Status of work at Cincinnati on a focusing DIRC option

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Part I

- *why consider a focusing DIRC?*
- *a focusing DIRC design that will fit*
- *simulation results*

Part II

- *price of quartz bars from Zygo (USA)*
- *price of focusing mirror from OSI (USA)*

Why consider a focusing DIRC

Babar's DIRC a great success – a proven detector. It relies on both x and y position, using timing only to resolve ambiguities. Problem with such a detector for a Super-B factory experiment is that large standoff box introduces problematic beam-related backgrounds. To eliminate this, one introduces focusing: greatly reduces standoff region, but requires finely segmented photon detectors. These were not possible in 1995 when Babar DIRC was finalized, but they are possible now.

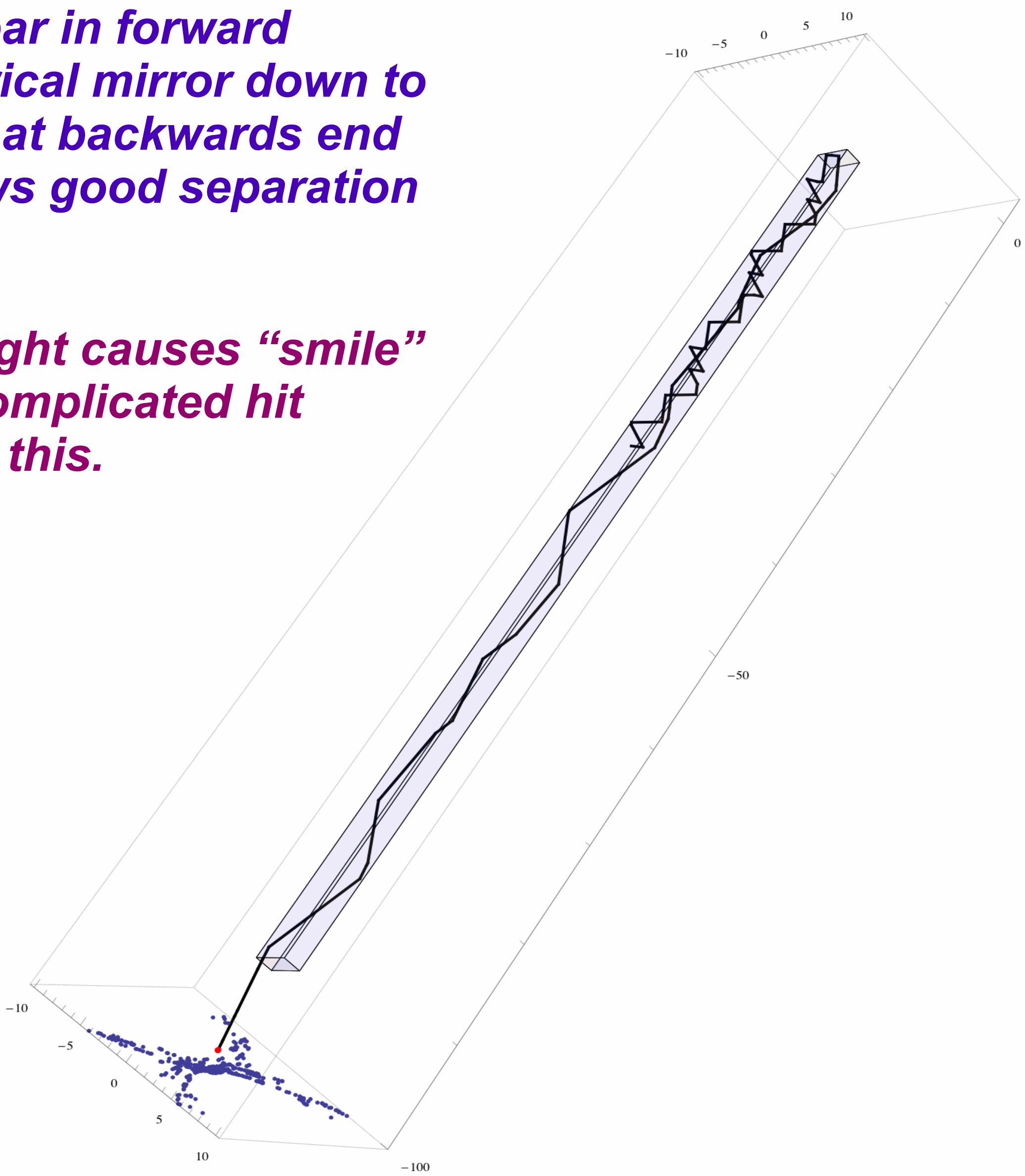
New problem for super-Belle: even a small standoff region does not fit inside Belle solenoid – space very tight. Solution: use timing for y coordinate, i.e., TOP counter. But this requires very precise timing, and time-of-propagation doesn't work for tracks in the forward direction. (Also, need wide bars.) Another solution: use quartz bar itself as the stand-off region; then fDIRC can fit inside sBelle. This increases the number of readout channels over TOP, but an fDIRC doesn't need as precise timing. Works with narrow bars.

Third option: iTOP (Hawaii). This is a non-focusing DIRC with very finely-segmented readout. The fine segmentation reduces standoff region. BUT: since no focusing, one desires thin bars for better resolution/discrimination, and light yield becomes an issue.

Focusing DIRC design that f ts

Radiated light reflects down bar in forward direction, is focused by spherical mirror down to detector surface (focal plane) at backwards end of bar. Long focal length allows good separation of π and K hits.

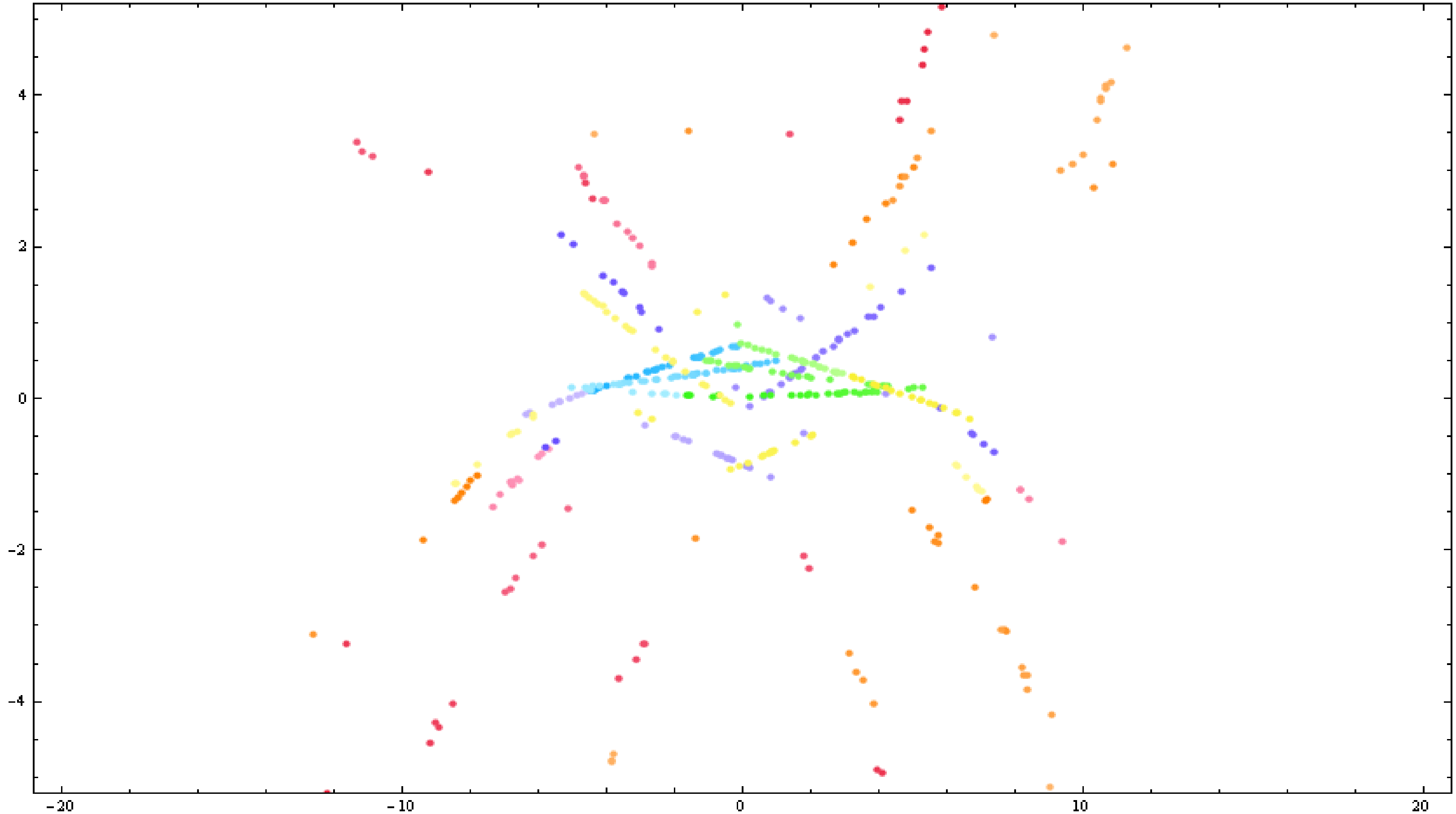
BUT: reflections in focused light causes "smile" to fold-back on itself; gives complicated hit pattern. Use timing to resolve this.



Trace photon hits with Mathematica

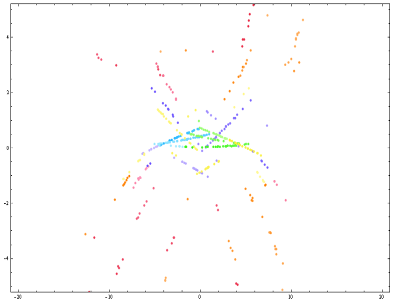
Vertical track (0 dip angle, p= 4 GeV/c), **photon hits at detector plane:**

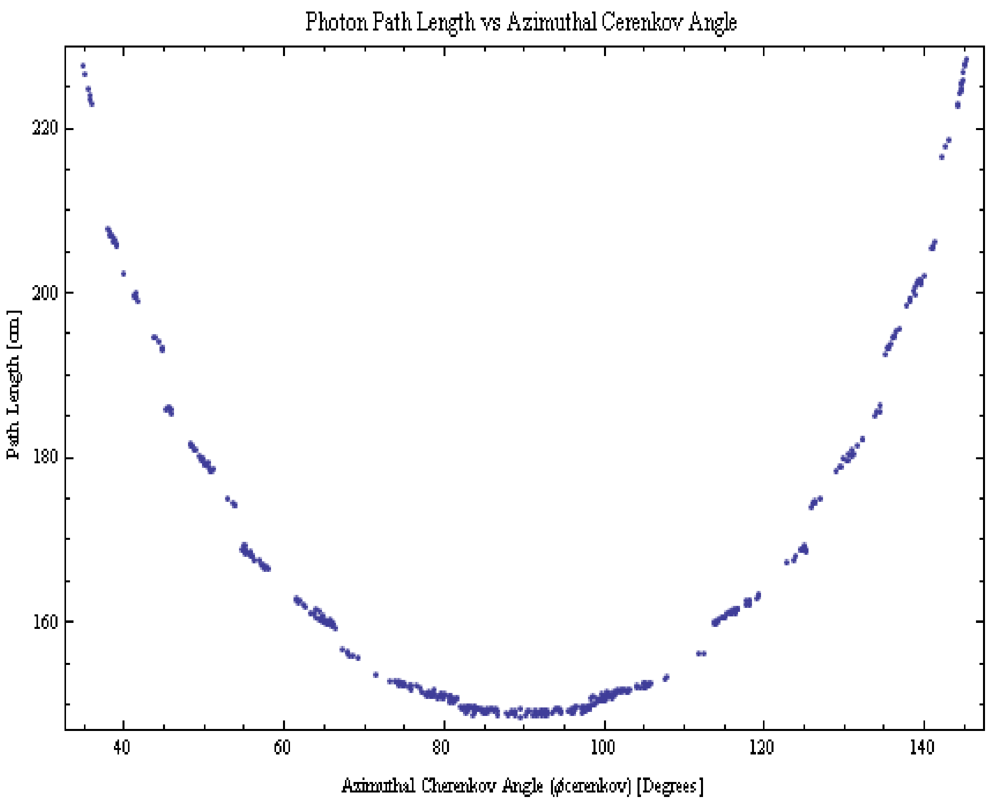
- ***colors correspond to different ranges of azimuthal angle***
- ***hits exhibit "foldback" pattern, complicated overlap***



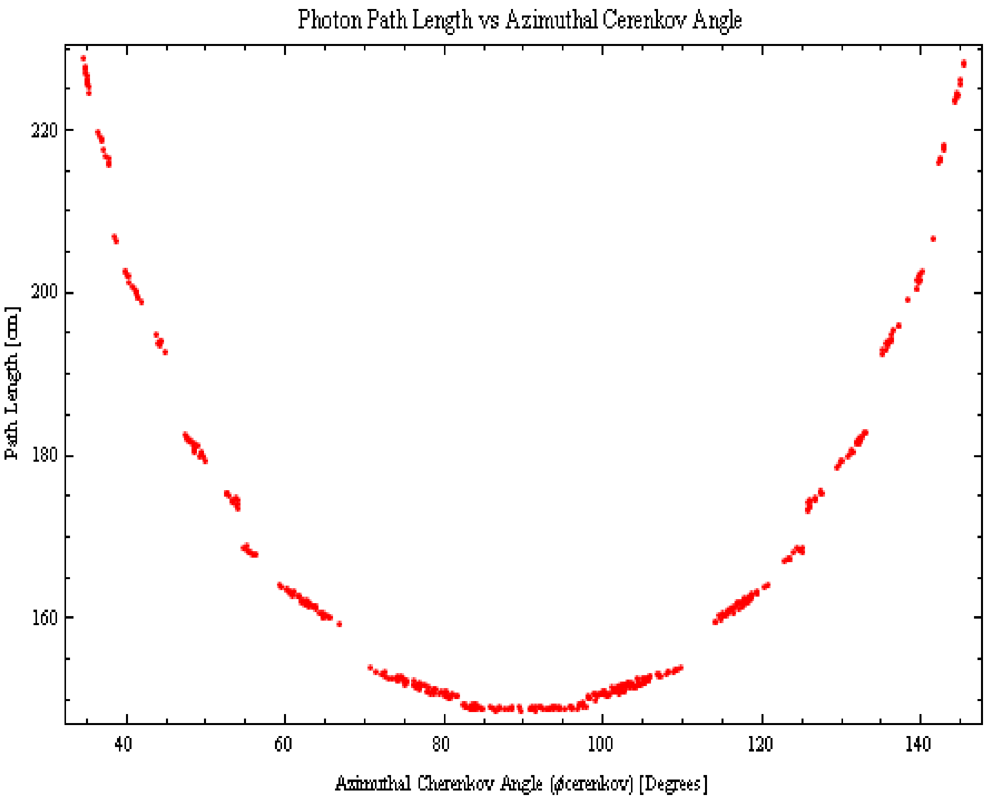
ddd

Patterns correspond to different azimuthal ranges, which correspond to different path lengths in bar. These can be potentially discriminated with timing:





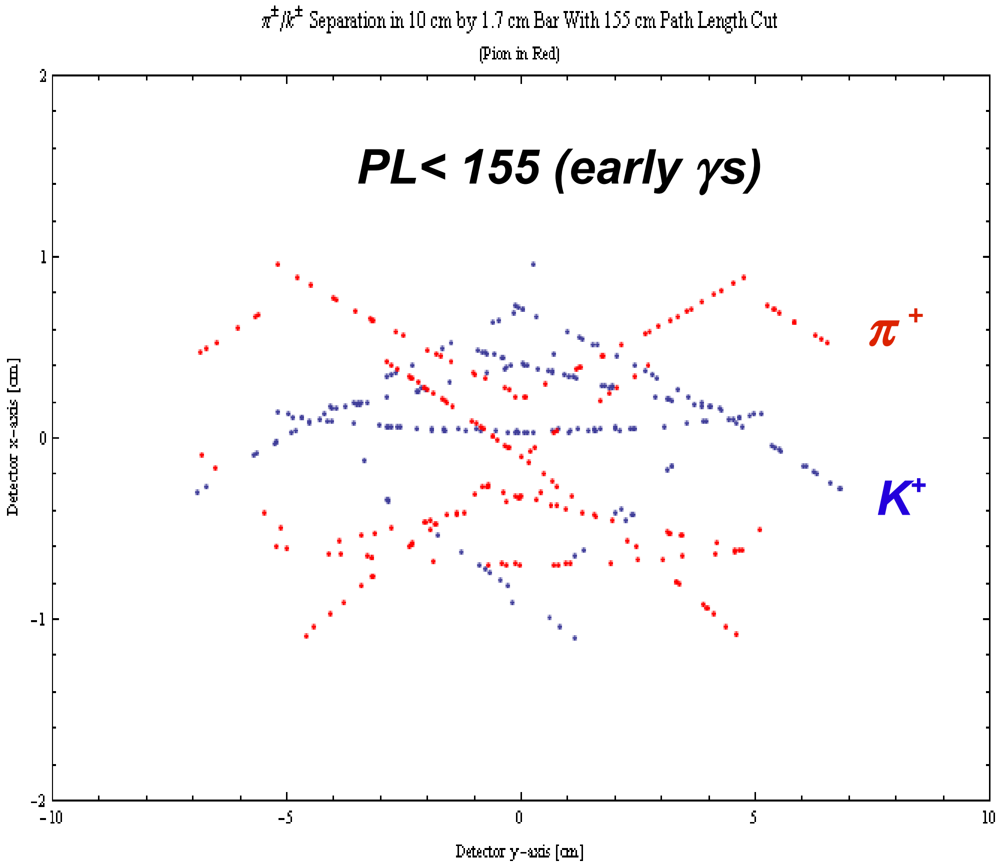
path length Kaon

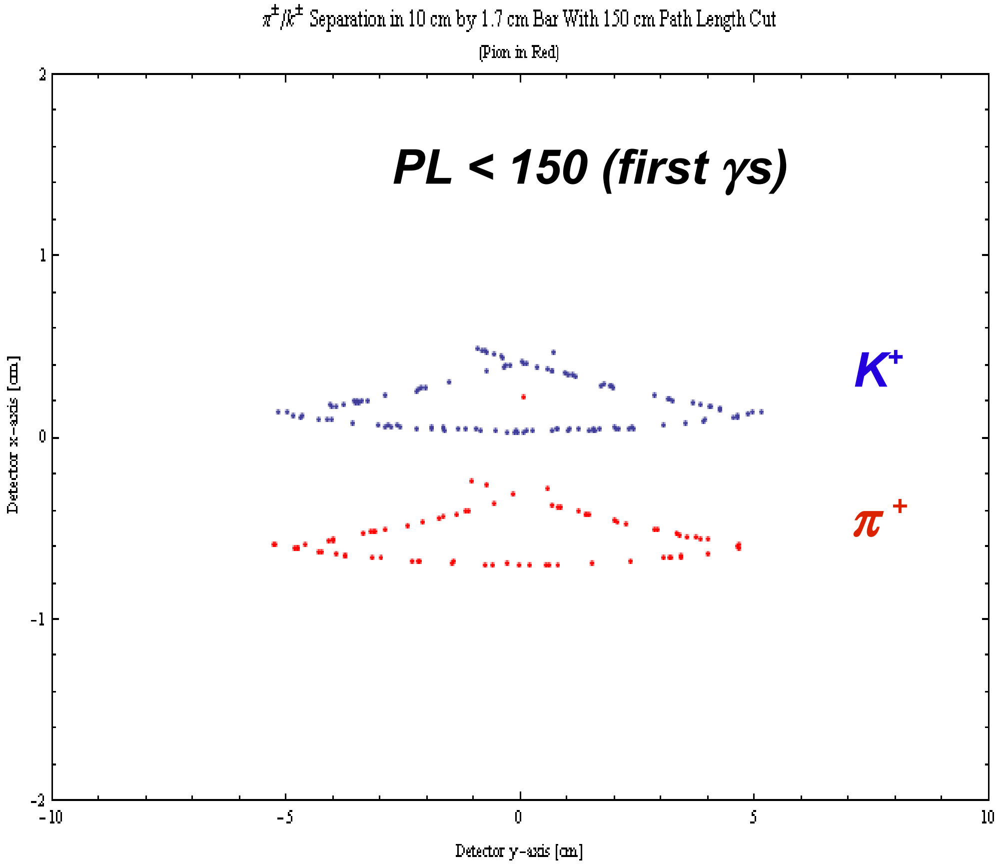


path length pion

Mathematica study

Correlation between path length (= timing) and hit positions (4 GeV track):





Promising separation for p=4 GeV/c ...

Detailed simulation (A. Drutskoy)

mid-forward track: θ(dip) = 20°, ϕ = 0°, p = 4 GeV/c

Quartz bar: 1.73 cm x 3.5 cm x 122.5 cm
(Babar-type, not optimal)

Focusing mirror: R =265 cm, f = 132.5 cm
(tilt angle not optimized)

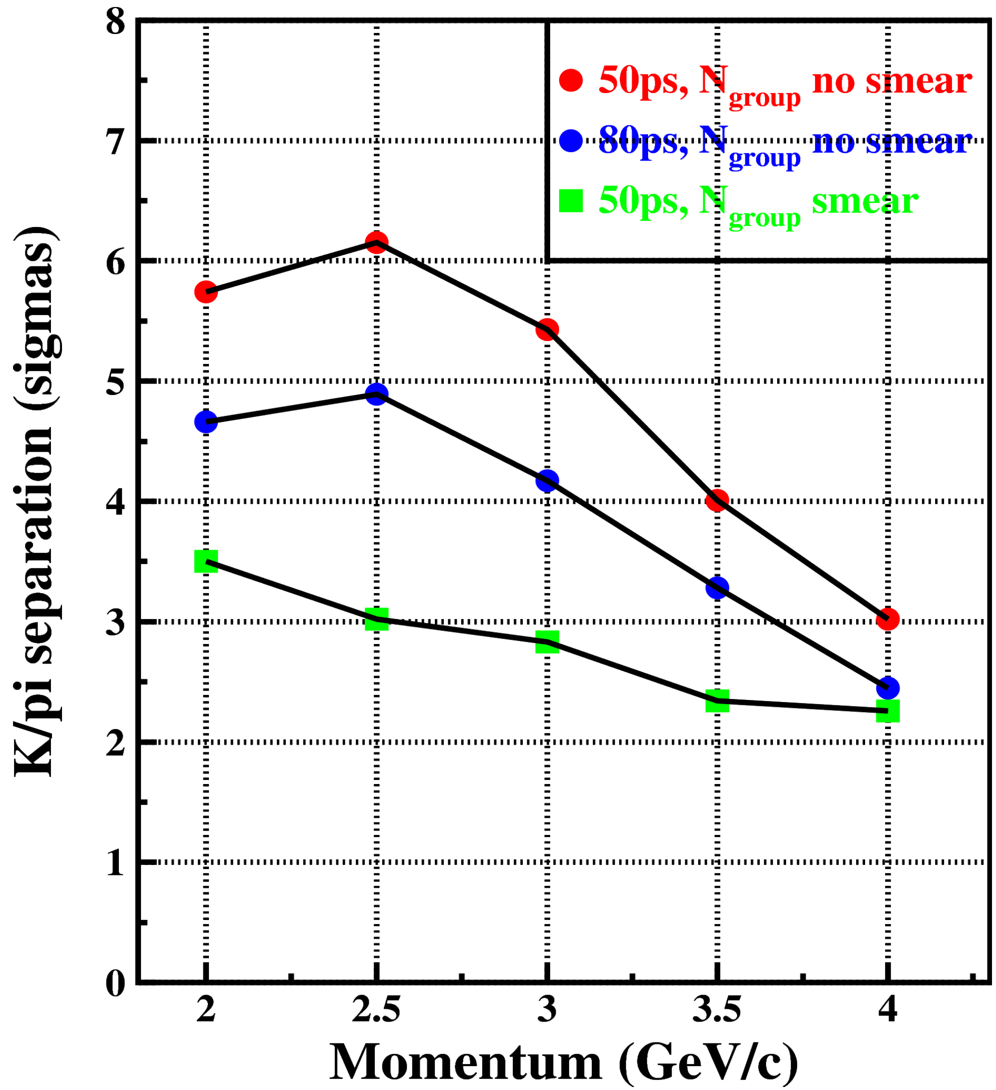
Photon detectors:
10 cm from bar, 6 mm x 6 mm granularity
(e.g., Burle MCP 85010)

Systematics:
include chromatic dispersion, but not (yet) imperfections in bar or mirror surface, or possible misalignment

Discrimination:
calculate probability densities for π and K tracks, take ratio of densities to get likelihood function.

Simulation (cont'd)

Narrow (3.5 cm) bar:



π/K separation in 2-6σ range for momentum of 2-4 GeV/c

Timing resolution difference Δ= 30 ps lowers separation by 0.5-1σ (20% of absolute separation)

Chromatic dispersion (N_{group}) lowers resolution by 1-3σ (30-50% of absolute separation -ouch)

Separation sensitive to track DIP angle and also azimuthal angle – Alexey studying this now

These results are for a narrow (Babar-like) bar: not optimal. With Mathematica we saw a notable improvement for wider bars – will study this to find optimal width.

Quartz bar fabrication

Babar bar fabrication initiated by a small company in Albuquerque subsequently bought by Boeing. Bar production completed by Boeing at a financial loss. SLAC also considered Zygo corporation (CT), a large company that specializes in fabricating optical components for demanding applications. Made many prototype quartz bars for Babar. Highly recommended by SLAC (Va'vra, Ratcliffe).

Sept. 26: requested preliminary pricing for synthetic fused silica bars, either Spectrosil or Suprasil-P20 or equivalent.

Specifications from Inami-san:	Babar bars:
(2.0 x 40.0 x 91.5) cm^3	
(2.0 x 40.0 x 76.0) cm^3	
Flatness: < 2 lambda (< 1 micron)	< 5 lambda
Roughness: < 0.5 nm (Ra)	< 1.0 nm
Squareness: <~ 1 arcminute	< 1.5 arcminute
Edge: C0.3 (-C0.5)	

Oct. 2: conference call with Zygo team (Dir. Sales, Dir. Optics, Manuf. manager, Eng. manager, applications engineers...), reviewed specs. They commented that tolerances were notably more aggressive than what Babar requested.

Quartz bar fabrication

Quote two widths (assuming radial position = 1.2 m):

Wide bars (TOP):	
2.0 x 40 x 91.5 cm^3	38 bars
2.0 x 40 x 76 cm^3	19 bars

Narrow bars (fDIRC):	
2.0 x 10 x 120 cm^3	152 bars (+ spares)

Zygo ROM quotation OC-09-0133, recv'd Oct 29, Dec 1:

* Surface flatness < 25um [1um was request; Stanford was flat to 25um]
* Roughness <= 10A RMS [~5A was request]
* Perpendicularity / Squarenss < 1 arc min [spec was <=1 arc min; Stanford was < 1.5arc min]
* Chamfer 0.3-0.5mm leg width at 45 deg [spec needs clarification of leg width or face width]
* Dimensional tolerances +/- 0.5mm

Corning 7980 0D

38 PCS., [2.0cm X 40.0cm X 91.5cm], $88,000 each [extended price of $3,344,000]
19 PCS., [2.0cm X 40.0cm X 76.0cm], $84,000 each [extended price of $1,596,000]
Estimated NRE for either or both of the above items: $210,000

Total + 4 spare bars: $5,494,000

St. Gobain Spectrosil

38 PCS., [2.0cm X 40.0cm X 91.5cm], $86,000 each [extended price of $3,268,000]
19 PCS., [2.0cm X 40.0cm X 76.0cm], $84,000 each [extended price of $1,596,000]

Hereaus Suprasil P30 (would not quote P20 grade for the larger pieces):
as for Corning 7980 OD x 6

Quartz bar fabrication

Zygo ROM quotation OC-09-0133, recv'd Oct 29, Dec 1:

Narrow bars (fDIRC):	
2.0 x 10 x 120 cm^3	152 bars (+ spares)

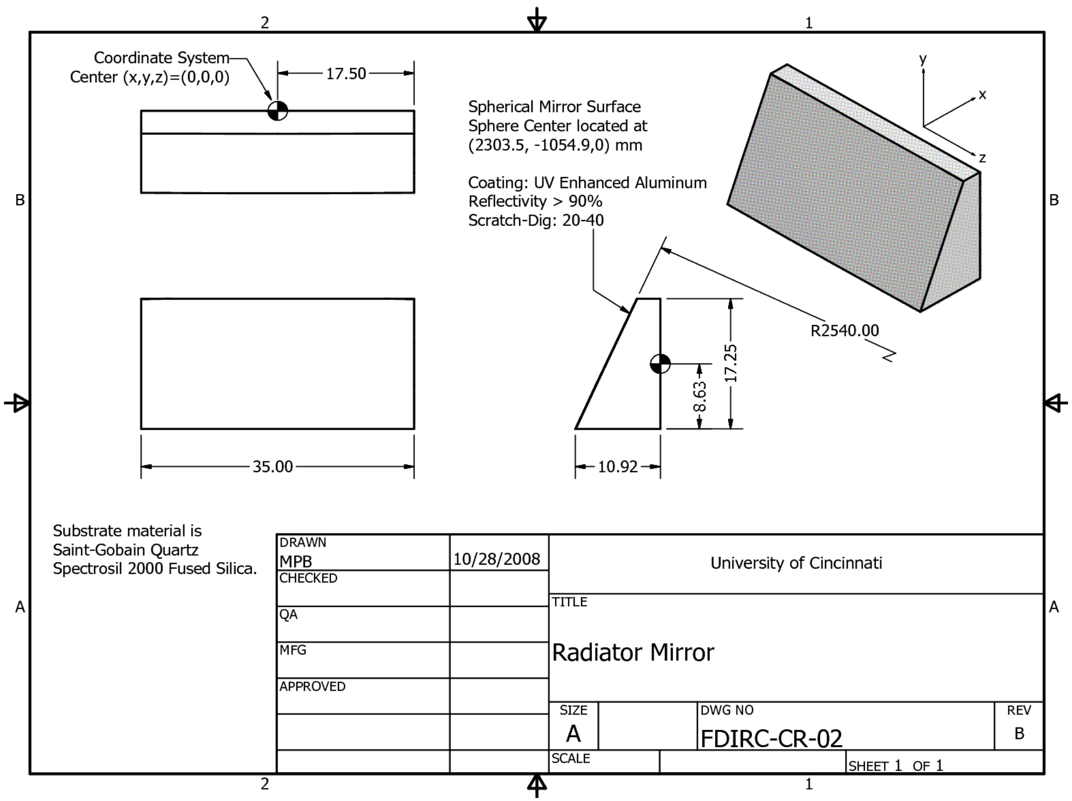
Corning 7980 0D
152 PCS., [2.0cm X 10.0cm X 120cm], $83,000 each   [extended price of $12,616,000]
Estimated NRE: $300,000
Total + 6 spare bars: $13,414,000 (!)

St. Gobain Spectrosil
152 PCS., [2.0cm X 10.0cm X 120cm], $88,000 each   [extended price of $13,376,000]

What drives price?   (Meeting at Cincinnati on Dec. 4 to discuss)
- Width not an issue – can easily polish wide bars
- Handling an issue – narrow, long bars are flimsy (hence larger NRE)
- Chamfer spec a big issue: tight spec will very easily chip, lower yields (hence cost/bar so similar, despite very different surface areas)
- Material: Suprasil very expensive, Corning should be fine, least expensive is fused silica from Nikon Hikari Glass, but no guarantee on specs.

Mirror fabrication

Zygo recommends a small company in New Hampshire that does very high quality work: Optical Solutions Inc. (OSI). Have reviewed design with them and they are fabricating a prototype from fused silica. Tentative plant visit on Dec. 29th.



Estimated cost:

$5K-- $15K per piece, depending on width, off-axis tilt, and quality specs

(wide mirrors will be more expensive)

152 x $ 5K = $760K (narrow bars)

19 x $20K = $380K (wide bars)

Summary

Focusing DIRC option appears technically feasible. π/K separation for narrow bars appears similar to that for TOP; this may improve for wider bars. Timing is important, but in principle one does not need as good resolution as required for TOP (as focusing DIRC measures 2-d position). More complete MC studies now underway (Drutskoy)

Zygo has capability for making all quartz bars to spec and on schedule, and they are interested in this project. Their quality is very high. BUT: they are expensive. Pricing indicates wide bars would be much more economical. Corning or Spectrosil fused silica would be notably more economical than Suprasil.

Optical Solutions Inc. (OSI) believes they can fabricate all mirrors to spec. They are working on preliminary pricing (but need more information – will discuss with Inami-san).