The DIRC particle identification system of the BABAR experiment → GlueX

Baptiste GUEGAN

Introduction

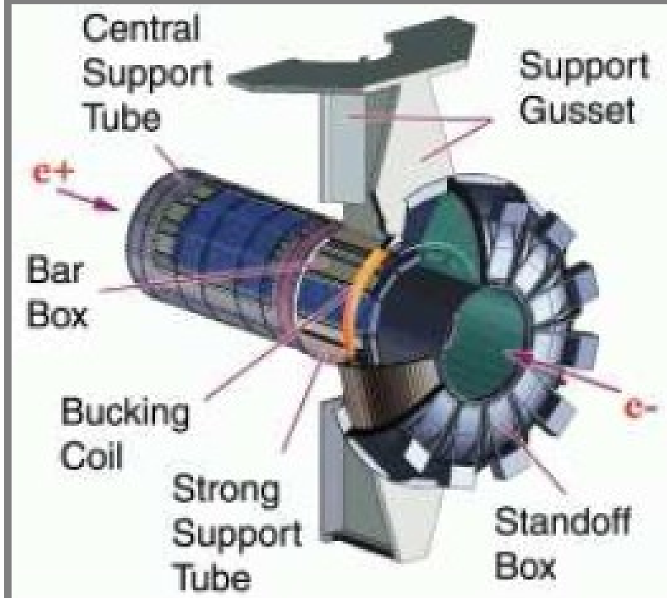
- A new type of ring-imaging Cherenkov detector has been used for PID in the BABAR experiment at the SLAC

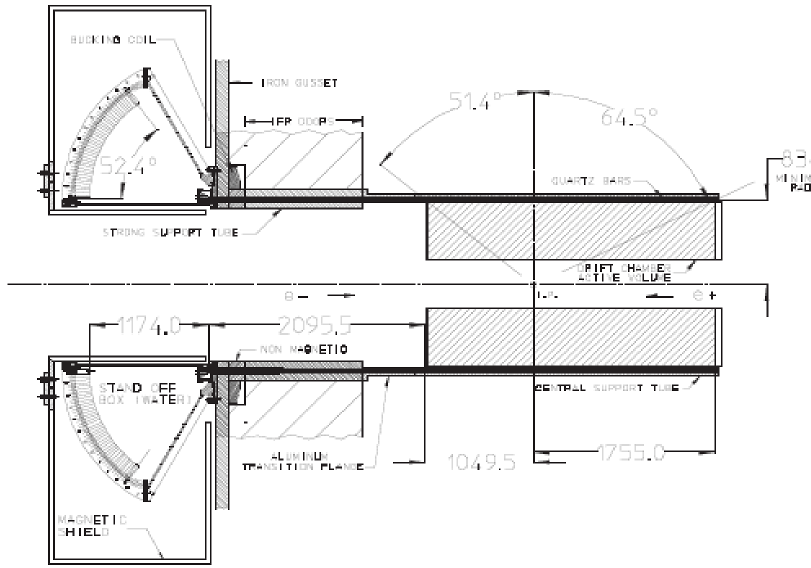
- **DIRC**: Detection of Internally Reflected Cherenkov (Light)

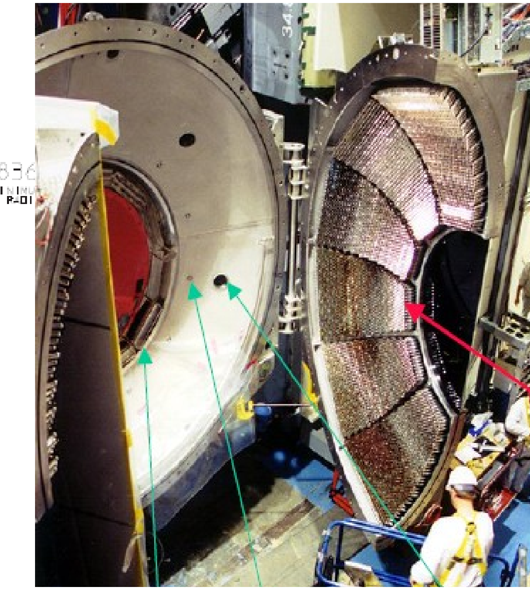
- **Aim:** π/K separation of ~4σ or greater, for all tracks from B-meson decays from the pion Cherenkov threshold up to 4.2 GeV/c. PID below 700 MeV/c relies primarily on the dE/dx measurements in the Drift Chamber and the Silicon Vertex Tracker

  $\rightarrow$ similar to GlueX requirements

Design and requirements

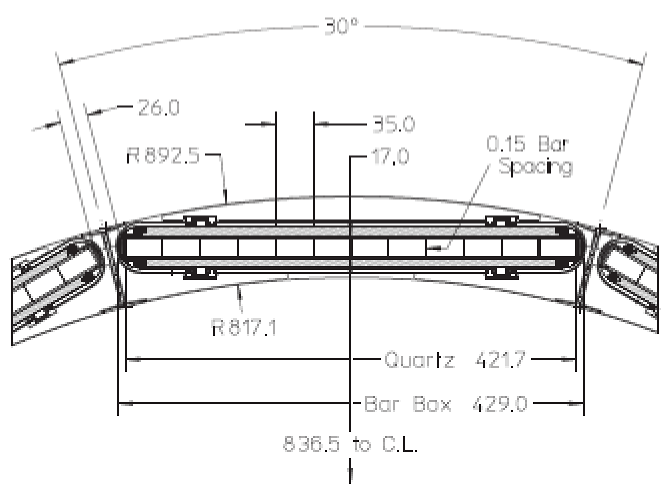


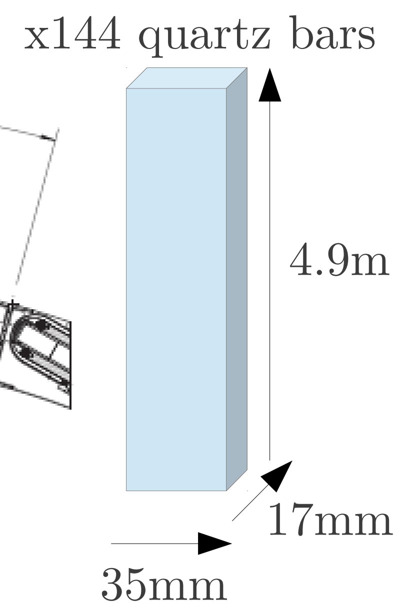




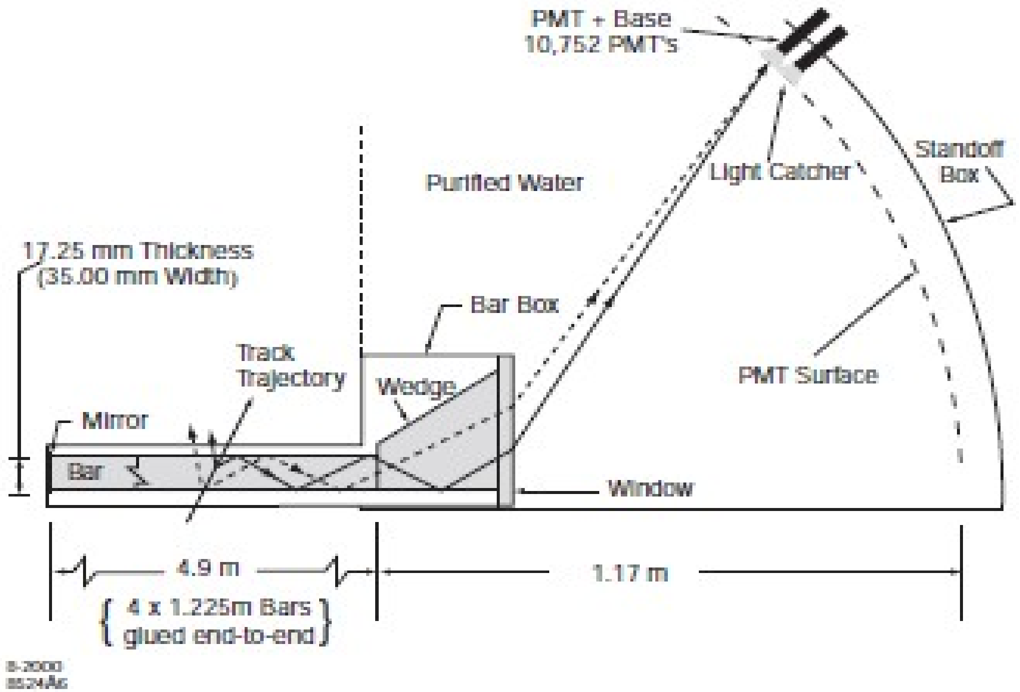
- Pions and kaons (from B0 → π+π-and B0 → K+π)-must be well-separated: 1.7 and 4.2 GeV/c

- The PID system should be thin and uniform in terms of radiation lengths (80mm of radial space, 19% radiation length)





Principle



- Bars with rectangular cross section (radiators and as light pipes) for the portion of the light trapped in the radiator by total internal reflection

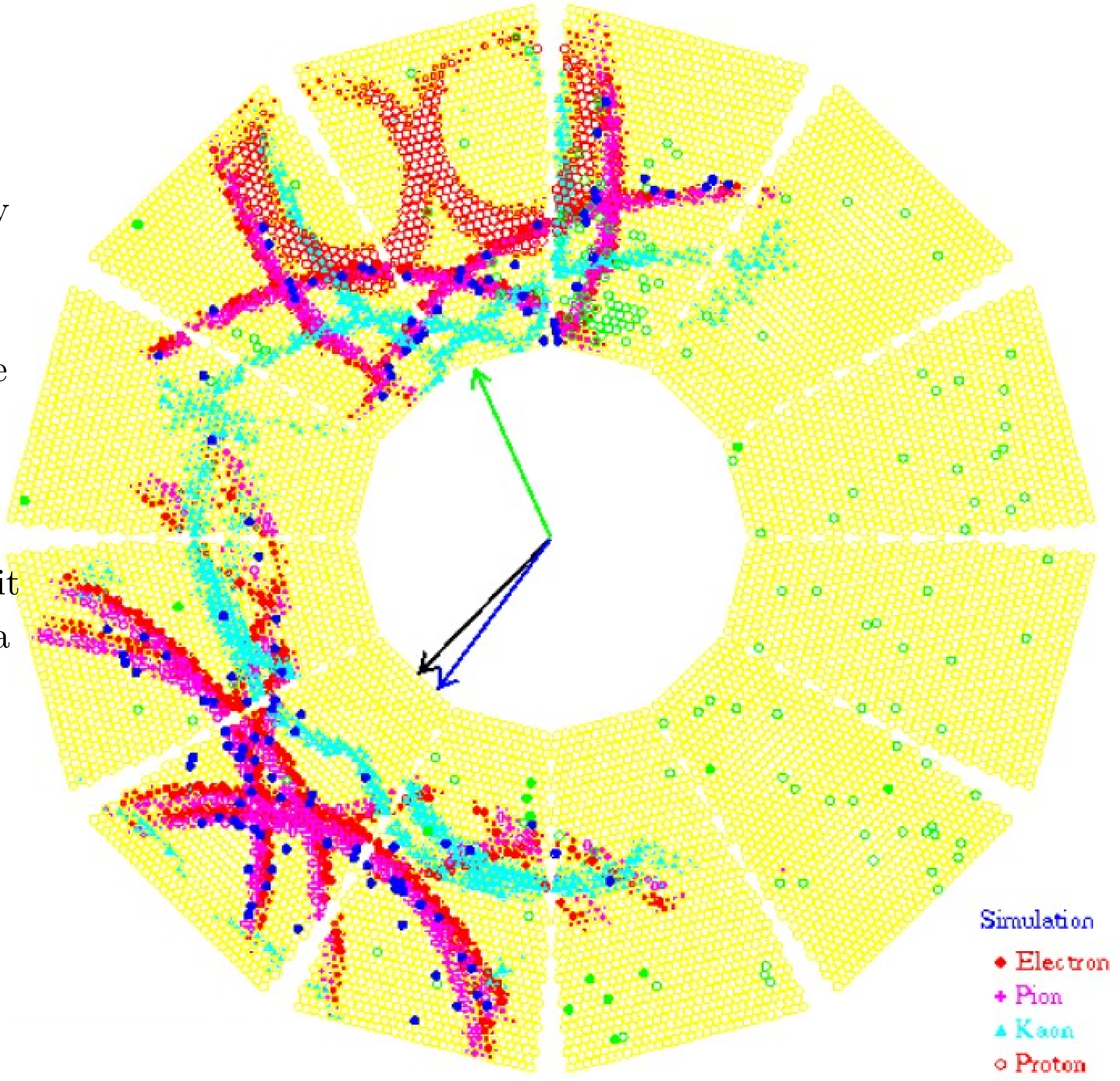
$$\cos\theta_c = 1/n\beta$$

- The overall single photon resolution is estimated to be about 10mrad
- The mean index of refraction of quartz (n = 1. 473)
- 896 PMTs (29 mm-diameter), inside the water volume

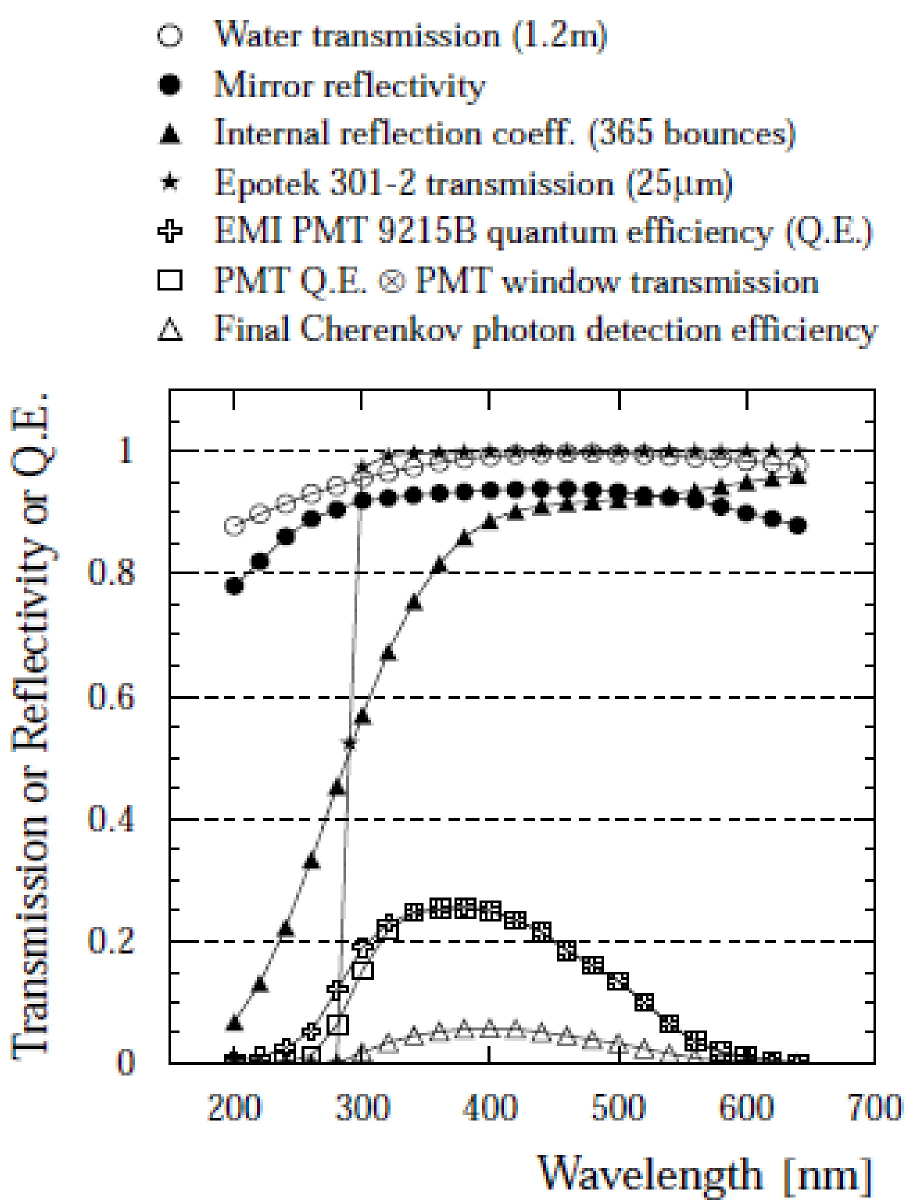
The standoff box contains about 6,000 liters of purified water :

→ inexpensive and has an average index of refraction (n ≈ 1. 346) reasonably close to that of fused silica, thus minimizing the total internal reflection at silica-water interface

The expected Cherenkov light pattern at this surface is essentially a conic section, where the cone opening angle is the Cherenkov production angle modified by refraction at the exit from the fused silica window.



Efficiency



- 80% of the light is maintained after multiple bounces along the bars
- The expected number of photoelectrons (Npe) is ~25 for a $\beta = 1$ particle entering normal to the surface at the center of a bar, and increases by over a factor of two in the forward and backward directions.

Angular Resolution

The angle resolution of a single Cherenkov photon is dominated by

1. Imaging (bar dimension) (~ 4.2 mrad in BaBar)
2. Detection (granularity) (~ 6.2 mrad)
3. Chromatic smearing ($n = n(\lambda)$) (~ 5.4 mrad)
4. Photon transport in bar (~ 1 mrad)

... added in quadrature ➔ $\sigma_{\theta\gamma}$ = 9.3 mrad in BaBar

With a different imaging (e.g. focus) limited by 3. and 4.

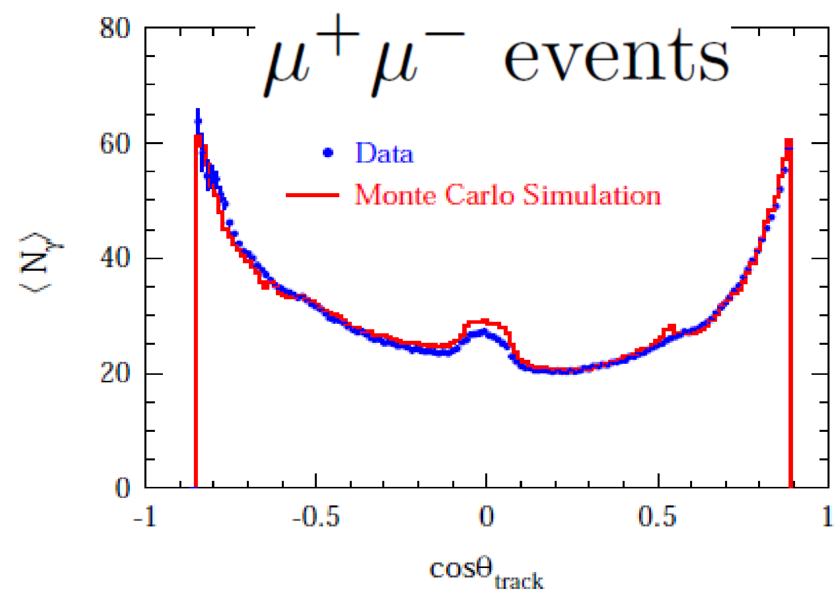
➔ $\sigma_{\theta\gamma} \approx 6$ mrad

Expect 25 photons (N_γ) or more

➔ total resolution/track, σ_{θ_C} :

$$\sigma_{\theta_C} \approx \sigma_{\theta\gamma} / \sqrt{N_\gamma} \oplus \sigma_{track}$$

≈ 1.2 mrad $\oplus\ \sigma_{track}$

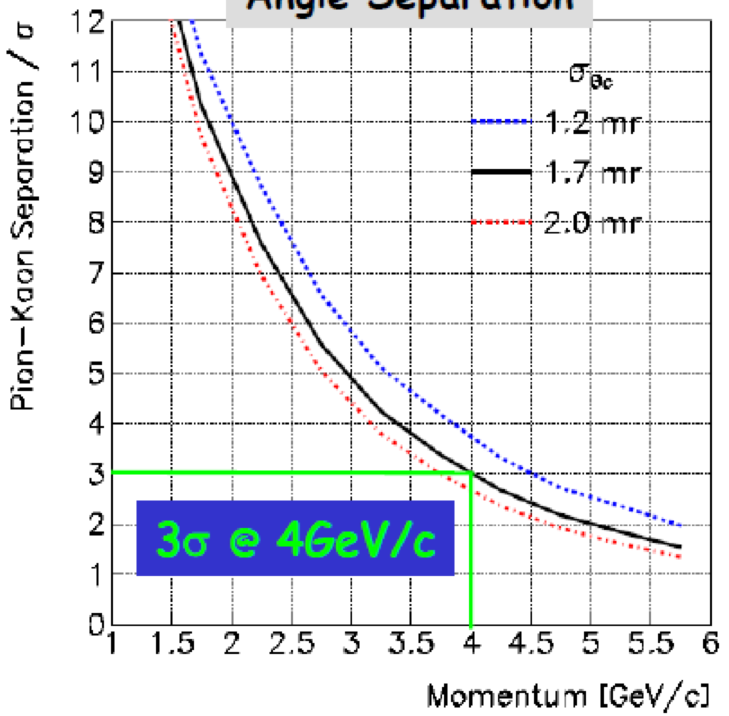


Kaon Identification

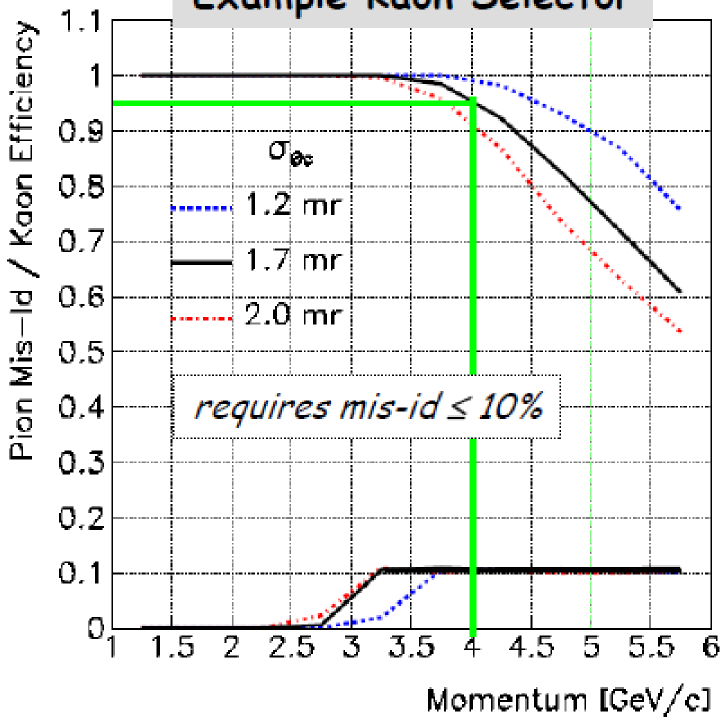
The characteristics of pion – kaon identification (separation) versus momentum with the track reconstructed in the FCDC for three different ***Cherenkov angle resolutions in a DIRC*** :

- 1.2 mrad : the best achievable
- 1.7 mrad : a design close to the BaBar DIRC
- 2.0 mrad : pessimistic scenario

Angle Separation



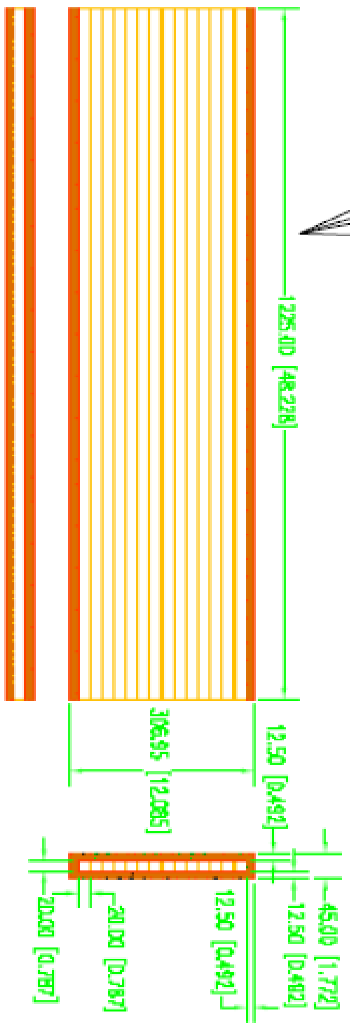
Example Kaon Selector



The mean kaon selection efficiency and pion misidentification are ~95% and <10% resp.

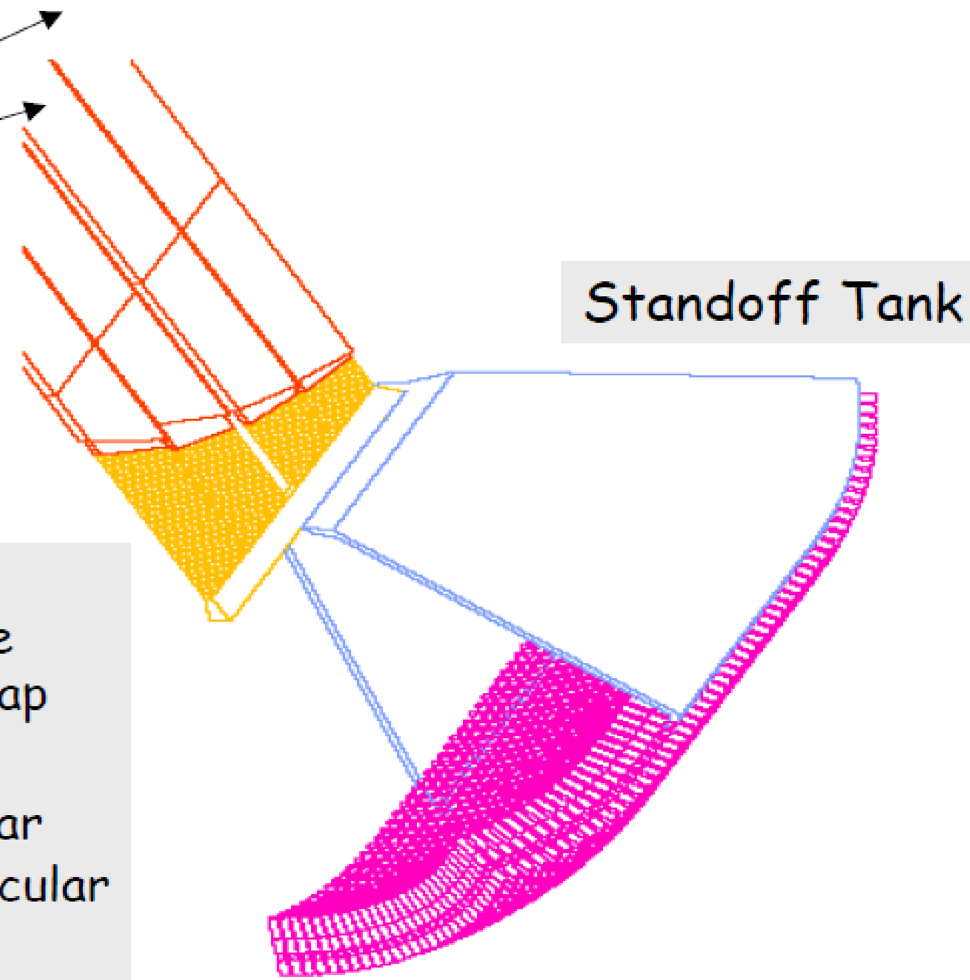
To a GlueX DIRC design

Turn cylindrical DIRC into flat DIRC e.g. with same imaging principle:



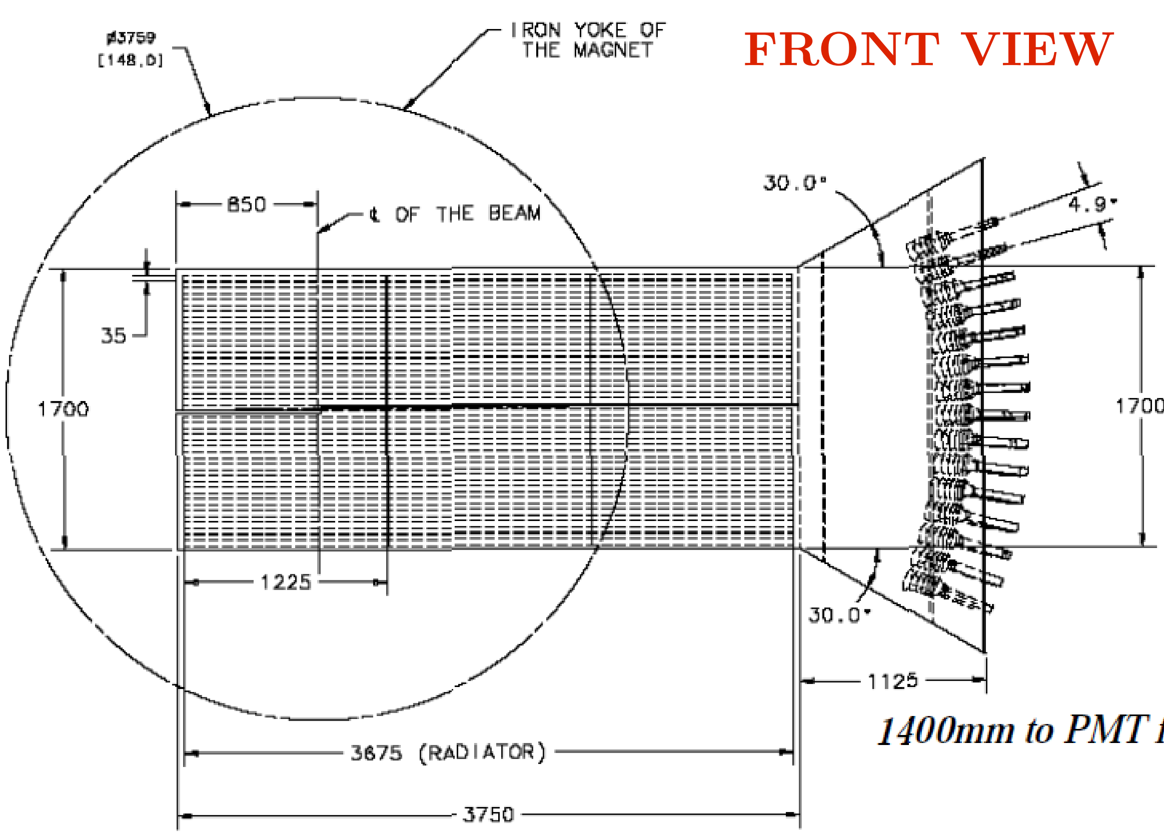
4 bar boxes each placed behind the Solenoid with a gap for the beam.

~$\frac{1}{2}$ length of BaBar or less due to circular hole.

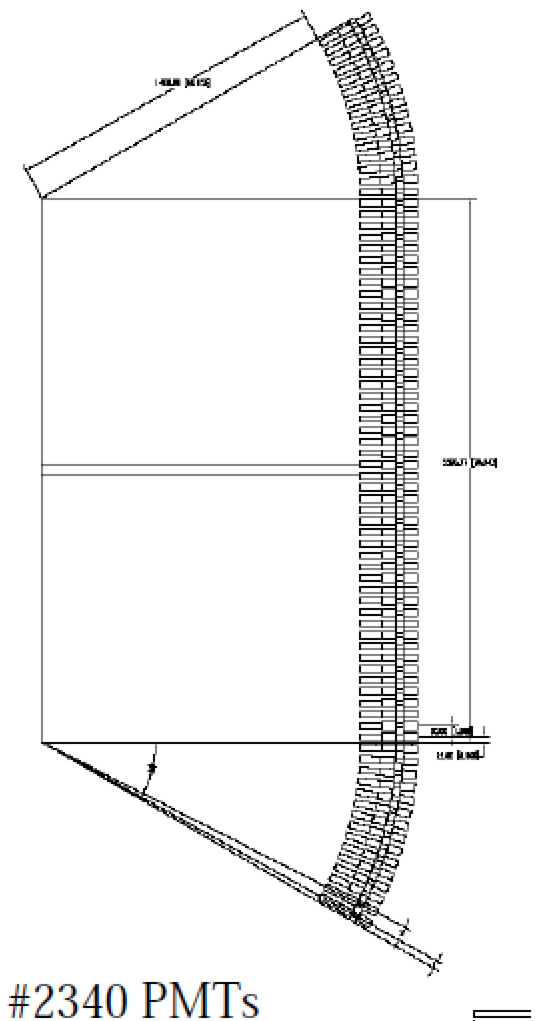


~ 1500 photo-multiplier tubes

FRONT VIEW

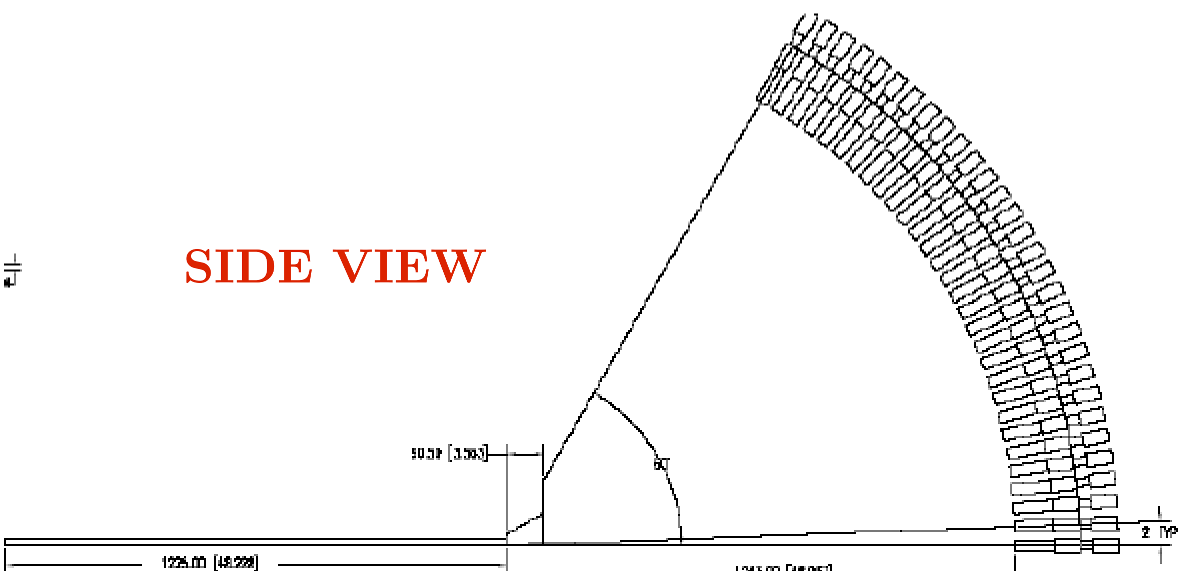


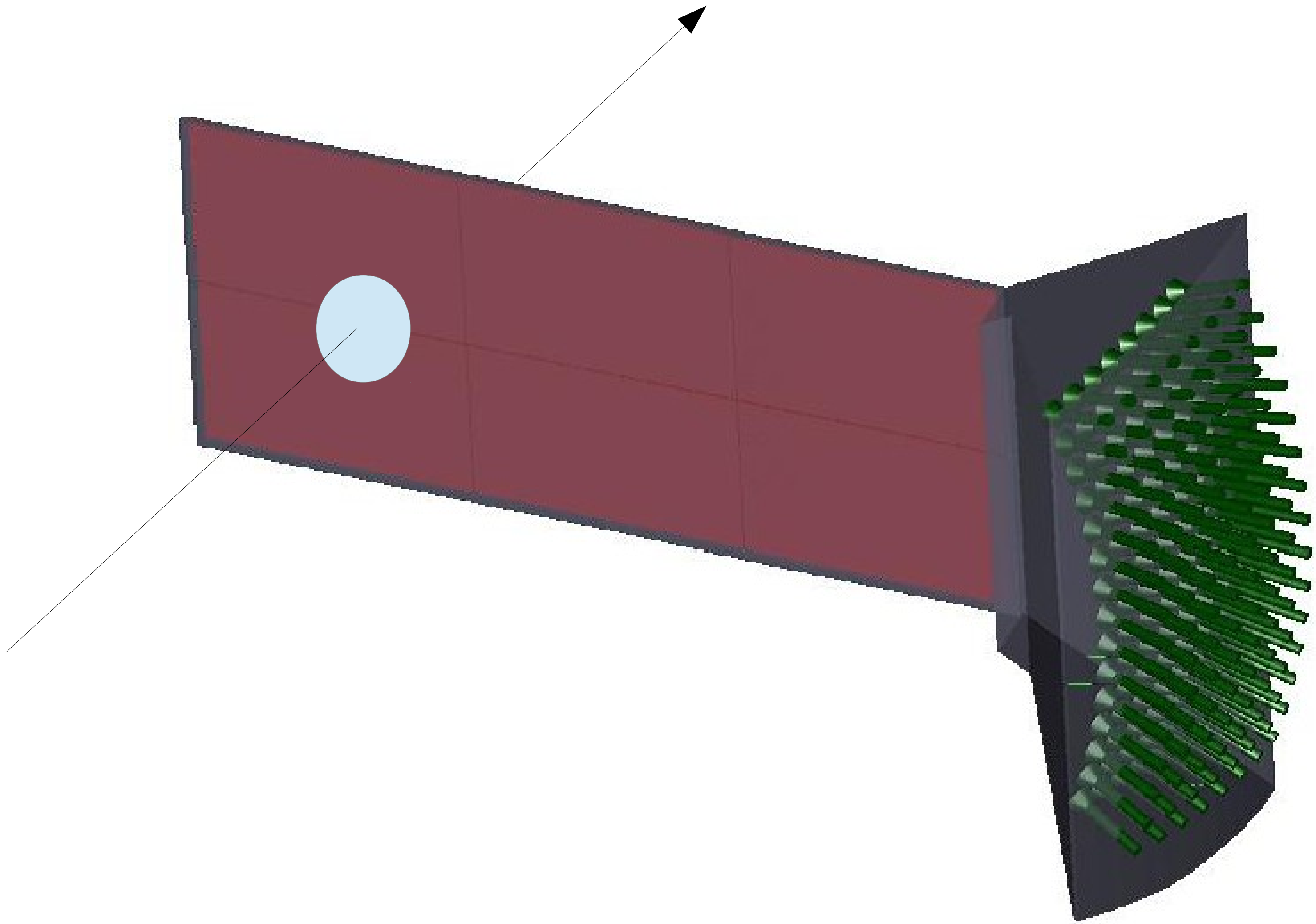
1400mm to PMT front

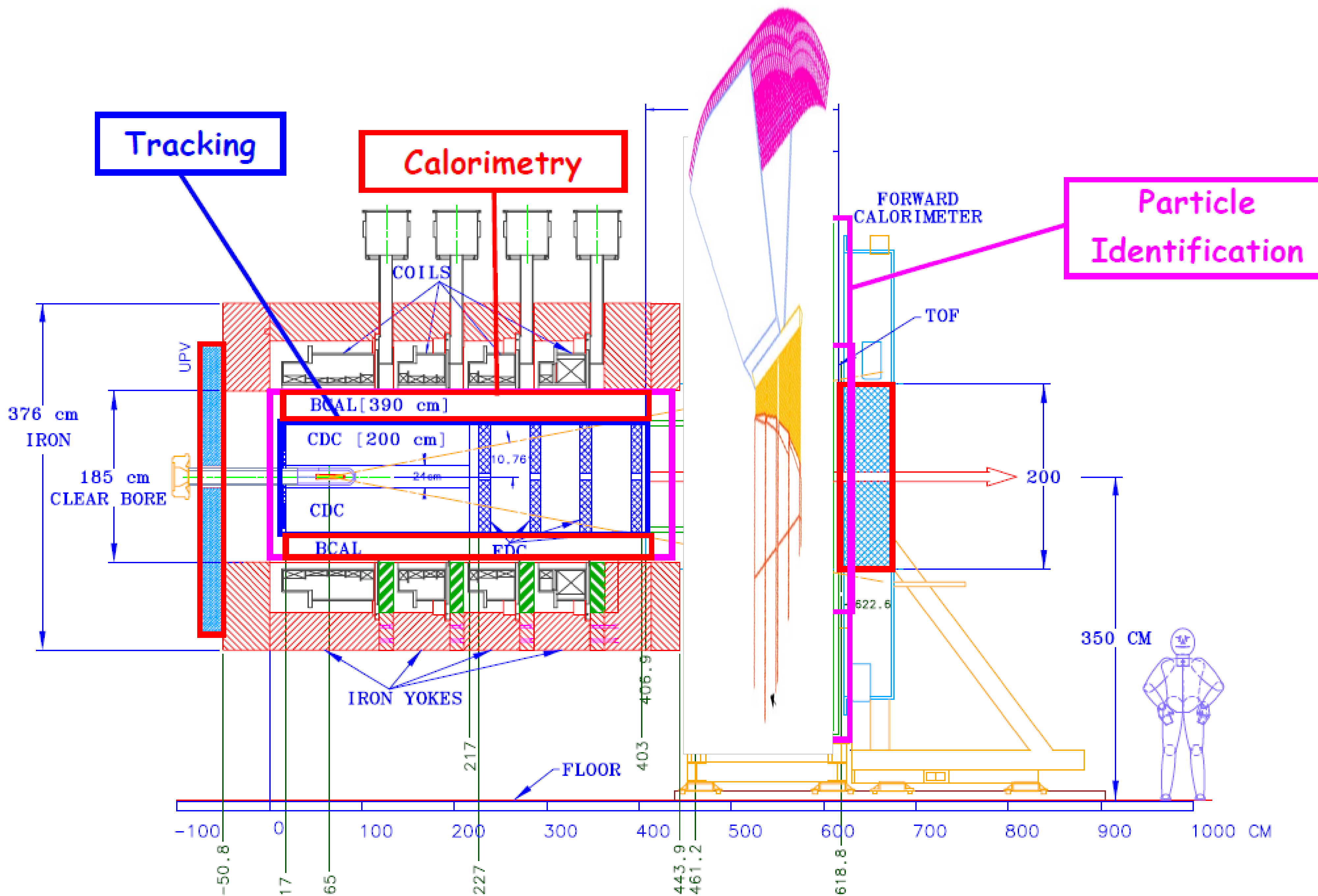


#2340 PMTs

SIDE VIEW



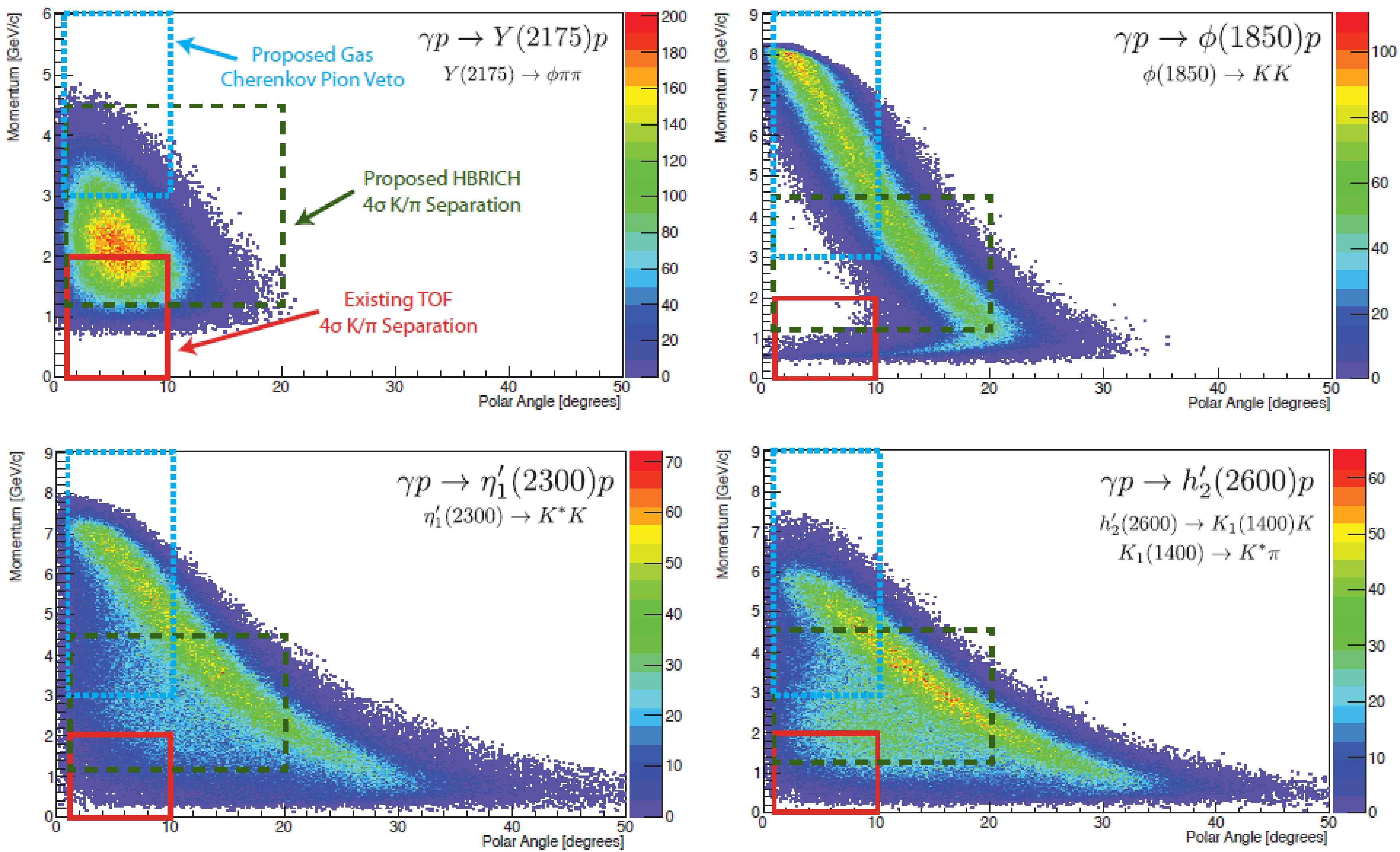




Tracking
Calorimetry
Particle Identification
COILS
FORWARD CALORIMETER
TOF
UPV
376 cm IRON
185 cm CLEAR BORE
BCAL[390 cm]
CDC [200 cm]
CDC
BCAL
FDC
10.76
24cm
200
622.6
350 CM
IRON YOKES
FLOOR
-100
0
100
200
300
400
500
600
700
800
900
1000 CM
-50.8
17
65
217
227
403
406.9
443.9
461.2
618.8

A focusing Design:

- will improve performance towards higher momenta
- a compact design with reduced maintenance (no water tank)
- uses reduced amount of quartz elements



$\gamma p \rightarrow Y(2175)p$
$Y(2175) \rightarrow \phi\pi\pi$
Proposed Gas
Cherenkov Pion Veto
Proposed HBRICH
4σ K/π Separation
Existing TOF
4σ K/π Separation
$\gamma p \rightarrow \phi(1850)p$
$\phi(1850) \rightarrow KK$
$\gamma p \rightarrow \eta_1'(2300)p$
$\eta_1'(2300) \rightarrow K^*K$
$\gamma p \rightarrow h_2'(2600)p$
$h_2'(2600) \rightarrow K_1(1400)K$
$K_1(1400) \rightarrow K^*\pi$
Momentum [GeV/c]
Polar Angle [degrees]