SPD Collaboration Week

FEE for Straw Readout

JOINT INSTITUTE
FOR NUCLEAR RESEARCH

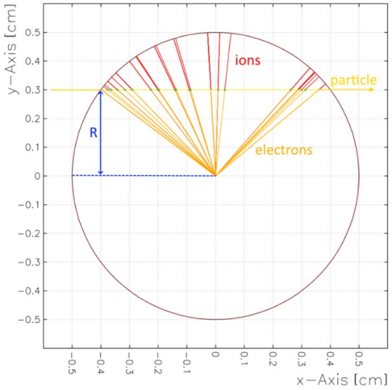
Speaker: Vitaly Bautin
on behalf of Straw Tracker Team

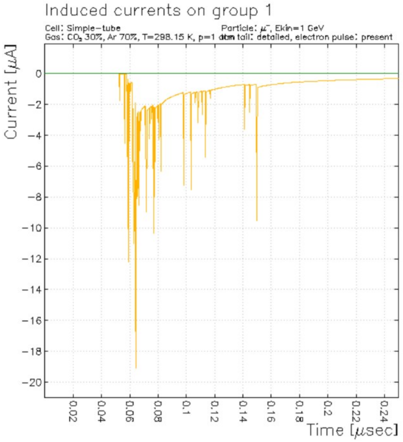
05.11.2024

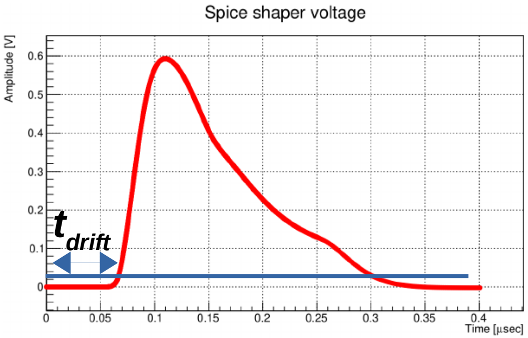
Straw tubes – operation principle

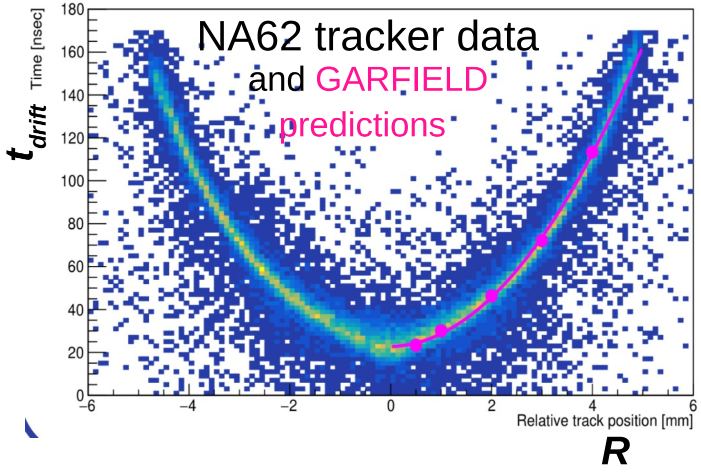
- thin wall drift tube of small (O(cm)) diameter
- proportional mode
- drift time of ~first (or ~second) closest to anode electrons represents quite well the distance between the track of the ionizing particle ***R*** and anode wire

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.









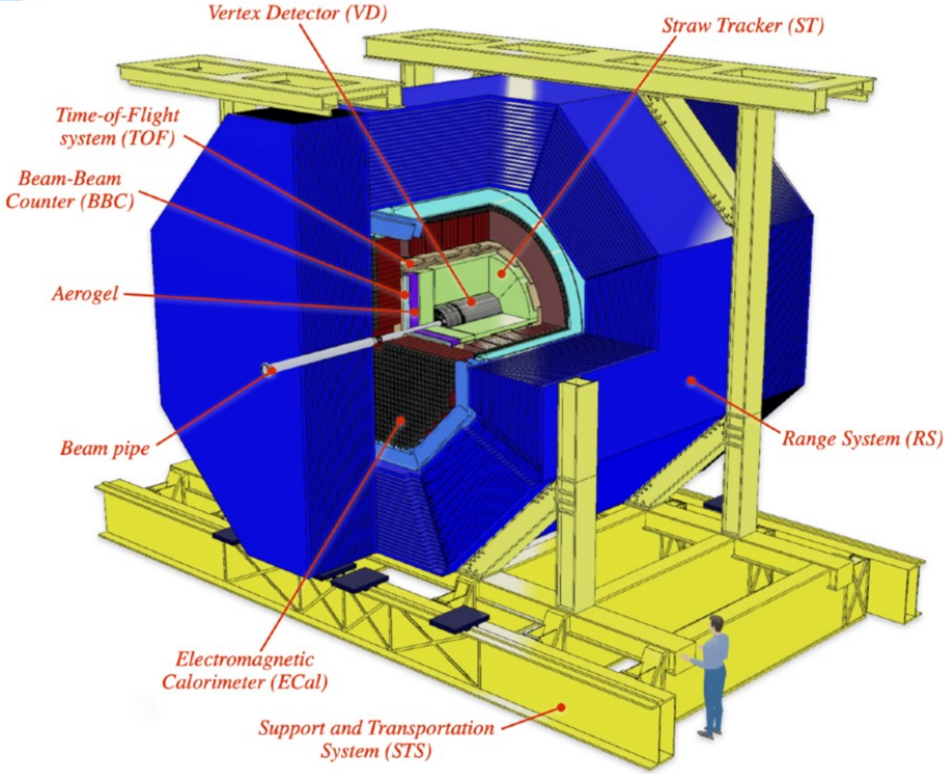
GARFIELD + LTSpice allows to predict straw response for a given readout model.

See S. Nasybulin report at SPD Physics and MC meeting #21: https://indico.jinr.ru/event/2981/contributions/15896/attachments/12139/20276/MagneticInStraw_spice_results.pdf

Motivation:

- 30k+ channels
- 150um spatial resolution
- 8% dE/dX charge resolution
- Simultanious Charge & Time measure

A dedicated R&D is ongoing to study the possibilities for STT Front-End Electronics (FEB) solution.



Test beam setup evotution

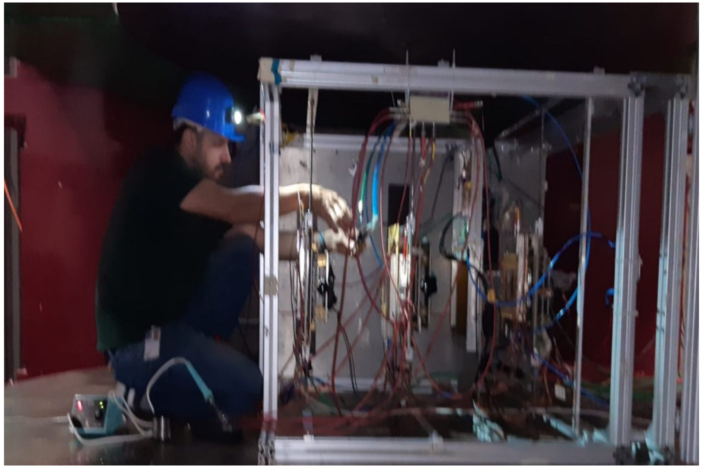
Setup 1

CERN, H4 (Nov 2021)
3 GEMs + straw station
VMM3a readout

Setup 2

CERN, H4 (2022)
4 MMs w/ APV25 readout + straw station w/ VMM3 readout

Setup 3

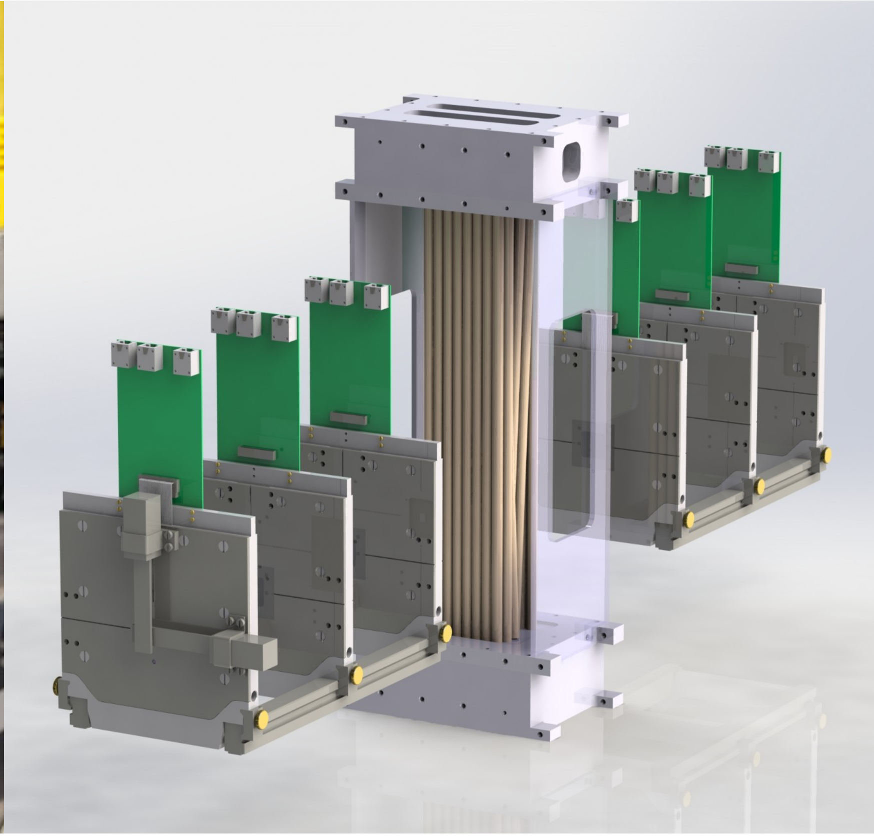


CERN, H8 + H4 (2023)
4MMs + straw station
TIGER readout

+ data taking in magnetic field

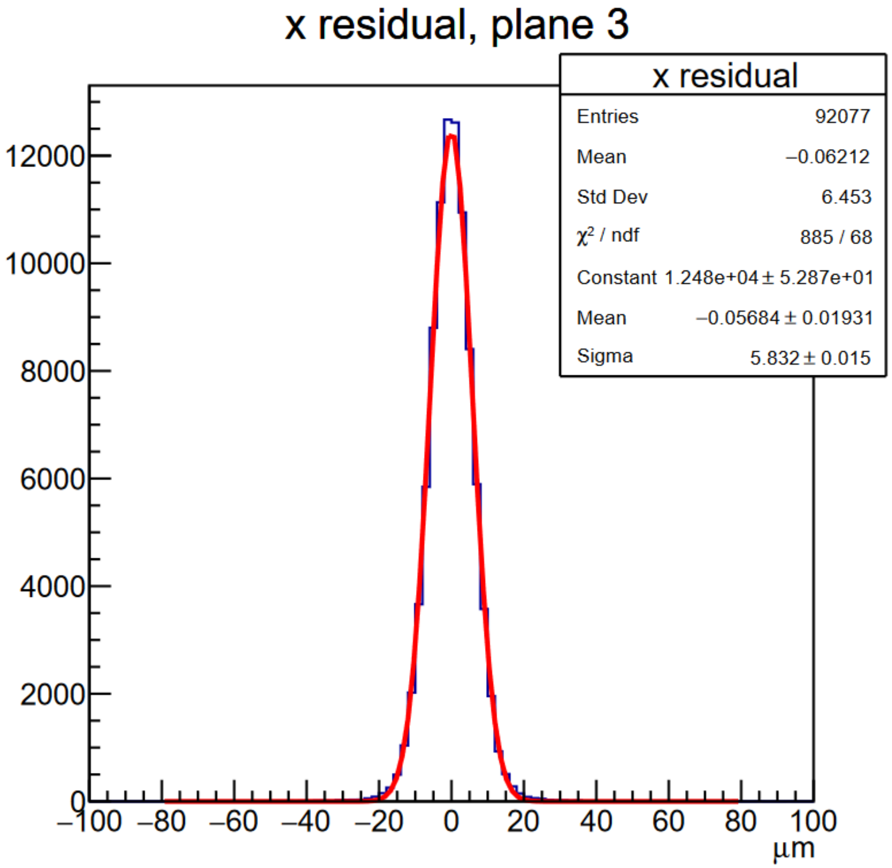
The VMM3a readout option was rejected based on testbeam 2021 results, due to a channel latching logic in Time-of-Threshold readout mode issues.

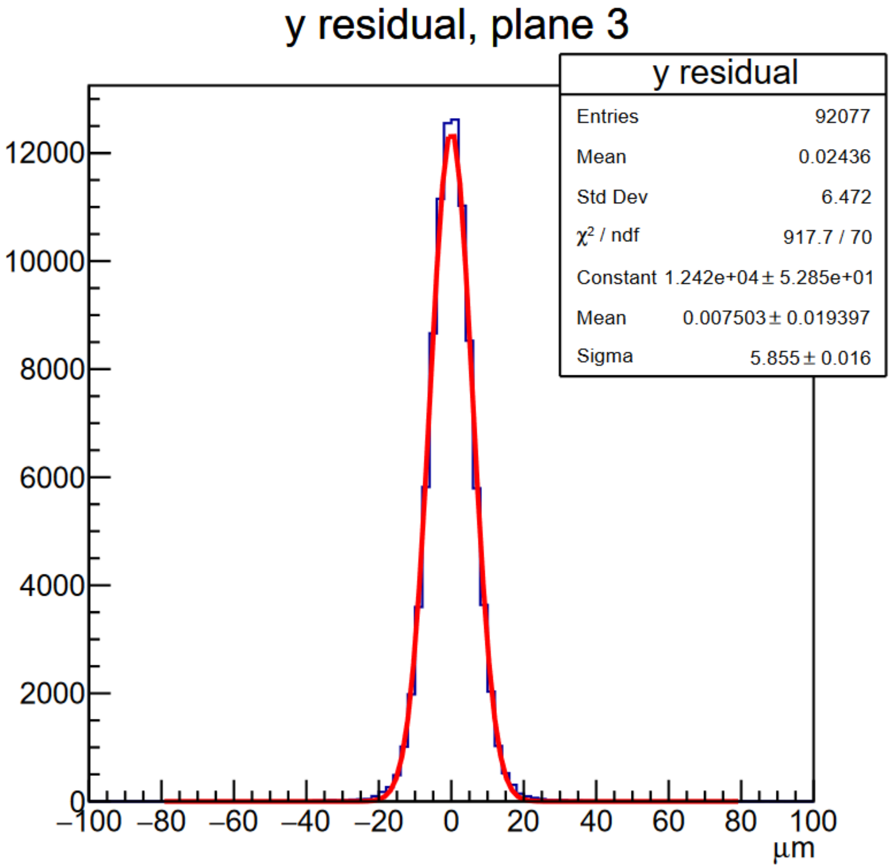
Test beam setup evotution



CERN, H8 + H4 (**2024**)
6x Si planes
VMM / TIGER/ ATLAS ASD readout

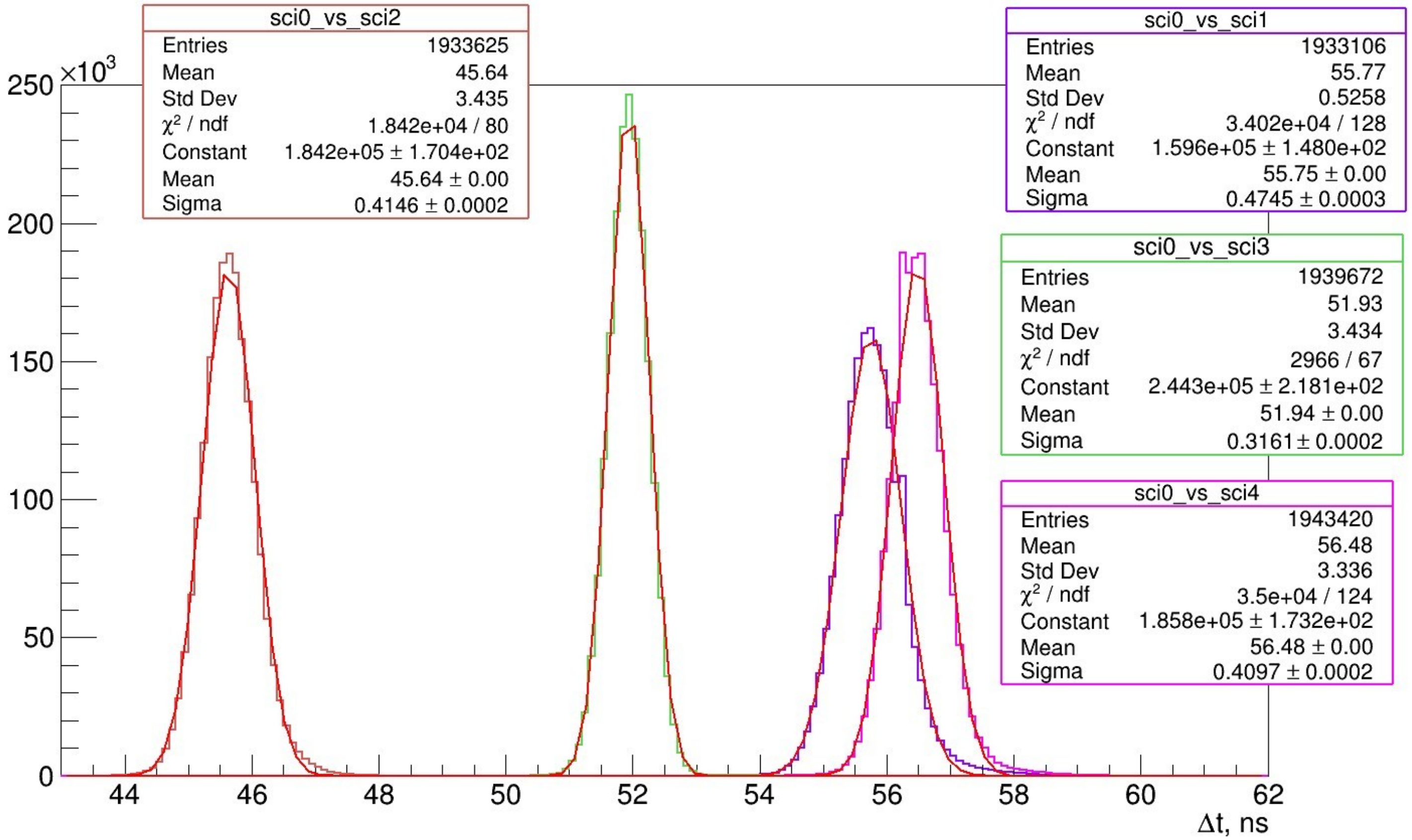
Test beam setup evotution





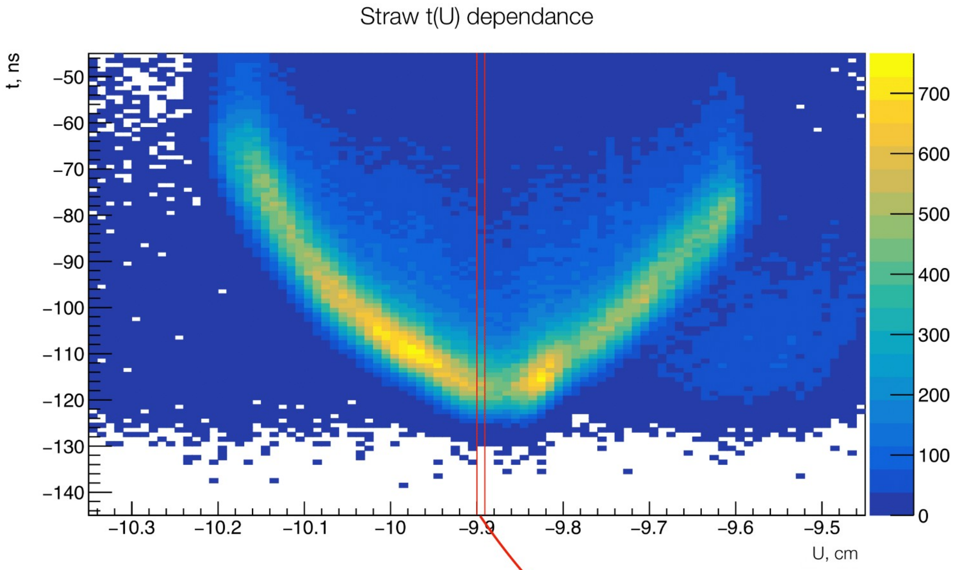
Tracking resolution was significantly improved by using Si-tracker.

Test beam setup evotution



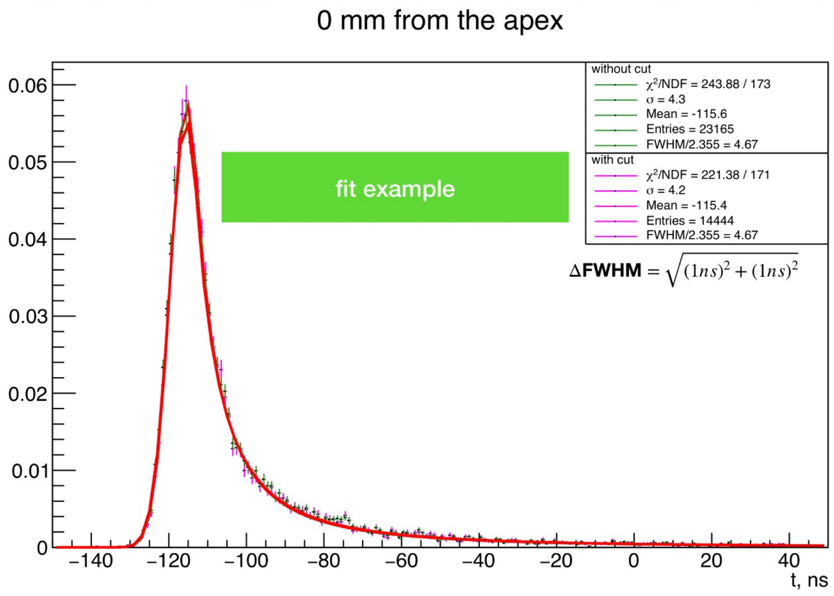
T0 resolution is still better than 1ns with our scintillators

Coordinate resolution as a function of Time resolution



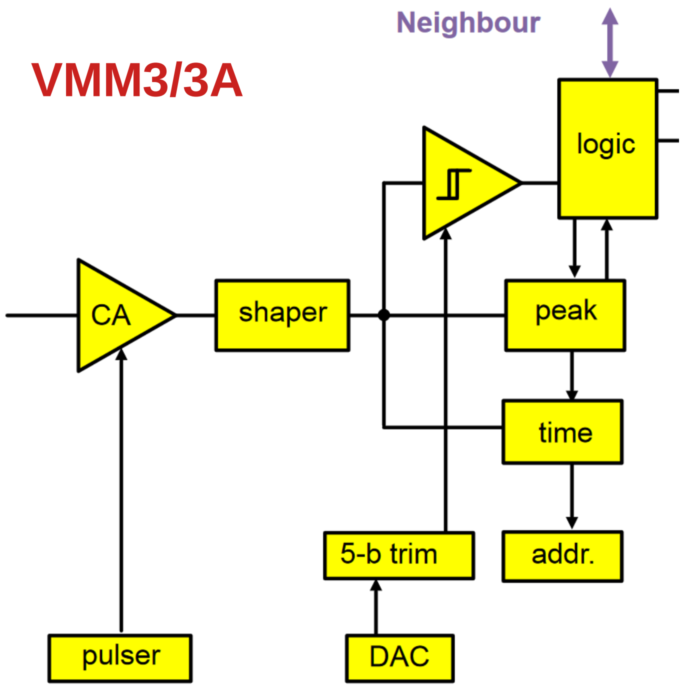
σ_T from the fit associated with Time resolution. The Idea is to obtain the **Spatial** resolution from the **Time** resolution

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



See D. Sosnov report at VIII SPD Collaboration Week tomorrow

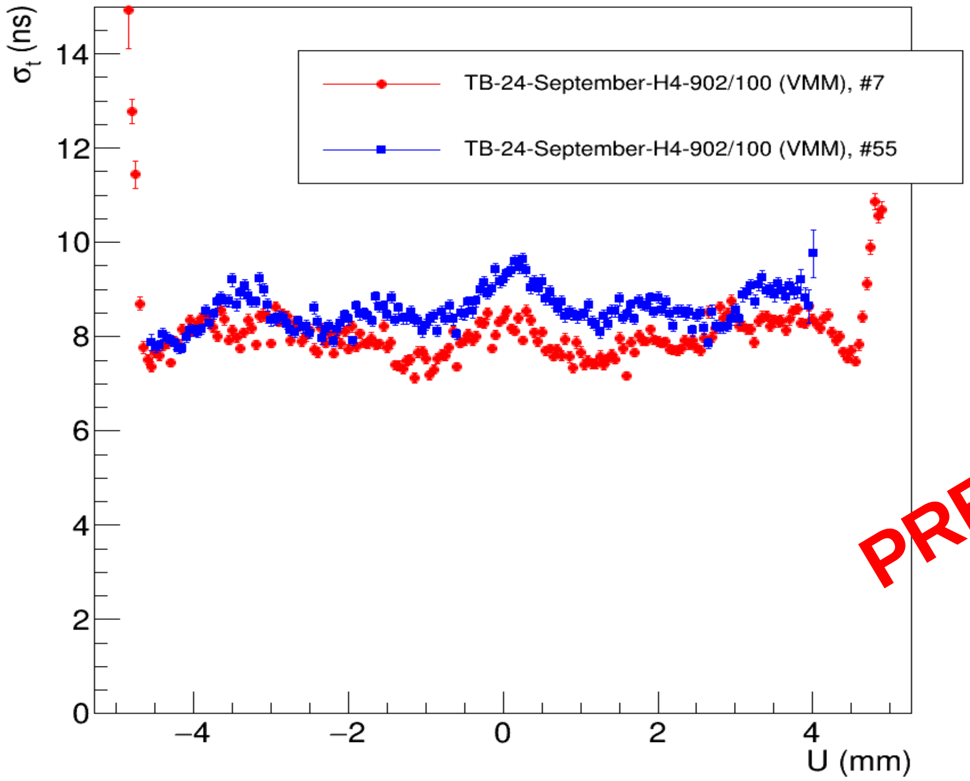
Investigating existing readout solutions

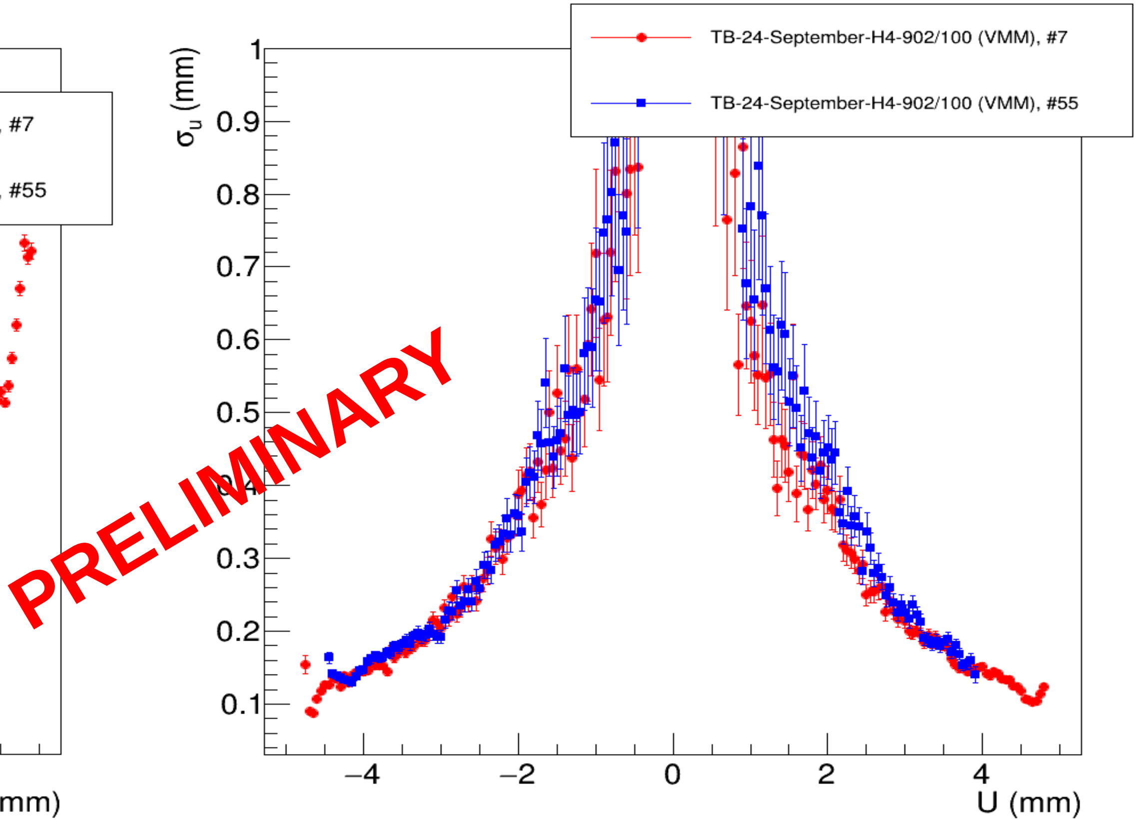


Number of channels	64
Clock frequency	10...80 MHz
Input capacitance	<300 pF
Dynamic range	up to 2 pC
Gain	0.5, 1, 3, 4.5, 6, 9, 12, 16 mV/fC
Peaking time	25 / 50 / 100 / 200 ns
ENC (energy branch)	<3000 e^-
TDC binning	~1 ns
Maximum event rate	140 kHz/ch
Consumption	15 mW/ch

VMM3/3A ASIC is well known chip for gaseous detectors. It has amplifier and shaper adjustable in a wide range. But it was not really done for the timing measurements so fastest shaping is 25ns and ToA mode has some issues.

10mm Straw Resolution

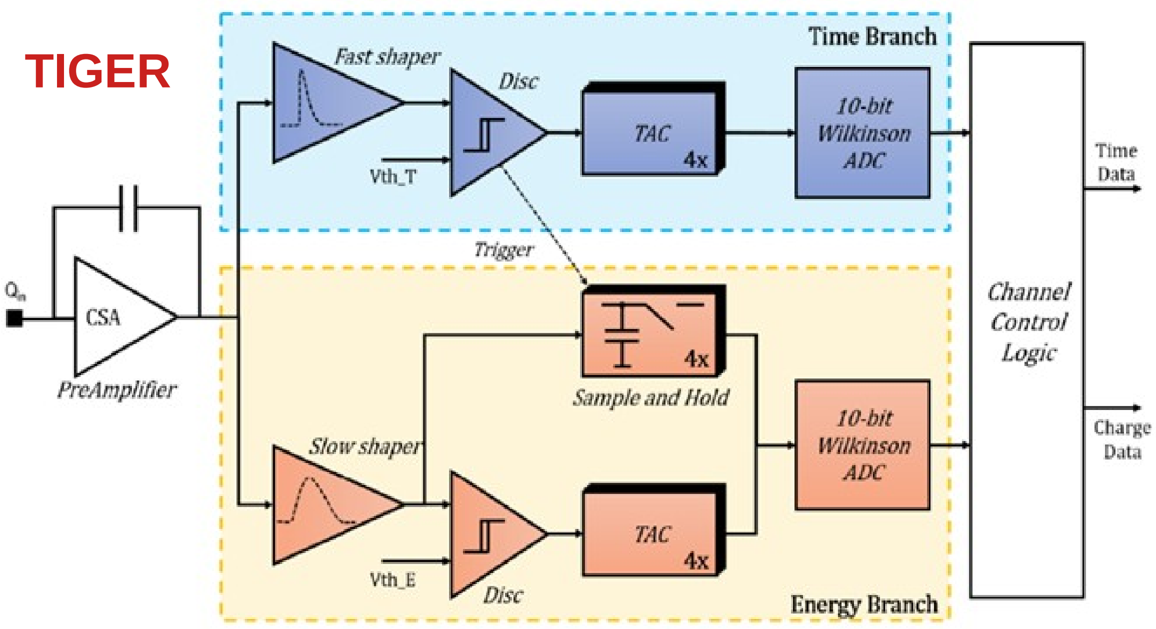




1. The weighted mean of spatial resolution (w/o +/- 1mm area) distribution is **~170 μm**
2. The time 'resolution' is about **8 ns**

Investigating existing readout solutions

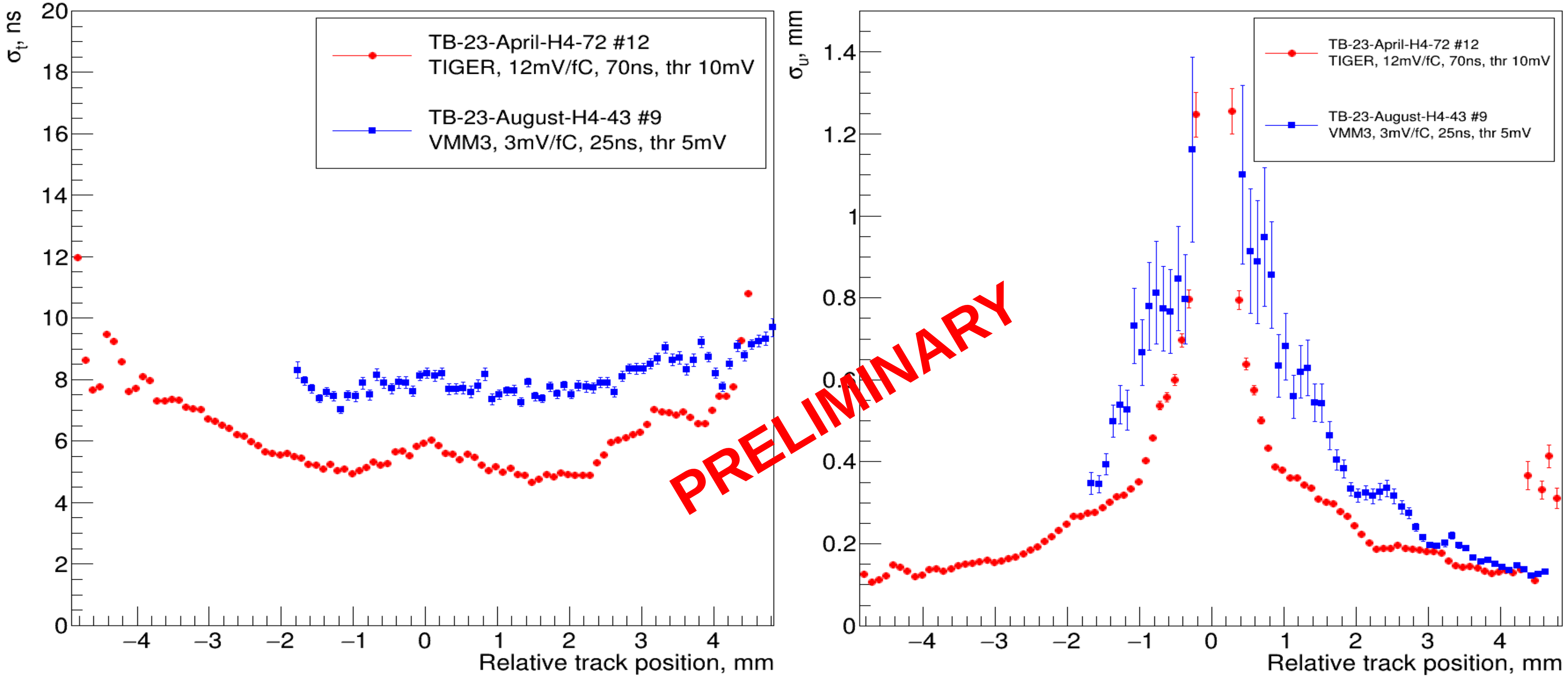
TIGER



Clock frequency	160...200 MHz
Input capacitance	<100 pF
Dynamic range	50 fC
Gain	12 mV/fC
Peaking time	70 / 200 ns
ENC (energy branch)	<1500 e^-
TDC binning	50 ps
Maximum event rate	60 kHz/ch
Consumption	12 mW/ch

TIGER architecture seems to be more reasonable, because of having two different shapers for Time and Energy measurements. Two threshold levels are also possible.

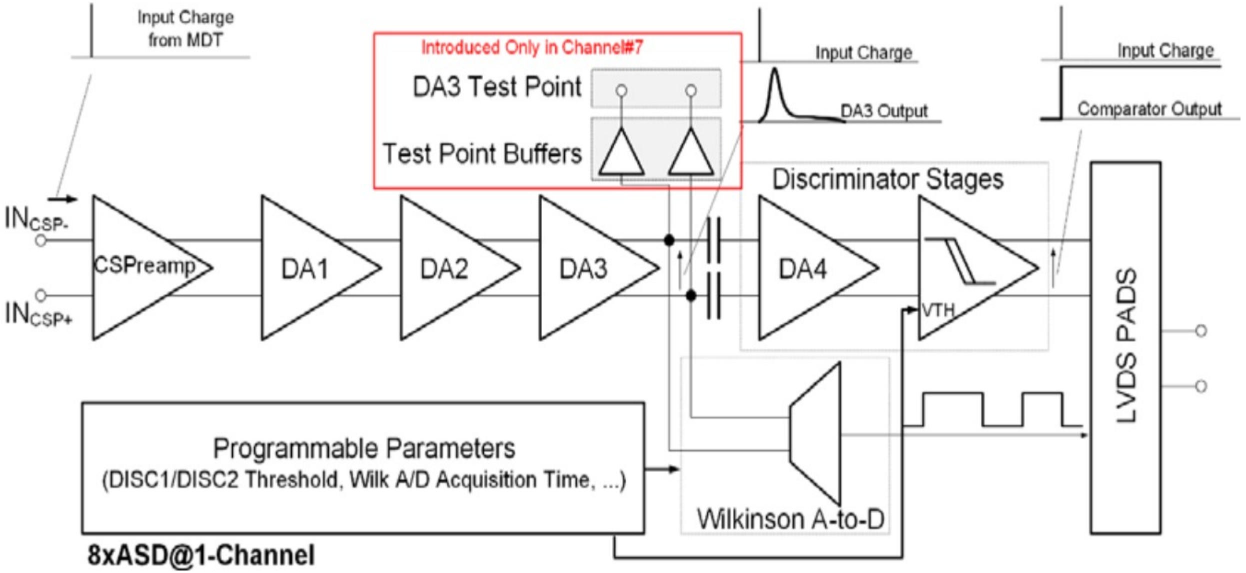
10mm Straw Resolution



1. The weighted mean of spatial resolution (w/o +/- 1mm area) distribution is **150 µm**!
2. The time ‘resolution’ is about **6 ns**!

Investigating existing readout solutions

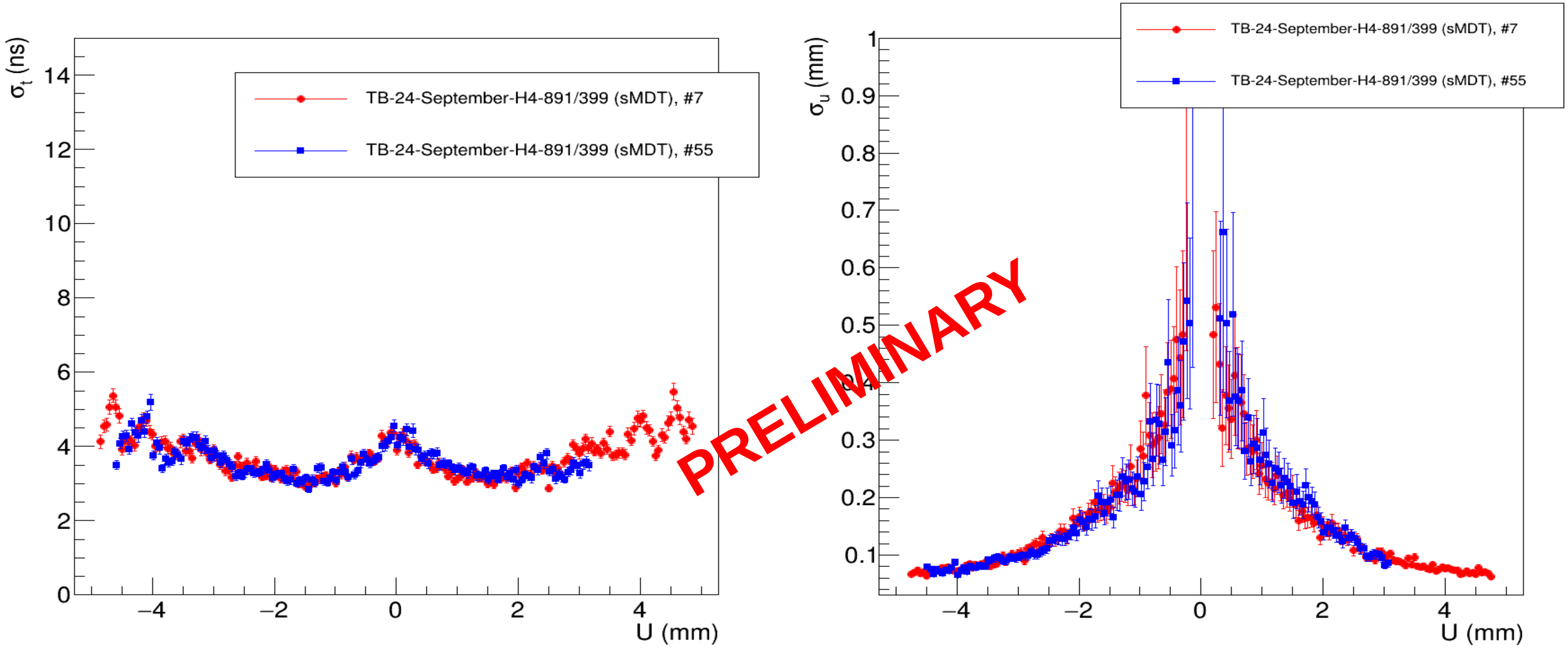
ATLAS sMDT ASD2



Number of channels	64
Clock frequency	---
Input capacitance	< 100 pF
Dynamic range	up to 200 fC
Gain	9 mV/fC
Peaking time	15ns
ENC (energy branch)	< 6000 e^-
TDC binning	**~800 ps**
Maximum event rate	**~400 kHz**
Consumption	**50 mW/ch**

ATLAS sMDT ASD2 chip is the closest solution for the tracker from analog point of view. It has fastest shaping time and good gain. It is capable for the simultanious charge measurements as well. But the resolution with that shaping time is to be studied.

10mm Straw Resolution



1. The weighted mean of spatial resolution (w/o +/- 1mm area) distribution is **<100 μm**!
2. The time 'resolution' is about **4 ns**!

Summary table of SPD Straw Tracker parameters

Detector type	barrel	end-cap
Detector tasks	dE/dx	xy coordinates, dE/dx
Working mode	triggerless	triggerless
Detector inner diameter, mm	540	
Detector outer diameter, mm	1700	
Number of layers	30 (double layer)	2x, 2y, 2u, 2v
Number of stations, sections	8 sections	12 stations
Number of channels	32288	8192
Tube diameter, mm	10	10
Maximum tube length, mm	2400	1700
Central core diameter, mm	0.03	0.03
Maximum detector capacitance, pF	26	18,5
Gas detector	70 Argon, 30 CO_2	70 Argon, 30 CO_2
Operating voltage, V	+1650	+1650
Multiplication factor, HV=1750	4.5E4	4.5E4
Charge from the first electron, fC	7.7	7.7
Electron drift velocity, μm/ns	65	65
Electron drift time, ns	120	120
Ion drift time, μs	100	100
Spectral resolution, μm	150	150
Maximum load, kHz per tube	150	

See A. Solin report at SPD Coll. Meeting: https://indico.jinr.ru/event/3189/contributions/17520/attachments/13230/22121/14_Development%20of%20an%20ASIC%20for%20straw%20and%20micromegas%20detectors%20of%20the%20NICA-SPD.pdf