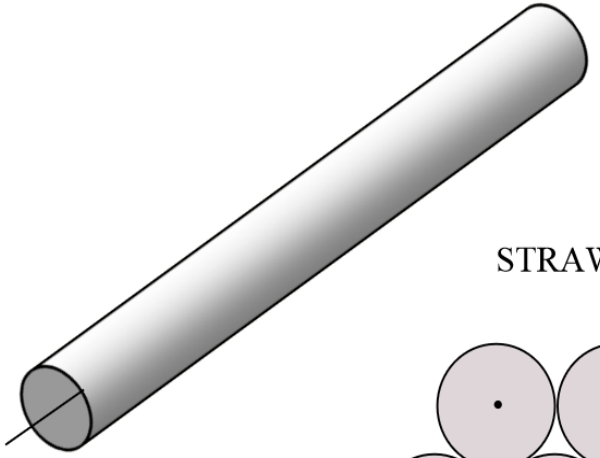
Straw Technologies and Perspectives

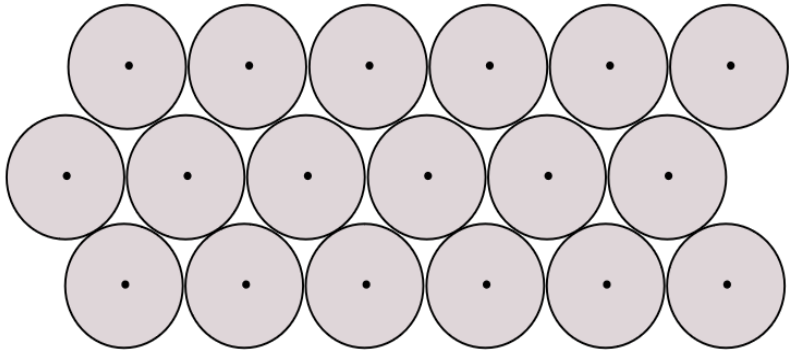
Temur Enik
on behalf the StrawTrackerR&D Team

WHAT IS STRAW TRACKERS?

- Sort of proportional drift tube
  - Tracking detector
- Difference
  - Low material budget
  - Smaller in diameter (2-10 mm)
  - Large number of detector elements crossed by particle
  - Can be used also for particle identification (TRT)
  - (tuned to sustain high particle rate)



STRAWS ARRAYS:



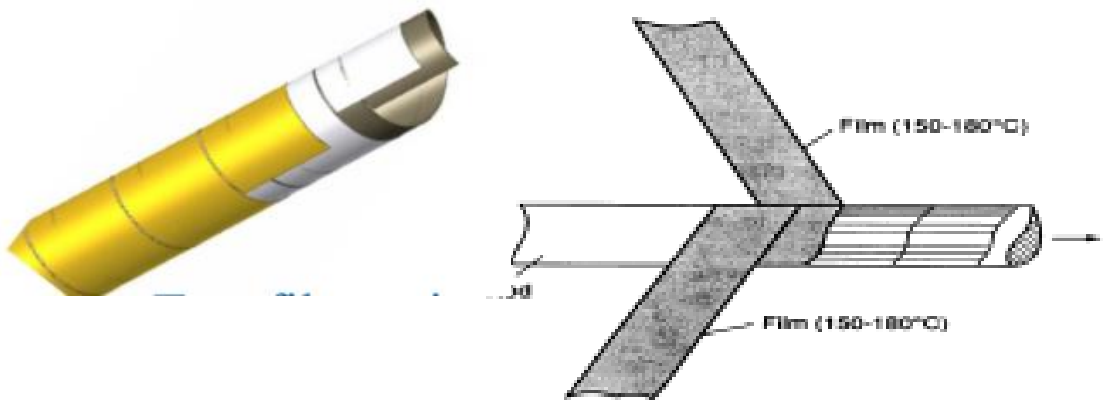
Large area straw tracker:

+ small material budged (minimal multiple scattering)
+ large area acceptance (unreachable for Si trackers)

sometimes

+ operation in vacuum (reliability + negligible leak rate)
+ operation in magnetic fields
+ ionization losses (dE/dx) allowing particle identification (thanks to proportional mode)
- limitations: rate capability – depends on the straw length, diameter, gas mixture,...

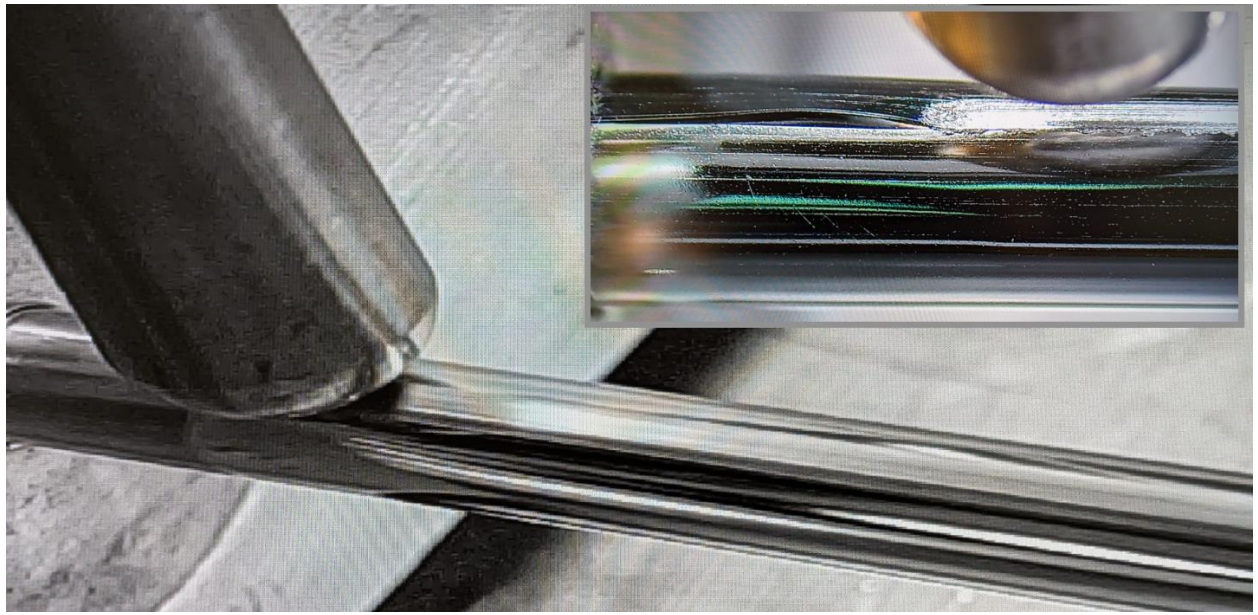
Two technologies of the straw-tube production

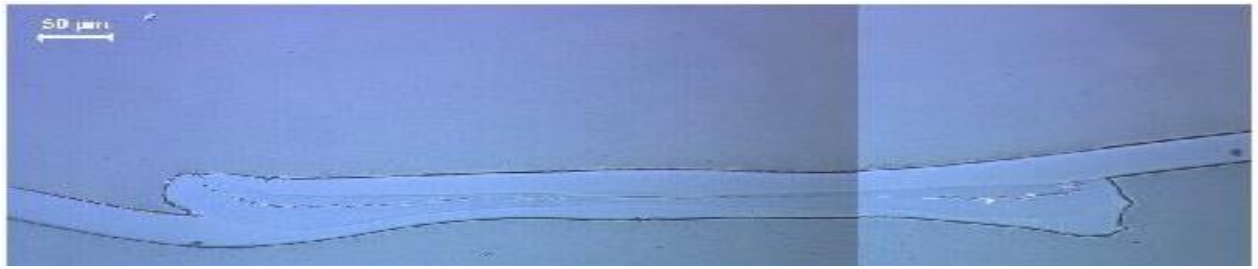


Straw winding

Two films revolve and stick together among themselves. Also industrially produced by Lamina

straw diameter from 2 mm to 18 mm





Ultrasonic welding

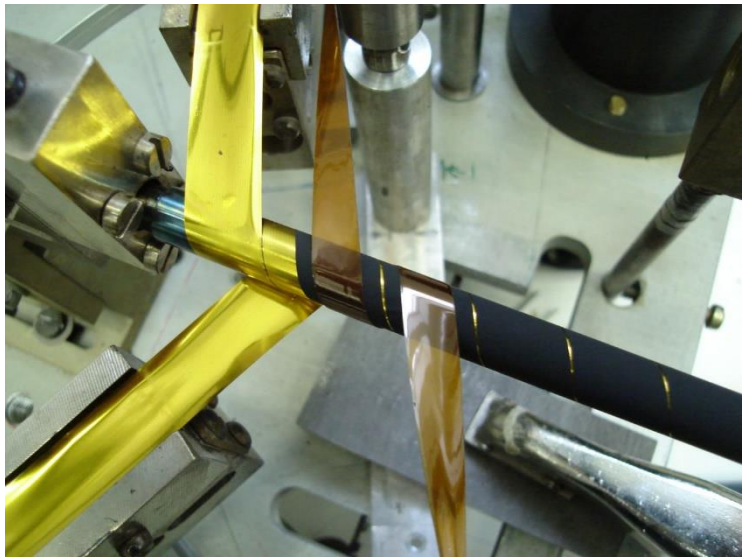
Single film is rolled into a tube and the overlapped edges are welded together

straw diameter from 5 mm to 20 mm

Production

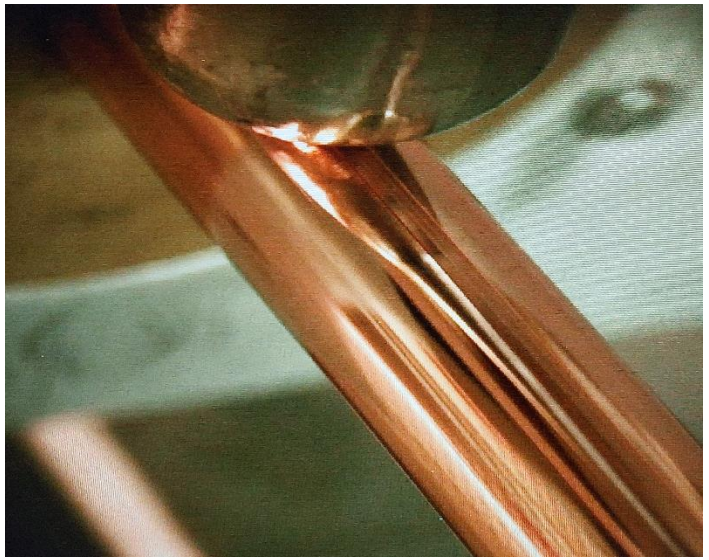
STRAW winding

- Production- 1m/мin
- Lenth- 5.5m
- Diameter-2,4,6, 10, 20mm
- Wall thickness-15+ um



STRAW welding

- Production- 1m/мin
- Lenth- 5.5m
- Diameter-от 5, 10, 20mm
- Wall thickness-12+ um



The straw trackers in the different experiments

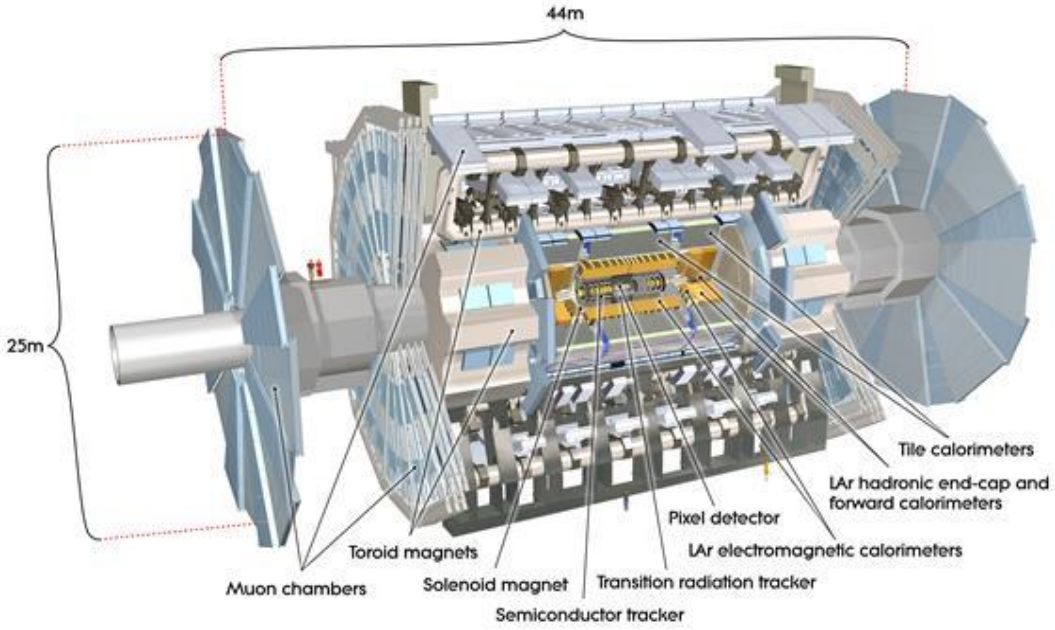
Straw winding

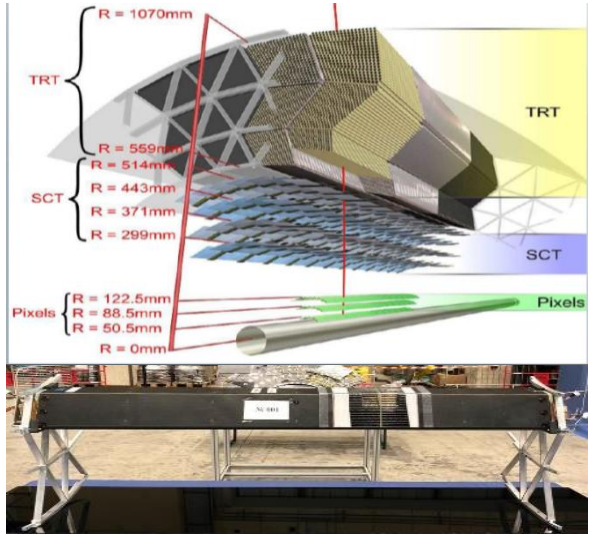
- ATLAS
- LHCb
- COMPASS
- COZY-TOF
- NA64
- Mu2e
- PANDA
- CBM
- SVD-2
- …

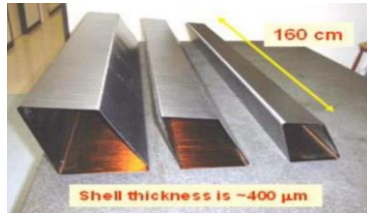
Straw welding

- NA62
- COMET
- SHiP
- DUNE
- SPD NICA
- …

ATLAS TRT (CERN, Geneva)

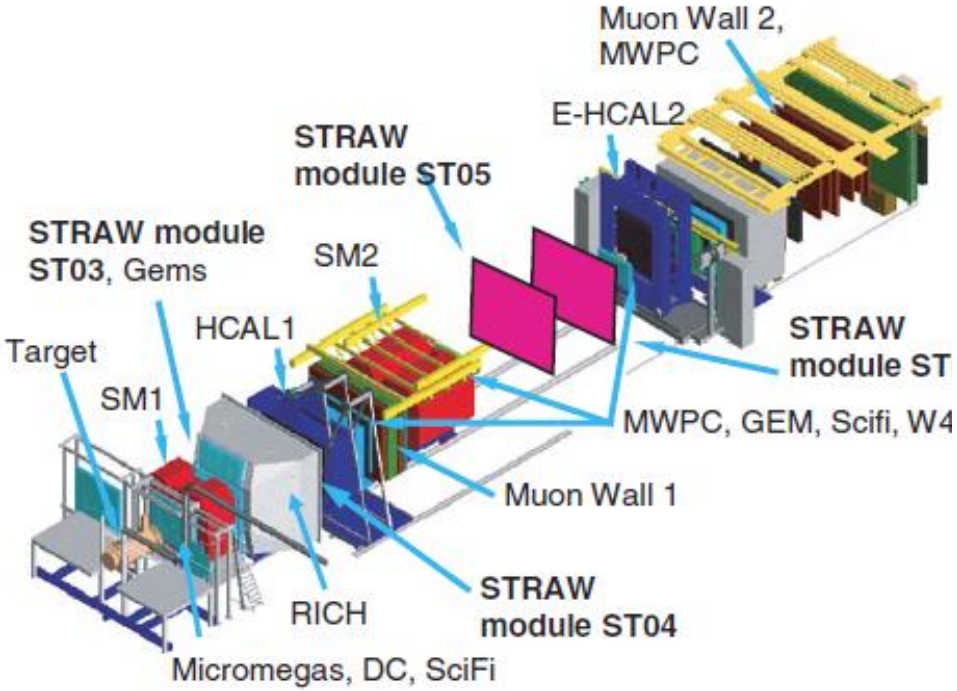






- 350,000 read-out channels
- Volume: 12m^3
- Straw diameter: 4mm diameter, 30um gold-plated tungsten wire
- 50,000 straws in Barrel, each straw 144 cm long. The ends of a straw are read out separately
- 250,000 straws in both endcaps, each straw 39 cm long
- Resolution of 170 um

COMPASS (CERN,Geneva)



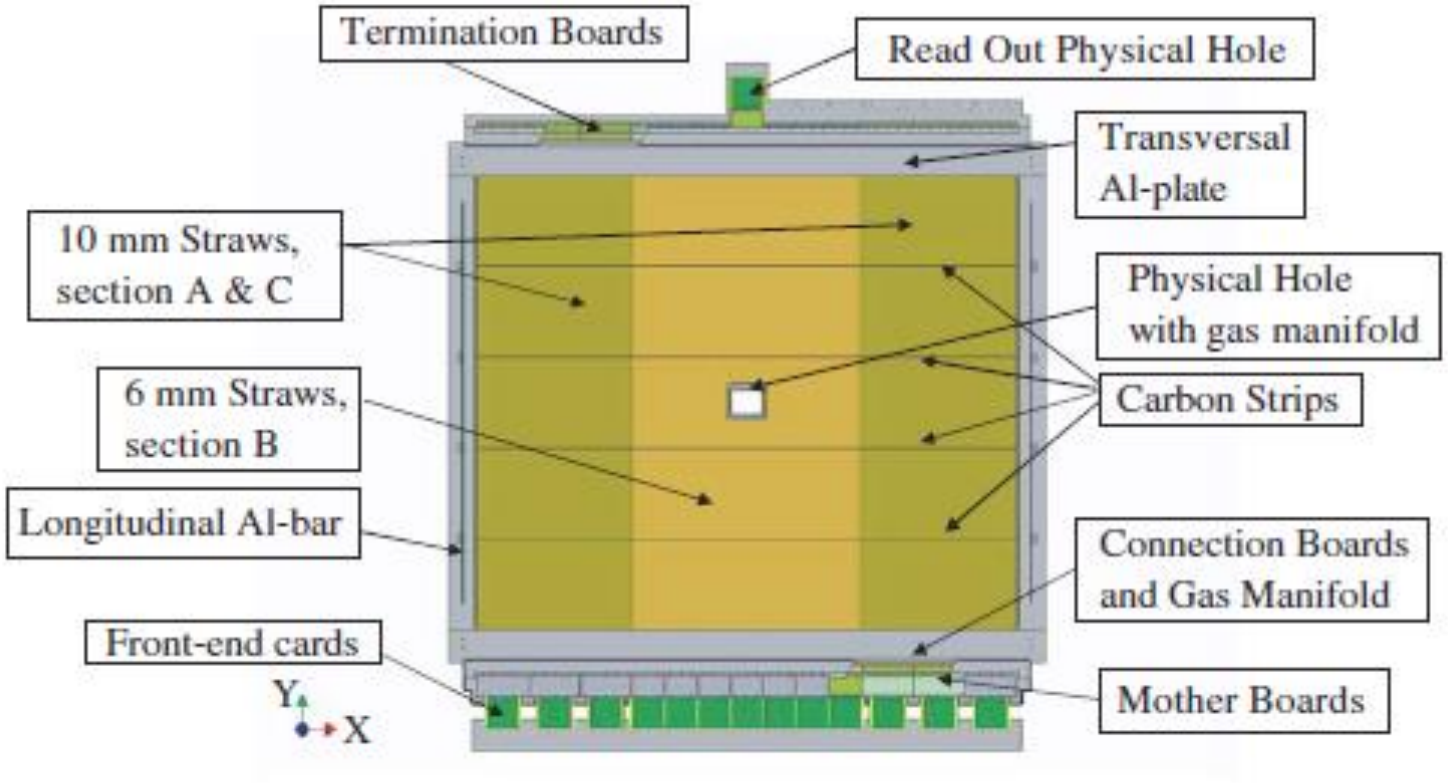
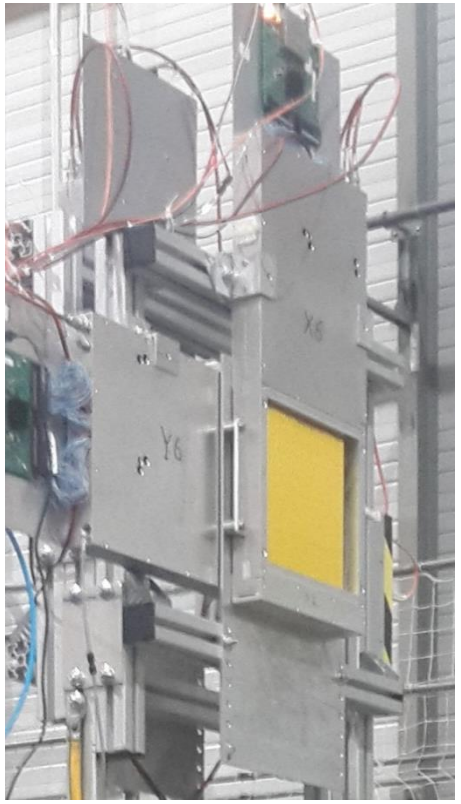


Fig. 2. Schematic view of a chamber (type X).

- 12440 read-out channels
- Volume 130m^2
- Sensitive area 2802x3232(mmxmm) for X, 3254x2427(mmxmm) for Y
- Basic detector 2 element: straw tube with 6mm and 10mm diameter; 30um diameter gold-plated tungsten wire
- Resolition: 200 um

NA64 (CERN,Geneva)

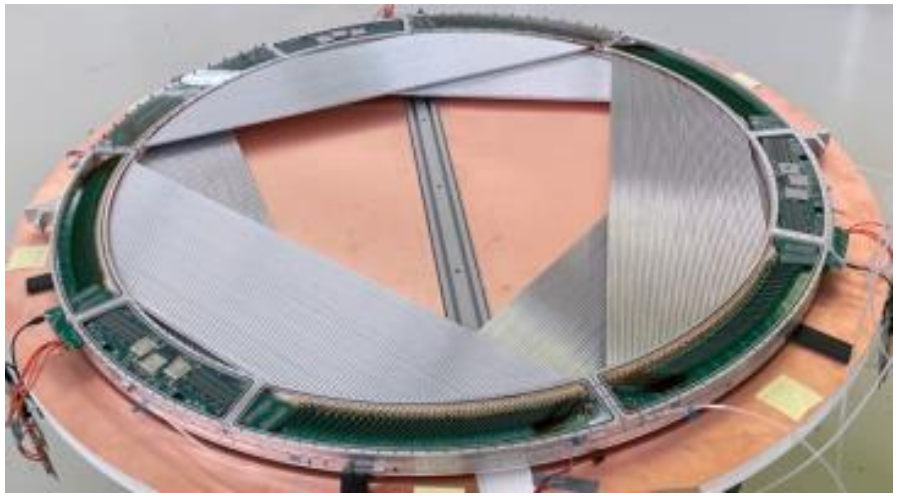


- Straw : 6mm diameter, wire: 30um diameter gold-plated tungsten wire
- Length straw 20 cm
- Resolution : 200 um

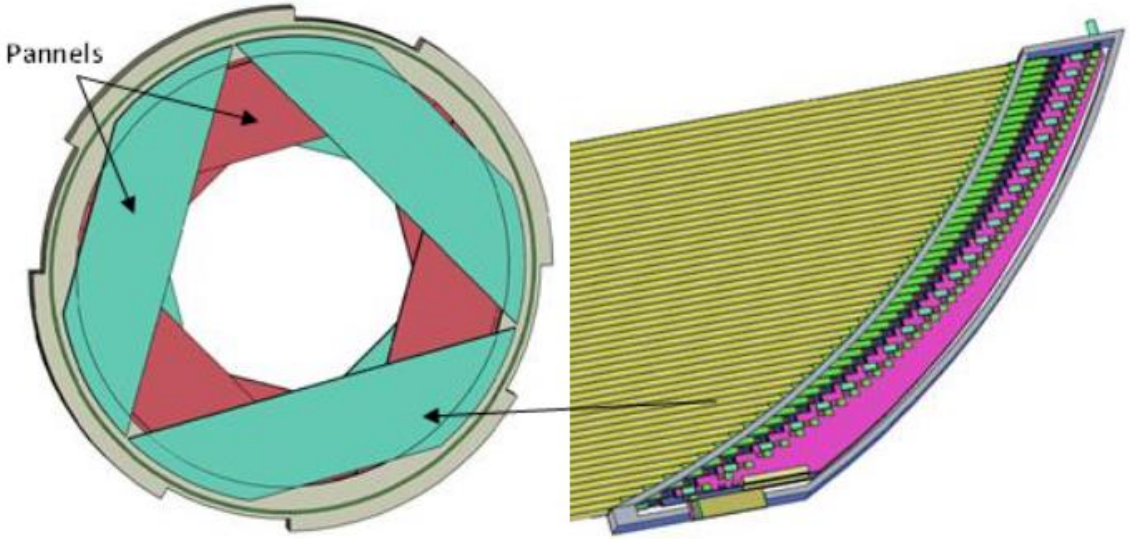
- 7 UV station with size 120x600 mm ~ 4000 straws
- 6 XY station with size 200x200 mm ~ 800 straws

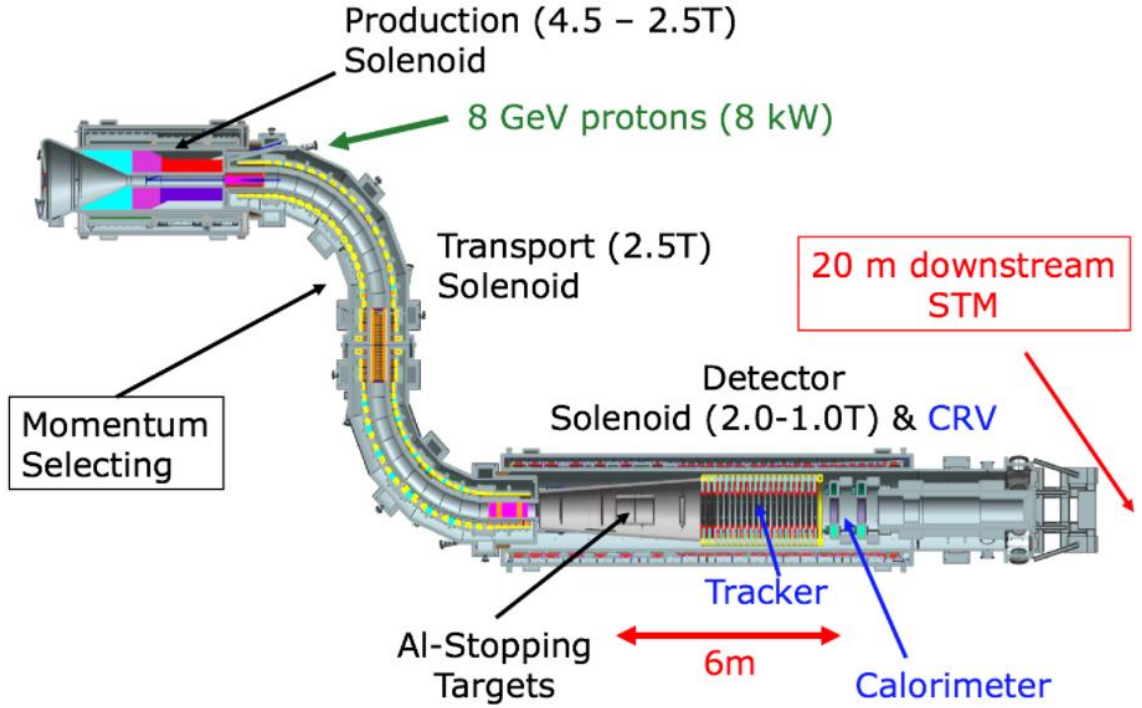
Mu2e (Fermilab, Chicago)

electron trajectory in a 1T magnetic field
Hit rate: > 5MHz/channel, 500 ns after proton bunch hits production target
Operation time: > 10 yrs
20,736 straws 7 µm Mylar + 1 µm adhesive + 7 µm Mylar double helical wrap
High radiation survival (structure & electronics) 5 mm diameter
Lengths: 45 to 120 cm Inner wall coating: 500Å Al + 200Å Au, Outer wall coating: 500Å Al



Tracker must be improved → ~2028 – 2030

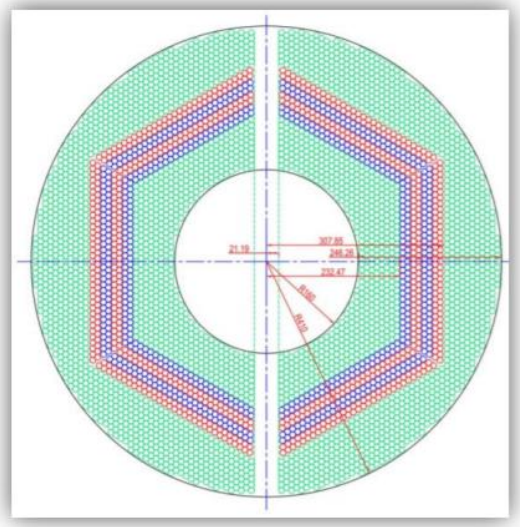


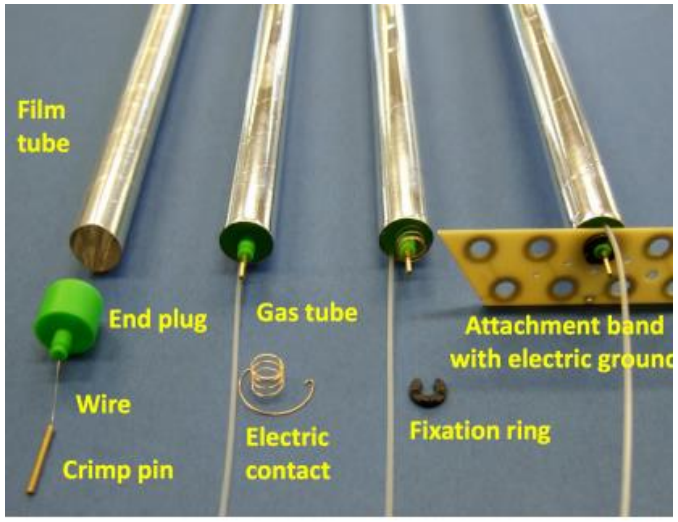


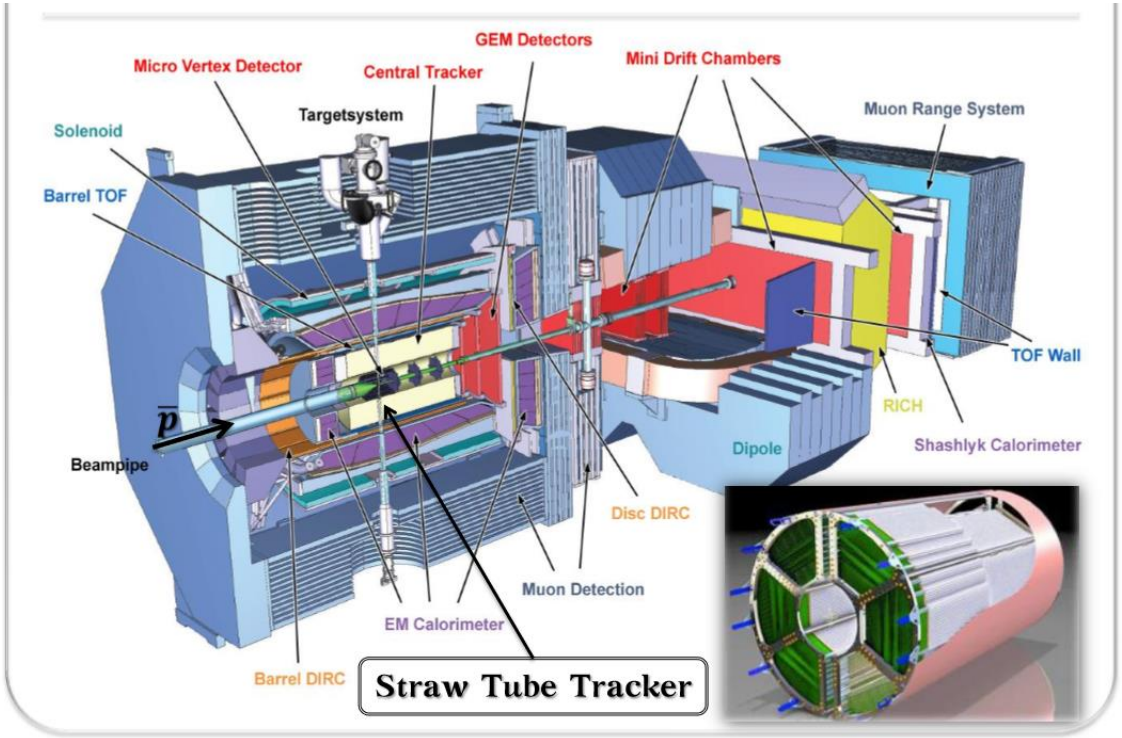
PANDA (FAIR, Darmstadt)

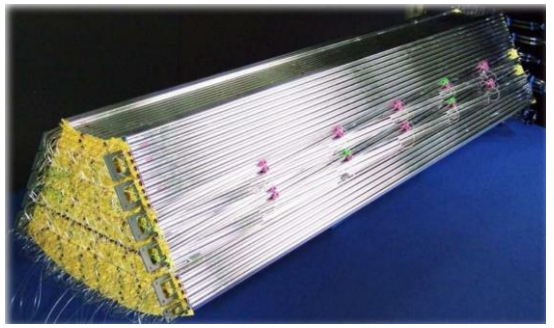
STT LAYOUT

- 4636 straw tubes in 2 semi-barrels around beam/target pipe
- 23-27 planar layers in 6 hexagonal sectors
  - 15–19 axial layers (green) parallel to the detector axis
  - 8 stereo layers ($\pm$ 2.89°) for 3D reconstruction (blue/red)
- Length: 1500mm + 150mm (RO upstream)
- R_{in}/R_{out}: 150 / 418 mm
- Angular acceptance: near 4π
- High momentum resolution: δ_p/p ~ 1-2% at B = 2 Tesla
- High spatial resolution: $\sigma_{r\varphi}$ ~ 150 (100) μm, σ_z ~ 3.0 (2.0) mm (single hit)







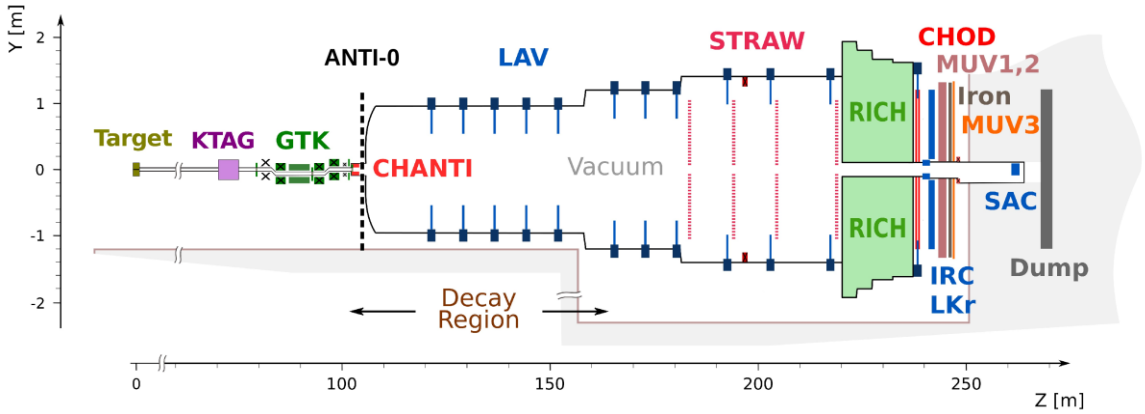


NA62 (CERN,Geneva)

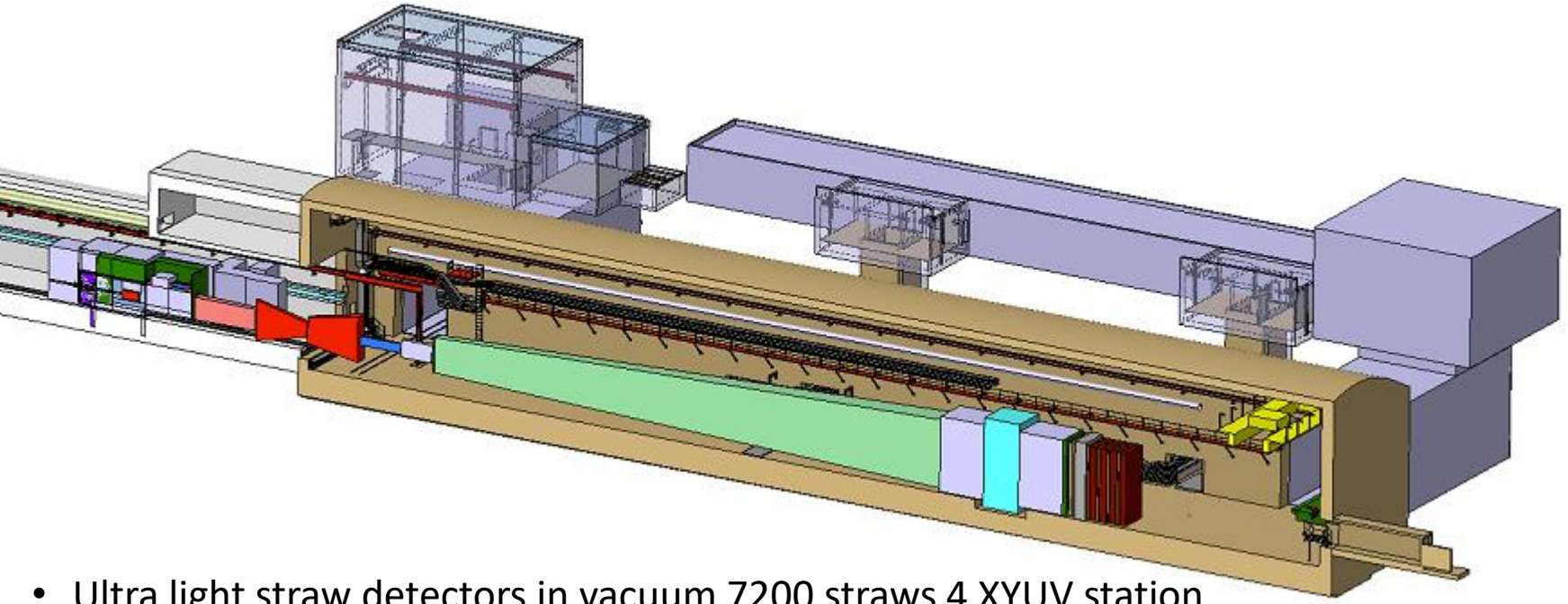
Current NA62 straw spectrometer:

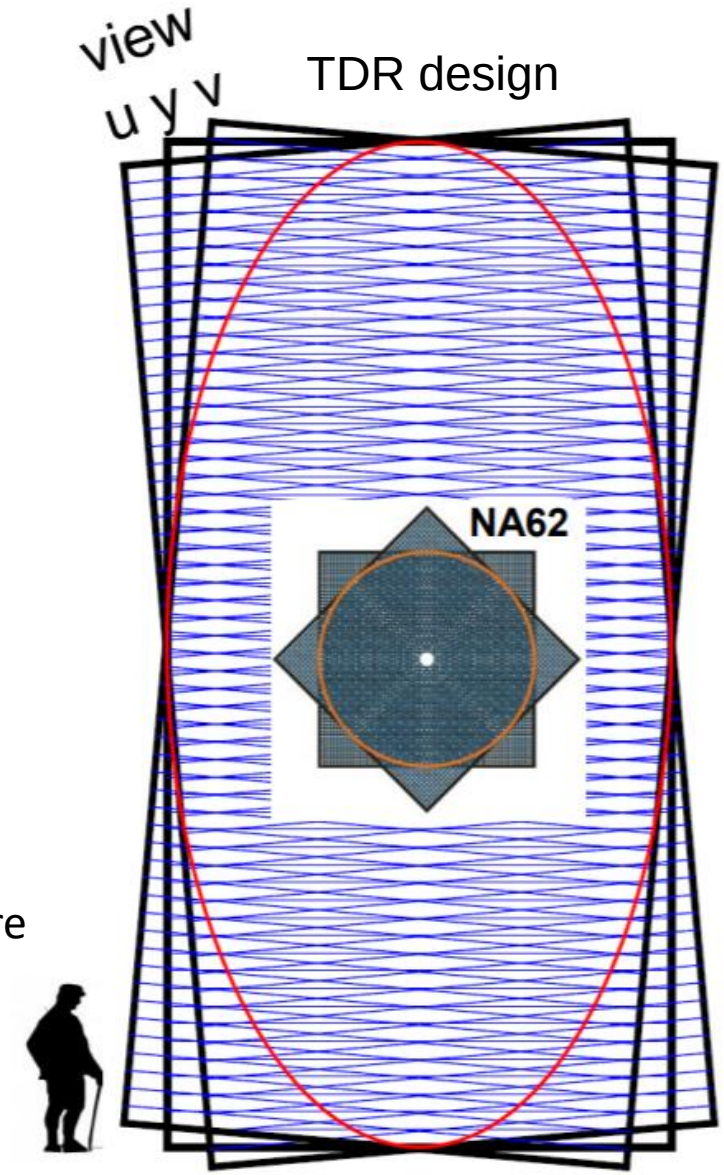
- **Straw diameter: 9.8 mm**
  - Material: 36 µm thick PET
  - Plating: 50 nm copper + 20 nm gold
  - Wire: 30 µm tungsten wire
- **Gas: Ar+CO_2 (70:30)**
- **4 chambers, 7168 straws in vacuum**
  - 30 straw hits per track
- **Total material budget: 1.7% X_0**
  - Dominated by the PET (70%)
- **Single straw timing performance:**
  - Maximum drift time: 150 ns
  - Leading time resolution: 3-4 ns
  - Trailing time resolution: 30 ns

Operating in vacuum from 2014

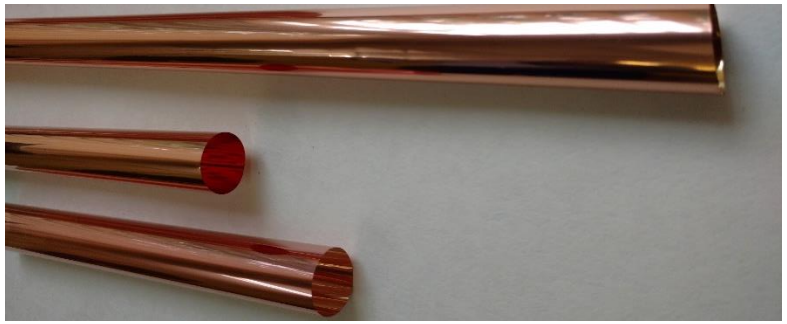


SHiP (CERN,Geneva)



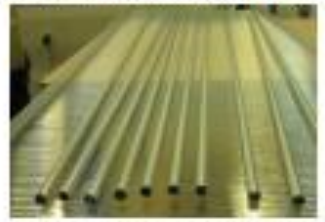


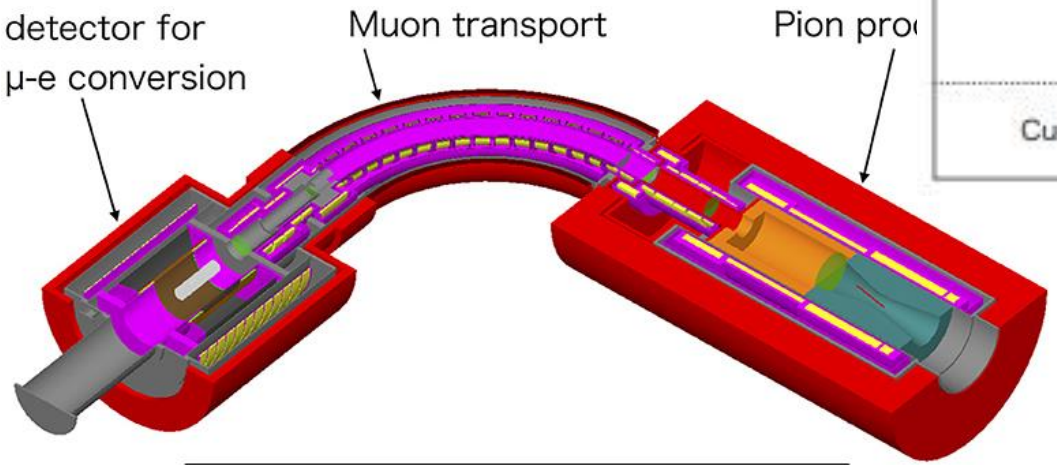
- Ultra light straw detectors in vacuum 7200 straws 4 XYUV station
- Sensitive Area 5x10m ⟶ 4x6 m2
- Straw tube with 20mm diameter, in the center a 30 um diameter gold-plated tungsten wire
- Length straw 4m
- Precision measurement of 160 um
- Hit rate O(10kHz), larger in alignment mode



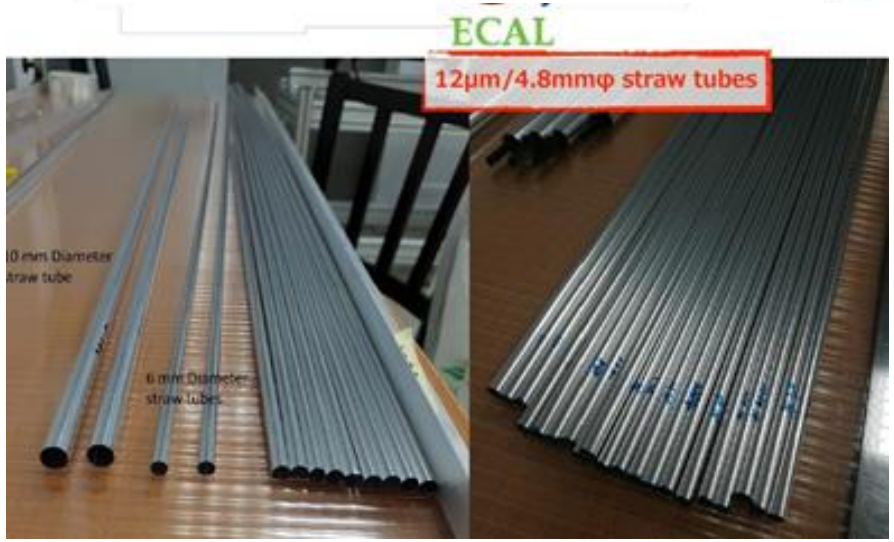
COMET (J-PARC,Tokai)

9.75 mm diameter conducting straws, metalized polyimide film of 20 µm thickness. Anodic wires 25 µm diameter gold plated Tungsten wire. The baseline choice of the gas is Ar/Ethane (50:50).

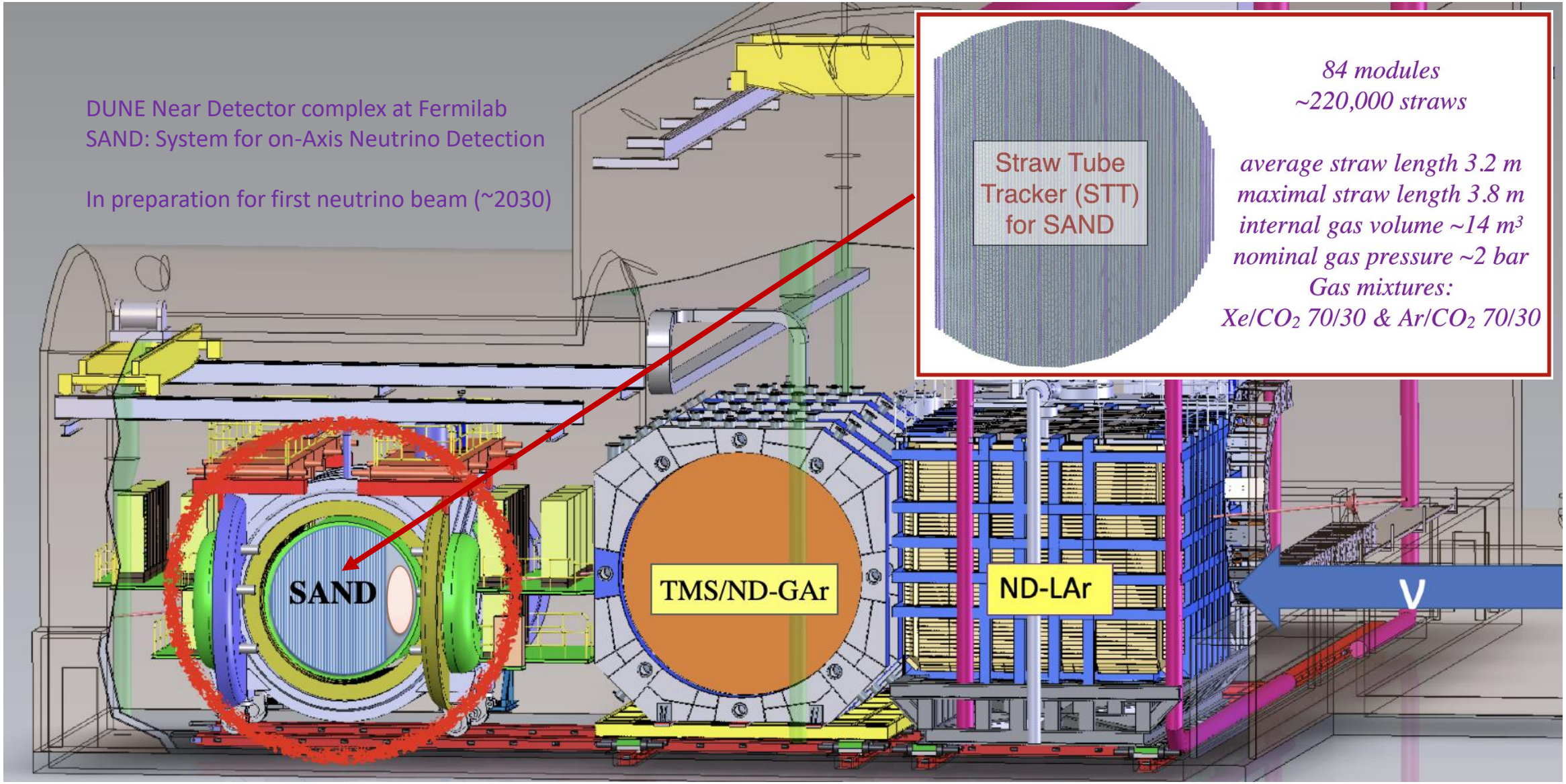
	NA62	COMET Phase-I	New Straw
Straw Wall Thickness	36 µm	20 µm	12 µm
Straw Diameter	9.8 mm	9.8 mm	4.8 mm
Metal Deposition	Cu+Au, 70nm	Al, 70 nm	*Al, 70 nm
Photo			
Current Status	In Operation	Under Construction	Just Developed



COMET Phase-I Layout

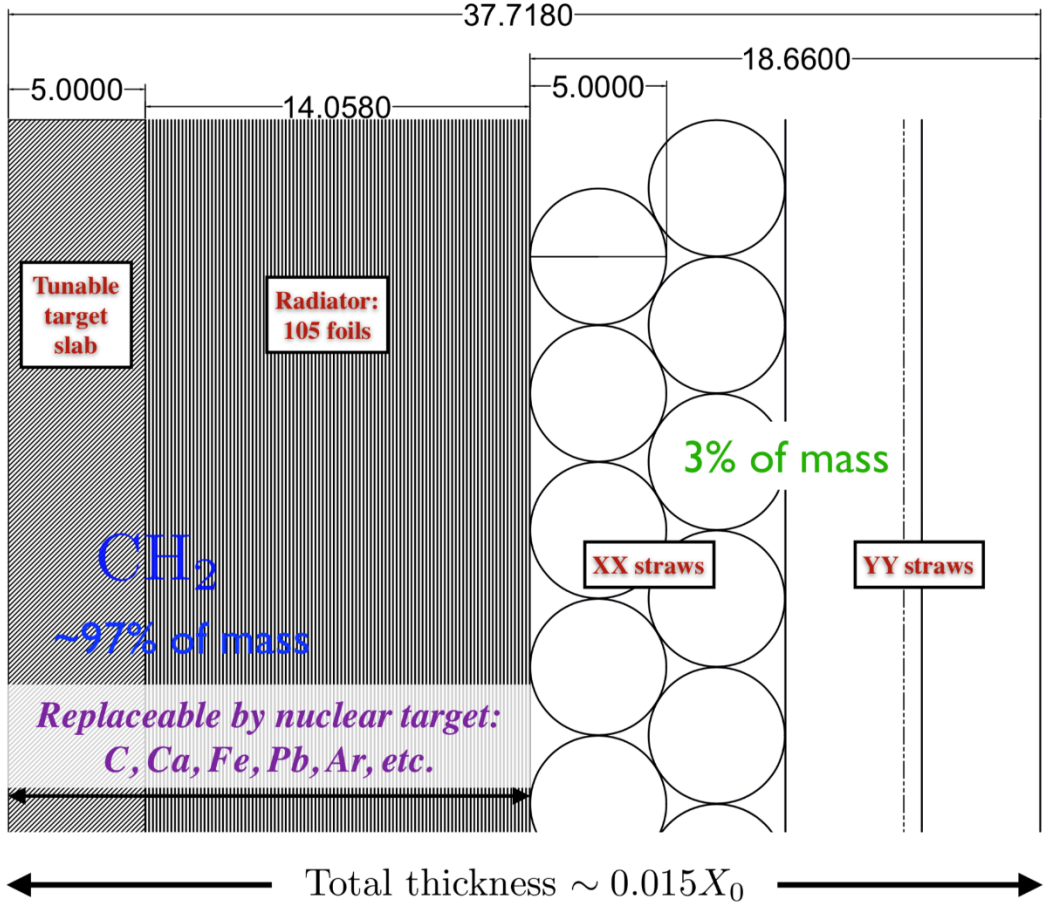


DUNE (Fermilab, USA)



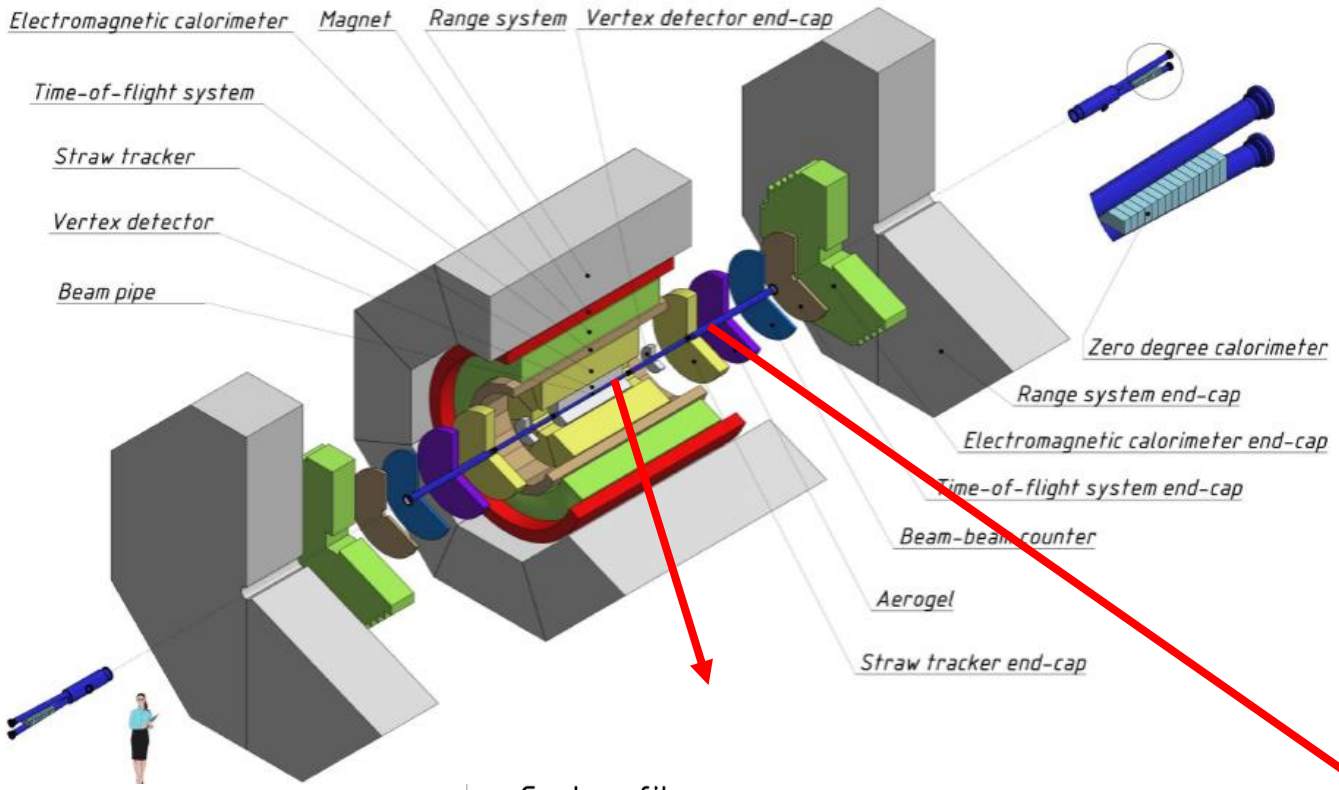
STT for DUNE

- Thin (1-2% X_0) passive target(s) separated from active tracker of negligible mass (STT)
- Many target layers dispersed within tracker by keeping low average density ρ~0.18 g/cm^3
- Replaceable targets of high chemical purity give ~97% of total STT mass (straws ~3%)
- "Solid" hydrogen target from subtraction between CH_2 (polypropylene) and C (graphite)

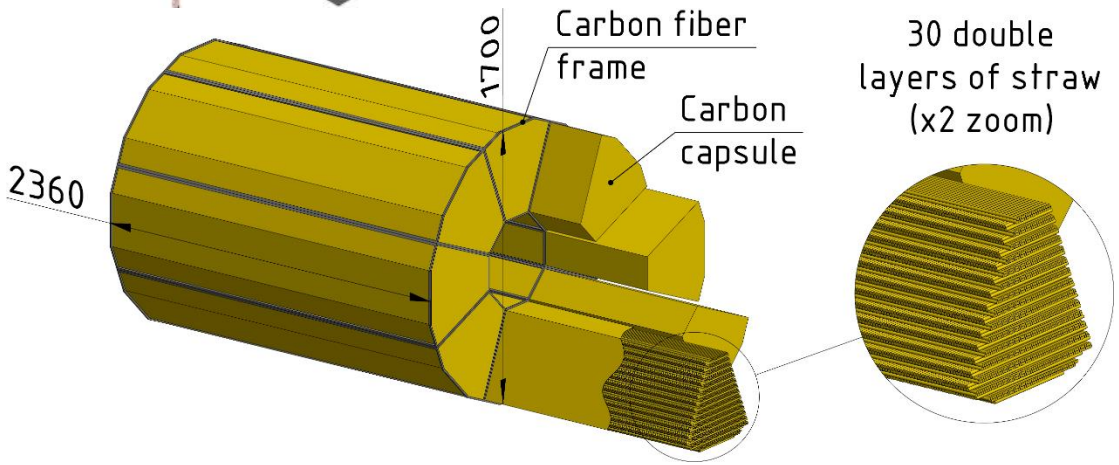


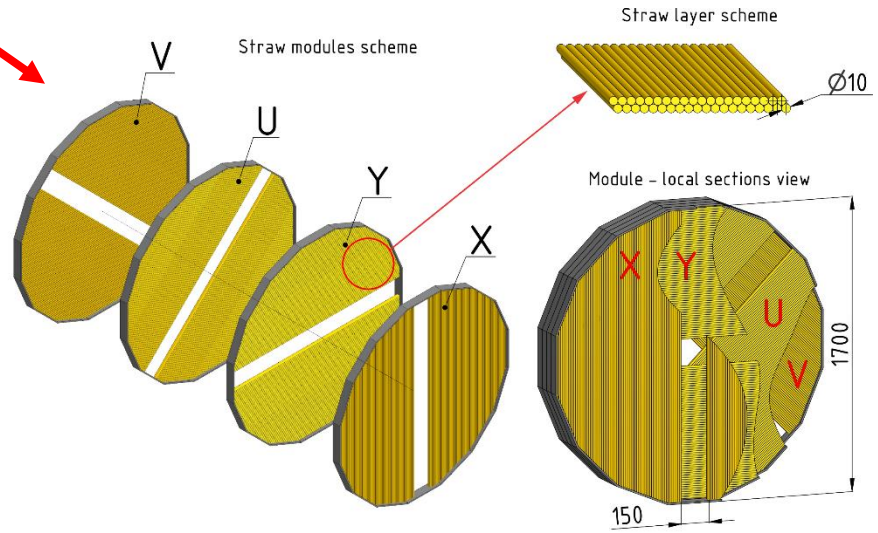
- Straw outer diameter: 5 mm
- Wall thickness: 20 μm or lower
- Double film metallization: 70 nm (inner) + 70 nm (outer)
- Wire: W/Re 20 μm diameter
- 4 straw layer XXYY glued assembly
- Operated at internal overpressure of about 1 bar (2 bar absolute)
- Thin modules with light C-composite frames
- Compact low-power frontend readout integrated into frames

SPD NICA (JINR,Dubna)



- Main tracker system of SPD
- Straw diameter 10mm thickness 36mkm PET
- Spatial resolution of 150 um
- Barrel is made of 8 modules with up to 30 double-layers, with the ZUV orientation
- Endcaps are made of 12 double-layers with the XYUV orientation
- Rate O(100 kHz)



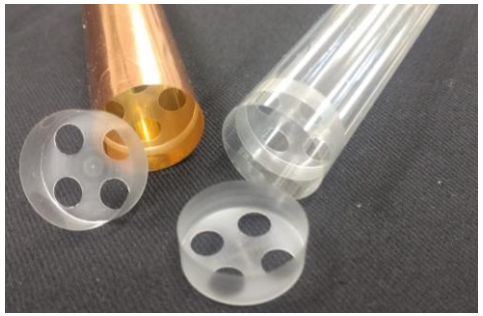


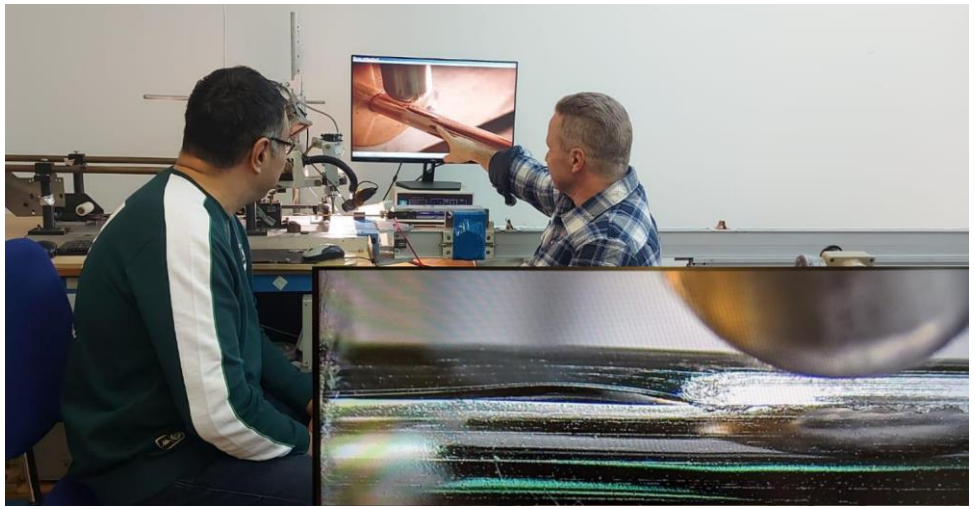
Ongoing R&D on welded straws

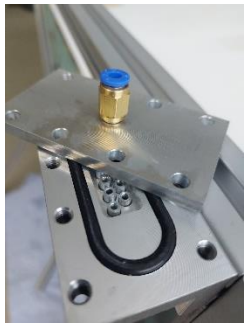
Straw production
- Different diameters
- Different metallization
- Developing production lines in INP Kazakhstan

Components
- Pins for anode
- Endplag for straw
- Adhesives
- Crimpers

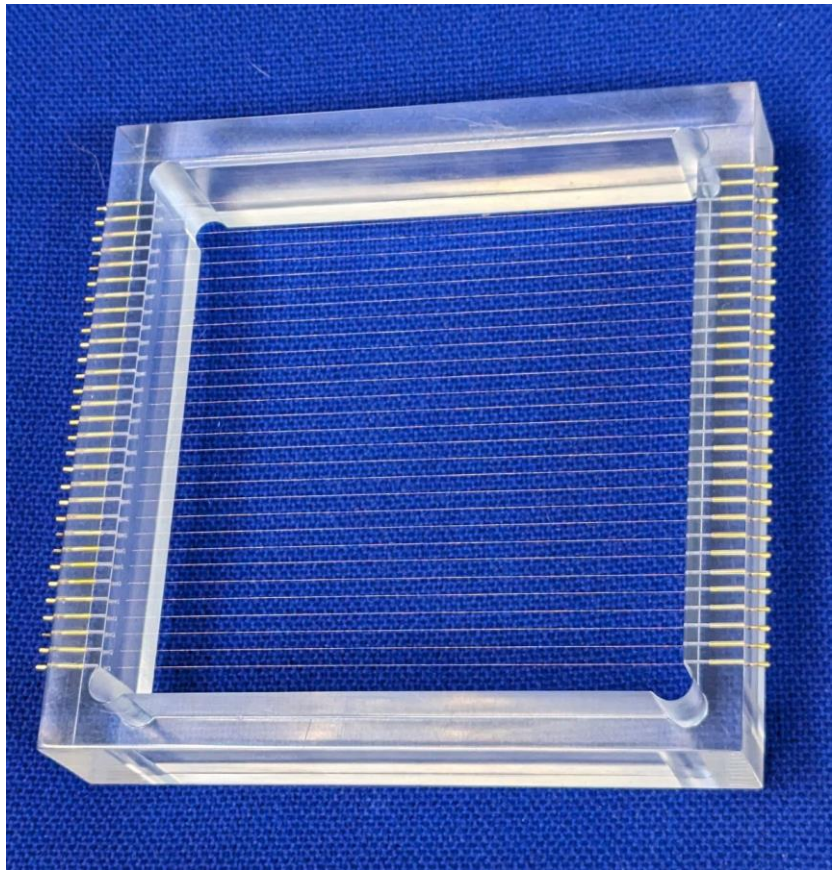
Prototypes
- Straws different diameter 5,10,20mm(110str)
- First DUNE prototype
- Prototype ZUV(~110str)

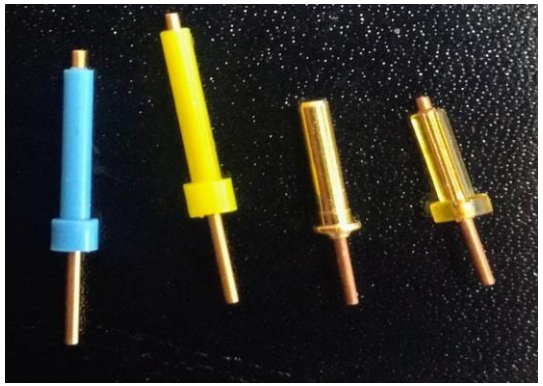






Pins, crimping, end-plug and spacer R&D (together with DUNE STT)





ATLAS, COMPASS, NA64 pins

End-plug and spacer mechanical precision – 5 um
(the same as the one of the inned straw diameter)

Straw quality tests

- precision of the inner straw diameter – 5 um
  - it is controlled during the production with a laser
  - after production: additional measurements with a "calibrator"

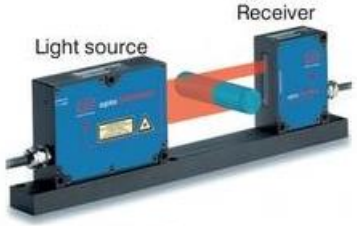
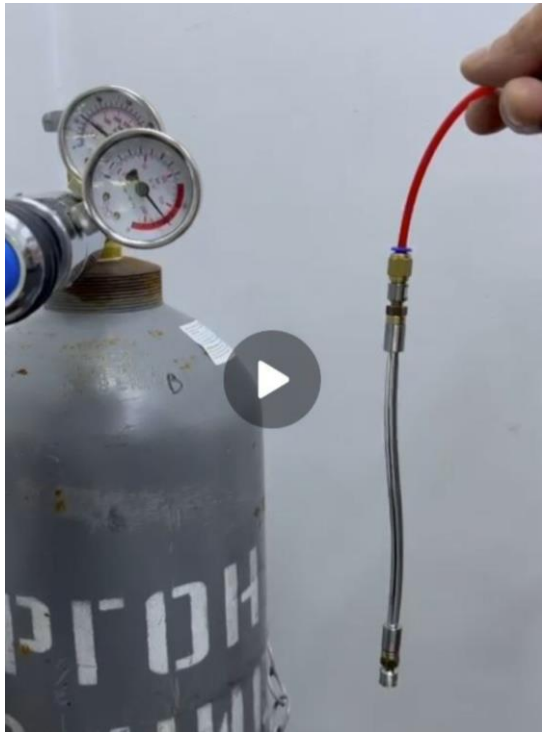


Fig. 5 Sensor unit SU

Fig. 6 Controller CU

A measurement system consists of:
- laser
- receiver
- controller

- Several quality tests are done after the straw production:
  - Express mechanical test – cutting out a straw piece and measuring the breakage force
  - All produced straws are tested under overpressure of ~3 bar for several minutes
  - All produced straws are kept under overpressure of ~1 bar with respect to the operational pressure until the assemblig



5 mm straws (DUNE type)
- inelastic deformation – after 10 atm

How to readout future large straw trackers?

- SHiP ~20k channels, time (~ns), optional Q (signal vs noise, signal (mu) vs BG (e))
- DUNE ~200k channels, time (~ns), Q (PID)
- SPD ~20k channels, time (~ns), Q(PID)
- Large dynamic range for PID
- all – triggerless readouts

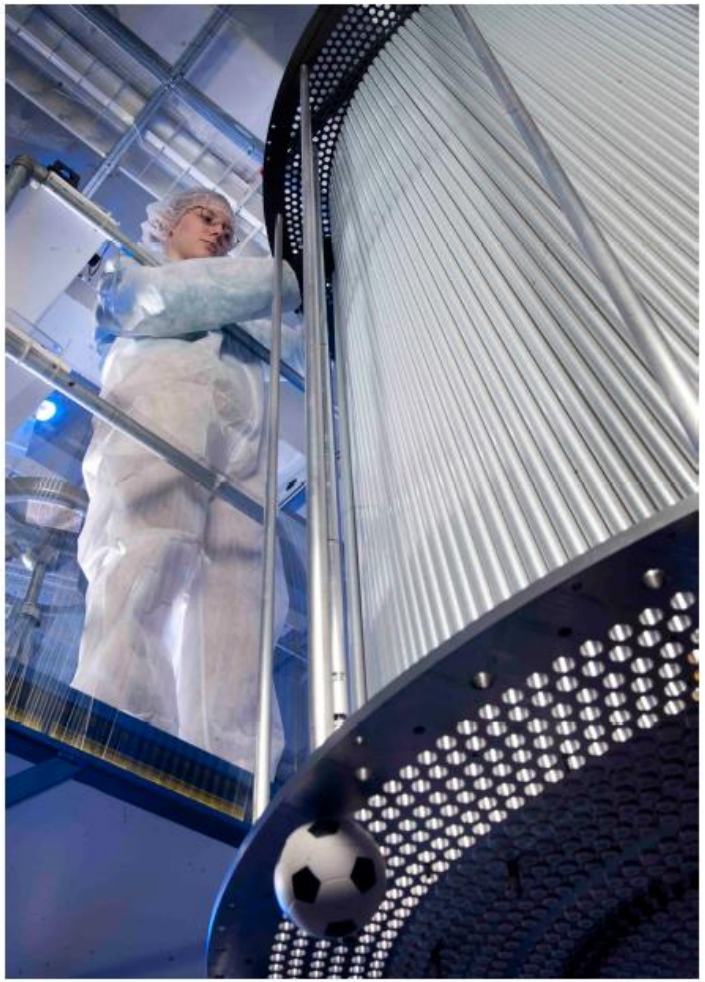
Possible solutions

- Existing solutions? Tested at the StrawTrackerRD setup – see talk on Friday by Yerzhan Mukhamejanov
  - VMM3/3a? http://cds.cern.ch/record/2693463/files/ATL-MUON-PROC-2019-009.pdf?version=1 - G.Iakovidis for ATLAS NSW - potentially matching performance (compromizing between charge and time resolution)
  - TIGER (BESIII GEM readout)- TIGER: A front-end ASIC for timing and energy measurements with radiation detectors A.Rivetti et al.
  - - not matching the charge range

- Good base for the further development – see the talks on Wednesday by
  - Gianni Mazza
  - Roberto Petti

THANK YOUR FOR ATTENTION

GLUEX(JLab,Virginia)



Straw tube chamber

1.5m long x 1.2m diameter

3522 straws, 1.6cm diameter

28 layers, 12 straight, 16 stereo