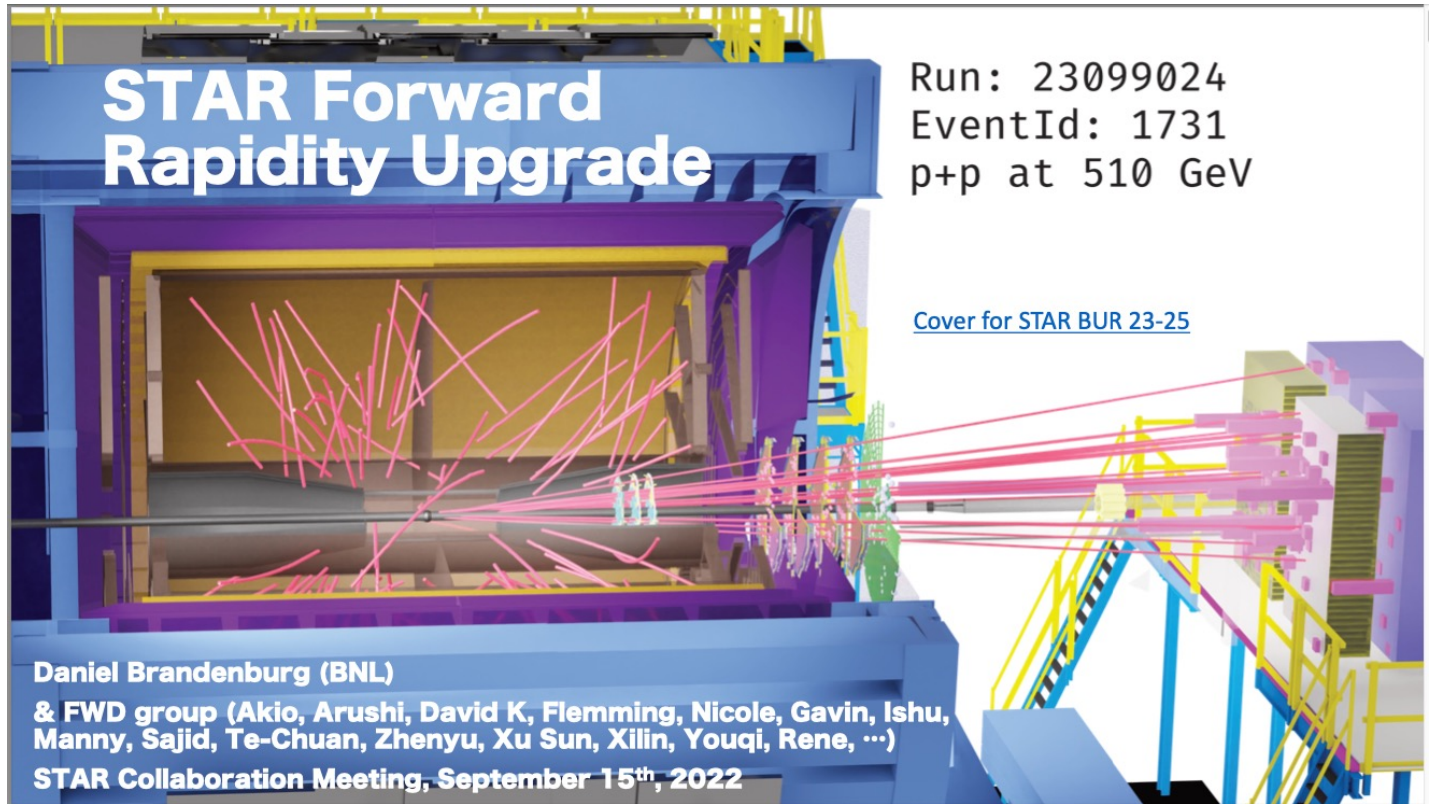
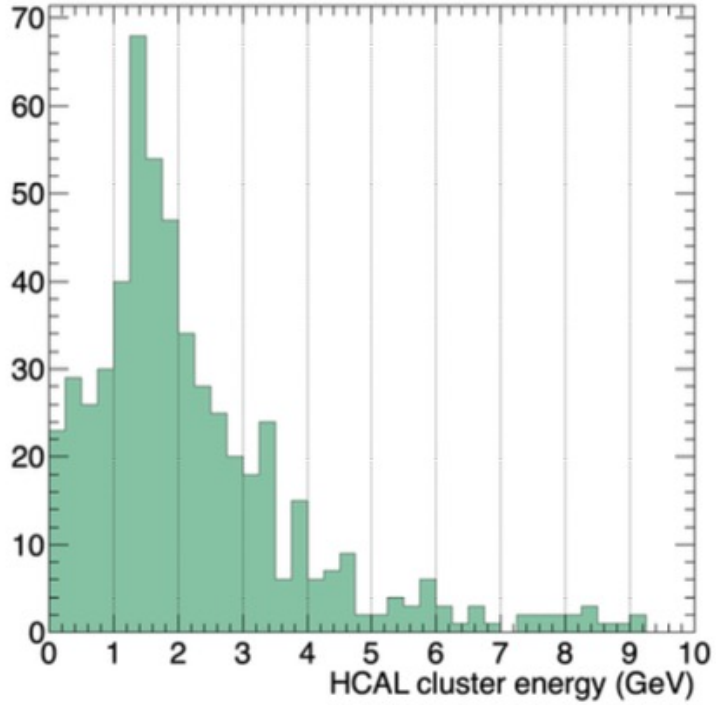
Noise and Radiation Damages in STAR FCS





Run22 FCS Hcal small cluster energy tagged by a forward track & Ecal MIP. MIP peak in Hcal is expected to be at 1.4GeV

Akio Ogawa

2024/04/24

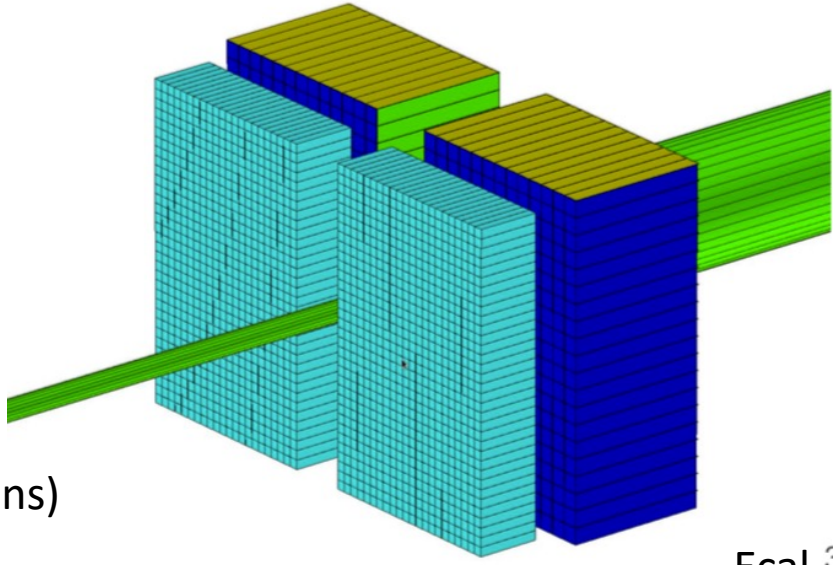
EIC Experimental Equipment DAQ and Electrical Engineering round table

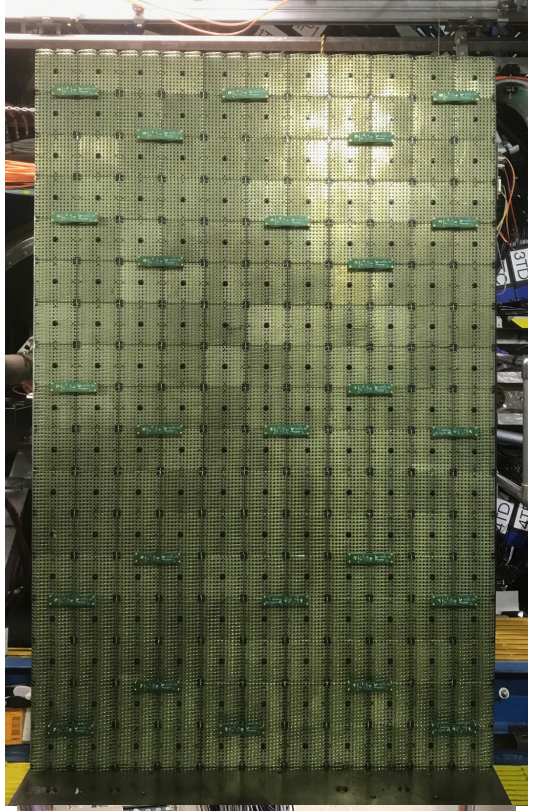
STAR at FCS

Ecal 34x22x2 = 1496ch of Phenix+PbSci
4 SiPM per Tower
~1500 pixels/GeV
Operated at low Vov (-0.5V ~ -1.0V)
On FEEBd attenuated (x 1/5)

Hcal 20x13x2 = 520ch of Fe+Scinti
6 SiPM per Tower
~180 pixels/GeV (1.5GeV & 270 pixels for muons)
Operated at high Vov (~ +0.5V)
On FEEBd attenuator not used

From GSTAR



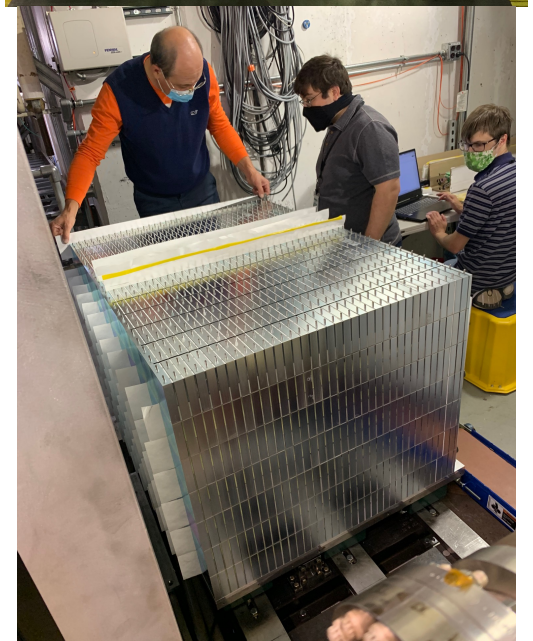


Ecal

SiPM Hamamatsu S12572 3x3 mm^2 15um
SiPM bd + FEEBd attached to detector
DEP board (ADC + DAQ + Trigger on FPGA + Slow Control) on floor, 8 time bins per RHIC clock
LED monitor system shining at ”back” side of detector

Both Ecal and Hcal set to have 5.3MeV/ADC ch
ET equiv of 0.02MeV/ch (near beam) ~ 0.15MeV/ch (far beam)
At trigger 30MeV/count (drop low 7bits)

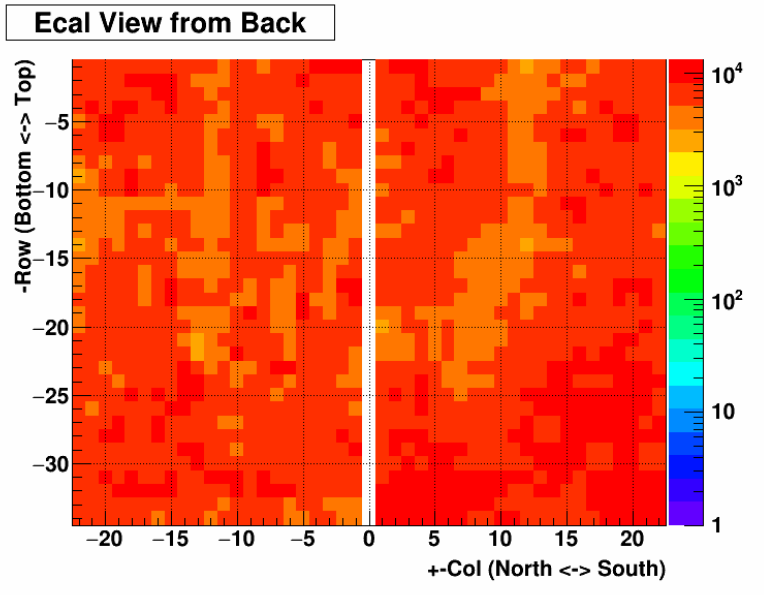
Run22 (pp510) radiation dose was expected to be roughly 5 x 10^11 (~Run17)

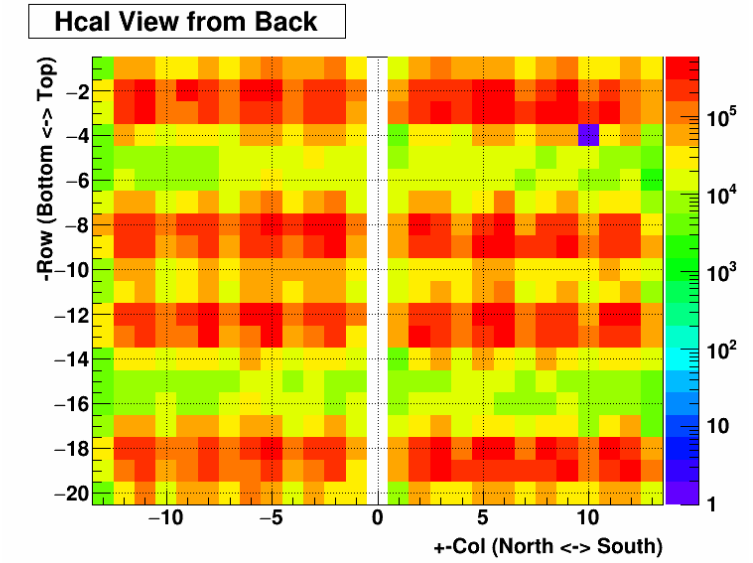


Hcall

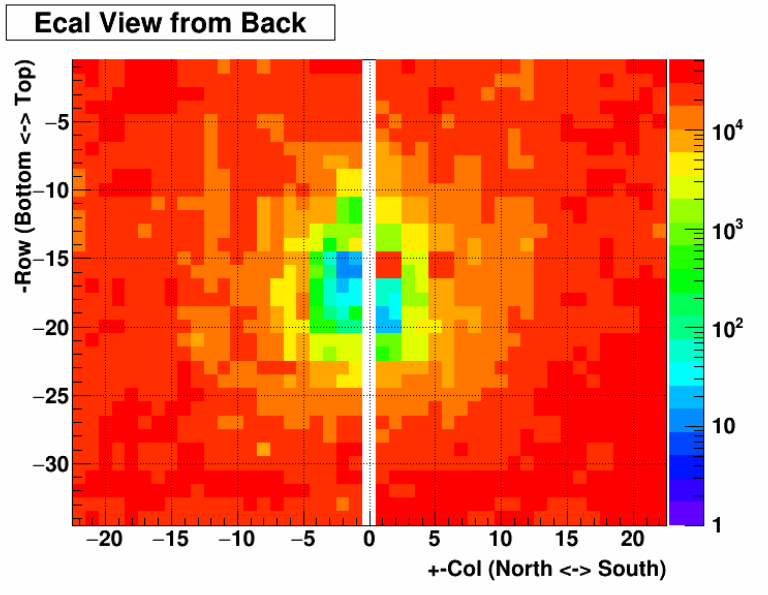
STAR LED Monitor

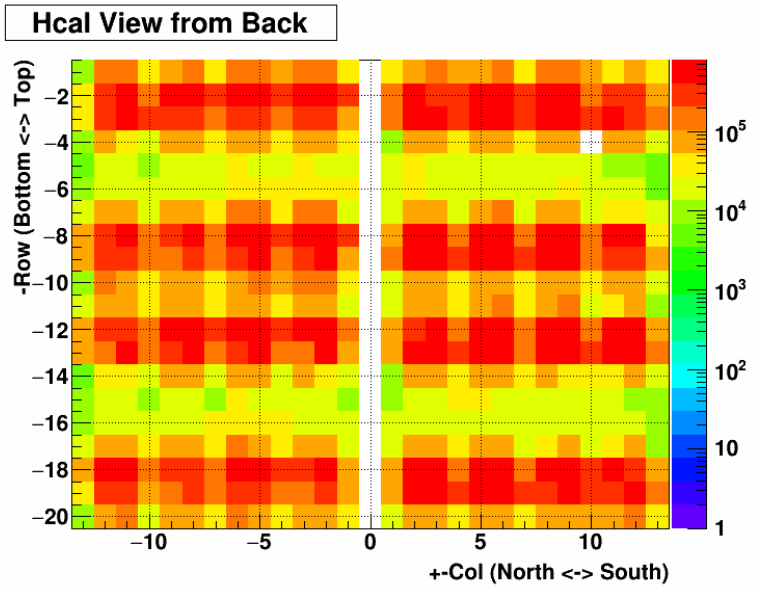
LED run early run22



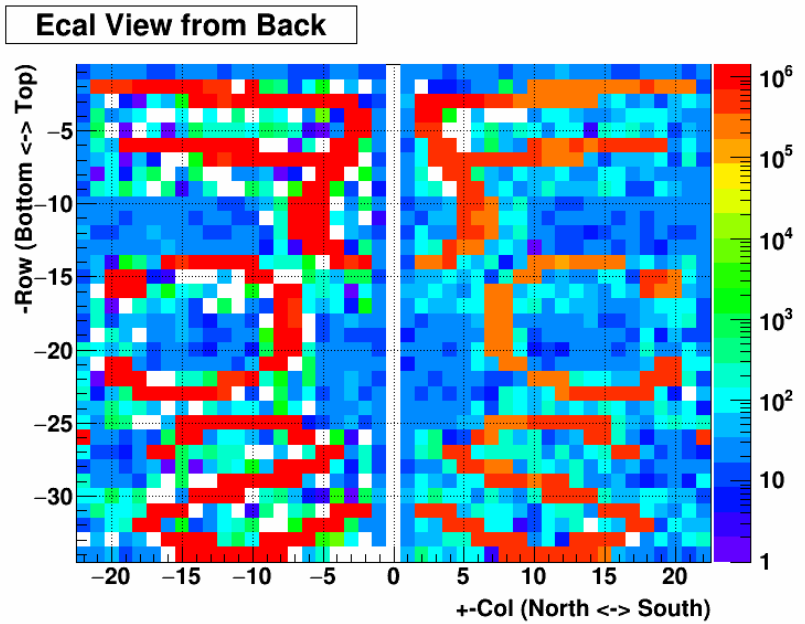


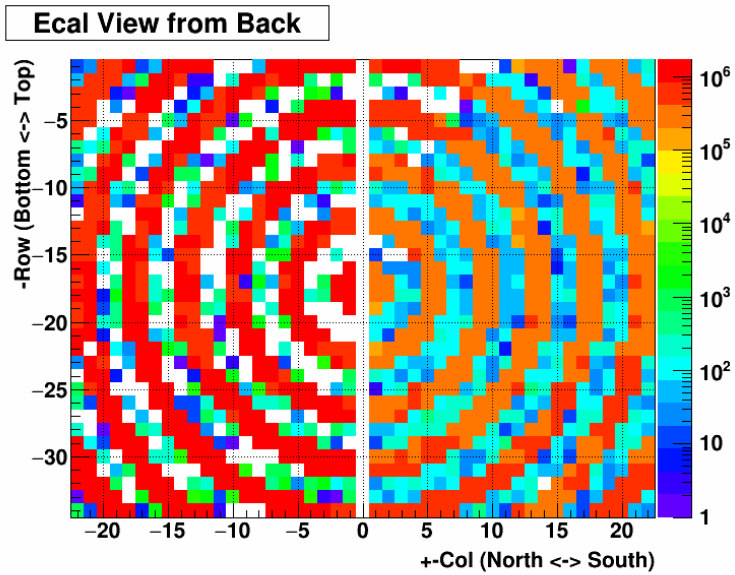
LED run late run22





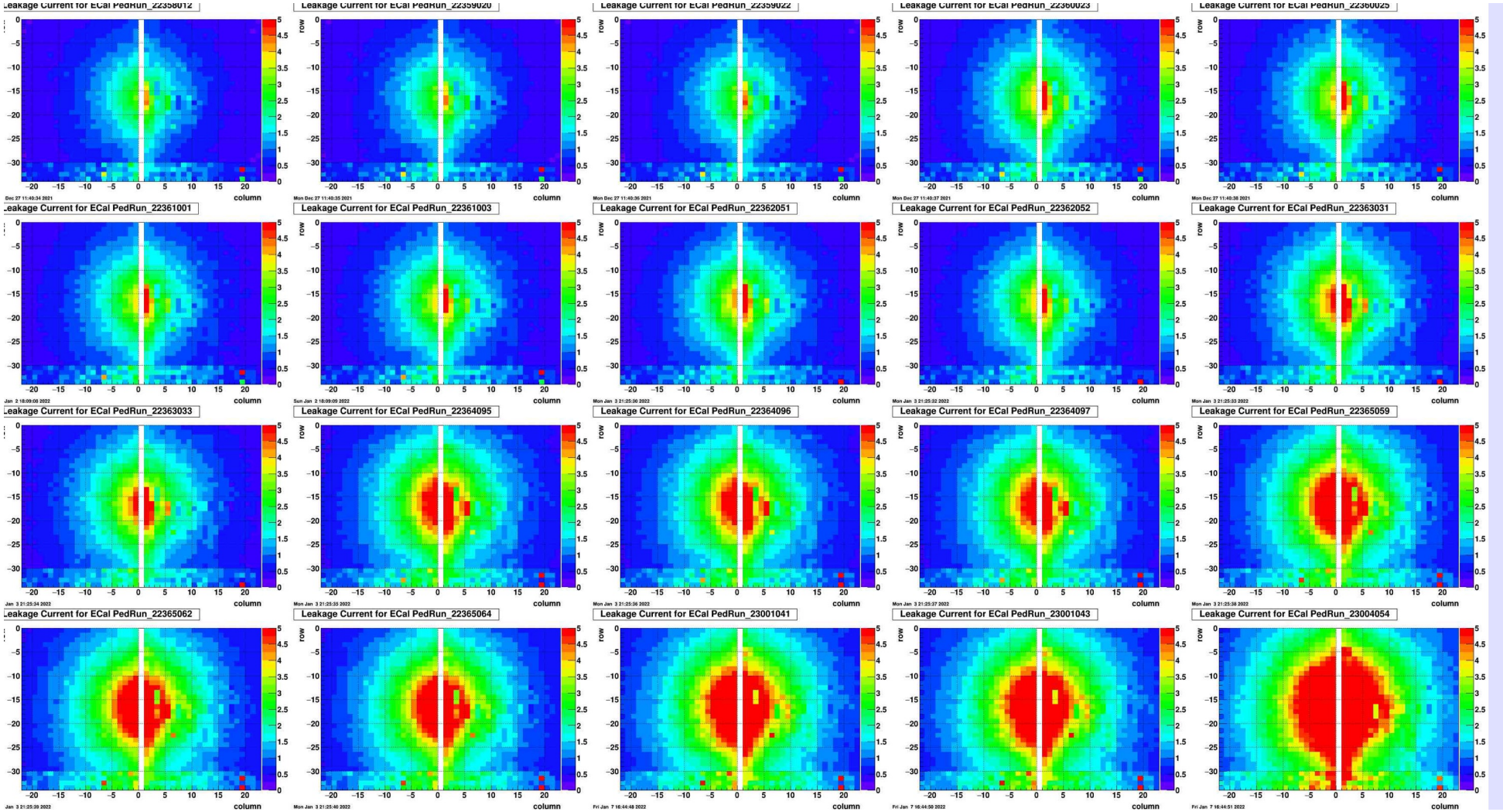
Map checking LED run with HV patterns





SiPM Dark Current Monitor
No beam @ operating voltage

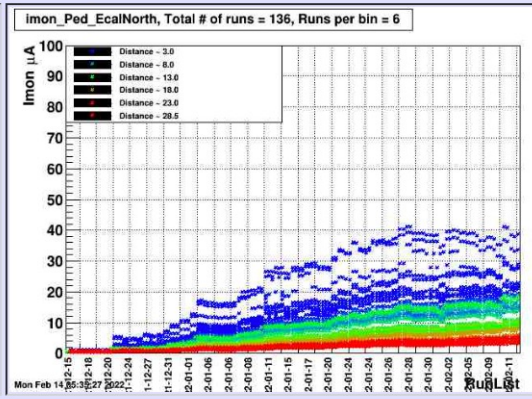
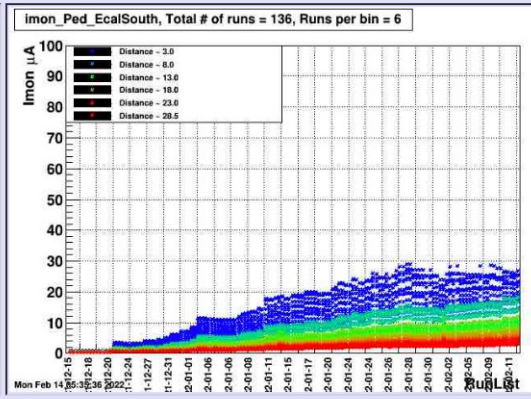
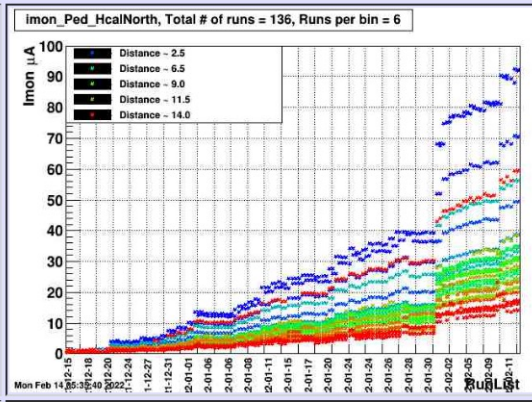
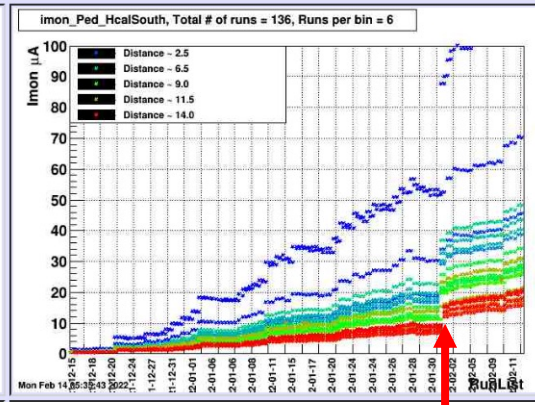
Currents from SiPMs are recorded at beginning of each run

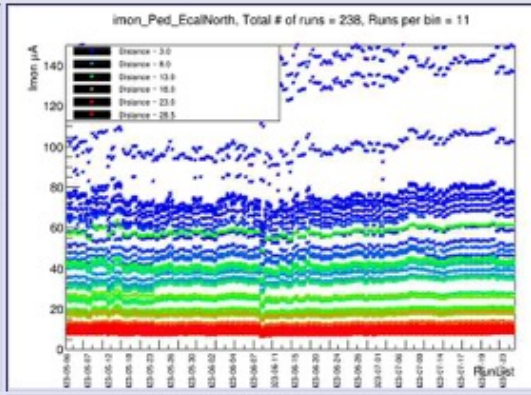
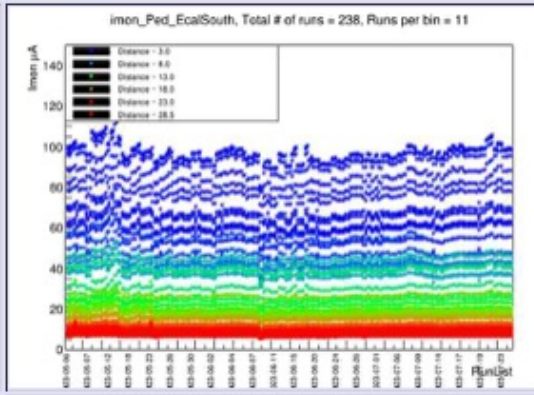
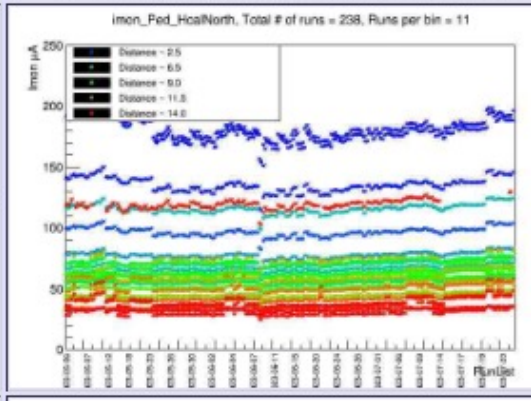


SiPM Dark Current Monitor History
No beam, @ operating voltage

Early Run22 (pp510)

Run23 (AuAu200)

ype	History North	History South
ED Ecal		
ED Hcal		

Type	History North	History South
PED Ecal		
PED Hcal		

Hcal Voltage Change 2022/01/27

Limits are 400uA (Ecal) and 600uA(Hcal)

We see increase of dark current as it accumulates radiation damages on SiPM during pp510, but not much during AuAu200

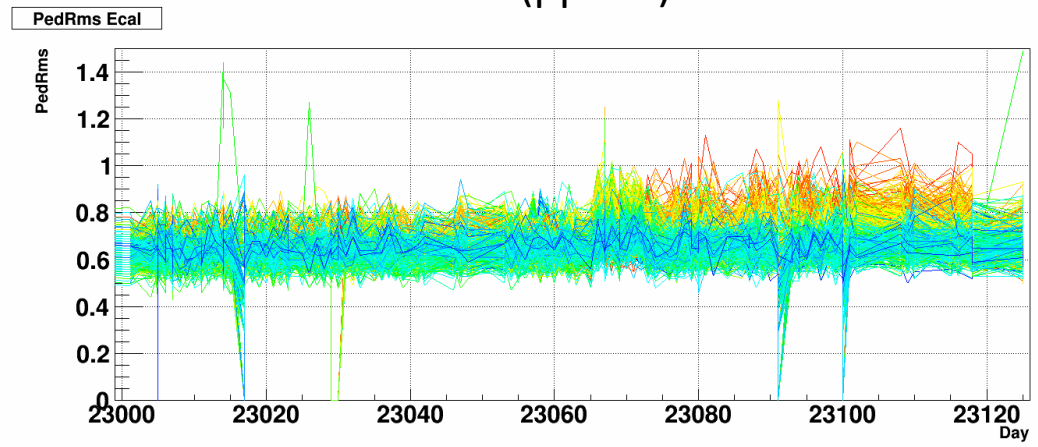
For lifetime of FCS, we will survive through Run25

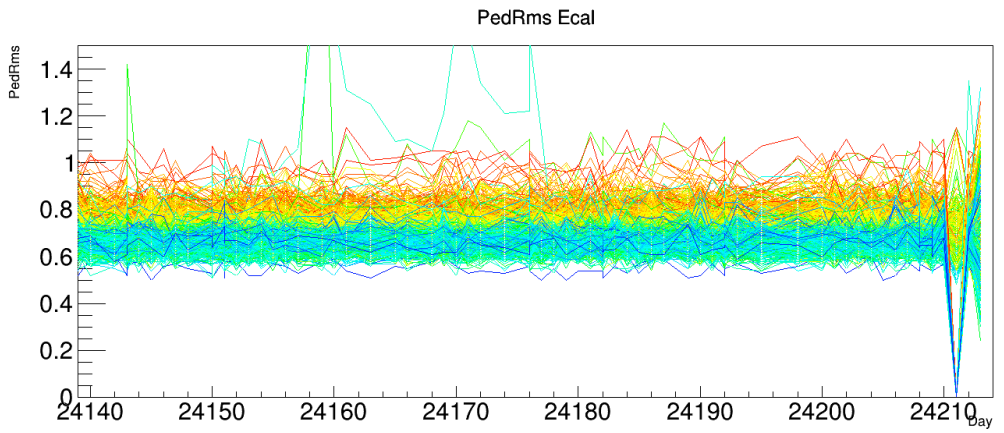
Pedestal RMS History

Run22 (pp510)

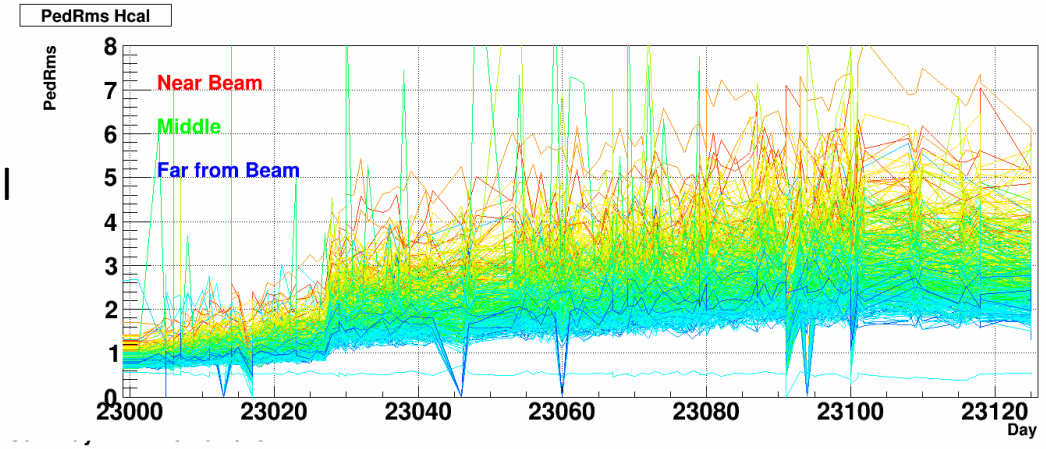
Run23 (AuAu200)

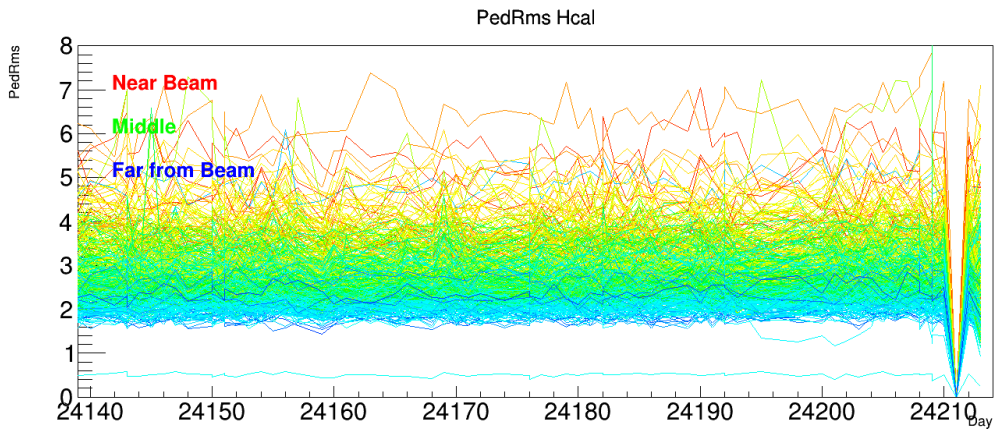
Ecal





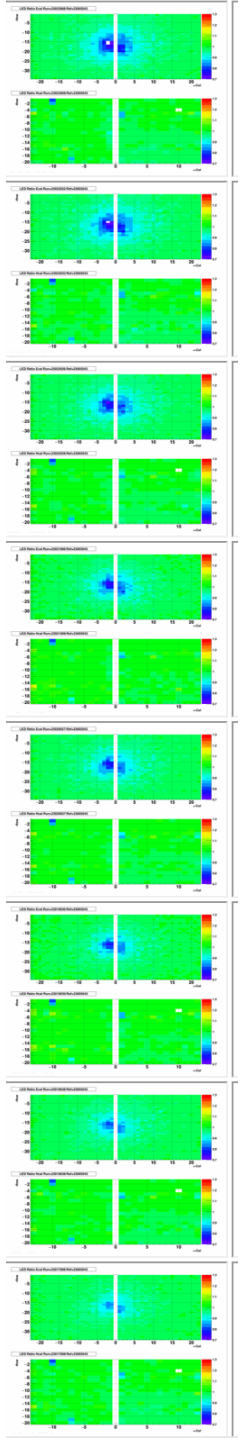
Hcal





ECAL with more lights/GeV, operated at lower voltages, with 1/5 attenuation on FEEBd, see no effect on Pedestal RMS

Hcal with less lights, operated at higher voltages (no attenuation) see increase in pedestal RMS as it accumulates radiation damages

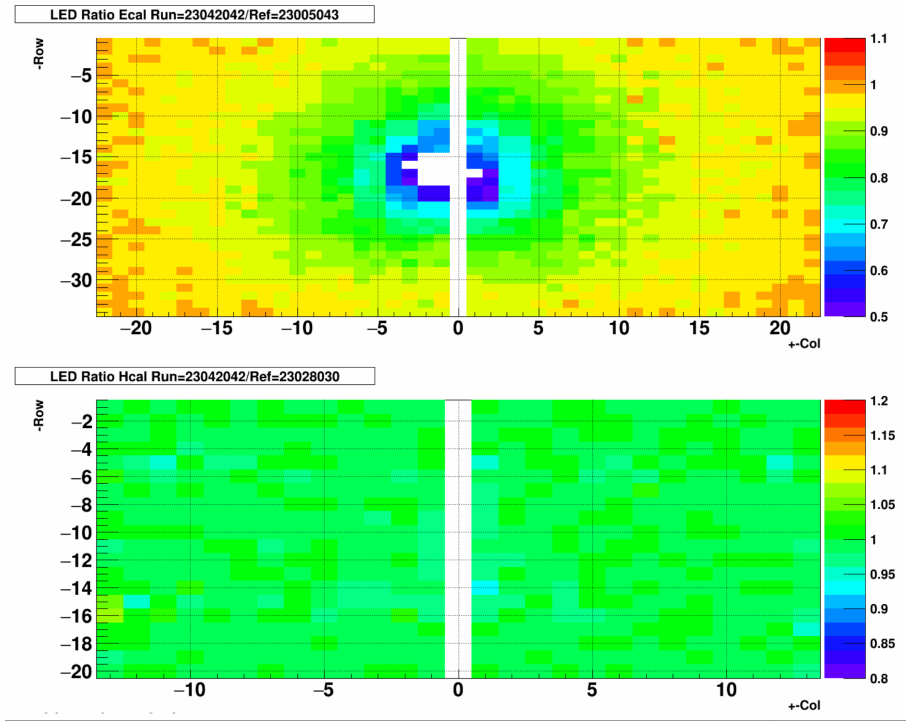


1/23

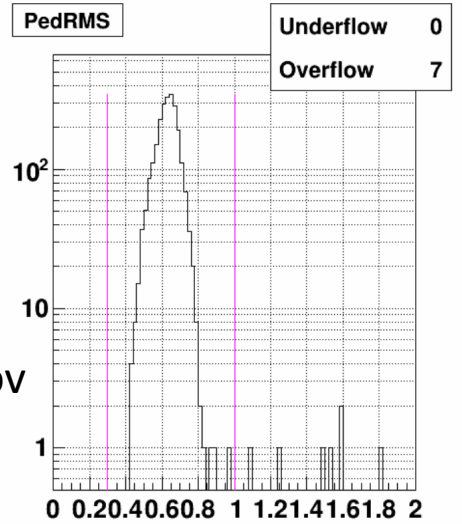
1/17

Radiation damages in something else : FEEBd

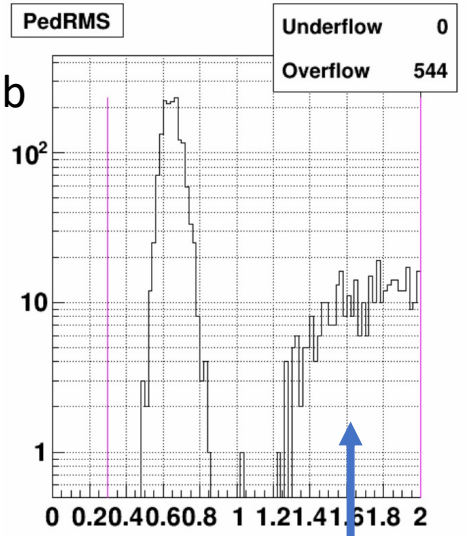
LED Ratio plot 2/11 over 1/05



Pedestal RMS
2021 Nov



2002 Feb



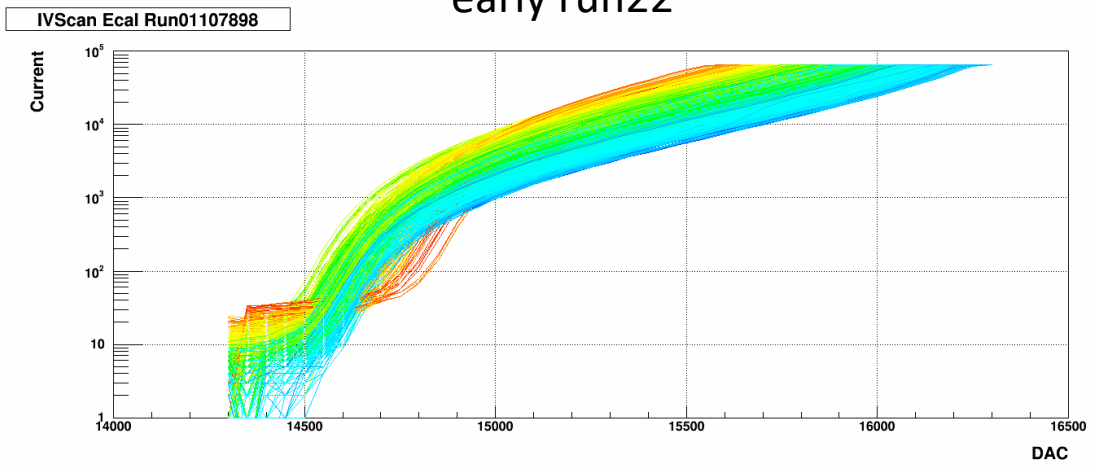
EPD

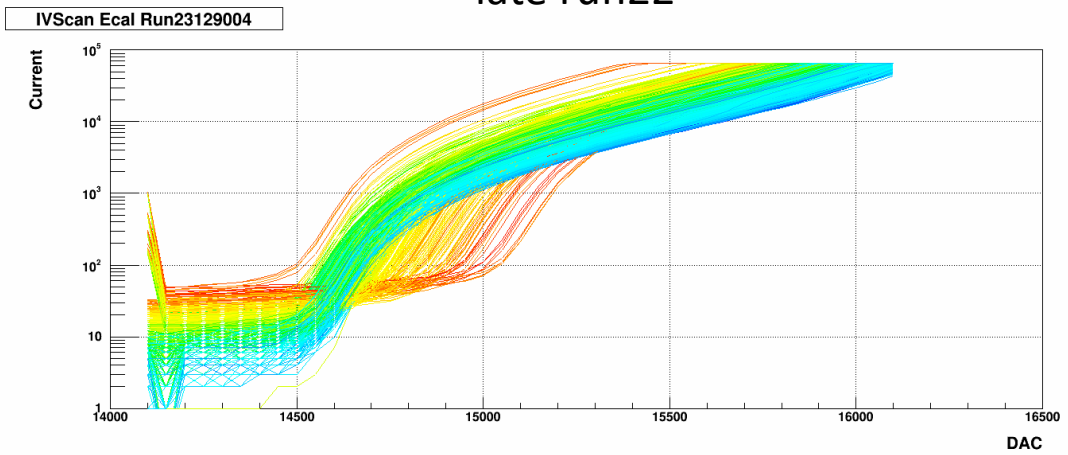
- Ecal loosing gains as much as ~50% near beam over a month
- Hcal is stable
- Pedestal RMS is still < 1ch, even near beam

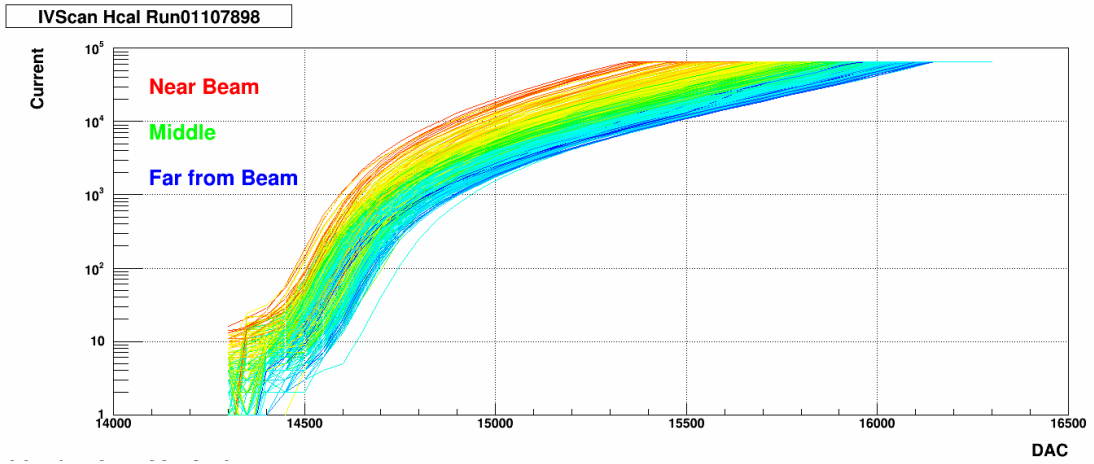
Weekly IV scan run

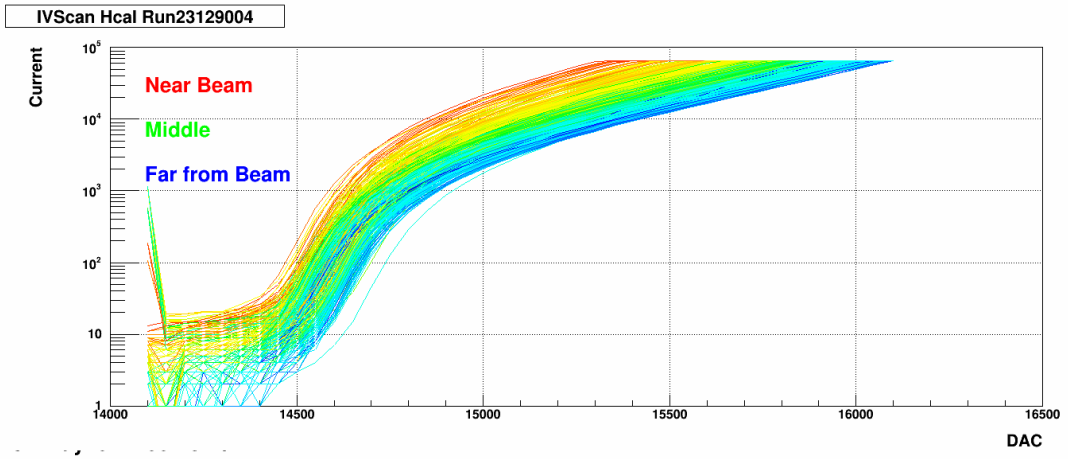
early run22

late run22



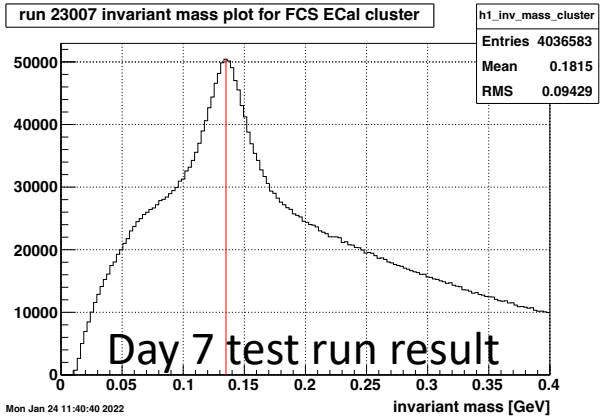


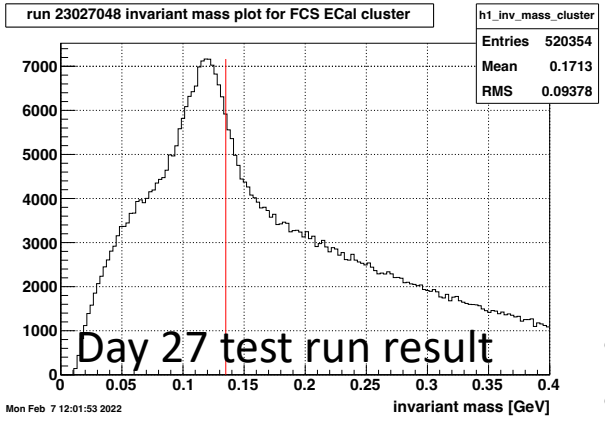


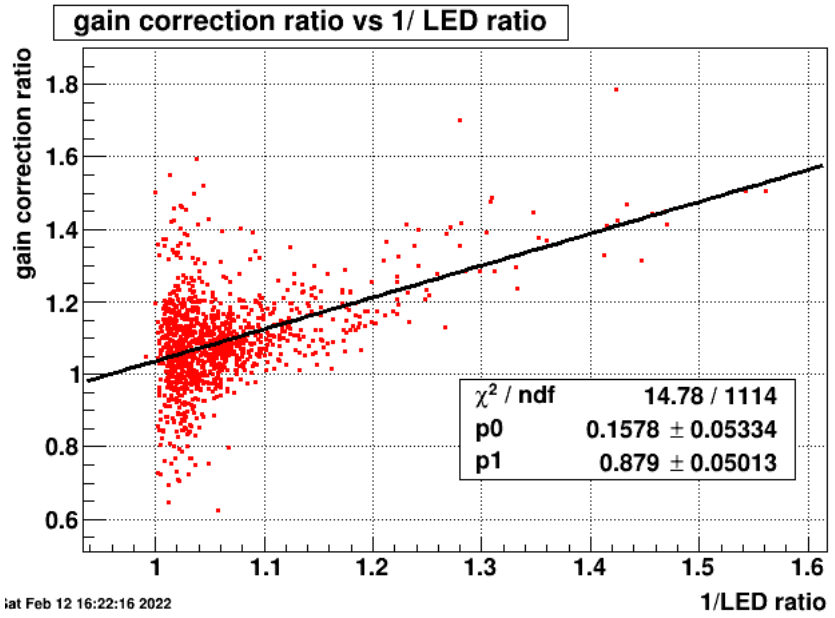


Ecal Near beam (Red) shows IV curve shifted to right

Gain loss confirmed by fast-offline Pi0 calibration







Between day7 and day27:

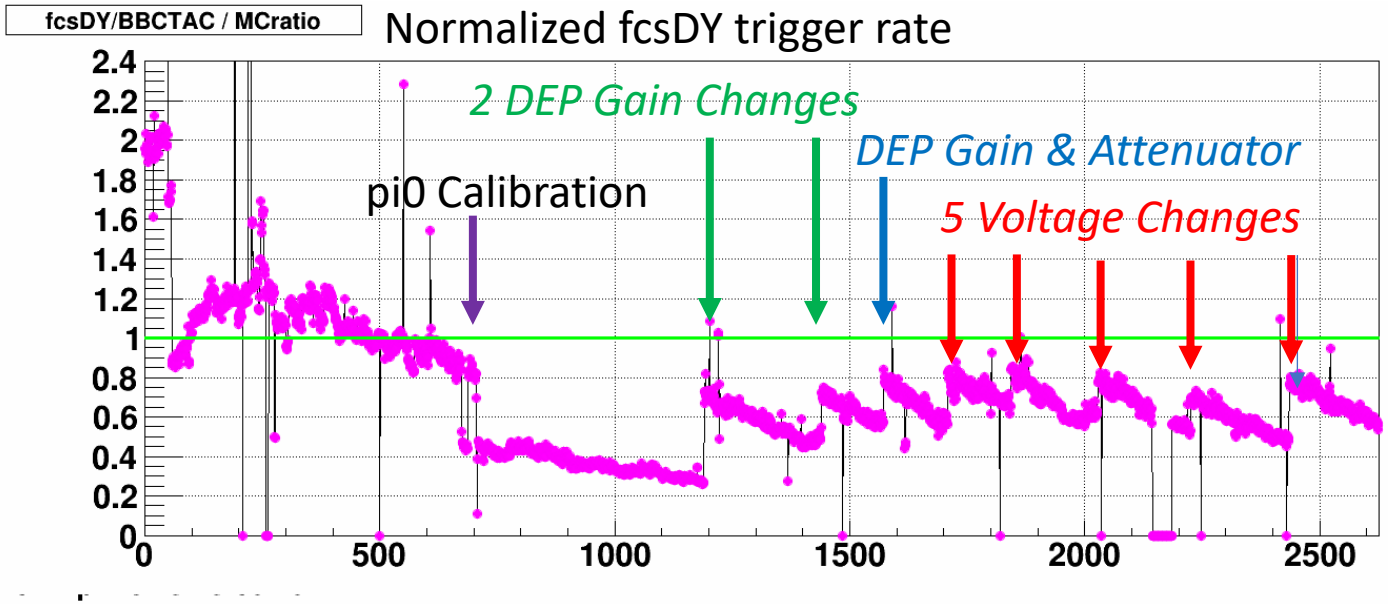
1/LED ratio
vs
GainCorrectoon factor ratio

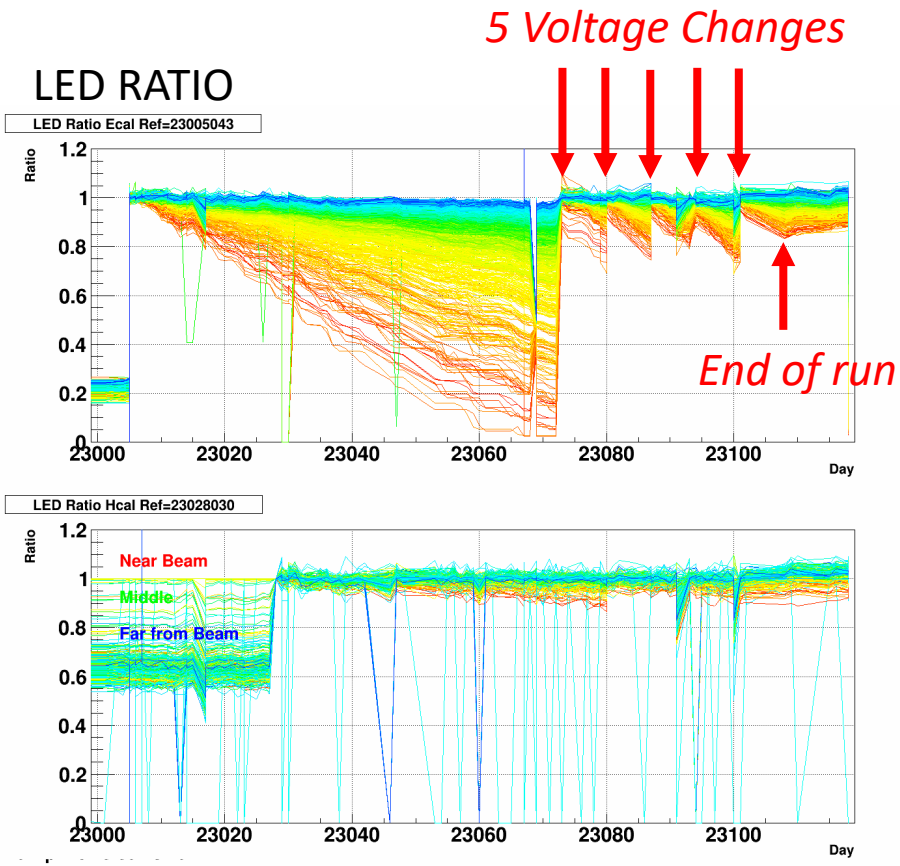
- Light loss seen in LED is also confirmed by Pi0 analysis
- LED and EM shower (pi0) see similar amount of light loss (not trivial)
- But variation is large (cannot use LED ratio for tower by tower gain)
- ASAP, we need to install tower by tower gain (electronics gain file) for DEP (trigger)

- More low-luminosity MB trigger calibration runs?
- Or physics data taking is enough?

FeeBd Radiation damage during Run22

- Significant radiation damage, loosing ~20% signal / week @ Ecal near beam
- Compensating signal loss
  - Jan~Feb : “DEP gain” for triggering only
  - Early March: Reduce ”FEEBd Attenuator"
  - March~ : “voltage” change based on LED ratios





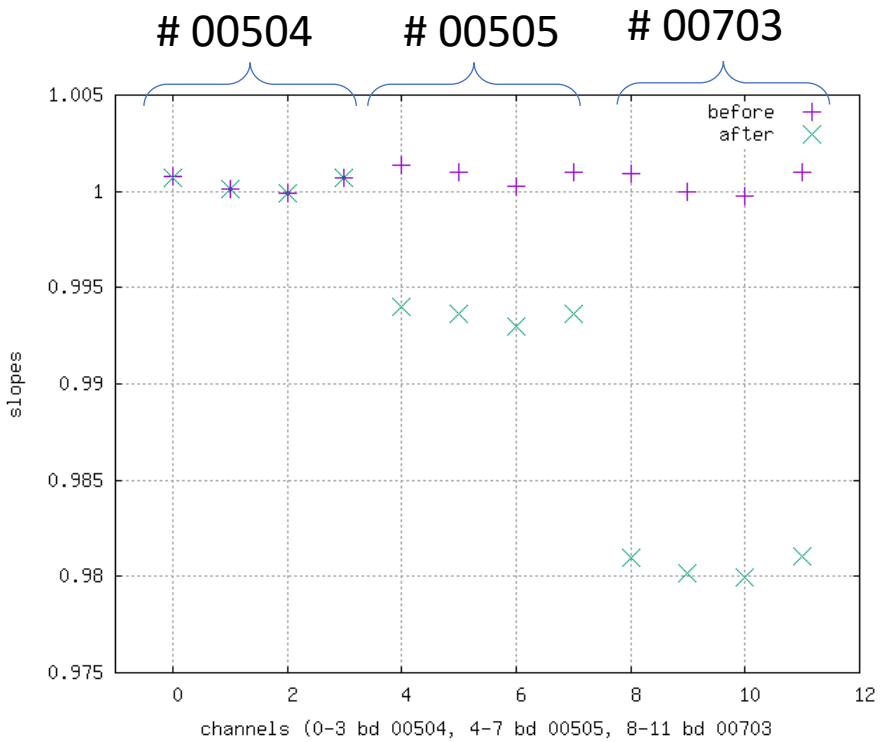
Radiation Damage on Voltage Reference chip (AD # ADR392) on FEEBd

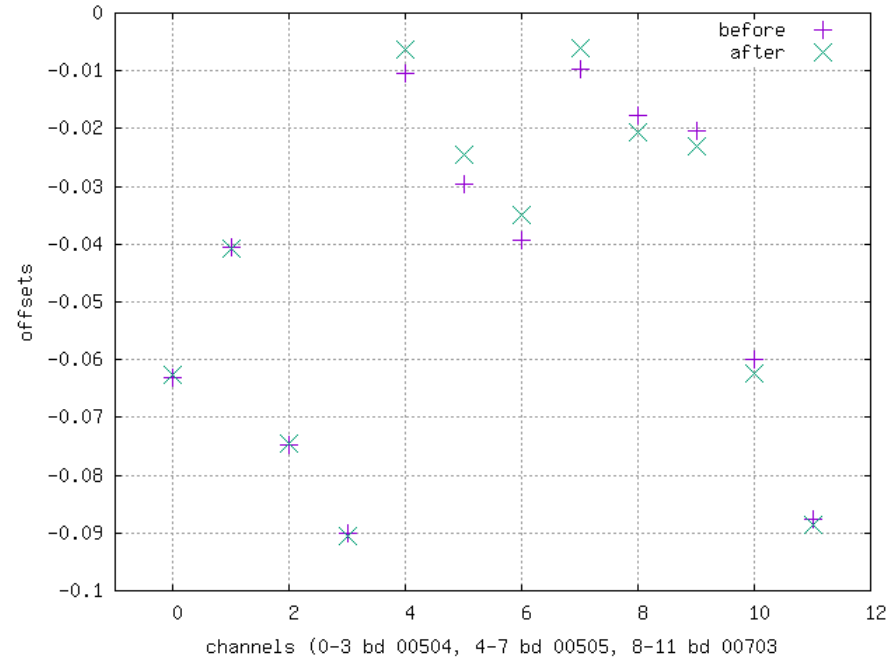
~2% drop on VREF slope after Run22
No change in offsets

V = Vbr + Vov and SiPM Gain ~ Vov^2

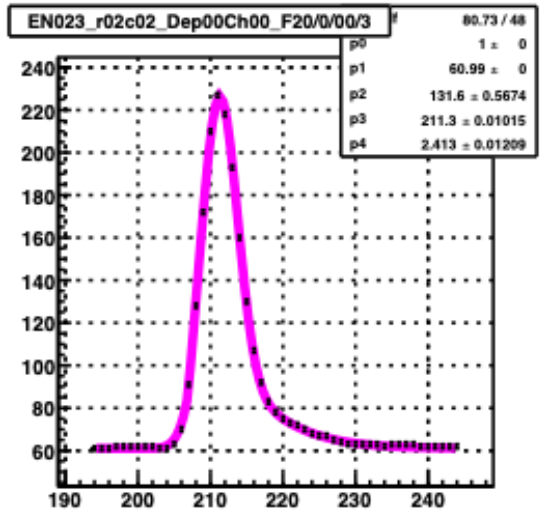
61.5V = 60V + 1.5V
↓ loosing 2% in reference voltage
60.3V = 60V + 0.3V

Gerard Visser : “In ePIC, I am probably thinking to have the V reference chip external, mounted at patchpanel board type of location at outer radius of the detector, to reduce its radiation damage. But I am still tbd and potentially I learn of a suitably radhard reference to use on the FEE board directly. I know I definitely won't use the type I used in FCS!”
Oleg Tsai: “the same chip for Ref. Voltage we used during prototyping in Run17, and at that time we have not seen degradation of that chip. So irradiation tests people are doing for electronics may need to be done on ‘production’ chips.”





Summary



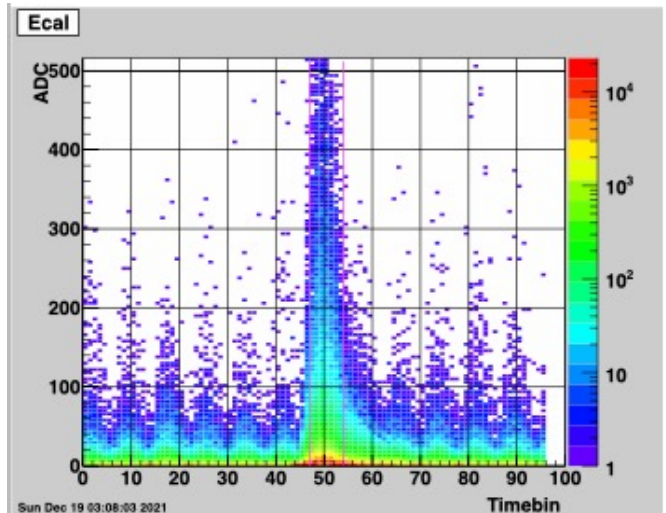
Single LED pulse vs time bin with fits (purple)

- STAR FCS saw 2 kinds of radiation damages

- Radiation damages on SiPM
  - Noise (dark current) increased
  - Hcal pedestal RMS increased (not much Ecal)
  - Possible slight (<10%) hint gain loss in Hcal, but hard to separate from FeeBd gain loss

- Radiation damage on FeeBd voltage reference chip
  - ~2% loss of slope after Run22 (pp510), which is >90% reduction on Vov, for Ecal
    - We compensated using DEP gain (trigger only), FeeBd attenuator and adjusting voltage based on LED
  - Much less effects on Hcal
    - Less gamma? Ecal FEEBds are in front of Ecal, and Hcal FEEbd are in back of Ecal and Hcal
    - We operated Hcal at much larger Vov

- Very important to monitor
  - SiPM dark currents
  - Pedestal and its RMS
  - LED
  - Trigger Rates
  - Fast offline calibration
  - Occasional IV-curve scan



Pulse shapes vs time bin from many events overlapped during pp 510 physics running

What should we maybe expect on radiation effects on a voltage reference?

- I did not yet find anything online for the chip we are using (AD # ADR392)
- The datasheet for an example radiation-hard chip's (ST # RHF1009A) shows a typical 0.1% decrease in Vref for 300 krad (gamma).
  - BTW probably unaffordable anyways, it's meant for space hardware
- We see 2% decrease, for some unknown dose – any dose guesses?
- Perhaps expect on the order of 1% decrease at 200 krad for "generic" (but older) reference IC's, according to this paper

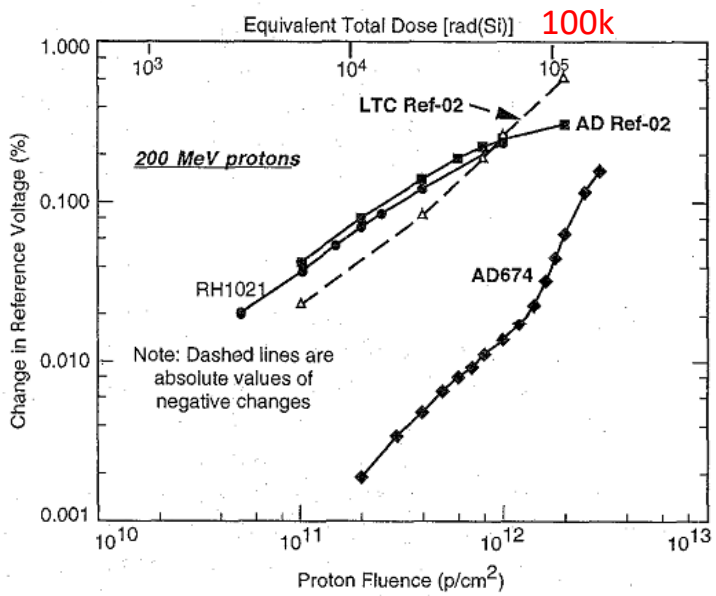


Figure 5. Proton Degradation of Moderate-Precision Reference Devices

protons. neutrons can be much worse than γ

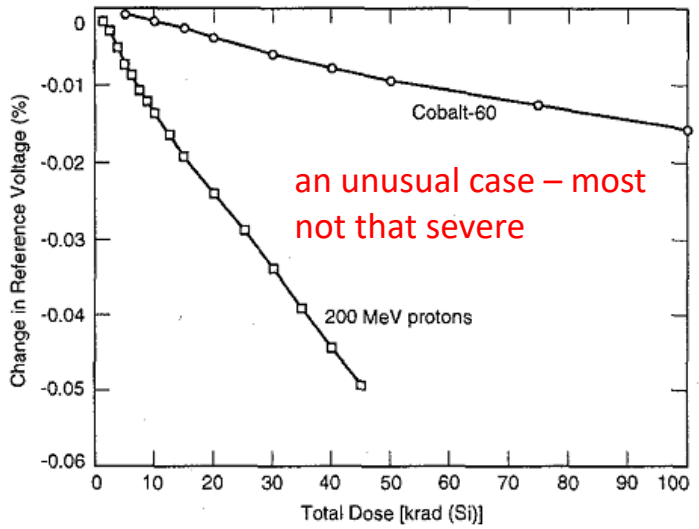


Figure 1. Comparison of the Effects of Proton and Gamma Radiation on Degradation of the AD2710 Precision Reference

B. G. Rax, C. I. Lee and A. H. Johnston, "Degradation of precision reference devices in space environments," in *IEEE Transactions on Nuclear Science*, vol. 44, no. 6, pp. 1939-1944, Dec. 1997, doi: 10.1109/23.658965.