Micromegas Test Beam

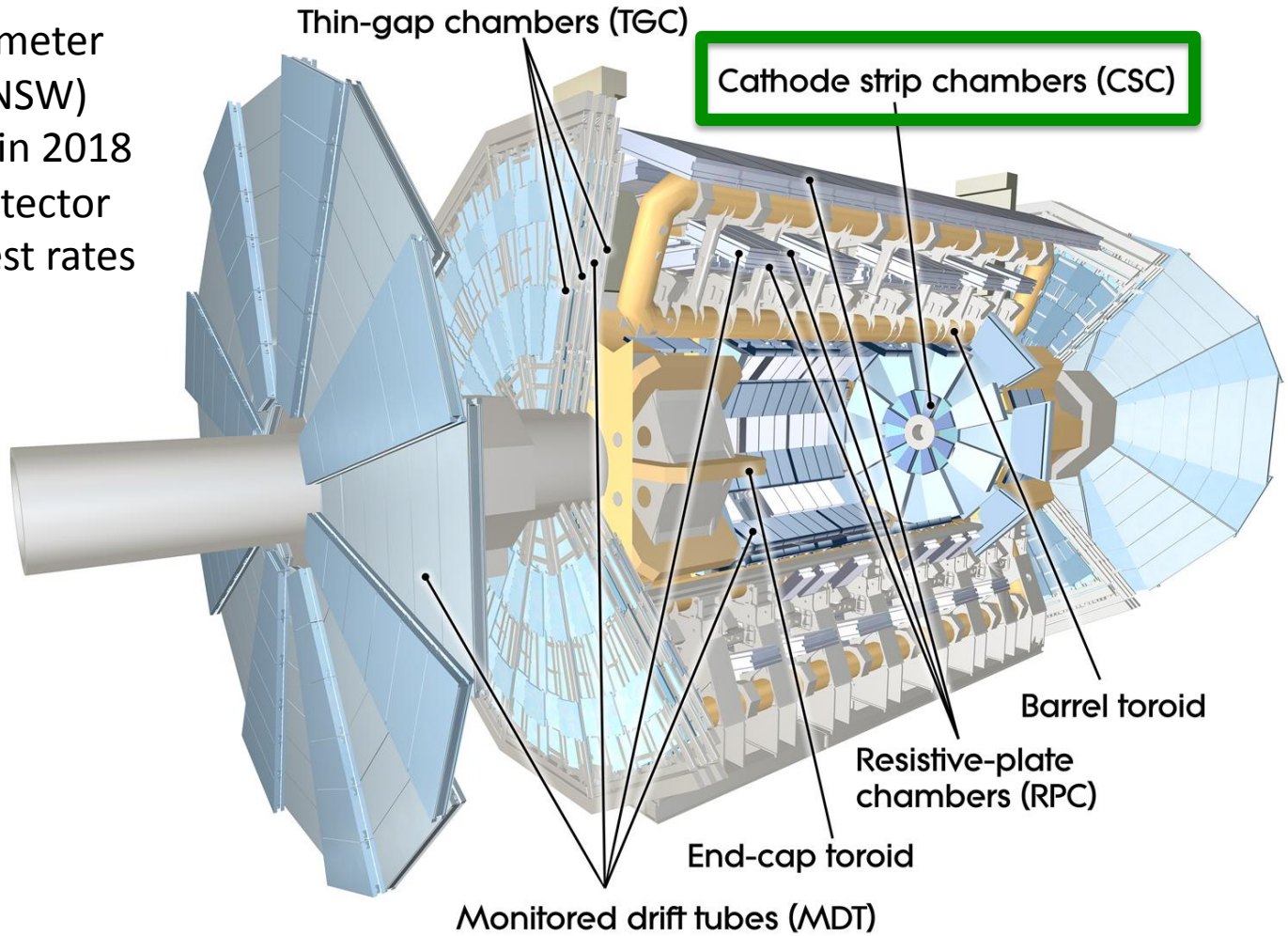
Jessica Metcalfe

Micromegas

- Introduction to the New Small Wheel
    - Micromegas
    - VMM1
- VMM1 Operation
    - Precision tracking
    - Fast trigger
- Test beam
    - Set up
    - Preliminary results

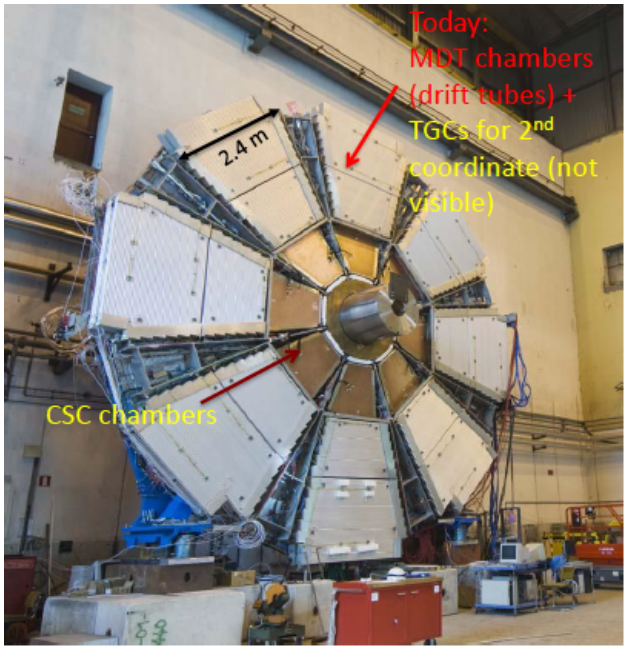
New Small Wheel

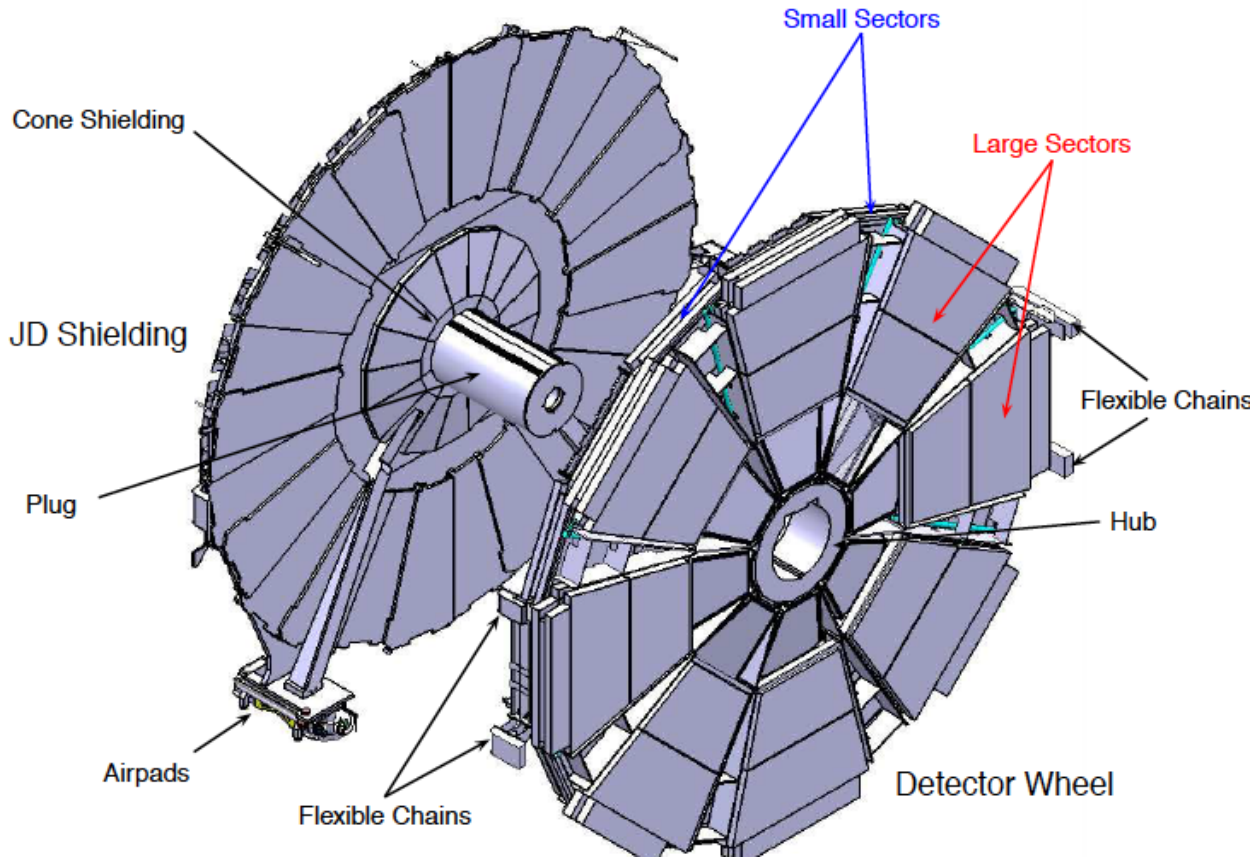
ATLAS Muon Spectrometer
- New Small Wheel (NSW)
- upgrade in phase 1 in 2018
- innermost muon detector
- subject to the highest rates



New Small Wheel

- New Small Wheel will make use of the current SW infrastructure
- Thin Gap Chambers (TGC's)
- ***Micromegas***

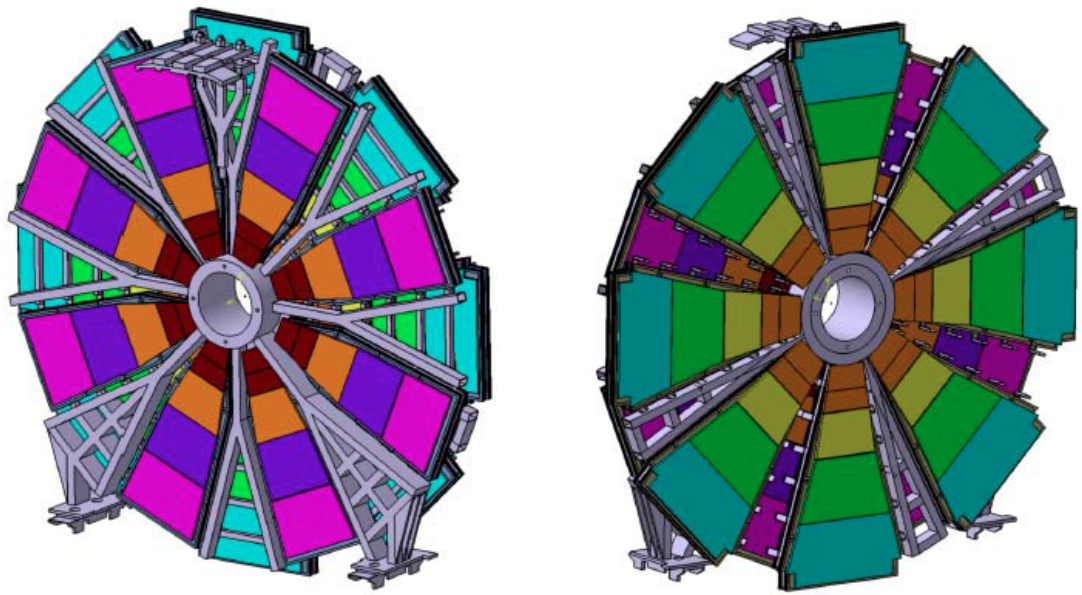




NSW Motivation

NSW Motivation

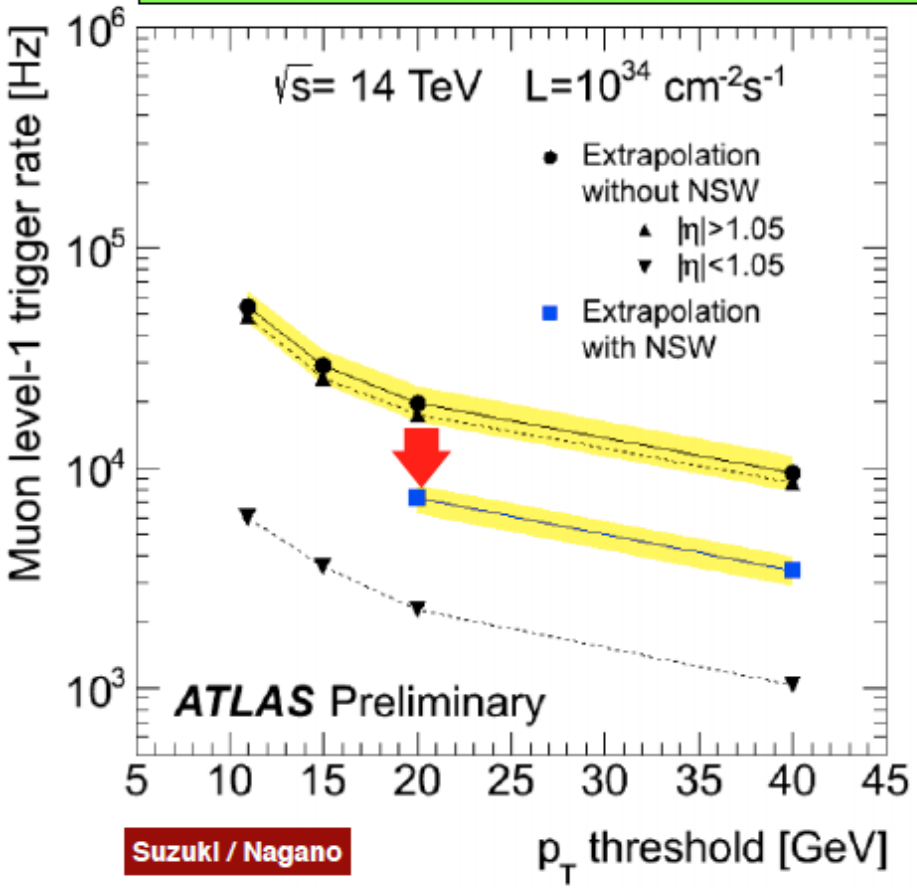
- Upgrade needed for high luminosity up to 5-7x10^{34}
  - reduce fakes to avoid pre-scale of the L1 trigger rate and loss of physics
    - high precision tracking pointing to the IP in the NSW
    - excellent angular resolution of 1 mRad
    - track p_T resolution



Motivation

2 to keep L1μ P_T threshold ~20GeV ...

rate : L1μ_20 : 60kHz ⇒ **22kHz (NSW)** @ 3e34

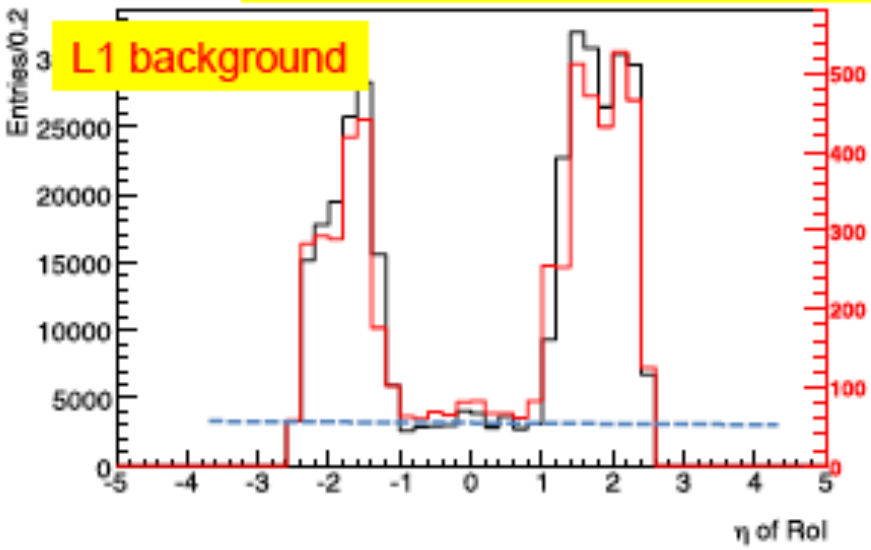


NSW is crucial to run with higher inst. luminosity

Slide from Masaya Ishino

Motivation

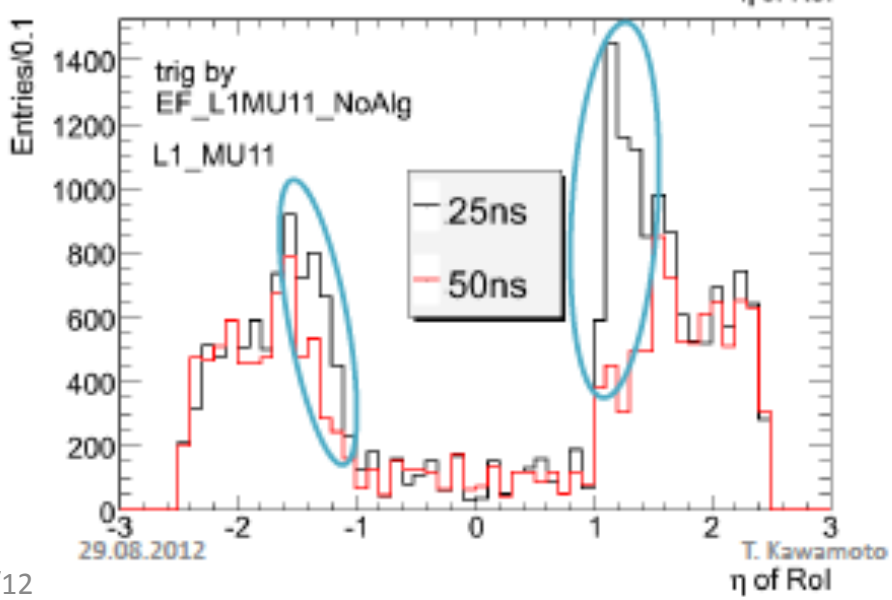
Motivation of upgrade (1)



MU20 vs η 2010/2011 data

50 ns interval

~ 6-7x higher L1 rate in Endcap than in the barrel



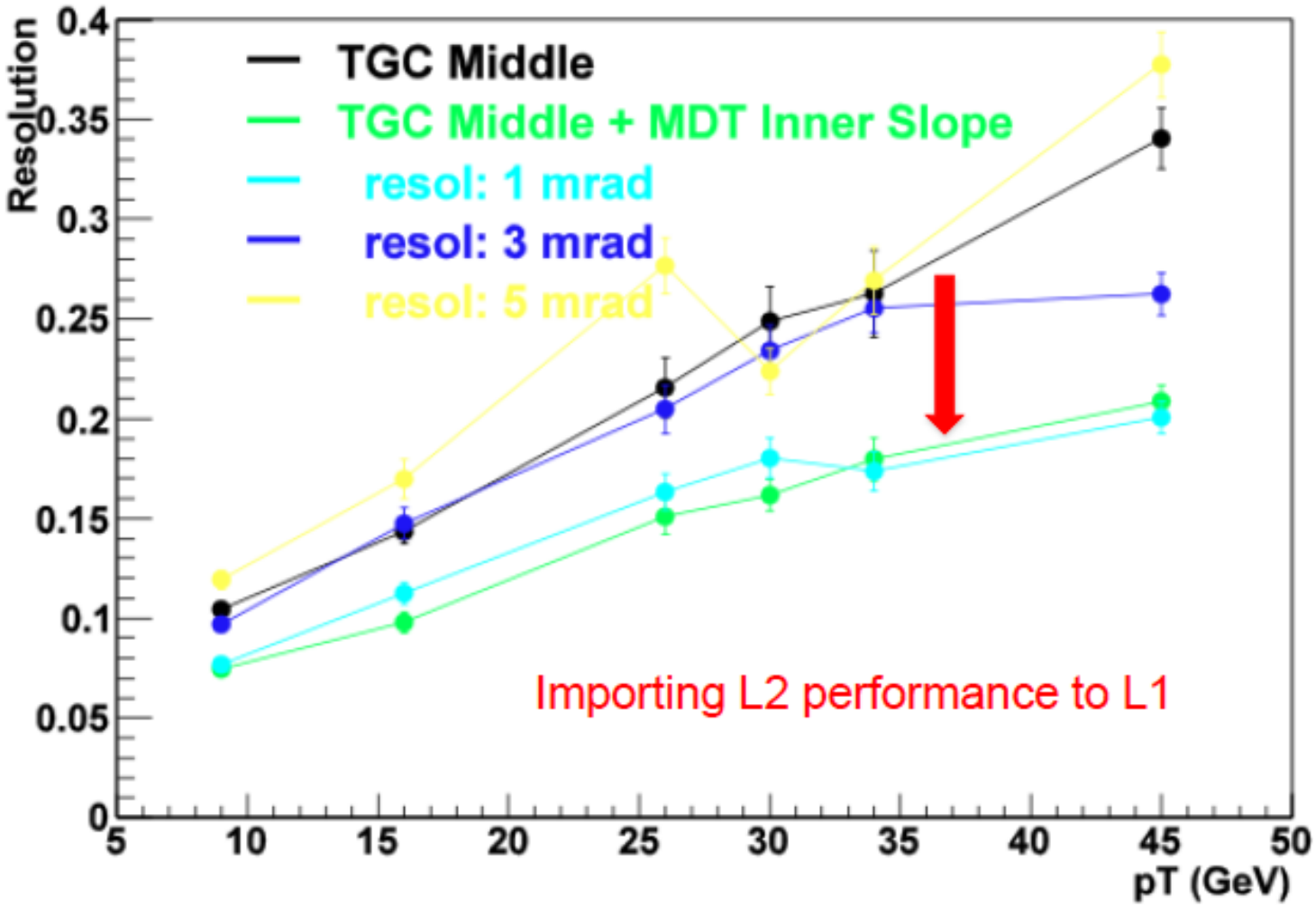
MU11 vs η 25 ns test in 2011

Additional background in $\eta = 1.0 - 1.5$

Slide from T. Kawamoto

Motivation

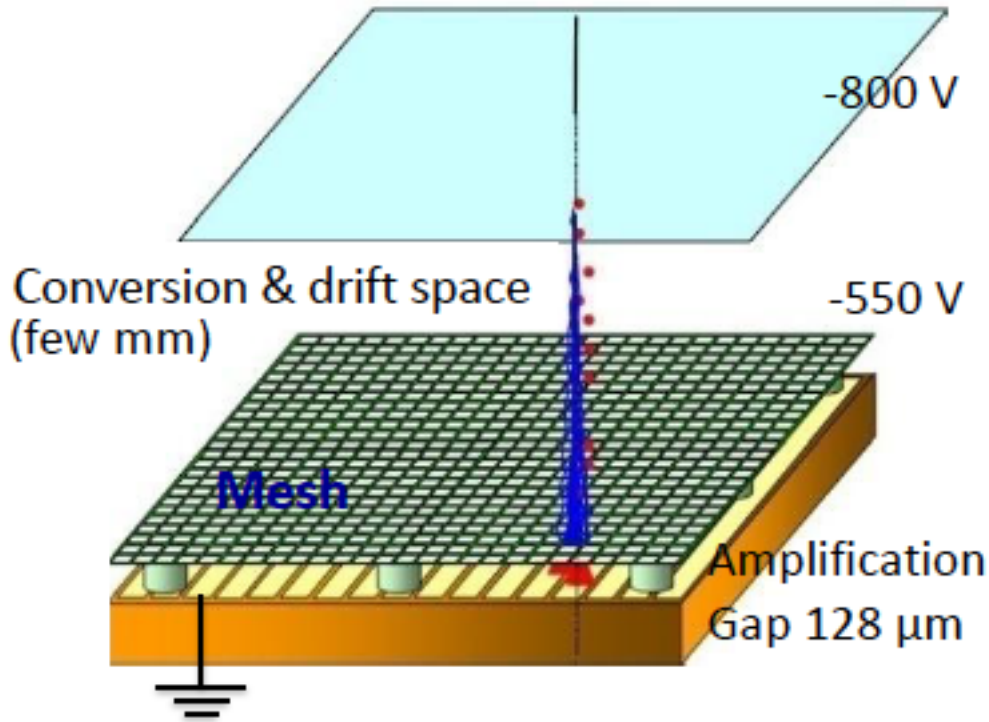
Plot from T. Kawamoto:

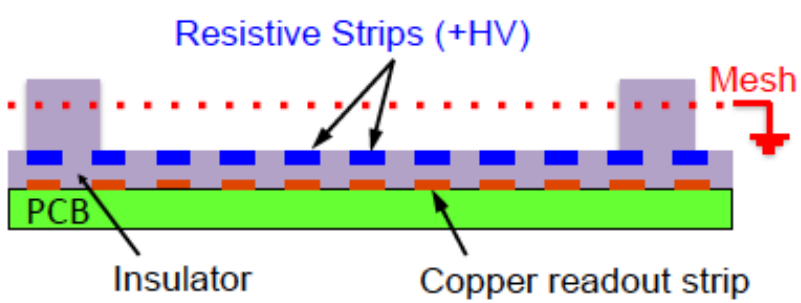


Micromegas

Micromegas (MM) Design
- Printed on PCB
- 2 amplification regions
- Resistive strips to prevent sparking

For test beam:
- Drift gap = 5 mm
- strip pitch = 400 µm
- gas Ar:CO_2 93:7

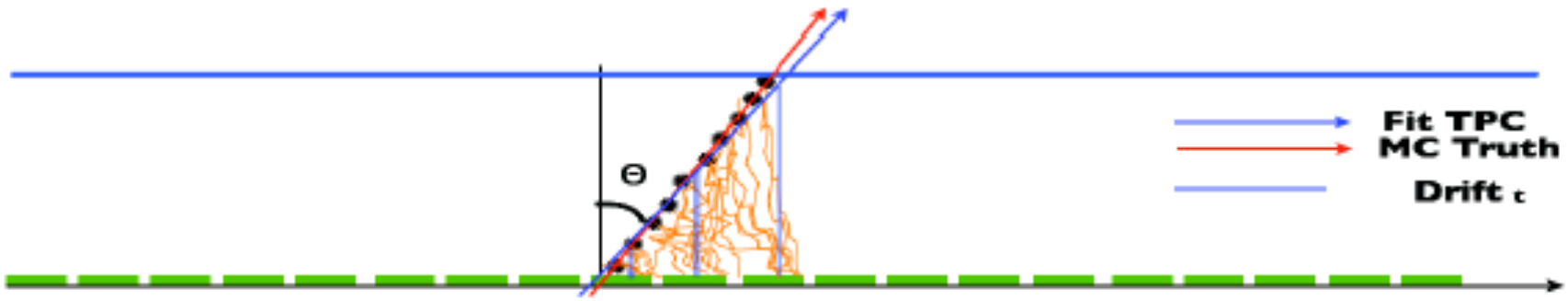




Micromegas

Micromegas Muon Detection:

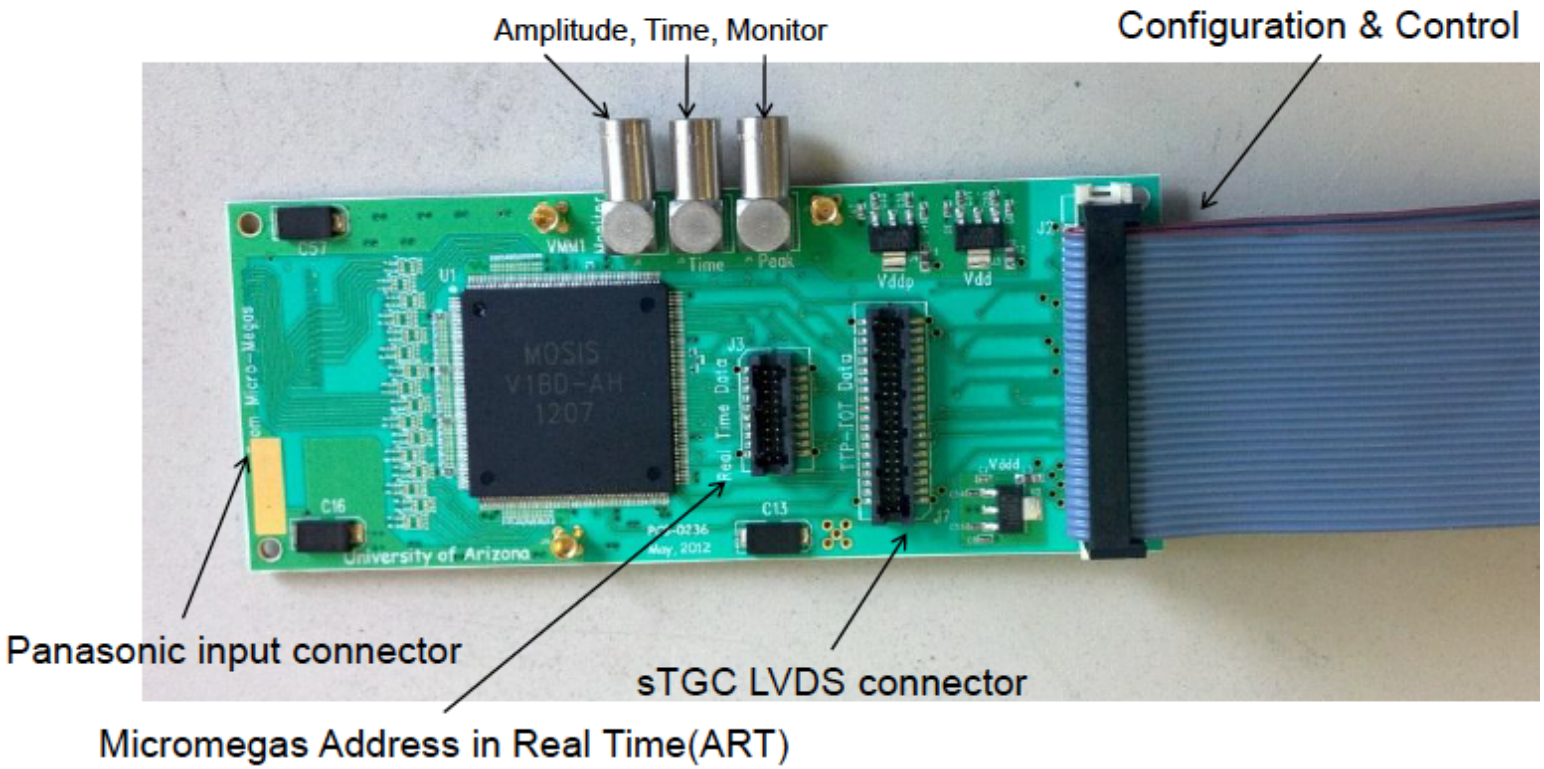
- muon leaves ionization trail
- charge drifts to strips
- drift velocity = 47 µm/ns
- NSW will have tracks between 8° and 30°



VMM1

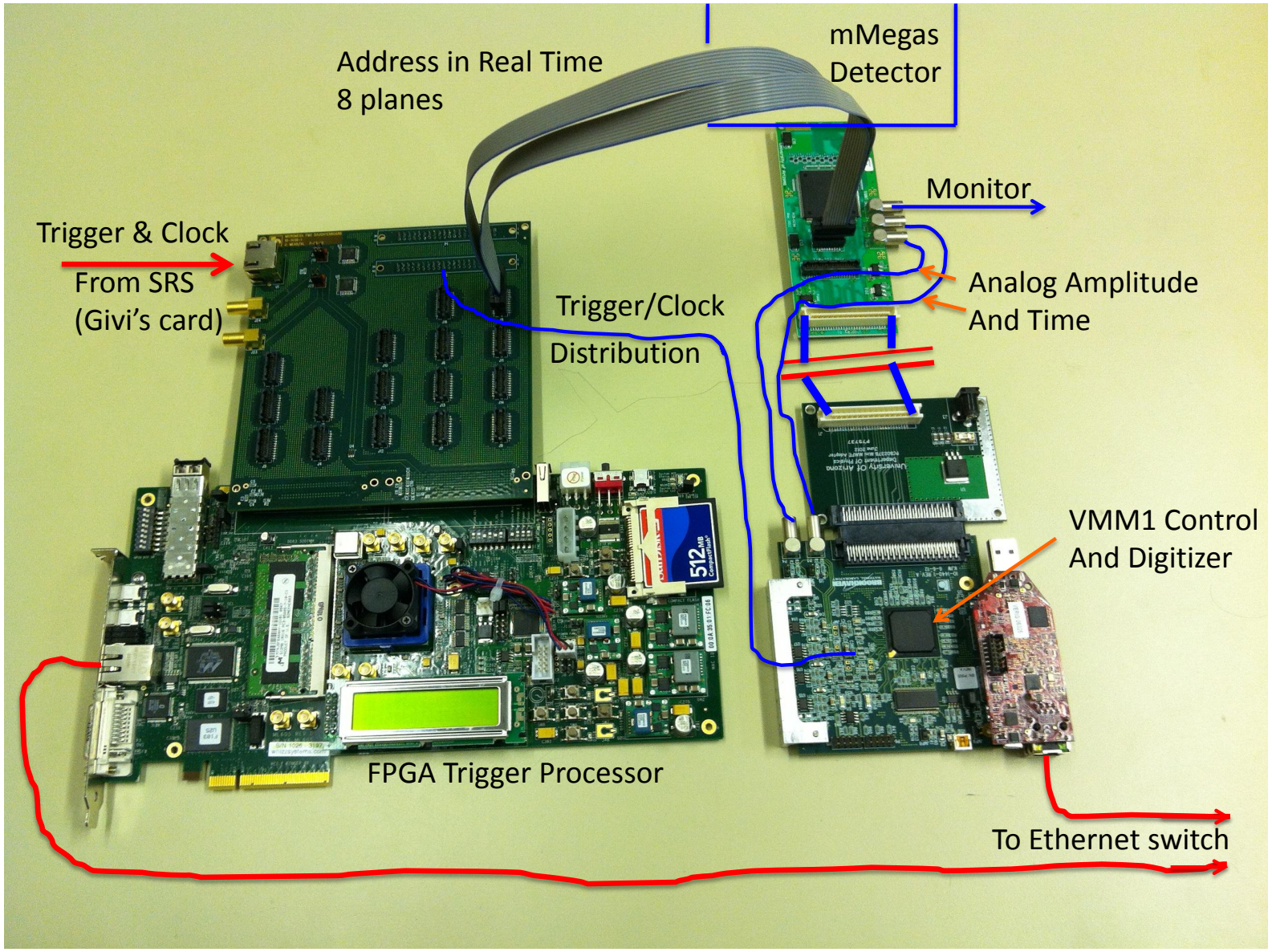
VMM1 Readout

- Flexible design can be used for MM and TGC
  - variable gain and peaking time configurations
  - reads out only signals over threshold and option to read neighbor channels
- Measures signal peak amplitude (PDO) and time (TDO)
- Fast channel address of first hit (ART)



VMM1

VMM1 Readout



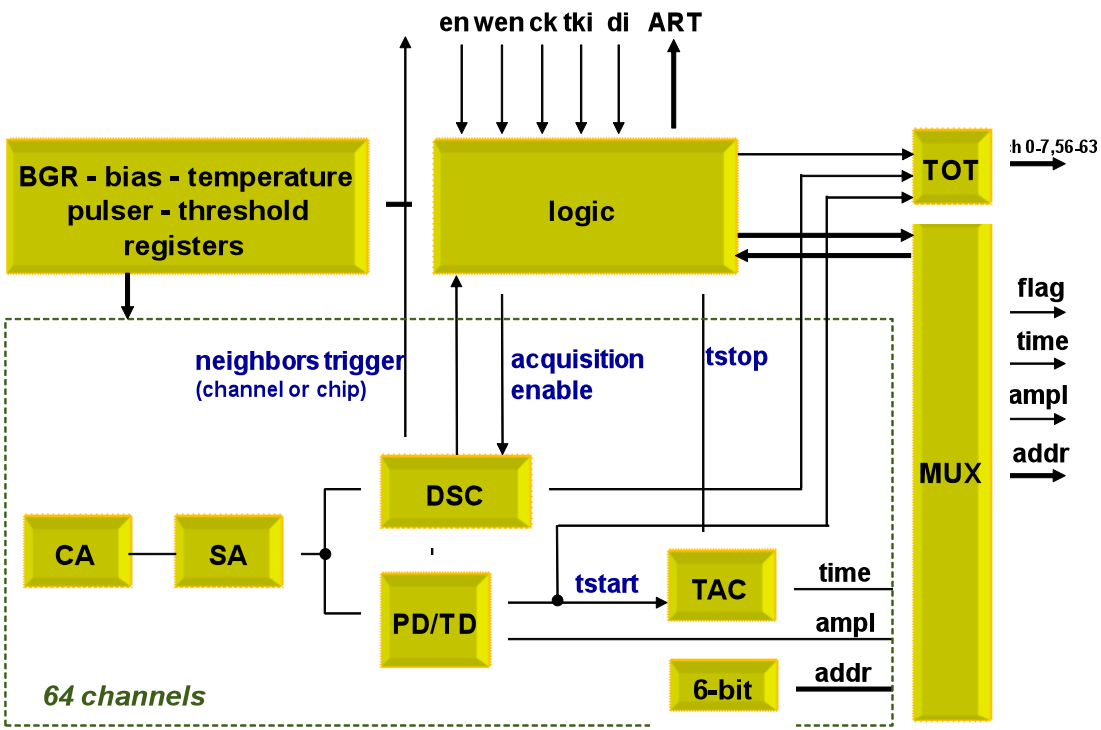
VMM1 ASIC

VMM1 ASIC

Technology: CMOS 130nm 1.2V from IBM (8RF)

Layout size, device count: : 5.934 x 8.433 = 50.033 mm², 500k MOSFETs, 80k capacitors, 200k resistors

Power dissipation: 1.2 V x 300 mA = ~ 360 mW (~5.5 mW/channel)



Acquisition:

events are detected and processed (amplitude and timing)

- charge amplification, filtering, discrimination, peak- and time-detection
- address in real time (ART) of the first event
- direct timing (over-threshold or to peak) available for channels 0-7 and 56-63

Readout:

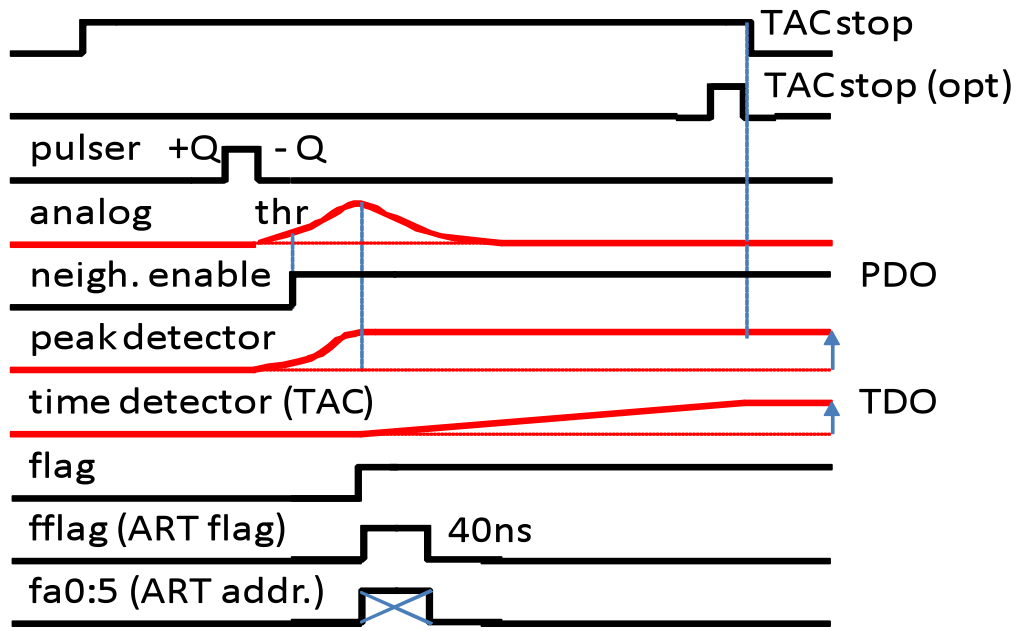
events are read out in sparse mode with smart token passing (amplitude, timing, address)

Configuration:

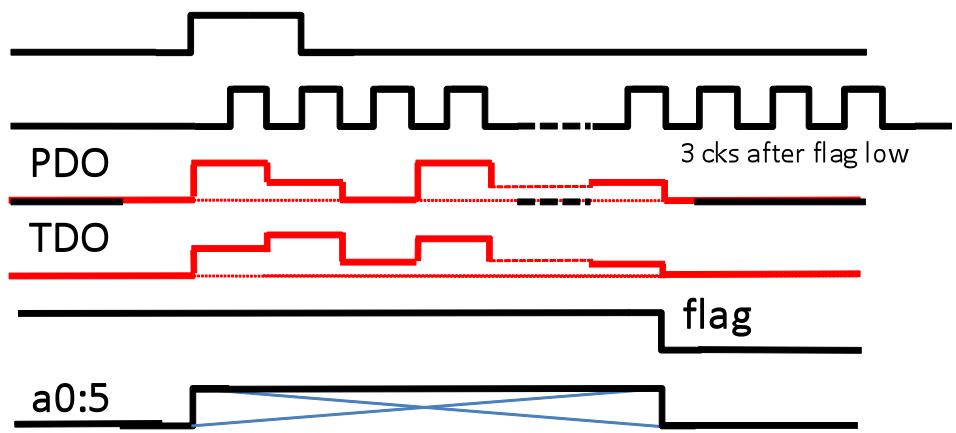
global and channel registers are accessible for configuration

VMM1 Signals

Acquisition:



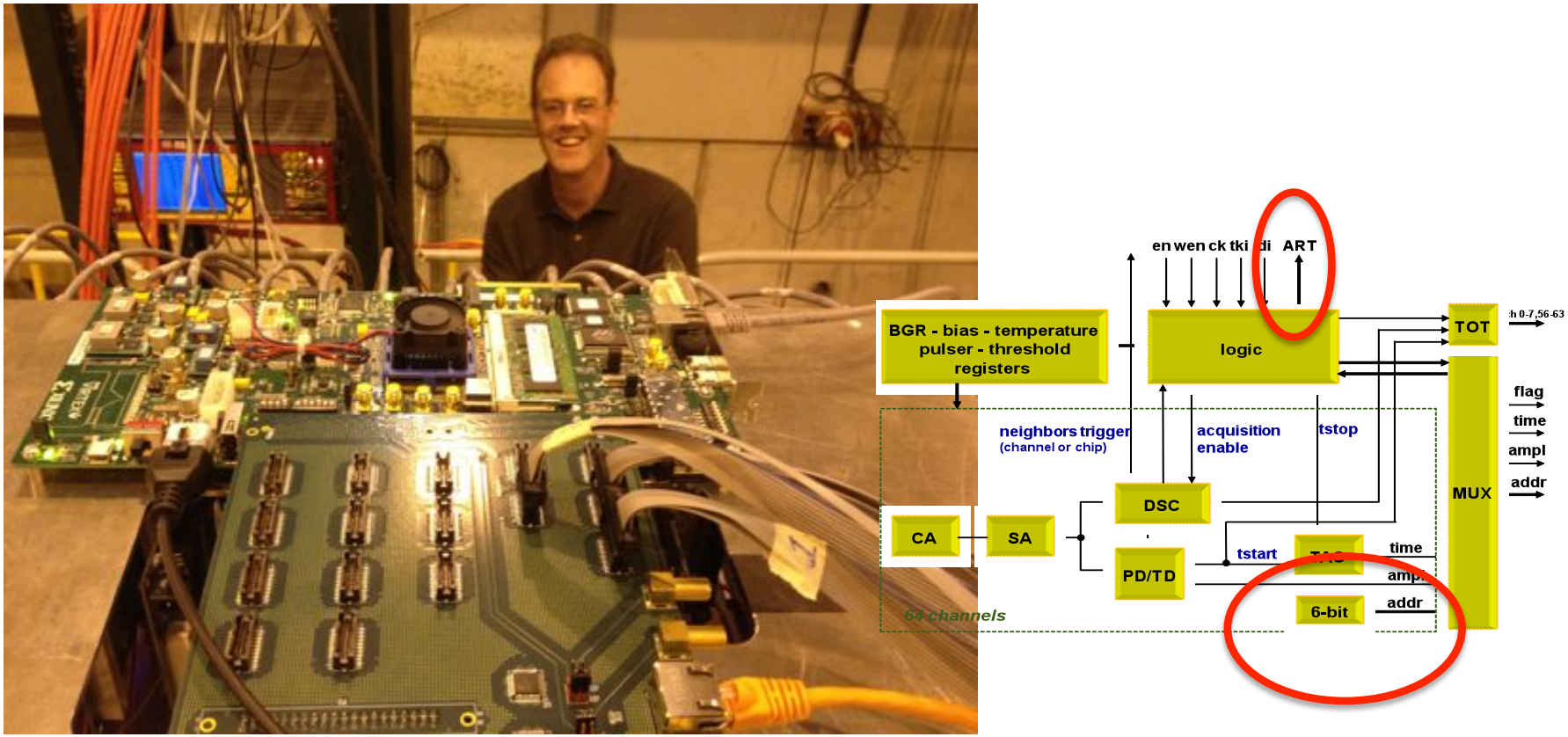
Readout:



Fast Trigger

Address in Real Time (ART)

- 200 MHz clock: fast enough to use as a trigger
- reads out channel ID, clock (time to within 5 ns), and trigger #



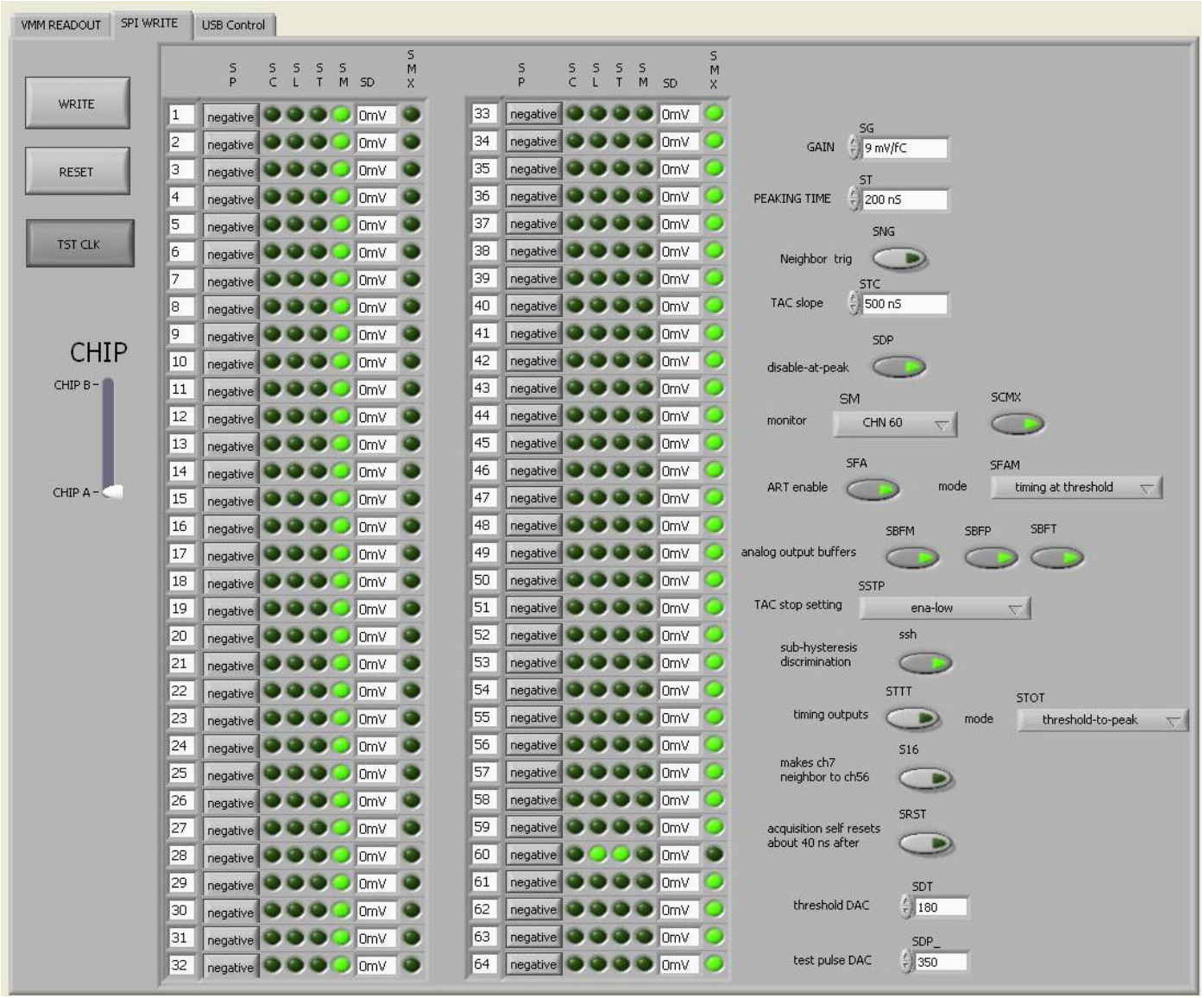
Labview for VMM1

<u>Global Configurables:</u>

- Gain
- Peaking Time
- Time Amplitude Conversion (TAC)
- Threshold
- Neighbor Trigger
- Sub-hysteresis
- ToT/TtP enable
- ART enable (fast trigger)
- Pulsar DAC
- monitor

<u>Channel Configurables:</u>

- test pulse enable
- threshold trim
- monitor

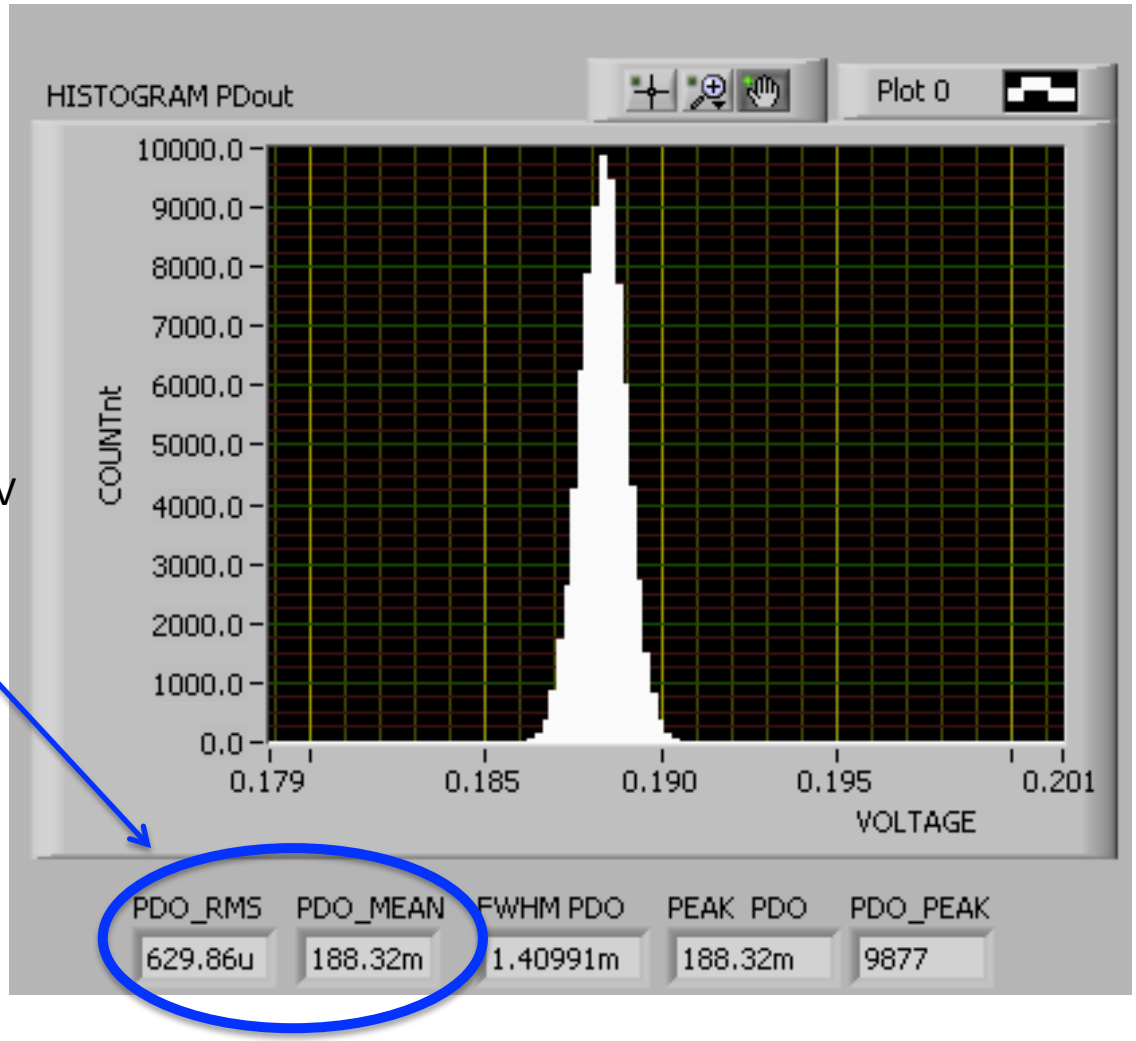


VMM1

Example of PDO readout in Labview:

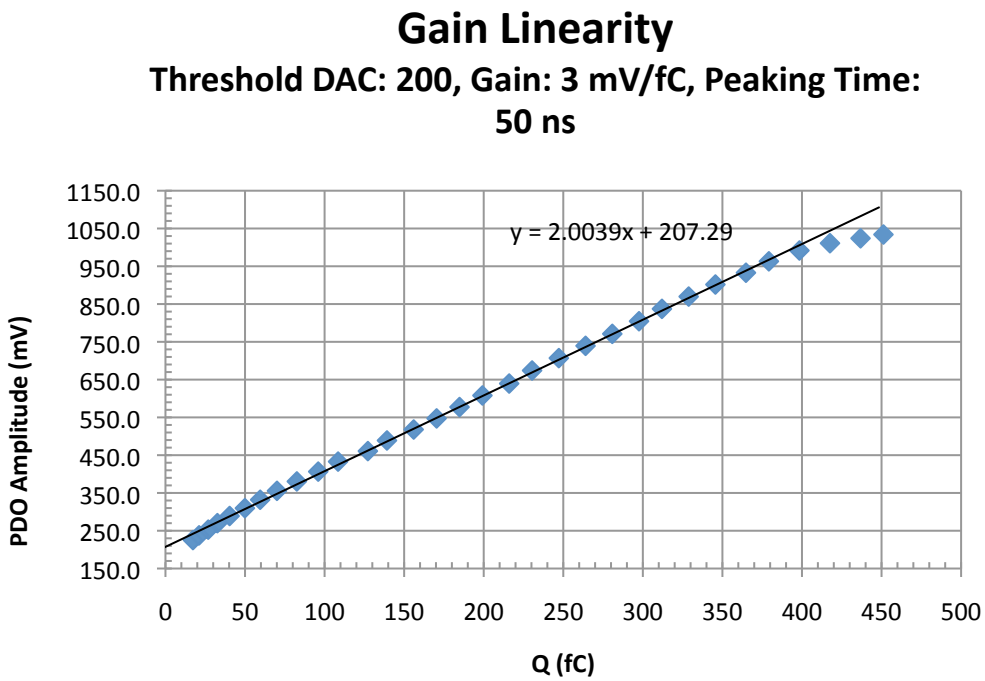
- with internal test pulse (1.2 pF)

Mean = 188.3 mV
rms = 0.6 mV
(640 e)



Gain = 9 mV/fC
Peaking time 50 ns

VMM1 Gain



Channel Gain
- Linear response (mostly)
- variation on peaking time
- measured gain is below the nominal gain

Measured Gain Values

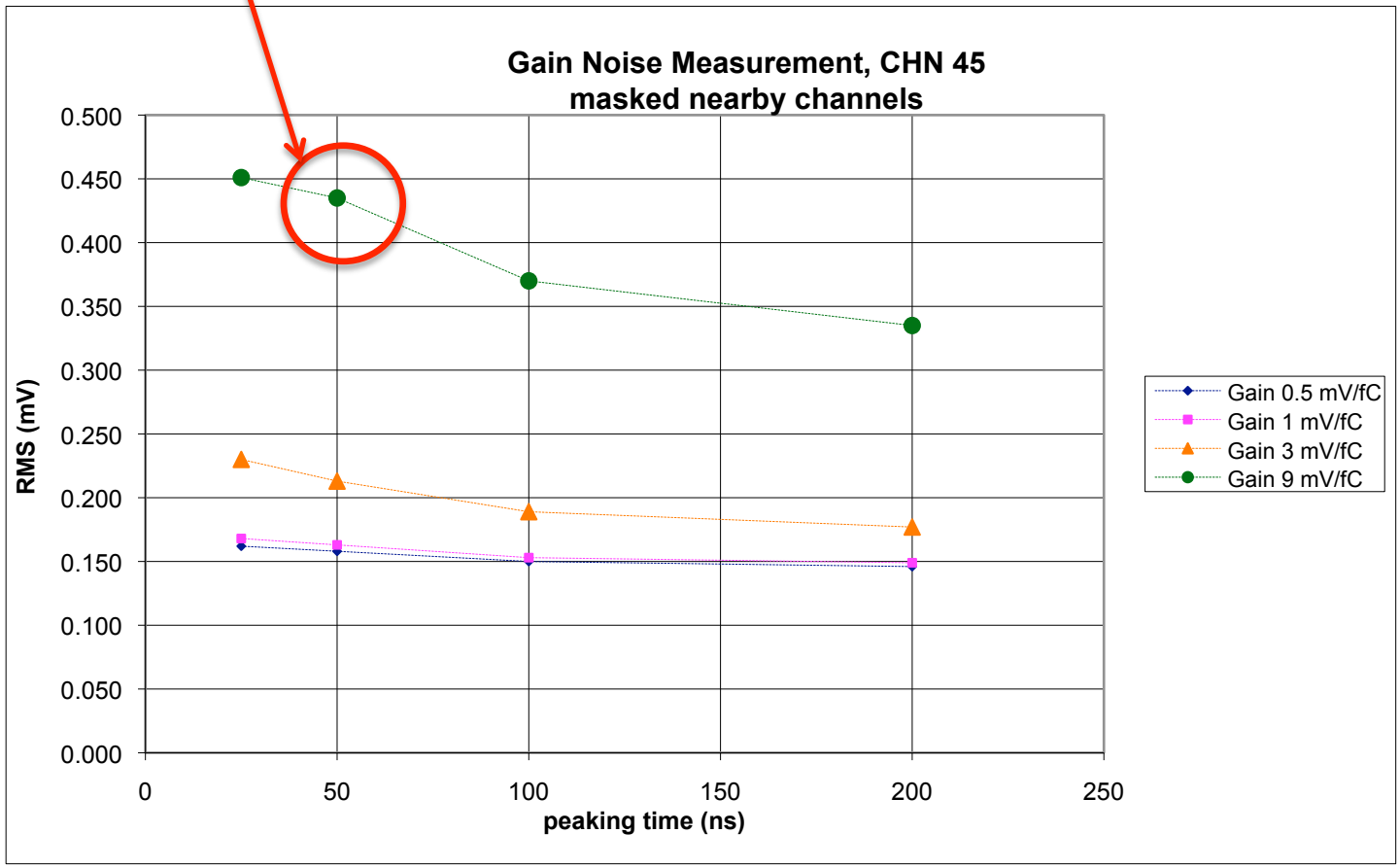
	Peaking Time (ns)			
Gain (mV/fC)	25	50	100	200
0.5	0.2811			0.4971
1	0.6743	0.6897		0.9847
3	2.0144	2.0039		2.7592
9	4.7274	6.1258		8.1193

VMM1 Noise

Noise:

@ 50 ns & gain 9 mV/fC :

0.435 mV ÷ 6.1258 mV/fC = 0.710 fC = 443 electrons

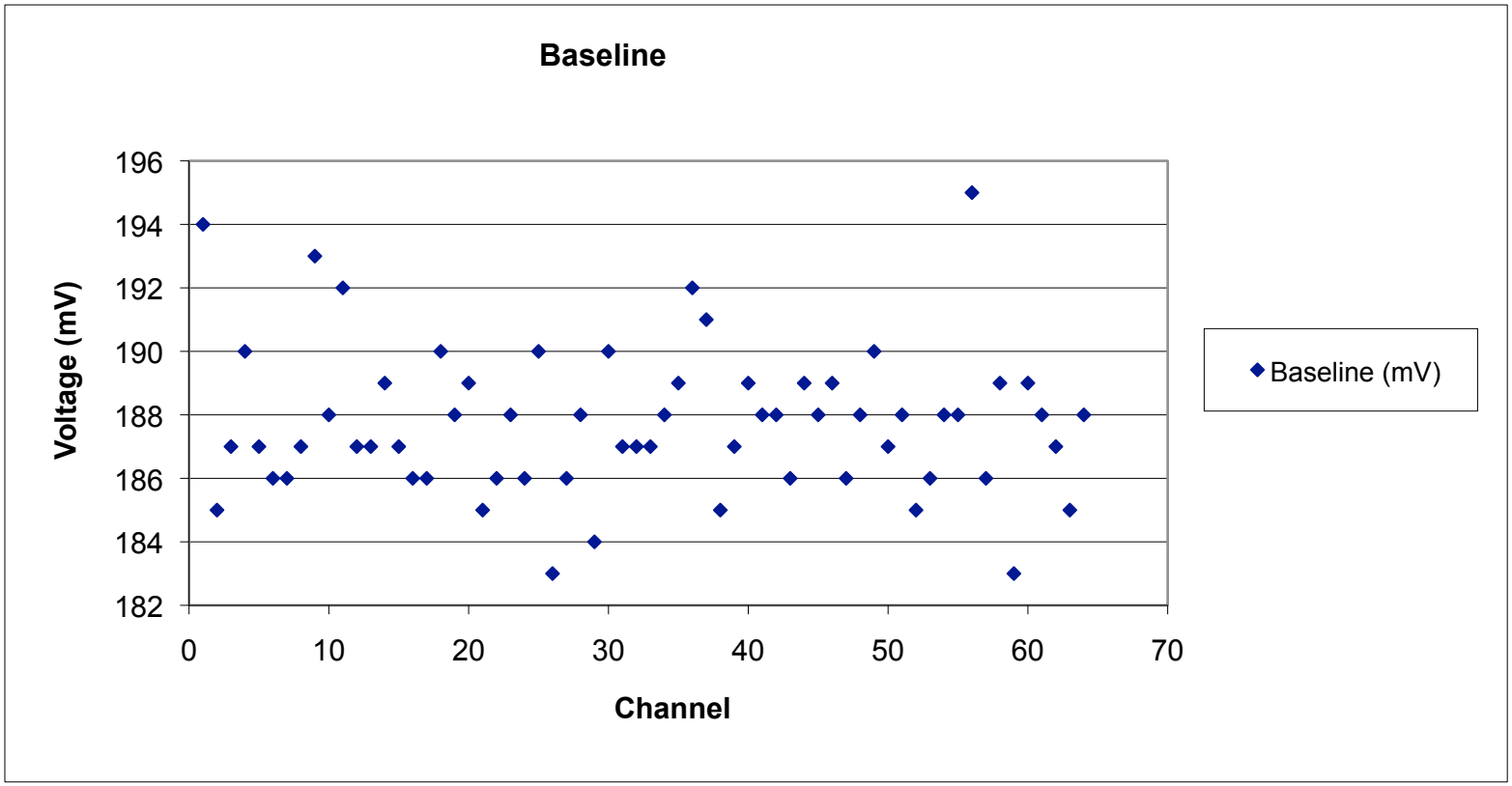


VMM1 Baseline

Baseline Channel to Channel Variation

Average Baseline = 188 mV (+7 -5)

=> Calibration Needed!

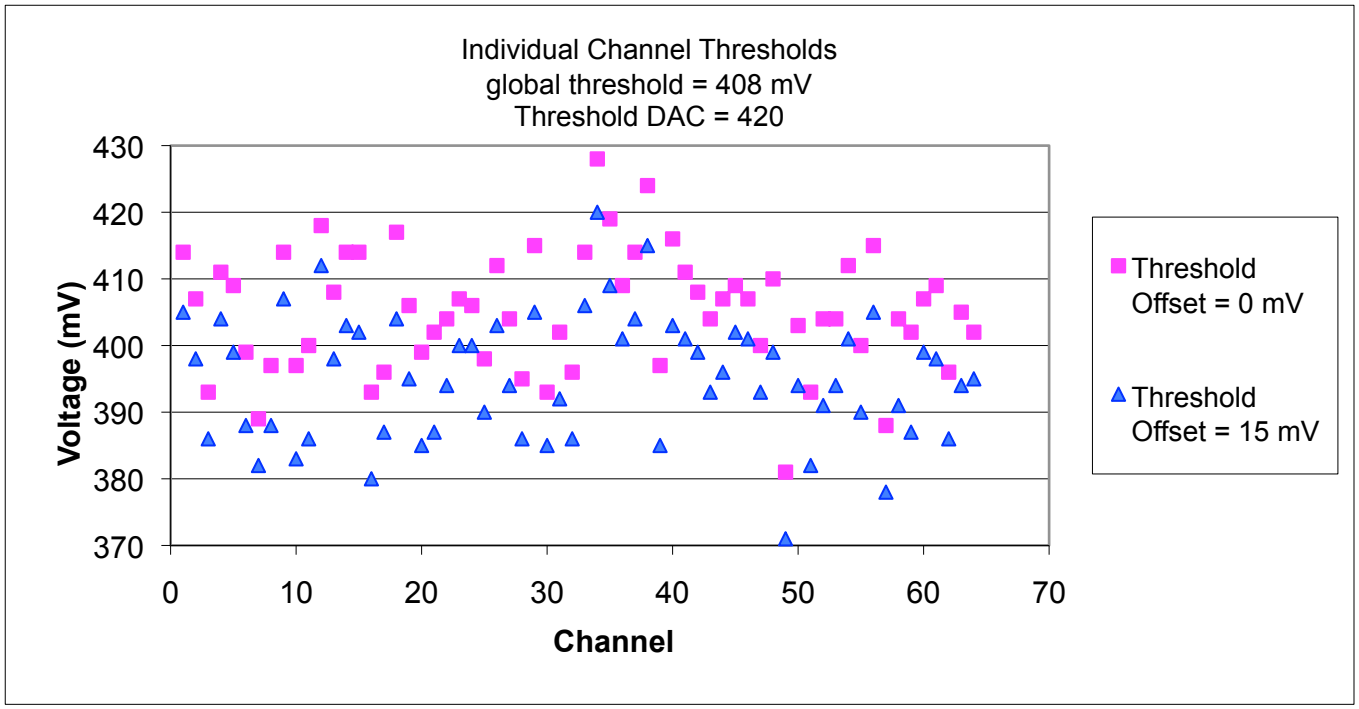


VMM1 Threshold

<u>Threshold Channel to Channel Variation</u>

Trim ranges have no common value

=> Need larger threshold trim range (next version)

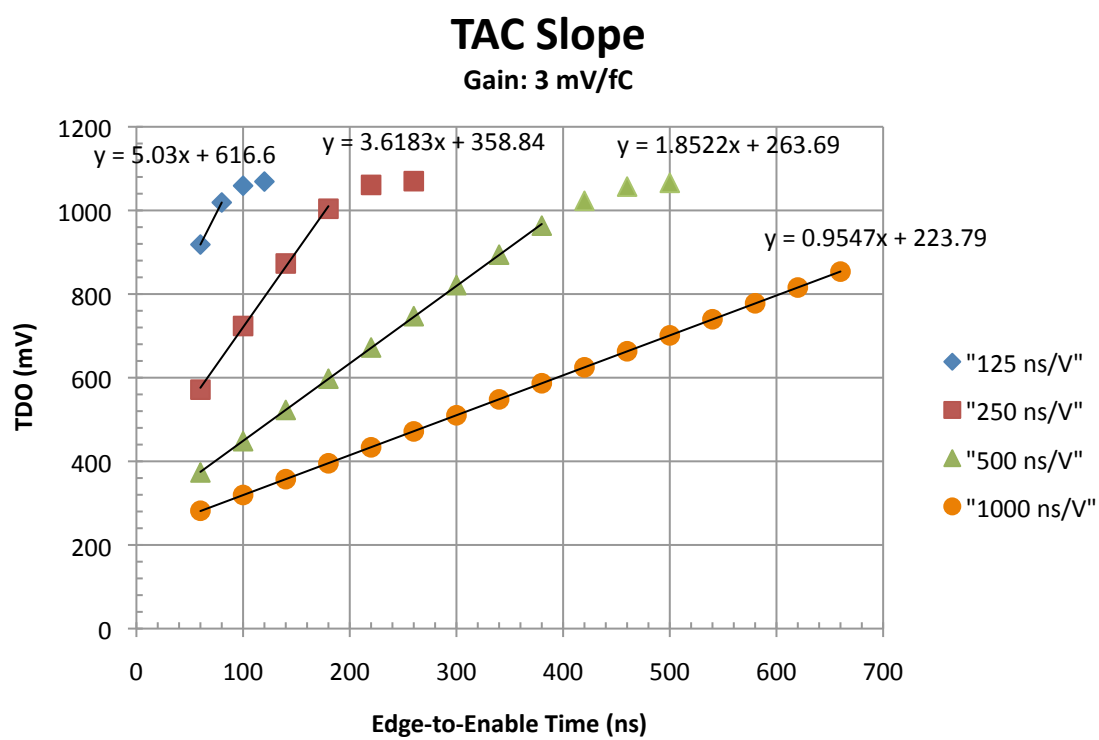


VMM1 Time Output

Time Amplitude Conversion
- slope converts TDO (mV) to time
- mostly gain independent
- need to calibrate channel-by-channel

TAC Conversion Table
1/TAC (ns/mV)

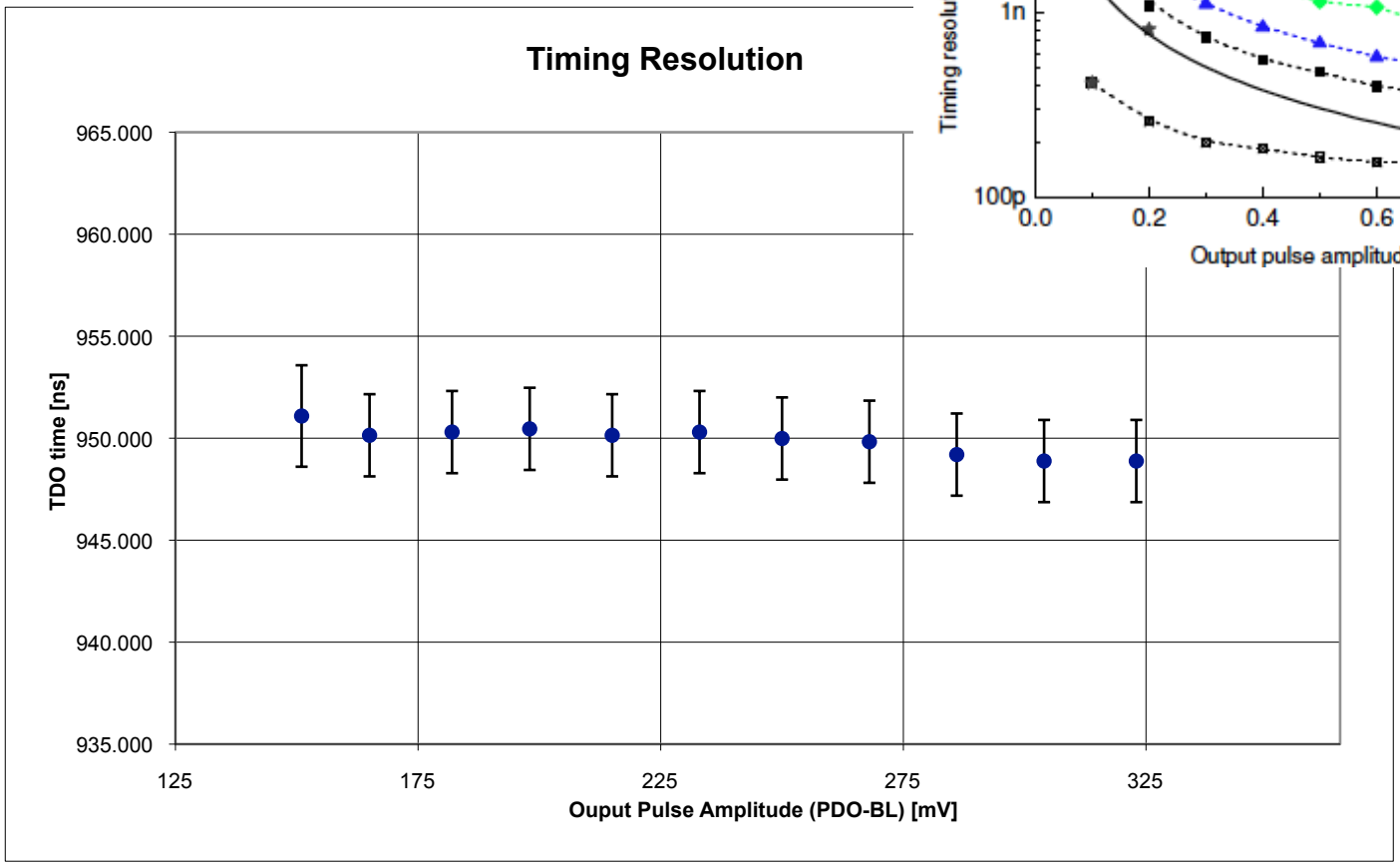
	TAC Slope			
Gain	125 ns	250 ns	500 ns	1 μs
0.5	0.22	0.34	0.64	1.22
1	0.20	0.28	0.54	1.05
3	0.20	0.28	0.54	1.05
9	0.19	0.28	0.54	1.05

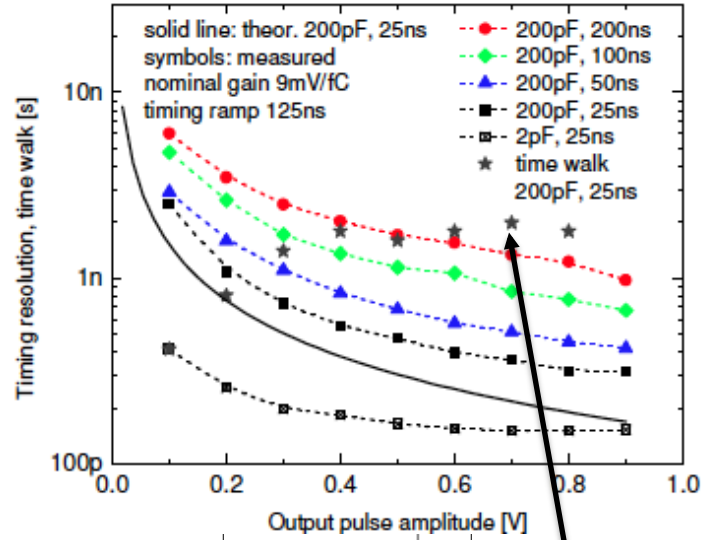


VMM1 Time-walk

Time-walk: jitter in peak value measurement

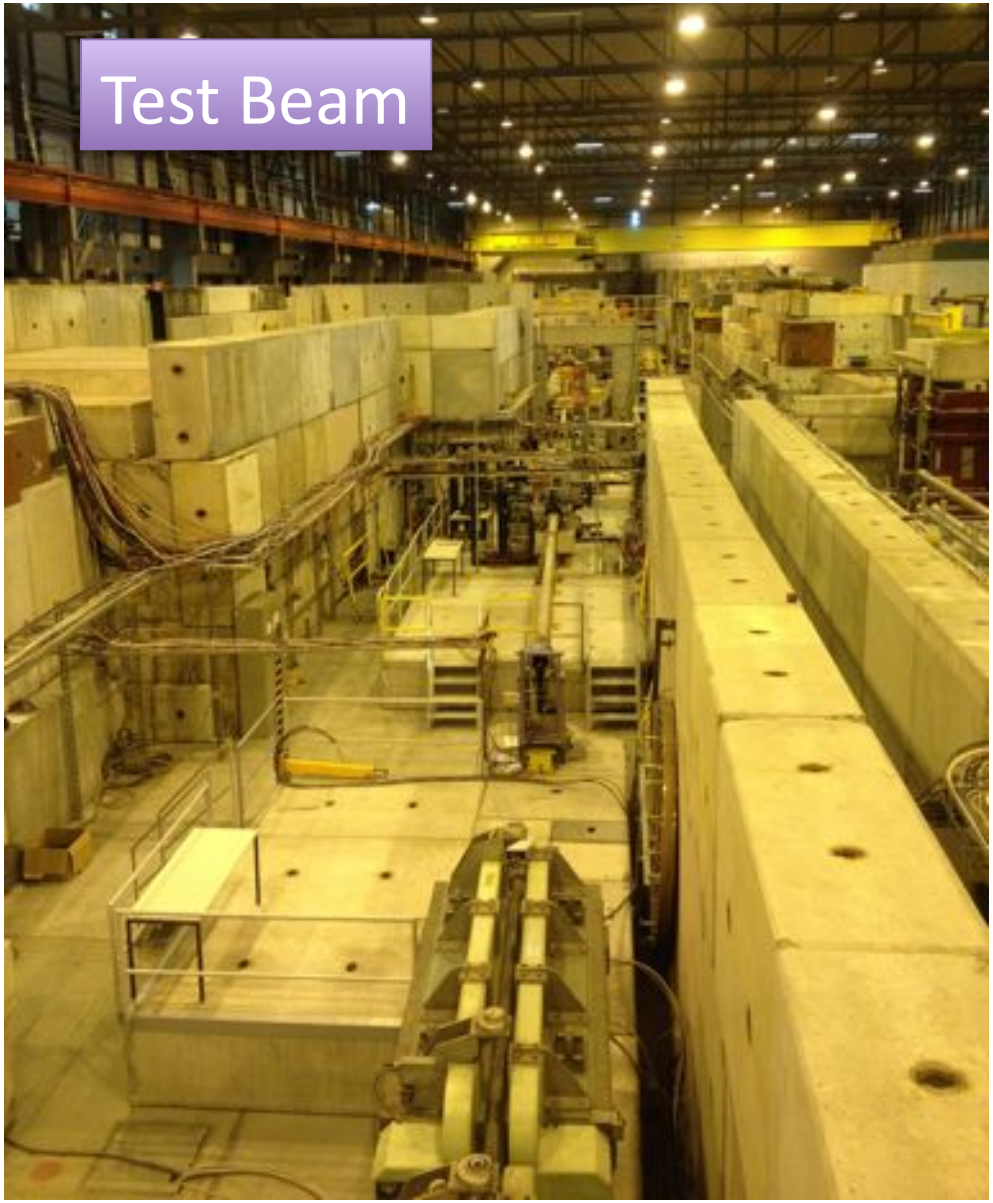
- Less the 2.2 ns difference
- Gain = 1 mV/fC peaking time = 25 ns
- 1.2 pF input capacitance (internal)





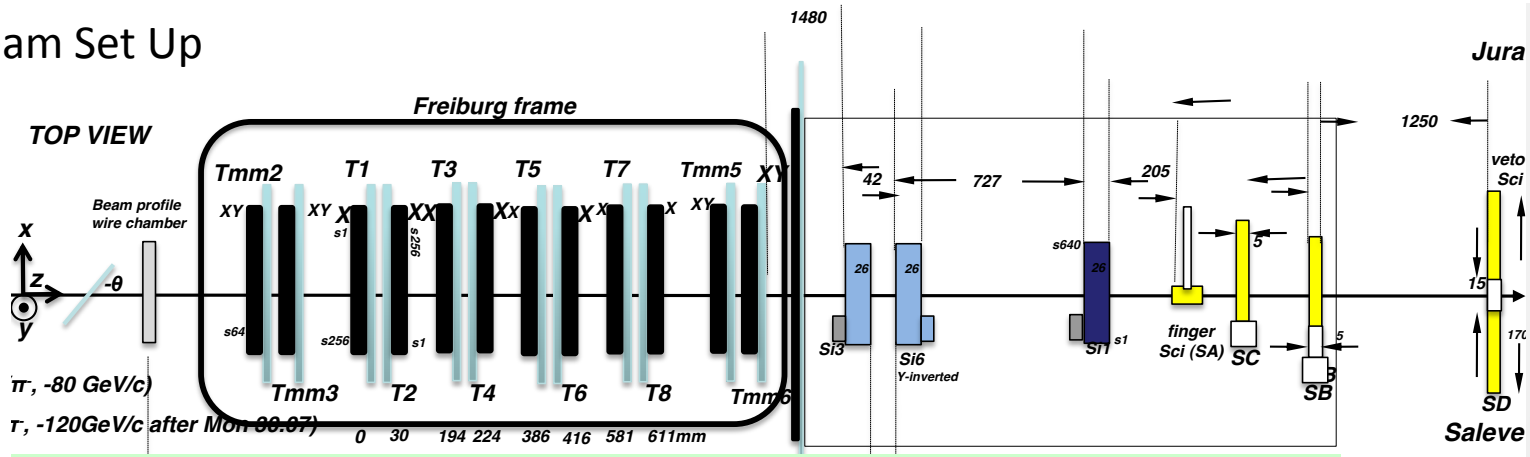
Time-walk simulation

H6 Test Beam

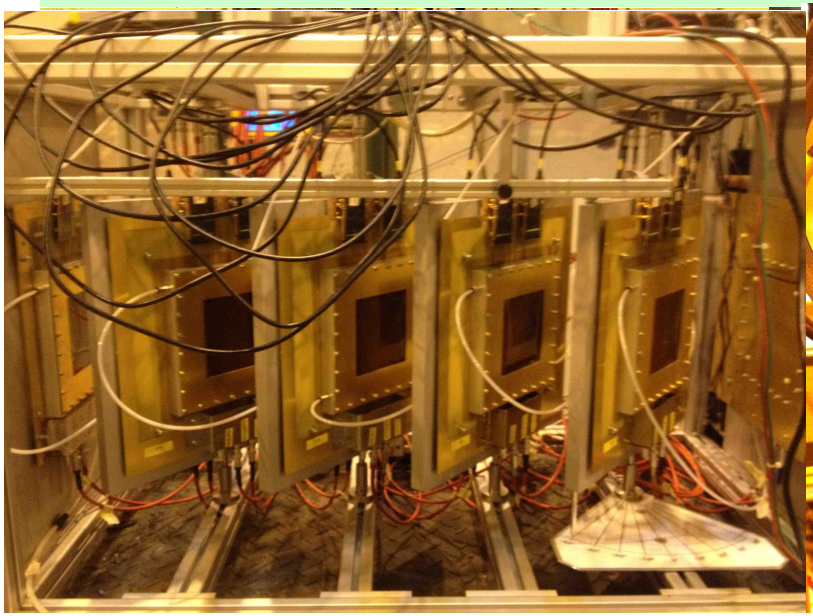


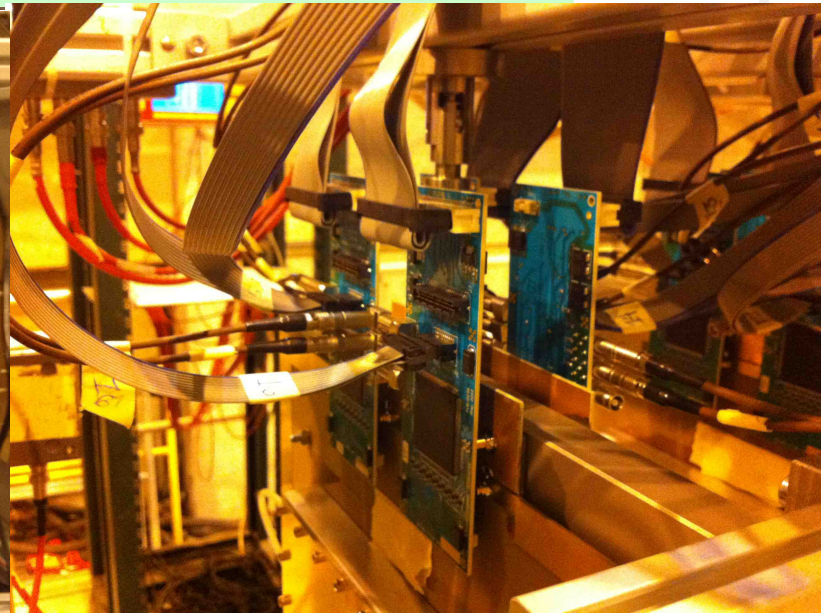
Test Beam Set Up

Test Beam Set Up



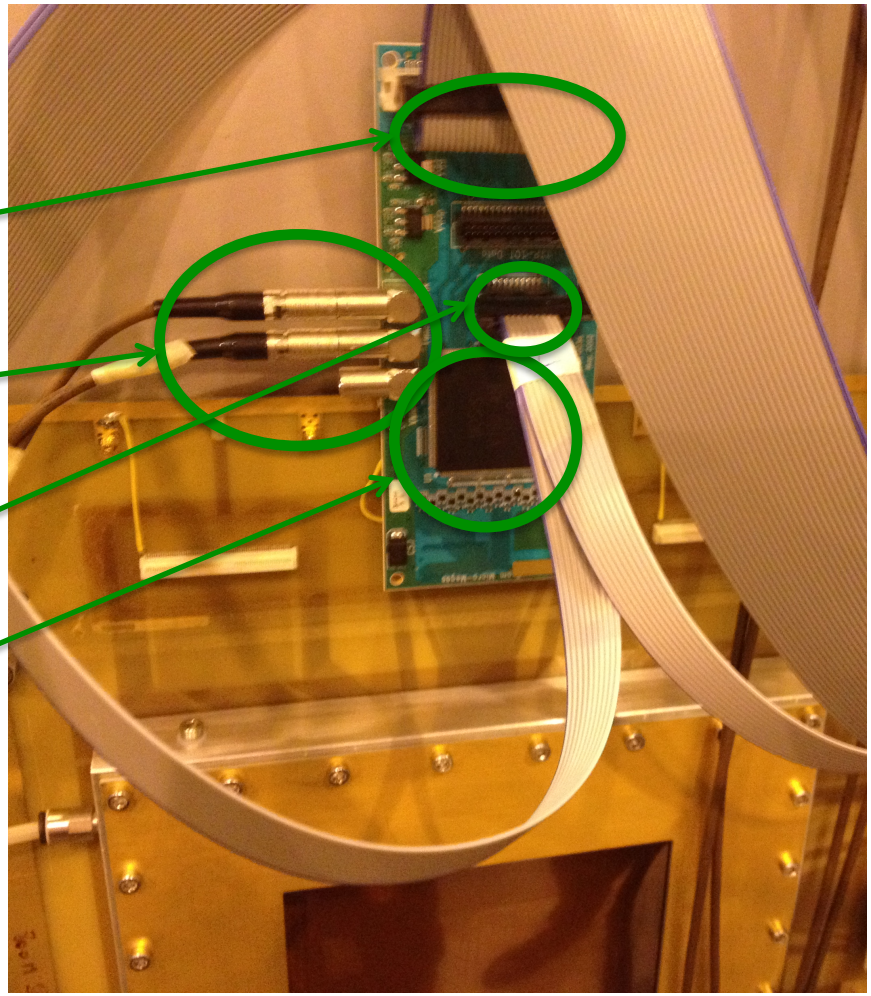
T1-8; S=10x10cm^2; p=0.4mm; dg=5mm; gG=10^4; Ar-CO$_2$ 93-7; v$_d$=47um/ns; Elx=APV25; daq=SRS





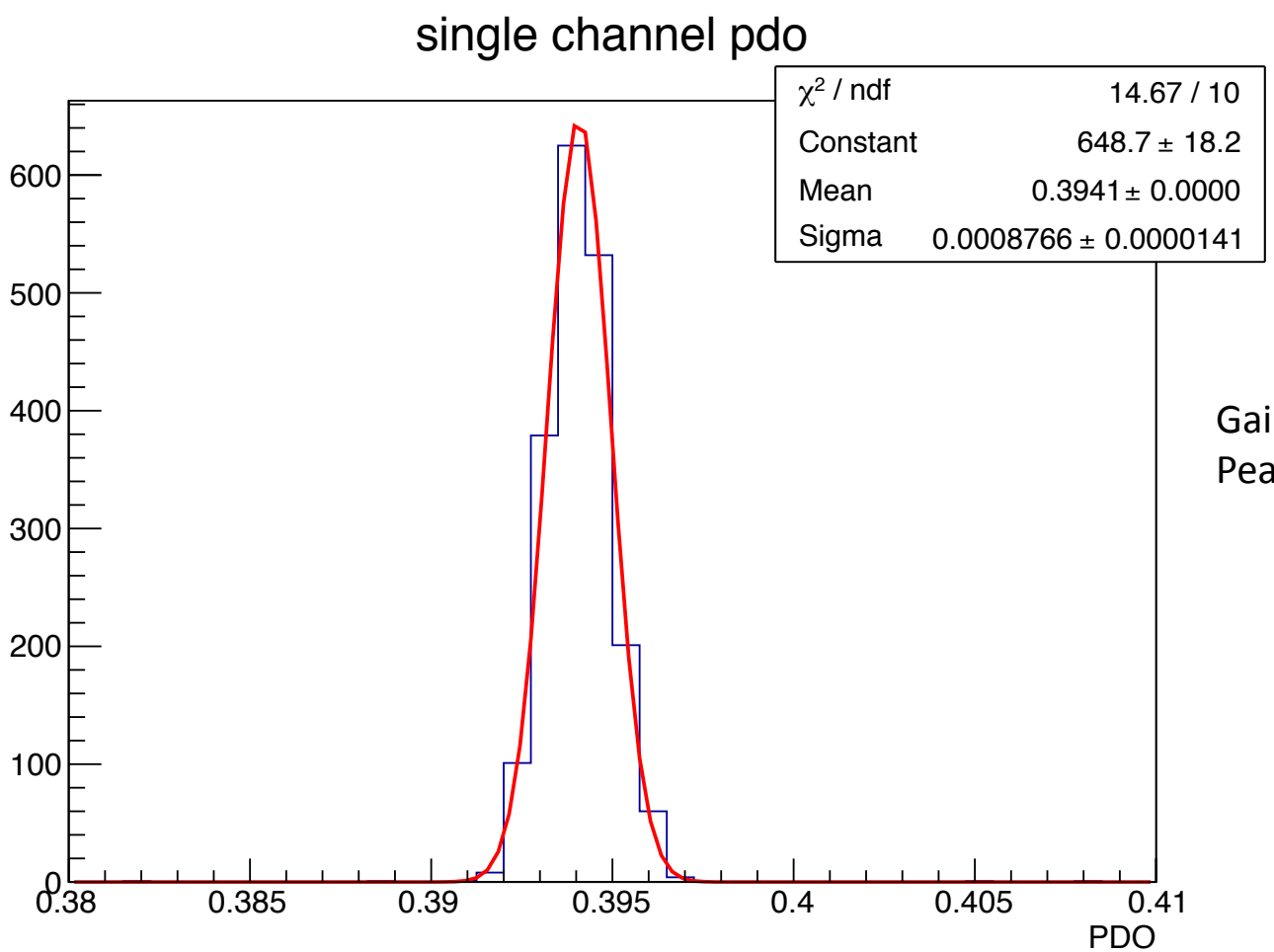
Test Beam Set Up

VMM1 in the test beam



Micromegas

Noise

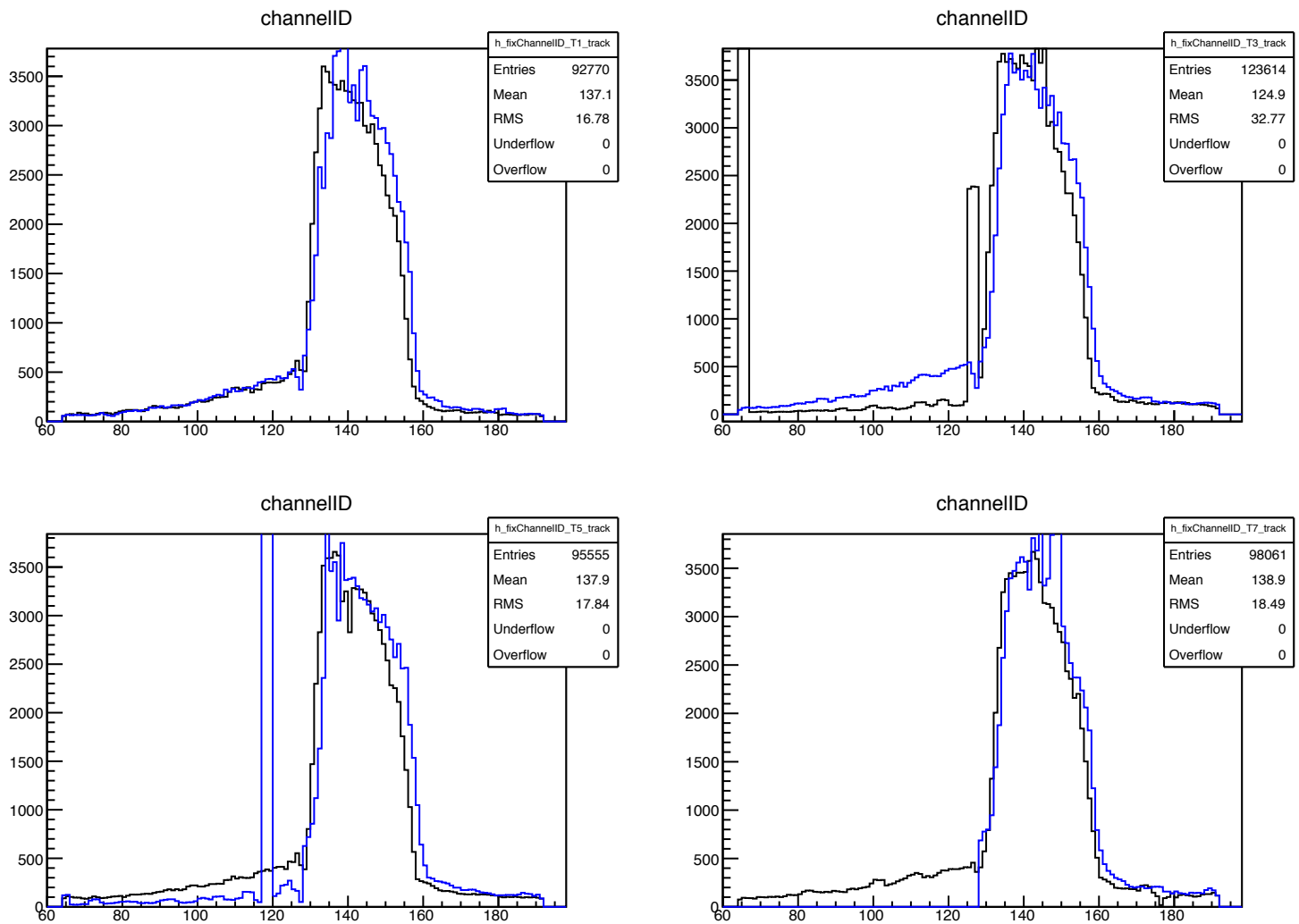


Gain = 3 mV/fC
Peak time = 50 ns

Check: Amplitude using a test pulse for a single channel while connected to Micromegas
Noise = 0.8766 mV => 2740 electrons

Beam Profile

Beam Profile/Alignment

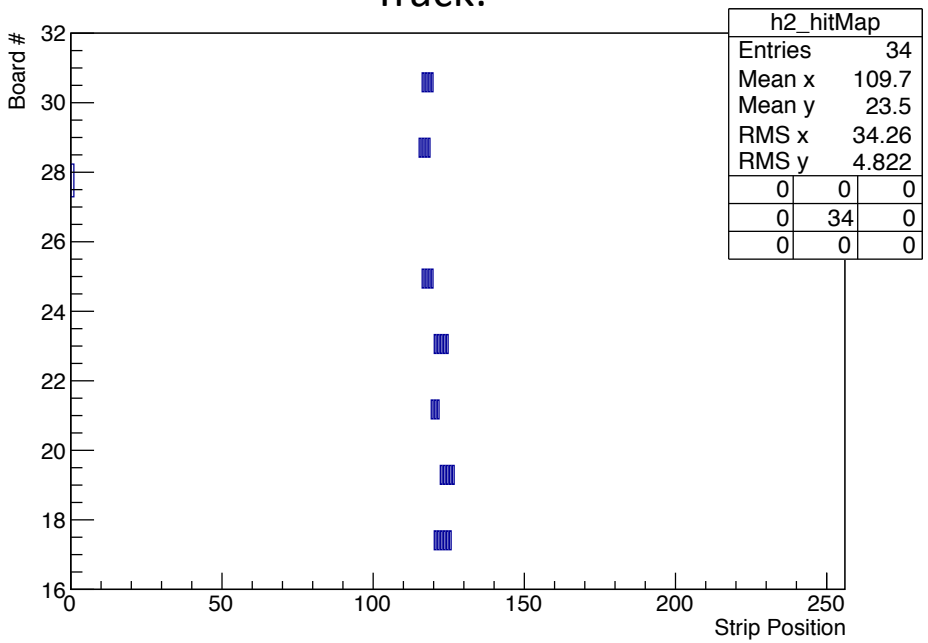


Events

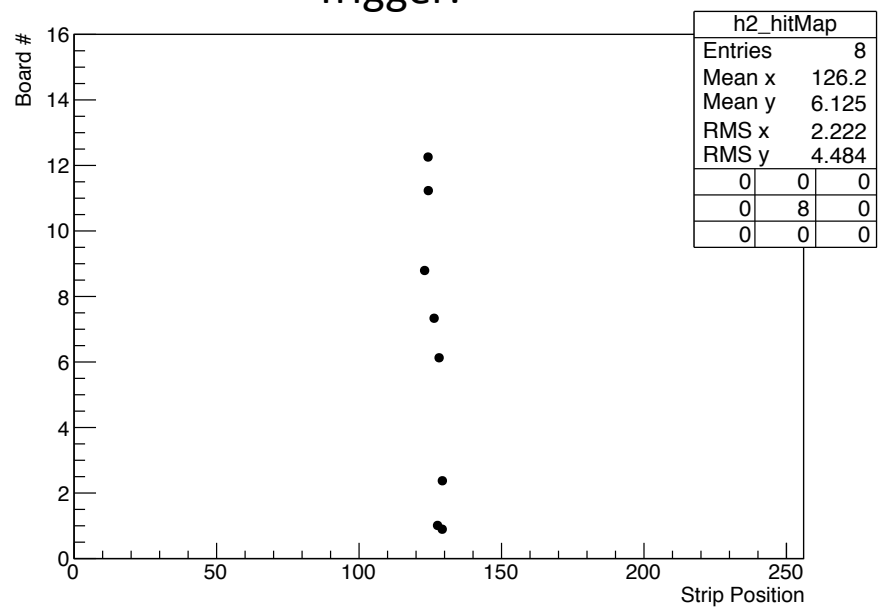
Individual Event:

- alignment still needs to be done

Track:

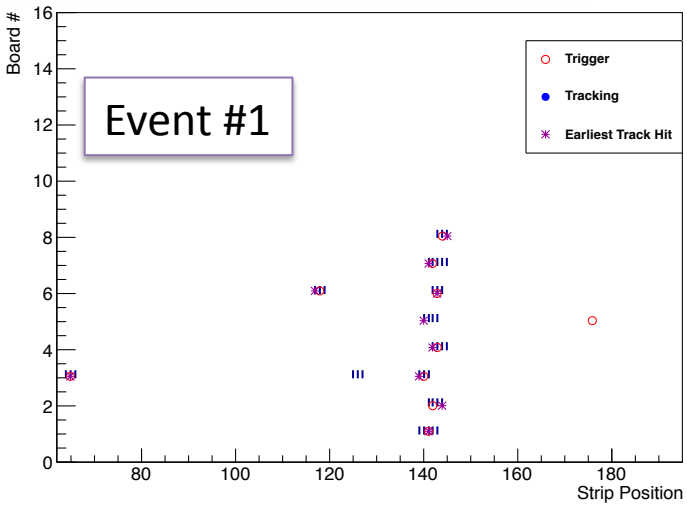


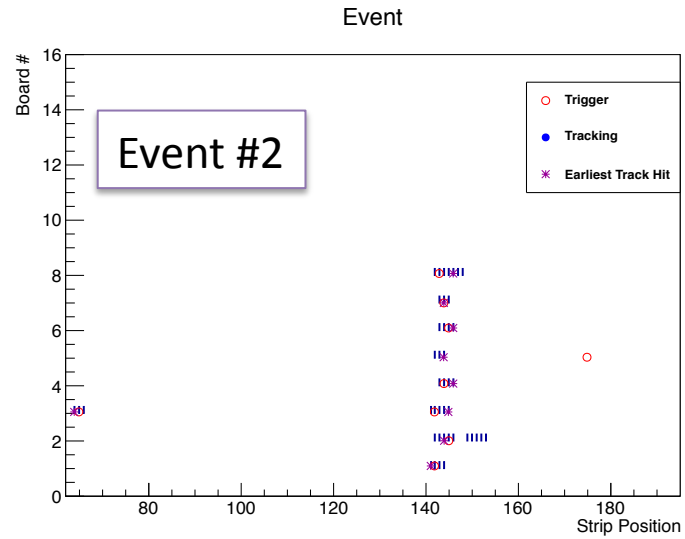
Trigger:

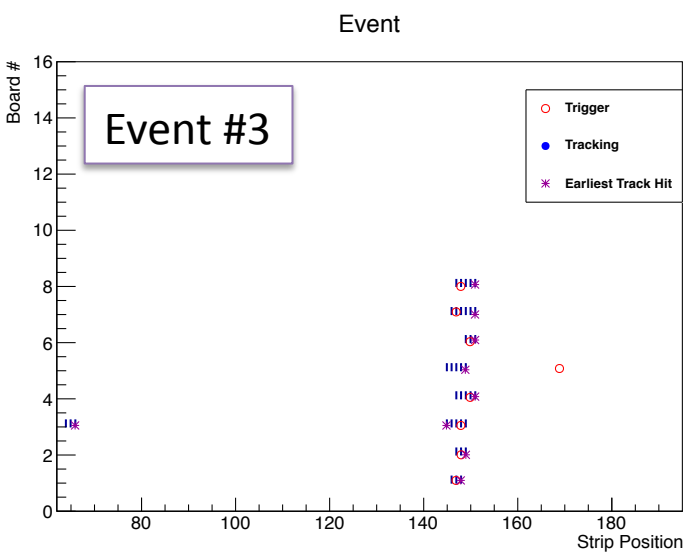


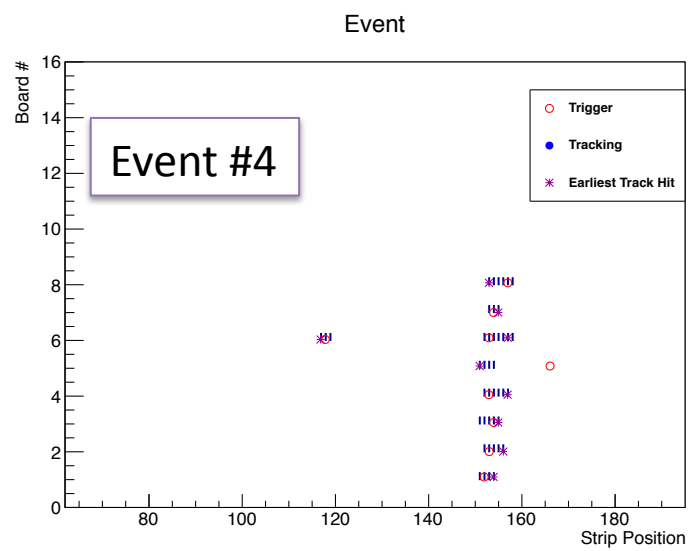
Track and Trigger Synchronization

Track and trigger combined:



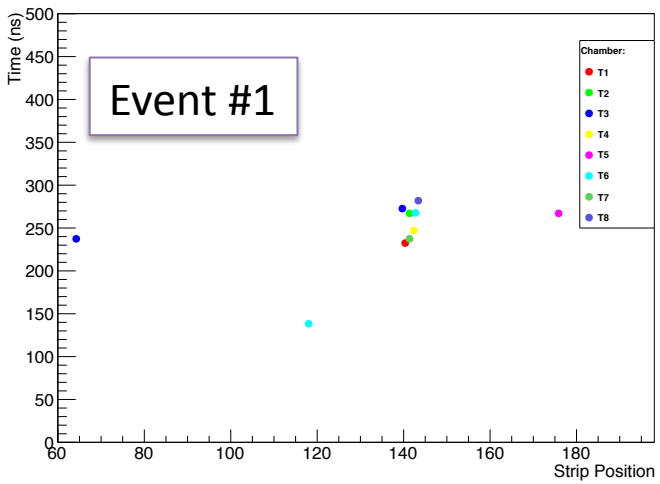


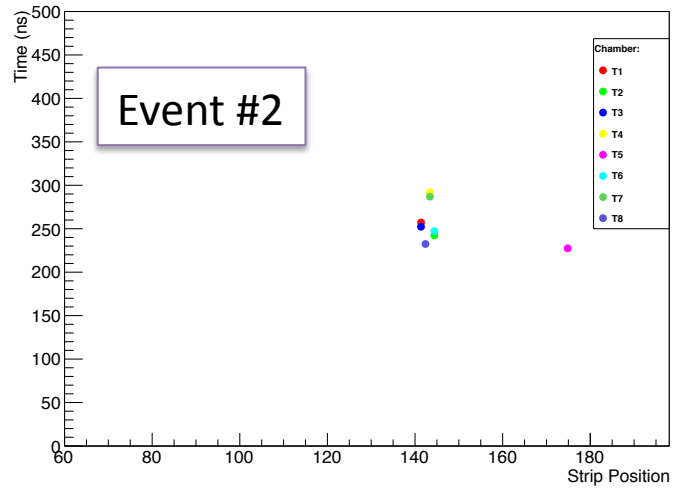


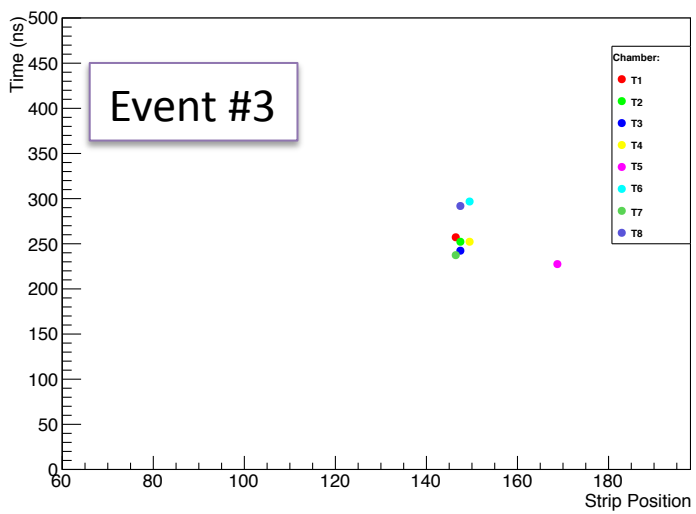


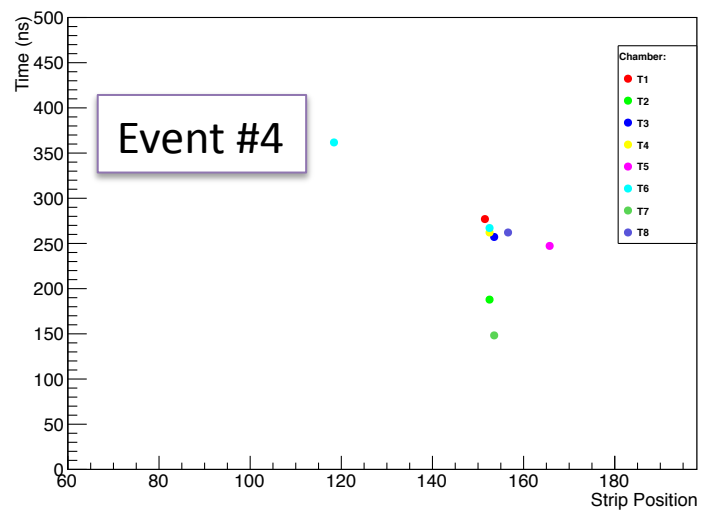
Timing

Timing Clusters ~100 ns



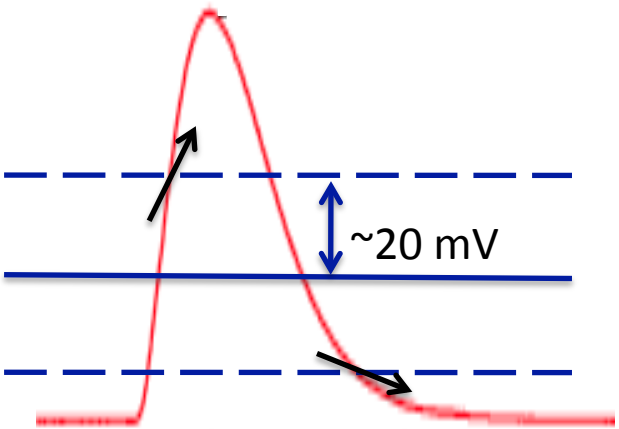




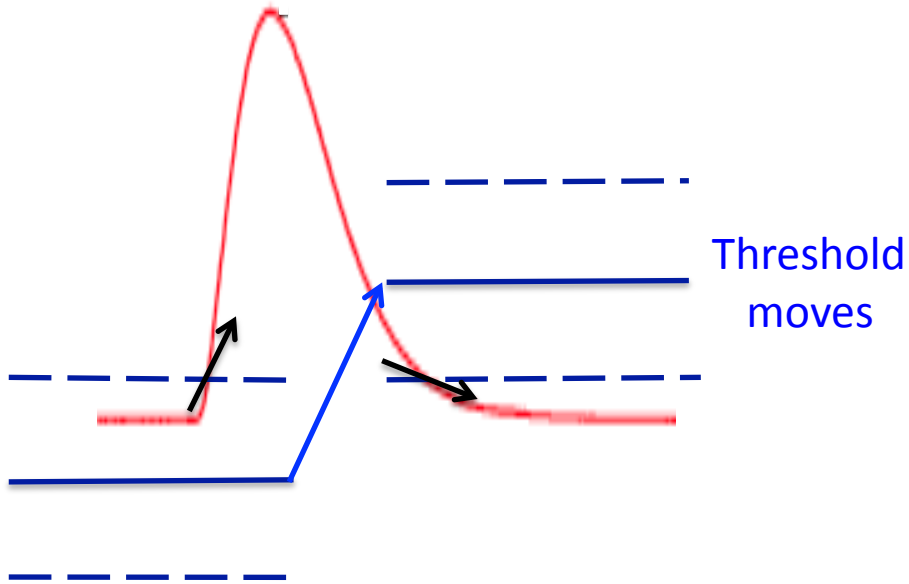


VMM1 Threshold

Sub-Hysteresis Off



Sub-Hysteresis On

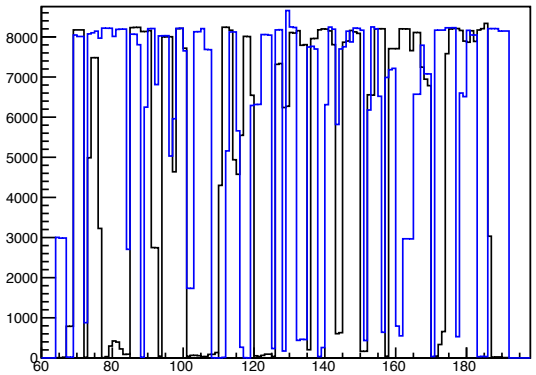


Sub-hysteresis: threshold range moves to catch rising and falling edges -> allows the threshold to be set to lower effective values (possibly as low as a few mV)

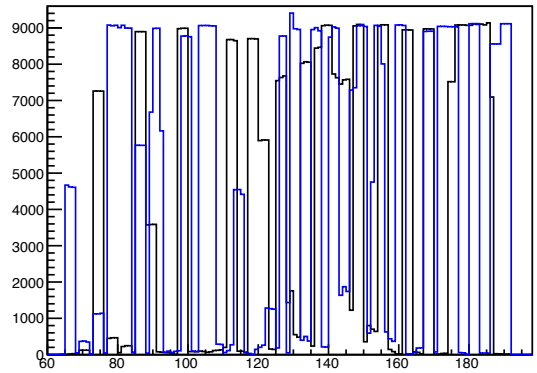
Threshold Scans

Beam Profiles

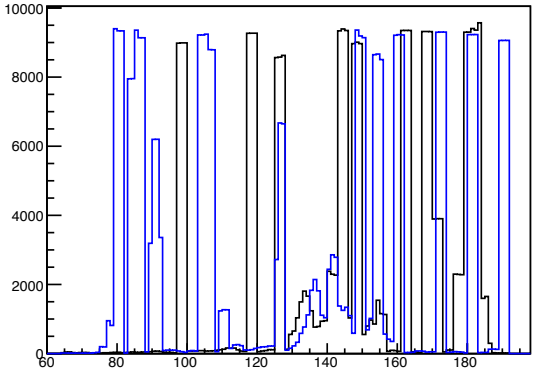
TDAC = 160



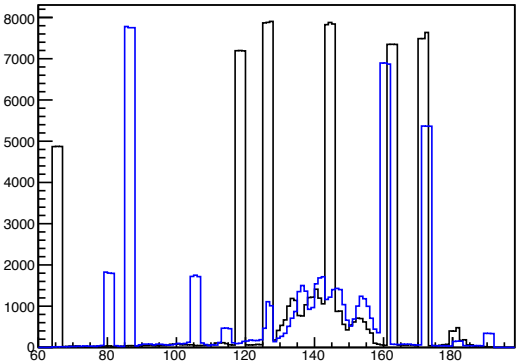
TDAC = 170



TDAC = 180



TDAC = 190



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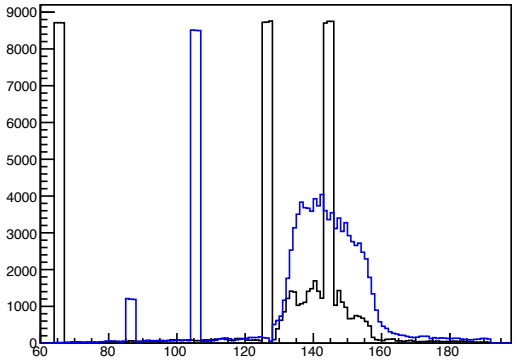

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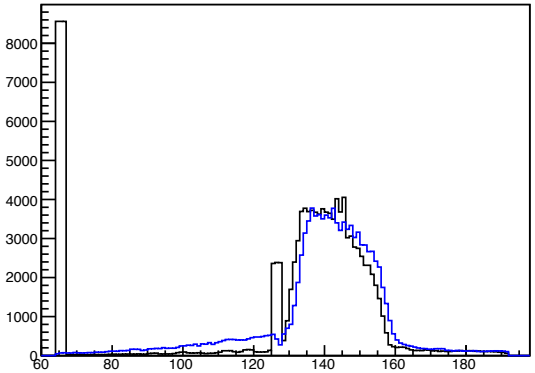
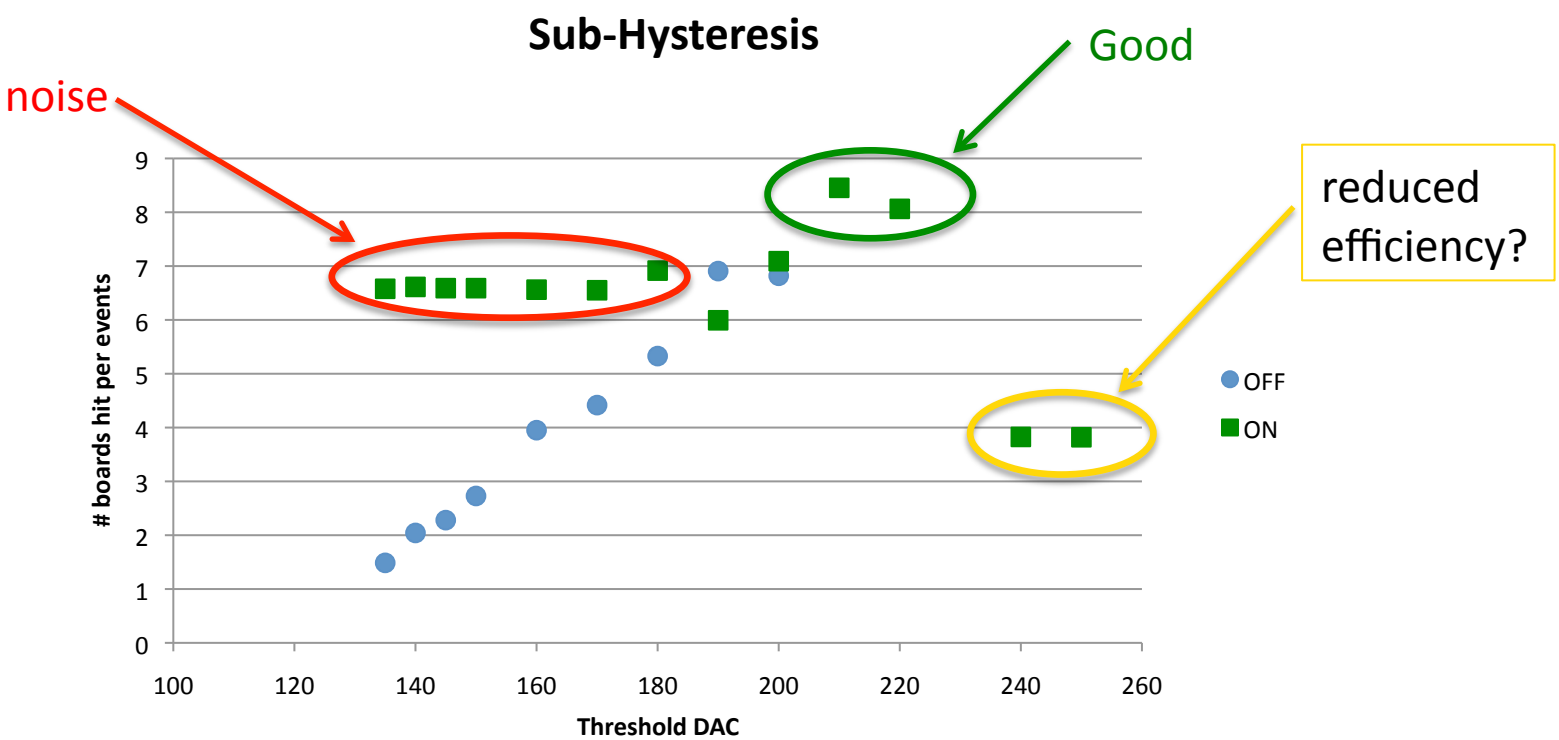


Sub-hysteresis ON

Threshold Scans

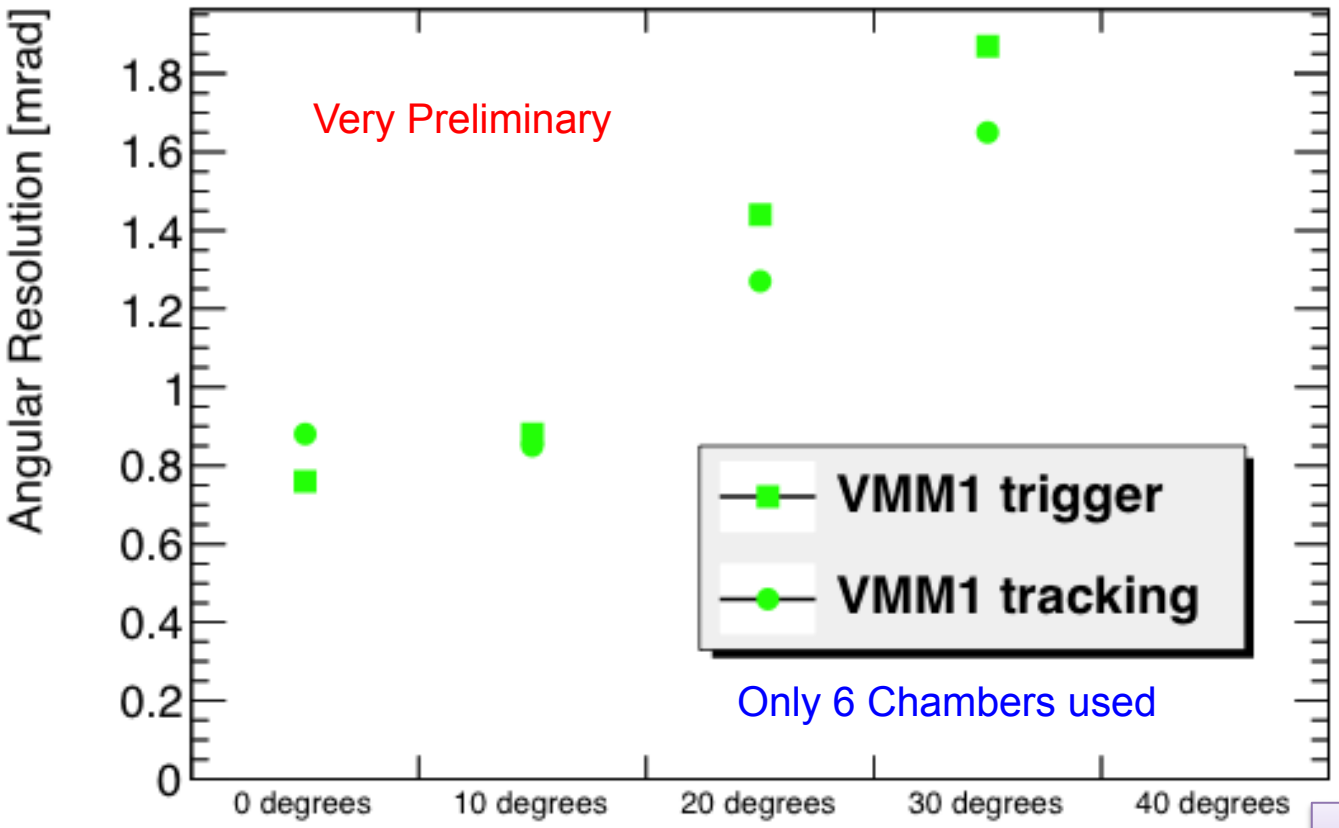
Threshold Scans

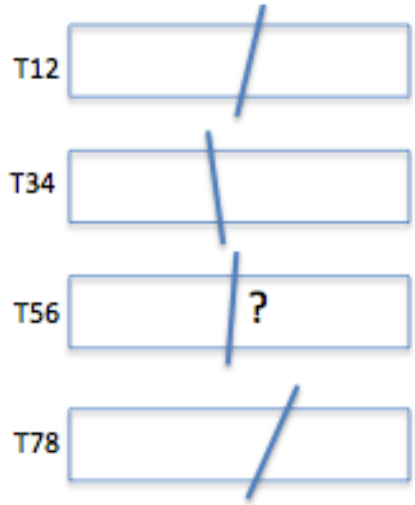
- Effect of Varying the Threshold and Sub-hysteresis Enable
- Work in progress!!



Angular Resolution

Angular Resolution
- fit track angles by chamber
- encouraging preliminary angular resolution





Theo Alexopoulos, et. al.

Summary

Very promising initial results!

- low noise
- start to understand the dynamic range of VMM1
    - gain/peaking time
    - threshold
- verification of trigger concept
- un-calibrated angular resolution < 2 mRad
- identify criteria for next VMM design
    - increase threshold trim
    - mode to measure baseline
    - digitization on chip

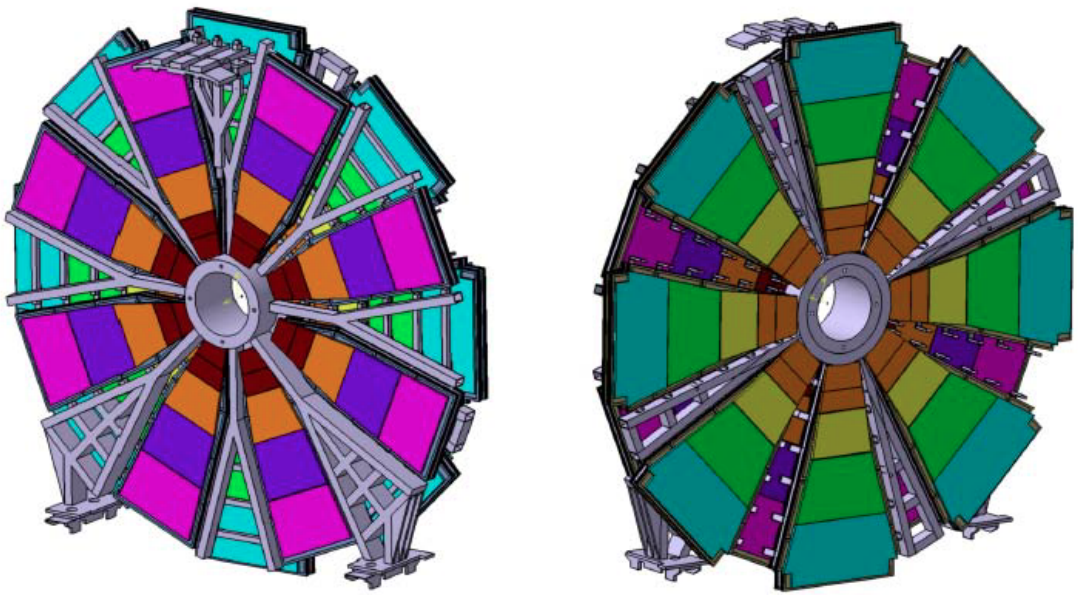
Next Plans:

- Calibrations--of thresholds, TAC slopes, gain (pdo and baseline)
- Alignment
- Timing resolution
- Next test beam in late October
- SEU tests

Back Up

Back Up

NSW Design



Equip the Small Wheels with micromegas detectors (0.5–2.5 m^2)

- Combine precision and 2nd coord. measurement as well as trigger functionality in a single device
- Each detector comprises eight active layers, arranged in two multilayers
- Each layer comprises two coordinates with 0.5 and 1.5 mm strip pitch
  - ⇒ 2M readout channels
  - ⇒ a total of about 1200 m^2 of detection layers

Micromegas

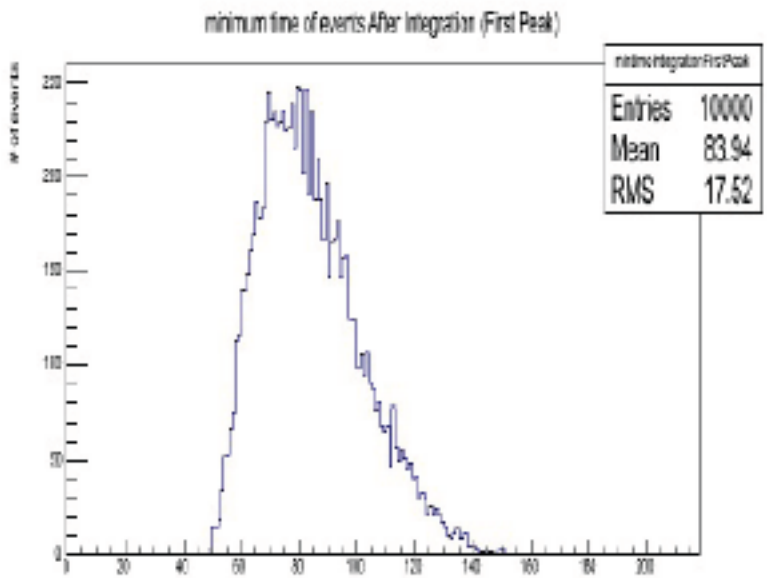
T. Kawamoto

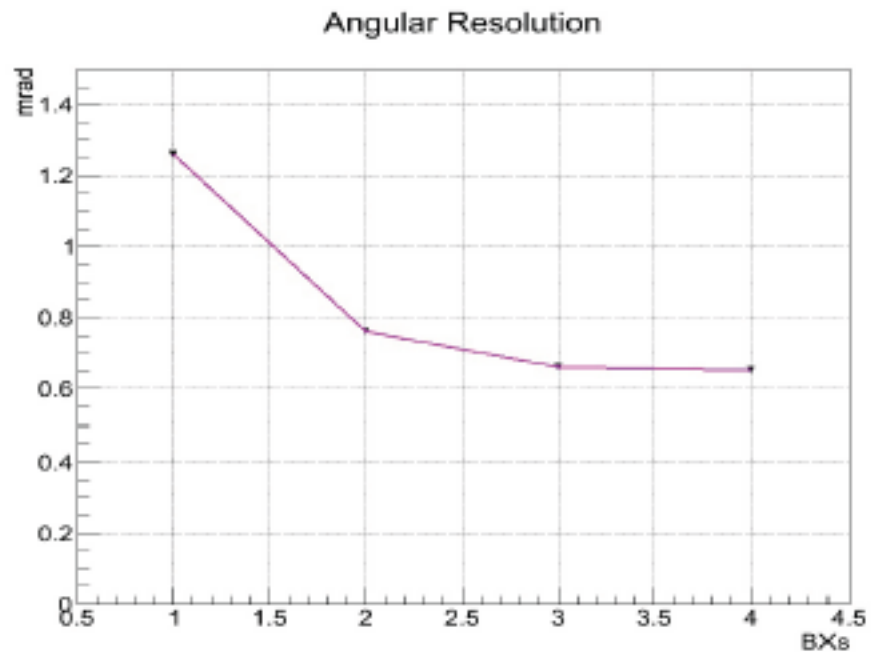
Detector performance

- Works at high rate up to14kHz/cm^2
- 3000 fb^{-1} → 1C/cm^2 of integrated charge
- Space resolution 80-100 μm/point
- 40 μm alignment accuracy
- 1mrad online angle resolution for trigger
- BCID
- Compatibility with phase-1 and phase-2

- The proposed detectors (sTGC and MM) have potential to satisfy these
- The proposed layout 4+4+4+4 layers of T-M-M-T will provide high redundancy good(or essential) for
  - efficient tracking/trigger and
  - long term running with limited access to detectors.

Angular Resolution





- Due to charge collection/electronics integration time need to collect signals over multiple bunch crossings (BX) for best angular resolution.

TGC Concept

TGC design

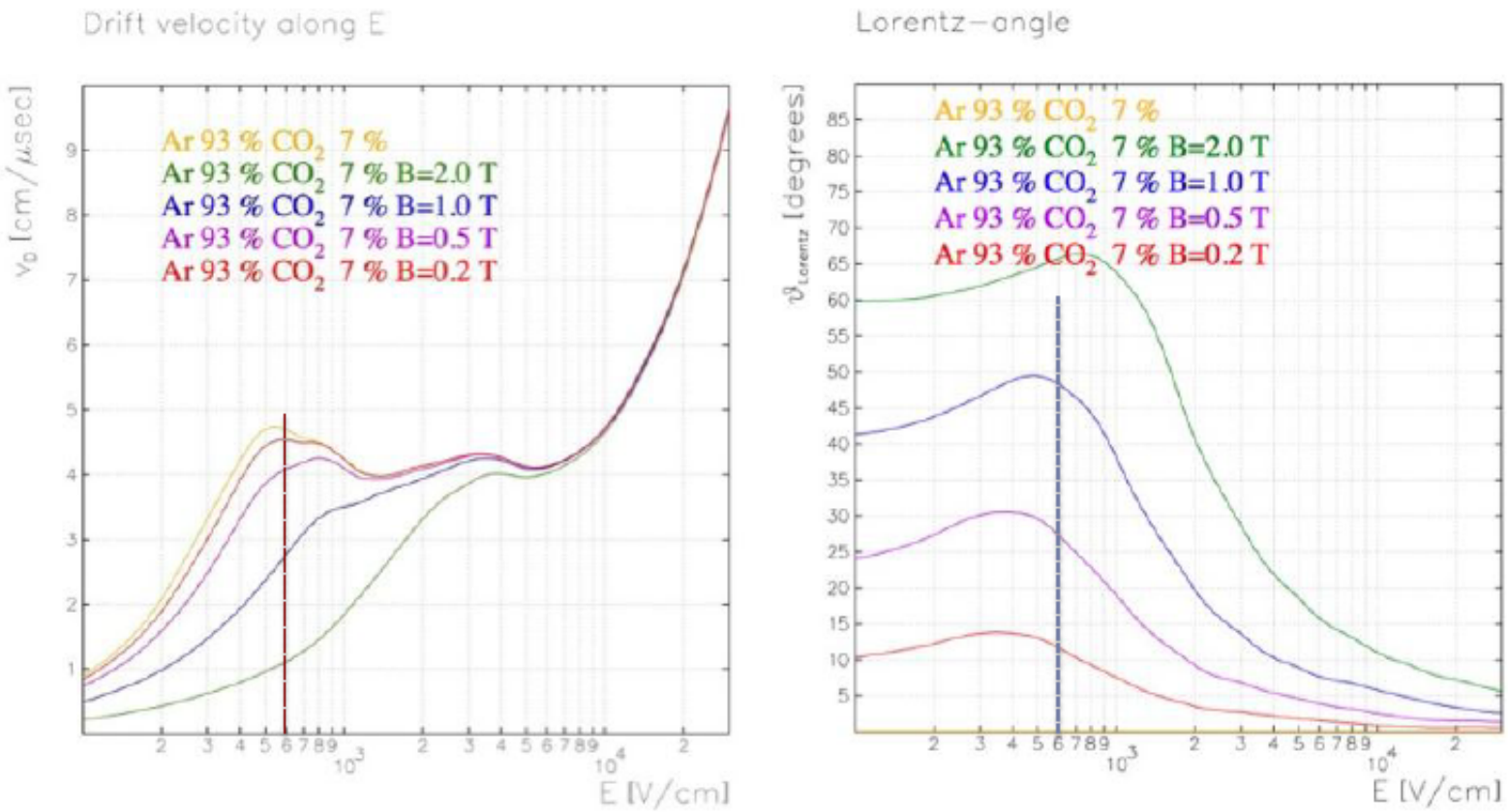
VMM1

Latency(nsec)

Muon TOF	25 nsec
Detector Response (drift time+ peaking time)	50-100
SerDes*	40 -70
To USA15 (90 m fiber)*	495
GBTx Latency	170
Software micro-ROI (4x4x2 – 4x4-5 ns)	32-80
Difference of strip addresses*	5-10
Calculate slope*	5
To Sector Logic serializer*	5-10
Total	827 – 965

* Similar operations, estimate taken from sTGC concept

Garfield simulation



- Maximum ***B*** field in SW ~0.5T
- Maximum Lorentz angle ~30° (depends on the drift field)

Micromegas

Micromegas