FDIRC tests in the SLAC cosmic ray telescope

J. Va'vra, SLAC
G. Varner, Hawaii Univ.

FDIRC

- **Successfully tested in the SLAC test beam:**
- J. Benitez, I. Bedajanek, D.W.G.S. Leith, G. Mazaheri, B.N. Ratcliff, K. Suzuki, J. Schwiening, J. Uher, and J. Va'vra, "Development of a Focusing DIRC," IEEE Nucl. Sci., Vol. 3, pp. 1550-1556, Conference Record, October 2006, and SLAC-PUB-12236.
- J. Va'vra, J. Benitez, D.W.G.S. Leith, G. Mazaheri, B. Ratcliff, J. Schwiening, and K. Suzuki, "The Focusing DIRC – the first RICH detector to correct the chromatic error by timing, and the development of a new TOF detector concept," Presented at Vienna conference on Instrumentation, February 19, 2007, Vienna, Austria, September 2007, SLAC-PUB-12803.
- J. Benitez, D.W.G.S. Leith, G. Mazaheri, B.N. Ratcliff,, J. Schwiening, J. Va'vra, L. Ruckman, G. Varner, "Status of fast forcusing DIRC (fDIRC)," Nucl. Inst. & Meth., A595(2008)104-107.
- J. Va'vra, "Simulation of the Focusing DIRC Optics with Mathematica," Presented at IEEE in Dresden in 2008, SLAC-PUB-13464. October, 2008; IEEE conference records.

- **FDIRC main points:**

- Its "pixel imaging quality" is the same as that of BaBar DIRC - the same σ_θ

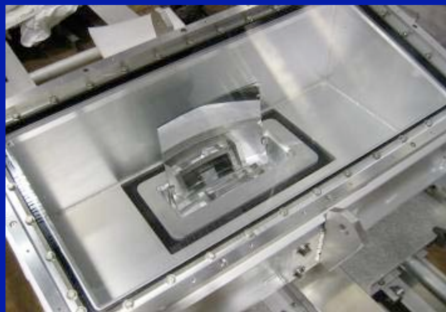
- However, it is ~10x faster that BaBar DIRC =>

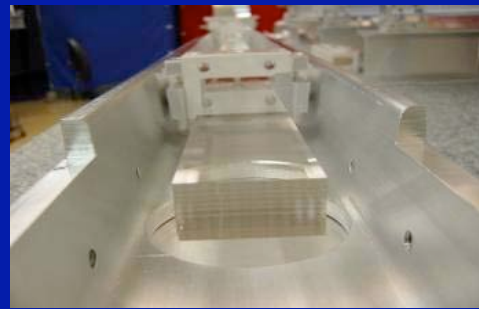
=> can correct chromatic error by timing,

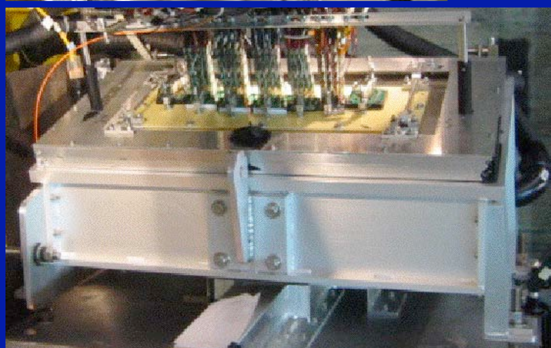
=> less sensitive to background.

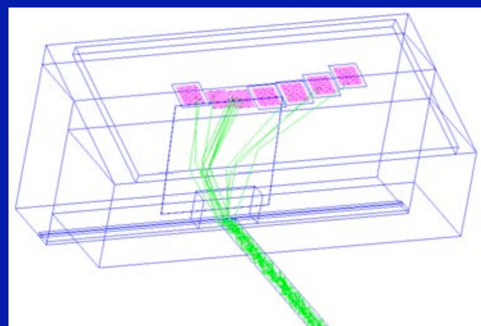
- Its "detector canvas" size is ~2x smaller than a non-focusing DIRC with similar detector concept.

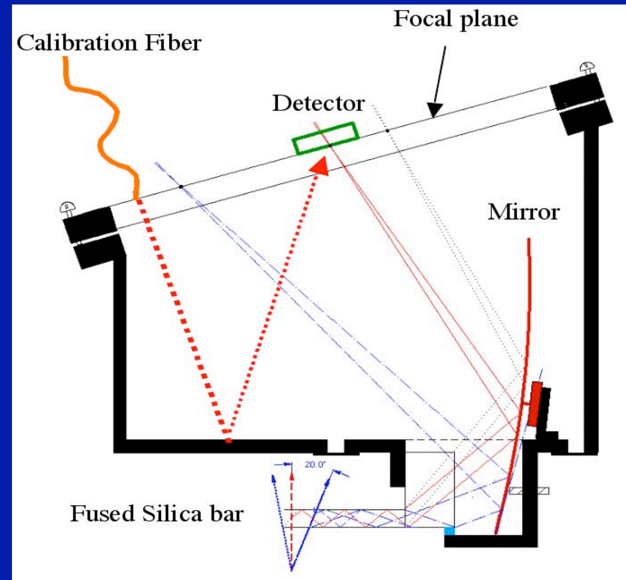
Focusing DIRC Prototype Optics







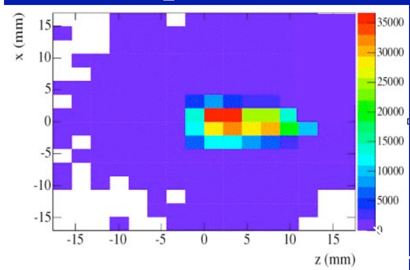


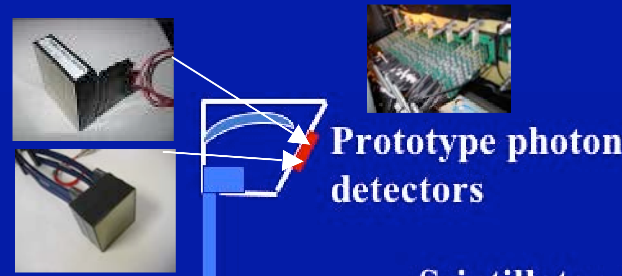


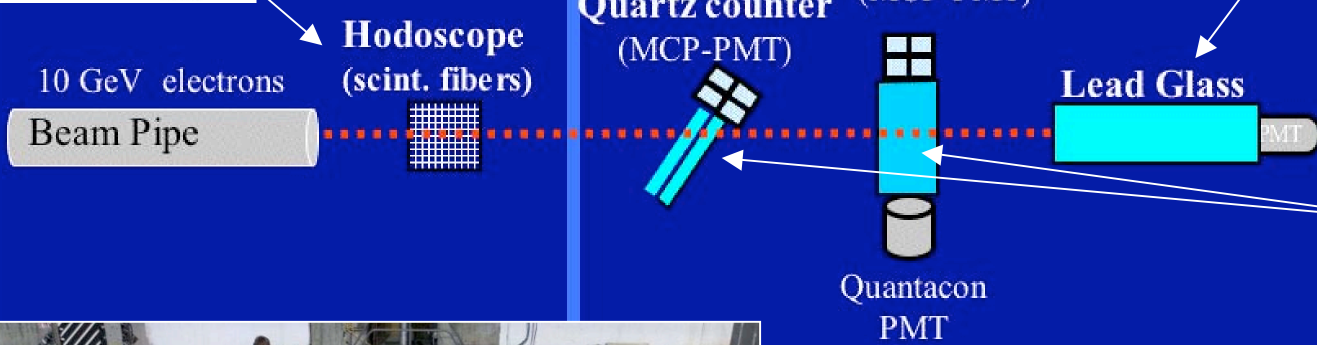
- **Radiator:**
  - 1.7 cm thick, 3.5 cm wide, 3.7 m long fused silica bar (spares from BABAR DIRC).
- **Optical expansion region:**
  - filled with a mineral oil to match the fused silica refraction index (KamLand oil).
  - include optical fiber for the electronics calibration (PiLas laser diode).
- **Focusing optics:**
  - a spherical mirror with 49 cm focal length focuses photons onto a detector plane.

Focusing DIRC Prototype beam test (T-492)

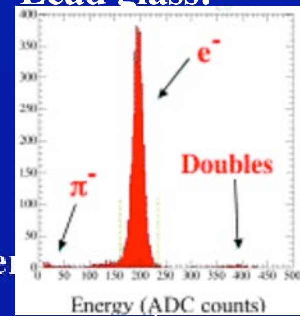
Beam spot: σ < 1mm



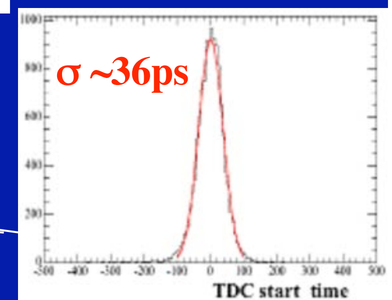


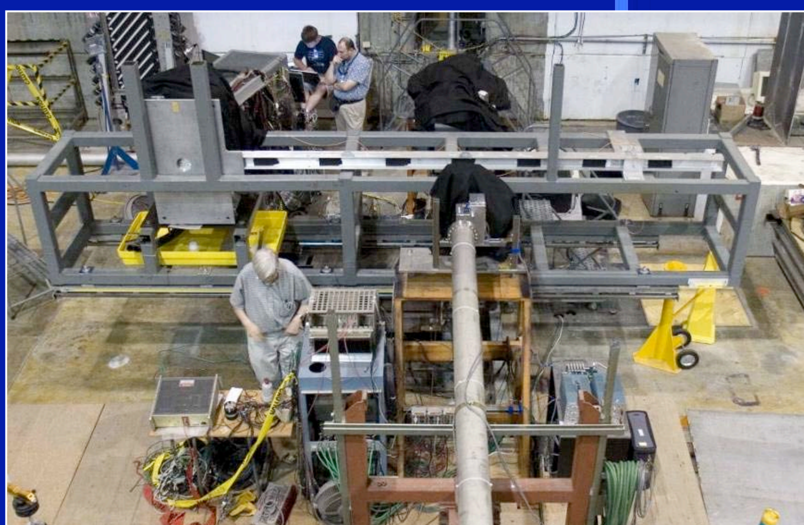


Lead glass:

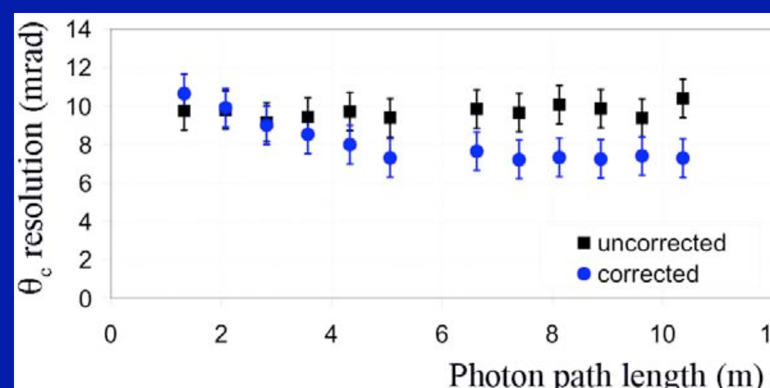


Local START time:





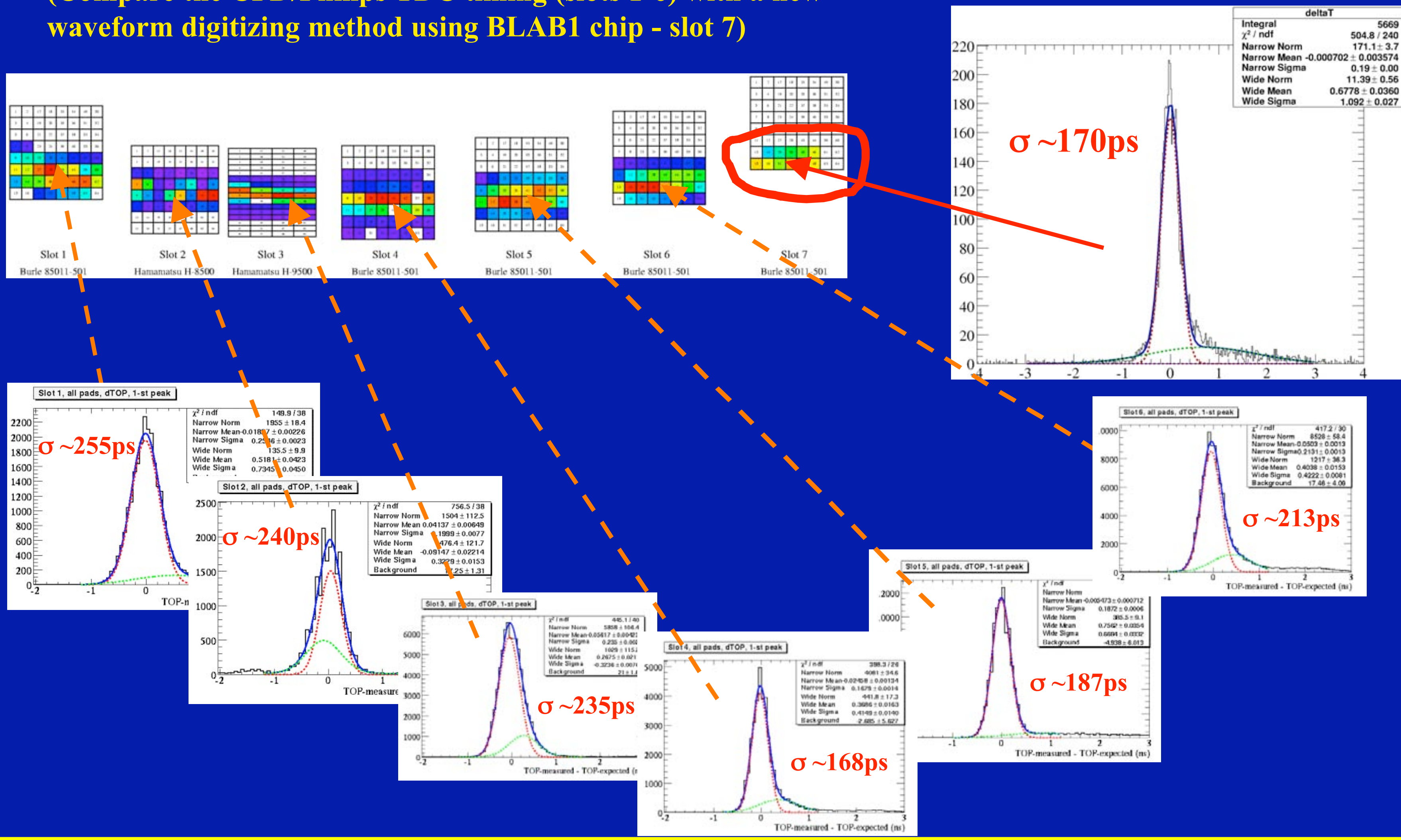
Effect of the chromatic correction by timing:



Beam test results at SLAC:

(Compare the CFD/Philips TDC timing (slots 1-6) with a new waveform digitizing method using BLAB1 chip - slot 7)

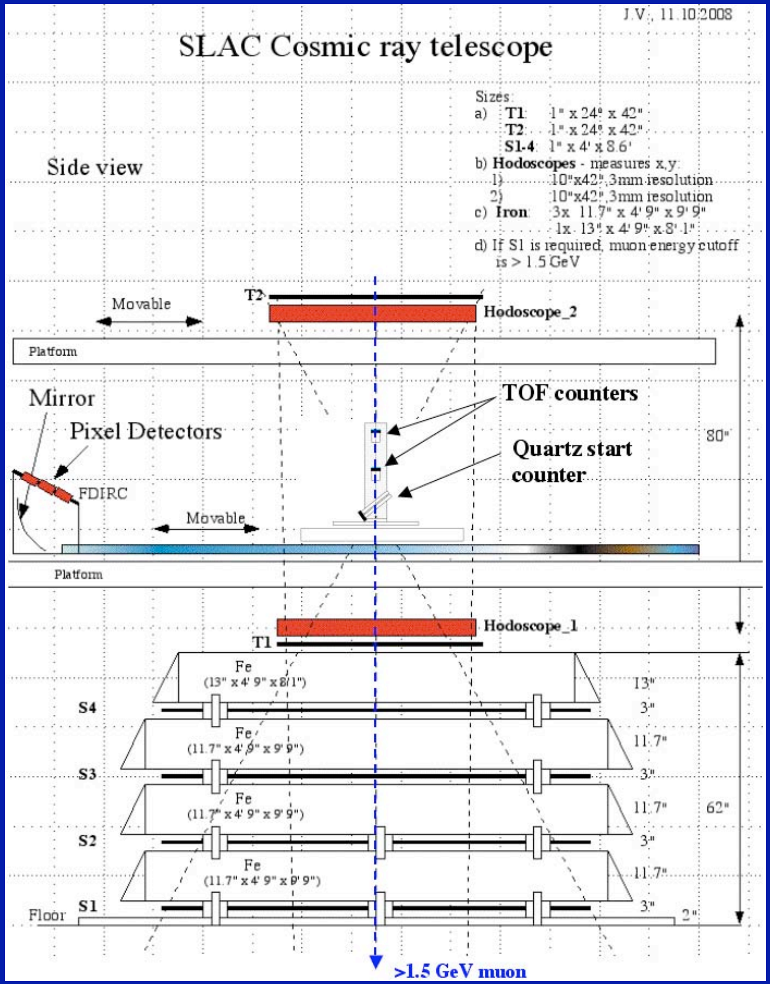
New BLAB-based Readout (slot 7, pad 15)**:**



Based on promissing results we decided to upgrade all channels to new BLAB2 electronics

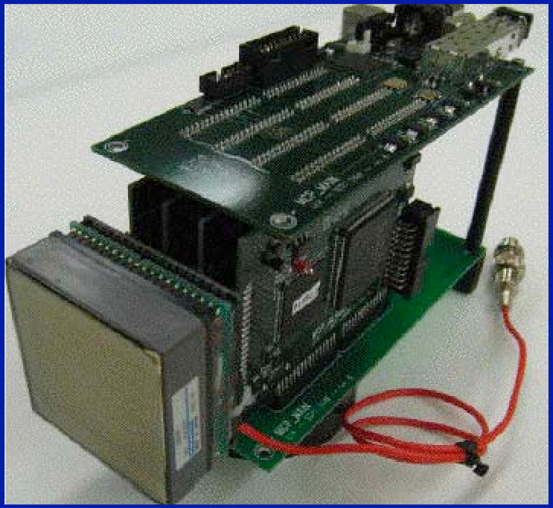
delta(time) (ns)

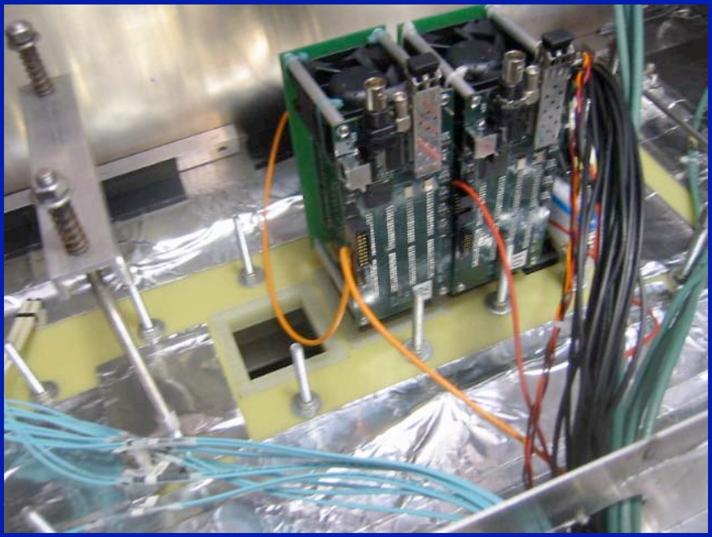
SLAC cosmic ray telescope - our "test beam" for the next 1-2 years

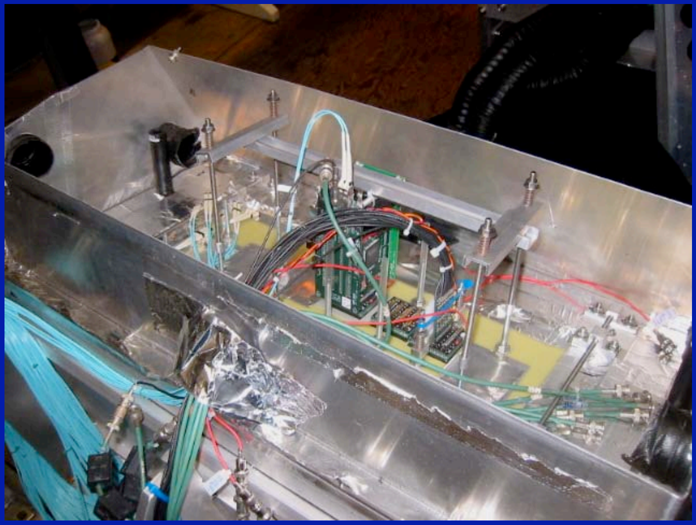


- ~ 4 feet of iron (an old TPC magnet) => ~ 1.6 GeV muon energy cutoff
- Tracking resolution: ~1 mrad.
- Status: taking data with the 1-st Hawaii electronics package; 6 more in March.

Test setup in the cosmic ray telescope

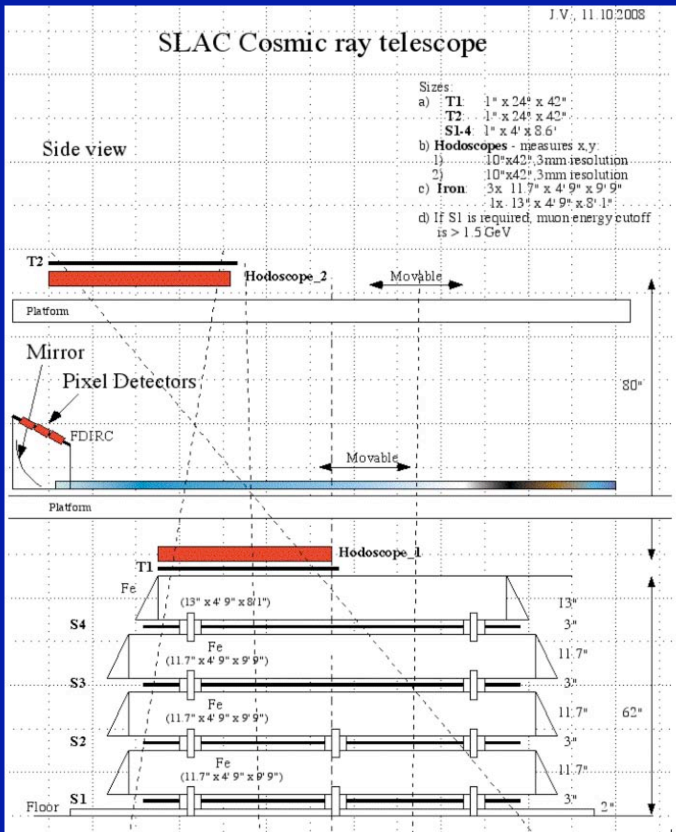




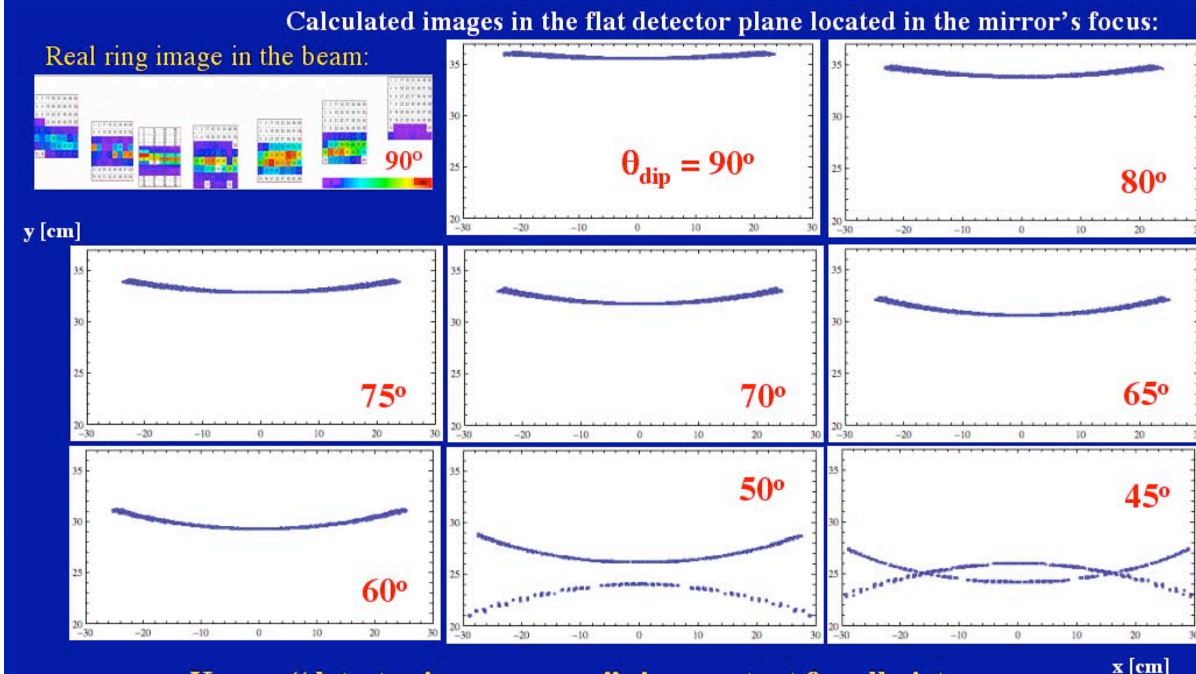


Images in the SLAC cosmic ray telescope

Side view:



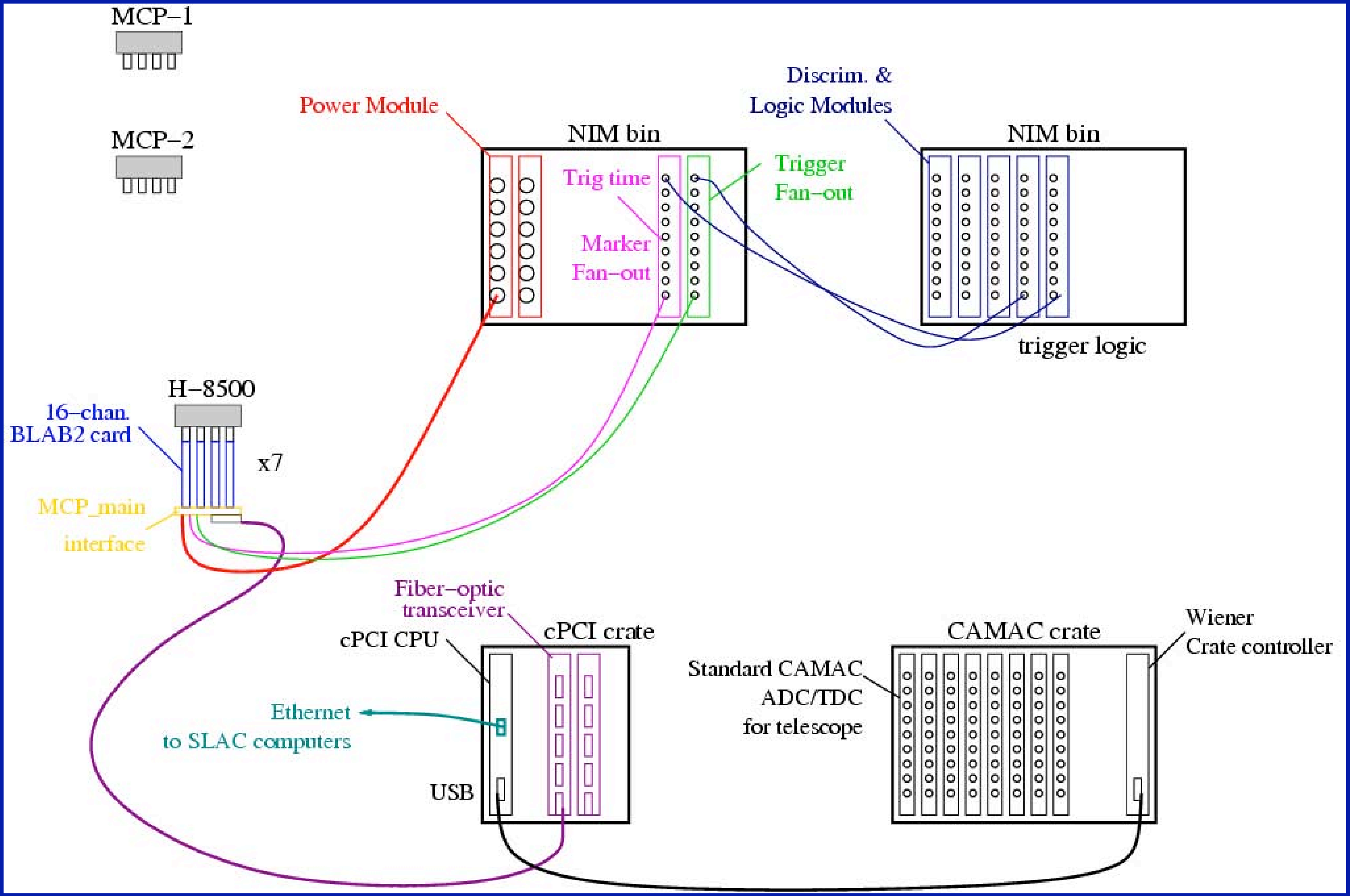
Ring image simulation for FDIRC prototype with:
no wedge, spherical mirror, flat detector plane (vary θ_{dip})



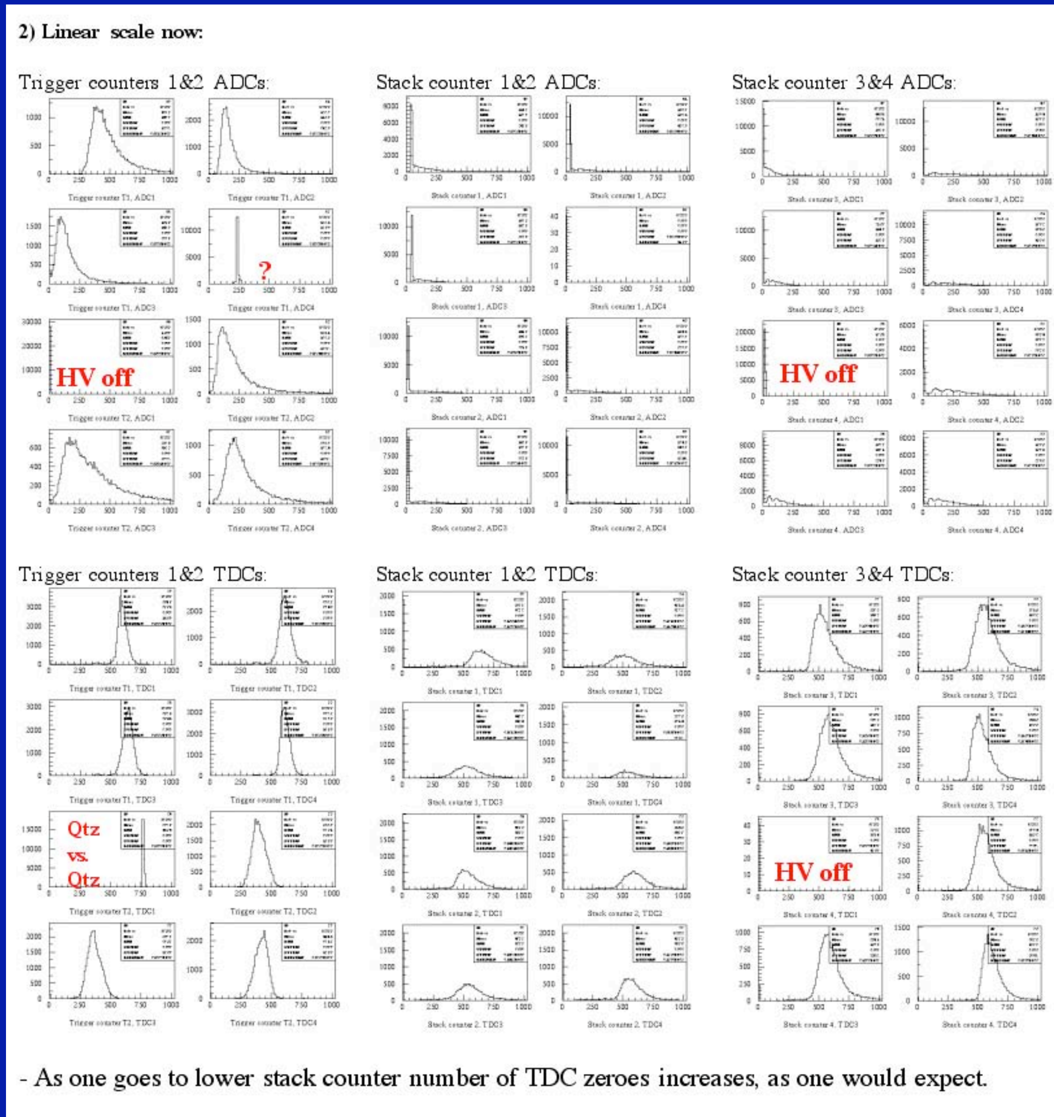
- **Keep a "detector image canvas" size constant for all pictures**

- **Will start with a nominal position: $\theta_{dip} \sim 90^o$ & position # 3.**
- **Need to shift the detector plane to reach smaller dip angles (~1.8 cm/10° dip angle).**
- **With some modification we could reach, perhaps, $\theta_{dip} \sim 75^o$.**

New readout configuration



Cosmic ray telescope counters:



Trigger rates:

- T1*T2 ~ 5-6 Hz
- T1*T2*S1 ~ 1-2 Hz
- T1*T2* Quartz_counter ~ 5-6 k/day
- T1*T2*S1*Quartz_counter ~2-3 k/day

Note:

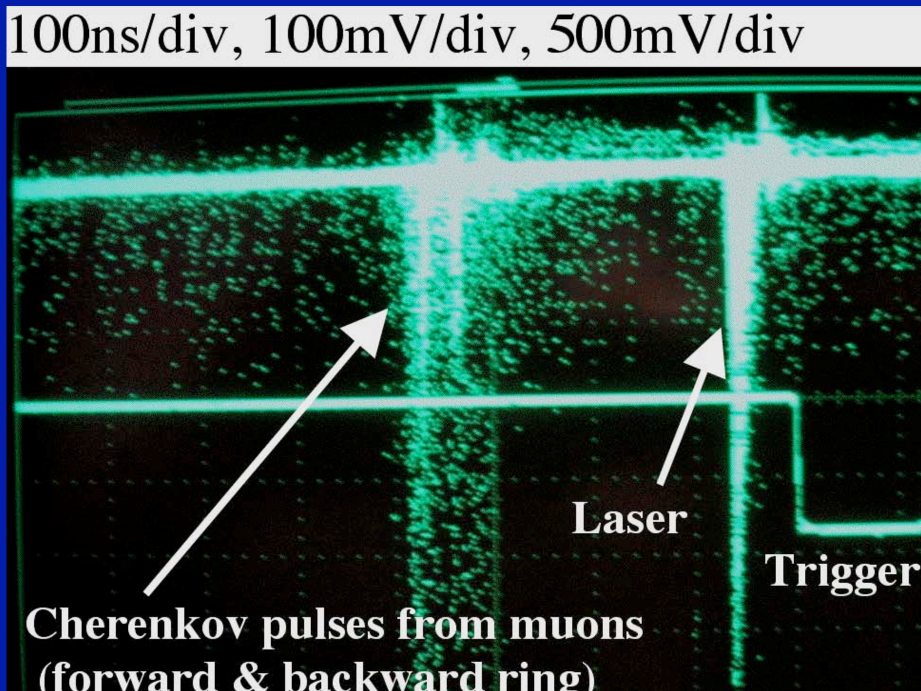
We use T1*T2* Quartz_counter trigger

Status:

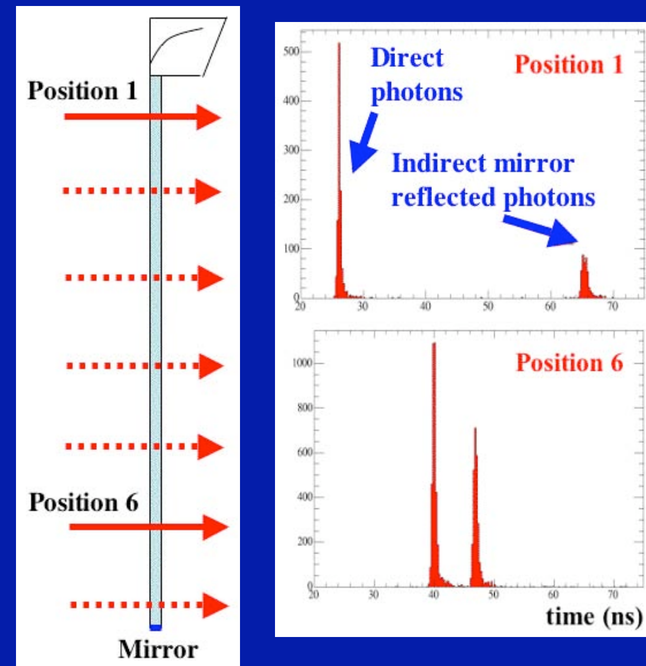
- Taking data
- CAMAC running
- BLABs need timing calibration

Monitoring of FDIRC in the telescope

On-line monitor:



Cherenkov photons in time domain



- **See forward and backward part of the Cherenkov ring in time domain, the PiLas laser monitoring pulses and the BLAB2 trigger**

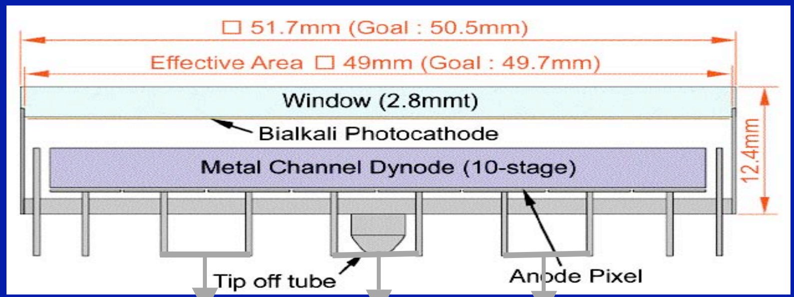
The new Hawaii electronics

FDIRC electronics chain

Gary Varner, Larry Ruckman, Kurtis Nishima, and Andrew Wong, Nucl.Instrum.Meth. A591,534-545,2008

H-8500

MaPMT:



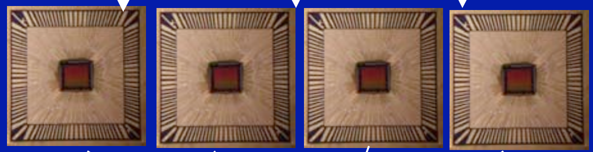
64 pixels, 8x8

64 Amplifiers/MaPMT,

Amp. gain ~ 40x

BLAB2

ASIC:



Waveform sampling electronics:

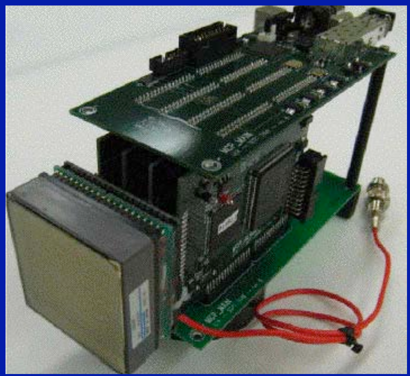
4 BLAB2 chips / MaPMT

Waveform sampling rate: ~ 2.5 GSa/s

Timing resolution goal: σ_{final} ~ 150-170 ps

FPGA array

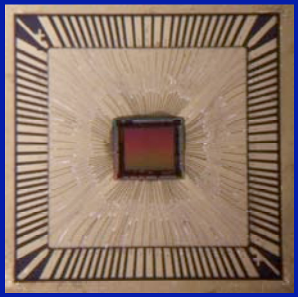
Initial geometry:



Status:

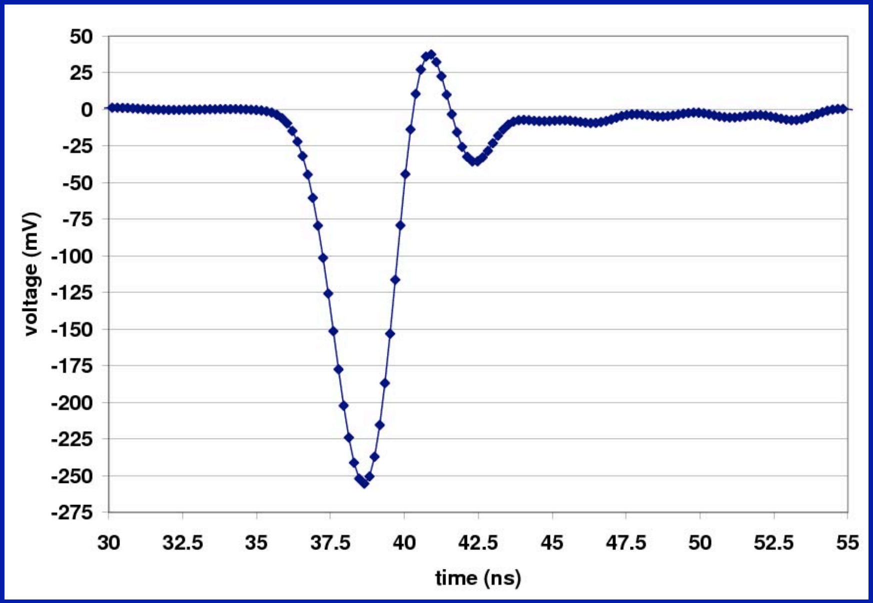
- One H-8500 is running in the telescope.
- Will have six more ready in March.

BLAB ASIC further studies

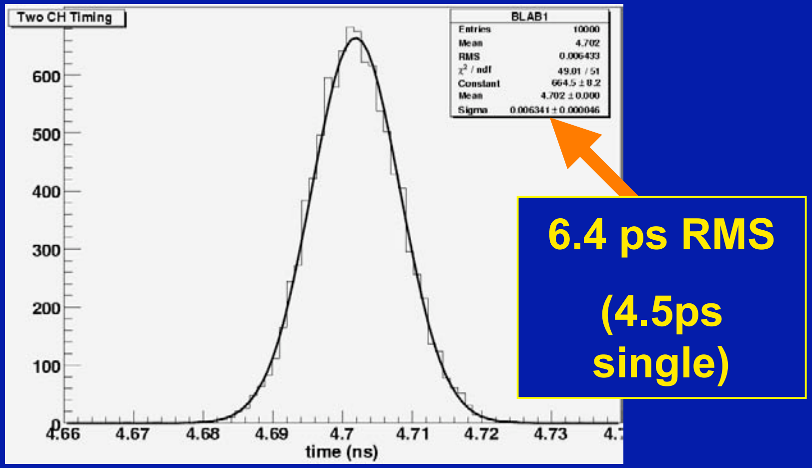


BLAB1 chip

Nucl.Instrum.Meth. A591,534-545,2008, and arXiv:0805.2225



- Comparable timing performance to best CFD + HPTDC methods
- MUCH lower power, no need for huge cable plant!
- Using full samples significantly reduces the impact of noise
- Photodetector limited



Summary of BLAB2 ASIC parameters

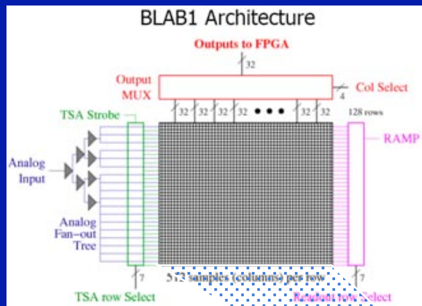
G. Varner

Parameter	Value
Samples	6 rows & 1024 samples
Triggering mode	Trigger on individual pixel
Analog BW of the present BLAB2 chip	~ 0.85 GHz
BLAB2 chip input impedance	30-80 Ω (adjustable)
Number of MaPMT pixels / BLAB2 ASIC	16
Number of BLAB2 ASICS / MaPMT (final vs. prototype)	2 - 4
Dynamic range	1mV / 1V
Cross-talk	< 0.1%
BLAB2 wafeform sampling speed	1 - 10 GSa/sec
On chip ADC	1 GHz Wilkinson
Number of Wilkinson conversions in parallel	32
ADC resolution	10 bits
ADC conversion time for 10 bits	1 μs
Number of words / event	32 - 512
Read time for 16 channels (1 BLAB2 chip) / event	16 μs
Sustained readout speed	50 kHz
12 μs latency accomplished by	Self-trigger & analog or digital storage
Cost per chanel	< $10 in volume

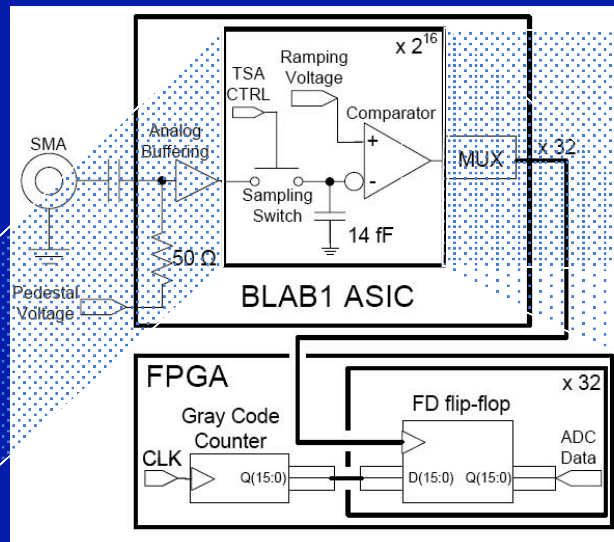
Details

Waveform sampling principle: Switched Capacitor Array

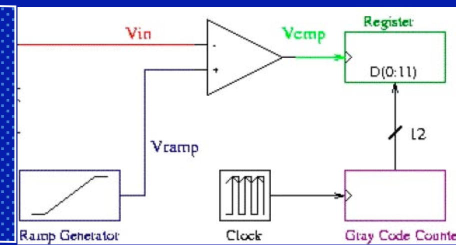
G. Varner, Larry Ruckmann and A. Wong, arXiv:0802.2278v1 [physics.ins-det], submitted to NIM, 2008



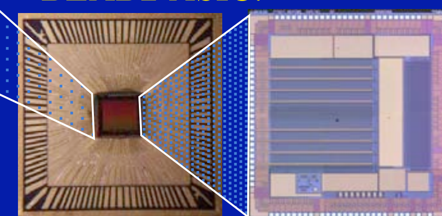
Capacitor array:



Wilkinson ADC:



BLAB2 ASIC:



Principle of wafeform sampling in BLAB chip:

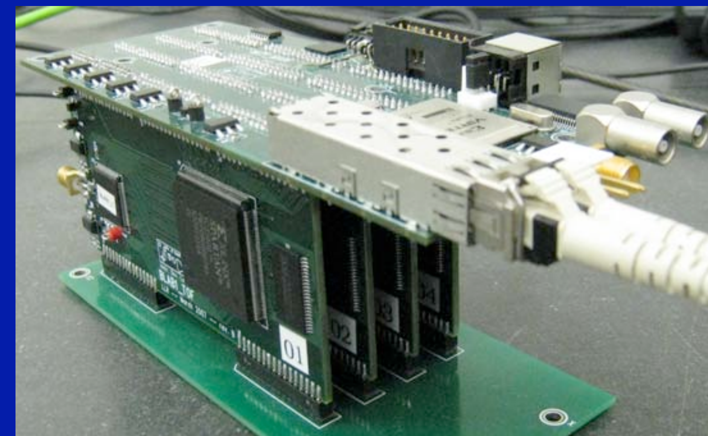
- Fast signal waveform is terminated in 50 Ω on the chip
- BLAB2 ASIC: 17ch & 6 rows & 1024 samples (102k storage cells)
- Each row can be independently addressed to initiate a storage cycle
- When analog switch is closed the instantaneous signal is stored on a 14 fF capacitor
- ADC conversion is done via the Wilkinson method:
  Comparators done inside BLAB chip & high speed encoding done in FPGA
  32 samples are converted in parallel
- 10-bits corresponds to a conversion time of 1 μs in the current scheme.
- Up to 10 GSa/s (100ps sampling interval <=> ~5 samples on the leading edge); the present limit: 2.5GSa/s.
- 12 μs latency: (a) TOF: self-trigger and digital temporary storage
  (b) FDIRC: analog storage

Highly Integrated Readout

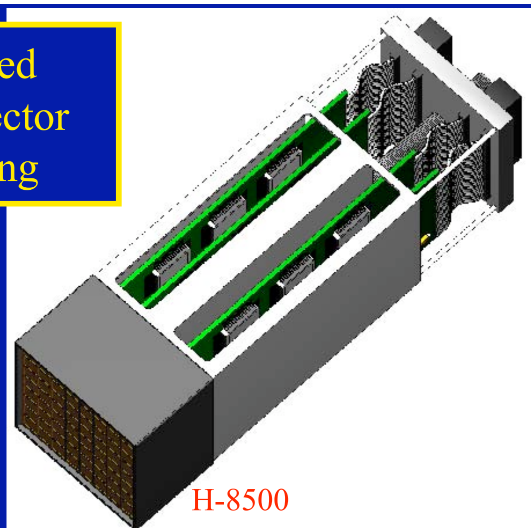
- **Buffered LABRADOR**

TABLE II: *BLAB2 ASIC Specifications.*

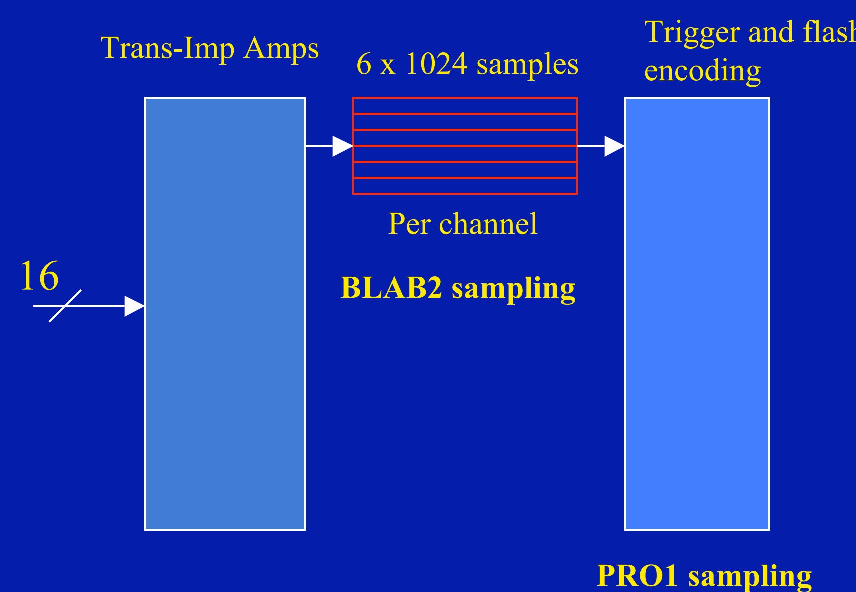
Item	*Value*
Photodetector Input Channels	16
Linear sampling arrays/channel	2 → 6
Storage cells/linear array	512 → 1024
Sampling speed (Giga-samples/s)	2.0 - 10.0
Outputs (Wilkinson)	32



Integrated Photodetector packaging

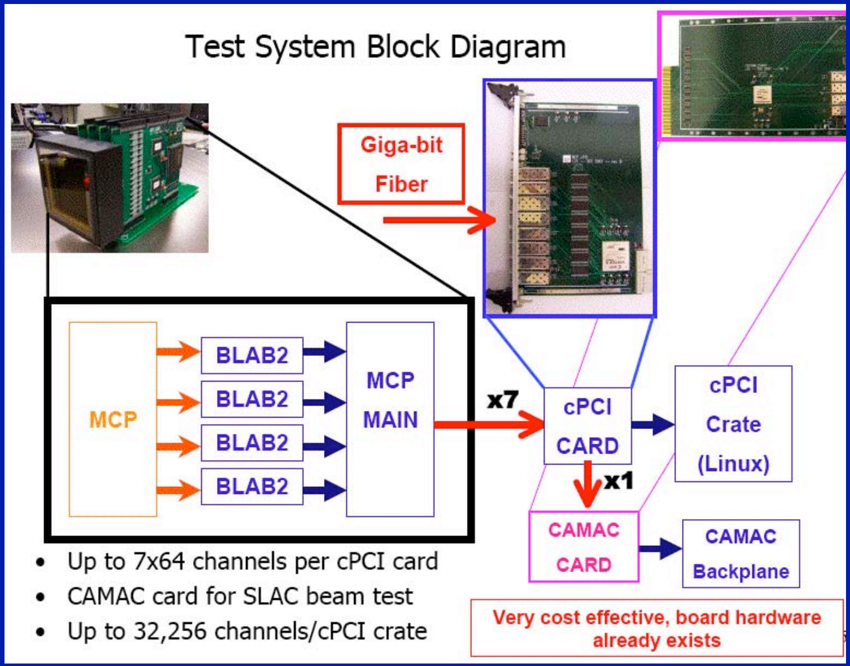


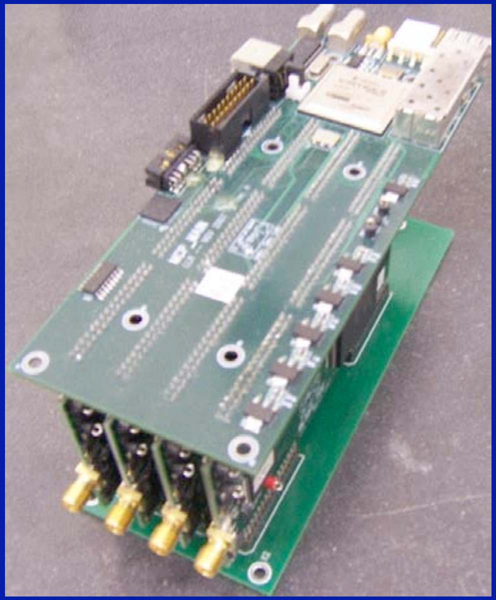
BLAB2 ASIC



BLAB2 lectronics for the next beam or cosmic ray tests at SLAC

Gary Varner & Larry Ruckman

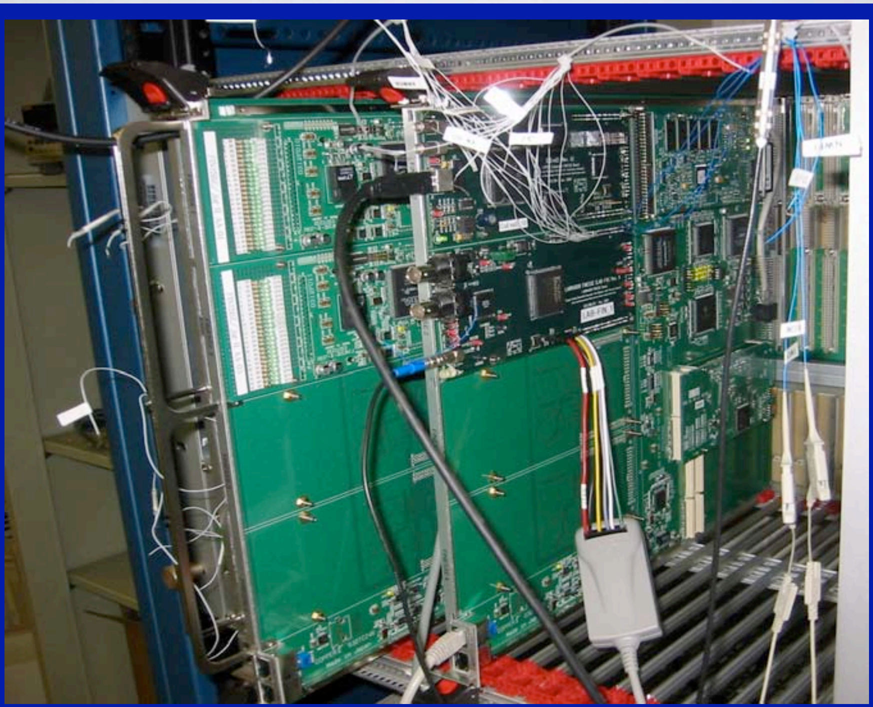




- Prototype boards with BLAB1 chip now exists; BLAB2 chip is almost ready and will be sumbitted to a foundry on June 2.
- To instrument all 64 pixels one needs 4 BLAB chips. That is what we want to have in the prototype in the fall. However, the final DIRC will very likely use 2 chips per MaPMT (2 pads ganged together, 32 pixels/MaPMT).
- Worry about a minituarization later.

Readout Requirements

4x fiber pairs/FINESSE
(= 1 iTOP) module
2x dual Shark DSP/FINESSE

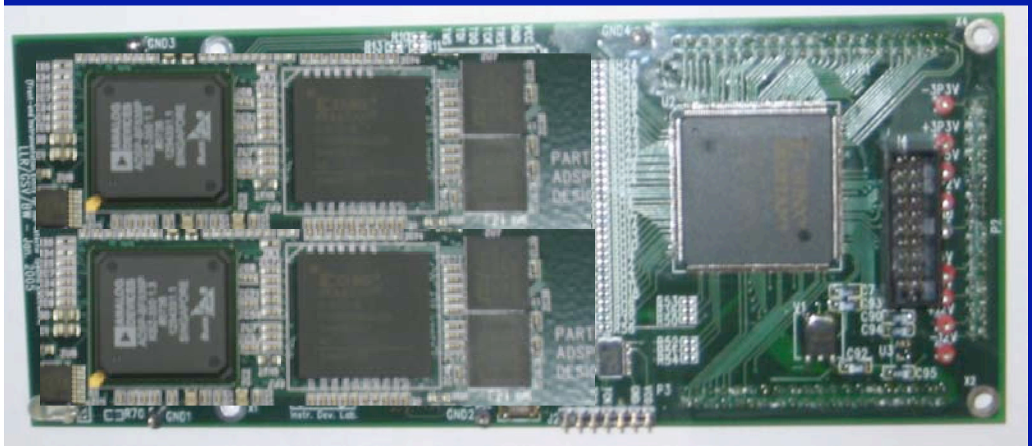


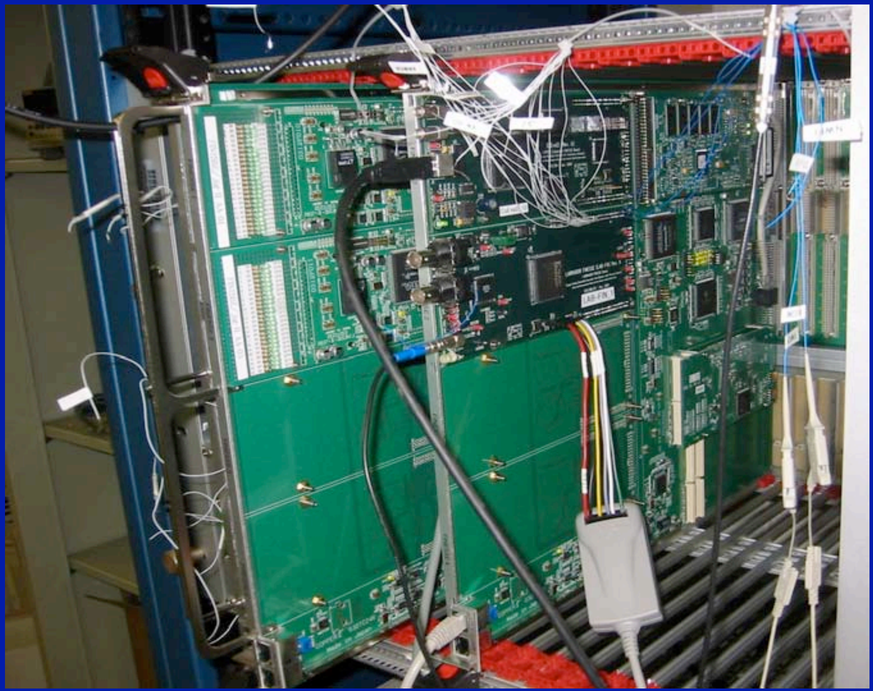
4 FINESSE/COPPER (2k chan)
8 COPPER Total
16k total system channels

Even less if use GaAs (4-channel PMTs)

8x COPPER-sized cards for trigger
collection/Trigger fan-out

Data volume estimate





Assume:
100kHz charged track hits on each bar

~32 p.e./track (1% of 100ns windows)
30kHz trigger rate
Each PMT pair sees <8> hits
240k hits/s
Each hit = 64samples * 8bits = 512bits
➔~125Mbits/s
(link is 1.2Gb/s ~ x10 margin)

<u>BlackFin DSP</u>

- Pedestal subtract
- Feature extract ➔ T, Q

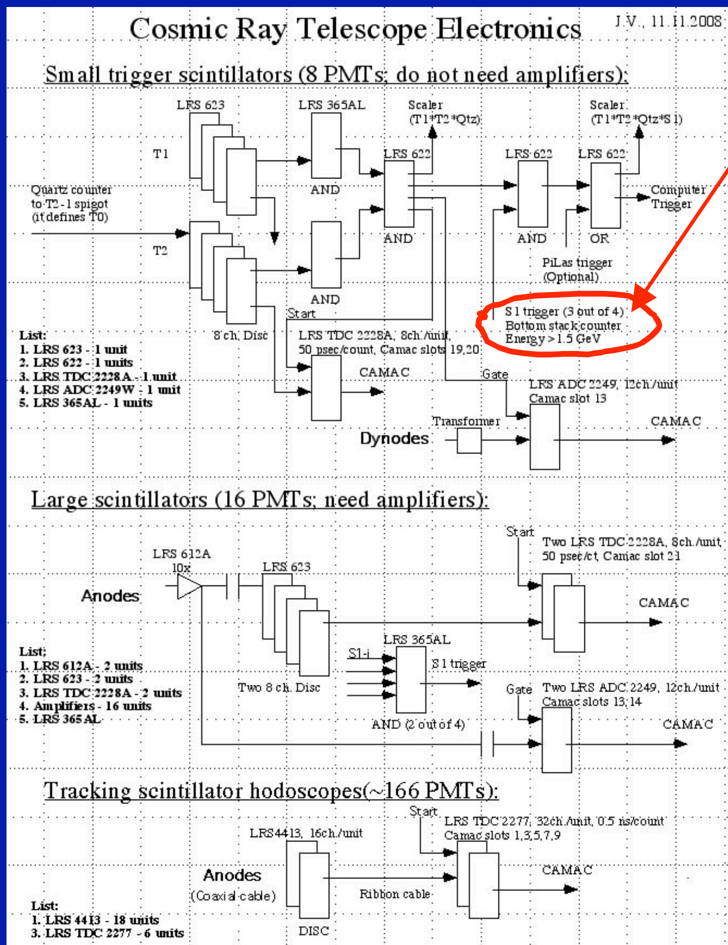
(tentatively allow up to 4x hits in 100ns)

- Time = 2Bytes, Q = 2Bytes

8 hit chan * 1 hit typ * 4By = 32By/link
256 By/iTOP counter
1kB/event/COPPER

8kByte/event iTOP

SLAC cosmic ray telescope



Energy

Trigger rates:

- T1*T2 ~ 5-6 Hz
- T1*T2*S1 ~ 1-2 Hz
- T1*T2* Quartz_counter ~ 5-6 k/day
- T1*T2*S1*Quartz_counter ~ 2-3 k/day

New DAQ:

- μPCI ceate: μPCI CPU - master, fiber optics transievers talk to boards on H-8500 MaPMTs
- Communicate with the rest of CAMAC via the CC-USB controllers
- The new DAQ system created by Gary Varner & Kurtis Nishima

- **Status: cosmic ray telescope is running, together with the PiLas laser diode.**