



Straw testbeam results

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on behalf of SPD Tracker group

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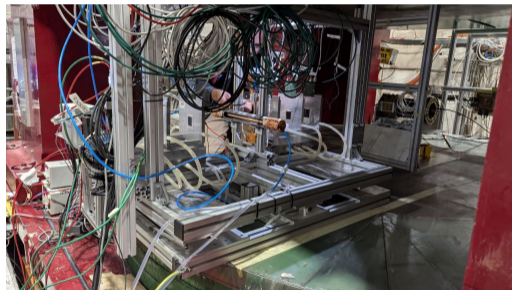
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SPS H4 testbeam goals

The main goal – to probe the best achievable spatial resolution:

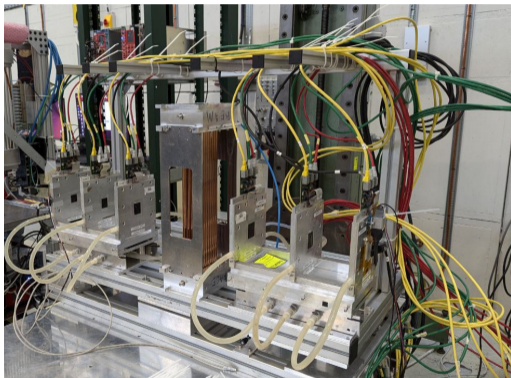
- Greatly improved reference tracking resolution (AZALEA tracker)
- Measurements with two different ASIC
 - VMM3 (Mu2E readout board)
 - ASD of ATLAS sMDT
- Measurements in the magnetic field (AZALEA + straw ASD readout in Goliath magnet)



PS T9 testbeam goals

The main goal – to probe the best achievable charge resolution:

- Measurements with a custom charge sensitive pre-amplifier with ~ 500 ns integration time, developed by O. Minko, JINR
- Low momentum particles:
 - Hadrons 0.3, 0.5, 1, 2 GeV/c
 - Electrons: 2 GeV/c
- Additional measurements: spatial resolution for 15 and 5 GeV hadrons with Mu2E and ASD readout

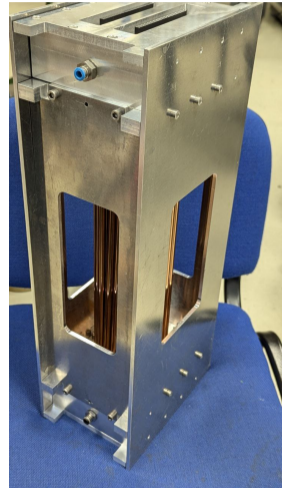
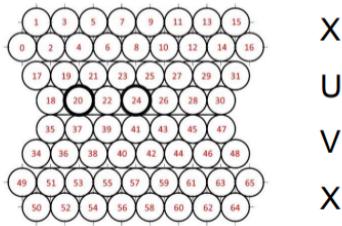




Test with first SPD tracker prototype with stereo planes

New stereo-prototype (μ Straw Tracker, μ ST):

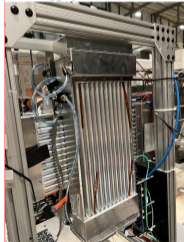
- 4 double-layer planes: Y-U-V-Y
- Stereo angle: 2°



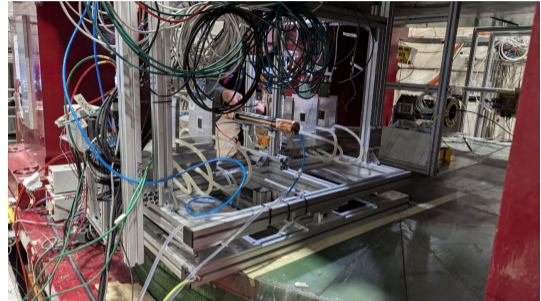


SPS H4 testbeam setup

- Reference tracking systems:
 - Small acceptance, high precision
 - AZALEA tracker
 - Large acceptance, $\sim 100\mu\text{m}$ resolution
 - Legacy MicroMegas, $250\mu\text{m}$ pitch
 - sMDT reference tracker
- Straw prototypes
 - Combined Straw prototype (20mm, 10mm & 5mm straws)
 - μST (10mm, Y-U-V-Y)
- Readout
 - Mu2E board (VMM3-based)
 - sMDT (ASD based)



The UM sMDT telescope
8-layers in x and y directions



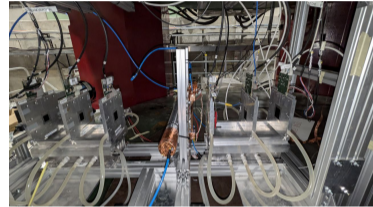
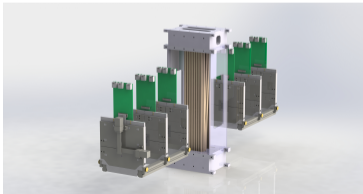
Data obtained

- Small acceptance:
 - VMM3/ASD & μST , gas Ar:CO₂ 70:30 and 93:7
 - ASD & μST , gas Ar:CO₂ 93:7, magnet 1T/1.5T
 - ASD & μST , gas Ar:CO₂ 70:30, pressure +1/2Bar
- Large acceptance
 - ASD & Combined Straw prototype, Ar:CO₂ 70:30

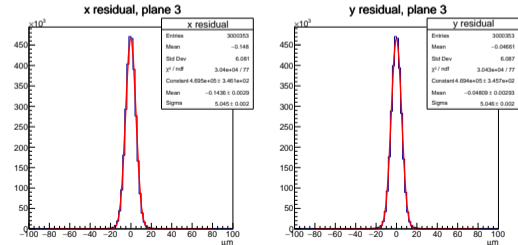


AZALEA tracker

- AZALEA: The AIDA-2020 Zero-suppressed Acquisition Located at the East-Area telescope
- The AZALEA tracker is one of the devices developed within of the EUDET project.
- Consist of:
 - 6 pixel detector planes with MIMOSA 26 sensors (18.4 μm pitch)
 - FEI4 Si plane, providing trigger
 - Trigger Logic Unit (TLU)
- Track resolution: $\sim 6\mu\text{m}$



Track resolution for muons at SPS H4



ASICs used

Straw readout under the test:

- Mu2E board (VMM3-based), used with 3mV/fC, 25ns peaking time
- ATLAS sMDT readout (ASD-based)

The main difference:

- ASD: ~ 2 times shorter peaking time
- ASD: ~ 3 times larger electronic gain
- Additionally, ASD capable of two charge collection modes: Wilkinson ADC and Time over Threshold. ToT mode analysis in the work.

For details, see [V. Bautin talk \(05.11.2024\)](#)

VMM3 parameters

Number of channels	64
Clock frequency	10...80 MHz
Input capacitance	<300 pF
Dynamic range	up to 2 pC
Gain	0.5, 1, 3, 4.5, 6, 9, 12, 16 mV/fC
Peaking time	25 / 50 / 100 / 200 ns
ENC (energy branch)	<3000 e ⁻
TDC binning	~ 1 ns
Maximum event rate	140 kHz/ch
Consumption	15 mW/ch

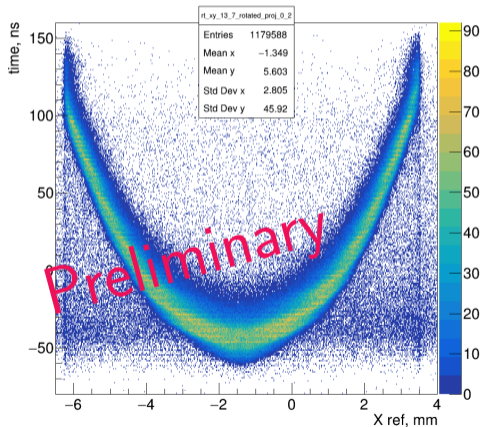
ASD parameters

ATLAS sMDT ASD Spec.	
Technology	CMOS 130nm
#. of channels	8
Power consumption	10 mA/ch
Input capacitance	60pF
Shaper	bipolar
Peaking time	12 ns
Dynamic range	5-100 fC
sensitivity	8 mV/fC
ENC	1 fC
Charge readout	ADC, ToT

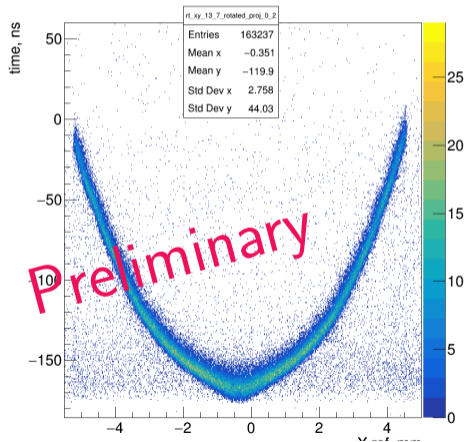


The R-T dependency plot

VMM3



ASD





SPS Testbeam results: time resolution

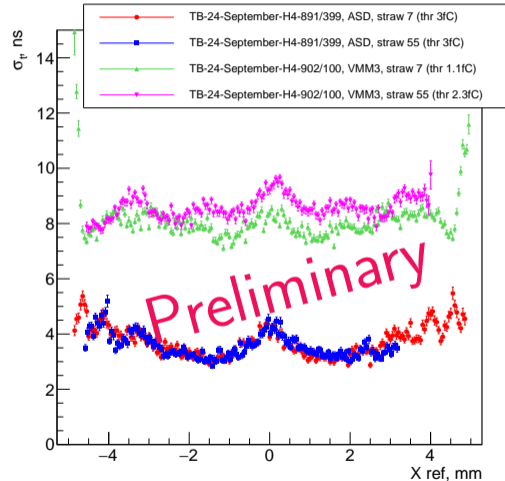


Time resolution

Time resolution:

- VMM3 ASIC: $\sim 8-9$ ns
 - Not calibrated
 - Larger peaking time
- ASD ASIC: $\sim 3-4$ ns

Analysis and calibration is ongoing





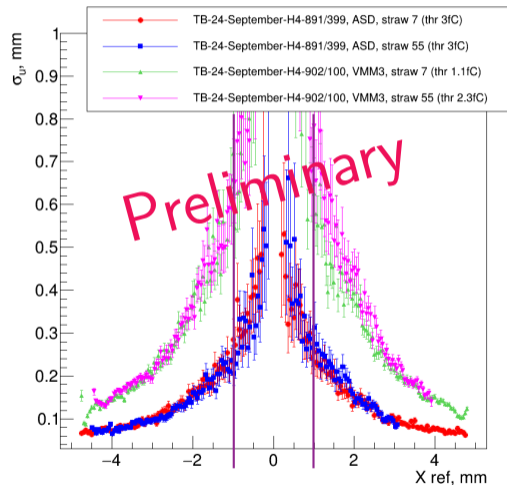
Spatial resolution

Analysis ongoing.

Prompt reco with data-driven method: the first results for spatial resolution

(simple mean for range $\pm[1 - 5]$ mm is shown):

- VMM3 ASIC, straw 7: $270 \mu\text{m}$
- VMM3 ASIC, straw 55: $320 \mu\text{m}$
- ASD ASIC, straw 7: $122 \mu\text{m}$
- ASD ASIC, straw 55: $139 \mu\text{m}$

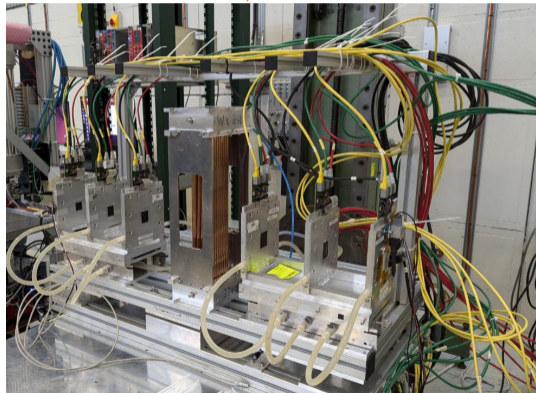




PS T9 testbeam setup

- Tracking system: AZALEA tracker
- Cherenkov for electron tagging
- Straws:
 - Combined Straw prototype (20mm, 10mm & 5mm straws)
 - Single 10mm straw
- Charge measurements
 - Custom single channel charge sensitive pre-amplifier by O. Minko, JINR (~ 500 ns integration time)
 - Hadrons 0.3, 0.5, 1, 2 GeV/c
 - Electrons: 2 GeV/c
- Time measurements
 - VMM-based and ASD-based readouts
 - Hadrons, 5 & 15 GeV/c

photo





SPS Testbeam description

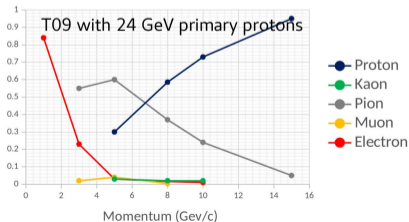


- High momenta - timing performance

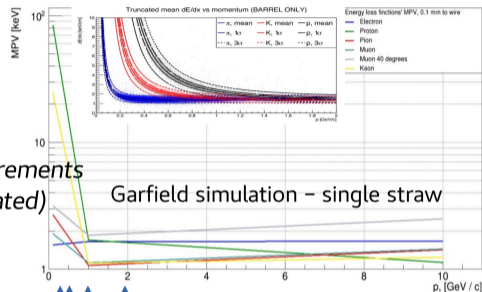
t vs R with VMM3 and ASD readouts
15, 5 and GeV h+, large statistics

- Low momenta ≤ 2 GeV - charge measurements

- 2, 1, 0.5, 0.3 GeV (purity to be evaluated)
- Q vs P (single straw)
- time-over-threshold vs P (ASD readout)



MPV as function of particle momentum. 0.1 mm distance to wire



Garfield simulation - single straw

@ T09: pi+mu+e (<5 GeV)

Electrons are tagged with the Cherenkov detector 15 mV threshold

Tried to veto muons behind the concrete block

Last two days :

- decreased momenta of primary protons (down to 15 GeV)
- => higher population of low momentum hadrons

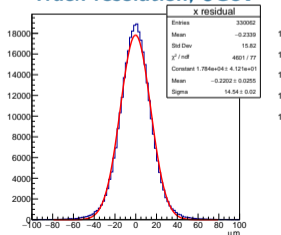


Reference tracking for low momentum particles

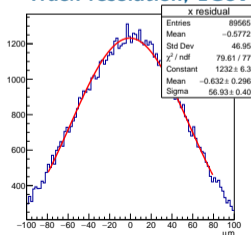
- Not optimized for particle energy below 6 GeV
- Track reconstruction optimization is ongoing
- Current track resolution: $\sim 60\text{-}110\mu\text{m}$
- For charge resolution we do not need precision tracking, only the track chord length



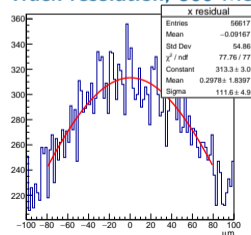
Track resolution, 5GeV



Track resolution, 1GeV



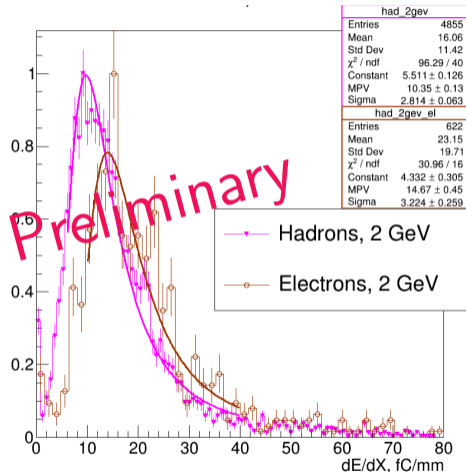
Track resolution, 500 MeV





PS T9 current results

- The custom charge amplifier was used
- The integration time around 500ns, larger than straw drift time will allow to study the straw potential
- Analysis is ongoing





Summary

- First measurements with the ASD readout - good time resolution is achievable
- Analysis on time and charge resolution on ASD-based readout are ongoing
- Time resolution studies with 93:7 Ar:CO₂ and different overpressure
- First data taking with a small prototype with 2 degree stereo-angle
- Measurements with low momenta hadrons - analysis ongoing

StrawTrackerRD team is very grateful to the sMDT group of the University of Michigan for the common datataking with ASD readout and to CERN SPS/PS and DRD1 teams for beam opportunity and instrumentation.