Study of Timing and Efficiency Properties of Multi-Anode Photomultipliers

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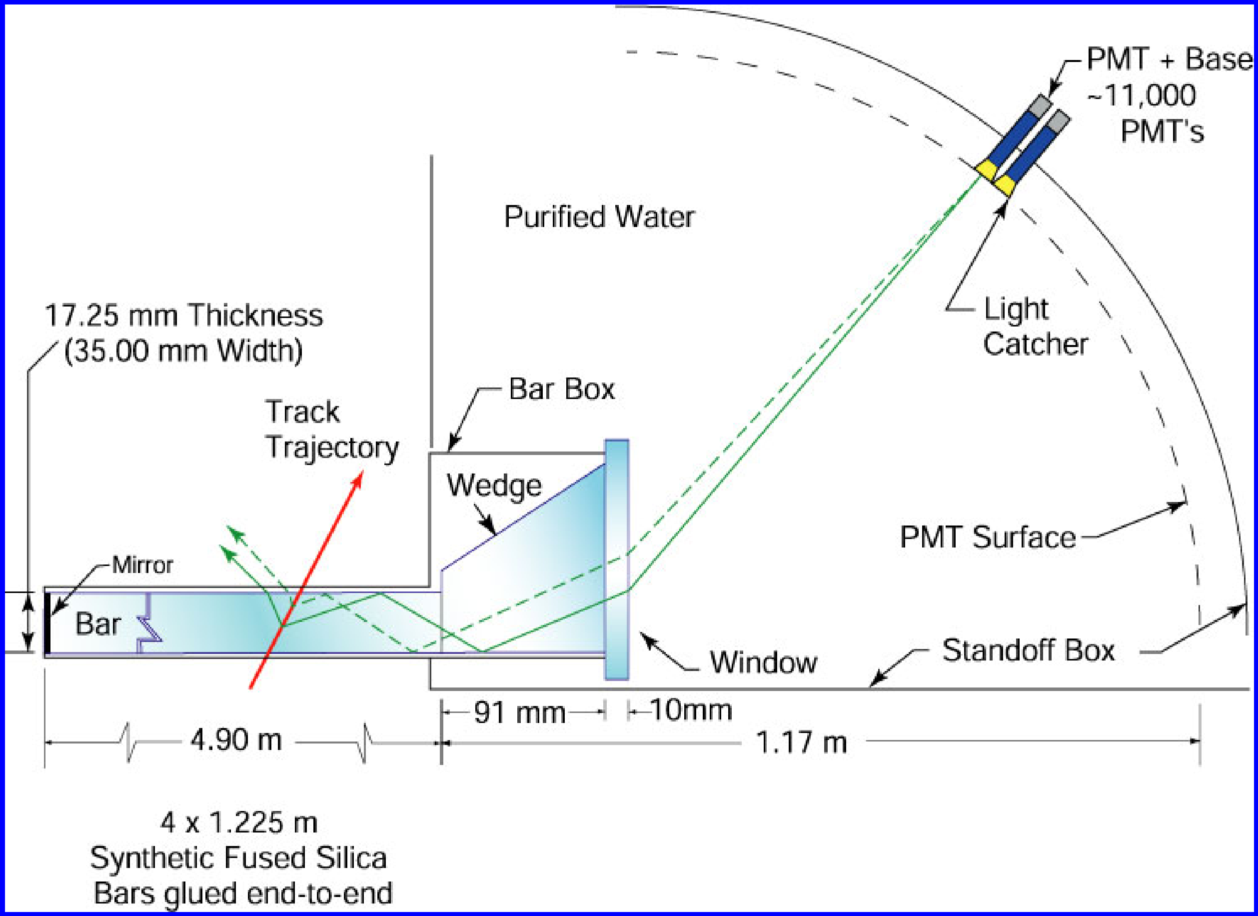
Motivation

Using PMTs in Cherenkov detector:
DIRC particle identification subsystem in BaBar detector



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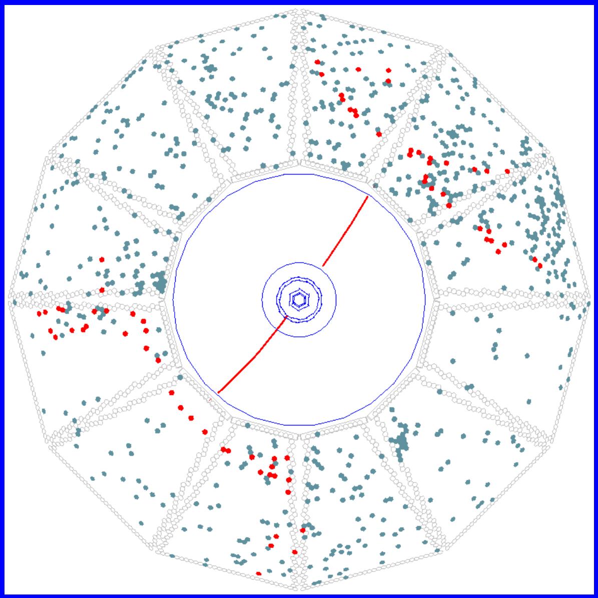
Using PMTs in Cherenkov detector:

DIRC particle identification subsystem in BaBar detector
≈ 11000 EMI 9125FLB17 PMTs,
1.7 ns timing resolution, 30 mm diameter
Measuring PMT position and photon arrival time
Timing mainly used for signal vs. background separation



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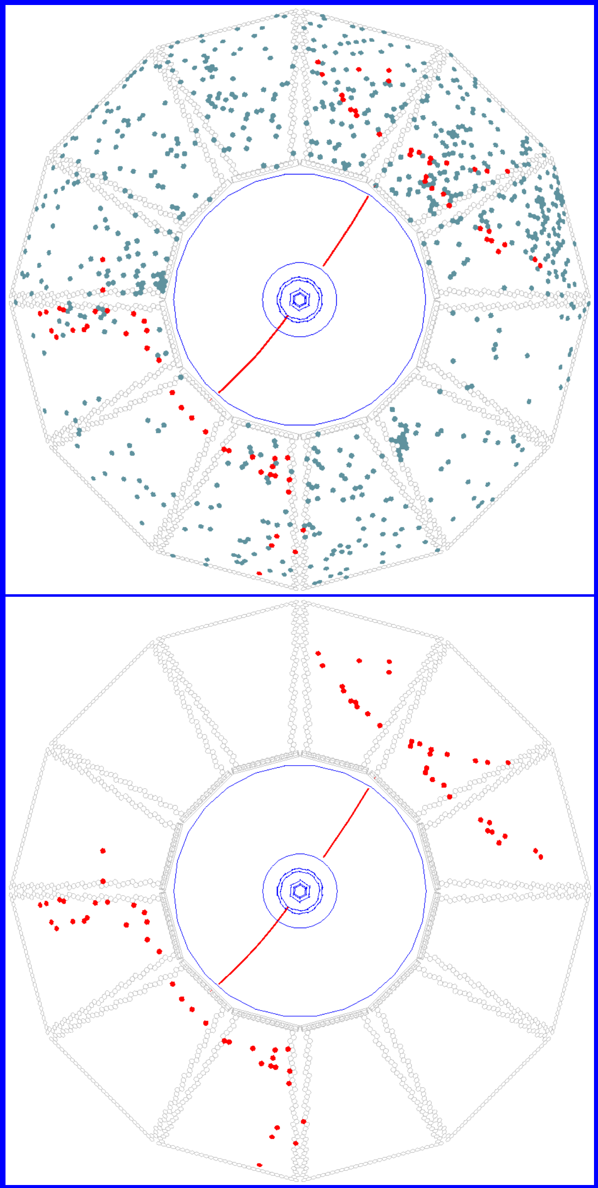

Event display without(top) and with(bottom) time cut

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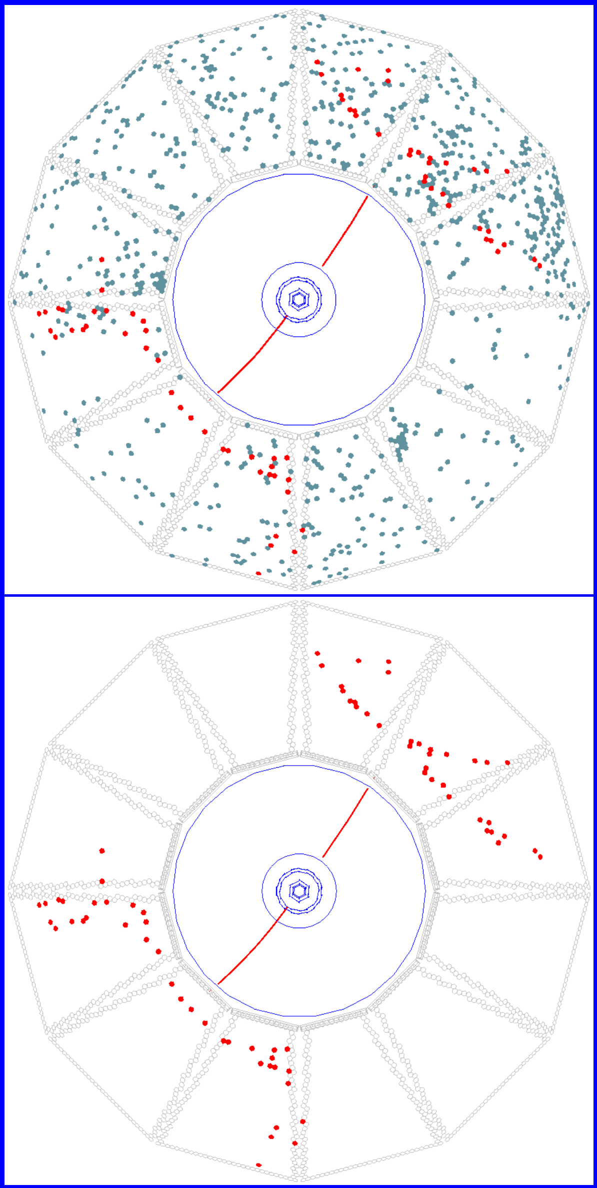
Performance:

	Current limit	**Could be improved by**
size of bar	≈ 4.1 mrad	focusing optics
size of PMT pixel	≈ 5.5 mrad	smaller pixel size
chromaticity		
$n = n(\lambda)$	≈ 5.4 mrad	better time resolution
total single photon	≈ 9.6 mrad	
total per track	≈ 2.4 mrad	



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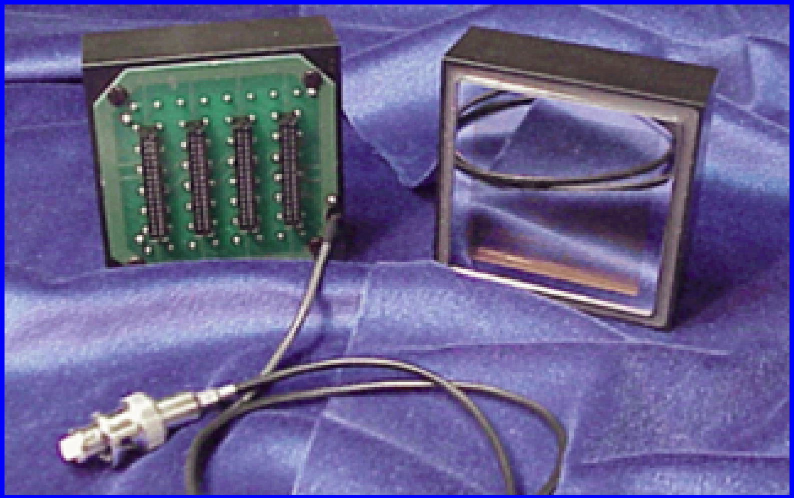
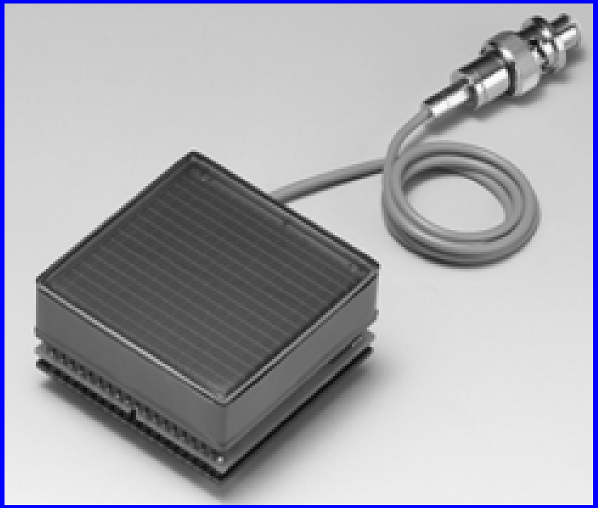
Motivation

	Burle MCP 85011	Hamamatsu PMT H-8500
		
Multiplier	25 μm pore MCP	12 stage metal channel dynode
Effective area	51 mm $\times$ 51 mm	49 mm $\times$ 49 mm
Packing density	67%	89%
Spectral response	165 nm . . . 660 nm	300 nm . . . 650 nm
Gain	0.5×10^6	1×10^6
Uniformity	1: 1.25	1:3
Transit time spread	50 ps . . . 60 ps	400 ps

(all data from company data sheets)

Motion Controlled Setup

Light source

Pilas pico-second laser

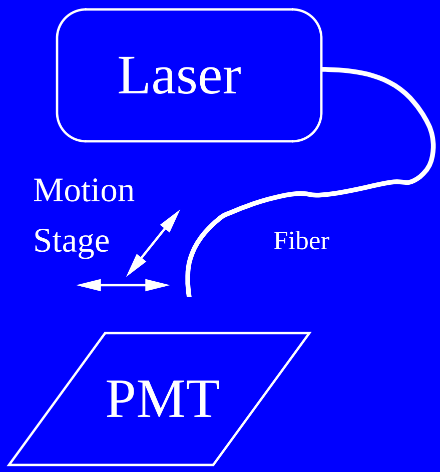
$\lambda = 635$ nm$/430$ nm

σ pulse < 35 ps$/60$ ps

Operated in single photon mode

Motion Controller:

Repeatability $< 7\ \mu$m



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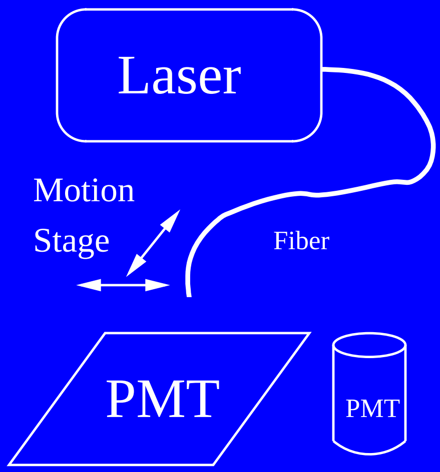

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PMT

Hamamatsu H-8500/Burle MCP-85011

Laser Intensity Monitoring

Two standard PMTs used for calibration

(Photonis XP2262B, EMI 9125FLB17)

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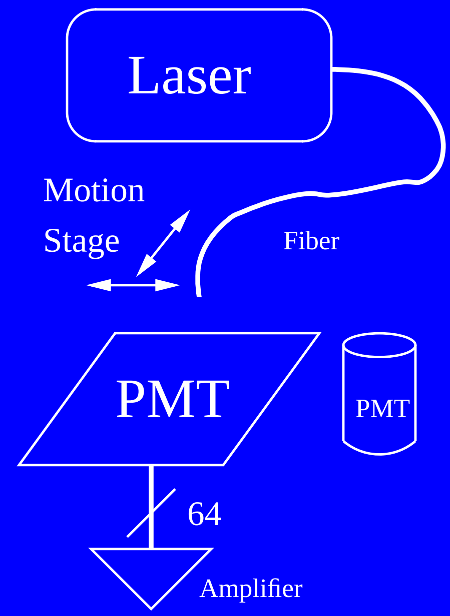

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Amplifier

Elantec, EL2075C, $40\times, 2$ GHz bandwidth

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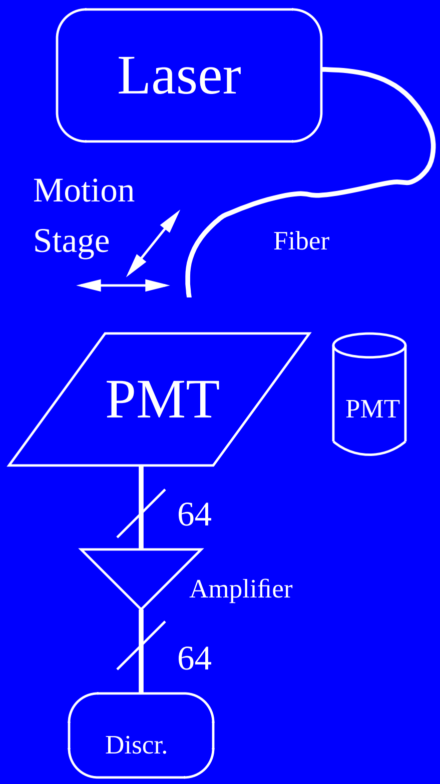

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Single threshold discrimination

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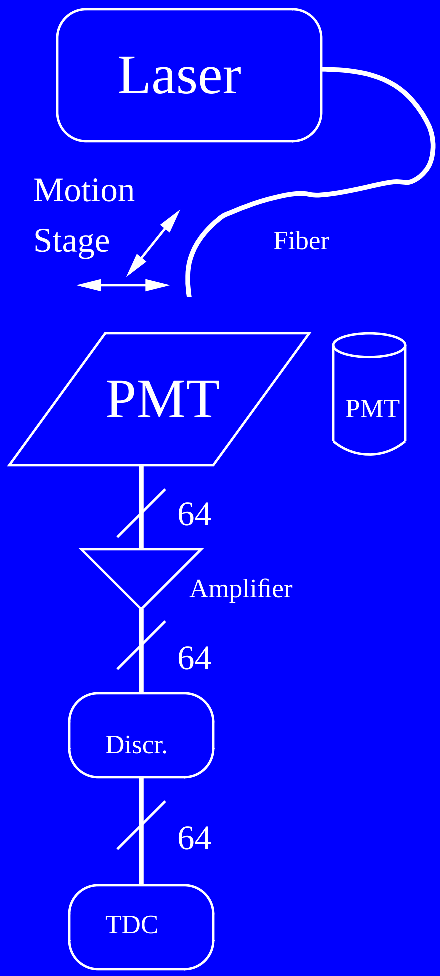
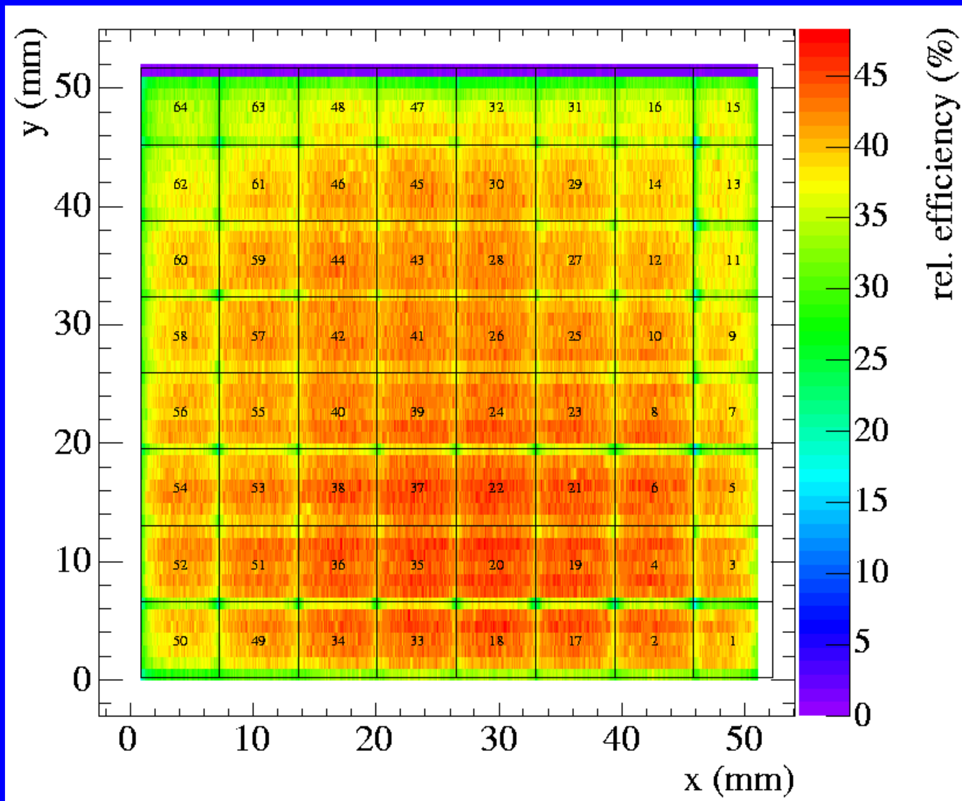
Single threshold discrimination
CAMAC based readout
500 ps per count TDC (LeCroy 2277)
connected to Linux PC

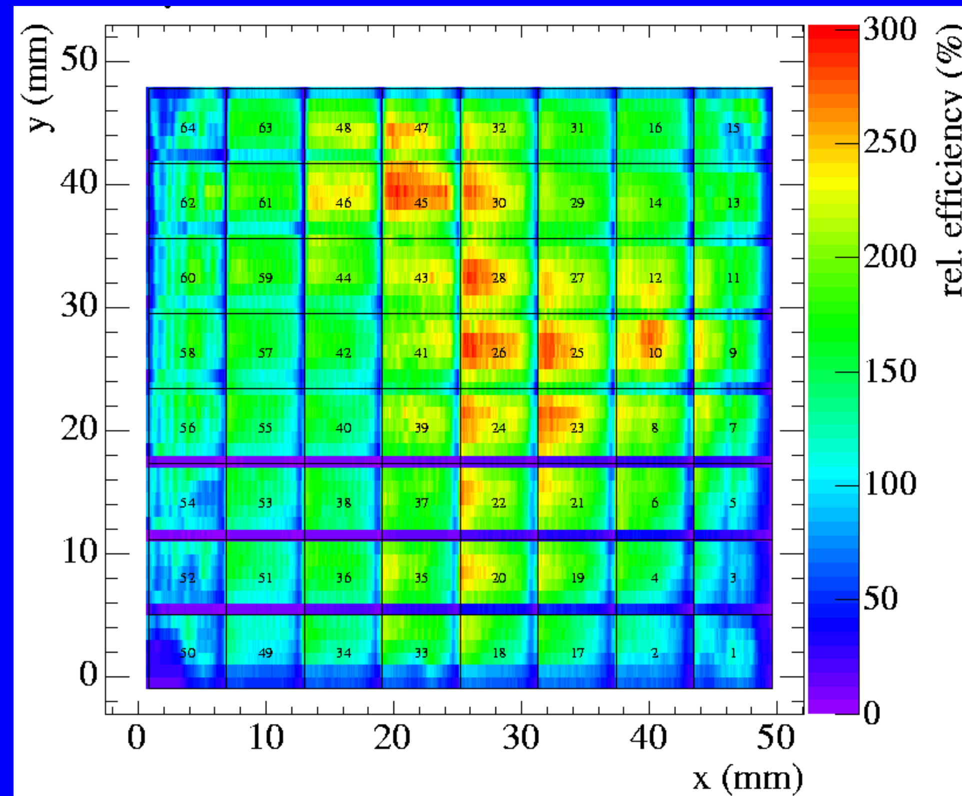


2D Efficiency Comparison – Red (635 nm)

Burle



Hamamatsu



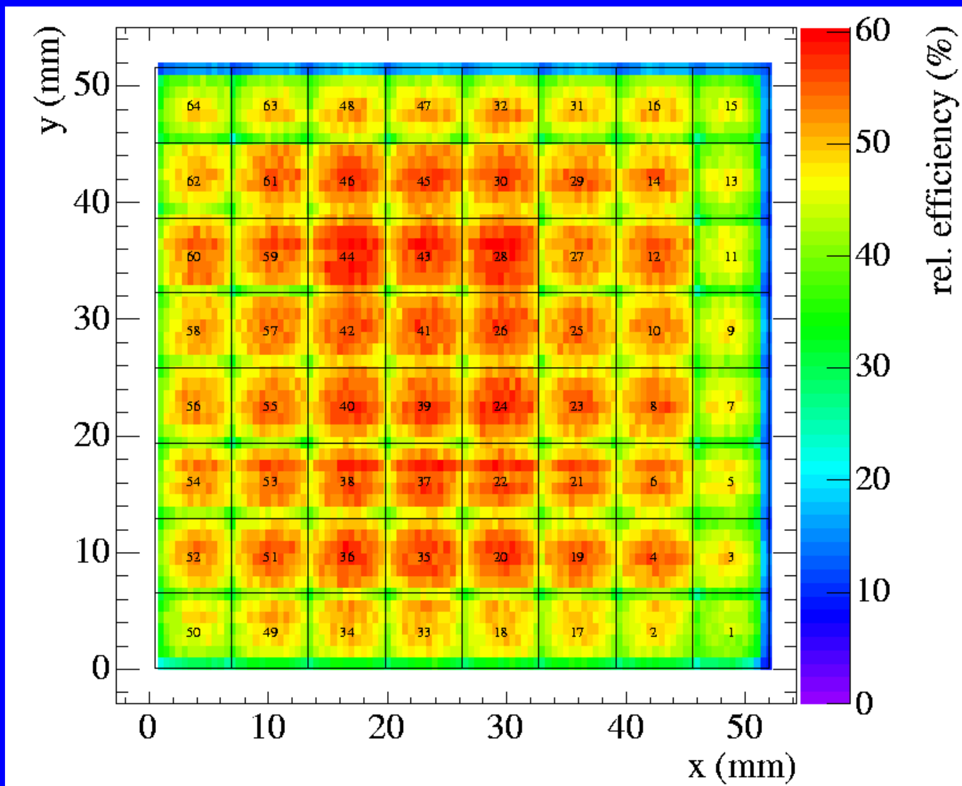
Scans: 100 μm $\times$ 1 mm

Efficiency relative to Photonis XP2262B PMT.

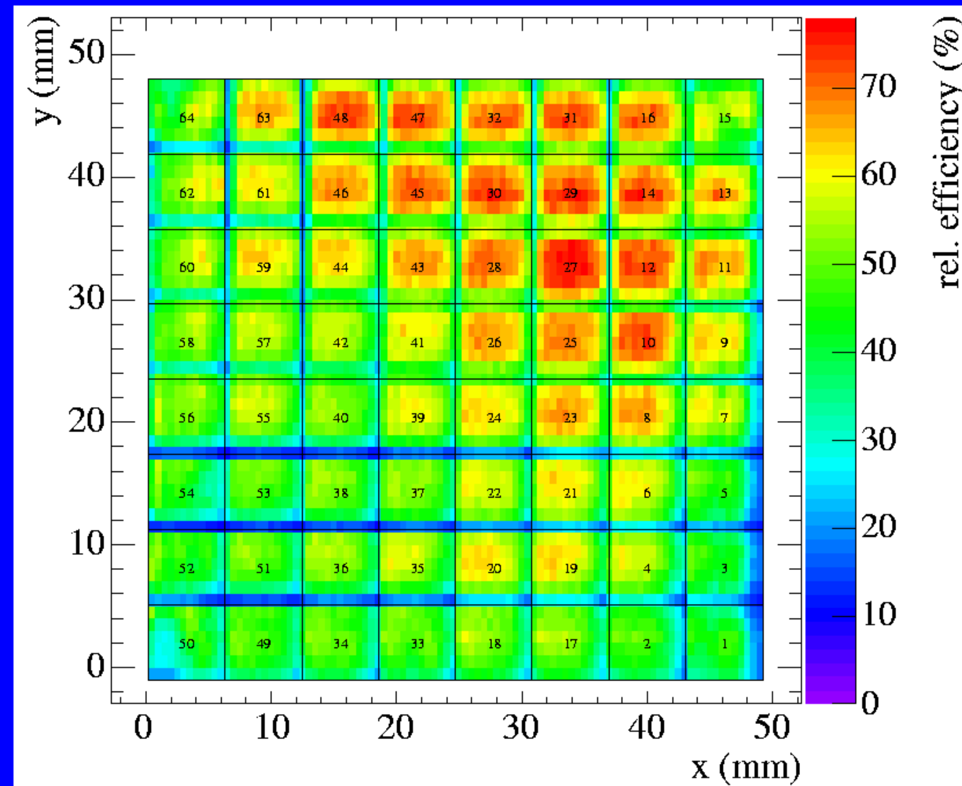
Burle more uniform, but Hamamatsu higher peak efficiency.

2D Efficiency Comparison – Blue (430 nm)

Burle



Hamamatsu



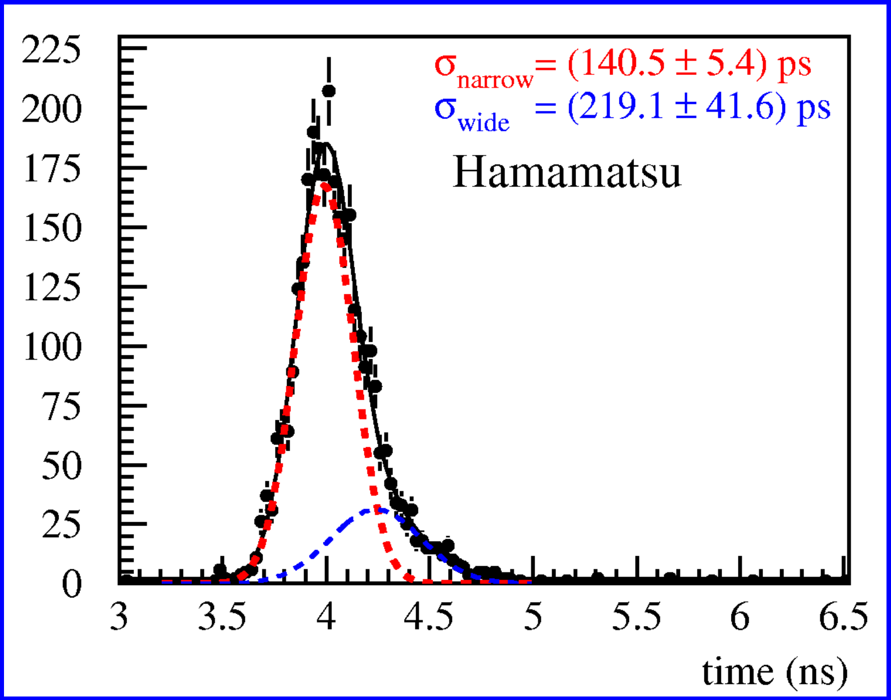
Scans: $500\ \mu$m $\times$ 1 mm

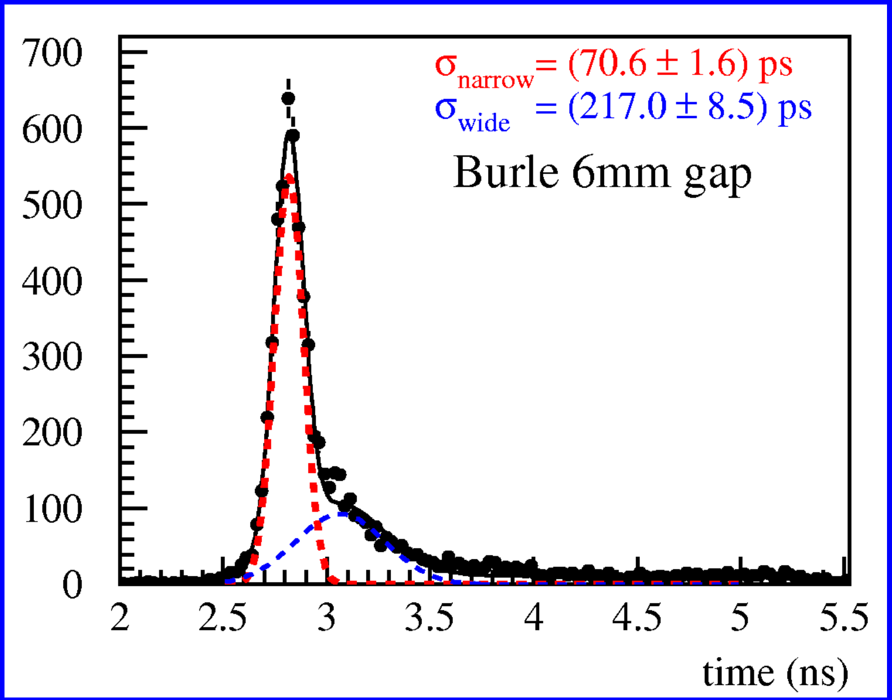
Efficiency relative to Photonis XP2262B PMT.

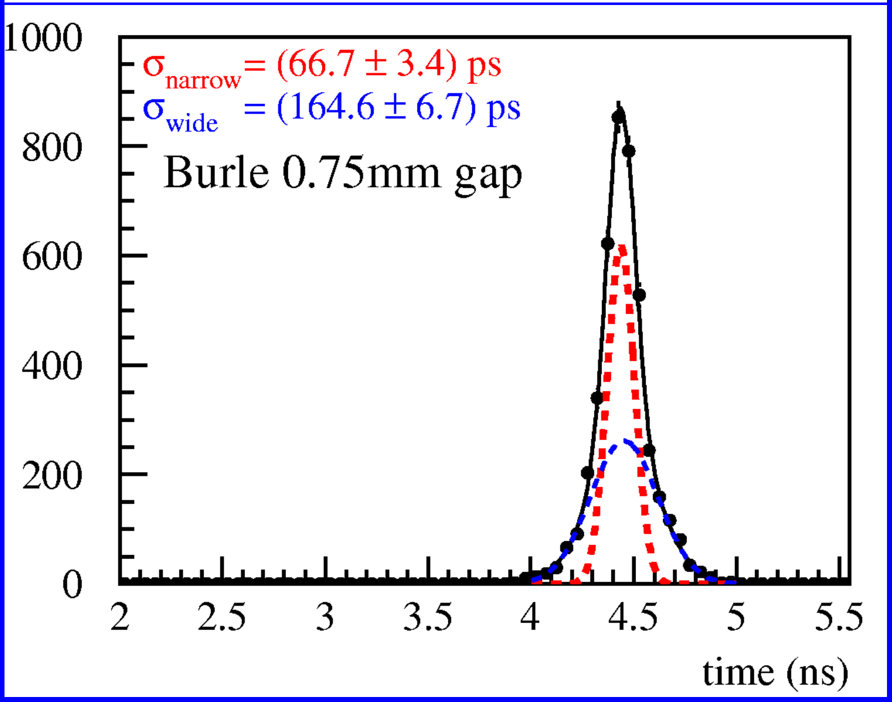
For Cherenkov detectors the more relevant wavelength region.

Burle more uniform; similar efficiencies.

Timing





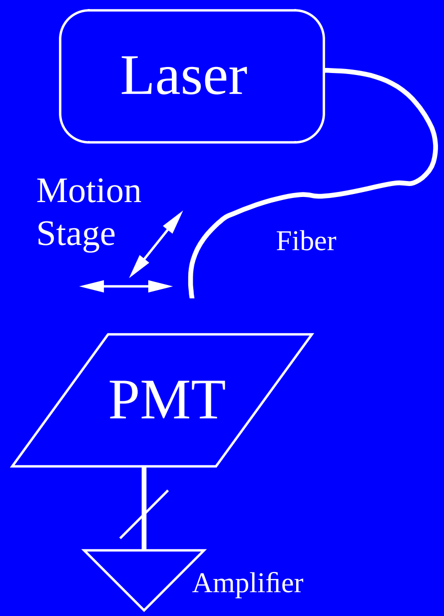


Pilas @ one point on PMT

Burle: narrow main components smaller MCP-to-cathode gap version: smaller tail.

Timing

To measure timing properties:
need faster electronics !



Using Burle MCP with reduced MCP-to-cathode gap: $750\ \mu$m (std: 6 mm)

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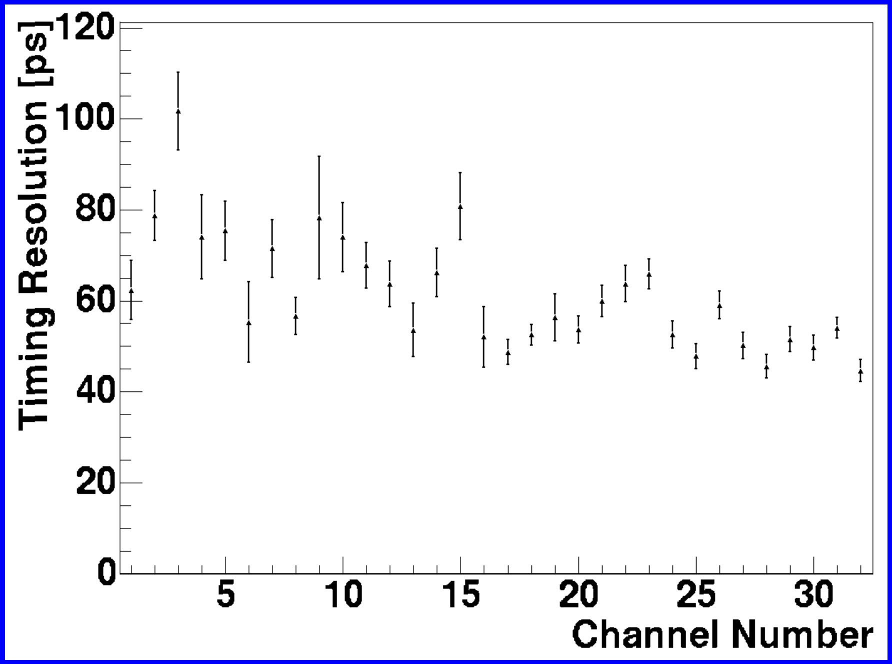
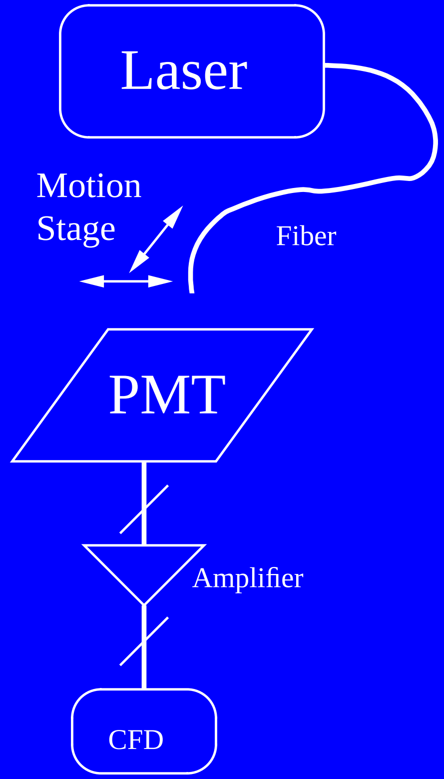
Our group developed:
Constant Fraction Discriminator





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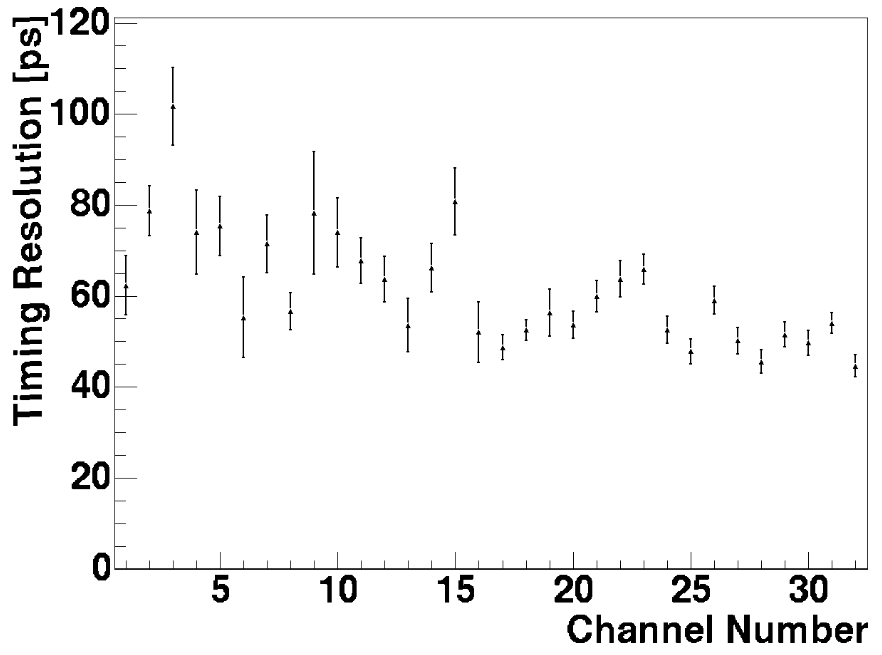
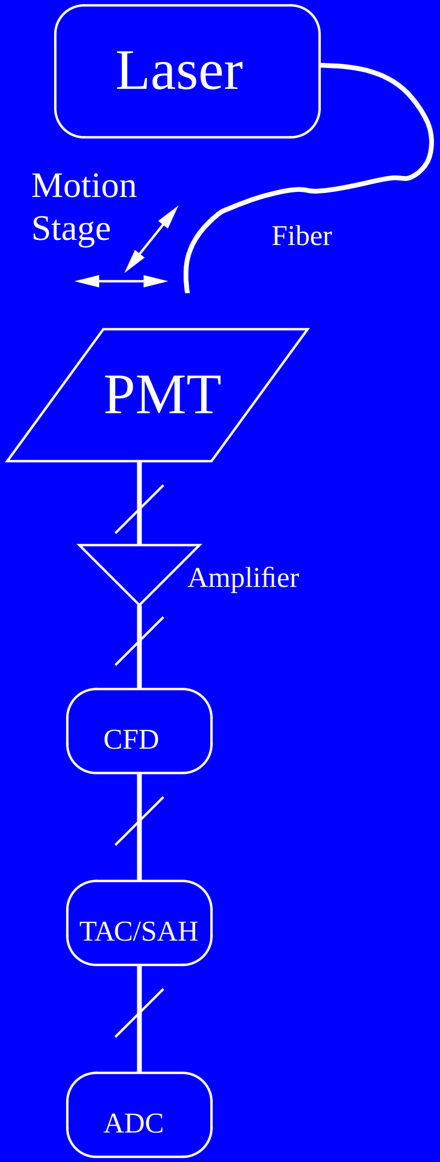


Time-to-amplitude converter
Sample-and-hold
VME based 12-bit ADC
$\Rightarrow \approx 25$ ps resolution
Using Burle MCP with reduced MCP-to-cathode gap: $750\ \mu$m (std: 6 mm)



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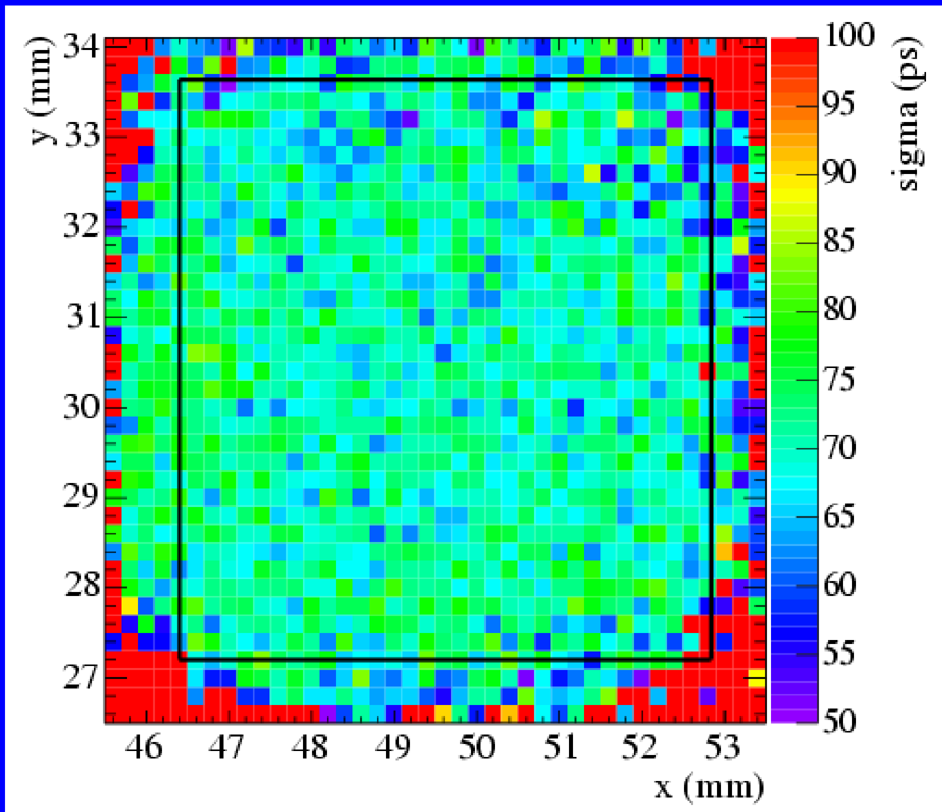
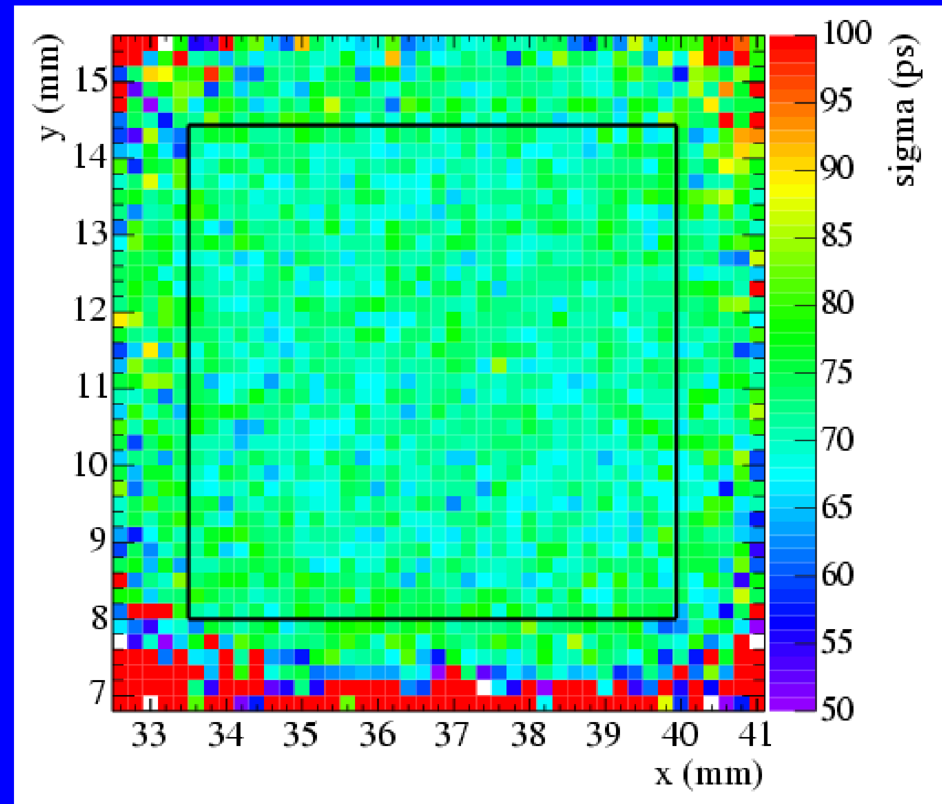


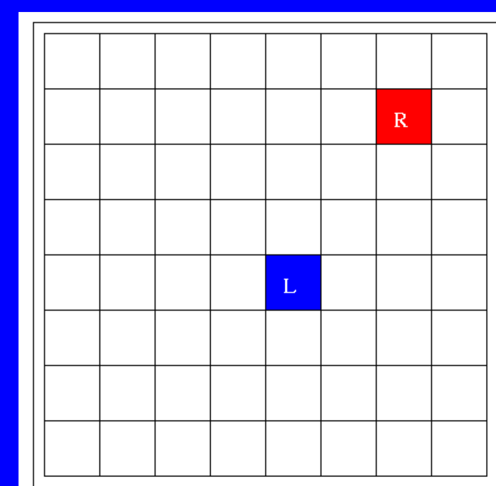


Hit Time distribution fitted with double Gaussian + flat background.

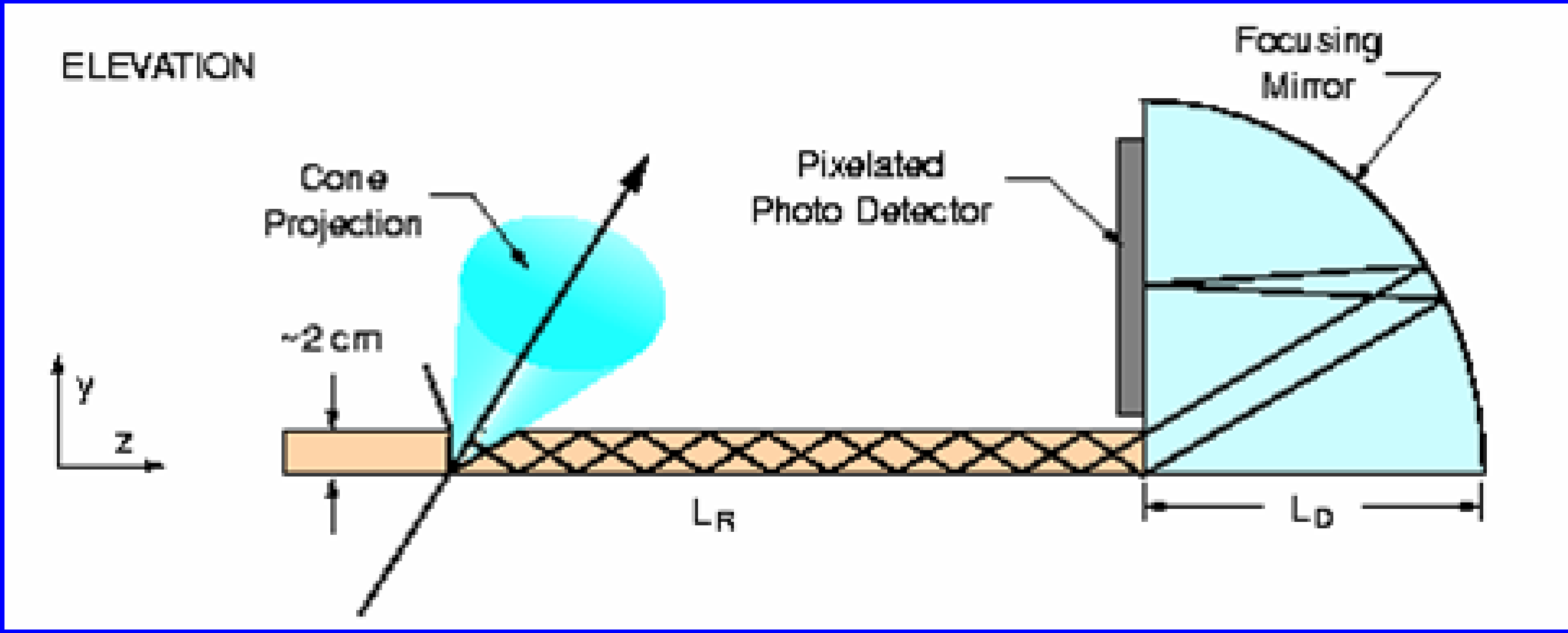
Plotting sigma of narrow Gaussian.

Very uniform, very good timing (≈ 70 ps)

Outside of pad, low number of hits $\Rightarrow$ larger uncertainty.



Prototype and Test Beam



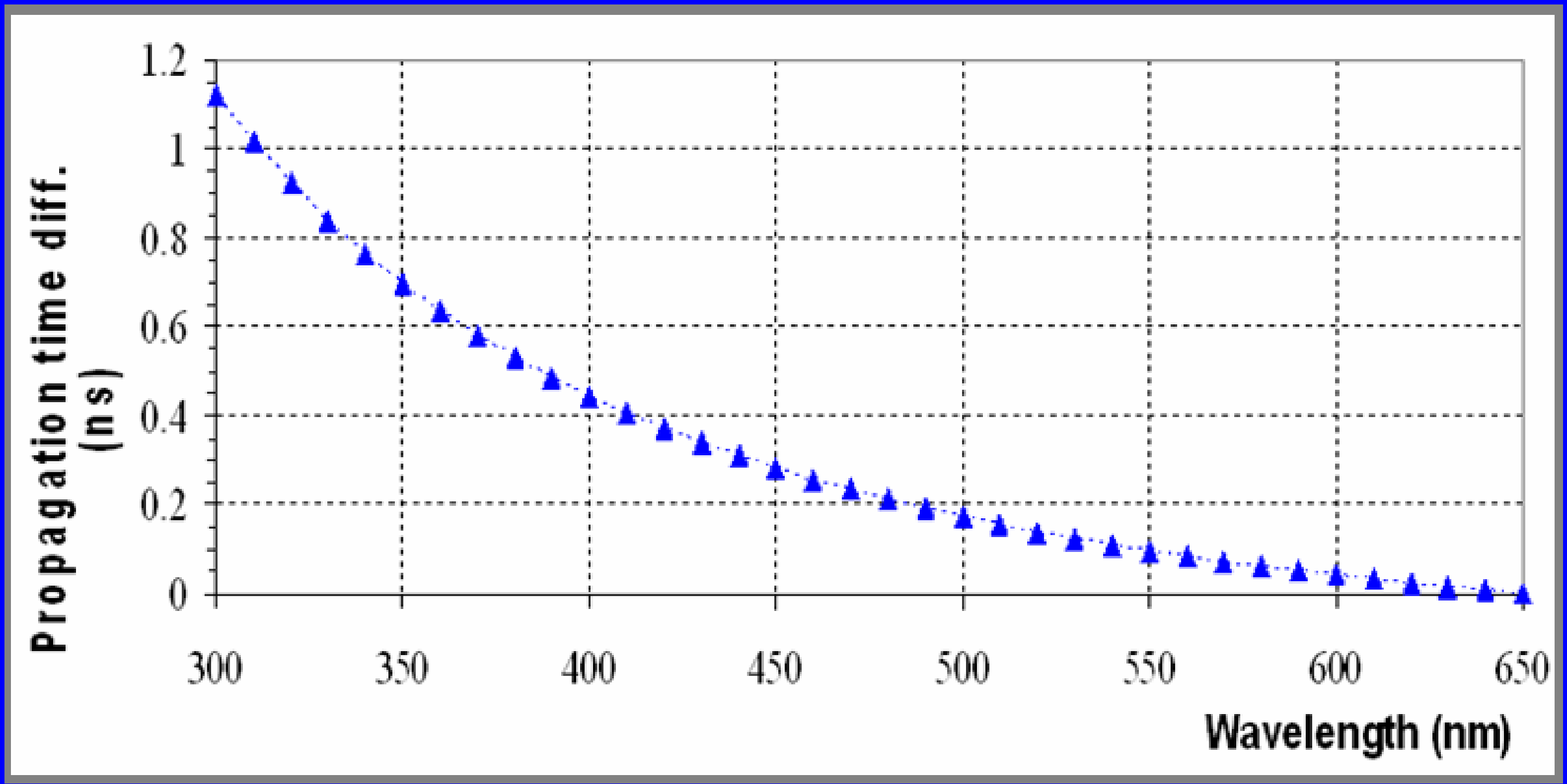
- Focusing optics eliminates effect of bar size
- Smaller pixels improve the θ_c resolution
- Smaller expansion region reduces amount of background hits
- < 100 ps timing enables better signal vs. background separation
- < 100 ps timing enables partial correction of chromatic effect

Prototype and Test Beam

How to correct for chromatic effect ?

- Precision timing (< 100 ps) for propagation time
- Use dispersion effect to constrain λ

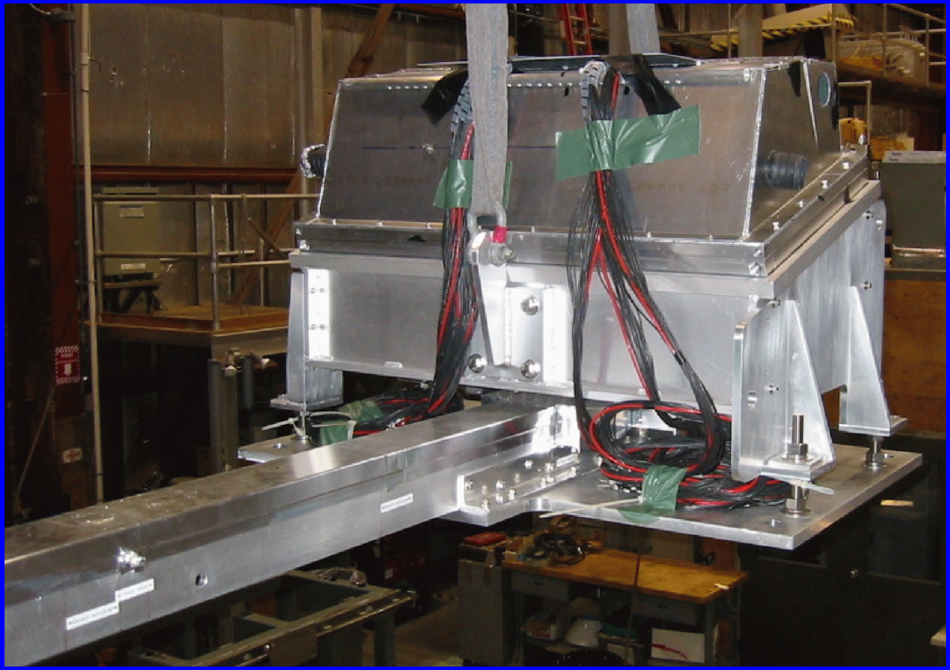
Calculation:

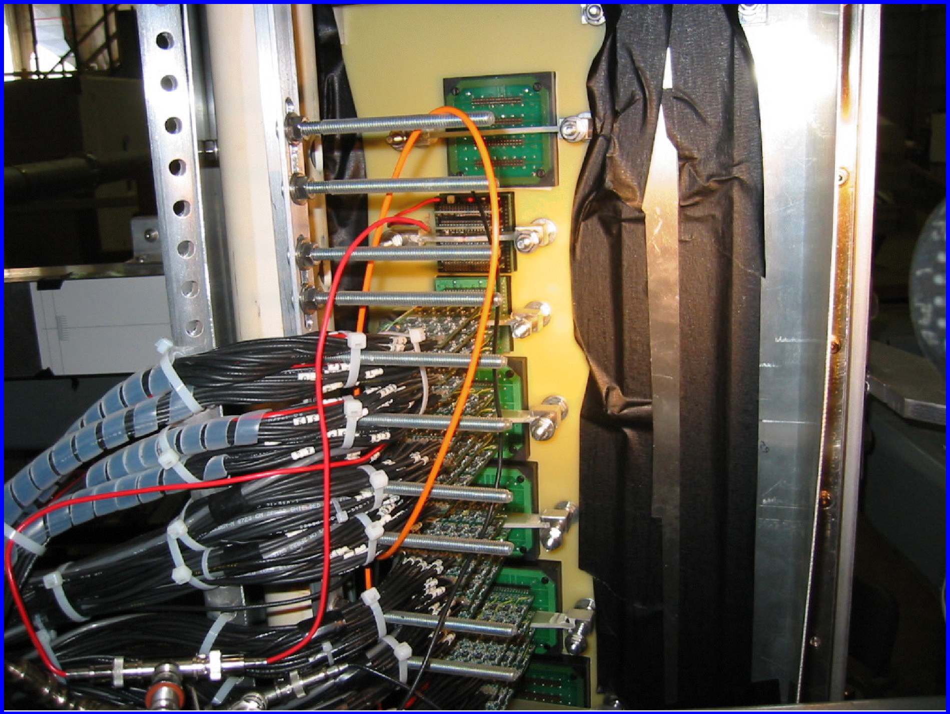


3.66 m long DIRC fused silica bar: ≈ 1 ns difference over 300 nm to 650 nm range

Prototype and Test Beam

- Prototype has been build
- Single fused silica bar
- Spherical mirror for focusing
- Mineral oil as matching liquid (KamLAND)
- 4 Burle MCPs
  2 Hamamatsu PMTs





Test beam ($\approx$ pions @ 10 GeV) at SLAC in Nov 04, Dec 04, Feb 05

Goals :

- validate design
- measure and correct chromatic effect