New small FDIRC

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Abstract for RICH 2016

- We have previously built and tested a full scale prototype of a Focusing DIRC (FDIRC) detector [1]. This device was based on the BaBar radiators and bar box enclosures attached to a new cylindrically focused camera, and intended for the upgrade of the BaBar detector for the SuperB factory. Similar optical concepts are now being considered for the GLUEX experiment at JLAB, and possibly, the Electron-Ion collider PID detector at BNL.
- BaBar bar boxes may be available and we hope that this may encourage people's consideration of using them in their application.
- In this paper, we probe the Cherenkov angular resolutions attainable with similar radiator designs and FDIRC style cylindrical lens focusing:
  - (a) SuperB FDIRC design with 3mm x 12mm pixels (H-9500) and & BaBar bar boxes as they are,
  - (b) New smaller FDIRC focusing block (FBLOCK) with 3mm x 12mm pixels (H-9500), and BaBar bar boxes as they are (in the appendix we also evaluate 1.6mm x 25.6mm pixels (XP-85022)),
  - (c) The same as (b), but with modified BaBar bar box which includes bars and a plate.

- No time-based analysis performed in this talk, only dTOP = $TOP_{measured} - TOP_{expected}$ cut (no chromatic correction, no full 3D likelihood analysis).
- The talk will compare and contrast the MC angular performance attained by each scheme. This MC was tested earlier on the SuperB FDIRC design [1].

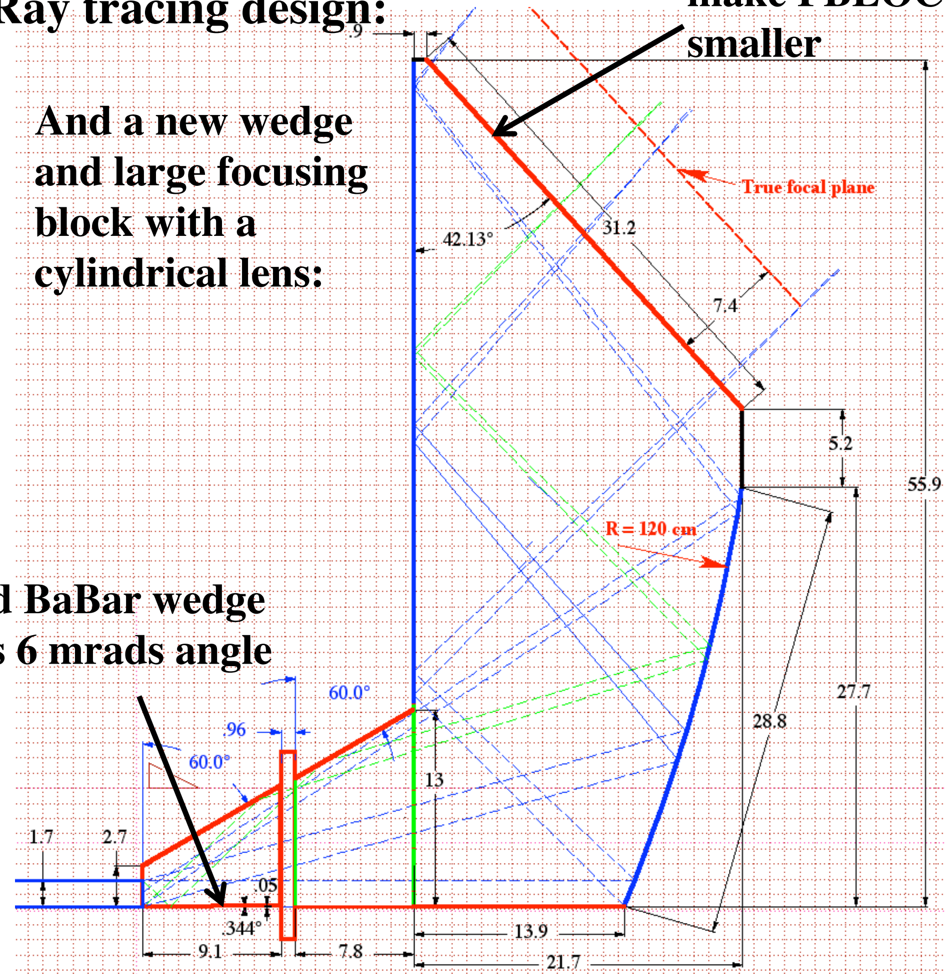
SuperB FDIRC design

Ray tracing design:

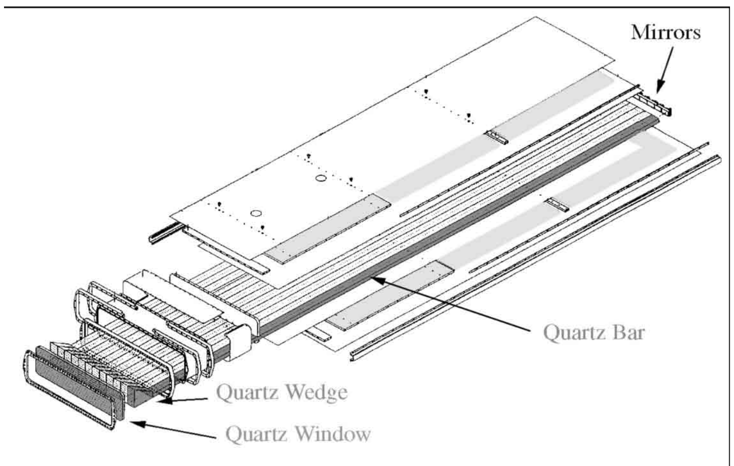
The detector plane is not in a focus to make FBLOCK smaller

And a new wedge and large focusing block with a cylindrical lens:

Old BaBar wedge has 6 mrads angle



BaBar bar box with 12 bars:



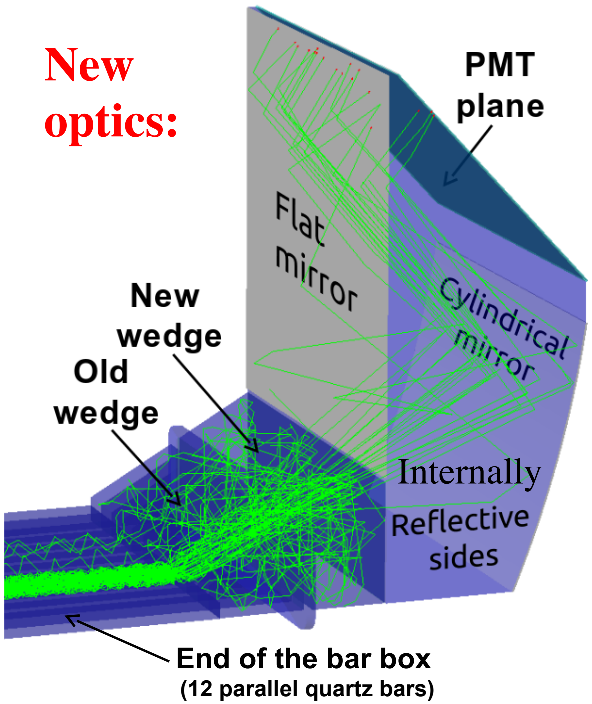
- Large size of FBLOCK designed to be used with 6mm x 6mm pixels (H-8500).
- Reuse the BaBar bar box without any changes, i.e., 12 individual bars & old wedge.

SuperB Focusing DIRC R&D accomplishments

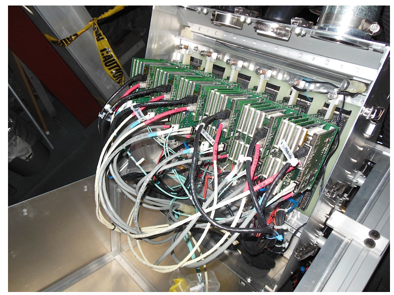
Detailed results published in NIMA 775(2015)112-131.

- **Detector used full size BaBar bar box, new optics, 12 H-8500 MaPMTs, waveform digitizing electronics, and 3D tracking in a large SLAC cosmic ray telescope (CRT).**

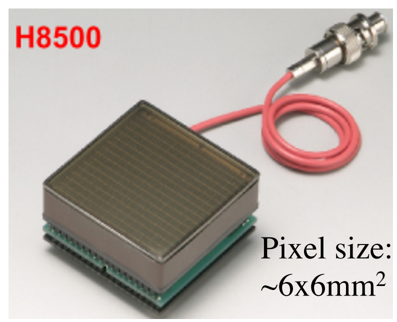
New optics:



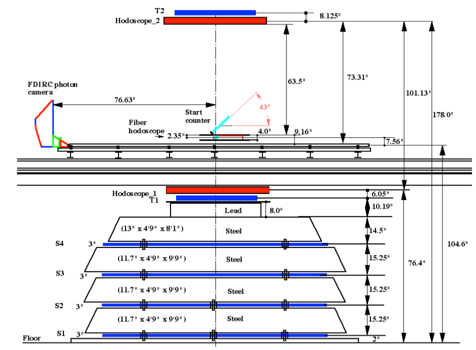
Gary's IRS electonics:



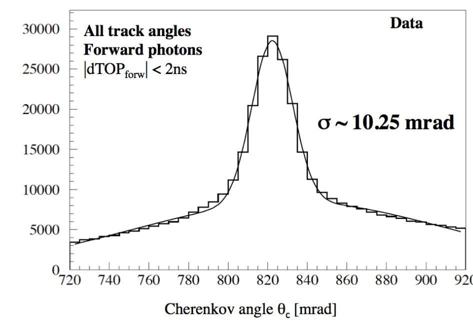
64-pixel MaPMT:



CRT telescope:



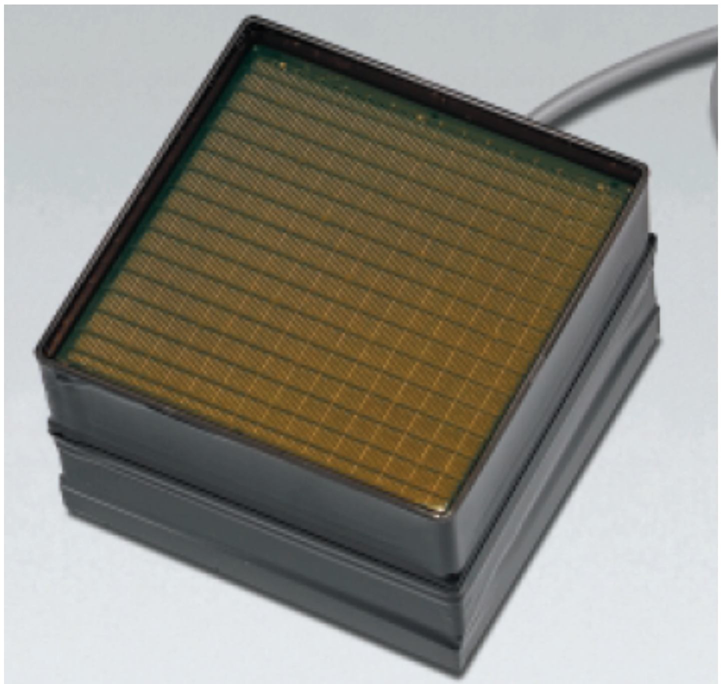
Resolution with 3D-tracks in CRT:



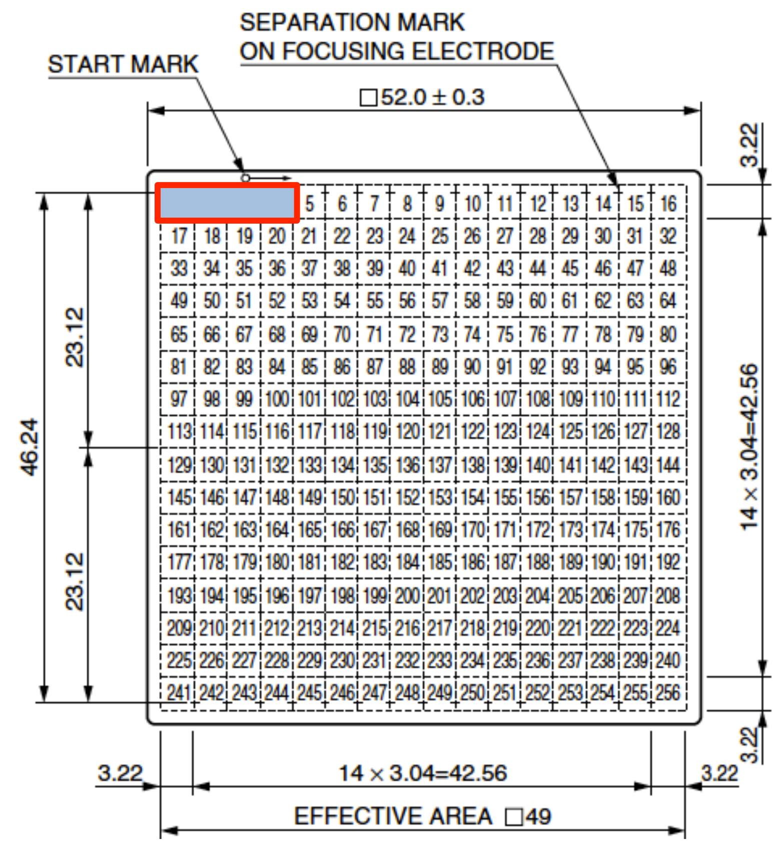
- **Detector achieved the design performance. Results agreed with the MC simulation.**
- **Tested in the CRT telescope which added ~2 mrads to the resolution due to tracking resolution, muon energy spread and 3D tracking.**
- **We asked a question: what limits the θ_c-resolution for FDIRC type of optics ?**

Detectors with smaller pixels

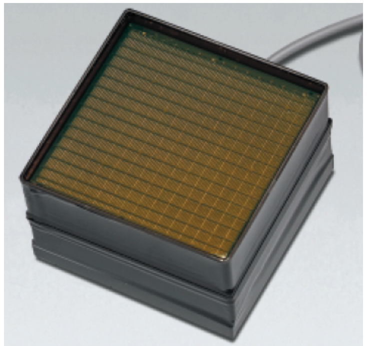
Hamamatsu 256-pixel MaPMT:



Hamamatsu with 256-pixel H-9500 MaPMT:



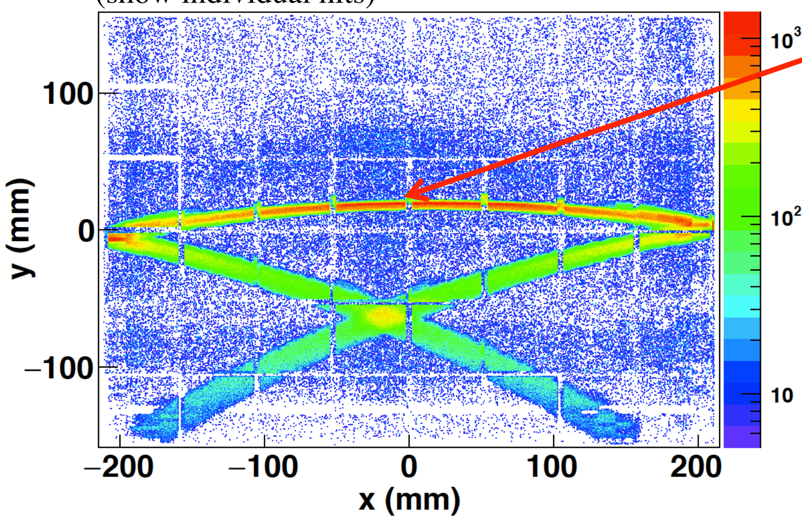
- **Modify Hamamatsu 256-pixel detector into a 64-pixel detector by combining 4 pixels in the x-direction.**
- **This is to be used with a 64-channel IRS electronics, for example.**



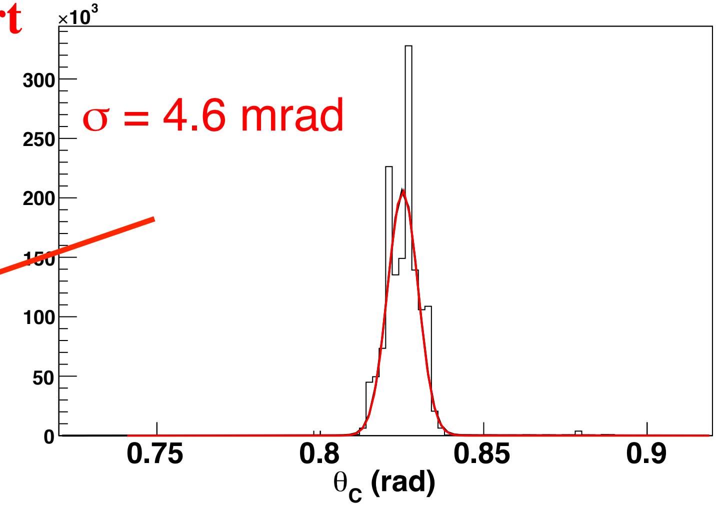
SuperB design with 3 mm pixels

Combine 4 pixels
in x-direction

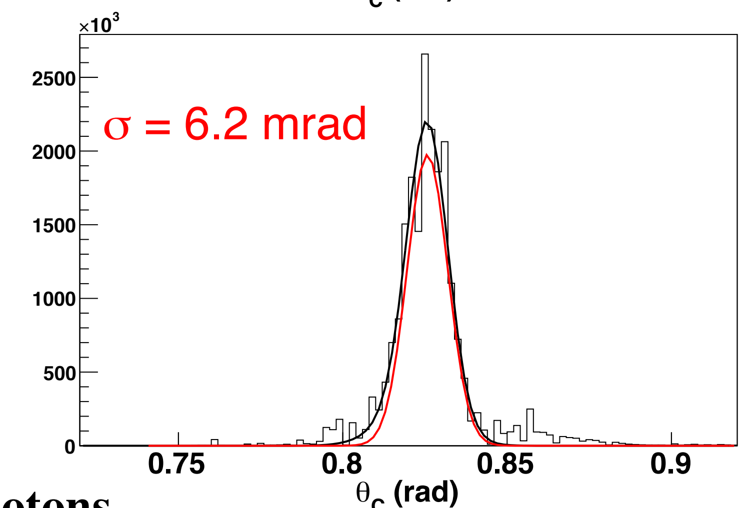
Cherenkov ring x-y image in FDIRC:
(show individual hits)



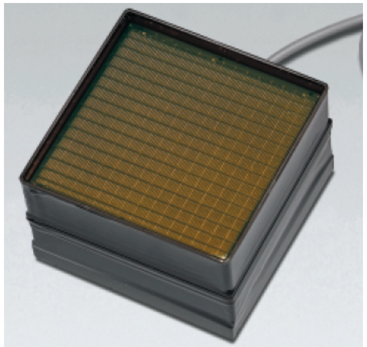
Just central part of the ring:



Entire ring:



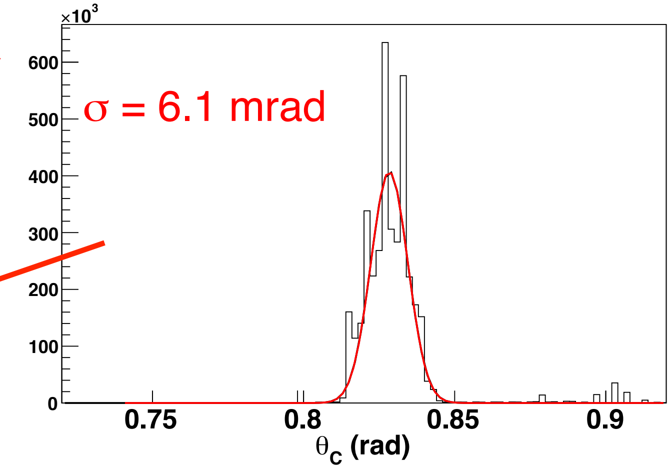
- Pixel sizes: ~ 3 x 12 mm.
- 10 GeV muons at normal incidence.
- Single photon resolutions for backward going photons.
- The ring resolution broadening is due to the kaleidoscopic effect in DIRC.



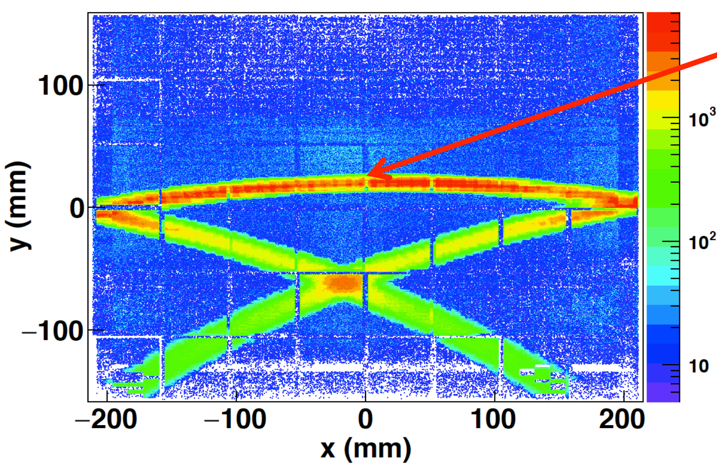
SuperB design with 3 mm pixels

Combine 4 pixels in x-direction

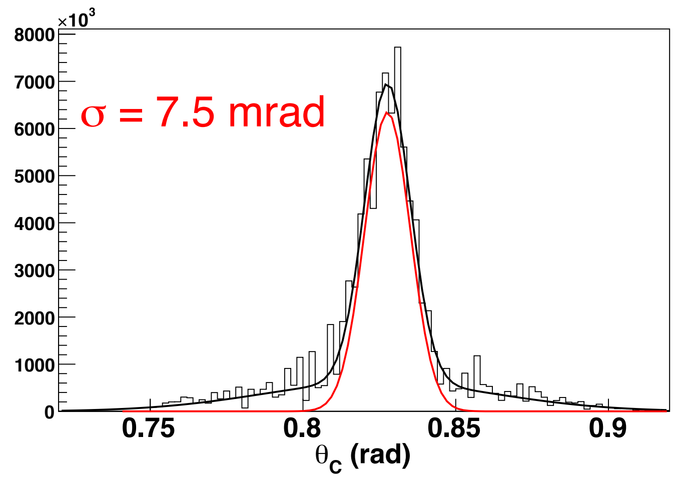
Just central part of the ring:



Cherenkov ring x-y image in FDIRC:
(show individual hits)



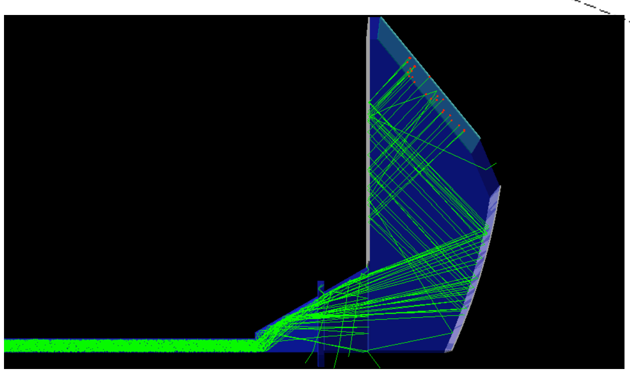
Entire ring:



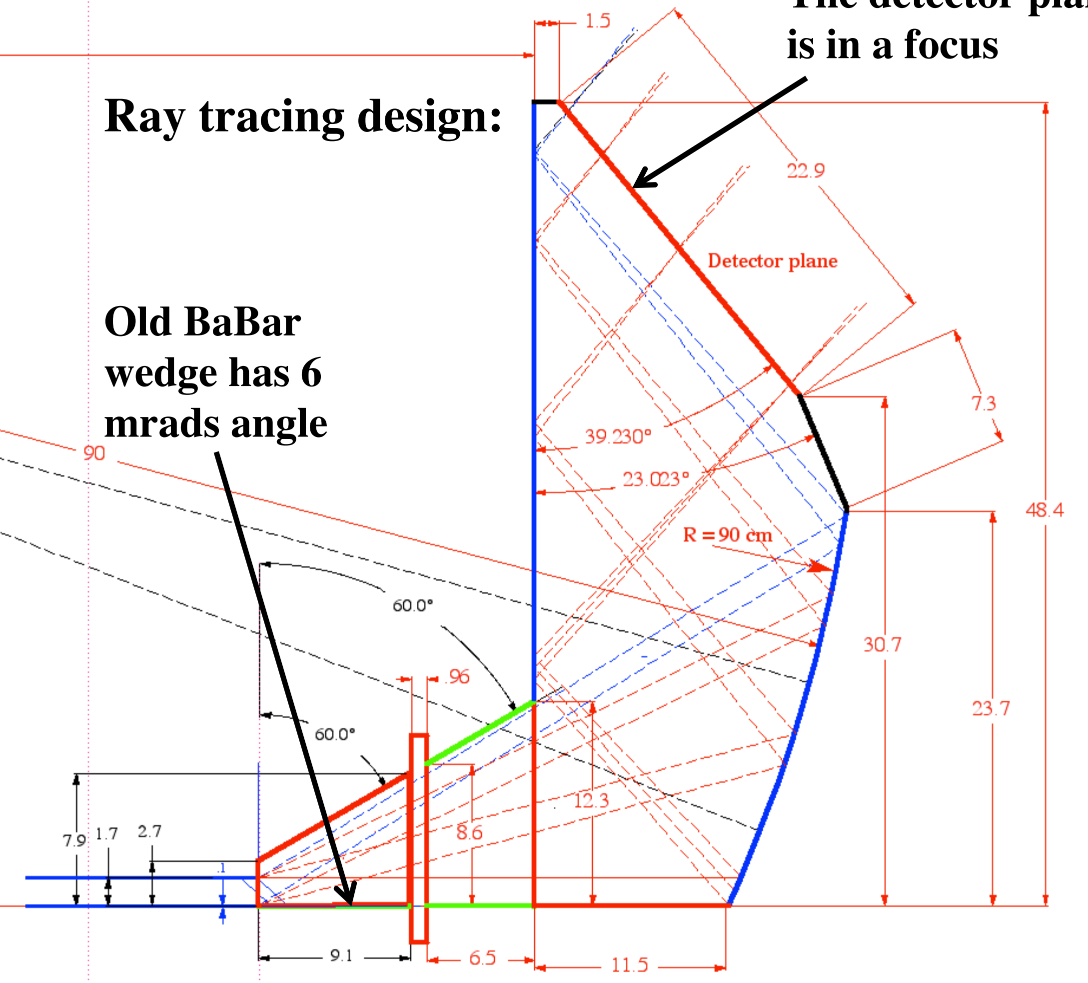
- **Pixel sizes: ~ 3 x 12 mm.**
- **10 GeV muons at normal incidence.**
- **Single photon resolutions for forward going photons.**
- **The ring resolution broadening is due to the kaleidoscopic effect in DIRC.**

New smaller FDIRC design #1

MC simulation:

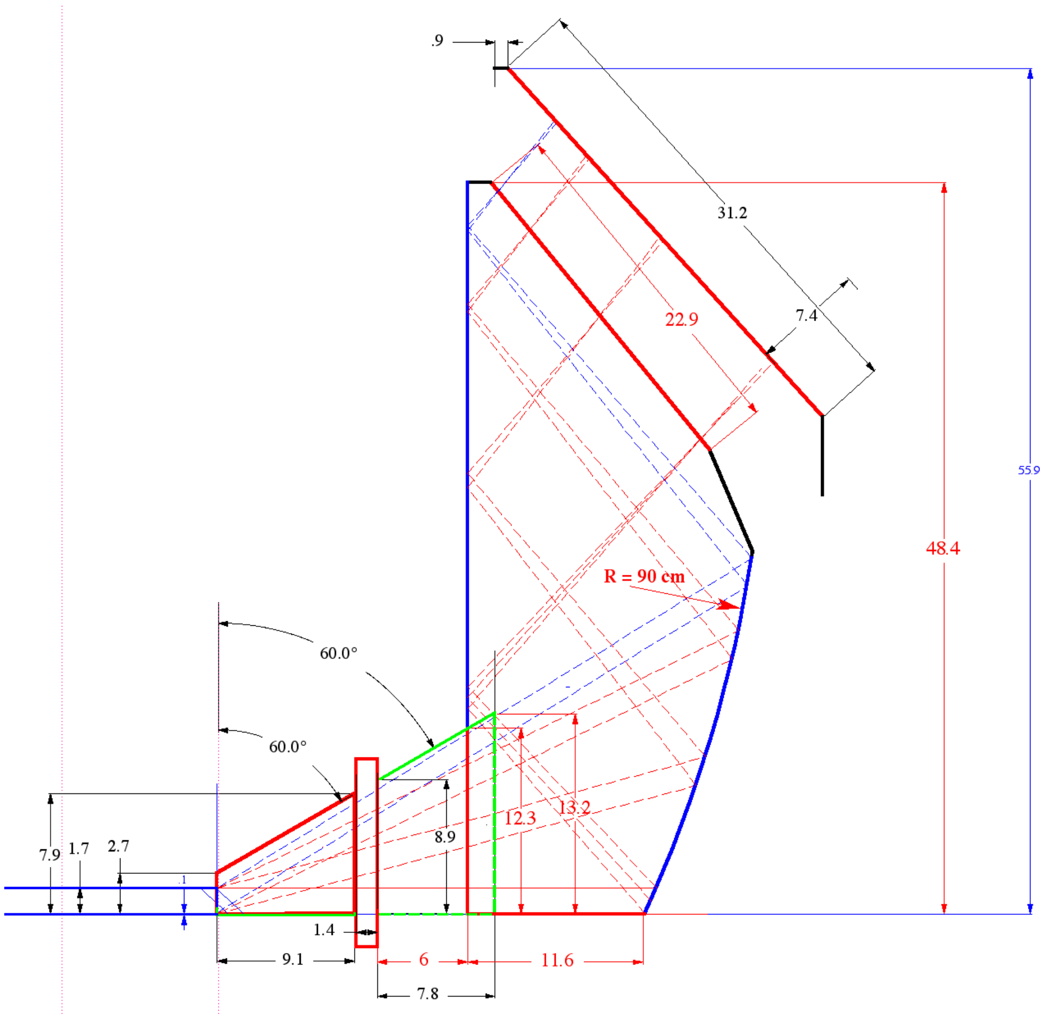


Ray tracing design:



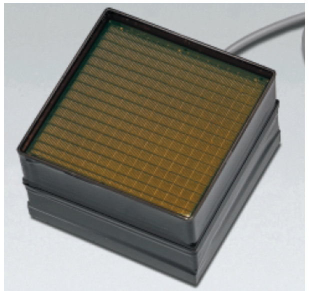
- Smaler FBLOCK, cylindrical mirror, and smaller detector image plane.
- BaBar bar box without any changes. Old wedge has 6mrads angle.

New smaller FDIRC design #1 vs. SuperB FDIRC



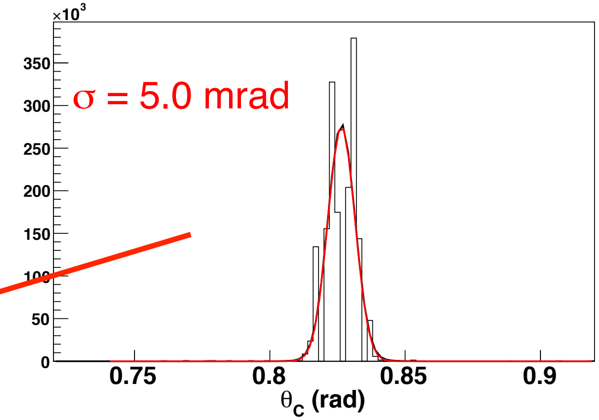
- **New FDIRC represents a considerable reduction in size, roughly a factor of two in volume.**

New design #1: 3 mm pixels

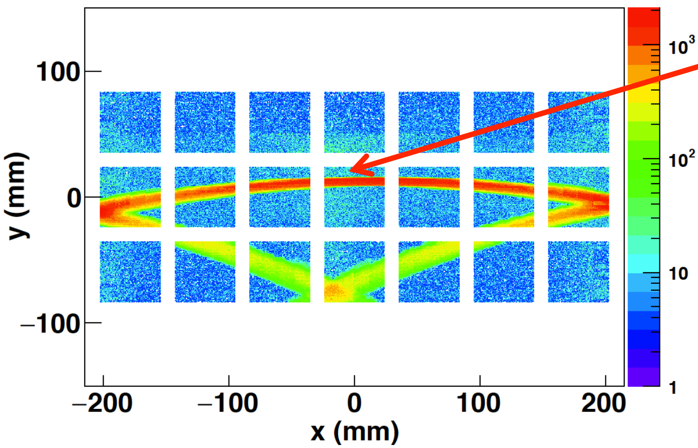


Combine 4 pixels
in x-direction

Just central part
of the ring:

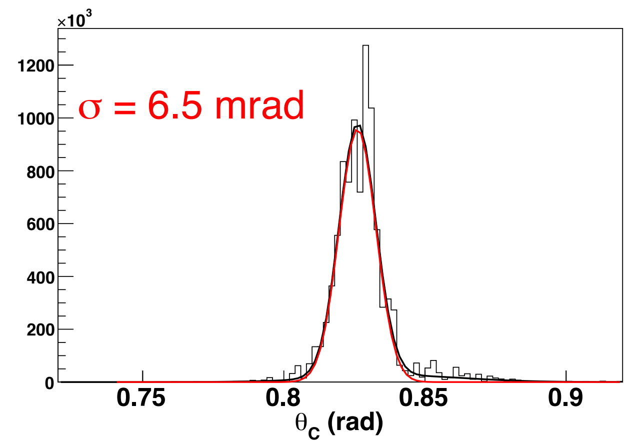


Cherenkov ring x-y image in FDIRC:
(show individual hits)



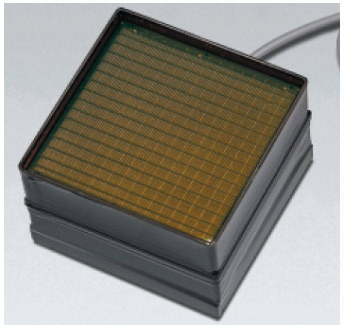
Only 3 rows used
(can be corrected)

Entire ring:



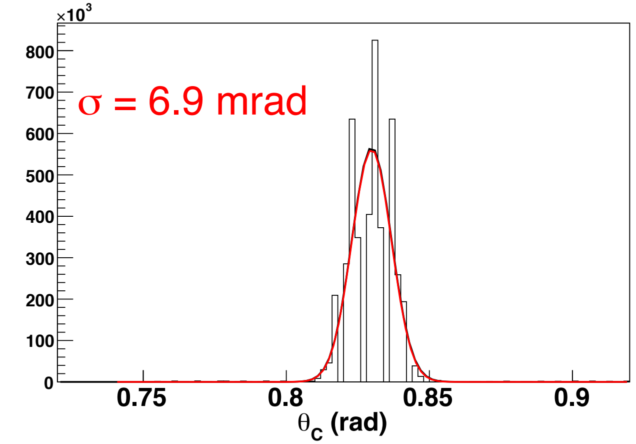
- Pixel sizes: 3 x 12 mm.
- 10 GeV muons at normal incidence.
- Single photon resolutions for backward going photons.
- One can see a double image due to the old wedge design in the bar box.
- The ring resolution broadening is due to the kaleidoscopic effect in DIRC.

New design #1: 3 mm pixels

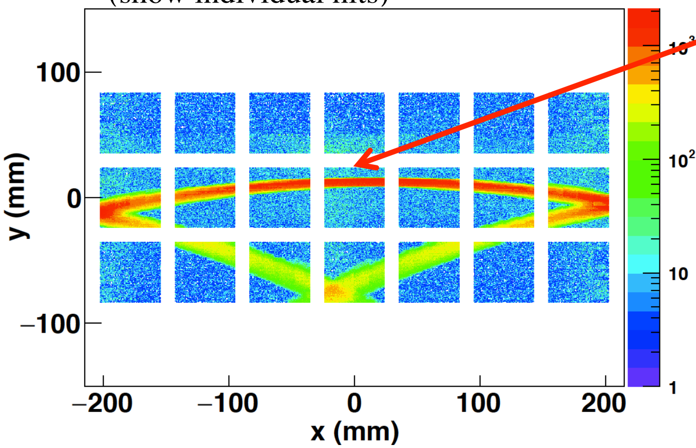


Combine 4 pixels in x-direction

Just central part of the ring:

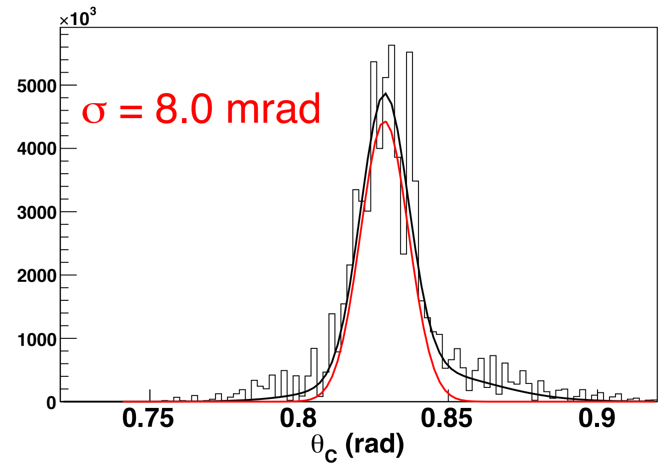


Cherenkov ring x-y image in FDIRC:
(show individual hits)



Only 3 rows used (can be corrected)

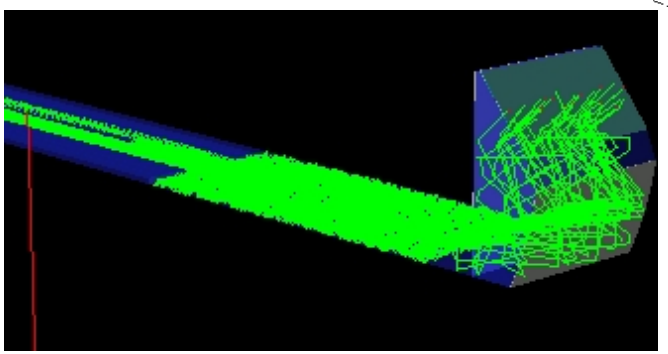
Entire ring:



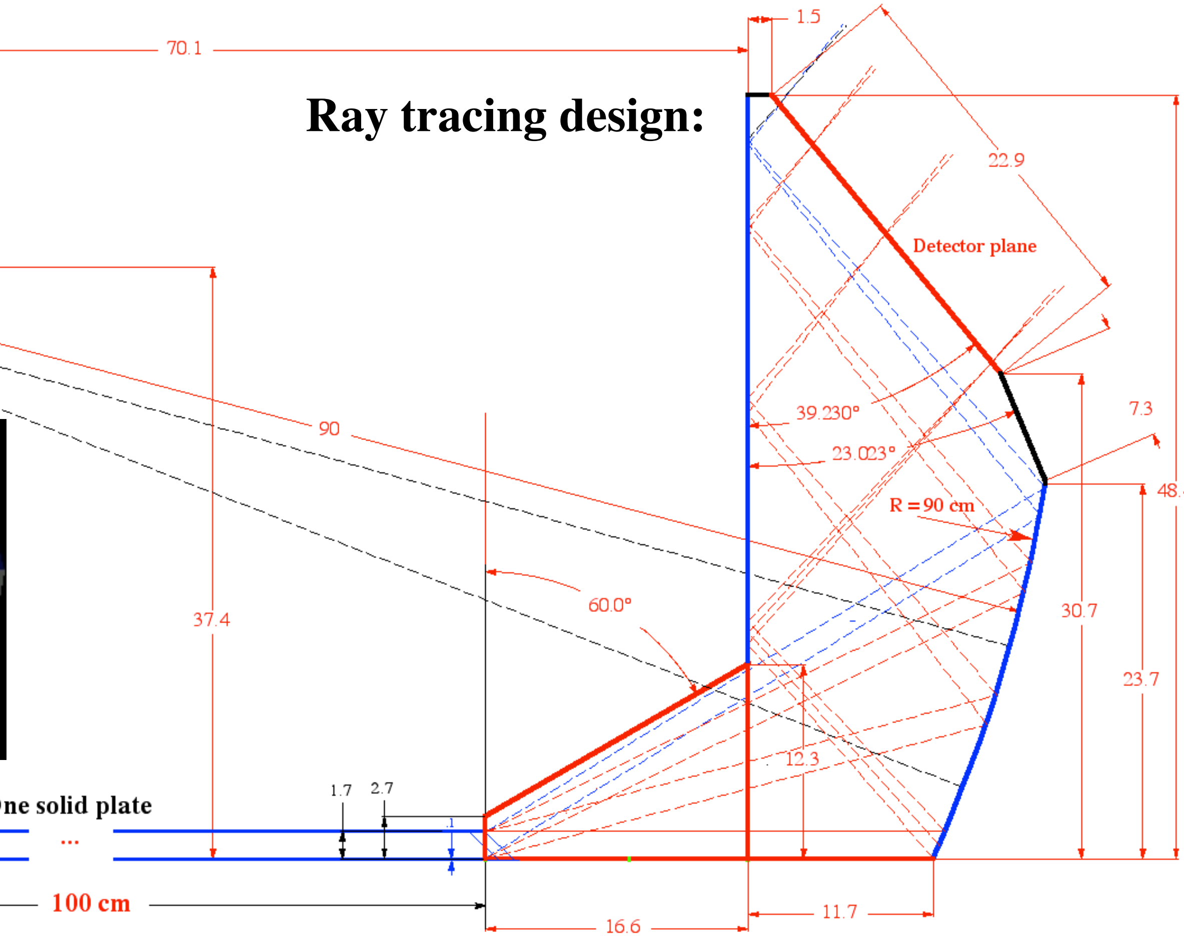
- **Pixel sizes: 3 x 12 mm.**
- **10 GeV muons at normal incidence.**
- **Single photon resolutions for forward going photons.**
- **One can see a double image due to the old wedge design in the bar box.**
- **The ring resolution broadening is due to the kaleidoscopic effect in DIRC.**

New design #2 with a plate and small FBLOCK

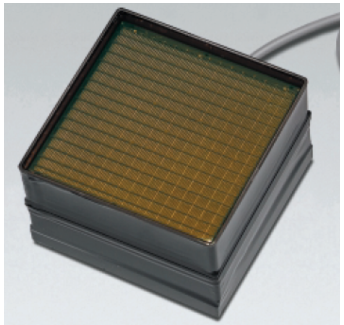
MC simulation:



Ray tracing design:



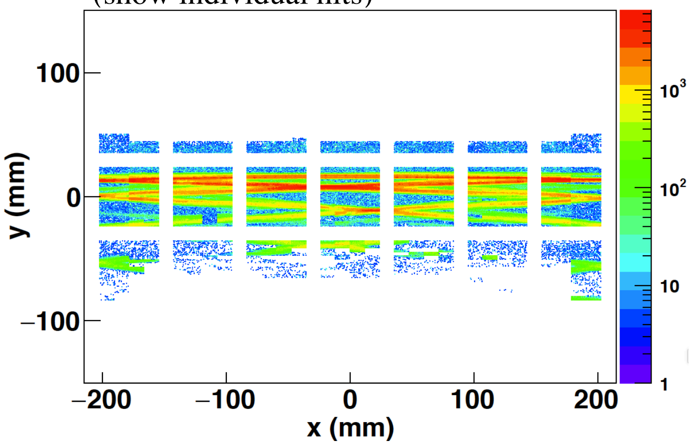
- **Babar bar box is modified: the last group of bars is replaced by a 1m-long wide plate.**
- **New wedge without 6 mrads angle, which was used by old BaBar old wedge.**



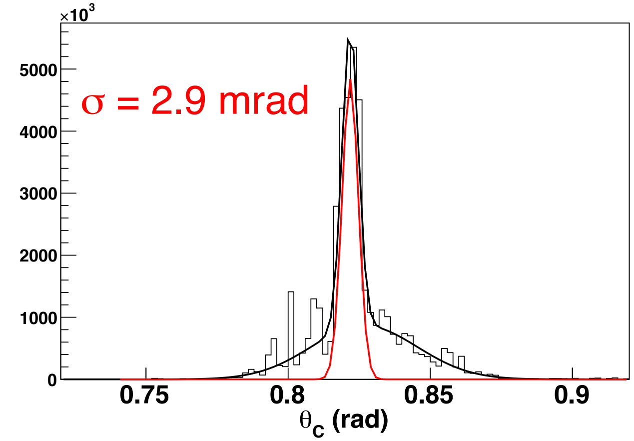
New design #2 with a plate

Combine 4 pixels
in x-direction

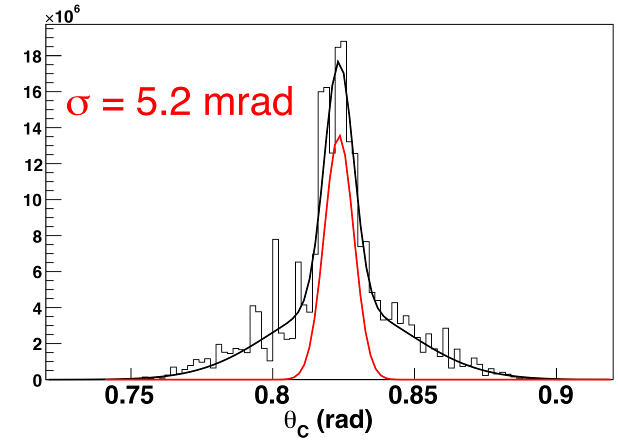
Cherenkov ring x-y image in FDIRC:
(show individual hits)



Entire ring backward:



Entire ring forward:



- Pixel sizes: 3 x 12 mm.
- 6 mrad angle on old wedge in BaBar box removed in this design.
- 10 GeV muons at normal incidence.
- This design provides the best resolution, however, we do see larger tails.
- Probably this plate design might be better suited for a time-based analysis.

Conclusions

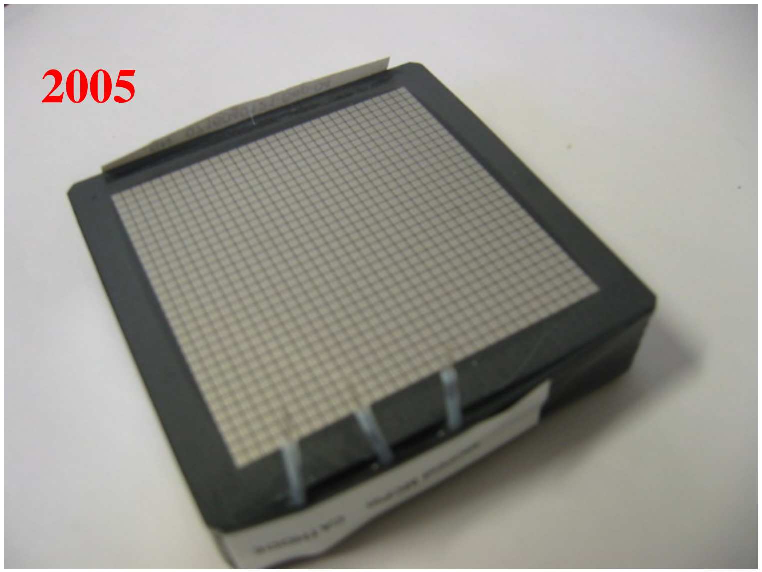
- **SuperB FDIRC design with 3mm x 12mm pixels is providing very good resolution.**
- **New FDIRC design with the smaller FBLOCK would do equally well with smaller 3mm x 12mm pixels, and it would safe money for quartz material.**
- **New FDIRC design with smaller 3mm x 12mm pixels and a combination of old DIRC bars coupled to a plate gives the best Cherenkov angle resolution.**

- **Results are still very preliminary.**

Appendix

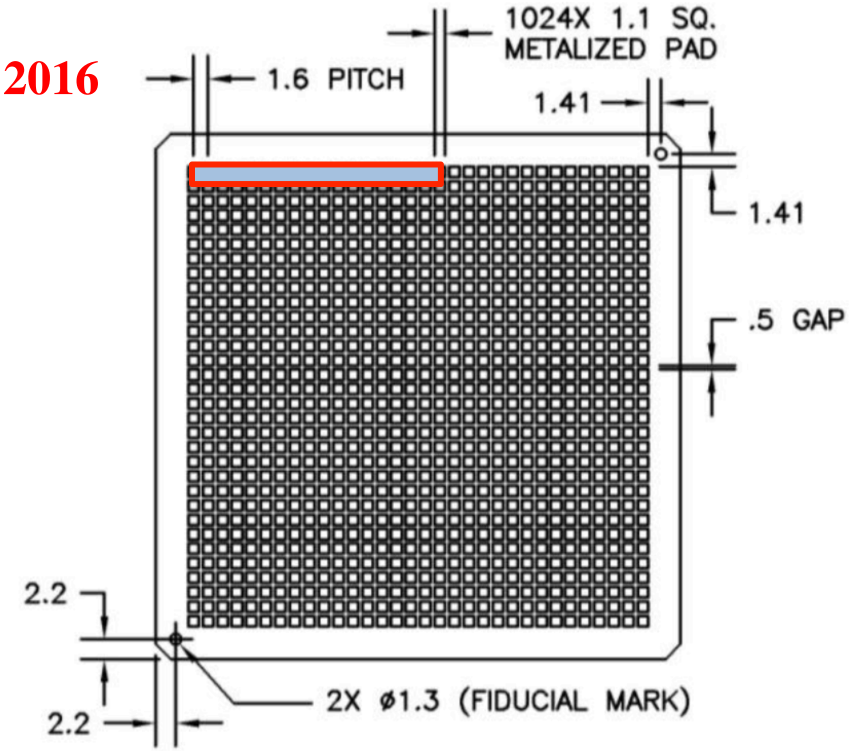
Detectors with smaller pixels

Burle Planacon 1024-pixel MCP-PMT:



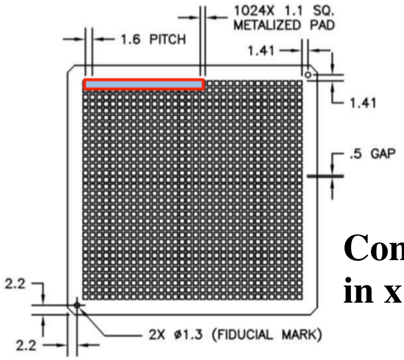
Photoniswith 1024-pixel XP-85022 MCP-PMT:

2016



- **Modify Photonis 1024-pixel detector into a 64-pixel detector by combining 24 pixels in the x-direction into a new pattern of with 1 x 24 small pixels.**
- **This is to use a 64-channel electronics.**

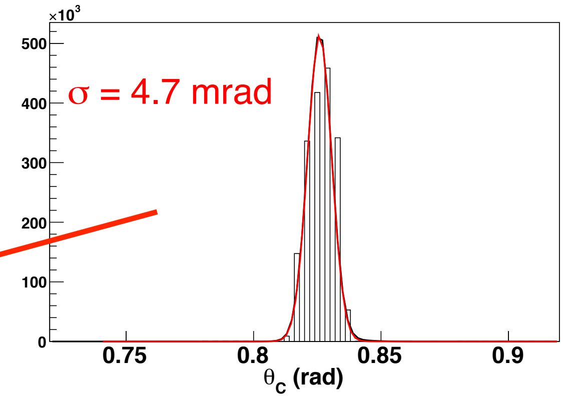
Photoniswith 1024-pixel XP-85022 MCP-PMT:



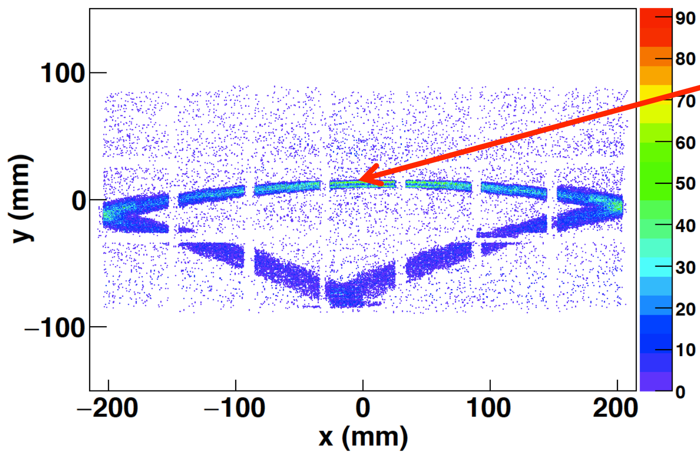
New design #1: 1.6 mm pixels

Combine 24 pixels in x-direction

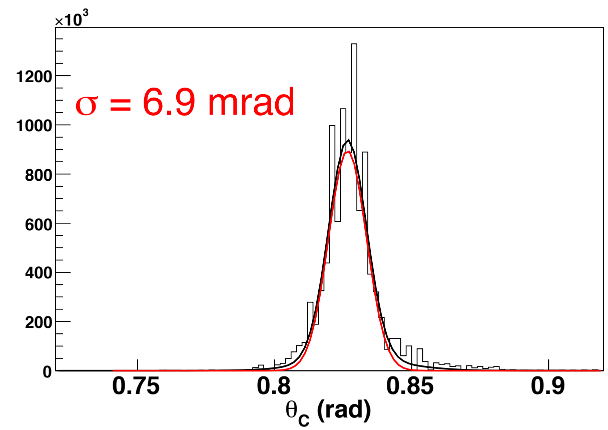
Just central part of the ring:



Cherenkov ring x-y image in FDIRC:
(assume infinite resolution)

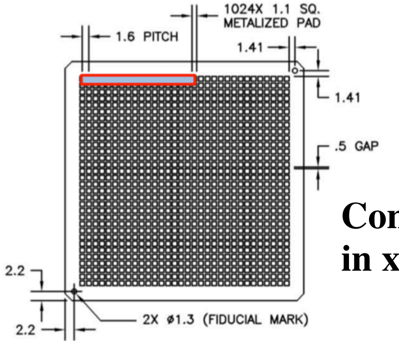


Entire ring:



- **Pixel sizes: 1.6 x 25.6 mm.**
- **10 GeV muons at normal incidence.**
- **Single photon resolutions for backward going photons.**
- **The resolution broadening is due to the kaleidoscopic effect.**
- **One can see a double image due to the old wedge design in the bar box.**

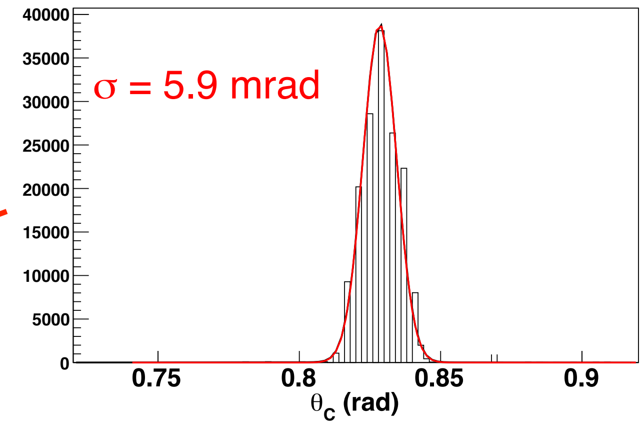
Photoniswith 1024-pixel XP-85022 MCP-PMT:



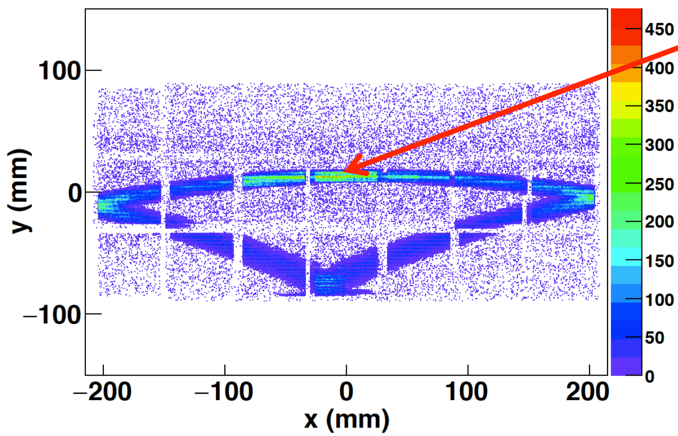
New design #1: ~1.6 mm pixels

Combine 24 pixels in x-direction

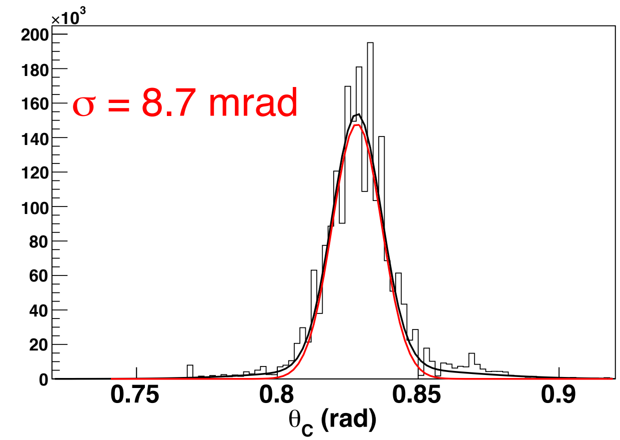
Just central part of the ring:



Cherenkov ring image in FDIRC:



Entire ring:



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