PDF sensitivity with LHCb

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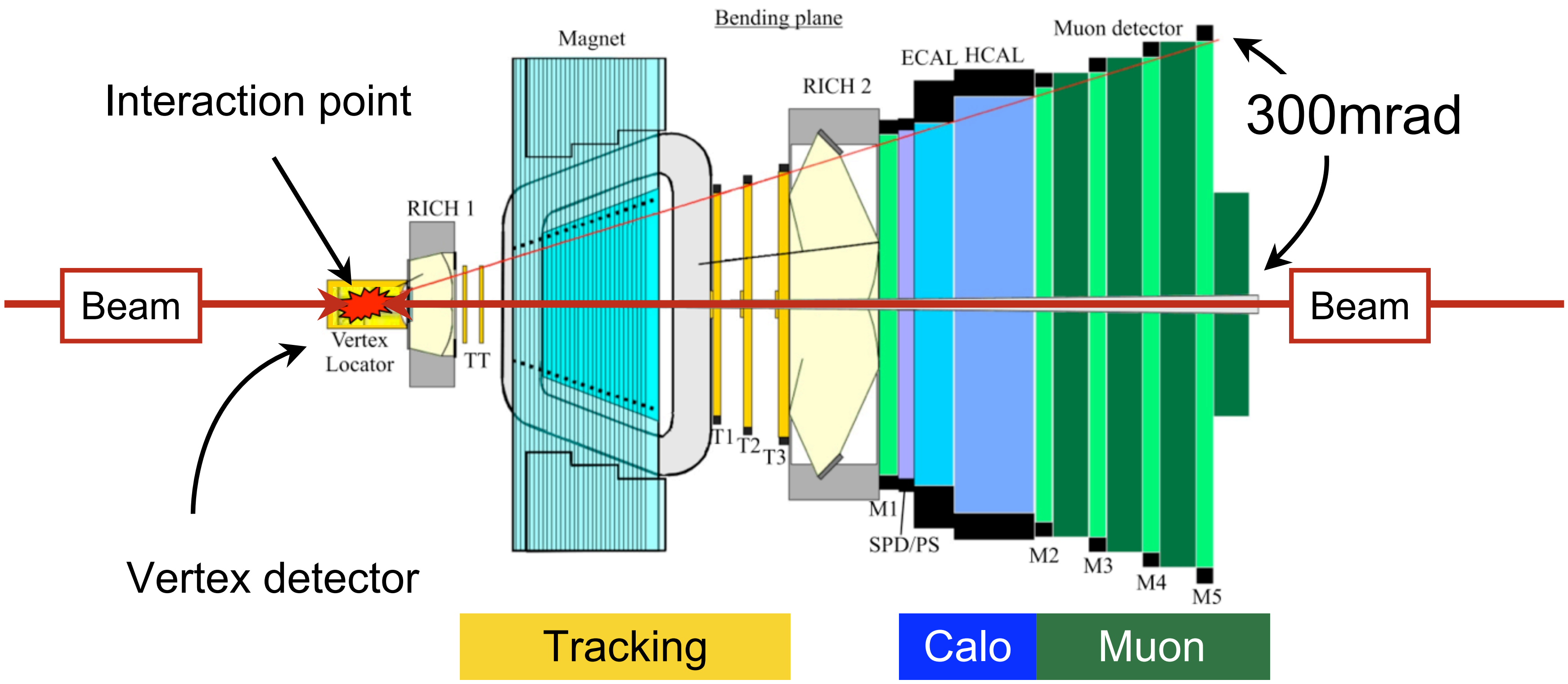
LHCb

Kinematic range
Measurements

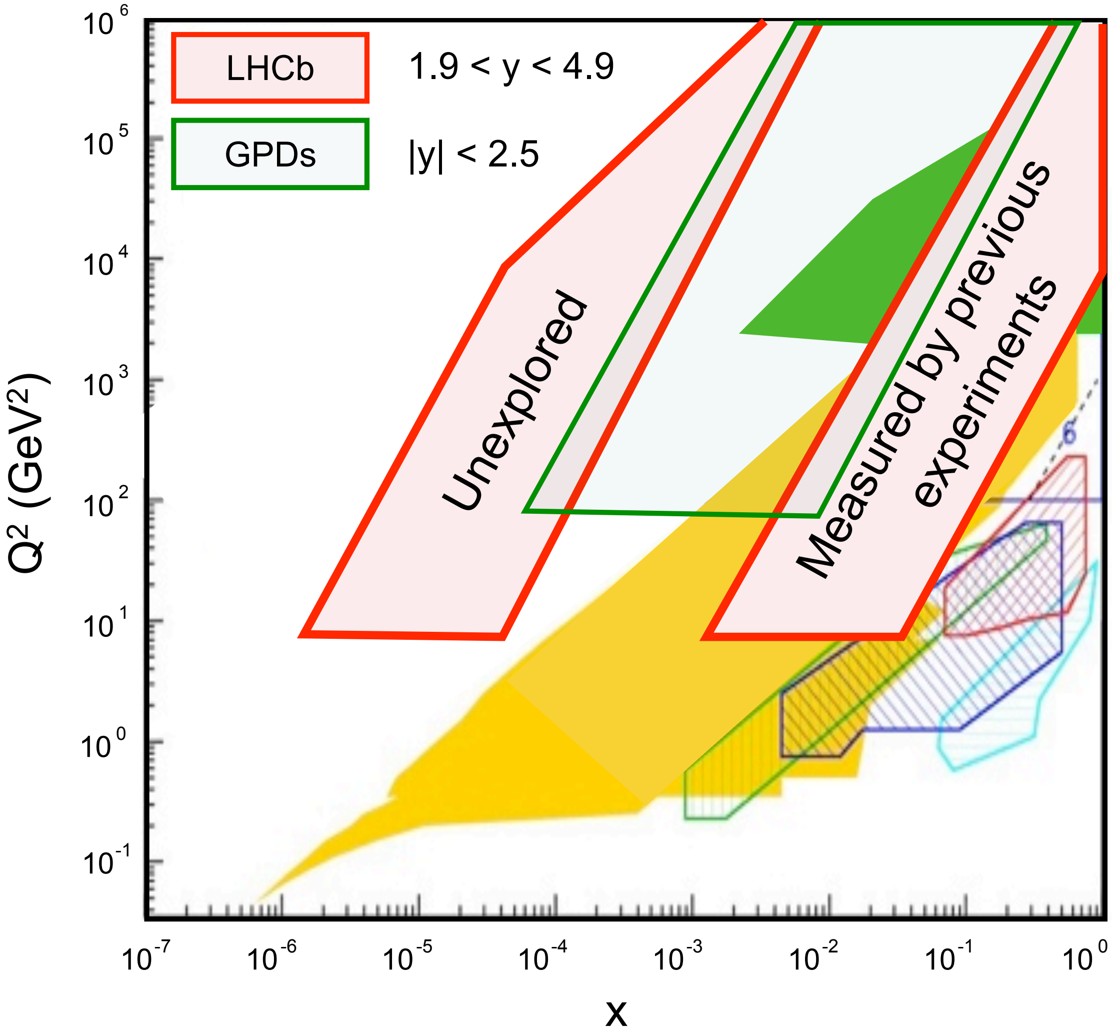


Fully instrumented within $1.9 \leq \eta \leq 4.9$

Trigger: $p_\mu > 3$ GeV, $pt_\mu > 0.5$ GeV, $m_{\mu\mu} > 2.5$ GeV

Kinematic range

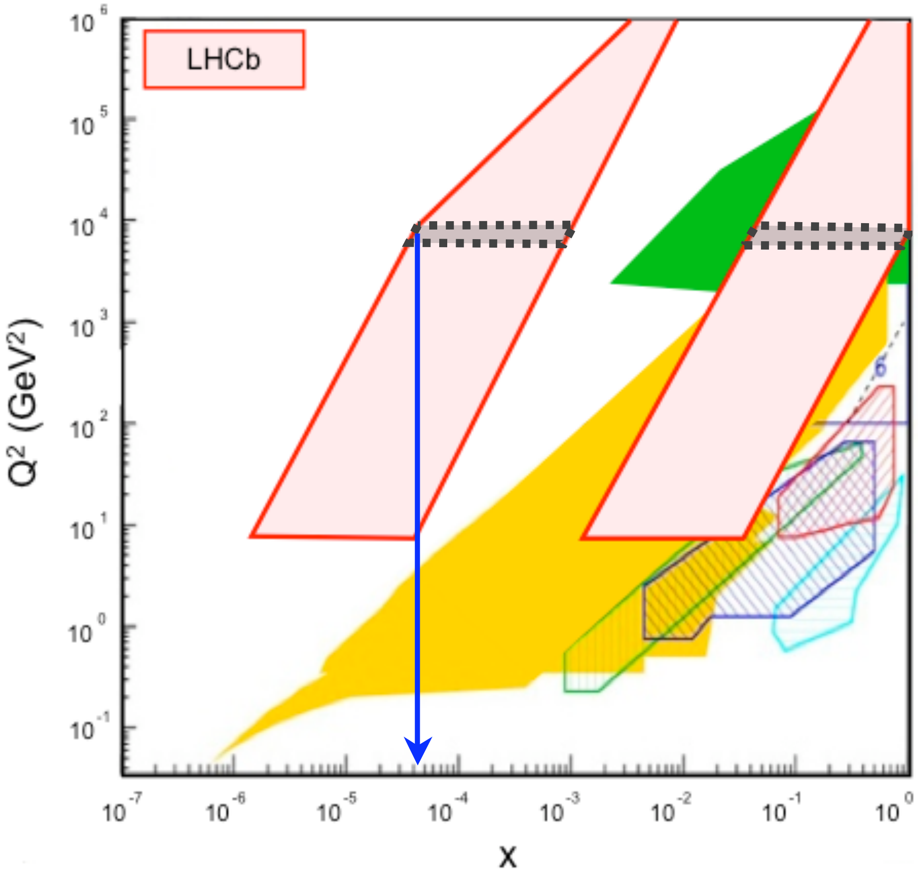
Angular acceptance + trigger thresholds ensure range of low x, high and low Q^2 can be probed.

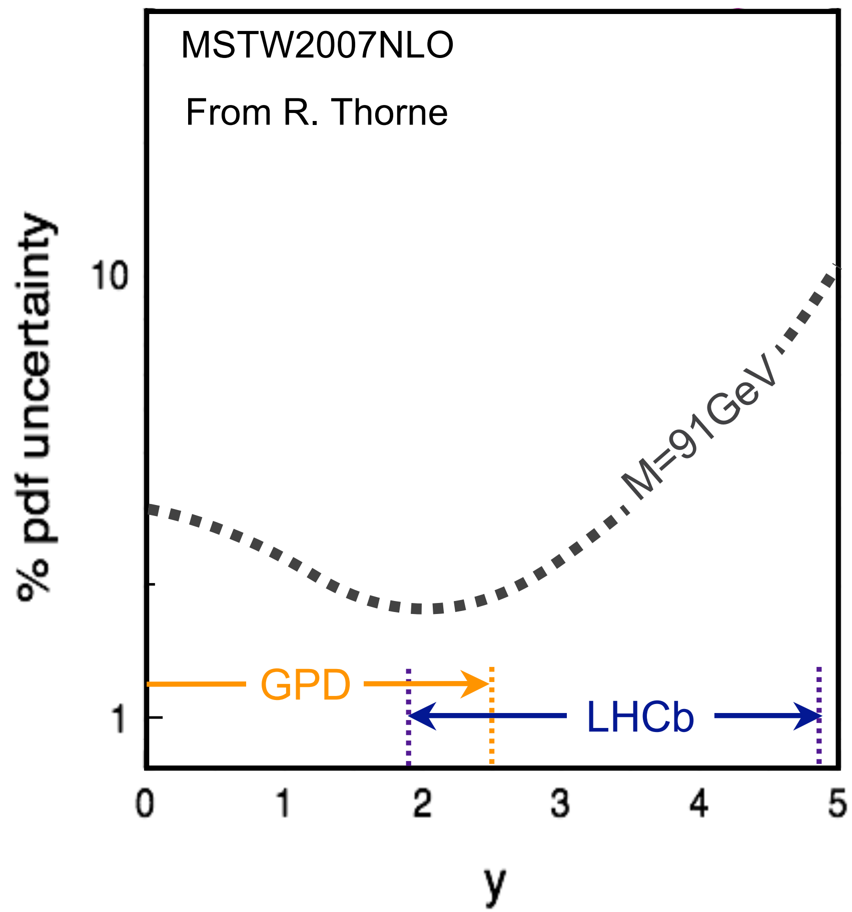


LHCb

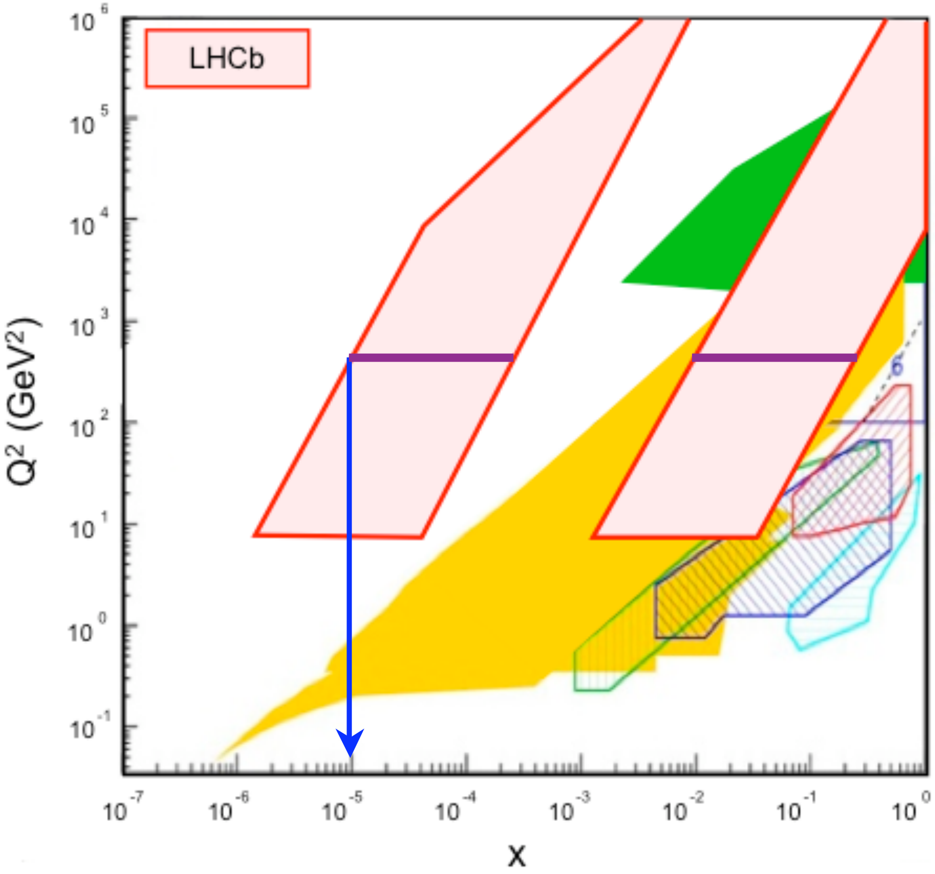
Kinematic range

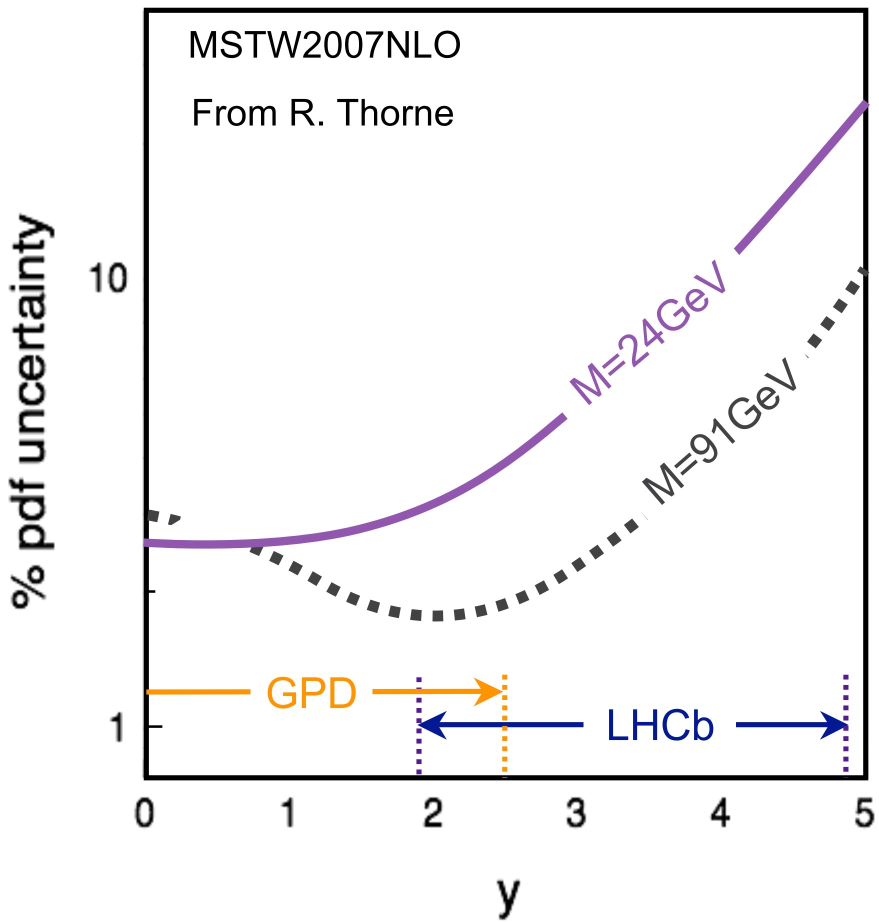
Measurements





Kinematic range

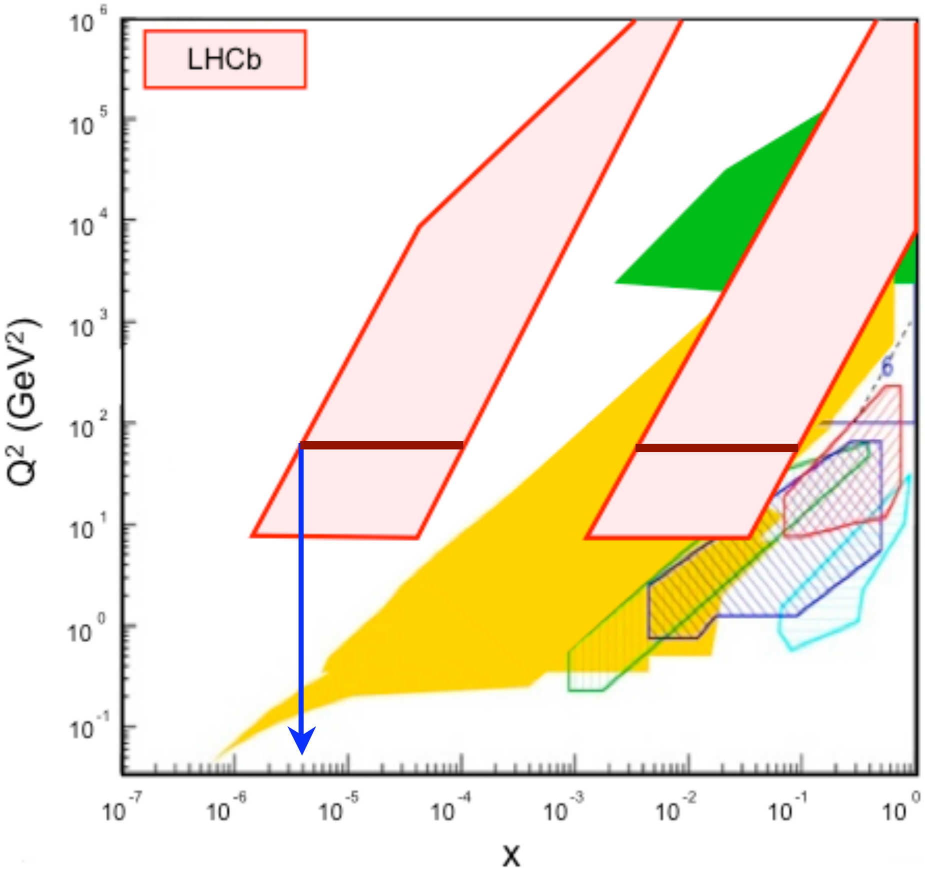


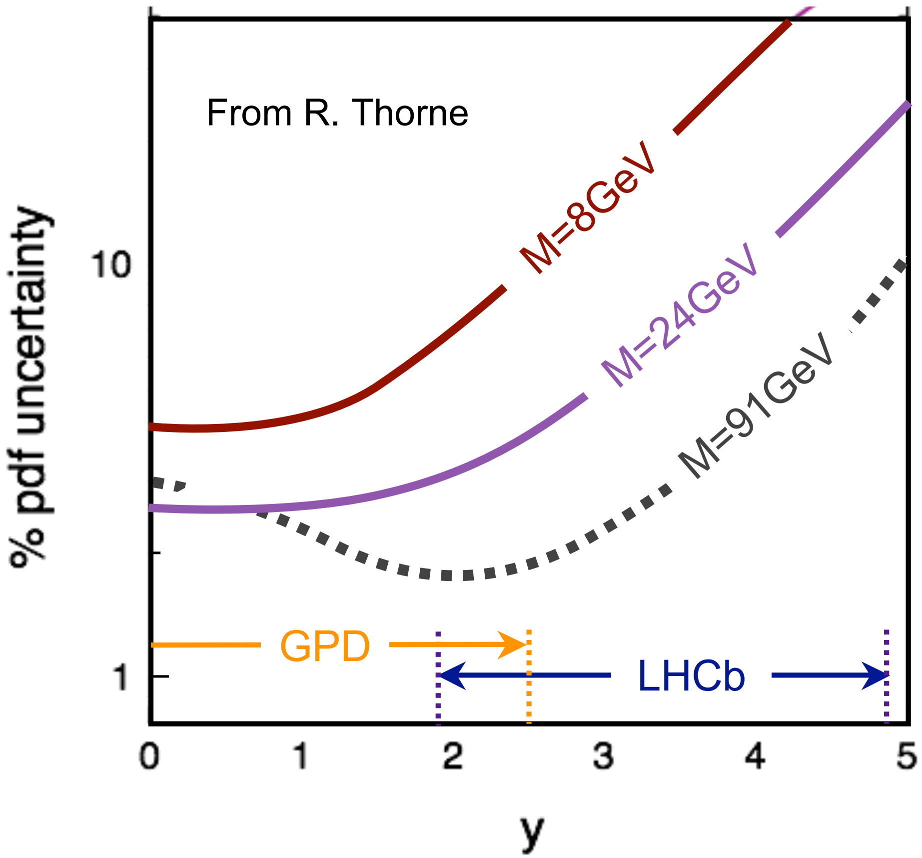


LHCb

Kinematic range

Measurements





$Z \rightarrow \mu\mu$

$W \rightarrow \mu\nu_\mu$

$\gamma^* \rightarrow \mu\mu$

Probing:
$Q^2 = 10^4 \rightarrow 10$
$x = 10^{-4} \rightarrow 10^{-6}$

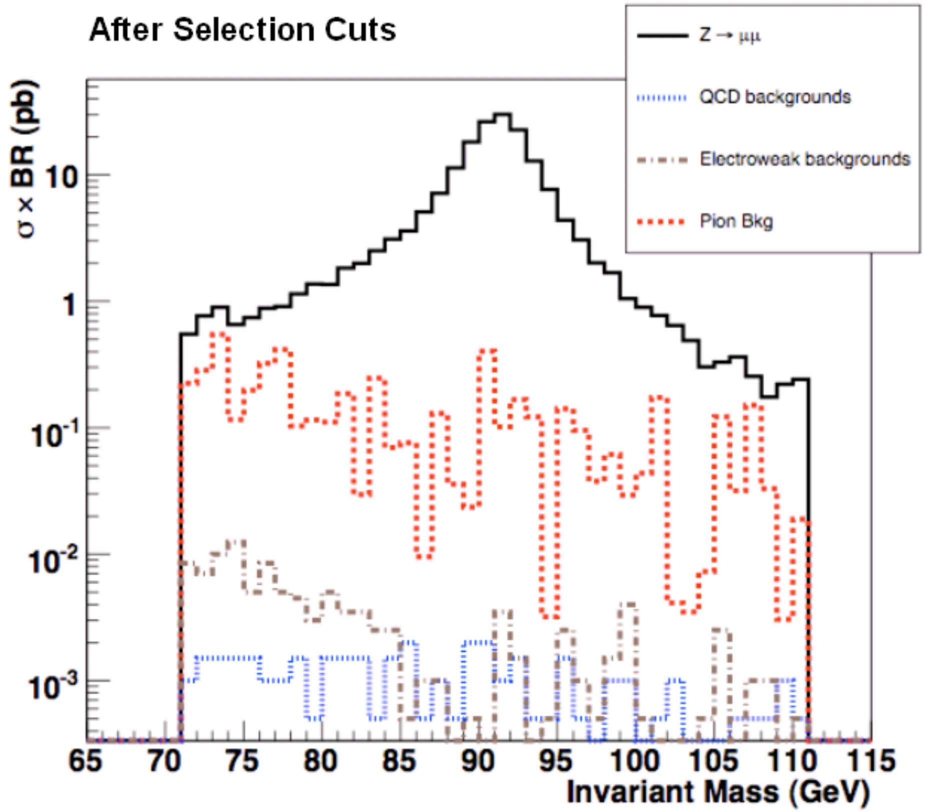
Trigger:

- 2 muons, $pt_\mu > 10$ GeV
- $M_{\mu\mu} > 50$ GeV

Reconstruct:

- $pt_\mu^{1(2)} > 20$ (15) GeV
- IP_μ significance < 5
- $E_{had} < 50$ GeV
- $71 < M_{\mu\mu} < 111$ GeV

Trigger efficiency 86%;
Selection efficiency 91%;
Purity 97%.



See J. Anderson, CERN-THESIS-2009-020

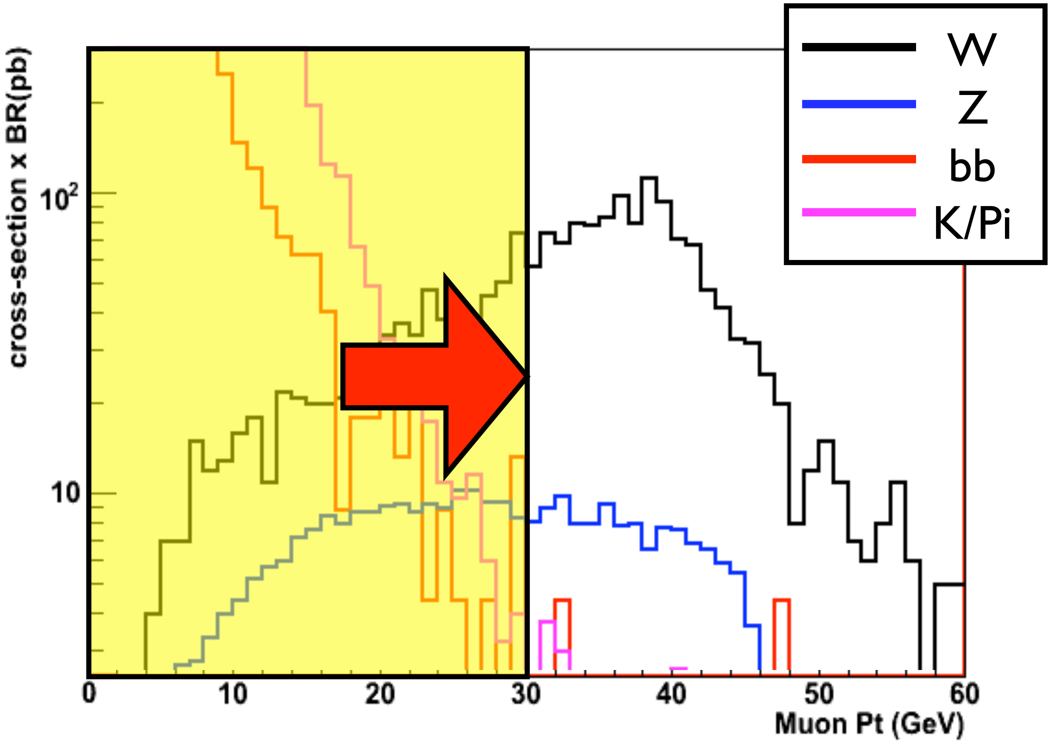
Trigger:

- pt_μ > 20 GeV

Reconstruct:

- pt_μ > 30 GeV
- pt asymmetry A_{pt} > 0.85

$$A_{pt} = \frac{pt_\mu - pt_{rest}}{pt_\mu + pt_{rest}}$$

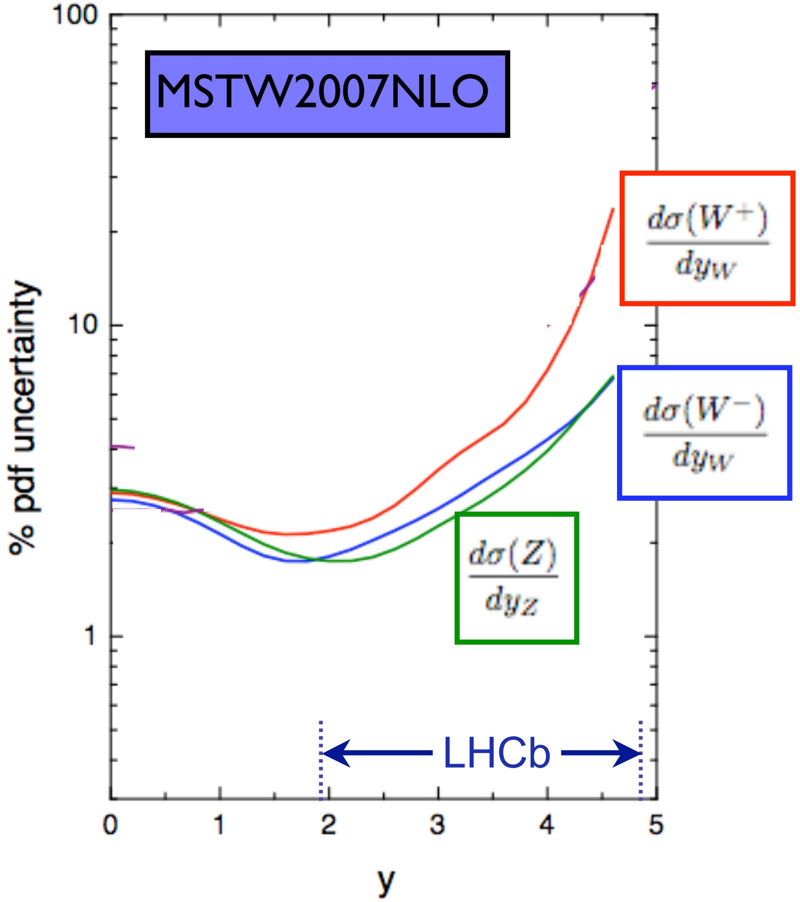


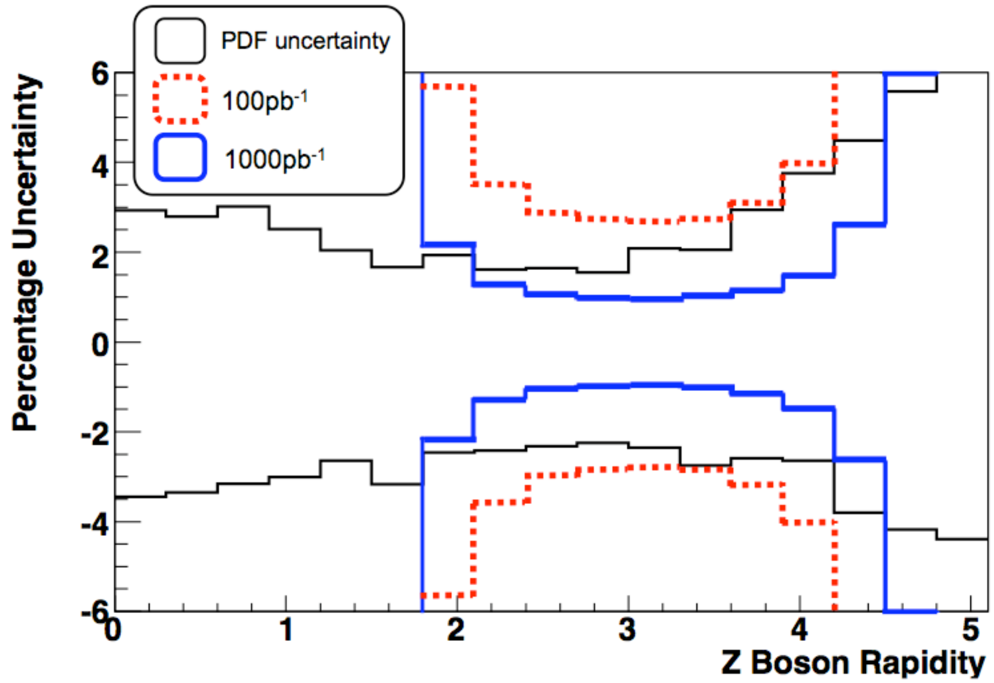
Trigger efficiency 74%;
Selection efficiency 35%;
Purity 90%.

See S. Traynor, DIS09

% Measurement Uncertainties with $100 pb^{-1}$		
	$W \to \mu\nu_\mu$	$Z \to \mu\mu$
Statistical	0.5	0.8
Background	0.3	0.2
Reconstruction efficiency	0.2	0.3
Trigger Efficiency	0.1	0.1
Luminosity	1-5	1-5

Note: estimates (still under study).





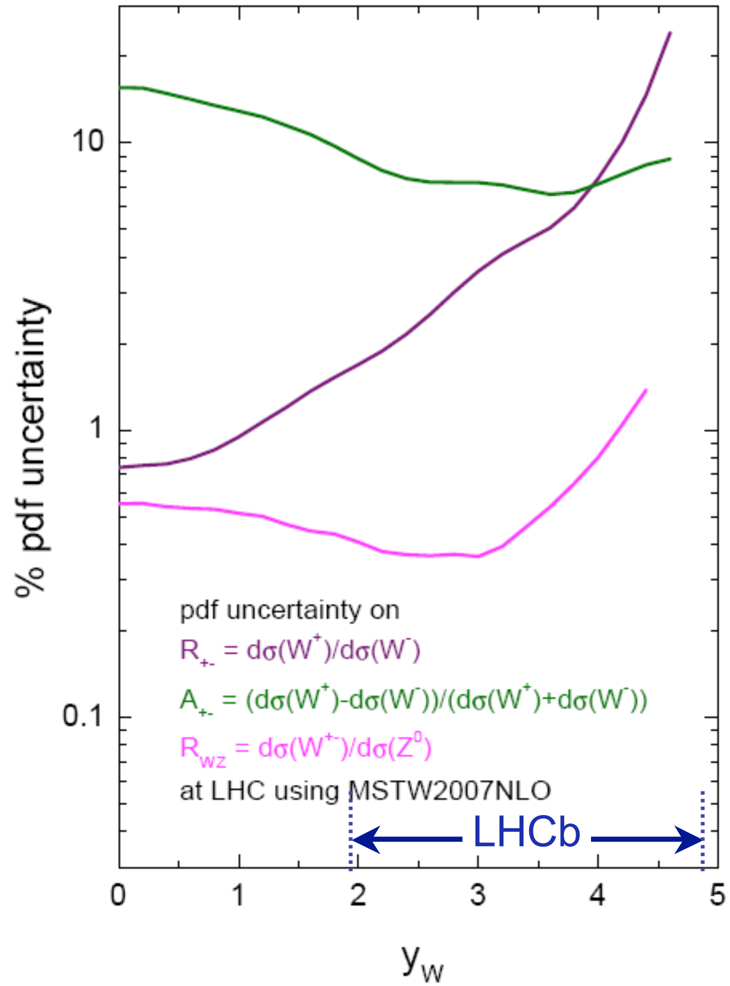
Similar experimental precision for W

Ratios of W, Z production reduce lumi dependance

R_{+-} : sensitive to d/u ratio

R_{WZ}: many theoretical uncertainties cancel: test Standard Model (0.4%)

A_{+-}: sensitive to u_V d_V difference



But more information obtained by fitting W, Z **together**

Idea:

compare measured $d\sigma/dy$ for W, Z to PDF prediction, **constraining PDFs and fitting integrated luminosity**.

Test:

- Choose a PDF set. Take central value to be **truth**
- Generate many pseudo-data sets (assuming multinomial distribution for eigenvector errors), corresponding to a given luminosity
- Fit each pseudo-data set: **pseudo-measurement**
- Compare **pseudo-measurement** to **truth**
  - centre of distribution gives bias
  - width of distribution gives precision

See F. De Lorenzi DIS09,
R. McNulty PDF4LHC 29/05/09

Method using **MSTW, CTEQ, Alekhin**;

$$f_0 = \frac{d\sigma}{dy}$$: distribution obtained with central eigenvectors

$$f_i = \frac{d\sigma}{dy}(\lambda_i = 1, \lambda_{\neq i} = 0)$$: distribution with i^{th} e.v. moved 1σ

Fit

$$\chi^2(\lambda_0, \lambda_i) = \sum_{j=1}^{\#bins}\left[\frac{x_j - \lambda_0\left(f_0 + \lambda_i\left(f_i - f_0\right)\right)}{\sigma_j}\right]^2 + \sum_{i=1}^{\#e.v.}\lambda_i^2$$

Normalisation (Luminosity)

data in j bins, each with uncertainty σ

Method using NNPDF;

$$f_i = \frac{d\sigma}{dy}$$ for i[th] replica

Fit $$\chi^2(\lambda_0) = \sum_{j=1}^{\#bins}\left[\frac{x_j - \lambda_0 f_i}{\sigma_j}\right]^2$$

... and only consider consistent replicas
(Chisquared probability > 1 %)

Fitting differential cross-sections

	0.1 fb^{-1}			
	MSTW08	CTEQ66	Alekhin	NNPDF
W+	1.8	2.4	2.0	2.9
W-	1.9	2.6	2.2	2.7
Z	1.9	2.4	2.2	2.4
WWZ	1.7	2.3	1.8	2.0
	1 fb^{-1}			
	MSTW08	CTEQ66	Alekhin	NNPDF
W+	1.6	2.2	1.8	2.4
W-	1.6	2.3	2.1	2.4
Z	1.7	2.1	1.9	1.8
WWZ	1.3	2.1	1.4	2.2
	10 fb^{-1}			
	MSTW08	CTEQ66	Alekhin	NNPDF
W+	1.3	2.0	1.5	2.5
W-	1.2	1.9	1.6	3.0
Z	1.4	1.9	1.9	1.9
WWZ	0.8	1.7	1.0	-

Percentage statistical uncertainty on **fitted luminosity**

Fitting differential cross-sections

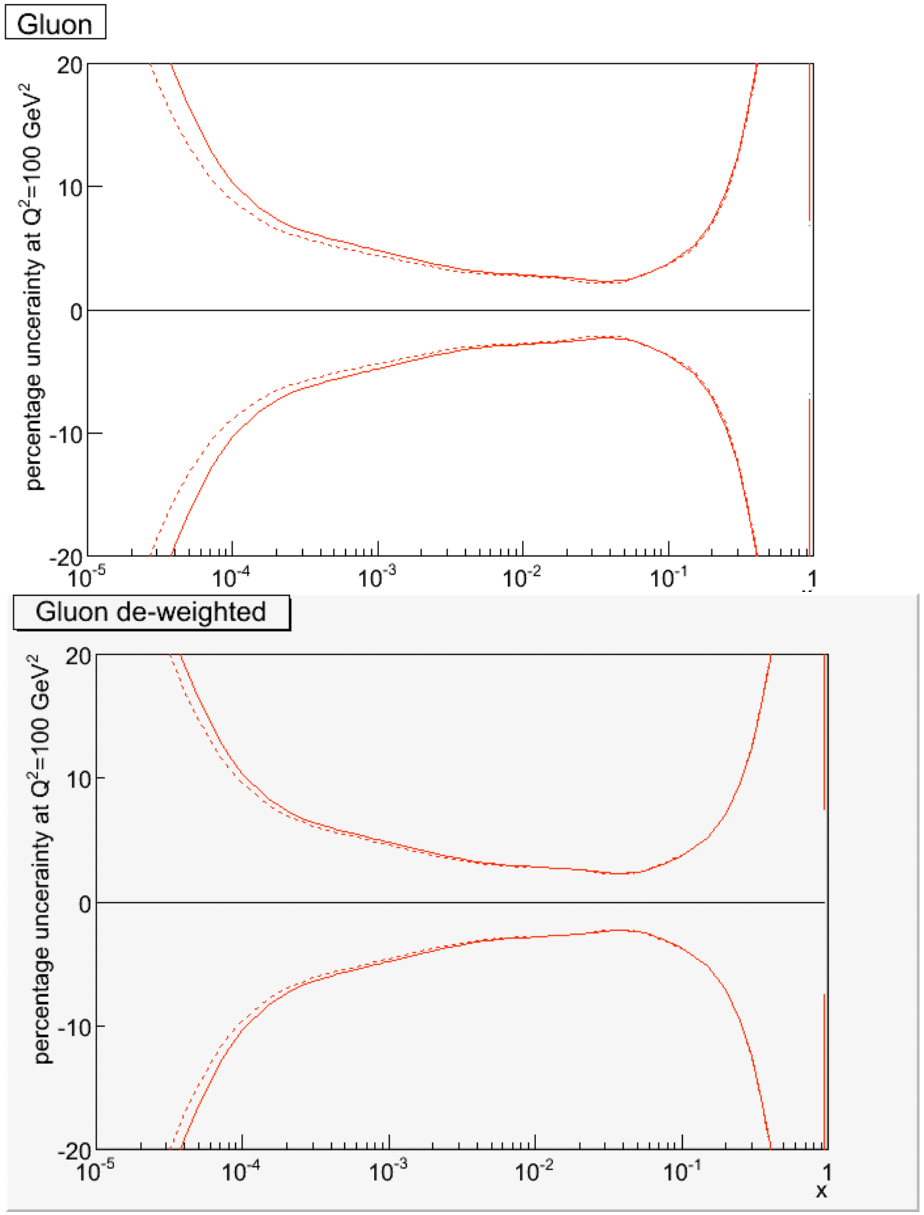
- Method could have bias if correct PDF not known.
- Selecting only good fits with χ^2 probability > 1% allows **test of PDF model consistency**
- Reduces systematic uncertainty due to model dependence

	$0.1\ fb^{-1}$		
	CTEQ66	Alekhin	NNPDF
W+	-3.2	-3.7	5.0
W-	0.1	-2.0	-1.5
Z	-1.4	-5.6	3.4
WWZ	-0.7	-3.6	5.0

Percentage bias on fitted luminosity generated with MSTW08 central values

This procedure fits eigenvalues as well as luminosity.

– it can constrain our knowledge of the PDFs.



Effect on gluon PDF for MSTW08 ($1fb^{-1}$)

solid line: current uncertainty

dashed line: with LHCb **Z data**

Straight fit

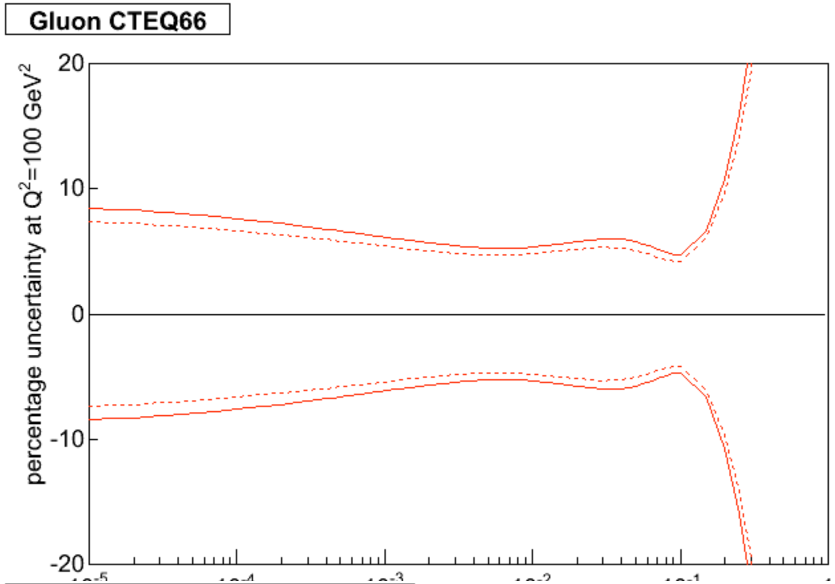
$x=10^{-4}$, 11% → 8%

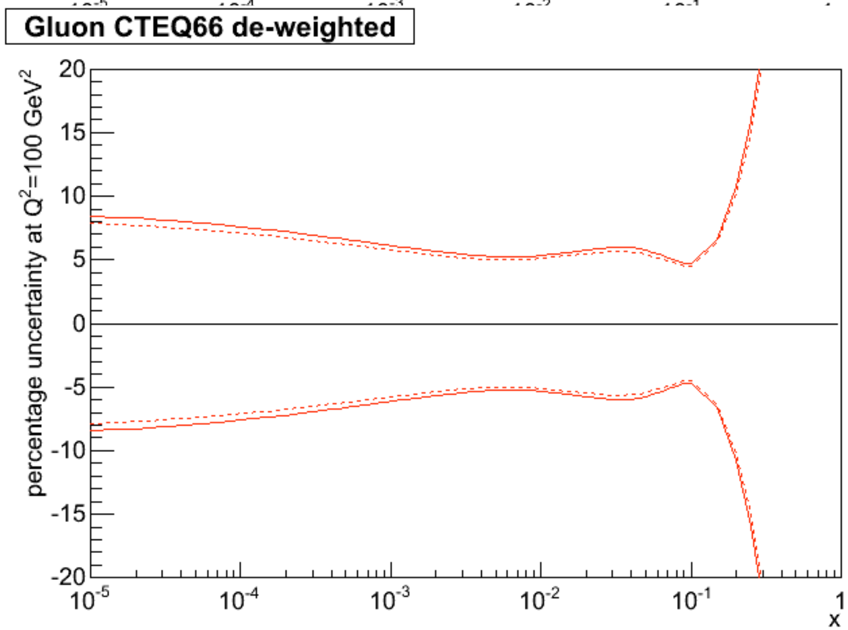
$x=5.10^{-5}$, 17% → 13%

Deweighted fit

$x=10^{-4}$, 11% → 10%

$x=5.10^{-5}$, 17% → 15%





Effect on gluon PDF for CTEQ66 ($1 fb^{-1}$)

<u>Straight fit</u>

$x=10^{-4}$, 7.5% → 6.5%

$x=5.10^{-5}$, 7.5% → 6.5%

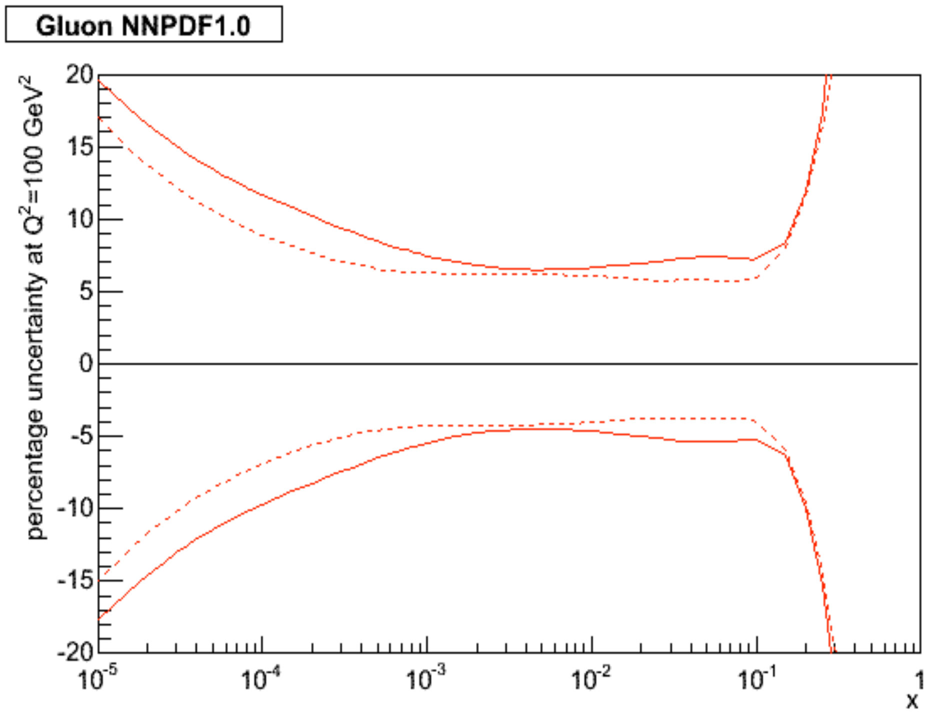
<u>Deweighted fit</u>

$x=10^{-4}$, 7.5% → 7%

$x=5.10^{-5}$, 7.5% → 7%

(Smaller difference because impact of data is less)

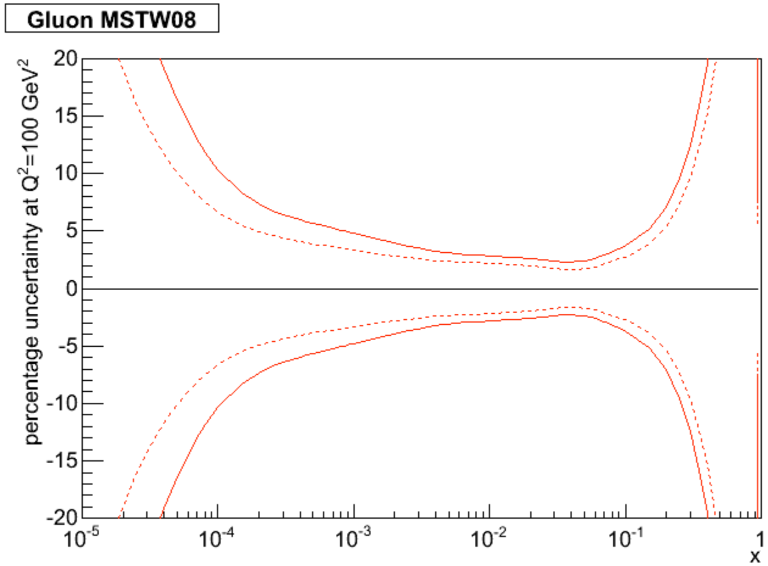
Fitting differential cross-sections

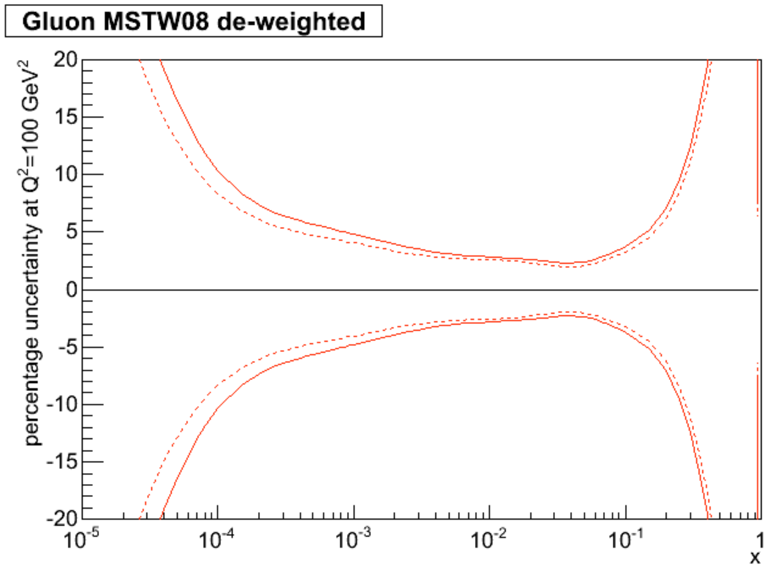


Effect on gluon PDF for NNPDF1.0 ($1fb^{-1}$)

$x=10^{-4}$, 12% → 9%

$x=5.10^{-5}$, 13% → 11%



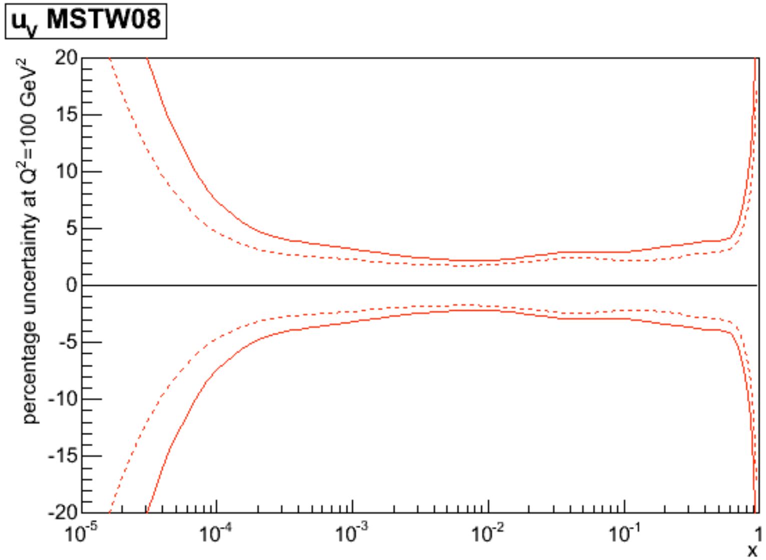


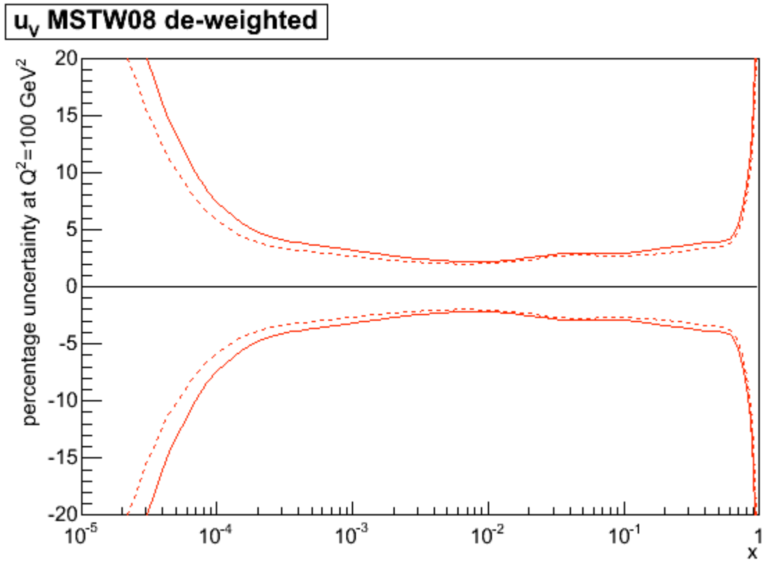
Effect on gluon PDF for MSTW08 ($1fb^{-1}$) using WWZ data

$x=10^{-4}$, 11% → 7% (8%)

$x=5.10^{-5}$, 17% → 10% (13%)

New: thanks Francesco





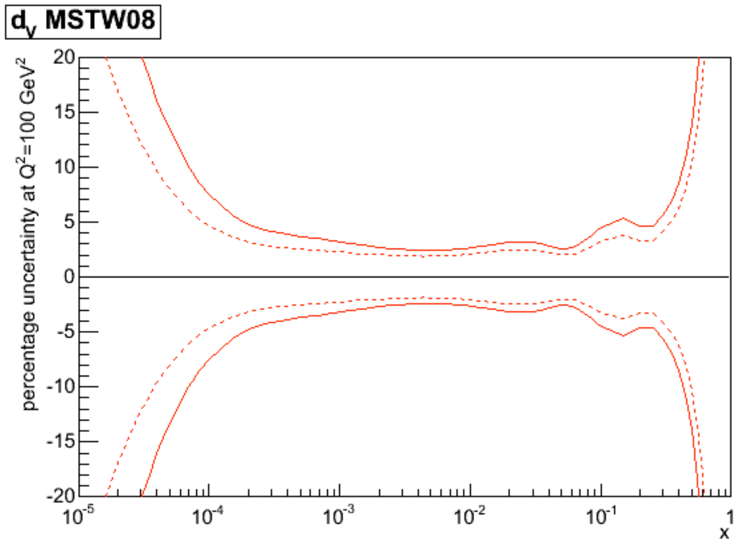
Effect on u_V PDF for MSTW08 ($1fb^{-1}$) using WWZ data

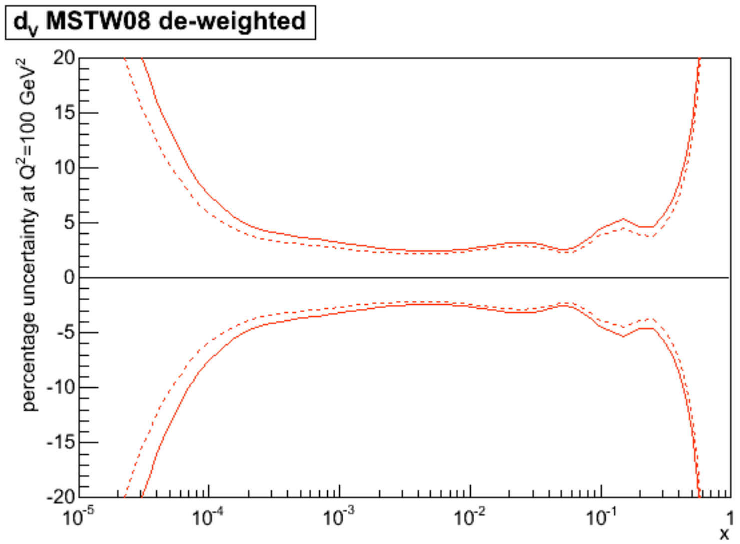
$x=10^{-4}$, 8% → 4% (6%)

$x=5.10^{-5}$, 15% → 10% (13%)

New: thanks Francesco

Fitting differential cross-sections





Effect on d_V PDF for MSTW08 ($1fb^{-1}$) using WWZ data

$x=10^{-4}$, 8% → 5% (6%)

$x=5.10^{-5}$, 17% → 10% (14%)

New: thanks Francesco

γ^*

Trigger:

- 2 muons, $\Sigma pt_\mu > 1.6$ GeV

Reconstruct:

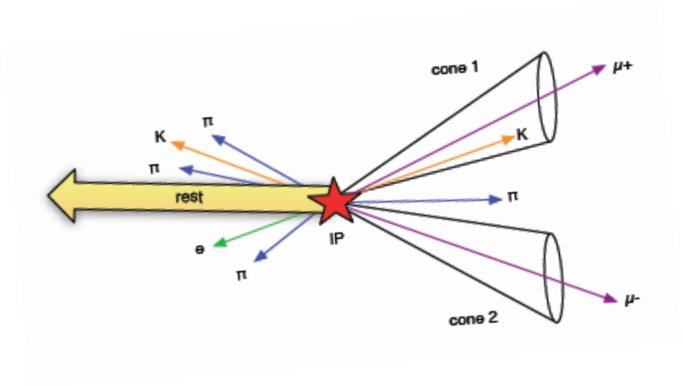
- $p_\mu > 21$ GeV
- IP_μ significance < 3
- P_μ asymmetry variables

$A(P_{\mu 1}, P_{cone1})$

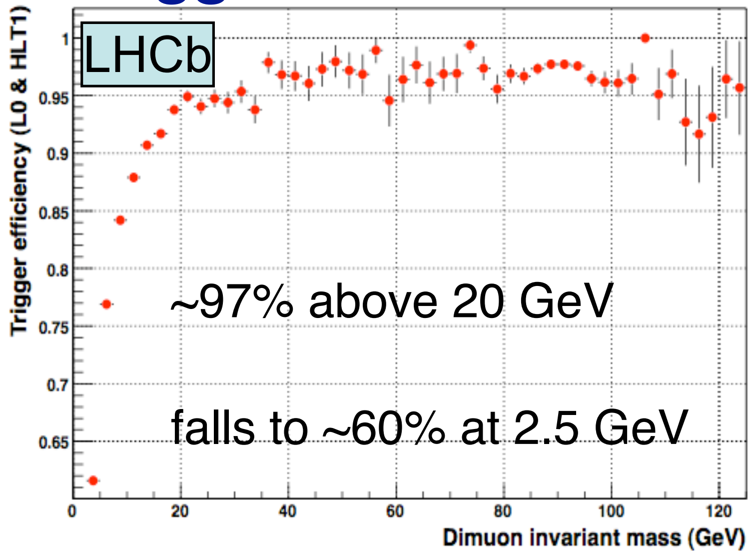
$A(P_{\mu 2}, P_{cone2})$

$A(P_{\mu 1} + P_{\mu 2}, P_{rest})$

$A(P_{cone1} + P_{cone2}, P_{rest})$

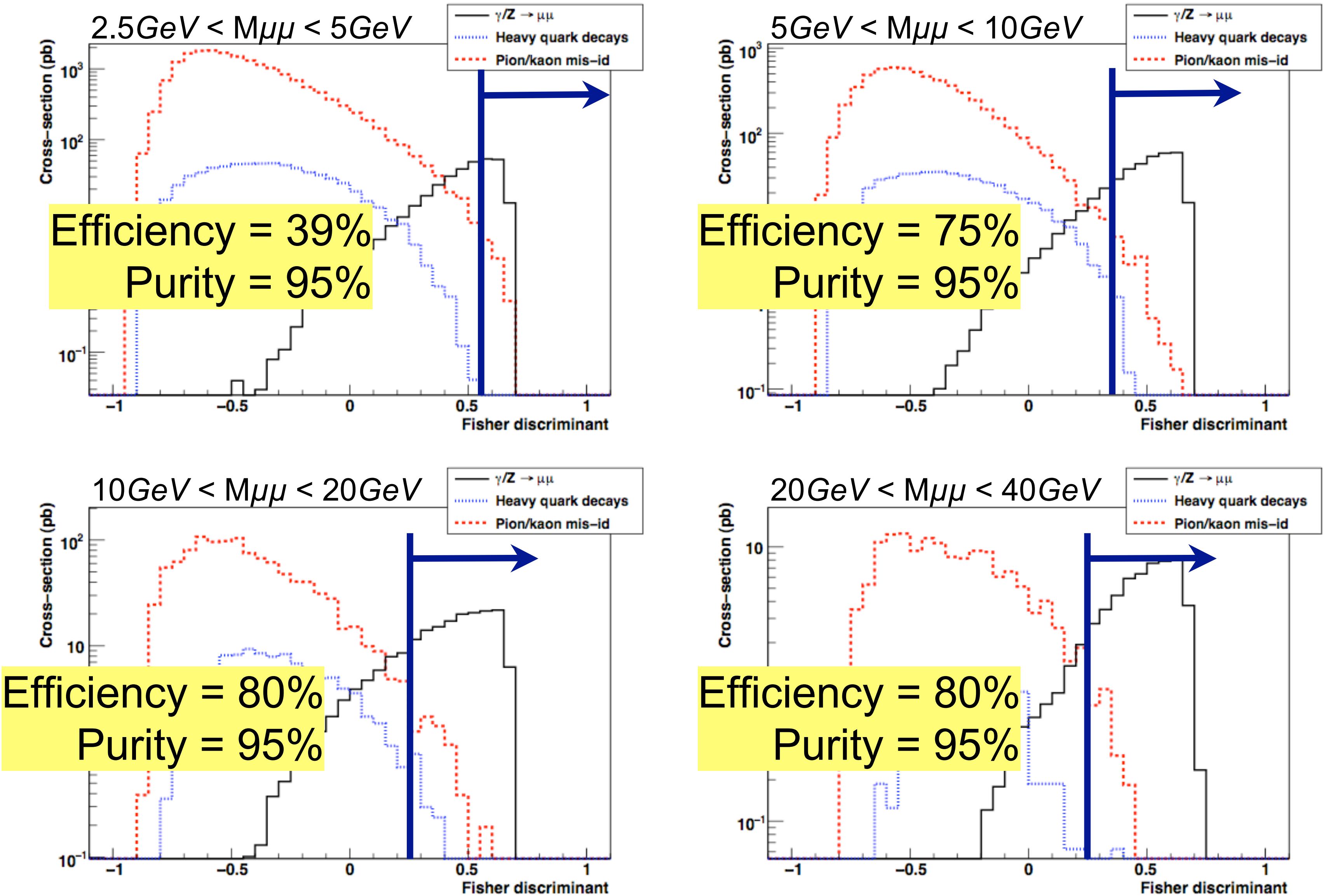


Trigger



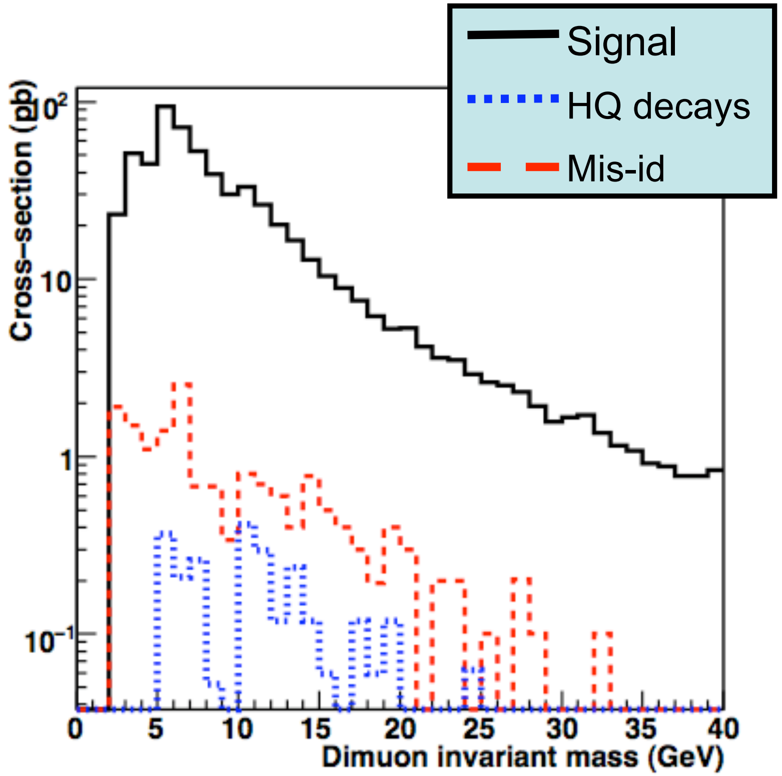
See J. Anderson, DIS09

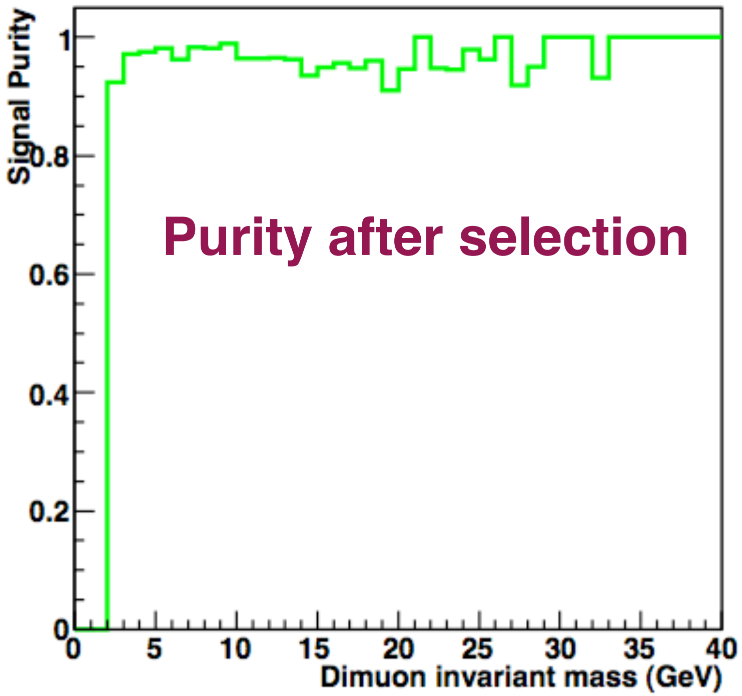
γ^*



Combine variables into Fisher discriminant

γ^*

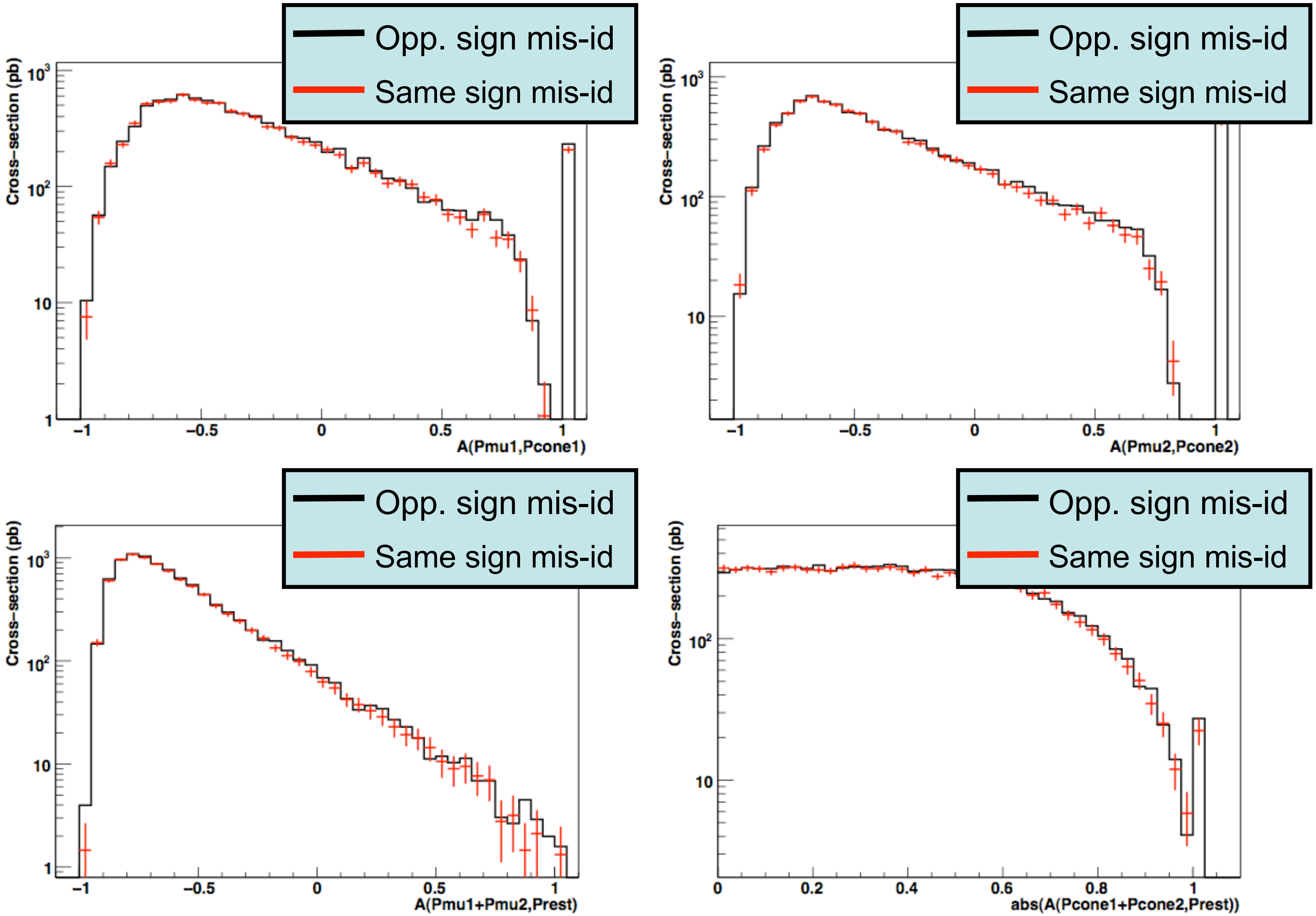




Mass range (GeV)	Events/pb^{-1}
$2.5 < M_{\mu\mu} < 5$	119.1 ± 1.0
$5 < M_{\mu\mu} < 10$	287.3 ± 1.6
$10 < M_{\mu\mu} < 20$	147.6 ± 0.9
$20 < M_{\mu\mu} < 40$	42.3 ± 0.4

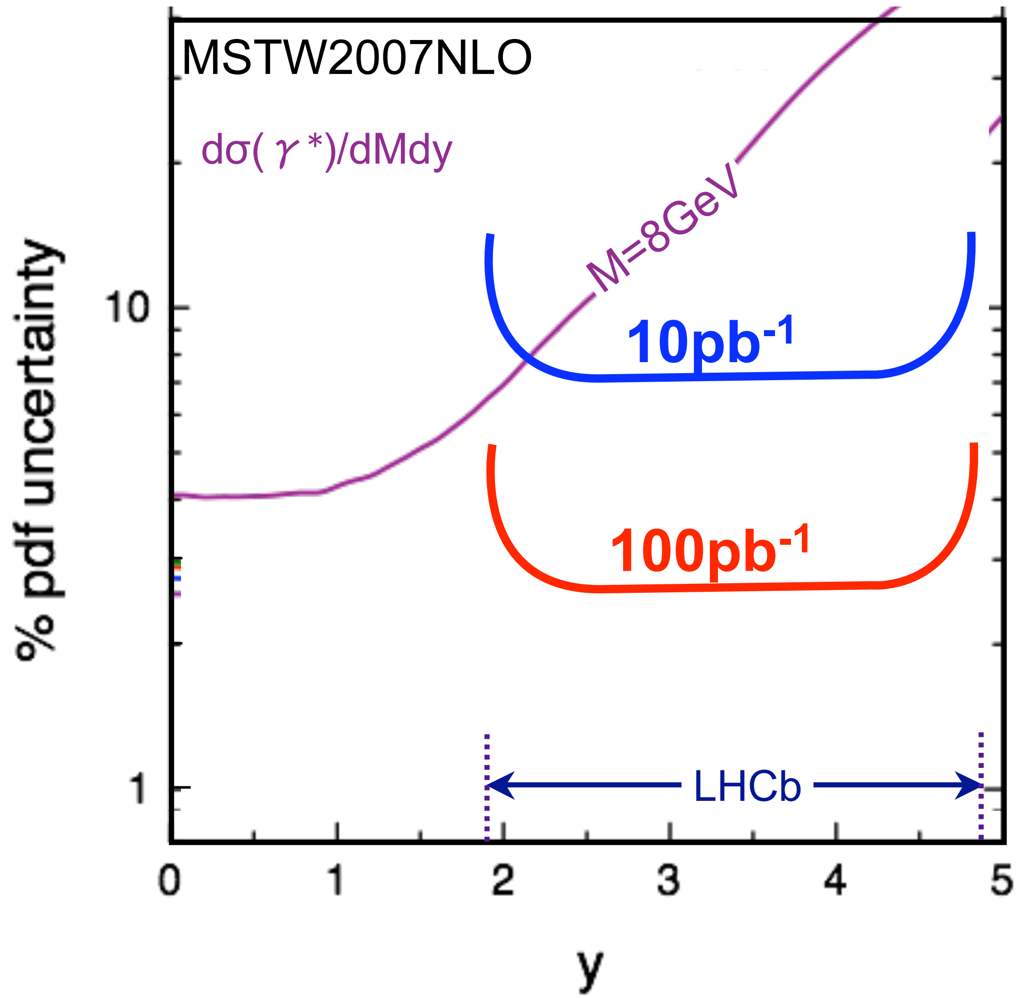
Systematic errors under study

Understanding backgrounds with data



γ^*

Experimental precision (stat.) quickly exceeds theoretical precision.



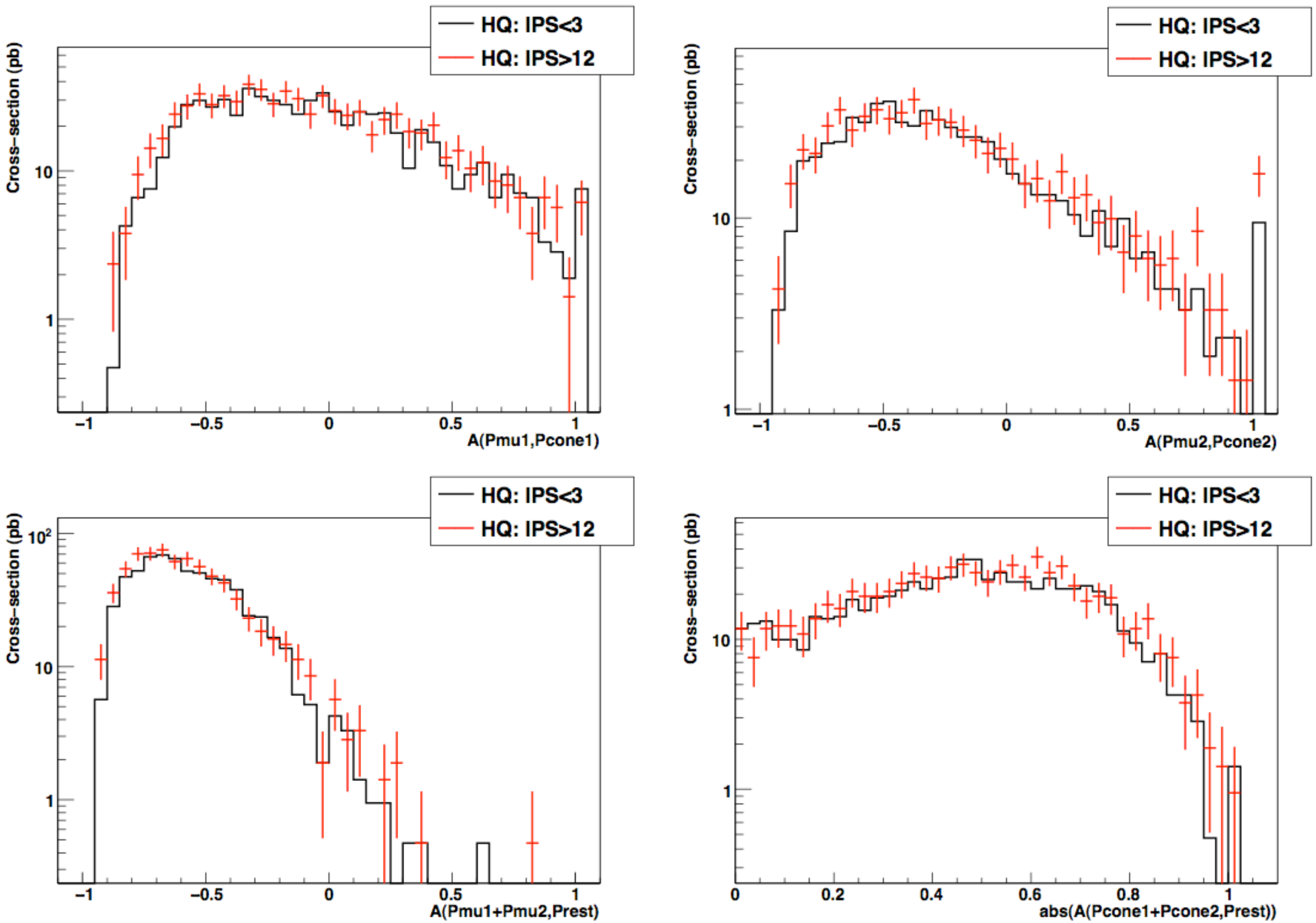
4. Conclusions

LHCb can measure Z, W, low invariant mass γ^* in the forward region with good precision.

Measurements probe partons down to x of 10^{-6}

Fitting W,Z differential cross-sections can constrain PDF descriptions.

Understanding backgrounds with data



Do Z shapes match lower masses?