Pion beam momentum calibration

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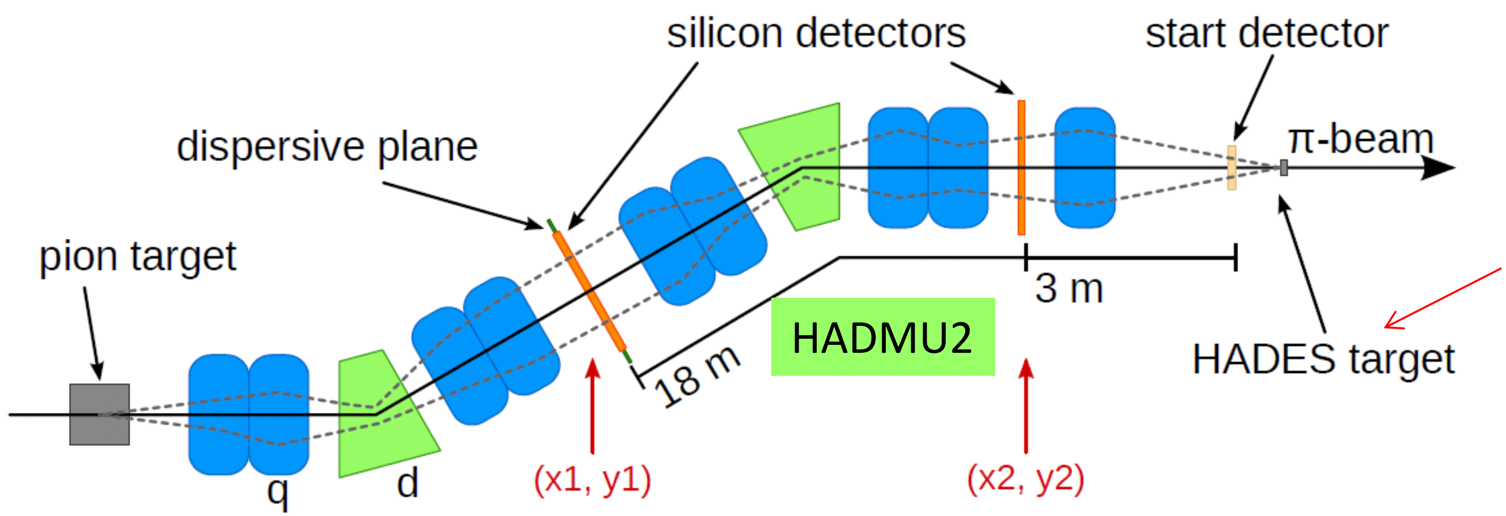
Krakow, 15 January 2016

Beam alignment procedure

Pion beam tracker Diamond detectors



HADMU1

2 Double-Sided Silicon sensors
100 x100mm^2, 300µm thick
2 x128 channels

1. Primary beam focused at pion target using kickers (very bad precision, relies on beam line calculation)
2. Pion beam line set to theoretical values for reference momentum
3. Check of beam spot on Start detector→ adjustment changing HADMU1 (<1/1000) and HADMU2 (4/1000)

How to extract δ (and θ_i, φ_i and y_i)

H and V are strongly coupled + chromatic terms in vertical

2 equations (one measured X position at detector 1, another one at detector 2) with 8 terms

HV coupling

Chromatic 2nd order V coupling

Coupling to φ

$$X = \cancel{T_{11} x_i} + T_{12}\theta_i + T_{14}\varphi_i + T_{16}\delta + \cancel{T_{116} x_i}\delta + T_{126}\theta_i\delta + T_{146}\varphi_i\delta + T_{166}\delta^2$$

$$Y = T_{33} y_i + T_{34}\varphi_i + T_{36}\delta + T_{32}\theta_i + T_{336} y_i\delta + T_{346}\varphi_i\delta + T_{366}\delta^2$$

Chromatic 1st order **HV coupling** **Chromatic 2nd order**

2 equations (one measured Y position at detector 1, another one at detector 2) with 7 terms

- **Coupling to θ**
- **1st order + 2nd order terms × 10**

System of 4 non-linear equations with 4 unknown θ_i, y_i, φ_i and δ (x_i term 'neglected')
→ solved iteratively

Method involving the diamond detector (6 quantities measured) developed by E. Atomssa→ limited improvement

Calibration of pion beam line

- Using proton beam at p=2.7 GeV/c in April-May 2014 at different δ, x0, $\phi 0$, y0

- Dispersive terms measured with good precision:
  - Most important term T16(det1) for pion momentum reconstruction only 3% lower than theory
  - differences for T16(det2), T36(det1) and T36(det2) are larger,
  - up to a factor 2 for T16(det2) but effect on pion momentum is small.

- Horizontal first order terms T11 (det1), T12(det1), T11 (det2) ,T12(det2) could also be measured with rather good precision:
  - T12 (det1) much larger than expected (focal plane probably shifted) $\rightarrow$ effect on resolution at large deltas (especially negative ones)
  - Other terms have smaller effect

- Vertical terms (T33, T34) could not be extracted reliably: probably due to uncontrolled position of beam in vertical plane and/or beam enveloppe cut.
  T33 and T34 have an effect on y0 and $\varphi 0$ reconstruction but not on pion momentum

Ideas for a better calibration of pion beam line
(Thierry at Bratislava)

- Repeat the previous calibration procedure with control on position of the primary beam at the pion production target. (i.e. with detectors measuring this position)

- Collimators with holes at the entrance of the first Qpole to reconstruct the pion beam at definite emission angles (check of T12(det1), T34(det1), T12 (det1), T34 (det2))

But, data provide already a lot of checks…

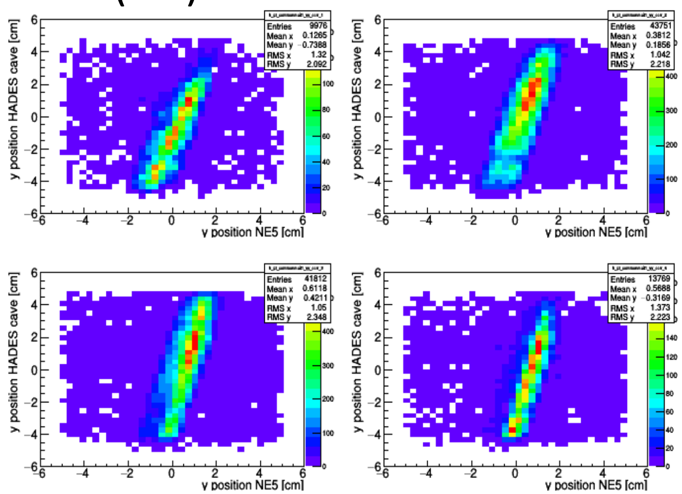
- Major (foreseen) problem is the uncontrolled position of primary beam in vertical plane

Ydet1*Ydet2 correlation

Simulationp=1.7 GeV/c with multiple scattering

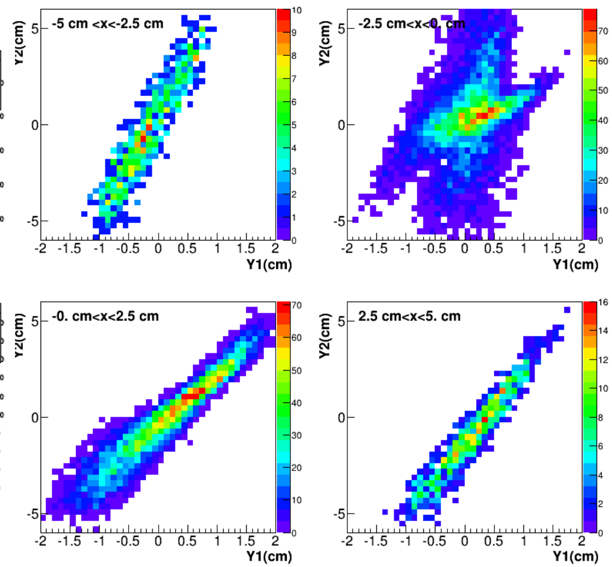
data p=1.7 GeV/c (July)

Ydet2(cm)

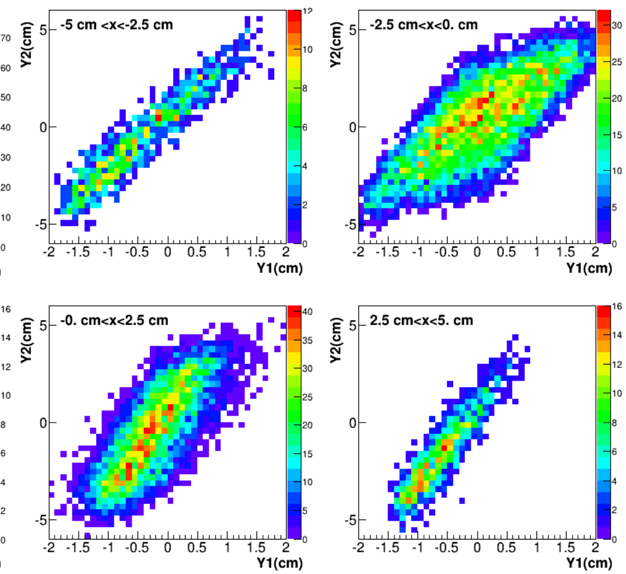


Ydet1(cm)

« measured « coefficients



« Transport » coefficients

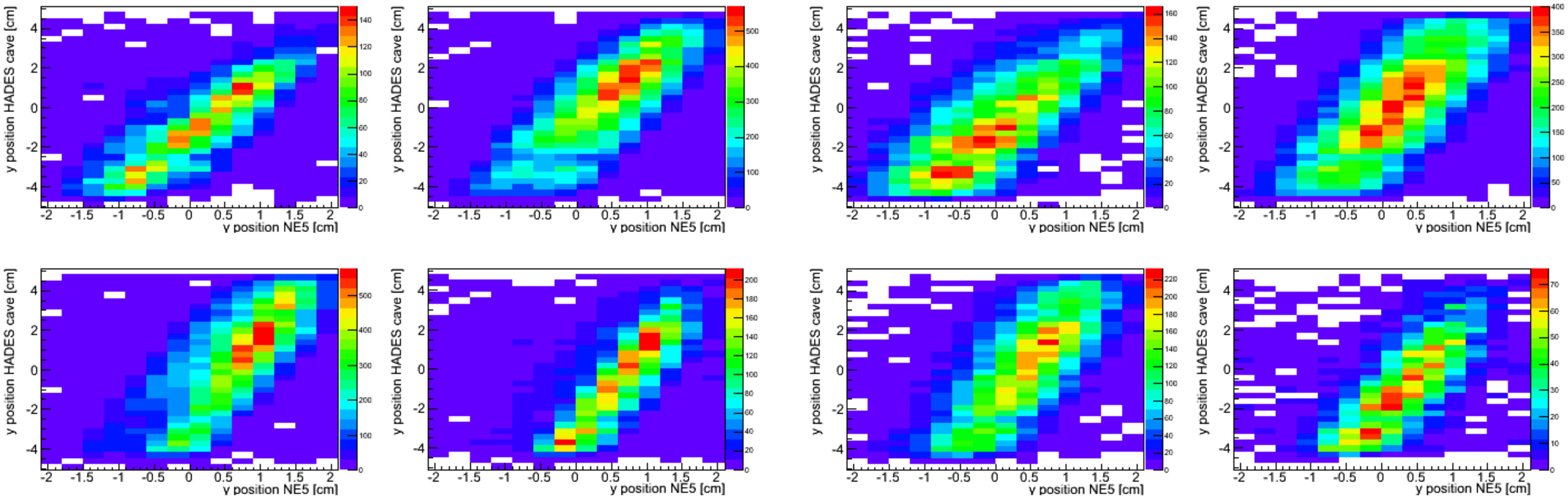


Results from simulation

- Correlation consistent with simulations. It is mainly due to scaling factor (~3.6) between the main coefficients for Ydet2 and Ydet1
- Distribution of counts strongly dependent on y0
- General trend much closer to «TRANSPORT » coefficients than « measured » ones
- Seems to corroborate the fact that the vertical coefficients were not measured accurately

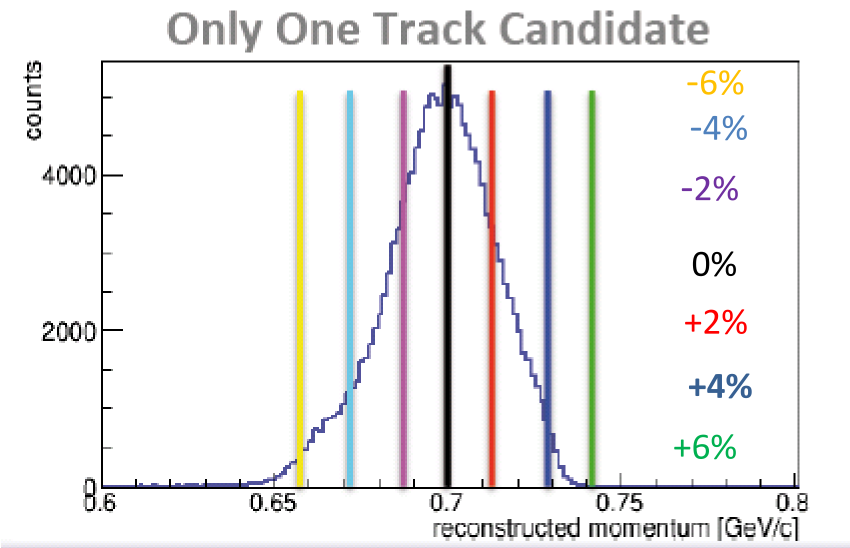
Stability of Ydet1*Ydet2 correlation

Two files at p= 1.7 GeV/c (July) from Joana

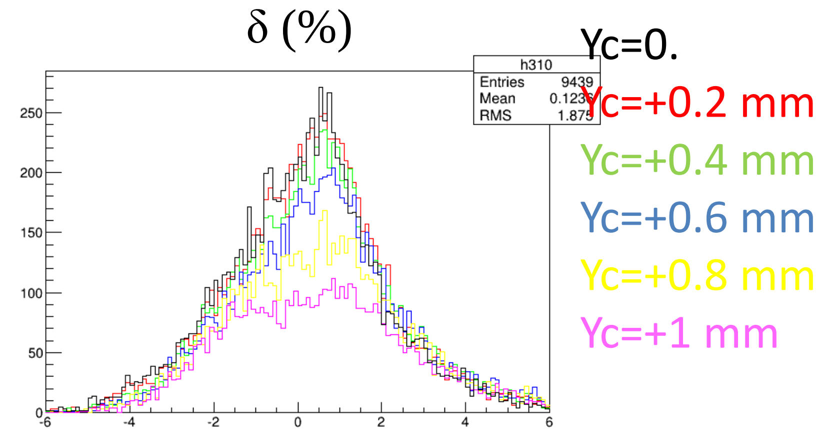


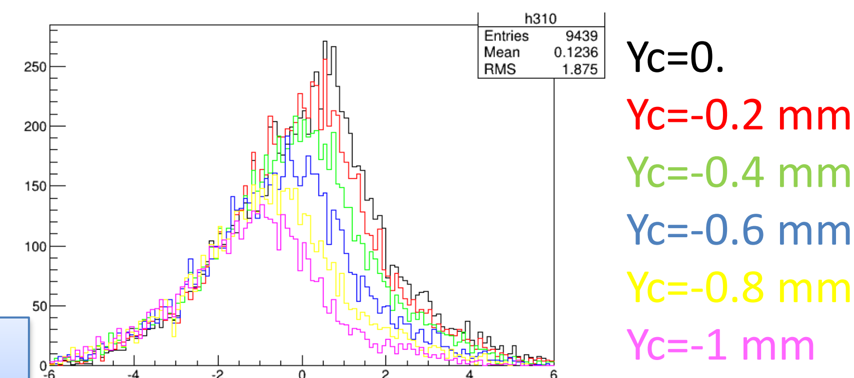
- exactly same profiles for the two sets of July data (checked by Joana), but different yields along the correlation line
- Indication for shifts of the primary beam in vertical plane of a few mm/10

Comparison of experimental and theoretical transmissions



Width of experimental distribution (σ~2.4%) significantly broader than calculated one (σ~1.5%)





Sensitivity to shifts in y:

- mean value shifted towards lower δs
- Acceptance reduced
- Larger effect for negative shifts

Shifts in x only shift the distribution 0.2%/mm (no effect on acceptance)

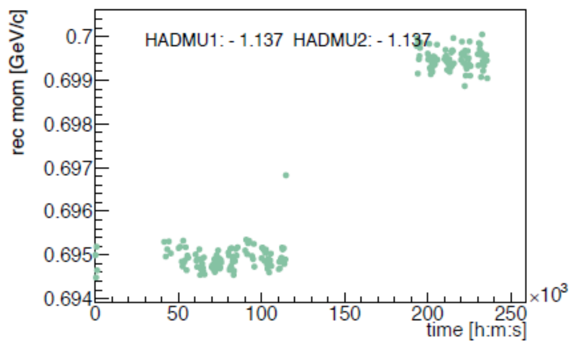
Jumps of mean pion momentum

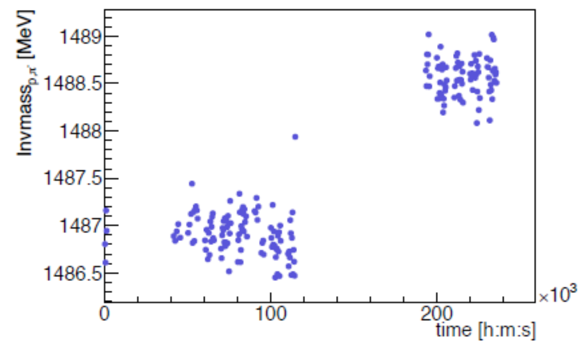
From Joana

p_π from pion tracker

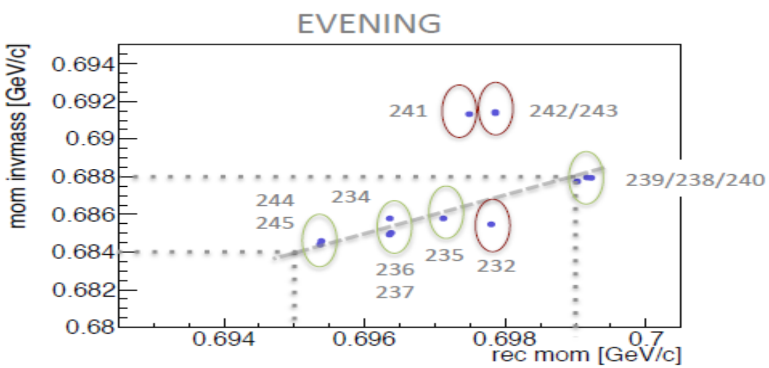
πp invariant mass

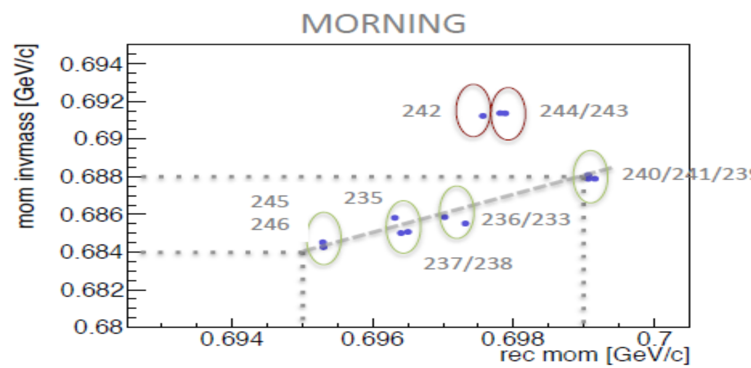
Day 238





Summary at 0.690 GeV/c

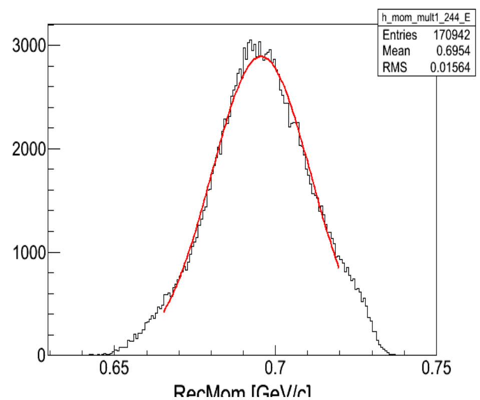




- Shifts of primary beam in x $\rightarrow$ error on pion reconstruction, no effect on transmission i.e. HADES measurement not affected
  $\rightarrow$ bad correlation between HADES and beam tracker
- Shifts of primary beam in Y $\rightarrow$ large effect on transmission (shift and reduction) shift of mean pion momentum, correlation between HADES and pion beam tracker conserved
- Y0 shifts to be checked by analysing the reconstructed y0 spectra

How to use the pion beam momentum from beam tracker

Day 244
evening
σ= 1.5%



- In a stable period, the acceptance width is as expected from simulation !
- But it varies in average position and magnitude from one period to another

Finally:

- We can trust the momentum reconstruction, except for small shifts in x
- Better use the measured dispersive and horizontal plane first order coefficients, but not the vertical ones !
- The shape of the transmission is close to the calculated one (to be checked more quantitatively).
- But we suffered from shifts of primary beams of a few mm/10 (also to be checked)

For each stable period,

- The mean pion momentum can be readjusted (using an offset) to the HADES value
- The magnitude (but not the width) of the acceptance is changing, but it is not a problem due to the normalisation to elastic scattering

Suggestions for the future at FAIR (SIS18?)

Thierry, Bratislava

- **Measure field maps** of Dipoles and Q-poles for a much better description of the transport beam line through TRANSPORT calculations
- Add **diagnostics elements** at the pion production target and before (eventually record the position information to further be able to correct even if not possible on an event-by-event basis)
- Make the **horizontal size** of the primary beam as **narrow** as possible
- Make a 1st order **intermediate focus** in both H and V for the 1st detector
- **Avoid bending in vertical plane**
- Add **sextupole(s)** to cancel out T_{126} (and T_{346} if needed) effects and realize a 2nd order focusing at the 1st detector ('cancelling' the effect of multiple scattering)
- Install a **collimator with holes** (intellectual satisfaction, since no benefit from a resolution point of view for the HADES case). This avoids trying to realize large primary beam incident angles

Back-up

Tuning the beam with an θ angle offset