FDIRC prototype in CRT:

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update on the BLAB2 waveform digitizing electronics performance

J. Va'vra, SLAC

FDIRC prototype tests in CRT

- **People involved at present:**

Work from Hawaii university:

- Gary Varner (godfather of BLAB2 and next B:AB3 chip designs)
- Larry Ruckman (student, data analysis, MC simulation - worked out the pixel-based k_x, k_y, k_z constants, PC board designs, firmware)
- Kurtis Nishimura (postdoc, lab pulser tests, CRT DAQ, firmware)

Work from SLAC:

- Jerry Va'vra (CRT hardware, data analysis)
- David Aston (Unix issues, general software help)
- Dmitry Shtol (student, a visitor from Novosibirsk, just arrived, working on the pixel-based TOP constants)

- **Aim:**

- **Compare previous SLAC electronics CFD/TDC/ADC, used in previous beam tests, with a new BLAB2 chip waveform digitizing electronics. Learning valuable lessons.**

Previous results with FDIRC prototype

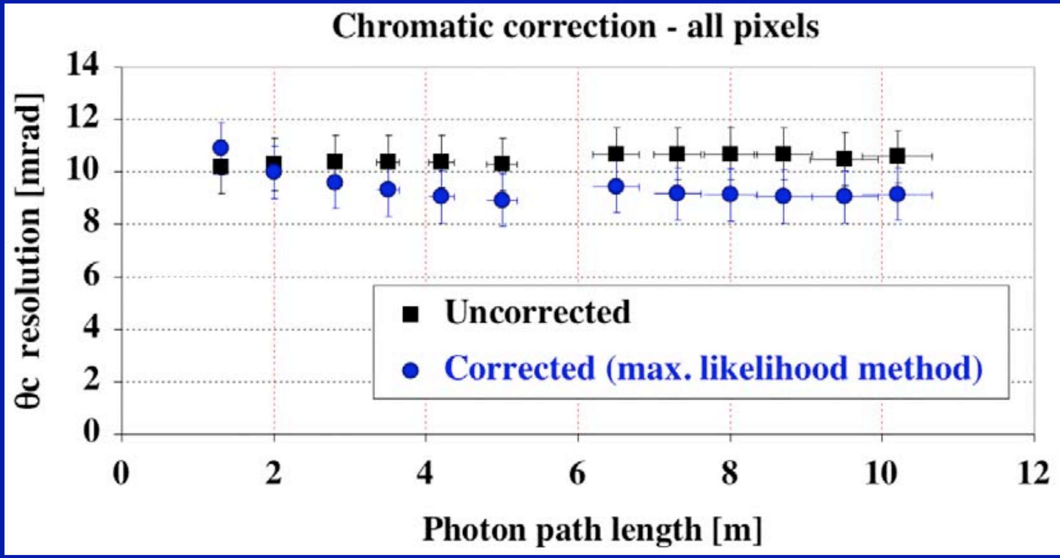
- Benitez, I. Bedajanek, D.W.G.S. Leith, G. Mazaheri, B.N. Ratcliff, K. Suzuki, J. Schwiening, J. Uher, and J. Va'vra, SLAC-PUB-12236, October 2006.
- J. Va'vra, J. Benitez, D.W.G.S. Leith, G. Mazaheri, B. Ratcliff, J. Schwiening, and K. Suzuki, SLAC-PUB-12803, March 2007.
- J. Benitez, D.W.G.S. Leith, G. Mazaheri, B.N. Ratcliff, J. Schwiening, J. Va'vra, L. Ruckman, and G. Varner, Nucl. Inst. & Meth., A595(2008)104-107.
- J. Va'vra, "Simulation of the FDIRC optics with Mathematica", SLAC-PUB-13464, October, 2008.
- C. Field, T. Hadig, D.W.G.S. Leith, G. Mazaheri, B. Ratcliff, J. Schwiening, J. Uher and J. Va'vra, "Development of photon detectors for a fast focusing DIRC," Nucl. Instr.&Meth., A553(2005)96-106.
- C. Field, T. Hadig, M. Jain, D.W.G.S. Leith, G. Mazaheri, B. Ratcliff, J. Schwiening, and J. Va'vra, "Novel photon detectors for focusing DIRC prototype," Nucl. Instr.&Meth., A518(2004)565-568.

- **FDIRC prototype was the 1-st RICH detector ever to perform the chromatic correction by timing.**

Previous beam test results with SLAC CFD/TDC electronics

J. Va'vra, J. Benitez, D.W.G.S. Leith, G. Mazaheri, B. Ratcliff, J. Schwiening, and K. Suzuki, SLAC-PUB-12803, 2007, presented at Vienna conference, 2007.

SLAC ESA test beam:
- 10 GeV e^- beam
- Perfect start time
- Small beam spot
- Tiny beam divergence
- Θ_{dip} = 90 deg

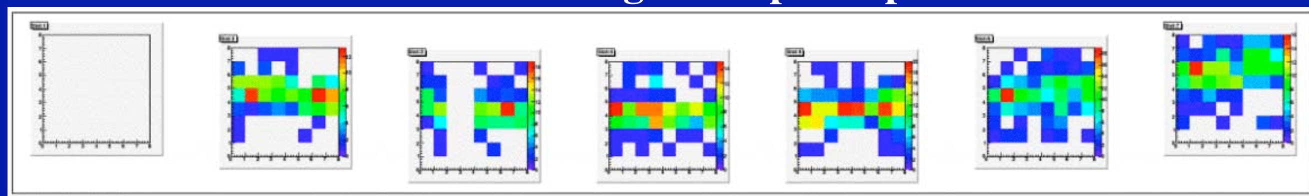


- **Measured an uncorrected $\sigma_{\theta c}$ (measured) ~10.5 mrads for 6mm x 6mm pixels. This agreed with a G4 MC simulation.**
- **The chromatic correction, or photon color tagging, by timing requires a timing resolution at a level of 150 -200ps.**

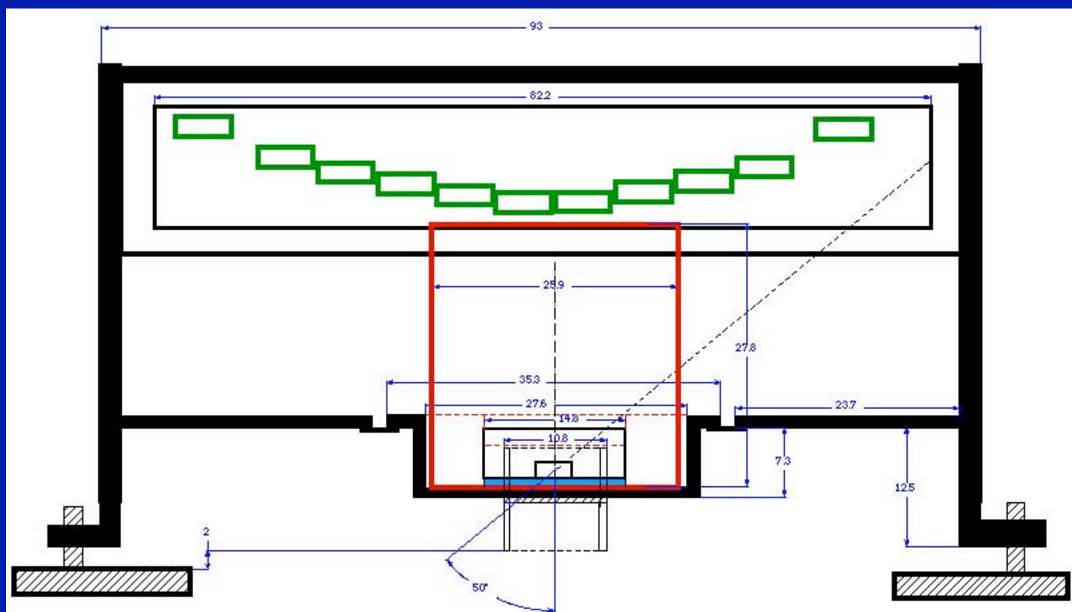
New detector plane using six H-8500 MaPMTs

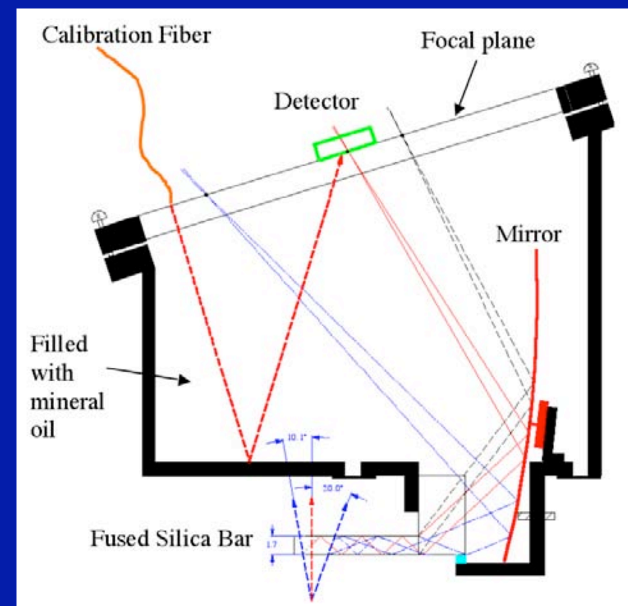
New detector holder:

Cherenkov ring in the pixel space:



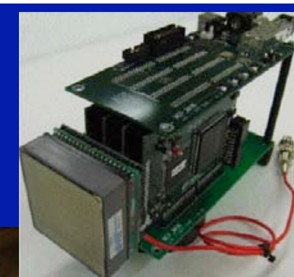
New BLAB2 electronics:



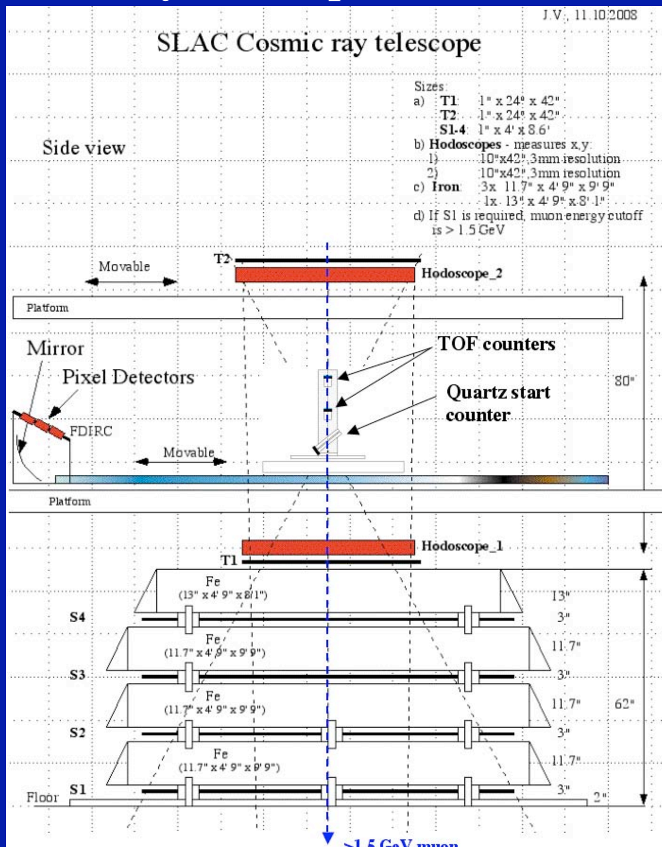


- New BLAB2 ASIC electronics
- New detector holder with six H-8500 MaPMTs

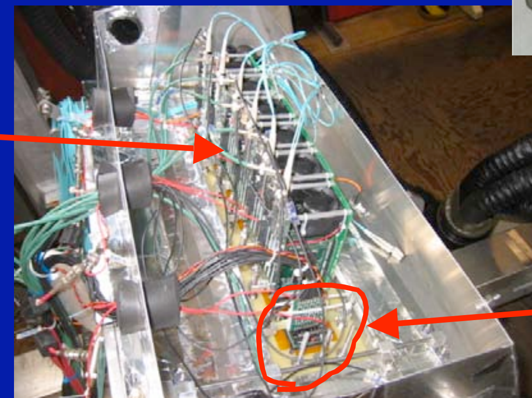
FDIRC tests in CRT



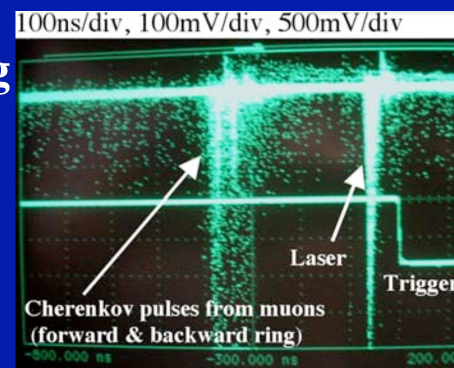
Cosmic Ray Telescope (CRT):



BLAB2 electronics



Analog Monitoring



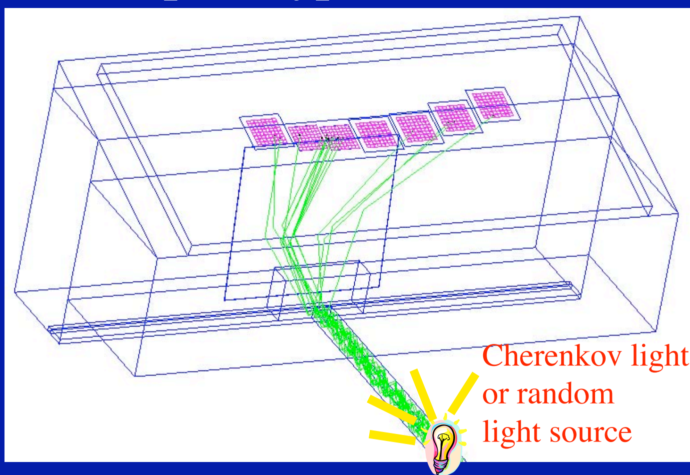
Old SLAC amplifier for monitoring purposes

- **T1*T2*S1*Qtz_counter rate ~ 6k/24 hours <=> E_{muon} > 1.6 GeV**
- **Slot 1 has an old SLAC amplifier; slots 2-7 have new BLAB2 chip electronics.**

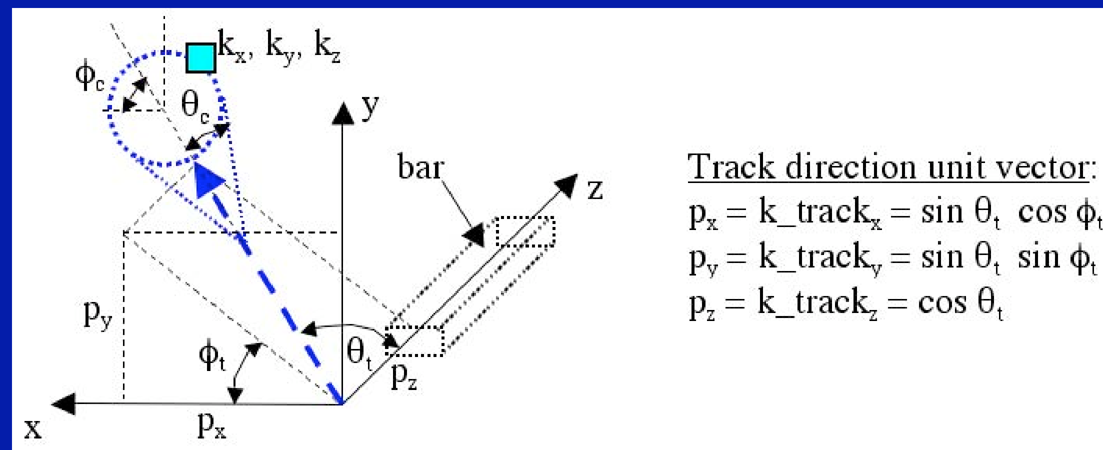
Cherenkov angle with tracking in 3D

$$\cos\theta_c = k_x * k\_track_x + k_y * k\_track_y + k_z * k\_track_z$$

FDIRC prototypeG4 Monte Carlo:

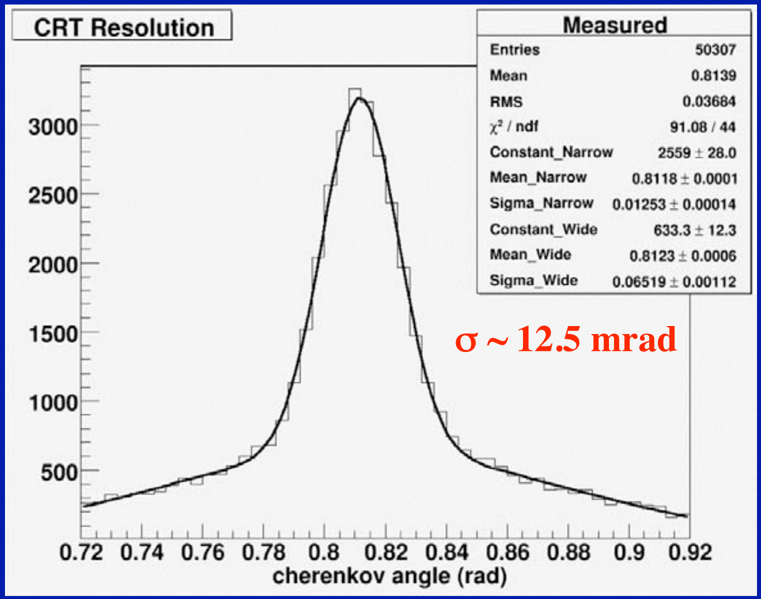


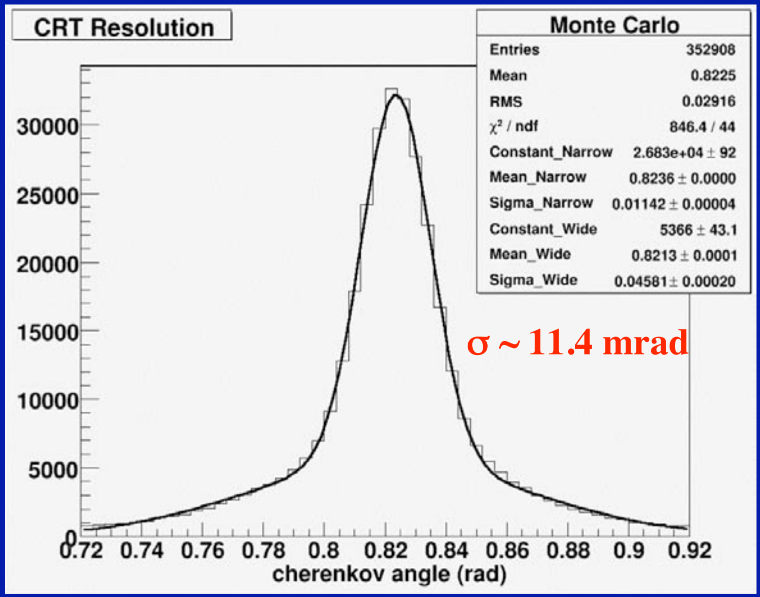
External tracking geometry:



- **To get all this going correctly in CRT was quite an effort:**
  - Generate k_x, k_y, k_z assignments for each pixel from FDIRC prototype Geant 4 MC.
  - Get k_track_x, k_track_y and k_track_z from the CRT hodoscope tracking.
  - Make the above transformation to get θ_c.

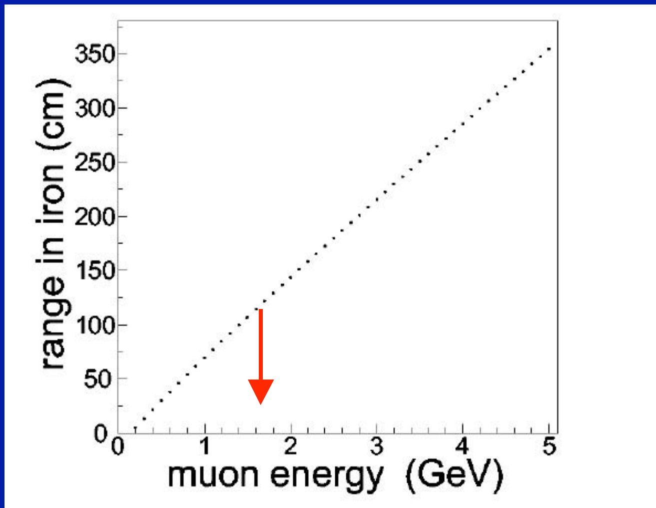
Data vs. MC using the pixel information only





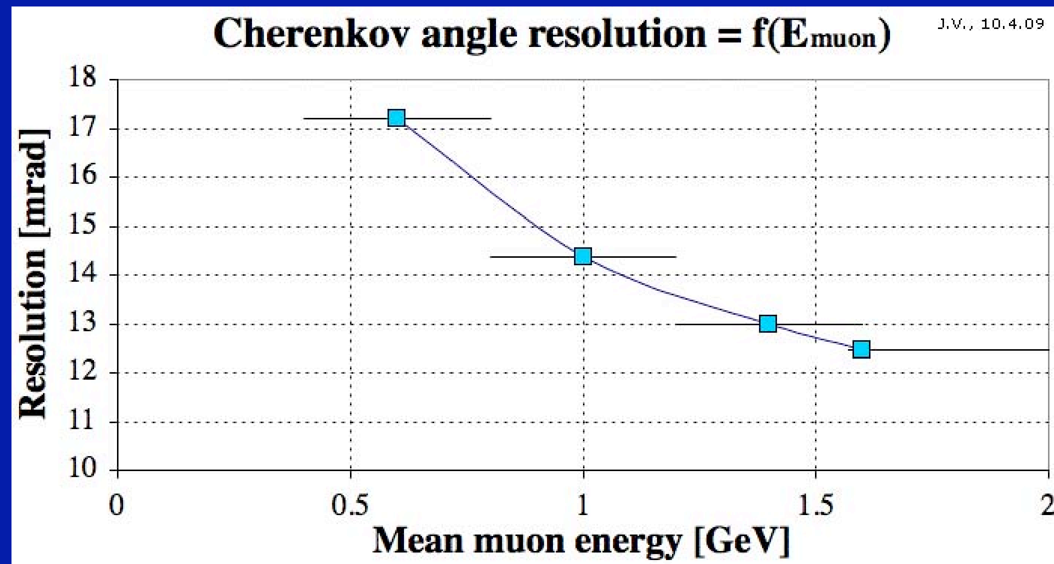
- **FDIRC concept has one major advantage: One can obtain a good Cherenkov resolution even with a relatively poor timing ($\sigma \sim 1$ ns), which we have at present.**
- **Cherenkov angle distributions have a bit larger width than expected:**
  - **Cross-talk ?** Data analysis indicates that this is a small effect.
  - **Dependence on ϕ_{track} ?** Data analysis indicates that the answer is no.
  - **Is muon energy (>1.5 GeV) hard enough ?** This is actually a culprit. See next page.

Muon stack is not thick enough



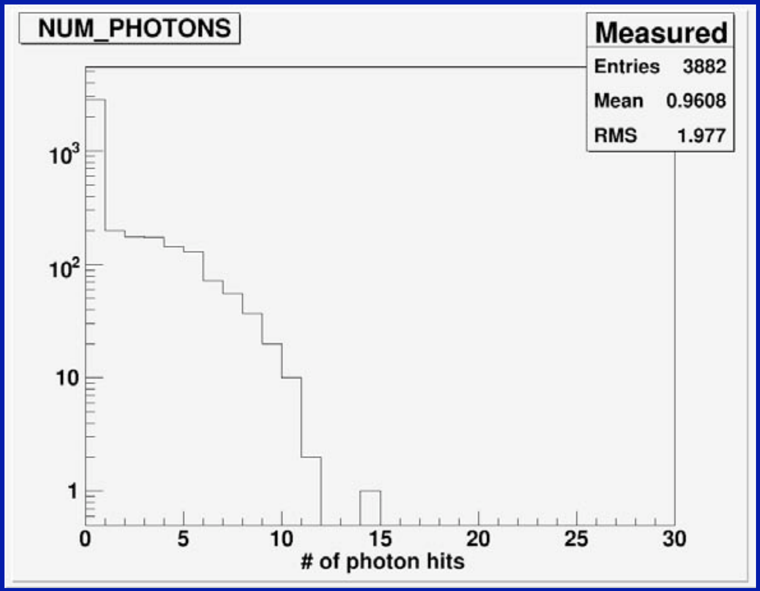
Muon range in iron vs. muon energy calculated using the GEANT code.

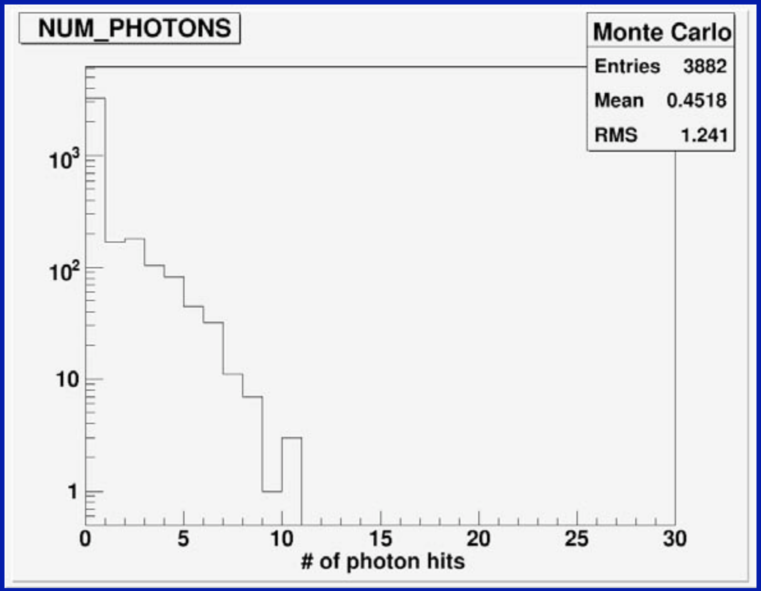
Data analysis requiring a different absorber thickness:



- **Muons have still too low energy, i.e., iron stack is not thick enough.**
- **They multiple scatter in the bar, affecting both the θ_c- angle and a track direction.**
- **We are not at the minimum of the resolution due to this effect.**

Number of photoelectrons for $\theta_{dip} = 90^{o}$





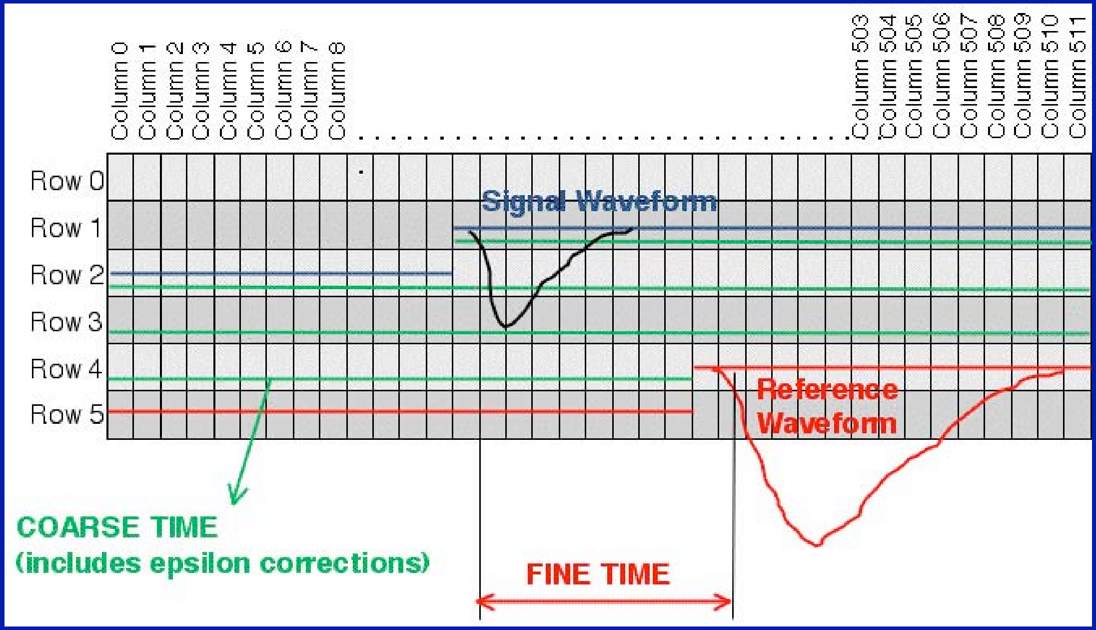
- **Some discrepancy between data and MC simulation.**
- Cross-talk, producing extra hits ?

Timing with a present version of firmware in the BLAB2

Principle of timing with BLAB2

Coarse & fine time:

Time = 1300 ns – (COARSE TIME + FINE TIME)



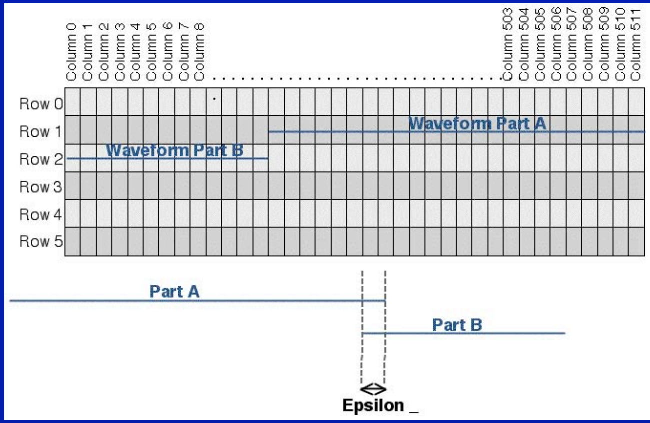
BLAB2:
- **17 Channels**
  - **16 Signal channels**
  - **1 Reference channel (records trigger signal)**
- **Each channel**
  - **3072 sampling cells**
  - **6 rows, 512 columns**
- **Each channel amplification (~40x)**

- **With the initial version of the firmware, we were able to achieve a timing resolution of only σ ~1ns, which is not good enough to do the chromatic corrections.**

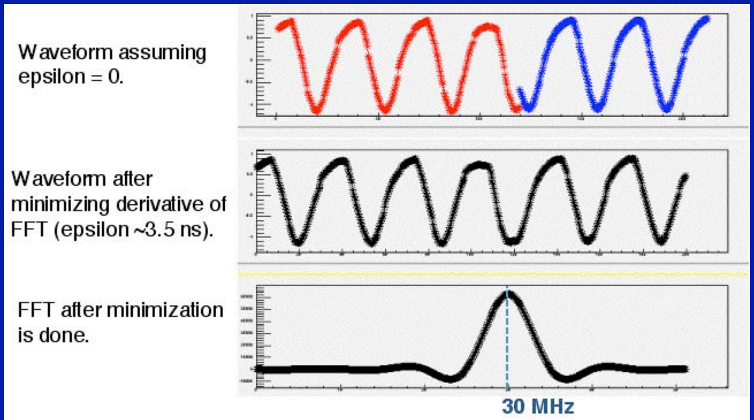
Problem with BLAB2 ?

Epsilon time stitching :

Chip organized into rows & columns:



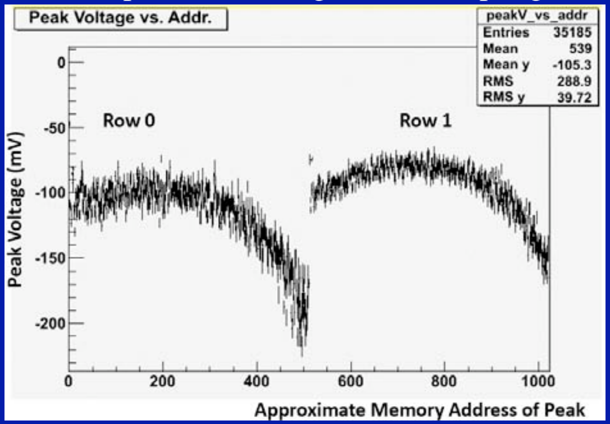
Calibration of epsilons with a 30MHz sine wave :



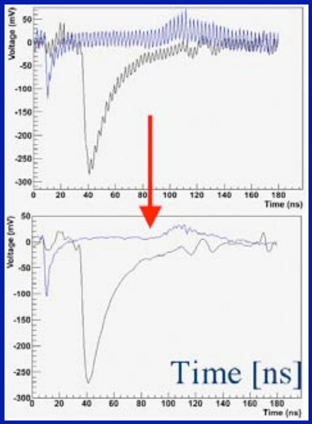
Stitching is not perfect

Amplifier gain variation

(due to capacitance change when sampling)



Amplifier oscillation:



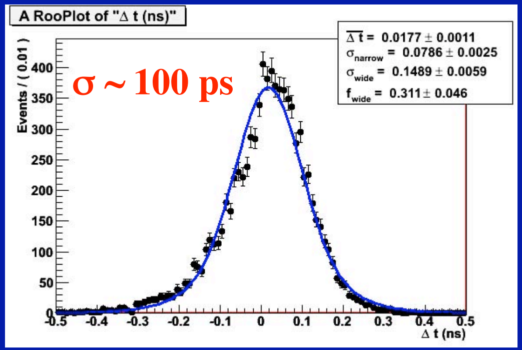
Fixed by a software digital filter

- **Until this point the firmware did not have all these corrections.**

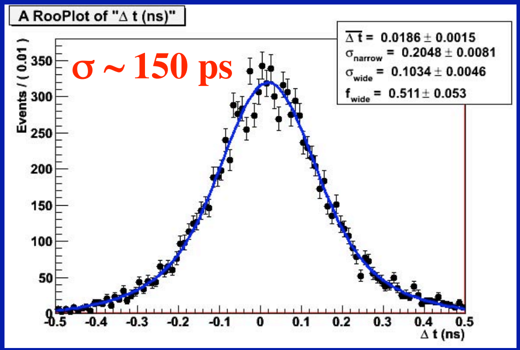
Two major lessons learned from the FDIRC prototype

- **Need a new firmware.** Kurtis is presently working on a firmware fixes. We will installthese fixes in the FDIRC prototype in the fall. Preliminary resolution with a fixed firmware (timing between two different pads within one BLAB):

Diff = $(\text{Pixel}_i - \text{Pixel}_k)_{BLAB}$ - Row 0



Diff = $(\text{Pixel}_i - \text{Pixel}_k)_{BLAB}$ - Row 1



- **Need a new BLAB3 chip.** It is clear that one needs to correct the problems in the hardware in the long run. The BLAB3 design is now close to submission.

From BLAB2 to BLAB3

G. Varner

Parameter	BLAB2	BLAB3
Samples/channel	6 rows x 512 columns	32768
Number of MaPMT pixels / BLAB2 ASIC	16	8
BLAB2 waveform sampling speed	2.5 GSa/sec	4 GSa/sec
On chip ADC	1 GHz Wilkinson	0.7 GHz Wilkinson
ADC resolution	10 bits	10 bits (12 bits recording)
ADC conversion time for 10 bits	1 μs	1 μs
Number of words / event	32 - 512	32 - 512
Read time for 16 channels (1 BLAB2 chip) / event	16 μs	2 - 8 μs
Sustained readout speed	50 kHz	> 30 kHz
Trigger latency	12 μs	5 μs
Dynamic range	1mV / 1V	1mV / 1V
BLAB2 chip input impedance	30-80 Ω (adjustable)	Current input (TIA)
Cross-talk	< 0.1%	< 0.1%
Amplifier analog BW	~ 0.85 GHz	~ 0.5 GHz
Amplifier gain (TIA = trans-impedance amp)	40 (2kΩ TIA)	60 (3kΩ TIA)

Next steps

a) The firmware fixes will be installed in the CRT in December.

b) At that point we start taking data capable of chromatic corrections.

c) In parallel, we will develop TOP constants from G4 MC.

d) Try to develop the chromatic correction analysis in 3D.

e) One reason we were bitten by the BLAB2 chip problems is that we did not have operating the scanning setup, as this electronics is not compatible with it. Therefore, we are putting some effort to restart the scanning setup. Thould will allow detailed bench tests with MaPMT and detailed waveform analysis.

f) Incorporate a new Orsay TDC/ADC electronics in the CRT readout, and the scanning setup as well. Are we getting amplifiers as well ? Or, should I use our old SLAC amplifiers ? That limits a choice of the old MaPMTs only, as the connector was made for those tubes only.

g) Need more people here at SLAC, if we want to do all this.