PLANS FOR MUON/TAIL CATCHER TEST BEAM AT FERMILAB

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Fermilab

2009 LCW

Rubinov LCWSA09
Previously, at MT6

- We did a quick run in 2008 (parasitic with Minerva)
From testbeam

- \(~100\%\) Efficient ?! A few hundred traces from 1 spill

Don’t miss the scale change!
From testbeam

- We even tried to measure attenuation

Need more lever arm!
From testbeam

- Sketch of the TB 2008 setup
New tests

- Want to measure
  - More channels
  - Much longer strips (284 inches)
  - Double ended readout
New tests

- Losses in the crack between adjacent strips
- Losses in scint behind SiPM

MUST KNOW THE POSITION OF PARTICLES PRECISELY
Do we need tracking for Muon TB

- **NO**
  - Heterogeneous system – everything different
  - Num of channels goes from 16 or 32 to 1016 or 1032
  - I’m scared of tracking because I’m a wimp

- **YES**
  - Very good position resolution without hurting rate
  - Very good two track rejection
  - Powerful tool that can be used in future studies
    - E.g. testing of dual readout crystals
  - I’m scared of tracking because I’m a wimp
New tools

- New strips
- New electronics – my main emphasis
New since LCW08

- Our plan for readout was (and is)
  - Fall 08: just an amplifier in a NIM bin using 500hm cables
  - Spring 09: Integrate amp, ADC, bias on one board
  - Fall 10?: SiPM readout ASIC

- New electronics ready to go for TB
  - A board that strikes a good balance of high performance and reasonable cost to support SiPM studies
  - self sufficient, simple to use and flexible
  - reuse known designs whenever possible.
TB4 key features

- Works like a 4ch of digital scope, but one that has a 0.5mV/DIV scale and precision 100V power supply
  - 12 or 14 bit, 210 or 250 MSPS, gain up to ~40db
  - Largish FPGA (with 4kpts memory/ch)
  - USB interface, High Speed i/o
  - On board bias generation for SiPMs (and current meas)

~$1K for 210MSPS 12bit
~$1.2K for 14bit
Emphasis on simple

- Plug in 5V/15V power
- Plug in SiPM into an end of a 50 ohm cable
- Plug the other end of the cable into the TB4 board
- Plug in the USB connector into your computer
- Start the software, and press the RUN button
TB4 continued

- For slightly larger applications, like test beam
  - 4x TB4 combined on 1 motherboard
  - Mother board provides:
    - Ethernet interface, USB interface, triggering, clocking
    - High speed LVDS (2 x 1 Gbps)
For fast readout: LVDS links (2 x 1 Gbps) go to a VME module (1 module has 4 links) with sufficient memory (512KB) to act as a buffer for better throughput.
TB4: memory = 4kpts/ch → 20μS

ADC
14bit, 210MBPS

ADC
14bit, 210MBPS

ADC
14bit, 210MBPS

ADC
14bit, 210MBPS

2.8Gbps/ch
11Gbps per TB4

trig
clk

Commands
Data

USB

Internal bus

0 10 20 30 40 50 60 70 80 90 100 110 120
8100 8110 8120 8130 8140 8150 8160 8170
2 Gbps

2 x 50ohm inputs
2 x 50 ohm outputs

Commands
Data

USB

LVDS to VLSB

2 Gbps

100 Mbps

Ethernet (UDP)

44Gbps

DB \rightarrow MB

MOTHERBOARD

2 x 50ohm inputs
2 x 50 ohm outputs

Commands
Data

USB

LVDS to VLSB

2 Gbps

100 Mbps

Ethernet (UDP)

44Gbps

DB \rightarrow MB

MOTHERBOARD
VLSB can buffer 300k Samples

- 4ch
- 128kB per ch
- ~75kPts per ch

VME Bus

20bit 1Gbps LVDS ch

FPGA

LVDS Rx
Numerology

- Realistically for TB:
  - 16ch $\rightarrow$ 1MB
  - $\sim$100 pts per trig storage
  - 1 MB and 1 VLSB with 2 links
  - Can store about 180 triggers
  - read only between spills

- Worst case
  - Assume $\sim$200 pts/ch per trig
  - 2 Motherboards per VLSB (means VLSB can buffer 45 trig)

- Decent readout during spill ($\sim$10MB/s over VME32) to get $\sim$100Hz rate required
Needs and next steps

- Muon beam, by its nature, is easy to share
  - We need to reach out to other potential users

- Complete MOU with Fermilab TBF
  - Formalize our needs and institutional responsibilities
END
OF
TALK
Function Generator: Tektronix AFG 3252
Power Supply: Kenwood
<table>
<thead>
<tr>
<th>Amplitude (V)</th>
<th>Input Charge (pC)</th>
<th>Mean charge Counts (ADC)</th>
<th>1ADC (fC)</th>
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<tr>
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<td>0.331</td>
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<td>10550.00</td>
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<tr>
<td>3.1</td>
<td>6.2</td>
<td>19094.50</td>
<td>0.324</td>
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</table>
Inverse of the slope gives charge per channel

\[(\text{slope})^{-1} = 0.329\text{fC/Channel}\]

Therefore, \(1\text{ADC count} = 0.329\text{fC}\)
Hamamatsu100 SiPM Plots and Gain calculations

raw data 68.9V

69.1V

raw data 69.5V
Gain vs Reverse Bias Voltage

Gain $\times 10^6$ vs RB (V)

- Gain increases as RB increases.
- The graph shows a linear relationship between Gain and RB.
SenSL devices (1mm x 1mm)
Photon Statistics

- This is the ultimate limit for noise/efficiency

This is with 100ns gate. Noise is ~1Mhz
IRST SiPMs for muon-counter/tailcatcher application study at FNAL

On commission from INFN Udine/Trieste, SiPMs have been produced by FBK-IRST (Trento, Italy) for this application.

Geometry: circular
diameter: 1.2 mm
Microcell: 40 x 40 μm
Improved fill-factor (44%)
Breakdown voltage ~30.5V

They are presently packaged (To18) with photocathode protected by epoxy(glob-top)
Bench Tests reveal:

- Low operating voltage (~30V)
- Relatively large operating range (5V)
- Very uniform characteristics

<table>
<thead>
<tr>
<th>SiPM #</th>
<th>Vbd (V)</th>
<th>Iov (uA)</th>
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<td>4.7</td>
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<td>3.5</td>
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<td>50</td>
<td>30.3</td>
<td>4.9</td>
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Test beam (fnal: T956)
~20 p.e./mip from T956 extrude scint. bar read out by wls fiber.
Detailed characterization, under controlled climactic conditions reveal:

- A low, well-behaved break-down voltage $V_{BD}$ varying with temperature as illustrated below.

\[ y = 0.0002x^2 + 0.0482x + 29.168 \]
-- a dark count ranging between 
\( \sim 10^4 \) Hz at low temperatures and 
\( \sim 10^6 \) Hz at ambient temperatures

- and a gain of \( \sim 10^6 \) at ambient temperatures which varies linearly with bias voltage

The effects of \( \gamma \) and neutron radiation have also been studied and, as expected are not of concern at the larger radii occupied by the neutron counters
Gain vs Reverse Bias Voltage

Gain vs Reverse Bias Voltage

Gain (10^5)

RB (V)
This is the model I use. I got it from talks by C. Piemonte and others.

Where available, I use parameters measured by Adam and co.

Where not available, I guess and fiddle.

In my view, this sort of work is useful to develop a feel for things, and guide studies. Good predictions require a lot more work.
There are 4 values of Crq from 1 to 10 fF. So Crq is important for “spike” but not “tail”.
The shape of the spike depends critically on the shaping function of the amplifier – you can also get “ripples”
I think it makes sense to “integrate” this spike away before digitizing waveform.
Readout of the SiPM

- I have seen the future of SiPM readout
  - Readout electronics will be integrated into the SiPM!
    - because
    - SiPM is an inherently digital device
    - We digitize the signal from the SiPM
    - So why do we have an analog step in between?!?
      - Because we want to get started!