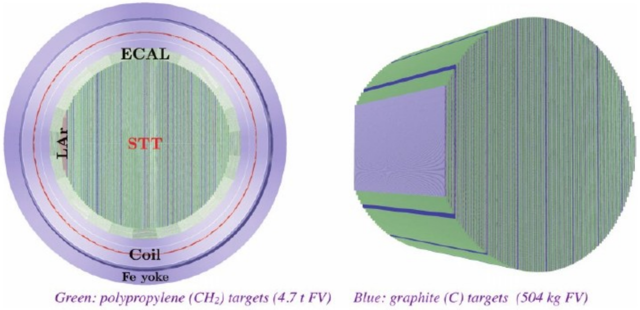
# TIGER ASIC as a candidate front-end electronics solution for future Straw Trackers

Speaker: V. Bautin
on behalf of Straw Tracker team

30.10.2023

# Motivation

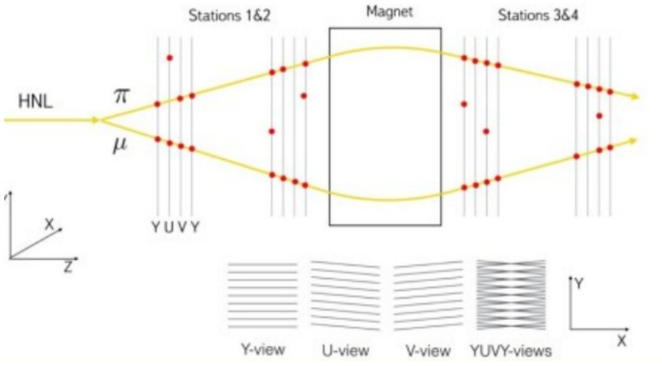
## Straw Tube Tracker (STT)




Beam monitoring (with ECAL) and neutrino flux measurements

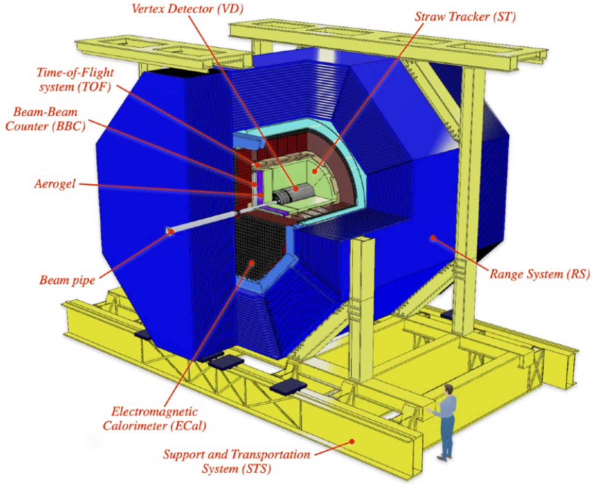
**200k** straws in total

## Spectrometer Straw Tracker (SST)




Tracking and vertex reconstruction for HiddenSector Detector
**20k** channels

## Straw Tracker (ST)

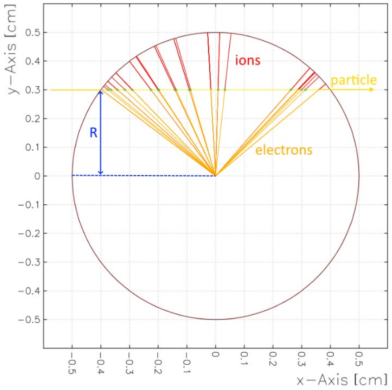


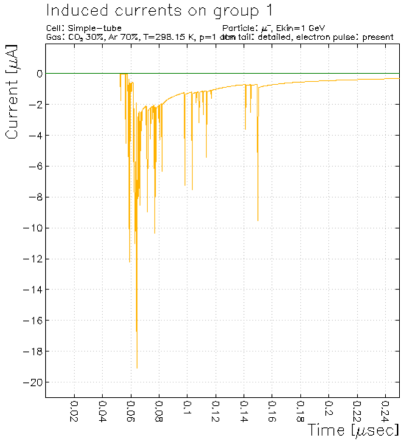

Tracking and PID
**30k** channels

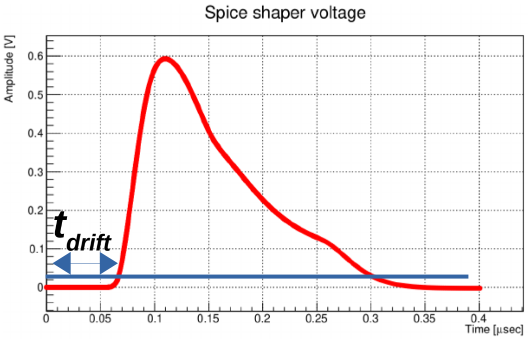
# Straw tubes – operation principle

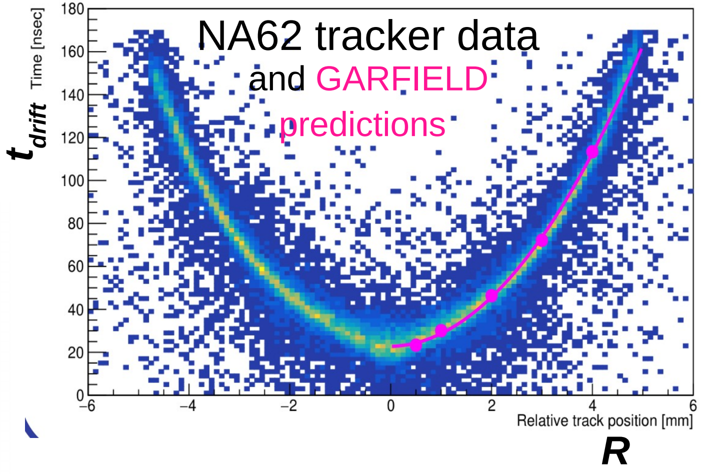
- thin wall drift tube of small (O(cm)) diameter
- proportional mode
- drift time of ~first (or ~second) closest to anode electrons represents quite well the distance between the track of the ionizing particle ***R*** and anode wire

The drift time $t_{drift}$ is measured as the difference between time $t_0$ when an ionizing particle crossed the straw and the time when the induced straw signal exceeded a given threshold.



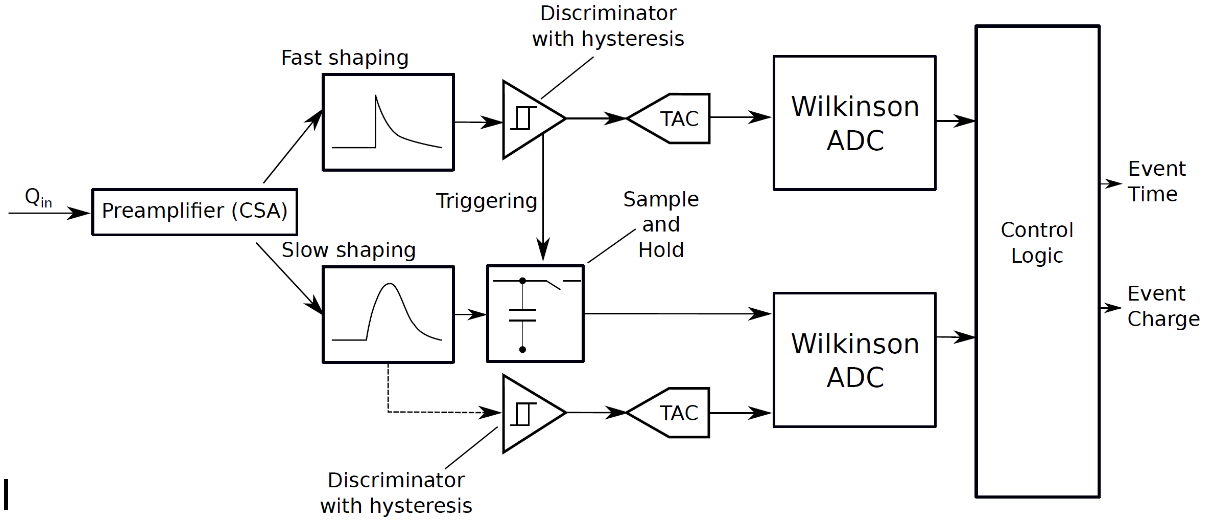



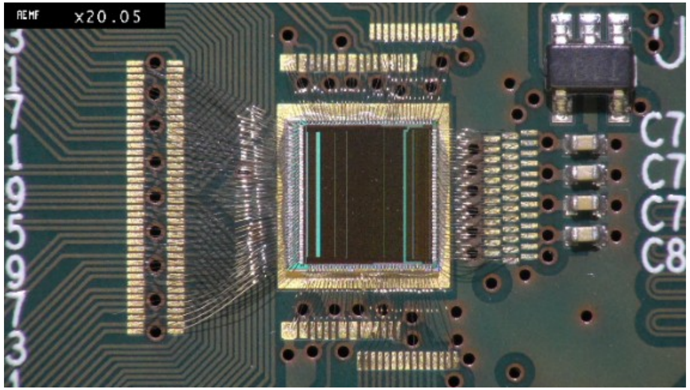

**GARFIELD + LTSpice allows to predict straw response for a given readout model.**

# Torino Integrated GEM Electronics Readout



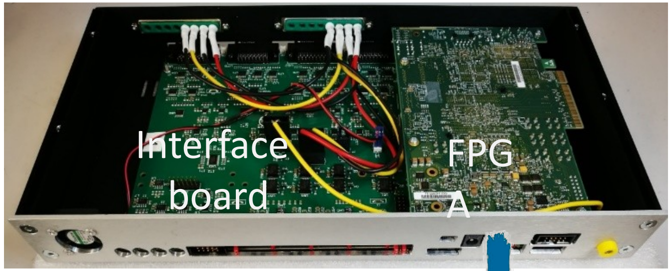

## Chip features:

- 64 channels
- Power consumption < 12 mW/channel
- Sustained event rate 100 kHz
- Input dynamic range up to 50 fC
- Time resolution < 5 ns
- ENC < 2000 e- rms with 100 pF input capacitance
- Analog read out providing charge and time measurement
- Digital logic  protected from single event upset (SEU)
- Tunable internal test pulse generator
- 110 nm technology




*TIGER: A front-end ASIC for timing and energy measurements with radiation detectors, In: Nucl.Instrum. Meth, A, 924 (2019).*

# GEM ReadOut Cards



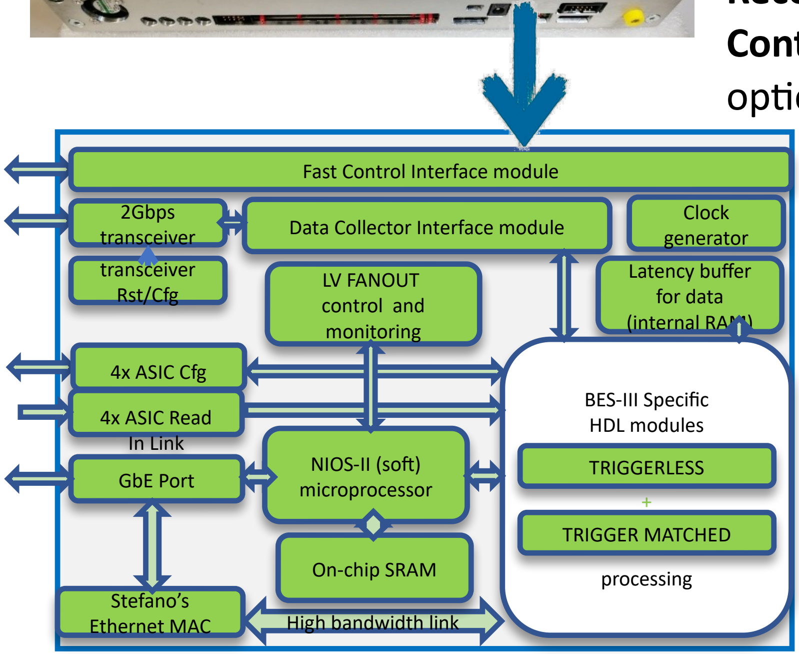

**Power** the FEBs

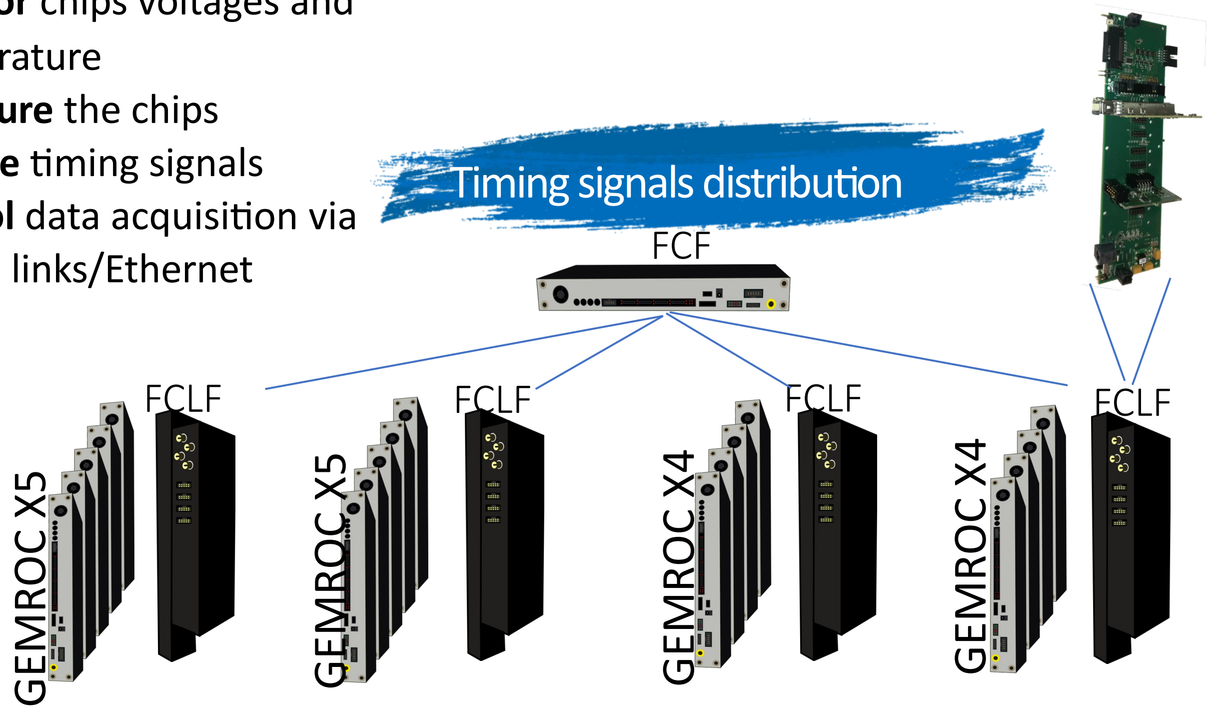
**Monitor** chips voltages and temperature

**Configure** the chips

**Receive** timing signals

**Control** data acquisition via optical links/Ethernet



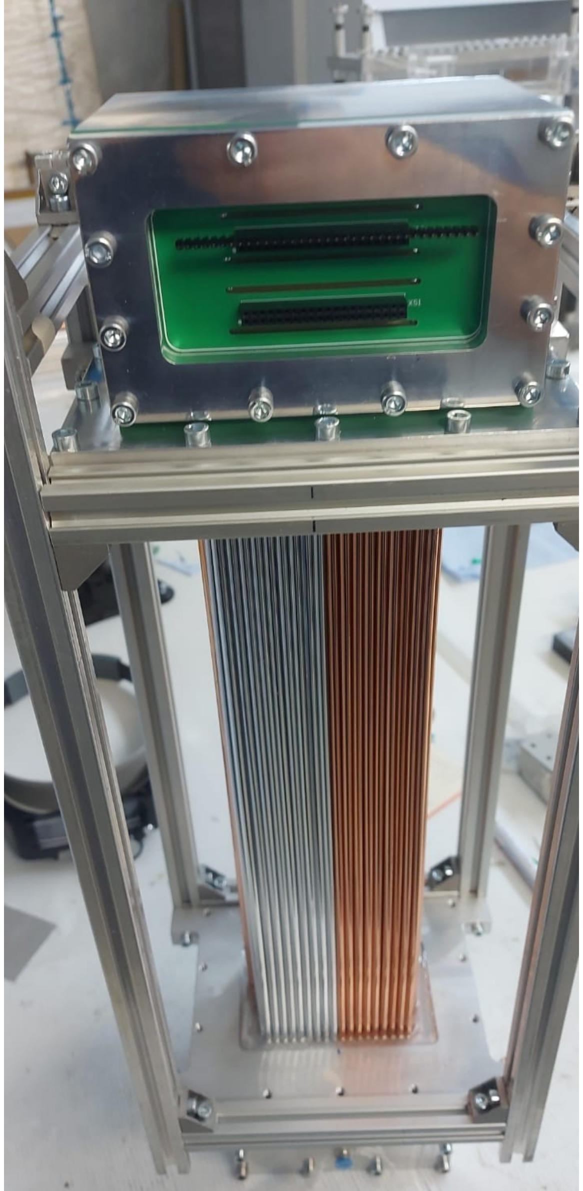




**F**ast **C**ontrol system **F**anout

A modified GEMROC module which connects to the fast control signals (CLK, TRIGGER, TRIGGER_CHK, FULL) from the BESIII FCSF

**F**ast **C**ontrol system **L**ocal **F**anout

A low cost, not programmable, fanout module which distributes the fast control signals between the FCF and a group of GEMROCs



# Straw Prototype

Straw and wire diameters:

20mm / 30um : SHiP type

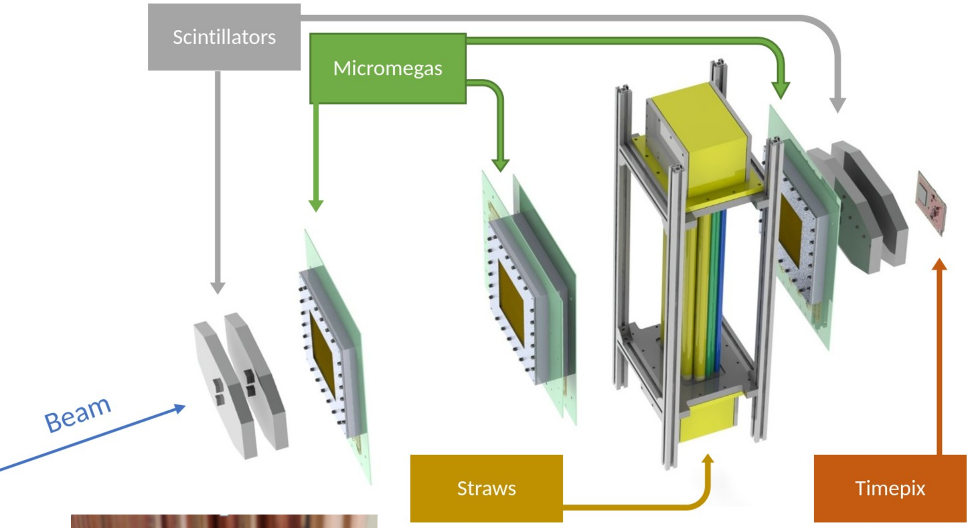
10mm / 30um : SPD type

5mm / 20um :

NA62 upgrade (Cu/Au coating)

DUNE (Al metallisation)

# The Setup

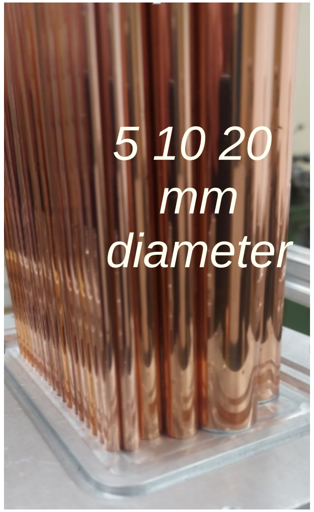


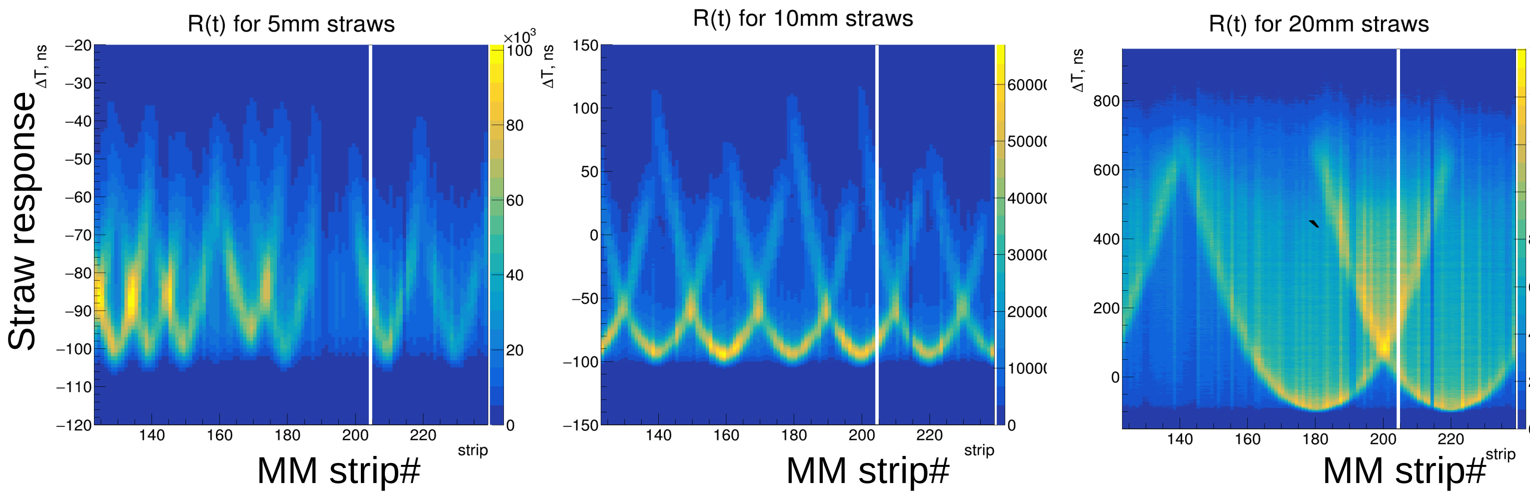

**Reference tracking:**

- MM detectors (250 um) + Tiger readout (Torino University)
- Timepix4 – 50um x 50um

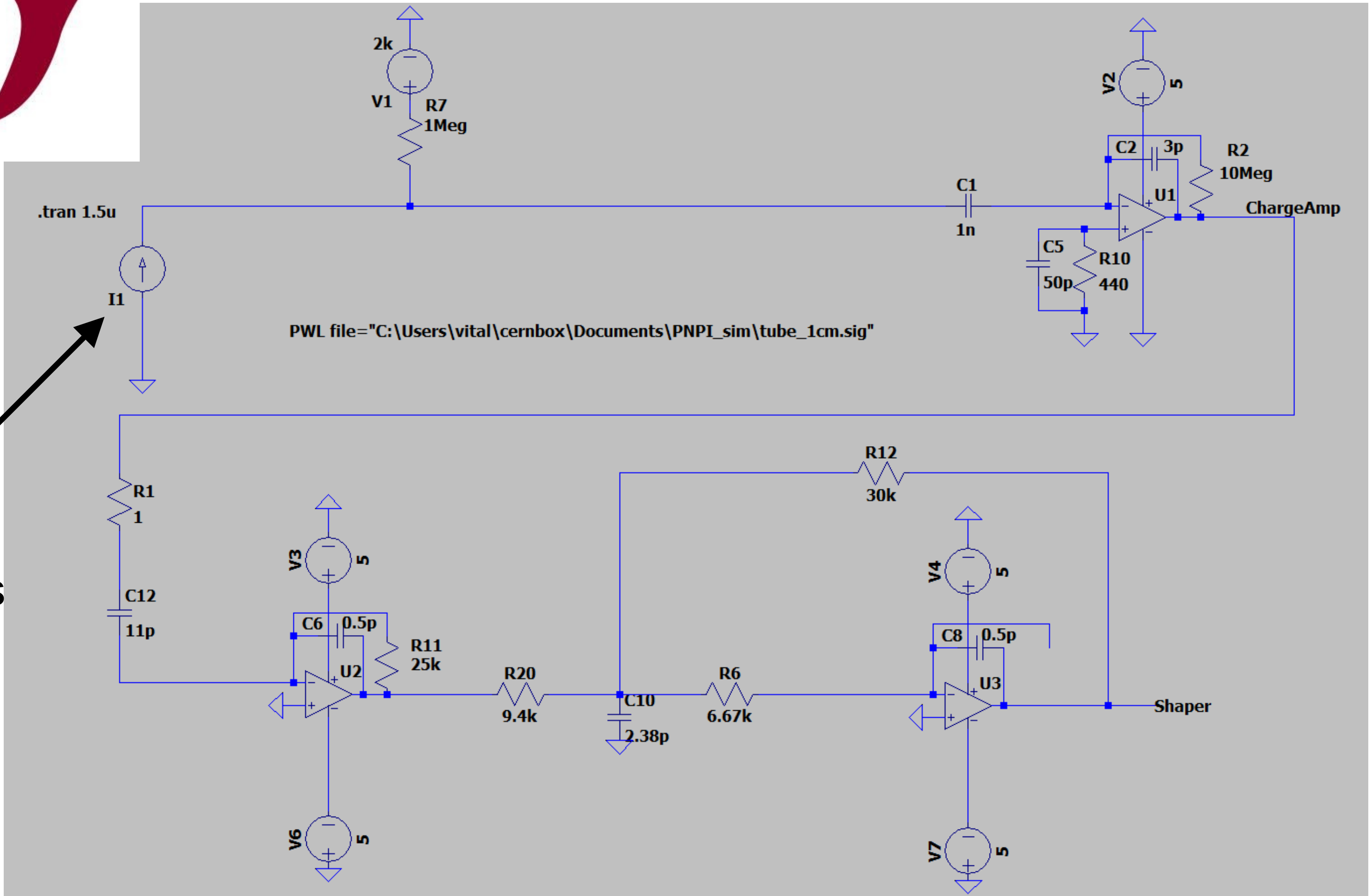
**Under the test: a combined straw tracker prototype with the Tiger readout**

Good data taking with MM+straw and success in integrating the Timepix4



# TIGER + Straw Model




Straw Tube is represented as a current source

# Piecewise Linear (PWL) Function

monitor.py | new 1 | ion-hosted-payload-example-1.py | trackDist_0_1mm_short_TrN_1.sig

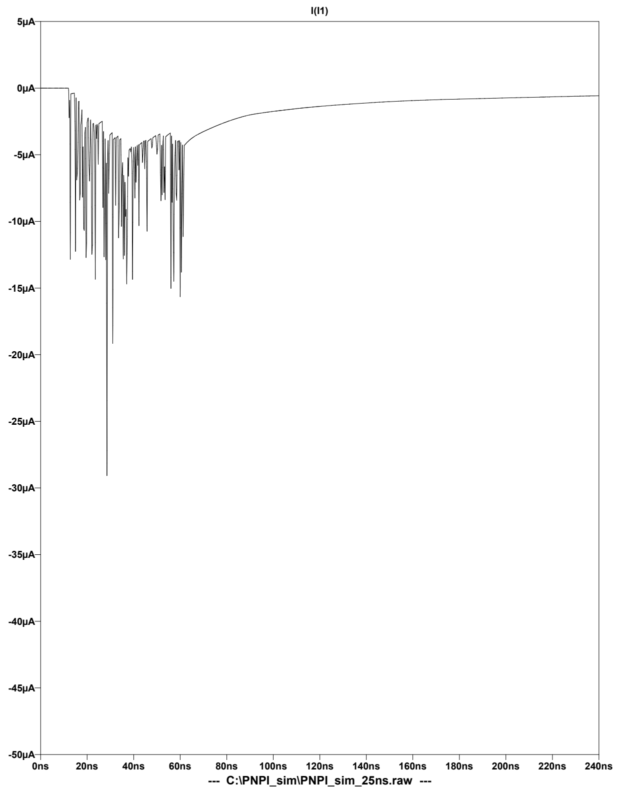
```
0.00000000E+00  -0.13163994E-06
0.25000002E-09  -0.32042186E-06
0.50000004E-09  -0.11047580E-05
0.75000001E-09  -0.47493999E-04
0.10000001E-08  -0.21733147E-04
0.12500001E-08  -0.10063292E-04
0.15000000E-08  -0.14846243E-04
0.17500000E-08  -0.39242454E-05
0.20000002E-08  -0.39040842E-05
0.22500002E-08  -0.16422046E-04
0.25000002E-08  -0.17792334E-04
0.27500002E-08  -0.22766224E-04
0.30000000E-08  -0.16585016E-04
0.32500000E-08  -0.16635986E-04
0.35000001E-08  -0.12319028E-04
0.37500003E-08  -0.64639084E-05
```

ASCII file:

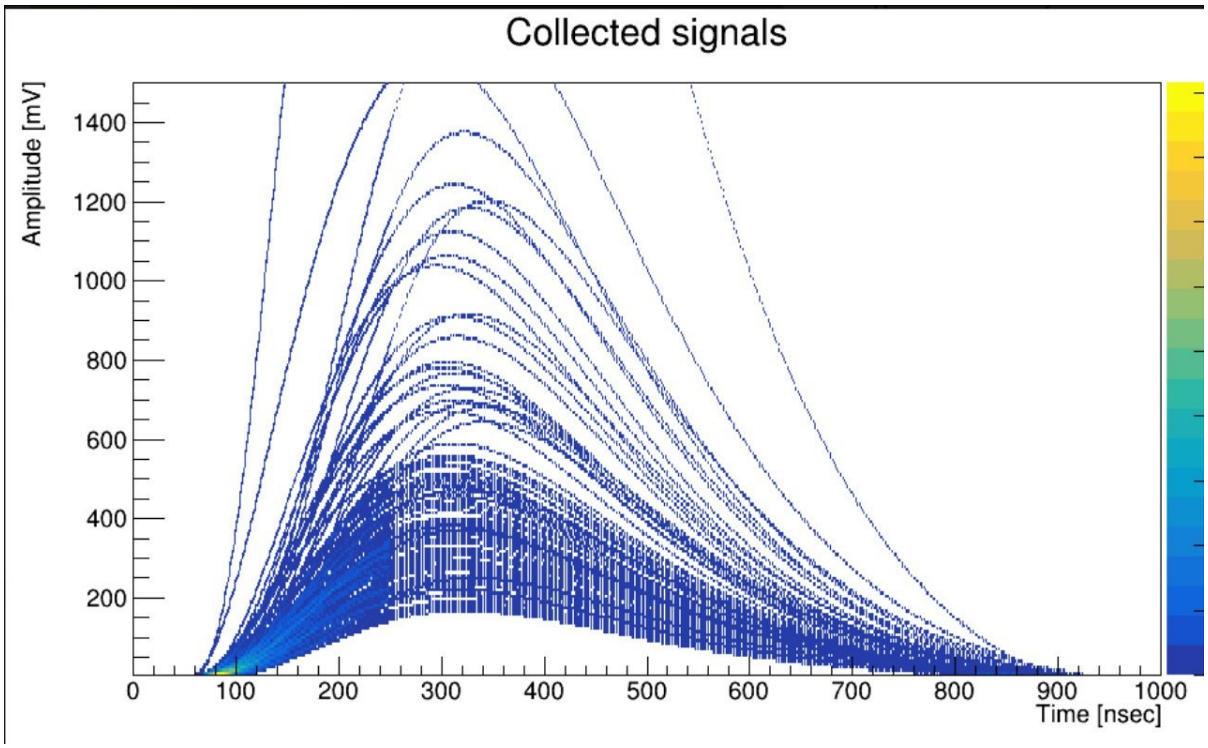
Result of Garfield simulation is provided to the input of LTSpice

LTSpice uses the metric system so in the example above Garfield stores the induced signal in amps vs seconds as in the example above.

# Garfield + LTSpice simulation




Garfield simulated signal from straw tube




LTSpice amplifier & shaper response to the signals provided by Garfield

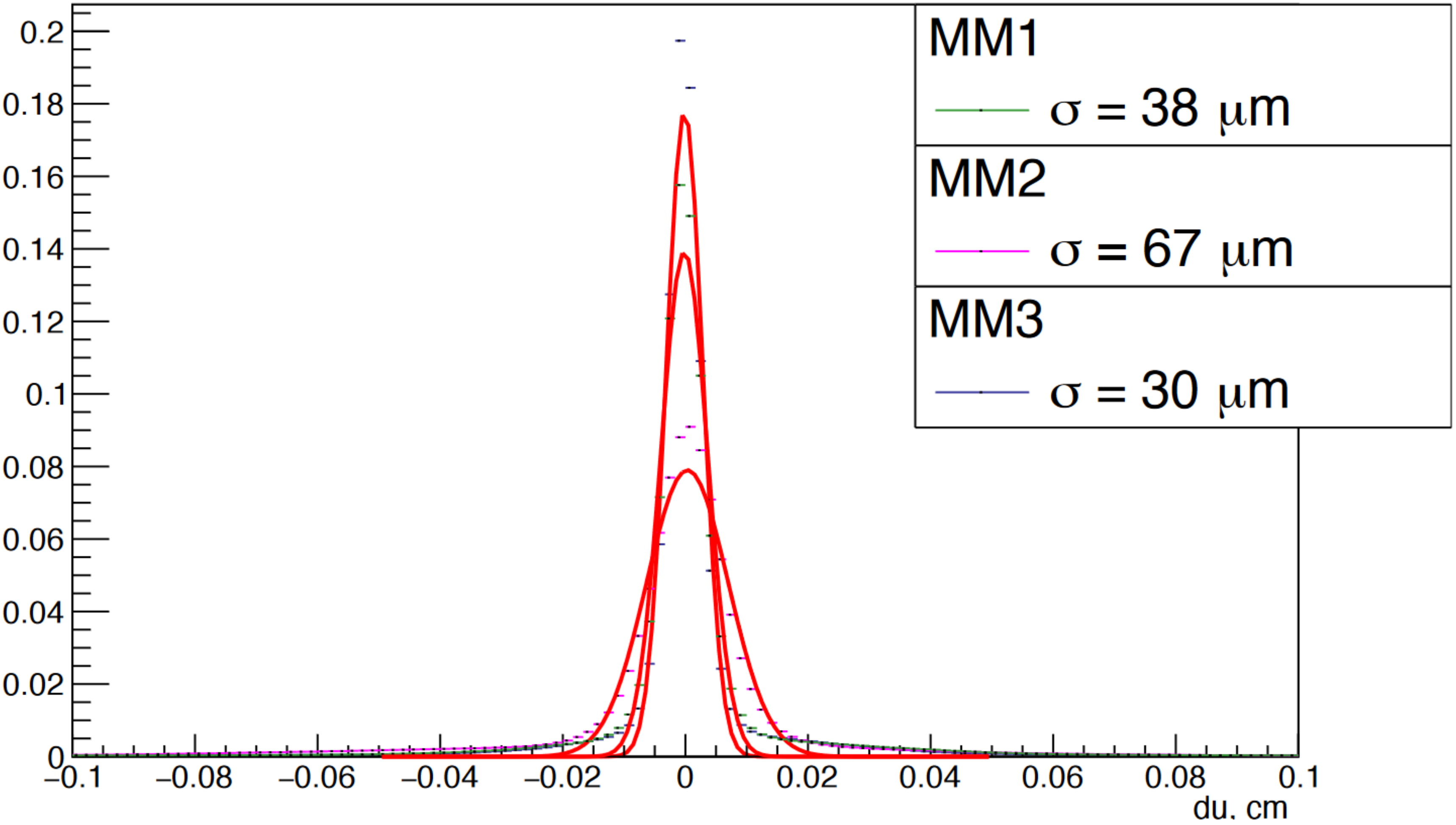
# Data quality and very first results from the Spring TB

- checking the reference tracking (without Timepix at the moment)

- checking T0 performance

- very preliminary resolution analysis

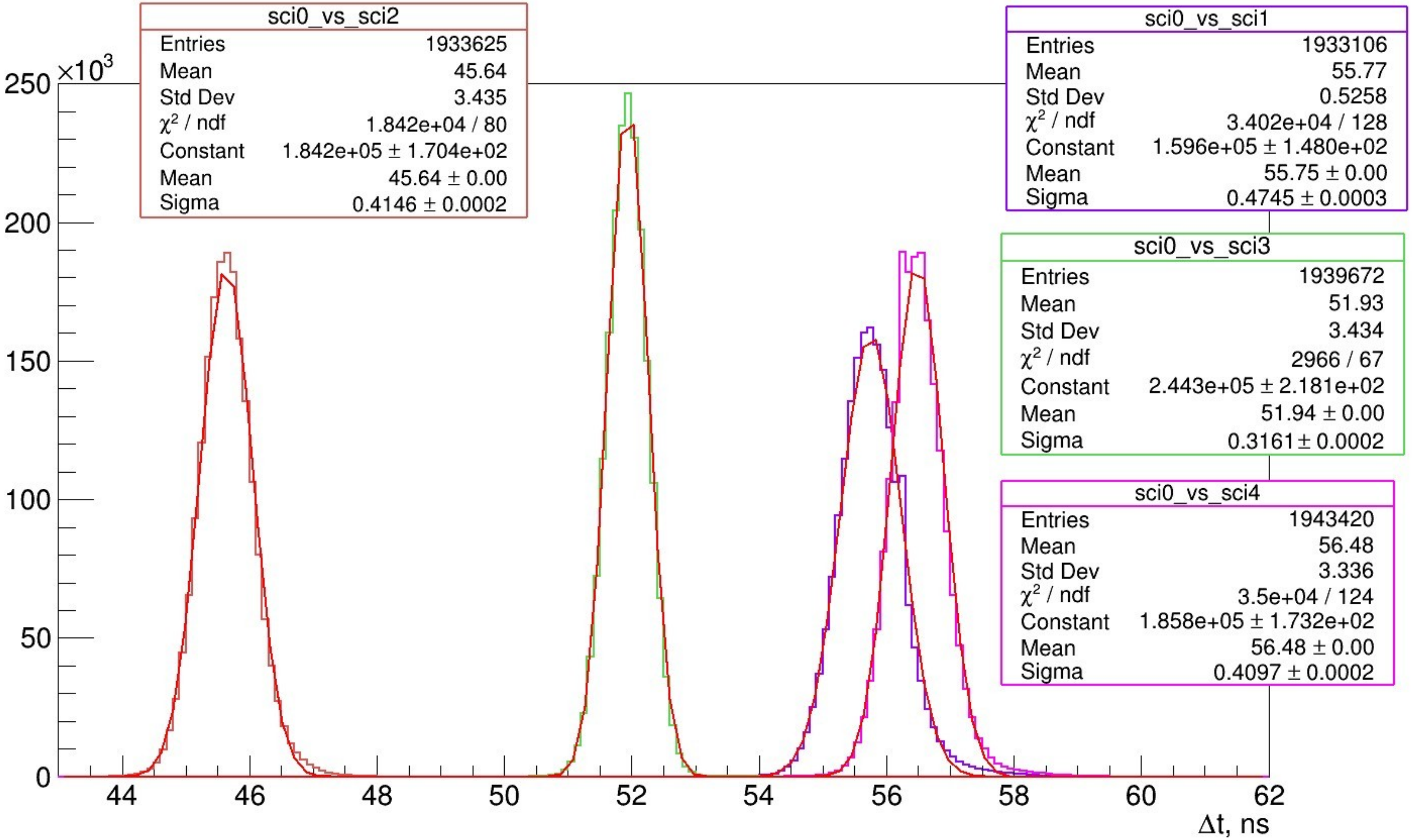
# Reference tracking -- residuals





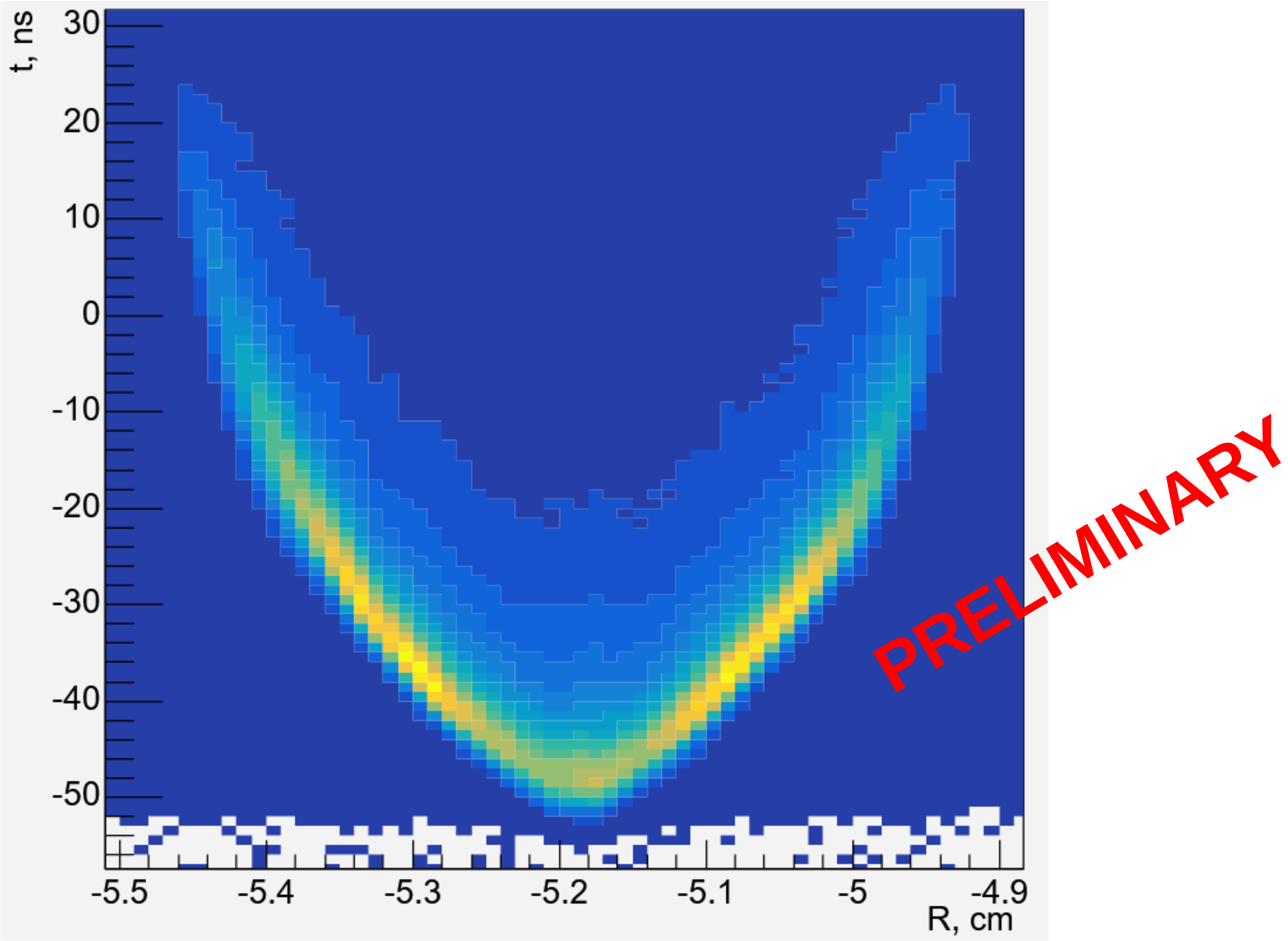

Significant improvement wrt TB22 due to careful MM alignment: maximal sigma of 67um instead of ~100um

# Time resolution -- T0

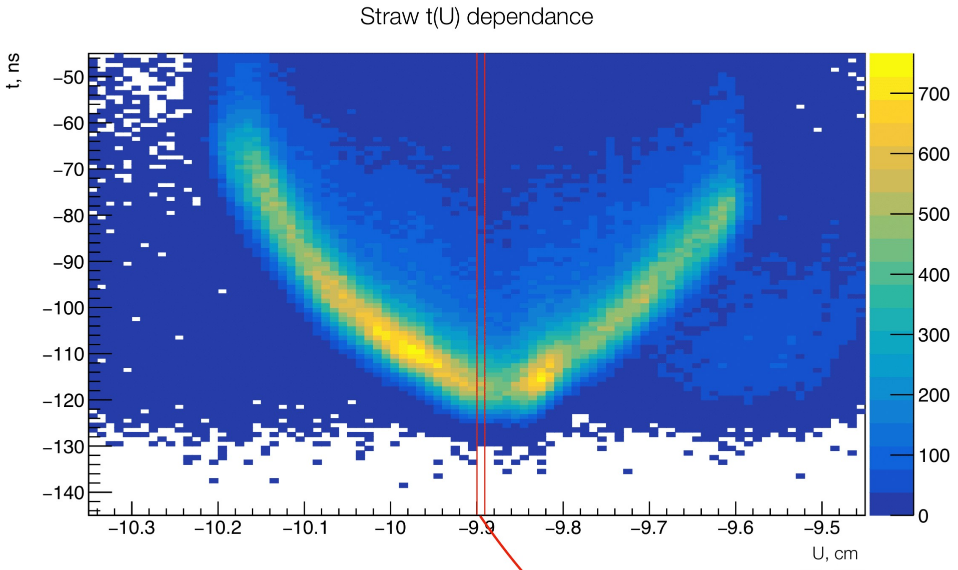



Significant improvement wrt TB22: four scintillators with adjusted thresholds/delays each with sigma ~ 400/1.4 ps wrt ~1ns in 2022

# 5mm Straw V-Shape



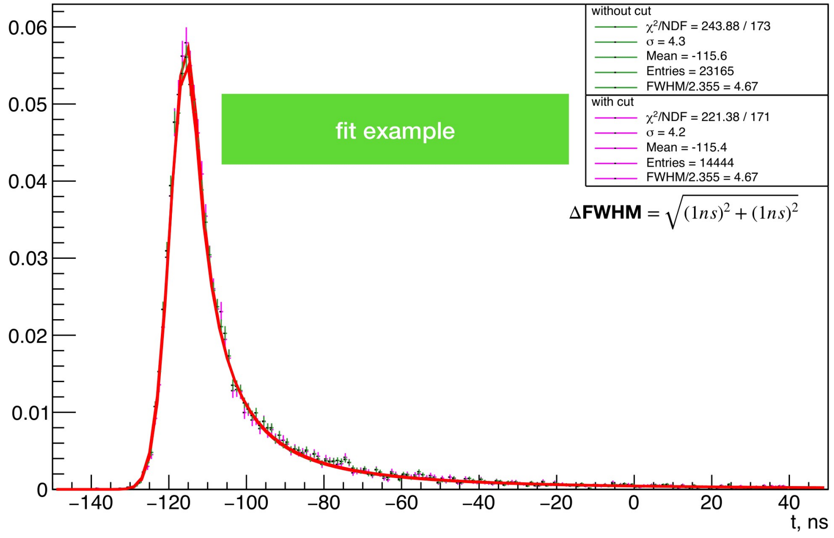
# Coordinate resolution as a function of Time resolution



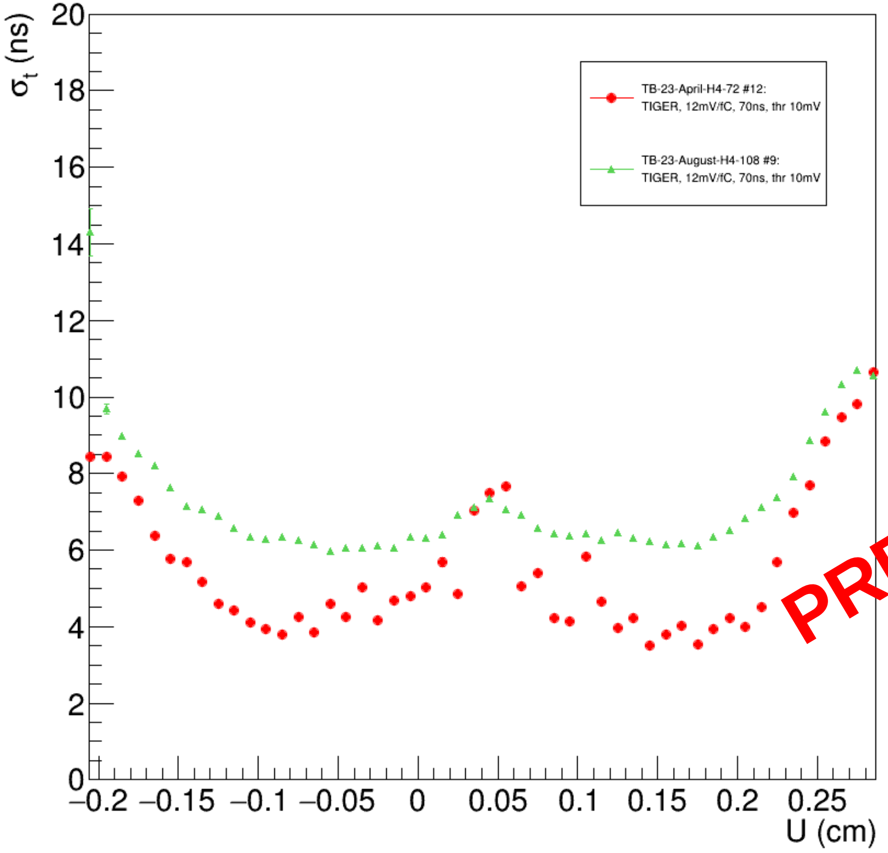

$\sigma_T$ from the fit associated with Time resolution. The Idea is to obtain the **Spatial** resolution from the **Time** resolution

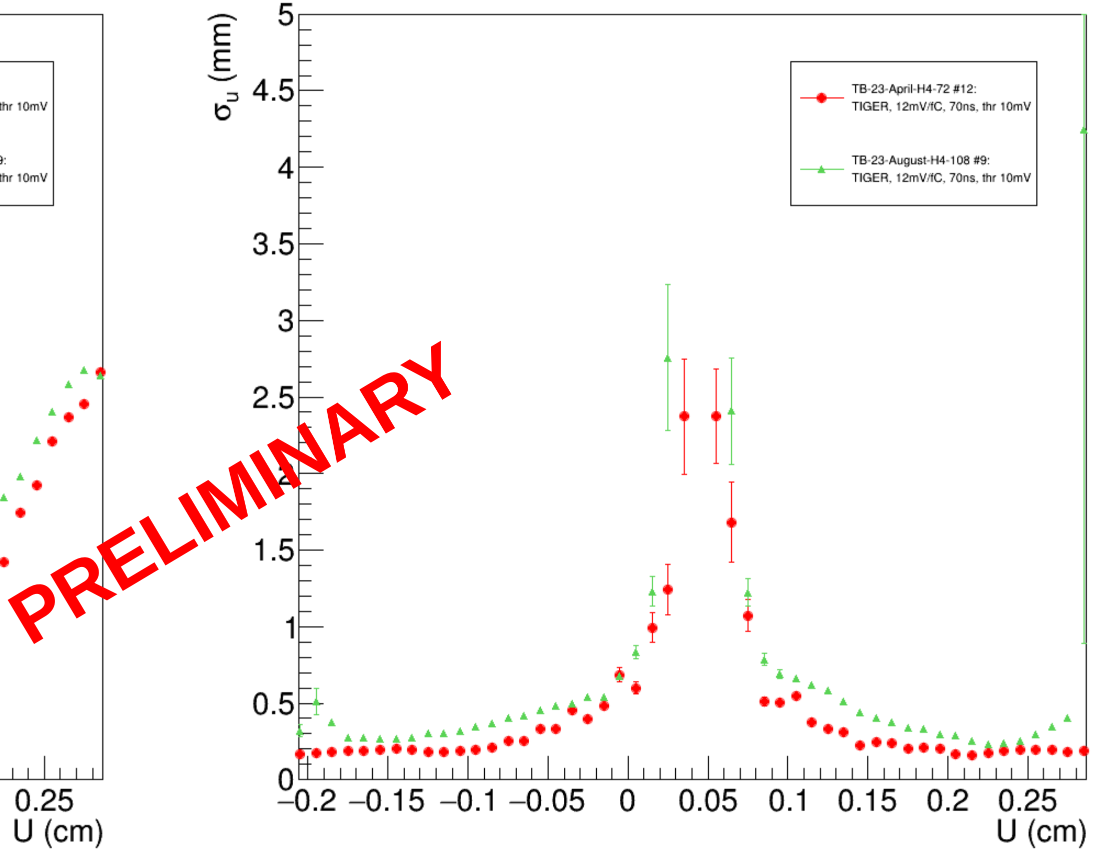
$$\sigma_U = \frac{\sigma_T}{|f'(U)|}$$

0 mm from the apex



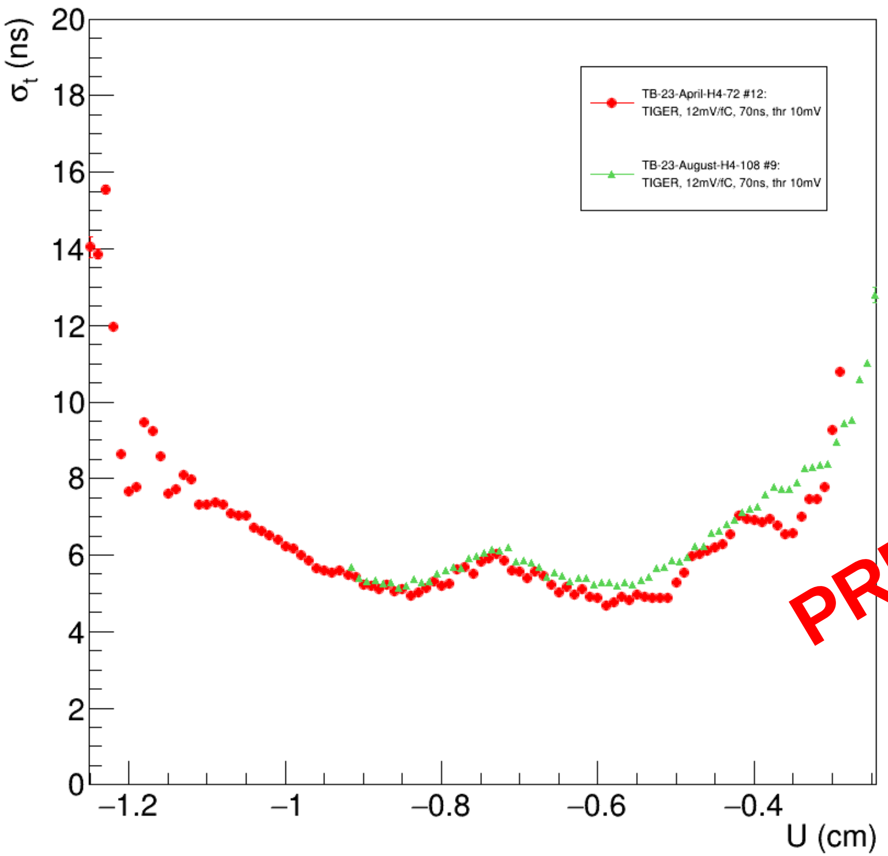
# 5mm Straw Resolution

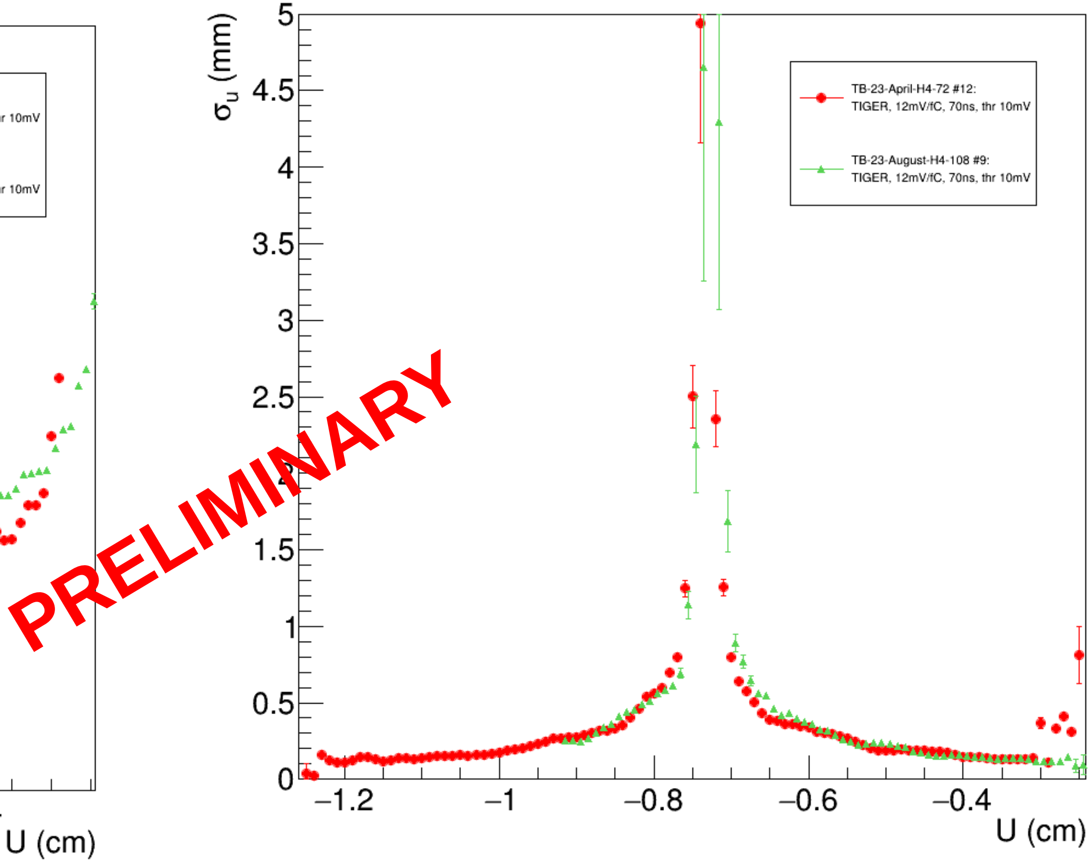



1. The best time ‘resolution’ is about **4 ns**!
2. The weighted mean of Coordinate resolution distribution is **180 μm**!

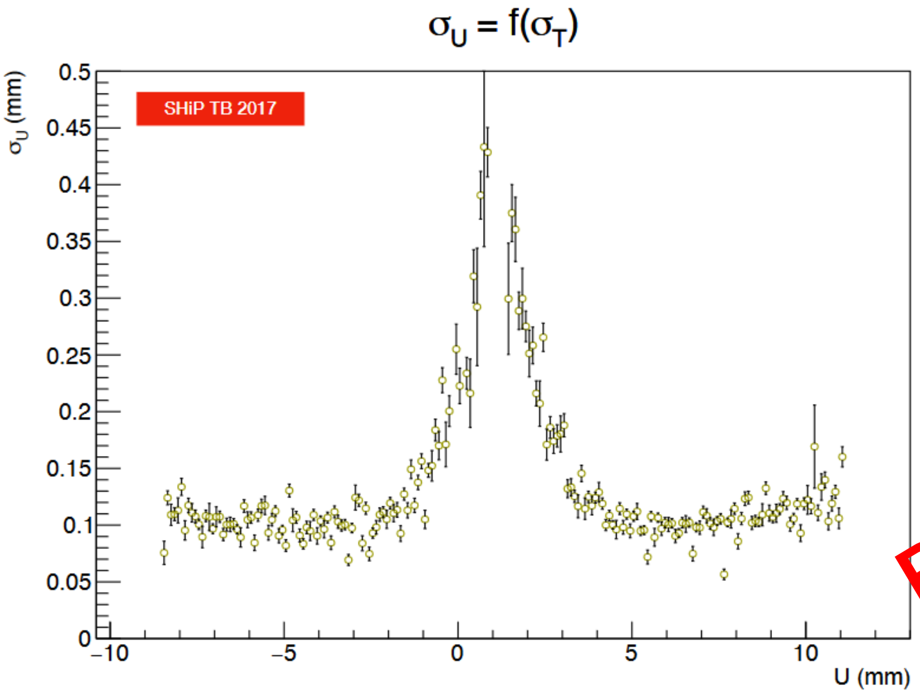
# 10mm Straw Resolution

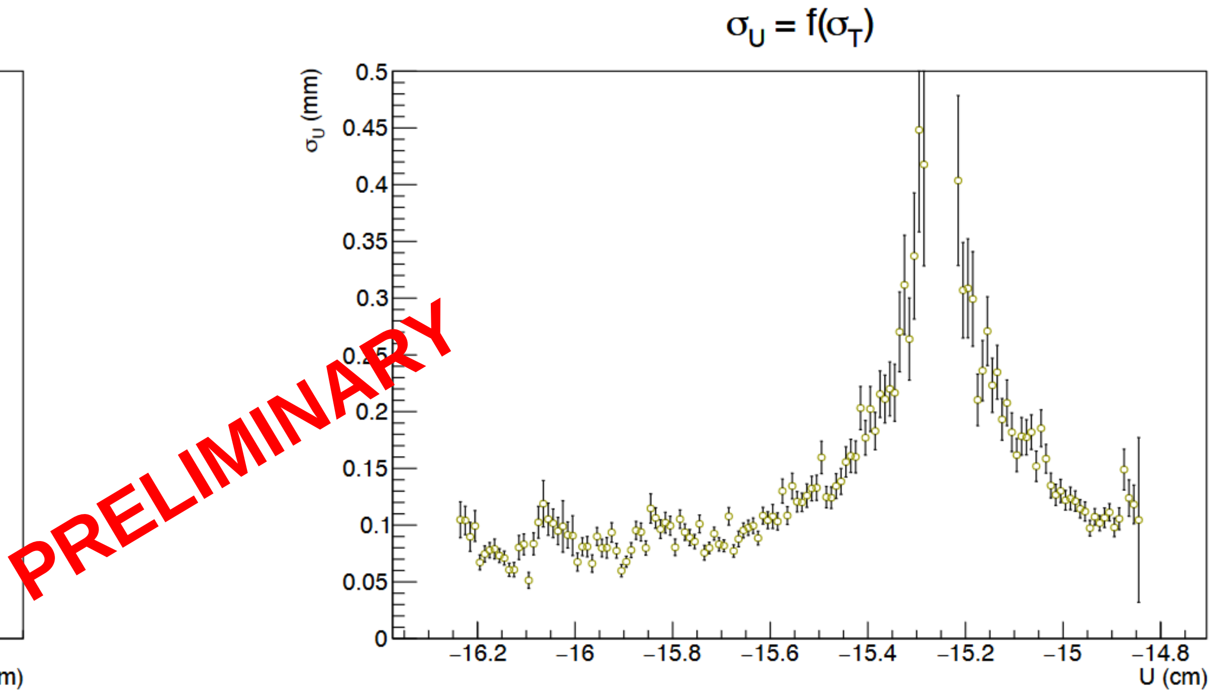



1. The best time ‘resolution’ is about **5 ns**!
2. The weighted mean of Coordinate resolution distribution is **150 μm**!

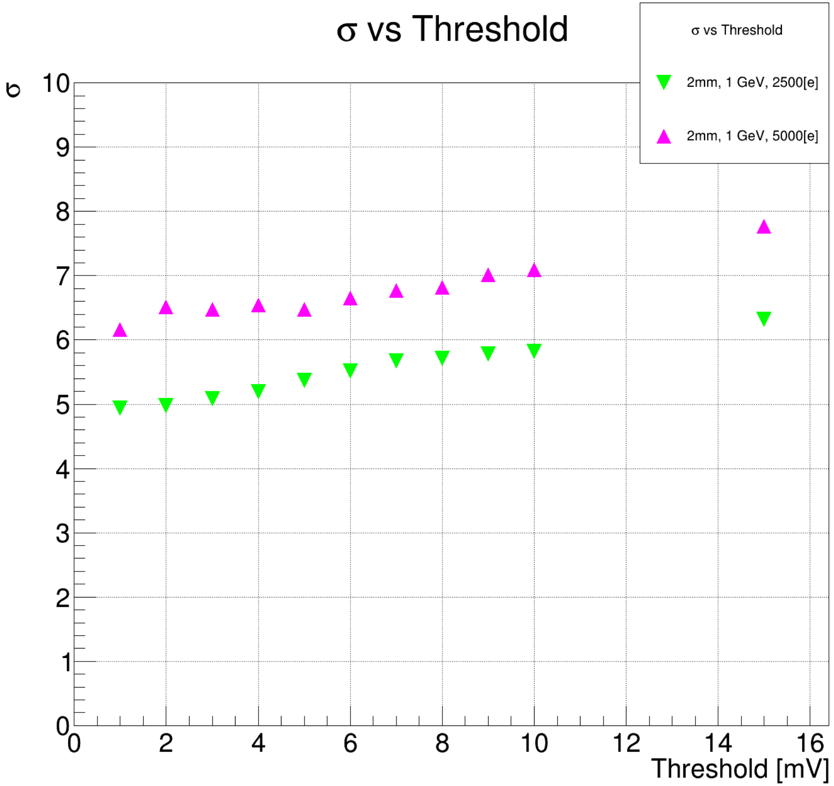
# 20mm Straw Resolution



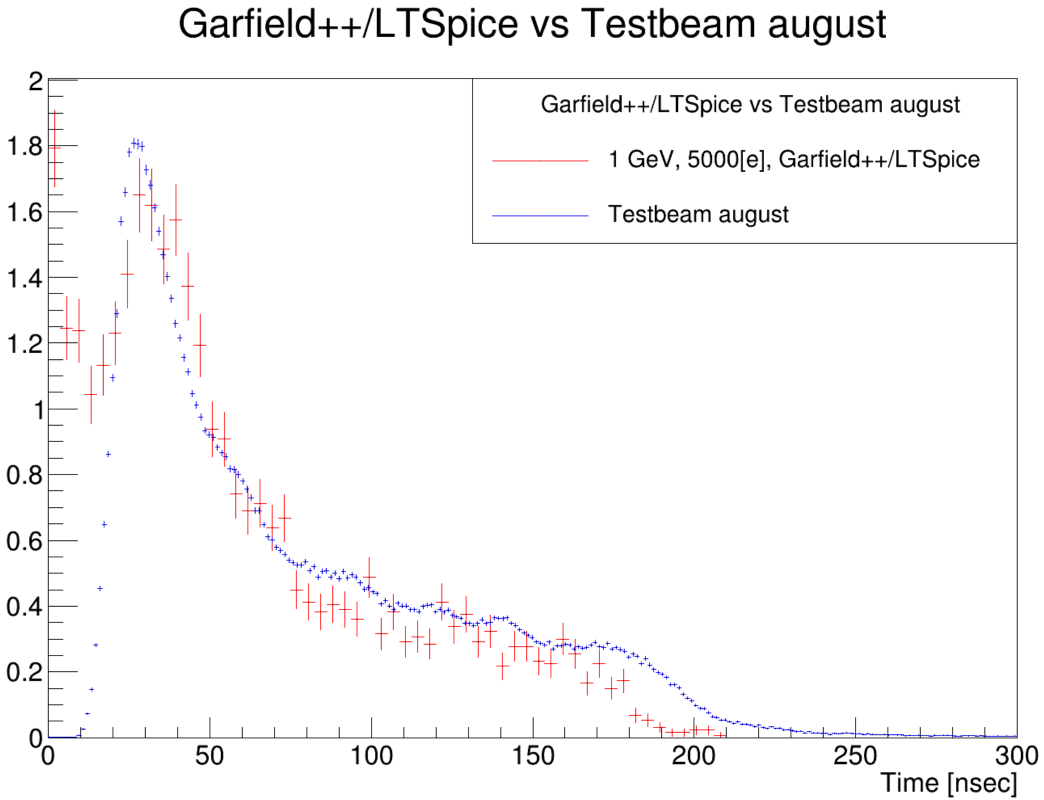




1. The best time ‘resolution’ is about **4 ns**!
2. The weighted mean of Coordinate resolution distribution is **100 μm**!

# Good simulation agreement




Time resolution with different thresholds and noise level simulation




Uniform tracks drift time distribution LTSpice and real Testbeam data compared

# CONCLUSION

- Combined straw tracker prototype with 5, 10 and 20 mm straws has been produced
- During April, May and August TestBeam the data with TIGER readout were aquired
- Data with TimePix in the reference tracking has bin taken. Data merging is ongoing
- Data analysis is ongoing

The work is performed in close collaboration between the Straw Tracker R&D team and Tiger experts of Torino University. While we have obtained valuable results testing the STRAW detectors with TIGER ASIC some limiting factors have been confirmed. As a result, it was decided to integrate a compatibility to readout wire detectors into the new ASIC bring designed at Turin. During the new ASIC design, we will consider the experience gained with TIGER.

Preliminary results were presented at NA62 Tracker and SHiP Collaboration meetings.

We are very grateful to the RD51 Collaboration and SPS team for the test beam opportunity and support, to Martin van Beuzekom and Kevin Heijhoff from NIKHEF LHCb VELO group for their help with TimePix.

# Backup

# TIGER vs VMM3

| | VMM3 | TIGER |
|---|---|---|
| Number of channels | 64 | 64 |
| Clock frequency | 10...80 MHz | 160...200 MHz |
| Input capacitance | <300 pF | <100 pF |
| Dynamic range | Linearity within ±2% up to 2 pC | 50 fC |
| Gain | 0.5, 1, 3, 6, 9, 12, 16 mV/fC | 12 mV/fC |
| ENC (energy branch) | $<3000\ e^-$ | $<1500\ e^-$ |
| TDC binning | ~1 ns | 50 ps |
| Maximum event rate | 140 kHz/ch | 60 kHz/ch |
| Consumption | 15 mW/ch | 12 mW/ch |

# VMM3/3a preamplifier/shaper model

DE GERONIMO AND LI: SHAPER DESIGN IN CMOS FOR HIGH DYNAMIC RANGE
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 58, NO. 5, OCTOBER 2011

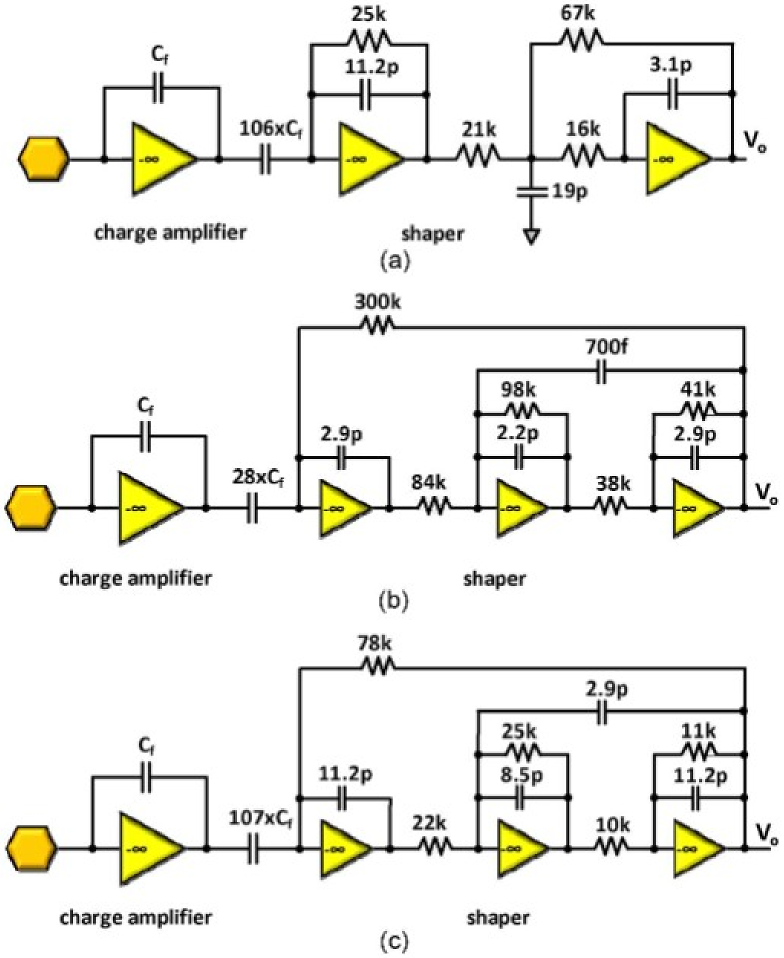
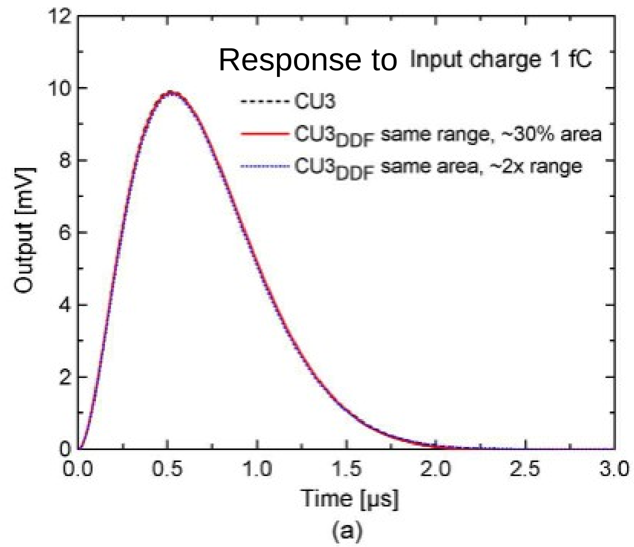
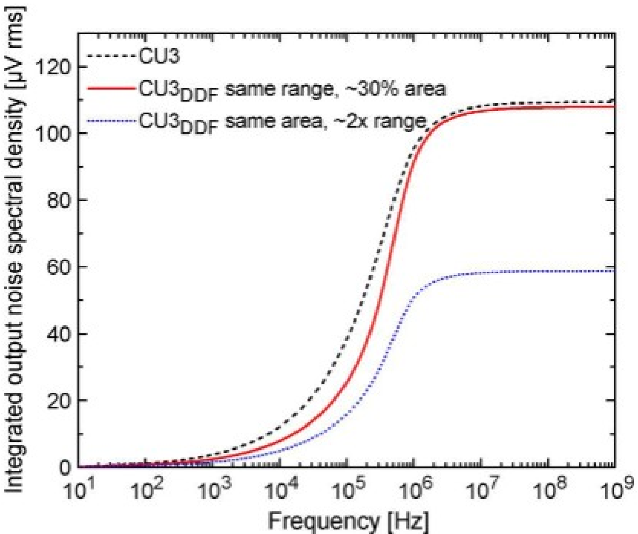
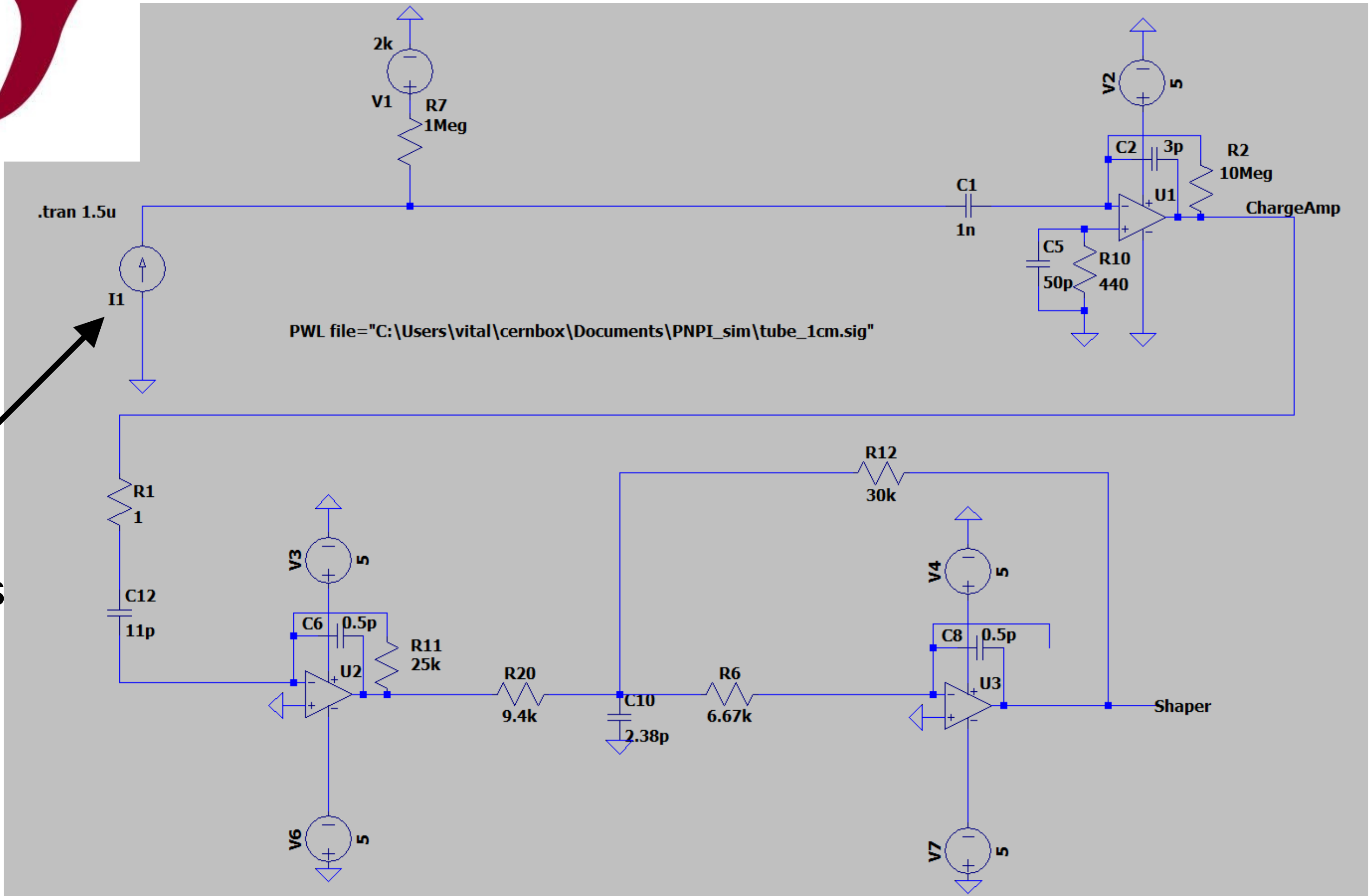



Fig. 10. Examples of realizations using the approach in Fig. 5 (a) and the DDF in Fig. 8 at equal dynamic range (b) and at equal total capacitance (c).



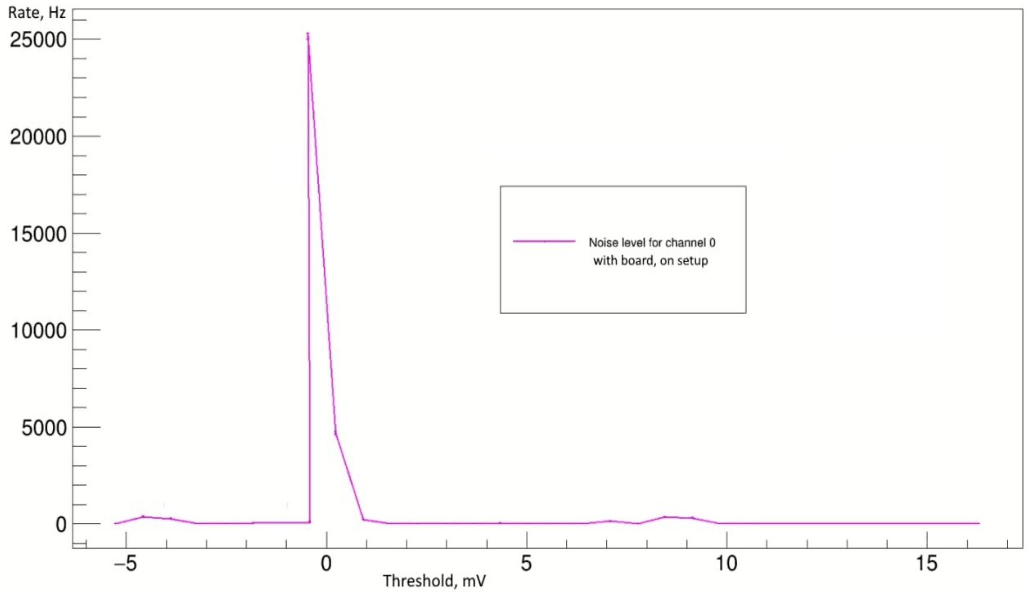



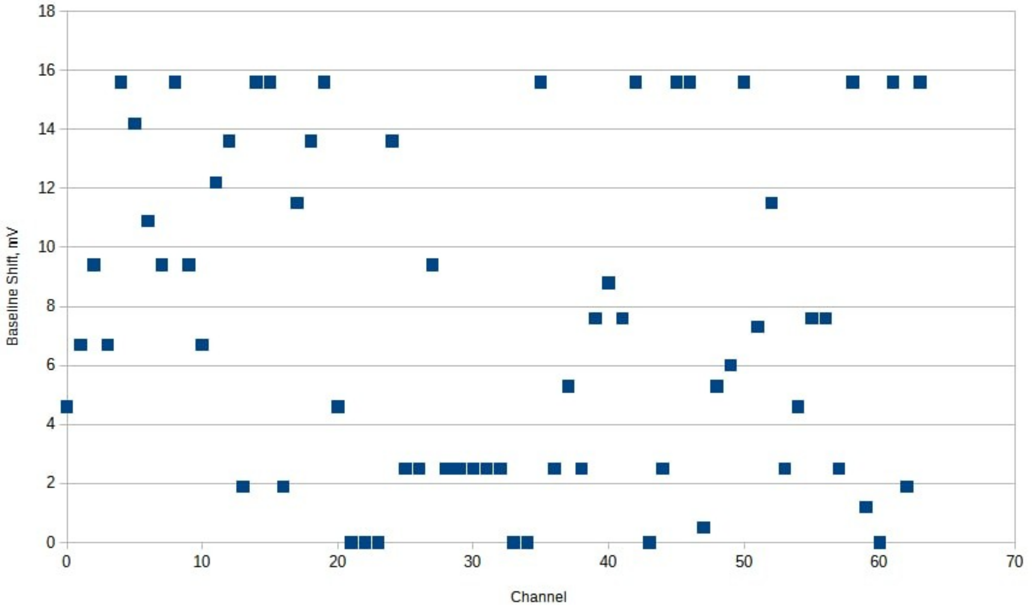
# VMM3 + Straw Model




Straw Tube is represented as a current source

# Threshold selection



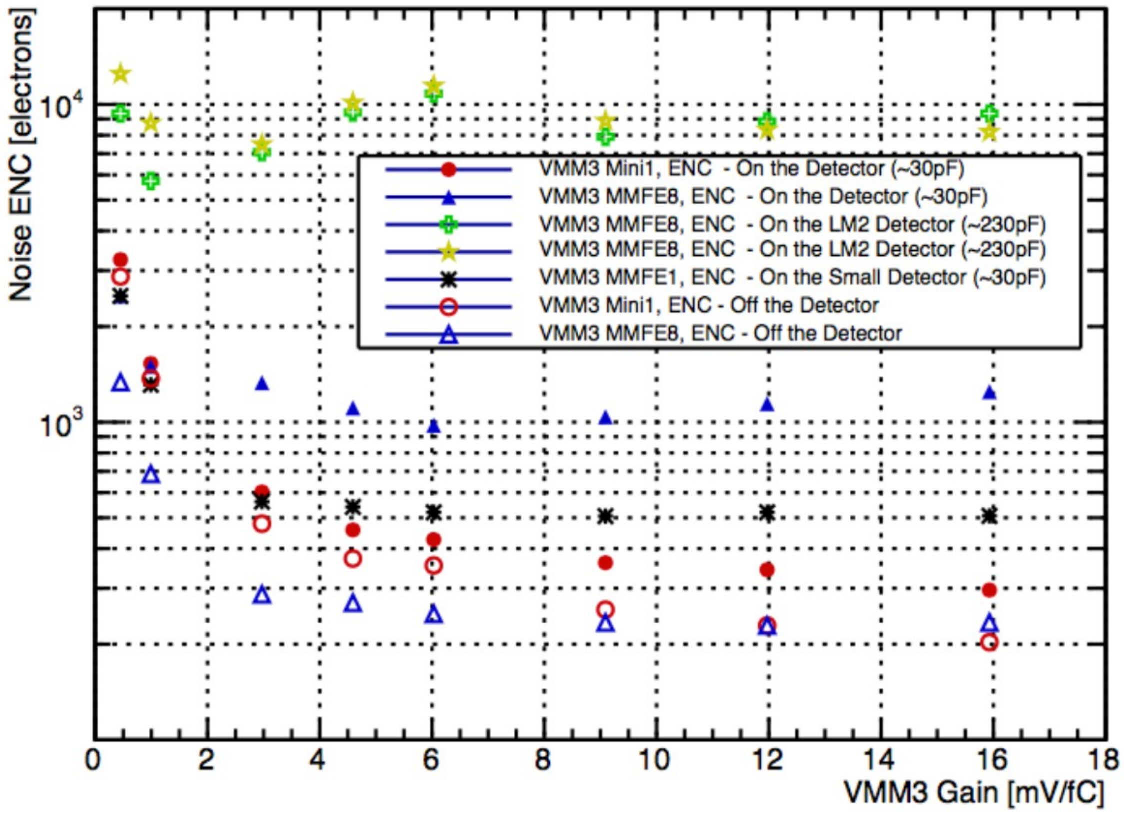



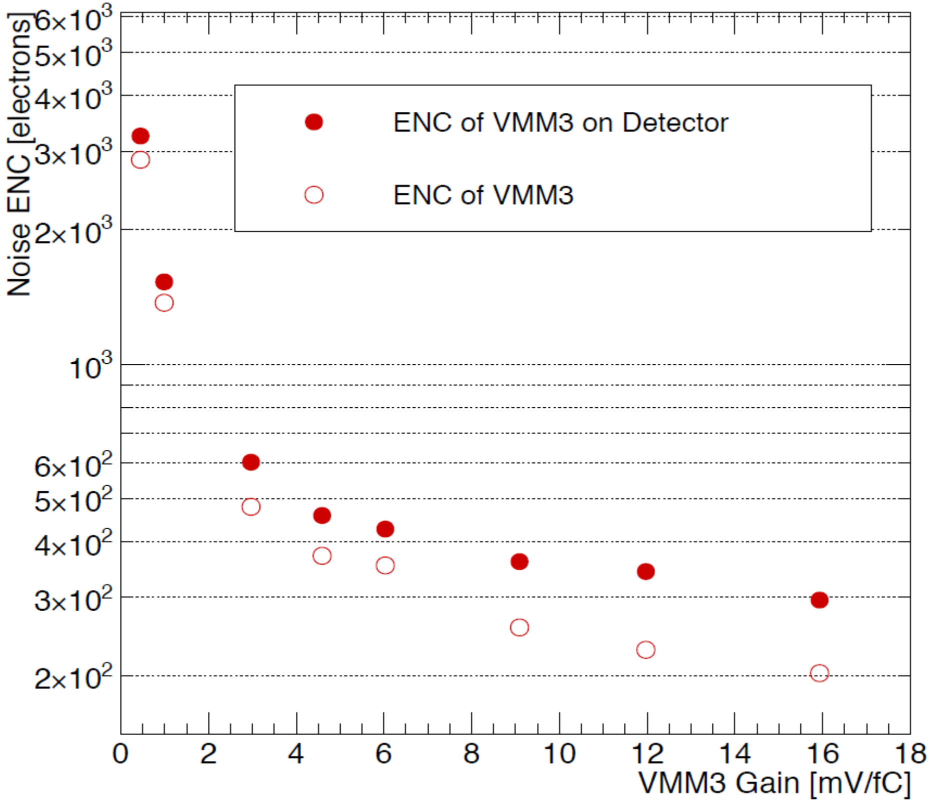

We have made a threshold scan with Mu2E board on real setup. Noise amplitude seem to be low, less than 3mV for most of channels.

The only issue is that each channel has its own baseline bias, but threshold level is one for all channels. Each channel has trimming circuit for its baseline, but we were not able to get precise (~2-3mV) trimming. So, 10mV was selected as reasonable value for simulation and can be easily reached on real setup.

# VMM3 Noise Studies

by George Iakovidis




**3000 e ~ 0.48 fC**

# Testbeam Schedule 2023