the argon induce scintillation light

Sensitive to Weakly Interacting Massive Particles (WIMPs)



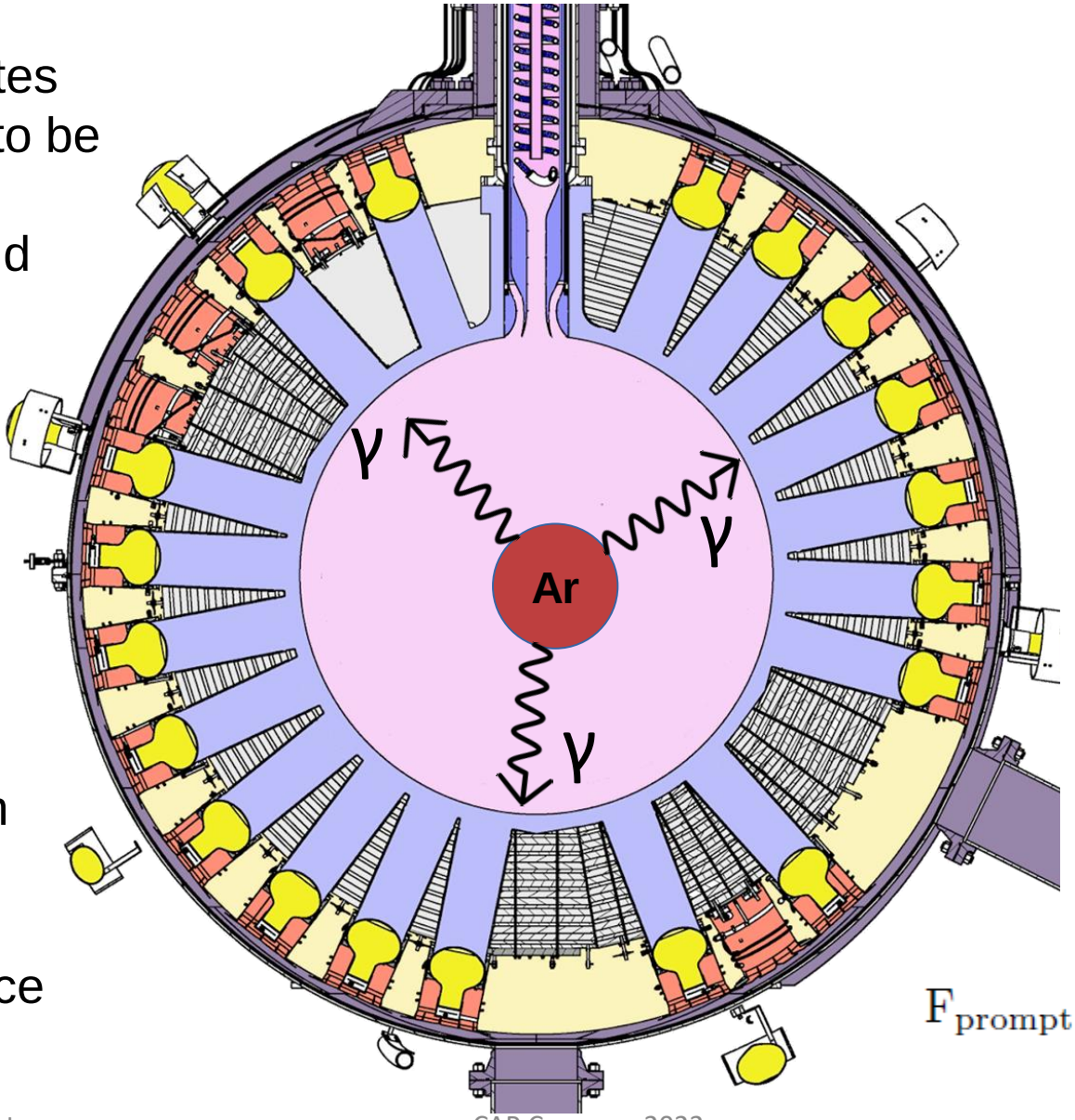
Dark Matter Search using DEAP-3600



WIMP enters the LAr and scatters off the Ar nucleus

Dark Matter Search using DEAP-3600

LAr scintillates 128 nm γ's to be detected by PMTs around the acrylic vessel (AV)



Light is wavelength shifted to 420 nm at inner surface of AV

Nuclear and electronic recoils produce different ratios of singlet and triplet states

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

Why should we upgrade DEAP-3600?

Goals:

Reach design sensitivity

Prove that these techniques can be used in future detectors, namely DarkSide-20k and ARGO

Validate background model

Upgrades:

Reduce and tag neck events with pyrene-coated flow guides

Remove any potential particulates from the bulk LAr and improve particulate filtration of argon

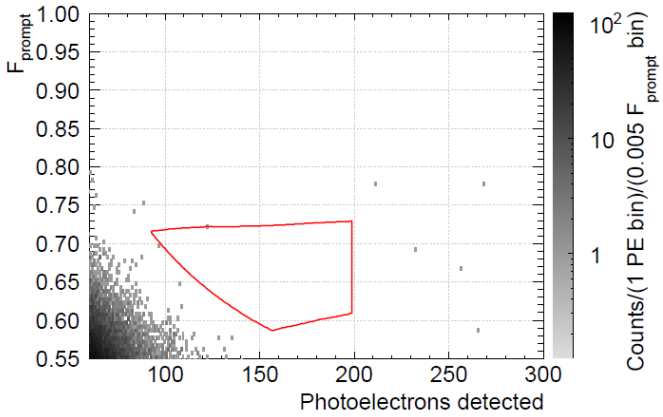
Background budget

Broken into 6 components:

- Electronic recoils
- Cherenkov light produced in acrylic
- Radiogenic neutrons
- Cosmogenic neutrons
- α-decays from the AV surface
- α-decays from the neck flow guides

Background rate around 1 event per tonne-year in the WIMP ROI

Comparable to the lowest ever achieved in any of the DM experiments!



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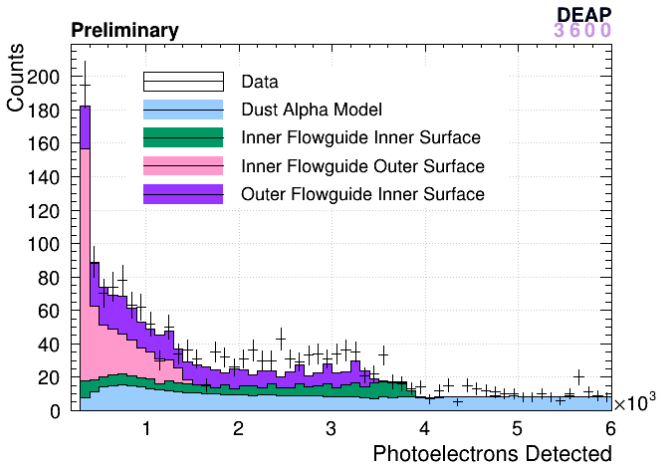
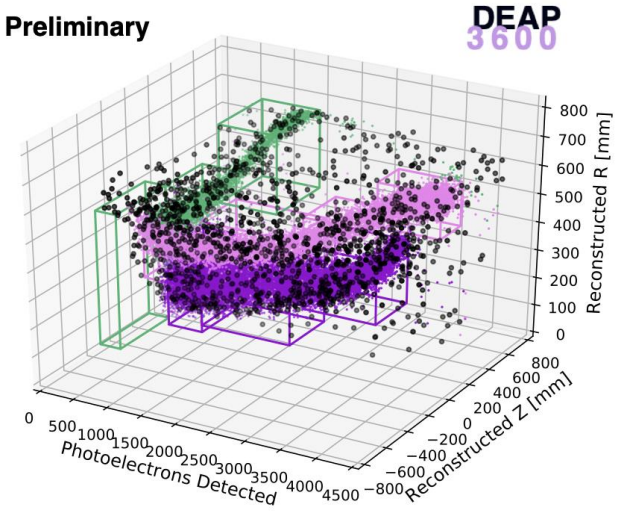
	Source	N^{ROI}
β/γ's	ERs	0.03 ± 0.01
	Cherenkov	< 0.14
n's	Radiogenic	$0.10^{+0.10}_{-0.09}$
	Cosmogenic	< 0.11
α's	AV surface	< 0.08
	Neck FG	$0.49^{+0.27}_{-0.26}$
	Total	$0.62^{+0.31}_{-0.28}$

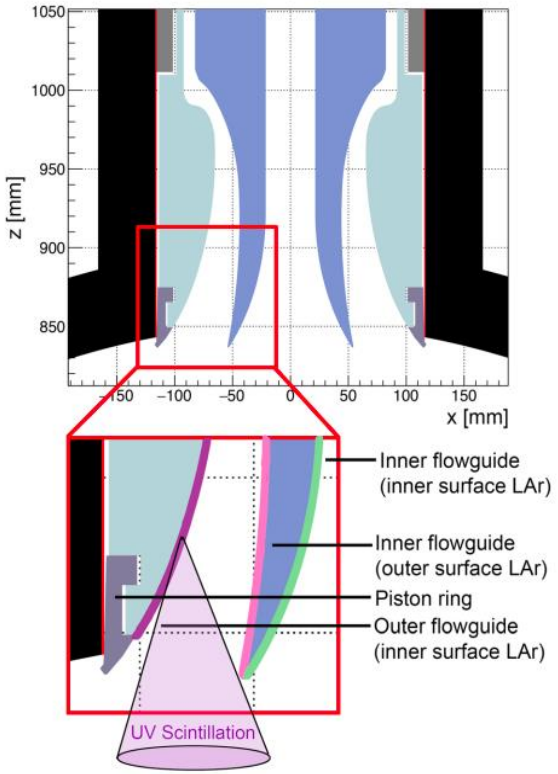
Neck alpha backgrounds

Alphas originating in the neck flow guides can cause scintillation light to shine into the AV

Neck alpha position reconstruction is more difficult due to shadowing by the flow guides



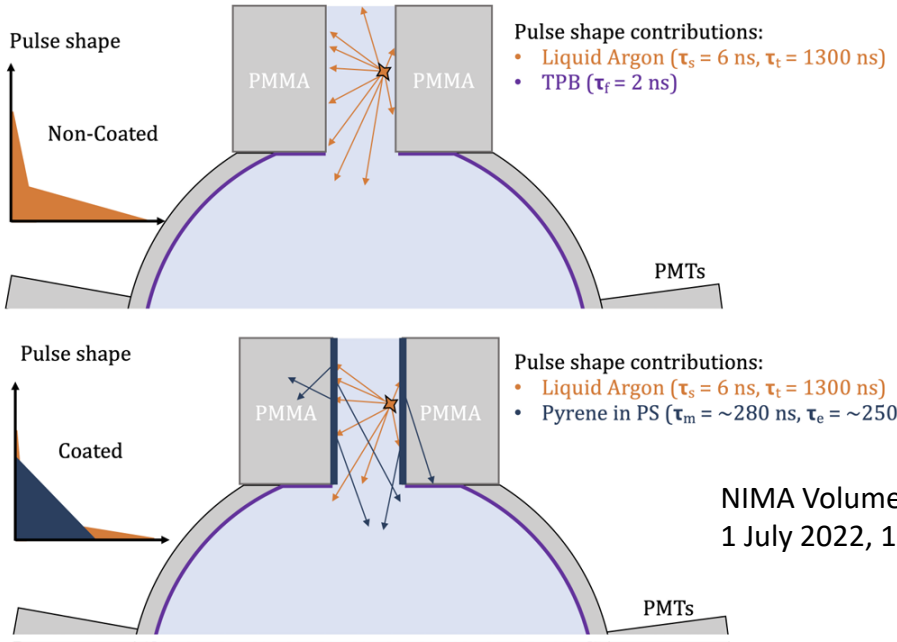




Installation of new flow guides with a wavelength-shifting (WLS) coating

Degraded light collection from non-coated flow guides shifts α events to lower energies, potentially into WIMP region of interest

WLS coating produces a significantly different PSD that can be tagged very effectively



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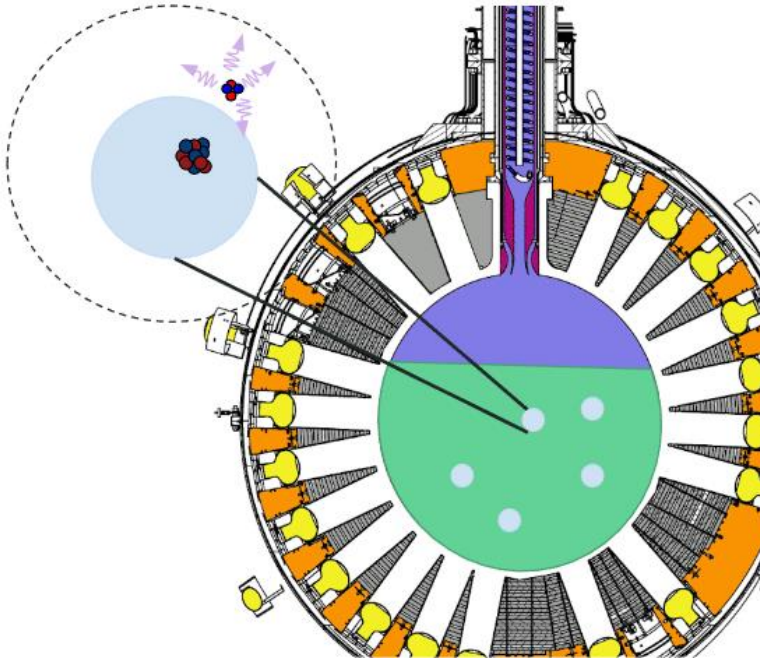
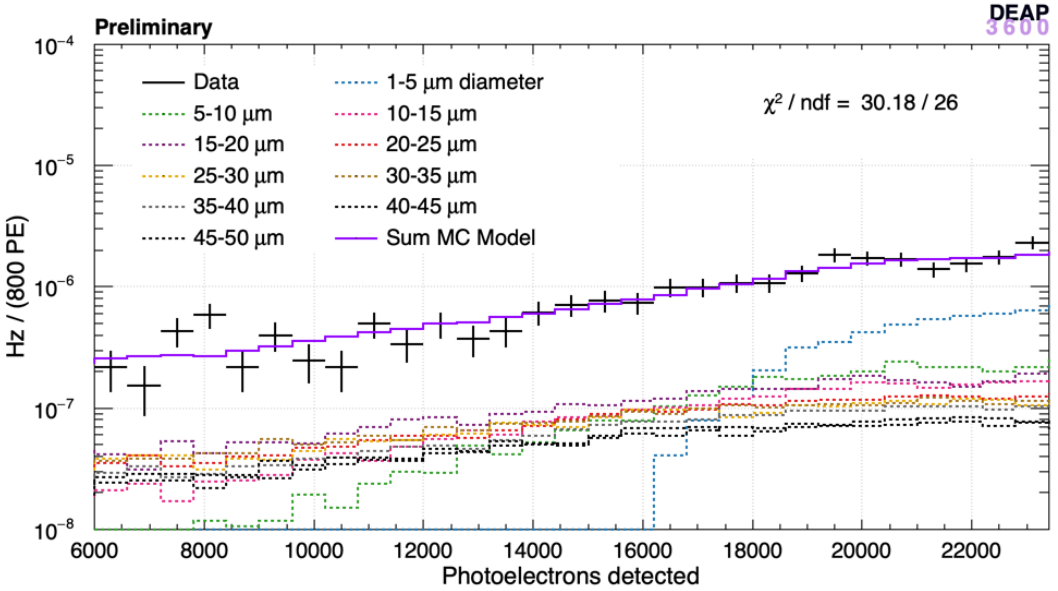
Flow guides machined at University of Alberta and then coated at Carleton University

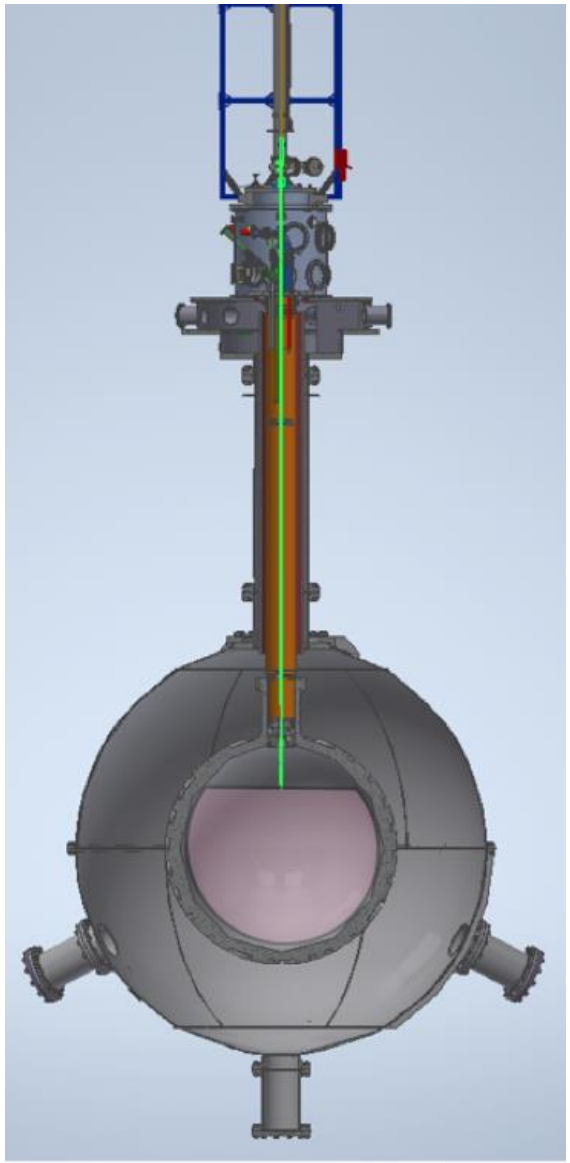
Potential dust particles create problematic alpha backgrounds in the bulk LAr

Alpha decays in dust particles can create high F_{prompt} and shadowed events, mimicking WIMP events





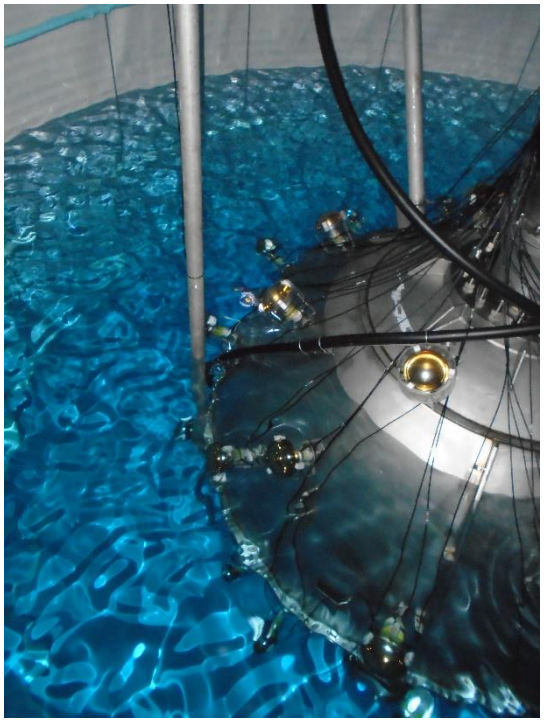
Alternate cooling and dust removal (external) system

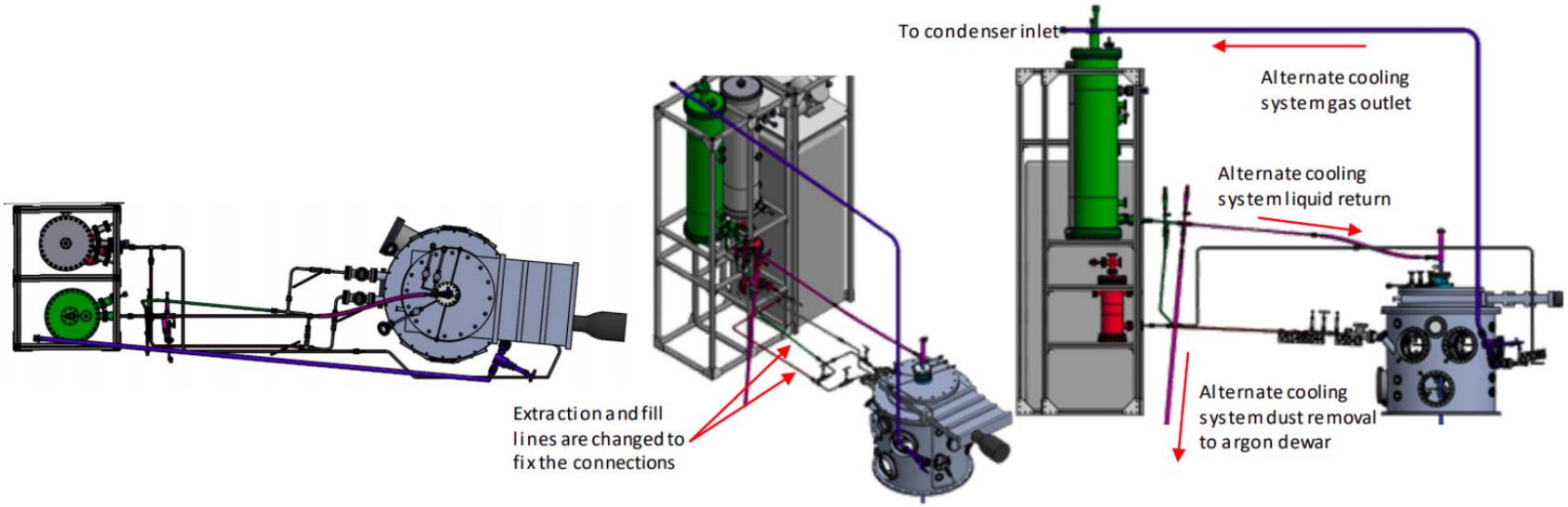


- New external system is on site and ready to be installed
- Reduction in dust background via LAr removal and filtration
  - Removal of bulk LAr through a tube deployed to the bottom of the AV will pull dust out
  - Installation of high-throughput filter on the argon purification system will prevent new dust ingress into the AV
- External cooling of the argon
  - Warmer neck will prevent LAr film from forming on flow guides
  - Alpha scintillation in LAr film allows leakage into ROI

Many other improvements and upgrades to DEAP systems

- Liquid nitrogen cooling system maintenance
- Argon dewar upgrade
- Replacement of 10 veto PMTs
- New argon process lines
- Installation of a new hoist for removal of the neck





Hardware upgrade status and progress

- New flow guides are complete and underground awaiting installation
- Alternate cooling and dust filtration system also complete and awaiting installation
- Installation and commissioning of new hardware to take place through the end of 2022
- Third LAr fill scheduled to begin Winter 2022
- Data-taking scheduled to begin Spring 2023

Third fill run plan

- Begin by cooling the AV with gas, followed by a small LAr fill (about 300 kg)
- Drain the liquid with the external system to remove particulates
- Fill with LAr to the same height as the second fill for directly comparable results with past data
- Automated weekly analysis to determine effect of hardware upgrades
  - Assess reduction in dust and neck alphas compared to the previous fill

UC Riverside joining in July