Computing systems for ALICE/LHC: run3 and beyond

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Outline

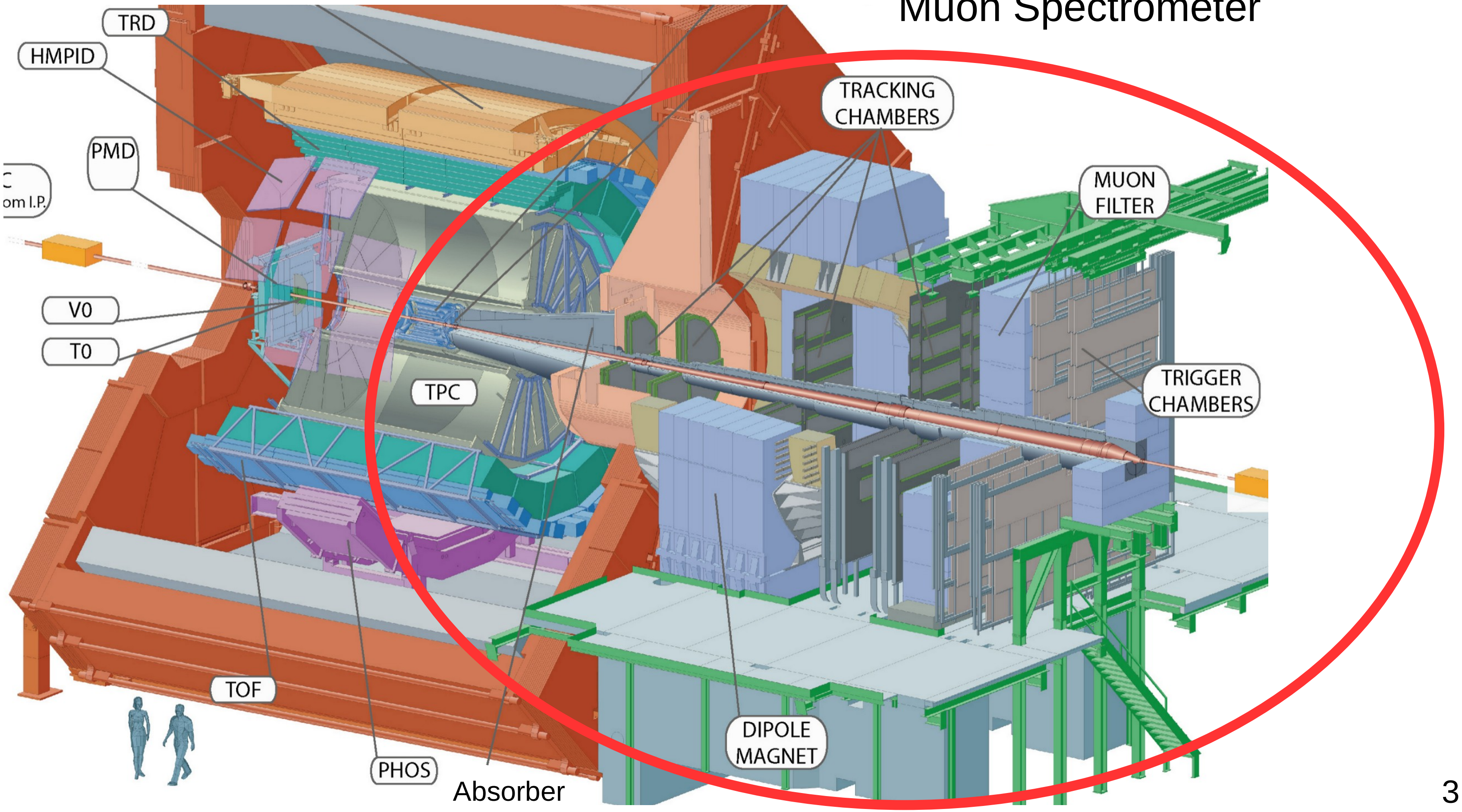
- Forward tracking in ALICE
  - Muon Spectrometer
  - Muon Forward Tracker
  - Run5 and beyond
- ALICE O2: ALICE On-line Off-line computing system
  - Forward tracking data model, tracking classes

Disclaimer: WIP/Preliminary results!

ALICE/LHC - A Large Ion Collider Experiment

- Quark-Gluon Plasma

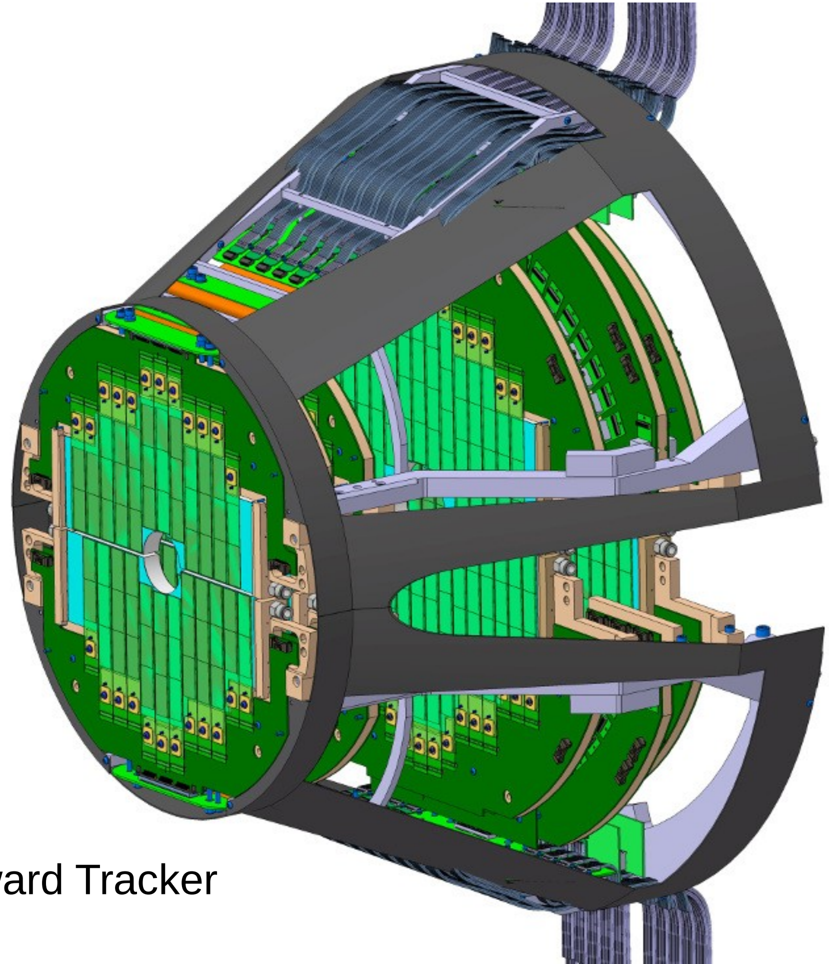
Muon Spectrometer



Absorber

Muon Forward Tracker

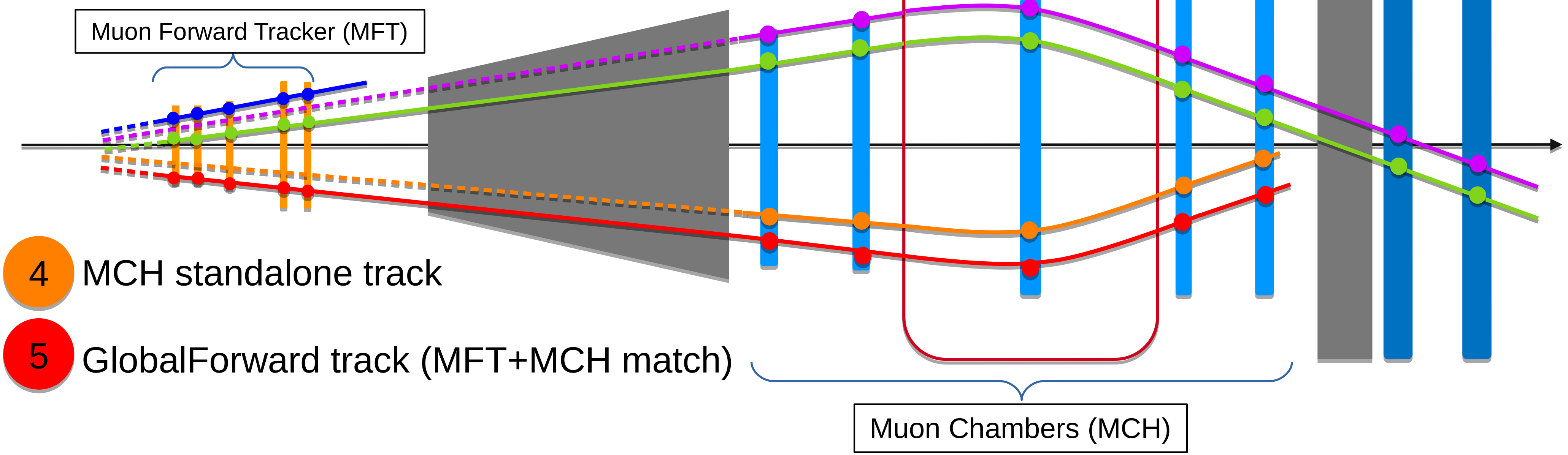
- Forward pseudorapidity: -3.6 < eta < -2.45
- 5 disks / 10 active layers
- 936 ALICE Pixel Detectors (ALPIDE)
  - MAPS: Monolithic Active Pixel Sensors
- Improve vertexing resolution at forward
  - B mesons studies
    - prompt/non-prompt dimuon separation



ALICE Collaboration, Technical Design Report for the Muon Forward Tracker
http://cds.cern.ch/record/1981898

RUN3 forward tracks overview*

1. MUON standalone track (Run2: MCH + MID)
2. MFT standalone track
3. GlobalMuon track (MFT+MCH+MID match)

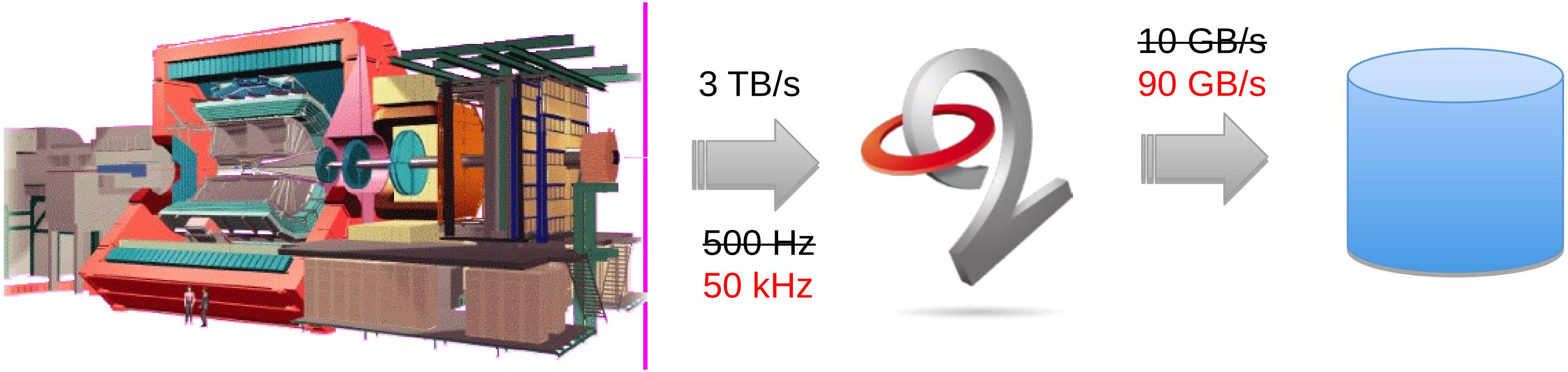


4. MCH standalone track
5. GlobalForward track (MFT+MCH match)

Online-Offline computing system

Run3 ALICE data taking objectives

- For Pb-Pb collisions:
  - Reach the target of ~~1~~ 13 nb^{-1} integrated luminosity in Pb-Pb for rare triggers.
  - The resulting data throughput from the detector has been estimated to be greater than 1TB/s for Pb–Pb events, roughly two orders of magnitude more than in Run 1



Predrag Buncic, Analysis in Run 3 (Offiline Week 08/11/2017)
https://indico.cern.ch/event/675166/

Challenges in forward tracking: new computing model at forward

- High multiplicity
  - Demand high efficiency tracking/reconstruction
  - New track model and dataformats at foward
- Matching MCH and MFT tracks
  - Separated by ~4 meters of graphite+concrete
- Performance studies for a new dedicated Heavy Ion Experiment at the LHC → ALICE 3 LOI

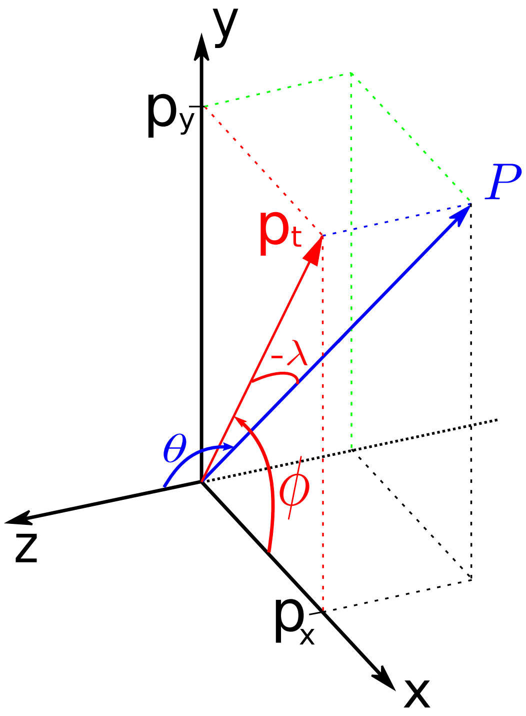
Forward track model and Coordinate System

- Helix track model

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} x_0 - \frac{H_z}{(q/p_{t0})k} \sin(\phi_0) \cos\left(\frac{(q/p_{t0})\Delta z k}{tan\lambda_0}\right) + \frac{H_z}{(q/p_{t0})k} \sin(\phi_0) + \frac{\cos(\phi_0)}{(q/p_{t0})k} \sin\left(\frac{(q/p_{t0})\Delta z k}{tan\lambda_0}\right) \\ y_0 + \frac{H_z}{(q/p_{t0})k} \cos(\phi_0) \cos\left(\frac{(q/p_{t0})\Delta z k}{tan\lambda_0}\right) - \frac{H_z}{(q/p_{t0})k} \cos(\phi_0) + \frac{\sin(\phi_0)}{(q/p_{t0})k} \sin\left(\frac{(q/p_{t0})\Delta z k}{tan\lambda_0}\right) \\ \Delta z + z_0 \end{bmatrix}$$

$$k = 0.3\,|B_z| \qquad H_z = \frac{B_z}{|B_z|} \qquad \theta = -\frac{(q/p_{t0})\Delta z k}{tan\lambda_0}$$

- State vector / coordinate system: $\vec{s} = (x, y, \phi, \tan\lambda, q/p_t)$
  - $\phi \rightarrow$ p_t direction (azimuth)
  - $\lambda \rightarrow$ Complementary polar angle:



$$\lambda = \frac{\pi}{2} - \theta_{\text{Polar}}$$

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O2 implementation of forward tracks

- TrackParCovFwd Class
  - Data members: parameters & covariances matrix
  - Methods
    - Track propagation (analytic)
    - Multi coulomb scattering effects
    - Kalman filter update
- Used by MFT standalone tracks and GlobalMuonTracks
  - Global Muon Tracks in separate repository

Kalman filter:

'p_k:'

$$\begin{bmatrix} x_k \\ y_k \\ \phi_k \\ tan\lambda_k \\ (q/p_{tk}) \end{bmatrix}$$

'm_k:'

$$\begin{bmatrix} x_m \\ y_m \end{bmatrix}$$

'V_k:'

$$\begin{bmatrix} \sigma_x^2 & 0 \\ 0 & \sigma_y^2 \end{bmatrix}$$

'H_k:'

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

'h_k:'

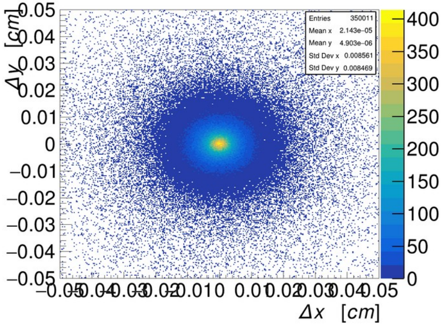
$$\begin{bmatrix} x_m & 0 & 0 & 0 & 0 \\ 0 & y_m & 0 & 0 & 0 \end{bmatrix}$$

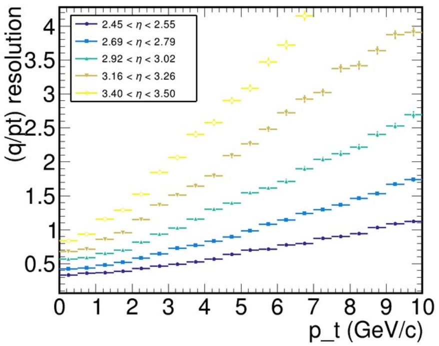
'K_k = CP*H_k.T*(V_k+H_k*CP*H_k.T).inv(): '

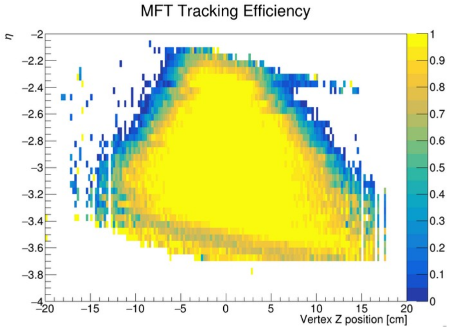
$$\begin{bmatrix}
\frac{cp_{00}\left(\sigma_y^2+cp_{11}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} - \frac{cp_{10}^2}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} & -\frac{cp_{00}cp_{10}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{10}\left(\sigma_x^2+cp_{00}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} \\
-\frac{cp_{10}cp_{11}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{10}\left(\sigma_y^2+cp_{11}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} & -\frac{cp_{10}^2}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{11}\left(\sigma_x^2+cp_{00}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} \\
-\frac{cp_{10}cp_{21}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{20}\left(\sigma_y^2+cp_{11}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} & -\frac{cp_{10}cp_{20}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{21}\left(\sigma_x^2+cp_{00}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} \\
-\frac{cp_{10}cp_{31}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{30}\left(\sigma_y^2+cp_{11}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} & -\frac{cp_{10}cp_{30}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{31}\left(\sigma_x^2+cp_{00}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} \\
-\frac{cp_{10}cp_{41}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{40}\left(\sigma_y^2+cp_{11}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} & -\frac{cp_{10}cp_{40}}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)} + \frac{cp_{41}\left(\sigma_x^2+cp_{00}\right)}{-cp_{10}^2+\left(\sigma_x^2+cp_{00}\right)\left(\sigma_y^2+cp_{11}\right)}
\end{bmatrix}$$

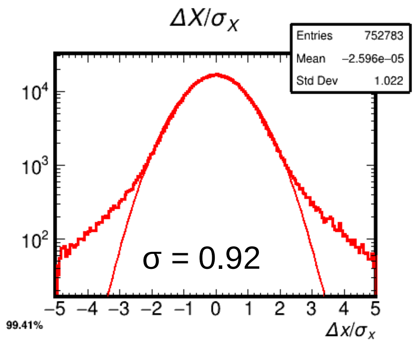
MFT tracking performance evaluation

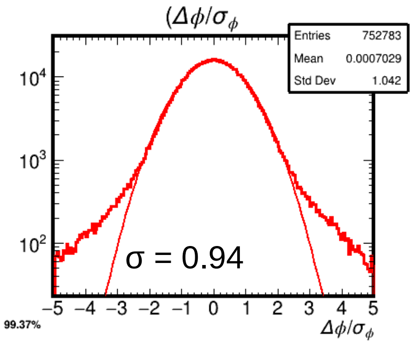
(WIP)

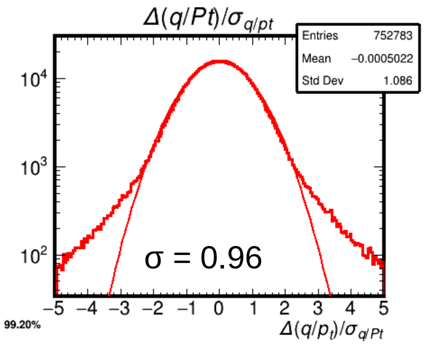


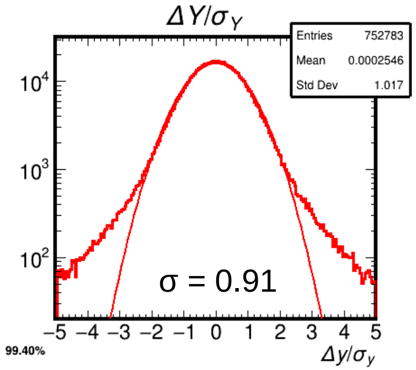


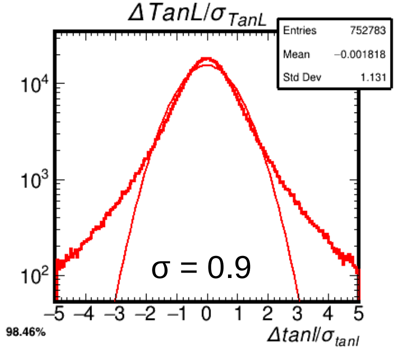


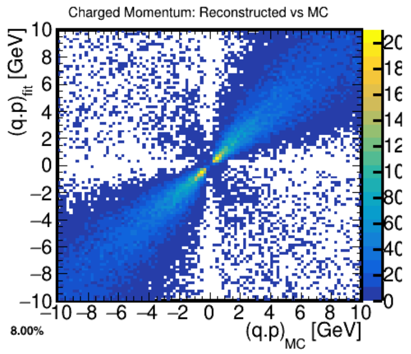










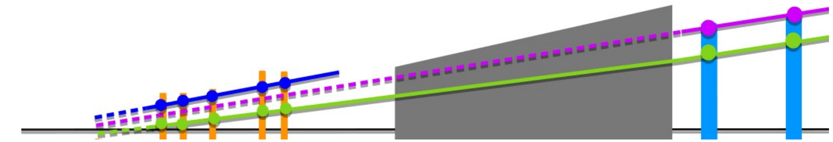


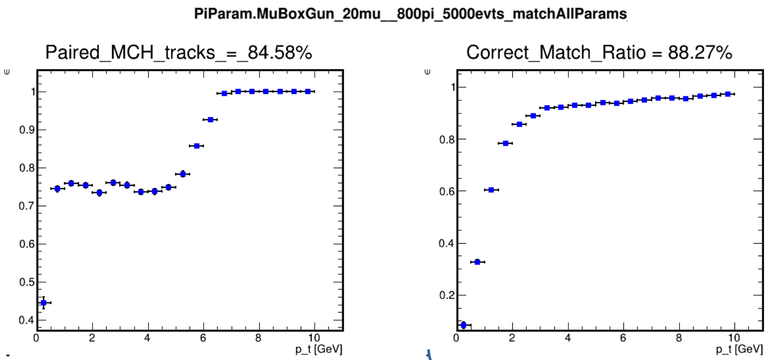
Global Muon Tracking

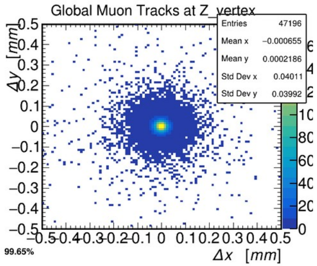
1 MUON standalone track (Run2: MCH + MID)

2 MFT standalone track

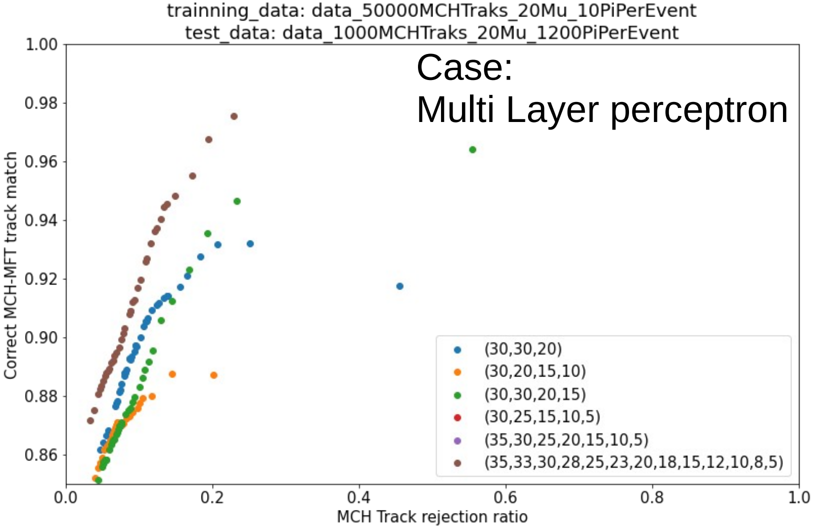
3 GlobalMuon track (MFT+MCH+MID match)







Chi² matching

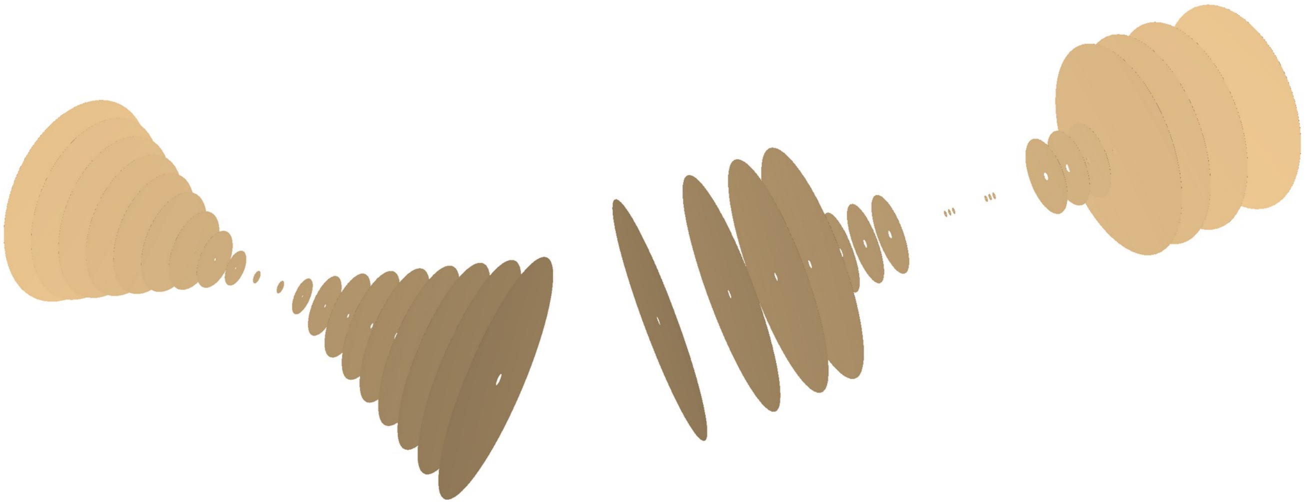


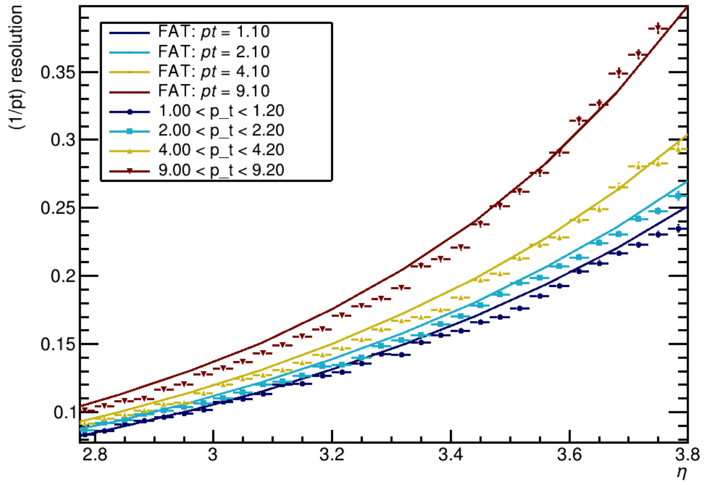
Machine Learning:

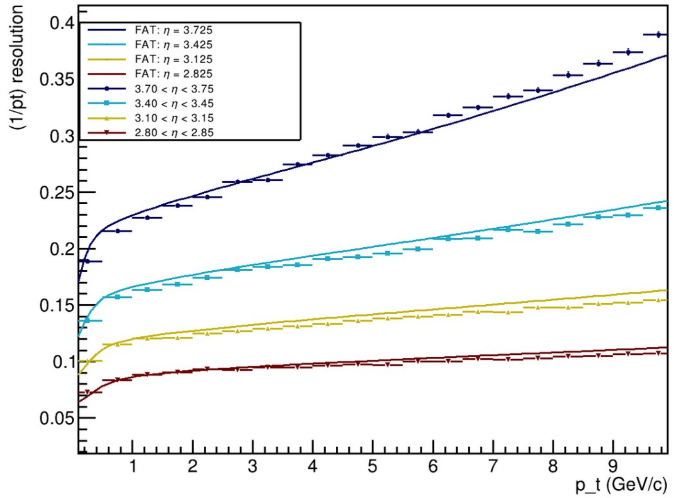
- Exploring novel applications of machine learning
  - track reconstruction and physics analysis
- Matching interface with ML Libraries
  - Root TMVA
  - SciLearn Kit

Forward tracker studies

- Performance evaluation and layout optimization of next generation tracker for RUN5 and beyond.







Summary

- ALICE/LHC demands a new computing system for run3 and beyond
- GEFAE is exploring the limits of forward tracking by addressing several forward-related computing challenges for ALICE
  - Track model, reconstruction, track matching, machine learning
  - ALICE 3 LOI

Backup slides

Physics interest for each topology of forward tracks (run3+)

1 • MUON standalone tracks (MCH+MID) → Any muon-based analysis in the "Run1+2" style.

2 • MFT standalone tracks (MFT only: any charged particle) → Multiplicity analyses, underlying event characterization at forward rapidity, UPC, …

3 • Global Muon Tracks (MFT+MCH+MID) → Any muon-based analysis in the "Run3+4" style.

4 • Particular case 1: MCH tracks without MID identification and without MFT information. Possible use: analyses targeting very soft muons, e.g. dimuon observables at vanishing pT in ultra-peripheral collisions.

5 • Particular case2: MCH+MFT tracks without MID identification. Possible use: as before, but with improved mass resolution for low-mass resonances and a better correction for the absorber effects.