Low Mass Drell-Yan Status Report

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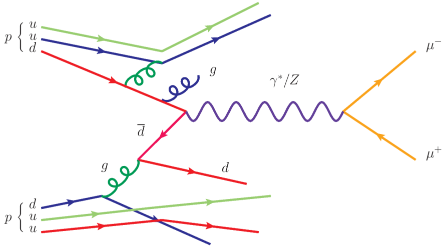
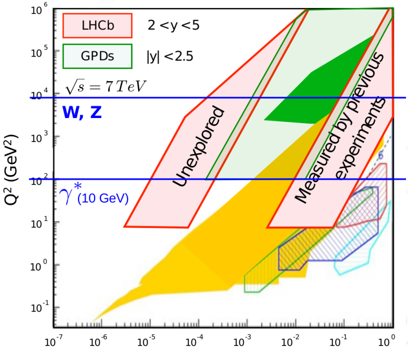
Introduction to Drell-Yan

- Drell-Yan are process of two quark anihilations in which neutral coupling 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 and 2012 data set.
- Plan to measure them separately as well as the ratio (cancellation of systematics).
- 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.

The Goal

⇛ Since there is no normalization channel, we will use the integrated luminosity for cross section calculations

⇛ The measurement will be performed in the bins of dimuon mass and pseudo-rapidity:

$M_{\mu\mu}$ [GeV/c^2]	10.5 – 11.0	11.0 – 11.5	11.5 – 12.0
	12.0 – 13.0	13.0 – 14.0	14.0 – 15.0
	15.0 – 17.5	17.5 – 20.0	20.0 – 25.0
	25.0 – 30.0	30.0 – 40.0	40.0 – 60.0
	60.0 – 70.0	70.0 – 80.0	80.0 – 90.0
	90.0 – 100.0	100.0 – 110.0	110.0 – 120.0
y	2.0 – 4.5		

$M_{\mu\mu}$ [GeV/c^2]	10.5 – 12.0	12.0 – 15.0	
	15.0 – 20.0	20.0 – 60.0	
y	2.0 – 2.25	2.25 – 2.5	2.5 – 2.75
	2.75 – 3.0	3.0 – 3.25	3.25 – 3.5
	3.5 – 4.5		

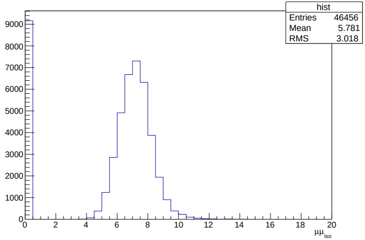
Isolation

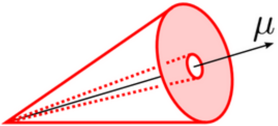
- Drell-Yan unfortunately do not peak in mass $\twoheadrightarrow$ need another variable to control the purity.
- Instead we define an isolation variable:

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

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

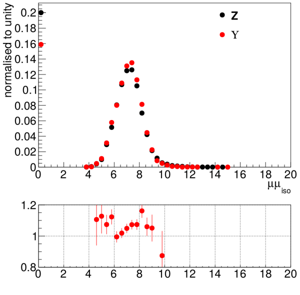
$$\mu\mu_{\text{iso}} = \max(\mu^+_{\text{iso}}, \mu^-_{\text{iso}})$$



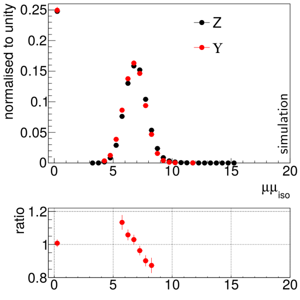


Isolation mass dependence

- Unfortunately the $\mu\mu_{iso}$ is showing some mass dependence:



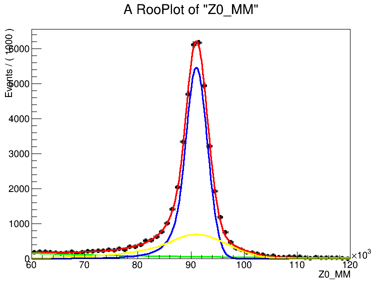
(a) data

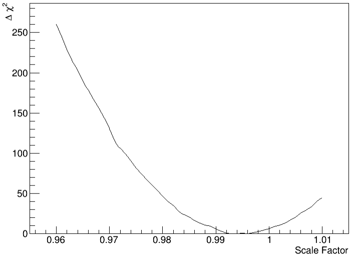


(b) simulation

Signal template

- We do not want to use MC for determination of the signal $\mu\mu_{iso}$ template.
- We adopted a data driven procedure:
  - The template is taken from data and scaled to account for $\mu\mu_{iso}$ mass dependence.
- Possibility 1:
  - Take the *Splot* $Z \to \mu\mu$ from data and multiply it by the scale factor determined from minimalising the χ^2 between MC Z and DY in particular region.



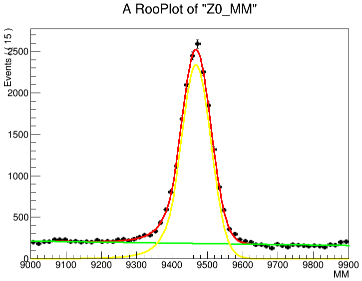


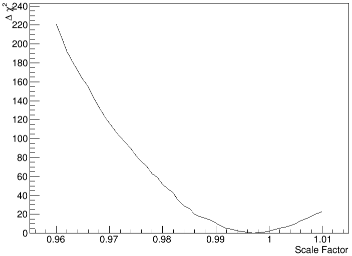
Signal template

- Possibility 2:
  - Use a second decay from data: $\Upsilon \to \mu\mu$.
  - The template for a given mass range $(M_{\min}, M_{\max})$ is choose as:

$$\mathrm{Temp}(M) = \mathrm{Temp}^{\Upsilon} \frac{(M_Z - M_{\Upsilon} - (M - M_{\Upsilon}))}{M_Z - M_{\Upsilon}} + \mathrm{Temp}^{Z} \frac{M - M_{\Upsilon}}{M_Z - M_{\Upsilon}}$$

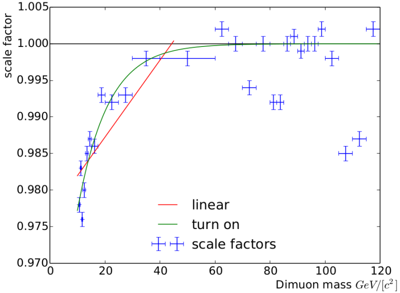
  - Then the new obtained template is scaled in the same way as the previous one.





Signal template - Summary

- We are investigating the impact on the analysis for the different approaches
- For now it looks like the results do not change with using different signal templates.
- Because templates are data driven we need to ensure a large statistics in each of the $m_{\mu\mu},\ y$ bins, because of this the last y bin is larger then the rest.



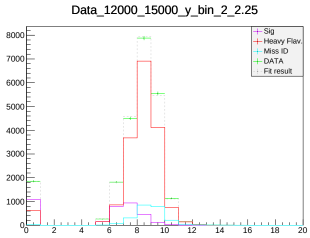
Backgrounds

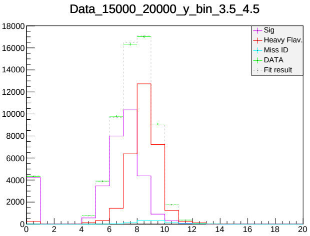
- There are two sources of backgrounds:
  - Heavy flavour decays.
  - Mis-ID.
- For fitting the $\mu\mu_{iso}$ we need to know both the signal and background distribution.
- Background templates can be determined from data
  - Heavy flavour decays:
    ↬ Requiring the $\chi^{2,\mu\mu}_{vtx} > 16$
  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

Over all fits

- Using the above 3 mentioned templates the fits converge without any problems.
- The higher one goes in mass the cleaner the signal is.

Mass bin	Purity
$[40, 60]$ GeV	0.879 ± 0.019
$[30, 40]$ GeV	0.754 ± 0.015
$[25, 30]$ GeV	0.657 ± 0.011
$[20, 25]$ GeV	0.507 ± 0.008
$[17.5, 20]$ GeV	0.402 ± 0.007
$[15, 17.5]$ GeV	0.316 ± 0.006





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

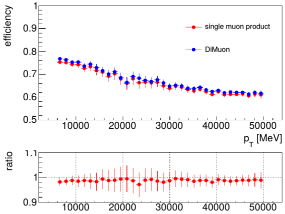
- ϱ signal fraction from the fit.
- f^{MIG} correction to bin-bin migration.
- $\mathcal{L}$ integrated luminosity.
- $\varepsilon^{\mathrm{SEL}}$ efficiency on the vertex requirement.
- $\varepsilon^{\mathrm{MUID}}$ muon identification efficiency.
- $\varepsilon^{\mathrm{GEC}}$ global event cut efficiency.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

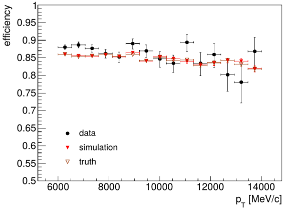
Luminosity

- Thanks to our colleagues the error on the luminosity in LHCb is $1.16(1.71)\%$ for 2012(2011) data.
- For the $8\ \mathrm{TeV}$ data we removed: 111802-111890 , 126124-126160, 129530-129539 runs.
- Lost $14.68\ \mathrm{pb}^{-1}$ of data in total.
- For the $7\ \mathrm{TeV}$ data we removed: 101401, 101403-101415 runs.
- Lost $8.23\ \mathrm{pb}^{-1}$.

Trigger efficiency

- We take the trigger efficiency from MC. We are using the dimuon trigger that were always well simulated.
- We performed a cross check using tag and probe method that ensures the luminosity is correctly simulated.

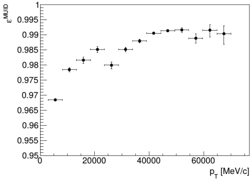




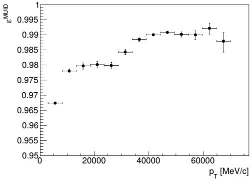
- An systematic uncertainty of 0.01 is assigned.

Muon Identification

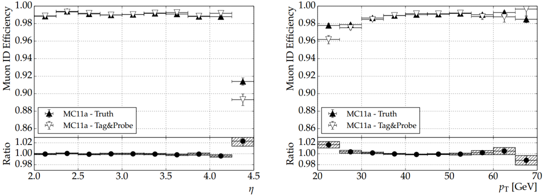
- Only muon ID requirement in this analysis is the `isMuon`.
- The efficiency is taken from MC.
- Has been cross-checked that it agrees in `LHCb-INT-2014-030`



(a) μ^-



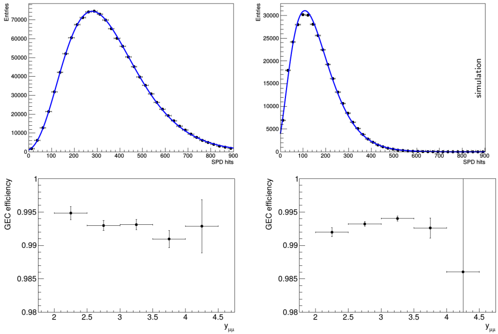
(b) μ^+



- The systematics is 0.005 (needs to be checked for the low p_T).

Global even cut efficiency

- There is a SPD cut for the dimuon trigger: SPD<900.
- A data driven method is used to estimate the cut.



$\varepsilon^{\rm GEC}$ as a function of y for Υ candidates (background subtracted)

$\varepsilon^{\rm GEC}$ as a function of y for Z candidates

- No dependence is observed of the $M_{\mu\mu}$ and the y in data.
- Similar to the W and Z analysis.

Conclusions

- Analysis is well advanced!
- The analysis note is beeing written as we speak: `svn+ssh://svn.cern.ch/reps/lhcbdocs/Users/mchrzasz/DY_ANANote`
- $+30$ pages!
- To do list:
  - Calculate the theory predictions for $8\ \mathrm{TeV}$ data.
  - Missing systematics: bin-bin migration, templates determination.
  - Hopefully the ANA note in WG review soon!

Backup