Plans for a LHCb m_W measurement

Mika Vesterinen
University of Oxford

W mass workshop, CERN, 22/6/2017

With input from O. Lupton,
and largely based on **EPJC (2015) 75: 601**
with G. Bozzi, L. Citelli, A. Vicini.

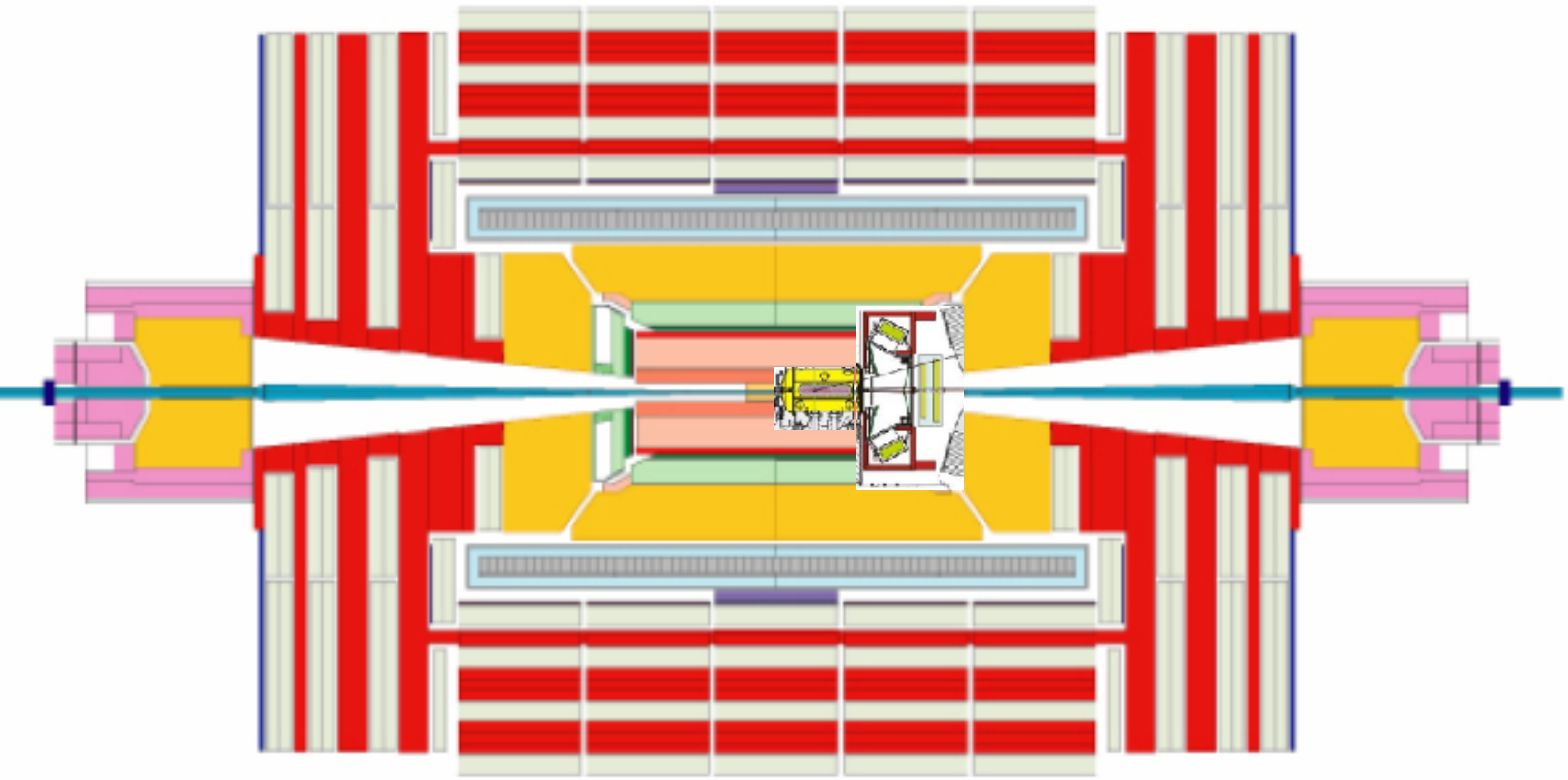
Why at LHCb?

Surely not? Smaller kinematic acceptance than ATLAS/CMS. No missing p_T, hence poorer purity.

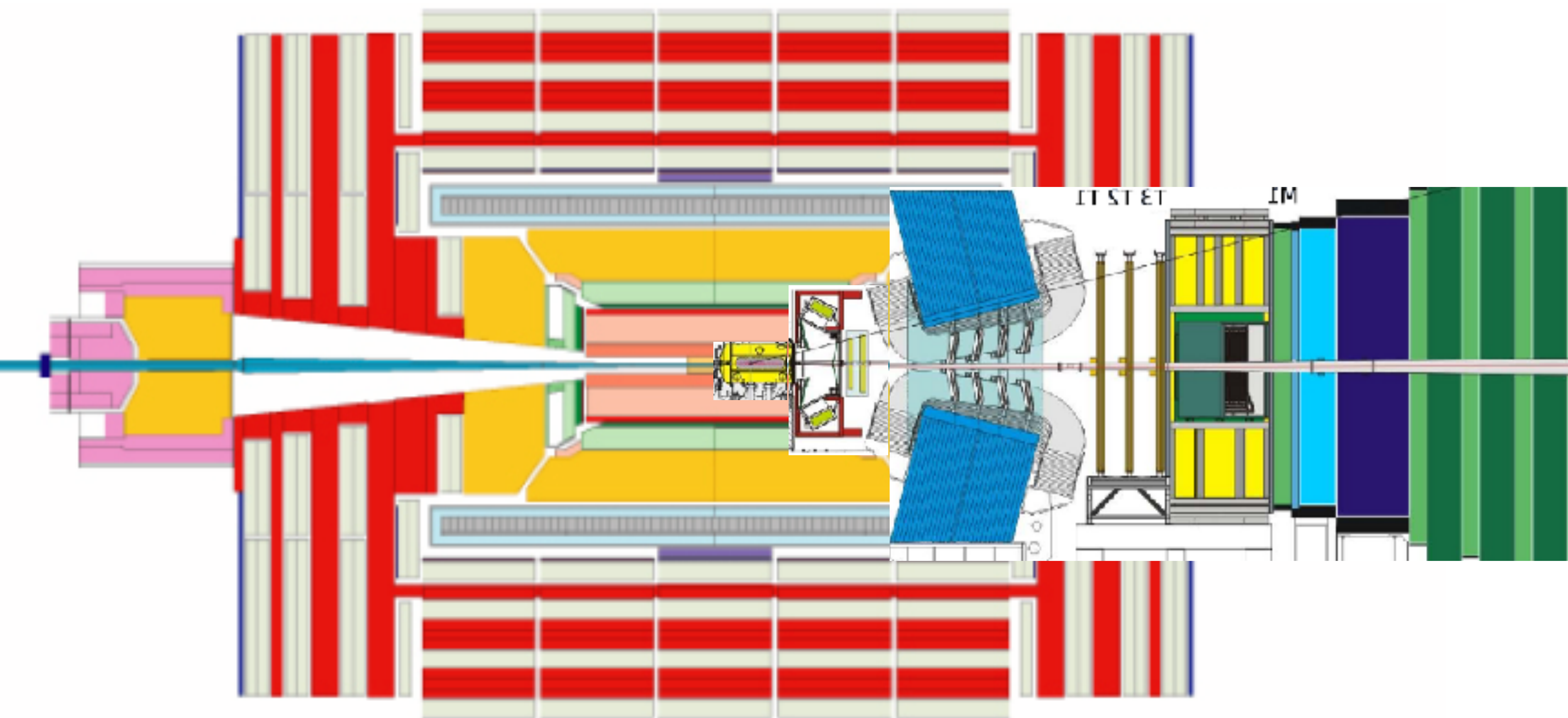
The unique kinematic acceptance is exactly WHY we want to measure m_W with LHCb.

Statistics isn't an issue. LHCb will have ~10M W decays by the end of Run-II.

Complementarity

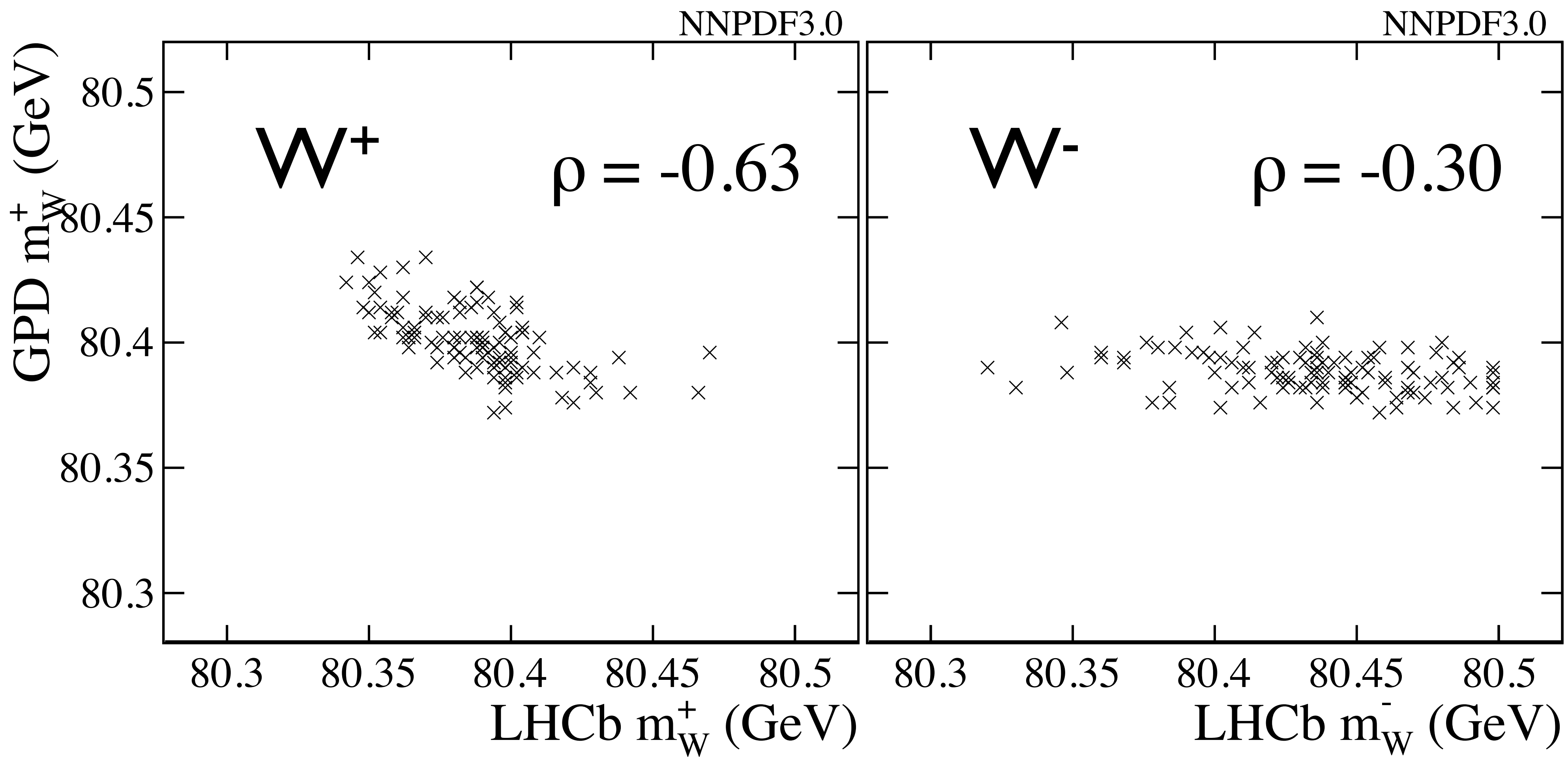


Complementarity



Effect on PDF uncertainties

(Assuming only p_T^{lept} based measurements)



The lepton-acceptance driven PDF uncertainty is highly anti correlated between central and forward m_W measurements.

Table 5
The uncertainties on different LHC averages for m_W. The separate experimental and PDF uncertainties are listed, as are the weights that minimise the total uncertainty

Scenario	Experiments	δm_W (MeV)			
		Tot	Exp	PDF	α
Default	$2\times$GPD + LHCb	9.0	4.7	7.7	(0.30, 0.44, 0.22, 0.04)
Default	$1\times$GPD + LHCb	10.1	6.5	7.7	(0.31, 0.40, 0.25, 0.04)
Default	$2\times$GPD	12.0	5.8	10.5	(0.28, 0.72, 0, 0)
PDF4LHC(3-sets)	$2\times$GPD + LHCb	13.6	4.8	12.7	(0.43, 0.41, 0.12, 0.04)
PDF4LHC(3-sets)	$1\times$GPD + LHCb	14.6	7.3	12.7	(0.43, 0.40, 0.12, 0.04)
PDF4LHC(3-sets)	$2\times$GPD	17.7	5.5	16.9	(0.50, 0.50, 0, 0)
$\delta_{\rm exp}^{\rm LHCb} = 0$	$2\times$GPD + LHCb	8.7	4.0	7.7	(0.31, 0.41, 0.24, 0.04)
$\delta_{\rm exp}^{\rm LHCb} = 0$	$1\times$GPD + LHCb	9.8	5.9	7.9	(0.31, 0.37, 0.28, 0.04)
$\delta_{\rm exp}^{\rm LHCb} = 0$	$2\times$GPD	12.0	5.8	10.5	(0.28, 0.72, 0, 0)
$\delta_{\rm exp}^{\rm GPD} = 0$	$2\times$GPD + LHCb	7.9	1.9	7.7	(0.29, 0.48, 0.19, 0.04)
$\delta_{\rm exp}^{\rm GPD} = 0$	$1\times$GPD + LHCb	7.9	1.9	7.7	(0.29, 0.48, 0.19, 0.04)
$\delta_{\rm exp}^{\rm GPD} = 0$	$2\times$GPD	10.5	0.1	10.5	(0.26, 0.74, 0, 0)
$\delta_{\rm PDF} = 0$	$2\times$GPD + LHCb	4.6	4.6	0.0	(0.34, 0.34, 0.22, 0.10)
$\delta_{\rm PDF} = 0$	$1\times$GPD + LHCb	5.8	5.8	0.0	(0.23, 0.23, 0.37, 0.17)
$\delta_{\rm PDF} = 0$	$2\times$GPD	5.5	5.5	0.0	(0.50, 0.50, 0, 0)
$\delta_{\rm exp}^{\rm LHCb} \times 2$	$2\times$GPD + LHCb	9.6	5.6	7.7	(0.29, 0.50, 0.17, 0.04)
$\delta_{\rm exp}^{\rm LHCb} \times 2$	$1\times$GPD + LHCb	10.8	7.6	7.7	(0.30, 0.46, 0.20, 0.05)
$\delta_{\rm exp}^{\rm LHCb} \times 2$	$2\times$GPD	12.0	5.8	10.5	(0.28, 0.72, 0, 0)
$\delta_{\rm exp}^{\rm GPD} \times 2$	$2\times$GPD + LHCb	11.2	7.9	8.0	(0.32, 0.35, 0.29, 0.04)
$\delta_{\rm exp}^{\rm GPD} \times 2$	$1\times$GPD + LHCb	13.9	10.5	9.0	(0.31, 0.26, 0.37, 0.05)
$\delta_{\rm exp}^{\rm GPD} \times 2$	$2\times$GPD	15.6	11.5	10.6	(0.32, 0.68, 0, 0)
$\delta_{\rm PDF} \times 2$	$2\times$GPD + LHCb	16.0	4.7	15.3	(0.30, 0.45, 0.21, 0.04)
$\delta_{\rm PDF} \times 2$	$1\times$GPD + LHCb	16.7	6.7	15.3	(0.30, 0.44, 0.22, 0.04)
$\delta_{\rm PDF} \times 2$	$2\times$GPD	21.7	5.9	20.9	(0.27, 0.73, 0, 0)

EPJC (2015) 75: 601

Table 5
The uncertainties on different LHC averages for m_W. The separate experimental and PDF uncertainties are listed, as are the weights that minimise the total uncertainty

Scenario	Experiments	δm_W (MeV)			
		Tot	Exp	PDF	α
Default	2 × GPD + LHCb	9.0	4.7	7.7	(0.30, 0.44, 0.22, 0.04)
Default	1 × GPD + LHCb	10.1	5.5	7.7	(0.31, 0.40, 0.25, 0.04)
Default	2 × GPD	[illegible]	[illegible]	10.5	[illegible]
PDF4LHC(3-sets)	2 × GPD + LHCb	13.6	4.8	12.7	(0.43, 0.41, 0.12, 0.04)
PDF4LHC(3-sets)	1 × GPD + LHCb	[illegible]	[illegible]	[illegible]	[illegible]
PDF4LHC(3-sets)	2 × GPD	17.7	5.5	16.9	(0.50, 0.50, 0, 0)
$\delta_{exp}^{LHCb} = 0$	2 × GPD + LHCb	[illegible]	[illegible]	7.7	[illegible]
$\delta_{exp}^{LHCb} = 0$	1 × GPD + LHCb	9.8	5.9	7.9	(0.31, 0.37, 0.28, 0.04)
$\delta_{exp}^{LHCb} = 0$	2 × GPD	12.0	5.8	10.5	(0.28, 0.72, 0, 0)
$\delta_{exp}^{GPD} = 0$	2 × GPD + LHCb	7.9	1.9	7.7	(0.29, 0.48, 0.19, 0.04)
$\delta_{exp}^{GPD} = 0$	1 × GPD + LHCb	7.9	1.9	7.7	(0.29, 0.48, 0.19, 0.04)
$\delta_{exp}^{GPD} = 0$	2 × GPD	10.5	0.1	10.5	(0.26, 0.74, 0, 0)
$\delta_{PDF} = 0$	2 × GPD + LHCb	4.6	4.6	0.0	(0.34, 0.34, 0.22, 0.10)
$\delta_{PDF} = 0$	1 × GPD + LHCb	5.8	5.8	0.0	(0.23, 0.23, 0.37, 0.17)
$\delta_{PDF} = 0$	2 × GPD	5.5	5.5	0.0	(0.50, 0.50, 0, 0)
$\delta_{exp}^{LHCb} \times 2$	2 × GPD + LHCb	9.6	5.6	7.7	(0.29, 0.50, 0.17, 0.04)
$\delta_{exp}^{LHCb} \times 2$	1 × GPD + LHCb	10.8	7.6	7.7	(0.30, 0.46, 0.20, 0.05)
$\delta_{exp}^{LHCb} \times 2$	2 × GPD	12.0	5.8	10.5	(0.28, 0.72, 0, 0)
$\delta_{exp}^{GPD} \times 2$	2 × GPD + LHCb	11.2	7.9	8.0	(0.32, 0.35, 0.29, 0.04)
$\delta_{exp}^{GPD} \times 2$	1 × GPD + LHCb	13.9	10.5	9.0	(0.31, 0.26, 0.37, 0.05)
$\delta_{exp}^{GPD} \times 2$	2 × GPD	15.6	11.5	10.6	(0.32, 0.68, 0, 0)
$\delta_{PDF} \times 2$	2 × GPD + LHCb	16.0	4.7	15.3	(0.30, 0.45, 0.21, 0.04)
$\delta_{PDF} \times 2$	1 × GPD + LHCb	16.7	6.7	15.3	(0.30, 0.44, 0.22, 0.04)
$\delta_{PDF} \times 2$	2 × GPD	21.7	5.9	20.9	(0.27, 0.73, 0, 0)

Even with a modest target for our experimental uncertainties, the LHCb measurement would improve the *total* uncertainty on the LHC average by ~30%.

EPJC (2015) 75: 601

Even with a modest target for our experimental uncertainties, the LHCb measurement would improve the *total* uncertainty on the LHC average by ~30%.

This study may be underselling LHCb since it assumes that ATLAS/CMS could perfectly veto events with $p_T(W) > 15$ GeV.

It is obvious that we must carefully co-ordinate the treatment of correlated systematics so that we can best exploit our complementarity.

Table 5
The uncertainties on different LHC averages for m_W. The separate experimental and PDF uncertainties are listed, as are the weights that minimise the total uncertainty

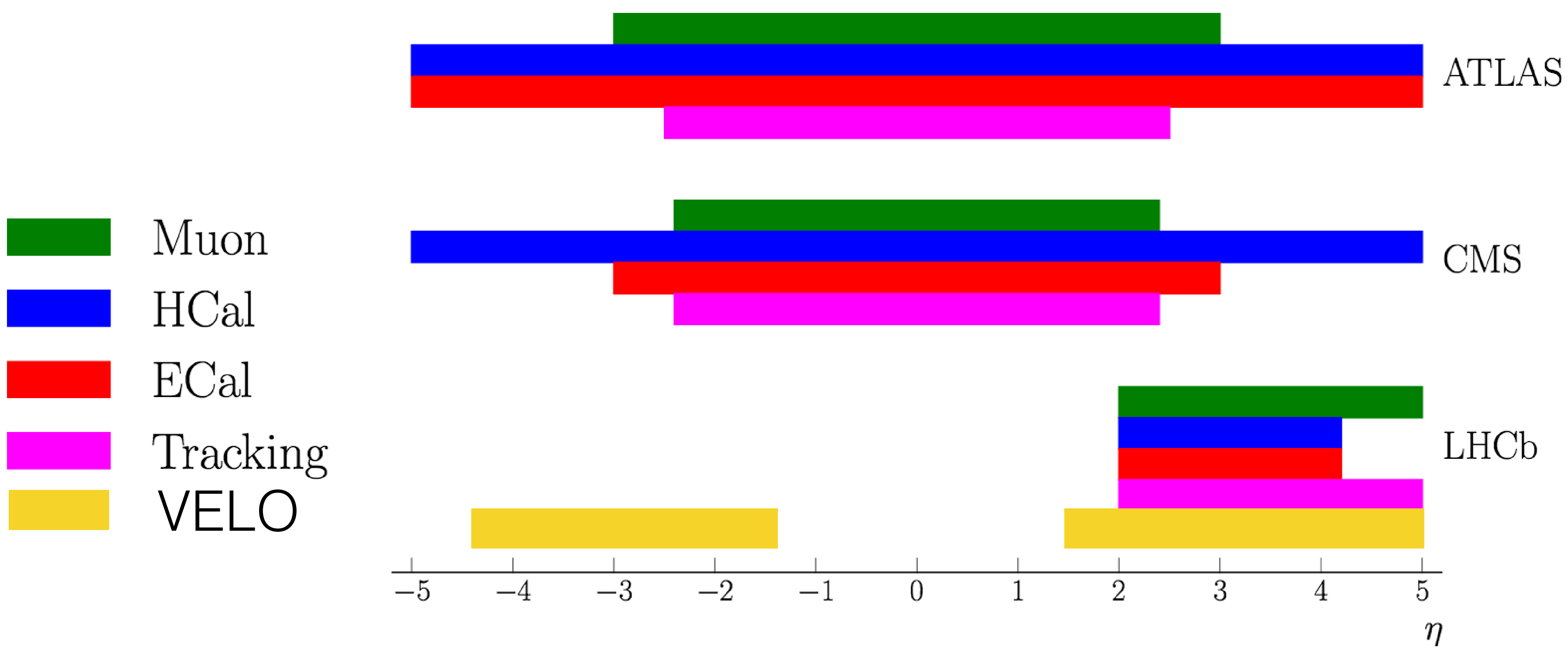
Scenario	Experiments	δm_W (MeV)			
		Tot	Exp	PDF	α
Default	2 × GPD + LHCb	9.0	4.7	7.7	(0.30, 0.44, 0.22, 0.04)
Default	1 × GPD + LHCb	10.1	[illegible]	7.7	(0.31, 0.40, 0.25, 0.04)
Default	[illegible]	[illegible]	[illegible]	10.5	[illegible]
PDF4LHC(3-sets)	[illegible]	13.6	4.8	12.7	(0.43, 0.41, 0.12, 0.04)
PDF4LHC(3-sets)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PDF4LHC(3-sets)	2 × GPD	17.7	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	7.7	[illegible]
$\delta_{exp}^{LHCb} = 0$	1 × GPD + LHCb	9.8	5.9	7.9	(0.31, 0.37, 0.28, 0.04)
$\delta_{exp}^{LHCb} = 0$	2 × GPD	12.0	5.8	10.5	(0.28, 0.72, 0, 0)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$\delta_{exp}^{GPD} = 0$	1 × GPD + LHCb	7.9	1.9	[illegible]	(0.29, 0.48, 0.19, 0.04)
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
$\delta_{PDF} = 0$	2 × GPD + LHCb	4.6	4.6	0.0	(0.34, 0.34, 0.22, 0.10)
[illegible]	1 × GPD + LHCb	5.8	5.8	0.0	(0.23, 0.23, 0.37, 0.17)
$\delta_{PDF} = 0$	2 × GPD	5.5	5.5	0.0	(0.50, 0.50, 0, 0)
$\delta_{exp}^{LHCb} \times 2$	2 × GPD + LHCb	9.6	5.6	7.7	(0.29, 0.50, 0.17, 0.04)
$\delta_{exp}^{LHCb} \times 2$	1 × GPD + LHCb	10.8	7.6	7.7	[illegible]
[illegible]	2 × GPD	12.0	5.8	10.5	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	8.0	[illegible]
[illegible]	1 × GPD + LHCb	[illegible]	10.5	9.0	(0.31, 0.26, 0.37, 0.05)
[illegible]	[illegible]	15.6	11.5	10.6	[illegible]
$\delta_{PDF} \times 2$	[illegible]	16.0	4.7	15.3	[illegible]
$\delta_{PDF} \times 2$	1 × GPD + LHCb	16.7	6.7	15.3	(0.30, 0.44, 0.22, 0.04)
$\delta_{PDF} \times 2$	2 × GPD	21.7	5.9	20.9	(0.27, 0.73, 0, 0)

About the LHCb measurement

- Only with charged lepton p_T.
- Only with muons.
- Plan to proceed directly to 7,8,13 TeV analysis.
- (Limited?) use of recoil activity.

About the LHCb measurement

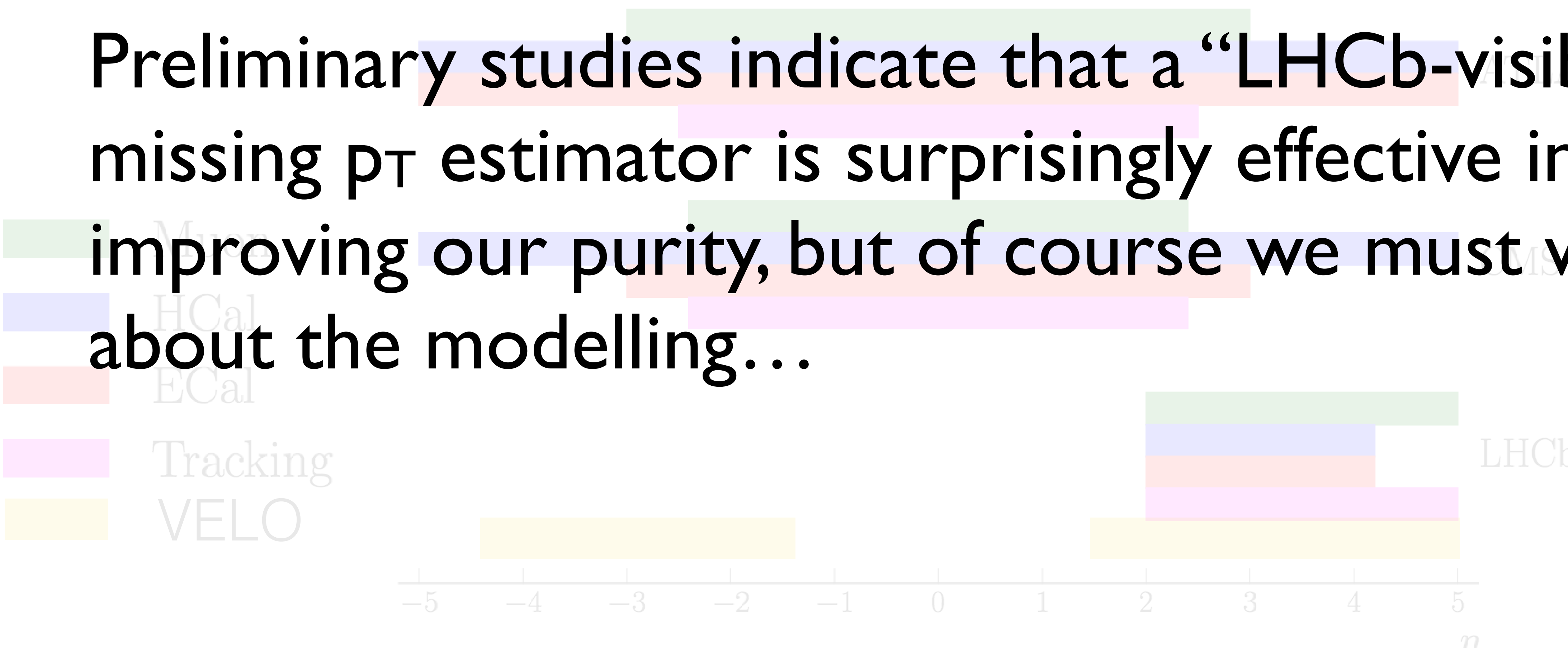
- Only with charged lepton p_T.
- Only with muons.
- Plan to proceed directly to 7,8,13 TeV analysis.
- (Limited?) use of recoil activity.



About the LHCb measurement

- Only with charged lepton p_T.
- Only with muons.
- Plan to proceed directly to 7,8,13 TeV analysis.
- (Limited?) use of recoil activity.

Preliminary studies indicate that a “LHCb-visible” missing p_T estimator is surprisingly effective in improving our purity, but of course we must worry about the modelling…



About the LHCb measurement

- Only with charged lepton p_T.
- Only with muons.
- Plan to proceed directly to 7,8,13 TeV analysis.
- (Limited?) use of recoil activity.

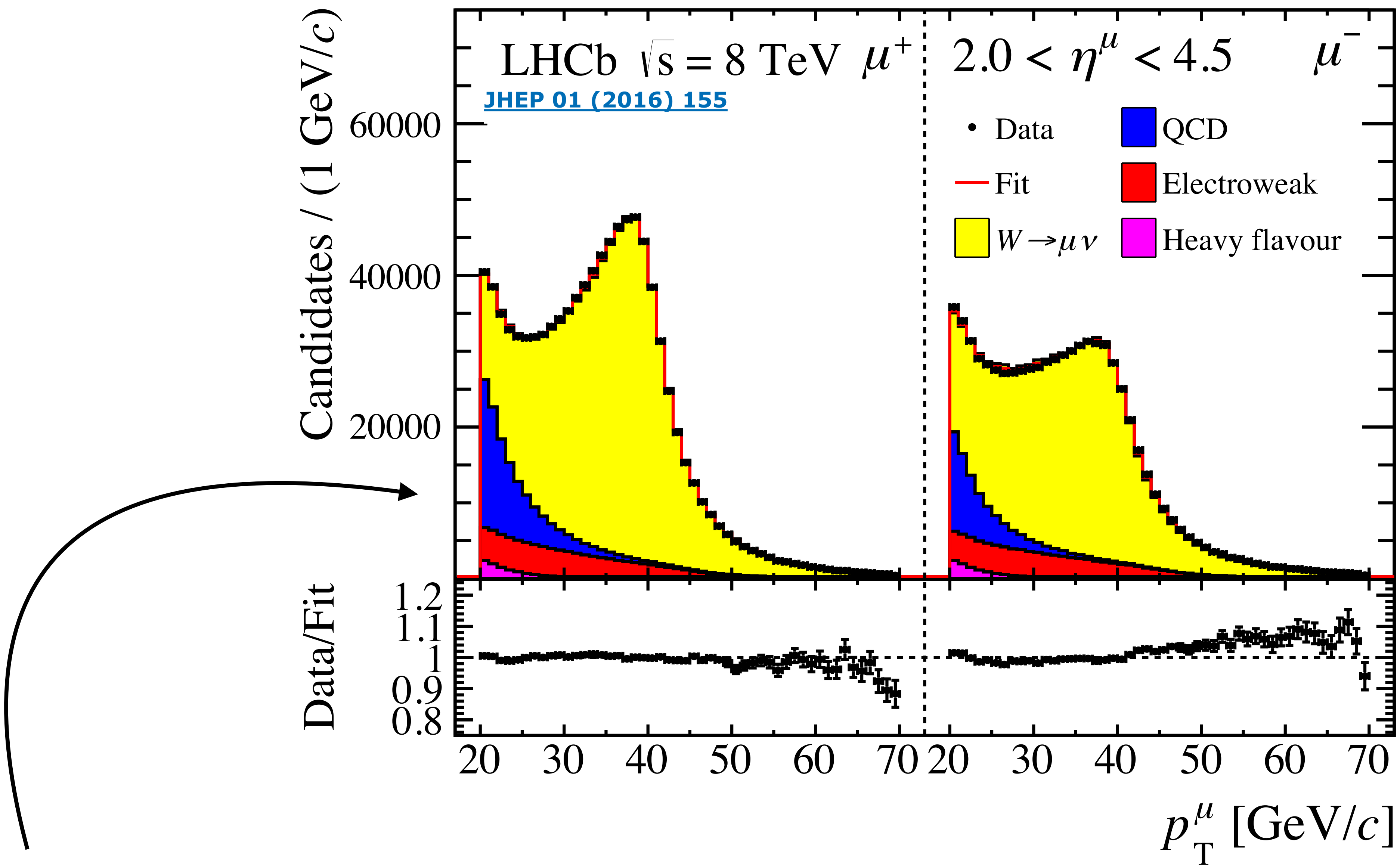
LHCb challenges:

p_T(W) model: less able to test modelling with recoil in *W* events. Modelling in forward direction is less charted territory — expect surprises!

Purity: no “proper” missing p_T.

W purity and yield

Expect to have ~10^7 *W* decays by the end of Run-II.



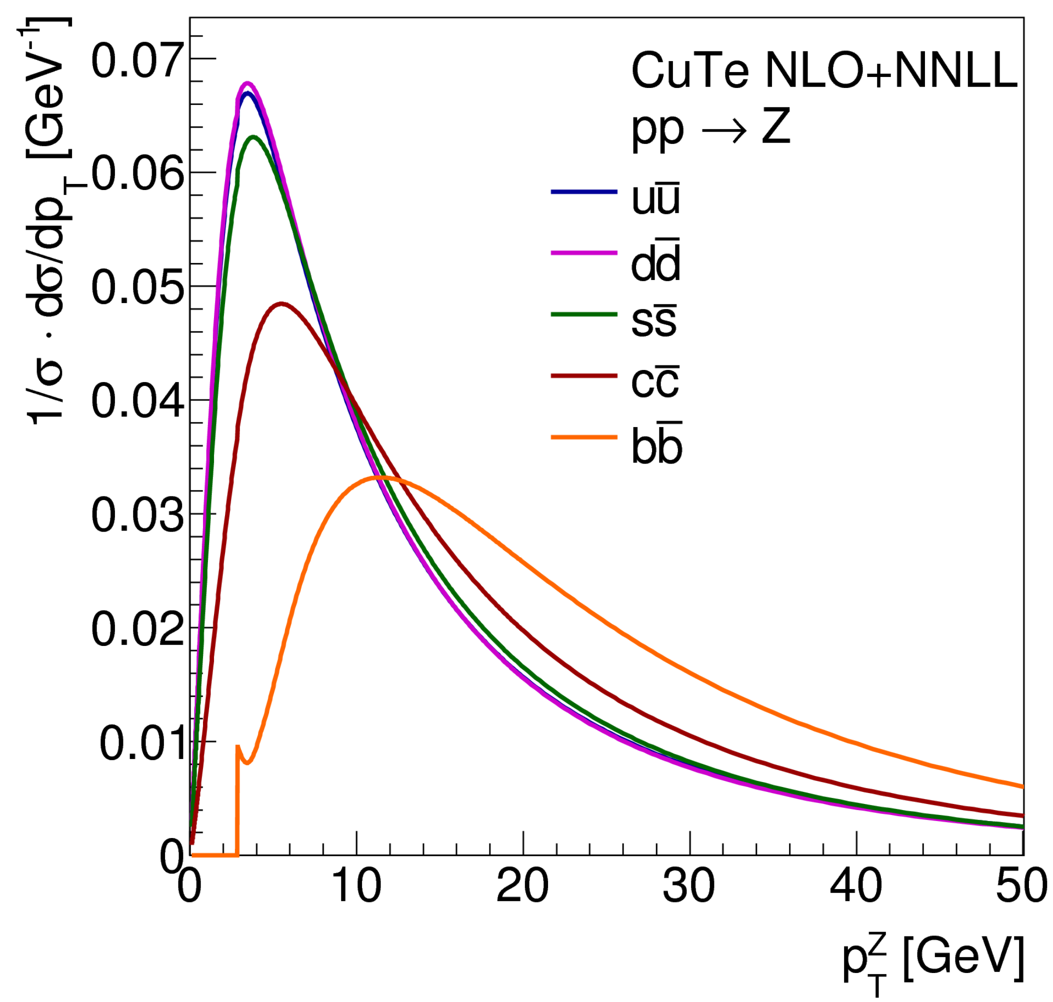
We must carefully control this background.

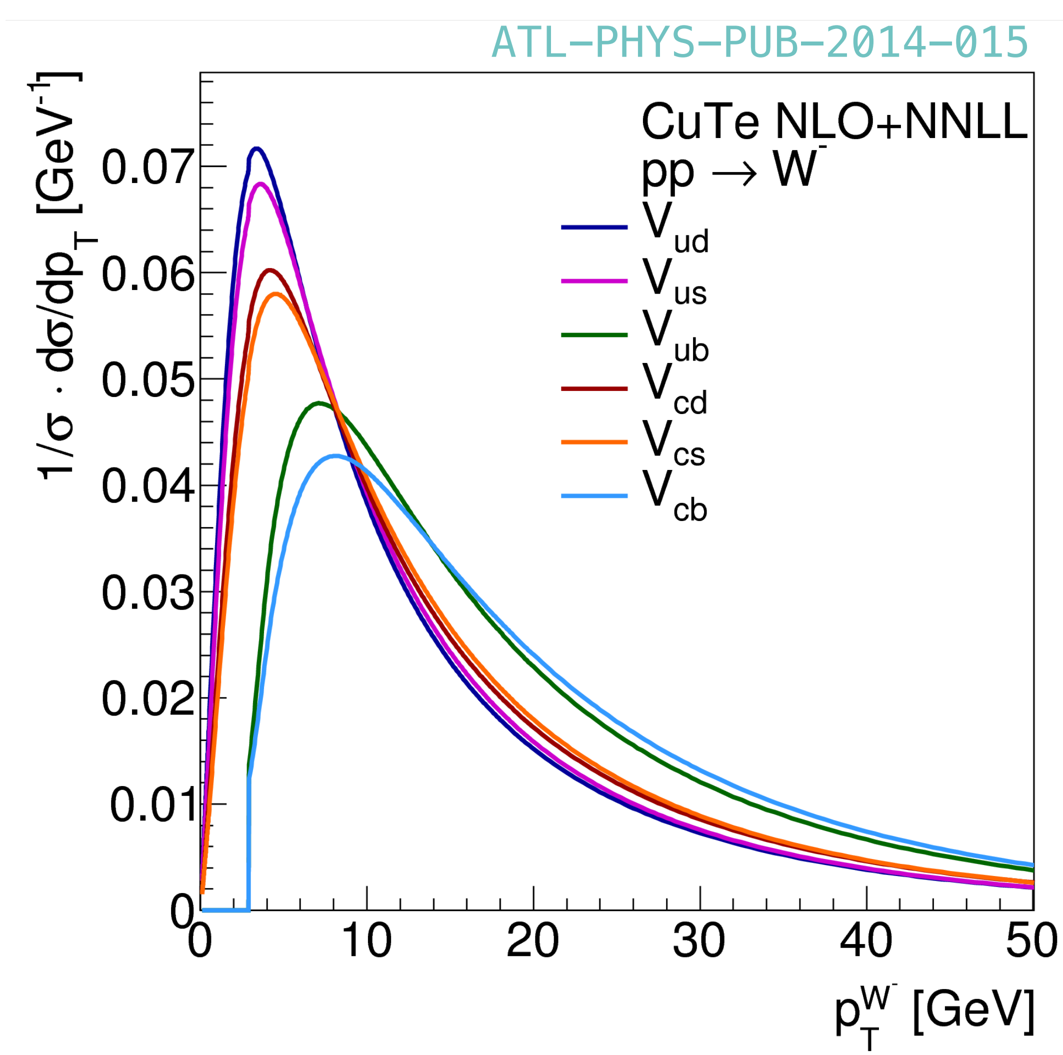
W pT model

We will have ~10^6 $Z/\gamma^* \rightarrow \mu\mu$ decays.

The problem is the translation *Z* to *W*.

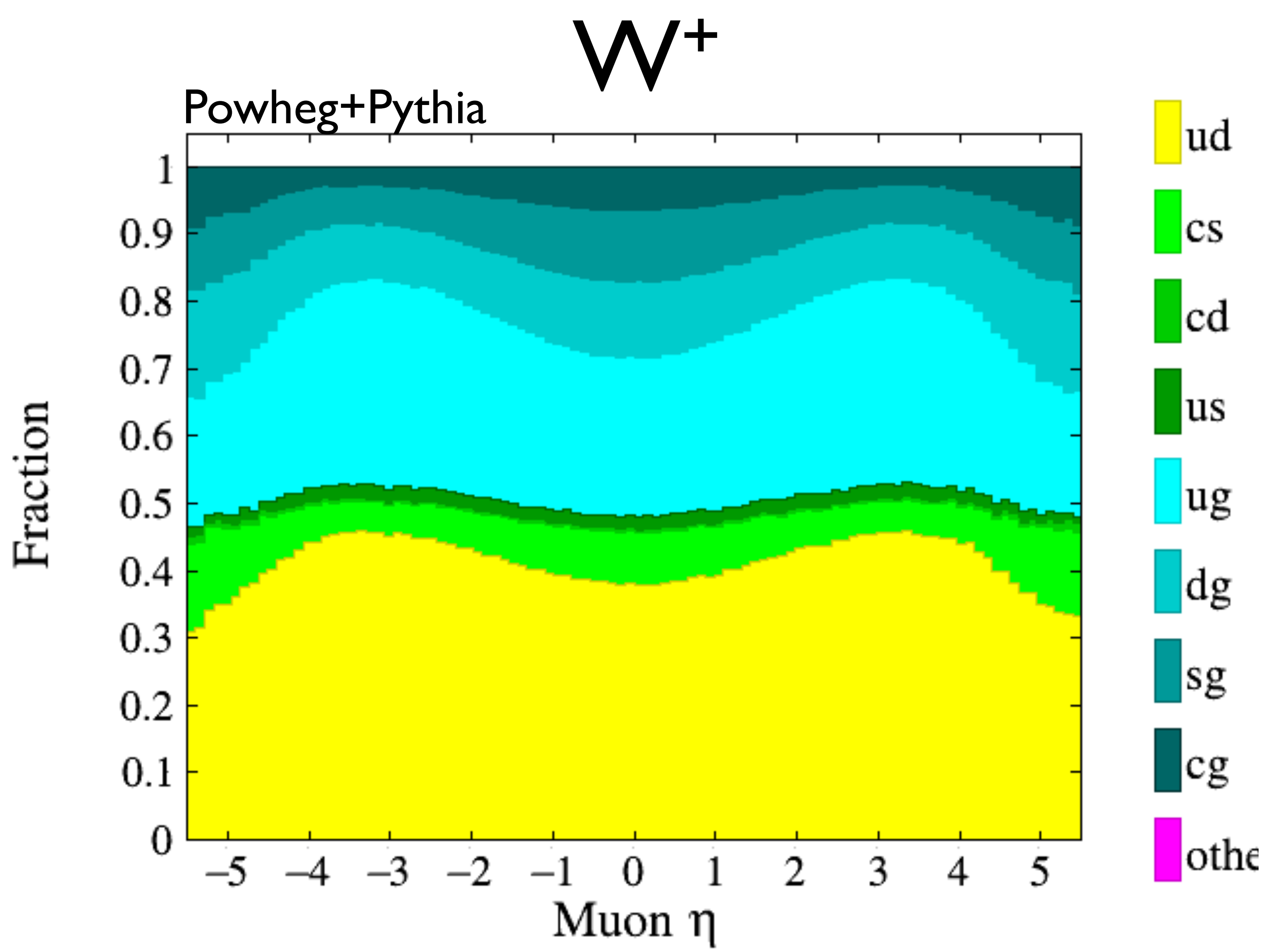
E.g. heavy quark effects

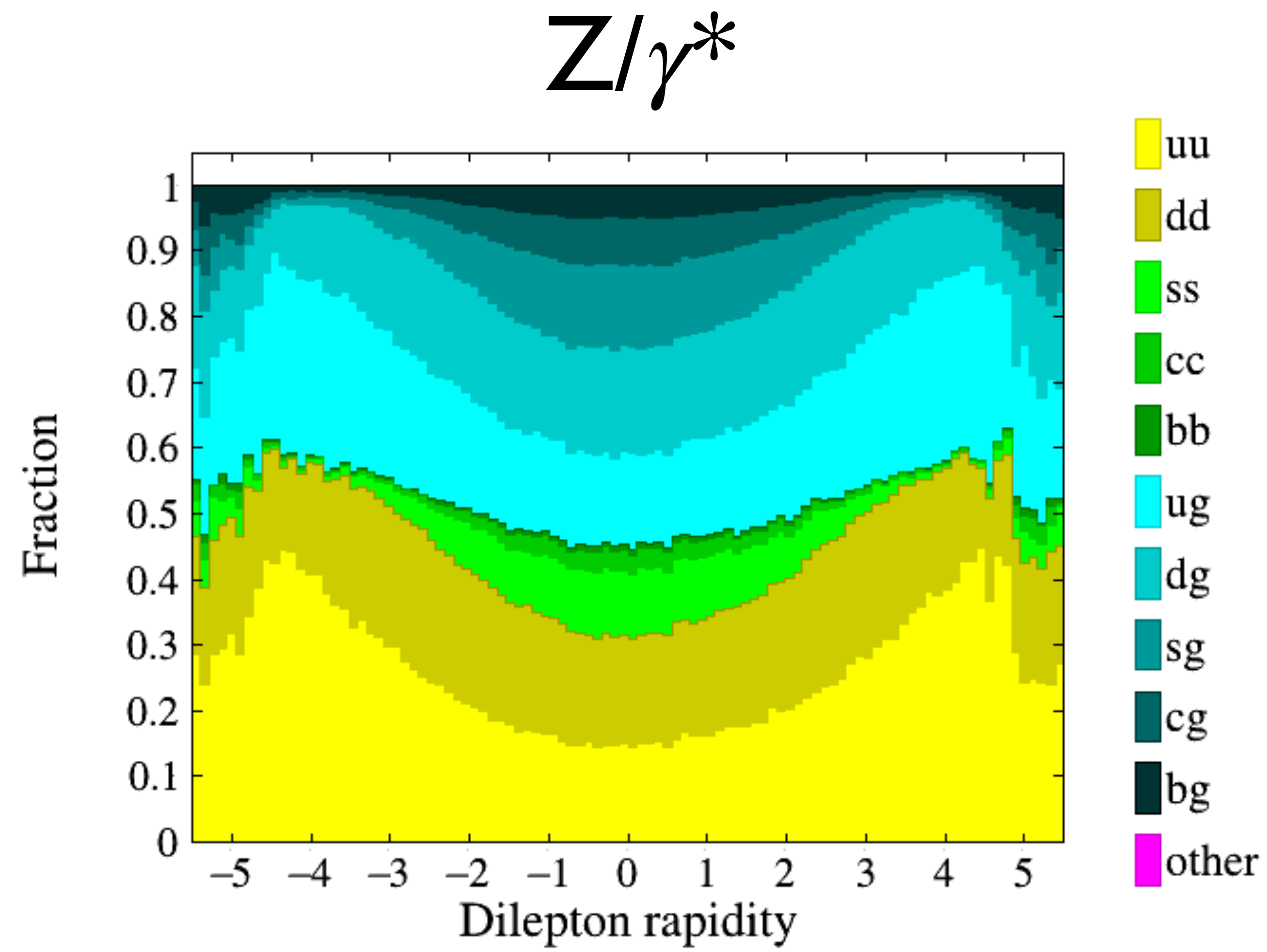




W p_T model

Perhaps this is even more motivation to make a m_W measurement in a unique kinematic region.





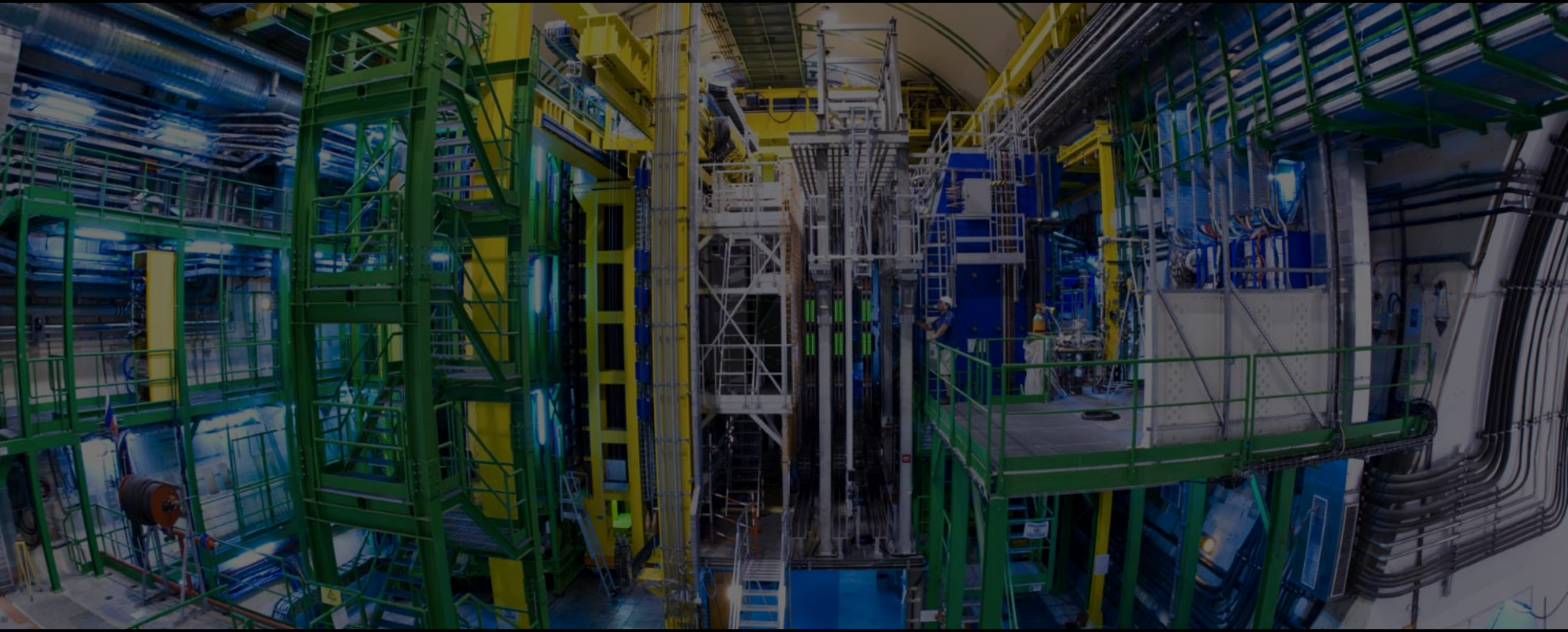
W p_T model

Question to our theory friends: What are the most important unfolded ($Z/\gamma^* \to \mu\mu$, or anything else) measurements that we should focus on in the short term?

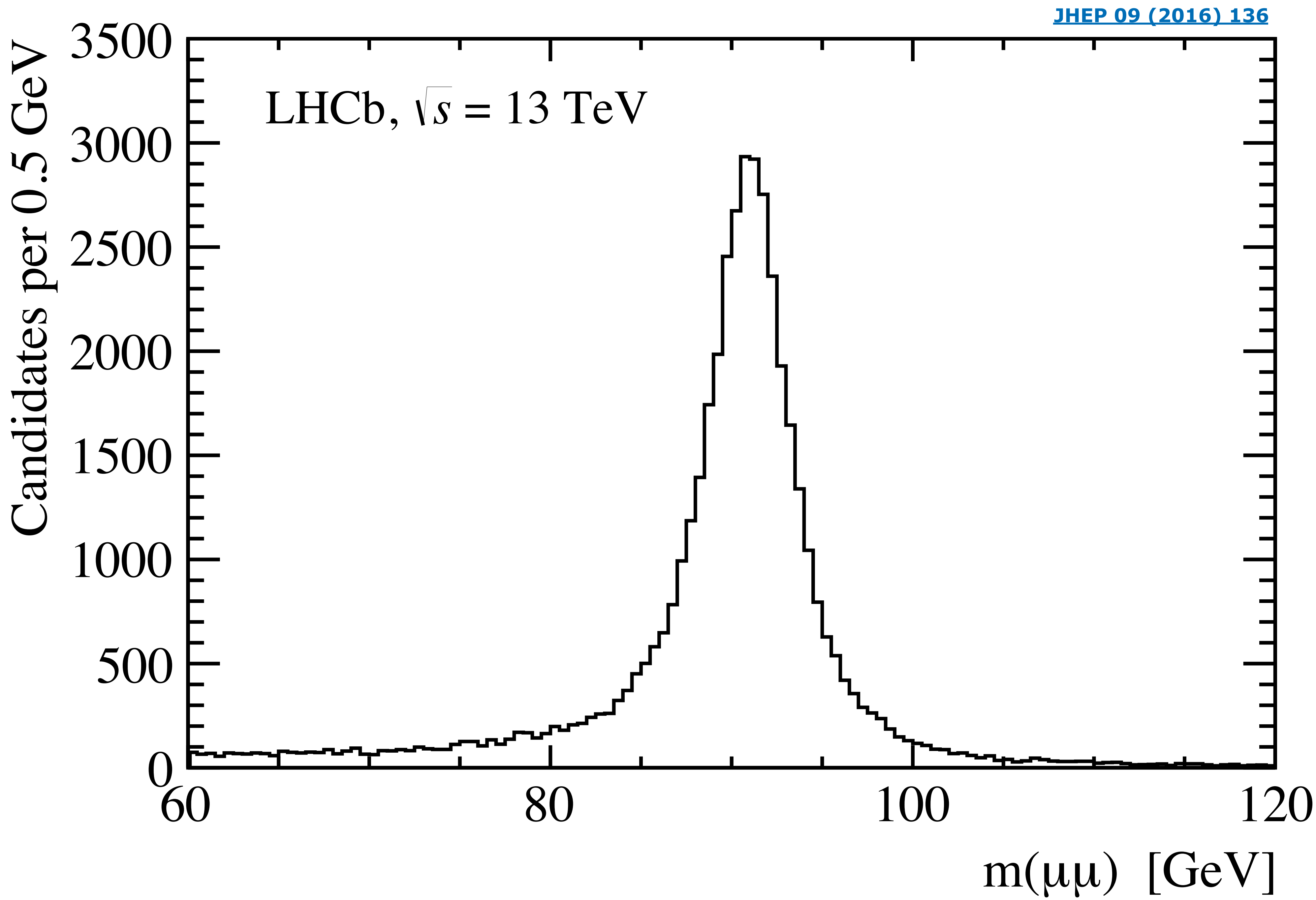
We certainly plan to make measurements of angular coefficients, and $(1/\sigma)\,(d^3\sigma/dp_T dy dM)$ with the finest granularity that our Z data statistically allows.

Conclusion

We look forward to joining our theory, ATLAS, CMS, CDF and D0 friends in this m_W effort!



Backup slides start here


JHEP 09 (2016) 136
LHCb, √s = 13 TeV
Candidates per 0.5 GeV
3500
3000
2500
2000
1500
1000
500
0
60
80
100
120
m(μμ) [GeV]