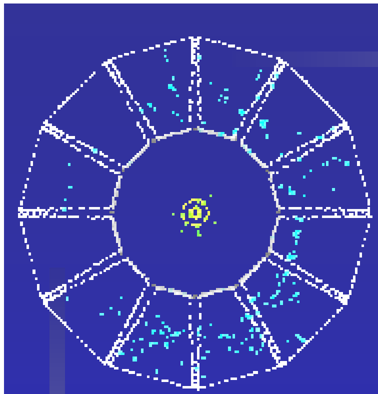
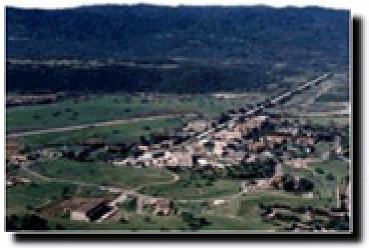


Timing and Detection Efficiency Properties of Multi-Anode PMTs for a Focussing DIRC

Outline:

- Motivation
  - R&D for upgrade of BaBar-DIRC
- Setup
  - Hamamatsu flat-panel PMT
  - Burle MCP
- Results
- Focusing DIRC Prototype and Test Beam Plans

Jochen Schwiening

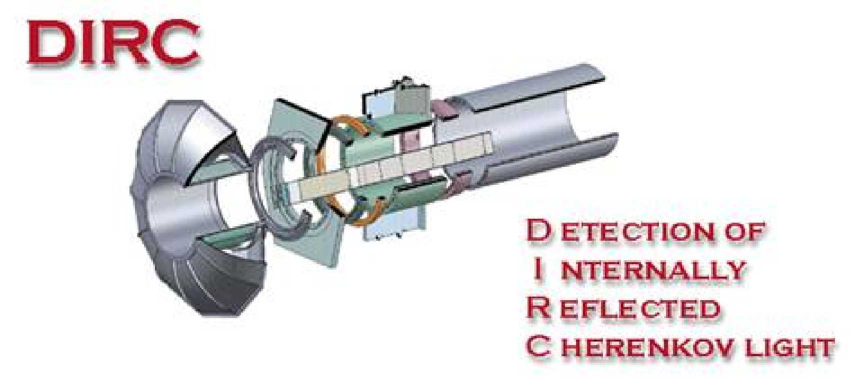


Stanford Linear Accelerator Center

A national laboratory funded by the Department of Energy

INTRODUCTION

Context:



SLAC group EB involved in design, construction, operation of BABAR-DIRC, novel[§] RICH detector, hadronic particle identification system for BABAR.

R&D program for compact, faster photon detection to further improve performance of BABAR-DIRC system at higher luminosity B factory
→ Focusing DIRC Prototype

Group of people working on R&D project at SLAC:

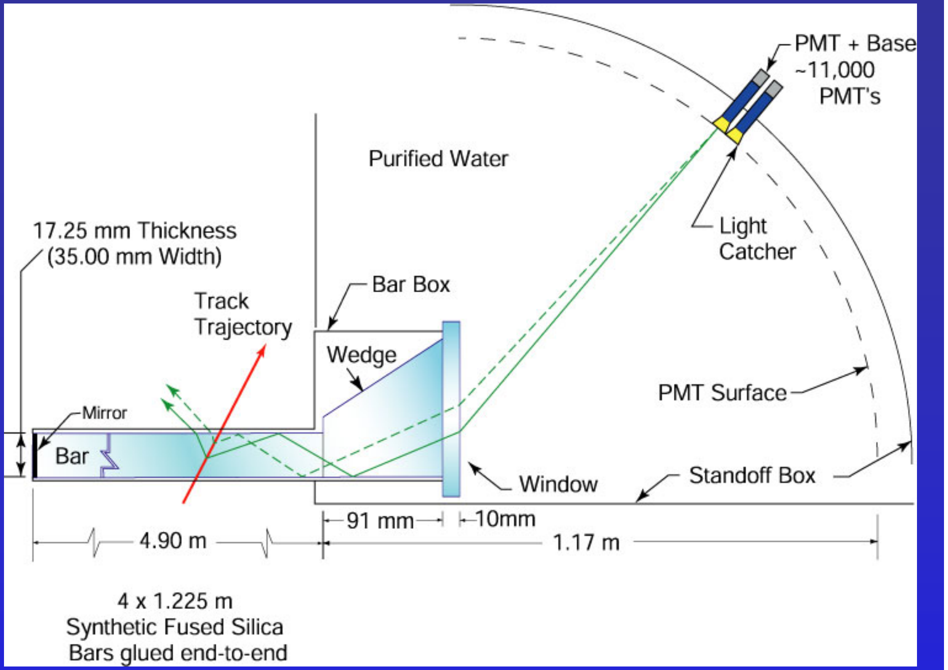
- R. Clive Field
- Mayank Jain
- Francisco LePort
- Blair N. Ratcliff
- Jochen Schwiening

- Thomas Hadig
- David W.G.S. Leith
- Gholam Mazaheri
- Aakash Sahai
- Jaroslav Va’vra

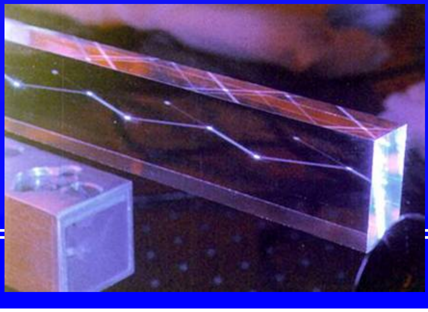
[§] *B.N. Ratcliff, SLAC-PUB-6047 (Jan. 1993)*

DIRC PRINCIPLE

- A charged particle traversing a radiator with refractive index n with $\beta = v/c > 1/n$ emits Cherenkov photons on cone with half opening angle $\cos\theta_c = 1/n\beta$.
- If $n>\sqrt{2}$ some photons are always totally internally reflected for $\beta\approx 1$ tracks.
- Radiator and light guide: Long, rectangular Synthetic Fused Silica (“Quartz”) bars
  (*Spectrosil:* average $\langle n(\lambda)\rangle \approx 1.473$, radiation hard, homogenous, low chromatic dispersion)



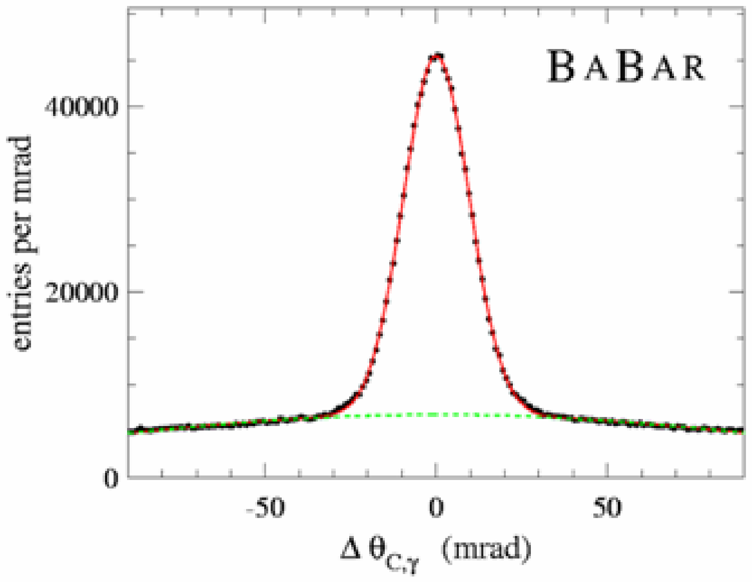
- Photons exit via wedge into expansion region (filled with $6\,m^3$ pure, de-ionized water).
- Pinhole imaging on PMT array (bar dimension small compared to standoff distance).
  (10,752 traditional PMTs ETL 9125, immersed in water, surrounded by hexagonal “light-catcher”, transit time spread ~1.5nsec, ~30mm diameter)
- DIRC is a 3-D device, measuring: x, y and <u>time</u> of Cherenkov photons, defining θ_c, ϕ_c, $t_{propagation}$ of photon.



BABAR-DIRC PERFORMANCE

BABAR-DIRC successful, essential to most BABAR physics analyses§.

Resolution, PID performance close to design.



Timing resolution: 1.7ns per photon

Cherenkov angle resolution: 9.6mrad per photon → 2.4mrad per track

Limited currently by:

▪ size of bar image	~4.1mrad	→	▪ focusing optics
▪ size of PMT pixel	~5.5mrad	→	▪ smaller pixel size → multi-anode PMTs
▪ chromaticity (n=n(λ))	~5.4mrad	→	▪ better time resolution → multi-anode PMTs

Could be improved by:

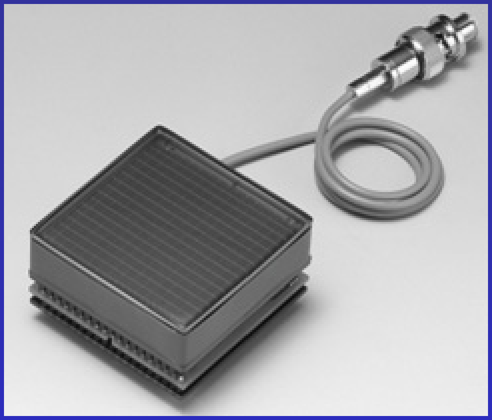
9.6mrad → 4-5mrad per photon → 1.5mrad per track

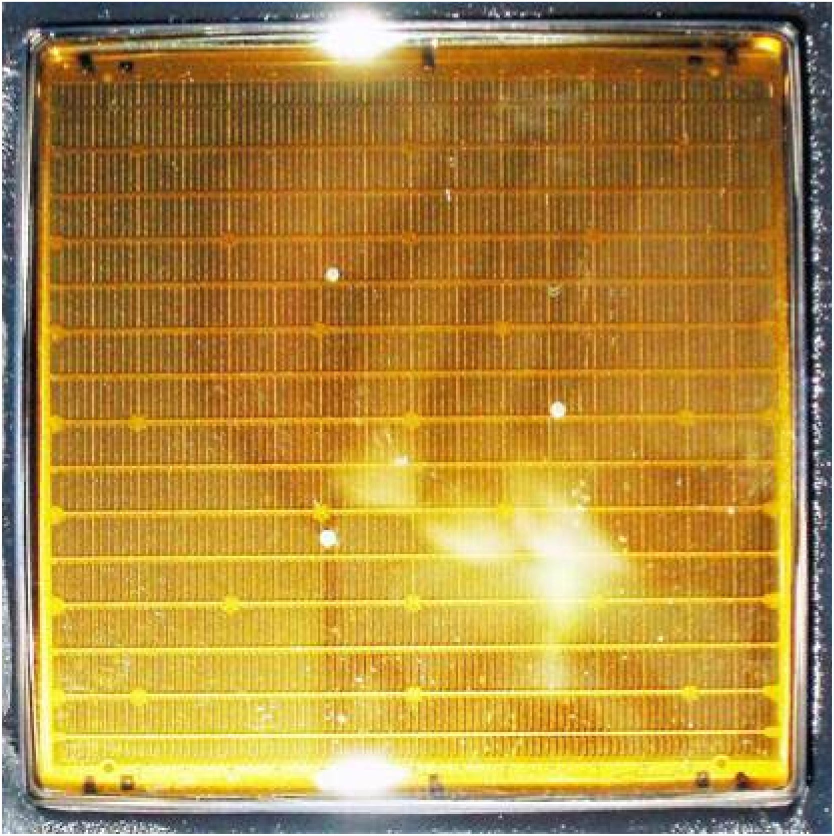
2.7σ → 4.3σ π/K sep. at 4GeV/c

Better time resolution also essential for background suppression at higher luminosities.

§ *J. Schwiening, RICH02, SLAC-PUB-9473 (Aug. 2002)*

HAMAMATSU FLAT-PANEL PMT H-8500



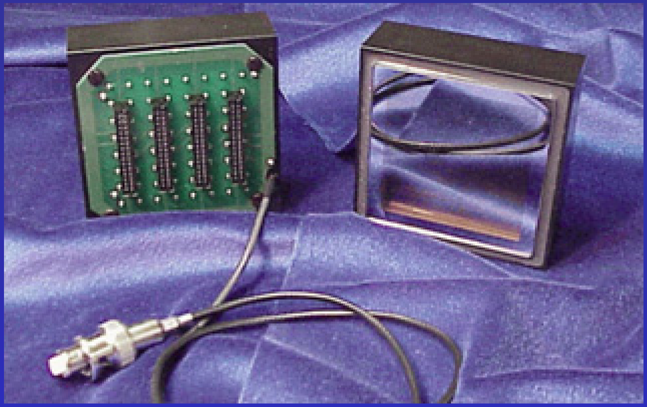


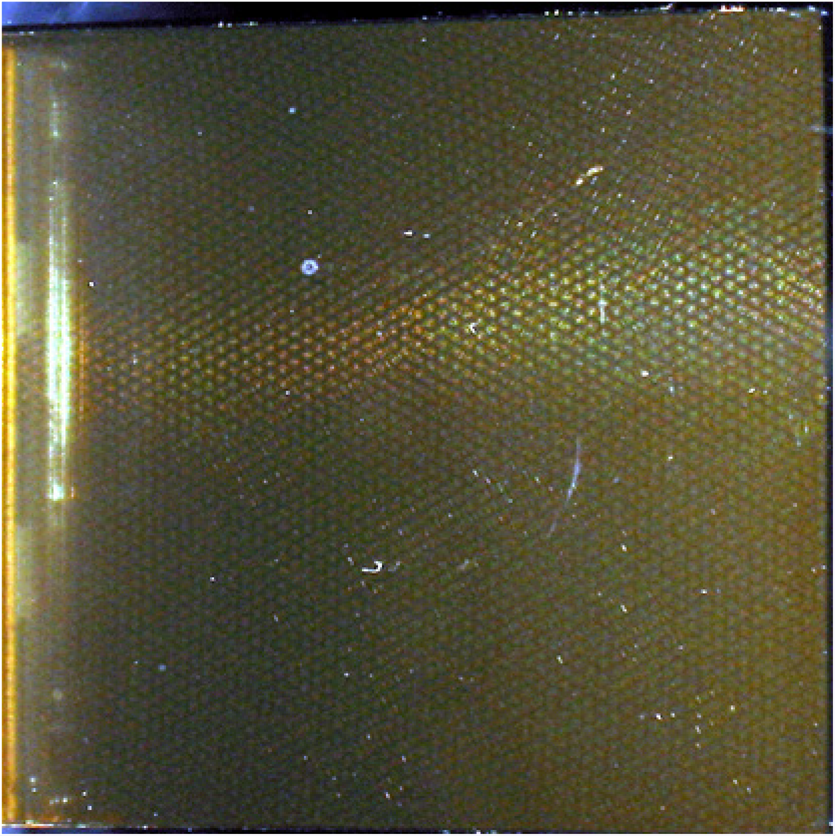
Multi-anode PMT with 64 pads

Photocathode:	Bialkali
Multiplier:	12 stage metal channel dynode
Geometry:	8 x 8 pads 49mm x 49mm effective area 89% packing density
Spectral response:	300nm … 650nm
Gain:	$1 \cdot 10^6$
Cross-talk:	< 3%
Uniformity:	1:3
Transit time spread:	400ps

(from Hamamatsu data sheet)

BURLE MICROCHANNEL PLATE (MCP) 85011-501





Multi-anode PMT with 64 pads

Photocathode:	Bialkali
Multiplier:	25µm pore MCP
Geometry:	8 x 8 pads 51mm x 51mm effective area 67% packing density
Spectral response:	165nm … 660nm
Gain:	$0.5 \cdot 10^6$
Uniformity:	1:1.25
Transit time spread:	50-60ps

(from Burle data sheet)

EXPERIMENTAL SETUP

Two setups used in parallel

Precision Timing
on one pad

PMT Uniformity
on all 64 pads

Light source:

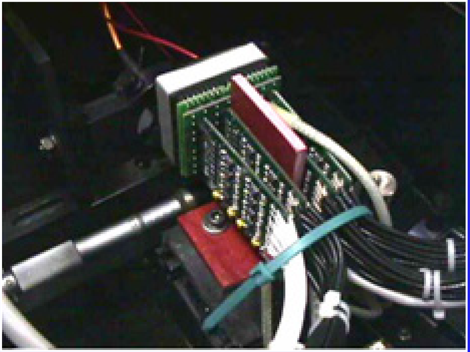
Pilas pico-second laser in single photon mode;
λ=635nm/430nm; pulse jitter FWHM < 35ps/60ps

Amplifier:

Elantec EL2075C,
40x, 2GHz bandwidth
(for MCP added
Philips 779, 10x)

Readout:

double-threshold discriminator
LeCroy 2228A TDC
(22ps per count)



Motion-controlled x/y stage:

typical scan step size 100µm
repeatability < 7µm

Amplifier:

Elantec EL2075C,
40x, 2GHz bandwidth

Readout:

single-threshold discriminator
LeCroy 2277 TDC
(500ps per count)

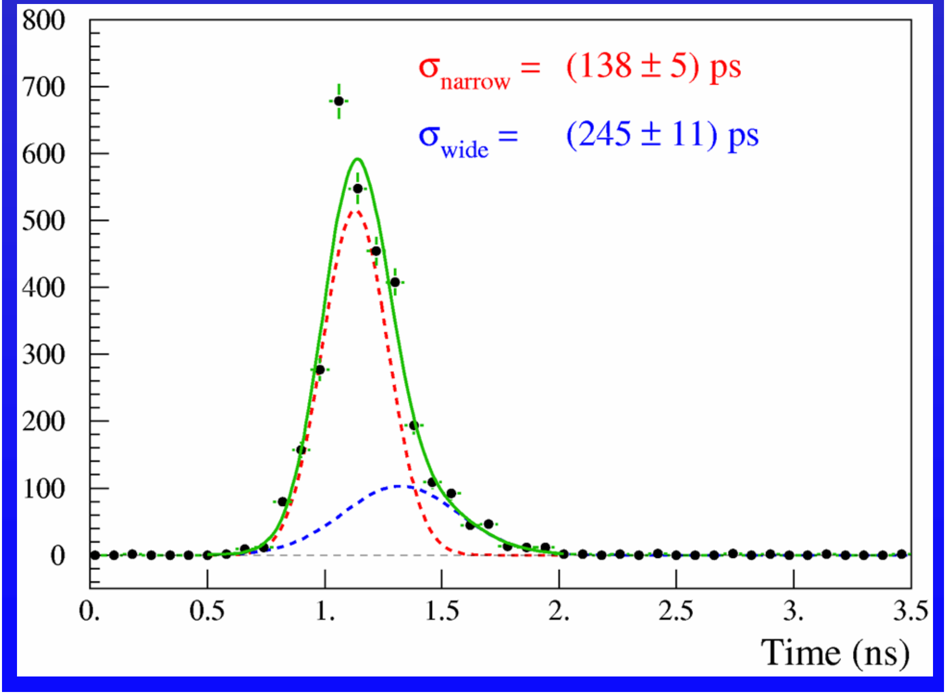
Recent improvements to electronics:
see poster N36-38

RESULTS I: TIMING

Hamamatsu H8500:

σ_{narrow} = 138ps (σ_{wide} = 245ps)

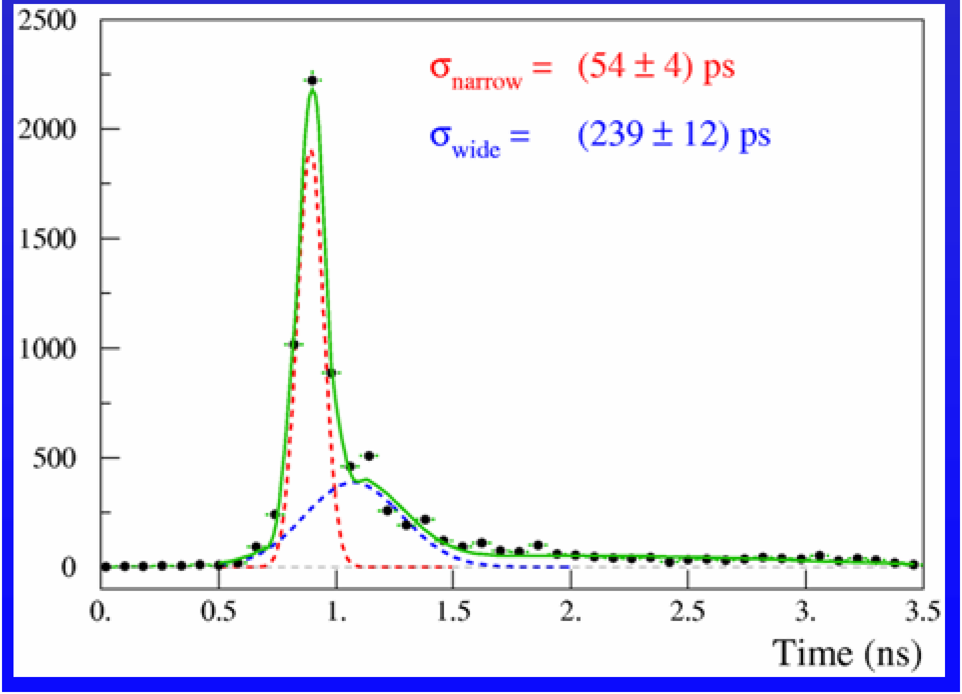
- resolution at upper limit of required precision for chromatic corrections



Burle 85011-501:

σ_{narrow} = 54ps (σ_{wide} = 239ps)

- core resolution excellent match to requirements
- long tail due to recoil electrons



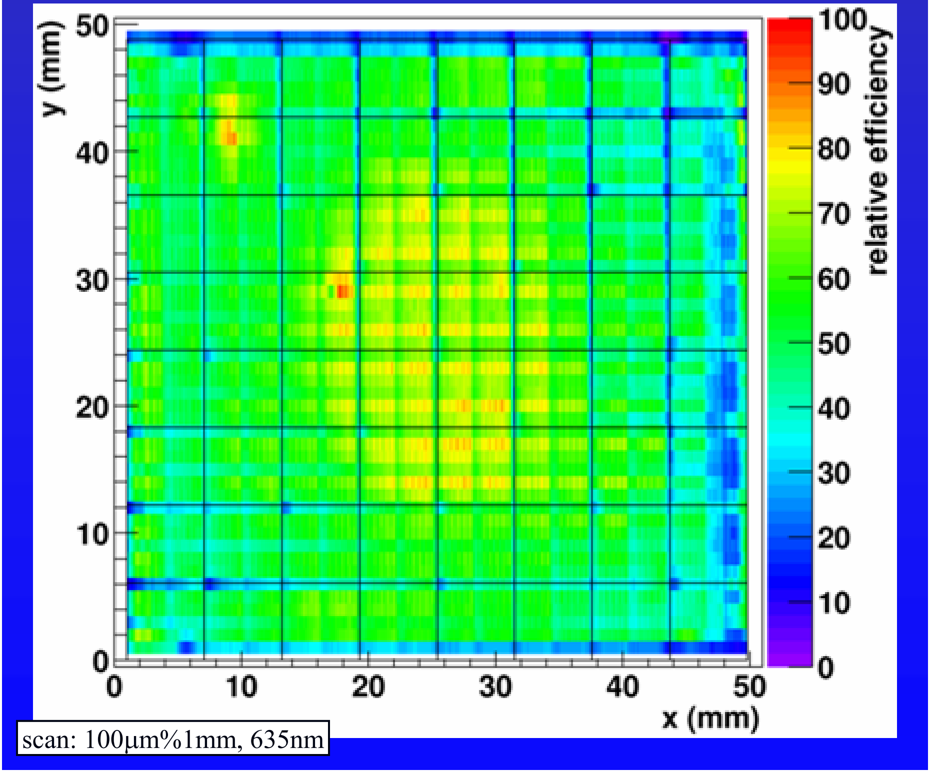
RESULTS II: UNIFORMITY

Detection efficiency measured relative most efficient point on PMT

(convolution of: cathode effic., collection effic., anode effic. spectral effic.)

Hamamatsu H8500 at 635nm:

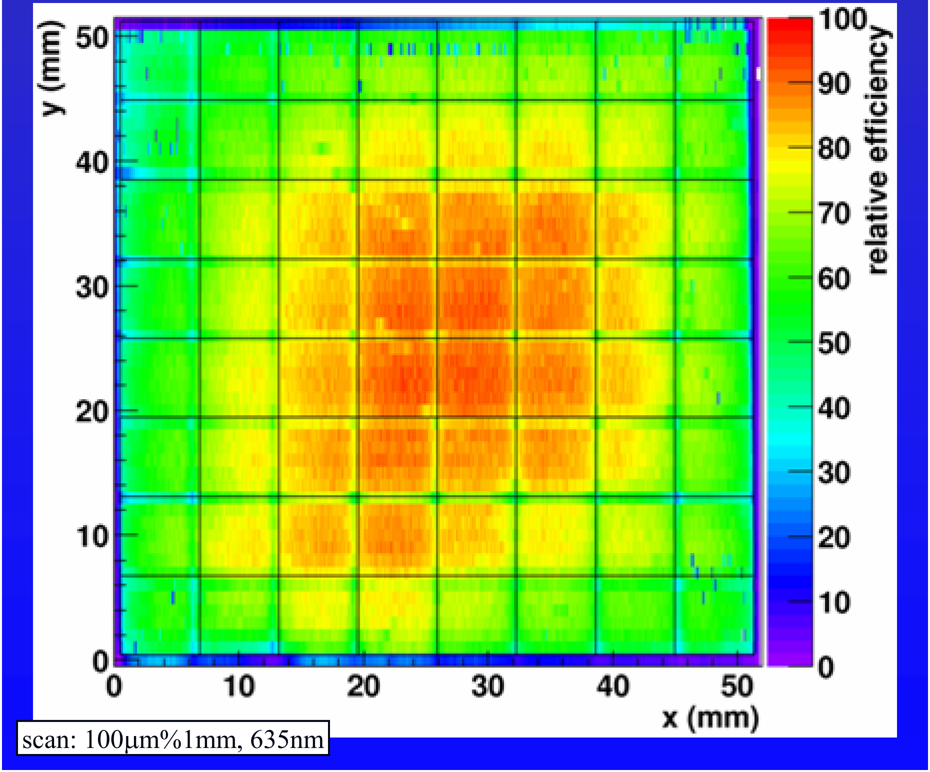
- uniformity ~1:2.5
- variations caused by
  lower gain along the edges



scan: 100µm%1mm, 635nm

Burle 85011-501 at 635nm:

- uniformity ~1:1.5
  - variations caused by
    lower gain along the edges



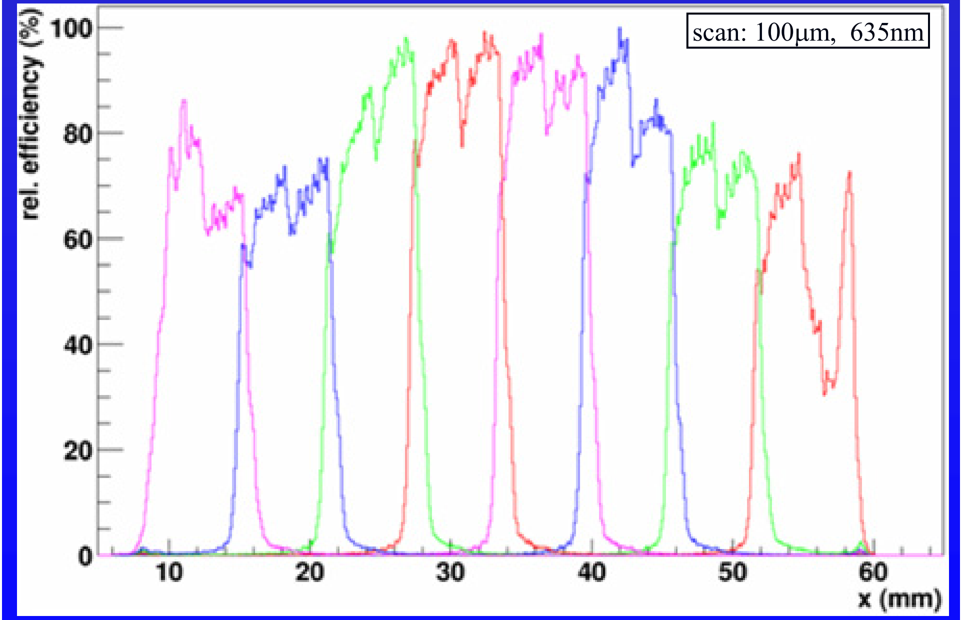
scan: 100µm%1mm, 635nm

RESULTS III: SUB-STRUCTURE

Uniformity variations within one line of the PMT

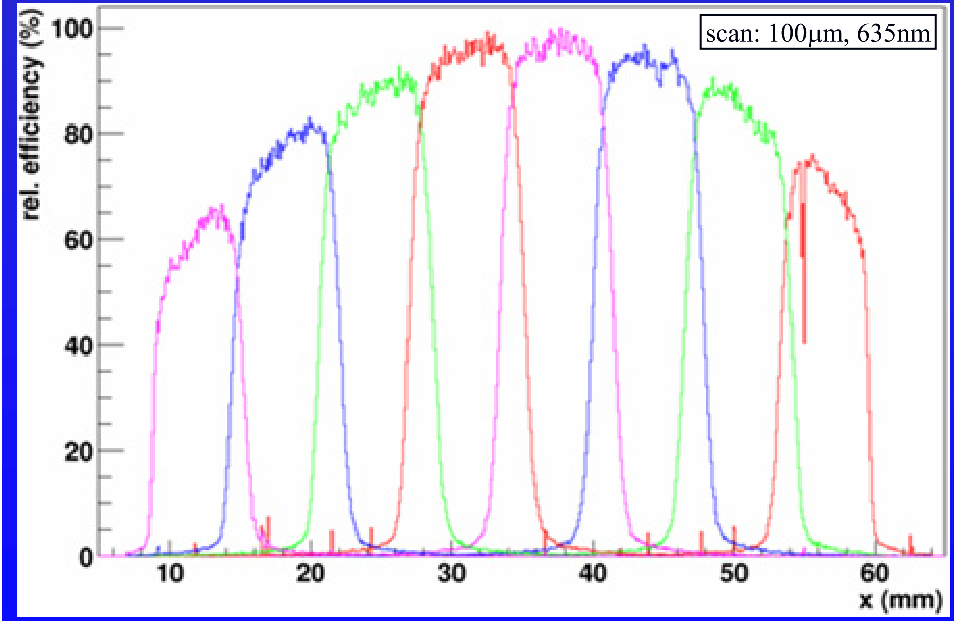
Hamamatsu H8500 at 635nm:

- significant variations from pad to pad
- two main maxima within pad
- slot microstructure clearly visible



Burle 85011-501 at 635nm:

- smooth variations from pad to pad
- no obvious substructure within pad

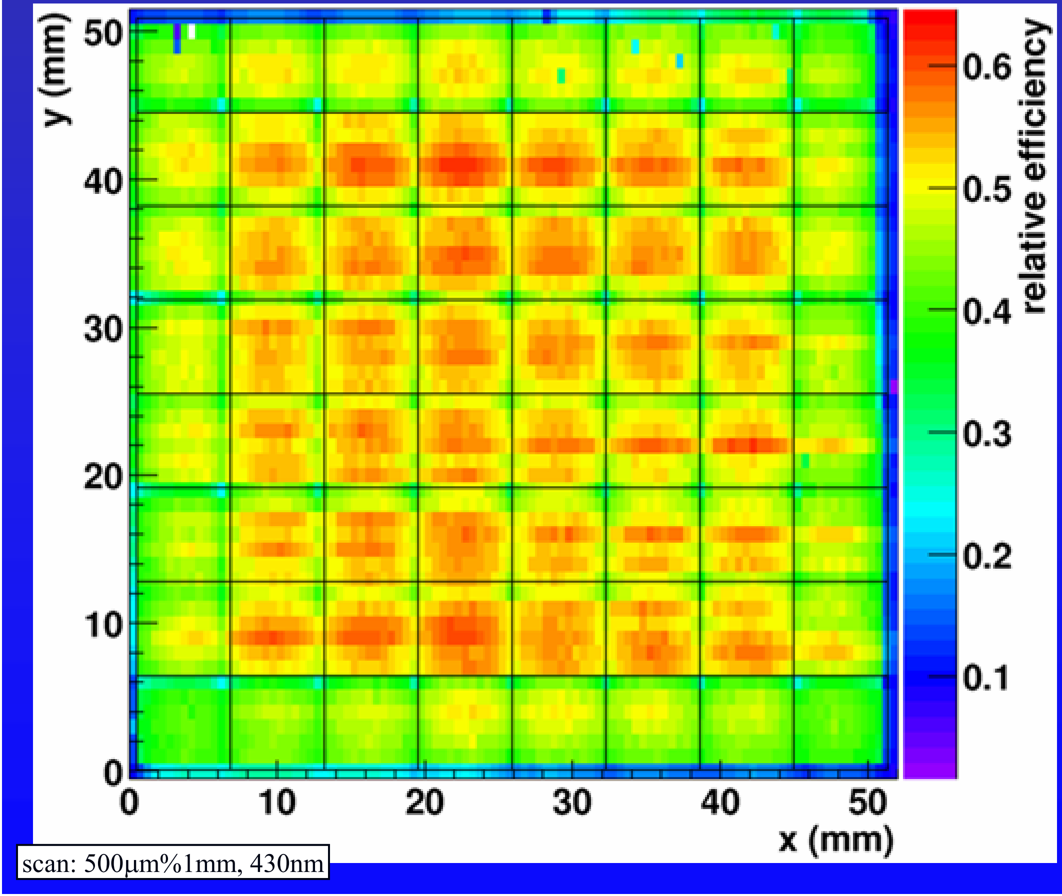


RESULTS IV: EFFICIENCY

Detection efficiency measured relative to DIRC PMT (ETL 9125FLB17)

Burle 85011-501 (ID#3) at 430nm

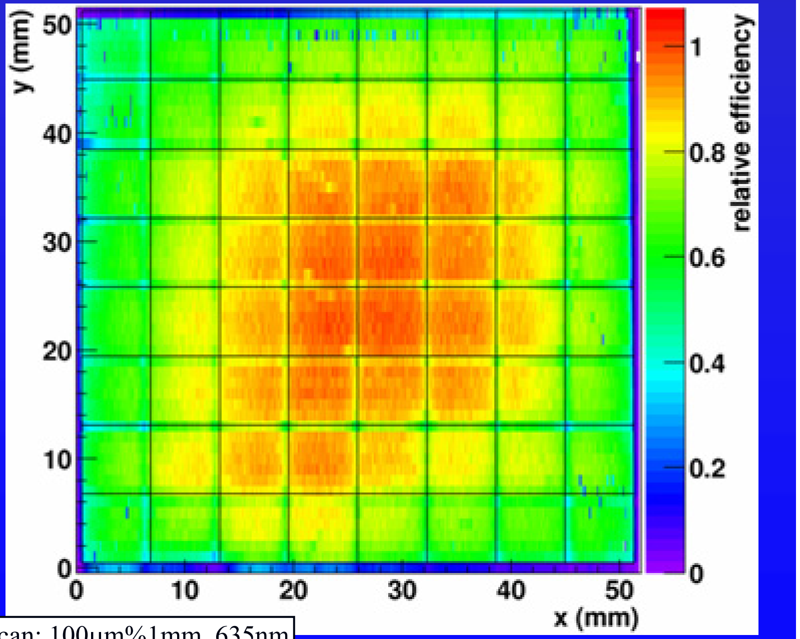
- good uniformity
- efficiency 50-60% of present DIRC PMT



scan: 500µm%1mm, 430nm

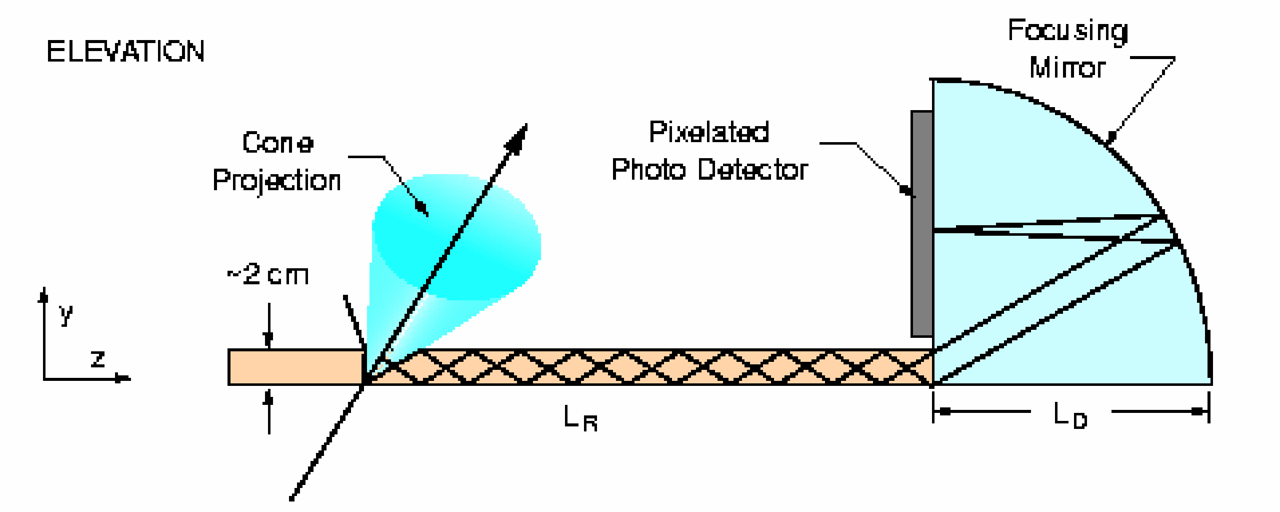
Burle 85011-501 (ID#2) at 635nm

- good uniformity
- efficiency 70-100% of present DIRC PMT



scan: 100µm%1mm, 635nm

R&D FOR FOCUSSING DIRC



- Eliminate effect of bar size with focusing optics.
- Smaller photo detector pixel → better θ_C resolution.
- Decrease size of expansion region (source of accelerator-induced background).
- 50-100ps timing allows partial correction of chromatic effects → better θ_C resolution.
- 50-100ps timing allows tight cuts to suppress background photons.

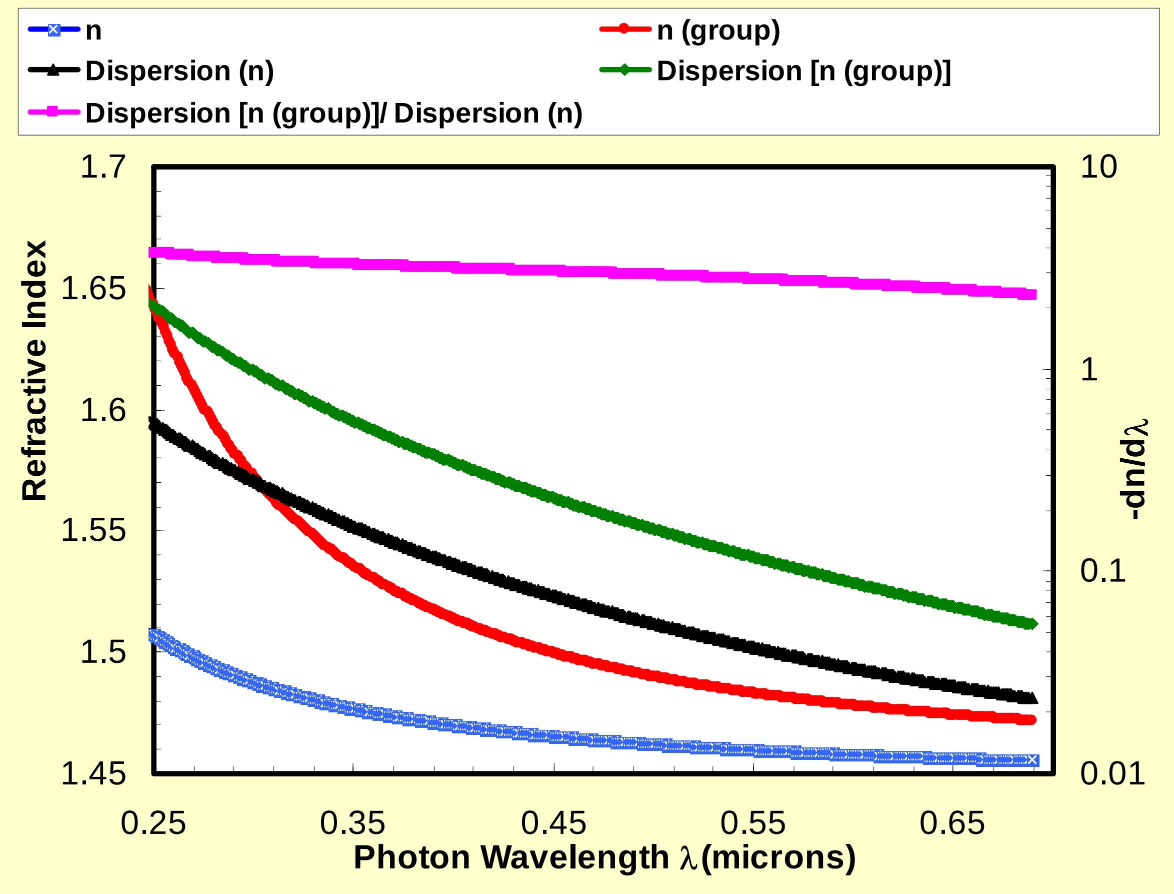
CHROMATIC EFFECTS IN DIRC

Cherenkov photon production - $\cos\theta_c(\lambda) = \dfrac{1}{\beta n(\lambda)}$

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

Time dispersion during photon transport - $v_{phase} \neq v_{group}$

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



Example: Fused Silica Bar
Refr. Index and Dispersion
vs. Wavelength

B.N. Ratcliff, RICH02,
SLAC-PUB-9508 (Sep. 2002)

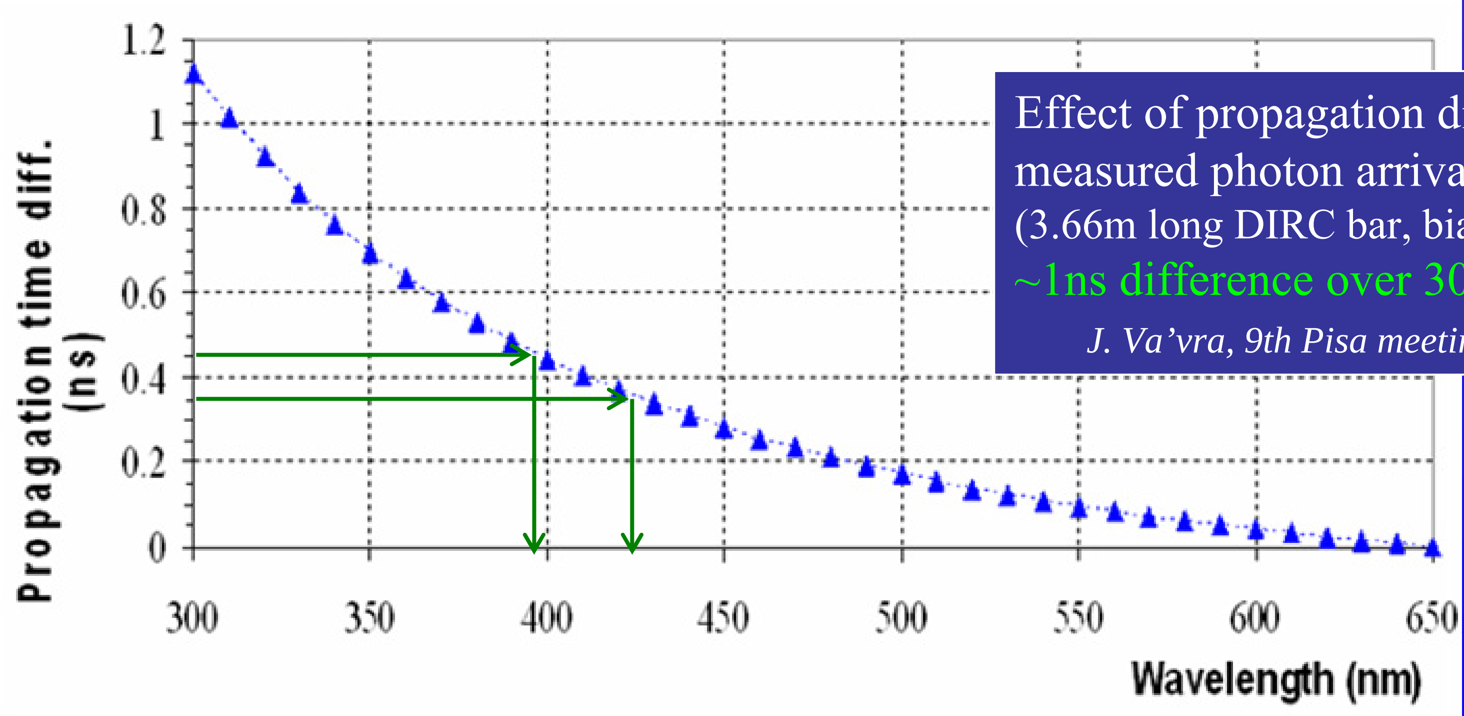
CHROMATIC EFFECTS IN DIRC

Chromatic error ($\theta_C = \theta_C(\lambda)$) so far considered to be irreducible contribution to error on Cherenkov angle measurement.

How can we correct for chromatic effects?

→ use propagation dispersion effect,

→ precision timing, 50-100ps resolution, required to constrain λ, correct θ_C.

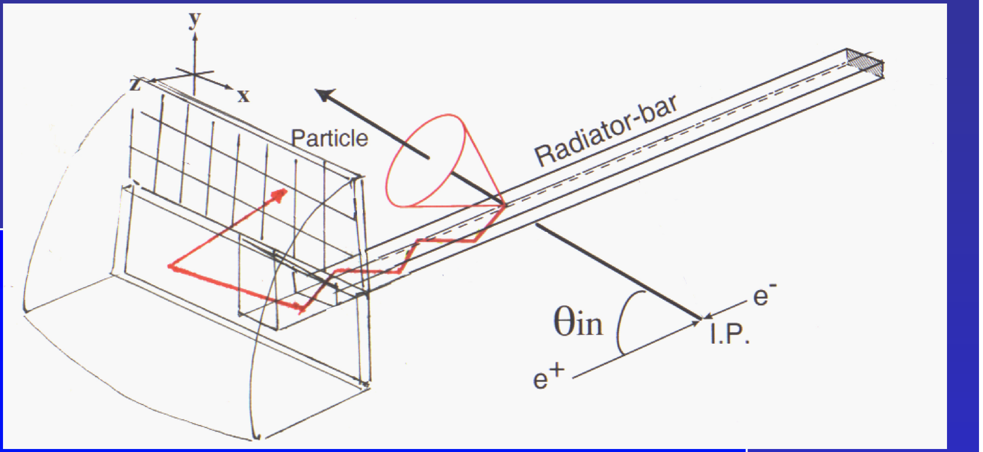


Effect of propagation dispersion on measured photon arrival time (3.66m long DIRC bar, bialkali photocathode):

~1ns difference over 300…650nm range

J. Va'vra, 9th Pisa meeting on advanced detectors

PROTOTYPE FOR FOCUSSING DIRC



- Prototype under construction.
- Single radiator bar (3.66m length)
  made from DIRC radiator bar pieces.
- Spherical mirror for focusing.
- Mineral oil as matching liquid (KamLAND) in expansion region.
- 10 Burle MCPs, 64 channels each;
  combine neighboring channels in x direction.
- 320 TDC channels, 50-100ps resolution per pixel per photon.
- Goal: measure and correct chromatic effects.
- Test beam at SLAC planned for spring 2004.

Stay tuned for IEEE 2004…