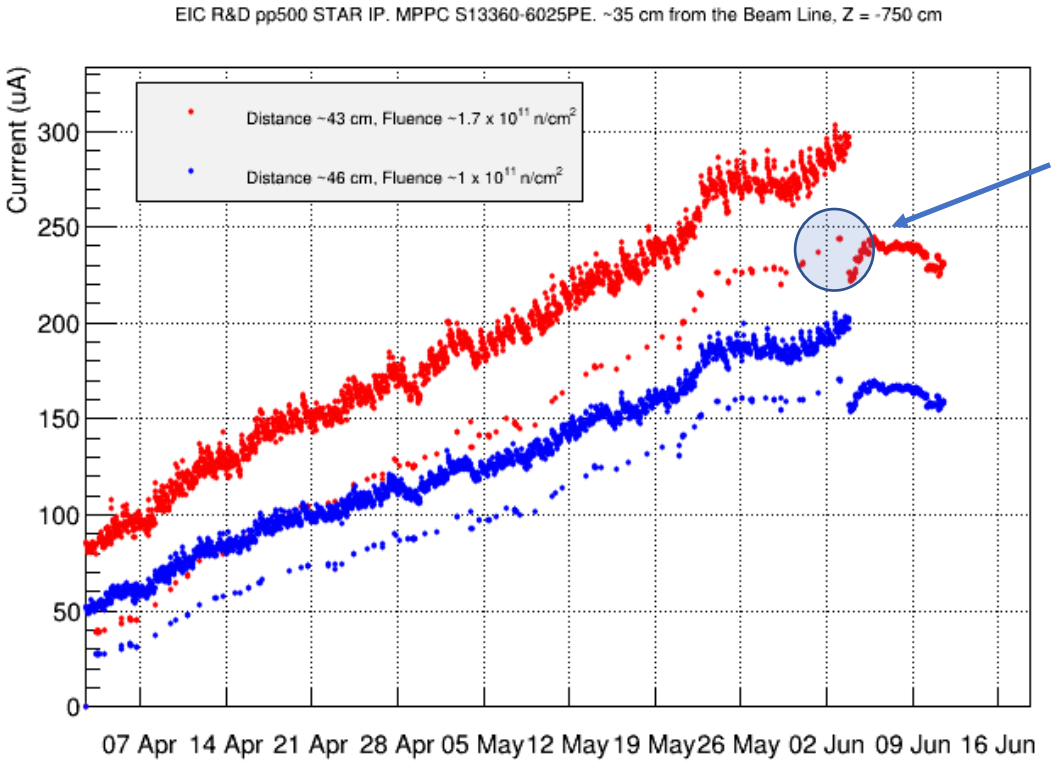
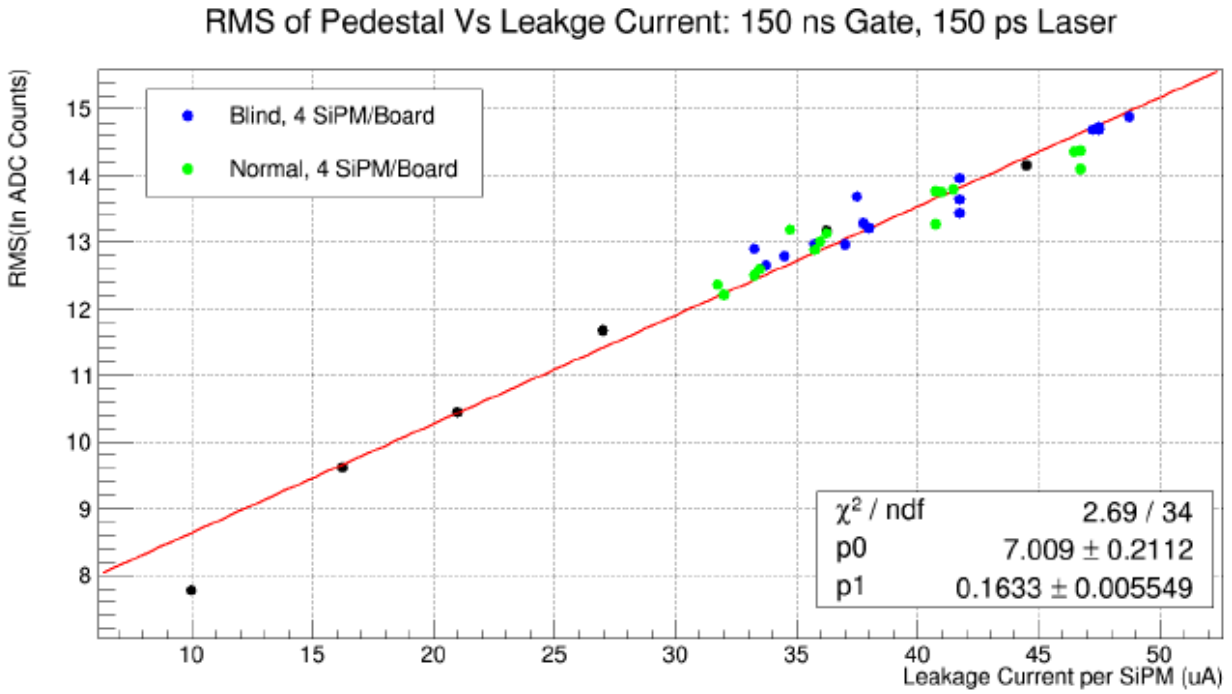
FCS Radiation damages, Summer Shutdown

O.Tsai 02.14.2022

SiPM rad damages.



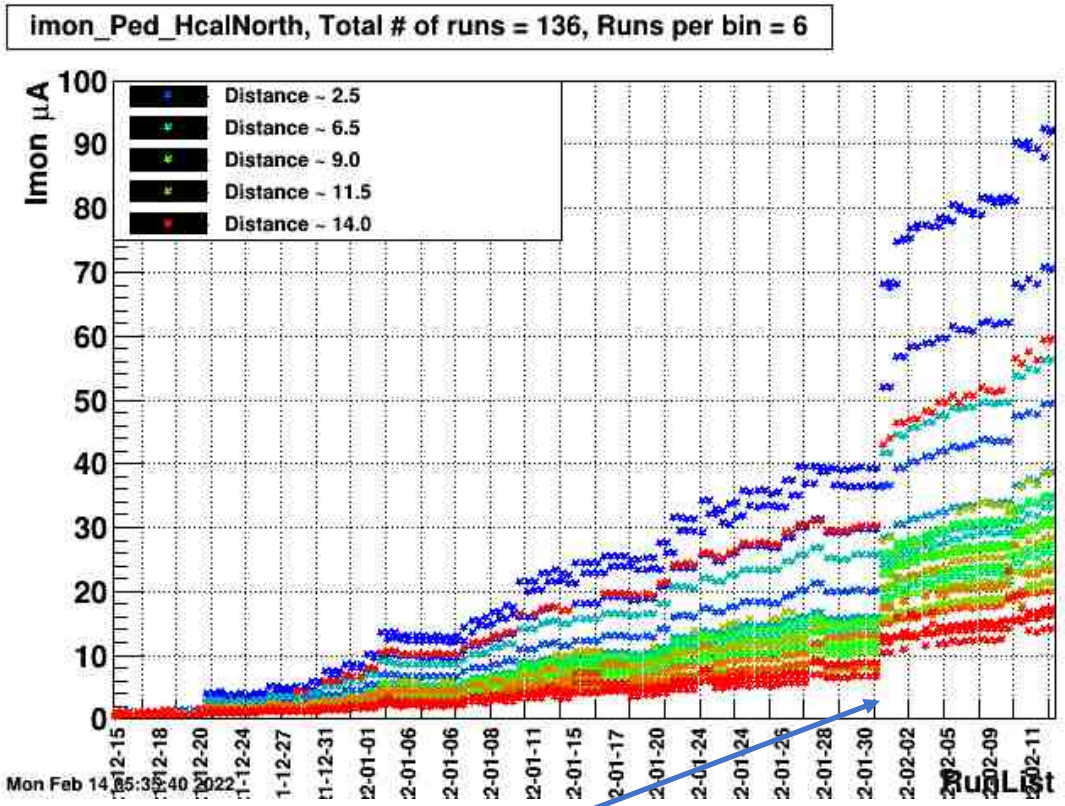
Defects accumulates -> Leakage current grows, roughly ~ delivered lumi.
Annealing at room temperature (~ 27 C) between pp and AuAu running



Noise grows linearly with leakage current

Back in 2017/18 investigation pointed to heating (very localized) of avalanche region by leakage current. Led to simple **requirement for FCS to keep current per SiPM below 100 uA.**

We set over bias as low as possible for FCS. Adjusted it for Hcal later.

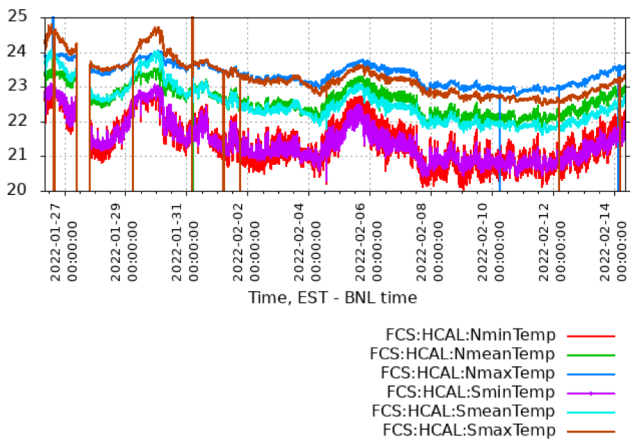


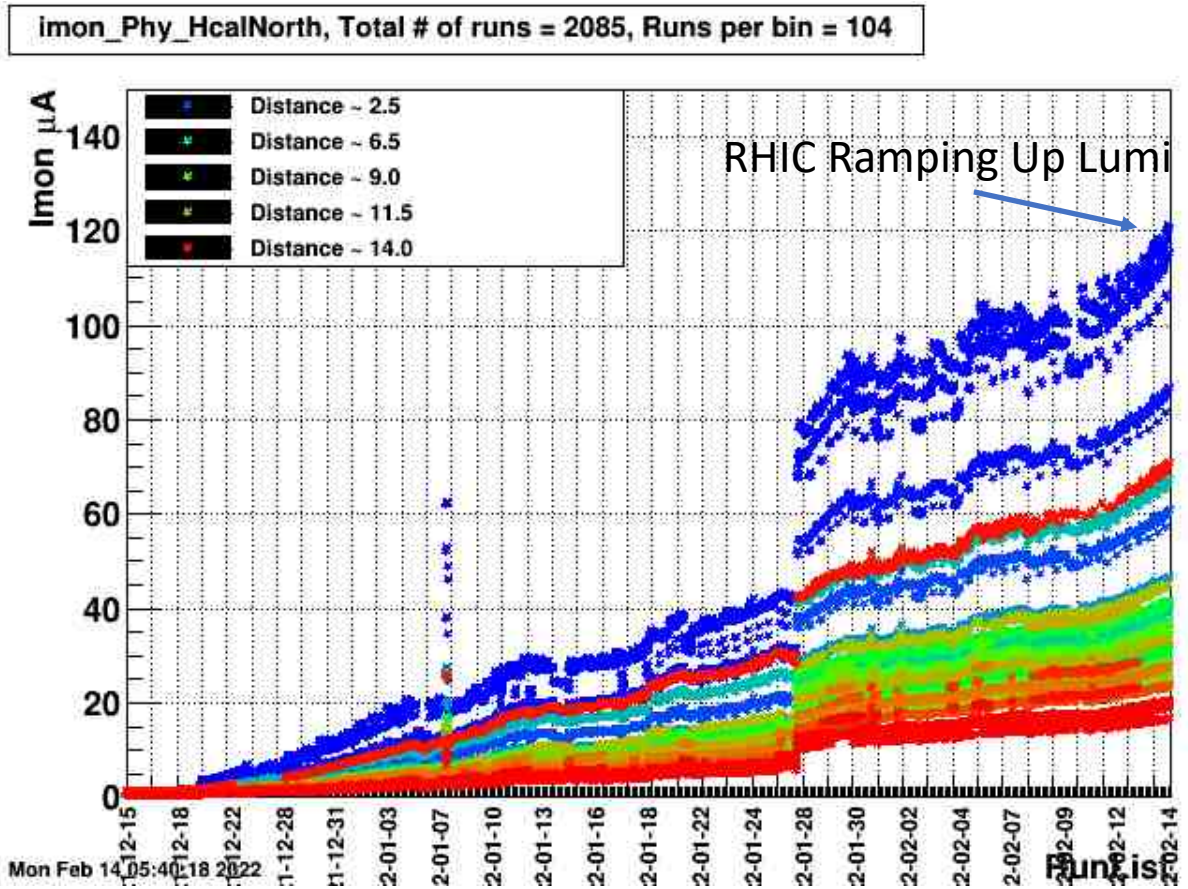
Hcal SIPMs currents looks reasonable at a glance:
Highest current due to signal ~ 30 uA
Highest current due to rad damages ~ 90 uA

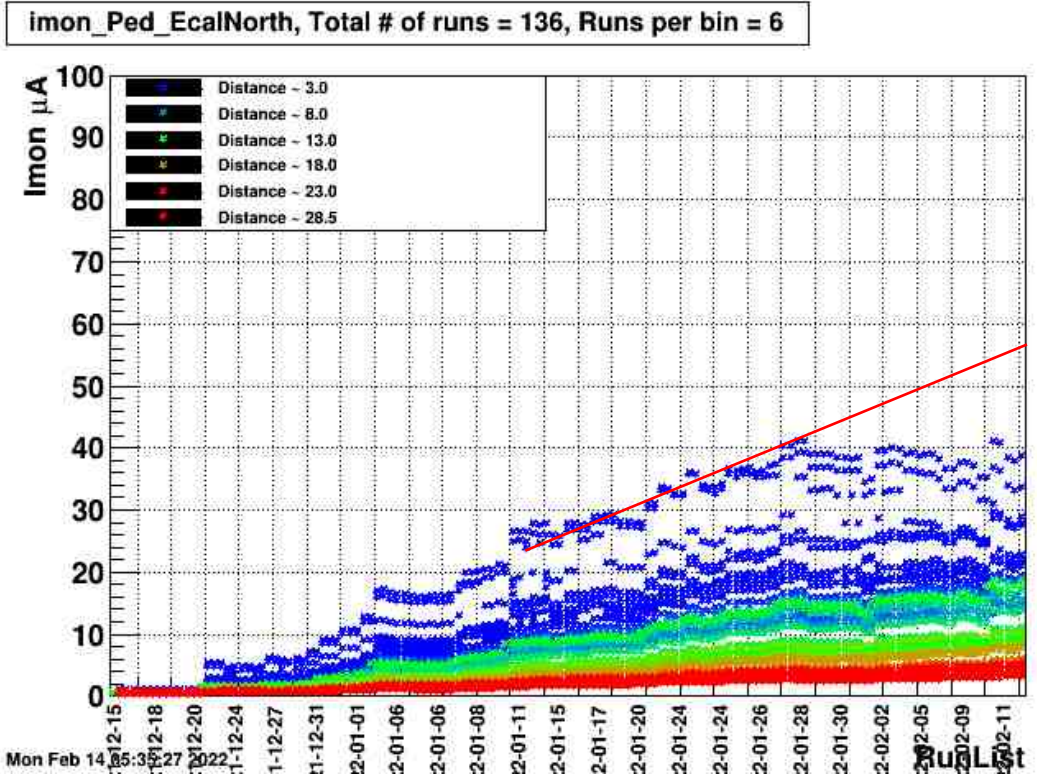
Projections dark current by end of April – 200 uA
Total ~ 230 uA, Hardware Limit 600 uA

Bias change to adjust gain

N.B. unlike Ecal no visible saturation for dark current due to cooldown of HCAL





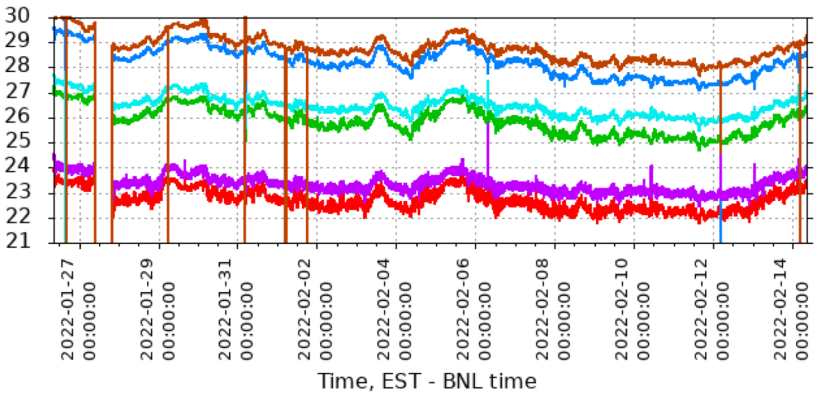


Unlike Hcal, dark current start to ‘saturate’ after Jan 28’th or so

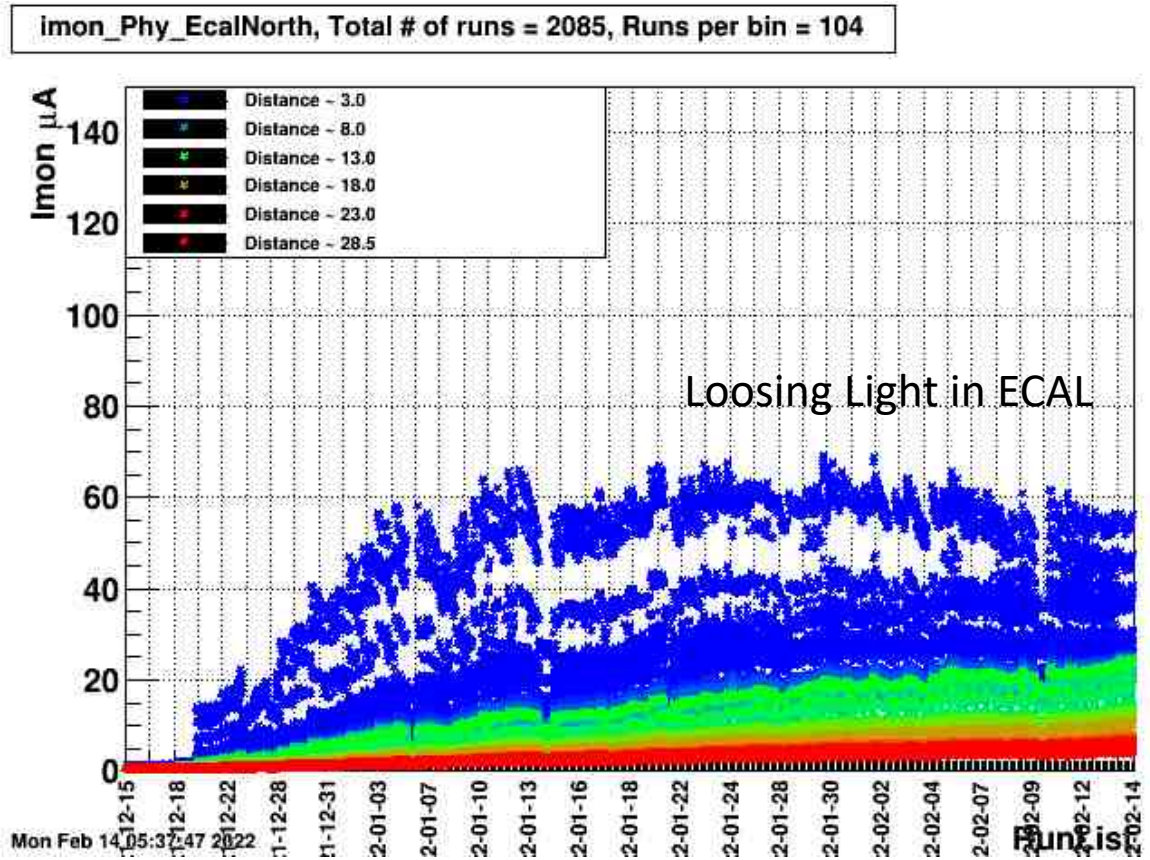
Temperature drop in Ecal at the same period was about 1.5 degrees.

Temperature increases by 5.3 degrees C – dark current doubles,
Roughly consistent, but still strange let’s keep watching….

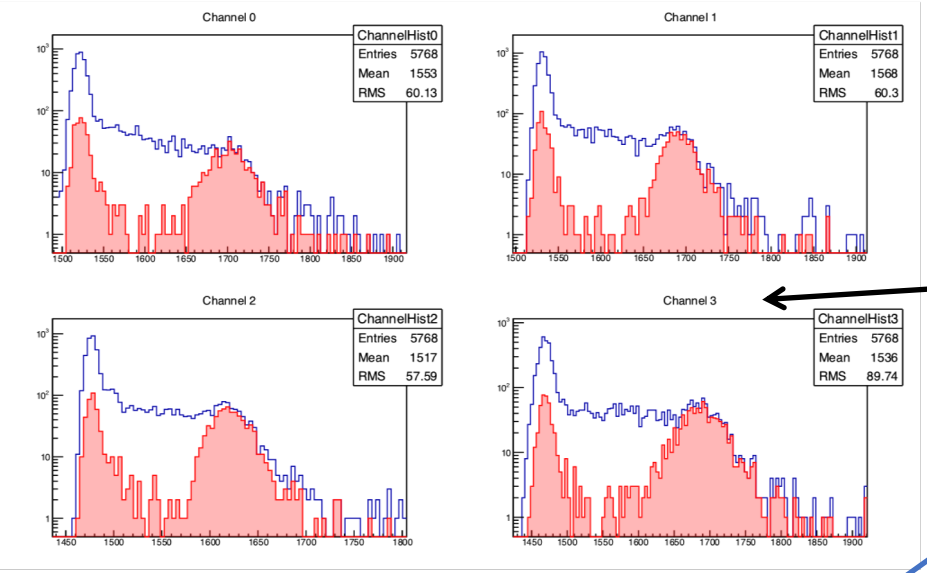
Projections: Highest current ~150 uA, Limit 400 uA



Ecal cooled by ~ 1.5 degrees



Noise. R&D 2017, Shashlyk S12572-15 four 3x3 mm SiPMs per tower.

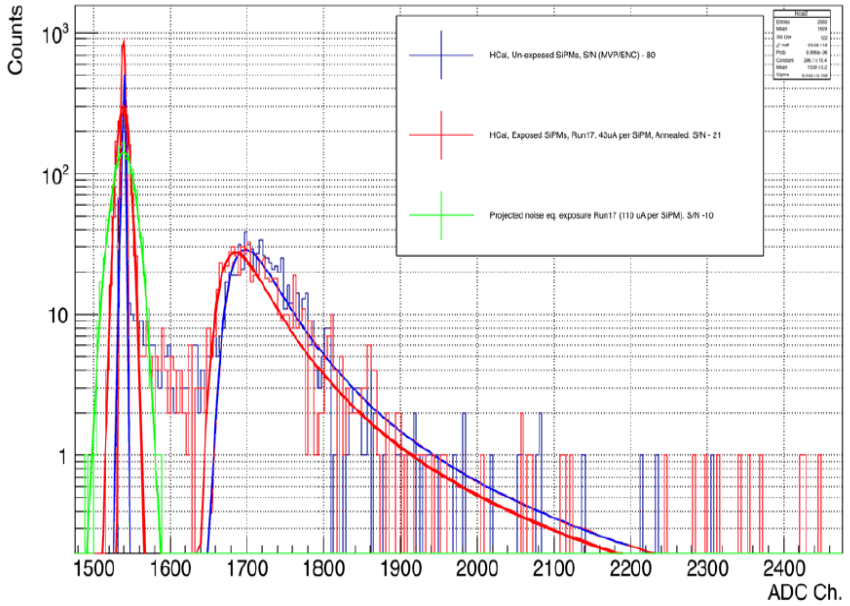


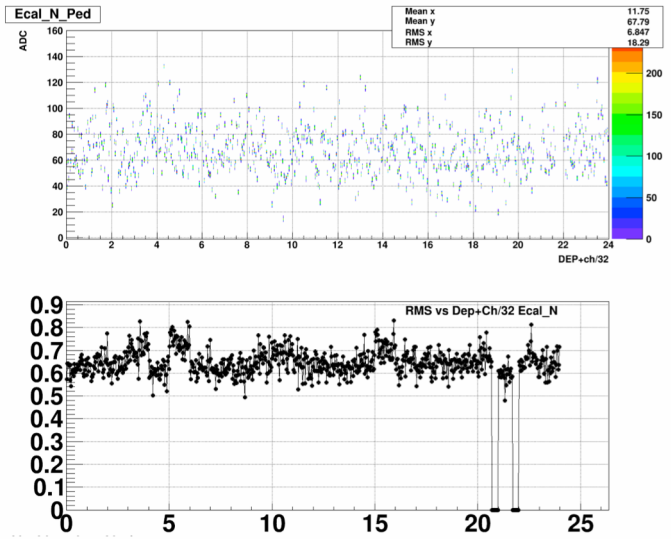
Cosmic Muons with un-exposed SiPMs ENF ~ 1.7 MeV

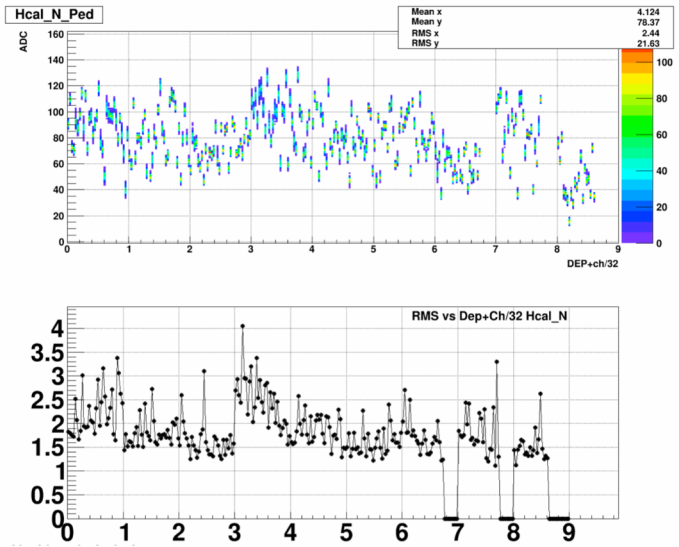
- SiPMs Degrade with exposure (details later in talk).
- 500 GeV pp (Run 17) was the worst case in terms of exposure.
- Cosmic Muons with exposed (Run17) SiPMs, ENF – 10 MeV/tower
- Hcal (6 SiPMs/tower) noise after exposure ~ 100 MeV (100 uA per SiPM)

N.B. S/N depends on over bias!

FCS 2022, pp 500 GeV. Feb. 3 2022 (~ 1/3 lumi delivered)







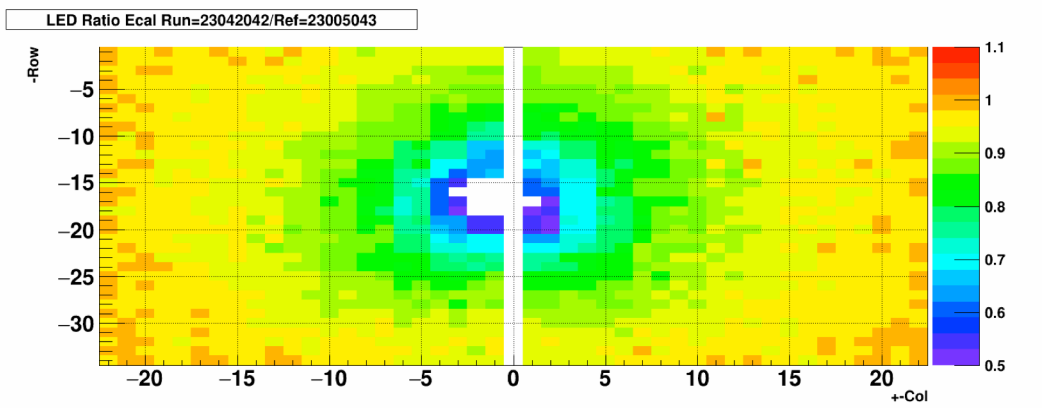
Ecal Noise ~ 3 MeV

HCal Noise ~ 16 MeV (average)

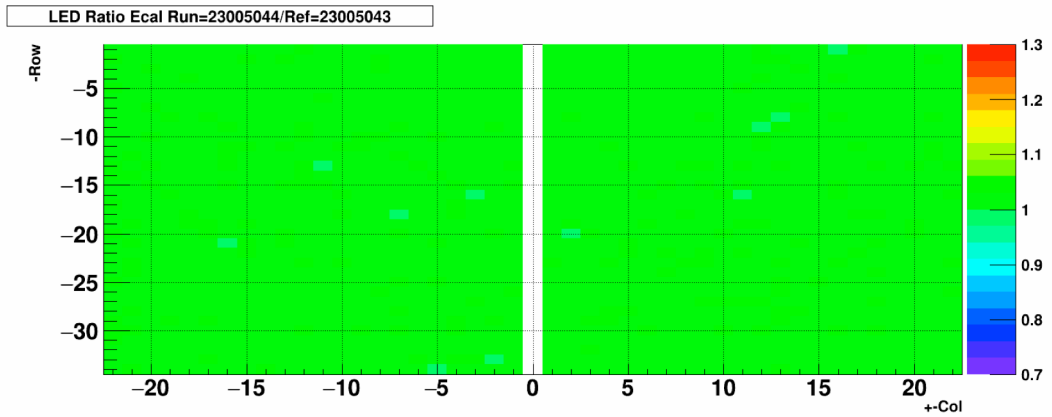
At the end of the Run22 noise in Ecal ~ 6 MeV*, Hcal ~30 MeV, highest ~70 MeV

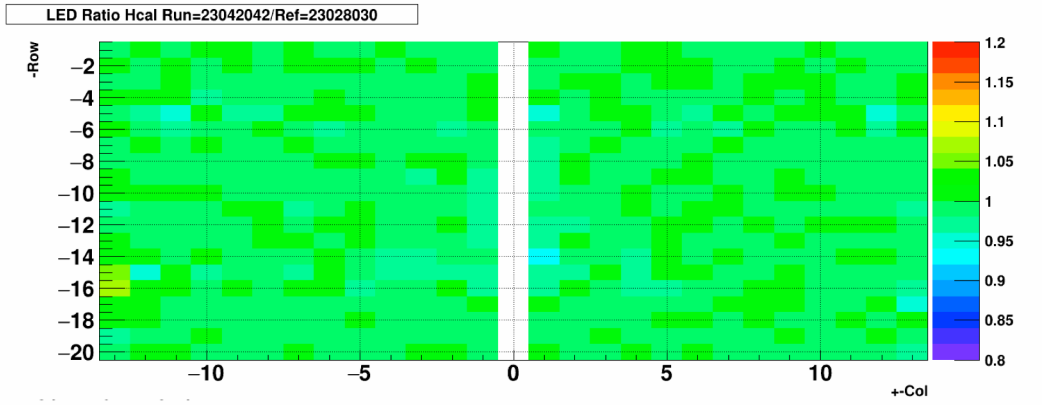
FCS Ecal Rad damages. Some channels close to the beam pipe lost ~ 30% in 20 days. That was not expected!

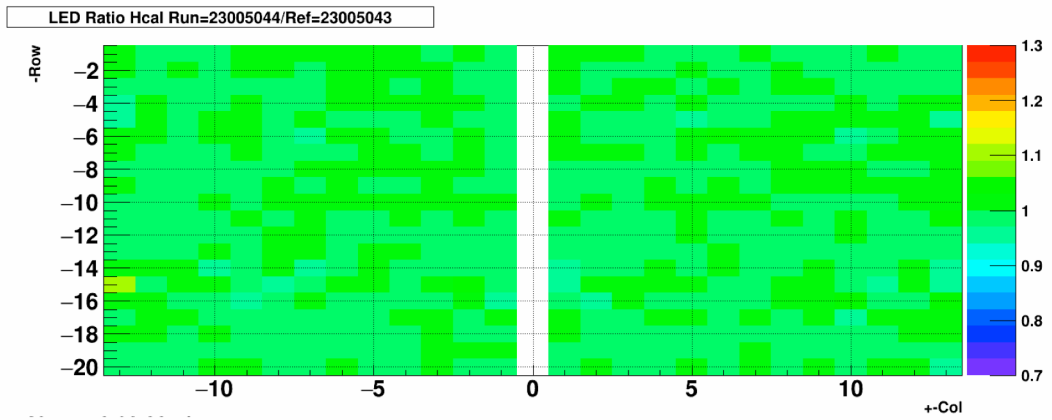
Feb 14



Jan 5





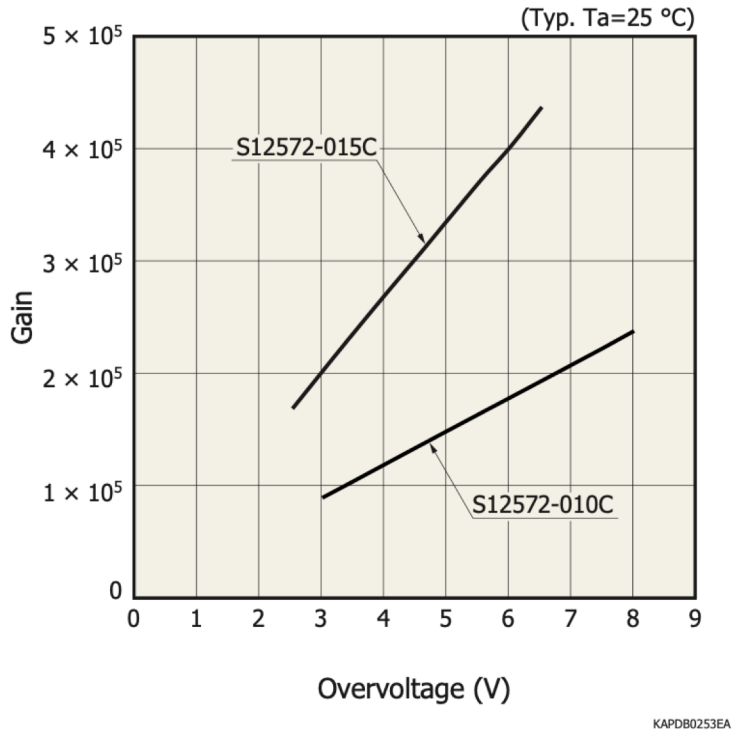


- More damages on North Ecal compare to South.
- No dramatic changes for Hcal (three blue blocks are due to replaced FEE cards)
- Expectation was worst exposure ~ 50-100 kRad in pp 500 Run
- Some degradation were expected but not at the level we are seeing, seemingly corresponding to x10 more rad exposure
- S/N on Ecal will change for central channels it may easily go to 12 MeV at the end of the run.

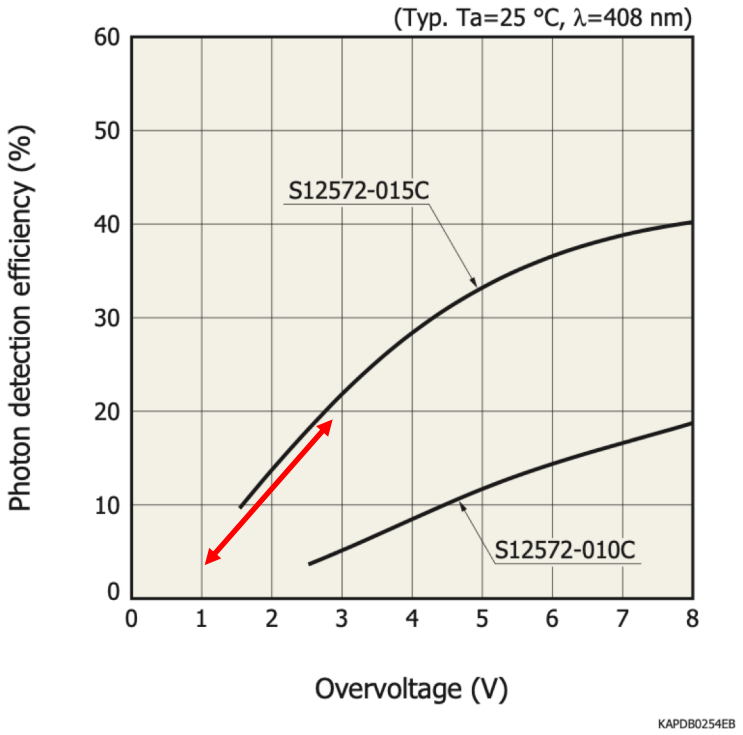
What to do with ECal rad damages?

We'll need to optimize SiPM setting for ECal After Run 22, or may be during Run 22

Gain vs. overvoltage



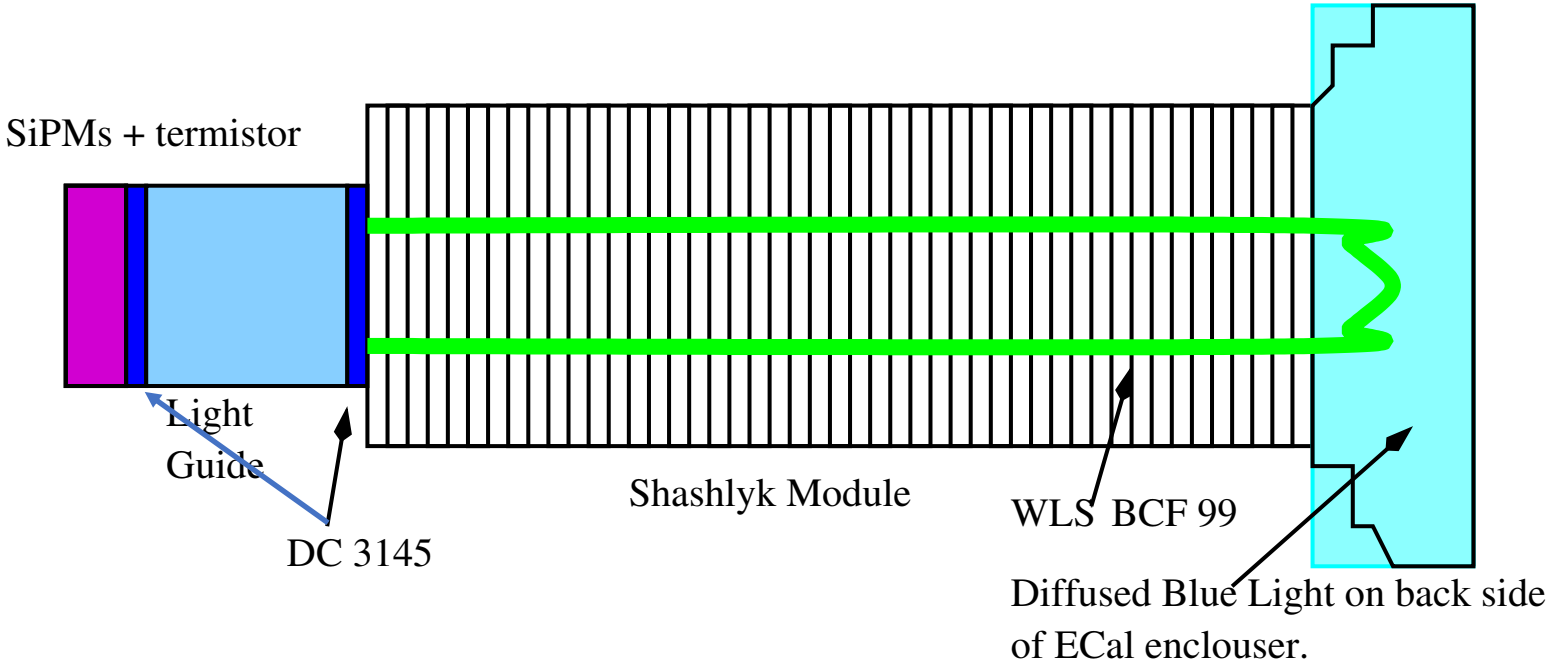
Photon detection efficiency vs. overvoltage



- We are operating SiPMs at very low over-voltage.
- Looking at ECal currents we may increase bias by ~ 2V, and still be OK (hardware limit).
- This will increase PDE ~ x3 or so.

S/N optimization should be done with exposed SIPM boards.

We have 16 SiPM boards frying next to the beam pipe, enough for everything (annealing tests, cosmics, lab tests)



What actually LED system is telling us?

Attenuation of green light from back of the module to SiPMs.

Components affecting LED signal:

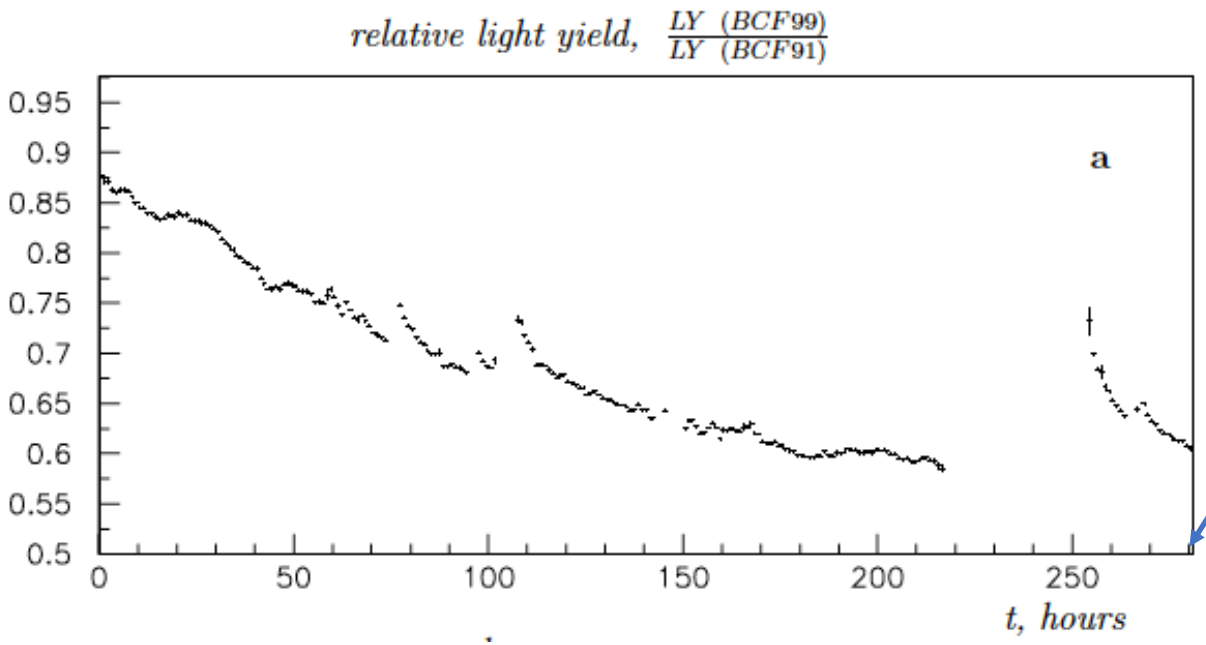
1. SiPMs (strange ECAL leakage current)
2. Termistor
3. DC 3145 RTV two joints
4. Acrylic Light Guide
5. WLS BCF 99
6. Diffused Blue LED light
7. FEE preamp

- Comparing Ecal channels away from the beam-pipe, and SiPM exposure to neutrons in Ecal and Hcal, and from literature regarding rad tolerances we can exclude 1,2,4,6.

- Something on preamp may degrade with exposure, unlikely?

Suspect components:

1. DC 3145 RTV (CMS Note 2001/030) considered rad hard for CMS. Sensitive to gamma irradiation, at 400 kRad absorption for 300 mkm layer is 50% higher, not sensitive to neutrons or protons. Same RTV for Hcal and Ecal SiPM/WLS gluing, but HCal gluing joint is not exposed to gammas. In Ecal total thickness may be higher than 300 mkm.
2. WLS BCF 99 is not particularly rad hard. LHCb did some tests shown below, up to 500 kRad. How aging of fibers may change what LHCb measured is not known, beside this BCF91 also degrades. (at STAR we used different Sc/WLS components)



Bottom line:

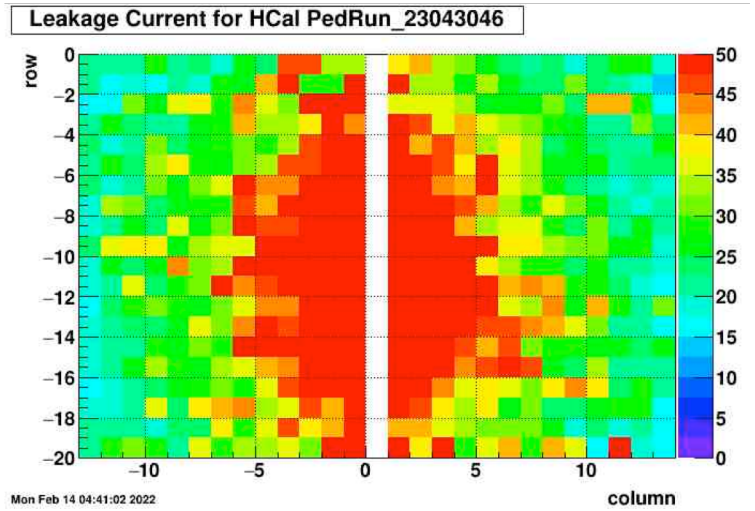
- FCS rad damages are much higher than expected.
- Pinpoint what actually is aging may be difficult.
- Background, leading to much higher doses (N Ecal compare to S Ecal)?

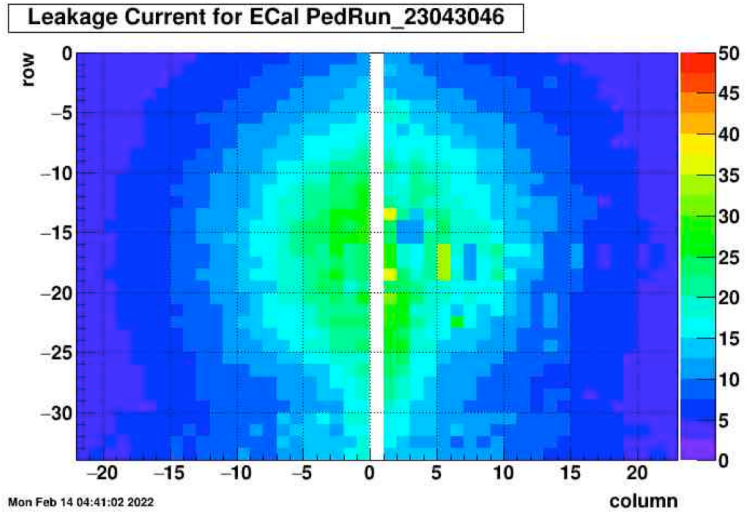
What to do?

- LED system tells about absorption of green light from the back of the module to SiPMs.
- This is not exactly relates to change in ‘gain’, i.e. adjusting attenuator or adding software gain coefficient for trigger purposes on basis of LED runs is questionable. At first order may work, unless Sc tiles also damaged a lot?
- Will be good to establish correlation between pi0 gain corrections and LED runs. – See Xilin/Akio talks.

Shutdown 2022:

- Usual maintenance.
- Survey with open Hcal.
- Annealing at elevated T (run with fans OFF, late summer/fall).
- Consider annealing ECal SiPM board in situ (requires testing).
- Consider annealing HCal SiPMs boards near the beam pipe (requires re-gluing SiPM boards to WLS. Was and can be done, pros no calibration for AuAu, or do annealing after Run 23. Need to think.
- Optimize SiPM bias setting for Ecal (cosmics 510) (May be put one/two Ecal blocks at the East side?)
- We may improve cooling using MCW for ecal/hcal shells , if we plan to run during summer months (Run 24).
- LED monitoring/monitoring was not finished, parts are in Gerard's hand. Not clear if we want to push this…





Summary:

- FCS radiation damages are tolerable.
- There are ways to mitigate them.

THANKS !