Karlsruhe Institute of Technology

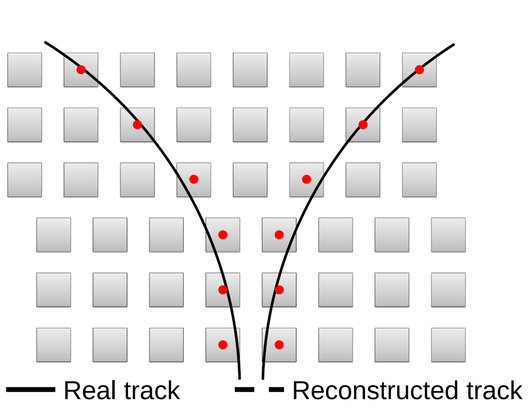
Institute of Experimental Particle Physics

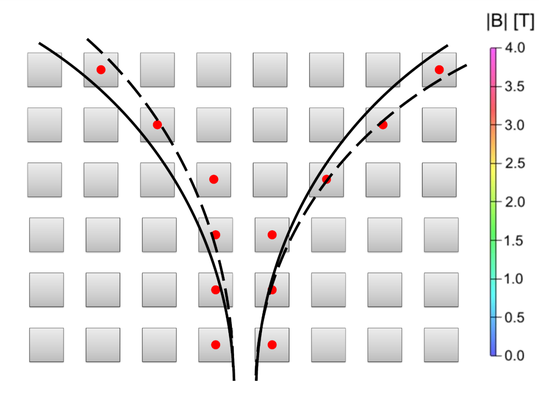
Momentum Scale and Resolution Calibration for Muons in CMS for Run 3

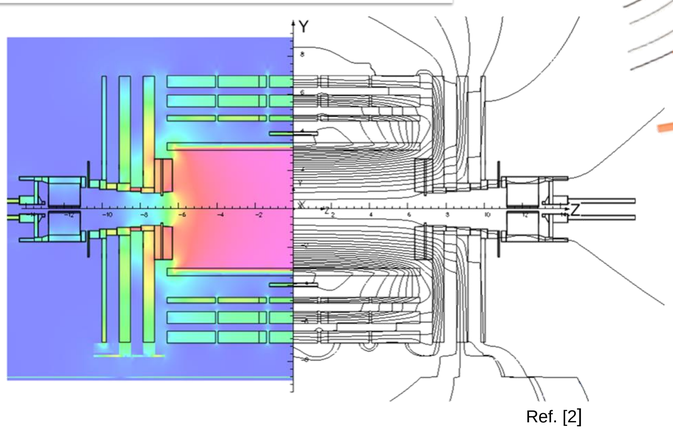
Dorian Guthmann* on behalf of the CMS Collaboration

Motivation

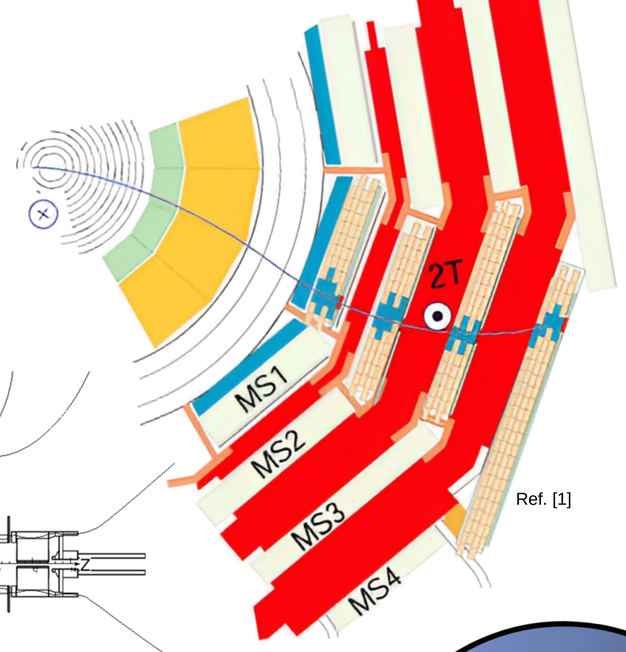
- Precise calibration of muon transverse momentum p_{T} is crucial for physics analyses
- p_{T} is measured via the curvature of the muon track in the magnetic field: $p_{\mathrm{T}} = Q \cdot r \cdot B$
- Despite highly accurate tracking systems, **small systematic biases on p_T** scale and resolution can be introduced by residual misalignments, slight variations in the magnetic field map, and simulation imperfections



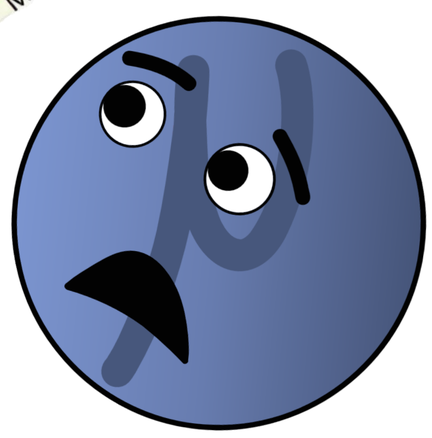




Ref. [2]



Ref. [1]



The Muon ScaReKIT

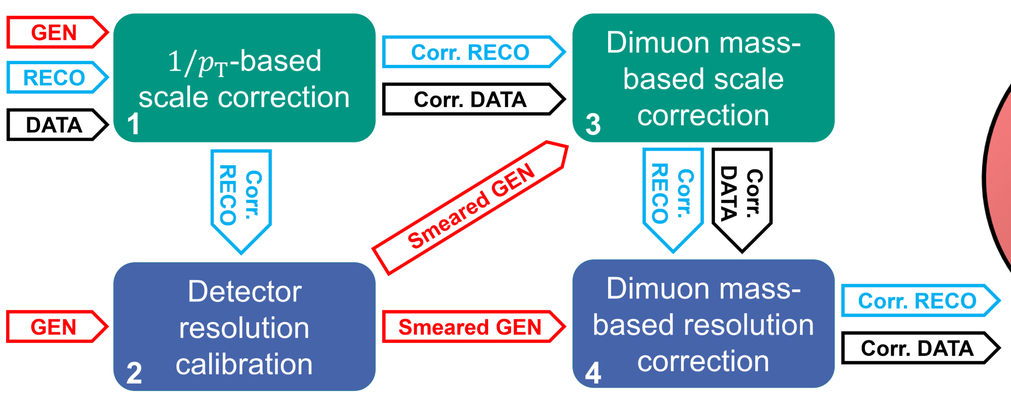
- Enables automated calculation of scale factors to **mitigate the biases in data and MC** based on Ref. [3]
- Utilizes muons from $Z \to \mu\mu$ or $\mathrm{J}/\psi \to \mu\mu$ **resonance decays** for calibration exploiting muon properties and information about the dimuon system
- Corrections are derived and applied as functions of detector coordinates
- A detailed description of the method can be found in Ref. [4]

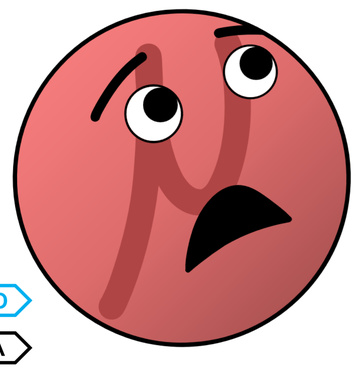
Scale Calibration

- A **multiplicative parameter $\kappa(\phi, \eta)$**, which accounts for magnetic field inaccuracies, and an **additive parameter $\lambda(\phi, \eta)$**, which accounts for misalignment, are defined for data and MC

$$\left(\frac{1}{p_{\mathrm{T}}}\right)_{\mathrm{corr}} = \frac{\kappa(\phi,\eta)}{p_{\mathrm{T}}} + Q \cdot \lambda(\phi,\eta)$$

- $\kappa(\phi,\eta)$ and $\lambda(\phi,\eta)$ are initialized utilizing the curvature $(1/p_{\mathrm{T}})$ of the muon tracks and are iteratively fine tuned using the Z and J/ψ resonances in the dimuon spectrum

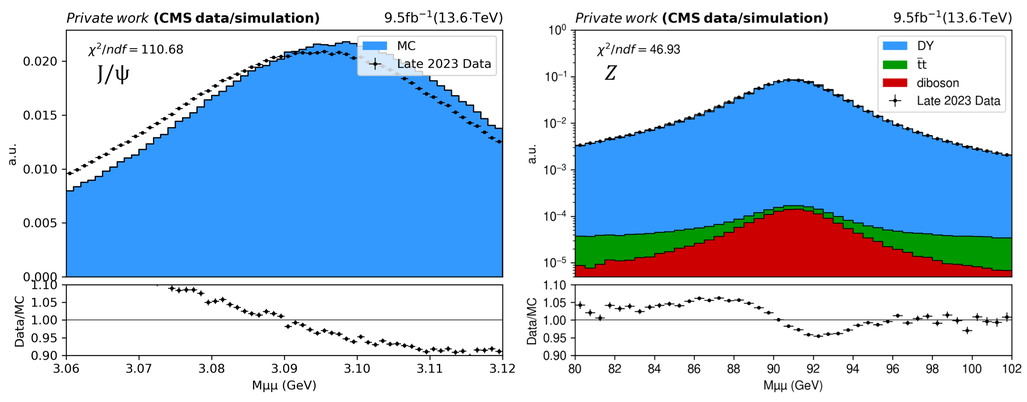




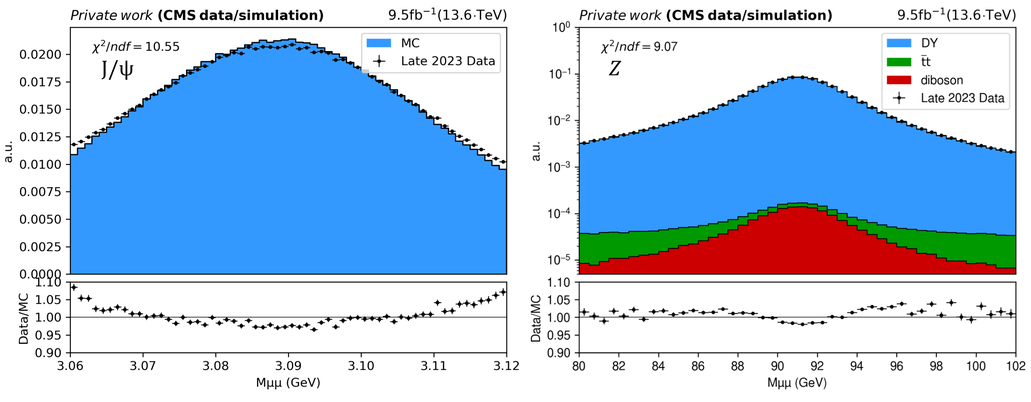
Resolution Calibration

- Detector resolution is determined by analyzing the distribution of $p_{\mathrm{T}}^{\mathrm{RECO}}/p_{\mathrm{T}}^{\mathrm{GEN}}$
- A residual smearing parameter is calculated by comparing the dimuon invariant mass distributions in data and simulation
- The resolution correction consists of 8 parameters in total **to apply a smearing on p_T^{RECO}** to ensure optimal agreement between real and simulated distributions

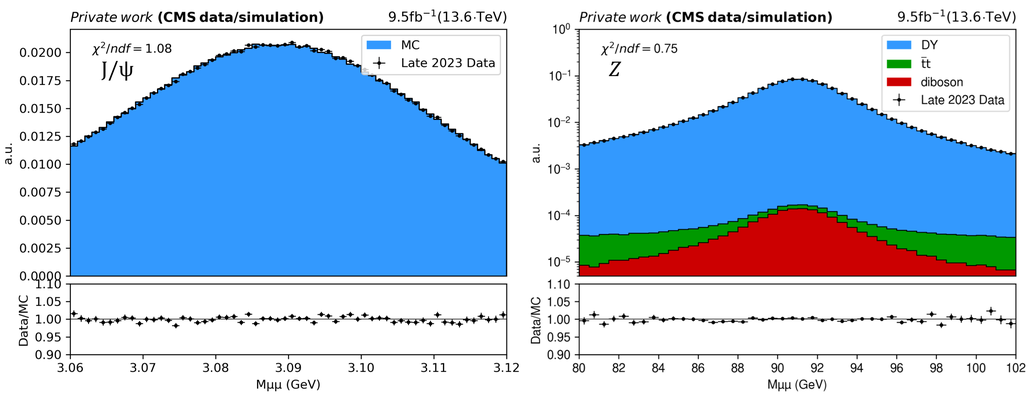
Dimuon Mass before Calibration



Dimuon Mass after Scale Calibration



Dimuon Mass after Scale & Resolution Calibration



*dorian.guthmann@kit.edu

References

[1] CMS Data Preservation & Open Access group “CMS Open Data Workshop lessons”. url: https://cms-opendata-workshop.github.io/workshop2024-lesson-cms-detector/images.html

[2] The CMS Collaboration. „Precise mapping of the magnetic field in the CMS barrel yoke using cosmic rays“. In: JINST 5 (2010), T03021. doi: 10.1088/1748-0221/5/03/T03021. arXiv: 0910.5530. url: https://cds.cern.ch/record/1215500

[3] Bodek et al. “Extracting muon momentum scale corrections for hadron collider experiments”. In: The European Physical Journal C 72.10 (Oct. 2012). url: http://dx.doi.org/10.1140/epjc/s10052-012-2194-8

[4] „Muon momentum calibration with proton-proton collisions at sqrt(s) = 13.6 TeV“. In: (2024). url: https://cds.cern.ch/record/2904701.