Dileptons with LHCb

Prospects on various aspect of the dilepton probe in hadronic physics

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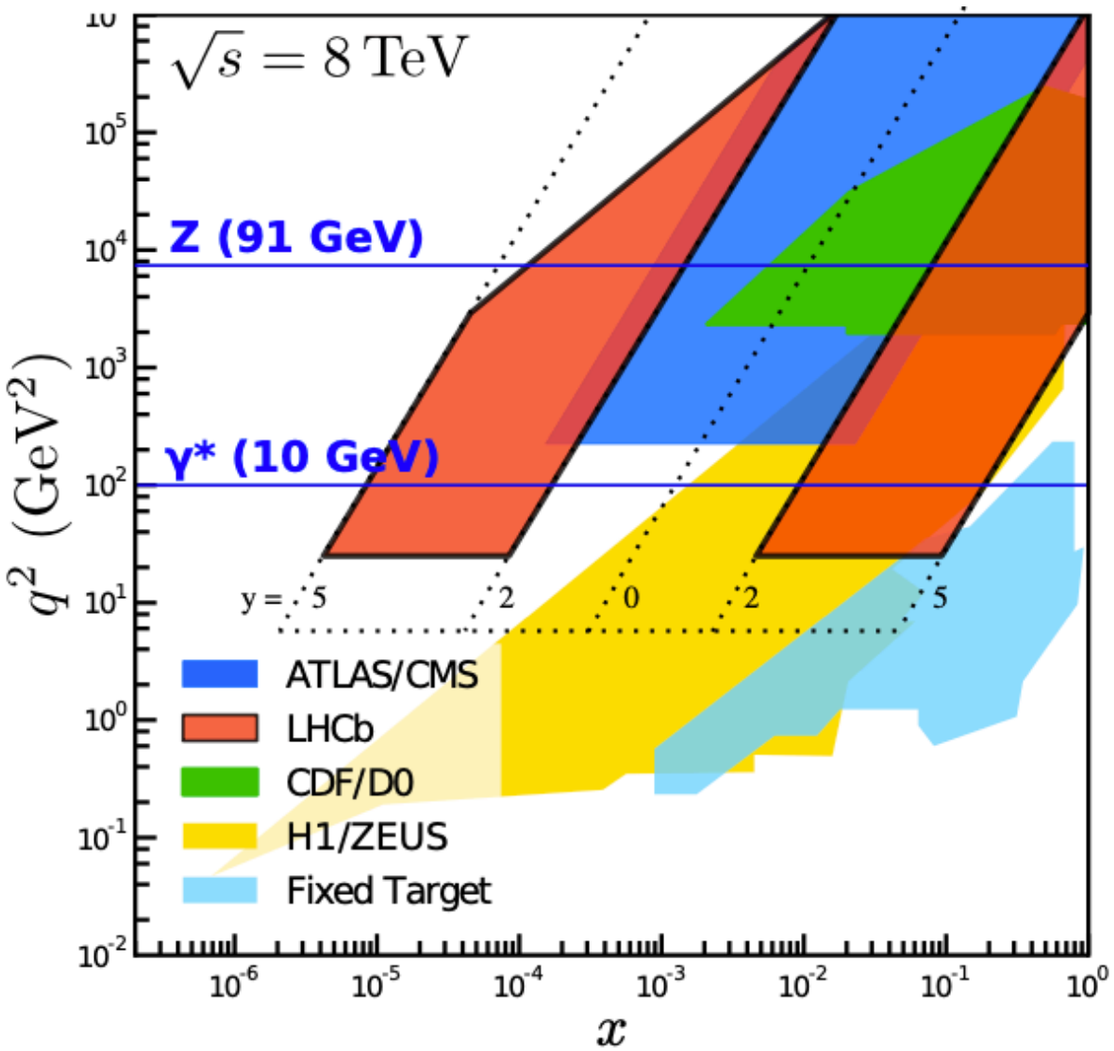
Study of dilepton production with LHCb

Drell-Yan production at low dimuon mass and forward rapidity:

- **pp**: probe the proton PDF at small Bjorken-*x*
- **pPb**: probe the gluon nPDF at small Bjorken-*x* (gluon saturation) and reference for nuclear modification in HF measurements
- **Fixed target**: probe high Bjorken-*x* region



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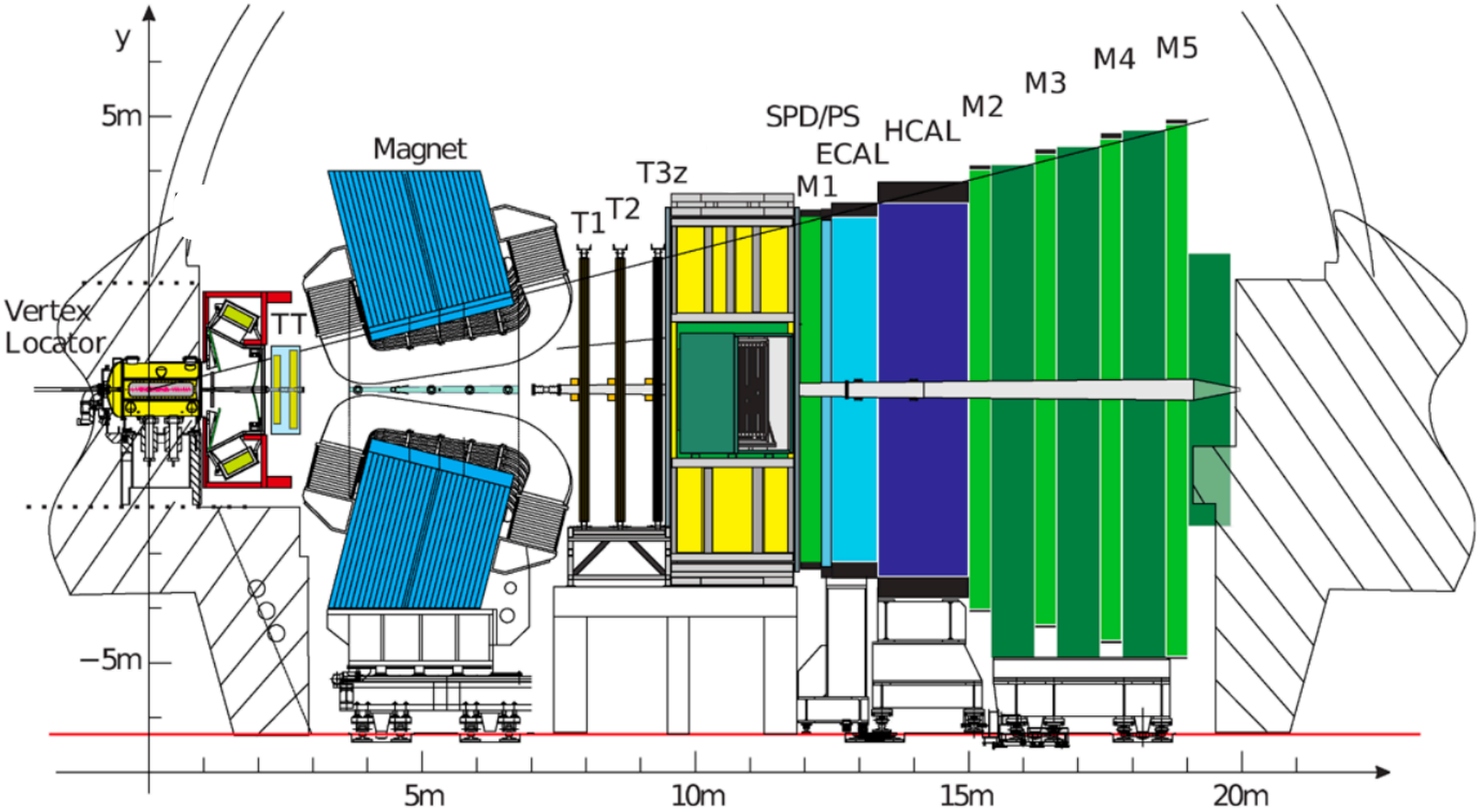
Dimuon measurement with LHCb

LHCb = forward spectrometer (unique configuration at LHC): $2 < \eta < 5$



- VErtex LOcator (VELO): PV position, secondary vertex (HF background rejection)
- Tracking system: TT (upstream) + 3 Tracking stations (downstream)
- Muon system: 5 muon stations for muon identification

Low mass DY in pp collisions at 7 TeV

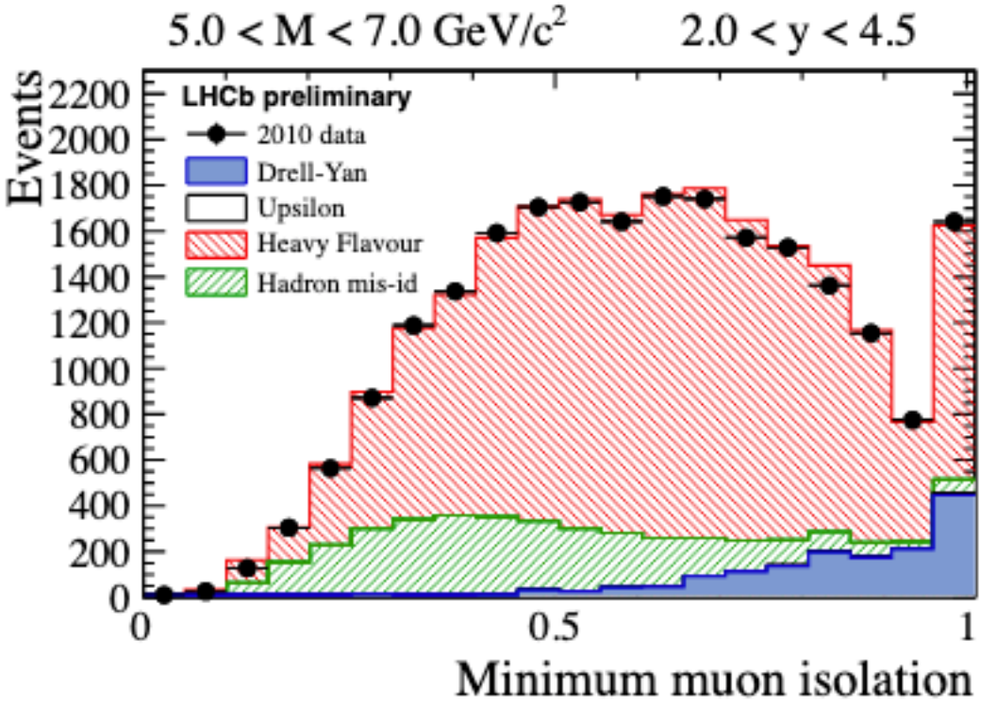
- **Data sample**: recorded in 2010 (LHC Run 1) pp collisions at 7 TeV: 37 pb^{-1}

- **Muon reconstruction and ID**:
  - Dimuon trigger with $p_T^{\mu} > 2.5$ GeV/c
  - Matching VELO tracks with hits in the tracking stations
  - Muon identification using informations from all systems

- **Selection of DY candidates ($5 \leq M_{\mu\mu} \leq 120$ GeV/c^2)**:
  - Muon tracks with $p > 10$ GeV/c, $p_T > 3$ GeV/c and $2 \leq \eta \leq 4.5$
  - For $M_{\mu\mu} > 40$ GeV/c^2: $p_T > 15$ GeV/c
  - Z, ϒ, J/ψ and J/ψK control samples to check data/MC agreement and for efficiency studies

- **Background sources**:
  - HF semileptonic decays
  - Pions and Kaons misidentification
  - ϒ decays (below 10 GeV/c^2)
  - $\gamma^*/Z \rightarrow \tau\tau$ (when both τ decay to muons)

- **DY signal yield extracted from template fits**



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Low mass DY in pp collisions at 7 TeV

Predictions:
- LO PYTHIA 6.4
- NLO FEWZ ($M_{\mu\mu} > 7$ GeV/c^2)
- NLO DYNNLO ($M_{\mu\mu} > 12.5$ GeV/c^2)

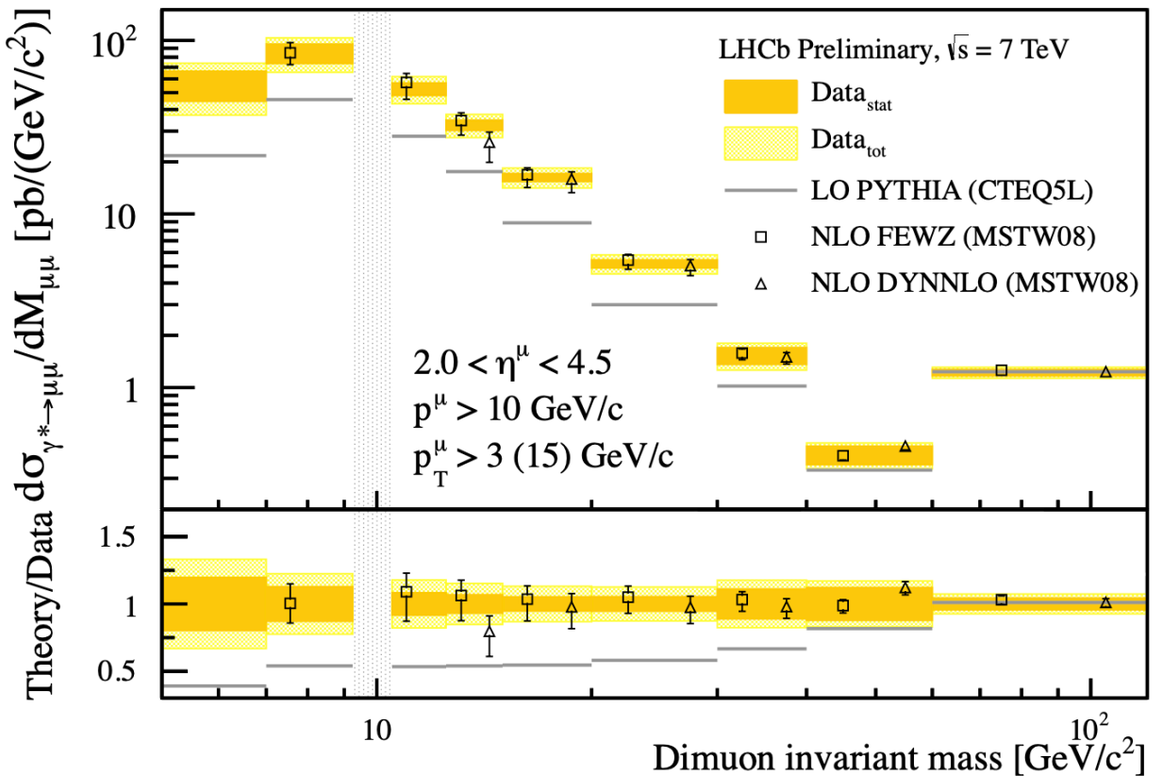
PDF sets:
- CTEQXX
- MSTW08
- NNPDF

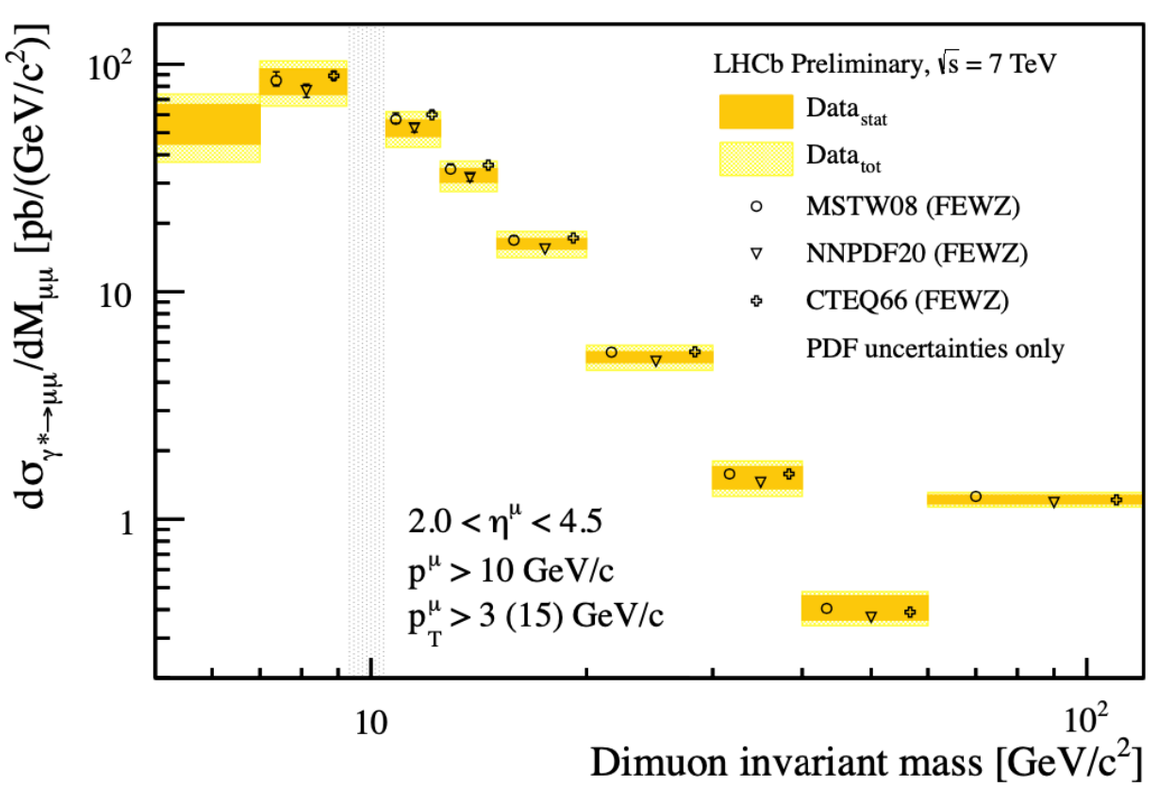
- Good agreement between the measured DY cross-section and NLO predictions (FEWZ with 3 different sets of PDFs)

- Data underestimated by PYHTIA (reasonable agreement in shape)

- Only a small part of LHCb luminosity now available (~1fb^{-1} for 2011)

➡ Significant reduction of the uncertainties could be achieved at low mass with much larger control samples for template fits (dominant source of uncertainty: ~24% in the lowest mass interval)





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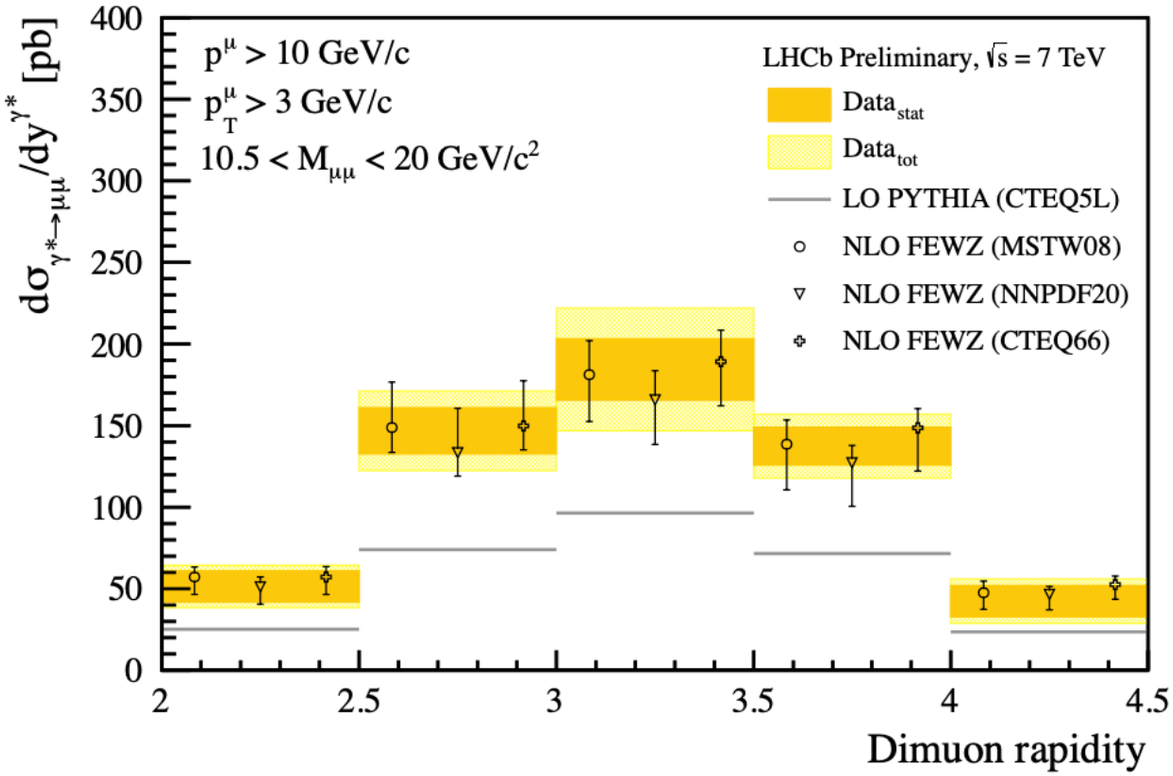
Low mass DY in pp collisions at 7 TeV vs rapidity

Predictions:

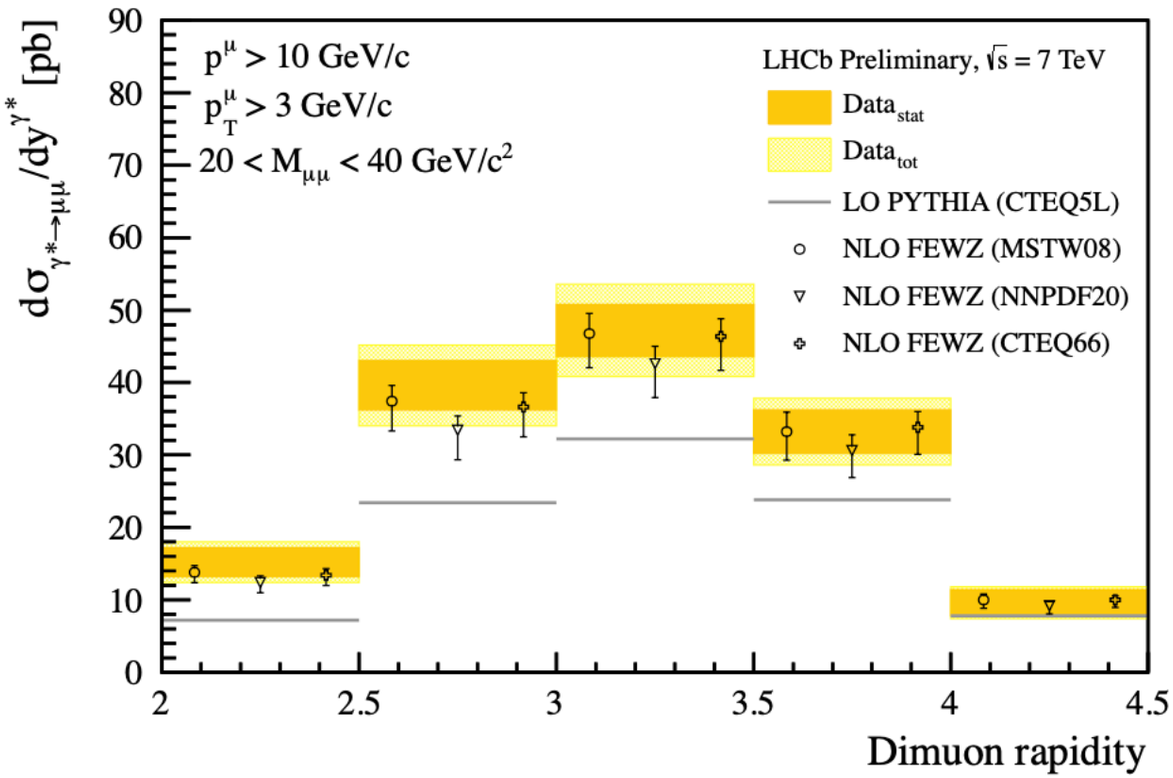
- LO PYTHIA 6.4
- NLO FEWZ ($M_{\mu\mu} > 7$ GeV/c^2)
- NLO DYNNLO ($M_{\mu\mu} > 12.5$ GeV/c^2)

PDF sets:

- CTEQXX
- MSTW08
- NNPDF



- Good agreement between the measured cross section and FEWZ predictions vs rapidity
- Data underestimated by PYHTIA (reasonable agreement in shape)



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Projections for DY in pPb at LHC Run 3 and 4

- Preliminary study in pp at 7 TeV used as a model for the projection study (similar analysis principle)

- **Assumptions on Run 3 and 4 data samples:**
  - Collisions at $\sqrt{s_{\mathrm{NN}}} = 8.8$ TeV
  - Integrated luminosity for pPb data sample: 500 nb^{-1}
  - Integrated luminosity for pp data sample: 104 pb^{-1}

- **pPb sample divided in rapidity bins with at least 1000 Z→μμ decays (as many as Run 1 pp measurement)**
  - pPb forward: 2000 Z in $1.5 < y^* < 2.5$, 1600 in $2.5 < y^* < 3.0$ and 1000 in $3.0 < y^* < 4.5$
  - pPb backward: 1000 Z in $-3.2 < y^* < -2.5$ and 1000 in $-5.0 < y^* < -3.2$

- Same sources of systematic uncertainties considered as in Run 1 measurement

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Projections for DY in pPb at Run 3 and 4

- nPDF predictions from EPPS16 at NLO
- Systematic and statistical uncertainties of similar size in low and high (Z) mass regions
- Statistical limitation in intermediate mass region
- Forward (low mass): clear suppression expected due to shadowing effect at low *x*
- Backward: more complex structure expected due to EMC effect
- Uncertainty from control samples dominant at low mass (template fit for signal extraction)

➡ Could be improved with a large sample in pp

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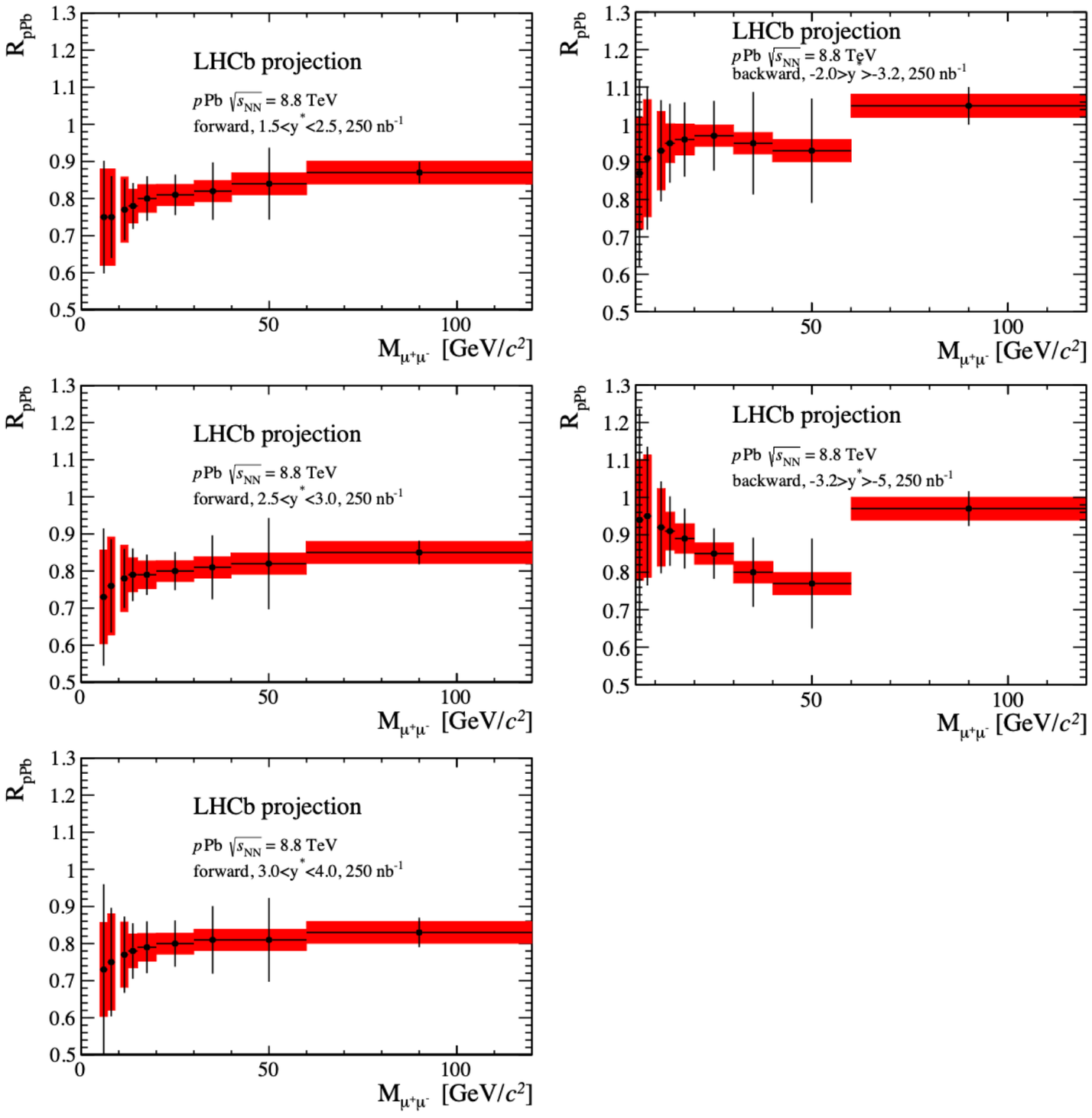
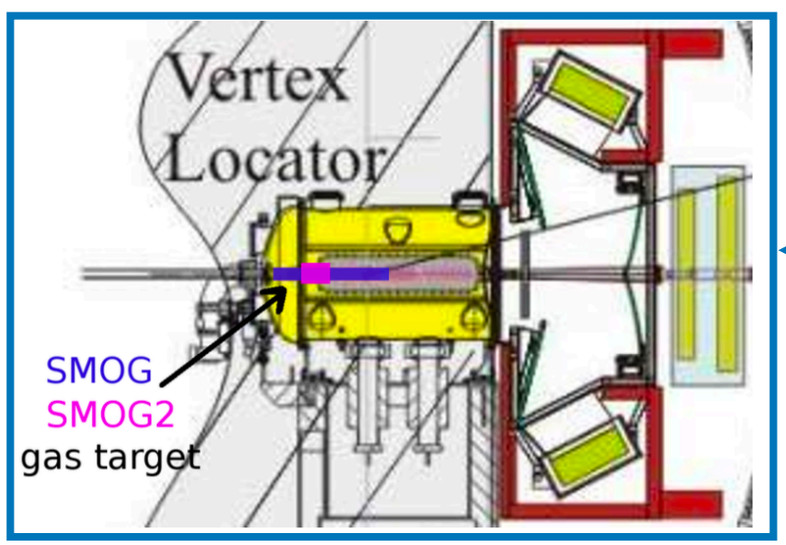
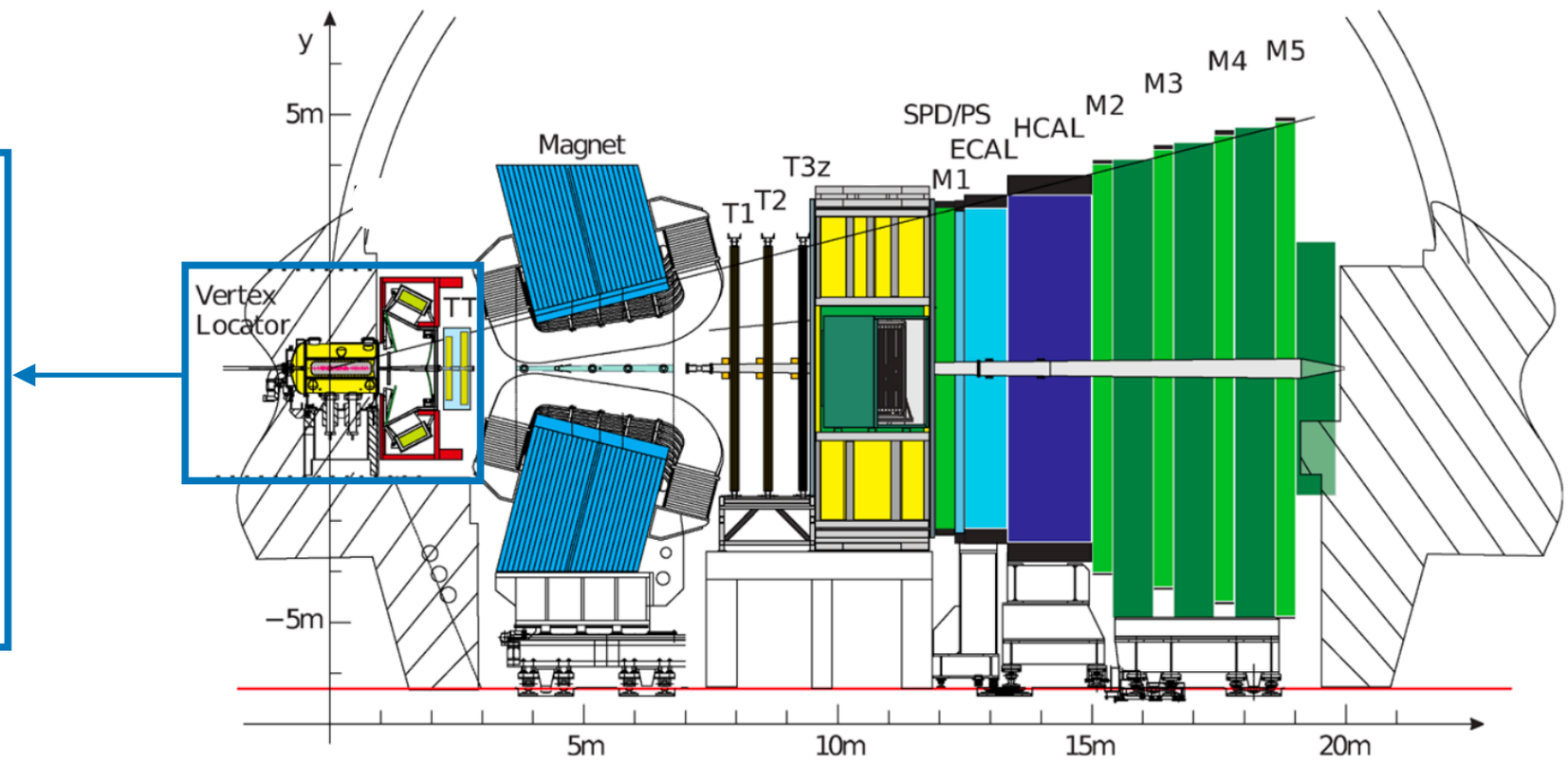
Forward | **Backward**



Physics opportunities with the fixed-target program





- **SMOG** (upgraded to SMOG2 for LHC Run 3): fixed target by injection of gas into the LHC beam pipe
- Collision energy up to 115 GeV in the nucleon-nucleon c.m. frame

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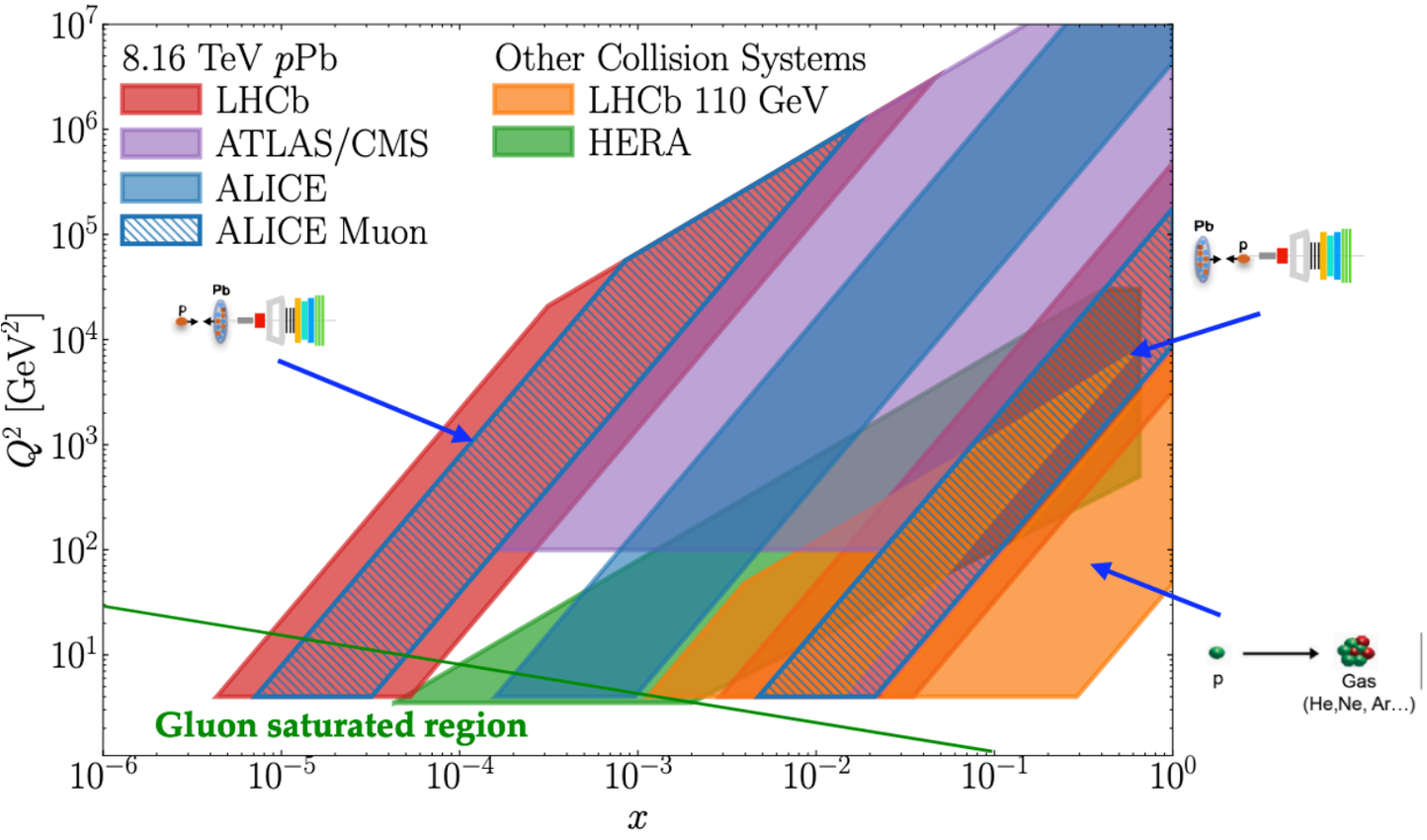
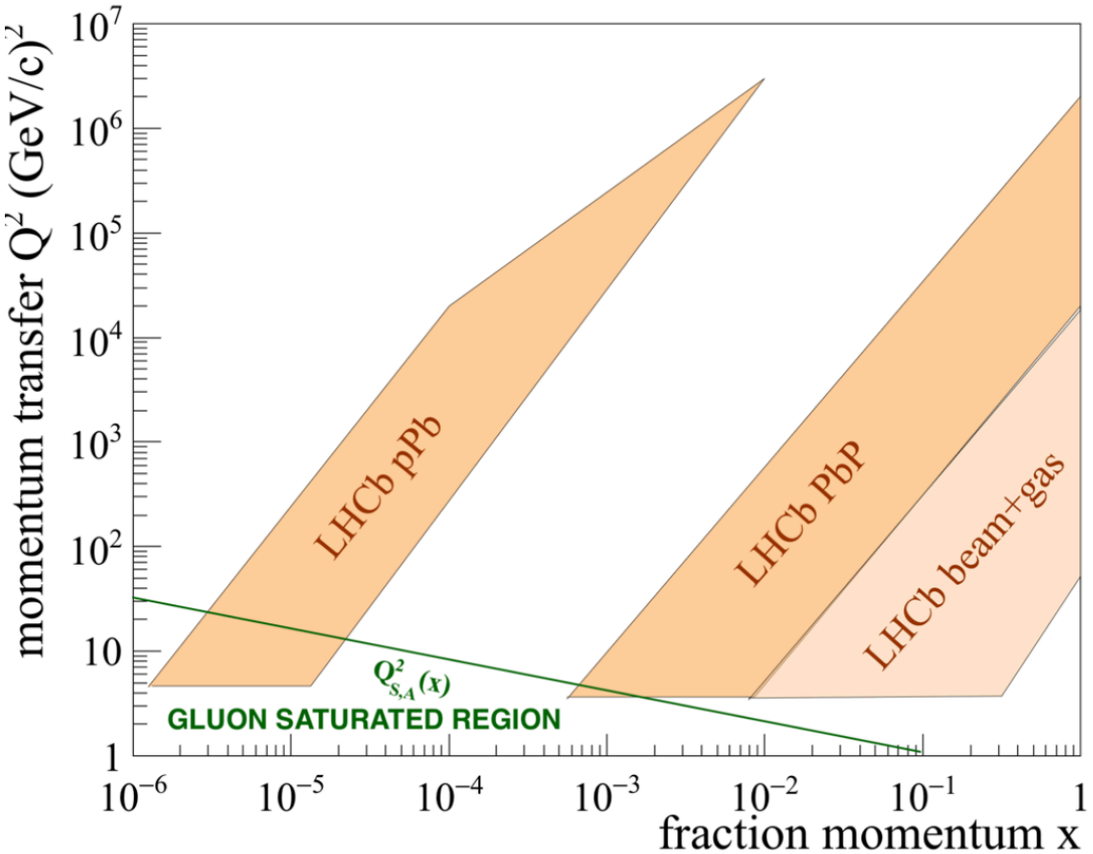
Physics opportunities with the fixed-target program





- LHCb SMOG: unique access to the large-x region at the LHC

B. Audurier 31/05/2021

Physics opportunities with the fixed-target program

	SMOG published result pHe@87 GeV	SMOG largest sample pNe@69 GeV	SMOG2 example pAr@115 GeV
Integrated luminosity	7.6 nb^{-1}	$\sim$ 100 nb^{-1}	$\sim$ 45 pb^{-1}
syst. error on J/ψ x-sec.	7%	6 - 7%	2 - 3 %
J/ψ yield	400	15k	15M
D^0 yield	2000	100k	150M
Λ_c^+ yield	20	1k	1.5M
$\psi(2S)$ yield	negl.	150	150k
$\Upsilon(1S)$ yield	negl.	4	7k
Low-mass Drell-Yan yield	negl.	5	9k

SMOG2 upgrade:

- Increase of target density (luminosity) by up to 2 orders of magnitude
- Possibility to inject more gas species
- Possibility to run in parallel of pp collisions

➡ Constraints on gluon nPDF at high-x expected at the end of Run 3

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Prospects on intermediate mass dileptons

- High luminosity LHC ~2031 (Run 5): increase of instantaneous luminosity by a factor ~50

- Upgrade phase II of the LHCb detector to allow measurements in HL-LHC heavy-ion conditions

- High performance of the VELO on background rejection + capacity of LHCb to measure low p_T muon tracks

➡ **Measurements of intermediate mass dileptons in heavy-ion collisions accessible to LHCb?**

➡ See Talk of M. Coquet: « Intermediate mass dileptons as pre-equilibrium probes in heavy-ion collisions »

Summary and conclusions

- The LHCb detector offers unique capacities for dilepton measurements at LHC in the forward region

- Low mass DY production measured in pp at 7 TeV (low luminosity)

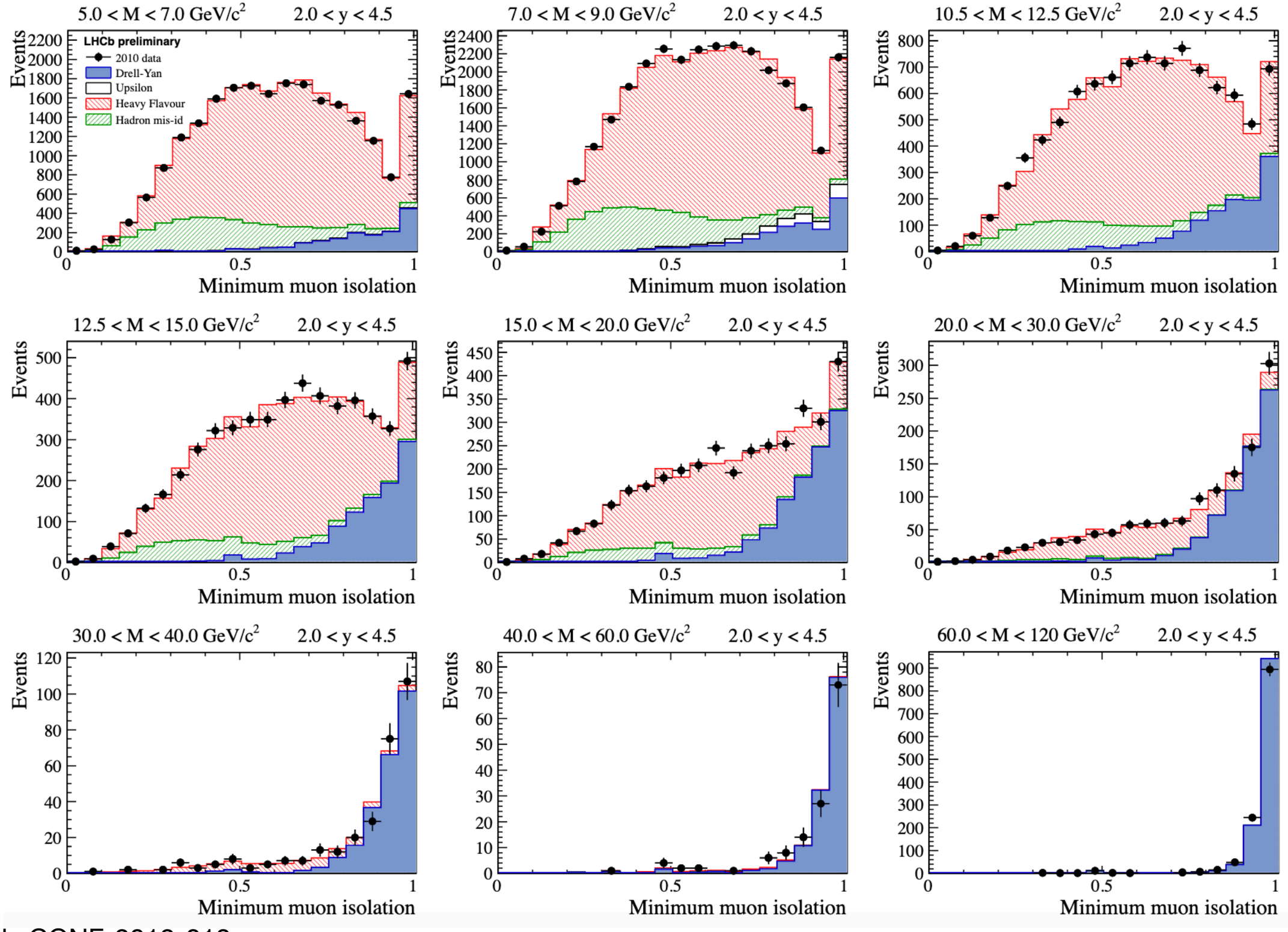
- Projections for DY in pPb at LHC Run 3 and Run 4

- Precise measurements in high-x region at Run 3 with SMOG2

- Feasibility study on « Intermediate mass dileptons as pre-equilibrium probes in heavy-ion collisions »: Talk of M. Coquet

Thank you!

Template fit for DY yield extraction (mass bins)



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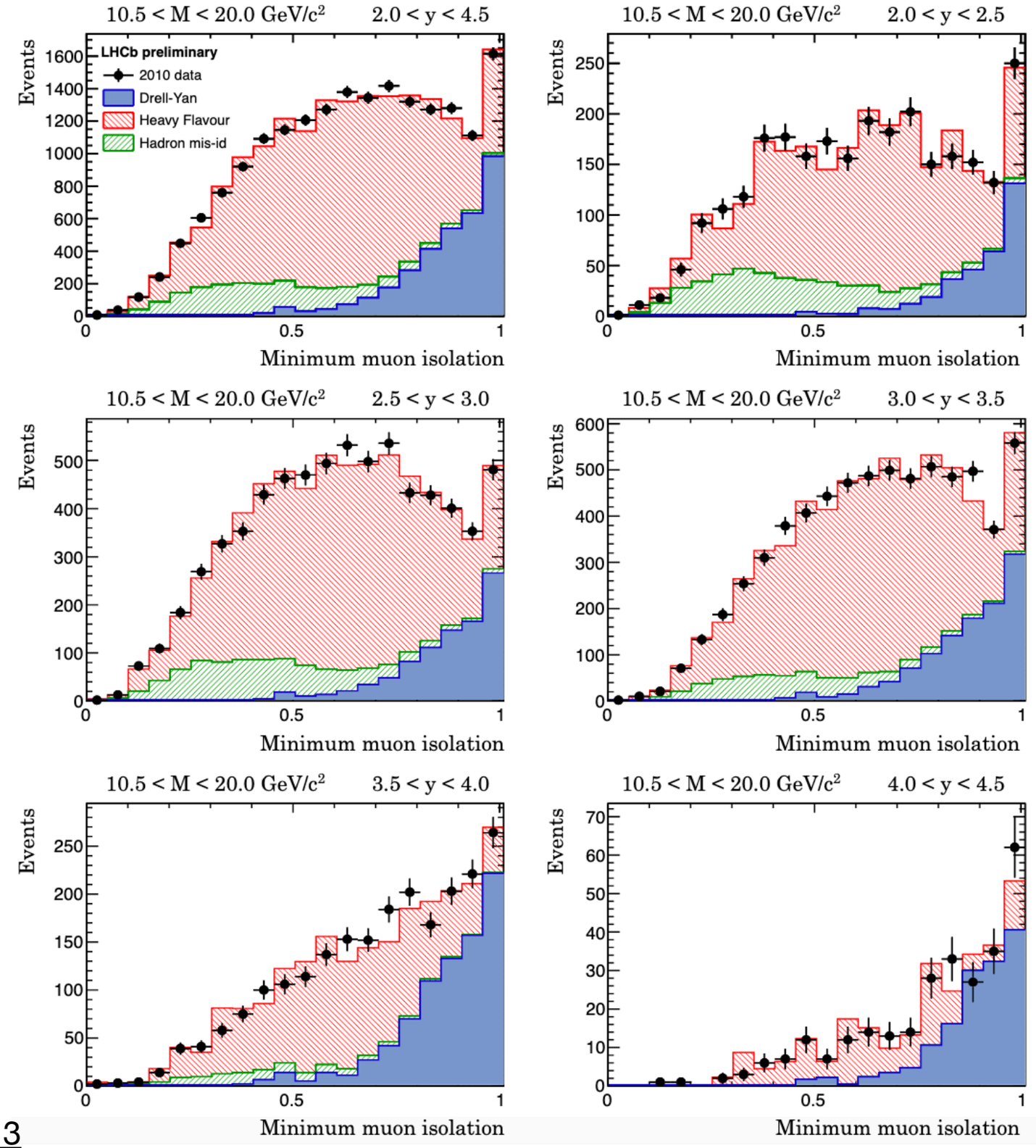
Template fit for DY yield extraction (rapidity bins)



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