(Some) T1019 Beam Test Experience

January 19, 2012
University of Hawaii
LAPPD Electronics Meeting
What to test – detector components

SL10 MCP-PMTs
4x4 anode structure
\( \sigma_t \approx 35 \) ps

\( l = 1200 + 1310 + 30 \text{mm} = 2540 \text{mm} \)

\( w = 450 \text{mm} \)

\( t = 20 \text{mm} \)

Belle II Particle Identification (p/K separation) upgrade
Start running at SuperKEKB in 2015

(Integrated Front-end)

R=5000mm

(Integration at Nagoya University)
Cherenkov Photon Arrival Patterns (MC)
Beam Test Electronics Elements

- Waveform sampling ASIC (IRS2/3)
- SCROD-based board stack (Spartan-6) (x3, total 384 channels, 320 instrumented)
- Timing/trigger distribution (CAT-6)
- Remote programming link (CAT-6)
- FTSW (timing distr. + remote JTAG)
- Aurora-based fiberoptic data
- DSP_cPCI (Spartan-6)
- NIM trigger logic
- CAMAC TDC (trigger phase alignment)

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Timing/Trigger Distribution

• Clock strategy:
  – Derive 21 MHz clock from FTSW-distributed 127 MHz (for final system, this is RF clock / 4; for now, it’s from a dedicated oscillator on FTSW).
  – 21.2 MHz clock must be phase aligned across all modules.
• Serial data stream from FTSW is used to divide and synchronize clocks across all modules. Some caveats:
  – Timing constraints are very tight.
  – Could only get this firmware to act stably by manually specifying the location of the PLL:

#The location of the FTSW receiver PLL seems to only work in specific locations.
#The one below is verified working... others may also work but have not been systematically tried.
INST map_clocking_and_ftsw_interface/map_FTSW_interface/map_belle2clk/map_pll/map_pll LOC = PLL_ADV_X0Y0;
  – If this timing link is ever lost (cable unplugged, high noise, etc.), it never recovers. Could be Spartan-6 limitation?
  – When timing link is down serial trigger stream decoder finds triggers constantly.
  – CAT-6 cable was found to be much more reliable than CAT-7.
Timing/Trigger Distribution

• Timing results from bench test between two SCRODs in August 2011:

Clocks are phase-aligned. ➔ Measured jitter: 20 ps RMS.

Measured phase and jitter of 21.2 MHz clock from two SCRODs (on oscilloscope)
Signal generator free running, usually 100 Hz.

Set to trigger on 1-input only.

Red part measures phase relative to reference clock... vital if you need to coordinate times with an external global trigger.
Standard Laser Runs - FTSW Timing

- Events are random with respect to FTSW trigger...
  - ...but laser fires at a fixed time relative to the global trigger.
  - Example 1:

\[ t_{\text{hit}} \]

\[ 32 \times \sim 47 \text{ns “windows”} \]

- PiLas TrigIn
- PiLas Fires
- System Trigger (CAMAC TDC start)
- 21 MHz FTSW Trigger Issued (CAMAC TDC stop)

Smaller \( t_{\text{hit}} \) \( \Rightarrow \) larger \( t_{\text{FTSW}} \)
Standard Laser Runs - FTSW Timing

- Events are random with respect to FTSW trigger...
  - ...but laser fires at a fixed time relative to the global trigger.
  - Example 2:

\[ t_{\text{hit}} \]

32x “windows” (~47 ns each)

PiLas TrigIn

PiLas Fires

System Trigger (CAMAC TDC start)

21 MHz FTSW Trigger Issued (CAMAC TDC stop)

Larger \( t_{\text{hit}} \) \( \Rightarrow \) smaller \( t_{\text{FTSW}} \)
Standard Laser Run - Distributions

Black – laser run data from exp. 10, run 33 (module 1, col 2, row 2, channel 0)
- Rough quality cuts applied, coarse timing cut to avoid reflected photons
Red – profile histogram of same data.

To first order, timing distribution works!
...But with what precision?

No fine calibration applied: assumed 2.7 GSa/s for all samples; 25 ps / count for CAMAC TDC.
Time extracted by software fixed threshold discrimination (-40 ADC counts).
Beam Test Timing – “Special” Laser Runs

- **Signal Generator (Agilent 33250A)**
- **Laser Control Unit (PiLas EIG1000D)**
- **Laser Head (PiLas PIL??S??)**
- **Coincidence Unit**
- **Gate Generator**
- **FTSW**
- **LVDS → NIM Converter**

- **Quartz Bar**
- **CAT6 timing/trigger**

**Triggered synchronous w/ 21 MHz front-end clock.**

**Mod0, Mod1, Mod2**

**Mod3**

Software triggered.

- **In this mode, the phase of 21 MHz clocks should be fixed relative to the global trigger time.**

Set to trigger on 1-input only.
Measured FTSW Timing - “Special” Laser Runs

- Typical TDC distribution of trigger phase:

  ➔ Absolute global time resolution will never be better than this!
  Is this due to intrinsic jitter in timing distribution, or jitter in the measurement?
Other issues: Waveform Processing

• Simplified waveform processing plan:
  – Each DSP core feature-extracts hits from a single SCROD.
    • One waveform in ➔ apply pedestal/timing cal. ➔ one time+charge out.

• More realistic plan:
  – DSP cores need to be aware of potential cross-talk hits from other anodes in the MCP-PMT. Feature extraction proceeds based on all available waveforms from a given PMT.

  ➔ Integrated front-end waveform processing may be more complex than anticipated…

Example SL10 waveform from beam data:

Black – primary hit
Red – cross talk on an adjacent channel
T1019 Summary

• T1019 beam test at Fermilab:
  – First system-level test of many components & features.
  – Lots of data, millions of photon candidates.
  – Analysis will be ongoing for some time... but we already some valuable feedback:
    • Timing distribution issues: requires a lot of care and attention.
      – Are event-by-event phase measurements necessary?
    • Distributed timing jitter: still under investigation... much worse than originally thought? If so, why?
    • Front-end waveform processing schemes may need to be considerably more complicated than 1 waveform ➔ 1 time/charge.

• Now duplicating as much as possible the beam test setup in Hawaii for further studies.
  – Will report more as we learn it...
National Science Foundation: Science Hard

INDIANAPOLIS—The National Science Foundation’s annual symposium concluded Monday, with the 1,500 scientists in attendance reaching the consensus that science is hard.

“Because we have embraced the pursuit of scientific knowledge as one of the noblest and worthiest of human endeavors, one leading to the enrichment of mankind both today and for future generations,” said keynote speaker and NSF chairman Louis Furian. “However, a breakthrough discovery is challenging our long-held perceptions about our discipline—the discovery that science is really, really hard.”

“My area of expertise is the totally impossible science of particle physics,” Furian continued, “and, indeed, this newly

see SCIENCE page 8

Right: Furian explains the NSF findings.