Test Beam Results on Focusing Aerogel

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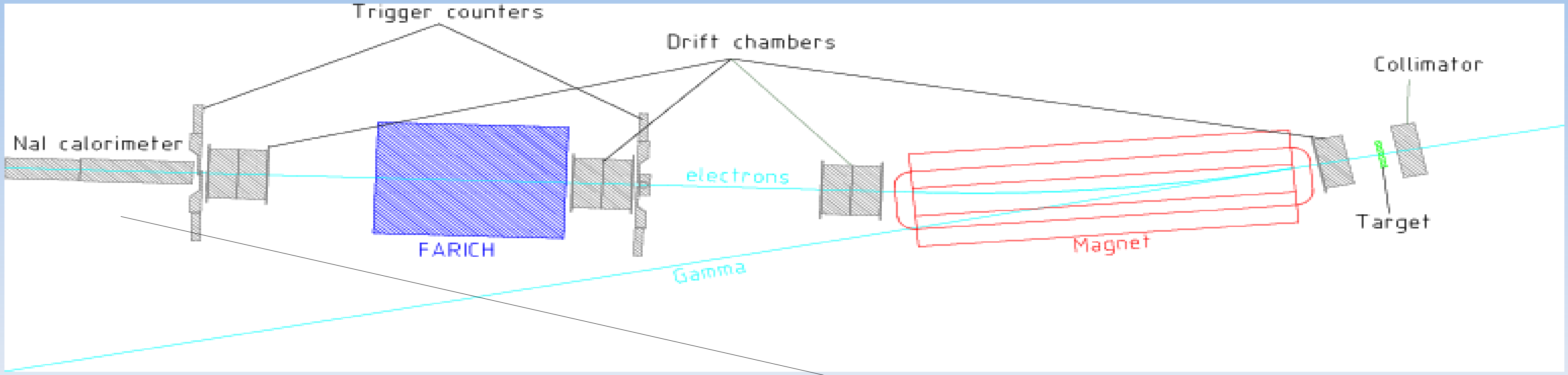
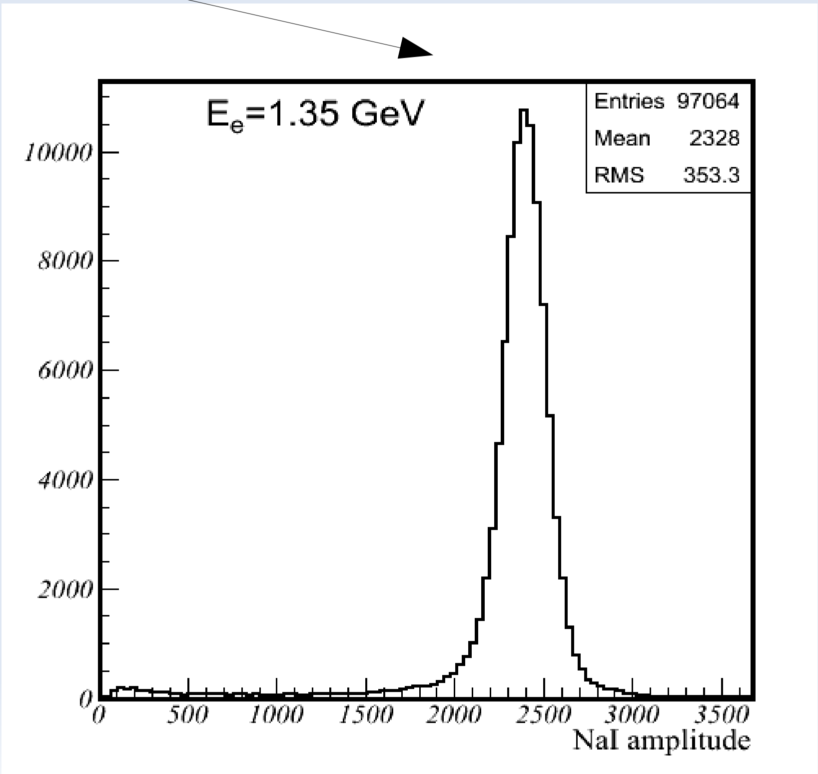
Outline

- Test beam facility
- Aerogel and photodetectors description
- Test beam measurements
- Recalculation for SuperB FARICH based on test beam results.
- Plans

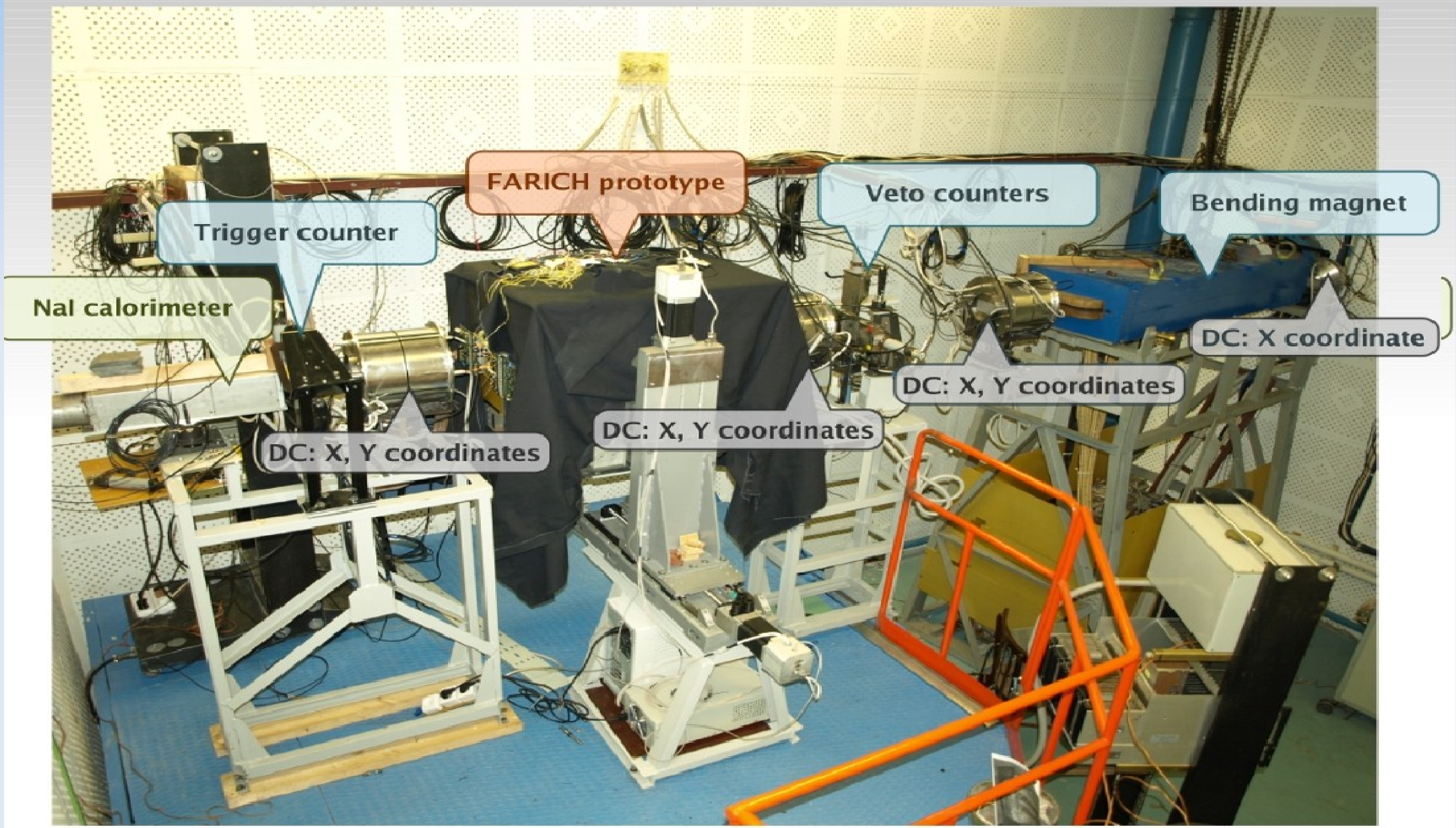
Test beam experiment



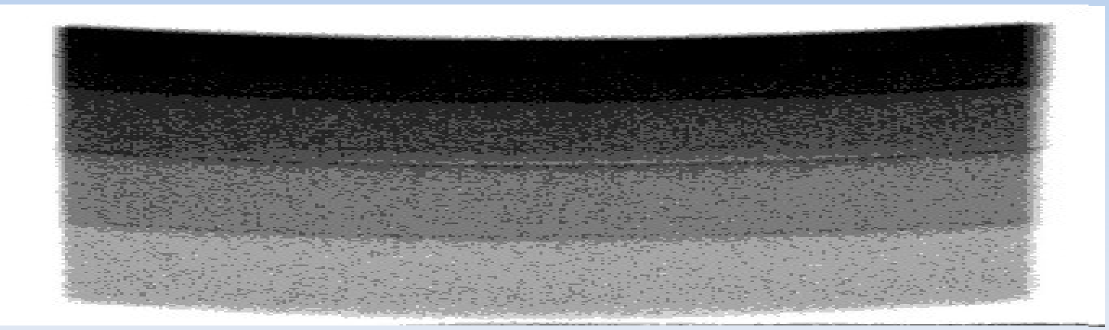
- **Test beam parameters:**
  - ”Converter mode”, ~10 mA, 3.5 GeV beam in VEPP-4M, –- ~50 Hz of 1.3 GeV secondary electrons (3 GeV maximum)
  - 50x15 mm^2 beam crossection (defined by trigger counter dimentions)
  - ~0.5 mm track spatial resolution



Test beam line



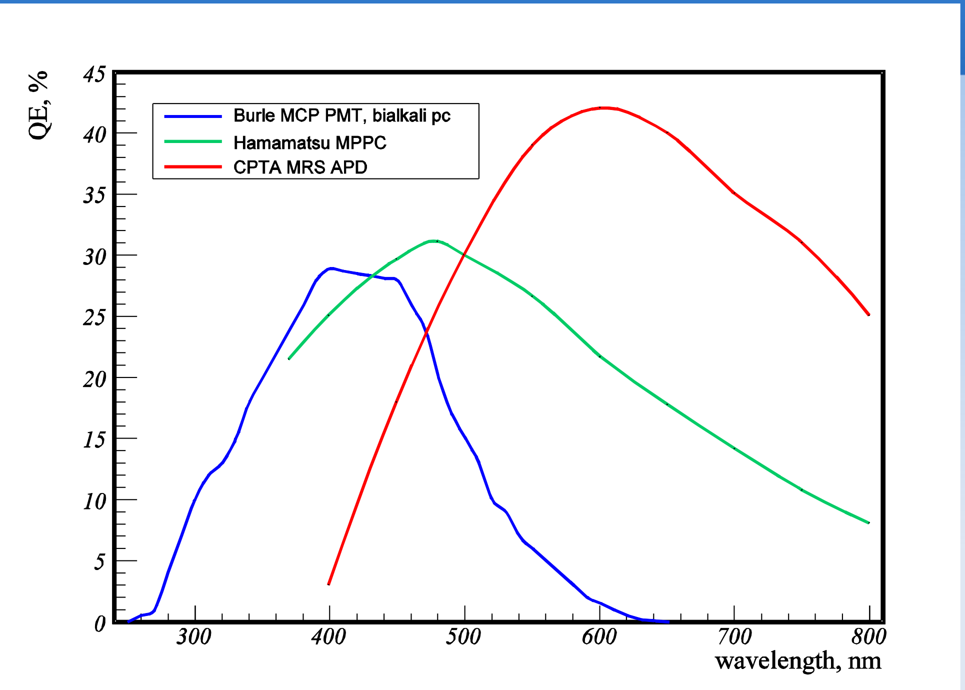
Aerogel sample

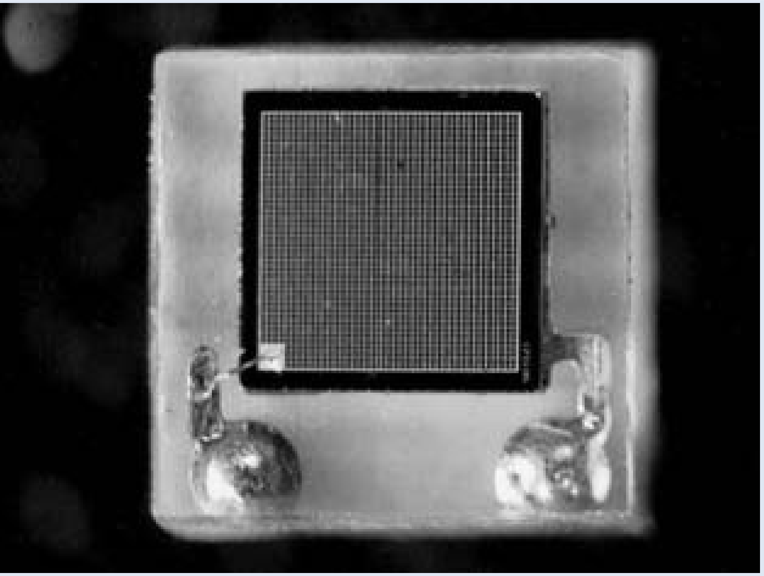


	n	h, mm
Layer 1	**1.050**	**6.2**
Layer 2	**1.041**	**7.0**
Layer 3	**1.035**	**7.7**
Layer 4	**1.030**	**9.7**

- $100 \times 100 \times 31\ mm^3$
- Lsc(400nm)=43 mm
- $n^2=1+0.438*\rho$

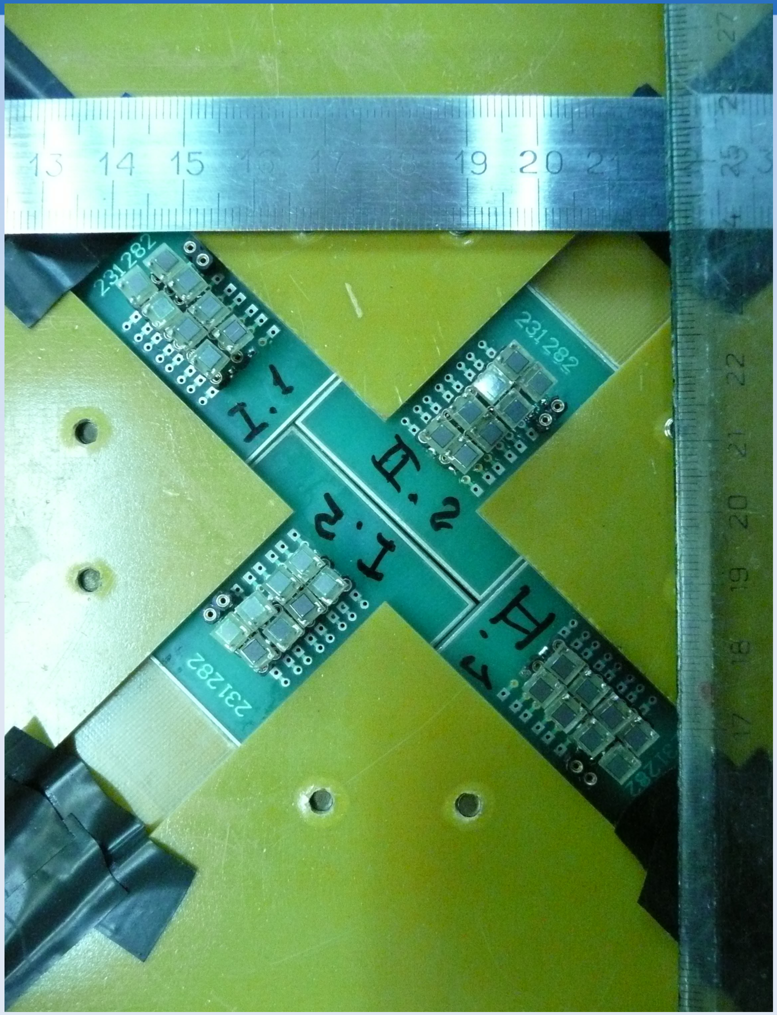
MRS APD Parameters



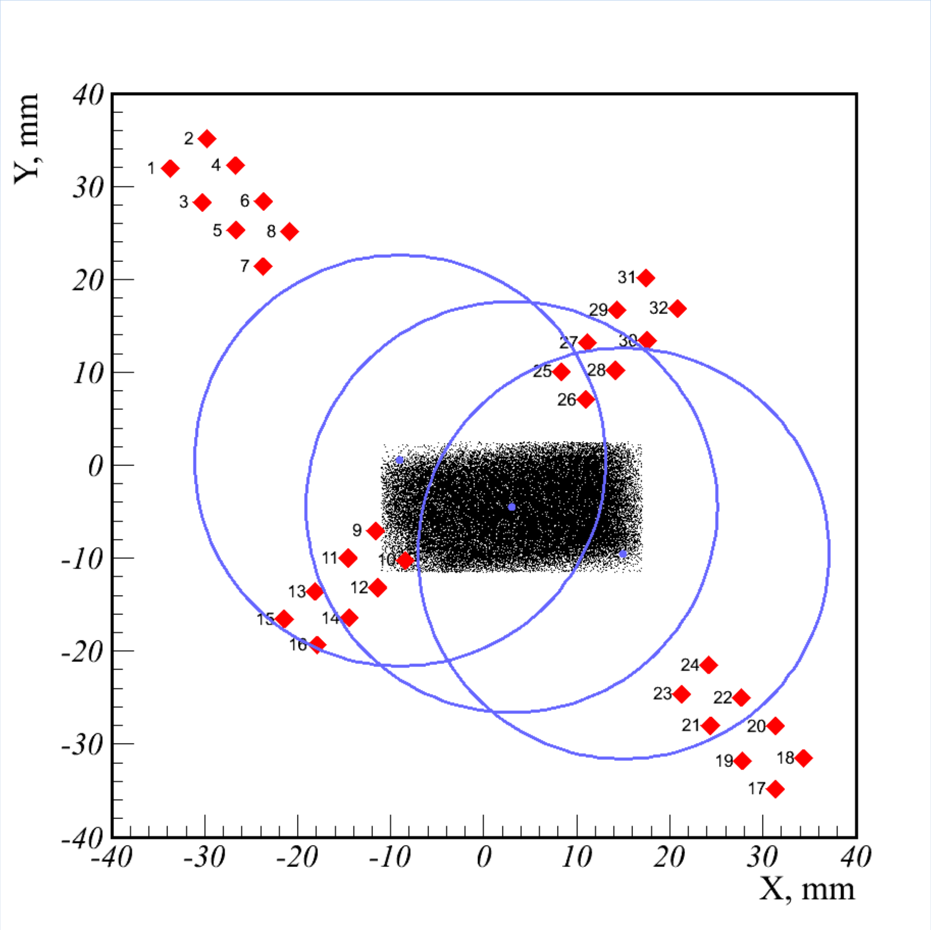


- Producer - Center of Perspective Technology and Apparatus – CPTA, Moscow http://www.spta-apd.ru/
- Genuine name - MRS APD (other names: silicon photomultiplier, PPD,MPPC…)
- 2.1x2.1 mm sensor
- 4x4 mm case size
- PDE=40% @ 600 nm (?)
- Gain ~ $4{\cdot}10^5$
- Time resolution ~100 ps
- Dark counts ~5--10 MHz (0.5pe threshold)

Photodetectors layout

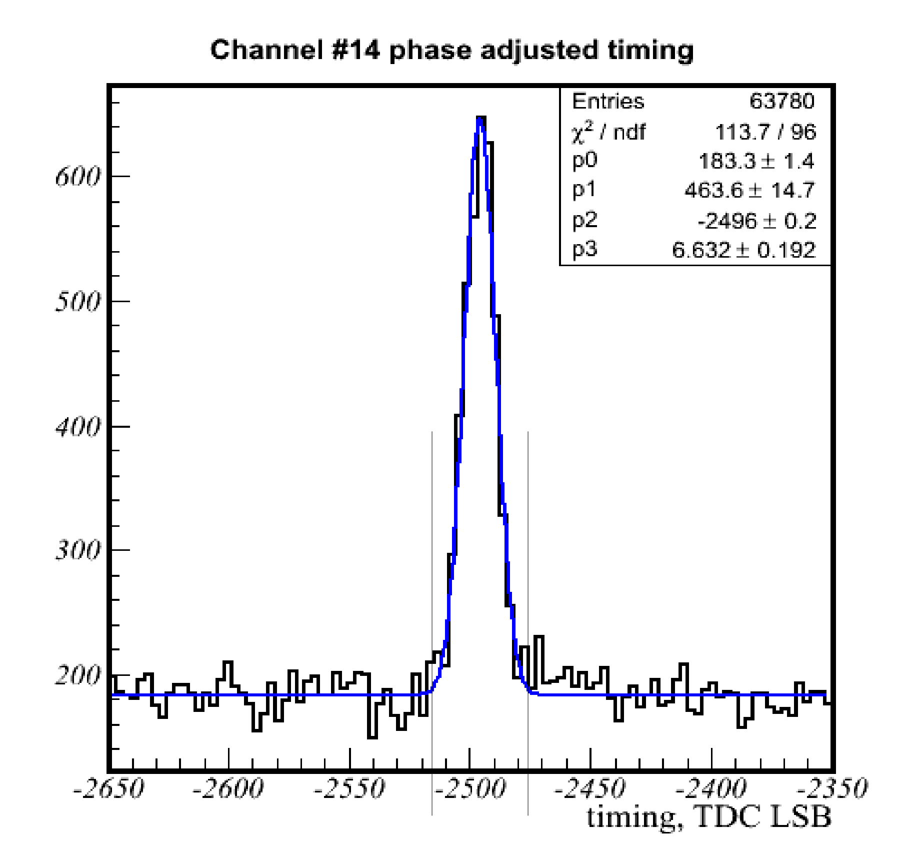


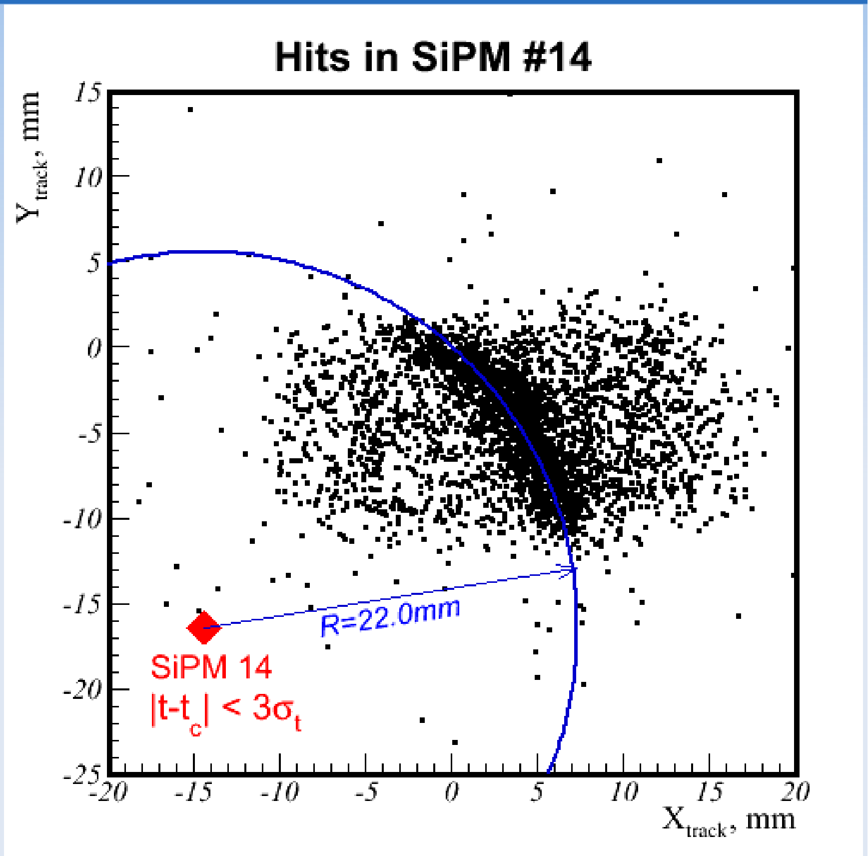
SiPM coordinates and trigger area



Electrons could pass at different distances from SiPM.

Event selection



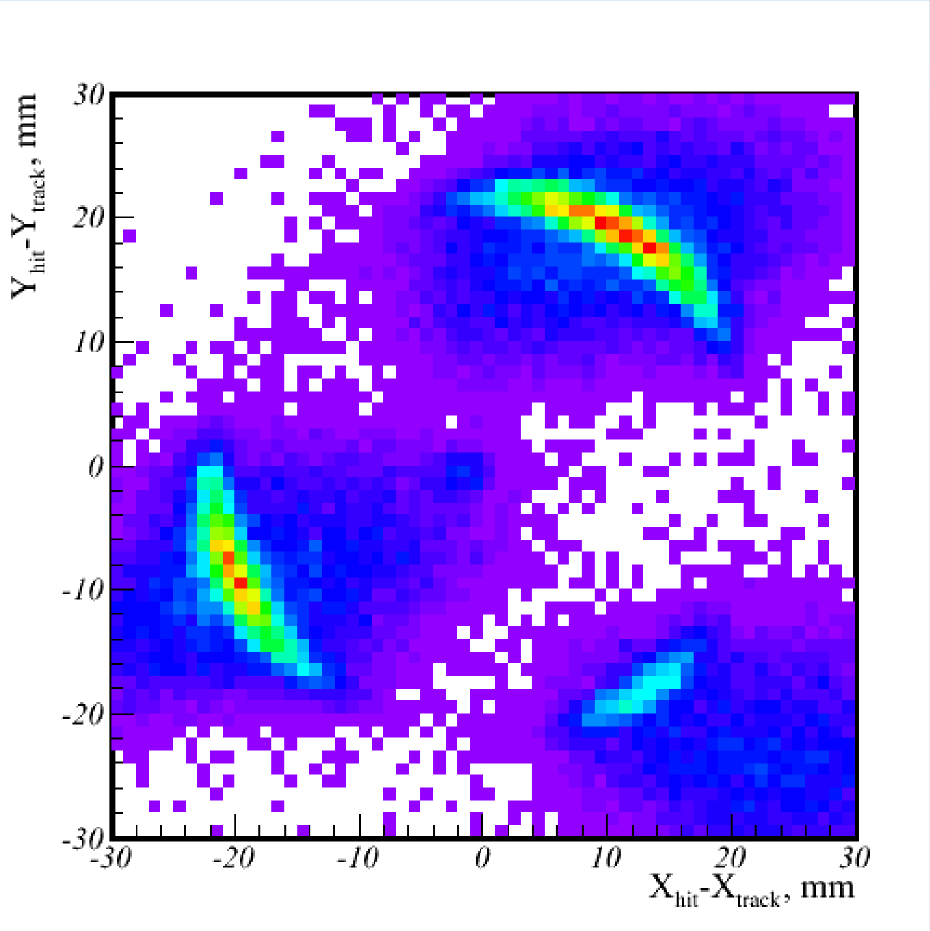


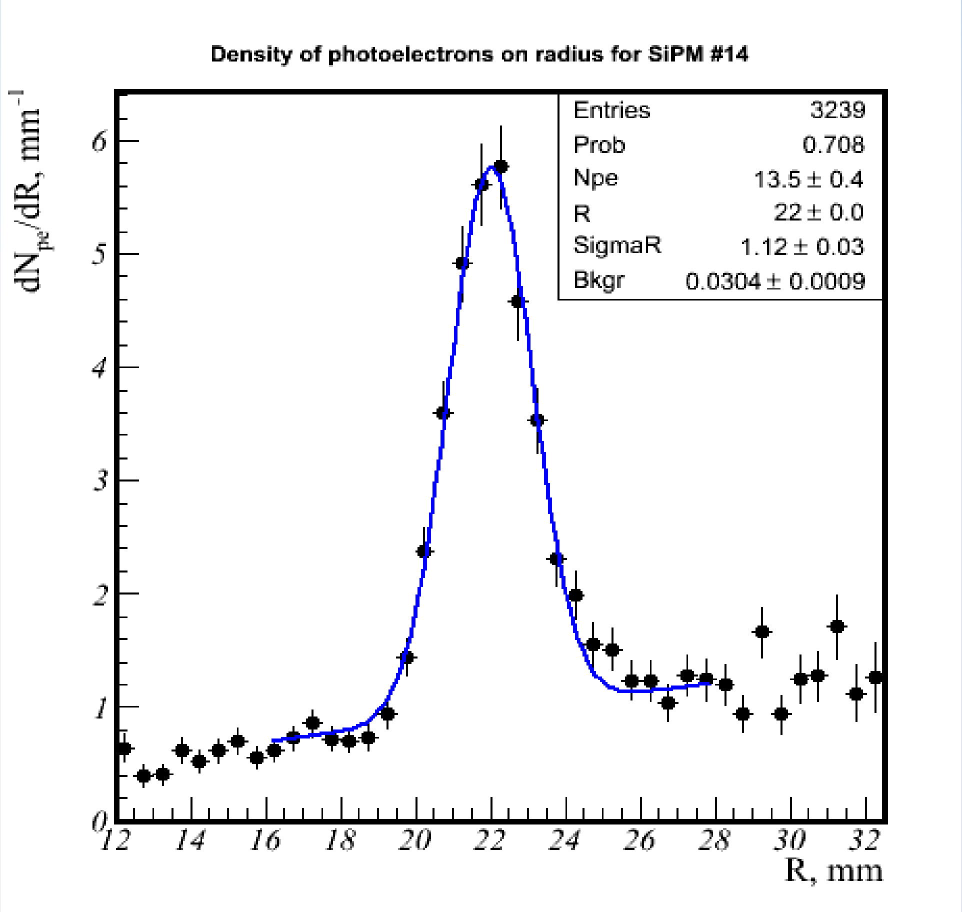
- **We select events with $|t-t_{ch}|<3\sigma_t$**

Cherenkov ring radius measurement(1)

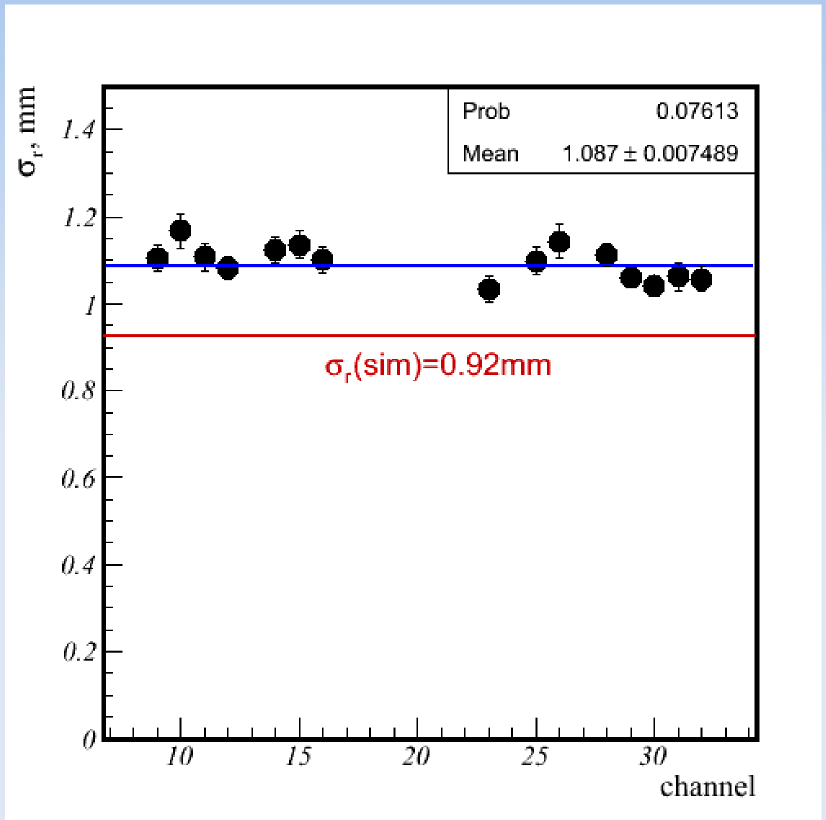
(X,Y)hit-(X,Y)track

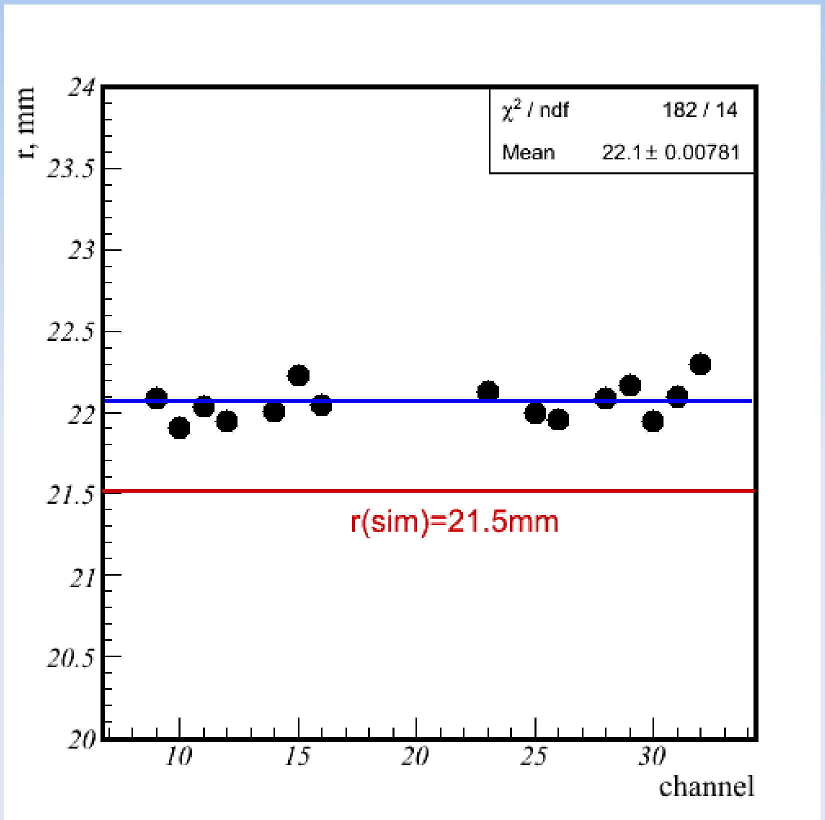
$R^2=(X_{hit}-X_{track})^2+(Y_{hit}-Y_{track})^2$





Cherenkov ring radius measurement(2)

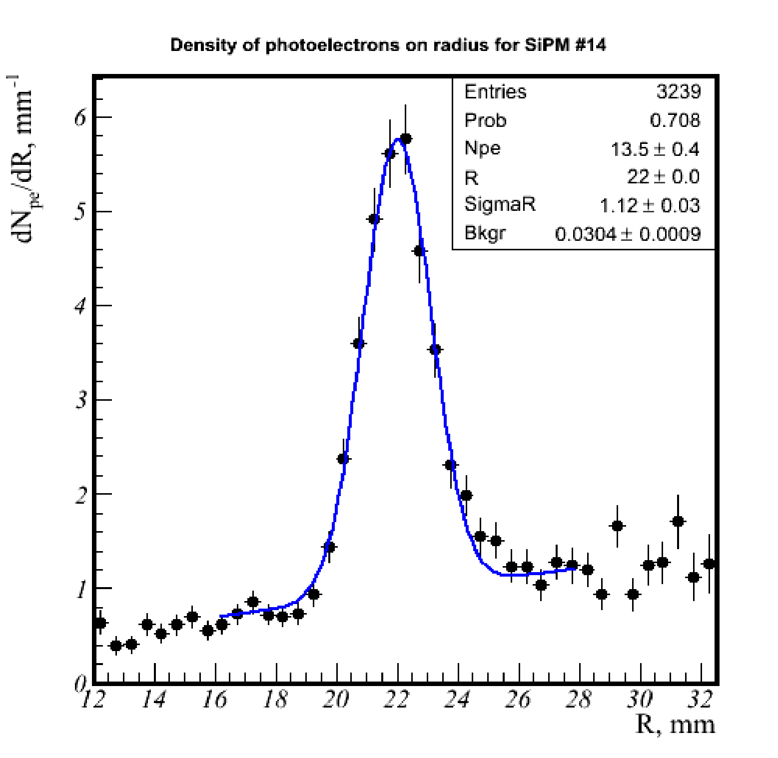


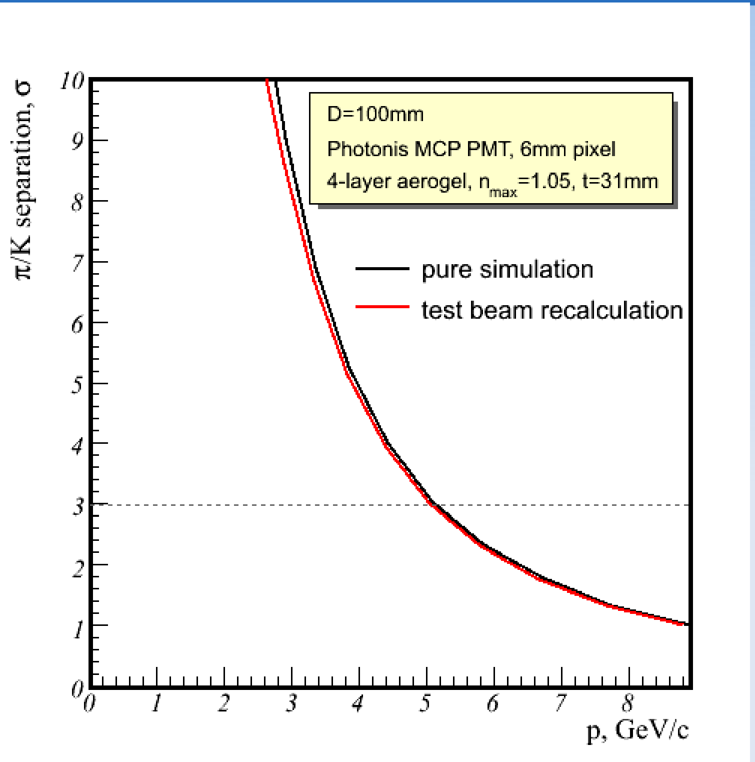


Difference between σ_r and σ_r(sim) comes mainly from track resolution (~0.5 mm)

22.1 – 21.5 = 0.6 mm –> 2.7%
Position accuracy –> 1.7%
error in $n_{aerogel}$ from dencuty –>

What PID will be at SuperB with such aerogel?





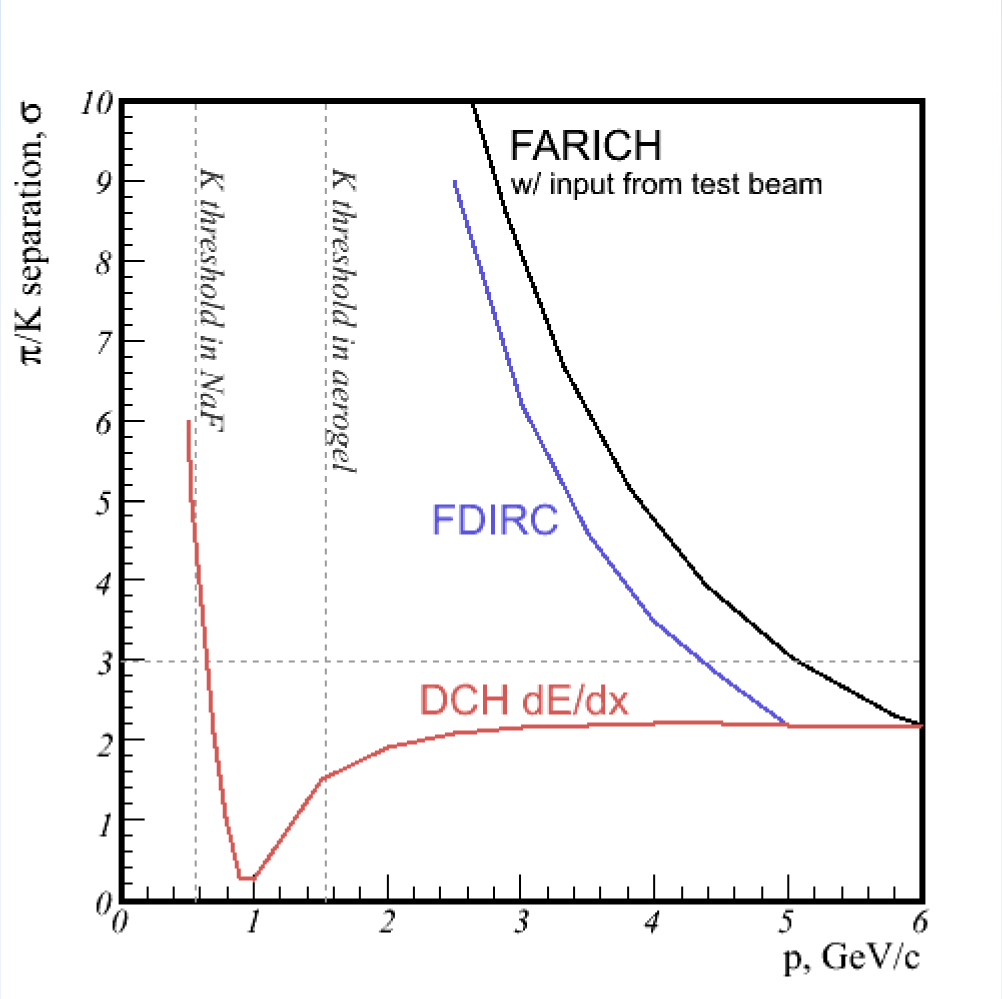
- Pure Gaussian + flat background (from randome coincedence with G-APD noise) at least in ±5σ region.
- $\sigma_r^2 = \sigma_{aerogel}^2 + \sigma_{pixel}^2 + \sigma_{track}^2$
- $\sigma'_{aerogel} = \mathrm{sqrt}(\sigma_r^2 - \sigma_{pixel}^2)$

  $= \mathrm{sqrt}(1.09^2 - 2.1^2/12) = 0.91$ mm

PID with $\sigma'_{aerogel}$=0.91 mm and 6 mm pixel.
Estimation of lower limit of PID.

Plans

- **Continue data analysis collected during test beam experiment.**
  - **List of measured samples:**
    - **2 single layer aerogels**
    - **2 4-layer aerogels**
    - **1 2-layer aerogel**
    - **water (5 mm)**
  - **List of experiments:**
    - **3 to 5 positions in focusing mode**
    - **2 positions in defocusing mode**
    - **surface scan of 4-layer aerogel**
- **Planacon PMTs**
- **Electronics**
- **Mechanics**



Conclusion

- Test beam measurements of 4-layer aerogel give us a lot of information on focusing radiator
- Test beam results confirm earlier MC simulations.

Additional slides

Signal fit function

$$\frac{dN_{hit}}{dx\,dy\,dx'\,dy'}(x,y,x',y') = \frac{dN_{trk}}{dx\,dy}(x,y)\frac{dN_{p.e.}}{dx'\,dy'}(x'-x,y'-y),$$

x,y – track coordinates; x',y' – photon coordinates

If we integrate on x',y' over active area of a particular pixel and assume symmetry on φ, we deduce

$$\frac{dN_{hit}}{dx\,dy}(x,y) \approx \frac{dN_{trk}}{dx\,dy}(x,y)\,S_{px}\frac{dN_{p.e.}}{dx'\,dy'}(r) = \frac{dN_{trk}}{dx\,dy}(x,y)\frac{S_{px}}{2\pi r}\frac{dN_{p.e.}}{dr}(r),$$

$r=\sqrt{(x_{px}-x)^2+(y_{px}-y)^2}$ – distance from pixel center to track,

S_{px} – pixel active area.

In some cases p.e. distribution can be described by a gaussian:

$$\frac{dN_{p.e.}}{dr}(r)=\frac{N_{p.e.}}{\sqrt{2\pi}\sigma_r}\exp\left(-\frac{(r-r_c)^2}{2\sigma_r^2}\right)$$

Fitting procedure (1)

Break track and hit distributions in 2D bins: $N_{hit}(i,j),\ N_{trk}(i,j),$

i, j – indices of bins on x and y with centers x_i, y_j

Mean number of hits $\nu_{hit}(i,j)$ is described by

$$\nu_{hit}(i,j) = N_{trk}(i,j)\left(\frac{S_{px}}{2\pi r_{ij}}\frac{N_{p.e.}}{\sqrt{2\pi}\,\sigma_r}\exp\left(-\frac{(r_{ij}-r_c)^2}{2\sigma_r^2}\right)+B\right),$$

r_{ij} – distance from bin center to pixel center

B – background parameter

$N_{hit}(i,j)$ is Poisson random number with mean $\nu_{hit}(i,j)$, hence we use likelihood function

$$-\ln L=\sum_{i,j}\left(\nu_{hit}(i,j)-N_{hit}(i,j)\ln\nu_{hit}(i,j)\right).$$

By the fit we determine parameters: $N_{p.e.},\ r_c,\ \sigma_r,\ B,\ \Delta X,\ \Delta Y,$ for each pixel (channel).

$\Delta X,\ \Delta Y$ – shift of FARICH r.f. relative to DCH r.f.

Fitting procedure (2)

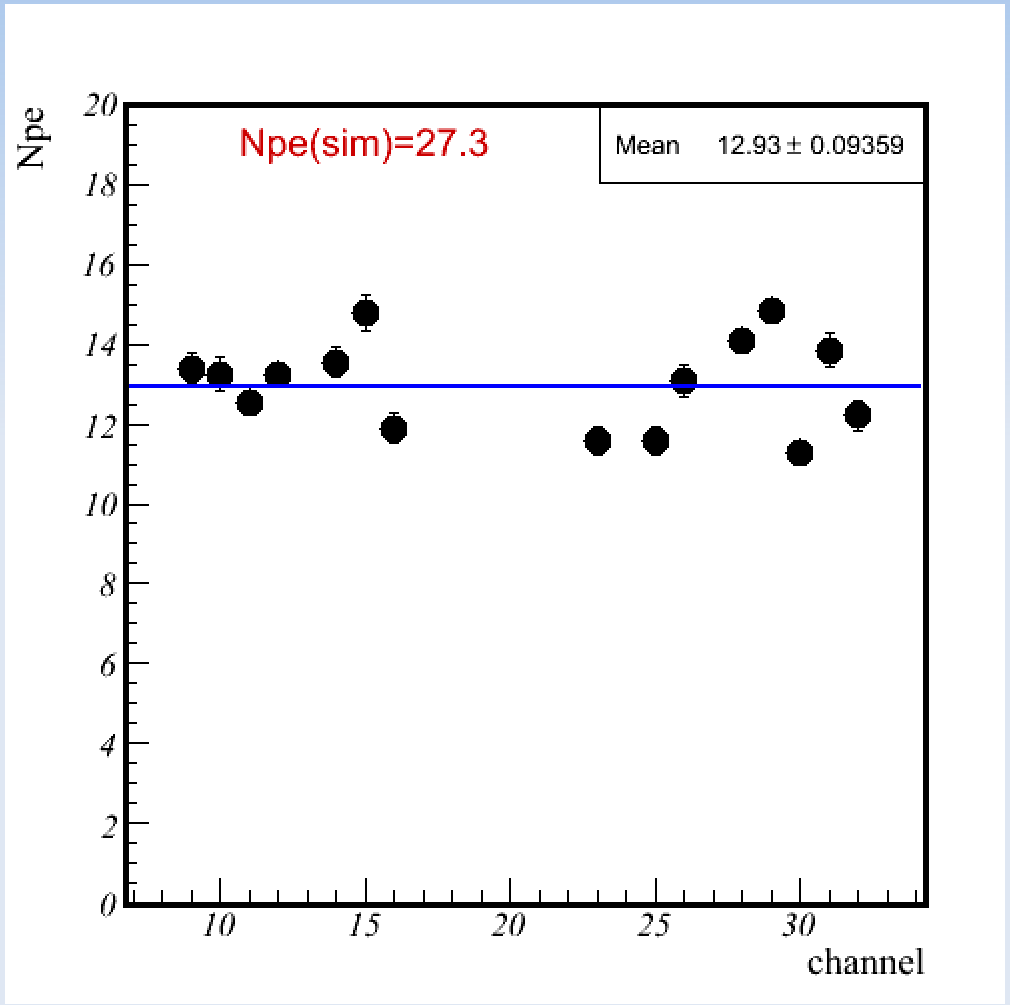
- Also we can do a global fit for all channels with common parameters $r_c, \sigma_r, \Delta X, \Delta Y$
- Having determined r.f. shift, we can build hit and track distributions on radius $N_{hit}(r_i), N_{trk}(r_i)$ and fit them:

$$\frac{dN_{p.e.}}{dr}(r_i) + \frac{2\pi r B}{S_{px}} = \frac{2\pi r N_{hit}(r_i)}{S_{px} N_{trk}(r_i)}.$$

- Background is not very well fitted with single parameter B in a large area 30x15 mm of track positions for some channels. Probable reasons:
  - Cross-talks between channels
  - Non-linearities in DCH track position determination

→ Use fits on radius in a narrower region $\pm 5\sigma_r$ around the ring.

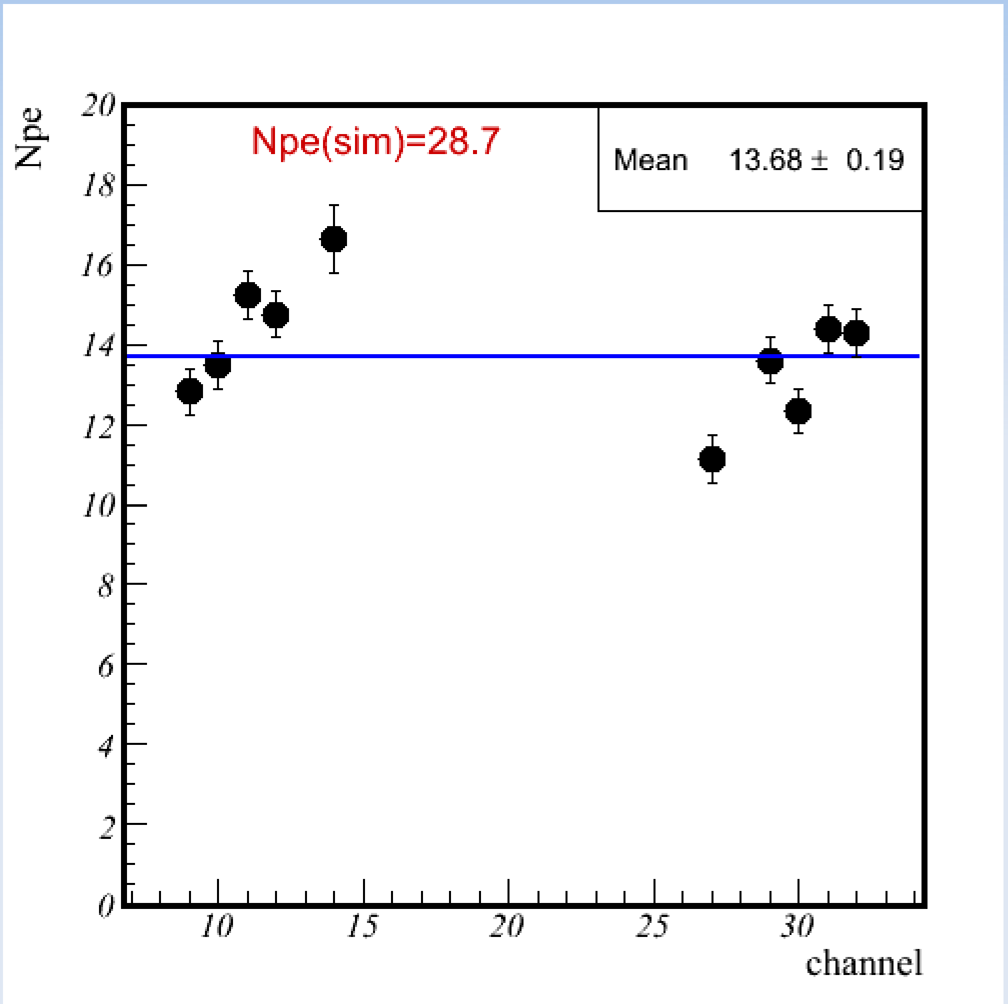
Number of photoelectrons (4-layer)



Discrepancy between Npe in simulation and experiment could be explained by:

- real detection efficiency of G-APDs is smaller than in data book
- electronics miscount

Number of photoelectrons (1-layer)



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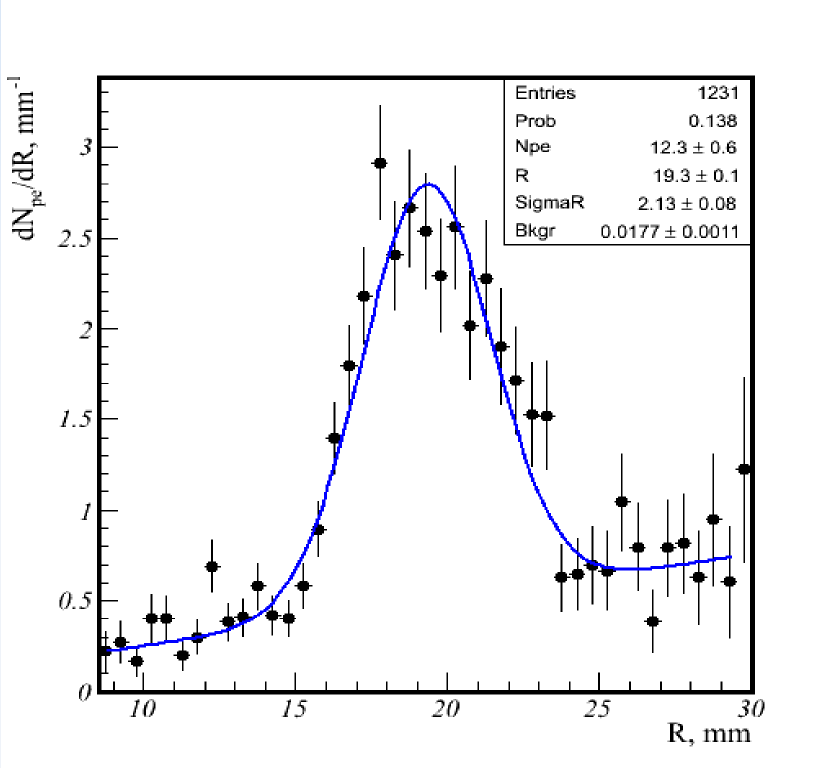
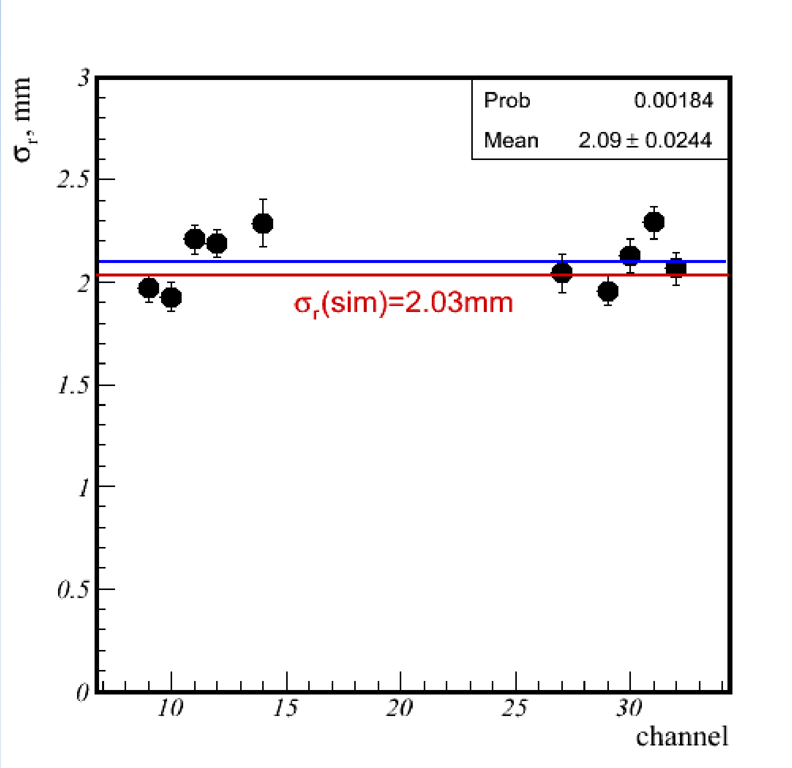
- electronics miscount

Single layer vs 4-layer aerogel

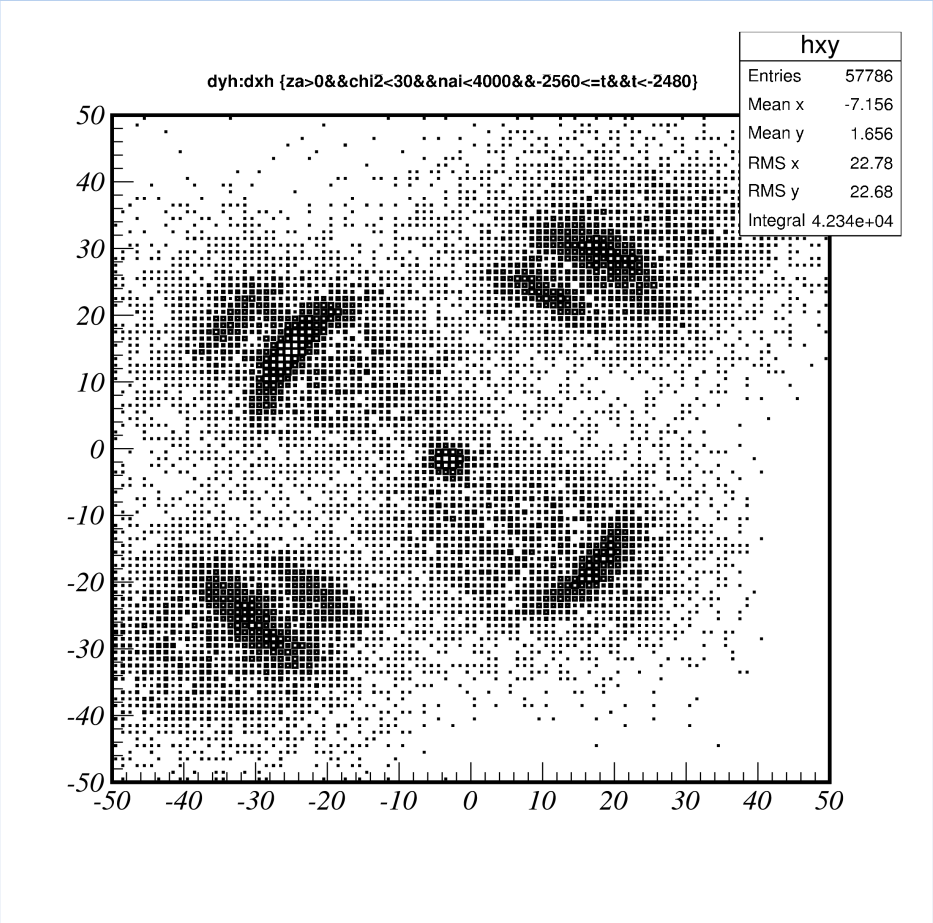
Single layer aerogel measurement





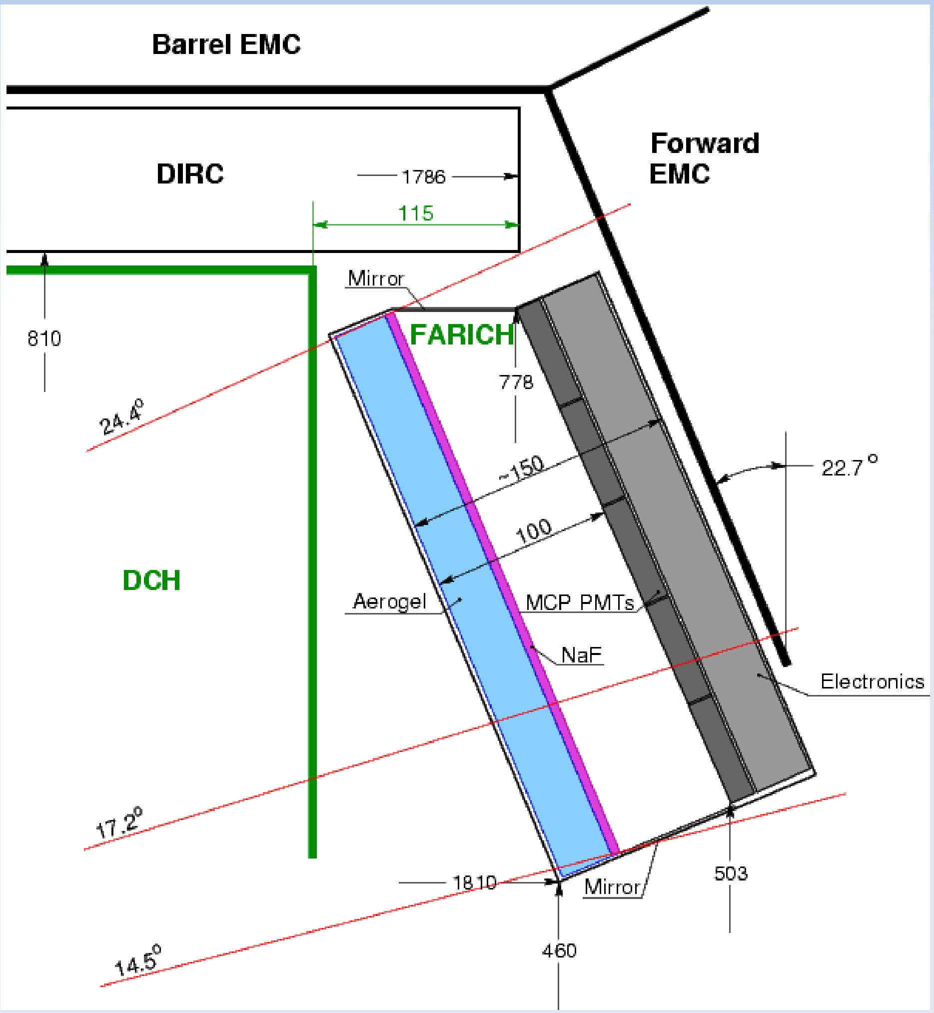
- 'Focusing' effect – 3 times decrease in ring width :
  - 2 cm thickness, single layer –> σr=2.1 mm
  - 3 cm thickness, 4 layer –> σr=1.1 mm

Defocusing measurements, 2-layer block



- Such measurements give direct answer what is the index of refraction of each layer.

FARICH layout

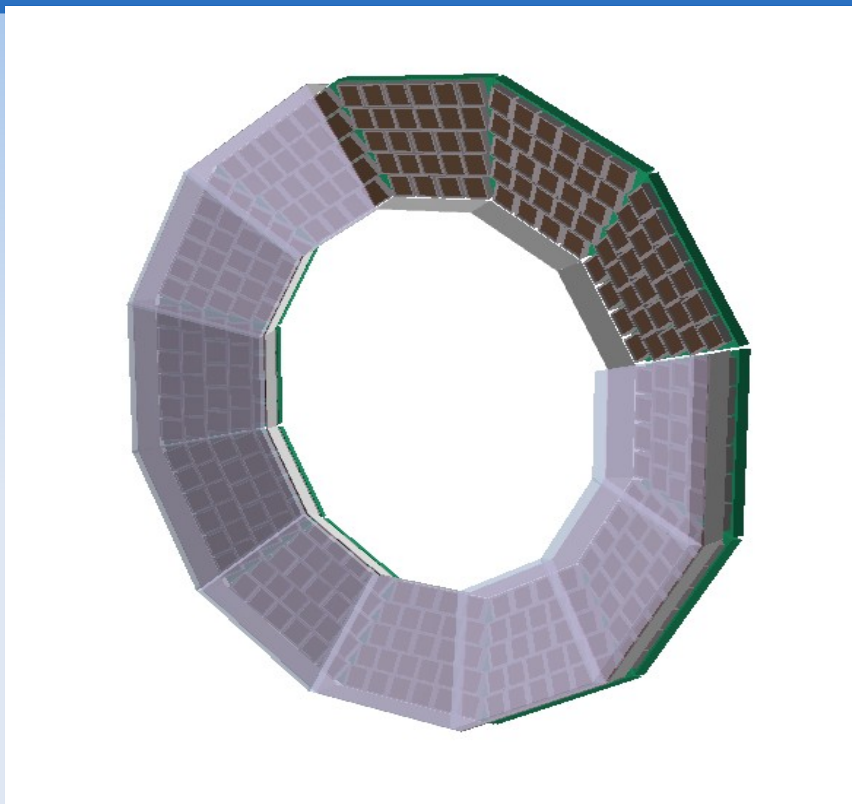


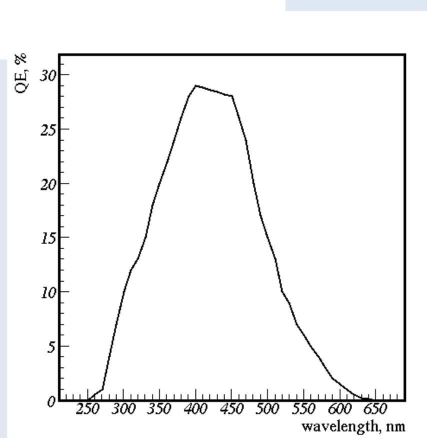
- MCP PMT photodetectors - Photonis XP85012
- Radiator - Focusing Aerogel + NaF

layer	marerial	n(400nm)	t, mm
1	aerogel	1.039	16.2
2	aerogel	1.050	13.8
3	NaF	1.332	5.0

- X/X0 = 2.4%(aerogel) + 4.3%(NaF) + 10%(PMT) + ~ 8% (support,FEE,cooling) ≈ 25%

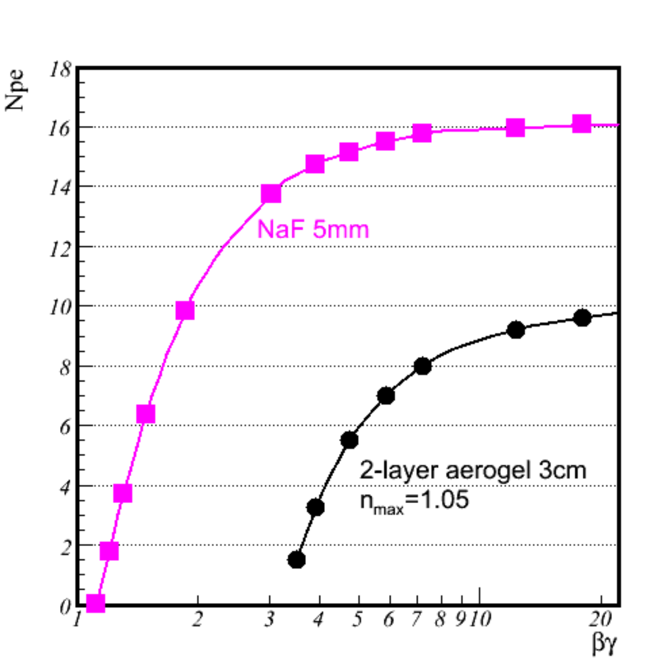
Photodetector



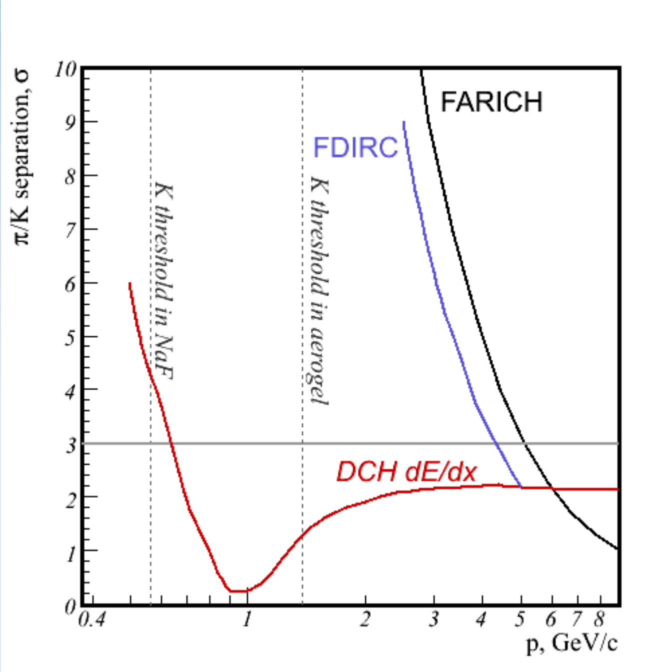


- Number of PMTs: 312
- Number of anodes: 8×8
- 6×6 mm anode size
- 59×59×13 mm case dimensions
- 81% active area fraction
- 70% MCP photoelectron collection
- QE(400nm)=29%
- Gain ~ $5 \cdot 10^5$;
- Time resolution ~ 40 ps;

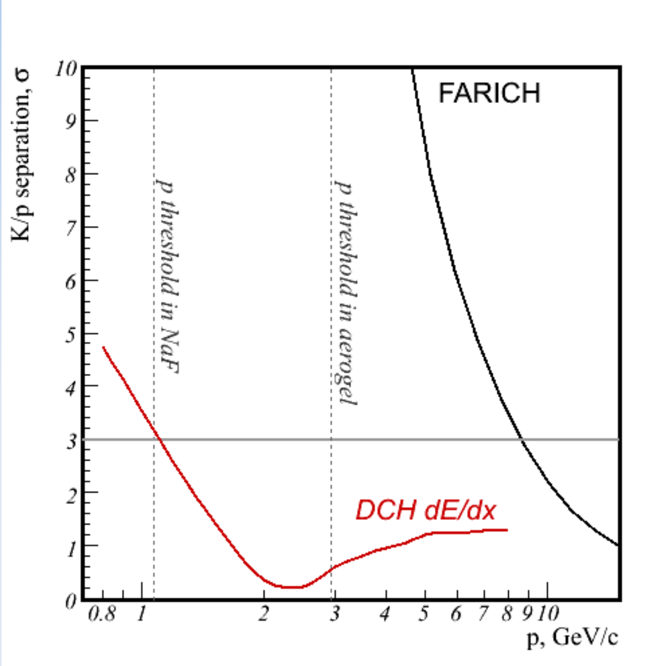
Monte Carlo Simulation



Number of photoelectrons



π/K separation of FARICH in comparison with FDIRC and DCH



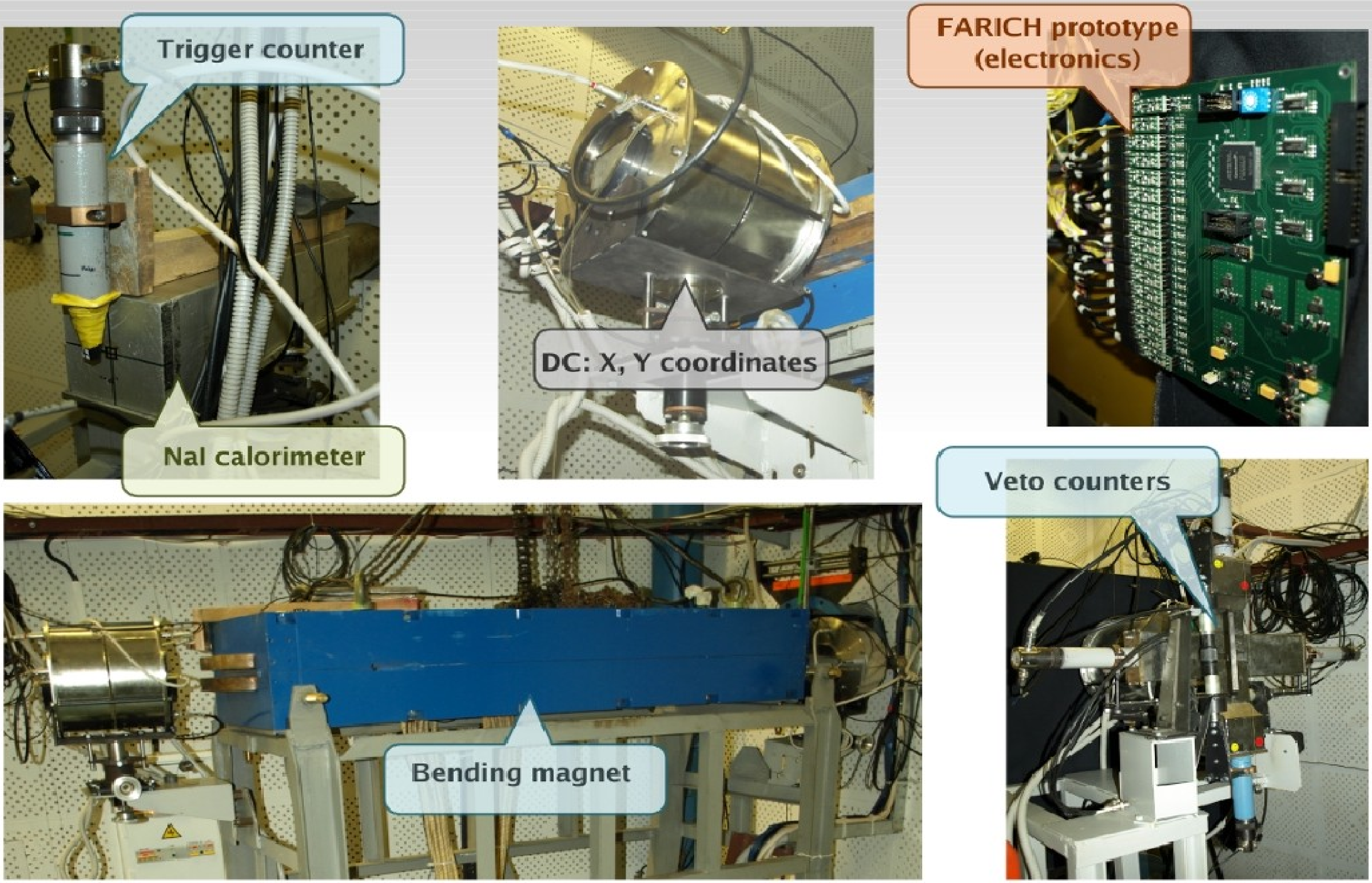
K/p separation of FARICH in Comparison with DCH

Cost estimation

Component	Unit price, kEuro	Cost, kEuro
Photonis MCP PMT*	6.5	2300
2-layer aerogel	3.0	400
NaF	2.0	200
Electronics		300
Mechanics		100
R&D		100
Total		3400

(*) - based on price of PMTs with 25mkm MCPs

Test beam apparatus



Electronics

- Fast FPGA are used as TDC:
  - Smaller number of components – it is easier to fit FARICH electronics into available space
  - zero dead time
  - Flexible logic
  - Commercially available
  - Low cost (~0.5 Euro/channel)
- FE ASIC – several candidates:
  - NINO13 (new version, designed for use with pixel MCP PMTs!)
  - DIRC ASIC

Matthieu Despeisse et.al., ”Low-Power Amplifier-Discriminators For High Time Resolution Detection”, IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 56, NO. 2, APRIL 2009

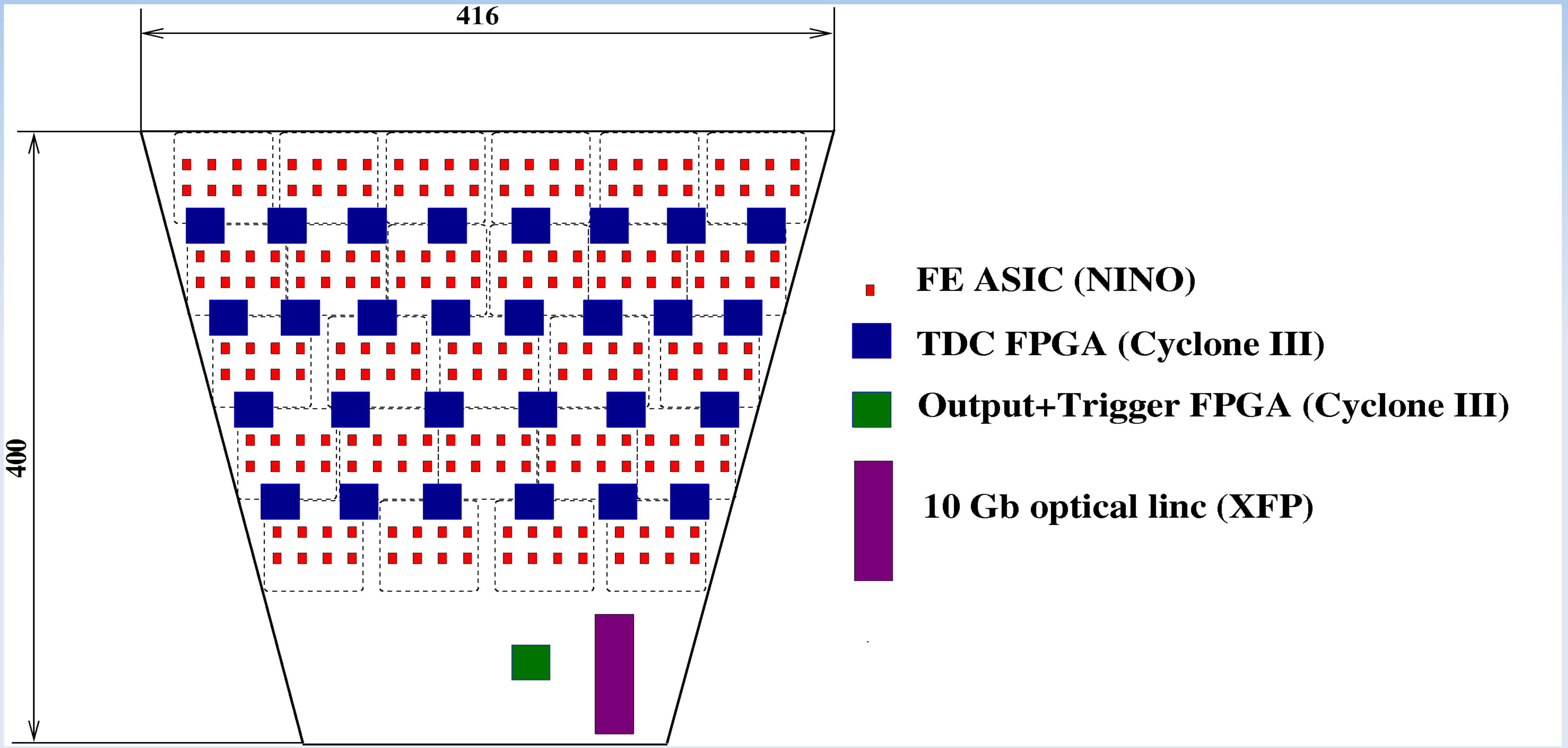
Electronics layout

One sector:

- 26 PMTs with 64 channels = 1664 channels
- FE ASIC (NINO13) – 5x7 mm frame,
  8 channels, 1664/8 = 208 chips on board
- FPGA TDC (Cyclone III) – 23x23 mm frame,
  60 channels, 1664/60 – 28 chips on board
- 10 Gb optical link(XFP)

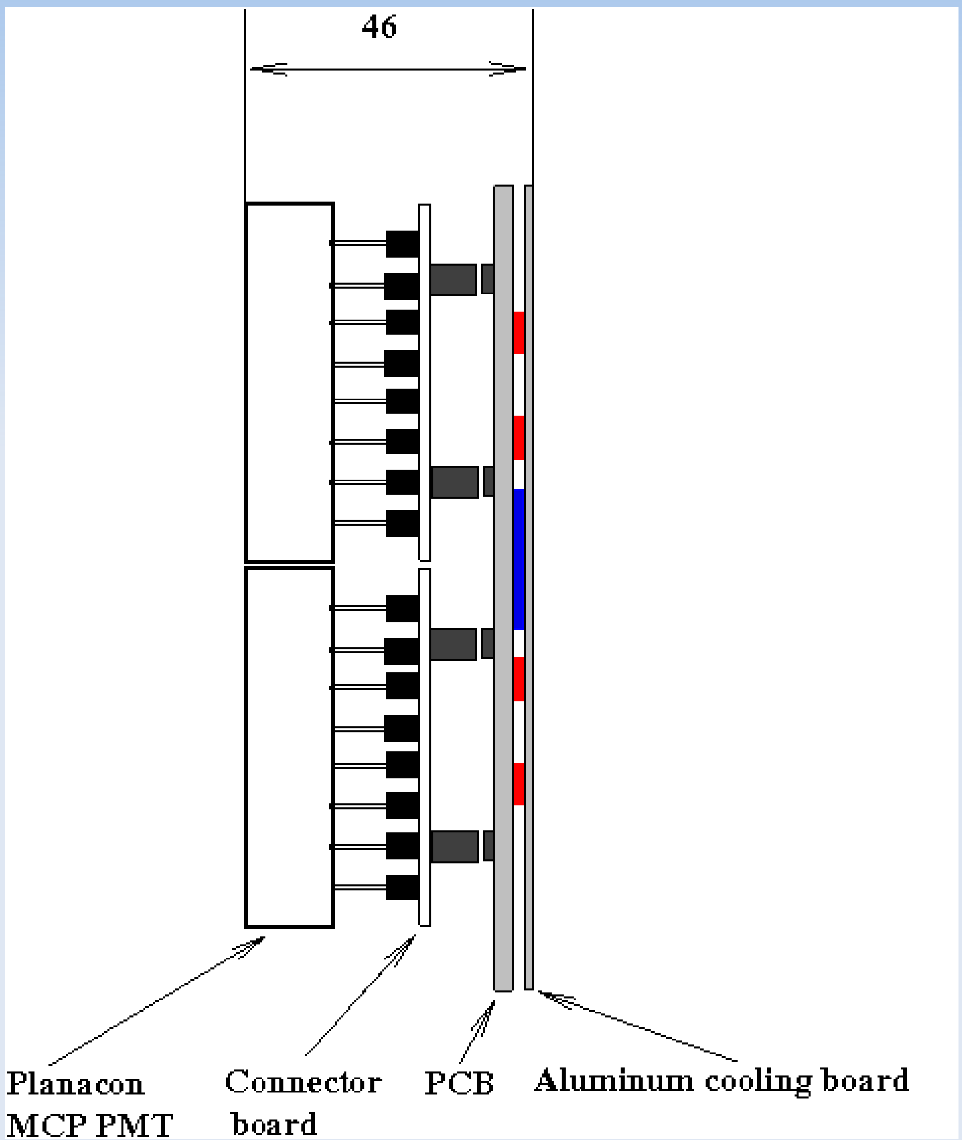
Is it possible to fit all this on single PCB or we need 2 PCBs?

Electronics layout (front view)



- 50 W heat dissipation per PCB → water cooling

Electronics layout (side view)



- We need only one PCB for signal digitization and readout
- Aluminum cooling board with water channels is coupled to PCB. 1 mm thickness (1% of X0)
- Separate connector board for each PMT is foreseen. It is used also to arrange HV divider.
- 46 mm total thickness
- Radiation hardness of FPGAs need to be investigated:
  - Total dose and particle flux in the forward?
  - Radiation hardness of Cyclone III and other FPGAs