Studies for experiments with the HADES detector and secondary pion beam at GSI

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Outline

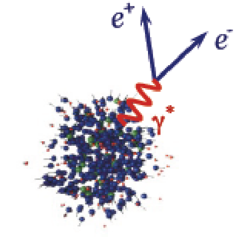
- Motivations of HADES experiments.
- Description of HADES detector.
- Pion beam experiments with HADES.
- Motivations of the test beam made at the end of April 2014.
- Analysis of the test beam results.
- Conclusion and outlook.

Motivations of HADES

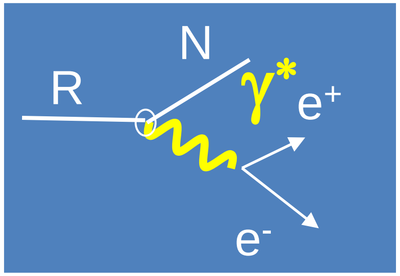
- The main goal of HADES experiments is to explore strongly interacting matter in heavy-ion collisions in A+A at 1-3 Gev/Nucleon.

- Although quarks and gluons remain confined inside the nucleons, modifications of properties of hadrons are predicted.

- The best probe for such studies is the positron-electron pair because they don't make strong interactions with the surrounding hadrons.



- p+p and d+p reactions are also measured
  - Reference for medium effects.
  - Study of the emission of $e^+ e^-$ pair by baryonic resonances. (R=Δ(1232) ,N(1520) ..) R→N $e^+ e^-$



HADES Detector

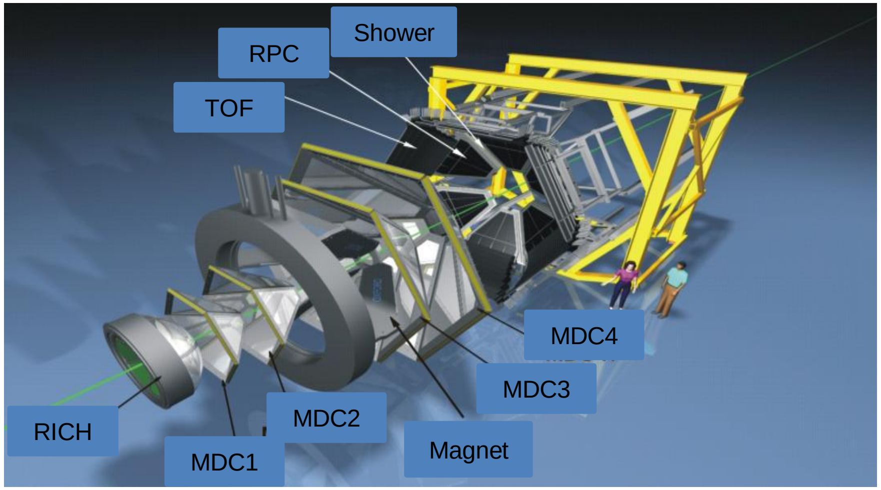
HADES (High Acceptance Di-Electron Spectrometer) is a detector that covers the whole azimuthal angle and covers polar angles from 16° to 88°with respect to the beam direction.

It is situated at GSI in Germany.

It is very well suited in:

•Measuring Di-Electron production.

•Detecting charged hadrons.



Pion beam experiment with HADES

- New experiment in preparation (summer 2014): π^-p and π^- A reactions
  - Pions are of great interest due to the better knowledge of pion-nucleon interactions than nucleon-nucleon reactions.
  - Direct production of baryonic resonances (π^-p→R instead of pp/pn →RN).

Challenges:

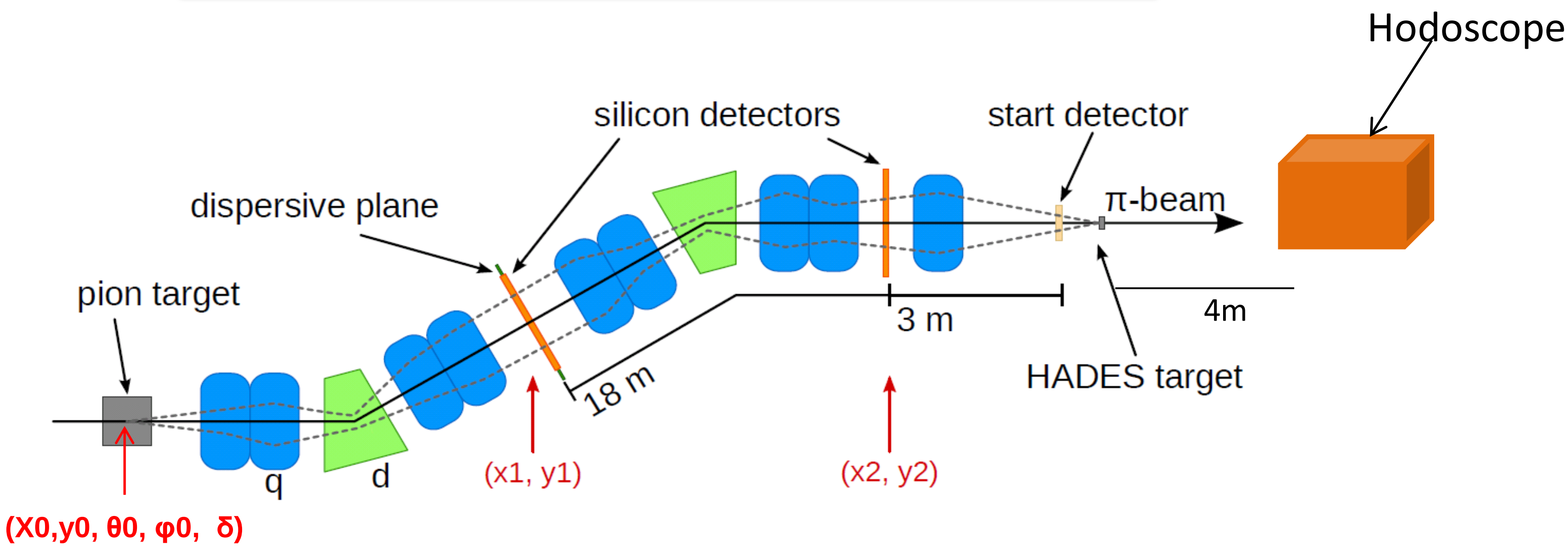
- Pion beam is a secondary beam. It is produced by the interaction of intense ion beam (proton for example) on a thick target.

- Pions have broad spatial and momentum distributions.

- pion momentum reconstruction is needed to Calculate the missing mass of undetected particles in exclusive channels (π^-p→ne+e-).

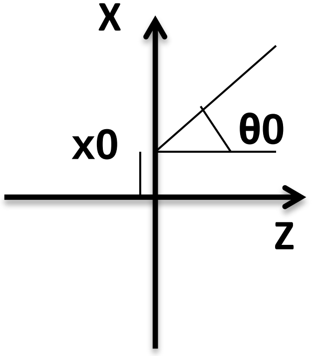
- position reconstruction at the HADES target is needed to reject the background coming from events produced with material surrounding the target.

Spectrometric line



- It is 33 m long.
- Contains 9 quadrupoles (q), 2 dipoles (d) and 2 silicon detectors (10cm x 10cm with 128 channels of 300μ thickness in X and Y).

Pion reconstruction



Transport of particles in magnetic line:

- each charged particle is represented by vector X= (x, θ, y, ϕ, ℓ, δ= Δp/p).
- at first order , each magnetic element is represented by 6x6 matrix R =

$$\begin{bmatrix} T_{11} & T_{12} & \dots & T_{16} \\ T_{21} & & \dots\dots & T_{26} \\ . & & & \\ . & & & \\ . & & & \\ T_{61} & & & T_{66} \end{bmatrix}$$

- the passage of each particle by magnetic element is represented by the equation: X(1)=R*X(0) and passing through many magnetic elements, the formalism can be extended with second order terms (for more precision) and the equation will be presented by:

$X_i(1)= \Sigma R_{ij} * X_j(0) + \Sigma T_{ijk} X_j(0) X_k(0)$.

An example of the matrix R for dipoles with vertical magnetic fields:

$$\begin{bmatrix} T_{11} & T_{12} & 0 & 0 & 0 & T_{16} \\ T_{21} & T_{22} & 0 & 0 & 0 & T_{26} \\ 0 & 0 & T_{33} & T_{34} & 0 & 0 \\ 0 & 0 & T_{43} & T_{44} & 0 & 0 \\ - & - & 0 & 0 & 1 & - \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Dispersion terms (as T_{16})
Where $T_{ij}=f(R,\alpha)$

An example of the matrix R for the drift space (a free-field region) :

$$\begin{bmatrix} 1 & L & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & L & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

→ $X = X_0 + L * \theta_0$

• Many transport coefficients have been neglected because their contributions to the positions are much lower than half resolution of the silicon detector, leading to the following simplified equations:

$$X^{de1} = T_{11}^{det1}\ x_0 + T_{12}^{det1}\ \theta_0 + T_{14}^{det1}\ \phi_0 + T_{16}^{det1}\ \delta + T_{116}^{det1}\ x_0\ \delta + T_{126}^{det1}\ \theta_0\ \delta + T_{146}^{det1}\ \phi_0\ \delta + T_{166}^{det1}\ \delta^2$$

$$X^{de2} = T_{11}^{det2}\ x_0 + T_{12}^{det2}\ \theta_0 + T_{14}^{det2}\ \phi_0 + T_{16}^{det2}\ \delta + T_{116}^{det2}\ x_0\ \delta + T_{126}^{det2}\ \theta_0\ \delta + T_{146}^{det2}\ \phi_0\ \delta + T_{166}^{det2}\ \delta^2$$

$$Y^{det1} = T_{31}^{det1}\ x_0 + T_{32}^{det1}\ \theta_0 + T_{33}^{det1}\ y_0 + T_{34}^{det1}\ \phi_0 + T_{36}^{det1}\ \delta + T_{336}^{det1}\ y_0\ \delta + T_{346}^{det1}\ \phi_0\ \delta + T_{366}^{det1}\ \delta^2$$

$$Y^{det2} = T_{31}^{det2}\ x_0 + T_{32}^{det2}\ \theta_0 + T_{33}^{det2}\ y_0 + T_{34}^{det2}\ \phi_0 + T_{36}^{det2}\ \delta + T_{336}^{det2}\ y_0\ \delta + T_{346}^{det2}\ \phi_0\ \delta + T_{366}^{det2}\ \delta^2$$

These coefficients have been calculated using the TRANSPORT code. By solving a system which is made from the above four equations, one gets the values of $x_0, y_0, \theta_0, \varphi_0$ and δ. But any error on the vertical and horizontal positions translates into errors on $x_0, y_0, \theta_0, \varphi_0$ and δ ; so we have to check these errors experimentally.

The resolution on δ is less than 0,3%, on Δx is less than 2mm and on Δy is at the level of few hundred microns.

Motivations of the test beam

A test beam was made at the end of April at HADES where it lasts a week with a proton beam of energy of 1,9 GeV.

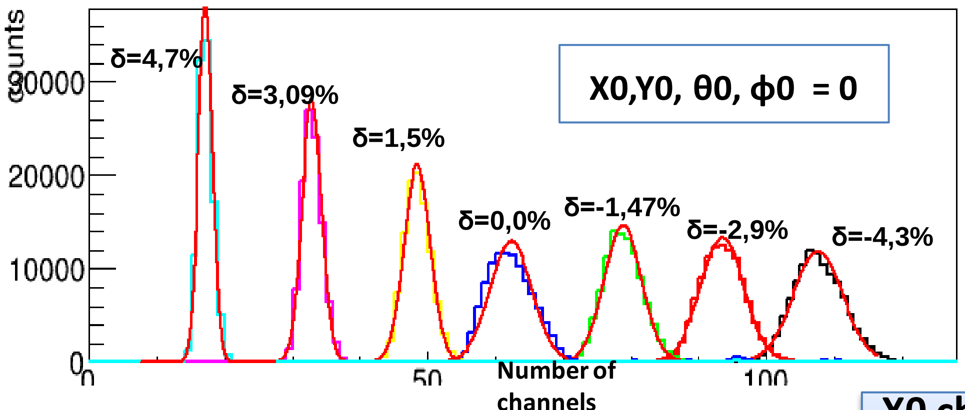
The goal of this test beam:

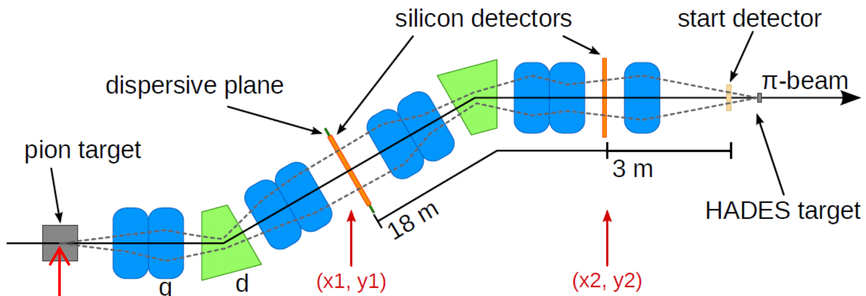
- **Test the newly built silicon detectors.**
- **check the transport coefficients.**

Configurations

- Different configurations were used (different values of x_0, y_0, θ_0, φ_0 and δ).
- δ was changed by changing currents in the spectrometric line which means changing the momentum of the reference trajectory and not that of the proton beam.
- x_0, y_0, θ_0, φ_0 were changed by adjusting the magnetic field in the two dipoles located before the production target.
- Horizontal and vertical positions on both detectors were measured for each configuration.

The first result of the test beam :
The silicon detectors are efficient and they are working well.



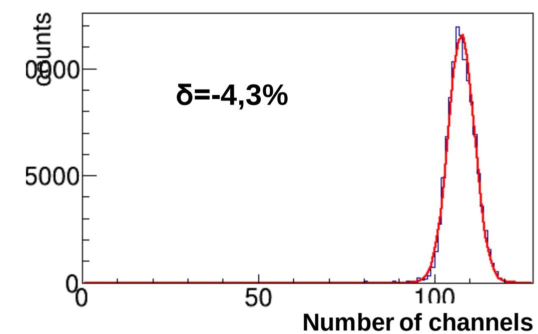


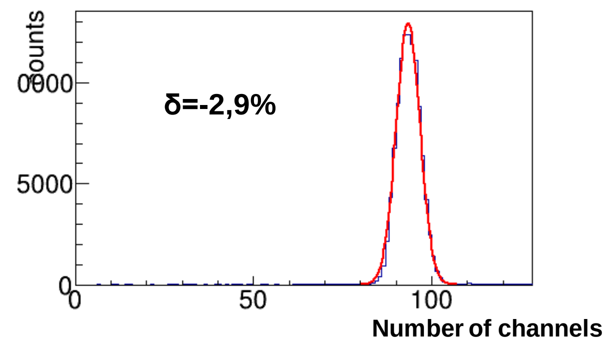
(X0,y0, θ0, φ0, δ)

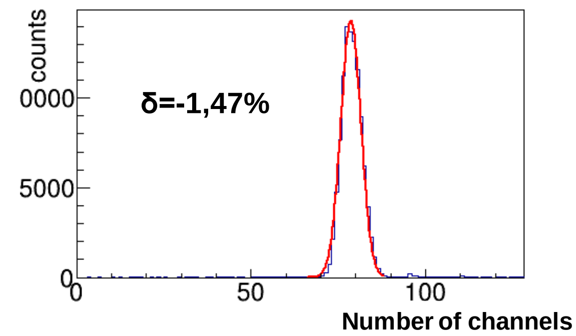
X0 changes between: [0 and 0,137] cm
y0 changes between: [0 and 0,07] cm
θ0 changes between: [0 and 2,2] mrad
ϕ0 changes between: [0 and 8] mrad

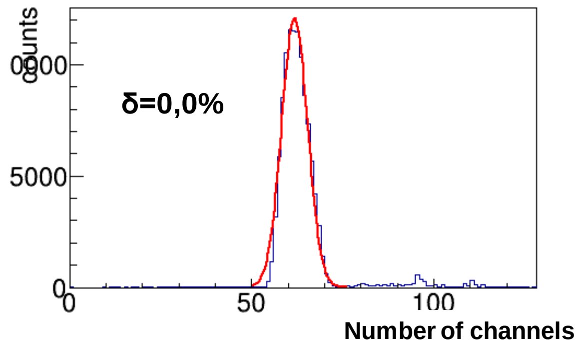
Extraction of positions on both detectors

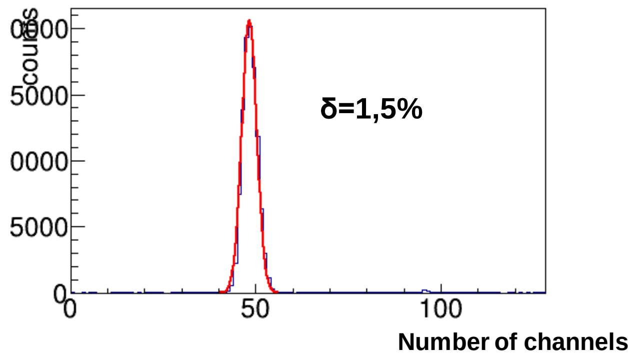
A gauss fit of the hit channel distributions for detector1 in the horizontal plane.

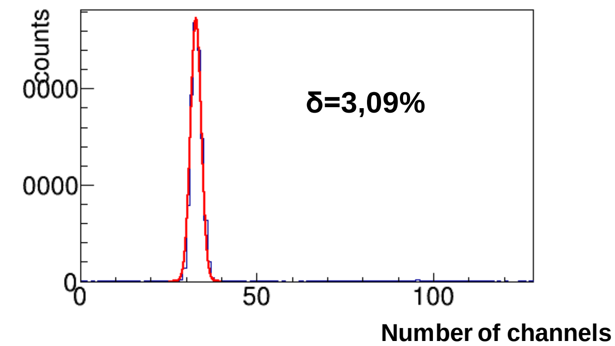


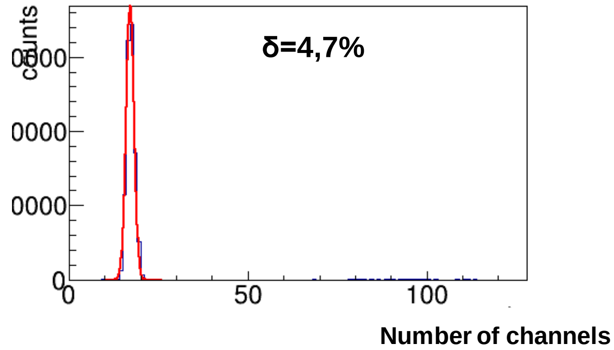




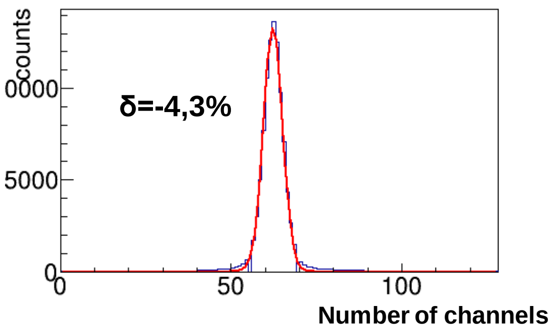


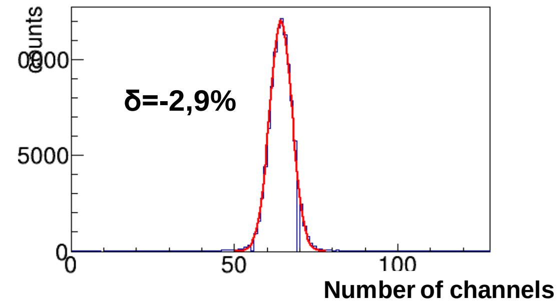


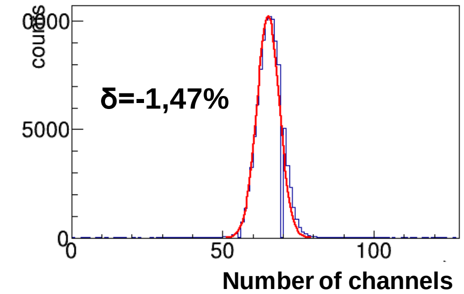


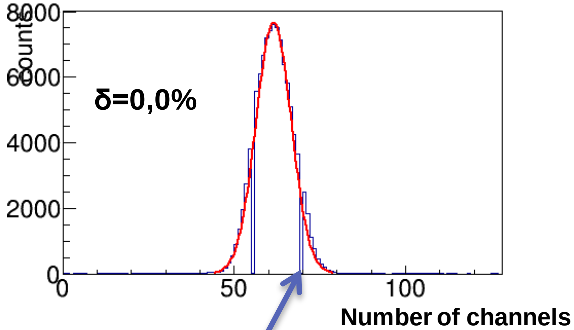


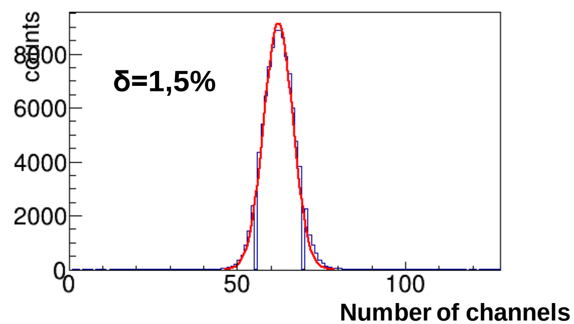
Same procedure for detector2.

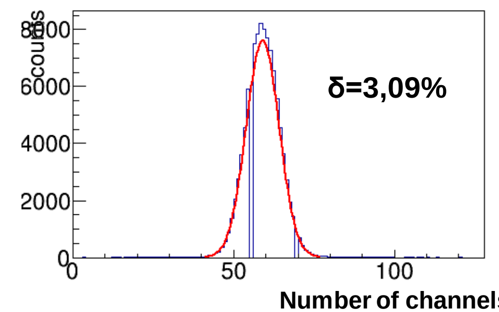




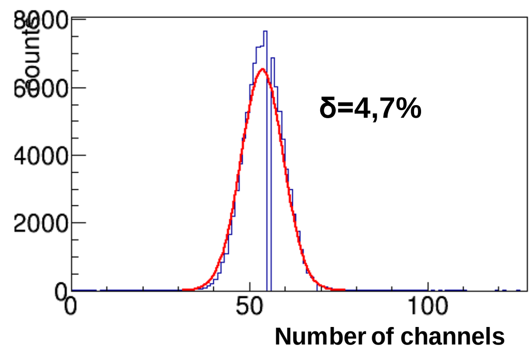






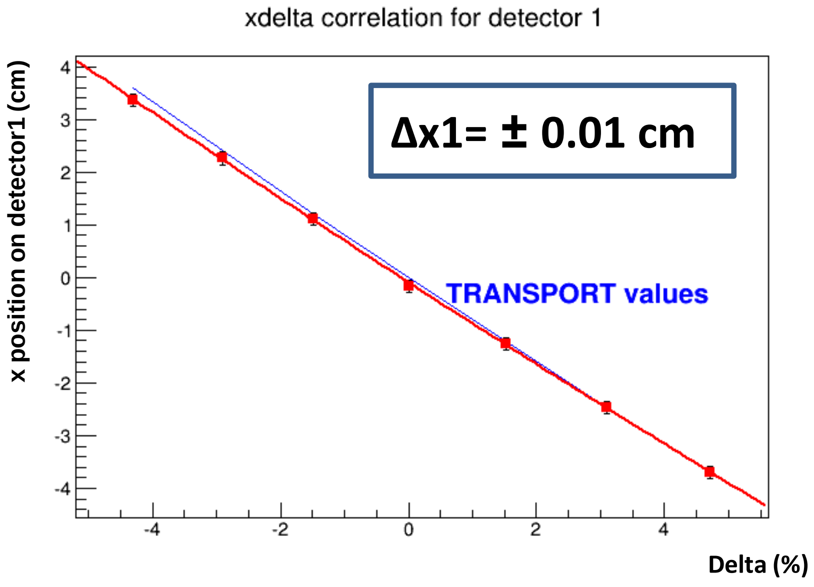


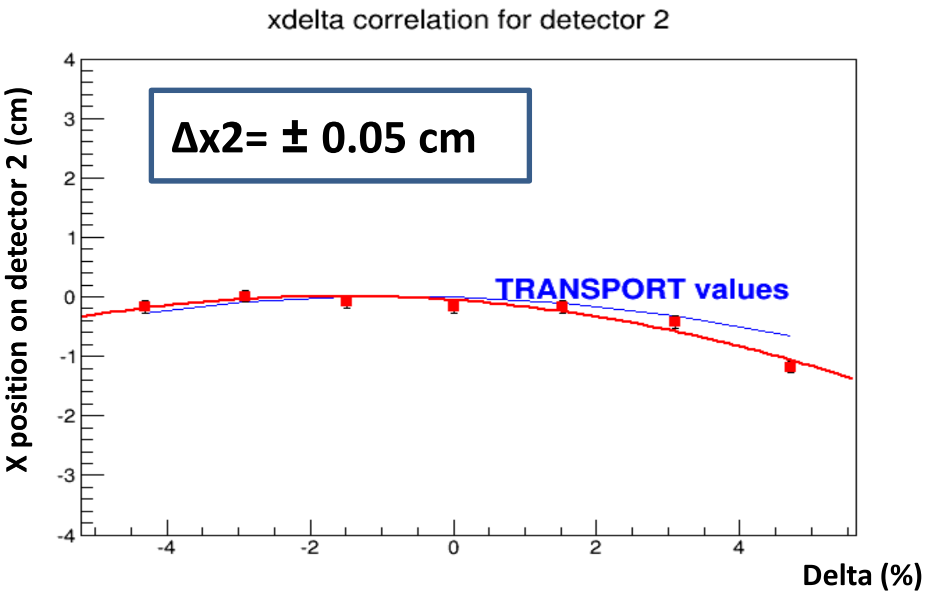
Dead channels in the Silicon detector.



Extraction of transport coefficients: T_{16} & T_{166}

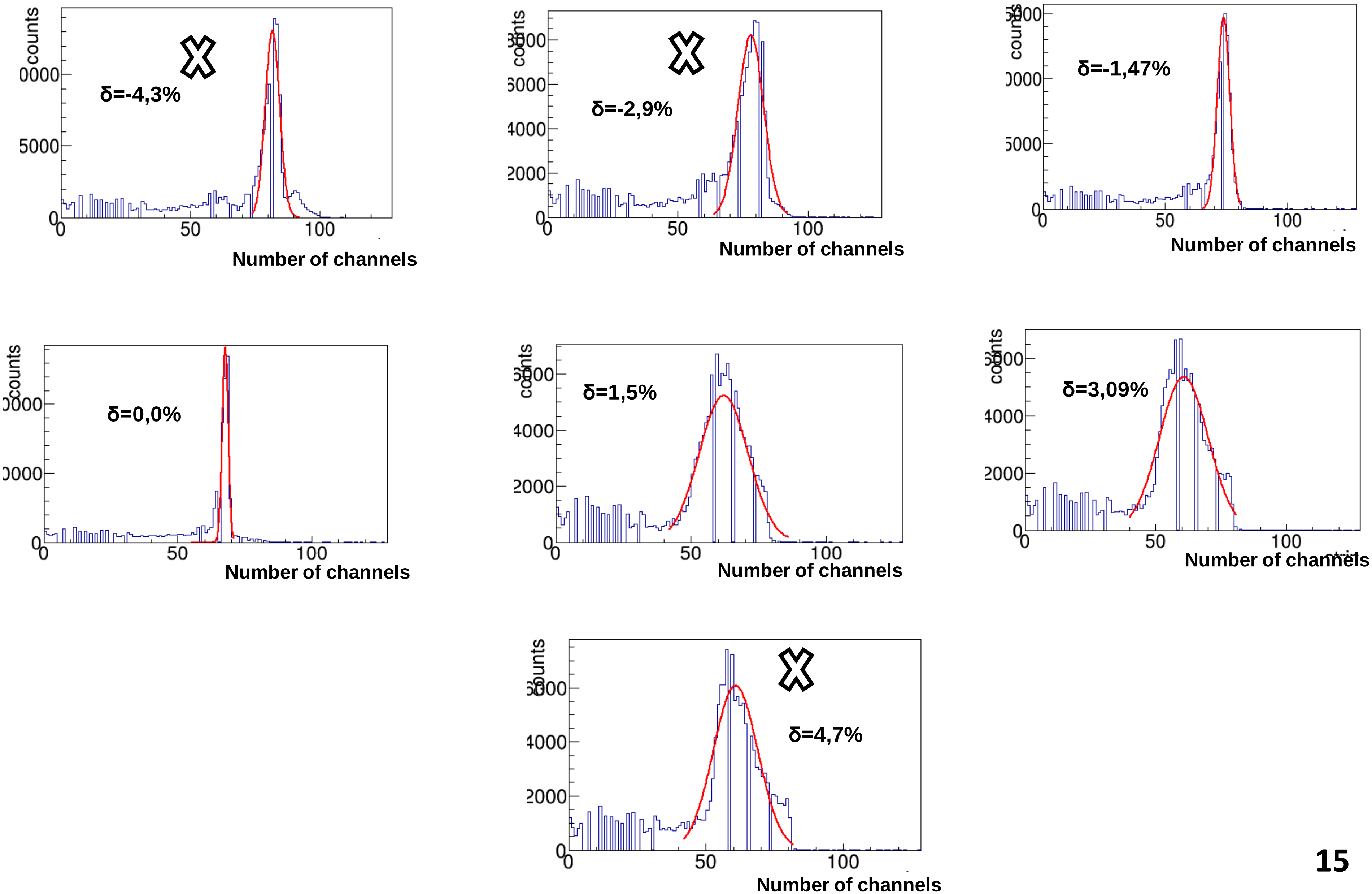
Fitting equation $X=Cte+T_{16}*\delta + T_{166}*\delta^2$ for both detectors in horizontal plane.



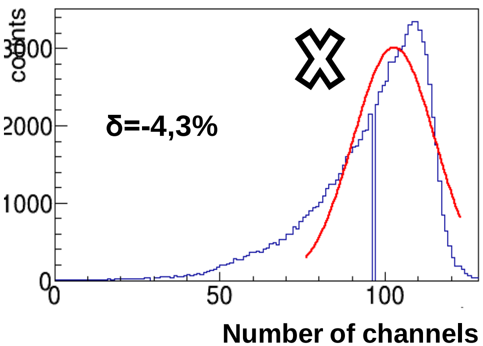


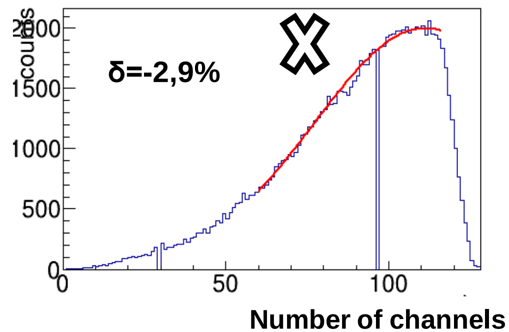
detector1	T_{16} (cm/%)	T_{166}(cm/%/%)	detector2	T_{16} (cm/%)	T_{166}(cm/%/%)
theoretical	-0,81	0,005	theoretical	-0,034	-0.022
measured	-0,78±0,01	0,004±0,006	measured	-0,081±0,01	-0,031±0,004

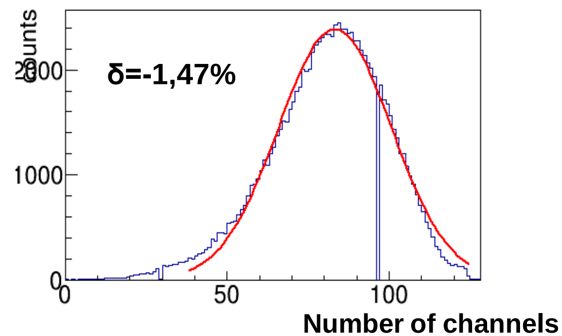
A gauss fit of the hit channel distributions for detector1 in vertical plane.

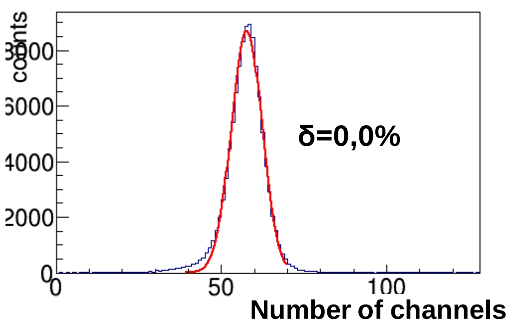


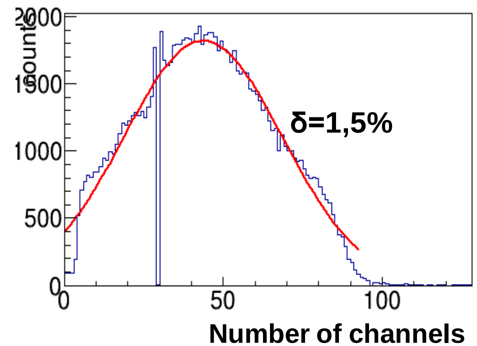
Same procedure for detector 2.

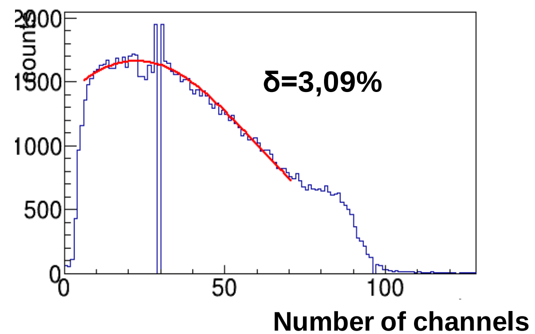


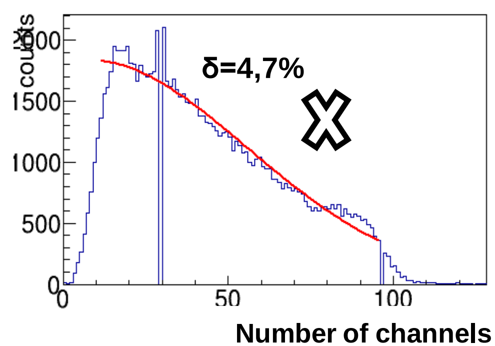






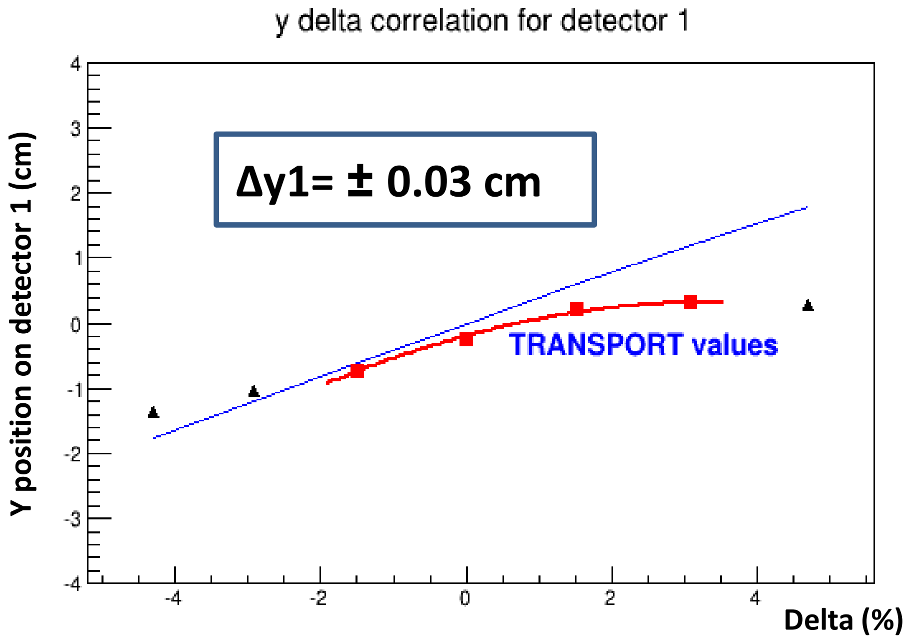


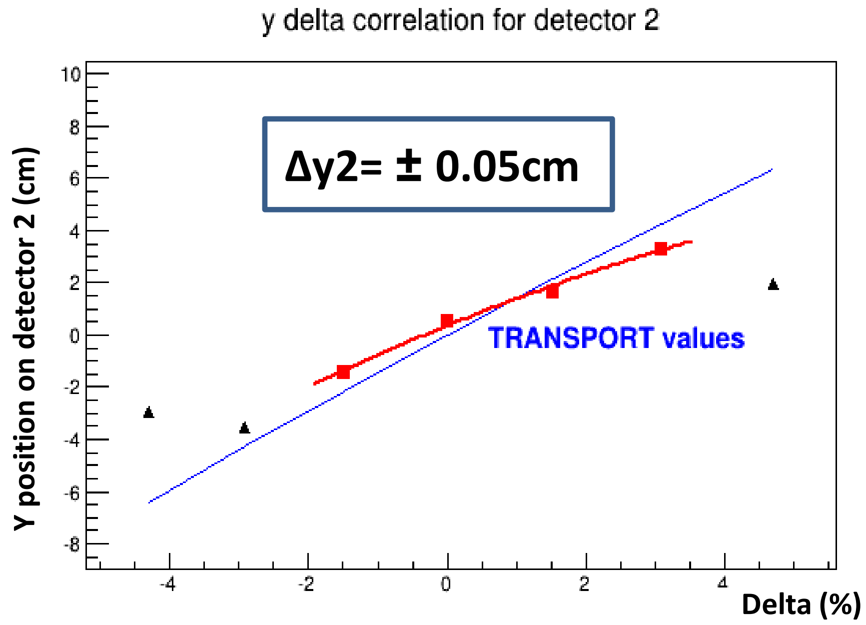




Extraction of transport coefficients: T_{36} & T_{366}

Fitting equation $Y=Cte+T_{36}*\delta + T_{366}*\delta^2$ for both detectors in vertical plane.





detector1	T_{36} (cm/%)	T_{366}(cm/%/%)
theoretical	0,395	-0,0036
measured	0,301±0,02	-0.0431±0,001

detector2	T_{36} (cm/%)	T_{366}(cm/%/%)
theoretical	1,42	-0,015
measured	1,12±0,04	-0,045±0,021

Conclusion

• During the first week of the internship, I stayed at GSI and I participated in the test beam ; the other weeks I was working at IPNO.

•My work consisted in data analysis.

•The results presented for dispersion matrix elements will be used in pion reconstruction.

Other transport coefficients are also fitted but need further investigation.

THANK YOU