Belle Upgrades and Possibilities: Part 4: STRAW2

Gary S. Varner
University of Hawai‘i
Local Belle meeting
April 2003
Schedule

- **Instrumentation** (Fall/Spring)
  - PID/Precision Timing
  - Monolithic Integrated Time Stretcher (MTS1)
- **STRAW2/High-speed sampling** (today)
  - Preliminary STRAW2 results
  - PID applications (student needed)
- **FINESSE and COPPER** (next time)
  - Pipelined Readout: $10^{35}$ Luminosity issues
  - Evaluation board for MTS w/HPTDC + TMC
  - USB high-speed interface (Yangheng)

Details subject to interest/feedback
Today’s Objectives

- **High Speed Sampling**
  - In ANITA context
- **STRAW2 results**
  - Ignore self-triggering
- **R&D Opportunity**
  - STRAW2 detailed testing (with TOF)
  - Pipelined high-speed sampling
TS Performance

- **Baseline – being “counted upon”; works well, but**

![Graph showing TS Performance](image)

**MTS1 Time Stretcher residuals**

- ID: 7777
- Entries: 2998
- $\chi^2$/ndf: 4.853 / 4
- Constant: 1.326 ± 29.59
- Mean: 0.475E-02 ± 0.473E-03
- Sigma: 0.251E-01 ± 0.251E-03

**LRS module test**

- $\sigma = 22.5\text{ps}$

**MTS1 Simulation**

- $\sigma = 26.3\text{ps}$
- RMS = 22.0ps
Study of Hadron Systematics Using the Belle TOF System

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Abstract

The Belle TOF system gives a time resolution of about 100 ps for high-momentum muons in dimuon events but 115 ps for pions and kaons in hadron events. This note examines various effects responsible for the poorer resolution for hadrons. Three effects are found to be associated with biases in mean times and with broadening of the time resolutions: tracks hitting near gaps between TOF counters, tracks with inconsistent predicted and calculated z positions, and tracks for which adjacent TOF counters have hits.

PACS numbers:
Core part ~100 ps
But tails!!! RMS ~150 ps

New!!

FIG. 15: TOF resolution versus momentum for negative pions (squares) and muons (circles) in 2-photon events. The pions are from 4-pion final states in exp. 17 runs 880-937. Muons are from dimuon final states in exp. 19 runs 1000-1599. For comparison, the resolutions for pions in HadronC events from exp. 23 runs 552-659 are shown as diamonds. The resolution values are from Gaussian fits to Δt distributions.
Why Such A Variance???

- **Intrinsic Performance:**
  - Tough to get
  - Beam tests don’t require sustained operation
  - Hadronic Calibration!
    - Very important – details omitted due to space limitations
    - Much work, no fundamental understanding
    - Velocity dependent (dE/dx?) fudge
    - Systematic, so no SQRT(2)
    - May be TWC technique dependent
  - Sad history of underperformance:
    - CLEO, CPLEAR, BESII, ...
  - Error Budget!!
Time Walk Correction

- Reasonable functional form
  - But as background increases...

- Many ideas: e.g. direct digitization at high speed?
ANITA

Antarctic Impulsive Transient Antenna
A long duration balloon mission to constrain the origin of the highest energy particles in the universe

University of Hawaii at Manoa
UC Irvine

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The Flux Problem

- At $E > 10^{21}$...
- Life is tough

$$\iiint drd\phi d\theta$$

$r, \phi, \theta$
Antarctic Impulsive Transient Antenna (ANITA)

- ANITA Goal: Pathfinding mission for GZK neutrinos
- NASA SR&T funded since October 2002, launch in 2006

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ANITA concept

Antarctic Ice at $f<1\text{GHz}$, $T<-20\text{C}$:

- ~Lossless RF transmission
- Minimal scattering
- largest homogenous, RF-transmissive solid mass in the world

~700km to horizon
observed area: ~1.5 M square km

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Single Point Measurement

\[ |E| = \frac{A_0 K \varepsilon}{R} \left( \frac{W}{1 \text{TeV}} \right) \frac{\nu}{\nu_0} \left( \frac{1}{1 + 0.4(\nu/\nu_0)^\delta} \right) \]

- Squeeze all possible info.
- Maximize R for better pointing... trigger latency
ANITA Payload

Simulated pulse—multiple antennas

- ANITA antennas view ~2π sr with 60 deg overlapping beams
- Beam intensity gradiometry, interferometry, polarimetry used to determine pulse direction & thus original neutrino track orientation
Askaryan Confirmation: SLAC T444 (2000)

- Use 3.6 tons of silica sand, brem photons to avoid any charge entering target
  \[\Rightarrow\] no transition radiation
- Monitor all backgrounds carefully
  - but signals were much stronger!

From Saltzberg, Gorham, Walz et al PRL 2001
Shower radio profile (~2GHz)

- Measured pulse field strengths follow shower profile very closely
- Charge excess also closely correlated to shower profile (EGS simulation)
- Polarization completely consistent with Cherenkov—can track particle source
STRAW2 Architecture

- Targeted for deep sub-micron process
STRAW2 Chip

- Self-Triggered Recorder Analog Waveform (STRAW)

16 Channels of 256 deep SCA buckets

Optimized for RF input Microstrip 50Ω

0.25µm TSMC process: 5metal, 1poly

Target input Bandwidth: >700MHz

Record length: 128-256ns

DACs

8192 analog storage cells

ADC

Self-Triggering:
- LL and HL (adj.) for each channel
- Multiplicity trigger for LL hits

On-chip ADC:
12-bit, >2MSPS

Sampling Rate:
1-3GSa/s (adj.)

Sampling Rates
>~8GSa/s possible w/ 0.25µm process

External option:
MUXed Analog out

Die: ~2.5mm²

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STRAW2 Evaluation

- Adjustable: 0.6 – 3.4 GSa/s
- 256 samples (70 – 300ns)

- RF signal input
RF Response (1)

- Sub-ns transient ping: <= 100ps leading edge
RF Response (2)

- Very nice tool: FFT analysis of RF transient pulse
- Have ideas how to improve – roll-off matches SPICE simulations of storage cells
High-speed Digitizers

- Kleinfelder speed but not high analog BW
- Analog BW tough
- Comm. ADC very high P

### High Speed Digitizer Comparison

<table>
<thead>
<tr>
<th>Analog Bandwidth [MHz]</th>
<th>Sampling Rate [MS/s]</th>
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<tbody>
<tr>
<td>10</td>
<td>10</td>
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<td>100</td>
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<td>1000</td>
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</table>

- ZEUS[12]
- RD2[13]
- Kleinfelder[14]
- Haller[15]
- ADeLine1[11]
- DSC/DRS[16]
- AD9410[17]
- CLC5957[18]
- TLV5580[19]
- ADS5102[20]
- MAX1449[21]

Desired Max. Operating Region
Antenna testing and development

- Anechoic test chamber
- Up to 400 lb embedded salt stack
- PCB antenna development
  - Muon test chamber
  - SLAC T460

Gaining RF experience
Cosmic-ray Radio Testbed

Testbed goals:
- Detect first Askaryan signals of cosmic origin
  - Use (rare) multi-TeV muon or single hadron showers
  - Scintillation counter trigger provides particle tag
  - 48 channel digitization via time-multiplexing
- Development of large-scale DAQ needed for full-scale detector
  - ~200 total antenna signals present

Operational since August 2002
- Data analysis underway

STRAW2 will replace
- Foreground: electronics rack & cable delay
- Background: salt chamber with amplifiers
πβ Domino Chip (thanks to S. Ritt)

Existing:
- 0.5 – 1.2 GHz sampling speed
- 128 sampling cells
- Readout at 5 MHz, 12 bit
- ~ 60 $/channel

Needed:
- 2.5 GHz sampling speed
- Circular domino wave
- 1024 sampling cells
- 40 MHz readout

C. Brönnimann et al., NIM A420 (1999) 264
TOF Counter Test

STRAW2 chip sampling @ 3.3 Gsa/s

@ 3.3 Gsa/s, 15 samples on 5ns risetime leading edge

TOF Counter, FM-PMT

STRAW2 (uncal.) vs. TDS scope

Time [ns]

STRAW2 vs. scope

scope (4GSa/s)

STRAW2

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**Precision Timing Estimate**

- **Time base stability**
  - Jitter tiny (\(\leq 10\text{ps}\))
  - Can phase lock to accelerator RF clock

- **Leading edge fitting**
  - A la g-2 (NIM ...)
  - Completely immune to Calorimeter backsplash
  - Significant robustness for pile-up
  - True multi-hit extraction
  - New way to get at *systematics* limitation!

- **Crude estimate:**
  - For 300ps steps, 100mV min sensitivity in threshold region:
    - 5mV quantization extrapolation \(\rightarrow 15\text{ps} \) resolution
  - Needs real evaluation! – can test with good Digital Signal Oscillo.

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STRAW Architecture Future

- **STRAW3 (August submission)**
  - 700MHz → 1200MHz analog BW
  - Rip out triggering logic (64x 20-bit DACs, 64x 32-bit scalers)
  - Fix ADC bug (& change ADC type)
  - Better impedance match

- **Pipelined SCA (Winter? Student opportunity)**
  - Fewer channels
  - Level 1 trigger latency (10-20μs)
  - True deadtimeless (Pipelined) readout
  - Trigger buffering?

- **FIR filter**
  - proven for slower Calo signals
Preview of Coming Attractions

- **FINESSE and COPPER** (next time)
  - Pipelined Readout: $10^{35}$ Luminosity issues (Yangheng)
  - Evaluation board for MTS w/HPTDC + TMC

- **Technology Review** (Future)
  - Board & chip design
  - TOP front-end chip example

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