Constraints on low-x PDFs from Drell-Yan processes and first studies of exclusive dimuon production with the LHCb experiment

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For the LHCb collaboration

Outline

- Unique features of the LHCb detector
- Why events at LHCb are particularly useful for exploring low-x
- W, Z and low mass Drell-Yan candidates at LHCb
- What impact 100 pb^{-1} of LHCb data might have on PDFs
- Exclusive χ_c candidates at LHCb

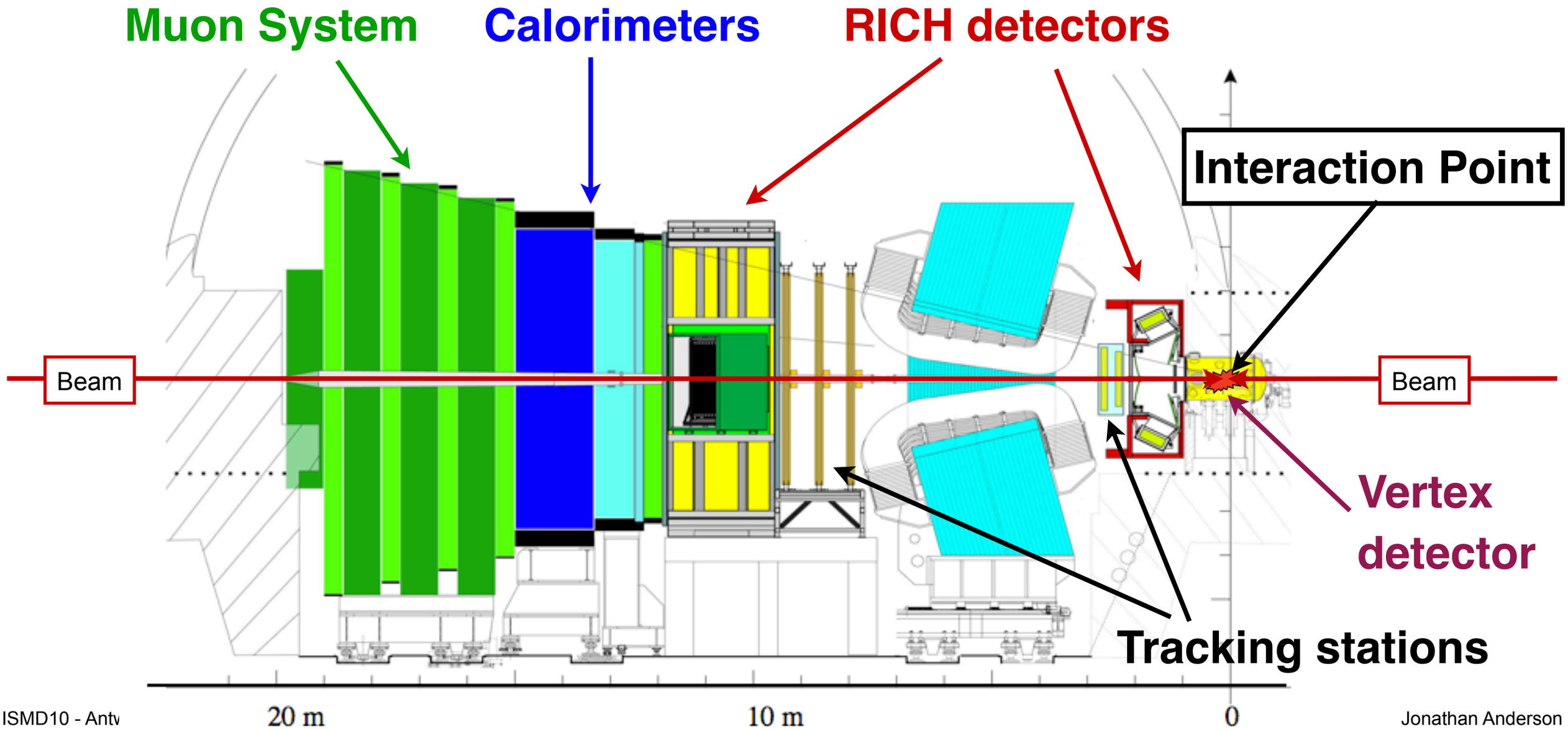
LHCb: A forward spectrometer

Fully instrumented at high rapidities

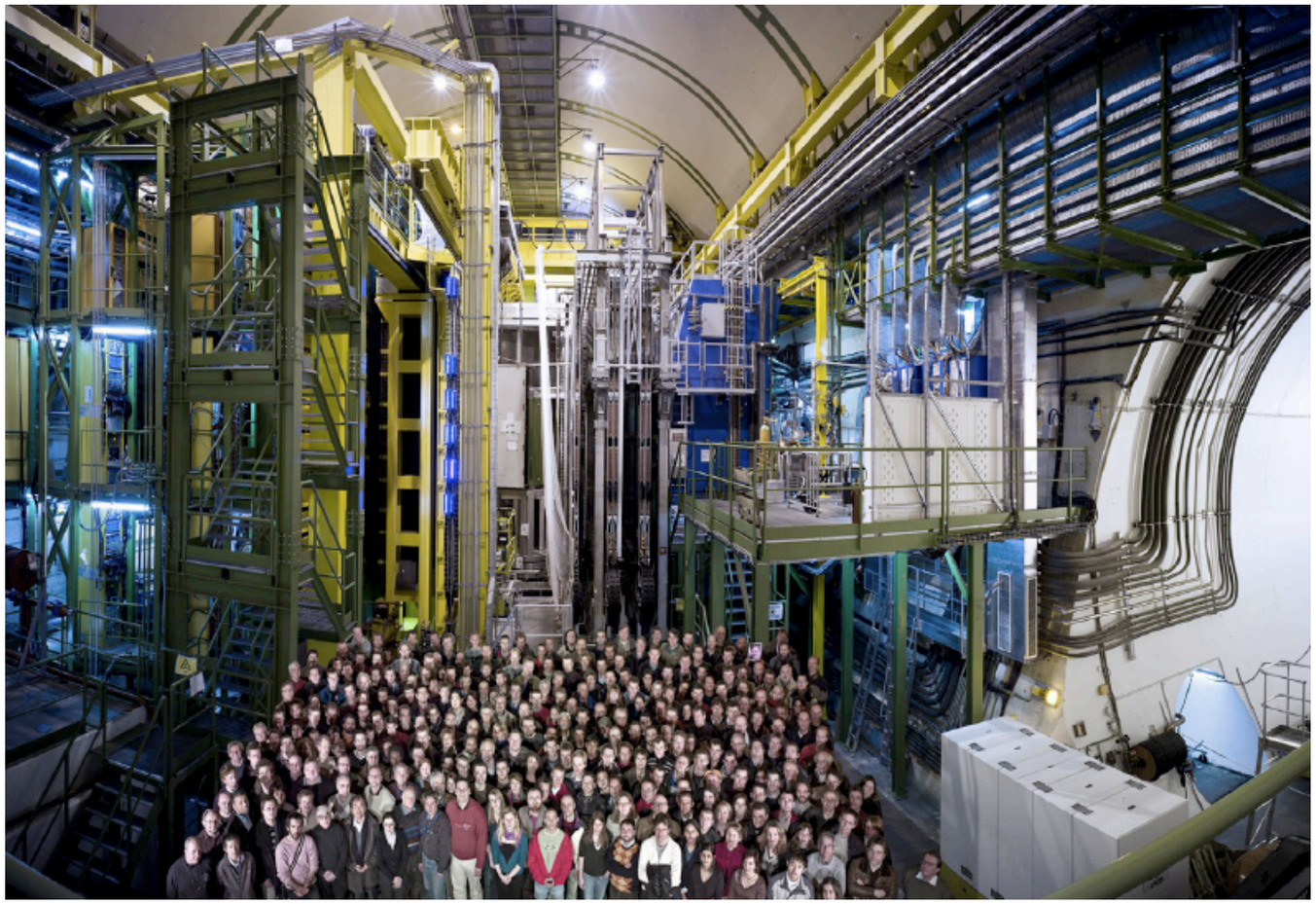
- Overlap region with Atlas/CMS $(1.9 < \eta < 2.5)$
- High rapidities unique to LHCb $(2.5 < \eta < 4.9)$

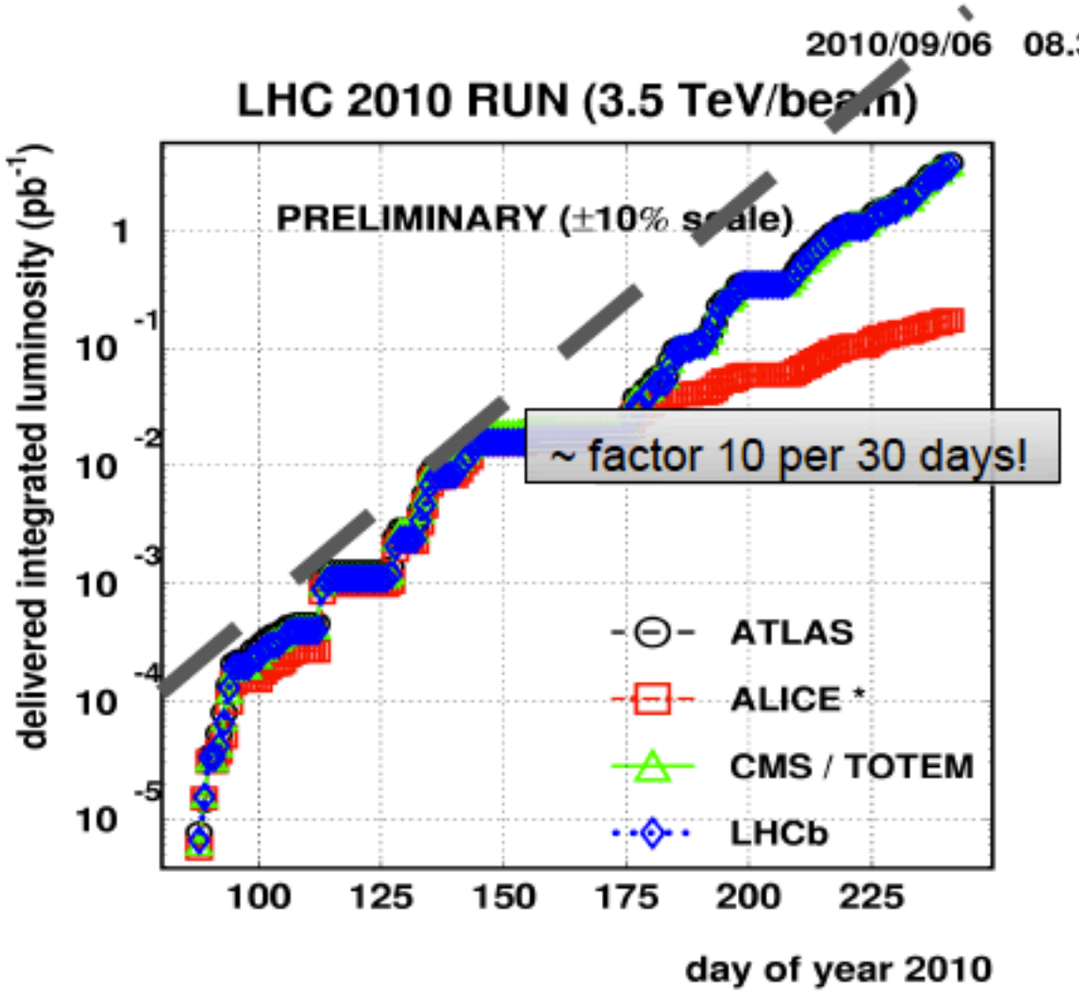
Can record low momentum muons

- Reco: $P > 3\text{GeV}$ & $P_T > 0.5\text{GeV}$
- Trigger: $M_{\mu\mu} > 2.5\text{GeV}$ & $\Sigma P_T > 1.5\text{GeV}$
- Exclusive trigger stream: $M_{\mu\mu} > 1\text{GeV}$



LHCb: A forward spectrometer





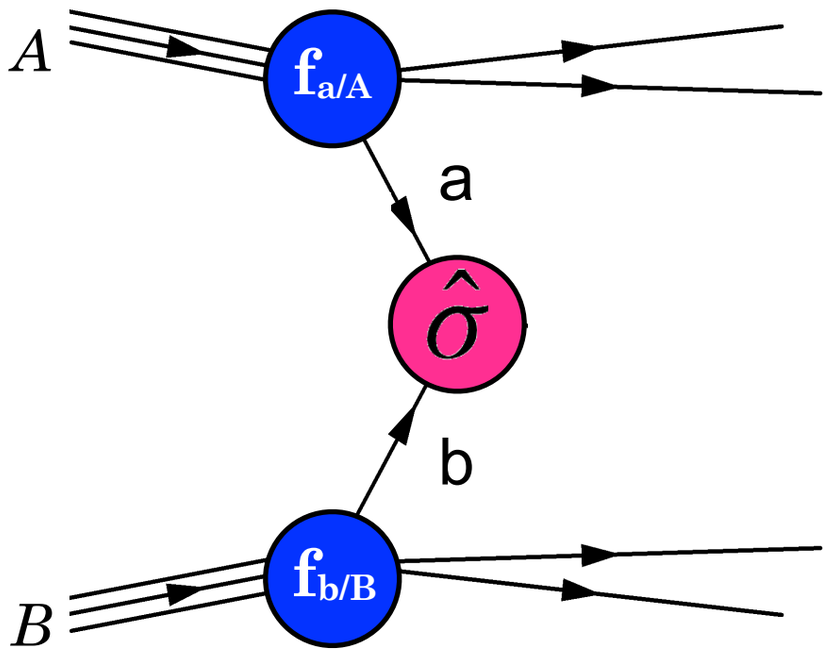
Fully installed, commissioned and taking data - 3.5 pb^{-1} of data on tape!
Increasing rapidly - 1 fb^{-1} expected by end 2011 (note: LHC will run at 7 TeV before 2012)

Also see talk of R. Muresan on Light hadron production at LHCb (Wednesday evening)

Calculations at the LHC

Primary partonic interaction can be described using pQCD

Parton distribution can't be calculated



Solution: factorise the calculation

$$\sigma_{AB\to X} = \int dx_a dx_b f_{a/A}(x_a, Q^2) f_{b/B}(x_b, Q^2) \hat{\sigma}_{ab\to X}$$

PDFs (from data)

Partonic interaction (pQCD)

W, Z: NNLO ~1% uncertainty

Partons: a reminder

Parton distributions are process independent and evolution with scale is calculable

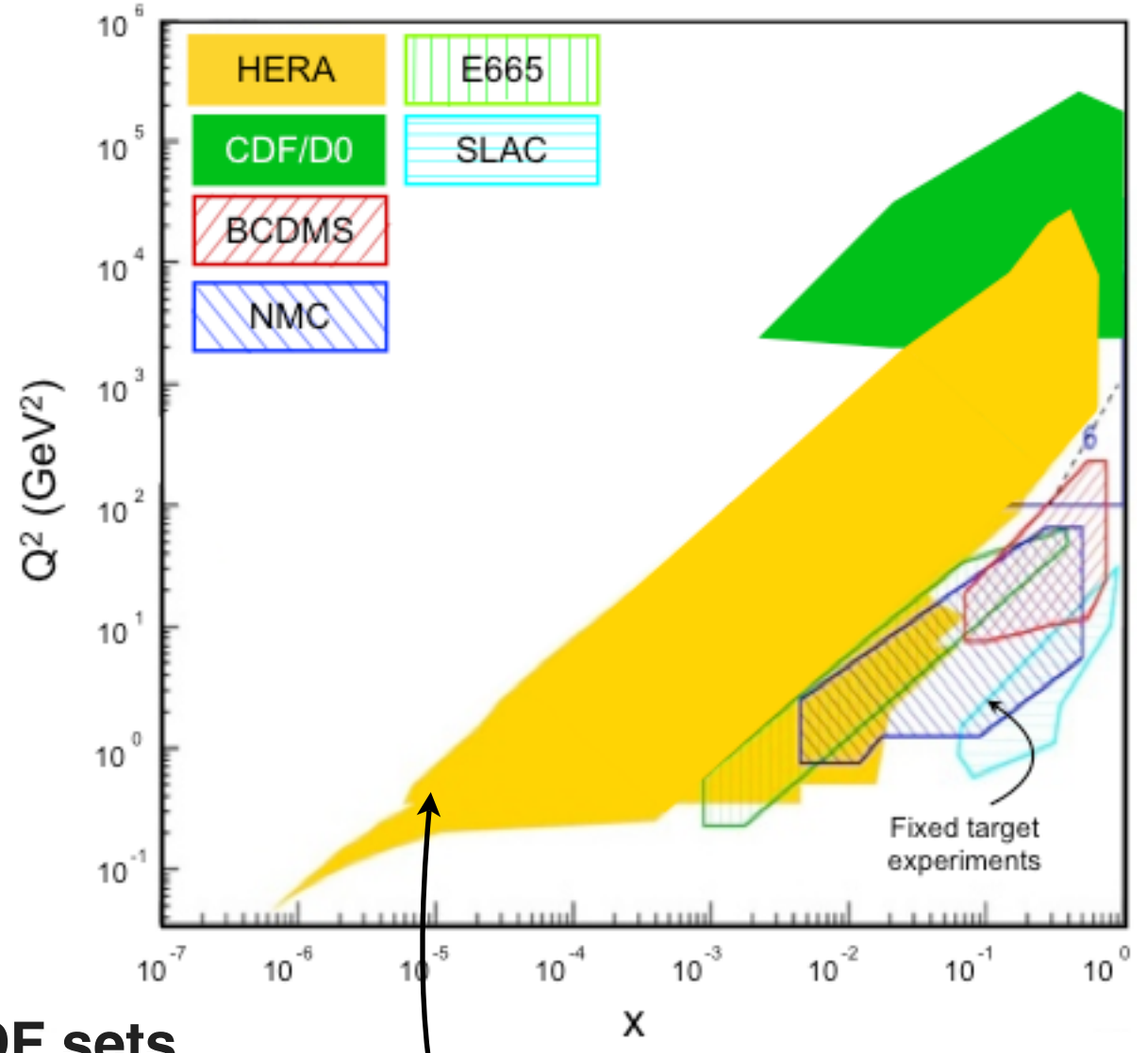
Measurements at one experiment can be used to predict other scattering processes

Many different measurements are used

- DIS at HERA (low-x quarks)
- DIS at fixed target (high-x quarks)
- Drell-Yan at E605, E866 (high-x sea quarks)
- High Pt jets at Tevatron (high-x gluons)
- W & Z production at Tevatron (high-x quarks)

Data is fitted by a variety of groups to produce PDF sets

- MSTW, CTEQ, NNPDF, Alekhin, ZEUS, H1 etc.

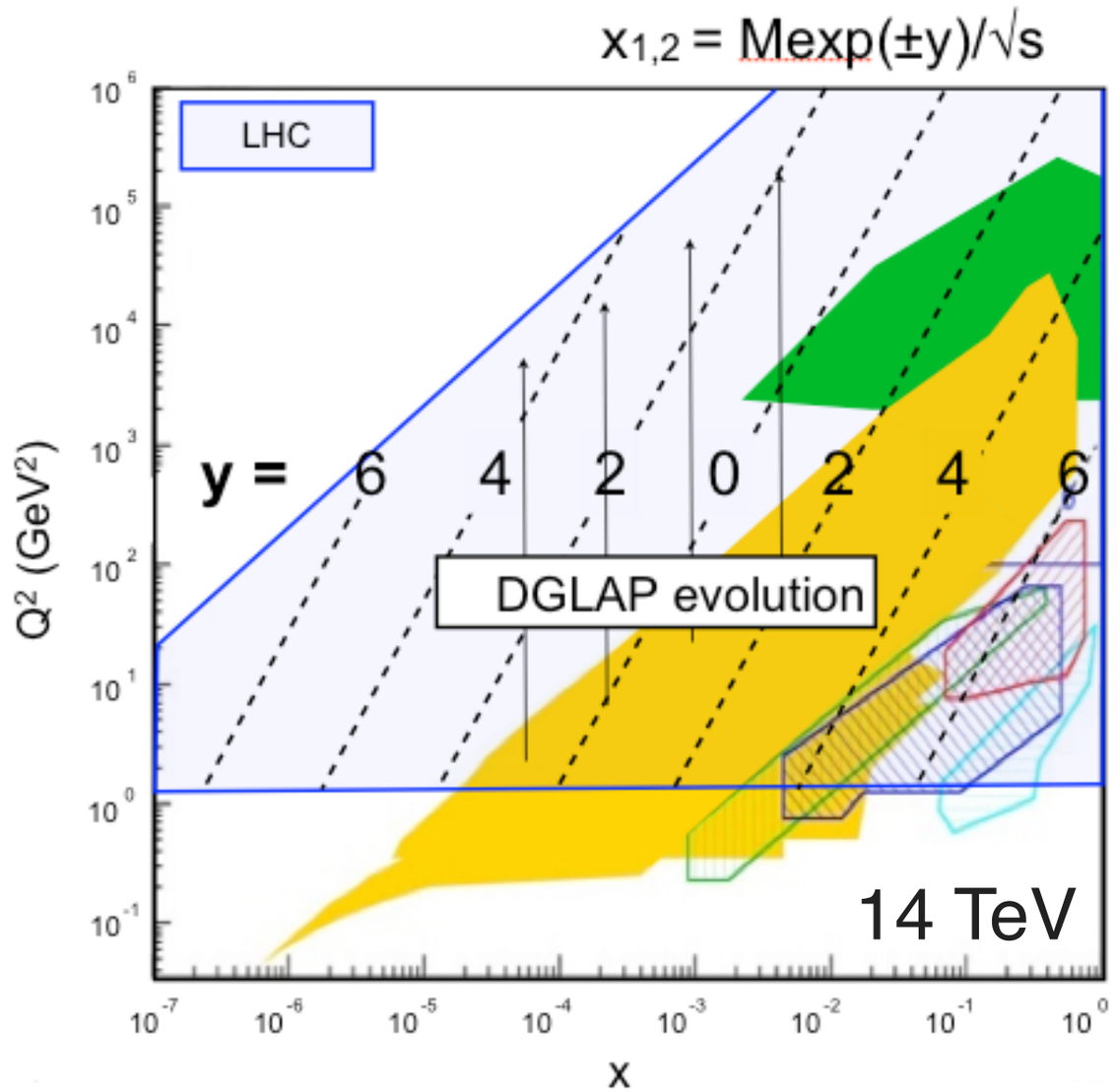


To date low-x only probed by HERA

Partons at the LHC (14 TeV)

Partons must be evolved using DGLAP equations

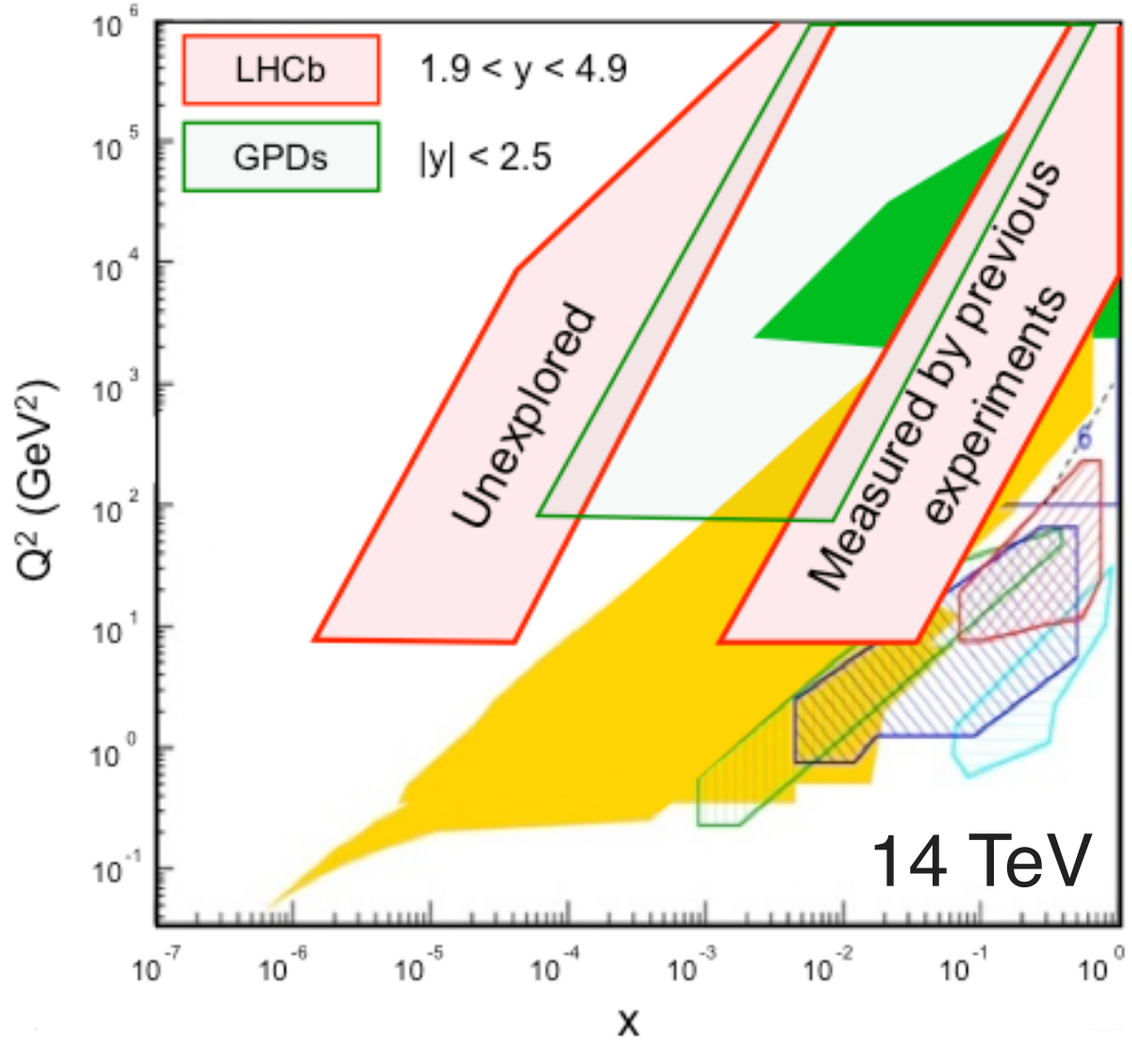
The kinematic region at LHC extends to higher Q^2 and lower x than previous experiments

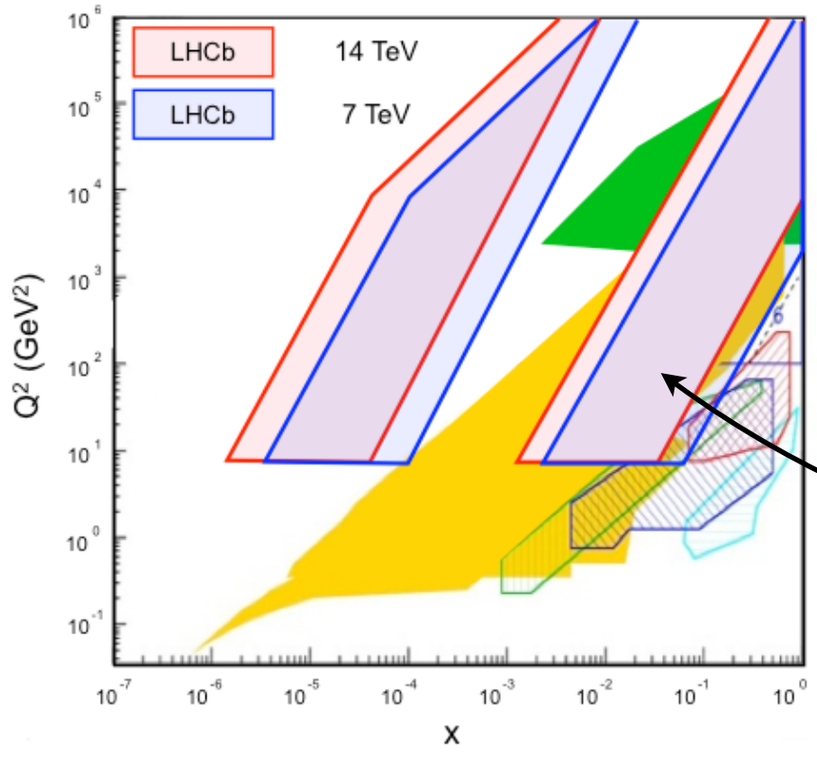


Partons at LHCb

LHCb will probe 2 distinct regions ($x_1 >> x_2$)

Due to its angular acceptance and low trigger thresholds, events at **LHCb will probe** a totally unexplored kinematic region. In particular it will have access to **low-x at both high and low Q^2**





Note that LHC will start at 7 TeV!

Partons at LHCb

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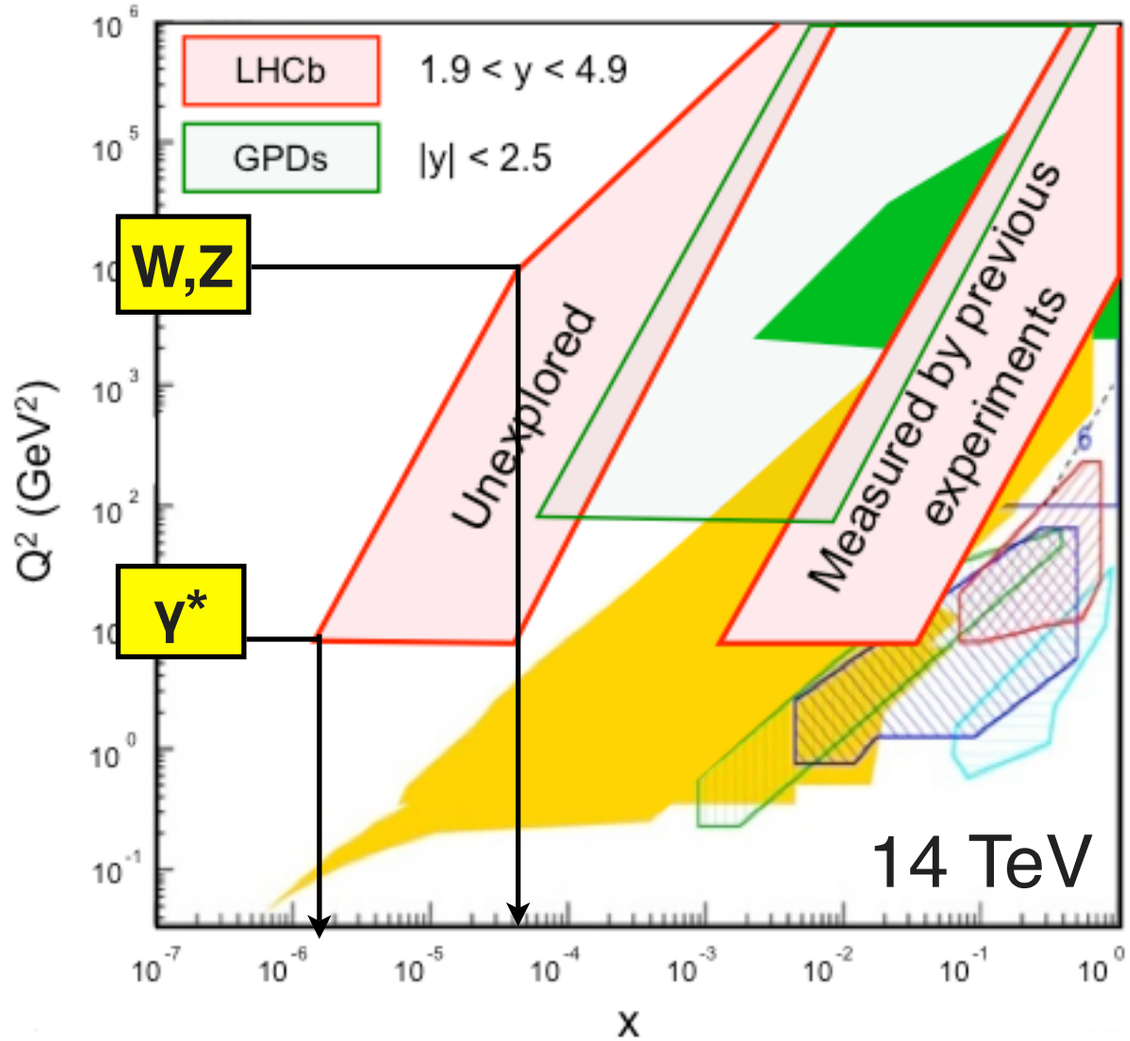
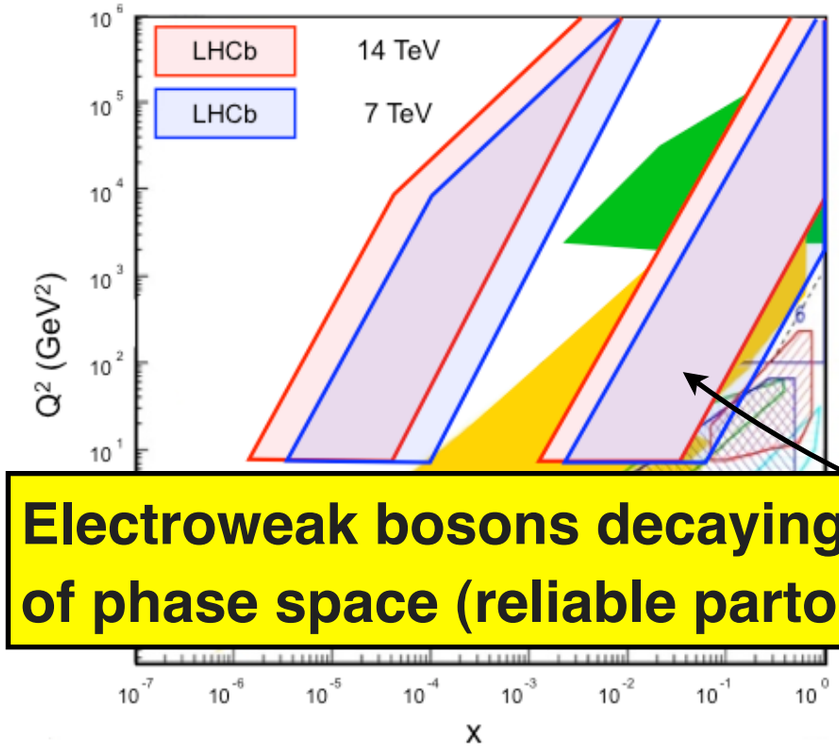




Electroweak bosons decaying to muons are ideal for exploring these regions of phase space (reliable partonic predictions & easily reconstructed final state)

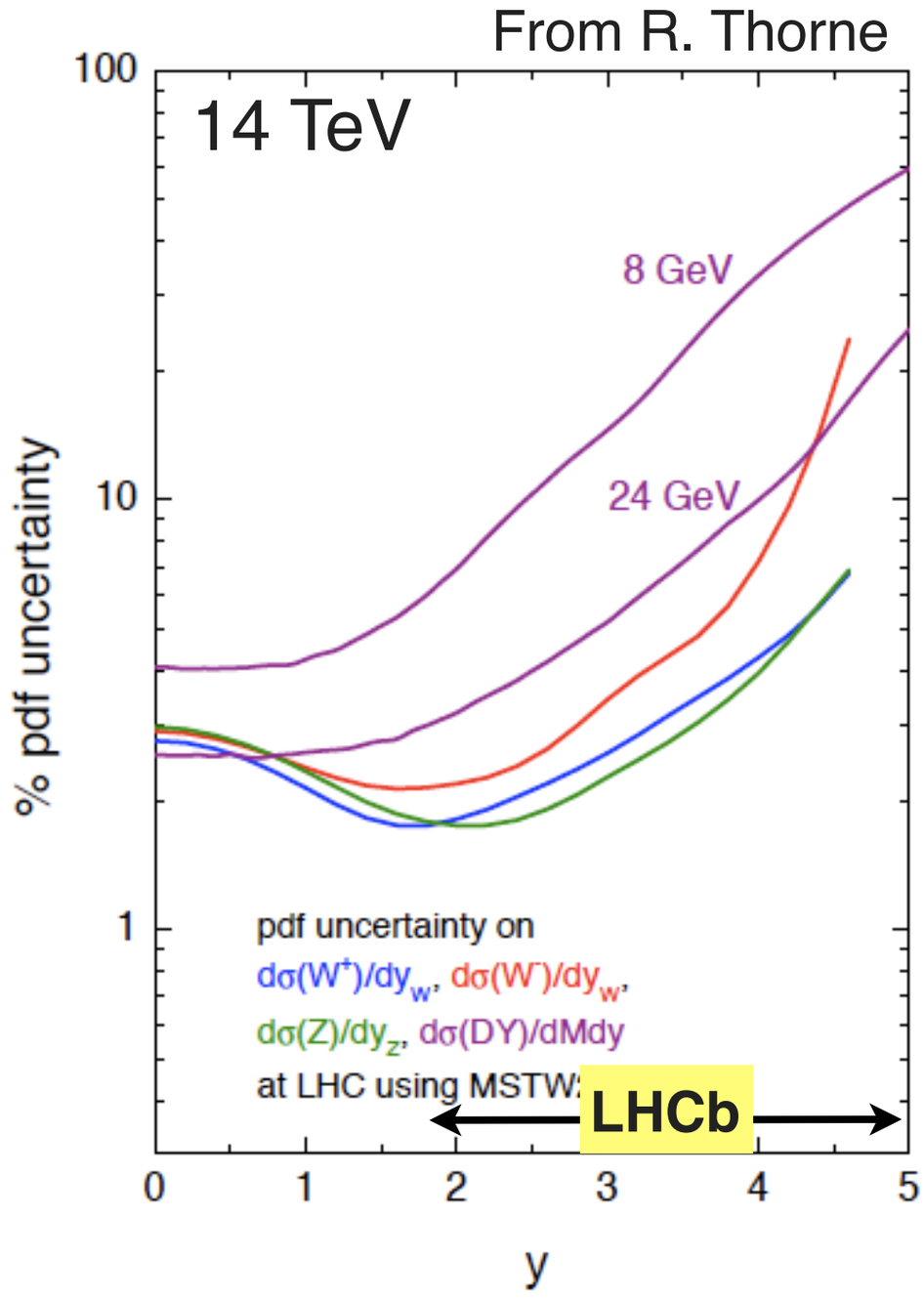
Effect of PDF uncertainties on cross-section predictions

W, Z production

- Dominant theoretical uncertainty comes from PDFs
- Clean experimental signature
- PDF uncertainty grows at large rapidity
- Cross-section measurement can constrain PDFs

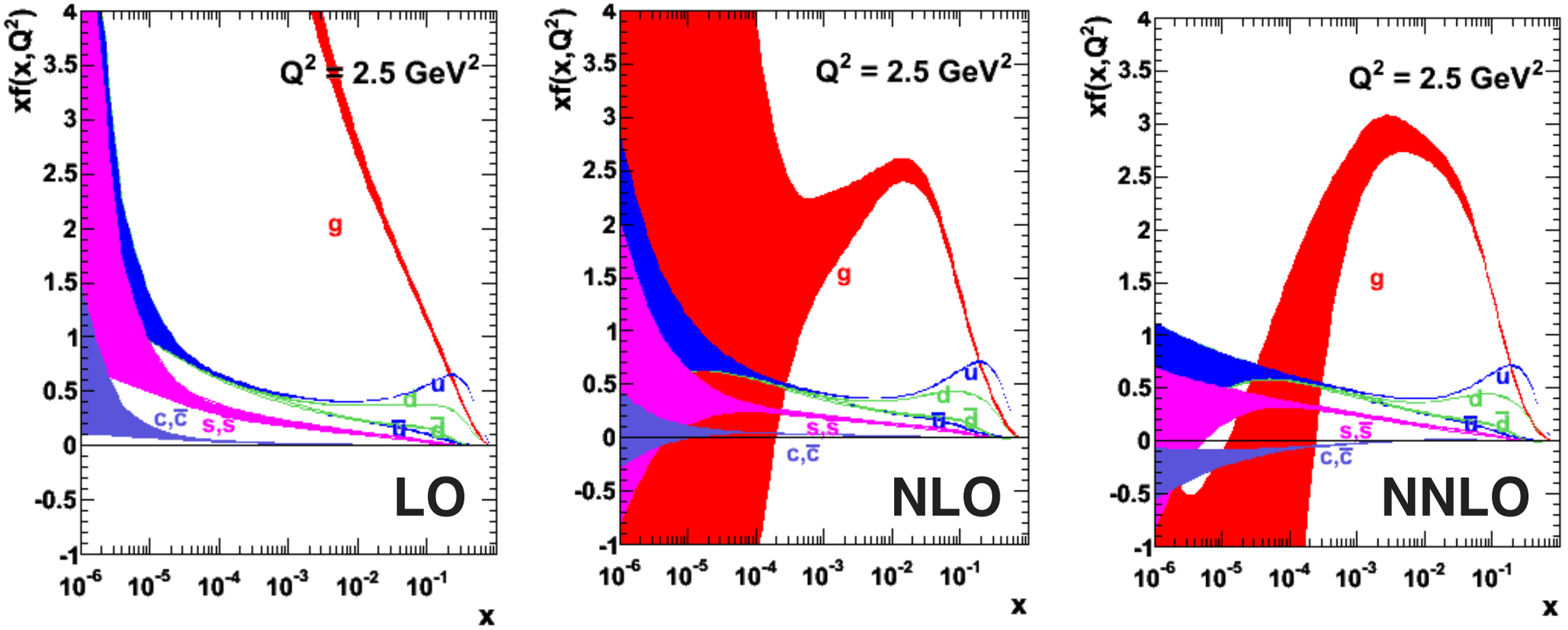
Low mass Drell-Yan production

- PDF uncertainty grows at low dimuon mass
- Depends on very low-x partons
- Differential cross-section measurement at LHCb can provide large constraint on PDFs



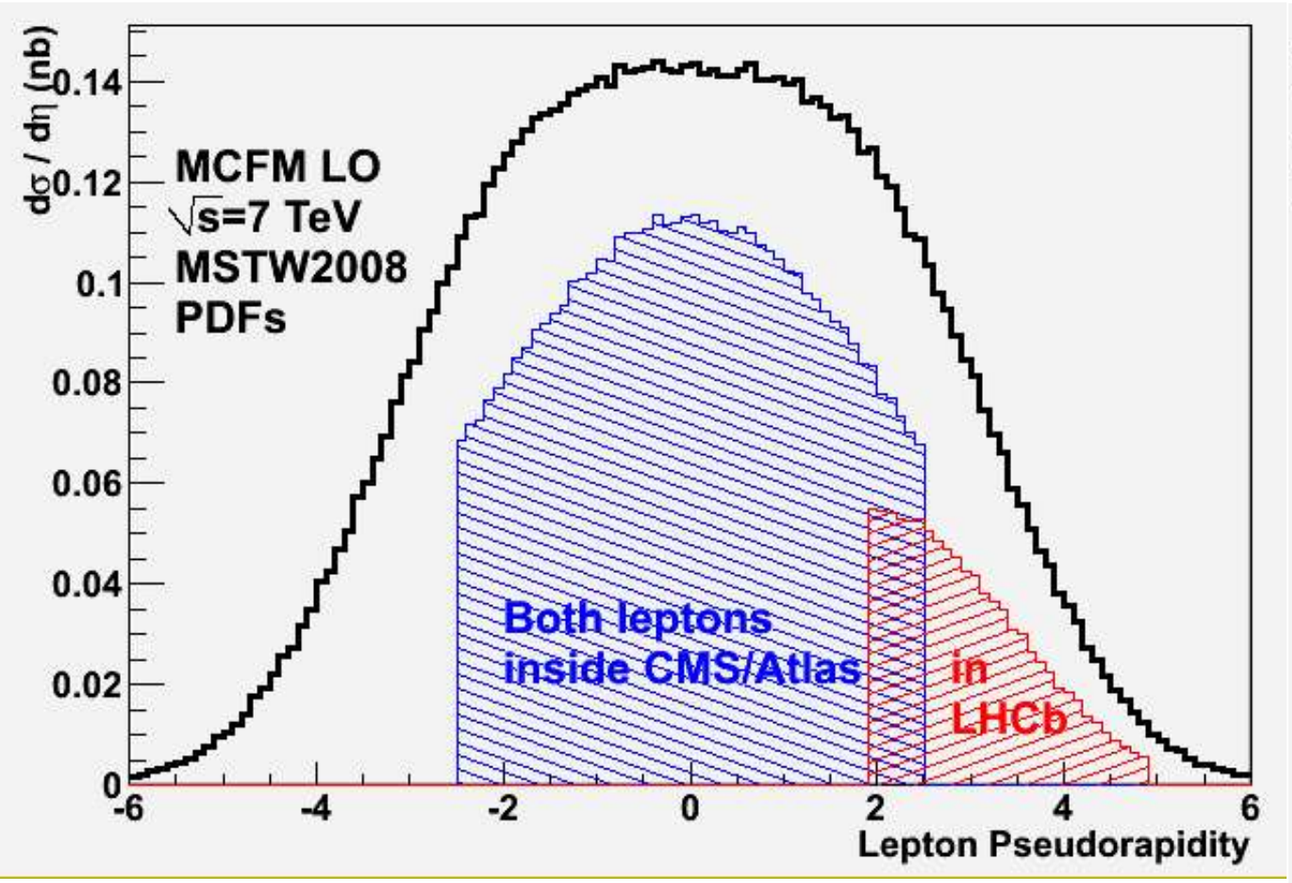
PDF uncertainties at low-x and low-Q^2

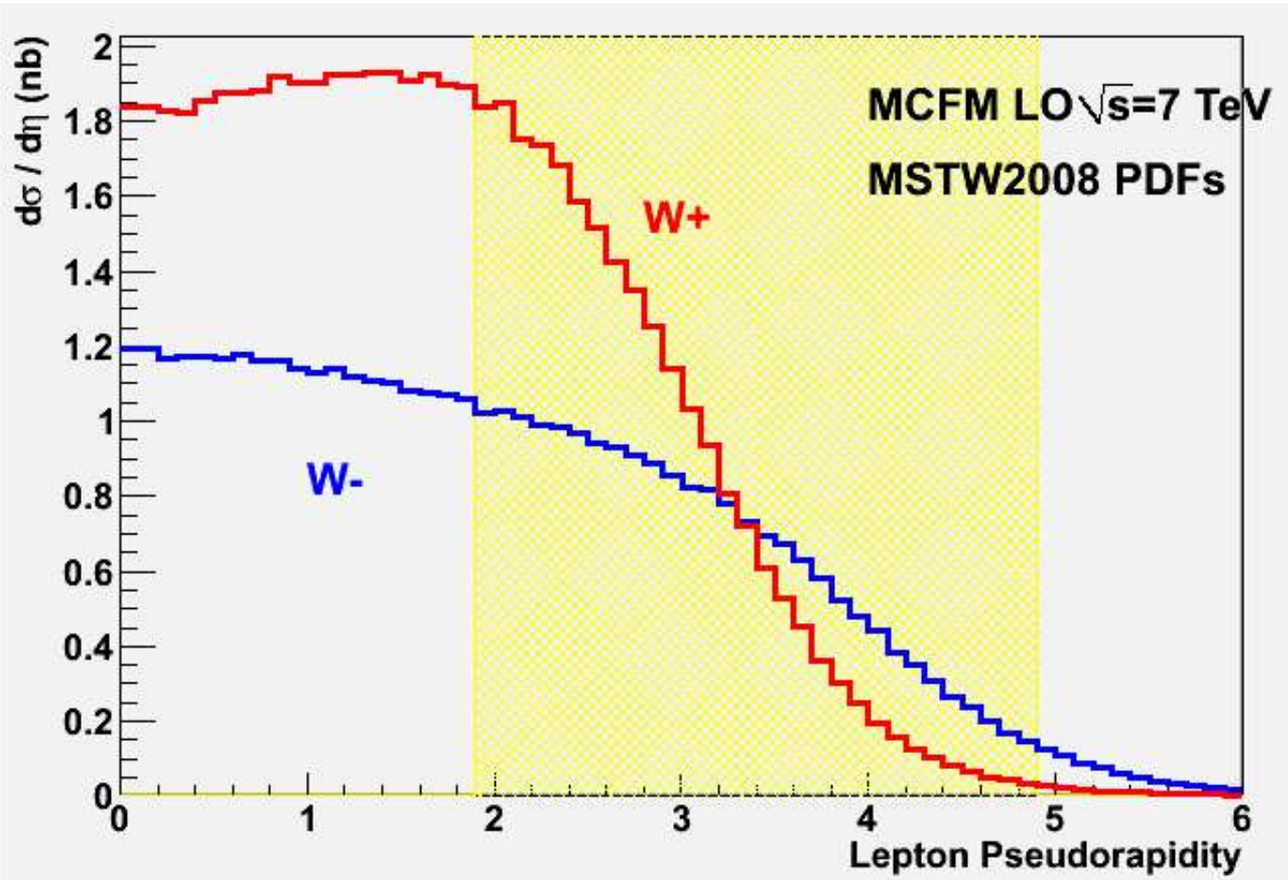
MSTW08 - from G. Watt



- Different behaviour and uncertainty depending on the order of the calculation
- Gluon is essentially unconstrained below $x = 10^{-4}$
- Low-x gluon re-summation effects.

W, Z production





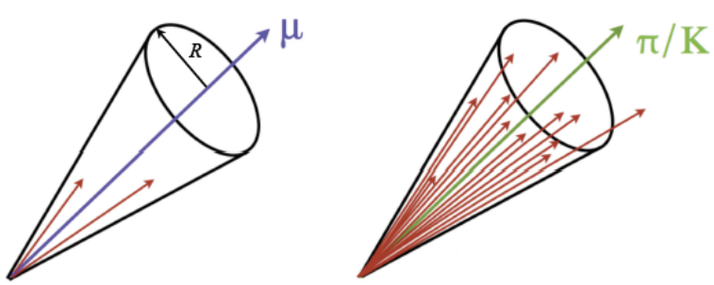
Ws from first LHCb data (59 nb^{-1})

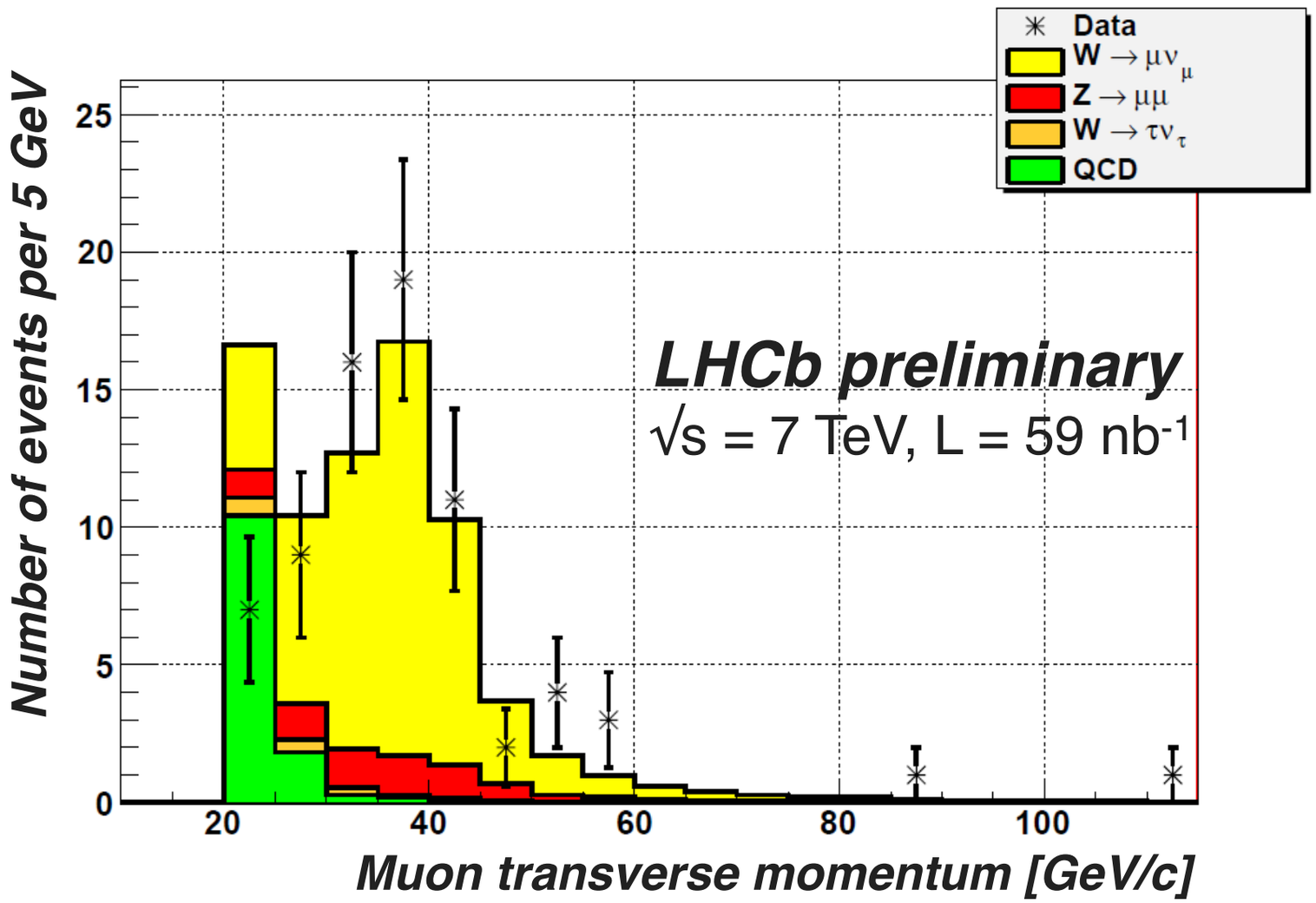
Require Isolated high PT muon

- Ensure track isolation
- Variety of backgrounds estimated
- Backgrounds from hadron mis-id estimated using **data** (hadrons scaled by mis-id probability)
- 66 candidates with Pt > 30 GeV

$$A_{P_t} = \frac{P_{t_\mu} - P_{t_{cone}}}{P_{t_\mu} + P_{t_{cone}}}$$

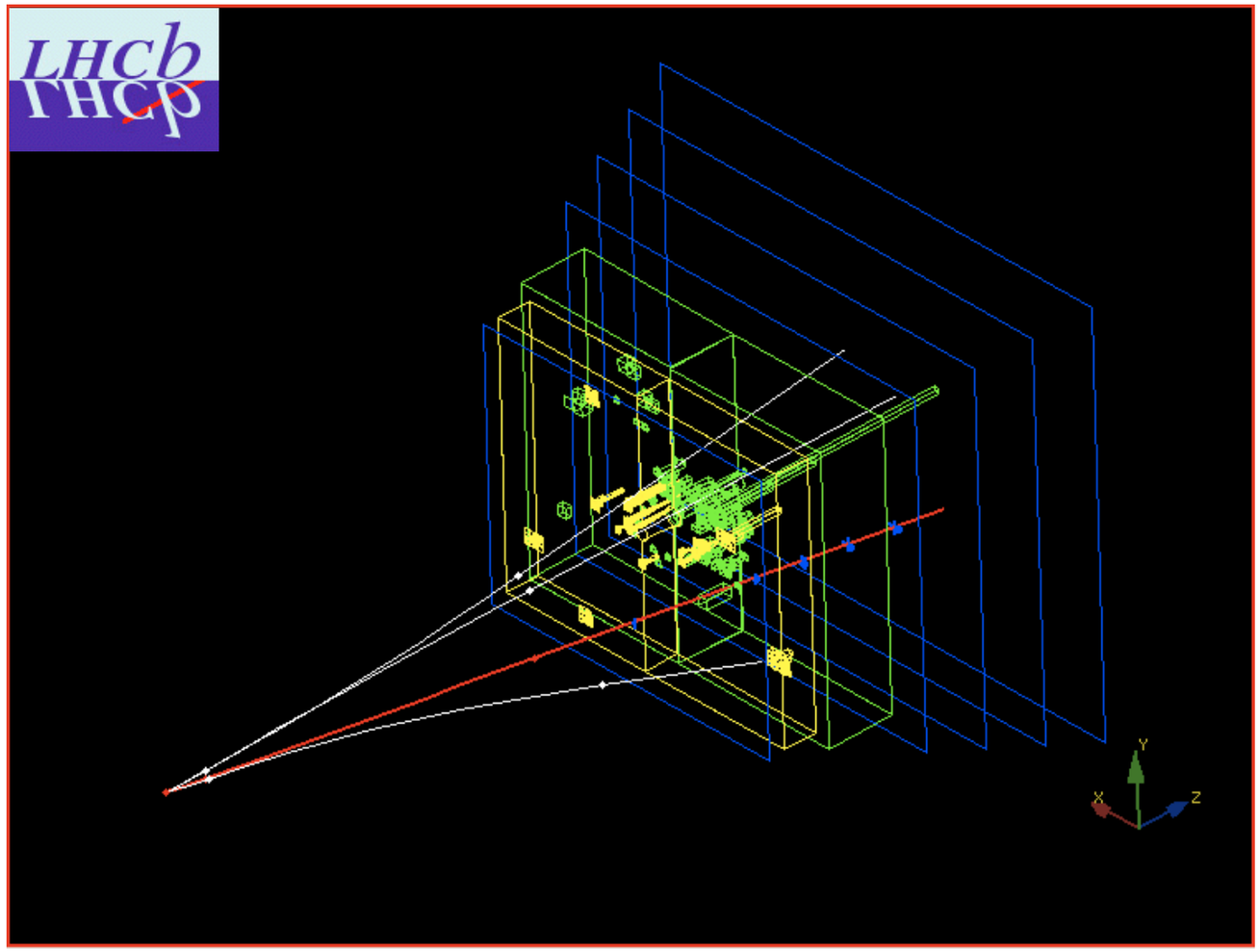
$$R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$



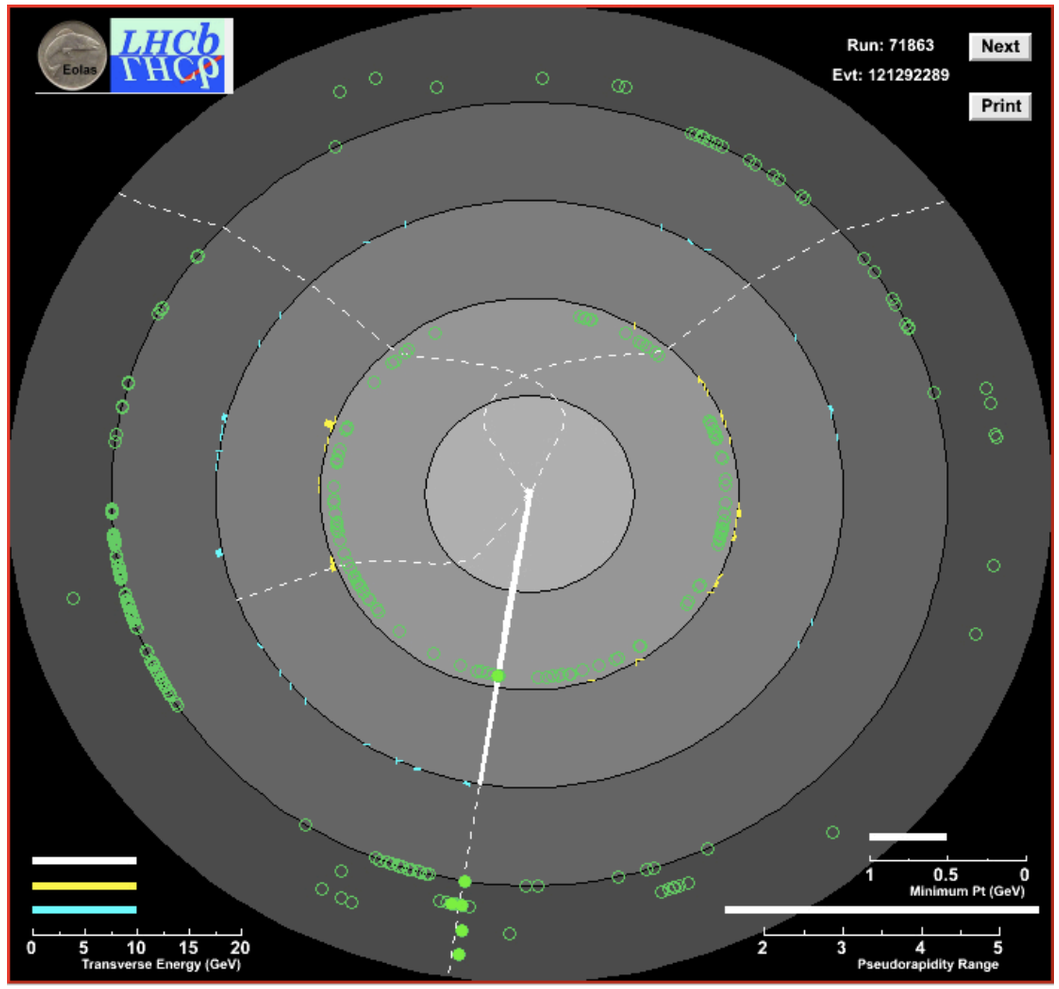


Example W candidate

X - Y - Z view



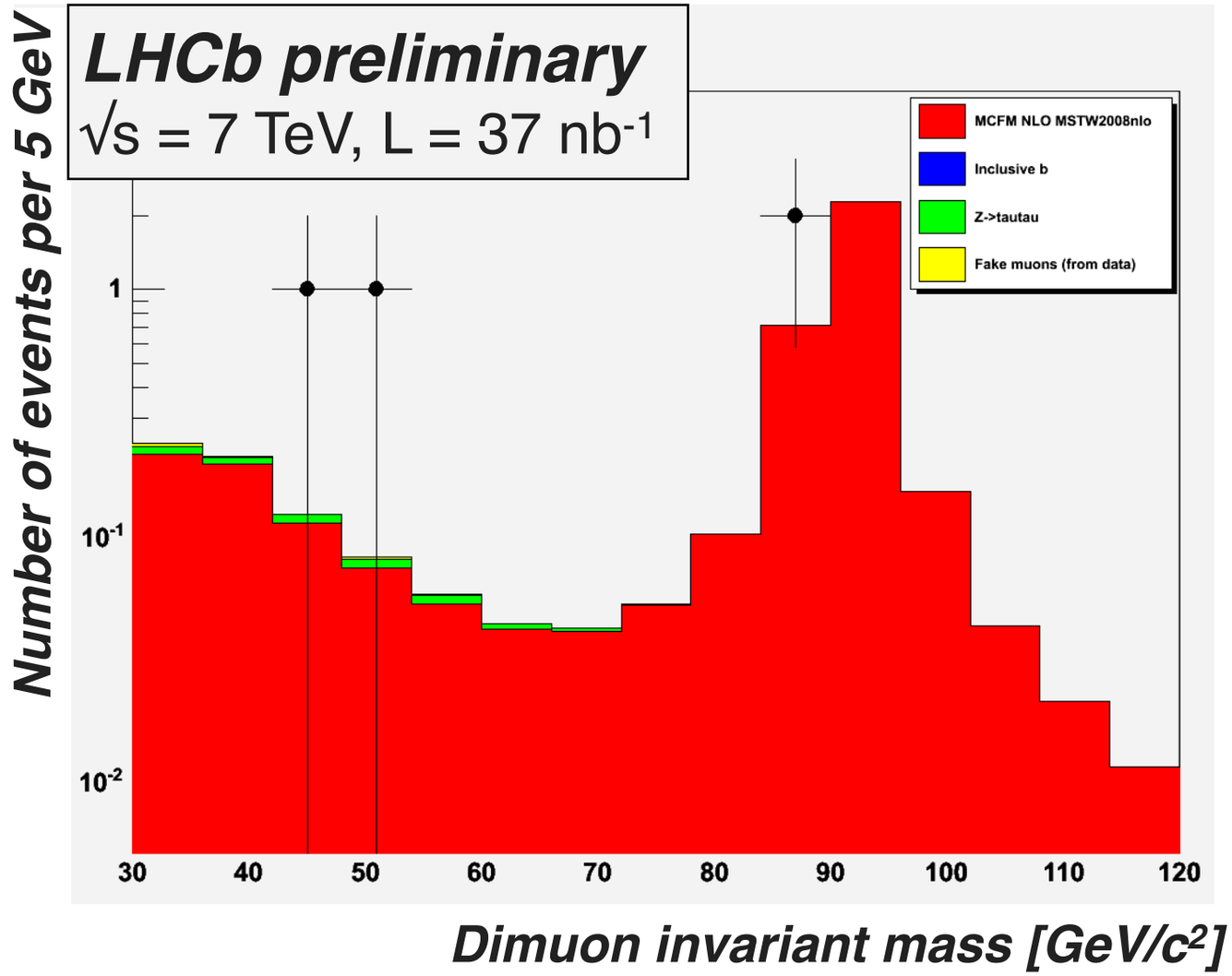
ϕ - Z view



Zs from first LHCb data (37 nb^{-1})

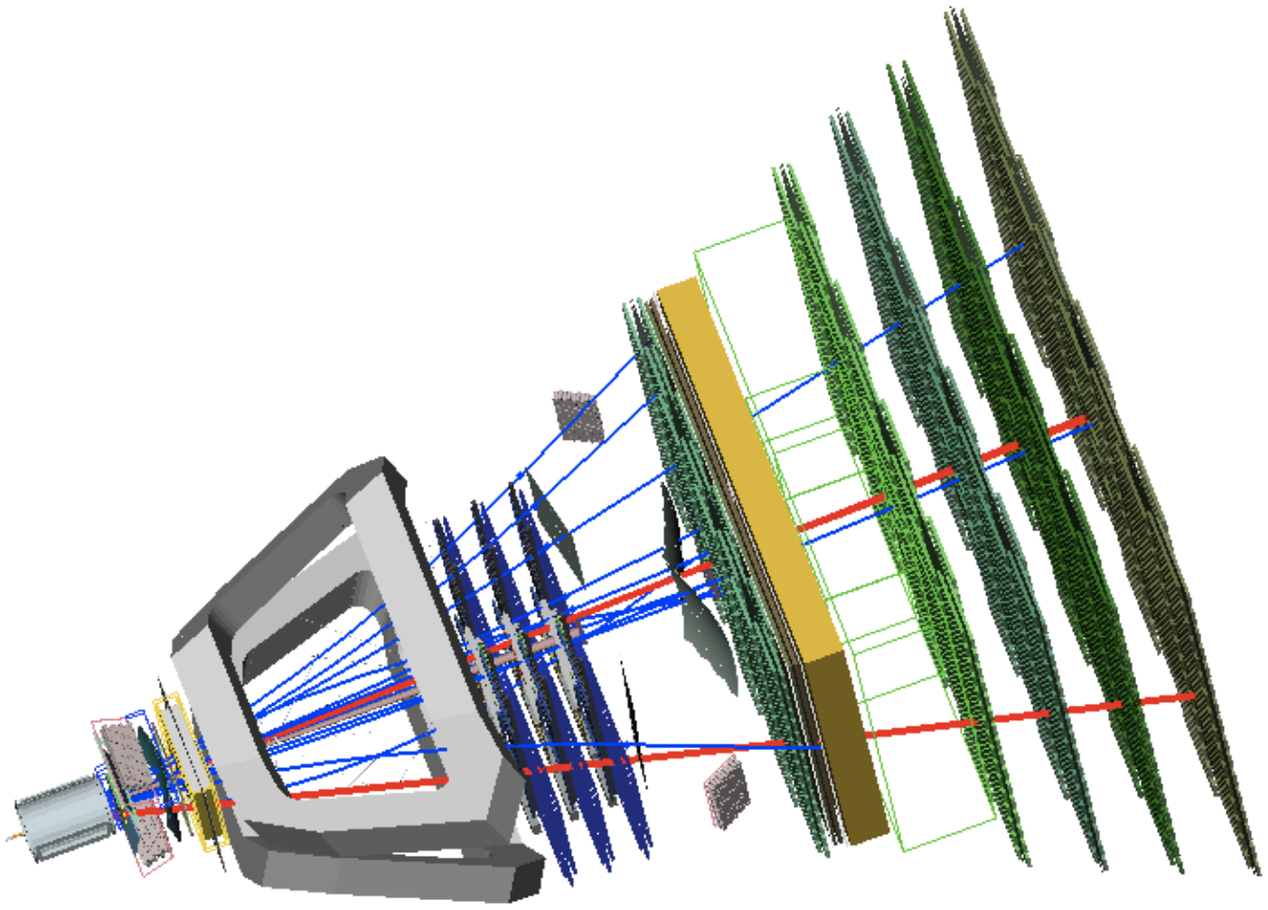
$Z \longrightarrow \mu\mu$

- Require 2 isolated high Pt muons
- Variety of backgrounds taken from simulation
- Backgrounds from hadron mis-id estimated using **data** (hadron pairs scaled by mis-id probability)
- 2 candidates, expect ~3

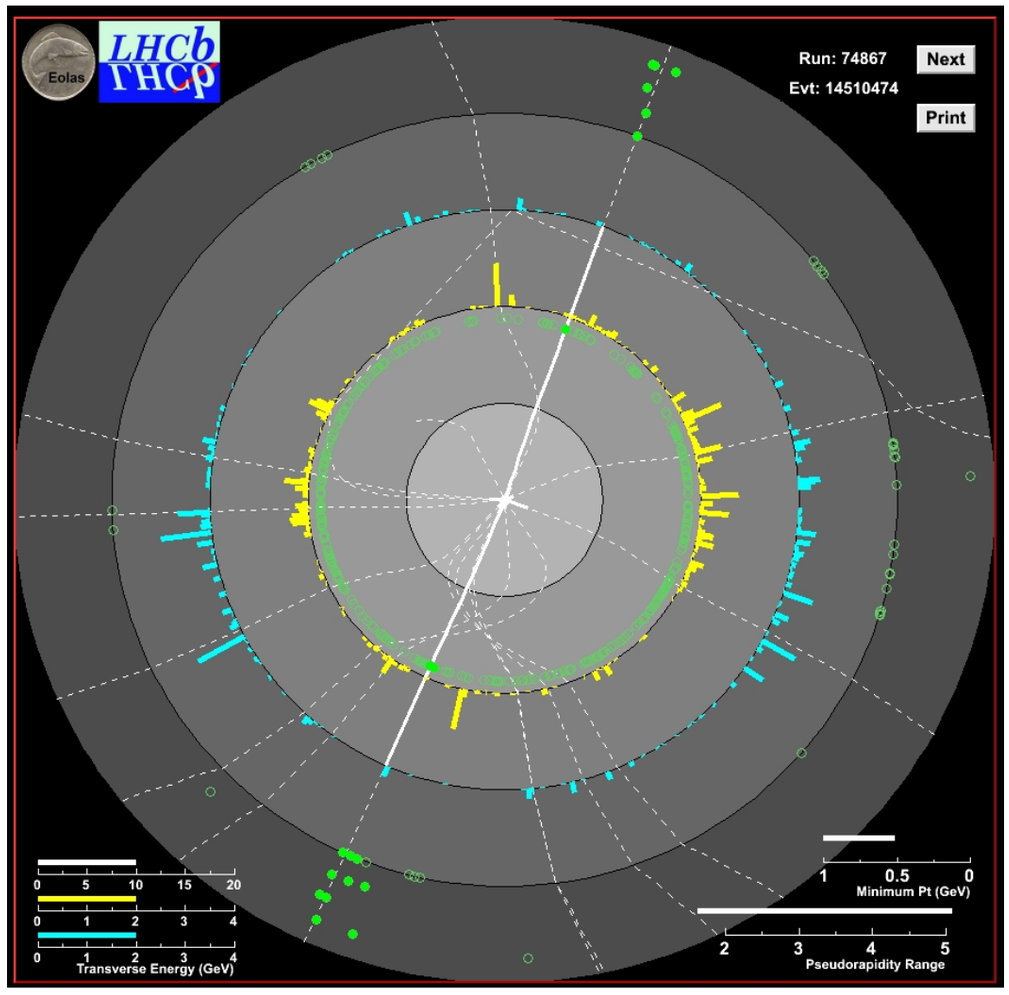


Example Z candidate

X - Y - Z view



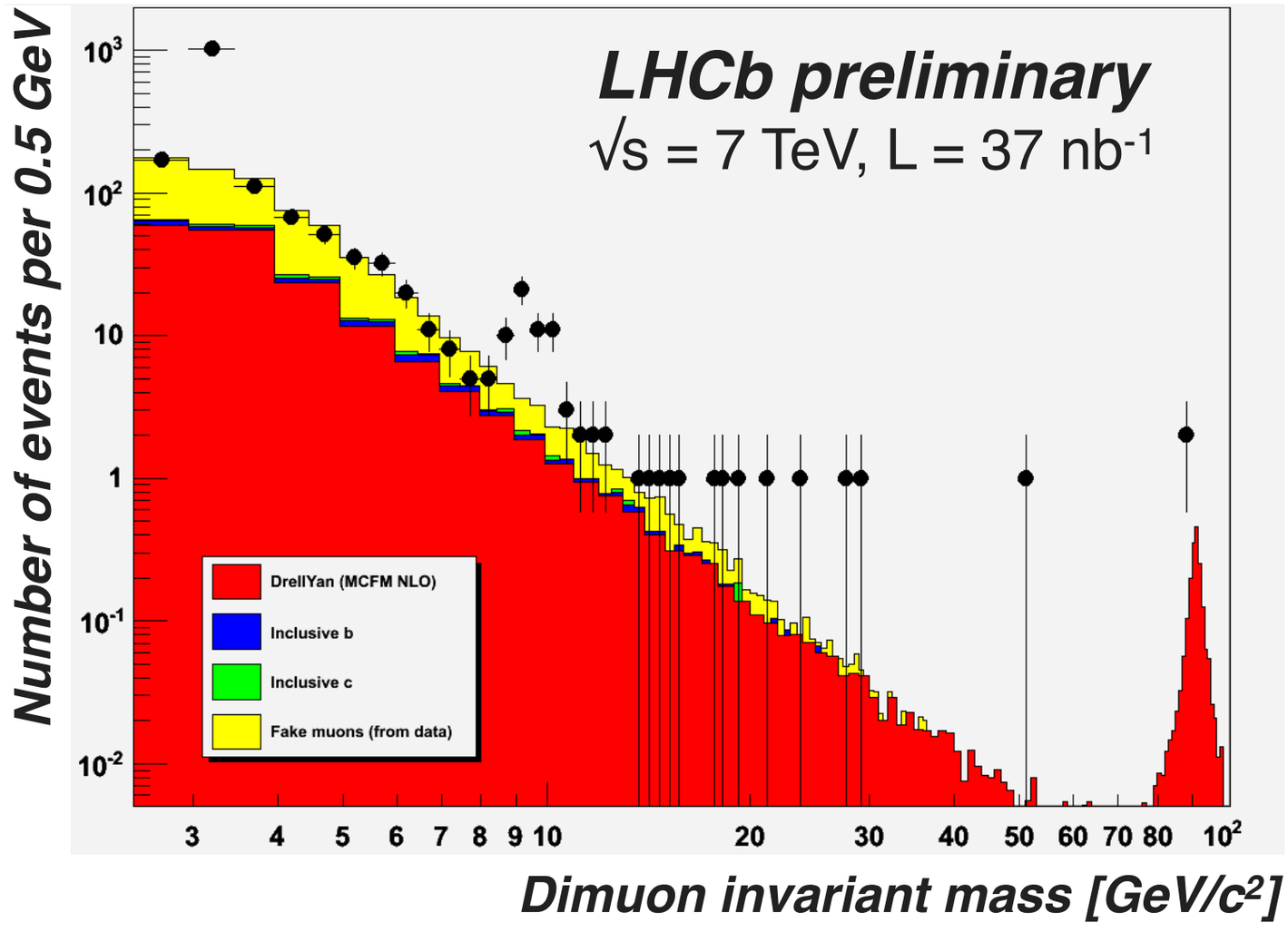
ϕ - Z view



Low mass DY pairs from first LHCb data (37 nb^{-1})

$\gamma^* \longrightarrow \mu\mu$

- Require 2 isolated muons with Pt > 1GeV consistent with primary vertex
- Background from heavy quark decays taken from simulation
- Backgrounds from hadron mis-id estimated using **data**
  (hadron pairs scaled by mis-id probability)

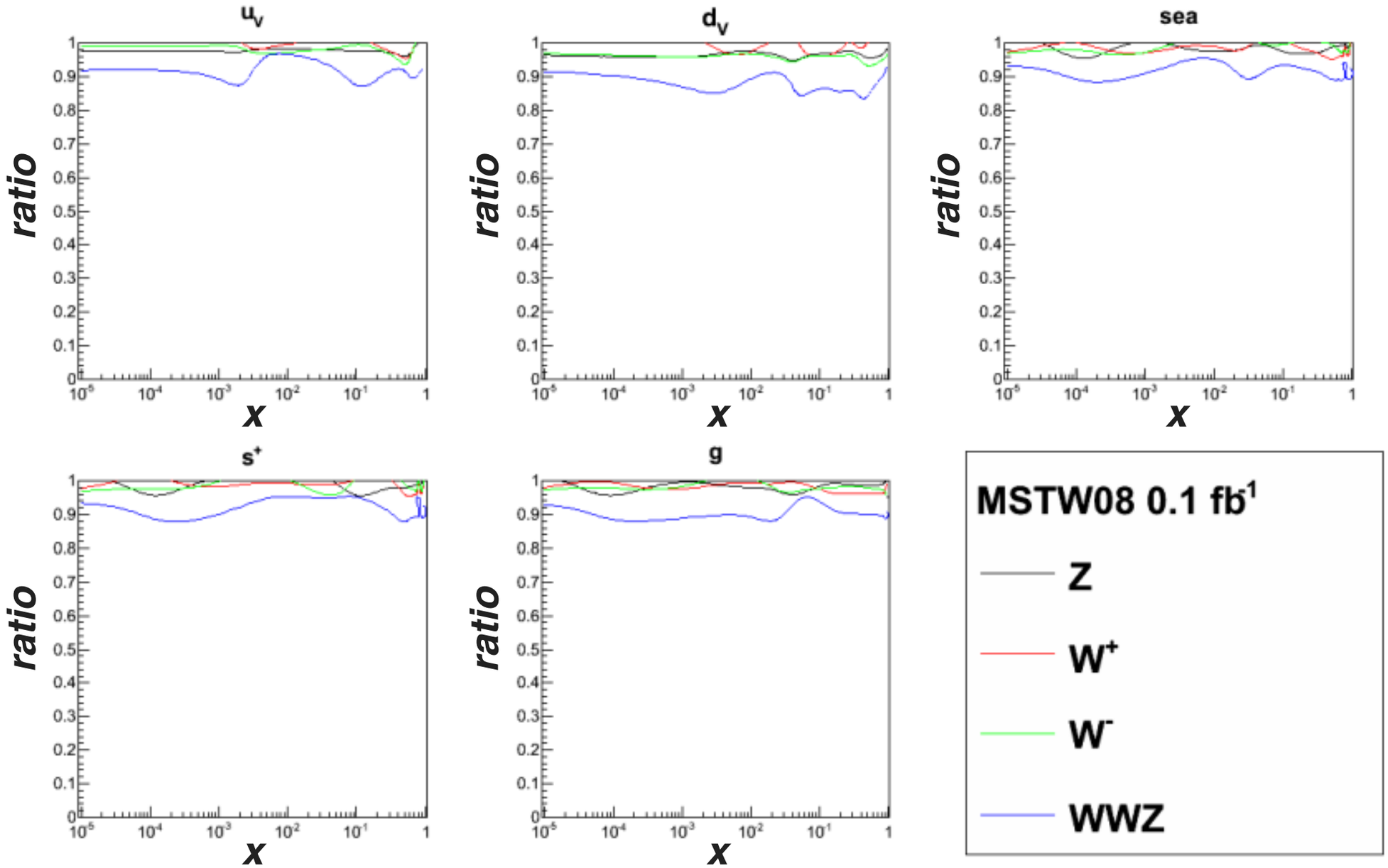


Drell-Yan pairs can be identified with reasonably high purity

Potential improvements to PDFs using LHCb data

We now have 1 pb^{-1} of data on tape, expect 100 pb^{-1} by the end of the year
Will have W, Z and low mass Drell-Yan cross-section measurements soon

Expected improvements using 100 pb^{-1} of W and Z data

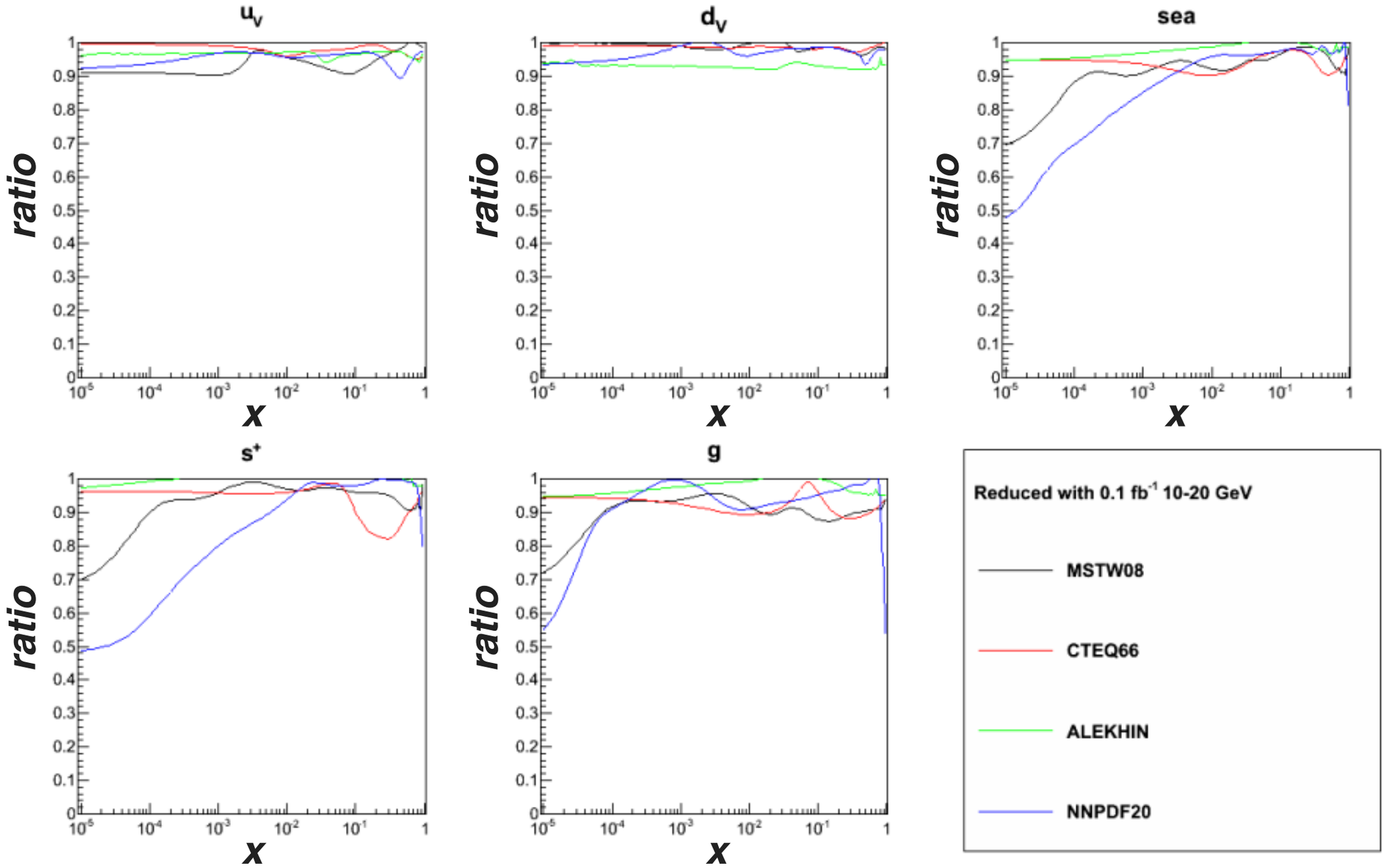


$$ratio = \frac{\delta_{after}}{\delta_{before}}$$

Potential improvements to PDFs using LHCb data

We now have 1 pb^{-1} of data on tape, expect 100 pb^{-1} by the end of the year
Will have W, Z and low mass Drell-Yan cross-section measurements soon

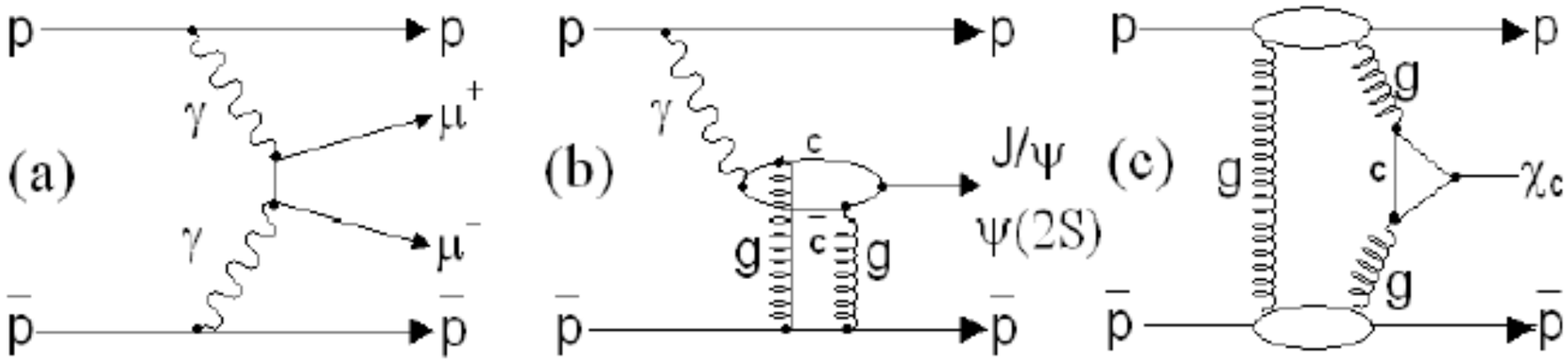
Expected improvements using 100pb^{-1} of low mass Drell-Yan events (10-20 GeV)



$$ratio = \frac{\delta_{after}}{\delta_{before}}$$

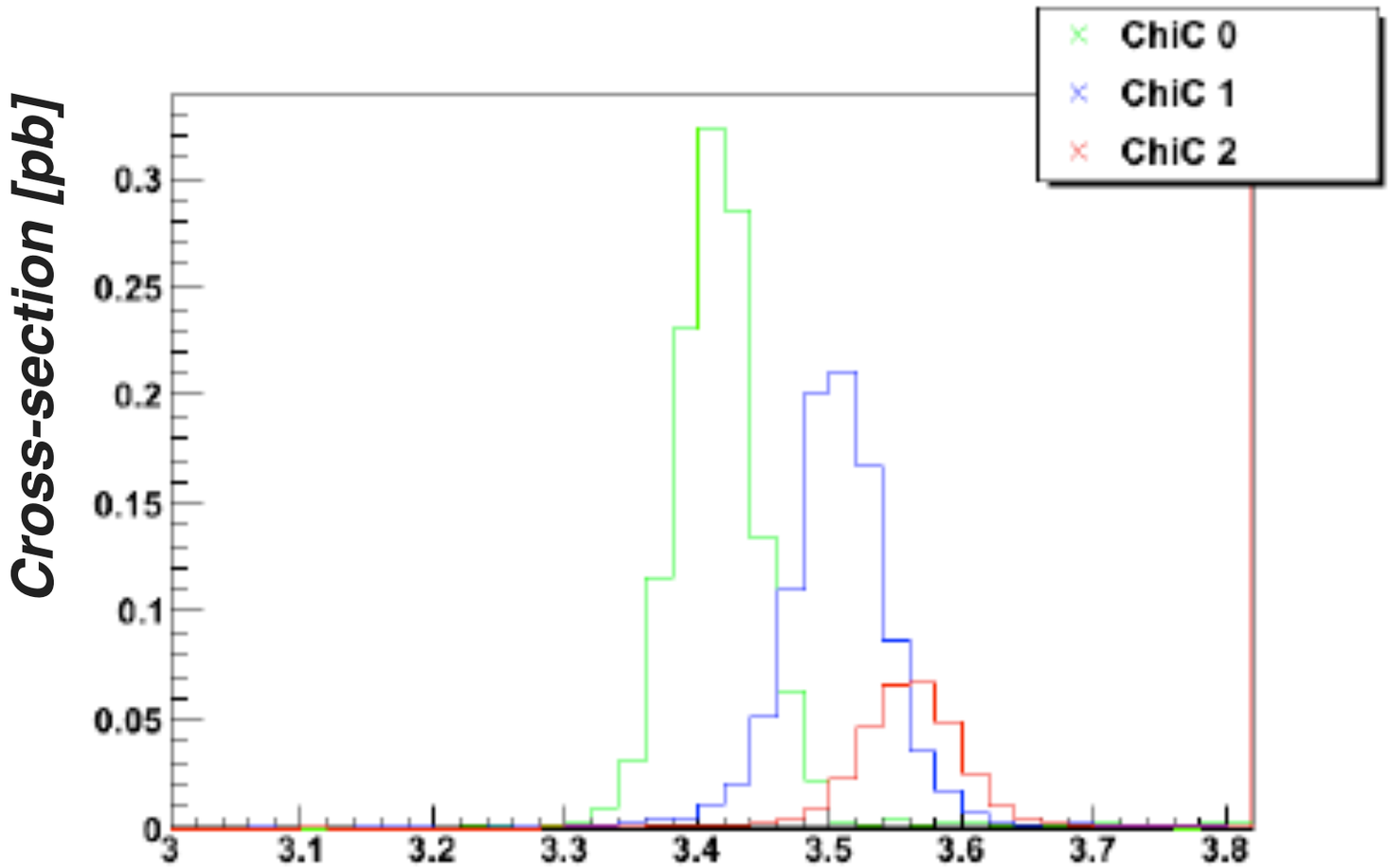
Exclusive ChiC production at LHCb

Plans to measure 3 exclusive processes at LHCb



- Dimuon production via photon fusion for luminosity measurement
- J/ψ , ψ(2S) and χ_c via pomeron-photon and pomeron-pomeron fusion
- Produced at low-x and low-Q^2 but now probing photon and pomeron
- χ_c: process similar to exclusive Higgs production
- Will only show χ_c candidates today

SuperChiC and LHCb detector simulation



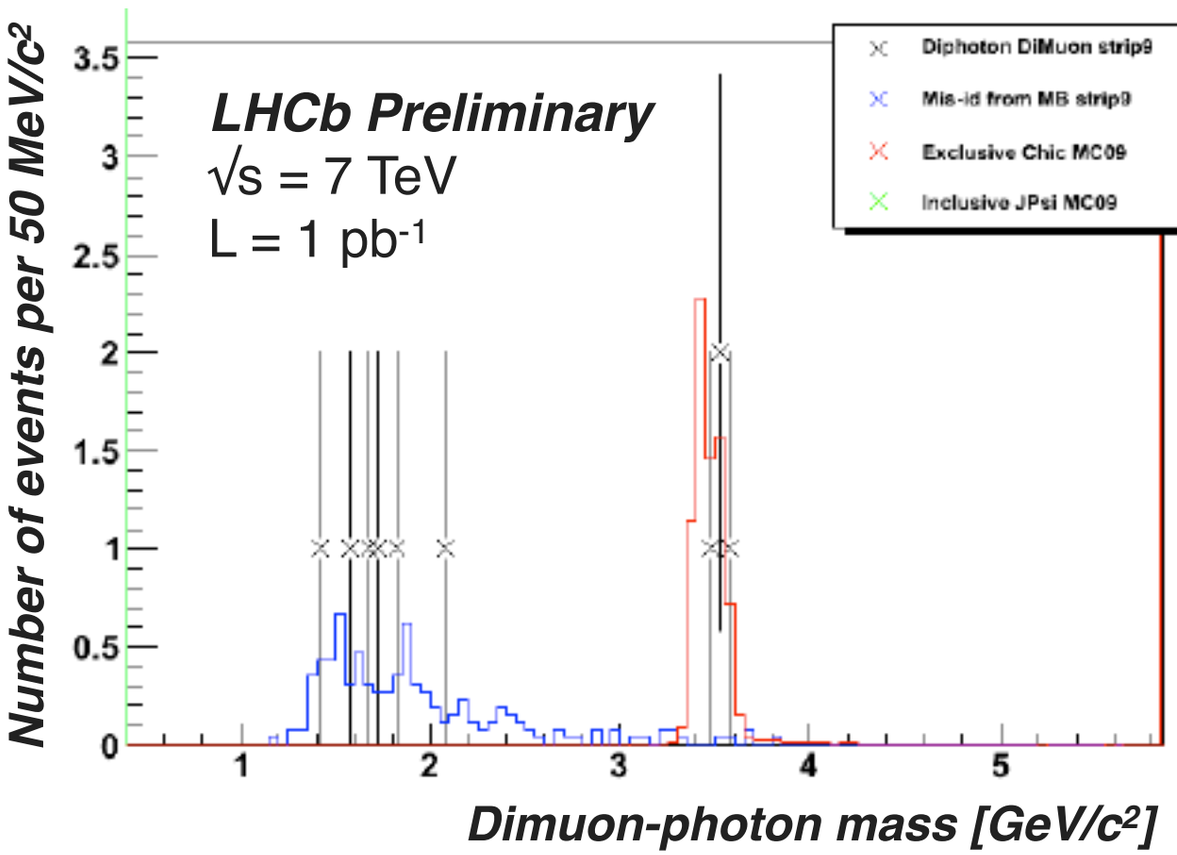
- Events from SuperChiC passed through full LHCb simulation
- Separation of $\chi_c(0)$ and $\chi_c(1)$ will be possible at LHCb

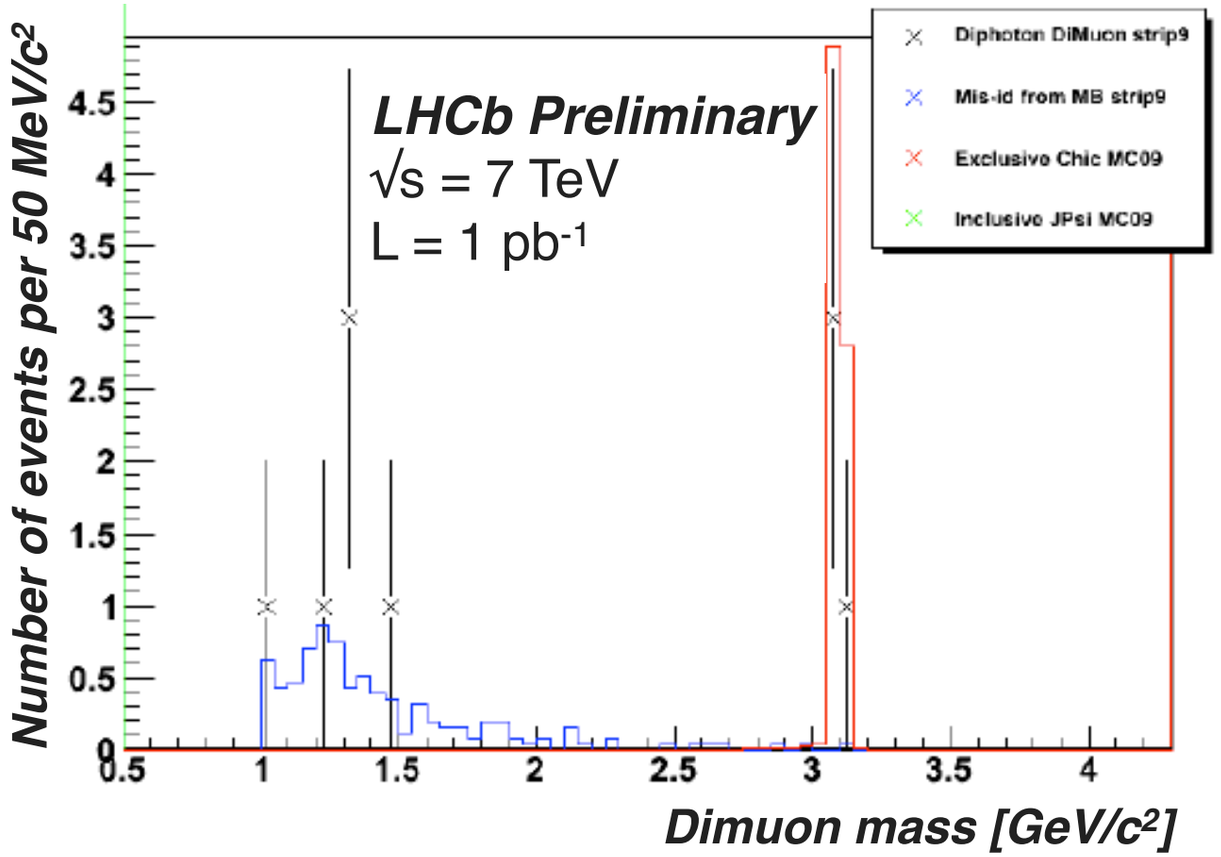
SuperChiC: L.A. Harland-Lang, V.A. Khoze, M.G. Ryskin, W.J. Stirling, Eur. Phys. J. C65:433-448 (2010)

χ_c candidates at LHCb (1 pb^{-1} of data)

Event selection

- Only 2 muons and 1 photon in the event
- Muon Pt > 400 MeV; Dimuon mass > 1 GeV; Dimuon Pt < 900 MeV



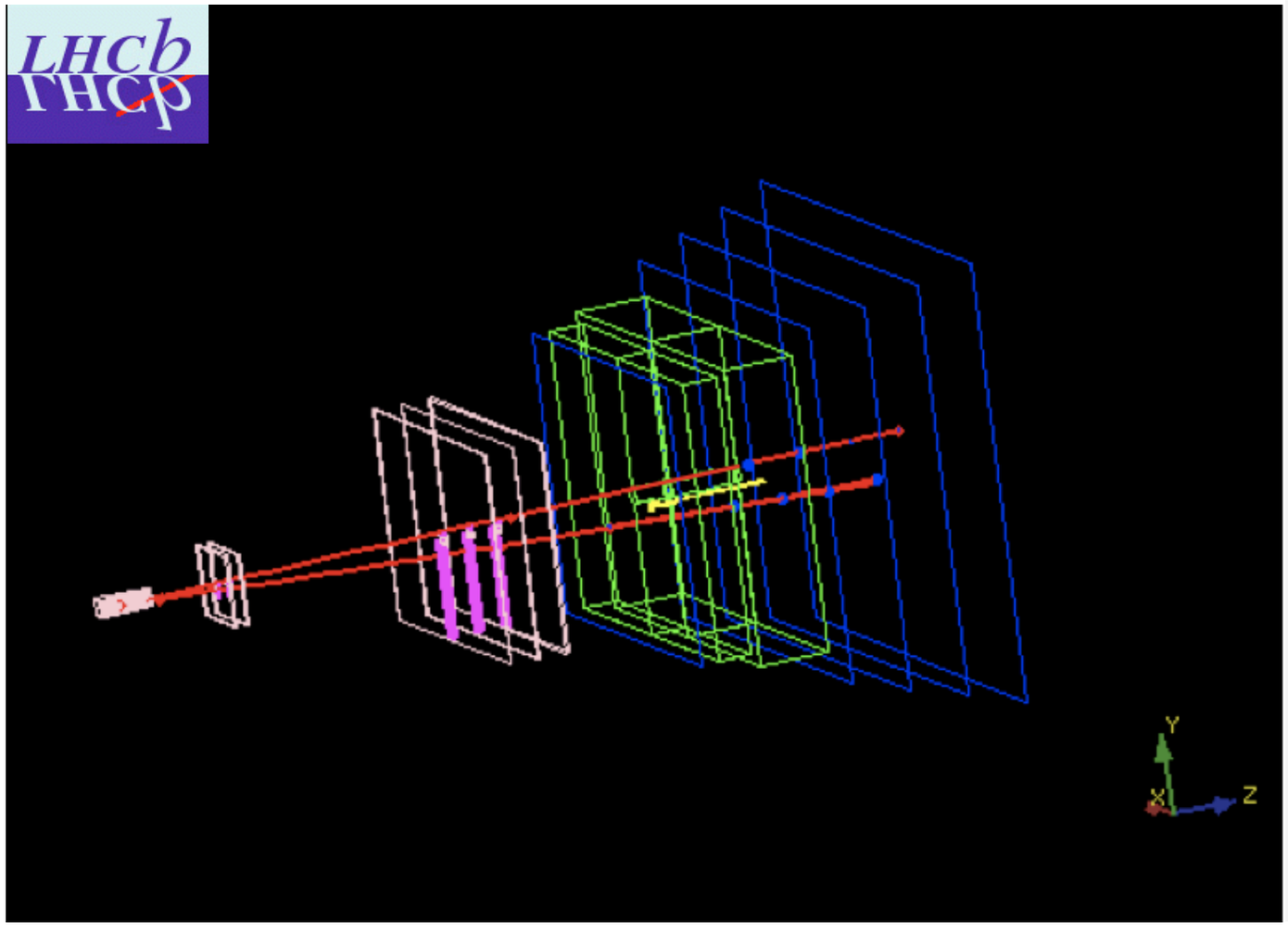


Note:

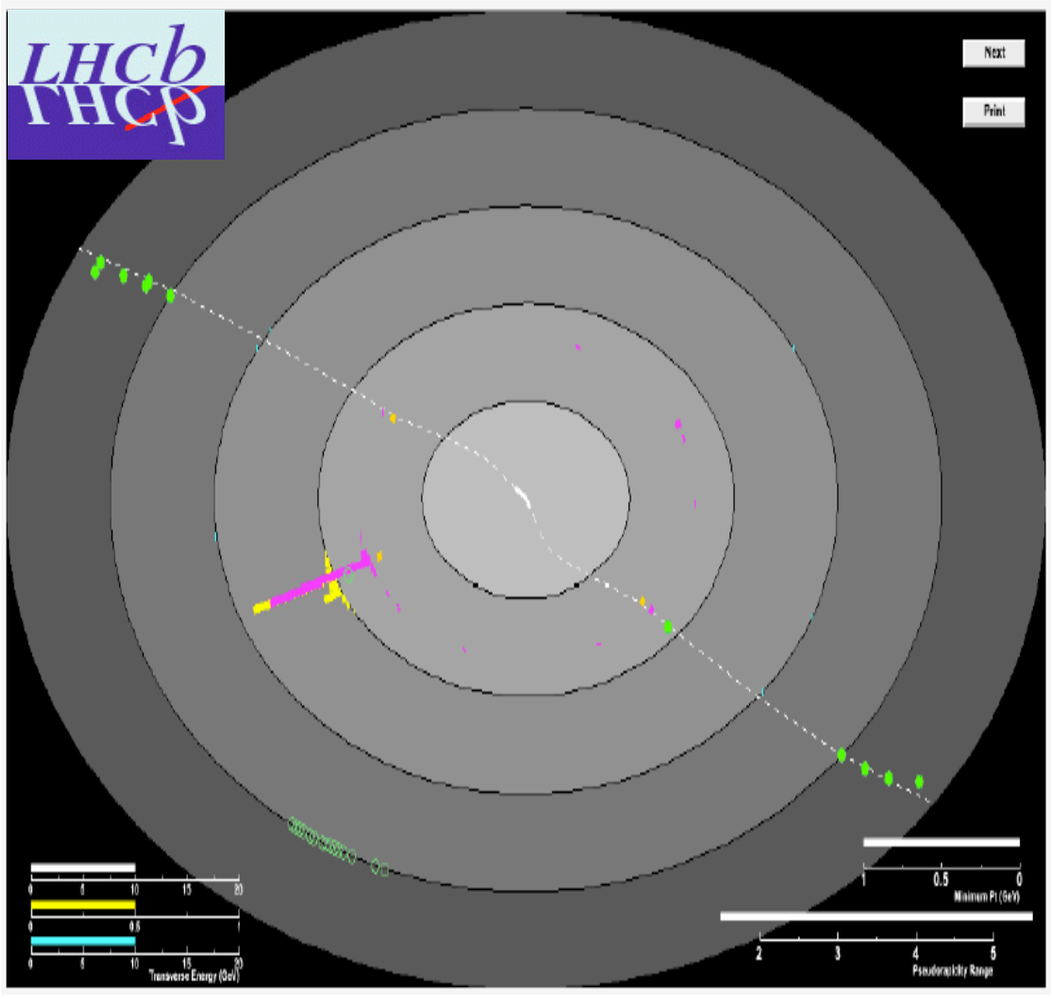
- LHCb currently running with high pile-up, reduces effective luminosity
- Efficiencies not yet calculated in detail. Normalisation may be unreliable

Example exclusive χ_c candidate

X - Y - Z view



ϕ - Z view



Conclusions

Events at LHCb will probe an unexplored low-x region of phase space

- Electroweak bosons are ideal for exploring this region

Candidate electroweak boson events at LHCb presented

- Using ~50 nb^{-1} of data we find 66 Ws and 2 Zs in agreement with expectations
- LHCb has 3.5 pb^{-1} of data on tape, expect cross-section measurements soon

Expect significant improvements to PDFs at low-x with 100 pb^{-1} of data

- Collected by the end of the year

Exclusive χ_c candidate events found using 1 pb^{-1} of LHCb data

- Also provides a probe of low-x, low-Q^2

Back-up slides follow

Studies of potential improvements to PDFs from LHCb

From global fits, PDFs described by a set of orthogonal eigenvectors, which which have a 'central' value $\vec{e}_0$, and 'uncertainties' $\vec{e}_i$.

$$\frac{d\sigma}{dy}(\delta_1, \delta_2, ..., \delta_N) = \frac{d\sigma}{dy}(\vec{e_0}) + \sum_i^N \delta_i \{ \frac{d\sigma}{dy}(\vec{e_i}) - \frac{d\sigma}{dy}(\vec{e_0}) \}$$

Current knowledge of PDFs mapped out by sampling δ_i from unit multinomial distribution.

We have performed pseudo-experiments, generating LHCb data and fitting for δ_i, to see how eigenvector knowledge improves.

Effect on MSTW08, CTEQ6.5, ALEKHIN2002, NNPDF2.0 studied.