The Central Straw Tube Tracker In The PANDA Experiment

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11th International Conference on Low Energy Antiproton Physics, June 10-15, 2013, Uppsala, Sweden

Outline: PANDA - Straw Tube Tracker

- PANDA physics
- Central Straw Tube Tracker (STT)
  - Minimal material budget
  - High-rate tracking and PID
  - Online event reconstruction ($\rightarrow$ next talk)
- Test systems and results
- Simulation studies
- Summary

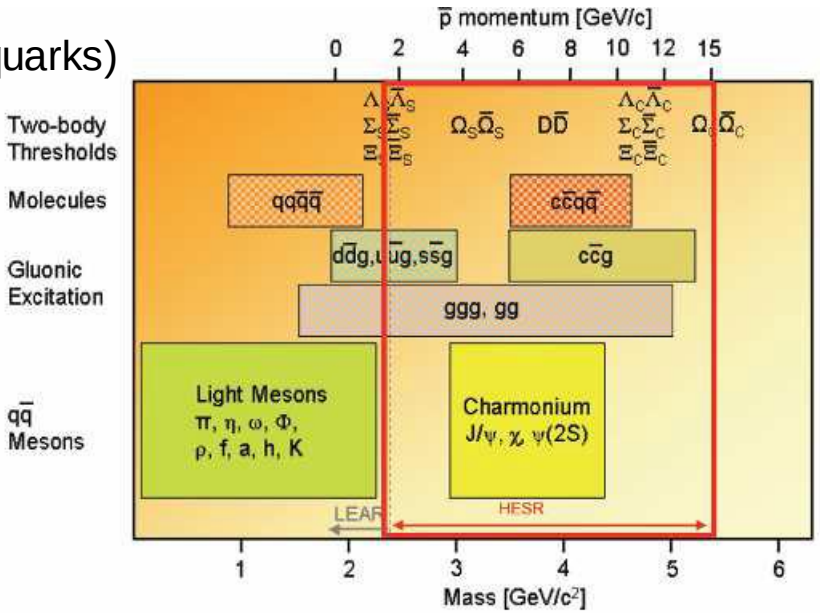
The $\bar{P}$ANDA Physics Program

→ Talks by A. Gillitzer (Tue), A. Sanchez (Wed), M. Maggiora, B. Kopf (Thu)

PANDA investigates $\bar{p}p$ and $\bar{p}A$ annihilation in the charm quark mass regime

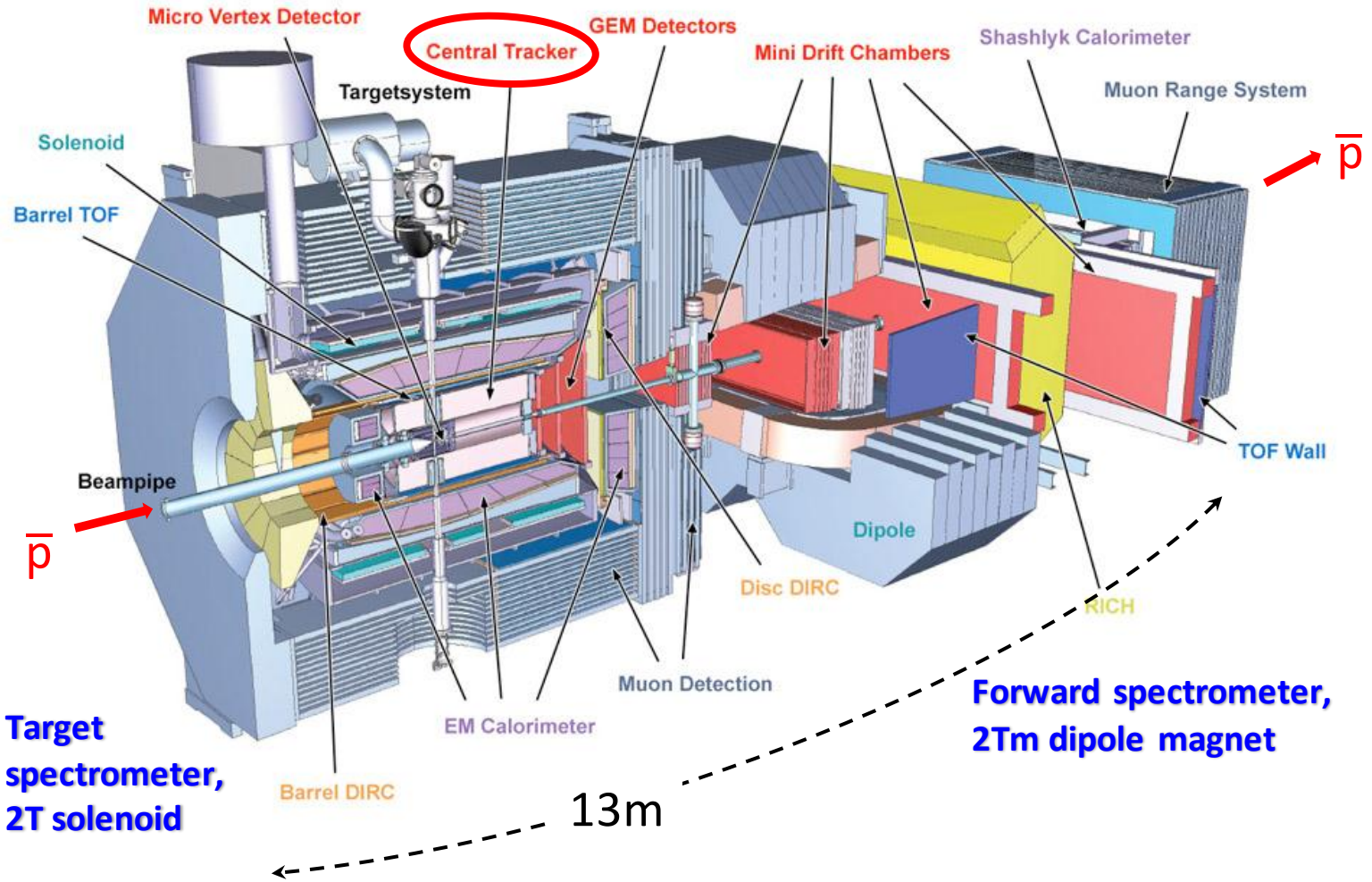
- Hadron spectroscopy *(m, Γ, J^{PC}, BR)*
  - Charmonium states
  - Open charm mesons (D-mesons)
  - Exotic states (glueballs, hybrids, multi-quarks)
  - Strange and charmed baryons
- Hadrons in nuclear medium
  - J/ψ – absorption, D meson mass shift
  - Hypernuclei ($_{\Xi^-}{}^{A}Z$, $_{\Lambda\Lambda}{}^{A}Z$), YY-interaction
- Structure of the nucleon
  - Electromagnetic formfactors
  - Generalized Distribution Amplitudes
  - Transverse nucleon spin (*full PWA*)

PANDA Physics Performance Report
arXiv:0903.3905 (216pp)



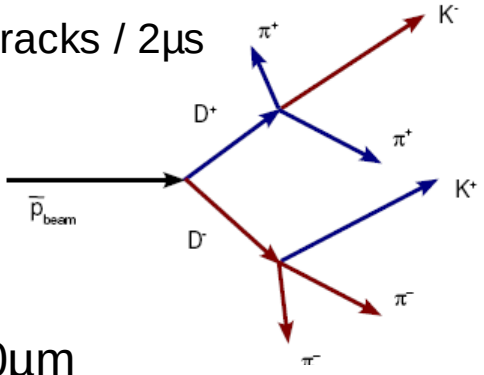
2.25 < √s < 5.47 GeV

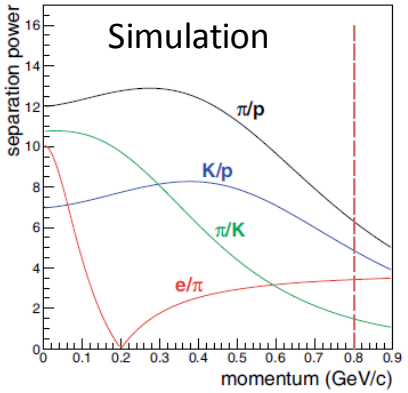
The $\bar{P}$ANDA Detector System In HESR → Talk by D. Calvo



Tracking At PANDA

- Variety of event topologies, all particle species involved
  - particle multiplicities up to 6 and higher, on average ~150 tracks / 2µs
  - broad momentum range ~ 100 MeV/c - 8 GeV/c
  - displaced vertices *O*(100µm) - *O*(10cm)
- 4π solid angle coverage (PWA)
- High momentum & spatial resolution: σ_p/p~1-2%, vtx ~50µm
- Particle identification: p/K/π <1 GeV/c (exclusively)
- Readout of (quasi-) continuous data stream
  - fast online track & event reconstruction, w/o t_0, evt. deconv.
  - flexible software triggering, specific reactions → data storage

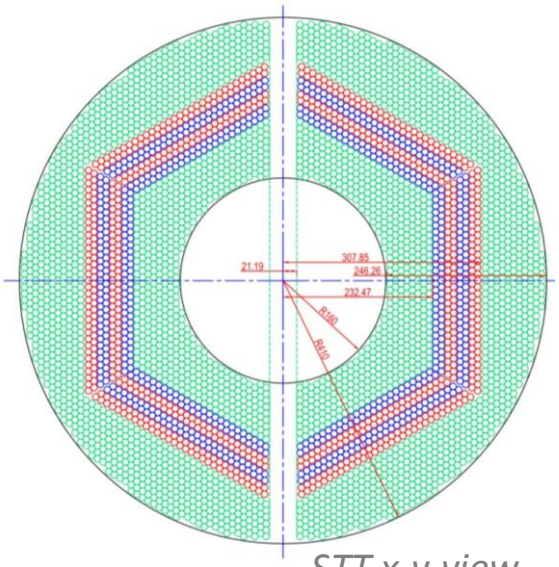




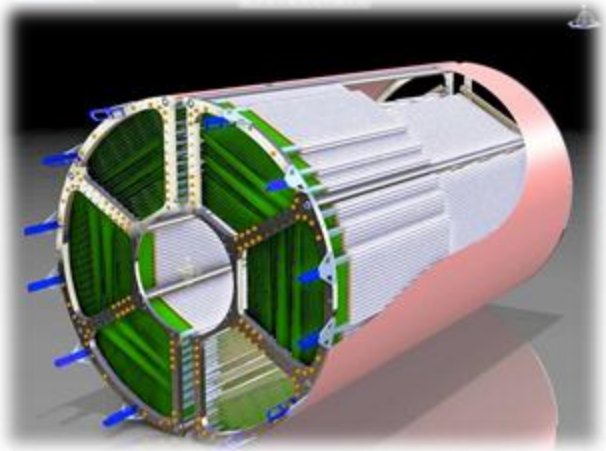
→Tracking system: MVD (vertex) + Central Tracker (large-vol) + GEMs (forwd)

Central Straw Tube Tracker (STT)

- 4636 straw tubes in 2 separated semi-barrels
- 23-27 radial layers in 6 hexagonal sectors
  - 15-19 axial layers (green) in beam direction
  - 4 stereo double-layers: ±3° skew angle (blue/red)
- Volume: R_{in} / R_{outr} = 150 / 418 mm, L~ 1650 mm
  - Inner / outer protection skins (~ 1mm Rohacell/CF)
- Ar/CO_2 (10%), 2 bar, ~ 200ns drift time (2 T field)
- Time & amplitude readout
  - $\sigma_{r\varphi}$ ~ 150 µm, σ_z ~ 2-3 mm (isochrone)
  - σ(dE/dx) < 10% for PID (p/K/π < 1 GeV/c)
- σ_p/p ~ 1-2% at B=2 Tesla (STT + MVD)
- X/X_0 ~ 1.25% (~ $^2/_3$ tube wall + $^1/_3$ gas)



STT x-y view

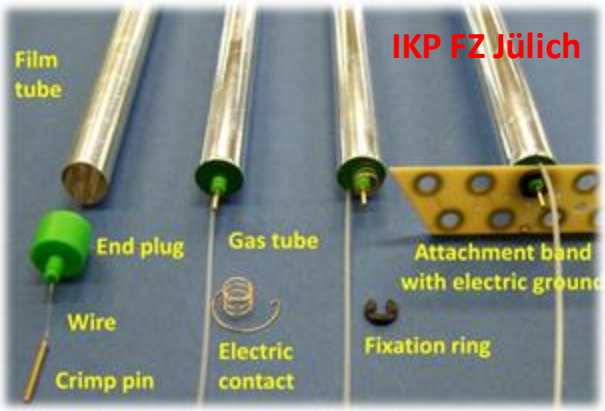

STT 3d-view

Straw Tubes

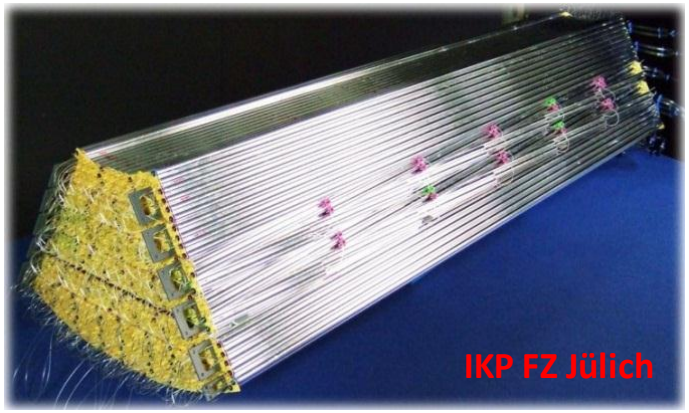
Material budget at lowest limit (2.5 g per assembled straw)

- thinnest Al-mylar film, d=27µm, ∅=10mm, L=1400mm
- thin-wall endcaps (ABS), wire fixation (crimp pins), radiation-hard
- self-supporting modules of pressurized straws (Δp=1bar)
  - close-packed (~20 µm gaps) and glued to planar multi-layers
  - replacement of single straws in module possible (glue dots)
- strong stretching (230kg wires, 3.2tons tubes)*, but no reinforcement needed

Straw components



Full hexagon sector

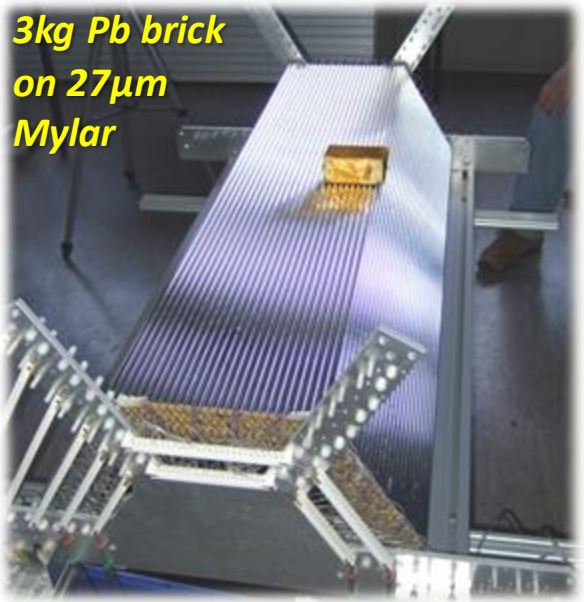


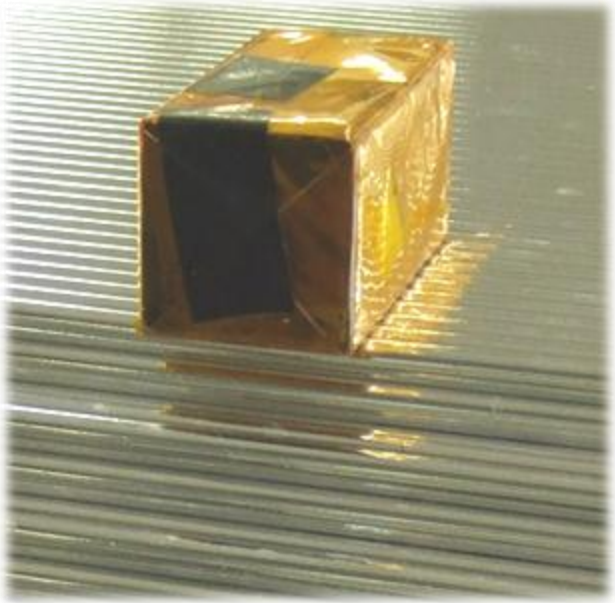
* Sum for 4600 straws in the PANDA-STT

Self-Supporting Straw Modules

.. technique first developed for COSY-STT (planar double-layers, in vacuum!)

.. upgraded for PANDA-STT (barrel geometry with 3d stereo-layers, quad-layers)

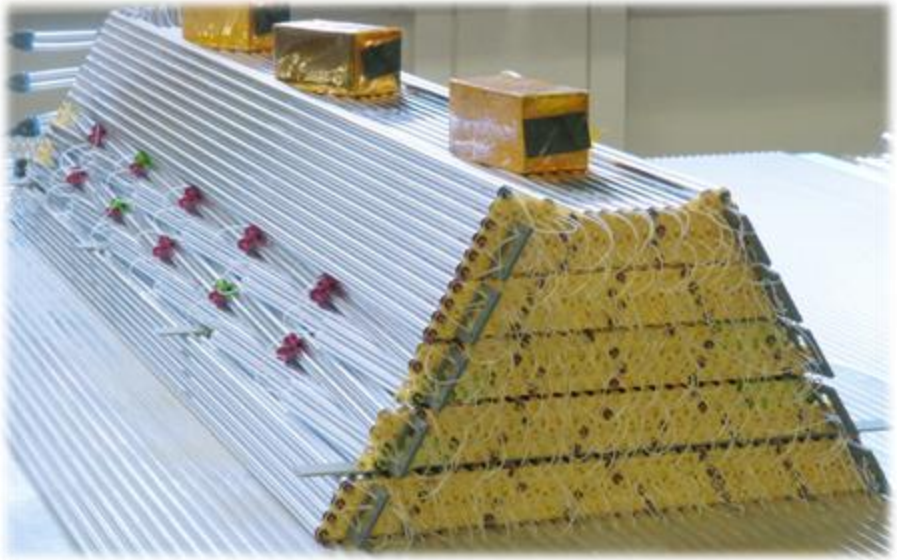




Pressurized, close-packed straw layers show a strong rigidity ..

STT Mechanical Prototype

Full hexagon sector, overpressure 1 bar

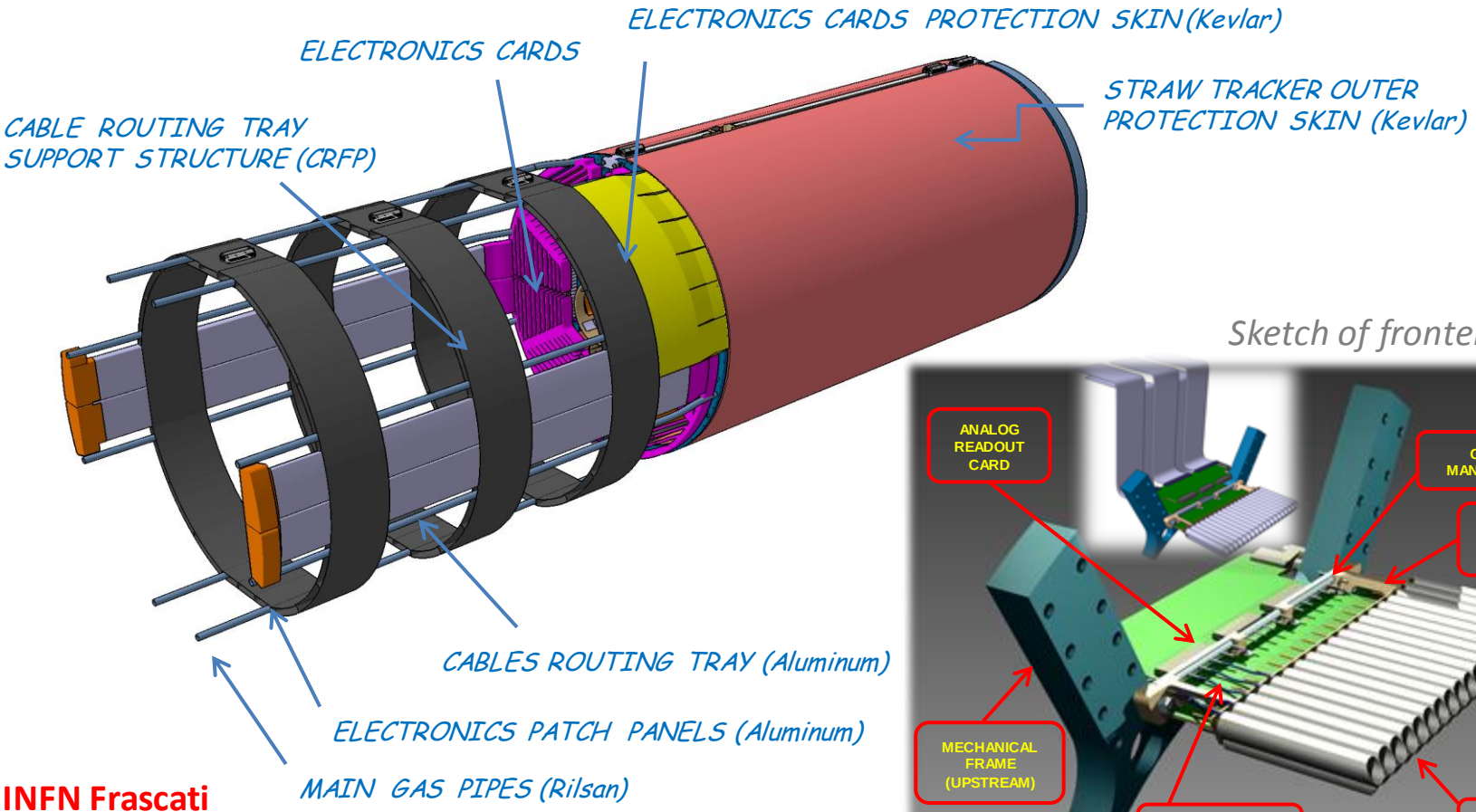


STT mechanical prototype, one semi-barrel

Even more confidence in the self-supporting straw modules through the years ..

.. 3×3kg!

Mechanical Frame Structure

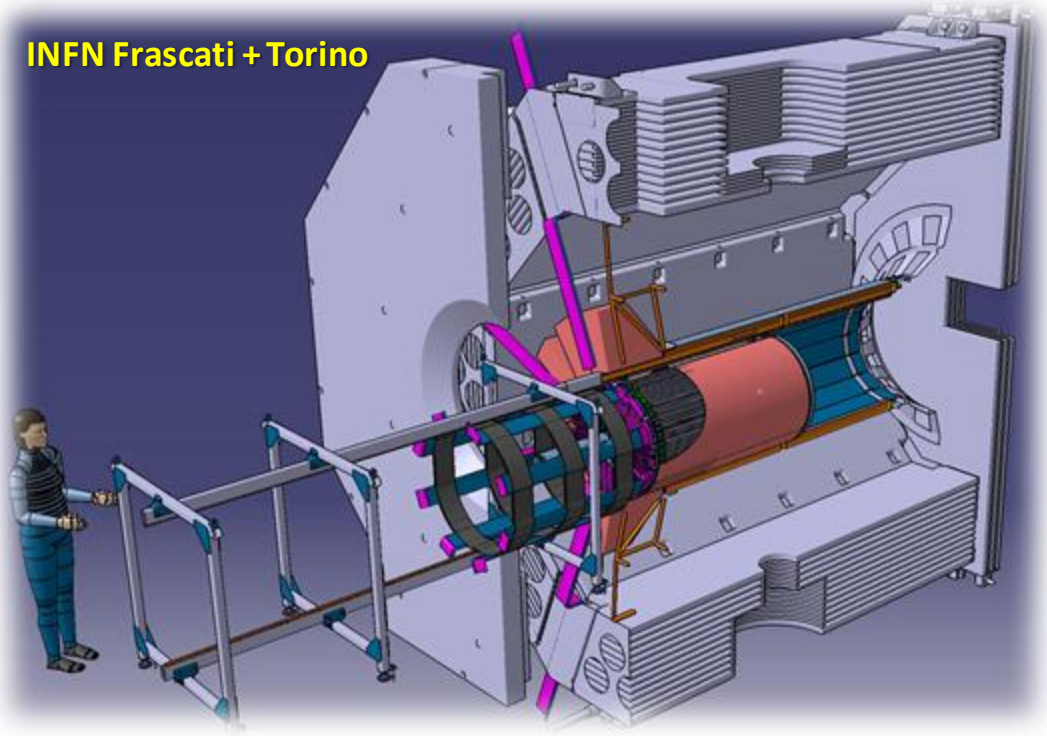


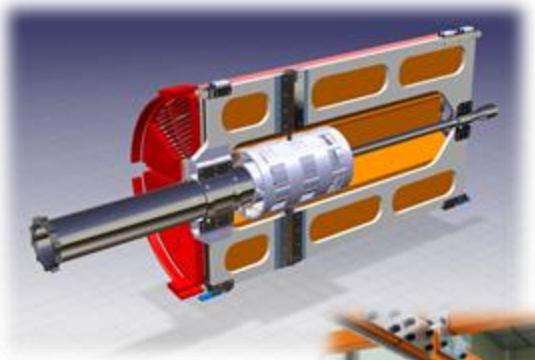
Sketch of frontend part

INFN Frascati

Final Assembly Scheme

- Central frame structure to support all central components
  - beam pipe + MVD + STT semi-barrels
- Rail system for insertion into the PANDA target spectrometer



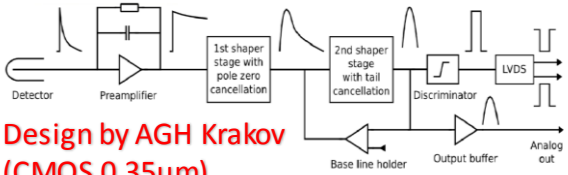


STT Readout

2 Concepts to measure drift time + signal amplitude (for dE/dx)

- Amplitude sampling: LE-Time + Q
  - Amplifier-shaper boards frontend at detector
  - Pulse sampling by FADC (240 MHz), pulse analysis and readout by FPGA
- Amplitude by time-over-threshold*: LE-Time + ToT(Q)
  - Ampl.-Shaper-Discr. (ASIC-chip) frontend at detector
  - Time Readout Boards (TRB), TDC in FPGA
- Requirements
  - ~ 2fC sensitivity (thresh. ~ 1.2×10^4 e^-)
  - ~ 1ns time resolution, ~ 200ns drift time range for Ar/CO_2(10%) at 2 T field
  - < 10% dE/dx resolution for PID
  - Hit rates: ~ 800 kHz/straw (max), ~ 400 kHz (avg.) at full luminosity
- FEE must be radiation-hard, low power consumption, minimum space

*ToT used for PID at ATLAS-TRT & HADES-MDC



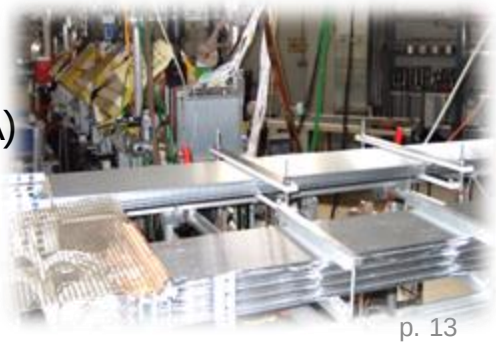
Design by AGH Krakov (CMOS 0.35µm)

Test Systems

- STT semi-barrel (1:1) for assembly techniques
- Mechanical central frame structure on rail system

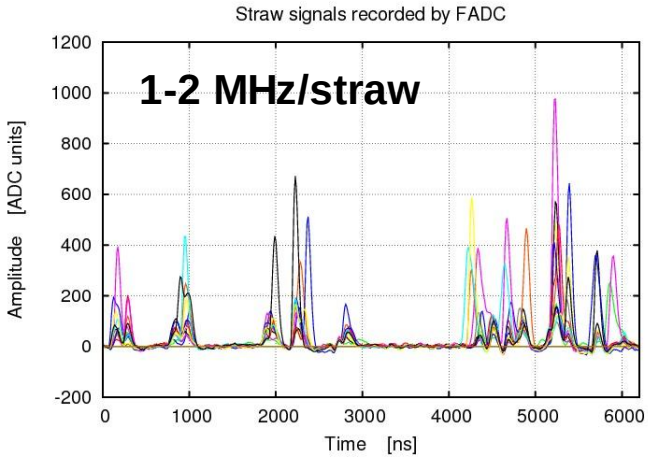
- STT detector in COSY-TOF experiment
  - "Global" test system for PANDA-STT (straw technique)
  - Spatial resolution: $\sigma \sim 140\mu m$ (2700 straws)
  - Operated (4 yr) in evacuated time-of-flight barrel ($25m^3$)
  - Leakage on permeation level (molecular flow thru mylar)

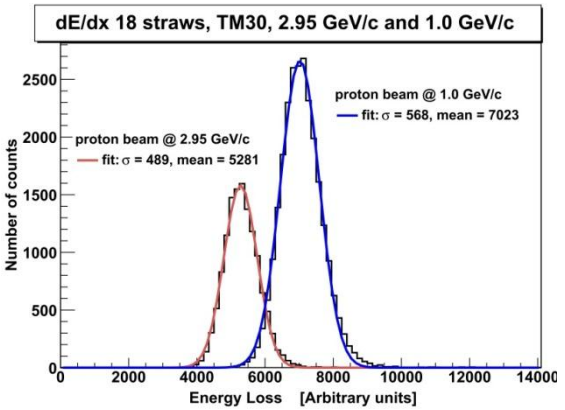
- Straw setups for in-beam tests (p/d-beam)
  - Aging tests done, charge loads ~1.2 C/cm (~ 5yrs PANDA)
  - High-rate readout tests ongoing, 1-2 MHz/straw
  - Beam momentum 0.6 - 3 GeV/c (dE/dx range ~ 3× mips)

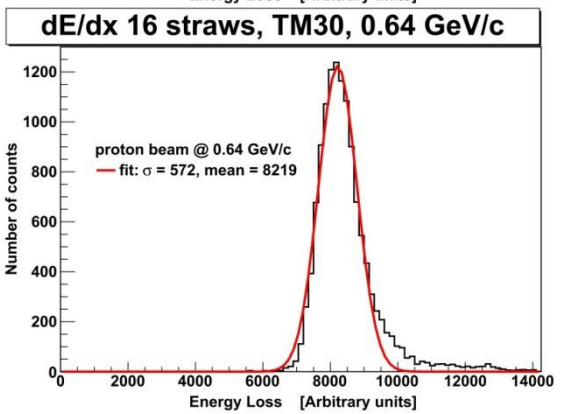


FADC Energy-Loss Measurements

- dE/dx resolutions measured in beam with FADC
  - $\sigma_{dE/dx}$ = 7.0% - 9.3% (0.6, 1.0, 2.9 GeV/c protons)
  - 30% truncation factor (Landau-tail)
  - < 19 straw hits per track → 25 layers at PANDA-STT
- $\sigma_{dE/dx}$ ~ 7.0 % feasible with PANDA-STT
- σ ~ 150µm spatial resolution measured
- High-rate FPGA analysis & readout ongoing



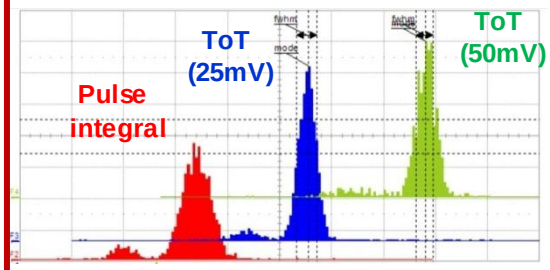




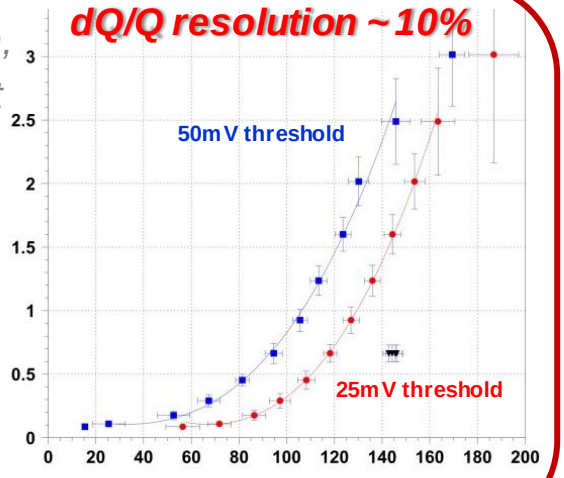
Time-Over-Threshold Method

- ASIC testversion with analog out, first in-beam test 2012
  - gain (3-24mV/fC), peak time (20/40ns), ion tail cancell., BL stability, ..
- Next ASIC version in production: 100 chips× 8 ch, few param. optimisations
- Calibration of ToT ↔ dE/dx with ^{55}Fe-source (simple) and beam protons
  - need >4 different beam momenta to get ToT ↔ dE/dx relation and resolution

^{55}Fe-signals, *220(110)e$^-$/200µm, pulse integral + ToT measuremt*

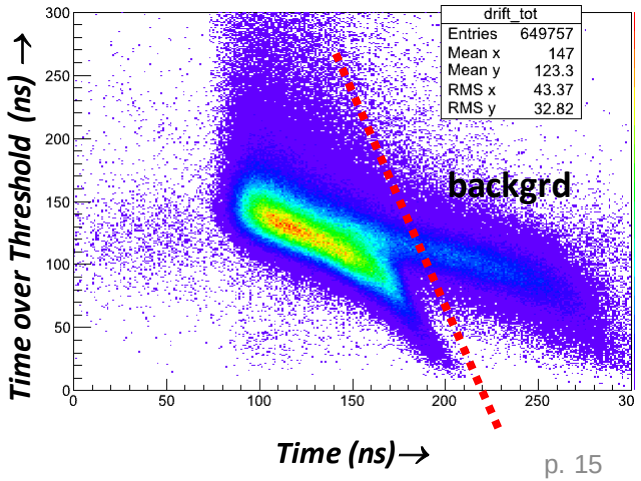


dQ/Q resolution ~10%



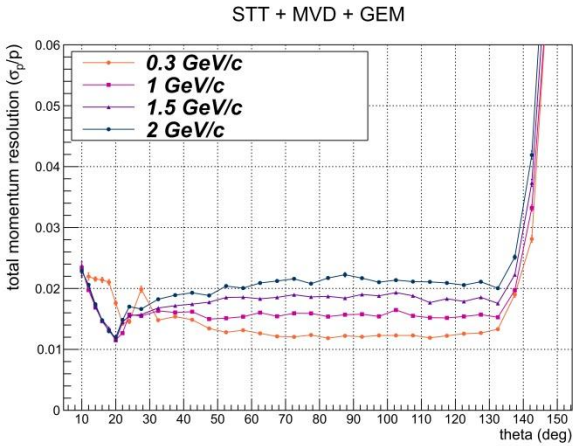
Charge (pC) vs ToT(ns)

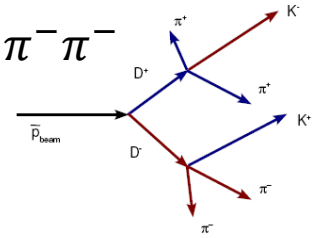
Beam on straws*, TRB readout*

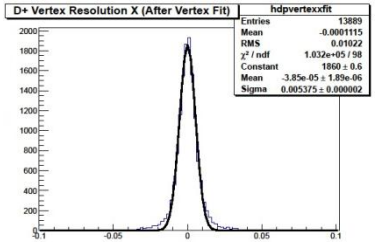


Simulation Studies

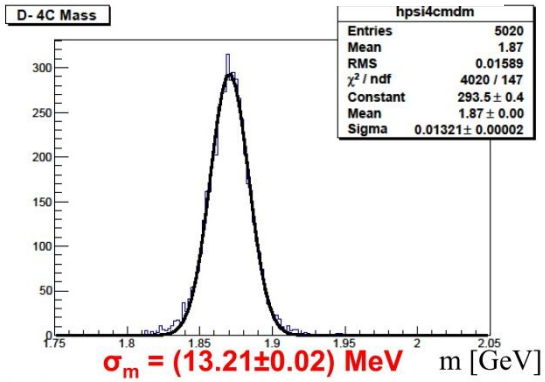
- Single track simulation (MVD+STT+GEM, B=2T)
  - Momentum resolution 1-2% for $\theta < 140°$
- Test of tracking system with benchmark channels
  - $\bar{p}p \rightarrow \pi^+\pi^-\pi^+\pi^-$
  - $\bar{p}p \rightarrow \eta_c \rightarrow \phi\phi \rightarrow K^+K^-K^+K^-$
  - $\bar{p}p \rightarrow \Psi(3770) \rightarrow D^+D^- \rightarrow K^-\pi^+\pi^+K^+\pi^-\pi^-$
  - *vertex resolutions and reconstructed mass of D-mesons*



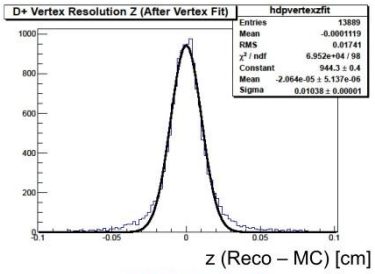




σ_x = (53.75±0.02) μm



σ_m = (13.21±0.02) MeV



σ_z = (103.8±0.1) μm

D-meson reconstruction numbers

Acceptance	24.5 %
Total Reconstructed	5.0 %
Vertex Resolution (xy)	54.5 μm
Vertex Resolution (z)	104.3 μm
Mass Resolution	13.1 MeV

Summary

- The PANDA-STT provides a complete measurement of charged particles: space, momentum, pid, (time)
- Test measurements and benchmark channel simulations confirm the required performance
- Technical design report of the STT was approved in 2012
- Funding process will be completed soon (Germany, Italy, Poland, Romania)
- Straw mass production during 2013-2016 (> 50% spares)
- Electronic readout optimisation in parallel, beam test times at COSY
- Comissioning of the detector setup with beam in 2016/2017 at COSY
- Shipping to FAIR and installation in PANDA 2017

Technical design report of the PANDA-STT, Eur.Phys.J.A49 (2013) 25