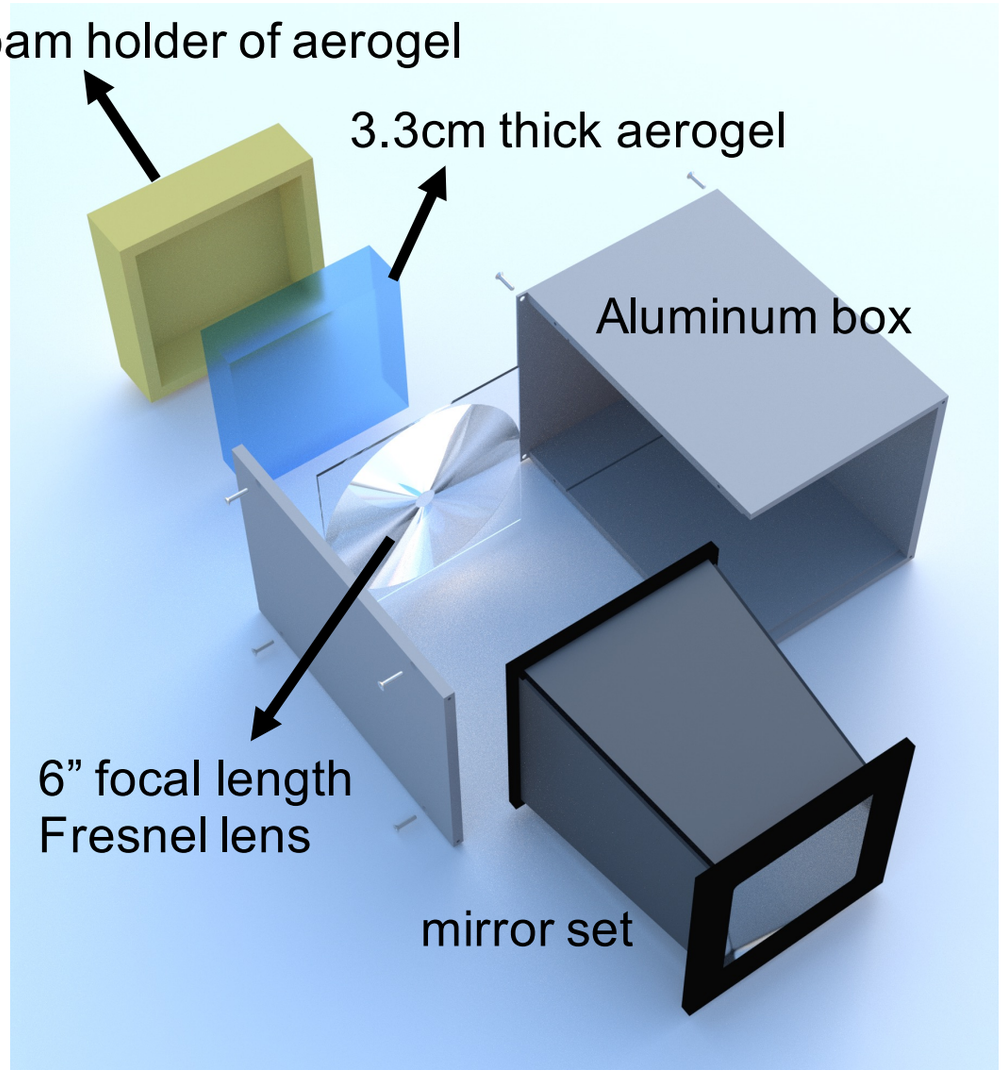
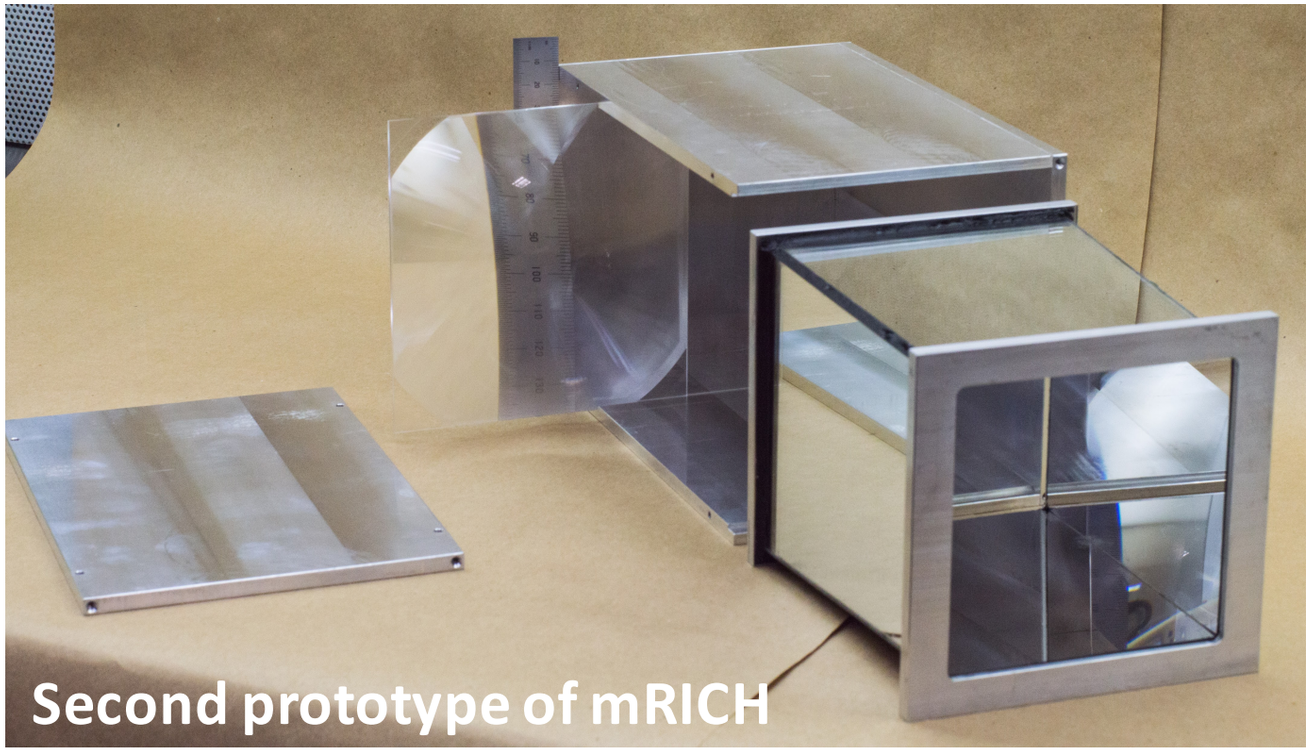
Test Beam Calibration Update with Beam Finder

Xu Sun
Georgia State University

2nd mRICH Prototype





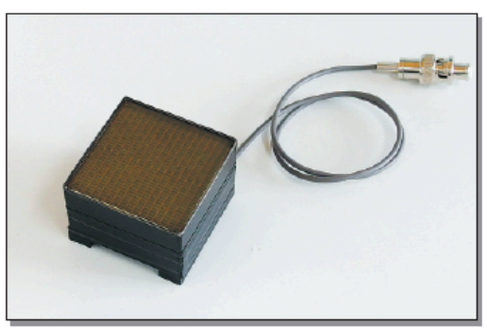
- **Longer focal length (6” Fresnel lens)**
- **Smaller pixel size sensors**
- **Test PID capability**

TECHNICAL INFORMATION OCT. 2016

FLAT PANEL TYPE MULTIANODE PMT ASSEMBLY
H13700 SERIES

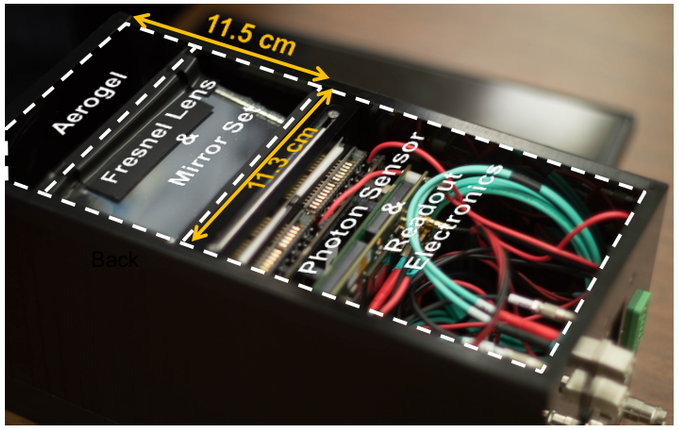
FEATURES

- High quantum efficiency: 33 % typ.
- High collection efficiency: 80 % typ.
- Single photon peaks detectable at every anode (pixel)
- Wide effective area: 48.5 mm × 48.5 mm
- 16 × 16 multianode, pixel size: 3 mm × 3 mm / anode

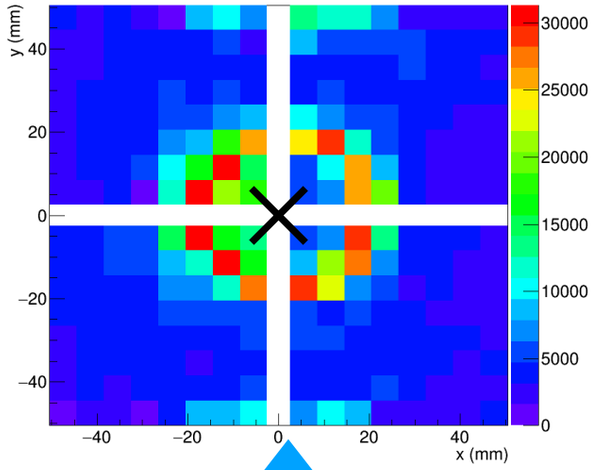


1st and 2nd Beam Test Comparison (120 GeV Proton Beam)

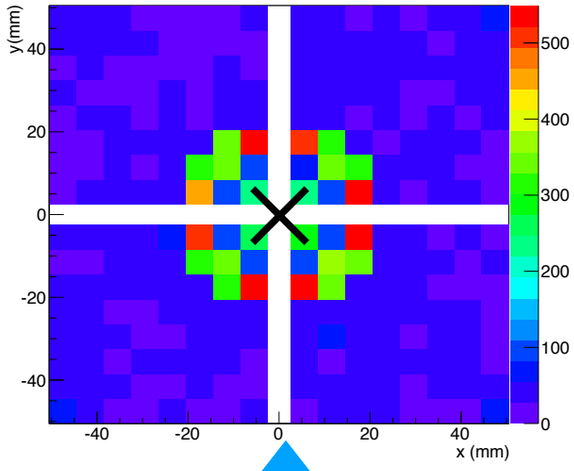
The 1st test beam result verified mRICH working principle and validated simulation



1st mRICH prototype was tested at Fermilab Test Beam Facility in April 2016

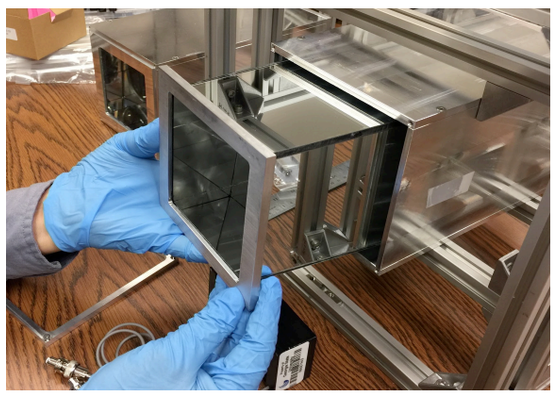


Images from 120 GeV Proton beam

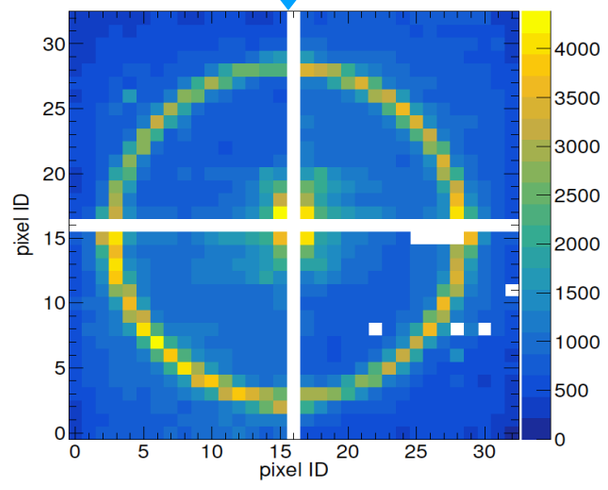


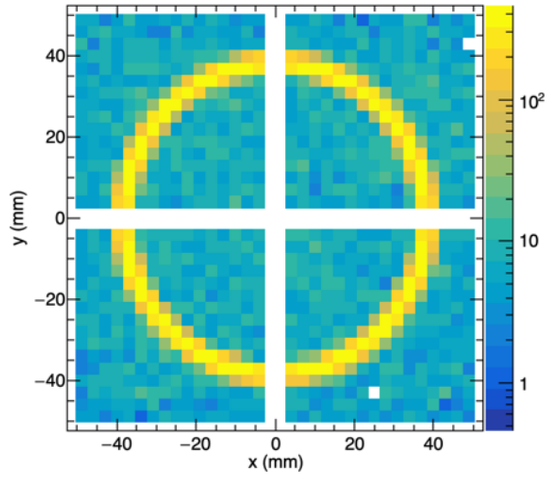
Simulated Images Using GEANT4

New features: a) separation of optical and electronic components; b) longer focal length (6”); c) 3mm x 3mm photosensors.



2nd mRICH prototype was tested at Fermilab Test Beam Facility in June/July 2018

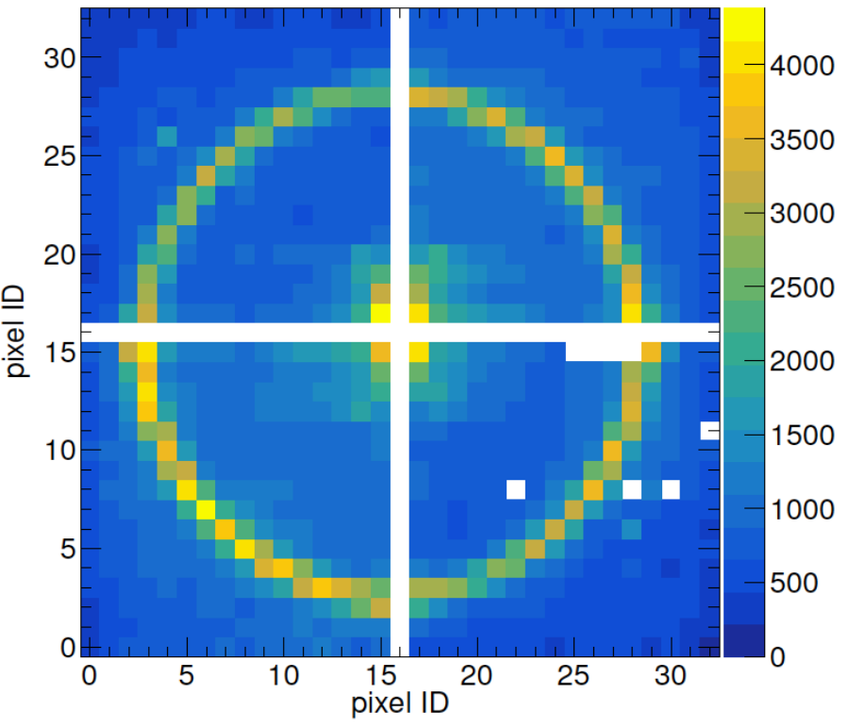




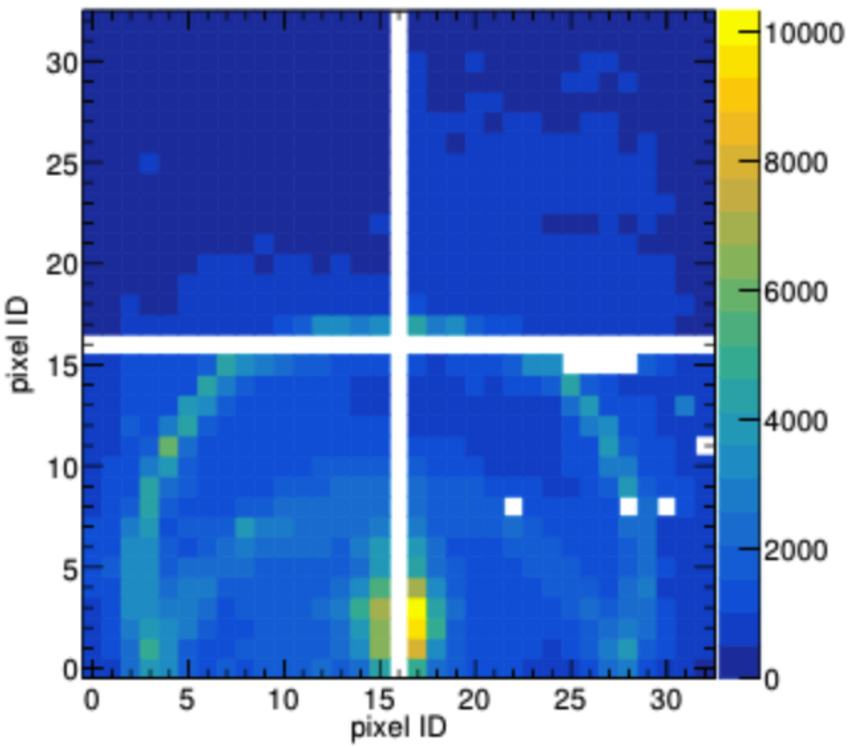
- 1st prototype 3” focal length & 6*6 mm pixel size
- 2nd prototype 6” focal length & 3*3 mm pixel size

mRICH Ring Images from PMTs

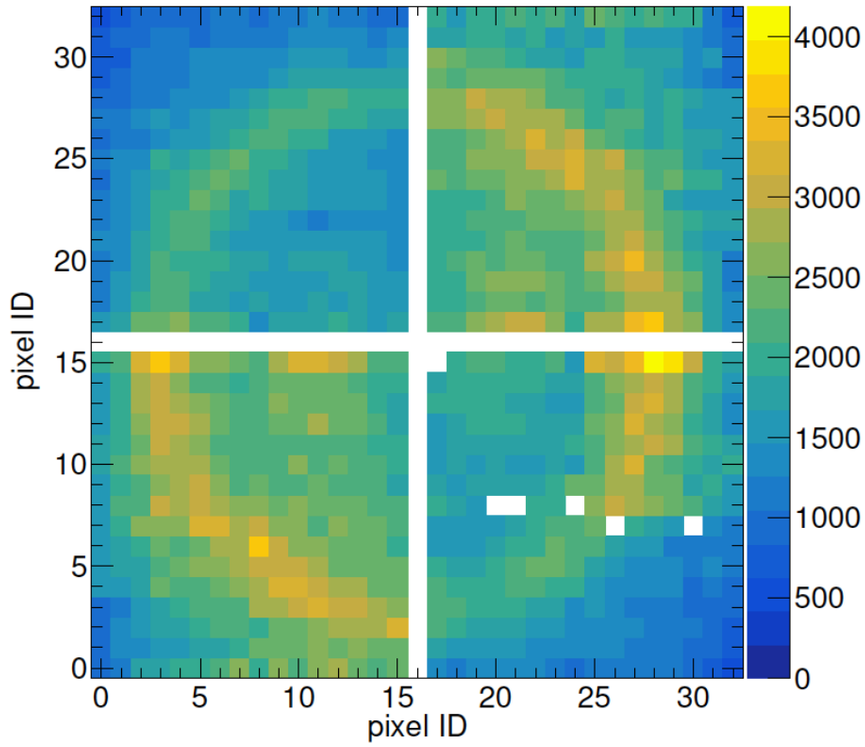
Examples of cumulative ring images from the second mRICH prototype beam test



Left: ring images formed by 120-GeV primary proton beam incident on the center of mRICH. White gaps are the PMT frames.



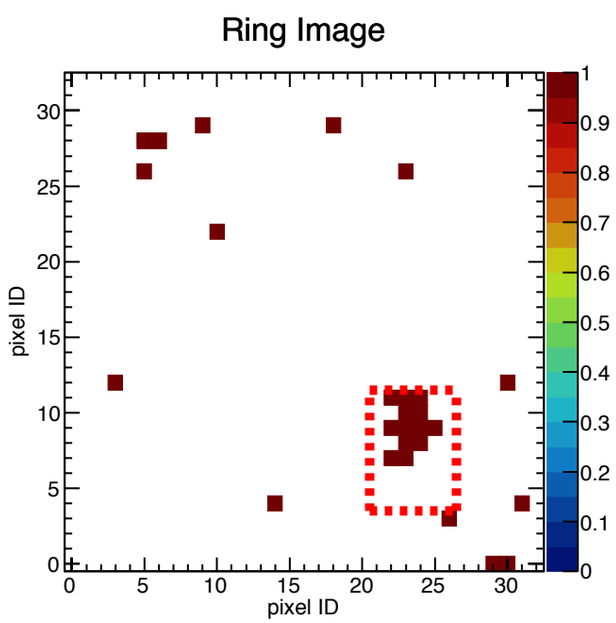
Middle: ring images from 120-GeV primary proton beam incident at an angle of 11° toward the lower section of mRICH.

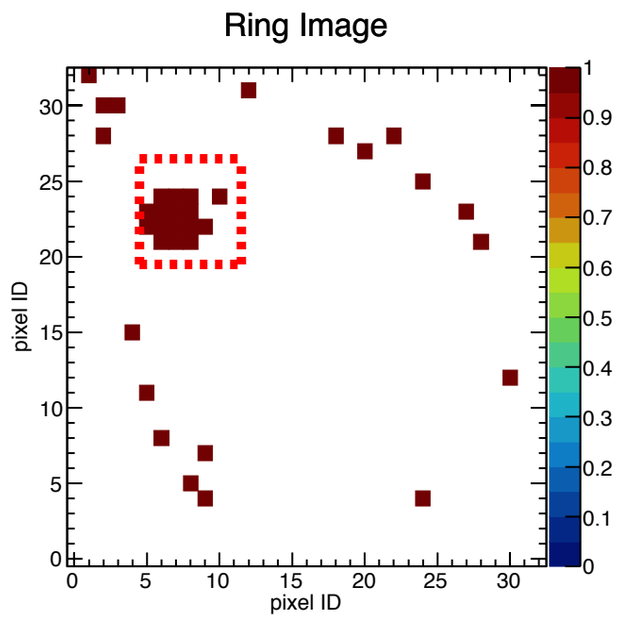


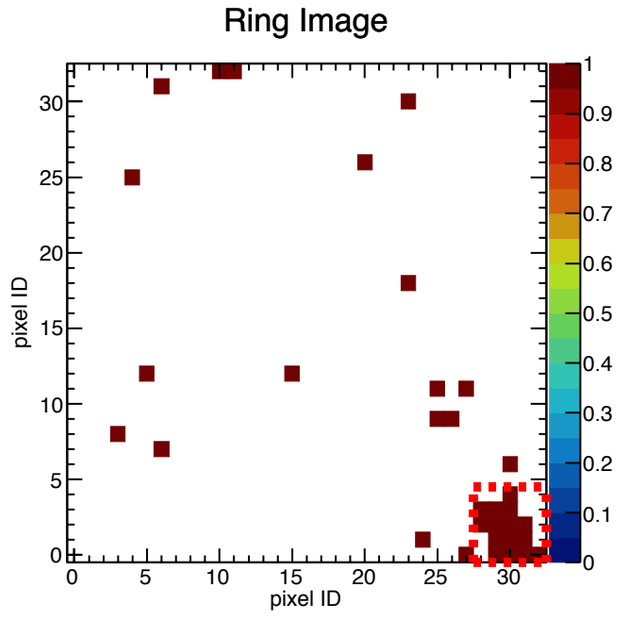
Right: images from an 8-GeV meson run. The challenge of this analysis is to determine the beam position since the beam hodoscope readout was not ready for this test.

Four Hamamatsu H13700 PMTs (3mm x 3mm pixel size; 16x16 channels) were used in these test runs. Each costs ~$5k. These sensors will NOT work in high magnetic field!!!

Beam Finder Algorithm

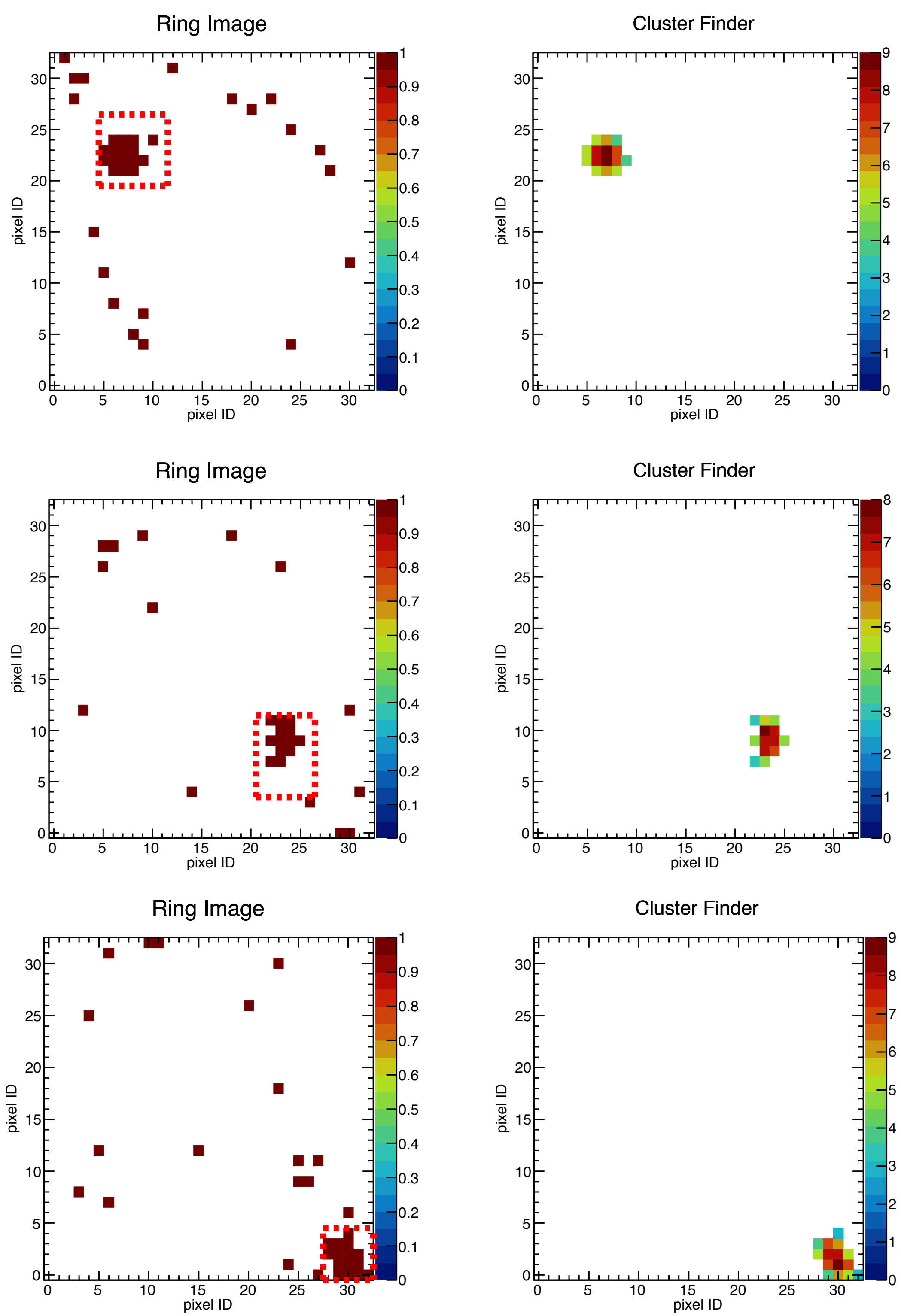


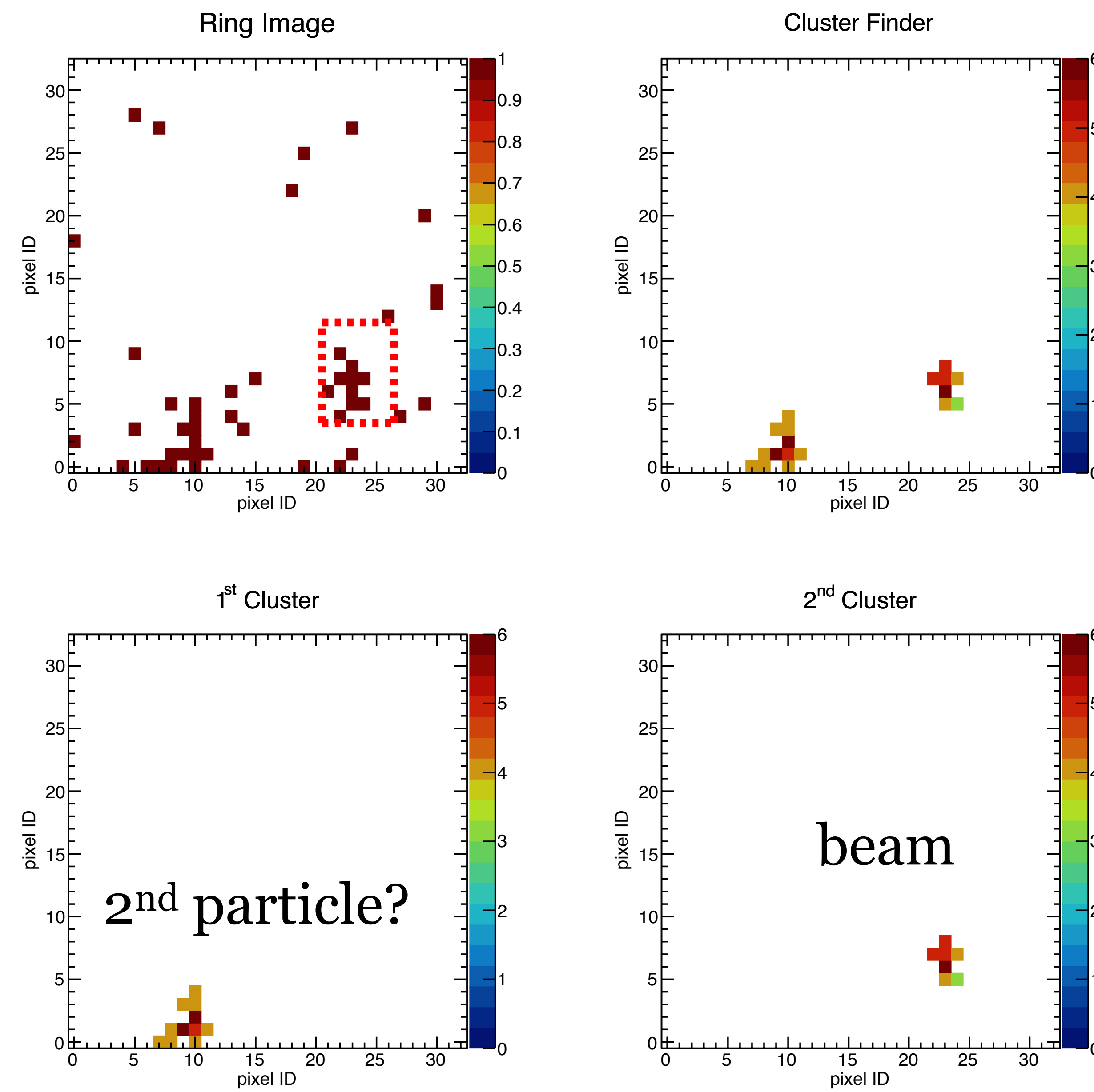




1. when beam hits one of PMTs, a large area of pixels got signal => cluster
2. pick one fired pixel (original ranking is 0) => calculate distance to the rest of pixels
3. if one pixel is within 3 pixels (5*5 cluster finding) => increase original ranking by 1
4. repeat 2-3 to all fired pixels => save all pixels with a ranking higher than 4 ==> all clusters with at least 5 adjacent pixels will be saved
5. pick the pixel with highest ranking => calculate the distance to the rest of saved pixels
6. if one pixel is within 5 pixels (make sure 2 5*5 adjacent cluster merged to 1 cluster) => group with the picked pixel ==> cluster 1
7. repeat 5-6 until all pixels got grouped => only save 3 clusters at most
8. can be also used for 3*3 clusters search

Beam Cluster

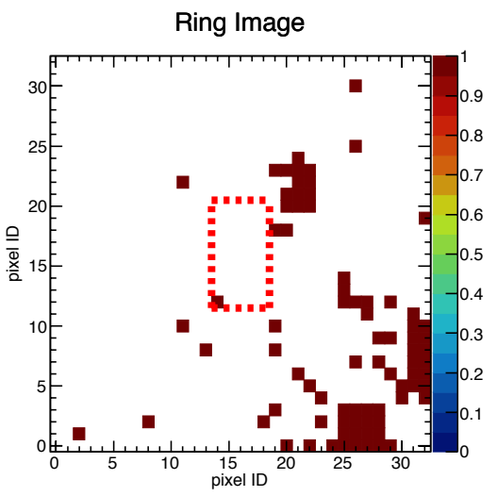




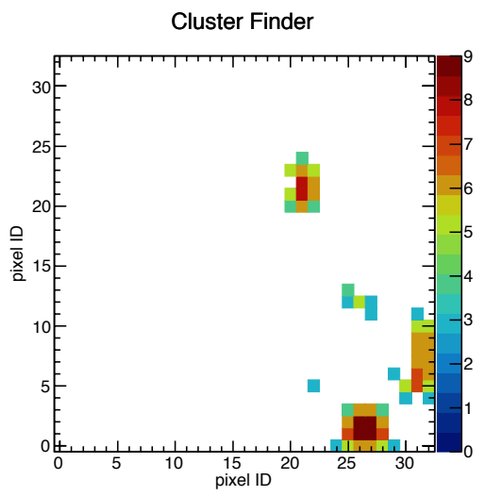
if an event have more than 3 clusters => considered too noisy

Beam Clusters in Calibration Runs

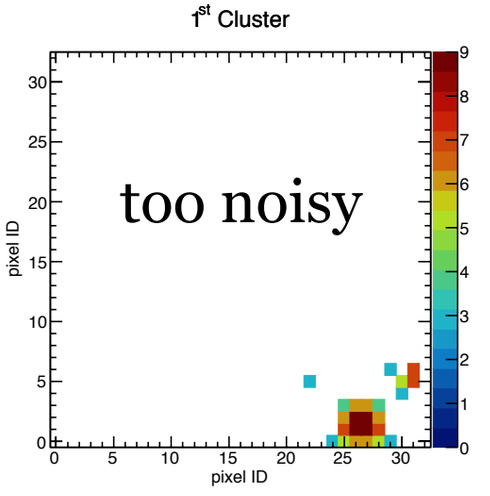
3 5*5 clusters

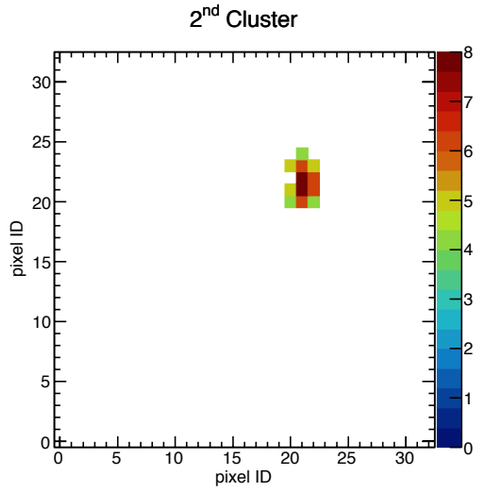


1st Cluster

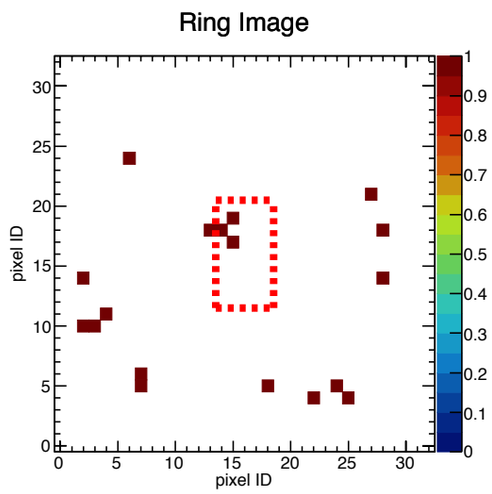


2nd Cluster

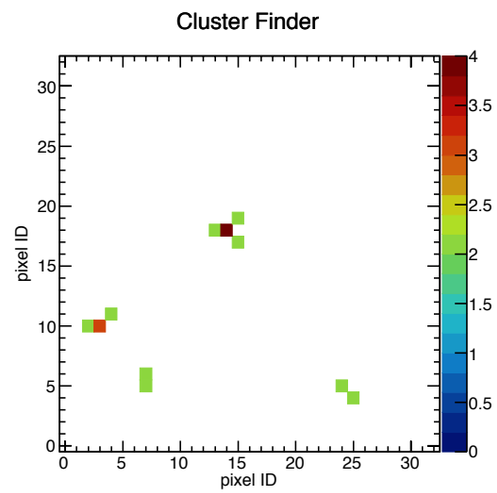




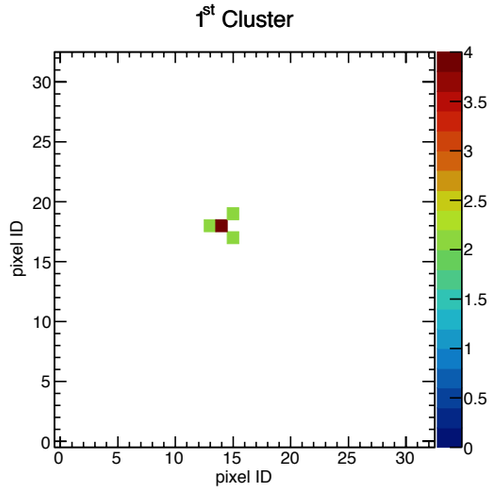
2 3*3 clusters

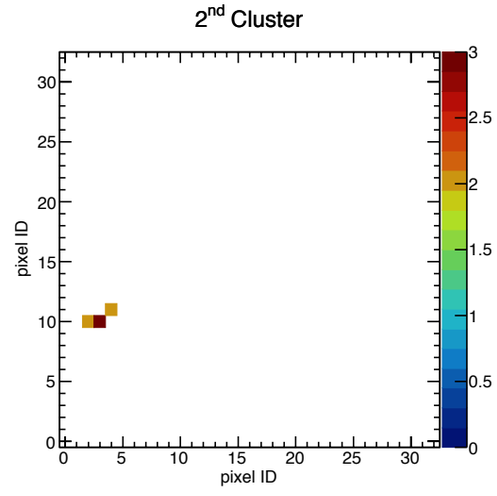


1st Cluster

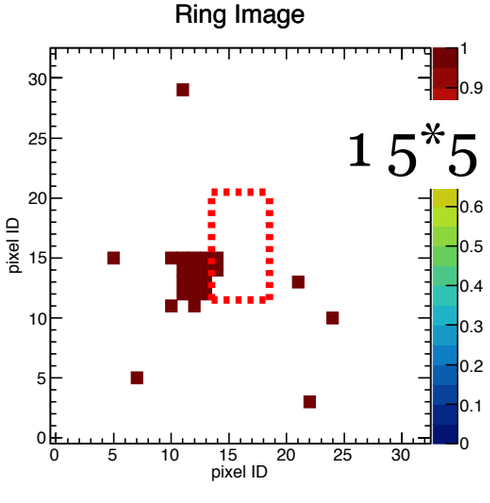


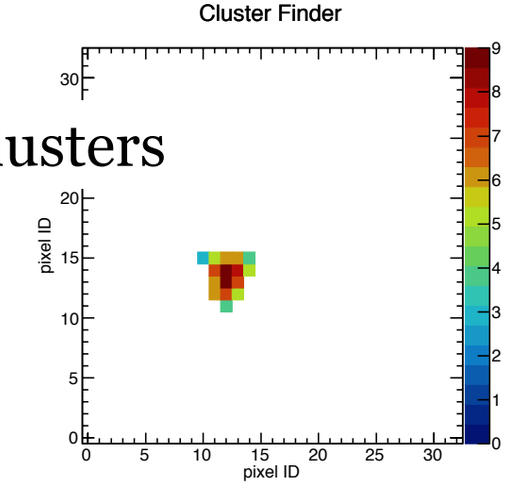
2nd Cluster





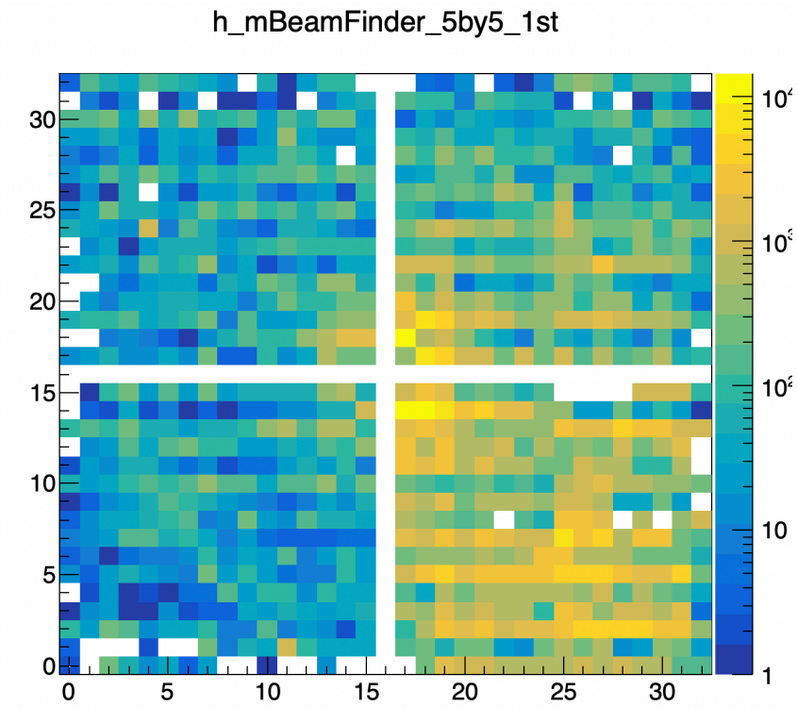
1 5*5 clusters

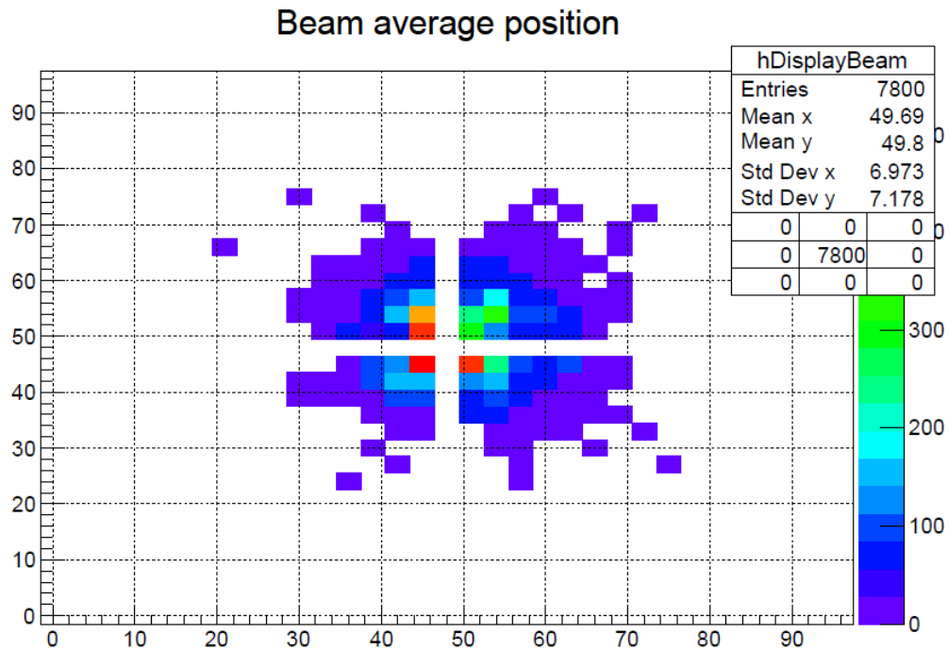




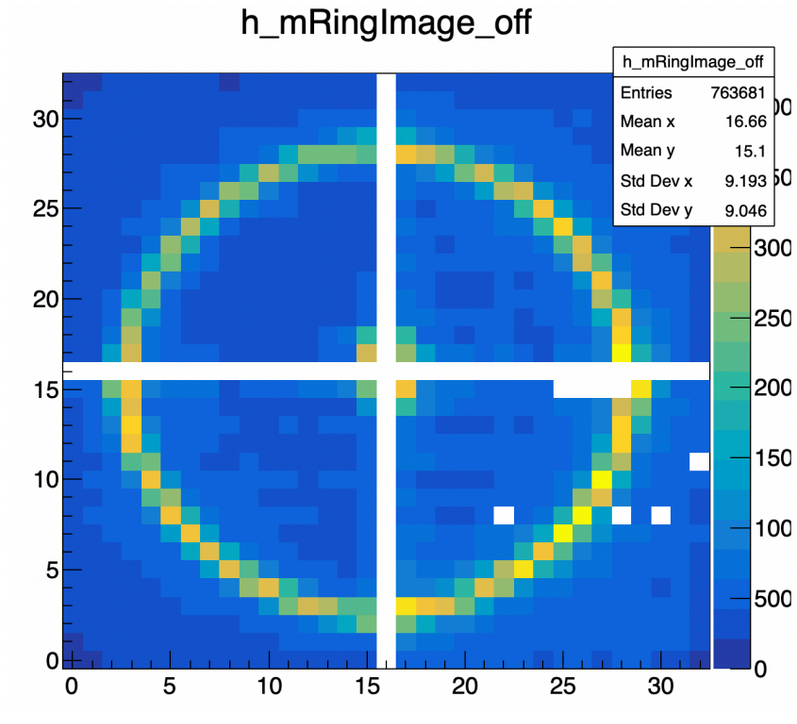
- for calibration analysis require no 5*5 and 3*3 clusters

Beam Cluster Distribution

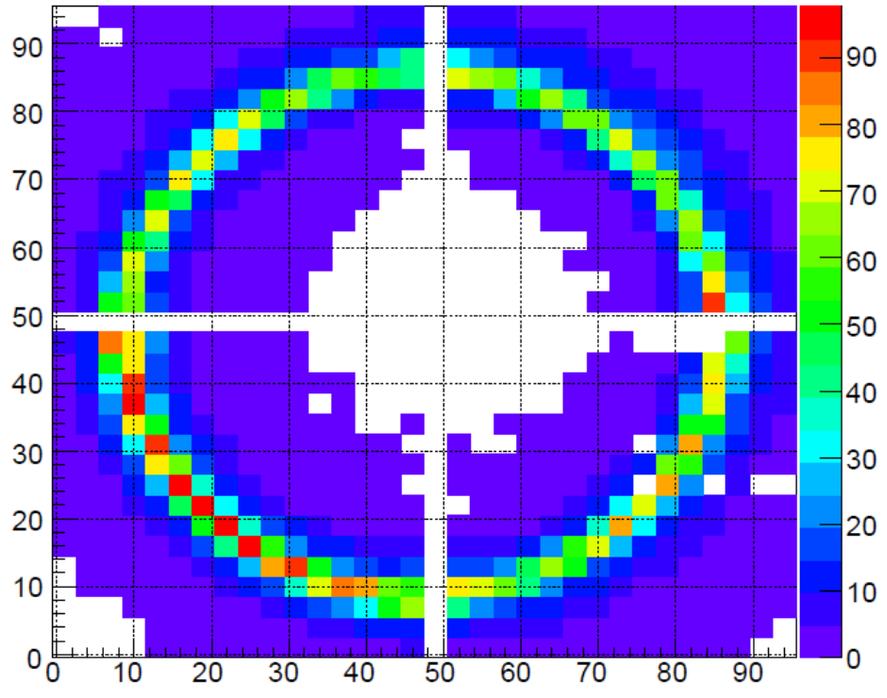




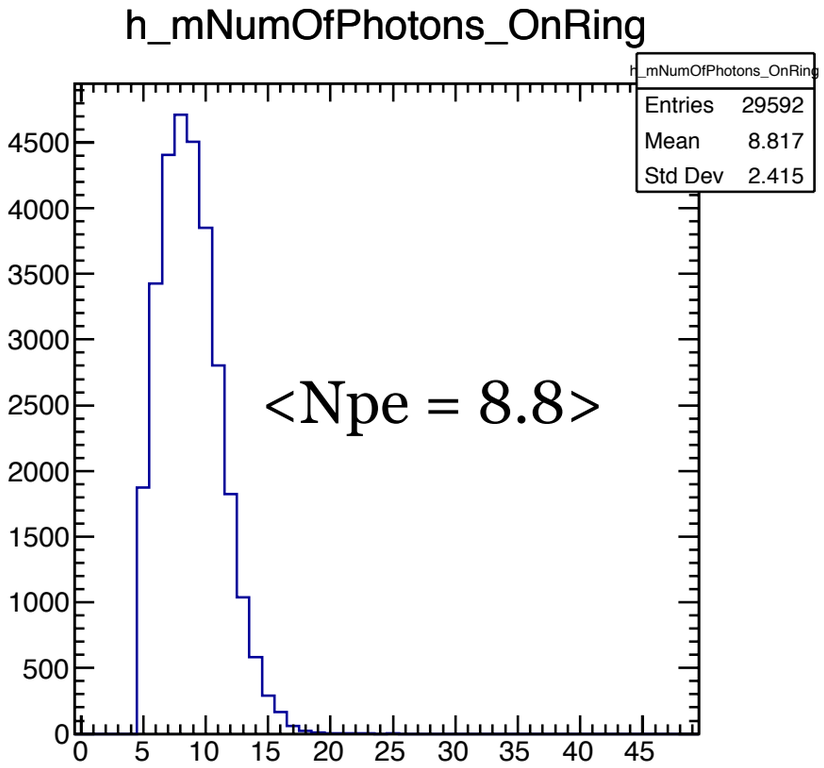
Marco's algorithm

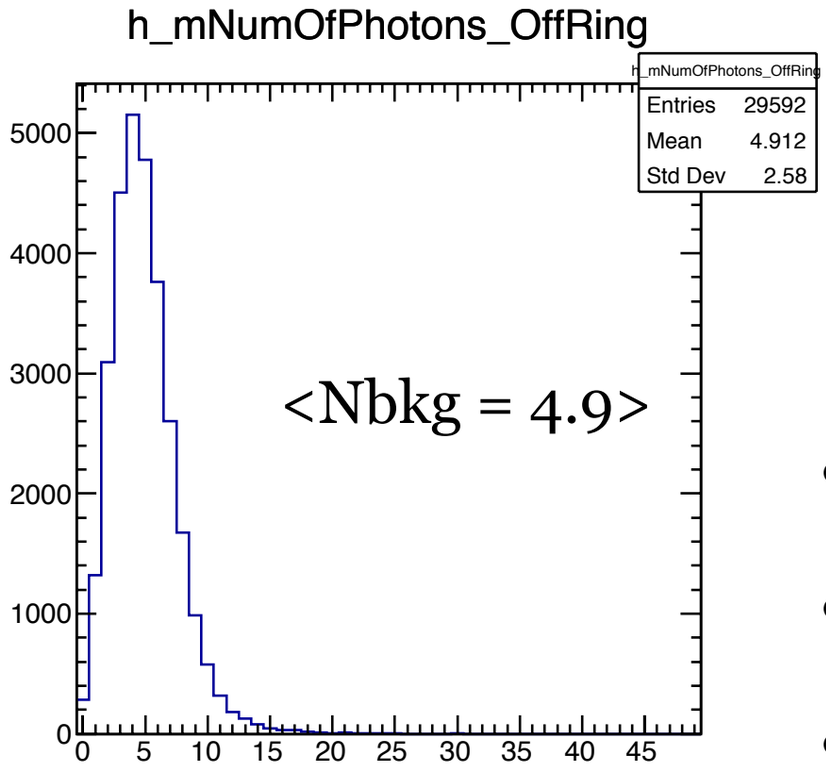


no 5*5 and 3*3 clusters

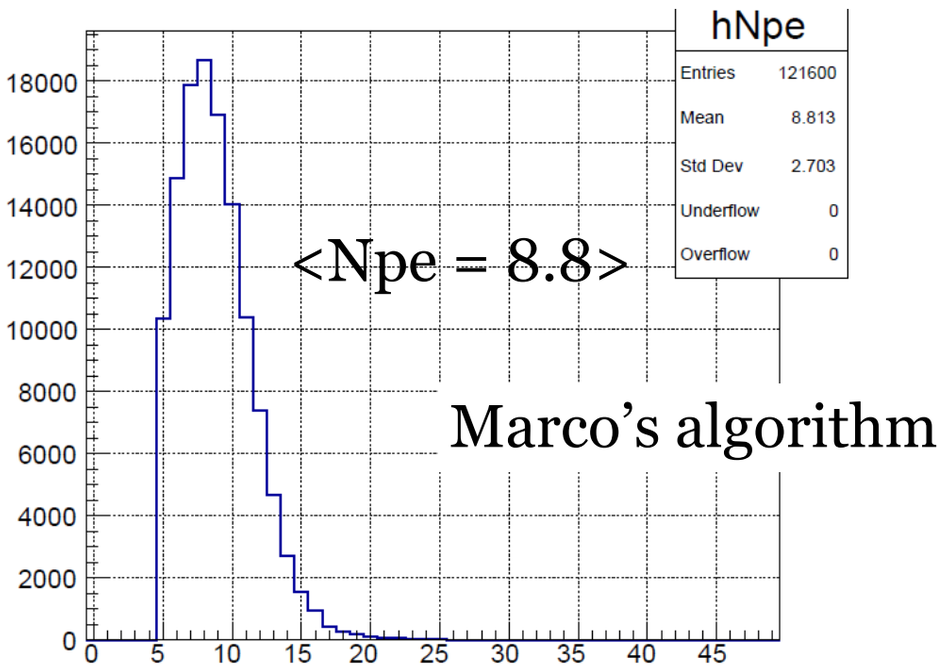


Number Of Photons

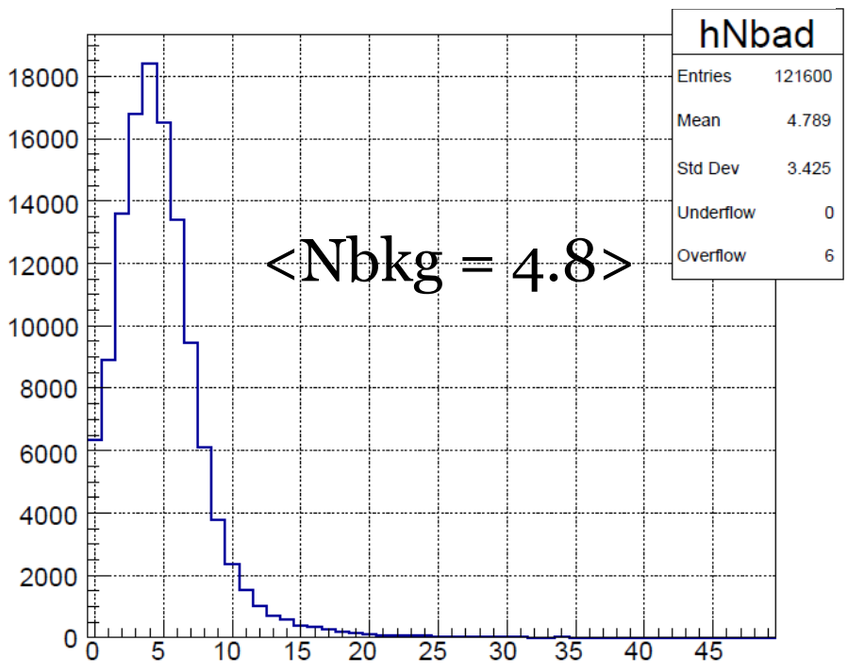




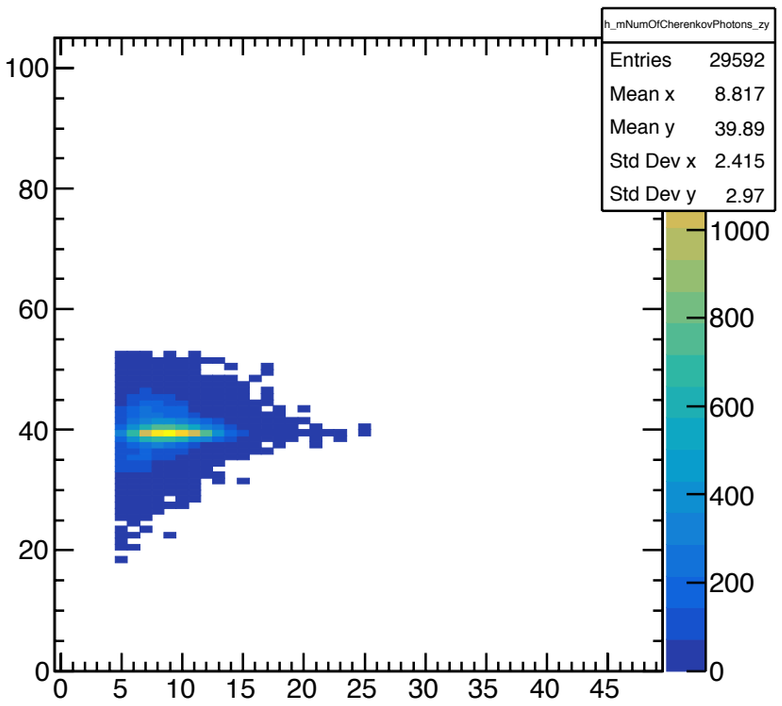
- Number of photon electrons are consistent
- Number of noise electrons are consistent
- Will use same number of noise electrons in simulation

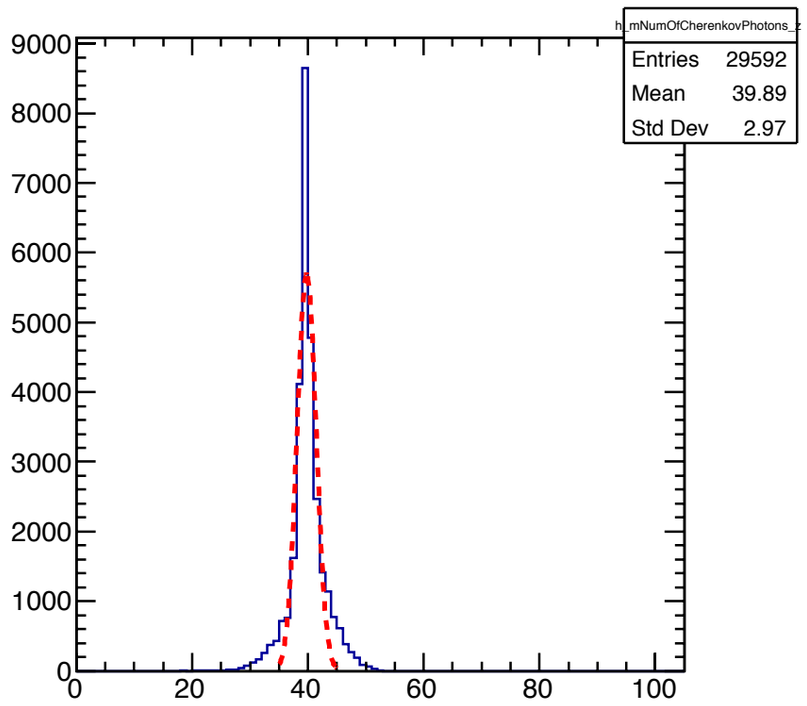


Marco's algorithm

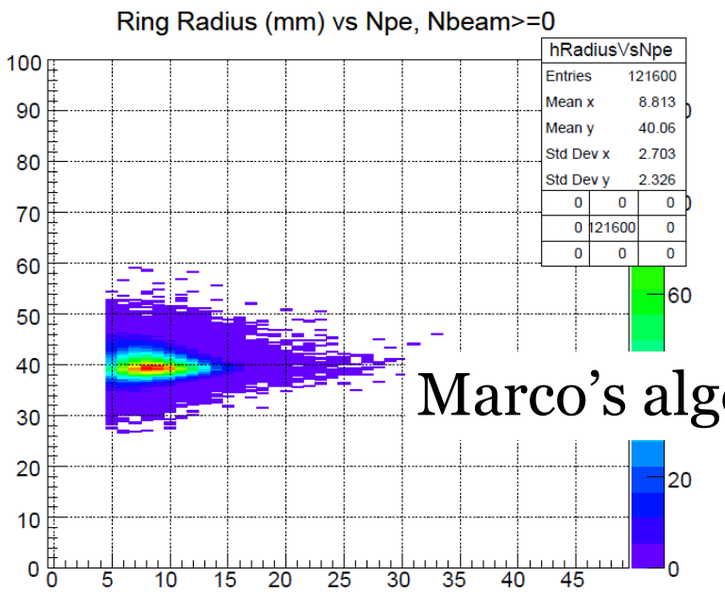


Ring Radius

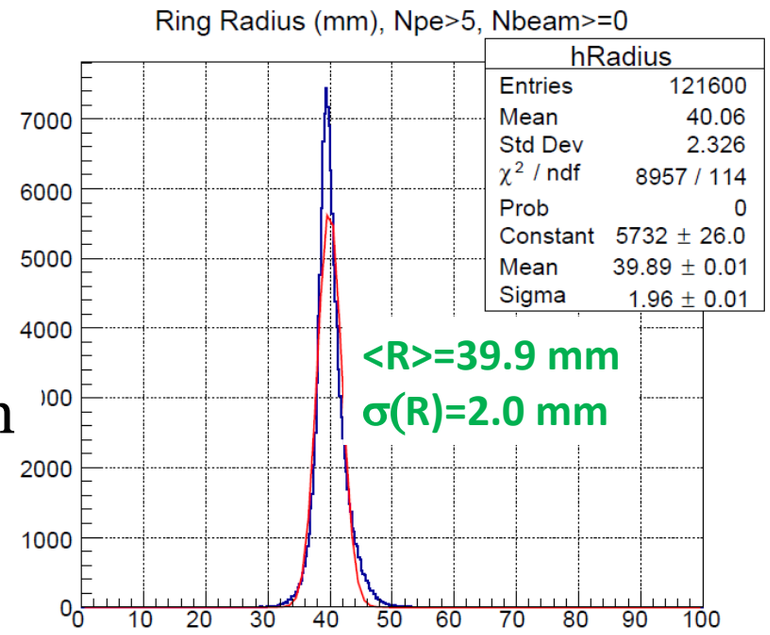




R = 39.8 +/- 1.7 mm

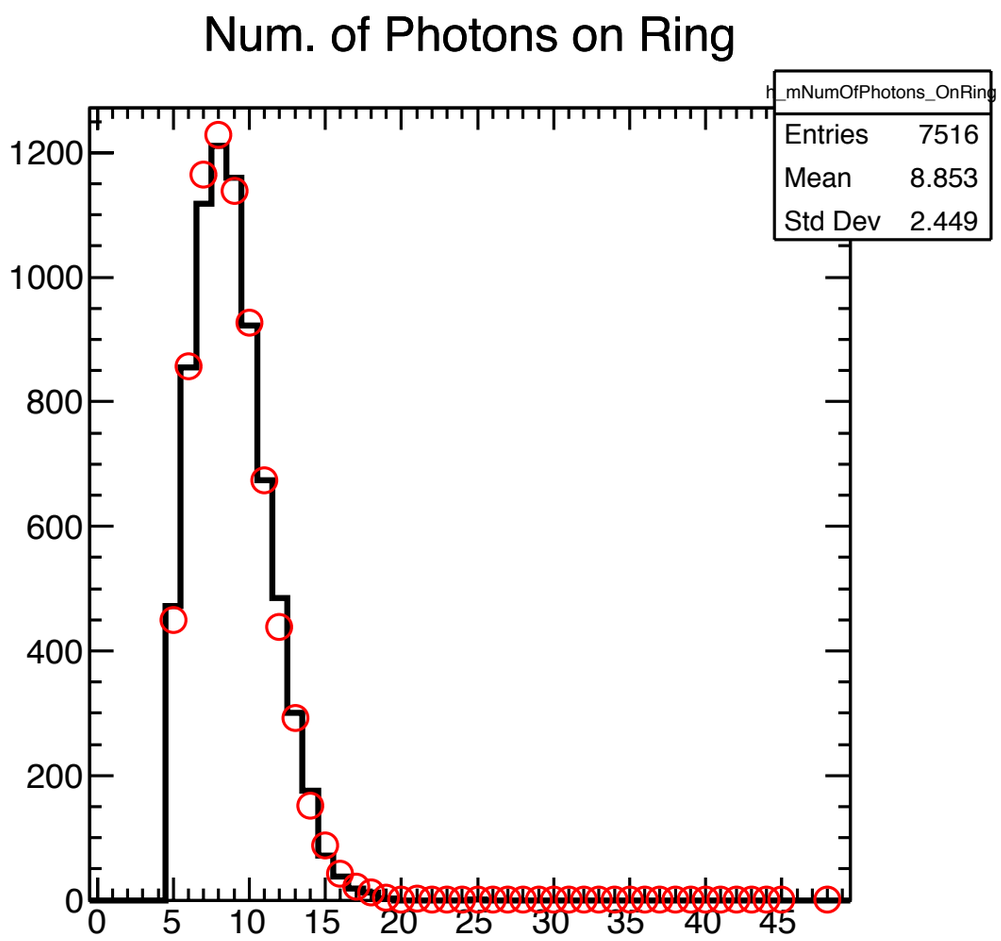


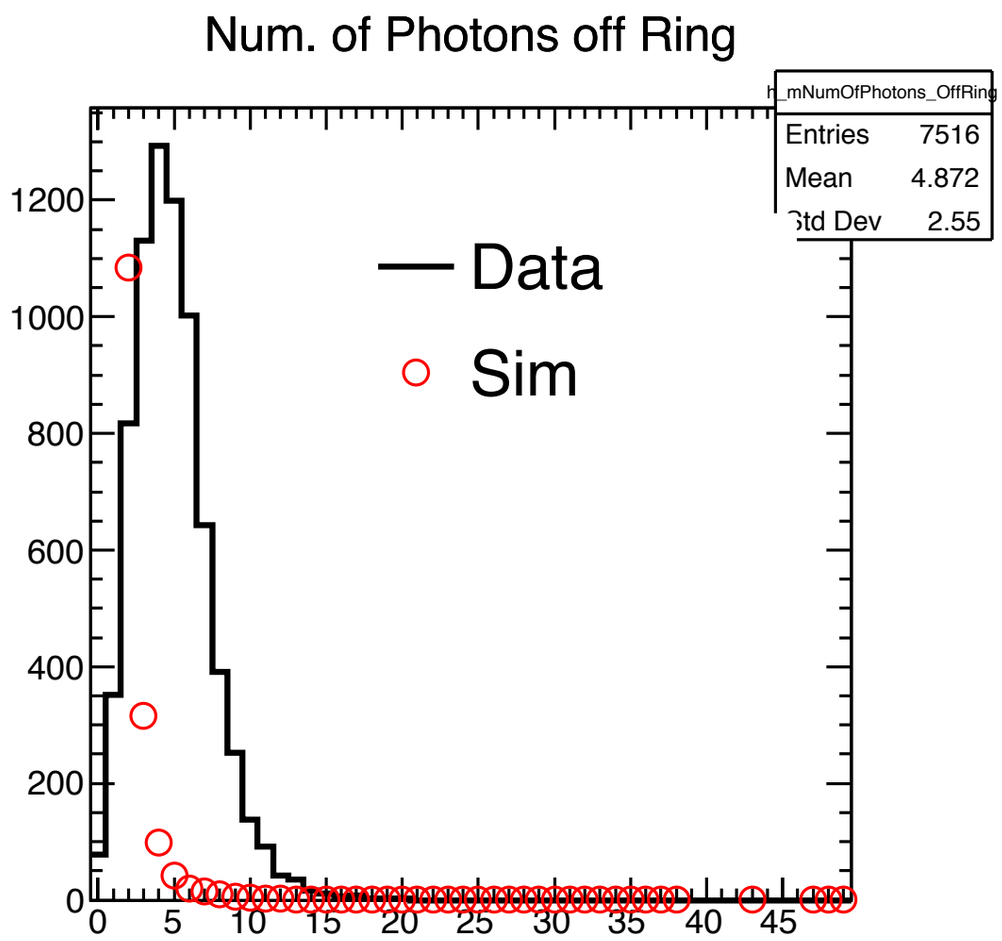
Marco's algorithm



- require ring center from Hough Transformation is located in the center of mRICH
- radius are consistent

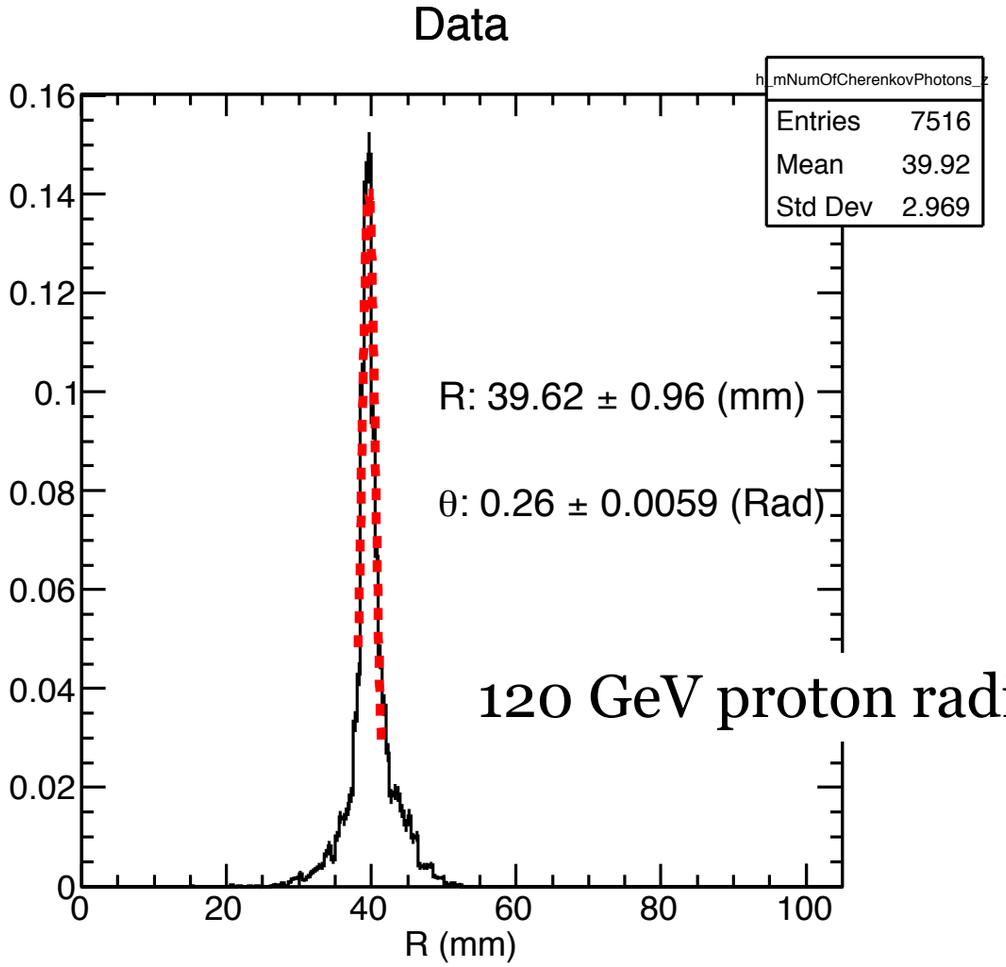
Number of Photons

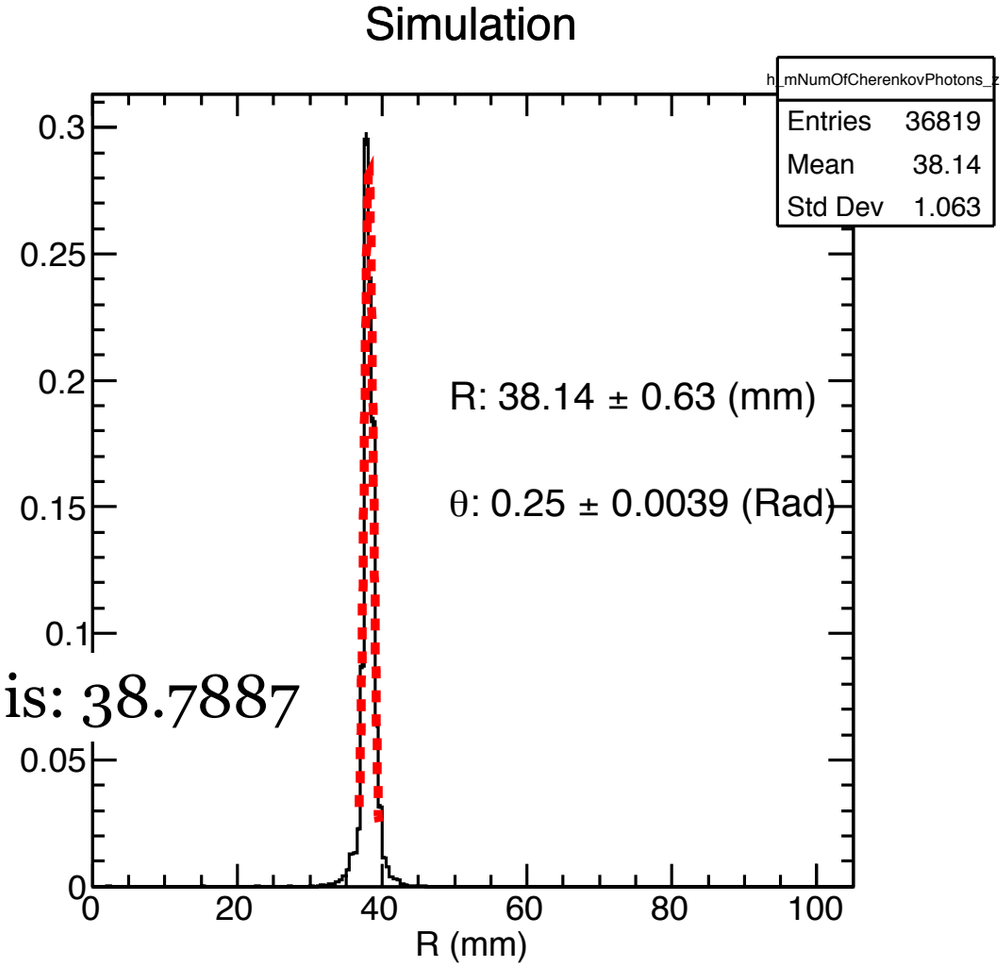




number of photons from data & simulation matched very well
noise level is about 4 photon-electrons per event
tdc & time cuts need fine tuning

Ring Radius





120 GeV proton radiaus is: 38.7887

$$\tan(\theta) = r/f$$

$$\sigma_\theta = \frac{1}{1+\tan^2(\theta)} \times \frac{\sigma_r}{f}$$

r => extracted ring radius
sigma_r => radius resolution
sigma_theta => angle resolution

- difference on radius is due to geometry => need precise measurement/drawing for PMT arrangement
- difference on radius resolution might be due to geometry & noise & smearing

Summary and Outlook

- Number of photons are consistent from data and simulation => 8.9/event

- Need to update geometry for simulation (detector setup) and data (PMT arrangement)

- Fine tuning the tdc & time cut => finish center runs analysis