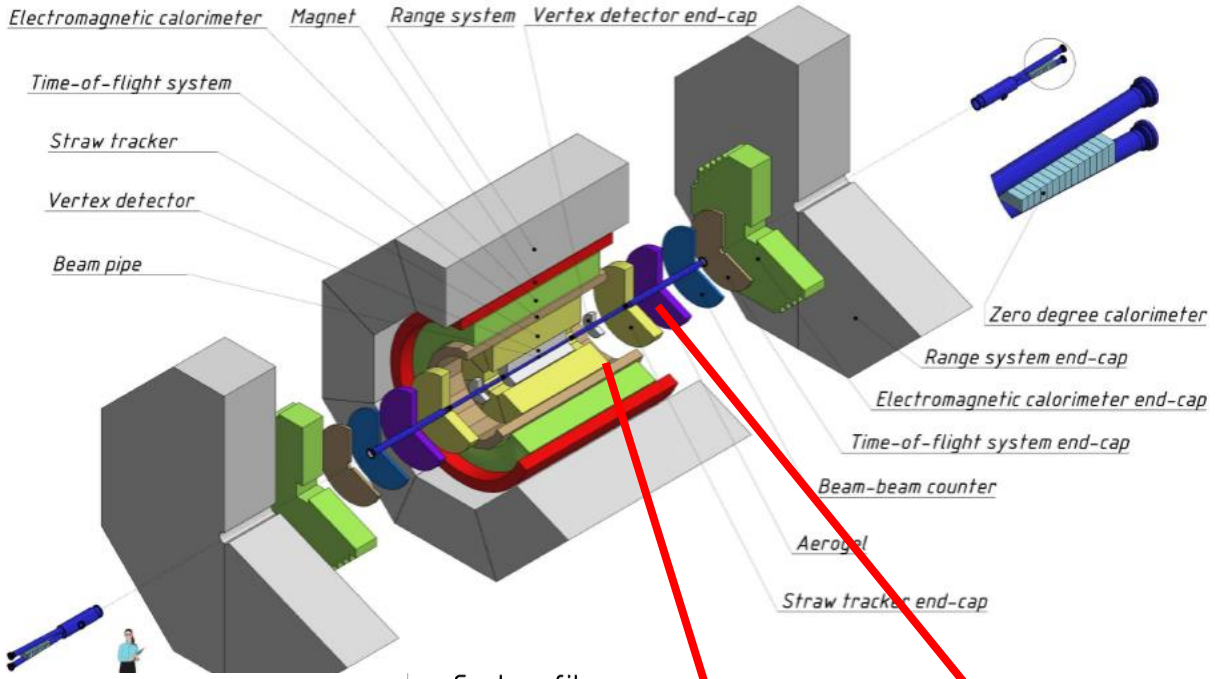
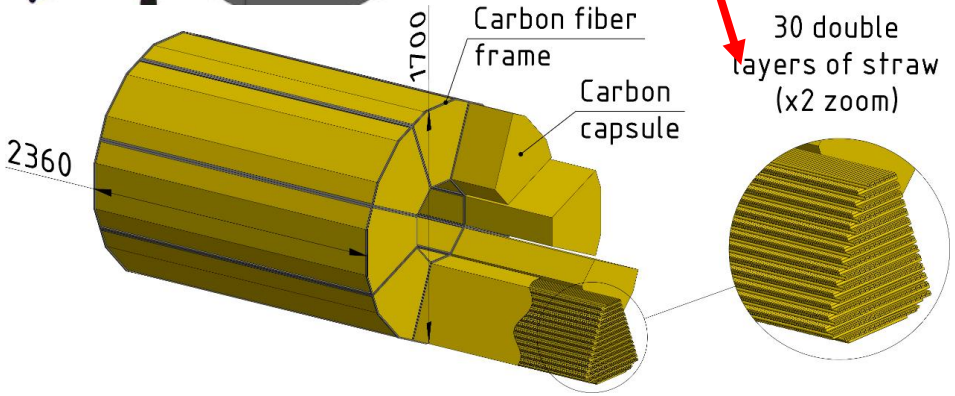
Straw Tracker of the future Spin Physics Detector at NICA collider

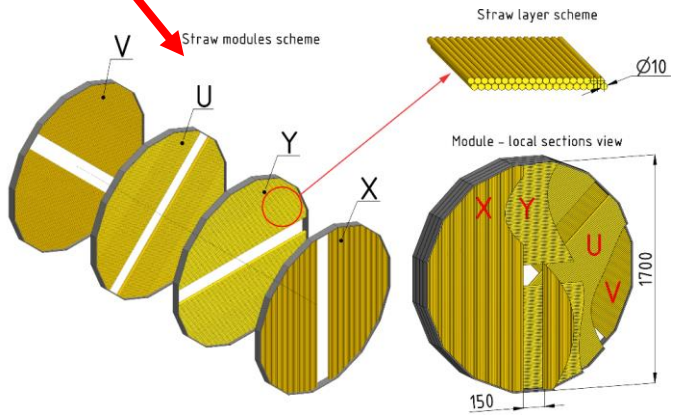
Temur Enik on behalf of SPD collaboration

TIPP 2023

Spin Physics Detector



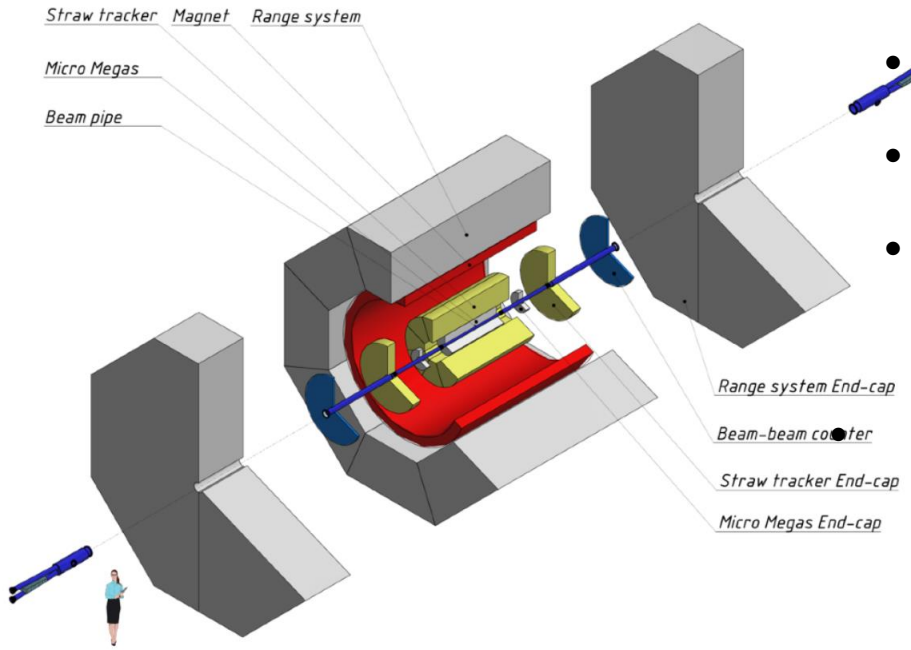




- Straw Tracker - the main tracking system of SPD
- Straw diameter: 10mm thickness 36um PET
- Expected spatial resolution of 150um
- Barrel is made of 8 modules with up to 30 double-layers, with the ZUV orientation (0^0,$+3^0$,-3^0)
- Endcaps are made of 12 double-layers with the XYUV orientation(0^0,90^0,$+45^0$,-45^0)

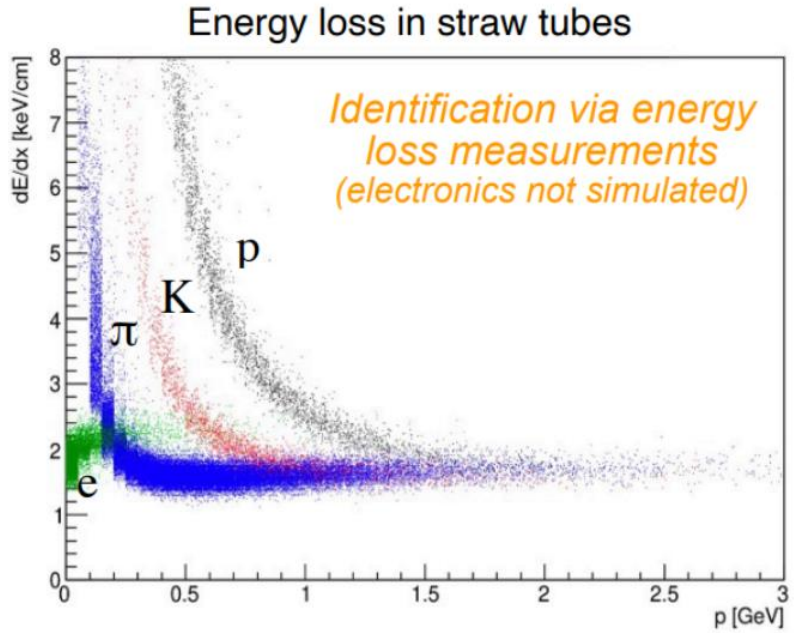
Straw Tracker requirements

- Nominal operation conditions (from 2030):
- p-beam: $\sqrt{s}$=27 GeV, L=10^{32} Hz/cm^2 with interaction rate of ~3 MHz
- Good momentum resolution in the magnetic field – spatial resolution of ~150 um
- More details: slides by A. Korzenev

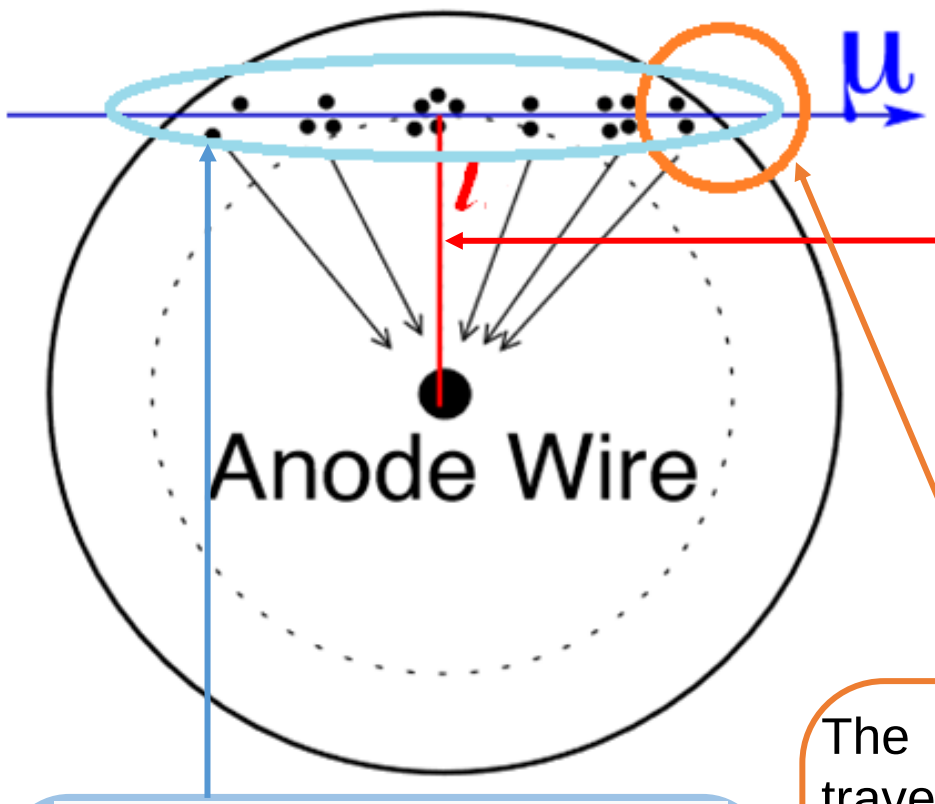


- **Stage1**: 2028-2030:
- p-beam: $\sqrt{s}$<15 GeV, L=10^{30} Hz/cm^2
- **BUT**:
  - Micromegas central tracking
  - No PID, no ECAL
  - **=> PID with**

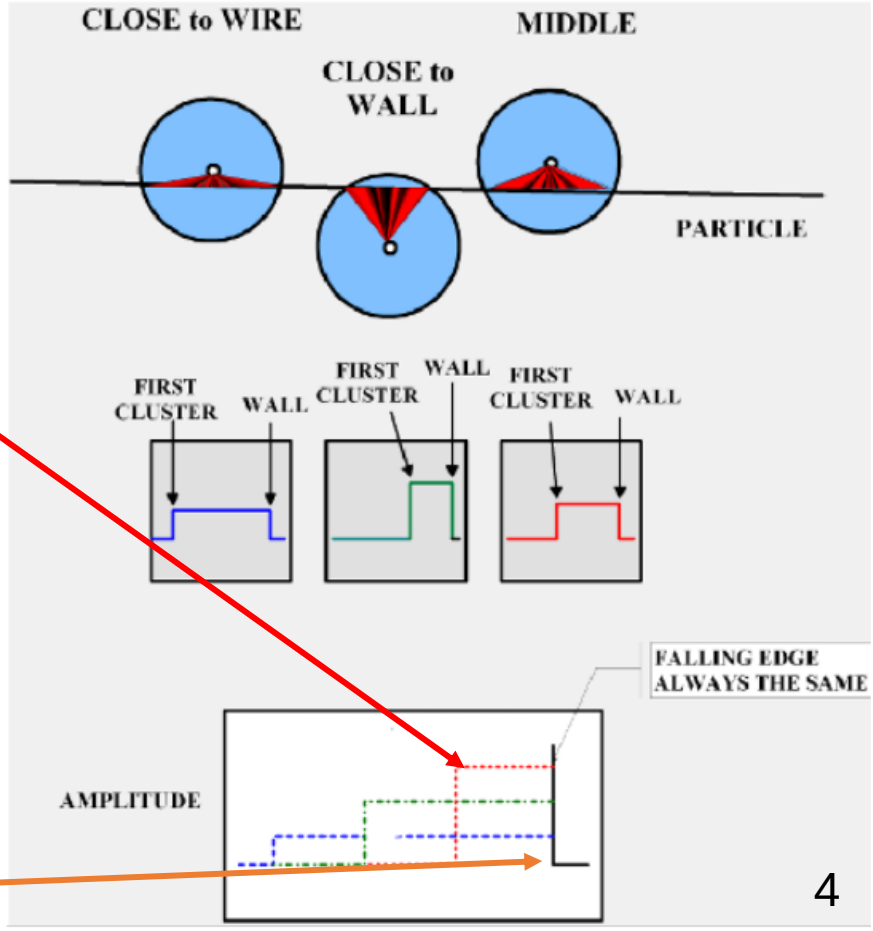
    the straw tracker



Straw detection principle



An ionizing particle passes at the distance ***l*** from the anode wire and creates primary ionization clusters along its path. The primary electrons drift towards the anode wire where the avalanche amplification occurs. Distance ***l*** is defined by the drift time of the primary electron i.e. by the rising edge of the signal



Straws operate in the proportional mode, so the total charge ***q*** of the iduced signal is proportional to the ionization energy loses dE/dx and may serve PID

The time when the particle traversed the straw, ***t0***, can be provided by an external detector or defined by the drift time of the last primary electron arriving to the anode, i.e. by the falling edge of the signal

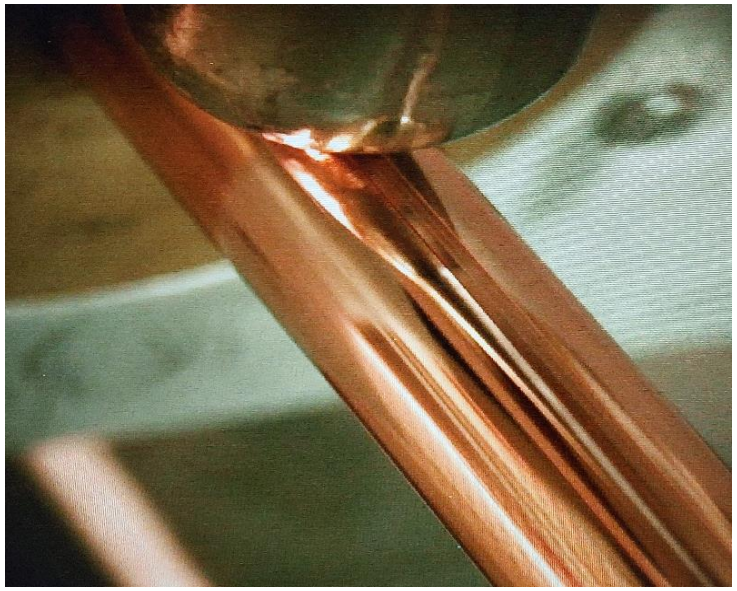
STRAW PRODUCTION

Winding

- Production speed: 1 m/min
- Maximal length: 5.5 m
- Diameters: 2,4,6,10,20 mm
- Wall thickness: 70+ um

Ultrasonic welding

- Production speed: 1 m/min
- Maximal length: 5.5 m
- Diameters: 5,10,20 mm
- Wall thickness: 15, 20, 36, 50 um



both of these technologies are well developed at JINR

STRAW TRACKER ARE USING OF IN THE DIFFEREN EXPERIMET

Straw winding

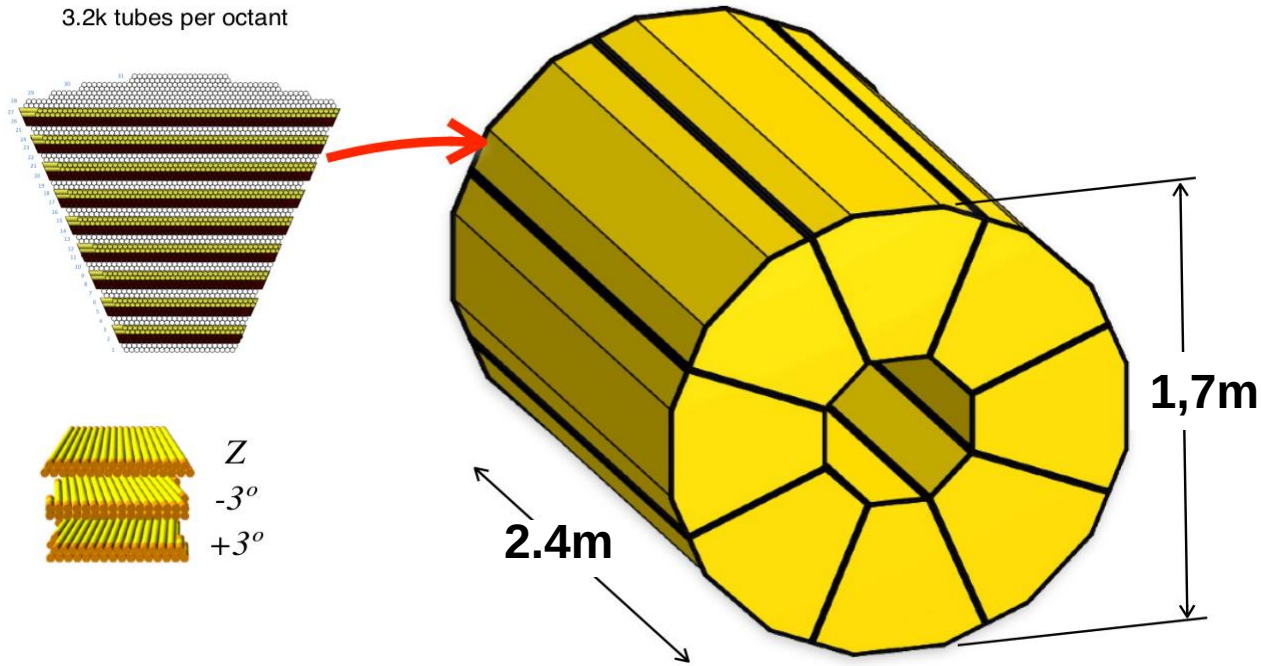
- ATLAS
- LHCb
- PANDA
- CBM
- COMPASS
- Mu2e
- NA64
- SVD-2
- GLUEX
- COZY-TOF
- ..

Straw welding

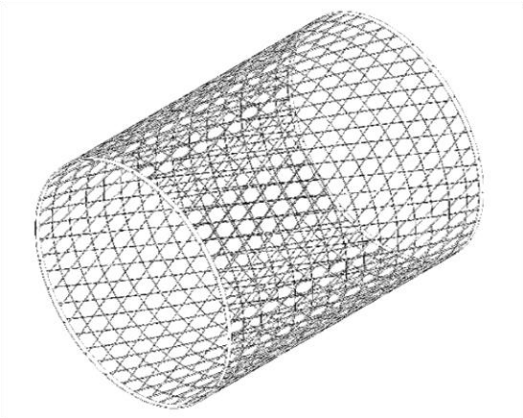
- NA62
- COMET
- SHiP
- DUNE
- SPD NICA
- ,,

red color- straw tracker created with our participation

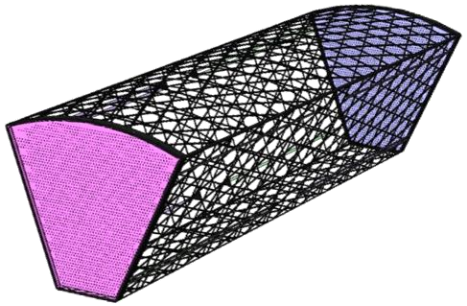
Barrel Straw Tracker



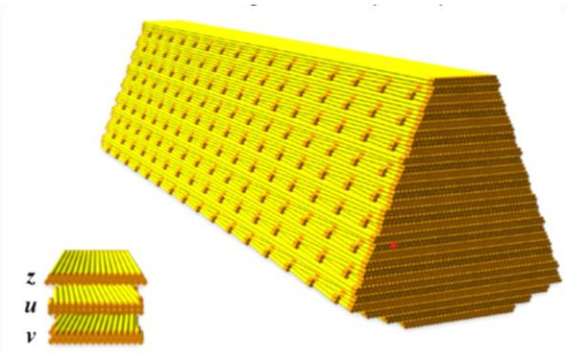
- the frame of the 8 octants is made of carbon fiber construction
- the cross section of hydrocarbon threads is different, but in average about 8 mm^2
- the use of material that allows you to permanently preserve the geometry



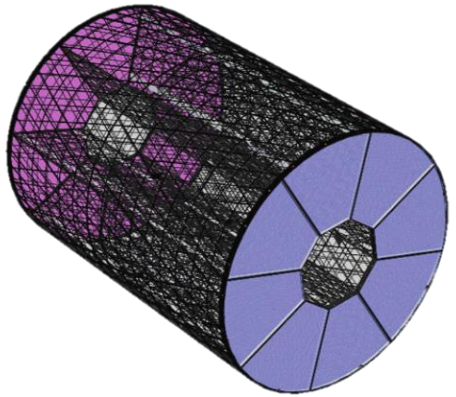
22 kg



8x11 kg



60 kg



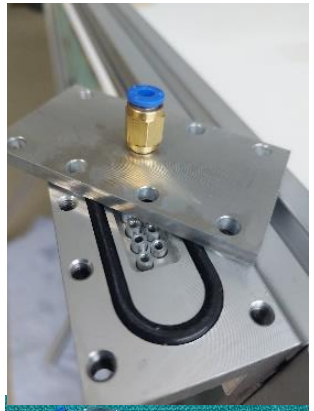
Total 170 kg

Material tests and prototyping

Component and assembly tests

- Foil tests, wire test
- Crimping: anode pins, crimpers
- Straw end-plugs
- Adhesives and sealing





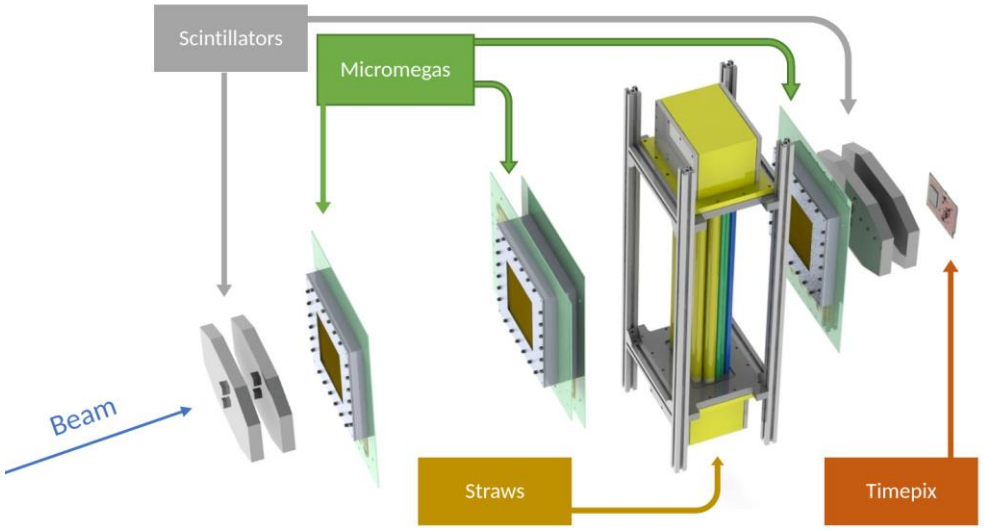

First prototypes:

- General R&D – straws of different metallization and diameter 5 (Dune, Hike), 10 (SPD, NA62) and 20 (SHiP) mm => 110 straws
- ZUV (~110 straws) - ongoing




Test beam activity within the general Straw Tracker R&D

Ongoing from year 2021



Current configuration:
Reference tracking:

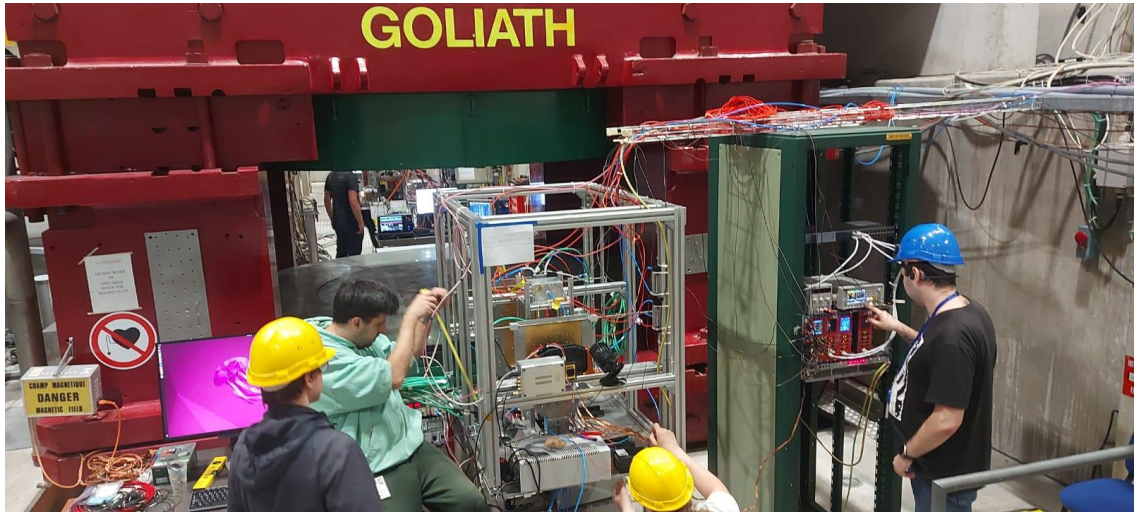
- MicroMegas (250 um) + Tiger readout (Torino University)

- Timepix4 – 50um x 50um

Goals:

- explore the existing readout possibilities (ASICs)
- if no solution exists,
  define the requirements for new ASIC development
- test the combined straw tracker prototype

ASICs tested:



- **VMM3a** in Time-at-Threshold mode (discarded after testing, see Proceedings to PM2021, NIM.A 1047 (2023) 167864)

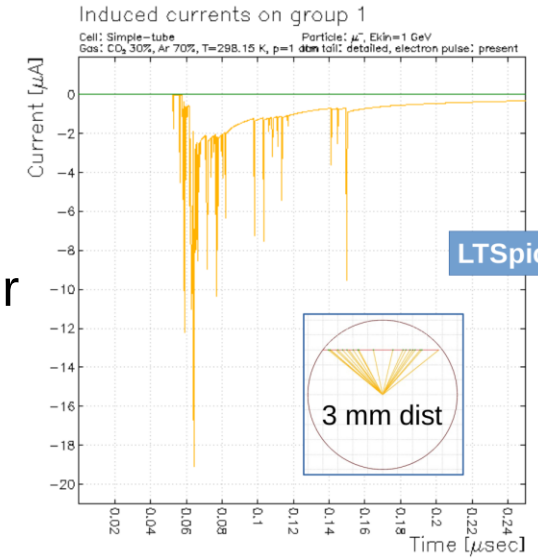
-**Tiger** (talk by V.Bautin at TIPP2023)

- **VMM3**

Straw response simulation – validation with experimental data

SPD straw - bare GARFIELD

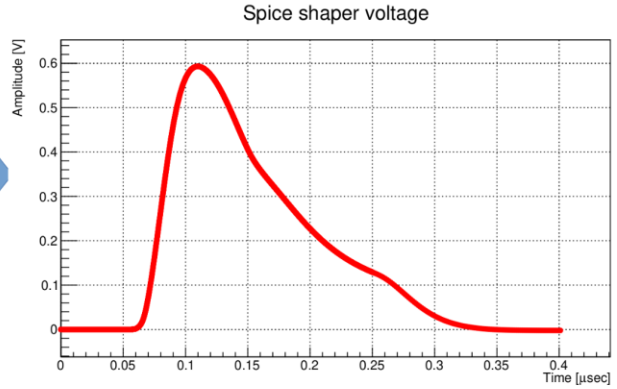
SPD straw geometry/gas are the same as of the NA62 Straw Tracker



GARFIELD output interfaced to LTSpice (read-out emulation)

We assume VMM3a-based readout

LTSpice



*We are grateful to **RD51 collaboration** for sharing the electronic circuit*

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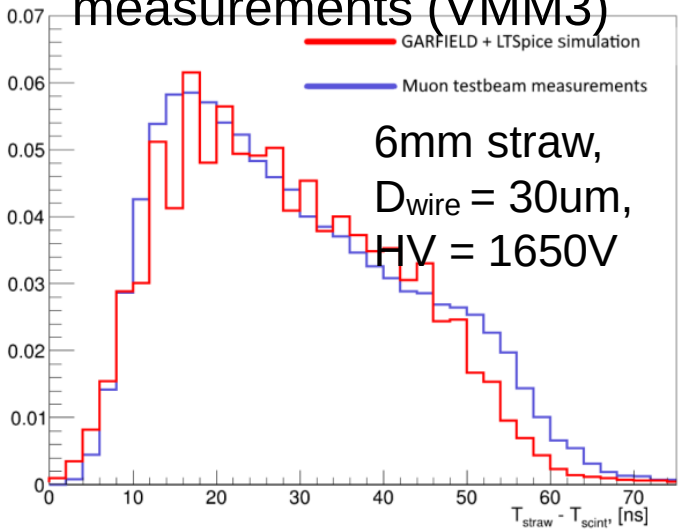
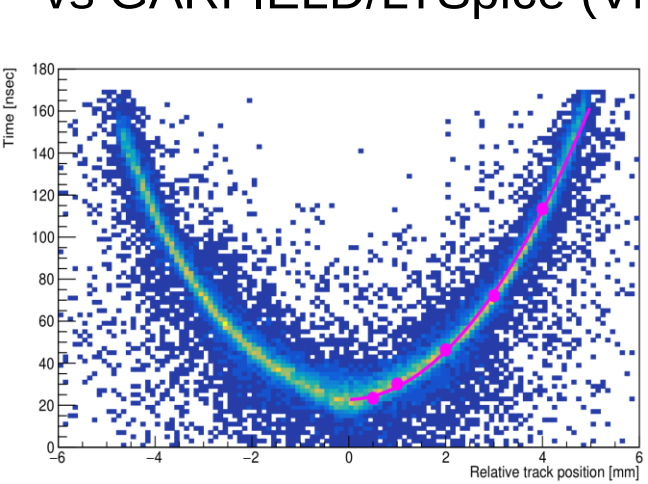
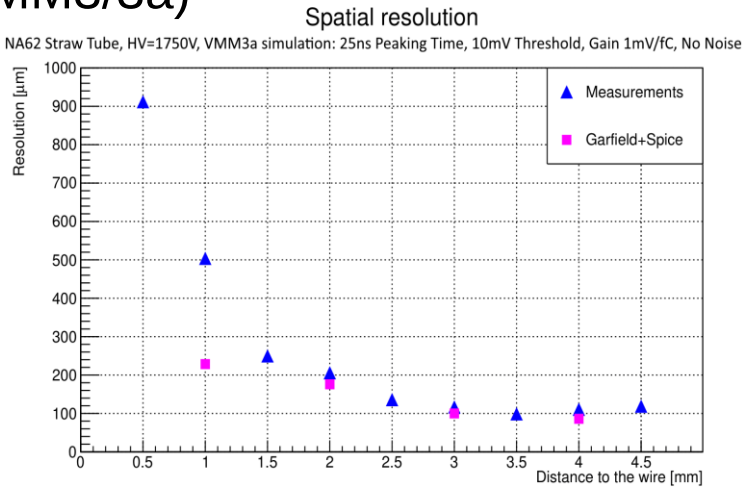
Validation:

GARFIELD/LTSpice (VMM3/3a) vs test beam measurements (VMM3)



Validation: NA62 measurements (CARIOCA) vs GARFIELD/LTSpice (VMM3/3a)

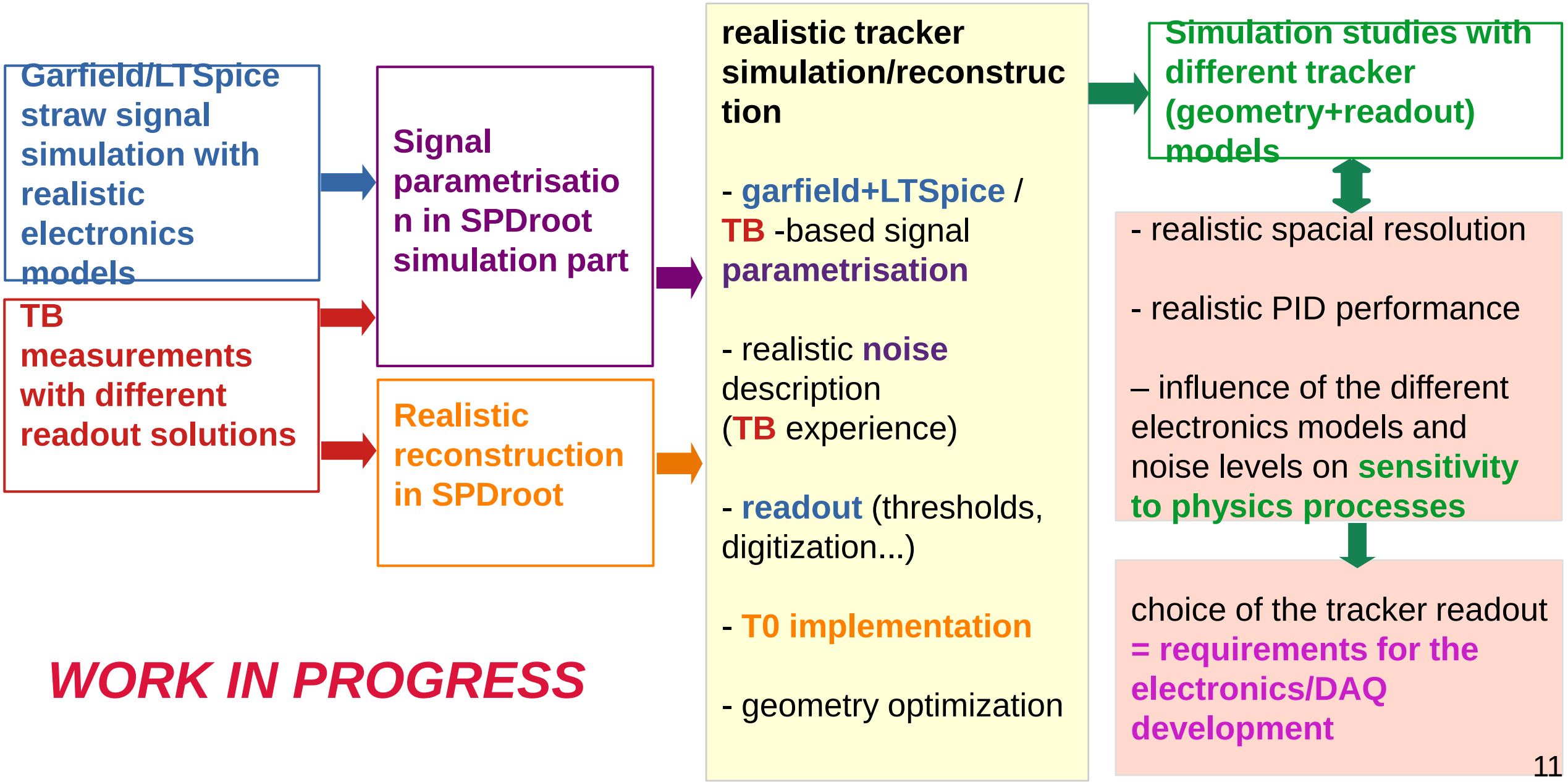




GARFIELD/LTSpice simulation validated with the test beam measurements allows to

- Predict performance of any new straw readout under development
- Provide input for the developing realistic simulation of the SPD Straw Tracker

Realistic simulation of the SPD Straw Tracker



WORK IN PROGRESS

CONCLUSION

- ✓ Active phase of the SPD Straw Tracker R&D is ongoing in many directions such as the detector construction optimization, engineering, prototyping, development of the readout electronics concepts and work on simulation and reconstruction software
- ✓ The activity is based on the experience of the operating and developing Straw Trackers (NA62, DUNE,…)
- ✓ R&D on the design of the supporting frame is ongoing aiming to reduce the material budget preserving the construction redundancy and maintenance flexibility
- ✓ SPD Stage 1 has more moderate requirements to the Straw Tracker hit rate capabilities, but is very challenging due to the requirements to combine good tracking and particle identification functions
- ✓ SPD Straw Tracker development profits from the ongoing general Straw Tracker R&D for the front-end electronics solutions. It has been shown that the existing options like VMM3a and TIGER can not be used out of the box for the straw readout with simultaneous time and charge measurements. The results obtained in the lab and test beam measurements allow to formulate requirements to the future ASIC development
- ✓ Complementary to the lab and test beam studies, simulation of straw detector performance based on Garfield++ and LTSpice software is under development. This approach will provide an appropriate tool for the SPD Straw Tracker design optimization and for optimization of the readout electronics concept

Thanks for your attention