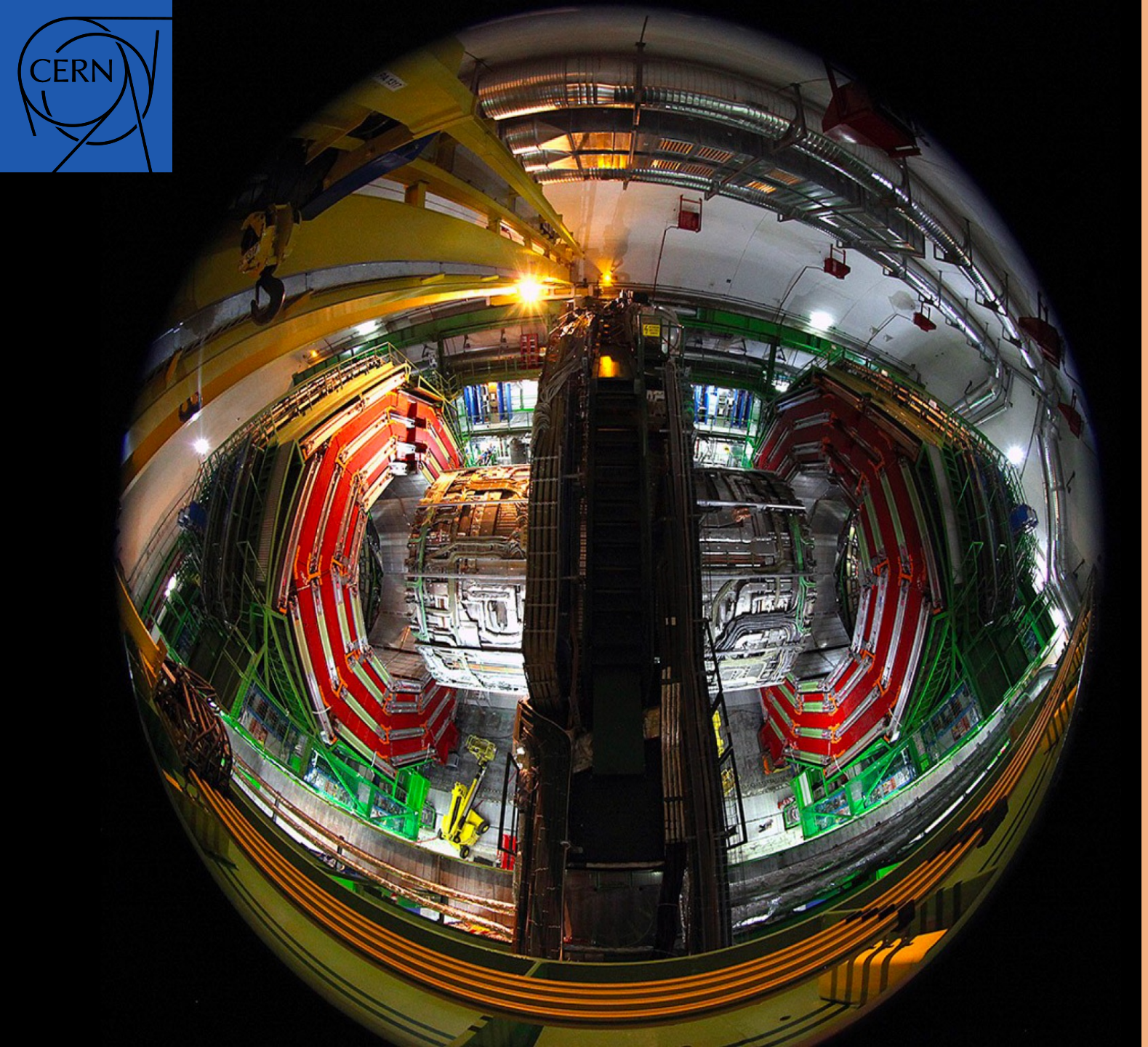


Phase 1 Upgrade of the CMS Hadron Barrel Calorimeter

Candan ISIK

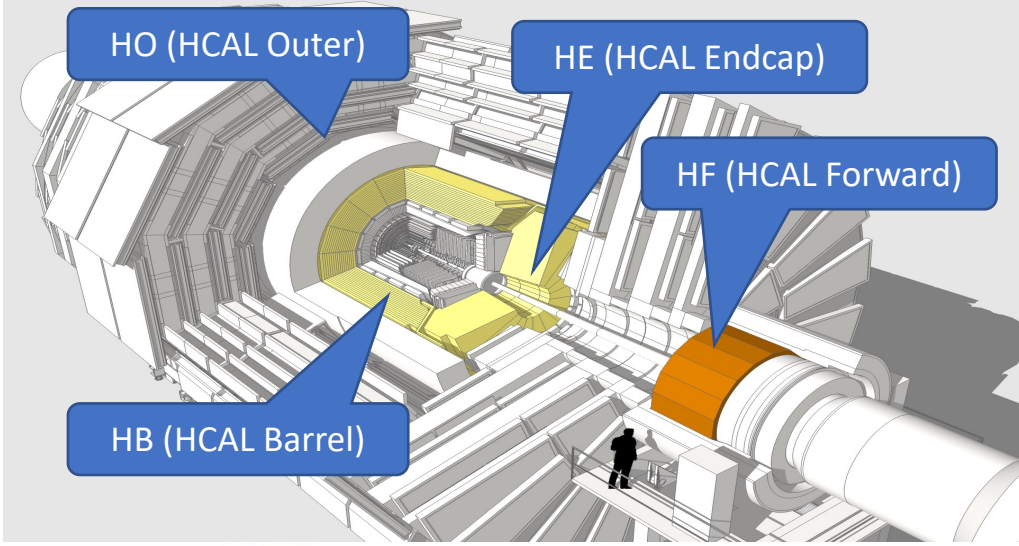
The 16th Vienna Conference on Instrumentation

21-25 Febuary, 2022

Outline

- Motivation
- Installation
- Commissioning
- Operation
- Conclusion

Motivation: HCAL Upgrades Timeline



HF & HEHB Phase 1 Back-end installations and operations

HO VME-to-uTCA Back-end upgrade

HB Phase 1 front-end installation

LHC

HL-LHC

Run 1 | Run 2 | Run 3 | Run 4 - 5...

LS1 | EYETS | LS2 | EYETS | LS3

7 TeV | 8 TeV | 13 TeV | 13.6 TeV | 14 TeV

splice consolidation
button collimators
R2E project

cryolimit
interaction
regions

Diodes consolidation
LIU installation
Civil Eng. P1-P5

HL-LHC installation

2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2040

experiment beam pipes

ATLAS - CMS upgrade *phase 1*

ALICE - LHCb upgrade

ATLAS - CMS HL upgrade

75% nominal Lumi | nominal Lumi | 2 x nominal Lumi | 2 x nominal Lumi | 5 to 7.5 x nominal Lumi

30 fb^{-1} | 190 fb^{-1} | 460 fb^{-1} | integrated luminosity 3000 fb^{-1} 4000 fb^{-1}

HF Phase-I Front-end and HE Demonstrator "HEP17"

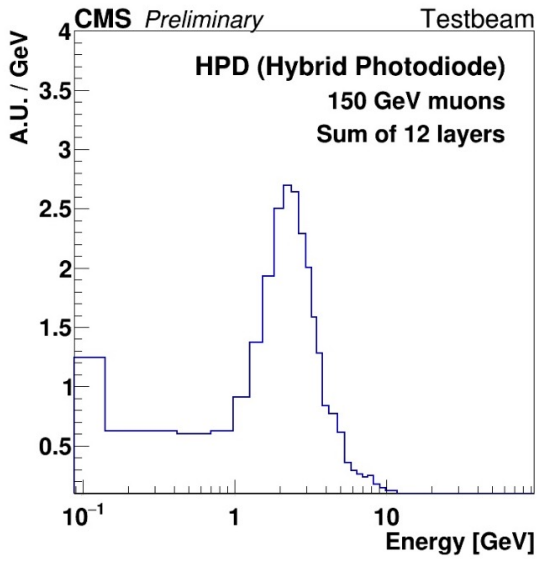
HE Phase 1 Front end

Endcap and Barrel Calorimeter Phase 2

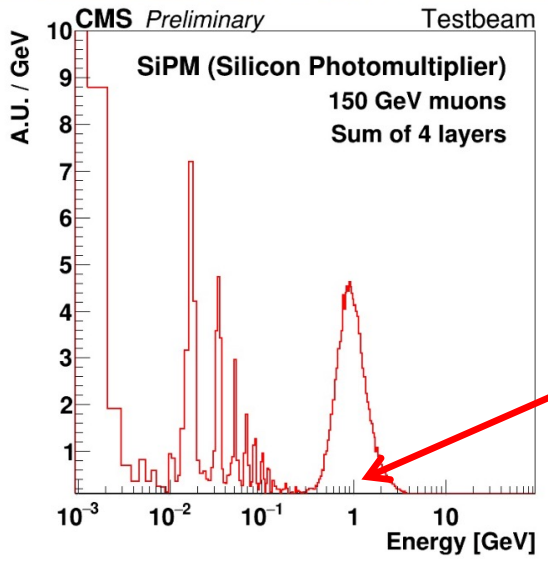
Motivation: HPDs to SiPMs

1. Replace HPDs (hybrid photodiodes) with SiPMs (silicon photomultipliers)

HPDs to SiPMs
- Higher gain
- Higher PDE
- Lower operating voltage



Calorimeter response to muons from HE prototype wedge at H2 beam line



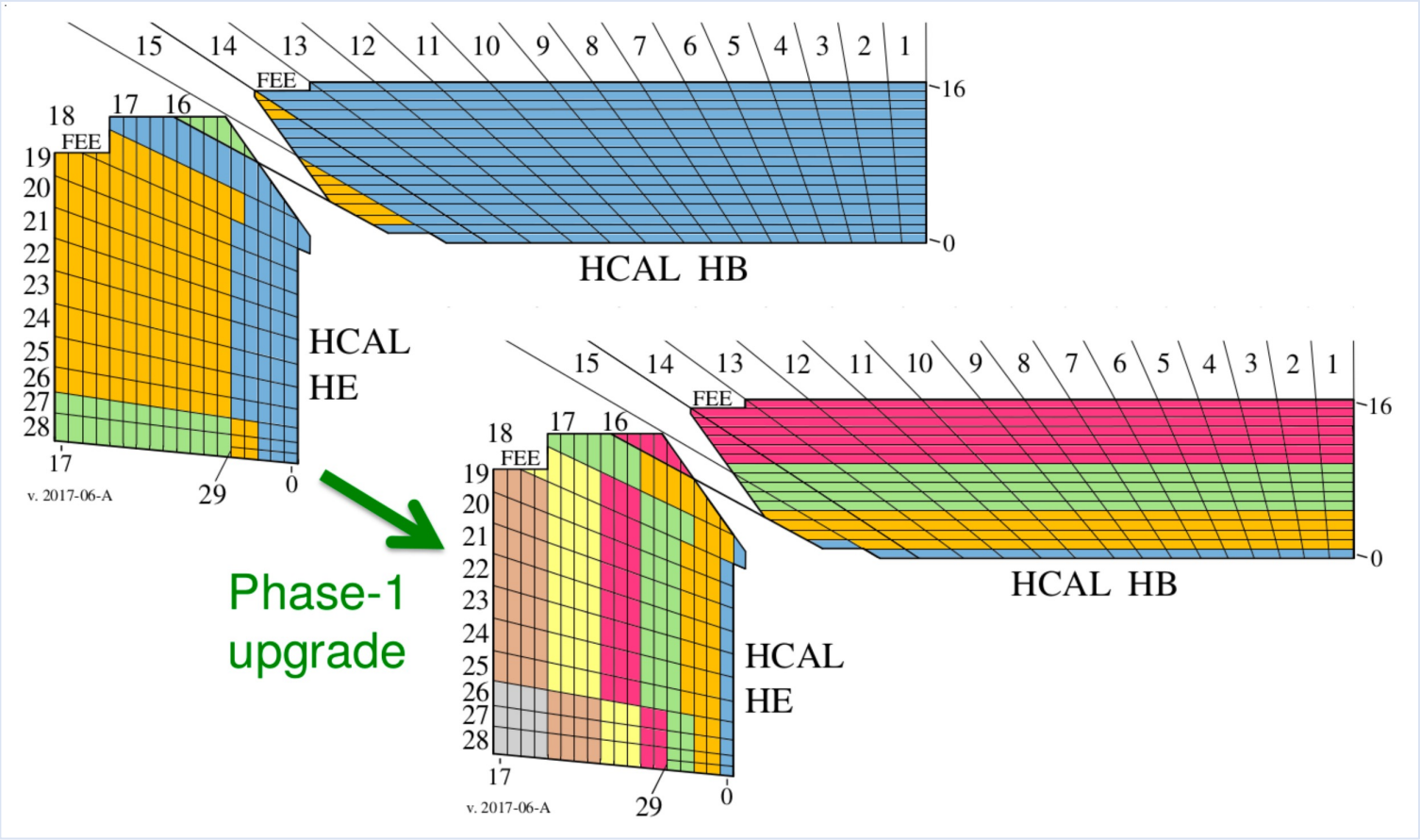
Higher gain provides strong electrical signals that reduce the importance of electrical noise and allow for signal splitting for TDC measurements.

Greatly improved resolution!

Motivation: Depth Segmentation

2. Improve longitudinal segmentation

- **Mitigate radiation damage to HE and HB scintillator (better calibration of depth-dependent effects)**
- **Physics benefits, such as long-lived particle detection (new for Run 3!)**



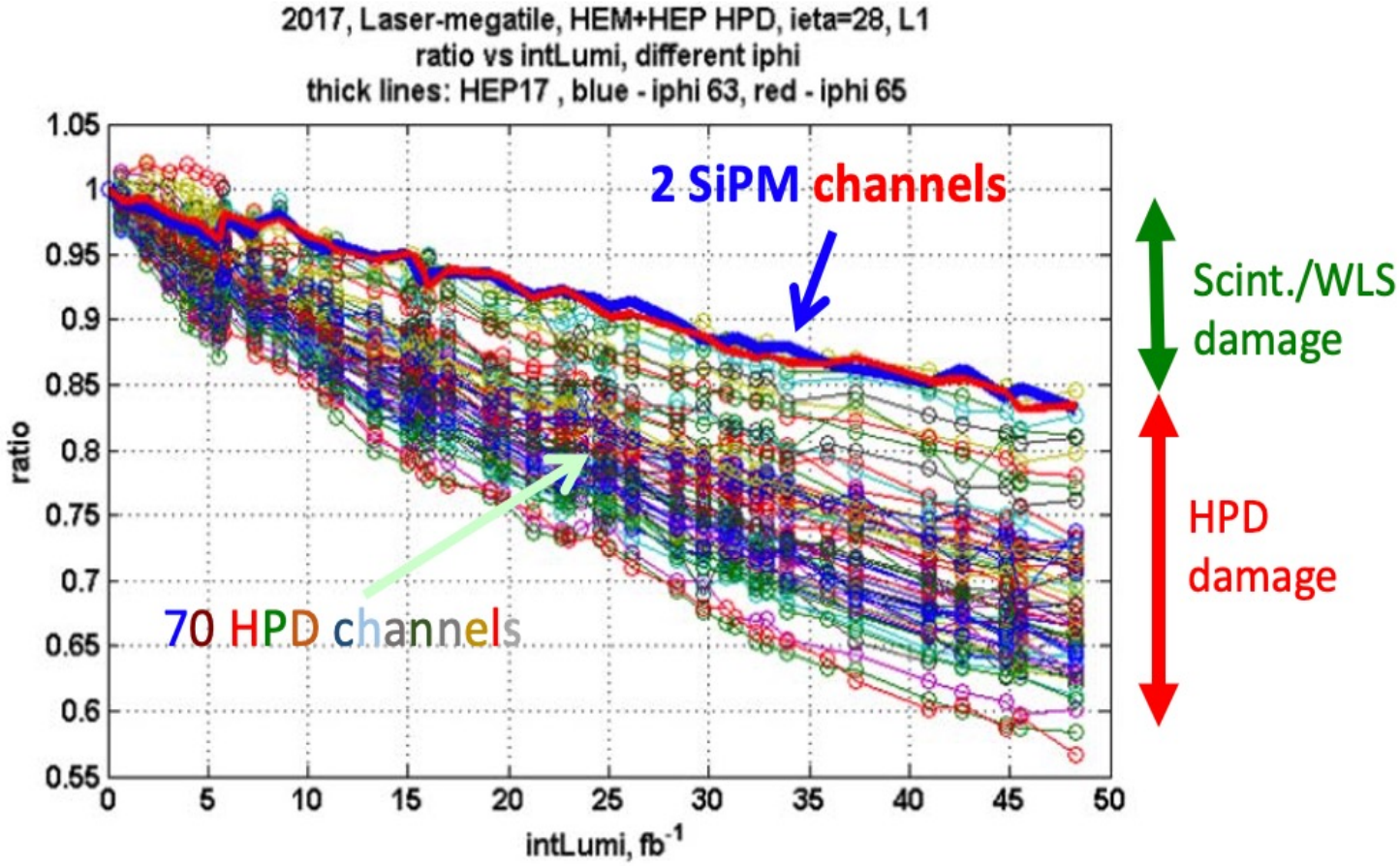
Maintain good physics performance for hadronic jets and missing transverse energy.

Motivation: Radiation Tolerance

3. Withstand expected radiation dose

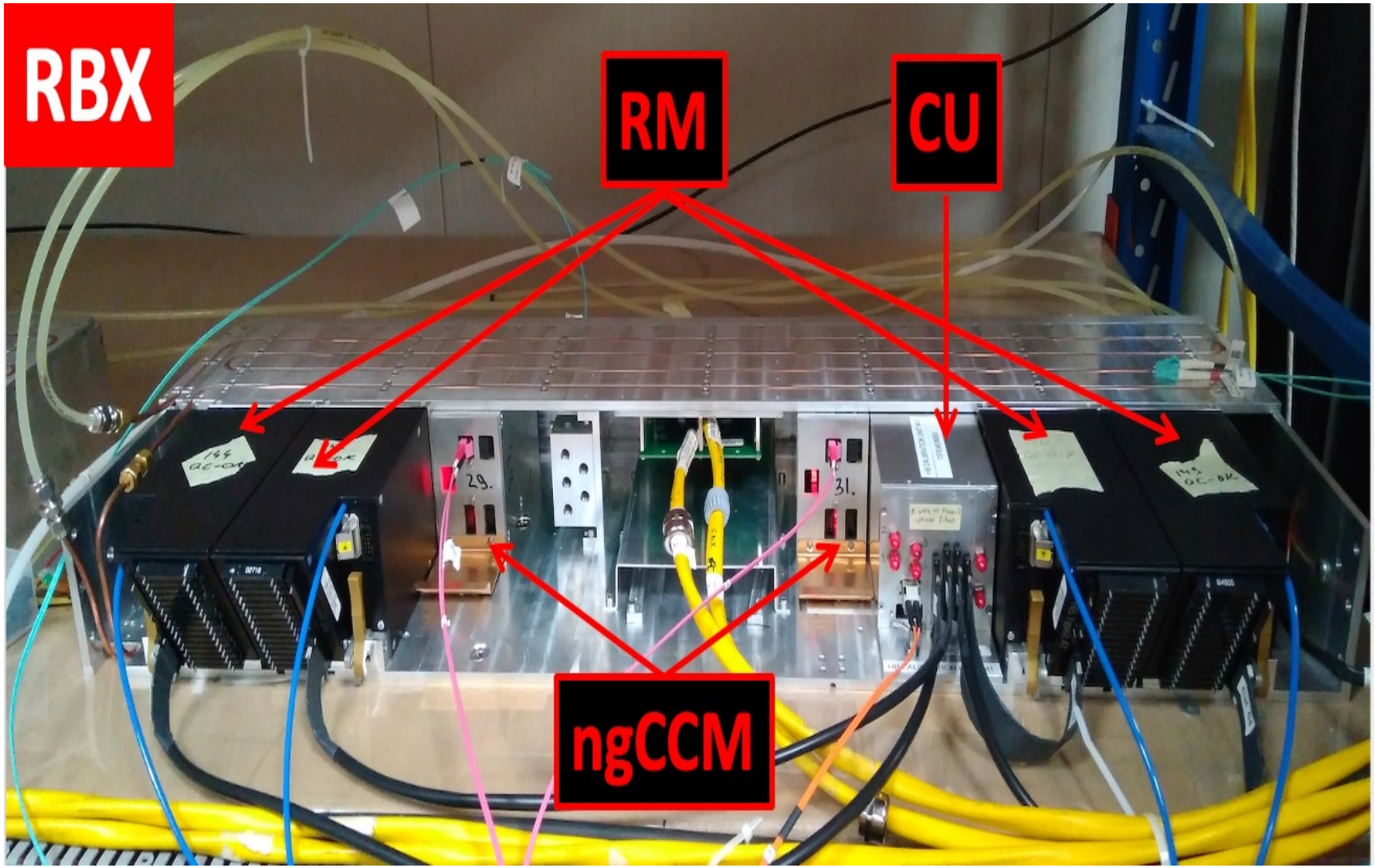
- HE **response loss** vs. integrated luminosity in 2017 for channels at:
  - same eta (ieta=28)
  - same Layer (L1)
  - different phi

- The signal loss for two scintillator tiles readout by SiPMs is smaller compared to scintillator tiles readout by HPDs.



Front-end electronics (FE) for the HB upgrade

- FE are installed on detector, within the Readout Box (RBX) at the edge of the HCAL absorber.

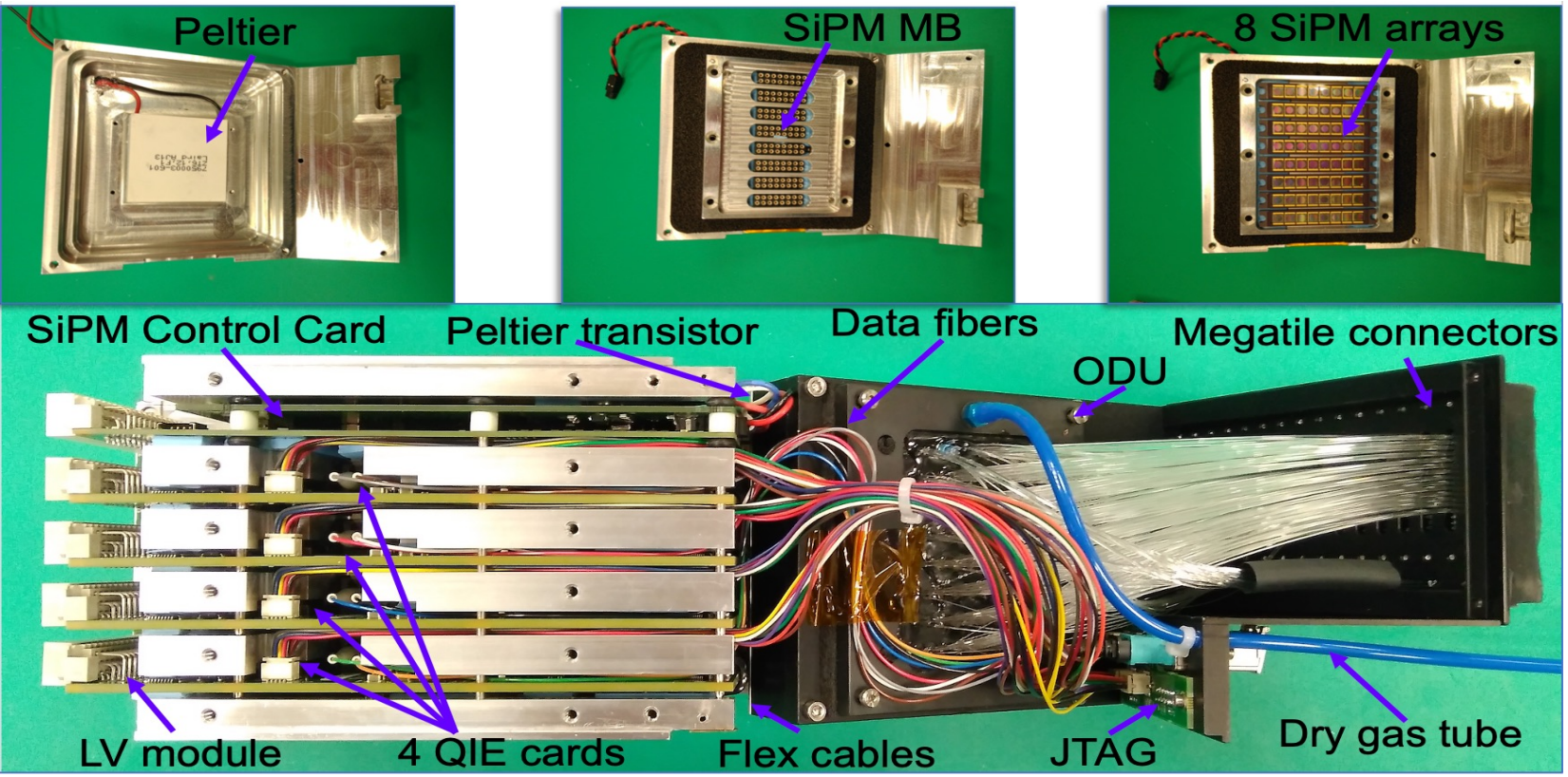


Major Components:

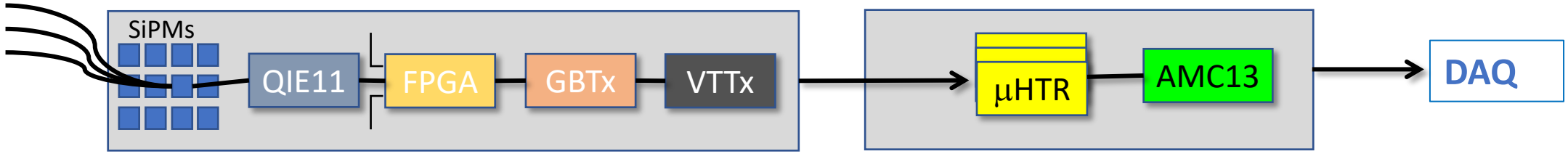
- Readout Module (RM)
- Clock Control Module (ngCCM)
- Calibration Unit (CU)

Inside an HB Readout Module (RM)

Readout Modules (RM): Decodes optical signal by transforming it into charge (fC) which is then encoded by the QIE (charge integrator and encoder) and sent off detector.

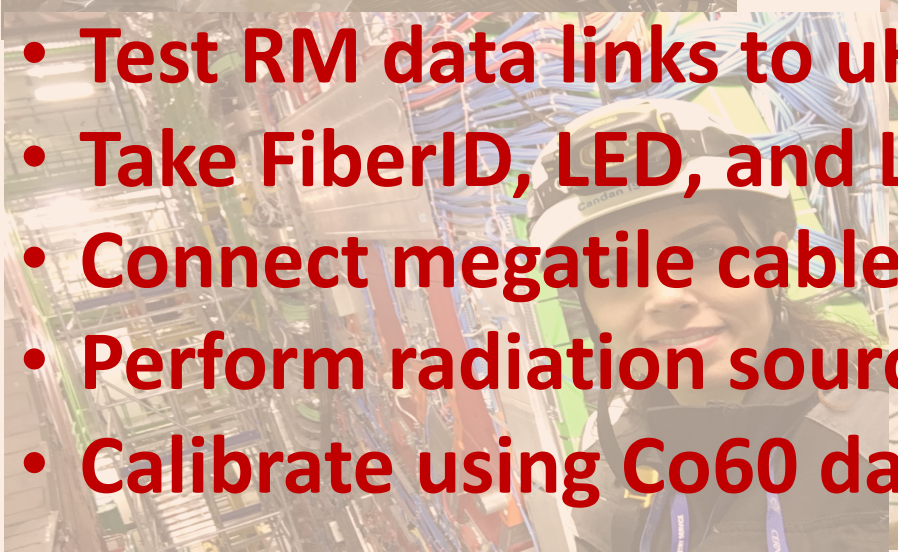


SiPMs receive the light from the calorimeter segments and converts it into electrical pulses. The electrical pulses are received on QIE boards and the digital results are transferred to FPGA. The data output to the back end is performed via a GBT chip and Versatile Link Transmitter (VTTx) residing on the QIE board.



Installation: Procedure

- Uninstall Phase 0 components from RBX.
- Install front-end electronics.
- Test control link and communication with ngCCM, RMs, and CU.
- Test RM data links to uHTRs.
- Take FiberID, LED, and Laser data.
- Connect megatile cables.
- Perform radiation sourcing scan with Co60.
- Calibrate using Co60 data.



Installation: Installation of HB Electronics

HB readout boxes are accessed from inside the **VacTank**

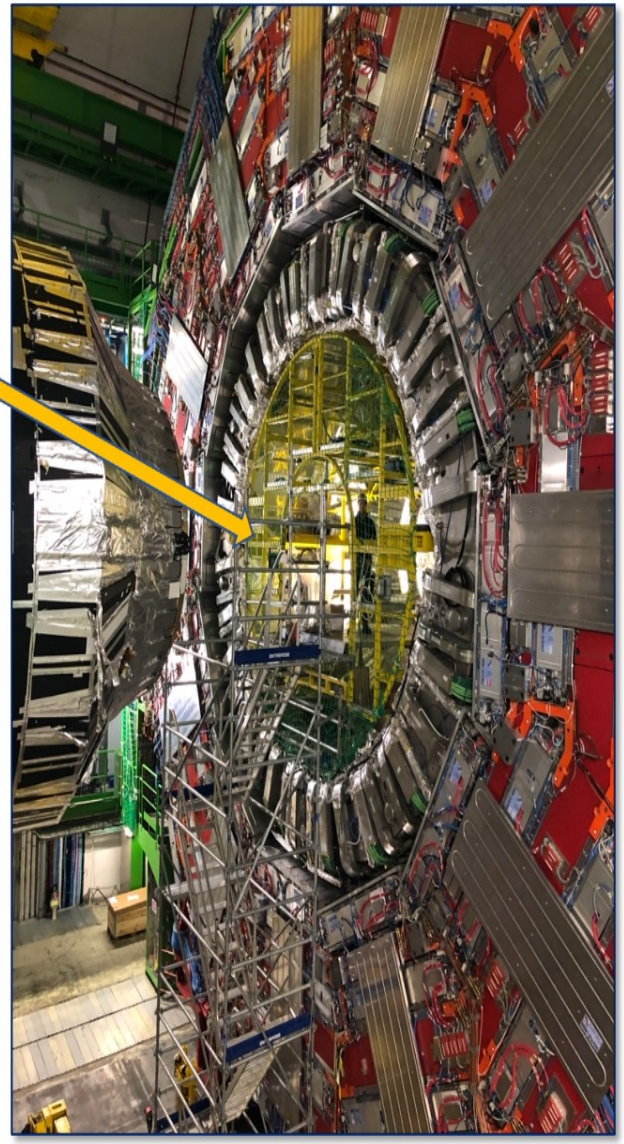
Access to VacTank via stair scaffold, "access tower"

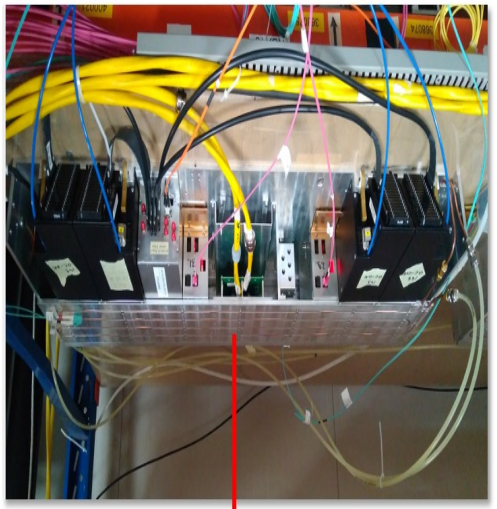
Work inside the VacTank using secured **Surkov Frame**

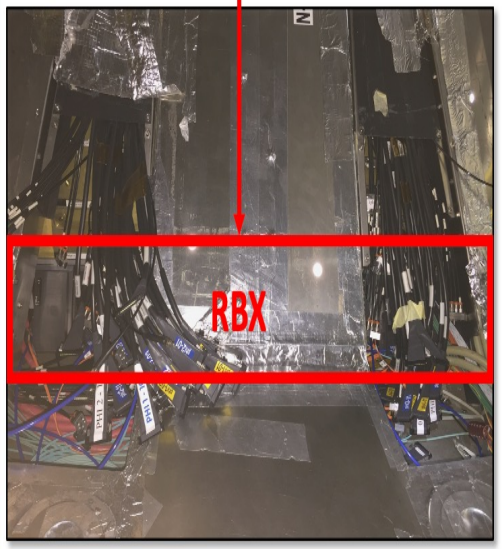
- Enough space for about 2 teams consisting of 2 people each per end
- Possible to work on minus and plus side in parallel

36 RBXs (18 per end)

- 144 RMs, 72 CCMs, 36 CUs, ~ 2500 MegaTile Connections





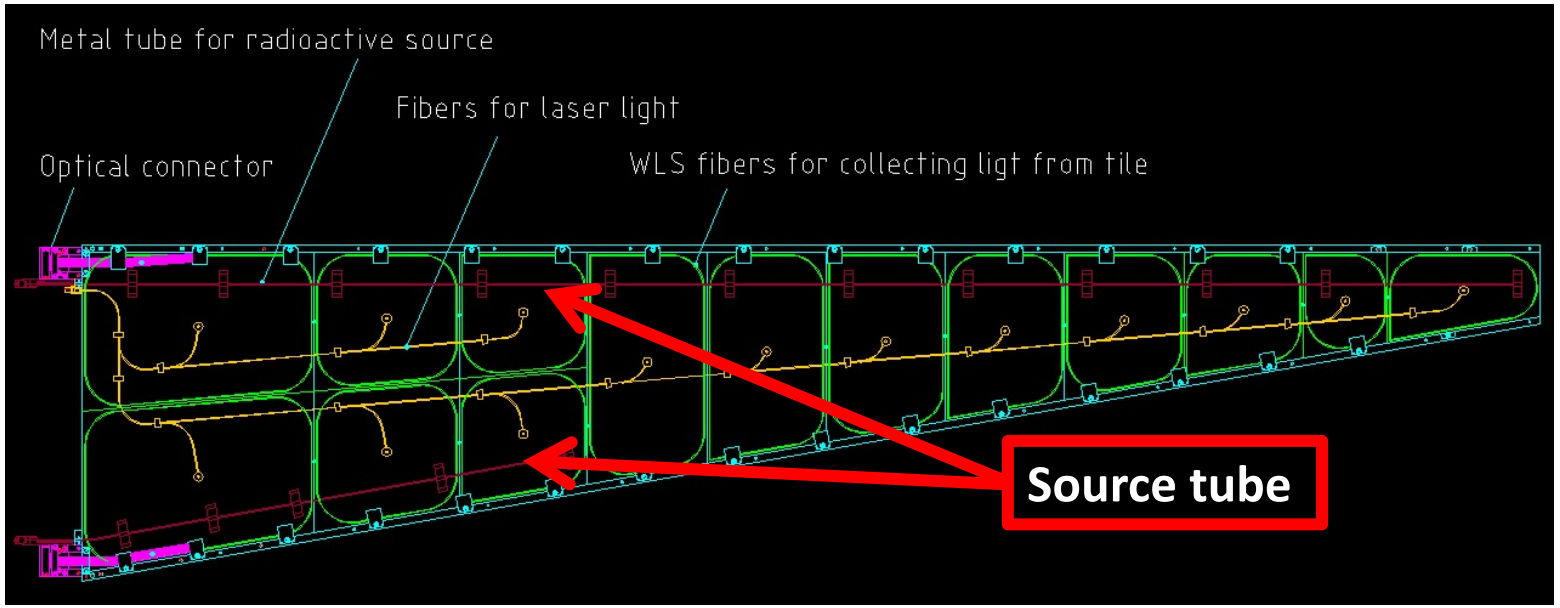


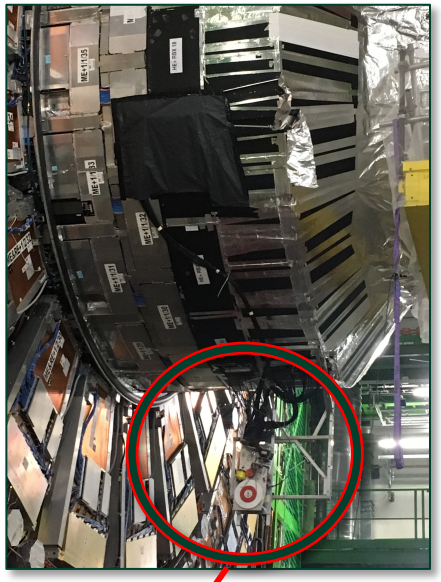
RBX is mostly **blocked** by Tracker cable tray

2 access panels to reach left and right side of RBX

Very challenging to see what you are doing inside of the RBX

Commissioning: Co60 Wire Source Calibration



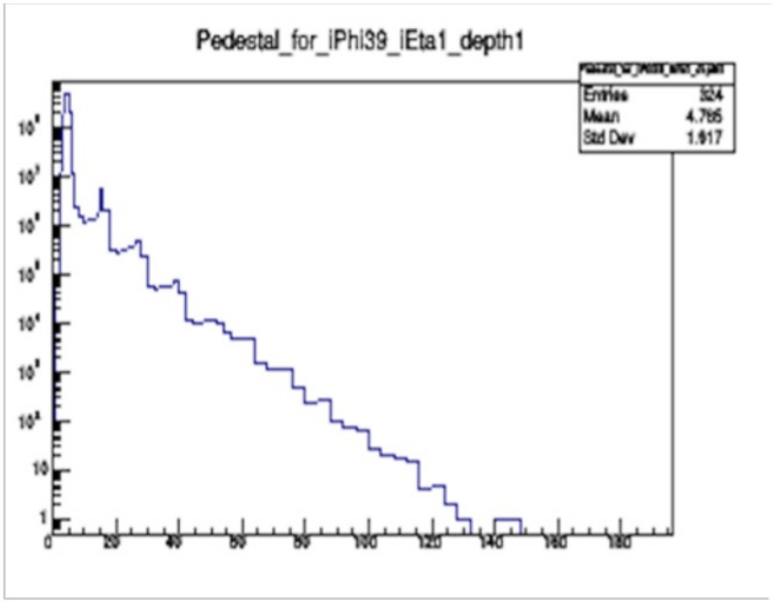


- Co60 data taking - “sourcing” - is data taking locally within HCAL with uHTRs in a special “histogramming mode”
- Co60 is used as a source of signal. It is delivered to individual HCAL tiles using a motor and a wire. Co60 is soldered at the end of the wire
- The wire travels inside HCAL along plastic tubes

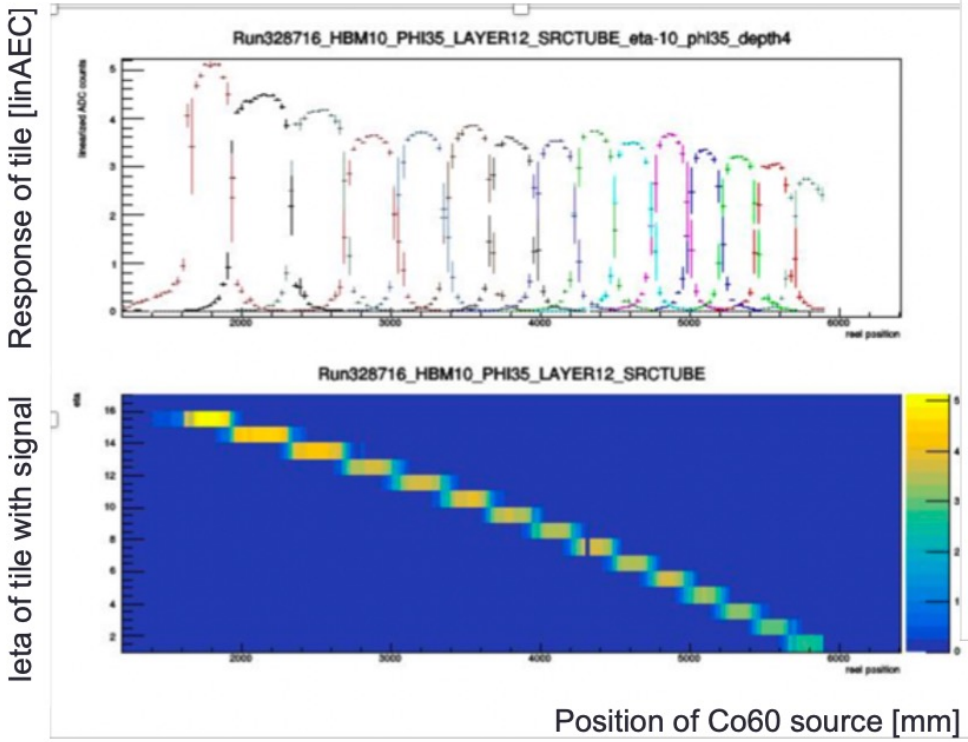
“Sea Monster”

Commissioning: Co60 Calibration

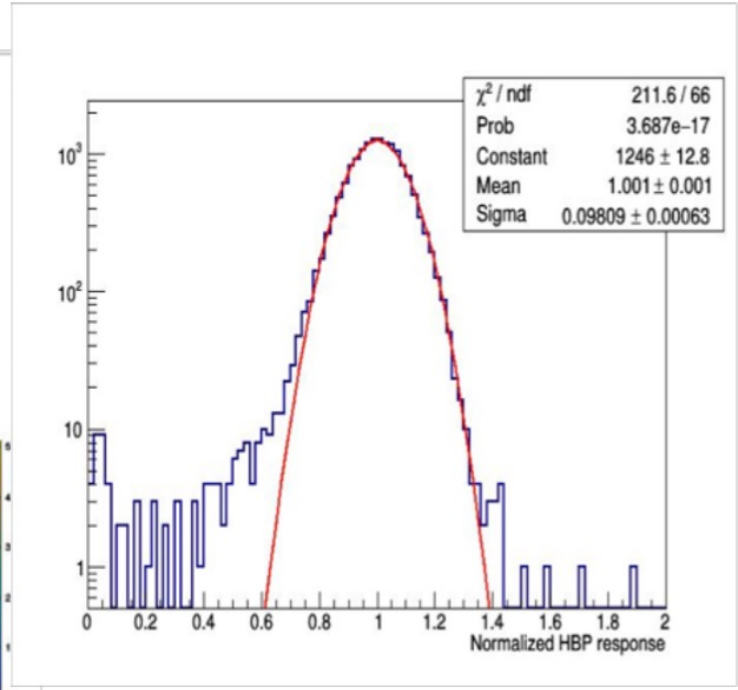
Photo-electron peaks visible in the histogramming mode



Signals with Phase1 (SiPMs) are much stronger than with Phase0 (HPDs)



Normalized signals from HB+ tiles



Two-fold role of Co60 calibration:

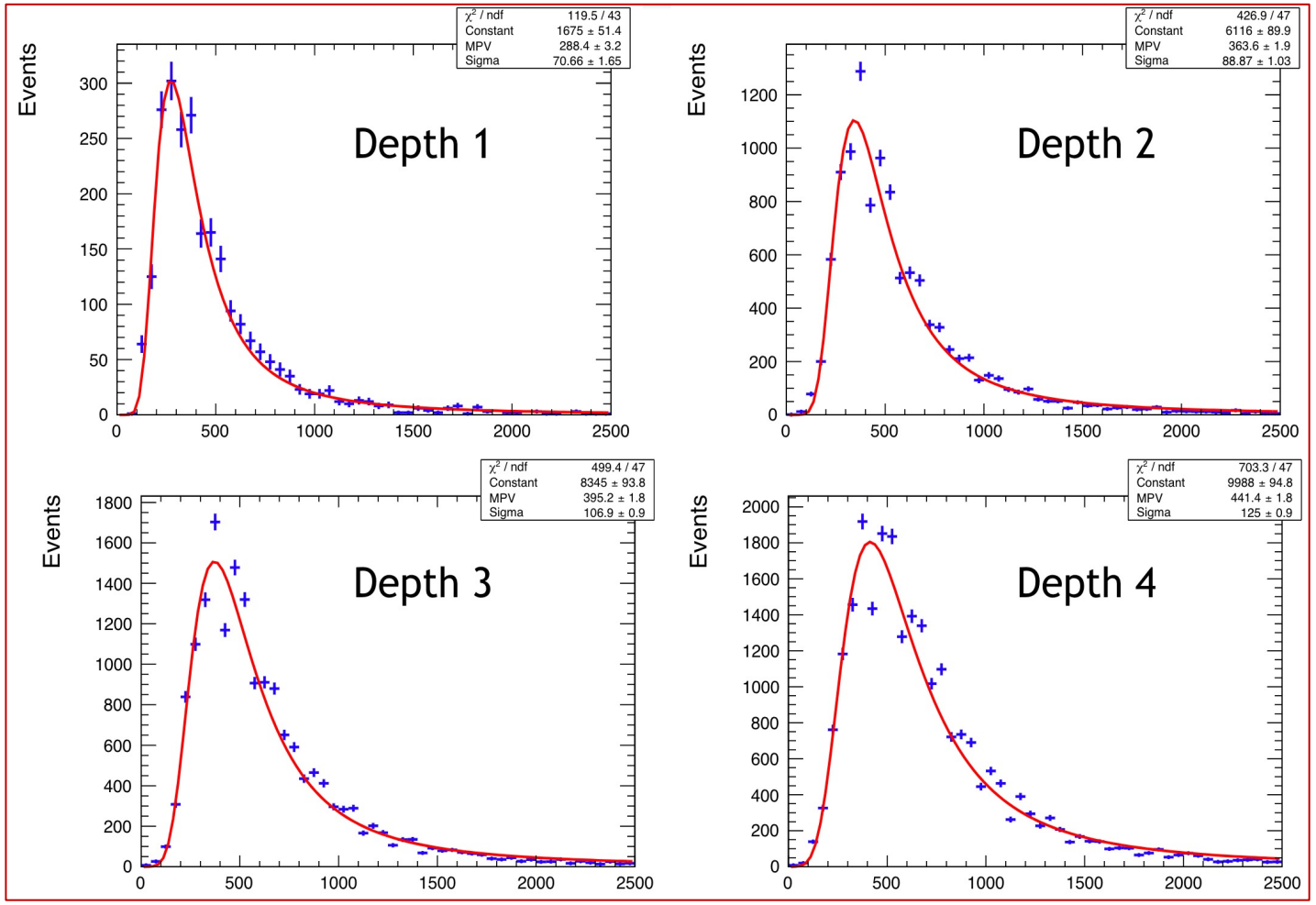
1. Validate connection of cables between scintillator tiles and Readout Modules (feedback from Co60 was definitely useful)
2. Response of individual tiles (layer by layer) to Co60 will be used to obtain start-up calibration constants for HCAL Barrel

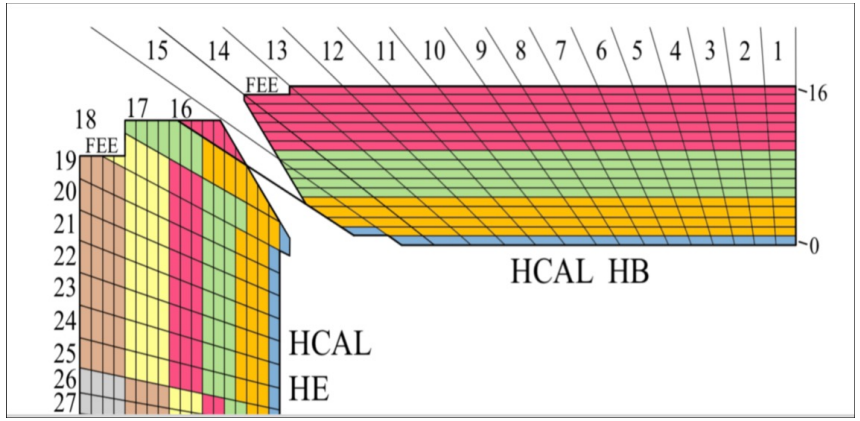
Operation: Response of HB to Cosmic Data

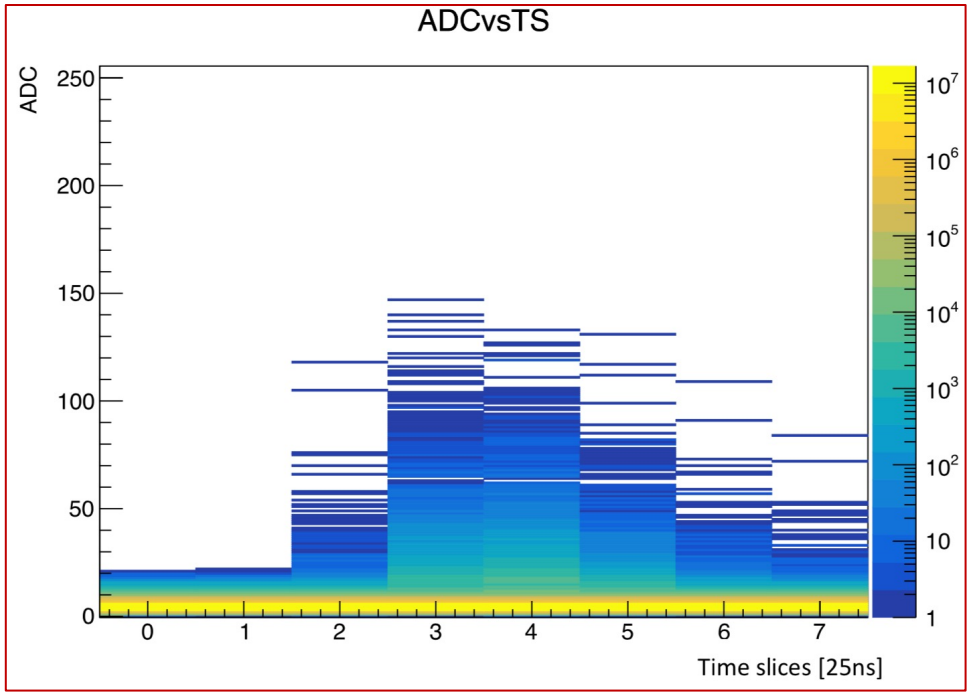
HCAL participated in global CMS runs data-taking at 2019

Muons + Cosmic Showers

Electronics working, expected performance achieved

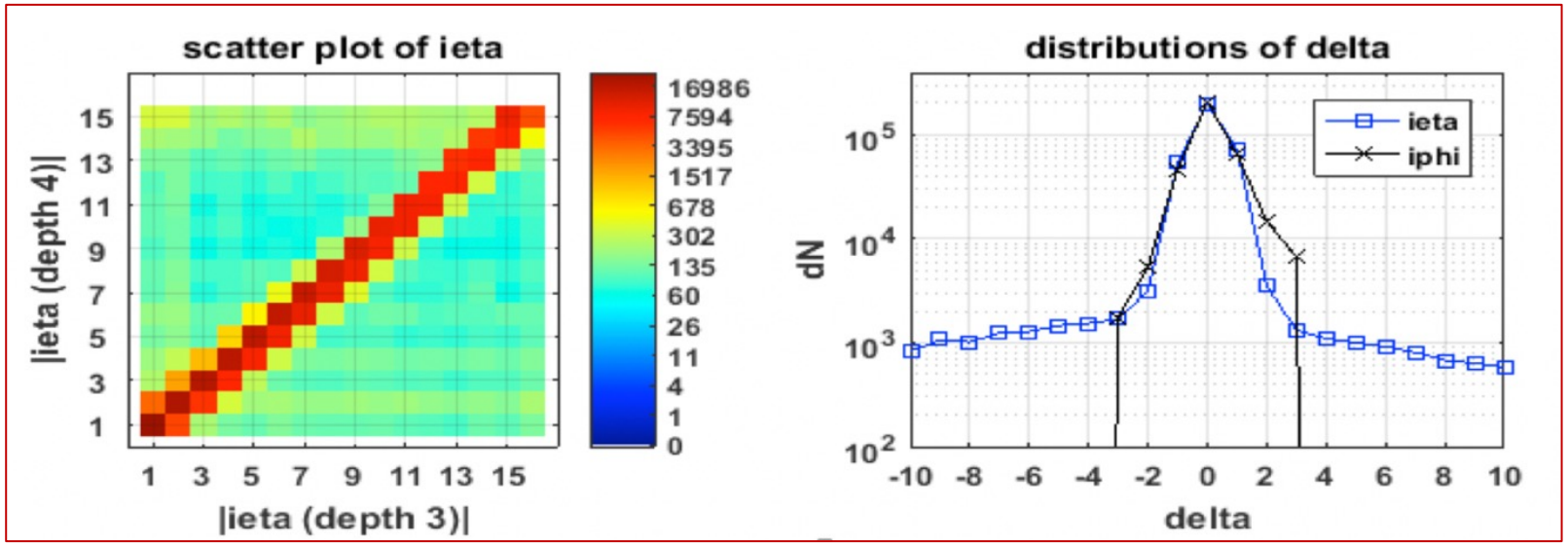


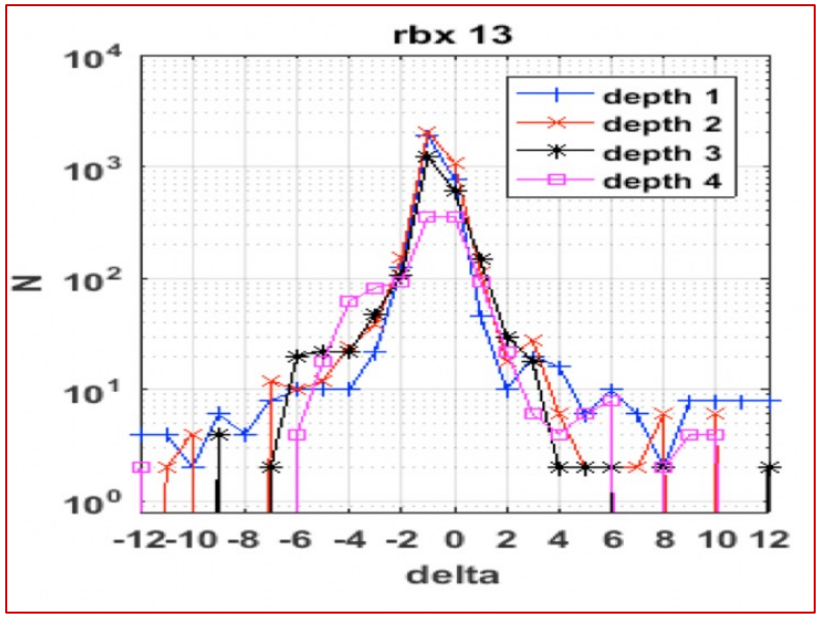


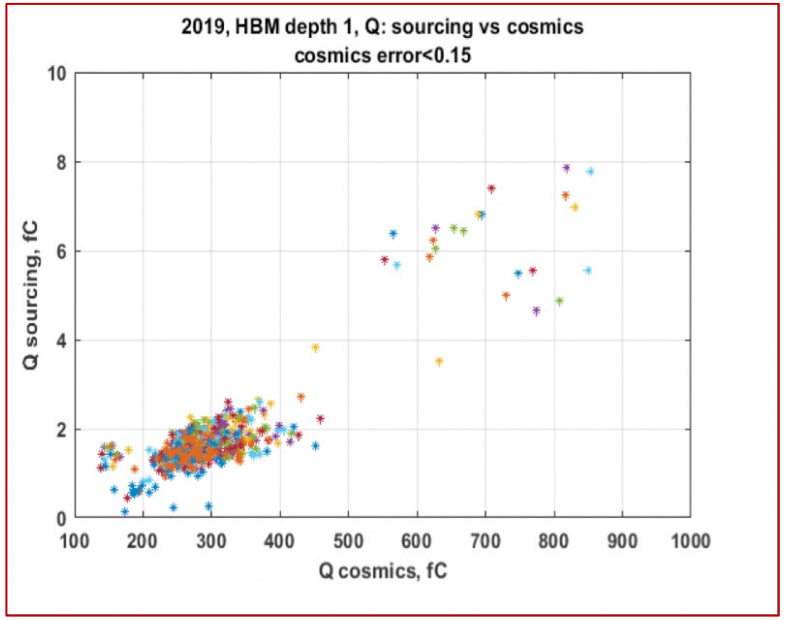


Operation: Response of HB to Cosmic Data

Correlation of signals for Depth4 vs Depth3 of HB: x-axis: eta of signal in Depth3; y axis: eta of signal in Depth4

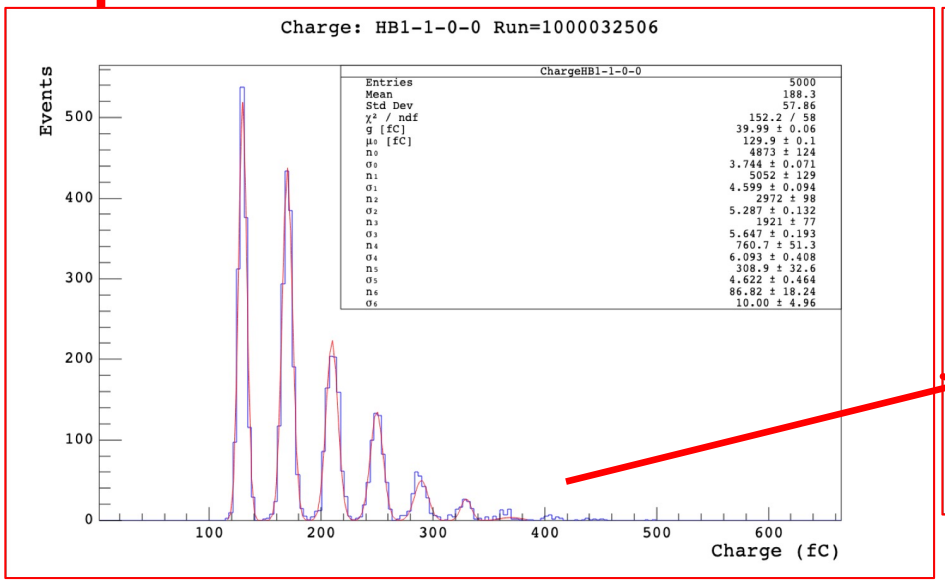


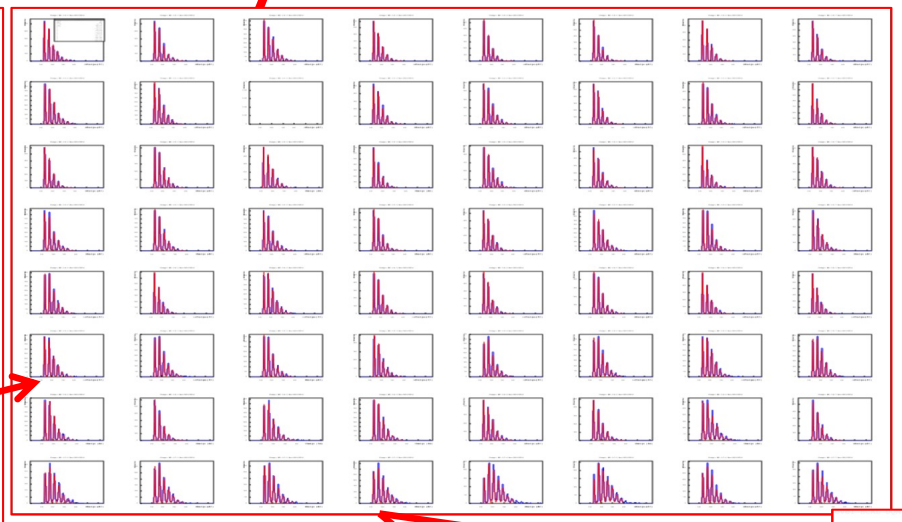


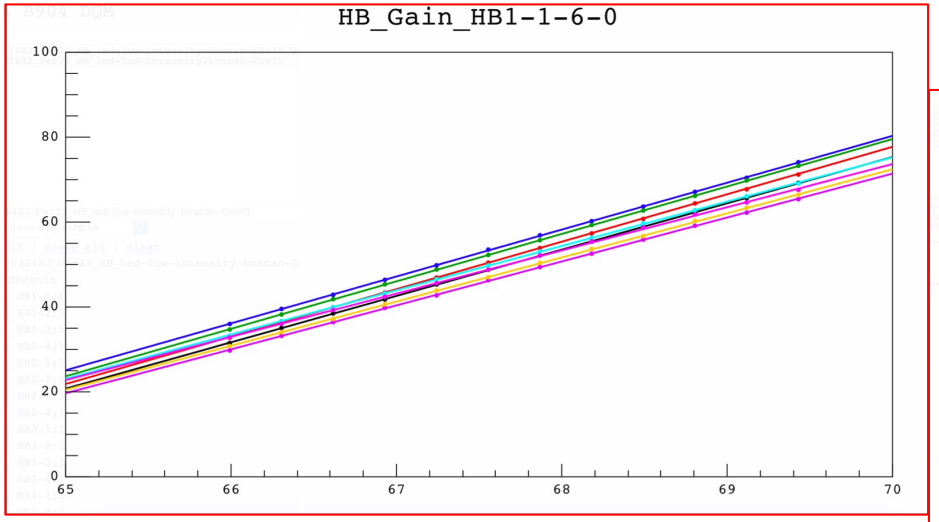


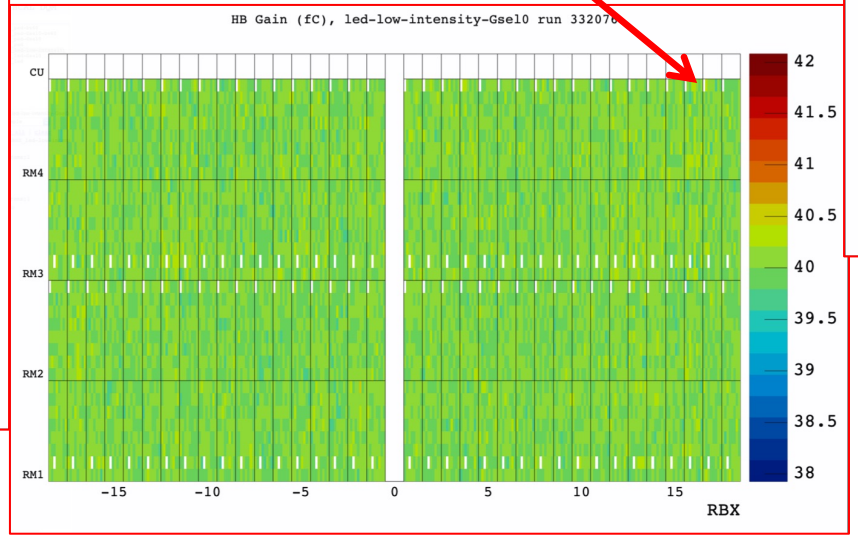
Operation: HB Low Intensity LED Run

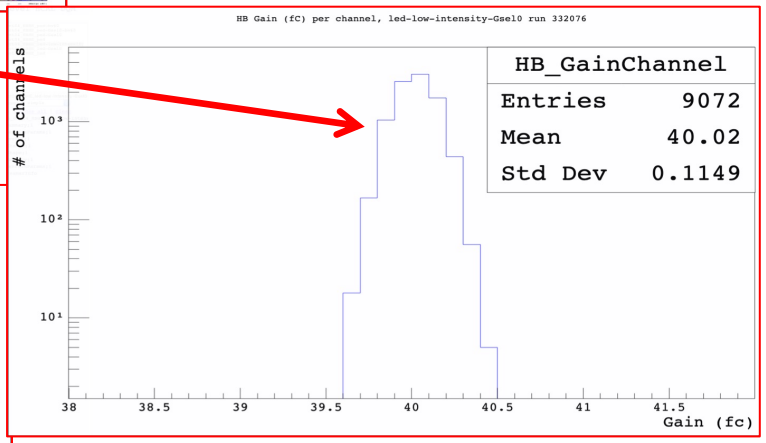
BVs are tuned
QIE pedestals tuned
Individual QIE calibrations











Conclusion

- HB Phase 1 Upgrade installation and commissioning has been progressing ahead of schedule.
- All issues/challenges have been solved or addressed.
- The full installation has been completed by the end of 2019.
- The HB Phase 1 upgrade brings improved detector response and uniformity.
- The Phase 1 HCAL Upgrade is has been an overall success. Campaign success owed to the many talented and diligent people.
- A very big thanks to everyone who had a hand in HCAL Phase 1 Upgrades!

✓For your questions you can contact me by candan.isik@cern.ch

or you can send me a direct message by Mattermost