Darkside-20k

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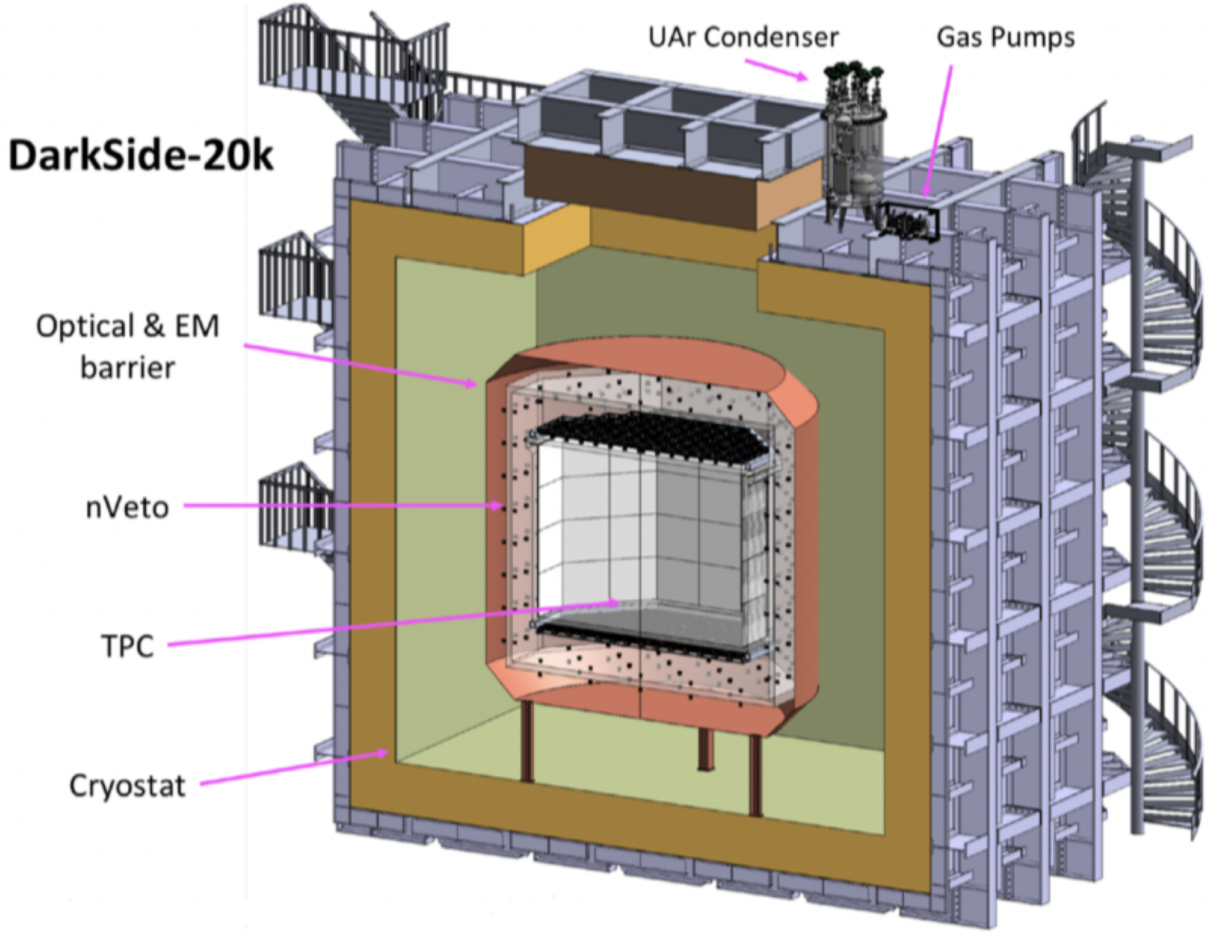
HEP Meeting, April 29th 2021

Outline

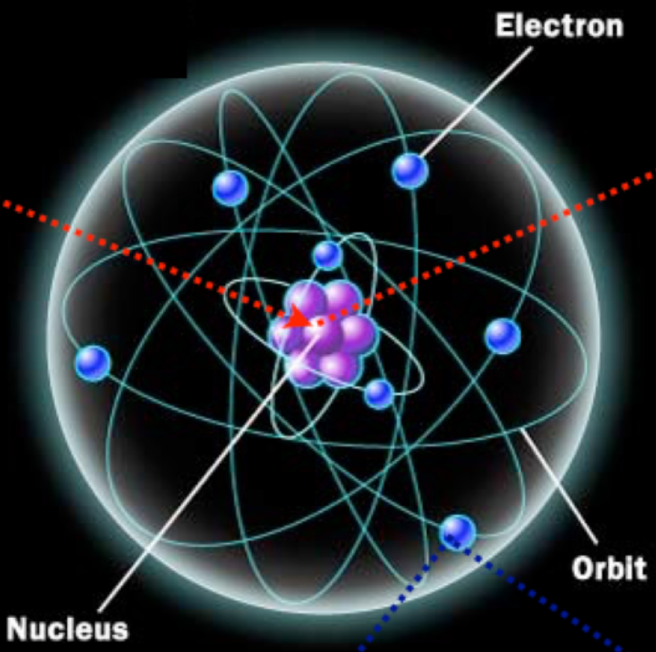
- Darkside-20k experiment overview
- Darkside-20k outer detector and new Liverpool activities



Why Liquid Argon?

- ✓ **Dense**: 40% denser than water
- ✓ **Easy ionization**: 55 000 e^-/cm for MIPs
- ✓ **High electron lifetime** if purified → long drifts
- ✓ **High scintillation light yield**: 40k γ/MeV
- ✓ **Pulse shape discrimination ability:** (S1:fast 6ns/slow 1.6 μs)
- ✓ **Broad recoil energy spectrum:** (0-100keV)
- ✓ **Abundant:** ~1% of the atmosphere (needs ^{39}Ar depletion for DM)
- ✓ **Cheap**: \$2/L (\$3000/L for Xe, \$500/L for Ne)

Dark Matter Direct Detection



WIMP-nucleon scattering

Nuclear recoils:
- *^{238}U and ^{232}Th in detector materials*
- *Cosmogenics*
- *(α,n) reactions*
- *Coherent neutrino scattering (irreducible)*

Electron recoils:
- *^{238}U and ^{232}Th decay chains*
- *Beta decays in TPC and cryostat*

experimental requirements: particle ID for recoil N, e-, alpha, n (multiple) final states

Darkside-20k Outlook

DarkSide-20k: 50t liquid underground Ar (UAr) dark matter target, inside a 700t liquid atmospheric Ar (AAr) outer detector

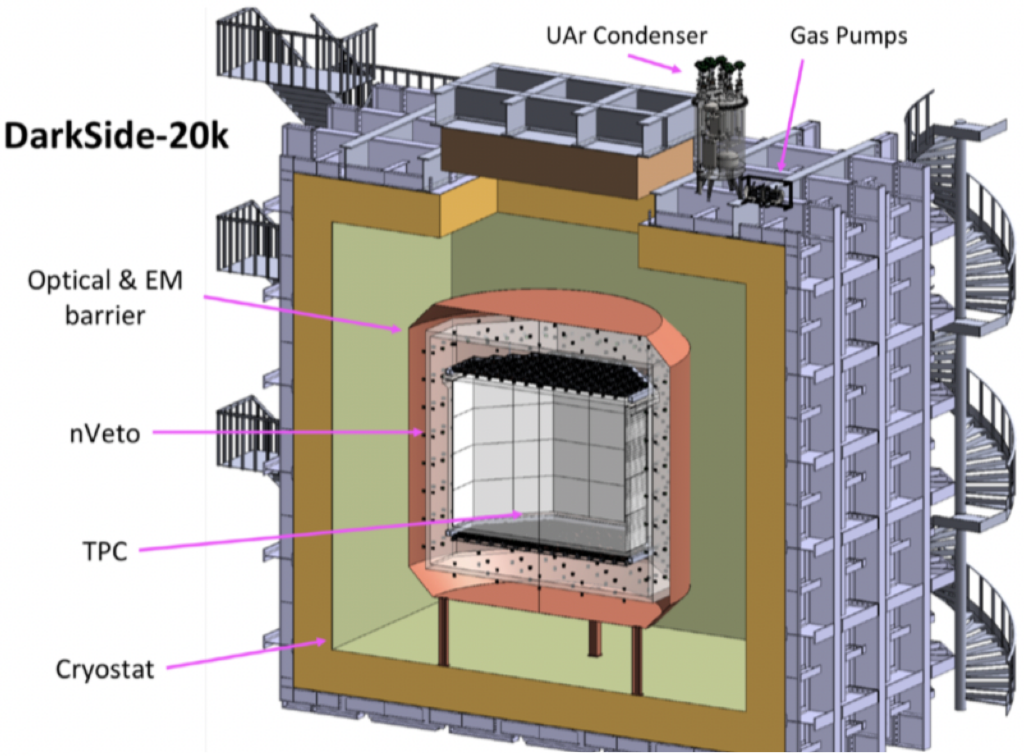
- Physics data-taking timescale 2023—2028.
- Expected sensitivity two orders of magnitude above current experiments at 1 TeV WIMP mass, with sensitivity from sub-GeV to the multi-TeV regime.

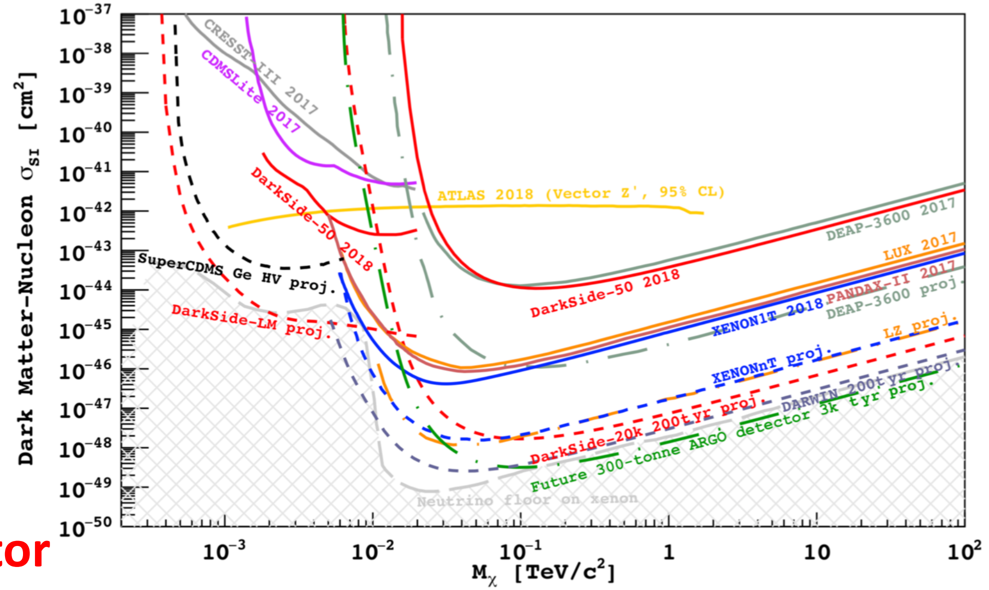
DarkSide-20k aims to be a background-free detector

- Expected background with full exposure <0.1 events.

First large-scale use of large-area cryogenic Si photodetection modules (”PDMs”) instead of PMTs

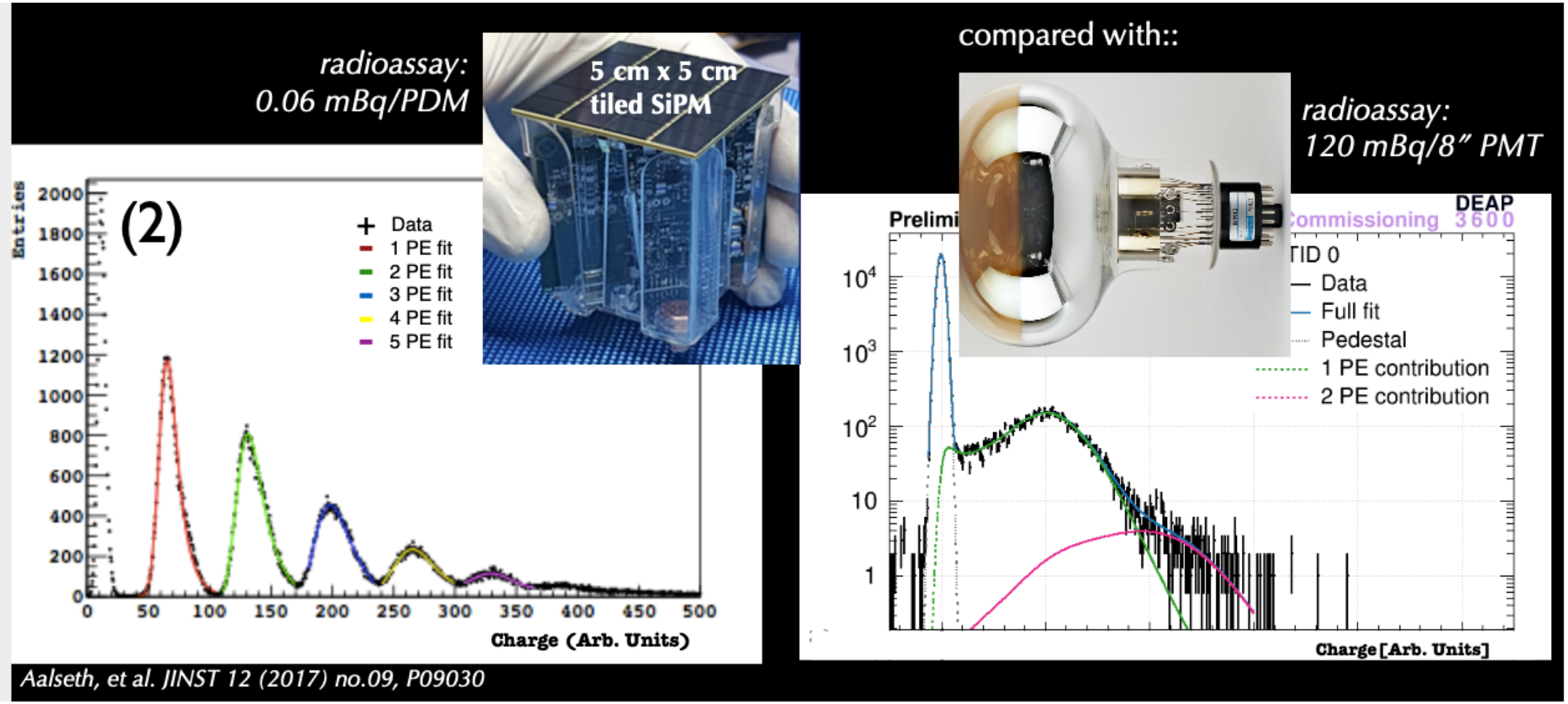
- **UK will deliver photodetection modules for the outer detector**





Darkside-20k: Key innovation on Photon Sensors

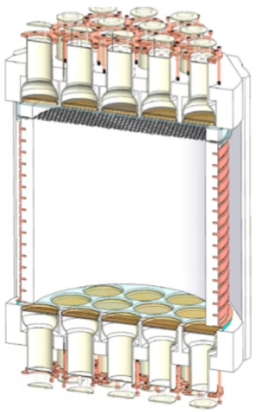
- Low noise, high efficiency, cryogenic Si sensors developed in collaboration with FBK in dedicated 5+ year program



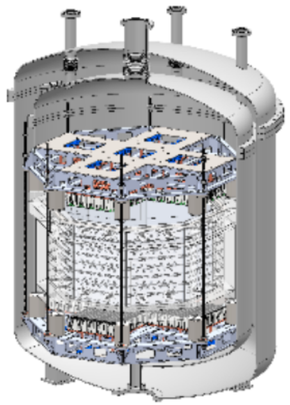
>3x photon detection efficiency, 10x lower noise, >50x lower radiogenic backgrounds than PMTs.

Darkside-History

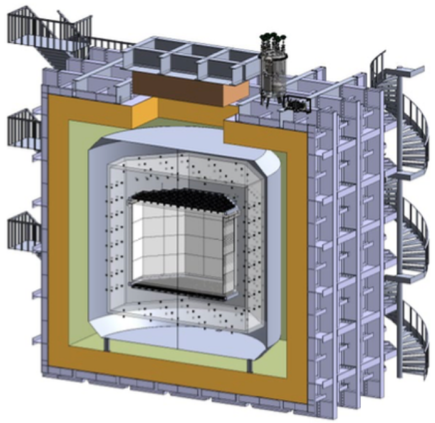
DarkSide is multi-stage program that aims to the direct detection of **Dark Matter**, by operating a dual phase **Underground Argon** (**UAr**) time projection chamber (**TPC**), at the underground **Laboratori Nazionali del Gran Sasso**.



DS-50
50Kg LAr



DS-proto-1t
175Kg LAr



DS-20k
50ton LAr

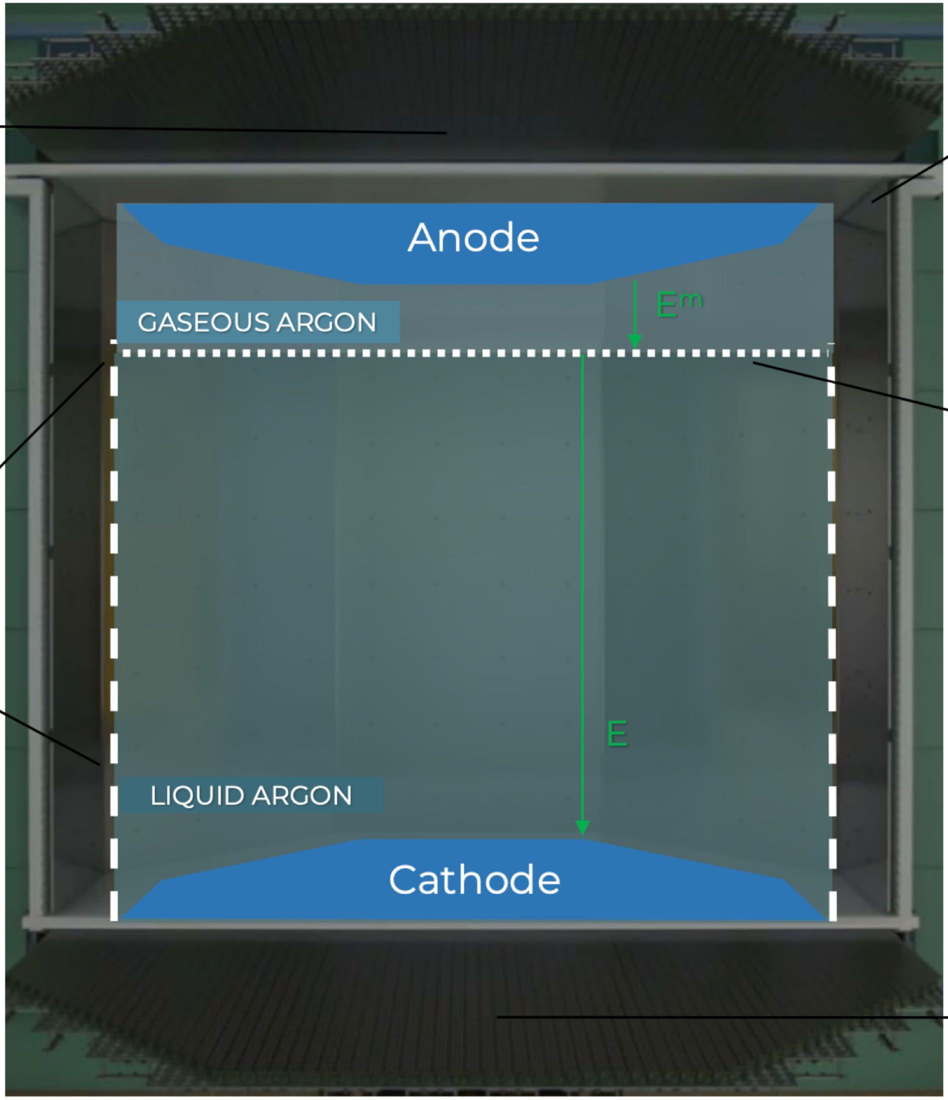
ARGO

kton scale

It lives within the Global Argon Dark Matter Collaboration (**GADMC**): past and current experiments (**DEAP-3600**, **MiniCLEAN**, **ArDM** and **DarkSide-50**) joining forces for the **next generation liquid Argon Dark Matter detectors**

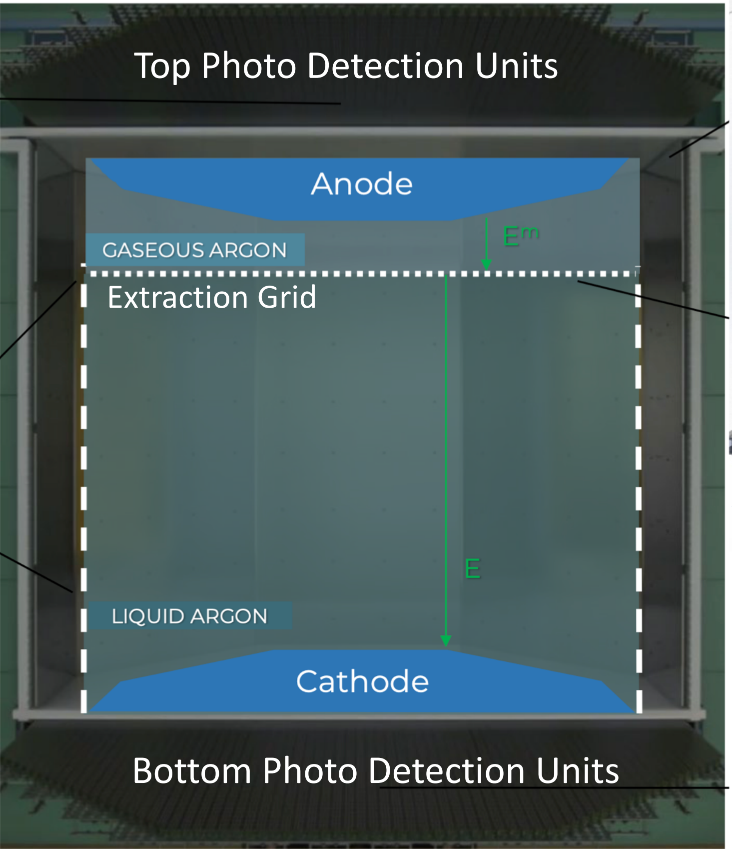
Global argon dark matter collaboration: >400 researchers
14 countries: Brazil, Canada, China, France, Greece, Russia, Italy, Mexico, Poland, Romania, Spain, Switzerland, UK, USA.

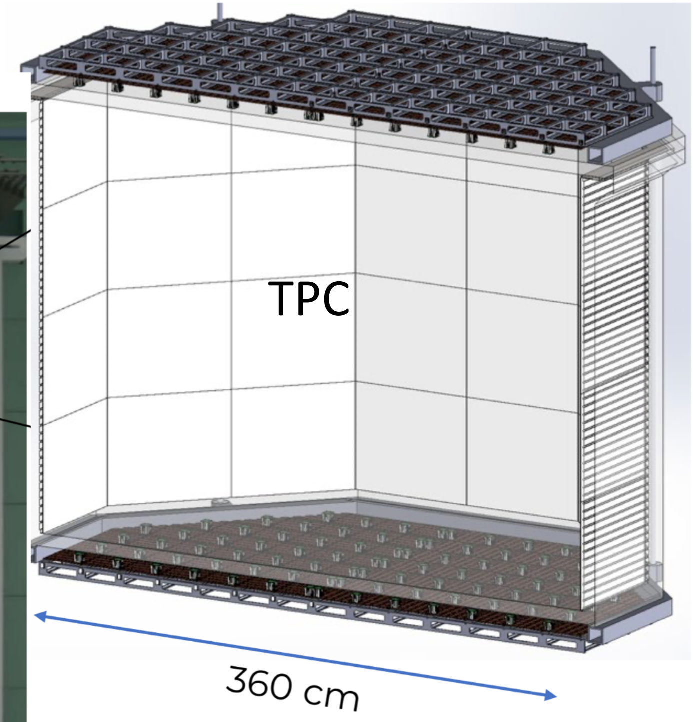
Darkside-20k: 50t TPC

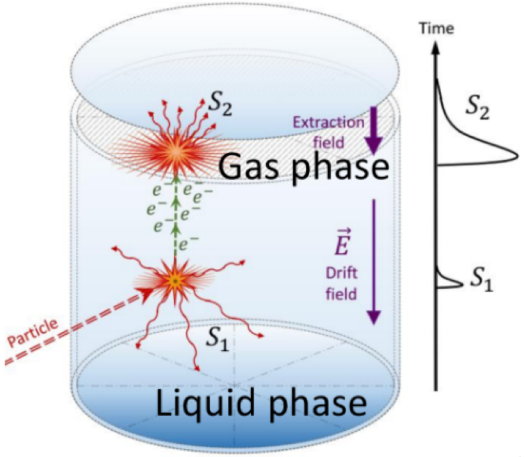


Dual phase Argon TPC

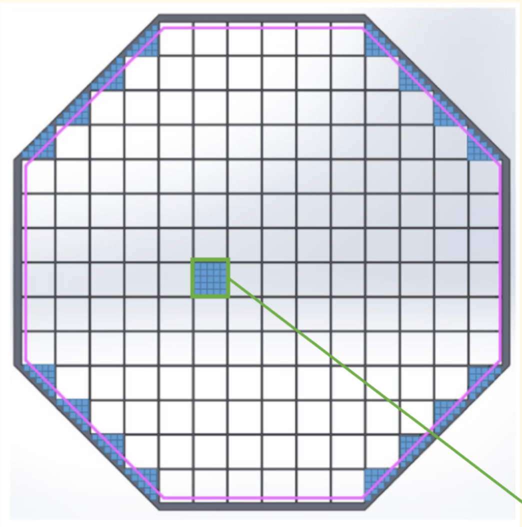
DarkSide-20k TPC



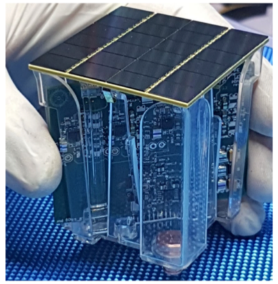




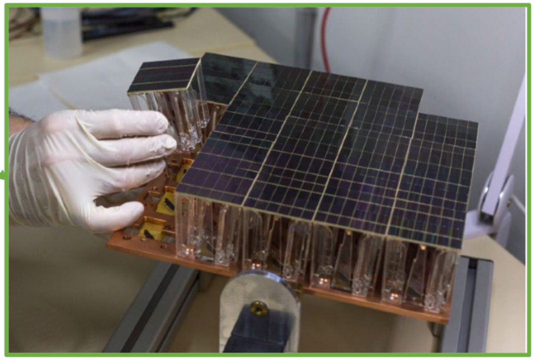
- 50t of depleted **UAr**
- Octagonal **sealed acrylic TPC**
- **Clevios** conductive polymer **coating** for anode, cathode and field cage rings
- Enhanced Specular Reflector
- **TPB coated** as **WLS**.



Each **detection plane** is composed by **4140 PDMs** grouped in **344** Photo Detection Units (**PDUs**)

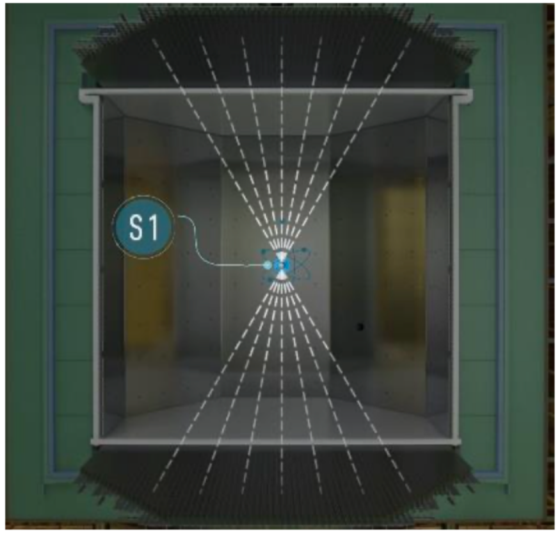


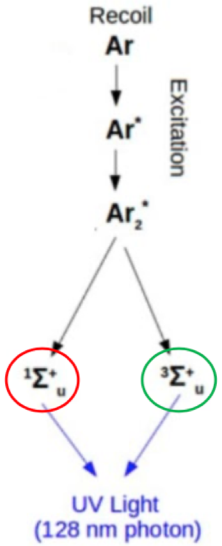
✖ **25**

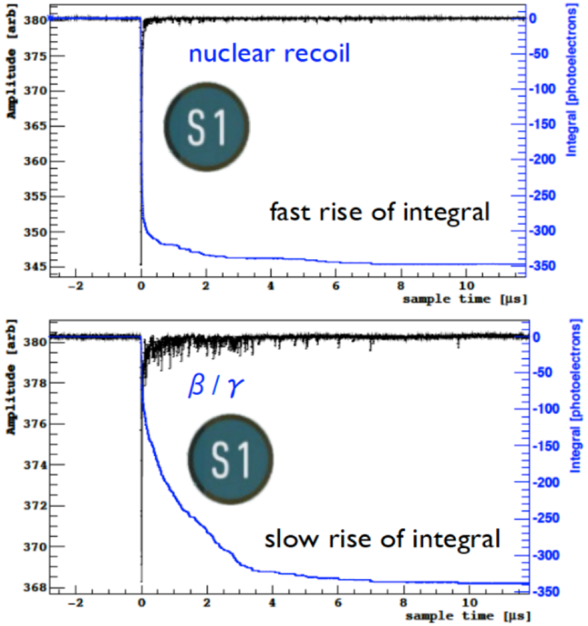


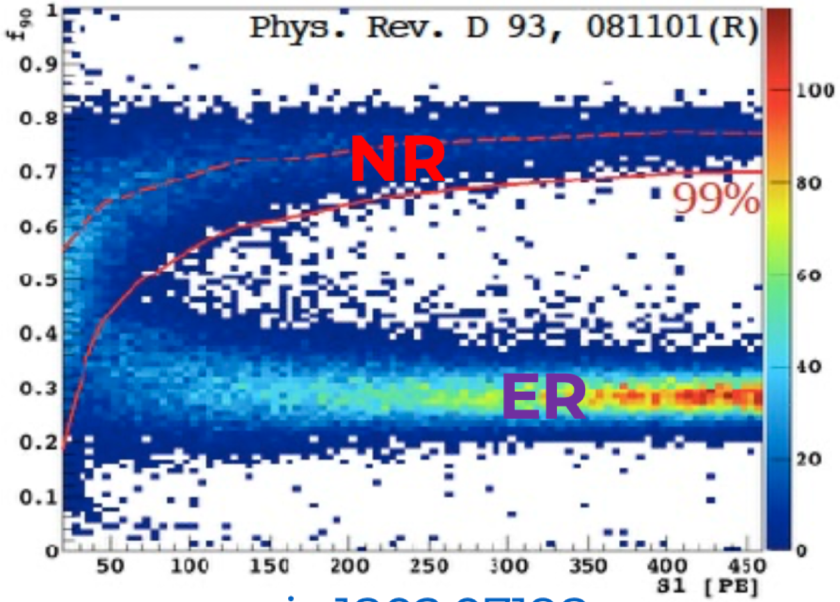
PDU: 25x25x5cm 25ch

Scintillation S1 light









arxiv:1802.07198

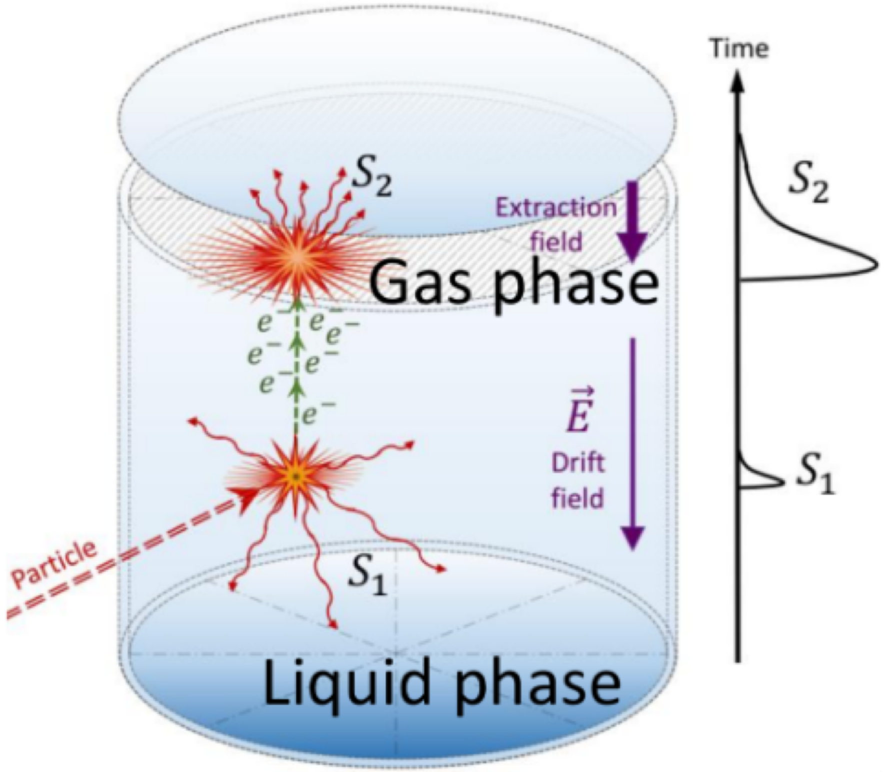
Very different decay times of **singlet** (~7ns) vs. **triplet** (~1.6μs) state.

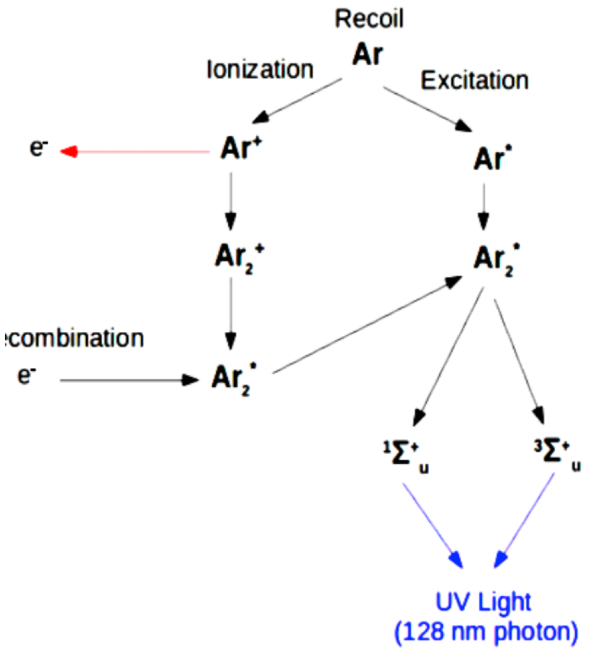
Electron **R**ecoils cause a higher fraction of **triplet** states than **N**uclear **R**ecoils.

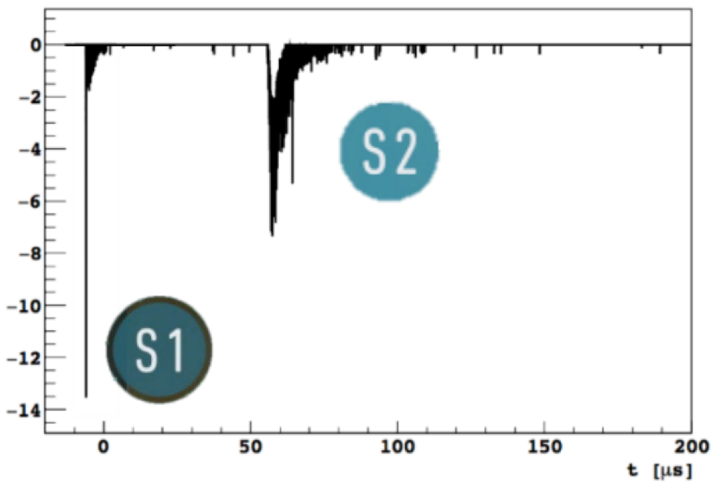
The resulting signals have different shapes that can be discriminated by using **PSD** techniques (**f_{90}** fraction of signal in the first 90ns).

NR band from the AmBe calibration
ER band from β-γ backgrounds.
Exceptional discrimination up to 10^9
(from DEAP-3600@SNOLAB)

Electroluminescence light S2

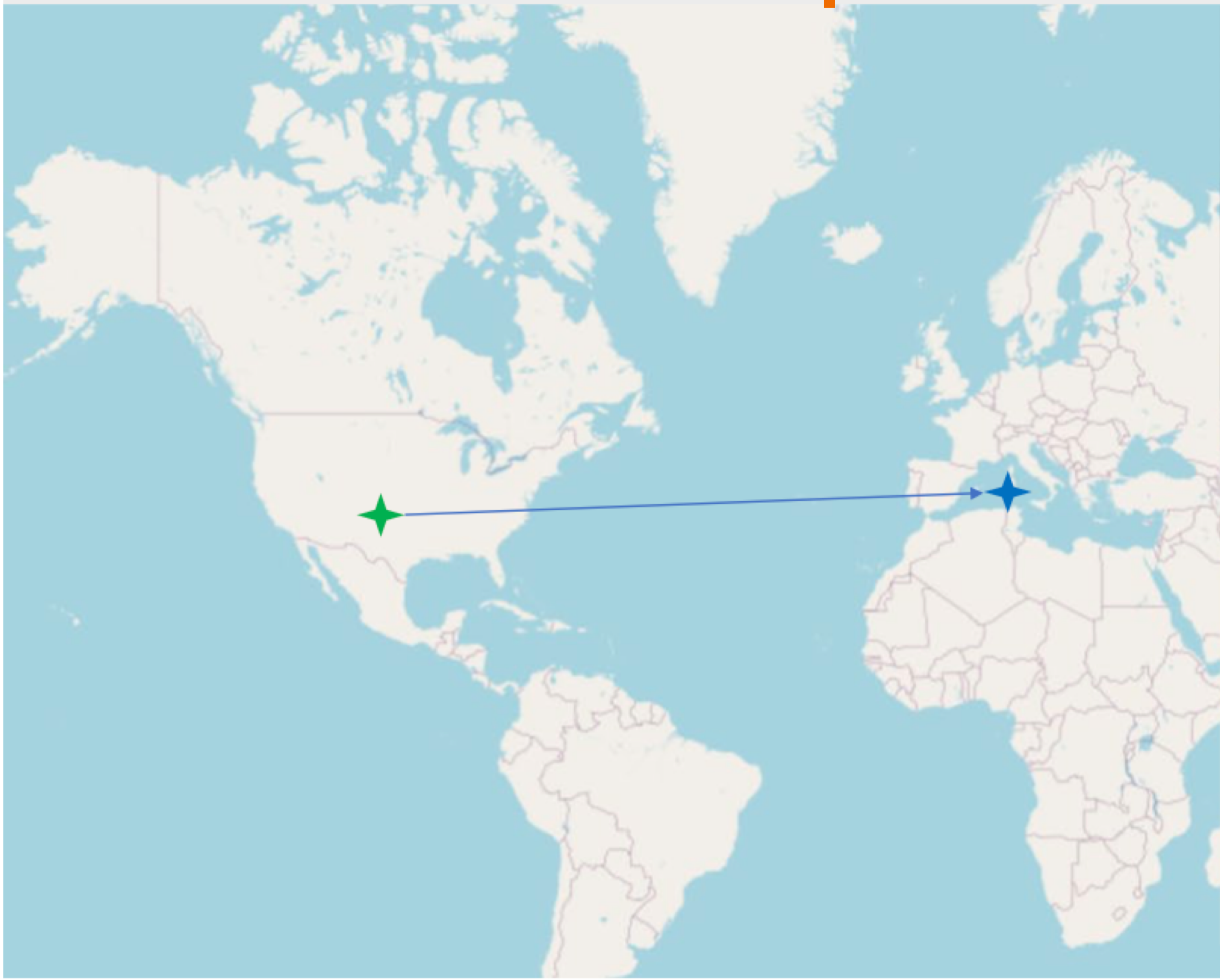






S2 proportional electroluminescence allows **xy** reconstruction. By the **S2-S1 time difference** the **z** coordinate of the interaction can be calculated.
Gain on ionization signal (**S2**) allows to easily detect **single ionization electrons** resulting in a lower the detection threshold (**Low Mass DM**)

Distillation Column - Depleted ^{39}Ar



ARIA

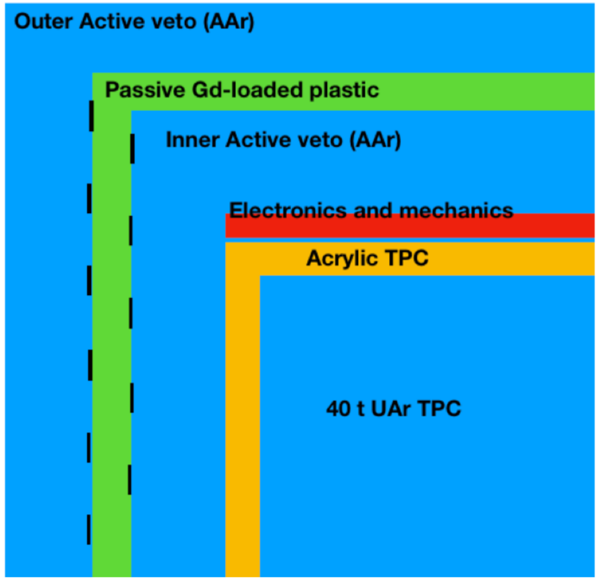
New **distillation column**, 350m tall installed in the coal mine well in Nuraxi Figus, **Sardinia**. **UAr** will be **chemically distilled** at a rate of **1t** per day. Further ^{39}Ar reduction factor 10 per pass can be achieved (most important in low mass DM search).

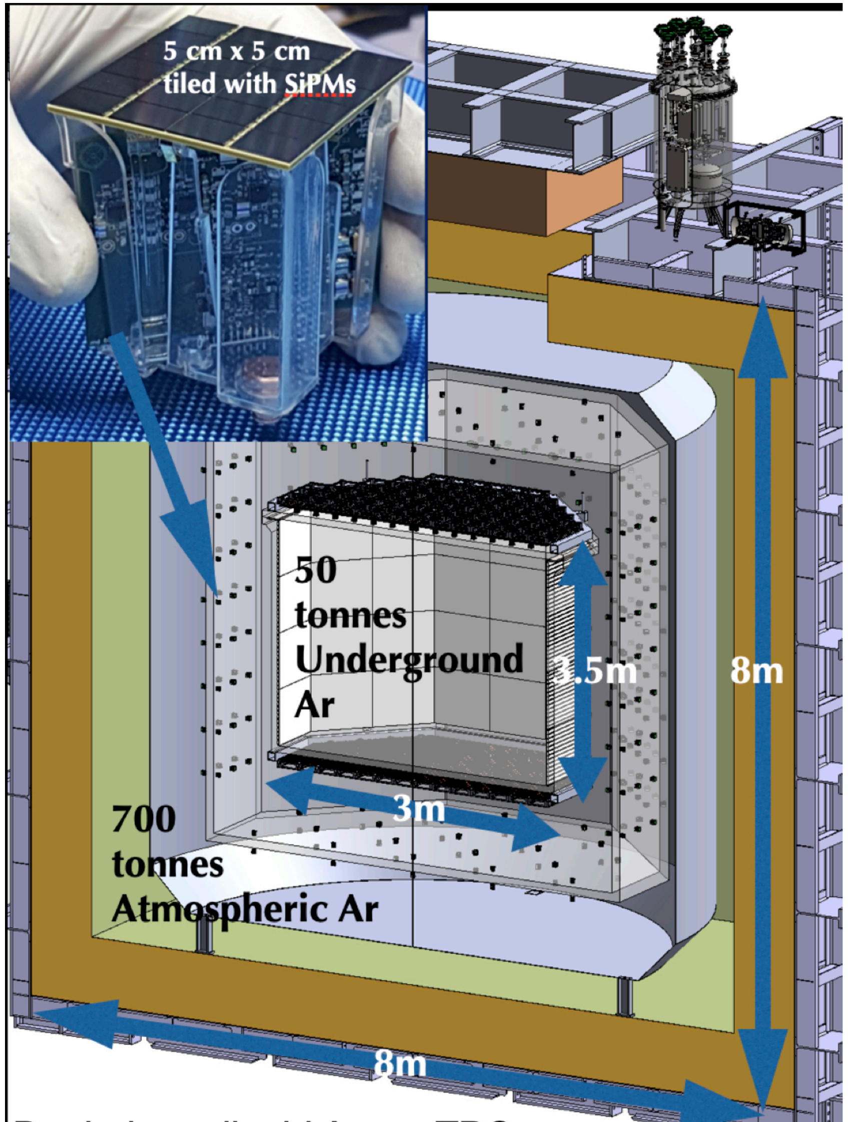
DarkSide-20k ARIA, URANIA and DArT

Darkside-20k Liquid Argon Neutron Veto

Veto is key to achieving design sensitivity

- Cryostat Proto-DUNE design delivered by CERN Neutrino Platform and DarkSide-20k project office at CERN
- *Allows elimination of Liquid Scintillator Veto and water tank*
- Design makes use of ultra-radiopure acrylic (DEAP) and Gd (SuperK)
- Must achieve 90% neutron capture efficiency





Dual-phase liquid Argon TPC

UK to produce 3000 Photo Detection Modules for the Veto!

DarkSide UK - Outer detector (Veto) PDMs production in UK

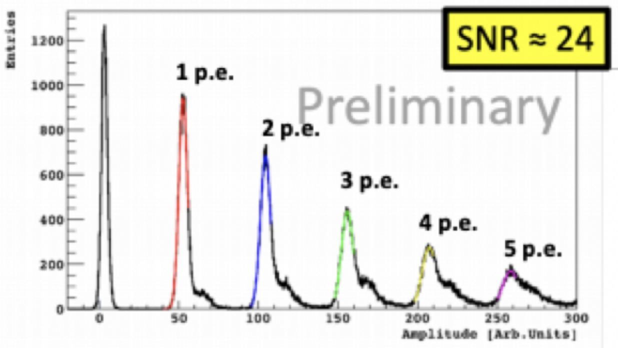
Successful STFC bid

UK institutions	Responsibilities
Liverpool	Epoxy Die Bonding, Cold Test platform
RAL	Flip chip Bonding, dicing development
Manchester	PDMs assembly
Birmingham	FEB
RHUL	Radiopurity qualification
Warwick	Warm optical calibration
Lancaster	Detector characterization analysis
Edinburgh	Detector characterization analysis

The team

Name	Role
Kostas Mavrokoridis	Overall coordination PDMs characterization Warm and Cold in UK
Joost Vossebeld	Overall coordination of low radioactivity bonding in UK
Jon Taylor	Epoxy Die Bonding
Technical staff	Epoxy Die Bonding
Adam Roberts	Cold platform and tests
More ….	

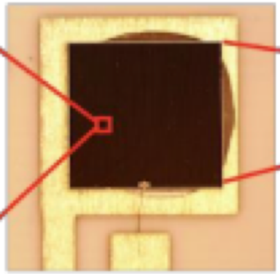
Darkside-20k: Large Area SiPM Readout



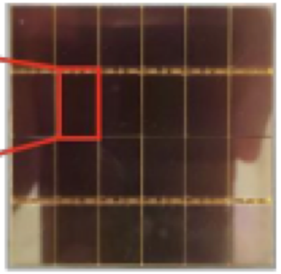
PDM single photoelectron spectrum

Ganging approach

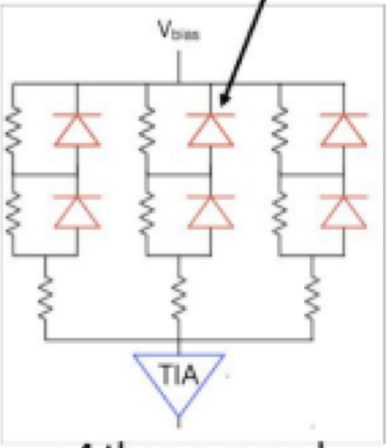
Individual SPADs
25-30 um²



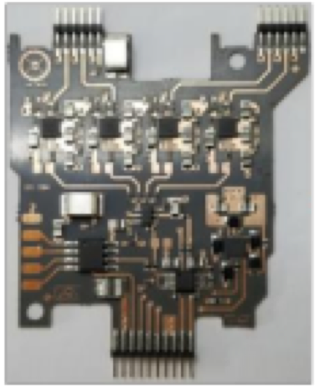
Single SiPM
≈ 1cm²



Single tile
(24 SiPMs;
(2_3||)x4;
≈ 5 cm x 5 cm)

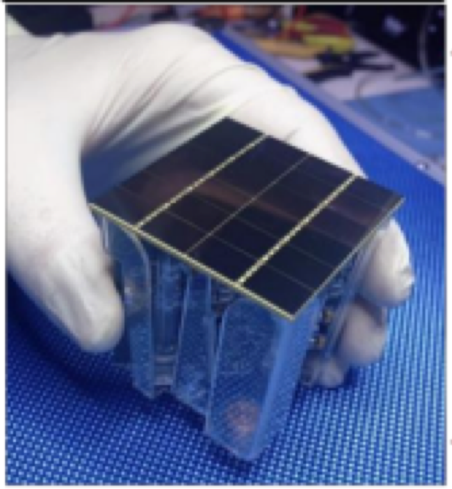


x4 then summed



Front End Board

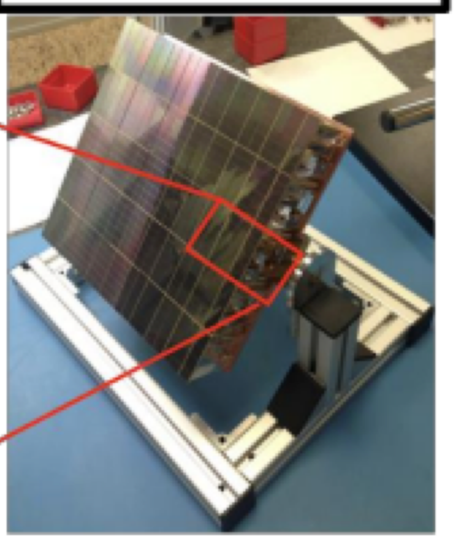
≈ 5 cm x 5 cm x 5 cm



PDM

Photo Detection Module
(Tile + FEB in acrylic cage;
base detection unit; one
summed readout channel)

≈ 25 cm x 25 cm x 5 cm

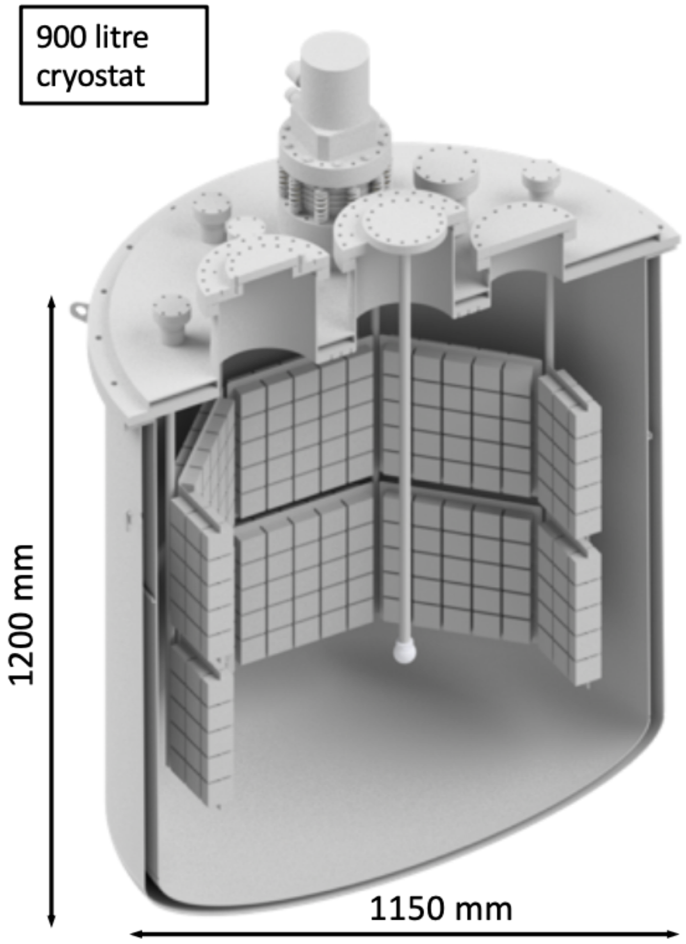


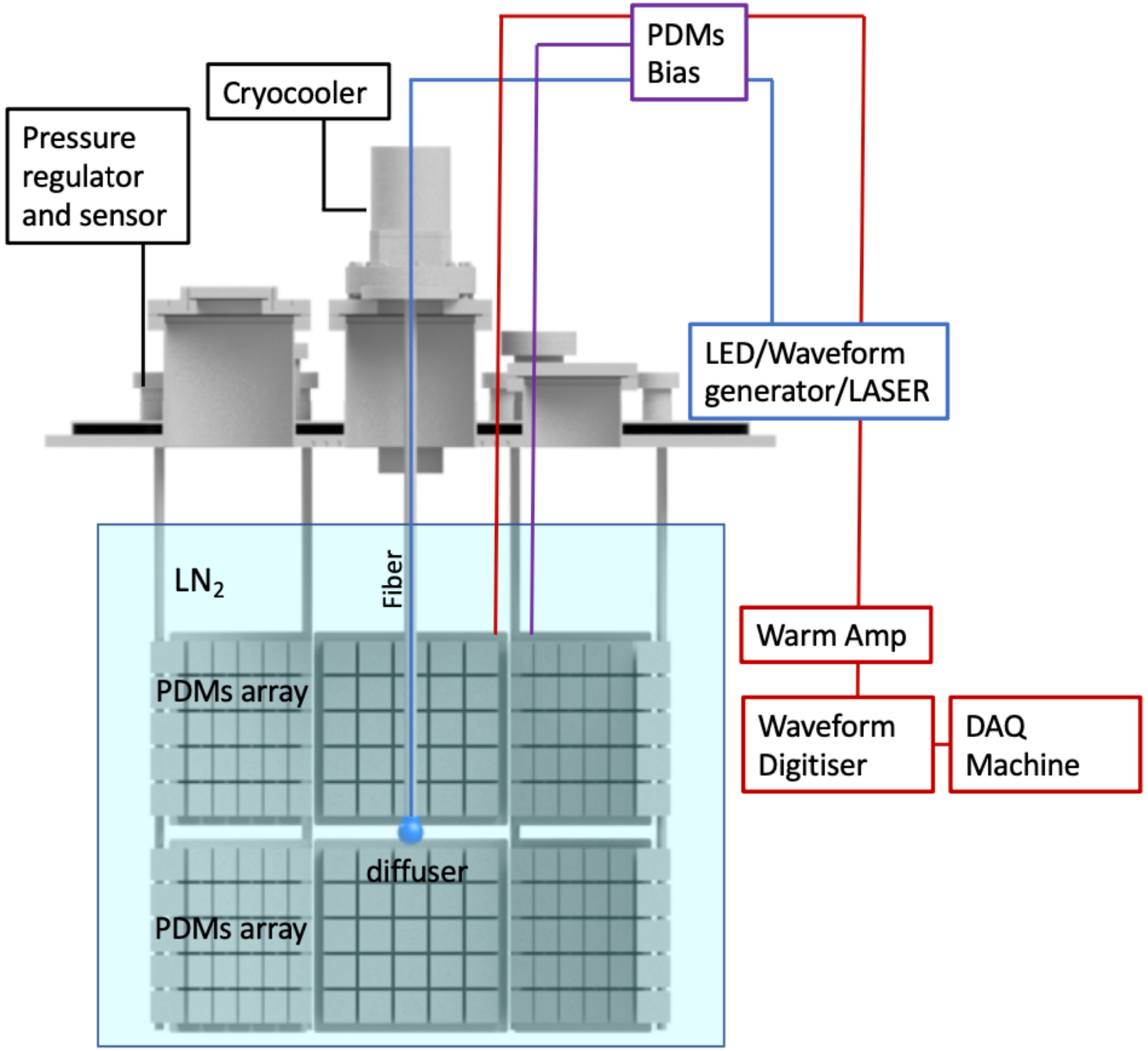
25 PDMs with mechanical support structure; base mechanical unit for DS-20k; routing structure for power and signal readout contained

IEEE Trans.Electron.Dev. 64 2, 521-526
IEEE Trans.Nucl.Sci. 65 (2017) 1, 591-596
IEEE Trans.Nuc.Sci. 65, no. 4, pp. 1005-1011, April 2018

Sensors (Basel). 2019;19(2):308.
F.Acerbi et al.,IEEE Trans. Electron Dev. 64, 2, (2017), 521-526

Cryogenic Characterisation of PDMs at Liverpool

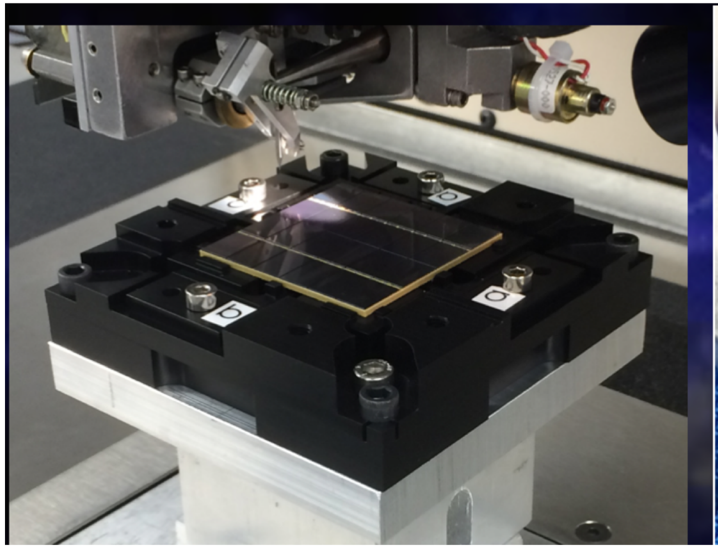


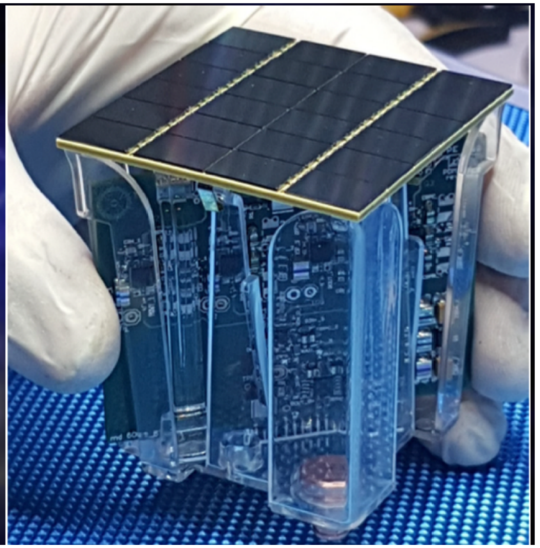


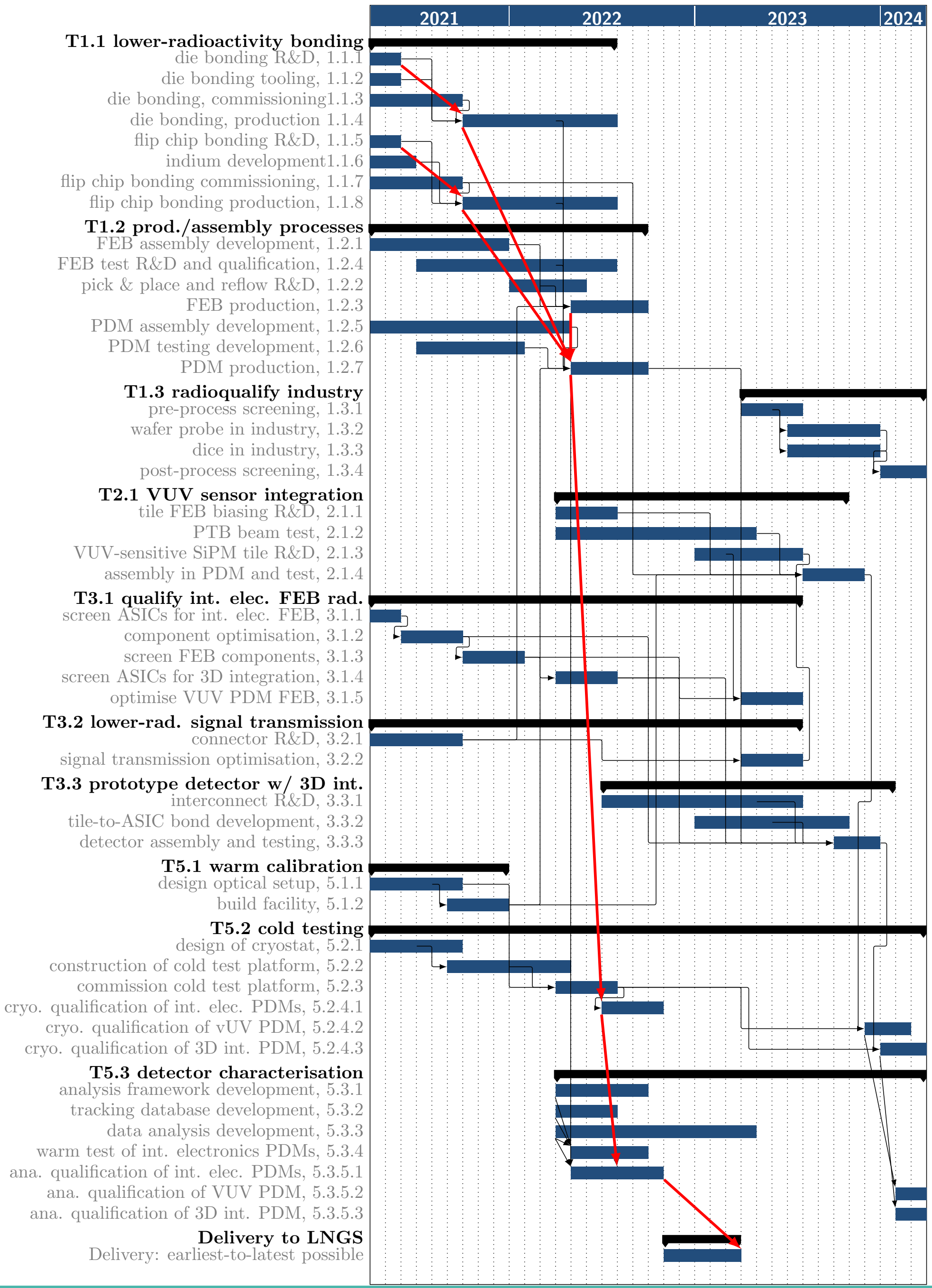
- Test up to 400 PDMs in the cryostat

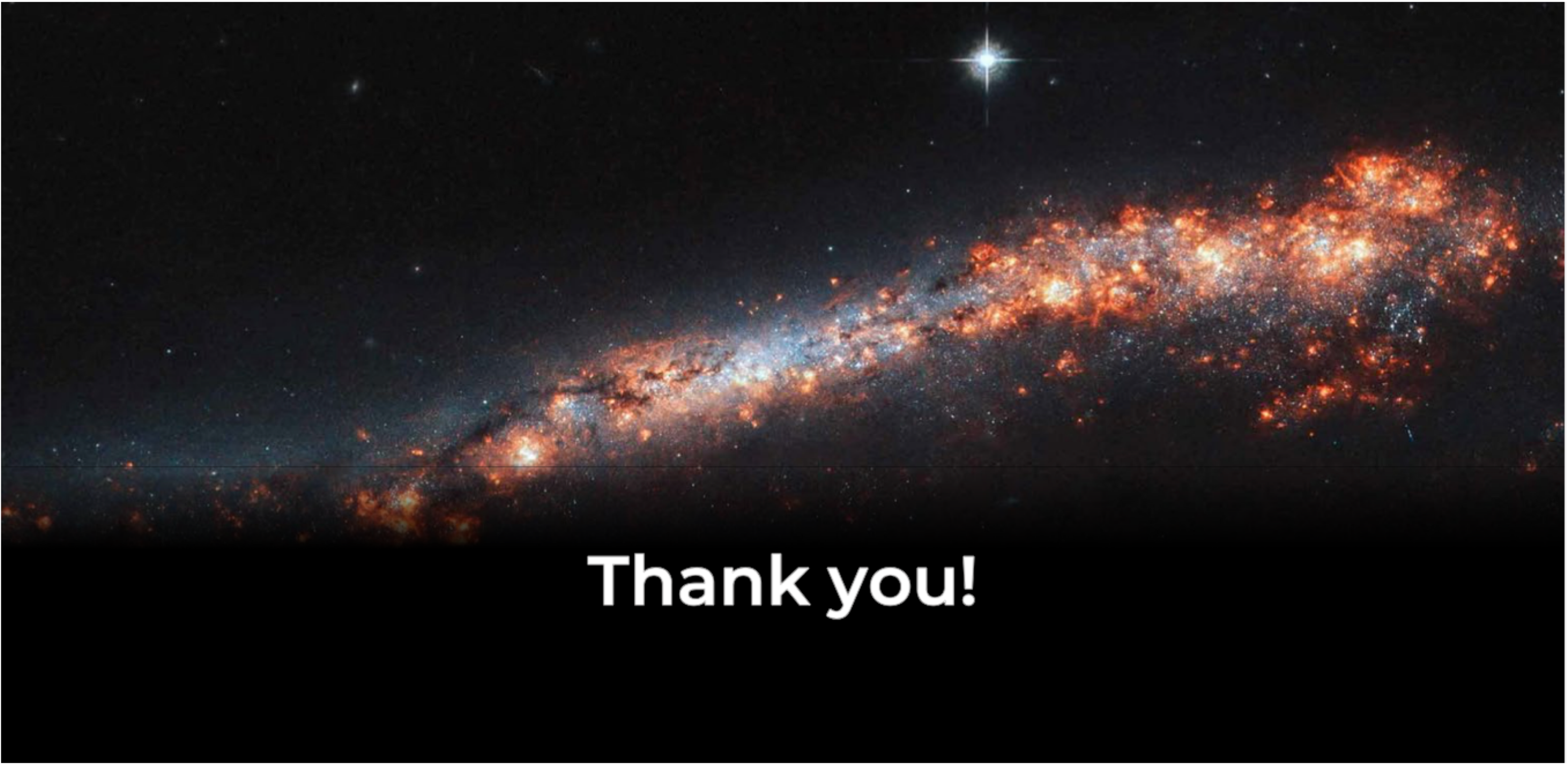
Tentative Schedule

Aim to build and test 3000 outer detector PDMs over the next 3 years for delivery to Gran Sasso.








Thank you!