Highlights of the MU2E Calorimeter 2019

S. Miscetti (INFN-LNF) Frascati

Mu2e

INTENSE General Meeting

November 6-7, 2019

Talk layout

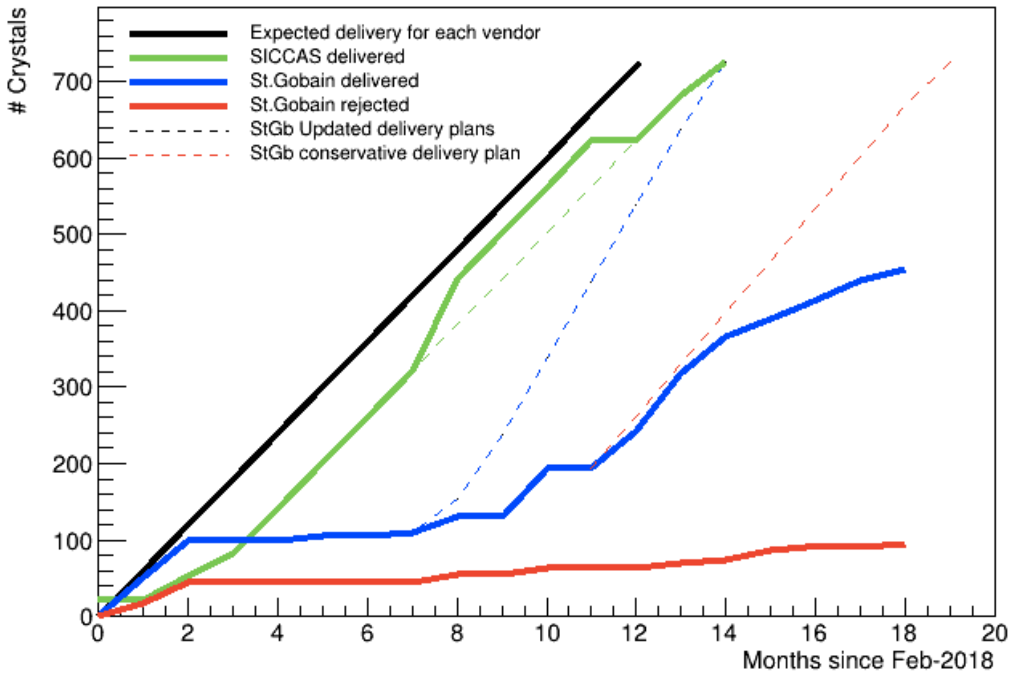
- Status of CsI production
- **Test of response for “irradiated” SiPMs (DOE-IPR-rec1)**
- **Status of electronics: PCB reviews and Next CRR**
- **Status of Calorimeter vertical slice test (DOE-IPR-rec2)**
- **Status of mechanics, cooling and services**
- **Assembly planning**

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

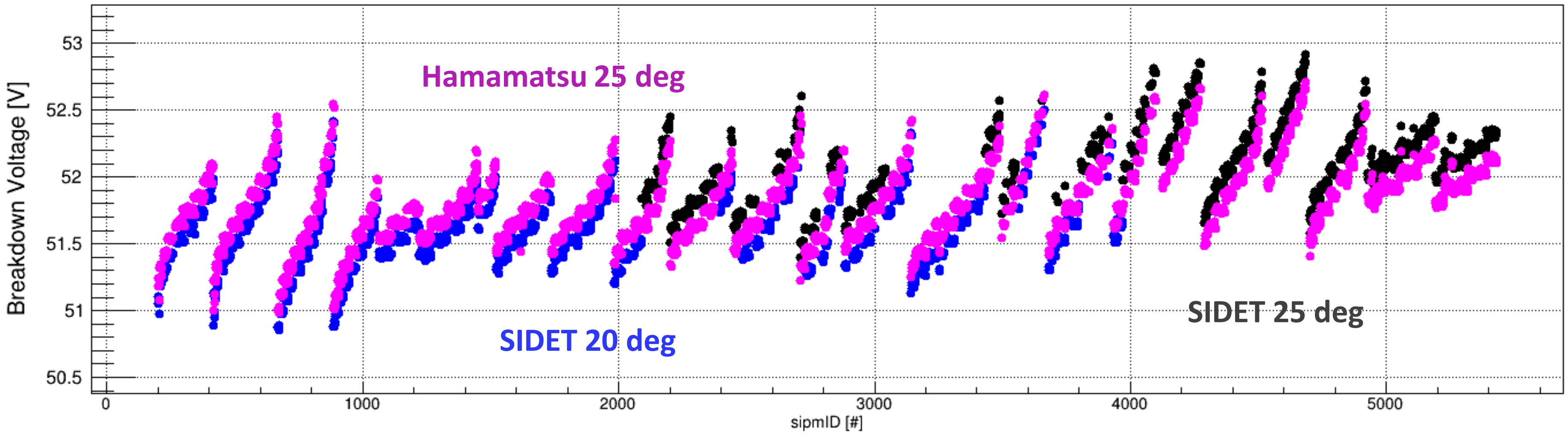
1. We have to send back to StGB the out-of-specs crystals (95 tot, 59 shipped)

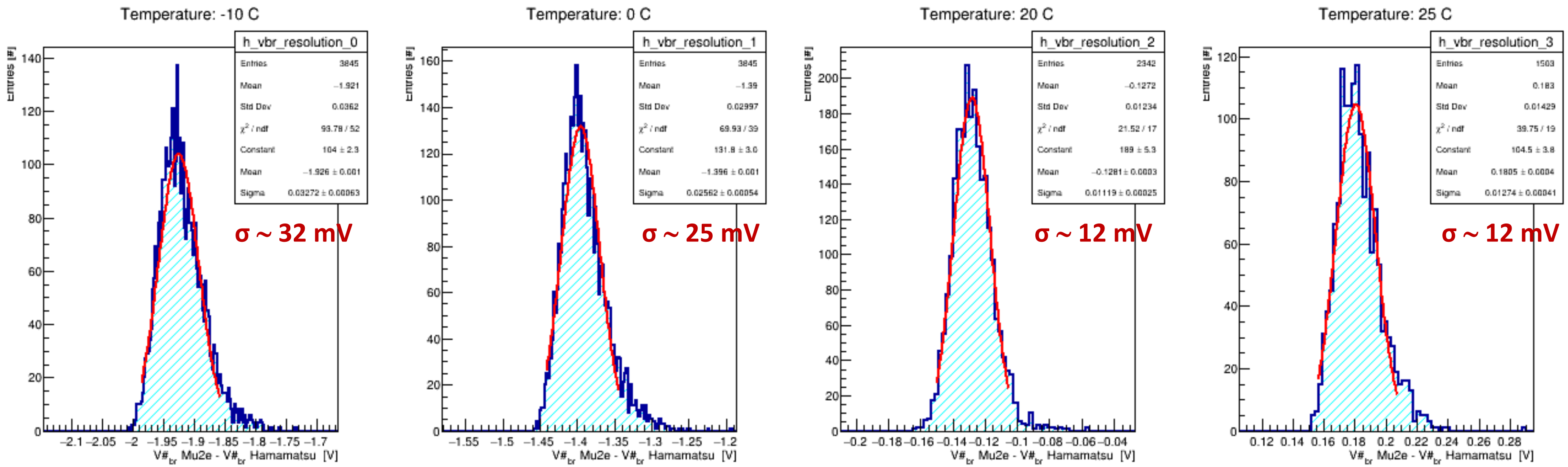
2. We have asked to SICCAS a quote for 300/330 and 360 crystals

3. We will buy a number of crystals that matches the residual budget and will reduce the # of spares accordingly .

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

SIPM QA plots → See L.Morescalchi





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DOE IPR 2018: recommendations

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

- ❑ 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 Idark)

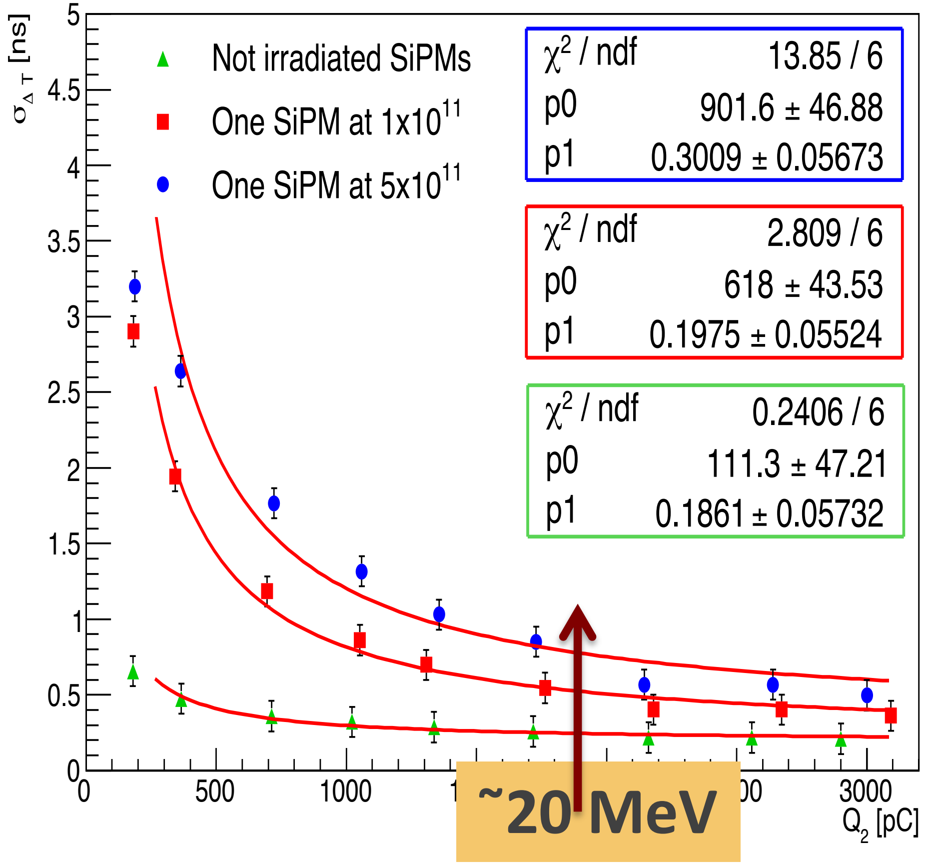
- ❑ SiPM irradiated up to batch # 7 (at EPOS) shows consistent Idark results w.r.t. neutron flux and temperature. **Basic rule is Idark decreases of O(2) each -10 ° C.**

- ❑ **SiPM irradiated @ FNG show a dark current of 2 x Idark (EPOS). Investigating**
  - **→ cross calibration of the two sites needed**
  - **→ try to run @ 2 MeV in FNG changing target from Tritium to Deuterium**

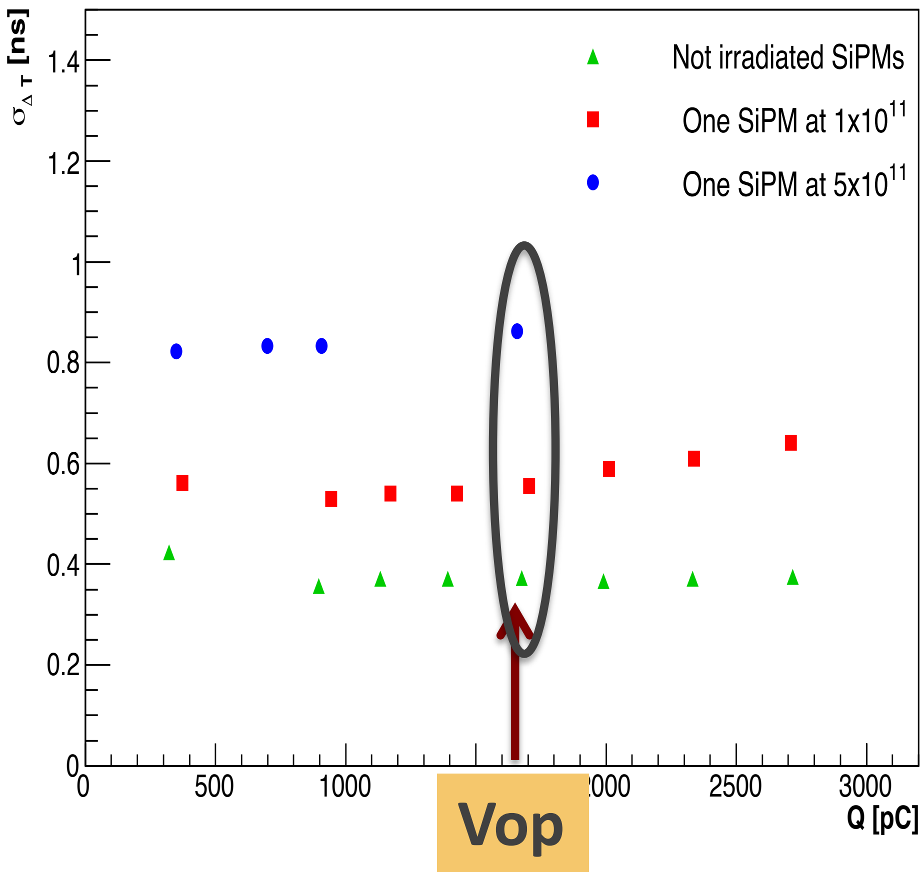
- ❑ **First Tests done at LNF in Module 0**
- ❑ **1 irradiated SiPM/group will be tested also in Pisa in 1 channel-station**

Summary of “n” SiPM tests with Laser

Time resolution vs Pulse Height

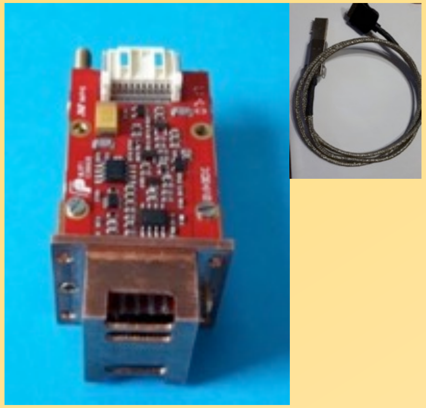


Time resolution vs Vbias

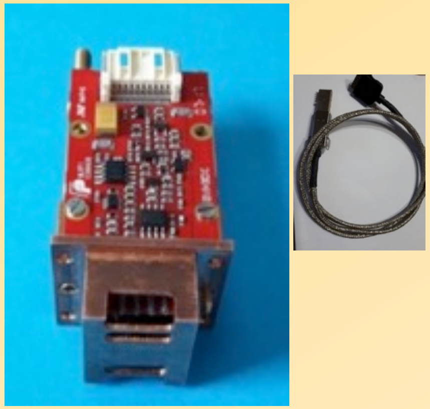


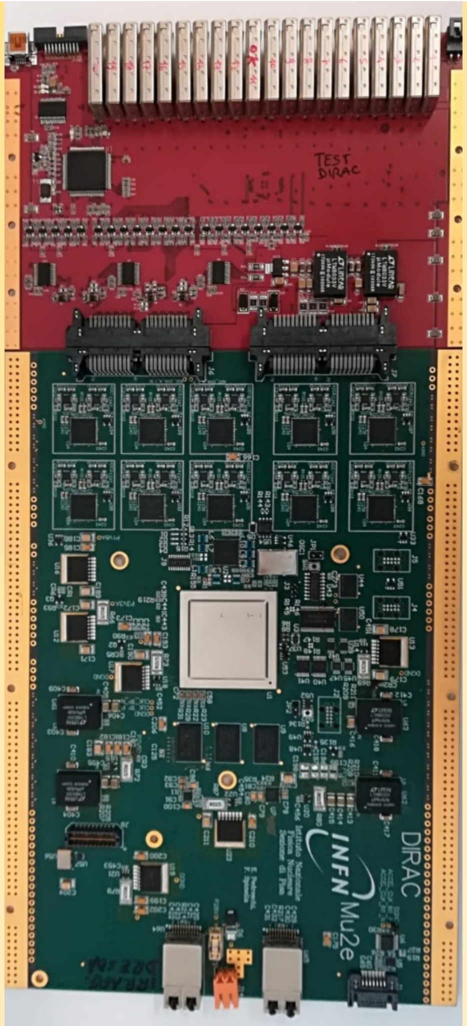
- First estimate is that one single sensor will get around 800 ps resolution at $5x10^{11}$ n/cm2 for an energy deposit of O(30 MeV).
- Factor of sqrt(2) achieved using two sensors/crystal → **560 ps , close to requirement**

Mu2e Calorimeter Electronics

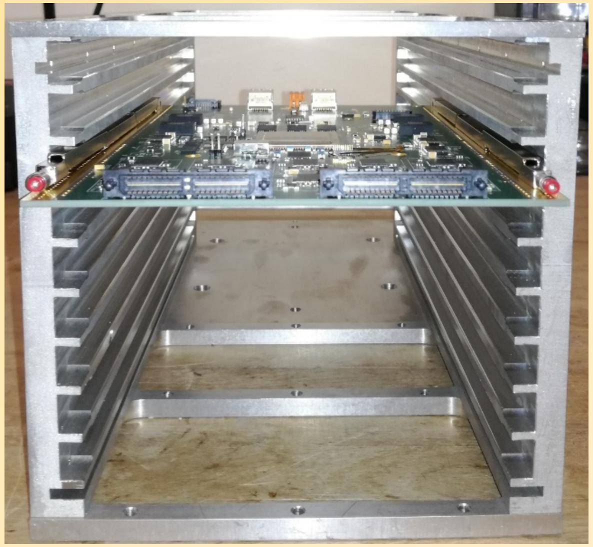


X20





X8



X20 (10 + 10)

FEE production .. F.Spinella DIRAC report

- ❑ **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**

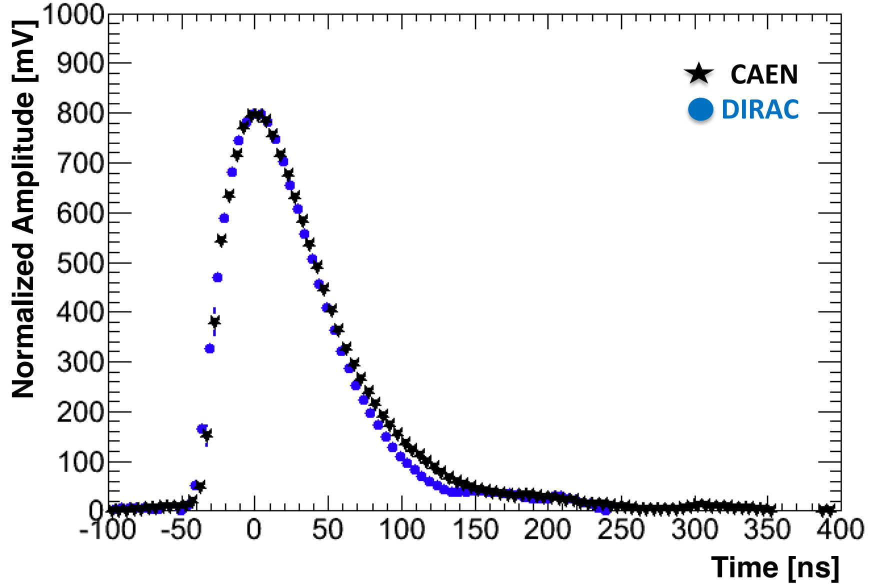
(INFN money released for production in September 2019)

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

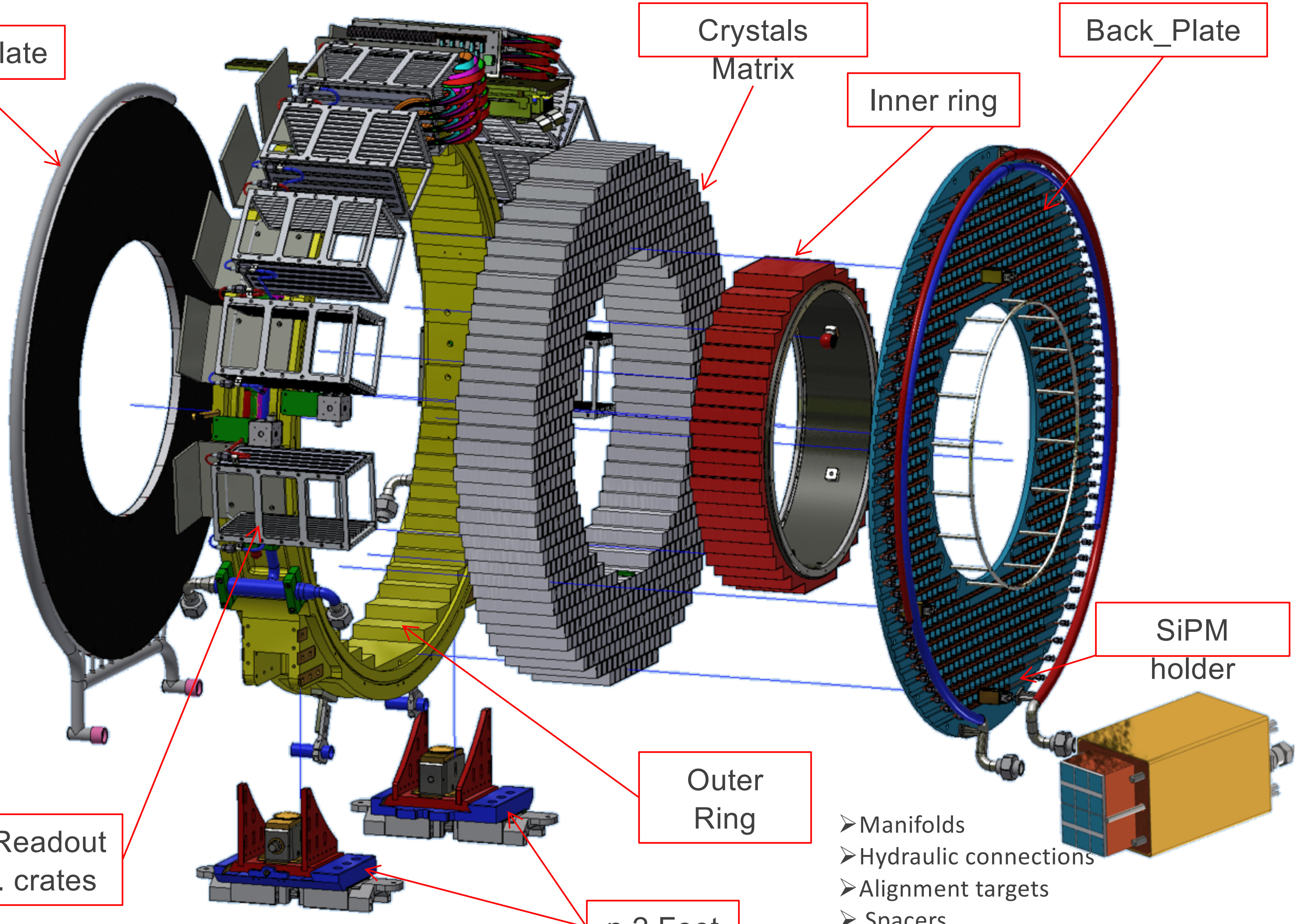
➔ Next year plans:

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

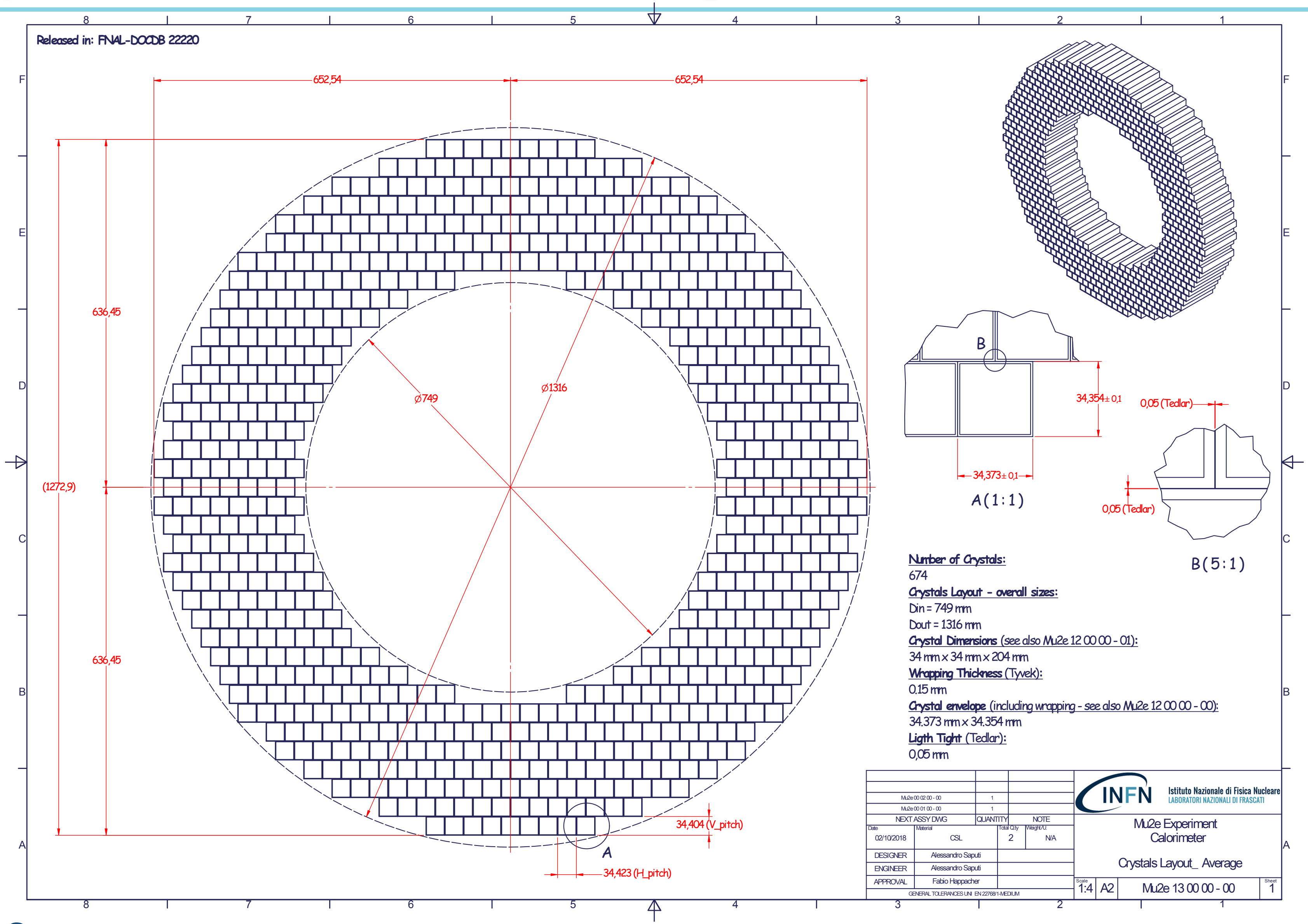
MAIN MECHANICAL COMPONENTS

Each disk consist of:



- Manifolds
- Hydraulic connections
- Alignment targets
- Spacers
- calibration

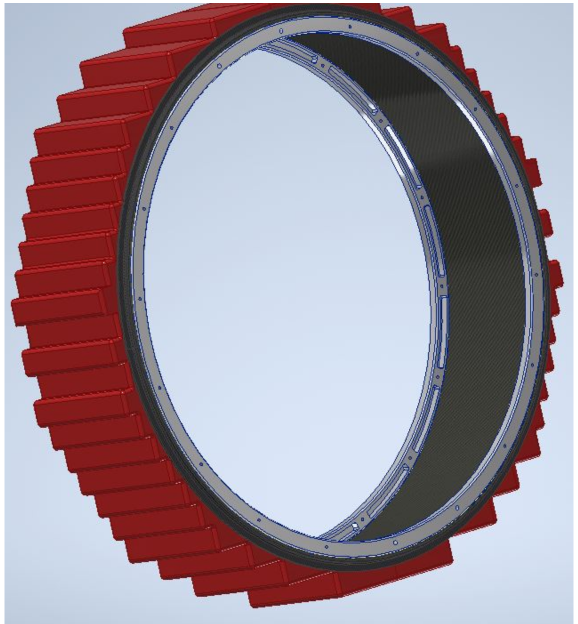
Crystal Matrix – final design

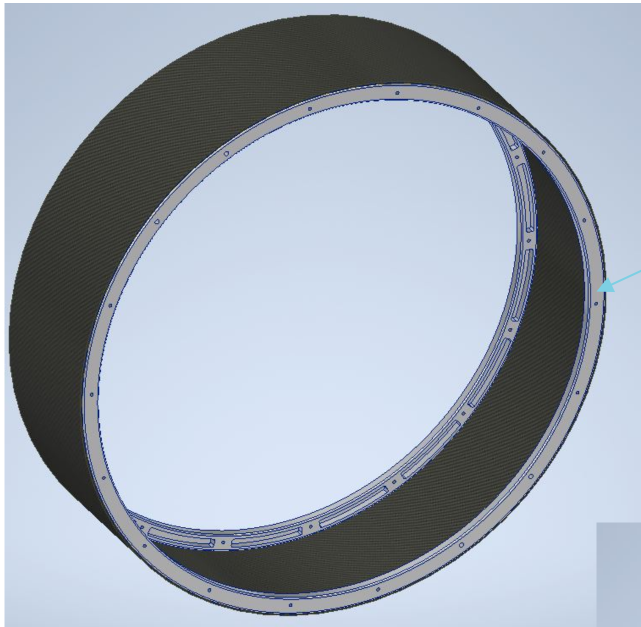


Status of Tenders and expected delivery

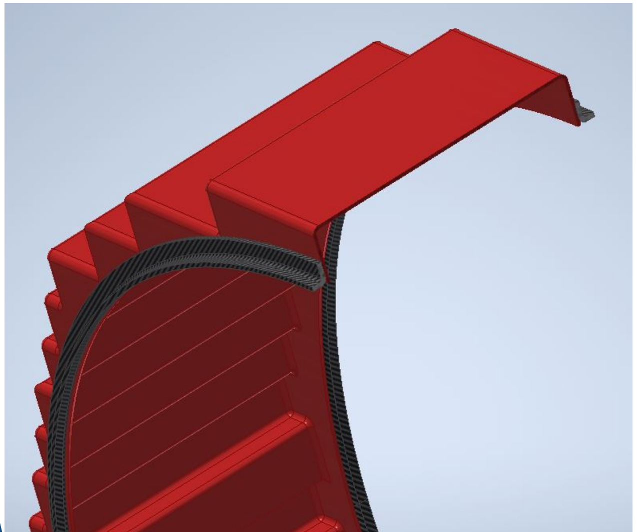
- ✓ Outer Al cylinder – Tender Out → Jan 2020
- ✓ Inner CF cylinder – Tender Out → March 2020
- ✓ FEE plate – Tender Out → March 2020
- ✓ Source Plate – Tender Out → March 2020
- ✓ Crates – Tender Out → April 2020
- ✓ SiPM Holder – Tender Out → November 2019
- ✓ Faraday cage – tender in progress
- ✓ 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



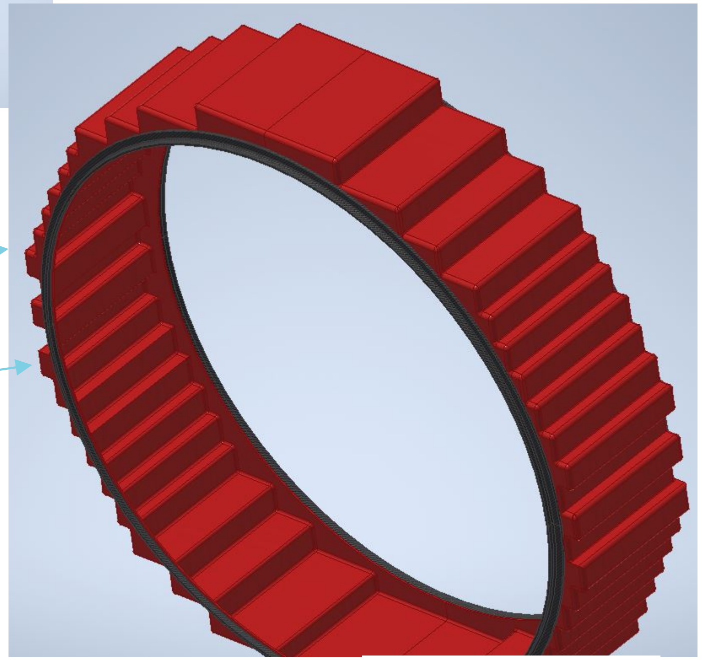


CF inner tube + aluminum rings



CF steps

L connecting profile



Coolant choice for Chiller Station @ -20 ° C

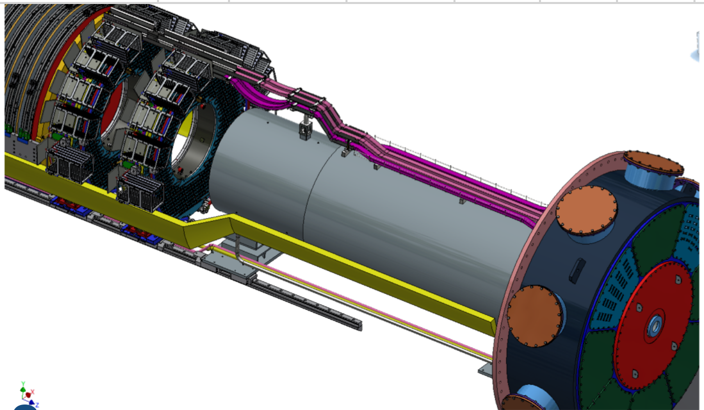
- **Due to the 7 ° C drop from chiller to SiPMs to get -10 ° C on SiPM surface required to have a coolant different from Water Glycol**
- Preliminary analysis of a different coolant carried out:
  → Best candidate already used in **CMS/LHCb is 3M PF-5060**
  i.e. the Perfluoro-hexane (C6F14).
  → A novel "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^3]	1000	1040
Specific heat [J/(Kg K)]	982	3759
Kinematic viscosity [m^2/s]	$3.8\ 10^{-7}$	$4{,}16 \times 10^{-6}$
Absolute viscosity [Kg /m s]	$6.4\ 10^{-4}$	$4{,}33 \times 10^{-3}$
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
LVTempInner+	0-1	0-1			4		10	innerP-d0-p0-c0-s0	CAL	IFB-CALPP	8	10	5,9	TEFLON/SILVER-COPPER	M16878/5BNL-2
LVTempInner-	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

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HV/LV – Cables outside DS and P.Supplies

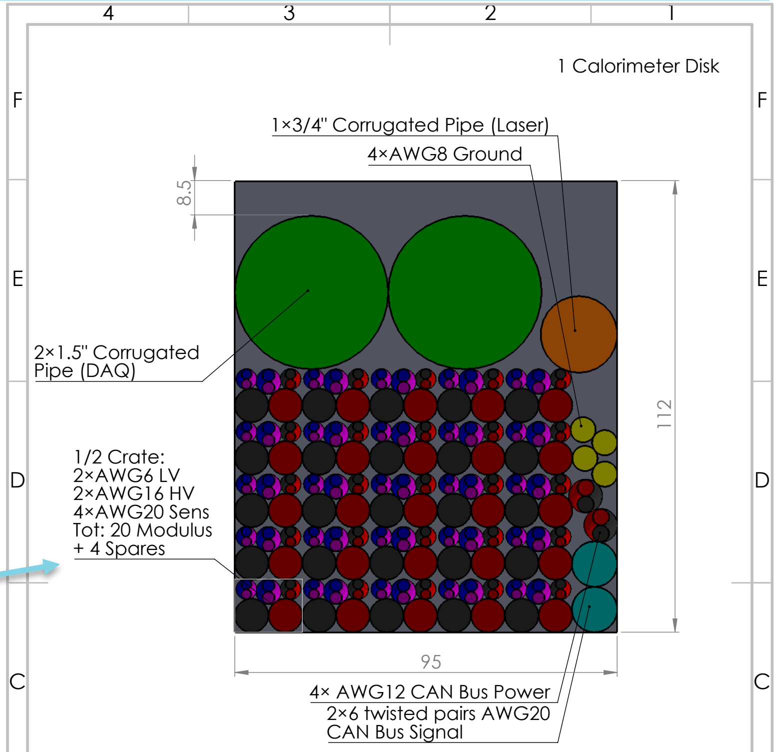
Configurations (per one DISK):

- Missing only the LVTemp cables for the inner ring (4 x 6AWG cables).

- Inside requirement with an overall cross section of 9.5 x 11.2 cm² ~ 105 cm²
- 2 x 1.5" Corrugated for the TDaq fibers
- 1 x ¾" Corrucated for the Laser fibers

Single module
½ 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



Cable	Code	Company	Quantity
AWG6 LV +	1283-6-266T-2	AWC	24
AWG6 LV -	1283-6-266T-0	AWC	24
AWG16 HV +	15-16-26T-6	AWC	24
AWG16 HV -	15-16-26T-7	AWC	24
AWG20 Sens LV +	15-20-10T-2	AWC	24
AWG20 Sens LV -	15-20-10T-0	AWC	24
AWG20 Sens HV +	15-20-10T-6	AWC	24
AWG20 Sens HV -	15-20-10T-7	AWC	24
AWG8 Ground	1028-8-133T-4	AWC	4
AWG12 CanBus +	15-12-65T-2	AWC	2
AWG12 CanBus -	15-12-65T-0	AWC	2
12×AWG20 CanBus Signal	0038606	LAPP	2
3/4" Laser			1
1 1/2" DAQ			2

Cables section crossedv9.2
Daniele Pasciuto 10/16/2019

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

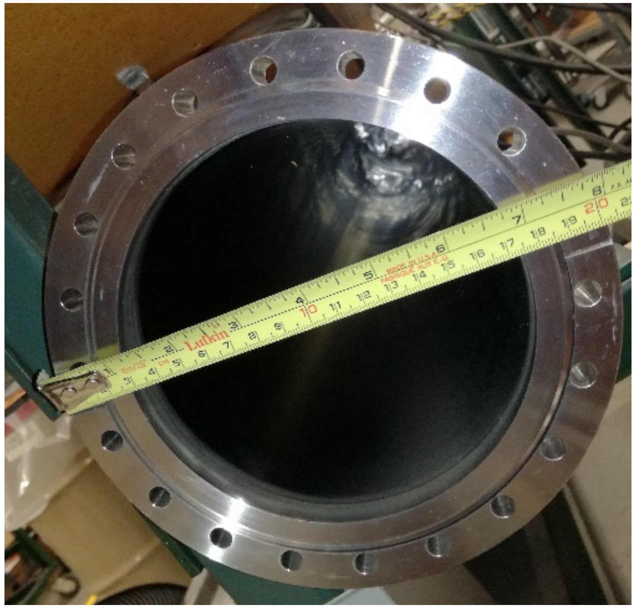
- sealing small openings

- cleanroom class verification

- storage units

Outgassing facility @ SIDET: status

- Heaters stripes outside ~60°C
- Nitrogen refill after outgassing
- Estimated time for outgassing (several batches): 2-3 months

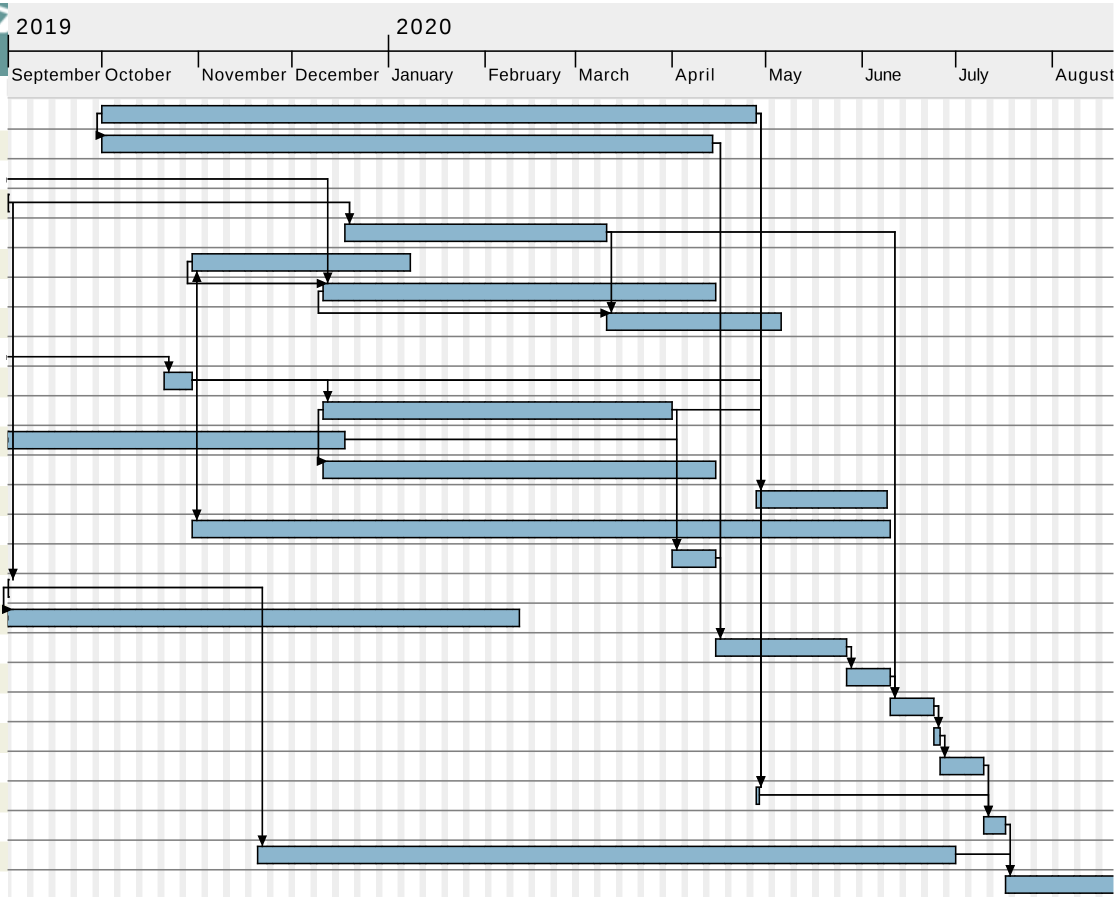


- Recycled stainless steel vacuum vessel Φ 700 mm × 1000 mm (missing flange, manufacturing in process in Italy)
- For Crystals and electronics outgassing
- To do: finalize the structure, recovery vacuum pumps

- Borrowed vacuum vessel Φ 150 mm × 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

Name	Begin date	End date
Crystal QA	10/1/19	4/27/20
Csi outgassing	10/1/19	4/13/20
SiPM QA	10/1/18	4/12/19
FEE V3 Design+PCB	7/31/19	8/13/19
FEE production	12/18/19	3/10/20
SiPM-Holders	10/30/19	1/7/20
SiPM gluing, QA & Outgass	12/11/19	4/14/20
SIPM FEE integration	3/11/20	5/5/20
CRR-Mech	5/20/19	5/31/19
Exe-Drawings	10/21/19	10/29/19
AlDisk + Ship + QA	12/11/19	3/31/20
FEE disk + Ship QA	8/14/19	12/17/19
CFring + Ship + QA	12/11/19	4/14/20
Crate Ship&QA	4/28/20	6/8/20
FrontPla	10/30/19	6/9/20
Step0: ALD + CFring	4/1/20	4/14/20
CRR-Ele + V-Slice	8/14/19	8/27/19
FEE-Cables	8/28/19	2/11/20
Step1: Csi Assembly	4/15/20	5/26/20
Step2: Crate on ALD	5/27/20	6/9/20
Step3: FEE on FEE-disk	6/10/20	6/23/20
Step4: Close Front Panel	6/24/20	6/25/20
Step5: Cable FEE	6/26/20	7/9/20
Fiber Ship&QA	4/28/20	4/28/20
Step6: Route fibers	7/10/20	7/16/20
DIRAC production	11/20/19	6/30/20
Step7: Mount &tes...	7/17/20	8/27/20



Disk fully assembled for the summer.

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

Conclusions

- CsI 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 5x1011 → -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