Modular RICH Detector Beam Test Result

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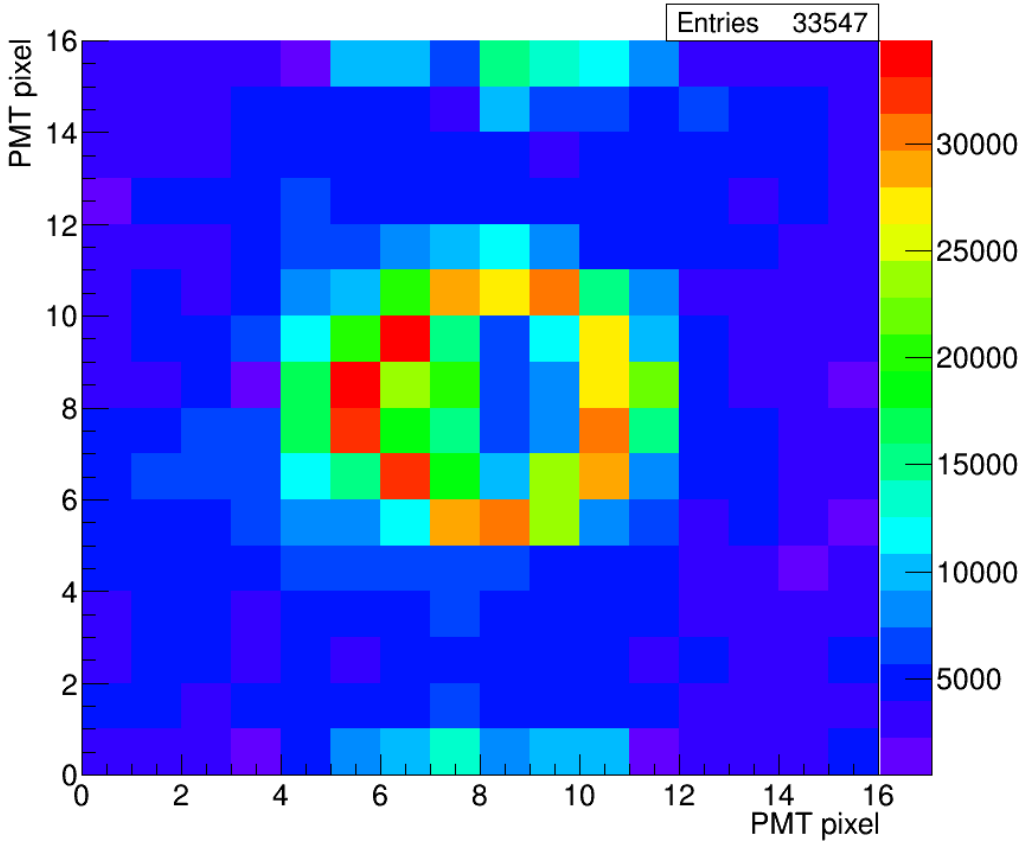
Outline

Compare simulation and beam test results

- runs with 120 GeV proton beams launched toward center of the detector
  - Aerogel n=1.03
  - Aerogel n=1.025
- Cherenkov Ring Radius
- Number of Cherenkov Photons

Aerogel n=1.03



Accumulated hit map from beam test run 70

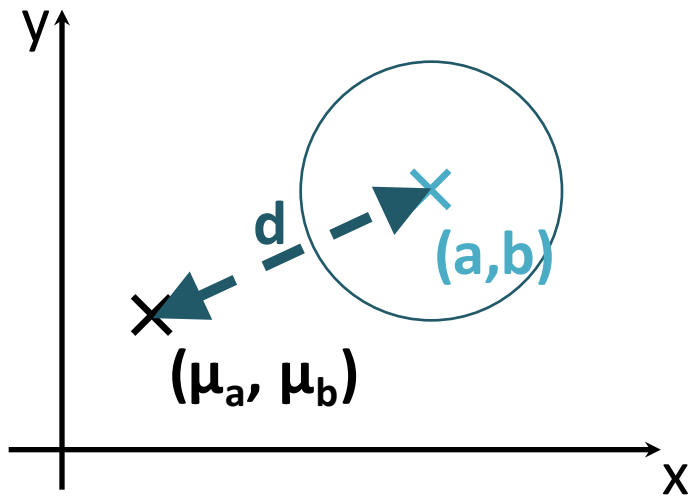
Simulation Setup

- Aerogel
  - n = 1.03
  - Thickness = 3.3cm
- Fresnel lens
  - f = 3” = 76.2mm
- Beam
  - 120 GeV proton
  - (x,y)=(0,0)mm

Analysis

- Sensor
  - Q.E. applied
  - Pixel size 6x6mm^2
- On Beam Test Data
  - HITTIMEWINDOW=200 μs
  - 40<Tover threshold<70 (signal amplitude)
- Ring Finder Algorithm
  - Expected (r,a,b)=(15.9, 0,0) mm
  - Deviation (σ_r , $\sigma_{a,b}$) =(3, 3)mm

Reduce noise/background

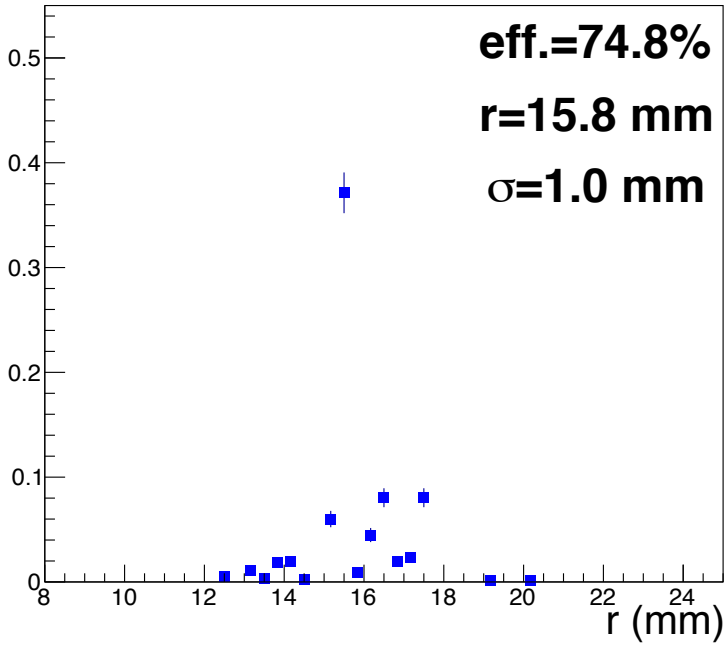


$$W_r = exp\left[-\frac{(r-\mu_r)^2}{2\times\sigma_r^2}\right] \qquad W_{center} = exp\left[-\frac{(a-\mu_a)^2+(b-\mu_b)^2}{2\times\sigma_{ab}^2}\right]$$

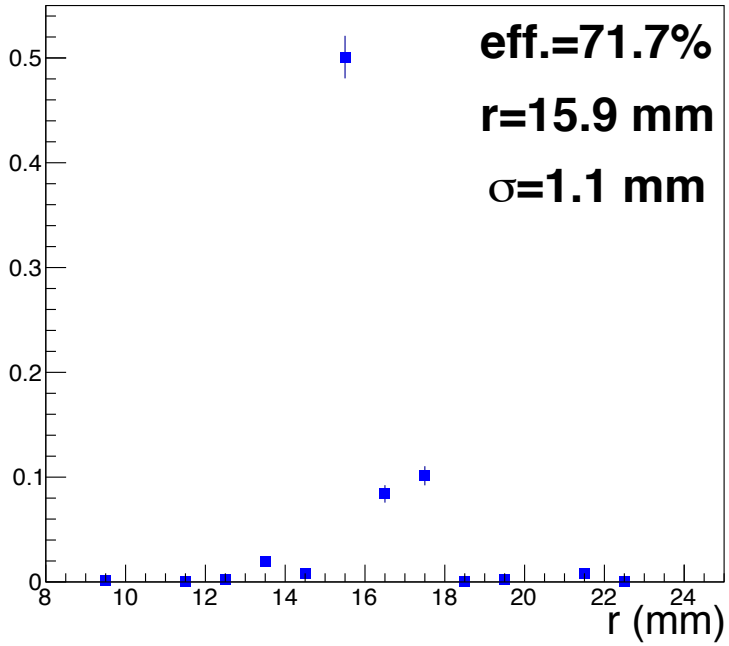
Cherenkov Ring Radius

Analytical calculation : $r_{120\ GeV\ proton} = 15.9$ mm

Simulation



Beam Test

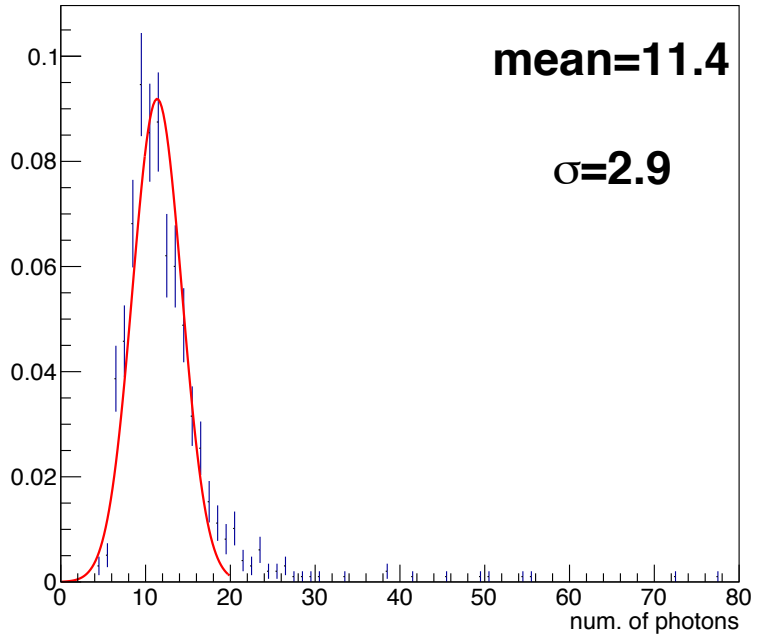


- Only the rings that are sitting in the central area of the sensor are counted
- Efficiency is the number of rings which have radius within expected range

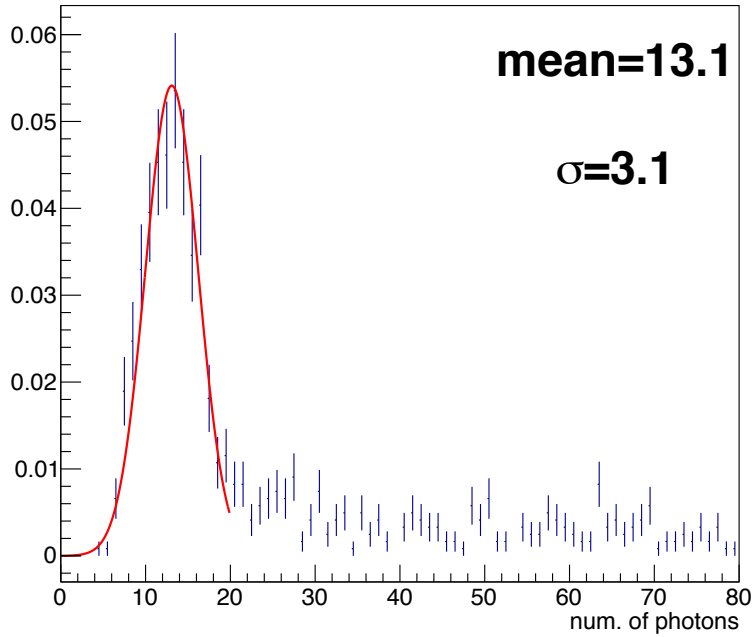
Number of Cherenkov Photons per Event

Analytical calculation : $N = 10.3$

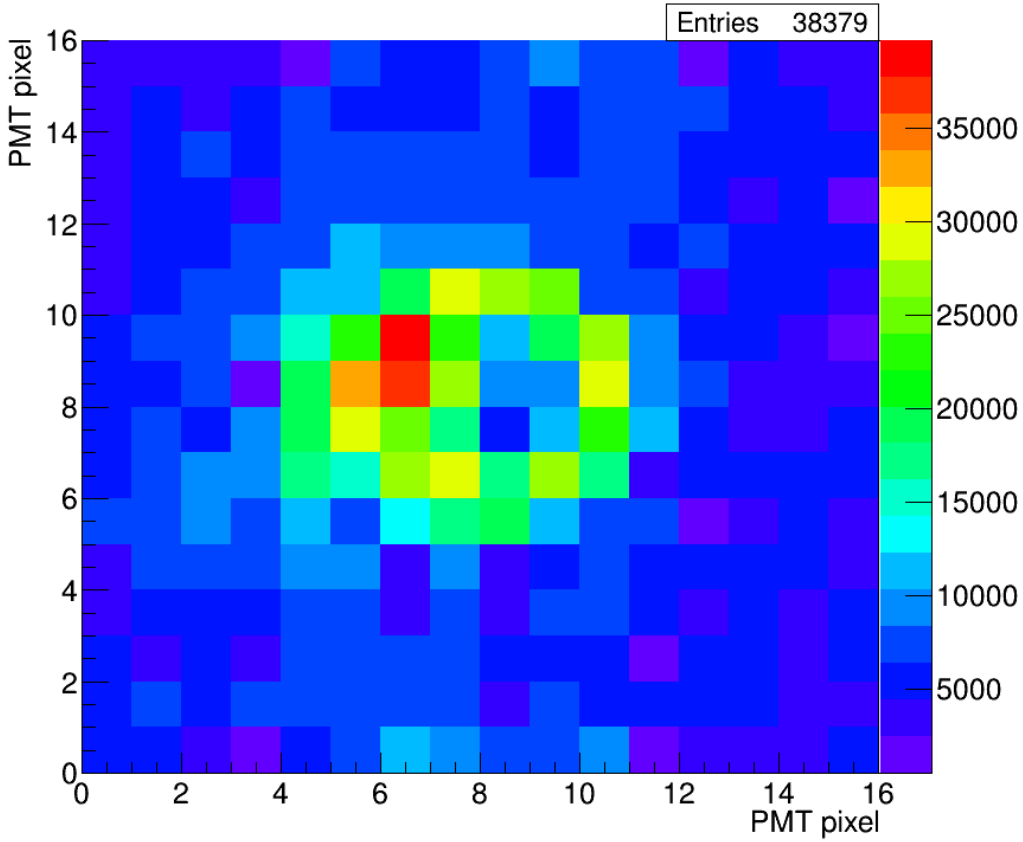
Simulation



Beam Test



Aerogel n=1.025



Accumulated hit map from beam test run 140

Simulation Setup

- Aerogel
  - n = 1.025
  - Thickness = 2cm
- Fresnel lens
  - f = 3” = 76.2mm
- Beam
  - 120 GeV proton
  - (x,y)=(0,0)mm

Analysis

Simulation

- Sensor
  - Q.E. applied
  - Pixel size 6x6mm^2
- Ring Finder Algorithm
  - Expected
    (r,a,b)=(14.0, 0,0) mm
  - Deviation
    (σ_r , $\sigma_{a,b}$) =(3, 3)mm

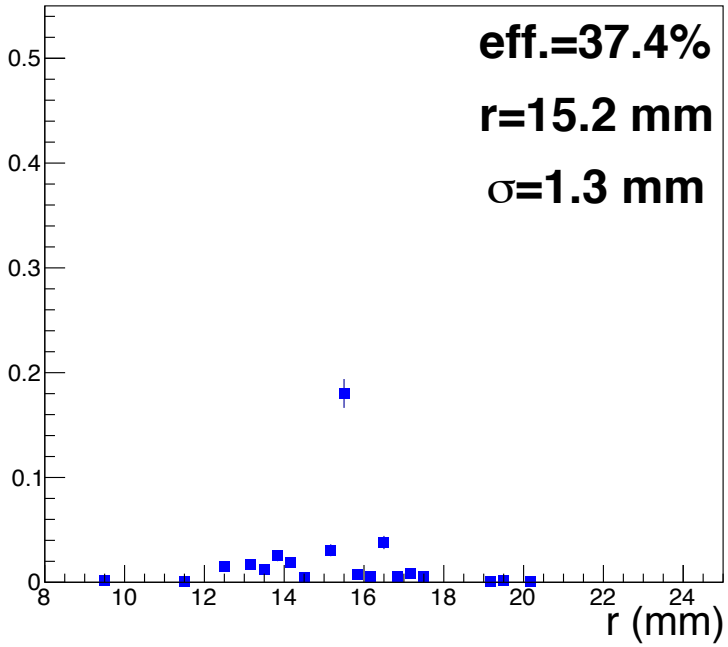
Beam Test

- Cut
  - HITTIMEWINDOW=200 μs
  - 40<Tover threshold<70
- Ring Finder Algorithm
  - Expected
    (r,a,b)=(14.0, 0,0) mm
  - Deviation
    (σ_r , $\sigma_{a,b}$) =(3, 6)mm

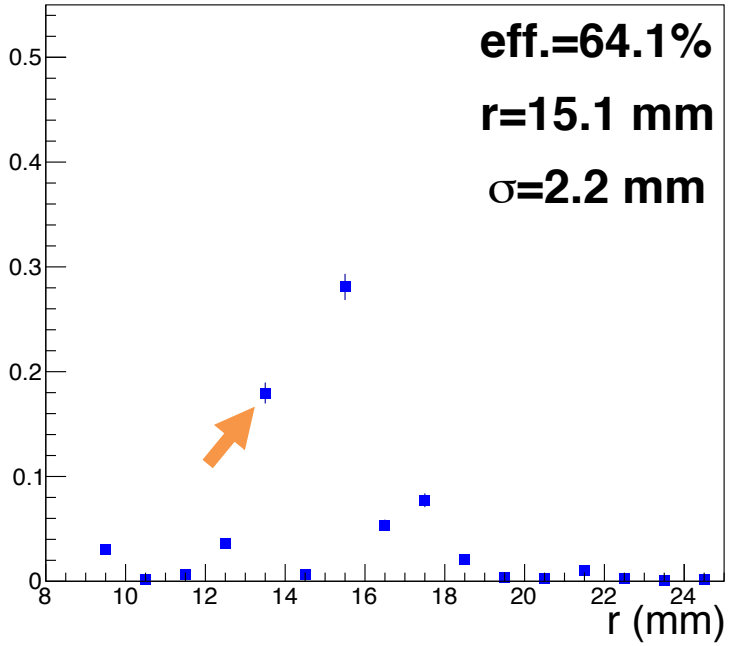
Cherenkov Ring Radius

Analytical calculation : $r_{120\ GeV\ proton} = 14.0mm$

Simulation



Beam Test



- We may see no difference between 14.0mm and 15.9 ring radii due to limitation of pixel size (6x6mm^2)

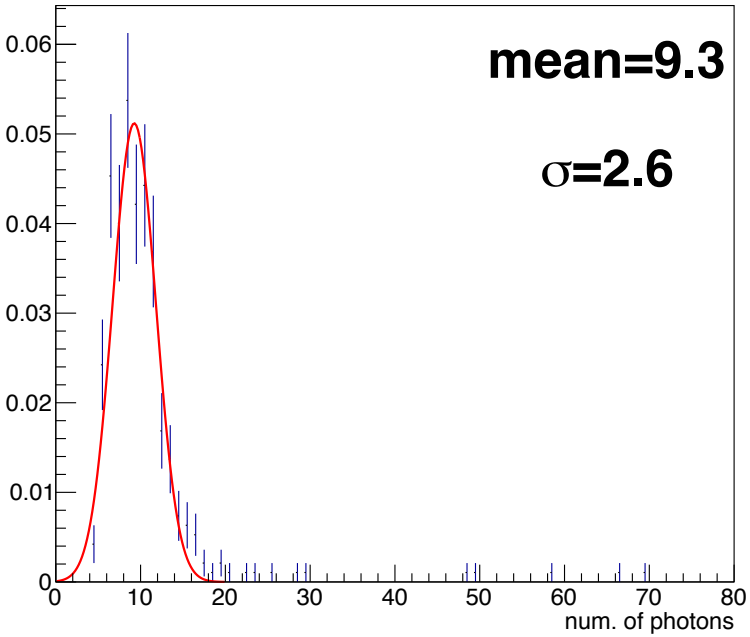
Number of Photons

$$N = 2\pi\alpha d\left(1 - \frac{1}{\beta^2 n^2}\right) \cdot 0.92 \cdot 0.92 \int_{\lambda_1}^{\lambda_2} 0.34 e^{-\frac{\left(\lambda - 345\times10^{-7}\right)^2}{2\times(119\times10^{-7})^2}} \cdot 0.83 e^{-\frac{d\times56.29\times10^{-20}}{\lambda^4}} \frac{d\lambda}{\lambda^2}$$

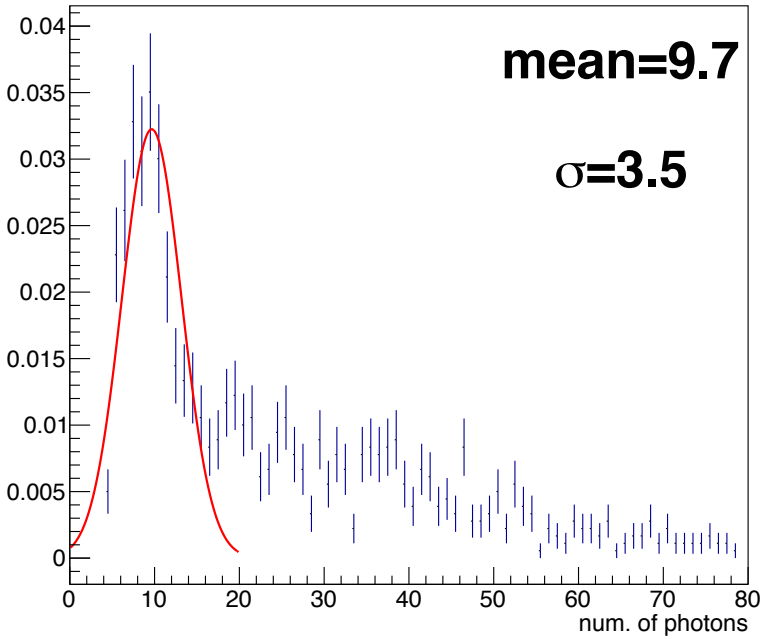
Aerogel transmission

Analytical calculation : $N = 7.3$

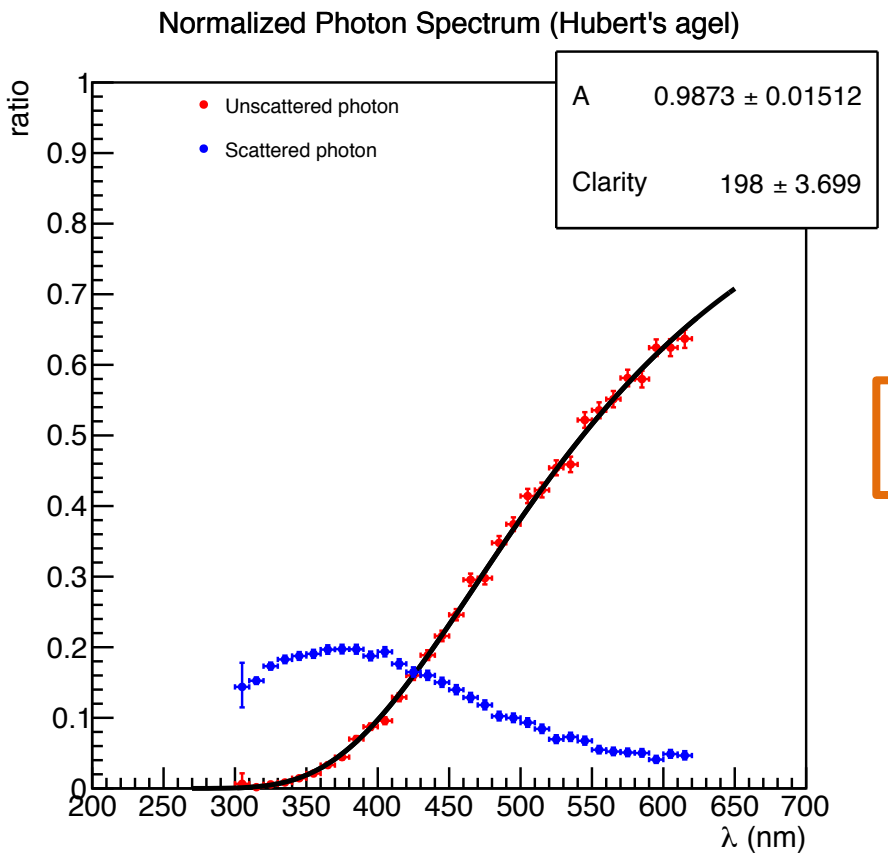
Simulation



Beam Test



Transmission of Hubert's Aerogel (03-28-2016)



$$\text{Transmission} = Ae^{-LC/\lambda^4}$$

Result Summary

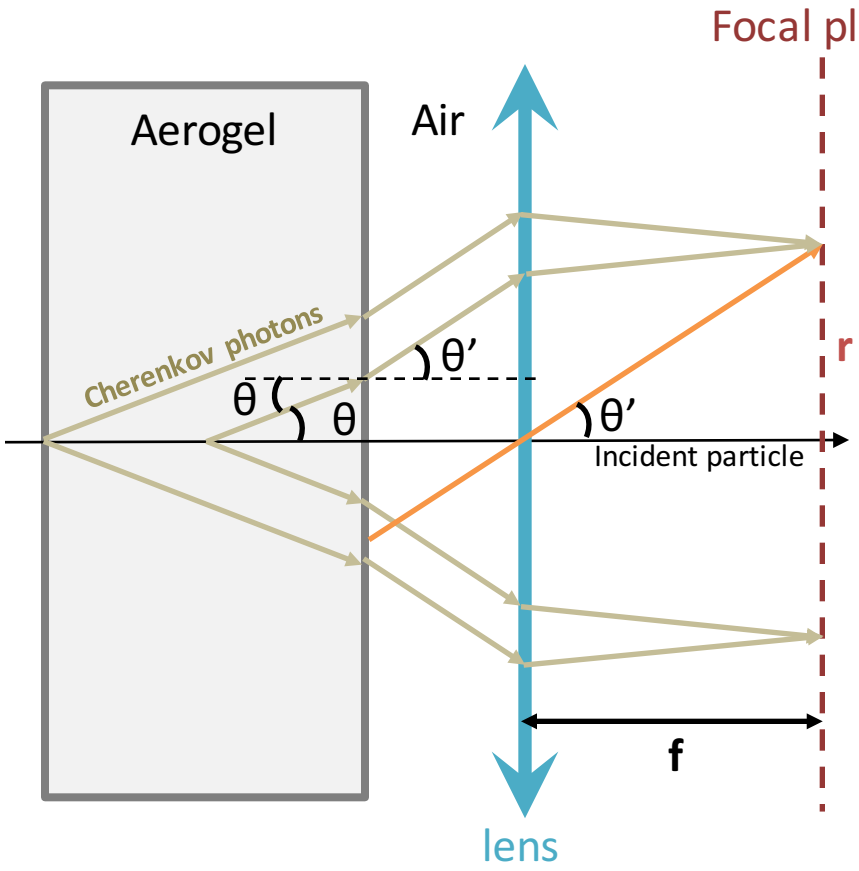
	Radius (mm)		Num. of Photon	
	n=1.03	**n=1.025**	**n=1.03**	**n=1.025**
Analytical number	15.9	14.0	10.3	7.3
simulation	15.8 ± 1.0	15.2 ± 1.3	11.4 ± 2.9	9.3 ± 2.6
Beam test	15.9 ± 1.2	15.1 ± 2.2	13.1 ± 3.1	9.7 ±3.3

To Do

- Beam test analysis
  - Review 120 proton beam data
  - pion runs
- Paper
- Belle 2 analysis

Back Up

Cherenkov Ring Radius



Estimated value of Cherenkov ring radius in modular RICH detector:

Proportional to focal length

Gaps between sensors

$$r = f \cdot \tan\theta' - 3.54$$

$$= f \cdot \sqrt{\frac{(n^2-1)p^2-\mathrm{m}_0^2}{(2-n^2)p^2+\mathrm{m}_0^2}} - 3.54$$

$$= 76.2 \cdot \sqrt{\frac{(1.03^2-1)p^2-\mathrm{m}_0^2}{(2-1.03^2)p^2+\mathrm{m}_0^2}} - 3.54$$

Number of Cherenkov Photons per Event

Maximum number of Cherenkov photons:

$$N = 2\pi\alpha d\left(1 - \frac{1}{\beta^2 n^2}\right)\int_{\lambda_1}^{\lambda_2}\frac{d\lambda}{\lambda^2}$$

Fine structure const.

Thickness of radiator

β=v/c

Refractive index of radiator

Estimated number of Cherenkov photons in modular RICH detector:

Fresnel lens transmission

Sensor quantum efficiency

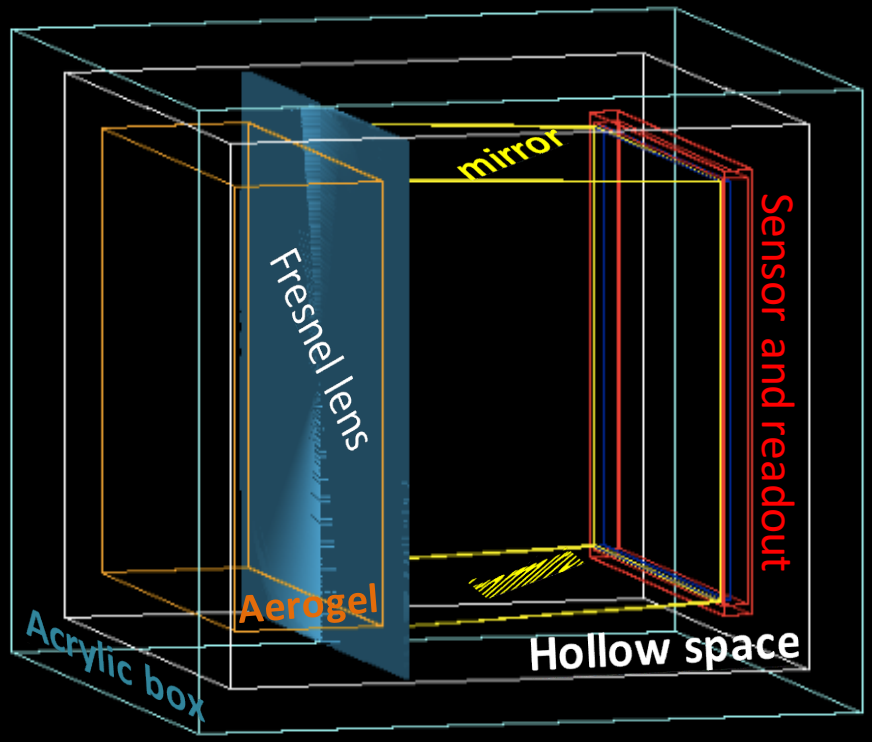
$$N = 2\pi\alpha d\left(1 - \frac{1}{\beta^2 n^2}\right)\cdot 0.92\cdot 0.92\int_{\lambda_1}^{\lambda_2} 0.34e^{-\frac{\left(\lambda-345\times10^{-7}\right)^2}{2\times(119\times10^{-7})^2}}\cdot 0.83e^{-\frac{d\times56.29\times10^{-20}}{\lambda^4}}\frac{d\lambda}{\lambda^2}$$

Glass window transmission

Aerogel transmission

Design of 1st Modular RICH Prototype

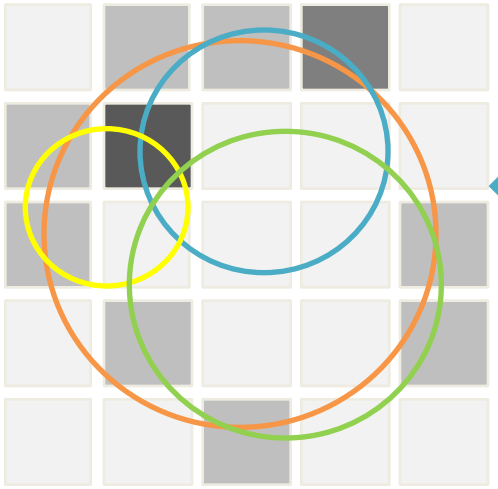
Aerogel	Thickness = 3.3cm Refractive index n = 1.03
Fresnel Lens	262 grooves Focal length f = 7.62cm
Mirror set	On four sides: top, bottom, left and right
Sensor plane	Effective area = 9.6cm x 9.6cm Pixel size = 6mm x 6mm

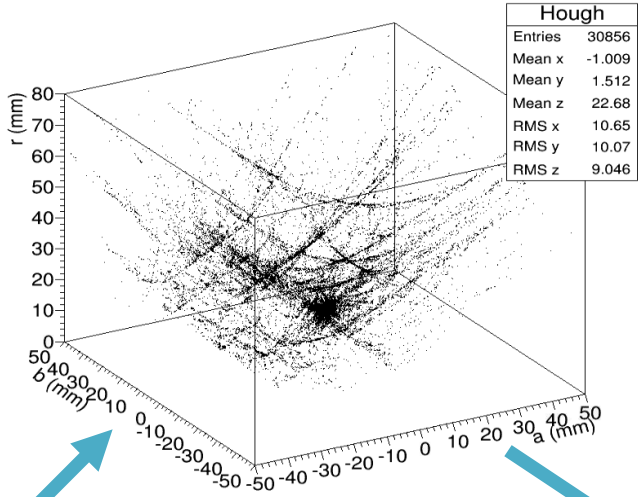


Ring Finder Algorithm

Hough Transform Algorithm

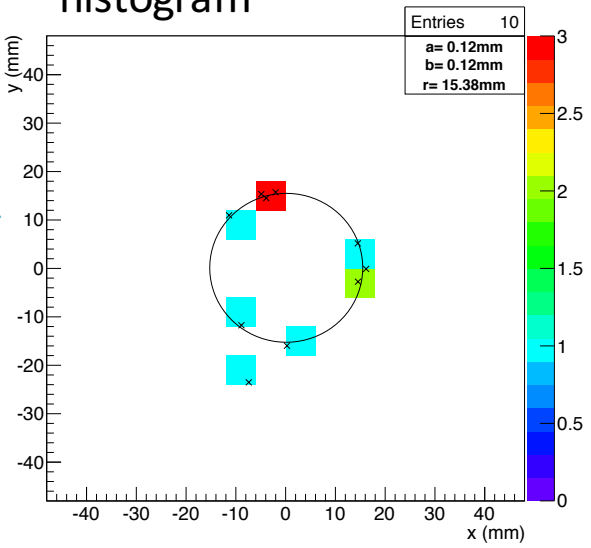
Find all possible rings in an event



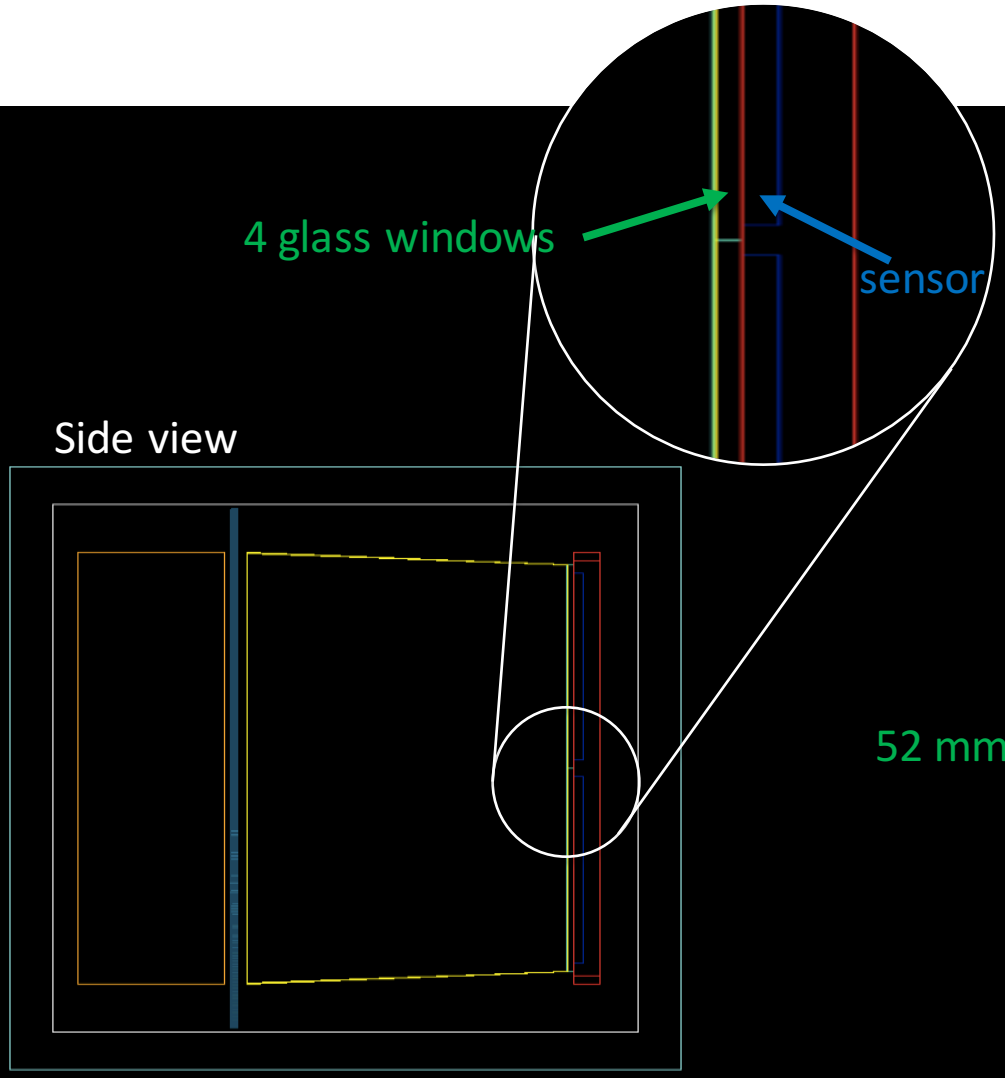


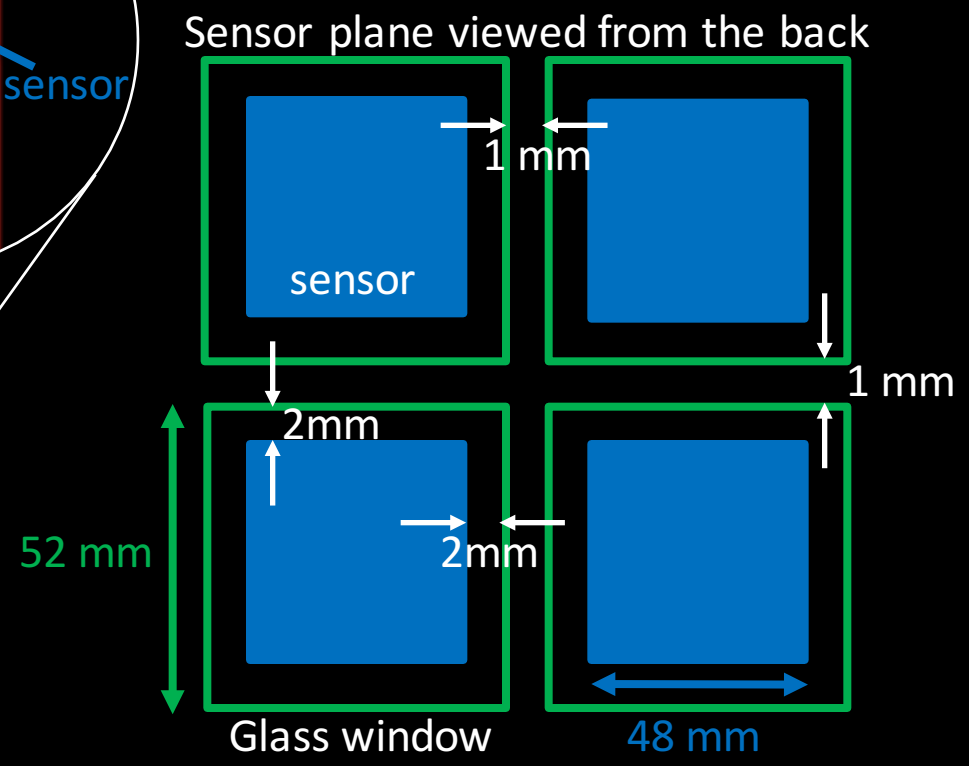
Fill possible rings' r, (a,b) in a probability density histogram

The most possible ring is the densest bin in the probability density histogram

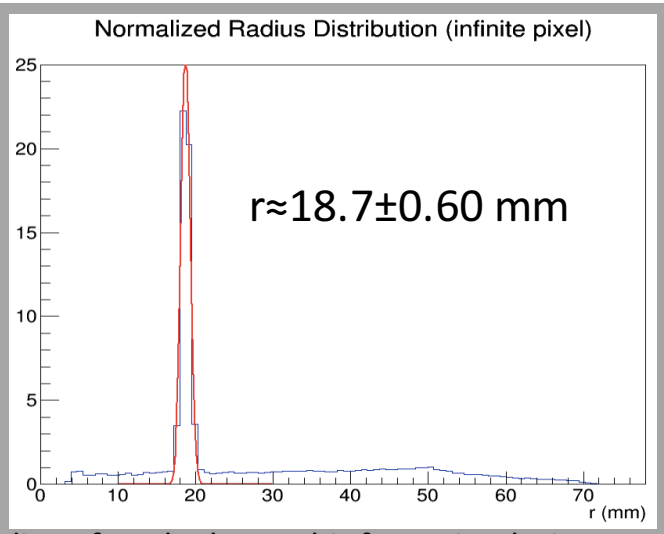


Details of Detector Setup

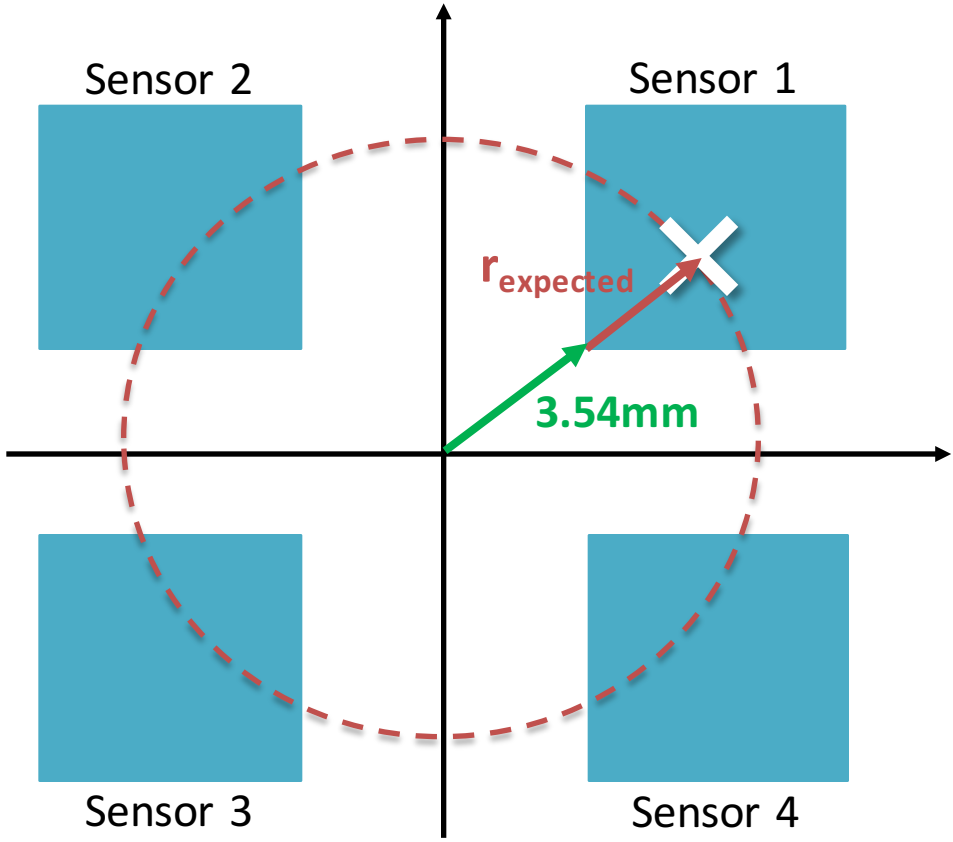




Radius (in each event) Distribution



- Radius of each photon hit from simulation result.
- No Q.E. applied



Not on scale

$r_{expected}$ =18.7-3.54 (gap) ±0.60 ±3 (half of single pixel size)
=15.2 ±3.6mm

Weight Functions

$$W_{center} = exp\left[-\frac{a^2+b^2}{2\times 3^2}\right] \qquad W_r = exp\left[-\frac{(r-15.9)^2}{2\times 3^2}\right]$$