

# Highlights of the MU2E Calorimeter 2019

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**Mu2e**

NEWS General Meeting  
November 4-5, 2019

# Talk layout

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- ◆ Status of Csl production
- ◆ **Test of response for “irradiated” SiPMs (DOE-IPR-rec1)**
- ◆ **Status of electronics: PCB reviews and Next CRR**
- ◆ **Status of Calorimeter vertical slice test (DOE-IPR-rec2)**
- ◆ **Status of mechanics, cooling and services**
- ◆ **Assembly planning**

# Crystal production status

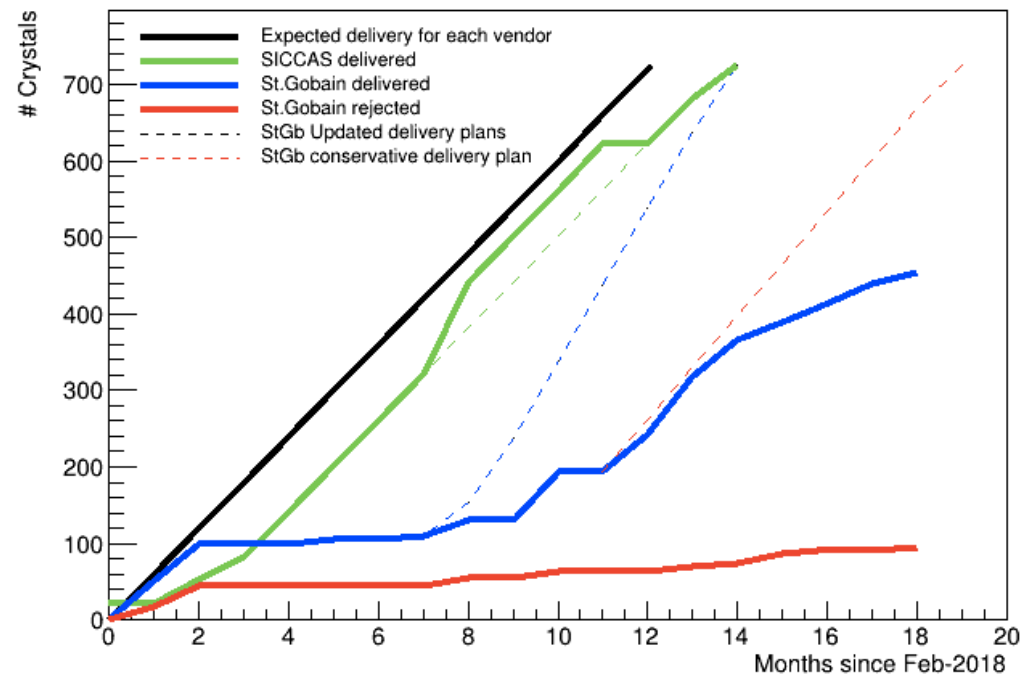
## SICCAS

- **725/725 crystals received**
- **# out-of-specs crystals: 30**  
→ 4% of the production

## St.Gobain

After two months of pain, we have closed the contract & we are swapping to SICCAS for the rest of production

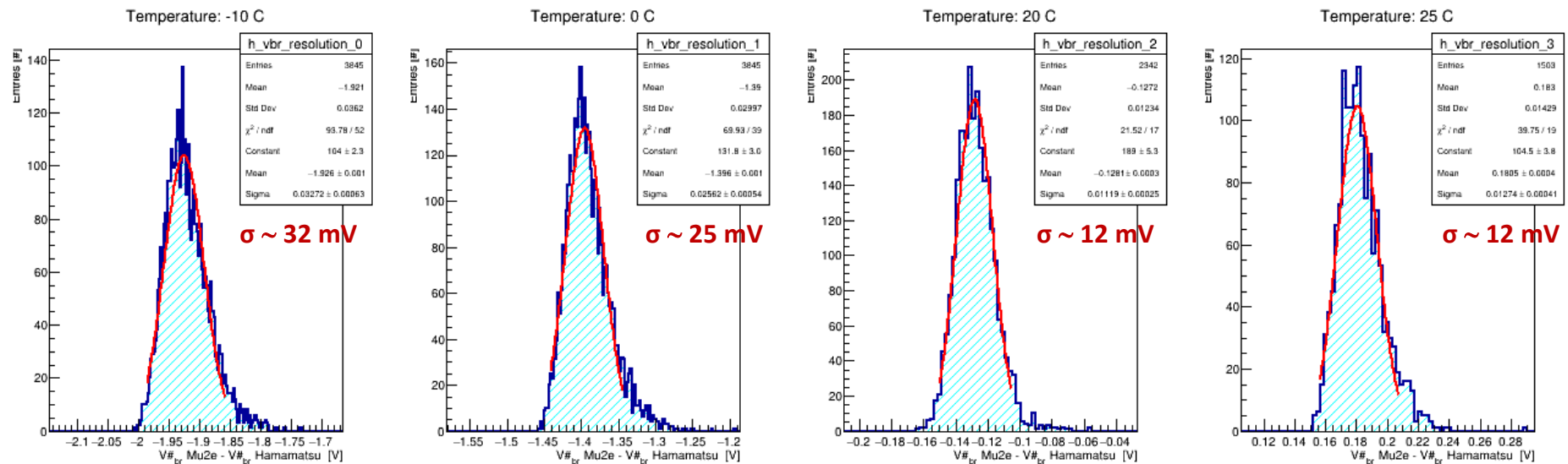
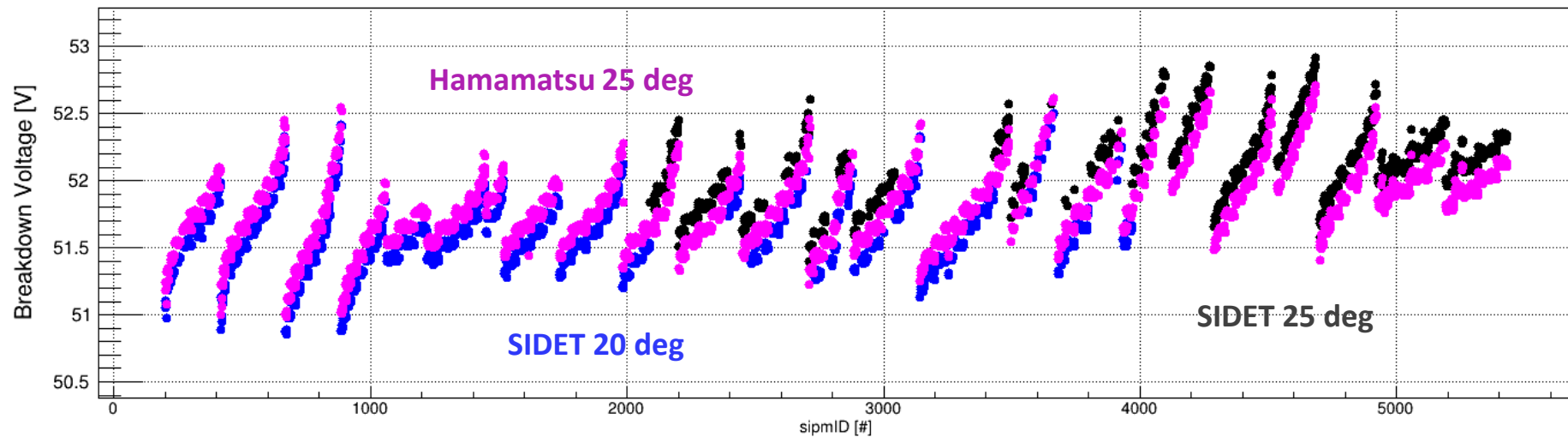
1. We have to send back to StGB the out-of-specs crystals (95 tot, 59 shipped)
2. We have asked to SICCAS a quote for 300/330 and 360 crystals
3. We will buy a number of crystals that matches the residual budget and will reduce the # of spares accordingly .



	SICCAS	St.Gobain	Total
<b>Shipped</b>	<b>725/725</b>	<b>460/725</b>	<b>1185/1450</b>
<b>CMM + inspection</b>	<b>725</b>	<b>454</b>	<b>1179</b>
<b>Sent to Caltech</b>	<b>257</b>	<b>146</b>	<b>403</b>
<b>Out-of-specs</b>	<b>30</b>	<b>95</b>	<b>124</b>
<b>Irradiation Caltech</b>	<b>9</b>	<b>3</b>	<b>12</b>

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# SIPM QA plots → See L.Morescalchi



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# DOE IPR 2018: recommendations

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Two recommendations were received @ the closeout of DOE-IPR 2018

- REC-1. Calorimeter SiPM were exposed to neutron radiation and increase of dark current measured. Mitigations of lower temperature and voltage were observed to reduce dark current. **Recommend that the loss of light yield, gain and resolution also be measured with dark current mitigation applied to irradiated SiPM as a direct test.**
- REC-2. Add simple pairwise integration tests in the 2019 integration plans in order to verify the validity of the TDAQ design and the compatibility of each of the sub-detectors with that design. **Advancing to two or all three sub-detectors into a combined integration test by the end of 2019 should be a goal.**

DOE-IPR review 2019 will be held in the usual 2.5 days format  
**from Dec 10 to Dec 12 – 2019 → reply written (see next)**

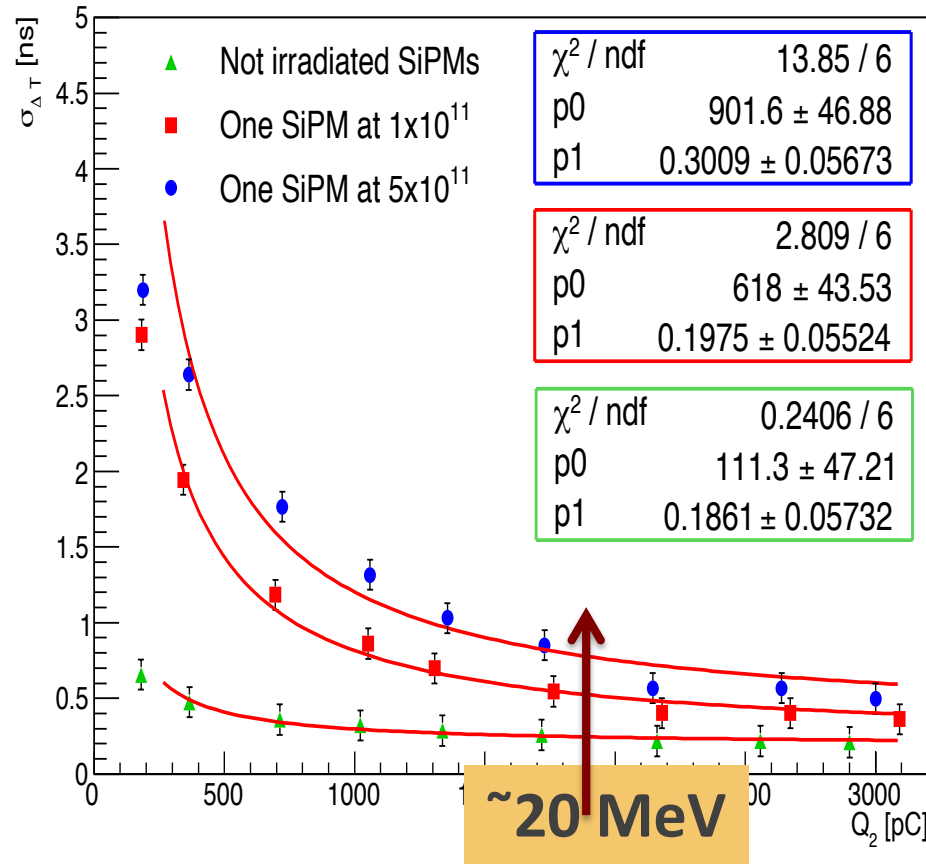
# IPR-2018, rec1: SiPM response to neutrons

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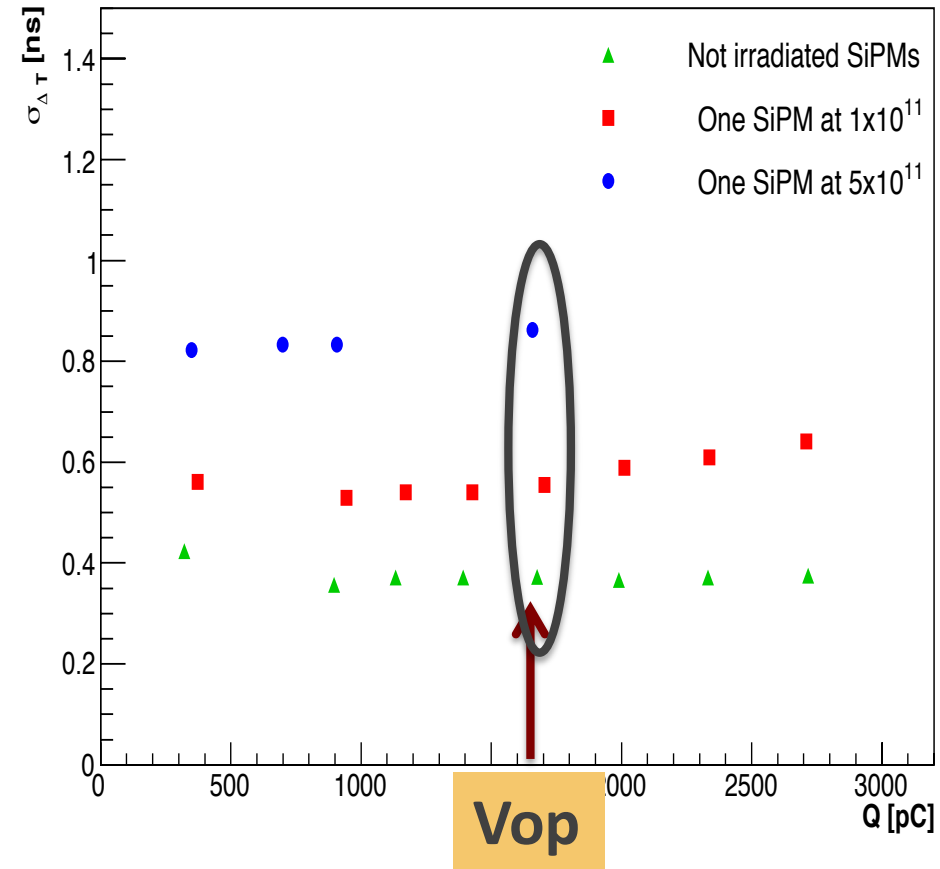
- ❑ SiPM production batches have been exposed to neutron fluxes in two places
  - HZDR at EPOS, average spectrum of O(1 MeV)
  - FNG at ENEA Frascati, average spectrum of O( 14 MeV)
- ❑ In both cases irradiation have been carried out with the sensors not biased.  
From past experience this is a conservative measurement (+30 % of  $I_{\text{dark}}$ )
- ❑ SiPM irradiated up to batch # 7 (at EPOS) shows consistent  $I_{\text{dark}}$  results w.r.t. neutron flux and temperature. **Basic rule is  $I_{\text{dark}}$  decreases of O(2) each  $-10^\circ \text{C}$ .**
- ❑ **SiPM irradiated @ FNG show a dark current of 2 x  $I_{\text{dark}}$  (EPOS). Investigating**
  - cross calibration of the two sites needed**
  - try to run @ 2 MeV in FNG changing target from Tritium to Deuterium**
- ❑ **First Tests done at LNF in Module 0**
- ❑ **1 irradiated SiPM/group will be tested also in Pisa in 1 channel-station**

# Summary of “n” SiPM tests with Laser

## Time resolution vs Pulse Height



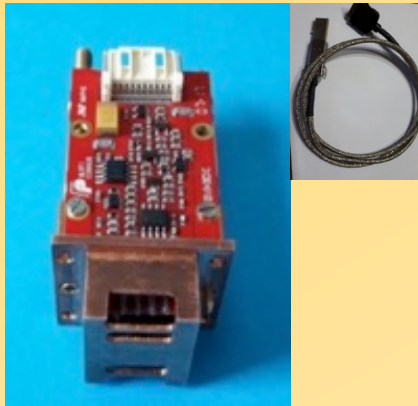
## Time resolution vs Vbias



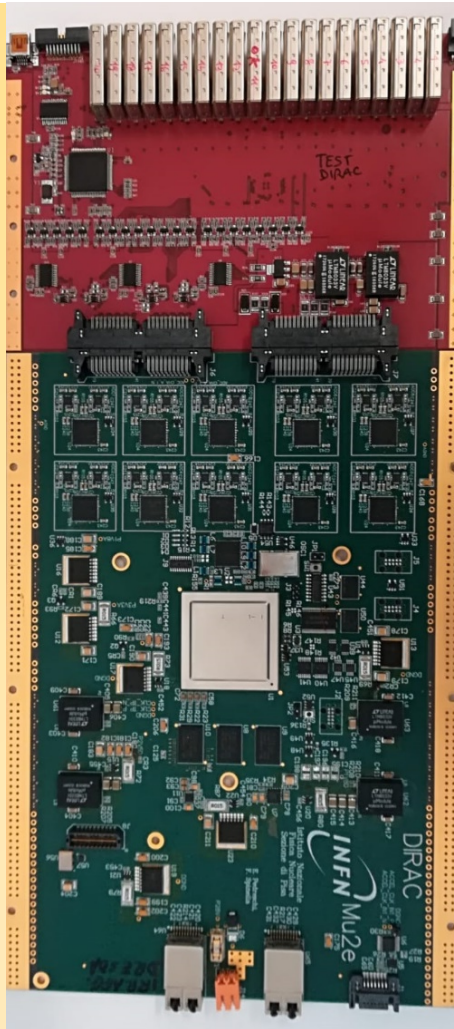
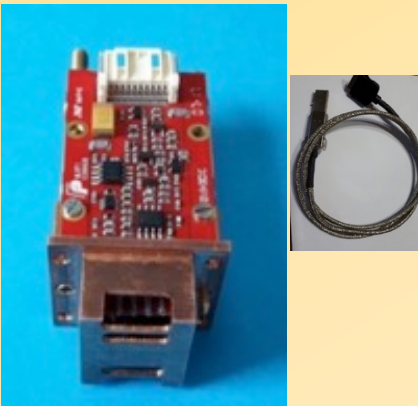
- First estimate is that one single sensor will get around 800 ps resolution at  $5 \times 10^{11}$  n/cm<sup>2</sup> for an energy deposit of O(30 MeV).
- Factor of  $\sqrt{2}$  achieved using two sensors/crystal → **560 ps, close to requirement**

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# Mu2e Calorimeter Electronics



X20



X8



X20 (10 + 10)

# FEE production .. F.Spinella DIRAC report

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## ❑ Production of FEE Boards is the most critical path in Calo assembly

❑ start production of FEE boards before the end of 2019

→ Production line is already set.

Tender for 3100 pieces **SUBMITTED**

→ It will take 4 weeks for the first 100 pieces, then 500 pieces/week

→ from Italy to DUBNA for QC test then shipped to SIDET

→ PCB review **DONE in July**

→ Light PCB review for DIRAC V2 in coming weeks

→ Separate CRR for FEE/MB-V2 (fall 2019)

and DIRAC V2 (beginning 2020)

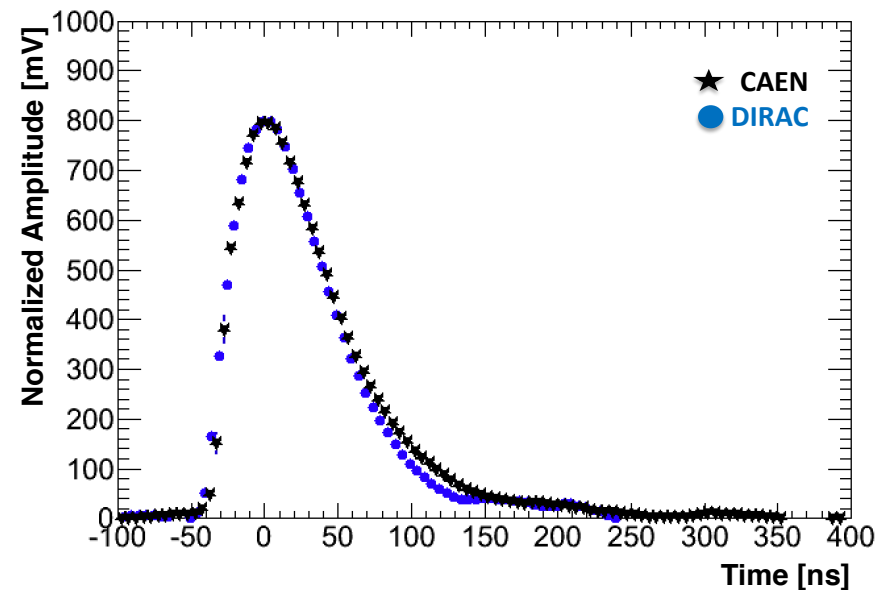
+ a final vertical slice test with the first DIRAC V2 protos

→ Plan is to submit production end 2019/beginning 2020

**(INFN money released for production in September 2019)**

# IPR-2018, rec2: combined slice test

- Prototypes of Dirac V2 under construction (next slides)
- Slice test up to DIRAC V1 done (reported in June 2019)
- Slice test with DIRAC V2 will be done in coming months



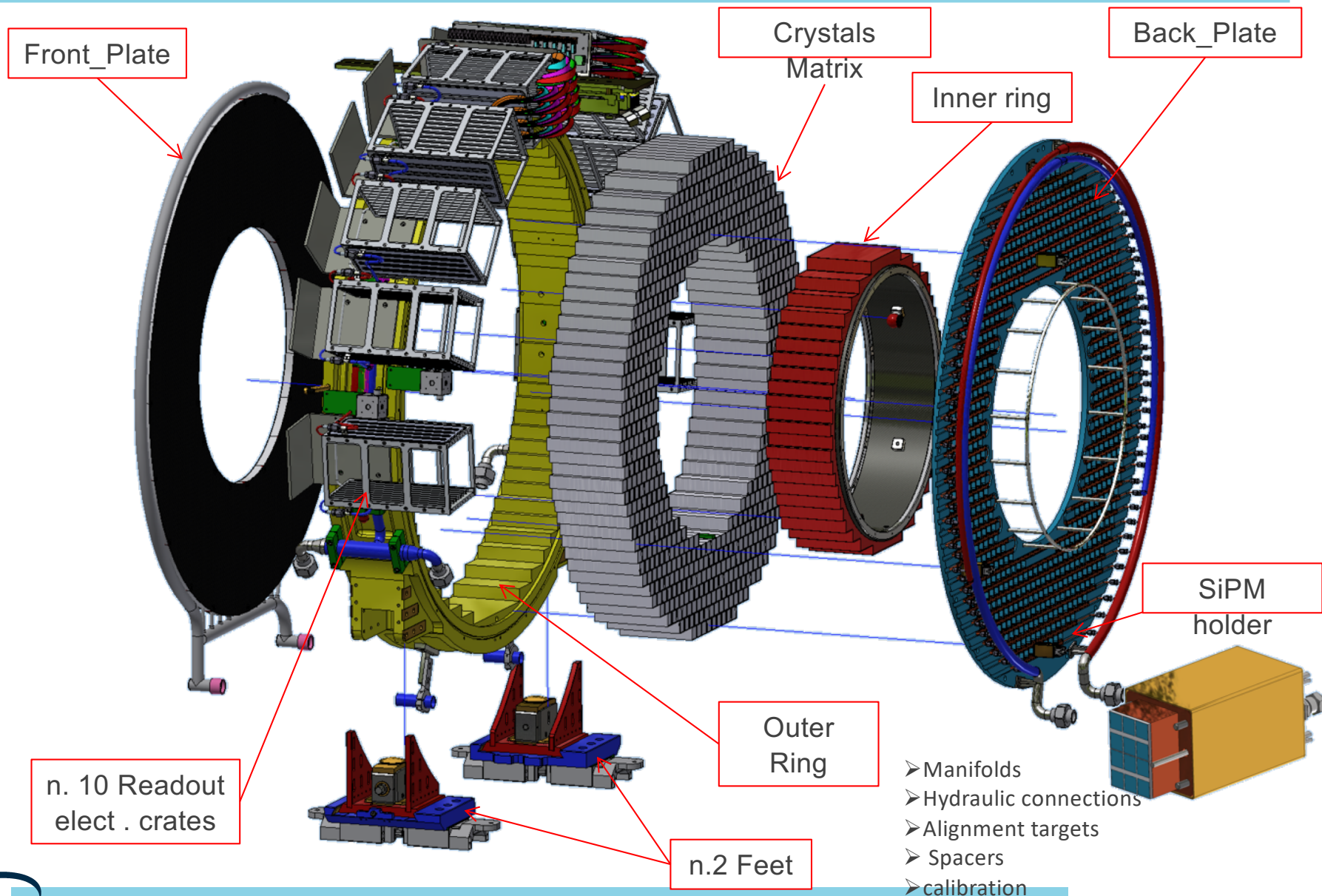
- Work on completing the readout by TDAQ fiber and VTRX
- Next year plans:
  1. a Module-0 BTF electron beam test
  2. long run with cosmics in different configurations in vacuum
  3. Preparation for Sidet integration → **in view of Transition To Operation**

**SEE Franco Spinella for More Details**

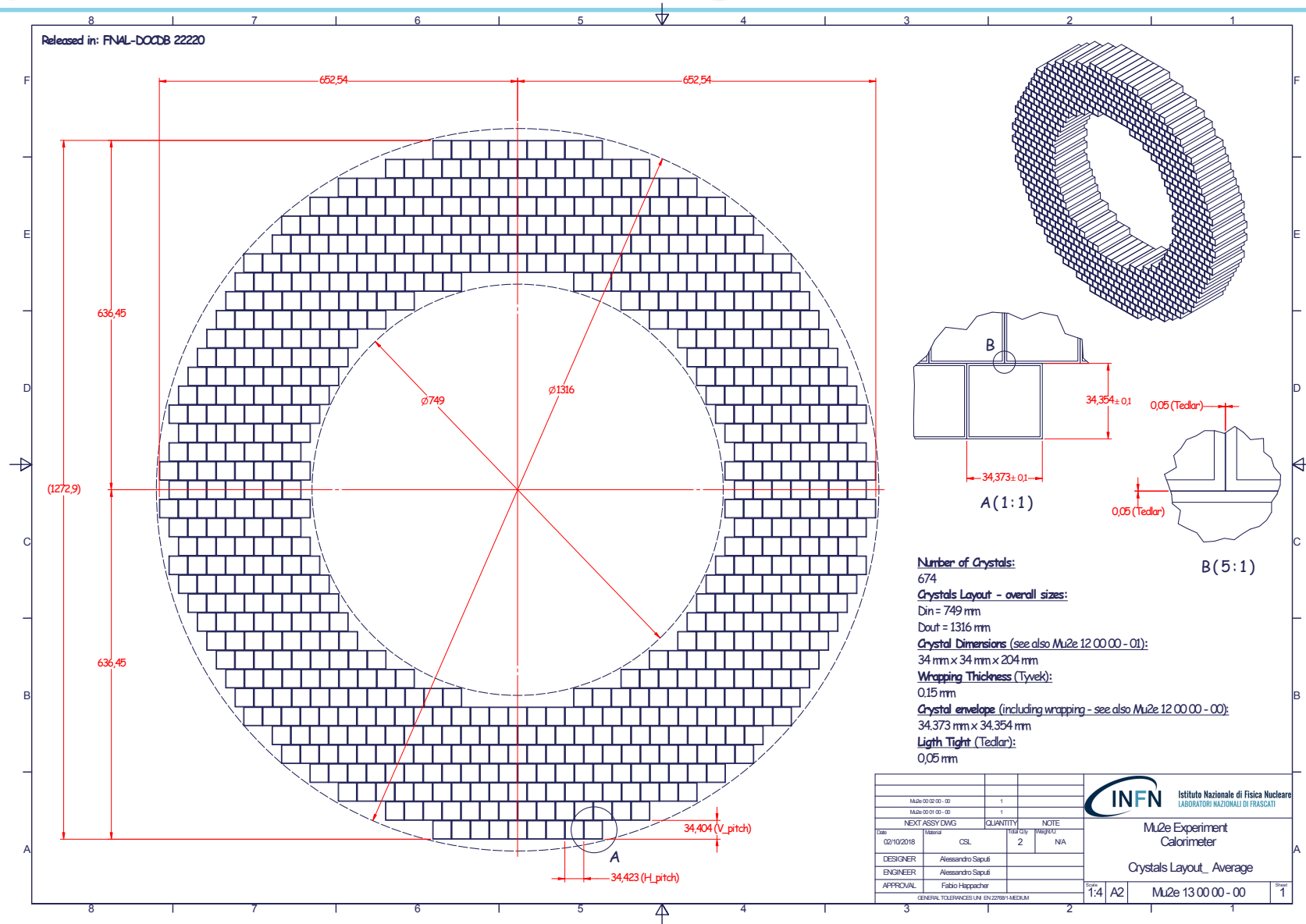


# MAIN MECHANICAL COMPONENTS

Each disk consist of:



# Crystal Matrix – final design



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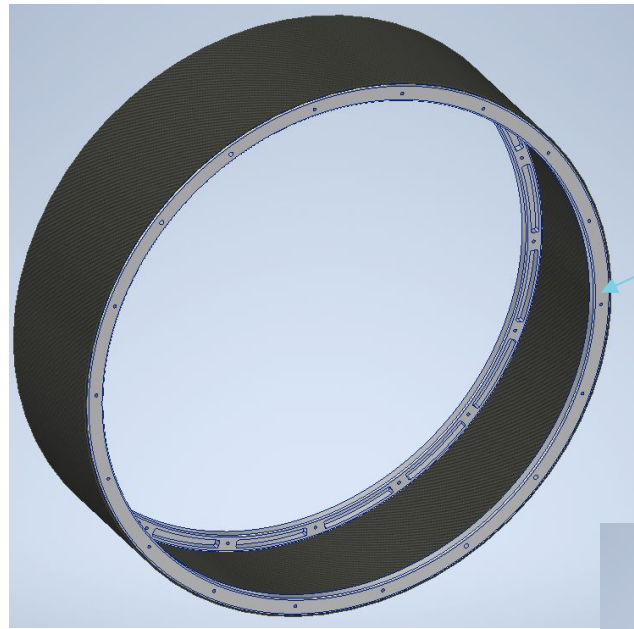
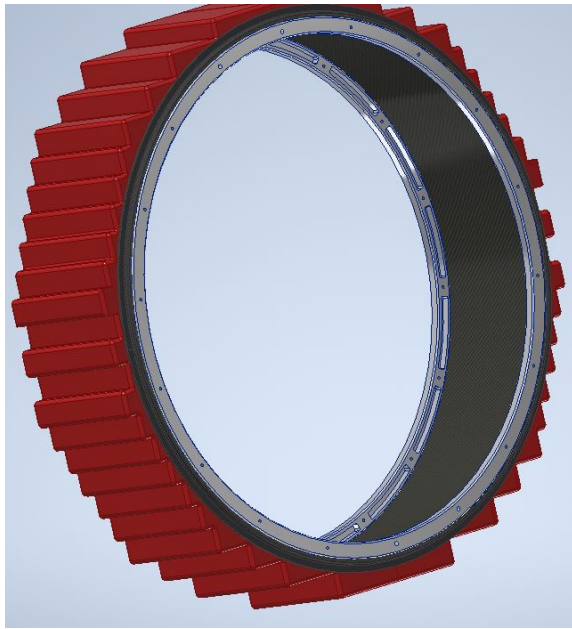


# Status of Tenders and expected delivery

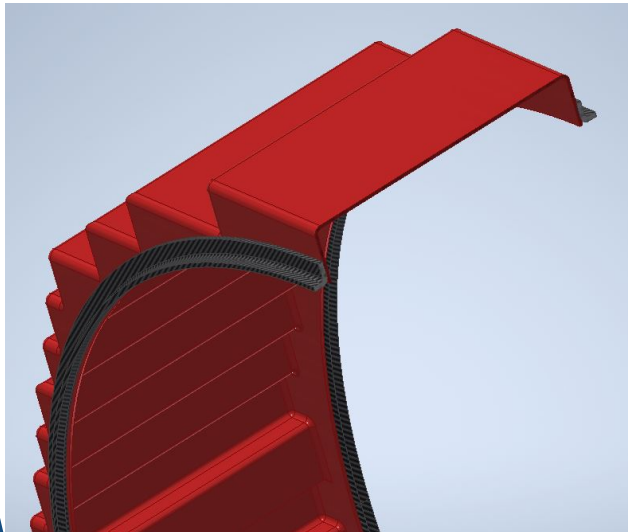
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- ✓ Outer Al cylinder – Tender Out → Jan 2020
- ✓ Inner CF cylinder – Tender Out → March 2020
- ✓ FEE plate – Tender Out → March 2020
- ✓ Source Plate – Tender Out → March 2020
- ✓ Crates – Tender Out → April 2020
- ✓ SiPM Holder – Tender Out → November 2019
- ✓ Faraday cage – tender in progress
- ✓ Fiber guide line – tender in progress
- ✓ Cable trays – finalizing design
- ✓ Assembly stand –finalizing design
- ✓ **Lifting tool – Conceptual design being engineered**

# CF inner steps - no foam, CF only

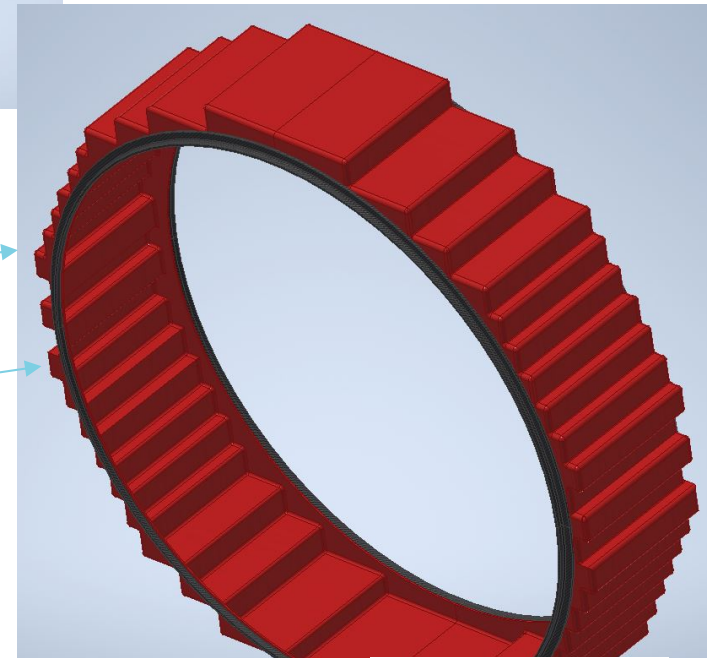


CF inner tube + aluminum rings



CF steps

L connecting profile



# Coolant choice for Chiller Station @ -20 ° C

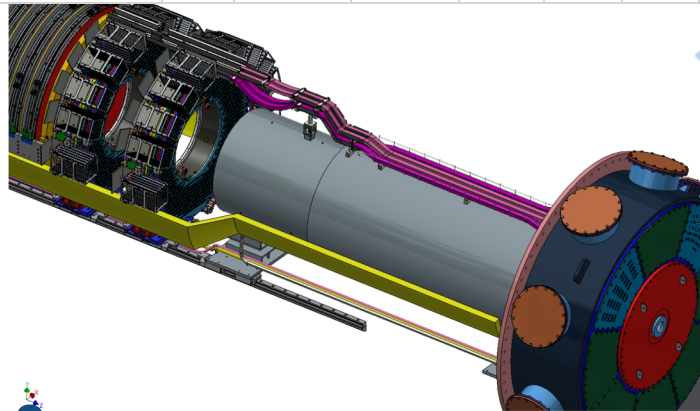
- ❑ Due to the 7 ° C drop from chiller to SiPMs to get -10 ° C on SiPM surface required to have a coolant different from Water Glycol
- ❑ Preliminary analysis of a different coolant carried out:
  - Best candidate already used in **CMS/LHCb** is **3M PF-5060**  
i.e. the Perfluoro-hexane (C6F14).
  - A novel “improved” eco-friendly coolant is **3M Novec 649 (radiation hardness?)**
- ❑ These coolants have a freezing temperature @ -90 ° C so leaving a lot of flexibility
- ❑ Temperature drop along the line is larger → needs additional -3 ° C from Chiller to SiPM, so coolant should be kept below -20 ° C

Property	C6F14 (a -20°C)	Monopropylene glycol 35%, water (a -10°C)
Density [Kg/m <sup>3</sup> ]	1000	1040
Specific heat [J/(Kg K)]	982	3759
Kinematic viscosity [m <sup>2</sup> /s]	3.8 10 <sup>-7</sup>	4,16 × 10 <sup>-6</sup>
Absolute viscosity [Kg /m s]	6.4 10 <sup>-4</sup>	4,33 × 10 <sup>-3</sup>
Thermal conductivity [W/mK]	0,057	0,429
Freezing temperature [°C]	-90	-17

# Cable services inside DS and Feedthroughs

1. Calorimeter internal distribution will be completed at Sidet
2. Internal distribution inside DS fully specified. In the hands of Gary /Karen and integration team **(100 % completed)**
3. List of feed-throughs and flange proposal in progress **(90% completed)**

IFB - Patch Panel Disk	Disk #	Xpos #	Crate #	Sensor pos #	N.Cables	N.Spare	I-Max(A)	Logical Name	System	LOCATION	AWG	L(m)	Diam. (mm)	Material	KIND
LV+	0-1	0-1	0-4	0-1	40	8	10	LVP-d0-p0-c0-s0	CAL	IFB-CALPP	8	10	5,9	TEFLON/SILVER-COPPER	M16878/5BNL-2
LV-	0-1	0-1	0-4	0-1	40	8	10	LVN-d0-p0-c0-s0	CAL	IFB-CALPP	8	10	5,9	TEFLON/SILVER-COPPER	M16878/5BNL-0
LV-sense+	0-1	0-1	0-4	0-1	40	8		LVSP-d0-p0-c0-s0	CAL	IFB-CALPP	22	10	1,8	TEFLON/SILVER-COPPER	M16878/5BFE-2
LV-sense-	0-1	0-1	0-4	0-1	40	8		LVSN-d0-p0-c0-s0	CAL	IFB-CALPP	22	10	1,8	TEFLON/SILVER-COPPER	M16878/5BFE-0
HV+	0-1	0-1	0-4	0-1	40	8	0,5	HVP-d0-p0-c0-s0	CAL	IFB-CALPP	12	10	3,6	TEFLON/SILVER-COPPER	M16878/5BLE-7
HV-	0-1	0-1	0-4	0-1	40	8	0,5	HVN-d0-p0-c0-s0	CAL	IFB-CALPP	12	10	3,6	TEFLON/SILVER-COPPER	M16878/5BLE-6
HV-sense+	0-1	0-1	0-4	0-1	40	8		HVSP-d0-p0-c0-s0	CAL	IFB-CALPP	22	10	1,8	TEFLON/SILVER-COPPER	M16878/5BFE-7
HV-sense-	0-1	0-1	0-4	0-1	40	8		HVSN-d0-p0-c0-s0	CAL	IFB-CALPP	22	10	1,8	TEFLON/SILVER-COPPER	M16878/5BFE-6
Can+	0-1	0-1	0-4		20			CANP-d0-p0-c0	CAL	IFB-CALPP	22	10	1,8	TEFLON/SILVER-COPPER	M16878/5BFE-3
Can-	0-1	0-1	0-4		20			CANN-d0-p0-c0	CAL	IFB-CALPP	22	10	1,8	TEFLON/SILVER-COPPER	M16878/5BFE-4
5V	0-1	0-1			4		0,5	CANLVP-d0-p0	CAL	IFB-CALPP	12	10	3,6	TEFLON/SILVER-COPPER	M16878/5BLE-2
ground_can	0-1	0-1			4		0,5	CANLVN-d0-p0	CAL	IFB-CALPP	12	10	3,6	TEFLON/SILVER-COPPER	M16878/5BLE-0
Copper Braid	0-1	0-1			4								3,18	Copper	MBC0.13CP
LVTemplnner+	0-1	0-1			4		10	innerP-d0-p0-c0-s0	CAL	IFB-CALPP	8	10	5,9	TEFLON/SILVER-COPPER	M16878/5BNL-2
LVTemplnner-	0-1	0-1			4		10	innerN-d0-p0-c0-s0	CAL	IFB-CALPP	8	10	5,9	TEFLON/SILVER-COPPER	M16878/5BNL-0
GND	0-1	0-1	0-1		8	0		GND-d0-p0-nc0	CAL	IFB-CALPP	8	10	5,9	TEFLON/SILVER-COPPER	M16878/5BNL-5



IFB-CONNECTORS	Flange #	Num. Connectors per Flange #	Spares #	KIND
Laser Fiber	0-1	2		FIBM3-IR00-02-S-3
TDAQ Fiber	0-1	4		Pavetech VS-18
LV	0-1	10	2	XAVAC9W4M/SI.2/AA
HV	0-1	10	2	XAVAC9W4M/SI.2/AA
GND	0-1	1		XAVAC9W4M/SI.2/AA
CAN	0-1	2		XAVAC15M/SI.0/AA
Inner ring	0-1	1		XAVAC9W4M/SI.2/AA

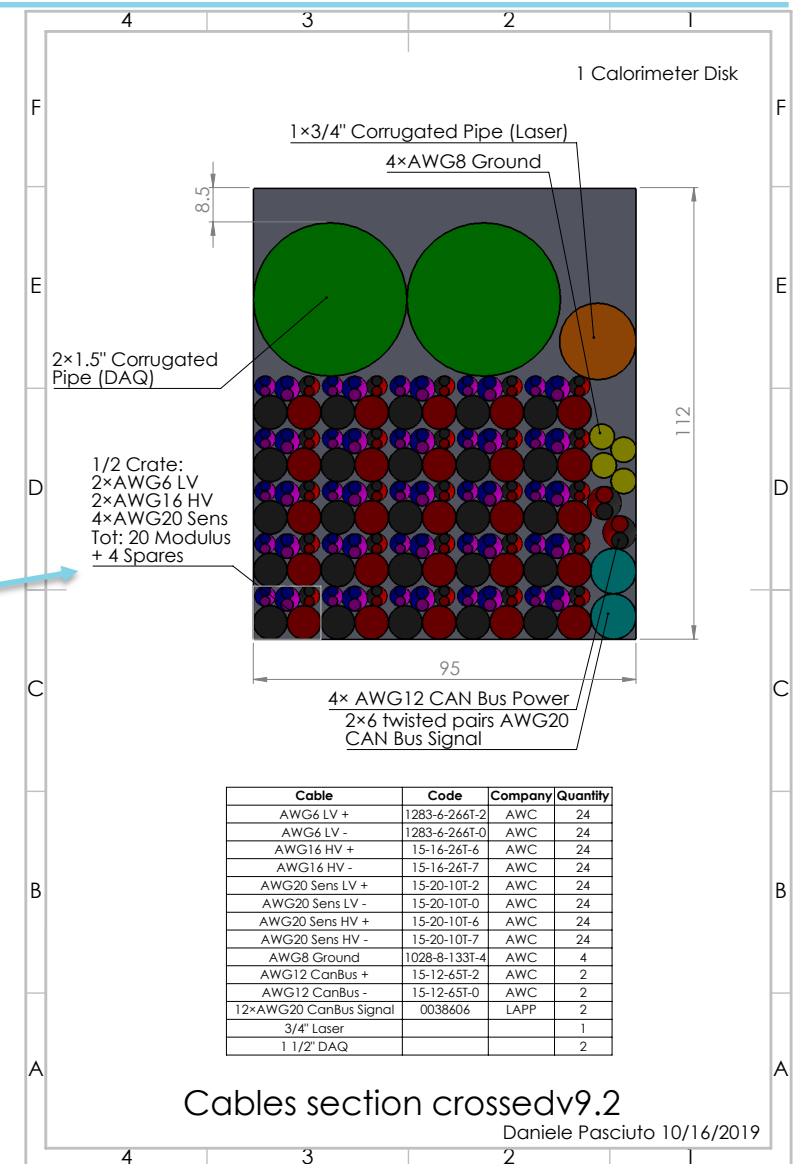
# HV/LV – Cables outside DS and P.Supplies

## Configurations (per one DISK):

- Missing only the LVTemp cables for the inner ring (4 x 6AWG cables).
- Inside requirement with an overall cross section of  $9.5 \times 11.2 \text{ cm}^2 \sim 105 \text{ cm}^2$
- 2 x 1.5" Corrugated for the TDAQ fibers
- 1 x 3/4" Corrugated for the Laser fibers

Single module  
1/2 crate for LV/HV

- LV/HV supplies being selected
- Prototypes in SIDET
- Pre-ORC informal carried out yesterday
- Sign-OFF in 1 month from now





# Status of Assembly Area

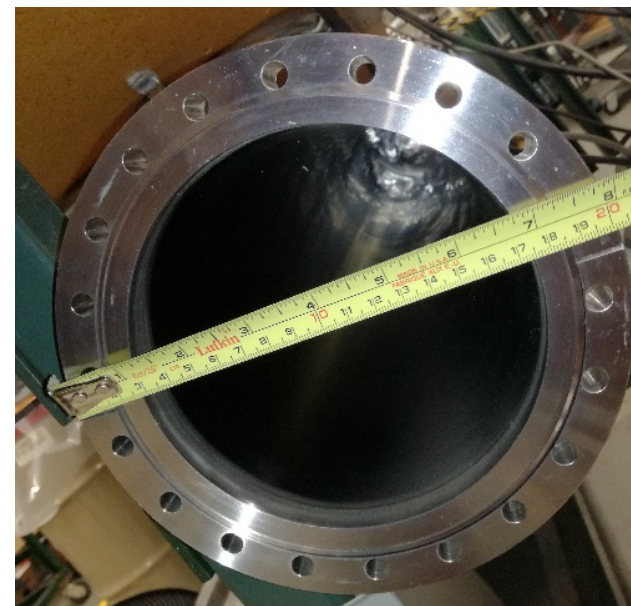


- Almost completed
- Access with crane for Calo truck loading
- Temperature and Humidity controlled and monitored
- Portable crane inside for components
- One mechanical assembling region
- One electrical and data acquisition region
- Testing of half disk a time
- Nitrogen and compressed air installed
- Electrical implant almost finished
- To do:
  - fire alarms
  - calibrating HEPA and HVAC system
  - sealing small openings
  - cleanroom class verification
  - storage units

# Outgassing facility @ SIDET: status

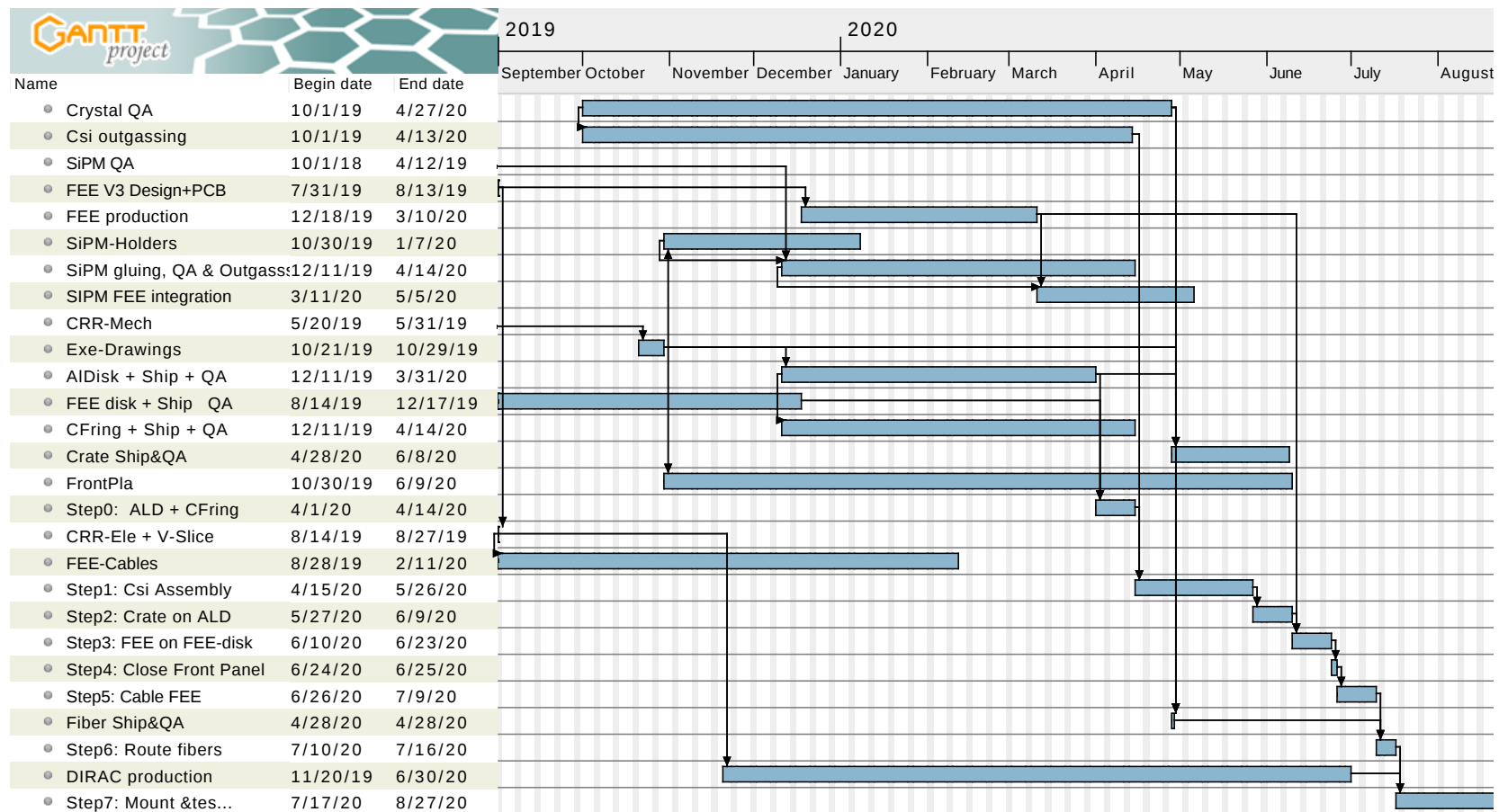


- Heaters stripes outside  $\sim 60^{\circ}\text{C}$
- Nitrogen refill after outgassing
- Estimated time for outgassing (several batches): 2-3 months



- Recycled stainless steel vacuum vessel  $\Phi$  700 mm  $\times$  1000 mm (missing flange, manufacturing in process in Italy)
- For Crystals and electronics outgassing
- To do: finalize the structure, recovery vacuum pumps
- Borrowed vacuum vessel  $\Phi$  150 mm  $\times$  2000 mm (missing flange, manufacturing in process in Italy) Thanks to thin film facility
- For cables
- To do: bring at SiDet, recovery vacuum pumps

# Detailed INFN Gantt for Calo Assembly: updated



Disk fully assembled for the summer.

Aiming to have a partial disk assembled for reporting milestones in spring 2020



# Conclusions

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- ❑ Csl prod done @ O(85%), SIPM Completed 100%  
SICCAS completed its first 750 crystals. St.Gobain contract closed
- ❑ TEST of response for neutron irradiated SIPMs started  
→ Cal. Performance at limits @ 0 C and  $5 \times 10^{11}$  → -10 C proposed
- ❑ Electronics development is excellent:
  - Rad Hard FEE V4. Prototypes in hands
  - Rad Hard DIRAC V2 design completed → Prototypes in November
  - Vertical Slice test completed up to DIRAC V1 →  
AIMING TO CRR end 2019 / beg 2020 to start production
- ❑ Progresses on Mechanics
  - Fabrication drawings for Al disk and FEE plate ready to go
    - Measurements and estimate of outgassing improved
  - Integration of services OK for LV/HV/TDAQ/LASER
  - Integration of hard services and cooling station still in progress
- ❑ We are organizing the calorimeter assembly operations in SIDET,  
starting gluing of SiPMs and production of electronics