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FOR NUCLEAR RESEARCH

SPD NICA

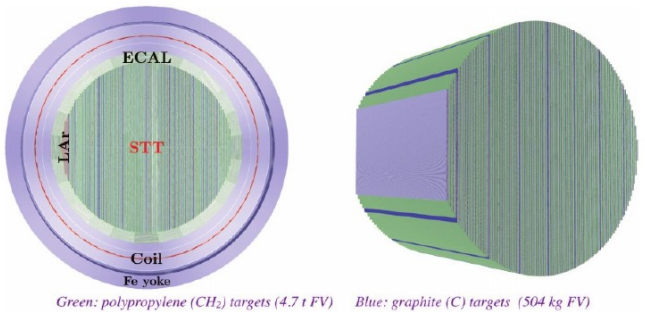
TIGER ASIC as a candidate front-end electronics solution for future Straw Trackers

Speaker: V. Bautin
on behalf of Straw Tracker team

05.09.2023

Motivation

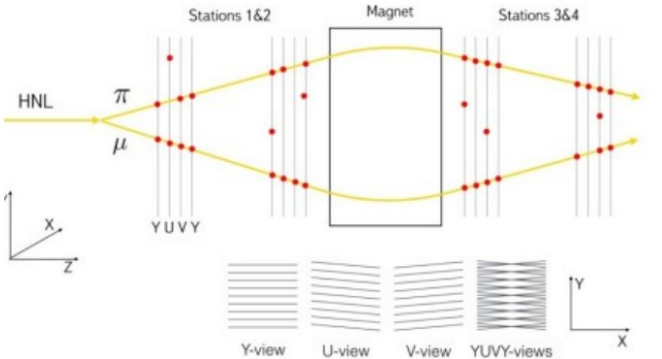
Straw Tube Tracker (STT)



Beam monitoring (with ECAL)
and neutrino flux measurements

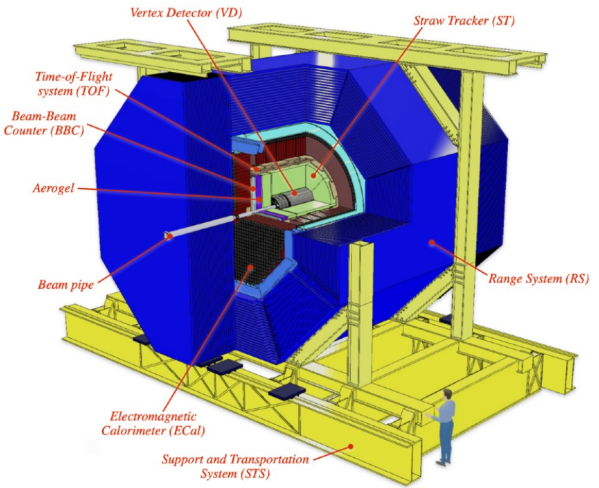
200k straws in total

Spectrometer Straw Tracker (SST)



Tracking and vertex reconstruction
for HiddenSector Detector
20k channels

Straw Tracker (ST)

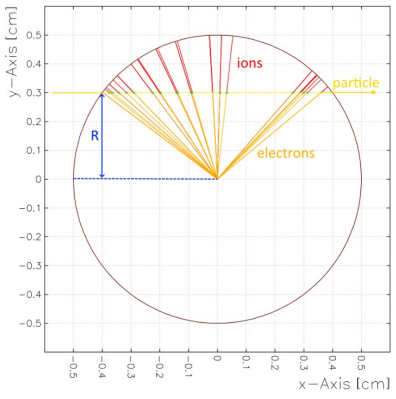


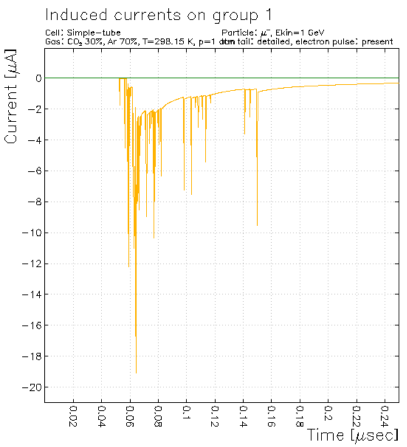
Tracking and PID
30k channels

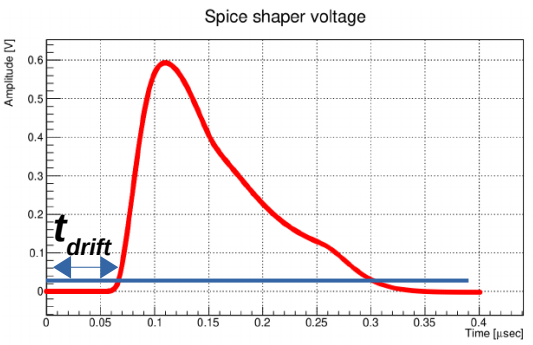
Straw tubes – operation principle

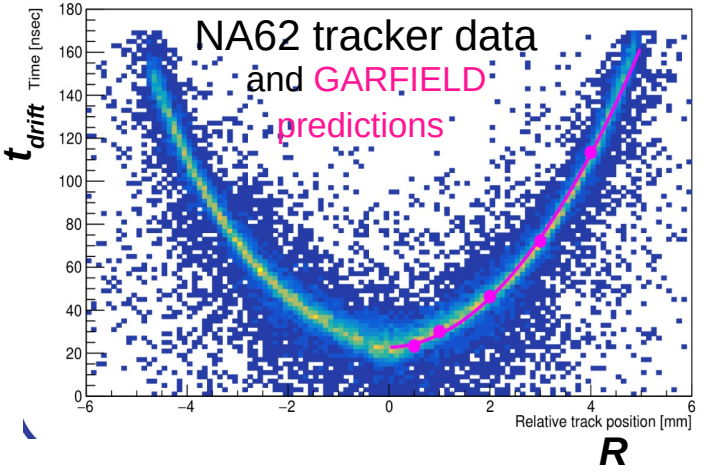
- thin wall drift tube of small (O(cm)) diameter
- proportional mode
- drift time of ~first (or ~second) closest to anode electrons represents quite well the distance between the track of the ionizing particle ***R*** and anode wire

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.

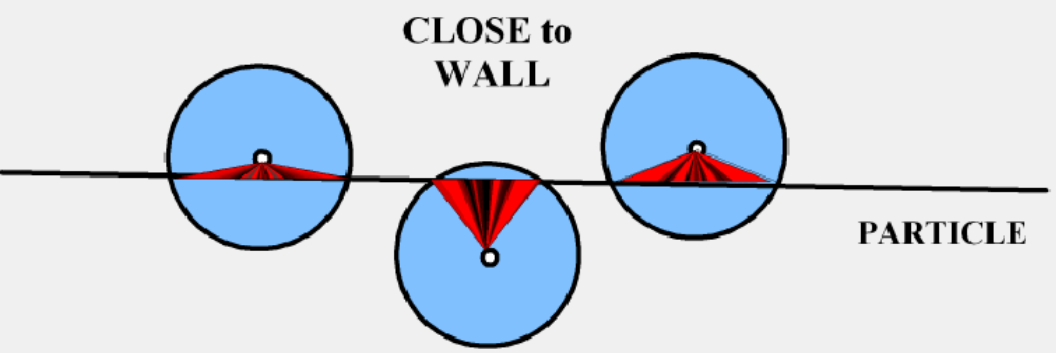


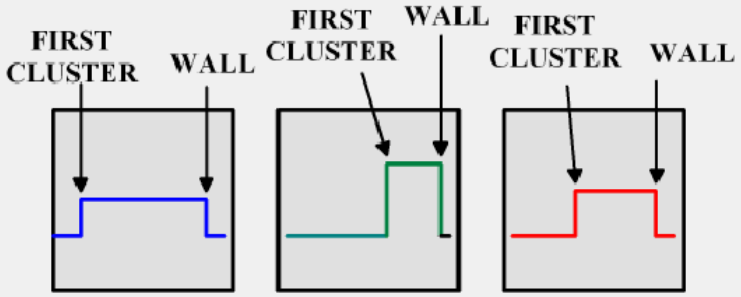


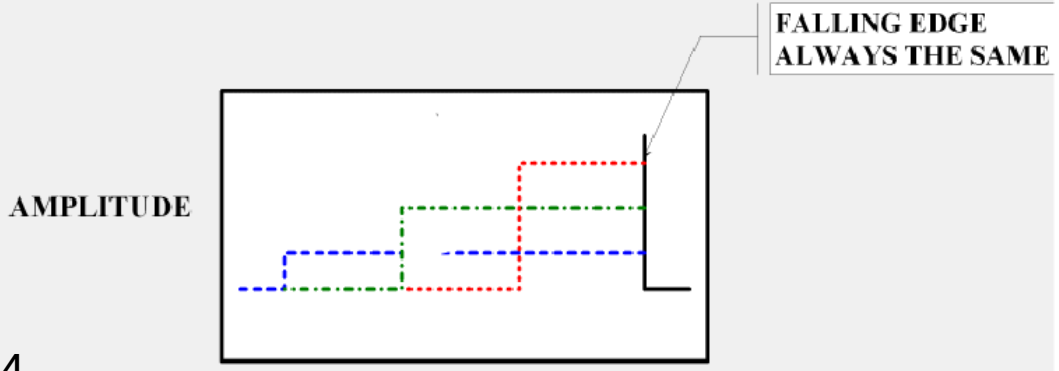




GARFIELD + LTSpice allows to predict straw response for a given readout model.



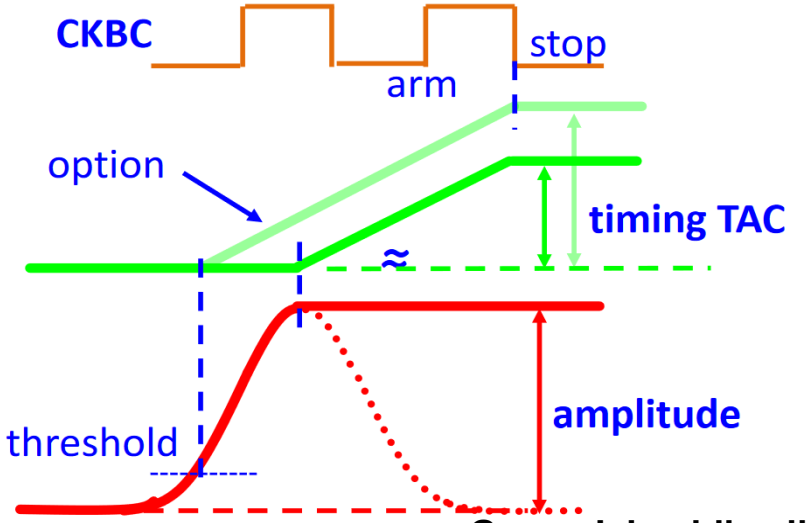




Peter Lichard slide

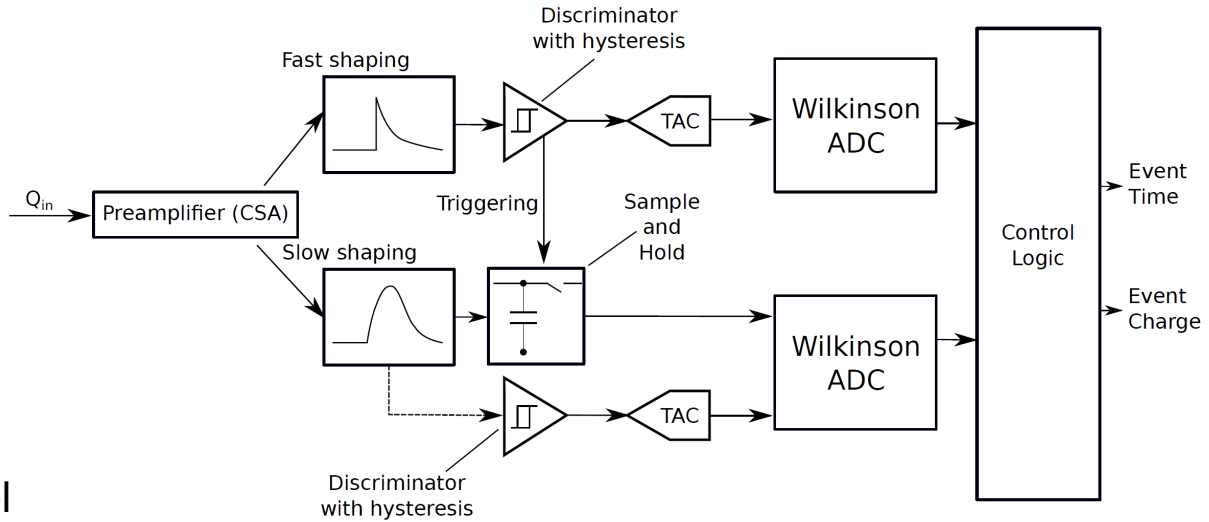
T@T Mode

- Falling edge has the same time for all straws on track.
- Rising edge gives the arrival time of the first cluster



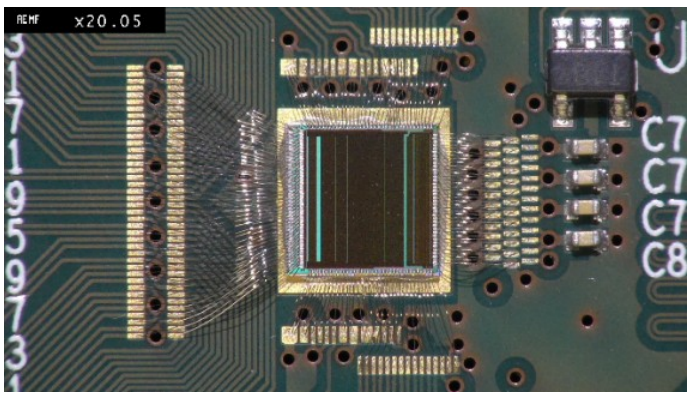
Geoge Iakovidis slide

Torino **I**ntegrated **G**EM **E**lectronics **R**eadout



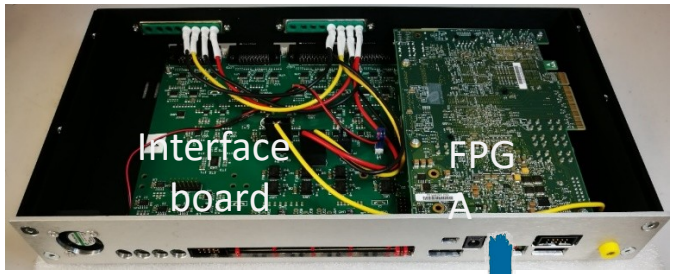
Chip features:

- 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

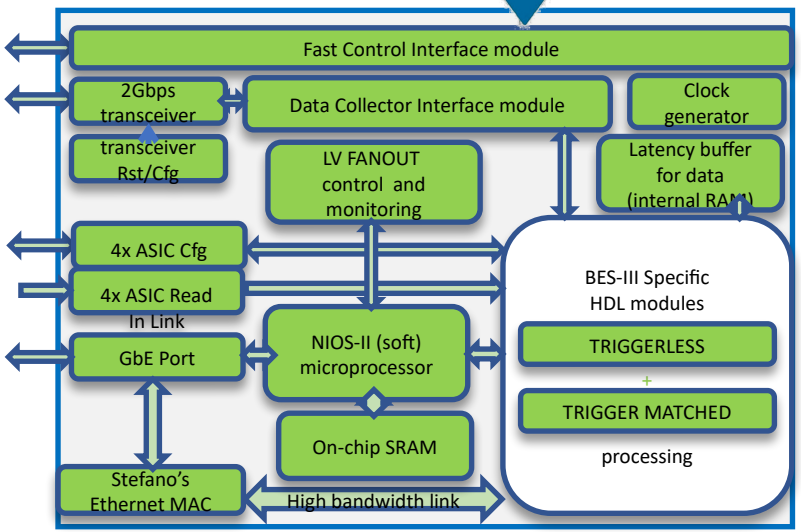


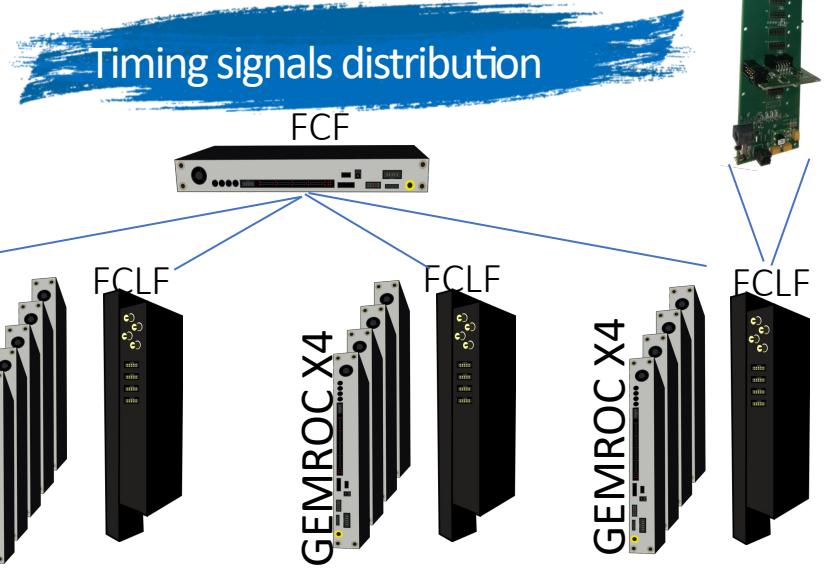
TIGER: A front-end ASIC for timing and energy measurements with radiation detectors, In: Nucl.Instrum. Meth, A, 924 (2019).

GEM ReadOut Cards



Power the FEBs
Monitor chips voltages and temperature
Configure the chips
Receive timing signals
Control data acquisition via optical links/Ethernet





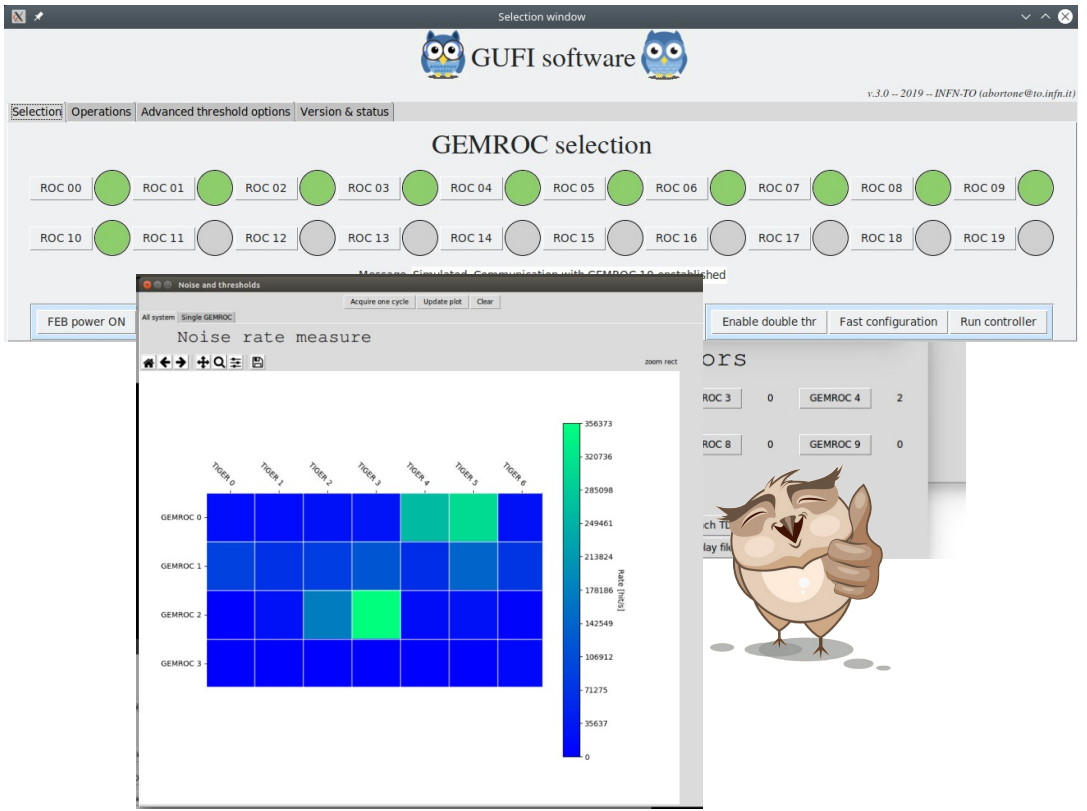
Fast Control system Fanout
A modified GEMROC module which connects to the fast control signals (CLK, TRIGGER, TRIGGER_CHK, FULL) from the BESIII FCSF

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

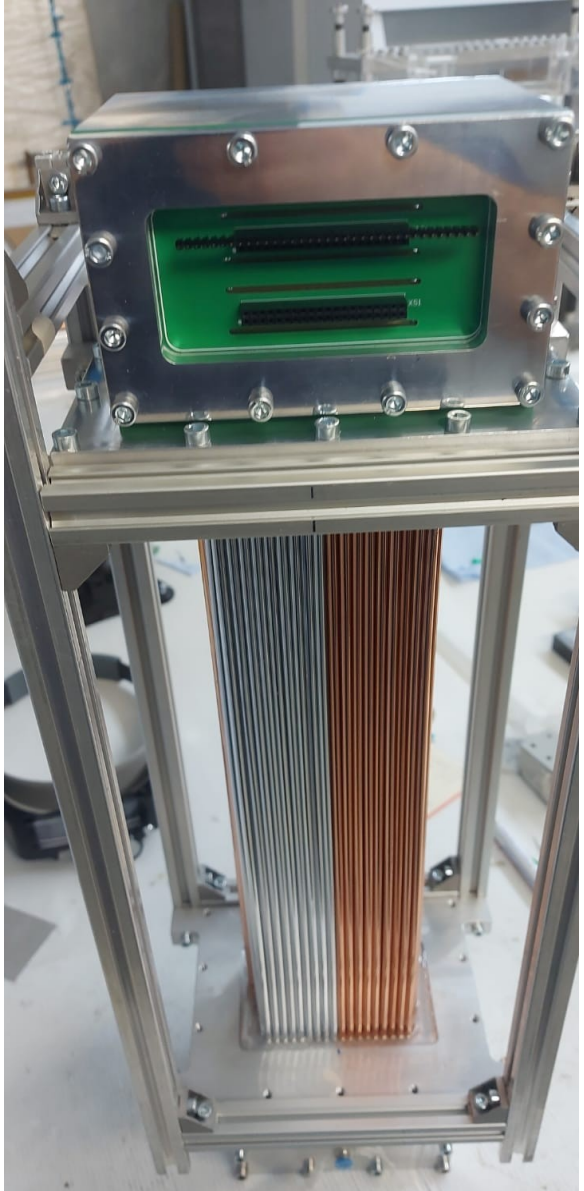
Graphical **U**ser **F**rontend **I**nterface

Python-based software to characterize, debug, and test the system before installation

- Interfaces with GEMROCs and TIGERs
- Configures both the devices
- Manages the acquisition
- Online monitoring
- Measures noise rate and other performance
- User-friendly interface (user mode/expert mode)



Conversion into the BESIII DAQ software ongoing



Straw Prototype

Straw and wire diameters:

20mm / 30um : SHiP type

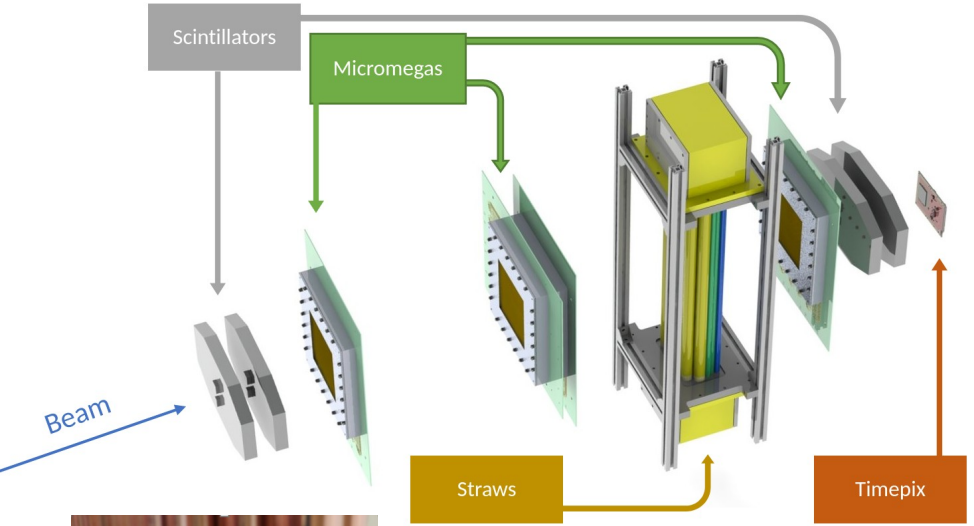
10mm / 30um : SPD type

5mm / 20um :

NA62 upgrade (Cu/Au coating)

DUNE (Al metallisation)

The Setup

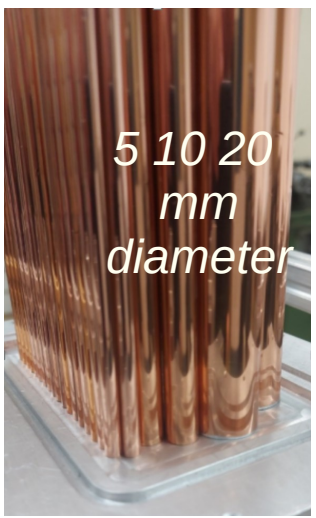


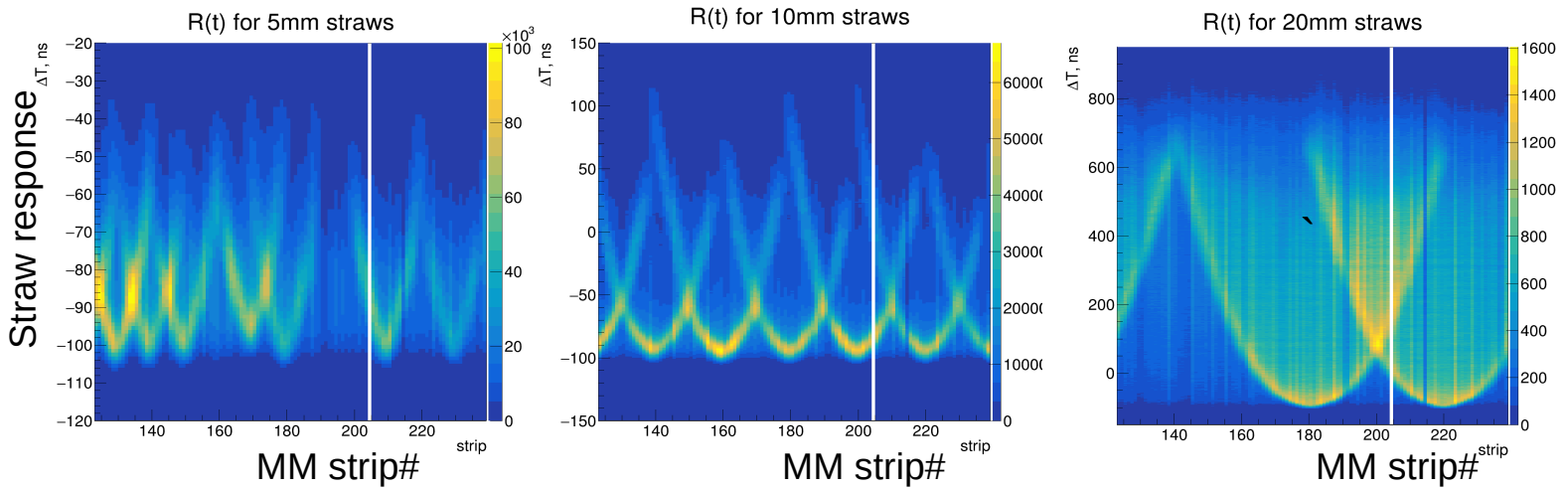
Reference tracking:

- 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





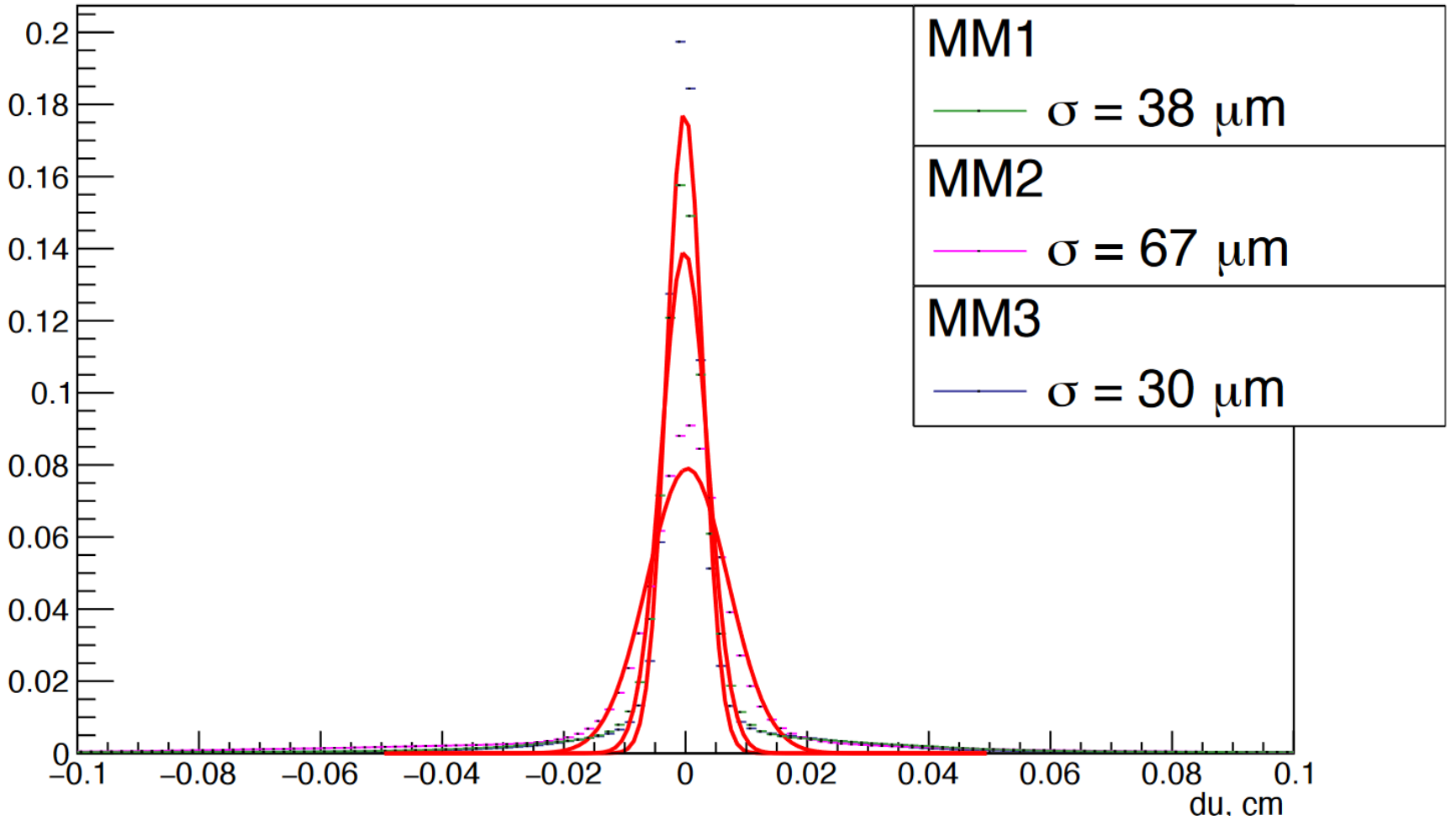
Data quality and very first results from the Spring TB

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

- checking T0 performance

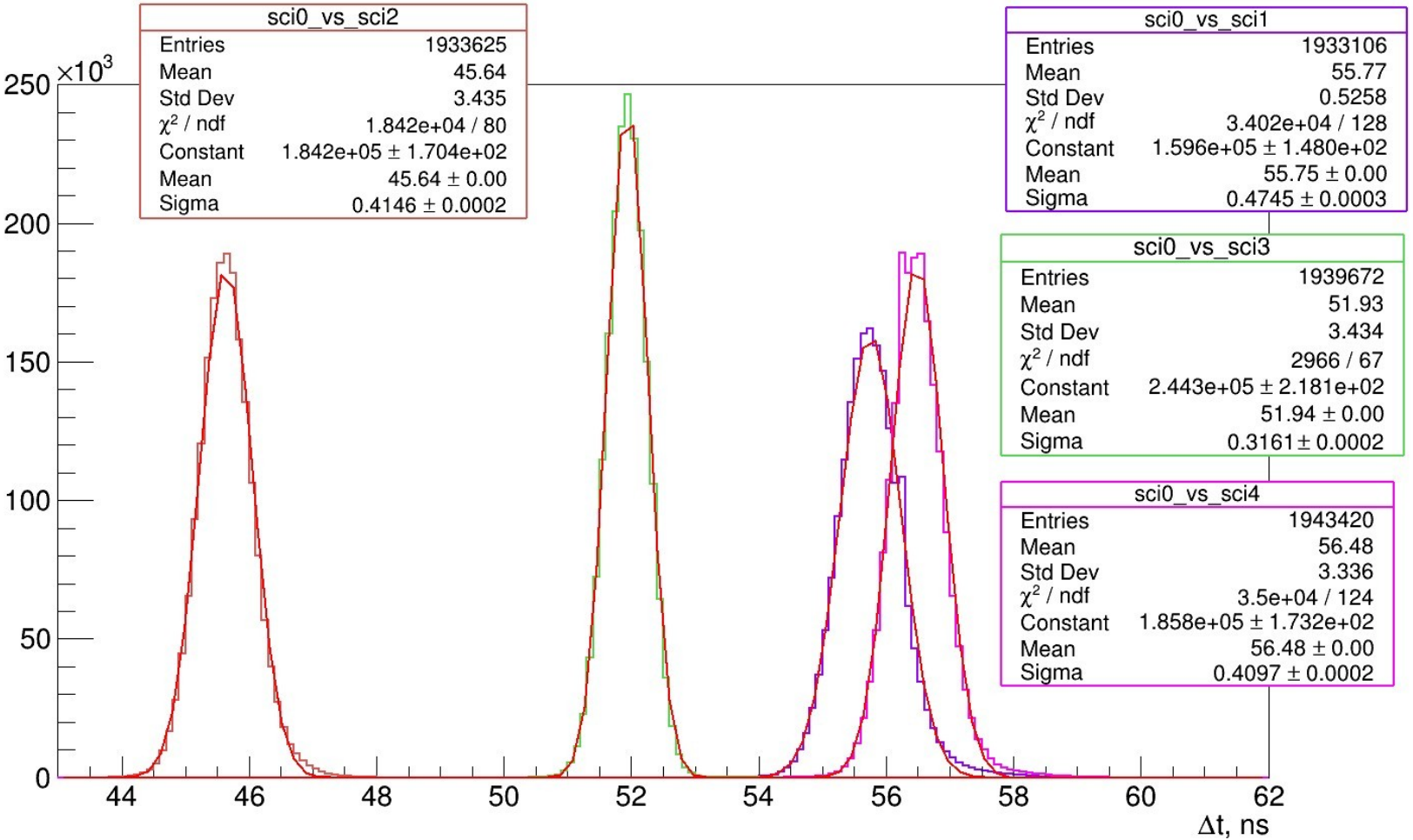
- very preliminary resolution analysis

Reference tracking -- residuals



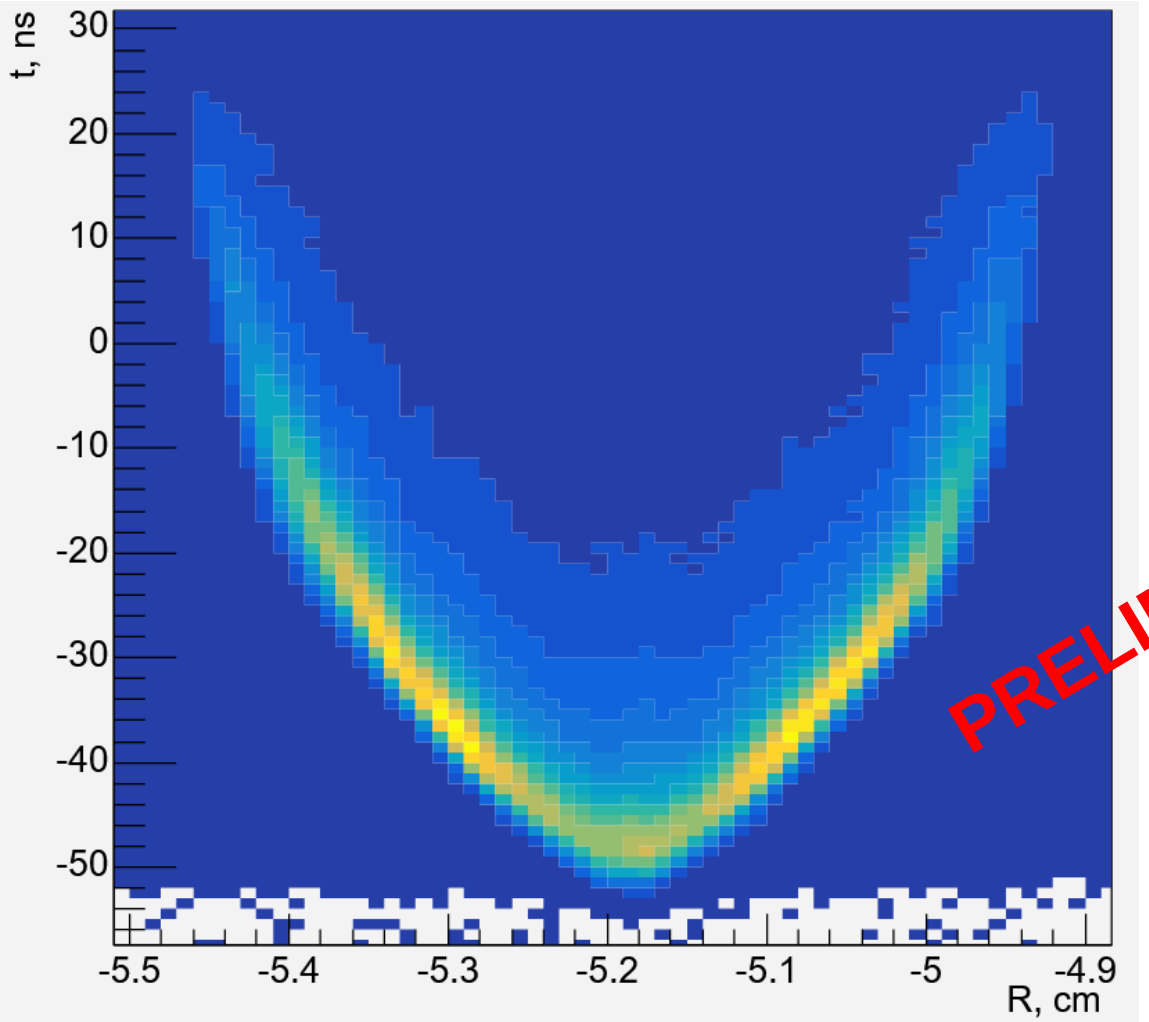
Significant improvement wrt TB22 due to careful MM alignment: maximal sigma of 67um instead of ~100um

Time resolution -- T0

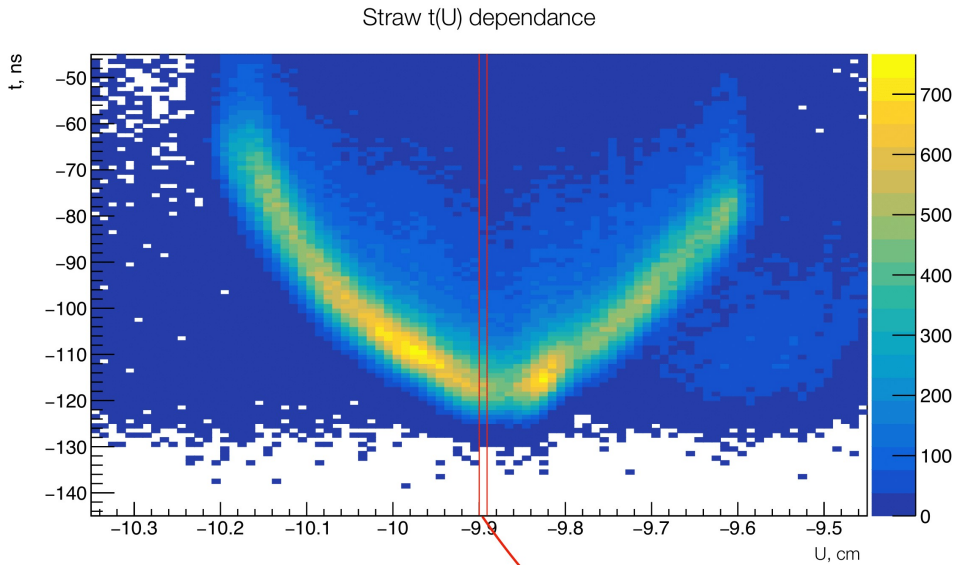


Significant improvement wrt TB22: four scintillators with adjusted thresholds/delays each with sigma ~ 400/1.4 ps wrt ~1ns in 2022

5mm Straw V-Shape

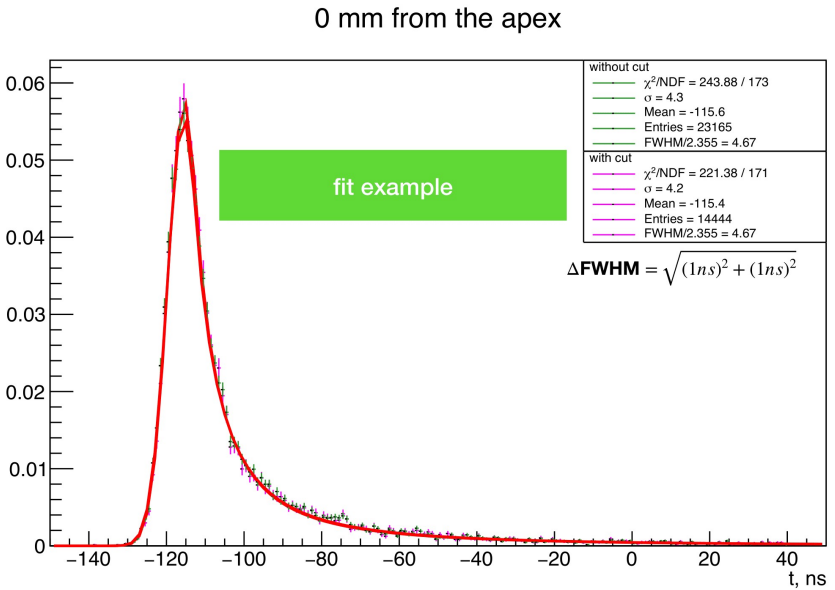


Coordinate resolution as a function of Time resolution

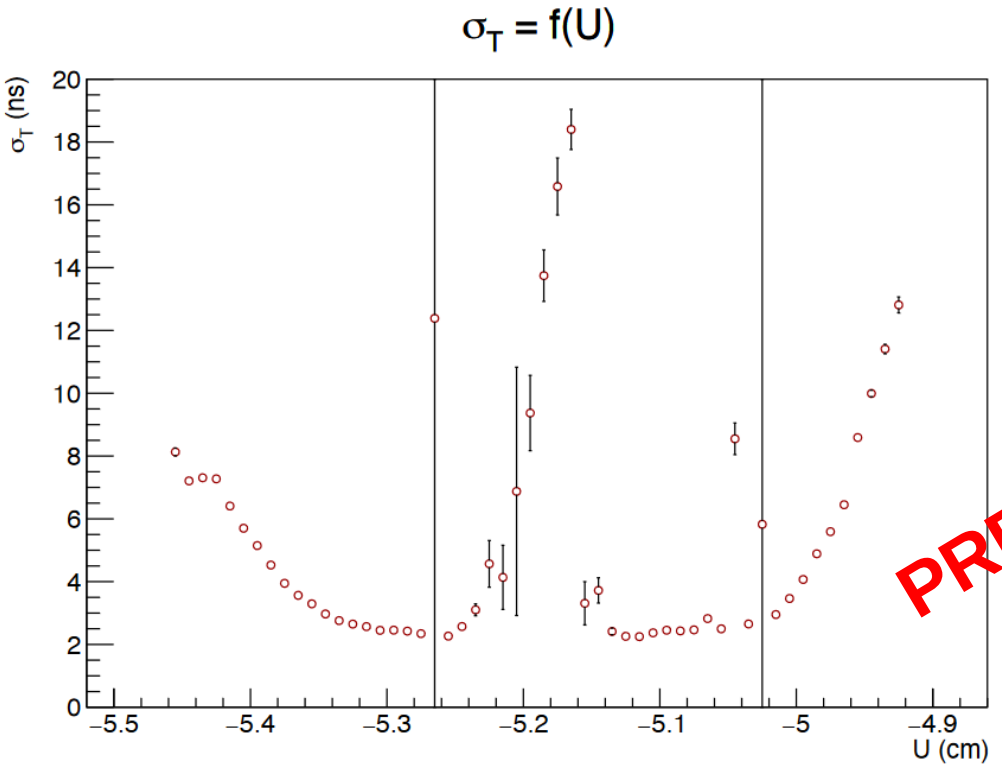


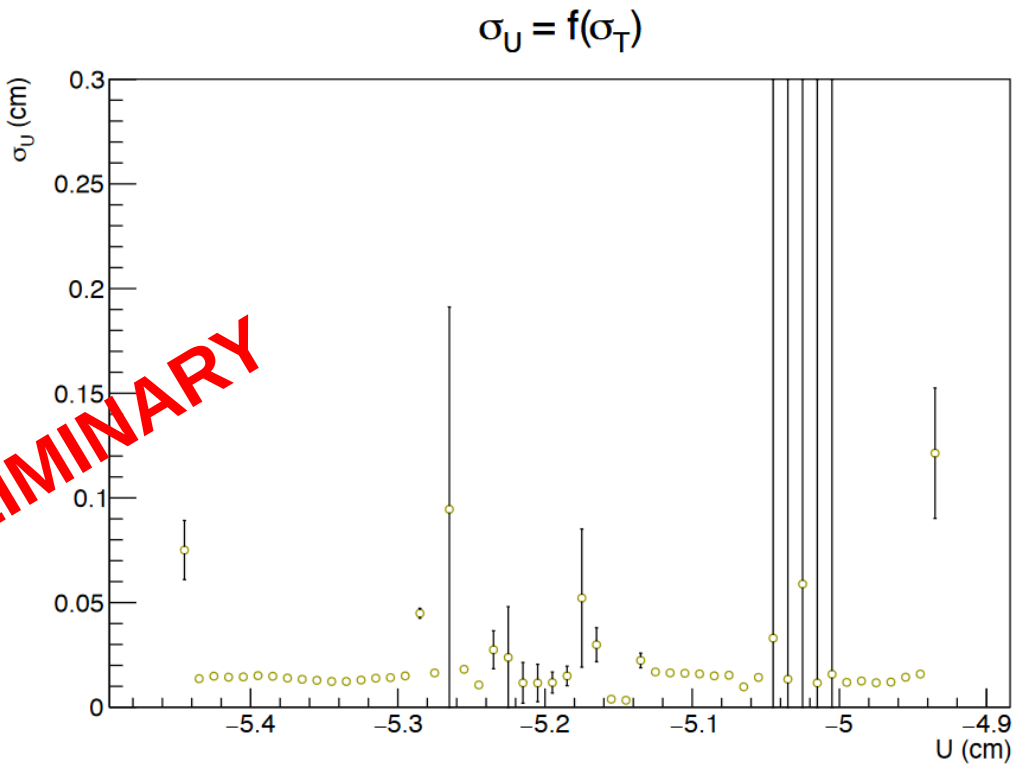
σ_T from the fit associated with Time resolution. The Idea is to obtain the **Spatial** resolution from the **Time** resolution

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



5mm Straw Resolution

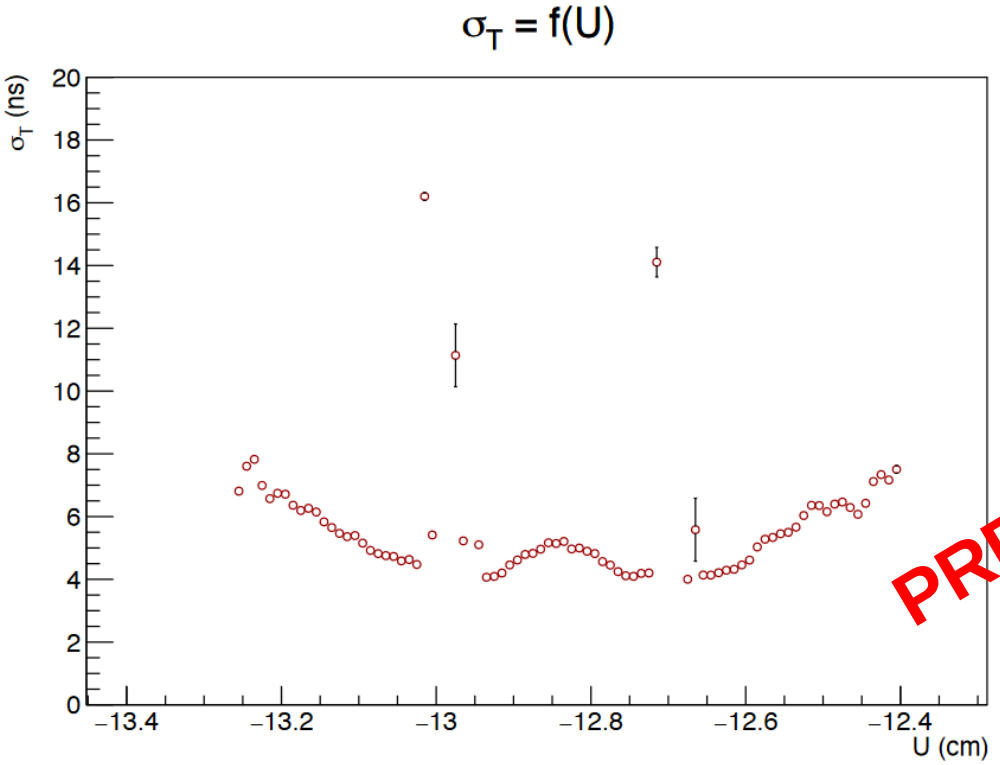


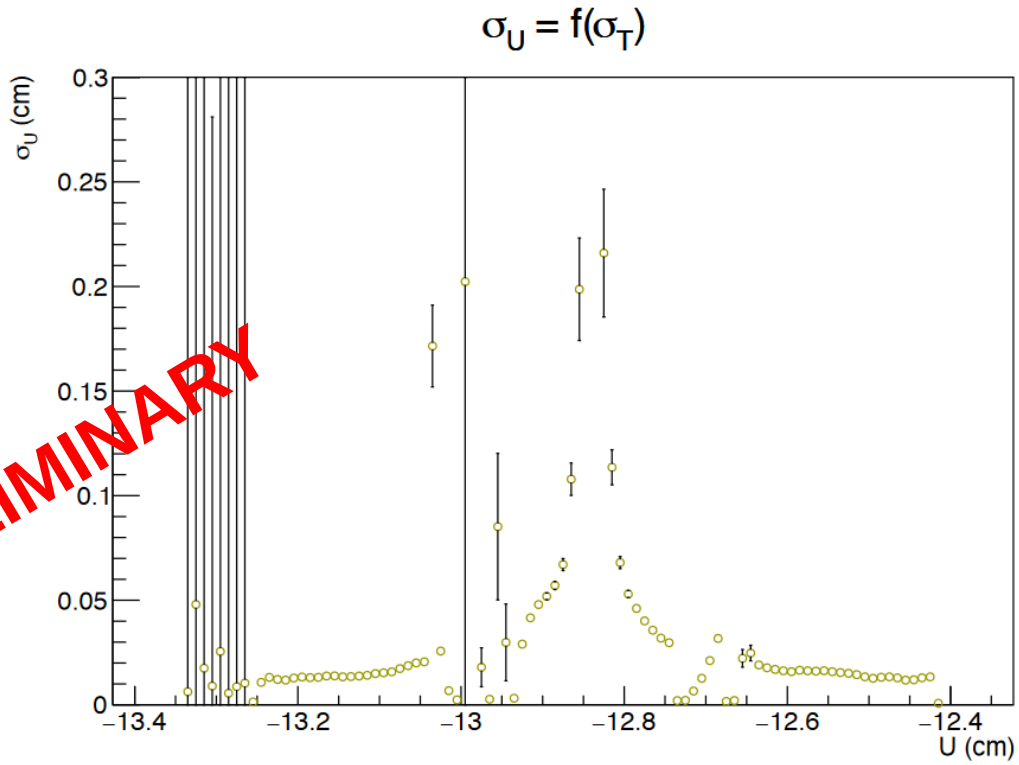


PRELIMINARY

1. The best time ‘resolution’ is about **2 ns**!
2. The weighted mean of Coordinate resolution distribution is **136 μm**!

10mm Straw Resolution

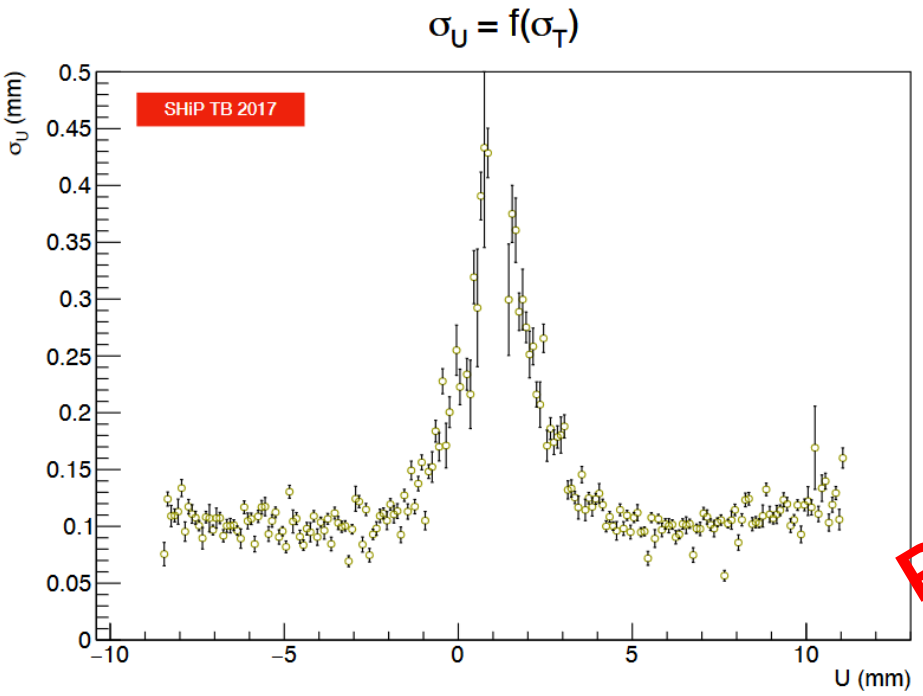


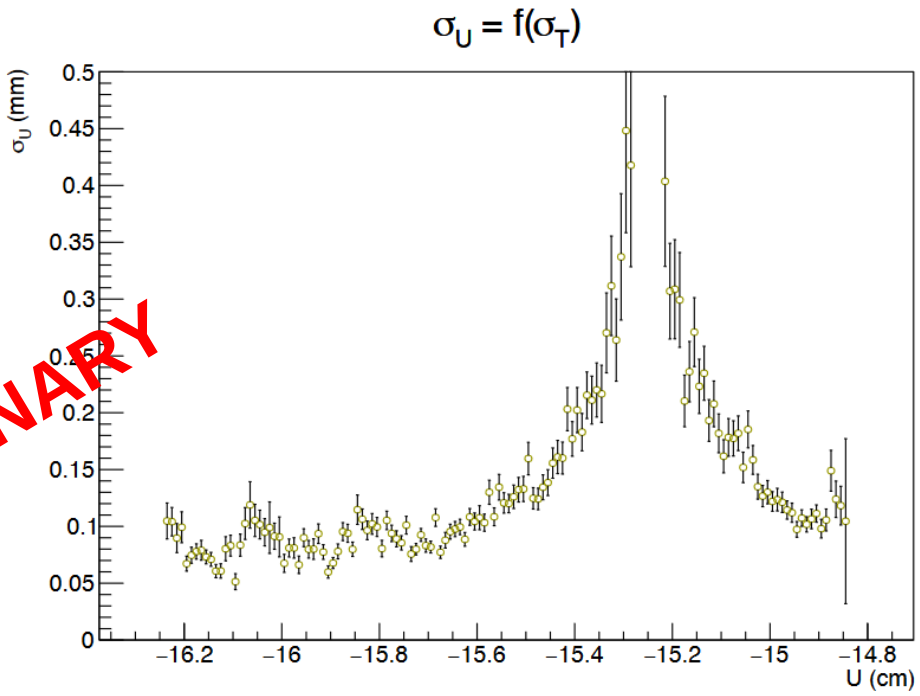


PRELIMINARY

1. The best time ‘resolution’ is about **4 ns**!
2. The weighted mean of Coordinate resolution distribution is **150 μm**!

20mm Straw Resolution





PRELIMINARY

1. The best time ‘resolution’ is about **3 ns**!
2. The weighted mean of Coordinate resolution distribution is **100 μm**!

CONCLUSION

- Combined straw tracker prototype with 5, 10 and 20 mm straws has been produced
- During April and May 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

IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 58, NO. 5, OCTOBER 2011

VMM3/3a preamplifier/shaper model

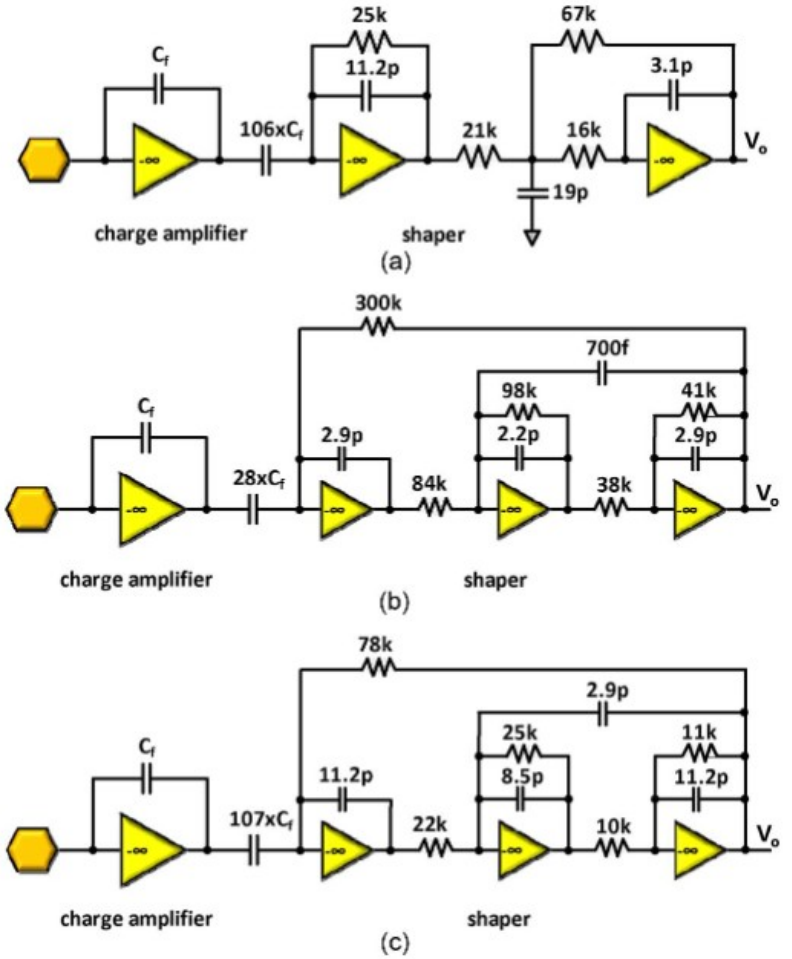
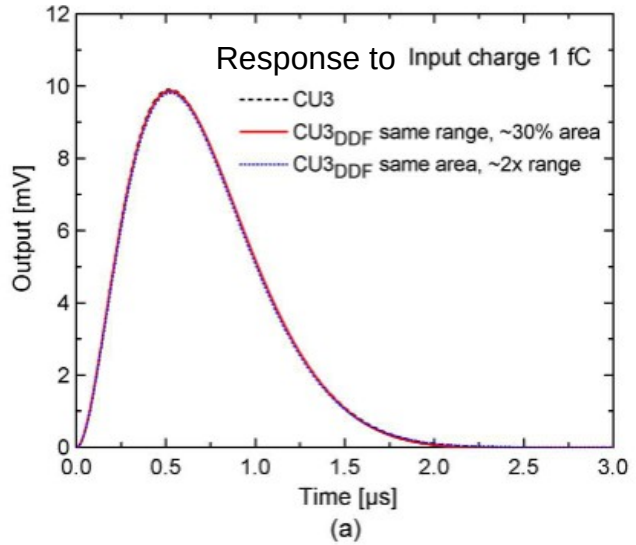
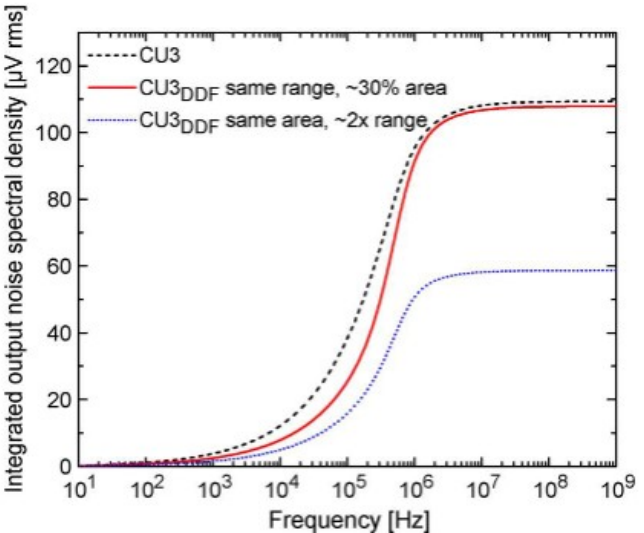
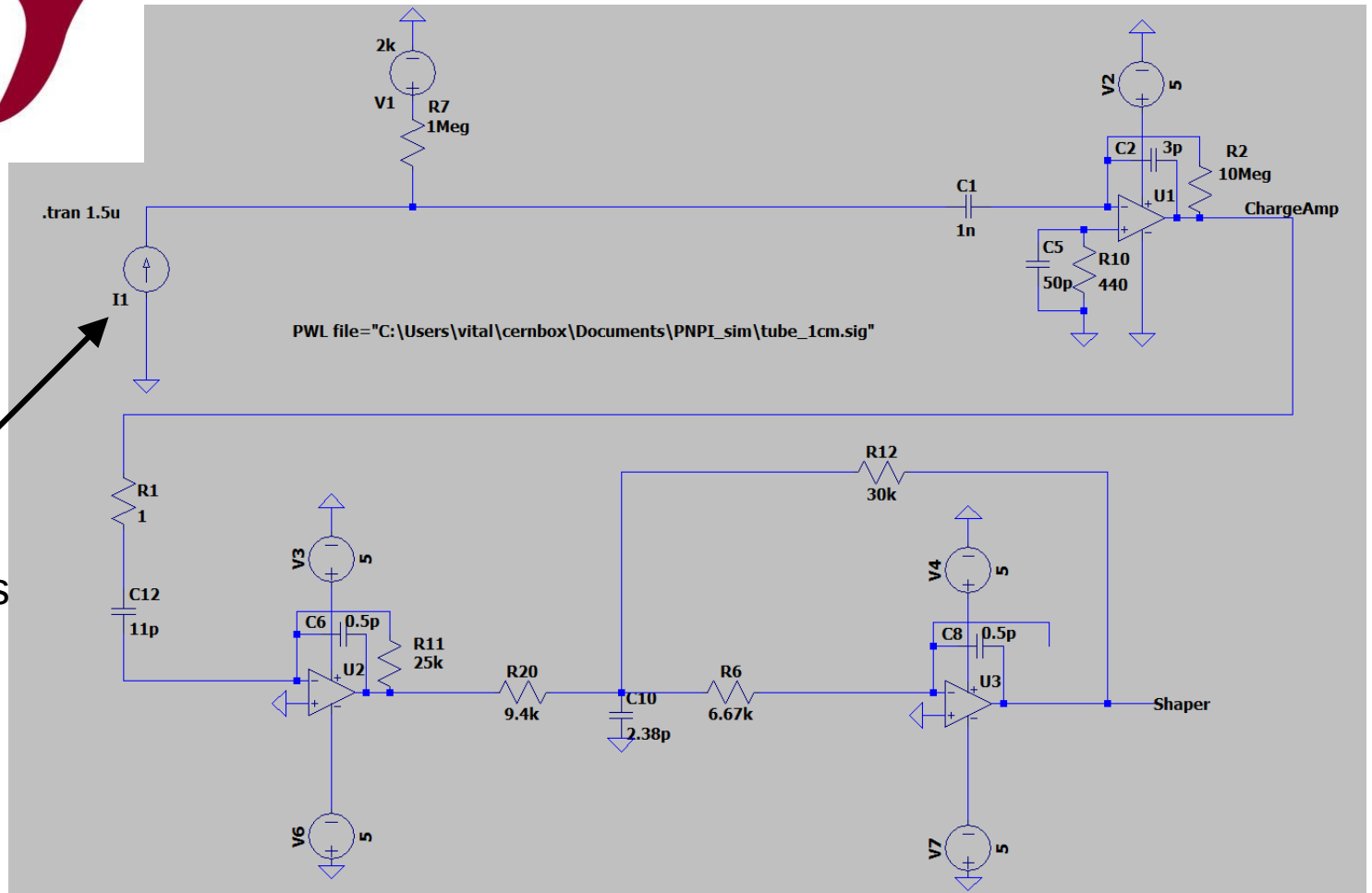


Fig. 10. Examples of realizations using the approach in Fig. 5 (a) and the DDF in Fig. 8 at equal dynamic range (b) and at equal total capacitance (c).



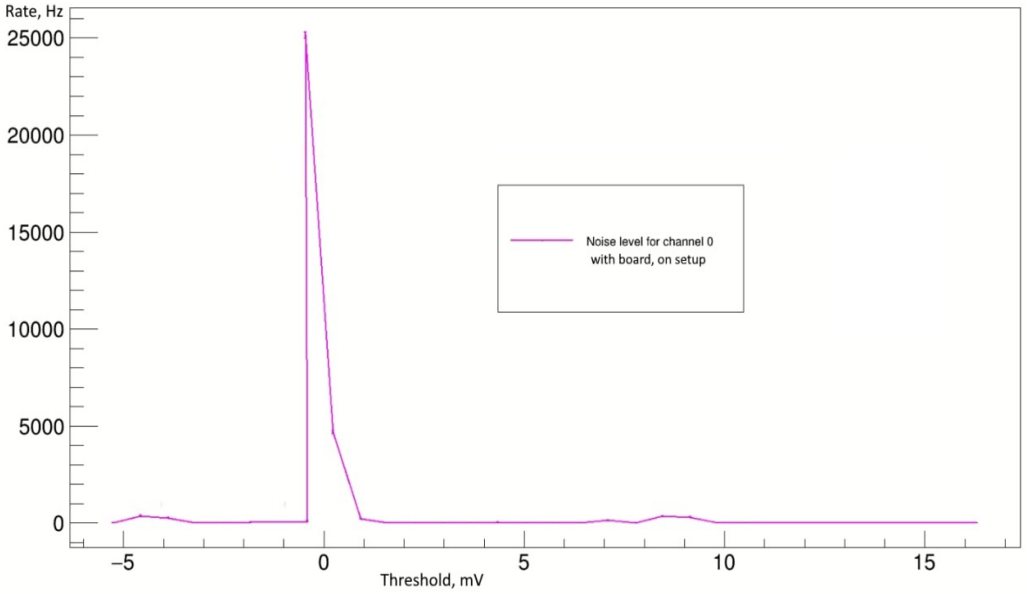


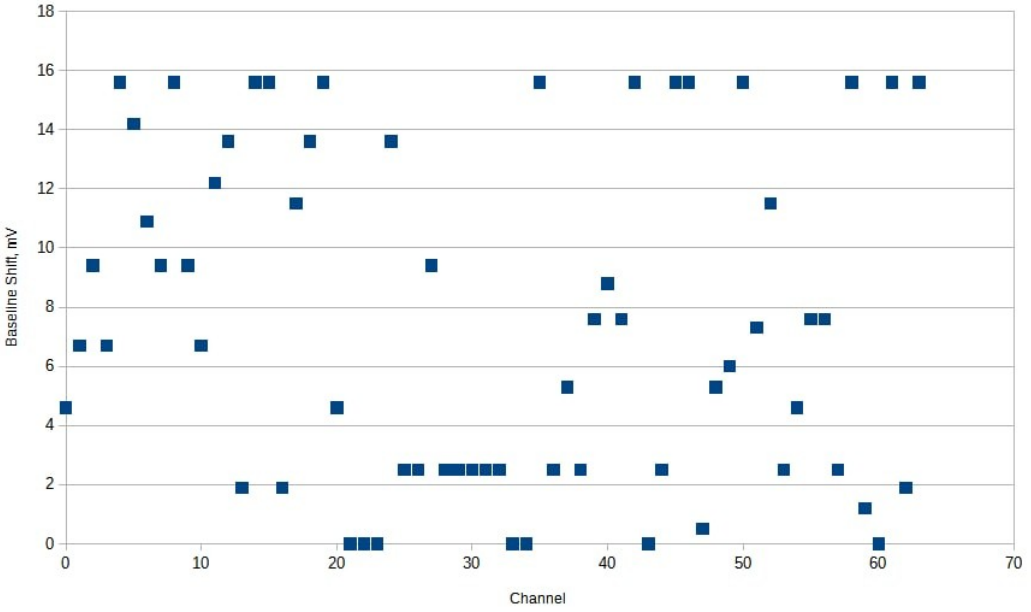
VMM3 + Straw Model



Straw Tube is represented as a current source

Threshold selection



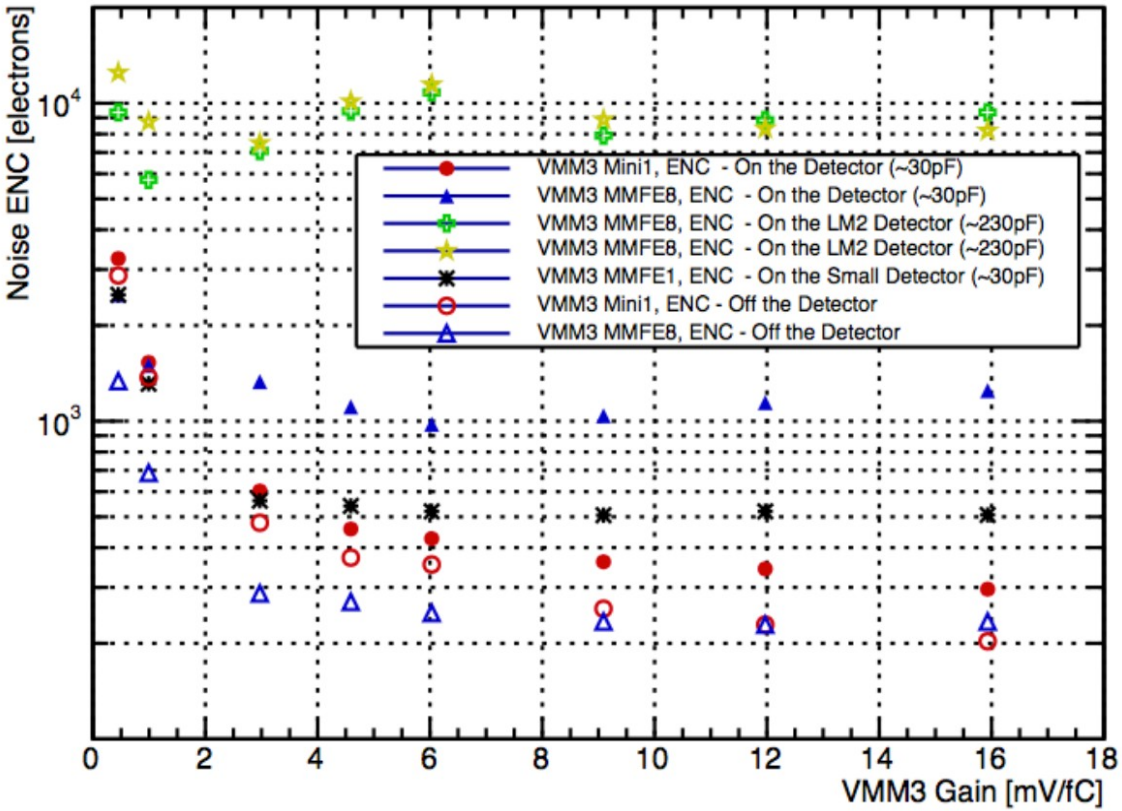


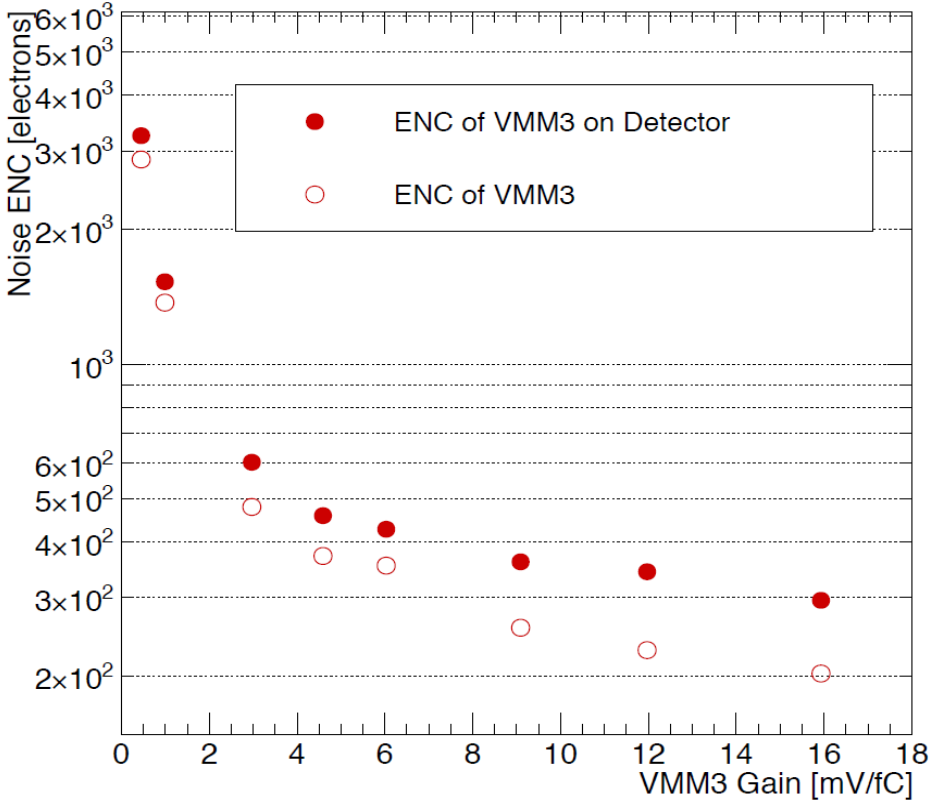
We have made a threshold scan with Mu2E board on real setup. Noise amplitude seem to be low, less than 3mV for most of channels.

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