STT – E-Readout and More

– STT System

– FOM (STT&STS)

– STT Reduced

– Discussion

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STT Mockup

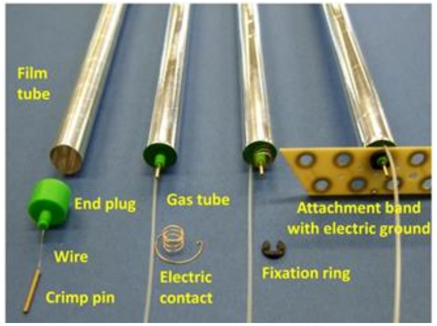
STS1 @ HADES

STT - Straw Tube Tracker

https://arxiv.org/abs/1205.5441

Straw tracker in 2T solenoidal B-field

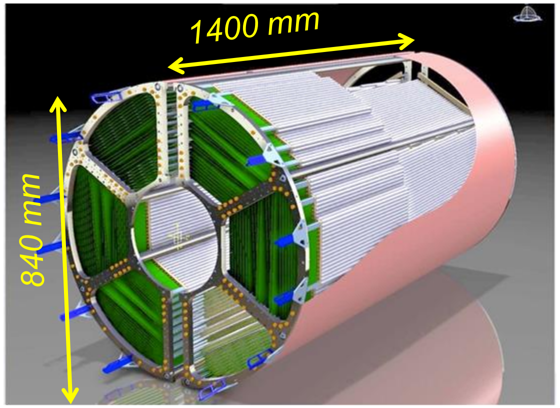
- **4224 straws in 19 axial + 8 stereo-layers** ($\pm 3°$)
- **Close-packed self-supporting layers by gas overpressure**
  - homogenuous tube stretching ($\varnothing$, length), F_{total} ~33 kN
  - precise wire tension, T_{wire} with low σ<2% ($\varnothing$ tolerance)
- **X ~0.04% X0 per layer**, **~3.3% X0 endcap region**
- **Drift time and time-over-threshold readout for PID**
- **σ(r) ~ 150µm, σ(z) ~ 2-3mm, π/K/p-separation < 1GeV/c**
- **Particle rates <1 MHz/straw, <10 kHz/cm^2**
- Δp/p ~ 1-2 % (with MVD)
- Input for SW trigger (hit to track to event assoc. & identification)



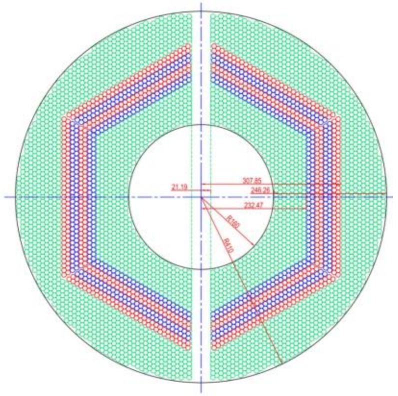
Straw components

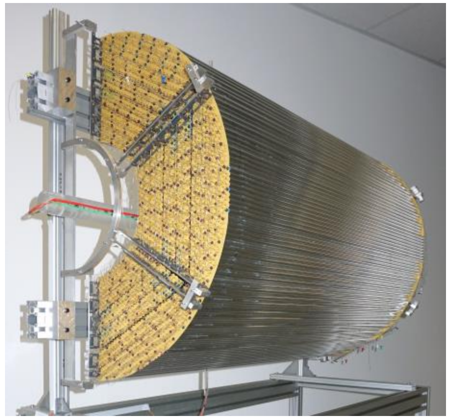

Close-packed layers (<50µm gap)

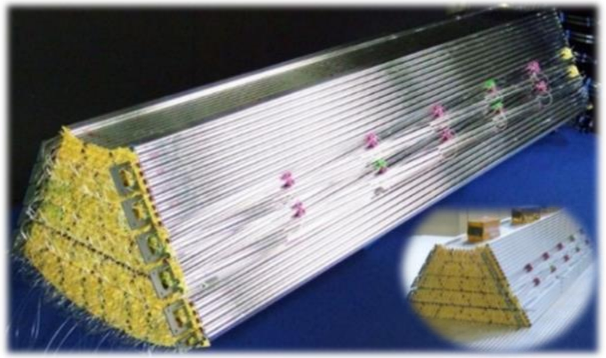
Parameter	Value	
Diameter	10 mm	
Wall	27 µm	Mylar-Al
Length	1.4 m	
Wire diameter	20 µm	W/Re(3), Au-plated
Gas	90/ 10	Ar/ CO_2
Gas pressure	2 bar	1 bar overpressure
Material budget (X/X0)	0.04%	per layer
Number tubes	4224	
Number layers	19/ 8	Axial/ stereo-layers
Stereo angle	$\pm 3°$	
Spatial resolution	150 µm	(σ, single hit)
Time resolution	~ 1 ns	
Total material budget /X/X0)	1.3%	incl. STT walls
Momentum resolution	1-2%	with MVD
Particle rates per straw	< 1MHz	< 10 kHz/cm^2



PANDA-STT (3D-view)


Straw layout (cross-view), stereo layers in red/blue.


STT-protoype (mockup)

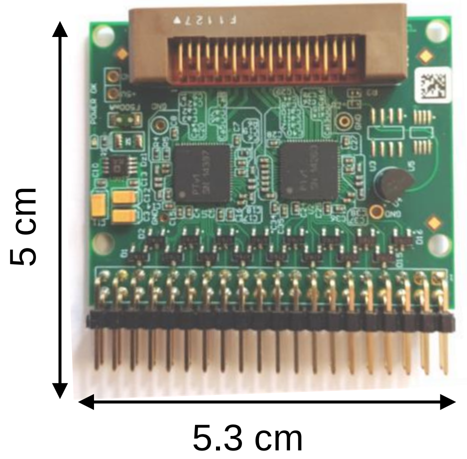

Self-supporting hexagon sector prototype and with 3×3kg Pb bricks on top (insert).

STT – E-Readout

– Status (AGH / JU Krakow)

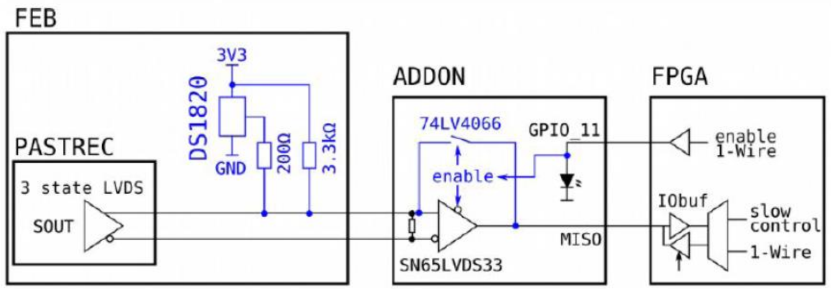
- PASTTREC-ASIC: > 100% available
- FEBv4: 800 produced (12800 ch) and tested
- TRB5 BW is compatible with full luminosity (TRB3 BW limited)
- TRB5+AddOn card (inline), FEBv4 control by TRB5 FPGA, prototyping done
- FEBv4/TRB5 readout prototyping done
- QA procedure established

New FEBv4 (with temperature sensor & chip e-ID)

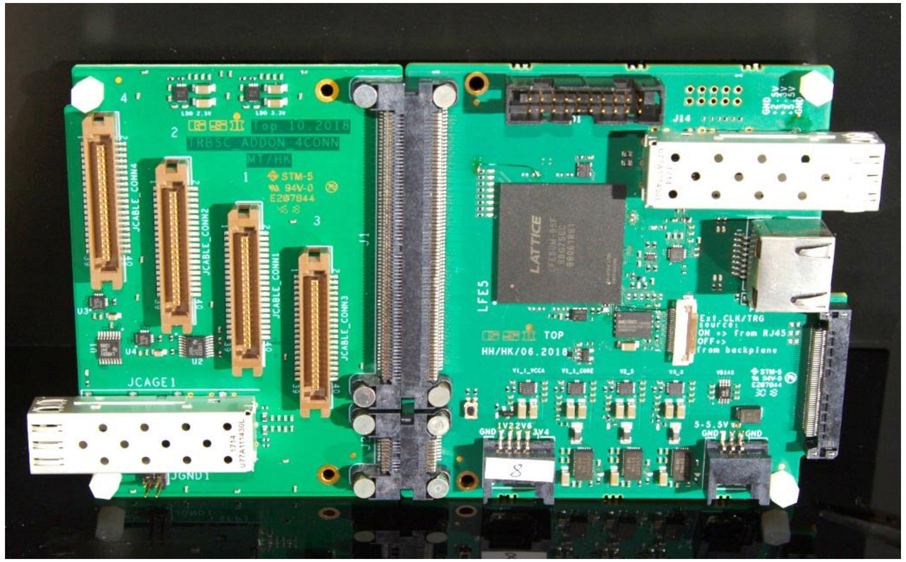


– Per TRB5 board

- Single FPGA, 32ch high-resolution TDC or 64ch lower resolution
- AddOn card for 4× FEBv4 per board



Circuitry of FEB readout and control by TRB5 FPGA



TRB5sc with inline 4-conn AddOn

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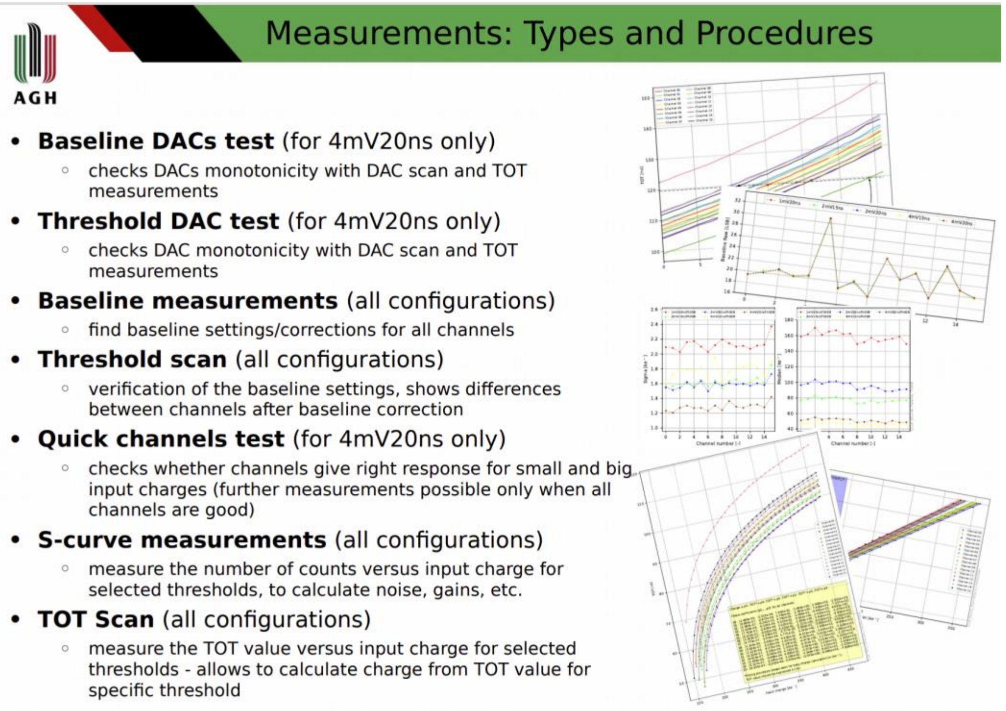
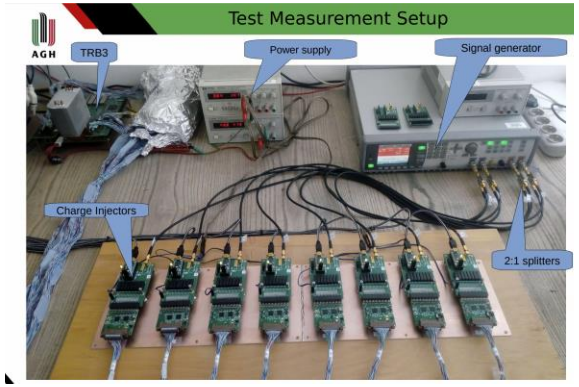
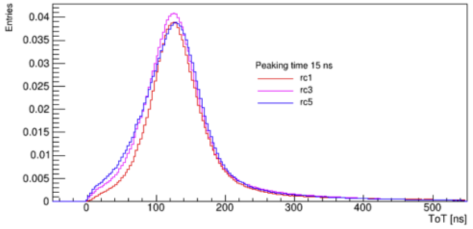
STT – E-Readout

- PASTTREC/TRB & DAQ system fully verified
- 4-week proton-proton experiment beam time with HADES
  - 4.5 GeV proton beam kin. energy
  - STS1+STS2 (704 + 1024 ch) for forward tracking
  - High particle load: 1-2×10^5/straw, max. 5-6×10^5/straw (high intensity runs)
  - ASIC parameters optimized for low NL and NL stable during BT
  - Low threshold and low gas gain (A~2×10^4, HV 1800V→1700V)
  - DAQ with ASIC settings control and 'continuous' verification by DAQ

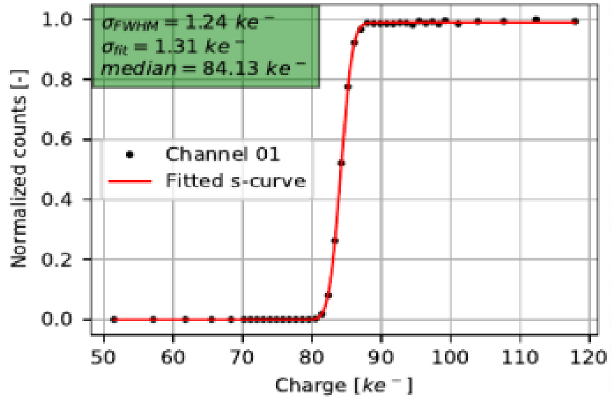


- FEB QA by charge injection and signal readout (FEBv4 + TRB3)
- QA procedure includes 7 criteria
- Fully automatic (python scripts)
- QA results in data base





Setting	HV	Gain	Peaking time [ns]	Peak at ~	FHWM
rc1	1800	1	15	126 ns	94 ns
rc3	1740	2	15	126 ns	104 ns
rc5	1650	4	15	129 ns	111 ns



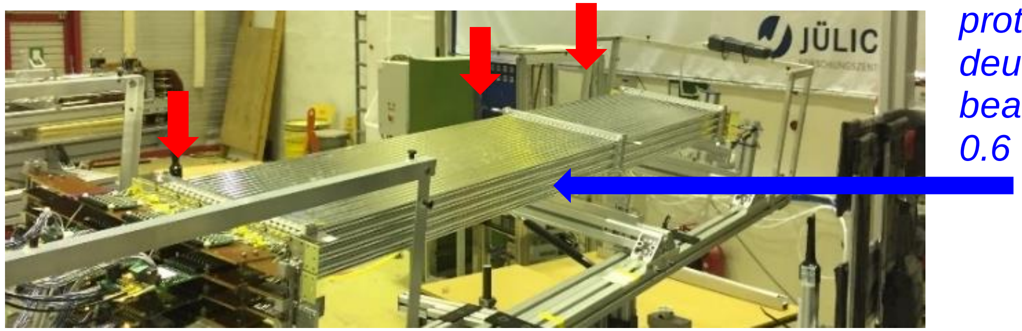
Performance Results

Prototype Systems and Experiment Installations

– Full system tests: **straws and e-readout**

– STT prototype at COSY
  – **High redundancy central tracker** (~ 24 straw hits/track)
  – Tracking and spat. resolution determination done
  – PID by ToT
  – 0.6 – 2.7 GeV/c proton/deuteron momentum range

– STS1 in HADES experiment beamtime
  – **Low redundancy forward tracker**
  – Same straw type as in STT
  – High particle rates in 4weeks experiment beamtime



In-beam test setup at COSY. Arrows mark alignment elements.

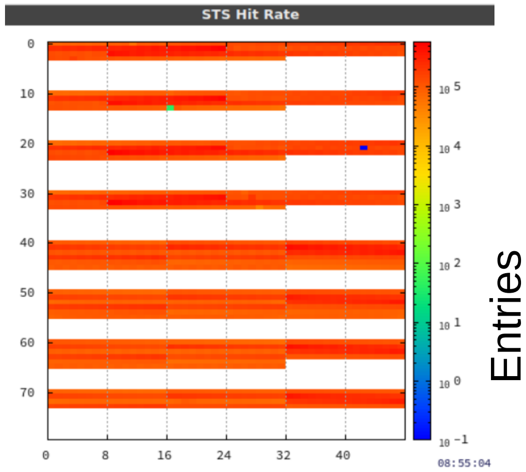
– Results on next slides
  – Particle rate capability
  – Time and time-over-threshold measurements
  – Timing methods
  – Calibration and tracking
  – Straw signal simulation
  – PID

– Conclusions for reduced STT in PANDA

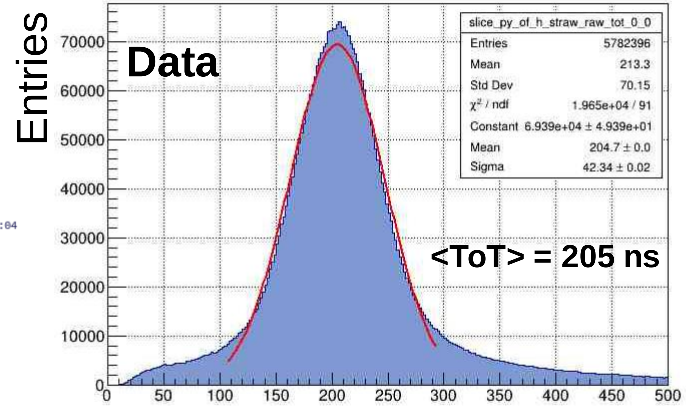
Performance Results

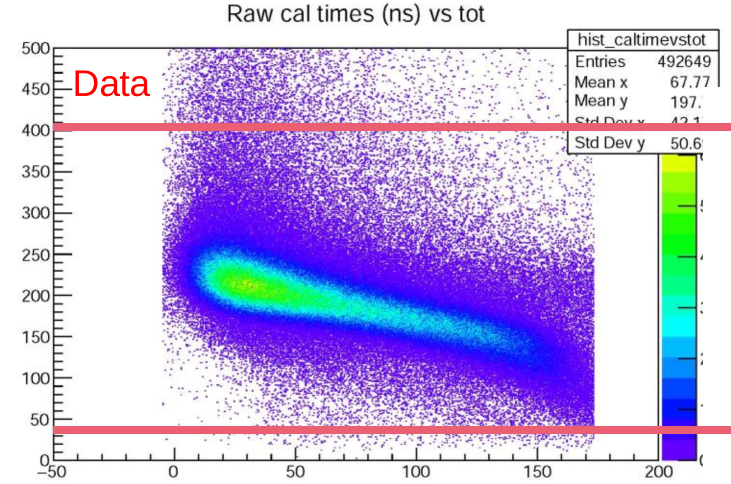
High Particle Rates

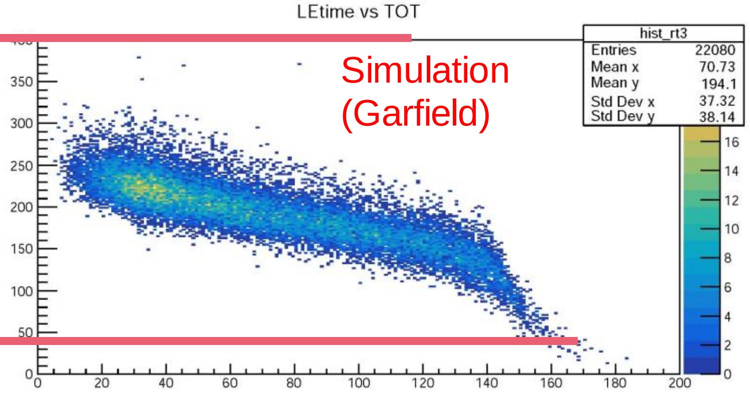
- Particle rates (STS1 & FEB & DAQ)
  - ~ 2×10^5/straw; high intensity runs: ~ 6×10^5/straw
  - HADES: DAQ trigger ~ 50kHz
  - Beam induced particle background in broad time range
- TDC times and time-over-threshold data (704 straw channels)
- Clean & in accordance with simulation
- Calibration (1st step) done with TDC spectrum & for each straw

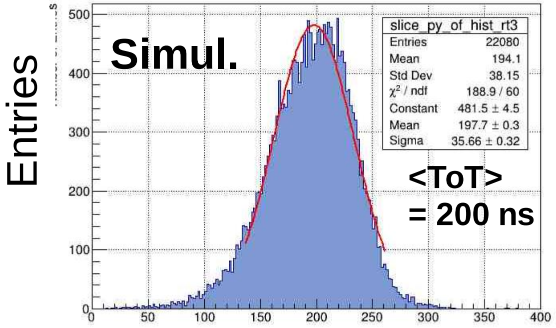


TDC scaler rates (/s) for STS1 & STS2. High intensity data runs.









Time-over-threshold (ns) versus Drift time (ns)

Time-over-threshold (ns) versus Drift time (ns)

Time-over-threshold (ns)

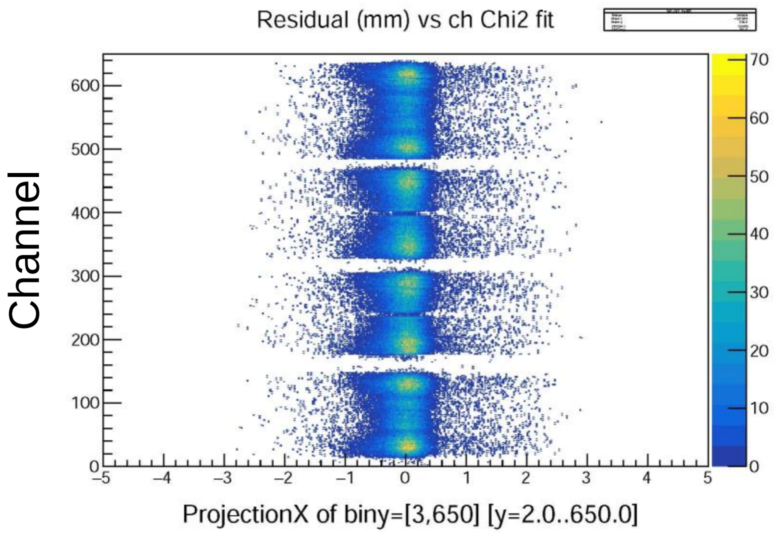
Performance Results

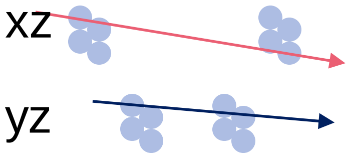
Calibration and Tracking

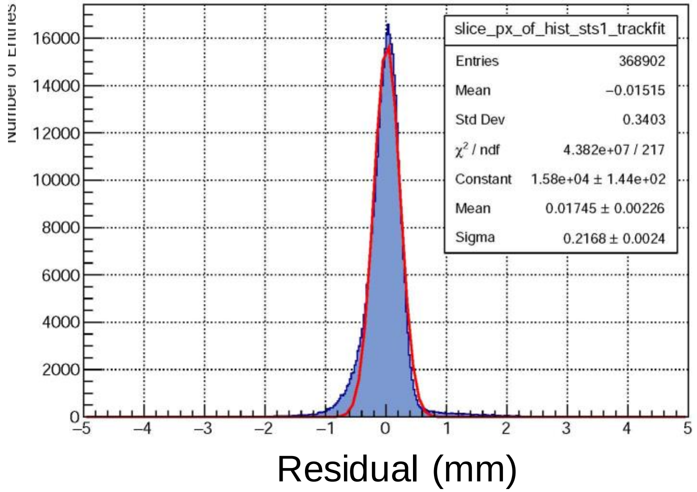
- **Aim: re-check tracking methods**
  1. Calibration procedure
  2. Tracking method
  3. Alignment method

- **Calibration procedure**
  1. r(t) isochrone - drifttime relation from TDC spectrum (G. Perez)
  2. r(t) iterative fitting using reco tracks (σ ~ 310µm → 217µm → ..)

- **Tracking resolution: σ = 217 µm** (mean = 17µm)
  - No hit filter, no δ-electron rejection (~ 1/8 hits probability)
  - χ2-fit, biased from close-to-wire hit (no redundancy)
  - l/r ambiguity close to wire difficult to resolve
  - Low gas gain (~2×10^4) chosen, little worse resolution close to wire (ion cluster spread)



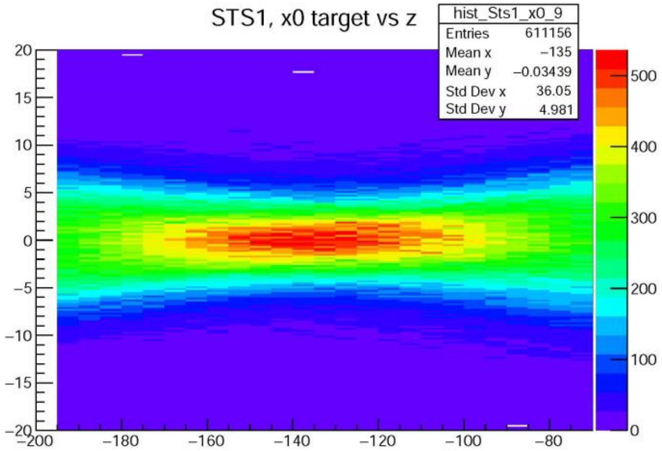


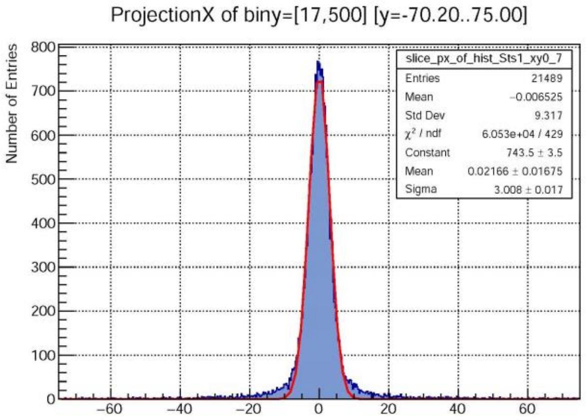


Performance Results

Tracking with No-Redundancy

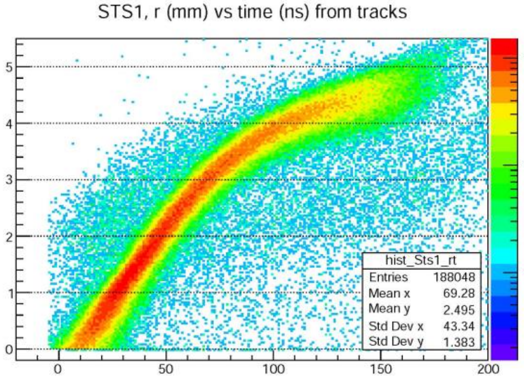
- Calculate target point (X0,Y0) at Z0 = -135mm from reco tracks
  - Smearing by ~ 3.5m back propagation
  - Influence of MCS: Δx,y ~ 700µm at Z0

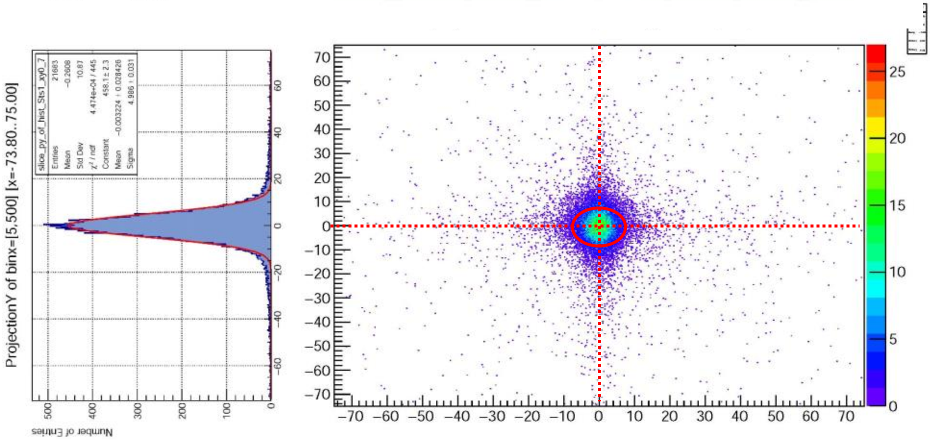




- Alignment of double-layers to shift target point to (0,0)
  - x-shift: 7.47 mm
  - y-shift: 2.72 mm

- Target distribution after STS1 position adjustment and recalibration
  - r(t) re-calibration using reco tracks
  - σ_X (target) = 3.01mm (m= 21µm)
  - σ_Y (target) = 4.99mm (m= -3 µm)
  - red circle marks lH_2 target cell diameter

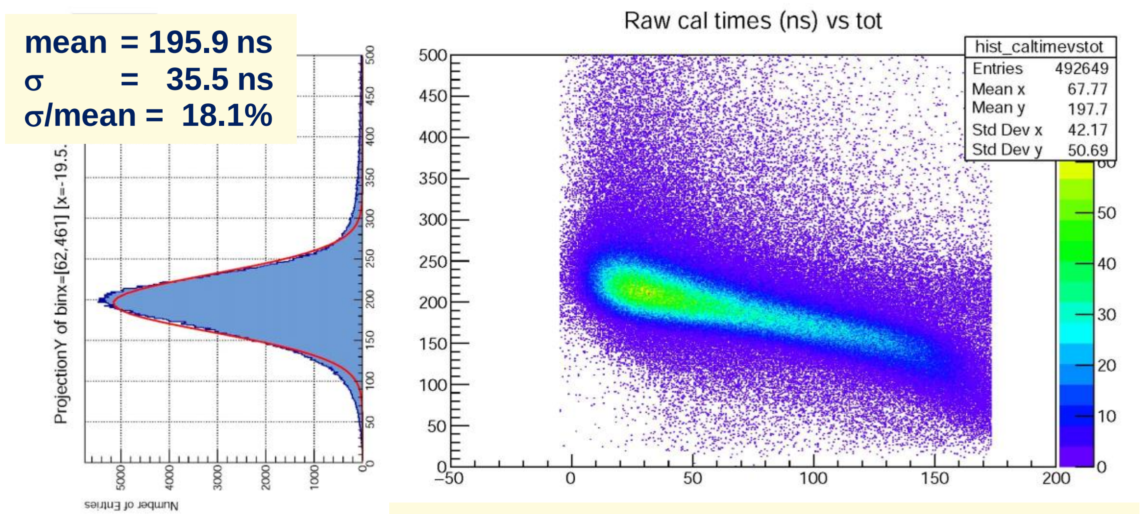




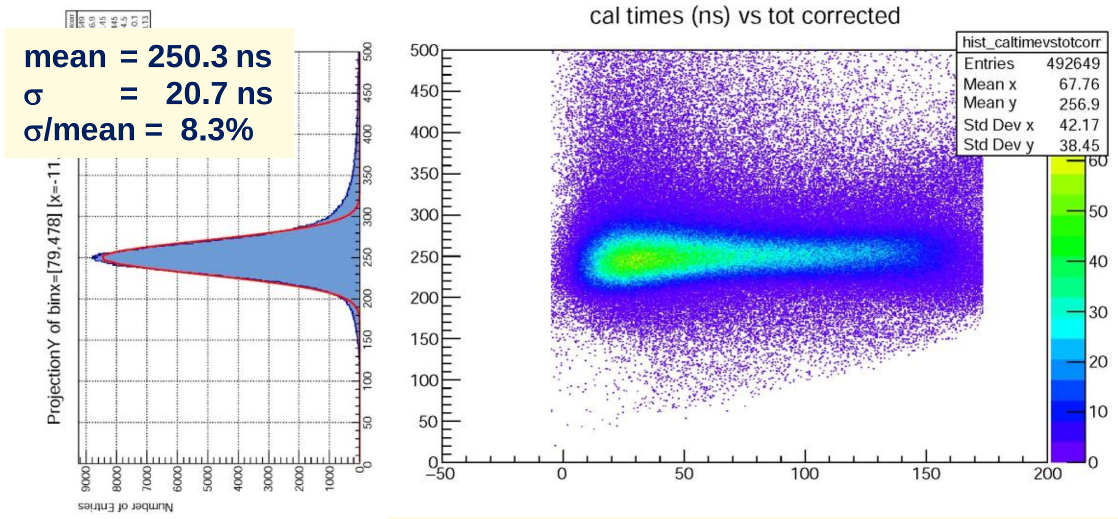
Target Y0 (mm) vs X0 (mm)

Performance Results

Time-Over-Threshold

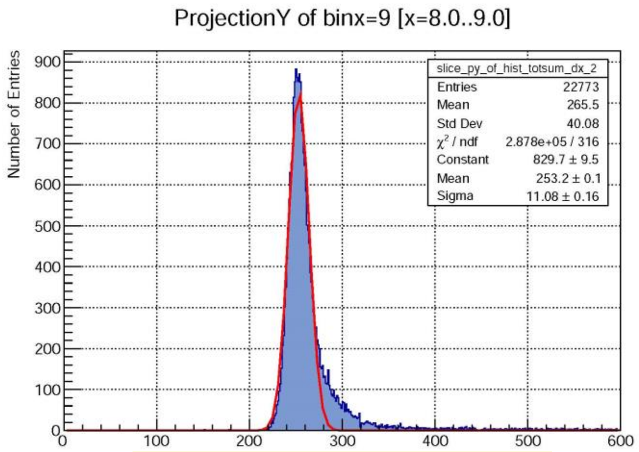


Time-over-threshold (ns) versus Drift time (ns)



Time-over-threshold (ns) versus Drift time (ns)

- All 640 channels, offset corrected drift times
- Top left: raw data, show characteristic ToT(driftime) distribution
- Top right: ToT with time dependence correction (fit)
- Single hit ToT: ~ 8.3% resolution
- **ΣToT/N_{hits} resolution: ~ 4.4 %**
- **8 hits per track, no truncation**



Time-over-threshold (ns)

Performance Results

Time Pattern Recognition

– Time pattern recognition for STS1 data (staggered double-layers)

– pp-elastic candidate events

– Averaged TE-time ($\sum$TE-time / N_{nits})

  – 4hits: m/σ = 259ns / 16.6 ns (more uncorr. hits)

  – 5hits: m/σ = 259ns / 12.9 ns

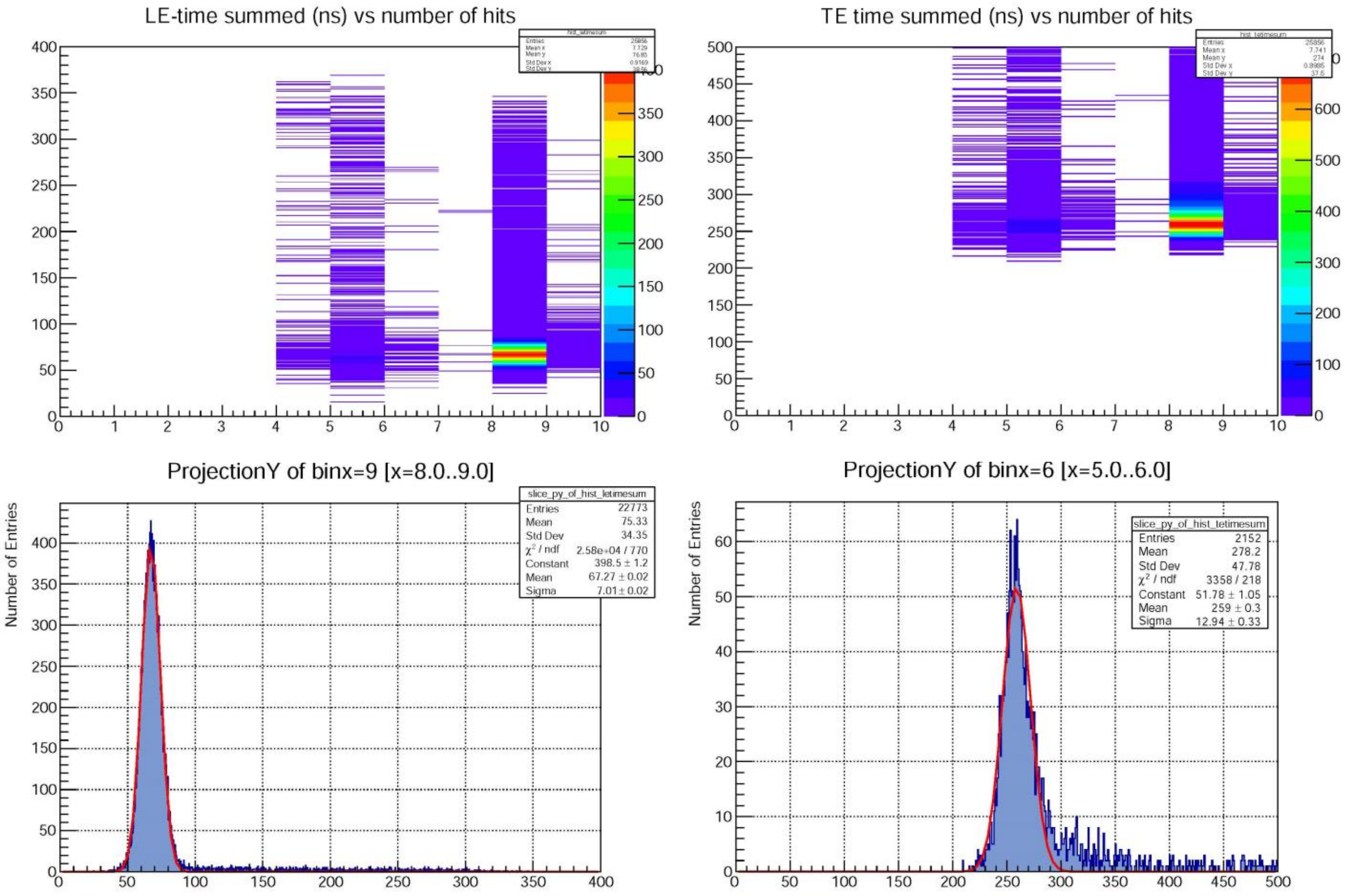
  – 8hits: m/σ = 261ns / 11.1 ns

– Averaged LE-time ($\sum$LE-time / N_{nits})

  – 4hits: m/σ = 67.7ns / 17.3 ns (more uncorr. hits)

  – 5hits: m/σ = 65.7ns / 12.3 ns

  – 8hits: m/σ = 67.3ns / 7.0 ns



LE-time (ns) averaged for 8 hits

TE-time (ns) averaged for 5 hits

Performance Results

Time Measurement and Space-Drifttime Relation

STS1 in-beam data

– r(t) calibration using TDC spectra ($r(t)/R=\sum n_i/N$)

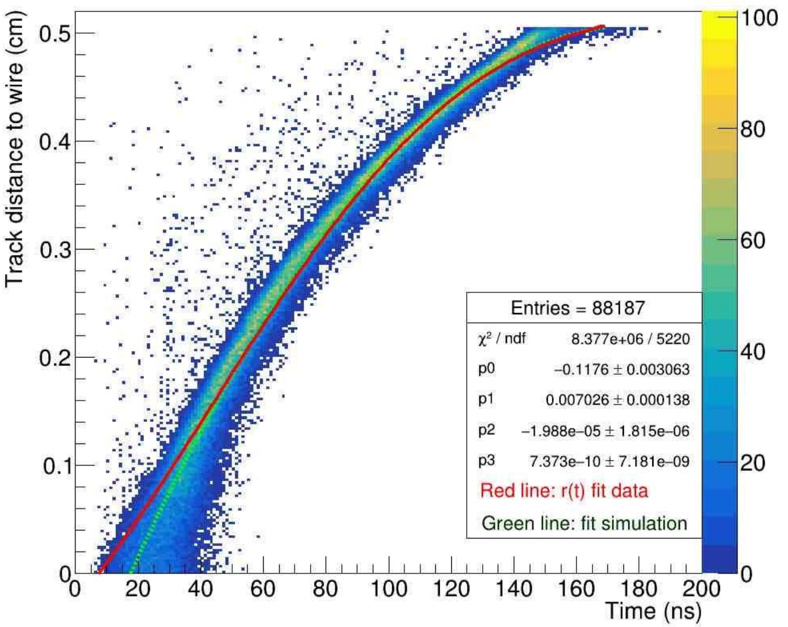
– in-beam data (red line) agrees well with single straw simulation (green line)

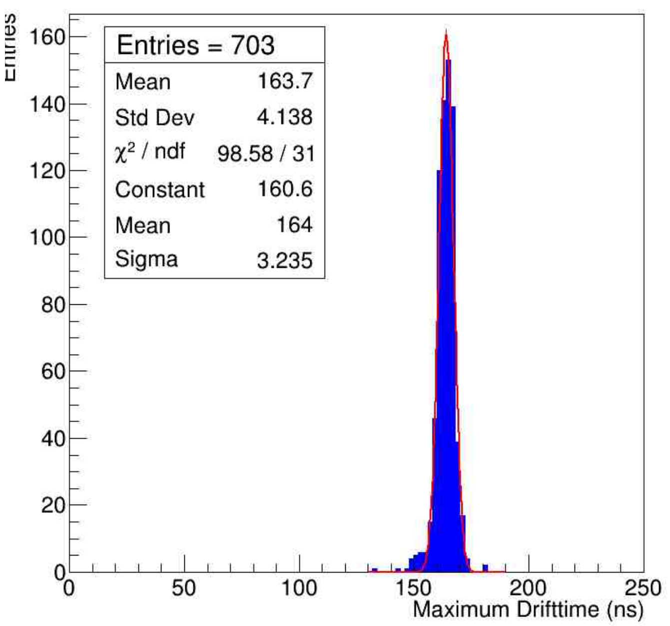
– deviations for r<1mm (prim. ionization)

– clean drifttime spectra

– only ~3.2ns spread in max. driftime for 703 ch

– corresponds to <40µm spread in straw radius





In PANDA-STT:

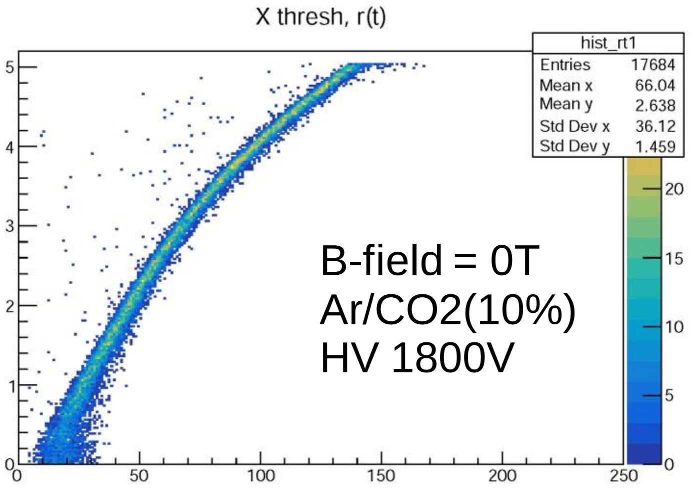
– iterative re-calibration r(t) with reco tracks

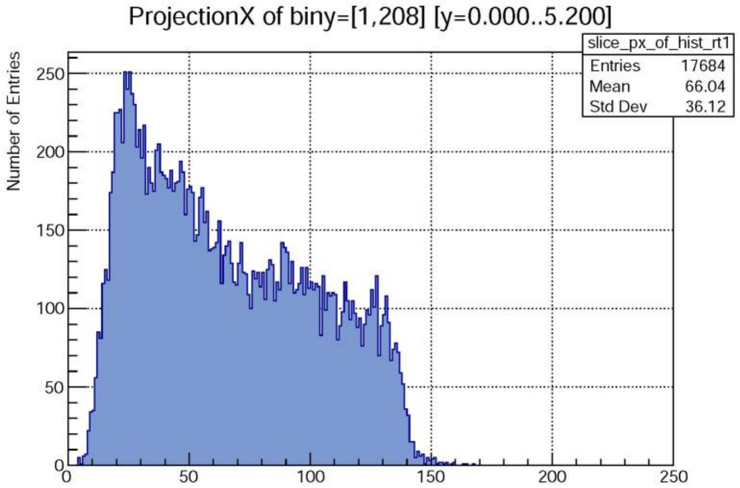
– high redundancy

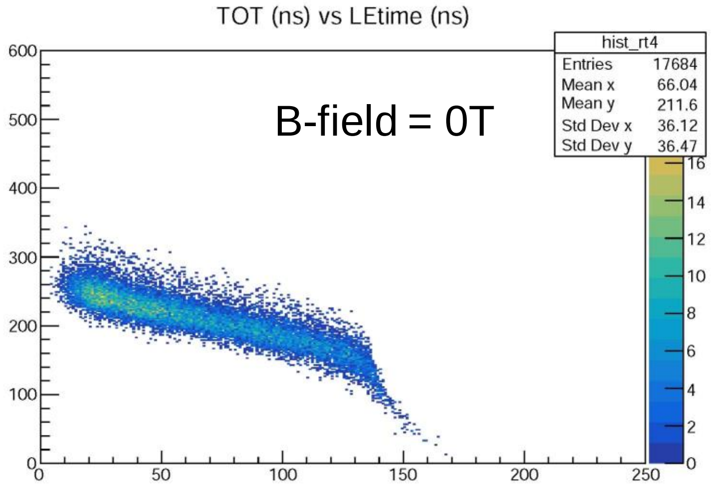
Pressurized straws with thin film-wall tube have a high geometrical precision

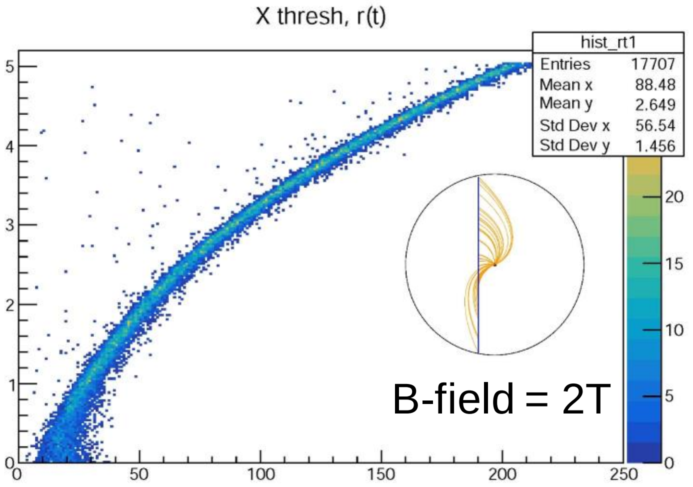
Performance

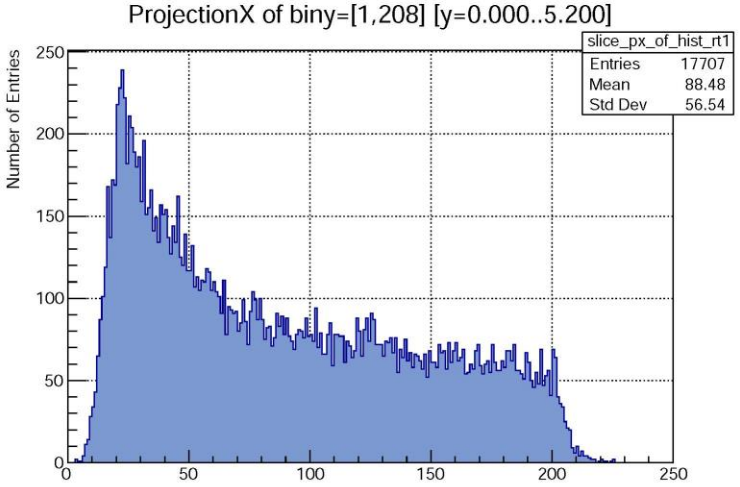
Simulation STT in B-Field

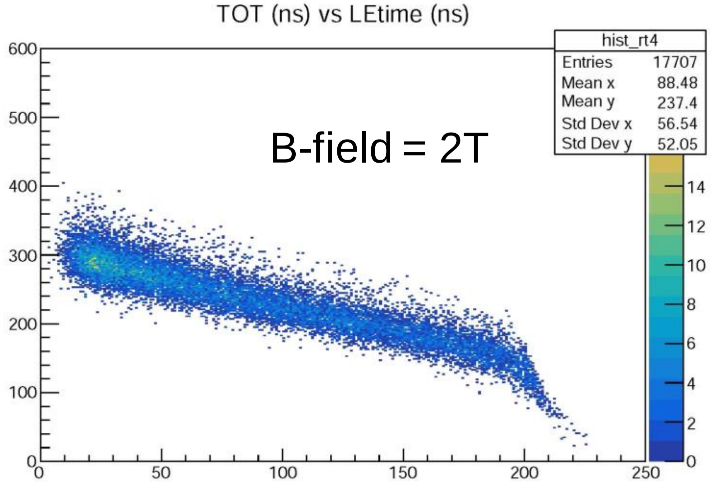






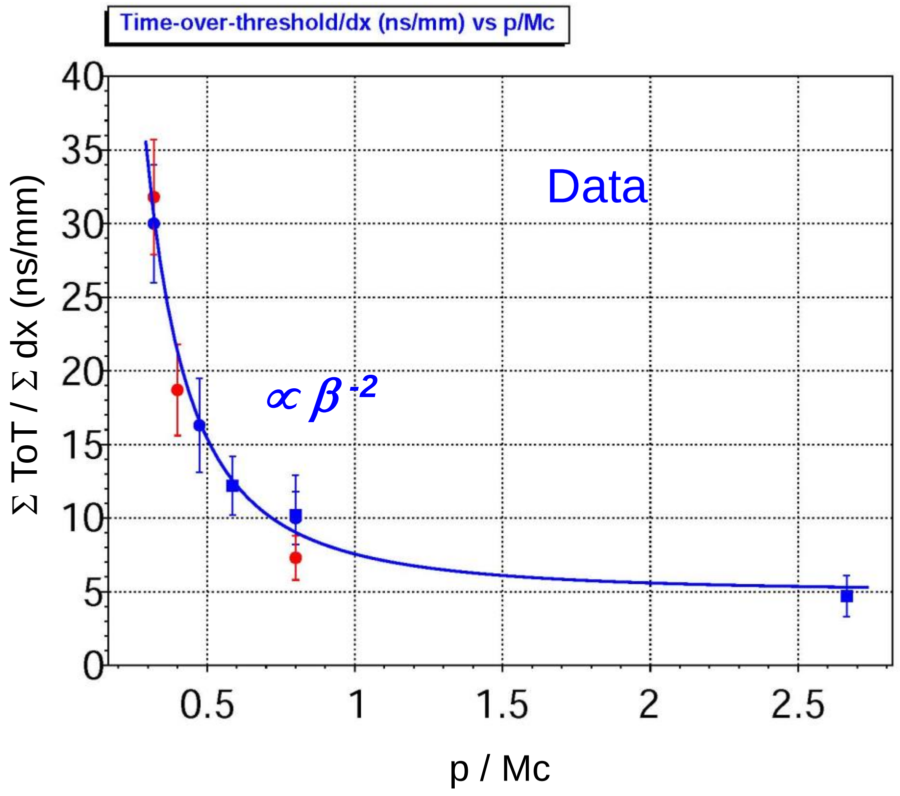


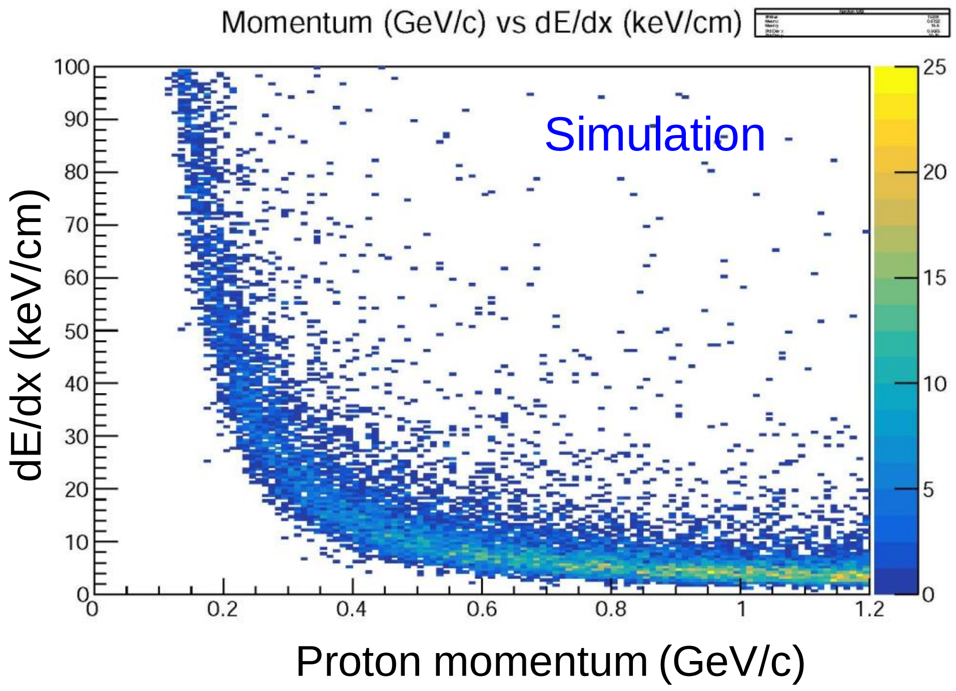


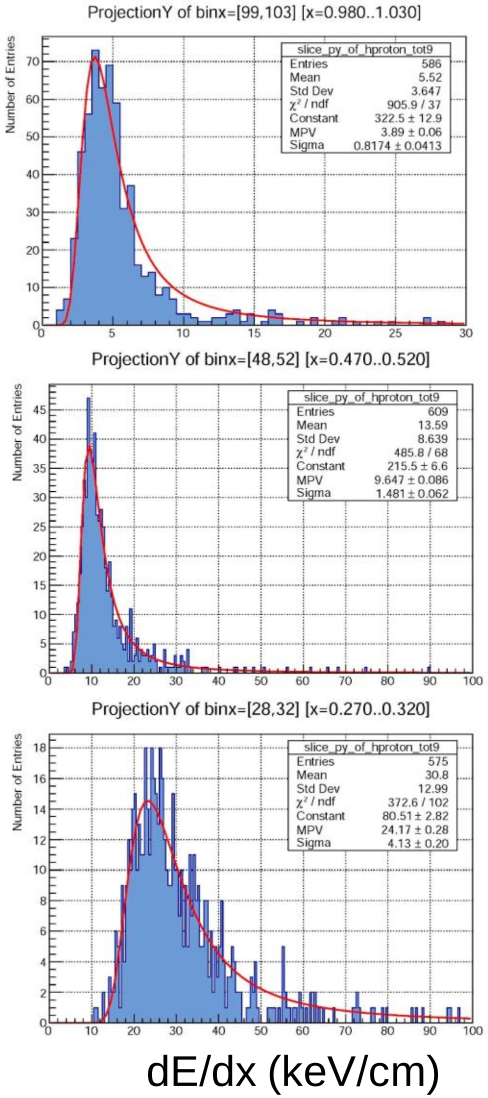


Performance Results

ToT/dx Measurement and dE/dx Simulation







- Totcorr = ToT – 20ns (peaking time)
- Proton and deuteron beam at COSY
- 0.6 to 2.75 GeV/c momentum range

Protons dE/dx simulation for STT straw:
1 GeV/c: 3.9 keV/cm
0.5 GeV/c: 9.6 keV/cm
0.3 GeV/c: 24.2 keV/cm

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Performance Results

Summary and Next Steps

Set up one STT sector (~700 straws) with readout and DAQ

- Cosmic data taking, radioactive source
- SW: data analysis, calibration, tracking, t0 extraction, ToT methods
- Most components existing (straws, electronic FEBs, ..)
- ToDo: assembly straw modules, FEE layout & cooling system, alignment method

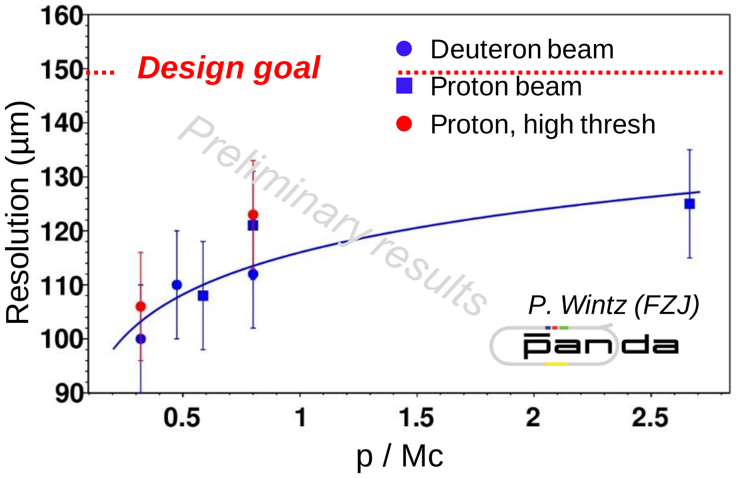
Performance goals (4D+PID tracker)

- Spatial resolution ~ 100µm
- ToT/dx resolution < 5% (dE/dx < 10%)
- t0 extracted from track data (Chi2 fit)
- Simulation

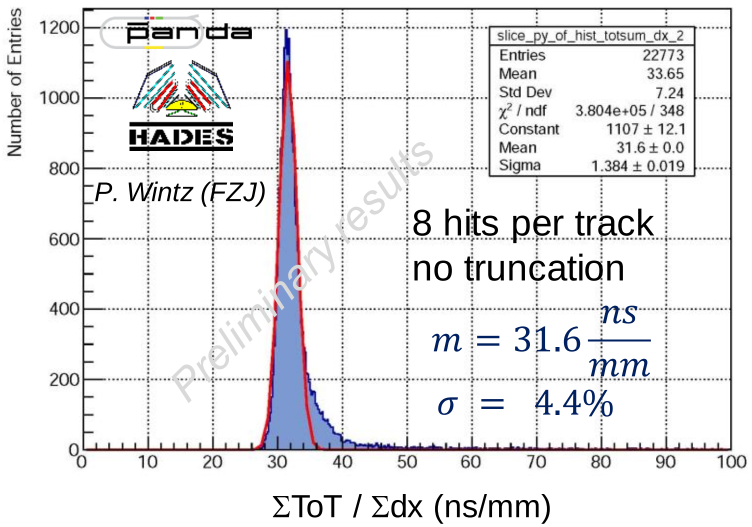
STT@COSY and HADES-STS as basis

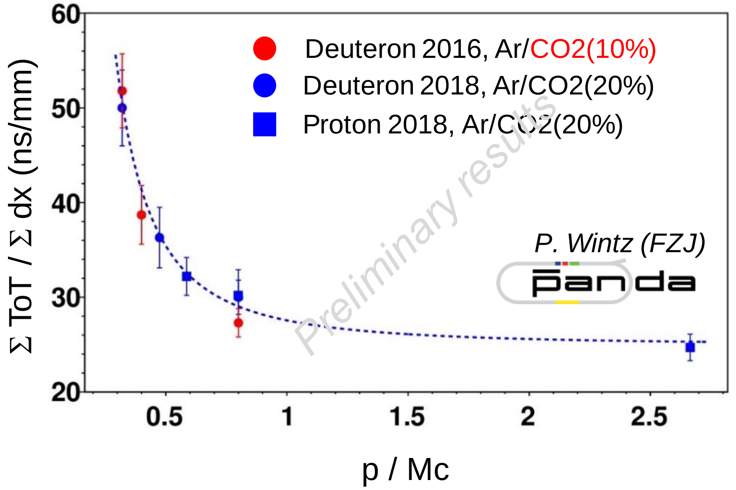
- Many more layers in STT sector
- dE/dx by ToT further optimisation
- Systematic study, e.g. signal peaking time ..

STT prototype measurements at COSY



HADES 2022 p-p beamtime





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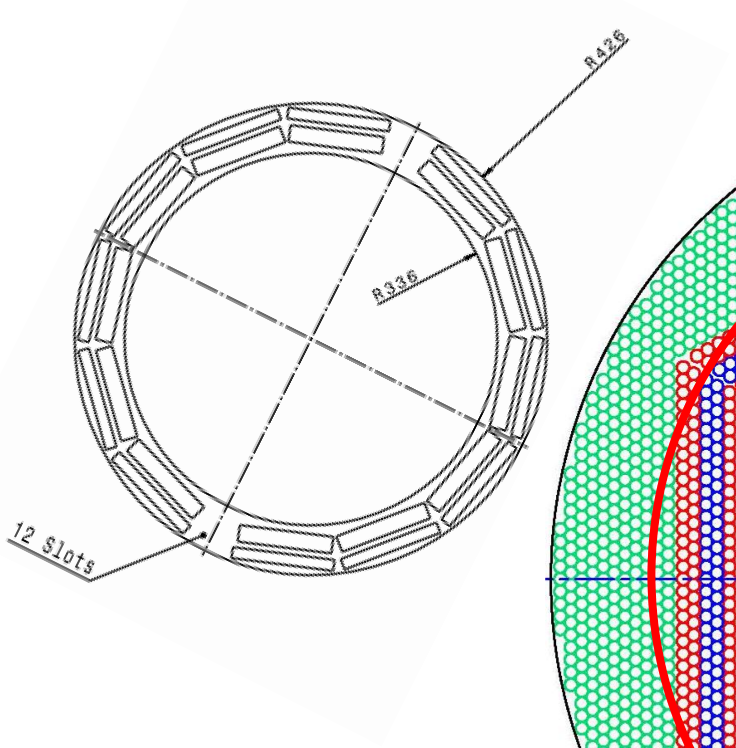
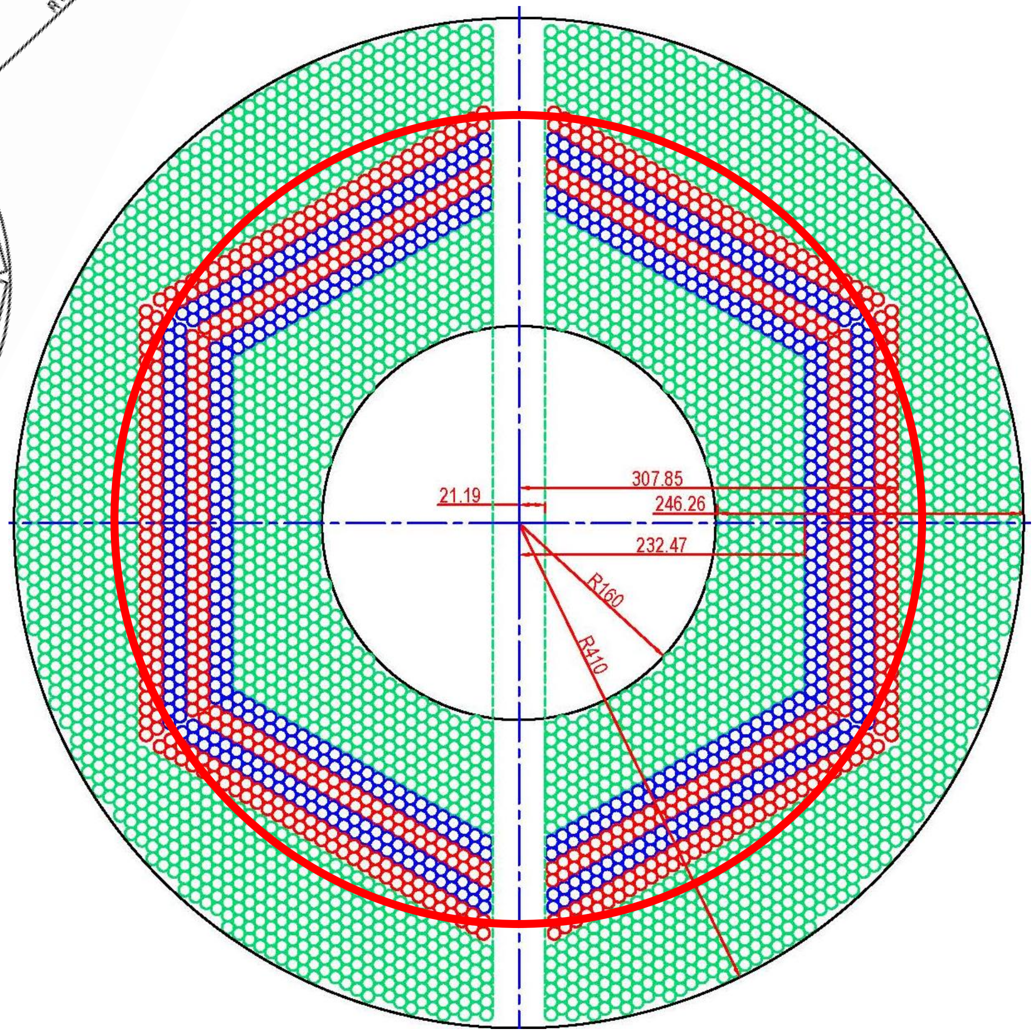
STT – Compact

- Assumption: ZEUS solenoid dimension
- MVD, DIRC-bar dimensions unchanged

- Impacts for STT geometry
  - PANDA org: R_{outer} = 44.8 cm
  - PANDA new (?): R_{outer} = 33.6 cm
  - 410 → 320 mm outer active radius (max.)
  - 27 → 16 layers (tbc) in radial direction
    - 19 → 10 axial, 8 → 6 stereo layers
  - Vertical → horizontal Central Frame
- Once straw modules assembled, no later modification

- Tracking performance under study (simulation)
  - Momentum resolution
  - Pattern recognition, curling tracks, ..





Summary

- Particle rates and charge load early determined by $\bar{p}p$-simulation for PANDA full luminosity — done
- FOM: rates for innermost layers: 1 MHz/straw and <10 kHz/cm, charge load uncritical — done
- PASTTREC ASIC parameters optimized for STT straws in PANDA, FEB size minimized — done
- ASIC/FEB/TRB and DAQ system fully verified in-beam with data analysed — done
  - High particle load in forward detector STS at HADES ✓
  - ASIC settings optimized (BL restoration and ion tail cancel., low NL, low thresh., low gas gain, ..) ✓
  - Full signal dynamical range dE/dx tested with STT tests @ COSY (4x1 week, p/d beam 0.6-3 GeV/c) ✓
  - Clean time measurements and ToT for PID, high resolutions, time PTR methods, coarse t0 extraction (<7 ns) ✓
  - Good ToT resolution for PID now already with 8 hits (BL tuning per channel, auto script) ✓

- STT reduced:
  - Actually: no electronic-specific issue left open
  - But essential: high efficient straws & readout, PTR (FPGA) and tracking due to lower number of hits
  - Spatial and momentum resolution will be lower
- **Main uncertainty: beam/target layout, B-field, .. and rates in innermost straw layers**

Thank you very much

for

your attention!