Summary of the Calorimeter System

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On behalf of the Mu2e calorimeter group

Meeting with INFN CSN1 Referees
Universita' degli studi di Roma "La Sapienza"
20 September 2019

Talk layout

- CsI and SiPM production

- Electronics of FEE: Rad Hardness and V4
- Digital Electronics: DIRAC → see Franco

- CRR of mechanics →
  Full report from Fabio + Fabrizio
  Here I describe only Cabling

- Status of calibration systems → LASER
- Assembly planning

- INFN MILESTONES

Crystals & SiPM Production

Crystal production

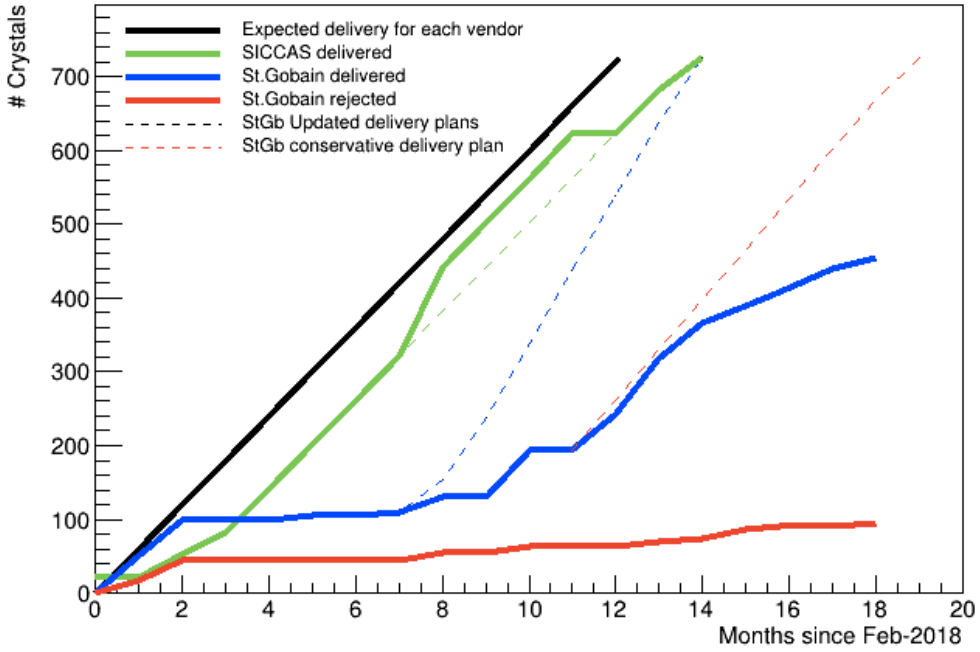
SICCAS

- **725/725 crystals received**
- **# out-of-specs crystals: 30**

  ➙ 4% of the production

St.Gobain problems persisting

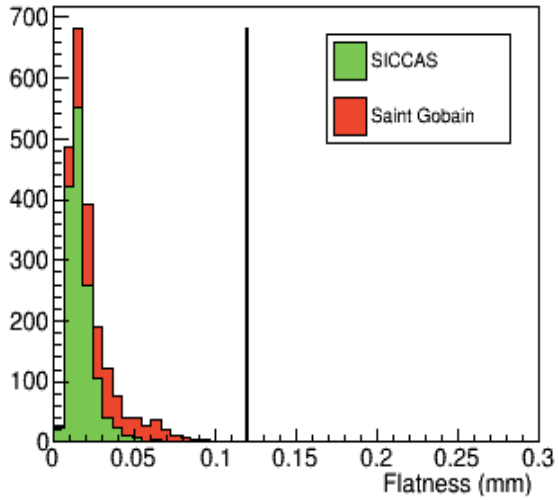
Proposal of closing the contract & swapping to SICCAS for the rest of production in progress

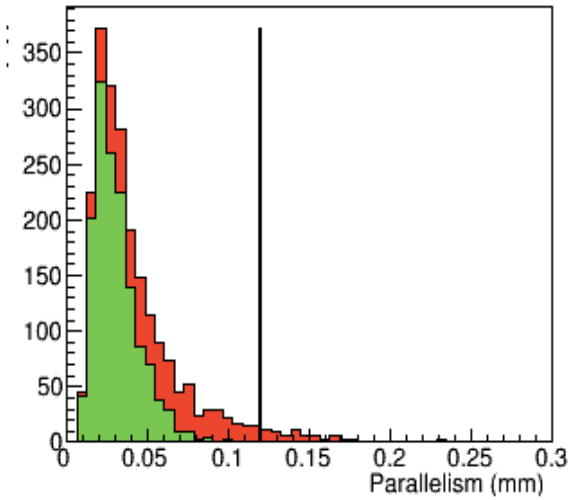


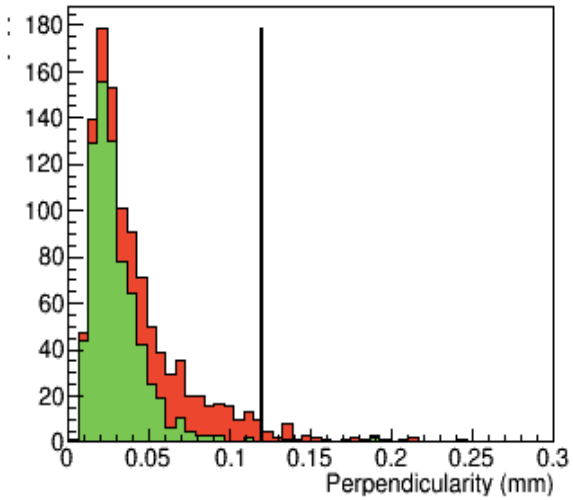
	SICCAS	St.Gobain	Total
Shipped	725/725	460/725	1185/1450
CMM + inspection	725	454	1179
Sent to Caltech	257	146	403
Out-of-specs	30	94	124
Irradiation at Caltech	9	3	12

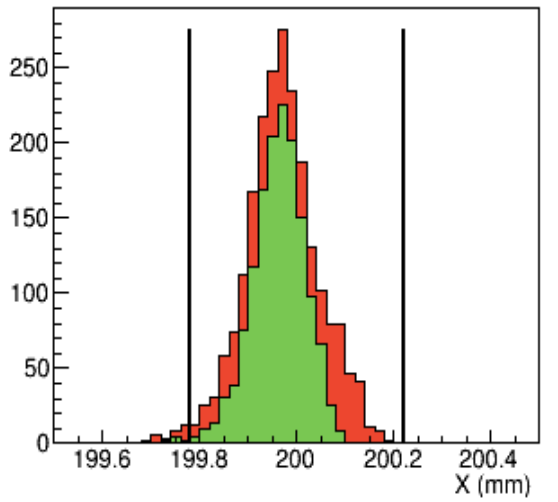
Plan is to re-start production with SICCAS in 1 month from now ..

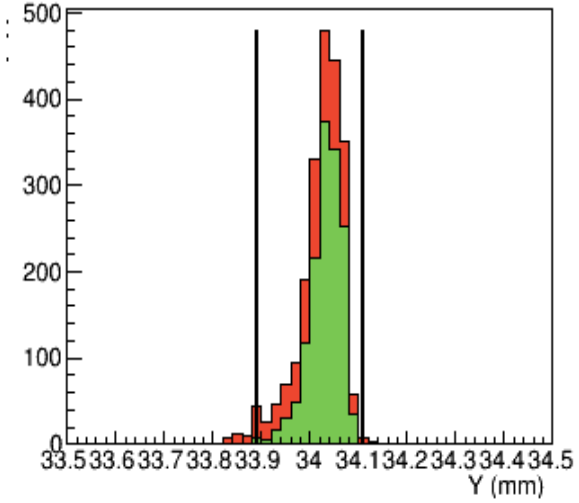
QA of crystal mechanical tolerance

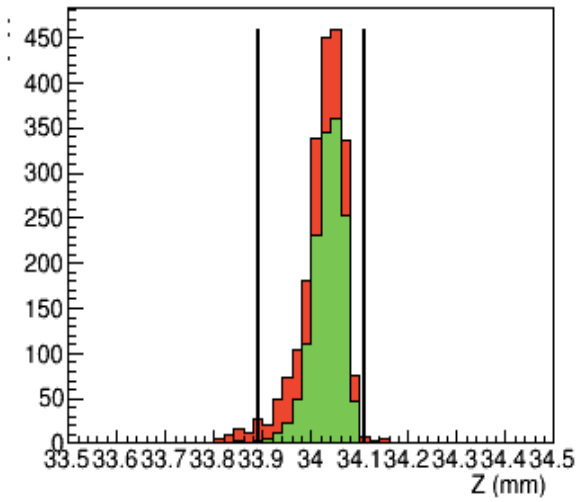




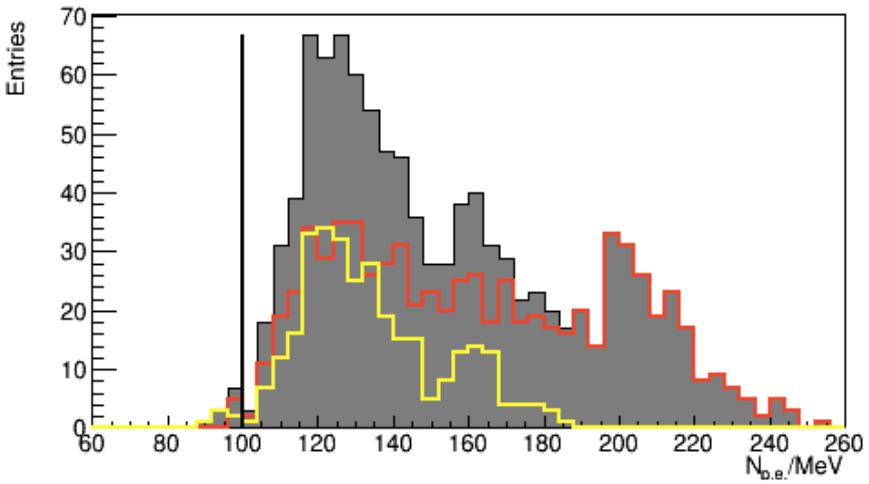


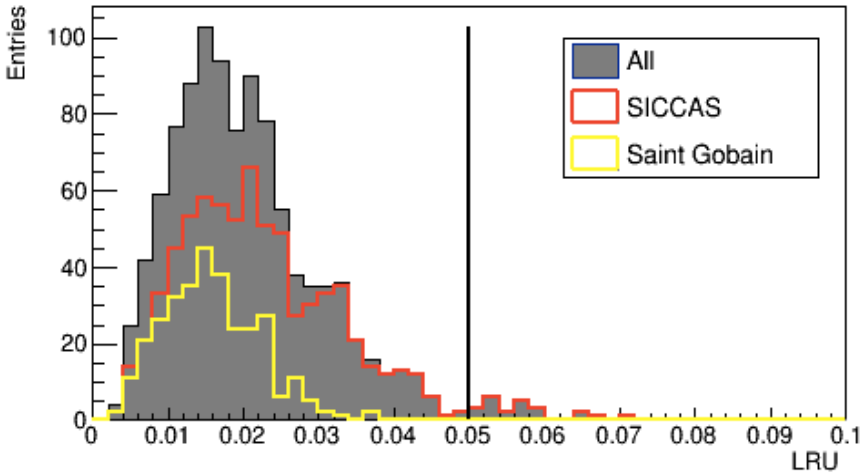


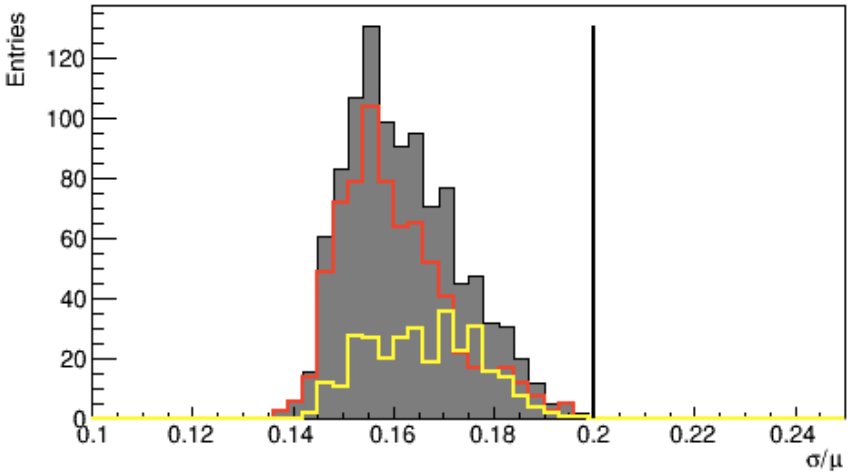


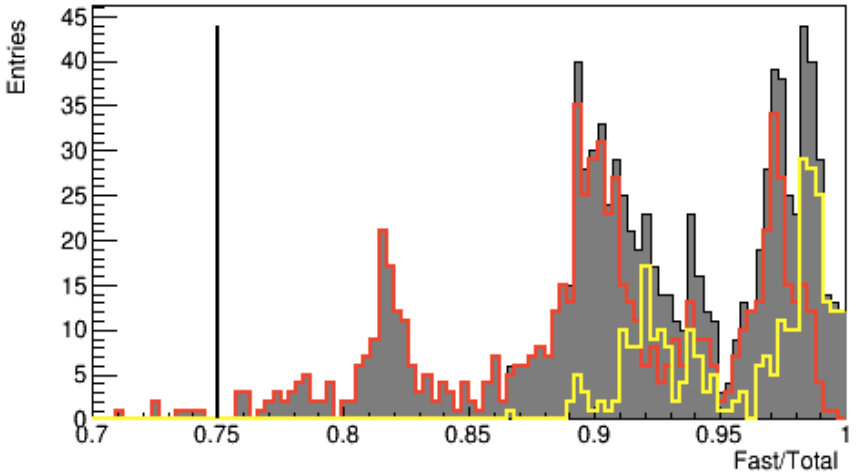


QA of crystal optical properties





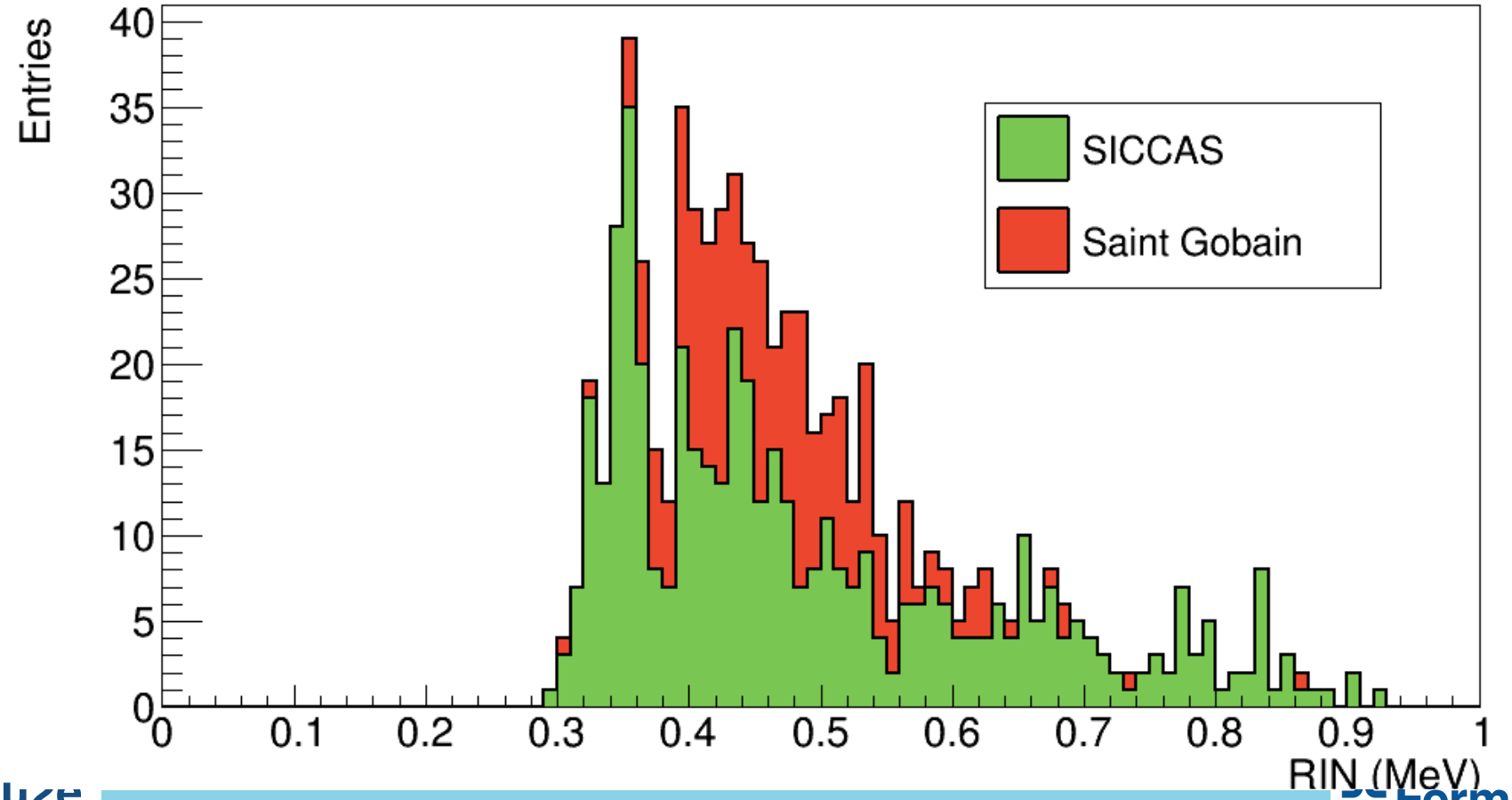




Radiation Induced Noise (RIN)

Radiation Induced Noise extrapolated @ 1.8 rad/h, 200 ns gate

- SiDet measurements up to Batch 691: 691 (472+219) crystals

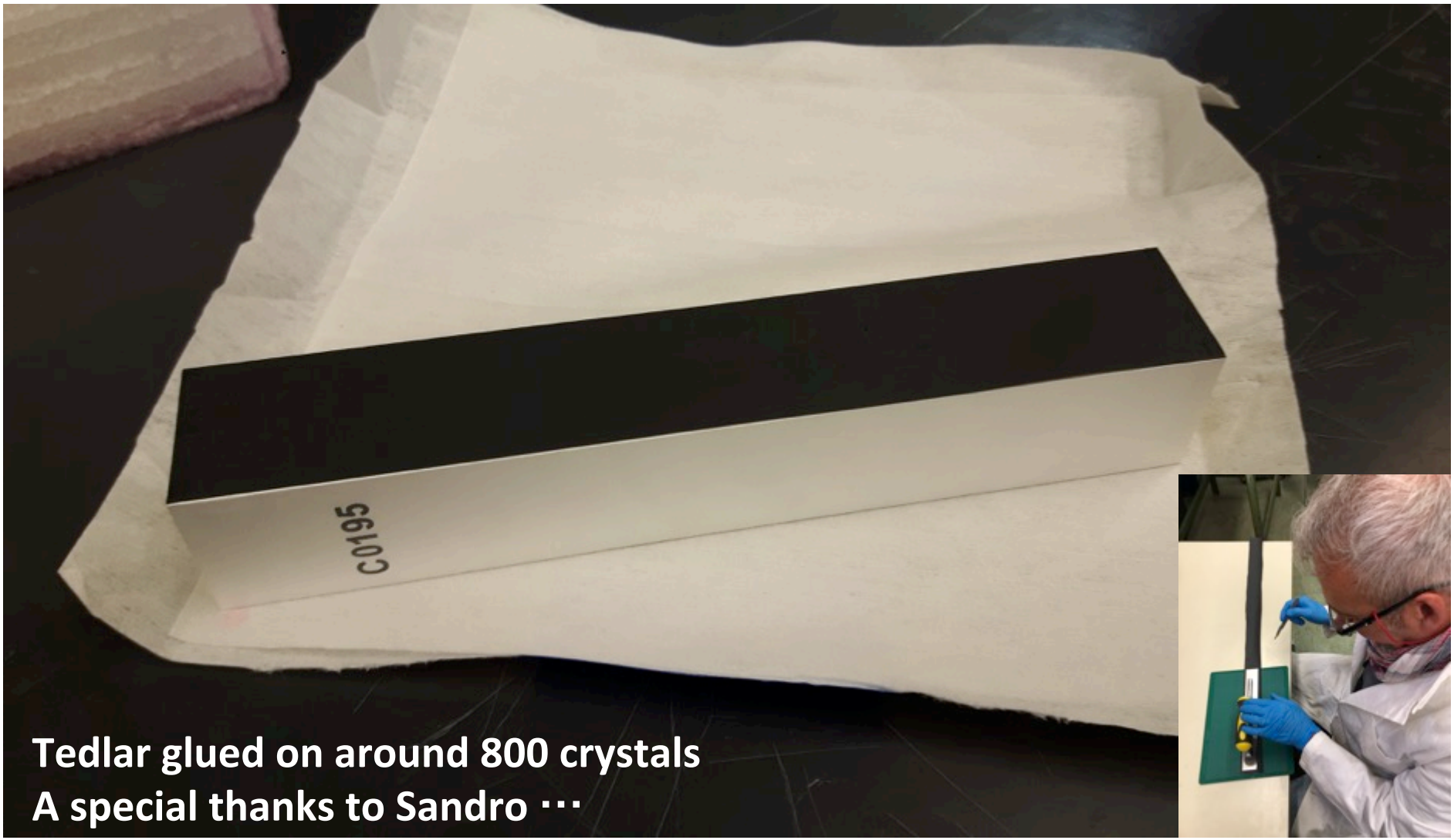


Optical x-talk +Tedlar wrapping + Outgassing

- ✗ Optical cross-talk between adiacent crystals of ~ 2% observed in Module 0 test beam data (Mu2e-doc-20862). Confirmed with laser measurements.
- ✗ **An extra wrapping of 50 μm Tedlar reduces the effect to a negligible level**
- ✗ Tedlar outgassing negligible (<0.08E^{-3} Torr/l×sec) (Mu2e-doc-26775)
- ✗ Thickness precisely measured adding several Tedlar layers
- ✗ Adopted solution for disk crystal assembly: single Tedlar foil between crystal planes + 1 Tedlar foil glued on Tyvek wrapping, on the aluminum taped side
- ✗ Process started two weeks ago. Three step procedure:
  1. Cap mounted on side opposite to the one providing best LY
  2. Crystal ID printed on cap
  3. Tedlar glued on Tyvek

NOW WORKING ON OUTGASSING FACILITY ON SIDET

Tedlar wrapping operation



SIPM production completed

We have concluded also the QA test for the overall 14 batches

- Neutron Irradiation OK with fluence $<10^{12}$ n/cm^2 operating @0°C
- MTTF evaluated > 10^7 hours

Details:

3950 SiPM arrived

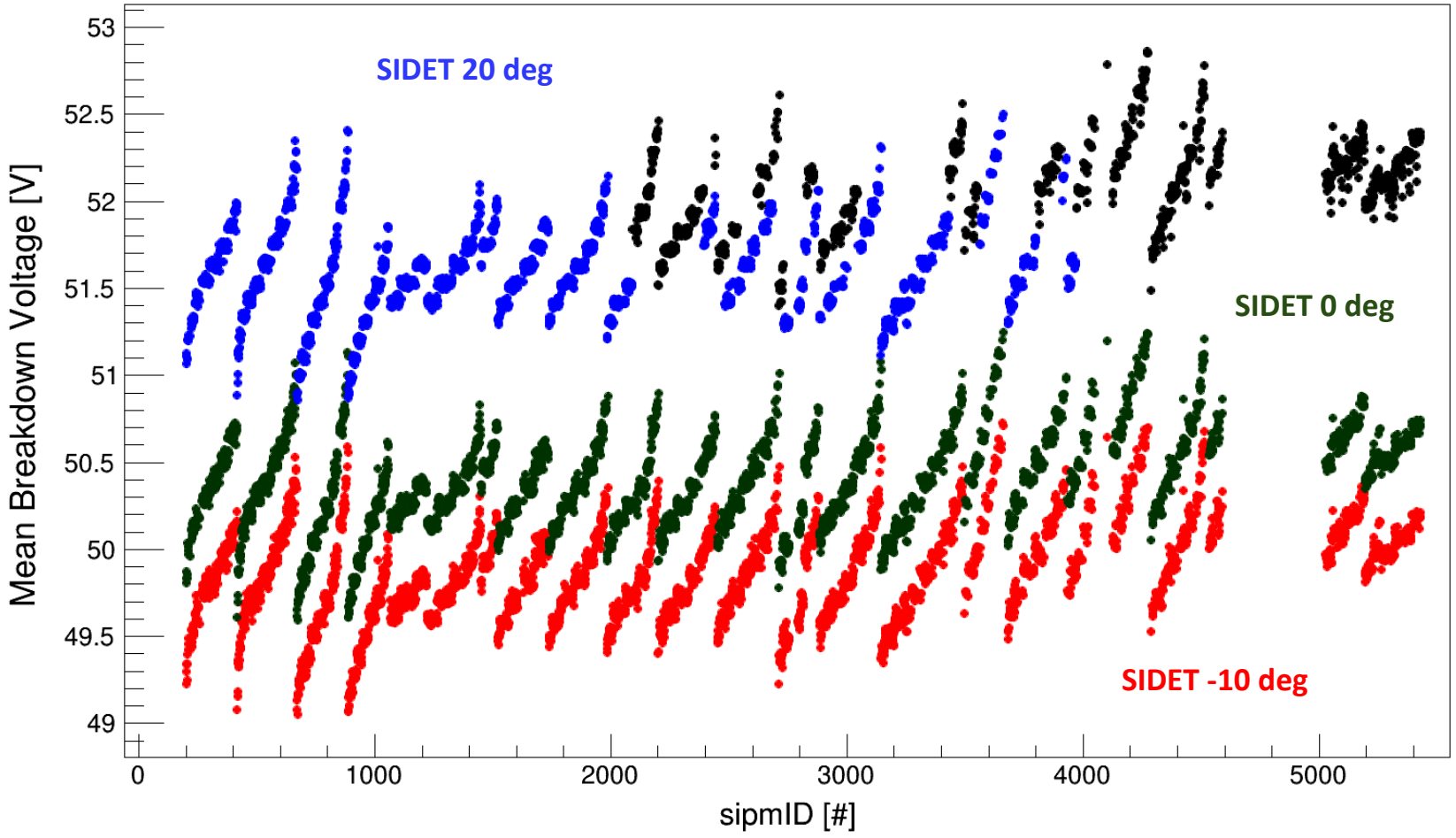
3902 SiPM accepted

- 5 SiPMs of batch 1 used as reference in the QA station
- 35 SiPMs irradiated (first 7 batches) + 20 must be irradiated = 55 SiPMs
- 180 SiPMs tested in the MTTF station → **MTTF > 12 million hours**

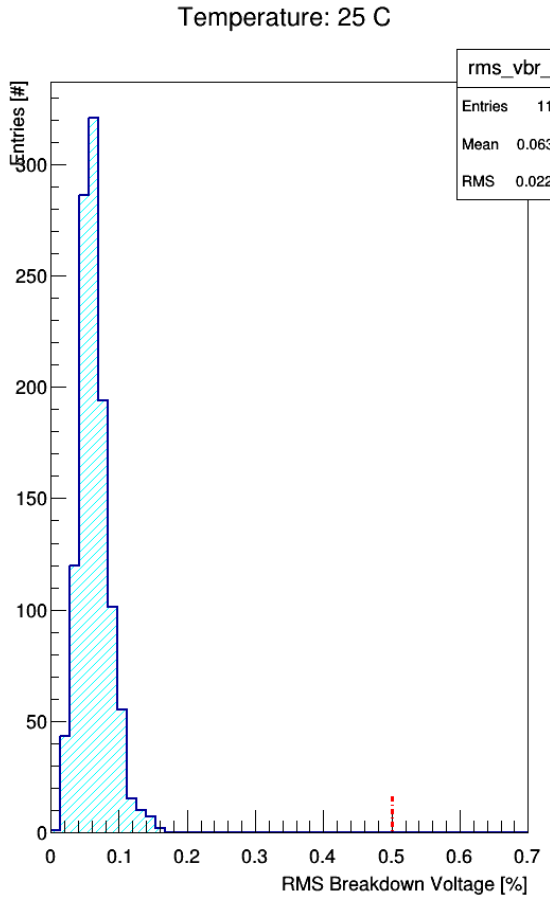
48 SiPM rejected → 1.2% of the total

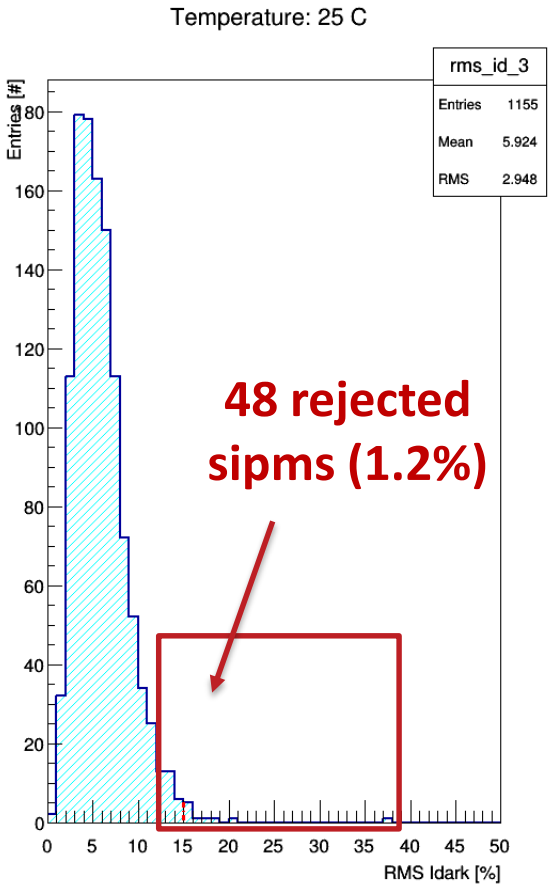
Great Production from Hamamatsu →
Great Job from OUR INFN team

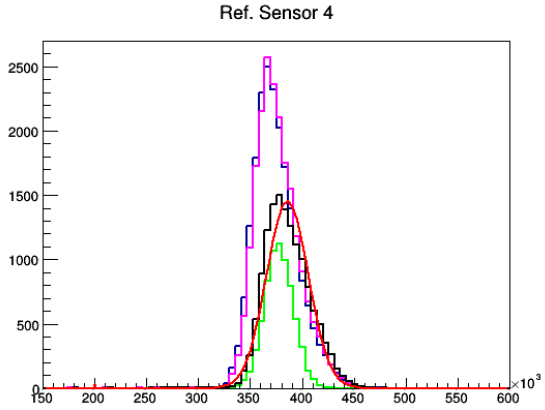
SiPM Vbr as a function of SiPM ID#



SIPM QA plots: RMS and GAIN







Magenta: -10°

Black: 0°

Blue: 20°

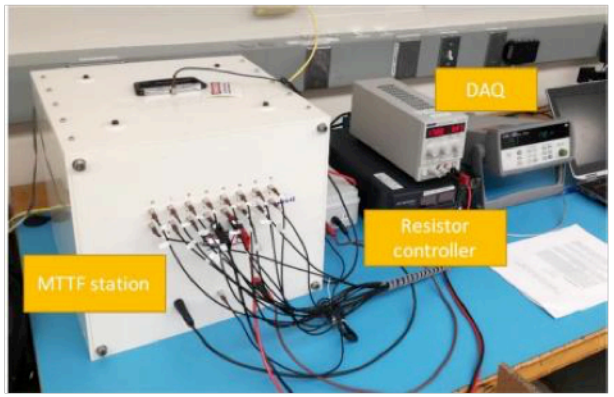
Green: 25 °

σ / μ ~ 4 %

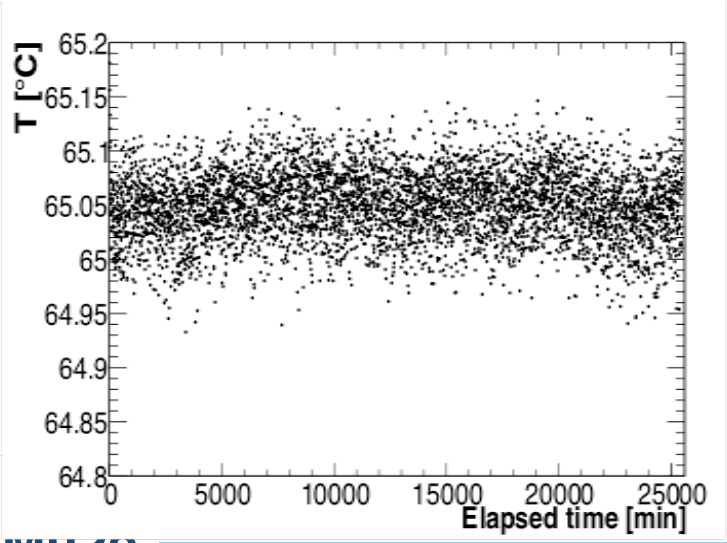
G x PDE ref = 4.e10^5

SIPM production: MTTF

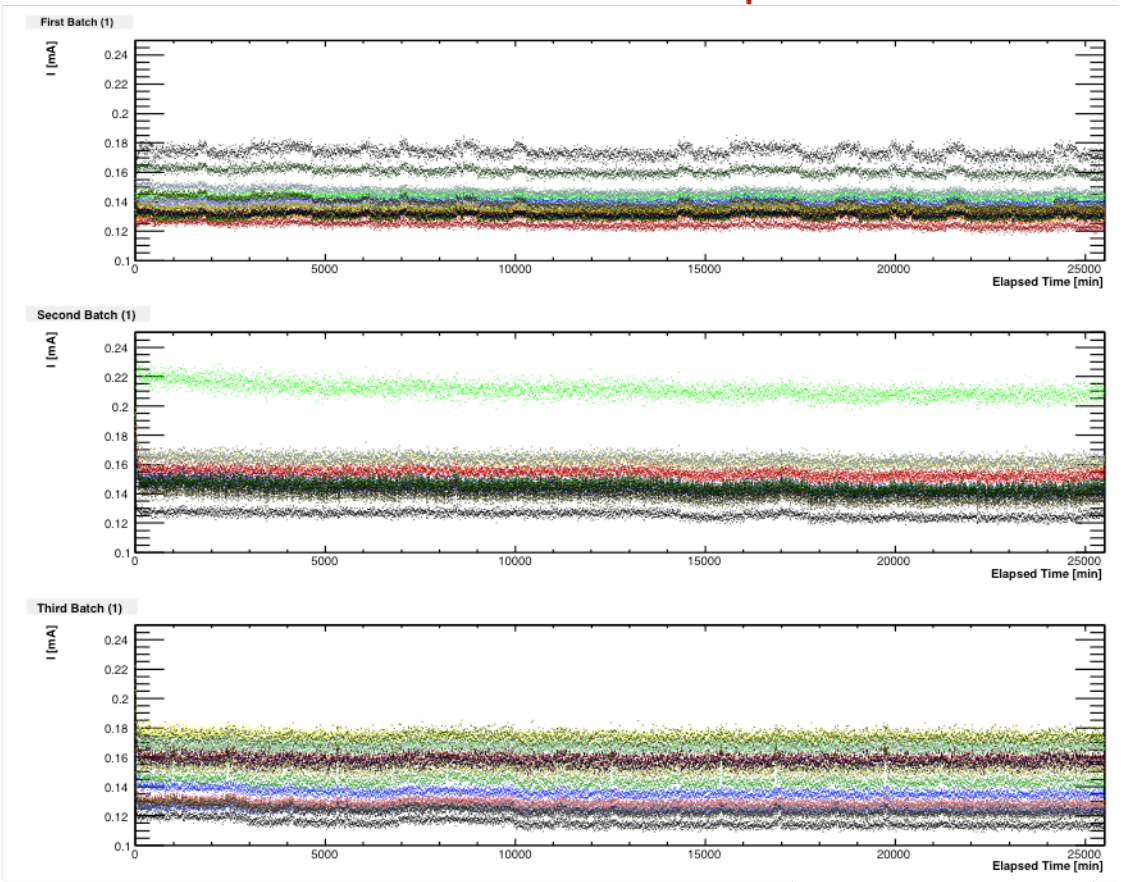
- Total MTTF: 12×10^7 hours .. No broken SiPMs during all tests



Temperature stability



Current as function of the elapsed time



SIPM: neutron irradiation (1)

- Estimated neutron flux is (4-5)xE^{10} n/cm^2 per year:
  - 5 years of run → ~ 2E^{11} n/cm^2
  - including a factor 3 of safety → ~ 6E^{11} n/cm^2

Tests on the irradiated SiPMs demonstrated that:

- We can operate at 0°C keeping the leakage current < 2 mA up to **1E^{12} n/cm^2**: → Reducing the Vbias of 3 V and loosing 15% of PDE and a factor of 2 of Gain

A fine tuning of the leakage current vs integrated flux is in progress.
We have tested in July at FNG-Frascati:

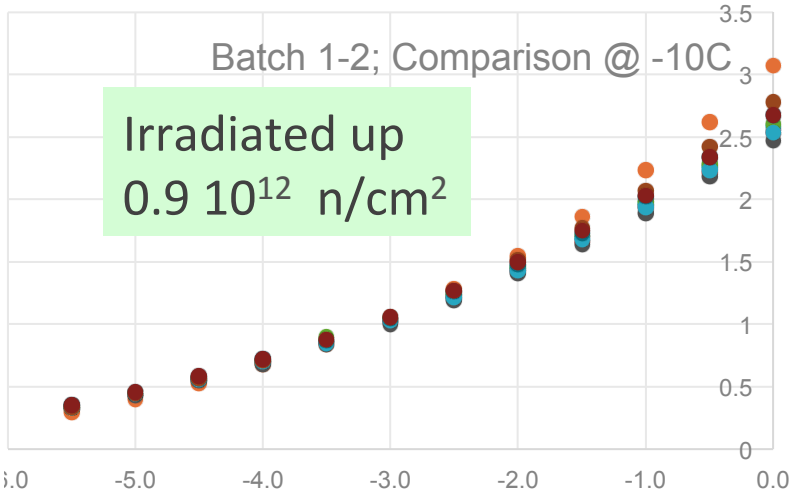
- 10 SiPMs @ 5E^{10} n/cm^2
- 10 SiPMs @ 1E^{11} n/cm^2
- 10 SiPMs @ 5E^{11} n/cm^2
- 20 SiPMs @ 1E^{12} n/cm^2 (5x4 batches remaining to test)

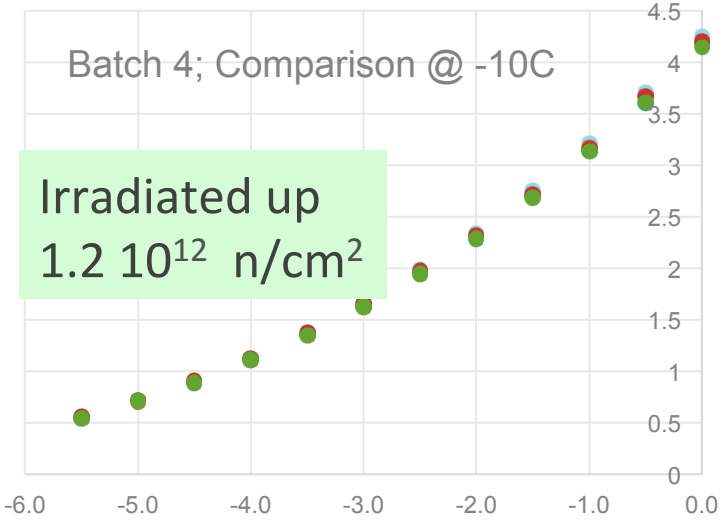
Double test in progress :

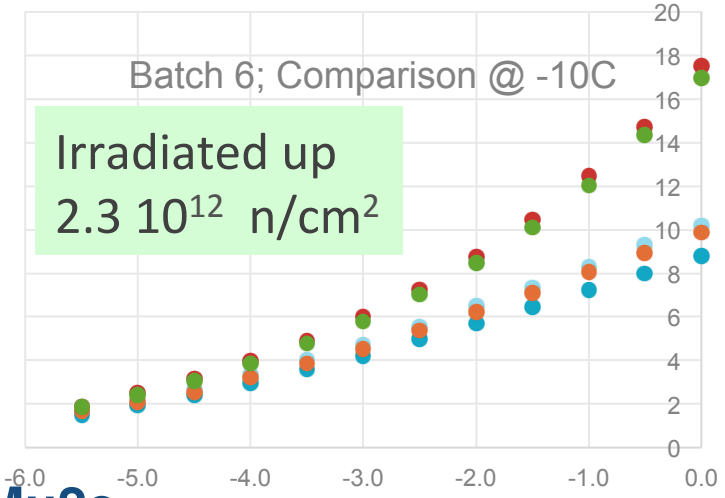
→ COMPARE with HZDR neutron irradiation → **FNG shows x2 Idark → -10 C?**

→ take data with irradiate neutrons at MODULE-0 (in progress now)

Production SiPM irradiation with neutron







- 5 SiPMs/batch "passively" neutron irradiated @ Dresden
- For Mu2e, the max n-flux in SiPM area is of around 4 x10^{10} n/cm^2

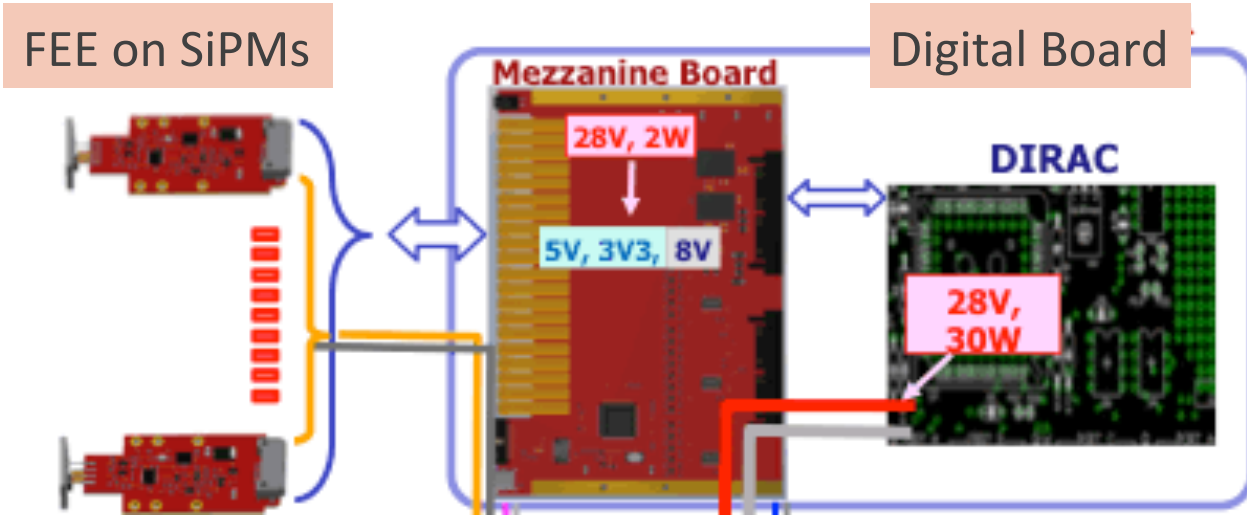
- Safety Factor 3(MC)x5(Years)x2(Prod) = 1.2 10^{12} n/cm^2
- Max I-dark current for operation of 2 mA

➔ Requires cooling of -10 C, Lower operation overvoltage to Vop-3V (for the MU2E series) , 20% of PDE relative loss

FEE/DIRAC

Status of electronics: FEE/MB/DIRAC

- 1 FEE /SiPM
  20 FEE/MB+DIRAC board
- 2017 Test beam done with FEE-V1 + CAEN digitizer
- 2017-2018 spent to make rad-hard FEE and rad-hard DIRAC



❑ **We are planning now to go to a PCB/CRR for the whole electronics**

However in the last months, we have completed the integration and interface with the mechanical system and the study of all services on the calorimeter

→ size and position of electronics on calorimeter model
→ all mech. Interferences of boards in crate , solved and tested
→ tests of single component prototypes in rad-environment
→ cable type selection, cable length and determined their routing path
→ stable estimate of power dissipation and cooling needs

Where are we now … after big RAD detour?

FEE should stand up to 100 krad, 10^{11} n/cm^2 and 10^{10} p/cm^2

After June 2018 TID test, we have revised most of FEE electronics while completing the design of rad-hard DIRAC (V2)

- FEE V1 → V2 Shaping adjusted (NIM-MB controlled)
- FEE V2 → V3 better cable controlled by MB-V1
- FEE V3 → V4 (RAD-HARD) f inal cabling vs MB-V2

V4 design completed in April

→ **SEU test for MB-V1 needed for ARM processor → done in May**
→ **DIRAC-V1 SEU test under planning for this fall**
→ **First slice test with few channels done up to DIRAC V1 in May**

→ 25 channels of V3 produced in May, being prepared for Module0
→ 5 prototype of MB-V2 produced this week
→ Module-0 readout with DIRAC V1
→ **Then proceed for slice test with V4-MB2 and DIRAC-V2 (Fall 2019)**

Development of RAD-Hard electronics

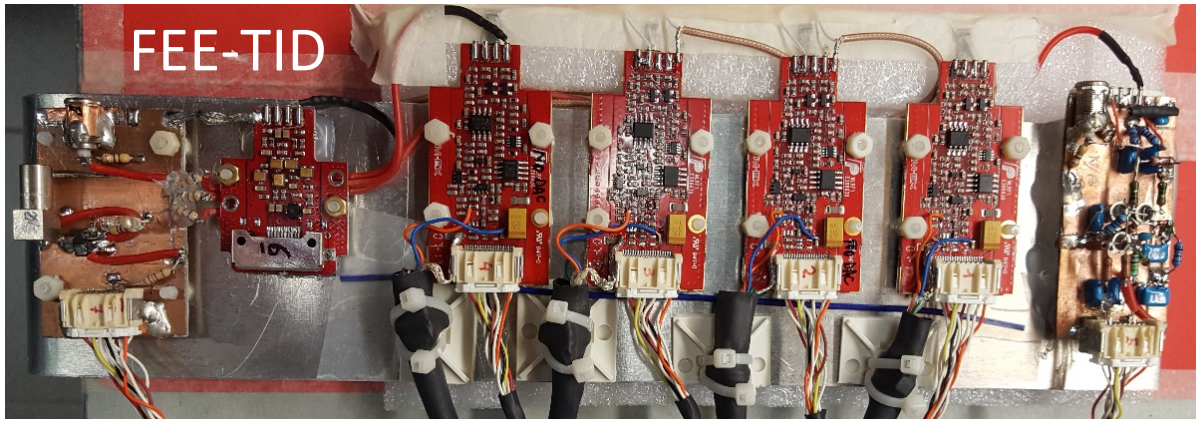
Long irradiation campaign carried out:

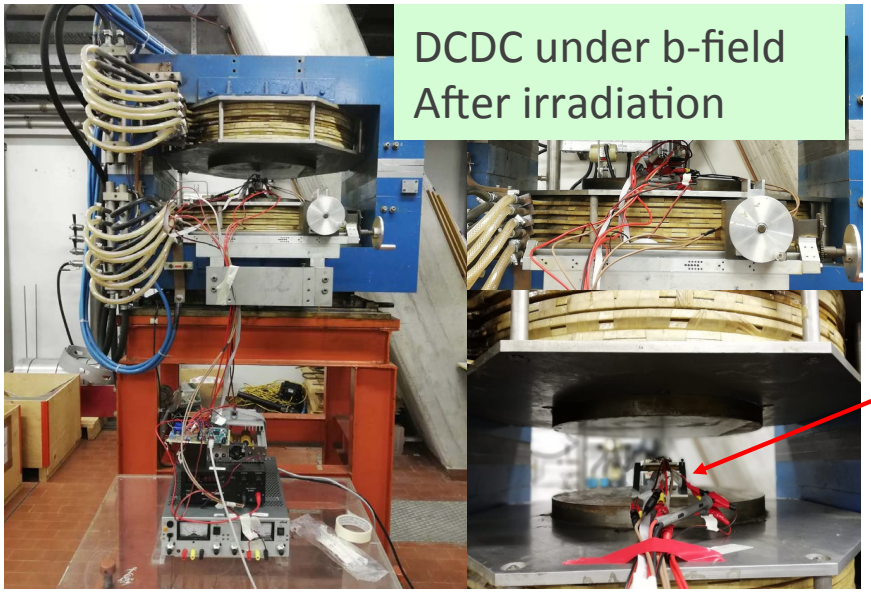
- ➔ Neutrons in FNG(Italy) HZDR(Germany)
- ➔ Dose in Calliope (Italy) HZDR (Germany)
- ➔ SEU in Warrenville (USA)

Results:

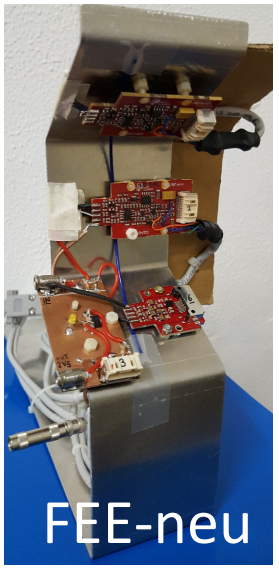
1) Final rad-hard components selected
2) FEE v4 OK
3) DC-DC converter OK
4) FPGA/ADC/DDR sections of DIRAC tested

→ SEU test almost completed
→ Dirac V2 design completed

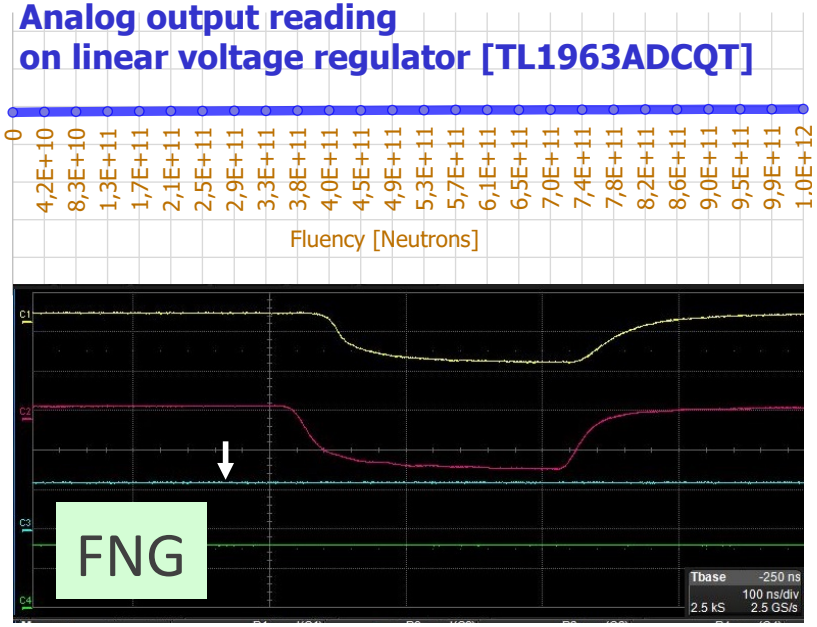


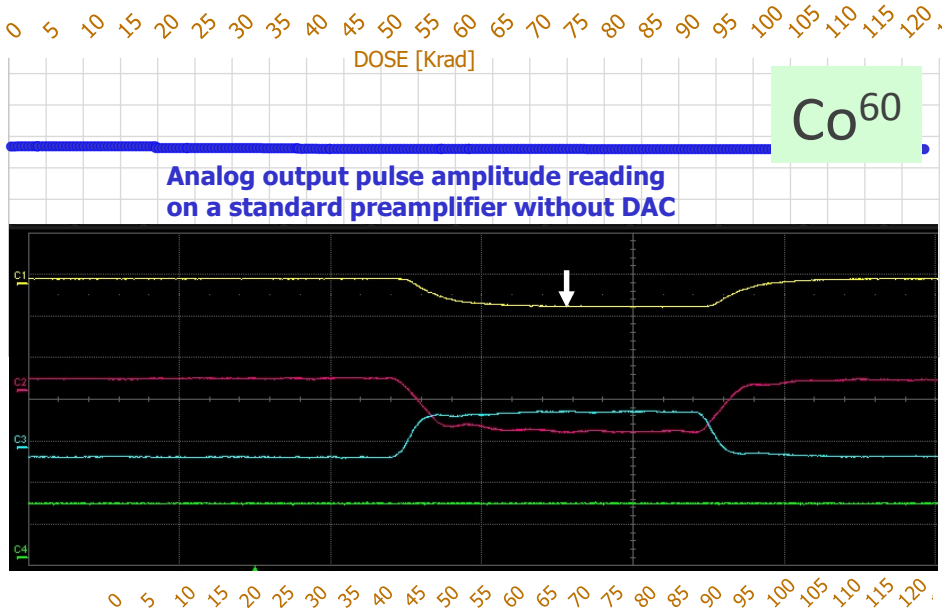


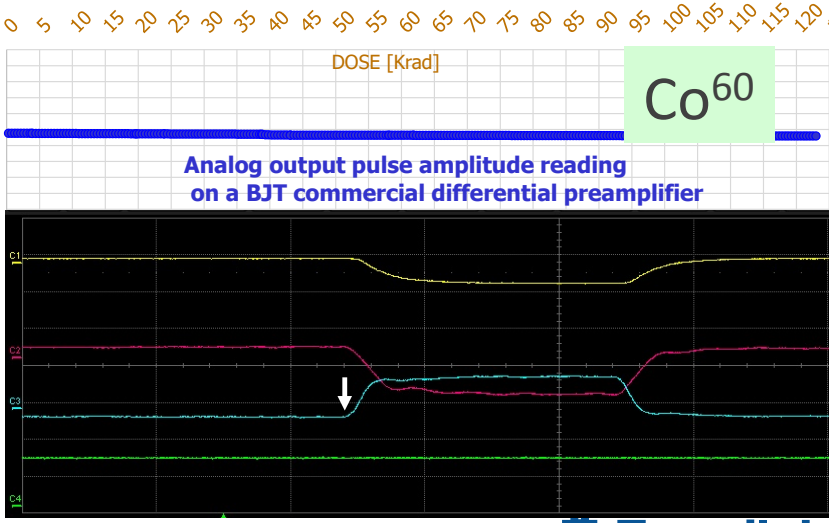
DCDC DEMO BOARD



FEE irradiation: neutrons (10^{12}) + TID(100 krad)



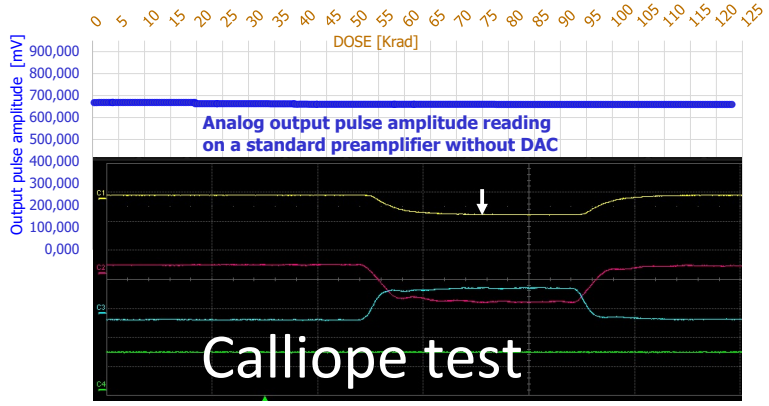


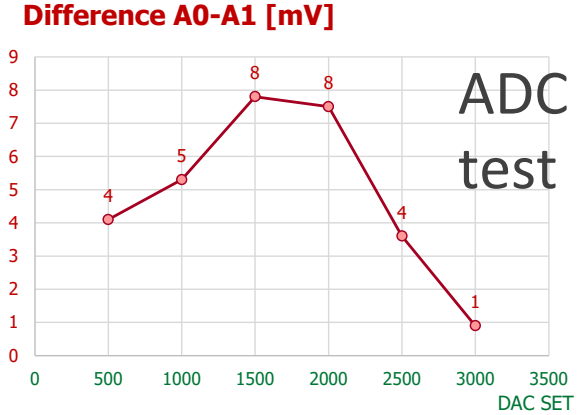


After replacing the original V-Ref with the rad-hard TL1431QDRQ1 everything looks stable in the HW sections for both the preamp and HV-regulator sides

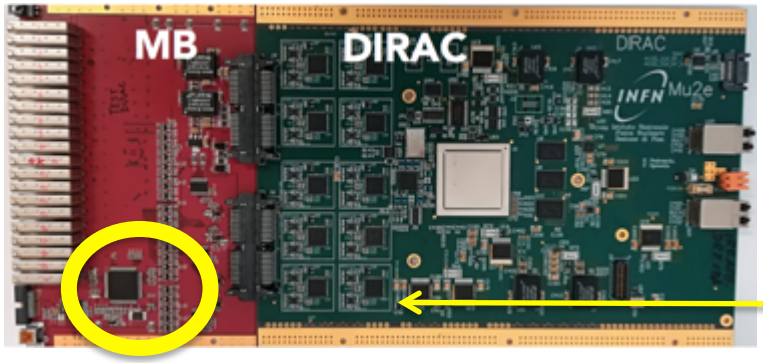
Both for n-flux and TID

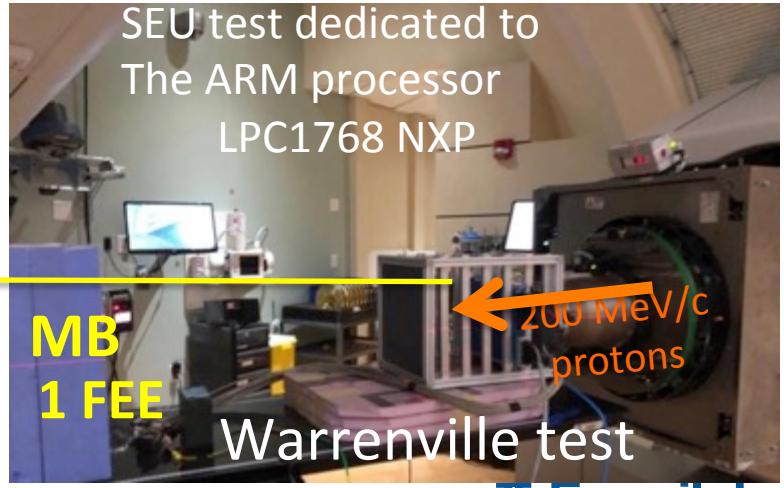
FEE irradiation: TID(100 krad) + SEU (10^{10} p/cm^2)





- **All analog parts of Amplifier and HV regulator now OK after changing Voltage reference chip**
- LT ADC/DAC of digital parts suffering from 10-15 krad
- New rad-hard ADC/DAC identified from Texas Instrument
- PCB with new TI ADC/DAC done 28 January, OK ➔ new protocol required 6 pairs/wire, new cable





Few SEU observed up to 1.5E^{10} p/cm^2 due to Ethernet connection. **Repeat with final MB**

FEE v3 → v4 (different ADC .. different cable)

ECDP-04-L2

- 1 connector per SiPM/Channel

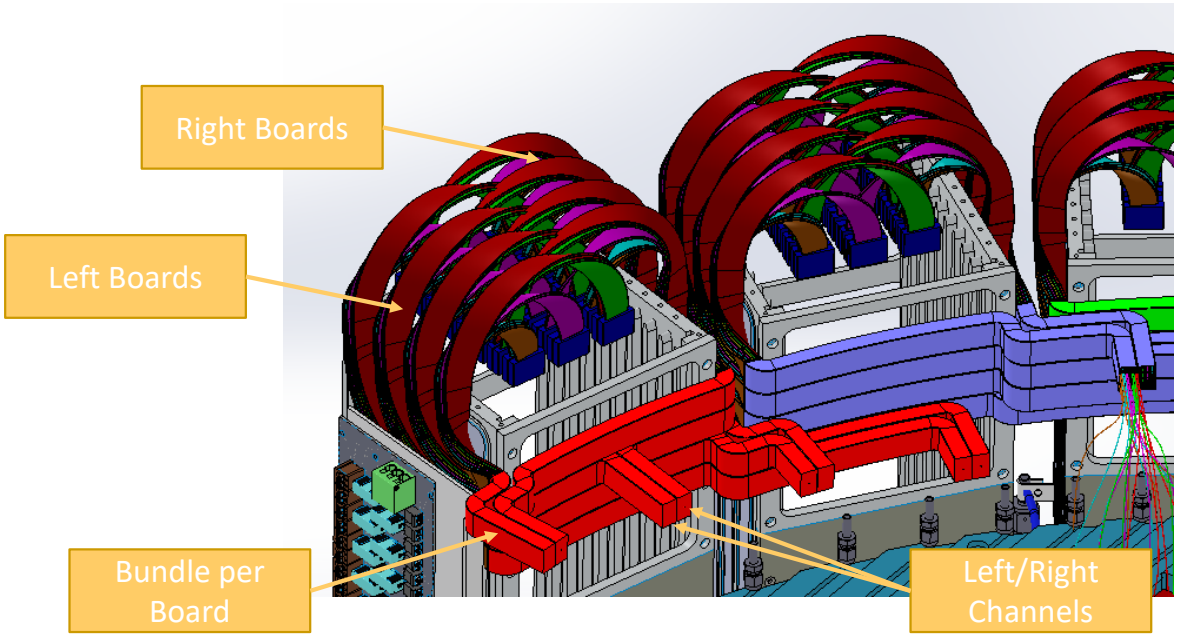
SPECIFICATIONS

For complete specifications see www.samtec.com?ECDP

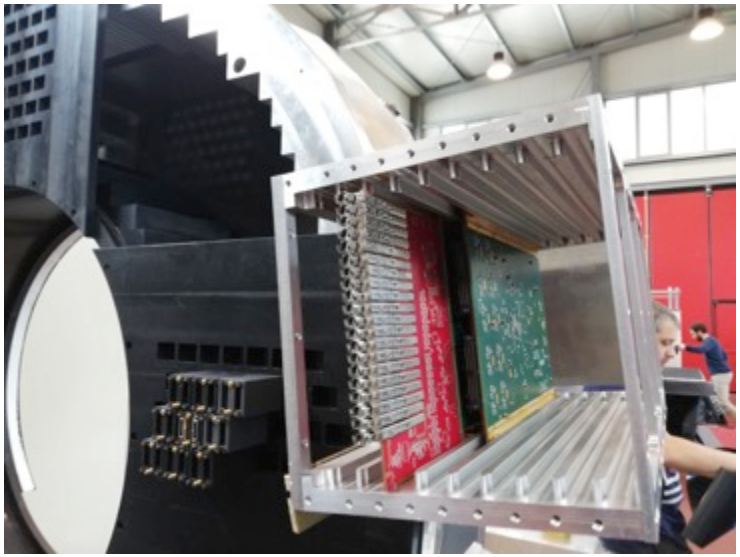
Cable:
30 AWG twinax cable
Plating:
Edge Card = ENIG, 3-10 microinches
Operating Temp Range:
-25 °C to +105 °C
Current Rating:
2.3 A per pin
(2 adjacent pins powered)
Impedance:
100 Ω Differential
Bend Radius:
(3.18 mm) .125"
Pinout Map:
See web address above
RoHS Compliant:
Yes

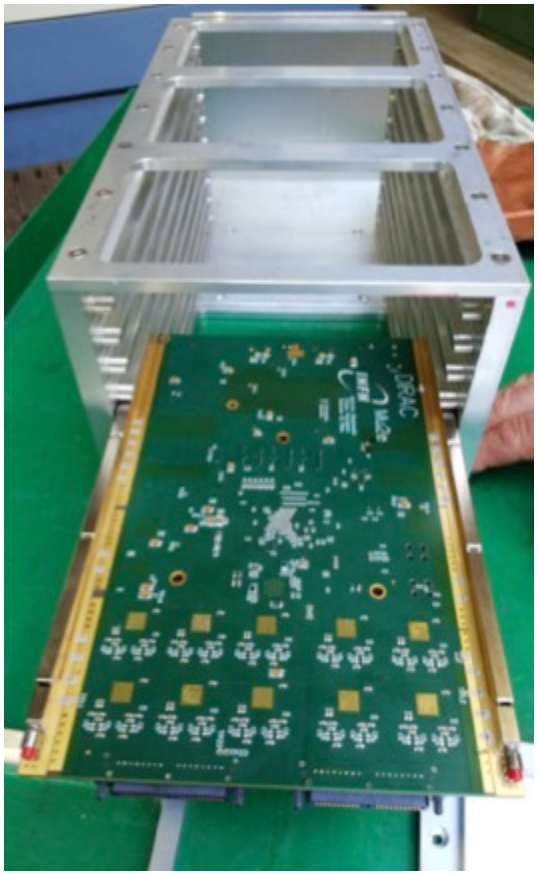
HDLSP

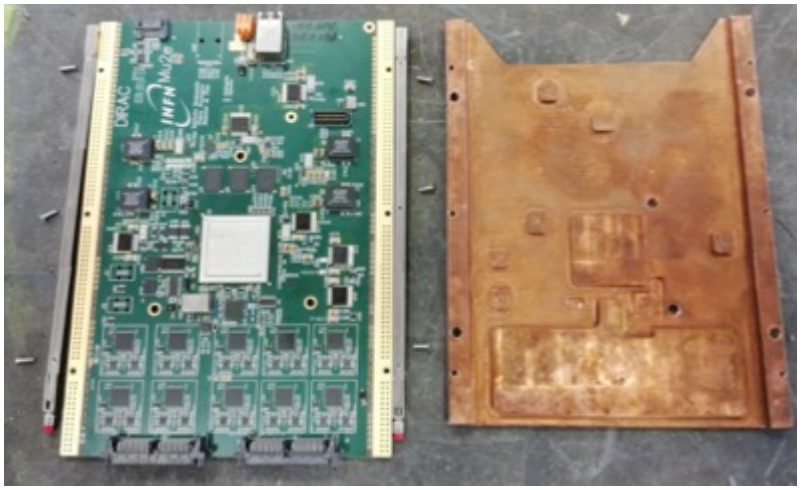
- 1 connector per 4 SiPMs/channels
- 5 connectors per Mezzanine board
- 2 x 12 TTF



MB-DIRAC-integration on crates

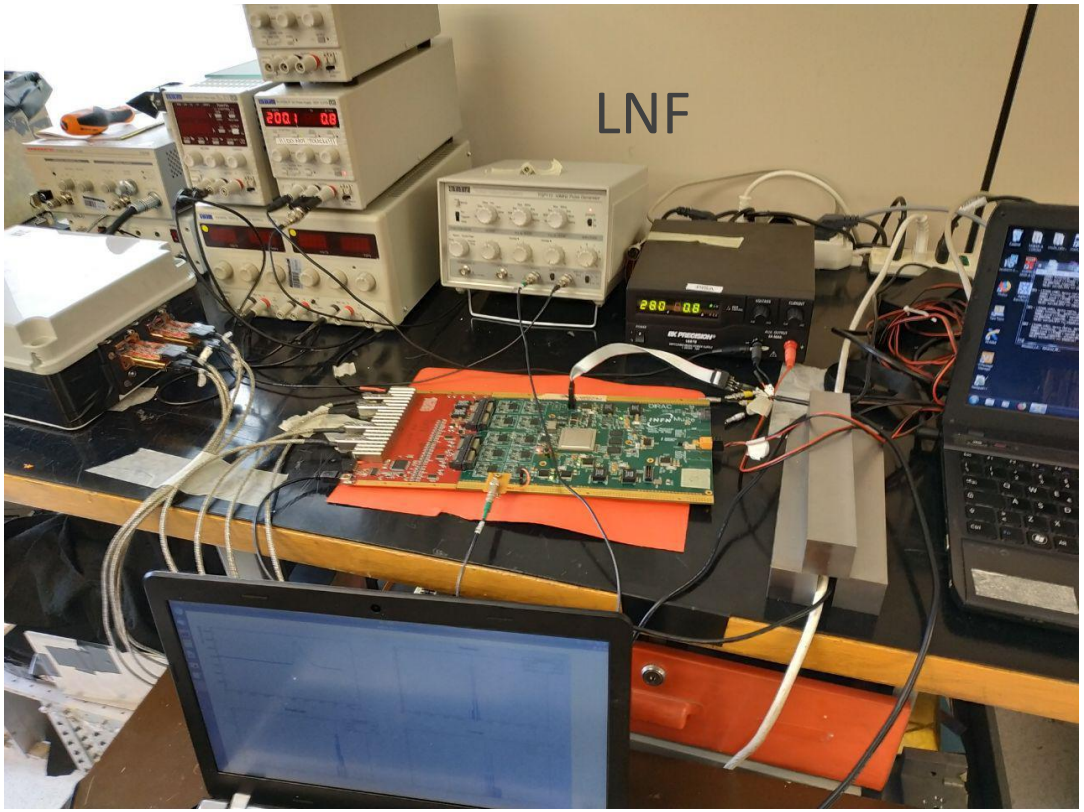






FEE-V3 – MB-V1 – DIRAC-V1 (1) docdb 26514-26778

- Second Step: we plugged the Dirac into the LNF SiPM + FEE test station described in **docdb-26514**
- Test of the linearity over the full dynamic range

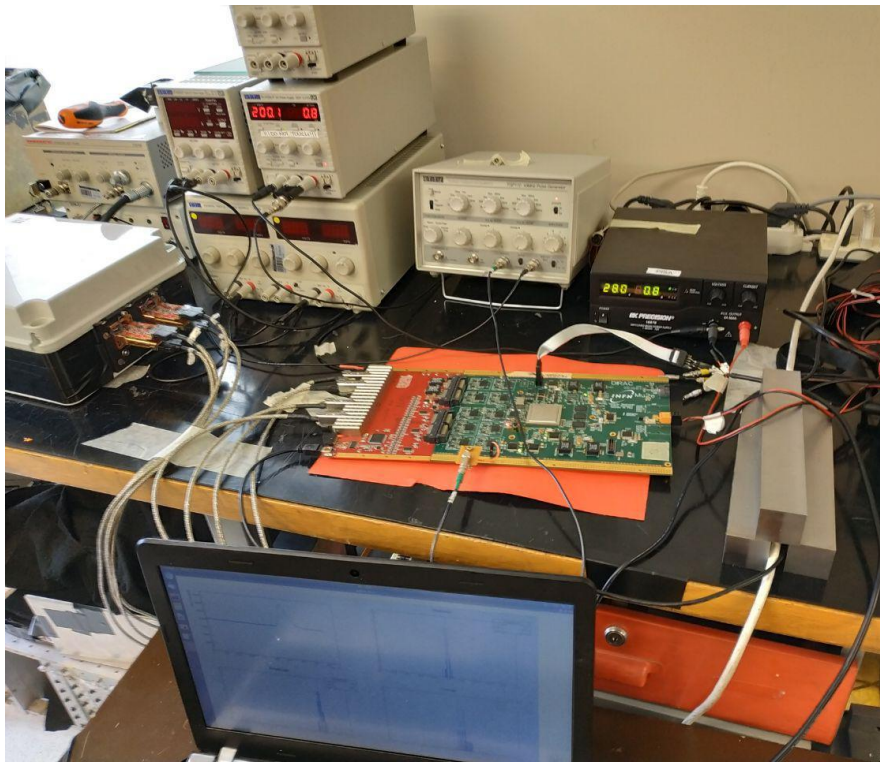


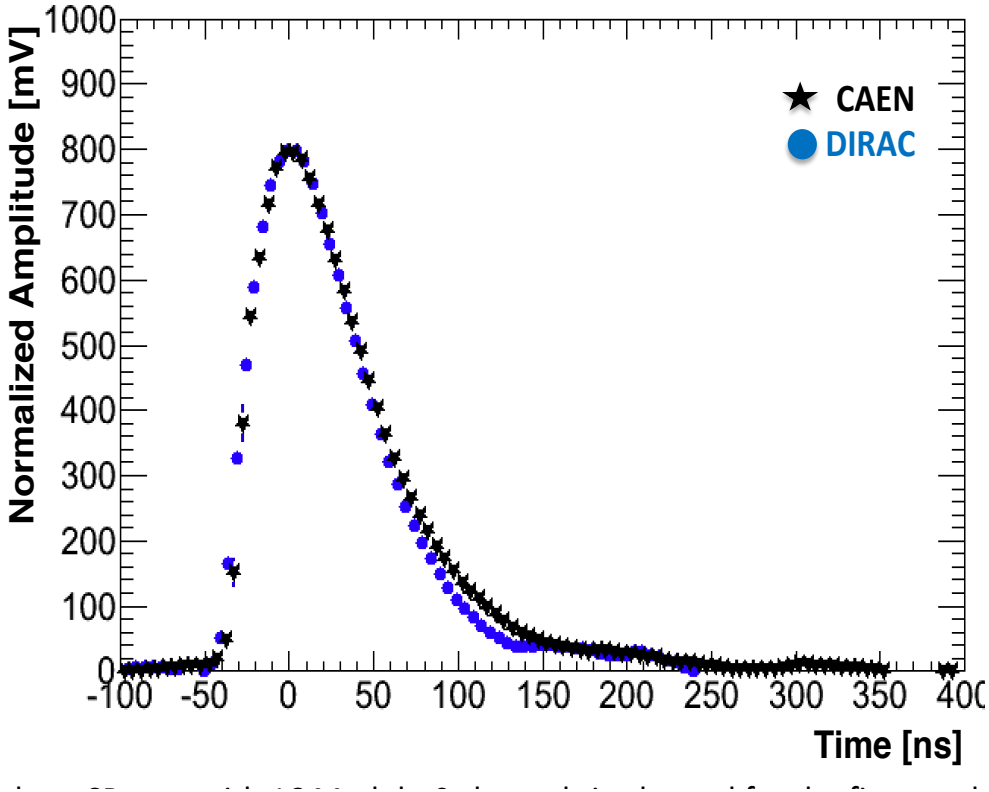
Station characteristics:

- Automatized Filter wheel to filter LED light (9 different positions)
- Possibility to test up to 4 channels (4 SiPMs, 4 FEE modules)
- Possibility to set the HV individually for each SiPM

FEE-V3 – MB-V1 – DIRAC-V1

- Second Step: we plugged the Dirac into the LNF SiPM + FEE test station described in **docdb-26514**
- Test of the linearity over the full dynamic range

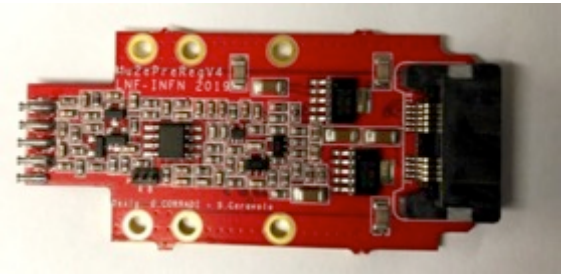




DIRAC vs CAEN digitizer comparison very successful →
SEE Franco for test with MODULE-0 et al.

PLANS for CRR + PRR

- For the electronics, we are now ready to move forward to CRR
  - ➔ Rad Hard tests practically completed ➔ **Another round in the fall**
  - ➔ **SEU tests done with MB** and SEU DIRAC in planning
  - ➔ FEE-V4, MB-V2 and DIRAC-V2 have a final design
  - ➔ **FEE-V4 proto are ready. MB being produced ➔ DONE**



What we need to do to remain in track with the schedule

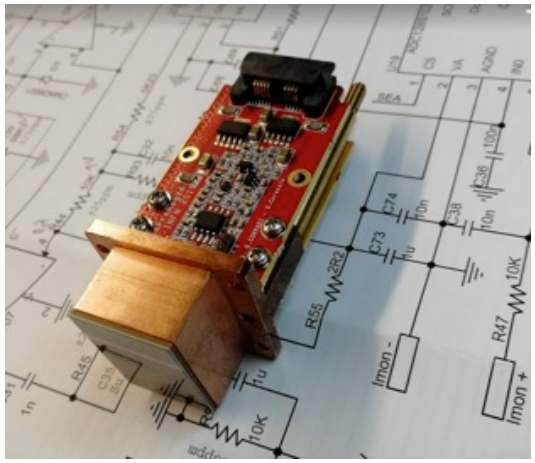
- ➔ start production of FEE boards in the fall.
- ➔ start production of MB boards beginning 2020
- ➔ start production of DIRAC boards spring 2020

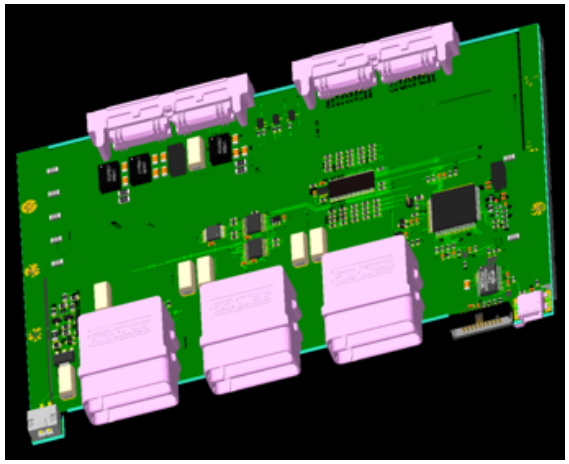
➔ PCB review for FEE **DONE IN AUGUST**

➔ Planning a joined CRR review for electronics in October after vertical slice test with TDAQ (need DIRAC V2) is completed

FEE-PCB review

- **PCB review carried out on 17-July @ Fermilab**
  - → both FEE and MB design requirements and schematics presented
  - → 3 hours review. Comments/recommendations received



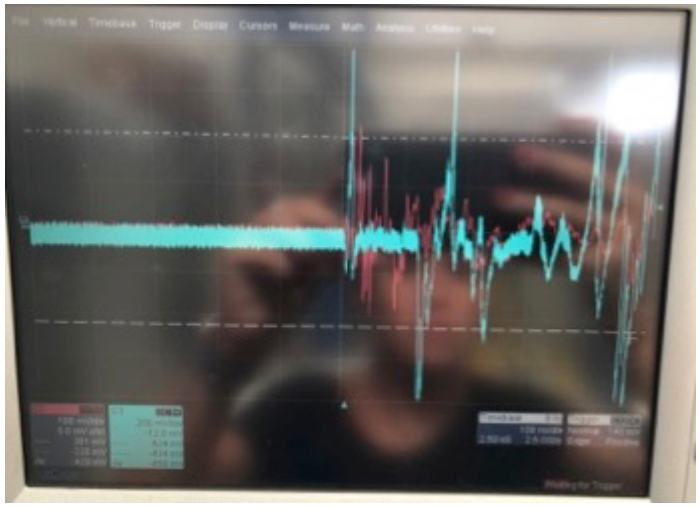


17. Operation in vacuum: The committee recommends that the design team review the routing of high voltage traces, vias, and parts placement, for proper operation (i.e. the absence of breakdown) as a function of vacuum.

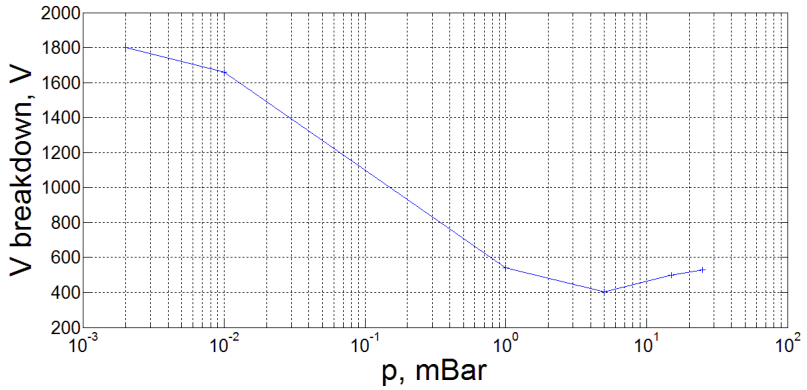
→ The team should either determine this analytically,
→ or measure the corona of the existing boards under bias as a function of vacuum.
→ An allowance for safety factor headroom is recommended.

FEE-PCB review: reply @ Paschen Minimum

Example of breakdown startup



HV [V]	25 mbar	15 mbar	5 mbar	1 mbar	10^{-2} mbar	$2x10^{-3}$ mbar
300	ok	ok	ok	ok	ok	ok
350	ok	ok	ok	ok	ok	ok
400	ok	ok	bd @ 405 V	ok	ok	ok
450	ok	ok		ok	ok	ok
500	ok	bd		ok	ok	ok
530	breakdown			ok	ok	ok
540				bd	ok	ok
600					ok	ok
900					ok	ok
1200					ok	ok
1600					ok	ok
					Bd @ 1660	Bd @ 1800



- **@ Paschen minimum , Vbr > 405 V (larger than 327 from flat electrods), x 2.2 times Vmax< 200 V**
- **@ 10^{-2} Torr , Vbr > 1650 V , factor of 8 safety granted**

Mechanics

Outcome of CRR for mechanics (21-22 May)

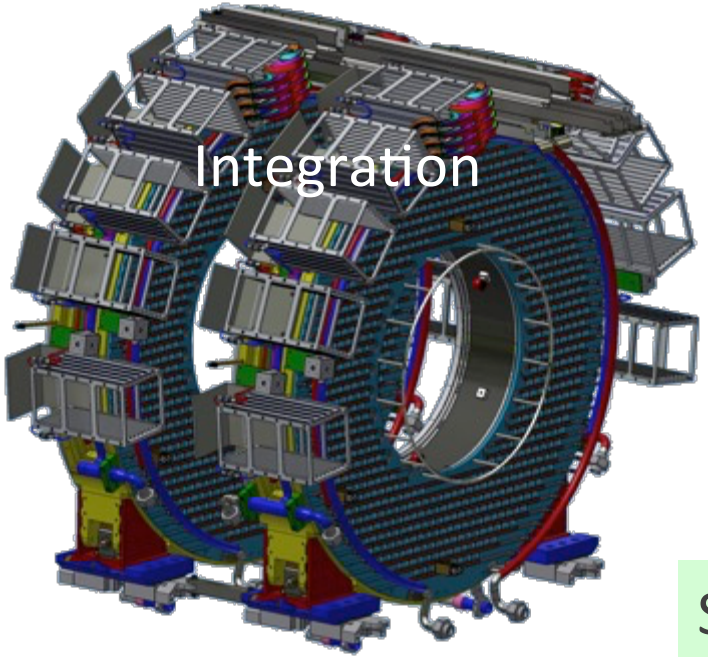
- All CRR materials can be found in the CRR review web https://mu2e.fnal.gov/public/project/reviews/CALCRR/

- CRR closeout was positive and the reviewers acknowledged the maturity of the Calorimeter Mechanics Design
- CRR findings, comments and recommendations in Doc# 26511

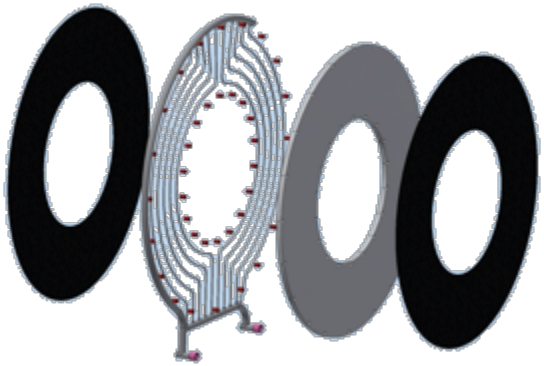
➔ Findings address the charges. Not full YES but many ALMOST.
➔ Main concerns:

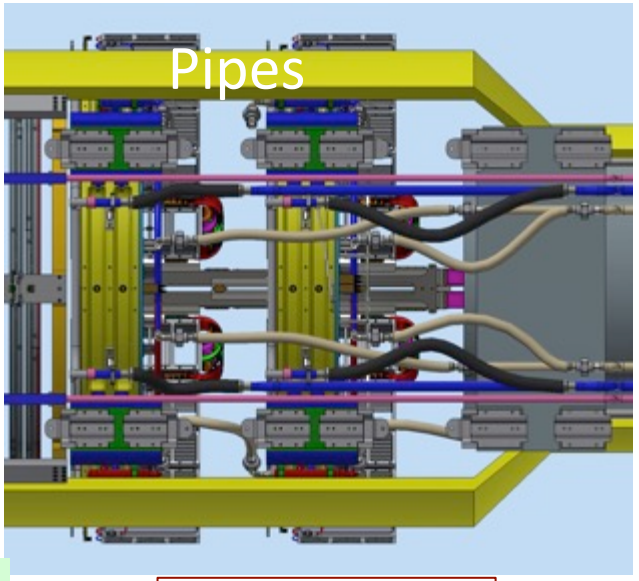
1) Complete detailed fabrication drawings
2) Carry out further outgassing tests + CF Inner Ring
3) Develop formal guidelines for cleaning/assembly & maintenance procedures

Mechanics CRR highlights: CAD complete

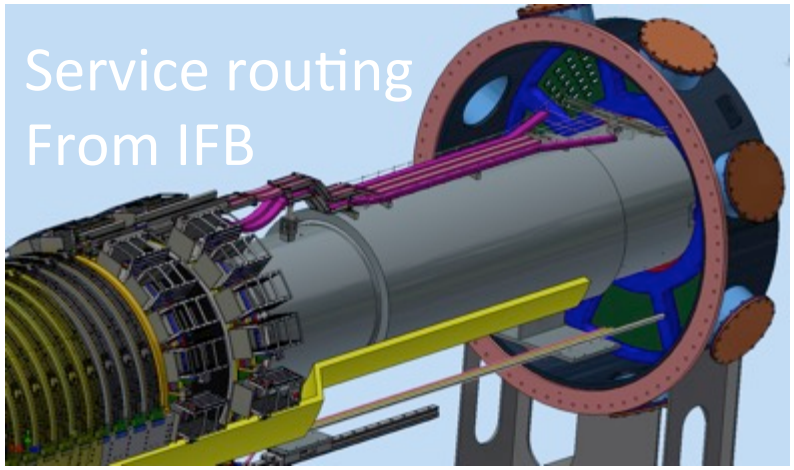


Front Panel CF with embedded source

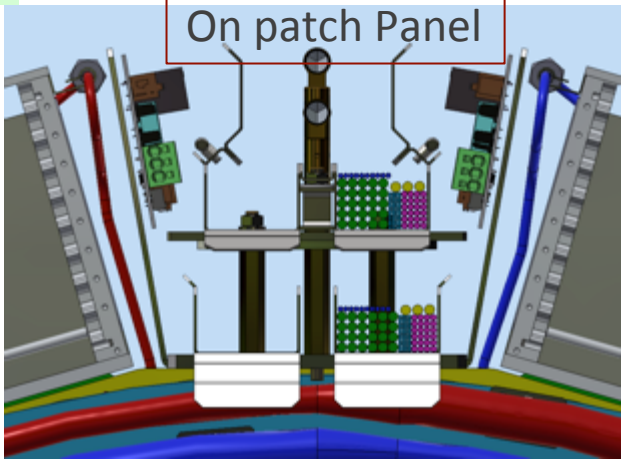




SEE FABIO & FABRIZIO



Cable routing
On patch Panel



Mechanics CRR: cabling and mockup

- Full size mockup at LNF done
- Mockup with FEE cable done at SIDET. Laser bundle selected. Routing in progress
- Routing of piping and services completed in CAD model → **See Fabio + XLS**
- Laser distribution system tested in SIDET → **See later in this talk**

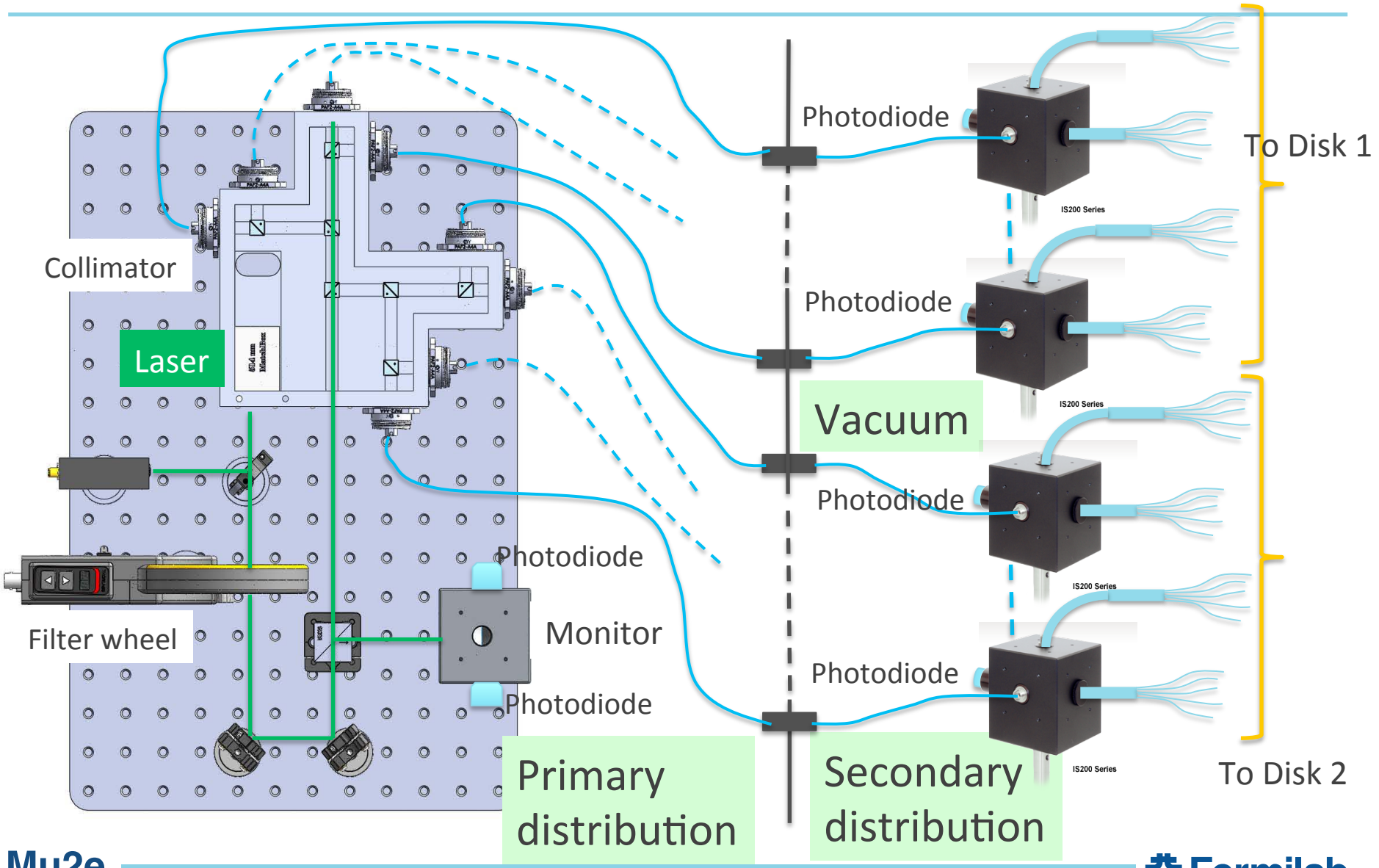
Update on outgassing of “unconventional” stuff

Component	Q (Torr x liters/sec)
Crystal-Tyvek	$2{,}40 \times 10^{-3}$
SiPM+FEE + holders	$2{,}10 \times 10^{-3}$
Diffusive Spheres	$0{,}12 \times 10^{-3}$
Laser Optical Fibers	$0{,}36 \times 10^{-3}$
Patch-Panel- IFB Service Cables	$0{,}10 \times 10^{-3}$
~~Old Cables~~	~~$1{,}9 \times 10^{-3}$~~
New Cables, no connectors	$0{,}01 \times 10^{-4}$
UL on connectors	$< 0{,}6 \times 10^{-3}$
V1 Dirac Boards + Copper +paste	1.1×10^{-3}
Mezzanine Boards	$< 0{,}6 \times 10^{-3}$
Shells+Connectors MB	$< 0{,}3 \times 10^{-3}$
Total	**$< 7{,}8 \times 10^{-3}$**

Requirement: $Q < 8 \times 10^{-3}$ Torr x liters/sec

Calibration systems

Laser System Scheme Final: Cordelli/Ferrari/Miscetti



Secondary Light distribution system

ThorLab-IS200 Sphere

- 1 input, 4 output ports
- 3 Bundles of fibers with SMA connector in the port and final ferrule needle on each fiber.

One sphere has been purchased
→ **Eight are being procured now**

MM 200 μm fiber:

- NA = 0.22 → Silica/Fluorine-Doped Silica cladding (FIP Optical Fiber from Molex)

RadHard test on 80 krad

- Test with ^{60}Co: no effect detected
- Two 10 m long fibers has been purchased for test (over 12) → **2020**

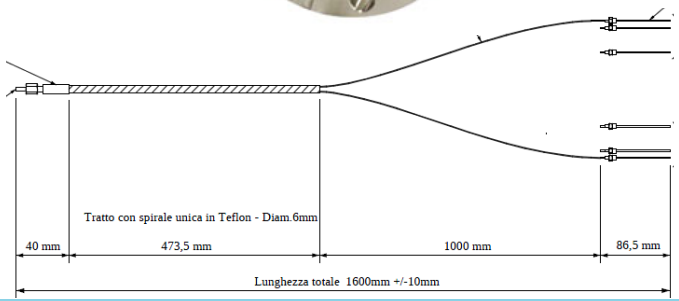
Vacuum optical feedthrough

- ConFlats 2.75"
- Feedthrough with Multifiber
- From Kurt J. Lesker

Mod. FIBM3−IR00−02−S−3 has been purchased for test (one over four) → **2020**

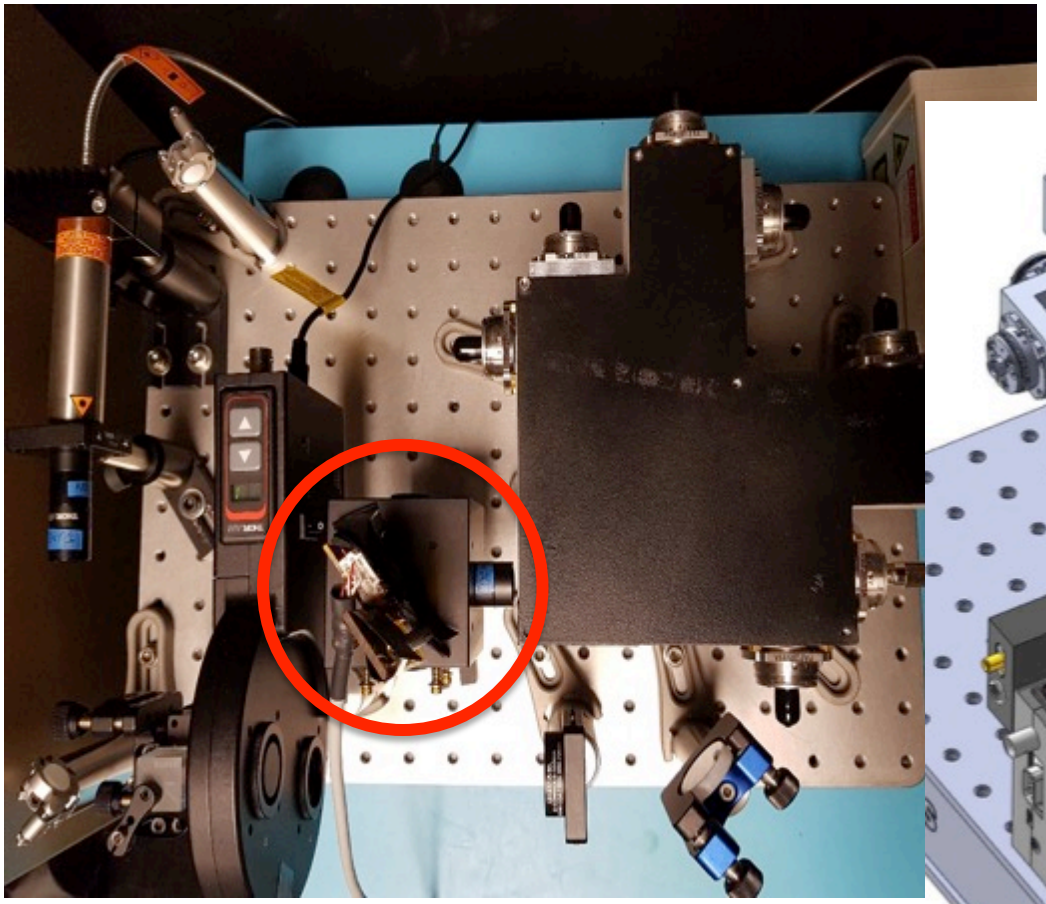
Fibers bundle

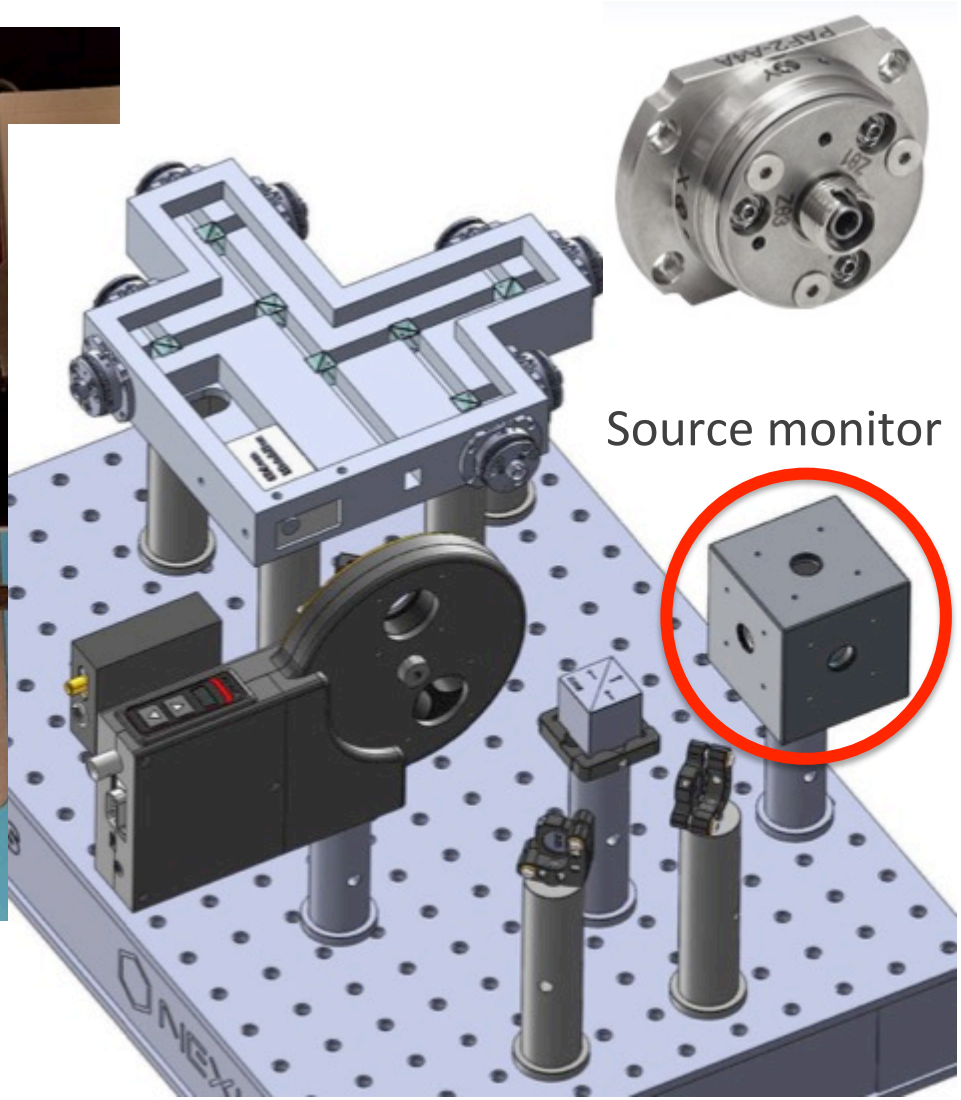
- 110 fibers
- Length (1600 ± 10) mm



One bundle has been tested (over 21)
→ **TENDER DONE**

Primary distribution system assembled at Sidet HUT





- New lens
- New cube splitter
- Room for a spare laser

Laser: Secondary Light distribution system

ThorLab-IS200 Sphere

- 1 input, 4 output ports
- 3 Bundles of fibers with SMA connector in the port and final ferrule needle on each fiber.

One sphere has been purchased (over eight)

MM 200 μm fiber:

- NA = 0.22 → Silica/Fluorine-Doped Silica cladding (FIP Optical Fiber from Molex)

RadHard test on 80 krad

- Test with ^{60}Co: no effect detected
- Two 10 m long fibers has been purchased (over ten)

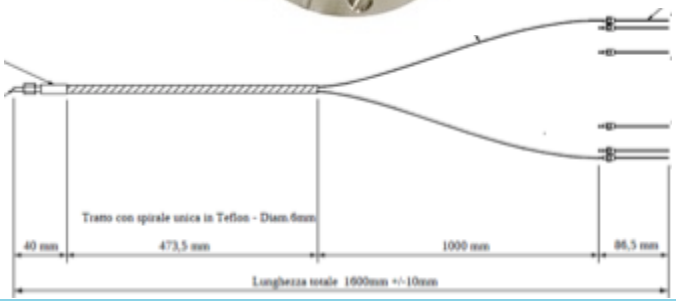
Vacuum optical feedthrough

- ConFlats 2.75"
- Feedthrough with Multifiber
- From Kurt J. Lesker

Mod. FIBM3−IR00−02−S−3 has been purchased (one over four)

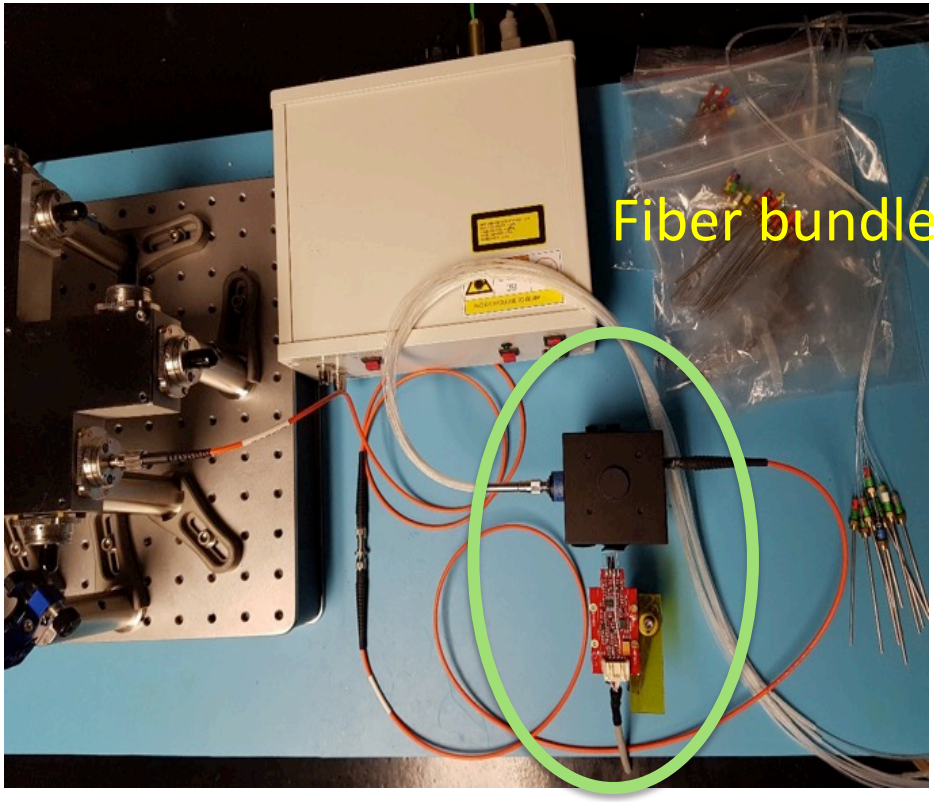
Fibers bundle

- 110 fibers
- Length 1600mm +/- 10mm

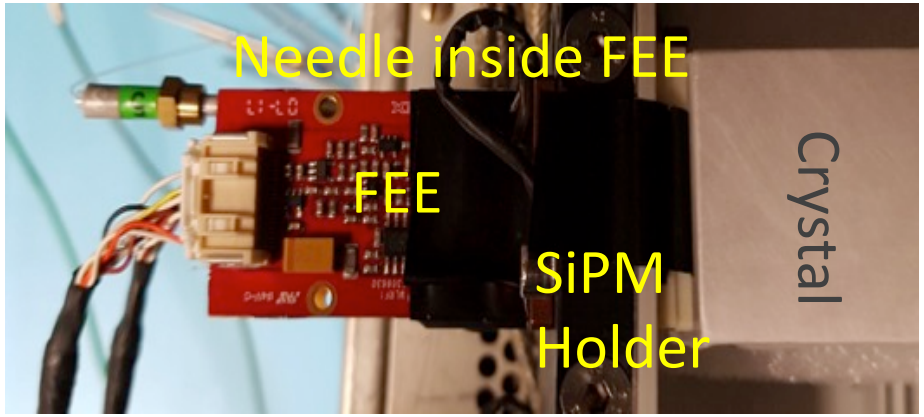


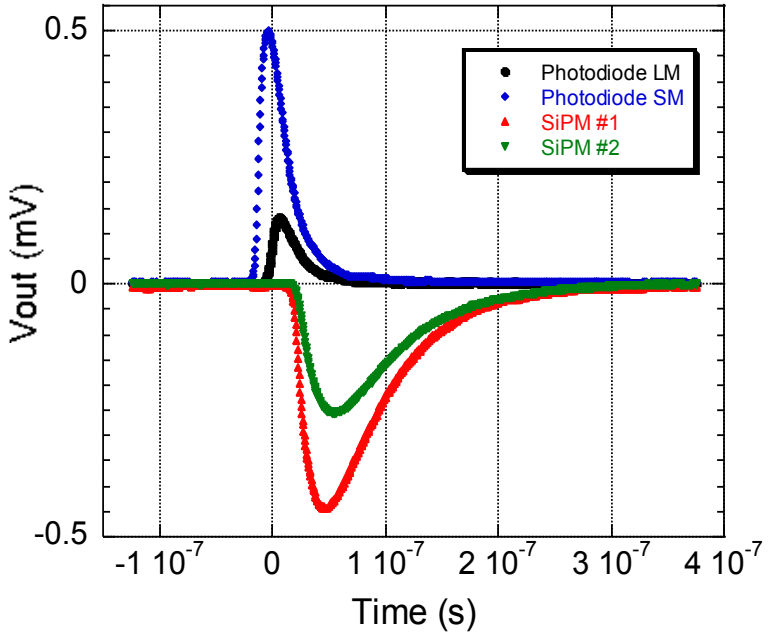
One bundle has been purchased (over 21)

Secondary Light distribution: test @ SIDET



Local monitor





To do list

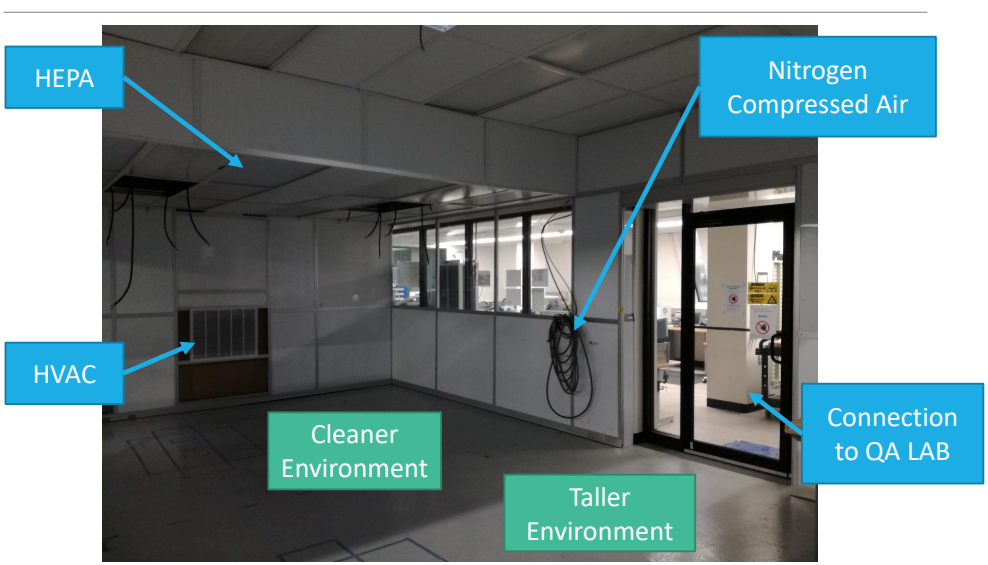
- Test the optical feedthrough and fibers bundle, **DONE in July**
- **Test the full optical system, from laser to SiPM, DONE in August**
- Procurement mod. S12698 from Hamamatsu for test: **July**
- LASER procured and tested with full chain→ **May-July**
- ^{60}Co irradiation and test of photodiodes → Calliope in the fall
- Test of new pre-amplifier boards → in the fall @ LNF

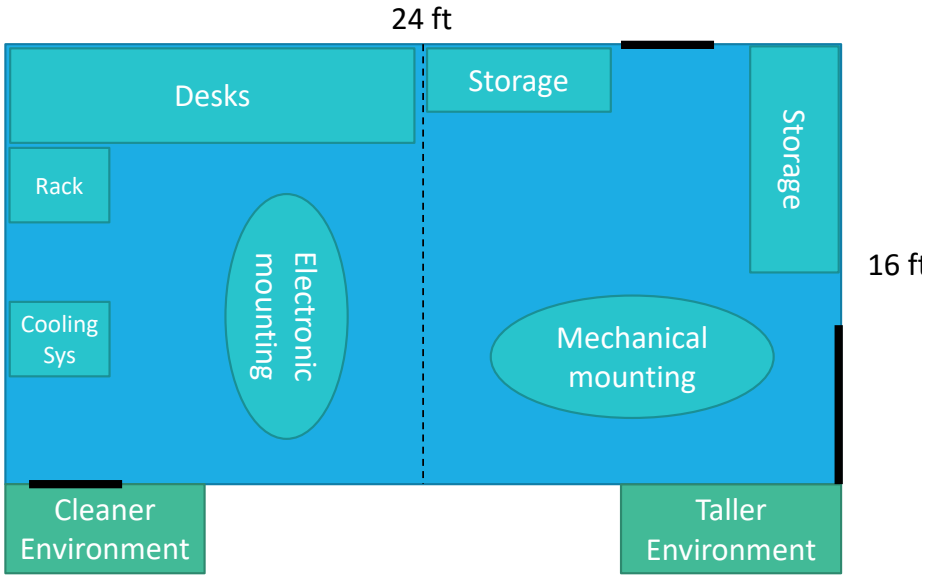
NEXT

- 20 photodiodes + Amp + cables + Peltier → from 2019 to 2020 @ LNF
- 3 optical feedthroughs (5000 Euro) @ PISA
- 10 launching fibers, short+long (20.000 Euro) @ PISA
- TDAQ integration (Dirac/MB, Pulse generator, sync) → 10 kEuro in 2020

Plans for assembly

Item 1: Complete the Assembly Area





- **Assembly room for installation completed**
- Main requirements are RH< 40%, stable temperature and clean area
- Logically divided in two working areas
  - → mechanical assembly area
  - → Sipm/Fee/Digital electronics mounting and test
- Infrastructures being prepared. Expect to complete for Sept 2019
  - → Assembly stand for disk, laser tracker targets, Outgassing chamber

Item 2: Production chain for SiPM gluing

- Procedure for gluing SiPMs on SiPM holder developed
- Mechanical frames for holding 25 SiPMs at once being prepared in Frascati
- Vacuum approved Glue selected **EP30AN**
- Scheduling first test with 25 SiPM holder prototypes and 50 SiPMs now
- Start of scheduled operation @ Sidet in October**: 3 Months process to complete**
- If everything proceeds as expected in December all “SIPM” units should be done

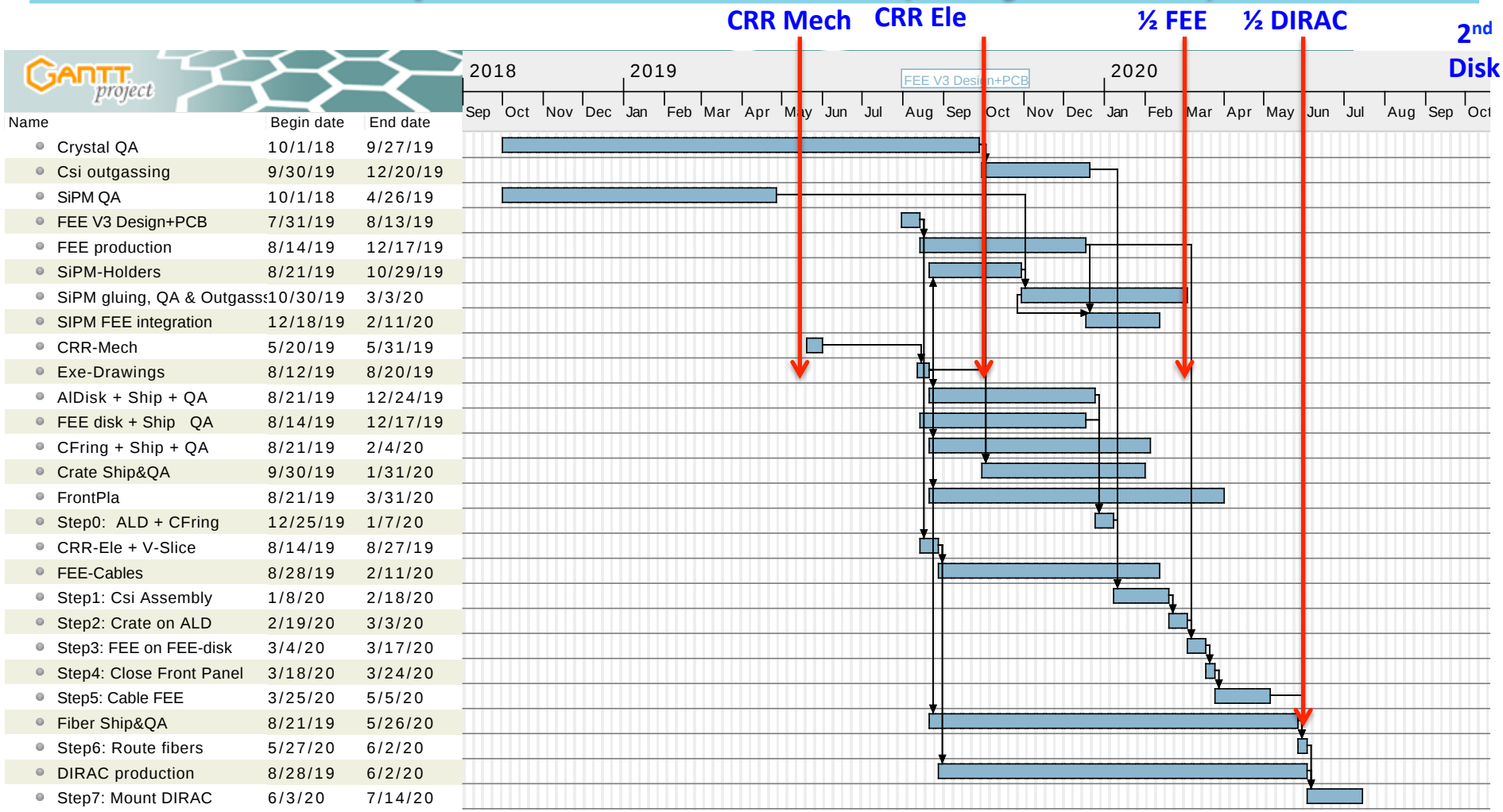
Prepare assembly/test document and … team

In preparation for the mechanics CRR and in view of the beginning of Assembly Operations
we have prepared a list of packages and an explanation of the tasks in DOCDB # 26076.
A first version of a summary and detailed GANTT can also be found there.

P1: Installation and survey of the Aluminum disk ;
P2: Installation and survey of the FEE Peek plate;
P3: Insertion and survey of CsI crystals;
P4: Insertion of the CF Inner Ring;
P5: Installation of the Source Front plate;
P6: Mounting of the FEE-crates;
P7: Connection and test of manifolds;
P8: Insertion of the SiPM/FEE holders on the FEE Peek plate;
P9: Routing of the FEE-MB Cable and single board test;
P10: Routing of Laser optical spheres and optical fibers;
P11: Installation of Primary Patch Panels and local services;
P12: Test and Installation of Digital boards
P13: Calorimeter test with Noise, Laser and Cosmics.

We will dedicate more time in the coming weeks to complete this document, circulate
It for corrections/suggestions/additions and preparing the team to execute it

Calorimeter update schedule (July 2019)



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

10 months of delay w.r.t. 2016 schedule.
Dominant contribution: Mech integration, FEE/DIRAC rad-hard

Maintain 4 months of Float to Cr. Path

Conclusions

- **SiPM production completed. High Quality .. Very small rejection**
- **CsI prod done @ O(85%):**
  SICCAS completed & High quality, St.Gobain problems persist

- **HW calibration systems are progressing well**
  → Neutron generator is arriving. Source mechanics integrated in calo structure
  → Laser system has selected all elements inside DS
- **Long TID campaign for FEE and WFD completed:**
  → **Rad Hard FEE V4 design completed. Prototypes in hands**
  → Rad Hard DIRAC V2 design completed → **Prototypes in September**
  → **Vertical Slice test completed up to DIRAC V1**

- **CRR of mechanical system completed**

- Main efforts are now: **(1) Organize the calorimeter assembly operations in SIDET and (2) start production of electronics**

ADDITIONAL MATERIAL

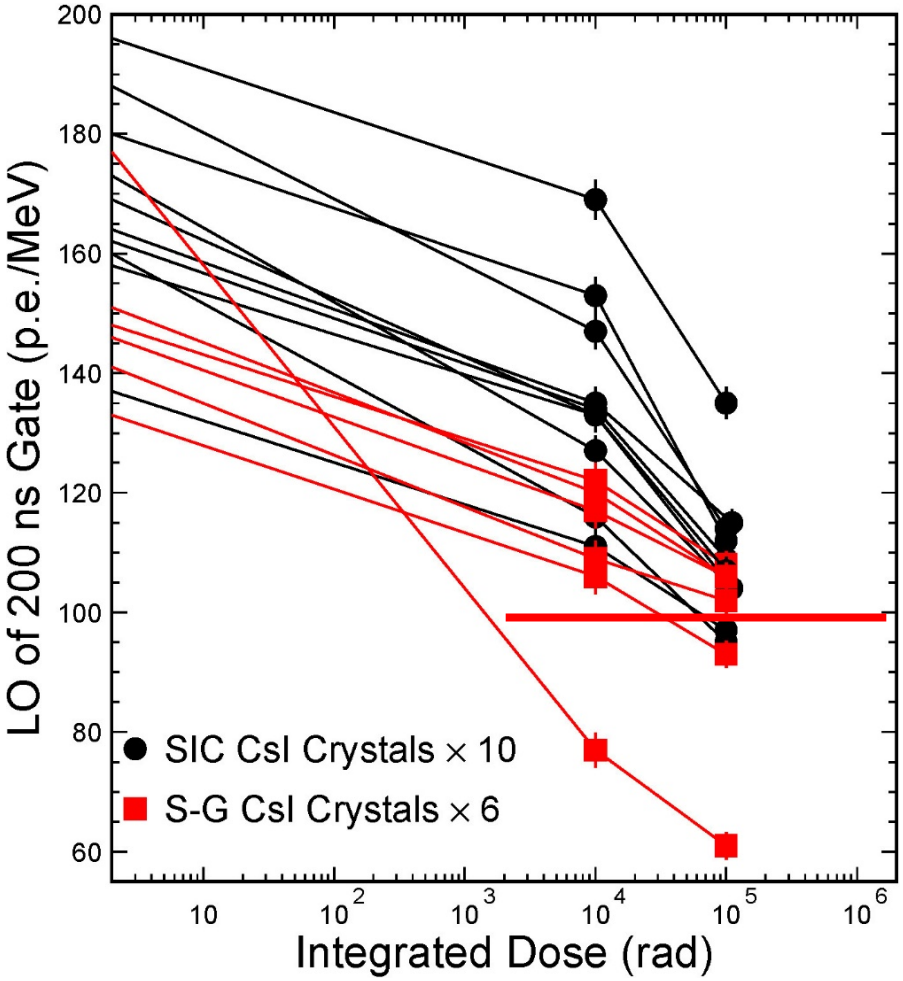
MILESTONES 2019

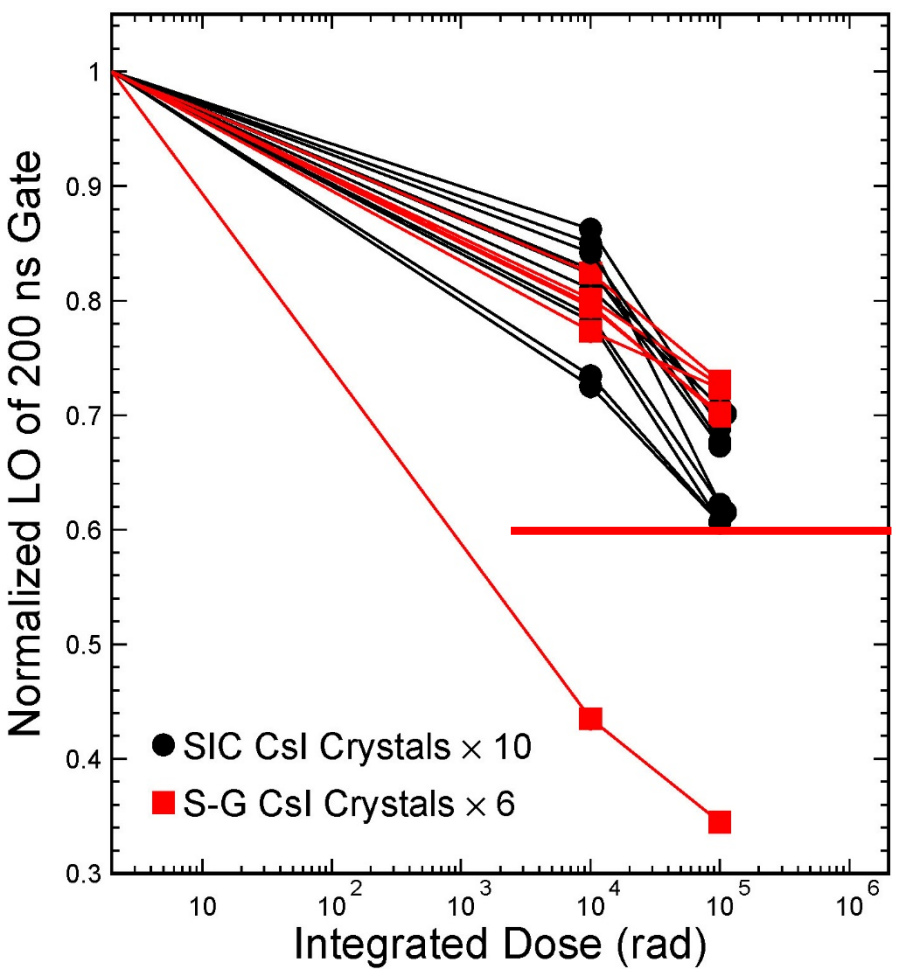
Descrizione	Data proposta	Percentuale guessed
Completamento Prod CsI+SiPM	31-07-2019	93%
Completamento Produzione FEE	01-11-2019 → 10-12-2019	50%
Assemblaggio primo disco	30-11-2019 → 25-12-2019	50%
Completamento Sistema distribuzione Laser	01-12-2019	80 % → 100%
Completamento prime schede V3 MB + V2 DIRAC	01-12-2019	100%

MILESTONES 2020

Descrizione	Data proposta
Completamento Costruzione e Test MB	31-07-2020
Completamento Costruzione e Test Dirac	31-10-2020
Completamento assemblaggio dei due dischi a SIDET	20-11-2020
Test Calorimetro con cosmici a SIDET	15-12-2020
Assemblaggio sistema Laser a SIDET	31-07-2020

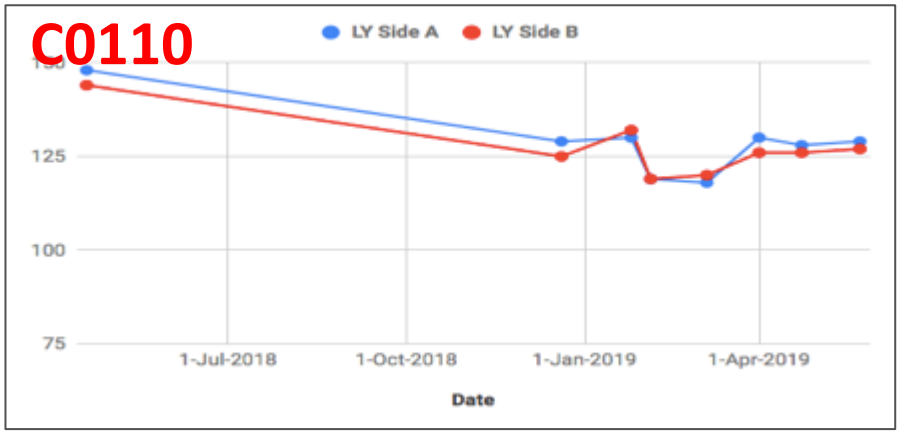
LY vs DOSE

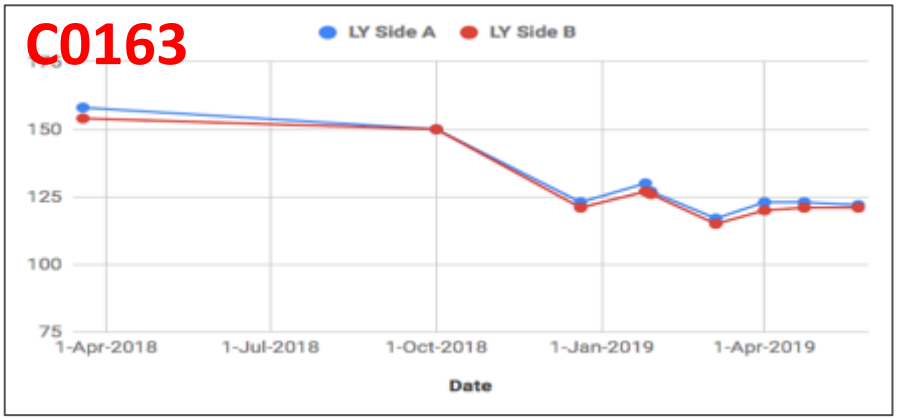

LO of 200 ns Gate (p.e./MeV)
Integrated Dose (rad)
SIC CsI Crystals × 10
S-G CsI Crystals × 6

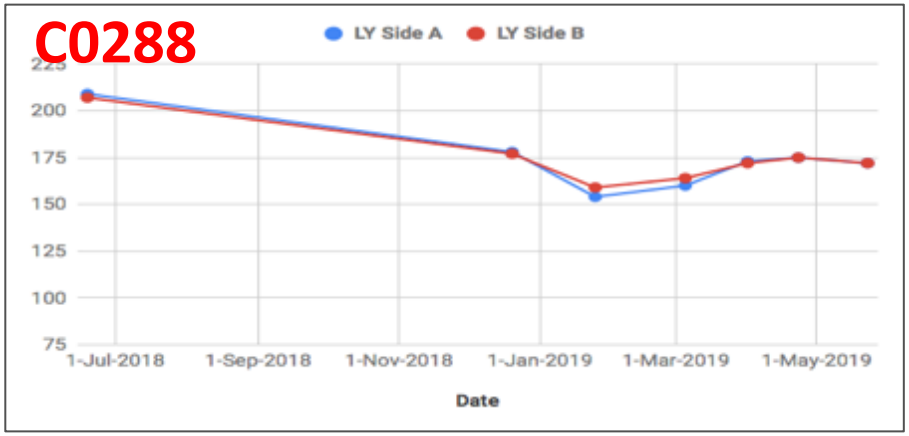

Normalized LO of 200 ns Gate
Integrated Dose (rad)
SIC CsI Crystals × 10
S-G CsI Crystals × 6

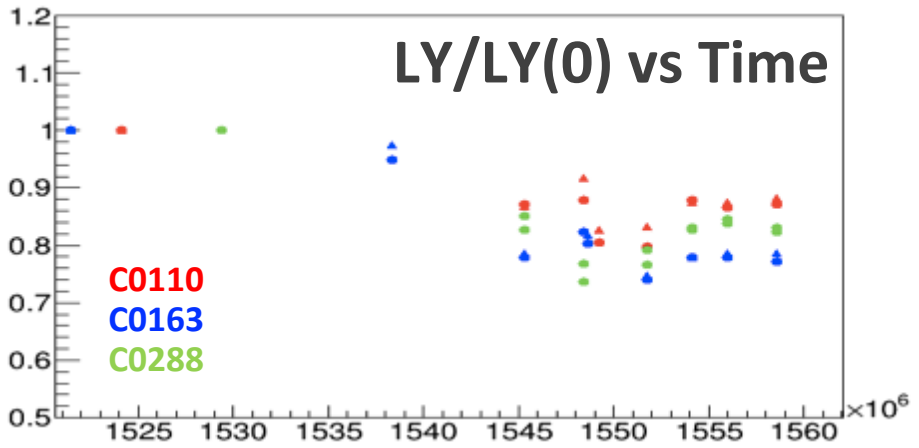
Light Yield stability

Measurement of LY for three crystals along the time







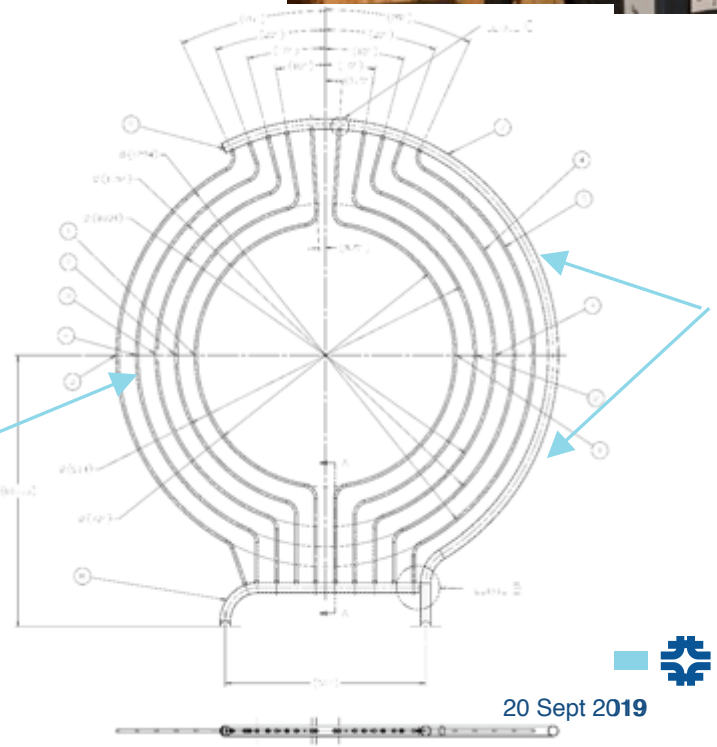


- Initial decrease of ~ 20% level after few months, more stable values in the coming months
- LY/LY(0) shows a similar behaviour for the 3 crystals → fluctuations looks related to env.

Source Calibration System Status

- **Neutron generator manufactured**
  - Vendor testing as DD
  - Tritium loading still to come
  - Preparing Mu2e pit and shielding for acceptance test

- **Plumbing plan inside DS mostly complete, ready to fabricate:**
  - Thin-wall tubing
  - Manifolds
  - Al-SS transition pieces



Answer to FEE recommendation:

→ The highest level recommendation of operation in vacuum has been deeply studied. These are our conclusions:

1. **Calorimeter operations between 10^{-2} to 10^{-4} Torr have a safety factor > 8**

2. Operation at Paschen minimum for the 300 um distance electrodes in the PCB have been calculated and tested:
   ➔ **We estimated Vbr > 600 V , we measured Vbr= 405.** This is a safety factor > 2.2
   ➔ This status is going to be just a transient. We do not need to work there.
   Procedure will be to turn-OFF HV anyhow when changing pressure.

3. **We have run 3 SiPM+FEE boards in vacuum at 10^{-2} Torr and 50 Torr.**
   ➔ No differences in the noise observed
   ➔ No corona spikes observed

4. SiPM+FEE boards were run also in the past showing no problems either in the considered operation regions or in proximity of the Paschen minimum