STATUS OF STS@HADES

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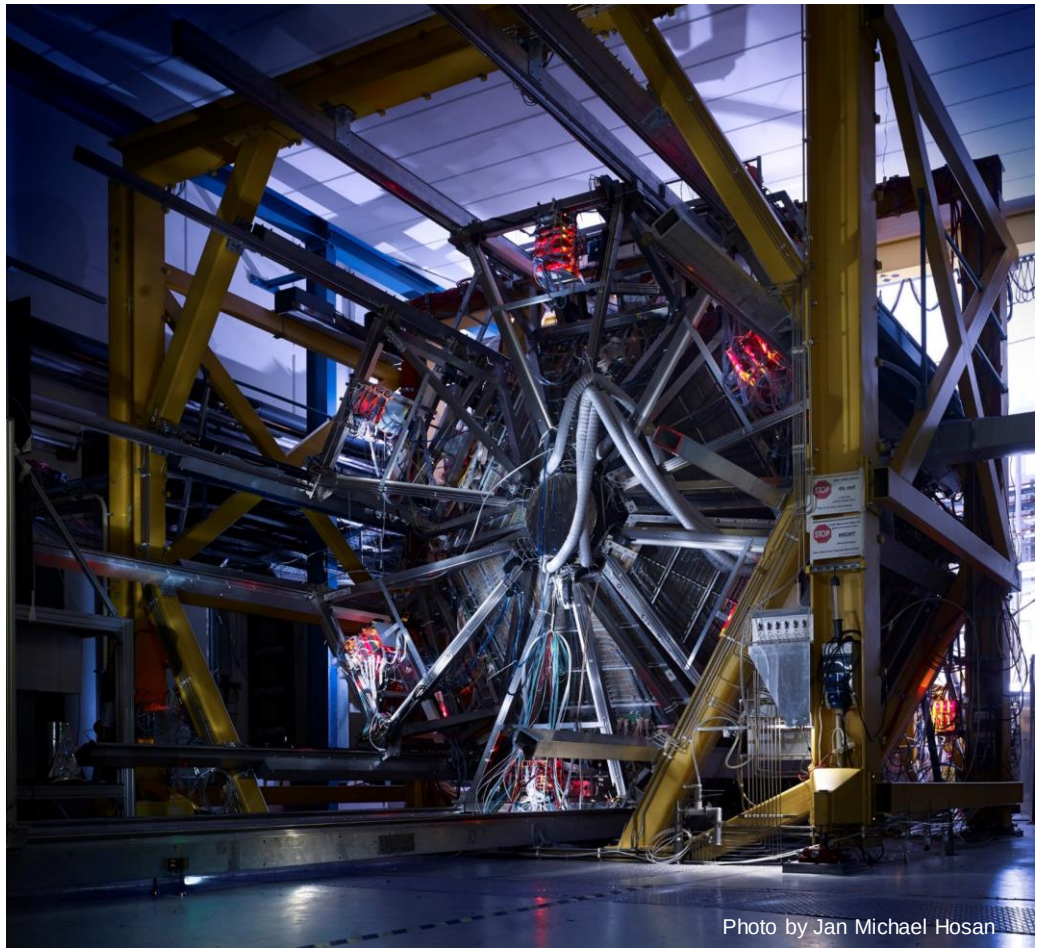
Tracking session
PANDA Collaboration Meeting 2022/1

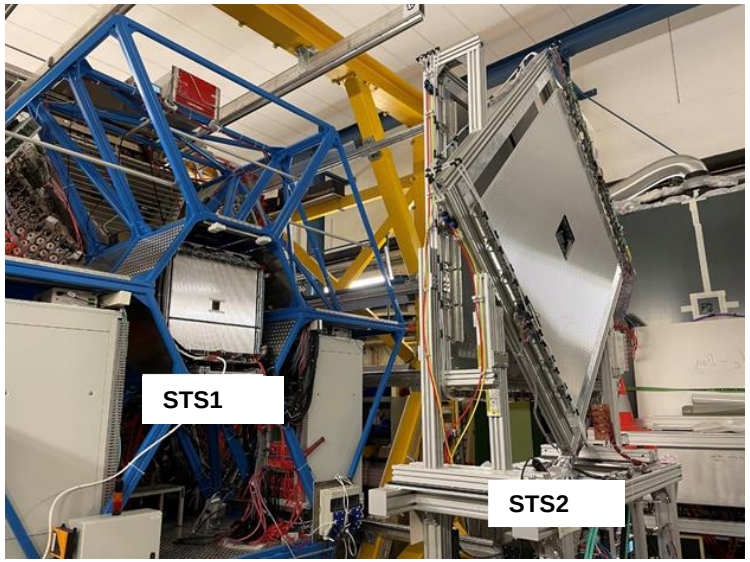
Overview

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

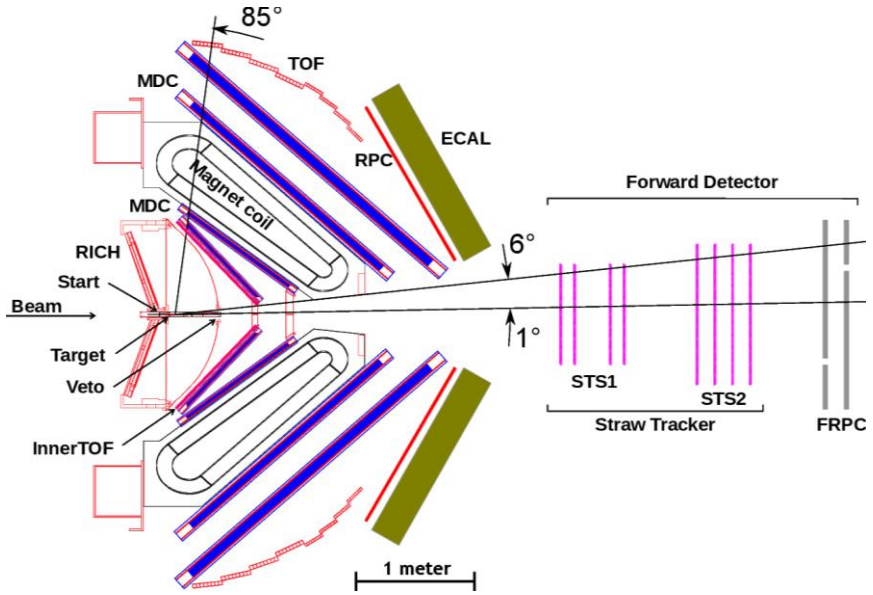


STS detector system

- 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)



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

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)

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**

- 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)

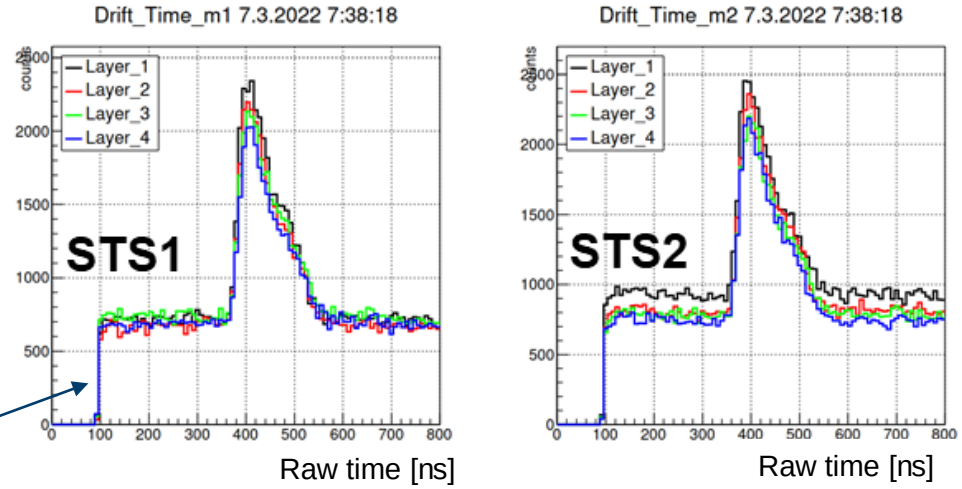
- HADES Production run in February/March 2022:
  - SIS18 proton beam (4.5 GeV kinetic energy)
  - 4 weeks beam on target

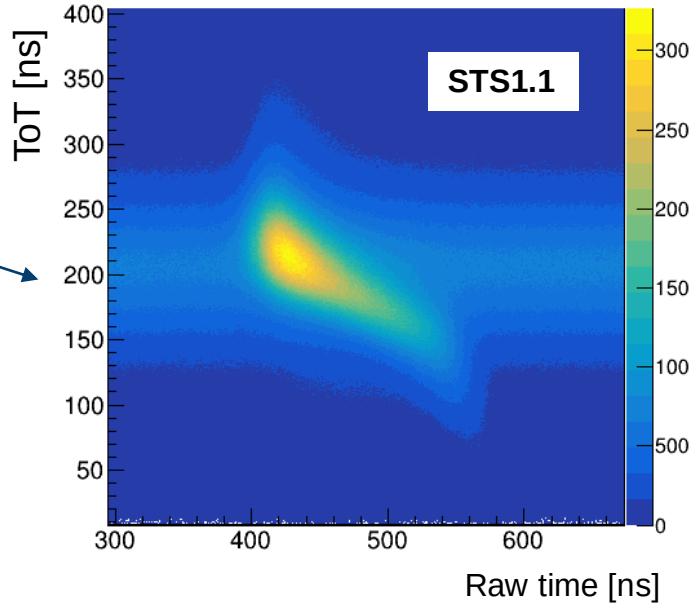
Straw Tracking Stations (coll. With PANDA@FAIR) σ(r) ~ 150 µm

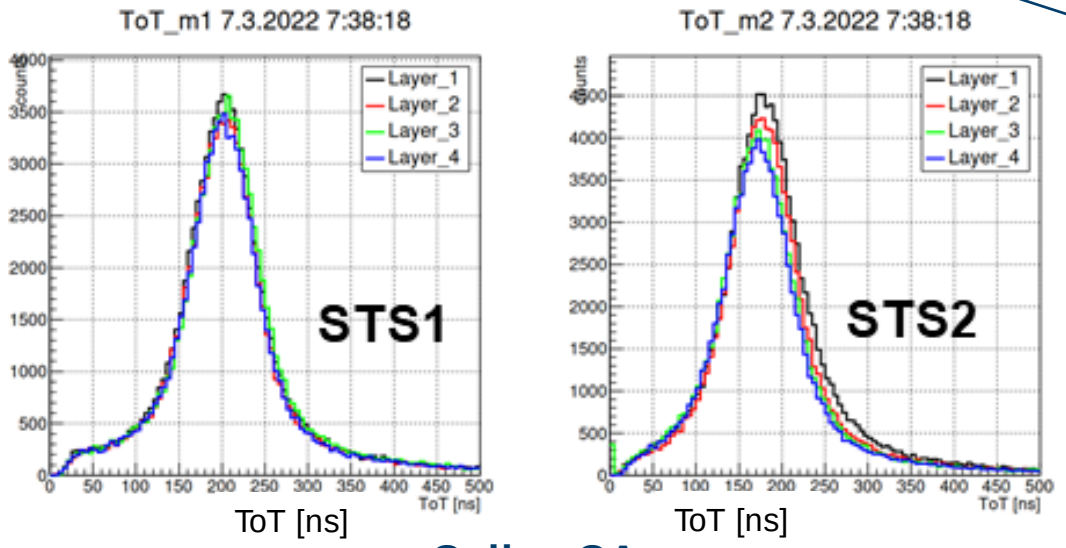
STS@Feb 2022 beamtime

- No HV failure over 4 weeks of beamtime
- Stable operation: **no changes in HV needed**
- Continuous ASIC setting verification (1700ch) during data-taking was set up
- 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*

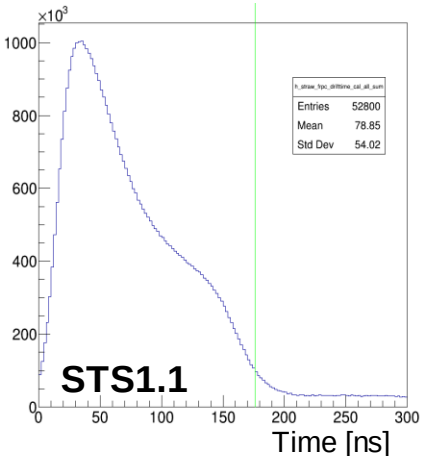
- t_0 , reference time measured by start detector
- *time offset,* caused by *e.g.* electronics
- ToF_i , time-of-flight to STS station i, derived from particle time of flight measurement by fRPC.

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

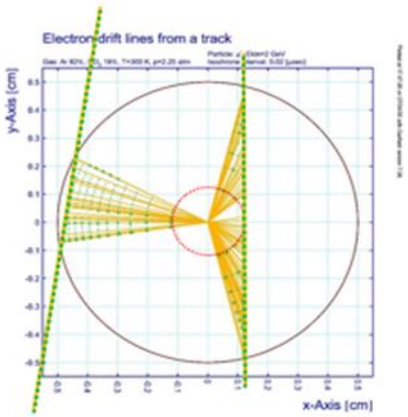
Calibration steps:

- 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

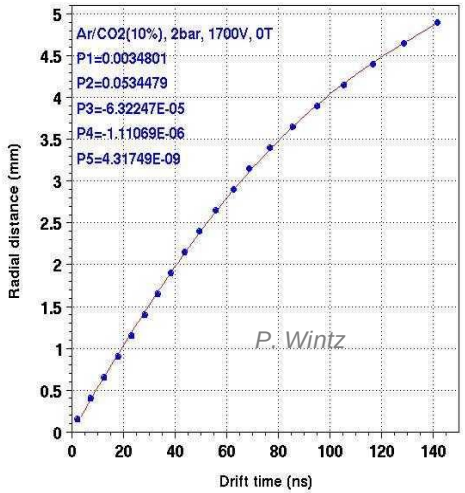
- First calibration done without ToF_i correction (mainly proton tracks, p ~ 4.5 GeV/c)



Typical straw drift time spectra

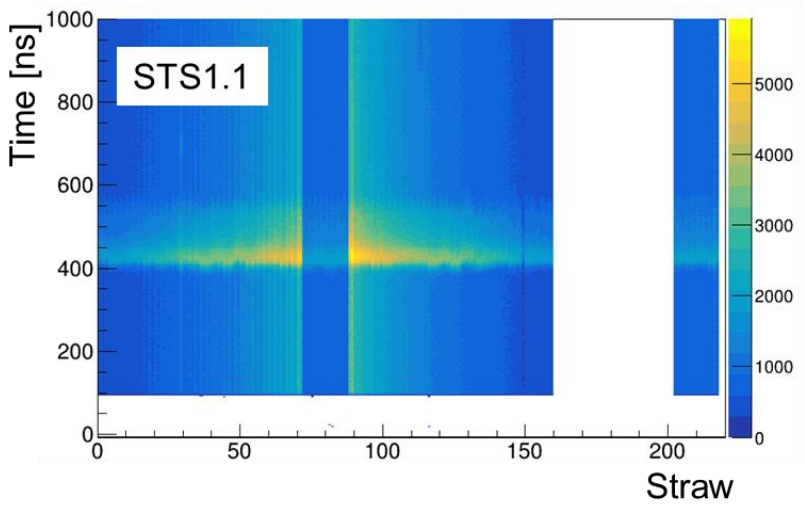


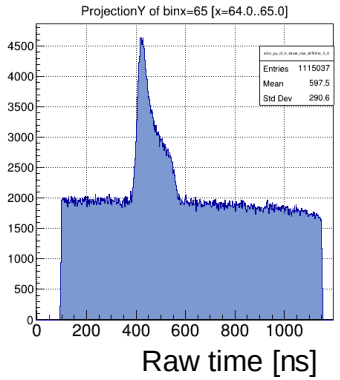
Drift path of electrons from the particle's path to the anode wire



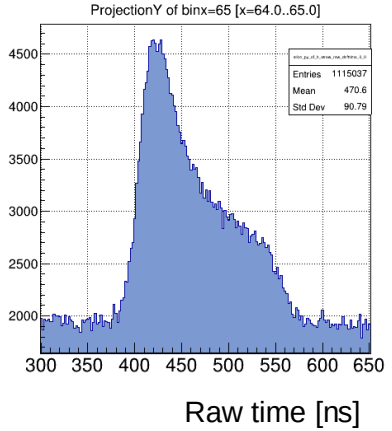
Isochrone parametrization from simulation

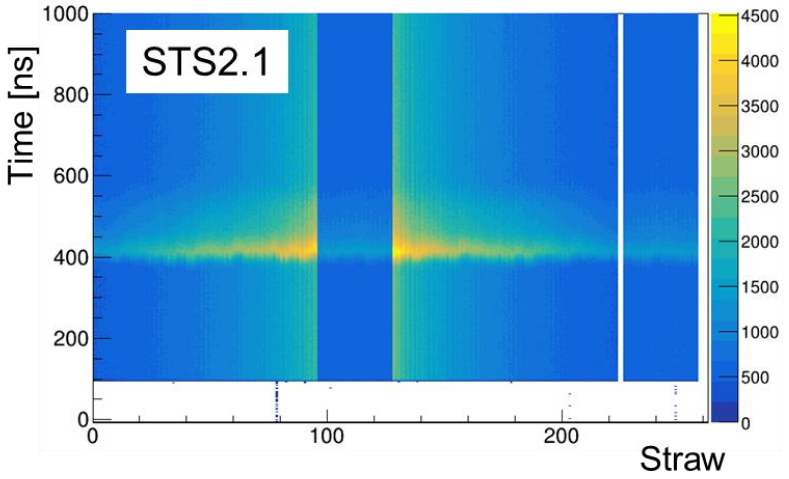
Raw TDC time

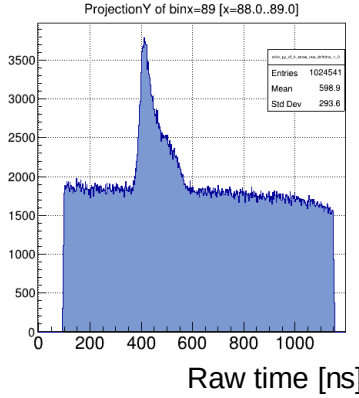




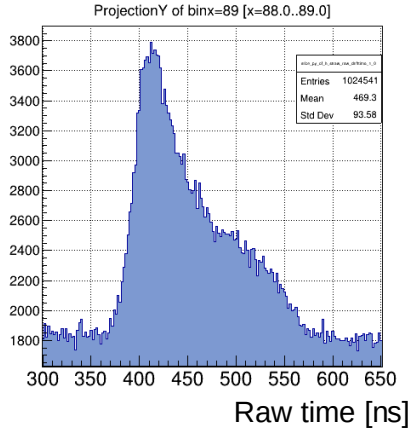
Zoom



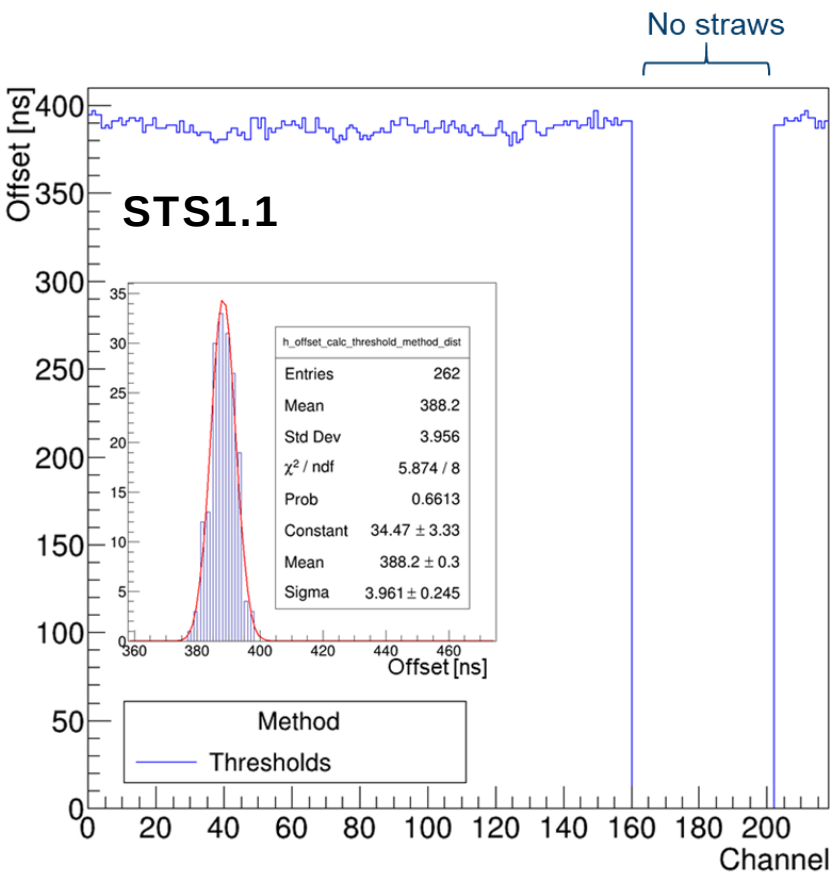


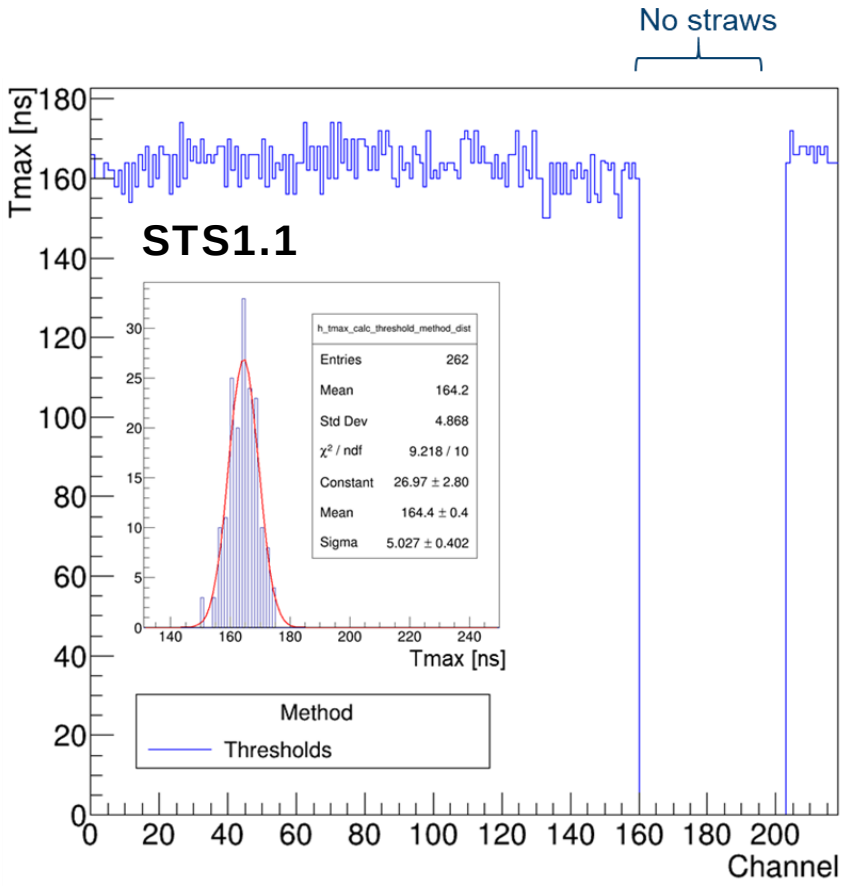


Zoom

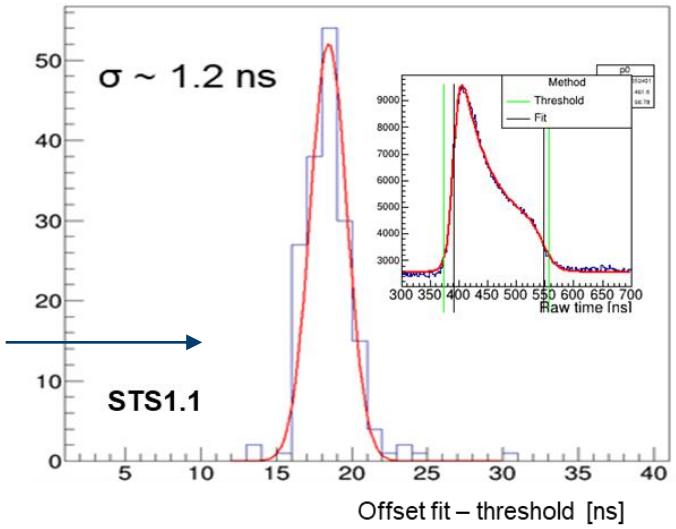


Offset and Tmax determination

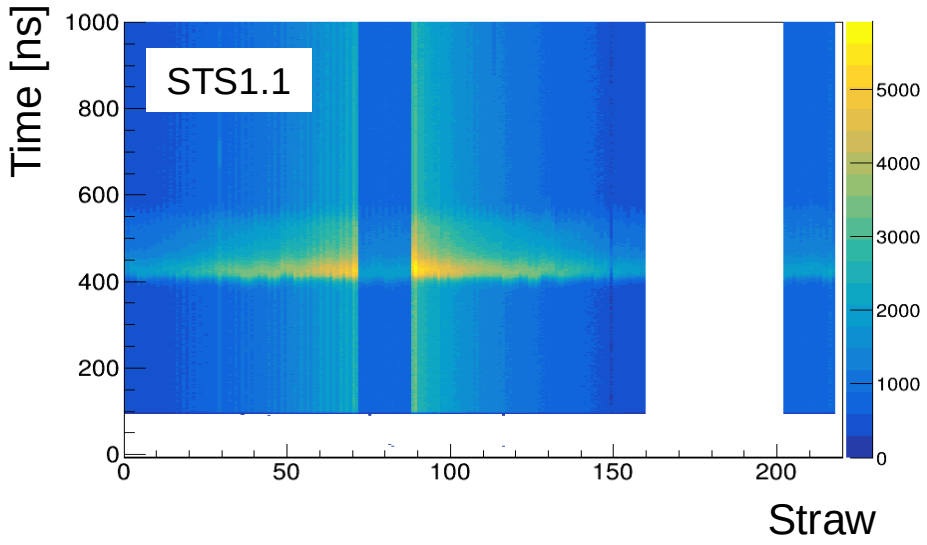


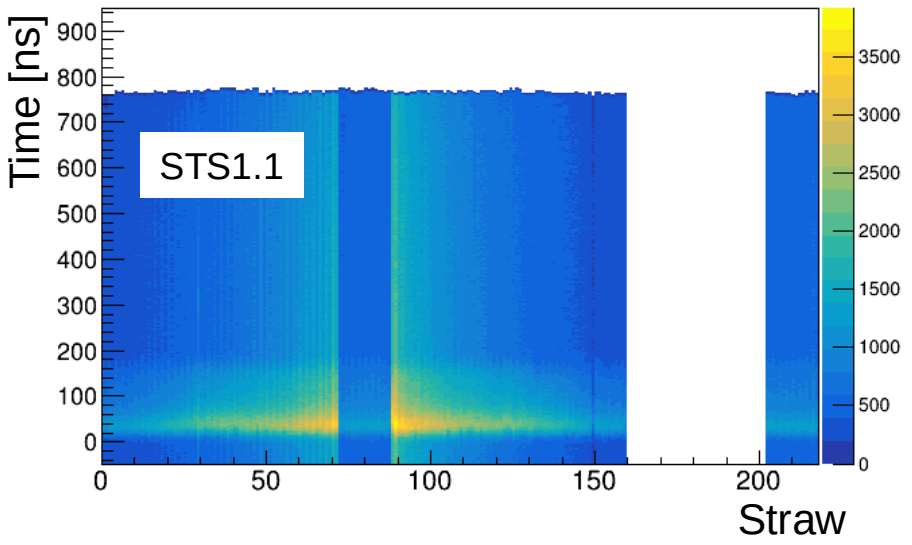


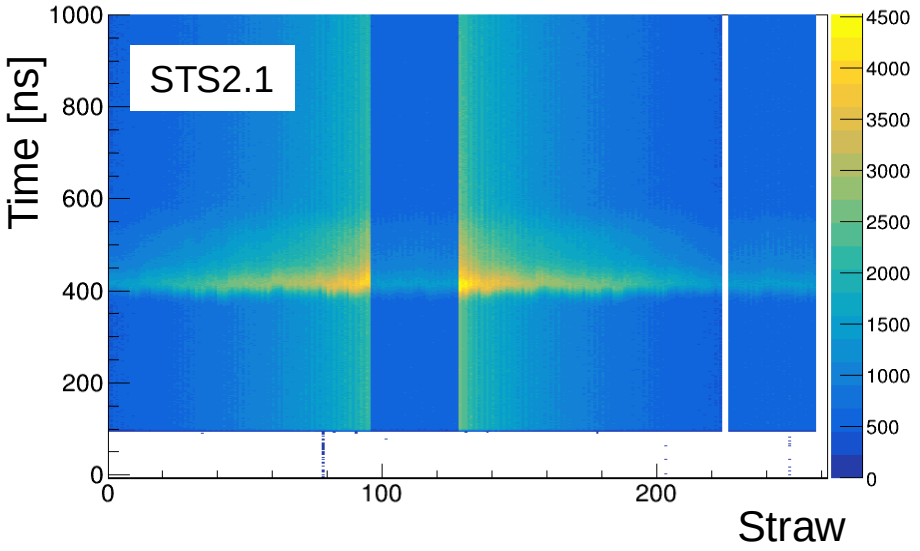
- Mean value: $\mu_{offset} = 388\ ns$, $\mu_{Tmax} = 164\ ns$
- Sigma: $\sigma_{offset} = 4\ ns$, $\sigma_{Tmax} = 5\ ns$
- Channel-specific offset determination/correction
- Systematic variations consistently seen in two offset determination methods (threshold crossing, edge fitting)
- Precision of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

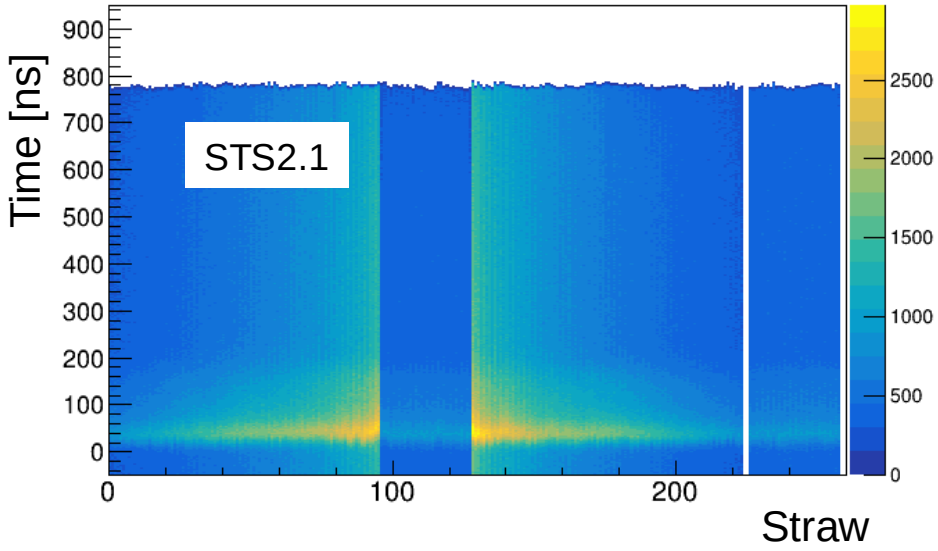


Offset correction: before and after





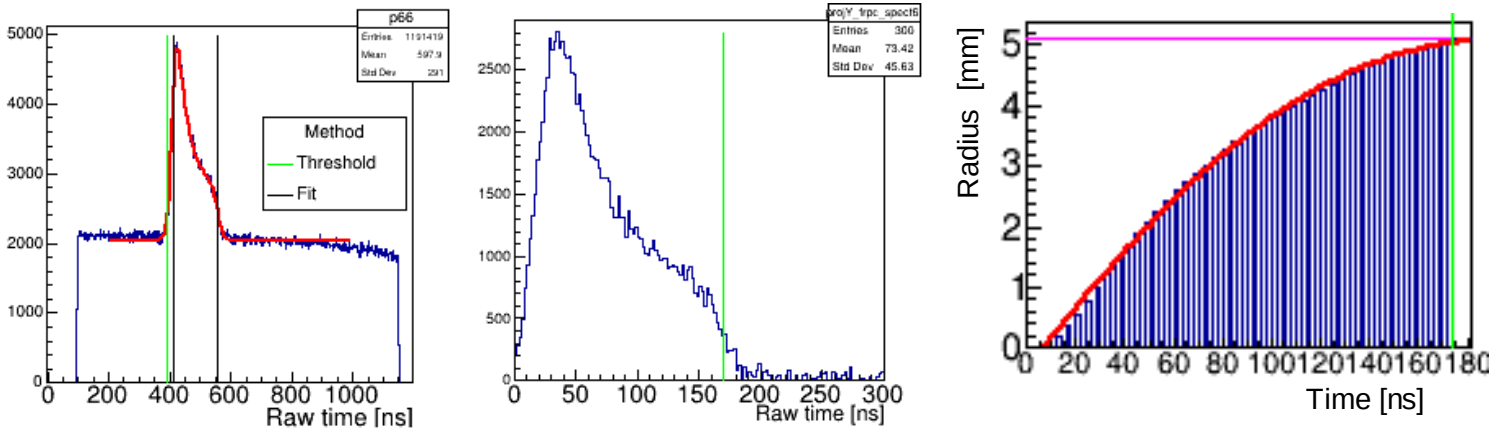




Isochrone parametrization

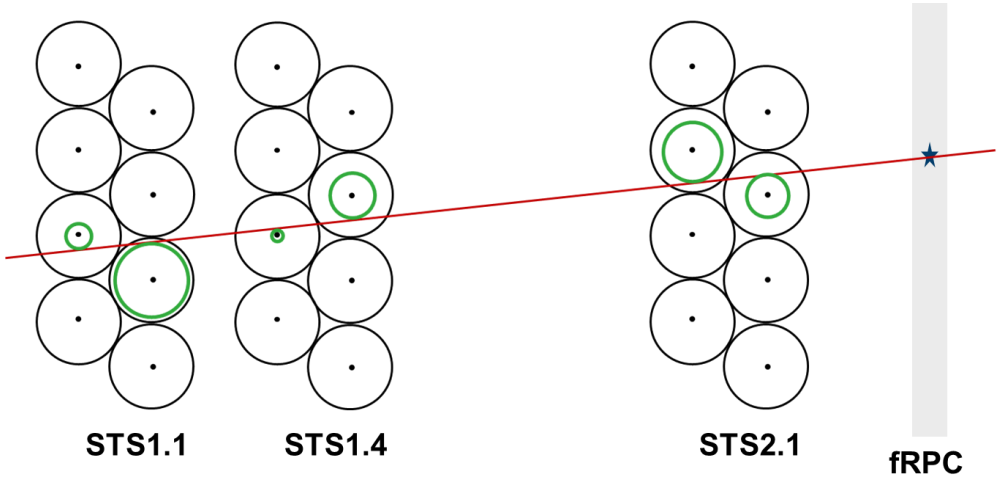
1. Offset correction calculated and applied
2. Calculate time-distance equivalence :

- $R(t) = \left(\frac{\sum_{i=0}^{i_t} N_i}{N}\right) \times (\mathrm{R}_{max} - \mathrm{R}_{\min}) + \mathrm{R}_{min}$
- $\mathrm{R}_{\max} = 5.1\ \mathrm{mm}$
- $\mathrm{R}_{\min} = 0.1\ \mathrm{mm}$
- 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

STS parameter integration

- Preliminary parameters obtained from data collected during day 049 :
  - Testing and validation is ongoing
- Additional calibration parameters connected with ToT and ToF_i to be determined
- Calibration parameters with data collected from different days is in progress

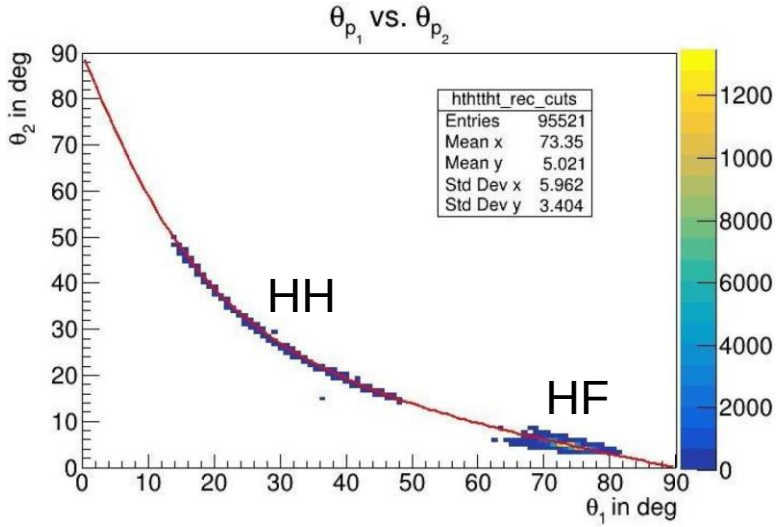
```
################################################################################
# Calibration parameters for the Sts
# Format:
# mod(0...1)  layer(0...3)  straw(0...255)  timeOffset  timeMax  timeSlope   tofRef  isoPar0  isoPar1  isoPar2  isoPar3  isoPar4  totPar0  totPar1
################################################################################
[StsCalPar]
// Parameter Context: StsCalProduction
//--------------------------------------------------------------------------
   0    0    0  381.00000  174.00000    0.00000    0.00000   -0.31564    0.05006 -1.7607e-05 -9.011e-07 2.1009e-09    0.00000    0.00000
   0    0    1    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0    2  381.00000  166.00000    0.00000    0.00000   -0.28914    0.04485 0.00011815 -1.8807e-06  4.253e-09    0.00000    0.00000
   0    0    3    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0    4  379.00000  178.00000    0.00000    0.00000   -0.31551    0.05074 -2.8765e-05 -8.4514e-07 2.0063e-09    0.00000    0.00000
   0    0    5    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0    6  381.00000  166.00000    0.00000    0.00000   -0.28220    0.04872 4.2483e-05 -1.3792e-06 3.1342e-09    0.00000    0.00000
   0    0    7    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0    8  371.00000  176.00000    0.00000    0.00000   -0.31613    0.04874 5.1472e-06 -1.0466e-06 2.4222e-09    0.00000    0.00000
   0    0    9    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0   10  373.00000  166.00000    0.00000    0.00000   -0.29082    0.04334 0.00014249 -2.0324e-06 4.6036e-09    0.00000    0.00000
   0    0   11    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0   12  373.00000  174.00000    0.00000    0.00000   -0.31295    0.05220 -4.8932e-05 -7.445e-07 1.8297e-09    0.00000    0.00000
   0    0   13    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
   0    0   14  375.00000  166.00000    0.00000    0.00000   -0.29019    0.04686 8.5745e-05 -1.7038e-06 3.9262e-09    0.00000    0.00000
   0    0   15    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000           0          0          0    0.00000    0.00000
```

Luminosity Determination (credits to Rafal Lalik, Jana Rieger, Konrad Sumara):

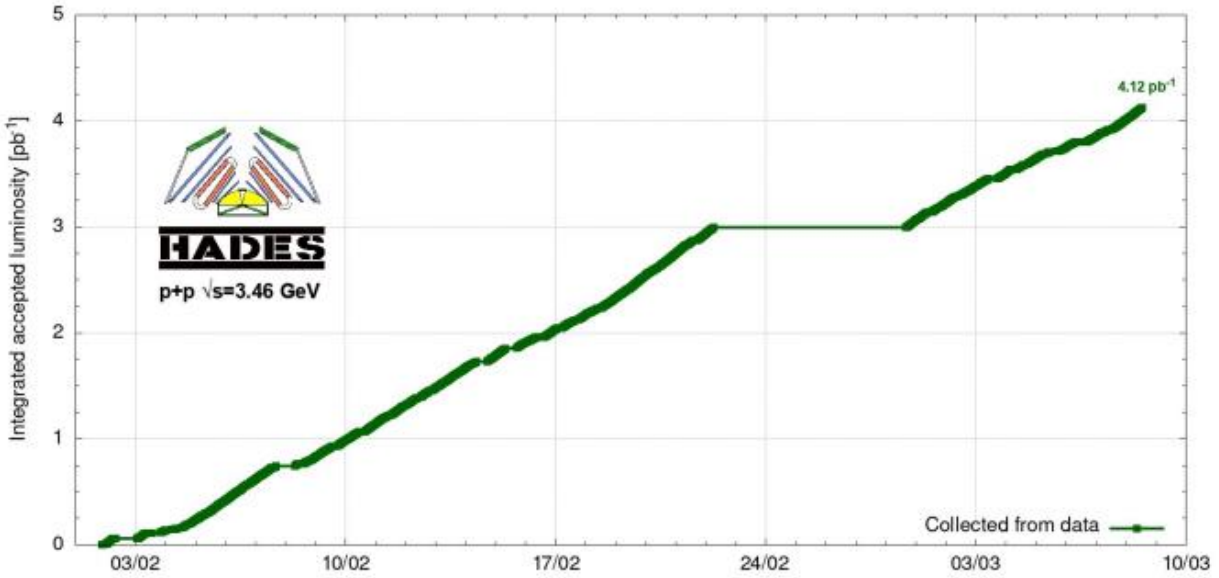
- Online yield of pp elastic scattering events used to determine **total integrated luminosity**:
  - Using preliminary calibrations and tracking efficiency estimated from simulations
  - Live monitoring of the collected luminosity: all registered files used.
  - Elastic scattering cross section extrapolated from existing data at other energies (SAID database)

- Hades-Forward (HF) elastic event selection:
  - One track in main HADES ($70° < \theta < 80°$) and one in FD ($\theta < 7°$)
  - Well defined cuts:
    - Coplanarity condition $\Delta\varphi = 180°$
    - $\tan\theta_1 \cdot \tan\theta_2 = 1/\gamma_{CM}^2 = 0.29429$

- **Final reconstruction efficiency still to be determined**



Theta angle distribution of the pp elastic tracks for 4.5 GeV kin. beam energy.



Total integrated accepted luminosity as a function of beam time.

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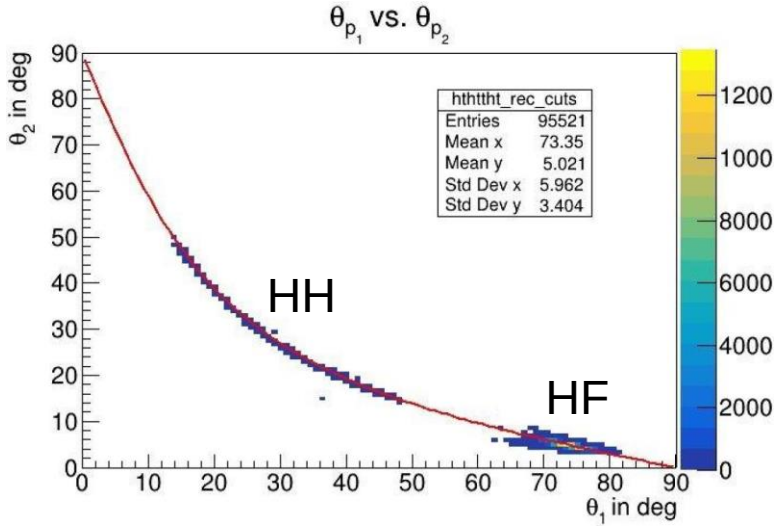
See Jana Rieger's presentation
(Hyperon session, 01/06/2022 at 14:00)



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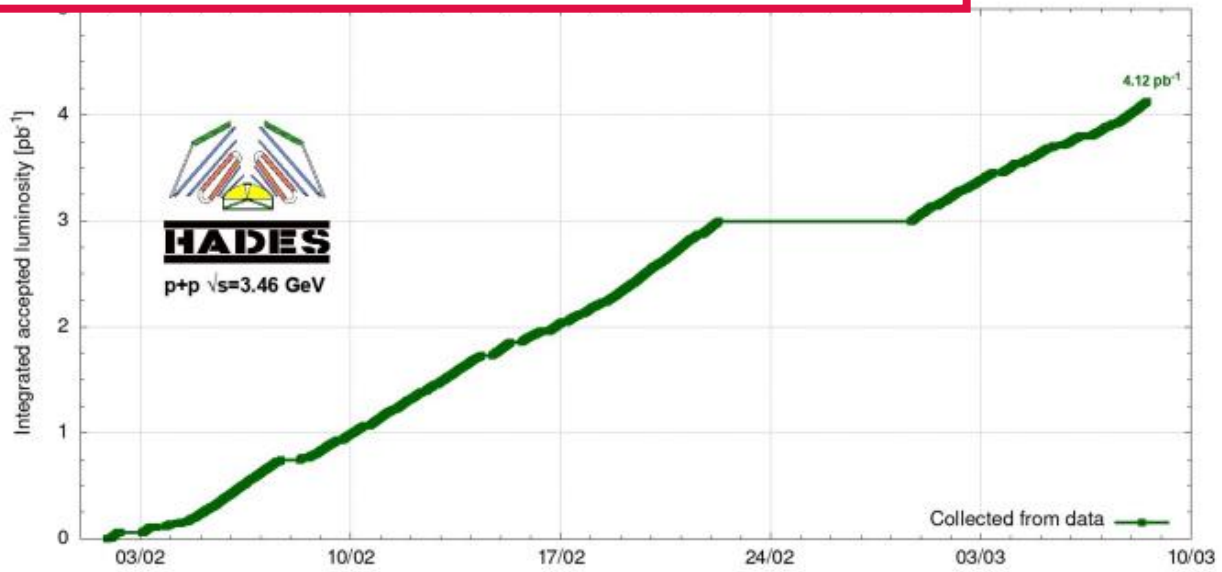

Total integrated accepted luminosity as a function of beam time.

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 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

- Online yield of pp elastic scattering used to determine **total integrated luminosity:**
  - One proton reco. in main HADES and one in FD.

THANKS!