

Giornate di Studio: Progetti del Centro Fermi 2020-2022

K-SiPM

(SiPMs at cryogenic temperatures)

M. Garbini
Centro Fermi

K-SiPM



- The Centro Fermi K-SiPM project (started in 2018) is a **R&D activity** (and not only) in the context of the DarkSide experiment (approved in 2017).
- DarkSide-20k will be a powerful experiment at LNGS to directly detect Dark Matter.
- It is a two phase (Liquid/Gas) Argon Time Projection Chamber.
- **The technological breakthrough in the DarkSide experiment is the use of SiPMs at cryogenic temperature instead of traditional PMTs.**

The Centro Fermi Group

Researchers

- D. De Gruttola (P.I.)
- F. Coccetti
- M. Garbini

Grants

- C. Pellegrino

Associate scientists

- F. Carnesecchi

The Expertise

- **Advanced detectors for particle and astro particle physics (ALICE, EEE, LVD, XENON)**
- **Computing**

The Centro Fermi Activities



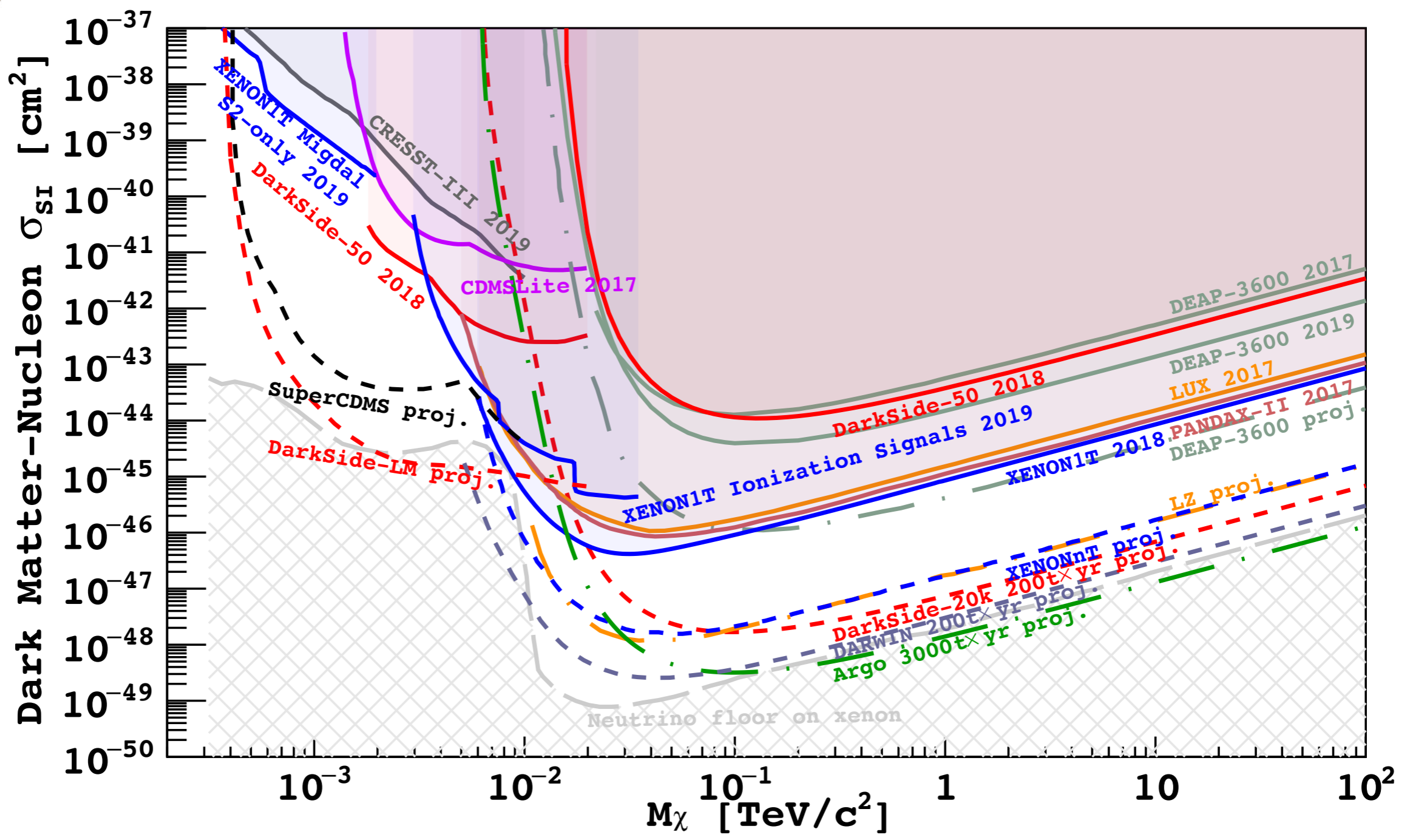
- Participation to the assembling, test and characterisation of the photodetectors of the DarkSide Experiment

- Development and maintenance of the DS construction Database

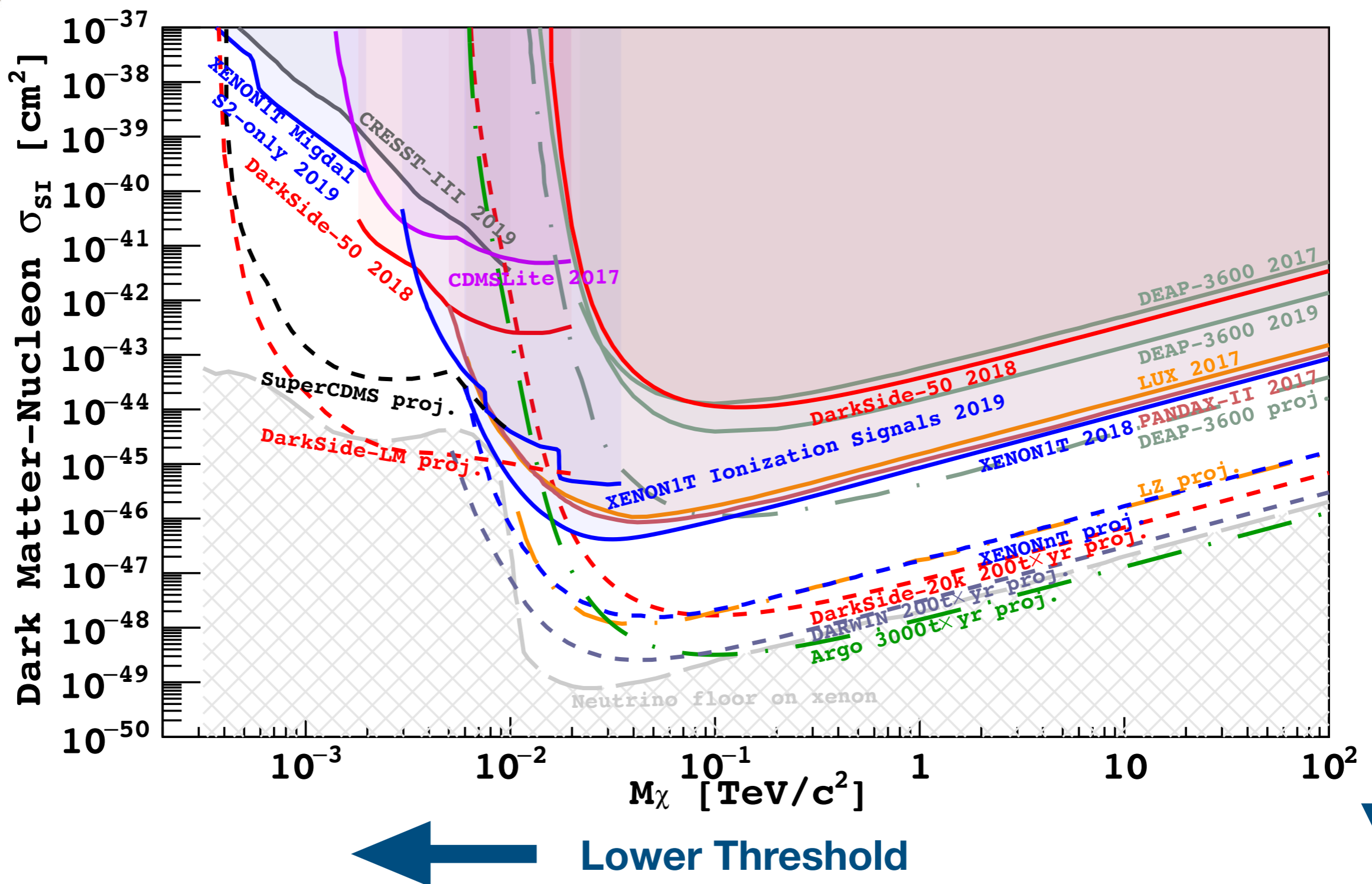
- Outreach activities

Detector construction

The WIMP Landscape



The WIMP Landscape



DM detector recipe



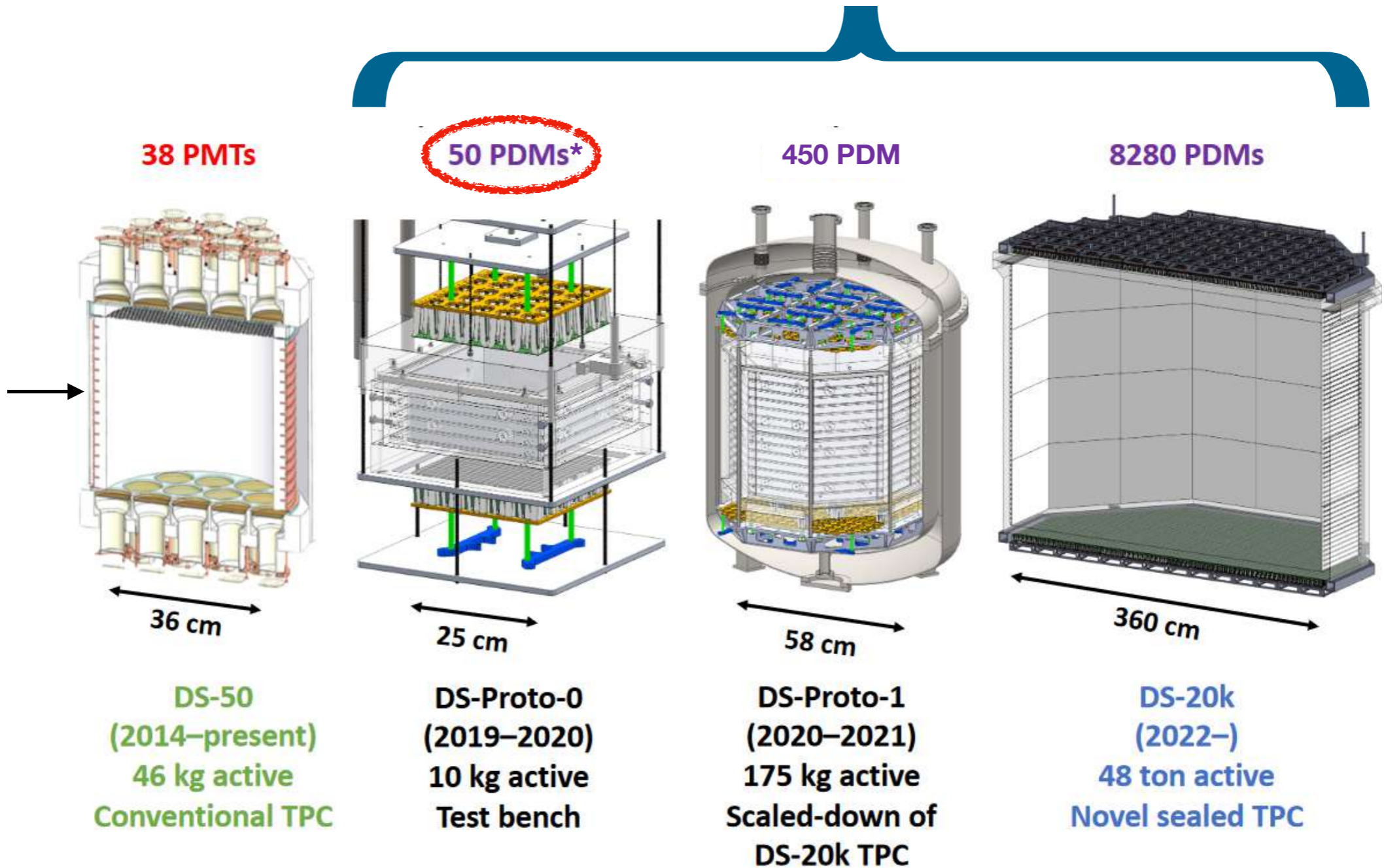
- Some tons of Noble gas, Argon works better
- Make it clean
- Make it cold until liquid
- Cook it underground
- Wait
-
- Keep waiting

The DarkSide Program



Transition from PMTs to **SiPMs** both for threshold and background mitigation

Running at LNGS



PDM: PhotoDetectionModule



The whole Centro Fermi group is collaborating to the activities of the DarkSide Photoelectronic (PE) group in charge of the assembling&tests of the PDMs and MBs of the DarkSide Program (from Proto-0 to DarkSide-20k).

2019 activities:

- **Weekly PE meetings**
- **Collaboration meetings**
- **Construction (in agreement with Bologna INFN Section) of a MB mechanical mockup for tests in PROTO-0**
- **Participation to the first PROTO-0 functional tests**

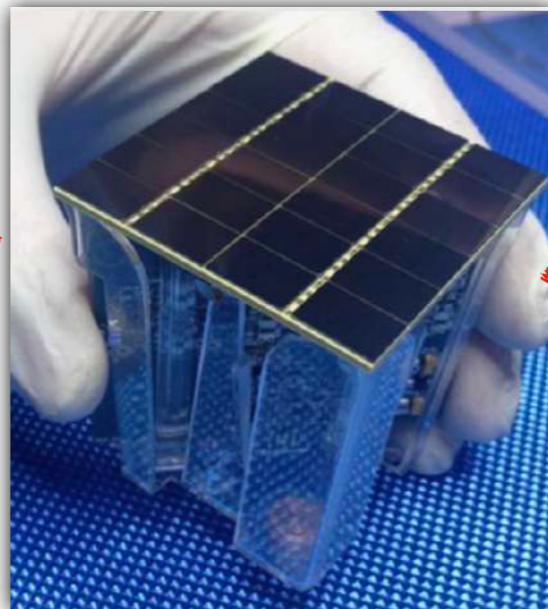
Foreseen 2020 activities:

- **Weekly PE meetings**
- **Collaboration meetings**
- **Participation to the assembly of PMDs for PROTO-1**

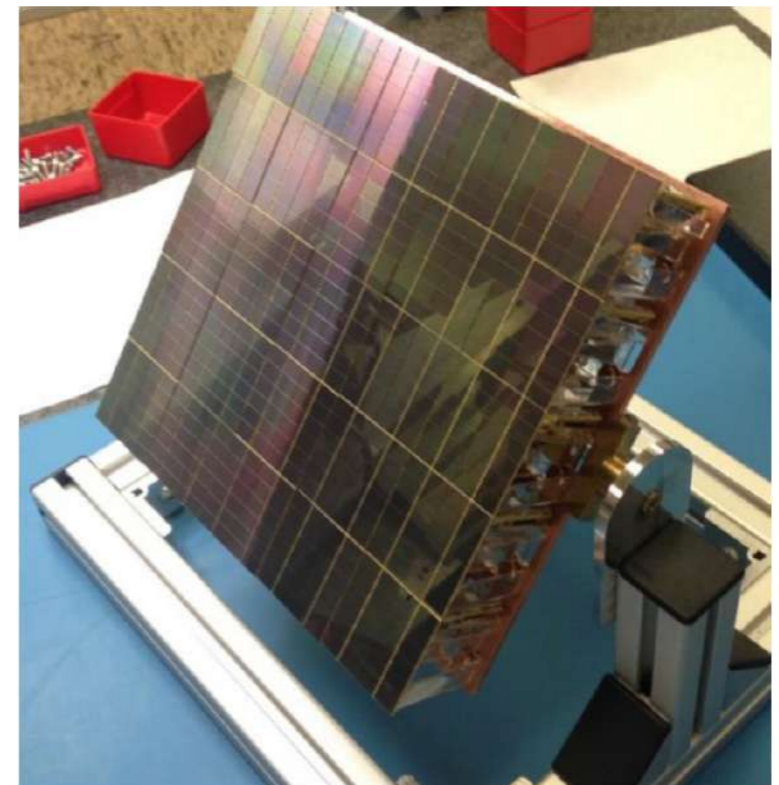
From SiPM to the PDM to the MB



8x12 mm²
 NUV-HD-Cryo SiPMs
 from FBK-LF



5x5 cm² + FrontEnd: PDM



25 PDMs (25x25 cm²) + Steering Module + Optical transmitter

SiPMs Pros'

- High PhotoDetection efficiency
- Better Single Photon resolution
- Lower background
- Lower cost

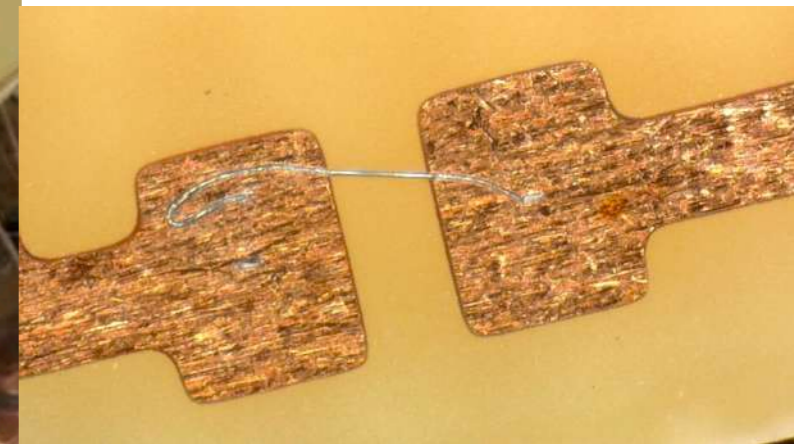
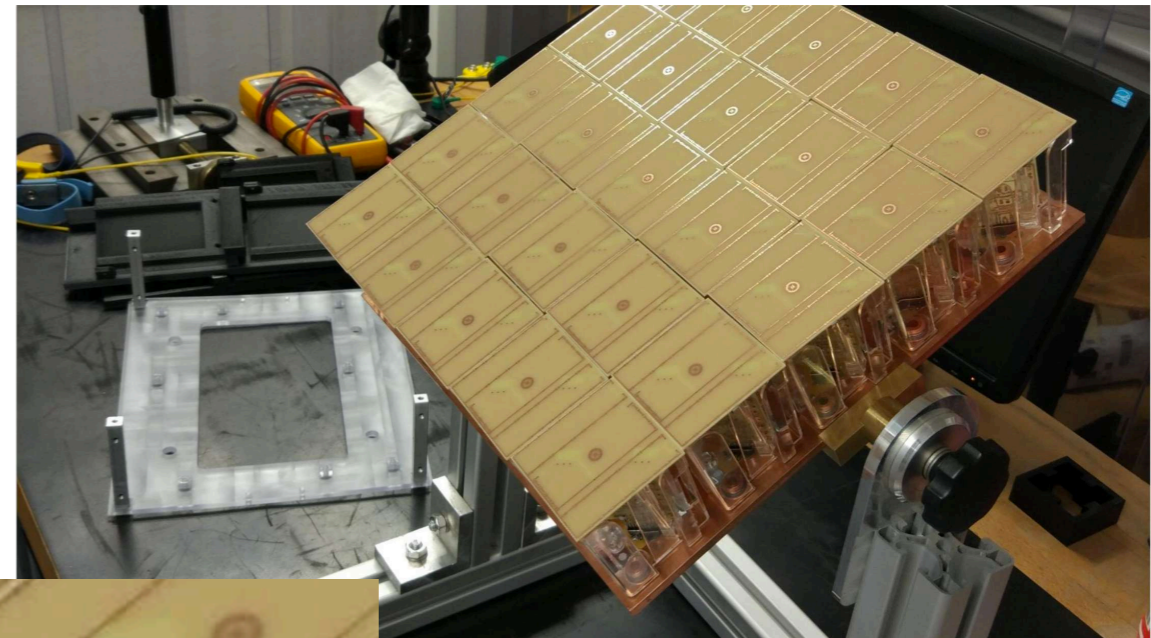
Detector	Nb. of MB	Nb. of PDM	Nb. of SiPMs
PROTO-0	2	50	1200
PROTO-1	18	450	10800
DS-20k	344	8280	198720

Assembly of mockup @ Bologna



Construction of a MB mechanical mockup for tests in PROTO-0.

- No SiPMs on the PDM but just wire bondings.**
The mockups has been used at CERN to
- check mechanical interferences in the PROTO-0 TPC**
 - establish mounting procedures**
 - define cool down and warm up procedures**



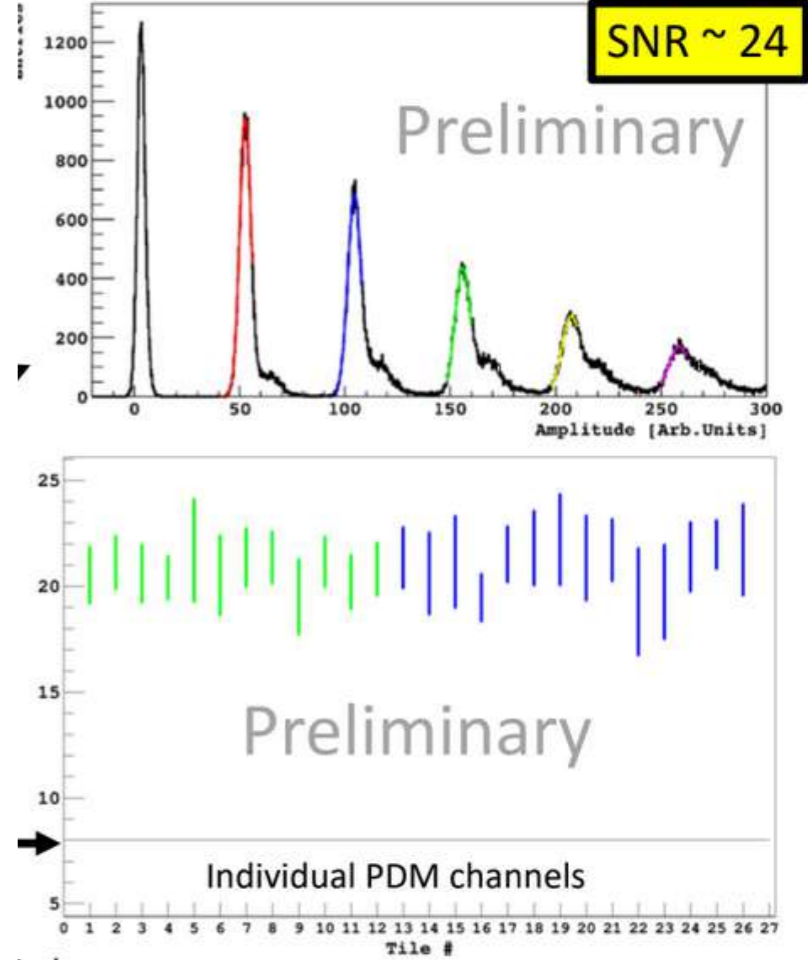
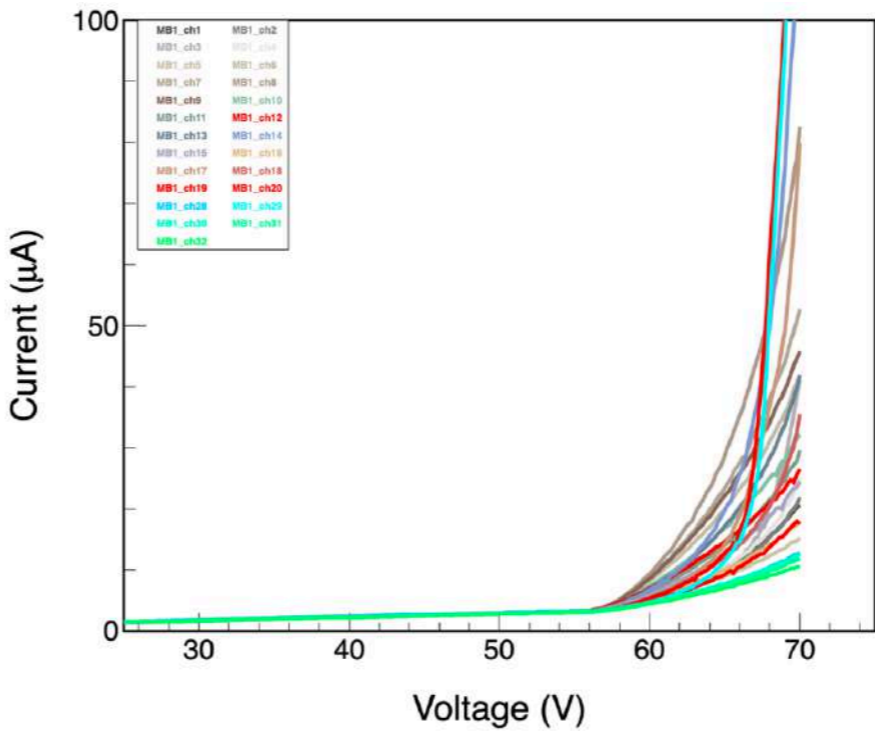
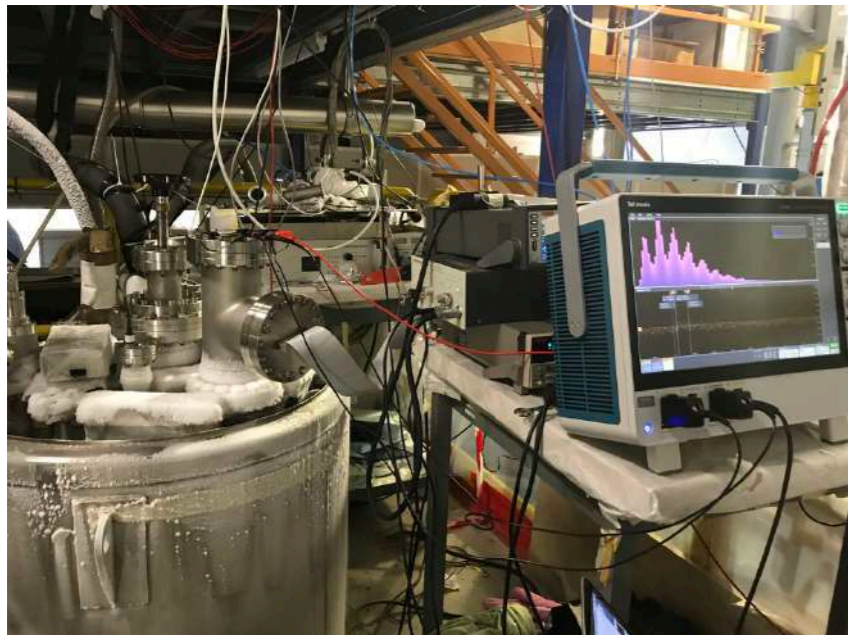
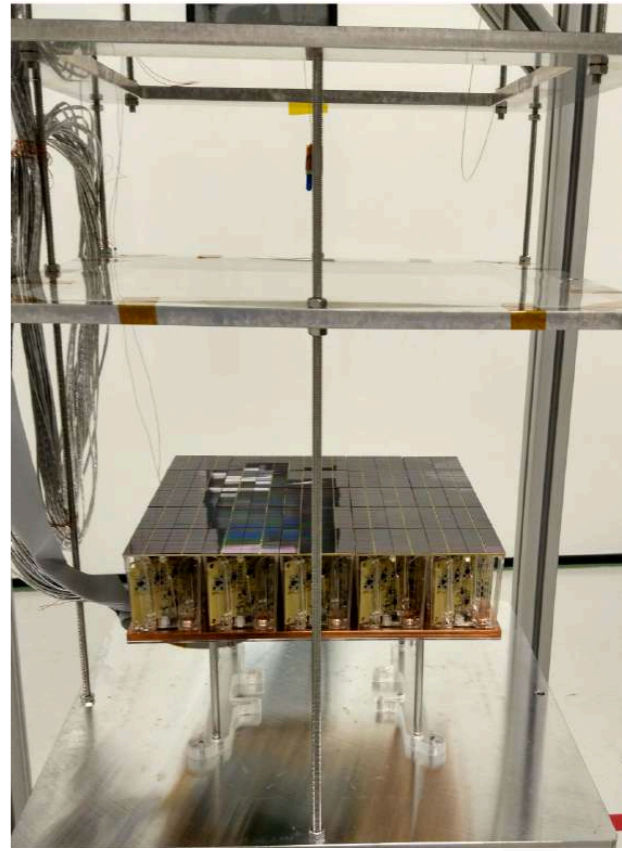
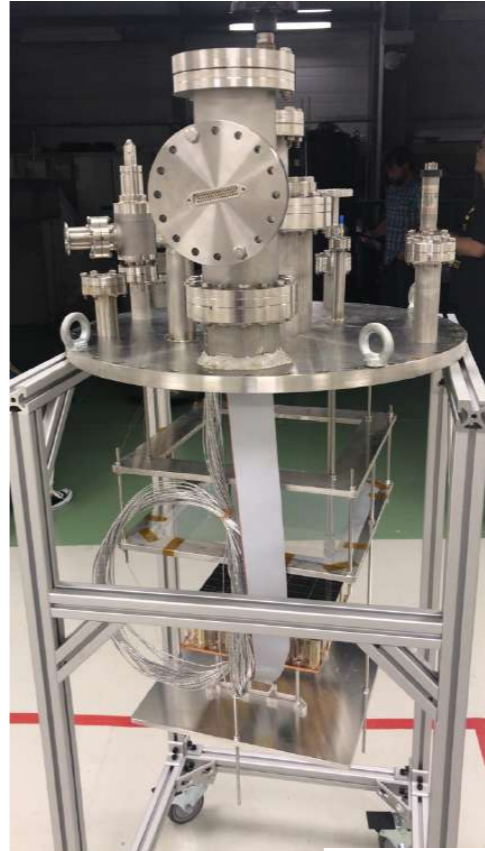
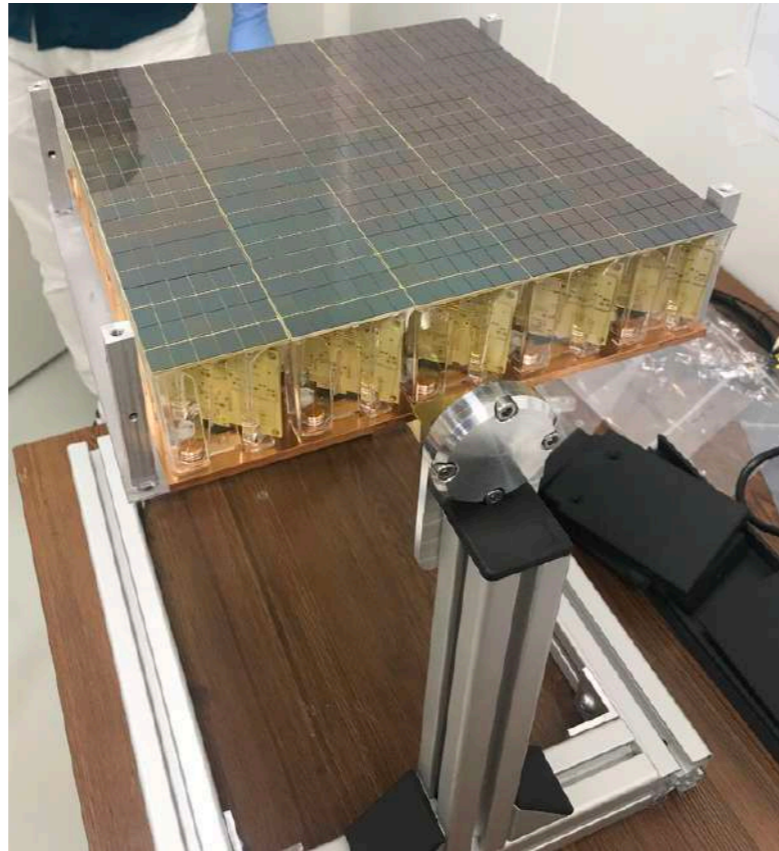
Also people from Salerno University people joined during this phase

Test successful —> proceed with MB test

First Tests of MB @ CERN



- First MB mounted in the PROTO-0 TPC at CERN
- First functionality tests in liquid Argon
- Tests on MB 2 in Gas phase finished few days ago



The Construction DataBase

Centro Fermi has the full responsibility of preparing the Construction Database of the DarkSide experiment



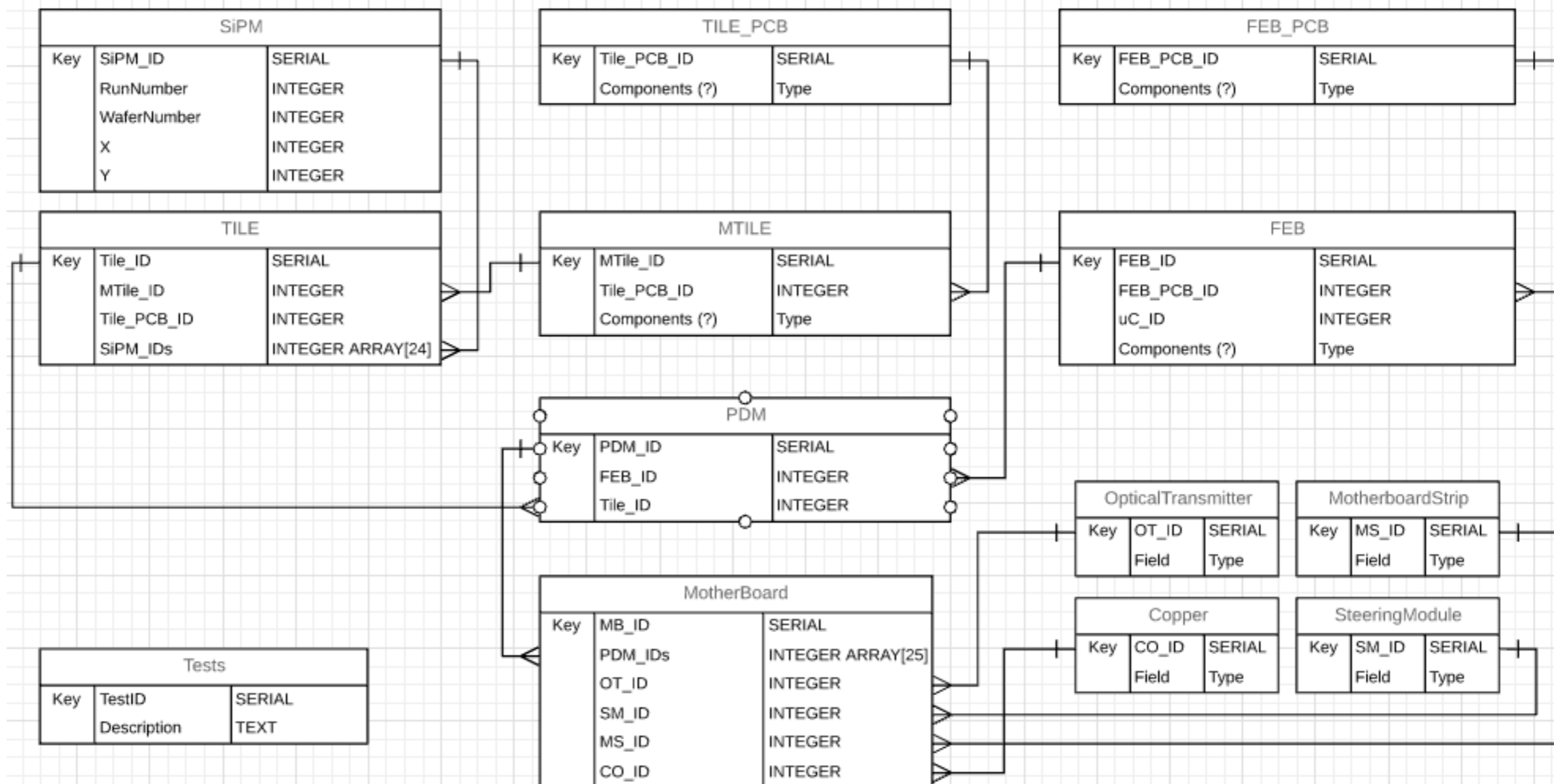
We started in January 2019 this task; main requests:

- **redundancy (backup in different sites)**
- **security (access management, log)**
- **remote access**
- **support for automation**
- **graphical user interface**

Recall the numbers!

Detector	Nb. of MB	Nb. of PDM	Nb. of SiPMs
PROTO-0	2	50	1200
PROTO-1	18	450	10800
DS-20k	344	8280	198720

DB Schema - Mappings



First graphical mapping of the DB tables

DB – Graphical User Interface



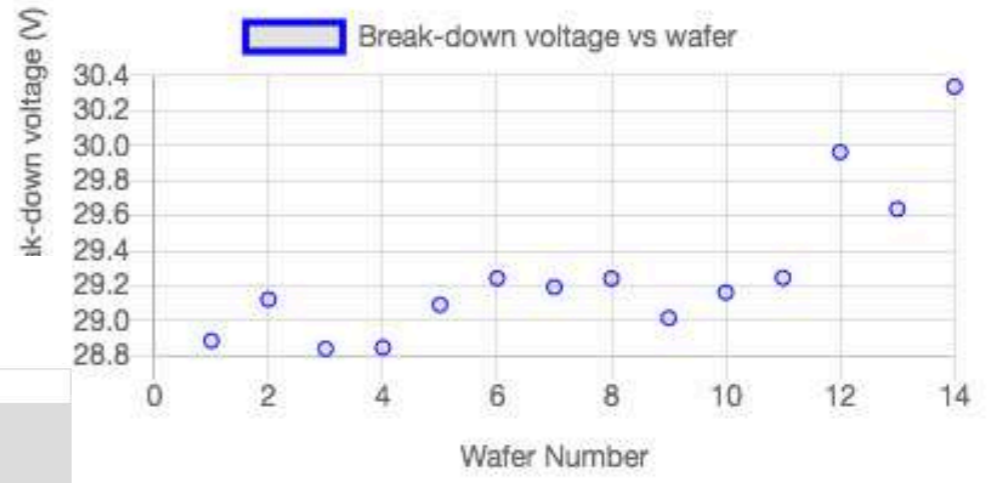
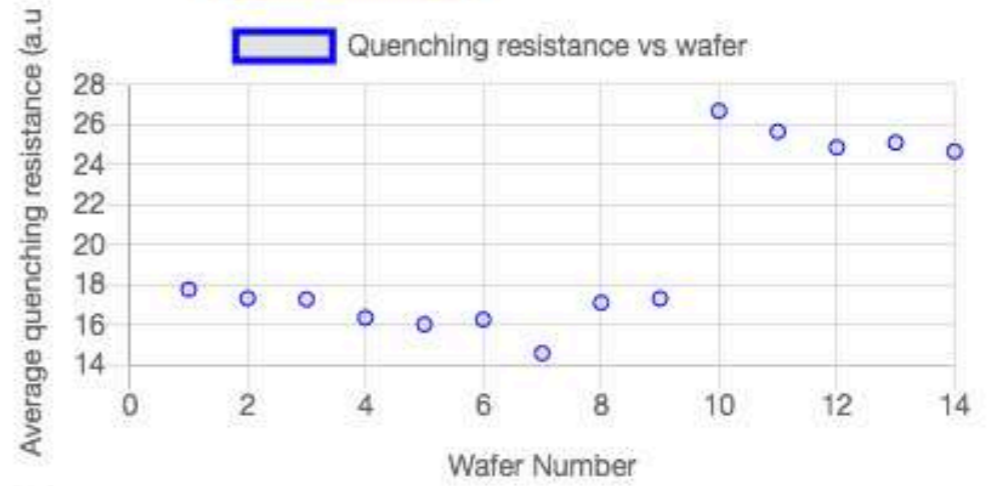
Visualise the SiPMs wafer (easy insertion of data)

Run list

Run #1 Run #2 Run #3 **Run #4**

Wafer list

Wafer #1 Wafer #2 Wafer #3 Wafer #4
 Wafer #5 Wafer #6 Wafer #7 Wafer #8
 Wafer #9 Wafer #10 Wafer #11
 Wafer #12 Wafer #13 Wafer #14



Previous wafer in run Next wafer in run

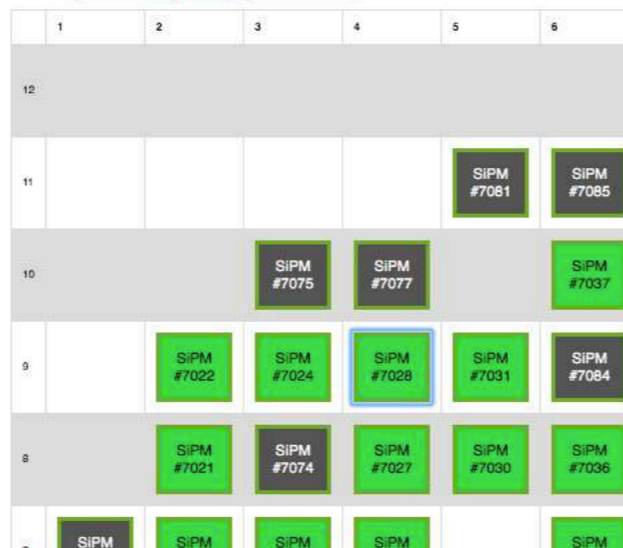
Wafer properties

KEY	VALUE
Manufacturer	FBK
RunNumber	4
WaferNumber	11
Wafer PID	61
Production date	2019-09-13T10:58:16.682955
SPAD size	undefined
Doping dose	undefined

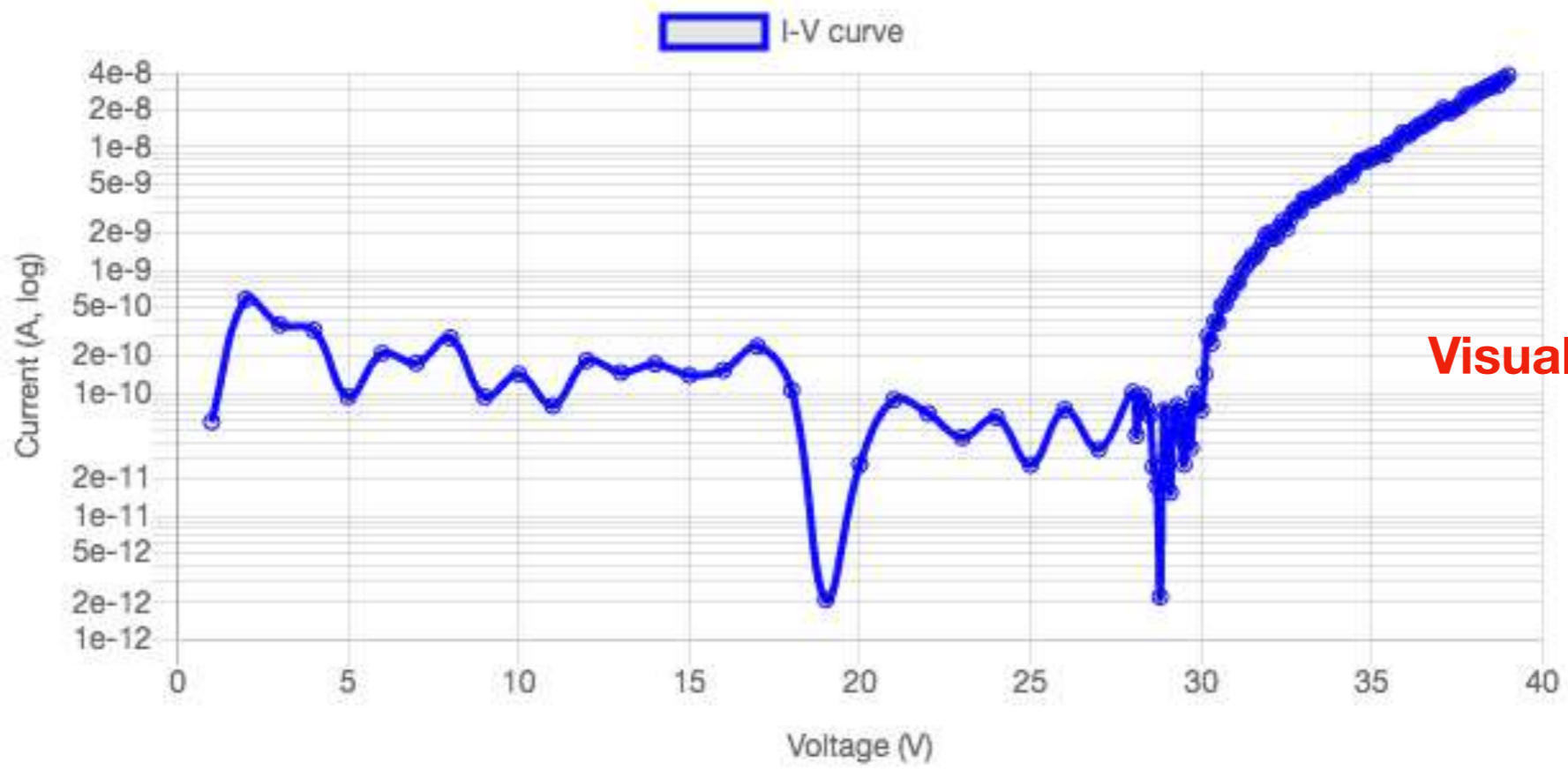
Calculated parameters

KEY	VALUE
Number of good SiPM	47
Number of possible tiles	1 tiles + 23 SiPM
Used SiPM	0
Unused SiPM	47
Still produceable tiles	1
Yield	32.19%

Legend: Useable Used Unuseable



DB – Graphical User Interface

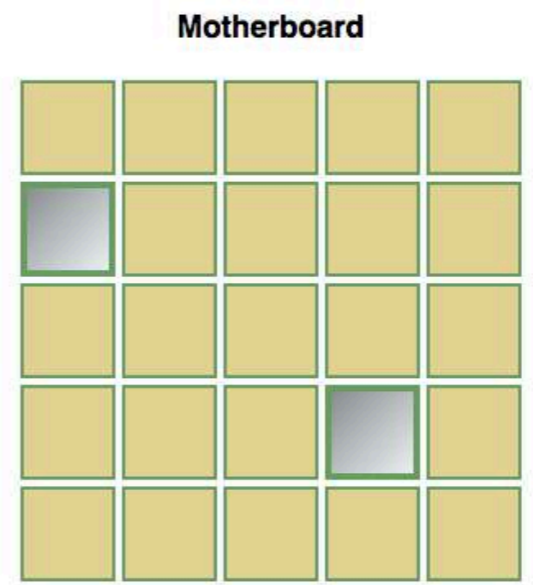


Visualise the SiPMs I-V curves

Assembly PDMs

PDM Shelf

Highlight	PDM	Name
<input type="checkbox"/>		PDM 1 <small>recall</small>
<input type="checkbox"/>		PDM 2 <small>recall</small>
<input type="checkbox"/>		PDM 3 <small>recall</small>
<input checked="" type="checkbox"/>		PDM 4 <small>recall</small>





Centro Fermi Activities

- **Active contribution to the assembly and to the test of the photodetectors for PROTO-0**
- **Direct involvement in the construction and tests of the photodetectors for PROTO-1**
- **Development of the Experiment Construction Database**

Outreach activities



Centro Fermi has the full responsibility of the outreach program for the DarkSide Experiment

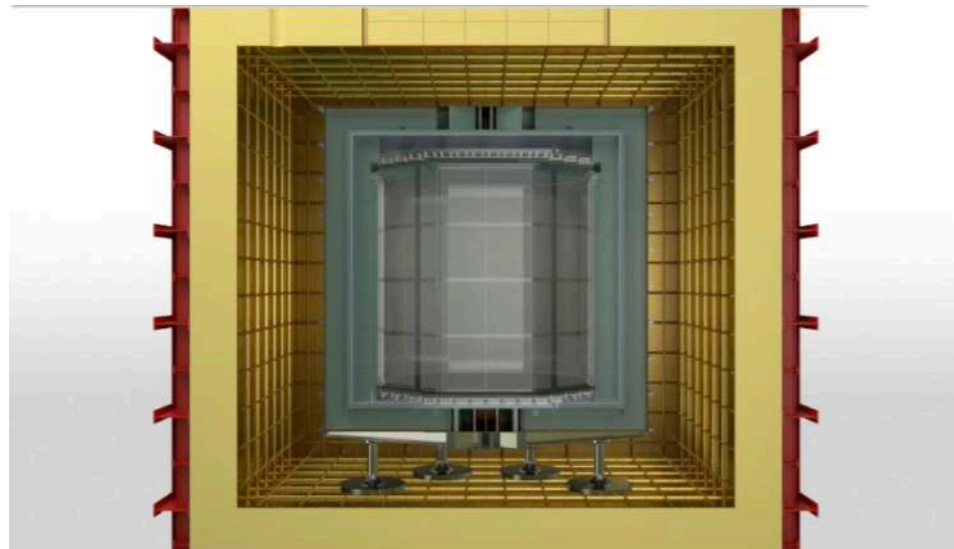
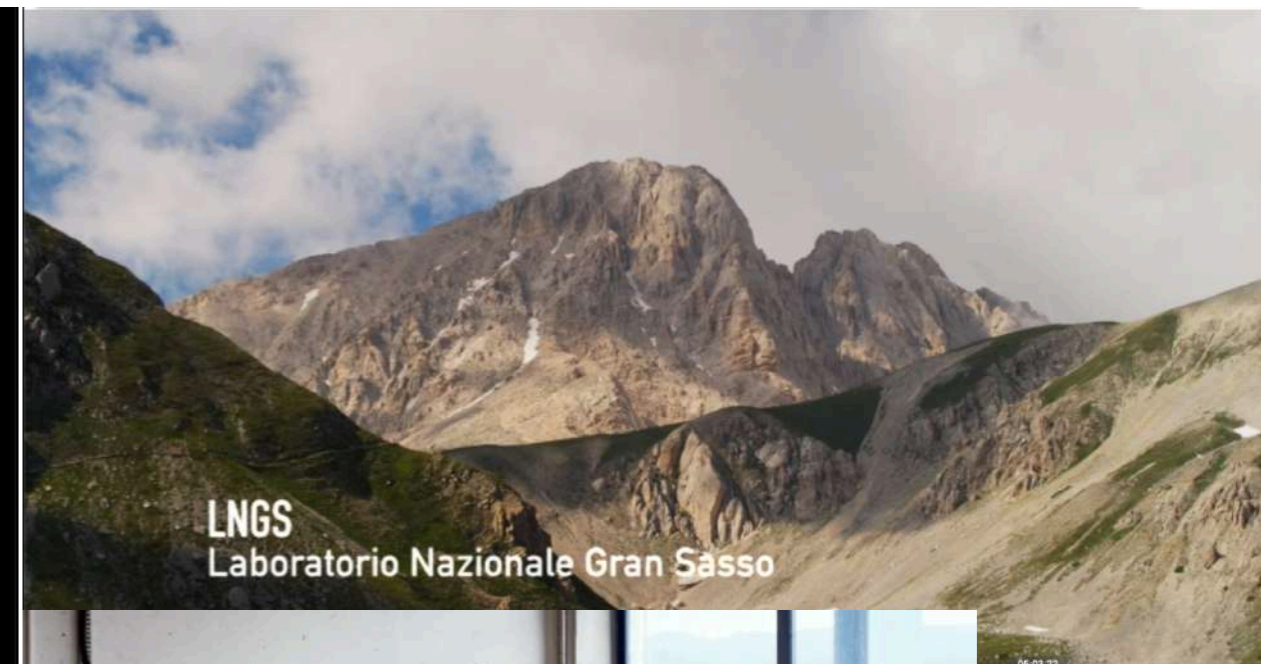
- **Experiment Promotional Video**
- **Masterclasses for high school students**
- **Social media**
- **Yearly education and outreach events**
- **Construction of the new DarkSide official website**

The outreach group led by Centro Fermi has now 30 members from the collaboration

Promotional Video

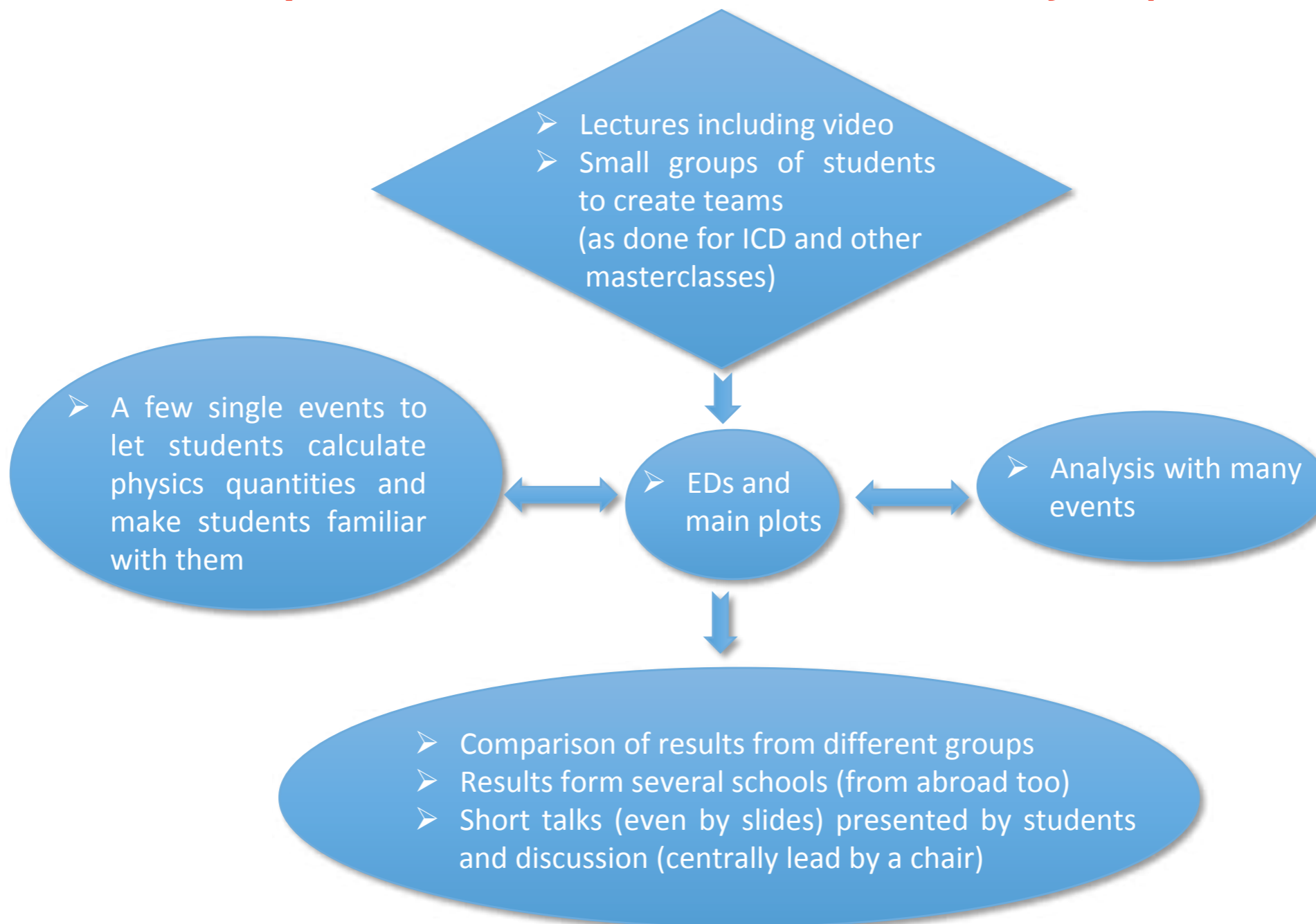


- The storyboard has been presented twice at DS Collaboration meeting
- The video is almost ready and it will be released soon
- Green light from DS Executive Board
- It can be added to DS web site, used in many kind of events, on social media etc



DS Masterclasses

The Centro Fermi group has experience in outreach activities for high school students developed in the mainframe of the EEE Project (and IPPOG).



Material ready and first test with high school in Vicenza fixed for January the 20th

Masterclasses - an example



★ *Proposal for social media*

- *DS-20k Instagram and Facebook accounts could be used*
- *Rather regular posts and news in order to be effective*
- *News could be shared on web site and social media*

★ *Yearly education and outreach events*

- *Dark Matter Day*
- *Futuro Remoto*
- *Visits to LNGS and ARIA*

★ *Renewing DS-20k website*

- *Existing site to be updated*
- *Wordpress used till now*
- *Work started using Google site*

SUMMARY



- **The Centro Fermi K-SiPM group is working on cryogenic SiPMs based detectors in the context of the DarkSide-20k experiment. We are actively participating to the DS-20k PE group to construct and test the detectors for all the DS program. Already in 2019 the group strongly contributed both to the construction and test of the first photodetectors.**
- **Beside this activity the Centro Fermi is developing the DS-20k construction Database which will store the information of all the detector components, providing a powerful tool for detector optimisation.**
- **Due to the experience of the group also an intense outreach program is ongoing and continuously updating.**



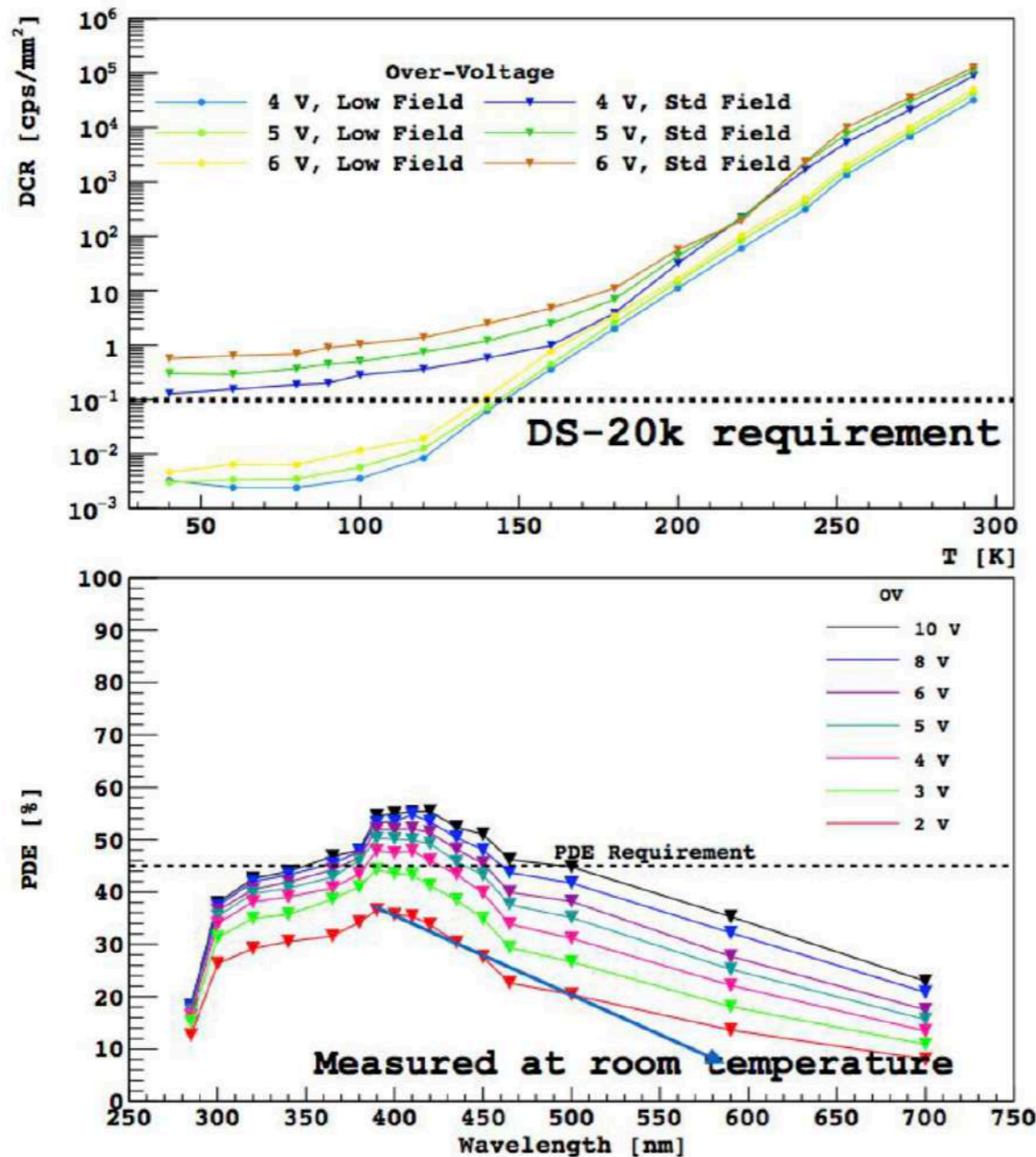
EXTRA

The DarkSide Collaboration





DS-20k: The Choice of NUV-HD-LF



Low Field technology proved to fulfill the strict requirements.

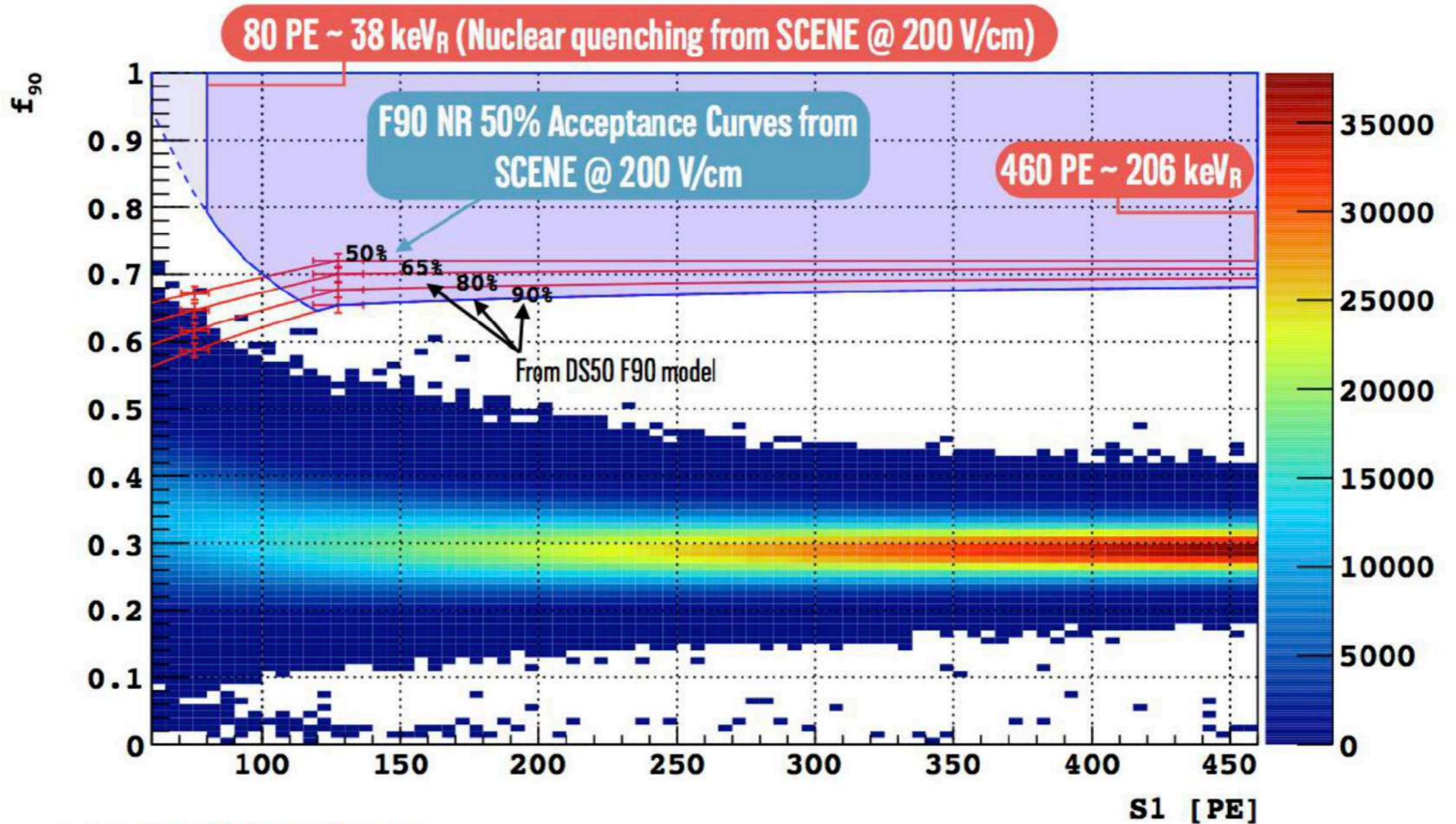
- **DCR** $\sim 4 \times 10^{-3} \text{cps/mm}^2$ at 5VOV, LAr temperature.
- **AP+DiCT** probability $< 60\%$ at LAr temperature.
- **PDE** 50% at 5VOV at 420nm.
- **Cell Recharge Time** at LN $\sim 500\text{ns}$.
- **Surface:** 1cm^2

IEEE Trans. Electron Dev.
64 2, 2017

DS-50 first results



Background free exposure of 1422 ± 67 kg \times day



[Phys. Lett. B 743 \(2015\) 456](#)

Corresponds to ≥ 20 yr exposure of DS-50 with UAr

Selected only single-hit interactions in the TPC fiducial volume (36.9 kg) with no energy deposition in the veto

DB Technical specifications



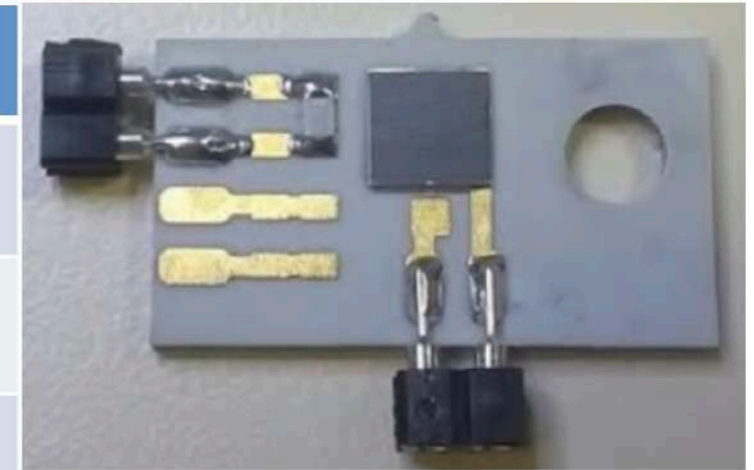
- Leveraged technologies:
 - nginx as a http proxy
 - PostgreSQL as DataBase Management System (DBMS)
 - RESTful API as an interface to the DB
- Current infrastructure deployed at CNAF (T1 + cloud)

PMTs vs. SiPMs



3" PMT

Pro's	Con's
High photodetection efficiency	Small area
High single photon resolution	Large number of components
Low cost	High capacitance per unit area



4x4 mm²

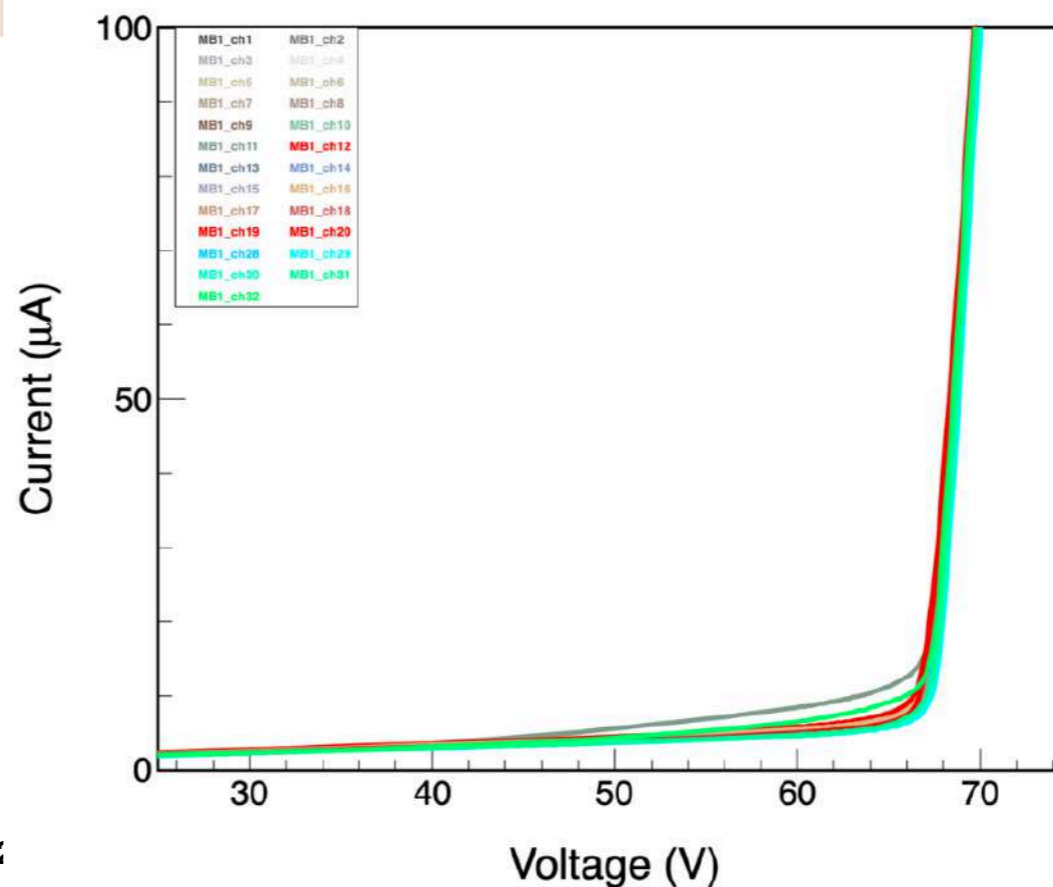
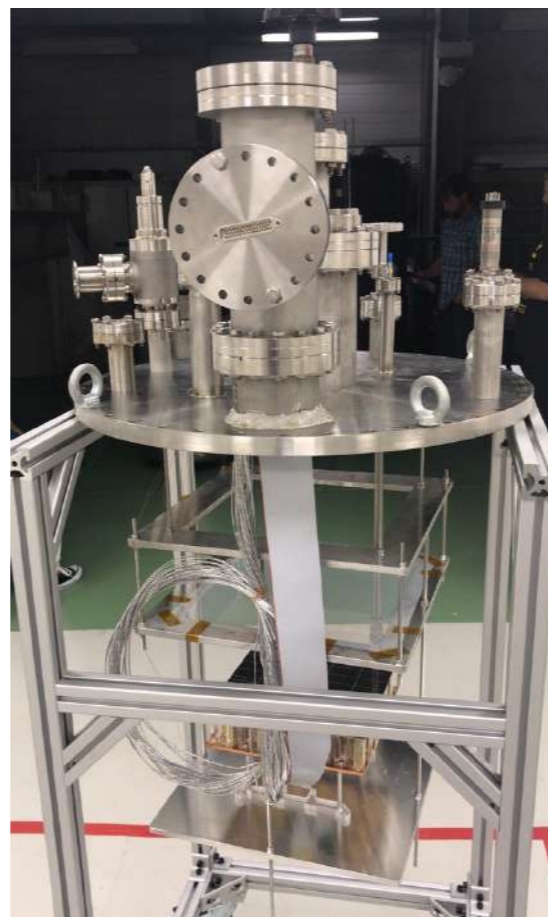
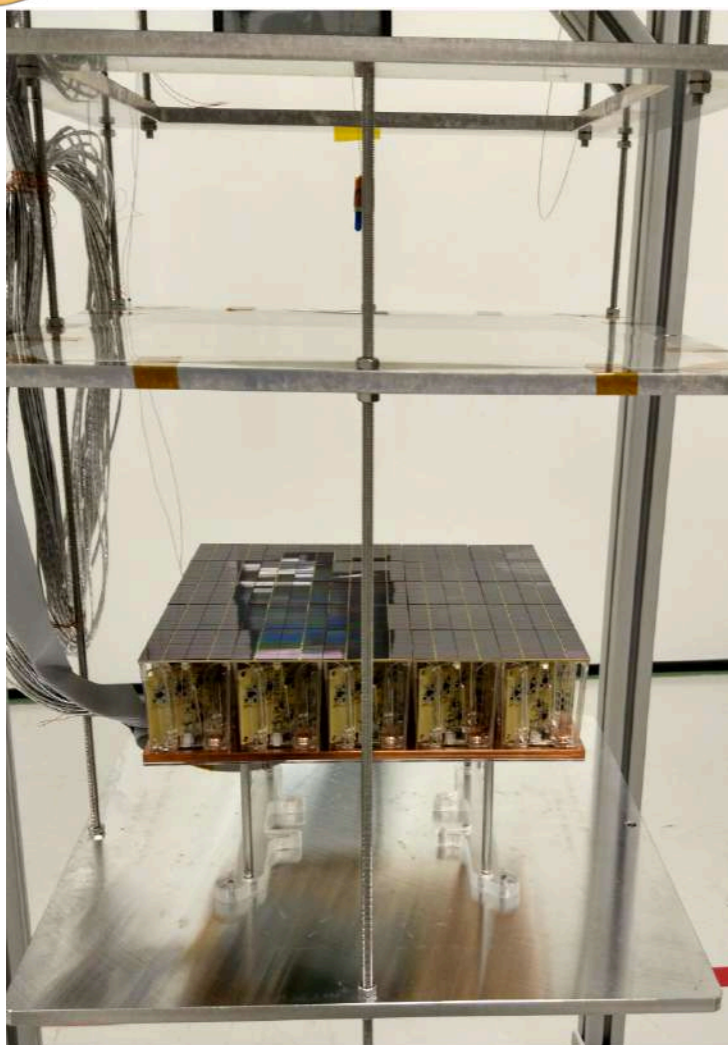
Strong R&D was needed to compete with PMTs

Features	PMT	SiPM
Bias Voltage	1000 ÷ 2000 V	30 ÷ 40 V
Sensitivity to magnetic fields	YES	No
QE/PDE @420 nm @300 K	30%	40 ÷ 50 %
SPE resolution	25%	2 ÷ 5 %
Gain	10 ⁶ / 3×10 ⁵ nominal / real	10 ⁶
Dynamic Range	>>10 ³	10 ³
DCR	1 cps/PMT	10 ÷ 1000 cps/mm ²
Packing efficiency	60%	80 ÷ 90 %

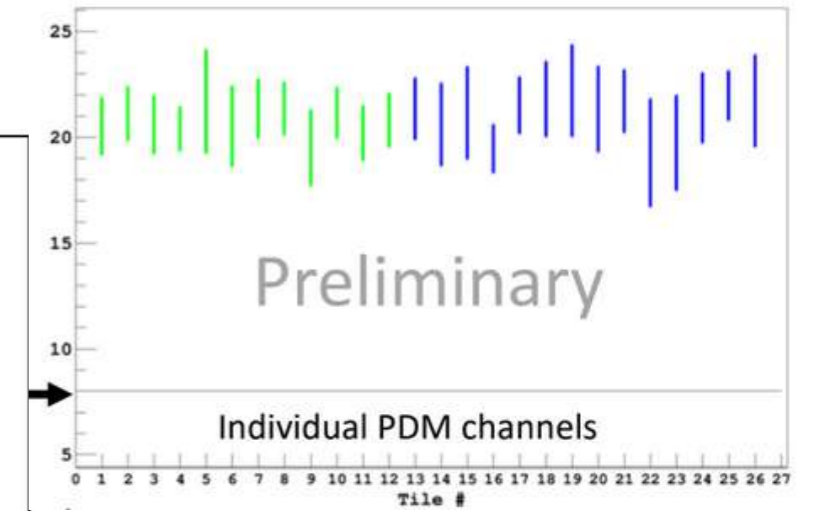
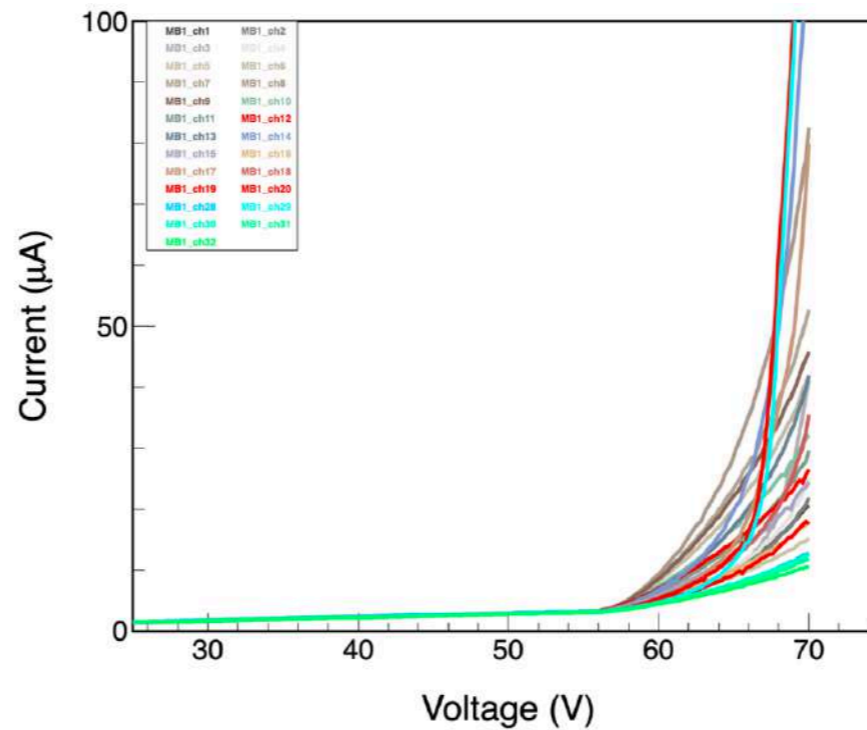
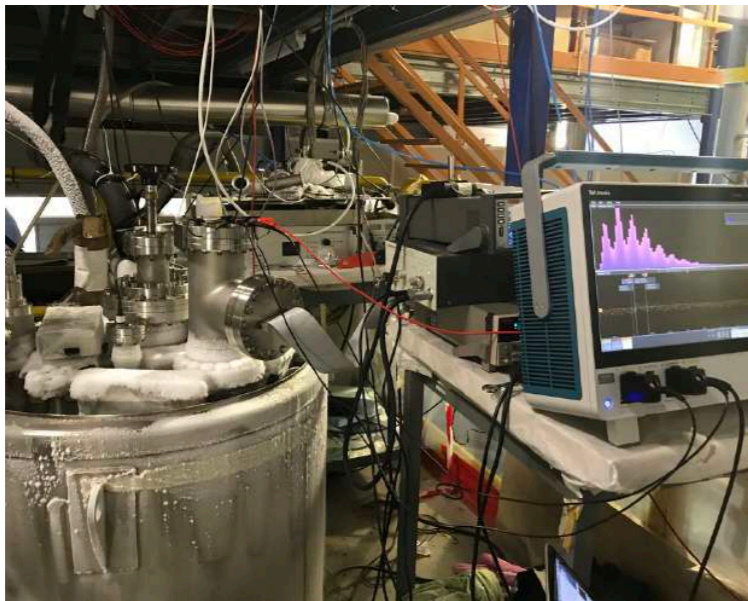
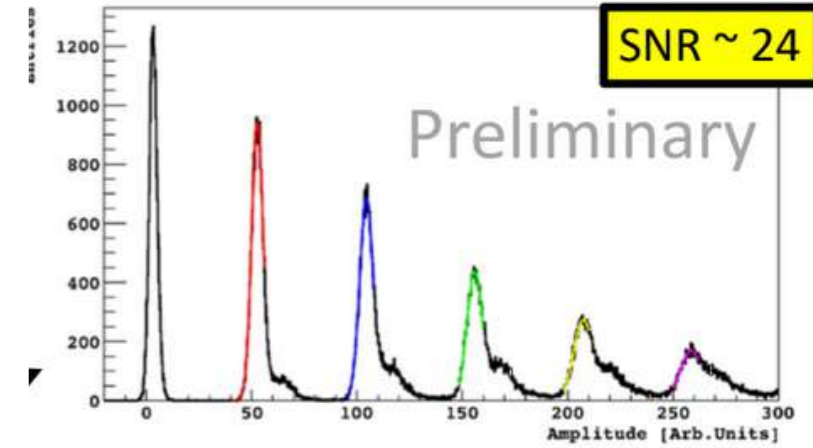
Comparison at Liquid Argon Temperature (87 K)

Back

Test @ CERN



Final Setup



PDMs illuminated with a Laser:
-First Spe Spectra in Liquid Argon
-First tests of DAQ system

Second test of PDU in Gas phase inside the TPC finished few days ago - data analysis ongoing

The DS Masterclass



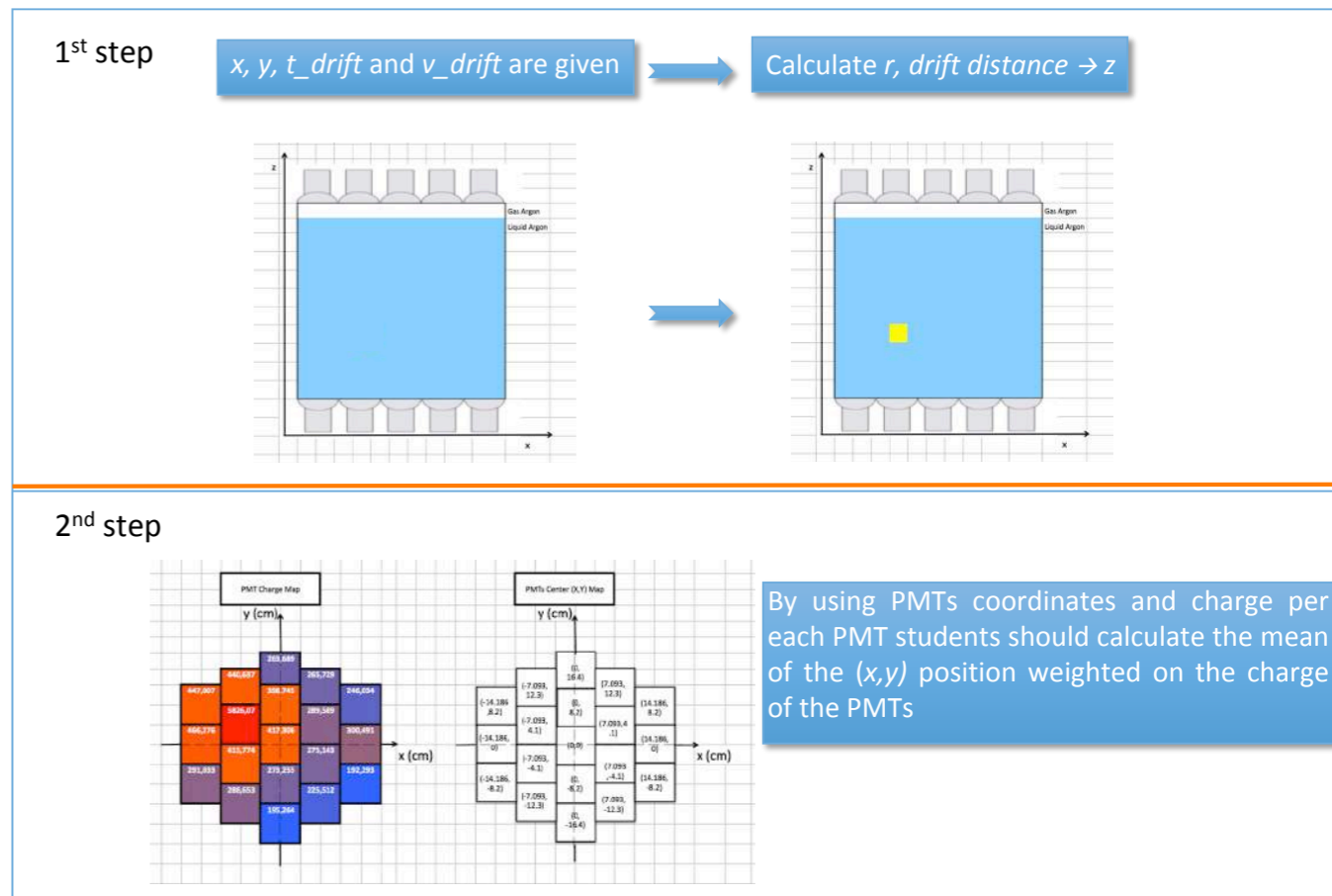
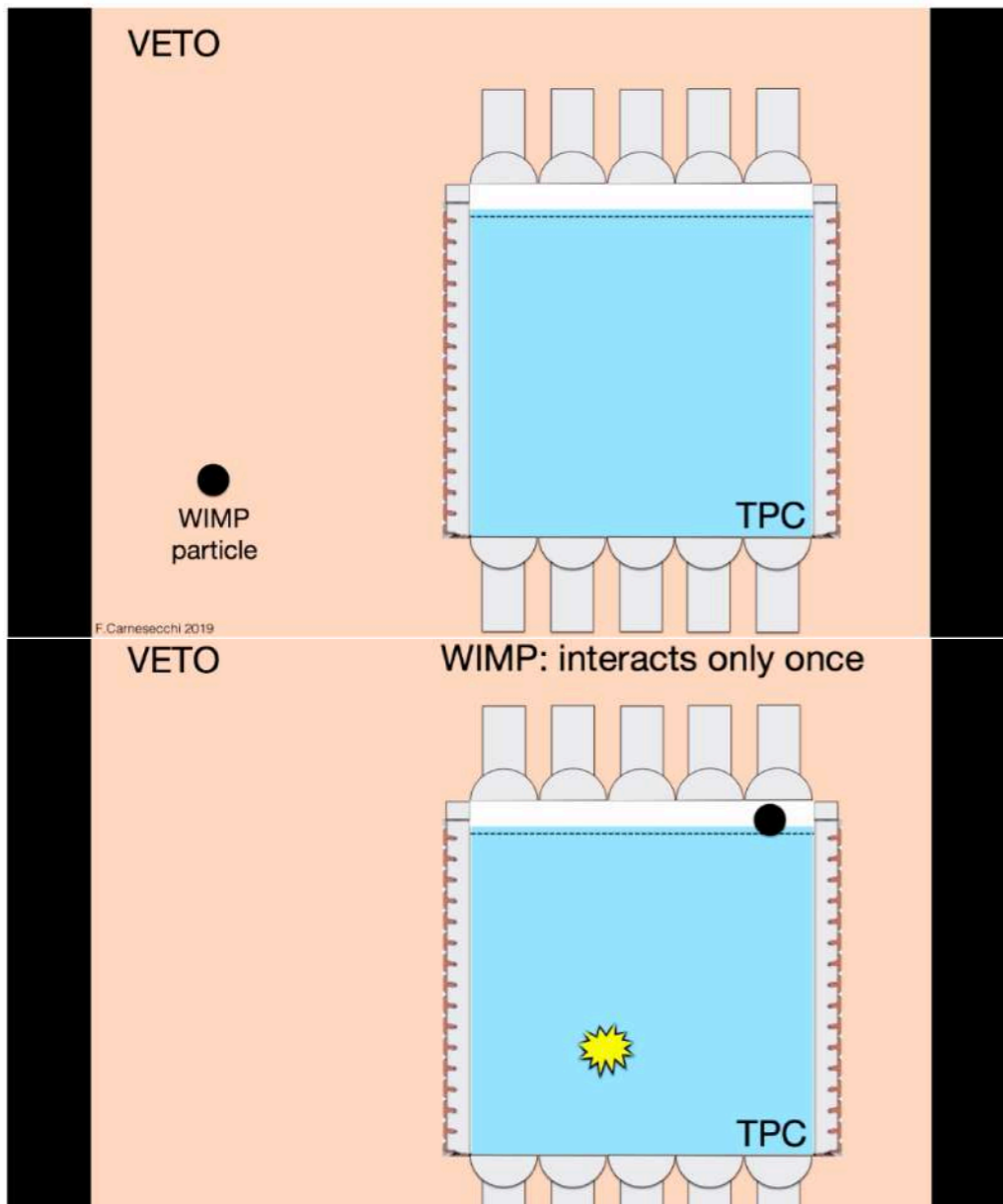
A dataset is usually made available by the experiment to let young students analyse data (A small set of DarkSide50 has been kindly provided by D. Franco and V. Ippolito)

The masterclass is usually divided in:

part 1: lectures on the physics case and the experiment

part 2: practical examples to analyse data, exercises done by the students

part 3: presentation of the results made by the students



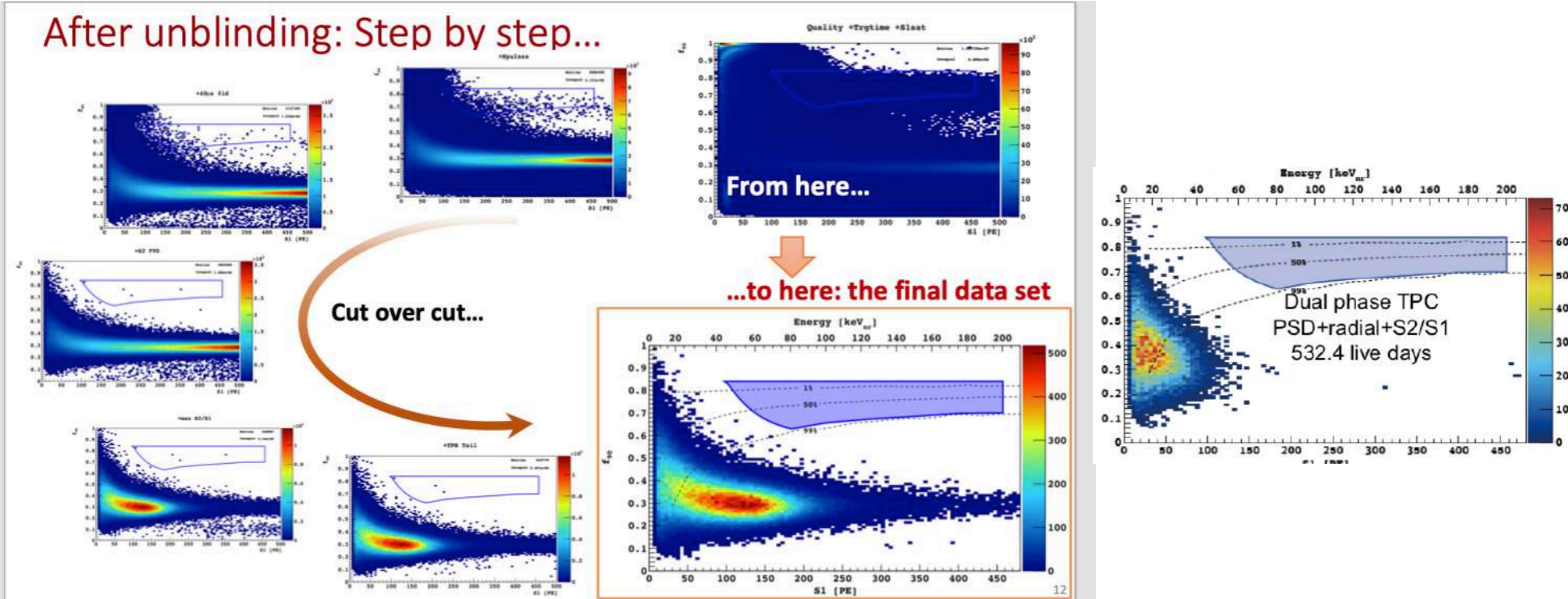
Example of both the lecture and the excel file for event display analysis

Looking for Dark Matter

Lecture on the data selection for DM analysis



After unblinding: Step by step...



And Excel file exercise

Point 1: Following the examples by the tutor calculate the quantities in RED

Event	S1(pe)	S190 (pe)	S2 (pe)	X (cm)	Y (cm)	L_drift (cm)	VETO (pe)	r90	r (cm)	Drift Distance (cm)	Z (cm)	Drift Velocity (cm/s)	TPC Total length (cm)
4	421.27	115.38	18394	-7.2221	3.5725	253.38	3.0715058	0.2739	8.0574	29.56434	12.036		
14	459.42	143.45	10155	-11	-6.6405	288.7	0	0.3122	12.849	26.8491	8.7503		
27	267.08	75.099	7108	1.4445	-5.3332	166.168	5.3563623	0.2812	6.4999	15.433624	20.146		
31	99.84	23.776	1560.1	-10.408	3.9914	48.384	2.5506225	0.2391	11.147	4.490712	31.1		
33	313.31	82.069	4011.1	-9.8463	-11.117	309.196	1.1224209	0.2619	14.831	28.750228	6.8448		
41	266.65	71.597	3499.9	-13.476	-1.0604	116.616	2.66002	0.2685	13.517	10.845288	24.795		
48	130.63	37.534	3131.6	6.7778	-3	41.608	4.467326	0.2873	7.412	3.888944	31.73		
56	403.22	125.3	10189	-8.203	-10.423	75.28	5.035	0.3107	13.264	7.00104	28.599		
63	159.67	45.621	1935.2	12.199	5.7459	314.356	2.2173235	0.2857	13.484	29.235108	6.3649		
64	431.13	127.95	7166.4	13	-1	64.652	4.3931766	0.2968	13.038	6.012636	29.587		
71	292.36	69.274	8612	5.9783	8.4353	60.94	1.0969406	0.2399	10.339	5.06742	29.933		
74	456.68	119.31	16536	5.411	-4.7276	182.288	2.6668608	0.2613	7.1853	18.952784	18.947		
79	354.32	94.34	11780	4.0165	-7.8525	147.768	1.059465	0.2683	8.8201	13.742424	21.858		
88	347.92	118.08	7421.6	5.6667	-11.821	293.476	2.508141	0.3394	13.109	27.293268	8.3067		
90	471.7	130.04	20155	0.7923	-3.383	113.1	1.7193816	0.2757	3.4746	10.51893	35.082		
100	69.416	26.527	469.94	4.572	12.556	138.036	1.0924681	0.3821	13.382	12.637348	22.763		
111	106	64.637	28.907	779.99	7.2222	-12.539	319.284	4.461494	0.4472	14.47	29.693412	5.9085	
120	236.36	49.965	1809.6	-11.459	-9.2748	39.272	1.6621748	0.2114	14.742	5.512296	30.088		
124	219.21	59.695	2911.3	-11.889	-4.5556	63.764	0.7601868	0.2729	12.732	5.900092	29.87		
133	128	332.45	85.809	13369	-1.2987	0.4382	72.88	3.8157358	0.2691	1.9706	6.77784	28.802	
141	286.75	78.186	4963.7	-14.799	-1	238.752	5.3976436	0.2727	14.833	22.203906	13.396		
147	321.53	94.033	4551.3	13.415	-2.5556	297.912	1.1942999	0.2025	13.658	27.705816	7.8942		
153	148	403.54	108.92	15213	-4.6306	4.2883	53.136	0.909169	0.2699	6.3113	4.941648	30.698	
164	235.54	72.556	7902.4	-0.1977	-2.8158	301.268	0.8029839	0.308	2.8427	28.017904	7.5821		

Point 2: Draw the plot of S1 vs S2

Scope Spectra (not optimised)

