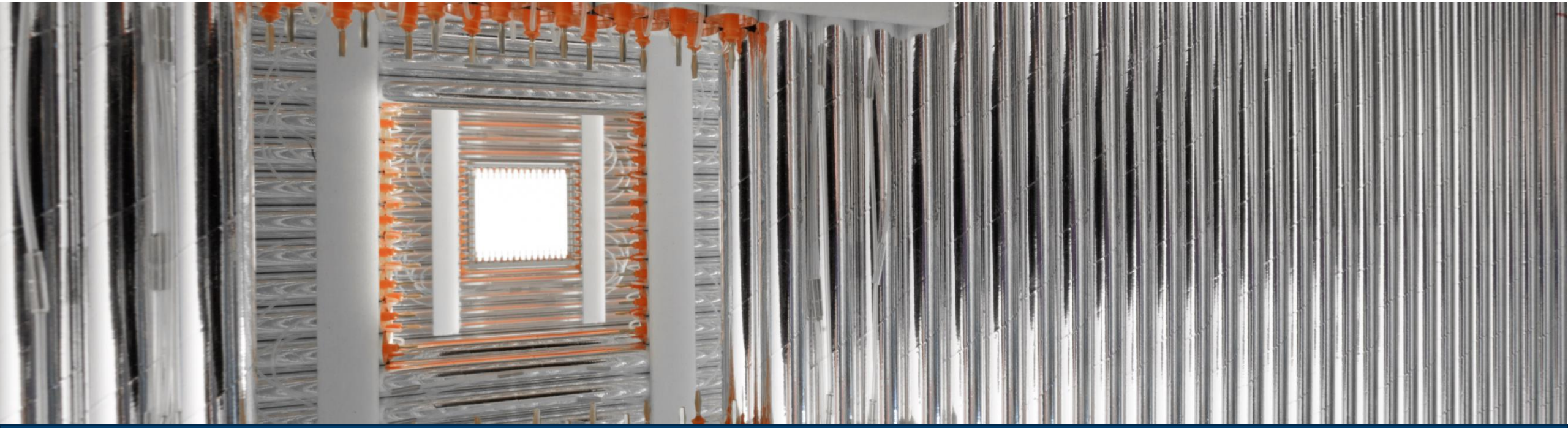


CONCLUSION FROM PHASE-0 STS FOR PANDA-STT

Peter Wintz (IKP, FZ Jülich) for the STS and STT Groups

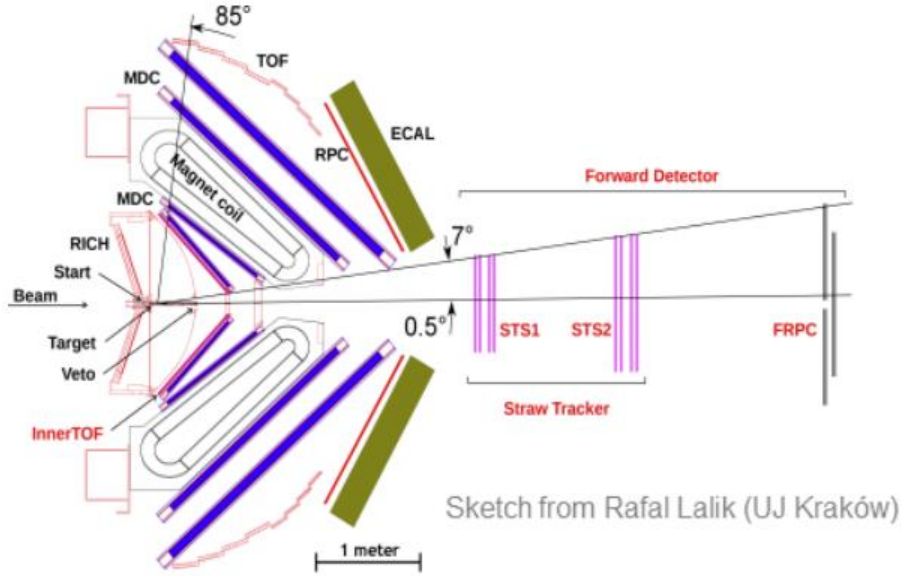
Outline

- Phase-0 Beamtime: STS @ HADES
- Benchmarks for PANDA-STT
  - Straw Operation Performance
  - PASTTREC & TRB3 Readout
  - Straw Calibration
- Conclusion for PANDA-STT

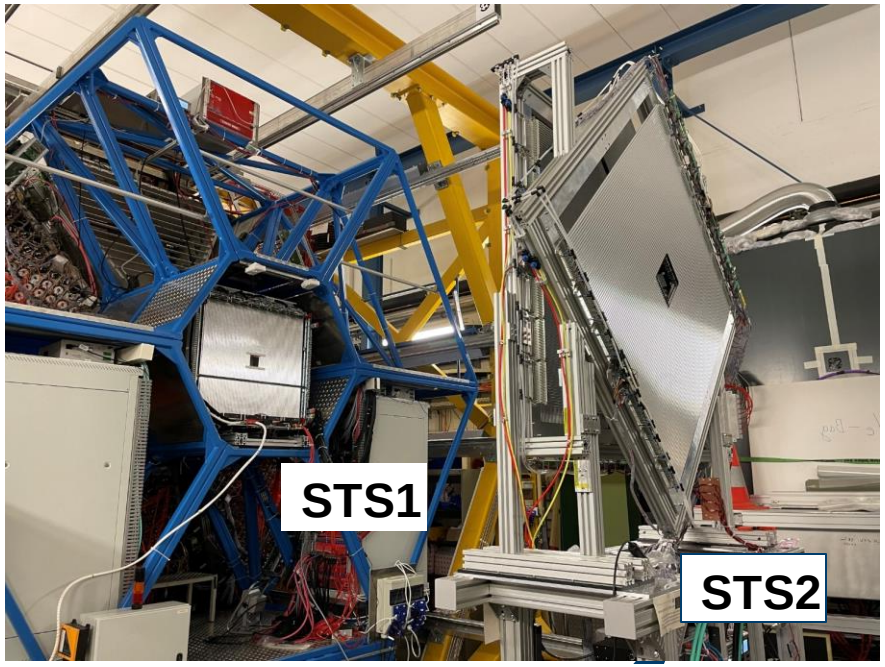
Phase-0: STS @ HADES

- Four weeks beamtime in Feb/Mar 2022
- Physics: hyperon production and decay
- p-beam with 4.5 GeV kin. energy on LH2 target
- New straw stations STS for forward tracking
- New fRPC for time-of-flight

Station	STS1 (FZJ)	STS2 (UJK)
No. of straws	704	1024
Straw length	766 mm	1200 mm
Straw orientation (azimuth.)	0°, 90°, 90°, 0°	0°, 90°, +45°, -45°
Straw film tube	27µm aluminised Mylar, 10 mm diameter	
Straw pitch in layer	10.14 mm	10.10 mm
Beam opening	80 x 80 mm^2	160 x 160 mm^2
Distance to target	3341 mm (STS1.1)	4910 mm (STS2.1)
Drift gas and pressure (abs.)	Ar/CO2(10%), 2 bar	
Electronic readout	PASTTREC and TRB3	



Sketch from Rafal Lalik (UJ Kraków)

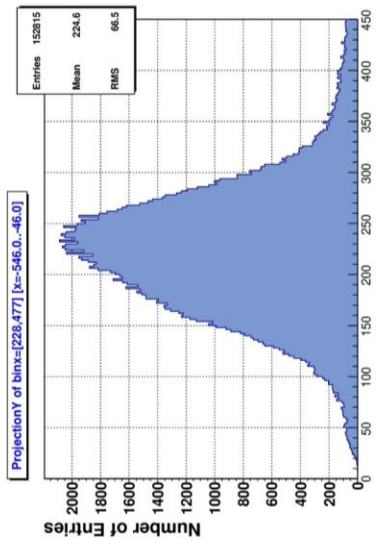


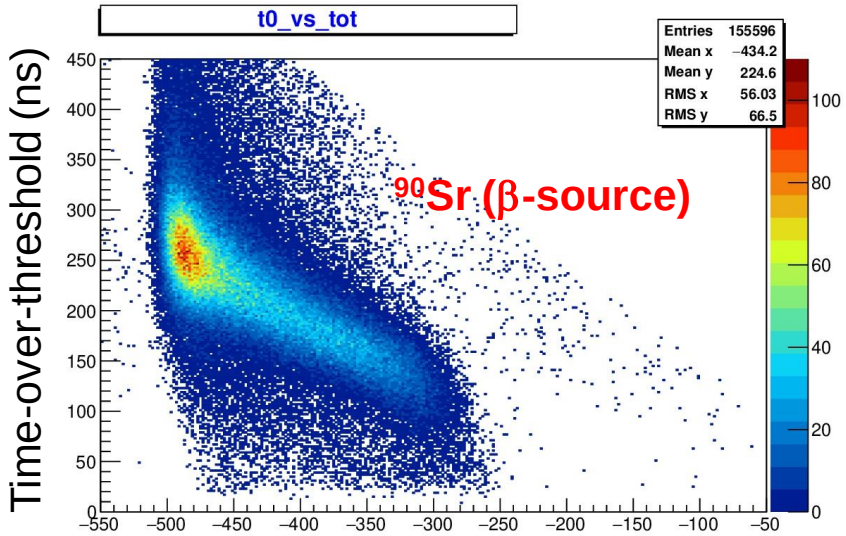
STS1 and STS2 at HADES (not in final position).

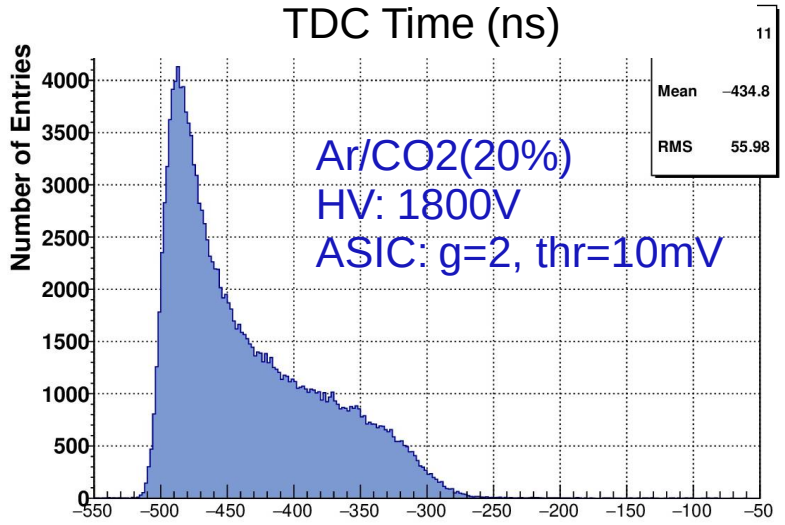
Phase-0: STS @ HADES

Straw Operation Performance

- STS1 system pre-commissioning in Julich (^{90}Sr, ^{55}Fe)
  - time and time-over-threshold data for all channels
  - high voltage and dark current tests
- STS commissioning proton beam time in 2021
  - system implementation in HADES-DAQ and HYDRA SW
- STS operation without failures during 2022 beamtime
  - straw rates (max): ~ 1-2 × 10^5 s^{-1}
    - short period with ~ 5-6 × 10^5 s^{-1} max. rates
  - particle momenta: < 5.2 GeV/c (pp elastic)
  - stable ionization currents, no dark currents (SIS18 extraction cycle: ~ few sec.)
  - low gas gain: ~1-2 x 10^4 (HV=1700V and Ar/CO2(10%) at 2 bar)
  - low signal threshold (20 mV), stable NL





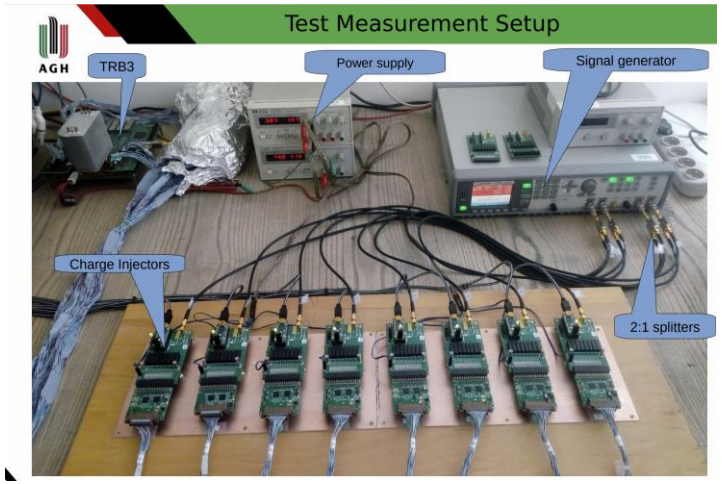


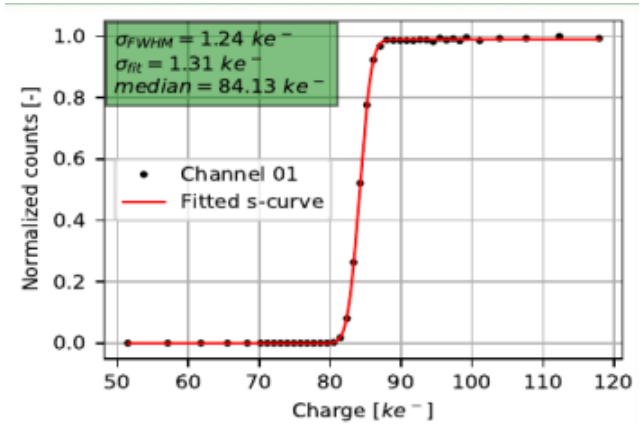
PASTTREC-Readout

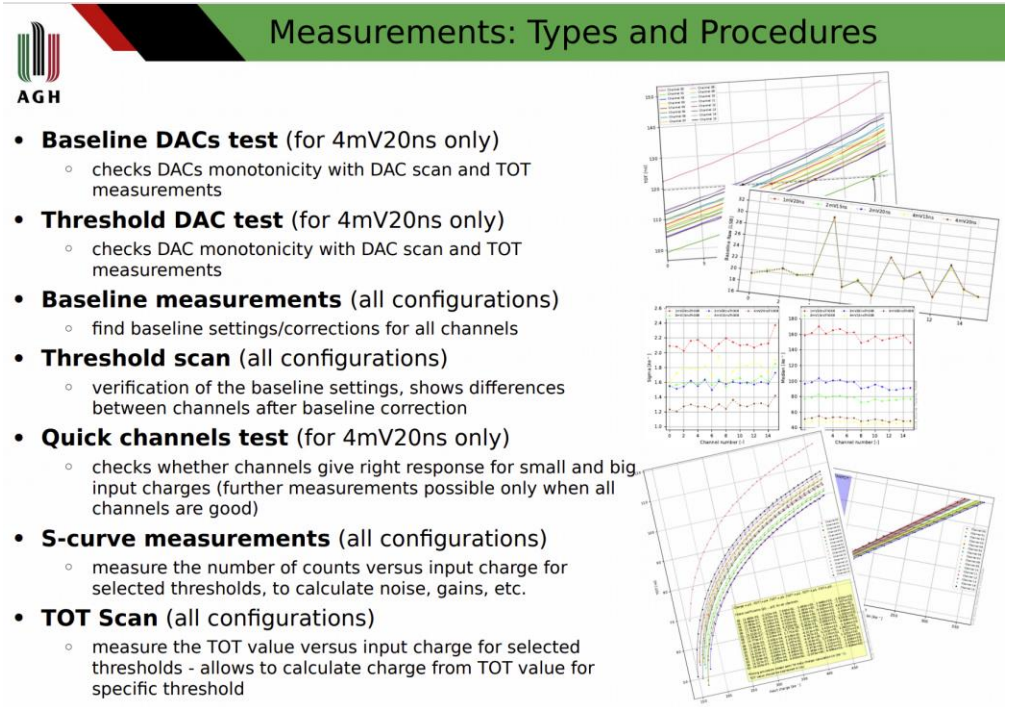
QA Procedures and Tests by AGH Krakow Group (Presentations by A. Molenda)

- Full functionality test of each PASTTREC board and channel
- Test equipment set up (charge injection, SW control, readout)
- QA measures: 7 test criteria (s.below)
- Five ASIC parameter sets
- Protocol for each FEB (QA database)
- QA example: 132 FEBs tested, 94% passed ok

Configuration name	Gain	T_{peak}	TC_{C1}	TC_{R1}	TC_{C2}	TC_{R2}
1mV20ns	1 mV/fC	20 ns	6.0 pF	23 kΩ	0.6 pF	11 kΩ
2mV15ns	2 mV/fC	15 ns	15.0 pF	7 kΩ	0.6 pF	8 kΩ
2mV20ns	2 mV/fC	20 ns	7.5 pF	27 kΩ	0.75 pF	17 kΩ
4mV15ns	4 mV/fC	15 ns	13.5 pF	19 kΩ	1.5 pF	23 kΩ
4mV20ns	4 mV/fC	20 ns	10.5 pF	27 kΩ	0.9 pF	20 kΩ







STS Readout Performance in Experiment

Readout Software and Control by UJ Krakow Group

- PASTTREC old FEBs and new type (´21 delivery) used, new type with QA tests passed ok
- ASIC baseline (BL) determination done for each channel (auto-script: BL shifting and scan noise rate)
- BL from QA test taken if NL too low (few channels in STS1)

- Continuous ASIC setting verification during data-taking implemented in DAQ
- Parameter readback (1700ch), ASIC resetting and parameter reloading

- No change in ASIC parameter settings necessary during beamtime (stable NL, stable BL at high rates)

- Parameter set used:
  - 4mV/fC gain, 20ns peaking time (TC param. see table p.5)
  - 20mV thresh. for STS1, 40mV for STS2

STS Calibration and Tracking Procedure

STS1/2 Calibrations by G. Perez-Andrade

Steps

- 1st stage: TDC time spectrum and assum. homogenous straw illumination
  - time offset determination and drift time extraction
  - parametridsation of isochrone radius - drift time relation r(t)
  - HADES start detector and particle time-of-flight calibration not yet final
  - high-β tracks (~ 5 GeV/c protons) dominating in raw data, constant time offset assumed for r(t) calibration

$$\frac{N}{R} = \frac{\sum_{t=0}^{ti} n_i}{r(t_i)} \rightarrow r(t) = \sum_{i=0}^{k} P_i \times t^i$$

- 2nd stage: use reco. tracks ⇒ track to wire distance (d=r) and drift time (t_{dr})
  - check if systematic errors and correct, e.g. straw and wire positions
  - re-fit r(t) and re-check & correct syst. errors
  - determine spatial resolution σ(r) as function of radius
  - repeat/iteration of χ2 track fit

$still\ to\ be\ done\ for\ STS1/2$ *

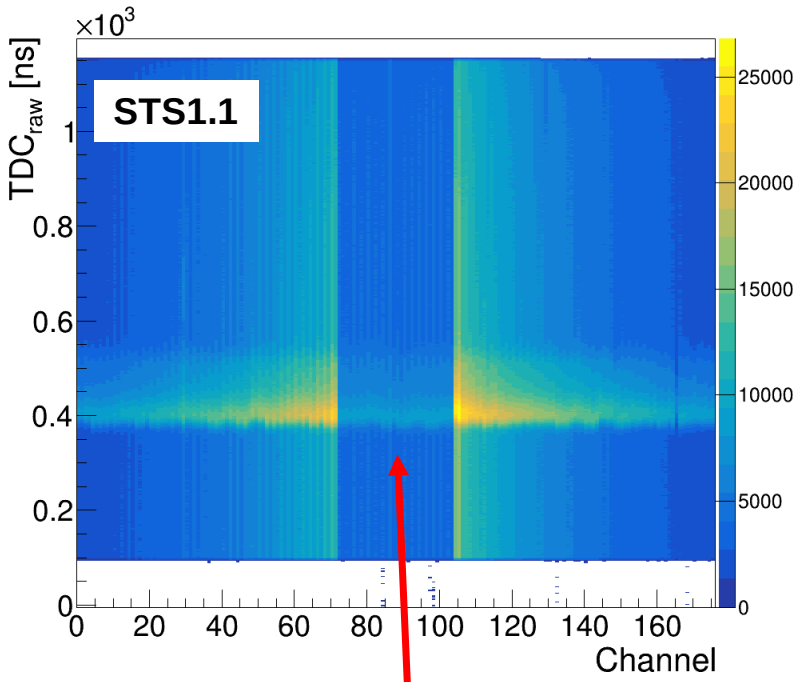
$$\chi^2 = \frac{1}{N-f}\sum_{i}^{N}\left(\frac{d_i - r(t_i)}{\sigma(r)}\right)^2$$

- STS 1st stage calibration checked with simulation (Garfield)
  - r(t) from TDC time spectrum fit reproduces e- drift motion and drift velocity $v_{dr}(r)$

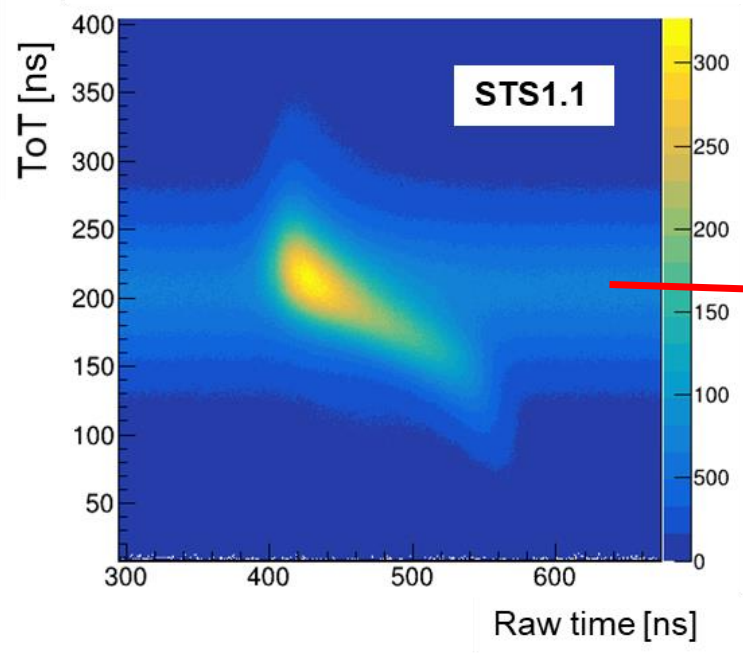
LGAD and fRPC calibration not yet final

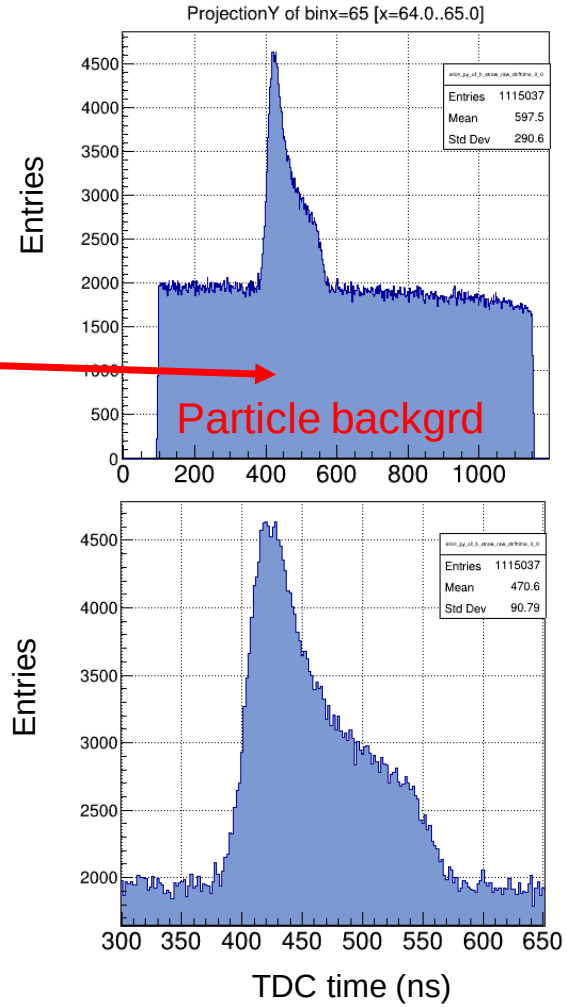
STS In-Beam Data

TDC-Times and Time-Over-Threshold (Presentation by G. Perez-Andrade)



Central short straws
(beamhole)



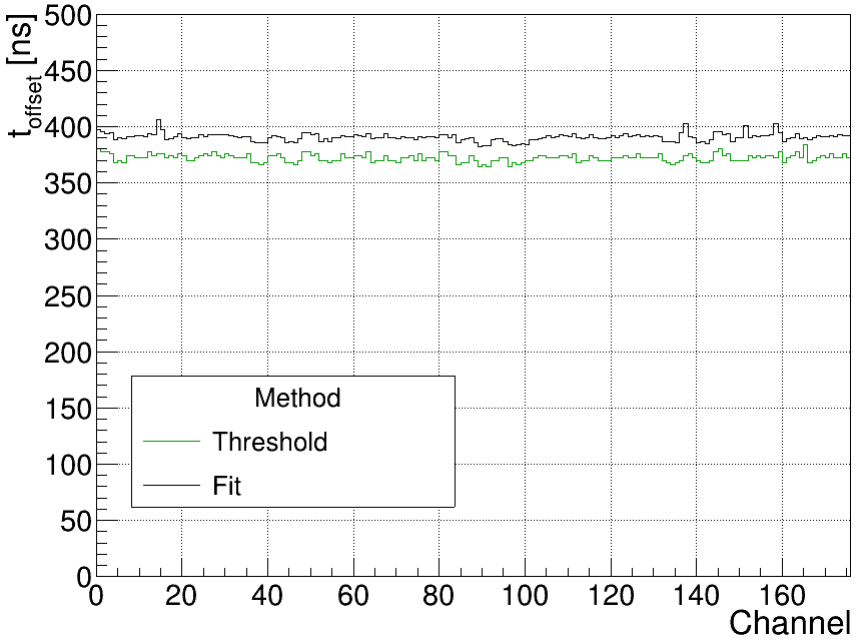


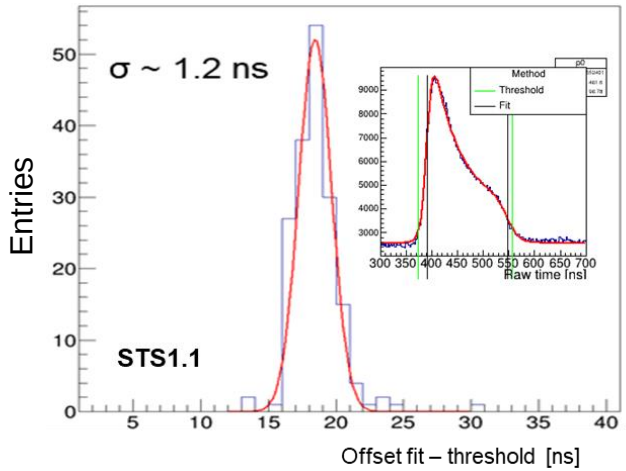
STS Time Offset Determination

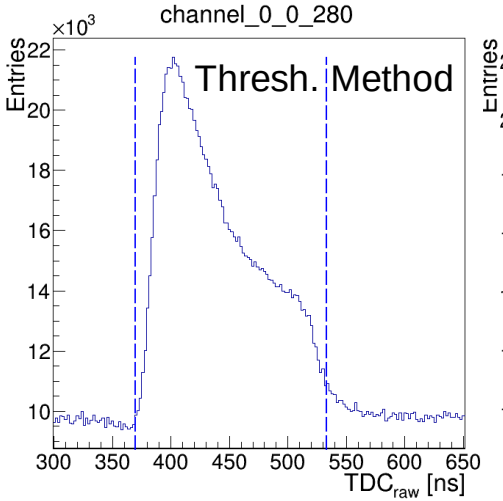
Calibration Results by G. Perez-Andrade

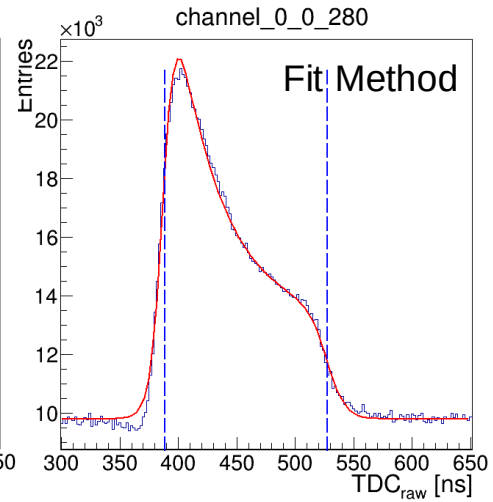
- Time offset (T0) determination for each channel (variation seen)
- Two methods to check systematic errors
  - Start (foot) of time distribution rising edge (threshold and slope)
  - Fit of time distribution shape (9 parameter fit, empirical)
- Result: t0 determination accuracy better than 1.5 ns (σ)

Station	T0 (ns) (Thresh.)	T0 (ns) (Fit method)
STS1.1	372.6	390.8
STS1.2	373.6	391.8
STS1.3	373.8	392.4
STS1.4	374.2	393.0
STS2.1	360.8	380.7
STS2.2	361.7	382.0
STS2.3	362.4	382.6
STS2.4	362.0	383.0







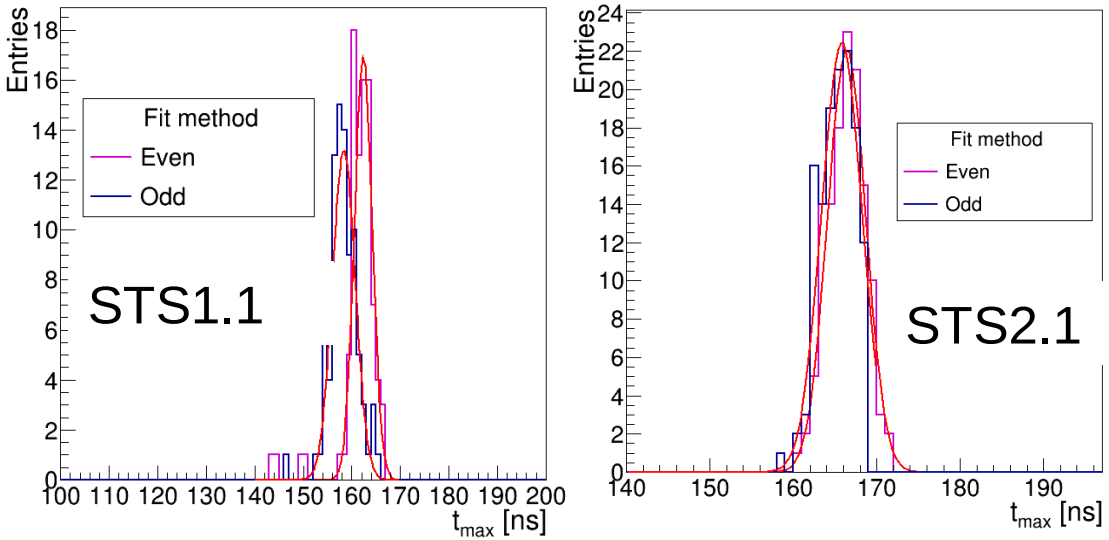


STS Maximum Drift Time

(Main Drift Time Measurement Parameter)

- Max. drift time marks end of drift time spectrum
- Tmax value effects: v_{drift} , ε, t_0/t_{max} method, ASIC, straw/wire geometry, ..
- Result: very small variation for all STS1&2 stations (< 1ns)
  - Slightly higher tmax in STS2 (longer straws)
  - Small differences found for even/odd channels in STS1 (tbd)

Day 64



Threshold method

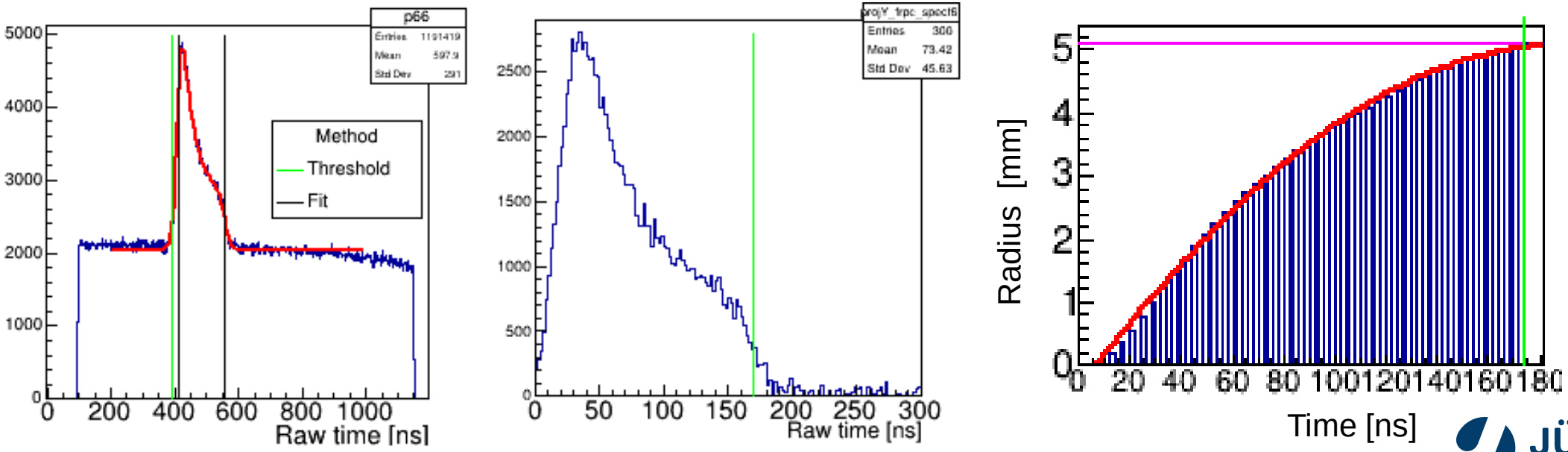
Station	Tmax Mean [ns]	Tmax Sigma [ns]
STS1.1	163.7	3.2
STS1.2	163.5	3.0
STS1.3	163.7	3.1
STS1.4	163.4	3.4
STS2.1	169.9	2.7
STS2.2	170.7	2.8
STS2.3	170.6	2.6
STS2.4	170.8	2.4

Fit method

Station	Channel	Mean [ns]	Sigma ns]
STS1.1	even	162.2	1.8
	odd	158.3	2.4
STS2.1	even	166.4	2.3
	odd	165.8	2.4

STS Space – Drifttime Relation

- Homogenuous straw illumination: $R(t) = \left(\frac{\sum_{i=0}^{i_t} N_i}{N} \right) \times (\mathrm{R}_{max} - \mathrm{R}_{\min}) + \mathrm{R}_{min}$
- $\mathrm{R}_{\max} = 5.05\ \mathrm{mm}, \mathrm{R}_{\min} = 0.1\ \mathrm{mm}$
- $N / R = \Sigma n_i / r(t_i) \Rightarrow r(t) = \Sigma\ P_i \times t^i$
- 4th order polynomial function, parameters: P_0 .. P_4 and t0

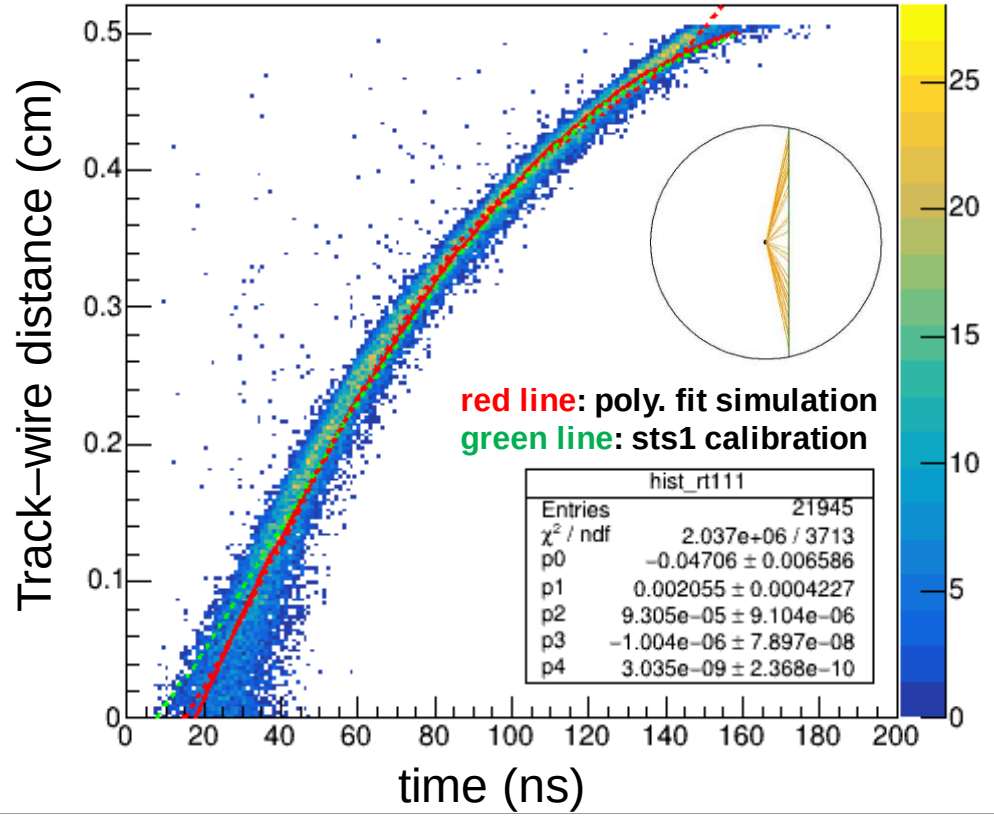


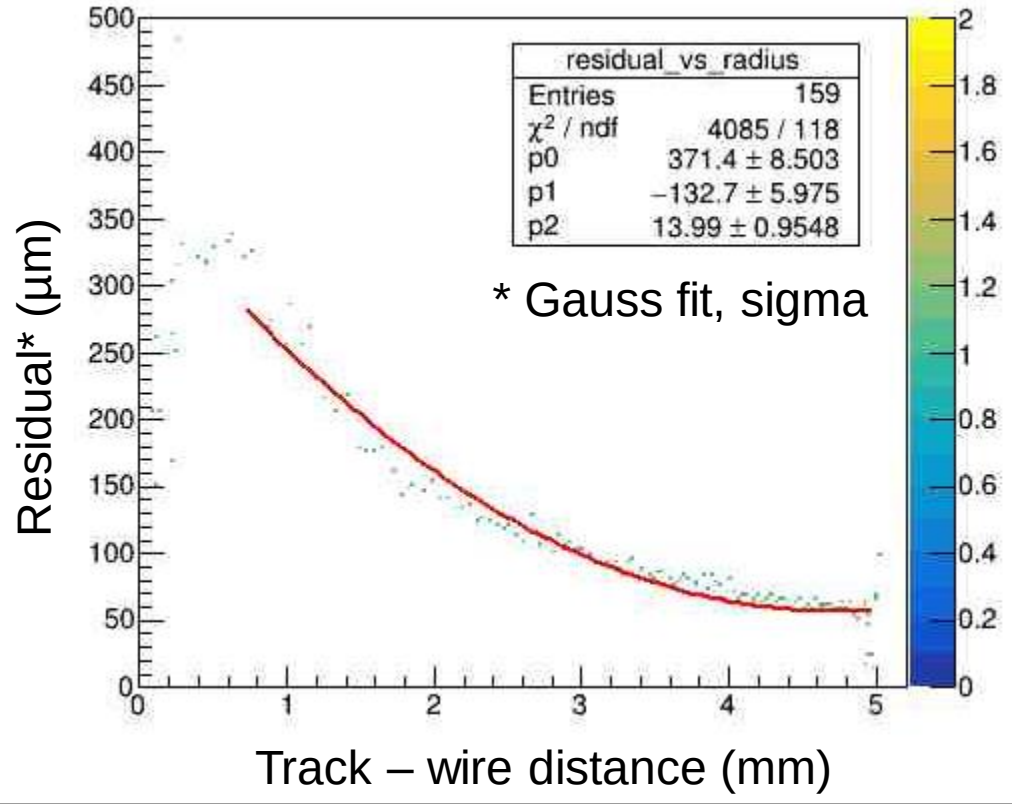
Example of the calibration steps for a single straw of STS1.1

Garfield Simulation: Drift Time

STS Straw Conditions

- Garfield simulation of random proton tracks through single straw, signal generation and drift time (red line fit)
- Comparison with sts1 space – drift time relation (green dashed line)
- Good agreement: sts1 calibration by time spectrum reproduces drift motion (r > 1 mm)

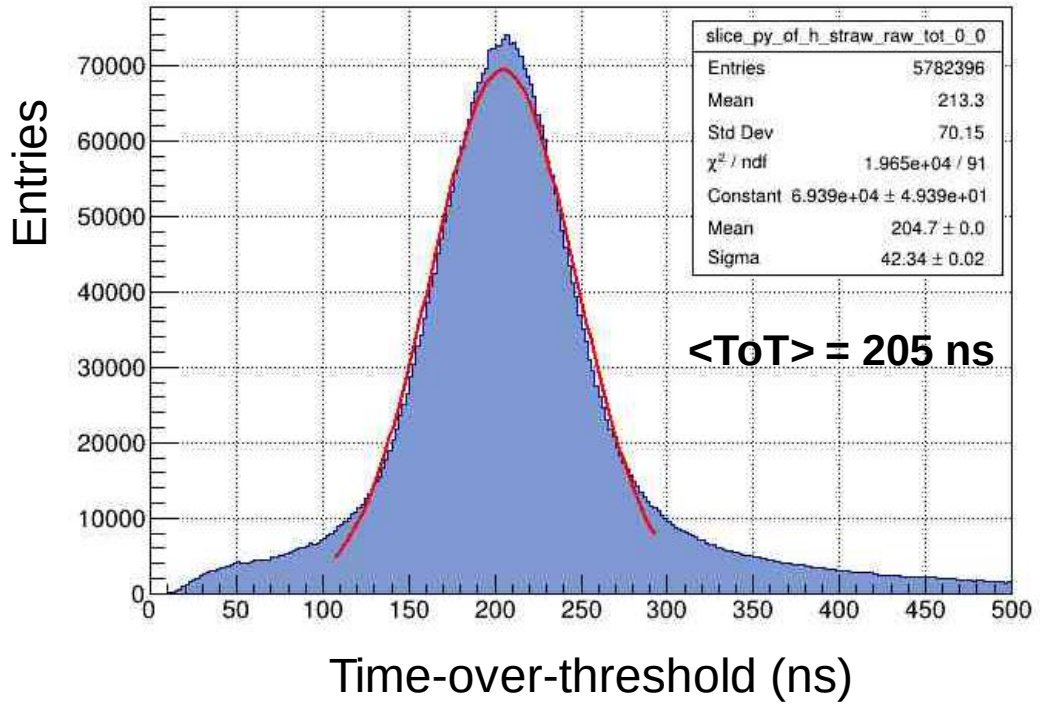


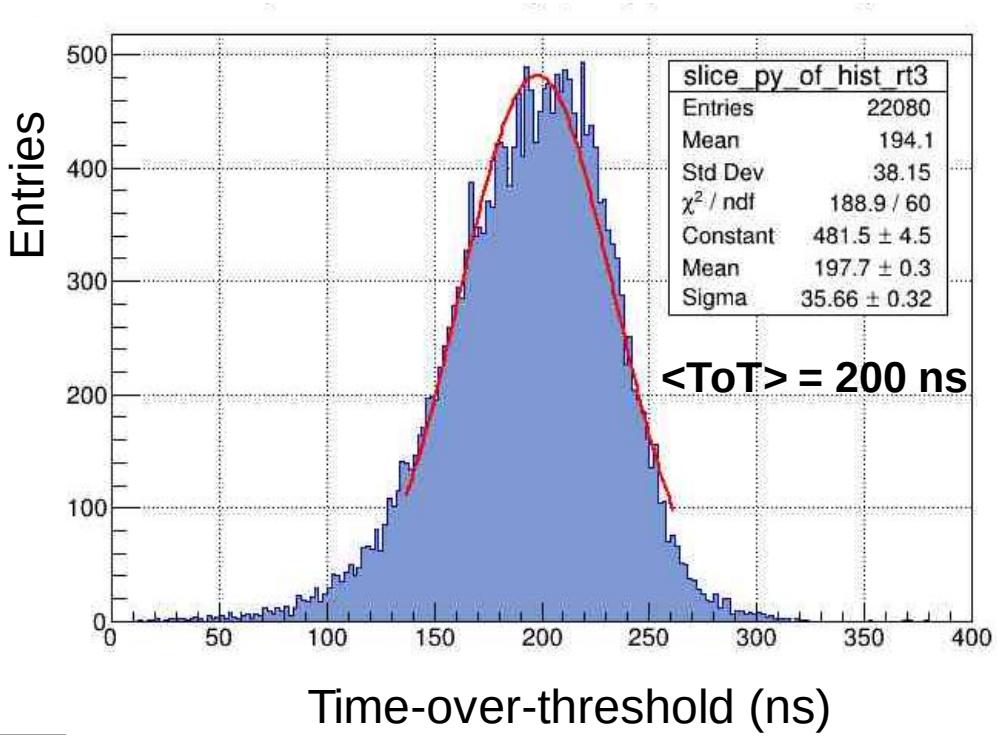


Garfield Simulation: Time-over-Threshold

STS Straw Conditions

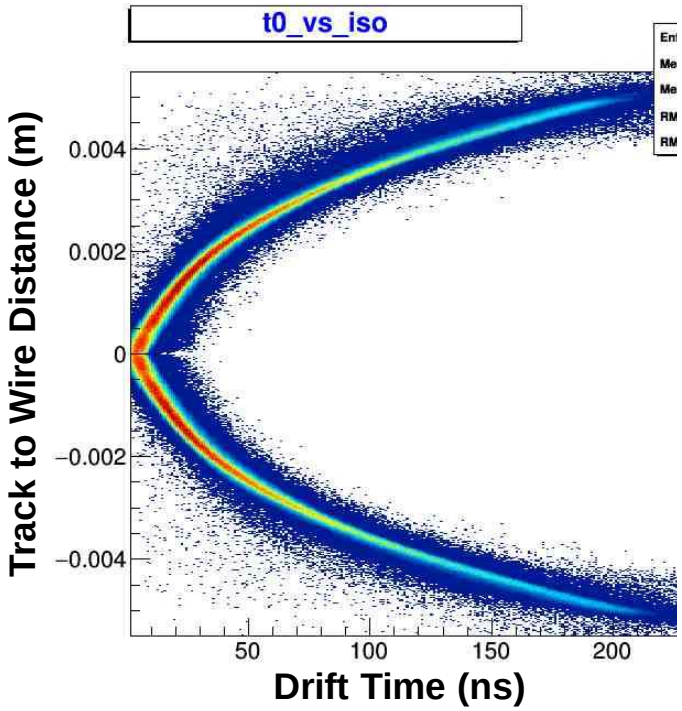
- Time-over-threshold data (left) and simulation (right)
- Simulation w/o delta-electron tracking
- PASTTREC parameters in transfer function and signal generation
- Good agreement between simulation and data

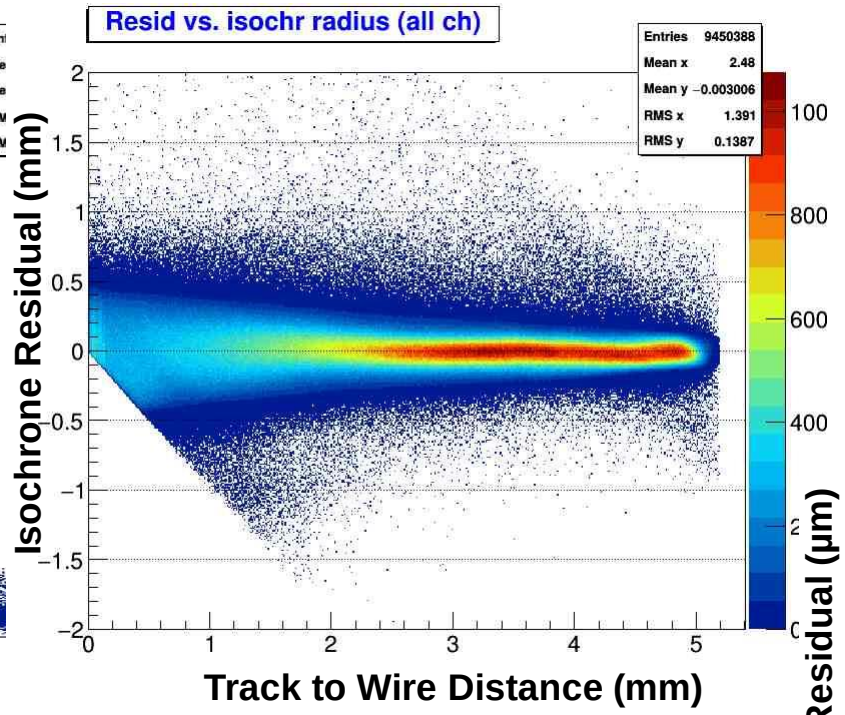


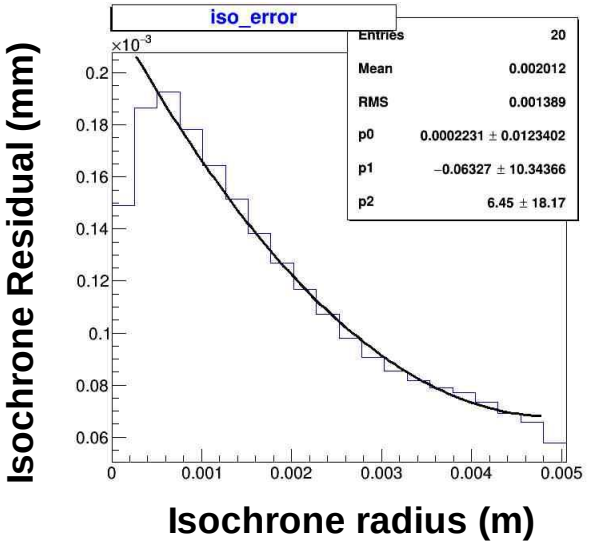


Recap: STT Testsystem: Calibration & Tracking

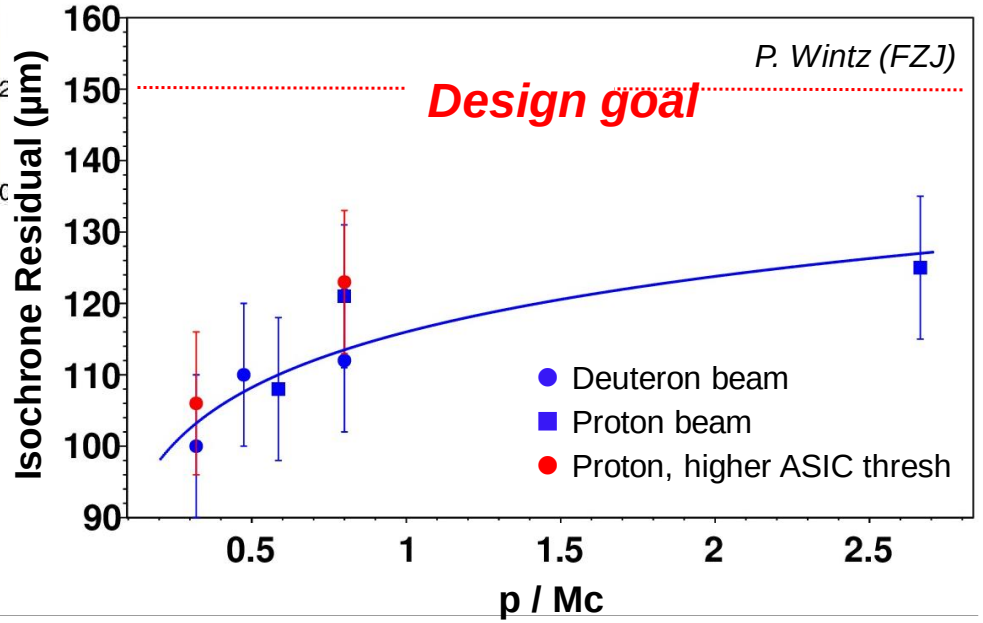
Track Reconstruction and Isochrone Resolution for Ar/CO2(20%)







PANDA-STT test setup in-beam at COSY



Summary of BM for PANDA-STT

Straw system performance

- Pre-commissioning by ^{90}Sr and ^{55}Fe data-taking reliable
- PANDA-straw stable operation under experiment conditions
- high particle rates and four weeks beam time period

PASTTREC QA procedures established and verified

- Continuous PASTTREC setting verification during data-taking established
- PASTTREC high rate capability confirmed, e.g. BL stability

Calibration method and procedures developed

- Isochrone calibration using time spectra done
- Calibration step using reco tracks soon

PANDA-STT issues:

- Time offset and time-of-flight for continuous HW-trigger-less readout
- Maybe useful for specific tests: cosmic HW trigger, B=0 tracking mode in PANDA-SW

Thank you

for

your

attention