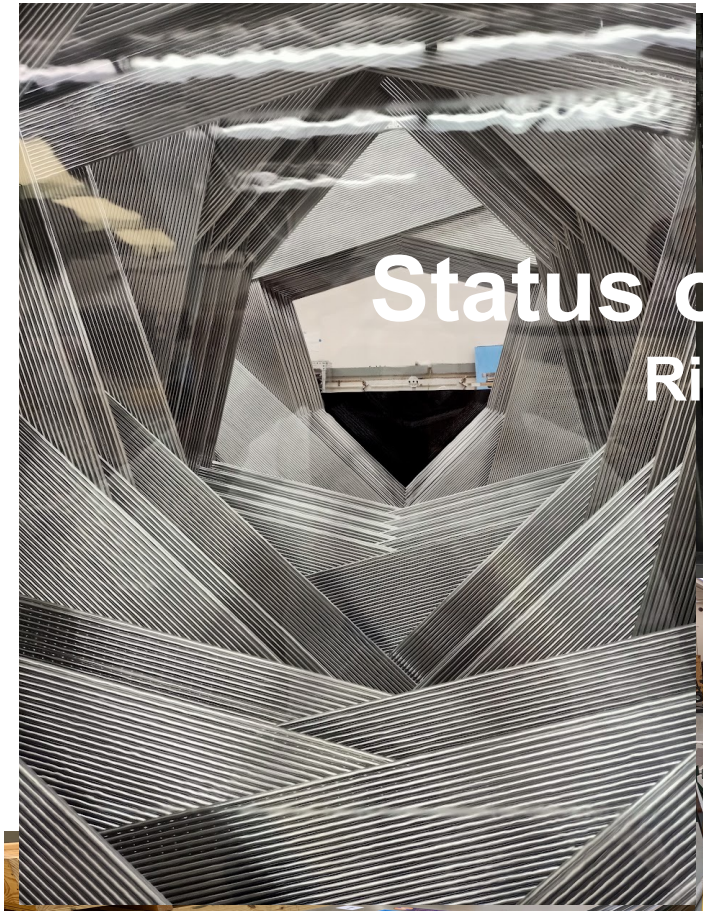
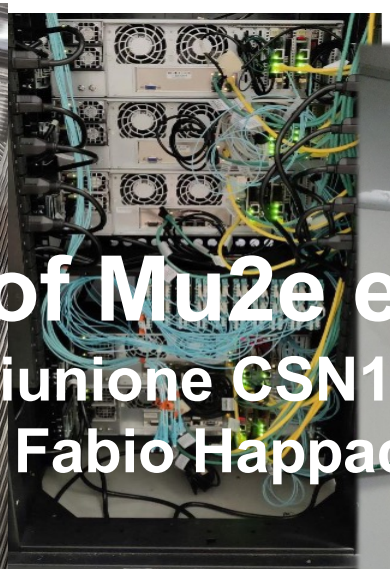
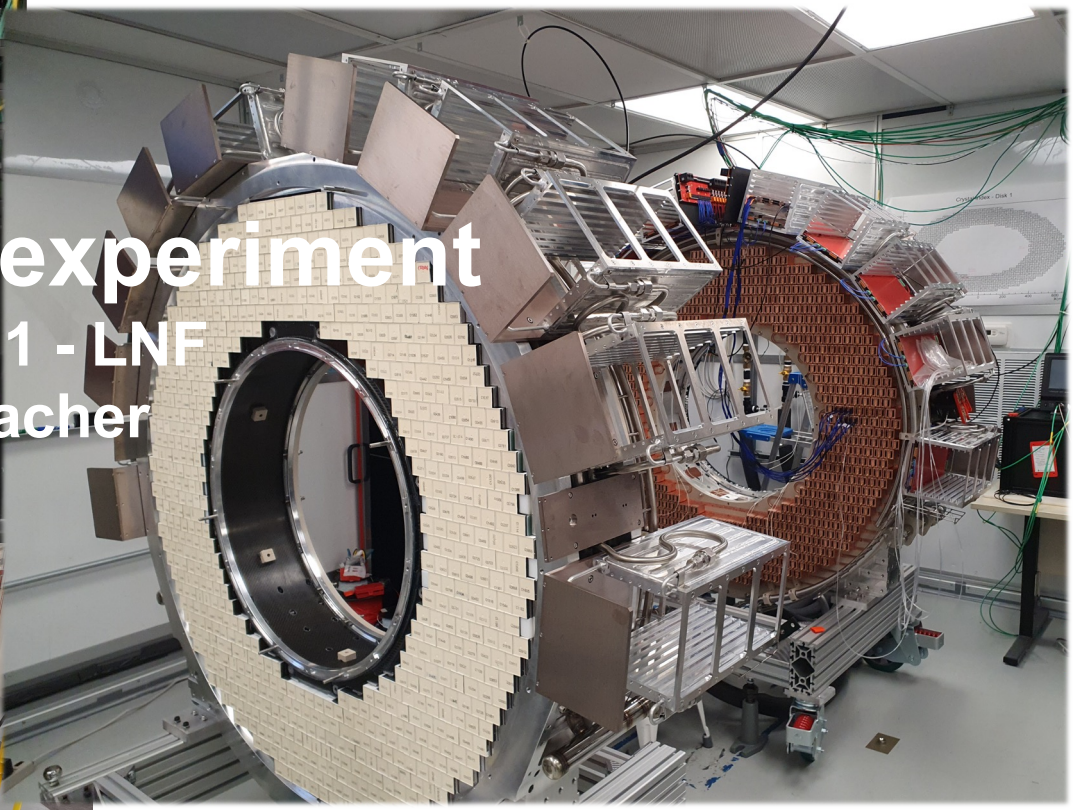
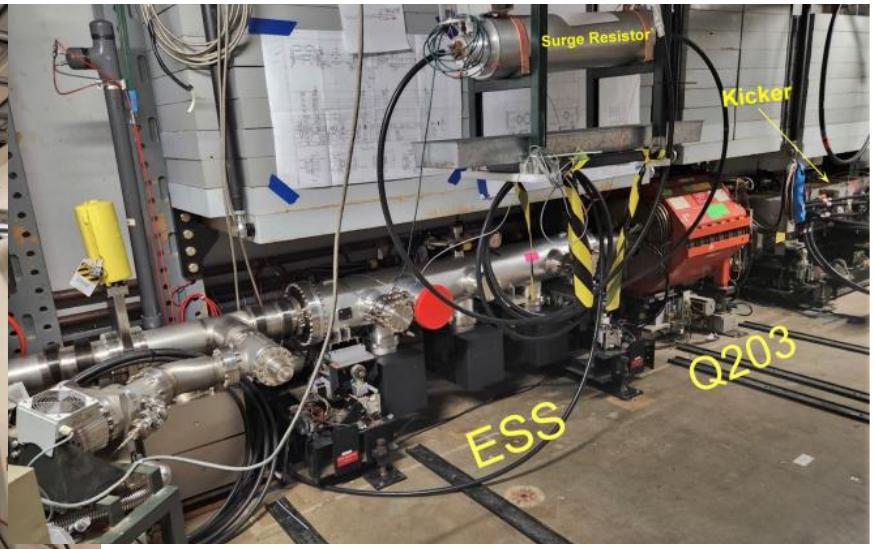






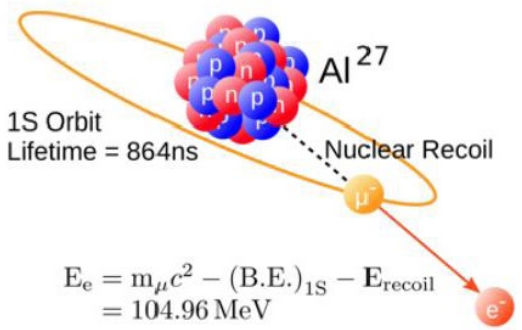
Status of Mu2e experiment

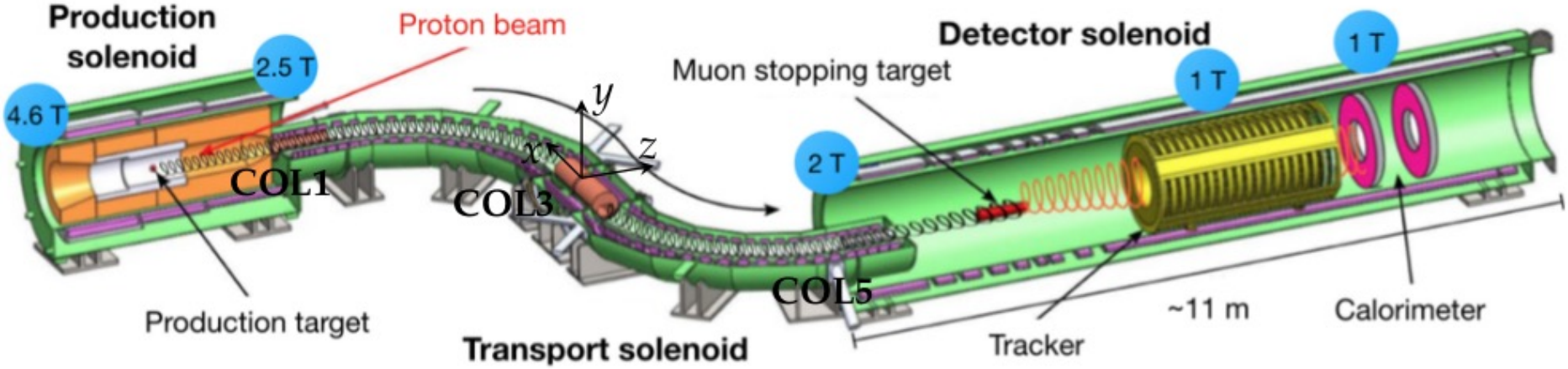
Riunione CSN1 - LNF
Fabio Happacher

The Mu2e Experiment at Fermilab

Mu2e searches for **Charged Lepton Flavor Violation (CLFV)** via the coherent conversion:

$$\mu^- + Al \rightarrow e^- + Al$$





$$R_{\mu e} = \frac{\Gamma(\mu^- + N \rightarrow e^- + N)}{\Gamma(\mu^- + N \rightarrow \text{all captures})}$$

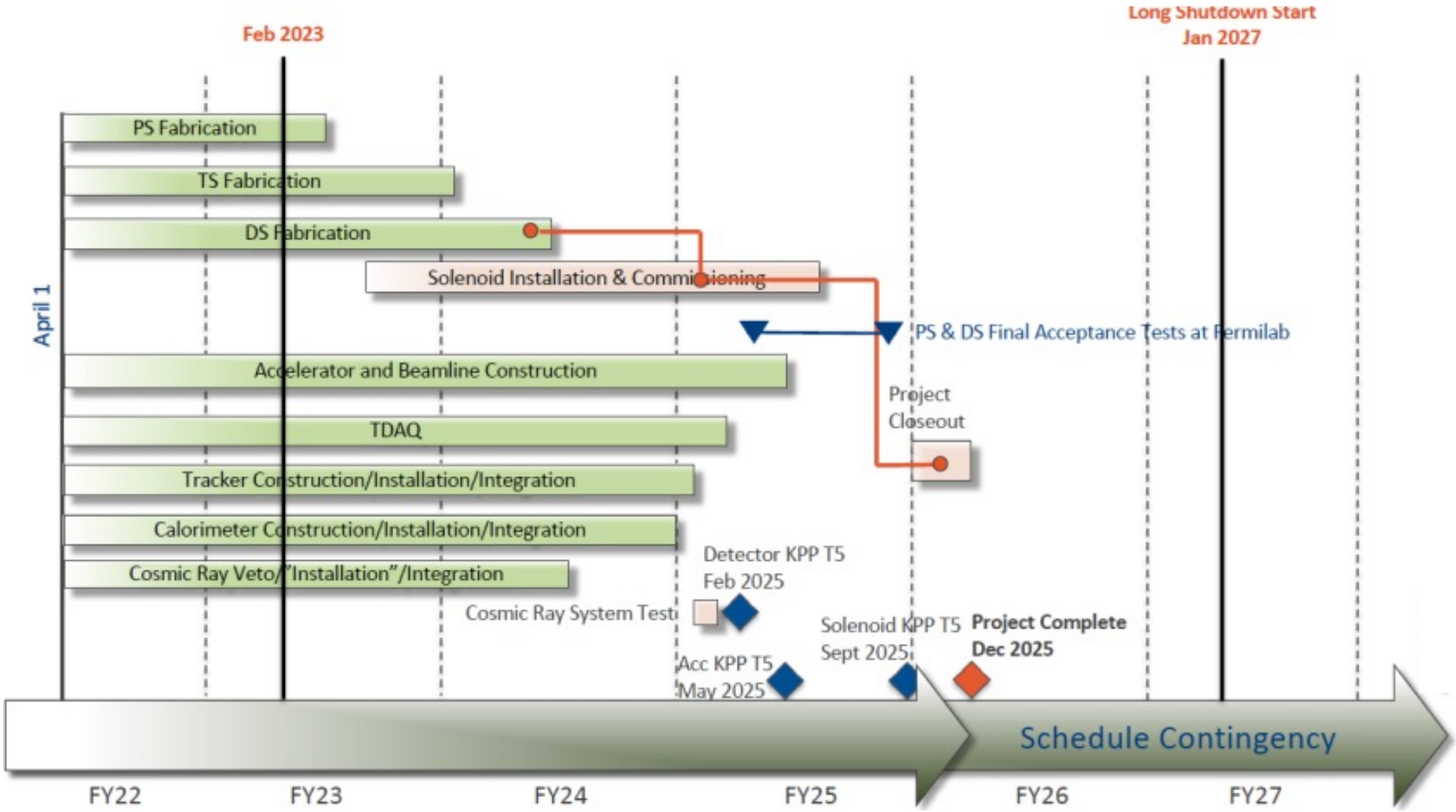
Current 90% CL limit:

$R_{\mu e} < 7 \cdot 10^{-13}$ SINDRUM II
Bertl et al.
Eur.Phys.J.,C47,337
(2006)

Mu2e goal: 5σ discovery or x10^4 limit improvement

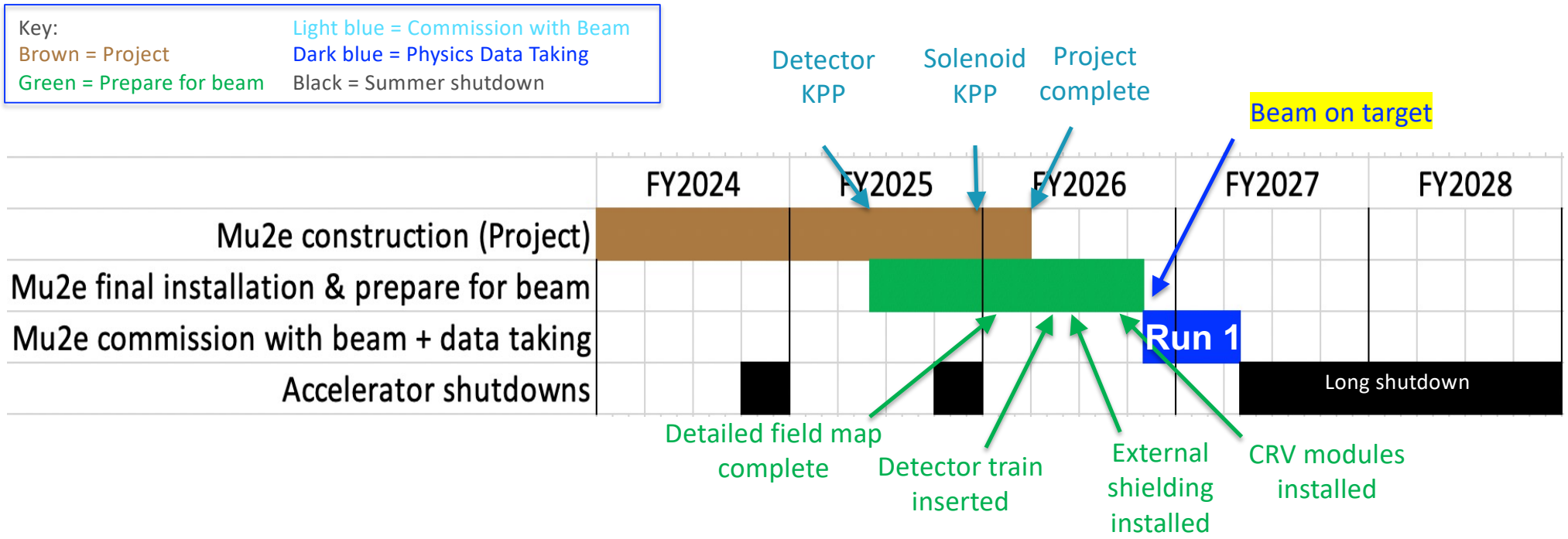
News from Mu2e

- **Stefano Miscetti** is the new Mu2e co-**spoke person**
- After 2022 rebaseline a new schedule has been released in Feb '23:



2024 will be devoted to detector installation in the Mu2e building!

Mu2e Run Plan



Run 1 goal: get 3×10^{19} POT to improve by $\times 10^3$ Sindrum II sensitivity*

Run 2 goal: get 3×10^{20} POT to add an additional factor 10 on sensitivity
(longer run, higher average beam intensity, better shielding and CRV, ...)

* *"Mu2e Run I Sensitivity Projections for the Neutrinoless mu- --> e- Conversion Search in Aluminum", Universe 9 (2023) 1, 54 (38 pages) http://arxiv.org/abs/2210.11380*

Some Pictures from Mu2e building

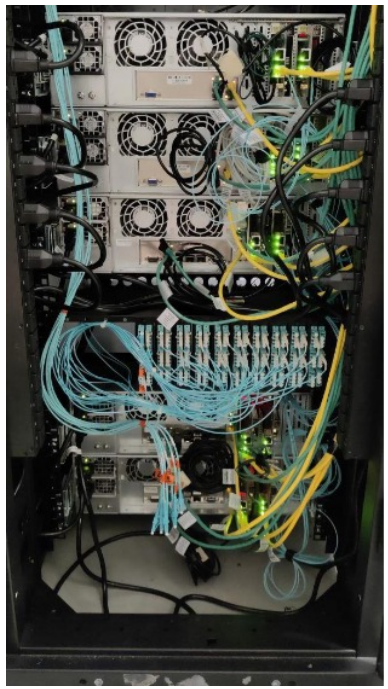
Cryogenic services*

Solenoids power supply

Rails and cable trails

Vacuum pumps

DAQ

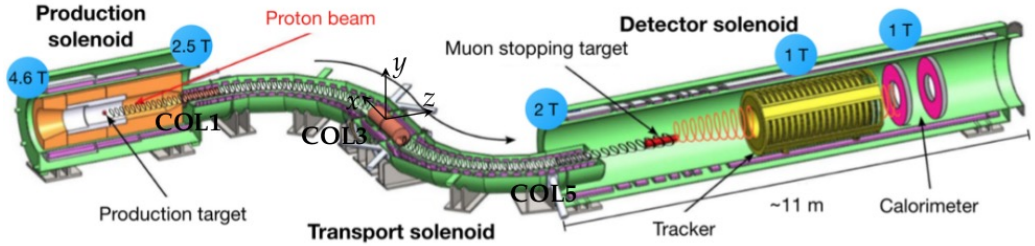


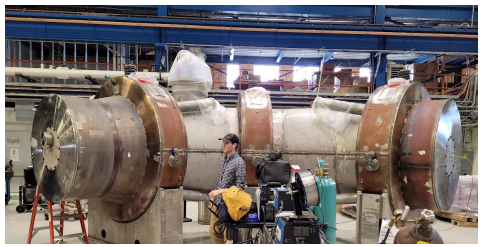
Concrete blocks

Extinction monitor

* First Liquid He produced and stored in Mu2e building in Aug

Solenoids



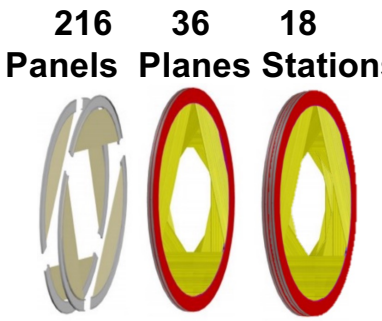


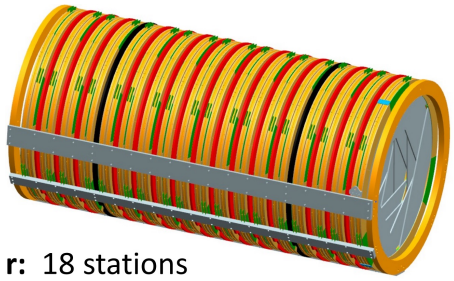
Production Solenoid:
3/3 coils completed
Cold mass assembled and integrated with the Inner thermal shielding
Rough B field map ok
TODO:Outer shield integration and sealing

Transport Solenoid (Nov '23):
Upper half completed, lower half almost Ready. Installation end of 2023

Detector Solenoid (on critical path):
11/11 coils built
7/11 coils tested
TODO: - cold mass assembling
- preliminary field map
- final sealing

Tracker status





216/216 panels completed

23/36 planes completed

Long term leakage test ongoing

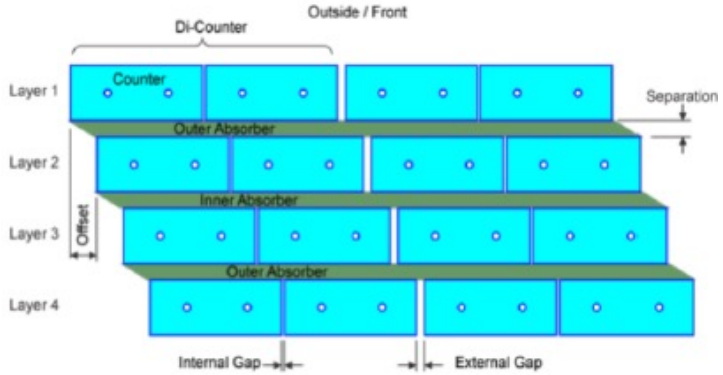
TODO: - FEE test and assembling
- stations sealing

Expected completion: summer 2024

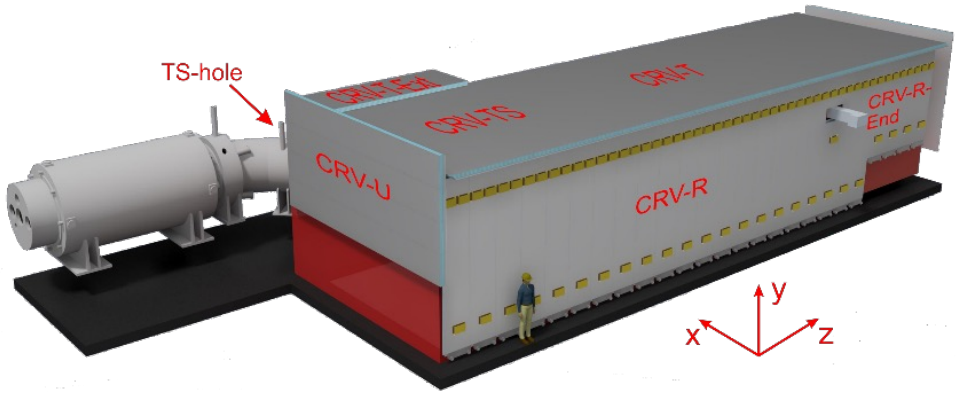
Installation in Mu2e experimental hall:

fall 2024

Cosmic Ray Veto Status



4 scintillator layers with WLS
Efficiency: 99.99%



Coverage: DS and Upper TS

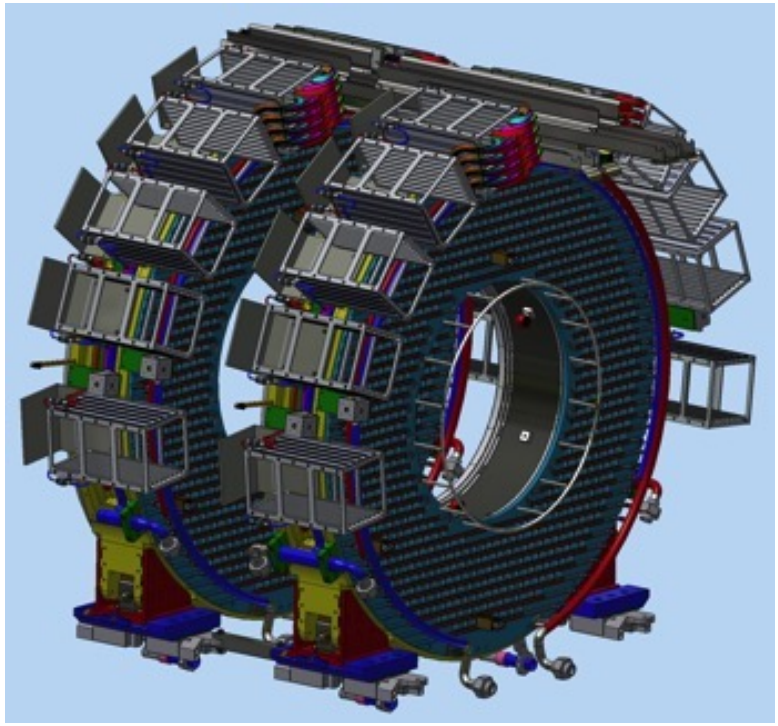
83/83 modules ready

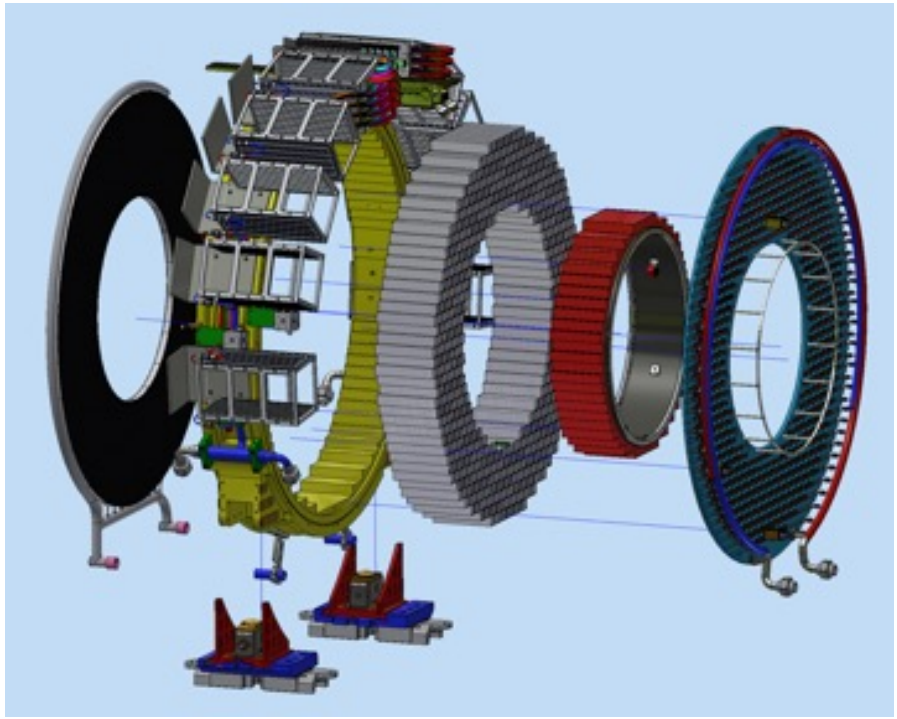
Cosmic ray stand to measure the aging rate

Small delays on electronics procurement (FPGA)

Installation in Mu2e building: 2025 (after concrete blocks placement)

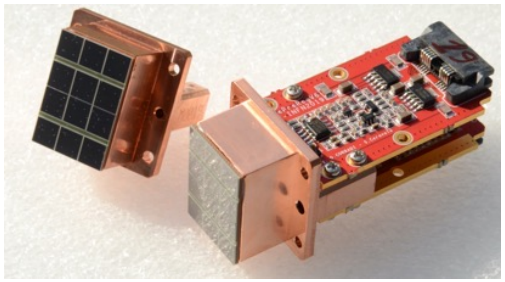
The Mu2e calorimeter



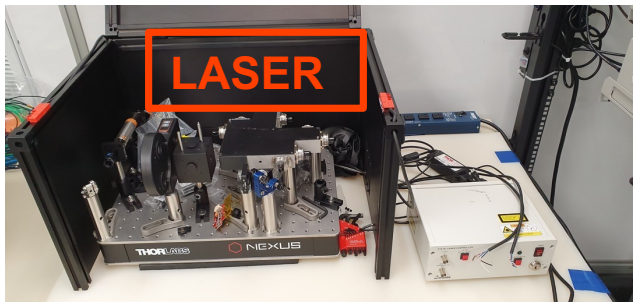


2 disks each consisting of
- 674 pure CsI crystals
- 1248 SiPMs+FEE boards

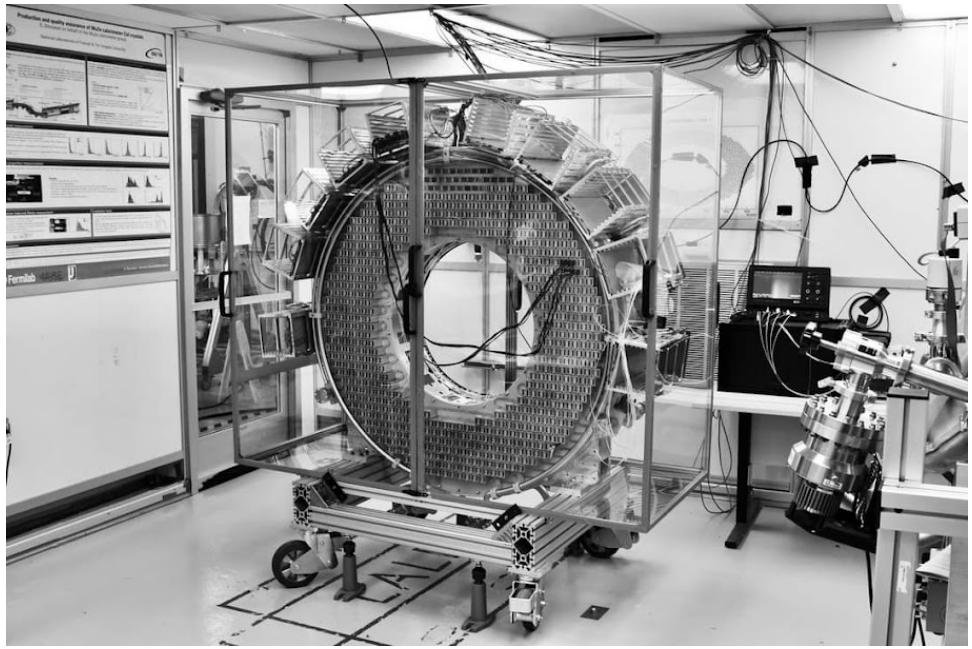
6 MeV Calibration source | **External crystals ring** | **Inner ring** | **Back plane with SiPM housing and cooling lines**

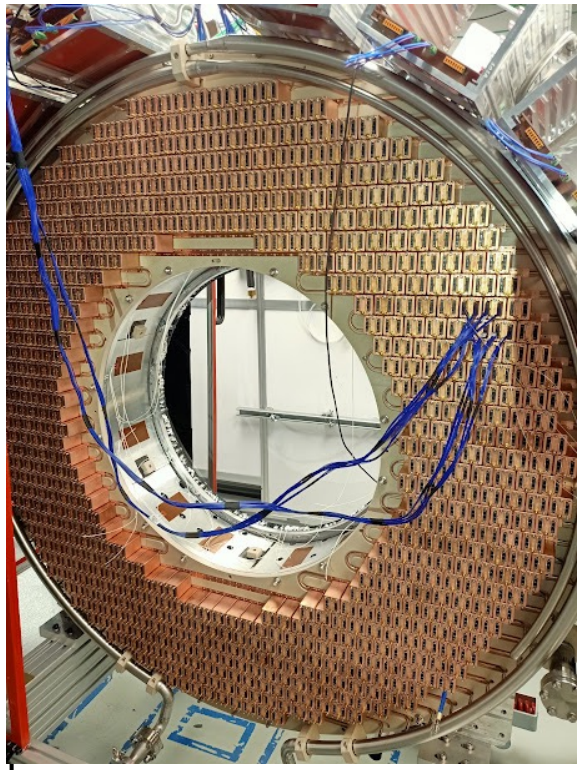


Hole for laser calibration



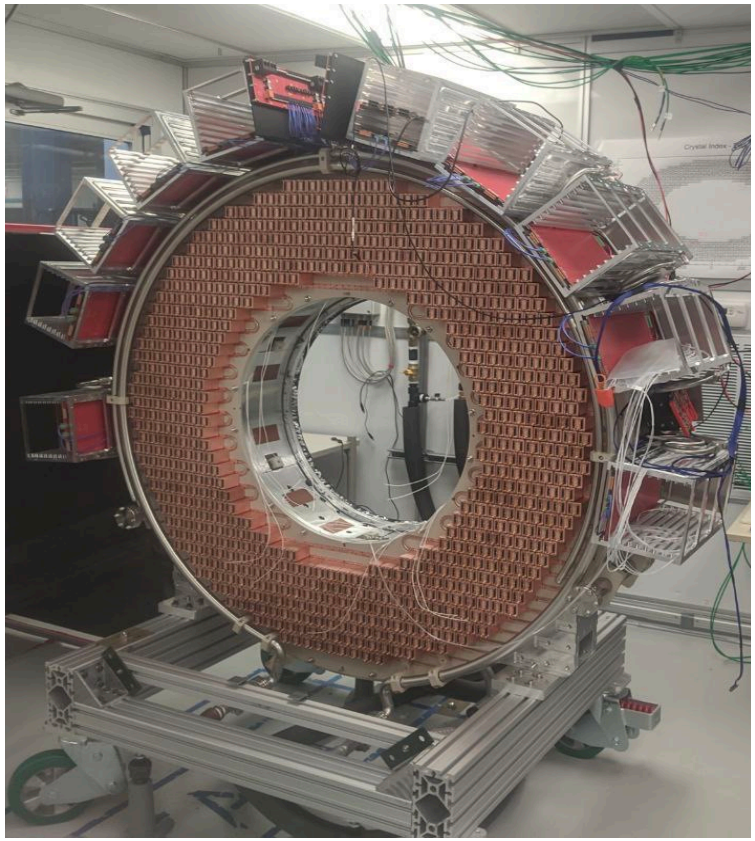
Status and plans: first disk assembled





- All the components to assemble the disks to FNAL been shipped
- Assembling and testing ReadOutUnits (ROU) at LNF and shipping them to FNAL
- ROU's installed on first disk FEE plate after the crystal stack completed and crates mounted
- Mezzanine boards being produced and will be shipped to FNAL
- A long face of cabling and test in the first quarters 2023 + DIRAC installation and TDAQ runs
- By end of 2023 both disks have to be ready to be transferred to Mu2E hall for commissioning
- Many minor mechanical details, pipe and cable tray/panel supports still to be built
- SW development for commissioning is well ongoing + CRT and Laser integration

Calorimeter Disk 1 status



‘Disk 1’ status:

- mechanical parts assembled

- Crystals and SiPMs+FEE readout units installed

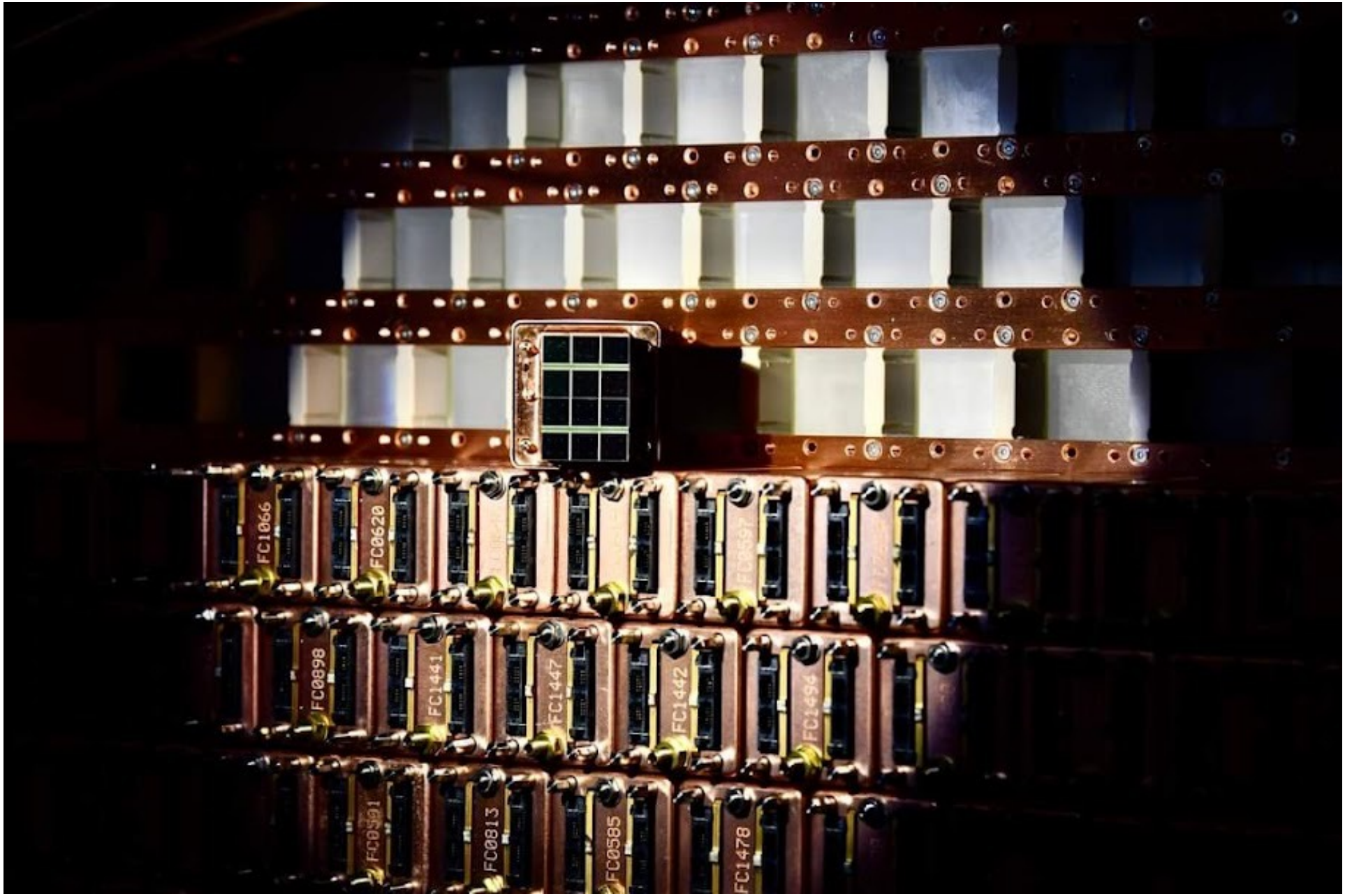
- digital electronic crates installed

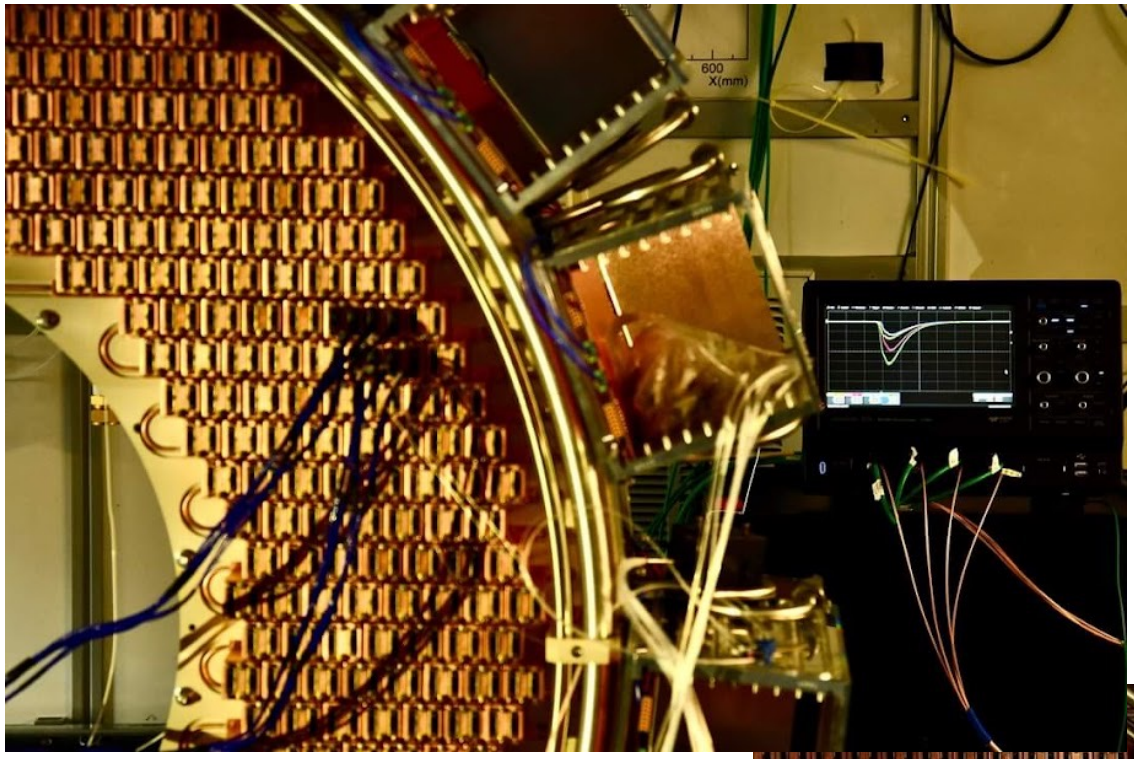
- quick leak test of cooling system performed

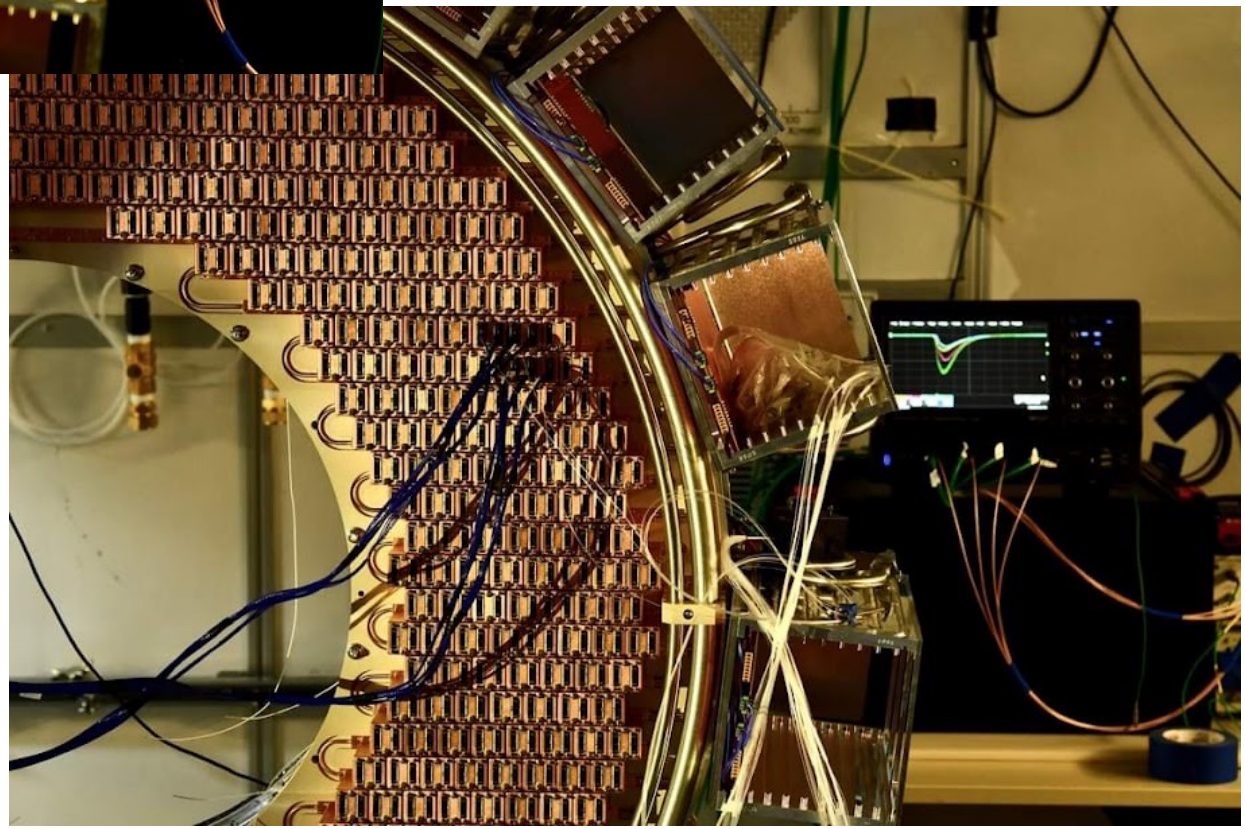
- all readout units tested with laser pulses

TODO (disk 1):

- digital electronics installation
- TRAD monitors installation
- cabling
- DAQ test
- Long term cooling system test
- complete laser calibration system (diffusive spheres and fibers)

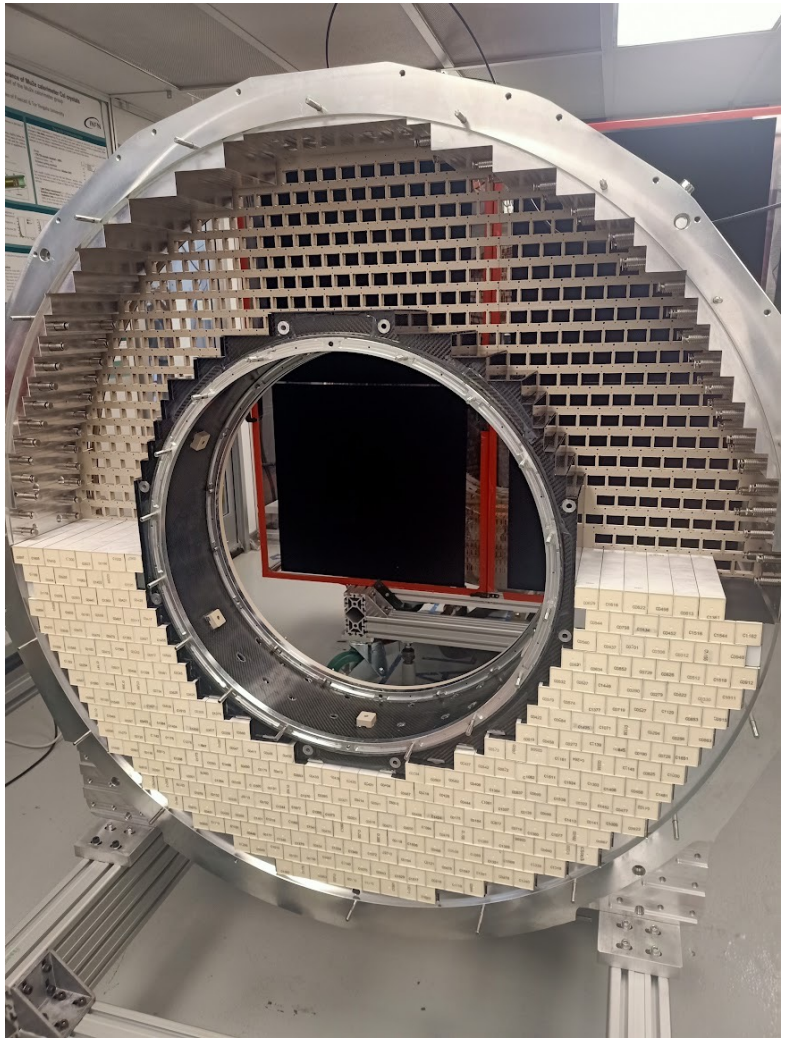

FC1066
FC0620
FC0898
FC1441
FC1447
FC1442
FC1494
FC0585
FC1478
FC0813



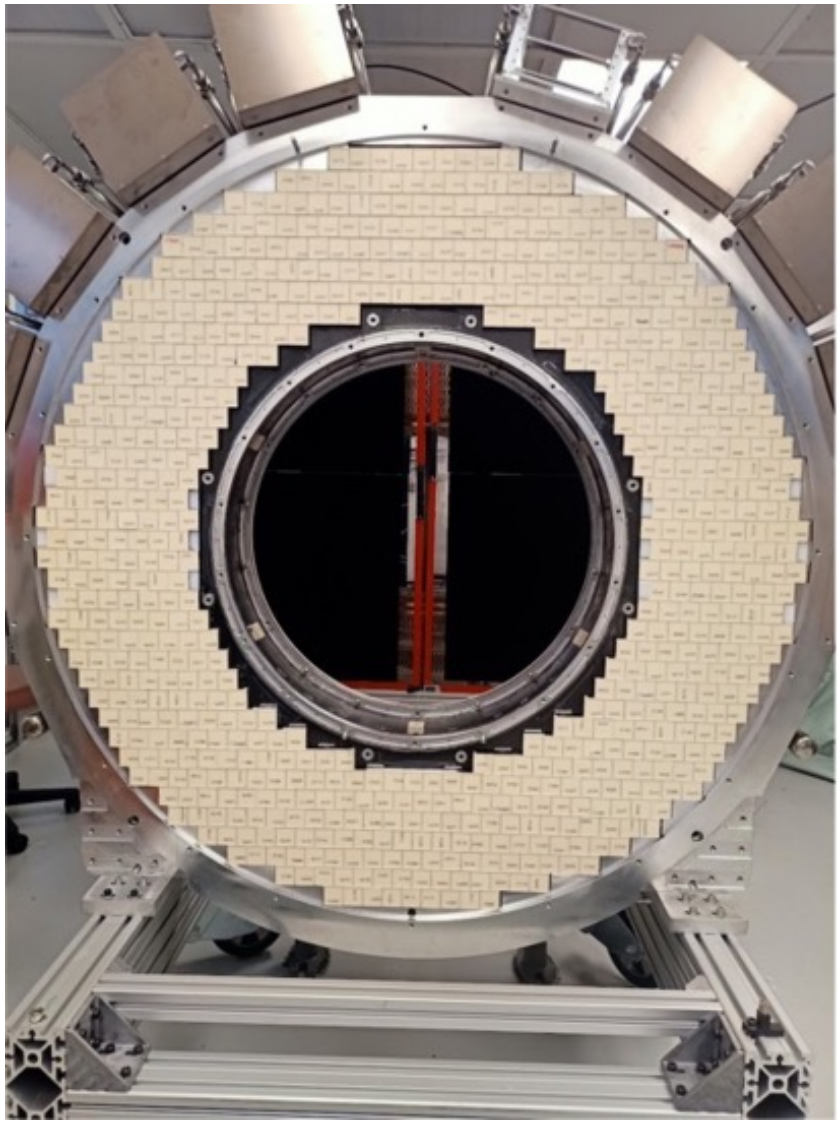


20/09/23

Crystals stacking for 2nd disk



Calorimeter Disk 0 status



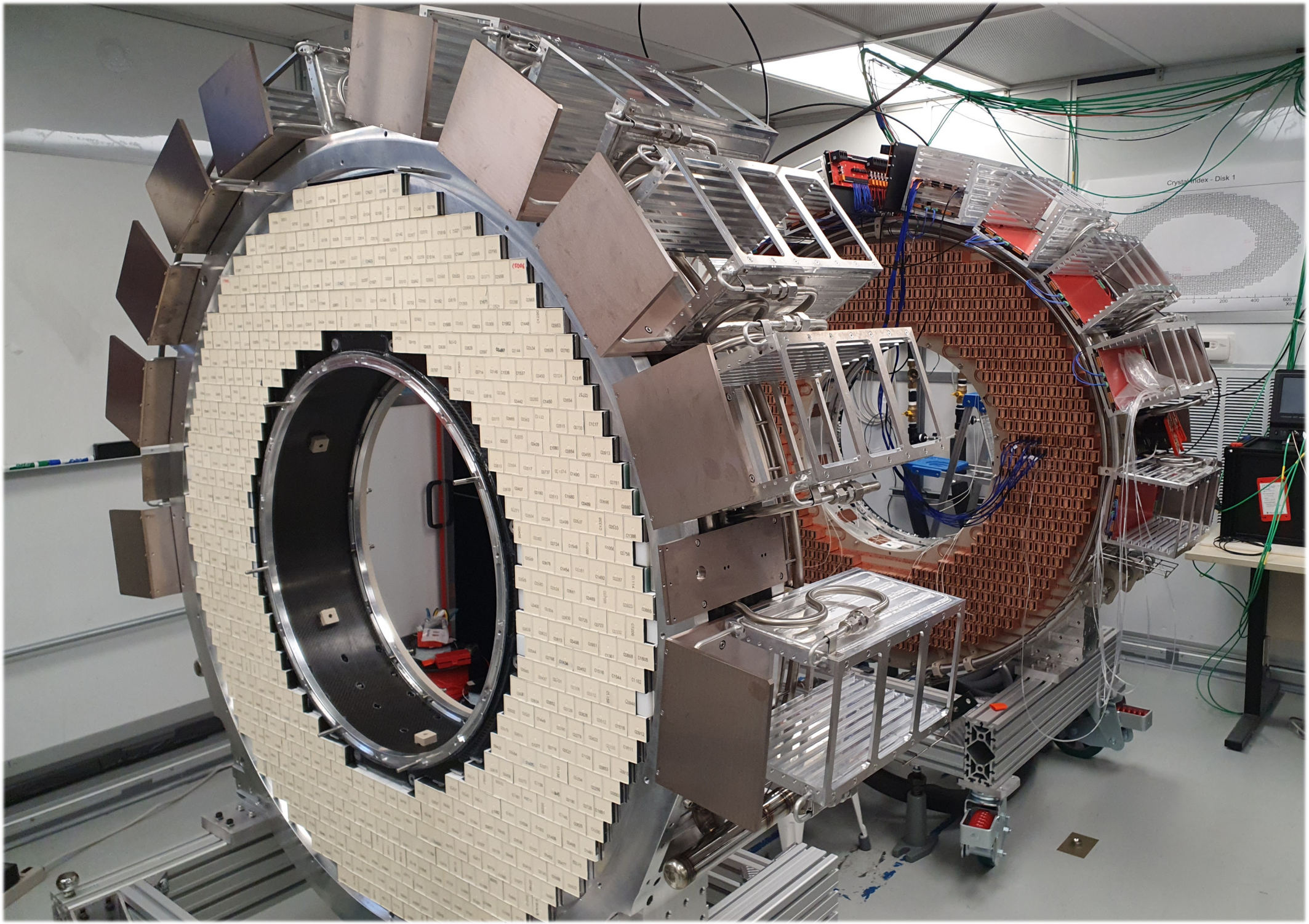
‘Disk 0’ status:

- mechanical parts assembled
- Crystals installed
- digital electronic crates installed

TODO (disk 0):
- install and test readout units
- install and test digital electronics
- install TRAD monitors
- cabling from FEE to crate
- DAQ test
- Long term cooling system test
- complete laser calibration system (diffusive spheres and fibers)

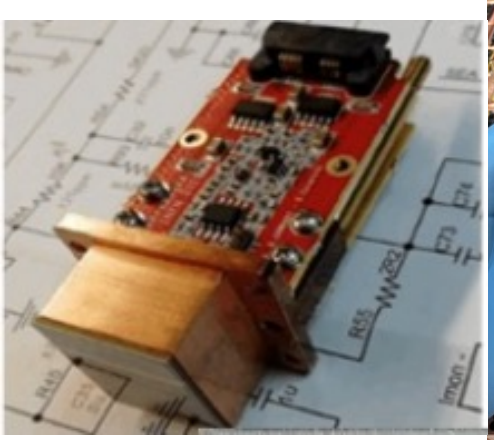
Installation in Mu2e building (both disks):

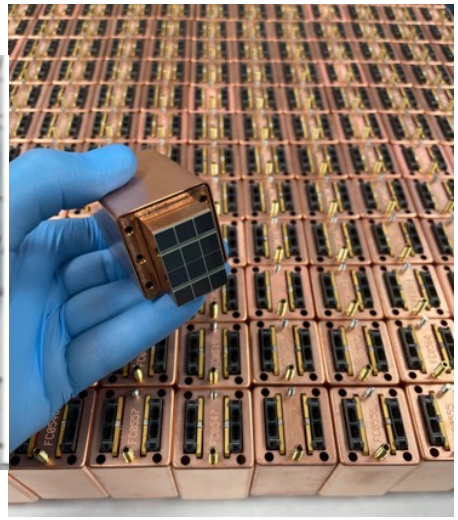
Autumn 2024


Crystal Index - Disk 1

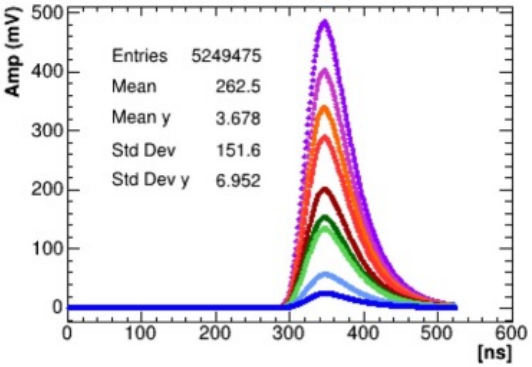
Status of production of basic components

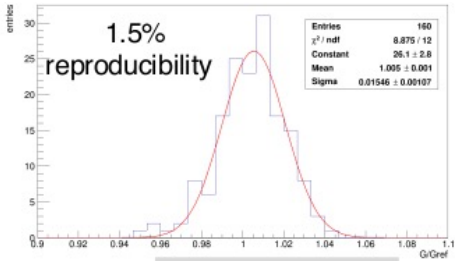
- 1500 crystals produced and tested
- (best 1348 selected)
- 4000 SiPMs produced and tested
- 3000 SiPM glued to 1500 SiPM holders
- 3300 FEE boards produced
- 400 FEE boards lost due to Russia-Ukraine conflict



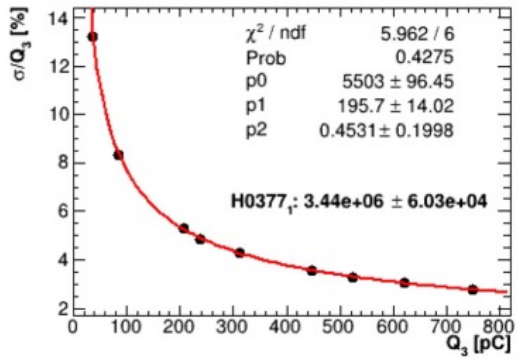


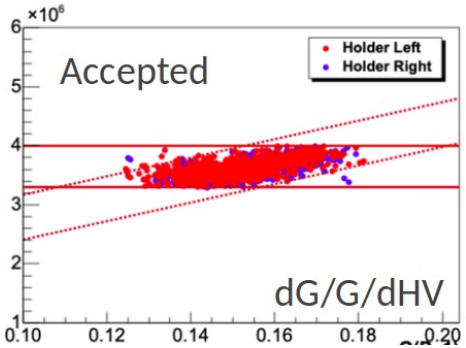
ROU quality assurance





$3.3 \times 10^6 < G_{L,R} < 4 \times 10^6$





- 1188/1226 ROUs (2 SiPM+2FEE+Faraday cage) passed QA out of a total need of 1348
- remaining 160 ROUs available by Sept 2023

ROU assembly and FEE new production

- Total # of ROU at FNAL now 1180 → 168 missing to close 2nd Disk
- FEE production progressing well.
  - → 60 have been already produced and are under calibration on LNF bench-test
    - → Additional 400 parts delivered at LNF + other 340 for September
    - → Successful BURNIN – 6 hours , 60 C – HV on for all pieces

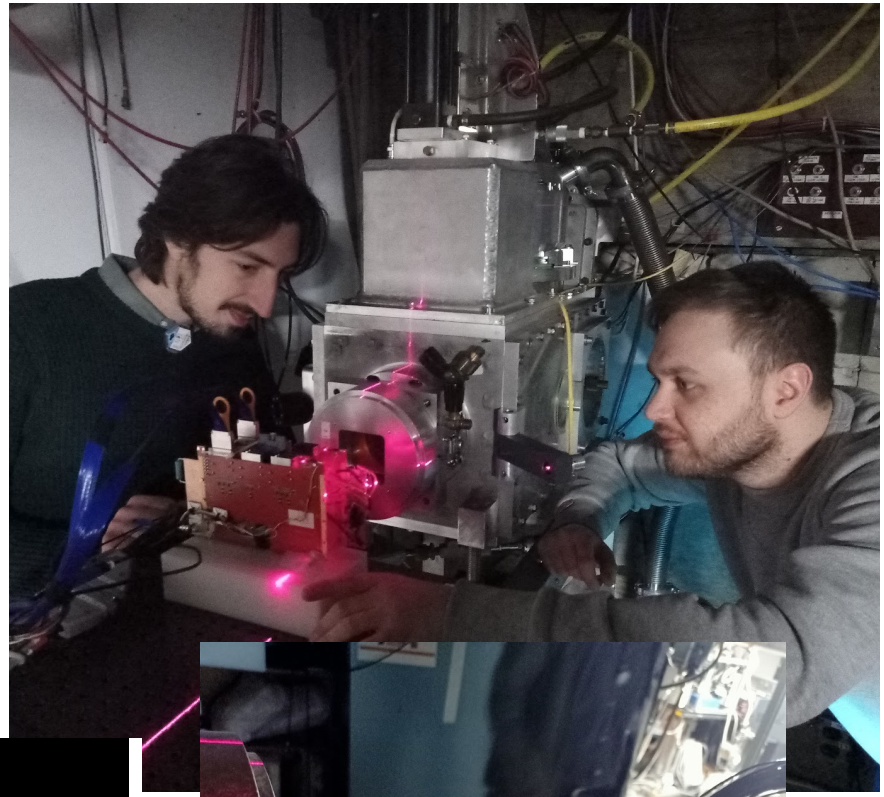
- FEE Calibration started and assemby of new ROU planned at LNF

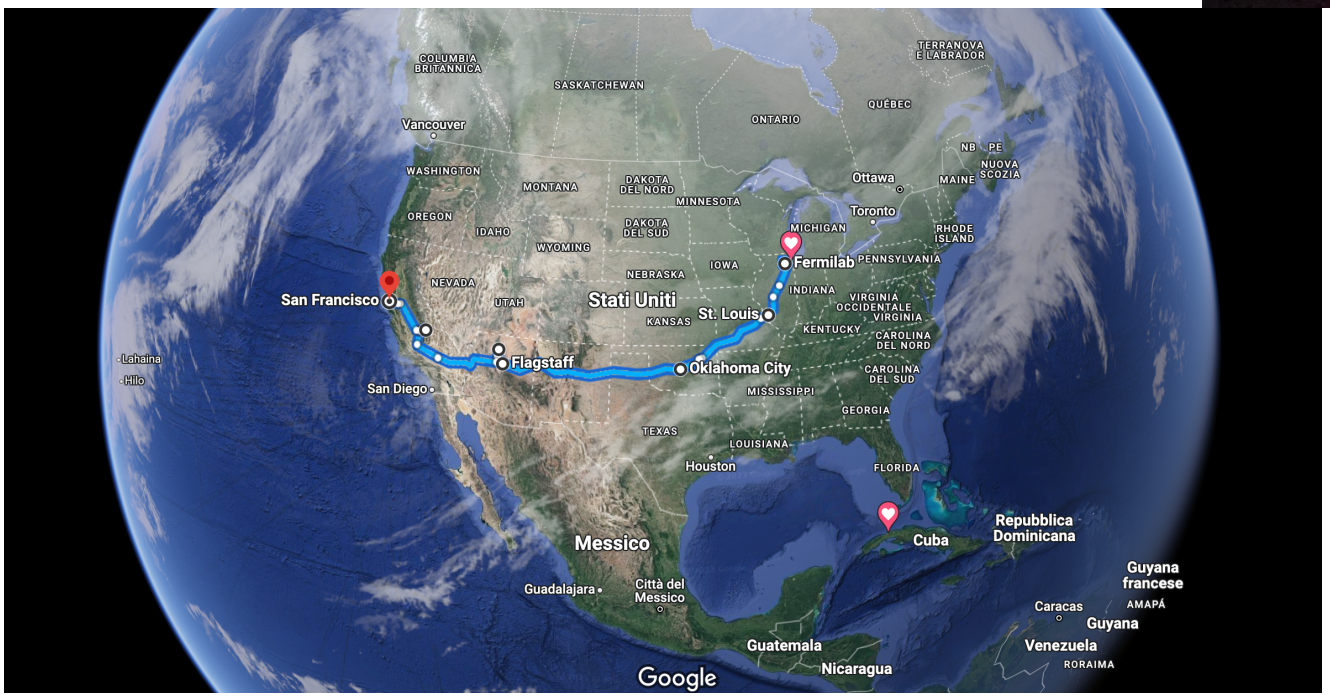
THANKS to CSN1 Referees and CSN1 committee for your support

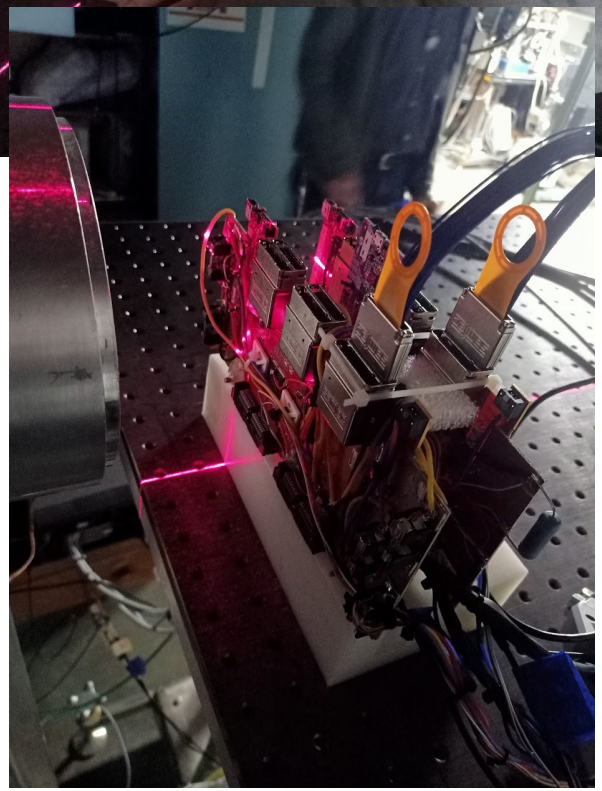
MZB: extra costs

Produzione MZB iniziata Maggio 2022
-170 naked PCB (senza componenti prodotte) + 20 boards prodotte a luglio 2022 come pre-serie testate con Burn-IN OK
-Nel frattempo test di protoni a Davis (CA)
-Fermata produzione.
-Eseguiti tests, disegnato circuito di protezione, nuovo layout

Extra cost consiste in:
- Rifare tutte le 170 PCB senza componenti con nuovo layout
-Aggiungere I componenti per circuito di protezione
-Rifare 20 schede ex novo
-Totale 23 kEuro (Preventivo arrivato)



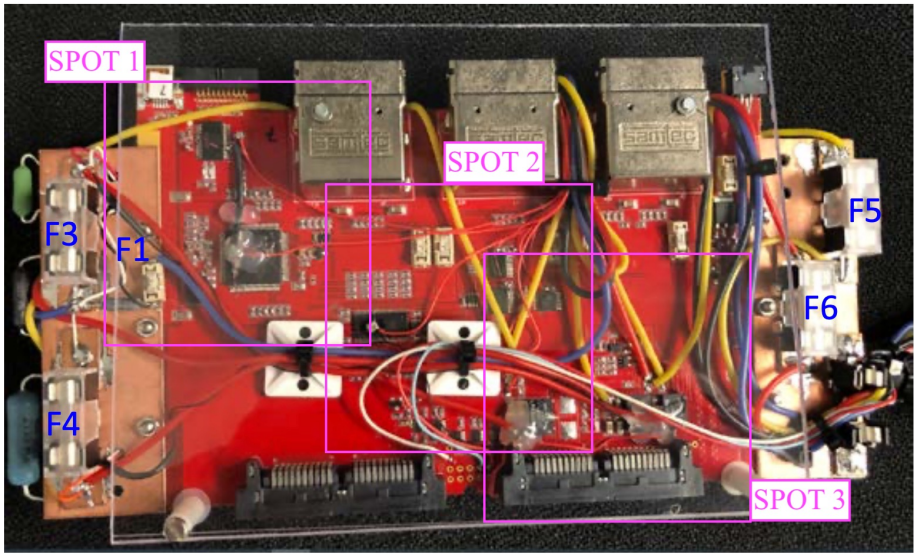




MZB: proton test and development of MZB SEL protected

3 MB with new ARM processor tested as the DIRAC in 3 different beams:

Warrenville proton Center, UC Davis, CNAO
Flux up to 3-5 E^9 p/cc using a 60 or 200 proton beam.

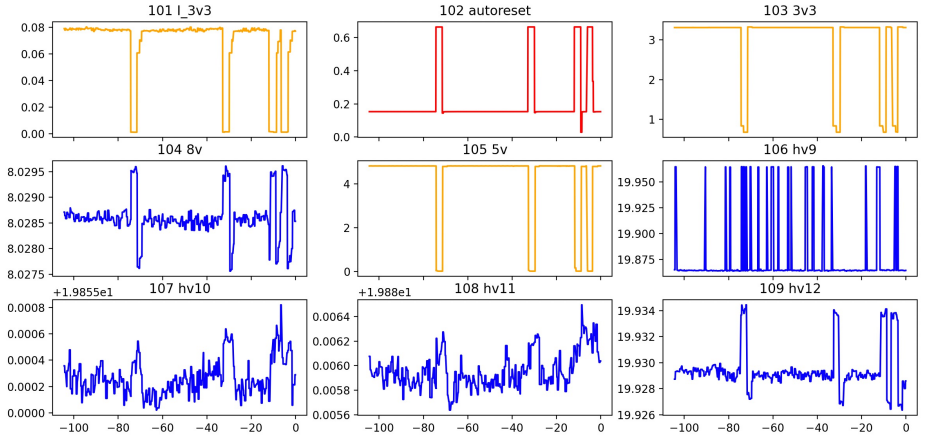


→ The number of SEFI at 60 MeV consistent within different measurements

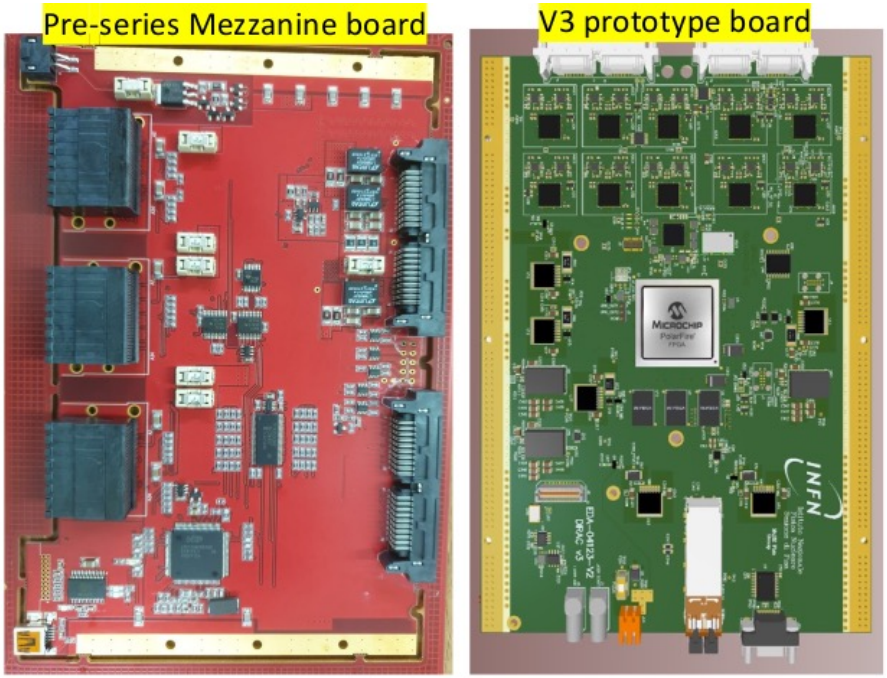
→ We developed a SEL protection circuitry that worked well

→ **SiPM HV remained stable during these operations no dead time on data taking**

→ New layout of MZB with the tested mitigation developed and 3 pro-series Being produced now (5 kEuro)

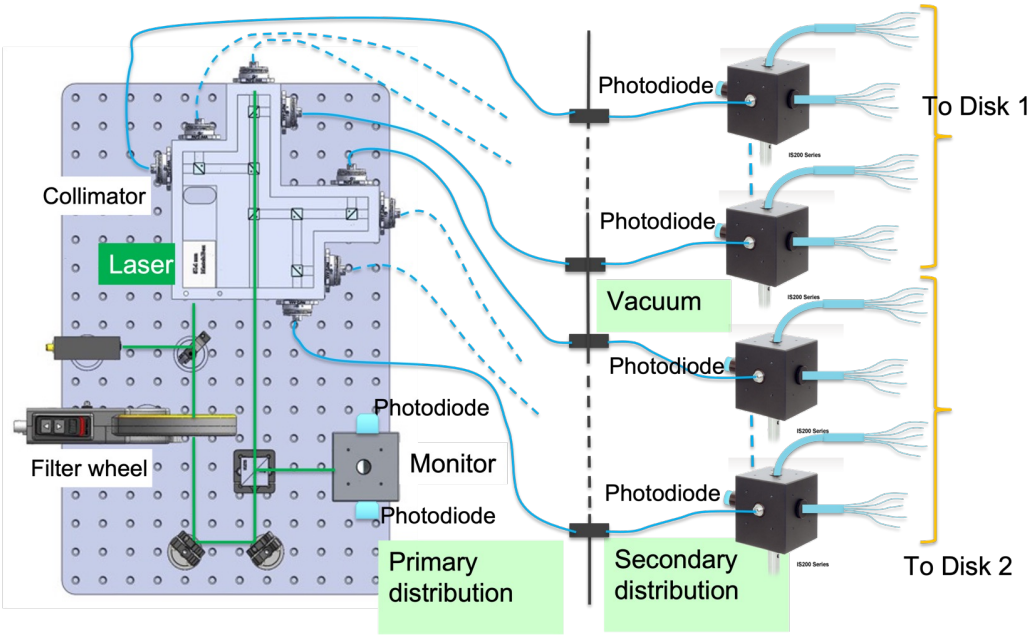


Status of digital electronic production

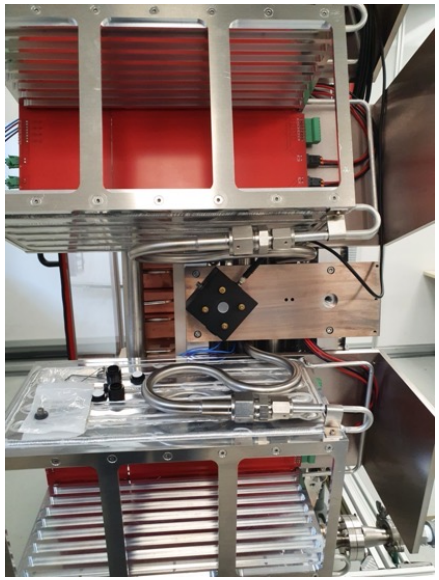


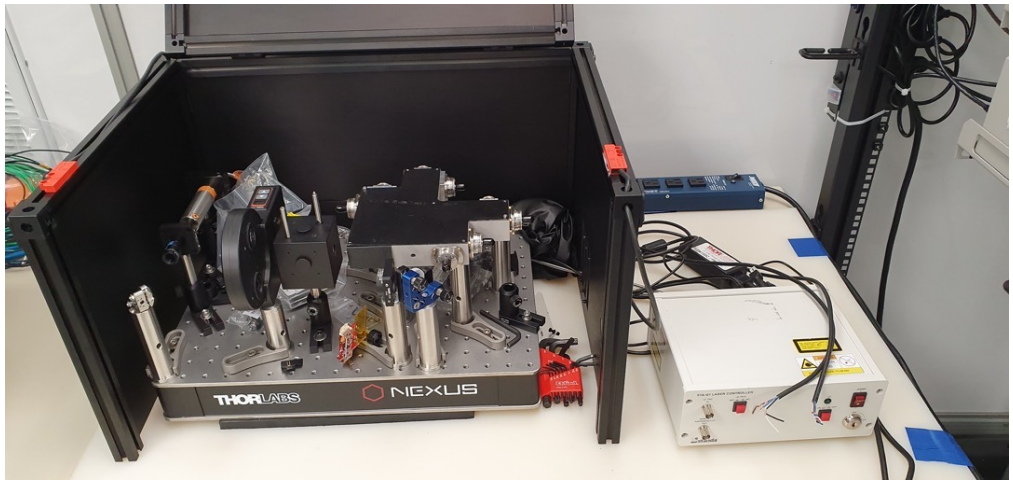
- Last test at CNAO in April 2023 has finally qualified the Mezzanine Board (MB) and the Digitizer Board (DIRAC) against the expected levels of neutron radiation
- The SEL protection circuit has also been validated
  - **Components procurement will be completed by the end of 2023 (with some extracost)**
  - **All 160 MB and DIRAC will be available by Spring 2024**

Laser System



A pulsed green **laser** will be sent to each crystal through a system of diffusive spheres and optical fibers. PIN diodes will check the system stability





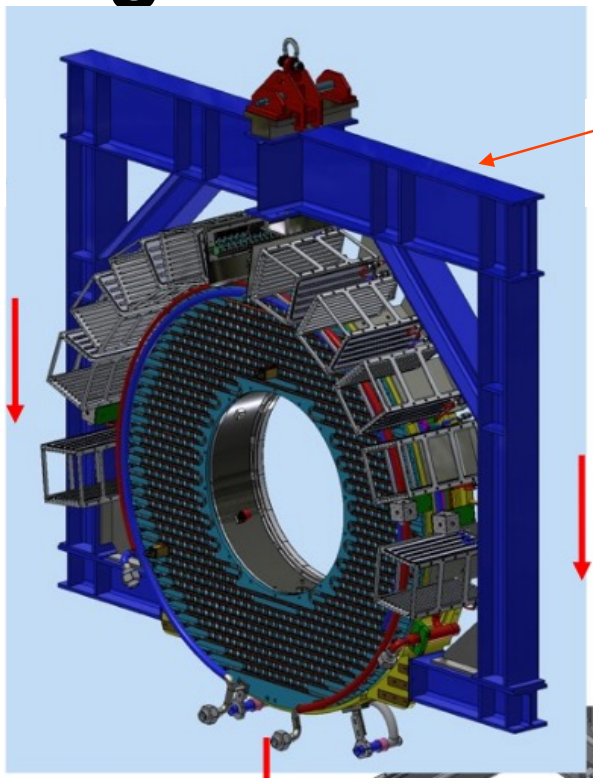
Mu2e Laser primary distribution optical system placed inside a Thorlabs black Enclosure

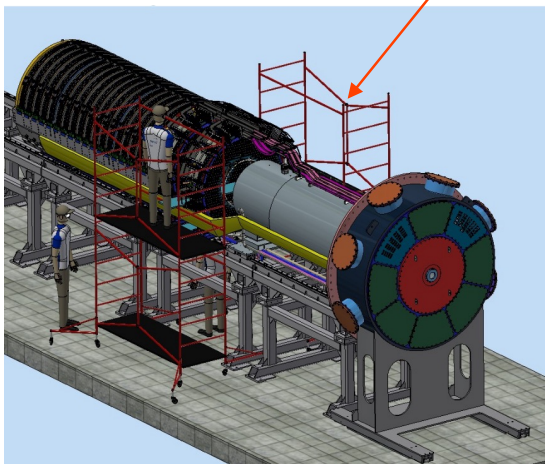
Laser Head # 1 – under test for stability along time.
Interlock system based on two magnetic switches.
Laser Key handling established
Nice results of light distribution losses down to integrating spheres and laser fiber needles in front of each crystal

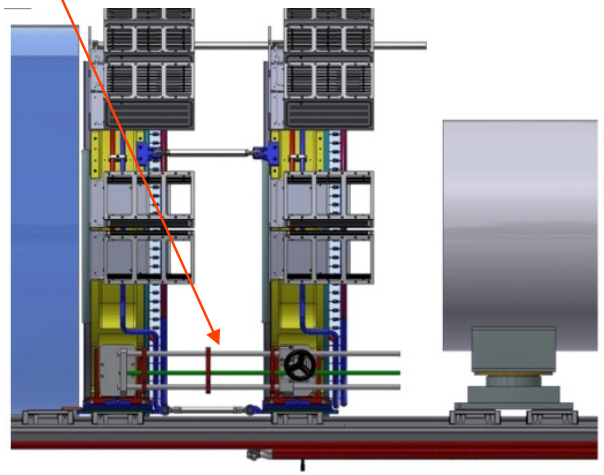
80 % of fiber bundles delivered at SIDET

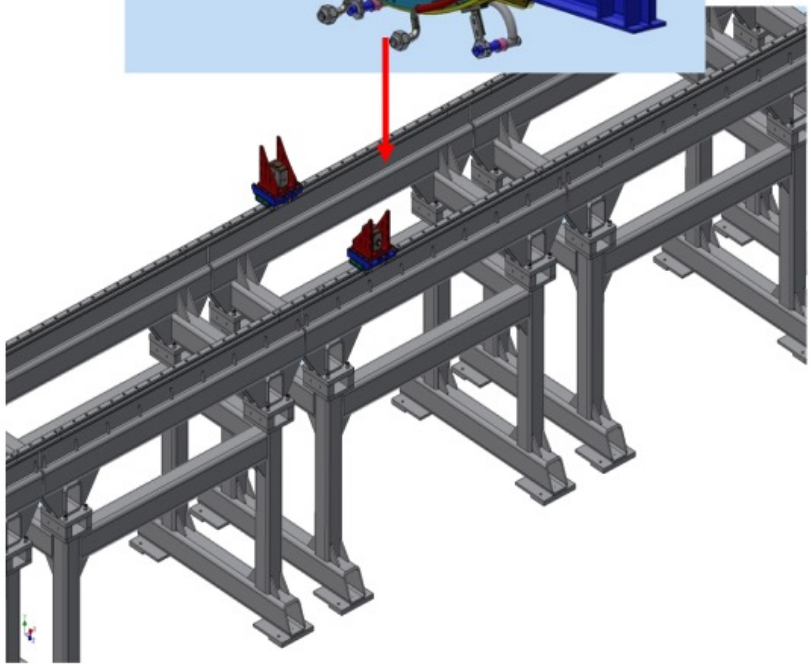
Moving the calorimeter to the Mu2e building

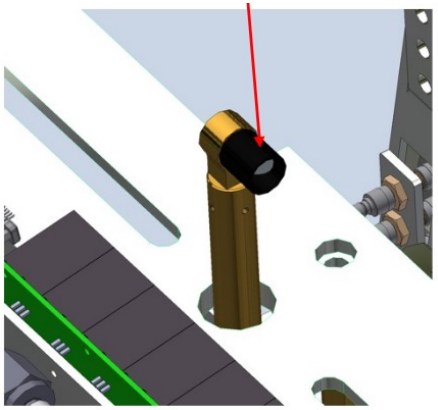
Additional tools are needed and still need to be constructed

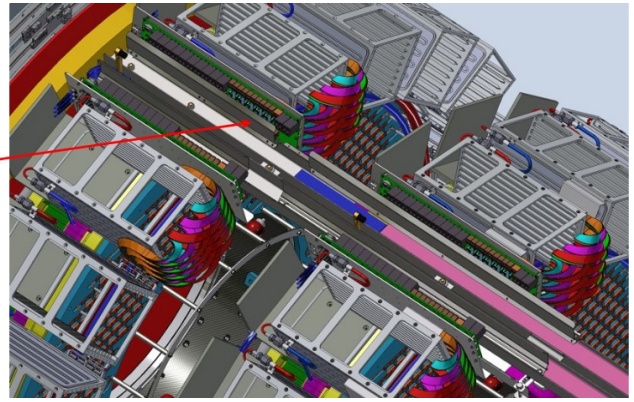




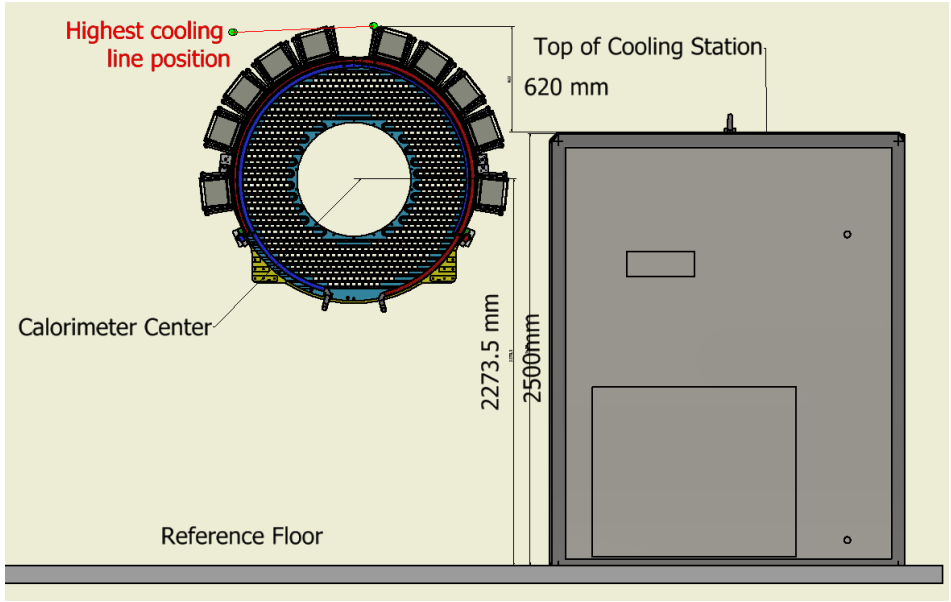








Calorimeter cooling station



A cooling station dedicated to the calorimeter will be located in the Mu2e building

A coolant liquid at -22° C will circulate in two indipendent cooling lines:

- to keep SiPMs at -10° C
- to keep all the electronic boards components below 50° C

The final design is completed

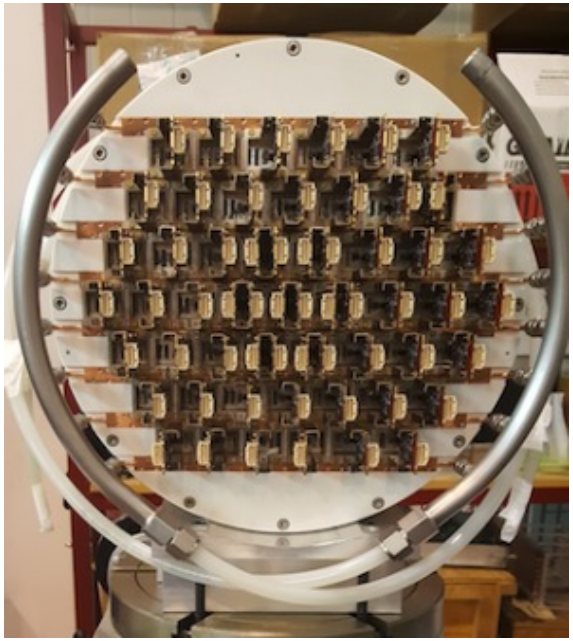
The last details of the tender are being discussed with Fermilab staff

The order is expected to be placed in 2024

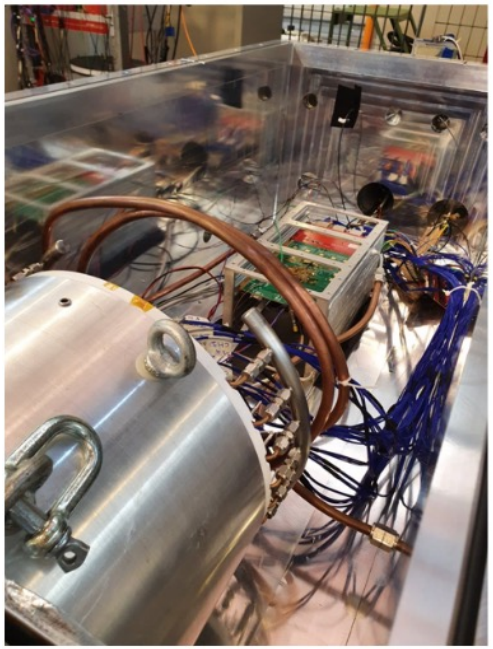
Requirements:

1. Operation during commissioning, at 15 °C, total power (TP) of 5.4 kW;
2. Operation at low power at standard low temperature, -12 °C, TP=5.4 kW;
3. Operation at high power and lowest possible temperature, -22 °C, TP=6.6 kW.

Vertical slice test with module 0 at LNF



Calorimeter module 0

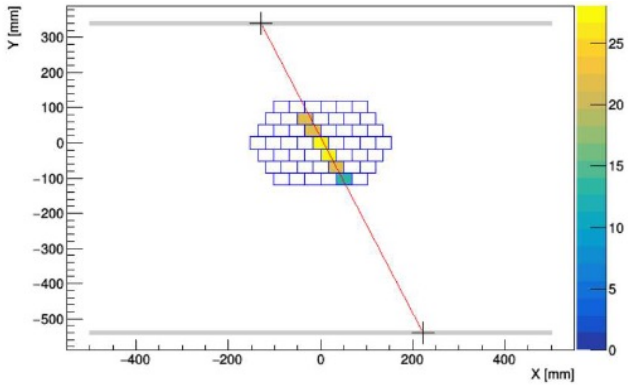


Calorimeter **module 0**, equipped with **51 pure CsI Crystals**, **51 ROUs, cooling lines** can be used to perform a vertical slice test of the full readout chain **under vacuum**

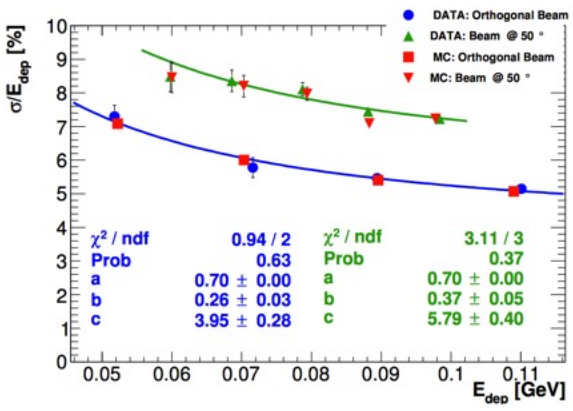
A preliminary test with a commercial digitizer and a serial readout has been succesfully completed

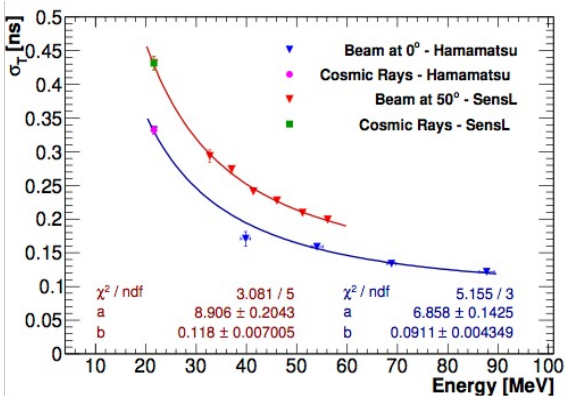
A dedicated Cosmic Ray Tagger has been built to allow a long term test with cosmic rays

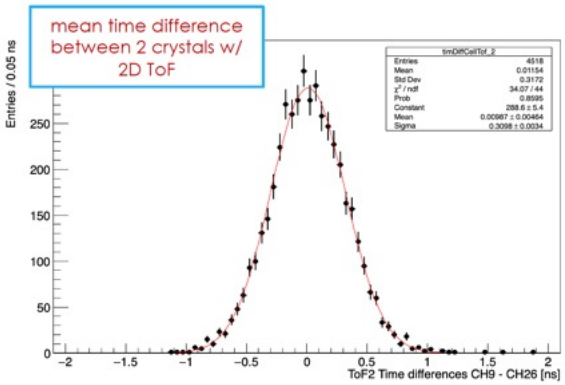
The Cosmic Ray tagger:
2 layers each with 8 scintillator bars read by SiPMs



Module-0 test beam







Calorimeter time and energy performances have been measured in 2017 with an electron beam at LNF BTF (doi:10.1016/j.nima.2018.09.043)

Since then Module-0 has been refurbished with production crystals and SiPMs, and optical cross talk has been mitigated using some black Tedlar between the crystals.

Module-0 will be used to measure the calorimeter performances in the final configuration also including production digital electronics.

Available beams in 2024: BTF@LNF, MAMI@Mainz

The Mu2e upgrade proposal: Mu2e-2

The PIP-II upgrade of Fermilab accelerator will allow to have an higher intensity muon beam increasing by a factor 10 Mu2e statistical error.

A relatively cheap upgrade of Mu2e apparatus, saving the superconducting solenoids, have been included in the Snow Mass program in March 2022 (arxiv 2203:07569).

A dedicated workshop has been held in Caltech in March 2023 (https://indico.fnal.gov/event/57834)

The proposal has been submitted to the Fermilab Phisycs Advisory Committee in June 2023

The proposal discuss possible improvements of the accelerator, of the target and of the detectors (tracker, CRV e ECAL) to deal with the increased rate of particles and radiation levels.

Our Mu2e collaborators consider natural an involvement of INFN in this upgrade. Can certainly be a good occasion for INFN to keep an important collaboration with Fermilab at a reasonable cost.

Mu2e-2 calorimeter: LYSO proposal

In Mu2e-2, we expect x10 increase in n-fluence up to 10^{13} n/cm^2

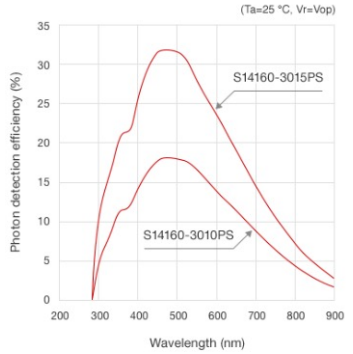
15 μm

Temperature [°C]	V_{br} [V]	$I(V_{br}+4V)$ [mA]	$I(V_{br}+6V)$ [mA]	$I(V_{br}+8V)$ [mA]
-10 ± 1	75.29 ± 0.01	12.56 ± 0.01	30.45 ± 0.01	46.76 ± 0.01
-5 ± 1	75.81 ± 0.01	14.89 ± 0.01	32.12 ± 0.01	46.77 ± 0.01
0 ± 1	76.27 ± 0.01	17.38 ± 0.01	33.93 ± 0.01	47.47 ± 0.01

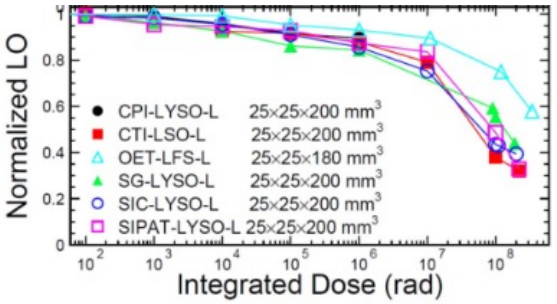
10 μm

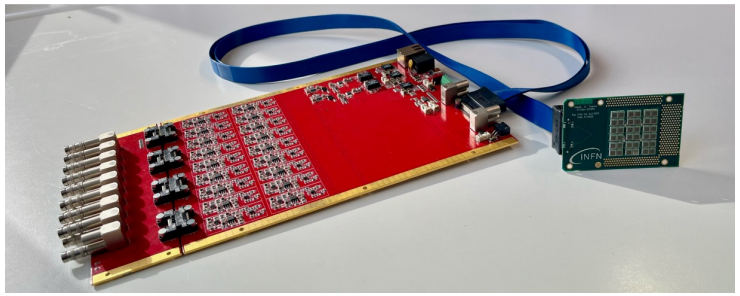
Temperature [°C]	V_{br} [V]	$I(V_{br}+4V)$ [mA]	$I(V_{br}+6V)$ [mA]	$I(V_{br}+8V)$ [mA]
-10 ± 1	76.76 ± 0.01	1.84 ± 0.01	6.82 ± 0.01	29.91 ± 0.01
-5 ± 1	77.23 ± 0.01	2.53 ± 0.01	9.66 ± 0.01	37.51 ± 0.01
0 ± 1	77.49 ± 0.01	2.99 ± 0.01	11.59 ± 0.01	38.48 ± 0.01

SiPMs with pixel 10 or 15 μm can survive but they have a lower PDE
Hamatsu & FBK R&D



Short LYSO crystals (34x34x80 mm^3) can provide a rad hard solution at a reasonable cost (x2 BaF_2)
Emission time: 40 ns





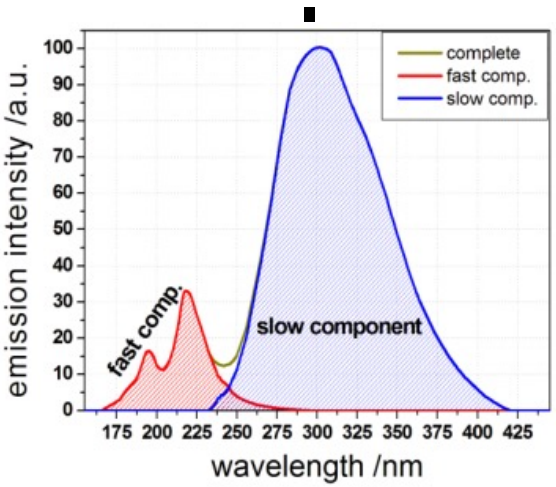
FEE would be connected to SiPMs via a coaxial cable to reduce radiation levels.
A synergic R&D for muon collider (CRILIN and NEXT-100) is already ongoing

Proposed R&D for 2024:
- support design with simulation (required signal width vs pileup)
- test a 2x2 array of 6x6 mm^2 SiPM with 10 μm pixel
- build a PCB to read 16 3x3 mm^2 SiPMs

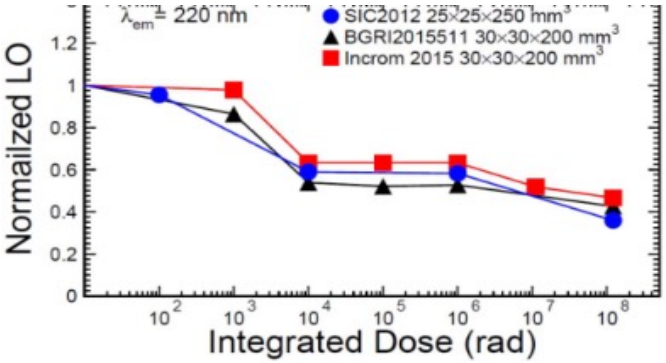
Mu2e-2 calorimeter: BaF_2 alternative

BaF_2 was the baseline also for Mu2e: it has a very fast component (0.6 ns) but an unacceptable dominating slow component (630 ns) that needs to be suppressed.

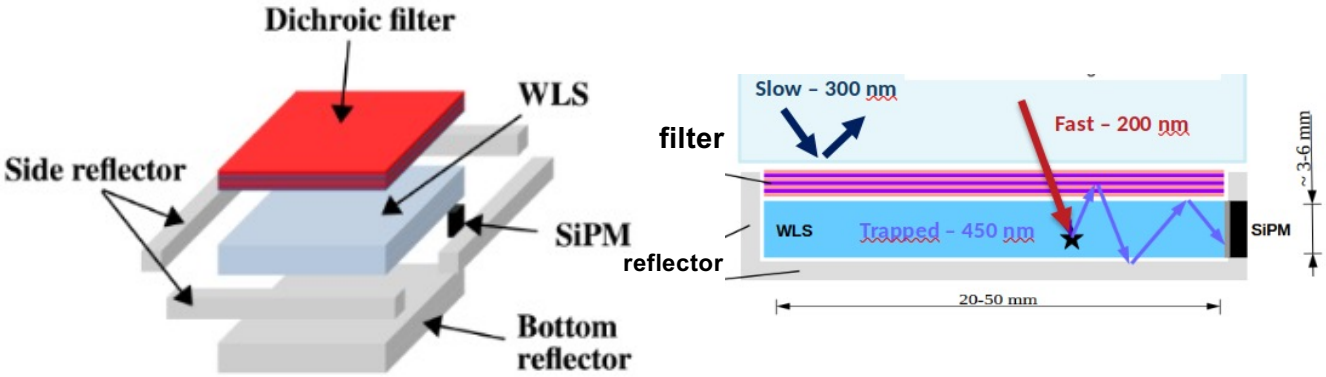
A long and expensive R&D to incorporate a filter in the sensor is going on (Caltech/JPL/FBK)

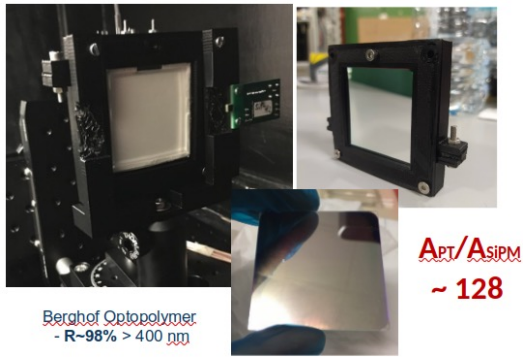


Radiation hardness is ok after an initial loss of ~40%



Alternative R&D proposal: **dichroic filter+ photon trap**





A phototrap prototype with 5% PDE

Proposed R&D for 2024:

- procure and test different combinations of filters and WLS
- build a prototype to evaluate Light Collection and timing
- build a PCB to host SiPMs, shaper and amplifier

Richieste LNF

DA RESTITUZIONI: Cooling Station + Laser Head	**92 (80+12)**			
Lifting Fixture ASME standard certif. 25KEuro	25	Critical Lift	Preventivo budgetario via e-mail + disegno	
cable trays between the disks	5	Installation	Disegno	
calo disk separation jacks	6	Installation	Disegno	
calo connecting plates	4	Installation	Disegno	
scaffholding for maintenance +Dry Air tent on Mu2e train	10	Installation	Disegno	
calo movement from sidet to mu2e	4	Transportation	plan	
shock absorbers and accelerometers for movement	5	Trasportation	plan	
Spare mechanical parts + Tooling	9 (SJ)			
TOTAL : Transport + Lift + installation	**68**			
EXTRA COST MB revision SEL protected	23	EXTRA COST protoni	Anticipabile 2023	Preventivo ARTEL
EXTRA COST cable (TID 200 krad --> 2 Mrad)	16	EXTRA COST Dose	Spostamento 5kEuro SJ 2023	Preventivo 1/4 AWC
Extra Cost TOTAL	**39**			
Metabolismo	13			
Mu2e Building Dry air pump + 2nd disk dry air enclosure	10(SJ)	consumo		
R&D Mu2e-2 (LNF-side)	14 (SJ)	Ivano's SLIDEs		
Totale Consumi	**37**			
TRASPORTI INFN FNAL	**5**			
MOF				
costruzione sistema scintillatori per Spill Loss Monitor (SLM) - 8 scintillatori da 13x2x2 cm, LYSO (old counters cut to shape), costo 3 kEuro - 8 PMTs EMI da 1" - 500 Euro l'uno —> 4 kEuro Supporto meccanico con profilati Bosch —> 2 kEuro ESR + grasso ottico + 3D Printing supports—> 2 kEuro Totale 11 kEuro	11	In-kind contribution equivalente a 20 kEuro	Picture and measurements at the scope. Proto N.1 done with consumables. Installed in beamline	
Test Flange for vacuum tests on Vaccum Vessel at SIDET	10	In-kind contribution equivalente a 20 kEuro	Disegno LOLLO o PPT sketch	

Missioni: Restituzione 2023

		Assegnato	Usato (kE)	Plan to use 12/ 2023	SJ (kE)	Da Restituire a Settembre	aMuse da 1/9(2022-2023)	aMuse plan to 12/2023
	LNF	**91+32.5(sj)**	**35**	**36**	32.5	**20+32.5(SJ)**	**45 kEuro**	**25 kEuro**

Missioni: Richieste 2024

	rich	SJ
Missioni Interne metabolismo 0.7 kE x FTE	10	
Gettone SpokesPerson (3+2 MU)	16,5	11
Missioni per responsabilita' 3M * L2 + 2 M * 4 L3 = 11 M a 5.5 kEuro/mese	60,5	
MEstere altri = 5,6 (FTE) * 1.3 MU * 5.5 kE/mese	40	
Tecnici x assemblaggio e installazione 4+2(sj) MU	22	11
ME 2+2(sj) mesi extra per Happacher e Sarra. Coordinatori assemblaggio	11	11
test beam mainz		15
SPS bent crystals (Garattini)		2
tot	**160**	**50**

assegnazioni

Sigla Loc.	Capitolo	Riunione	Note Alla Richiesta	Rich.	Rich. SJ	Assegn.	Assegn. SJ	Assegn. Dot.	Assegn. Ant.	Assegn. Ant. Dot.	Commento Alla Assegnazione
LNF	MISS	Assegnazioni	Gettone SpokesPerson (3+2 SJ MU)	16.5	11.0	16.5	11.0				
		Assegnazioni	3M * L2 + 2 M * 4 L3 = 11 M a 5.5 kEuro/mese	60.5	0.0	60.5					
		Assegnazioni	MEstere altri =5,6 (FTE) * 1.3 MU * 5.5 kE/mese	40.0	0.0	28.0					
		Assegnazioni	Tecnici x assemblaggio e installazione 4+2(sj) MU	22.0	11.0	11.0	5.5				
		Assegnazioni	ME 2+2(sj) mesi extra per Happacher e Sarra. Coordinatori assemblaggio/trasporto	11.0	11.0	5.5	5.5				
		Assegnazioni	test beam Mainz	0.0	13.5	0.0	3.0				
		Assegnazioni	test beam SPS	0.0	2.0	0.0	1.0				
		Assegnazioni	Missioni Interne metabolismo 0.7 kE x FTE	9.0	0.0	6.0					
		Totale MISS		**159.0**	**48.5**	**127.5**	**26.0**	**0.0**	**0.0**	**0.0**	
	CON	Assegnazioni	Mu2e Building Dry air pump + 2nd disk dry air enclosure	10.0	0.0	0.0	10.0				
		Assegnazioni	R&D Mu2e-2 (LNF-side)	0.0	14.0	0.0	8.5				
		Assegnazioni	metabolismo	13.0	0.0	11.5					1,3K * 8,8 FTE
		Totale CON		**23.0**	**14.0**	**11.5**	**18.5**	**0.0**	**0.0**	**0.0**	
	ALTRICONS	Assegnazioni	costruzione sistema scintillatori per Spill Loss Monitor (SLM)	11.0	0.0	0.0	11.0				contributo in-kind MOF
		Totale ALTRICONS		**11.0**	**0.0**	**0.0**	**11.0**	**0.0**	**0.0**	**0.0**	
	TRA	Assegnazioni	calo movement from assembly area to mu2e building	4.0	0.0	0.0					
		Assegnazioni	shock absorbers and accelerometers for movement	5.0	0.0	0.0					
		Assegnazioni	trasporti INFN-FNAL	5.0	0.0	5.0					
		Totale TRA		**14.0**	**0.0**	**5.0**	**0.0**	**0.0**	**0.0**	**0.0**	
	LIC-SW	Assegnazioni	Licenza INVENTOR per A. Saputi: necessaria per il completamento del disegno dei dischi, supporti di integrazione e zona IFB.	3.0	0.0	0.0					
		Totale LIC-SW		**3.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	
	MAN	Assegnazioni	Spare mechanical parts + Tooling	9.0	0.0	0.0					
		Totale MAN		**9.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	
	APP	Assegnazioni	DA RESTITUZIONI anni precedenti: Cooling Station+LaserHead	92.0	0.0	92.0					
		Assegnazioni	Lifting Fixture certificazione ASME standard	25.0	0.0	25.0					
		Assegnazioni	Test Flange for vacuum feed throughs tests	5.0	0.0	5.0					contributo in-kind MOF
		Assegnazioni	cable trays between the disks	5.0	0.0	5.0					
		Assegnazioni	calo disk separation jacks	5.0	0.0	0.0					
		Assegnazioni	calorimeter train connecting bars	4.0	0.0	4.0					
		Assegnazioni	scaffholding for maintenance +Dry Air tent on Mu2e rails	10.0	0.0	0.0					
		Assegnazioni	EXTRA COST cable	16.0	0.0	8.0					
		Assegnazioni	Extra Cost - Mezzanine Board revision SELF protecting from proton dose latch-up	23.0	0.0	23.0					
		Totale APP		**185.0**	**0.0**	**162.0**	**0.0**	**0.0**	**0.0**	**0.0**	
Totale LNF				**404.0**	**62.5**	**306.0**	**55.5**	**0.0**	**0.0**	**0.0**	
Totale Generale PMU2E				**404.0**	**62.5**	**306.0**	**55.5**	**0.0**	**0.0**	**0.0**	

Summary and conclusions

A lot of progresses in the construction of Mu2e at Fermilab

2024 will be a crucial year for the installation of Solenoids, Tracker and Calorimeter in the Mu2e building

Detector key performance should be demonstrated by the end of 2025. Still a lot of work and activity in situ is needed to maximize the results of the Mu2e Run 1 that will start in 2026

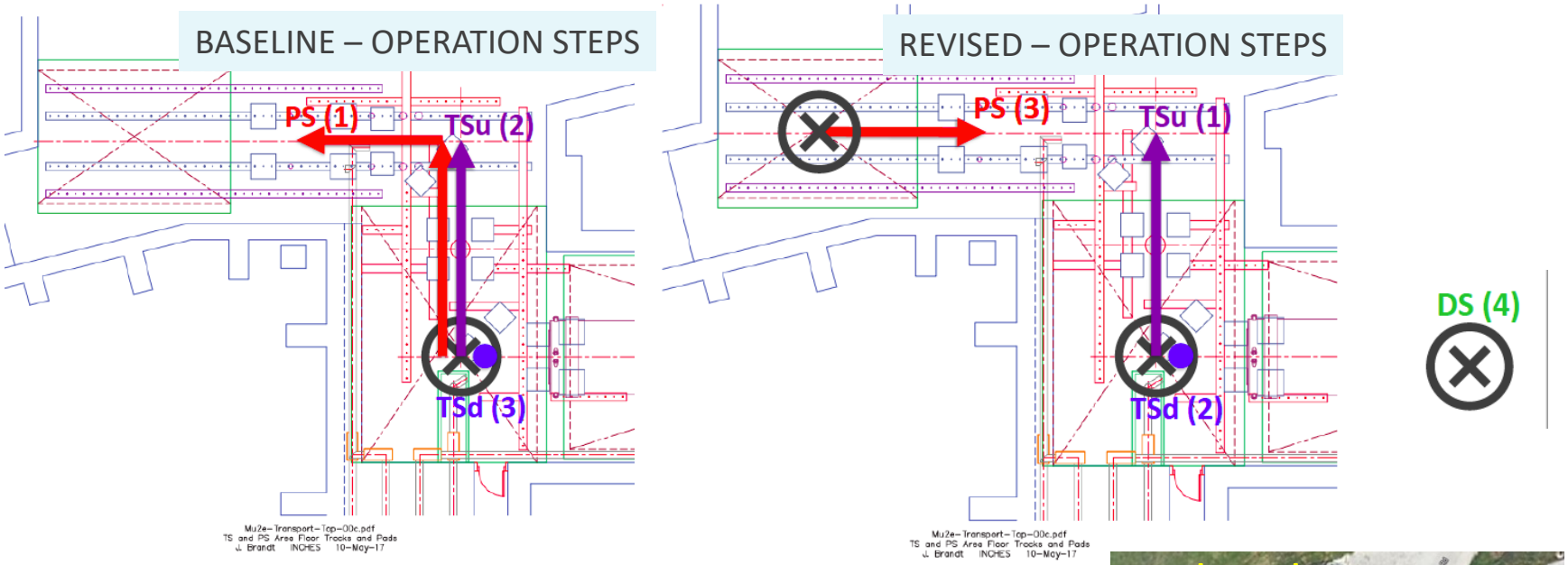
Common funds should start in 2024

INFN contribution is visible and much appreciated by the whole collaboration

BACKUP

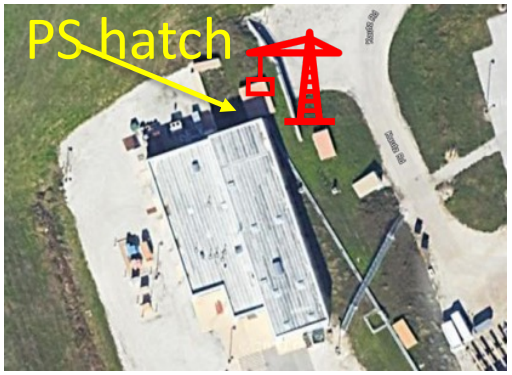
Solenoid installation : revised sequence?

- **PS delivery: October 2023 (Slight Slipping)**
- TSu delivery: October 2023 + TSd delivery: November 2023 (holding)
- DS delivery: May 2024 (holding)
- **It is likely that TSu/TSd will be ready to install before PS**



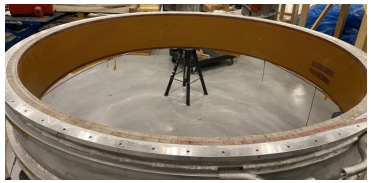
→ Do not interrupt installation in Mu2e Hall when magnets are ready
→ Need to use a different (PS) hatch + external crane

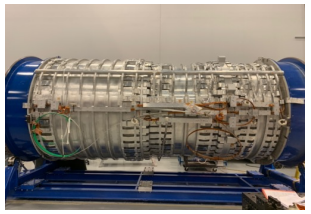
We will have the first magnet in the Mu2 hall in 2023!
It probably will be the one with Italian coils !!!!!



PS/DS fabrication steps

- Make a bunch of coils
- Assemble coils together into a “cold mass”
- Insert shielded inner bore into cold mass
- Insert cold mass/inner bore assembly into outer thermal shield and vacuum vessel
- Close up vacuum vessel





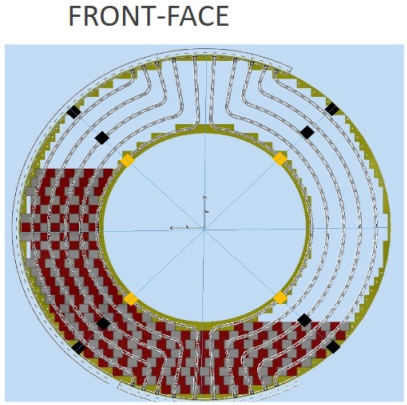
Long term test of cooling system at SIDET (FNAL)

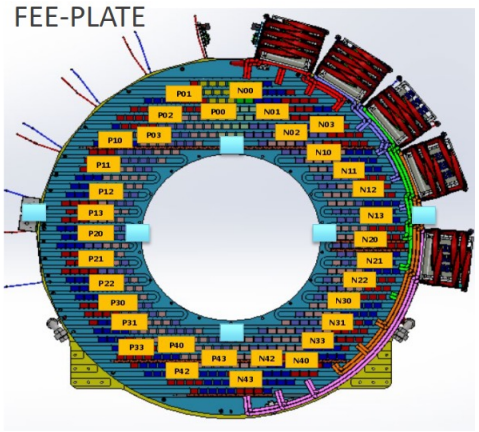
A first test of the cooling lines connected to the ECAL disks has been performed. The components used were too cheap to guarantee a stable performance over a long duration test.

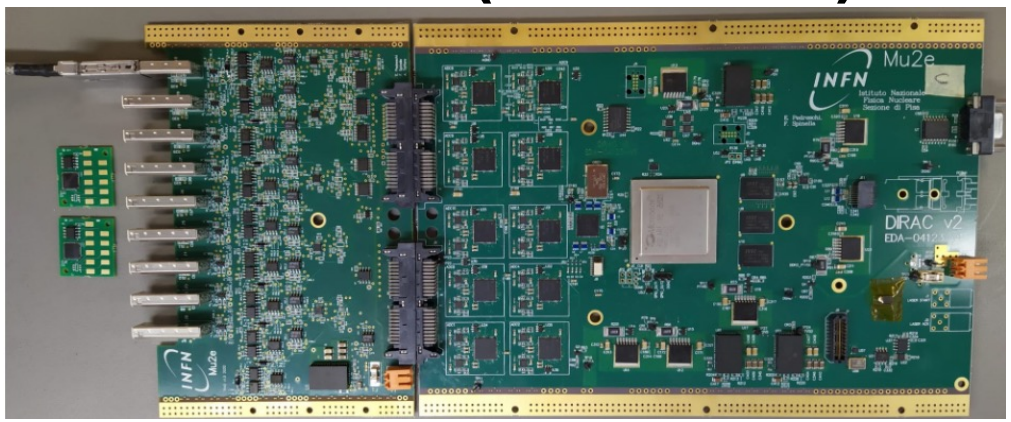
The final coolant selected (ZULU) is slightly more aggressive from the chemical point of view.
leggermente più aggressivo dal punto di vista chimico.

Higher quality pumps, sensors, valves, connectors, pipes ... are needed.

Temperature and Radiation monitor (TRAD-v2)







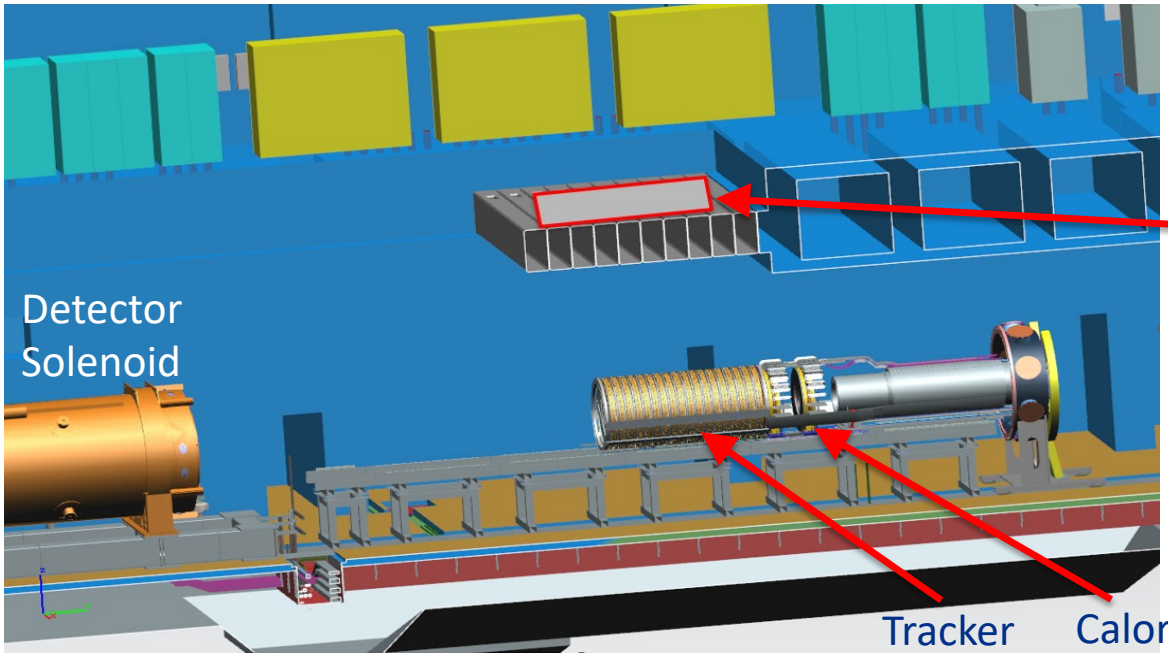
We want to monitor the temperature and radiation in different places on each disk.
A first prototype has been built to validate the tecnology choice
A second prototype (TRAD-v2), including the SEL protection, will be done by the end of 2023.

Final production by Spring 2024.

Next steps

- 2024: Test beam of module 0 fully equipped with the final electronics and DAQ
- 2024: Calorimeter disks installation in Mu2e building

- 2025: Commissioning with cosmic rays before the insertion
  - in the DS

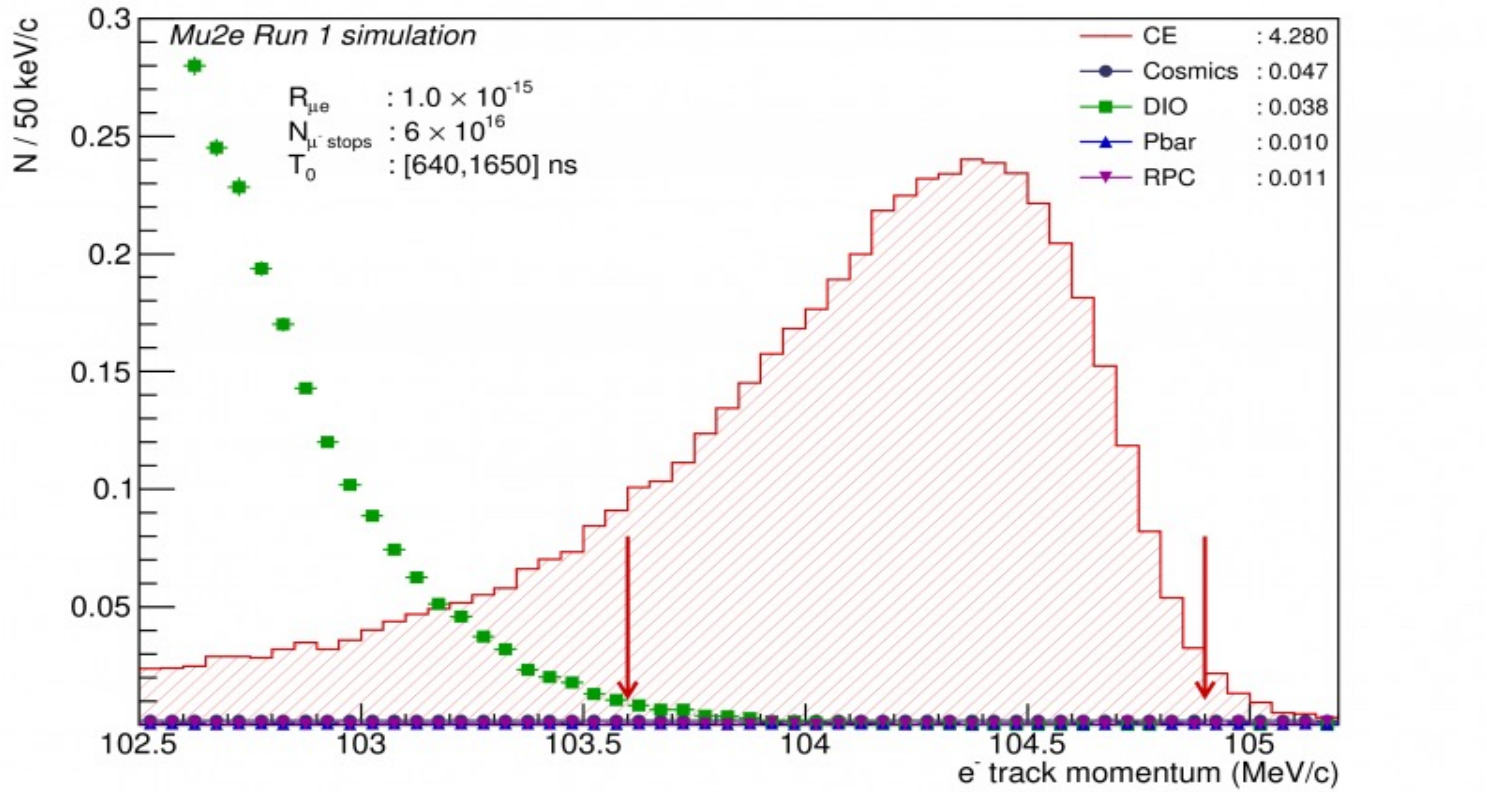


Mu2e expected backgrounds for Run 1 (assuming $6 \cdot 10^{16}$ stopped muons, mostly at half proton beam intensity*)

Channel	Mu2e Run I
SES	2.4×10^{-16}
Cosmic rays	$0.046 \pm 0.010\ (\text{stat}) \pm 0.009\ (\text{syst})$
DIO	$0.038 \pm 0.002\ (\text{stat})\ ^{+0.025}_{-0.015}\ (\text{syst})$
Antiprotons	$0.010 \pm 0.003\ (\text{stat}) \pm 0.010\ (\text{syst})$
RPC in-time	$0.010 \pm 0.002\ (\text{stat})\ ^{+0.001}_{-0.003}\ (\text{syst})$
RPC out-of-time ($\zeta = 10^{-10}$)	$(1.2 \pm 0.1\ (\text{stat})\ ^{+0.1}_{-0.3}\ (\text{syst})) \times 10^{-3}$
RMC	$< 2.4 \times 10^{-3}$
Decays in flight	$< 2 \times 10^{-3}$
Beam electrons	$< 1 \times 10^{-3}$
Total	0.105 ± 0.032

** More details in "Mu2e Run I Sensitivity Projections for the Neutrinoless mu- --> e- Conversion Search in Aluminum", submitted to MDPI Universe in October 2022 (38 pages) http://arxiv.org/abs/2210.11380*

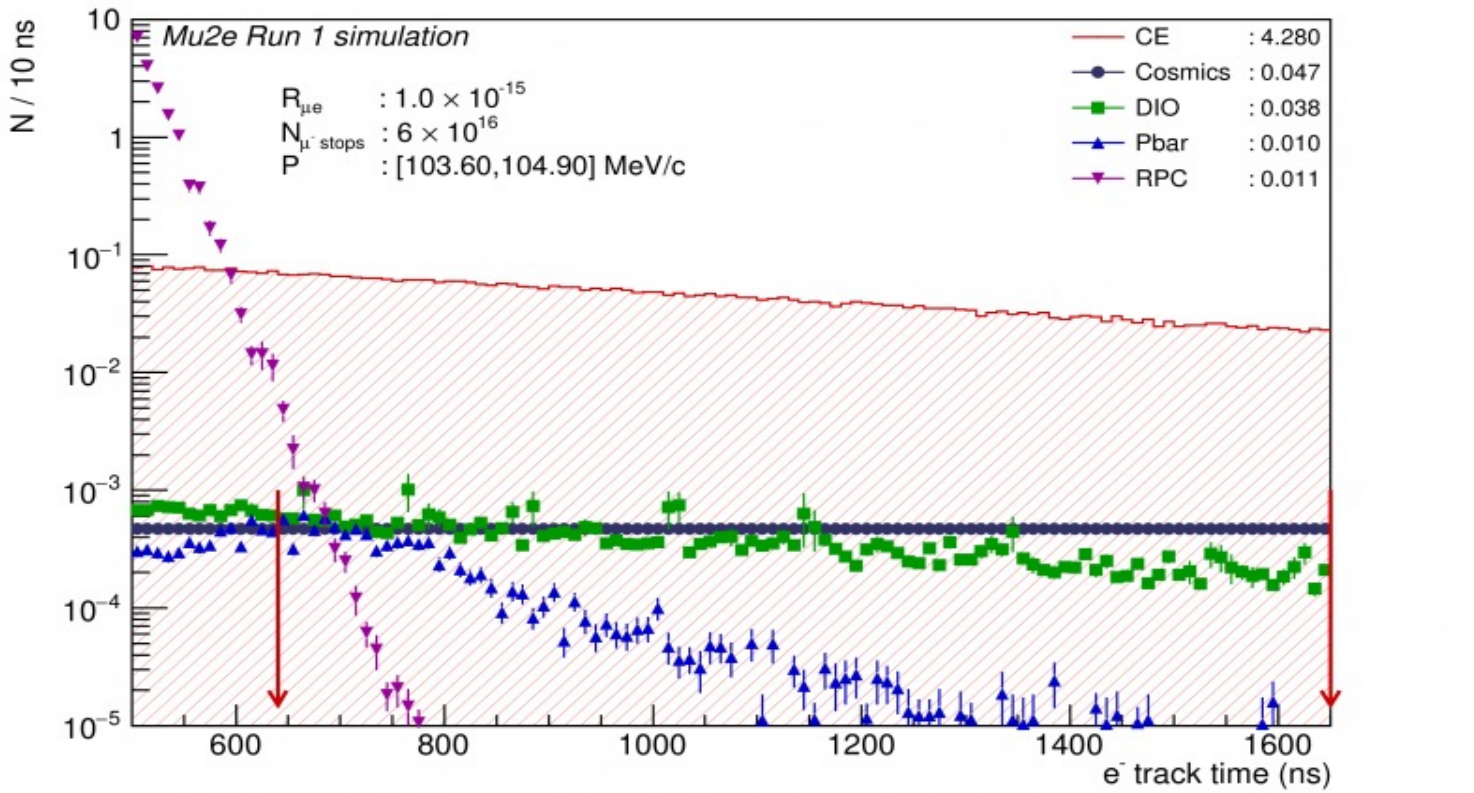
Electron momentum



The **DIO** spectrum falls as $(E_{max}\text{-}E)^5$ close to the end point

Can be suppressed by the momentum window cut

Electron time



Radiative Pion Captures (RPC) in the Al target producing photons converting in e^+e pairs can be suppressed by a time window cut
Also delayed pions coming from **antiproton** annihilation can be suppressed

Time and momentum windows **optimized** to get the best **discovery sensitivity**

Mu2e expected sensitivity for Run 1

Given the very low background level a **5σ discovery** will require Mu2e to observe just **5 events** of muon conversion

The $R_{\mu e}$ corresponding to a **5σ discovery** in Run 1 is:

$$R_{\mu e} = 1.1 \cdot 10^{-15}$$

Mu2e Run 1
5σ Discovery reach

If no events will be observed the **90% CL limit** will be:

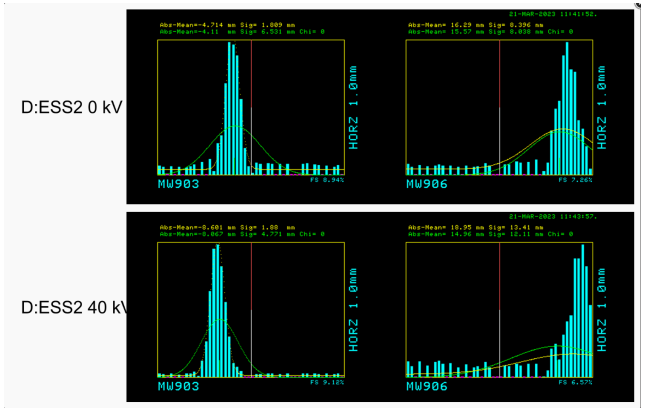
$$R_{\mu e} = 6.2 \cdot 10^{-16}$$

Mu2e Run 1
90% CL limit

that is more than **x1000** better than current best limit!

Accelerator

The first of the two Electro Static Septa (ESS) has been installed in the last segment of the beam line that will reach Mu2e



After a succesfull test of the AC dipole needed to extract theproton bunches, the first beam has been succesfully directed to the Mu2e beam dump (July ‘23)