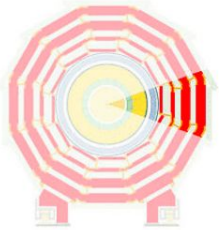
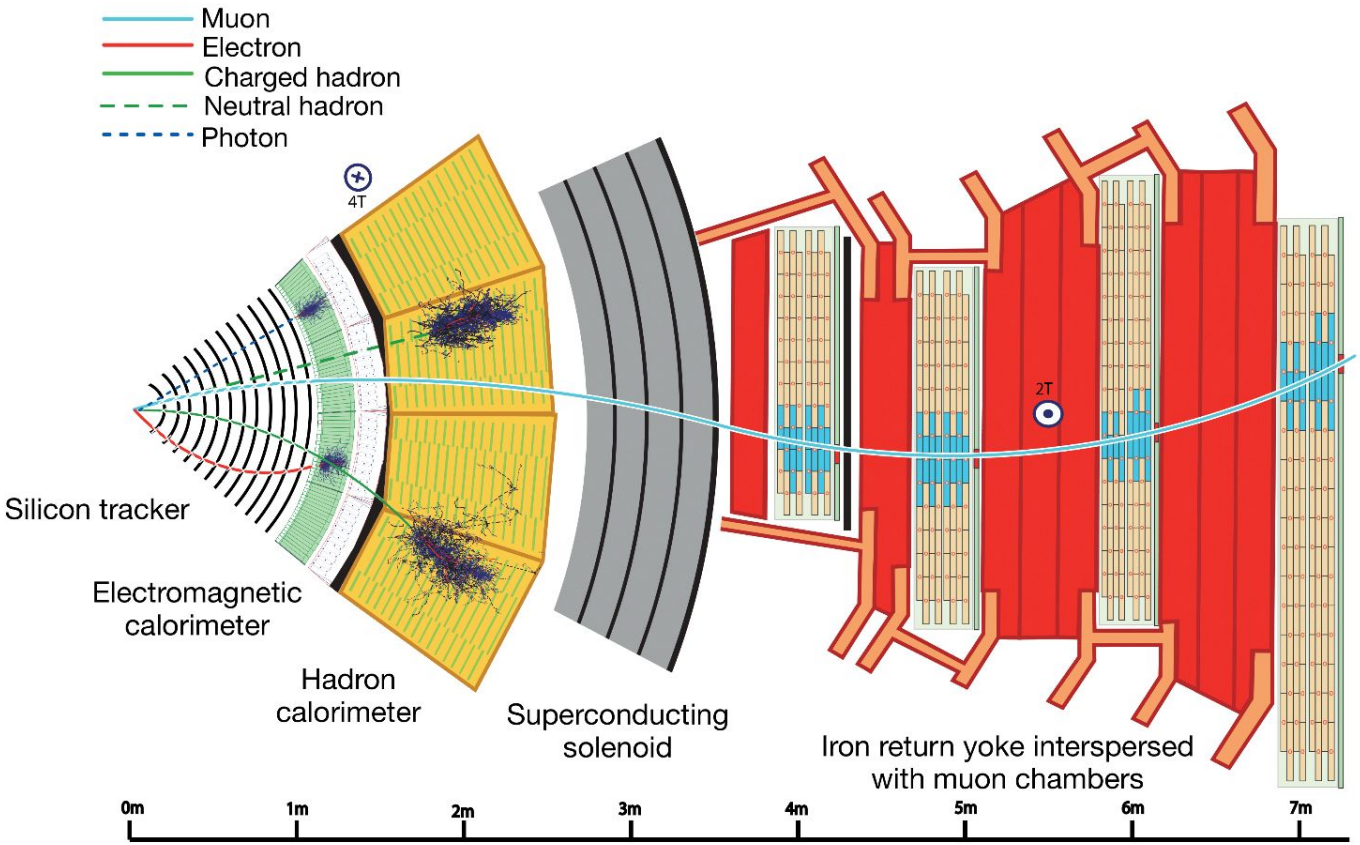
Assessing and optimizing Phase 2 muon reconstruction

Joseph Touzet master internship
Supervised by Florian Damas and Matthew Nguyen

Particle identification in CMS





Muon reconstruction in CMS

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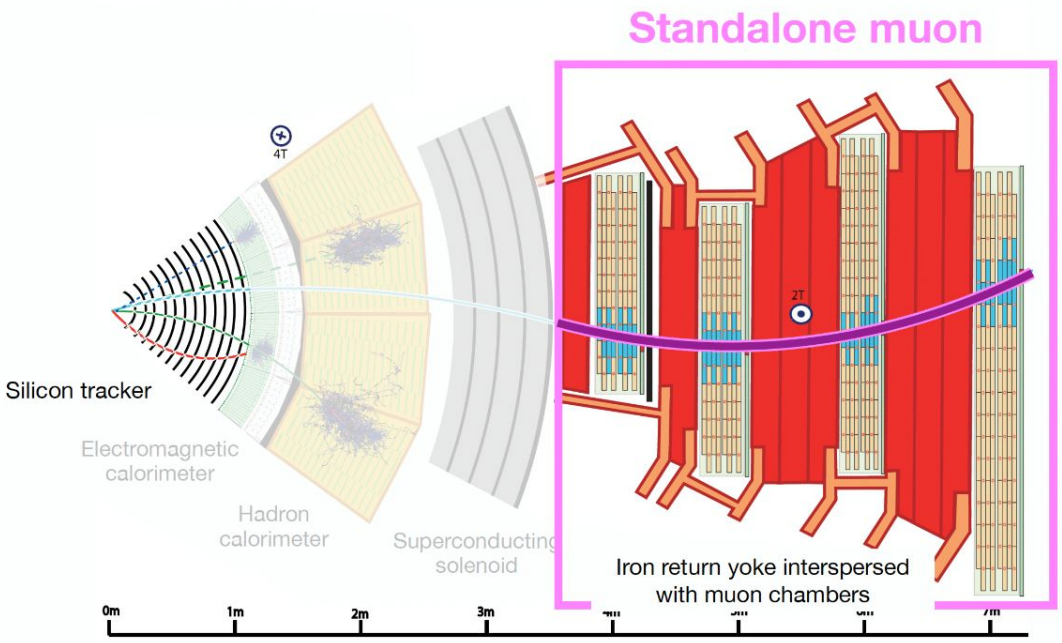
Figures kindly made by Batoul Diab 👑



Reconstruction only based on hits and segments in the muon chambers

✅ unambiguous identification and crucial for fast trigger decision

❌ poor momentum resolution

🚿 *spurious* cosmic ray muons

☛ not used in physics analyses

Tracker muon reconstruction

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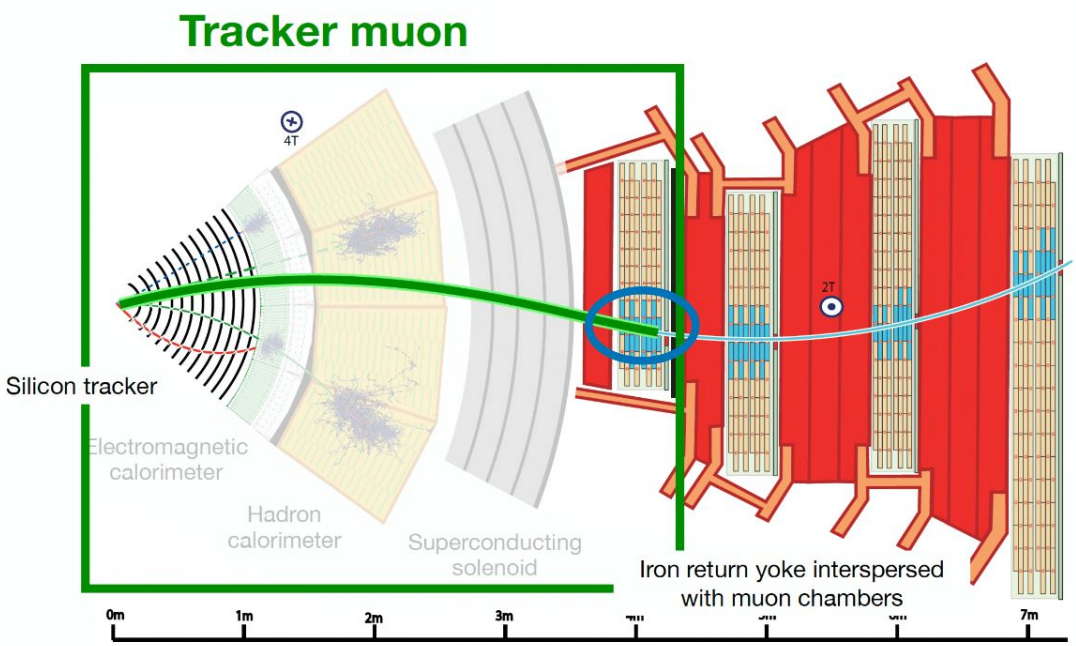
Figures kindly made by Batoul Diab 👑



Tracker tracks with p_T > 0.5 GeV and p > 2.5 GeV extrapolated to the muon system if at least one matching muon segment is found

☛ **lowest momentum muons**

😀 p_T resolution of the tracker ($\mathcal{O}(1\%)$)

😬 minimal track quality criteria

☛ **charged hadrons misreconstructed as muons from accidental matches (*fake muons*)**

Global muon reconstruction

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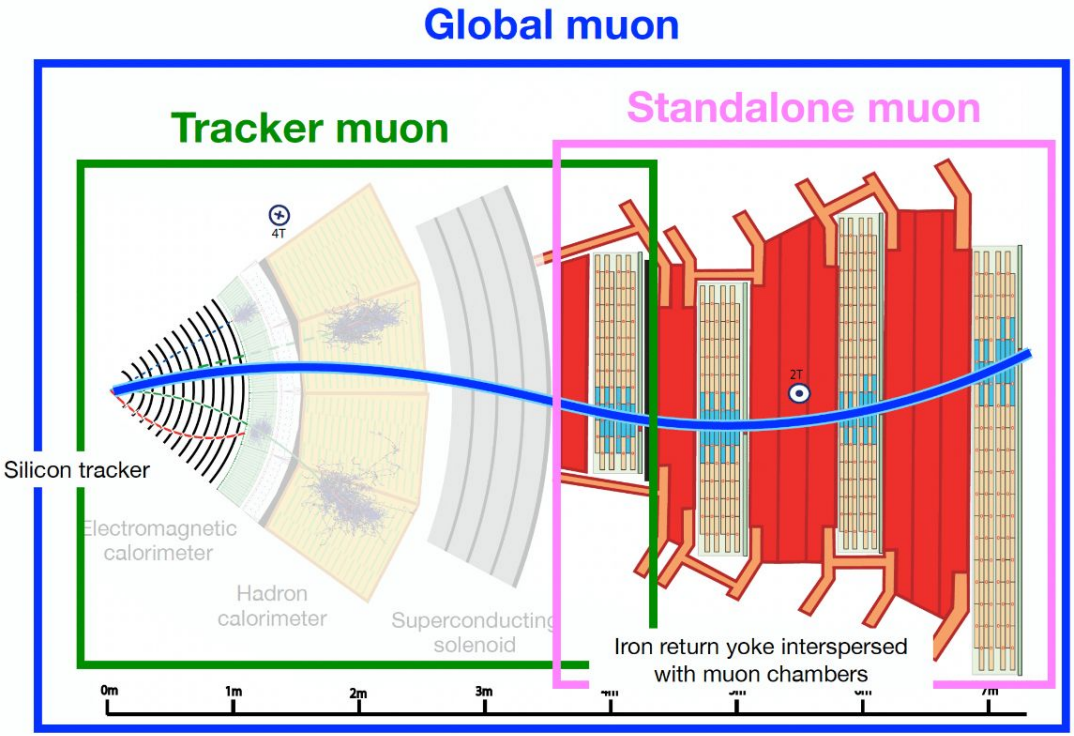
Figures kindly made by Batoul Diab 👑

Outside-in reconstruction by fitting a **standalone muon candidate** to a **matching tracker track**

🤝 *pure signal* combined with the p_T resolution of the inner tracker

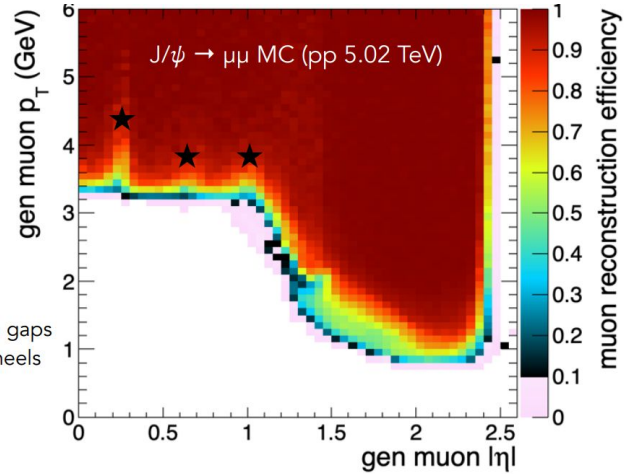
😕 less efficient than tracker muons at low momenta

🥵 occupancy in the tracker ☛ **multiple matching candidates to be *arbitrated***

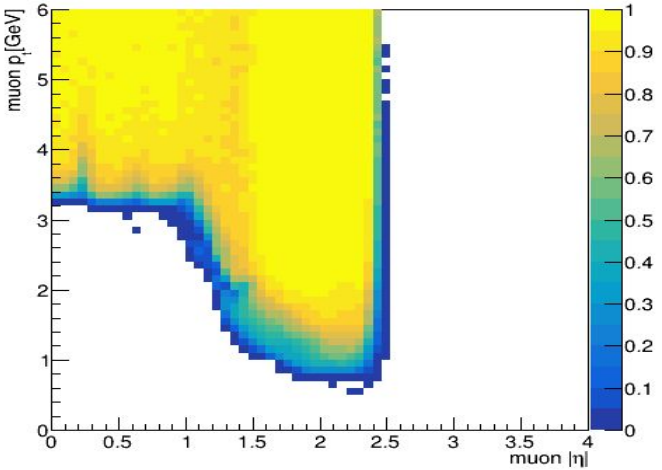


Phase 1, run 2-3 reconstruction performance

★ muon instrumentation gaps between the detector wheels



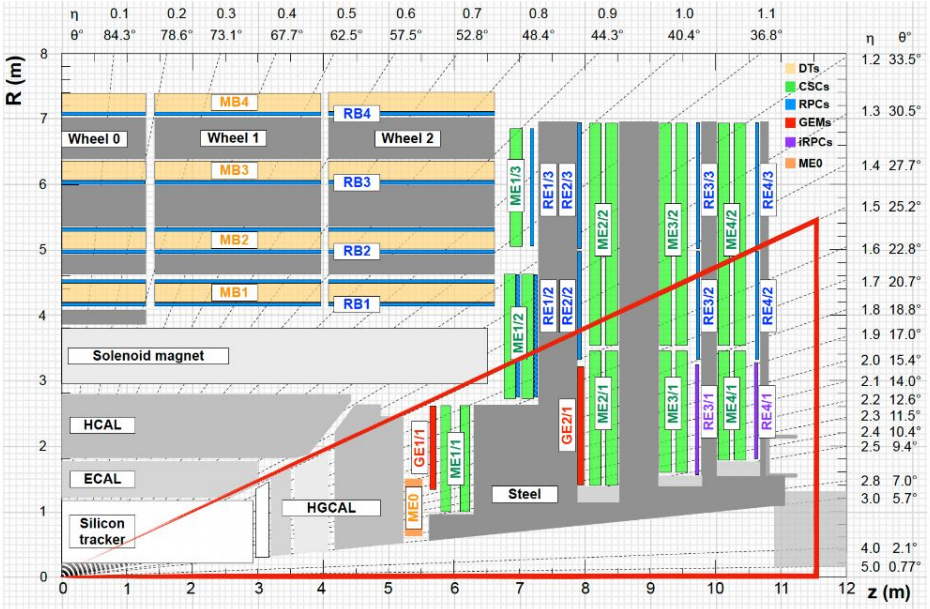
Run 2 muon reconstruction efficiency



Run 3 muon reconstruction efficiency

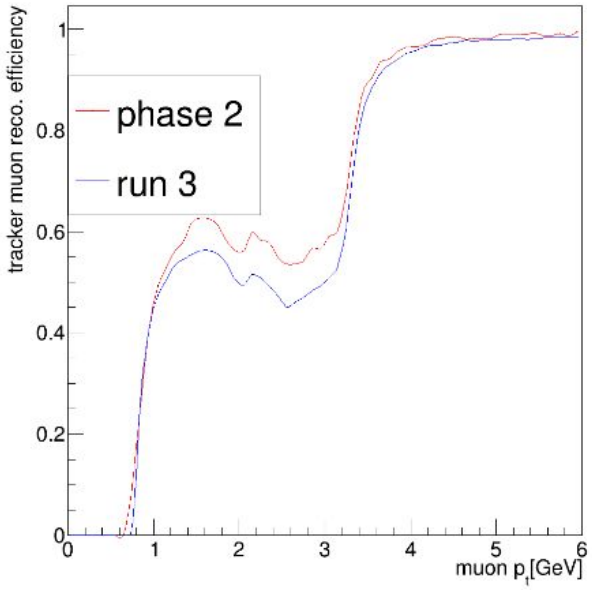
Phase-2 upgrade of the muon system [CMS-TDR-016]

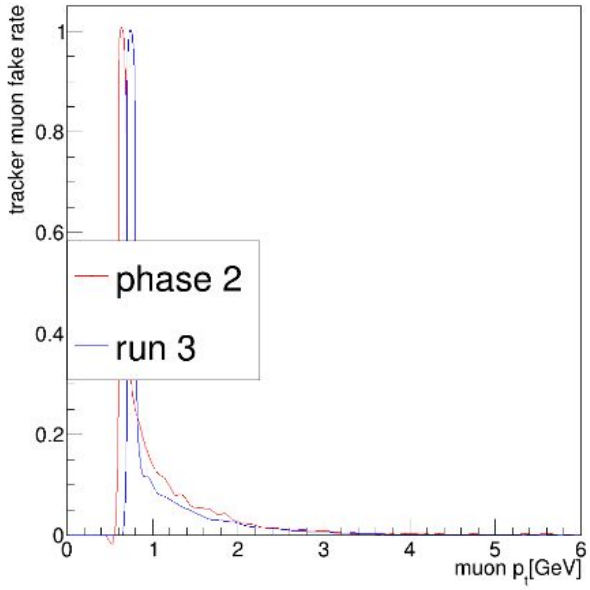
Main modifications in the **forward region where the detection conditions are the most challenging**



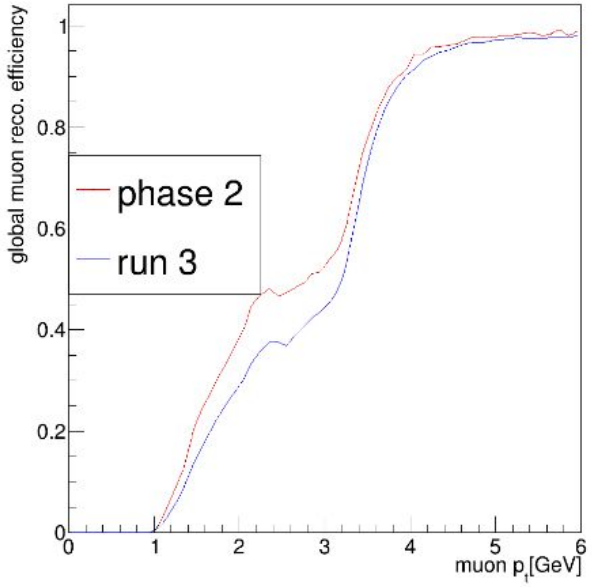
- additional chambers to **enhance the hit redundancy for track reconstruction** (already at trigger level!!!)
- improved RPCs and GEM chambers with **better time and spatial resolutions** (where the magnetic bending is the weakest)
- new station ME0 (six layers of triple-GEMs) **increasing the η acceptance from 2.4 to 2.8** (benifiting from the extension of the tracker)

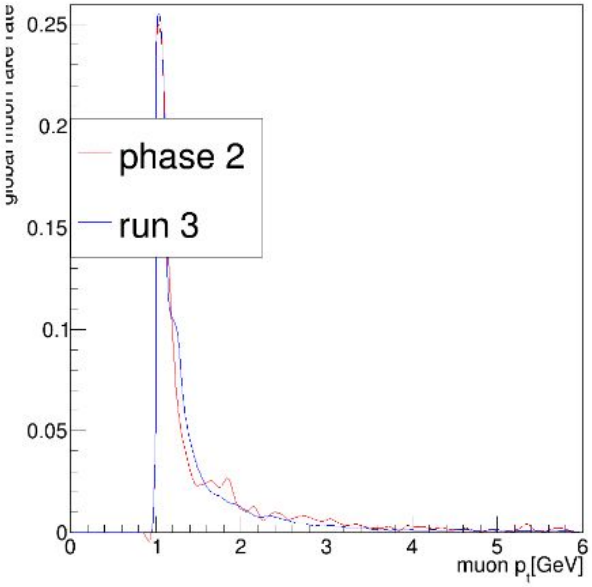
Phase 2 improvement over Run 3 for proton-proton collision: tracker muons



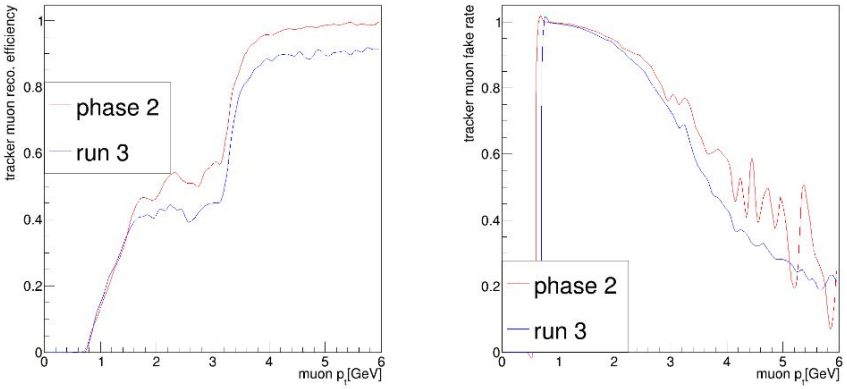


Phase 2 improvement over Run 3 for proton-proton collision: global muons

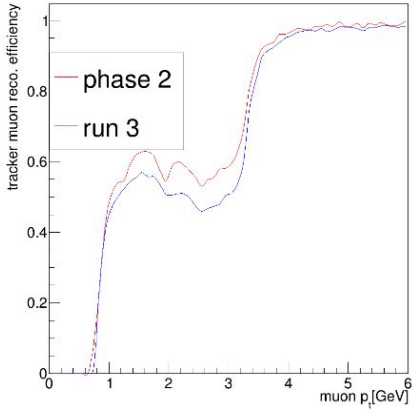


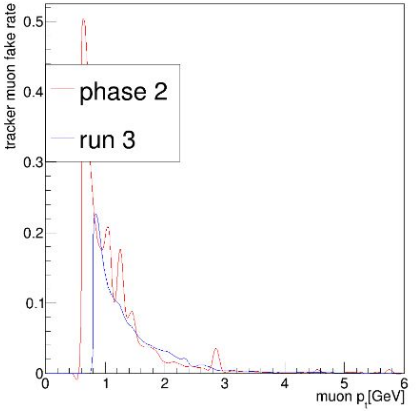


Phase 2 improvement over Run 3 for Pb-Pb collision: tracker muons



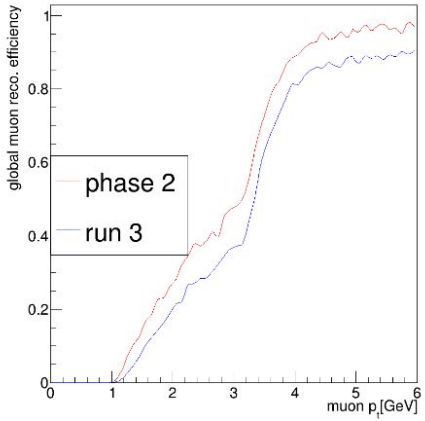
Phase 2 vs Run 3 embedded,
10% highest track count

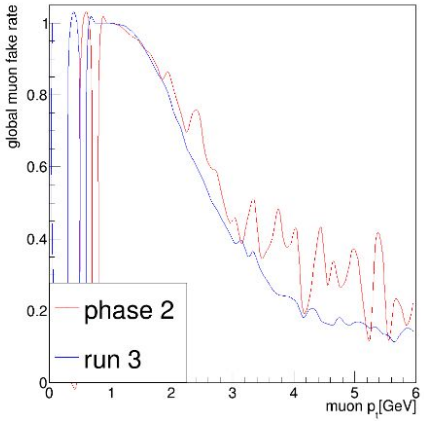




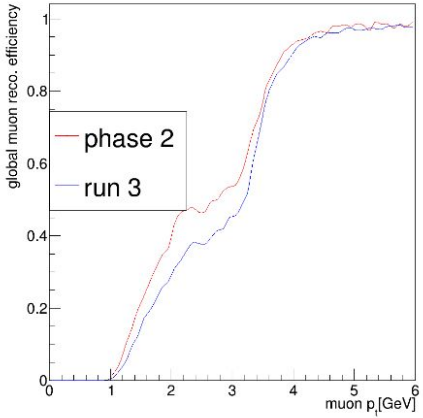
Phase 2 vs Run 3 embedded,
10% lowest track count

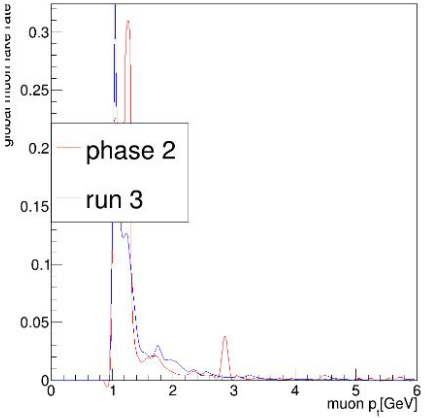
Phase 2 improvement over Run 3 for Pb-Pb collision: global muons





Phase 2 vs Run 3 embedded,
10% highest track count

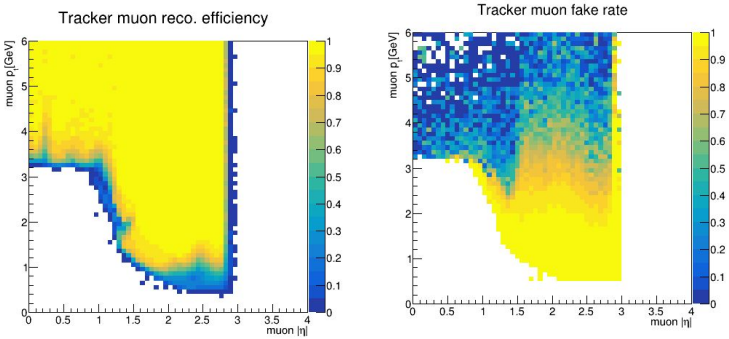




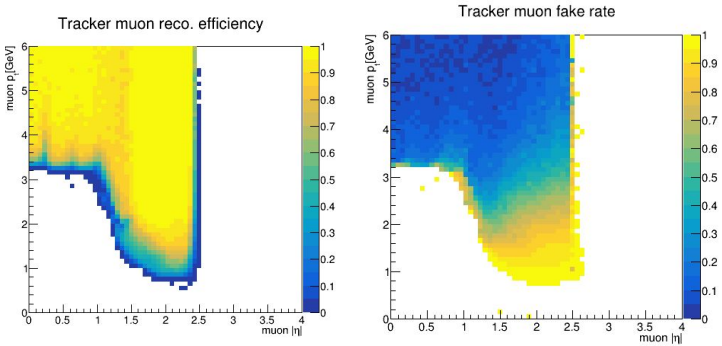
Phase 2 vs Run 3 embedded,
10% lowest track count

Phase 2 improvement over Run 3: GEM muons

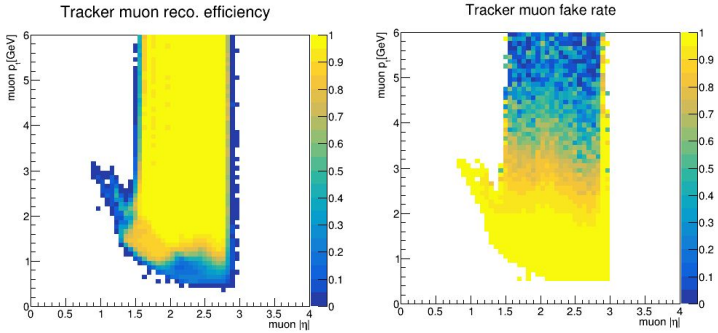
GEM and tracker muons, phase 2



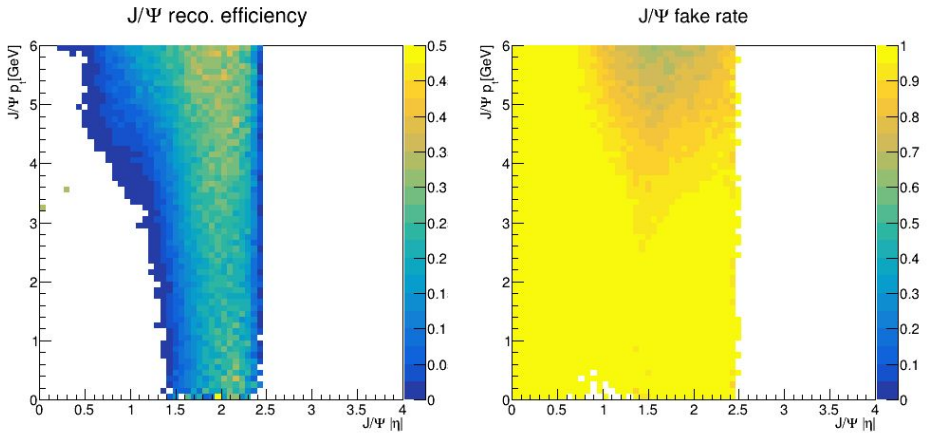
Tracker muons, run3



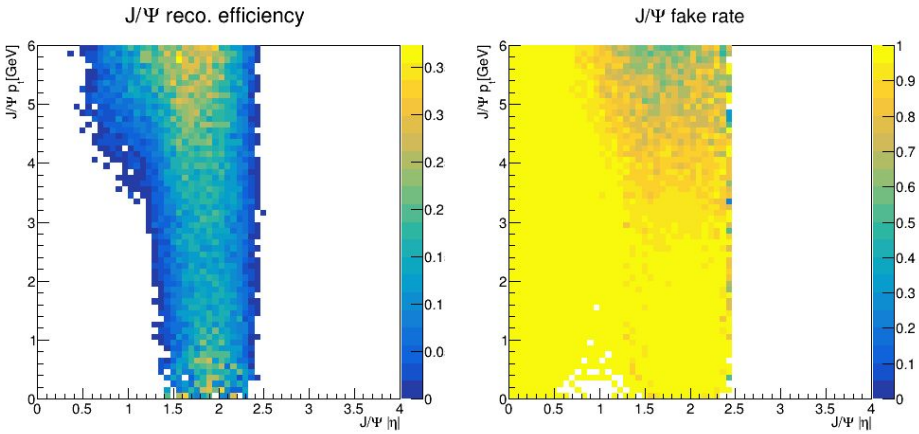
GEM muons only



Phase 2 improvement over Run 3: J/Ψ reconstruction



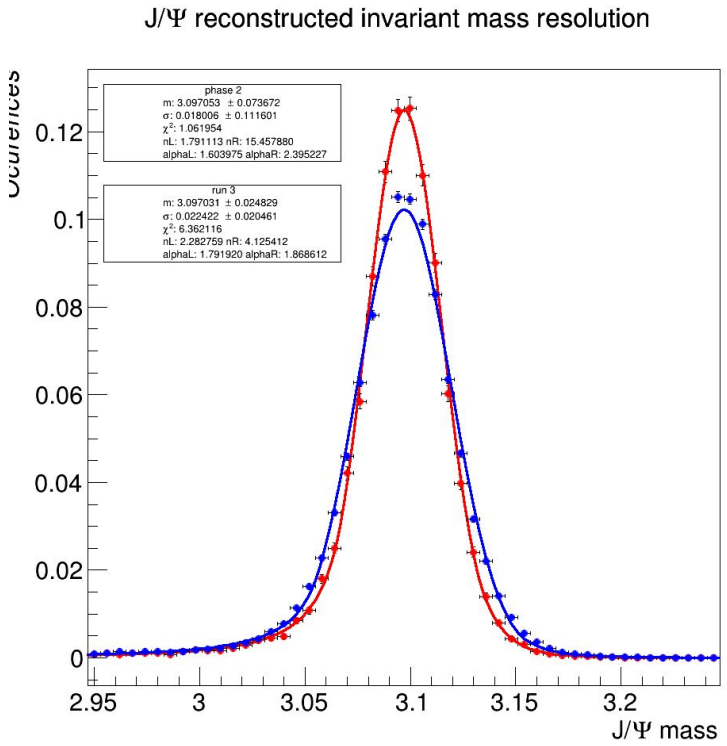
J/Ψ reconstruction for run3



J/Ψ reconstruction for phase 2*

*J/Ψ of Pt>2.4 are cut, this should be resolved later on

Phase 2 improvement over Run 3: J/Ψ mass resolution



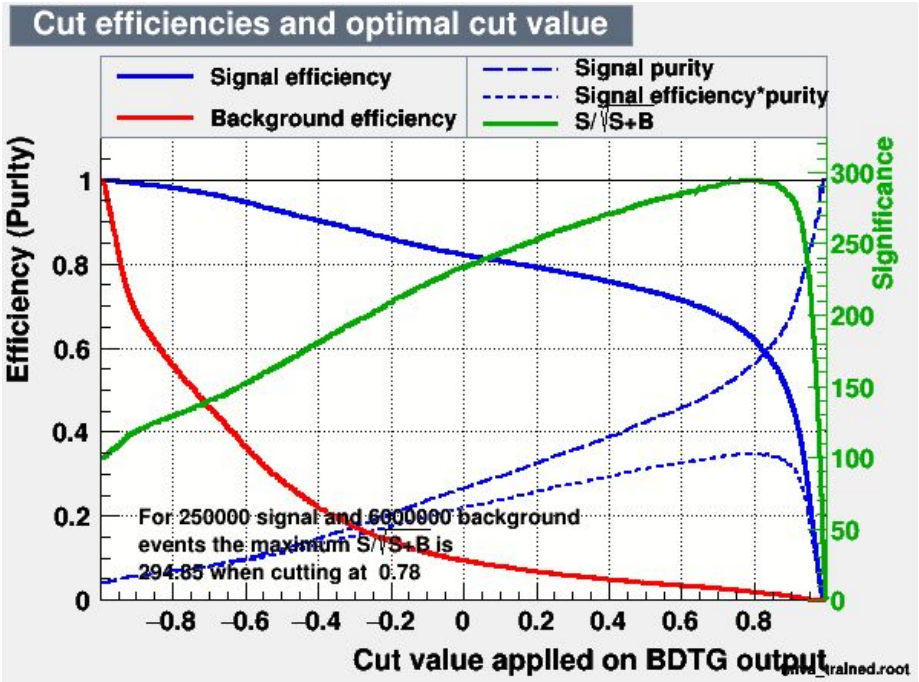
For J/Ψ with y<1

Run 3: σ=22MeV
Phase 2: σ=18MeV

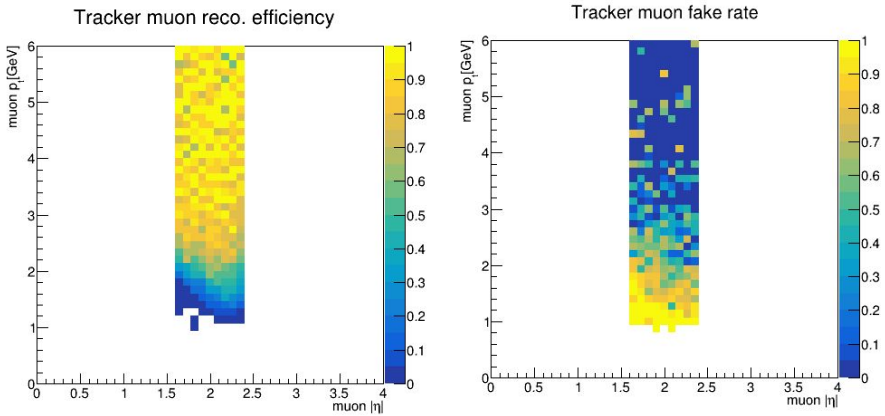
Improving the fake rate of GEM muons: TMVA Results

Variables used for classification:
- Reco_mu_nMuValHits*
- Reco_mu_nTrkHits
- Reco_mu_nPixValHits
- Reco_mu_localChi2
- Reco_mu_pt
- Reco_mu_eta
- Reco_mu_dxy
- Reco_mu_dz
- nPV
- Reco_mu_nMatches*

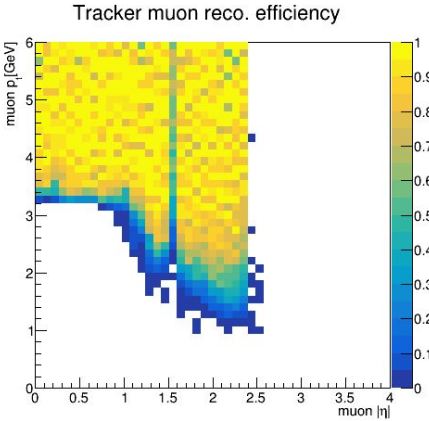
*not well defined as they don't included data from GEM for now

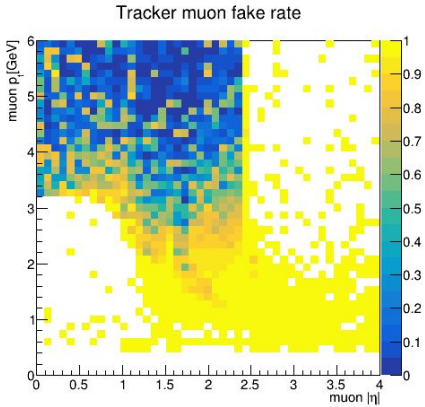


Improving the fake rate of GEM muons: Muon reconstruction improvements



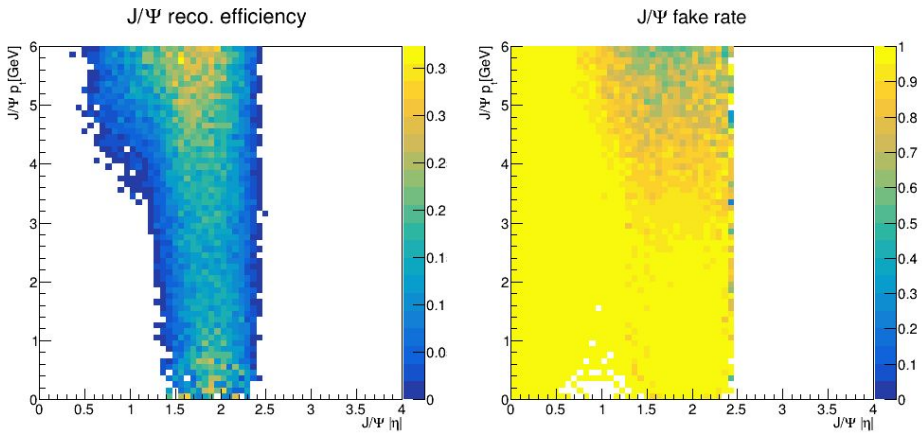
GEM reconstruction efficiency and fake rate after ID



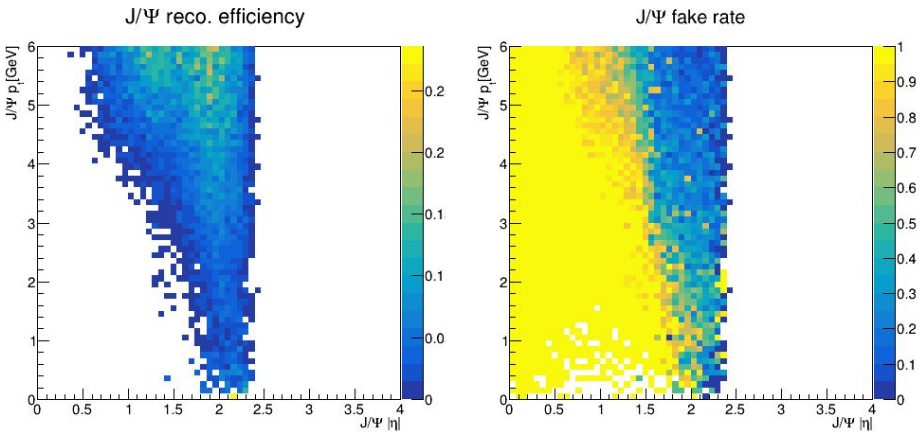


Reconstruction efficiency and fake rate after ID for all muons

Improving the fake rate of GEM muons: J/Ψ reconstruction improvements



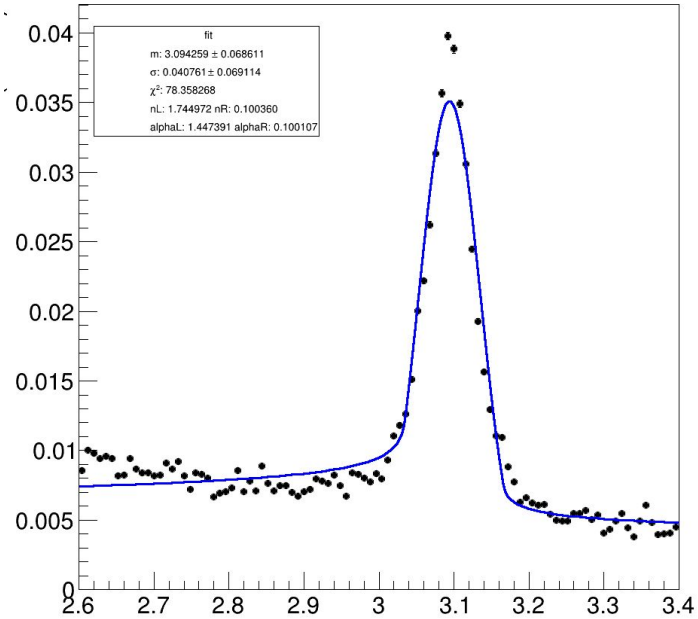
J/Ψ reconstruction for phase 2
Without ID*



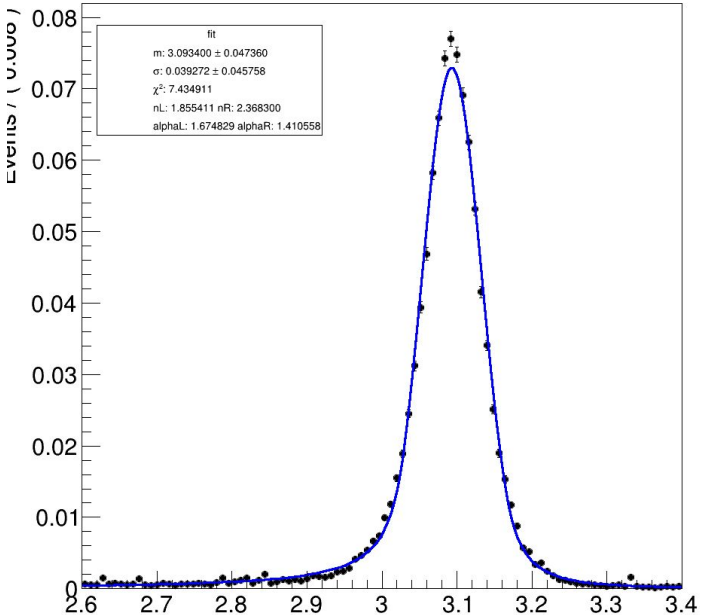
J/Ψ reconstruction for phase 2
With ID*

*J/Ψ of Pt>2.4 are cut, this should be resolved later on

Improving the fake rate of GEM muons: J/Ψ reconstruction improvements



J/Ψ mass resolution for phase 2
Without ID



J/Ψ mass resolution for phase 2
With ID