A DIRC for GlueX

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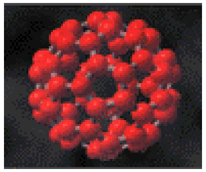
for the GlueX Collaboration

OAK RIDGE NATIONAL LABORATORY



The University of Tennessee
Department of
Physics & Astronomy

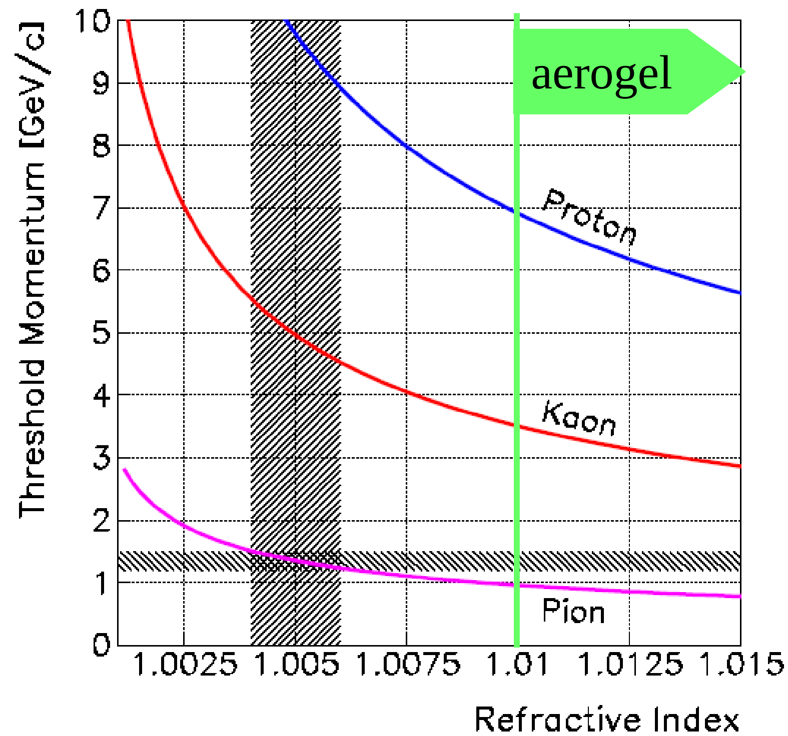
• Cherenkov Detector for GlueX

- GlueX requires
  pion & kaon identification with high and constant efficiency in the momentum range **1.8 – 3 GeV/c and above** in continuation of the TOF detector, and proton identification up to a momentum of ~2 GeV/c.

- Threshold Cherenkov Detectors do not easily match this range:
  - *gas* : C_4F_{10} needs 3.3 atm pressure
  - *aerogel* : only $n \geq 1.01$ available.

- Imaging Cherenkov Detectors
  - several options available
  - a **DIRC** matches elegantly the required momentum range.
  - the DIRC is a well established detector in BaBar (for same momenta).

Threshold Momentum



• Imaging with Quartz

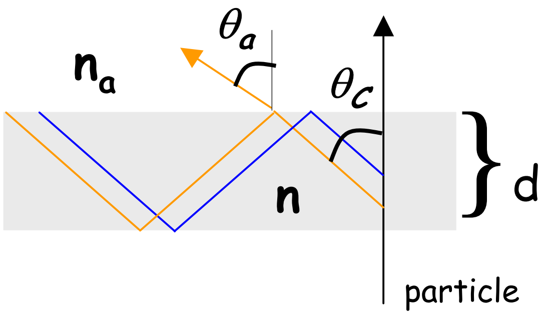
Detection of **I**nternally **R**eflected **C**herenkov Light

<u>Radiator</u>: synthetic quartz bars

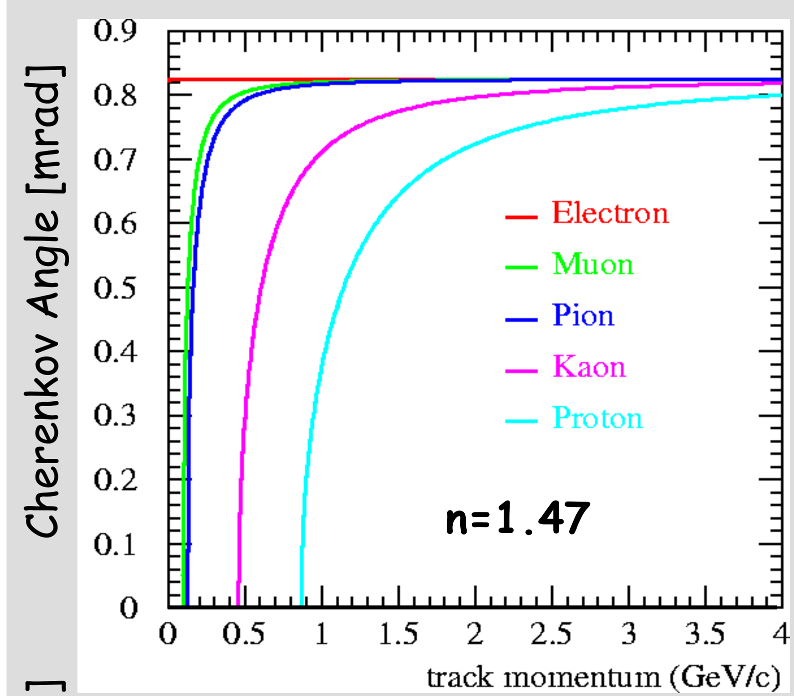
$$\cos\theta_C(\lambda) = \frac{1}{\beta\, n(\lambda)}$$

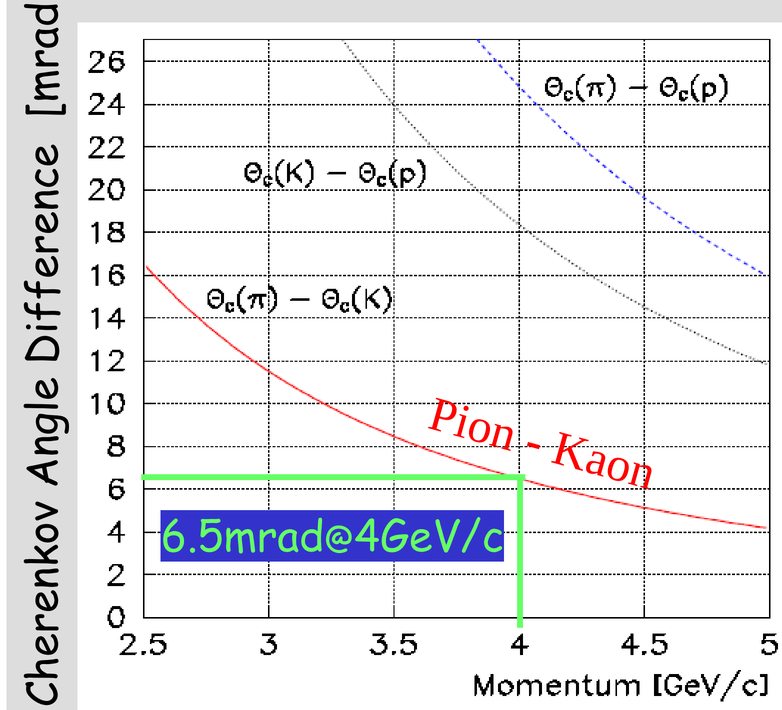
θ_C: Cherenkov angle with respect to track
n : refractive index (quartz: $n \approx 1.47$)
β : speed of particle (= v/c)

<u>Total internal reflection:</u>



$$n = \sqrt{2} \;\rightarrow\; \text{quartz}$$

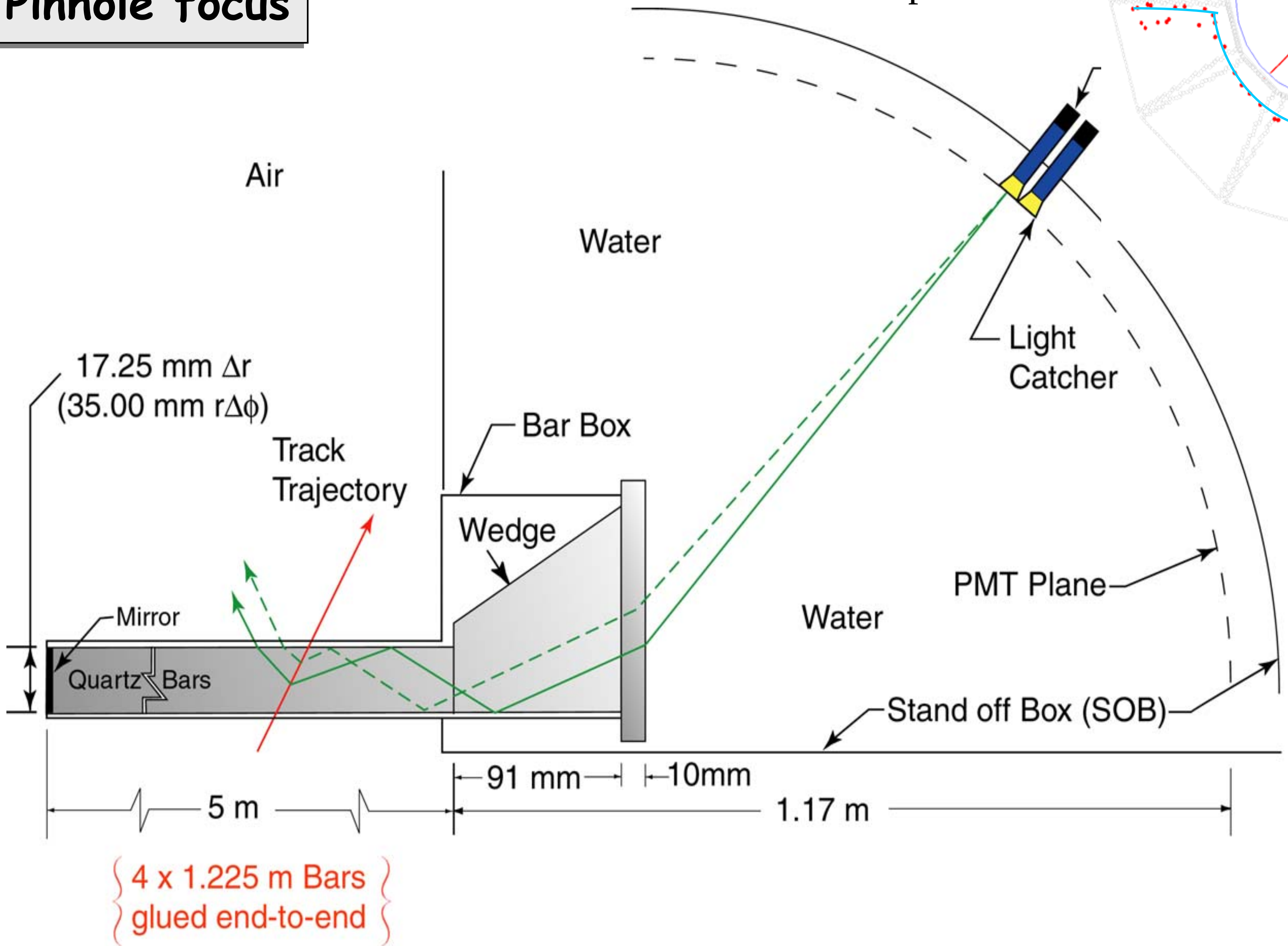


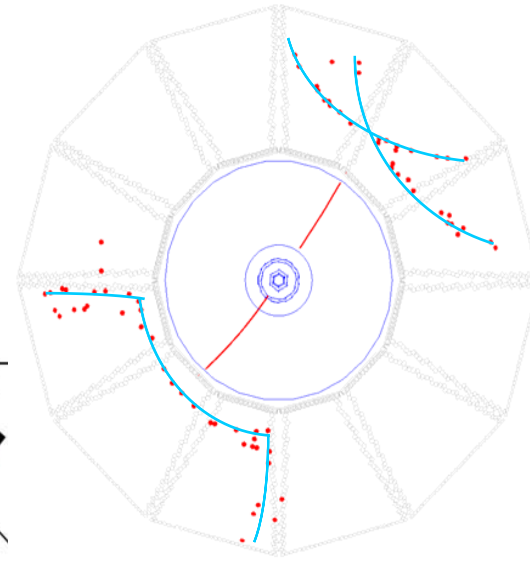


• Principle of the BaBar DIRC

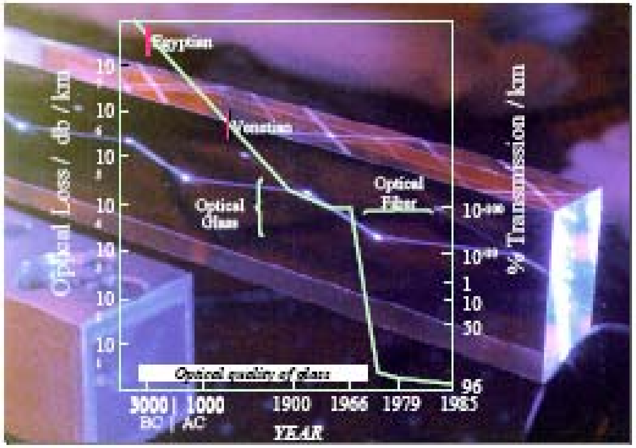
Pinhole focus

~ 11000 conventional Photo-Multiplier Tubes





• The Bar Quality



synthetic fused silica (amorphous silicon dioxide),
cutting, grinding and polishing in several steps.
Efficiency loss per component less than 20%.

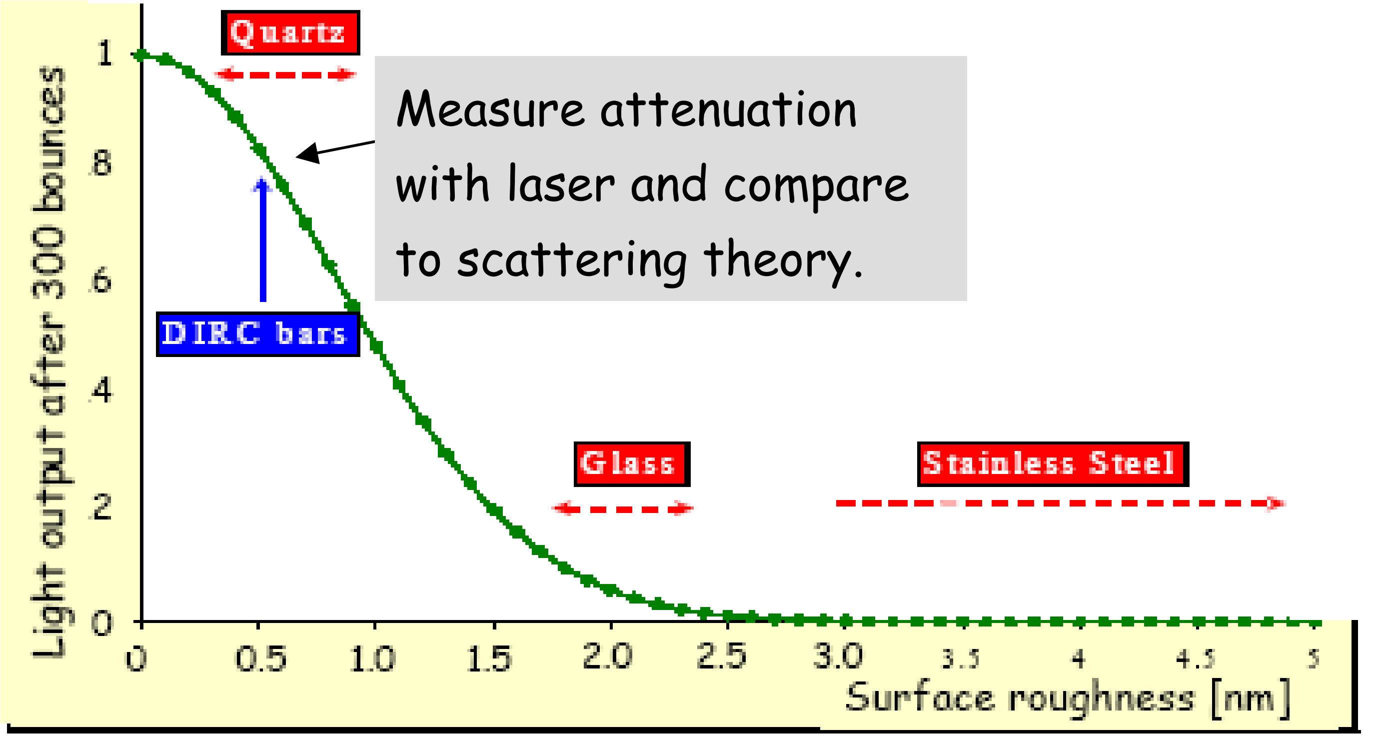
Typical photon: λ = 400 nm,
path length in quartz = 6 – 20 m,
bounces on surface: = ~ 200 – 300

- **bulk absorption** (Raleigh scattering; attenuation length $\propto \lambda^4$)
  light transmission @ 442 nm : (99.9 ± 0.1)%/m
- **surface scattering** (attenuation length $\propto$ roughness^{-2})
  reflection : (99.96 + 0.01)%/bounce
- Mirror
  reflection : ~ 92%
- **Radiation hardness**
  rated lifetime dose > 250 krad (no degradation observed)

• Super-polished Surfaces

Internal reflection:

(99.96 ± 0.01)% / bounce



Polished to roughness < 5Å

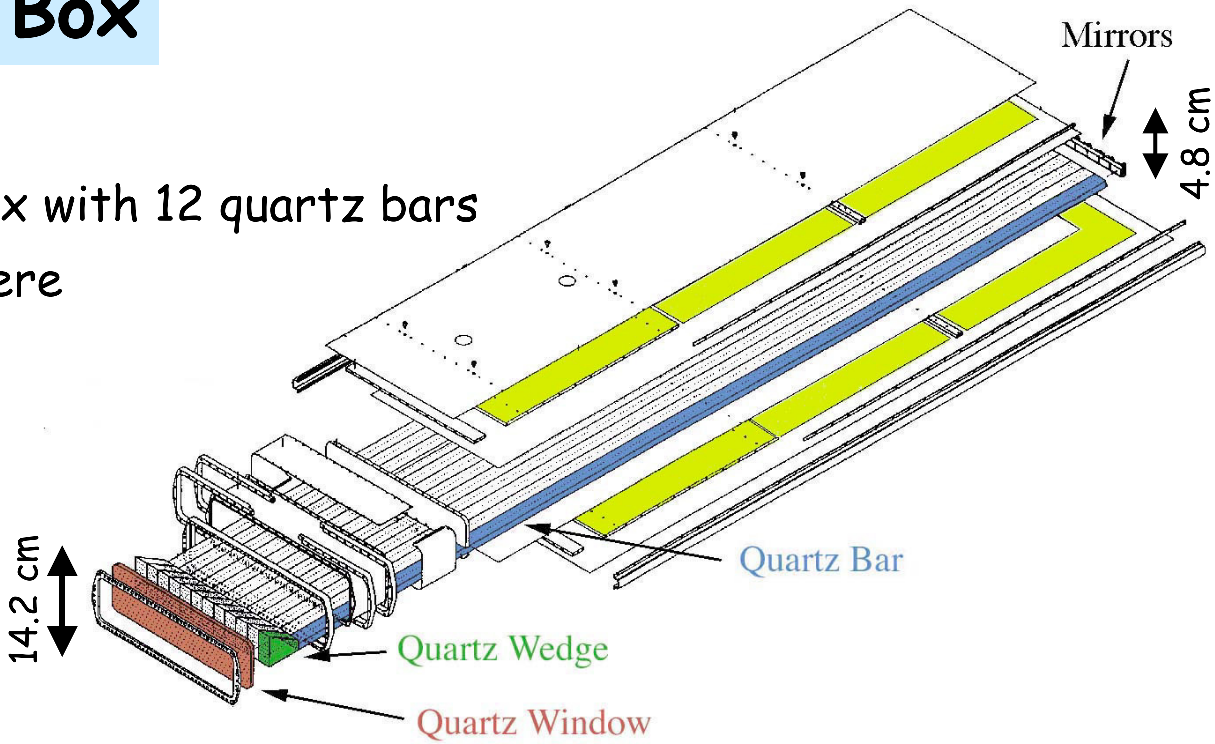
• The BaBar Bar Box

- 12 DIRC sectors
- each has one aluminum box with 12 quartz bars
- kept in nitrogen atmosphere
- <u>Coverage</u>:

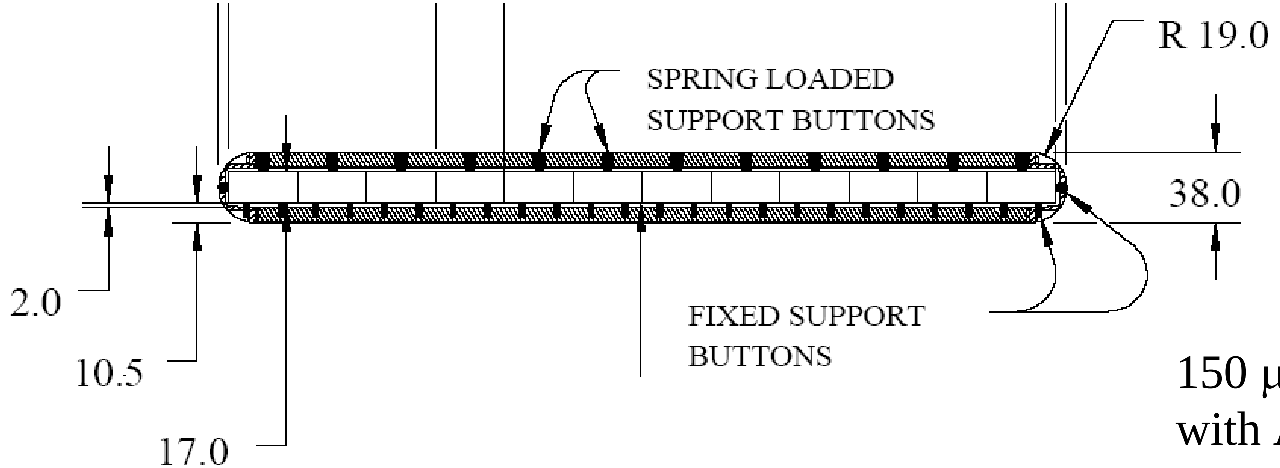
  87% C.M. polar angle,

  94% azimuthal angle

  19% radiation length incl. supports

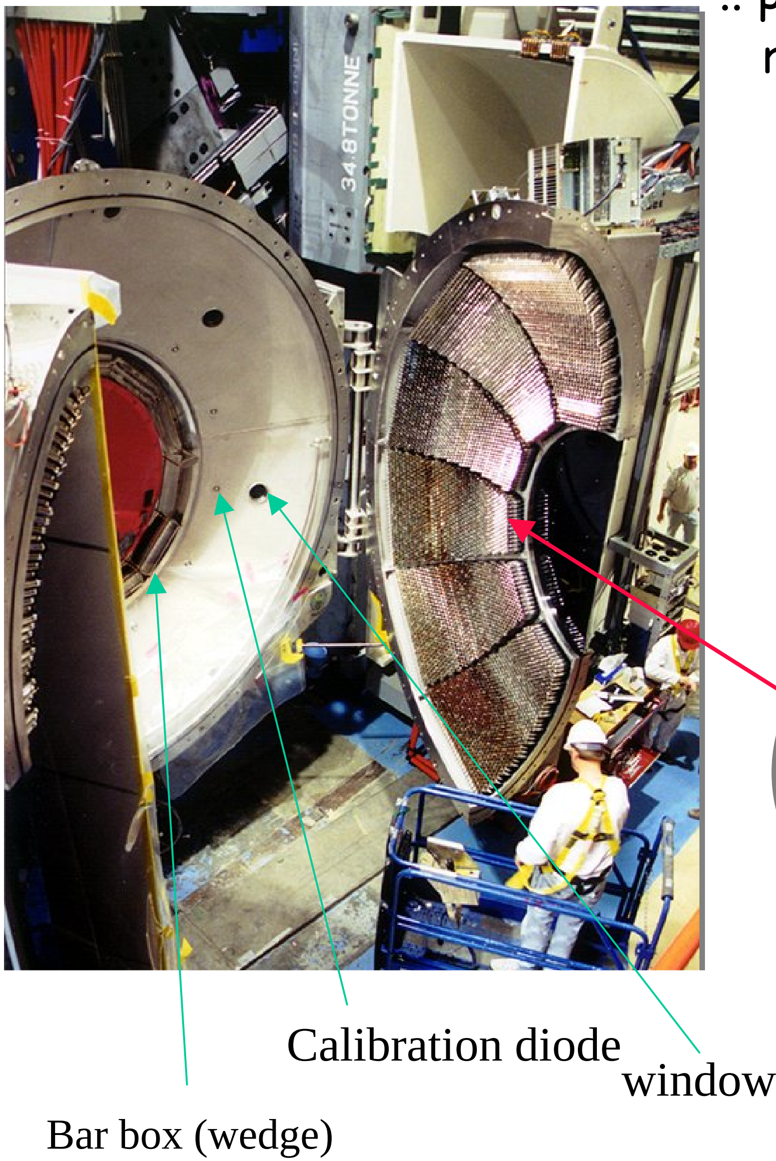


Cross section



150 µm bar spacing
with Aluminum shims

• The BaBar Photon Detector



.. photons exit from wedge into expansion region filled with 6000 l pure water ($n \approx 1.346$).

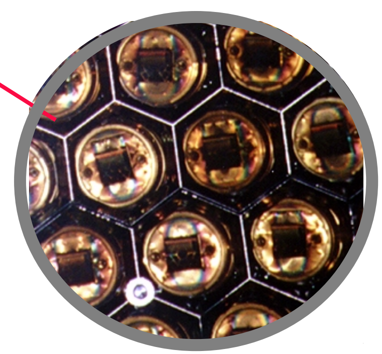
10,752 conventional photo tubes

- immersed directly in water

- hexagonal light catchers

- time resolution: 1.5 ns rms = overall resolution

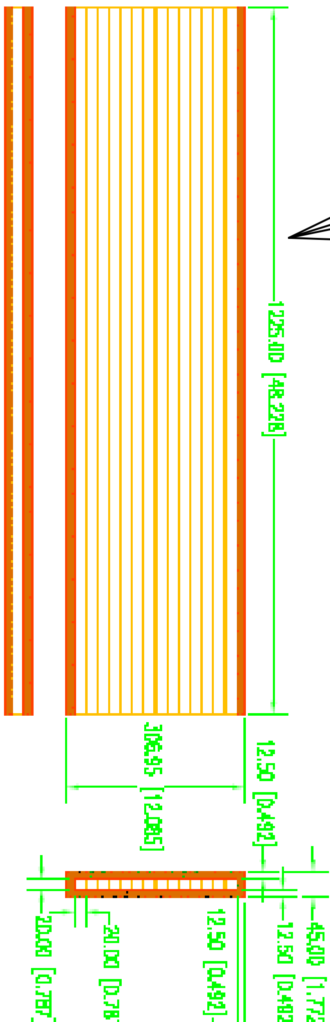
- max quantum efficiency 25%@410 nm

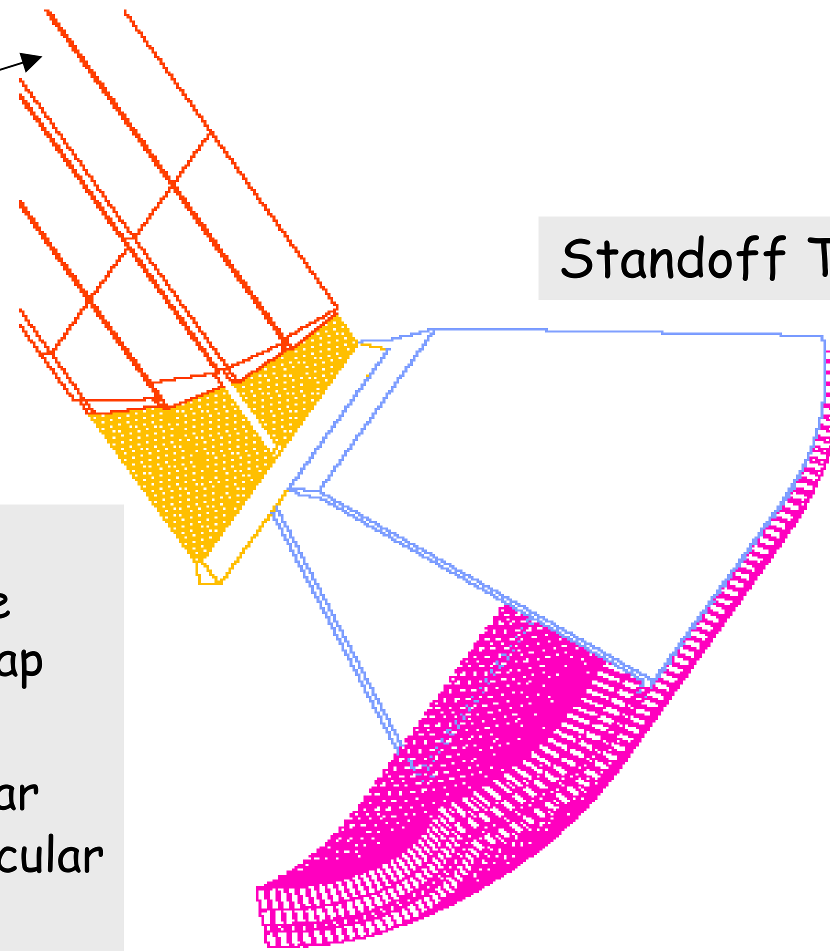


Magnetic shielding:
passive and active
B_T at the PMT < 0.2 Gauss

• A GlueX Scenario

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





Standoff Tank

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

~½ length of BaBar or less due to circular hole.

~ 1500 photo-multiplier tubes

• Cherenkov Angle 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.

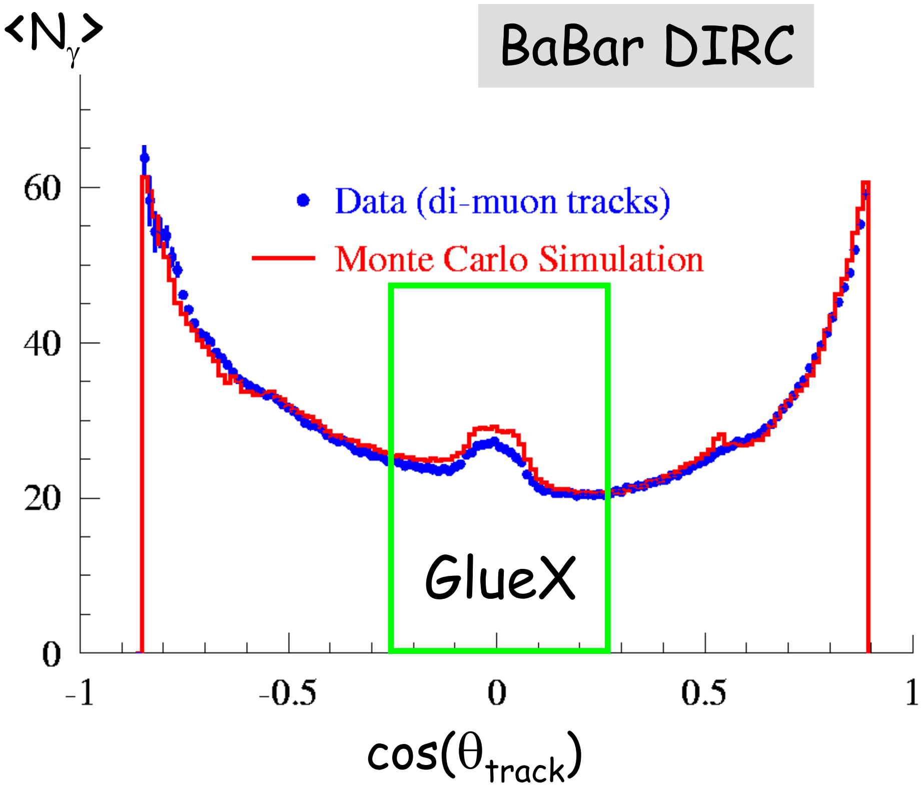
➔ $\sigma_{\theta\gamma} \approx 6$ mrad

Expect 25 photons (N_γ) or more

➔ total resolution/track, σ_{θ_C} :

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

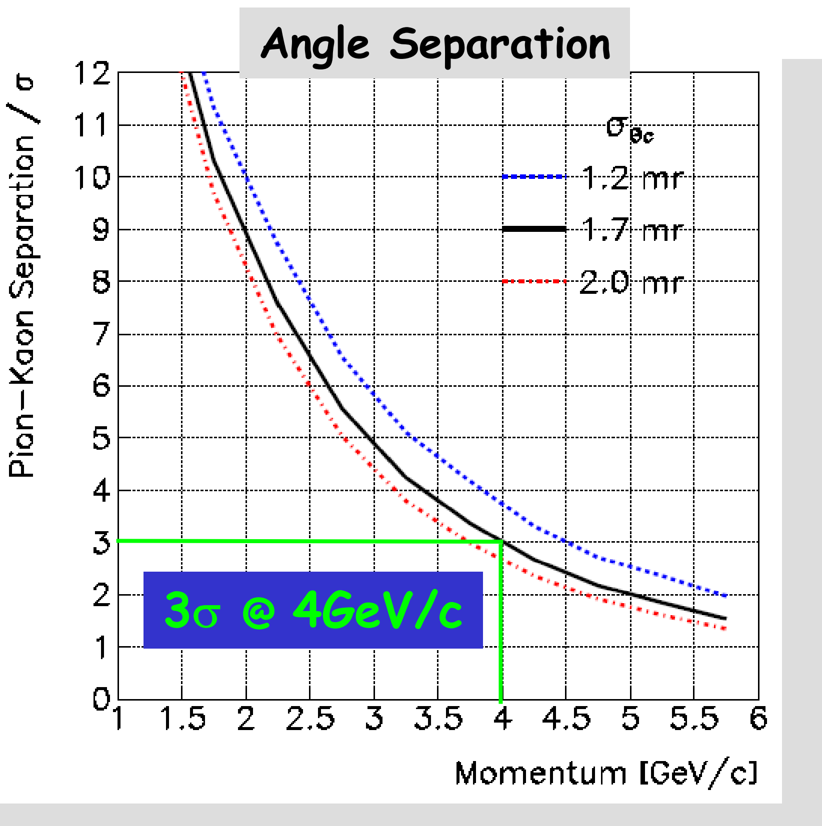
$$\approx 1.2 \text{ mrad} \oplus \sigma_{track}$$

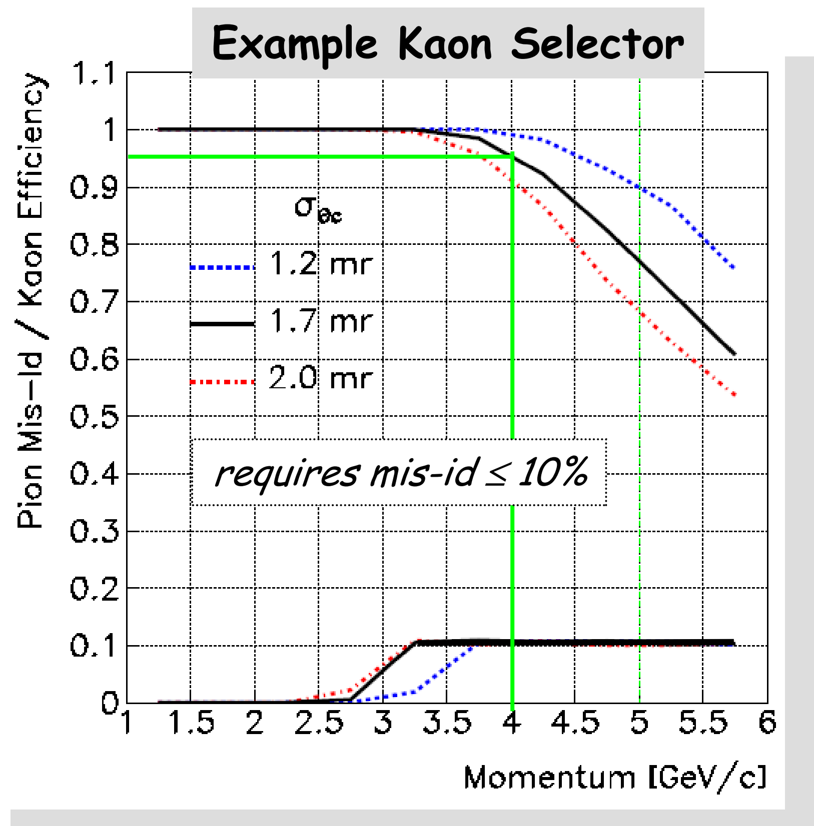


• Kaon Identification

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

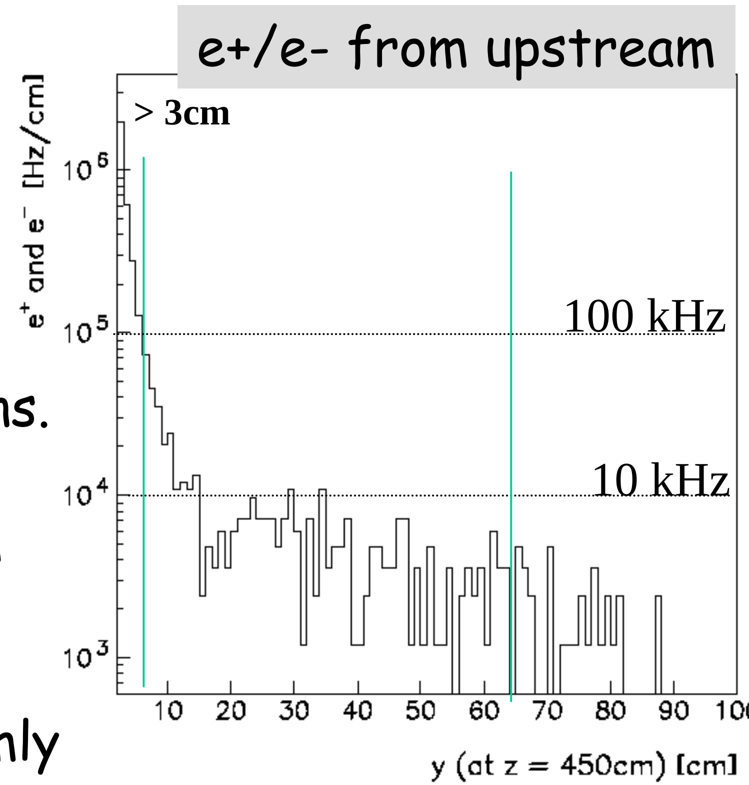




• GlueX Beam Background

… consists primarily of electrons/positrons from upstream and from conversions of photons in the Cherenkov detector (15% probability/photon).

- Simulate with GEANT in xy-plane behind the solenoid at z = 450 cm
- Choose high luminosity scenario (I_e = 3μA)



➔ For a gap |y|>6cm (>10cm) integrating over all x we expect 21 (16) background photons in an event time window of 100 ns.

➔ **2 background photons in reconstruction** which allows a time window of < 10 ns.

➔ **Hit rate per phototube** for 1000 randomly hit PMTs = 210 kHz/tube.

➔ **Irradiation**: Flux < 100 kHz/cm² for radius r > 3cm
→ **dose < 51 krad/year** assuming minimum ionizing particles.

• GlueX Magnetic Field

Strong fringe fields require shielding.

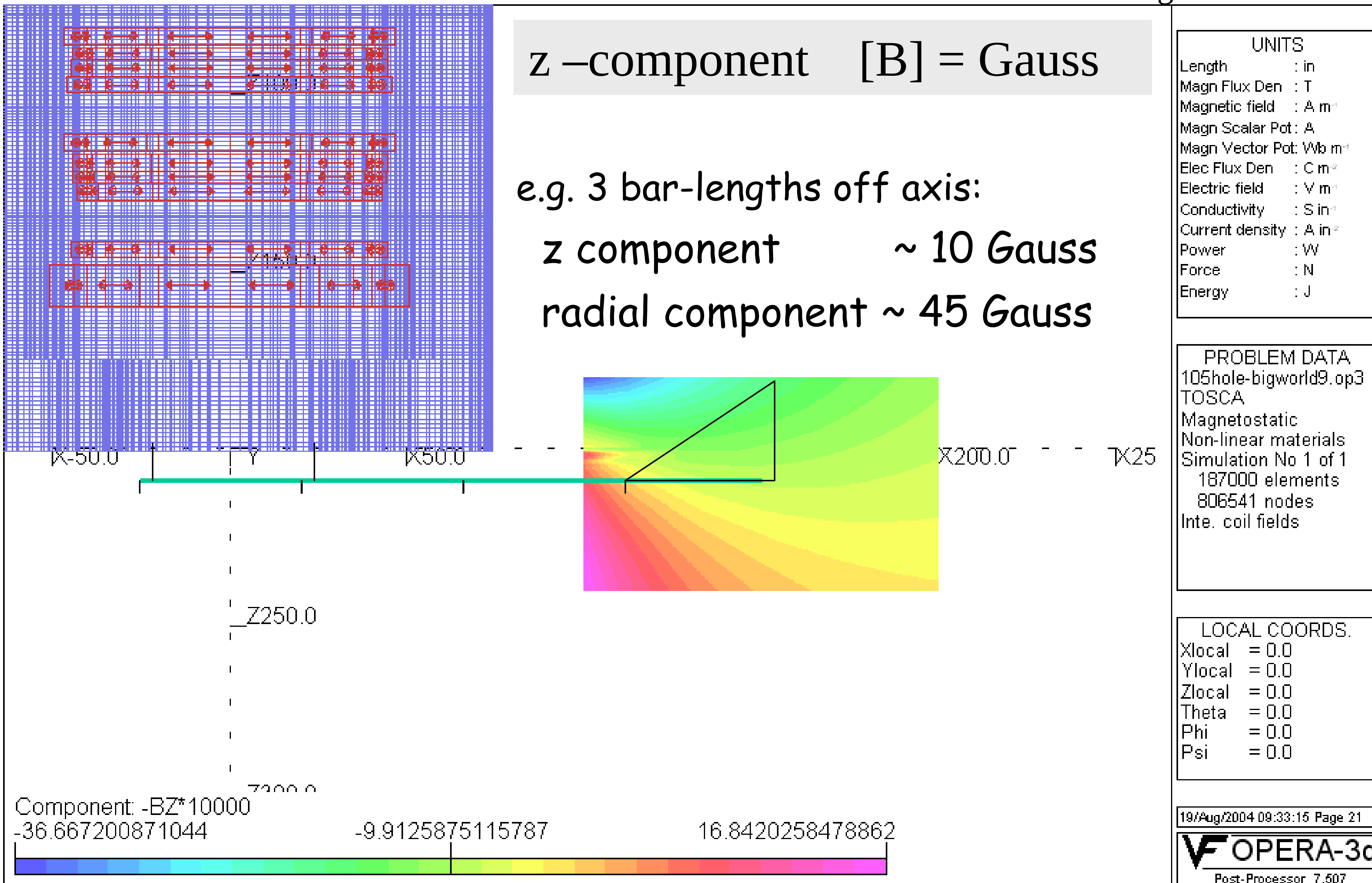
Nodal mesh integral coil method

z –component [B] = Gauss

e.g. 3 bar-lengths off axis:

z component ~ 10 Gauss

radial component ~ 45 Gauss



• Summary

- **There is a DIRC solution for GlueX**
  - Cherenkov imaging matches the required momentum range,
  - compact assembly → reduces overall cost of GlueX,
    → not much material (X_0 < 20%),
  - beam background suppressed due to intrinsic time resolution,
  - fast device: event time less than 100 ns (5m BaBar bars),
  - radiation robustness: >250 krad lifetime (no effect there),
  - easy access to detector components / modular.

- **University of Tennessee and Oak Ridge National Lab are exploring the possible design for the GlueX Cherenkov detector.**

Extra slides …

• The Principle

3D - device