# Low Mass Drell-Yan Status Report

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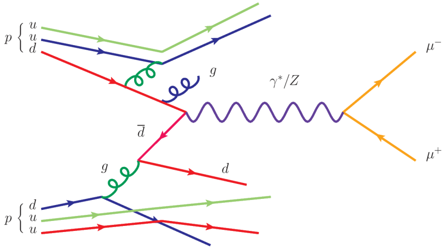
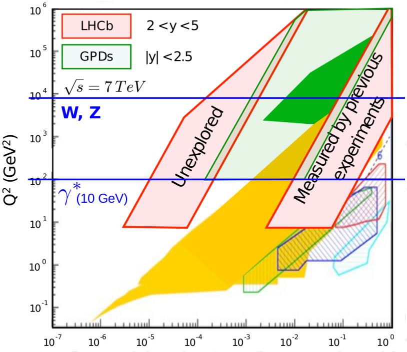
# Introduction to Drell-Yan

- 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

- Analysis based on 2011, 2012 data set. Now adding 2016.
- 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.

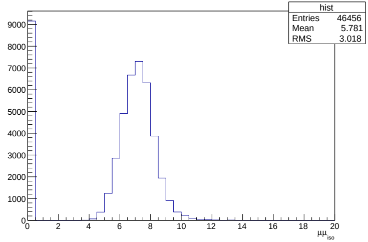
# Isolation

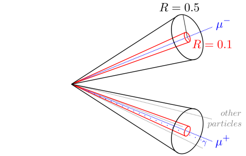
- Drell-Yan unfortunately do not peak in mass $\twoheadrightarrow$ need another variable to control the purity.
- Instead we define an isolation variable:

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

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

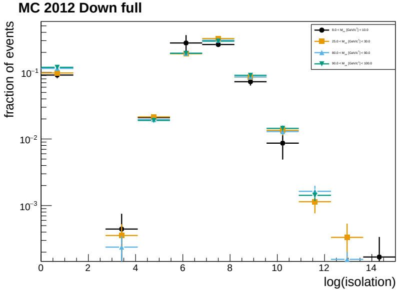
$$\mu\mu_{\text{iso}} = \max(\mu_{\text{iso}}^{+}, \mu_{\text{iso}}^{-})$$

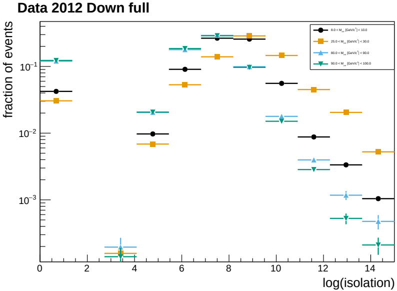


# Isolation as a function of mass

Normalized log(isolation) in selected mass bins:

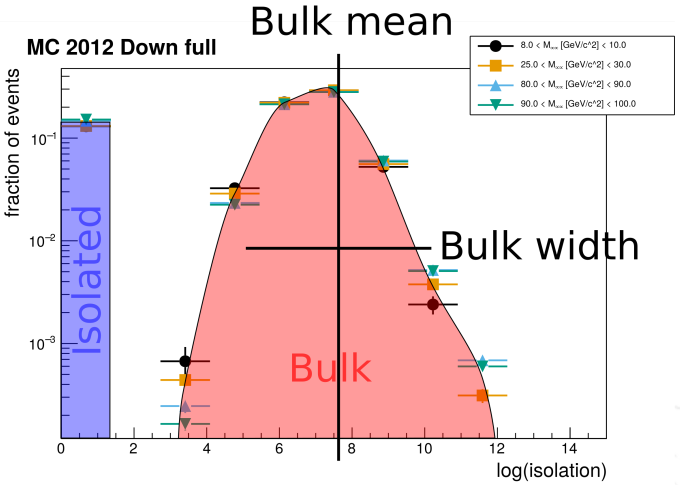



Backgrounds smear the isolation in data, especially away from resonances (orange). In MC very small mass-dependency, which we need to study.

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

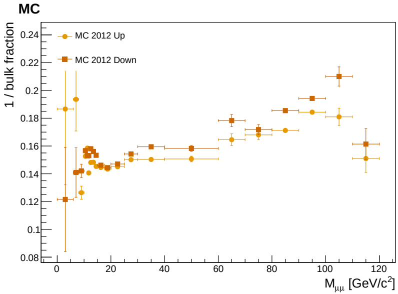
# Explanation of variables

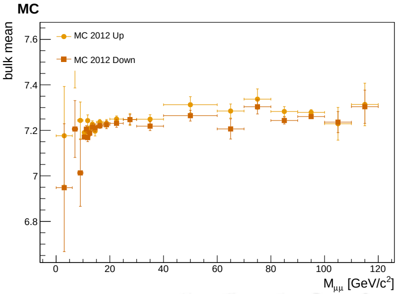



$$1/\text{bulk fraction} = \frac{\int \textcolor{blue}{isolated}}{\int \textcolor{red}{bulk}}$$

# Mass dependency of bulk

MC, 2012



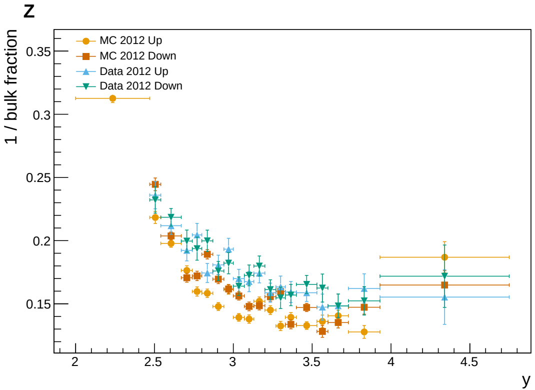

Large mass-dependence of bulk fraction, but smaller mass-dependence of bulk mean.

Difference between MagUp and MagDown to be investigated.

# Effect of rapidity

## $Z$-peak

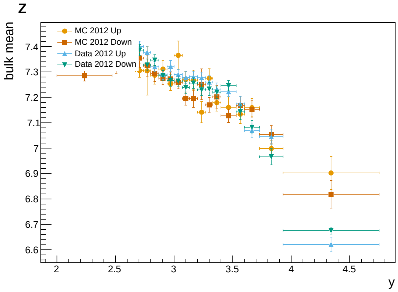
Strong dependency of bulk fraction of rapidity.

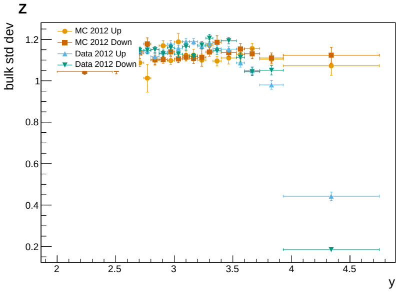



1 / bulk fraction under-estimated in MC.

# Effect of rapidity

## $Z$-peak

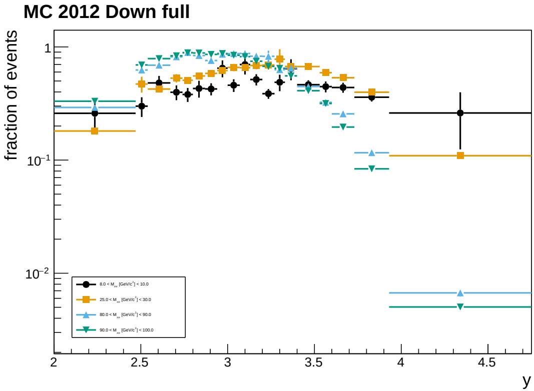



MC and data bulk mean and width agree at $Z$-peak. Data shows some dependency of bulk width for high $y$, MC not.

# 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 (to be finished by next week).

# 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

- $\varrho$ signal fraction from the fit.
- $f^{\mathrm{MIG}}$ 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.

## $\varepsilon^{SEL}$

⇛ Evaluated using MC sample:

| | |
|---|---|
| 2011 MagDown | $0.21320 \pm 0.00014$ |
| 2011 MagUp | $0.21306 \pm 0.00014$ |
| 2012 MagDown | $0.20402 \pm 0.00013$ |
| 2012 MagUp | $0.20372 \pm 0.00013$ |

⇛ Good agreement between polarities!

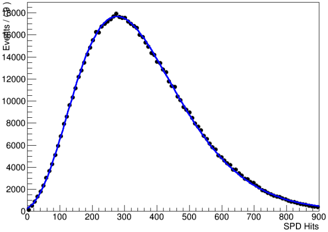
⇛ 2012 efficiency is lower than the 2011.

⇛ Will merge the polarities:

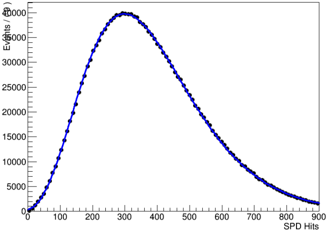
| | |
|---|---|
| 2011 | $0.21313 \pm 0.00010$ |
| 2012 | $0.20387 \pm 0.00009$ |

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

⇛ 2011 data:

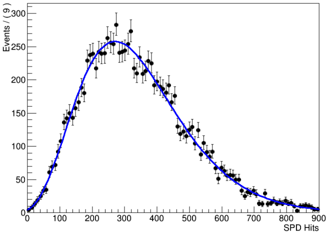



⇛ 2012 data:



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

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




⇛ 2012 data
$y \in (2, 2.25)$
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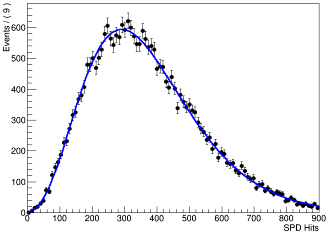
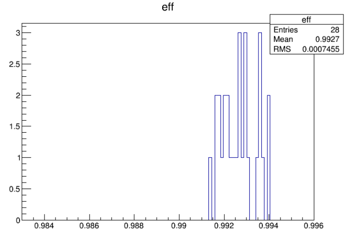


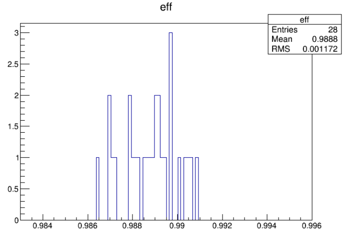

⇛ We didn't observe a variation of the efficiency as a function of $M_{\mu\mu}$ and $y$.

⇛ Proposed systematic:

⇛ 2011 data:




⇛ 2012 data:



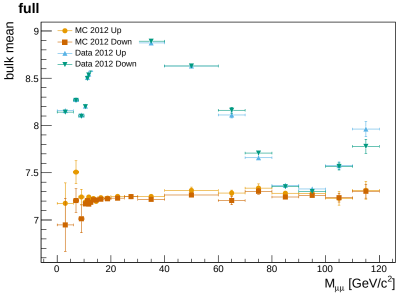

⇛ Suggest the RMS as small systematic.

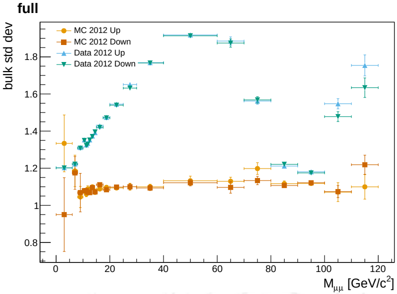
# Conclusions

- MC isolation template describes data at $Z$-peak reasonably well
- But some differences (mainly in $y$) 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

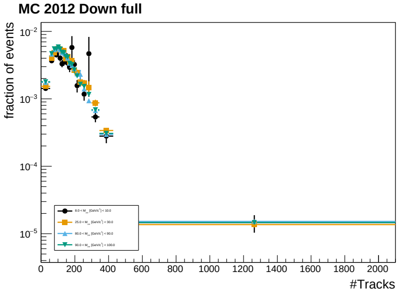


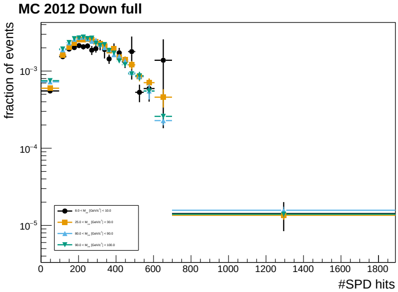




Near the $Z$-peak and the $\Upsilon$-peak good agreement.
Small mass-dependency even in MC ($value\%$).

# Effect of multiplicity

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

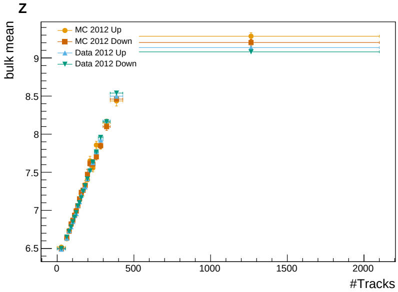


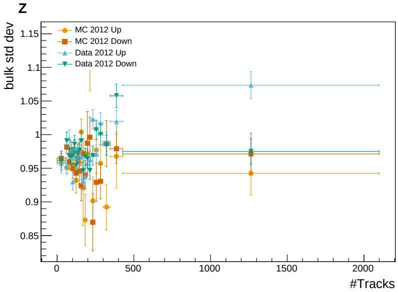




No mass dependency of multiplicity ($nTracks$ and $nSPD$) in MC

# Effect of multiplicity

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

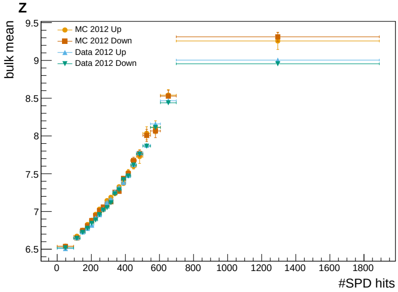


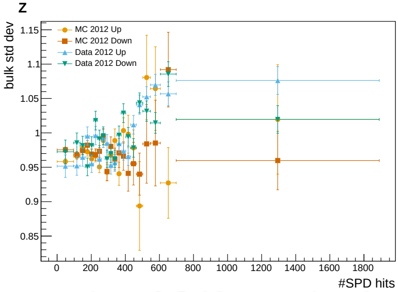




In data, width and mean of bulk dependent on $nTracks$, in MC only mean.

# Effect of multiplicity

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

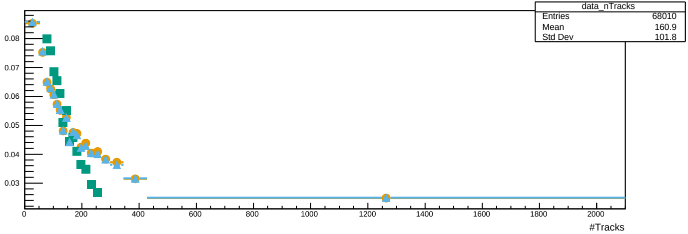


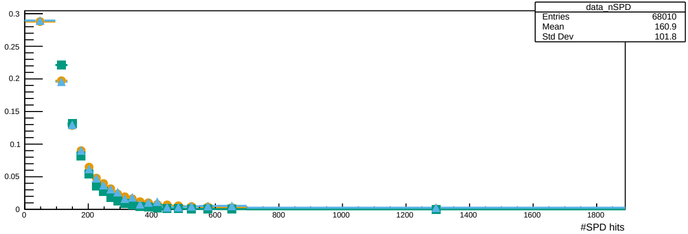




Mean of bulk agrees in data and MC.

# Multiplicity reweighting

## Data, MC befor reweighting, MC after reweighting



# Backup