Effective Calibration of Muon Spectrometer using $J/\Psi \rightarrow \mu\mu$

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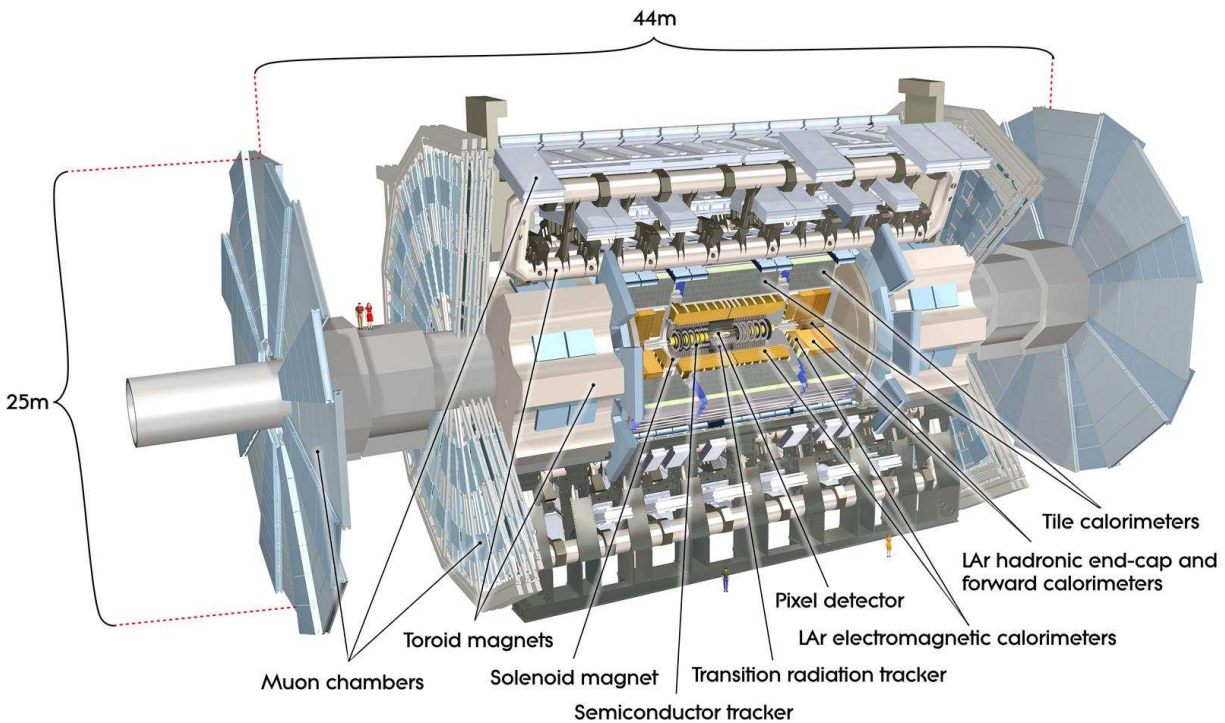
Overview

Goal and Motivation

- perfomance of the muon reconstruction is effected by multiply scattering, energy loss, alignment and imperfections in the magnetic field map
- without studying effects of these processes separately, we tried to do effective calibration of Muon Spectrometer (MS) using high statistics of $J/\Psi \longrightarrow \mu^{-}\mu^{+}$ resonance
- J/Ψ is one of the few "standard candles" that can be used for calibration
- J/Ψ is the most abdulant source in low transverse momentum region
- J/Ψ decays in two muons which are close together

ATLAS Detector

A Toroidal LHC ApparatuS



- Inner Detector measures the position, direction and momentum of charged particles (silicon pixel detector, silicon strip detector SCT and transition radiation tracker TRT). Covers the pseudorapidity range $|\eta| < 2.5$, magnetic field is $2\,\mathrm{T}$

ATLAS Detector

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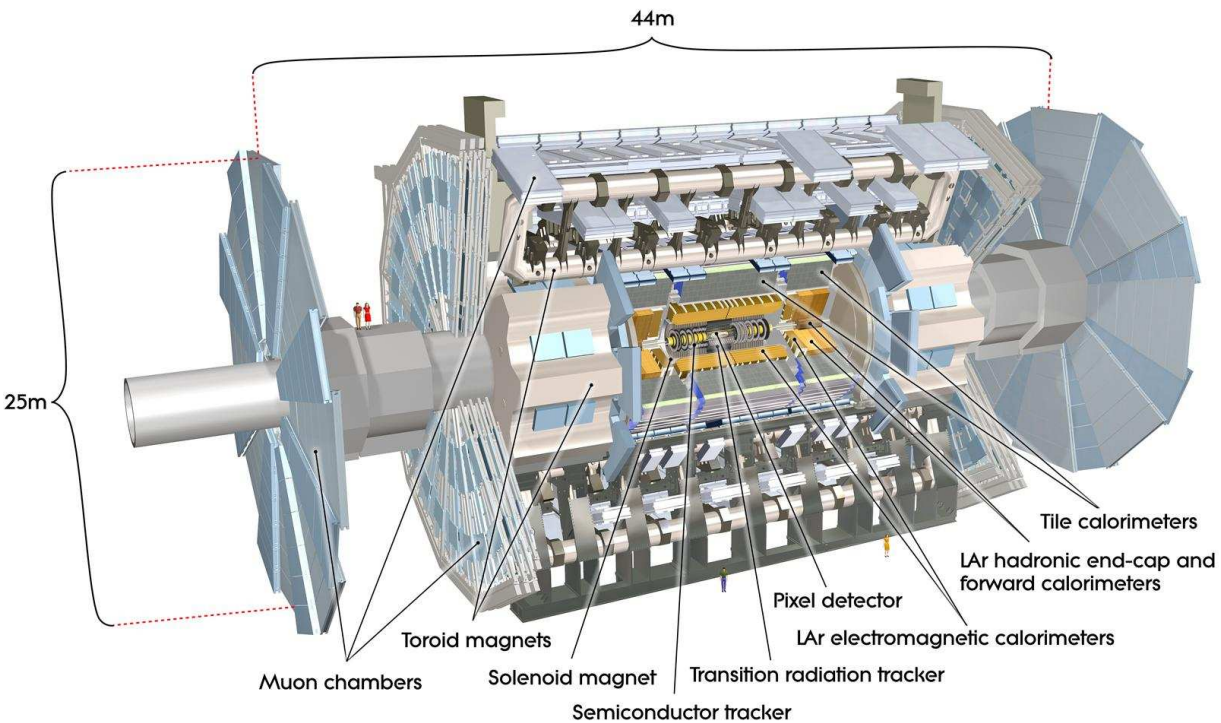
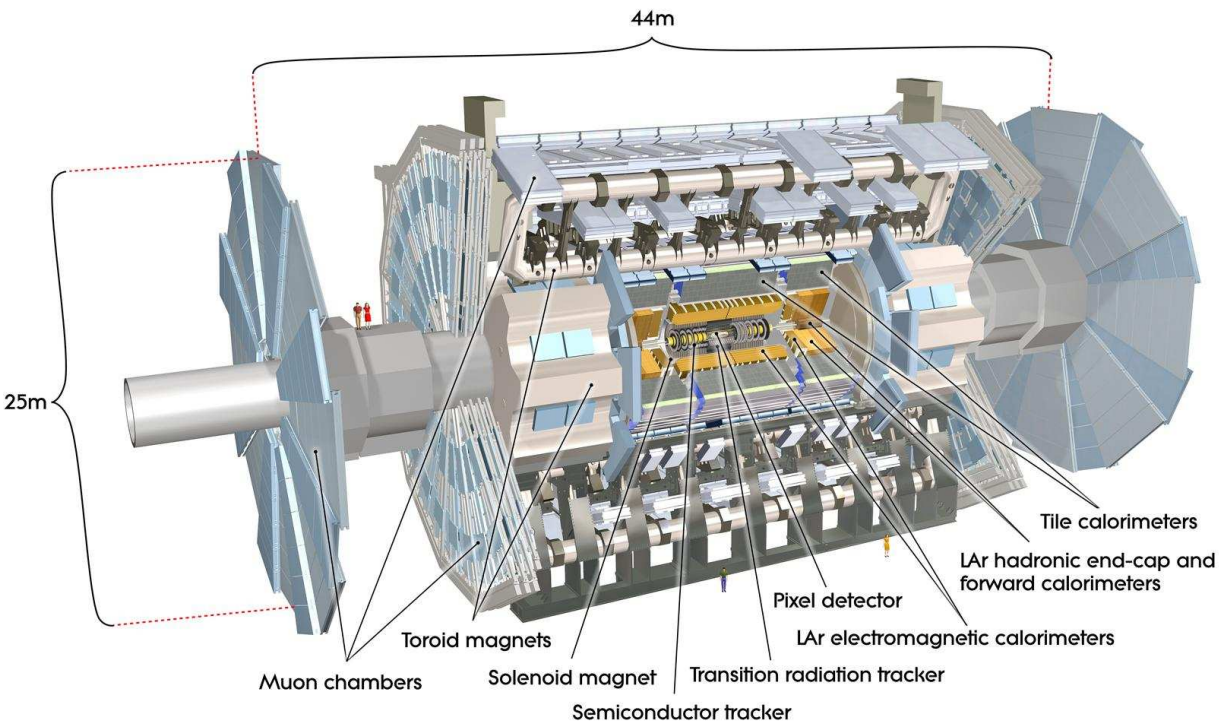


- Calorimeter is used for precision measurements of the energy of charged and neutral particles (electromagnetic and hadronic sampling calorimeters)

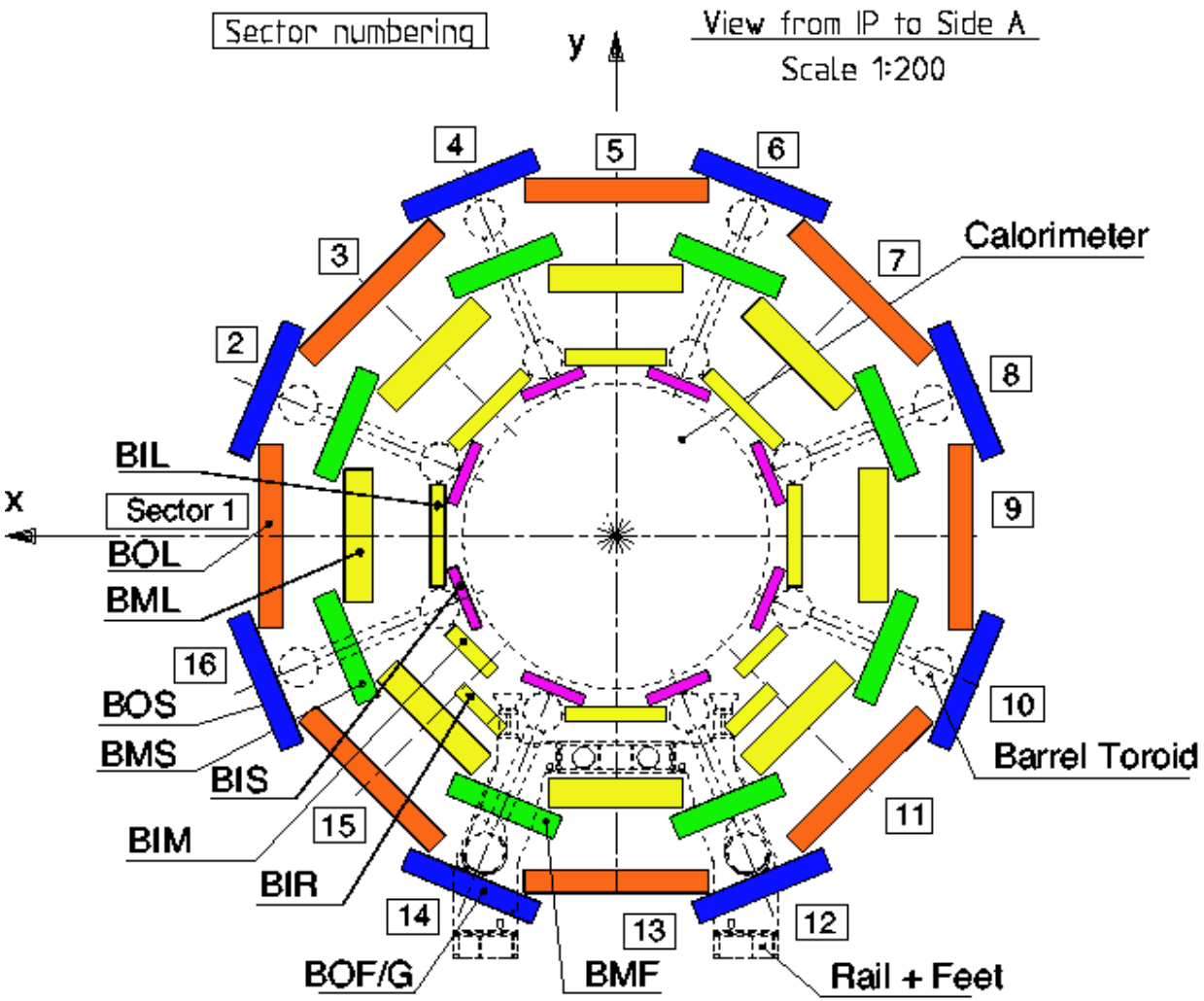
ATLAS Detector

A Toroidal LHC ApparatuS



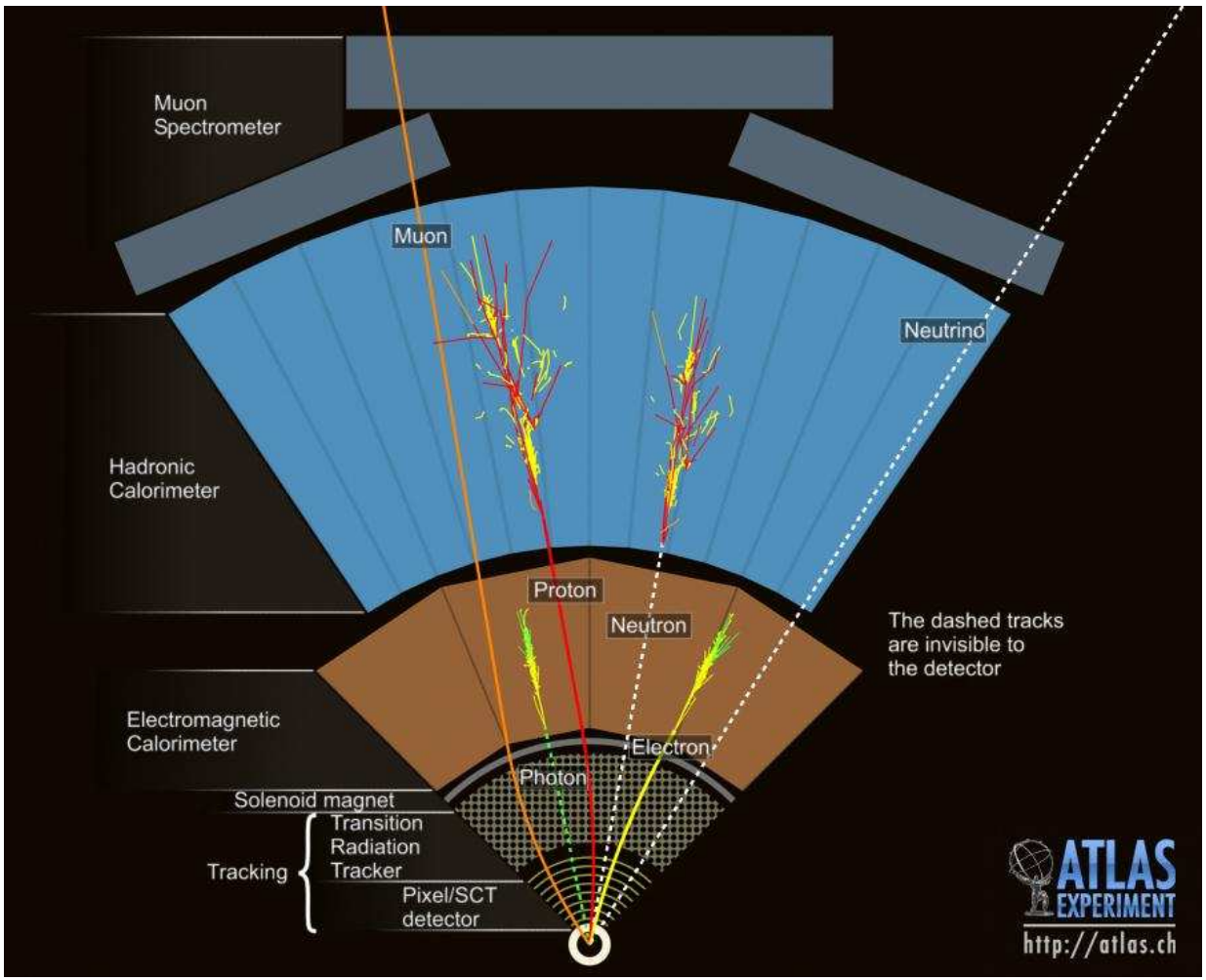
- Muon Spectrometer detects and measures the momentum of muons. It consists of four detectors using different technologies and is divided into a barrel region ($|\eta| < 1.05$) and two end-cap regions ($1.05 < |\eta| < 2.7$)

Muon Spectrometer



- Large toroidal magnet average magnetic field 0.5 T
- Monitored Drift Tube chambers (MDT) are precision tracking chambers in the barrel and endcap region (three layers)
- Cathode Strip Chambers (CSC) precision chambers
- Resistive Plate Chambers (RPC) in barrel region as trigger chambers
- Thin Gap Chambers (TGC) in end-cap region as trigger chambers

Muon Reconstruction



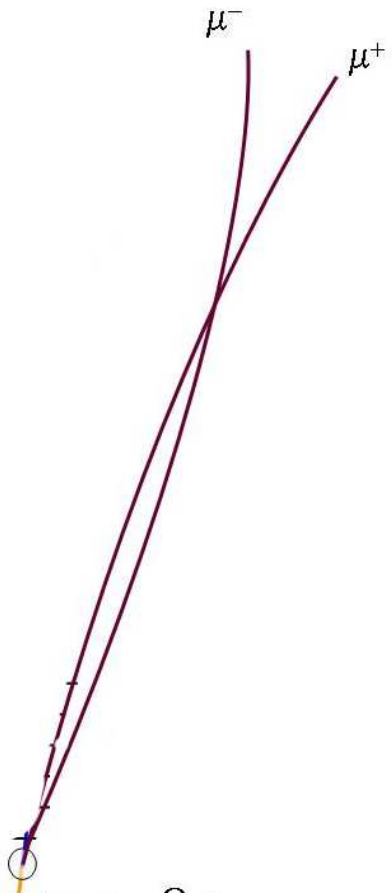
Muon Types:

- Combined momentum from ID and MS ($|\eta| < 2.5$)
- Segment-tagged momentum from ID ($|\eta| < 2.5$)
- Stand-alone momentum from MS ($|\eta| < 2.7$)
- Calorimeter-tagged momentum from MS ($|\eta| < 2.5$)

Muon Collections:

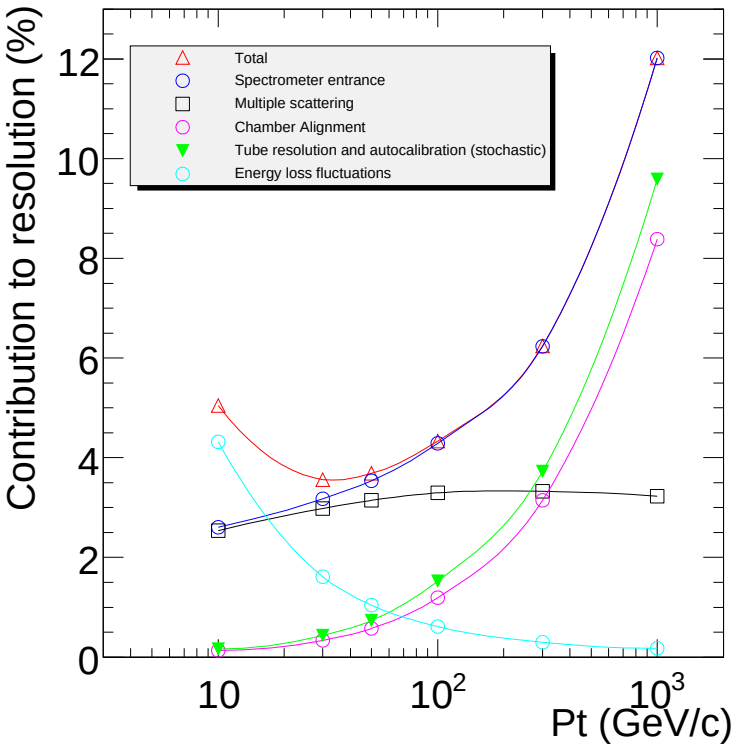
- STACO ID and MS tracks are combined statistically
- MuID ID and MS tracks are fitted as full-length track

J/Ψ



- J/Ψ is made of charm and anti-charm quark
- about 6 % of the time it decays to a muon anti-muon pair
- has a very narrow ($\approx 93\,\mathrm{keV}$) natural decay width (di-muon invariant mass plot has very sharp resonance)
- $m_{J/\Psi} = 3.096\,\mathrm{GeV}$
- J/Ψ decays in two muons produced in one collision, coming from the same vertex, that are very close

Scale and Resolution



- Muon Spectrometer momentum resolution and scale could vary as a function of muon transverse momentum
- at low momentum, resolution is dominated by fluctuations in the energy loss of the muons traversing the material in front of the spectrometer
- intermediate momentum range, important role plays multiple scattering in the spectrometer
- for high momentum (above 100 GeV/c) alignment and calibration dominates

Event Selection

- at least one primary vertex, with more than 3 tracks
- muon must have $p_{T\,\mu} > 3\,\mathrm{GeV}$ and $|\eta| < 2.7$
- exactly two combined muons with opposite charge
- invarant mass cut from combined measurement is:
  $3.0\,\mathrm{GeV} < m_{\mu\mu}^{combined} < 3.2\,\mathrm{GeV}$
- more details in backup

Distribution of number of J/Ψ candidates in (η, φ) box

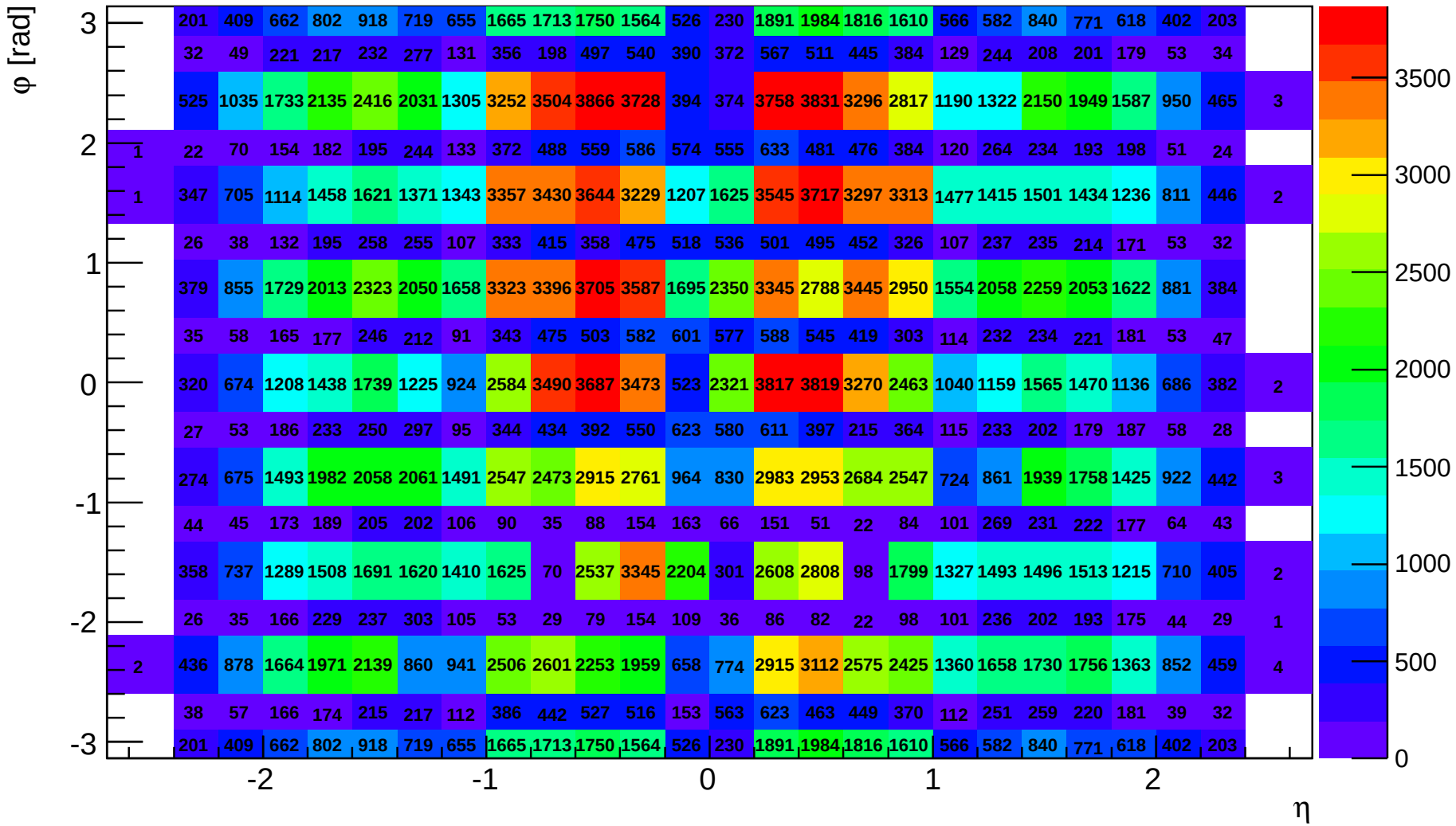
Box definition:

- η region is divided in 26 sectors
- φ region is divided in 16 regions, this segmentation approximately follows small and large sectors in Muon Spectrometer

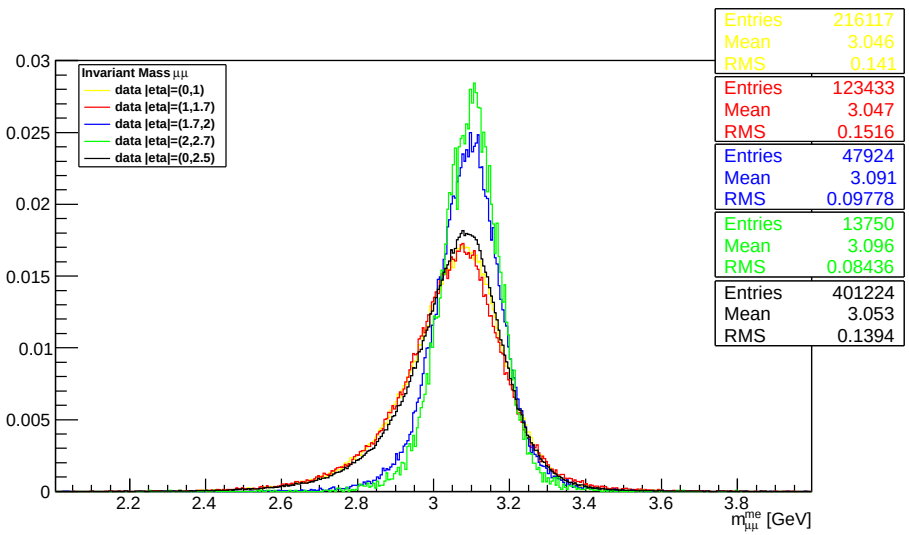
Selection criteria:

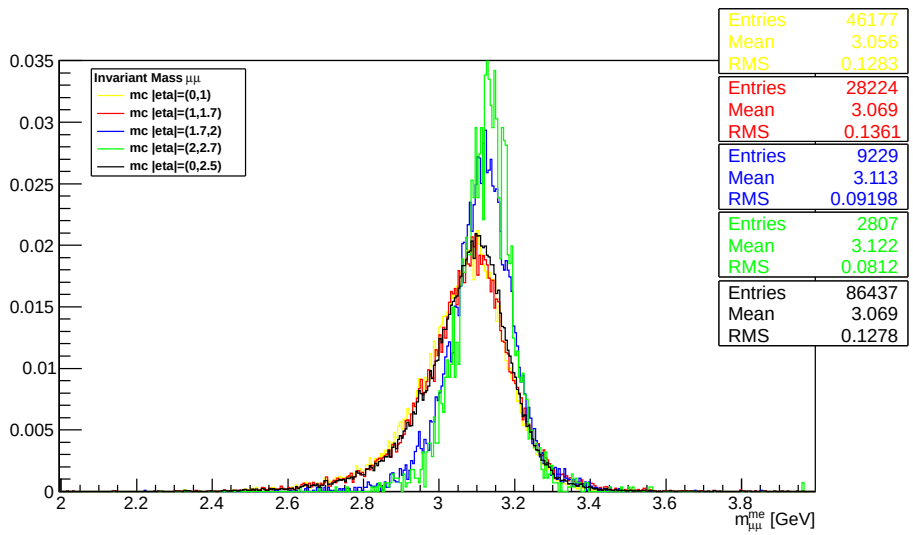
- BOTH combined muons have to be in same (η, φ) box
  $\eta_{\mu_1} \in (\eta_i, \eta_{i+1})$ $\eta_{\mu_2} \in (\eta_i, \eta_{i+1})$
  $\varphi_{\mu_1} \in (\varphi_j, \varphi_{j+1})$ $\varphi_{\mu_2} \in (\varphi_j, \varphi_{j+1})$
- There is $\approx 0.46\,\mathrm{M}$ J/Ψ candidates.
- for selection of muons, η and φ are from MS
- for invariant mass calculation transverse momentum is from ME (MS extrapolated to primary vertex with energy loss corrections) and η and φ are from ID

Distribution of number of J/Ψ candidates in (η, φ) box

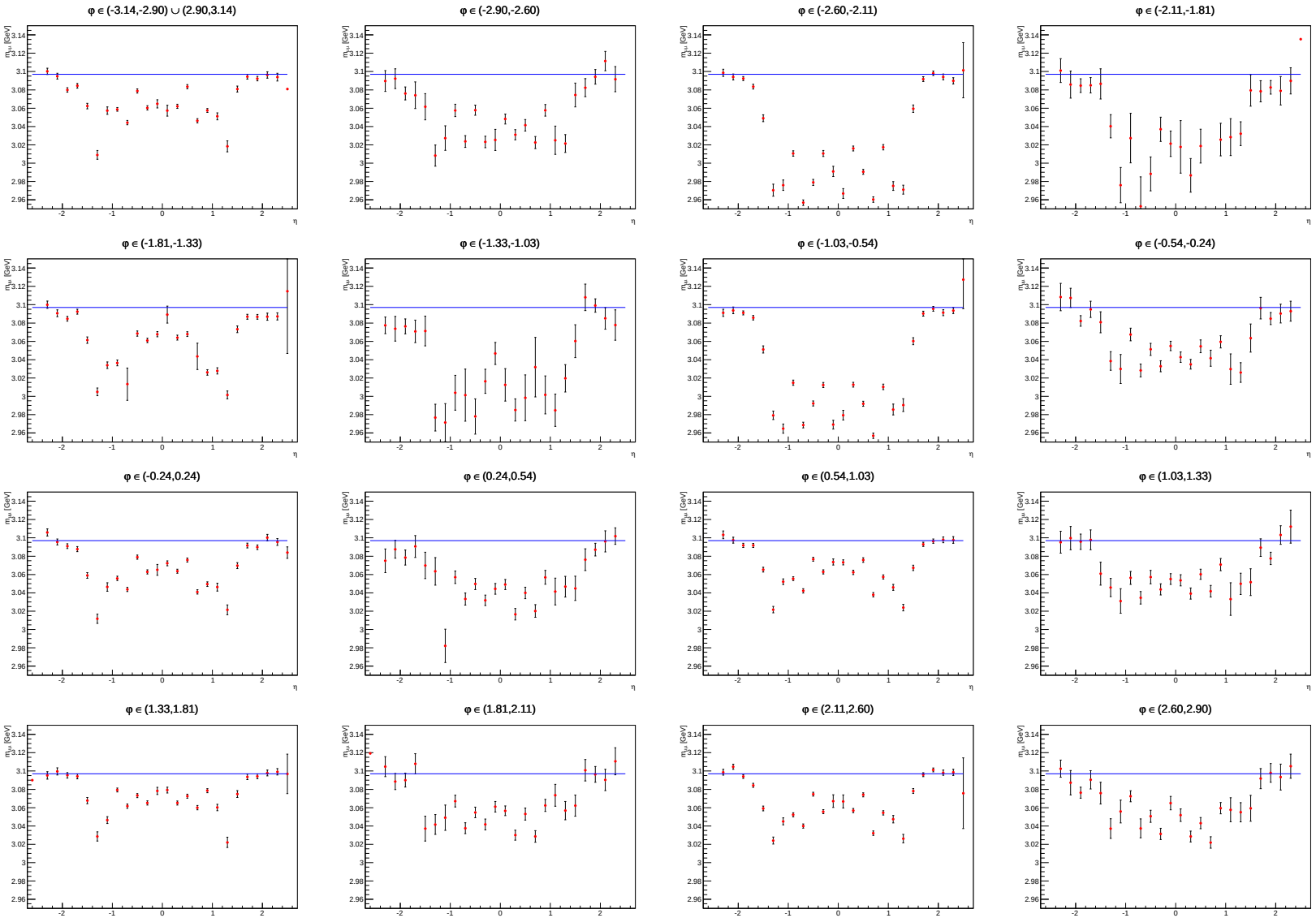


Invariant mass of muon pair for different regions of η





All sectors in MS



Conclusions and Outlook

- Difference in number of J/Ψ candidates in small and large sectors is due to acceptance.
- It seems that muon momentum in MS is underestimated for $2-3\%$ in barrel for large sectors.
- Similar result is for the small sectors, but there is less statistics.
- Apply corrections derived from these study to the Z boson invariant mass measurement.
- For small sectors in MS try to repeat calculations using p_{ME}/p_{ID}.

BACKUP

Event Selection

- 2011 data (tag p833) MC11 samples NTUP_ SMWZ ntuple

1 GRL muon combined performance
data11_ 7TeV.periodAllYear_ DetStatus-v36-pro10_ CoolRunQuery-00-04-08_ Muon.xml

2 Trigger
EF_ 2mu4_ Jpsimumu (RunNumber < 188902)
EF_ 2mu4T_ Jpsimumu (RunNumber > 188902)

3 Primary Vertex
at least one primary vertex, with more than 3 tracks

4 Muon Selection
muon must have $p_{T\,\mu} > 3\,\mathrm{GeV}$ and $|\eta| < 2.7$
combined muons: $|\eta| < 2.5$
standalone + combined muons: $|\eta| > 2.5$

Event Selection

4 Muon Selection

MCP recommendations:

- At least one BLayer hit, if one is to be expected
- Number of pixel hits + number of crossed dead pixel sensors > 1
- Number of SCT hits + number of crossed dead SCT sensors > 5
- Number of pixel holes + number of SCT holes < 3
- Impact parameter relative to the primary vertex $|z_0| < 10\text{mm}$

5 At least two muons

first two with opposite charge

6 Exactly two combined muons

7 Invariant Mass

Invariant Mass of $\mu\mu$ pair is calculated from combined p_T, η and φ

$3.0\,\text{GeV} < m_{\mu\mu}^{combined} < 3.2\,\text{GeV}$