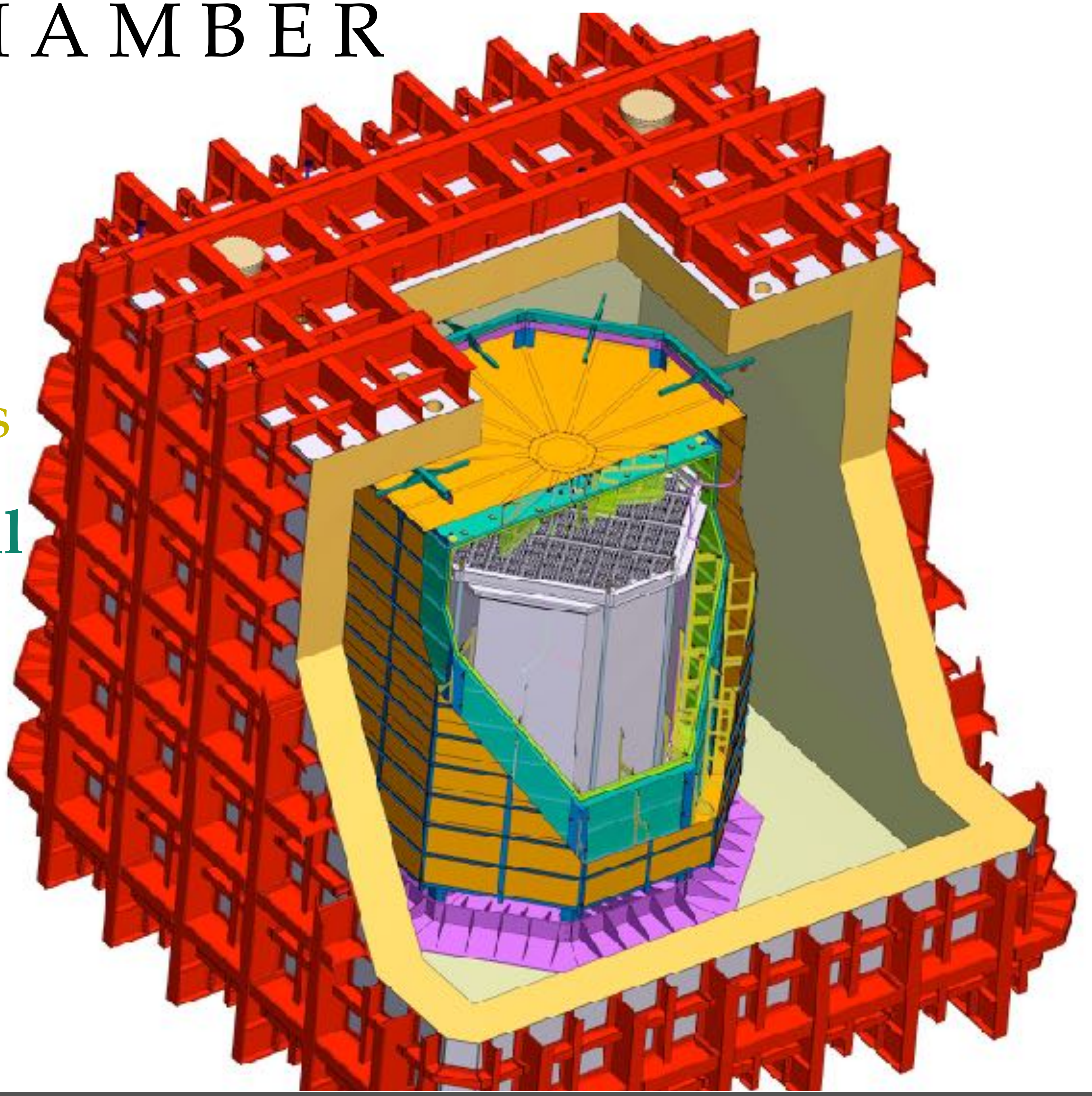
DEVELOPMENT OF DARKSIDE-20K DUAL-PHASE TIME PROJECTION CHAMBER



Low radioactivity LAr TPC

Two Atmospheric LAr Vetos

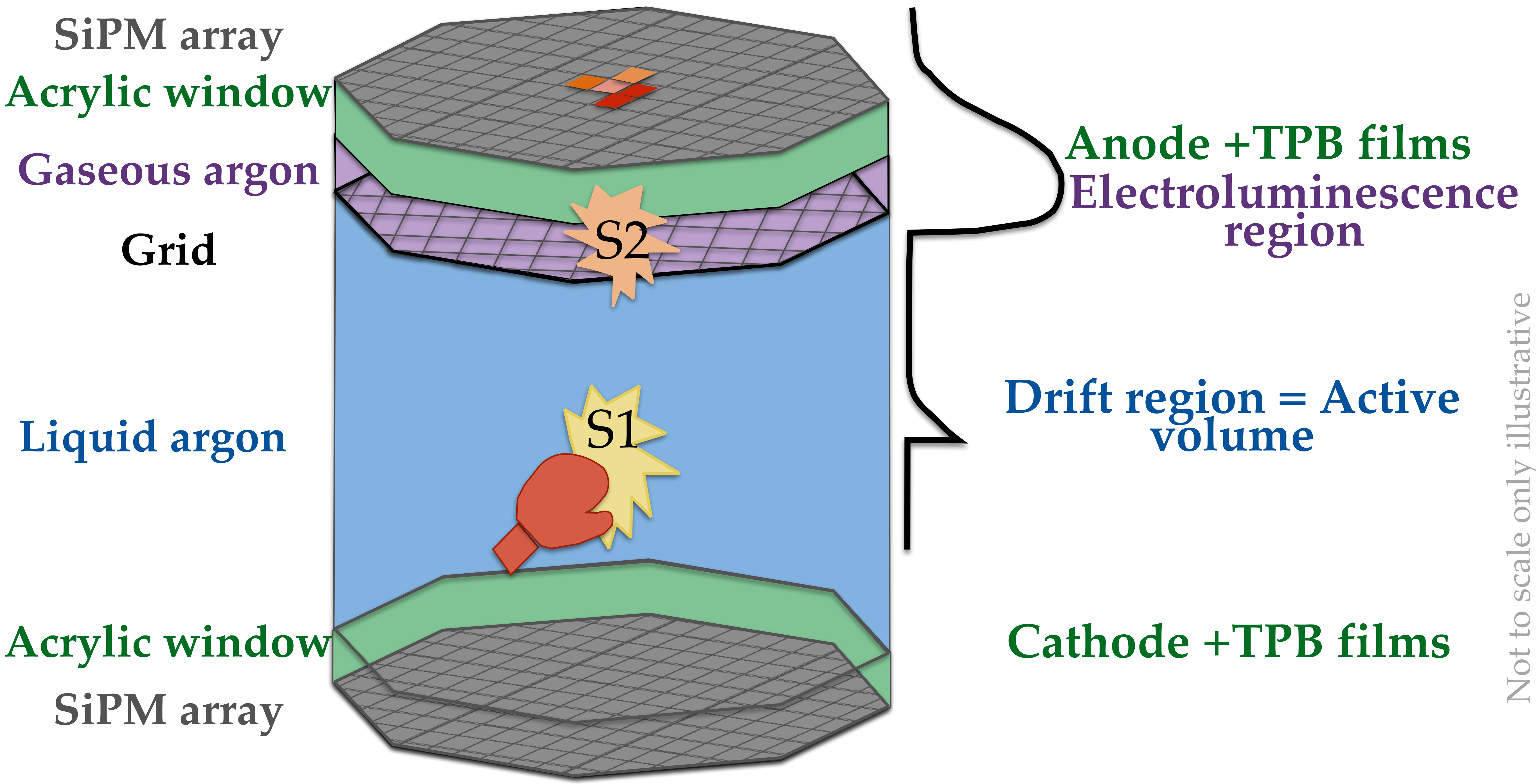
with Gd-loaded acrylic shell

Cu Faraday cage

ProtoDUNE- style membrane cryostat

@LNGS

DarkSide-20k Dual-phase LAr TPC



Calorimetry (S1, S2) + 3D positioning + Time profile of S1 (PSD) + S2/S1 + ….

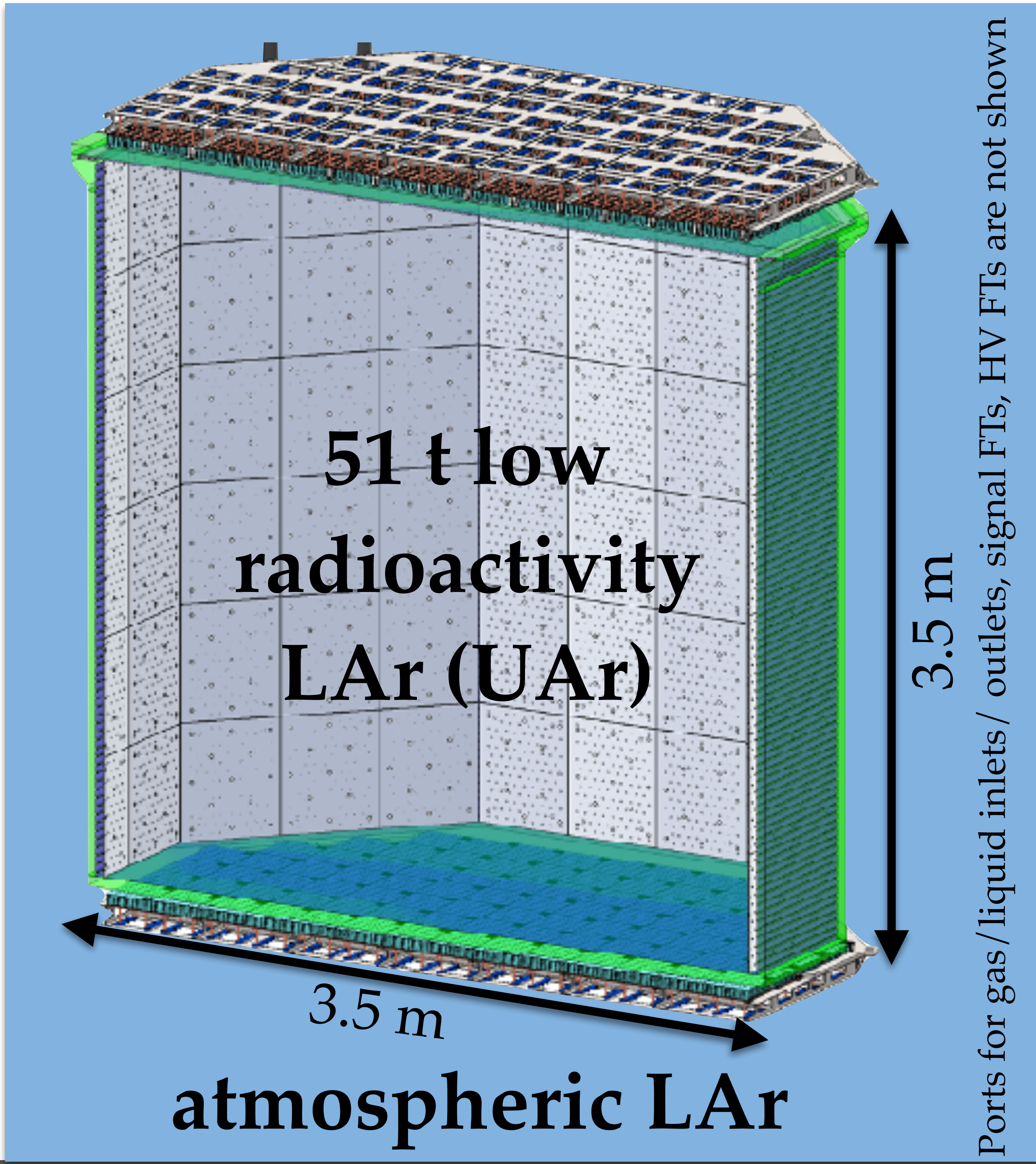
TPC inside a sealed acrylic vessel

Radio-pure acrylic vessel immersed in atmospheric LAr serves as containment for dual-phase TPC filled with 51 tones of low radioactivity LAr (UAr).

Ensures:
Minimal dead UAr volume

Eliminates:
The cryostat - potentially large contributor to the nuclear recoil backgrounds

Requires:
1. bonding/machining/annealing of large scale acrylic panels ✓
2. sealed ports for gas/liquid/cables with acrylic to metal transition ✓
3. taking care of mechanical stress and buoyancy of acrylic, and differential pressure. ✓

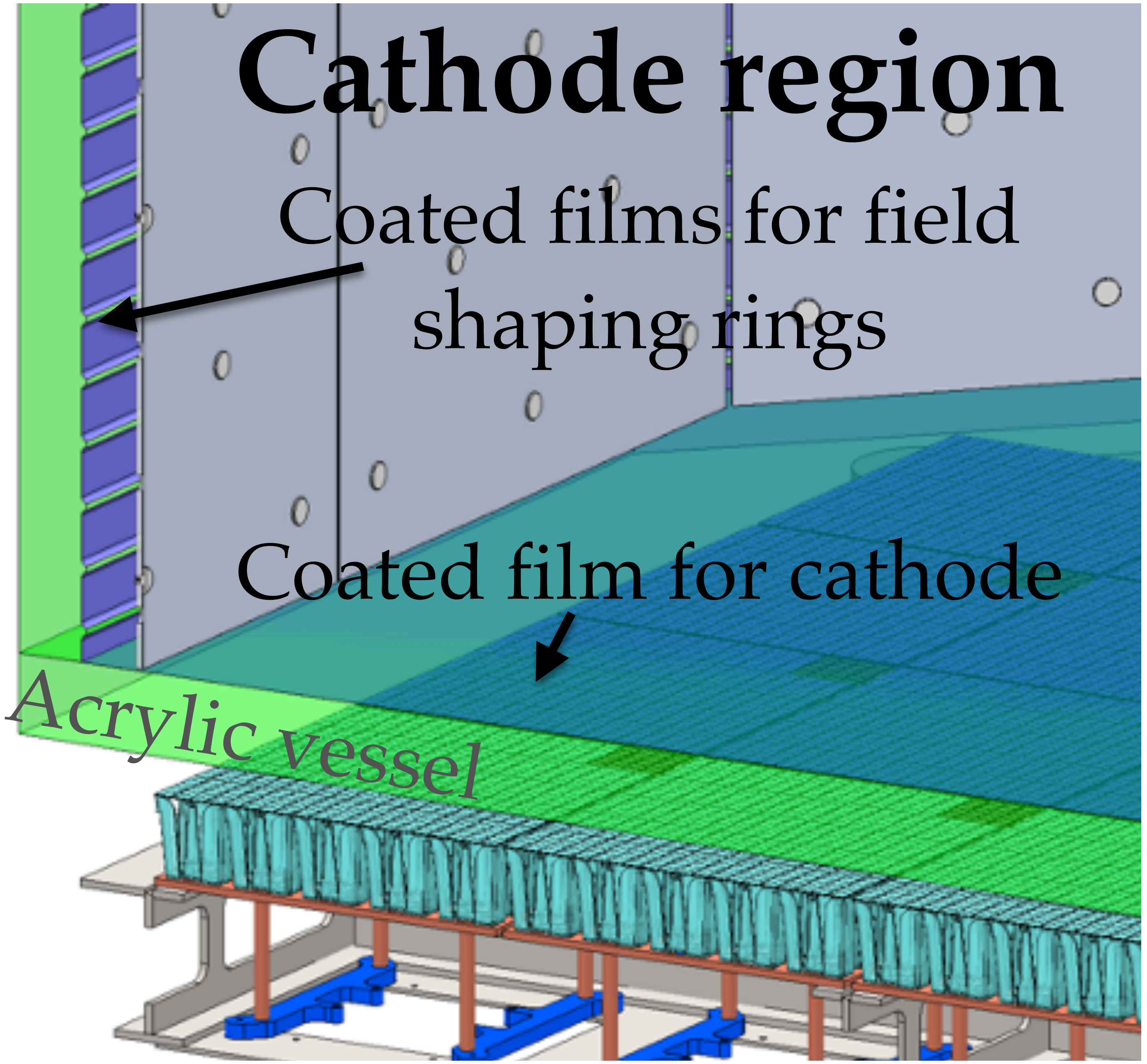


Field cage/electrodes integrated into acrylic vessel

Conductive polymer films (Clevios) spray coated for transparent electrodes and field shaping rings. The inner surface of the acrylic vessel grooved in a shape similar to a typical electrode ring.

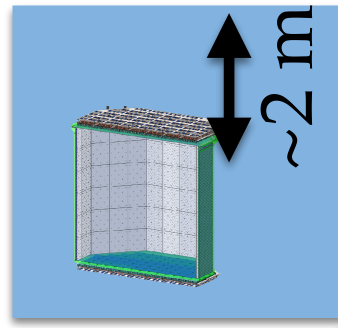
Eliminates:
The copper field cage rings which have more mass and hence shadowing effects between TPC and veto.

Requires:
1. Transparency measurement
2. Application and handling procedure.
3. Optimization of the geometry to maintain field uniformity.
4. Long term tests of the stability of the films and their performance

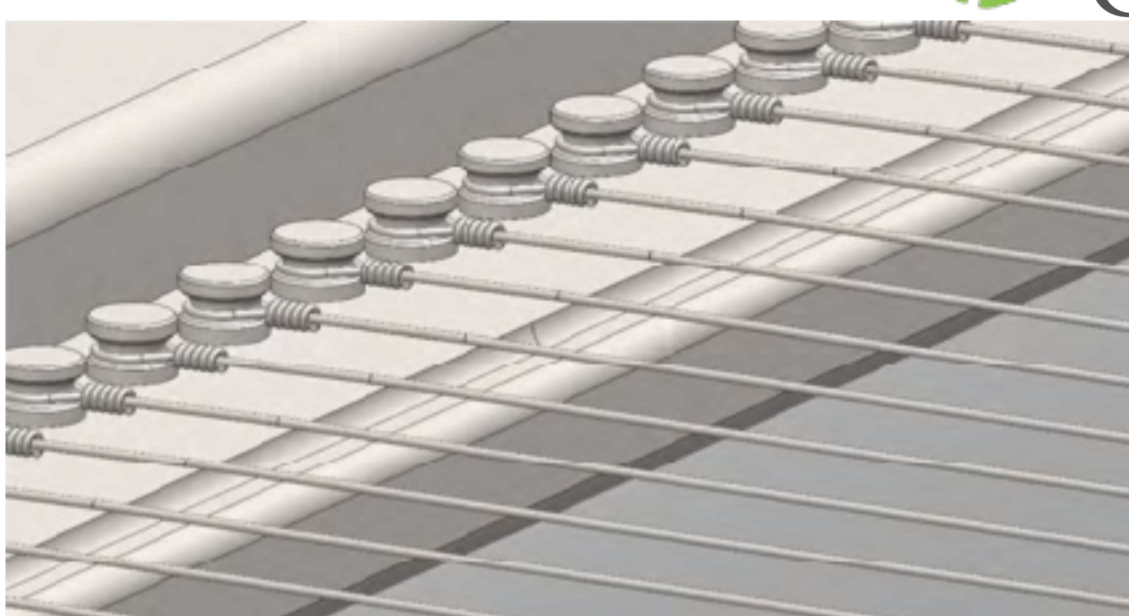


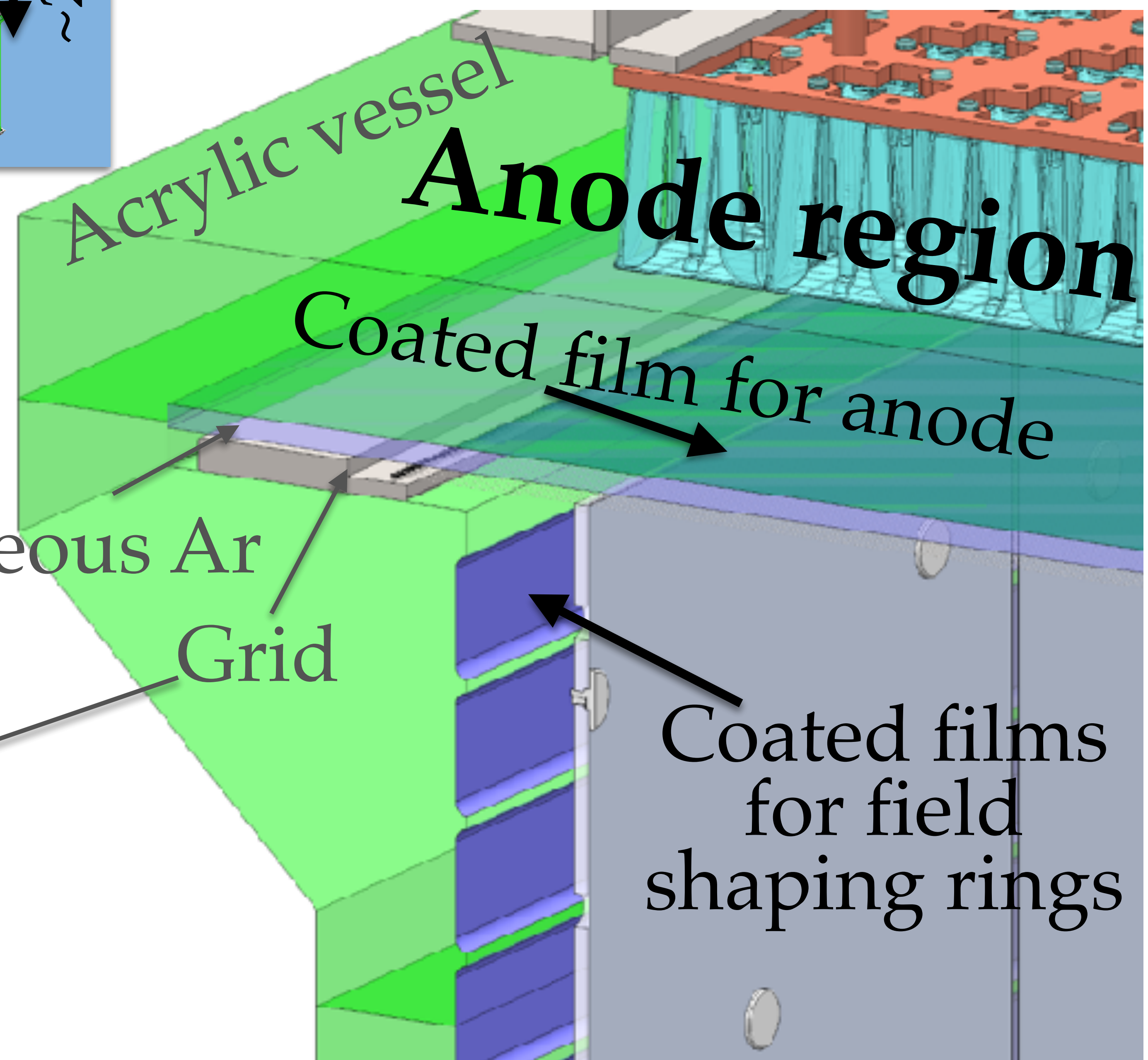
Electroluminescence region via diving bell

Gas pocket via diving bell (bubbler and gas feed-in). Stainless steel grid wire (with dense wire spacing of 3mm and optical transparency of 97%).



Requires:
1. Maintaining gas pocket at a depth of ~2m.
2. Maintaining the flatness of grid and anode over a large distance to achieve high tolerance on thickness of gas pocket (7± 0.5mm).

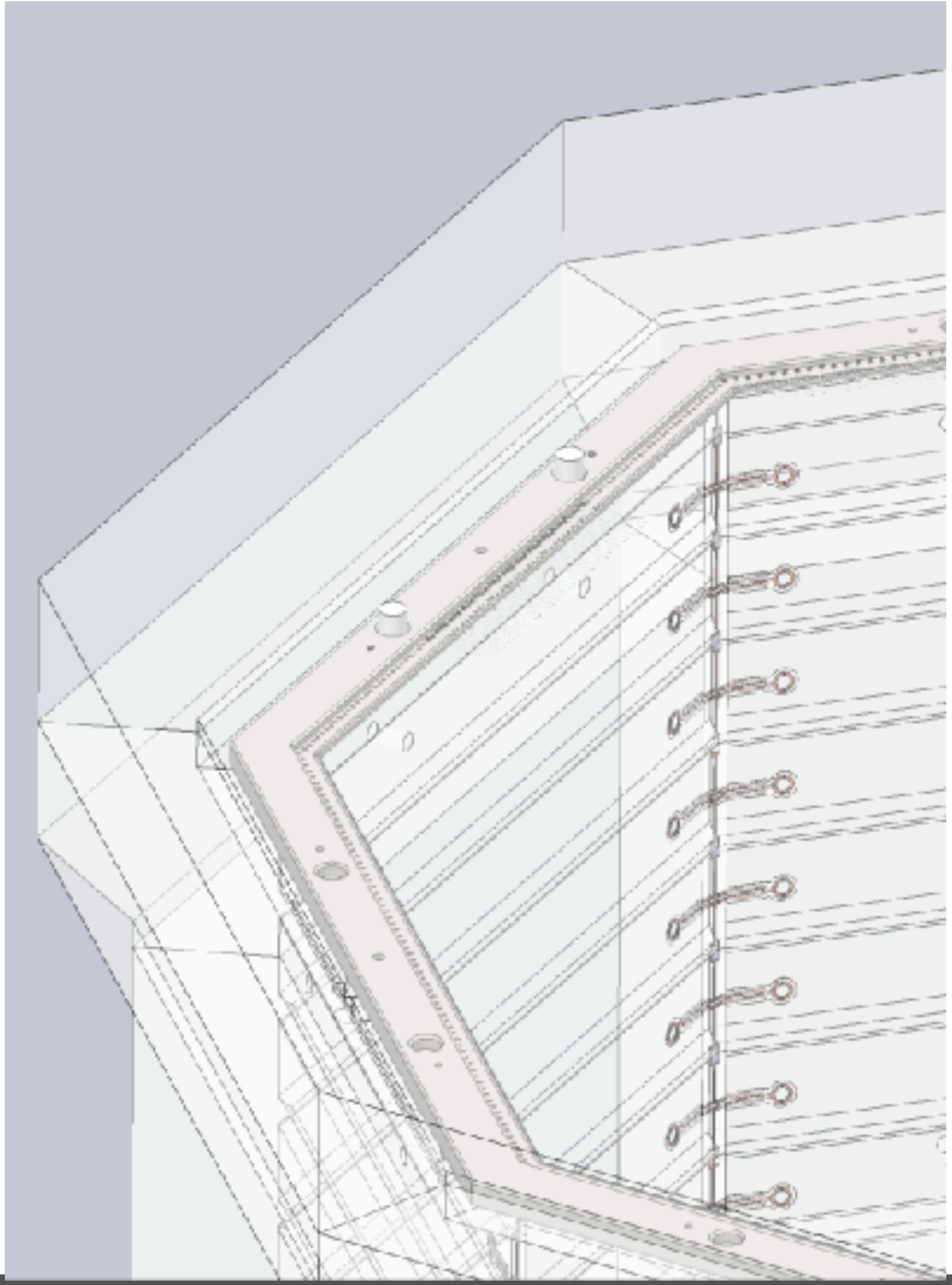


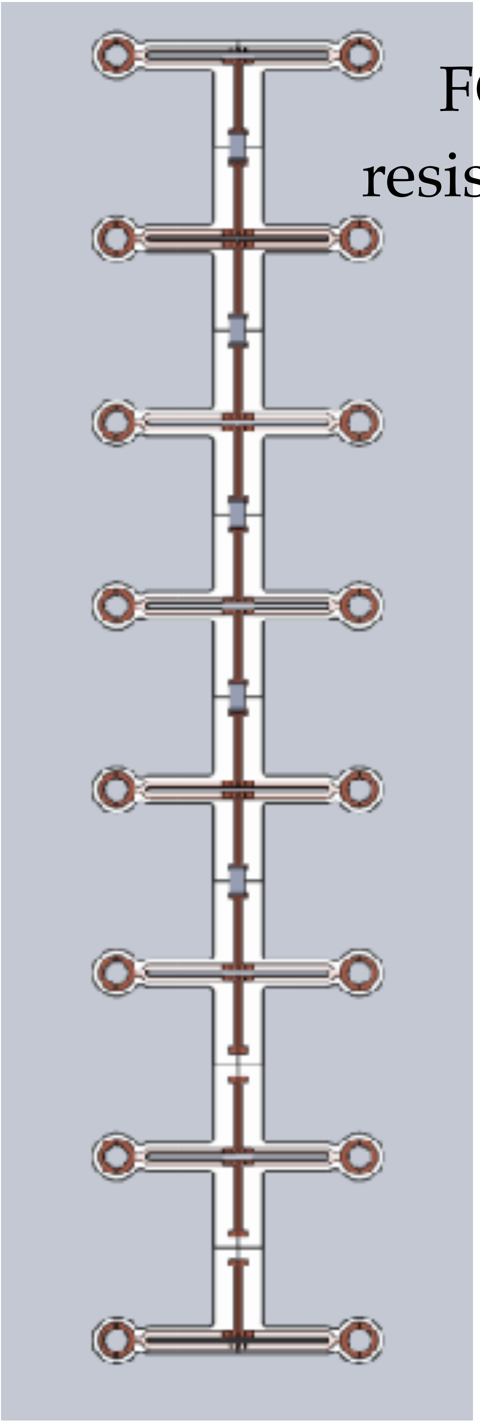


Flexible HV divider

Field cage resistors mounted on the flexible Cu-Kapton-Cu substrate with a modular design and installed for redundancy at four corners.

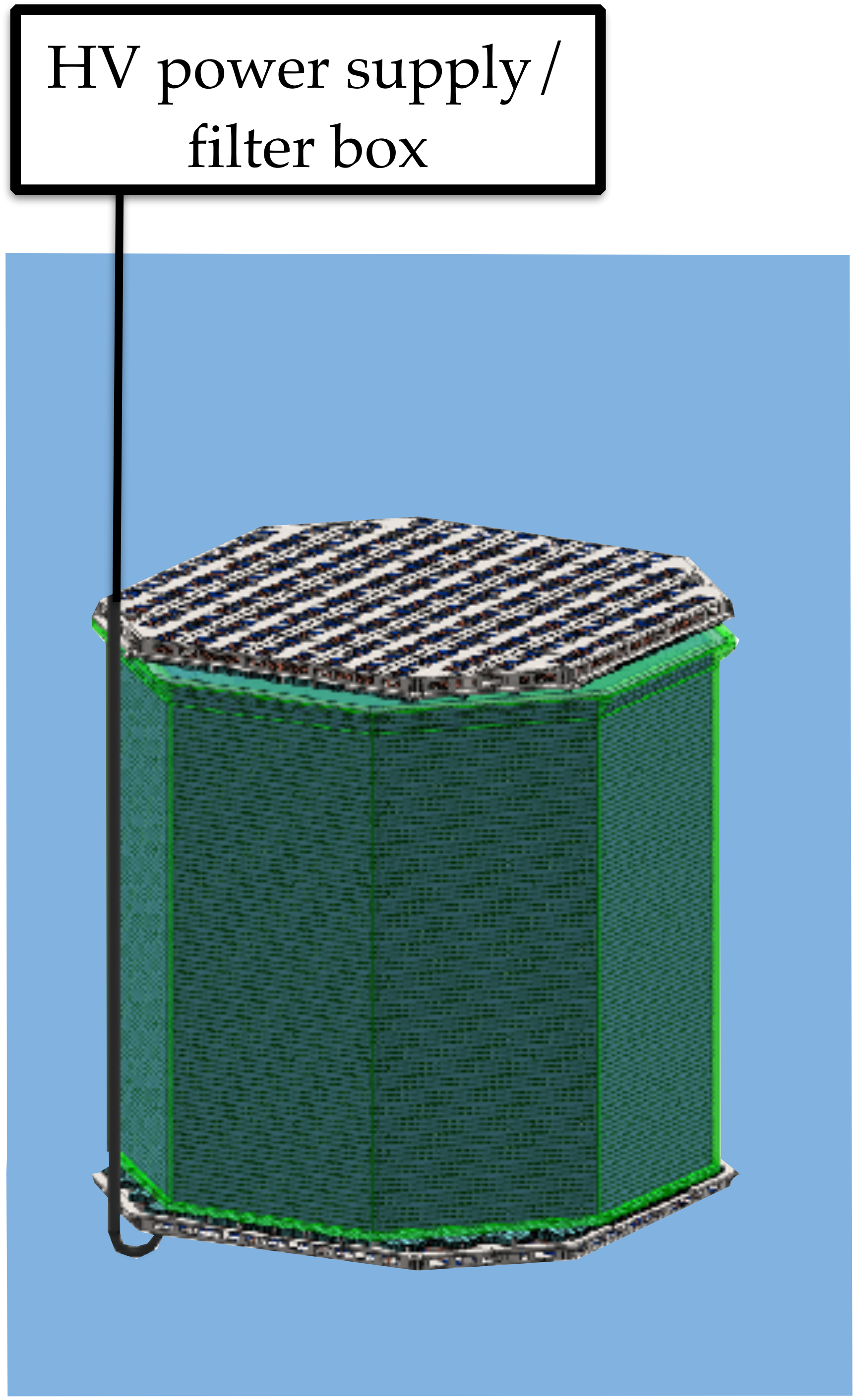
Provides:
1. Placement of field cage resistors in a low electric field region
2. Simplified mounting procedure





HV delivery via single coaxial PE cable

Continuous HV coaxial polyethylene cable from HV Power supply/Filter box until the cathode HV plug passing through membrane cryostat, copper cage and veto.



Eliminates:
1. the need for multiple breaking points
2. the mismatch of thermal coefficients in building materials

Requires*:
1. Long term R&D and testing
2. Taking care of cable shrinkage, bending and stresses over long distance ~8m in cryogenic setting
3. Development of Acrylic/metal FT
4. Development PE/metal joints

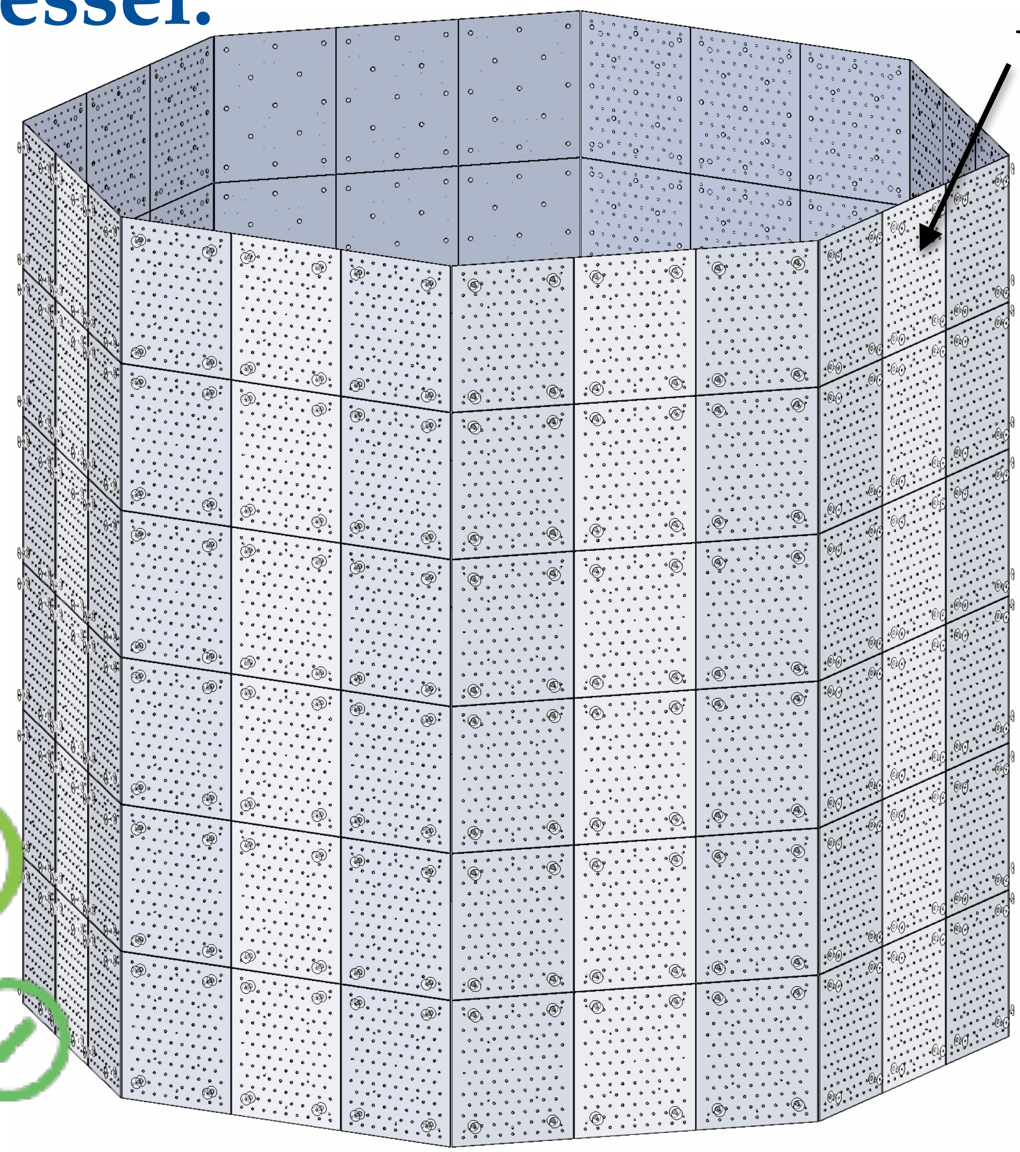
*More info in a poster session 25 May 2021: A new HV cable feedthrough concept for future DM and Nu exps.

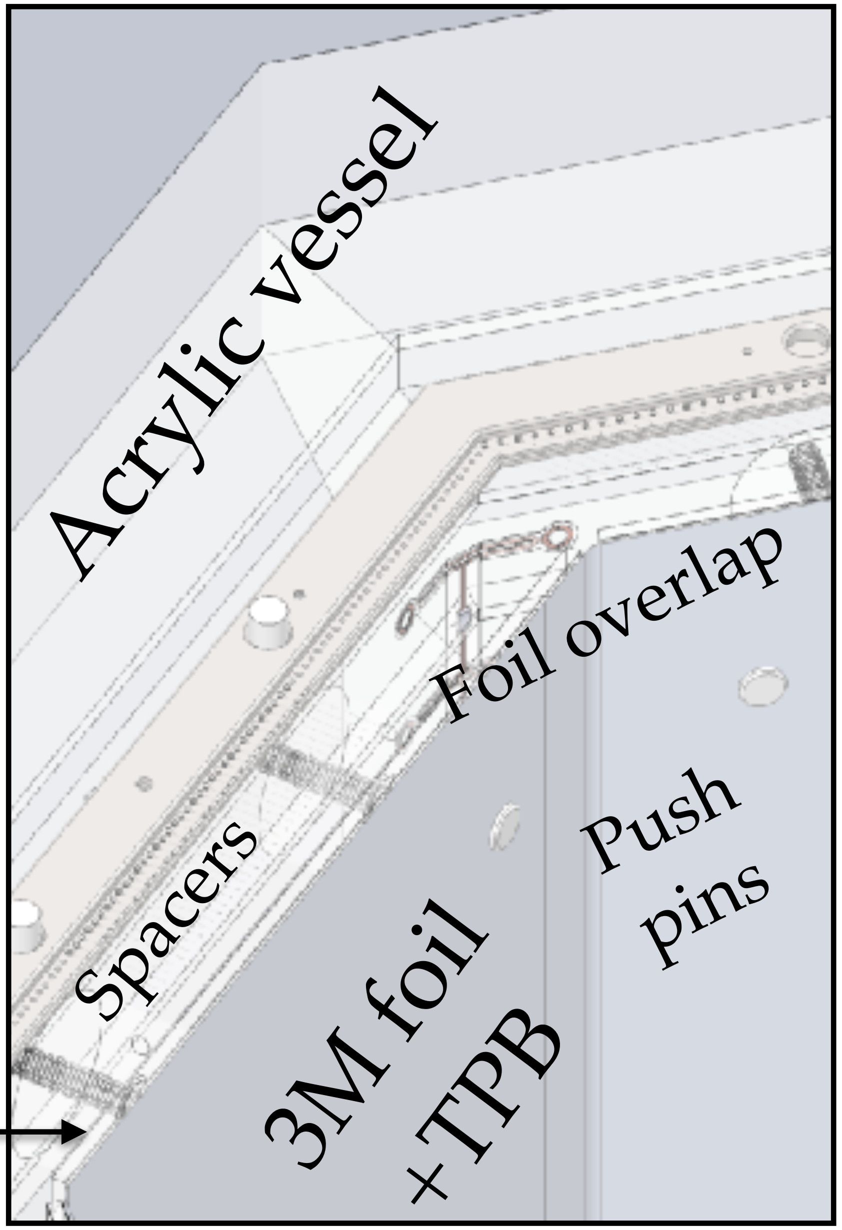
Modular 3M foil-based reflective cage +TPB

Array of wavelength shifter (TPB) coated 3M ESR foils held (via push pins) on a thin (~4mm) acrylic panel that is mounted directly on acrylic vessel.

Eliminates:
1. Teflon cage - potentially large contributor to the nuclear recoil and Cherenkov bgds.

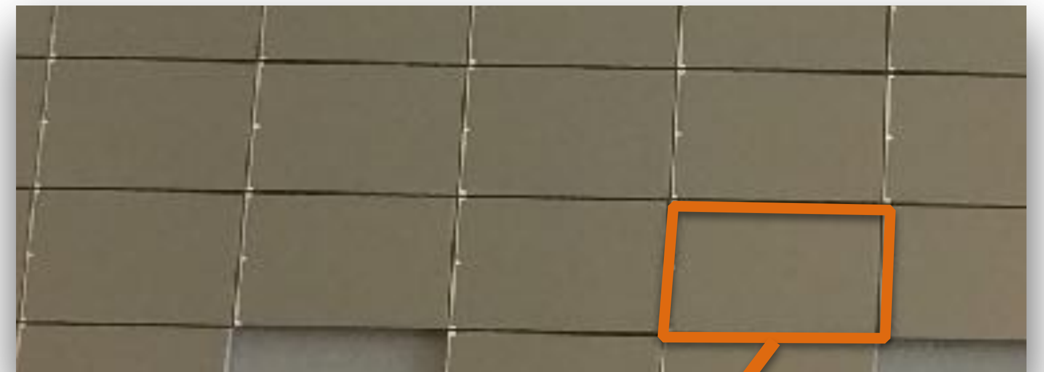
Requires:
1. Radio-purity screening (surface)
2. Application and handling procedure
3. Taking care of light tightness and thermal contraction in cryogenic conditions



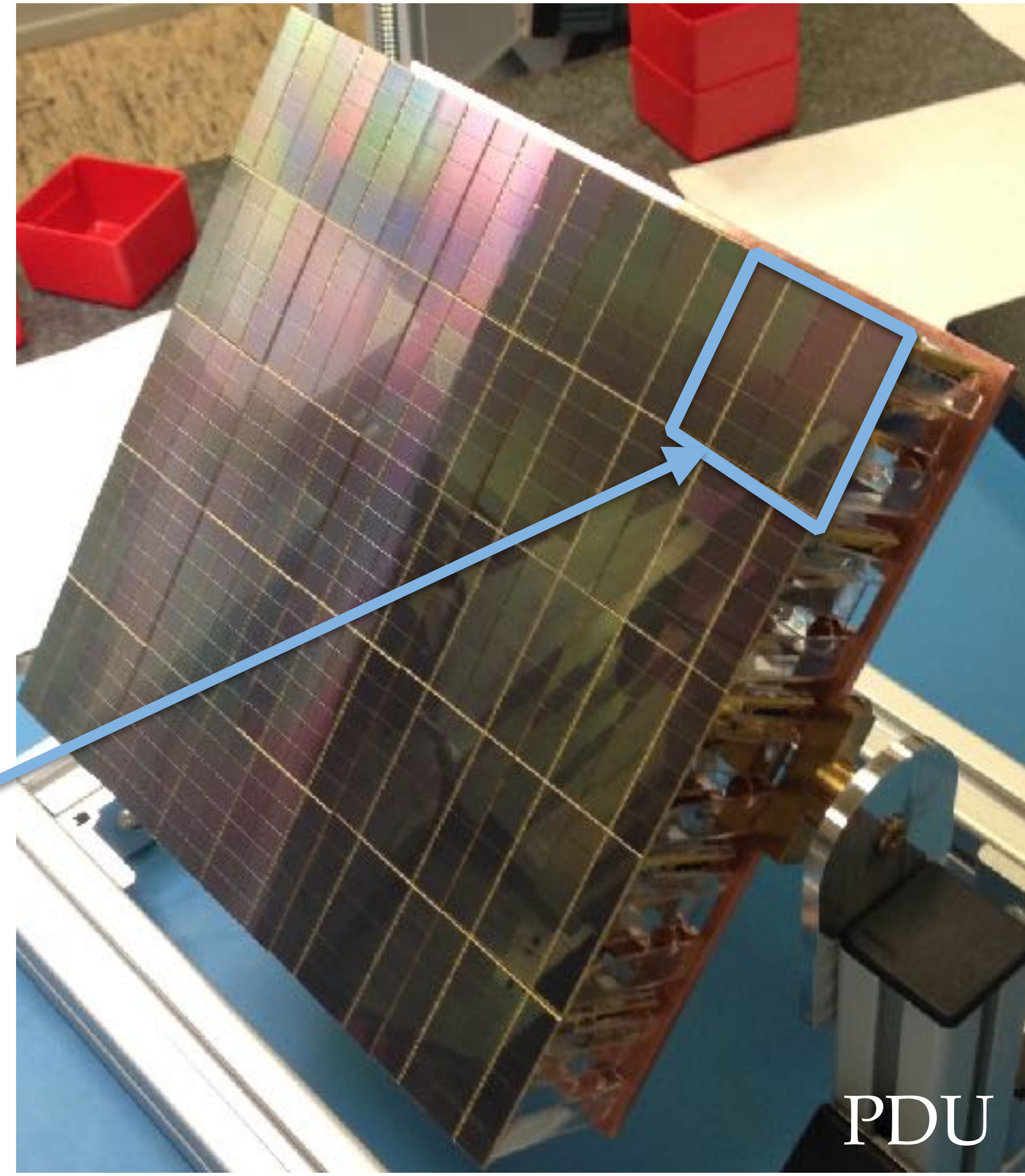


SiPM-based array of photodetector modules

SiMPs: 8x12 mm FBK LF NUV-HD



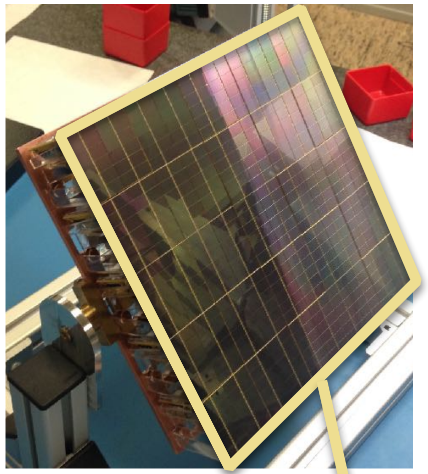
detector module = 5x5 cm^2 SiPM array plus front end electronics



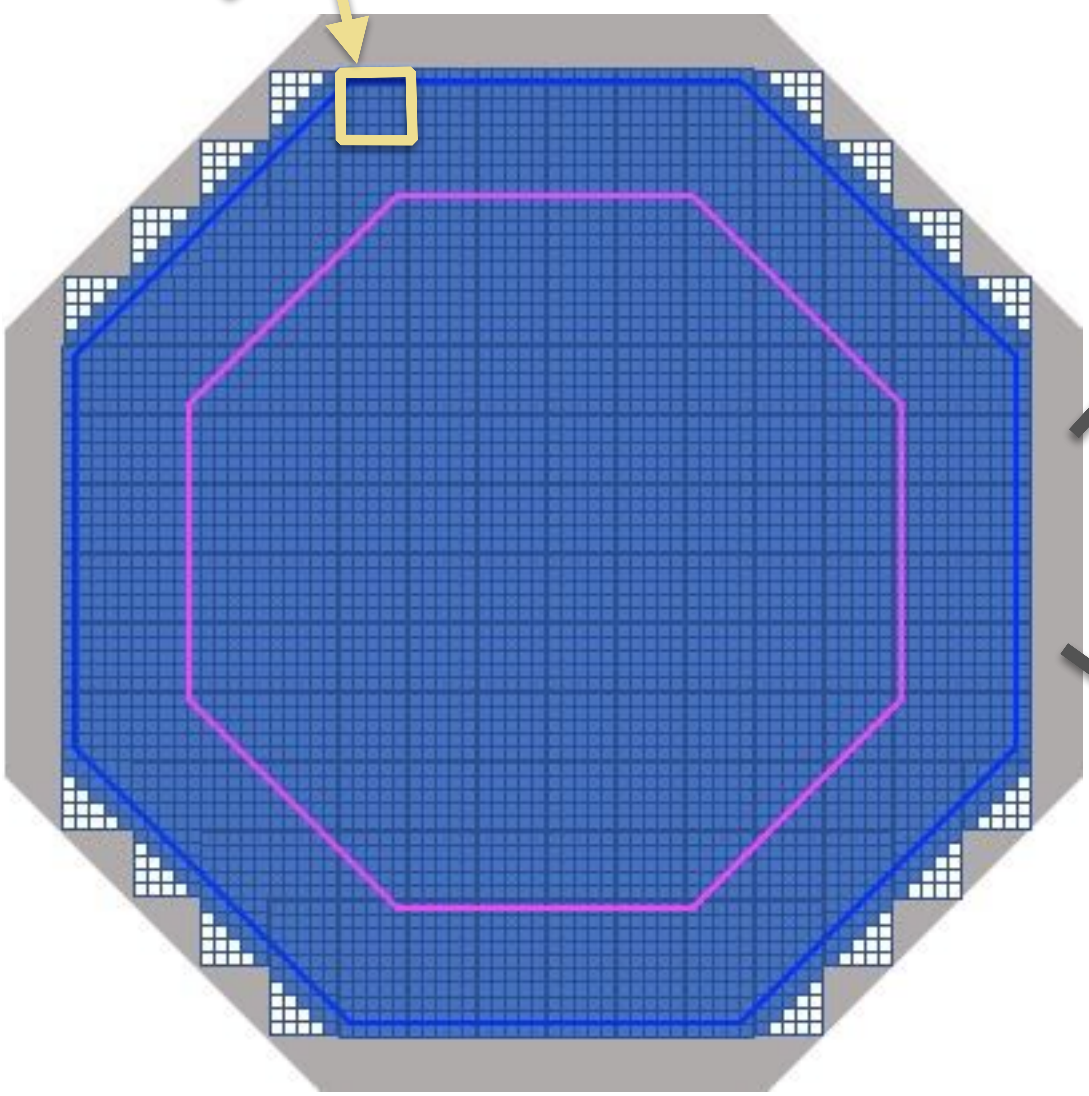
motherboard= 25x25 cm^2 array of detector modules + ‘steering module’ + transmitter

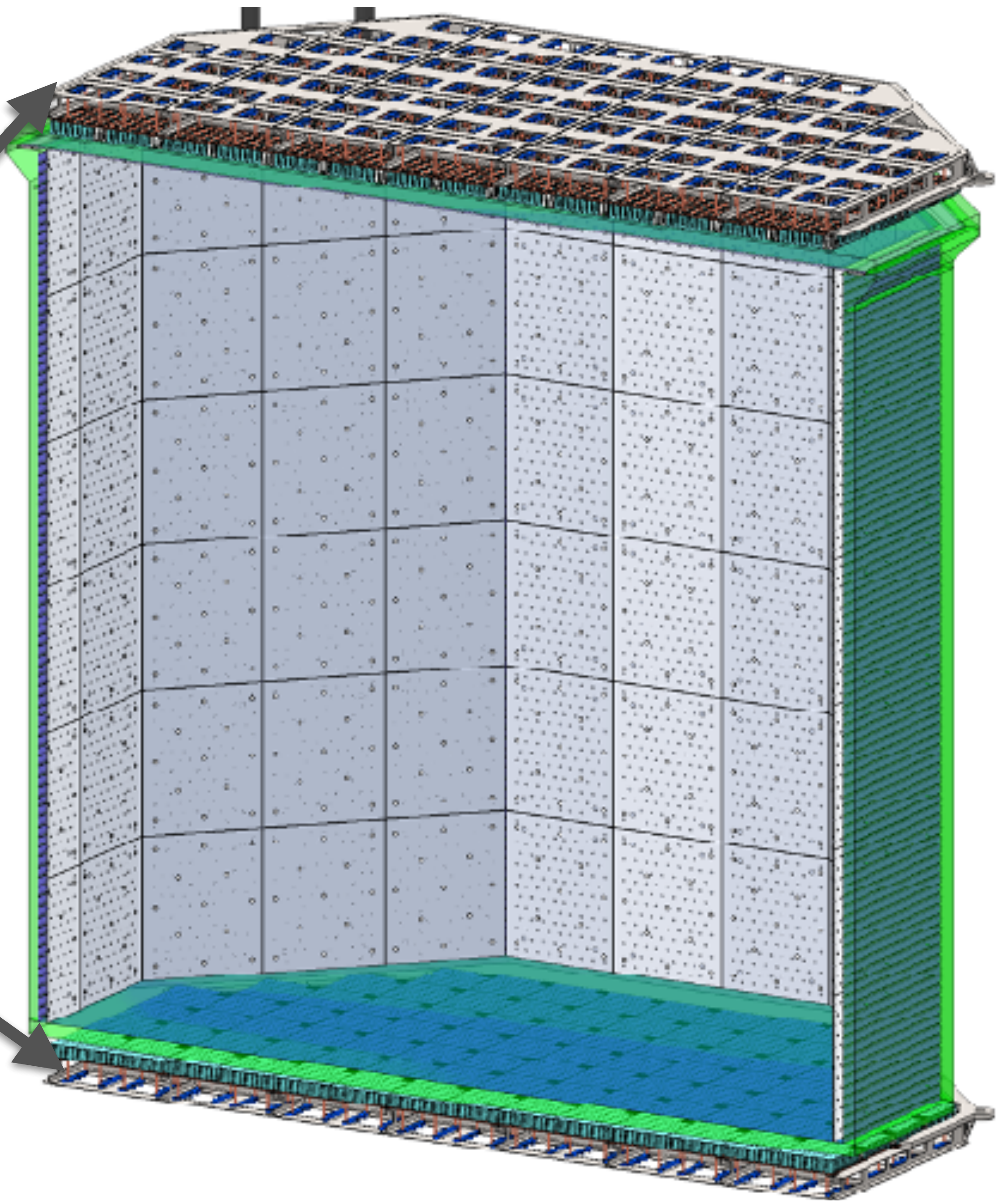
NUV => 40 % in 400–420 nm HD = border structure for high-density packing LF= low-field in the avalanche region,

21 m^2 of SiPM covered surface



Octagonal top and bottom SiPM-based arrays
are mounted outside acrylic vessel.

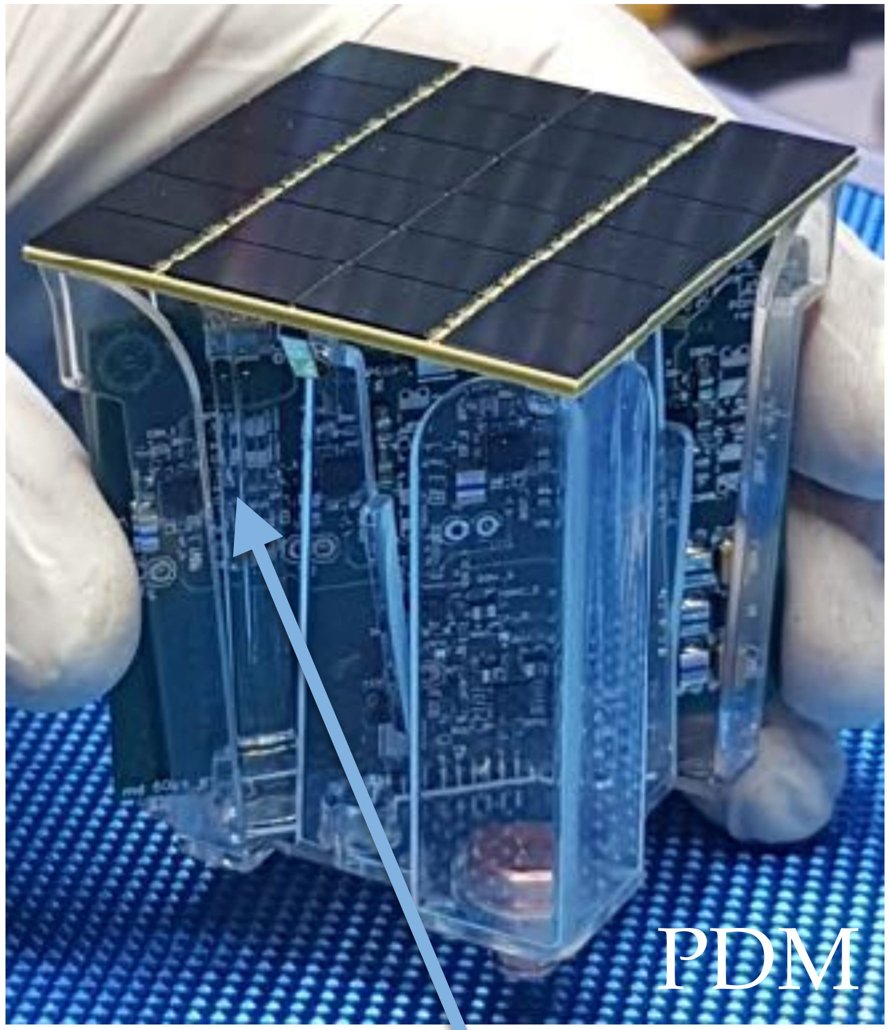


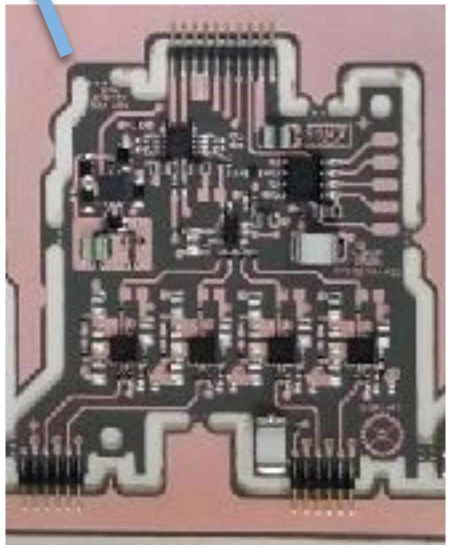


SiPM-based photodetector modules

Provides wrt comparable size PMT+base:
1. Operation in LAr
2. Higher photo-detection efficiency
3. Better single photon resolution
4. Lower bias voltage (Lower power dissipation)
5. Larger effective area vs full area
6. Lower radioactivity (U,Th chains) normalized per effective photo area*
7. More compact photosensor in height

Requires extensive R&D:
1. To optimize built-in and operation parameters as well as front-end cryogenic readout electronics to meet specs: PDE=45%, SNR>8, dark count rate <200cps, fill factor 90%, time resolution <10ns .….
2. To transfer the SiPM technology from FBK to larger facility LFoundry for mass production
3. Establishment of the facility for assembly/packaging of photodetector modules (NOA@LNGS)
4. Development of the readout chain for dynamic range of >50 PE



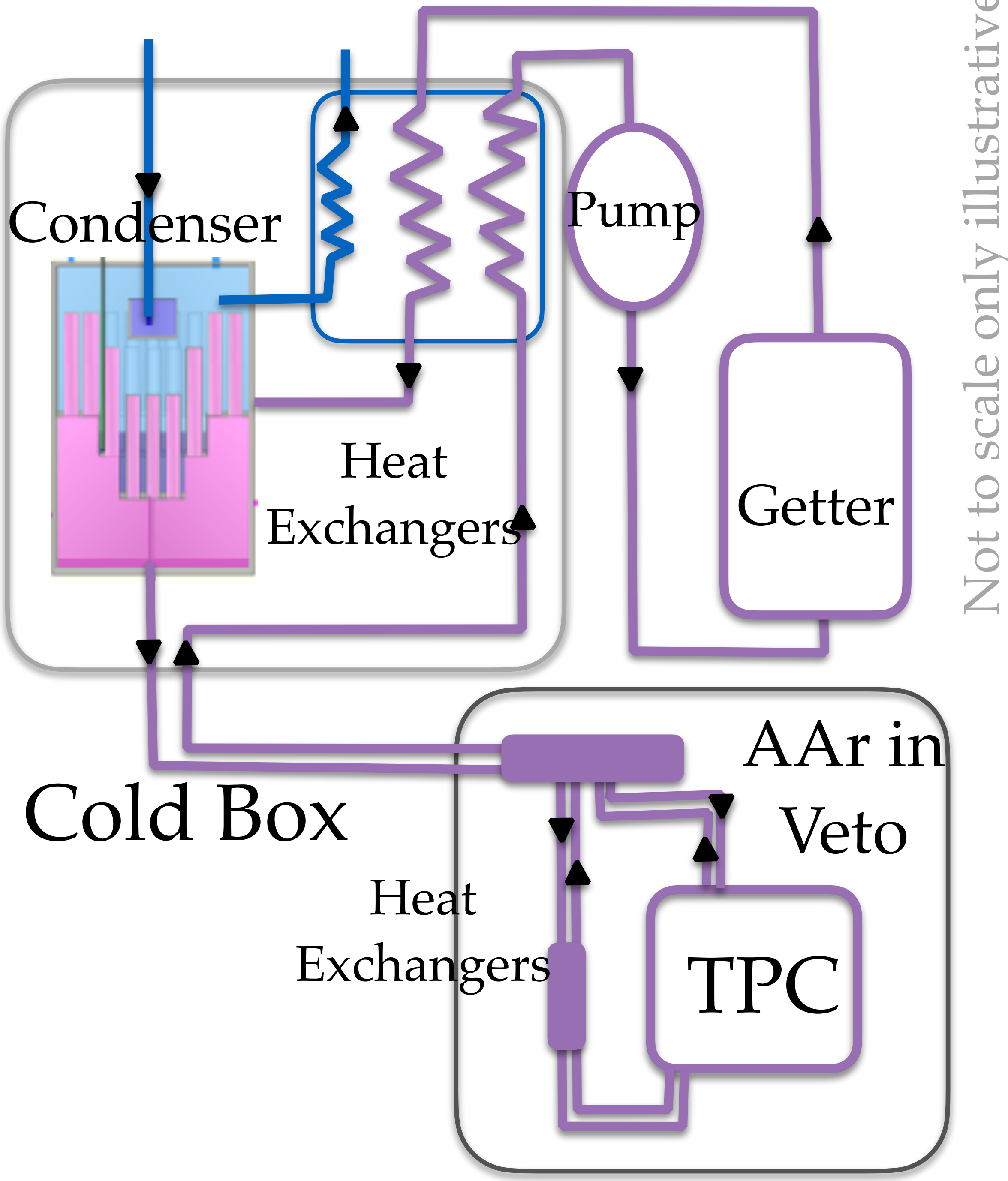


FEB

UAr cryogenic system with 500W cooling power

UAr cryogenics and gas handling system based on DS-50 design but scaled to accommodate circulation and purification speed of up to 1000 slpm and enable electron drift lifetime >5ms.

The integration and the test of the full-scale UAr cryogenic system completed @CERN



DarkSide-Proto(~1t): test detector components

Needed to:

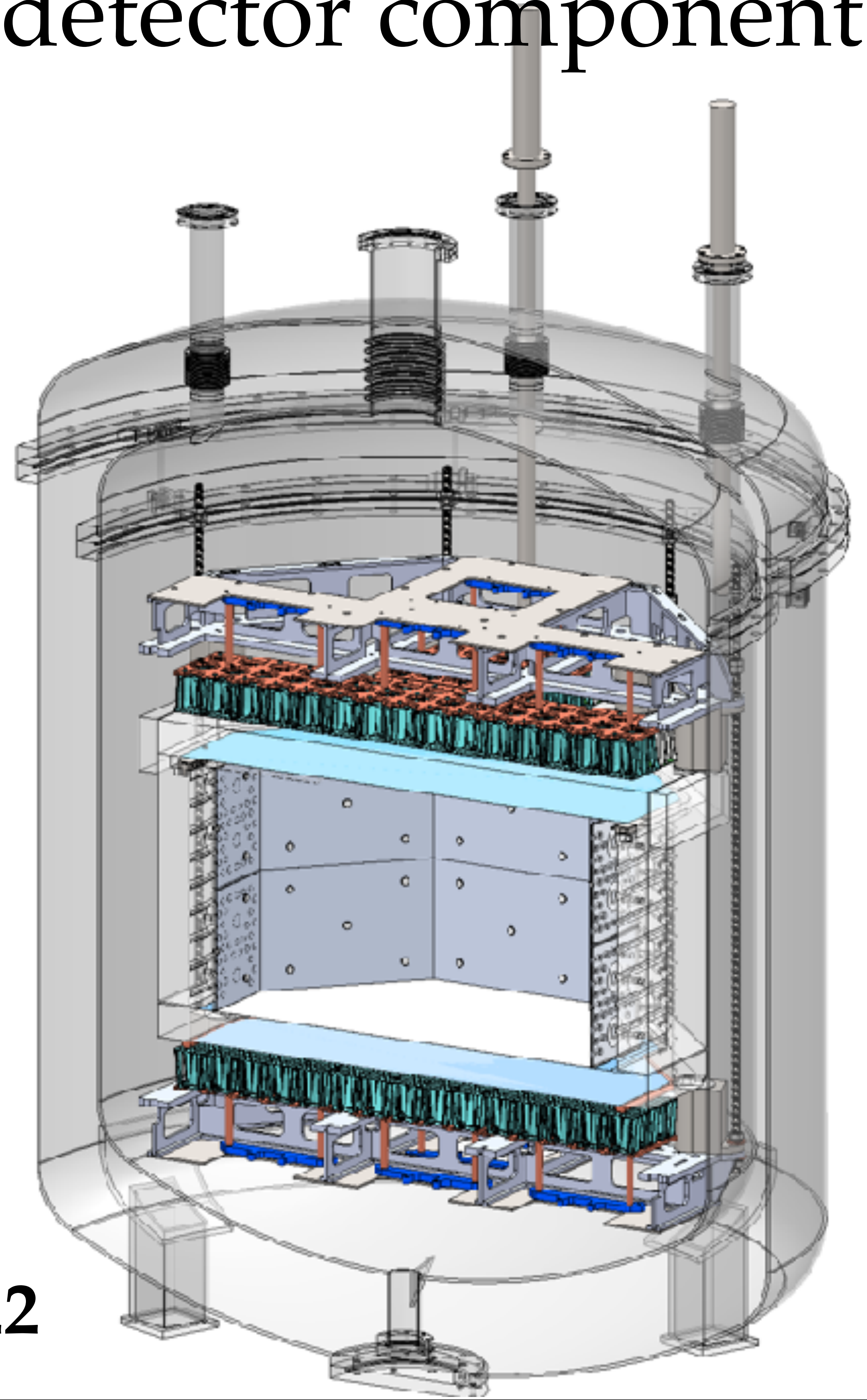
1.validate detector components (full size when possible) and their integration

2. validate photodetector motherboards and readout

3. perform second test for the cryogenic system

4. perform functionality and stability tests

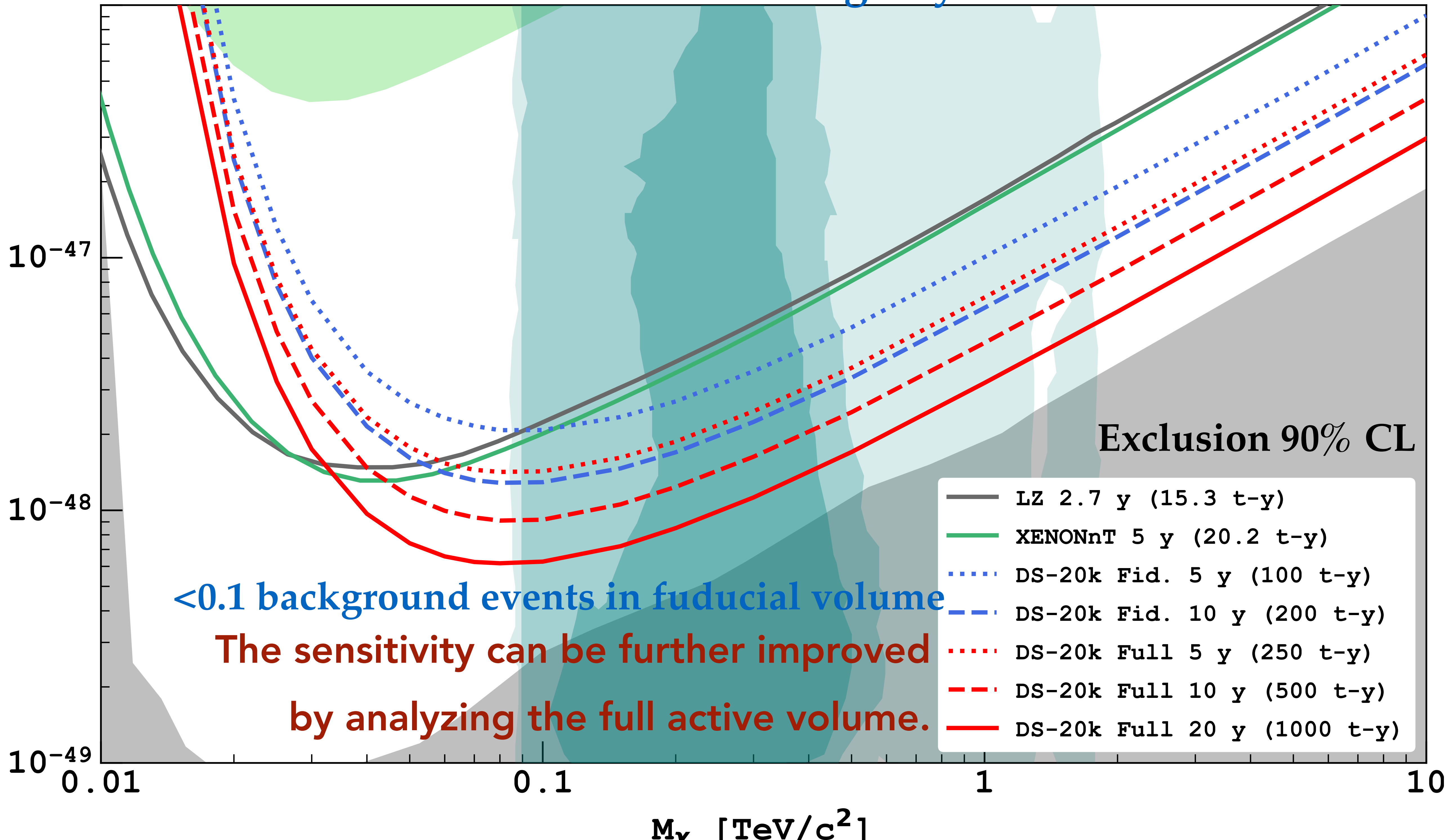
5 ….



Operation planned in 2022

The DarkSide-20k sensitivity to spin independent WIMPs

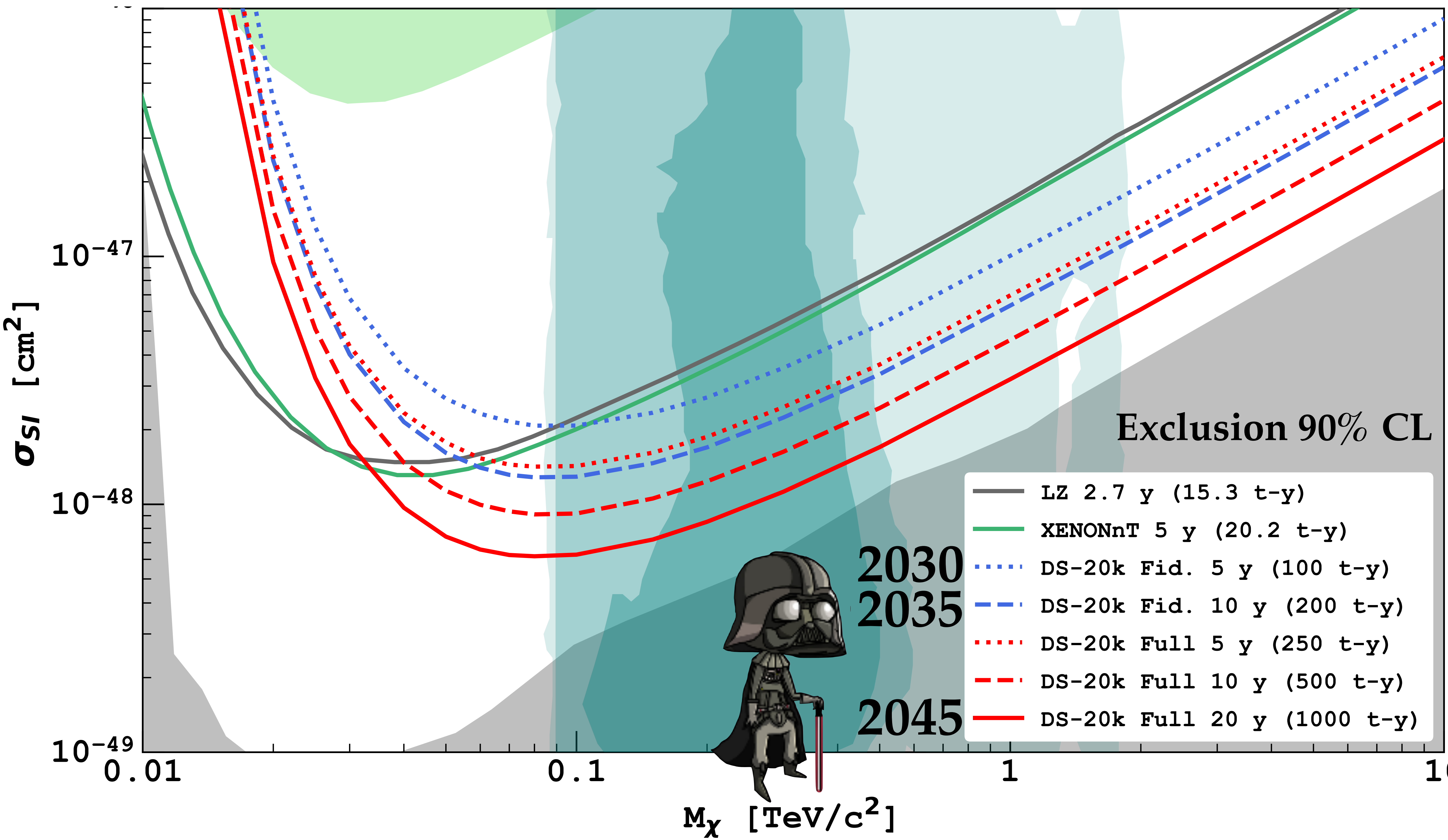
Goal: <0.1 background events except coherent neutrino scatters after all TPC &veto event selection criteria in ROI (20-200keVnr) within 20.2 t fiducial volume during 10 y run.



1,2.3 σ favored regions from pMSSM11 model constrained with the data in turquoise, neutrino floor in shaded gray

Summary:

Darkside-20k TPC and overall detector design will provide a very low background rate and allow a long exposure time bringing the sensitivity closer to neutrino floor.



1,2.3 σ favored regions from pMSSM11 model constrained with the data in turquoise, neutrino floor in shaded gray

Thank you

DarkSide-20k collaboration currently has more than 350 scientists.

DarkSide-20k project is funded via INFN, NSF, CFI, DOE-HEP, STFC and other grants.

Backup

DarkSide20k events in 200 ty exposure

Goal: <0.1 background events after all TPC &veto event selection criteria in ROI (20-200keVnr) within 20.2 t fiducial volume during 10 y run.

Source	Tools	Evts/[200t yr]
β/γ, e -ν	Material selection, Purified UAr, PSD, S2/S1, fiducialization/veto for γ	<0.1
(α,n) ns Fission ns ^{222}Rn diffusion/surface plate out	Material selection, Rn-suppressed air, veto, multiple scatter …	<0.09 <0.001 <0.004
Cosmogenic ns ns from lab rock	veto, multiple scatter, fiducialization	<0.03 <0.003
Random surface α + S2	Material selection, Rn-suppressed air, S2 width, pattern recognition, fiducialization, …	<0.005
Random Cherenkov + S2	Material selection, pattern recognition, fiducialization, ….	<<<<
ν-induced NRs	Irreducible physics	3.0± 0.6