Low Mass Drell-Yan Status Report

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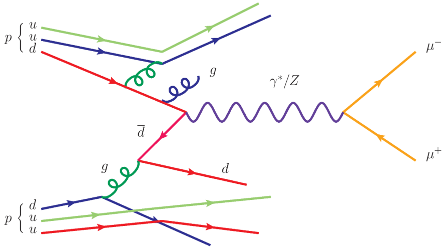
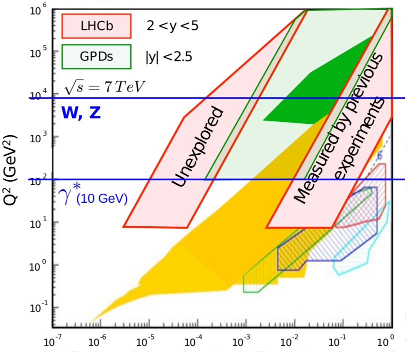
Introduction to Drell-Yan

- Drell-Yan are process of two quark anihilations in which neutral current couples to two leptons.
- The cross section of this process depends on two components:
  - Hard scattering process $\Rrightarrow$ NNLO pQCD.
  - Parton Distribution Function (PDF).
- Measurement of the cross section have a high sensitivity to the PDF
- Due to unique coverage $2 < y < 5$ LHCb probes the $Q^2 - x$ region not covered by other experiments.





Selection

- Main topic of Nicolas PhD.
- Analysis based on 2011 data set.
- Trigger:
  - `L0_L0DiMuonDecision`,
  - `Hlt1DiMuonHighMassDecision`,
  - `Hlt2DiMuonDY(3,4)Decision`
- Stripping:
  - `StrippingDY2MuMuLine(3,4)`
- Selection:
  - $2 < \eta^{\mu} < 4.5$,
  - $p^{\mu} > 10$ GeV,
  - $p_T^{\mu} > 3$ GeV,
  - $\chi^{2,\mu\mu}_{vtx} < 5$,
  - $10 < m(\mu\mu) < 120$ GeV.

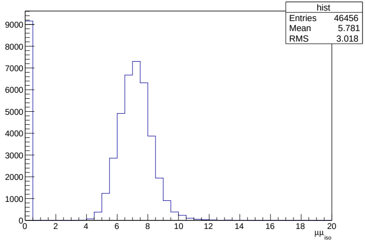
Isolation

- Drell-Yan unfortunately do not peak in mass ↠ need another variable to control the purity.
- Instead we define an isolation variable:

$$\mu_{\text{iso}} = \log(p_T^{cone}(\mu, 0.5) - p_T^{cone}(\mu, 0.1))$$

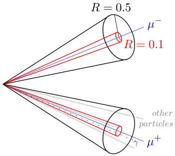
- For two muons we take the maximum of the two isolations:

$$\mu\mu_{\text{iso}} = \max(\mu^+_{\text{iso}}, \mu^-_{\text{iso}})$$



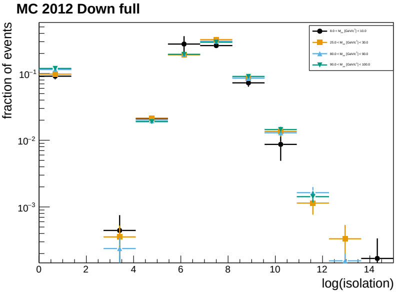
Define minimum isolation as:

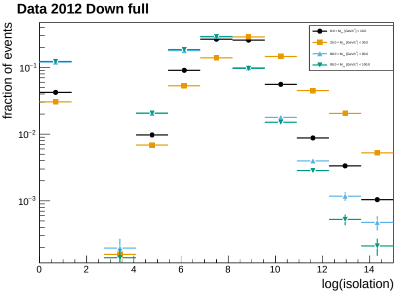
$max(p_T(\mu^+)_{R=0.5} - p_T(\mu^+)_{R=0.1}, p_T(\mu^-)_{R=0.5} - p_T(\mu^-)_{R=0.1})$



Isolation as a function of mass

Normalized log(isolation) in selected mass bins:

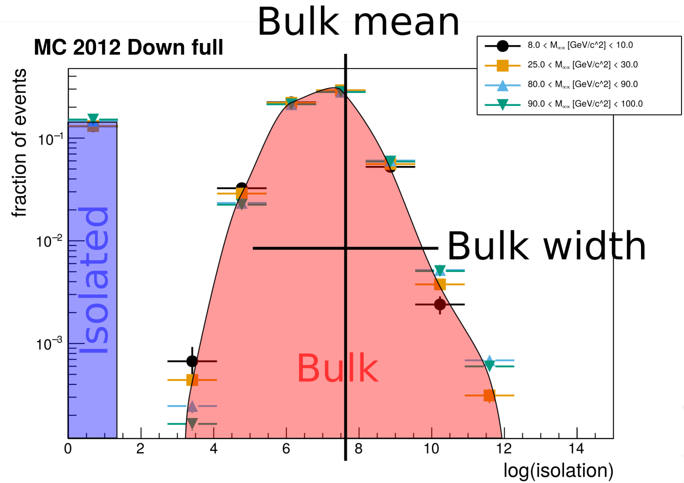




Backgrounds smear the isolation in data, especially away from resonances (orange). In MC very small mass-dependency, which we need to study.

Even at Z peak (blue and green), isolation bulk wider in data than in MC.

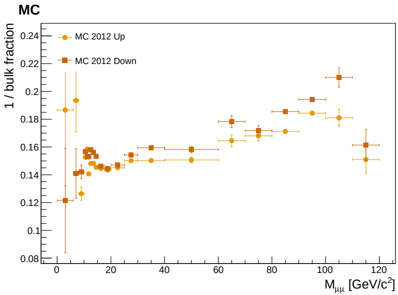
Explanation of variables

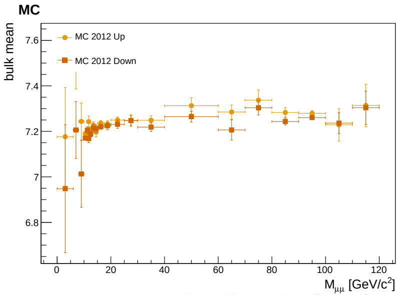


$$1/\text{bulk fraction} = \frac{\int \textit{isolated}}{\int \textit{bulk}}$$

Mass dependency of bulk

MC, 2012





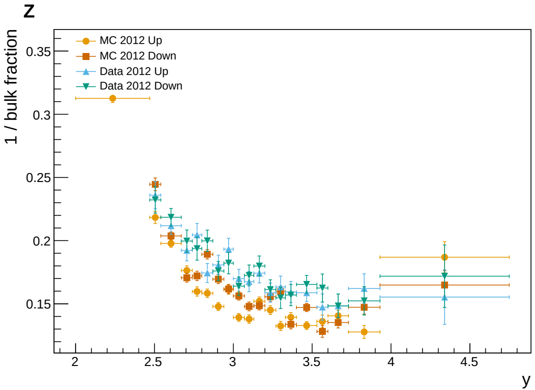
Large mass-dependence of bulk fraction, but smaller mass-dependence of bulk mean.

Difference between MagUp and MagDown to be investigated.

Effect of rapidity

Z-peak

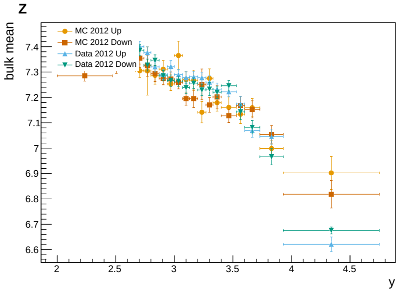
Strong dependency of bulk fraction of rapidity.

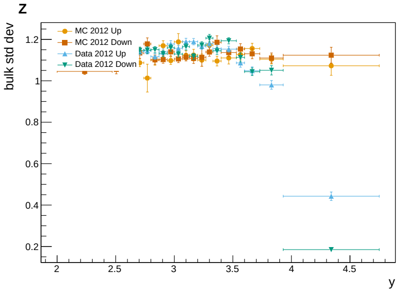


1 / bulk fraction under-estimated in MC.

Effect of rapidity

Z-peak

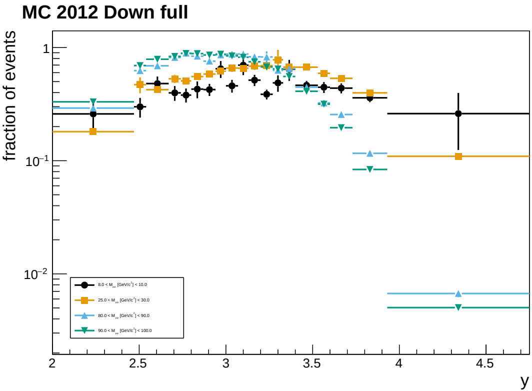




MC and data bulk mean and width agree at Z-peak. Data shows some dependency of bulk width for high y, MC not.

Effect of rapidity

Full mass-range



Rapidity distribution is not the same for different mass-bins (different regions in x). Working on finding out if mass dependence is given by this.

Backgrounds

- There are two sources of backgrounds:
  - Heavy flavour decays.
  - Mis-ID.
- For fitting the $\mu\mu_{iso}$ we need to know both the signal and background distribution.
- Background templates can be determined from data
  - Heavy flavour decays:
    ↬ Requiring the $\chi^{2,\mu\mu}_{vtx} > 16$
    ↬ For cross-check IP > 5 mm
  - Miss-ID:
    ↬ Require that both muons have the same sign.
    ↬ For cross-check take the minimum bias stripping line.

Cross section calculations

- To calculate the cross section the luminosity will be used:

$$\sigma = \frac{\varrho f^{\mathrm{MIG}}}{\mathcal{L}\varepsilon^{\mathrm{SEL}}} \sum \frac{1}{\varepsilon^{\mathrm{TRIG}}\varepsilon^{\mathrm{MUID}}\varepsilon^{\mathrm{GEC}}\varepsilon^{\mathrm{TRACK}}},$$

where

- ϱ signal fraction from the fit.
- f^{MIG} correction to bin-bin migration.
- $\mathcal{L}$ integrated luminosity.
- $\varepsilon^{\mathrm{SEL}}$ efficiency on the vertex requirement.
- $\varepsilon^{\mathrm{MUID}}$ muon identification efficiency.
- $\varepsilon^{\mathrm{GEC}}$ global event cut efficiency.
- $\varepsilon^{\mathrm{TRACK}}$ tracking efficiency.

$\varepsilon^{\mathrm{SEL}}$

⇛ Evaluated using MC sample:

2011 MagDown	0.21320 ± 0.00014
2011 MagUp	0.21306 ± 0.00014
2012 MagDown	0.20402 ± 0.00013
2012 MagUp	0.20372 ± 0.00013

⇛ Good agreement between polarities!

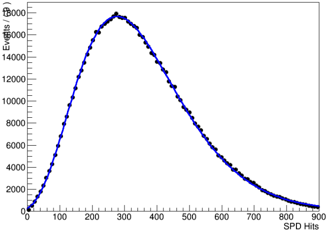
⇛ 2012 efficiency is lower then the 2011.

⇛ Will merge the polarities:

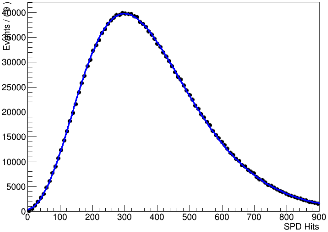
2011	0.21313 ± 0.00010
2012	0.20387 ± 0.00009

⇛ Evaluated on data directly, by fitting the Γ(SPDHits) to data:

⇛ 2011 data:



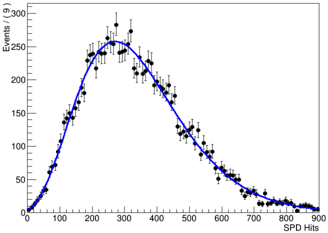
⇛ 2012 data:



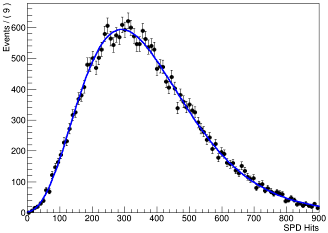
ε^{GEC}

⇛ Testing the $y - M_{\mu\mu}$ dependence:

⇛ 2011 data
$y \in (2, 2.25)$
$M_{\mu\mu} \in (10.5, 12)$ GeV :



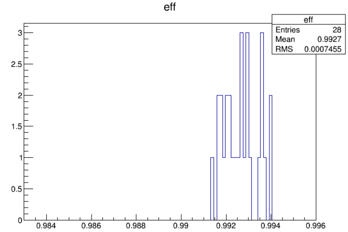
⇛ 2012 data
$y \in (2, 2.25)$
$M_{\mu\mu} \in (10.5, 12)$ GeV :



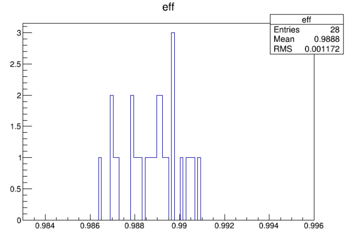
⇛ We didn't observe a variation of the efficiency as a function of $M_{\mu\mu}$ and y.

⇛ Proposed a systematic:

⇛ 2011 data:



⇛ 2012 data:



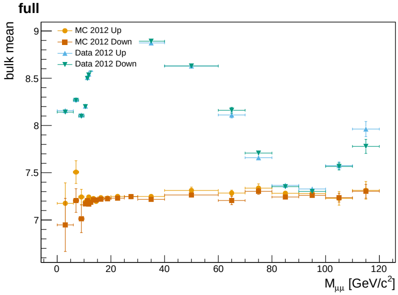
⇛ Suggest the RMS as small systematic.

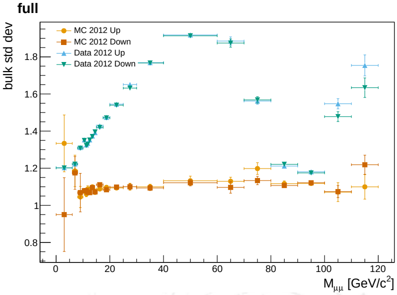
Conclusions

- MC isolation template describes data at Z-peak reasonably well
- But some differences exist, so have to take templates from data (MC can still serve as cross-check)
- Templates show a mass-dependence in MC (especially bulk fraction)
- Different mass-regions have different rapidity distributions
- Needs to be determined if mass-dependence is driven by rapidity-dependence
- 2016 MC requested

Mass dependency of bulk

MC vs data, 2012

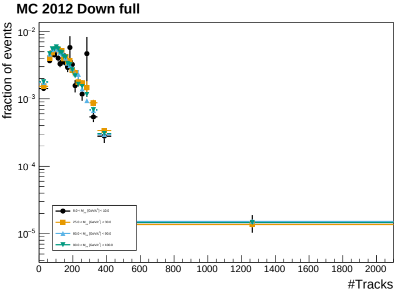


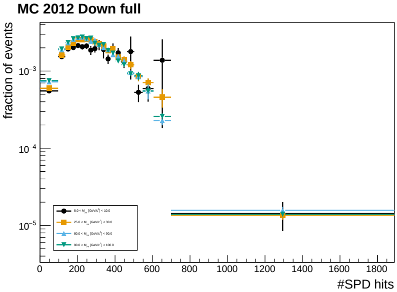


Near the Z-peak and the Υ-peak good agreement.
Small mass-dependency even in MC ($value\%$).

Effect of multiplicity

Isolation should, in general, be dependent on multiplicity. First, check if multiplicity is mass dependent.

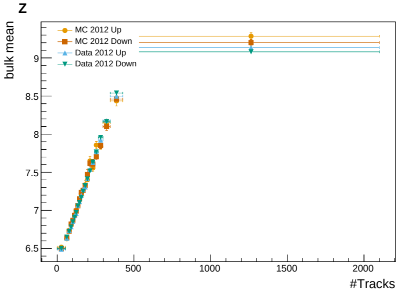


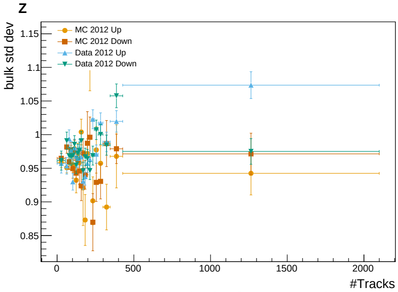


No mass dependency of multiplicity ($nTracks$ and $nSPD$) in MC

Effect of multiplicity

At Z-peak $(60 < M_{\mu\mu} < 120GeV/c^2)$
Isolation not independent of $nTracks$:

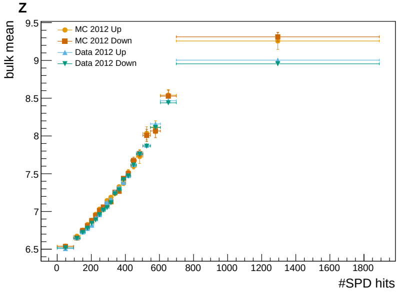


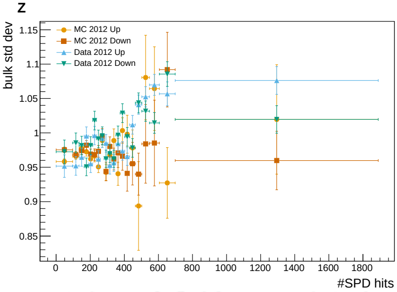


In data, width and mean of bulk dependent on $nTracks$, in MC only mean.

Effect of multiplicity

At Z-peak $(60 < M_{\mu\mu} < 120 GeV/c^2)$.
Bulk width not independent of $nSPD$:

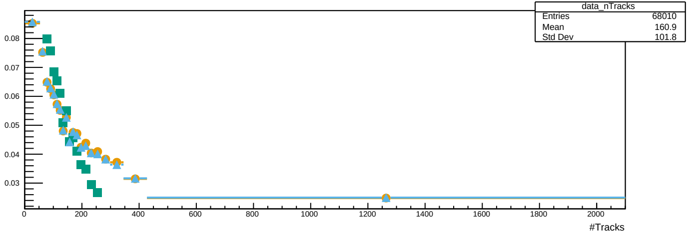


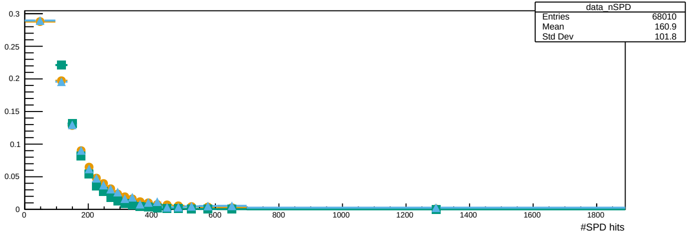


Mean of bulk agrees in data and MC.

Multiplicity reweighting

Data, MC befor reweighting, MC after reweighting





Backup