FDIRC tests in the SLAC cosmic ray telescope

J. Va’vra, SLAC
G. Varner, Hawaii Univ.
FDIRC

** Successfully tested in the SLAC test beam:**


** FDIRC main points:**

- Its “pixel imaging quality” is the same as that of BaBar DIRC - the same $\sigma_\theta$
- However, it is ~10x faster than 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.
• **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: $\sigma < 1\text{mm}$

Hodoscope (scint. fibers)

10 GeV electrons

Beam Pipe

Prototype photon detectors

Quartz counter (MCP-PMT)

Scintillator counter (MCP-PMT)

Quantacon PMT

Lead Glass:

Local START time:

$\sigma \sim 36\text{ps}$

Effect of the chromatic correction by timing:

2/12/09

FDIRC tests in the SLAC cosmic ray telescope

Photon path length (m)
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)

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

2/12/09

FDIRC tests in the SLAC cosmic ray telescope

delta(time) (ns)
SLAC cosmic ray telescope - our “test beam” for the next 1-2 years

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

2/12/09  FDIRC tests in the SLAC cosmic ray telescope
Test setup in the cosmic ray telescope
Images in the SLAC cosmic ray telescope

Side view:

- Will start with a nominal position: \( \theta_{\text{dip}} \sim 90^\circ \) & 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, \( \theta_{\text{dip}} \sim 75^\circ \).

FDIRC tests in the SLAC cosmic ray telescope

2/12/09
New readout configuration

FDIRC tests in the SLAC cosmic ray telescope
Cosmic ray telescope counters:

Trigger rates:
- $T_1*T_2 ~ 5-6 \text{ Hz}$
- $T_1*T_2*S_1 ~ 1-2 \text{ Hz}$
- $T_1*T_2*\text{Quartz counter} ~ 5-6 \text{ k/day}$
- $T_1*T_2*S_1*\text{Quartz counter} ~ 2-3 \text{ k/day}$

Note:
We use $T_1*T_2*\text{Quartz counter}$ trigger.

Status:
- Taking data
- CAMAC running
- BLABs need timing calibration

2/12/09
FDIRC tests in the SLAC cosmic ray telescope
Monitoring of FDIRC in the telescope

On-line monitor:
100ns/div, 100mV/div, 500mV/div

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**


**H-8500**

**MaPMT:**

64 pixels, 8x8

**BLAB2 ASIC:**

64 Amplifiers/MaPMT, Amp. gain ~ 40x

Waveform sampling electronics:

- 4 BLAB2 chips / MaPMT
- Waveform sampling rate: ~ 2.5 GSa/s
- Timing resolution goal: $\sigma_{\text{final}} \sim 150$-$170$ ps

**Status:**

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

2/12/09 FDIRC tests in the SLAC cosmic ray telescope
BLAB ASIC further studies

BLAB1 chip

• 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

6.4 ps RMS (4.5ps single)
## Summary of BLAB2 ASIC parameters

G. Varner

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

Principle of waveform 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

2/12/09

FDIRC tests in the SLAC cosmic ray telescope
Highly Integrated Readout

- **Buffered LABRADOR**

**TABLE II: BLAB2 ASIC Specifications.**

<table>
<thead>
<tr>
<th>Item</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photodetector Input Channels</td>
<td>16</td>
</tr>
<tr>
<td>Linear sampling arrays/channel</td>
<td>2 → 6</td>
</tr>
<tr>
<td>Storage cells/linear array</td>
<td>512 → 1024</td>
</tr>
<tr>
<td>Sampling speed (Giga-samples/s)</td>
<td>2.0 - 10.0</td>
</tr>
<tr>
<td>Outputs (Wilkinson)</td>
<td>32</td>
</tr>
</tbody>
</table>

**BLAB2 ASIC**

- Trans-Imp Amps
- 6 x 1024 samples
- Per channel
- BLAB2 sampling
- Trigger and flash encoding
- PRO1 sampling

2/12/09

FDIRC tests in the SLAC cosmic ray telescope
BLAB2 electronics 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 submitted 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)

BlackFin DSP
• 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

Trigger rates:
- $T1*T2 \sim 5-6$ Hz
- $T1*T2*S1 \sim 1-2$ Hz
- $T1*T2*Quartz\_counter \sim 5-6$ k/day
- $T1*T2*S1*Quartz\_counter \sim 2-3$ k/day

New DAQ:
- $\mu$PCI ceate: $\mu$PCI 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.

2/12/09

FDIRC tests in the SLAC cosmic ray telescope