The PANDA Central Straw Tracker

On behalf of the PANDA STT group,

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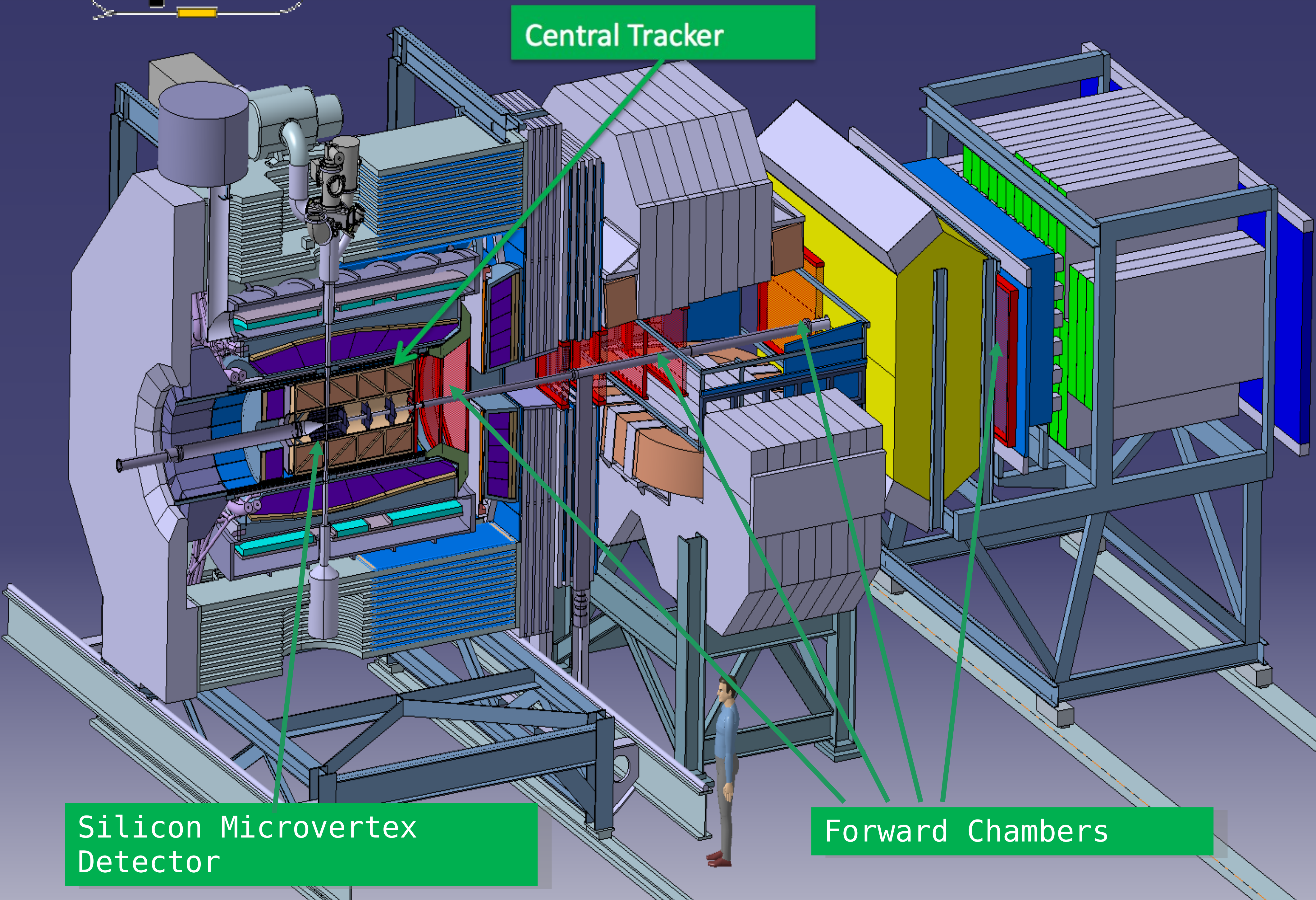
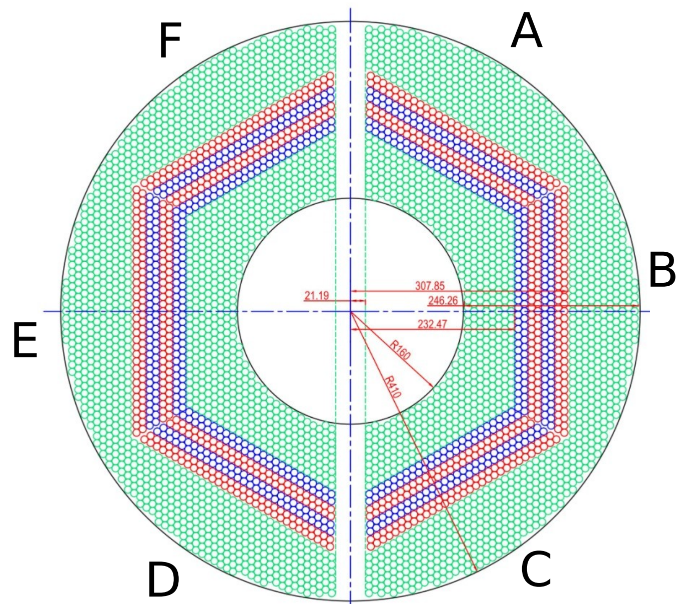

Central Tracker
Silicon Microvertex Detector
Forward Chambers

Requirements for central STT tracker of PANDA :

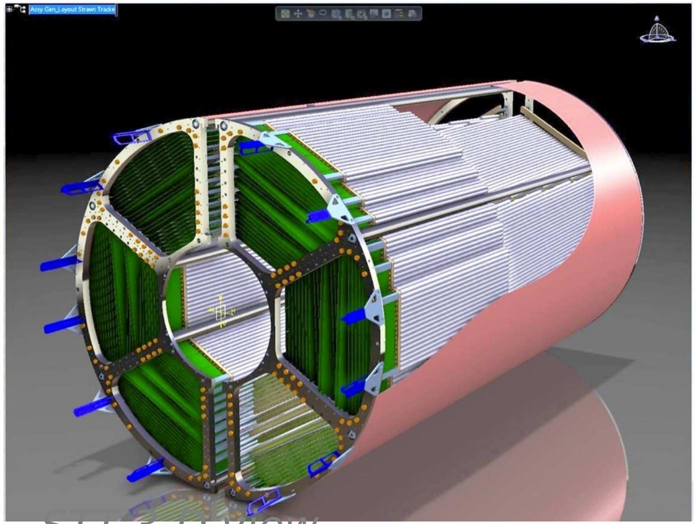
- efficient reconstruction of charged particle trajectories in angular range of 20 deg $\lesssim \theta \lesssim$ 140 deg;
- high precision determination of the particle momenta ($\delta dp/p \sim 1.5\%$);
- reconstruction of multiple tracks and secondary vertices;
- energy-loss resolution allowing for PID in low momentum range;
- minimal material budget in order to minimize multiple Coulomb scattering and secondary interactions;
- high rate capability ($1 \cdot 10^4$ events cm^{-2} s^{-1});
- radiation hardness (0.1 – 1 C cm^{-1} $year^{-1}$).

STT Layout

- 4636 straw tubes in 2 separated semi-barrels
- 6 hexagonal sectors (A-F)
- 23-27 planar layers in radial direction
  - 15-19 axial layers (green) in beam direction
  - 4 stereo double-layers: ±3° skew angle (blue/red)
- STT dimensions
  - Rinner/Router: 150/418 mm
  - Length: ~ 1400 + 150 mm
  - Inner / outer walls (~ 1mm kevlar)
- Material budget: X/X0 = 1.23 % (radial)



STT x-y view

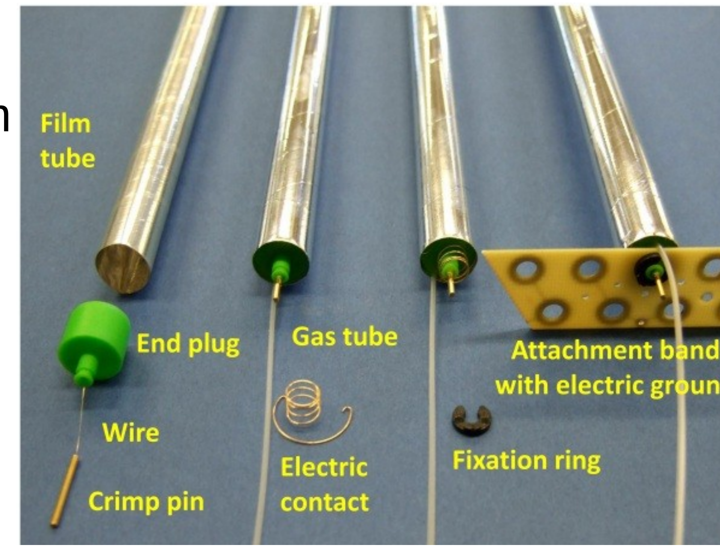


STT 3-D view

Straw Tube Design

Straw tube materials:

- Al-mylar film, d=27µm, ∅=10mm, L=1400mm
- 20µm sense wire (W/Re, gold-plated)
- End plug (ABS thermo-plastic)
- Crimp pin (Cu, gold-plated)
- Gas tube (PVCmed, 150µm wall)
- Cathode spring contact (Cu/Be, gold-plated)
- Locator ring (POM)
- Attachment strip (GFK) with electric ground
- 2.5g weight per tube
- $X/X_0=4.4\times 10^{-4}$ per straw tube



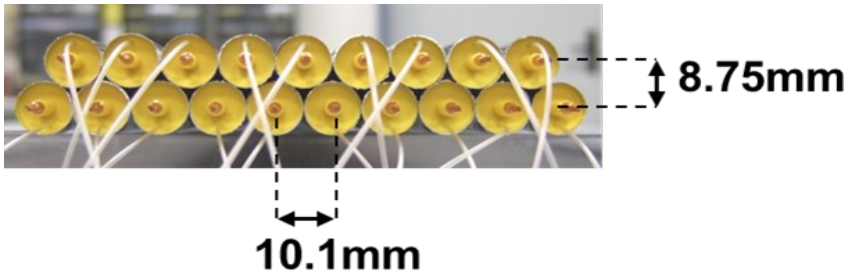
Element	Material	X [mm]	X_0 [cm]	X/X_0
Film Tube	Mylar, 27µm	0.085	28.7	3.0×10^{-4}
Coating	Al, 2× 0.03µm	2×10^{-4}	8.9	2.2×10^{-6}
Gas (2bar)	Ar/CO_2 (20%)	7.85	5966	1.3×10^{-4}
Wire	W/Re, 20µm	3×10^{-5}	0.35	8.6×10^{-6}
			Σ_{Straw}	4.4×10^{-4}

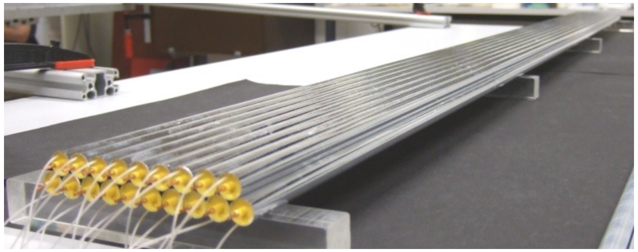
(Developed by P. Wintz (IKP-FZJ)
for COSY-TOF experiment)

Self-Supporting Straw Layers

Novel technique (from COSY-STT):

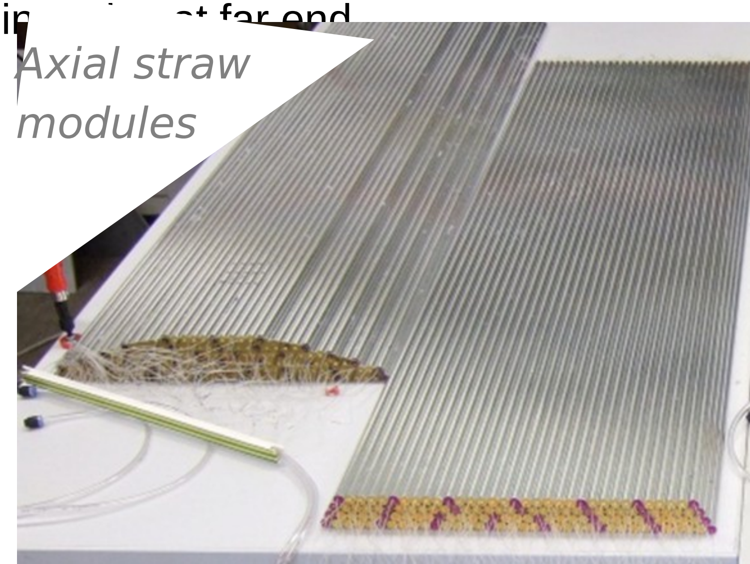
- Straw tubes are assembled under overpressure (Δp=1bar)
- Pressurized straws are close-packed (~20µm gap) in planar multi-layer
- and glued together (dot glueing)
- Strong rigidity: multi-layer straw module is self-supporting
- No stretching of straw ends from mechanical frame needed
- Perfect and strong cylindrical tube shape by overpressure
- No reinforcement structures along the length needed
- Lowest weight, precise geometry, maximal straw density





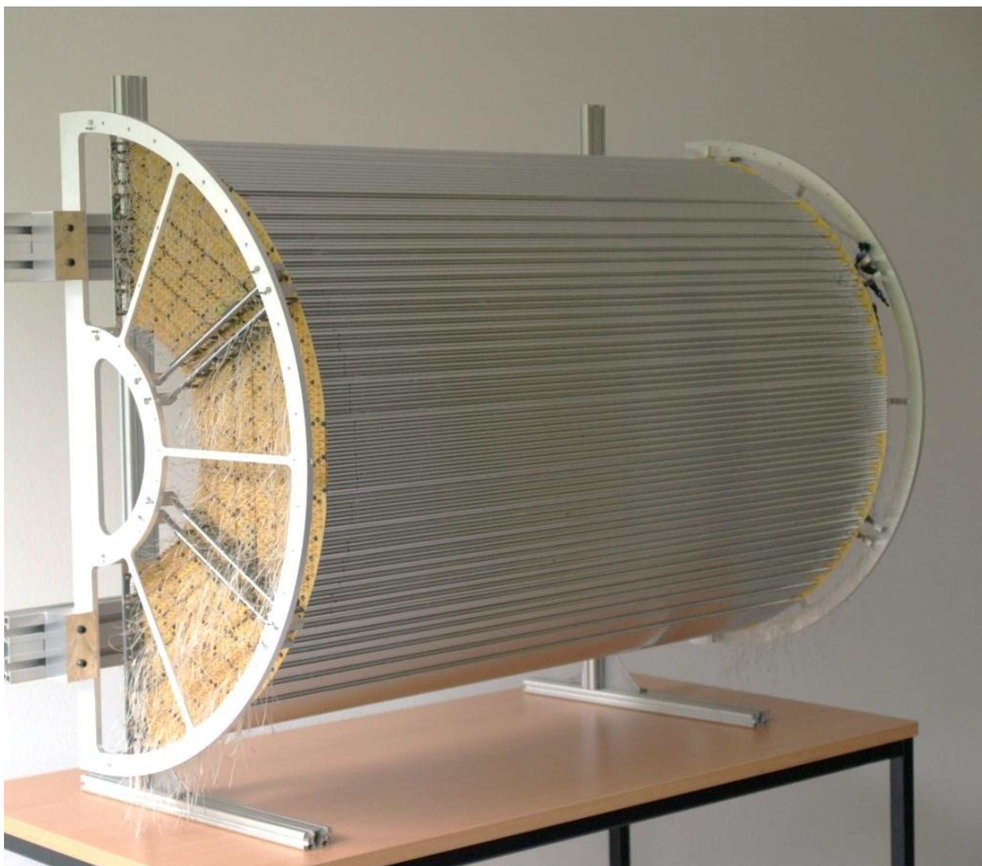
Axial Straw Modules

- Axial quad-layer module
  - 4 close-packed planar layers, (dot) glued together
  - Increased rigidity compared to double-layer
  - Replacement of faulty single straws still possible (from outer to inner layer)
  - Even number of straws and gas lines per module
- Only 1 inlet + 1 outlet gas pipe for one module
- In-/outlet at same end by connecting 2 straws in [illegible] at far end
- Outer axial module
  - 3-7 close-packed planar layers
  - Outer circular shape



Straw Modules Layout

Semi-barrel, length 1.2 m, final radial dimensions, reduced mech. frame



STT prototype, one semi-barrel

Hexagon sector, mounting brackets to fix modules in mechanical frame

STT sector consisting of 6 straw modules:

2 inner axial + 2 stereo + 2 outer axial

Performance of the PANDA Straw Tube Tracker

High tracking abilities of straw detectors are commonly known. Also the prototypes of PANDA STT proved very good performance with respect to:

- tracking (spatial resolution $\sigma_{r\Phi}$ = 140μm),
- HV operation,
- mechanical stability,
- tightnes,
- ageing.

Challenges

Energy loss measurement → proper calibration, careful signal integration and data truncation needed.

dE/dx resolution depends on tracking procedure, space resolution.

Track position measurement → depends strongly on signal quality, t0 determination, precise drift time-space relation fitting.

Preamplifier performance must be optimized for these requirements.

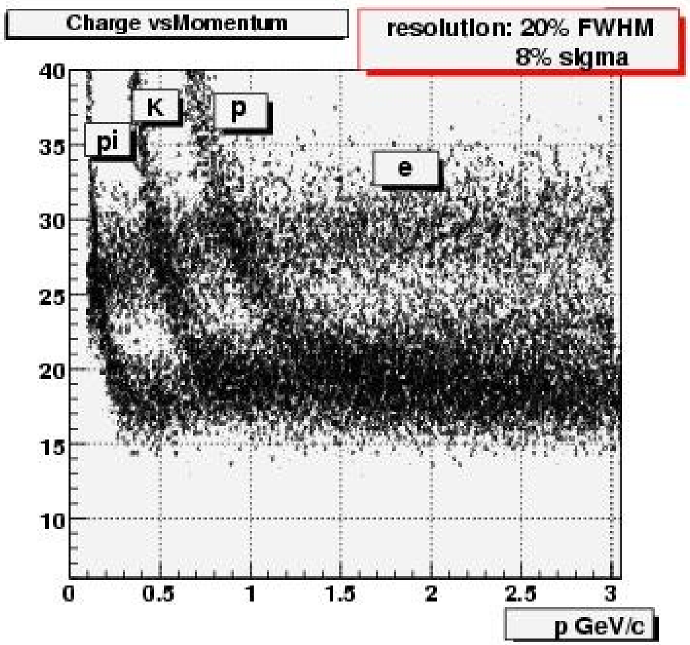
FPGA algorithms for signal evaluation in case of FADC have to be developed

All these problems have to be solved for the high rate environment of PANDA

Energy loss measurement in Straw Tube Tracker

Tests undertaken in IKP FZ-Juelich for :

- experimental check of the achievable energy-loss resolution in the Straw Tube Tracker,
- optimization of the detector working conditions, read-out electronics and data treatment in order to apply the particle identification method based on dE/dx.



Two optional STT readout

Two options of PANDA STT readout:

1. ASIC – specialized, programmable chip allowing for tail cancellation and baseline restoration:
   - time information (digital) (+ Time over Threshold → energy)
   - energy information (analog)

AGH University + Jagellonian University Kraków (Poland)

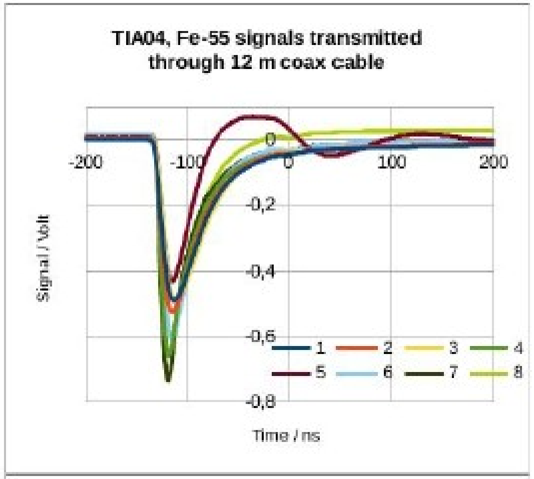
2. Signal booster + Shaper + FPGA-FlashADC; fixed optimal integration time, tail cancellation, baseline restoration:
   - time information (from FPGA discriminators)
   - energy information (from FPGA amplitude search procedure)

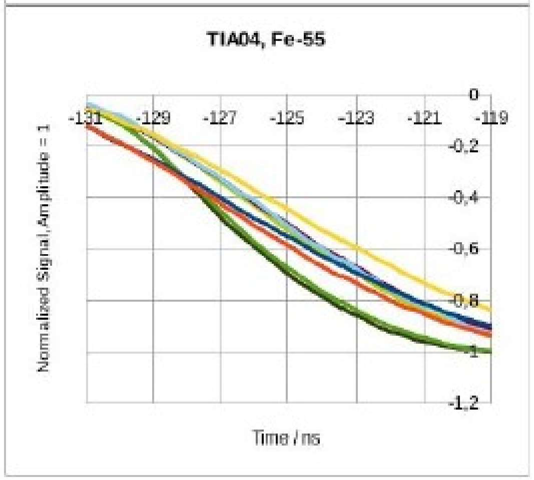
FZ Juelich (Germany) + INP PAN Kraków (Poland)

Parameter optimization

Tab. 2: Pulse risetimes (from 10% to 90% of the amplitude), signals amplitudes and noise voltages of TIA04 for pulse-generator signals or Fe-55. The electronical time resolution was estimated as $\sigma_{time} = \sigma_{rms} / (dV/dt)$. For simplicity the signal slope was taken as dV/dt = amplitude/risetime.

Ch. No.	10% - 90% Rise Time			Signal ampl.	RMS Noise	Time Resolution Estimate	Comments
	Generator		Fe-55			Fe-55	
	direct	via 12 m cable					
	ns	ns	ns	mV	mV	ps	
1	6,3	10.5	12,5	492	1.14	29	
2	5,5	9.4	11,3	532	1.13	24	
3	6,2	10.2	12,5	496	1.07	27	
4	4,3	6.4 ?	8,2	658	1.35	17	
5	5,7	8.6	11,1	432	1.01	26	Signal overshoot when 12 m cable is used; oscillates occasionally with ~ 20 MHz
6	**5,0**	**8.5**	**10,4**	**624**	**1.20**	**20**	
7	4,0	6.2	7,9	752	1.49	16	Oscillations on the trailing edge
8	5,2	8.9	11,1	596	1.22	23	Signal overshoot

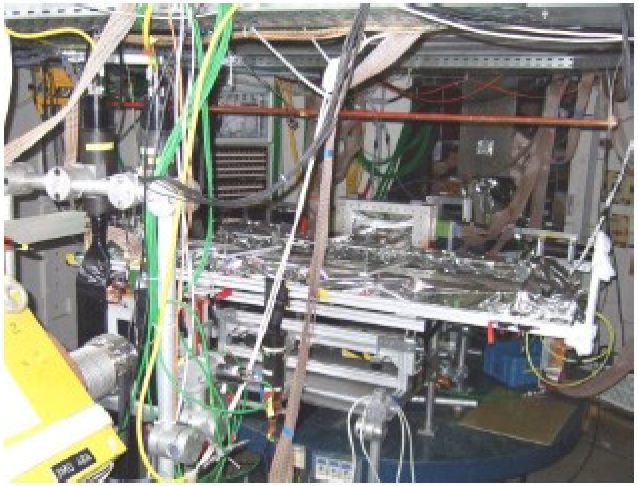




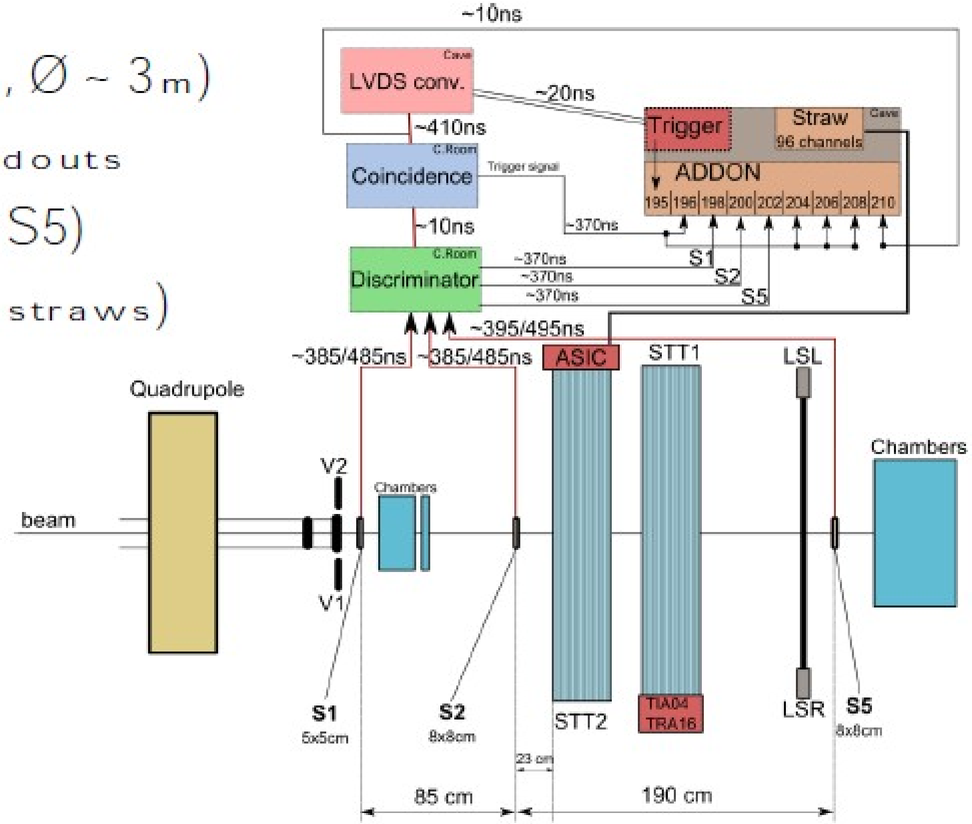
Henner Ohm's tests (parameter selection, long cables influence) → presentation in December CM

Straw Setups

- In COSY-BigKarl area (igloo, Ø ~ 3m)
- 2x straw setups for both readouts
- Trigger scintillators (S1, S2, S5)
- Additional chambers (GEM, straws)



Photograph of setups, beam from lower left



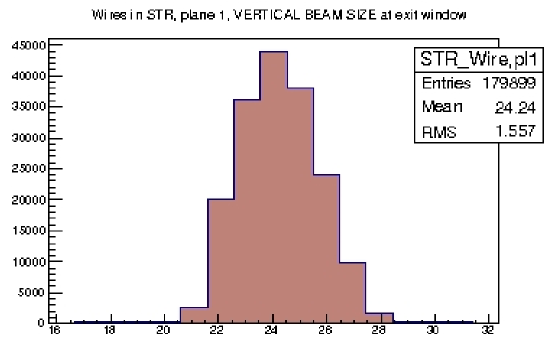
Sketch of system setups, beam from left

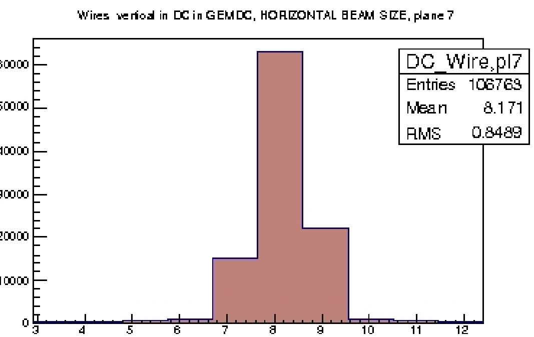
Beam profiles, 0.6 GeV/c
divergence horizontal~ 12mrad, vertical~9 mrad

vertical | horizontal

Pitch 0.41 cm

FWHM~1.4 cm



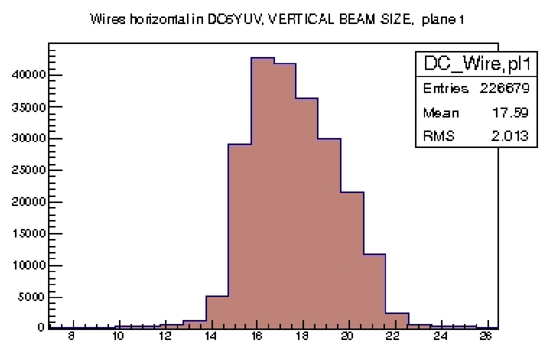


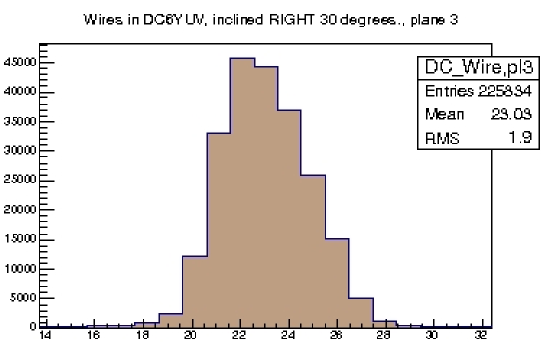
Pitch 1.0 cm

FWHM<~1 cm

Pitch 1.0 cm

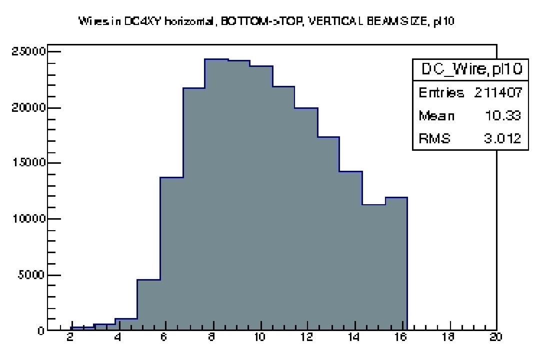
FWHM~5 cm

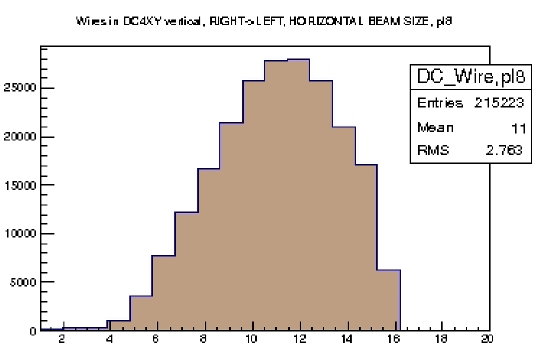




Pitch 1.0 cm

FWHM~11 cm





Pitch 1.0 cm

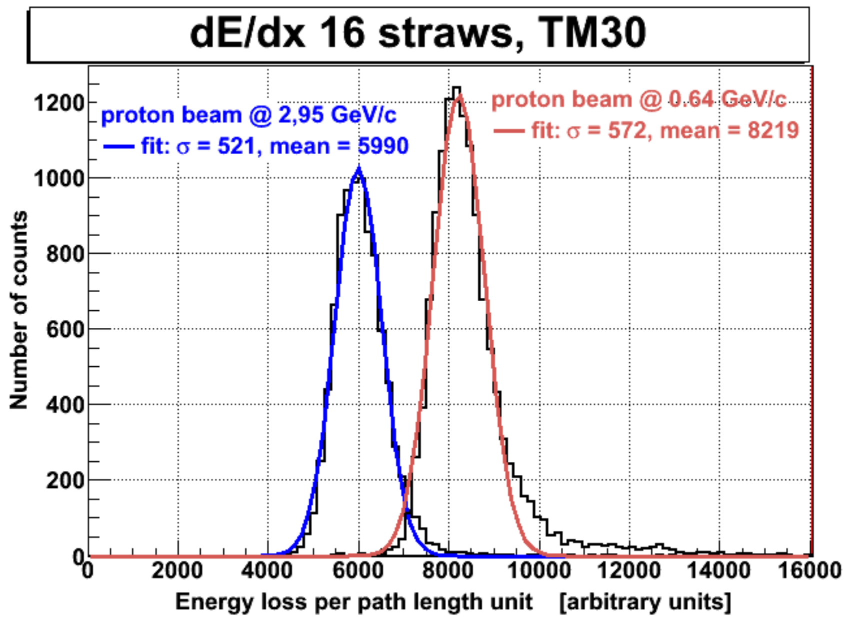
FWHM~8 cm

Straw & Readout Setups

- Readout channels
  - 96 straw channels (ASIC)
  - 32 + 64 straw channels (FADC)
  - Trigger & individual scintillators (offline timing)
- Straw settings:
  - Ar/CO_2 (10%) at 2 bar pressure (absolute)
  - Straw voltage range: 1750-1900V (= 3- 13 $\times 10^4$ gain)
  - Default: 1800V (= 5$\times$ 10^4 gain)
- ASIC (discriminator) settings
  - Lowest threshs ~ 20mV (noise level ~ 5-10mV), stable, no noise
  - Max. signal amplitudes 750mV (preamp saturation)
  - Tuned with pulser, noise level, cosmic runs, ..

3x ASIC boards a 32 channels

Results



The best achieved energy resolution (with 16 straws and at 0.64 GeV/c proton momentum):

$$\sigma_{dE/dx} = 9 \pm 1\ \%$$

Uncertainty sources:

- limited precision of drift time measurement (4.17 ns),
- limited ability for path length corrections for “tilted” tracks (only 2D tracking, precision of tracking, ...)

Summary

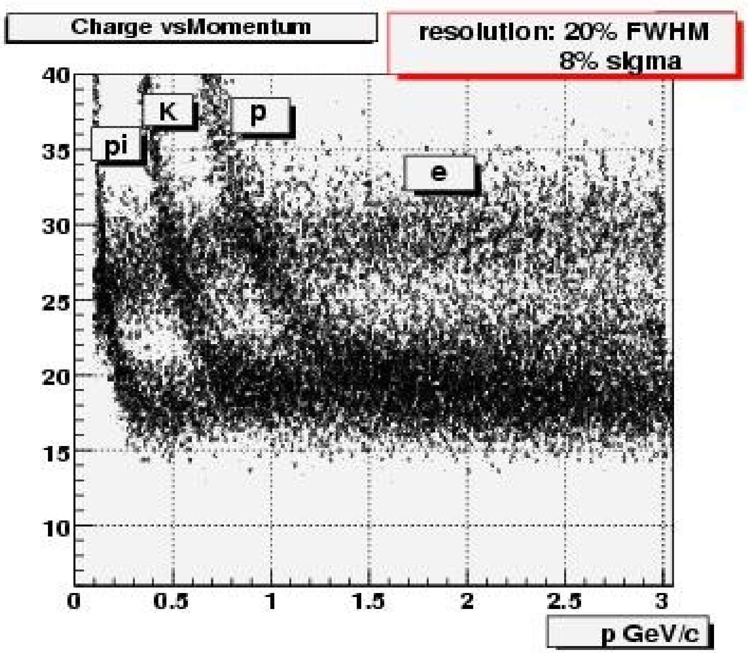
The central Straw Tube Tracker for PANDA is developed at the Institute of Nuclear Physics (IKP) in Forschungszentrum Juelich.

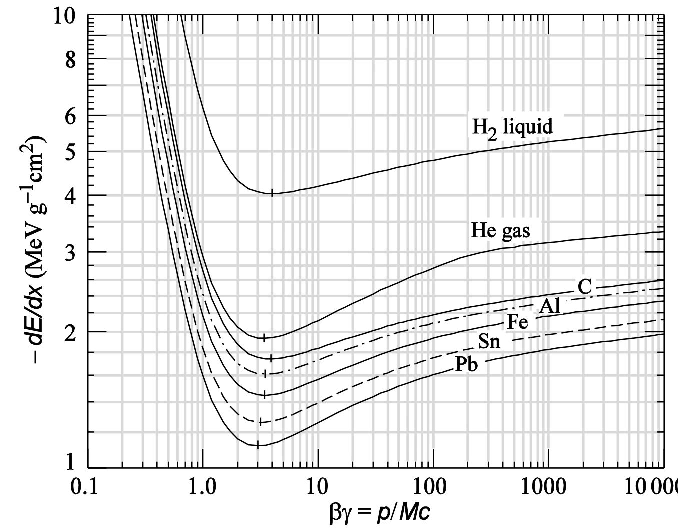
Mass production and quality assurance of individual straws is in progress.

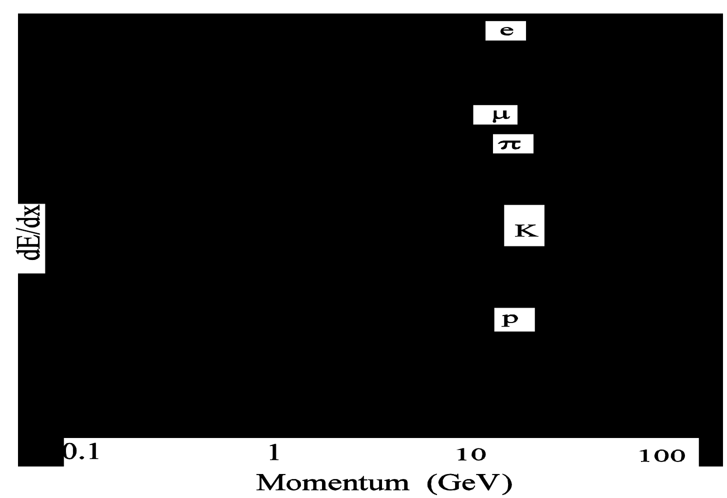
Two types of readout electronics are under development.

Beam tests at COSY with protons and deutrons at different momenta are in progress. Basic design characteristics of space and energy resolution are achieved.

Preliminary preassembly and commissioning of the STT is planned before the final transportation to GSI for the experiment


Charge vsMomentum
resolution: 20% FWHM
8% sigma
pi
K
p
e
40
35
30
25
20
15
10
0
0.5
1
1.5
2
2.5
3
p GeV/c


H$_2$ liquid
He gas
C
Al
Fe
Sn
Pb
$-dE/dx$ (MeV g^{-1}cm^2)
10
8
6
5
4
3
2
1
0.1
1.0
10
100
1000
10 000
$\beta\gamma = p/Mc$


e
μ
π
K
p
dE/dx
0.1
1
10
100
Momentum (GeV)