THE NEW FORWARD TRACKER SYSTEM FOR THE HADES FAIR PHASE-0 EXPERIMENT

FAIRNESS 2022

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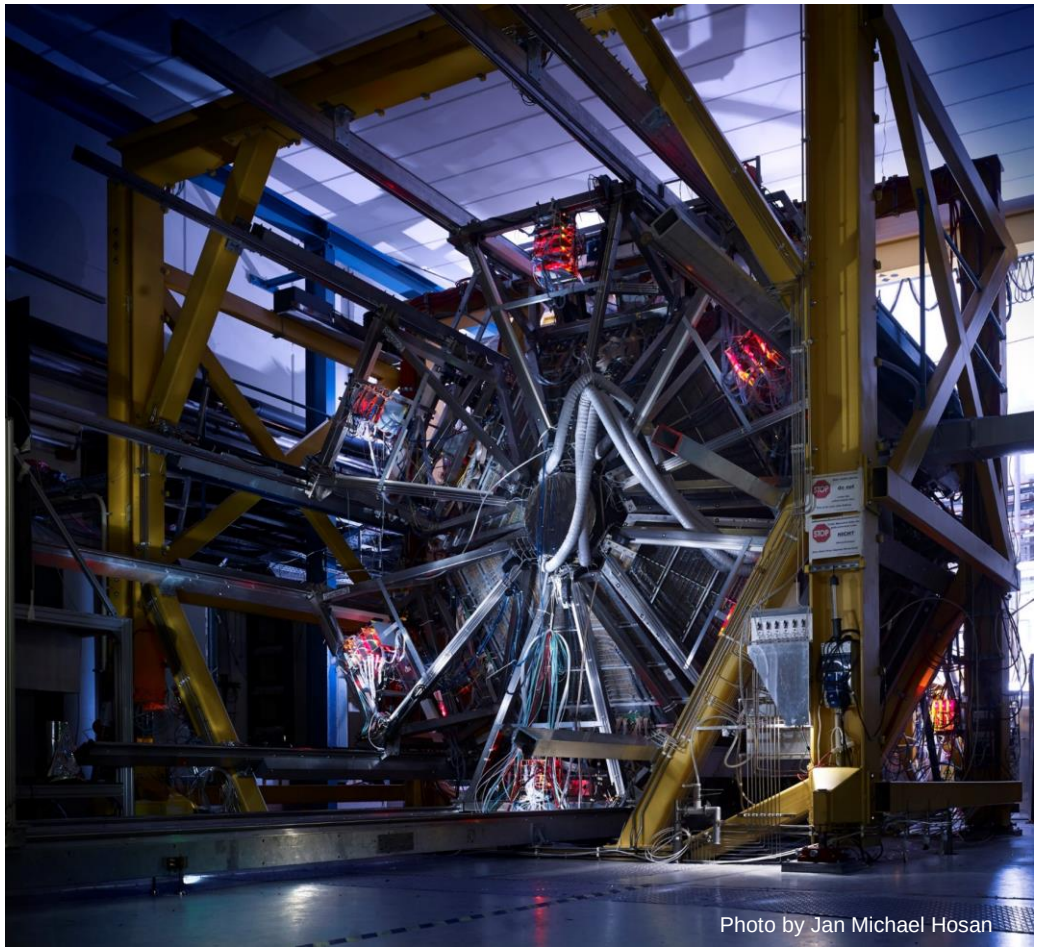
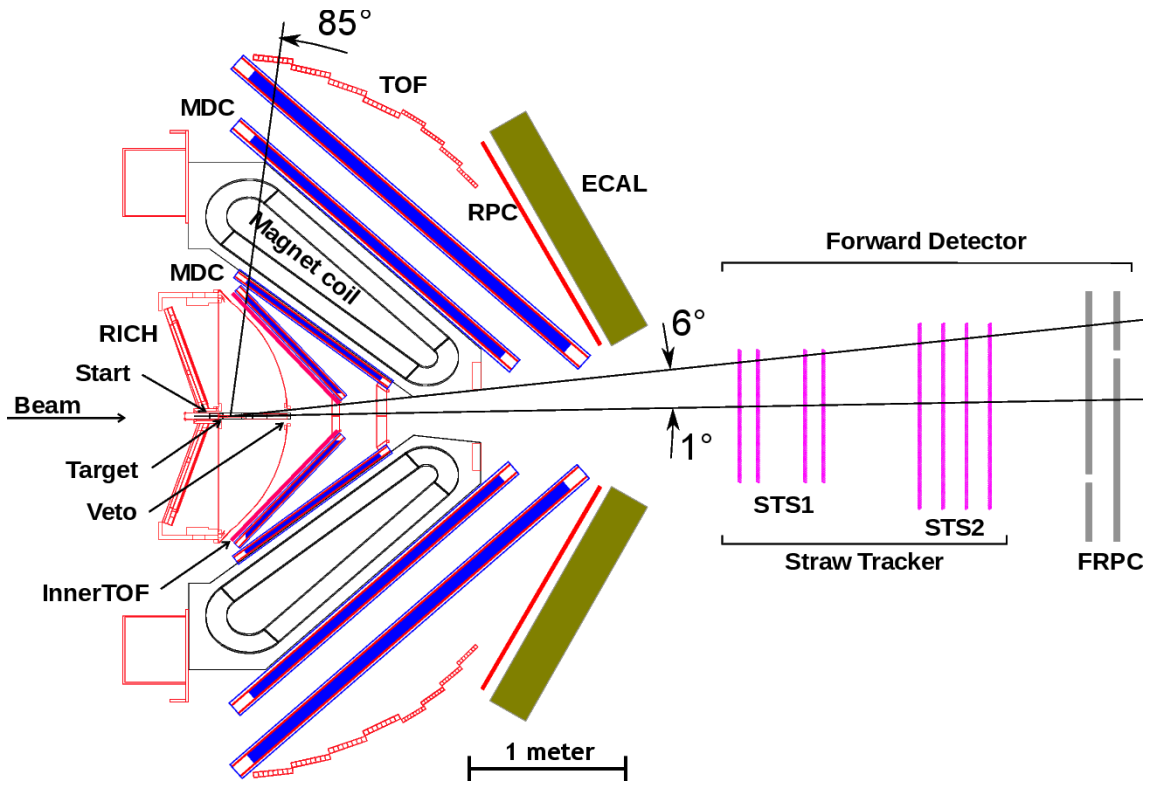
Overview

- HADES
- The STS detector
- FAIR Phase-0 STS@HADES
- STS Calibration
- Summary



The High Acceptance Di-Electron Spectrometer

Designed to measure charged **hadrons**, **leptons** and **photons** produced at few GeV in proton, secondary pion and heavy ion induced reactions on a fixed target (proton or nuclear).



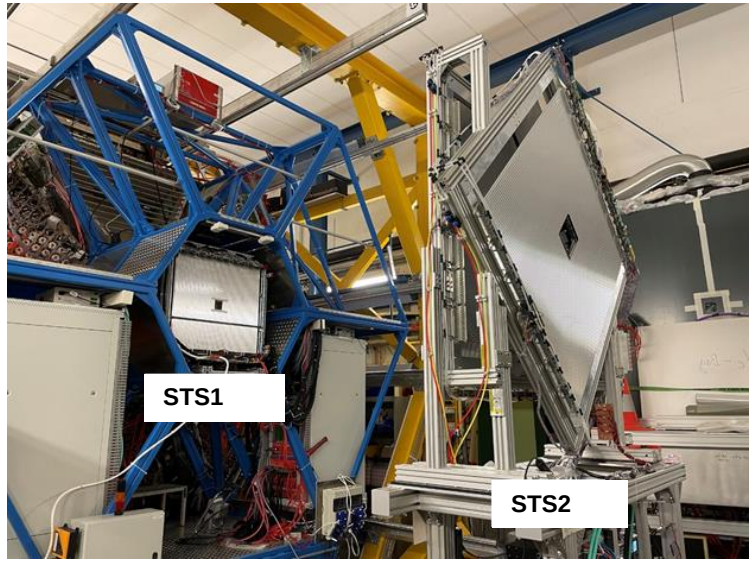
Schematic overview of the HADES spectrometer, including the newly added FD components.

Upgrade for FAIR Phase-0:

- Upgraded RICH and START detectors
- New ECAL and Inner TOF detectors
- **New Forward Detector (FD):**
  - **Straw tracker stations STS1, STS2 (low material budget)**
  - **Forward Resistive Plate Chamber (FRPC)**
  - **Angular acceptance extended to polar angles in the range 1 ° < θ < 6°**
  - **No magnetic field**
- Upgrade of DAQ system

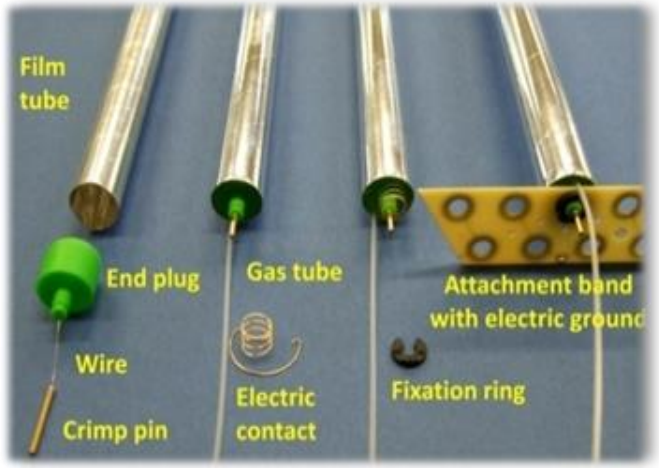
STS detector system

- Two stations (STS1/2) each consisting of four double layers of self-supporting gas-filled straws
- Straws design for STS1/2 (originally developed for PANDA):
  - 10 mm diameter, 27µm thin Al-Mylar walls with a 20 µm diameter W/Re wire along axis.
- Gas mixture: Ar/CO_2 (90/10) @ 2 bar
- STS default settings: HV = 1700 V, Gas gain factor = 4 mV/fC
- Front-end electronics(PASTTREC FE-boards), TRB3 readout, common DAQ STS1/2

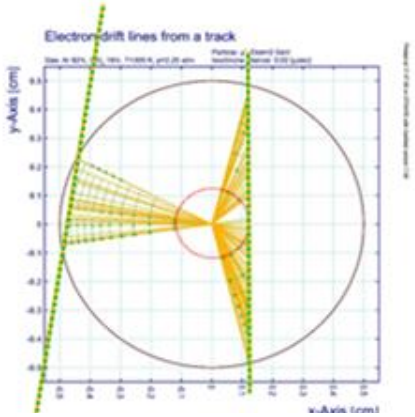


Photograph of installed STS system (not final positions)

Station	STS1	STS2
No. Straws	704	1024
Straw length	76 cm	125 cm
Orientation (azimuthal)	0º, 90º, 90º, 0º	0º, 90º, 45º, -45º
Beam opening	8 x 8 cm^2	16 x 16 cm^2
Distance to target	3.341 m (STS1.1)	4.910 m (STS2.1)



Photograph of straw components



Drift path of electrons from the particle's path to the anode wire

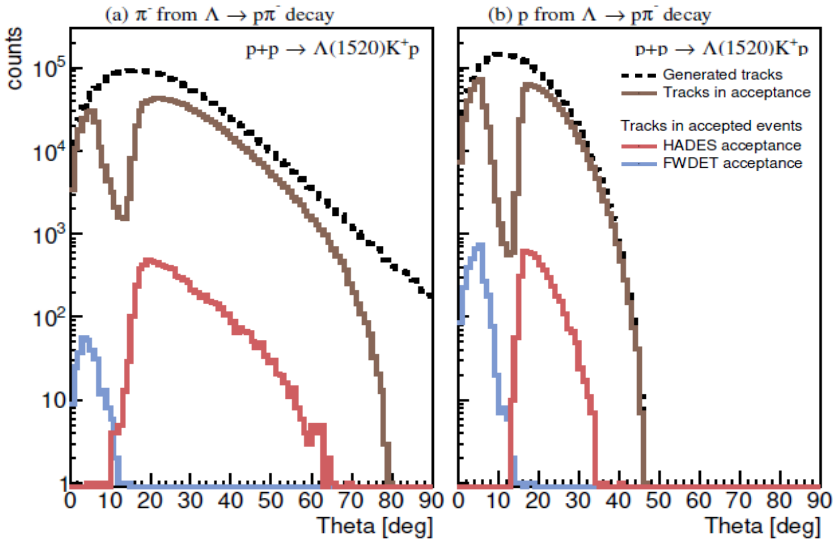
Detection method

- Charged particles traversing straws ionize gas molecules.
- Voltage difference between tube and wire: e^- drift towards wire
- Shortest distance from particle track to wire provided by earliest e^- to arrive.
- Drift time and charge readout by time over threshold used for tracking

FAIR Phase-0 STS@HADES

- HADES hyperon physics program at SIS18:
  - Hyperon radiative decays.
  - Multi-strangeness production.
- Daughter baryon from hyperon decay strongly forward peaked in the lab frame:
  - **FD crucial for hyperon reconstruction**

41% of the protons from Λ(1520) decays are within the FD acceptance

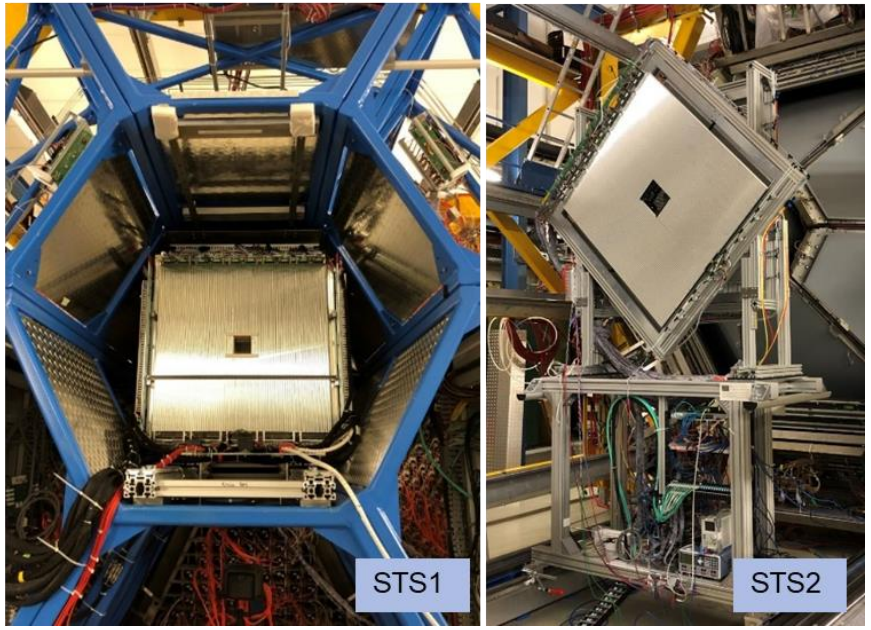


Polar angle distribution of the (a) pions and (b) protons emitted from Λ(1520) decay following the pp→pK+Λ(1520) reaction [1]

- Synergies between HADES and PANDA straw systems:
  - Straws design, front-end electronics(PASTTREC FE-boards), TRB readout, DAQ
  - Straw system tests under experiment conditions
  - STS will become part of the PANDA-FT

- Dedicated commissioning beamtime in February 2021:
  - SIS18 proton beam (2 and 4.2 GeV kinetic energy)

- HADES Production run in February/March 2022:
  - SIS18 proton beam (4.5 GeV kinetic energy)
  - 4 weeks beam on target



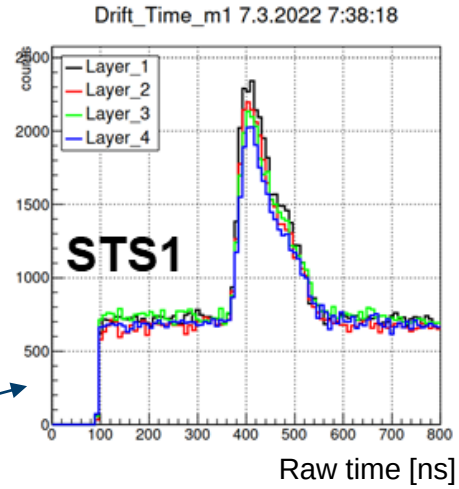
Straw Tracking Stations (coll. With PANDA@FAIR) σ(r) ~ 150 µm

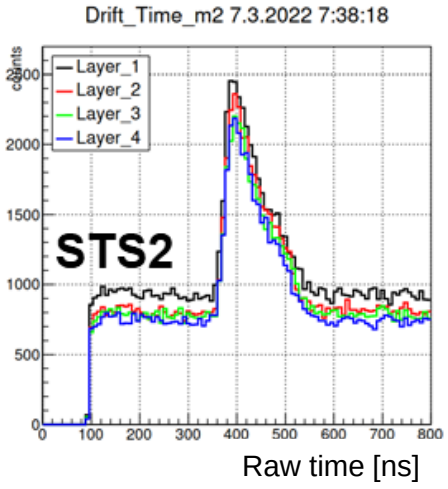
[1] Adamczewski-Musch, J., *et al*. "Production and electromagnetic decay of hyperons: a feasibility study with HADES as a phase-0 experiment at FAIR." *The European Physical Journal A* 57.4 (2021): 1-21.

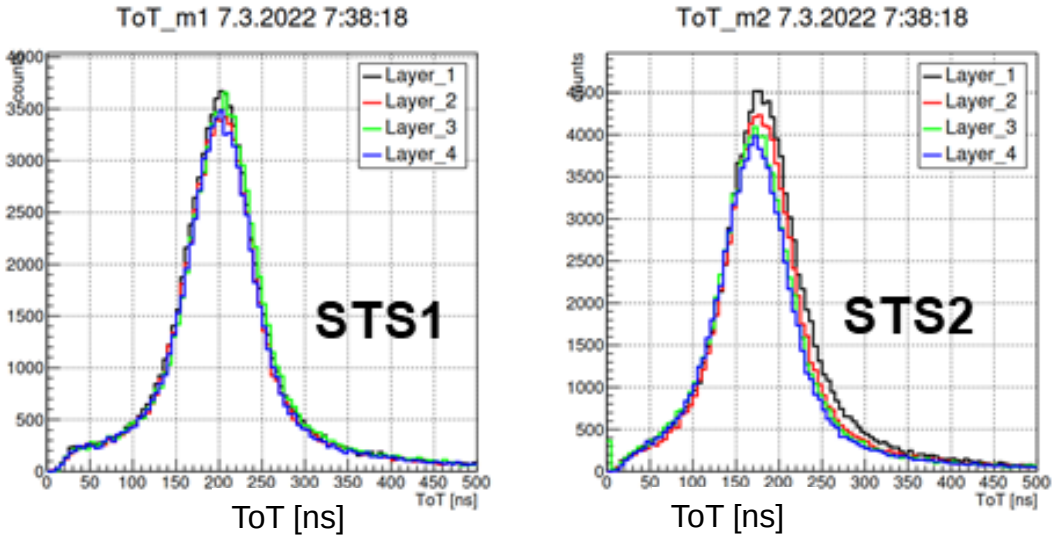
STS@Feb 2022 beamtime

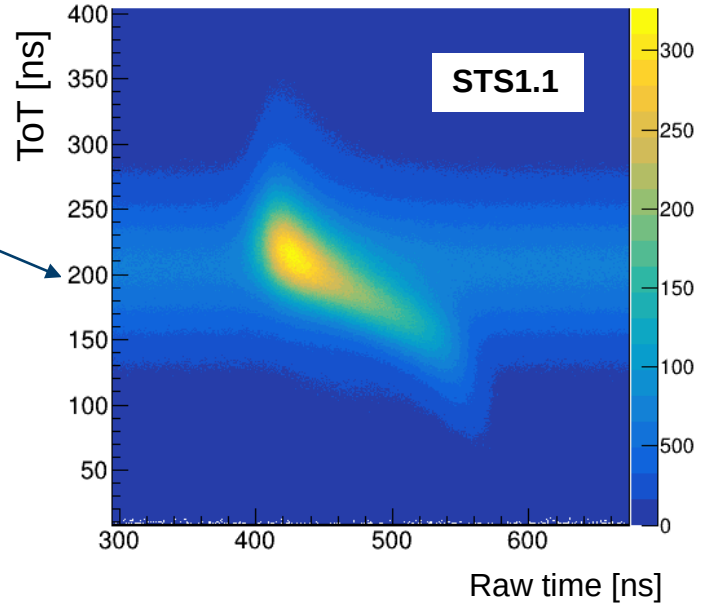
- No HV failure over 4 weeks of beamtime
- Stable operation: **no changes in HV needed**
- Single straw rates up to 2 x 10^5 p/s per straw
- Raw data: TDC time (drift time) and Time over Threshold (signal width)
- Clean ToT spectra: all channels aligned, no noise
- Particle background over full TDC time window

Online QA









Online QA

STS Calibration

Raw STS TDC time:

TDC time = t_0 + *time offset* + ToF_i + *drift time*

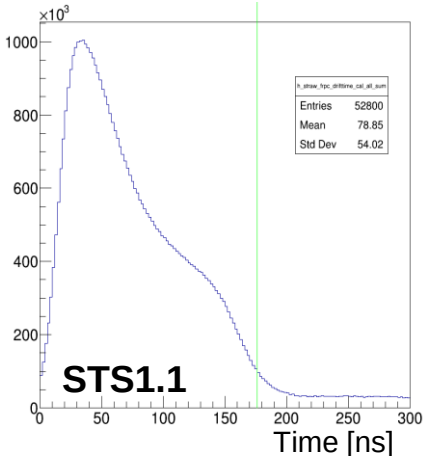
- t_0 , reference time measured by start detector
- *time offset,* caused by *e.g.* electronics
- ToF_i , time-of-flight to STS station i, derived from particle time of flight measurement by fRPC.

Calibrated time: *drift time = TDC time - t_0 - time offset – ToF_i*

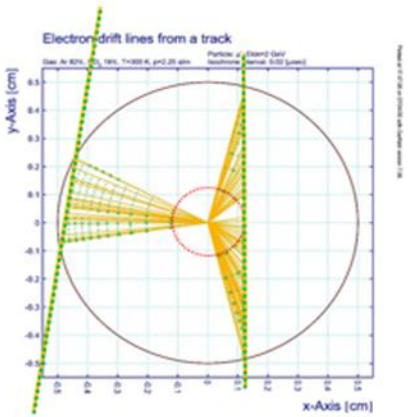
Calibration steps:

- Start time correction for each event
- Time offset determination for each channel
- Drift times obtained by subtracting channel-specific time offset
- T_{max} determination from TDC time spectra
- Space – drift time relation: Isochrone parametrization
  - Running integral over time spectra
  - Homogenous straw illumination assumption

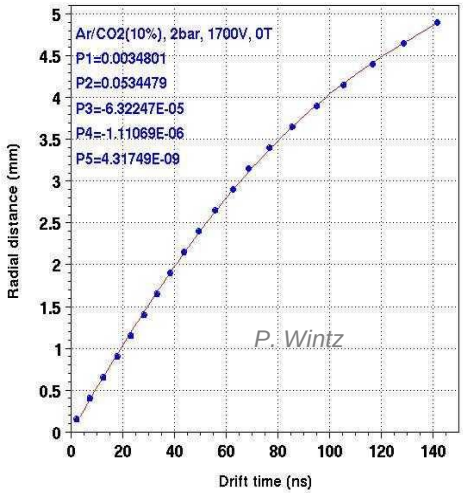
- First calibration done without ToF_i correction (mainly proton tracks, p ~ 4.5 GeV/c)



Typical straw drift time spectra

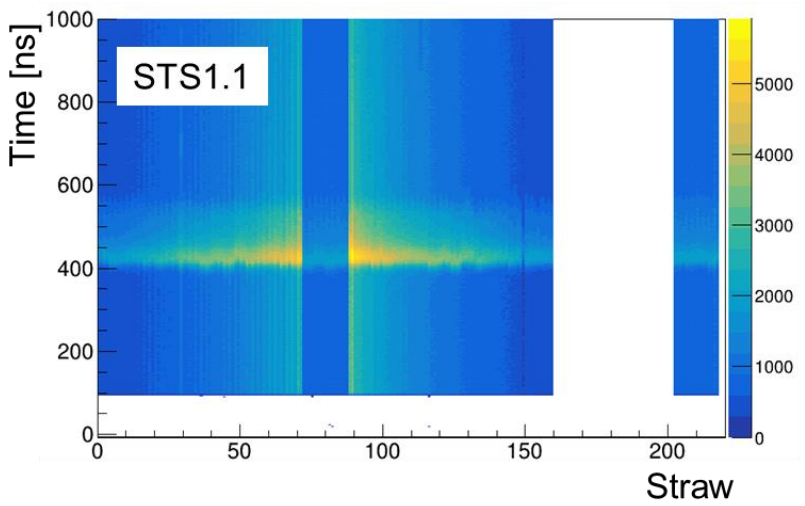


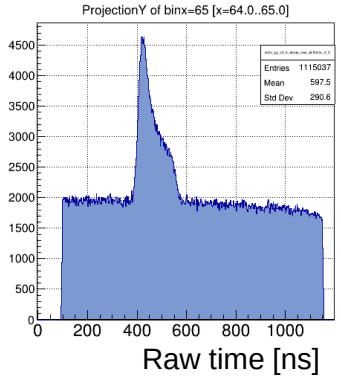
Drift path of electrons from the particle's path to the anode wire



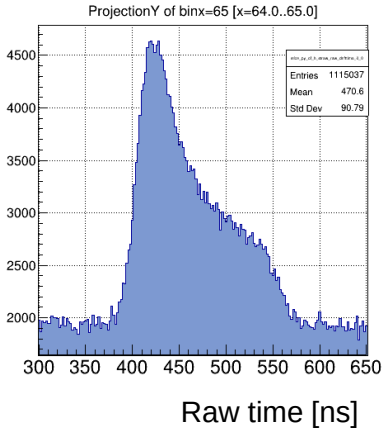
Isochrone parametrization from simulation

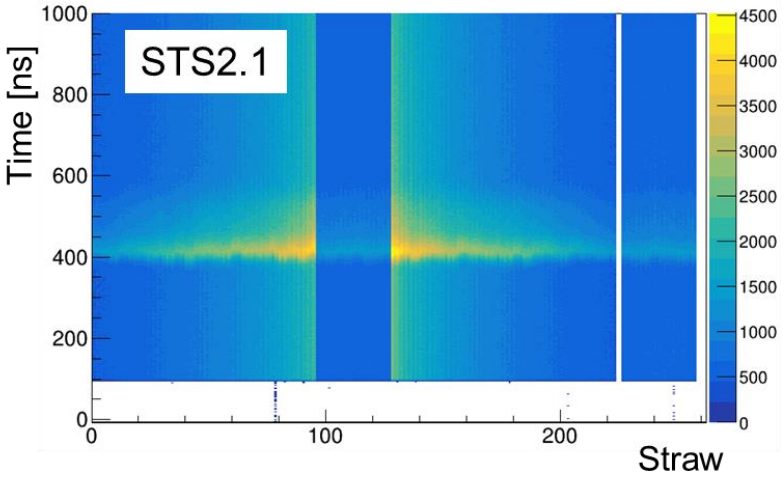
Raw TDC time

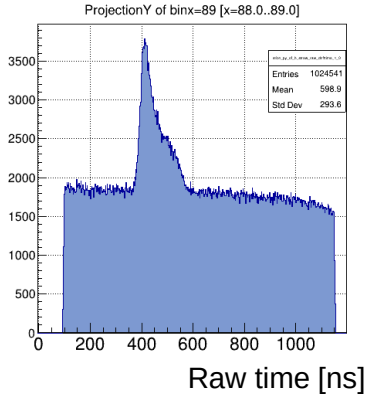




Zoom







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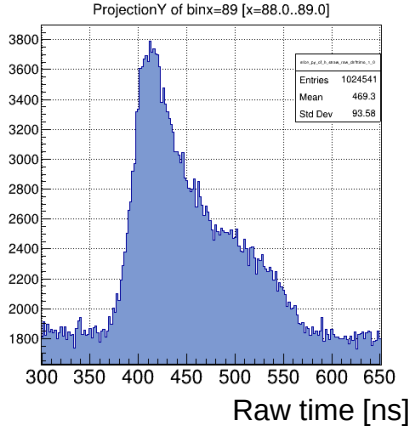
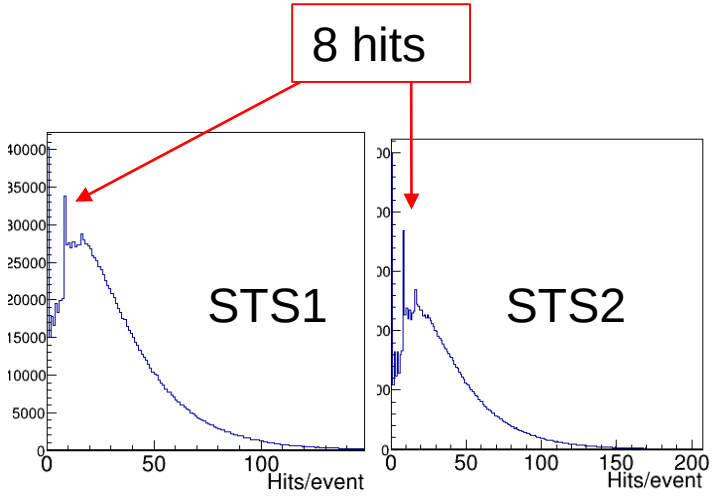
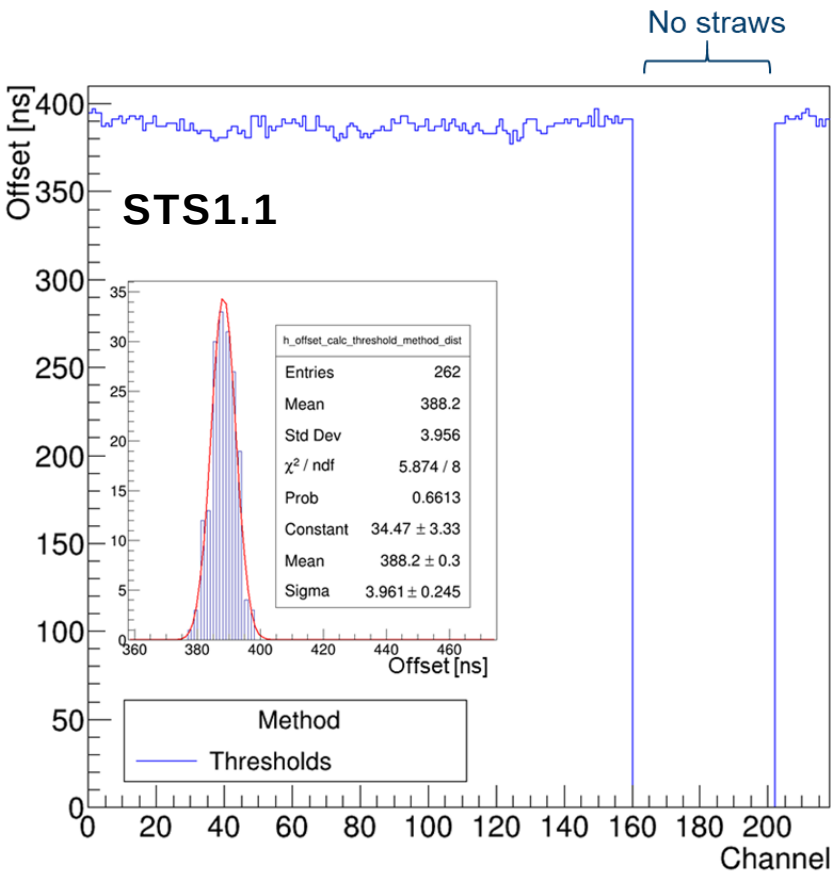
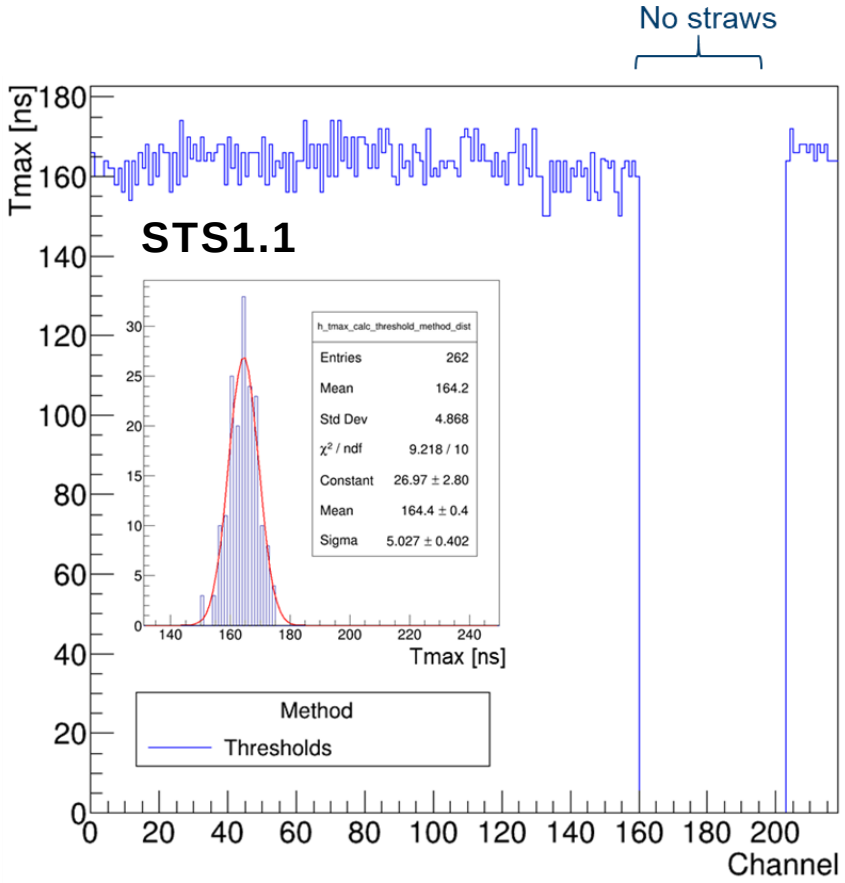


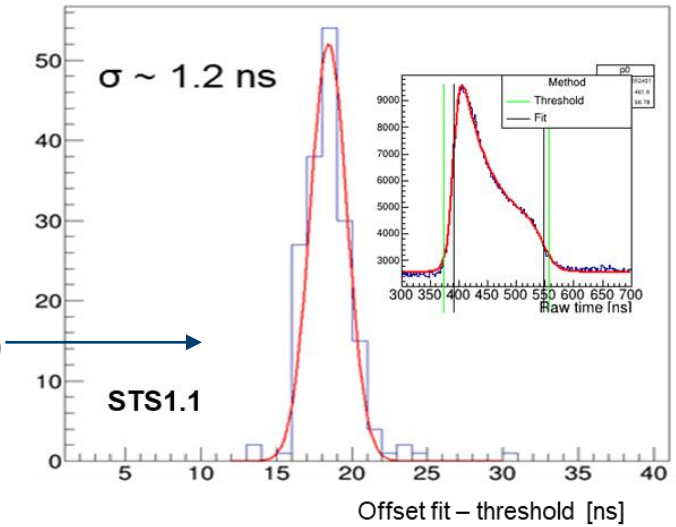


Offset and Tmax determination

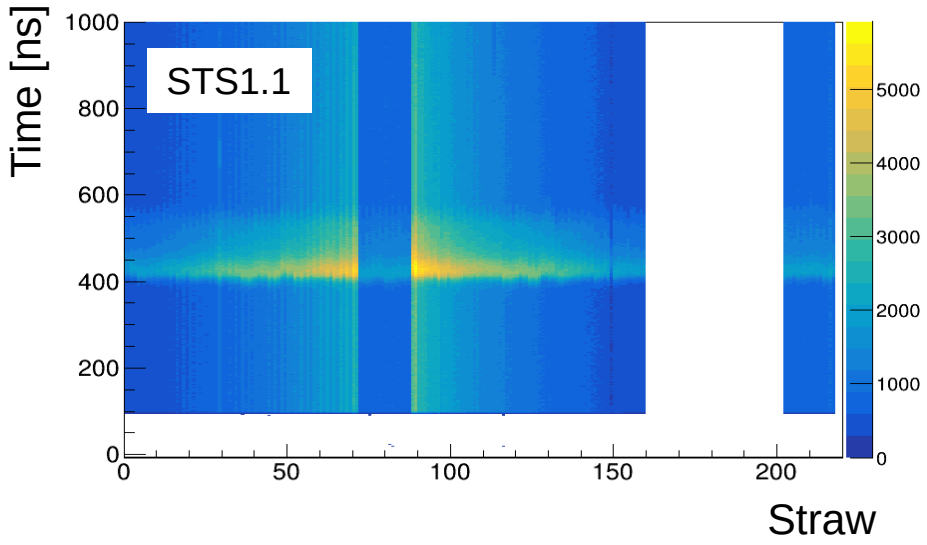


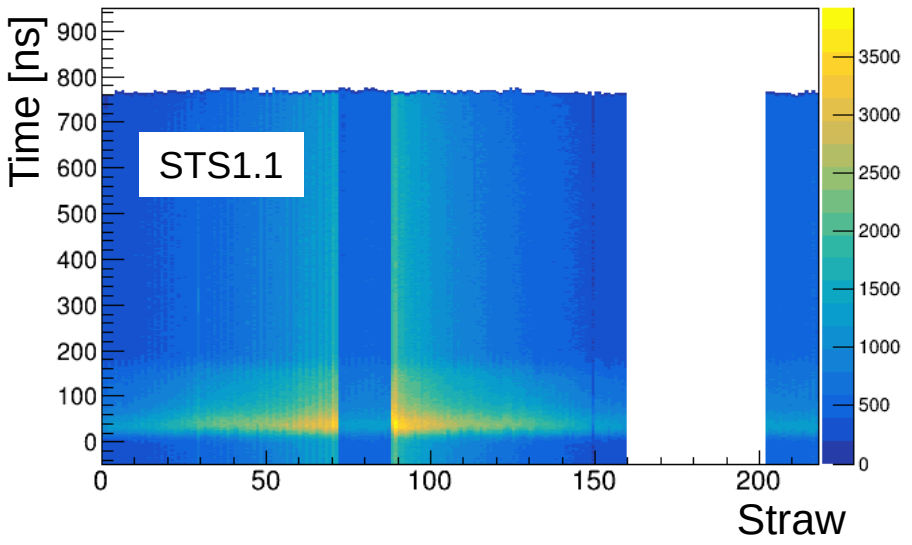


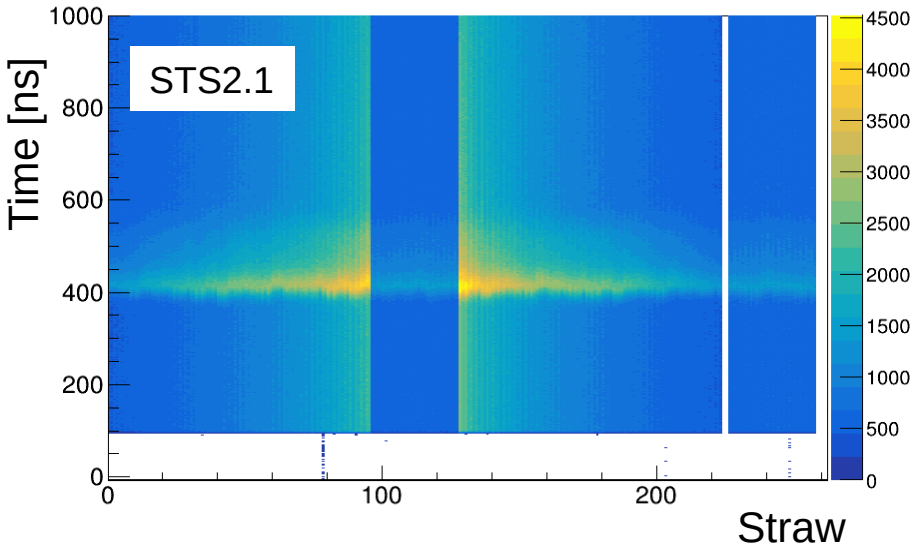
- Mean value: $\mu_{offset} = 388\,ns$, $\mu_{Tmax} = 164\,ns$
- Sigma: $\sigma_{offset} = 4\,ns$, $\sigma_{Tmax} = 5\,ns$
- Channel-specific offset determination/correction
- Systematic variations consistently seen in two offset determination methods (threshold crossing, edge fitting)
- Precision of time offset determination : σ ≤ 1.5 ns
- Most channels show typical drift time shape and range

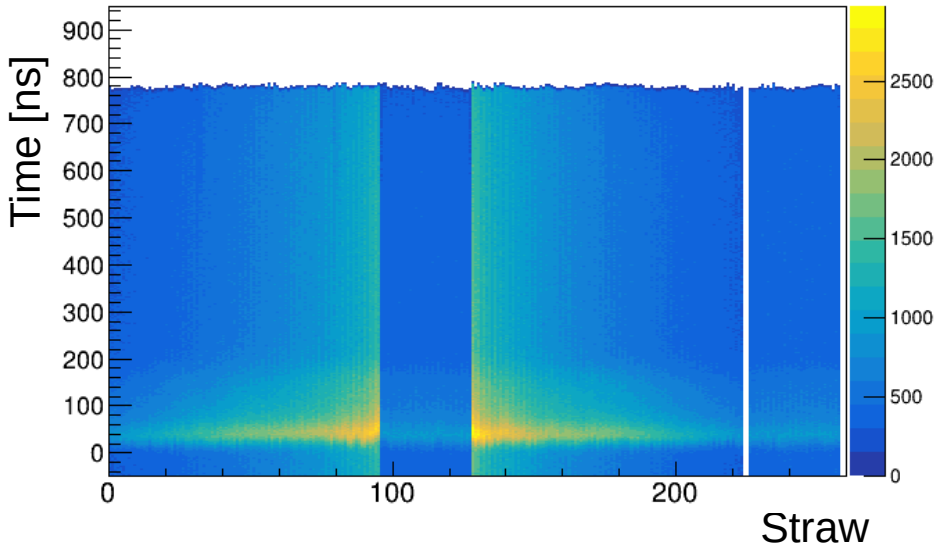


Offset correction: before and after





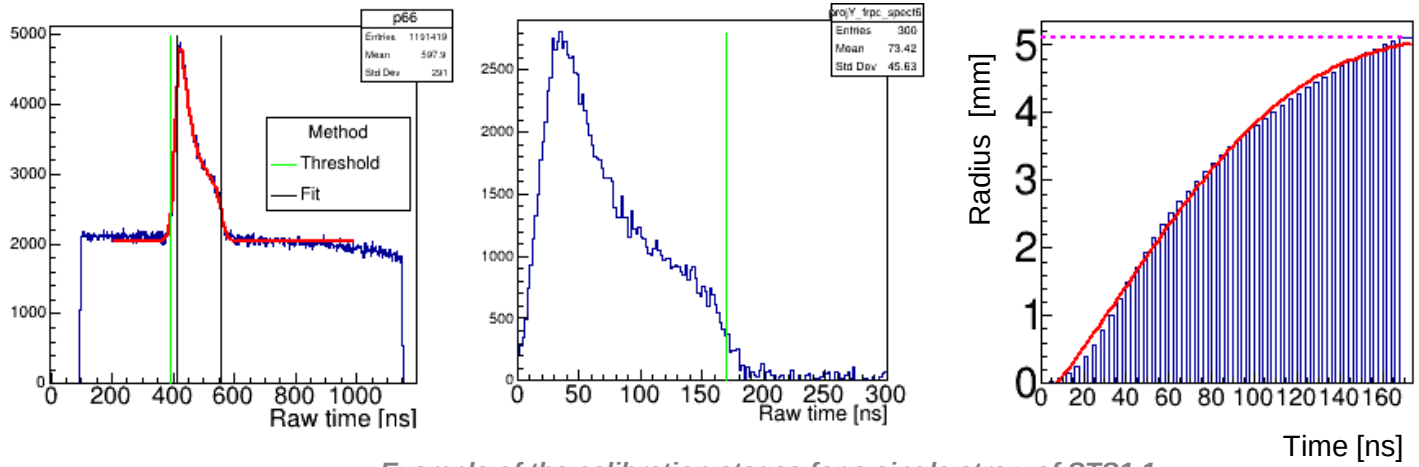




Isochrone parametrization

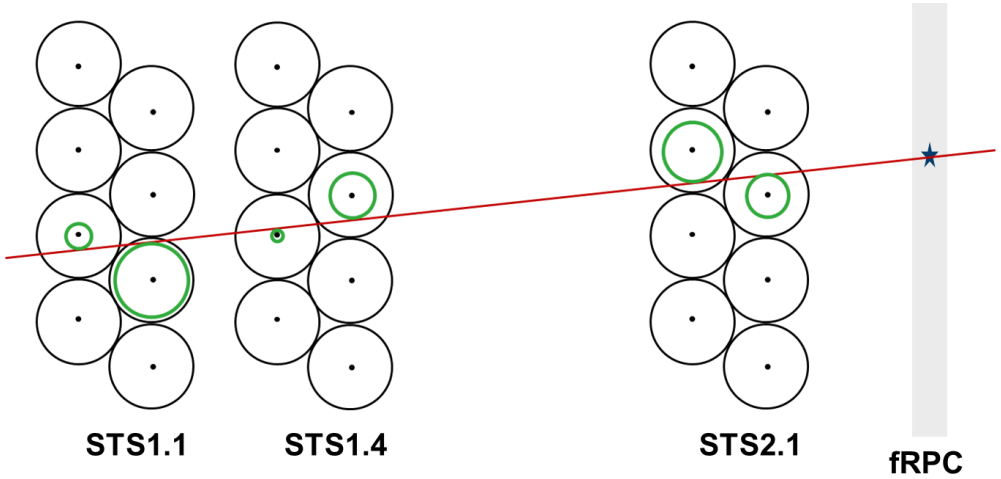
1. Offset correction calculated and applied
2. Calculate time-distance equivalence :

- $R(t) = \left(\frac{\sum_{i=0}^{i_t} N_i}{N}\right) \times (\mathrm{R}_{max} - \mathrm{R}_{\min}) + \mathrm{R}_{min}$
- $\mathrm{R}_{\max} = 5.1\ \mathrm{mm}$
- $\mathrm{R}_{\min} = 0.1\ \mathrm{mm}$
- Pol4 fit describes the r(t) relation.
  - E.g. (-0.24874) + (0.03077)*t + (0.00038926)*t^2 + (-3.6833e-06)*t^3 + (8.2491e-09)t^4
  - Single isochrone parametrization/double layer: (1728 x 5) parameters



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

- Parametrization limits defined to account for smearing effects close to the wire and close to the straw walls.



Scheme of the track reconstruction using the isochrones obtained within an event

Summary

- Upgrade of the HADES spectrometer and data-acquisition systems for the FAIR Phase-0

- The new FD components are crucial for hyperon reconstruction (FAIR Phase-0 physics program)

- STS system was installed in Dec. 2020 and tested during commissioning beamtime in Feb. 2021

- **STS operation was successful during the four week experiment beamtime with the upgraded HADES in February 2022:**
  - High quality data: 41.4 Billion events, 684 TB, 488.25 h

- STS calibration procedure developed and implemented:
  - Single channel offset determination with two different methods show consistent channel-to-channel systematic variations
  - Precision of time offset determination : $\sigma \leq 1.5$ ns
  - Time-distance parametrization curve obtained for each channel
  - Algorithm will be included in the HADES analysis software (Hydra)
  - Calibration parameters to be checked with data from the start, middle and end of the beamtime

THANKS!