

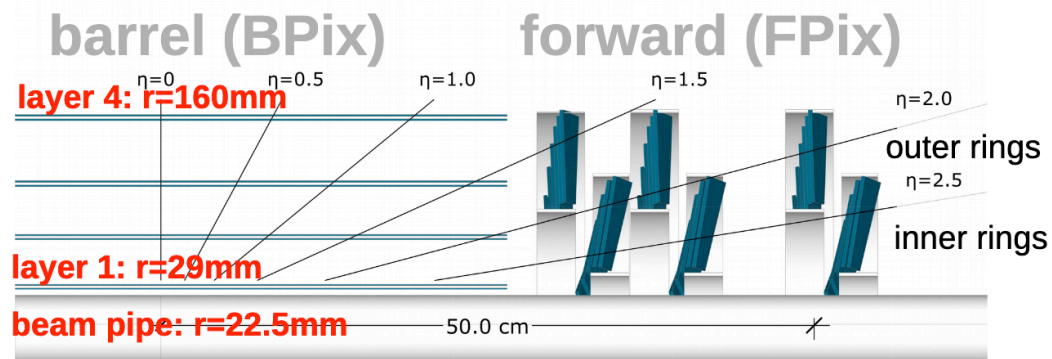
Refurbishment of the CMS Pixel detector during LS2 and projected lifetime in Run 3

Atanu Modak

On behalf of the CMS Collaboration



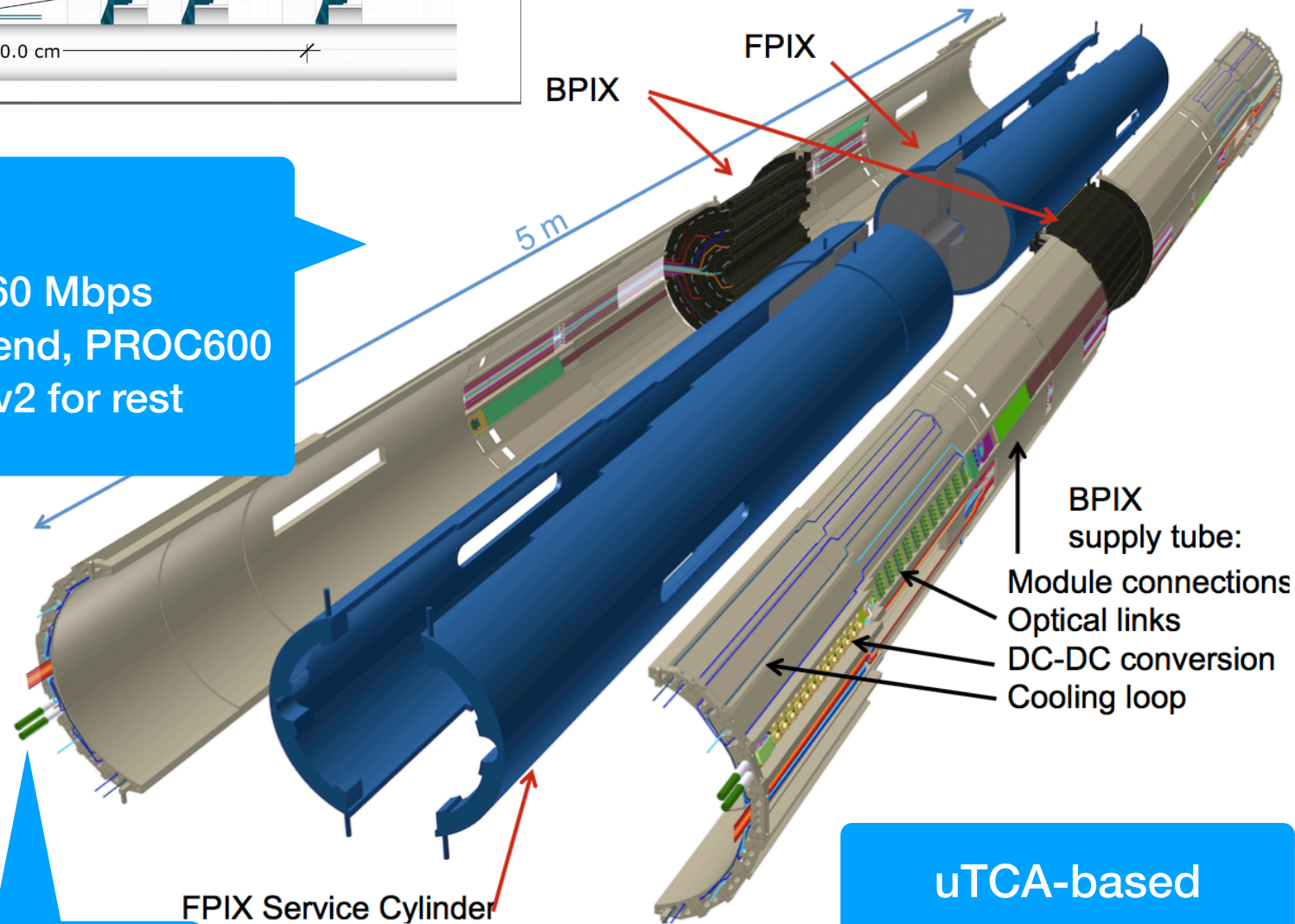
CMS Phase-1 Detector



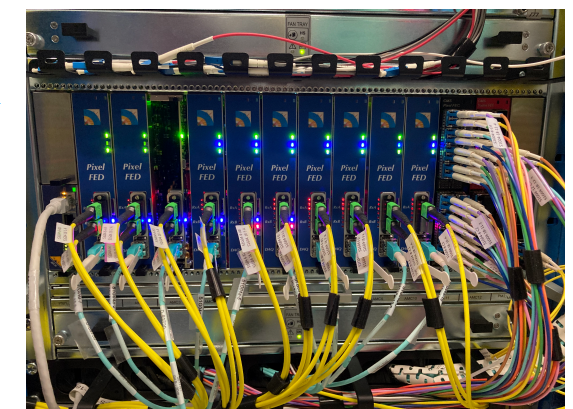
in operation since 2017 ...

- On-chip digitization
- Digital readout at 160 Mbps
- Two flavors of frontend, PROC600 for L1 and psi46digv2 for rest

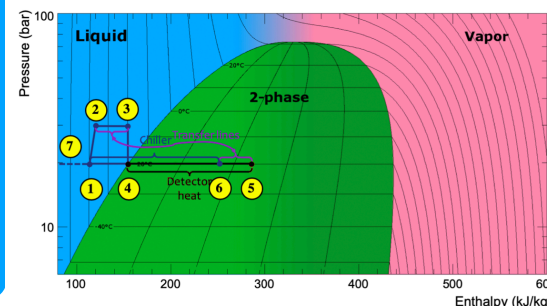
On-detector DCDC converter to deliver increased power requirement



uTCA-based compact backend system

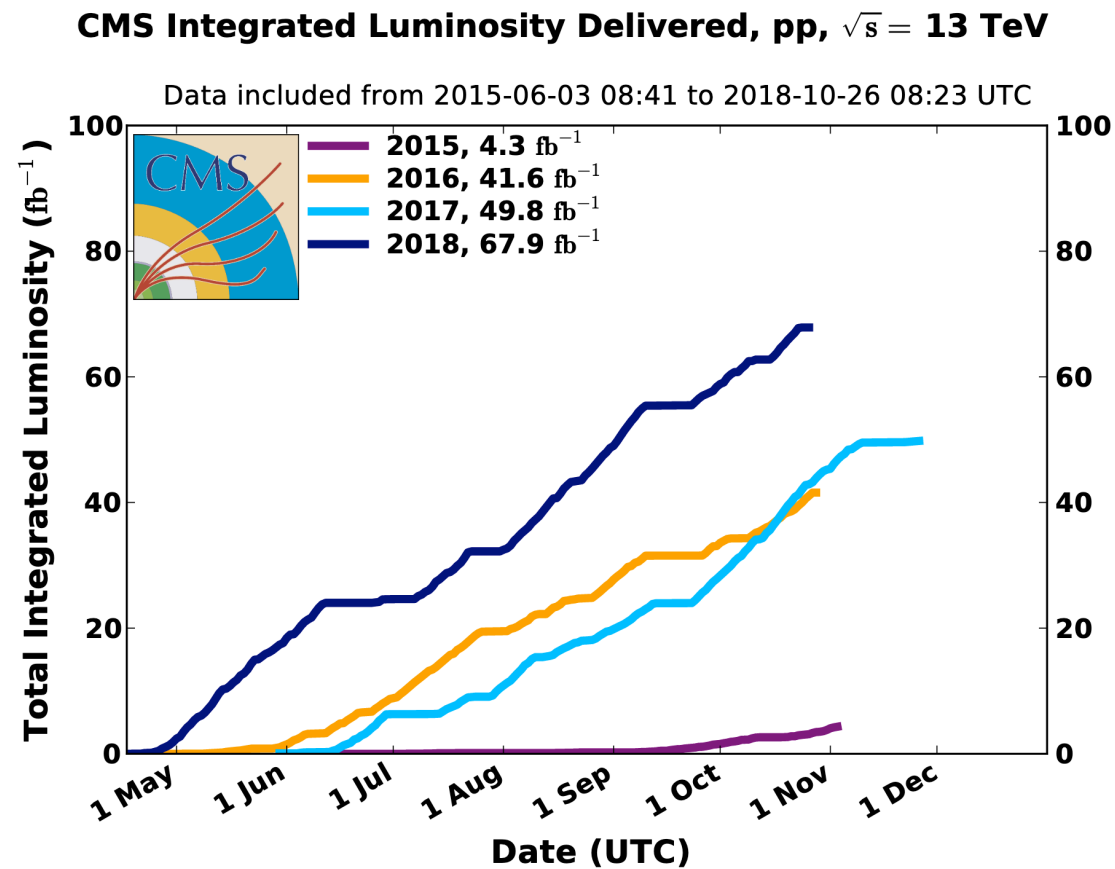


- Two-phase CO_2 cooling
- Set temp at $-22\text{ }^\circ\text{C}$
- Lightweight, stainless steel cooling pipes

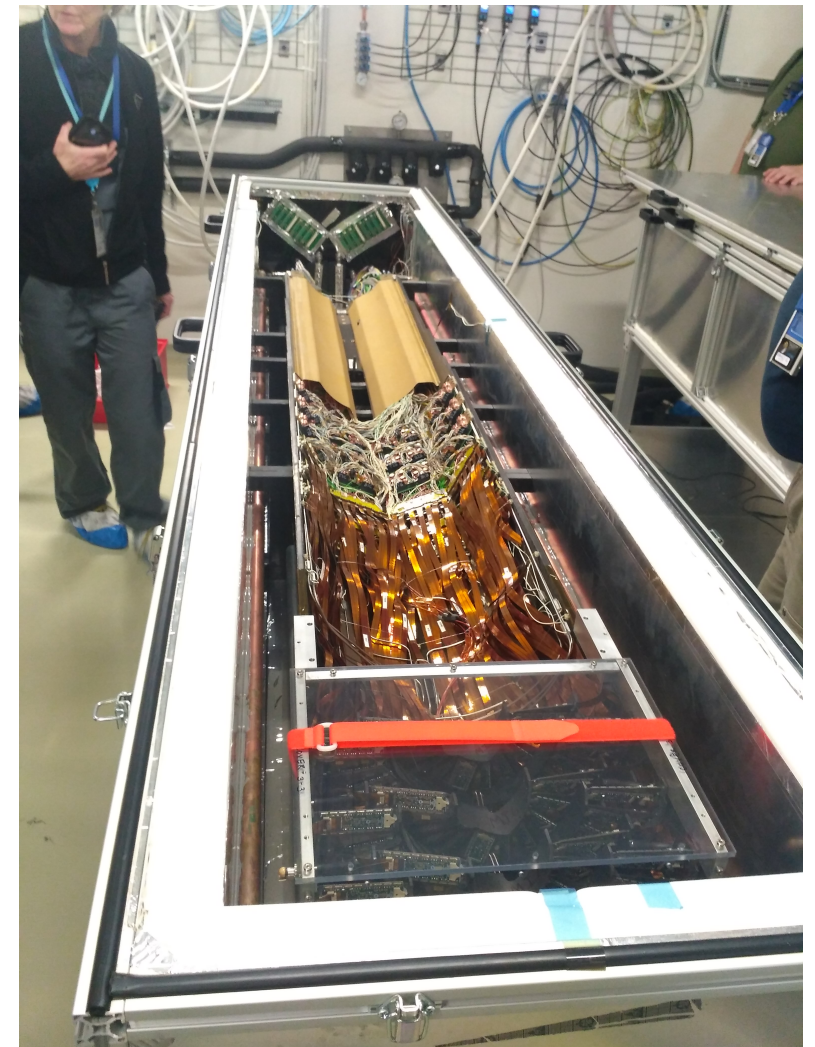


Run-2 and Beyond

CMS collected high quality data during Run2



At the end of Run2, Pixel was exacted from underground cavern in early 2019, and was kept cold and dry to protect the silicon sensors

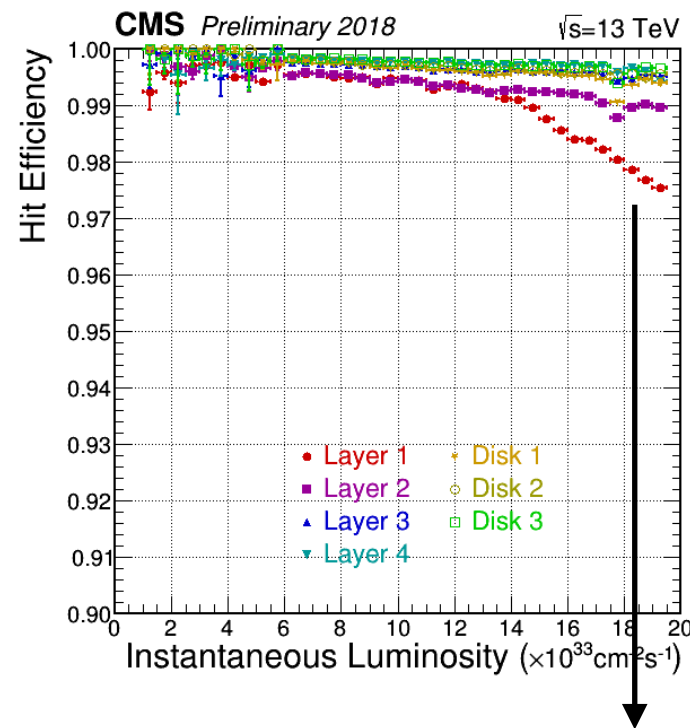


Detector Refurbishment during LS2

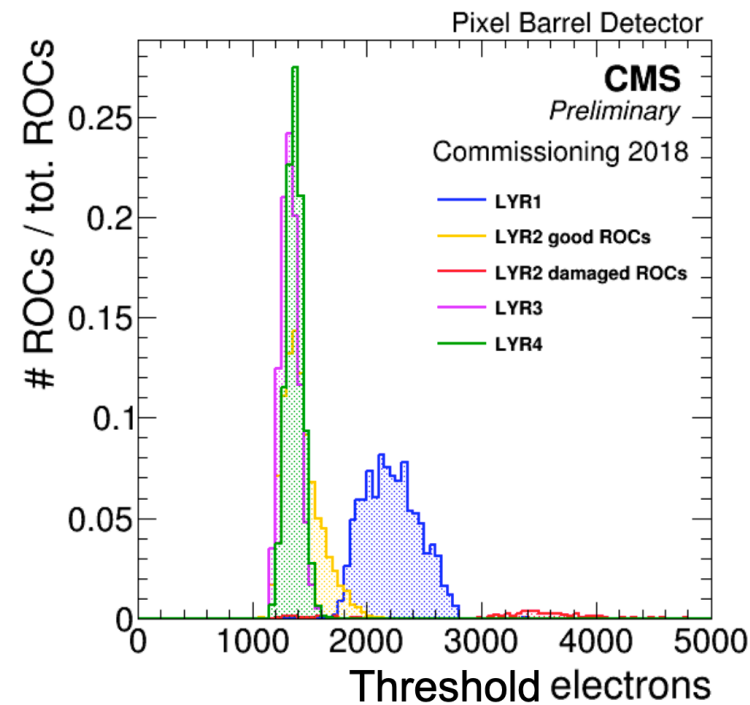
- ❑ Install new Layer-1
- ❑ Replace (accessible) DCDC-damaged modules (from 2017) in Layer-2
- ❑ Install new DCDC converters (with FEASTv2.3)
- ❑ Consolidate Forward Pixel cooling connection
- ❑ Test detector in warm and cold temperatures in cleanroom

New Layer 1

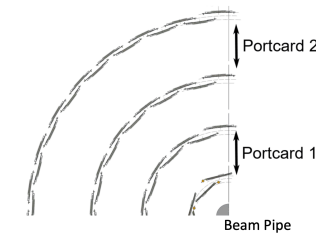
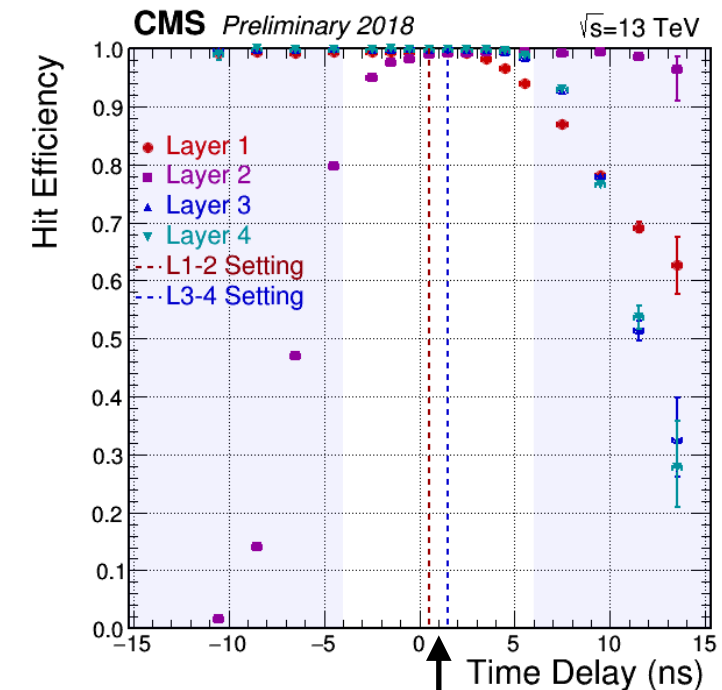
- Features a new readout chip (PROC600v4)
 - Fixed dynamic inefficiency issue, reduce crosstalk noise
- New Token-Bit-Manager (TBM10d) with delay and power reset option
- New HDI design to eliminate HV issues



Dynamic Inefficiency,
addressed in new ROC



High threshold for L1
due to crosstalk noise.



Delay chips shared by L1 and L2. Optimal range very narrow. New TBM10d offers a relative delay for L1.

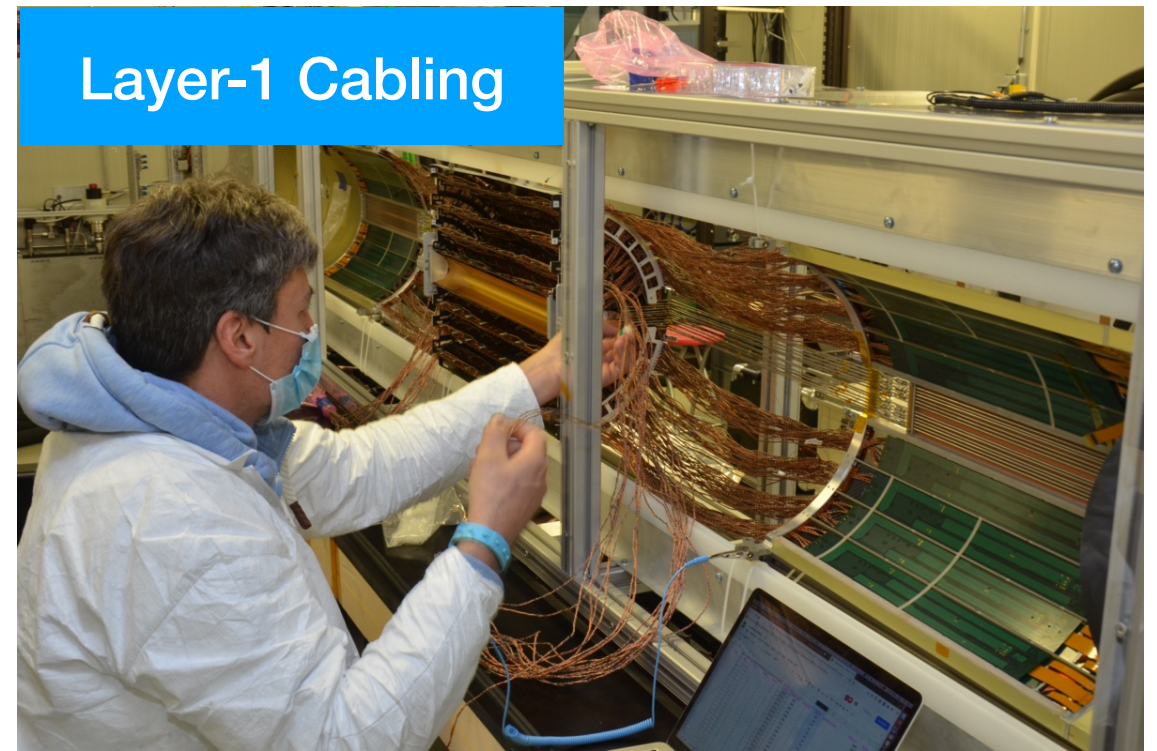
We needed a new Layer 1 anyway, why not make it better!

Layer 1 Integration

Layer-1 Mounting

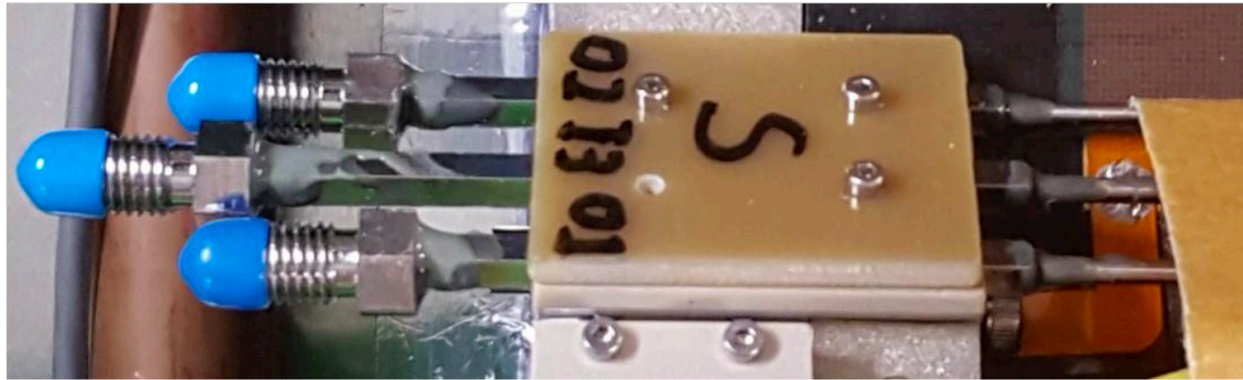


Layer-1 Cabling

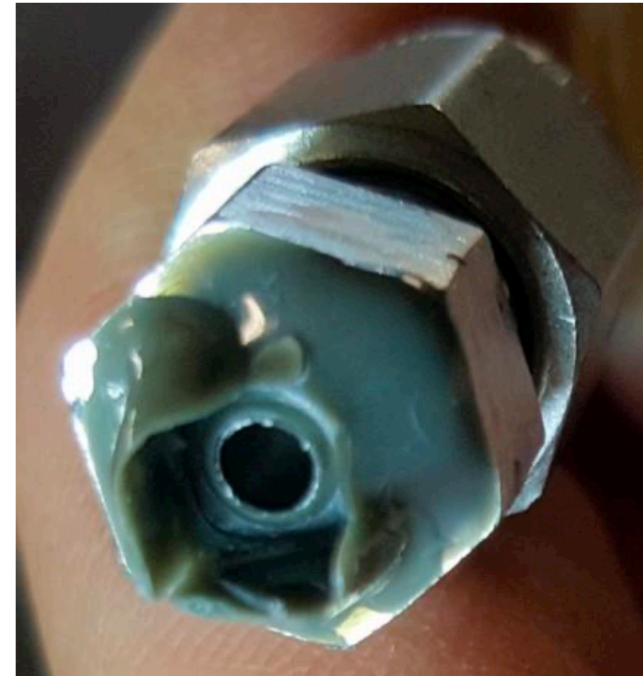


- Layer 1 was delivered at CERN/P5 in Oct 2020
- Detector integration and testing started in early 2021

FPix Cooling Connection

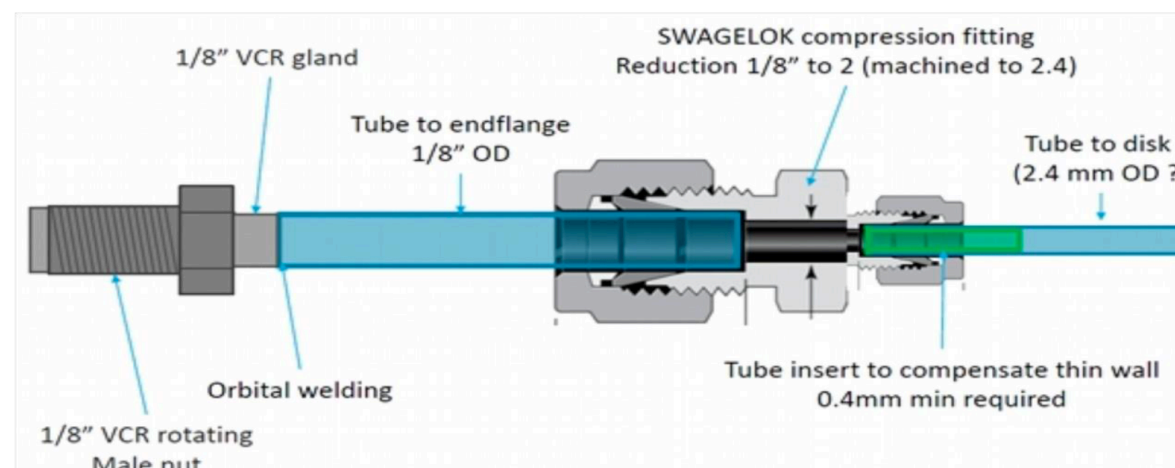


Forward Pixel CO2 cooling inlets



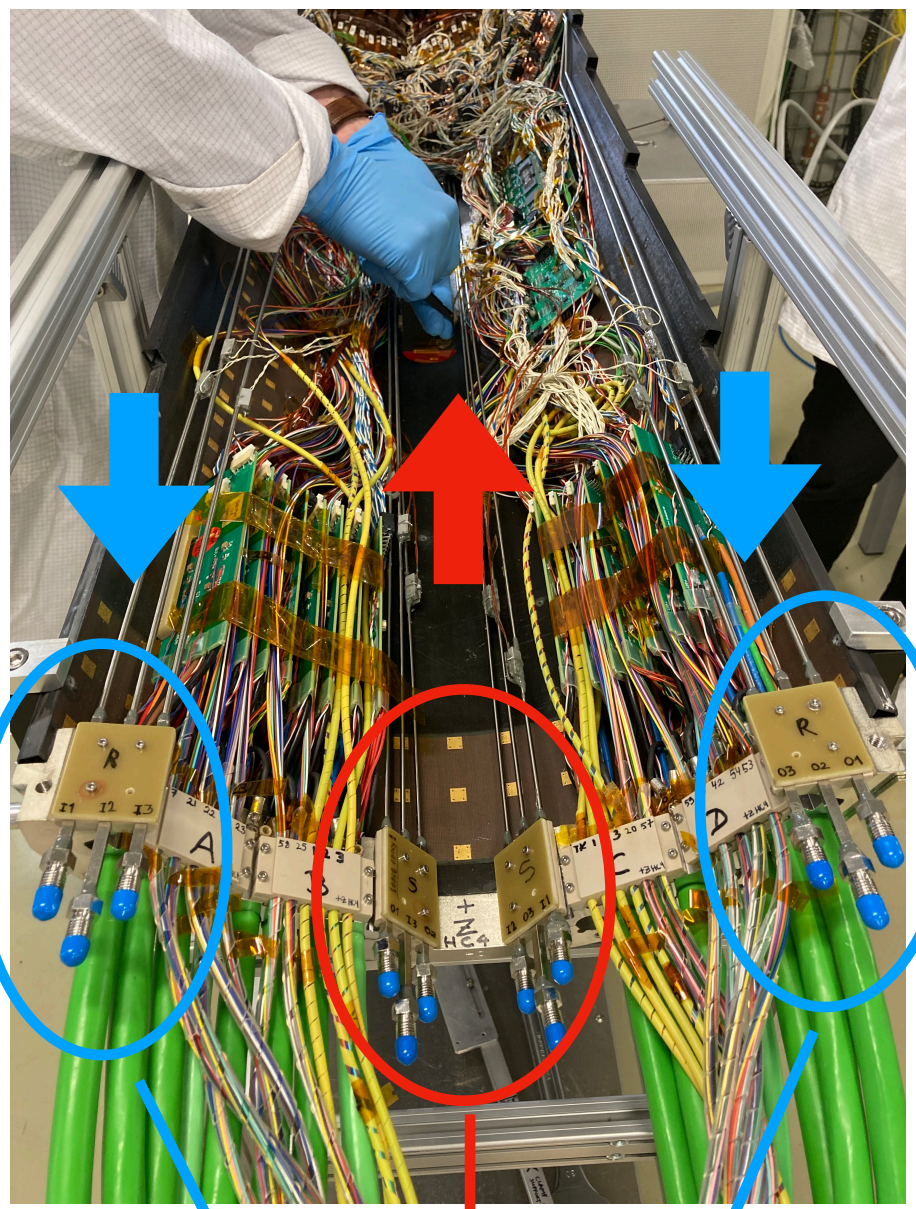
- ❑ Broke one connection during lab checkout
- ❑ Minimum mechanical torque needed to break off the fixed nut
- ❑ Risk was high to damage other connections during handling
 - ❑ Total 24 CO₂ inlet connections in Forward Pixel
- ❑ **The plan was to consolidate all the connections to ensure operational stability**

Rotating VCR nut
at end flange



Custom VCR
fitting solution

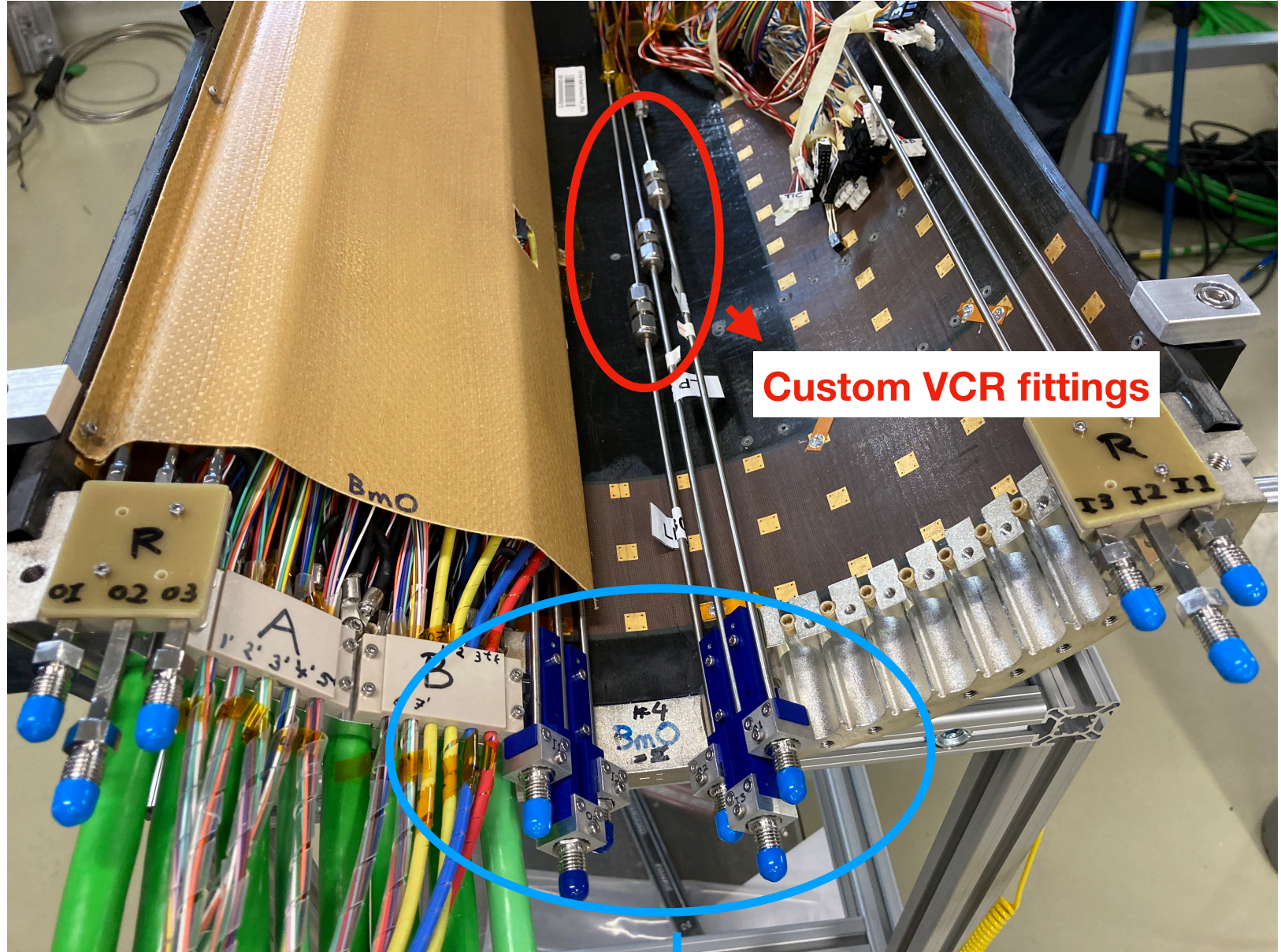
Cooling Repair



Cooling Inlets

Cooling Outlets

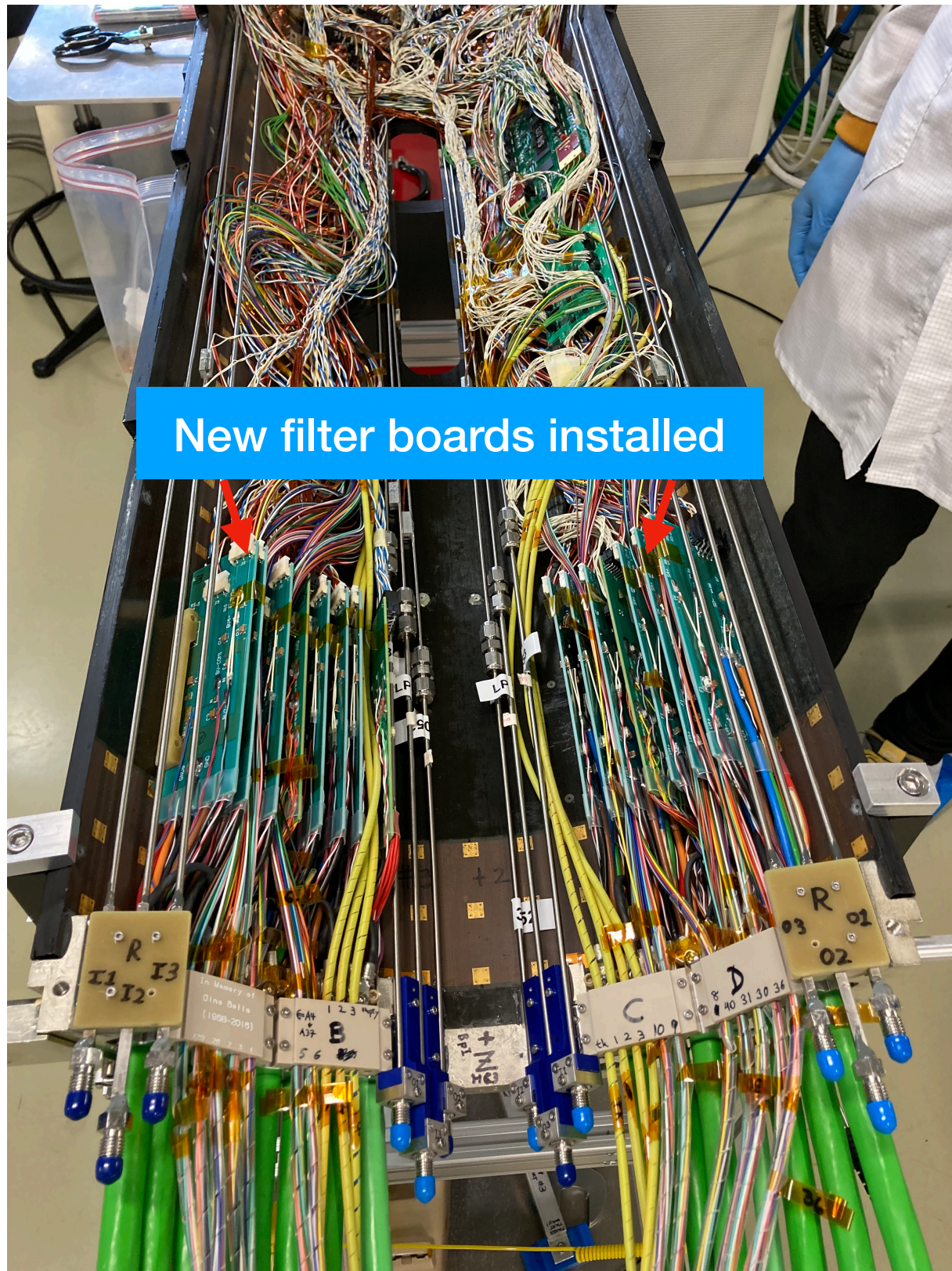
This is 1/4 th of FPix



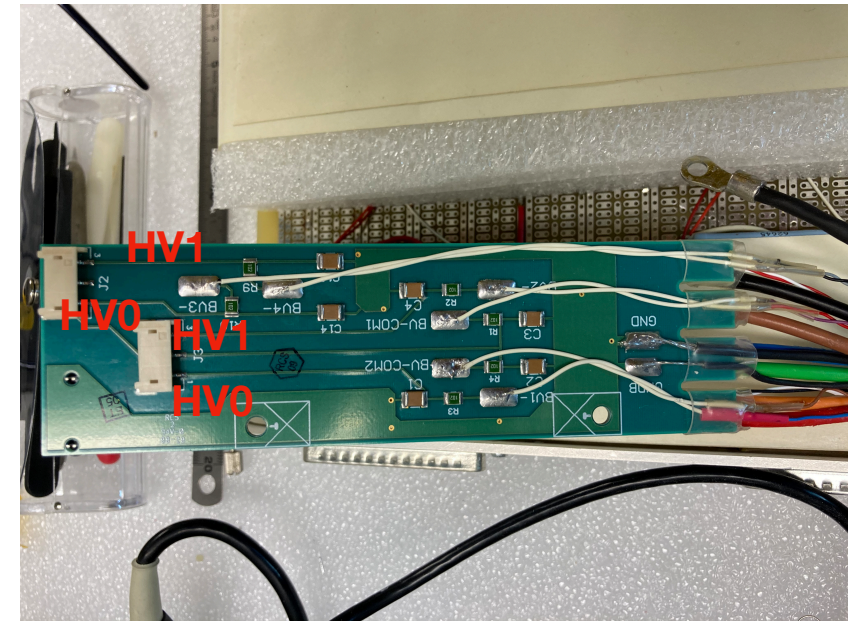
Custom VCR fittings

Newly installed supply inlets with redesigned mounts

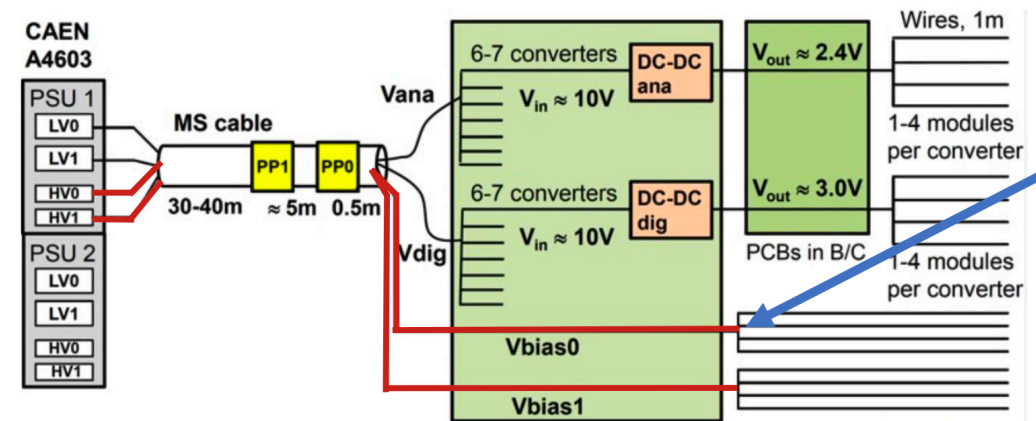
FPix Filter Boards



New board



4 independent HV lines
instead of two per power group

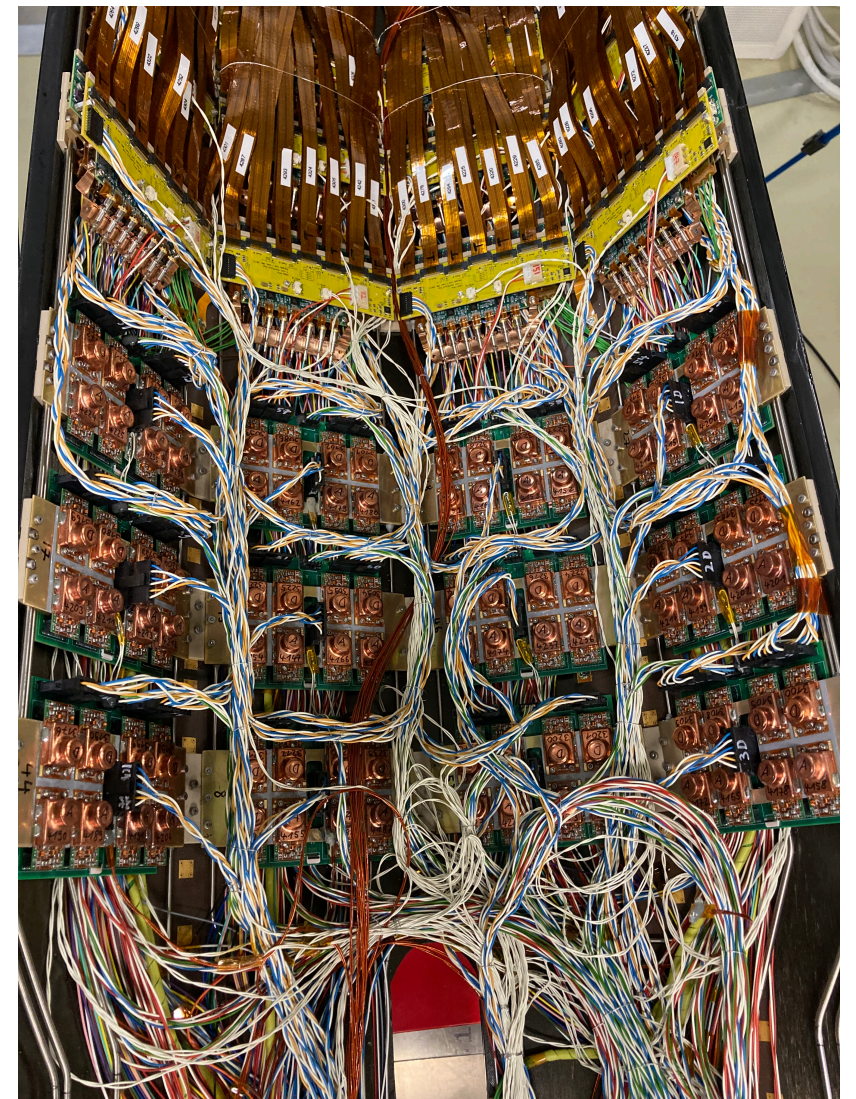


To better match the LV/HV granularity!

DCDC Converters

- New set of DCDC converters produced with the revised ASIC (FEASTv2.3)
- Fixed the failure mechanism in disabled state

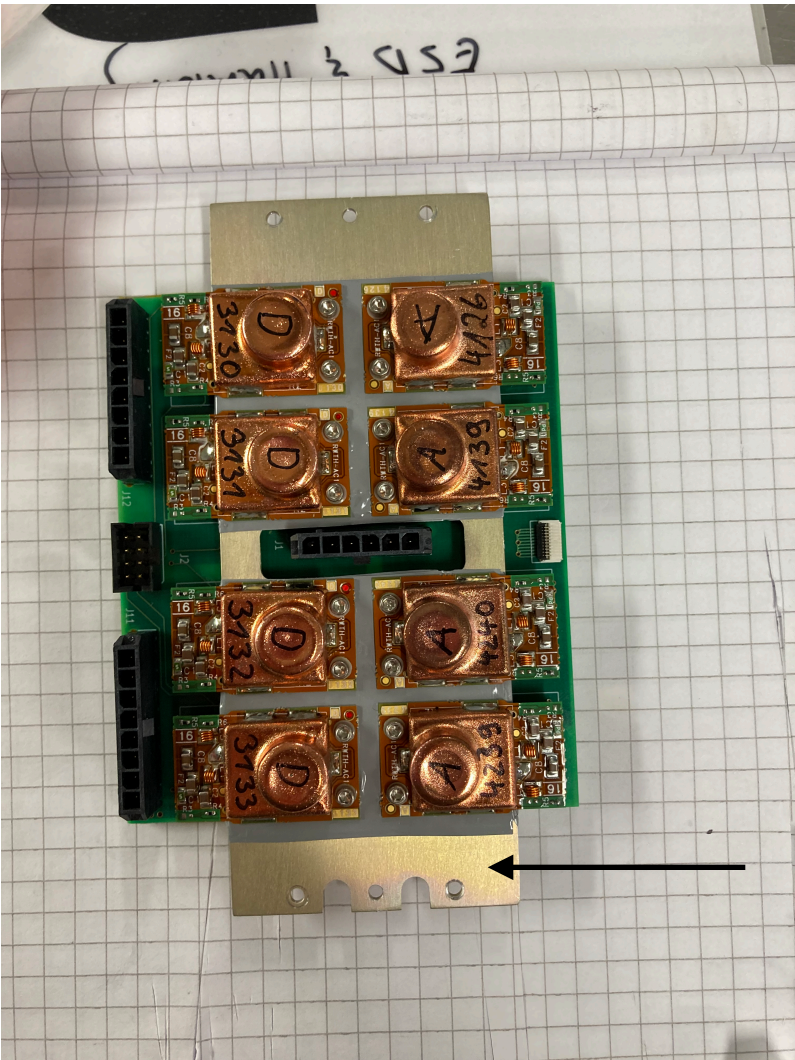
Type	Required
2.4 V (= Analog)	608
3.3 V (=Digital, BPix)	320
3.5 V (=Digital, FPix & BPix L2)	288



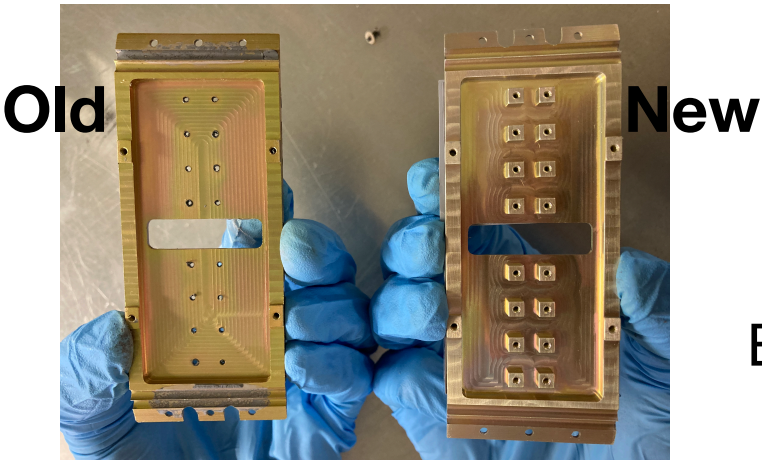
Installed 1216 new converters for Run3 detector

Other refurbishment

FPix Cooling Bridge Replacement



Aluminum Cooling Bridge

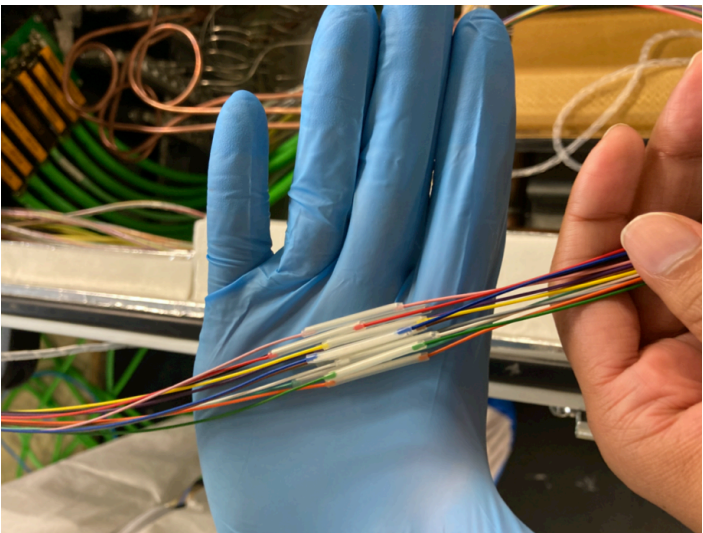


Better thread better thermal contact between DCDC and cooling bridge

Replace broken MTP connector



Splice the fiber bundle and replace with a new MTP



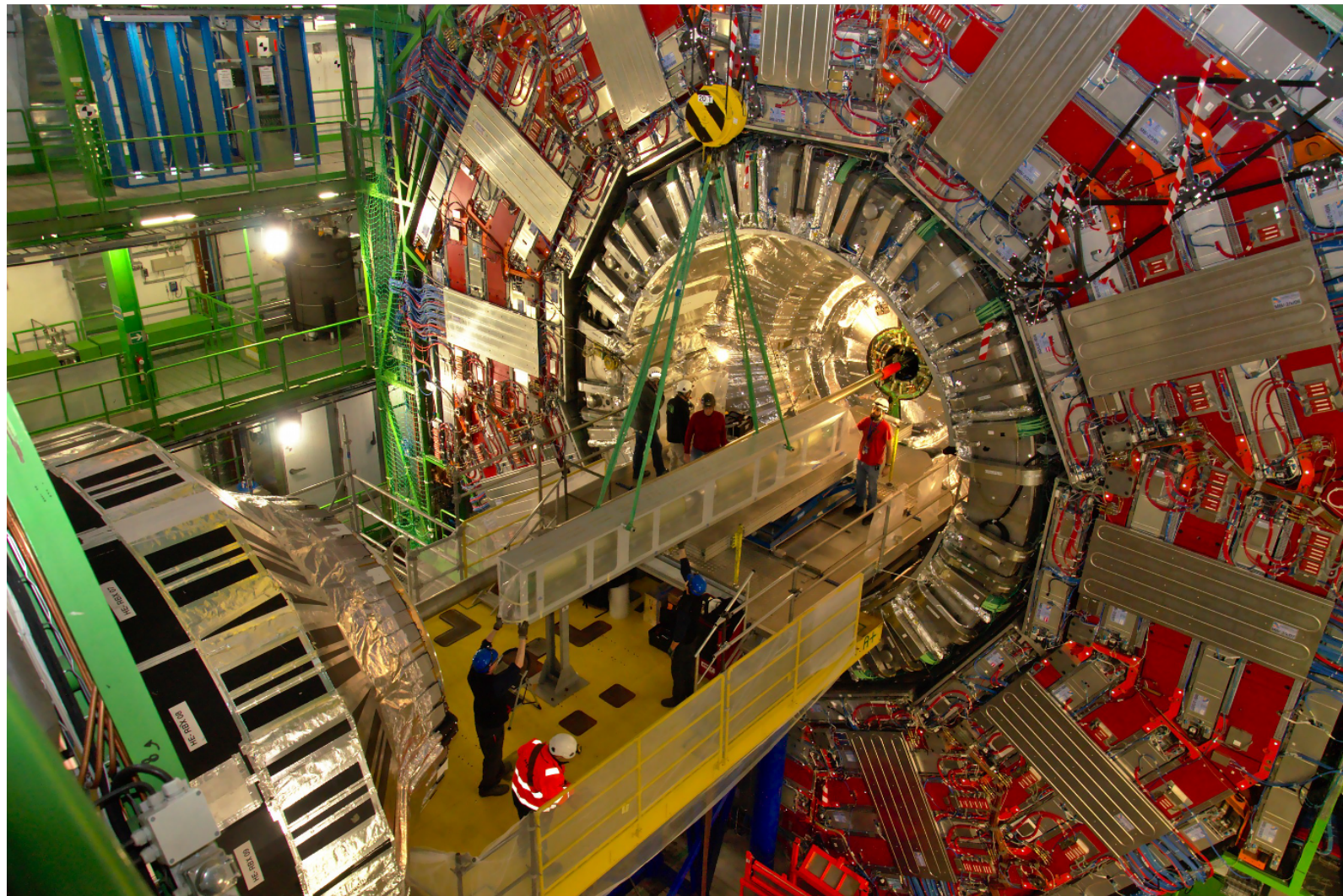
Detector Testing in Cleanroom

- ❑ Warm and cold tests are performed in the surface lab
- ❑ Best place to figure out issues before going for the cavern installation
- ❑ Utilize service infrastructure for CO₂ cooling and powering in the lab



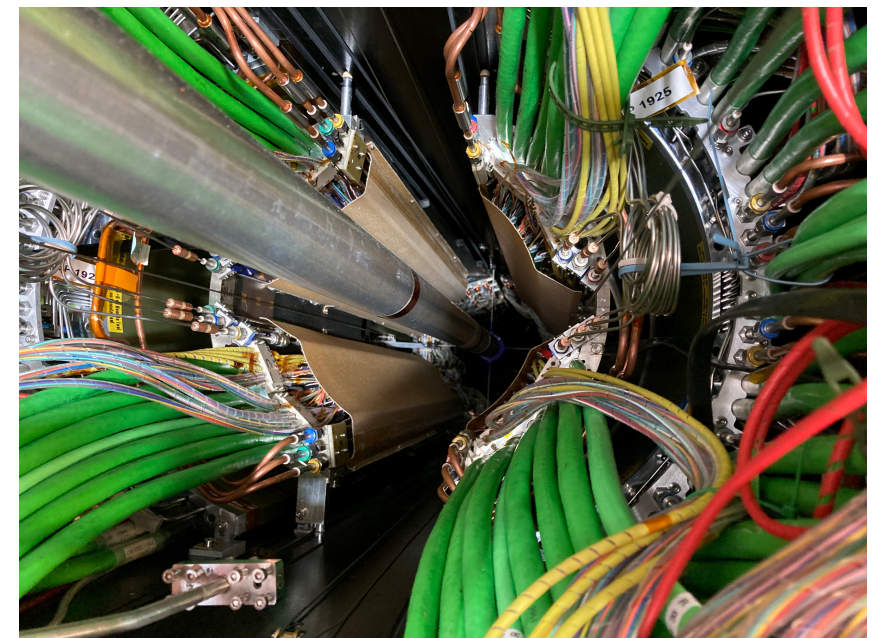
Test Test and Test!

Pixel Installation and Commissioning



Installed the detector
inside the cavern
during summer 2021

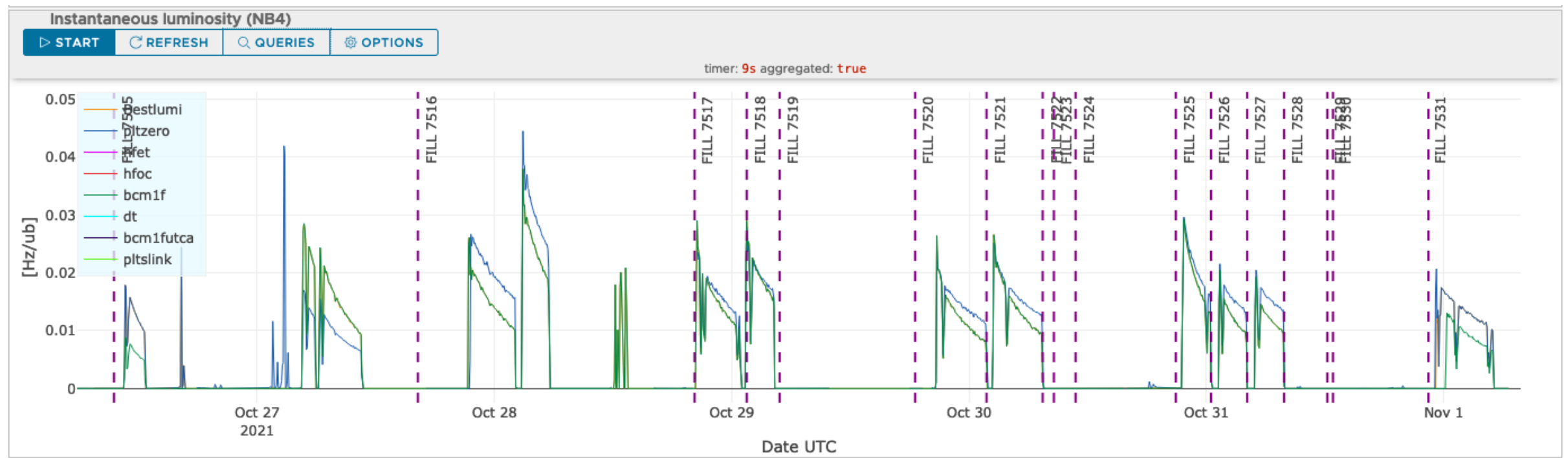
Detector was fully
commissioned after
re-installation without
any major issues



LHC Pilot Beam Test

Stable Beams almost after 3 years!

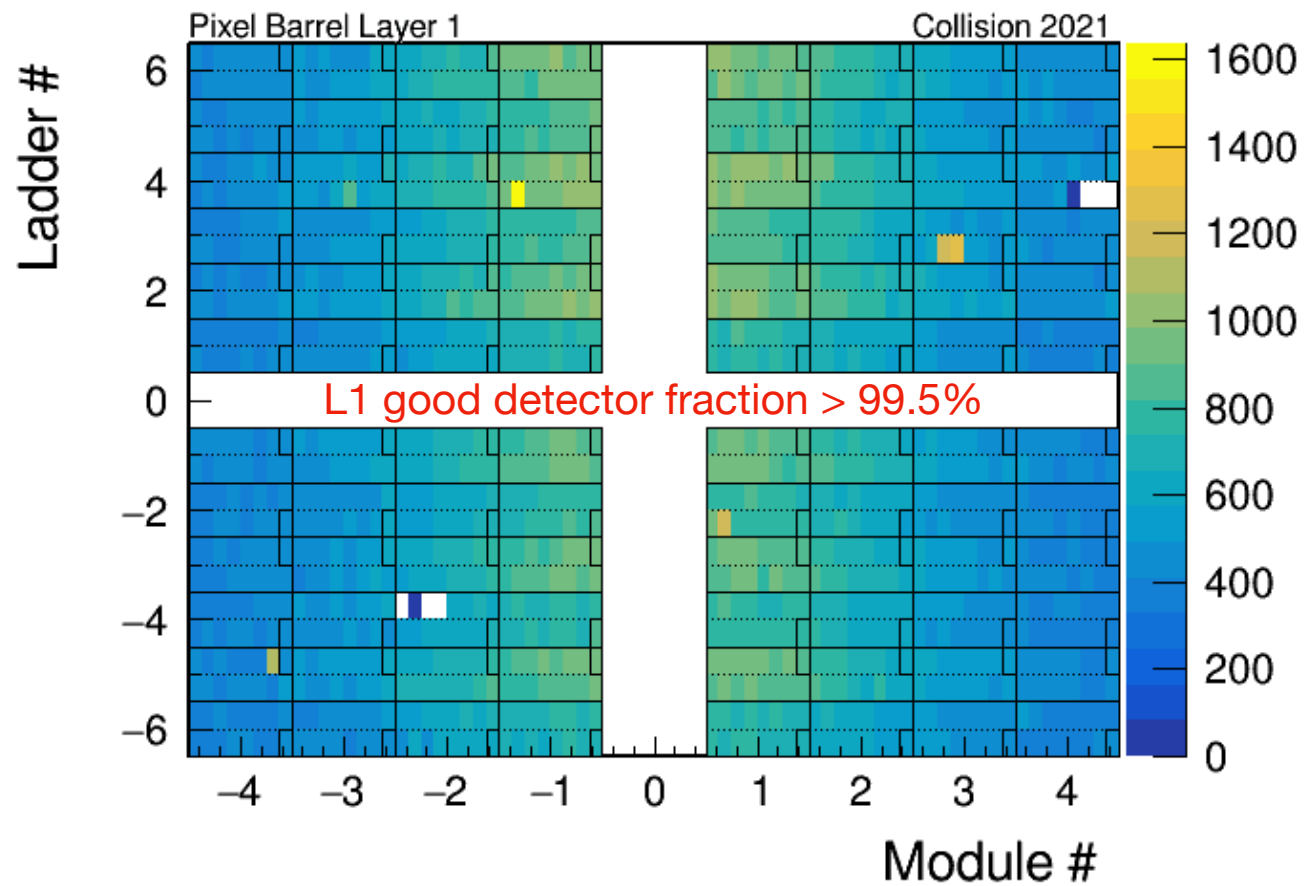
October 2021



- Very stable operation during the pilot beam test
- Pixel collected good quality data
- Time-aligned the detector using collisions
- Detector is optimally calibrated and ready for Run-3

Pilot Beam Test: Pixel Performance

Layer 1 occupancy during pilot beam

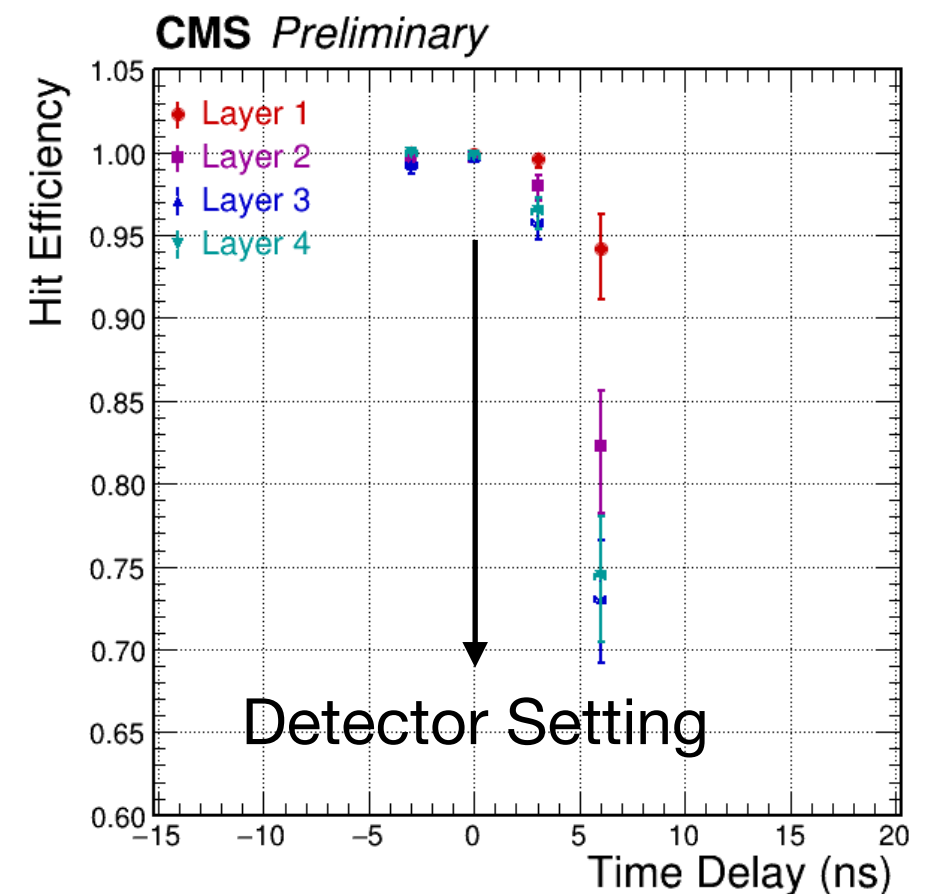


Active Detector fraction:
BPix 99% and FPix 98%

New Layer 1 and rest of
the detector placed at
optimal delay

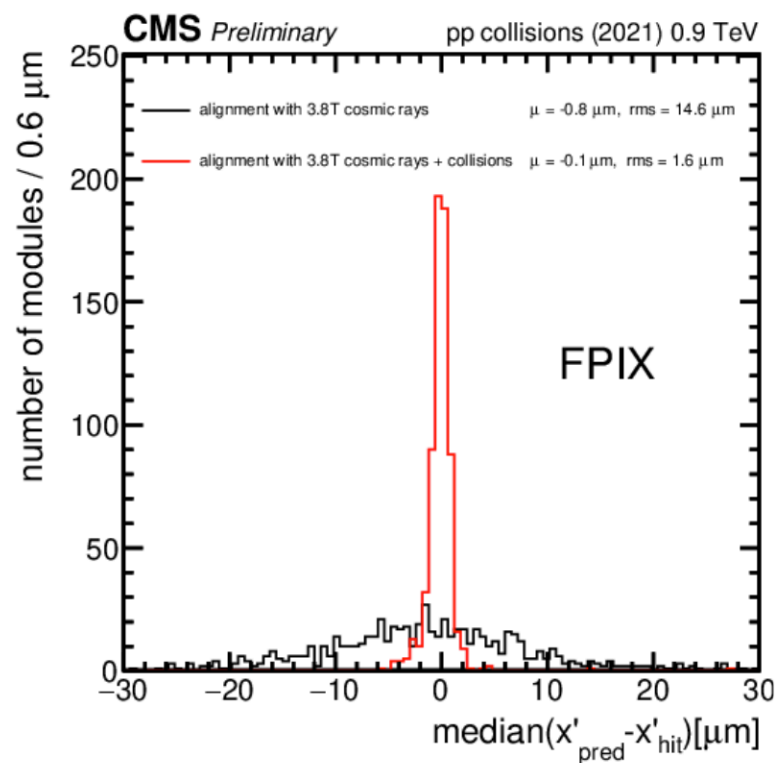
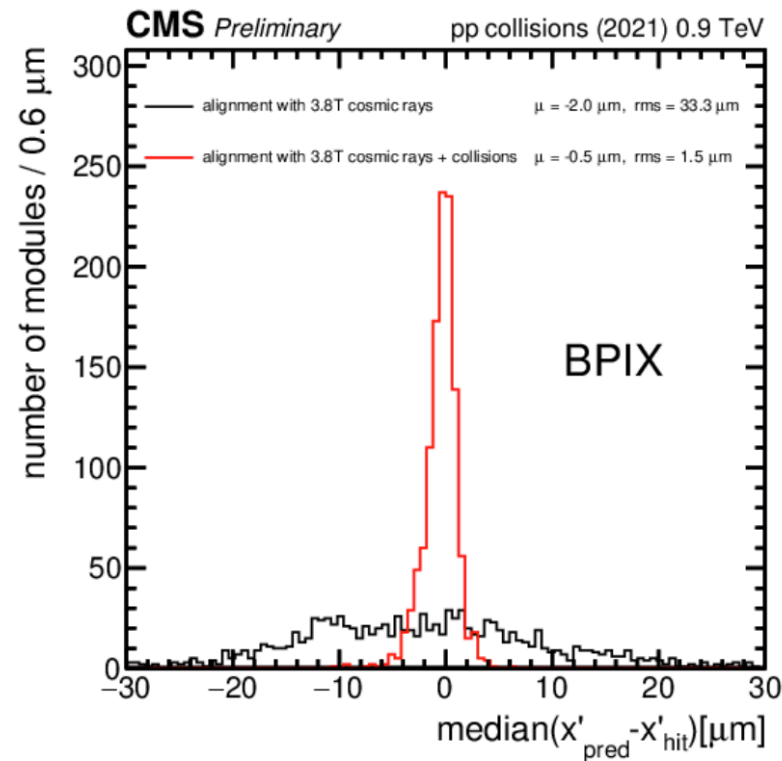
Utilized new TBM feature to set a
relative delay between L1 and L2

Coarse Timing Scan



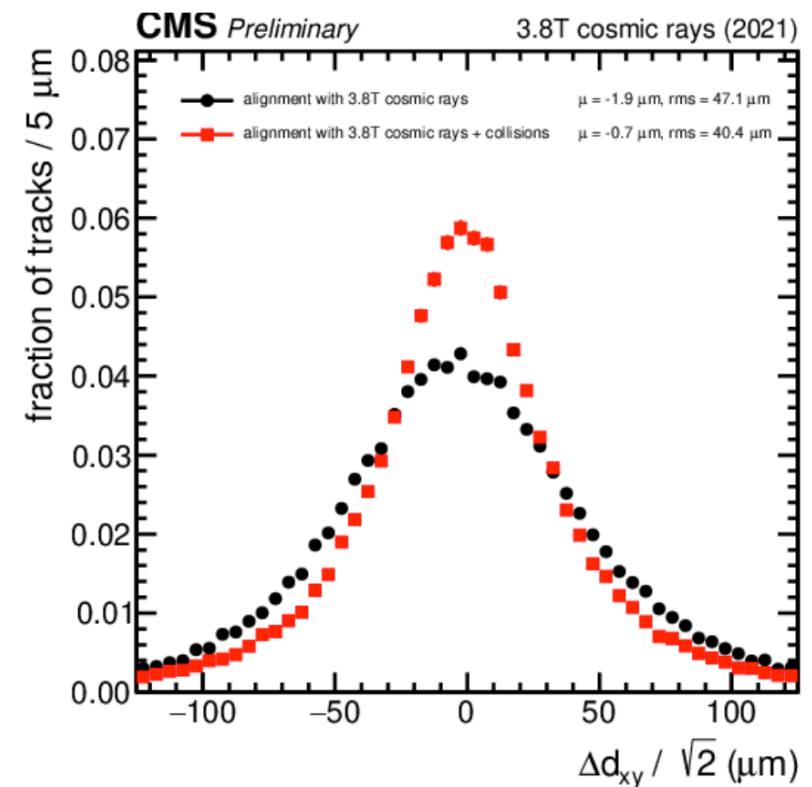
Pixel Alignment

Refurbished detector newly realigned after the installation



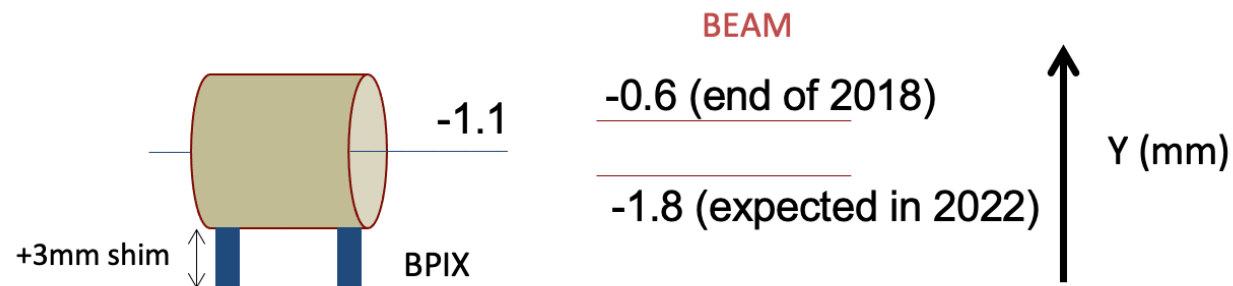
Improved
residuals with
collision data

Impact Parameter



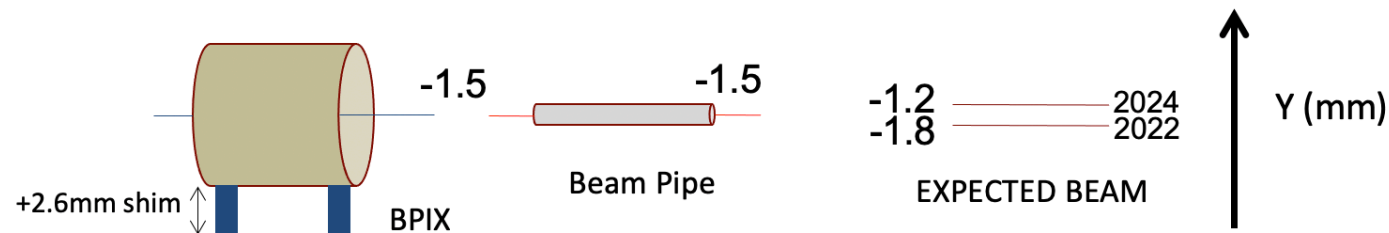
Pixel and Beam Pipe Position

Pixel Position at the end of 2018

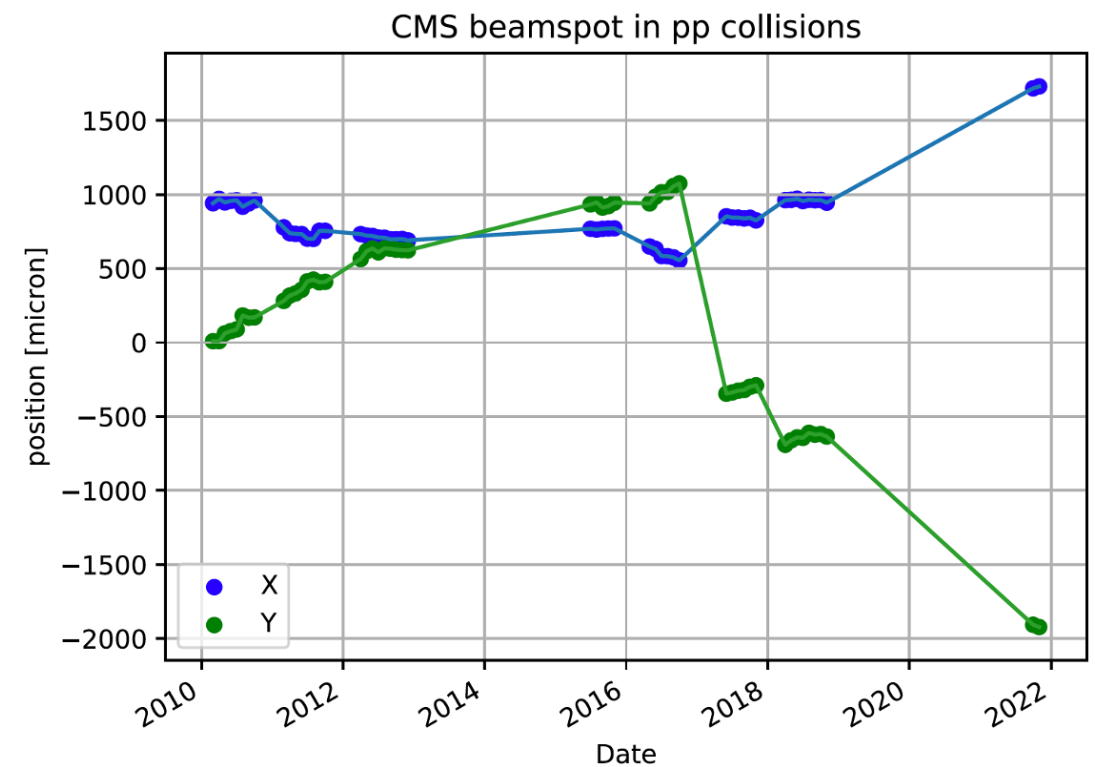


LHC beam drifts up in Y direction with time

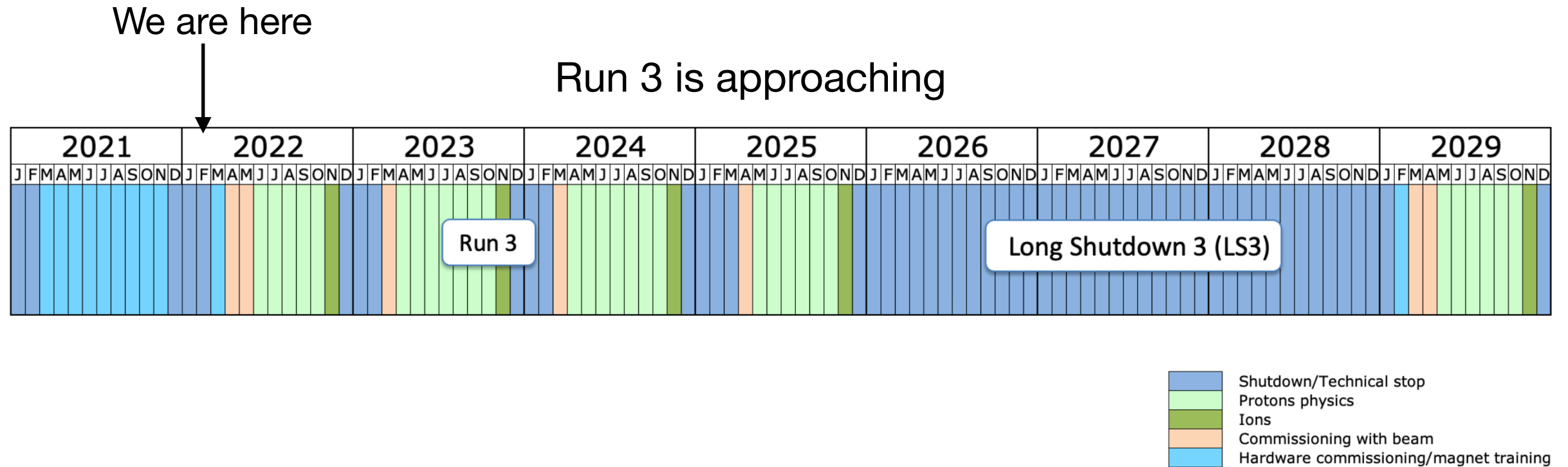
Where we wanted it for Run3 after re-installation in 2021



2021 pilot beam alignment data suggest that Pixel is perfectly positioned in Y coordinate



Summary and Outlook



- Detector refurbishment during the Long Shutdown 2
- Installed and commissioned the detector in Summer 2021
- Active detector fraction $> 99\%$ for BPix and $> 98\%$ for FPix
- Successfully participated during the LHC pilot beam in Oct 2021
- Pixel detector is in significantly improved state at the beginning of Run3