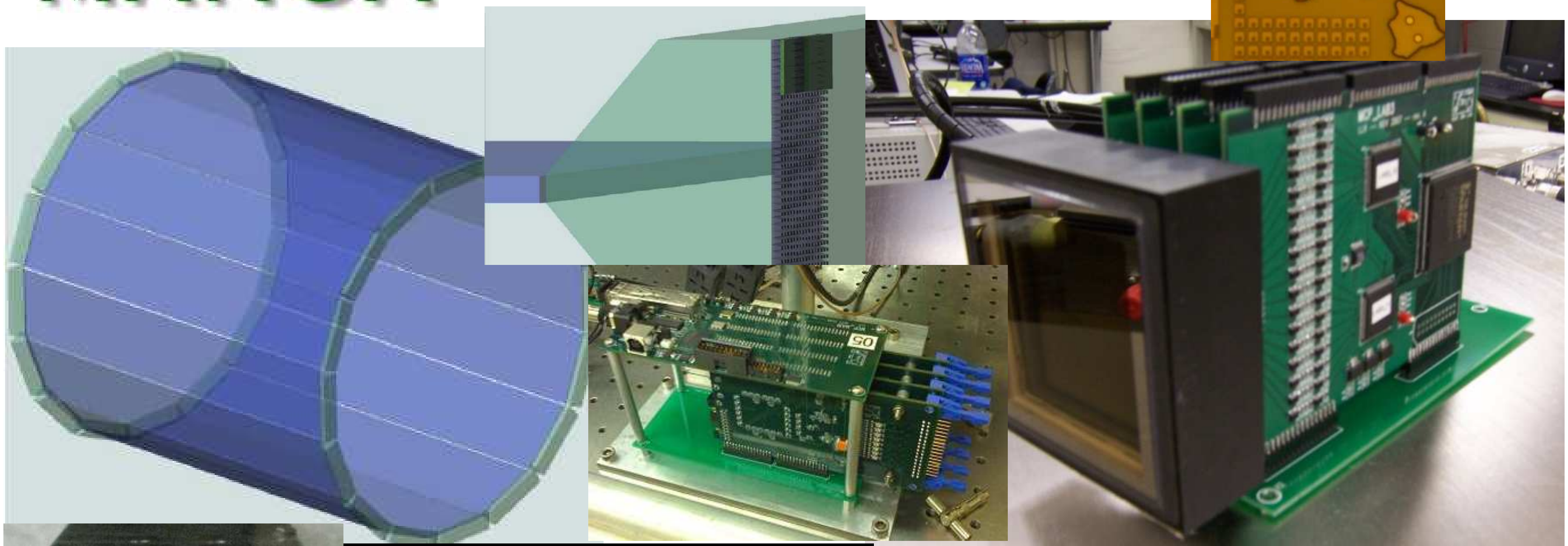
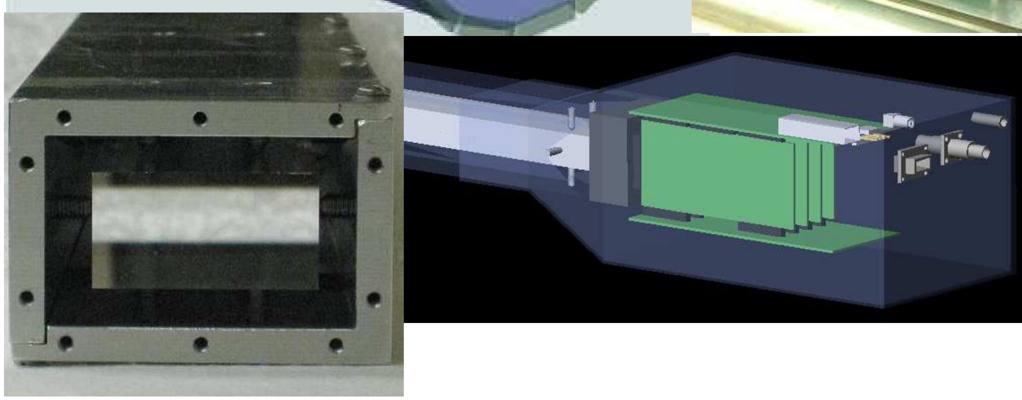
Imaging TOP (iTOP), Cosmic Ray Test Stand & PID Readout Update

UNIVERSITY OF HAWAII AT MANOA



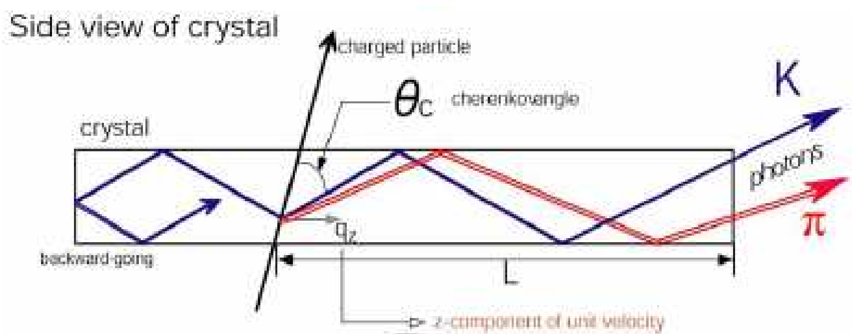


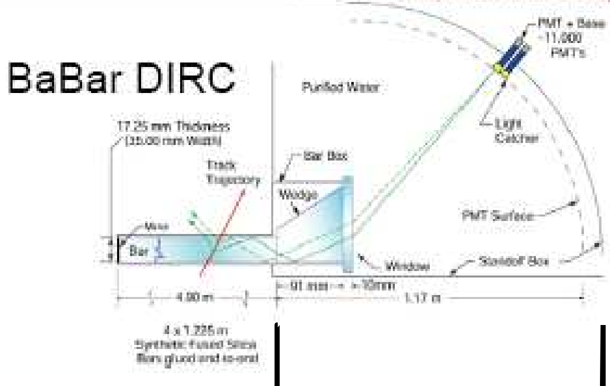
Tom Browder, Herbert Hoedlmoser, Bryce Jacobsen, Jim Kennedy, Kurtis Nishimura, Marc Rosen, Larry Ruckman, Gary Varner

Kurtis Nishimura | SuperKEKB PID Parallel Session | December 11, 2008

imaging TOP (iTOP)

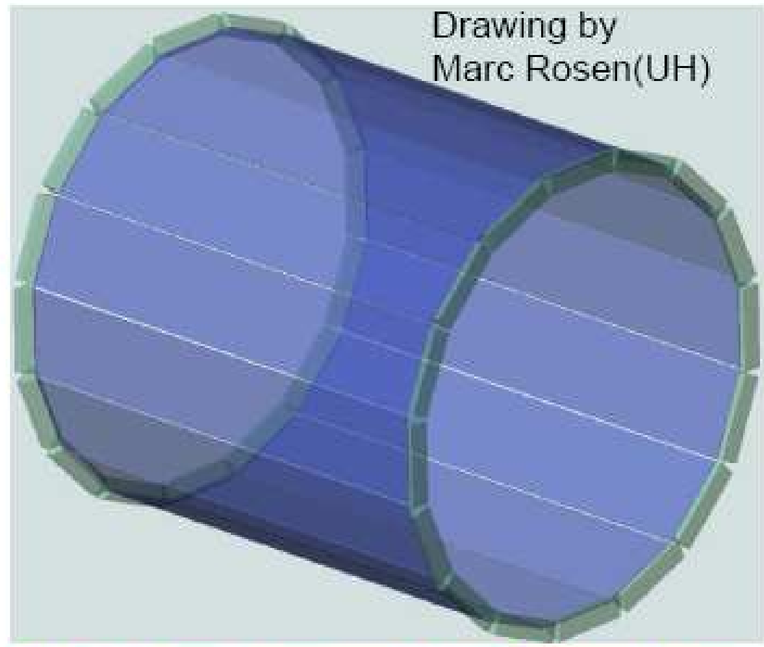
Concept: Use best of both TOP (timing) and DIRC and fit in Belle PID envelope





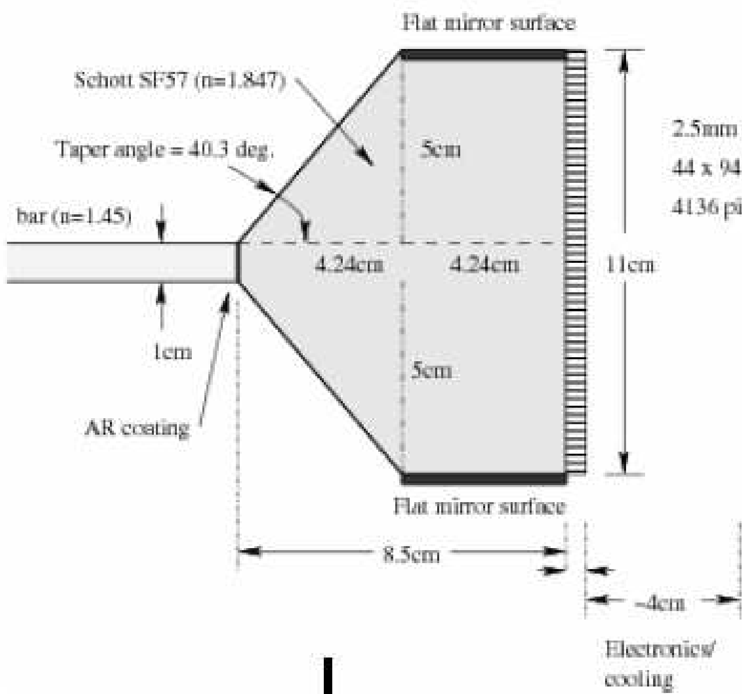
> 1 meter: Need more compact solution.

iTOP Concept Drawing



- Use new, compact solid-state photon detectors, new high-density electronics
- Use simultaneous T, θc [measured-predicted] for maximum K/π separation
- Keep pixel size comparable to DIRC

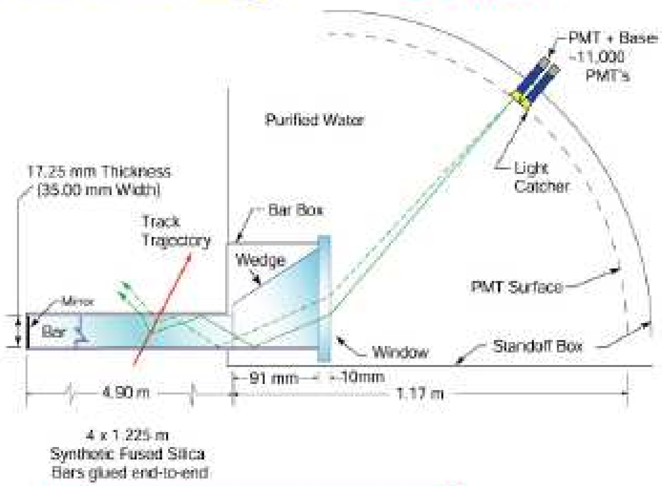
Simple refractive focusing

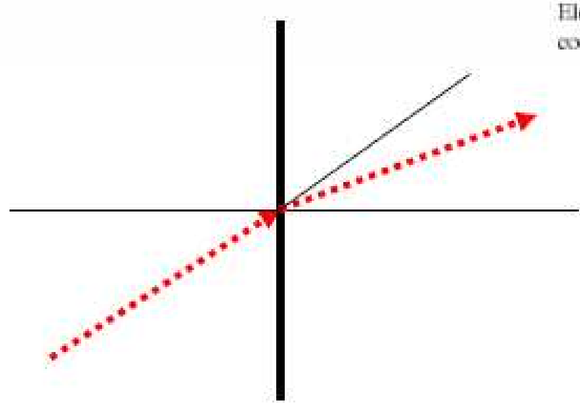


2.5mm

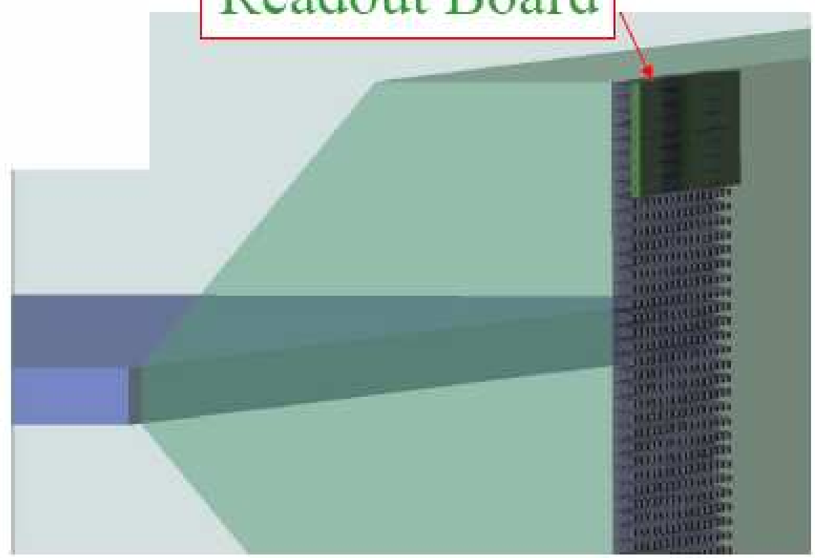
2.5mm (V) x 5mm (H) pixels
44 x 94 pixels
4136 pixels/plane

29mm





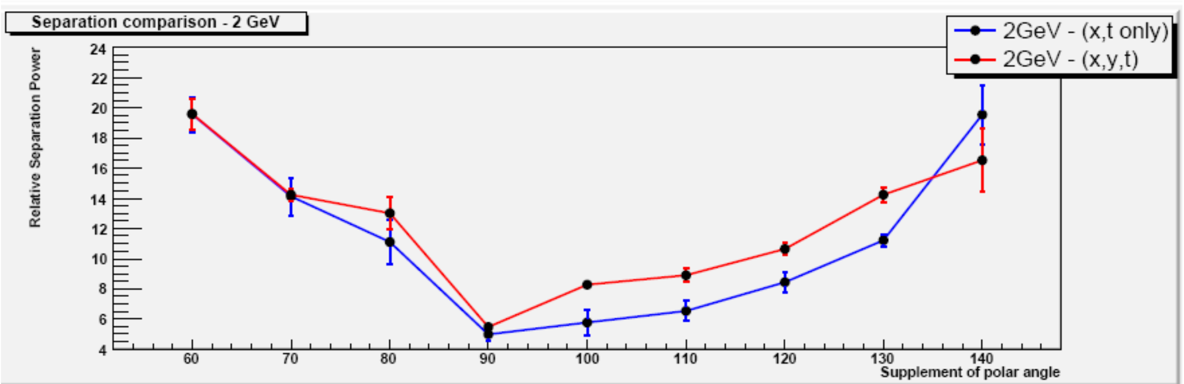
Readout Board

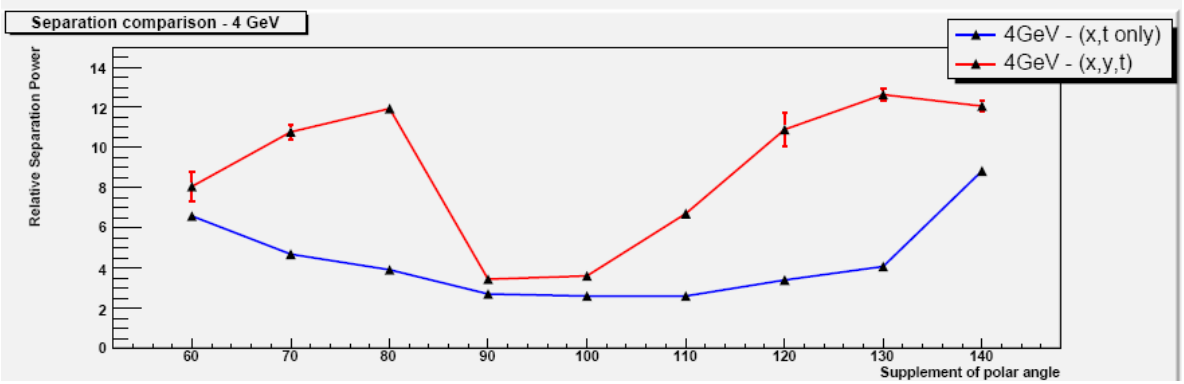


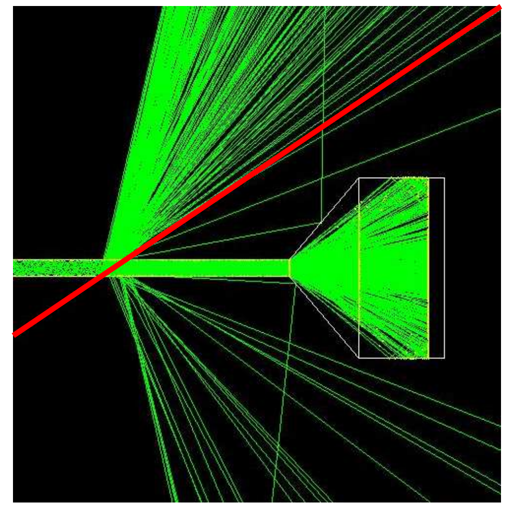
Refraction in stand-off block compacts the image.

Previous GEANT4 Simulation

- Simulations of relative K/π separation based on ΔLog(L) method:



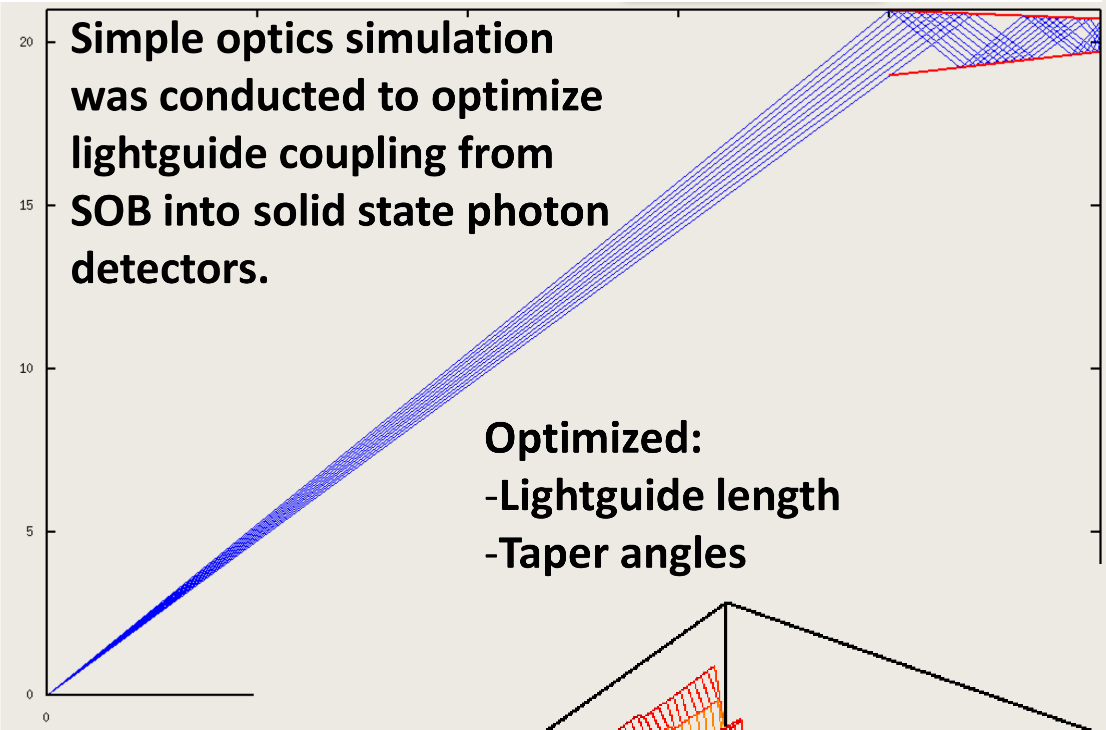




Some challenges with initial assumptions have been found.
Method needs testing & validation.

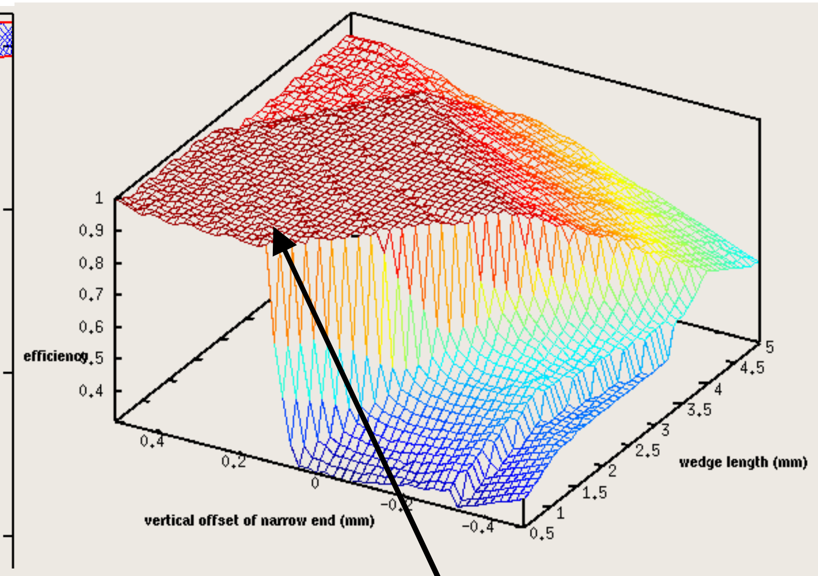
➔ **Adding second dimension of image reconstruction improves separation power!**

Refractive Focusing Challenges

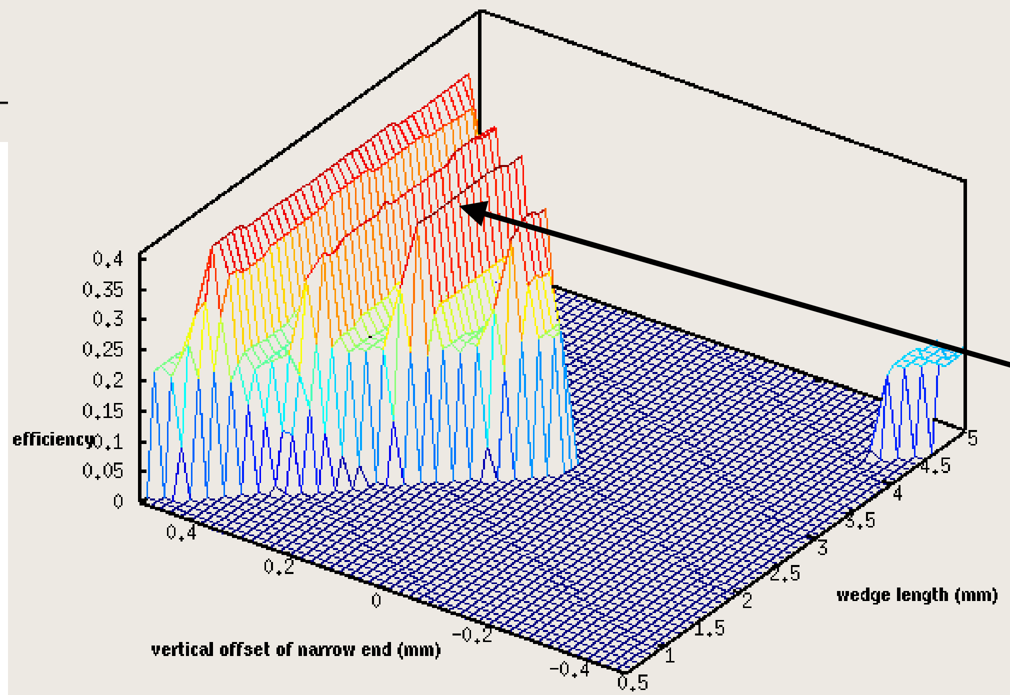


Simple optics simulation was conducted to optimize lightguide coupling from SOB into solid state photon detectors.

Optimized:
-Lightguide length
-Taper angles



With small offsets from bar axis, coupling can be done very efficiently (~100%).



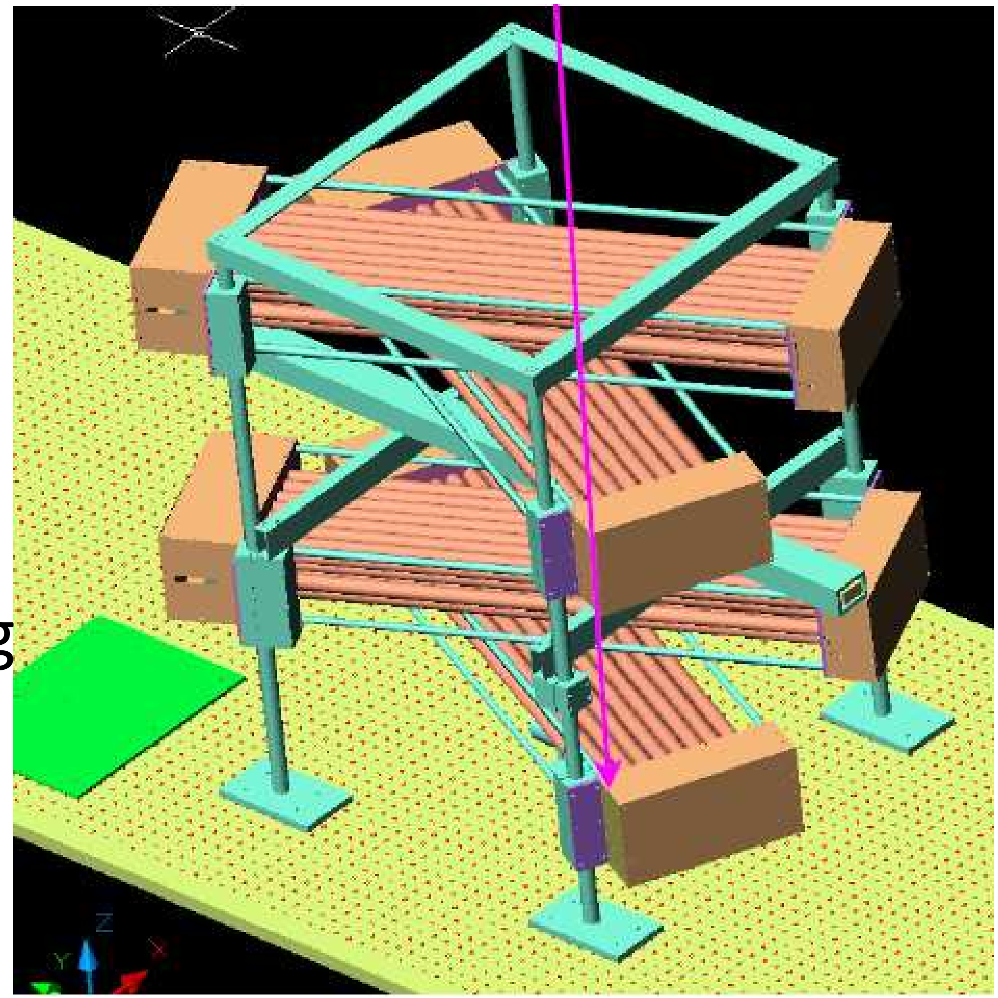
Off axis, maximum efficiency is limited (~40%)→light trapped.

Possible solutions:

- **Faceted SOB**
- **Different detectors**

Hawaii Testbed for Innovative Detectors & Electronics (HI-TIDE)

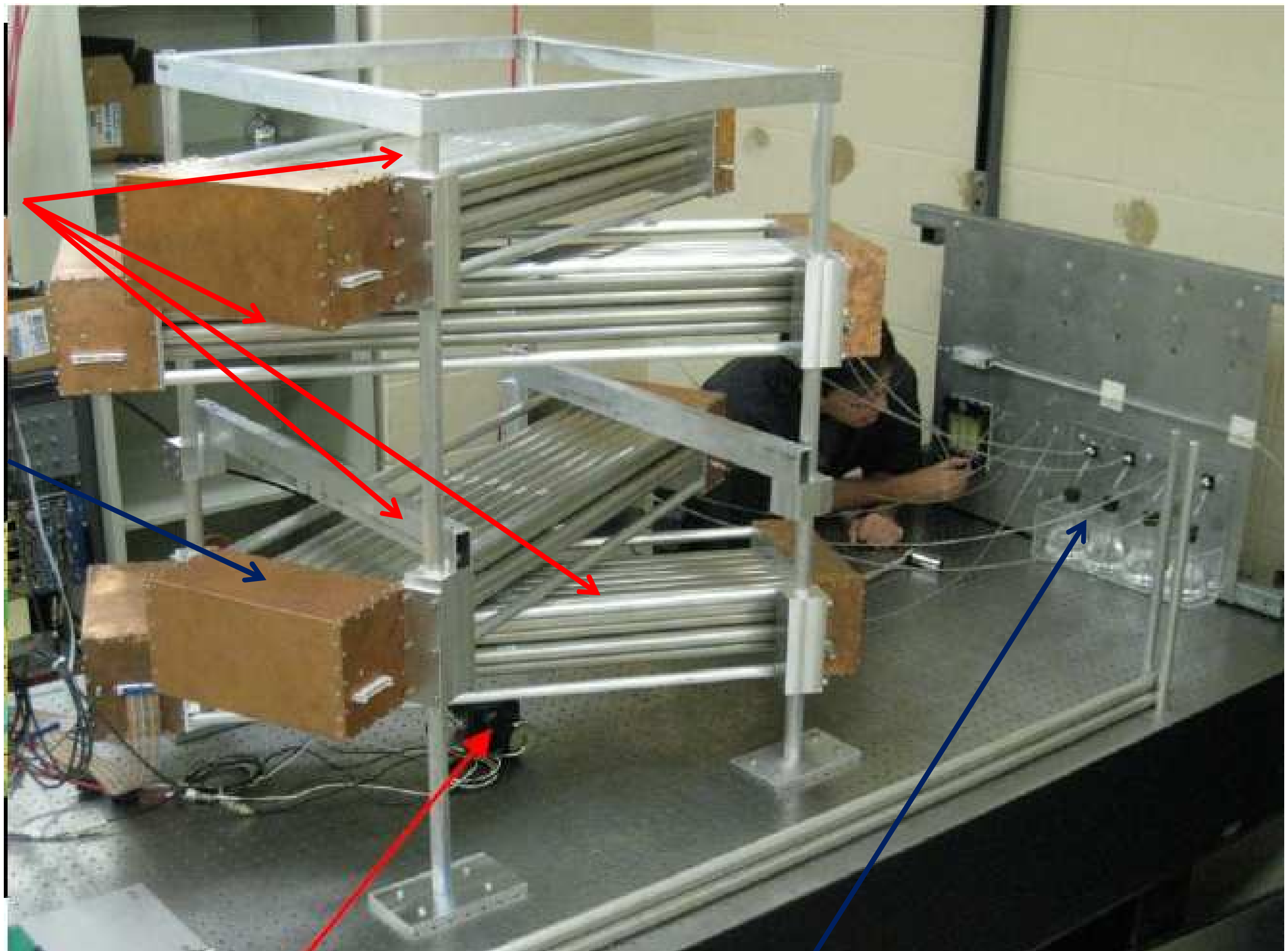
- Cosmic muon test stand for validation of simulations, testing of electronics in Hawaii.
- Initial system:
  - Basic tracking system completed, initial testing performed.
  - Quartz bar
- Upgrades underway.



Initial HI-TIDE System

128x Drift tubes: Al, 1” OD

4x 32x Preamplifiers (Inside copper cases)

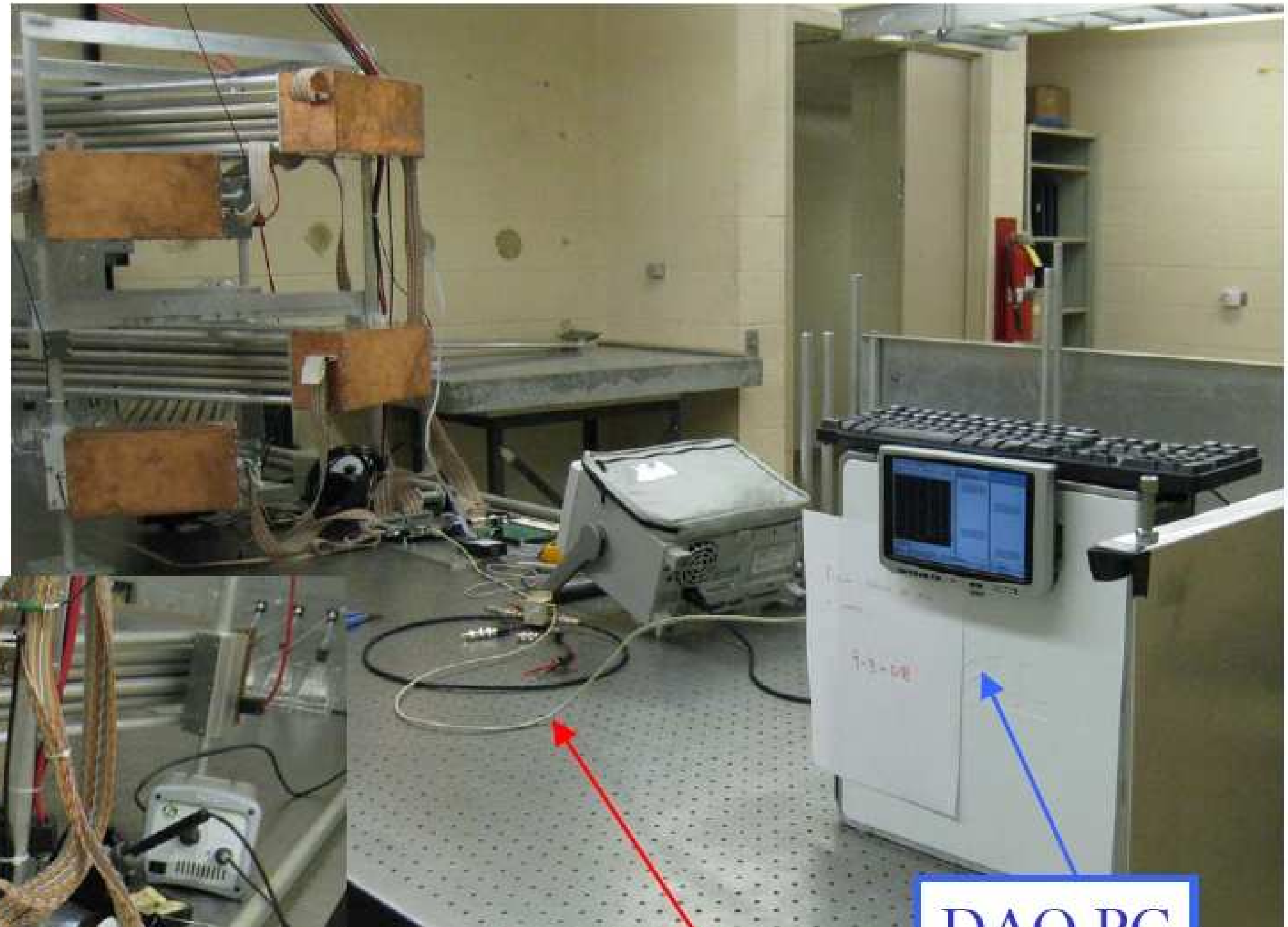


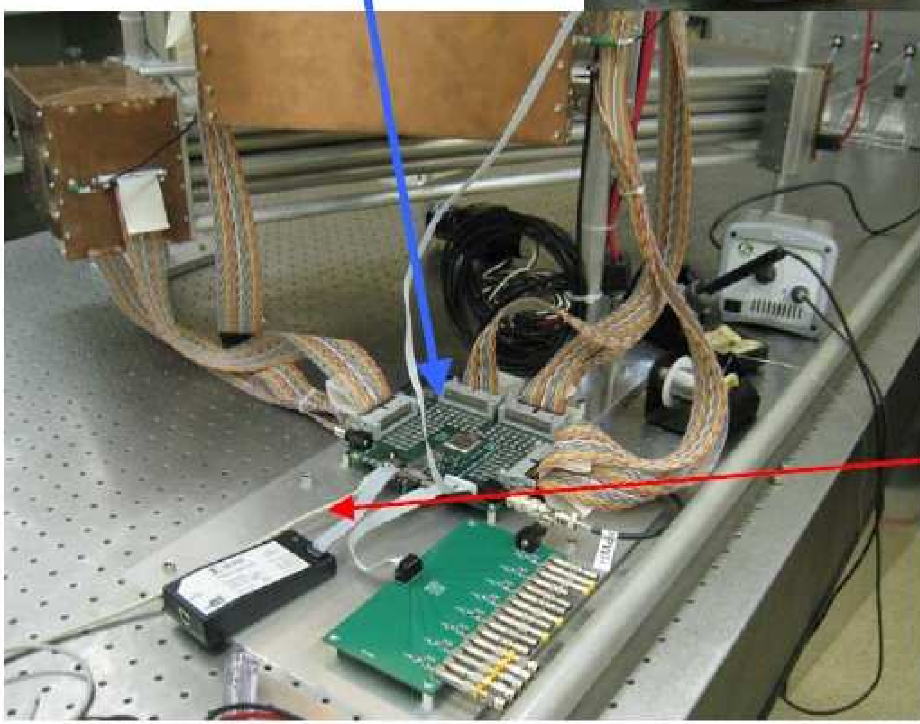
Precision Timing Block – Radiator bar w/ 2 PMTS

Gas – 90% Argon, 10% CO^2

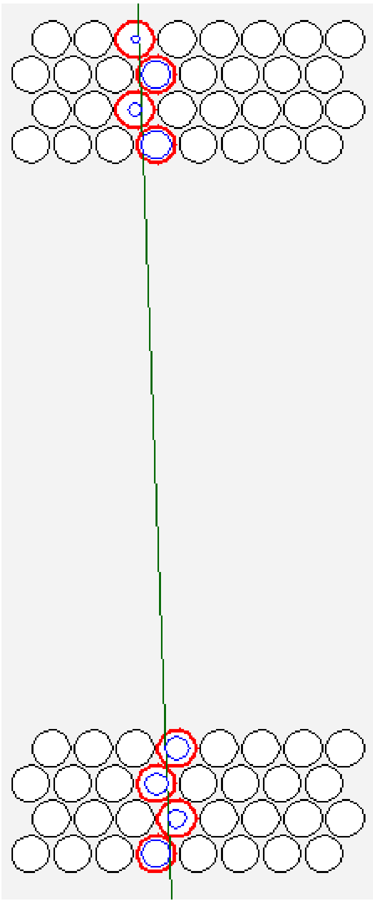
Cosmic Test Bench - Electronics

- 128 channel Discriminator and TDC board (TRAMP)

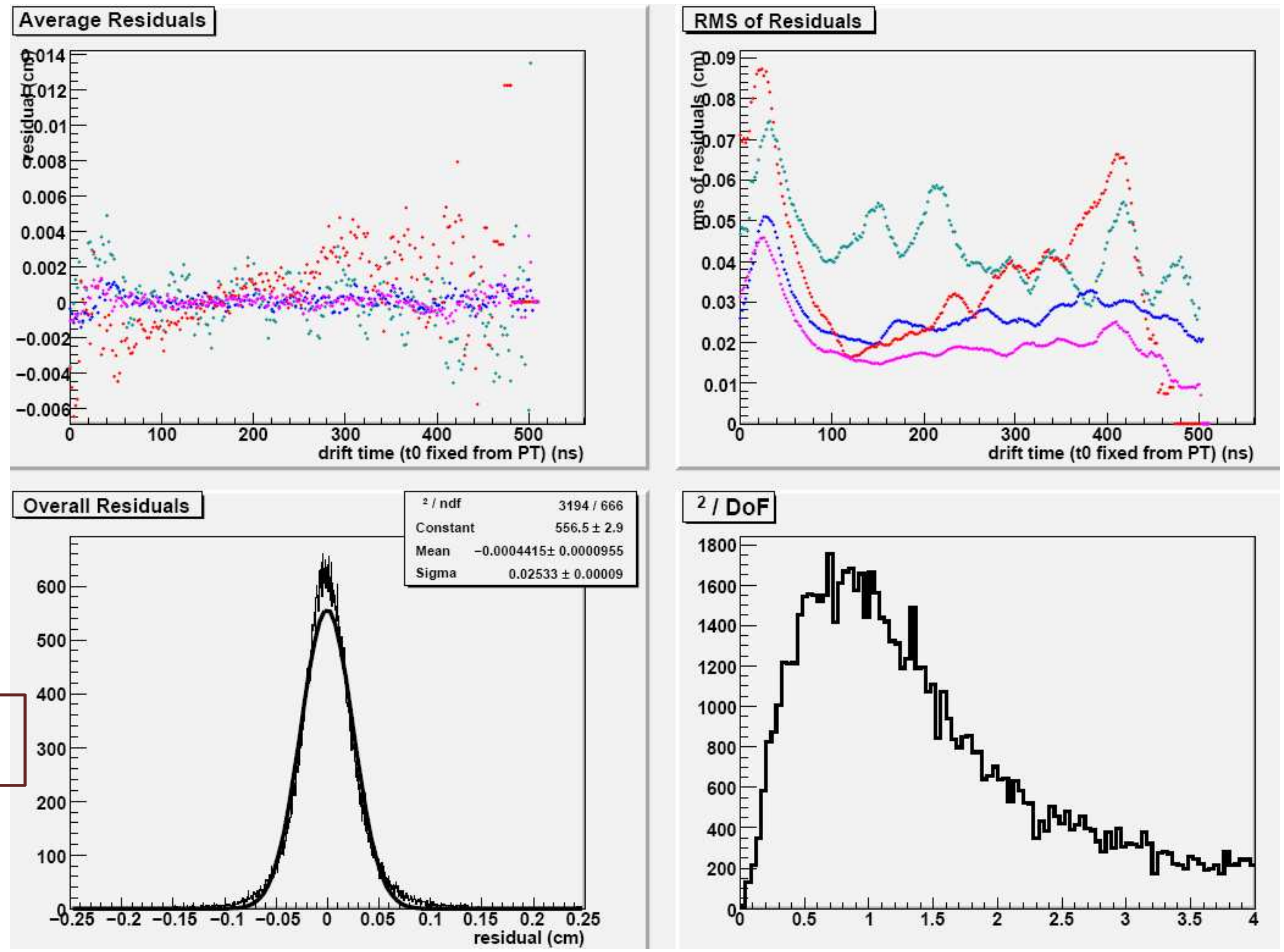




Calibration of Drift Tubes



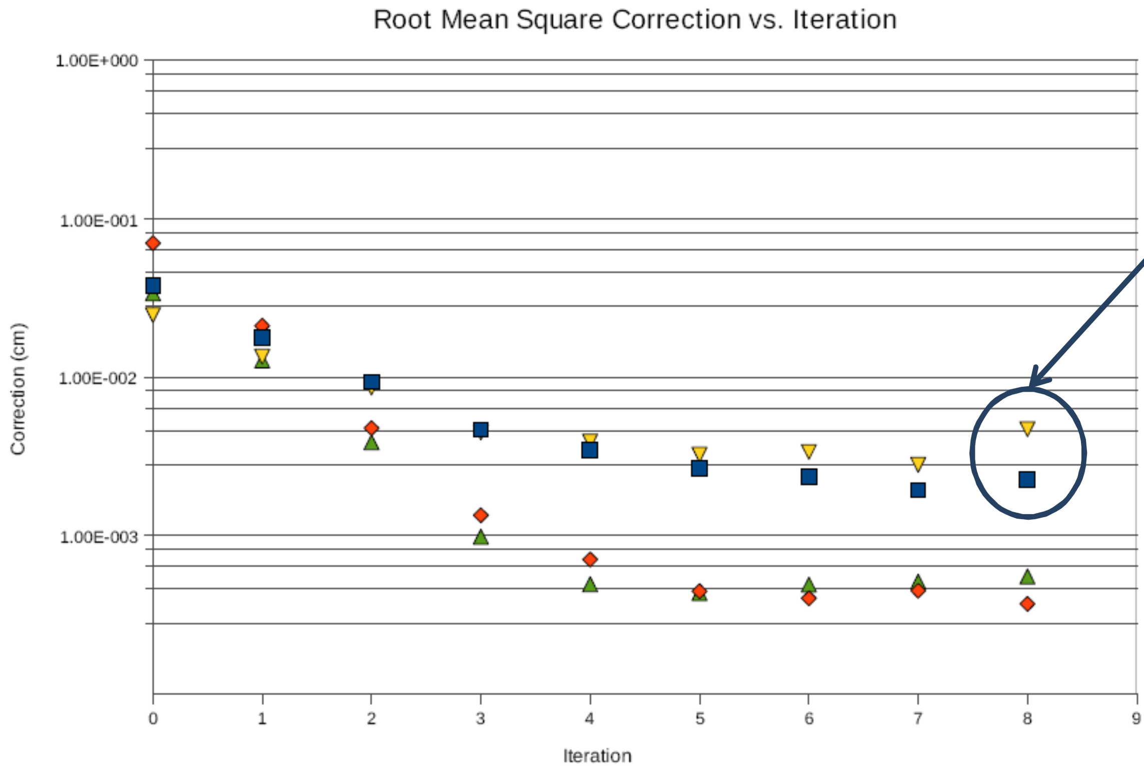
Fits performed in individual planes.
Residuals used iteratively to calibrate (results shown after 7 iterations).



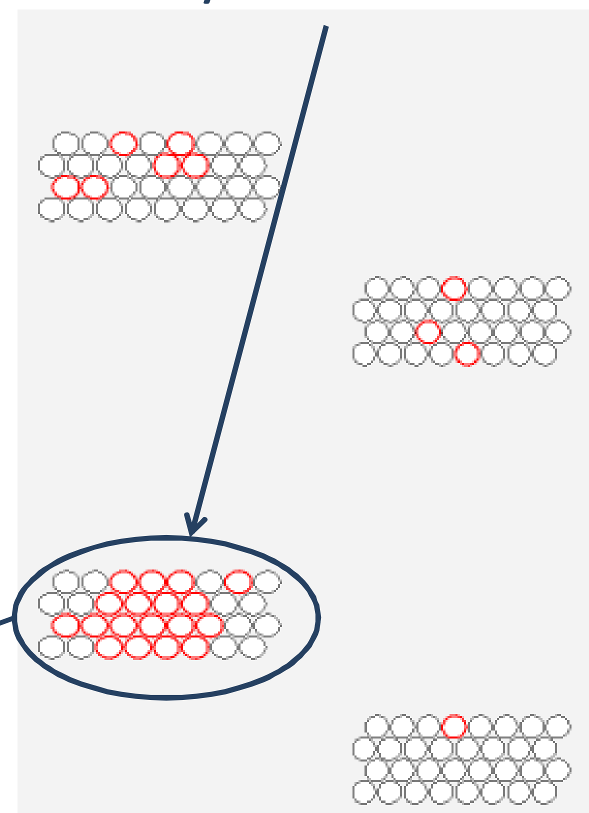
Overall σ_r = 25 μm

$$\sqrt{\sum_i \frac{\bar{\Delta}_i^{\,2}}{N_{bins}}}$$

Drift Tube Issues / Upgrades



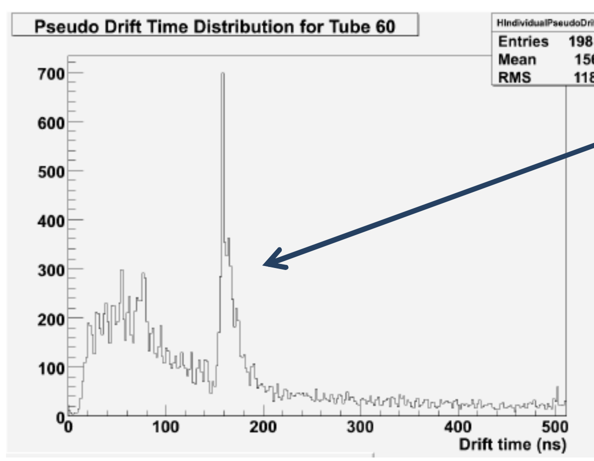
Problem in layers 1/3?
Maybe due to noise/crosstalk:



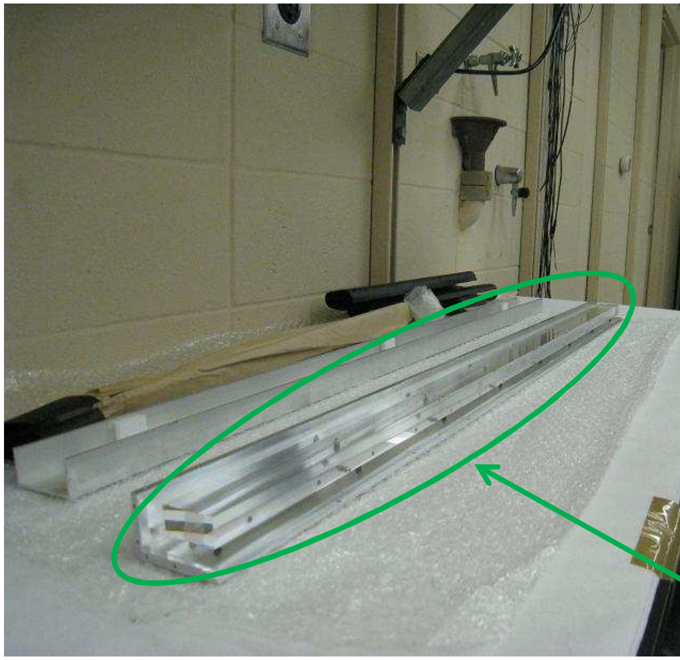
Crosstalk is difficult to detect from TDC values alone.

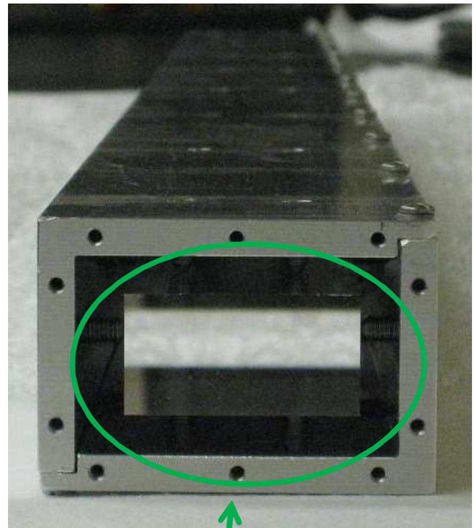
➔Upgrades underway:

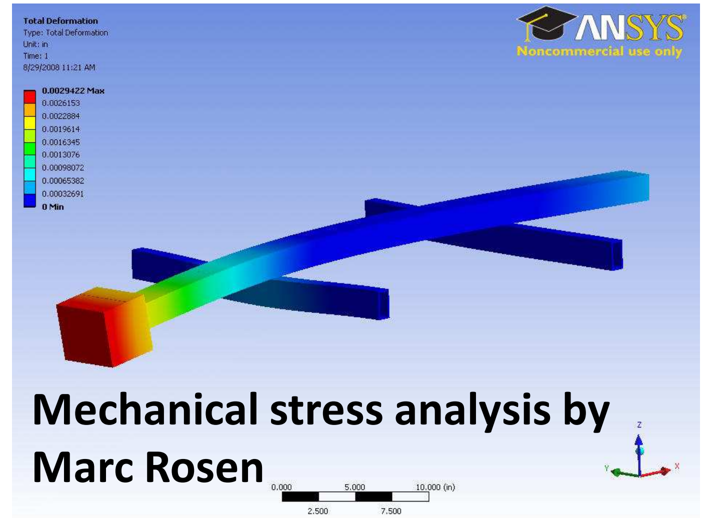
- **Full waveform readout with BLAB2 (fiberoptic).**
- **Readout from both sides of drift tubes.**

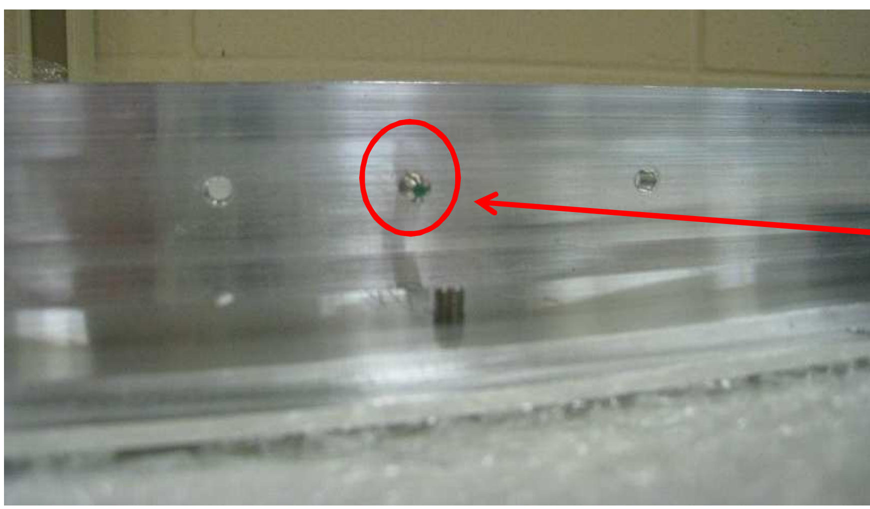


Quartz Bar Assembly & Support







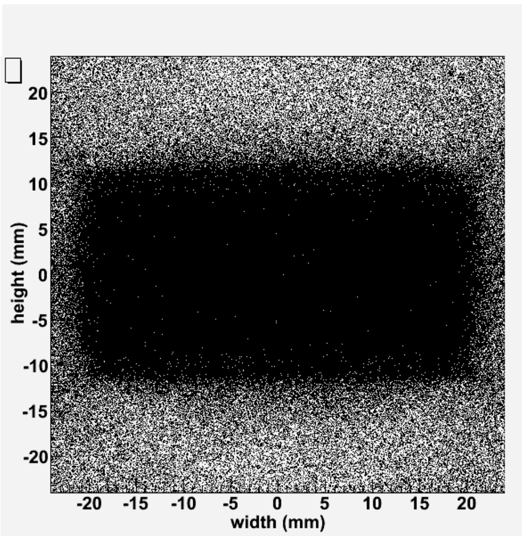


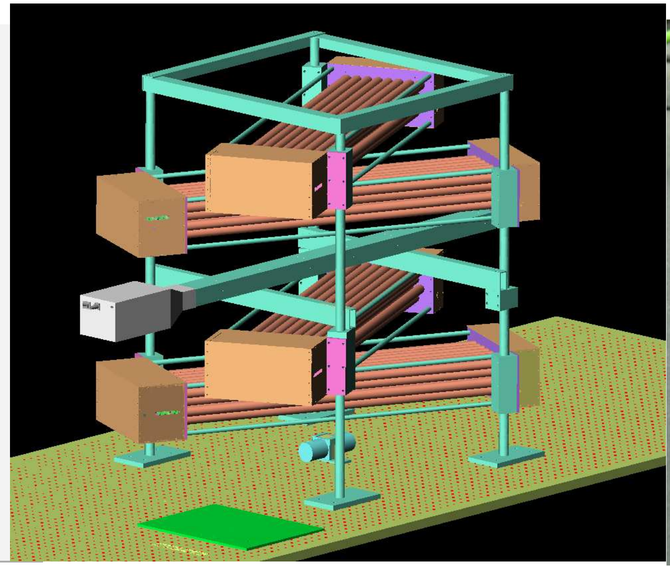
Quartz Bar (Zygo)
- 2 x 4 x 120 cm
- n = 1.47

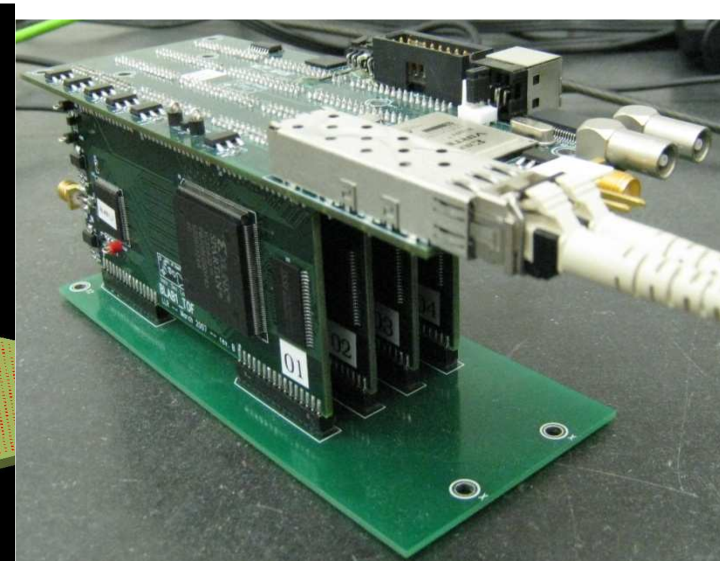
Nylon tipped screws support bar.

Mechanical cantilever support

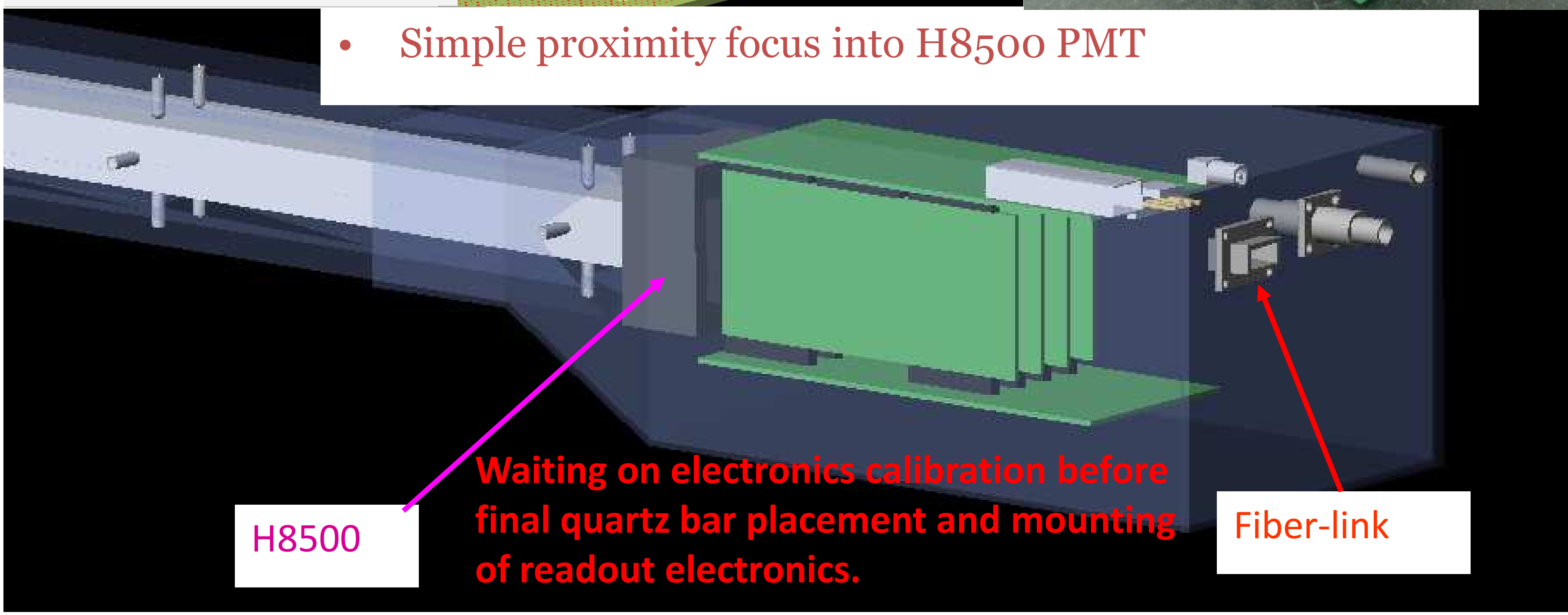
Initial Quartz bar test

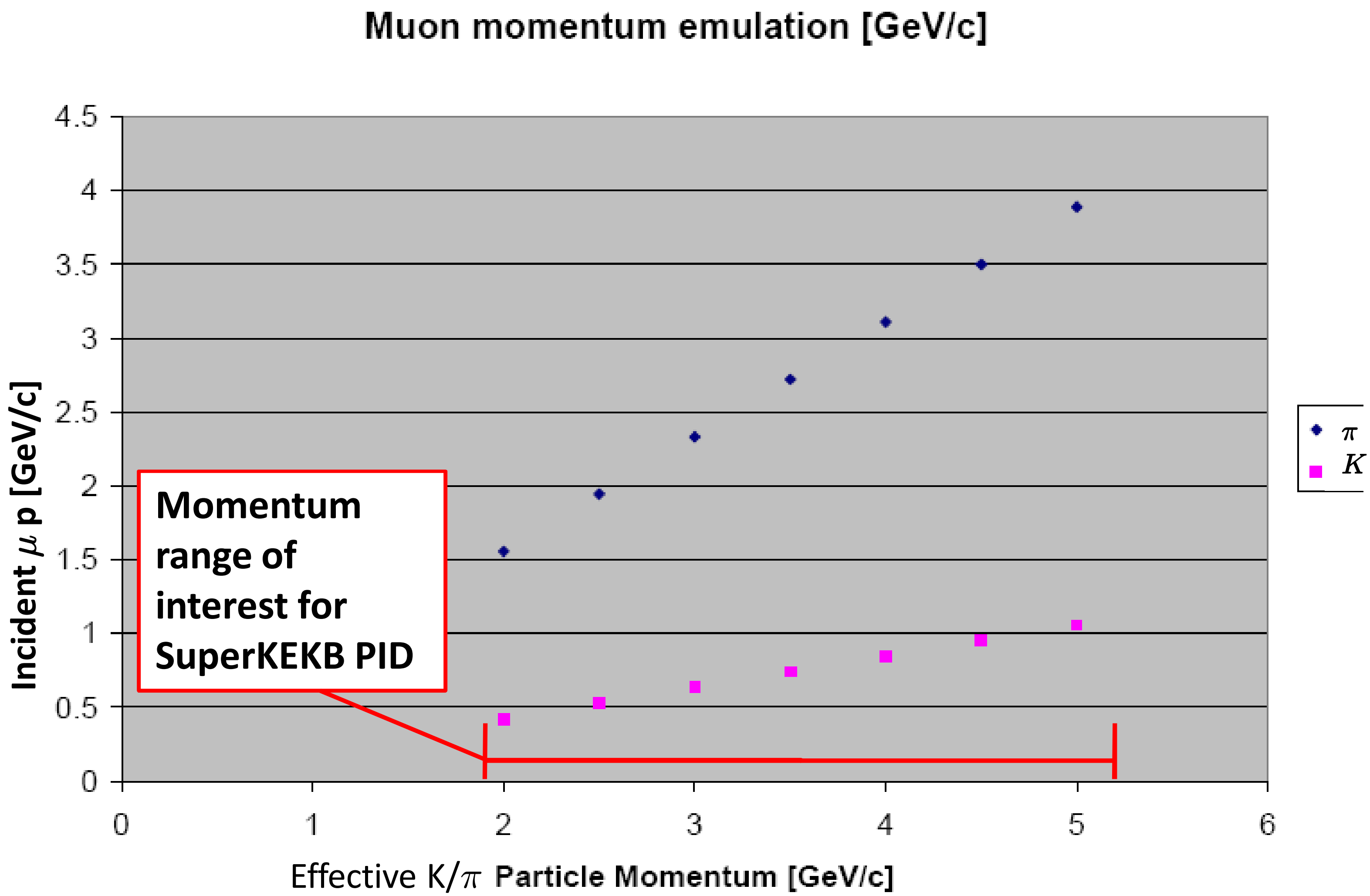






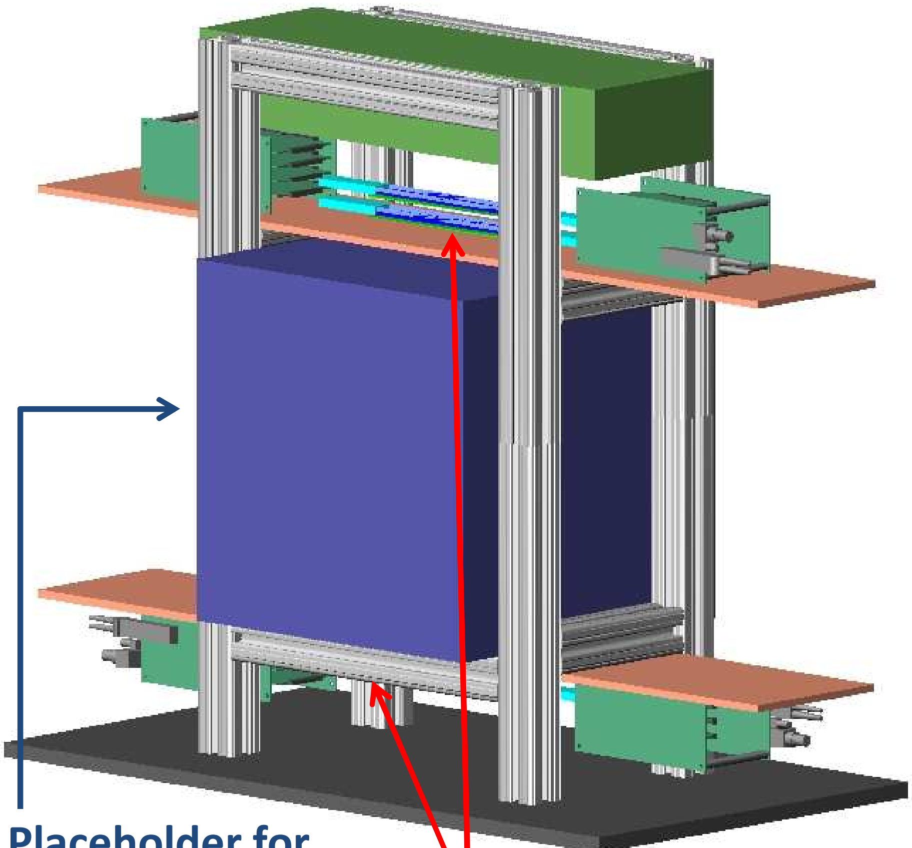
- Simple proximity focus into H8500 PMT





- Need momentum measurement to test K/π performance!
- Magnet assembly will measure momentum ➔ Initial simulation & magnet design have begun

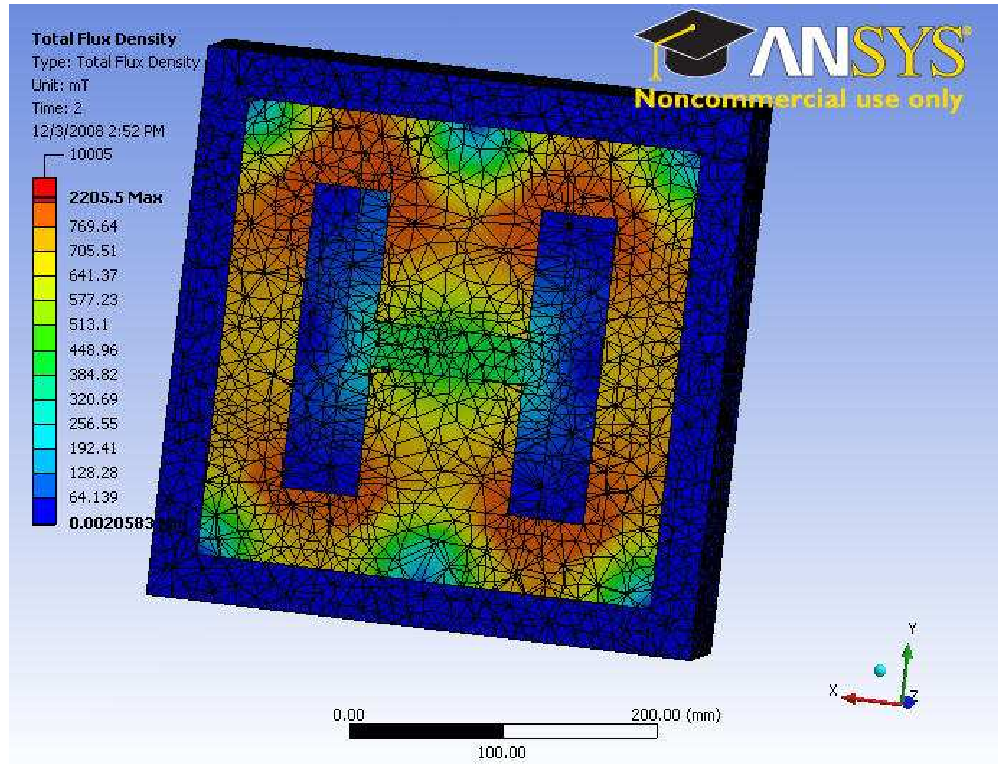
Ongoing Magnet Design



Placeholder for final magnet design

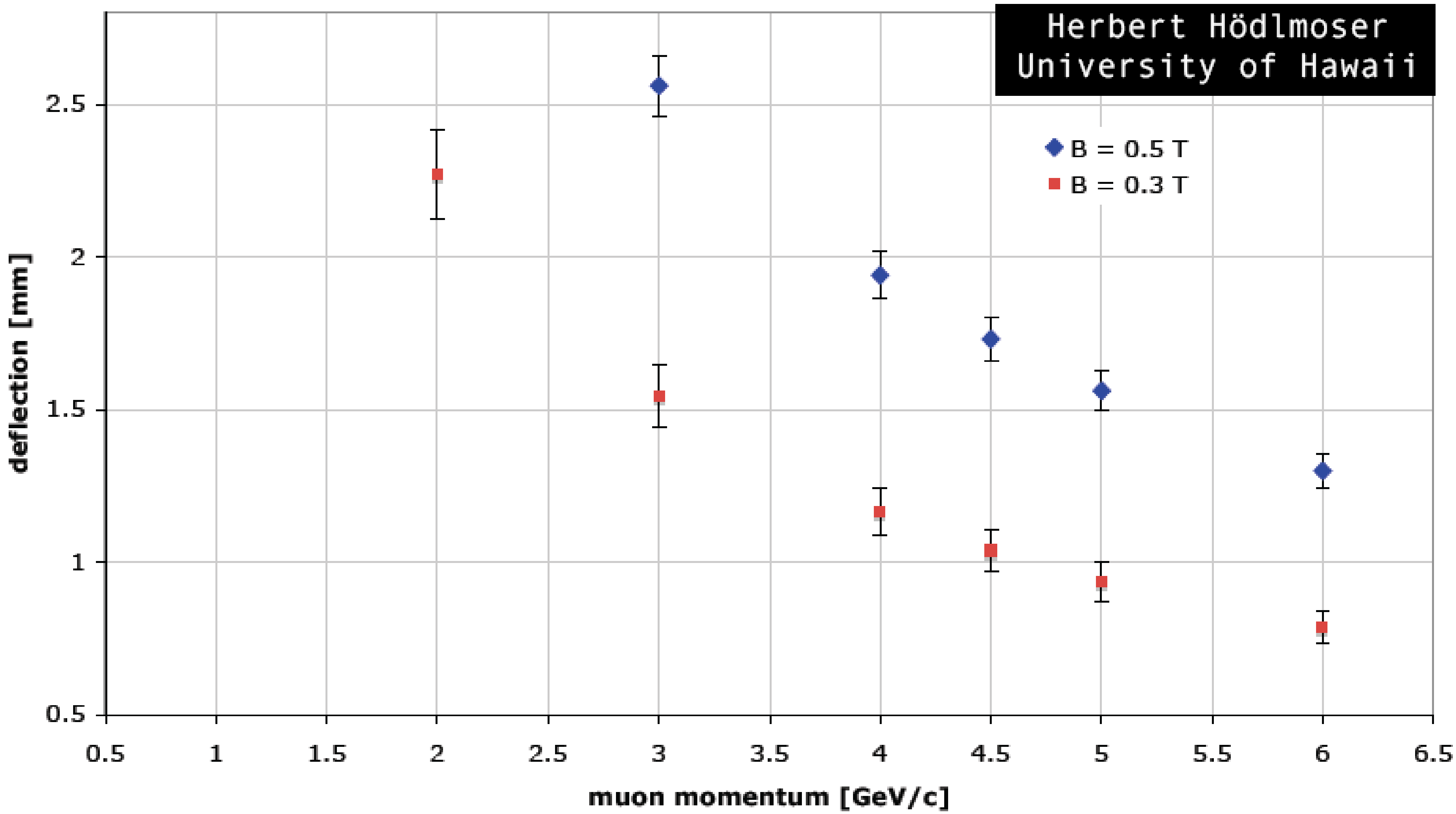
2+2 DSSD Ladders

- Readout to be integrated via fiberoptic with the rest of the assembly.



- FEA flux density simulations – Marc Rosen
- Magnet design by Bryce Jacobsen and Marc Rosen

Simulation of Muon Deflection w/ DSSDs

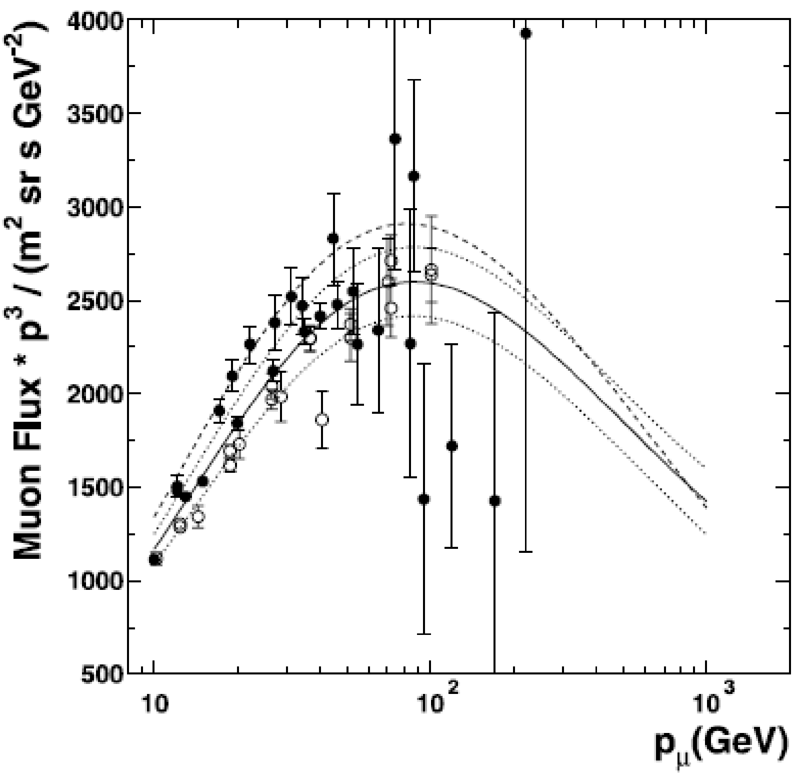


Higher field strength = improved momentum resolution

Current target: 0.5-0.6 T

Estimates of Event Rates

	Precision Timing Trigger	> 9 "good" hits, reasonable fits	Projected to hit momentum selector
Events Collected	4.94×10^6	4587	240
% of Total Events	100%	0.1%	0.0049%
Estimated Events Per Day	1.3×10^5	121	6.3

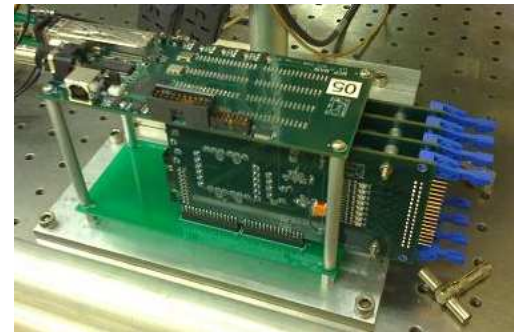


Based on ~ 1.5 months of running in original configuration.

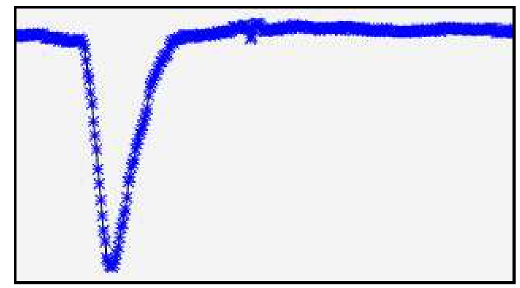
We roughly estimate a factor of ~2x improvement from upgrades to tracking readouts, new PT block.

Higher energy muons may be rare due to cosmic ray spectrum.

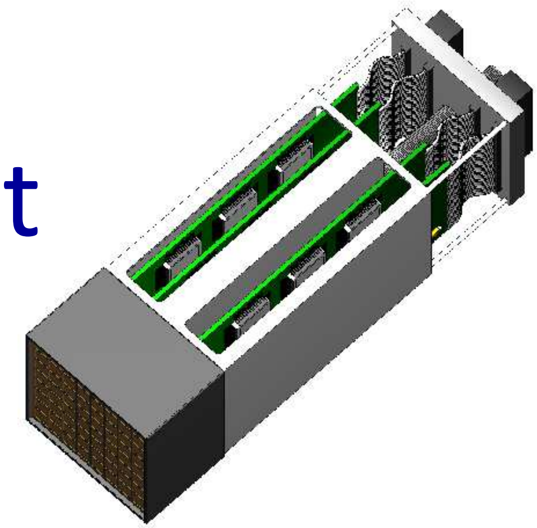
iTOP / HI-TIDE Status



- Done:
  - Drift tubes assembled, initial performance testing with TDC readout.
- Ongoing & immediate future (~weeks):
  - All electronics now on fiberoptic readout through cPCI.
  - New waveform electronics readouts implemented, performance tests waiting on readout calibrations.
  - Readout from both sides of drift tubes.
  - Initial quartz bar readouts, comparisons with GEANT4 MC.
- Future:
  - Momentum measurements using magnet, DSSDs.
  - Improved imaging scheme.

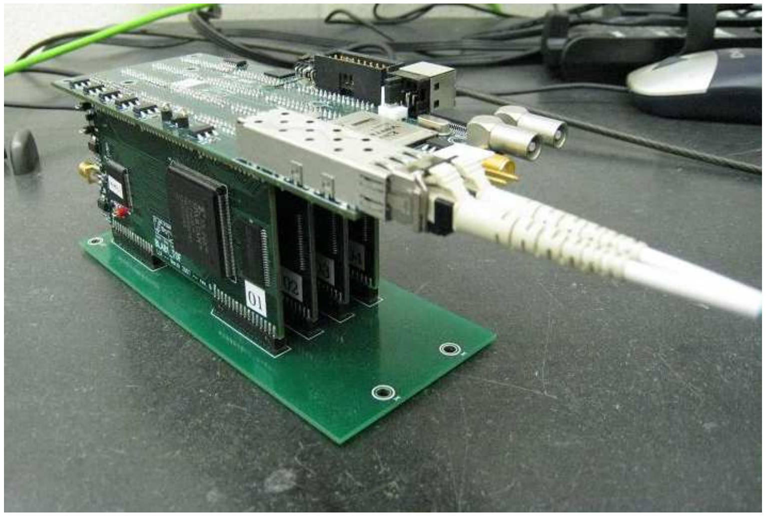


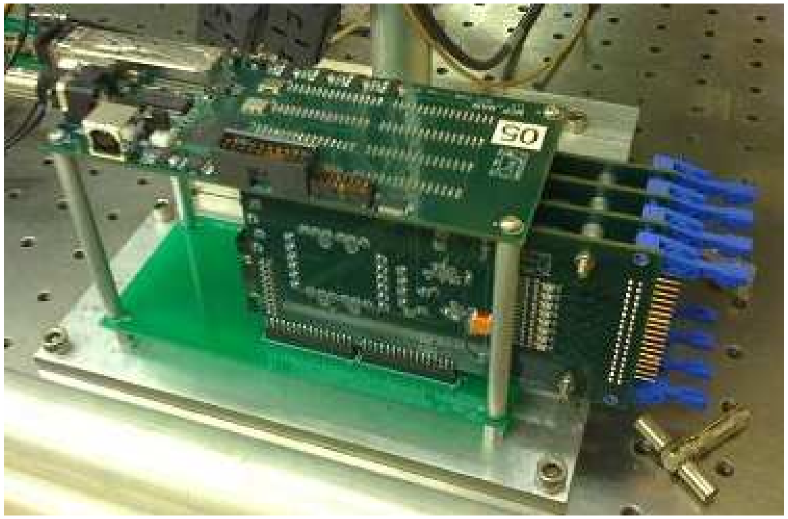
Particle ID Readout Developments



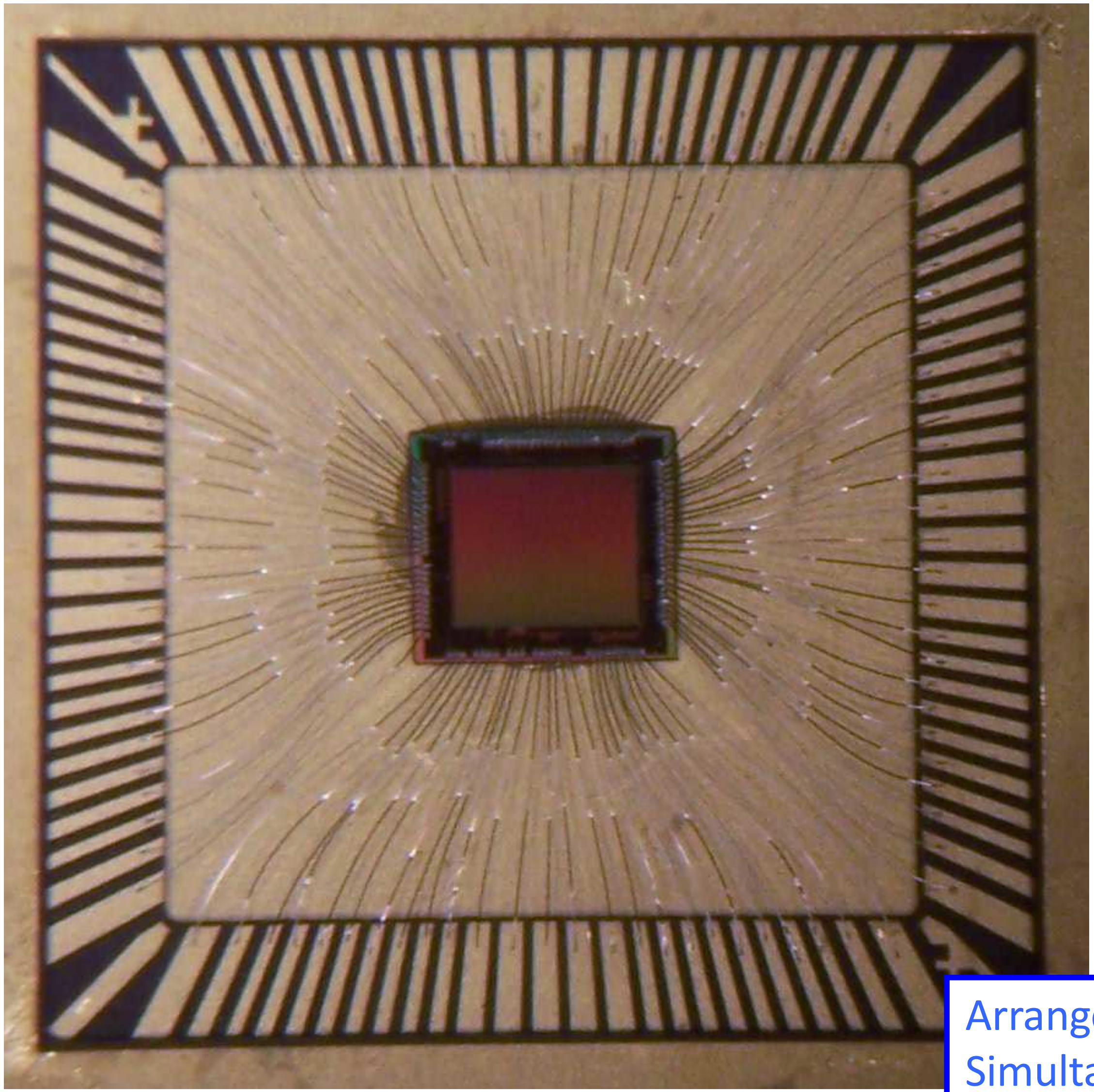
Gary S. Varner, Larry L. Ruckman, & Kurtis Nishimura

December 11th, 2008





Design Basis: Buffered LABRADOR (BLAB1) ASIC



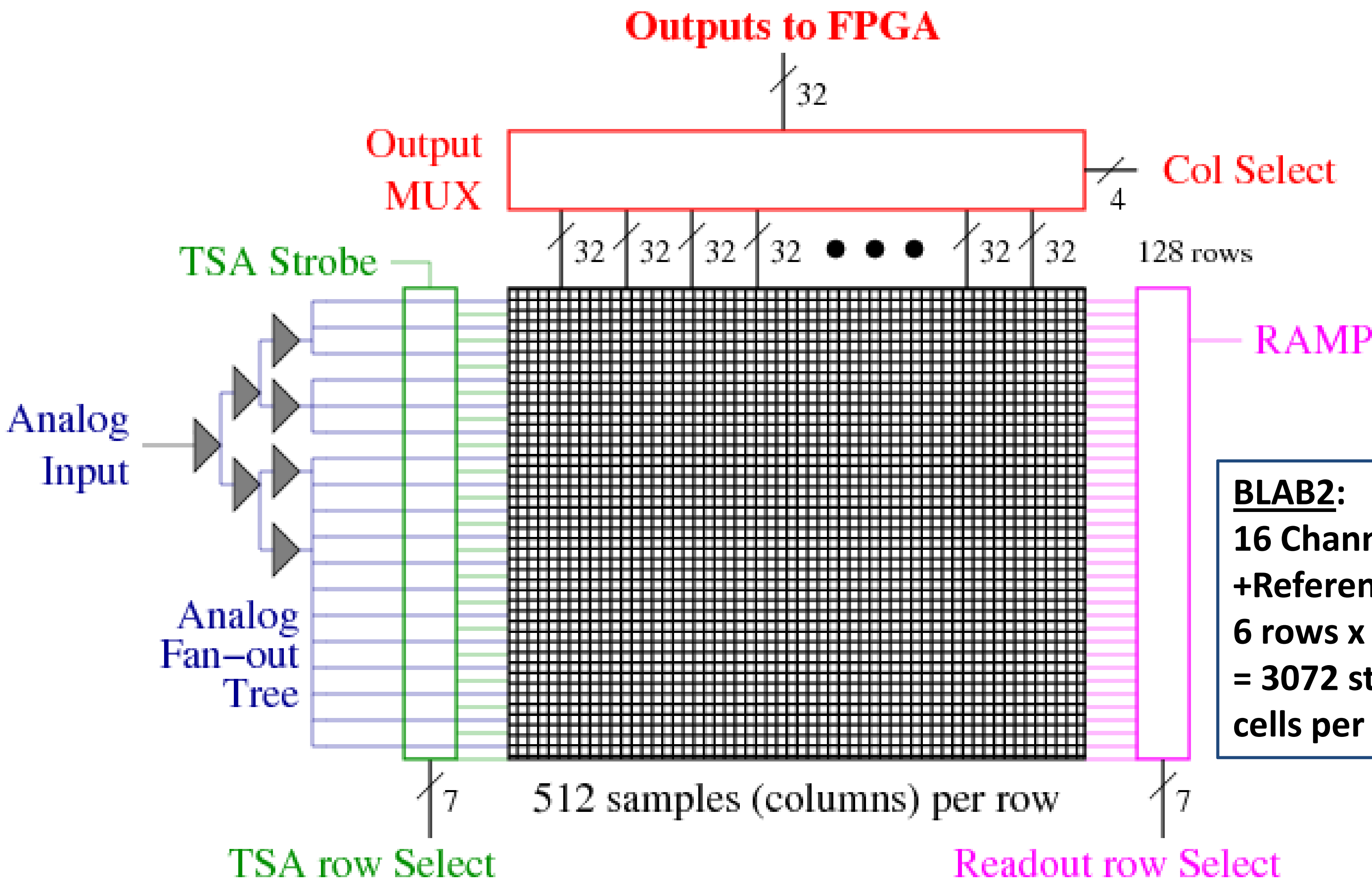
3mm x 2.8mm, TSMC 0.25um

- Single channel
- 64k samples deep, same SCA technique as LAB, no ripple pointer
- Multi-MSa/s to Multi-GSa/s
- 12-64us to form Global trigger
- BLAB1 details at:

  NIM A591: 534-545, 2008

Arranged as 128 x 512 samples
Simultaneous Write/Read

BLAB1 Architecture



BLAB2:
16 Channels
+Reference:
6 rows x 512 cols
= 3072 storage
cells per channel.

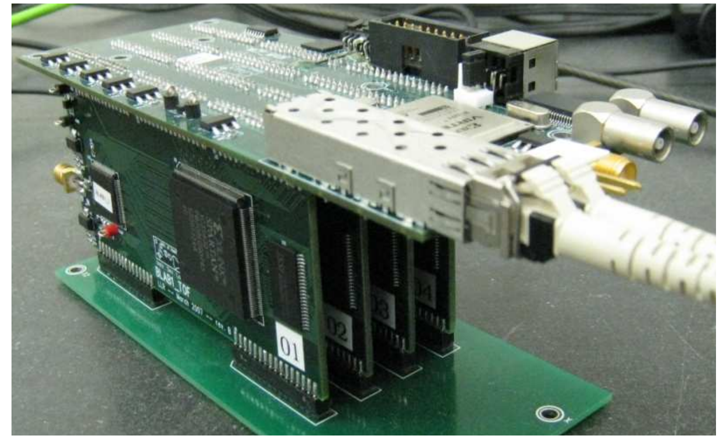
FPGA-based TDC: 10-bits in 1us (300ps resolution)

Highly Integrated Readout

- **Buffered LABRADOR**

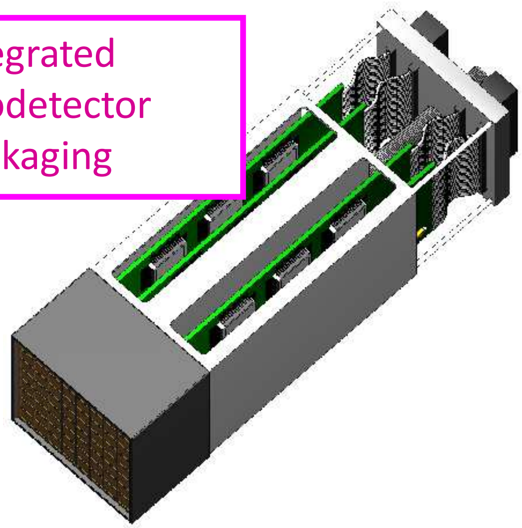
TABLE II: *BLAB2 ASIC Specifications.*

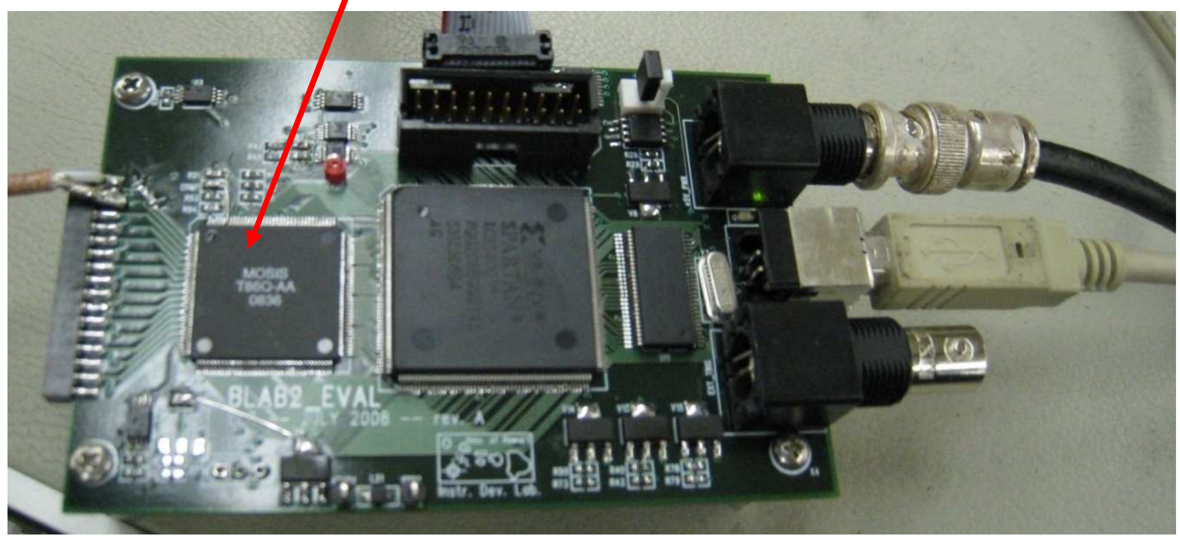
Item	*Value*
Photodetector Input Channels	16
Linear sampling arrays/channel	~~2~~ 6
Storage cells/linear array	~~512~~ 1024
Sampling speed (Giga-samples/s)	2.0 - 10.0
Outputs (Wilkinson)	32



BLAB2 ASIC

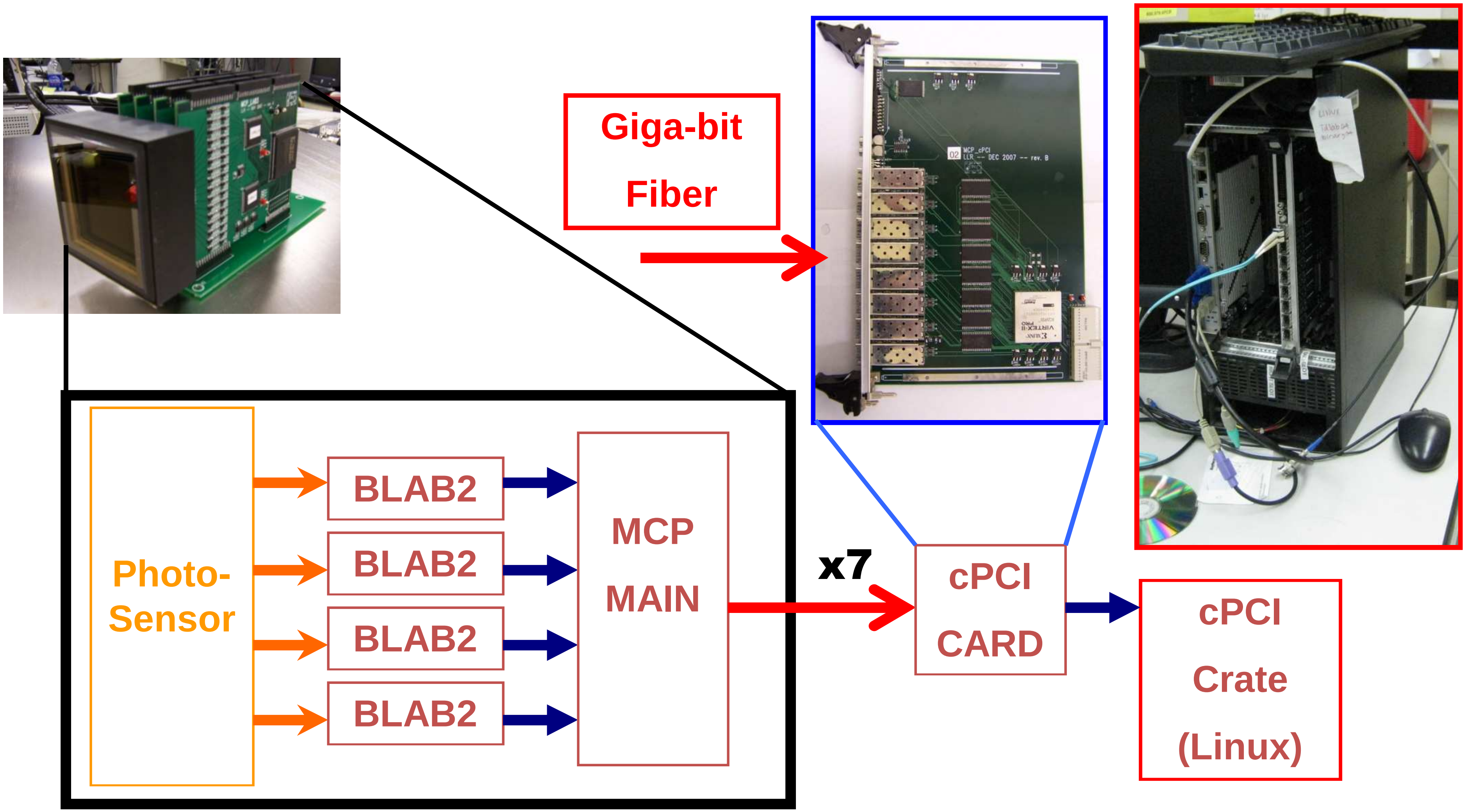
Integrated Photodetector packaging





BLAB2 ASICs recently received: now being tested & calibrated!

Readout System Block Diagram

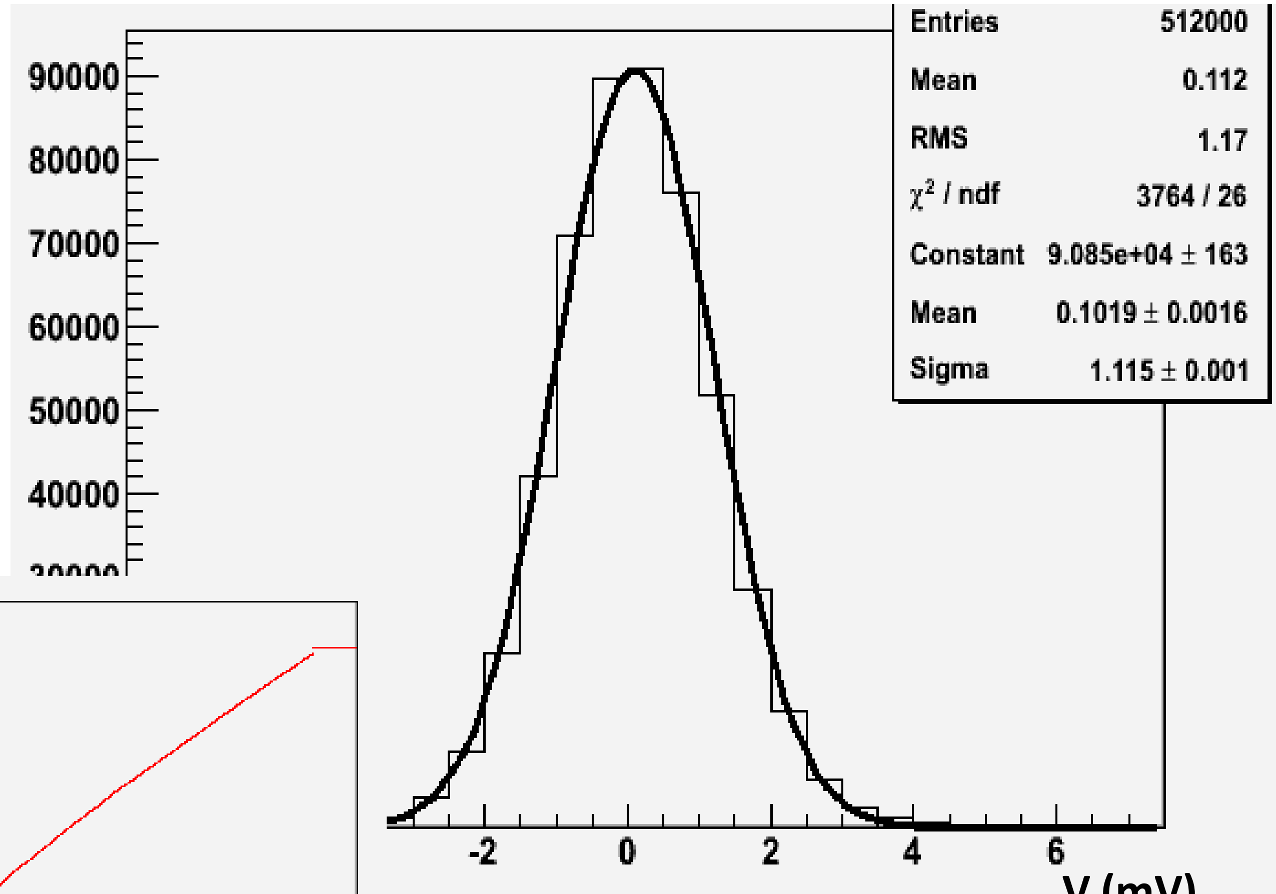


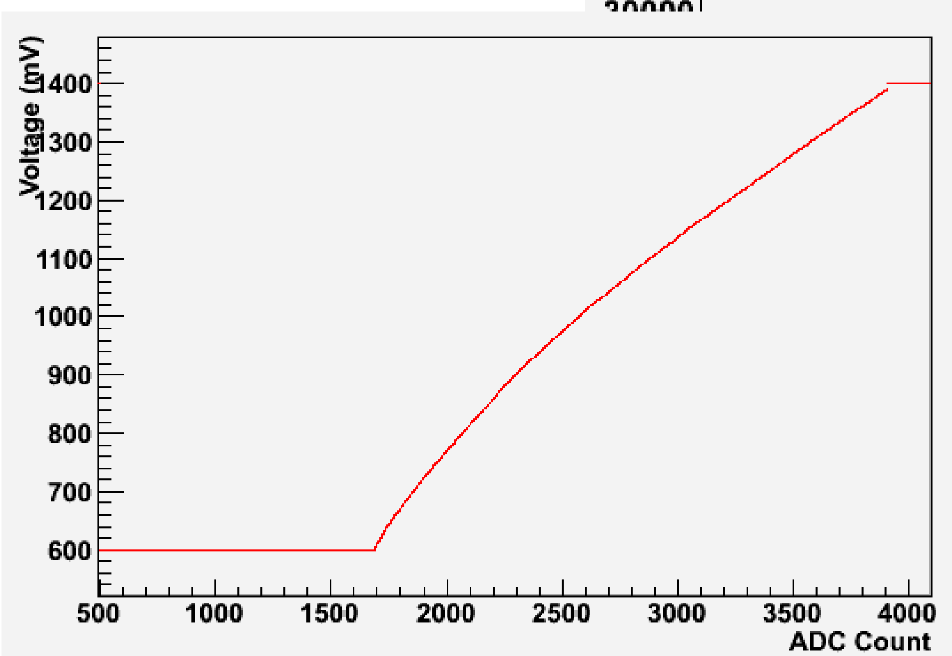
- Up to 7x64 channels per cPCI card
- Very portable DAQ
- Up to 32,256 channels/cPCI crate

Very cost effective, board hardware already exists, firmware/software dev.

BLAB2 Range & Noise Performance

Noise levels after pedestal calibration: $\sigma \approx 1$ mV

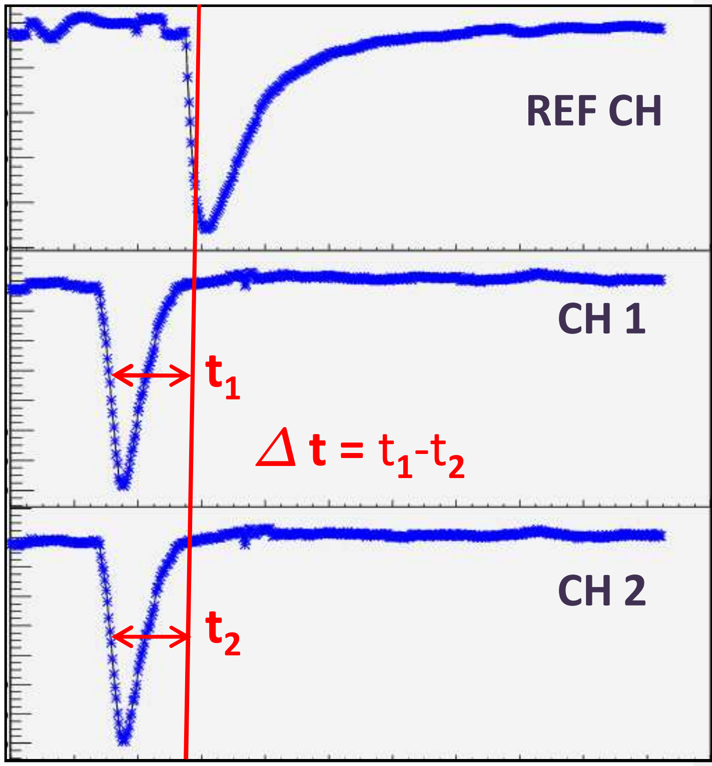


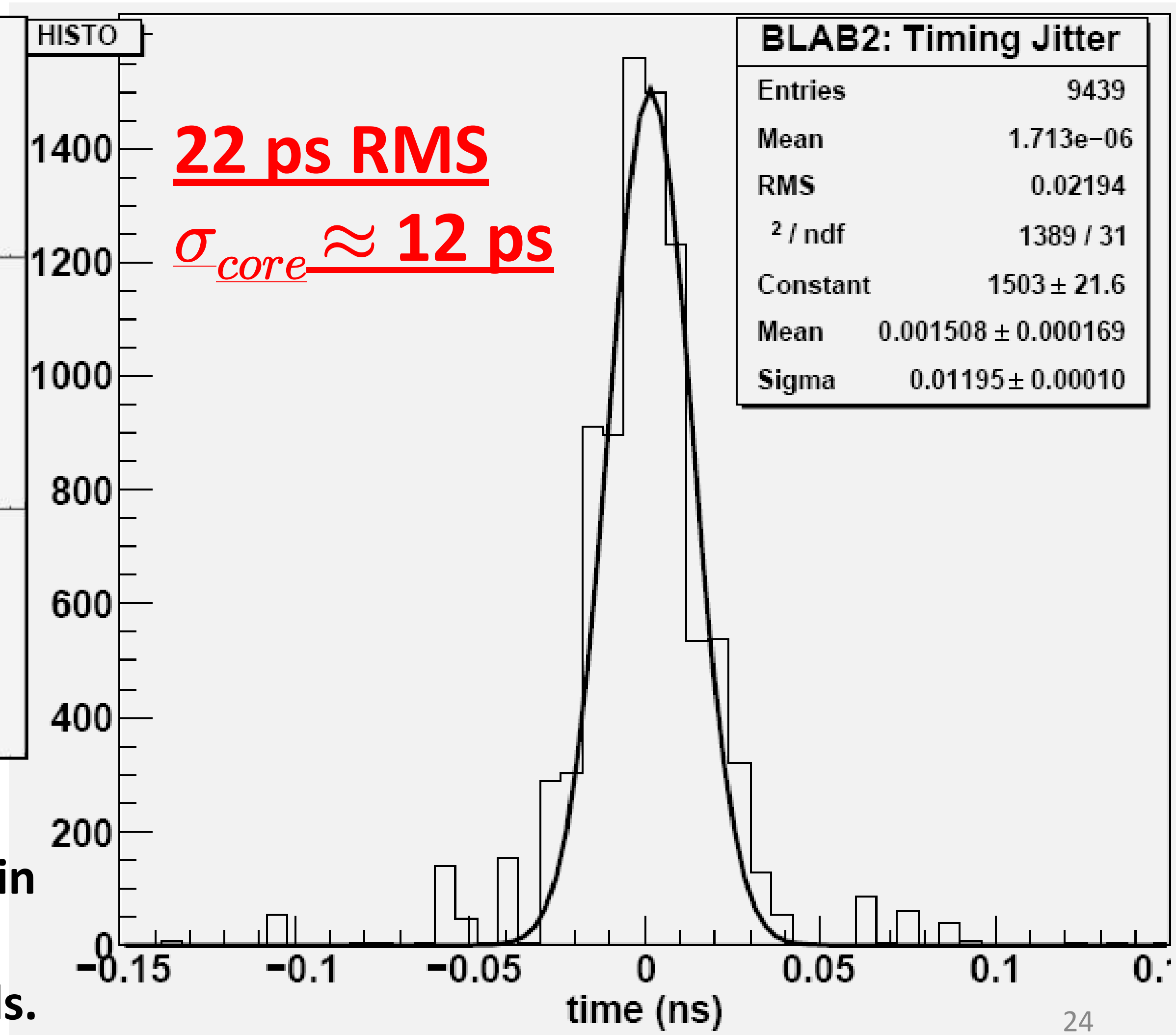


Dynamic range: 800 mV
Amplifier on input for small amplitude (1 p.e.) detection.

BLAB2 Timing Performance

Measured timing jitter between two channels (same BLAB2).





➔**Good timing calibration is vital! Ongoing improvements in calibration procedures may improve this result, reduce tails.**

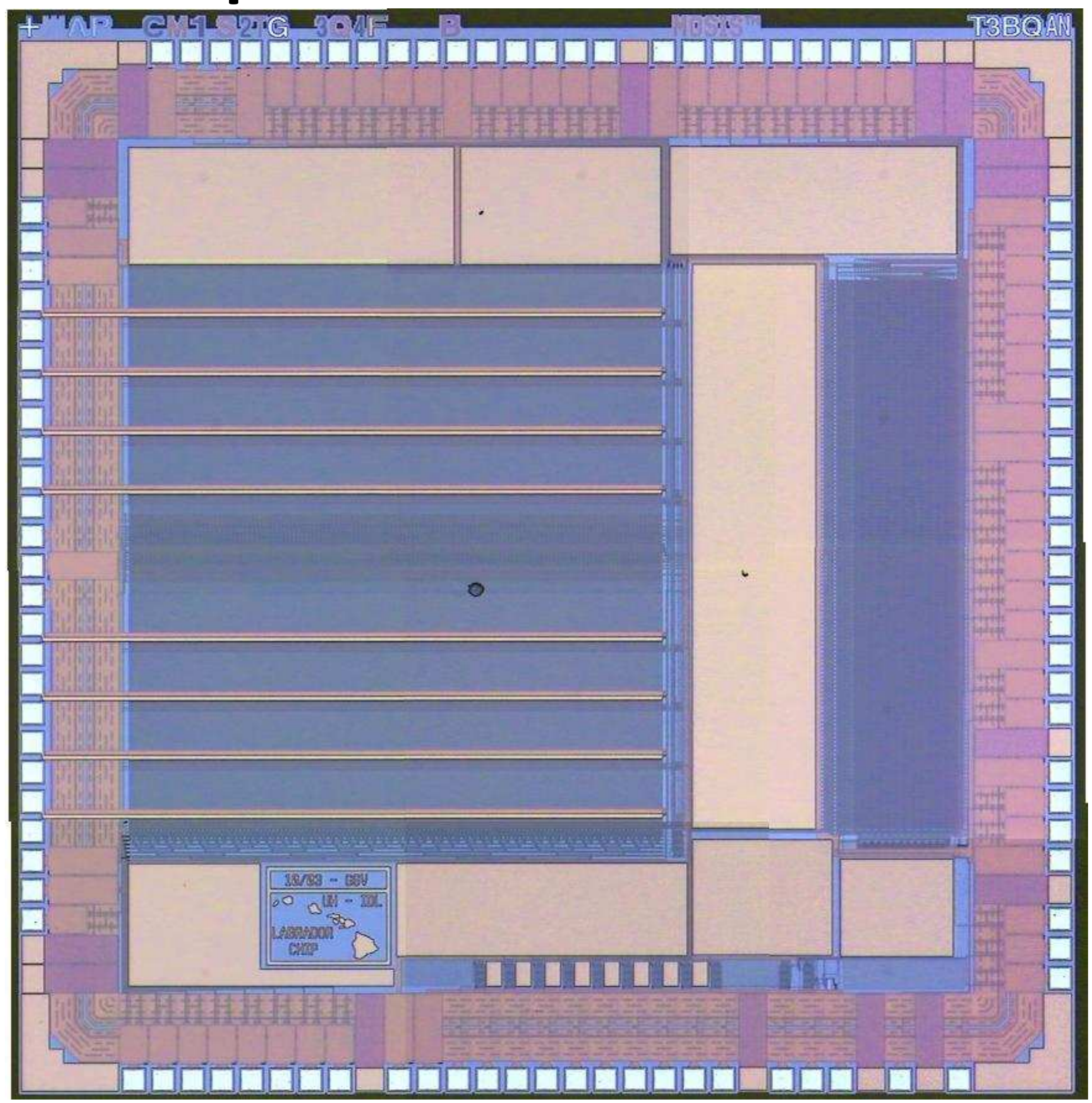
BLAB2 Overview

- Initial noise/timing performance comparable to BLAB1:
  - Limits of calibration are being explored, may ultimately improve performance.
  - Other performance parameters will be measured soon.
- Extremely flexible readout solution:
  - Variable sampling speed, depth.
  - Being tested at HI-TIDE with drift tubes, DSSDs, PMTs, solid state photon detectors.
    - All are integrated into a unified cPCI system via fiberoptic.

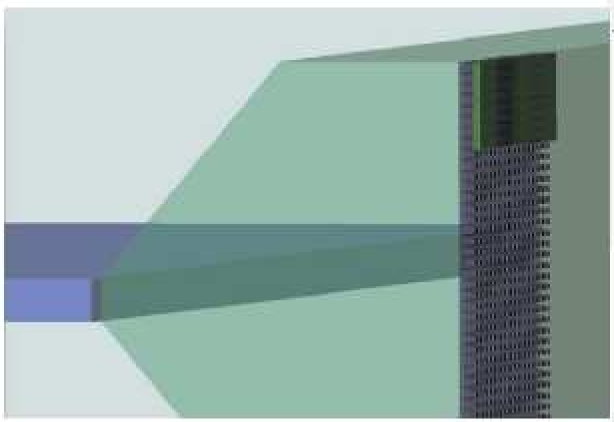
Summary

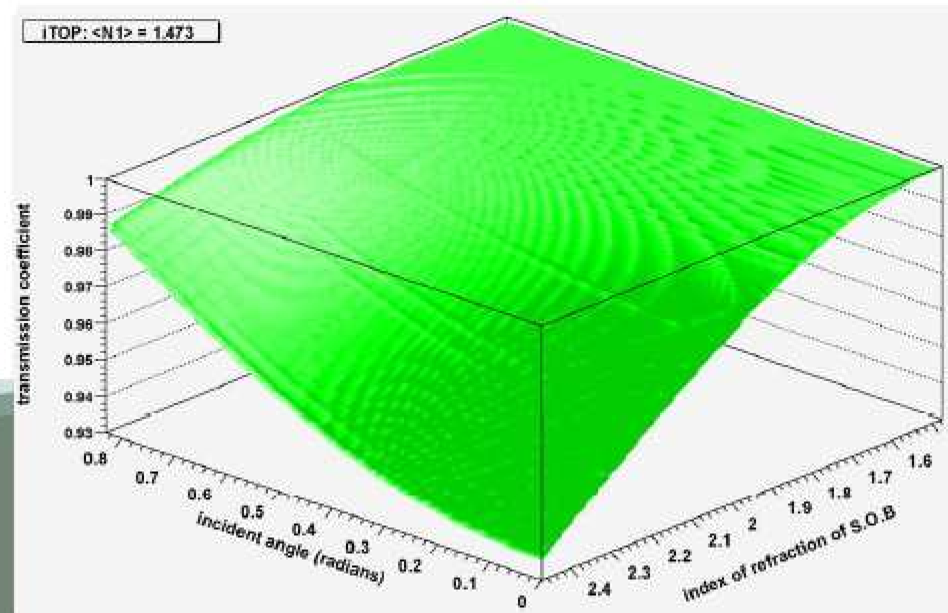
- iTOP Status:
  - Separability performance needs experimental validation.
    - Beginning soon in Hawaii; test stand nearly complete.
  - Geometry optimization, photon detector choice
    - May be guided in part by coupling issues from SOB→detector
- PID Readout Electronics:
  - BLAB2 has been fabricated, delivered.
  - BLAB2 performance limits currently being explored.
  - To be integrated & tested very soon with photon detectors.

Back-up slides



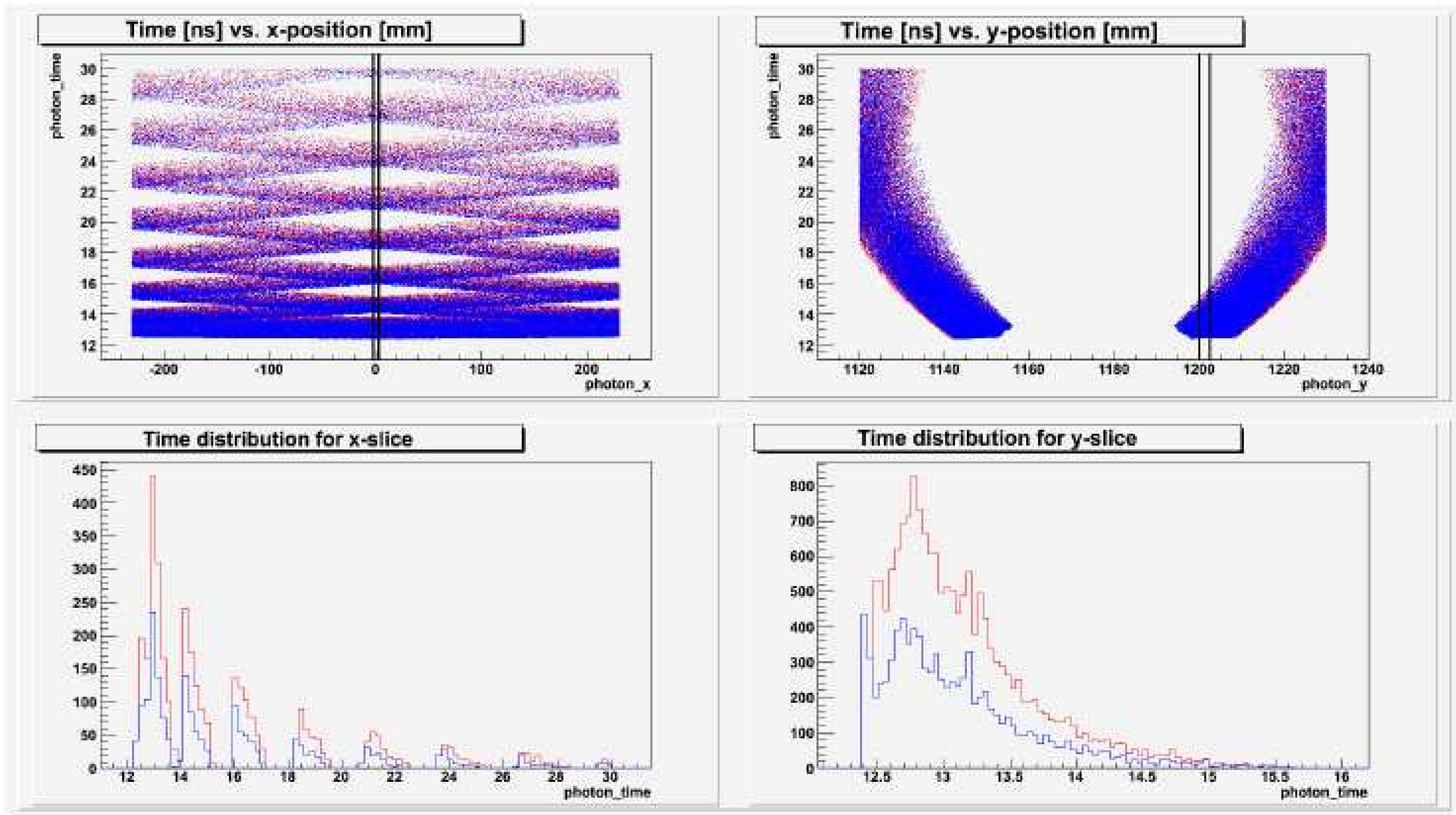
Stand-Off Block (SOB) Coupling





44 x 92 pix/plane = 4048 channels
16 bars x 2 ends x 4048 = ~130k channels

Timing comparison



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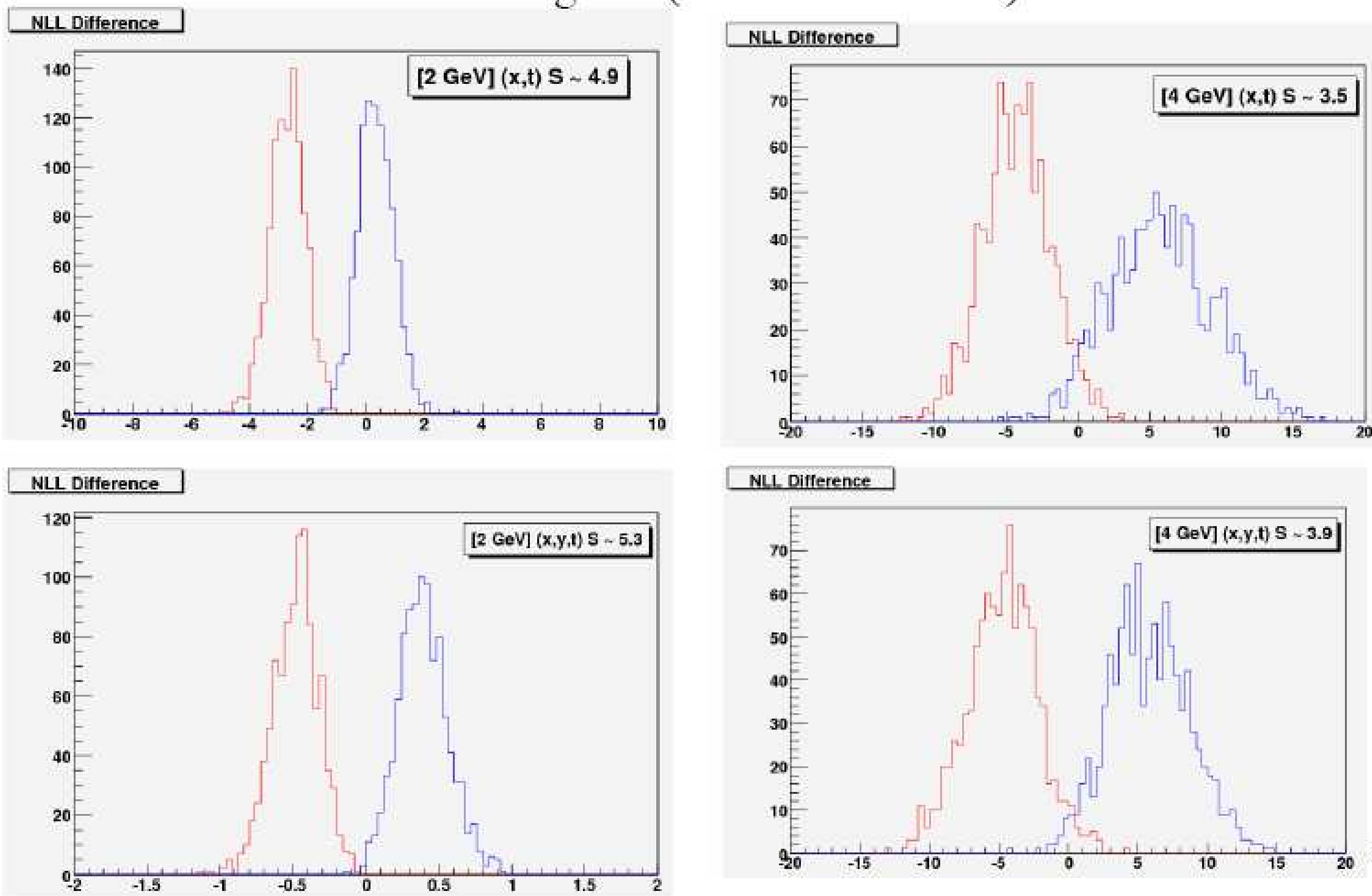
Separation Concept using Log $\mathcal{L}$

90 degrees (normal incidence)



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simulation setup

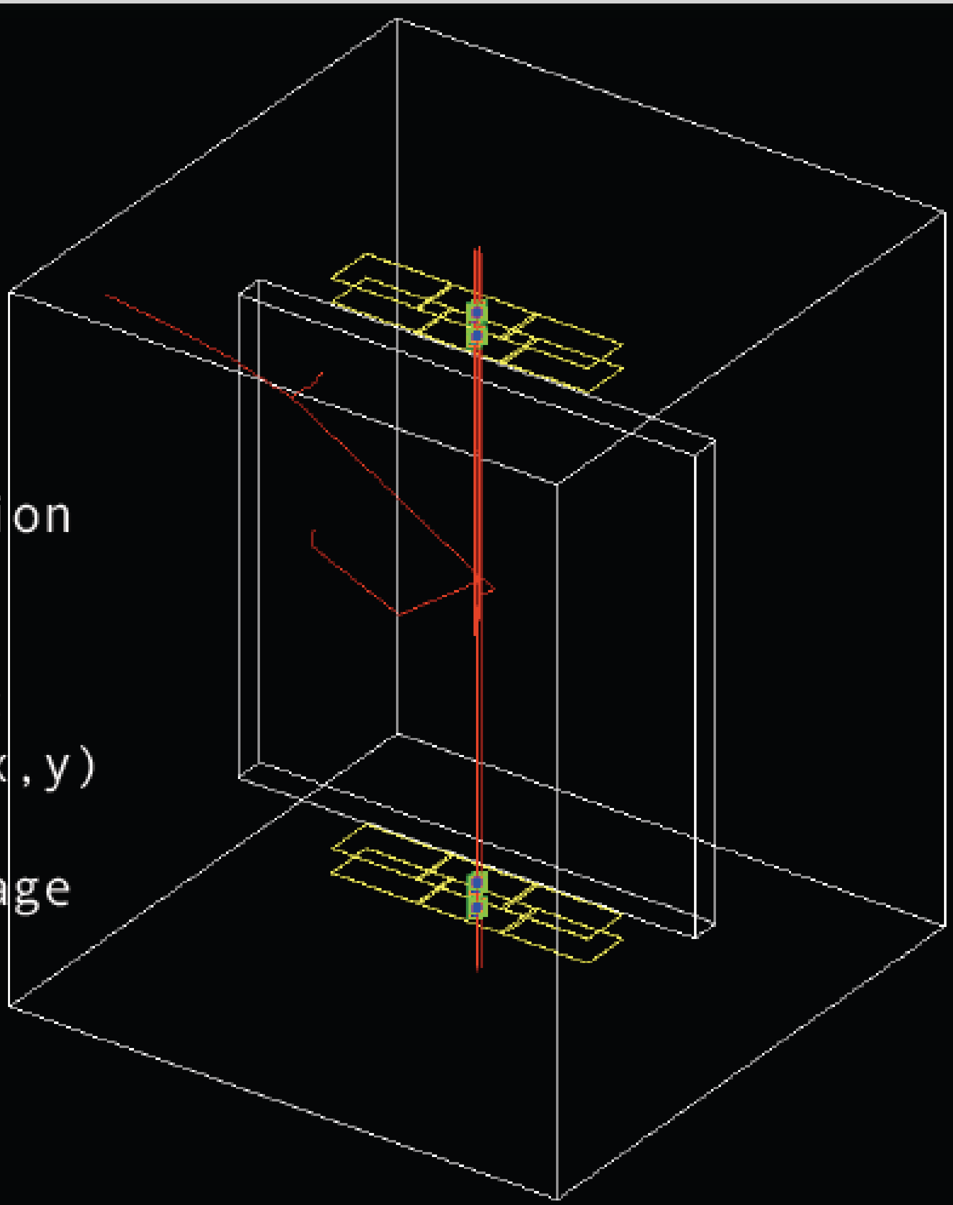
4 layers of dssd
with gaps of 1.5 cm

primary particle:

-normal incidence
-randomized origin position
 (5 mm radius)

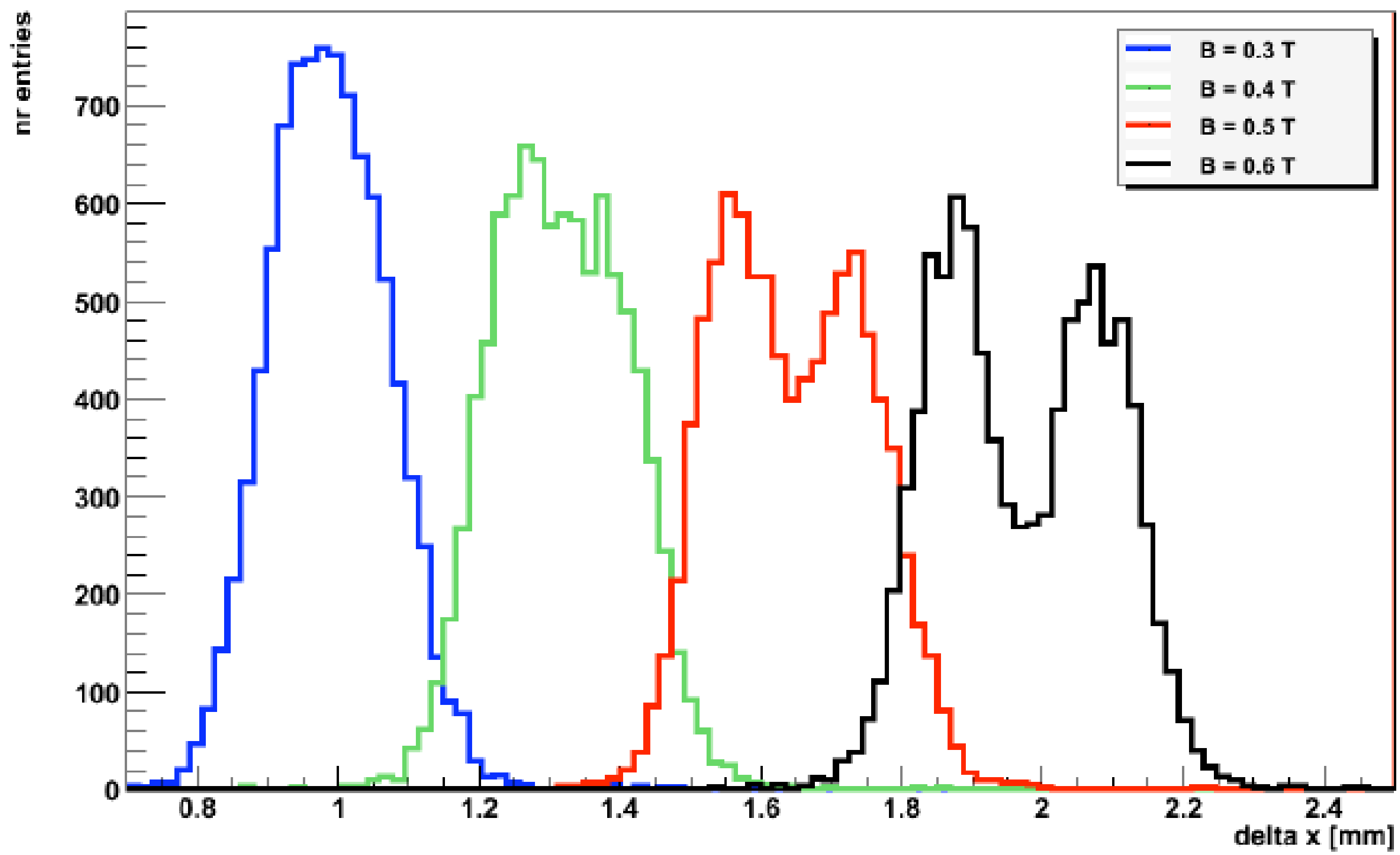
deflection calculated as:
cluster (x,y) - origin (x,y)

in most cases as an average
of layer 3 and 4

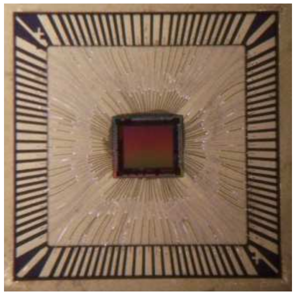


Herbert Hödlmoser
University of Hawaii

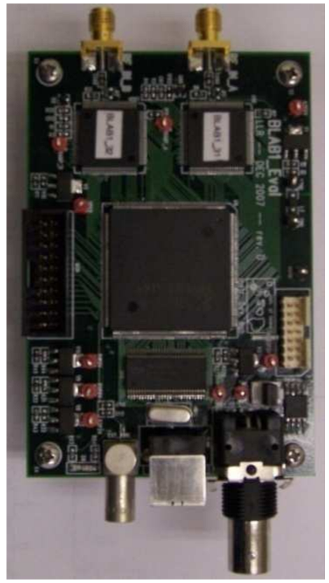
momentum separation: 4.5 and 5 GeV/c muons

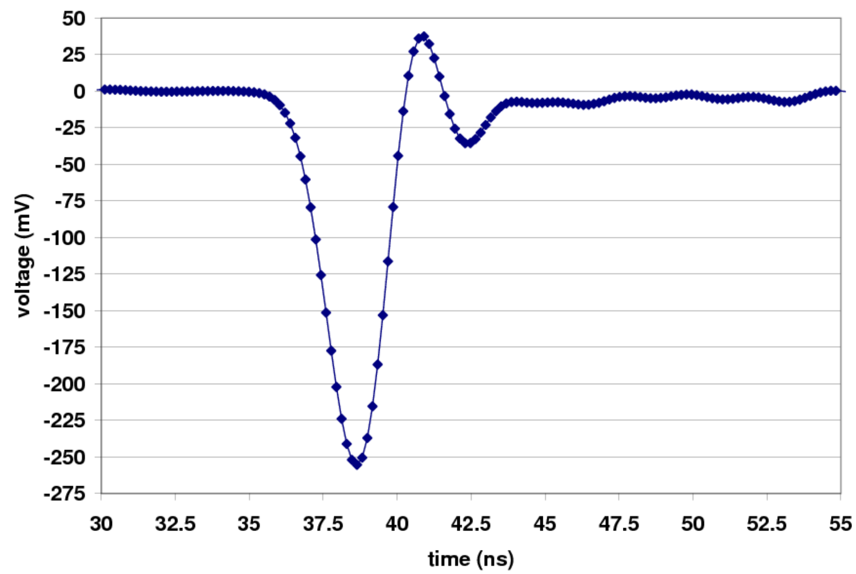


BLAB ASIC further studies

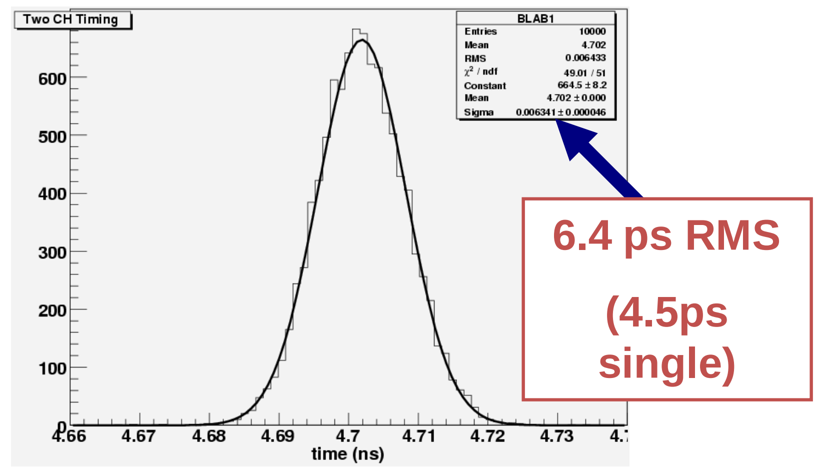


BLAB1 -- NIM **A591** (2008) 534





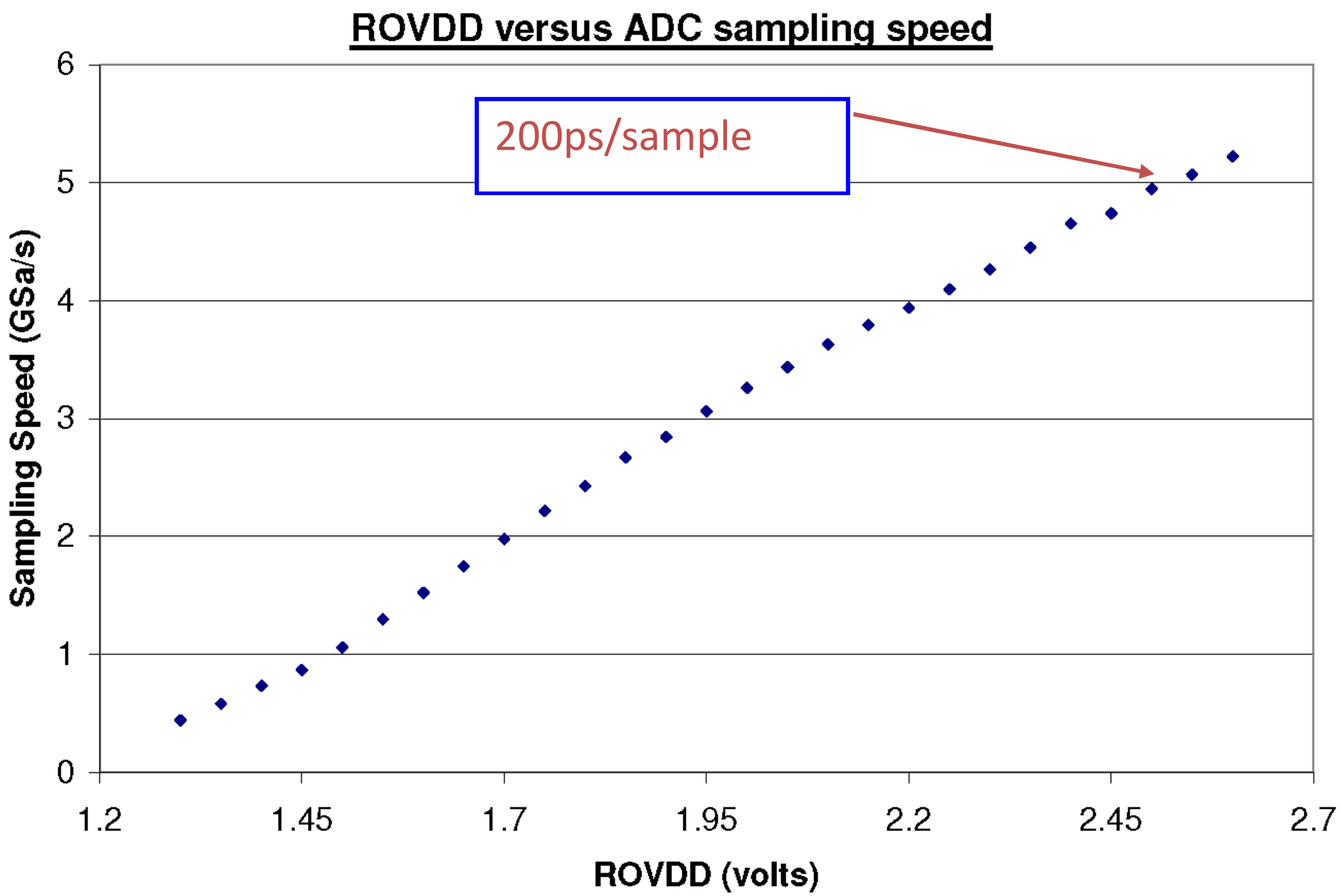
- Comparable performance to best CFD + HPTDC
- MUCH lower power, no need for huge cable plant!
- Using full samples significantly reduces the impact of noise
- Photodetector limited



Submitted NIM, arXiv:0805.2225

BLAB1 Sampling Speed

Can store 13us at 5GSa/s (before wrapping around)



Single sample:
200/SQRT(12)
~ 58ps

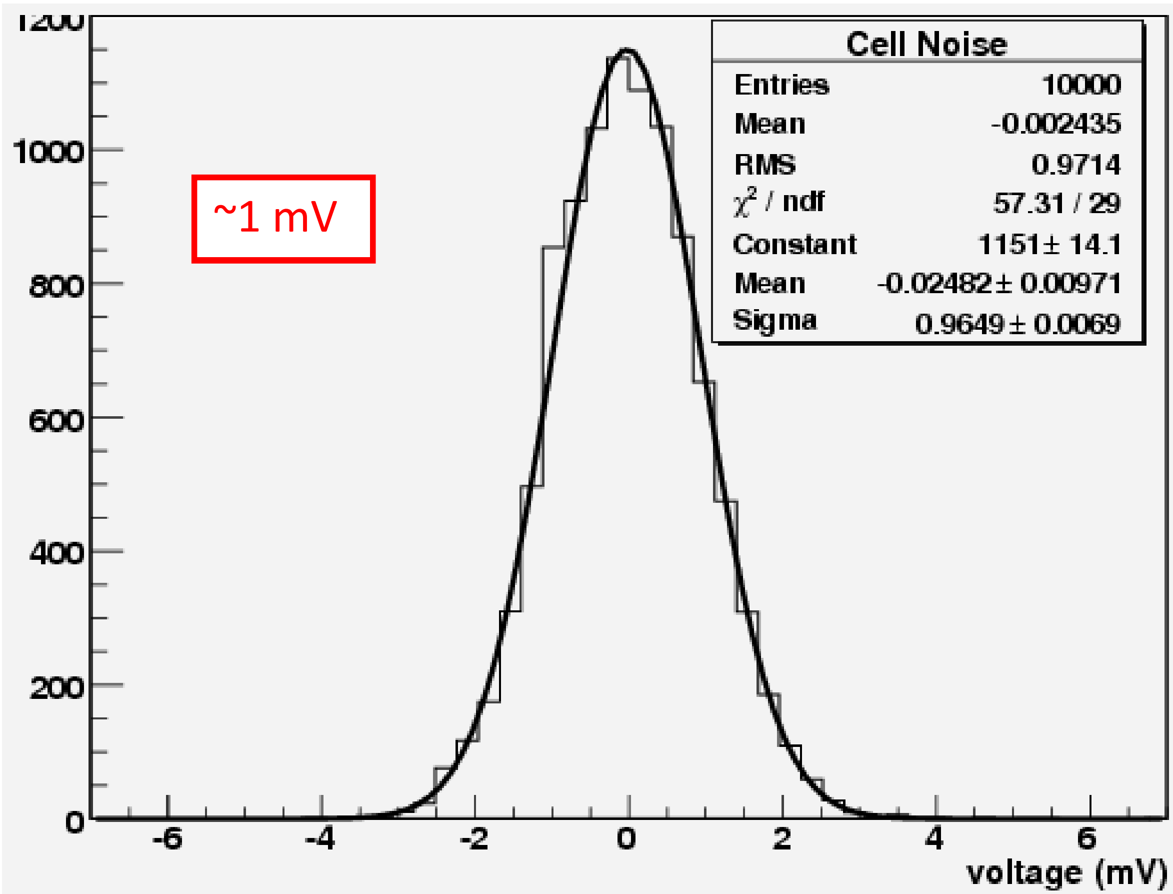
In practice, have often been using 512 samples

Buffered LABRADOR (BLAB1) ASIC

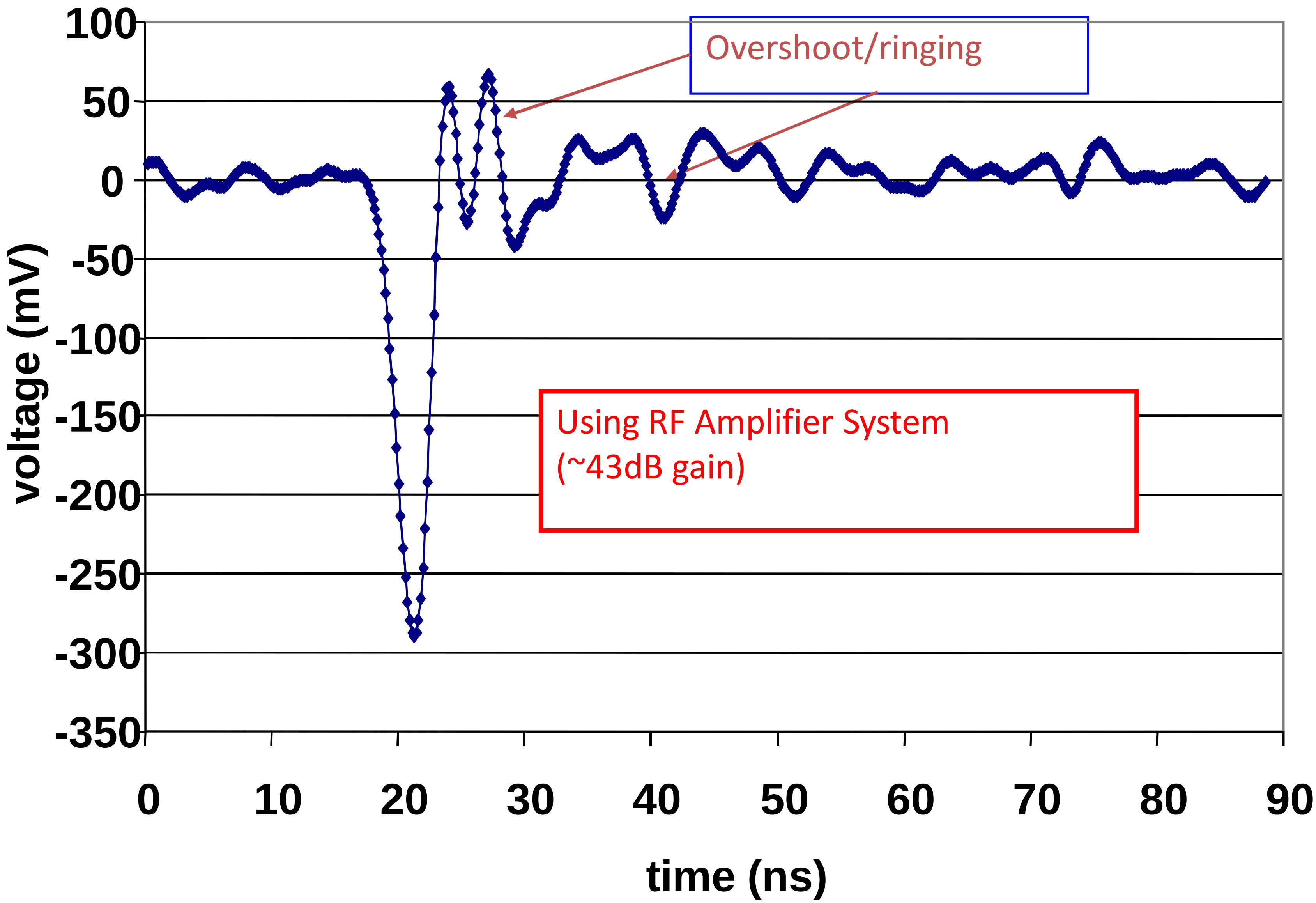
- 10 real bits of dynamic range, single-shot

Measured Noise

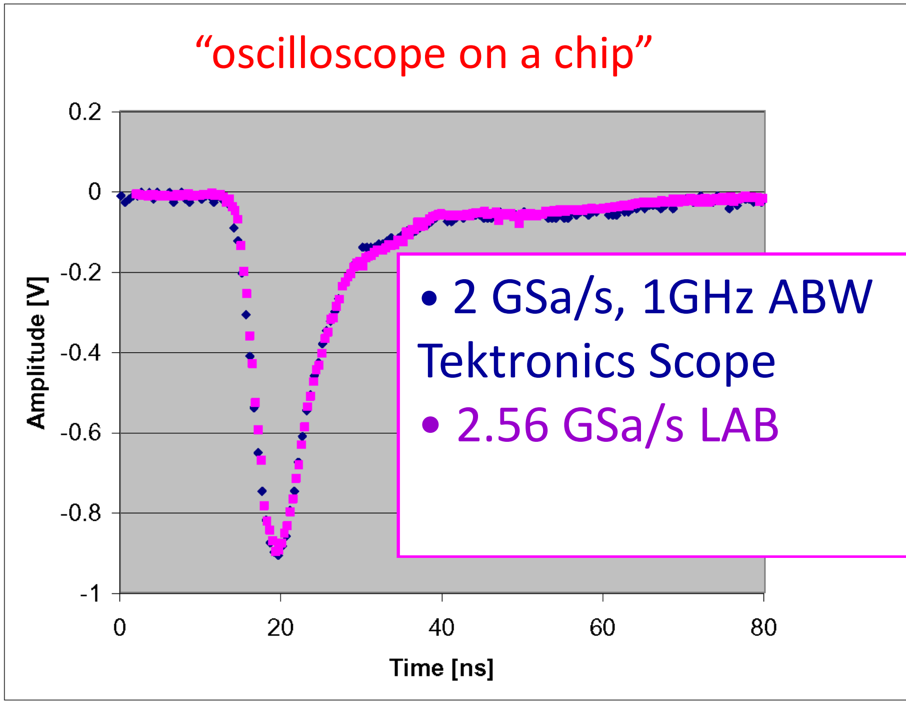
1.6V dynamic range



Typical single p.e. signal [Burle]



Key Enabling Technology



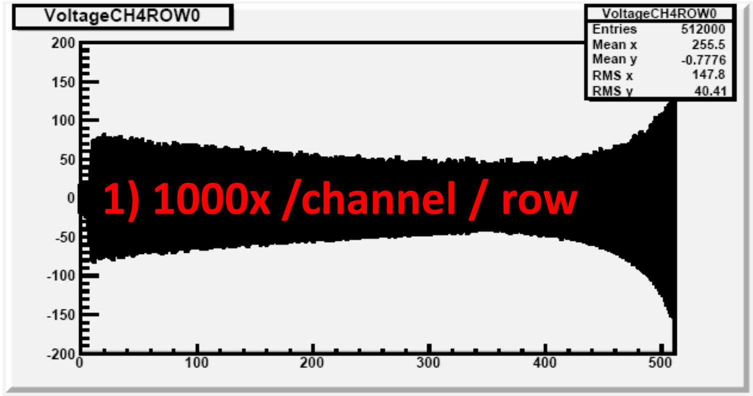
	LABRADOR	Commercial
Sampling speed	1-3.7 GSa/s	2 GSa/s
Bits/ENOBs	12/9-10	8/7.4
Power/Chan.	<= 0.05W	5-10W
Cost/Ch.	< $10 (vol)	> 1k$

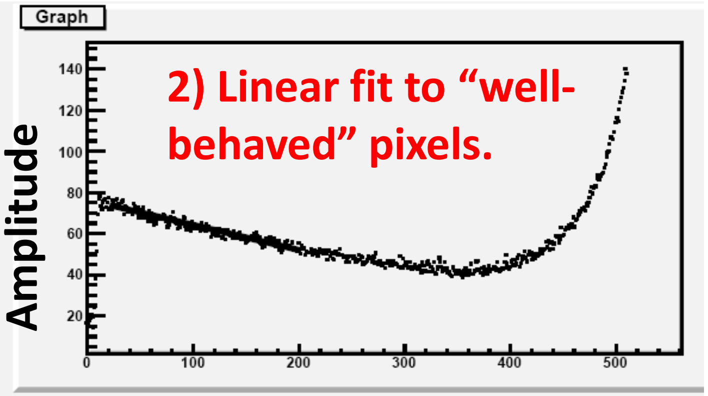
1. PoS PD07: 026, 2006
2. NIM A583: 447-460, 2007
3. NIM A591: 534-545, 2008
4. arXiv: 0805.2225 (submitted NIM A)

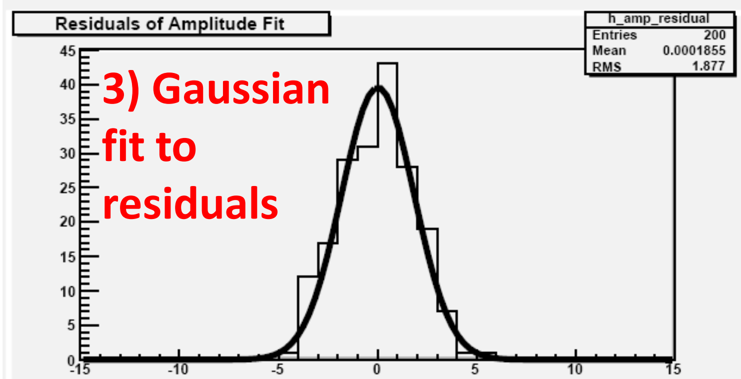
BLAB2: Veto/Timing Calibrations

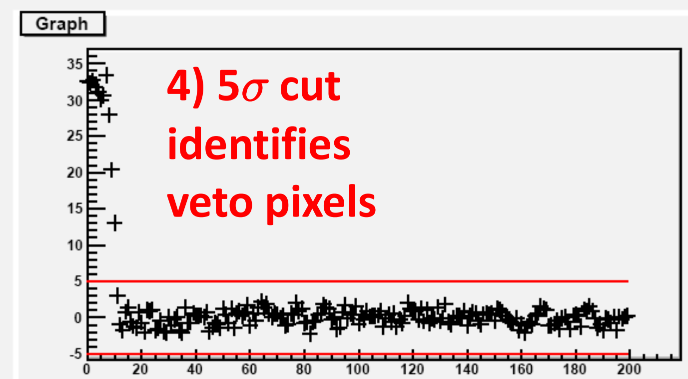
250 MHz sine wave input:

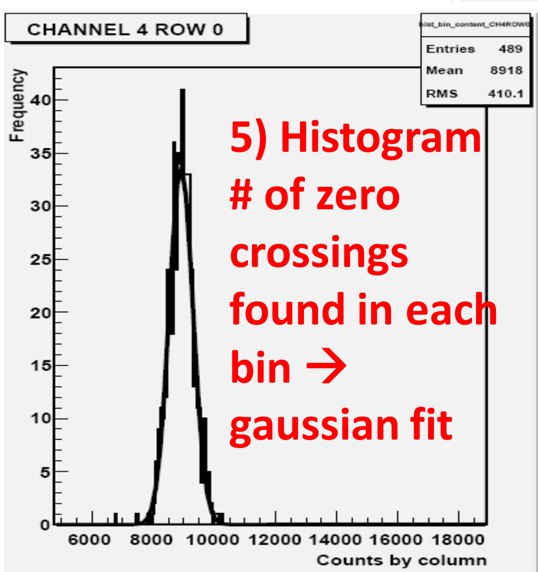
- “Veto” pixels are identified.
- Average distance between zero crossings is measured →Time per pixel is calculated.

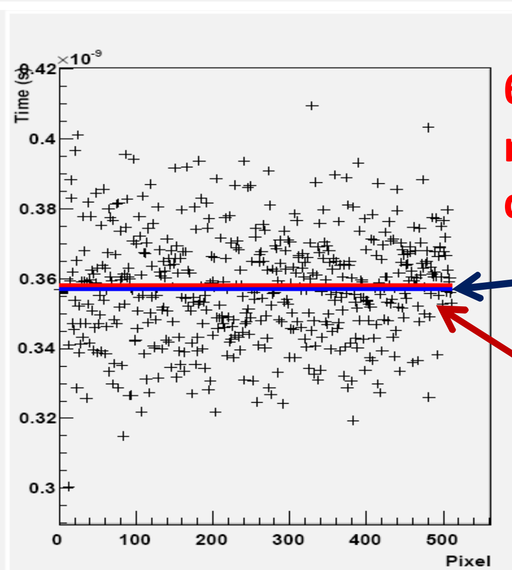












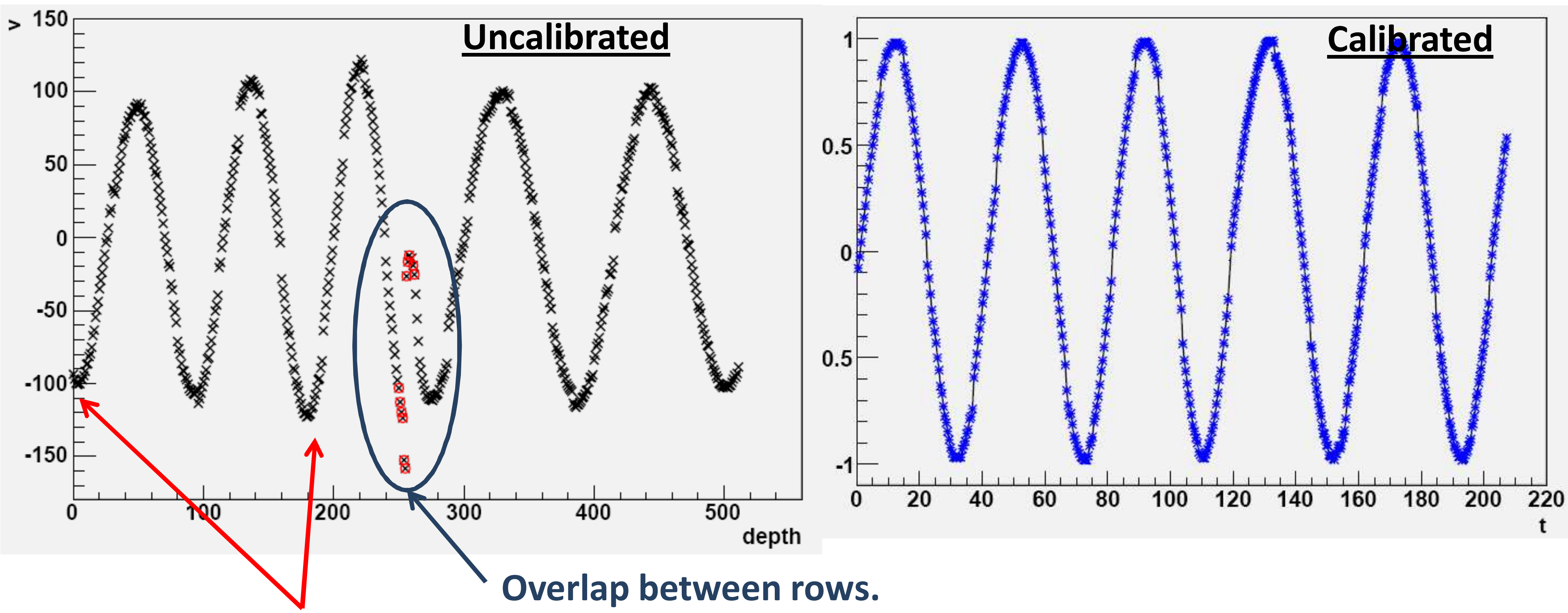
6) Ratio of zero crossings to mean number of zero crossings determines Δt

Blue line – expected mean time per pixel assuming uniform sampling

Red line – measured mean time per pixel from zero crossings

BLAB2 Gain/Offset Calibration

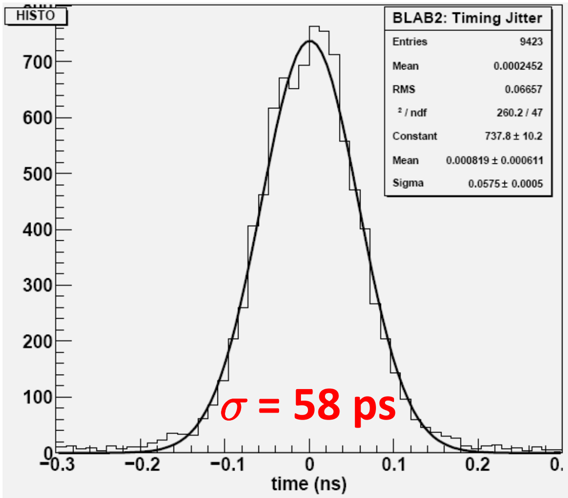
- Each pixel has unique frequency response.
- During transitions from row to row, some overlap (double sampling) occurs.
- These corrections lead to improved timing calibrations & performance.



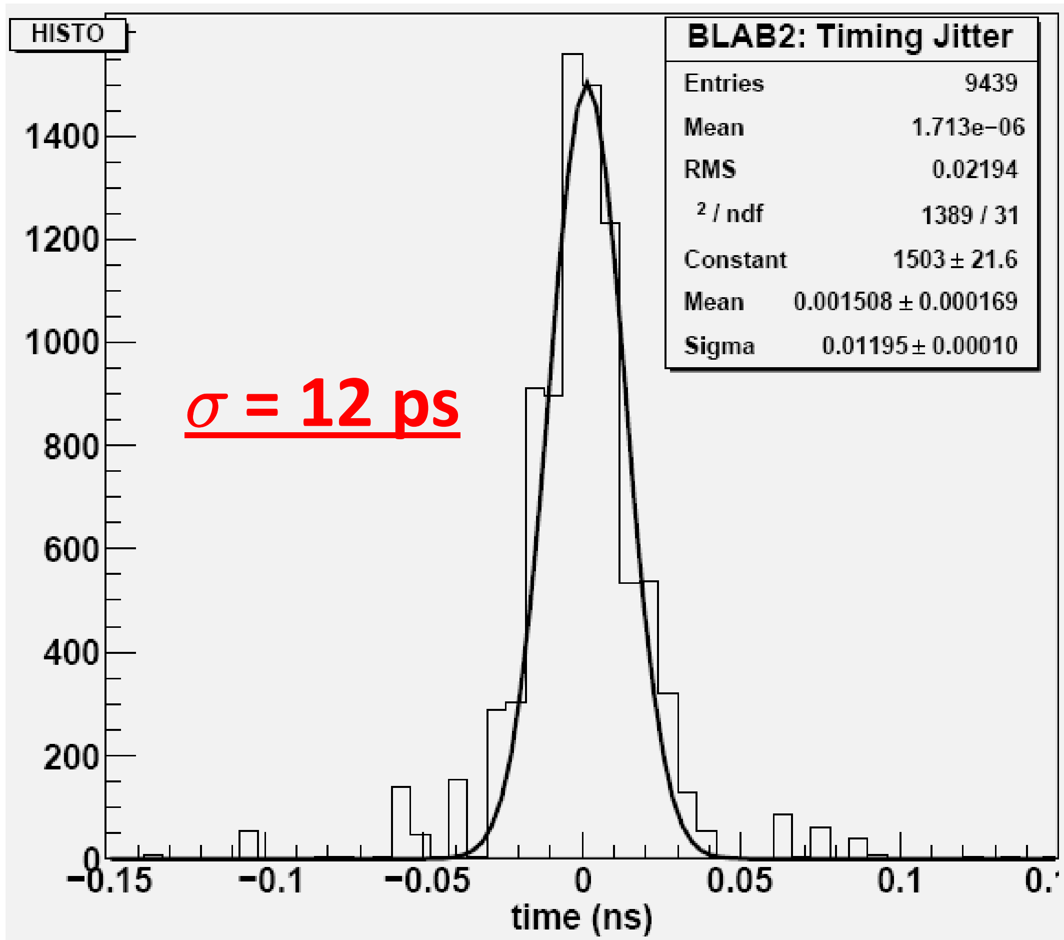
Overlap between rows.

Gain varies with
pixel position.

BLAB2 Timing Performance



- Measured timing jitter between two channels of a BLAB2.



Top – Before row overlap correction.
Right – After correction.

➔**Good timing calibration is vital! Ongoing developments may improve this result & remove outliers.**