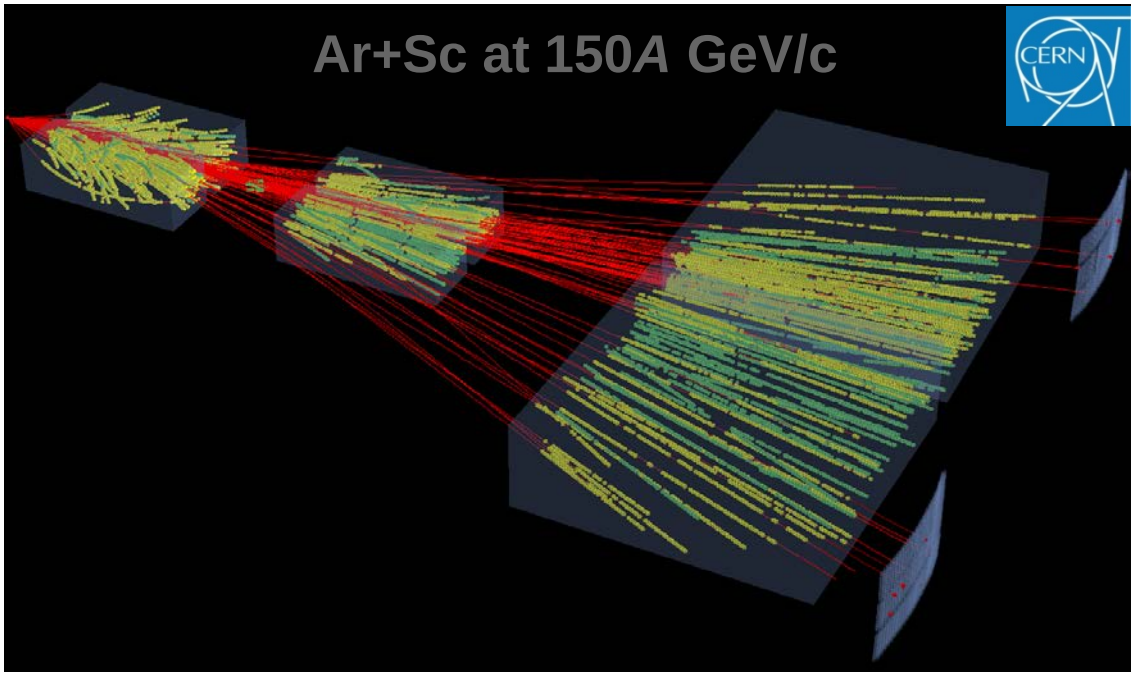
From raw to physical data.

Part II - calibration



Grzegorz Stefanek
Jan Kochanowski University in Kielce

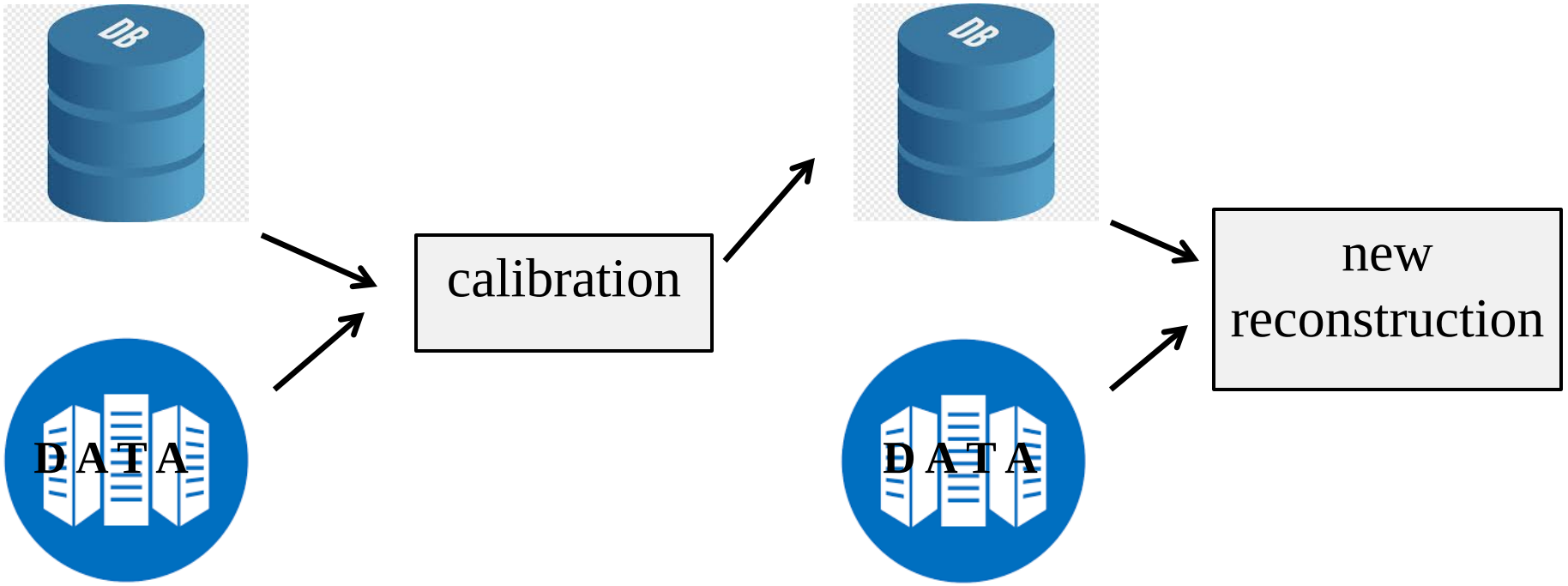
What is the calibration chain of NA61/SHINA data ?

The calibration is the chain of different activities required to obtain calibration factors and to correct reconstructed data using sets of calibration parameters from the Database.

The calibration parameters are obtained from the dedicated measurements or by running calibration software on recently produced data and using current factors from Database.

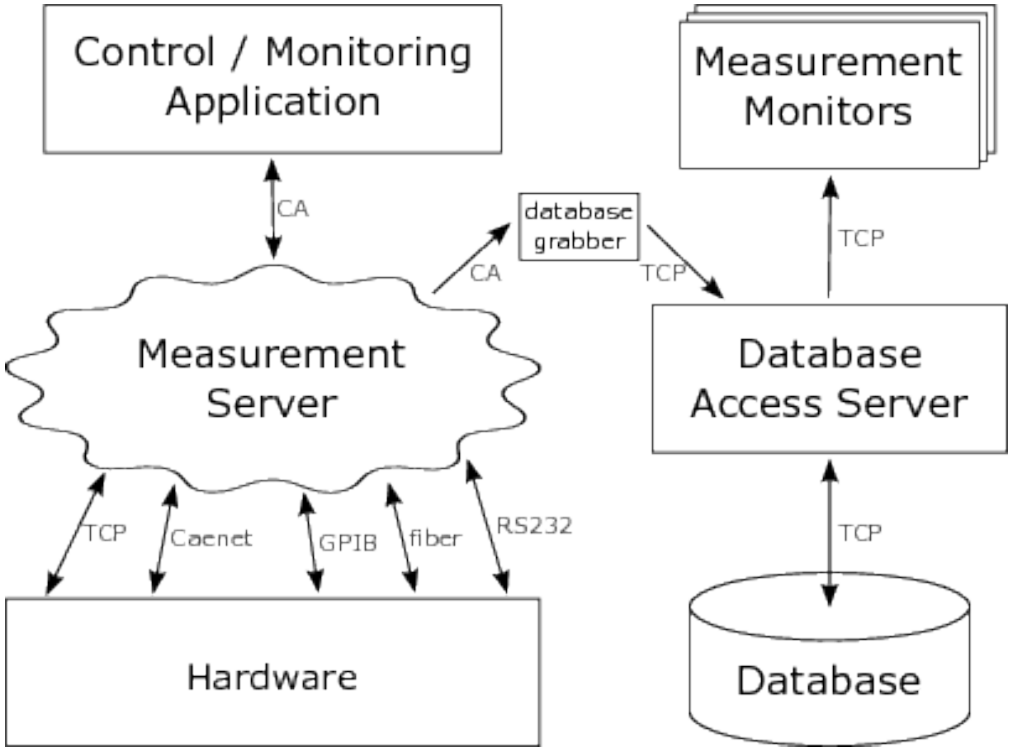
NA61/SHINE data and Database are stored in CERN Data Centre

One chain link using NA61/SHINE data



Reconstruction is done several times during whole calibration procedure.
Its done on full or representative statistics of events with many DB updates

Detector Control System



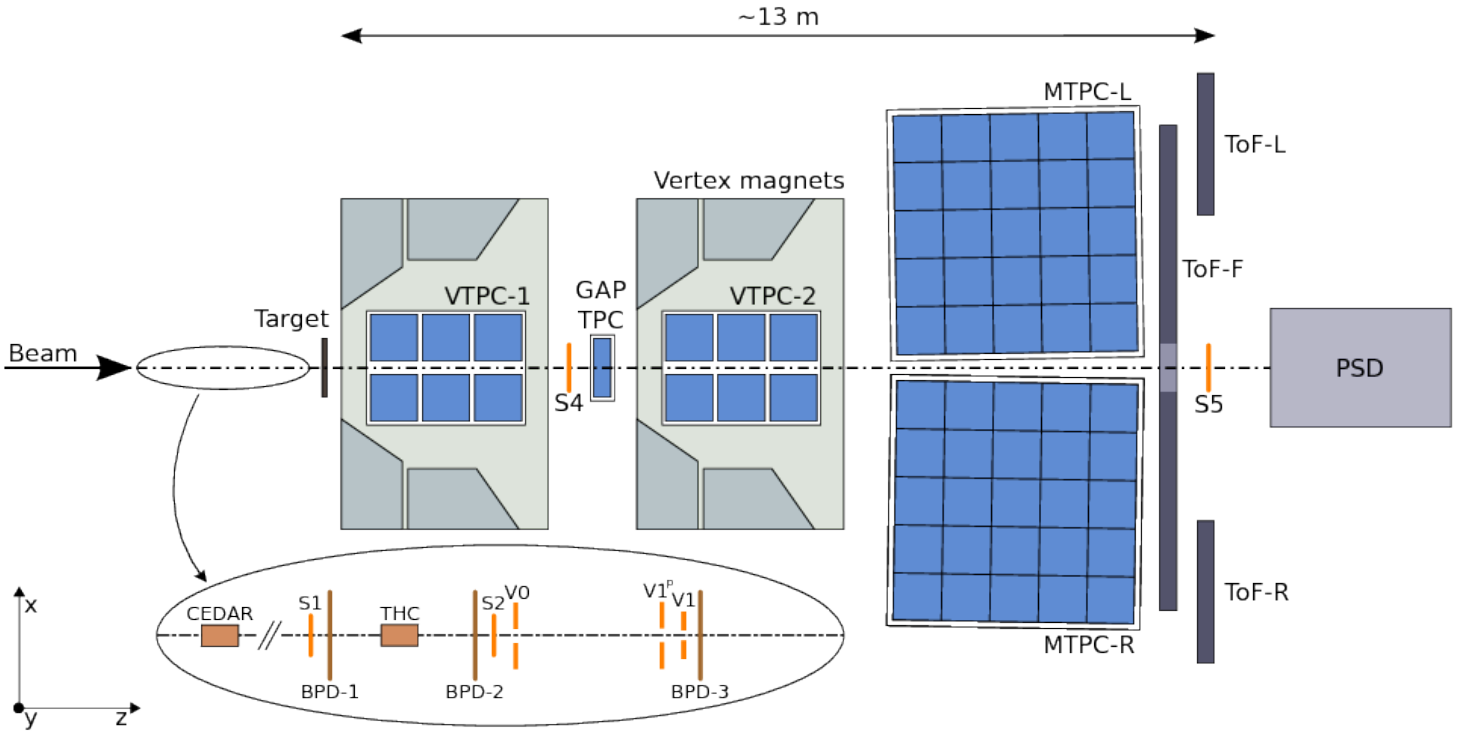
TPC gas mixture parameters:

- temperature
- pressure
- water and oxygene content
- drift velocity
- amplification
- ....

DCS is responsible for online monitoring, controling and writting to Database the working conditions of the detectors.

Calibration tasks in the chain

Calibration tasks using NA61/SHINE data are run sequentially detector by detector and parameter by parameter.

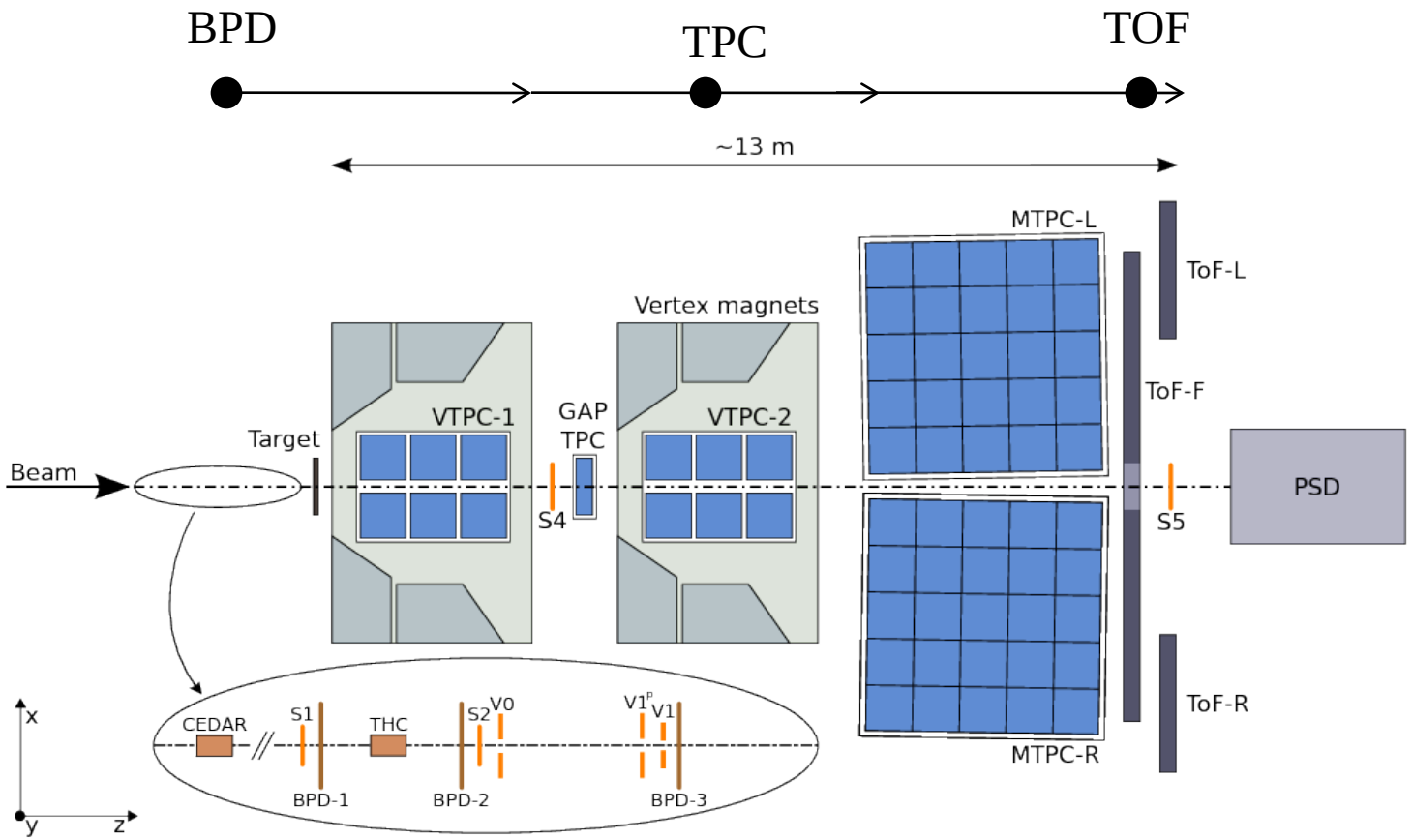


Several tasks are run independently of chain using data collected during dedicated mesurements with SPS beam or radioactive sources.

Calibration tasks in the chain

The chain starts from upstream beam detectors (BPD) and ends on Time Of Flight (TOF) walls.

The calorimeter (PSD) is calibrated independently.



Single task or even set of tasks is performed in an iterative process.

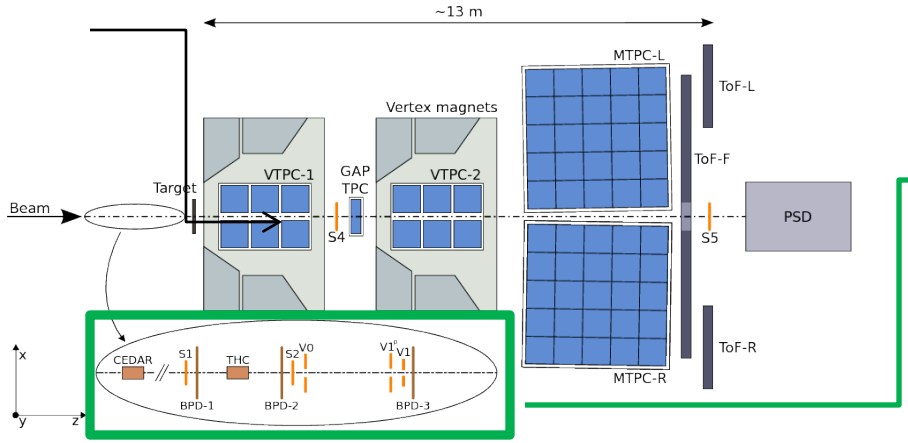
Main calibration tasks in the chain

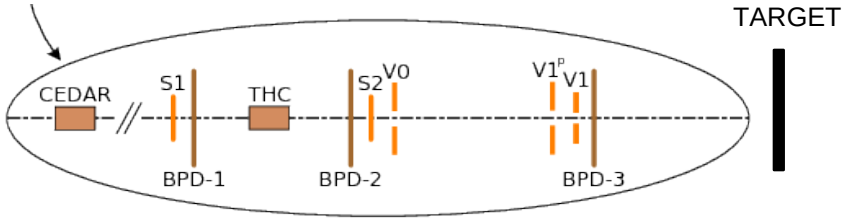
1. BPD (BPD 1,2,3) internal alignment
2. TPC calibration
   2.1 Vdrift, T0
   2.2 Residual corrections to cluster positions
3. BPD-TPC alignment
4 TPC energy loss (dE/dx) calibration
5. Magnetic field calibration
6. Vertex Detector (VD) calibration
7. TOF calibration

+

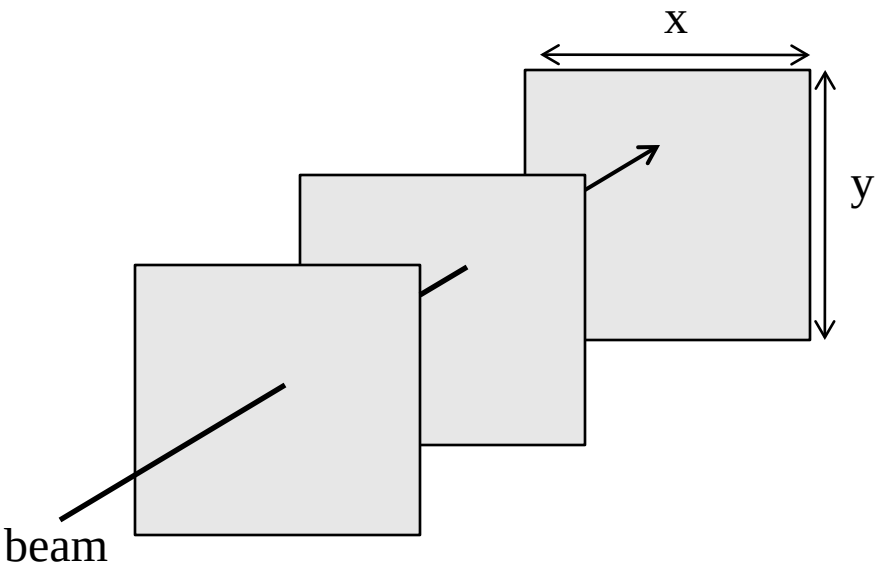
8. PSD calibration

BPD calibration





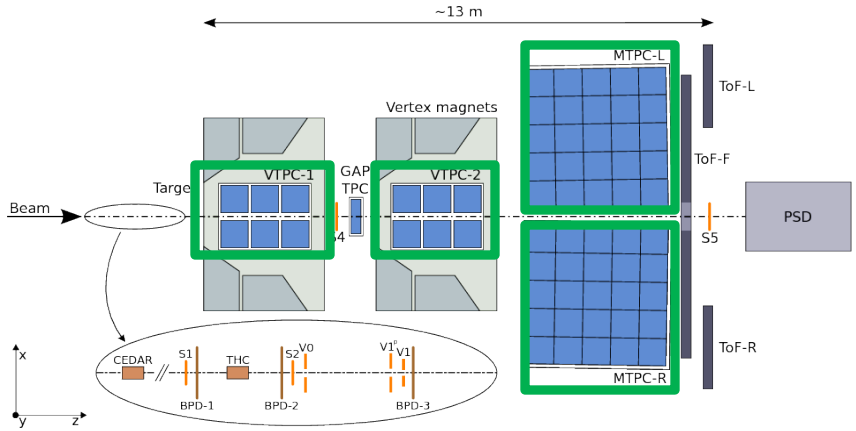
Initial BPD geometry is prepared based on survey and geometry from previous period.

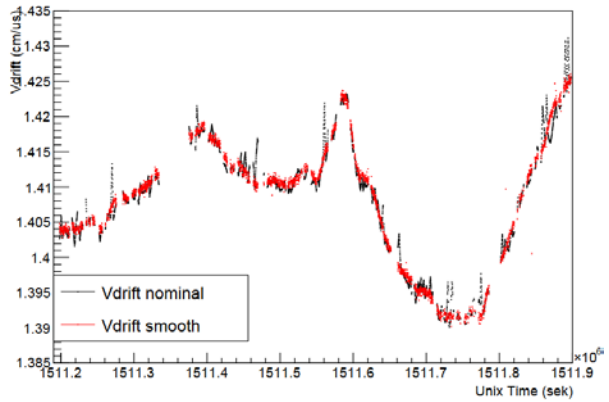


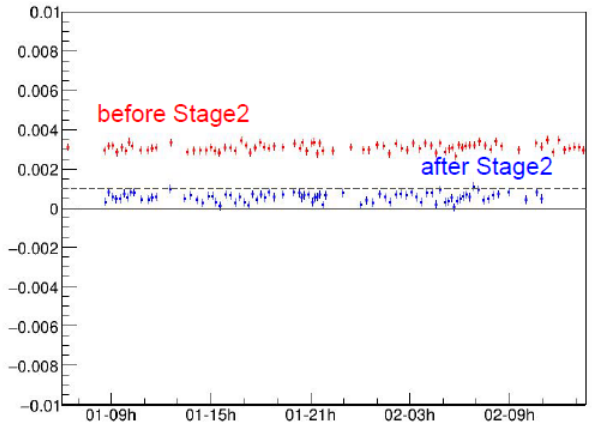
$\Delta x, \Delta y \rightarrow$ BPD new positions

After BPD calibration the set of 3 BPDs can be treated as single detector.

TPC calibration – Vdrift, T0





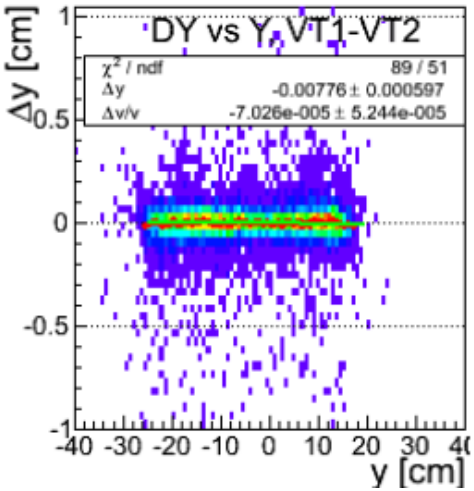


Initial TPC Vdrift, T0 are prepared based on DCS measurements and values used in previous data taking period.

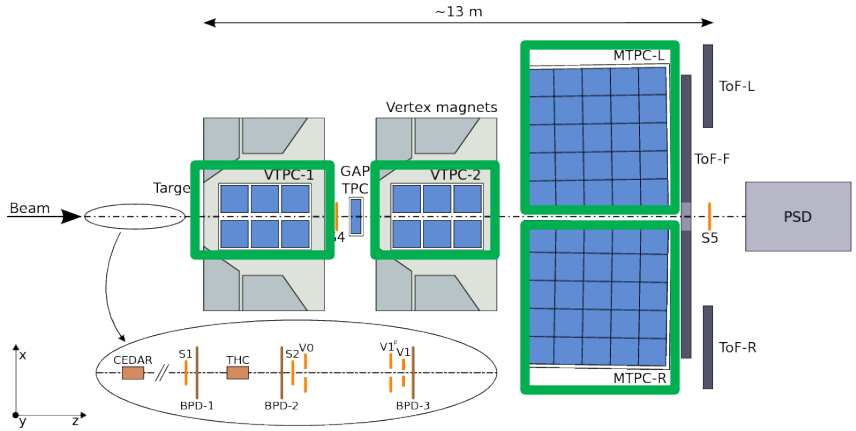
The procedure consists of several steps:

-TPC phase

- smoothing of DCS Vdrift(t) distributions
- scaling Vdrift
- global and chamber T0 corrections
- alignment validation

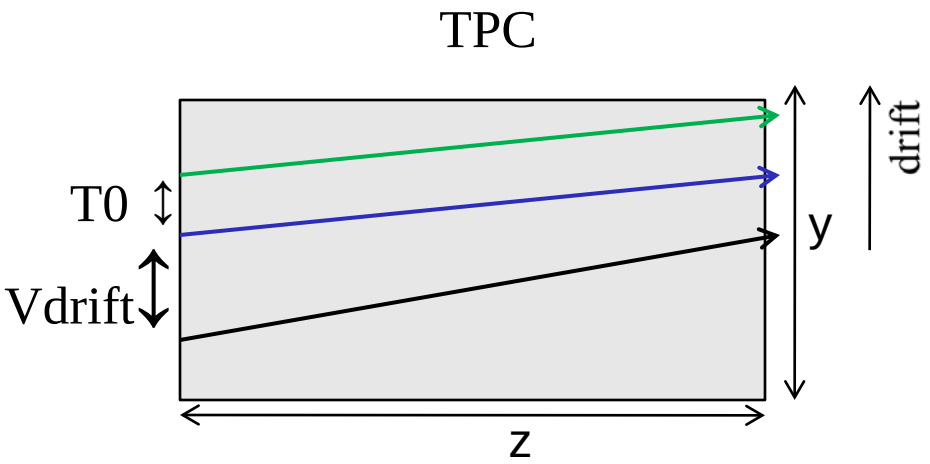


TPC calibration – Vdrift, T0



Calibration changes shape (slope) of tracks (Vdrift) and y-location of measured points (T0) for every TPC.

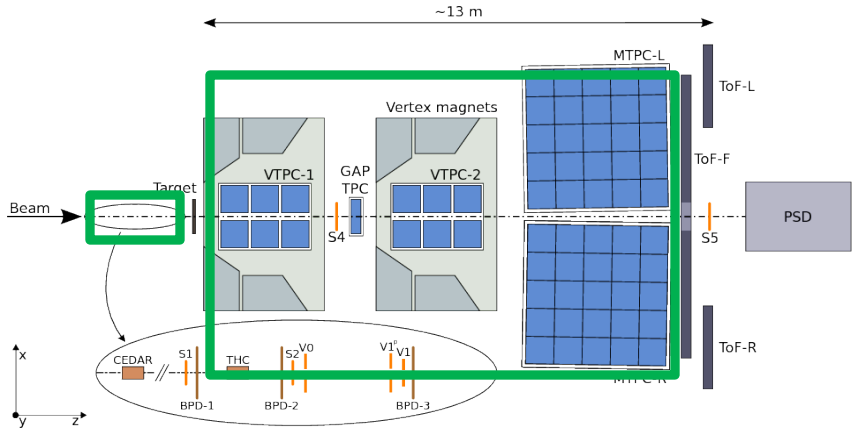
Precision of the method is on the level of 1‰.



new T0 for every TPCs

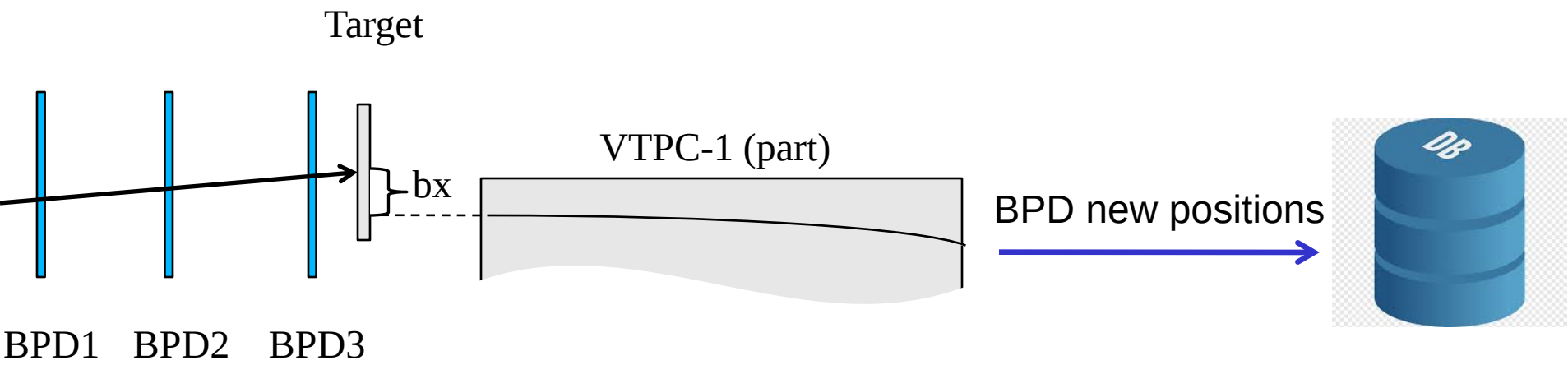
new Vdrift(t) for every TPCs

BPD-TPC alignment

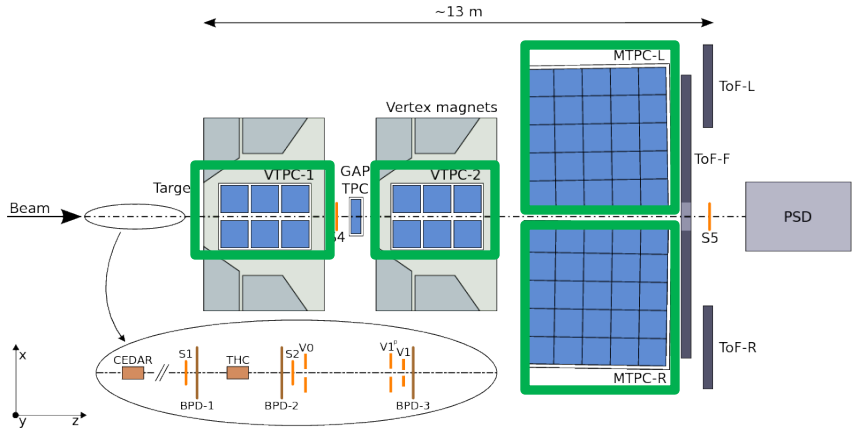


After independent calibration of BPD1,2,3 and TPC detectors they require relative alignment.

BPD-TPC alignment is based on Distributions of impact parameters bx, by of TPC tracks and BPD vertex at target Z position.

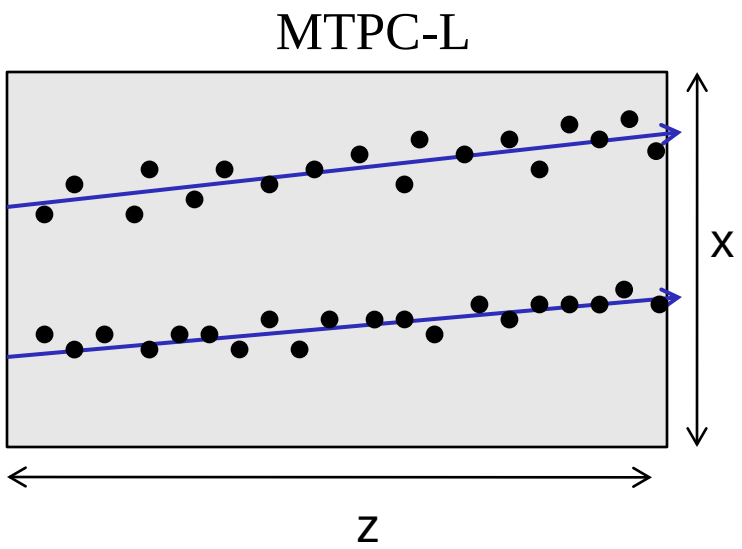


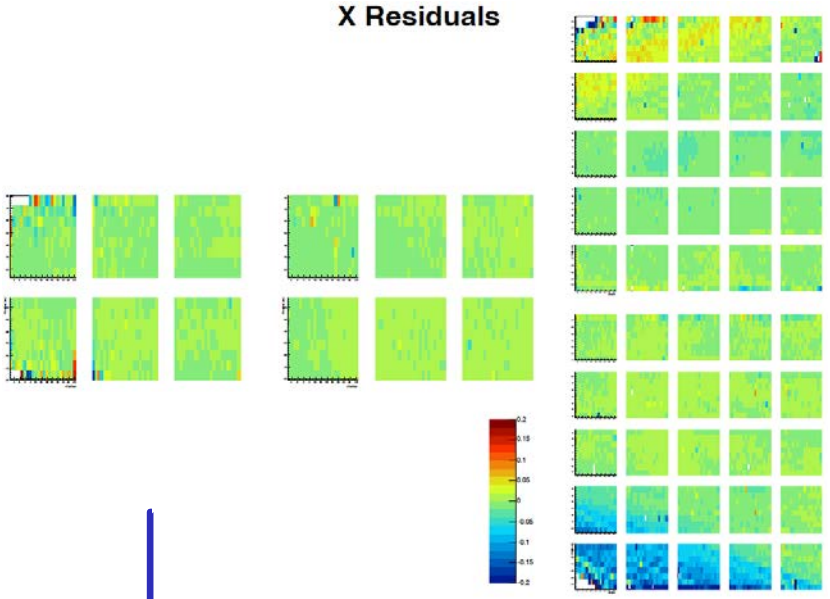
Residual corrections for TPC cluster positions



The calibration procedure creates 3D (x-y-z) map of systematic differences in x,y directions of cluster and track positions for all TPC pixels.

The map is created for many events and tracks.

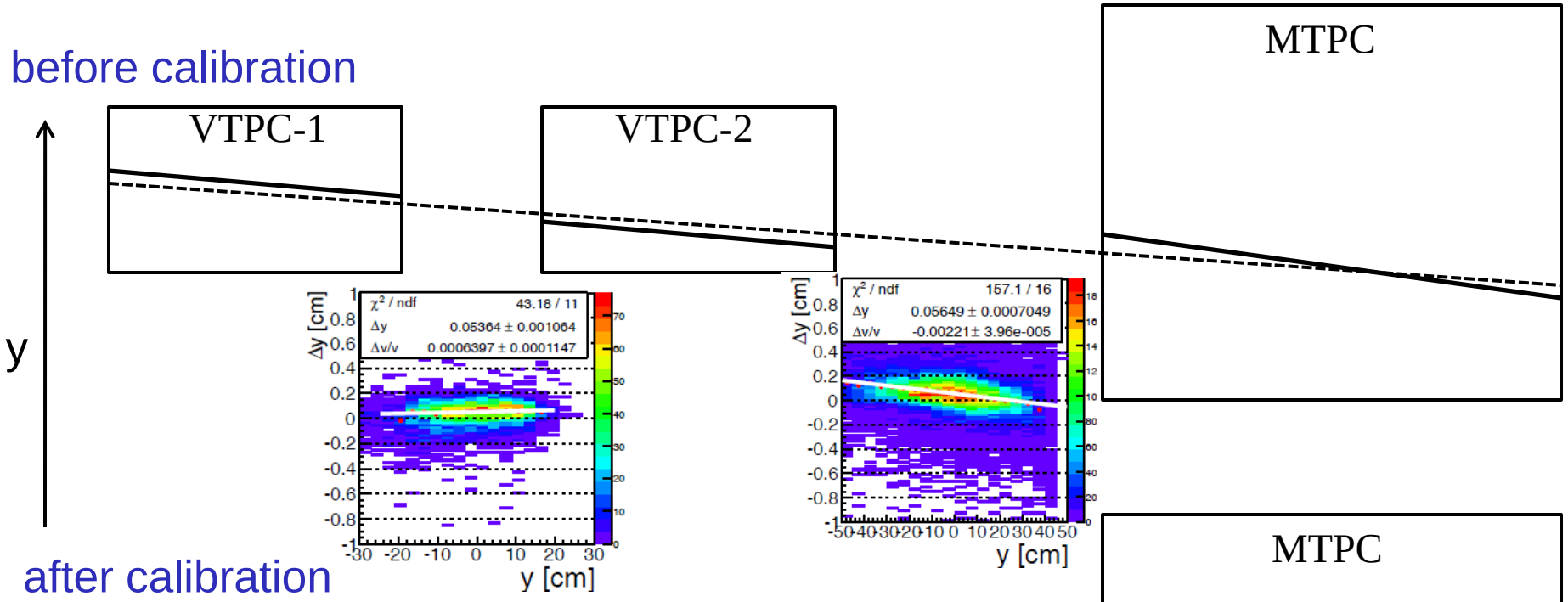




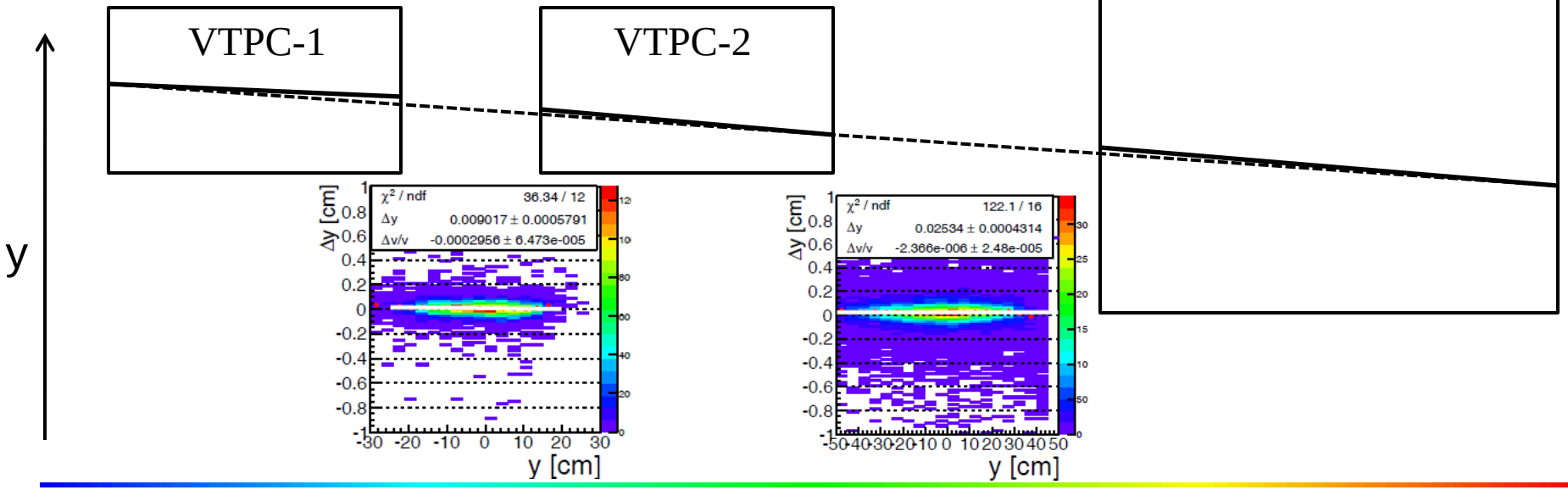
Cluster position corrections.

TPC calibration – influence on tracks

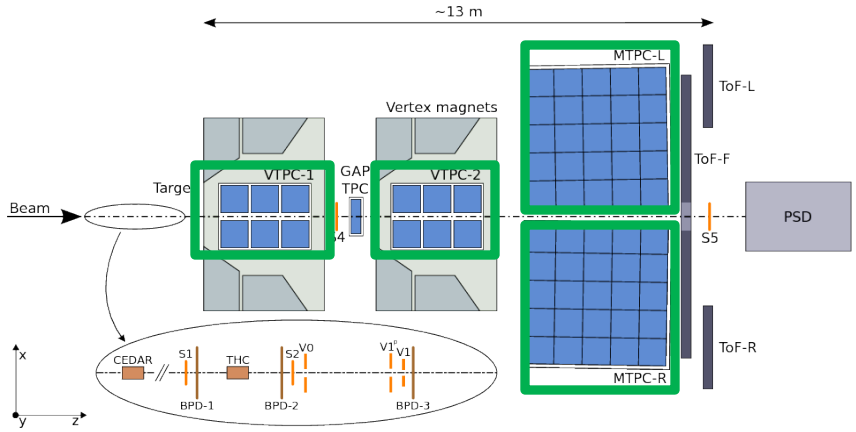
before calibration



after calibration

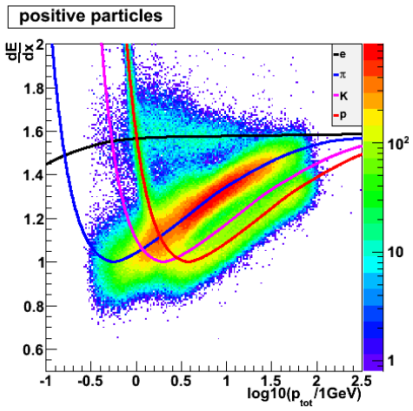


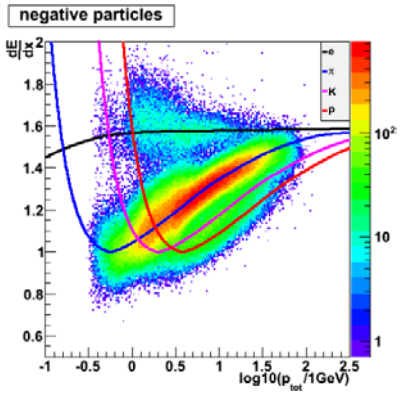
Energy loss (dE/dx) calibration.



Very complicated calibration procedure which provides values of energy loss (dE/dx) although TPCs measure only cluster charge.

It consists of :
- time dependence correction of gain variation for each TPC sector
- y dependence correction for charge loss during drift of electrons
- sector constance dependence correction (independent gain factor for every sector)

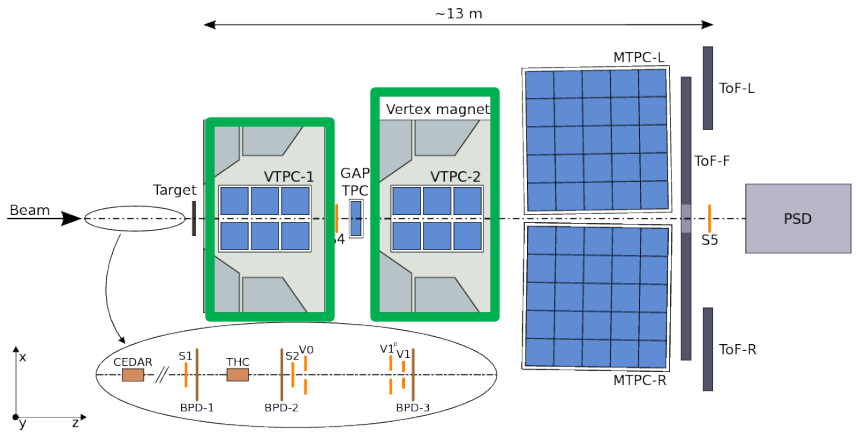




Calibration factors for all dependences and for every sector.

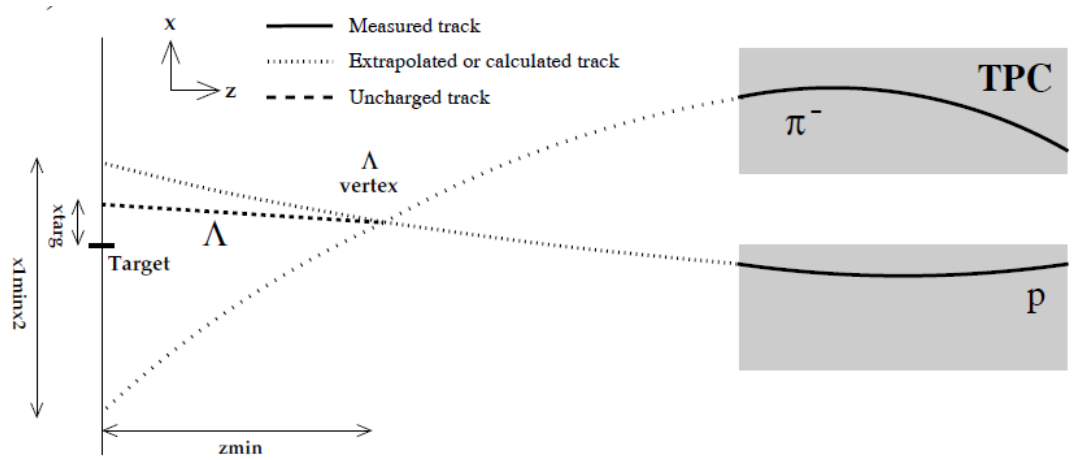
Quality assessment of the calibration
- resonable agreement with Bethe–Bloch dependence for various particle species

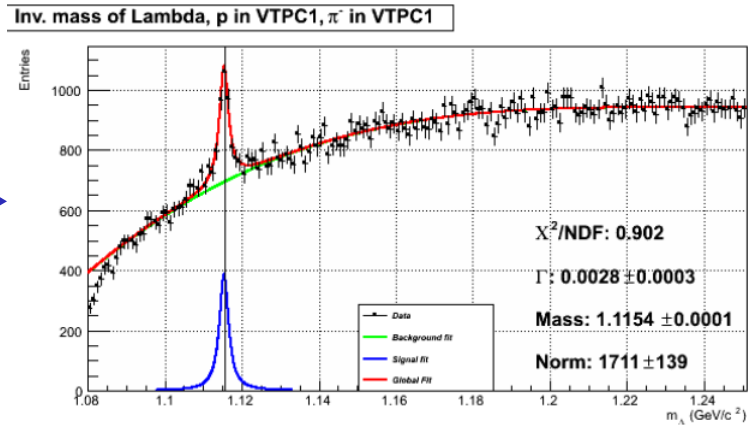
Magnetic field calibration



Calibration of magnetic field is based on scaling momentum of particles traveling trought VTPC1, VTPC2 and checking the invariant mass position for $K^0_s \rightarrow \pi^+ + \pi^-$ mesons and $\Lambda \rightarrow p + \pi^-$ hyperons.

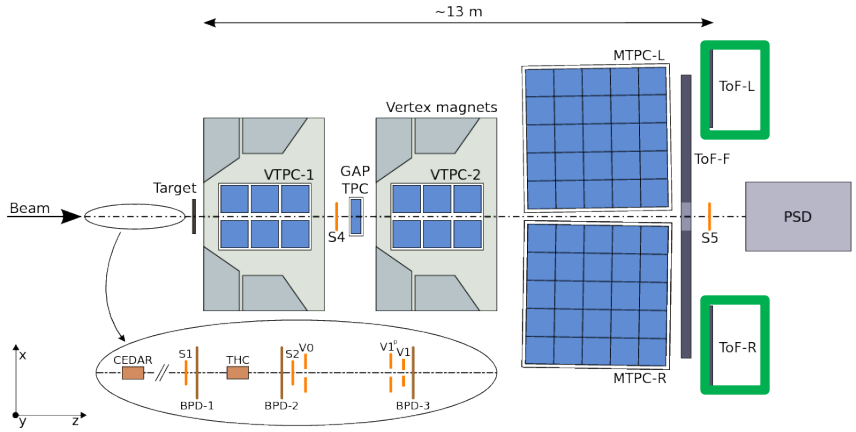
Comparison with PDG mass values provides scaling factors (VTPC-1, VTPC-2).





Correction factors for magnetic field.

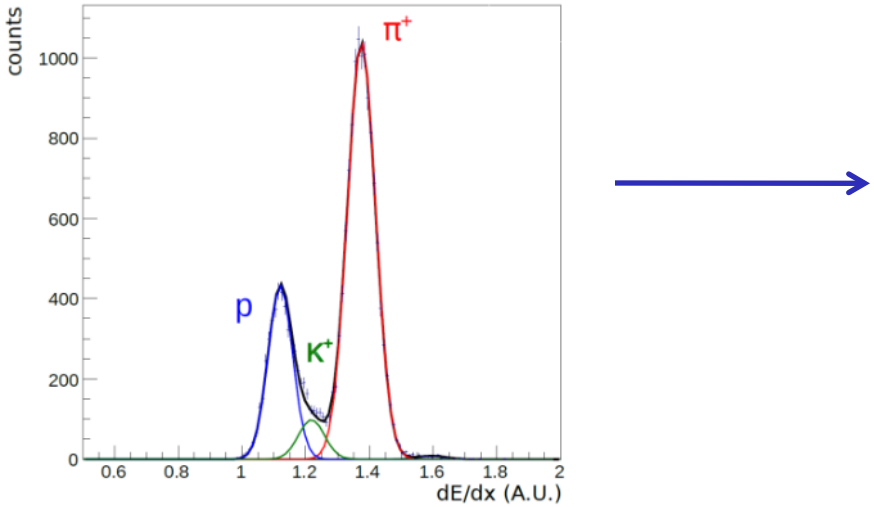
TOF-L/R calibration

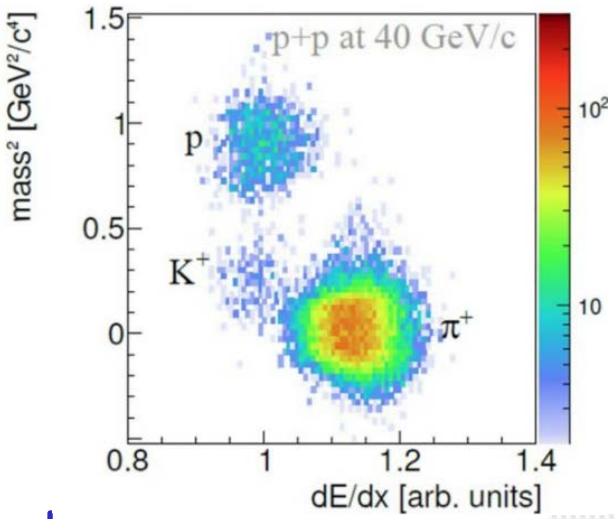


Computation of m^2 require measurements of momentum(p), length(L) and time-of-flight(t)

$$m^2 = \frac{p^2}{c^2}\left(\frac{c^2\,t^2}{L^2} - 1\right)$$

Measured time depends on many factors. Calibration decouples these factors and provides corrected time-of-flight.



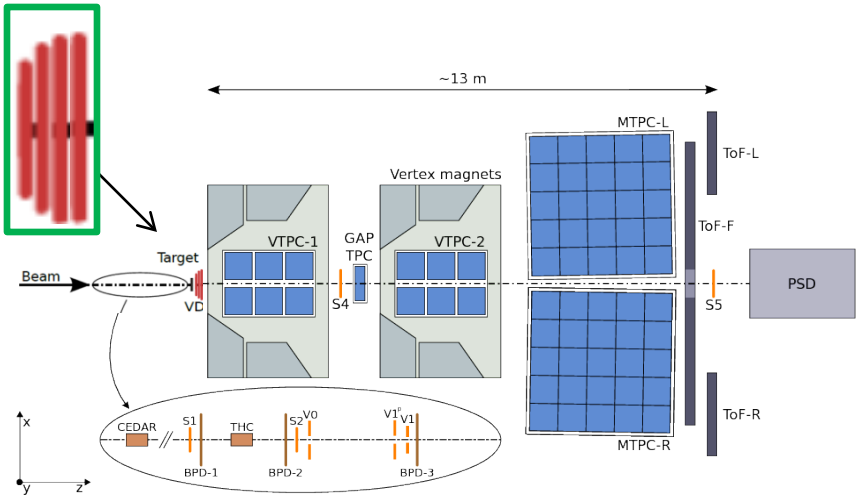


The sample of pions selected by TPC dE/dx is used for TOF calibration.

Corrections for time measured by TOF.

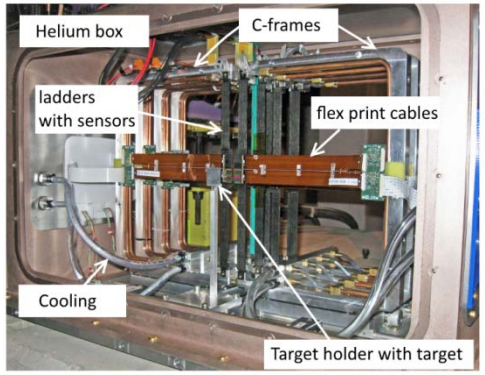
Pixel-wise and event-by-event corrections.

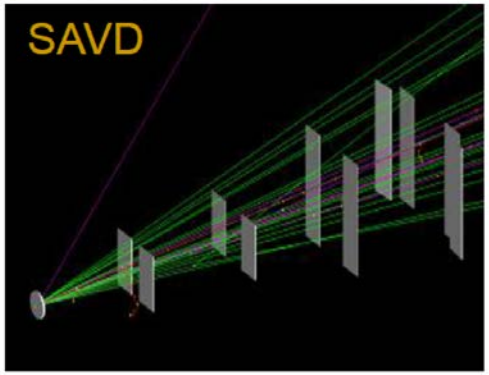
Vertex Detector calibration



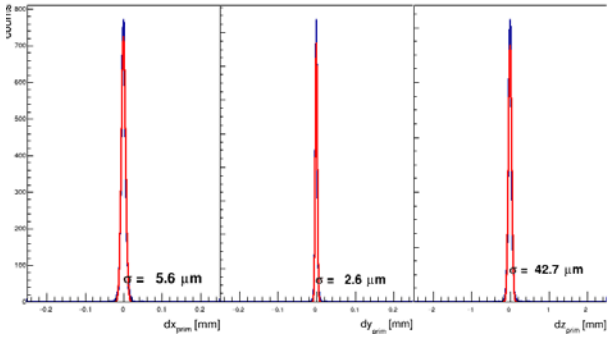
Calibration in 3 steps:

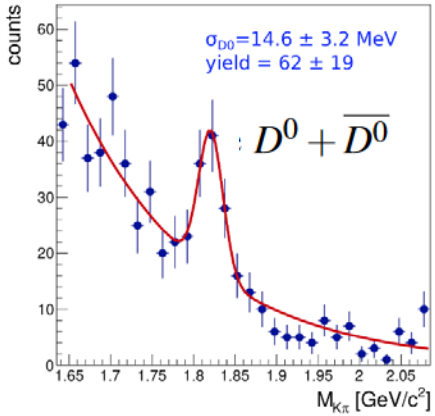
- Arm position calibration positions based on vertices from both arms and rotations in respect to beam direction - precision of several μm and μrad
- VD position calibration relative to TPC based on VD and TPC vertices positions
- Track matching parameters VD-TPC





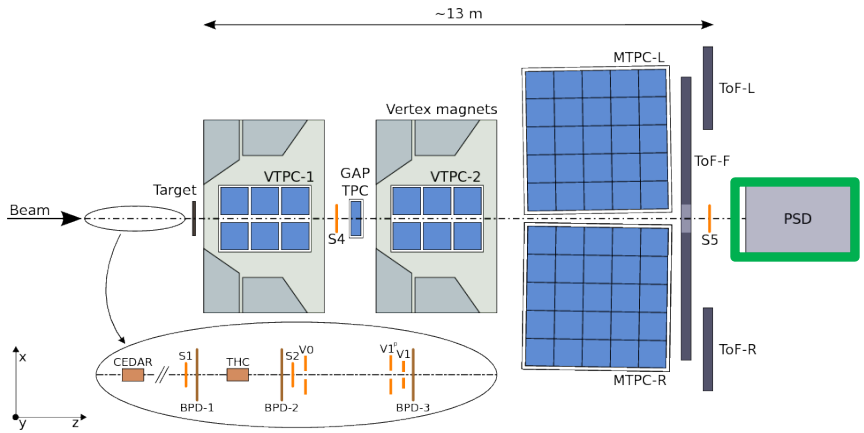
VD resol: σ_x = 2.8 μm, σ_y = 1.3 μm, σ_z = 21 μm.





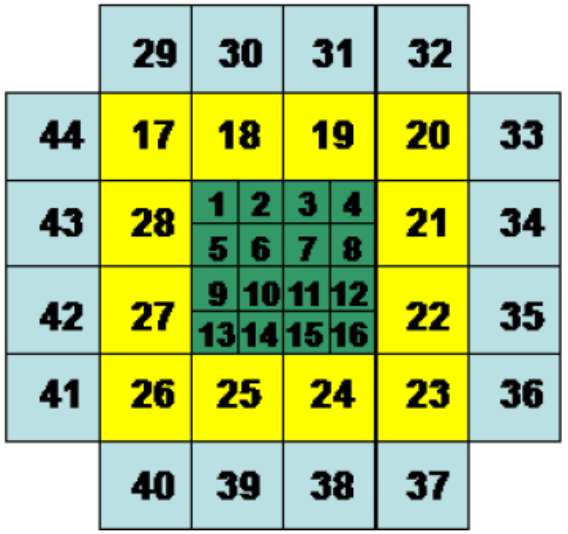
Corrections for arm and VD positions, rotation angles

PSD calibration

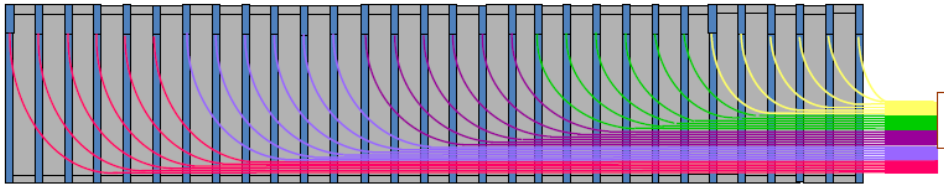


Calibration of PSD is based on:

- measurements using dedicated beams of miuons and protons focused on single modules or clusters of modules

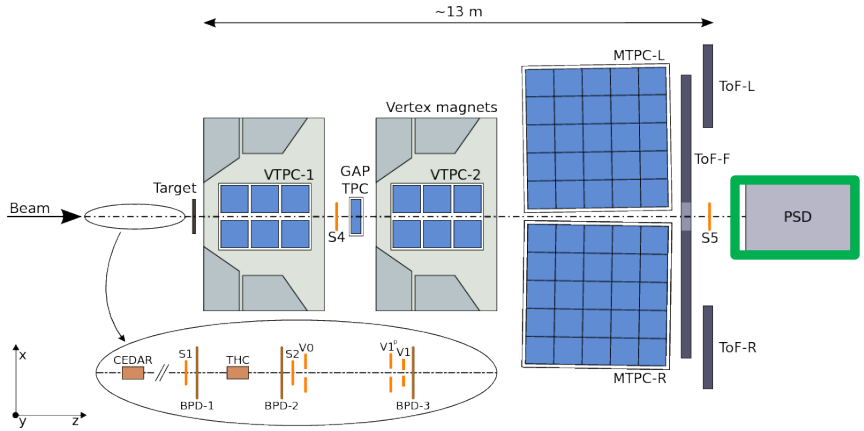


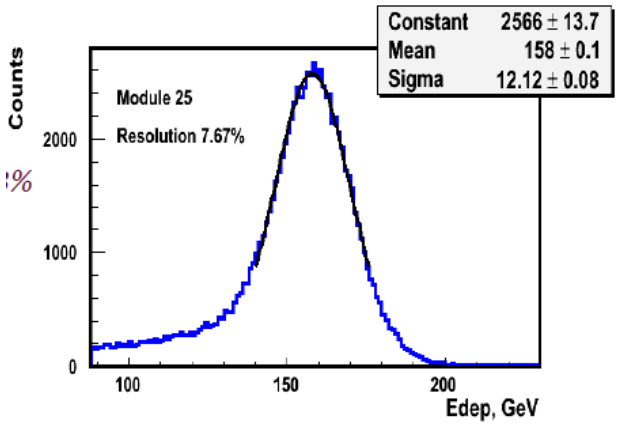
10 simultaneously measured amplitudes/module

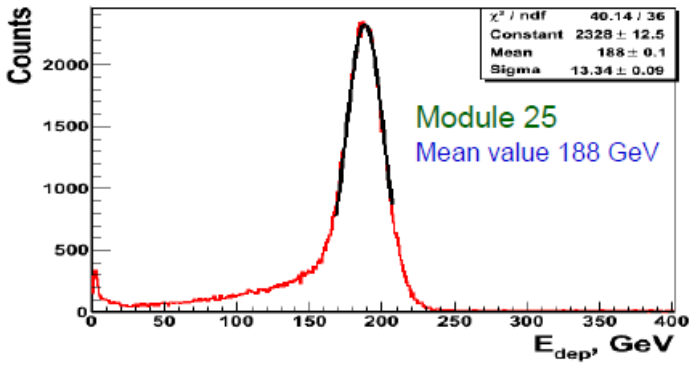


10 calibration parameters to be determined/module

PSD calibration

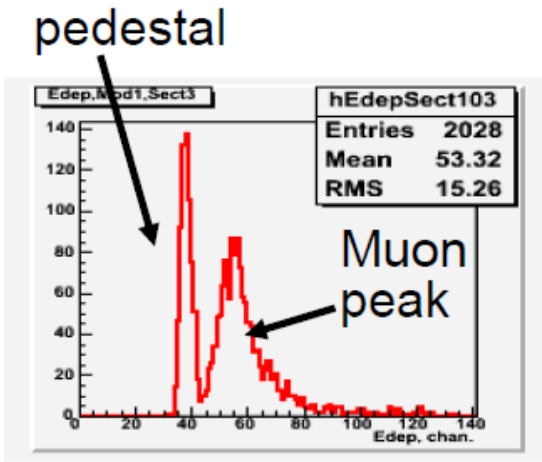






- calibration with muon beam

  Determination of muon energy deposition in each section



Calibration parameter is the ratio of muon energy deposition to ADC value.

- scan of the modules with proton beam, normalization of calibration parameters in single module to beam energy

→ matrix of equations for section parameters

and scan of module clusters

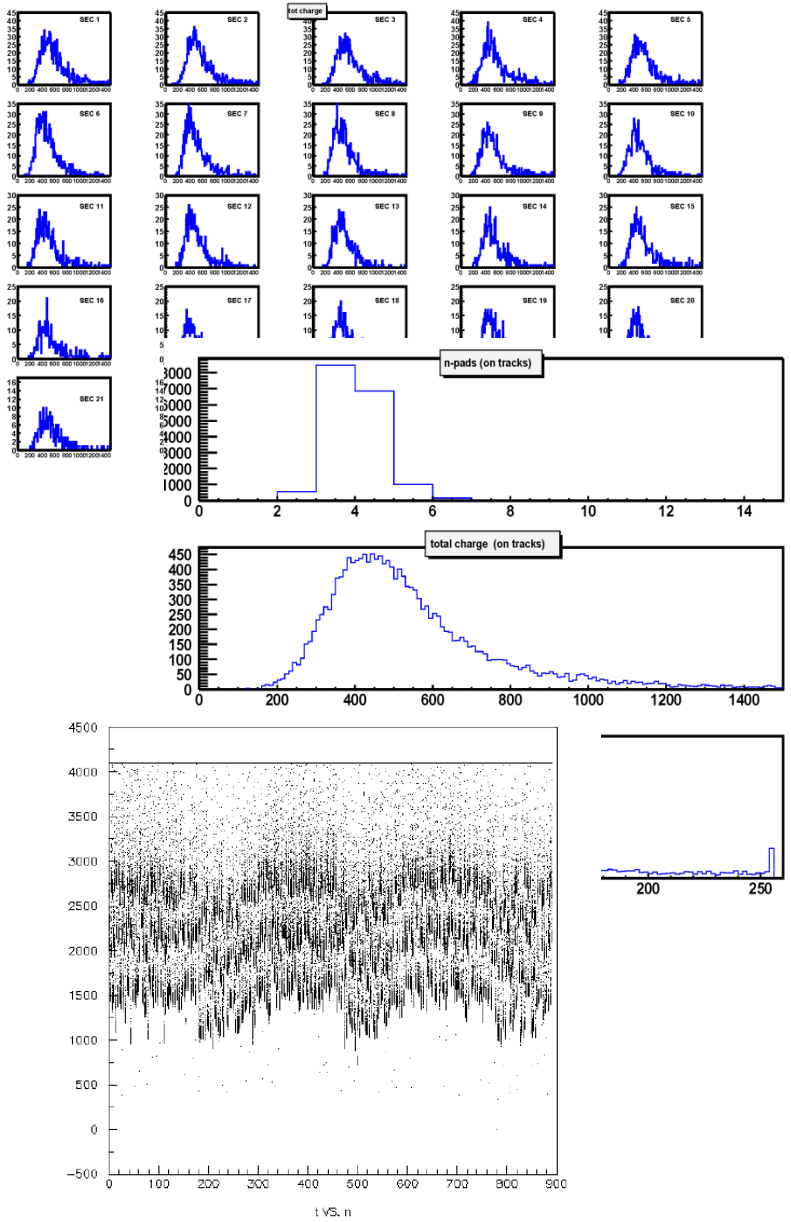
Summary

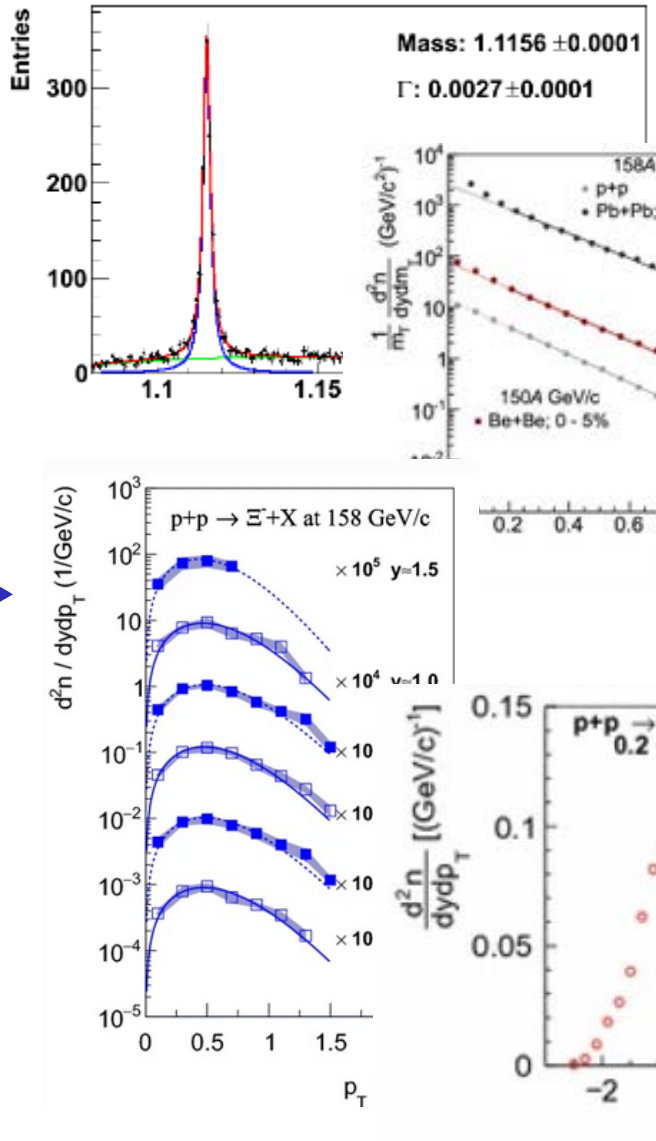
Results of calibration procedure:

- corrected positions of points in TPC
- more precisely reconstructed tracks
- more global, long tracks
- better fitted vertices
- corrected measurements of particle time of flight
- more realistic energy measured by calorimeter

It provides data ready for physical analysis.

From raw signals to physical values





Thank you