

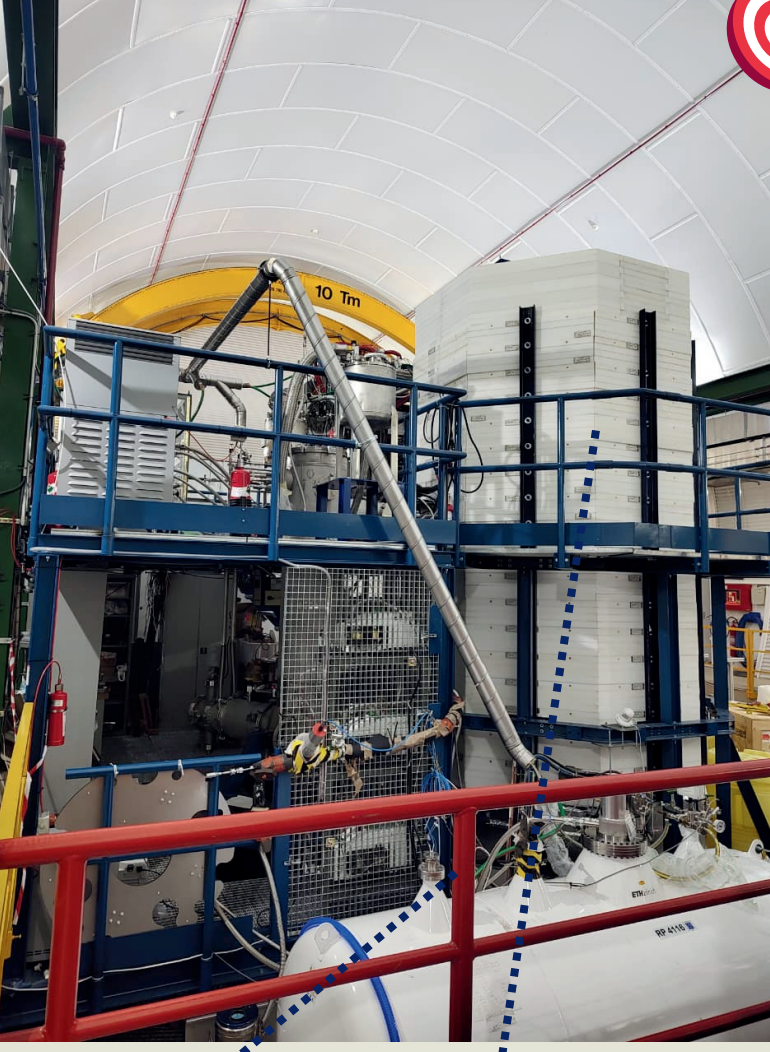
Simulation Studies for the DArTinArDM Detector for ^{39}Ar Measurements in Underground Argon

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On behalf of DArTinArDM Collaboration

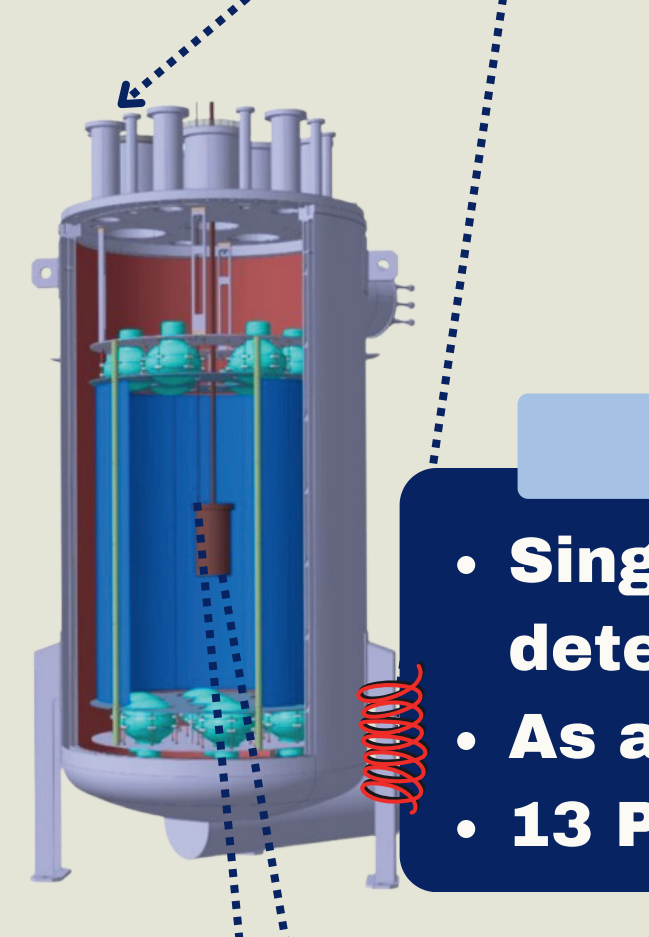
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DArTinArDM : Depleted Argon Target in Argon Dark Matter



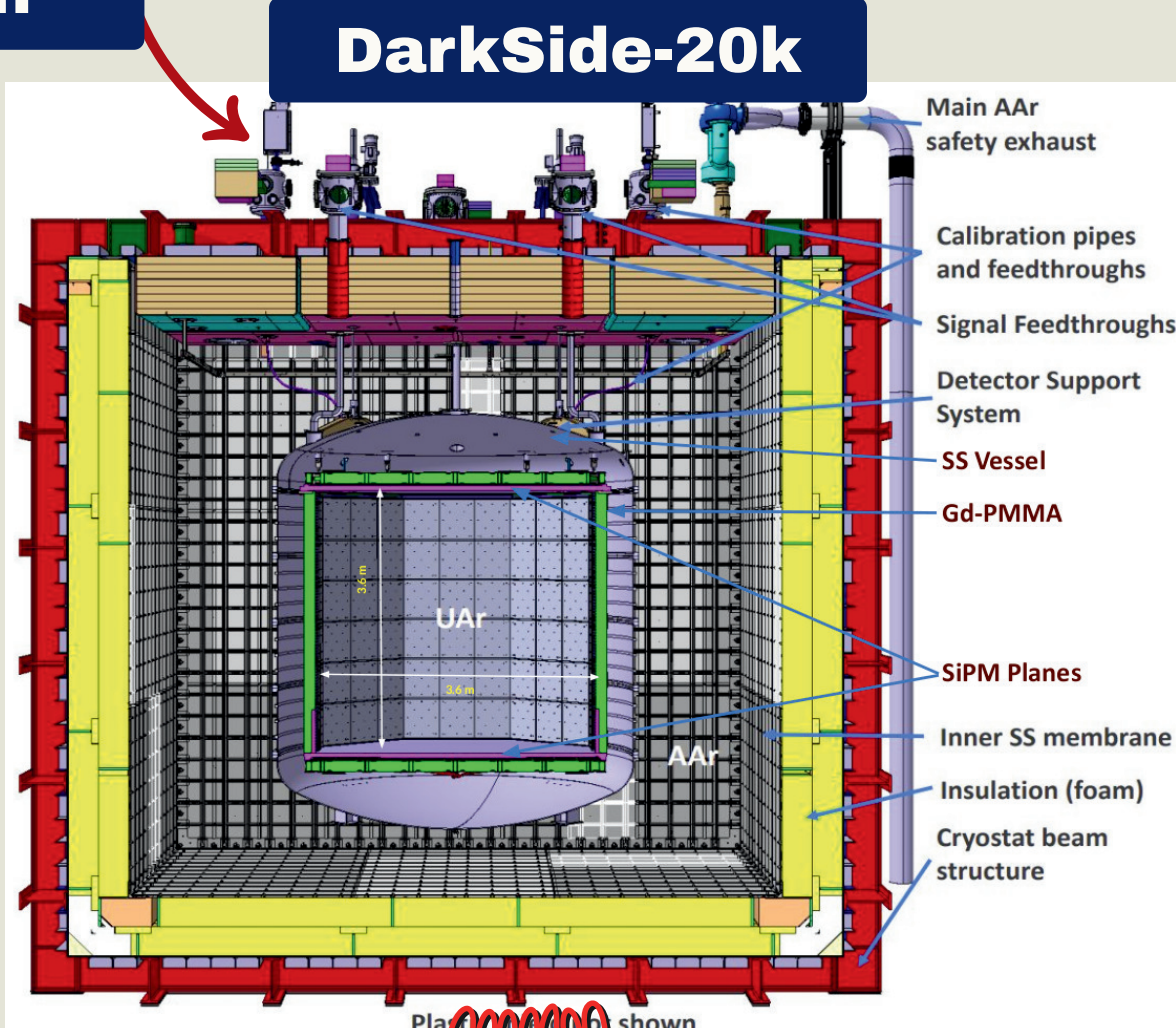
DArTinArDM is installed at the Canfranc Underground Laboratory (LSC) to measure the residual ^{39}Ar activity in underground argon with sensitivity below the mBq/kg level.
C. E. Aalseth et al., JINST 15 (2020) P02024.

Application



ArDM

- Single-Phase LAr detector
- As an active veto
- 13 PMTs [6(T), 7(B)]



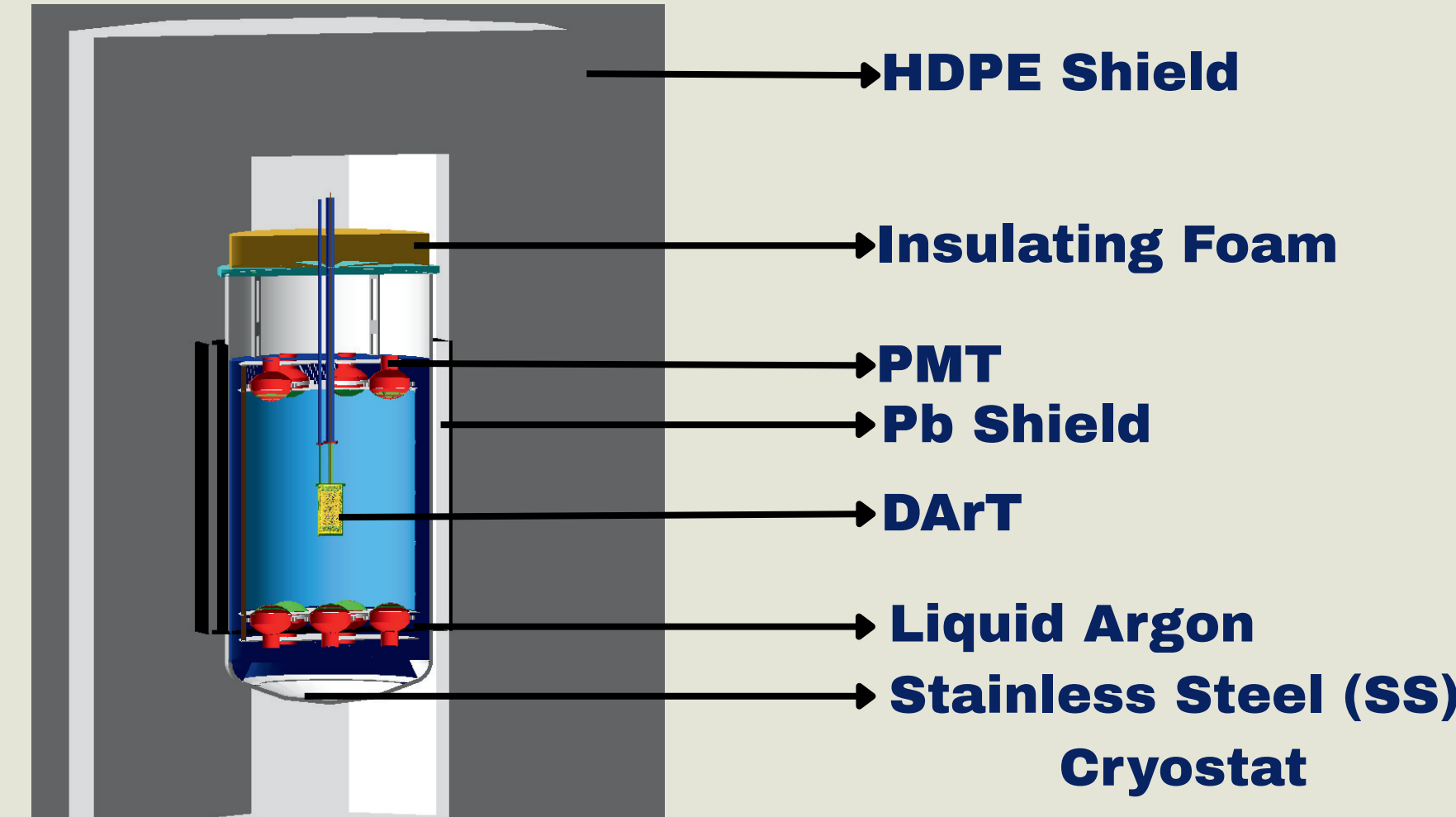
DarkSide-20k

Two-phase LAr TPC (fiducial mass 20 t) for WIMP searches in preparation at Gran Sasso Underground Laboratory (Italy)

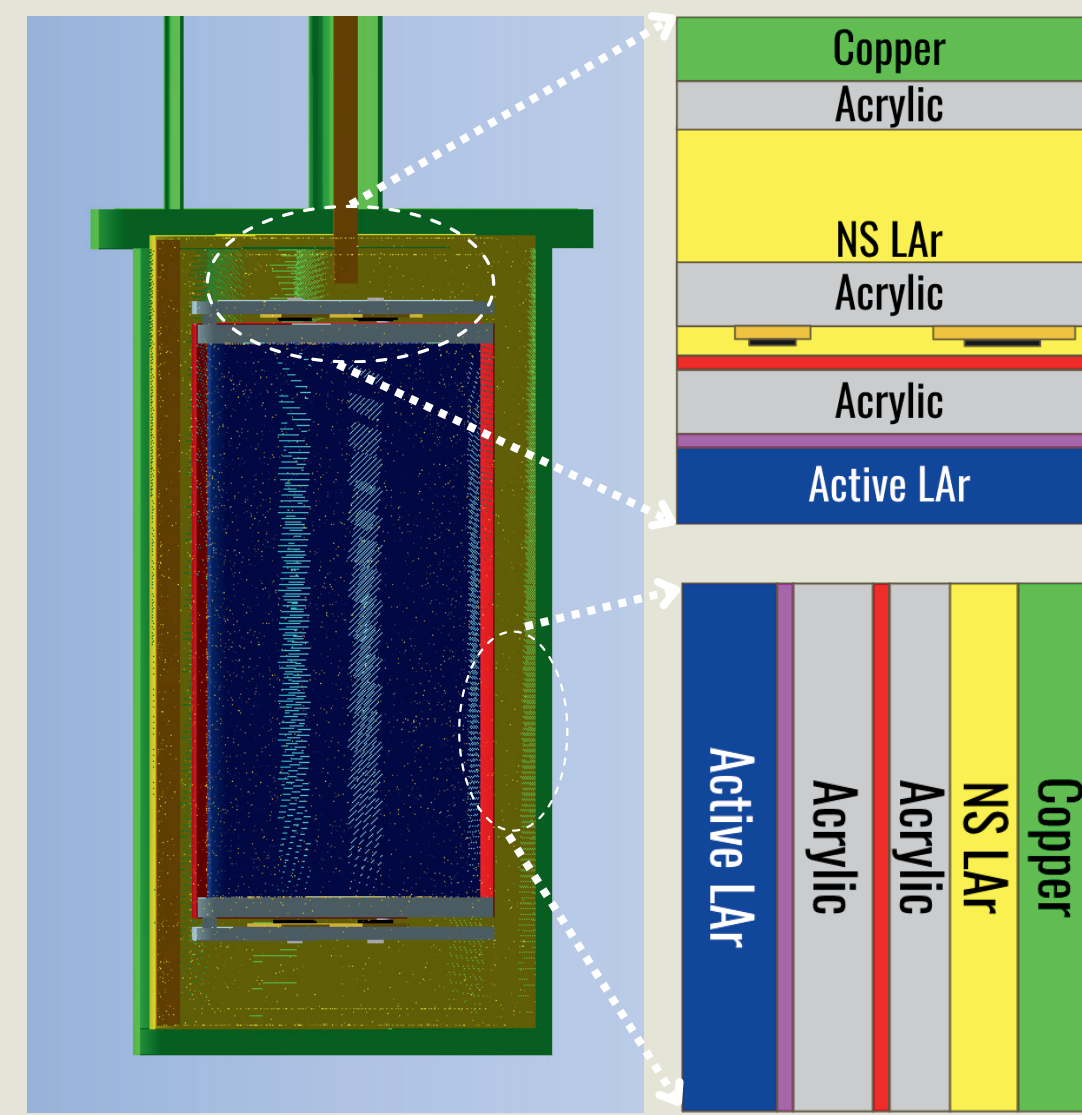
DArT

- Scintillation detected by 8 SiPMs

Detector Geometry in Simulation



DArT



Full Simulation Chain

G4DS

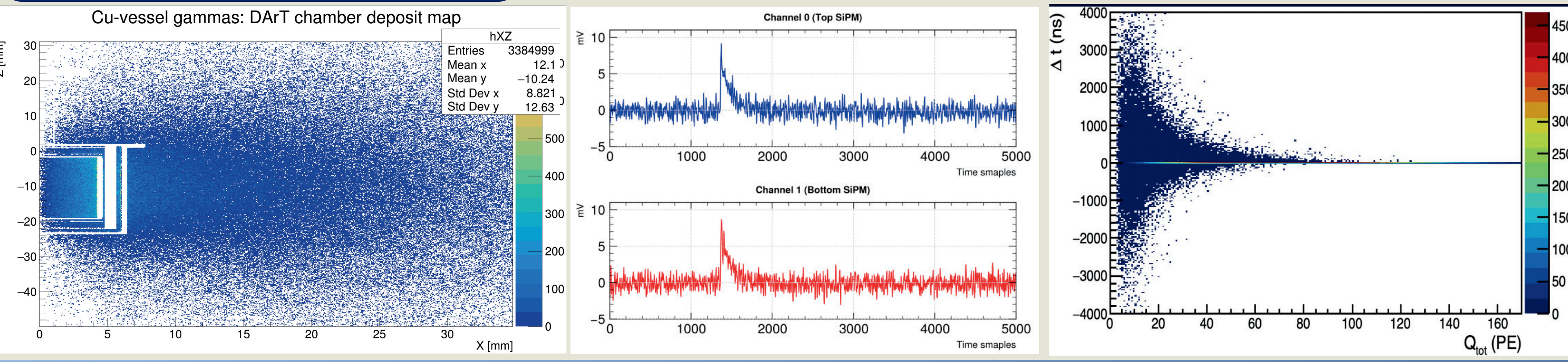
- Geant4 toolkit in DarkSide for
- Particle transport
- Energy deposition
- Scintillation photon propagation
- P. Agnes et al., JINST 12 (2017) P10015.**

DS-lab

- Electronic response
- DAQ simulation
- Waveforms generation

PyReco

- Waveform Reconstruction



Analysis Definition

- Signal events are electron recoils from ^{39}Ar beta decays in the DArT active argon volume.
- These events are expected to deposit their energy in DArT with no significant coincident signal in ArDM.
- Backgrounds arise from radioactive decays in detector materials and the surrounding environment, mainly through gamma particles that can Compton scatter in DArT and/or ArDM

Analysis Cuts and event classes

- **DArT Events** : $E_{\text{DArT}} > 0$ keV
- **DArT ROI** : $0 < E_{\text{DArT}} \leq 600$ keV
 - The DArT energy region below 600 keV defines the ^{39}Ar region of interest, where the beta decay signal is expected.
- **ArDM veto** : $E_{\text{ArDM}} > 10$ keV
 - Background events in the DArT ROI are classified as veto-tagged when they deposit more than 10 keV in ArDM. Events below this threshold remain untagged and define the residual background population.
- **Tagged ROI background** : DArT ROI and $E_{\text{ArDM}} > 10$ keV background events rejected by the ArDM veto.
- **Untagged ROI background** : DArT ROI and $E_{\text{ArDM}} < 10$ keV
 - Residual background population surviving the veto.

Background Analysis Table

Group	Component	Simulated events	NROI	Nuntagged	Veto _{eff}	Untagged [%]
ArDM	Cryostat SS	4.70E+08	9730	472	0.951	4.85
ArDM	HDPE shield	1.20E+09	131	4	0.969	3.054
ArDM	PMT glass	8.00E+06	614	23	0.962	3.745
DArT	Cu vessel	8.00E+06	402825	76129	0.811	18.898
DArT	Acrylic	8.00E+06	92012	49859	0.458	54.187
DArT	PCB_Substrate	4.00E+06	112900	57396	0.491	50.837

Conclusions and outlook

- A detailed G4DS geometry of DArTinArDM has been developed and is essentially final.
- A G4DS-based background-analysis framework has been developed to classify material-background events using the DArT ROI and the ArDM veto response at deposited-energy level.
- ArDM efficiently tags most external-background events entering the DArT ROI, with cryostat SS, HDPE shield and PMT glass showing $\approx 95-97\%$ veto efficiency.
- DArT materials show larger untagged ROI fractions and are therefore critical for the residual background model of the ^{39}Ar measurement.
- Next steps: fine tuning of the beta-gamma decay generator for selected isotopes, particularly ^{214}Bi , and improved treatment of specific source locations such as plastic cables around DArT.
- Construction of the background model through comparison with commissioning data, and study of sensitivity to ^{42}Ar / ^{42}K activity.

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