Photon timing studies with the BABAR DIRC

J. Schwiening, Group B R&D Meeting, SLAC, Sep 11, 2003

Photon time resolution in DIRC limited by DIRC PMT intrinsic (TTS) resolution → average resolution ~1.7nsec

Can we see chromatic effects in DIRC in spite of that poor resolution?

Yes (probably) because we reconstruct photons with very long path lengths (10-15m and more)

Can we learn something relevant to the R&D setup?

Well… I'm going to present a brief overview, form your own opinions…

Dispersion Effects in the BABAR DIRC

Recipe:

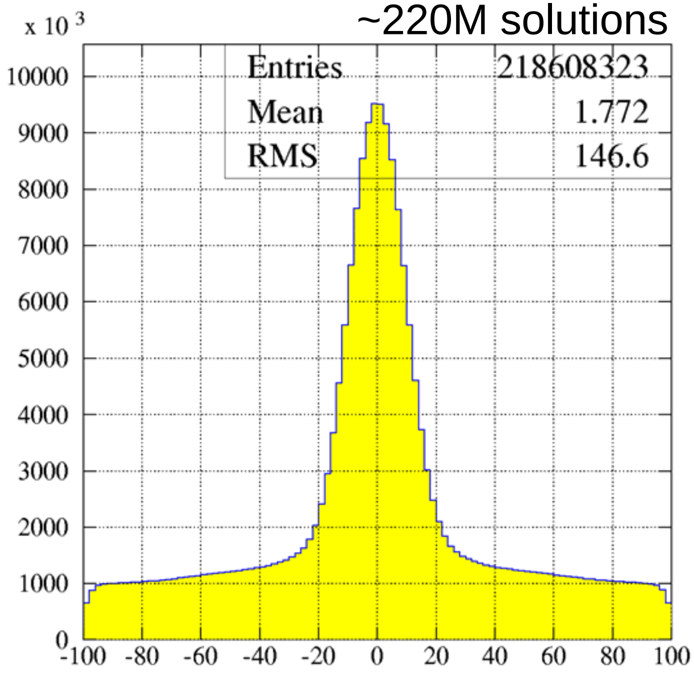
- Used di-muon events (~ 3.5 million tracks) from 2001, select clean events that are well-contained in DIRC.
- Hits in DIRC are associated with a given track, up to 16 ambiguous “solutions” per hit
- Most ambiguities are eliminated by physical constraints and DIRC timing (σ=1.7ns), typically 2-3 solutions per hit remain
- Calculate pathlength of solution in radiator bar, number of bounces, etc
- Plot delta(thetaC) difference between thetaC of photon and expected thetaC of muon track.
- Bin delta(thetaC) in pathlength, fit with Gaussian plus background function extract mean and sigma of Gaussian

Dispersion Effects in the BABAR DIRC

delta(thetaC) spectrum of all accepted tracks

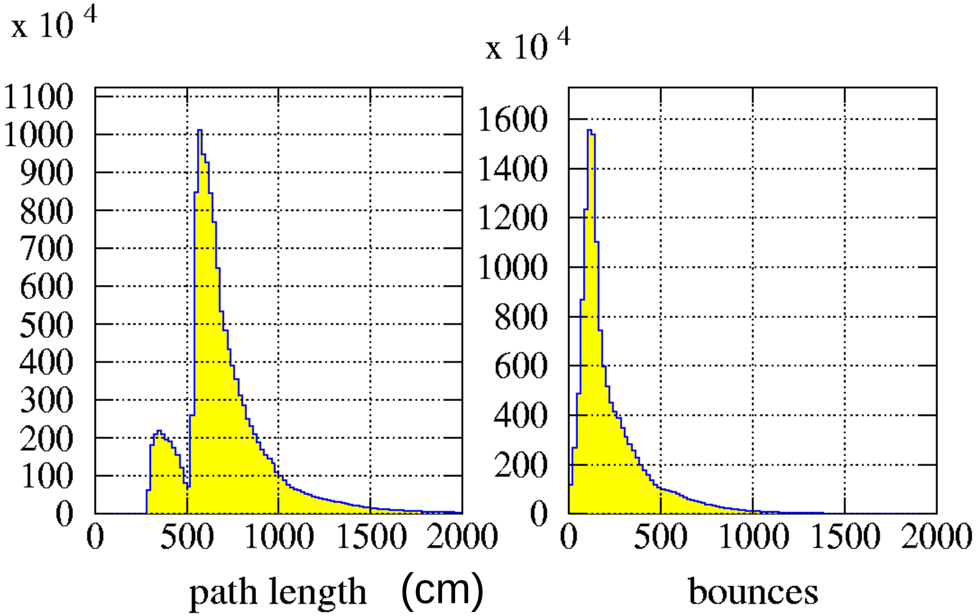
resolution ~10mrad

(background under peak due to ambiguities, accelerator, delta electrons, ...)



~220M solutions

delta(thetaC) (mrad)



Pathlength and Number of Bounces spectra for 3.5M muon tracks

(required that |delta(thetaC)|<30mrad)

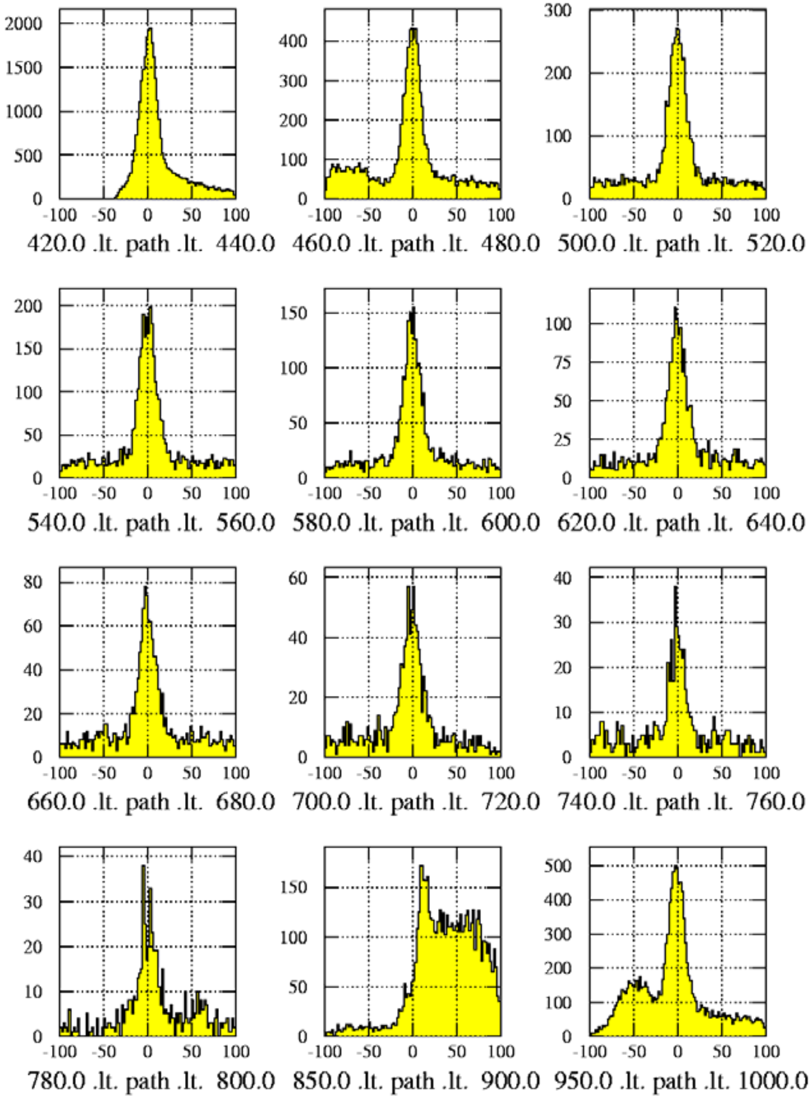
Dispersion Effects in the BABAR DIRC

example delta(thetaC) spectra in path bins

shape varies a lot (ambiguities!)

After careful fits, plot

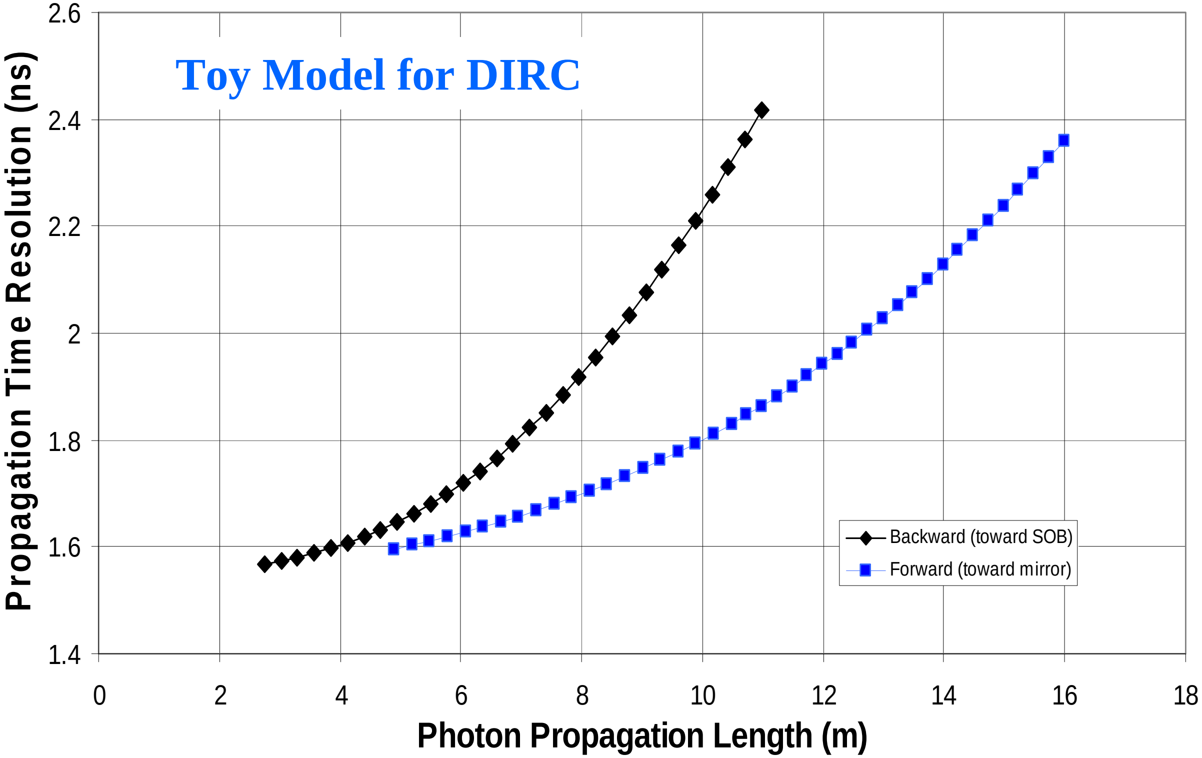
sigma from Gaussian vs. path…



Time Imaging In DIRCs-Conceptual Isssues

Example:Time Resolution in BaBar DIRC

$$\sigma_t = \sqrt{\underbrace{t_p^2[\delta^2(L_p) + \frac{2C(L_p,n_g)}{L_p n_g} + \delta^2(n_g)]}_{\boxed{\text{“B}^2\text{”}}} + \underbrace{\sigma_{t_0}^2}_{\boxed{\text{“A}^2\text{”}}}}$$



Dispersion Effects in the BABAR DIRC

Blue: photons go directly to PMT
Red: photons reflected on end mirror

"A" is a measure of PMT resolution

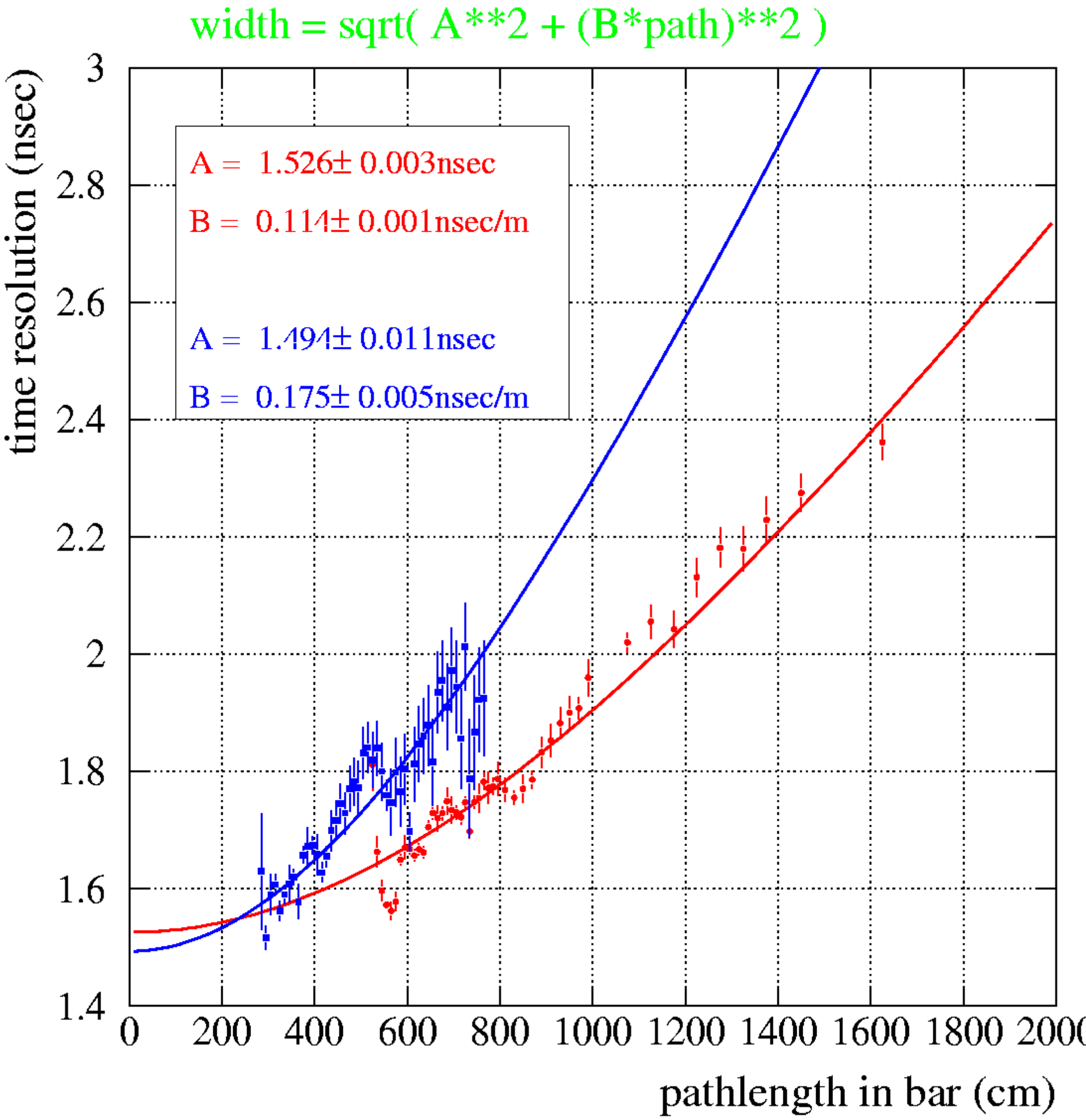
~1.5ns (consistent with TTS of PMT)

"B" is measure of dispersion effects

~180ps/m for direct photons
~110ps/m for reflected photons

(*not* an actual measurement of a meaningful number – that will come from our R&D setup…)

Consistent with Blair's toy model



Relevance to R&D Setup

Select events in which muon track hits bar at 90deg angle in dip (no selection in track phi)

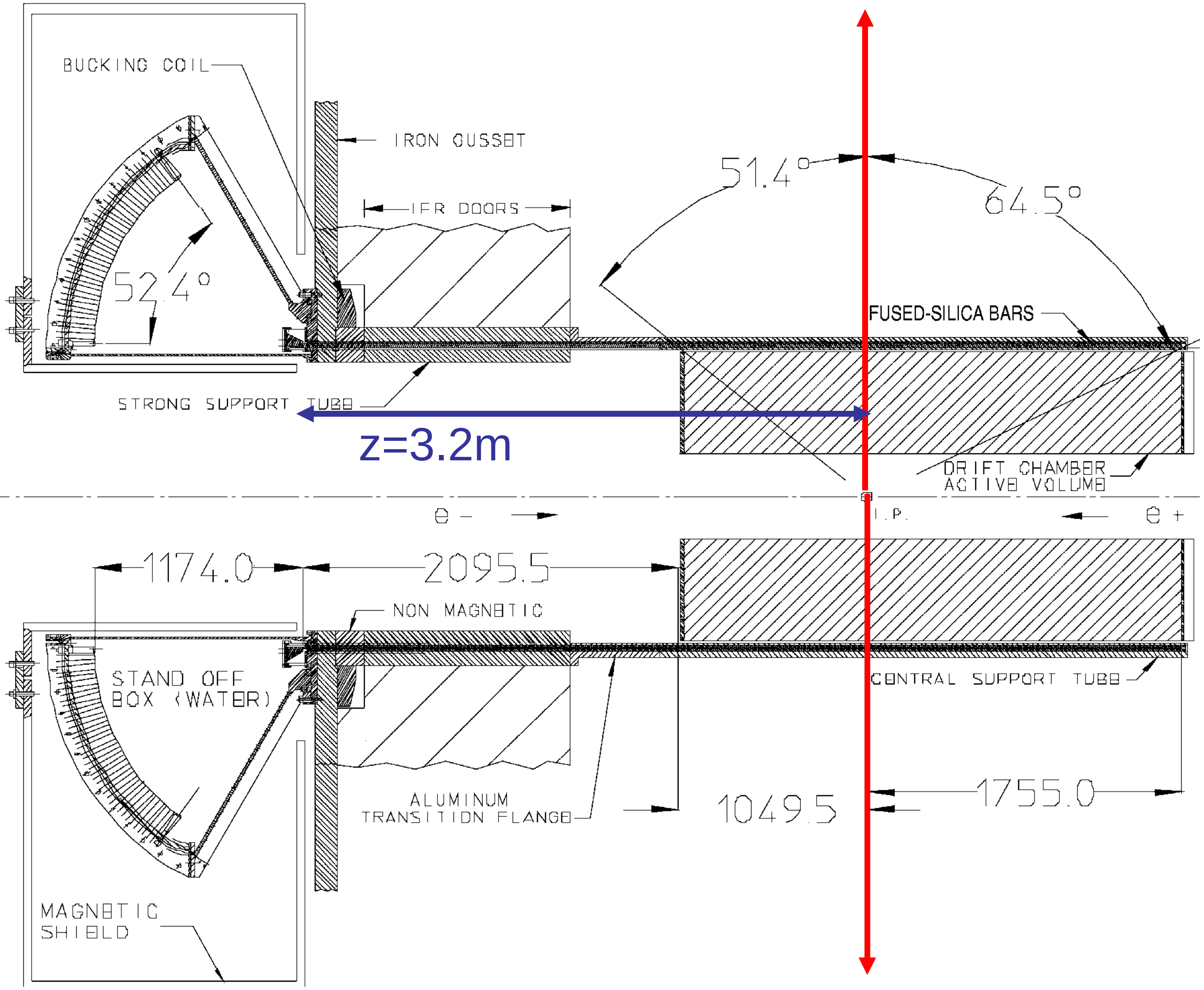
Require delta(dip)<10mrad

Approx. fixed z=3.2m

(close to position #2 in test beam setup)

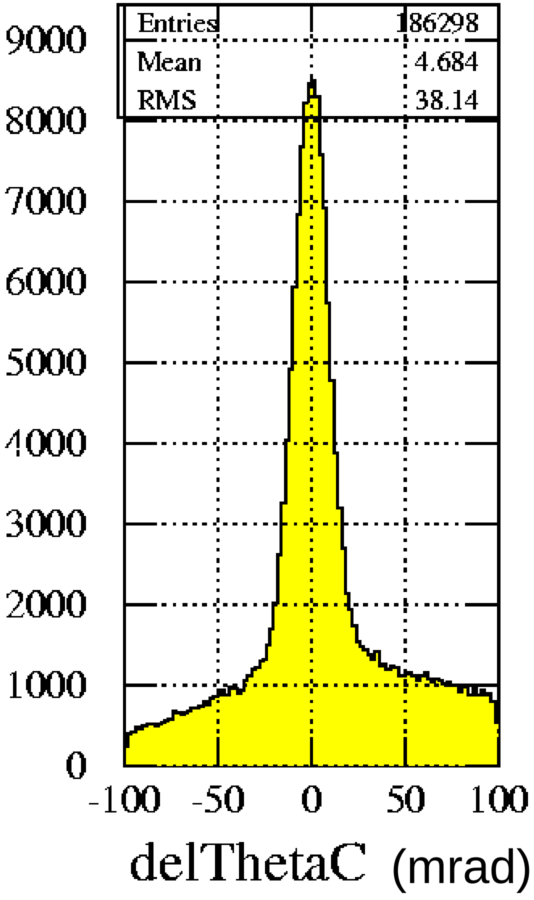
Use about 3500 muon tracks

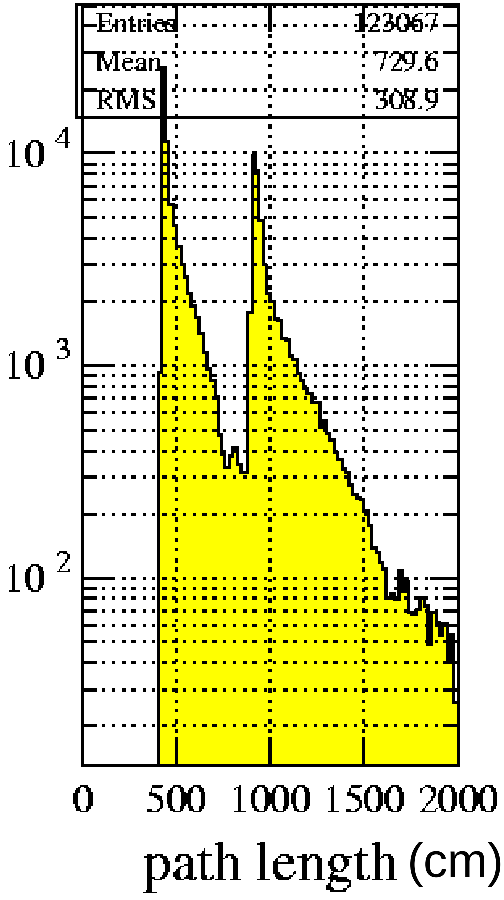
How do things look now?

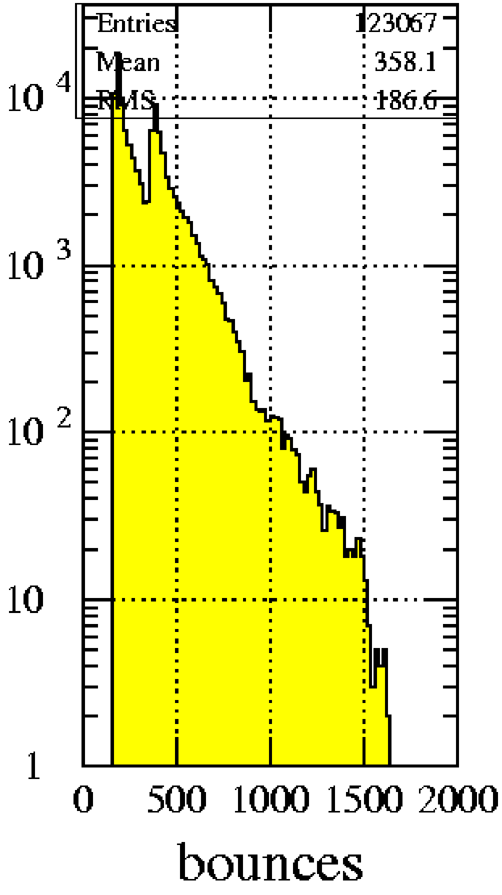


Relevance to R&D Setup

delta(thetaC), path, bounce spectra for ~3500 tracks, no cuts on photon exit angle

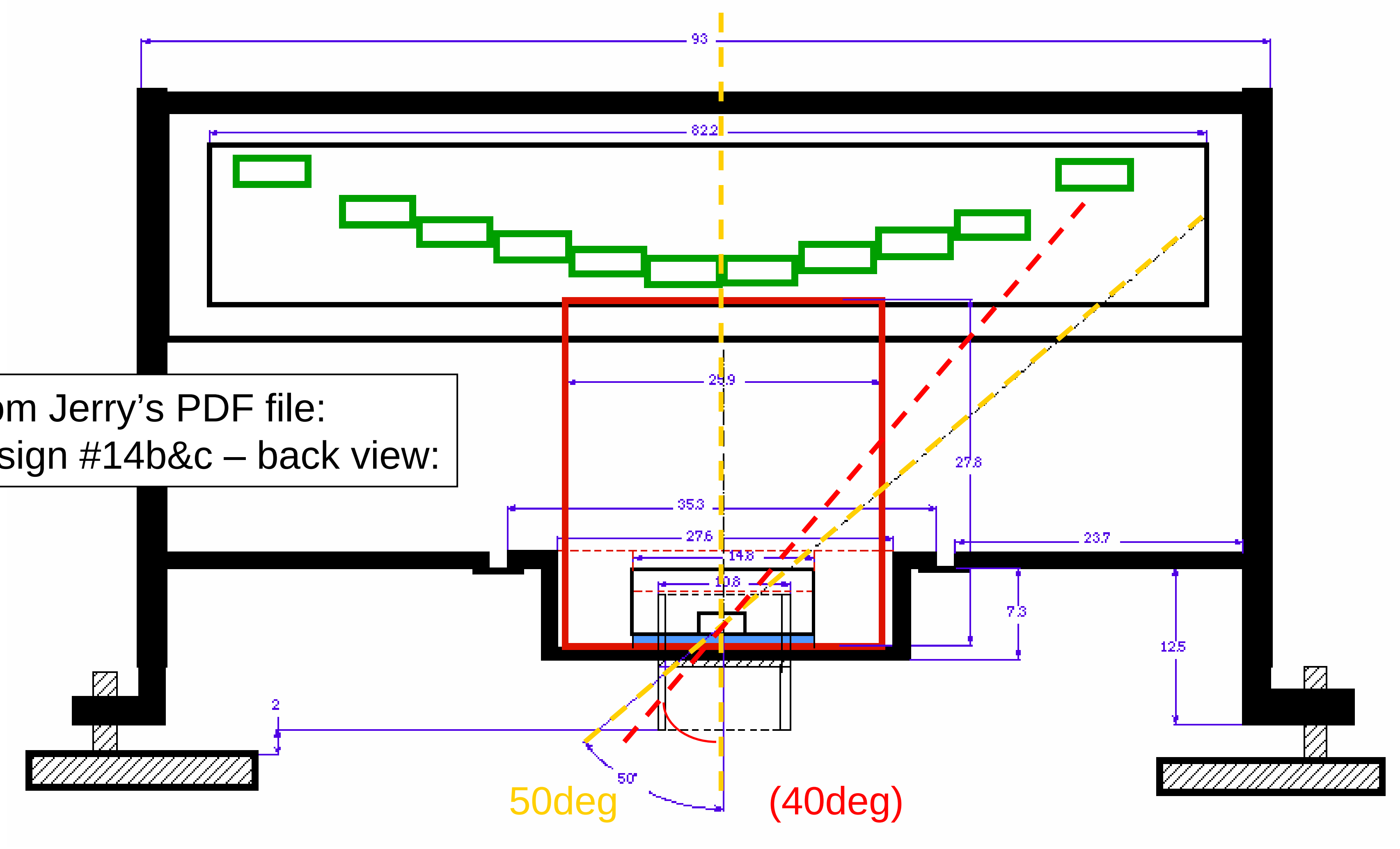






Relevance to R&D Setup

Limit exit angles of photon to ±40/50deg range available in test setup



From Jerry's PDF file:
Design #14b&c – back view:

Relevance to R&D Setup

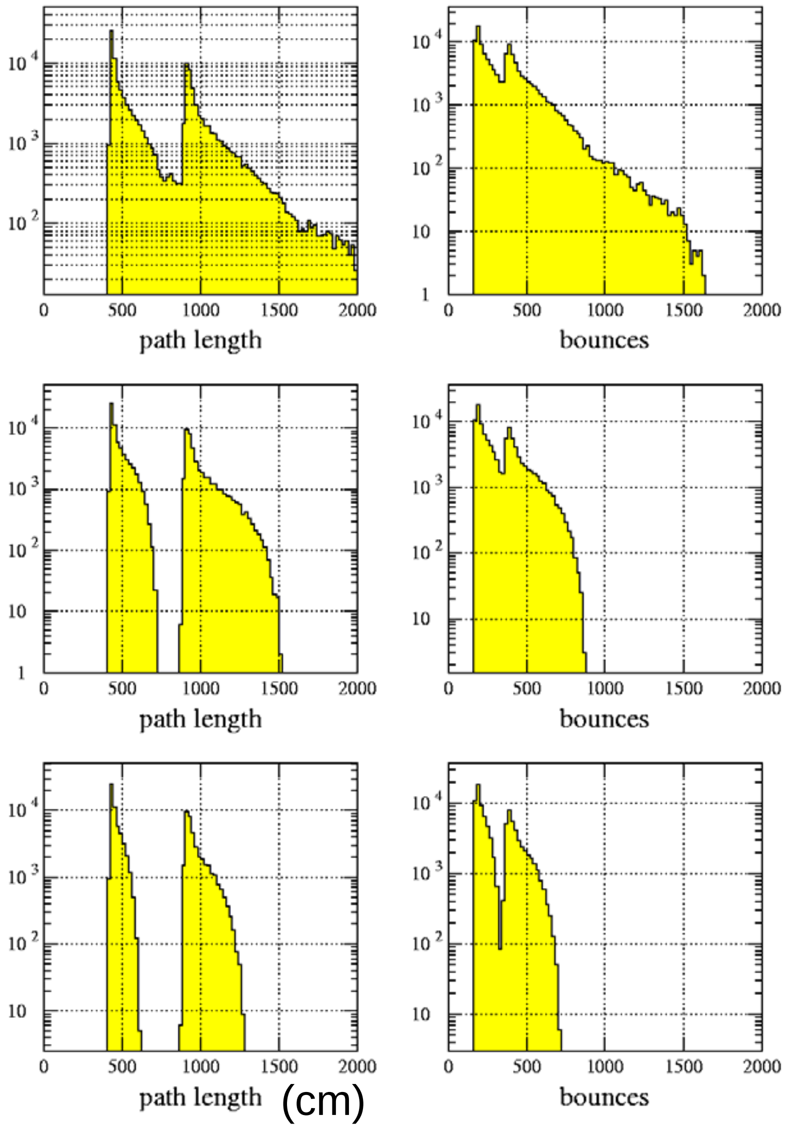
Pathlength and bounce spectrum for:

no cut on photon exit angle →
(~37,000 solutions with path>10m)

(10m translates to ~6m in position #2)

50deg cut on photon exit angle →

40deg cut on photon exit angle →
(~16,000 solutions with path>10m
- for a 4.9m long bar -)



Summary

What does all that mean for our test beam project?

Limitation in photon exit angle should limit us to range of ~4 … 6m pathlength at the second-to-last (initial) z position

That should still be enough to see some initial evidence for chromaticity effects.

A scan of seven z positions should provide good coverage in pathlength, significant overlap.

(No fine z scan within the seven z positions required)

The available range should be about ~0 … 9m pathlength.

Statistics of O(3k) good tracks per z position sounds reasonable and feasible.

Backup slides

Some more of Blair’s Pylos slides for reference.

Radiators-Dispersion

- Chromaticity at Cherenkov Photon Production:

$$\sigma_{\theta_c}(i) = \frac{\delta n}{\tan \theta_c} \qquad \text{For } \beta=1$$

- Time Dispersion during photon transport.

$$\delta^2 t_p(i) = \delta^2 L_p(i) + \frac{2C(L_p, n_g)}{L_p(i) n_g(i)} + \delta^2 n_g(i)$$

Typical Weighted Values

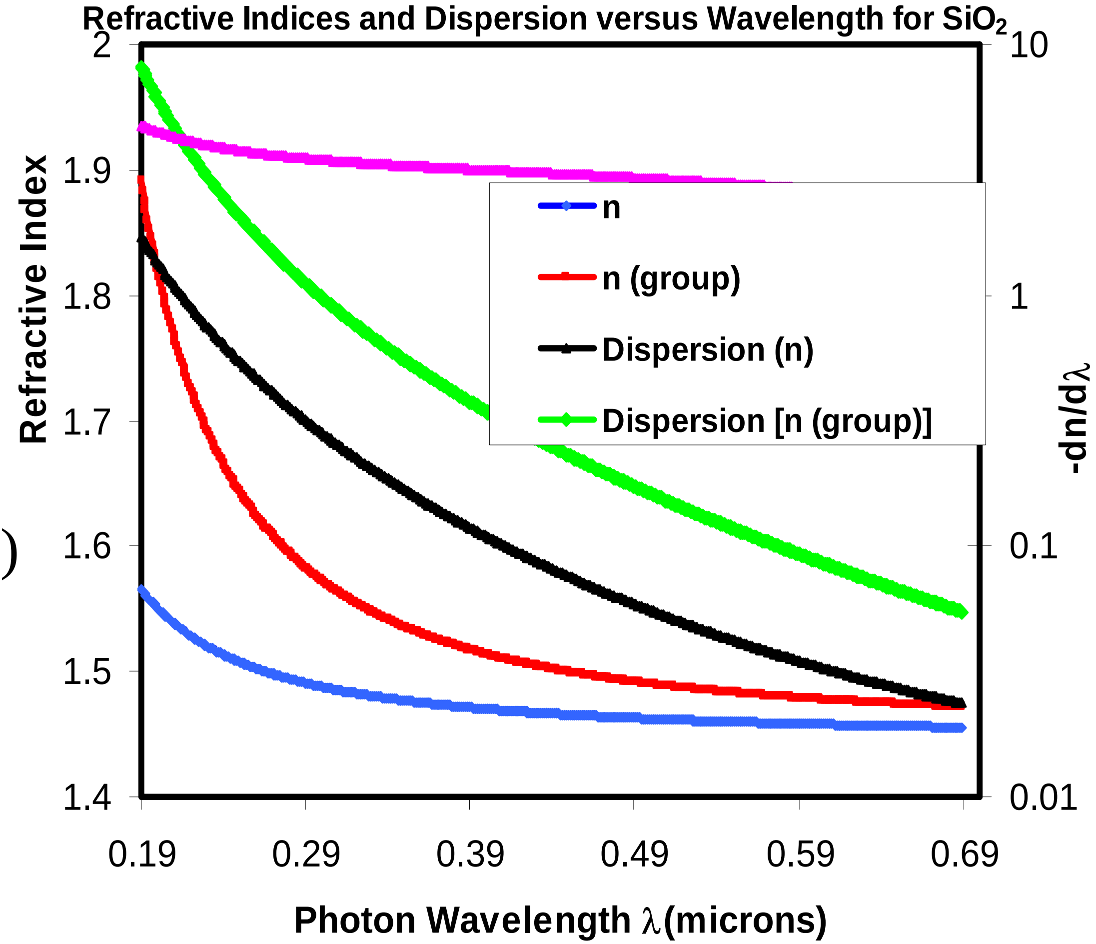
(DIRC EMI 9125 PMT & Fused Silica)

$$\sigma_{\theta_c} = \frac{\delta n}{\tan \theta_c} = \frac{0.0053}{1.08} = 4.9\,\text{mrad}$$

$$\delta t_p \approx \delta n_g = 0.016 * F$$

Where **2/3<F< 4/3**, depending on photon dip angle and its measurement accuracy.

Example



Time Imaging In DIRCs-Conceptual Issues

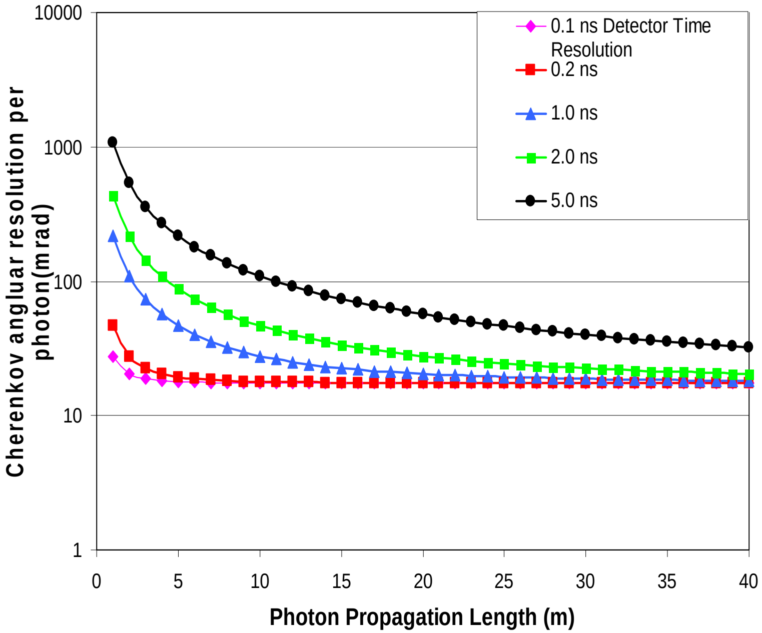
Angle Dependence.
(In Dispersive Limit)

Examples: **For $\beta=1$ particle, and α_x very well measured. EMI 9125 Bi-alkali Photodetector response detection curve**

1. $(\theta_t, \phi_t) = (90^o, 90^o)$ **uncorrelated limit**
   $\sigma_{\theta_{c.}} = \tan\theta_c(\mathrm{sqrt}[\delta^2(n_g) + \delta^2(t_p)])$

2. $(\theta_t, \phi_t) = (90^o, 90^o)$ **correlated limit with**

   $\sigma_{\theta_{c.}} = \tan\theta_c(\mathrm{sqrt}[\delta^2(n_g) + 2C(n_g, t_p)\,\delta(n_g)\,\delta(t_p)] + \delta^2(t_p)])$



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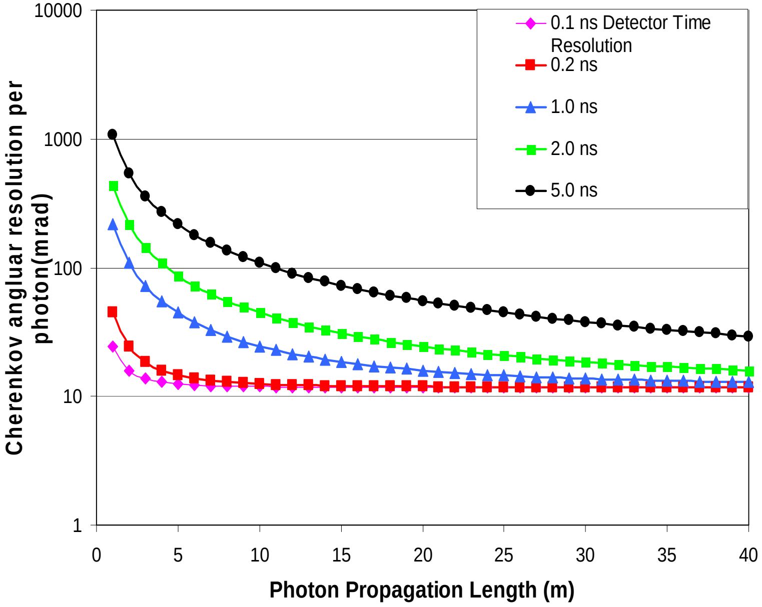

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Imaging In DIRCs-Conceptual Issues-Resolution

Measuring the Chromatic Smearing?

- Detectors have been proposed that could measure photon wavelength to about 0.15 ev (e.g., the TES (Transition Edge Sensor), but these detectors work at ~40 mk , and are rather slow….

➔impractical?

- Use the large dispersion in n_g in a 3-D DIRC to measure the photon wavelength….(I.e., compare the individual photon flight time with its measured angle.

➔ can improve chromatic limit by ~5x with 100 ps detector resolution at 6m. Scales with resolution.