The DarkSide 20k experiment

LIDINE 2023, Madrid

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Constructions started at LNGS in 2023!

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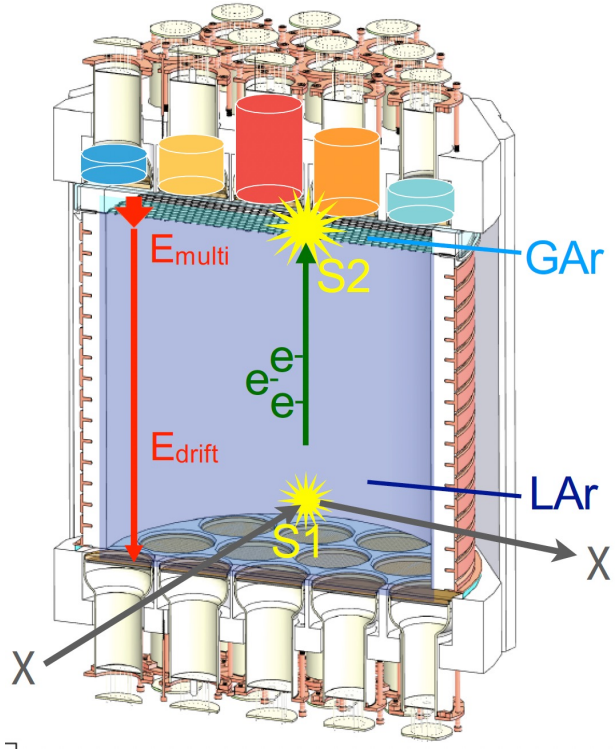
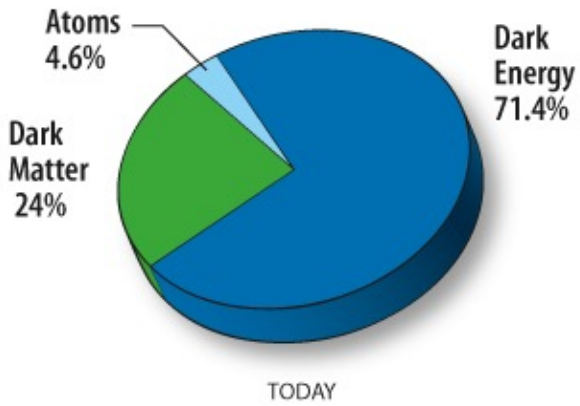
DarkSide 20k concept & goals

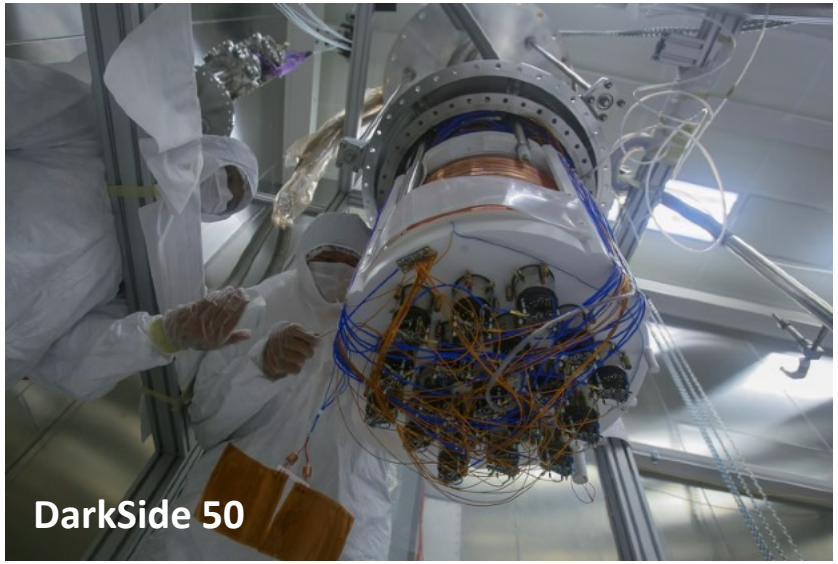
Direct WIMP dark matter research with noble liquids:

- Dual-phase argon time projection chamber (TPC)
- Light/Charge detection combined to obtain Particle ID

- Deep underground at LNGS, Italy (3400 m.w.e.)
- Experiment based on background suppression (passive) and rejection (active)
- Based on intense R&D program, culminated with the DS-50 detector at LNGS



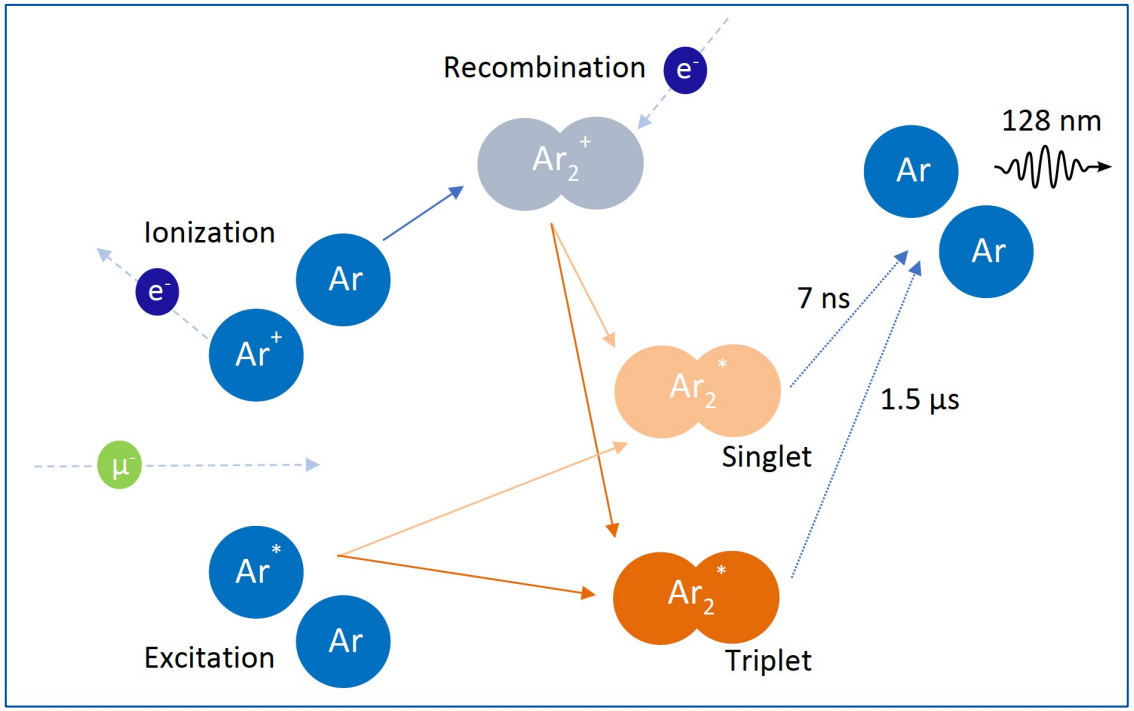


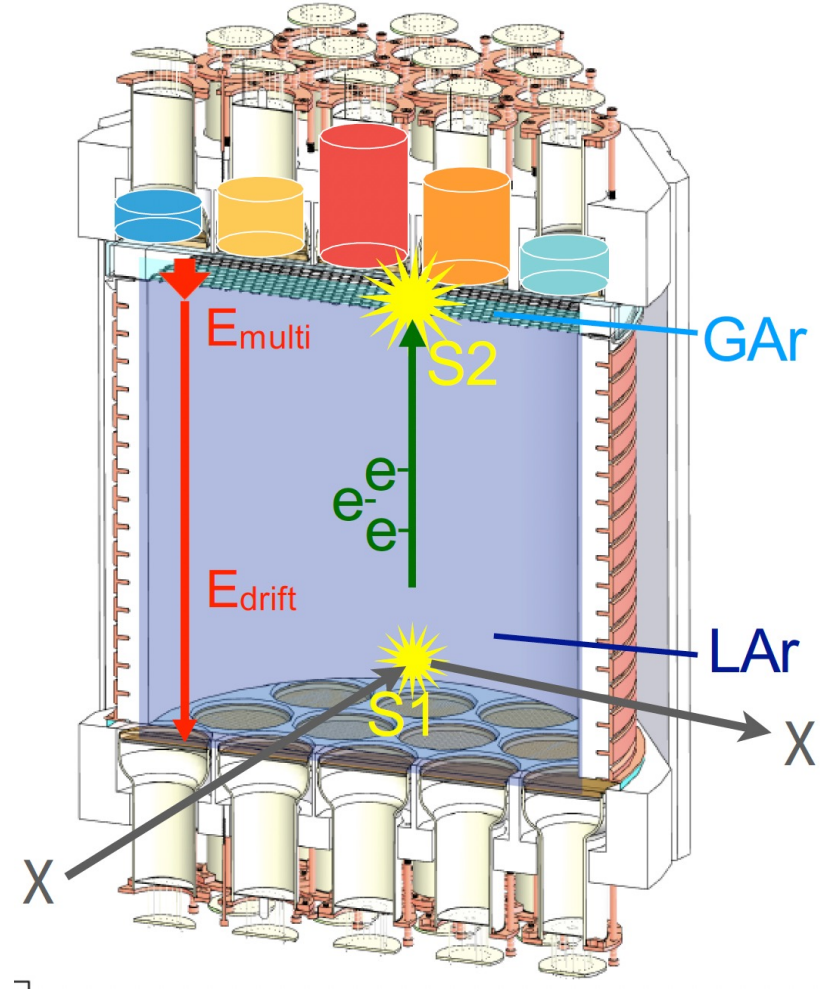


DarkSide 20k concept & goals

Direct WIMP dark matter research with noble liquids;

- Dual-phase argon time projection chamber (TPC)
- Light/Charge detection combined to obtain Particle ID
- Detecting **primary scintillation (S1)** from interaction in liquid and **proportional secondary light signal (S2)** from ionization electrons accelerated in gas pocket





DarkSide 20k concept & goals

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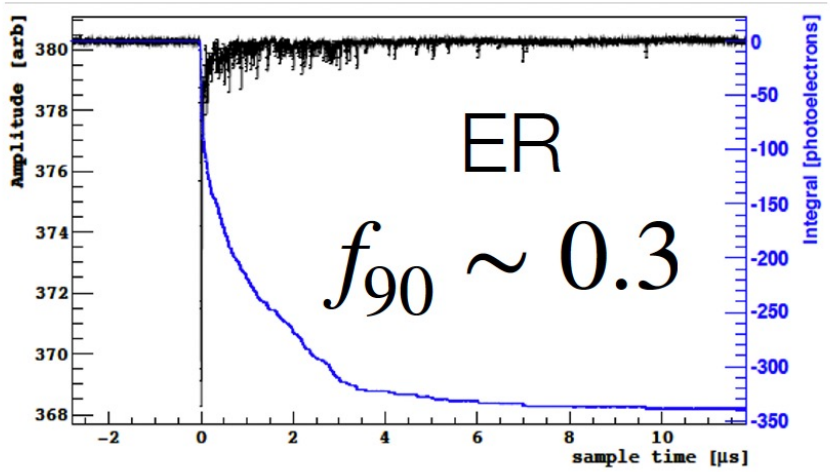
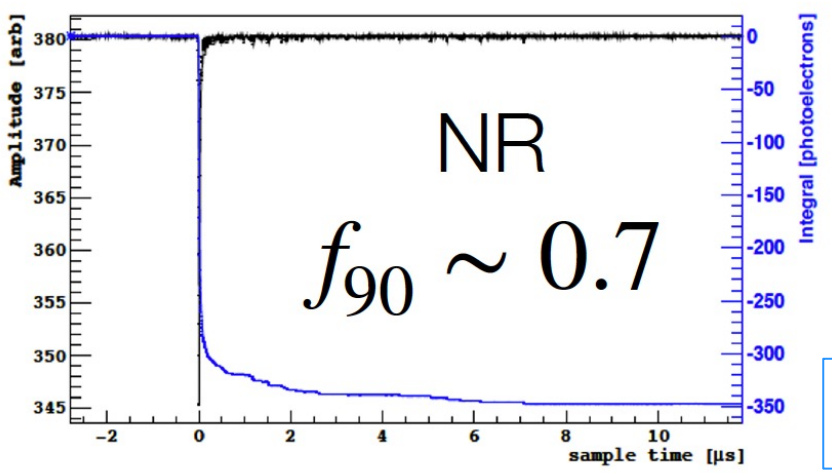
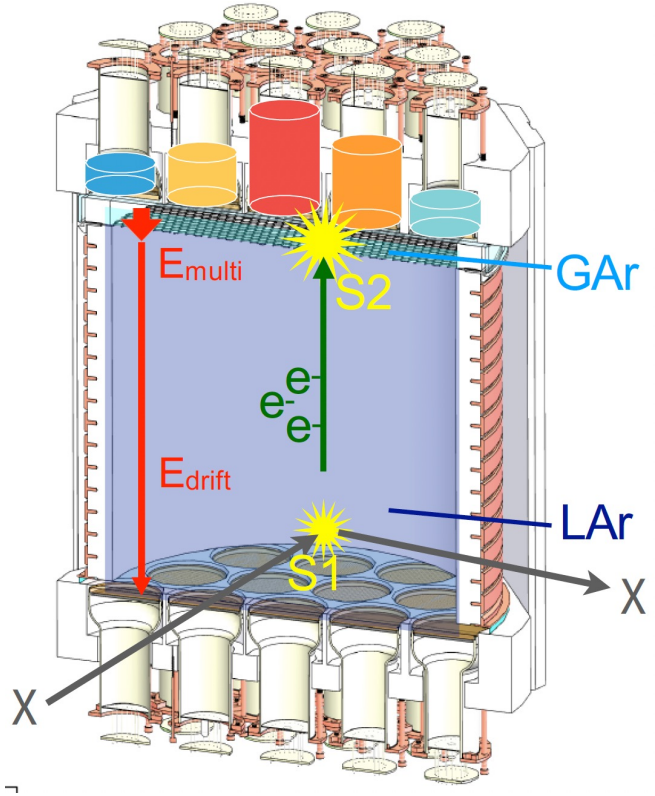






f_{90} = fraction of light emitted in the first 90 ns / total light

- Electron-induced recoils (ER) are dominated by scintillation light slow component (triplet -> S1 slow).
- Nuclear recoils (NR) – highly ionizing events - are fast and enhance recombination (smaller S2/S1 ratio)

Different flavours of Argon

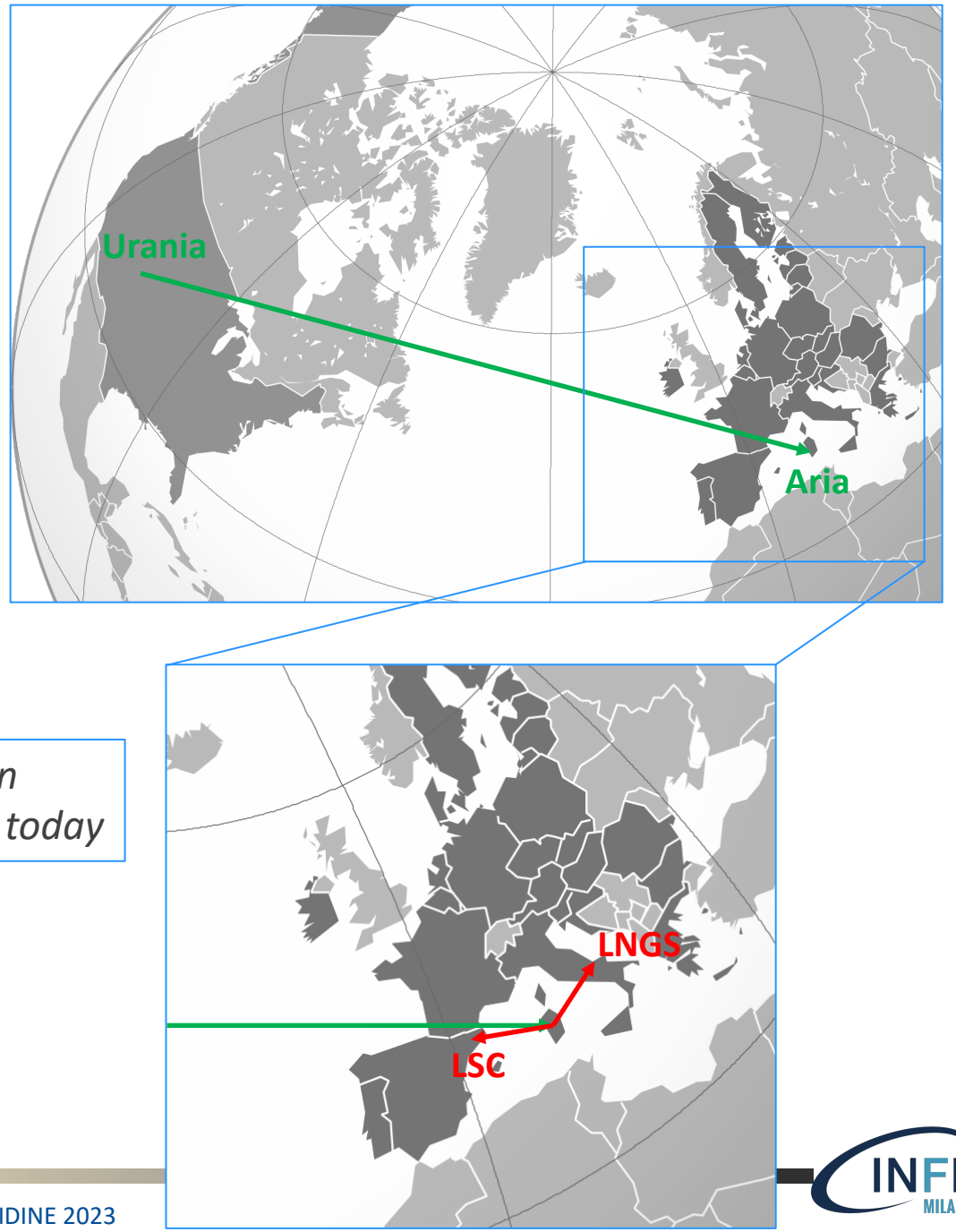
Underground Argon (UAr)

- Depleted of ^{39}Ar (~1400 depletion factor) produced in interaction with Cosmic Rays – main target
- Extracted in **Colorado** with **Urania** Plant
  – industrial site, 250 kg/d; purity 99.99%
- Further refined in **Aria** plant (**Sardinia**)
  – 350 m cryogenic distillation column; Purity 99.999%
- Characterized @ **Canfranc (LSC)** with DArT detector
  – Measurement of ^{39}Ar depletion factor
- Gas recirculation equipped with purification, Radon trap and custom liquefaction system

More on UAr in V. Cocco's talk today

Atmospheric Argon (AAr)

- Commercial 6.0 Argon (99.9999% pure)
- Recirculated and purified continuously, industrial plant derived from ProtoDUNE one
- Target for Outer Muon Veto
- Doubles as cryogenic bath for UAr volume



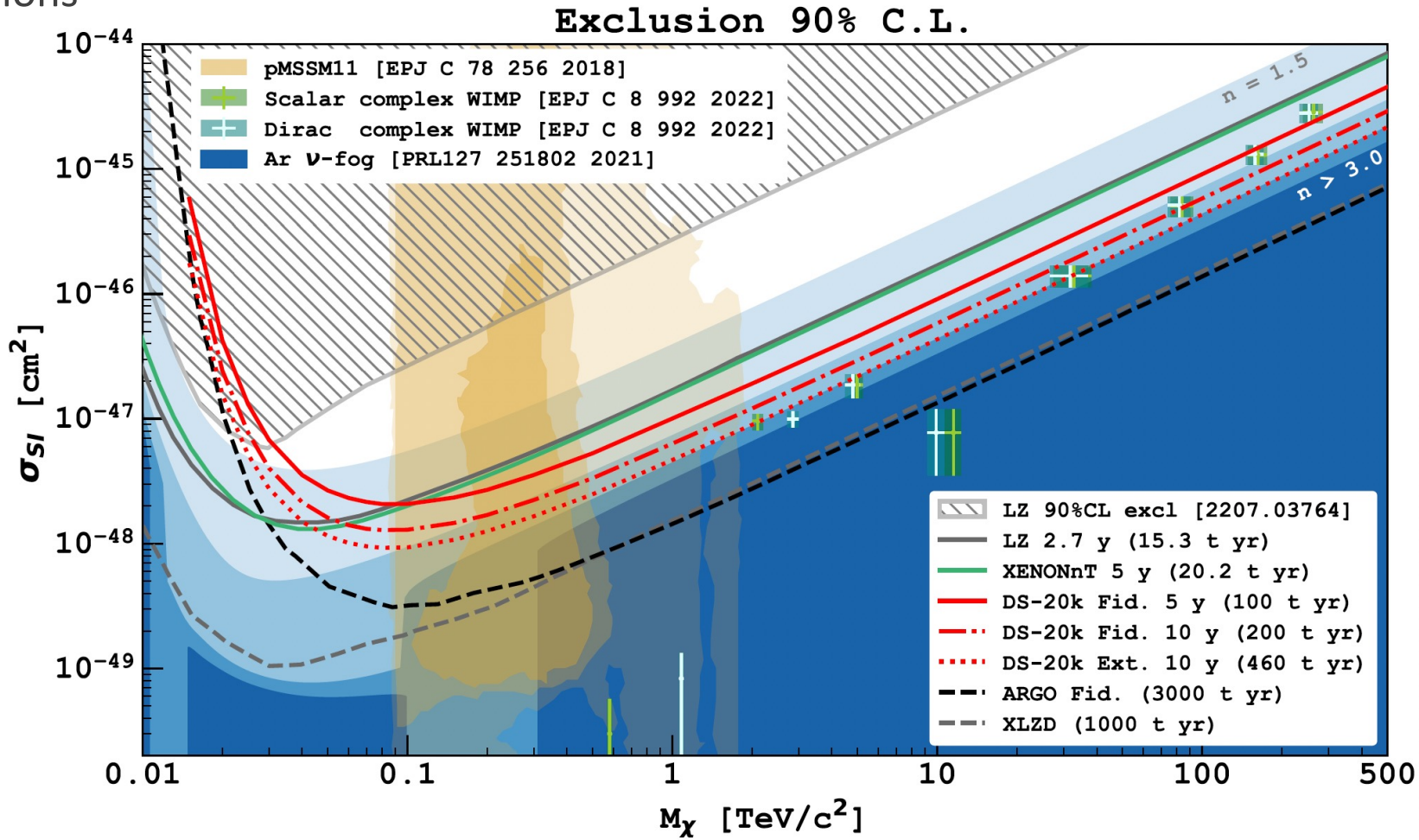
Sensitivity: DS20k & beyond

Sensitivity to Spin-Independent interactions

Nominal exposure (200 t-y) :

- 90% C.L. exclusion:
  - 6.3 x 10^{-48} cm^2 @1 TeV/c^2 ;
- 5 σ discovery:
  - 2.1 x 10^{-47} cm^2 @1 TeV/c^2 ;
- 3.2 CEvNS events expected.

Aimed instrumental background:
< 0.1 neutrons in Region of Interest
(E ~ 30 –200 keV$_{nr}$)



Future: next-gen experiment by the Global Argon Dark Matter Collaboration after DS20k is the ARGO project in SNOLAB (300 t fiducial)

Detector design - I

Octagonal shape dual phase argon TPC:

- Active UAr mass: 49.7 tonnes;
- Fiducial UAr mass: 20.2 tonnes;

Inner Neutron veto:

- Active UAr mass: 32 tonnes.

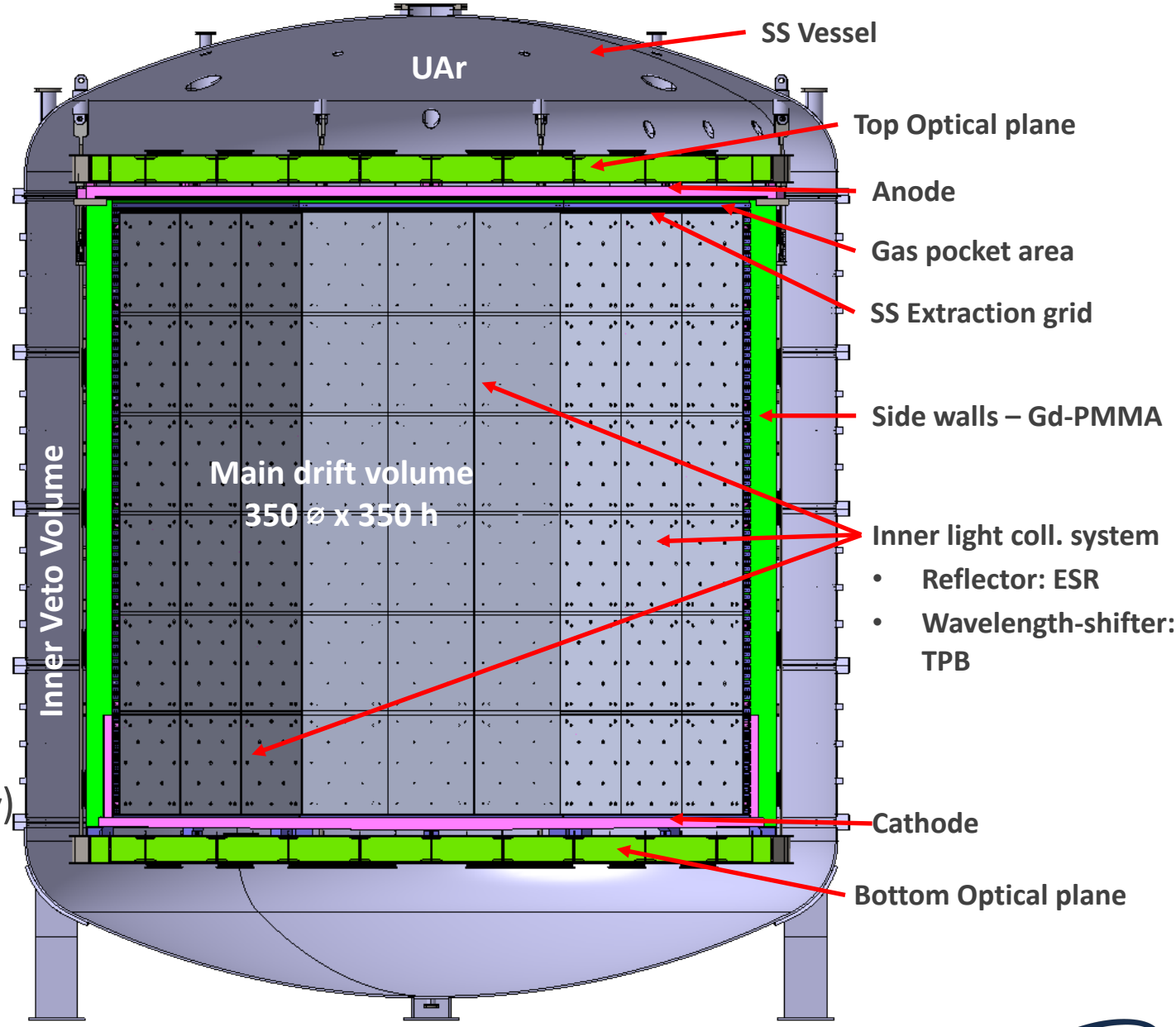
Drift field: 200 V/cm; Extraction field: > 2.8 kV/cm;

Cathode voltage: -73.38 kV (min).

Gas pocket thickness: 7.0±0.5 mm.

Structurally made in Acrylic: pure (anode/cathode) or 1% Gd-doped (side walls, for n-moderation)
(*more on Gd-PMMA and veto in A. Caminata's talk today*)

E-field definition: Conductive polymer (Clevios™) coating on anode, cathode and field cage rings;



Detector design - II

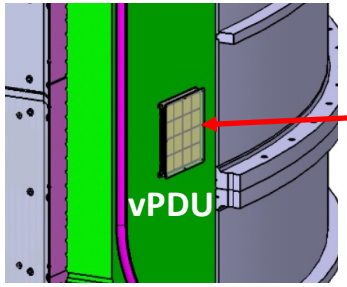
Readout based on Silicon PhotoMultipliers (SiPMs)

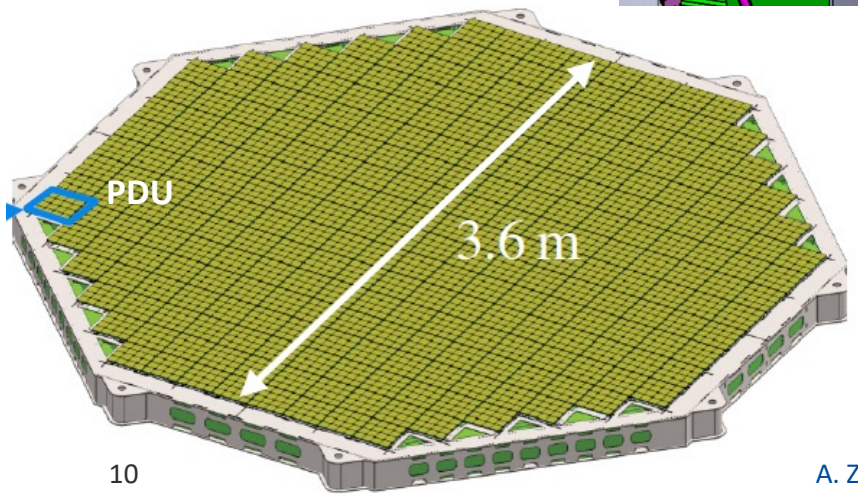
Single readout channel size: 10 cm x 10 cm;

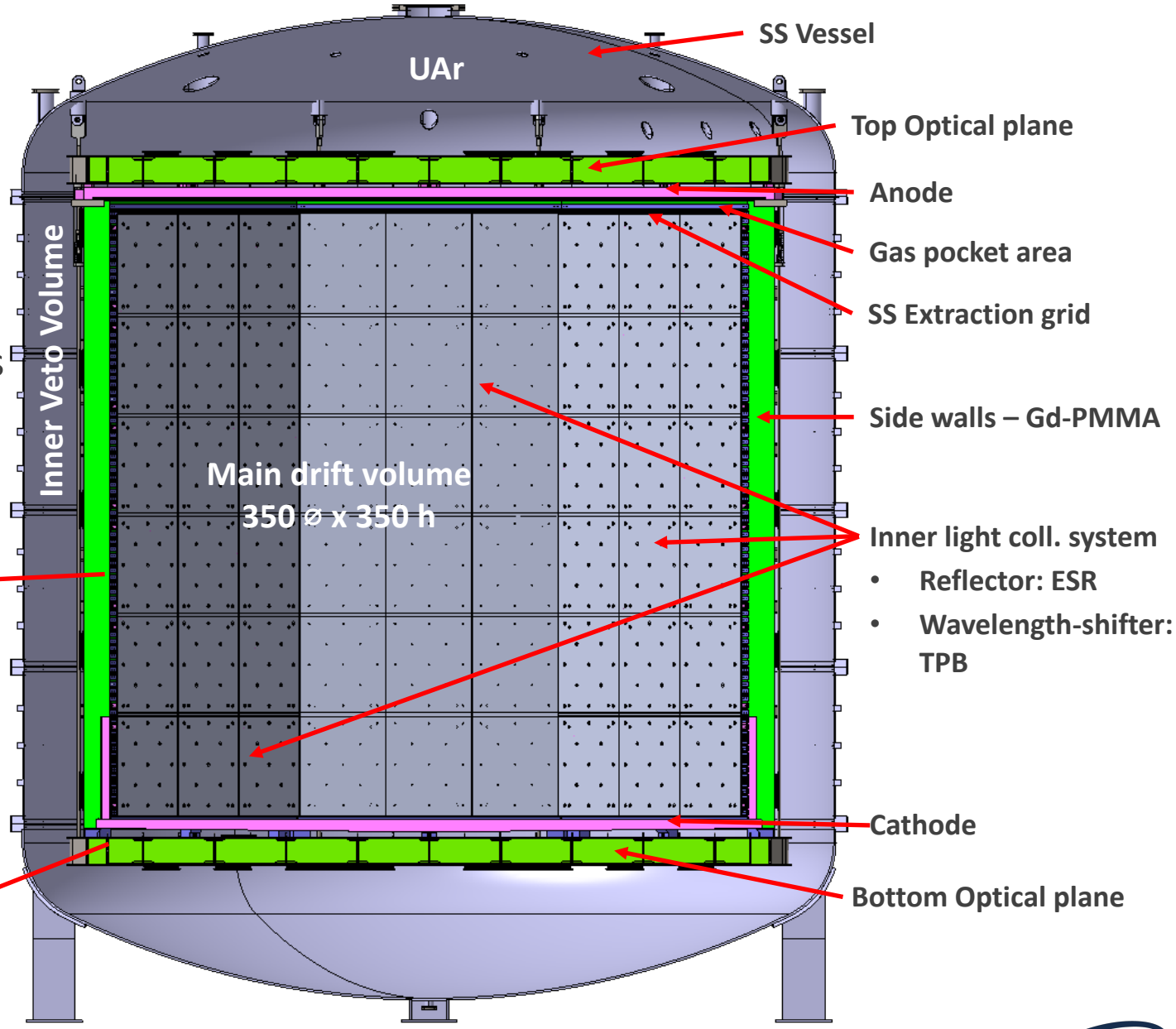
- TPC: 264 Photon Detector Units (PDU) / optical plane
- Veto: 120 vertical PDUs (vPDU) on barrel pieces and optical plane (looking outward).

Expected Light Yield(LY)

- S1 @null field: ~10 p.e./keV$_{ee}$;
- S2 yield > 20 p.e./e$^-$.

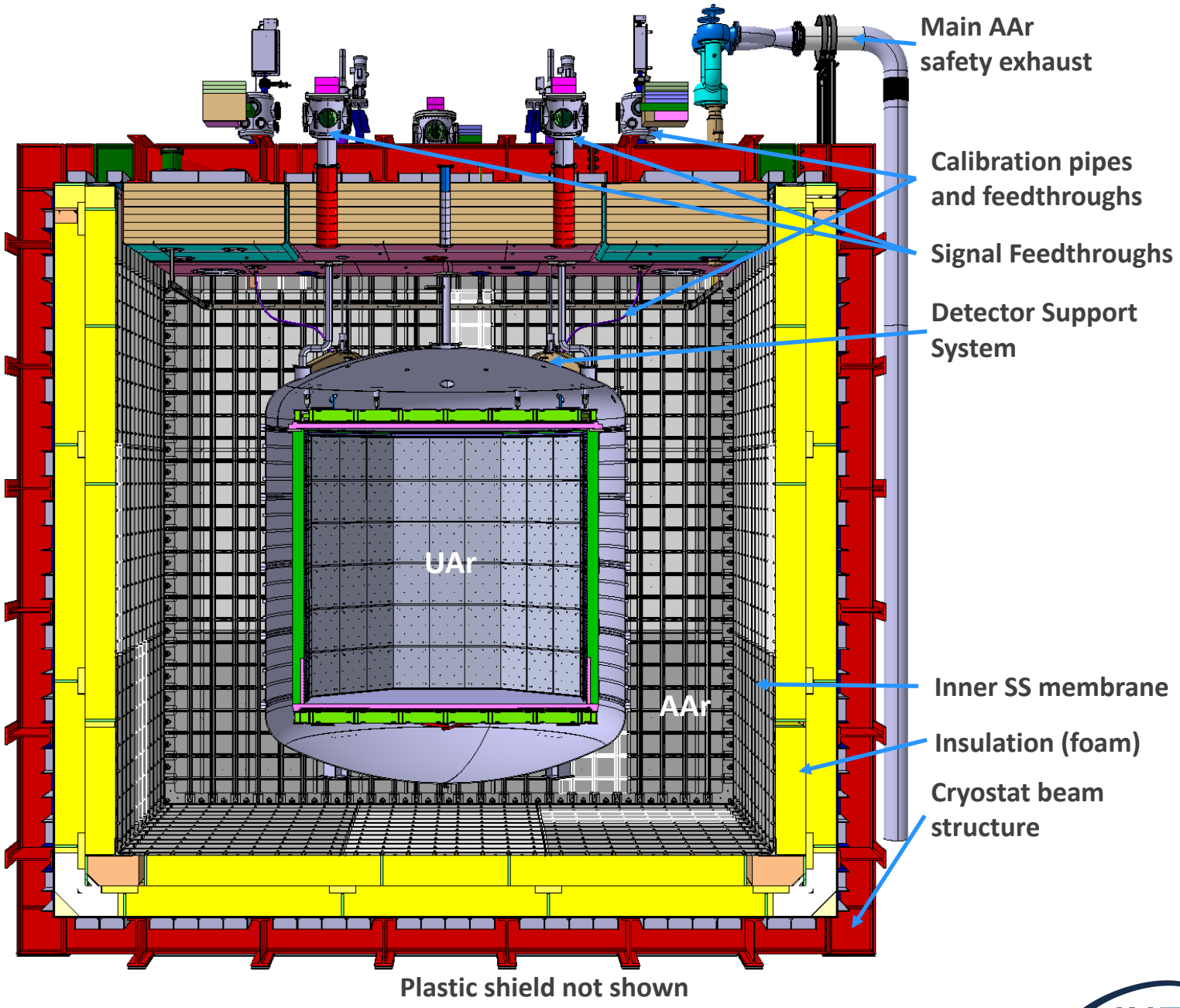






Detector design - III

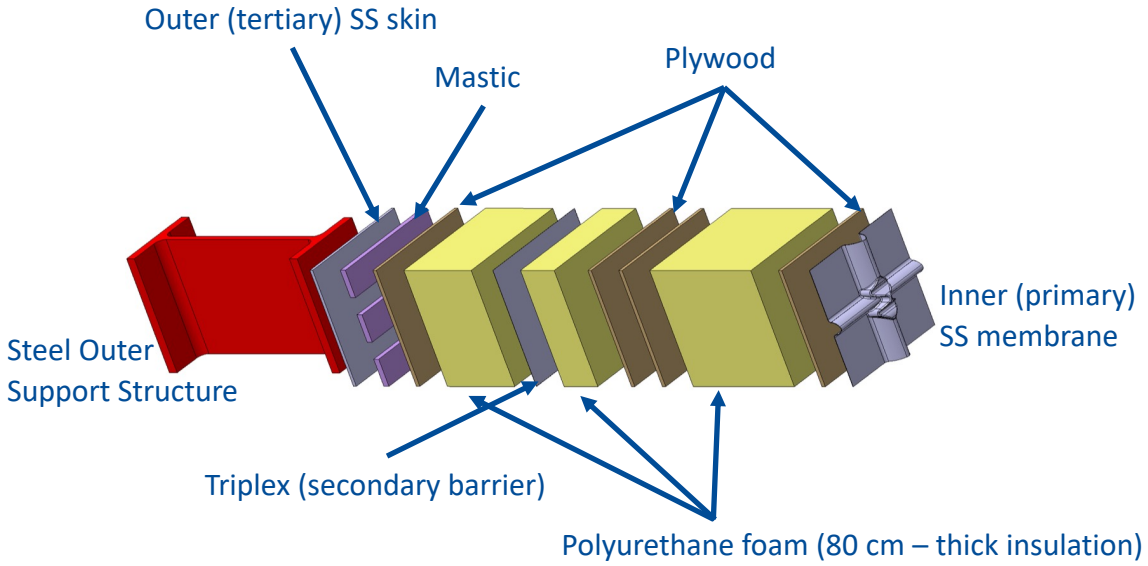
- Integrated TPC & Inner Veto within SS vessel & UAr
- ~5-10 cm plastic shielding around SS vessel (moderation of n from cryostat insulation, LNGS Hall C)
- Outer muon veto
  - 32 vPDUs
  - Installed on the outside of the plastic shielding
- DUNE-like membrane cryostat filled with AAr
  - 12 m side cube, external dimensions

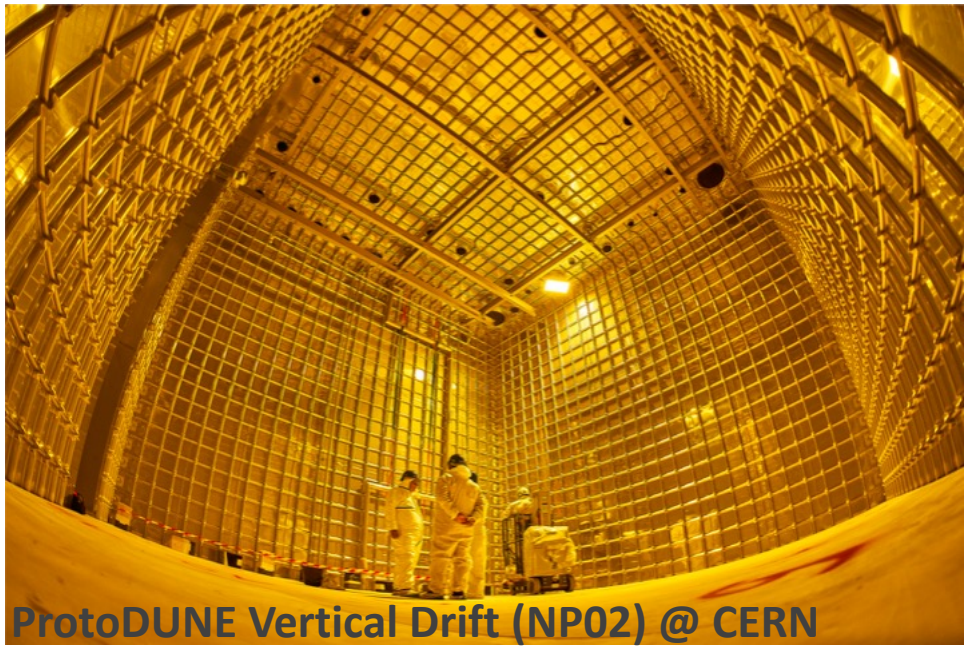


Cryostat construction

- **Modular design** for transport into underground labs
  - Scalability / Exact prototyping (ProtoDUNEs)
- **Membrane cryostats**
  - elastic, 1.2 mm thick stainless steel (SS) inner skin, accommodates cryogenic shrinking
  - used on LNG* transport ships – mature technology; commercial partners (GTT)
  - No need for vacuum -> argon purge
  - Started for neutrinos; exported concept to wider Physics panorama (Dark Matter -> DarkSide 20k)
  - Few months construction time (all parts)

*LNG = Liquid Natural Gas



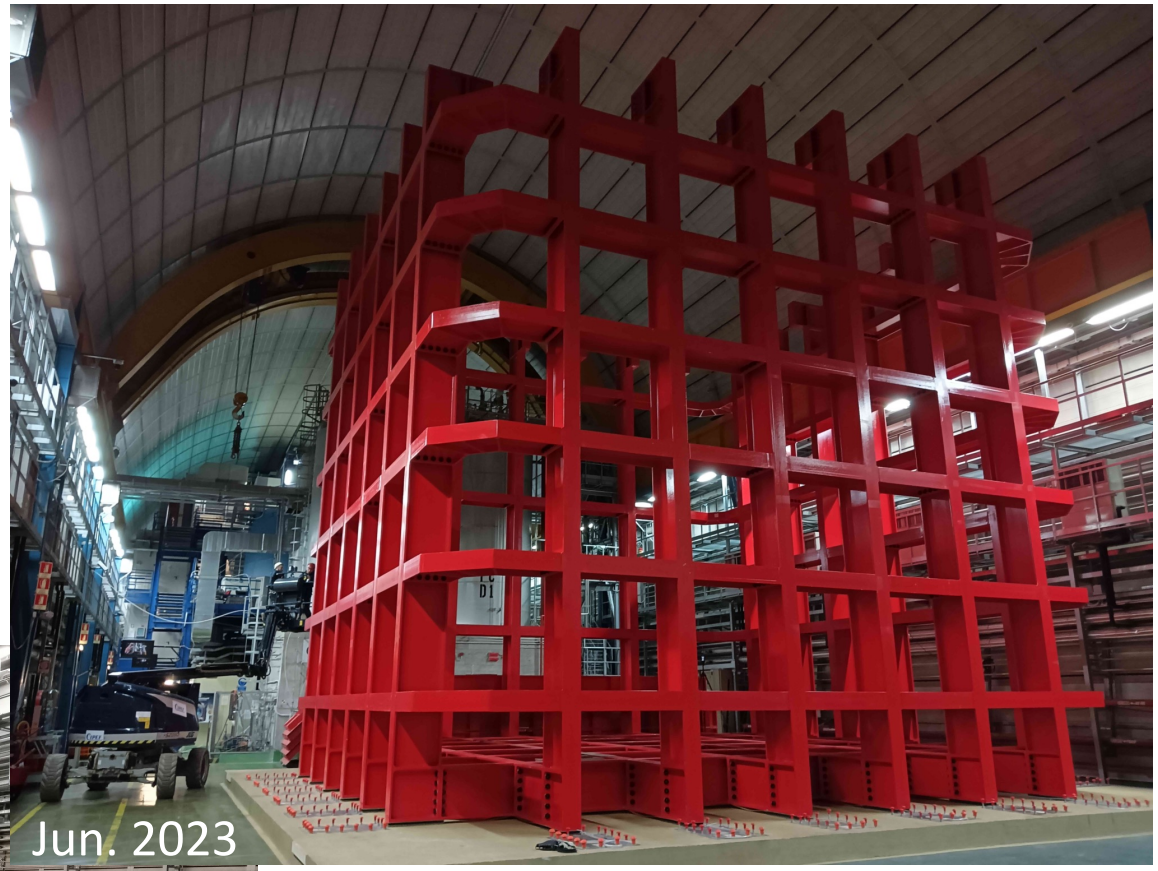

ProtoDUNE Vertical Drift (NP02) @ CERN

Cryostat construction

- Concrete base: poured in late 2022, resin layer in Jan. 2023
- Beam structure (load-bearing): 4 weeks construction in May 2023
- External membrane: installation & welding, Jun-Oct 2023
- “Cold part”: insulation & internal membrane: Nov 2023 – Feb 2024

- Top caps: roof is divided in 5 pieces, that are separately produced, in all their components.
  - Under production now, till end 2023 – early 2024
  - Then test installation and removal, to make space for clean room installation

Cryostat construction



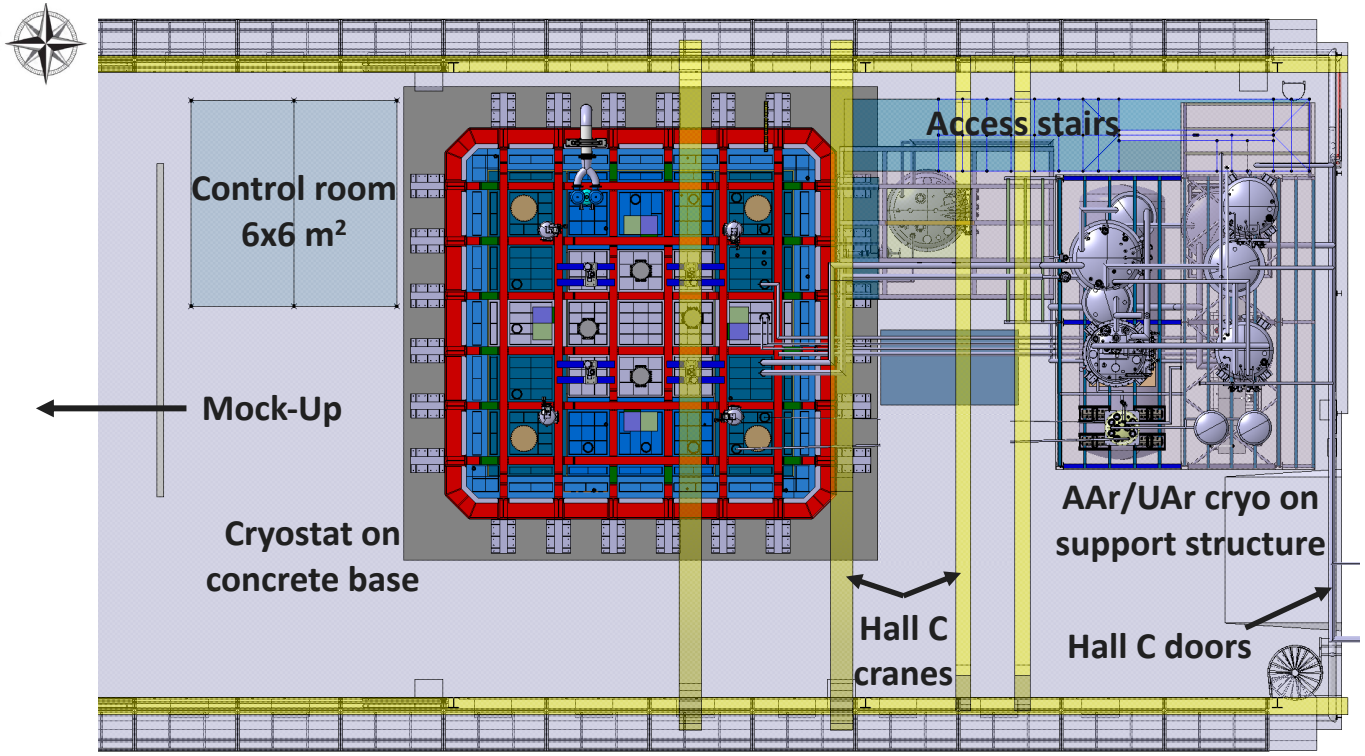
Hall C activities

Current:

- Cryostat – insulation construction to start soon
- Mock-up* activities

Coming up next

- Construction of infrastructures (access stairs, cryogenic plant support structure (end 2023 – early 2024)
- Cryostat clean room –> to allow detector assembly inside cryostat. (late 2024)
- Control room (2025)
- AAr cryogenics plant (in production – installed in late 2024)



*Mock-up

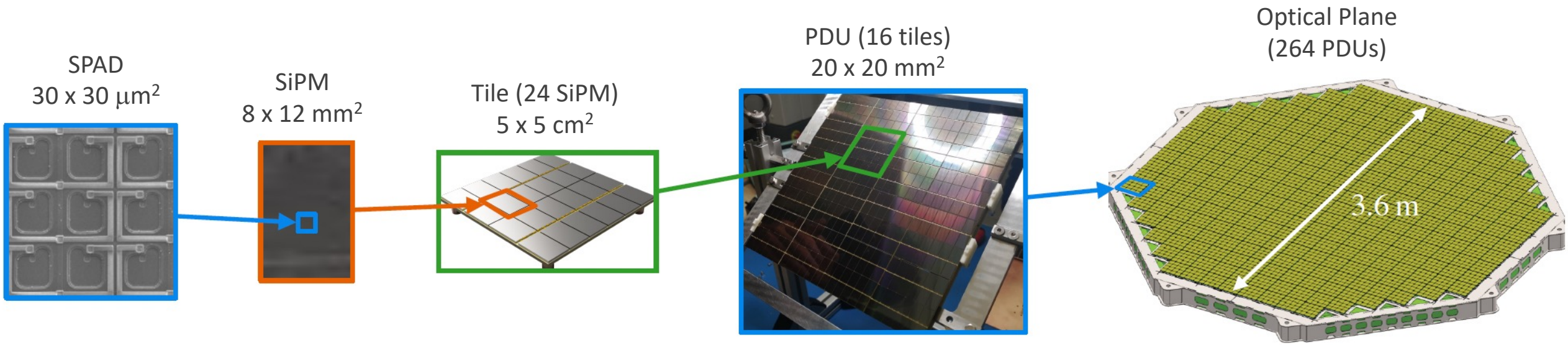
Installation in the North side of Hall C, aimed at:

- Optimization of UAr cryogenics
- Test runs of UAr cryogenics, cooling technique
- Aiming to host a mock-up of DS20k TPC, to certify design choices (mechanics, HV, coatings; no light read-out)

Towards PhotoDetectors production

PhotoDetectors for DS20k based on SiPM technology

- Developed with Fondazione Bruno Kessler (FBK)
- Grouped together to obtain large-area detection units
- Low-radioactivity, low-noise (@ cryo temp) devices w.r.t. PhotoMultipliers (PMTs)
- Photon detection efficiency (PDE) > 40% at 77K
- Dark count rate (DCR) < 0.01 Hz/mm^2 at 77K (7 Volts overVoltage)
- Signal-to-Noise ratio (SNR) > 8 (TPC PDU)



DarkSide Collaboration: "*Cryogenic Characterization of FBK RGB-HD SiPMs*", JINST **12** P09030 (2017)

Nuova Officina Assergi (NOA)

INFN Facility managed by LNGS – clean room class ISO 6

Two main rooms:

- **CR3**: 3.0 m x 350 m^2 -> photodetector production area, equipped with highly sophisticated packaging machines for the assembly of photosensors in a dust-controlled environment
- **CR2**: 5.8 m x 68 m^2 -> large volume detector assembly
- To be equipped with dedicated Rn-abatement system (currently, Rn level in CR3: 6-10 Bq/m^3)

Operative since Nov. 2022, completed in 2023

- Currently populated with machines needed by DarkSide for SiPM packaging, test and integration

- 2023, so far: start-up of activities, characterization of silicon wafers procured for the in-house production of the PhotoDetector Units (PDU).

Towards PhotoDetectors production

The DarkSide 20k team is now using the NOA facility

- 2023 was dedicated to the start-up of the activities, cryo-probing of silicon wafers
- Shift system set-up
- Training of machine operators and lessons learned

So far, 15% of wafers tested, with a >90% average yield

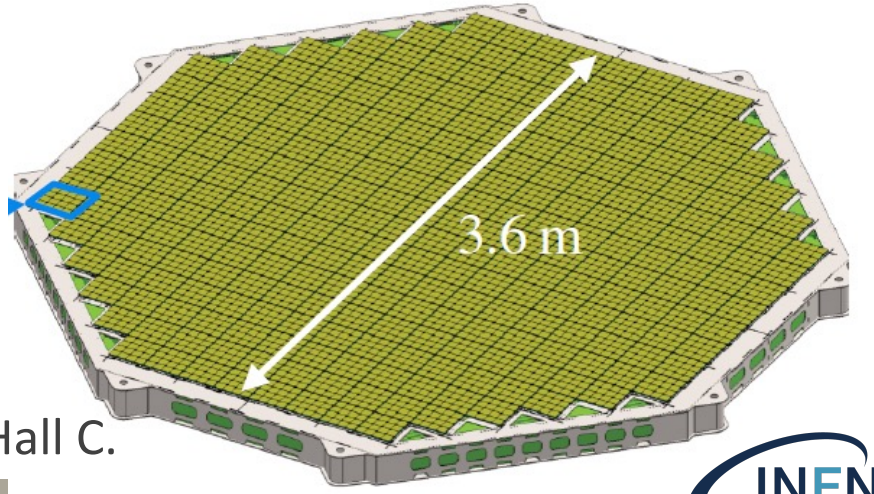
Despite some issues with the machines, **16 SiPM tiles were assembled, tested and integrated into the first PDU -> sent to the DS20k facility in Napoli for testing**

Pre-production chain planned for TPC PDU foreseen for Winter'23-Spring'24

Full production of TPC PDUs to start in NOA-CR3 in May 2024

Veto PDU production will proceed instead in UK

(*more on Veto PDUs in P. Franchini's talk on Friday*)



Integration of DS20k Optical Planes (SS structure, Gd-loaded acrylic bricks and PDUs) will then happen **in NOA-CR2 in first half of 2025**.

The two optical planes will then be transported as single objects to Hall C.

Walking first, then running…

2023 is a very important year for DarkSide…

- AAr cryostat construction started (along with related infrastructures)
- AAr cryogenic plant design and production has started (contracts signed)
- UAr cryogenic plant activities started (mock-up installation, design finalization)
- Important changes in TPC assembly strategy: now to be performed inside cryostat
- NOA clean room completed
- Silicon wafers characterization started
- Getting ready for PDU production

… but 2024 is going to be even more crucial!

- Cryostat completion, AAr plant installation
- Cryostat Clean room installation
- Completion of mock-up tests
- PhotoElectronics production
- Inner detector fabrication starts
- …

Commissioning is foreseen for end 2026 with the filling of both Atmospheric and Underground Argon

- *Neutron tagging with Gd-loaded PMMA* – A. Caminata – Today
- *The DarkSide-20k underground argon procurement chain* – V. Cocco – Today

- *Monitoring 39Ar Background for DarkSide-20k with DArTinArDM* – D.D. Mairena – Today
- *Analysis of S1 Triplet Component in Darkside-50 Experiment* – C. Sunny – Today (poster)

Thank you and stay tuned!

More DS talks are coming in these days

- *Study of cosmogenic activation above ground of Argon for DarkSide-20k* – S. Cebrian – Today
- *The DARKSIDE-20k Veto SiPM PDUs construction and characterization* – P. Franchini – Friday

- *Estimation of Ar-37 activation and decay rate in DarkSide-50 experiment* – I. Ahmad – Thursday
- *Study of low-energy nuclear recoils in liquid argon with the ReD experiment* – N. Pino – Thursday

Back Up