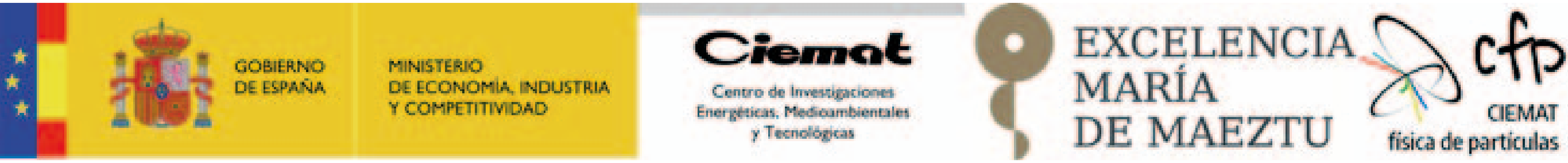
Dark matter search activities at CIEMAT

Pablo García (CIEMAT)

pablo.garcia@ciemat.es

14th MultiDark Consolider Workshop at IFT, May 25, 2017



Outline

- Detector R&D activities
- ArDM
- DarkSide-20k
- ArDM + Darkside:
  DART and DarkSide-proto

DM group

MSc student:

- Andrés Salinas

PhD student:

- Édgar Sánchez

Postdoc:

- Vicente Pesudo

Staff:

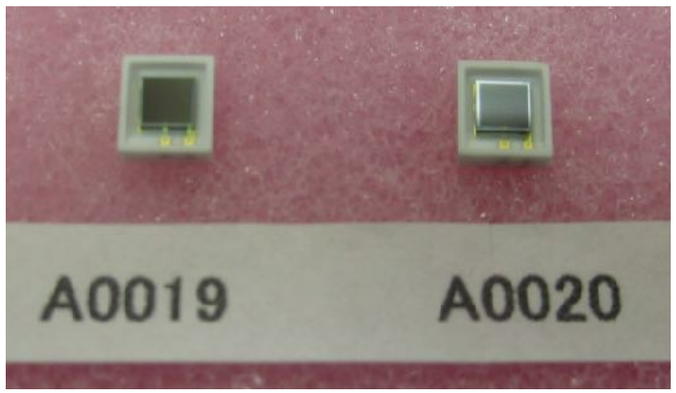
- Luciano Romero
- Roberto Santorelli
- Pablo García

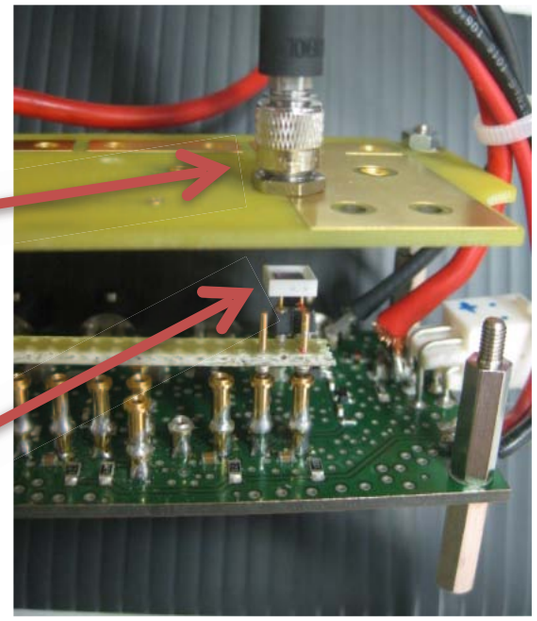
Detector R&D

- Light detection / transmission.
- Detector calibration.
- Detector design developments.
- Study the dynamics of the positive charge.
- SiPM characterisation at cryogenic temperature.
- Ar scintillation studies and HP-TPCs.
- New high voltage system for future large LAr detectors.
- Measurement of the ion feedback from the gas and the ion velocity in liquid.

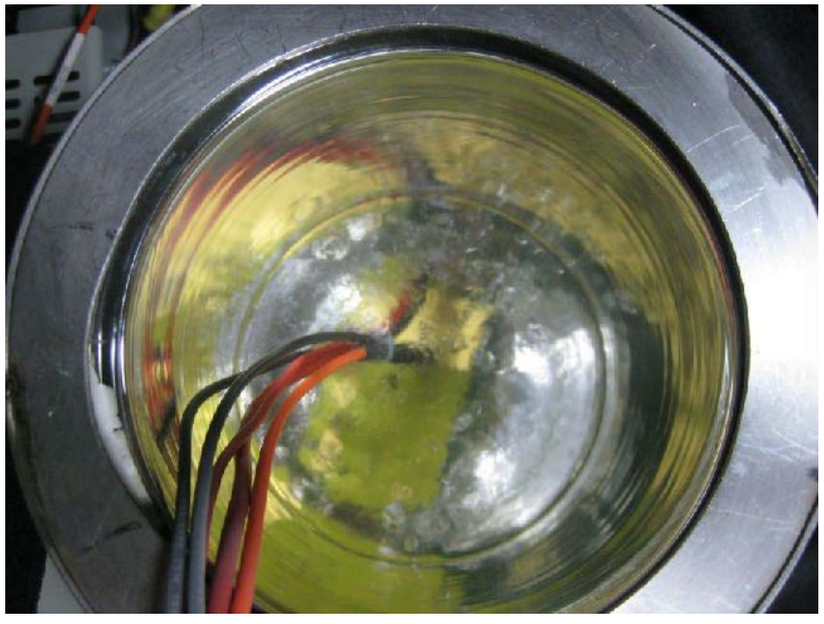
Novel light detection devices: VUV-SiPM

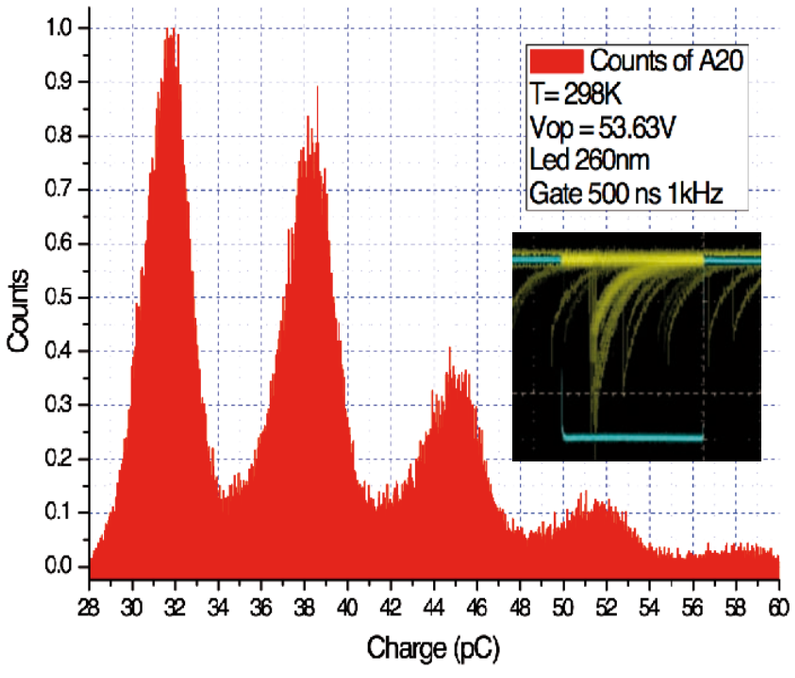
VUV-3 (Hamamatsu)
3x3 mm – 50 μm

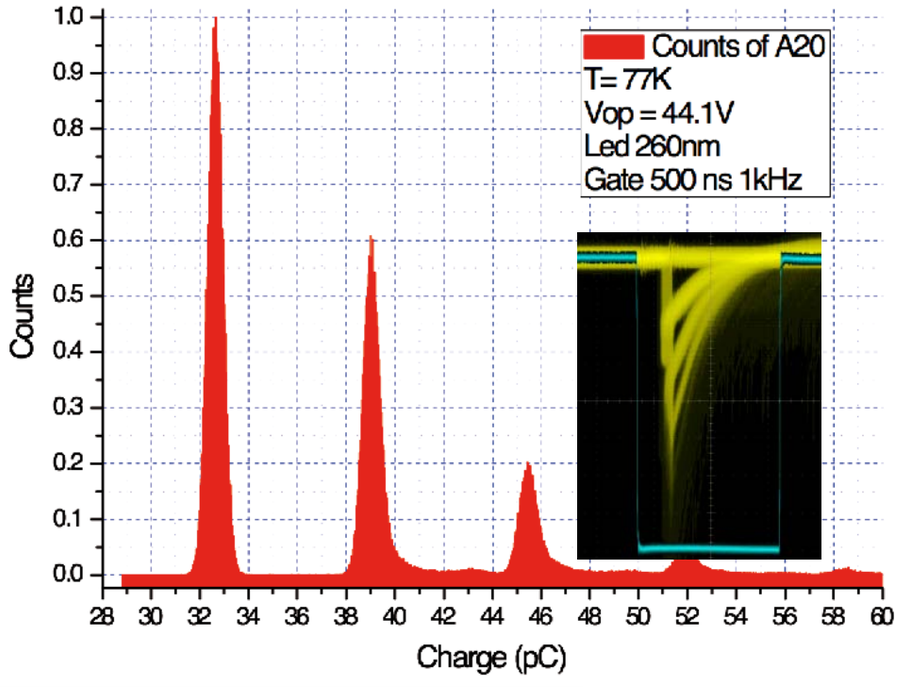




Gali S66 Amplifier (x6)
Thorlabs 260 nm LED
CAEN V965A QDC
Tek AFG3252 Signal Generator



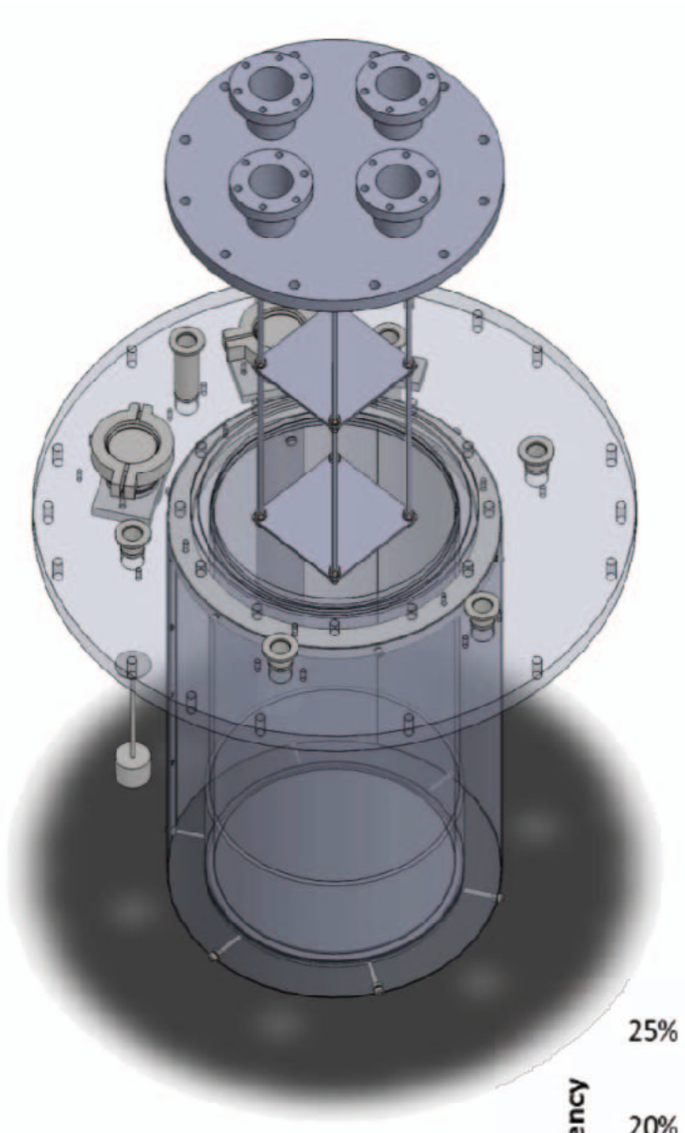


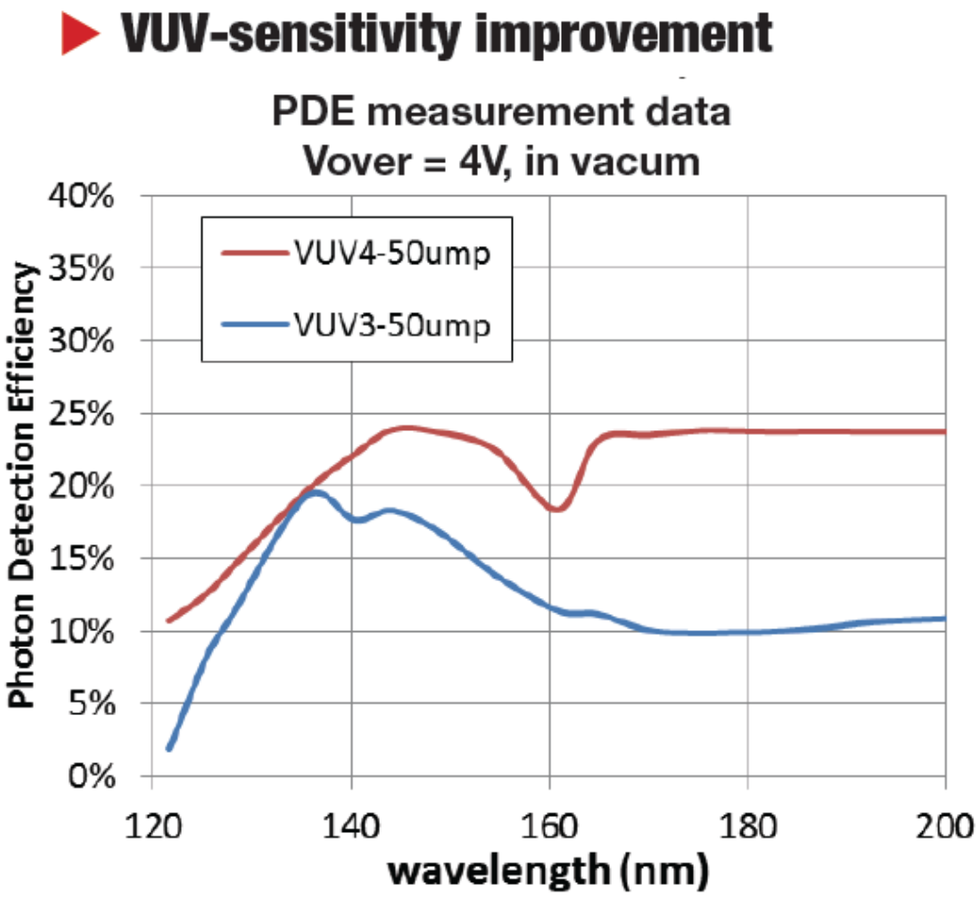


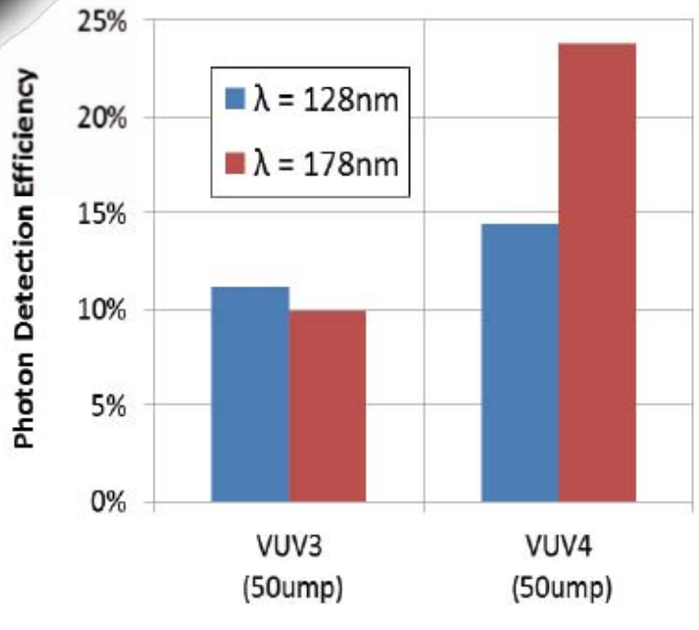
Serial N.	Vop (V)	Dark Counts (cps)	Gain
A0019	53.53	750k	6.40E6
A0020	53.63	675k	6.84E6

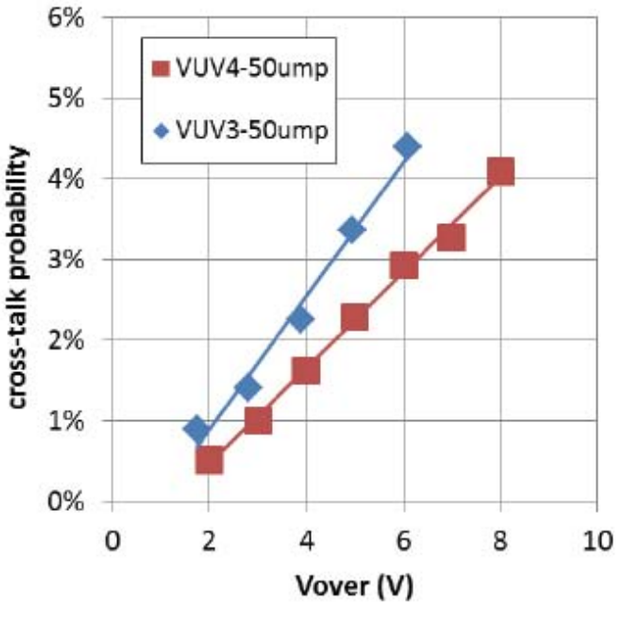
Serial N.	Vop * (V)	Dark Counts (cps)	Gain
A0019	44.0	~20	6.93E6
A0020	44.1	~20	6.71E6

SiPM test setup for LAr operations







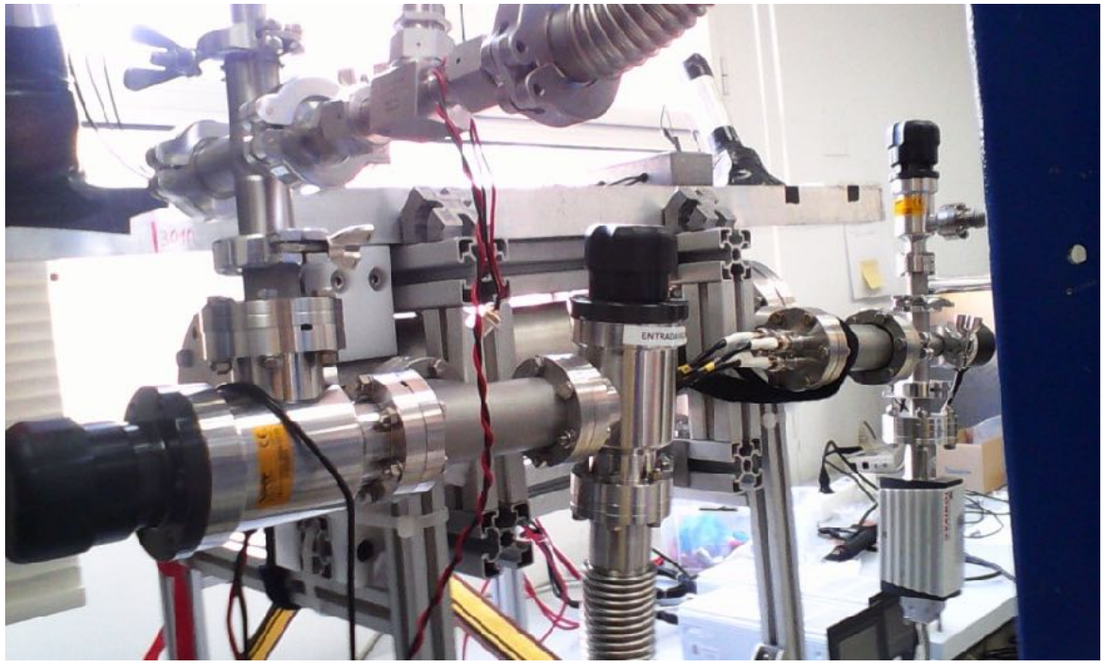


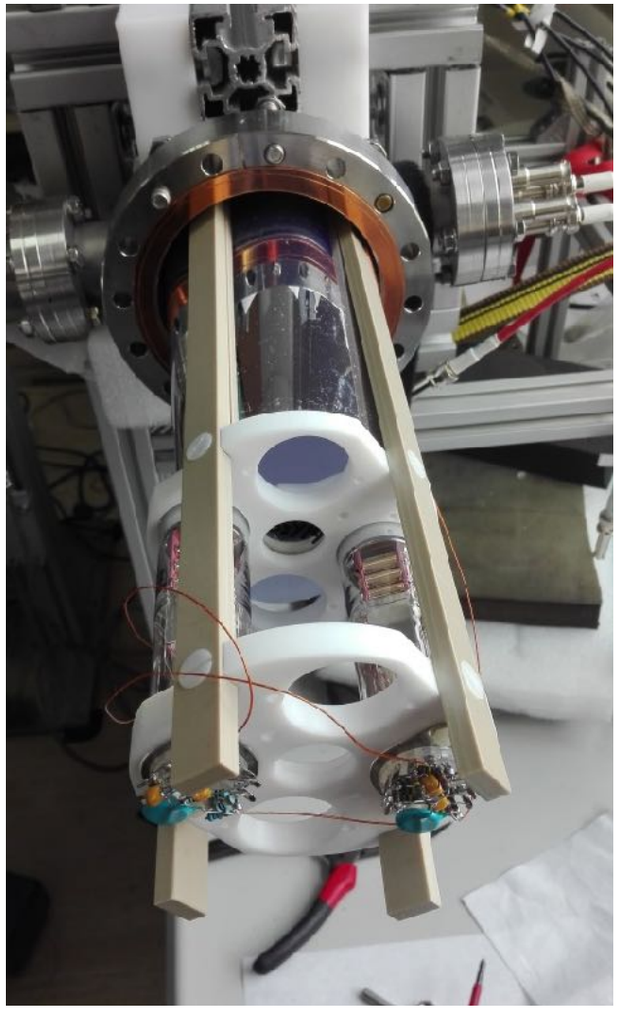
- VUV-4 characterisation/validation for LAr operations.
- PDE@128nm, dark counts, operating voltage, gain, linearity, etc.

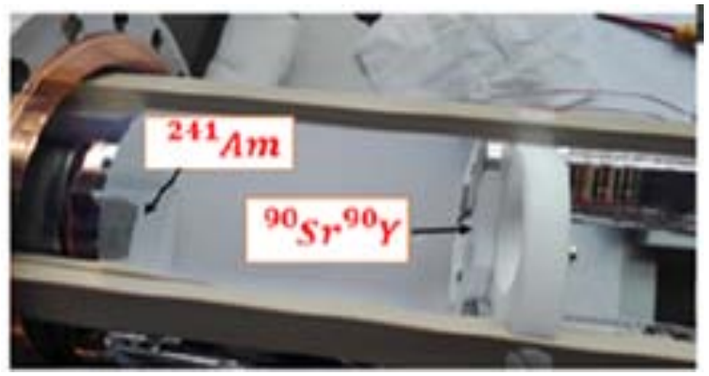
HPGAr TPC for light scintillation studies

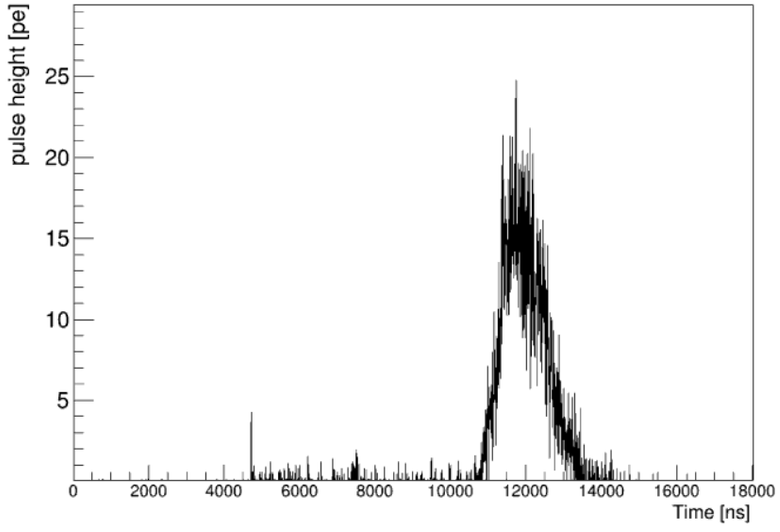
Study of the scintillation and EL light emission process in a HPGAr TPC:

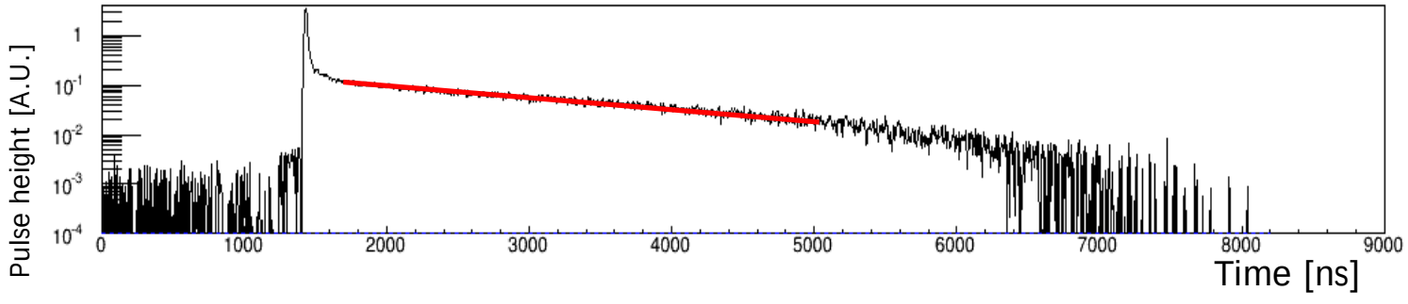
Scintillation components, wavelength, pressure dependence, etc.

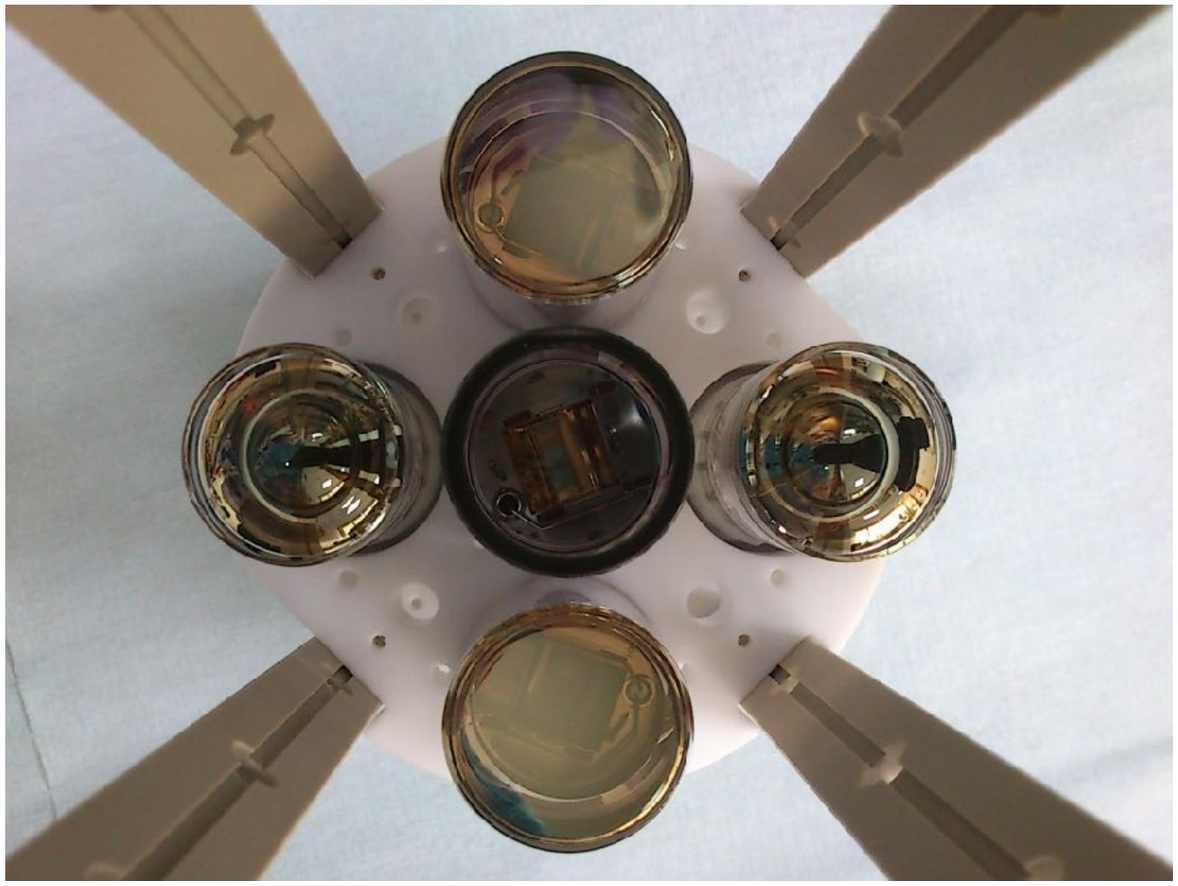


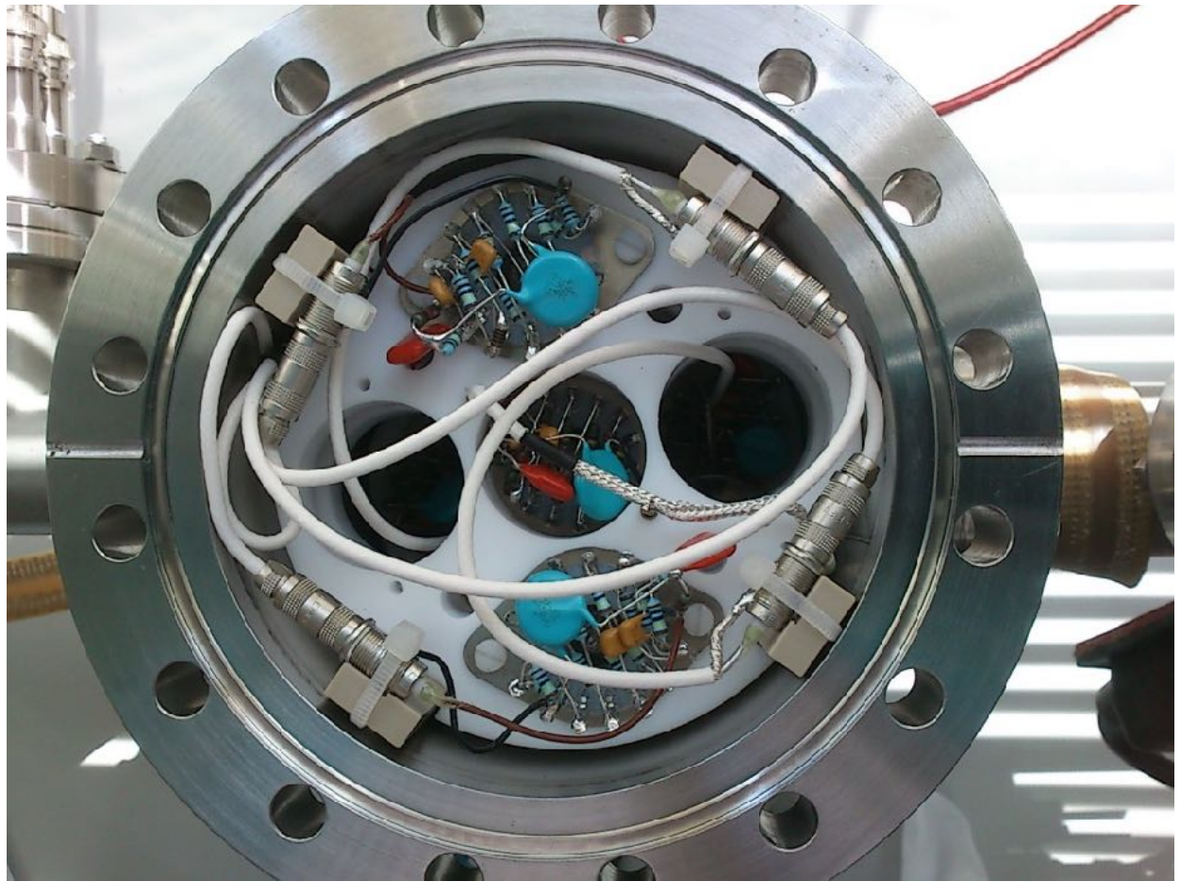


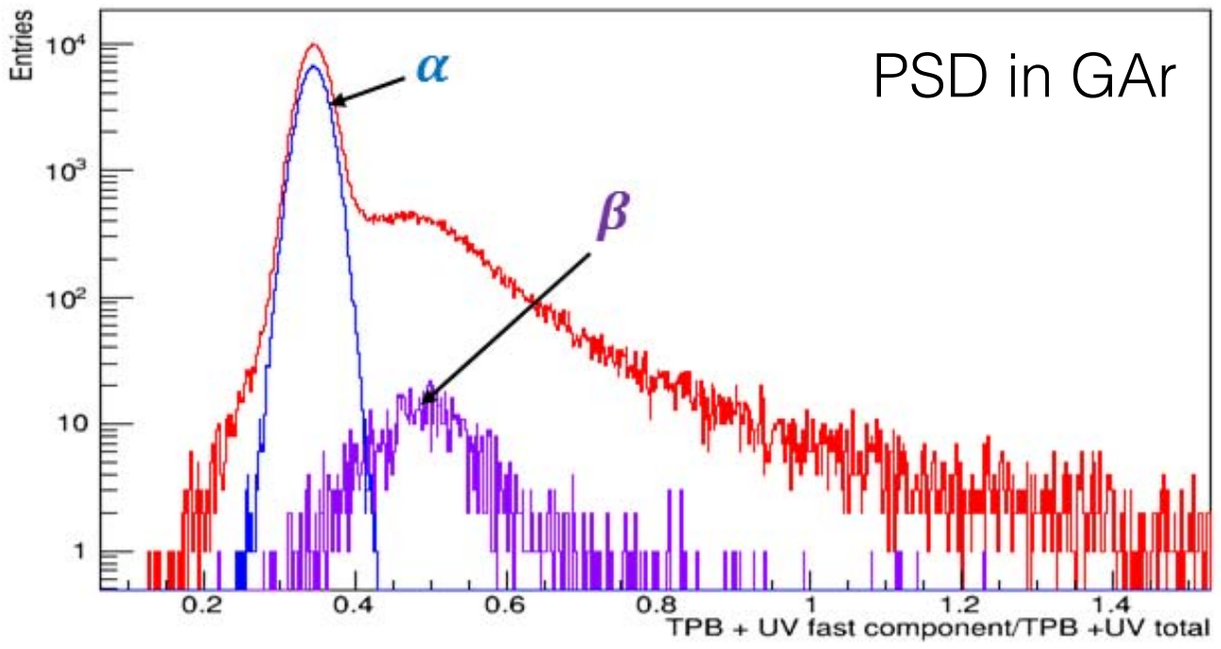








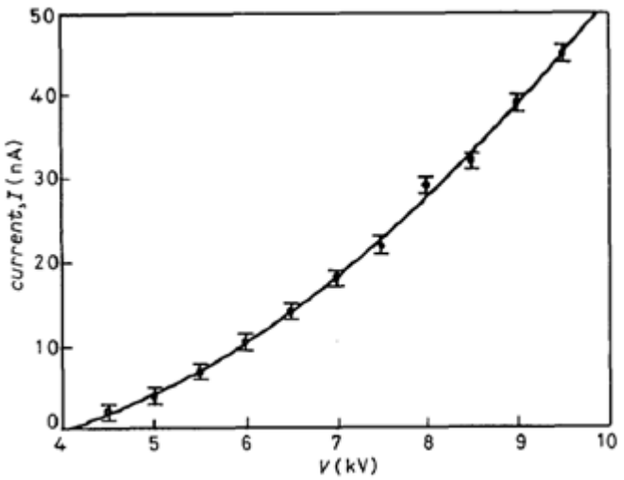



PSD in GAr
Entries
10^4
10^3
10^2
10
1
α
β
0.2
0.4
0.6
0.8
1
1.2
1.4
TPB + UV fast component/TPB +UV total

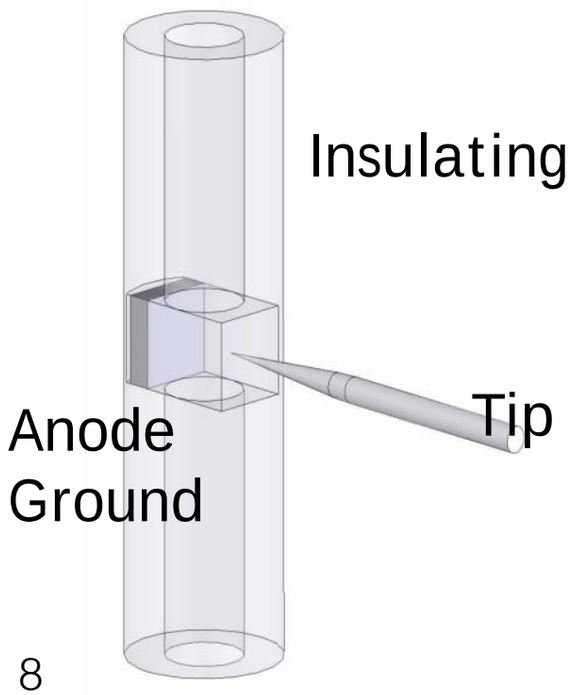
R&D on a novel HV system

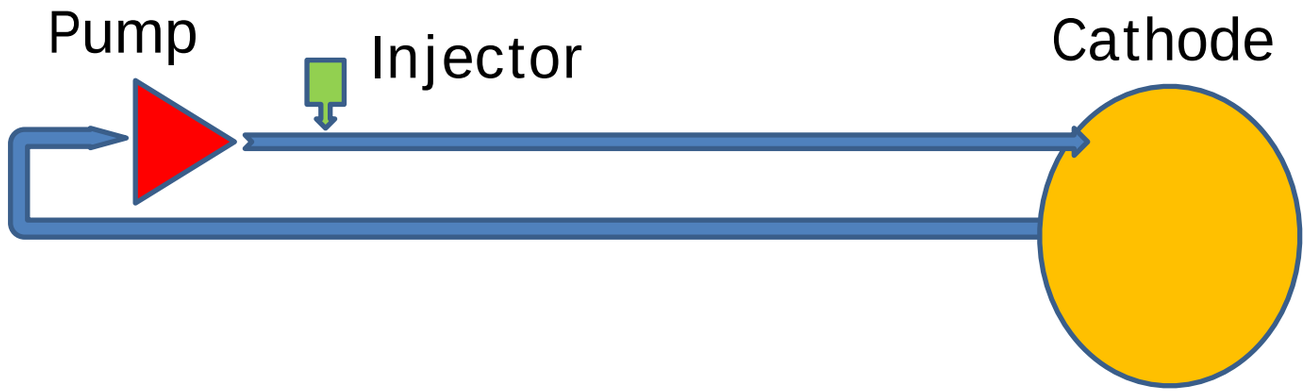
- Megavolts ranges HV sources required by the future detectors, with several meters drifts.
- Efficient removal of the positive charge cloud.
- Novel approach: to generate the HV directly inside the detector .

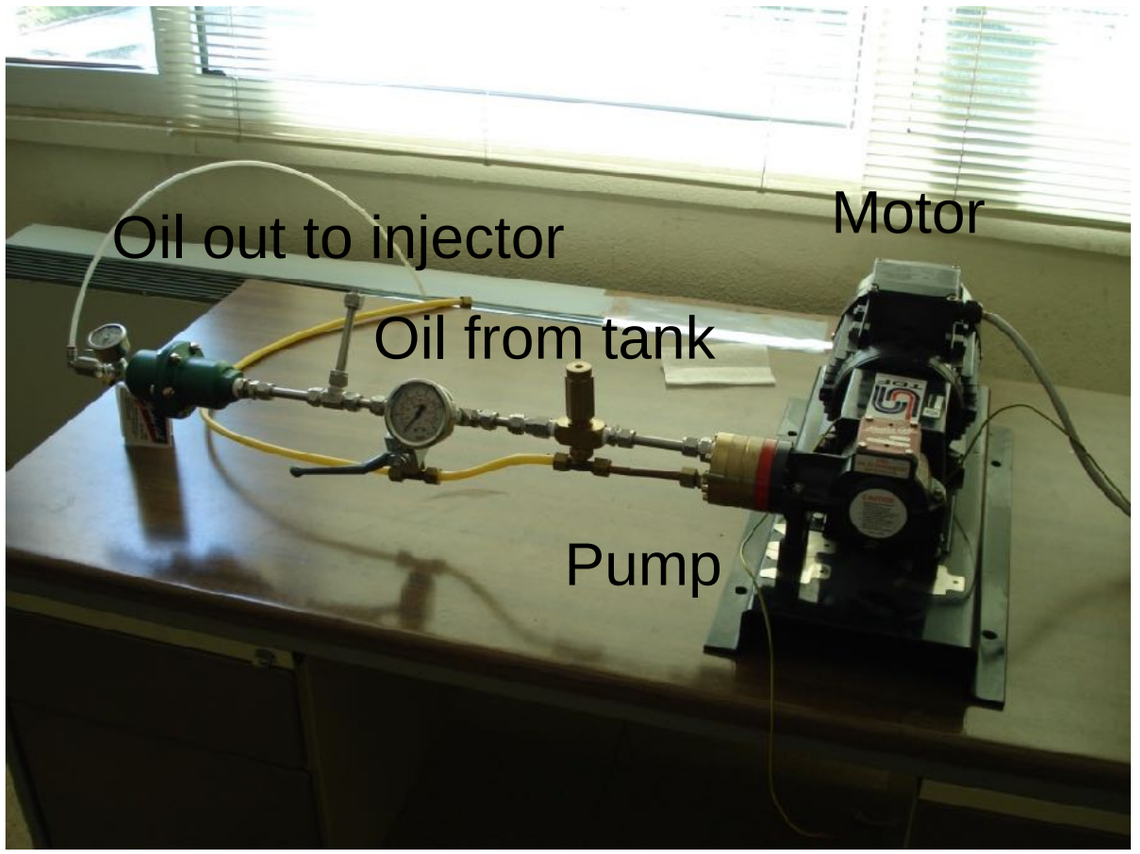
Il Nuovo Cimento Vol.13 D, N.8 (1991)



I.diameter: 1 mm



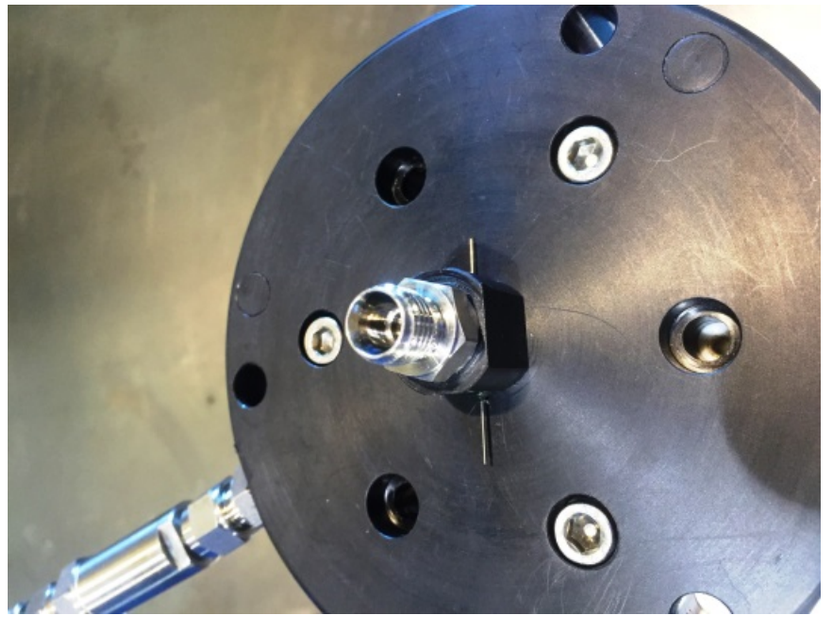




Tests already carried out with dielectric mineral oil:

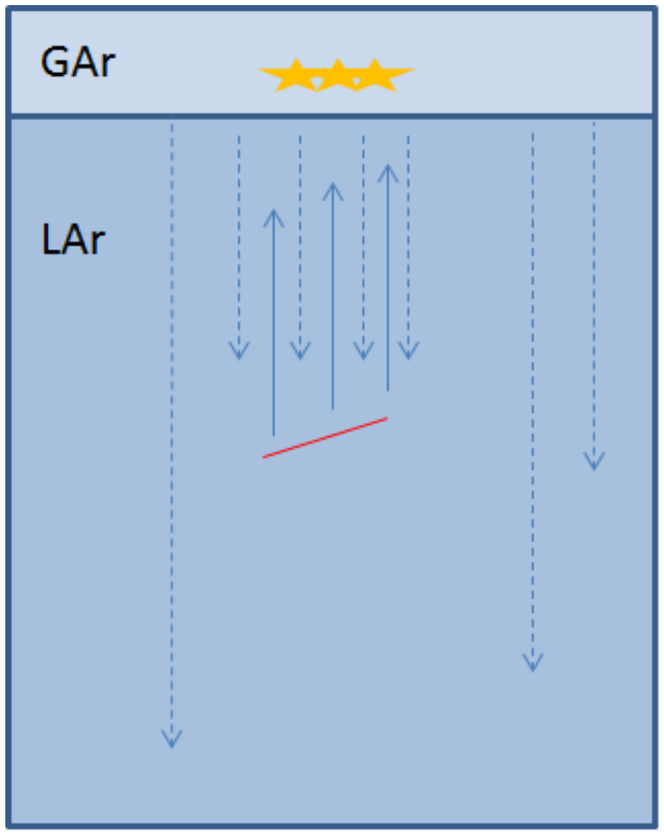
- High voltage measured at the cathode≈30 KV.
- Current ≈100nA

Novel high voltage system



To be operative this year !

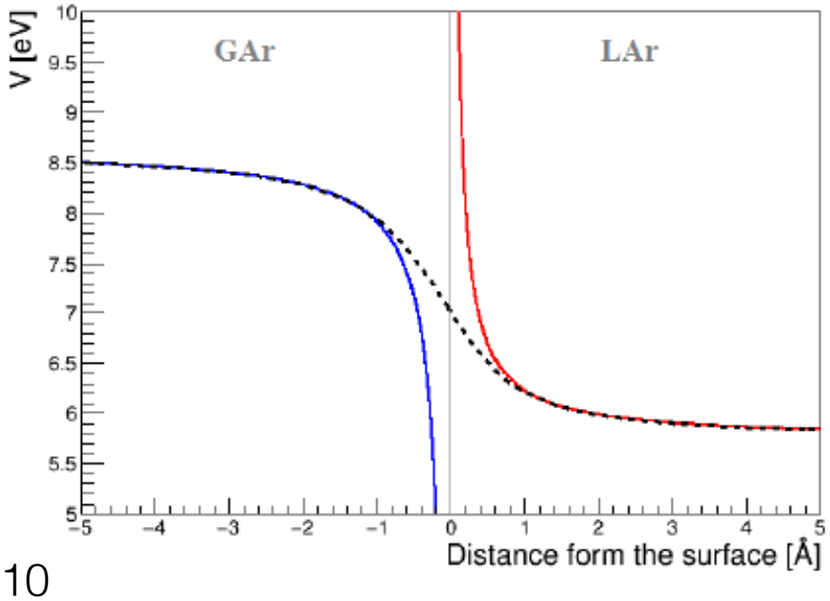
Study of the dynamics of the ions in LAr



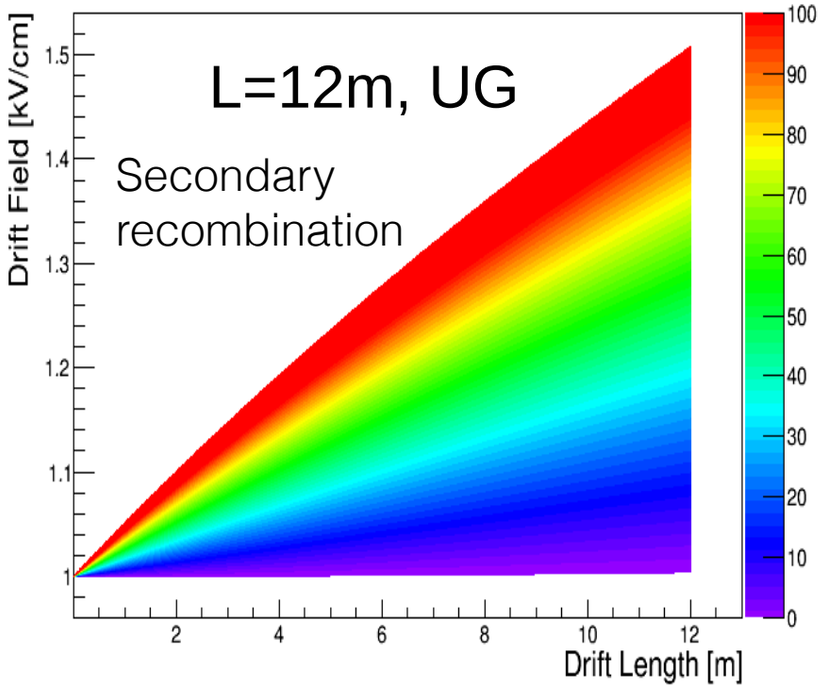
E_d= 0.5-1 kV/cm

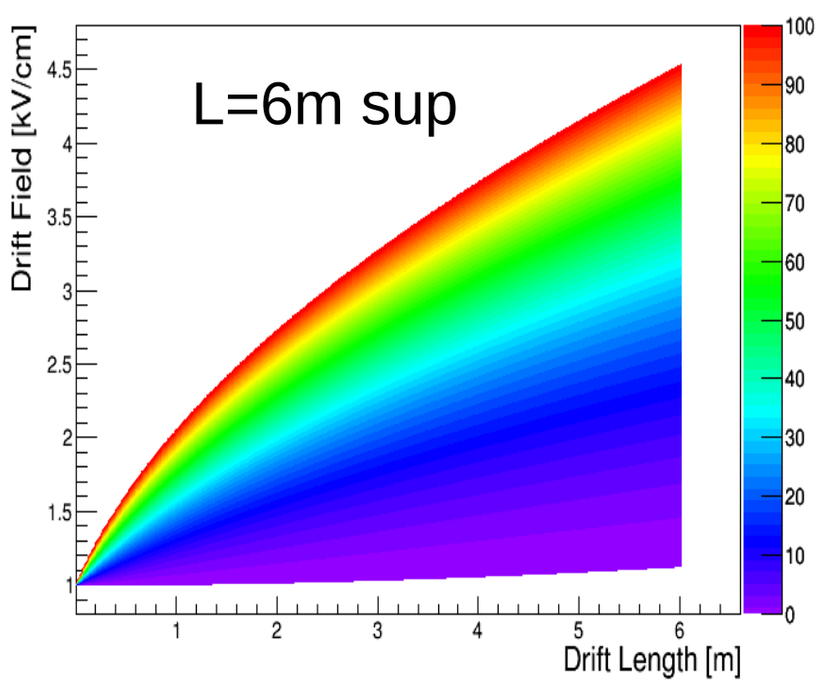
$v_e \approx$ 2 mm/μs

$v_i \approx 1.6 \cdot 10^{-5}$ mm/μs

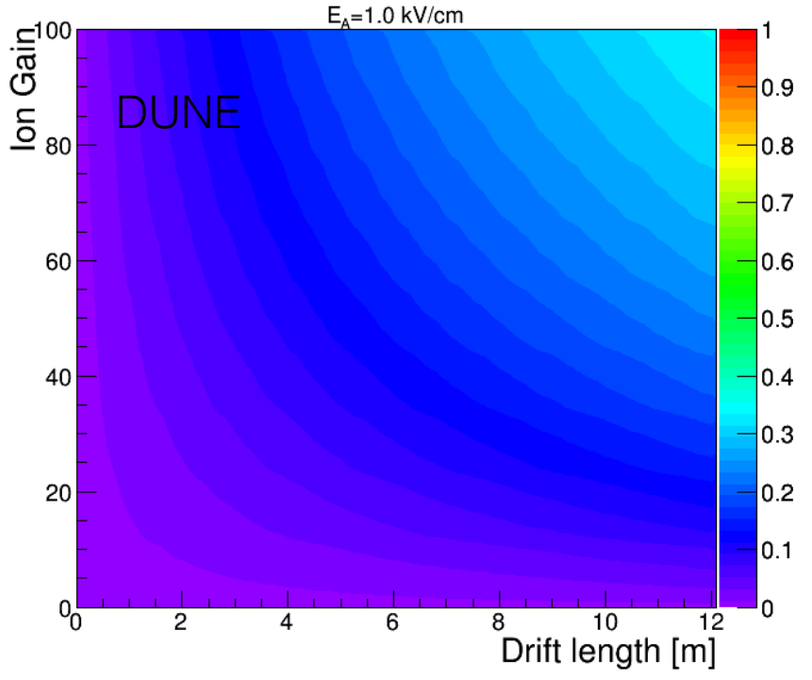


L. Romero, R. Santorelli, B. Montes:" Dynamics of the ions in Liquid Argon Detectors and electron signal quenching"
Astropart.Phys. 92 (2017) 11-20
https://arxiv.org/pdf/1609.08984v2.pdf

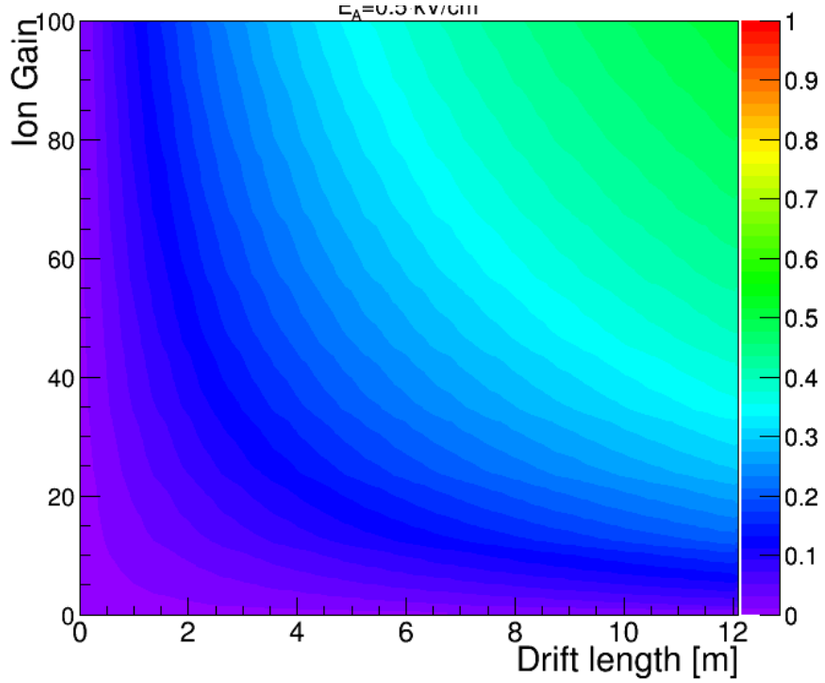




L=12m, UG, E=1 kV/cm

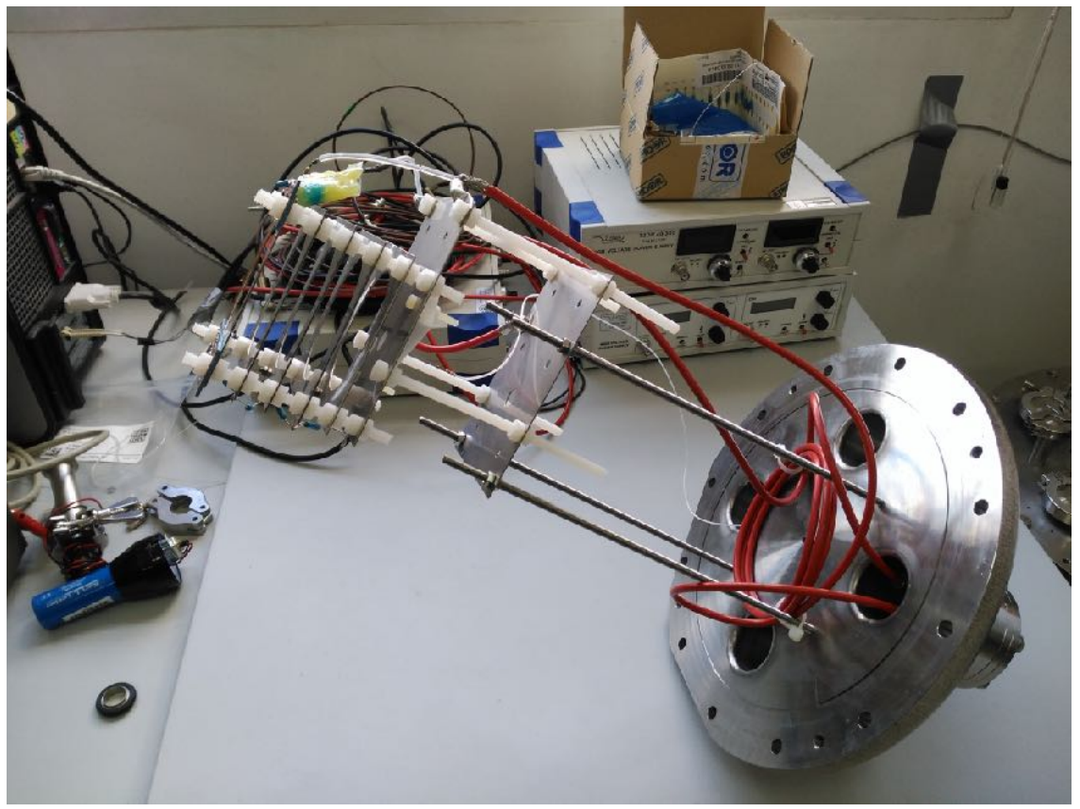


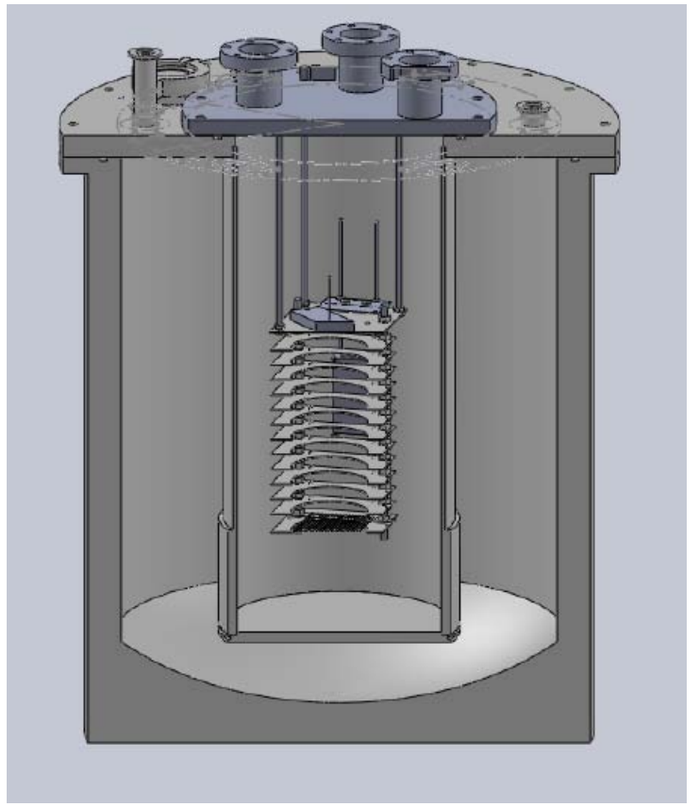
L=12m, UG, E=0.5 kV/cm

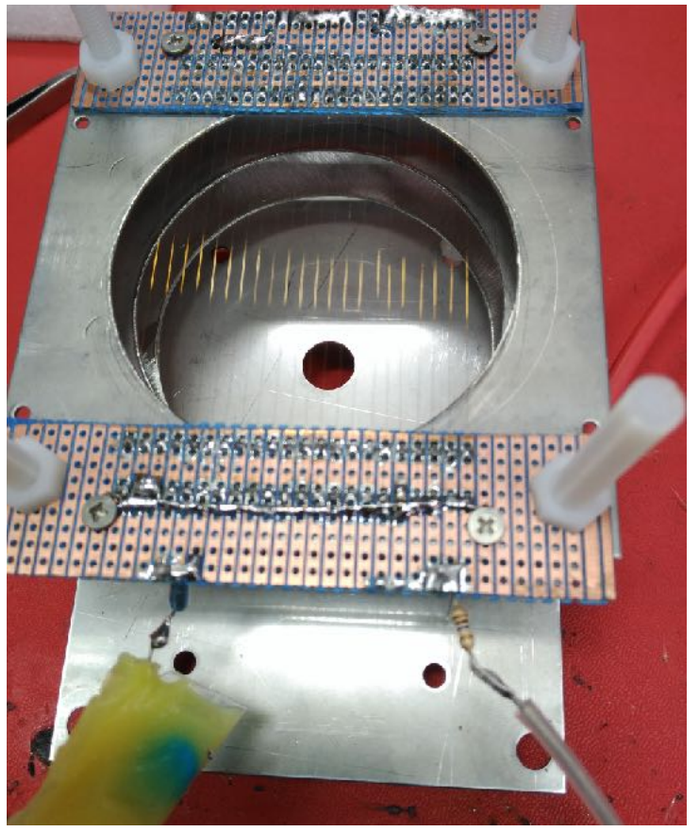


Ions in LAr: setup at CIEMAT

- Measurement of the ions drift velocity.
- Study of the dynamics of the ions at GAr/LAr interface.
- Study uniformity of the drift field.
- Electron signal quenching.







To be operative this year !

Collaboration with IFAE

R&D summary

- SiPM characterisation at cryogenic temperature.
- Ar scintillation studies in HP-TPCs.
- New high voltage system for future large LAr detectors.
- Measurement of the ion feedback from the gas and the ion velocity in liquid.

ArDM - a Ton-scale LAr TPC for DM research

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

ETH Institute for Particle Physics

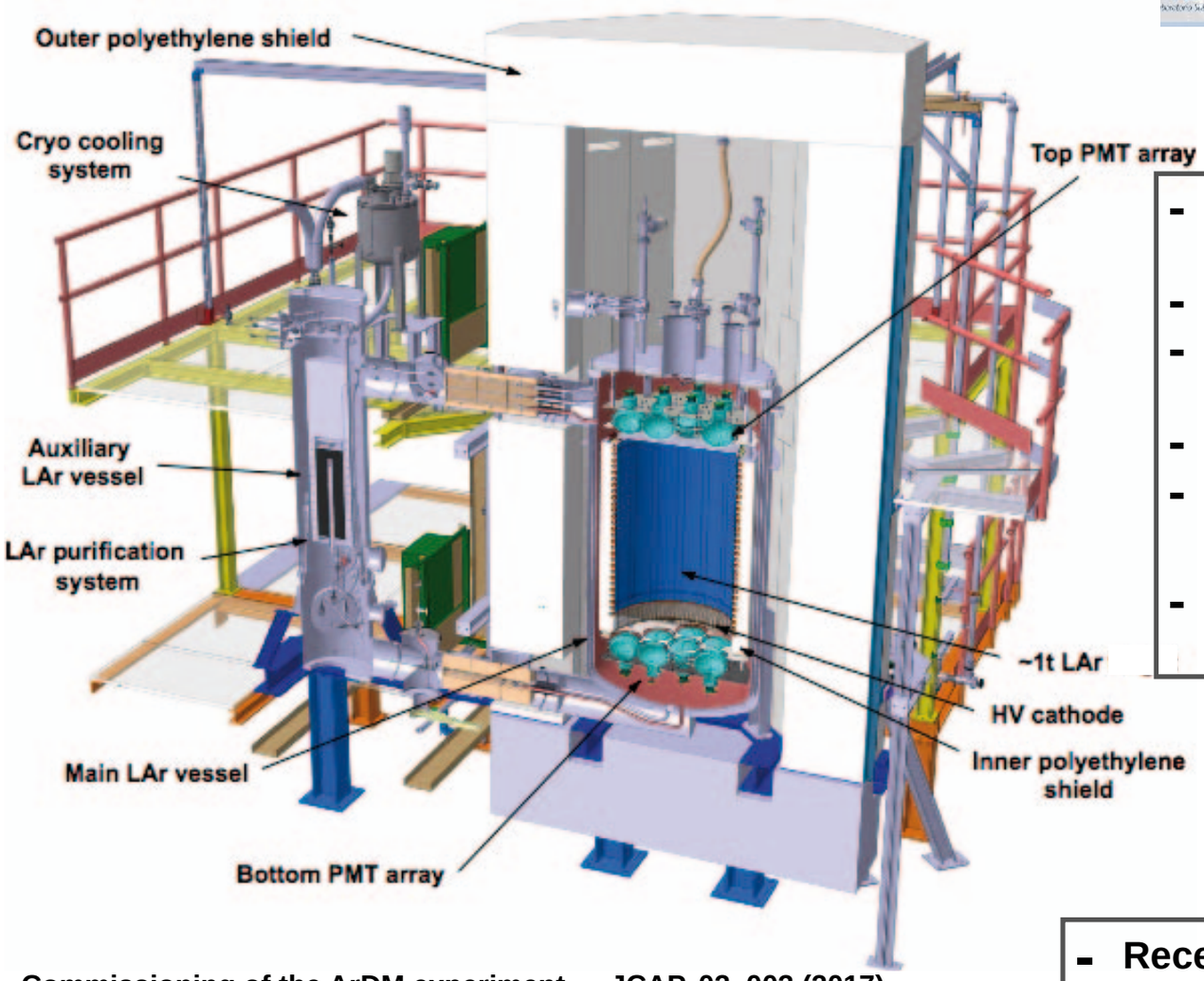
GOBIERNO DE ESPAÑA MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

CERN

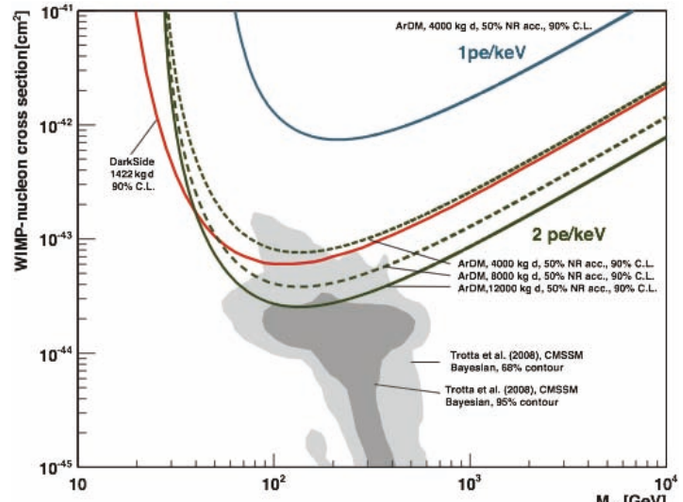
LSC

ETHZ led collaboration with CIEMAT, LSC, CERN ….

- **Contribution to searches of higher mass WIMPs!**
- **Design parameters / developments for future LAr facilities!**

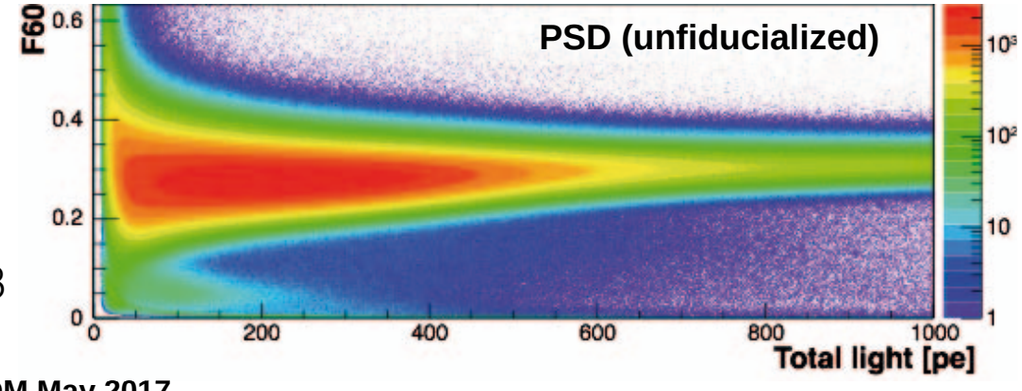


- **Experiment commissioned in single phase in 2015**
- **3×10^9 triggers recorded**
- **Low background goal confirmed**
- **Detector upgraded in 2016**
- **Double phase run planned for 2017**
- **Main tasks: Verification of sensitivity and neutron IA**



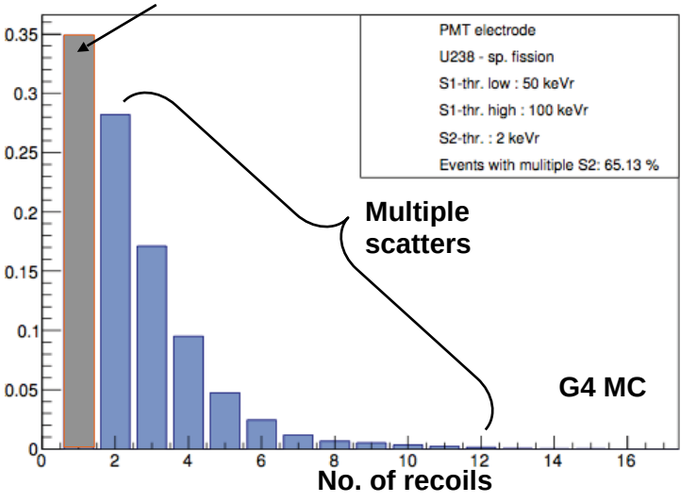
1 neutron event per ~20d expected

Commissioning of the ArDM experiment… JCAP, 03, 003 (2017)



- **Recent integration of ArDM in the DS project**
- **Combining efforts towards future G2 and G3 facilities**

Single scatter neutrons (indistinguishable BG)



^{39}Ar depleted argon research planned for 2018 and beyond

ArDM summary

- Single phase RUN-1 completed. Studied background and light yield, measured Ar transparence to its own scintillation light for the first time in a large detector. Short attenuation length (50 cm).

- Results published in 2 papers, another one is in preparation.

- Hardware upgraded to start RUN-II this summer in double phase.

- Full integration in DarkSide-20k (2018): DAr studies.

DarkSide-20k

- Ambitious program for DM discovery up to 10 TeV.

- International Collaboration: over 40 institutions. In 2015 the CIEMAT DM group was one of the original proponents.
  It gathers now most of the groups currently involved in ArDM, DarkSide-50 and DEAP-3600.

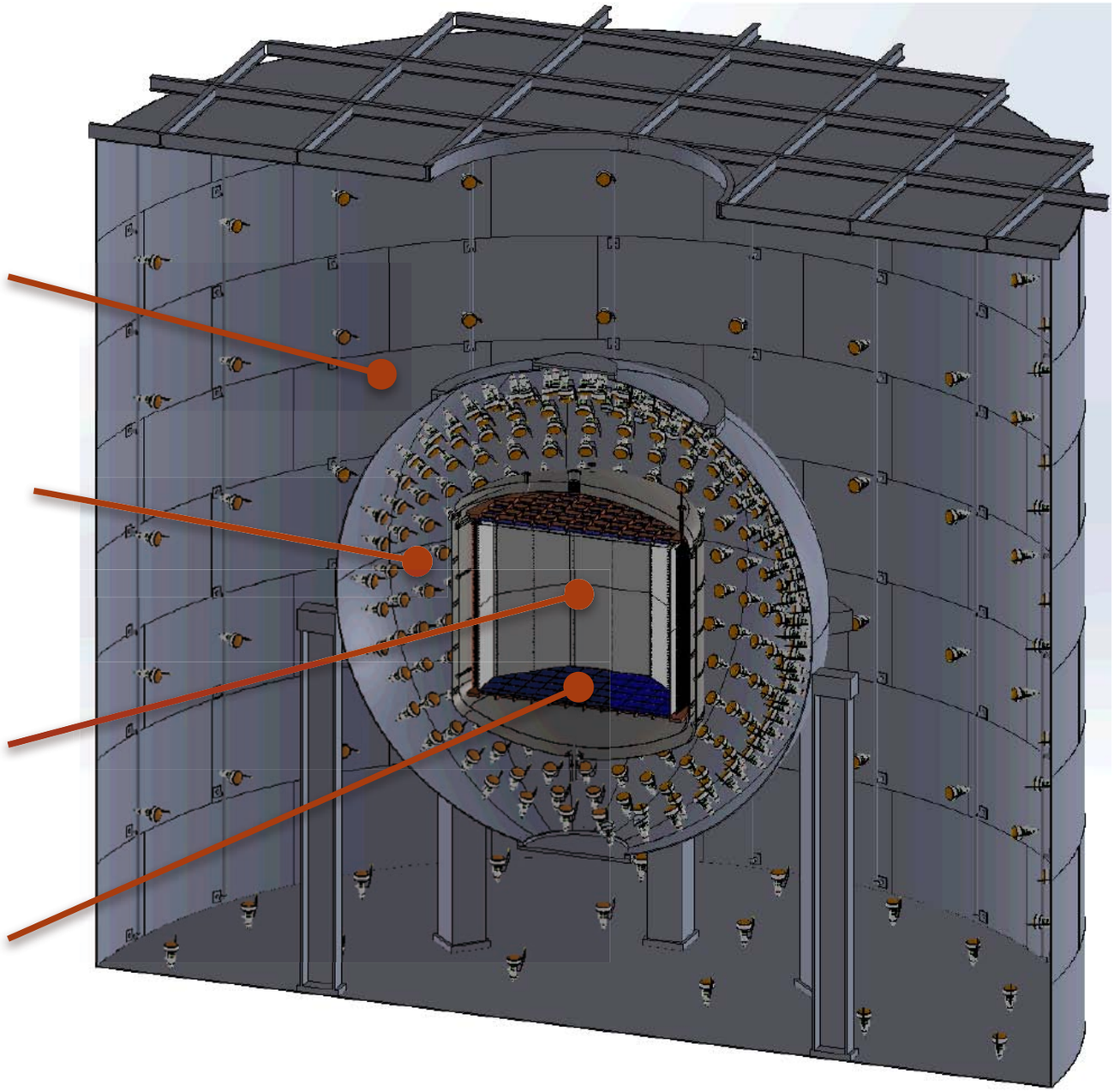
- Background-free dual-phase LAr TPC (exposure 100 ton y): depleted Ar, high discrimination power, radio-pure materials.

- Installation at the LNGS recently approved.

- DarkSide-20k formally approved by INFN-CSN2 (April 2017).

- Awaiting response from NSF.

DarkSide-20k



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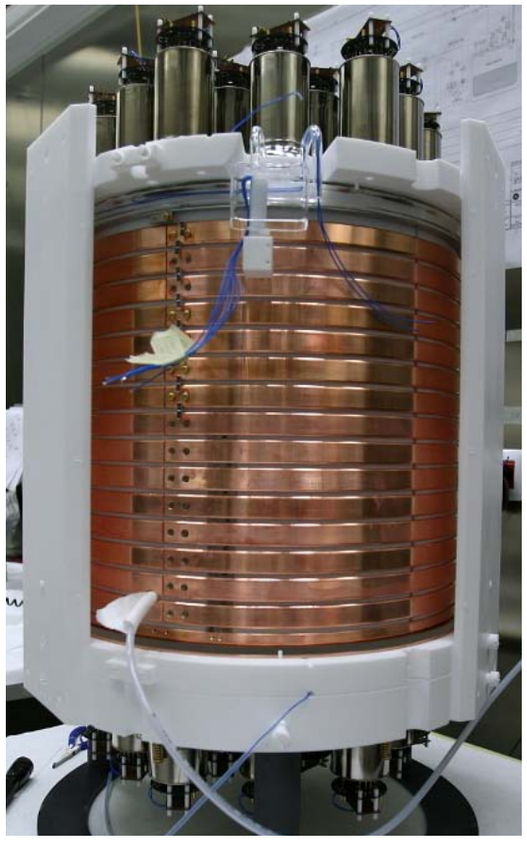
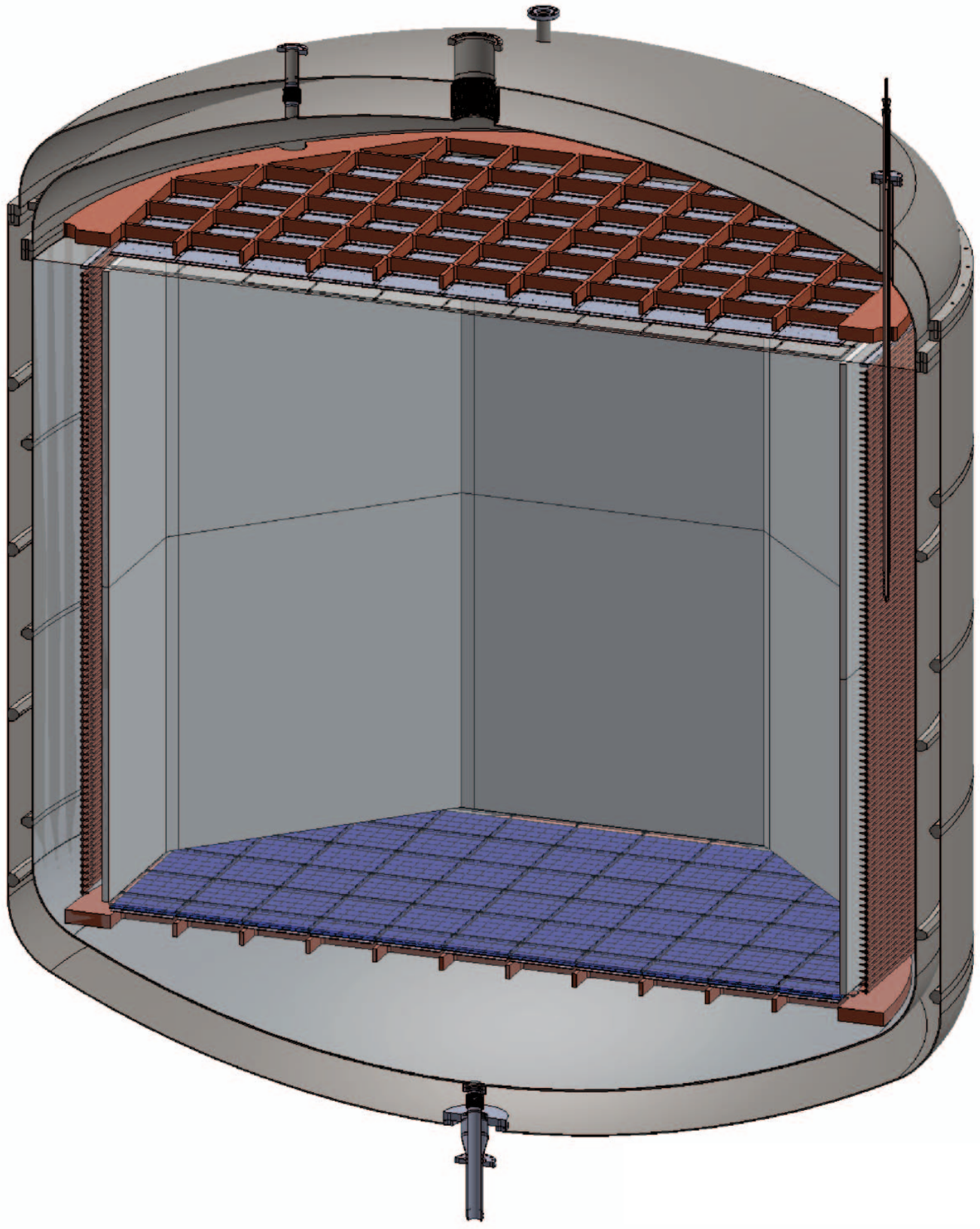


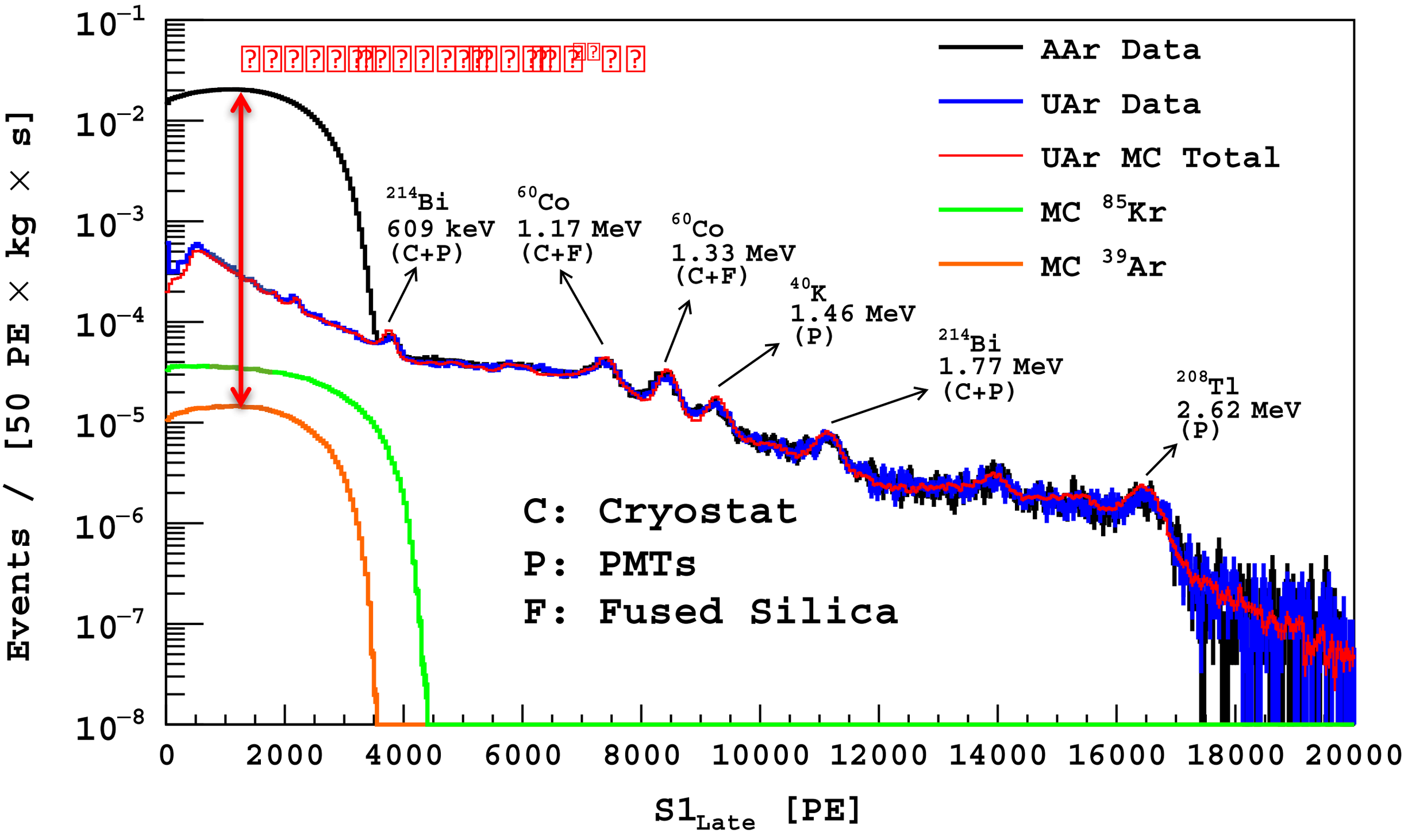
not to scale



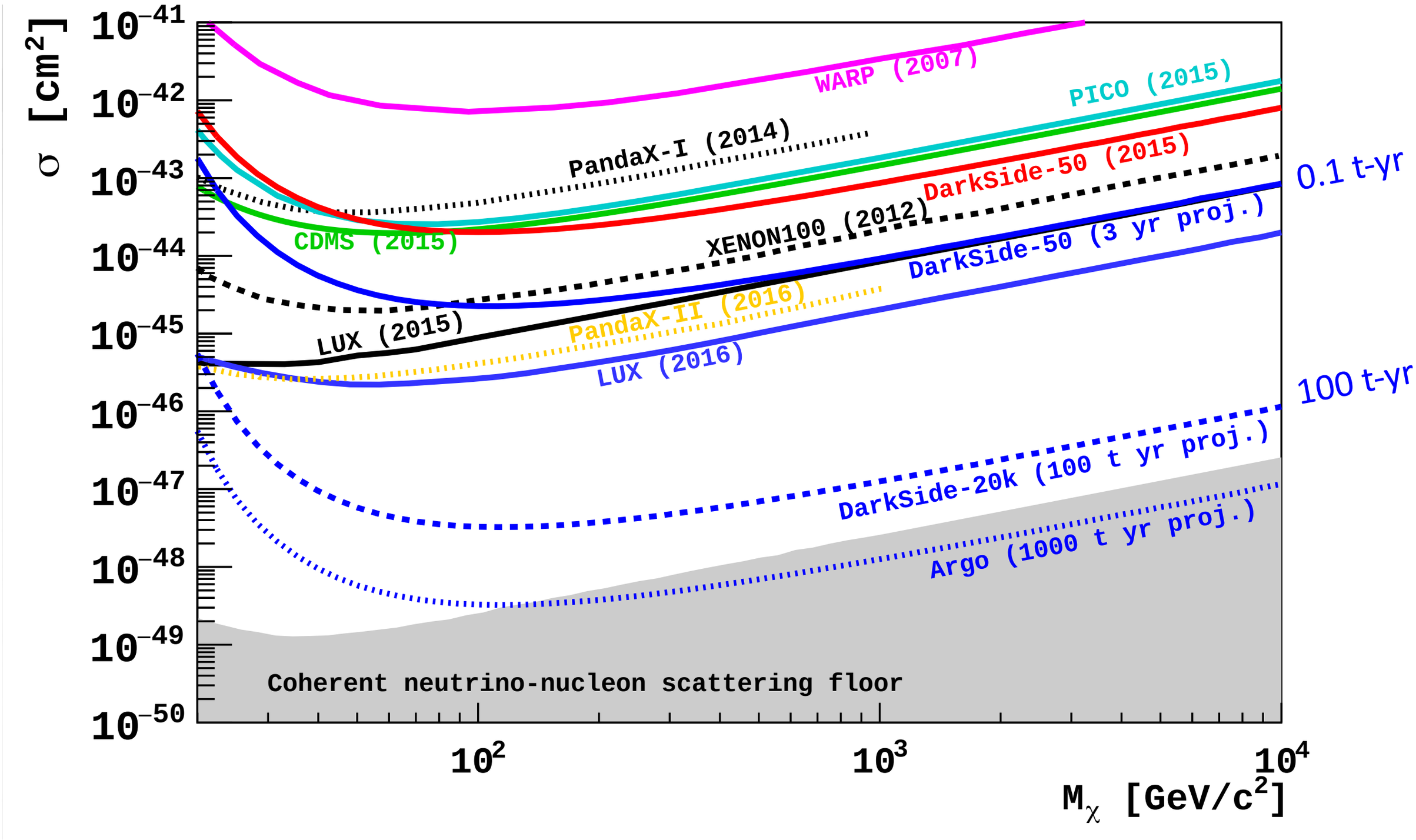
(2021 -)

- Light yield above 8 PE/keV.
- Electron meanlife > 5 ms
- ^{39}Ar contamination:1 Bq/kg in AAr,
  0.7 mBq/kg in UAr, depletion factor 1400.
- ^{222}Rn contamination < 2 μBq/kg.
- ArDM: fill the gap.

Background spectrum



DS-20k physics reach



low radioactivity UAr

- □ □□□□□□ □□□□□□□□□□
  - □ln7□ni□□7F, 1□7, 2 □□ □ □
  - □□2 □i, a7□ □□i□□ □7. □ b□□□□□□n□7F□n
  - □7, □anb, 1□
    - □□□□.F □□□r
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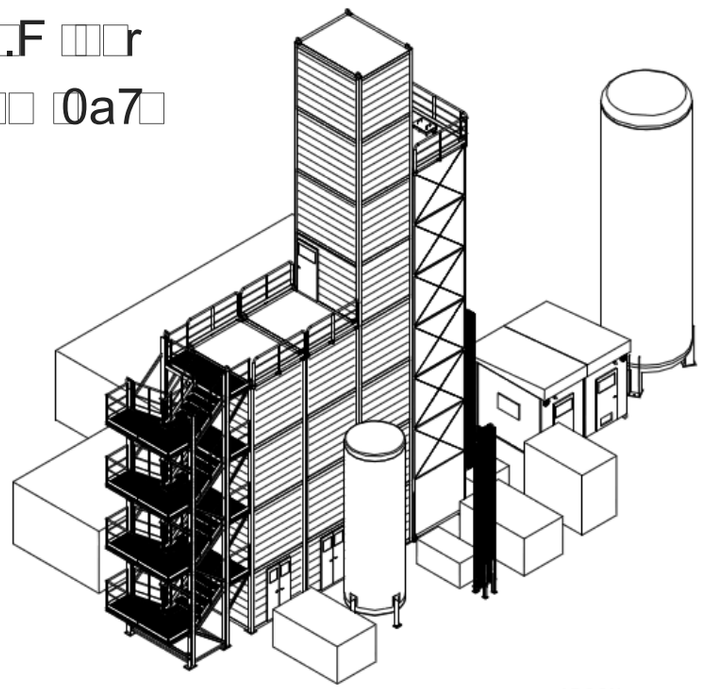

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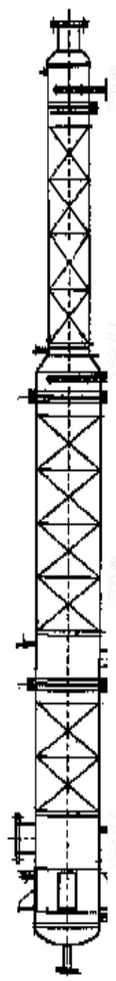
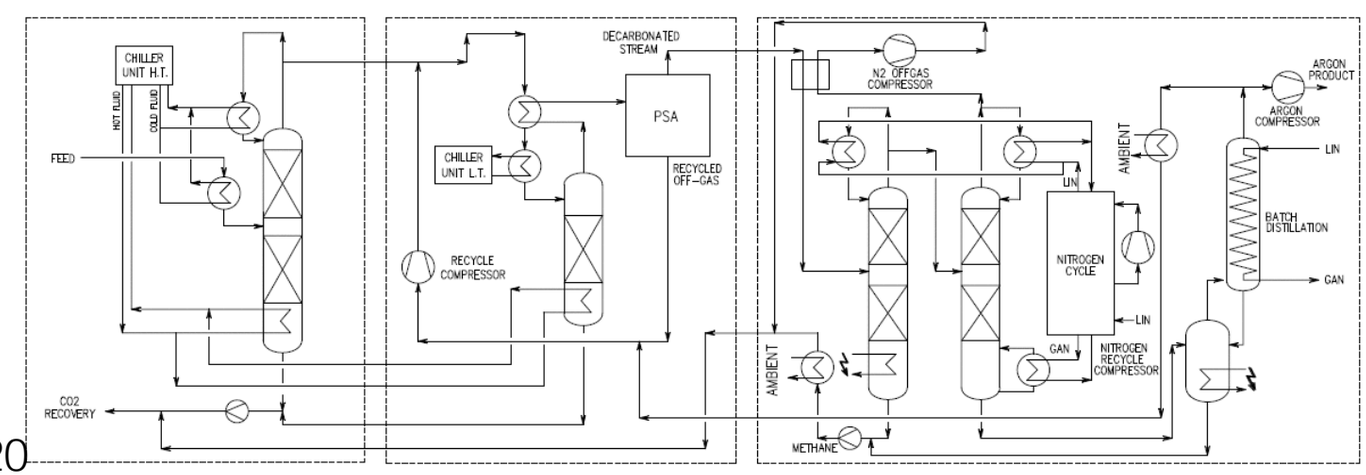
  - □bl □ □□7F, 1□0a7bb□ nb, 1
  - □ □0□□ □□, □b, n, 0□i□ 0□7□nb, 1□□□□7□□□0 □nb, 1□
  - □, □ n□□bl□ne□□□□7ab□ 2 bl□□bl□□□7□bl b□□□n□r



1ST CO2 SEPARATION

2ND CO2 SEPARATION

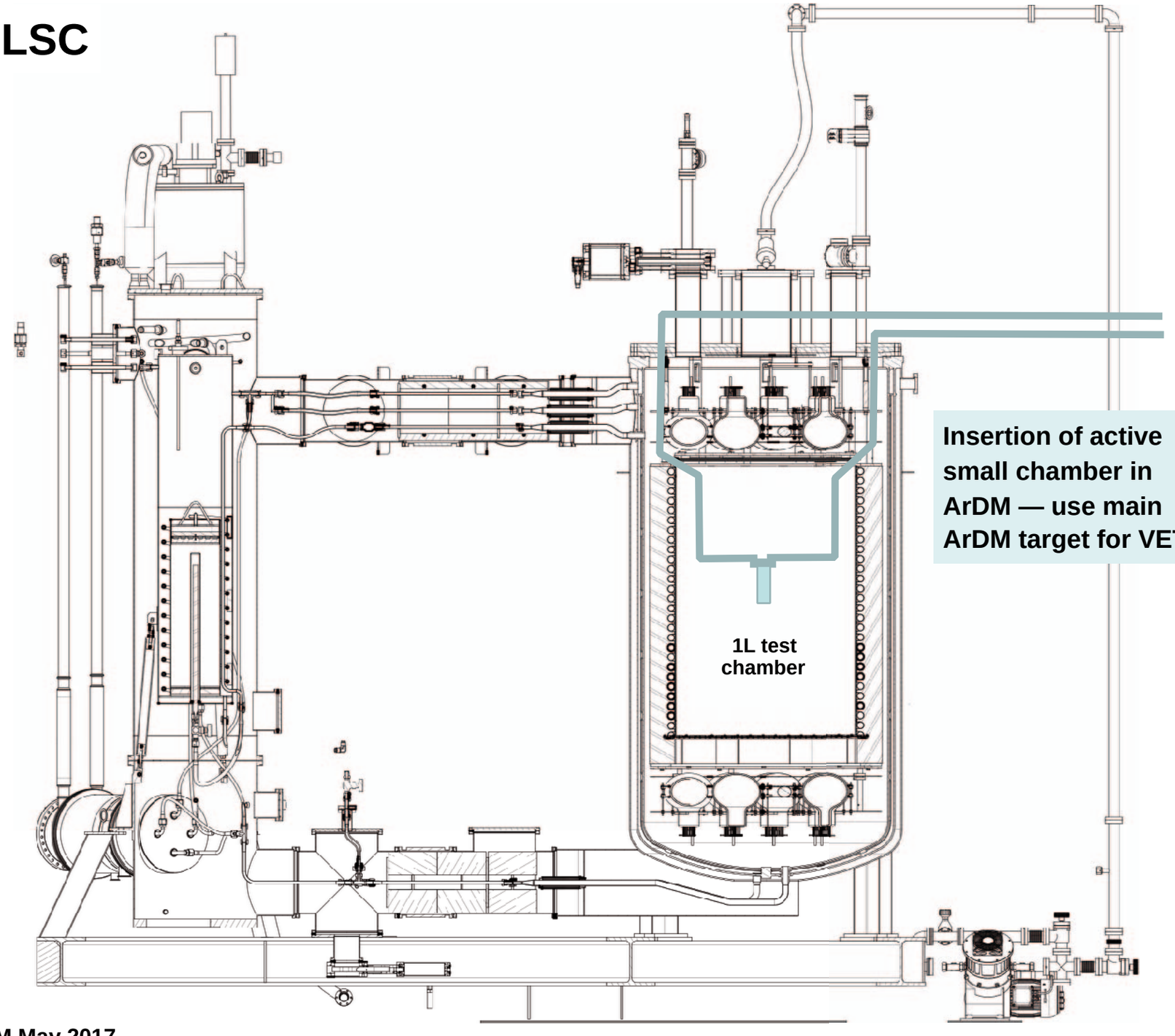
ARGON PURIFICATION



First step: DART@ArDM — Test of a small quantity of DAr@LSC (2018)

Exploiting the ArDM infrastructure at LSC and CERN for R&D

LSC

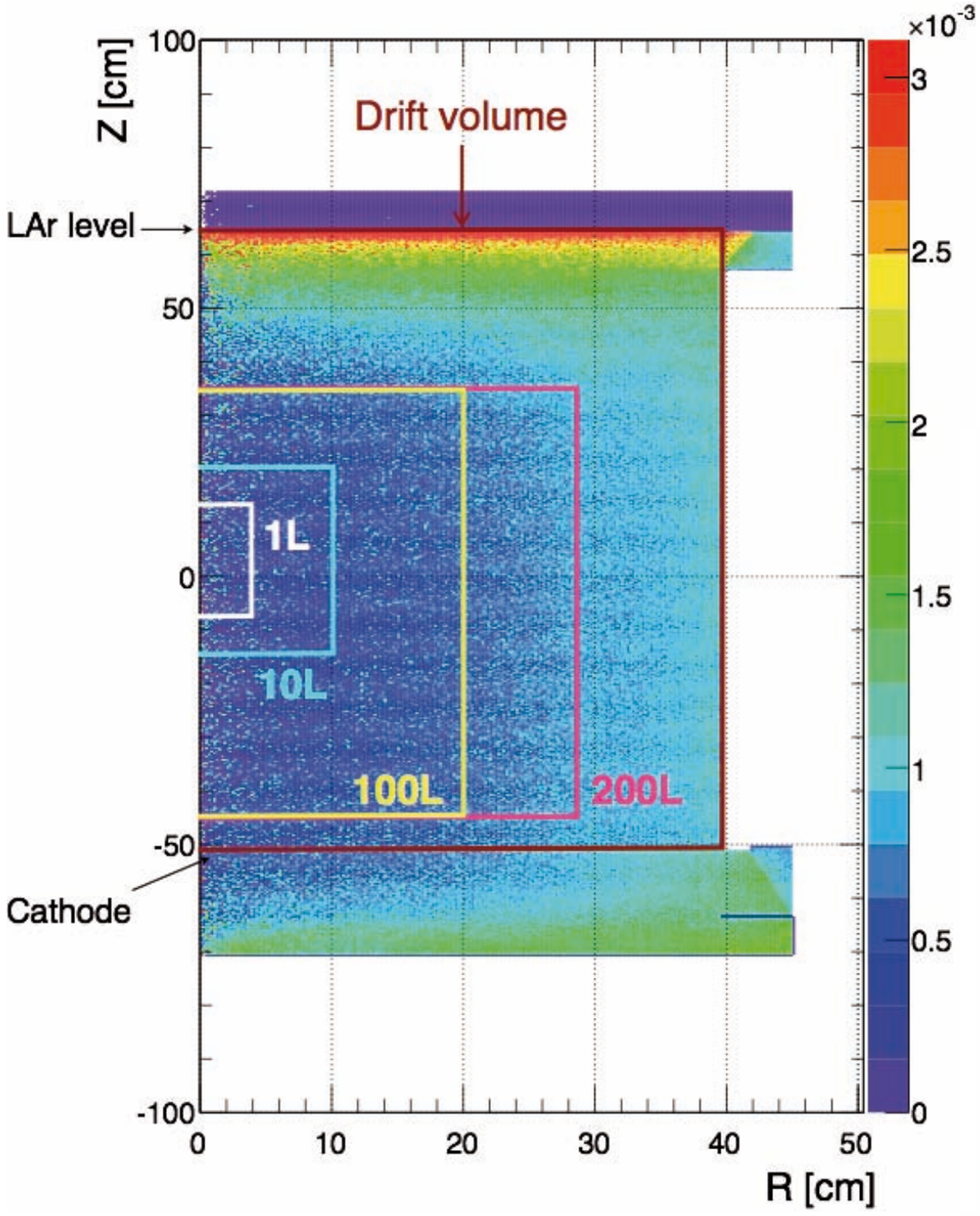


Insertion of active small chamber in ArDM — use main ArDM target for VETO

- **Ton scale test facilities.**
- **SiPMT based photo-detectors developments and tests.**
- **Characterization of (large quantities) of DAr.**

CERN

DAr sensitivity of ArDM — MC studies ongoing



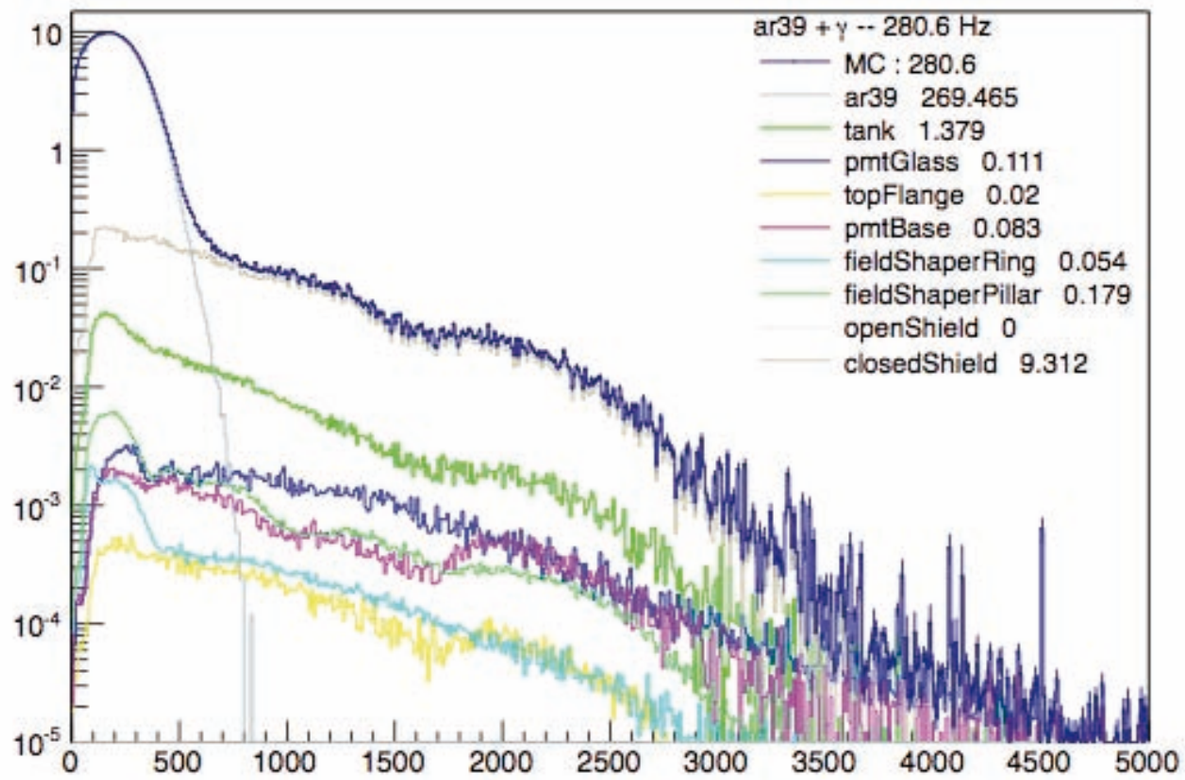
Gamma BG MC of internal (detector components) and external sources including U-238 and Th-232 chains, K-40 and Co-60

Scaled based on the measurements and then summed up

Fiducialization study :

Drift volume outside of the fiducial volume used as veto

Gamma Bkg in the 200-L fiducial volume



FV	Total γ Bkg in FV [Hz]	Rejected [Hz]	Remaining Bkg [Hz]	Rejection rate
200 ℓ	32.7	21.6	11.1	66.0%
100 ℓ	11.3	9.5	1.8	84.5%
10 ℓ	1.26	1.20	0.06	95.6%
1 ℓ	0.164	0.160	0.004	97.3%

CIEMAT at DarkSide-20k

- TPC mechanical construction (CIEMAT workshop).
- Material screening:
  - ICP-MS at CIEMAT
  - HpGe at LSC
  - BiPo (surface contamination) at LSC
- DAr depletion factor measurement using ArDM.
- Computing and simulation, electronics, calibration sources.

Remarks

- Our group is firmly committed to the search for DM as part of a world leading Collaboration, as well as to sustain related R&D activities.
- We seek future collaboration with other groups in this area to strengthen the Spanish participation in DS-20k and to develop new methods and techniques.