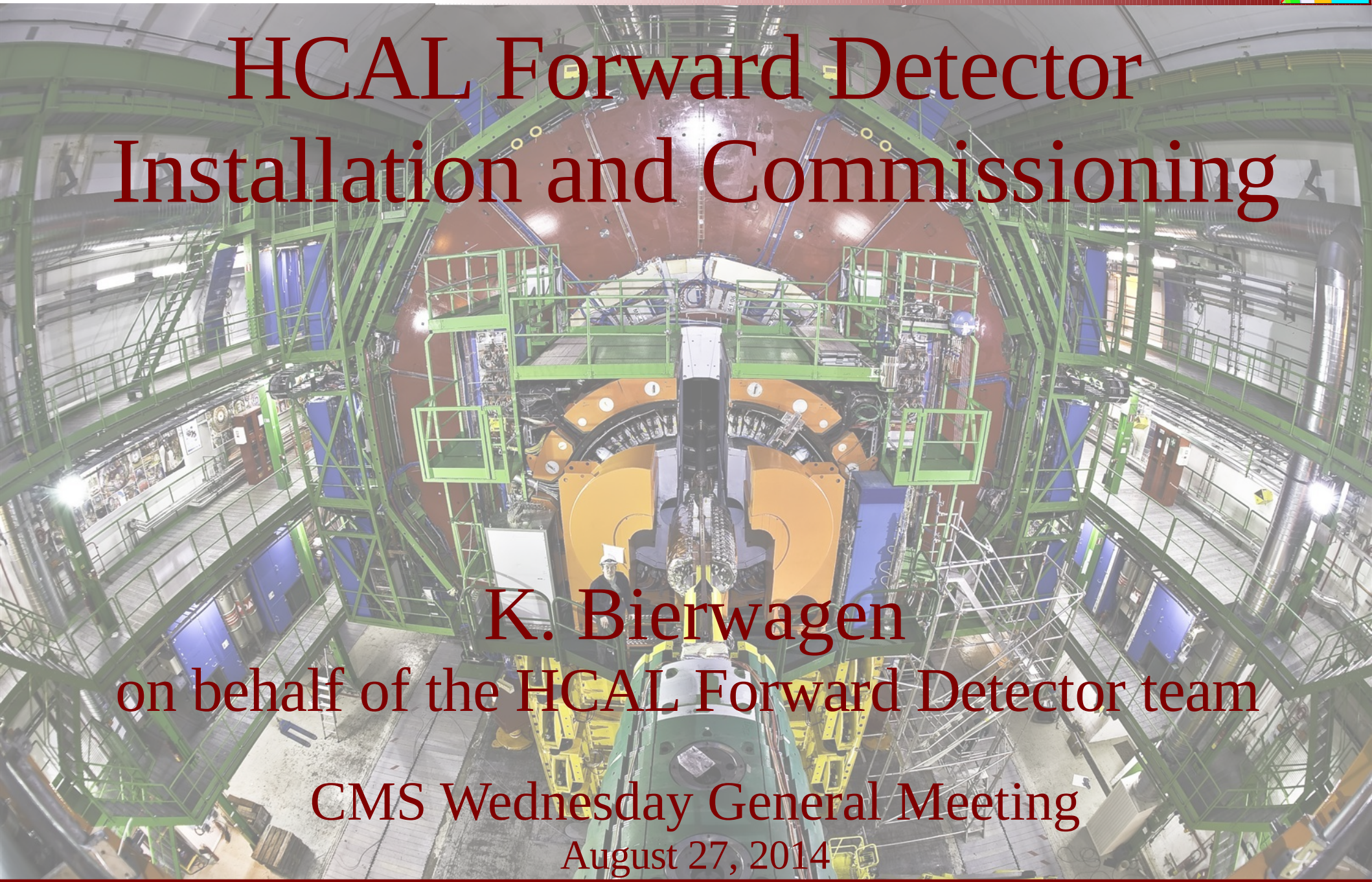
Massachusetts Institute of Technology



# HCAL Forward Detector Installation and Commissioning

K. Bierwagen

on behalf of the HCAL Forward Detector team

CMS Wednesday General Meeting

August 27, 2014

# HCAL Forward Detector Improvements

- Motivation for Improvements:
  - Observed Punch-through and Cerenkov light in PMT glass during Run1
- HF Improvement is a staged process:

LS1

- Replacement of PMTs (thick glass, single anode R7525 → thin glass, multi-anode R7600)
- Installation of new readout cables capable to provide 2-channel readout
  - All anode signals ganged into single readout channel in 2015

- Upgrade of HF backend uTCA readout system
  - Installation Readiness Review scheduled for Sept. 16
  - Installation foreseen to be completed by end of September / early October

2015/16 Break

- New HF Front End, including TDC and 2-anode channel will be installed during 2015/16 break

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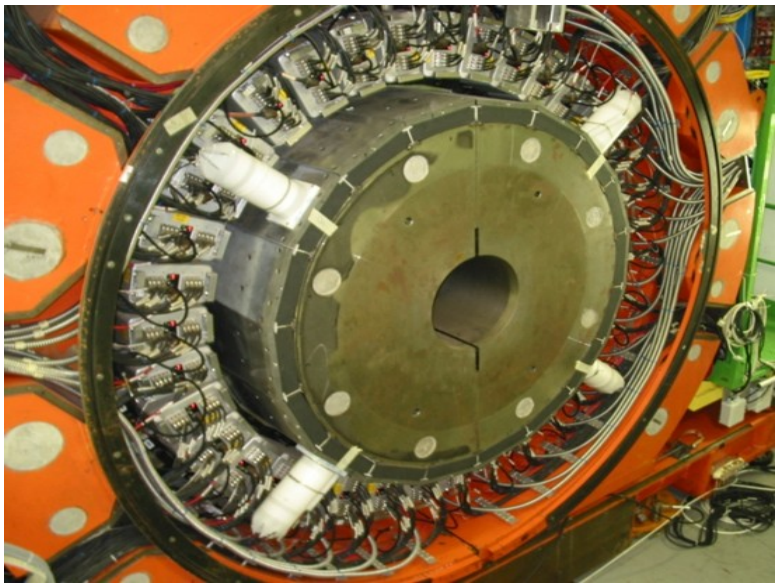
# HCAL Forward Detector Work

## ROBOX Assembly

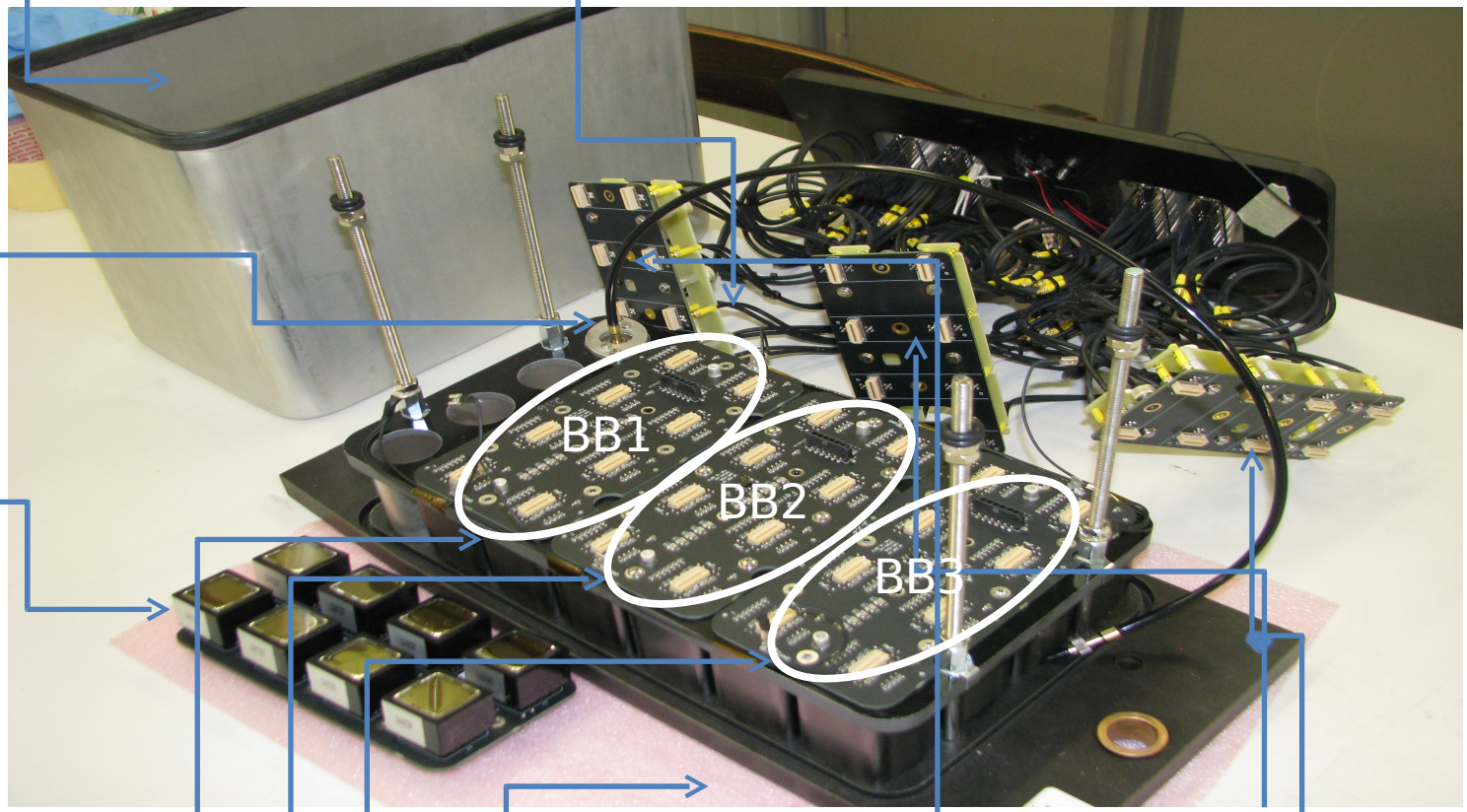
## ROBOX Teststand at SX5

## ROBOX Location in UXC



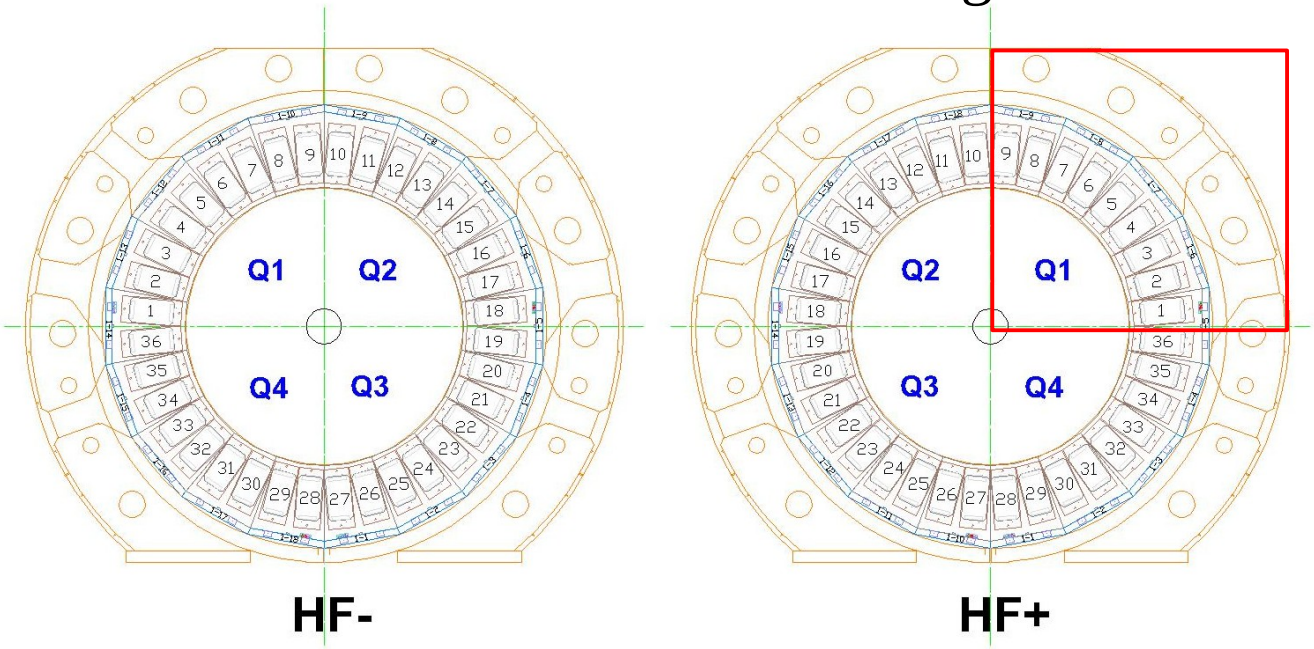
## ROBOX Installation in UXC

# Readout Box Components



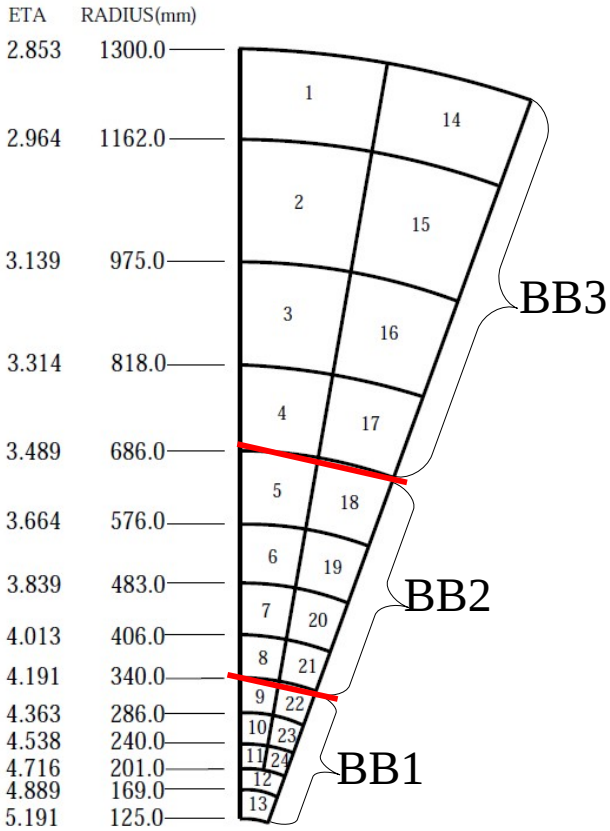
# HCAL Forward Detector Numbering

## Back view of HFM and HFP looking towards IP




- HF readout boxes installed in a circle around the beam axis
- Granularity in ϕ of HF changes with the η index
  - 10 degrees for η indices 29 to 39
  - 20 degrees for η indices 40 and 41
- η values increase for decreasing BB number
- Operational Voltages (OV) selected such that gains equalized in every quadrant and every ring

## HF Wedge



# HCAL Forward Detector Installation Tasks

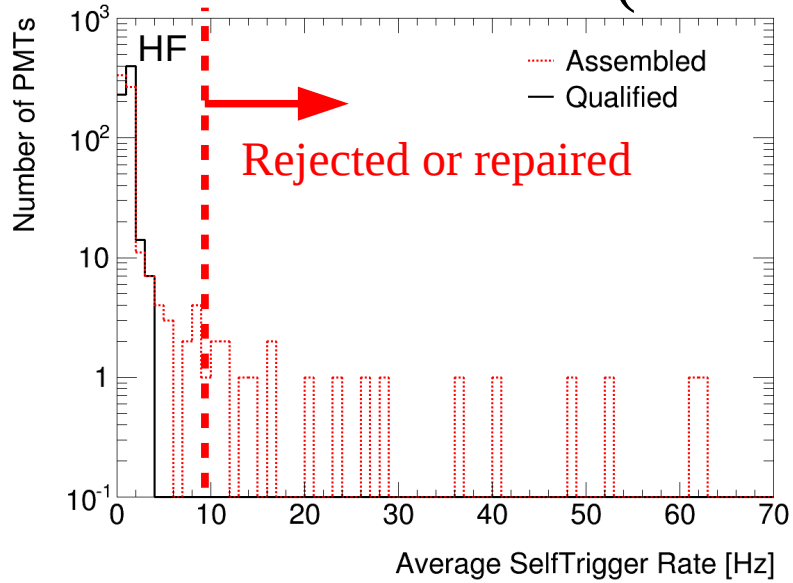
| Item | Status | Completed by |
|---|---|---|
| PMT qualification | DONE | 01/05/2013 |
| Robox components test | DONE | 01/05/2013 |
| Robox refurbishment & test | DONE | 20/12/2013 |
| Robox sign off | DONE | 31/03/2013 |
| Cables delivery/test<br>• Long Cables<br>• Pigtails<br>• Adaptor cables | <br>DONE<br>DONE<br>DONE | 01/03/2014 |
| On detector installation<br>• Robox<br>• Cabling | <br>DONE<br>DONE | <br>08/04/2014<br>13/06/2014 |
| Infrastructure<br>• Cable trays<br>• LV system reorganization<br>• HV system | <br>DONE<br>DONE<br>DONE | <br>17/04/2014<br>13/06/2014 |
| • HFP installed/readout<br>• HFM installed/readout | DONE<br>DONE | 01/03/2014<br>13/06/2014 |

Installation and commissioning of HF components completed

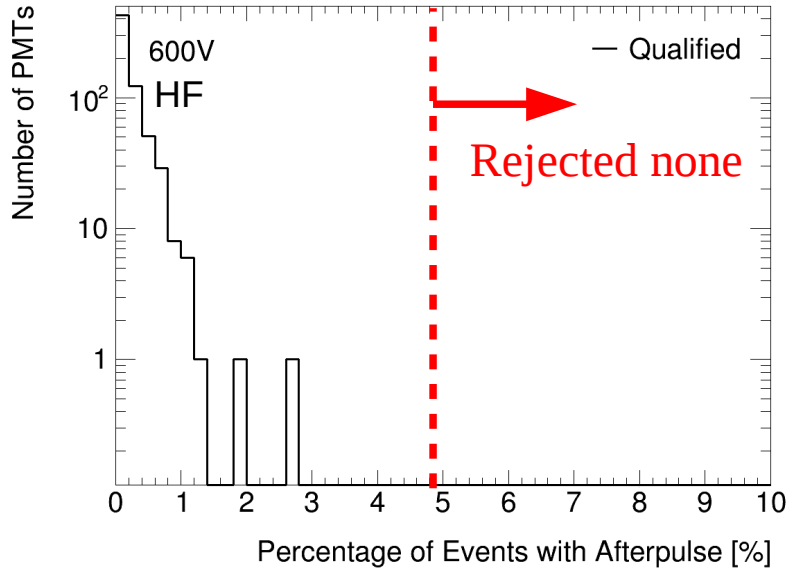
# Readout Box Qualification at the Teststand

- Each Readout Box (ROBOX) out of 72 with 24 PMTs each tested and qualified at teststand at operational voltage (OV) before installation
  - Basic detector parameters established (pedestal, gain, noise etc.)
  - Studied two PMT effects in addition:
    - Self Triggering: Measurering dark current (spontaneous emissions of electrons)
    - After Pulsing: Read 20 TS, inject light in 1st 10 TS and look for effect in 2nd 10 TS
- Problematic PMTs had been exchanged or repaired
- Everything functioning 100%

Average SelfTrigger Rate
Threshold 100 LADCs (25 GeV)




AfterPulse Rate

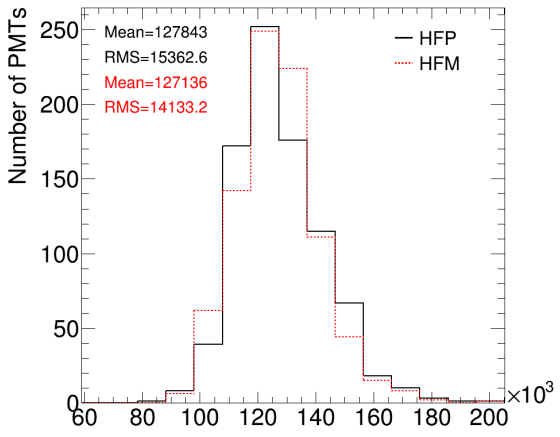


# HCAL Forward Detector Post-Installation Checks at UXC

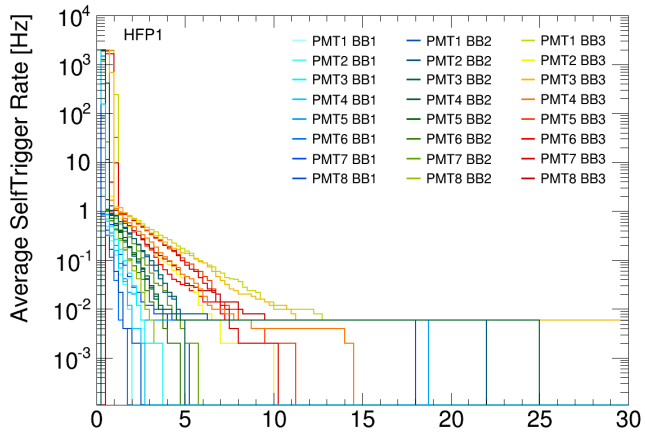
# HCAL Forward Detector Checkout

## ROBOX Checkout on the Detector

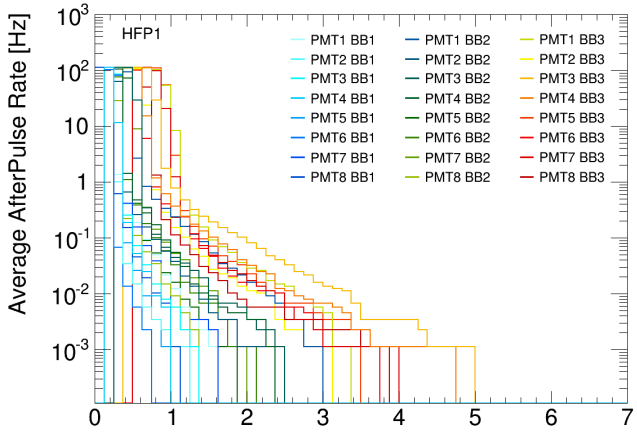
### Gain Measurement



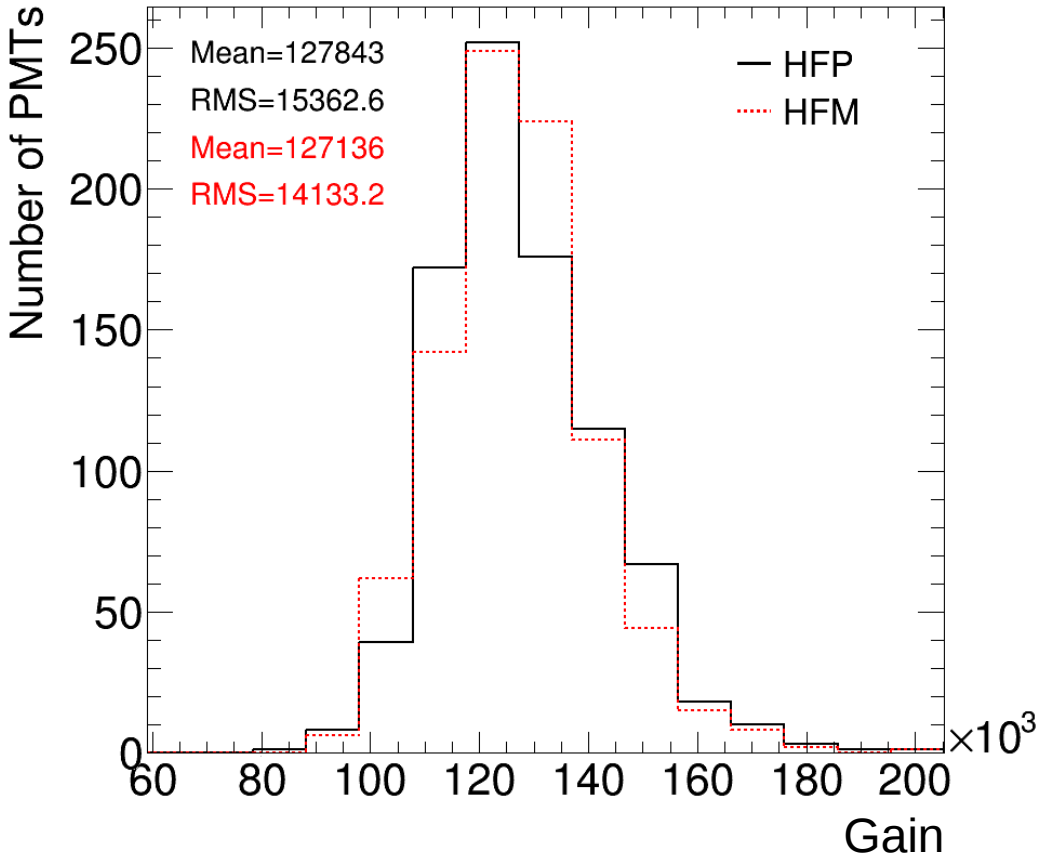

### SelfTrigger Rate




### AfterPulse Rate



# LED Gain Measurement at Operational Voltage at UXC

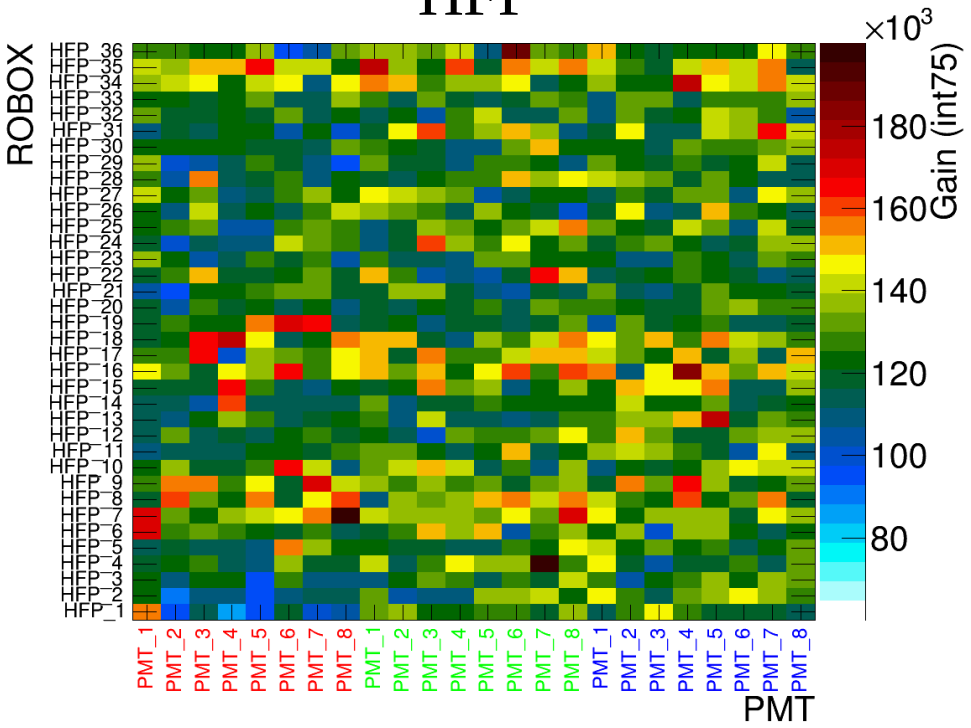



- Mean value: ~127k
- Spread: ~12%
- Saturation Value per PMT: ~8 TeV
- Handle on gain adjustment with radiation effects accumulating using HV

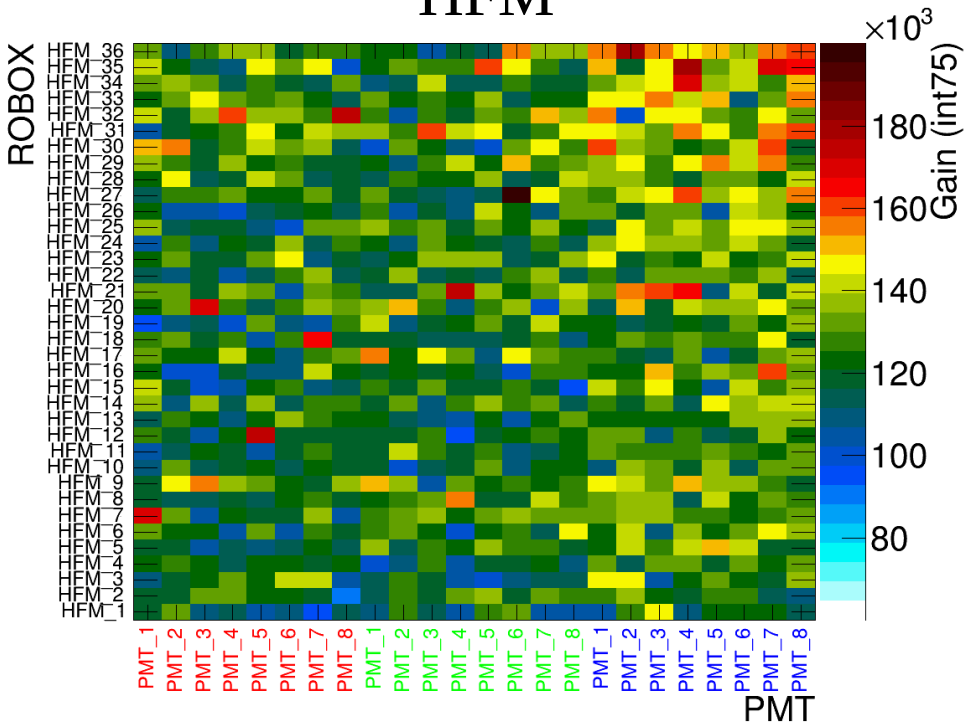
# HCAL Forward Detector Checkout

## LED Gain Measurement at Operational Voltage at UXC

HFP




HFM

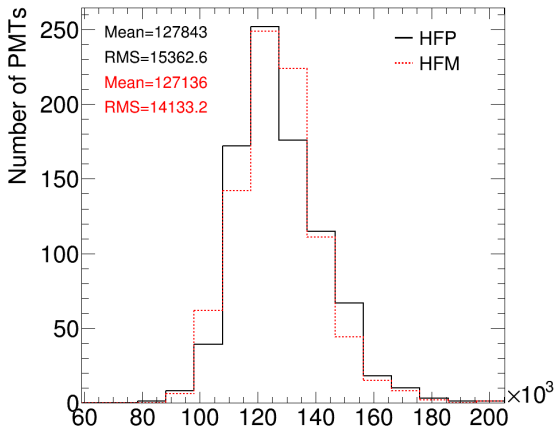



- LED Gain stable over whole HF
- No problematic channels
- 100% of the PMTs behave as expected

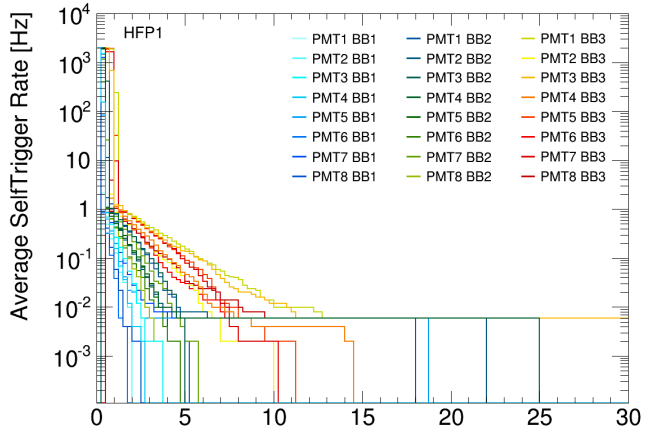
# HCAL Forward Detector Checkout

## ROBOX Checkout on the Detector

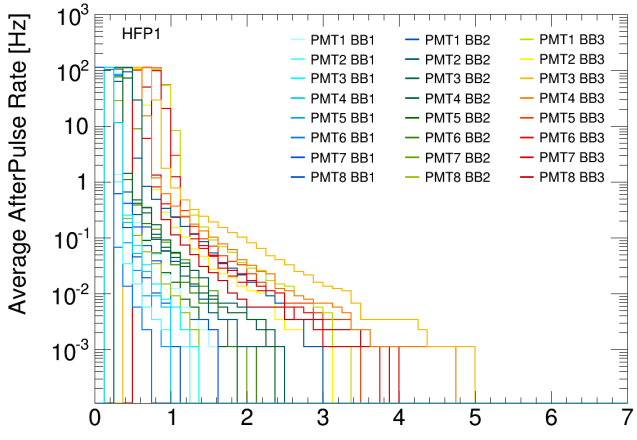
### Gain Measurement




### SelfTrigger Rate

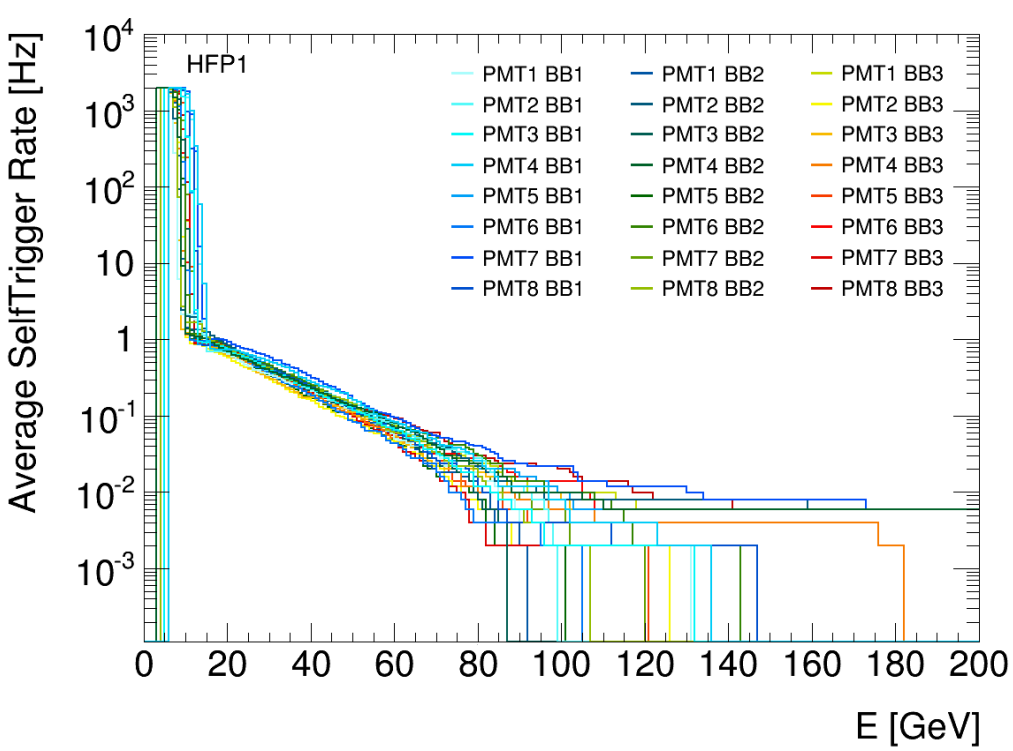


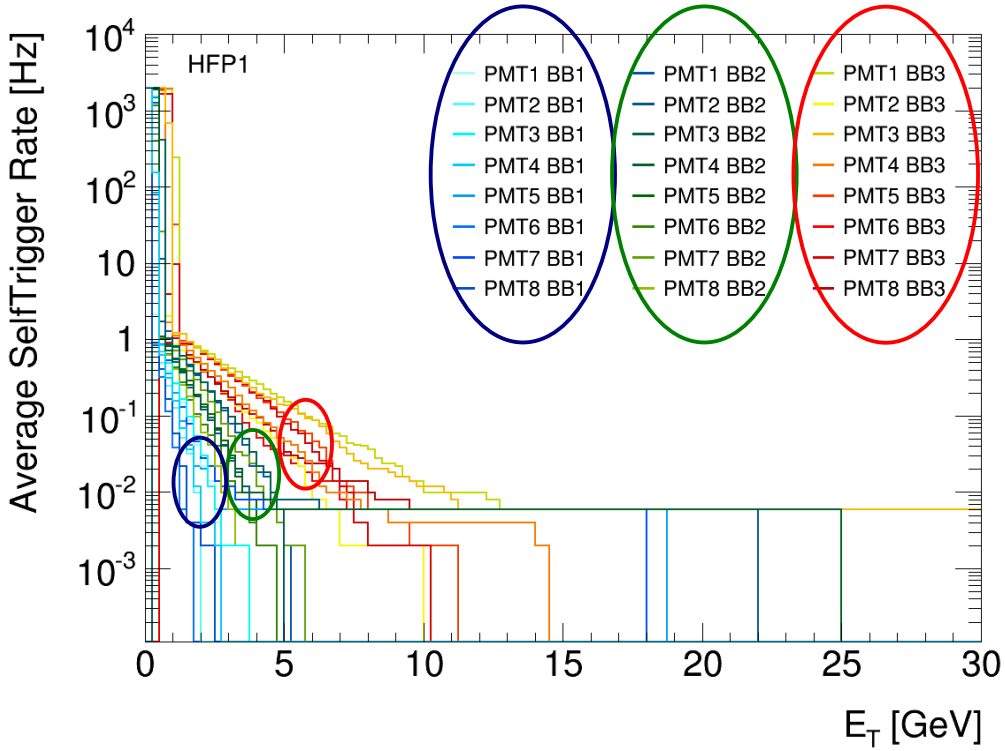

### AfterPulse Rate



# HCAL Forward Detector Checkout

## Average SelfTrigger Rate Profile for HFP1 at Operational Voltage

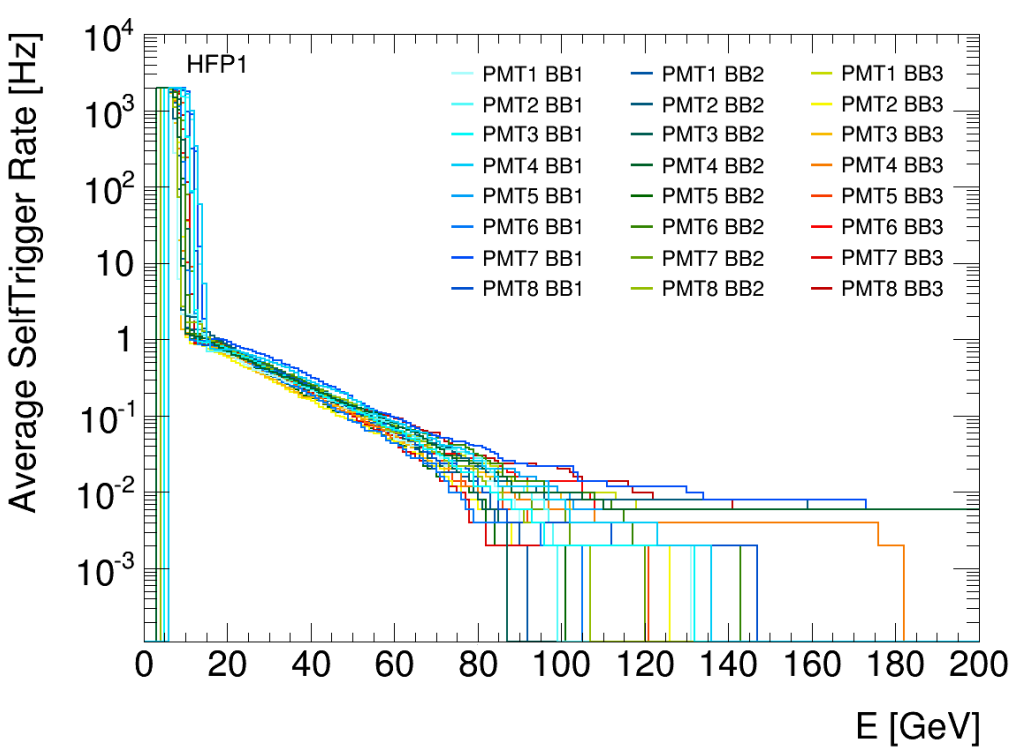


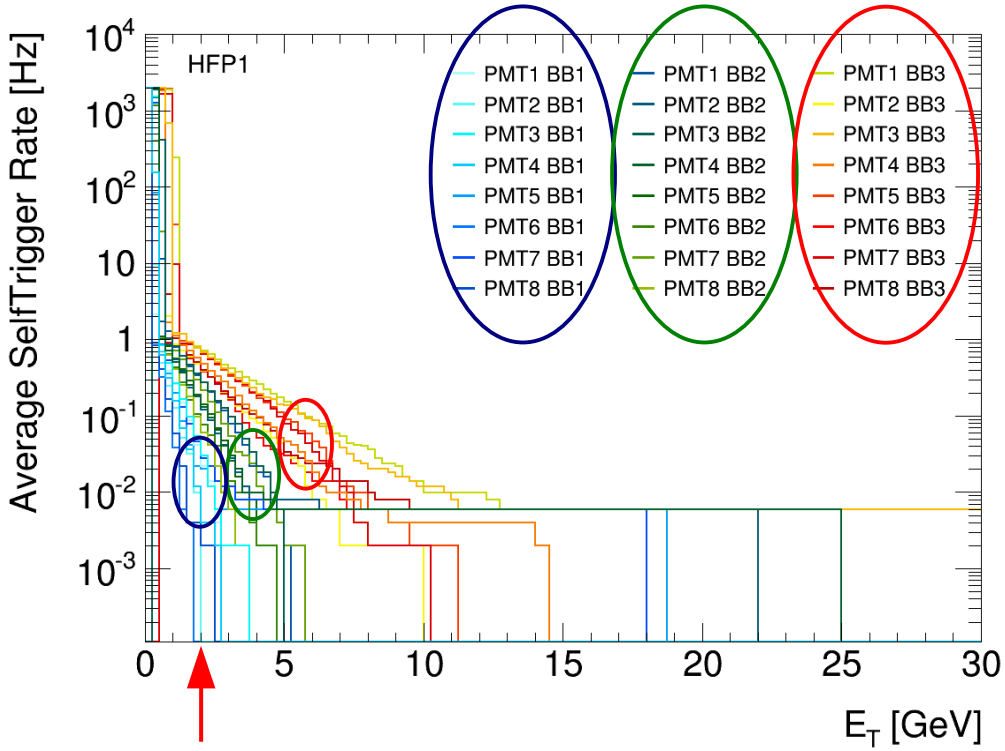




- Most PMTs have a similar average SelfTrigger Rate as a function of energy
- Physics Triggers use thresholds in $E_T$
- Conversion to $E_T$ introduces an expected $\eta$ dependence
  - For example: E=100 GeV corresponds to $E_T$~10 GeV for $\eta$=3 and $E_T$~1 GeV for $\eta$=5

# HCAL Forward Detector Checkout

## Average SelfTrigger Rate Profile for HFP1 at Operational Voltage

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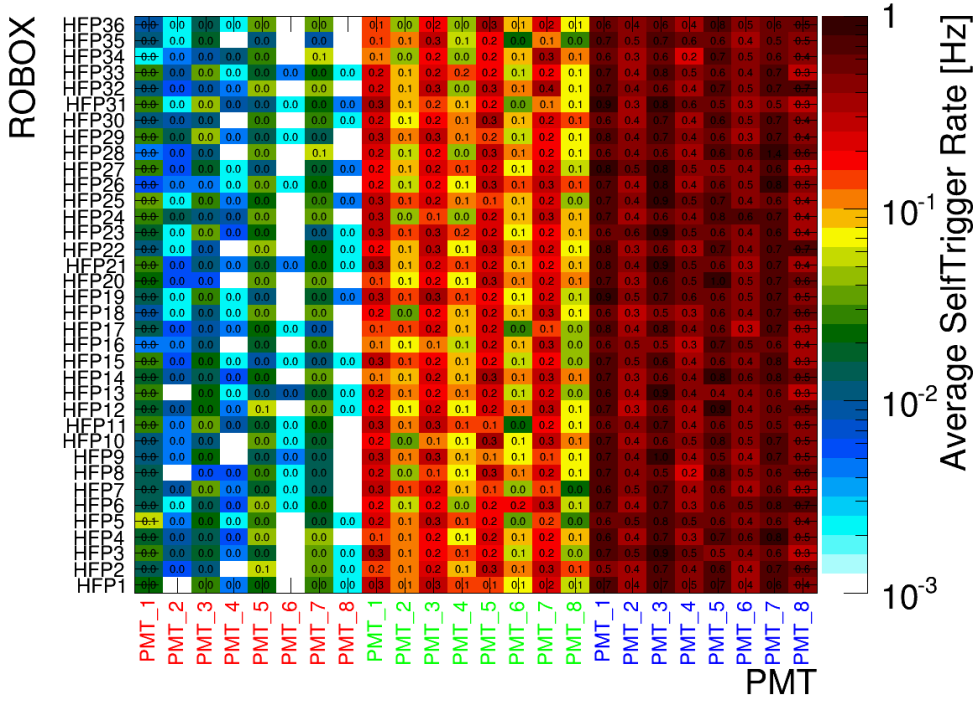
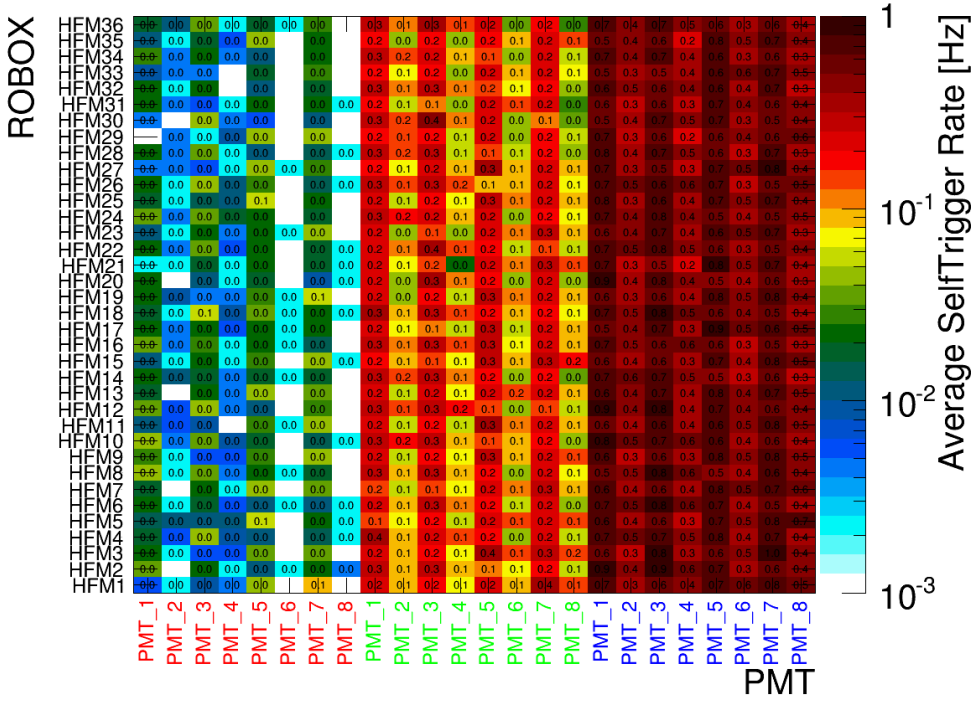
# HCAL Forward Detector Checkout

## Average SelfTrigger Rate Threshold $E_T$=2 GeV per PMT

HFP




HFM

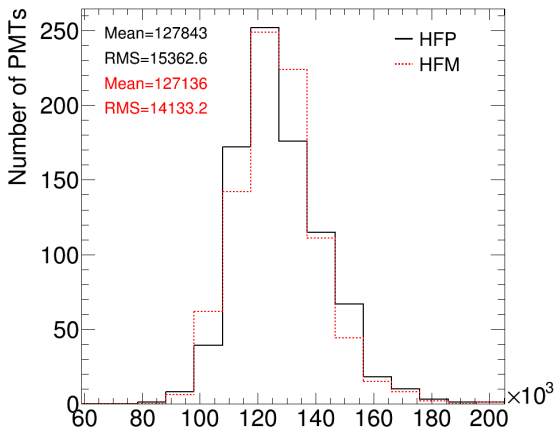



- All PMTs have a SelfTrigger Rate below 1 Hz
- The SelfTrigger Rate increases with decreasing η
- The overall SelfTrigger Rate for a single PMT above a threshold of $E_T$=2 GeV is ~8 Hz for BB1, ~90 Hz for BB2 and ~320 Hz for BB3

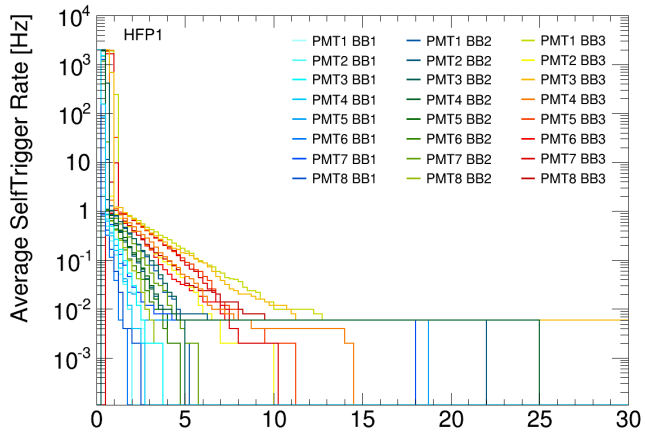
# HCAL Forward Detector Checkout

## ROBOX Checkout on the Detector

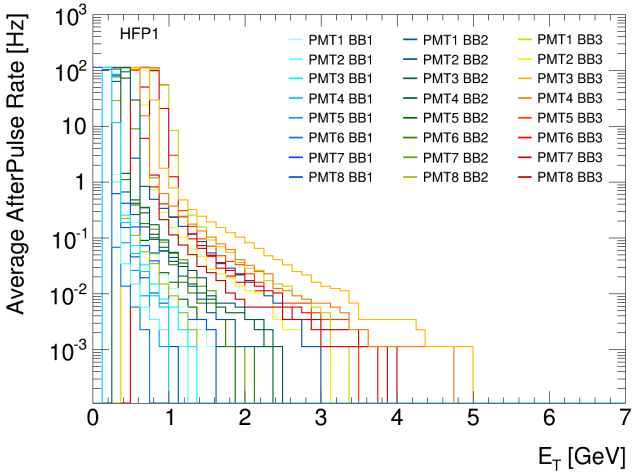
### Gain Measurement




### SelfTrigger Rate



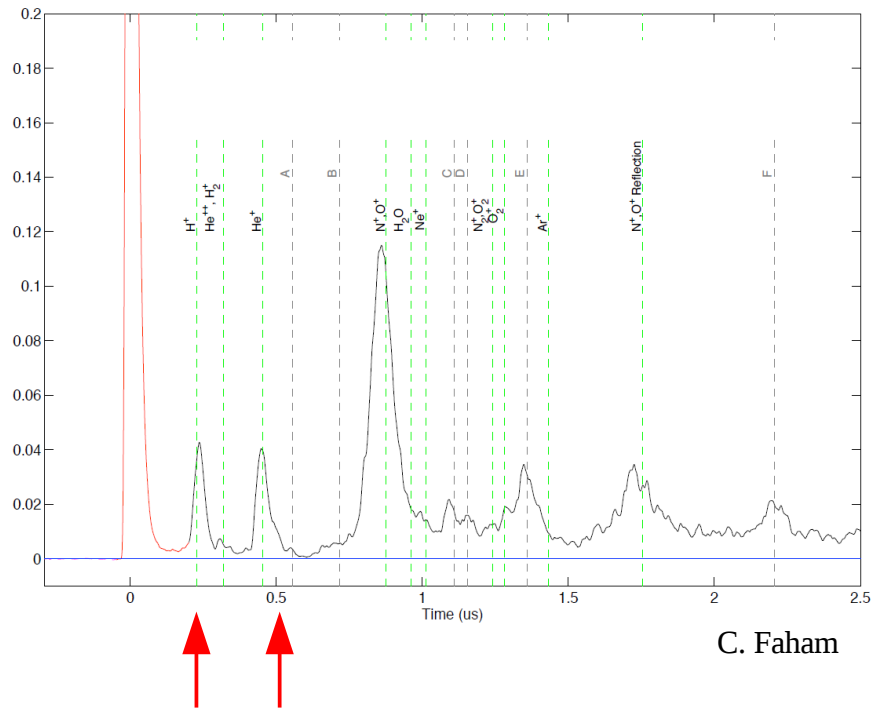

### AfterPulse Rate



# HCAL Forward Detector Checkout

- Definition: AfterPulses are spurious pulses which appear in the tail of real pulses
- 2 types of AfterPulses :
  - AfterPulses with short delays are caused by elastic scattering electrons
  - AfterPulses with long delays are caused by positive ions
- Looking for AfterPulses within 0.25 µs to 0.5 µs by studying 20 TS
  - Inject light in 1st 10 TS and look for effect in 2nd 10 TS

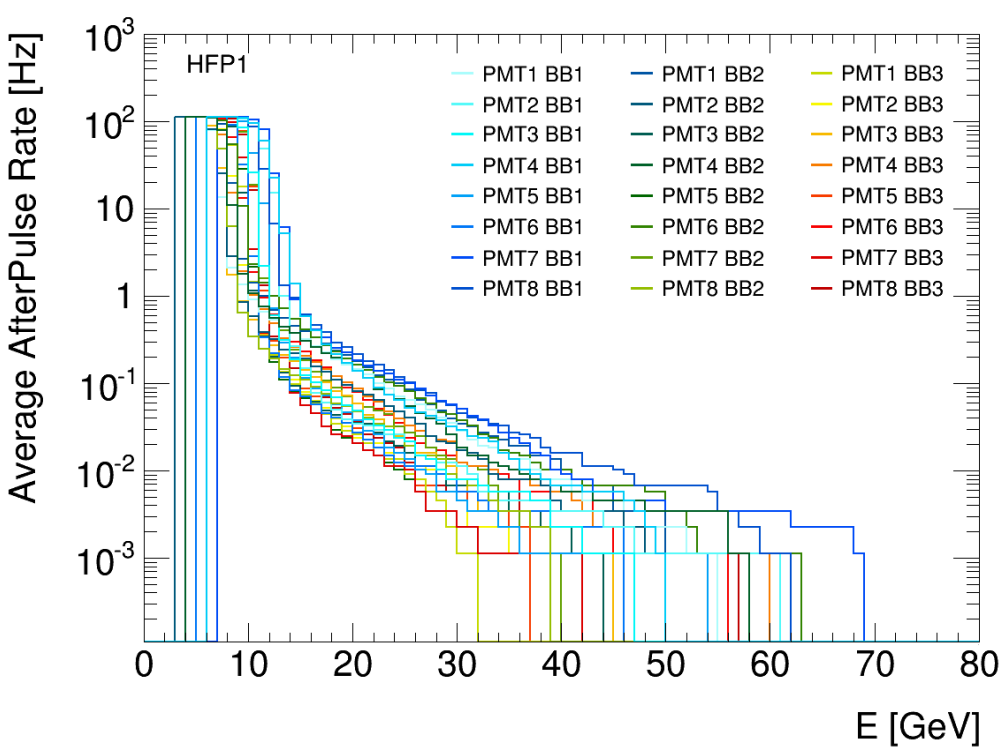
Generic Picture

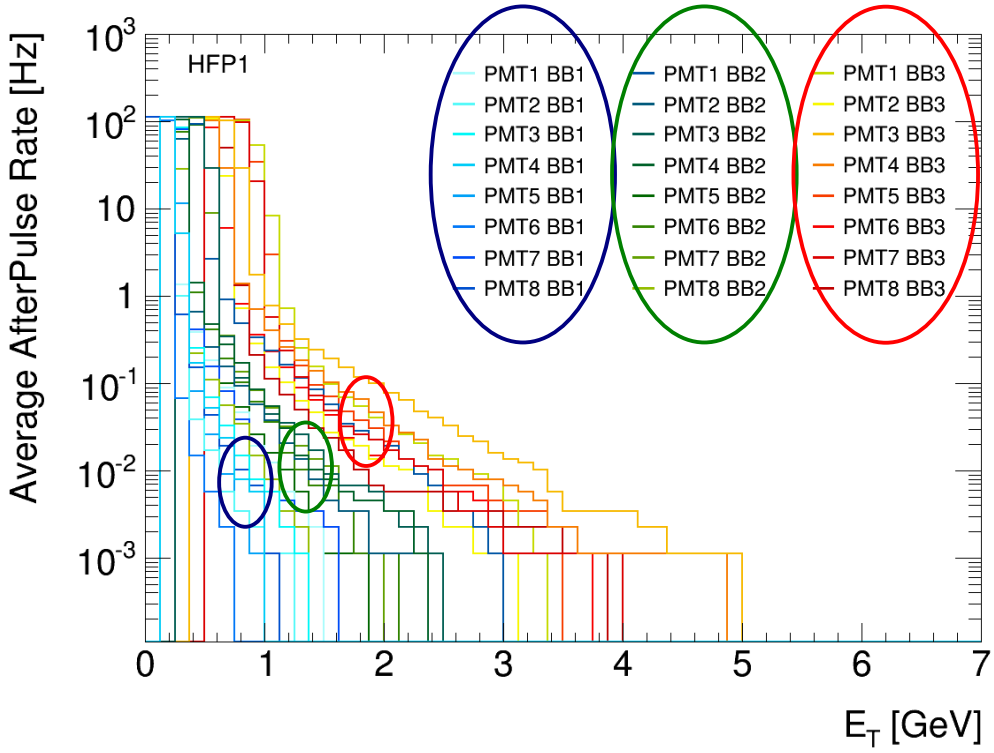



C. Faham

# HCAL Forward Detector Checkout

## Average AfterPulse Rate Profile for HFP1 at Operational Voltage




- Most PMTs have a similar average AfterPulse Rate as a function of energy
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# HCAL Forward Detector Checkout

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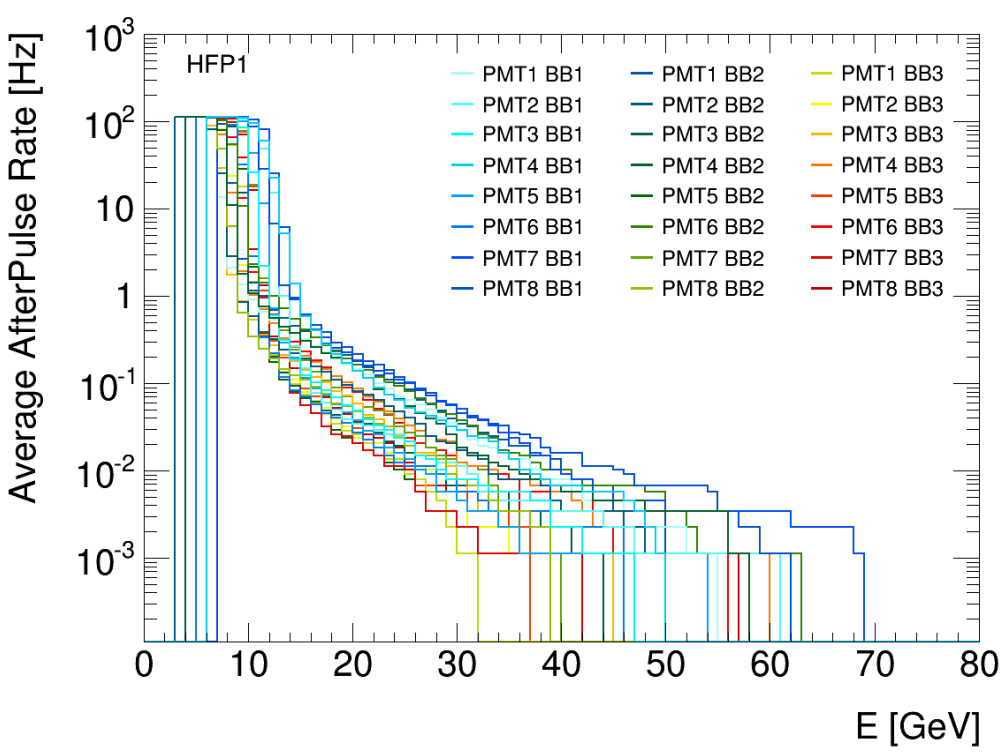


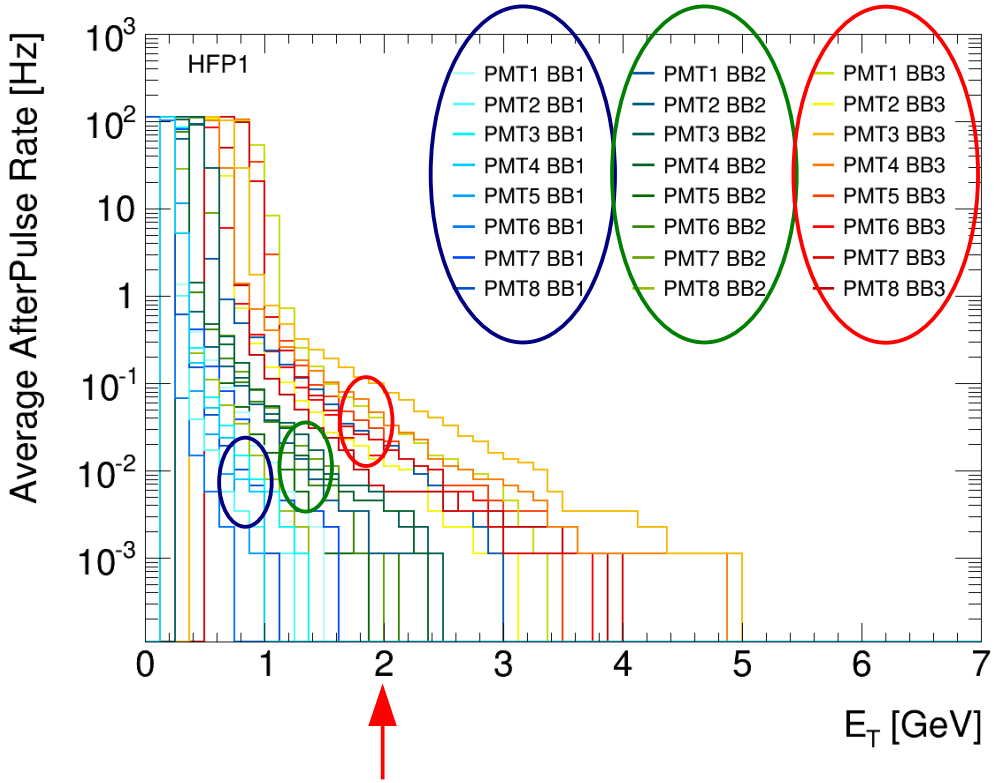


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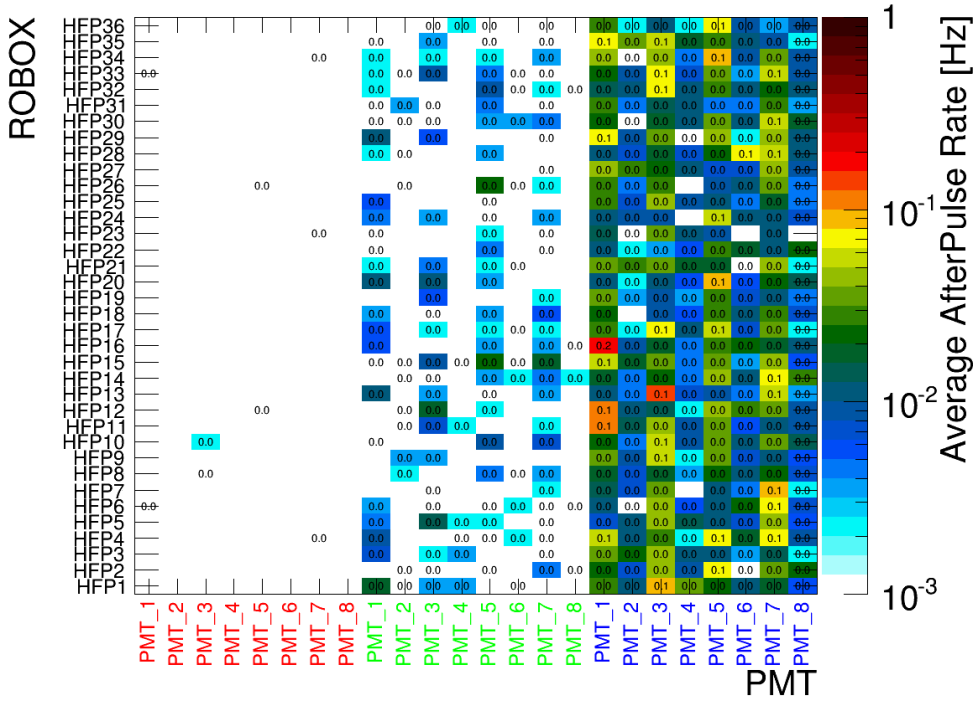
- Physics Triggers use thresholds in $E_T$
- Conversion to $E_T$ introduces an expected $\eta$ dependence

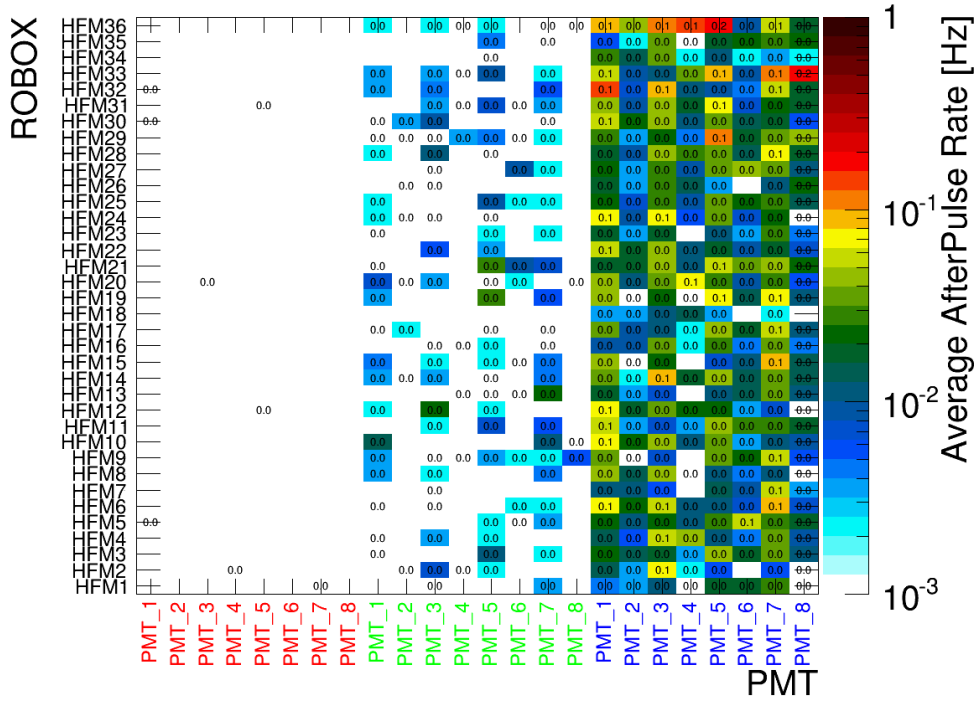
# HCAL Forward Detector Checkout

## Average AfterPulse Rate Threshold $E_T$=2 GeV per PMT for an average signal of 30 - 40 PE (75 -100 GeV) to each PMT

HFP




HFM




- All PMTs have a AfterPulse Rate below 1 Hz
- The AfterPulse Rate increases with decreasing η
- The overall HF AfterPulse Rate for a single PMT above a threshold of $E_T$=2 GeV is ~0.02 Hz for BB1, ~1 Hz for BB2 and ~14 Hz for BB3

# Summary

- HCAL Forward Detector installation and commissioning activity is finalized
  - Basic detector parameters established (pedestal, gain, noise etc.)
    - Results after installation match results from teststand
  - Two PMT effects (self triggering and after pulsing) will contribute extra energy to an event
    - SelfTrigger Rate (PMT Thr. $E_T$=2 GeV) is ~8 Hz for BB1, ~90 Hz for BB2 and ~320 Hz for BB3
    - AfterPulse Rate (PMT Thr. $E_T$=2 GeV) is ~0.02 Hz for BB1, ~1 Hz for BB2 and ~14 Hz for BB3
- **All 1728 PMTs are functioning well**

# Next Steps

- Upgrade of HF backend uTCA readout system in September/ early October
  - Integration and quality control of the modules taking place in 904
  - Commissioning of one crate fully ongoing at USC
  - Full production of uHTR cards just completed in India (tests ongoing, cards expected at CERN beginning of September)

- Looking forward to cosmic runs beginning November 2014 and the first 25ns collisions at 14 TeV