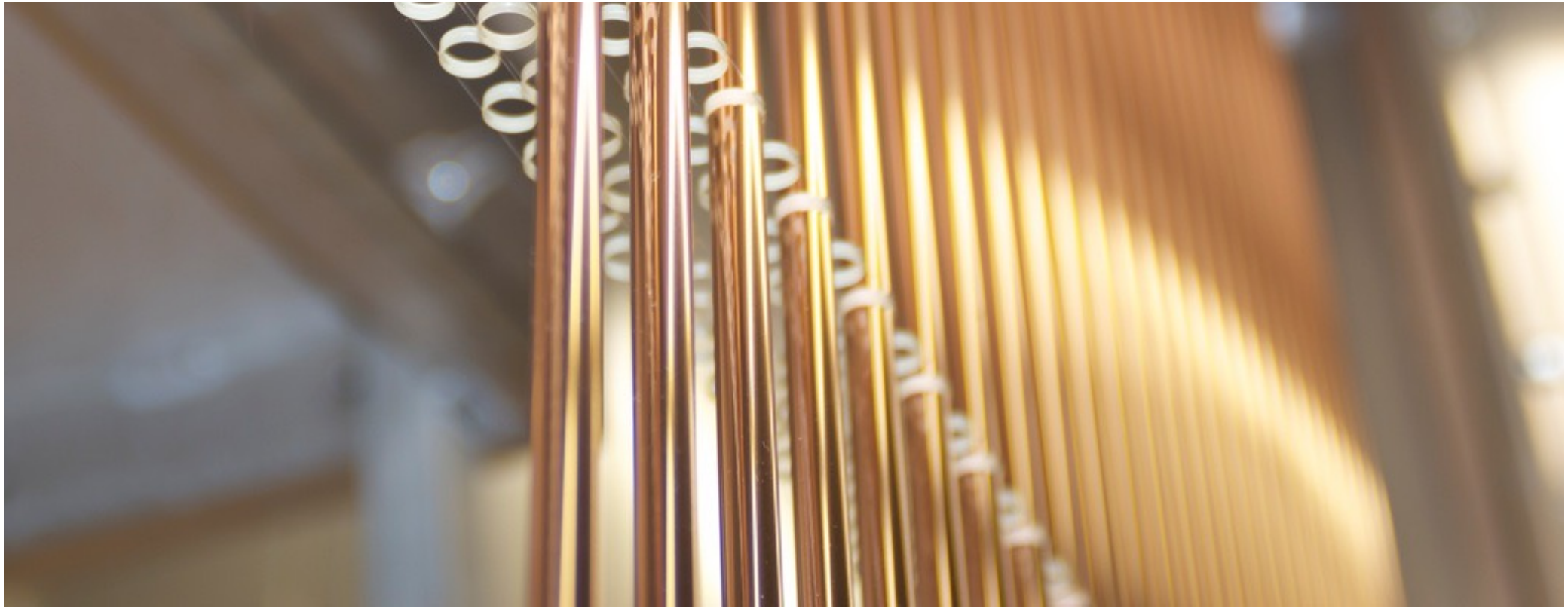
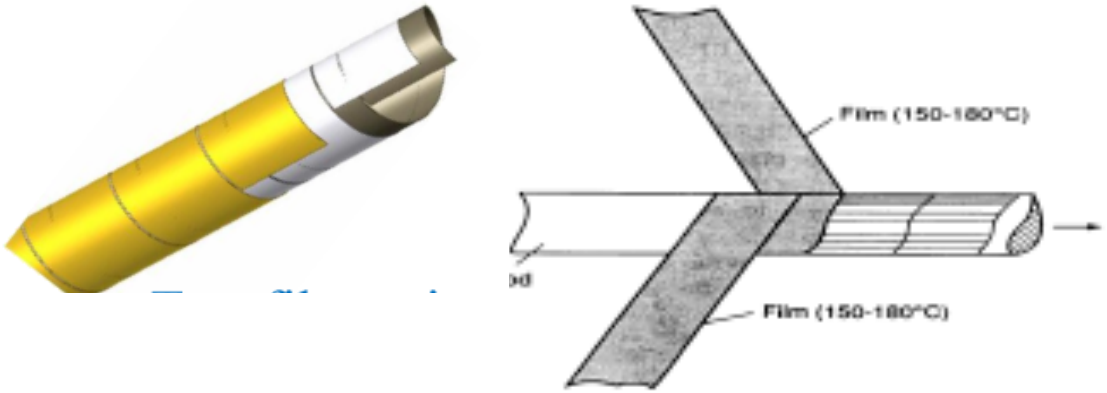
Straw tracker

Temur Enik, JINR

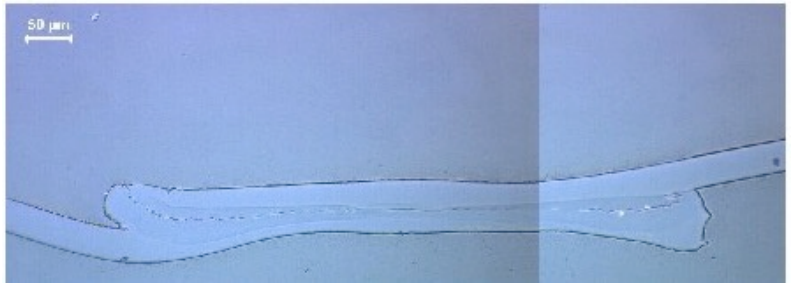


Two design of the straw-tube production



Straw winding. Two films revolve and stick together among themselves.

straw diameter from 2 mm to 18 mm



Ultrasonic welding of straws

straw diameter from 5 mm to 20 mm

both of these technologies are well developed at JINR

The straw tracker are using of in the different experiments.

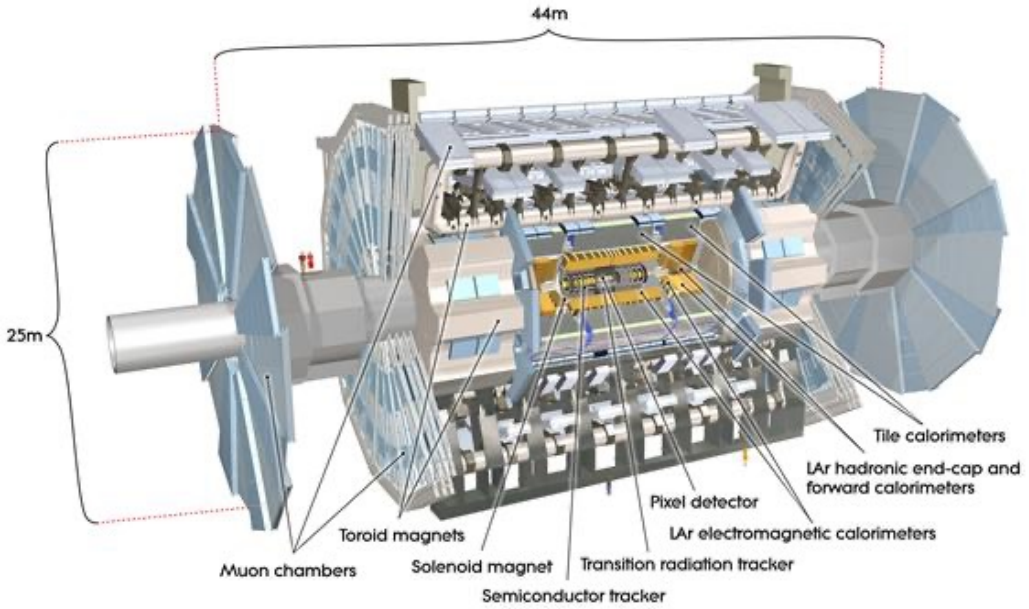
Straw winding

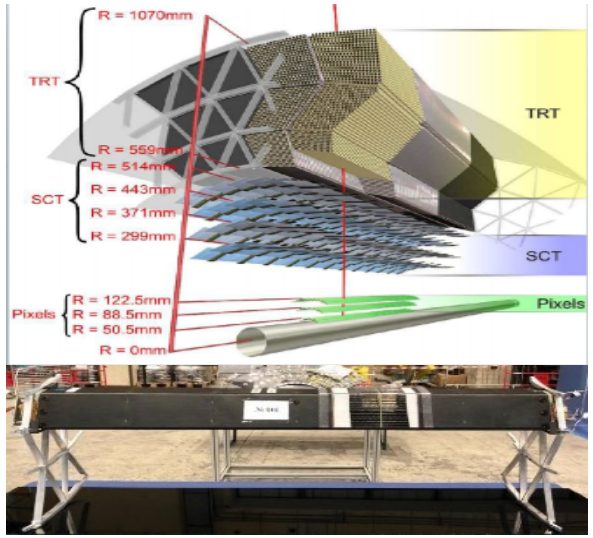
- ATLAS
- LHCb
- PANDA(overpressure)
- CBM
- COMPASS
- Mu2e(vacuum)
- NA64
- SVD-2
- GLUEX
- COZY-TOF
- ..

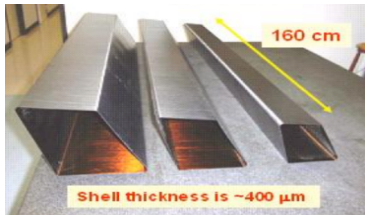
Straw welding

- NA62(vacuum)
- COMET(vacuum)
- SHiP(vacuum)
- DUNE(overpressure)
- SVD-2
- ..

ATLAS



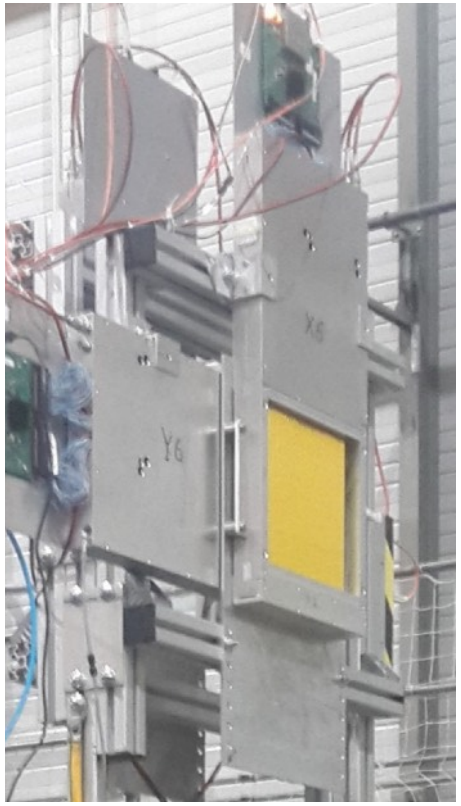




•350,000 read-out channels
•Volume 12m^3
•Basic detector element: straw tube with 4mm diameter, in the centre a 0.03mm diameter gold-plated tungsten wire
•50,000 straws in Barrel, each straw 144 cm long. The ends of a straw are read out separately
•250,000 straws in both endcaps, each straw 39 cm long
•Precision measurement of 170 mкm
•Provides additional information on the particle type that flew through the detector, i.e. if it is an electron or pion

- Endcap modules:	**248760 straw**
Module of type A (PNPI)	**147456 straw**
Module of type B (LHEP)	**98304 straw**

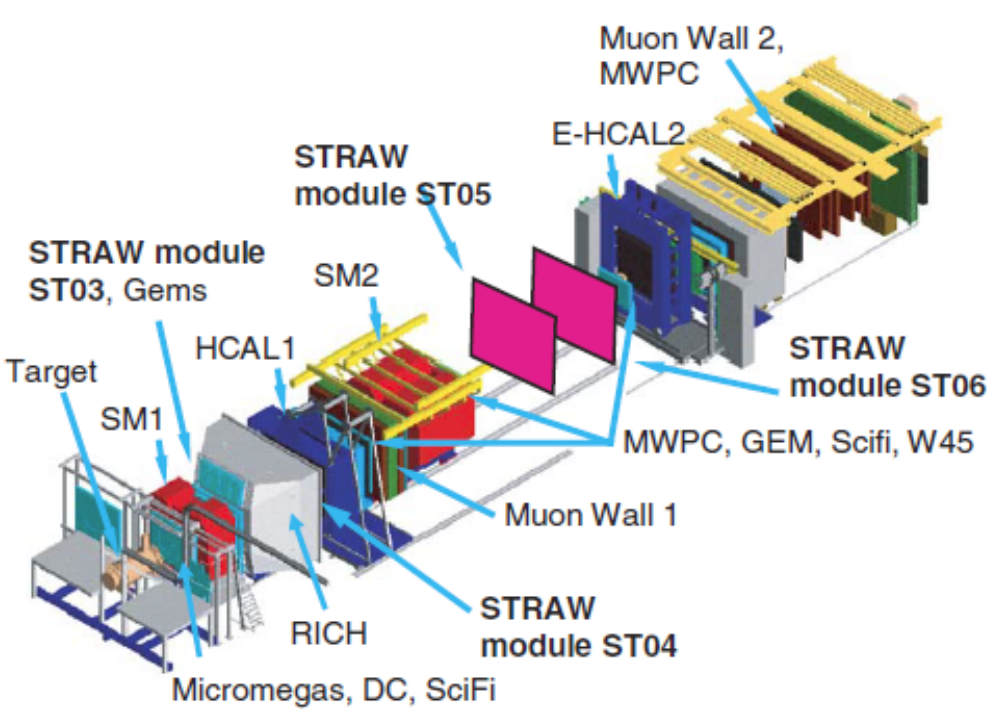
NA64



- 768 straws
- 6 XY station
- straw tube with 6mm diameter, in the centre a 30mκm diameter gold-plated tungsten wire
- Length straw 20 cm
- Precision measurement of 200 mκm

- Planned 8 XY station with size 1200x600 mm ~ 4000 channels

COMPASS



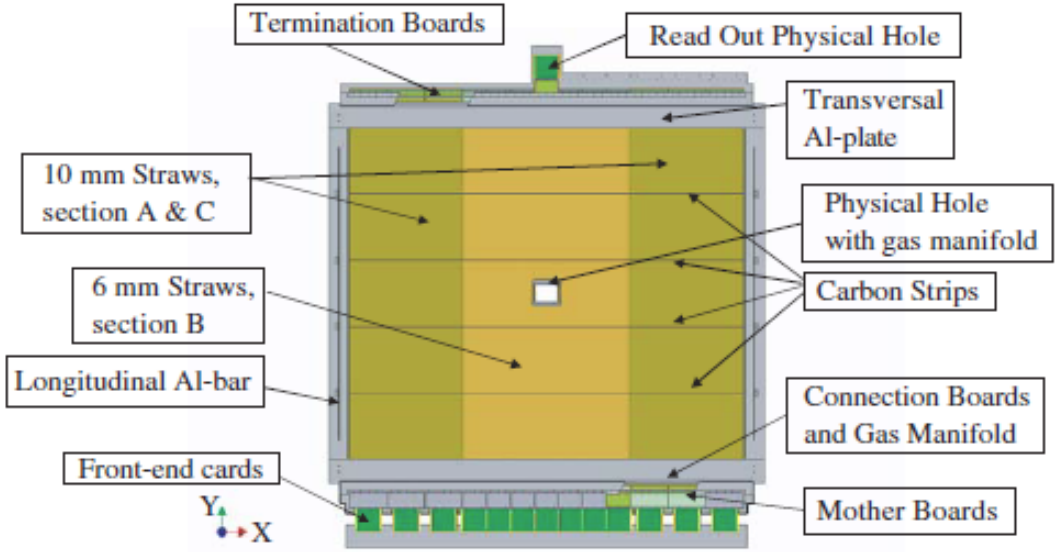


Fig. 2. Schematic view of a chamber (type X).

- 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, in the centre a 30mkm diameter gold-plated tungsten wire
- Precision measurement of 200 mкm

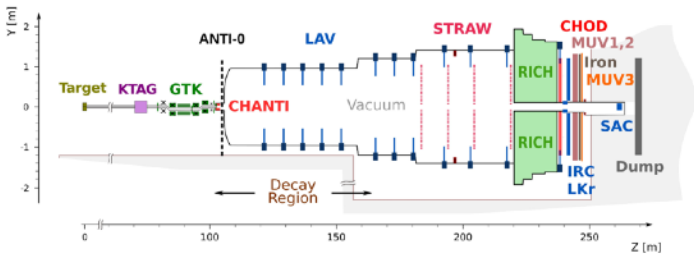
NA62

Current NA62 straw spectrometer:

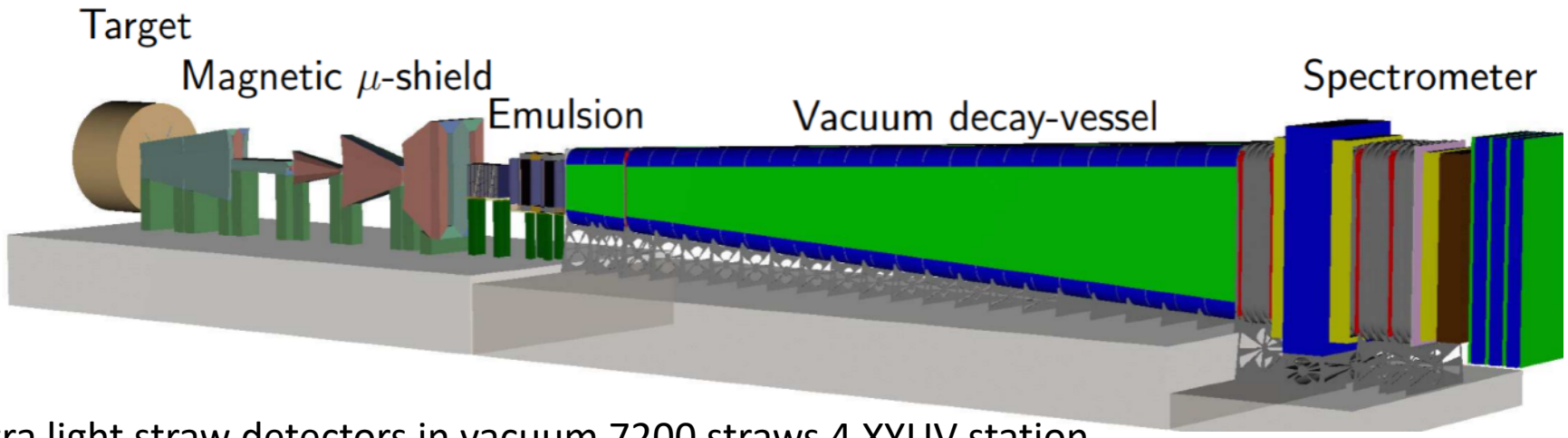
- **Straw diameter: 9.8 mm**
  - Material: 36 µm thick PET
  - Plating: 50 nm copper + 20 nm gold
  - Wire: 30 µm tungsten wire
- **Gas: Ar+CO_2 (70:30)**
- **4 chambers, 7168 straws in vacuum**
  - ∼30 straw hits per track
- **Total material budget: 1.7% X_0**
  - Dominated by the PET (70%)
- **Single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

New straw detector, main features:

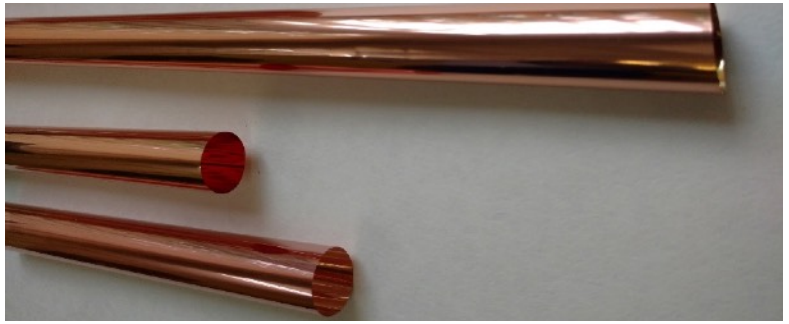
- Smaller straw diameter: 4.8 mm
  - Maximum drift time reduced to ∼80 ns
  - Trailing time resolution improved to ∼6 ns
- Keeping the 4 chambers layout, ∼21000 straws
  - Number of hits per track increased to ∼40
- Thinner straw material: 19 or 12 µm thick PET
- Lower total material budget: 1.0 – 1.5% X_0
  - Depending on the PET thickness option
  - Still dominated by the straw wall (60 – 70%)

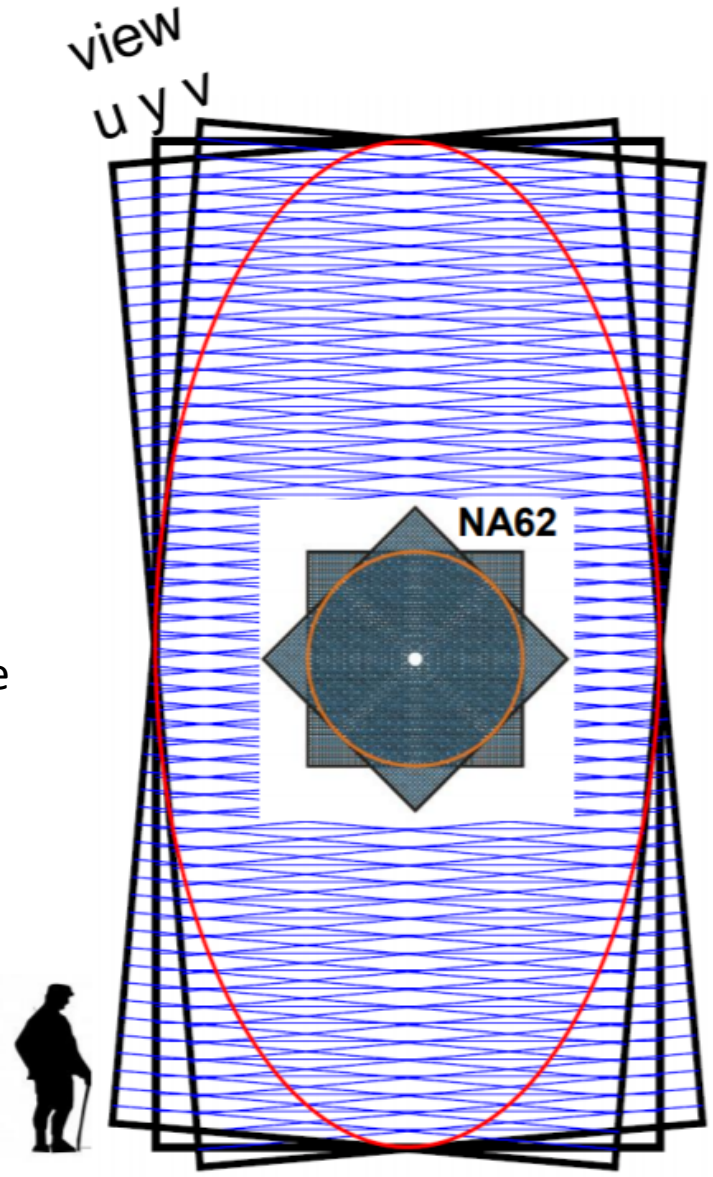


SHiP



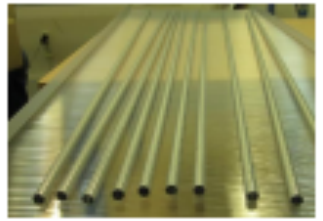
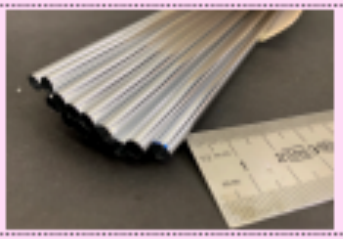
- Ultra light straw detectors in vacuum 7200 straws 4 XYUV station
- Sensitive Area 5x10m
- Straw tube with 20mm diameter, in the center a 30mkm diameter gold-plated tungsten wire
- Length straw 5m
- Precision measurement of 160 mkm

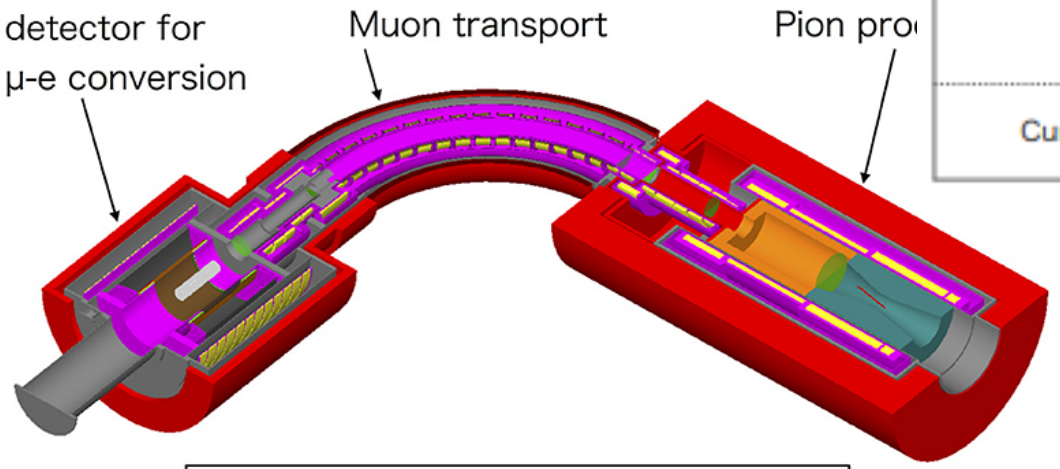




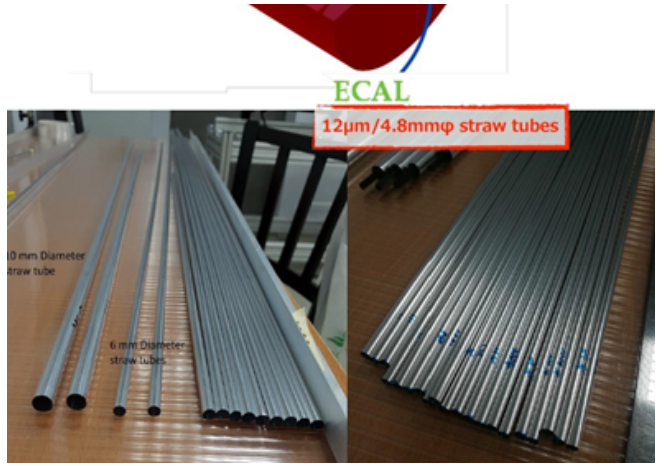
COMET

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

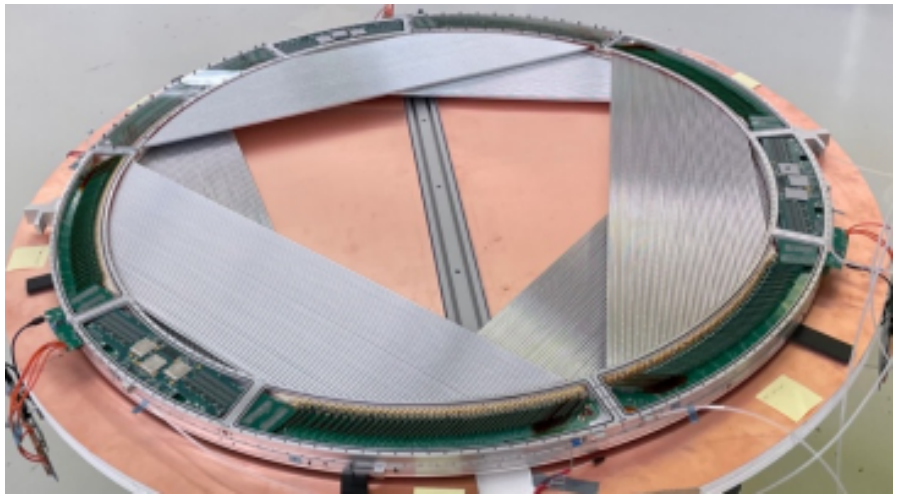


COMET Phase-I Layout

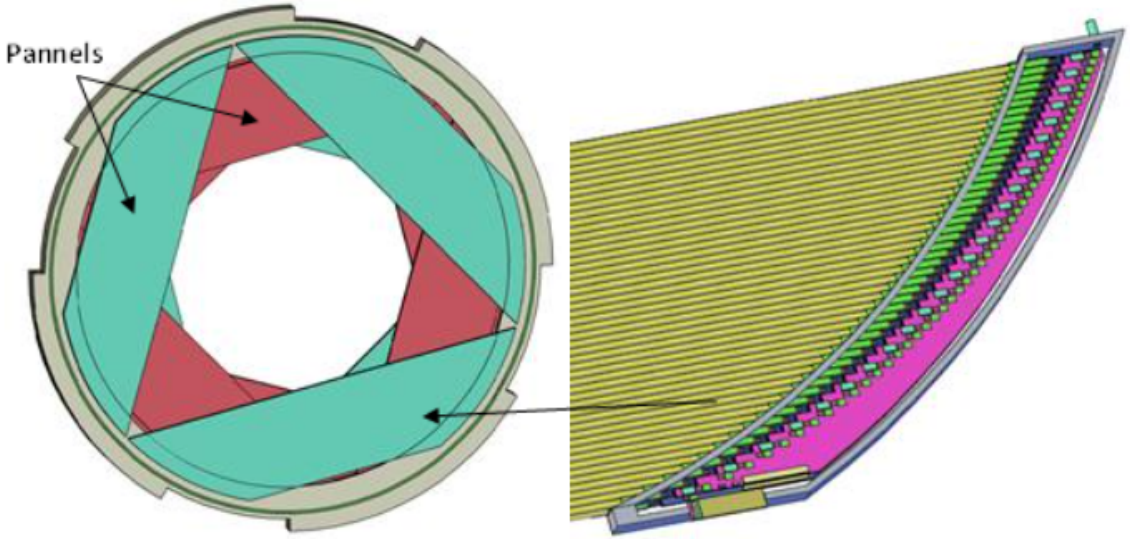


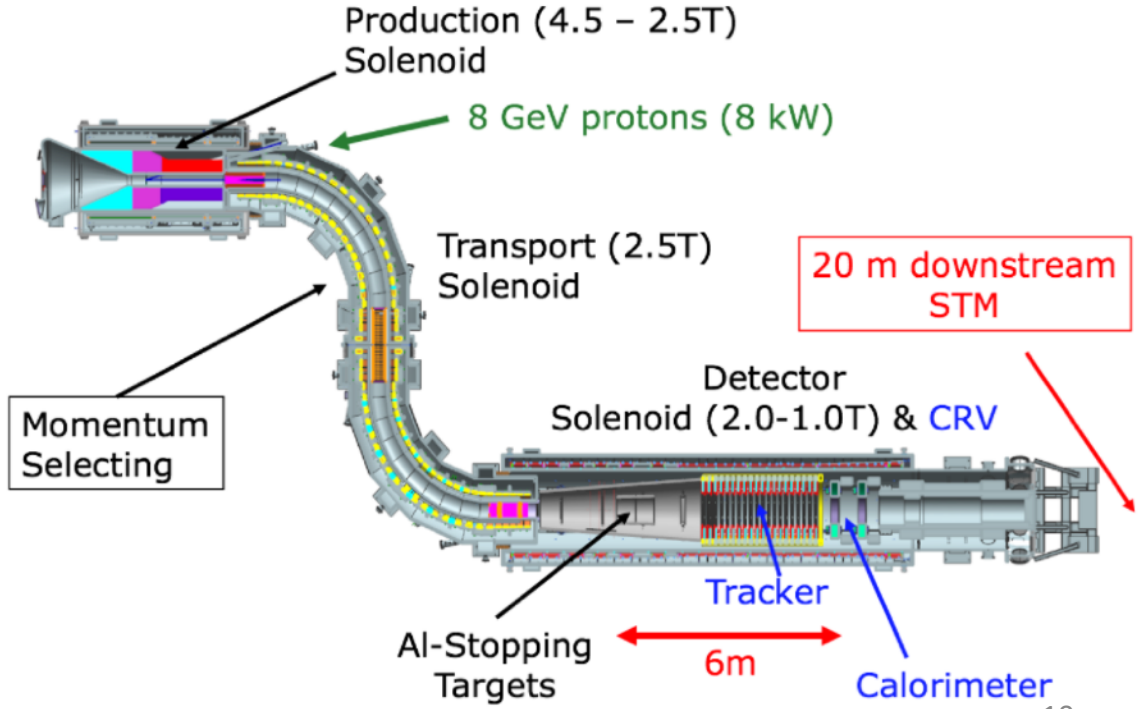
Mu2e

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 6 µm Mylar + 3 µm adhesive + 6 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

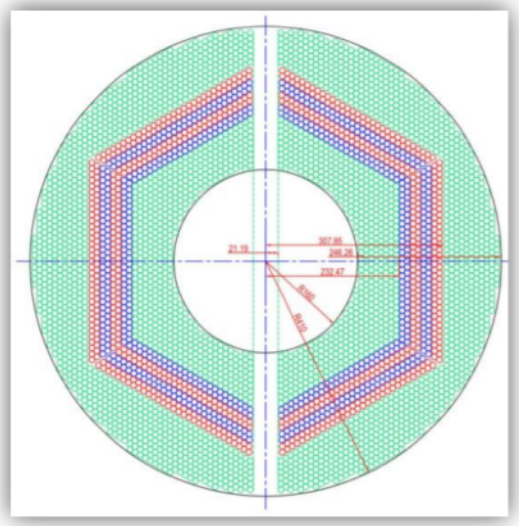


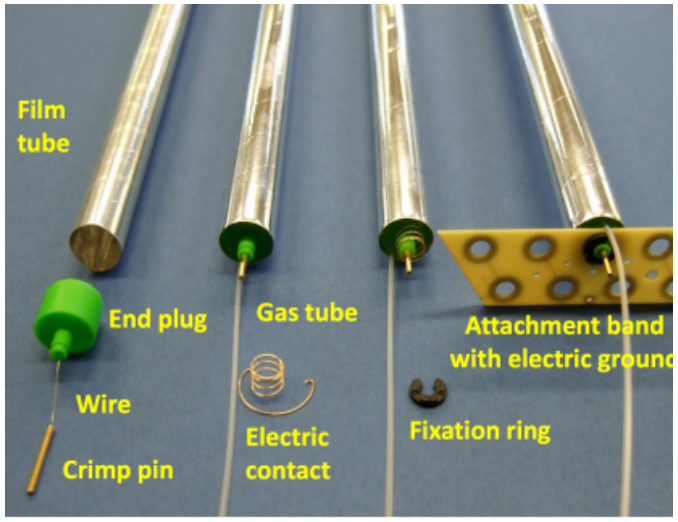


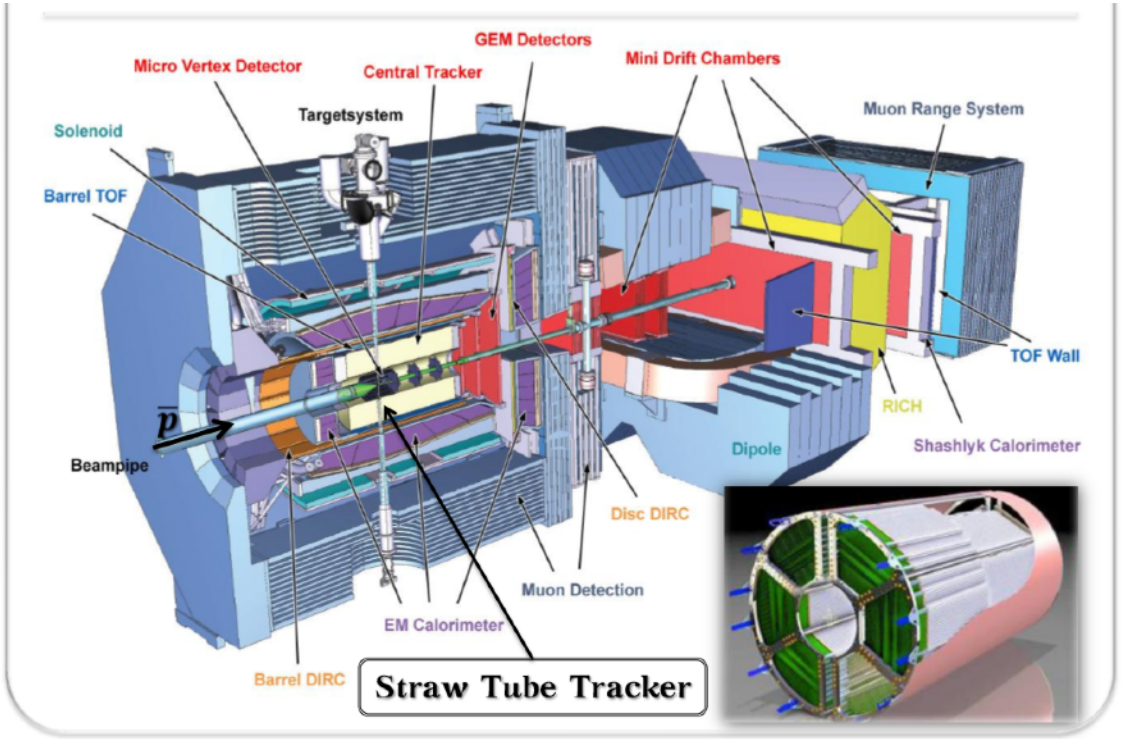
PANDA

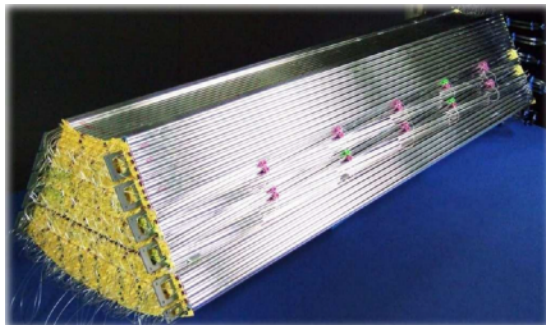
STT LAYOUT

- 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)

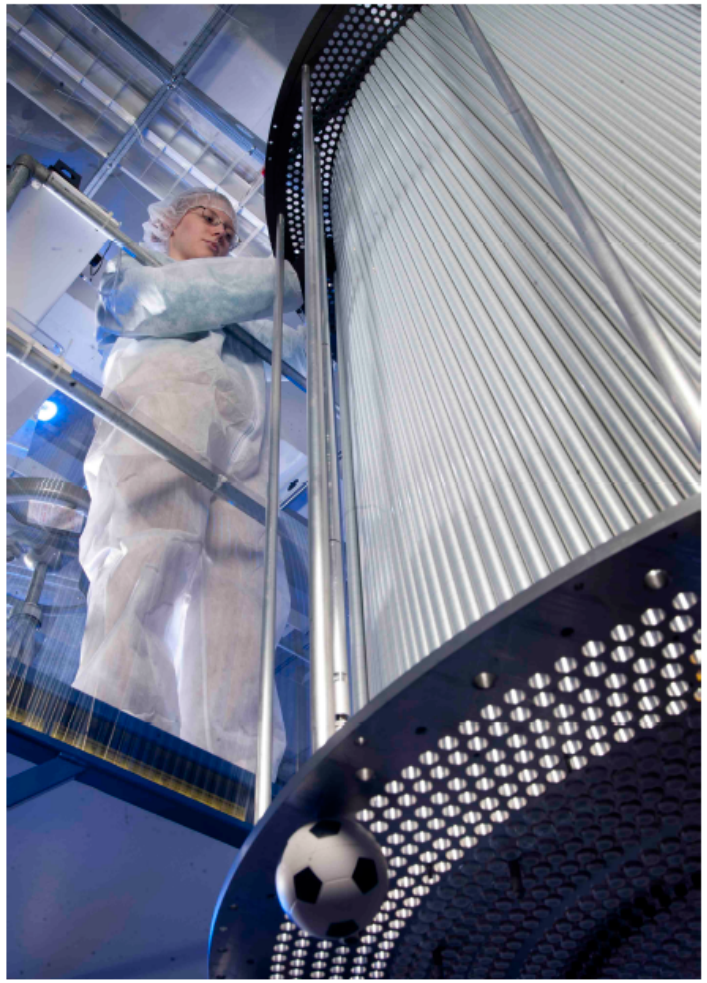








GLUEX

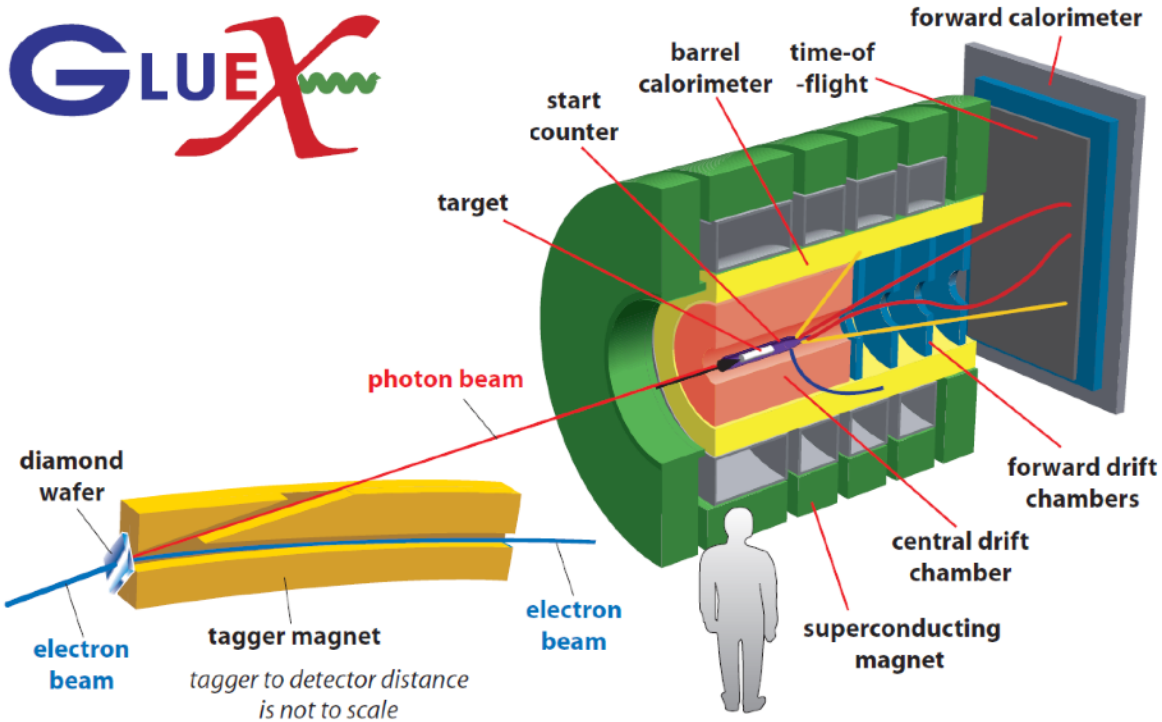


Straw tube chamber

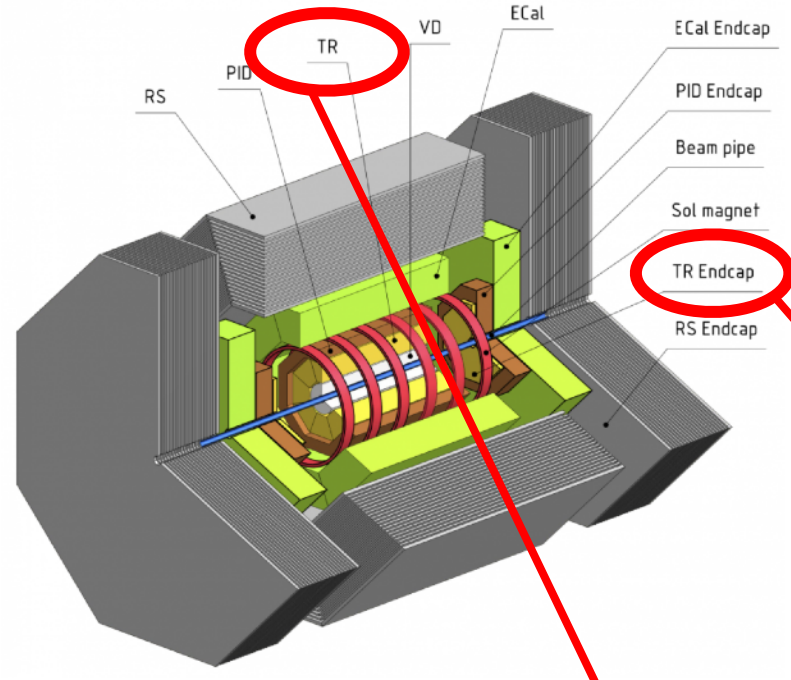
1.5m long x 1.2m diameter

3522 straws, 1.6cm diameter

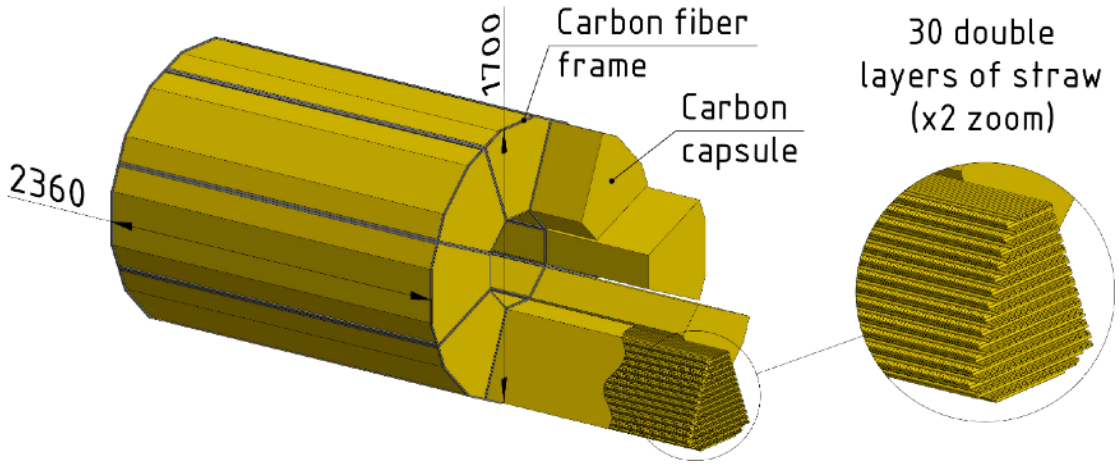
28 layers, 12 straight, 16 stereo

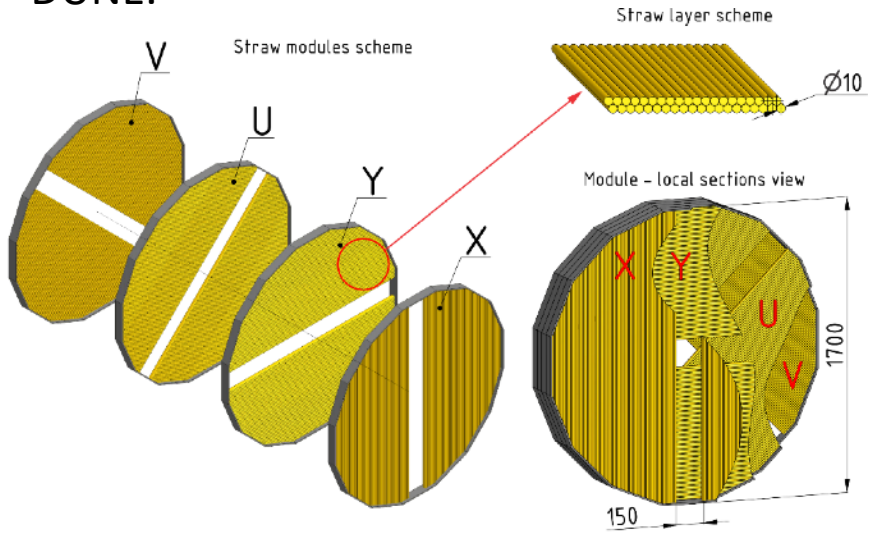


Straw tracker

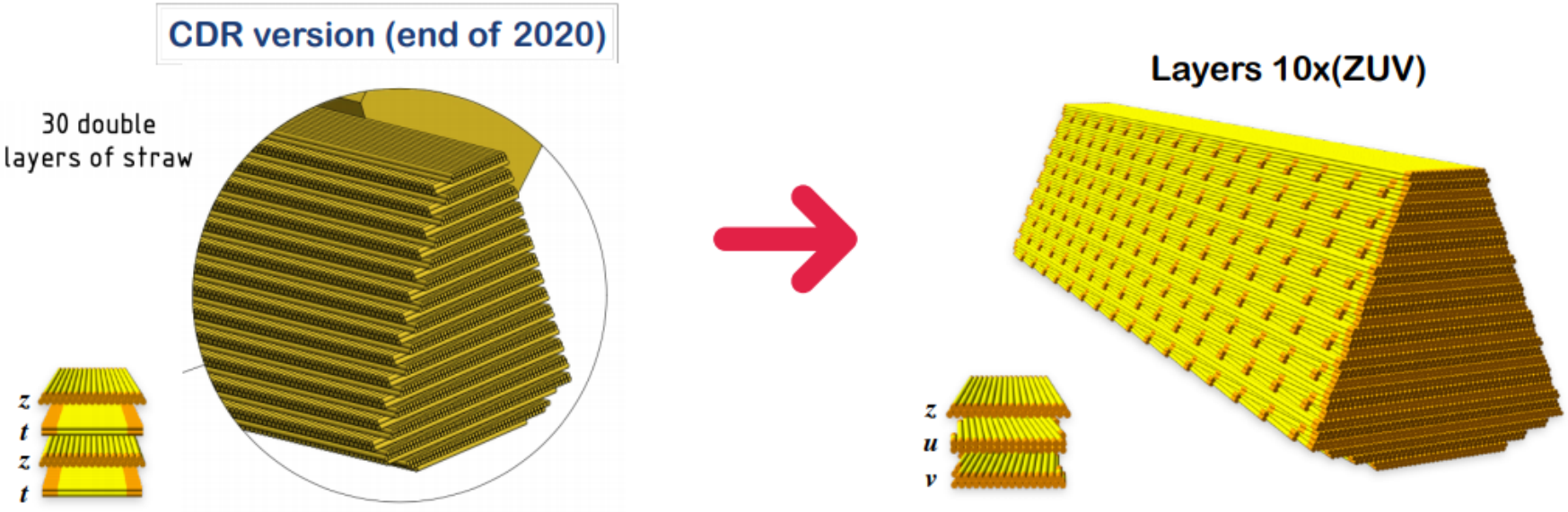


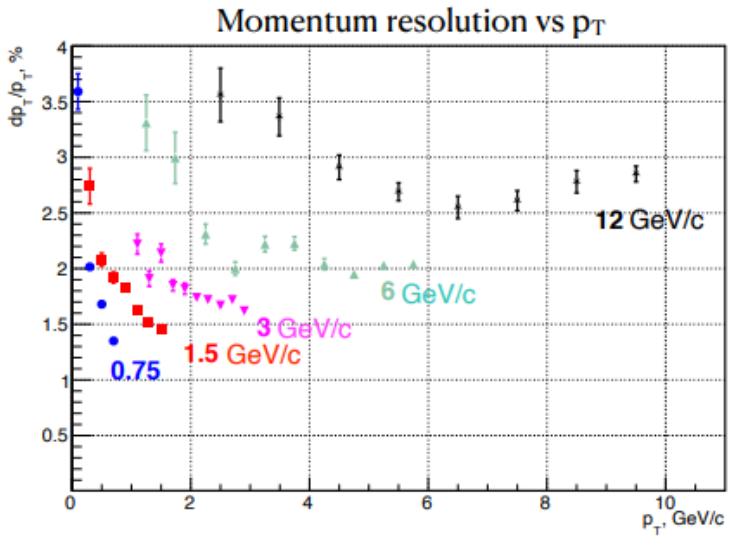
- Main tracker system of SPD
- Straw diameter 10mm thickness 36mkm PET
- Spatial resolution of 150mkm
- Barrel is made of 8 modules with up to 30 double-layers, with the ZUV orientation
- Endcaps are made of 12 double-layers with the XYUV orientation
- Vast experience in straw production in JINR for several experiment: COMPASS, NA-62, NA-64, SVD-2; prototypes for: CREAM, SHiP, COMET, DUNE.





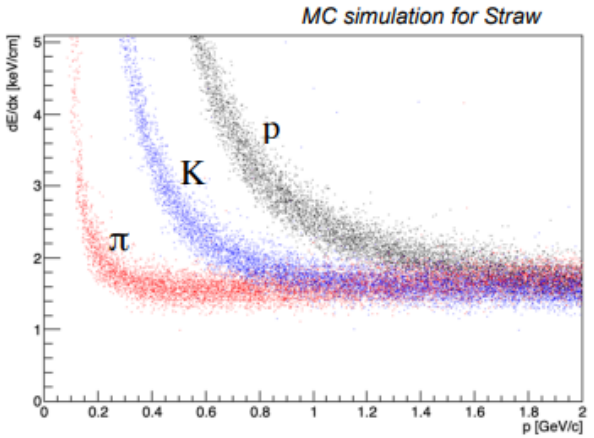
Straw Tracker (ST)



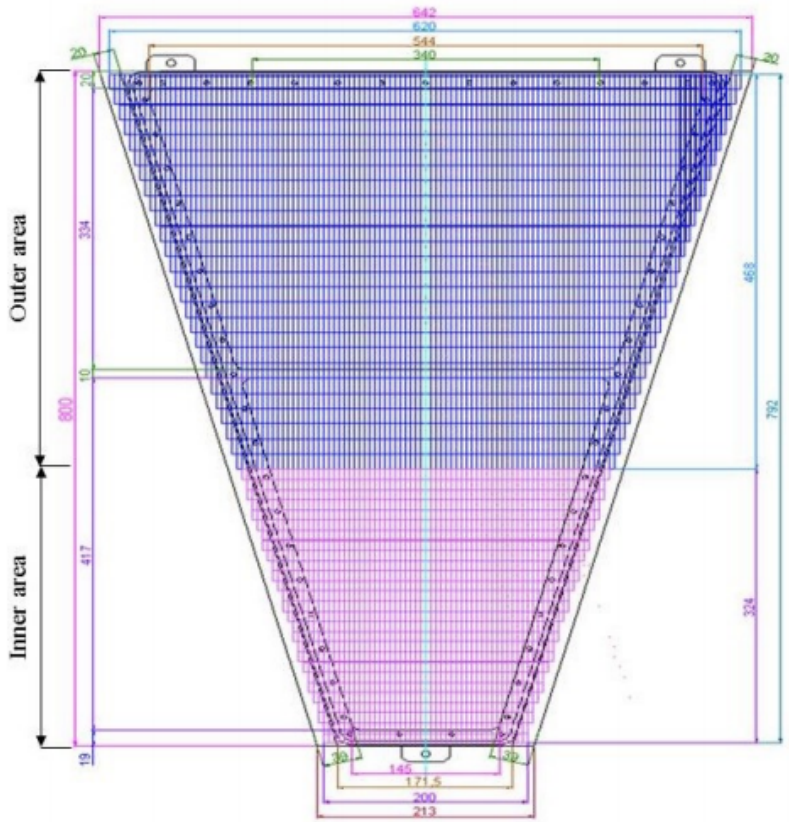


- Majority of tubes should be oriented ⊥ to the bending plane
- Number of channels can be reduced by a factor of 3
- Less dead space due to covers & electronics

PID: TPC compared to Straw in respect of the dE/dx analysis



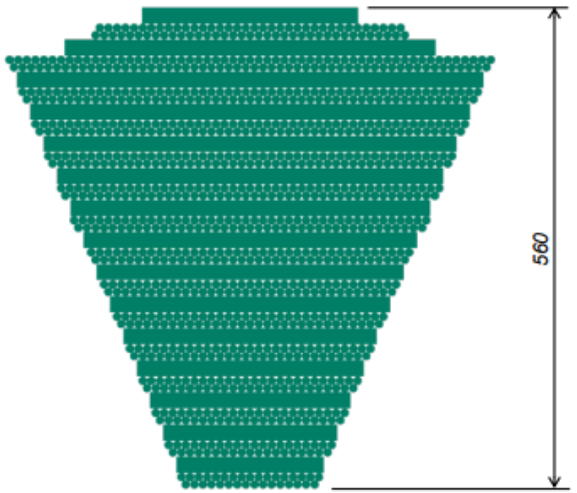
TPC of MPD



Inner pads: S = 5mm x 12mm = 60mm²
Outer pads: S = 5mm x 18mm = 90mm²

Maximum drift time 30 μs

Straw of SPD



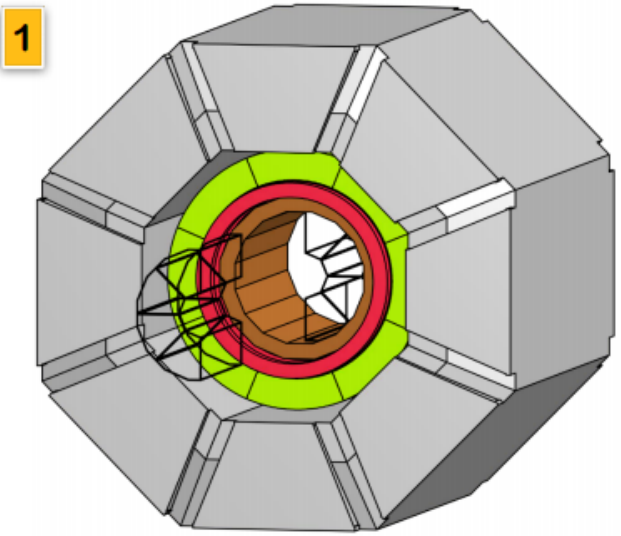
⌀=10mm straw: S = 78mm²
⌀=5mm straw: S = 20mm²

Maximum drift time 120 ns

ST assembling procedure

all will be done by hand

1



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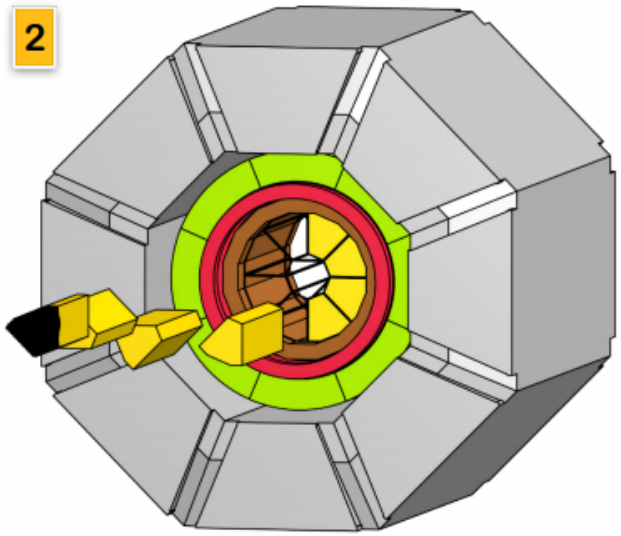

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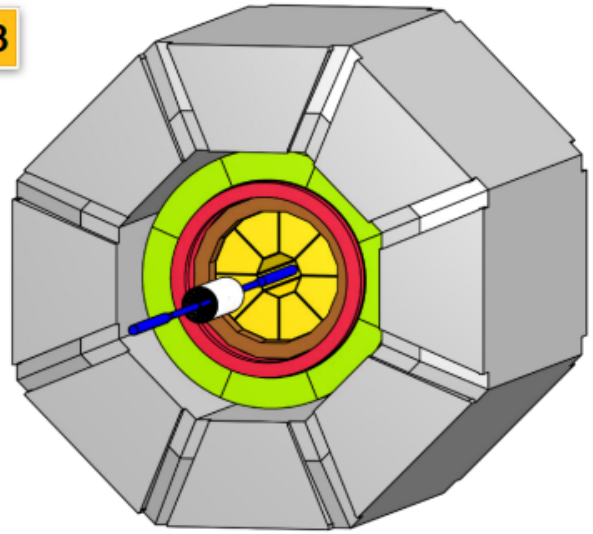

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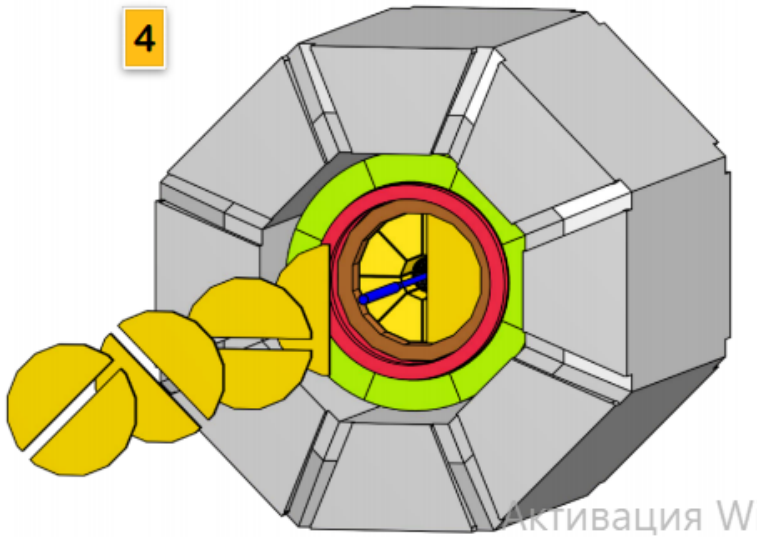
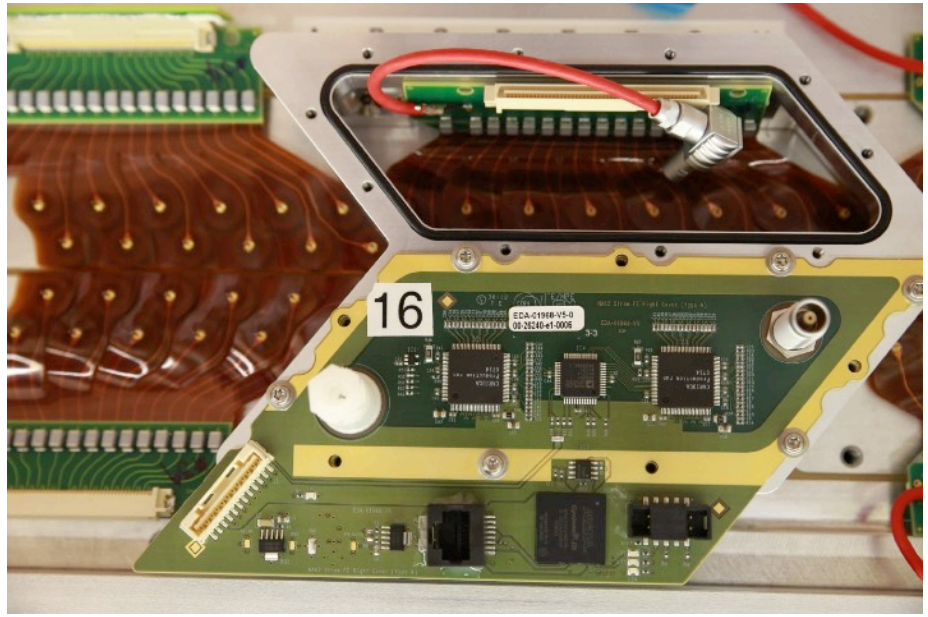


TRACKER ELECTRONICS NA62



		HPTDC (manual)	CYCLONE10 TDC
780ps	INL	+/- 0.25 bin	+/- 0.06 bin
	DNL	+/- 0.2bin	+/- 0.03 bin
390ps	INL		+/- 0.007 bin
	DNL		+/- 0.008 bin
	Double pulse resolution	10ns	0.195ns -> 6 ns (worst case)
	Max hit rate per channel	2 MHz	160 MHz leading edge +160Mhz trailing edge
	Max hit rate per chip	<40 MHz	40MHz -> 300 MHz
	Buffer per channel	4	1024 (more if needed)
	Buffer per group of 8	256	1024 (more if needed)

TRACKER ELECTRONICS NA64

iFTDC can work both in triggered or trigger-less mode (this has been tested and confirmed), has precision down to 150 ps: well above the requirements of the straw tracker.

FFE Electronics are based AST-1-1 from Solin

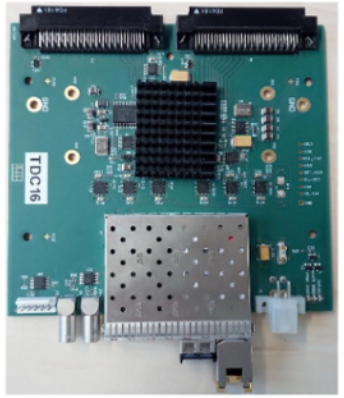
iFTDC

Specification

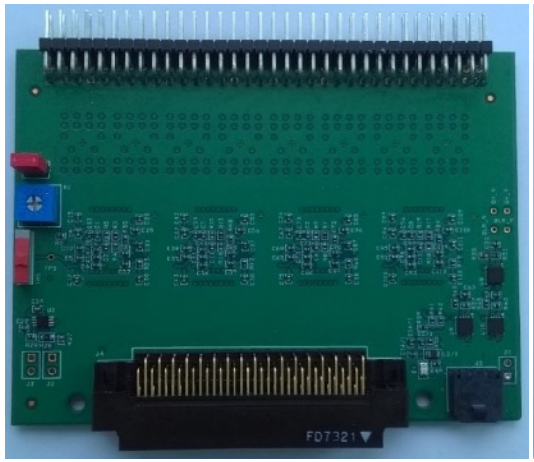
- ARTIX7 FPGA XC7A-35
- 64 channels,
- Programmable signal edge or both edges
- **Bin size : 1 ns, 0.5 ns, 0.25 ns (32 channels)**
- **Time resolution : 300ps, 170 ps, 10 ps**
- **Differential nonlinearity : 10%, 20%, 40%**
- **Trigger less capable data flow**

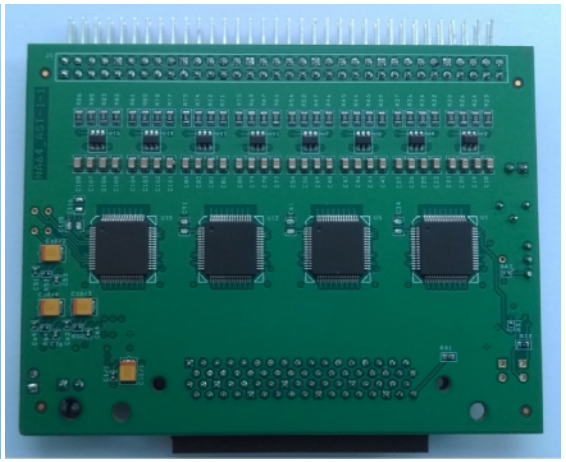
Applications

- MWPC(tested), Drift Chambers
- Scintillation Counters with limited requirements for time resolution



Напряжение питания микросхем	2.8 В
Длительность выходных сигналов	90 нс
Амплитуда выходных LVDS сигналов	150 мВ
Входное сопротивление	180 Ом





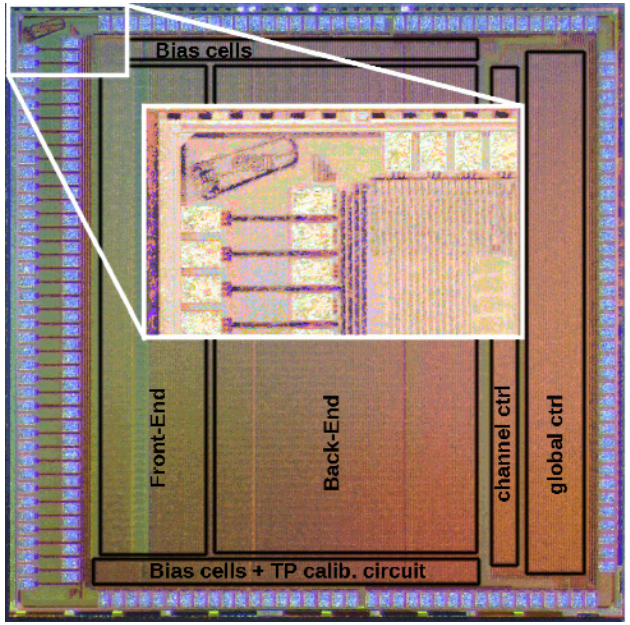
TRACKER ELECTRONICS TIGER

In Turin the electronics based on the **TIGER** chip (Turin Integrated Gem Electronics for Readout) is developed for trigger-less readout ***of the GEM detectors***.

Charge and time measurements provided.

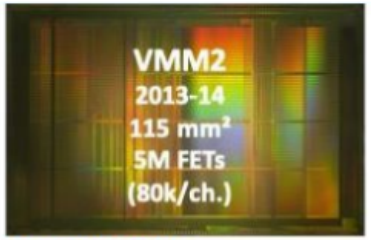
TIGER parameters

5 x 5 mm^2 110nm CMOS technology
64 channels: preAmp, shapers, TDC/ADC, local controller
Digital backend inherited from TOFPET2 ASIC (SEU protected)
On-chip bias and power management
On-chip calibration circuitry
Fully digital output
4 TX SDR/DDR LVDS links, 8B/10B encoding
Nominal 160 MHz system clock
10 MHz SPI configuration link
Sustained event rate > 100 kHz/ch

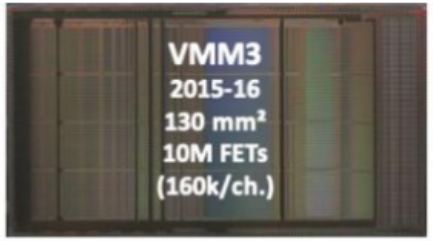


TRACKER ELECTRONICS DUNA

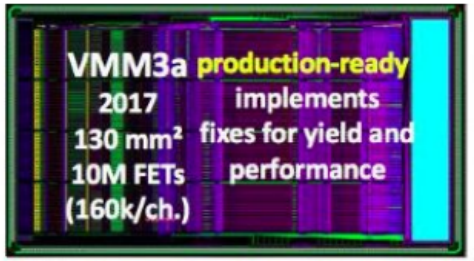
- mixed-signal
- 2-phase readout
- peak and timing
- neighbouring
- sub-hysteresis
- few timing outputs



- mixed signal
- continuous fully-digital readout
- current-output peak detector
- increased range of gains
- three ADCs per channel
- FIFOs, serialized data with DDR
- serialized ART with DDR
- additional timing modes
- 64 timing outputs
- ITAR
- additional functions and fixes



- mixed signal + digital
- continuous simultaneous readout
- SEU-tolerant logic
- Deeply revised front-end for TGC (2nF, 50pC, fast recovery, ...)
- L0 handling digital core
- SLVS and new config. interface
- new reset control and fast reset
- timing at threshold
- timing ramp optimisation
- pulser range extension
- ART synchronisation
- 32-channel skip
- additional functions and fixes

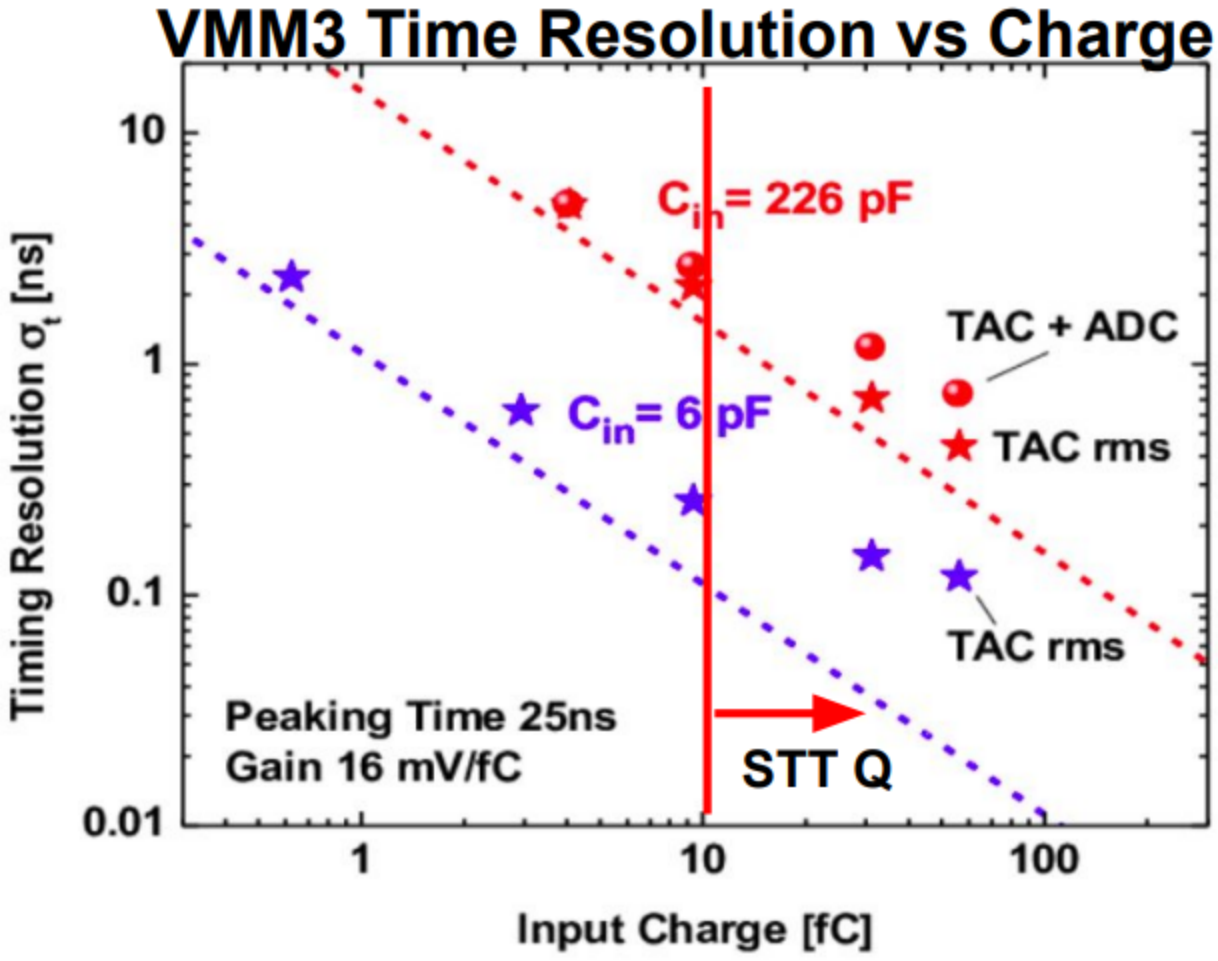


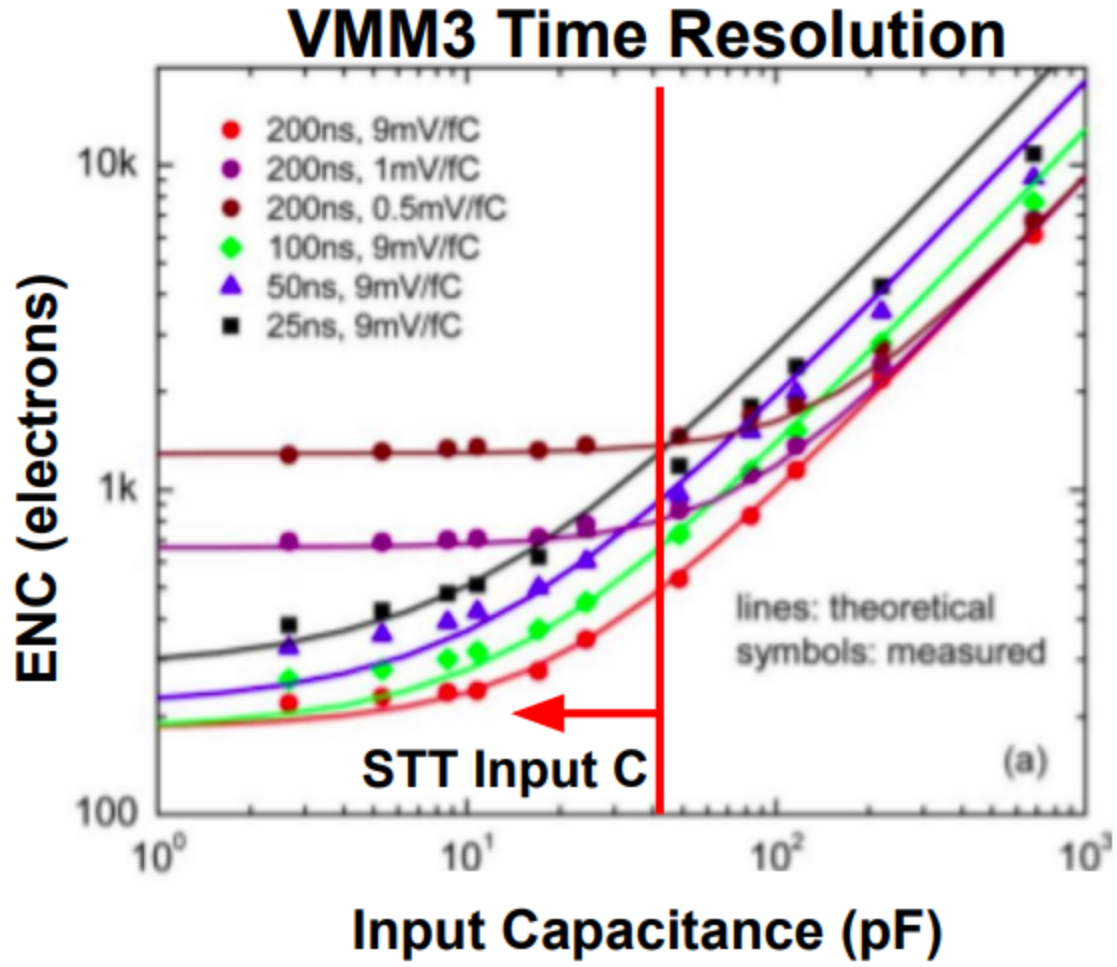
- Adjustable feedback currents
- Additional bug fixes
- Yield issues addressed

VMM3, the first prototype!
VMM3a - Production prototype, bug fixing

VMM3a ASIC is a mature design, developed for the ATLAS NSW

VMM3 Meets STT Readout Requirements

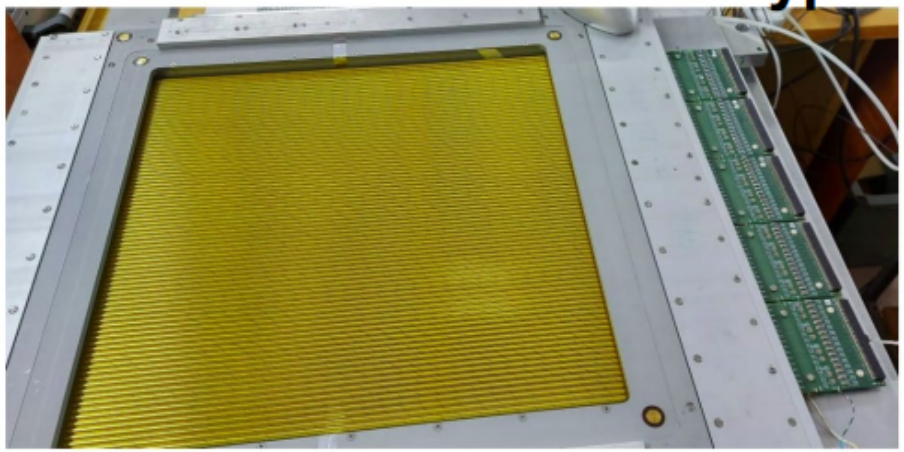




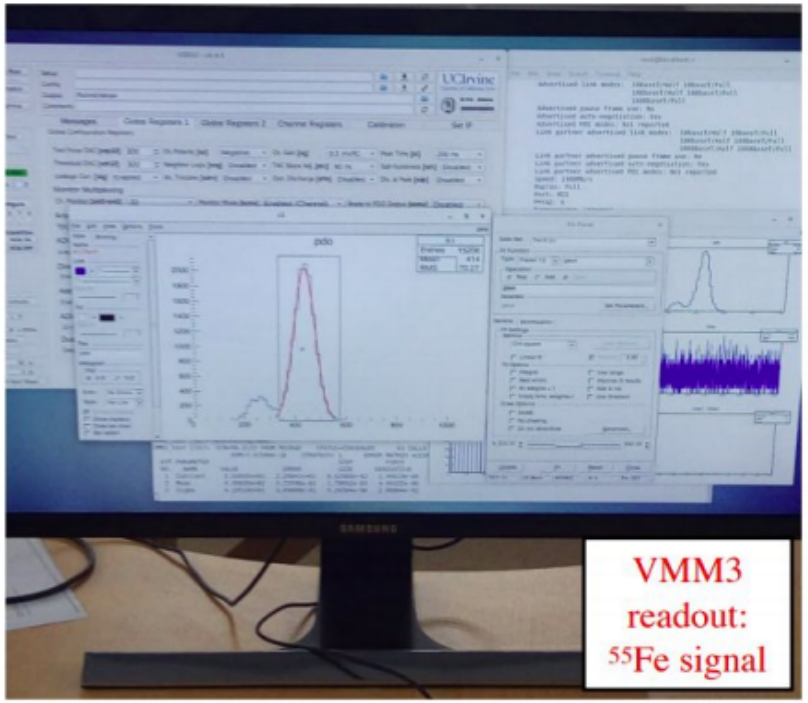
- VMM3a measures Q + T on each input for pulses above threshold
- VMM3a well matched to STT capacitance (<40pF) and charge signals (>10fC)
- Expect better than <1ns timing

VMM3 Readout Tests with STT Prototype

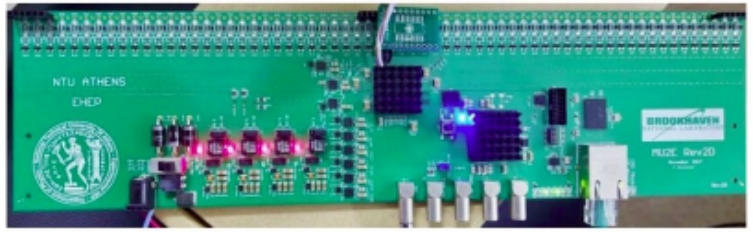
50cm x 50cm STT Prototype

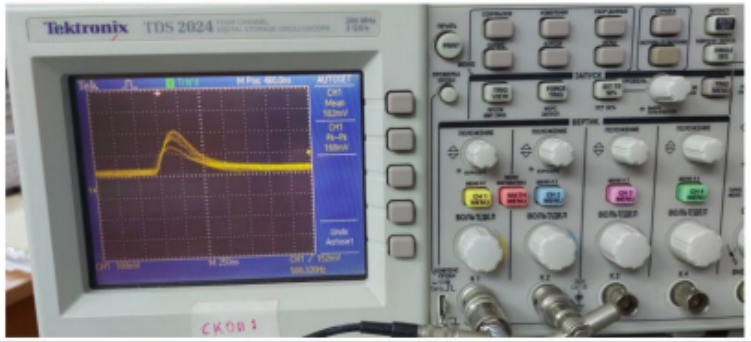


VMM3+STT Test DAQ Software



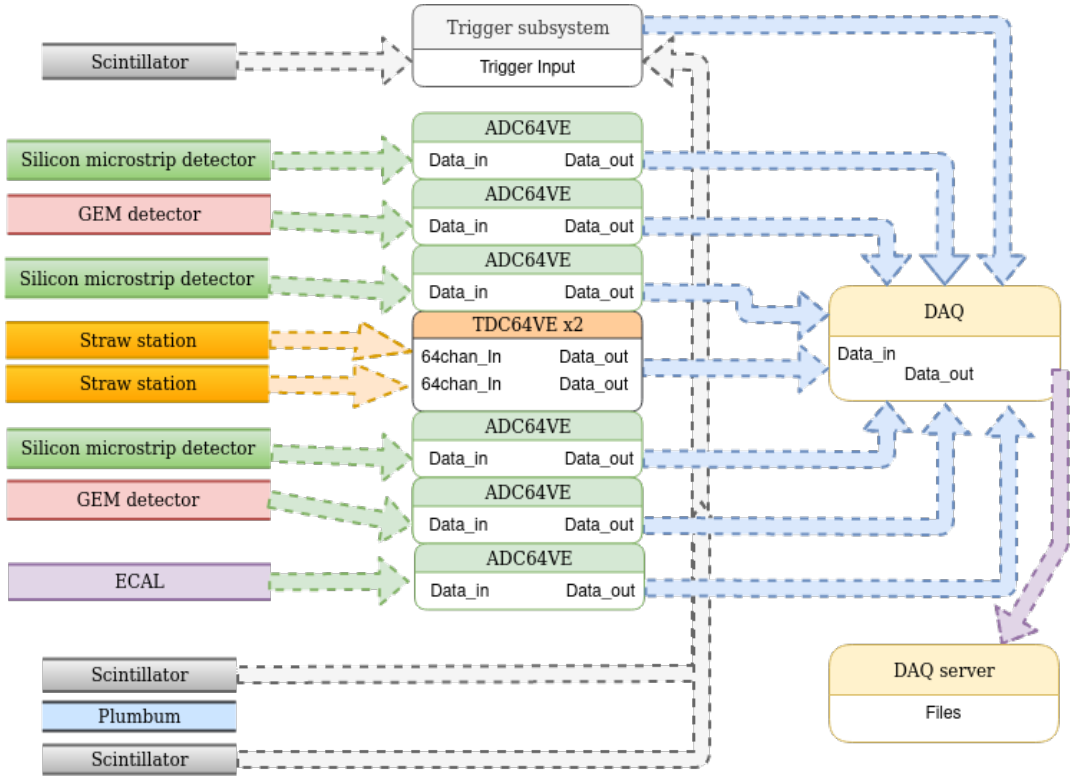
VMM3 Board with STT Signals Shown on Analog Output

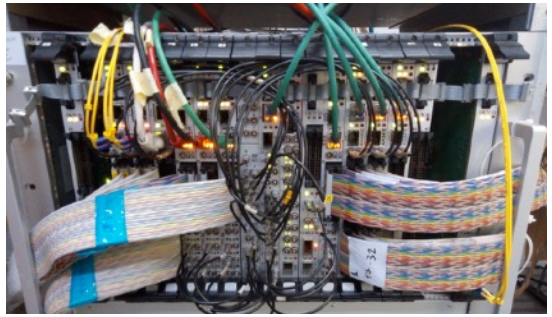


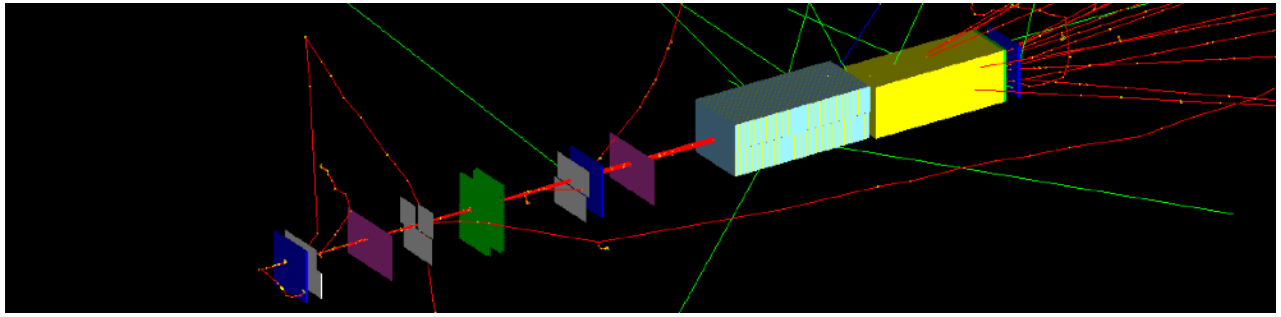


- VMM3 FEB single-ASIC prototype boards used to read out STT prototype in lab, validate readout
- Use existing VMM3 FPGA-readout test DAQ
- Tests ongoing, good charge resolution obtained
- 2 wafers of new VMM3a ASICs produced, covers prototyping effort and initial production

MiniSPD testing facility







future plans

- perform tests with existing electronics and cameras on the electron beam DLNP
- development and production of a prototype of a tracker barrel part
- conducting work on the use of VMM3a electronics for the straw tracker prototype
- perform tests with existing electronics and cameras on the test zone NICA SPD
- work on the development of the slow control system at the miniSPD facility
- training of personnel to work on the basic installation in the future