W/Z and direct photon production at the LHC

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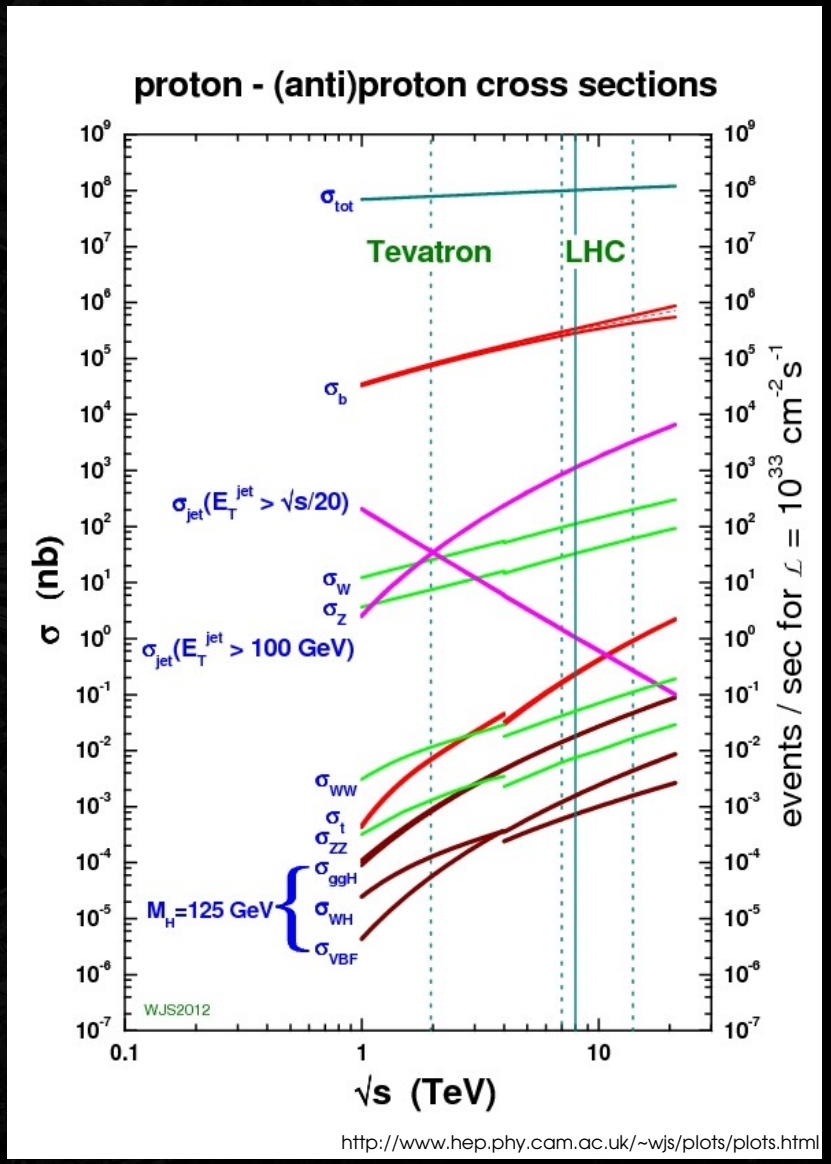
Outline

- The study of the electroweak gauge bosons at LHC is producing a very rich harvest of results. This talk will show a selection of results focusing on the most recent ones on full datasets:
  - overview and experimental apparatuses;
  - inclusive W/Z production cross-sections and Z transverse momentum at 8 TeV;
  - inclusive and differential W/Z production cross-sections at 7 TeV;
  - lepton charge asymmetry in W production;
  - prompt photon and diphoton production;
  - summary.

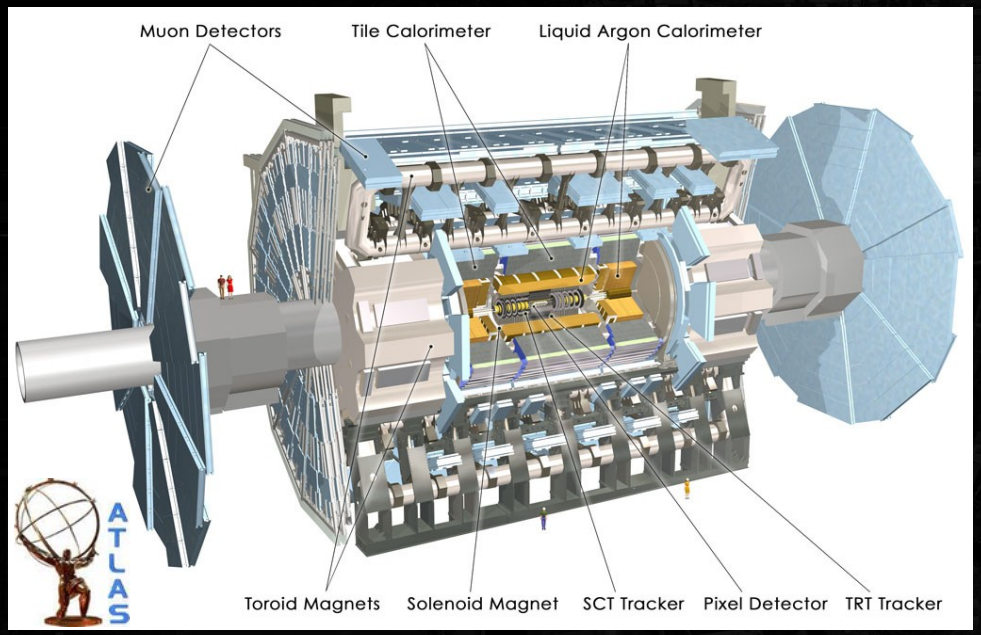
Overview

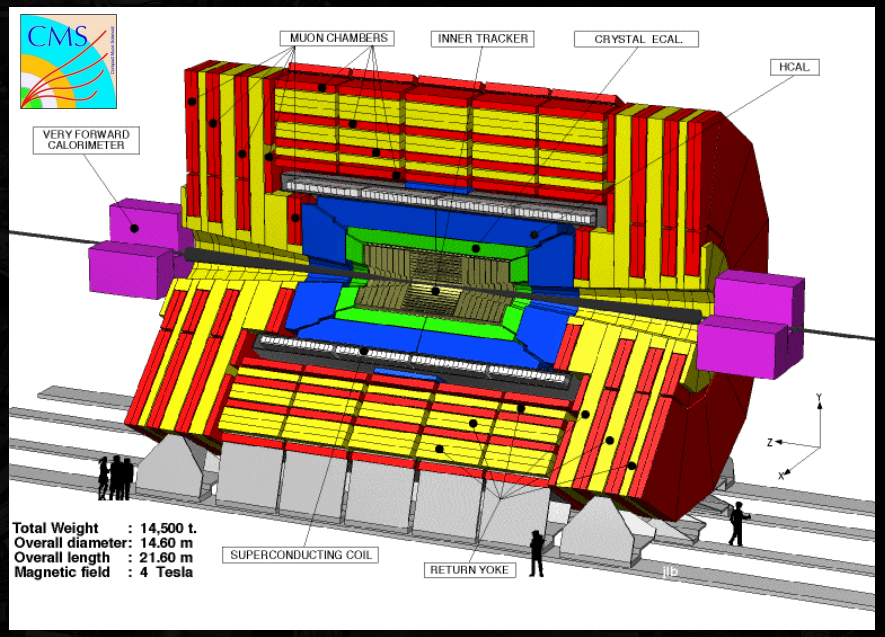
- The direct production of electroweak gauge bosons in pp collisions provides a colorless probe of the hard scattering process.
- Theory:
  - W/Z production known at NNLO in perturbative QCD.
- Experiment:
  - at LHC among the most abundant processes;
  - leptonic decays provide clean signatures;
  - challenge: precision measurements dominated by systematics.
- Theory/experiment comparison allows to perform stringent pQCD tests, to constrain and explore the proton PDFs in previously not-accessible kinematic regions.



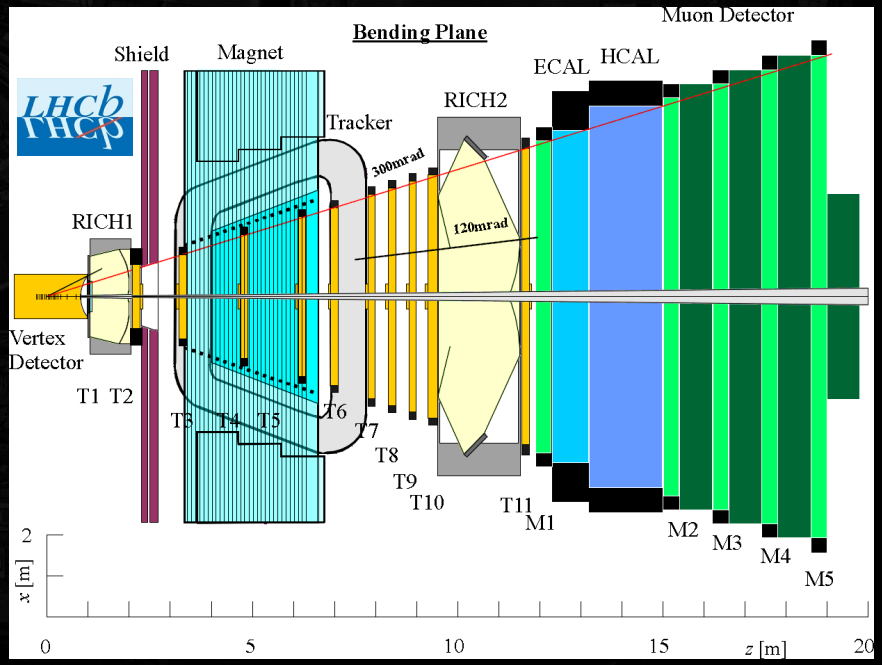
http://www.hep.phy.cam.ac.uk/~wjs/plots/plots.html

The experimental apparatuses



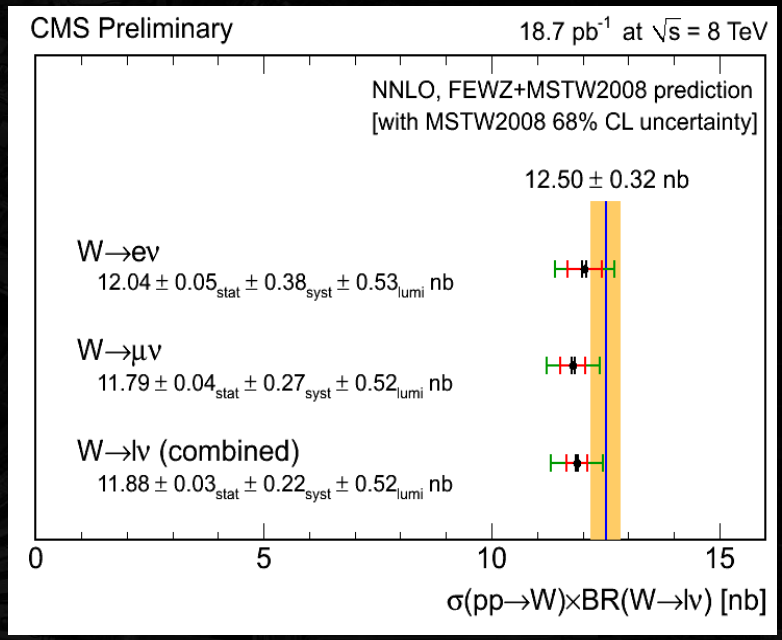


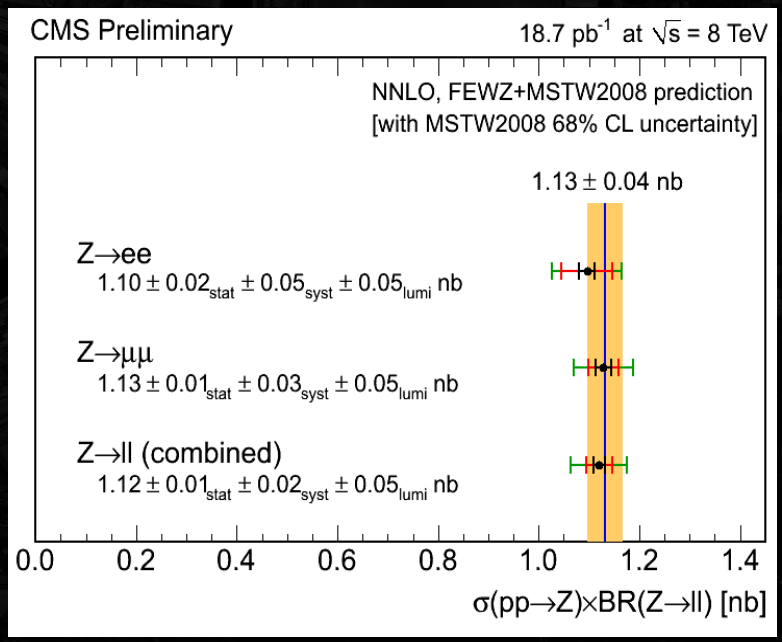
- General purpose detectors:
  - vertex detector and tracker,
  - electromagnetic and hadronic calorimetry,
  - muon detectors.
- ATLAS and CMS central detectors.
- LHCb instrumented within $2 < \eta < 5$.

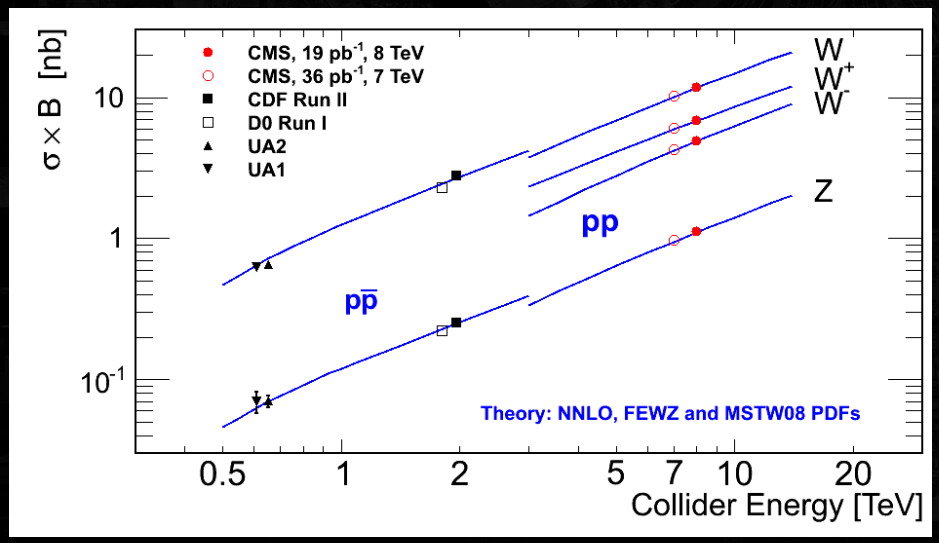


W/Z inclusive production @ 8 TeV

- Special 8 TeV low-pileup dataset (18.7 pb^{-1});
- $W \to \ell\nu$ and $Z/\gamma^* \to \ell\ell$ channels:
  - electrons: $E_T(e) > 25$ GeV/c, $|\eta(e)| < 1.44$ or $1.57 < |\eta(e)| < 2.5$;
  - muons: $p_T(\mu) > 25$ (20 for Z's) GeV/c, $|\eta(\mu)| < 2.1$;
  - $60 < M_{\ell\ell} < 120$ GeV/c^2.



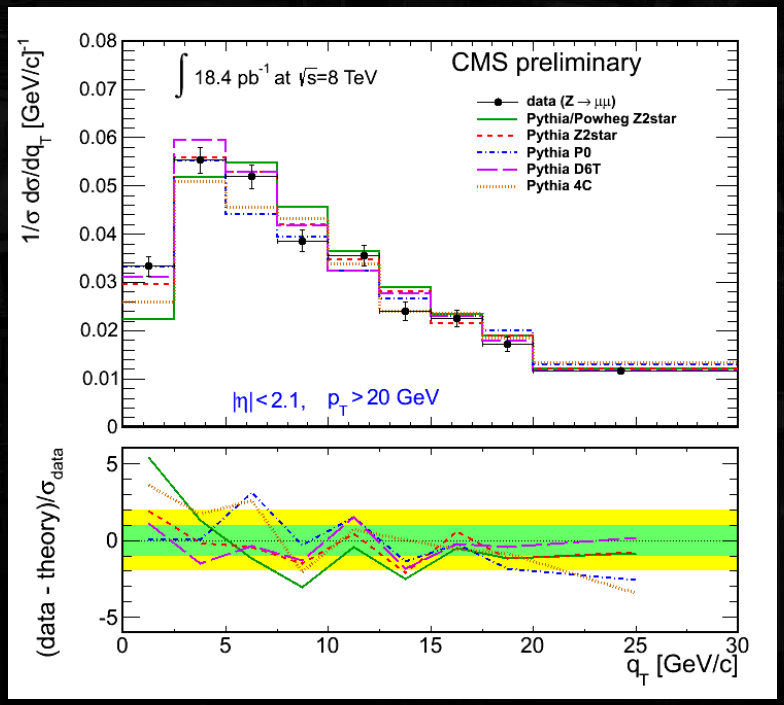


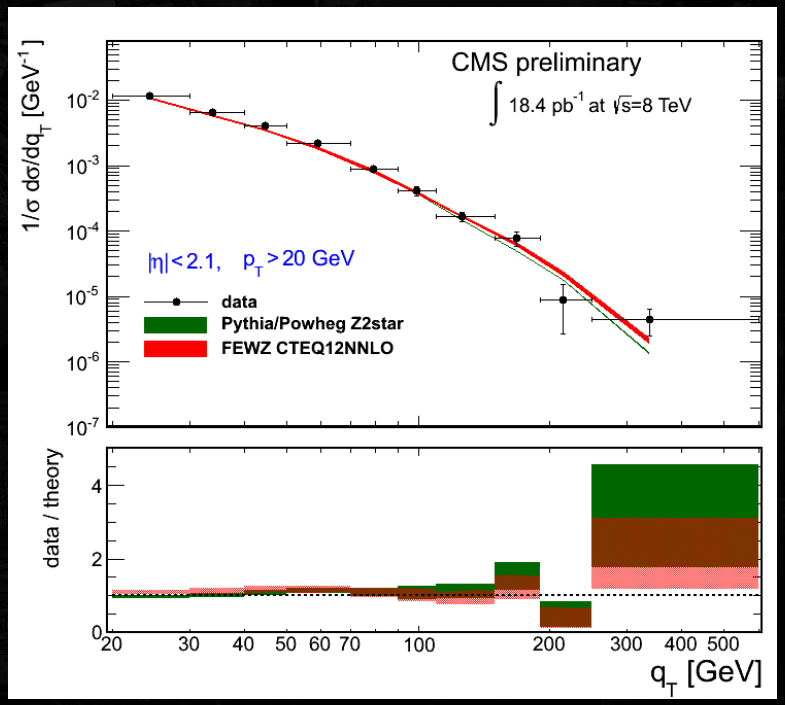


CMS-PAS-SMP-12-011

Z boson transverse momentum @ 8 TeV

- Special 8 TeV low-pileup dataset (18.4 pb^{-1});
- $Z/\gamma^* \rightarrow \mu\mu$ channel with:
  - $p_T(\mu) > 20$ GeV/c and $|\eta(\mu)| < 2.1$;
  - $60 < M_{\mu\mu} < 120$ GeV/c^2;
- low-q_T region tests non-perturbative soft gluon emission;
- high-q_T region probes pQCD hard gluon radiation in initial state.



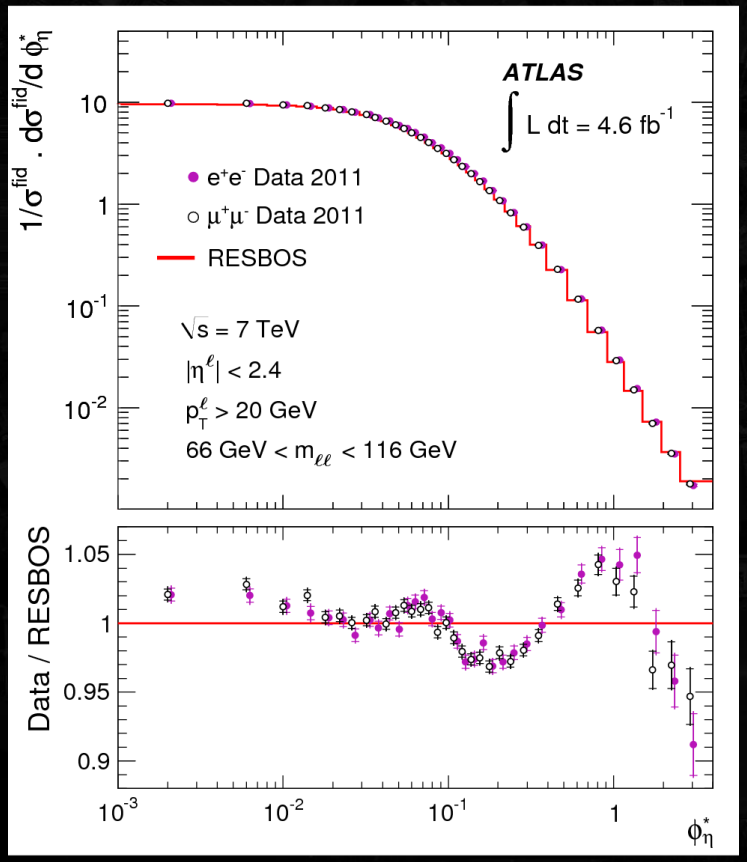


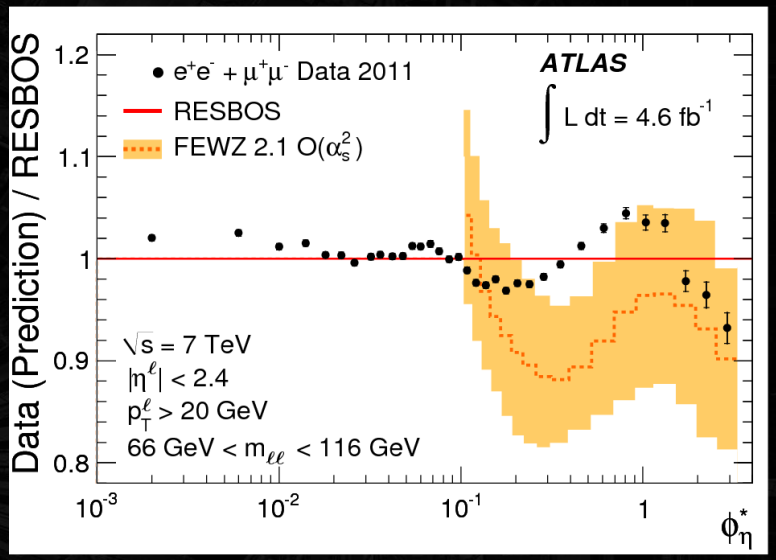
CMS-PAS-SMP-13-003

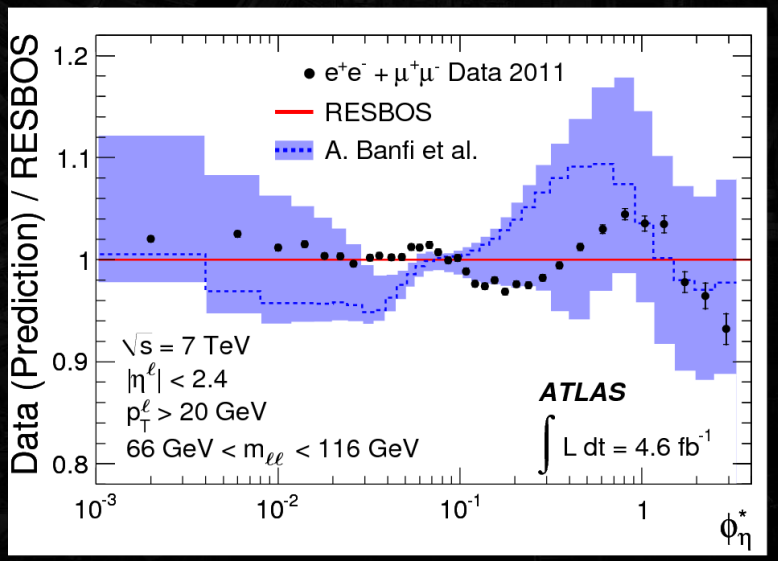
Drell-Yan leptons ϕ^* distribution

- Full 7 TeV dataset (4.6 fb^{-1});
- $Z/\gamma^* \rightarrow ee$, $\mu\mu$ channels:
  - $p_T(\ell) > 20$ GeV/c and $|\eta(\ell)| < 2.4$;
  - $66 < M_{\ell\ell} < 116$ GeV/c^2.

$$\phi^*_\eta = \frac{\tan[(\pi - \Delta\phi)/2]}{\cosh(\Delta\eta/2)} \approx \frac{P_T^Z}{M_{\ell\ell}}$$



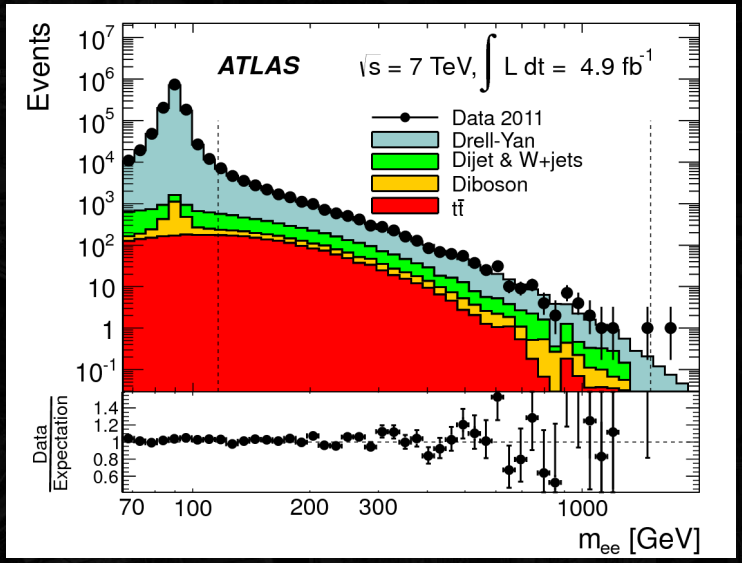


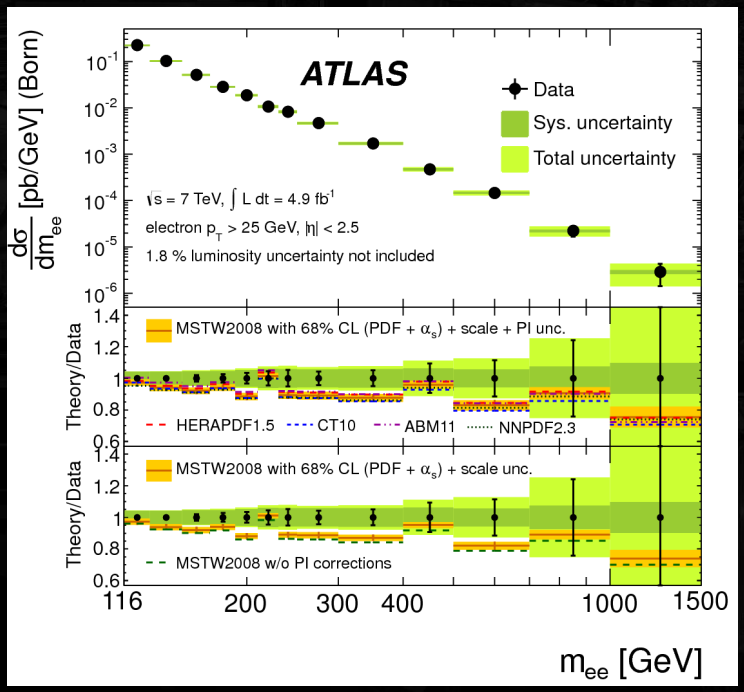


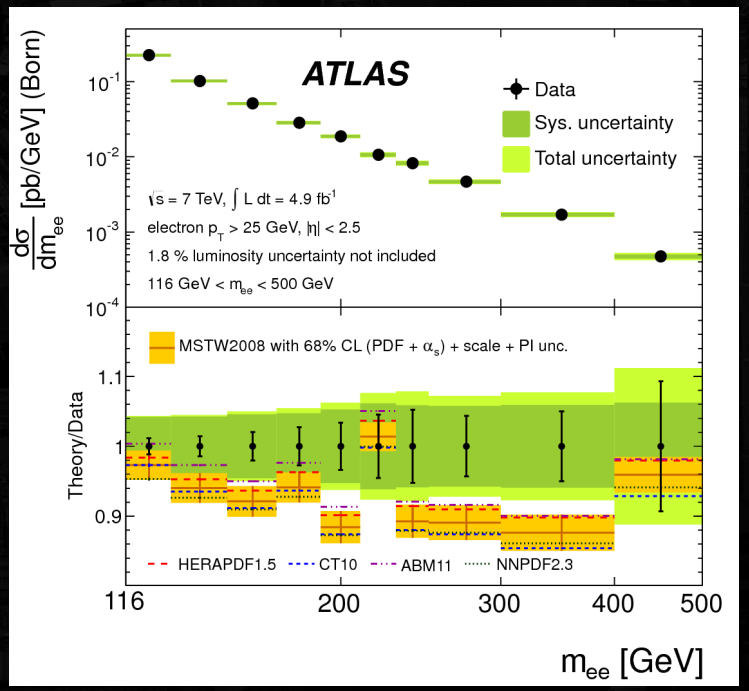
arXiv:1211.6899v2

High-mass DY differential cross-section

- Full 7 TeV dataset (4.9 fb^{-1});
- $Z/\gamma^* \rightarrow ee$ channel:
  - $p_T(e) > 25$ GeV/c, $|\eta(e)| < 2.5$;
  - $116 < M_{ee} < 1500$ GeV/c^2.



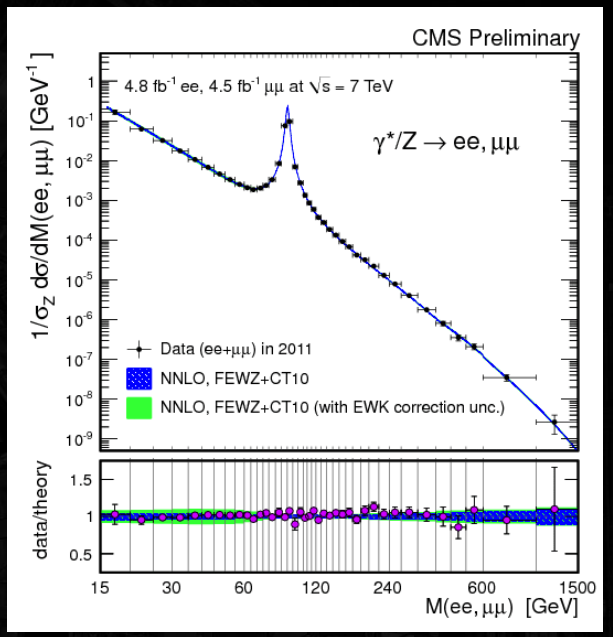


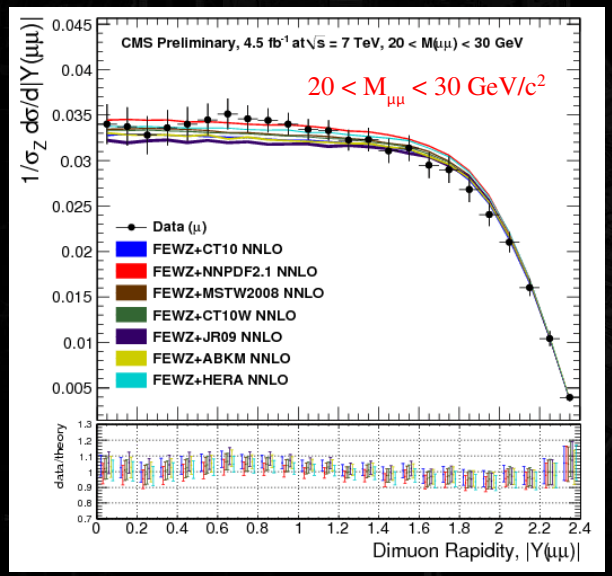


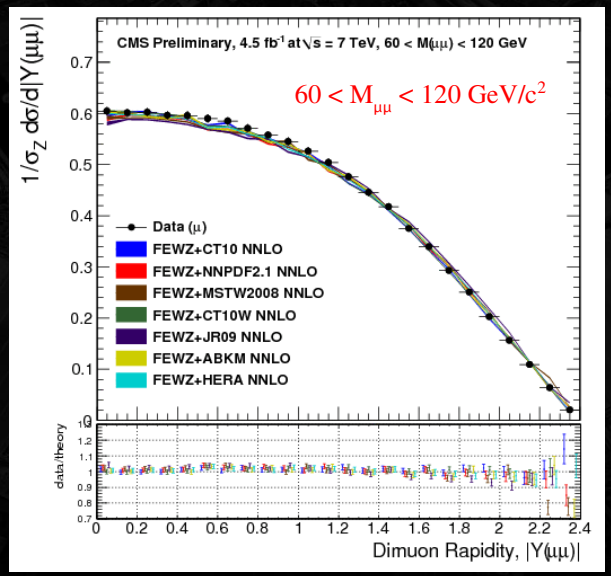
arXiv:1305.4192

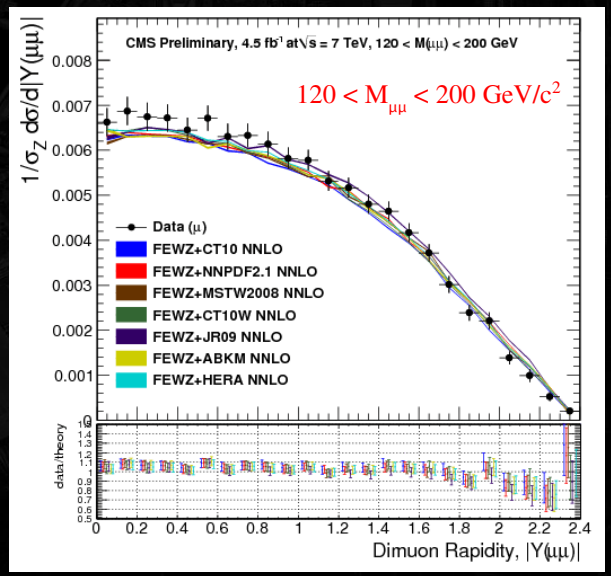
Drell-Yan differential cross-section

- Full 7 TeV dataset;
- $Z/\gamma^* \rightarrow \mu\mu$ channel (4.5 fb^{-1}):
  - $p_T(\mu_1) > 14$ GeV/c, $p_T(\mu_2) > 9$ GeV/c, $|\eta(\mu_{1,2})| < 2.4$;
  - $15 < M_{\mu\mu} < 1500$ GeV/c^2.
- $Z/\gamma^* \rightarrow ee$ channel (4.8 fb^{-1}):
  - $p_T(e_1) > 20$ GeV/c, $p_T(e_2) > 10$ GeV/c, $|\eta(e_{1,2})| < 2.5$;
  - $15 < M_{ee} < 1500$ GeV/c^2.





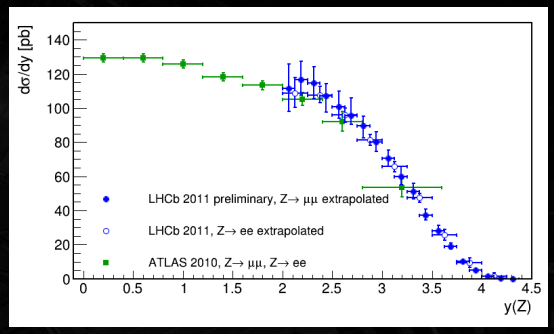


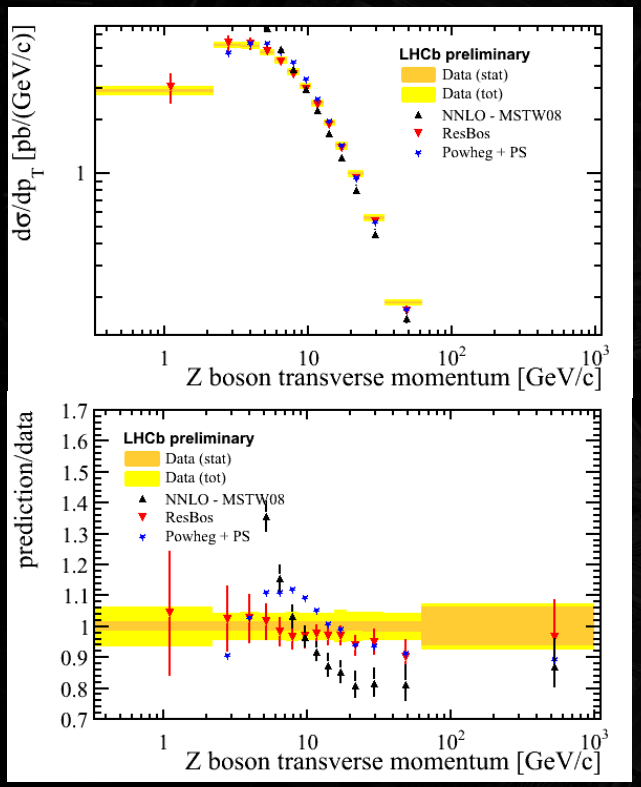


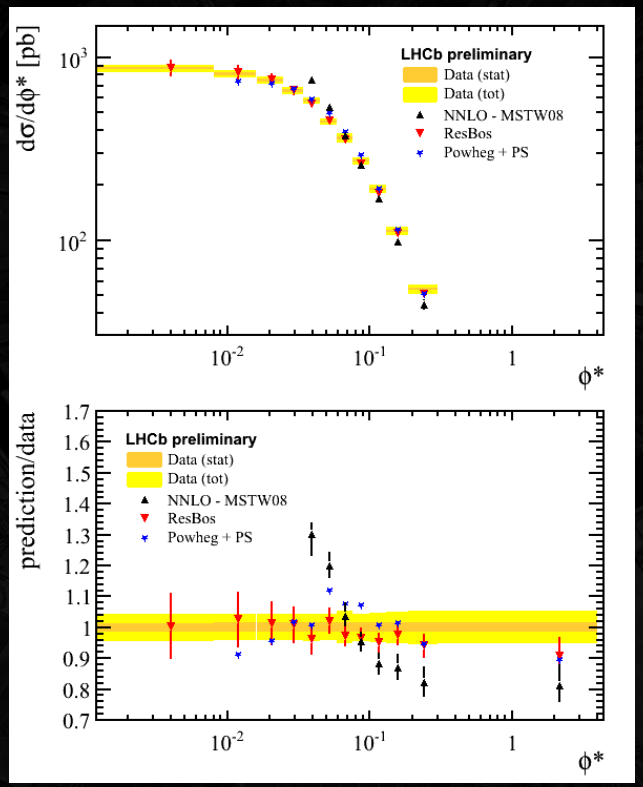
CMS-PAS-SMP-13-003

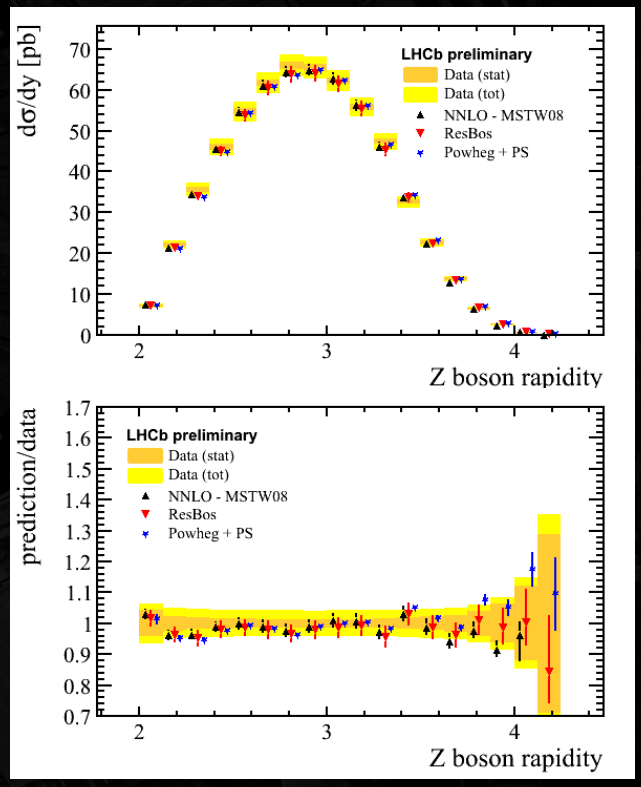
Z differential production cross-section

- 7 TeV dataset (1 fb^{-1});
- $Z/\gamma^* \rightarrow \mu\mu$ channel with:
  - $p_T(\mu) > 20$ GeV/c,
    $2 < \eta(\mu) < 4.5$;
  - $60 < M_{\mu\mu} < 120$ GeV/c^2.









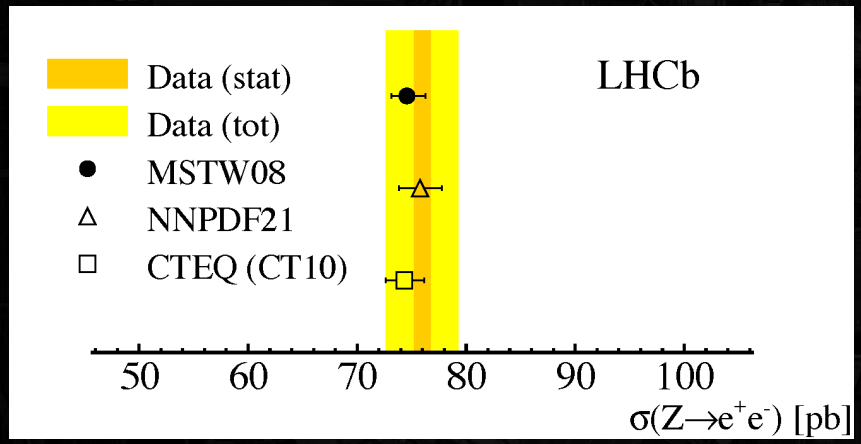
$$\sigma_{pp\rightarrow Z\rightarrow\mu\mu} = 75.4 \pm 0.3_{stat} \pm 1.9_{syst} \pm 2.6_{lumi}\ pb$$

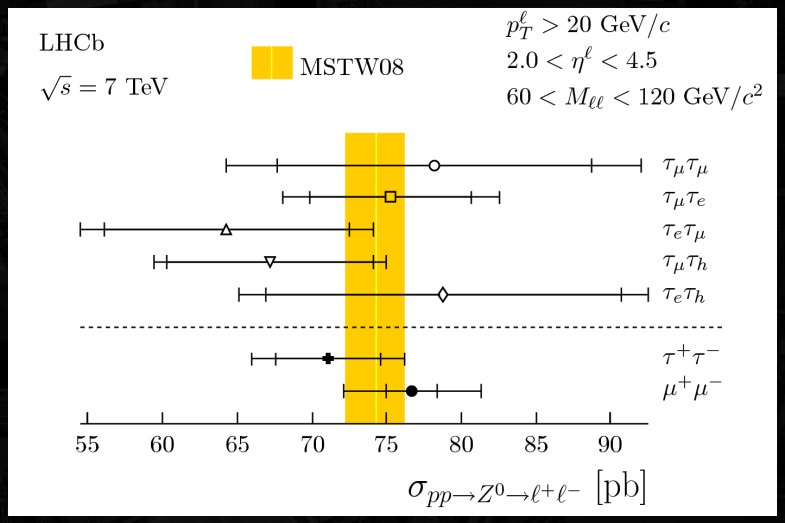
$$\phi^*_\eta = \frac{\tan[(\pi - \Delta\phi)/2]}{\cosh(\Delta\eta/2)} \approx \frac{P_T^Z}{M_{\ell\ell}}$$

LHCb-CONF-2013-007

$Z/\gamma^* \to ee/\tau\tau$ inclusive production

- 7 TeV dataset;
- $Z/\gamma^* \to ee$ channel (0.94 fb^{-1}):
  - $p_T(e) > 20$ GeV/c,
    $2 < \eta(e) < 4.5$;
  - $60 < M_{ee} < 120$ GeV/c^2.
- $Z/\gamma^* \to \tau\tau$ (1 fb^{-1}):
  - $p_T(\tau_1) > 20$ GeV/c, $p_T(\tau_2) > 5$ GeV/c,
    $2 < \eta(e,\mu) < 4.5$, $2.25 < \eta(\tau_h) < 3.75$;
  - $60 < M_{\tau\tau} < 120$ GeV/c^2.





$\sigma_{pp\to Z\to ee} = 76.0 \pm 0.8_{stat} \pm 2.0_{syst} \pm 2.6_{lumi}$ pb

$\sigma_{pp\to Z\to \tau\tau} = 71.4 \pm 3.5_{stat} \pm 2.8_{syst} \pm 2.5_{lumi}$ pb

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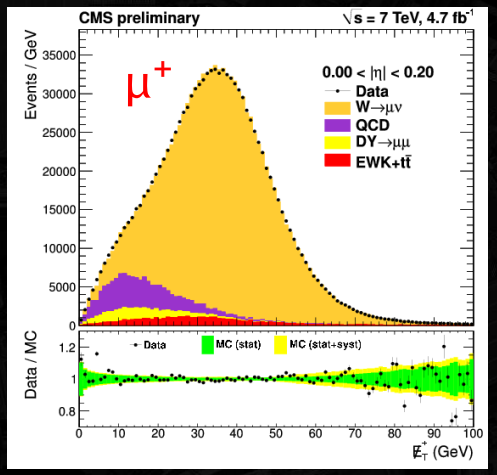
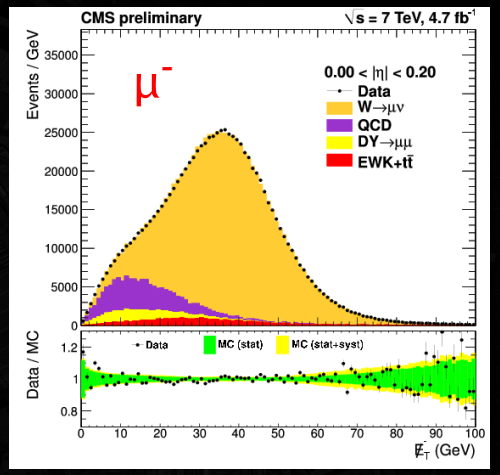
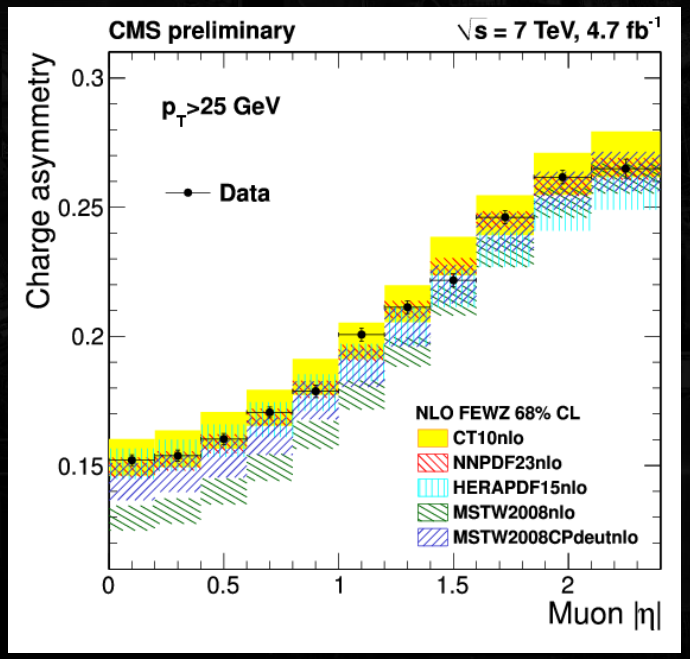
$\mu^{\pm}$ charge asymmetry in W production

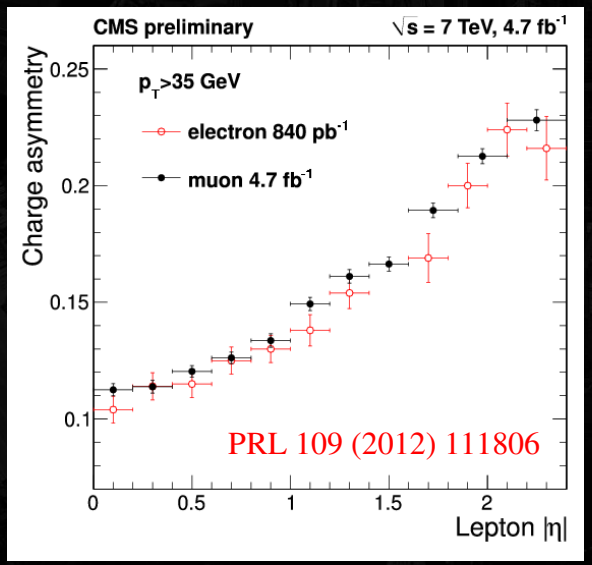
- 7 TeV dataset (4.7 fb^{-1});
- $W \rightarrow \mu\nu$ channel:
  - $p_T(\mu) > 25$ GeV/c, $|\eta(\mu)| < 2.4$;
- lepton charge asymmetry:

$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \rightarrow \ell^+\nu) - \frac{d\sigma}{d\eta}(W^- \rightarrow \ell^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \rightarrow \ell^+\nu) + \frac{d\sigma}{d\eta}(W^- \rightarrow \ell^-\nu)}$$







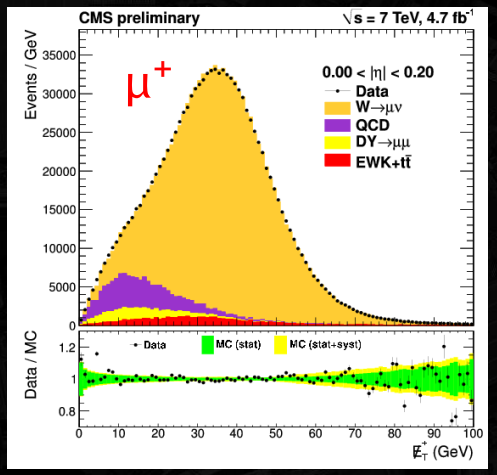


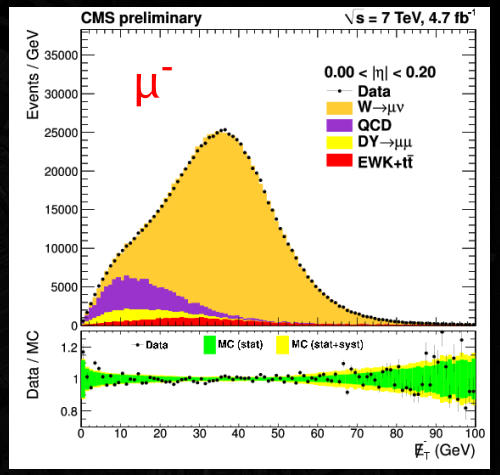
CMS-PAS-SMP-12-021

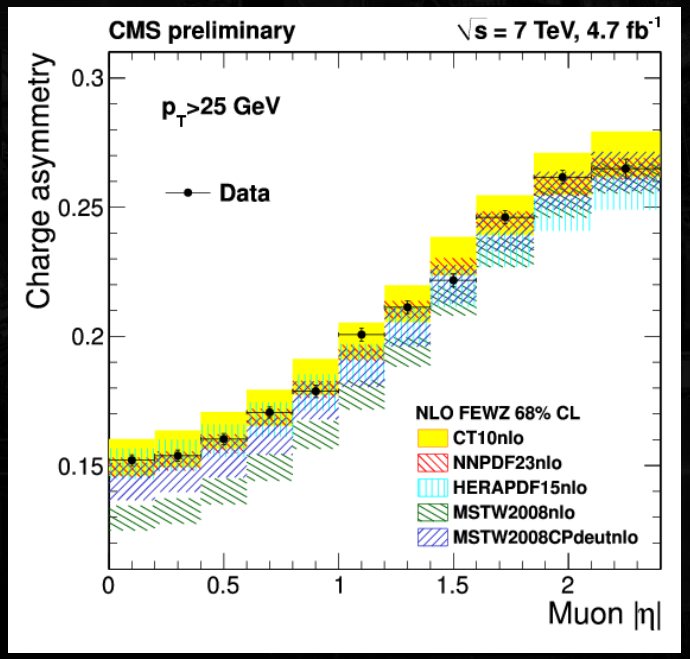
$\mu^{\pm}$ charge asymmetry in W production

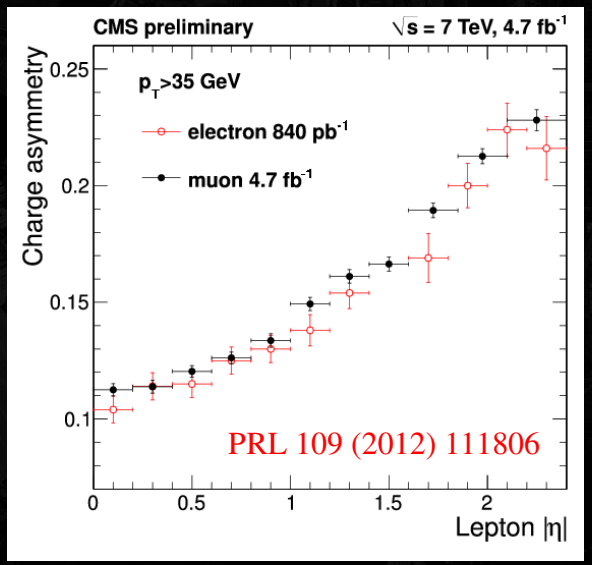
- 7 TeV dataset (4.7 fb^{-1});
- $W \rightarrow \mu\nu$ channel:
  - $p_T(\mu) > 25$ GeV/c, $|\eta(\mu)| < 2.4$;
- lepton charge asymmetry:

$$A(\eta) = \frac{\frac{d\sigma}{d\eta}(W^+ \rightarrow \ell^+\nu) - \frac{d\sigma}{d\eta}(W^- \rightarrow \ell^-\nu)}{\frac{d\sigma}{d\eta}(W^+ \rightarrow \ell^+\nu) + \frac{d\sigma}{d\eta}(W^- \rightarrow \ell^-\nu)}$$





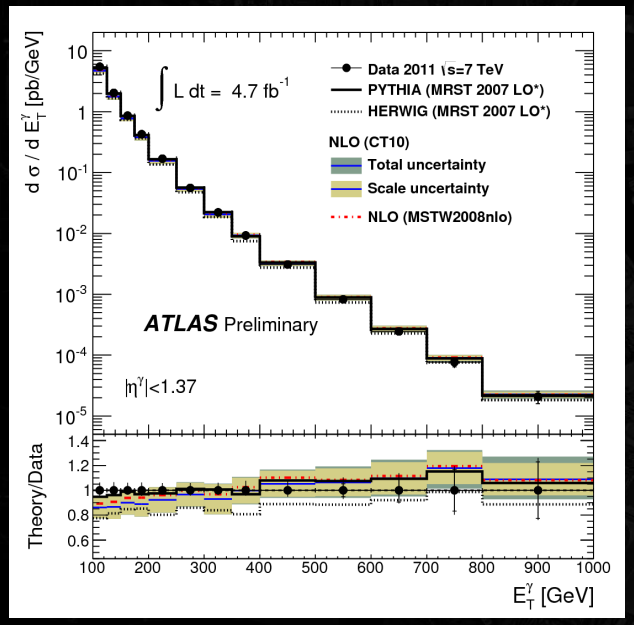


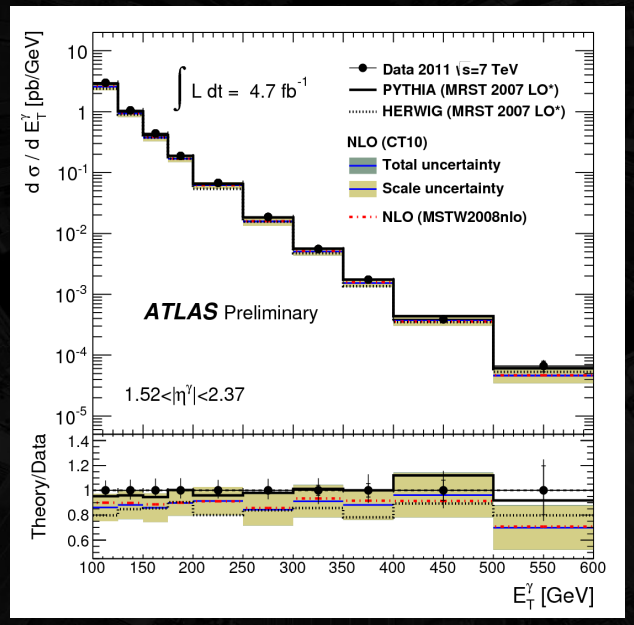


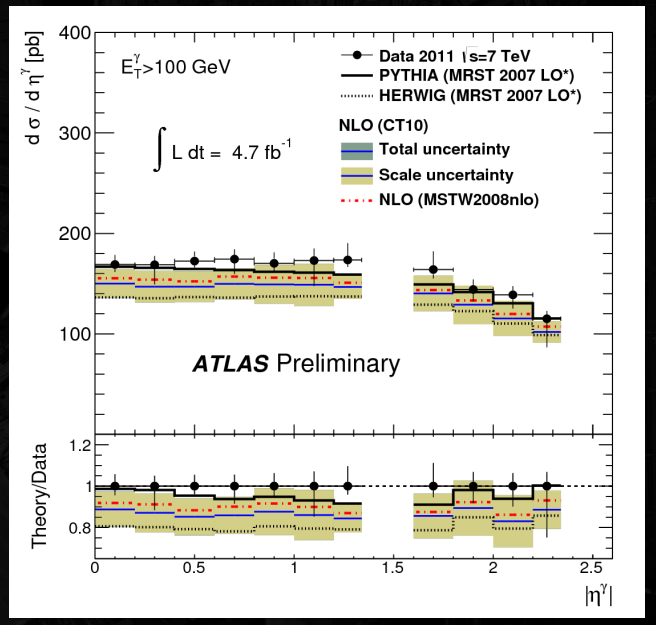
CMS-PAS-SMP-12-021

Isolated prompt photon production

- 7 TeV dataset (4.7 fb^{-1});
- Prompt photons (direct and from fragmentation):
  - isolation: $E_T^{ISO} < 7$ GeV in isolation cone $R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.4$;
  - $100 \leq E_T(\gamma) \leq 1000$ GeV,
  - $|\eta(\gamma)| < 1.37$ or $1.52 < |\eta(\gamma)| < 2.37$.







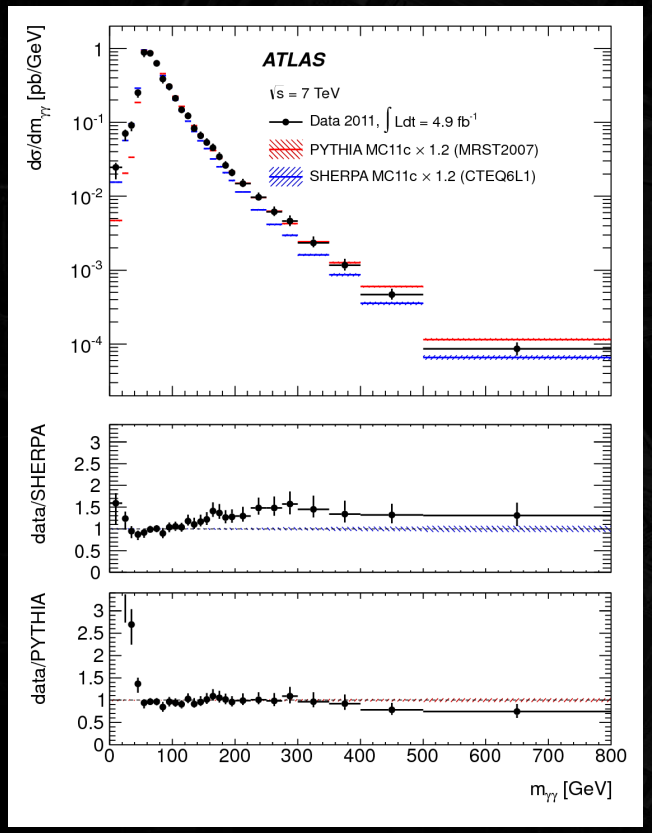
$\sigma_{pp\to\gamma X} = 234 \pm 2_{stat}\ ^{+13}_{-9\ syst} \pm 4_{lumi}$ pb

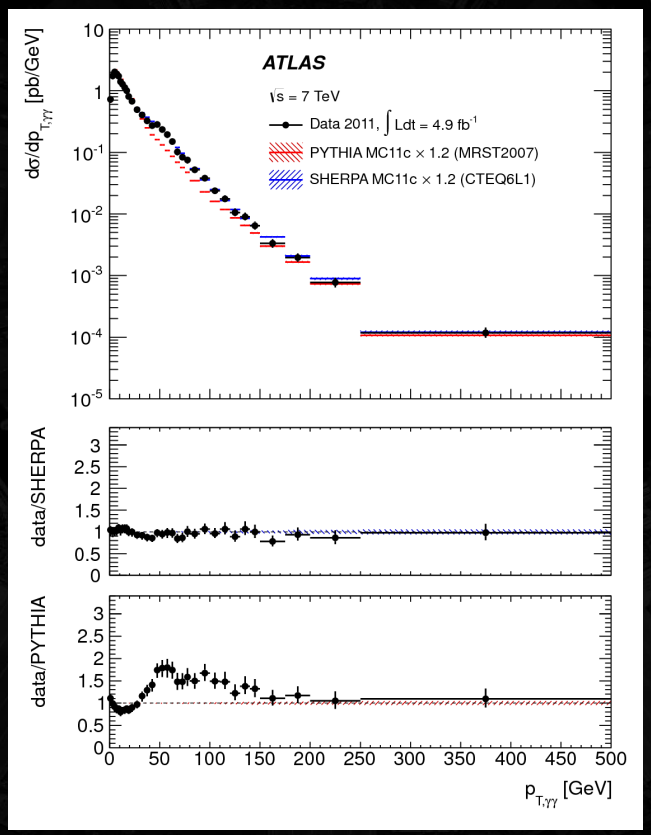
$\sigma_{pp\to\gamma X} = 122 \pm 2_{stat}\ ^{+9}_{-7\ syst} \pm 2_{lumi}$ pb

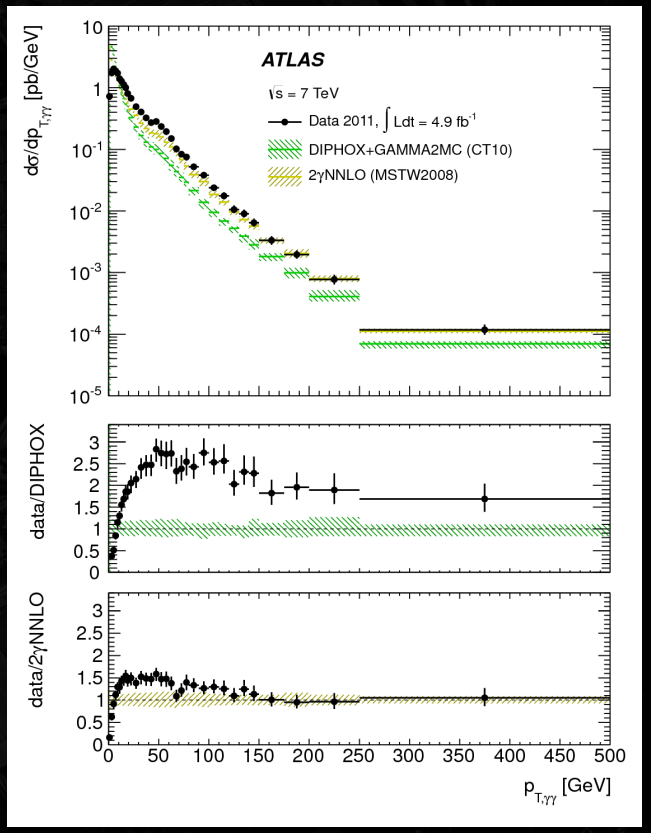
ATLAS-CONF-2013-022

Isolated photon pair production

- 7 TeV dataset (4.9 fb^{-1});
- Photon selection:
  - Isolation: $-4 < E_T^{ISO} < 4$ GeV in $R = \sqrt{\Delta\eta^2 + \Delta\varphi^2} = 0.4$;
  - $E_T(\gamma_1) > 25$ GeV, $E_T(\gamma_2) > 22$ GeV,
    $|\eta(\gamma_{1,2})| < 1.37$ or $1.52 < |\eta(\gamma_{1,2})| < 2.37$.







$$\sigma_{pp\to\gamma\gamma X} = 44.0\ ^{+3.2}_{-4.2}\ \text{pb}$$

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Summary

- An overview of recent ATLAS, CMS, and LHCb results has been presented.
- The pQCD predictions on W, Z, and direct photon production have been extensively tested using the 7 TeV datasets and a special low-pileup dataset at 8 TeV.
- Over 20 fb^{-1} (2 fb^{-1}) of data, collected by ATLAS and CMS (LHCb) at 8 TeV, are available for more precise measurements.