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Central Straw Tube Tracker Overview

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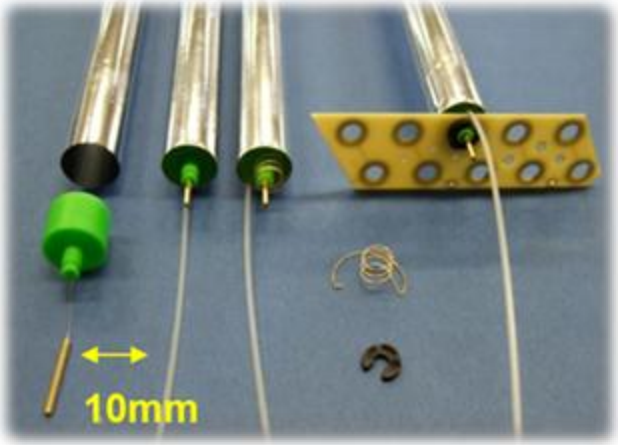
Outline

- STT Design
- Testsystems
- Readout issues
- Summary

Straw Tube Design

Straw tube materials:

- Al-mylar film, d=27µm, ∅=10mm, L=1500mm
- 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
- $X/X_0=4.4\times10^{-4}$ per straw tube

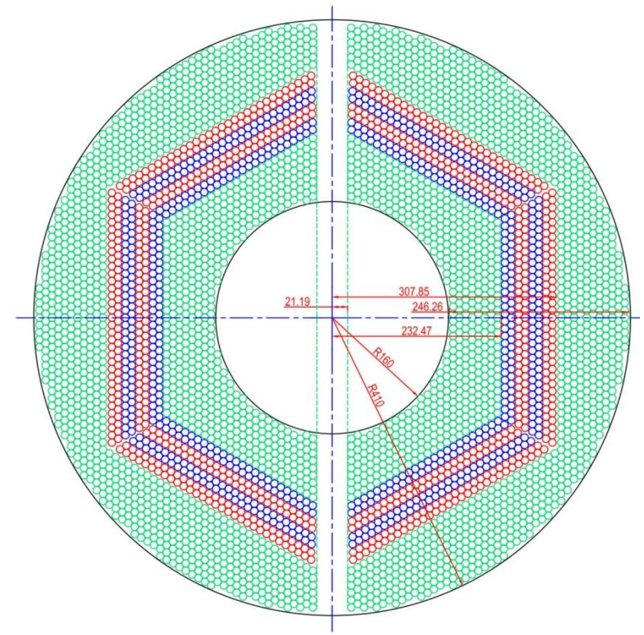


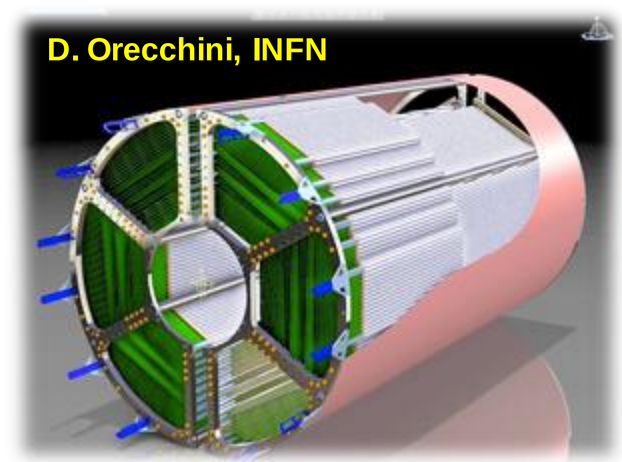
Element	Material	X [mm]	X_0 [cm]	X/X_0
Film Tube	Mylar, 27µm	0.085	28.7	3.0×10^{-4}
Coating	Al, 2× 0.03µm	2×10^{-4}	8.9	2.2×10^{-6}
Gas (2bar)	Ar/CO_2 (20%)	7.85	5966	1.3×10^{-4}
Wire	W/Re, 20µm	3×10^{-5}	0.35	8.6×10^{-6}
			Σ_{Straw}	4.4×10^{-4}

STT Layout

- 4636 Straw tubes in 2 semi-barrels
- 23-27 planar layers in 6 hexagonal sectors
  - 15-19 axial layers (green)
  - 4 stereo double-layers for 3D reconstr., with ±2.89° skew angle (blue / red)
- Time readout (isochrone radius)
- Amplitude readout (energy loss)
- $\sigma_{r\Phi} \sim 150\ \mu m$, $\sigma_z \sim 3.0$ mm (single hit)
- $\sigma_E / E < 10\%$ for π/K identification
- $\sigma_p / p \sim 1 - 2\%$ at B=2 Tesla
- $X/X_0 \sim 1.2\%$ ($^2/_3$ tube wall + $^1/_3$ gas)

- R_{in}/R_{out}: 150 / 418 mm
- Length: 1500mm + 150mm (RO upstream)

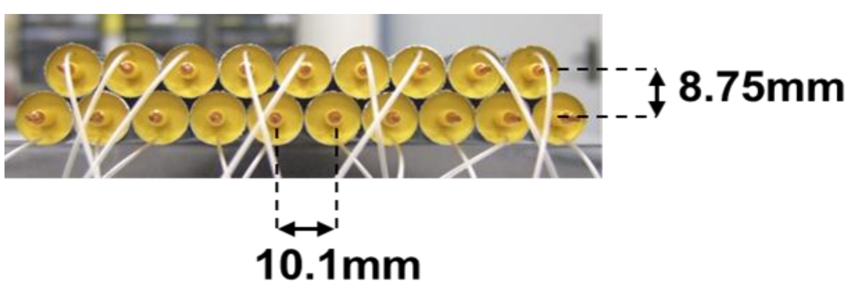


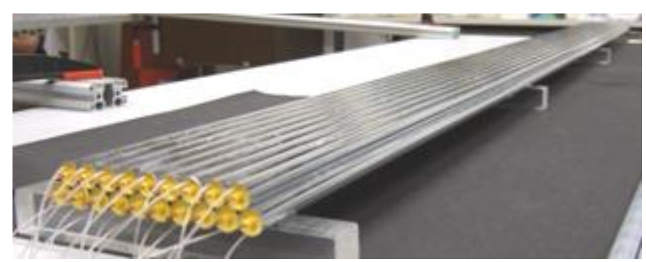


Self-Supporting Straw Layers

Novel technique (from COSY-STT):

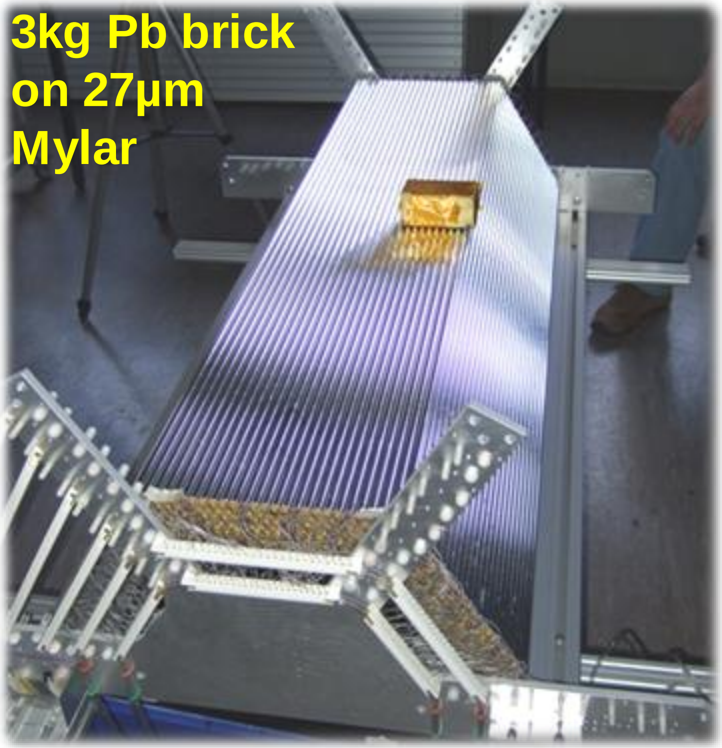
- Straw tubes are assembled under overpressure (Δp=1bar)
- Pressurized straws are close-packed (~20µm gap) in planar multi-layers and glued together (dot glueing)
- Strong rigidity: multi-layer straw module is self-supporting
- No stretching of straw ends from mechanical frame needed
- Perfect and strong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

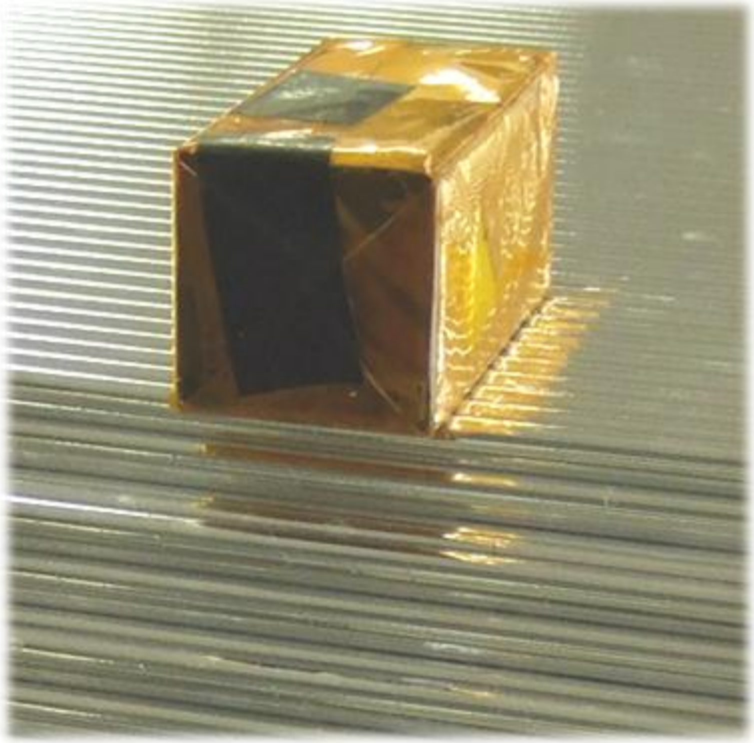




Self-Supporting Straw Layers ..

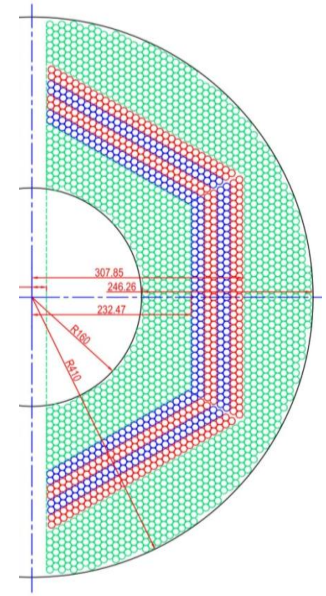
Pressurized, close-packed straw layers show strong rigidity, here demonstrated by 3kg Pb-brick

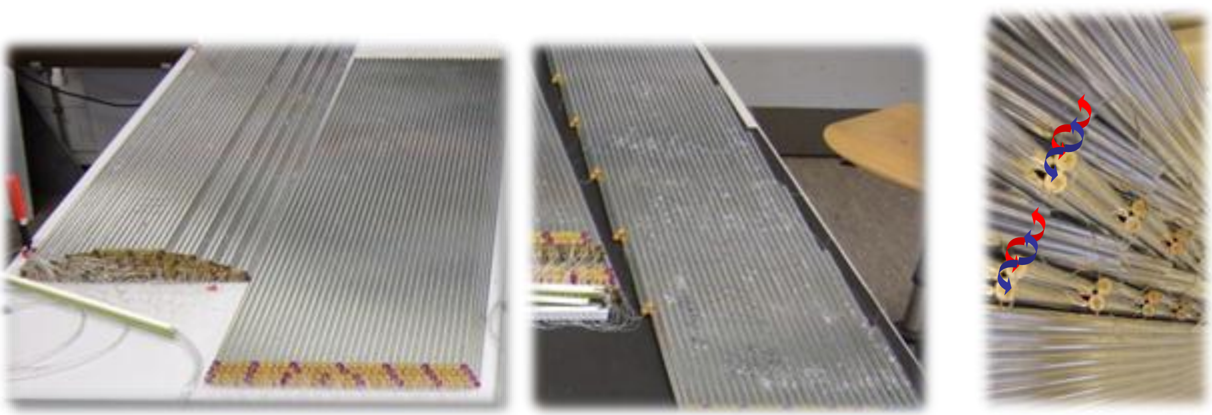




Axial and Stereo Layer Modules

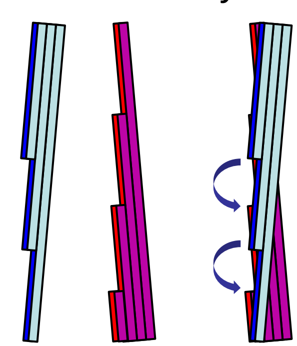
- Axial quad-layer module:
  - 4 close-packed axial layers, glued together (glue dots)
  - Increased rigidity compared to double-layer
  - Even number of straws and gas lines per module
  - Replacement of inner faulty single straws possible
- Stereo quad-layer module:
  - 2 Skewed double-layers (+2.89° / -2.89°)
  - Shorter tubes at corners, connected to next skew. dlayer





Axial and stereo straw layer modules

Connection scheme of skewed d-layers:

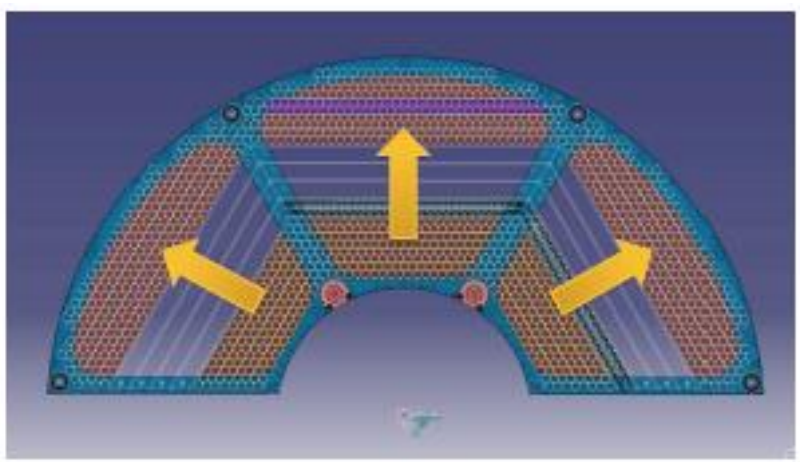


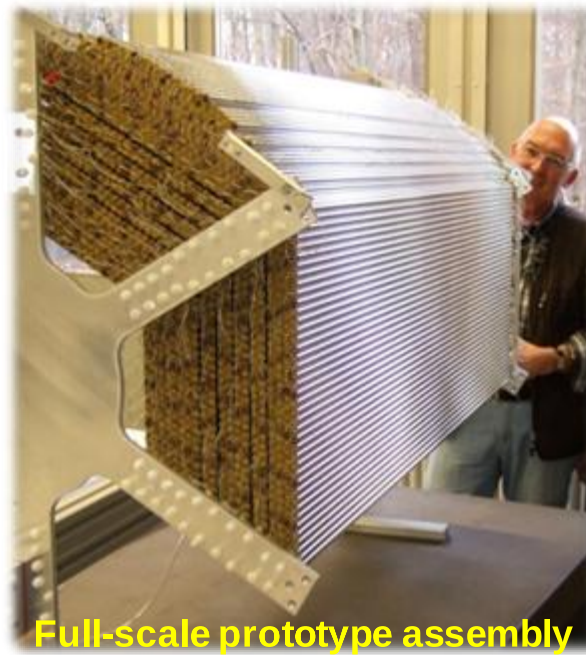
+2.89° -2.89° view from top

STT Assembly

Assembly method:

- Integrated quad-layer modules with gas manifolds and electric coupling
- Assembly complete hexagon sector on the table
- Insert sector into STT frame structure
- Plug on gas and electric connectors



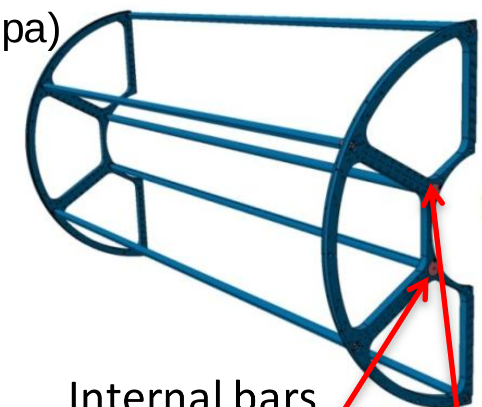


Full-scale prototype assembly

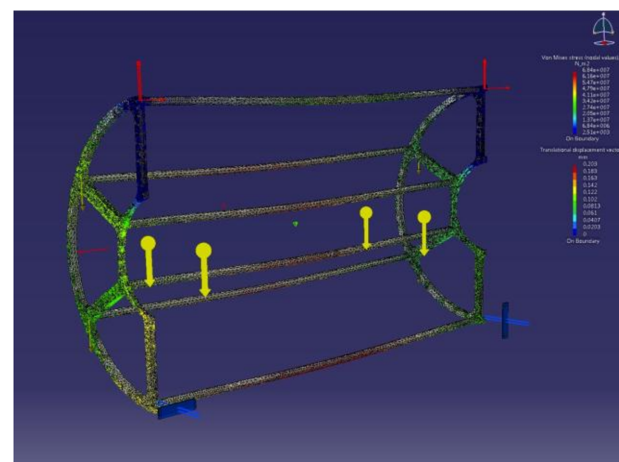
Note: no tube stretching from mechanical frame needed

Mechanical Frame

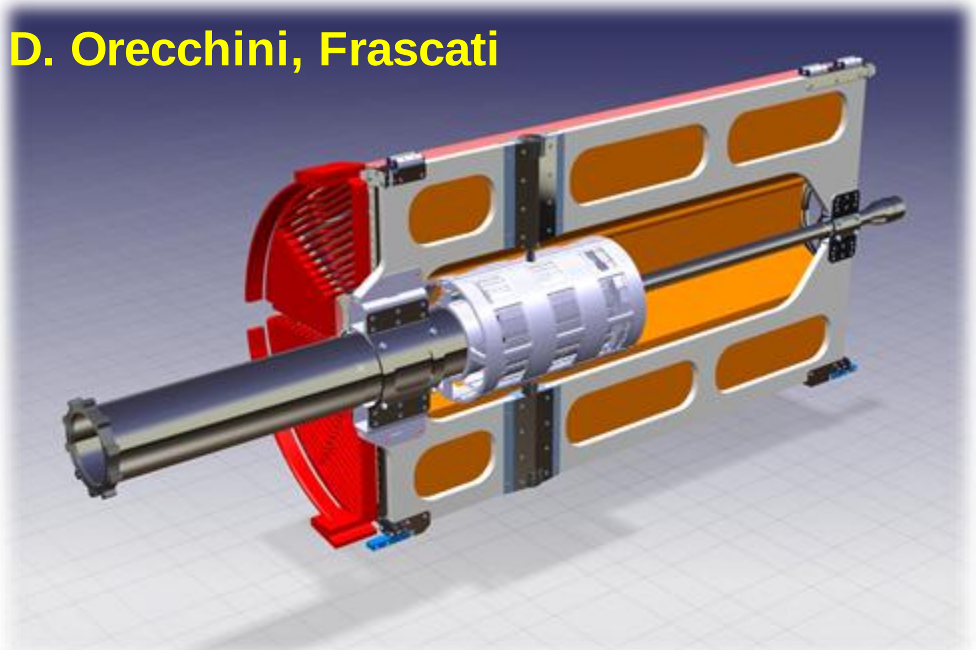
- Design and construction by INFN Frascati (D. Orecchini)
- Material: aluminum (ρ=2.7g/cm^3, Young's modulus: 70 Gpa)
- Radiation length X_o= 8.9 cm
- Thermal expansion: 24 ppm/°C
- FEM analysis: 0.03mm max. deflection
- Mechanical frame weight: 2× 8.2kg
- 11.6 kg Straw tubes (4636× 2.5g) with
  - strong wire stretching (230kg equiv.)
  - strong tube stretching (3.6t equiv.)



Internal bars can be removed

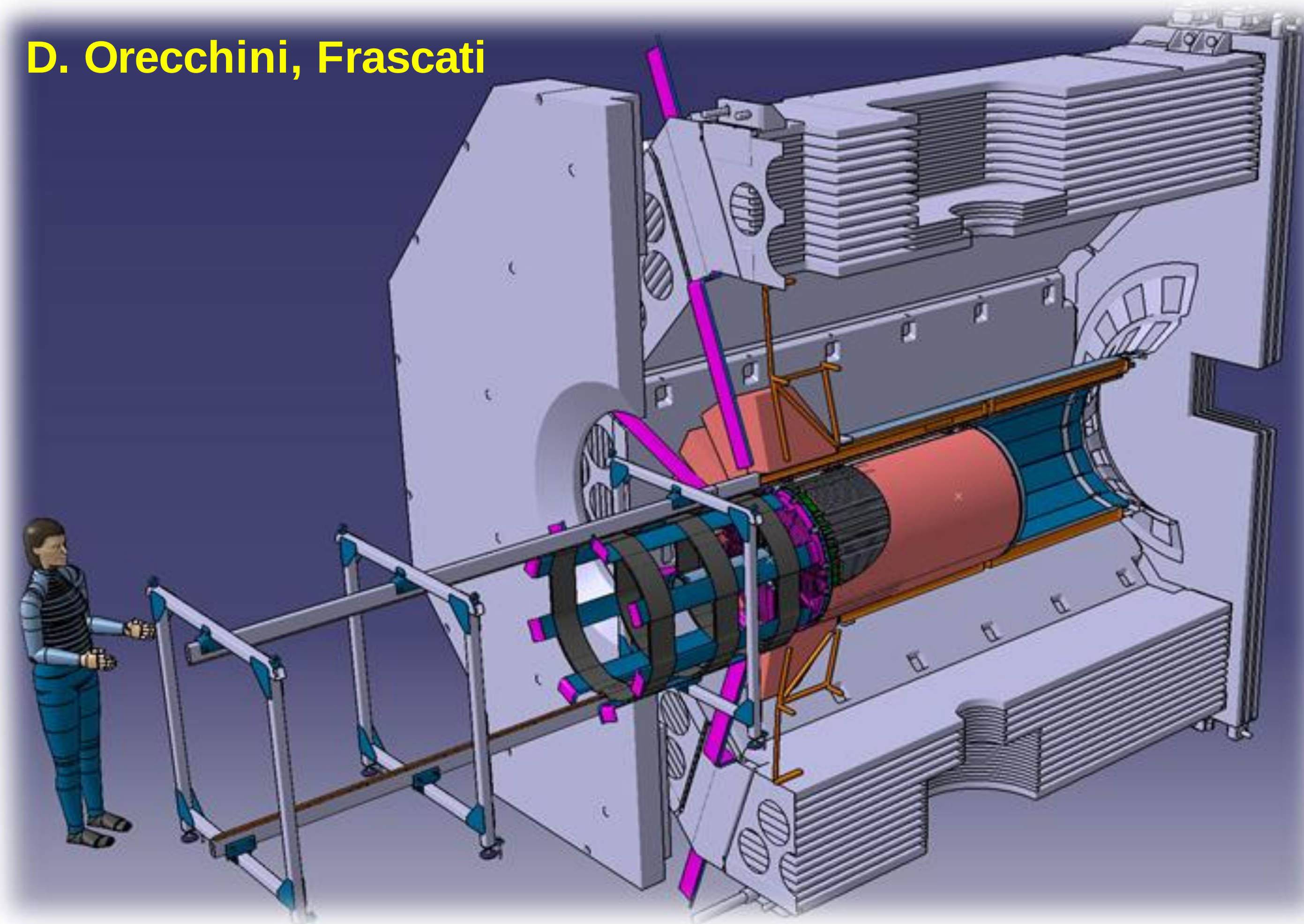


Central Tracker Mechanics



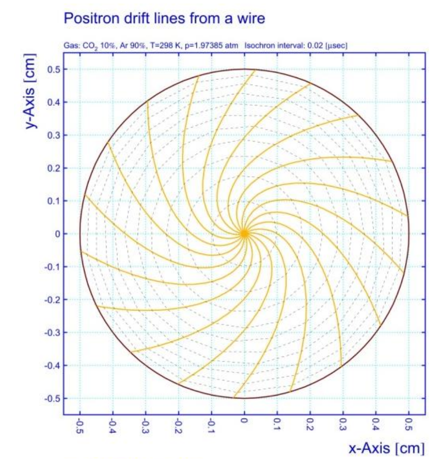
- **“CENTRAL SUPPORT FRAME” prototype by INFN Turin wshop**
- **“STRAW SUPPORT FRAME” prototype by INFN Frascati**
- **“AUXILIARY INSERTION STRUCTURE” by INFN Frascati**
- **“VERTEX” mechanical prototype: under development**
- **“CROSS-PIPE” prototype: planned in the next months**

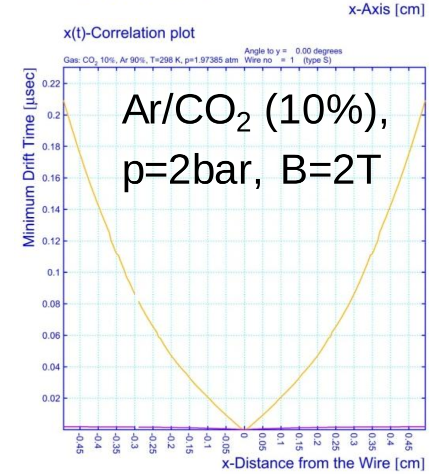
Final Assembly Scheme



Gas Mixture

- Ar/CO_2 is best gas mixture for high-rate hadronic environments
  - Highly tolerant to highest irradiation, no polymeric reactions
  - But: limited quenching capabilities of CO_2
  - CO_2 fraction 10-20%
  - Gas pressure p = 2 bar
  - Gas gain: $A \sim 5 \times 10^4$ (limited streamer threshold)
- Ionization numbers
  - Mips: 200 I.P./cm, dE ~ 5 keV/cm (@2bar)
  - Range: ~ 20-2000 I.P.
- Signal charge: ~ 1×10^6 - 1×10^8 e^-
- B=2T magn. field: spiral drift paths
- Max. electron drift times: 200-250ns





PANDA-STT Test Systems

Prototype systems:

- Full-scale system for developing assembly method of self-supporting modules in frame structure
  - Frontend readout and HV-/gas supply
- 2× Small-scale setups: RO developments, beam tests
  - 128 Straws in 8 layers, 1500mm length, ∅=10mm
  - 400 Straws, 3D-reconstr., 8 axial + 8 stereo layers

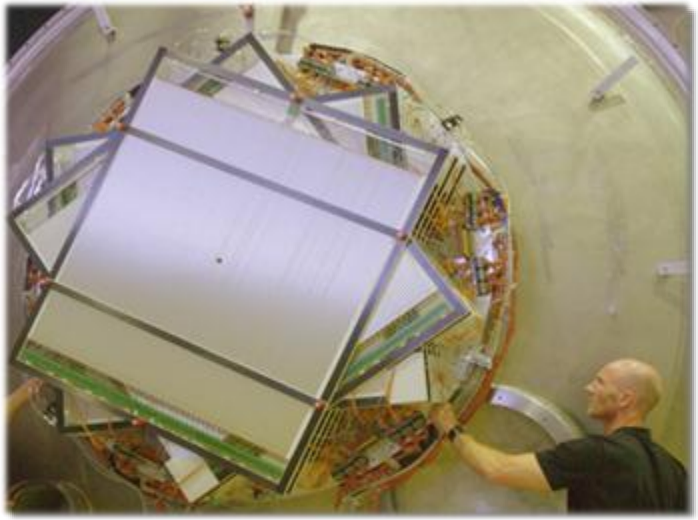
STT detector in COSY-TOF experiment:

- "Global" test system for PANDA-STT
  - Same straw design & materials
  - Geometry of planar self-supporting double-layers
  - Similar calibration: straw positions & isochrones
  - Test of mechanical precision and spatial resolution
- Installed and 1st experiment beam time in 2010

Testsystem: STT at COSY-TOF

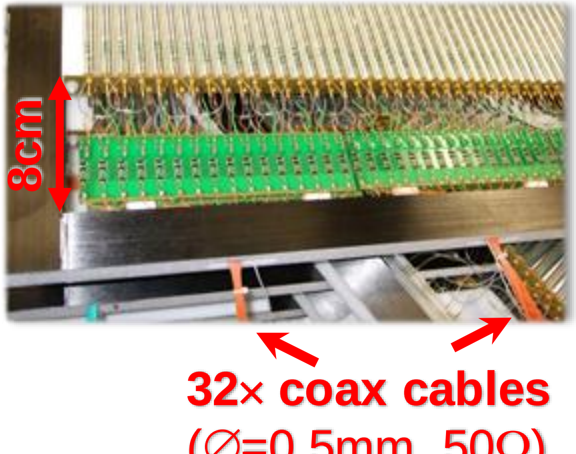
2704 straw tubes

- Al-mylar: d=32µm, ∅=10mm, L=1050mm
- 13 planar double-layers
- Skewed by i×60° for 3D reconstruction
- Ar/CO_2 (20%) at p=1.2bar
- Time readout: Discr. + TDC
- Operation in vacuum



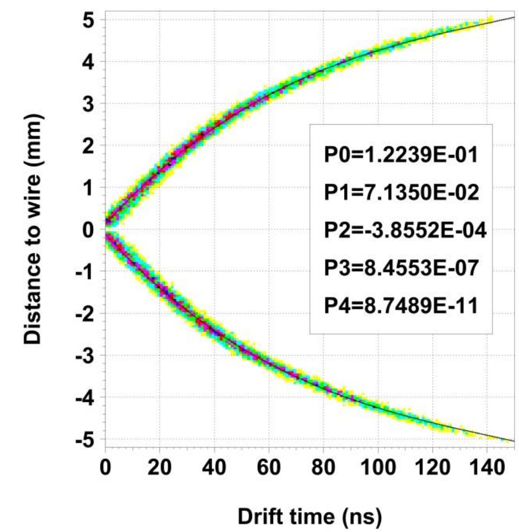
Readout scheme

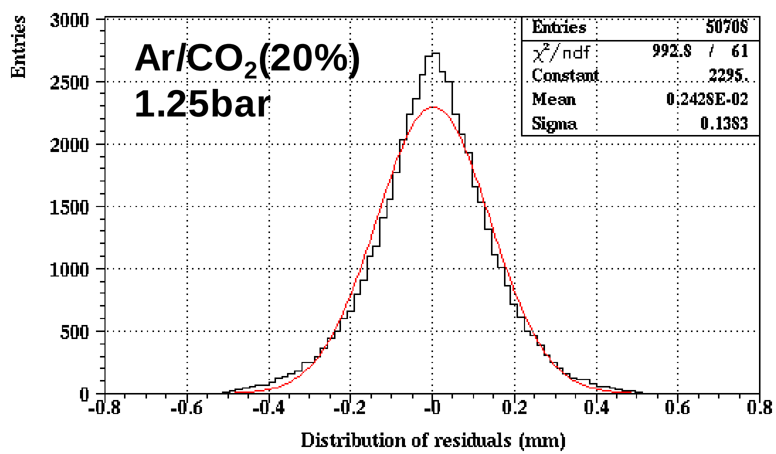
- Transimpedance preamps in vacuum (~3mW/ch)
- Thin coax signal lines, ∅=0.5mm, 50Ω
- 6-9V Preamp power supply on signal line
- Feed-through flange (3000×signals, 60×gas, 200×HV)
- Discr. (ASD8B) + TDC (GPX)

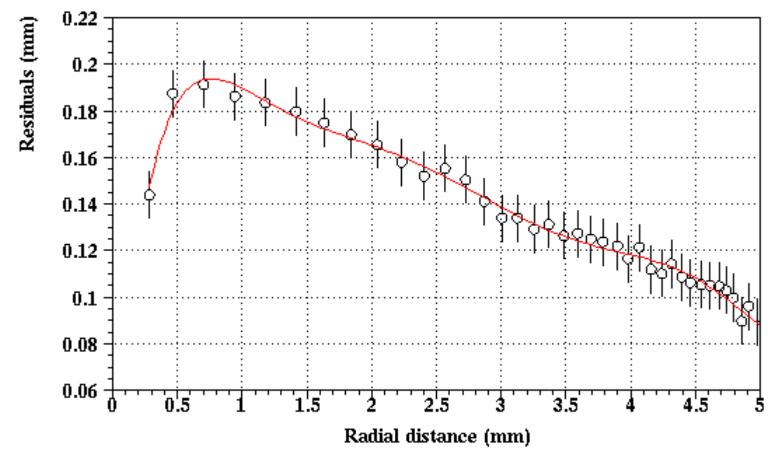


Spatial Resolution at COSY-STT

- Isochrone calibration r(t) by integration of drift time spectrum
  - Global parametrization by 4th order polynomial
- Track reconstruction by χ^2- fit to isochrones
  - Single δ-electrons filtered out
  - No correction of σ_{MS}, $\sigma_{\Delta t/L}$, σ_{tof}, ..
- Spatial resolution by residual distribution
  - $\sigma_{r\Phi}$ = 138µm (190 –100 µm over r_{straw})
- Estimated time resolution: σ_t~1ns







Readout Mechanical Design

Backward EMC limits space for readout, two options

- Complete readout at frontend
  - Space limitation: ΔL~15cm, A<4000 cm^2
  - Cooling system needed ?
  - Glassfibers out
- Reduced FEE boards frontend
  - Electric straw signal coupling, HV supply, + (transimp.)preamps ?
  - Signal out by coax cables
  - Readout crates close to magnet, ~5-8m cable length needed?
  - No cooling system needed
  - Compact readout space at frontend

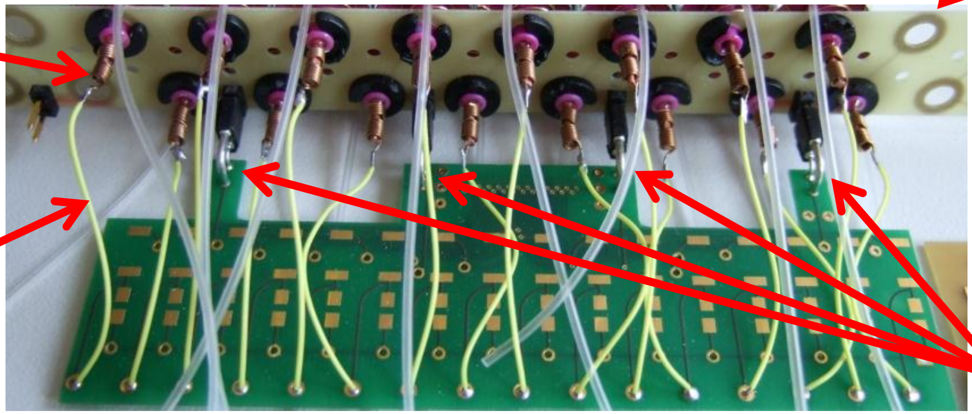
Straw Electric Coupling

- Number of straws different for every layer
- Higher straw density in hexagon corner regions
- Connector boards
  - Connect single straws individually by thin wire & contact spring
  - Include HV supply
  - Common ground pins = mechanical board support
  - 16ch line out to digitizers

crimp pin connected by spring

straw signal wire (used at COSY-STT)

straw grounding spots on inner side

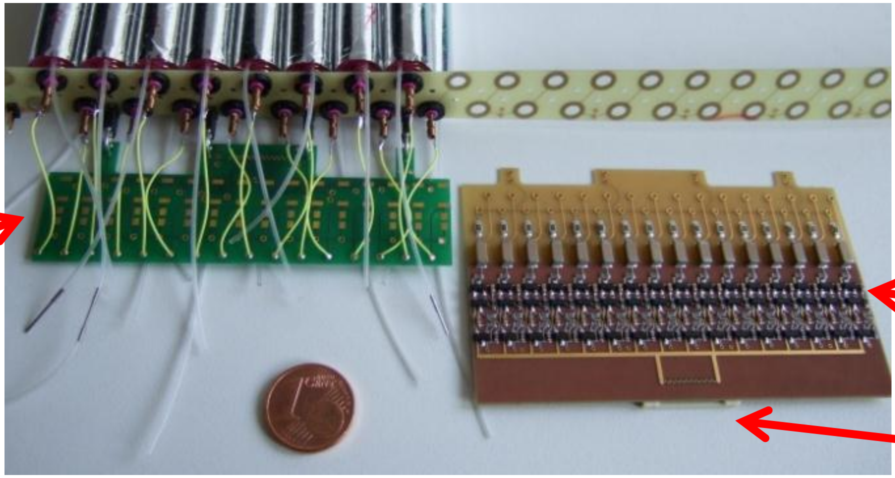


4× grounding pins = mech. support

Straw Coupling Boards

- Requirements for digitizers needed
  - Preamp + shaper ?
- Example board (5×8 cm²)
  - HV supply + transimpedance preamplifier
  - 16 ch coax line out to digitizers
  - Still under development, min. ch-ch distance, (~~capton cable~~)
- Open for other proposals or design wishes!

Only HV + 16ch line out



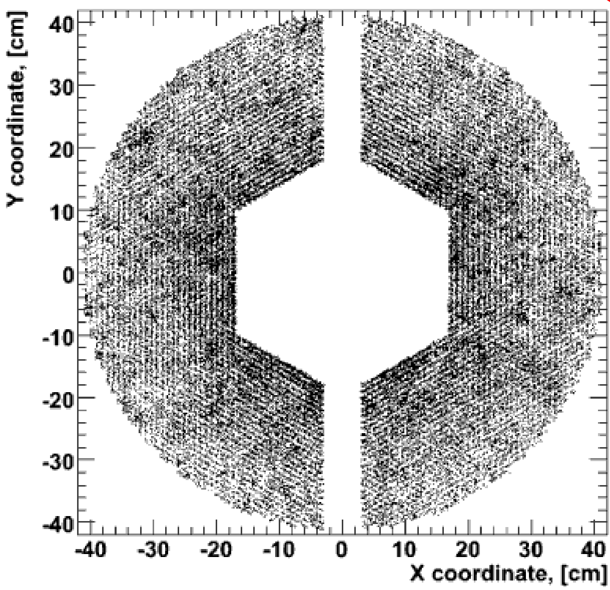
HV + preamp

16 ch line out

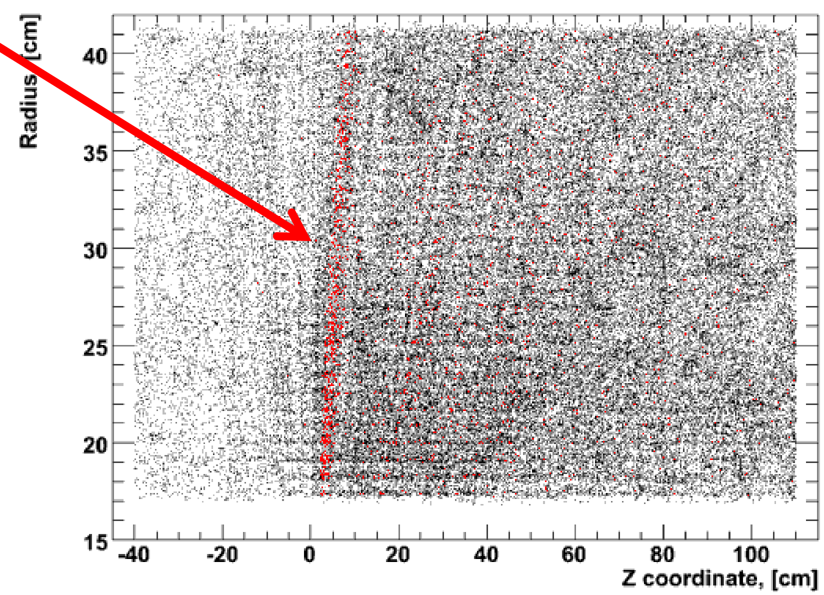
Event Simulations

- $\bar{p}p$ - simulation at 6 GeV/c beam momentum (DPM generator)
- STT geometry + frame material, MVD not with final material budget
- Derive straw hit distributions
- Mean multiplicity of ~ 4 tracks per event seen
- Low energy protons from elastic scattering at θ ~ 90°

Cross section



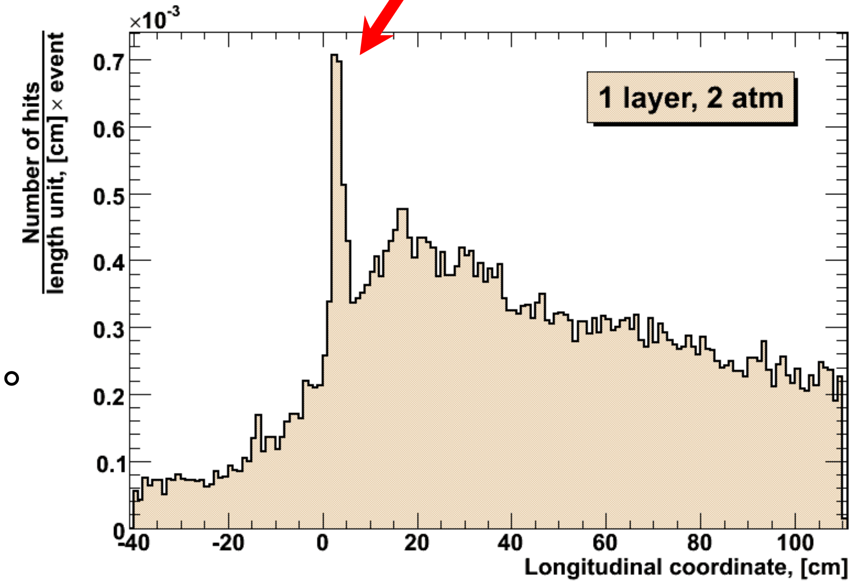
Rz-hit distribution



Expected Particle Rates

- Distribution of hit number per straw length unit (cm^{-1})
- All numbers for innermost STT layer and 1500mm length
- Event rate of 2×10^7 evts/ sec
- Particle rates
  - ~ 5-8 kHz/ cm in forward region
  - ~ 14 kHz/ cm at z= 2±1 cm
  - ~ 800 kHz/ straw
- Energy losses dE per cm
  - Min. from mips: ~5 keV/cm
  - Mean: ~ 10 keV/cm (2×mips)
  - Max: ~ 45 keV/cm (9×mips) from low energy protons at 90°

Low energy protons



Readout Developments

Two Methods for energy readout:

- Direct ΣQ measurement by integration of charge signal (FADC, MSGCROC)
- Indirect Δt (Q) measurement by signal width (TOT-Discr. + TDC)

Readout systems:

- Current amplifier + FADC (240MHz)
  - *Full signal information, useful for tests, comparisons..*
  - *4.2ns sampling: drift time resolution?*
- MSGCROC-ASIC
  - *Time stamp (T) + amplitude (E)*
  - *Parameters for MSGC detector, tunable for straws?*
- TOT-Discriminator + TDC
  - *Prototype with TOT + analog signal out (?)*
  - *Specific ASIC optimization (preamp+threshold) for straw signals*

Readout Parameters

- Parameters
  - ~ 4600 number of readout channels
  - σ_t ~ 1ns drift time resolution
  - $\sigma_E/E < 10\%$ energy resolution below 800 MeV/c
  - ~ 1×10^6 - 1×10^8 e^- input signal charge (~20-2000 I.P., A~5×10^4)
  - ~ 200-250ns max electron drift times
  - ~ 800 kHz particle rates per straw
  - ~ 2×10^9 straw hits per sec. (2×10^8 evts/sec., 4 tracks, 25 straws)
  - (Double-pulse resolution ~50ns helpfull, 500 hits / 250ns in STT)
  - No hardware trigger, time stamps and event building
- Limited space and cooling at detector frontend

Summary & Outlook

Current status

- STT design optimised: ~25 hit samplings per (radial) track
- $\sigma_{r\Phi}$ ~ 140µm spatial resolution measured with σ_t ~ 1 ns drift time resolution at COSY-STT with 2700 straws
- σ_E/E ~ 8±1% energy resolution demonstrated for layers of 16 straws and measured with FADC for protons at 640 MeV/c + 2.95 GeV/c

To Do: readout for final PANDA conditions

- Combined drift time + energy measurement and resolution
- Efficiencies + high rates
- Full readout setup
  - many channels, compact, final cable lengths,
  - calibration of many channels, ..
- New 3D-testsystem with 400 straws ready