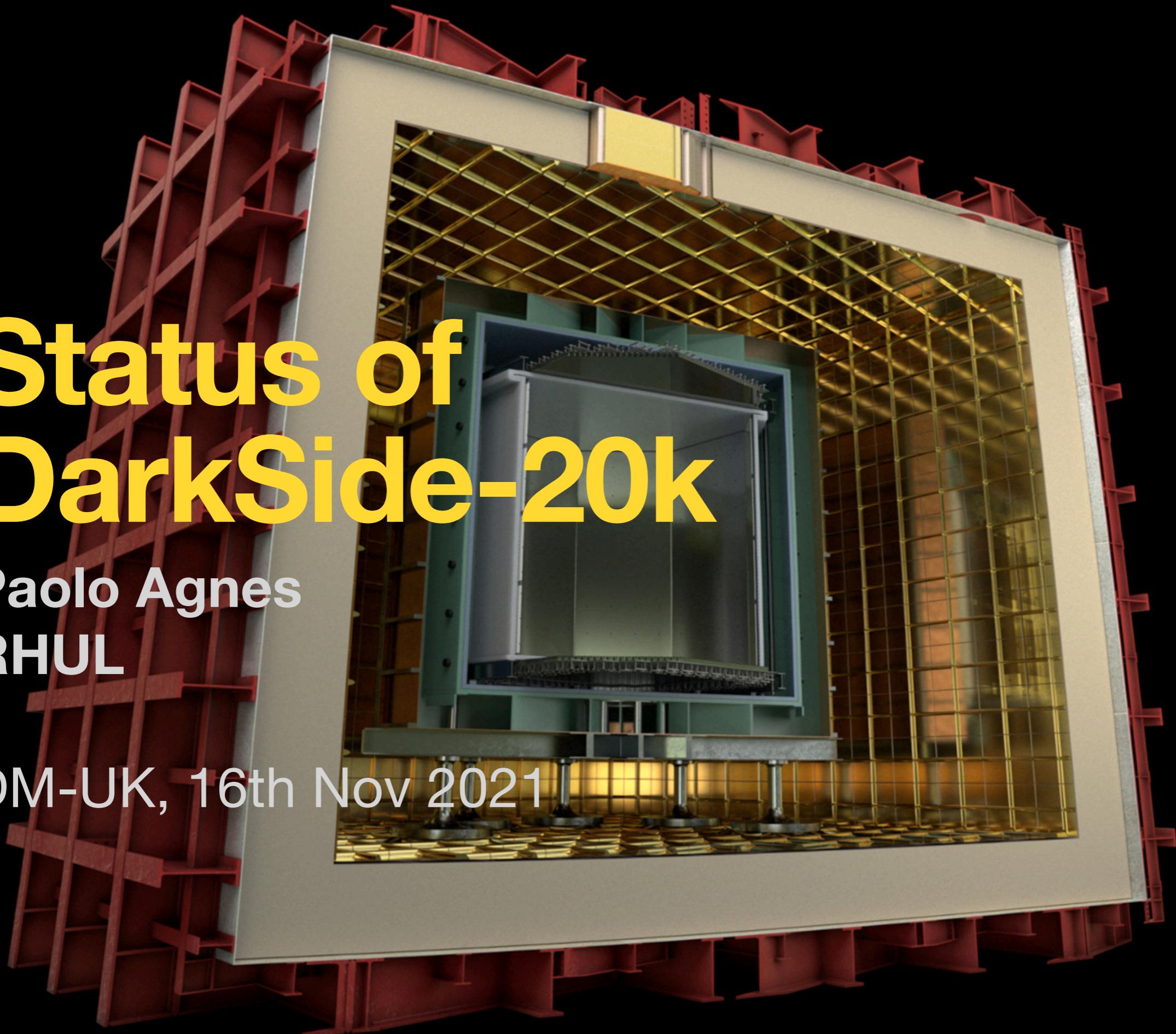




Status of DarkSide-20k

Paolo Agnes
RHUL

DM-UK, 16th Nov 2021



DarkSide-20k

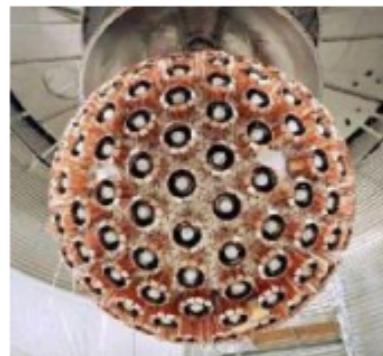
DarkSide-20k: next-generation LAr detector for direct detection of DM

Global Argon Dark Matter Collaboration (GADMC): 400 scientists, ~100 institutions!

DarkSide-50



ArDM



DEAP 3600



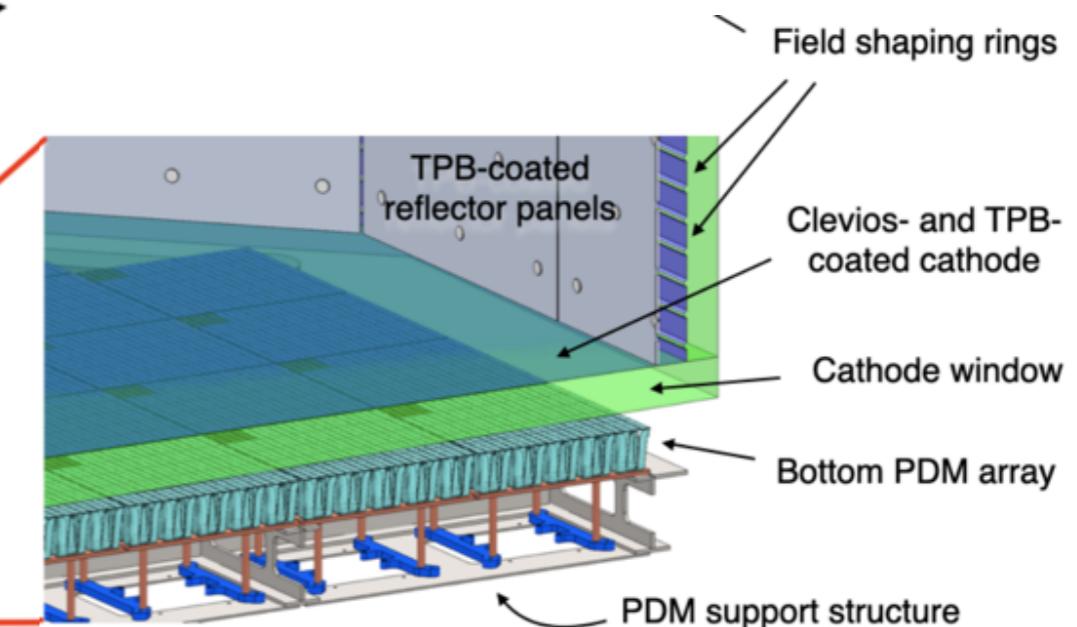
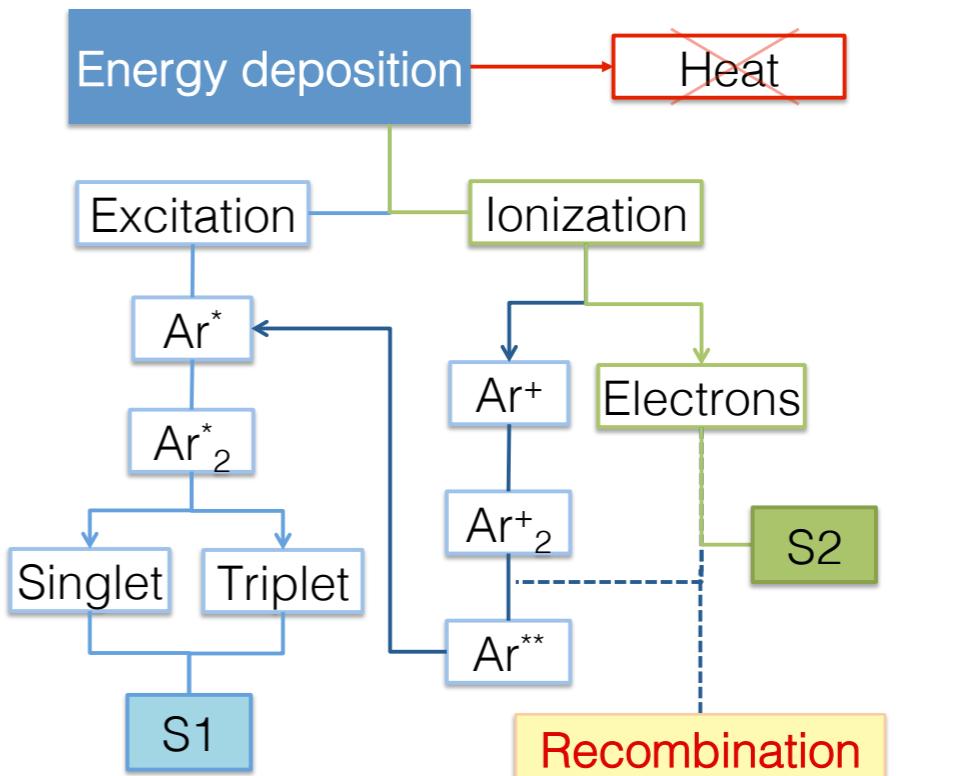
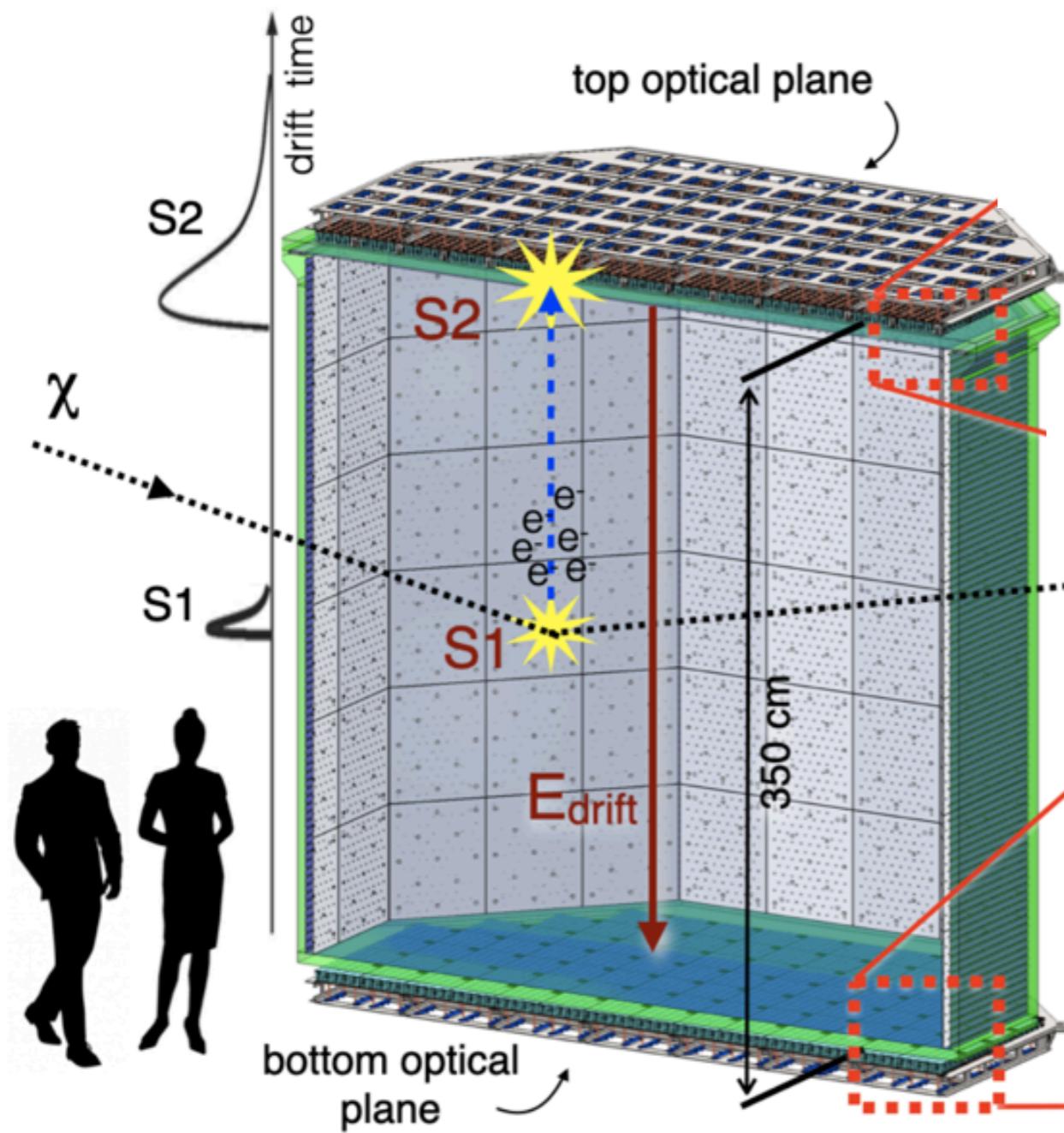
miniClean

DarkSide-20k, a 50 tonnes LAr target (>> current gen), aiming at **background-free** high-mass WIMP search:

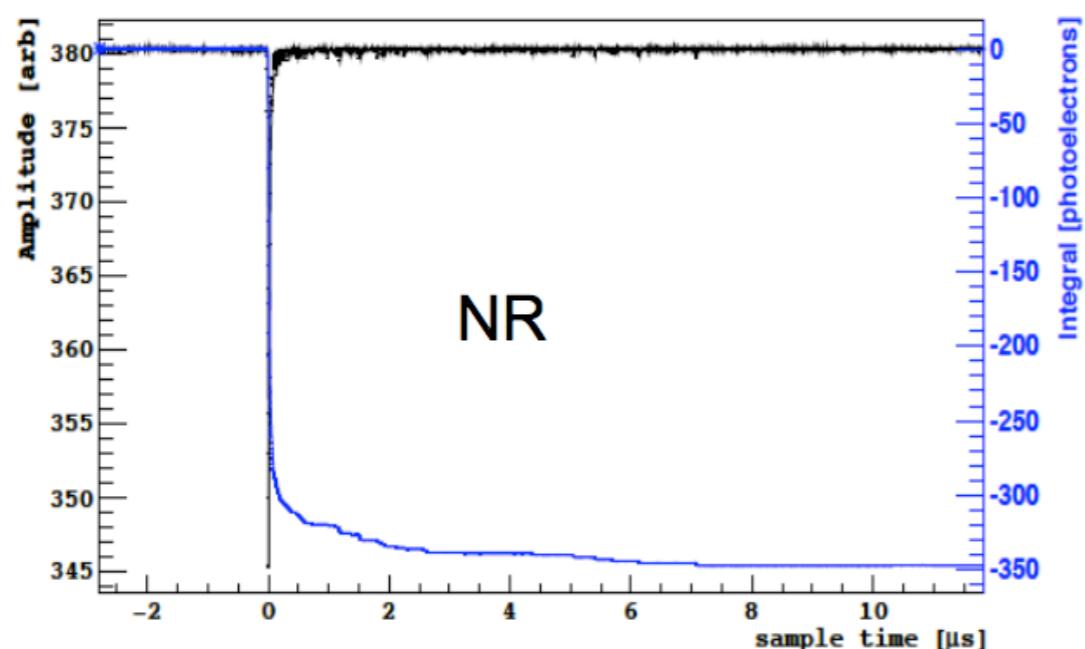
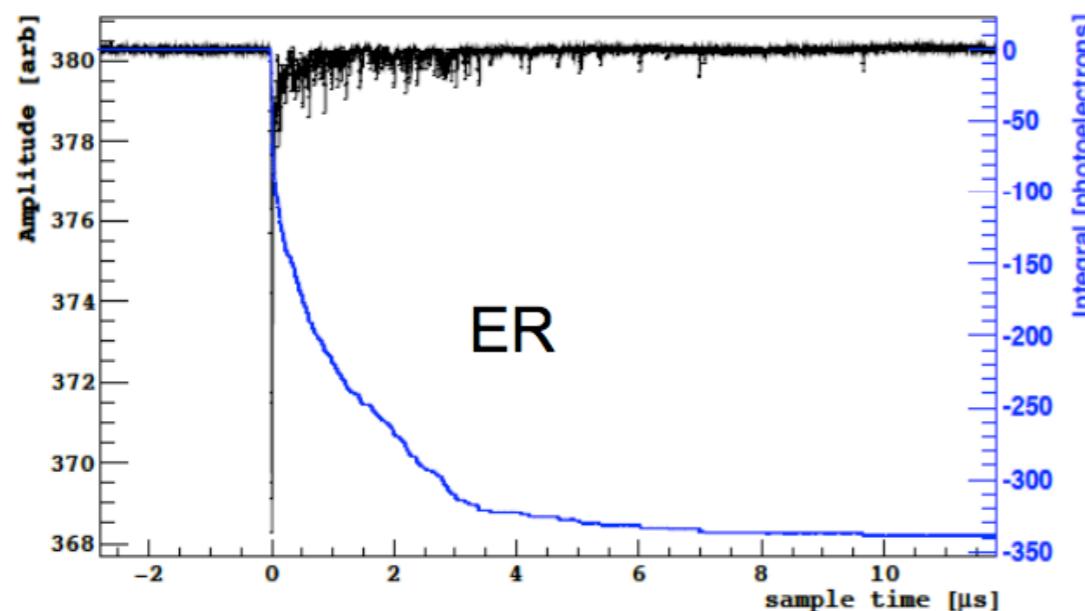
- Pulse Shape Discrimination (PSD) in Liquid Argon
- Argon extracted from underground (**UAr**)
 - URANIA*: facility in Colorado
- Chemical purification via *ARIA* in Sardinia
- Installed at LNGS in a copy of the protoDUNE cryostats (500 m³)
- Neutron veto made of 15 cm thick plastic scintillator loaded with GdOxide (R&D)
- Detection of scintillation using novel - custom-developed **Silicon Photomultiplier** (SiPM) arrays (multi yr R&D)
Requires > 20 m² !
- Construction started at LNGS
- Projected sensitivity ~10⁻⁴⁸ cm² at 100 GeV/c²

Dual-phase TPC

- 3.5 m drift length, 3.5 m diameter
- 200 V/cm nominal drift field
- 3D vertex reconstruction
(surface events, multi-sited events) !



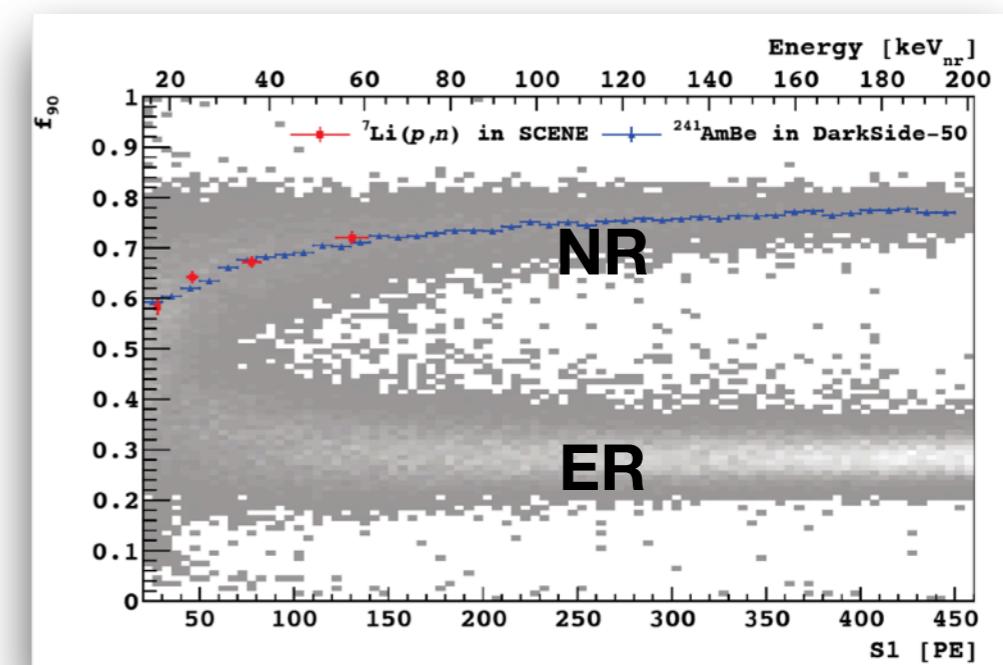
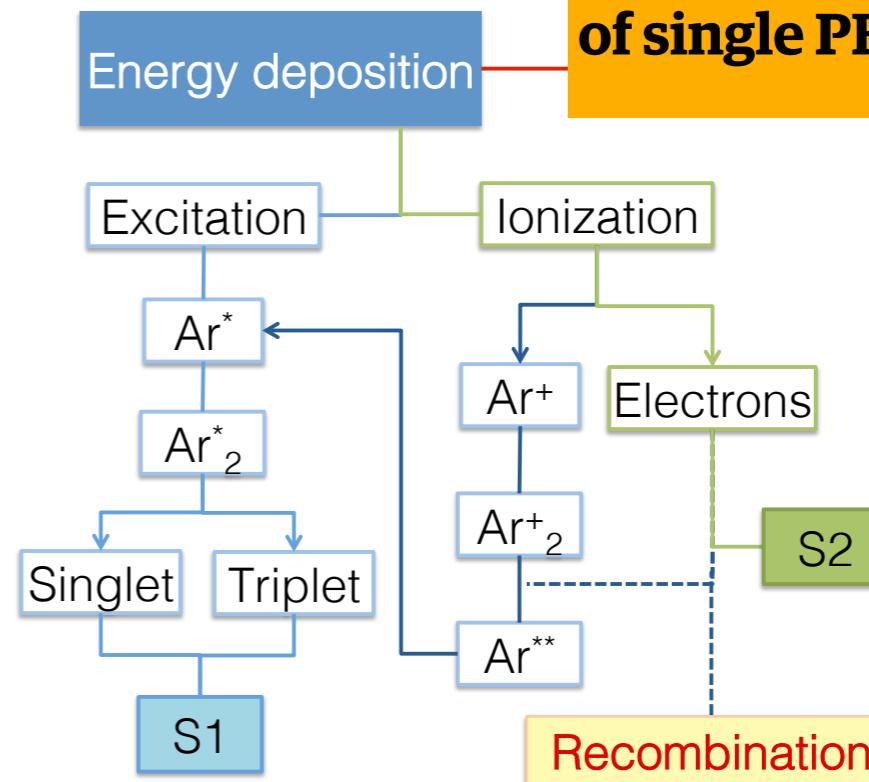
Pulse Shape Discrimination



$\tau_{\text{fast}} \sim 6 \text{ ns}$, $\tau_{\text{slow}} \sim 1.6 \mu\text{s}$

ER rejection factor: $> 10^8$ in LAr
(16 to 33 keV_{ee})

- Benefits from **high light collection efficiency**
- Requirement on **timing of single PE: O(10) ns**



DEAP-3600: Eur. Phys. J. C 81, 823 (2021)

DarkSide-50 NR calibration

Underground Argon procurement

Atmospheric argon contains cosmogenic ^{39}Ar (10^{-15} g/g)
→ β -decay, 565 keV endpoint and $t_{1/2} = 269 \text{ yr}$
→ **1 Bq / kg**

First batch of Underground Argon extracted from a CO₂ well, ~ 160 kg, demonstrated **x1400** activity reduction

NEED TO SCALE THIS UP!

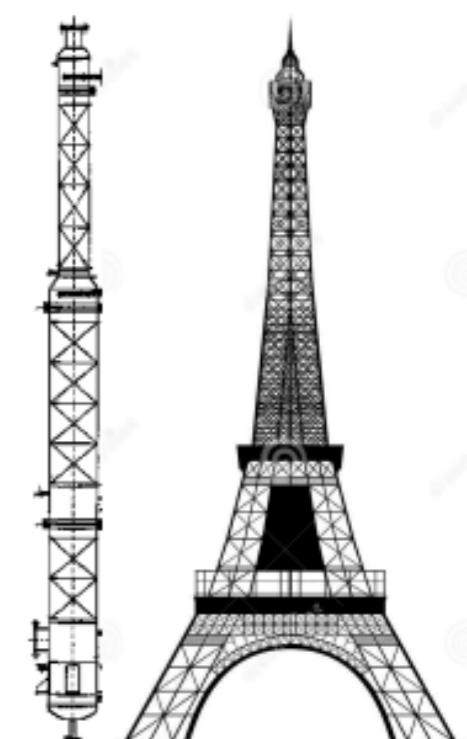
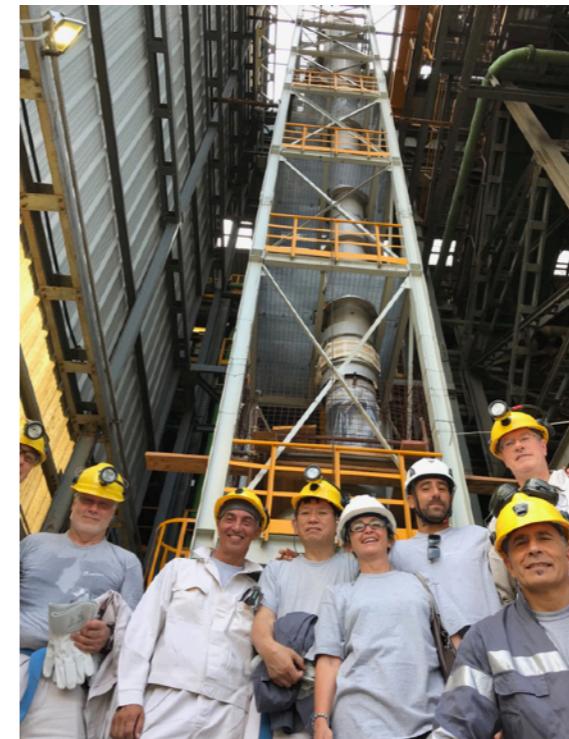
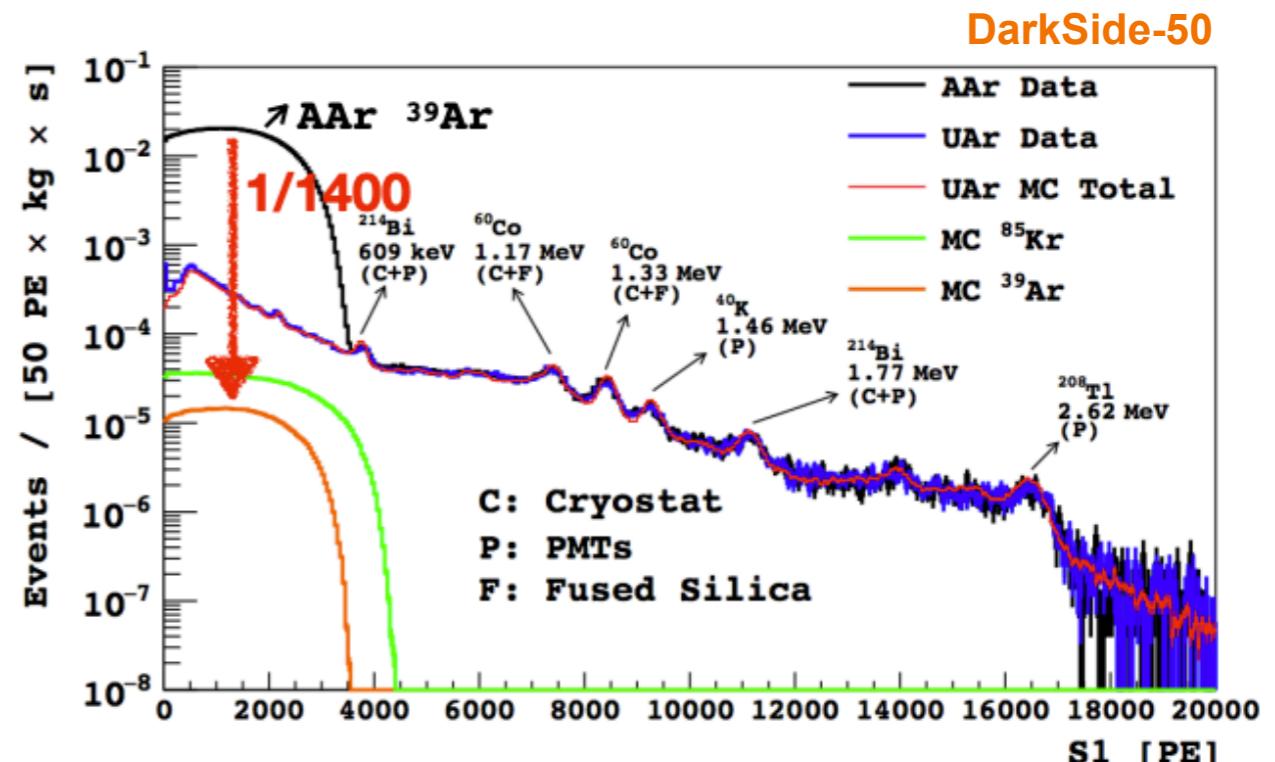
URANIA (underway):

Expansion of the argon extraction plant in Cortez, CO, to reach capacity of **330 kg/day** of Underground Argon

ARIA (1/10 prototype operated):

350 m tall distillation column in the Seruci mine in Sardinia, Italy, for high-volume chemical and isotopic purification of Underground Argon.

A factor 10 reduction of ^{39}Ar per pass is expected.



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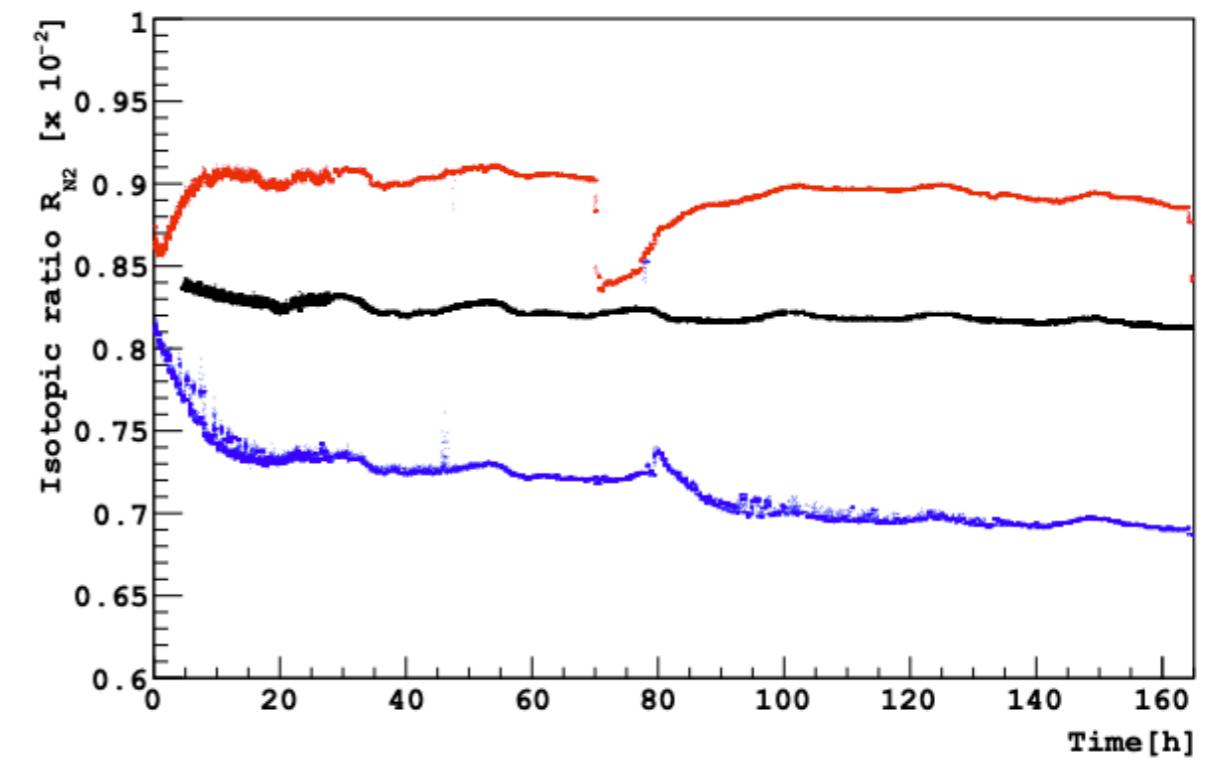
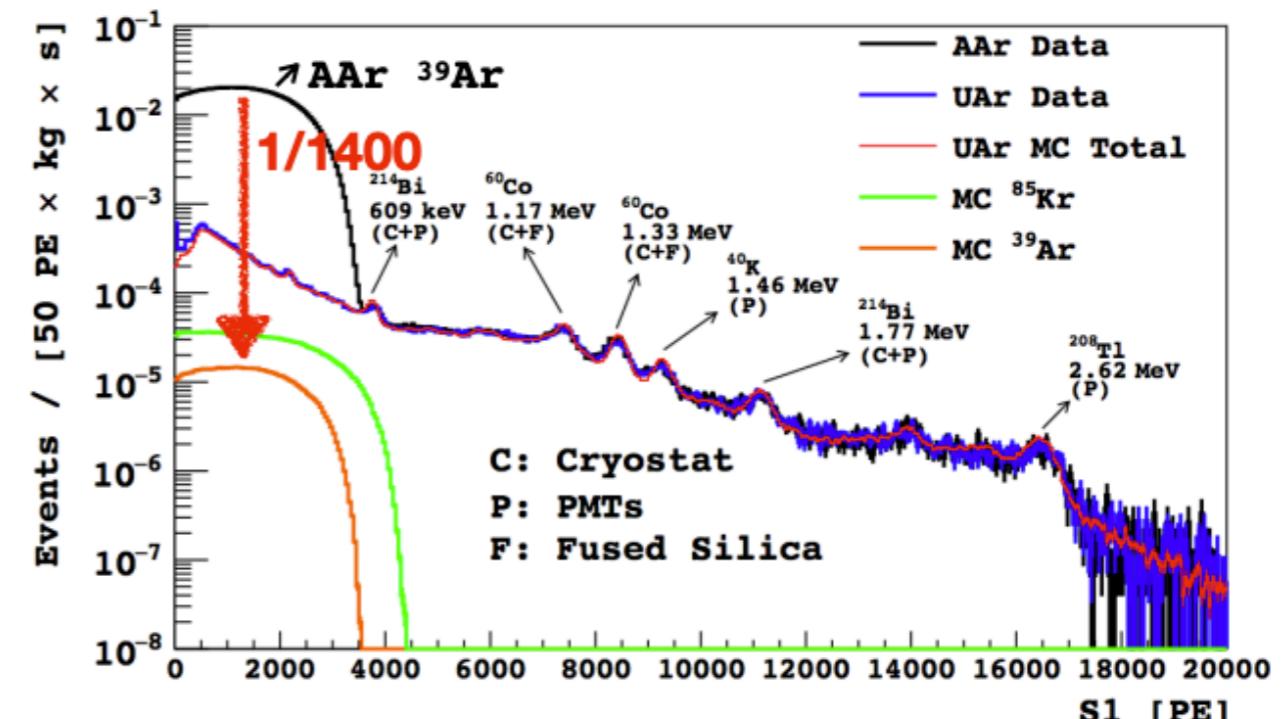
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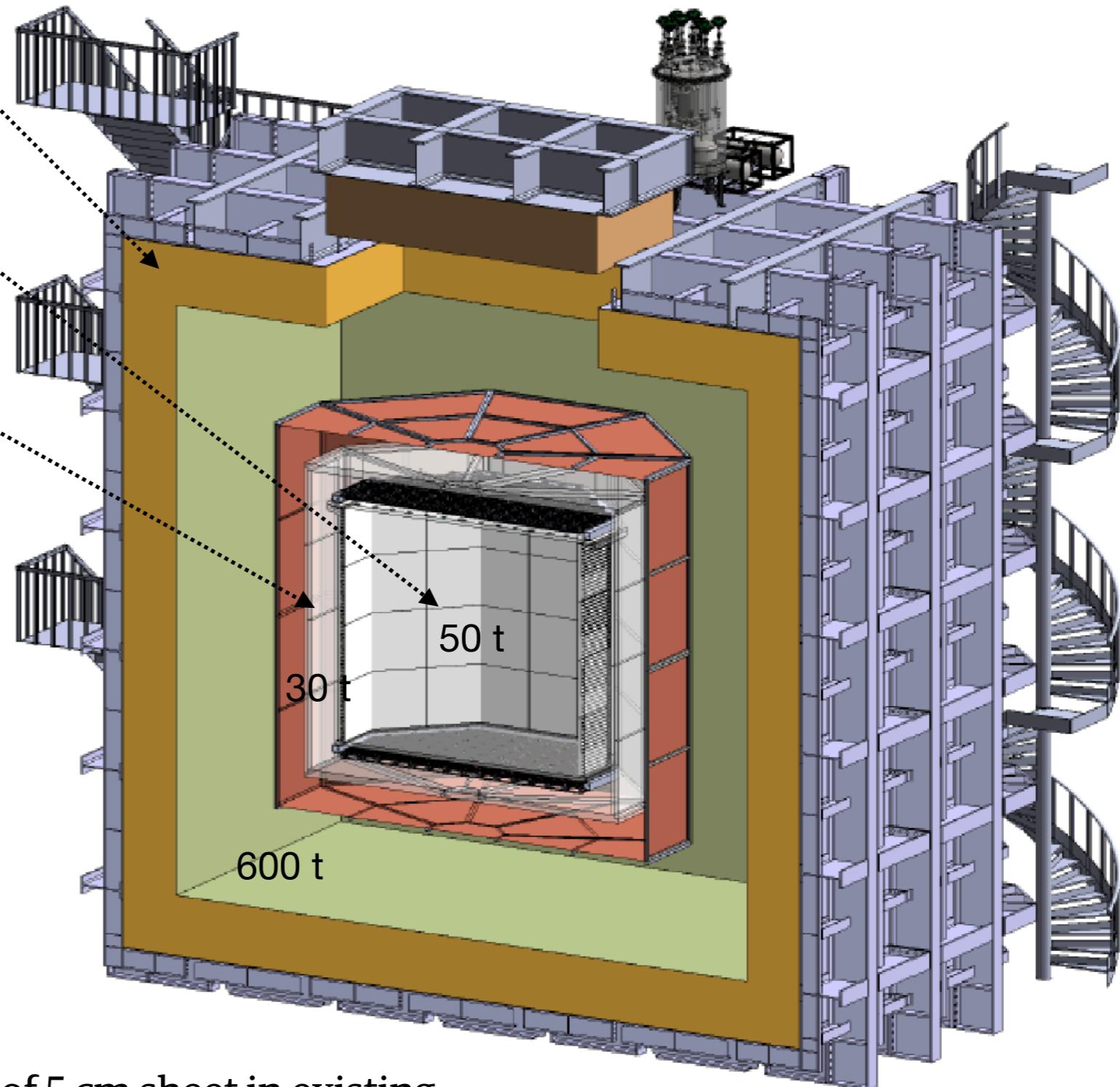
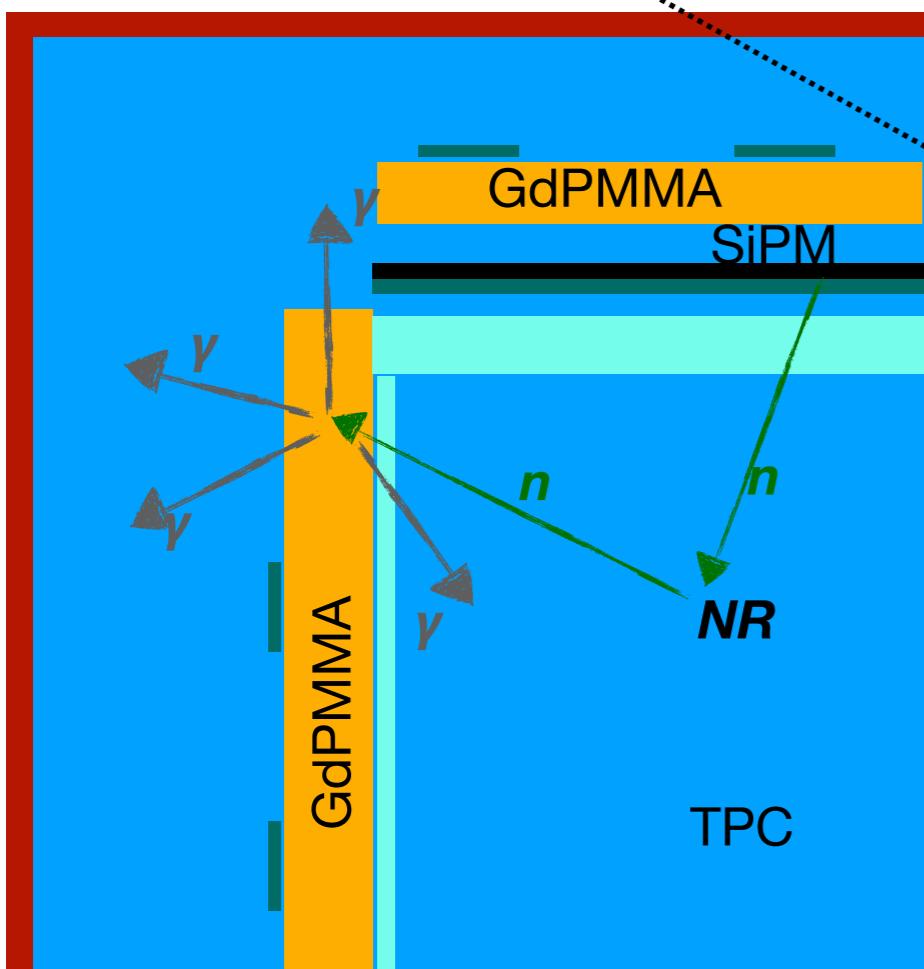
Overall Detector Design

(simplified)

50 tonne TPC is the DM target

~ProtoDUNE cryostat

Surrounded by neutron veto
(in UAr): GdAcrylic.



Cryostat preparation started!

GdPMMA R&D finalised!

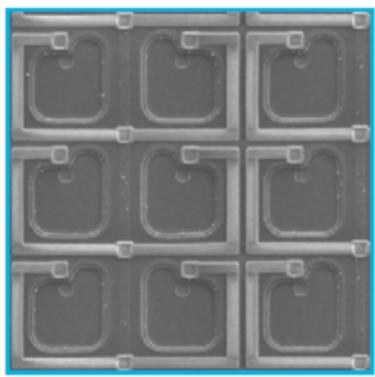
17 cm thick (collab) + industrial production of 5 cm sheet in existing
industrial lines (Donchamp) + 15 cm industrial production underway now

SiPM light readout

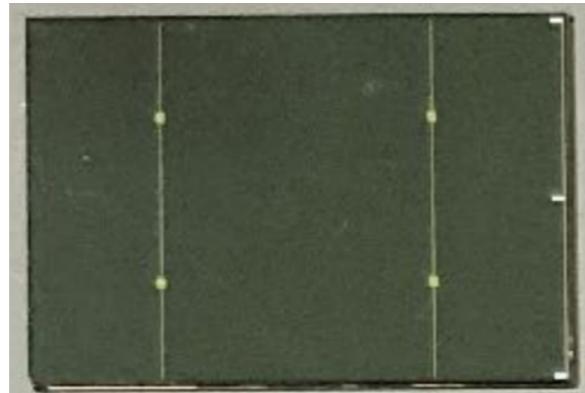
A **SiPM** is an array of **SPADs** (Single photo-avalanche diode) – operated above the break-down voltage.

Timeline of DarkSide SiPMs:

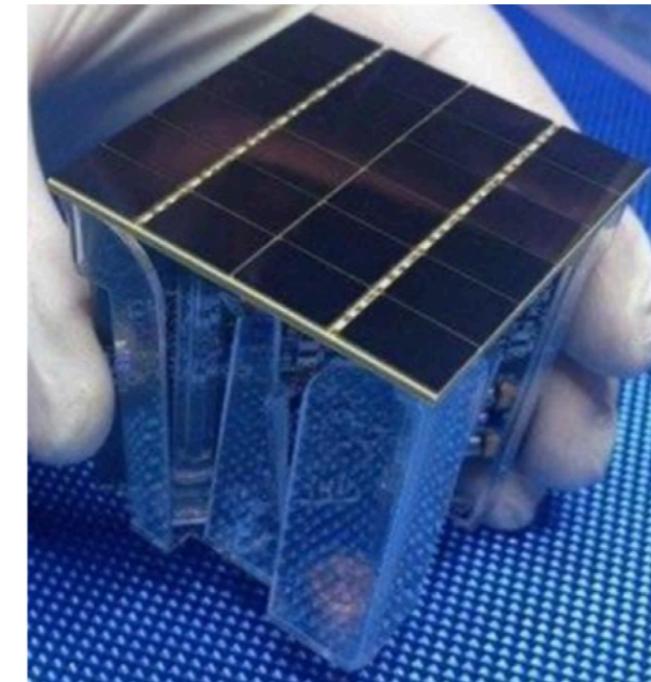
- 2014: Collaboration with FBK (Fondazione Bruno Kessler) started
- 2018: Technological transfer to LFoundry for the Silicon mass production
- End 2021: Si wafer production complete



$30 \times 30 \mu\text{m}^2$

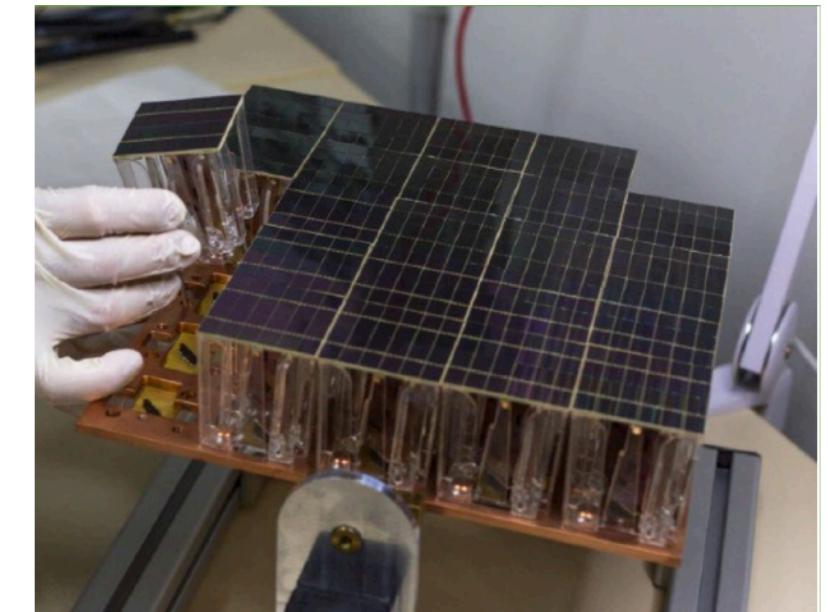


$\times 10^5 : 9 \times 11 \text{ mm}^2$



$\times 24 : 5 \times 5 \text{ cm}^2$

- + Higher photo-detection efficiency
- + Better single photon resolution
- + Lower background (lower mass)
- + Lower cost per unit area



up tp $\sim 20 \text{ m}^2$

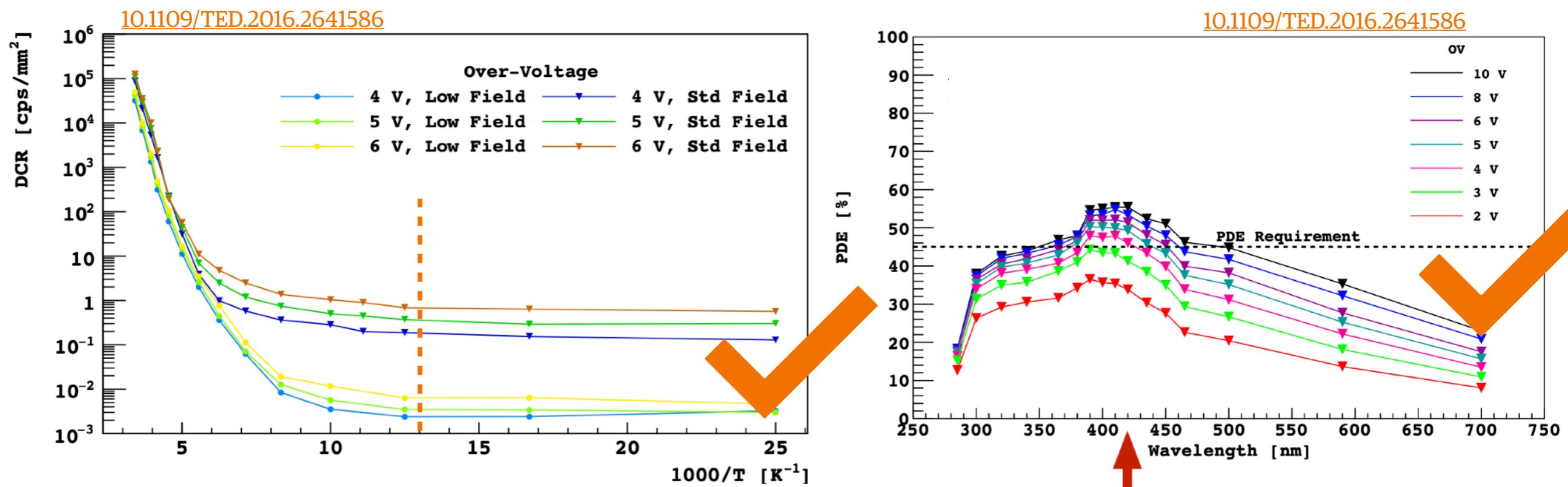
Challenges:

- High dark count rate (DCR)
- Small cell size
- high capacitance per unit area

Requirements the experiment (PSD):

- DCR < 0.1 Hz / mm²
- time resolution < O(10) ns
- detection efficiency > 40%

Technology achievements (FBK)



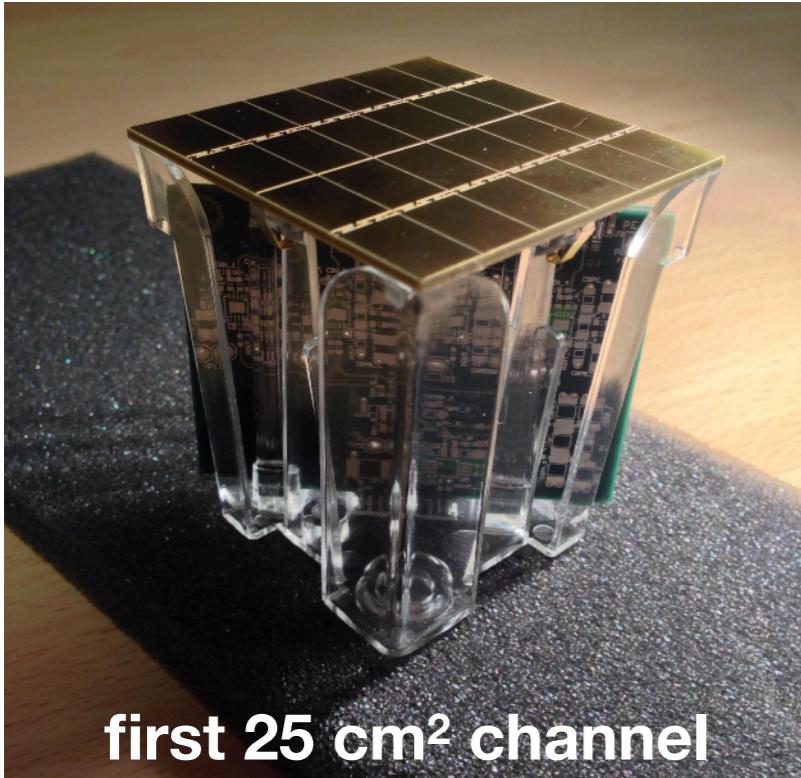
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Requirements the experiment (PSD):

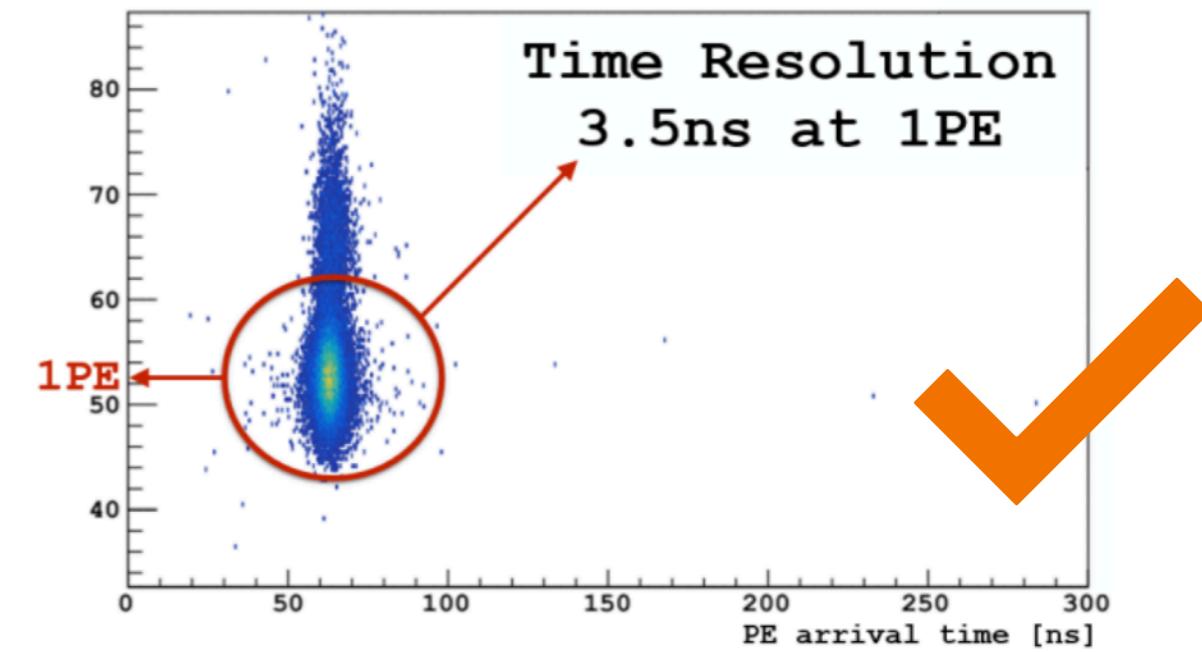
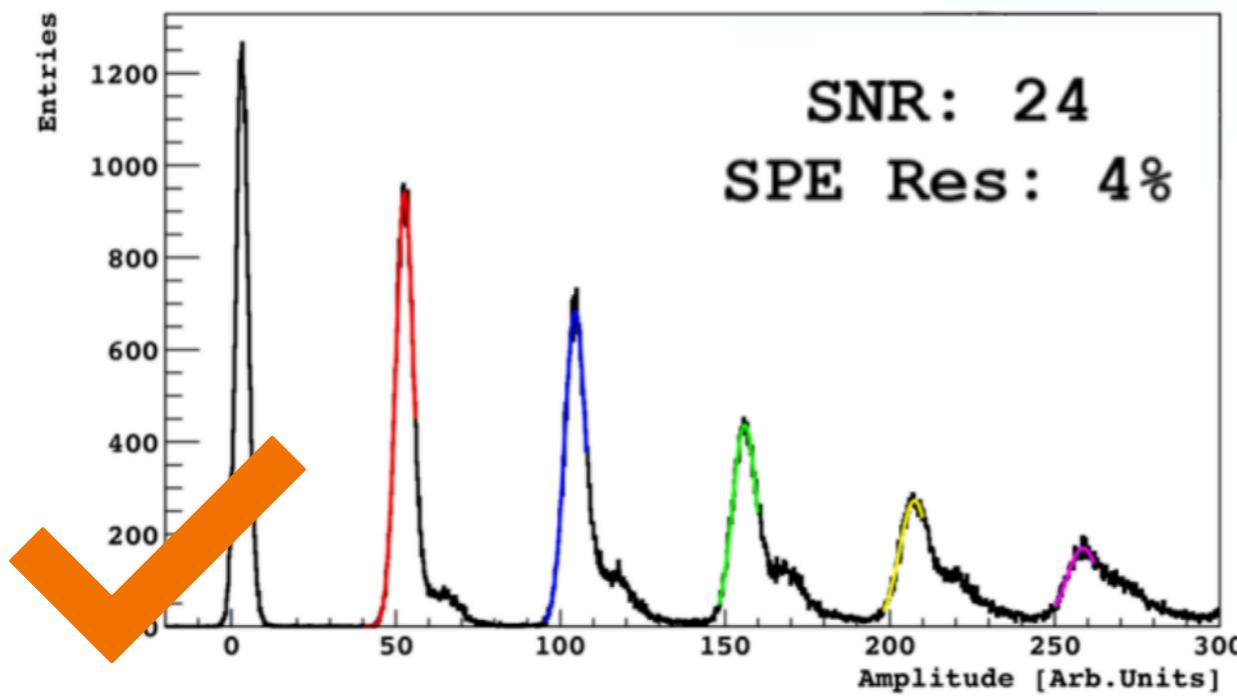
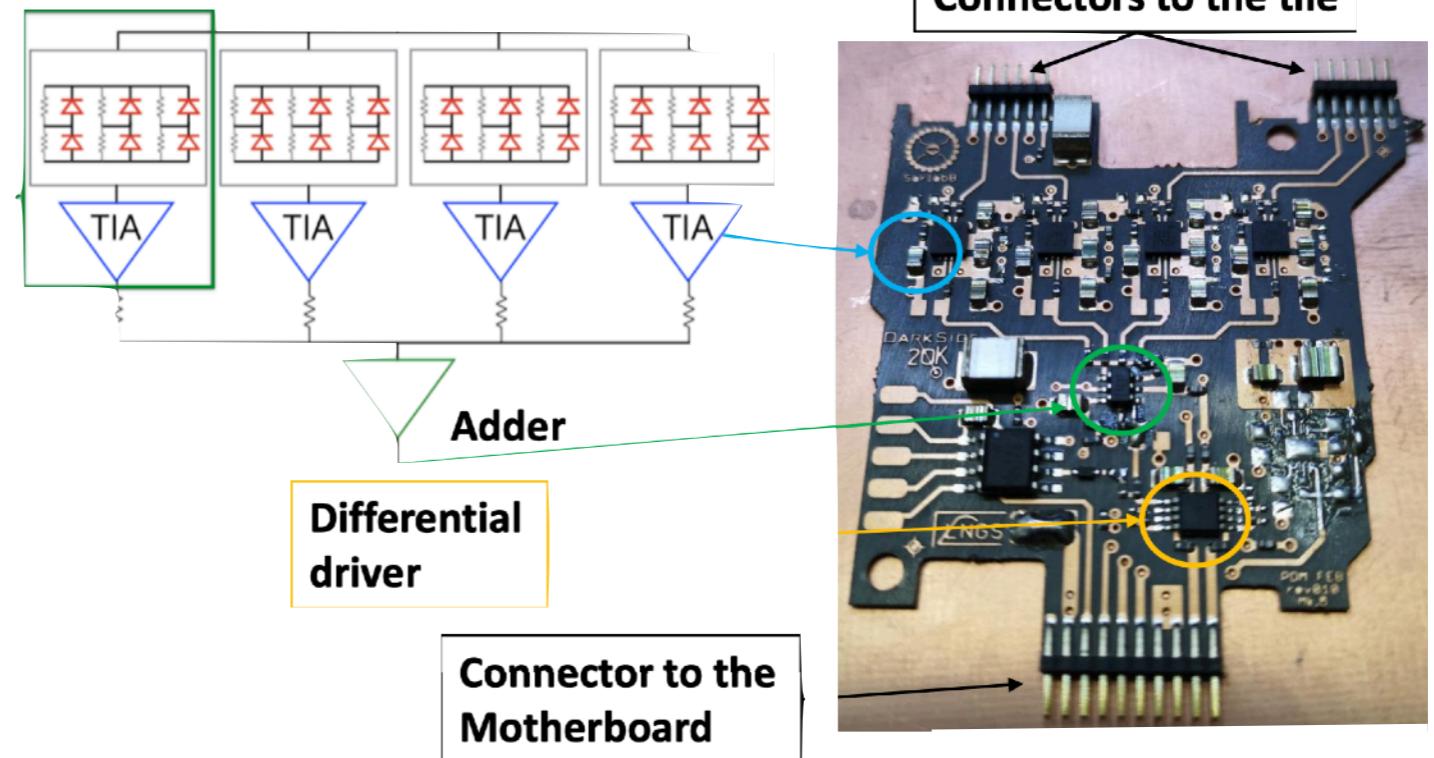
- DCR < 0.1 Hz / mm²
- time resolution < O(10) ns
- detection efficiency > 40%

Cryogenic FEB



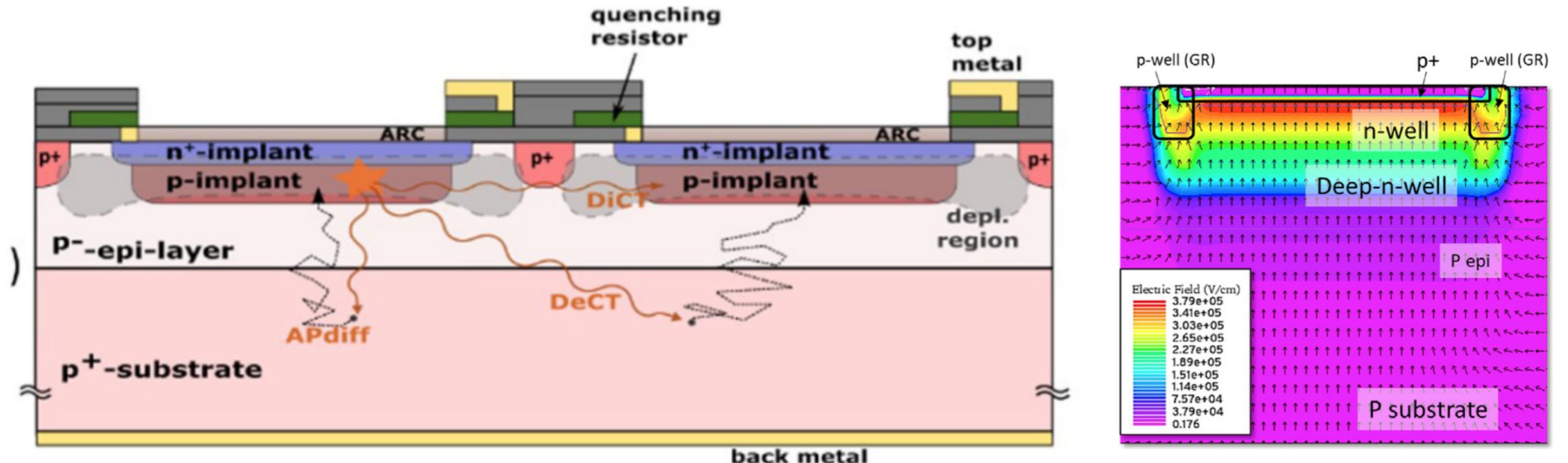
...Need 12000 of these!

Reading out 2s3p only increases the capacitance x1.5



This design can be further improved

SiPM - characterisation



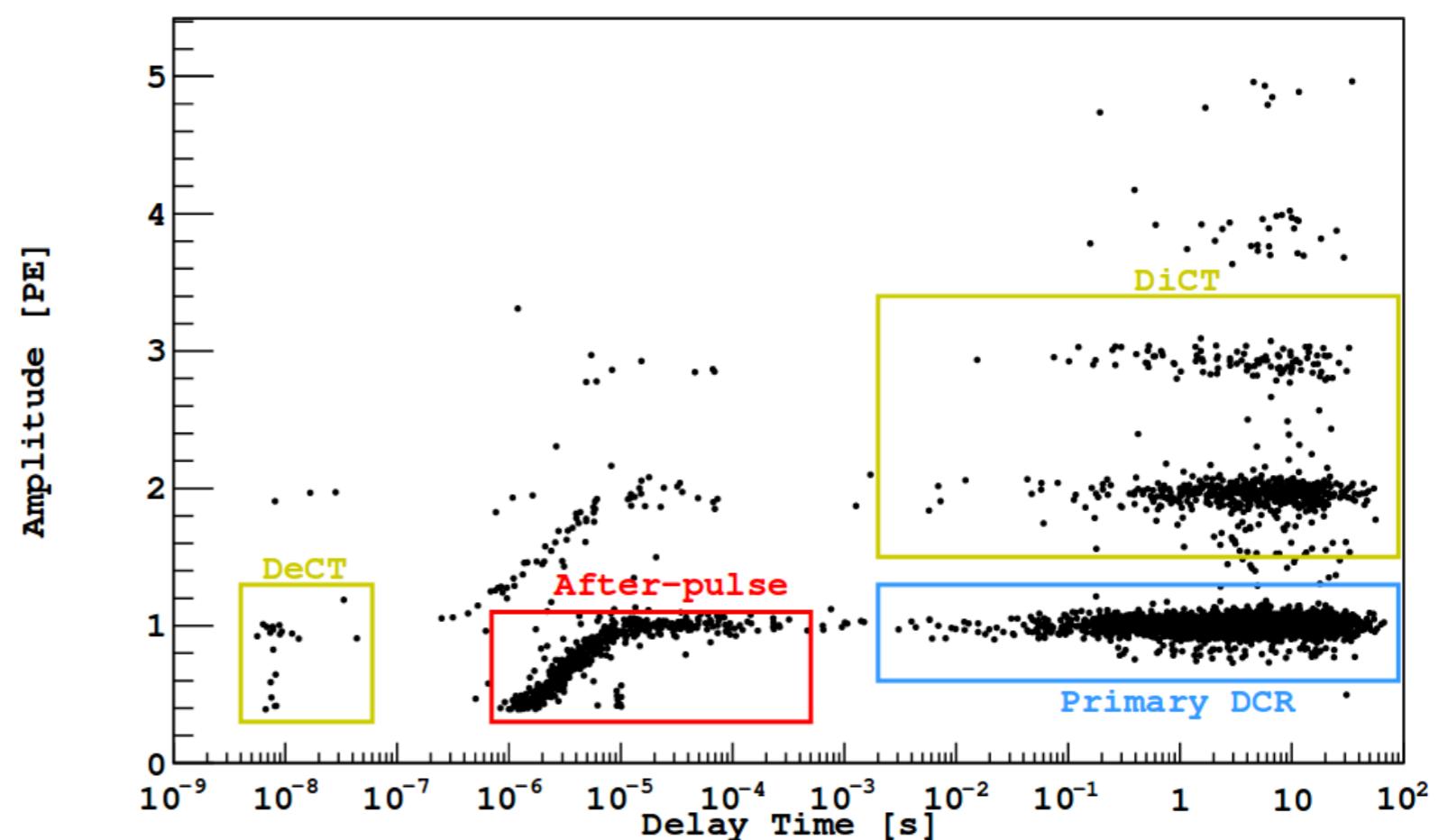
DiCT: 1 - 10 ns

DeCT:
< 100 ns

DCR (uncorrelated)

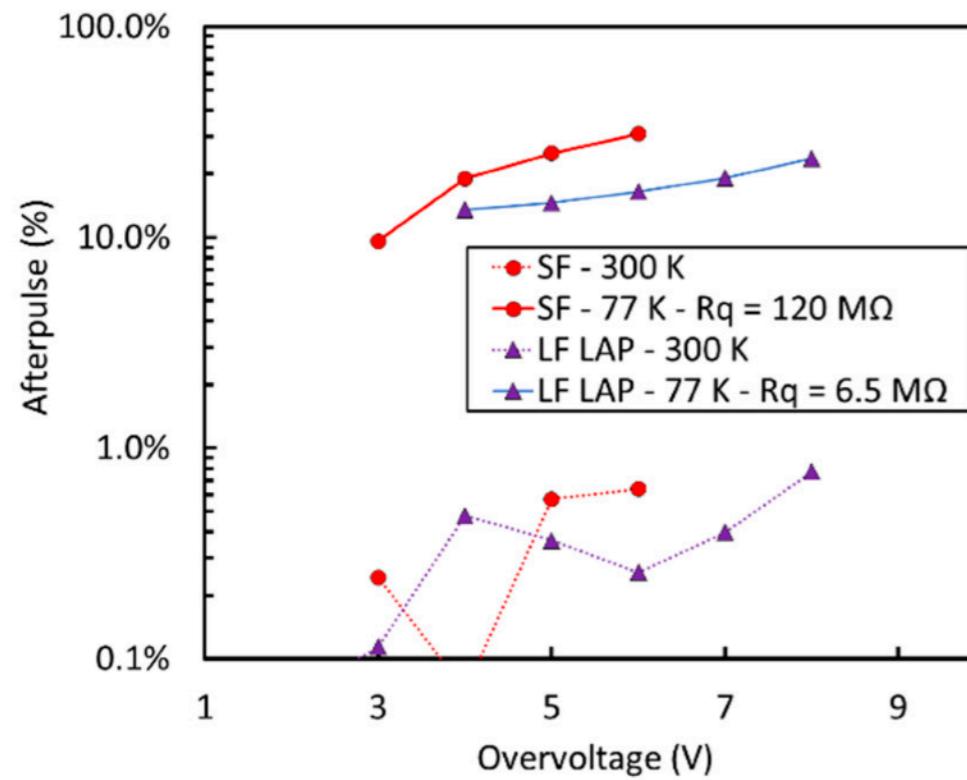
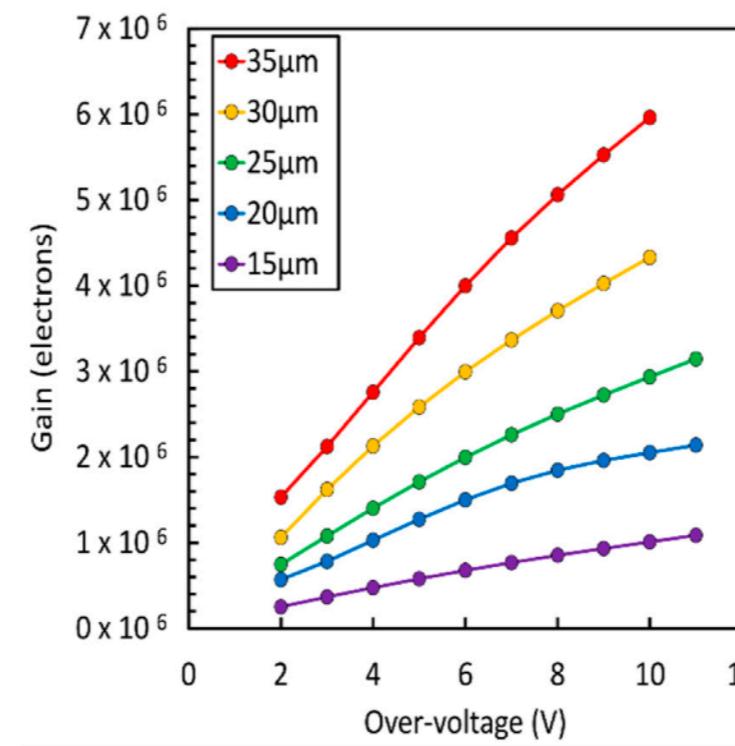
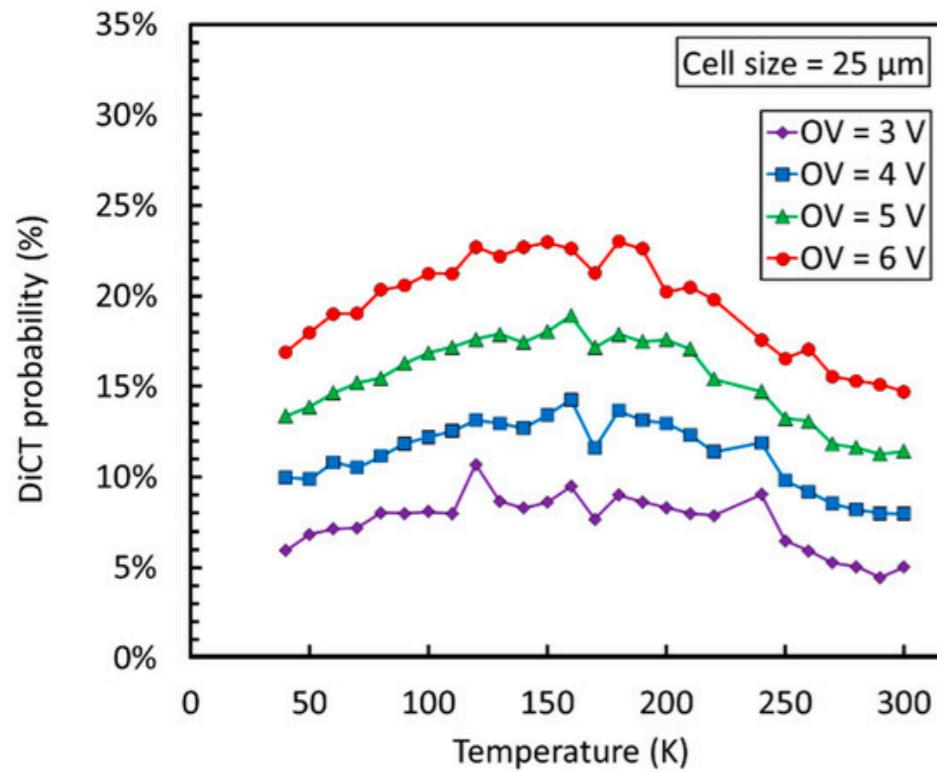
APs: 1 - 100 us

Assessing impact on
PSD, data rate, DAQ
requirements...



SiPM - characterisation: benchmarks

from <https://doi.org/10.3390/s19020308>



Glossary

OV: Over Voltage

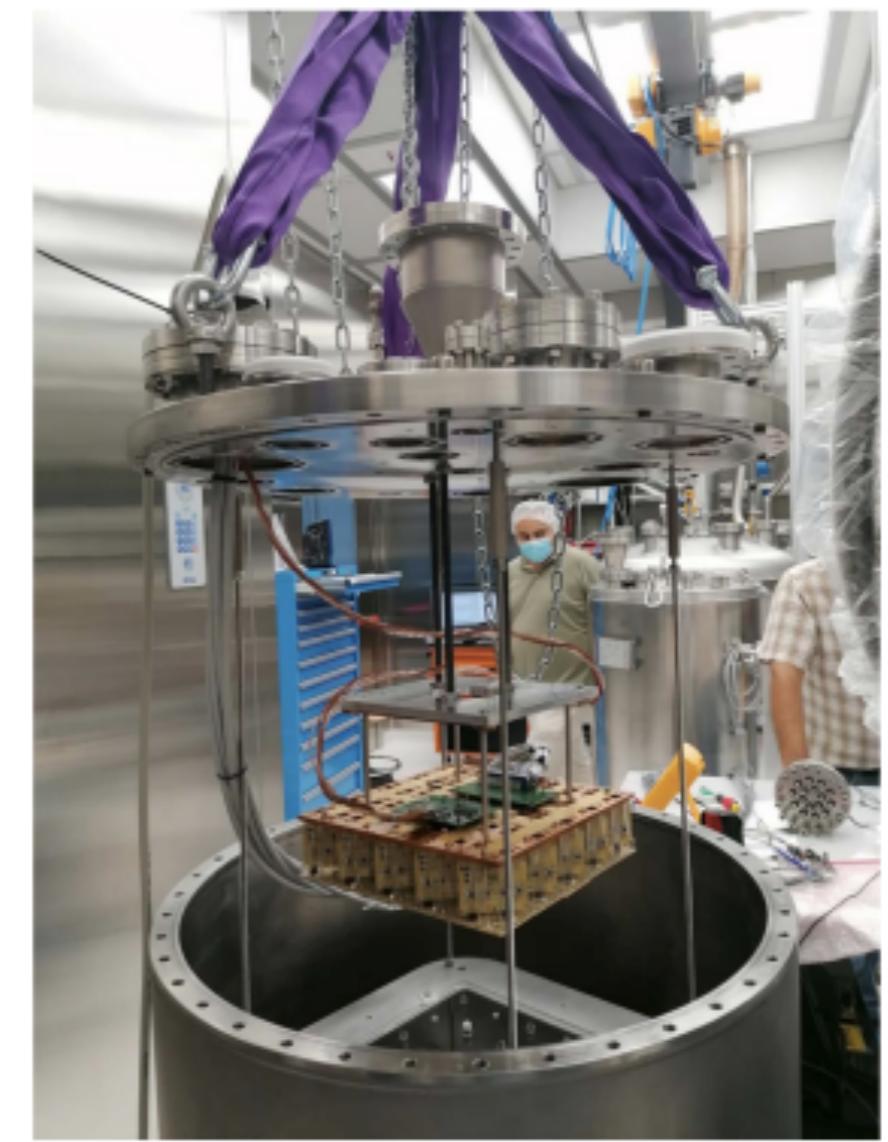
SF: std field

LF: low field

LAP: low After Pulse

Tests ongoing in several locations (RHUL, Naples)

- stability
- statistics
- correlated noise probabilities
- investigate strange behaviours



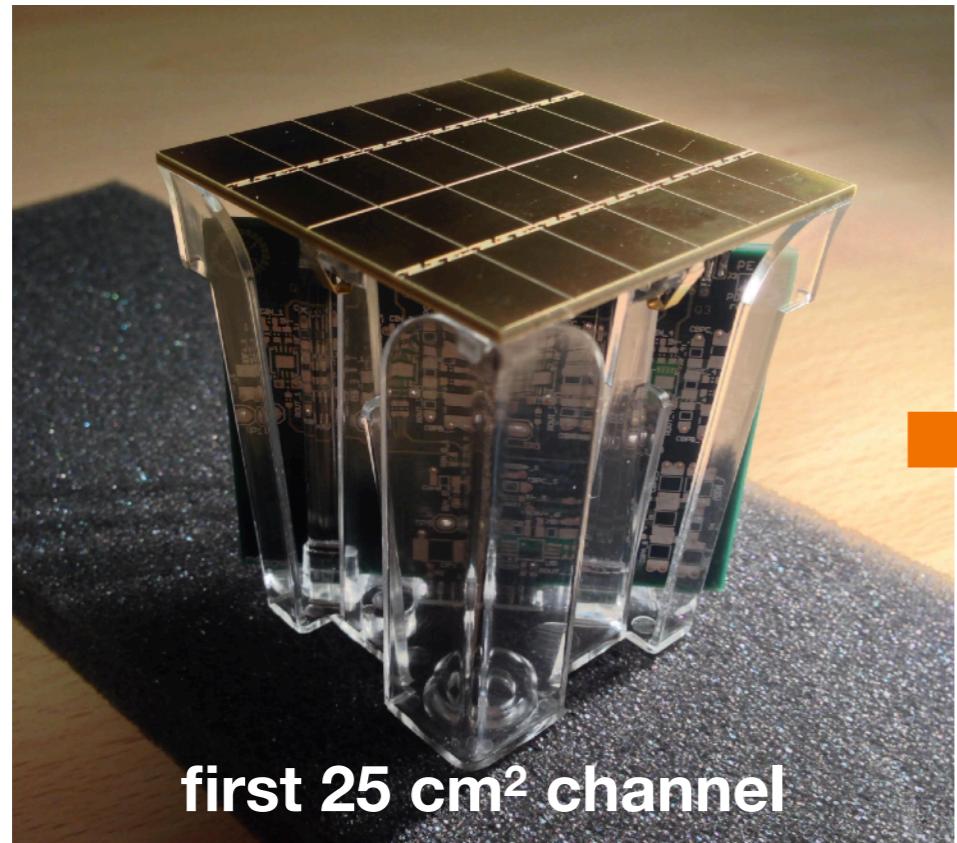
Redesign of the board and readout

Same SiPM tiles used for the **neutron Veto too**

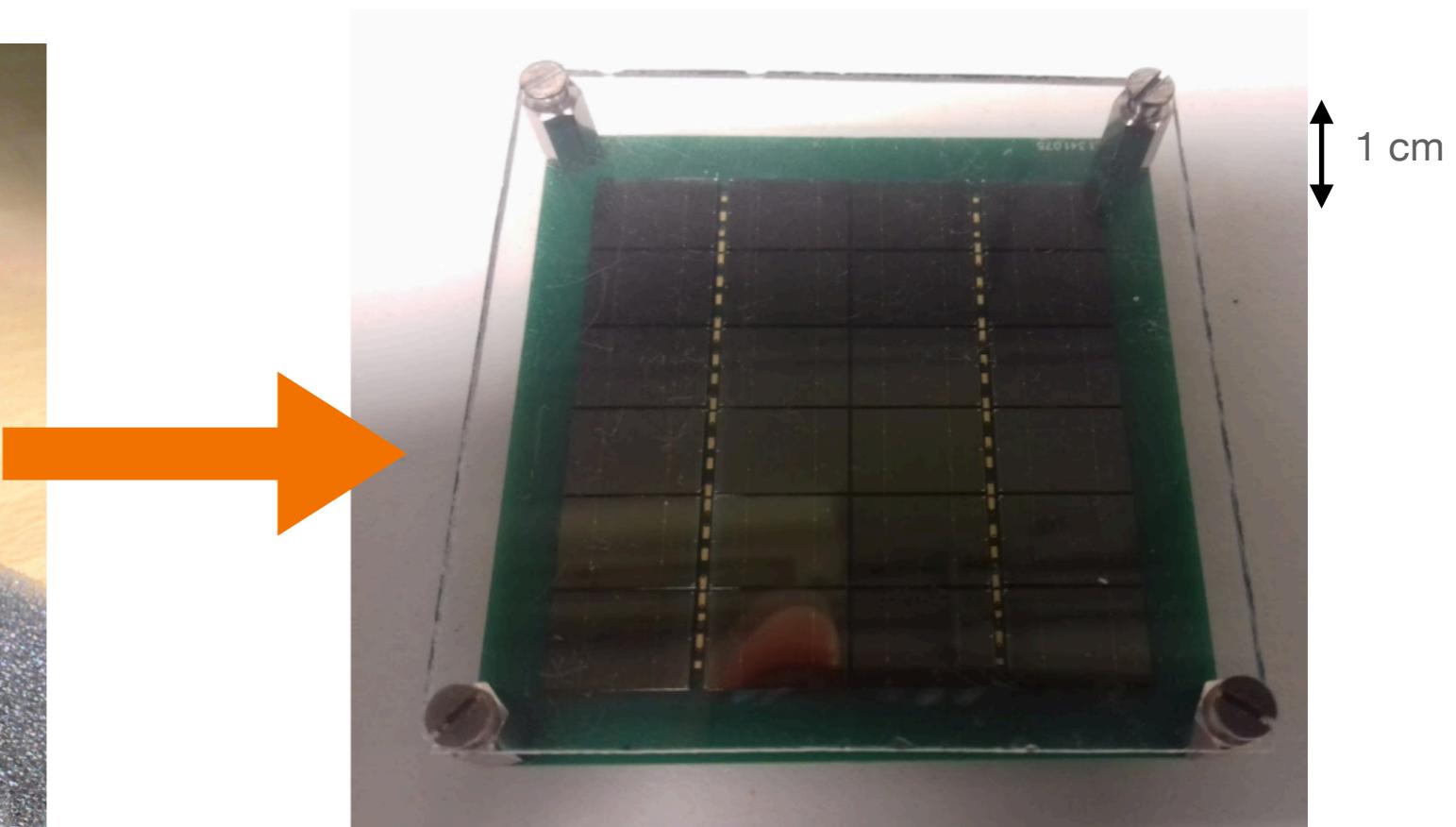
Neutron captures on Gd (8 MeV): higher threshold, high-dynamic range, timing > 10 ns

Recently completed **review process** and **redefinition** of the design

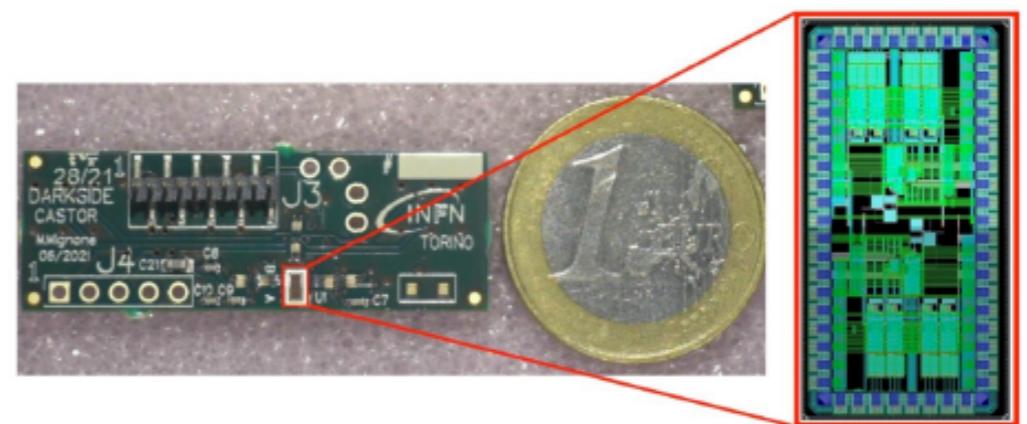
(better radio-purity, different readout and mechanics – reduces complexity, improves robustness)



first 25 cm² channel

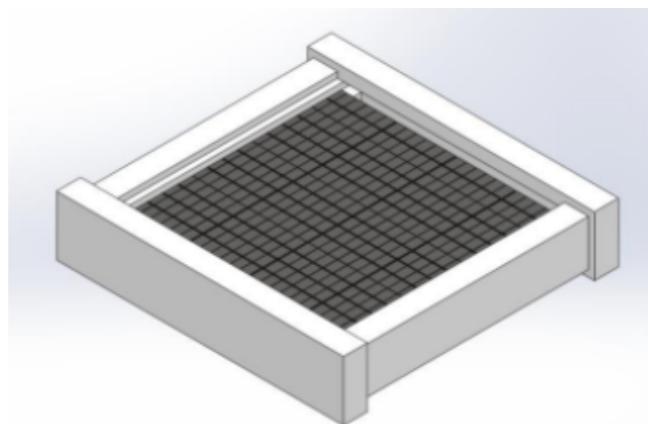


Overall radioactivity
reduced by ~ 2x

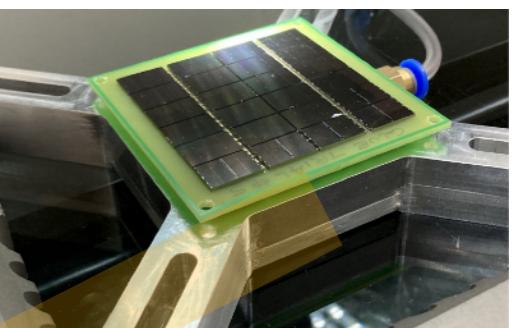
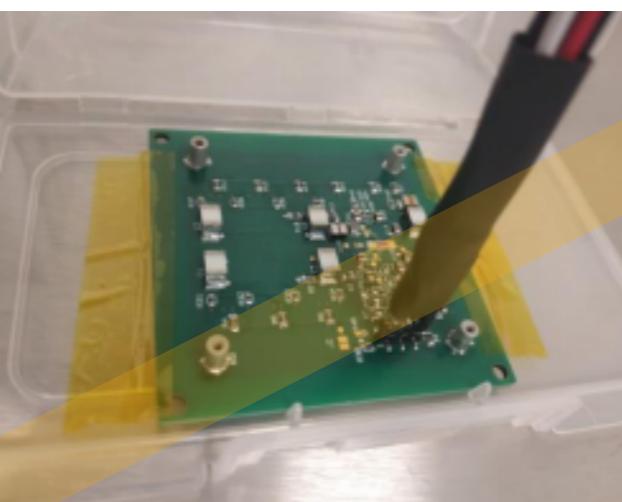


The Veto Photo-Electronics

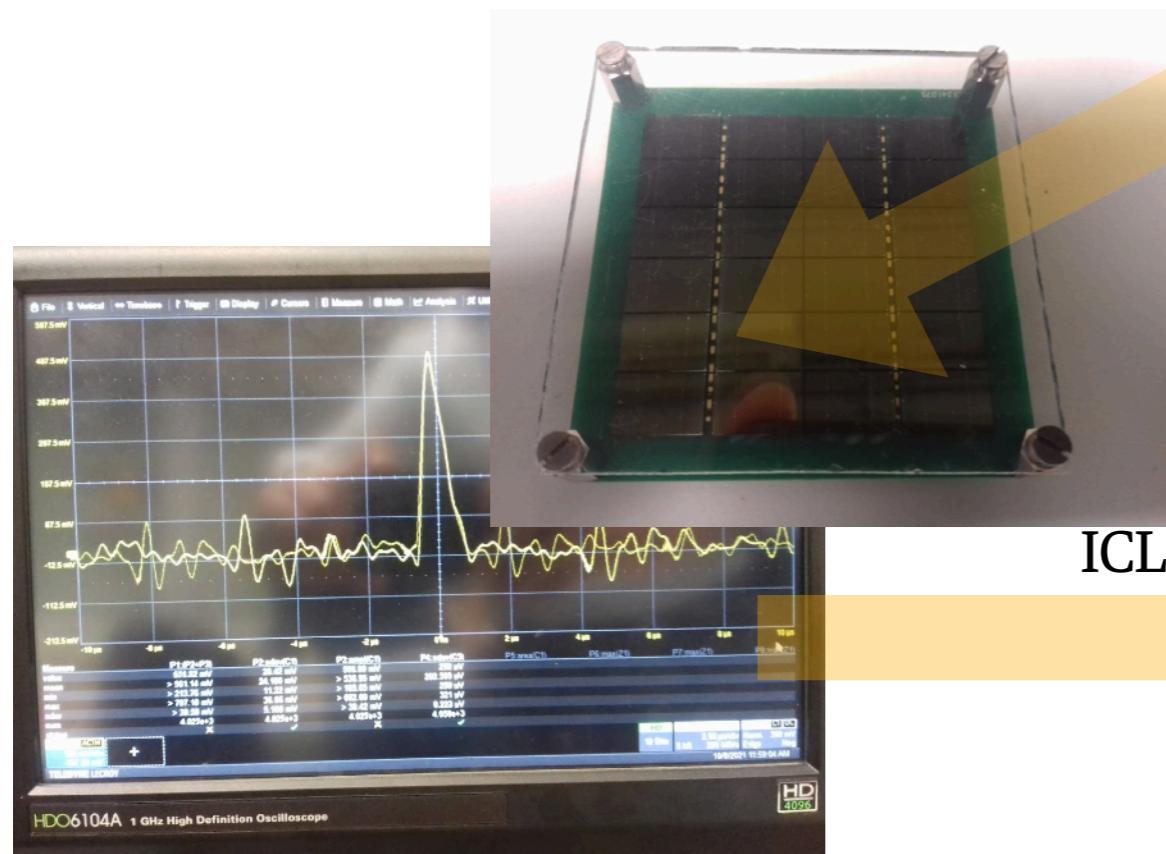
- Production
 - Qualification
 - Radio-assay
 - Assembly
 - Testing
 - Installation
- ... led by **UK** institutions



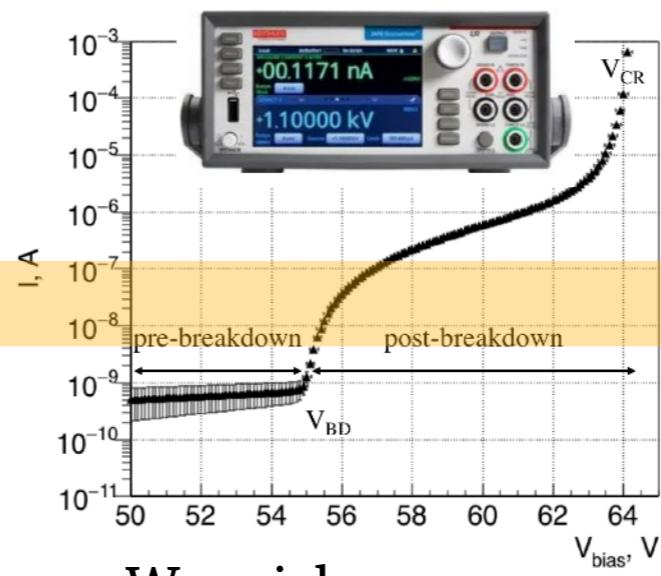
Manchester



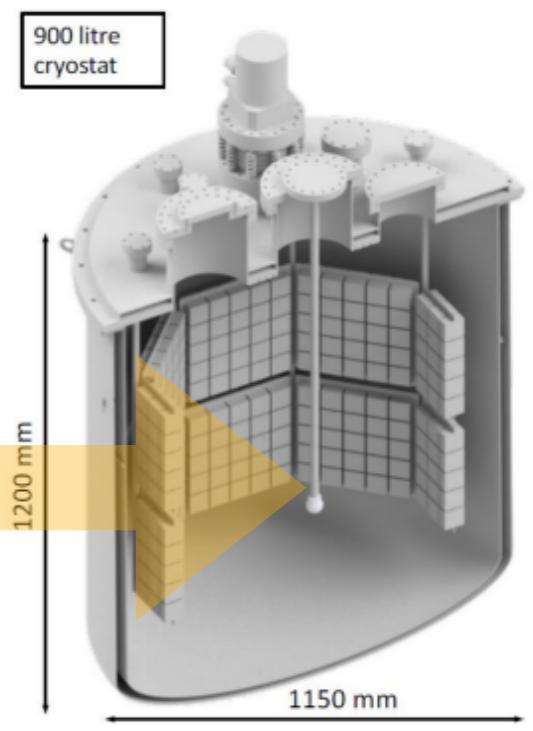
STFC Interconnect
+Liverpool



INFN Genova+Torino



(SW) +RHUL+Lancaster+Edinburgh

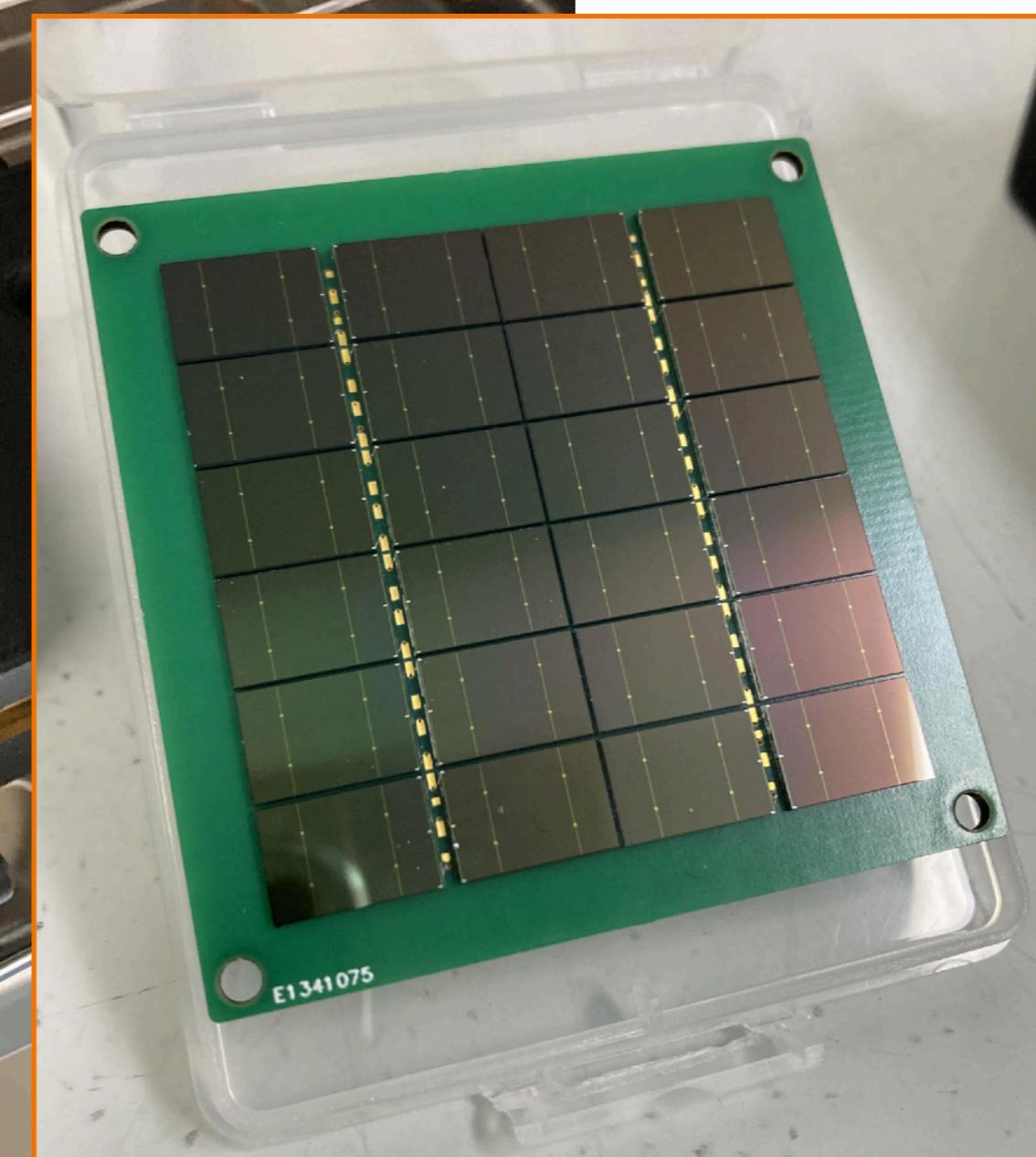
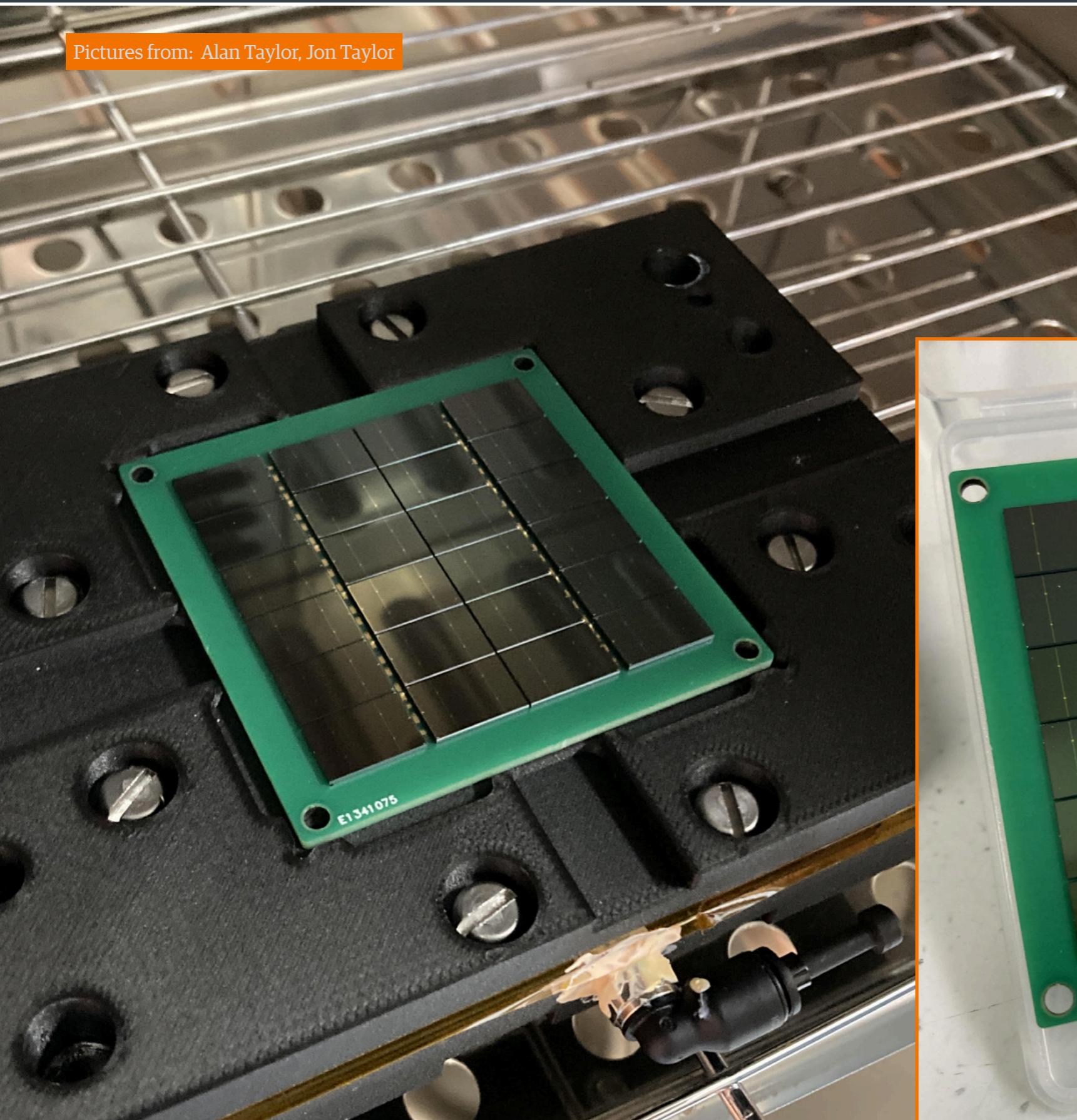


Liverpool

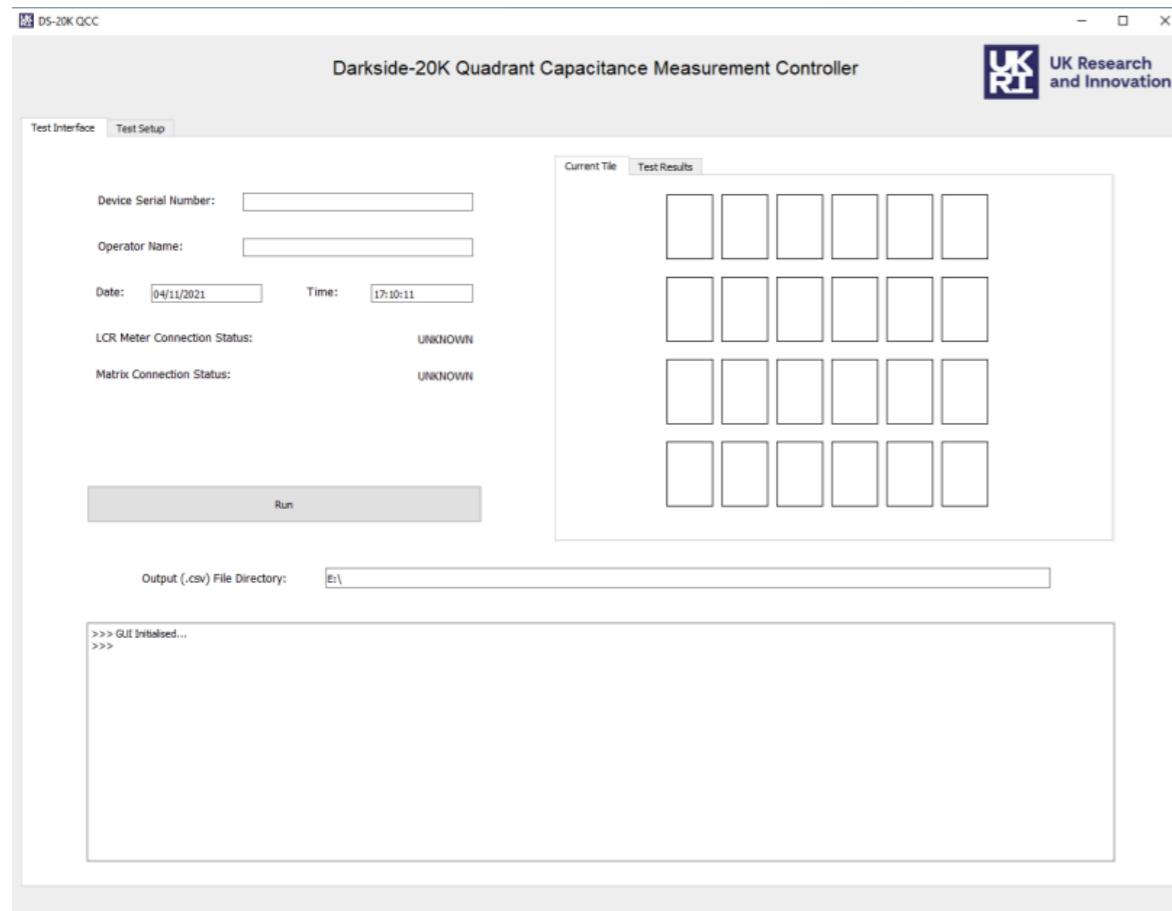
Liverpool

Pictures from: Alan Taylor, Jon Taylor

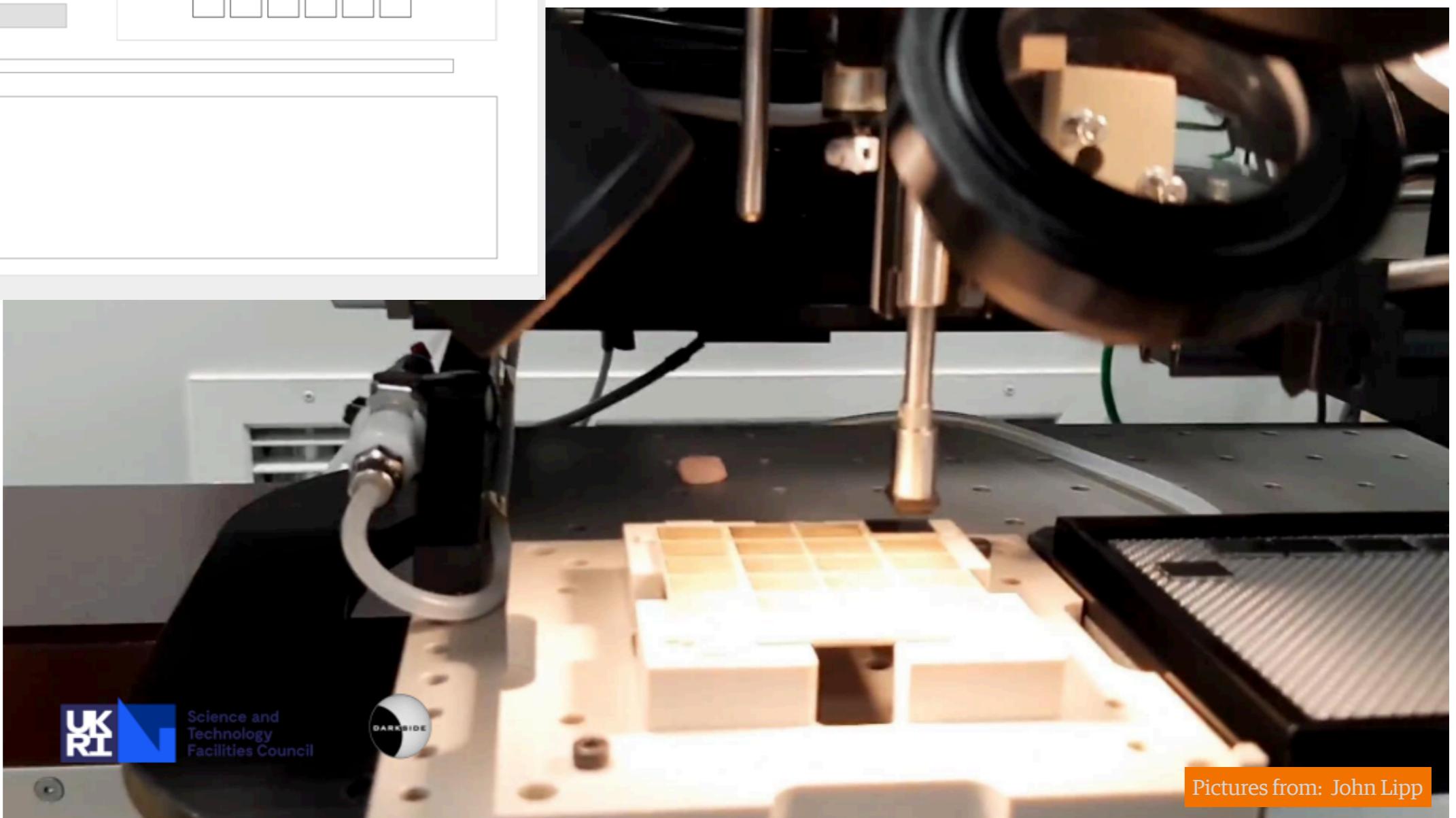
Pictures from G Giovanetti



STFC Interconnect @ RAL

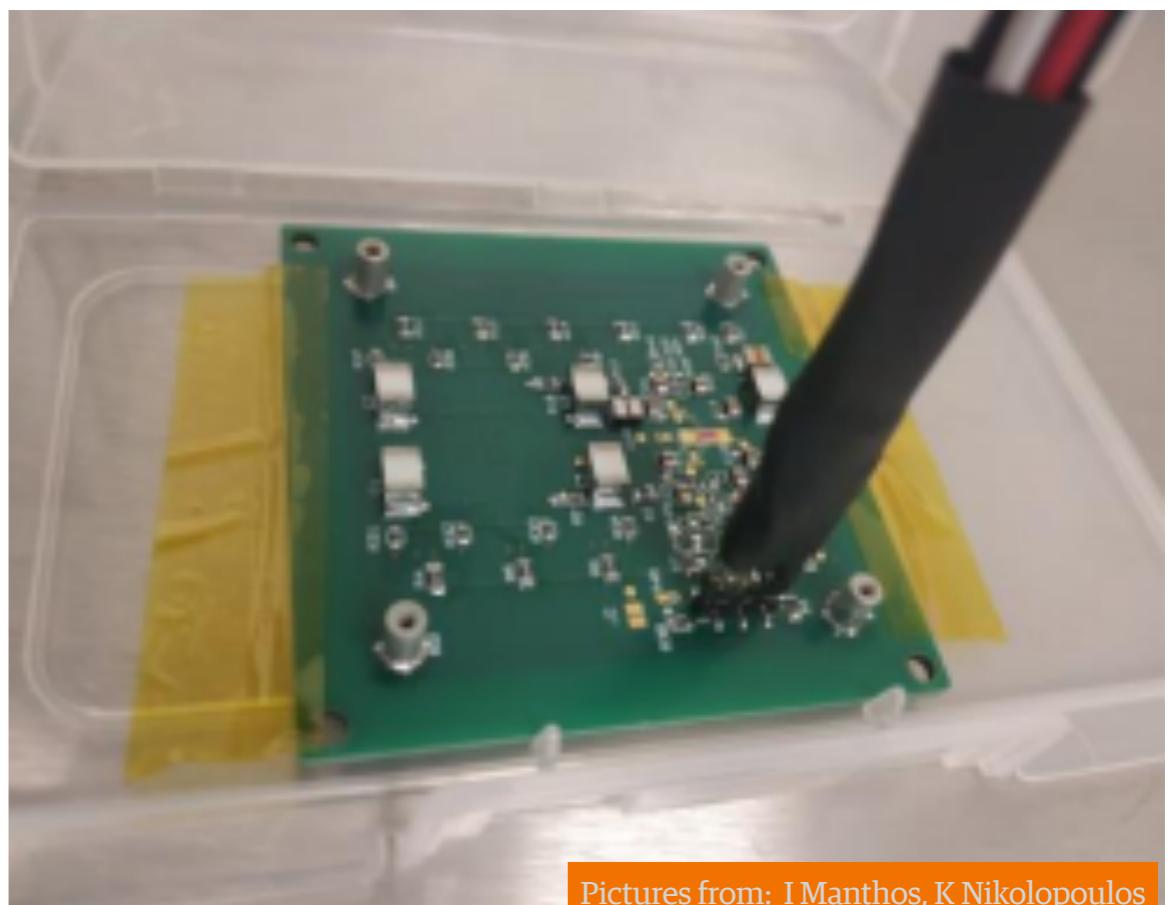
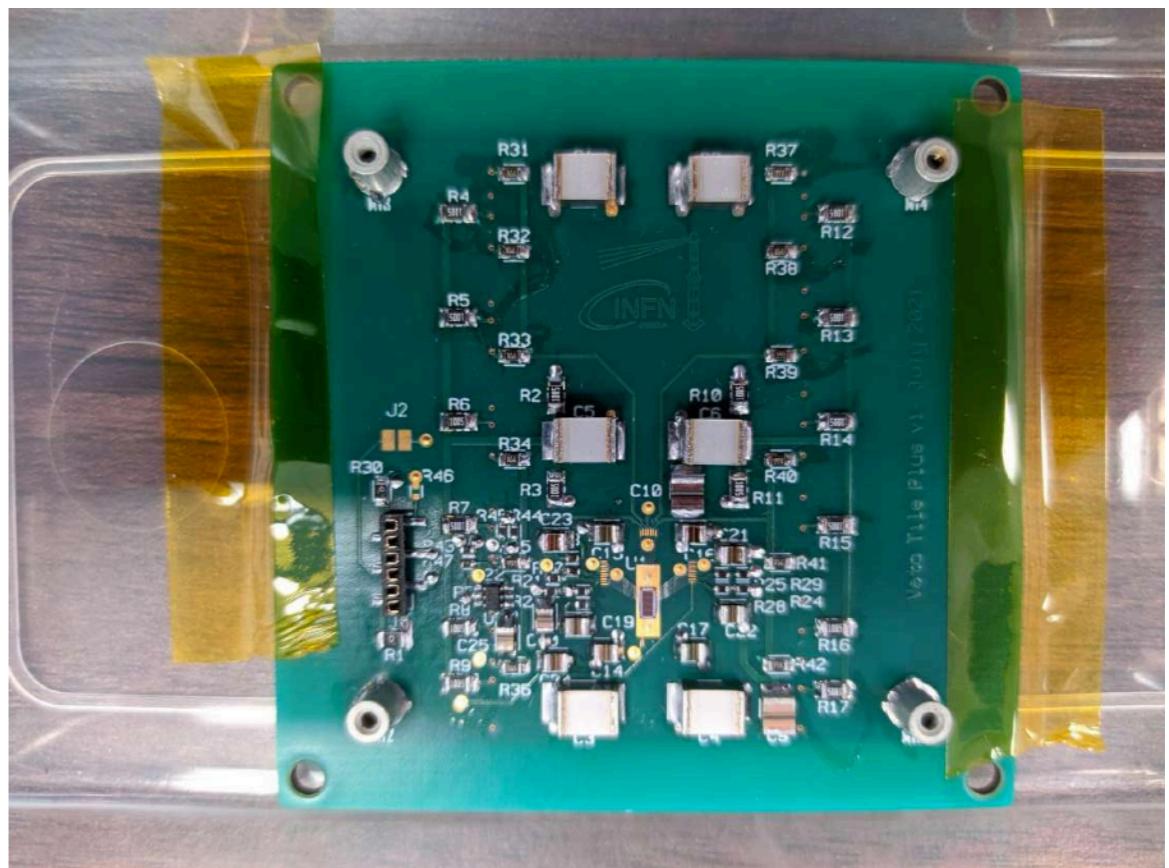


- + Flip chip bonding (indium bumps at low-T)
- + Cryo Probing and LRC testing
- + Wire Bonding



Birmingham and ICL

- PCBs are populated at Birmingham (automated pick and place) and ICL.
- Dedicated reflow oven for radio-clean operations (low-background experiments)
- Warm and Cold tests of the populated PCBs

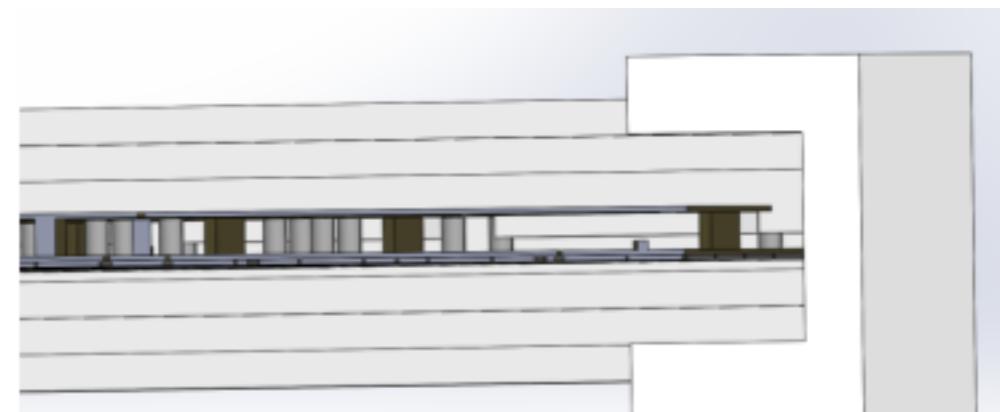


Pictures from: I Manthos, K Nikolopoulos

Manchester, Warwick, Edinburgh, RHUL

Storage, shipment, installation box

[Manchester]



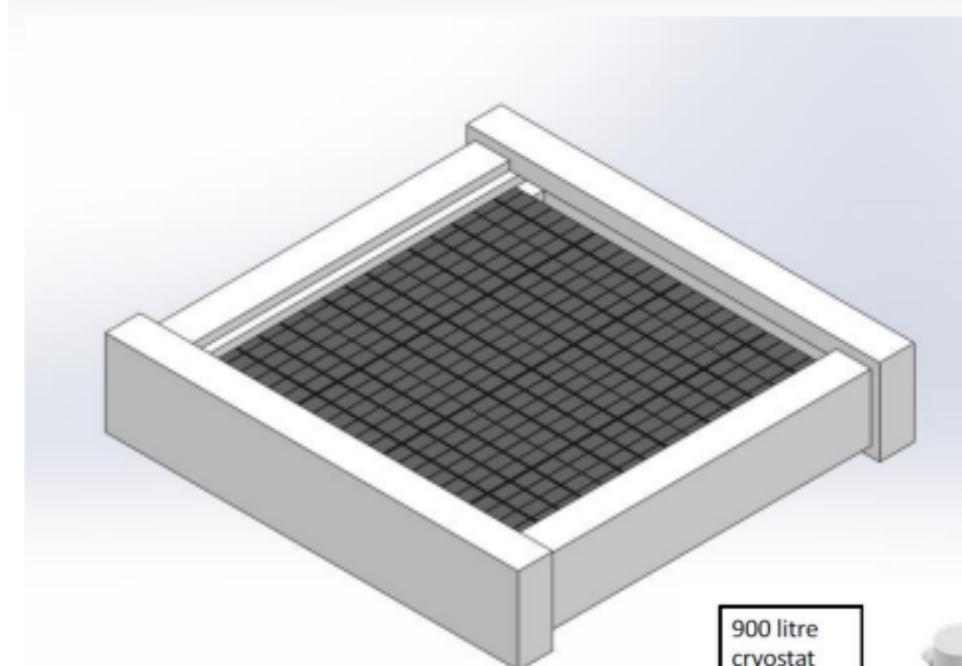
Radioactivity assessment at **Boulby**

Warm Test Setup [Warwick]

IV curves, Noise power spectra

Cold Test Setup [Liverpool]

- 400 channels simultaneously (largest)

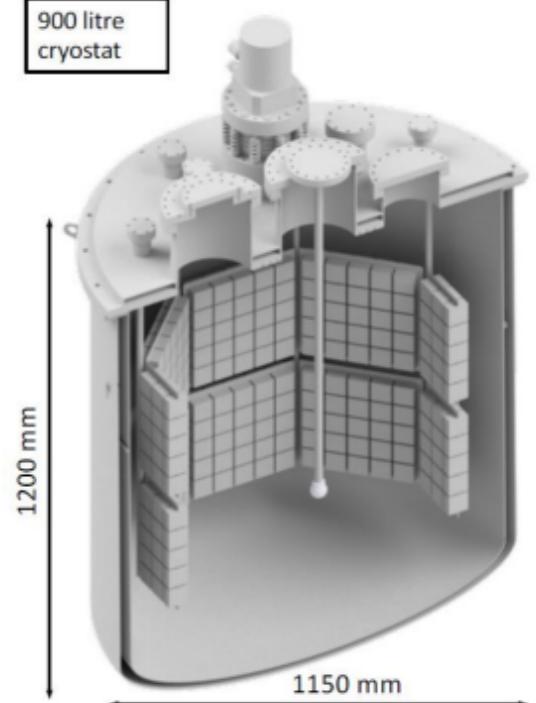
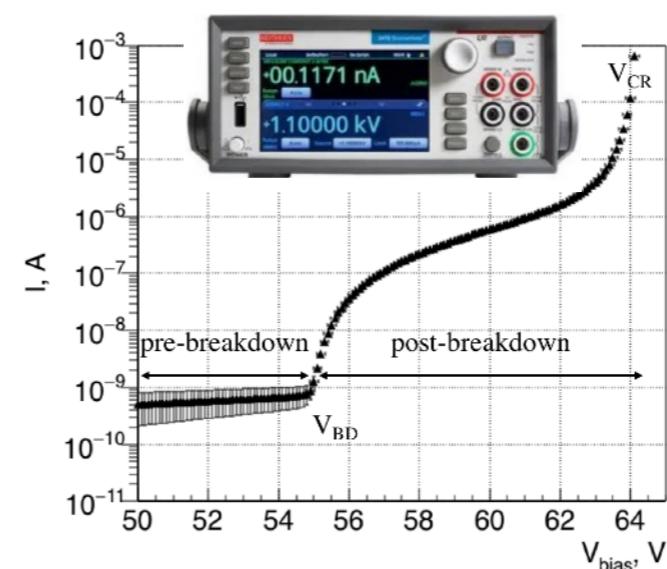


900 litre cryostat

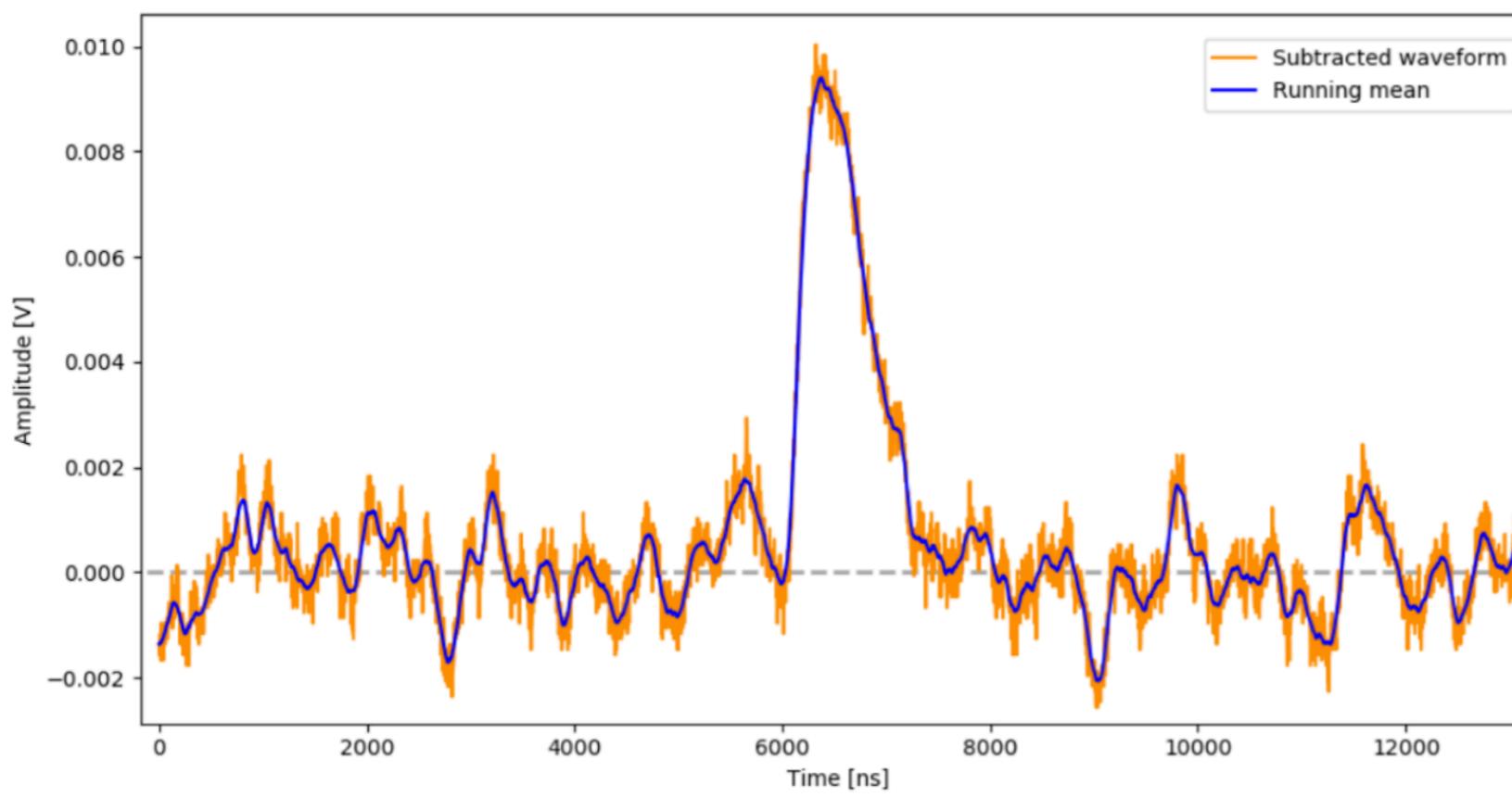
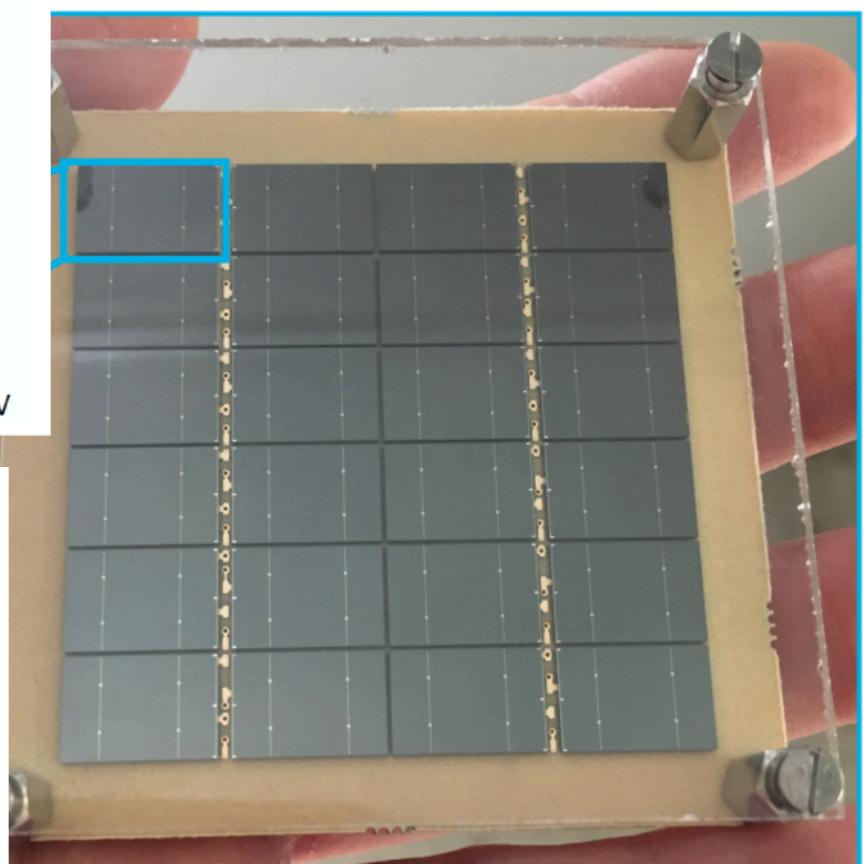
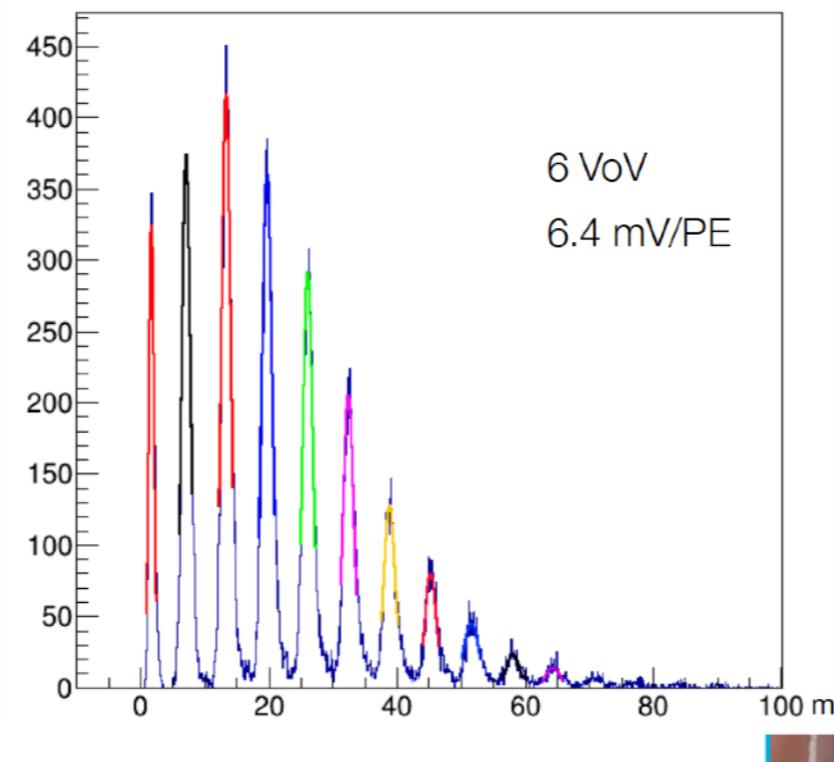
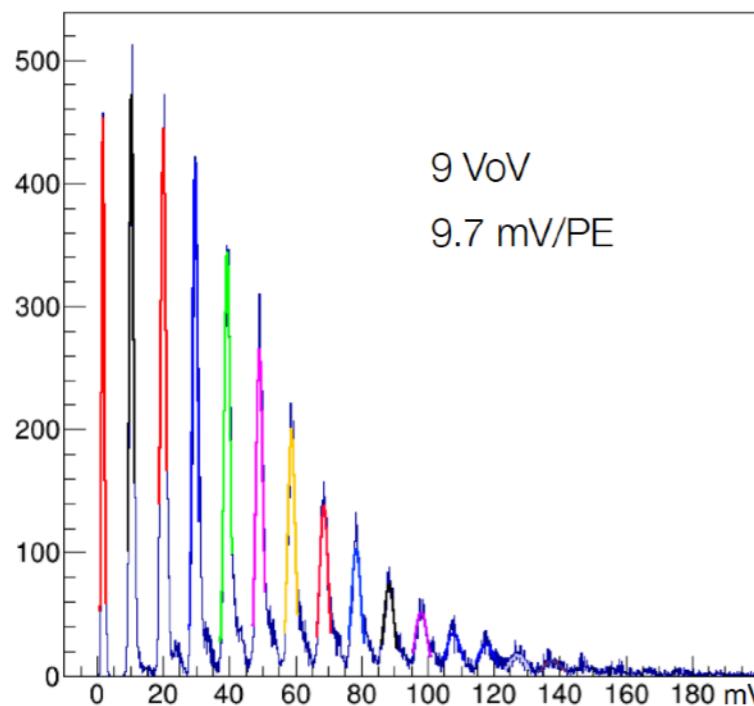
SW (analysis, database) and quality assurance [Lancaster, Manchester, RHUL, Edinburgh]

- Develop Analysis framework and data handling procedures
- Define performance requirements

...



First vTile Prototype



Conclusions

Several successful R&Ds provided solutions and green light to start the construction phase

- GdPMMA for neutron veto
- cryostat site preparation
- TPC photo-electronics
- Neutron veto Optical Module development (led by UK institutions)

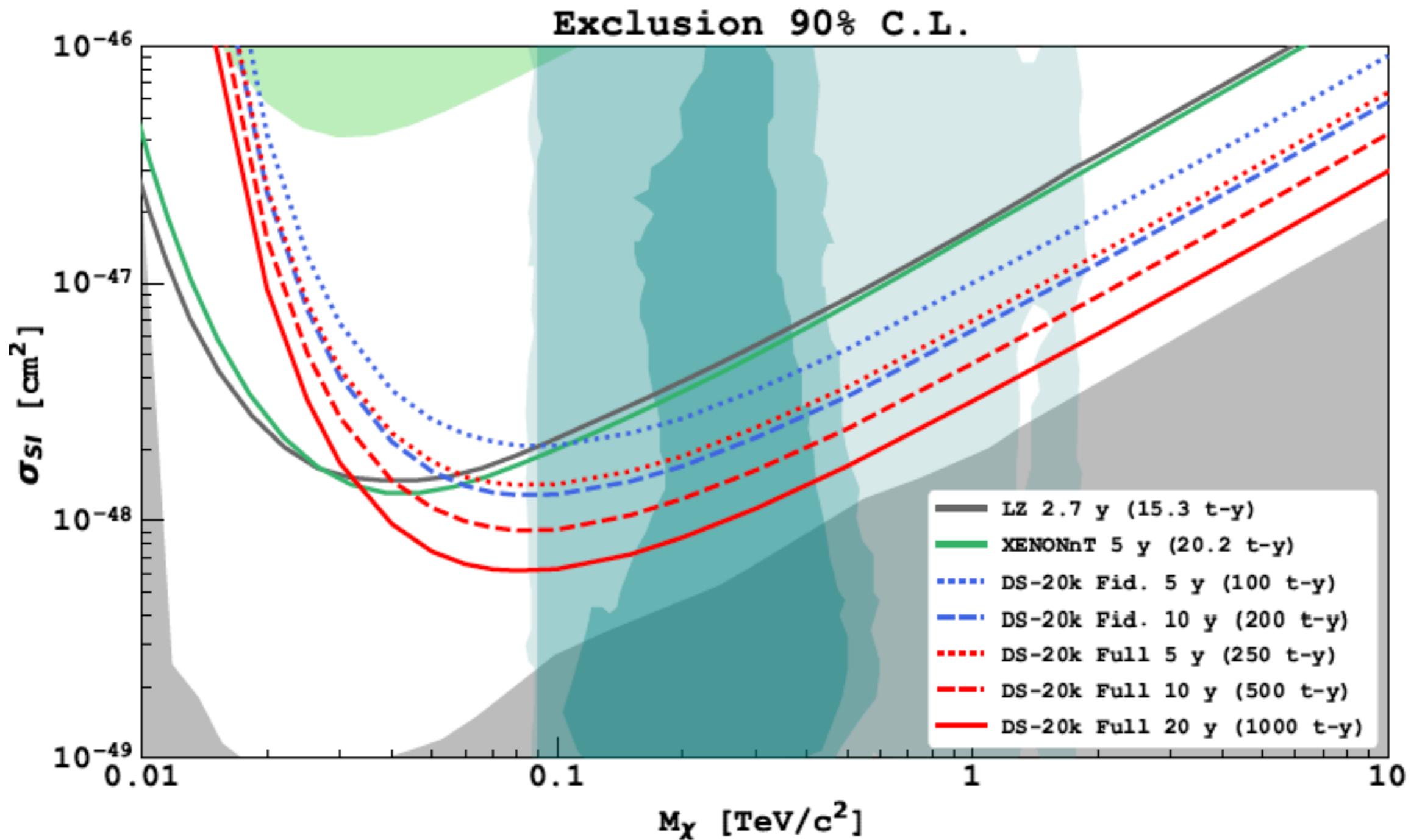
Now starting to deal with mass production, testing and characterisation



DarkSide-UK Collaboration Meeting

Sensitivity projections

PSD (<0.1 ER) + < 0.1 NR (instrumental backgrounds) + CNNES



RHUL test stand

