Twelfth Conference on the Intersections of Particle and Nuclear Physics

May 19-24, Vail, Colorado

FYZIKÁLNÍ ÚSTAV
Akademie věd ČR, v.v.i.

Pavel Staroba

Obsah

- Informace o konferenci
- Vybrané výsledky
- Měření vlastností W a Z na LHC – výsledky z Runu 1

Twelfth Conference on the Intersections of Particle and Nuclear Physics

http://cipanp2015.yale.edu/

CIPANP is a conference designed to explore areas of interest to scientists working in **elementary particle physics**, **nuclear physics**, **astrophysics**, **particle astrophysics**, **nuclear astrophysics**, and **cosmology**. Topics include **theory**, **experiment**, and **instrumentation**, as well as **facilities** needed for the study of fundamental interactions, elementary particles, nucleons and nuclei, astrophysical phenomena, and cosmic rays.

Previous CIPANP Locations and Dates

CIPANP 1984: Steamboat Springs, Colorado; May 23-30, 1984
CIPANP 1986: Lake Louise, Alberta, Canada; May 26-31, 1986
CIPANP 1988: Rockport, Maine; May 14-19, 1988
CIPANP 1991: Tucson, Arizona; May 23-29, 1991
CIPANP 1994: St. Petersburg, Florida; May 31-June 6, 1994
CIPANP 1997: Big Sky, Montana; May 25-June 2, 1997
CIPANP 2000: Quebec City, Quebec, Canada; May 22-28, 2000
CIPANP 2003: New York City, New York; May 19-24, 2003
CIPANP 2006: Rio Grande, Puerto Rico; May 30-June 3, 2006
CIPANP 2009: San Diego, California; May 26-31, 2009
CIPANP 2012: St. Petersburg, Florida: May 29-June 3, 2012

Program

302 referátů, 488 autorů

Fyzikální okruhy	Referáty v paralelních sekcích	Plenární referáty
Physics at High Energies	28	3
Precision Physics at High Intensities	26	3
Cosmic Physics and Dark Energy/Inflation	9	2
Neutrino Masses and Neutrino Mixing	37	4
Tests of Symmetries and the Electroweak Interaction	13	3
Dark Matter	24	4
Particle and Nuclear Astrophysics	11	3
Heavy Flavor and the CKM Matrix	18	3
QCD, Hadron Spectroscopy and Exotics	18	3
Partonic Distributions in Nucleons and Nuclei	28	3
Hadronic Physics and the Structure of Nucleons and Nuclei	25	5
Quark Matter and High Energy Heavy Ion Collisions	27	2

Referáty experimentů ATLAS a CMS

Higgs Properties: Mass, Width, Spin, Parity

Higgs couplings measurements at CMS and ATLAS

Higgs couplings combinations and interpretations

Prospects for Higgs properties measurements at future colliders

Measurements of the weak mixing angle in ATLAS and CMS

LHC measurements of the non-Abelian nature of EW interaction

ATLAS Drell-Yan measurements

W/Z measurements at LHC

Top production at the LHC

Top Property Measurements from the CMS, ATLAS, D0, and CDF Collaborations

SM precision W/Z and top measurements at HL-LHC and future colliders

αs Measurements at the LHC

Precision tests of the SM and pQCD with Jets and Photons at LHC

Referáty experimentů ATLAS a CMS

Long lived particles, displaced vertices, and lepton jets
Extra Dimension-Inspired Models: Z', W', Dijet resonances, Black Hole Searches
Search for new phenomena at the LHC in multi-lepton or multi-jet nal states
Searches for Bosonic and fermionic top and bottom partners at CMS

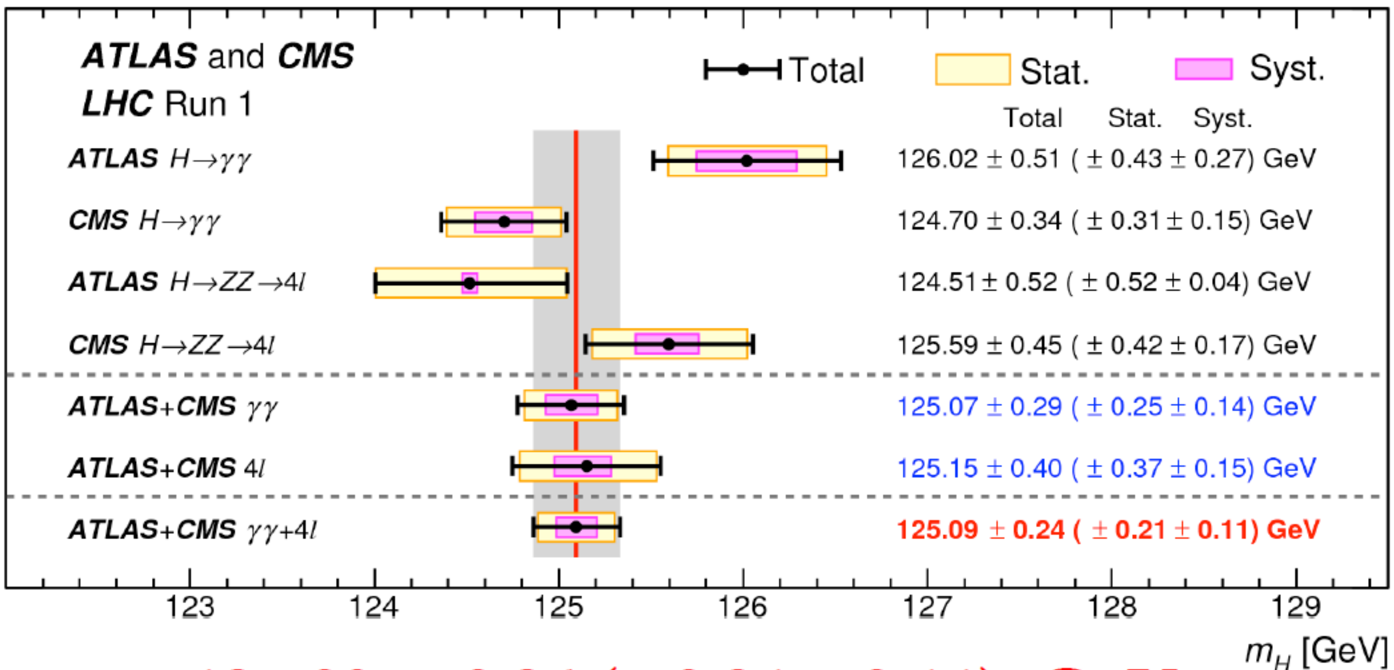
Beyond the Standard Model Higgs Searches at ATLAS and CMS

Exotic Higgs searches at the LHC

Search for SUSY light electroweak objects at the LHC

Searches for squarks and gluinos at the LHC

Mass Combination



125.09 ± 0.24 (± 0.21 ± 0.11) GeV

CMS and ATLAS Width Determination using on- to off-shell production

g^2_{ggH}: couplings of Higgs to gluons
g^2_{HZZ}: couplings of Higgs to Zs

$$\sigma^{\text{on-shell}}_{gg\to H\to ZZ^*} \sim \frac{g^2_{ggH} g^2_{HZZ}}{m_H \Gamma_H} \quad \text{and} \quad \sigma^{\text{off-shell}}_{gg\to H^*\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{(2m_Z)^2}$$

CMS Technique: Measure ratio of on-shell (105.6 GeV – 140.6 GeV) to off-shell (> 220 GeV) H➔ZZ production to extract width
Use llll and llνν final states

ATLAS: Measure on- to off- shell ratio for H➔ZZ➔4l and H➔ZZ➔2l2ν and H➔WW➔eνμν to place a limit on the ratio of the width to the SM width

Expected SM Value: $\Gamma_H^{SM} = 4.15\,\text{MeV}$

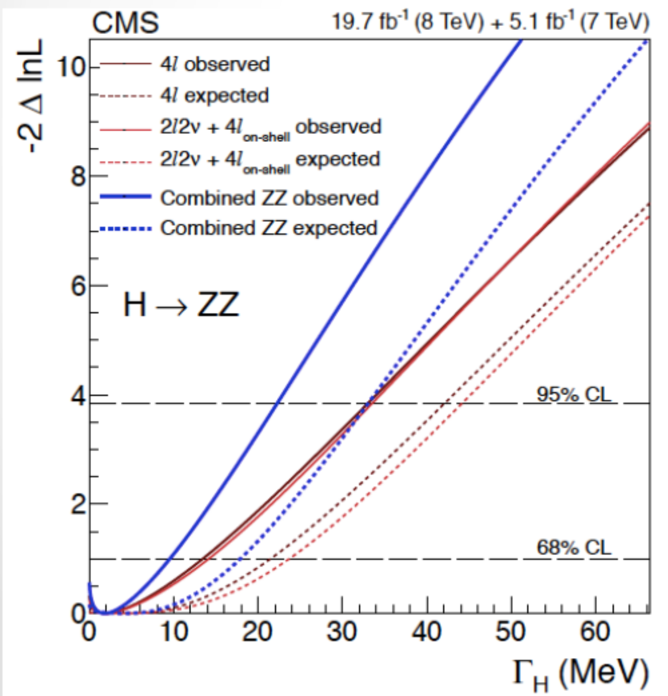
Higgs Properties: Mass, Width, Spin, Parity
Sarah Demers for ATLAS and CMS

Results

CMS

Combined unbinned log likelihood fit upper limit:

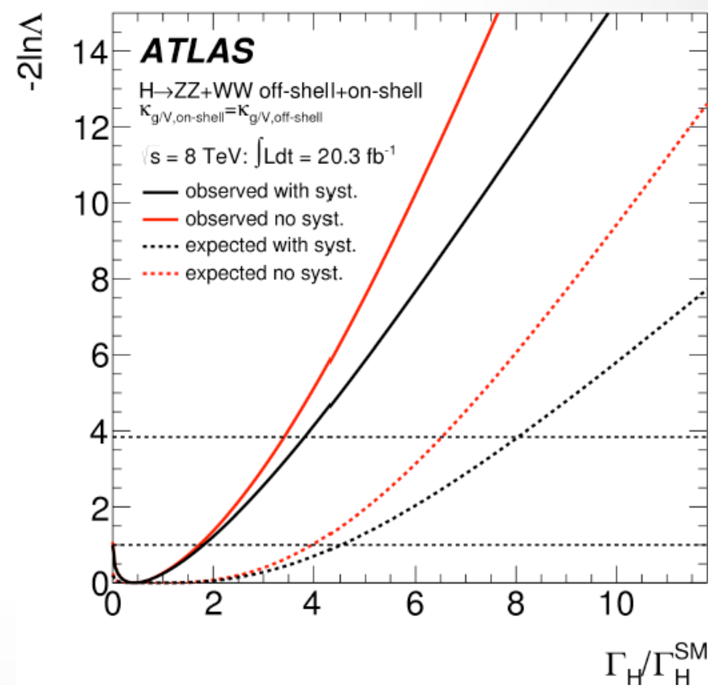
Γ_H < 22 MeV at a 95% CL
(5.4 times the expected SM width)



ATLAS

95% CL upper limit on Γ_H/Γ^{SM}_H in the range 4.5--7.5 (6.5--11.2)

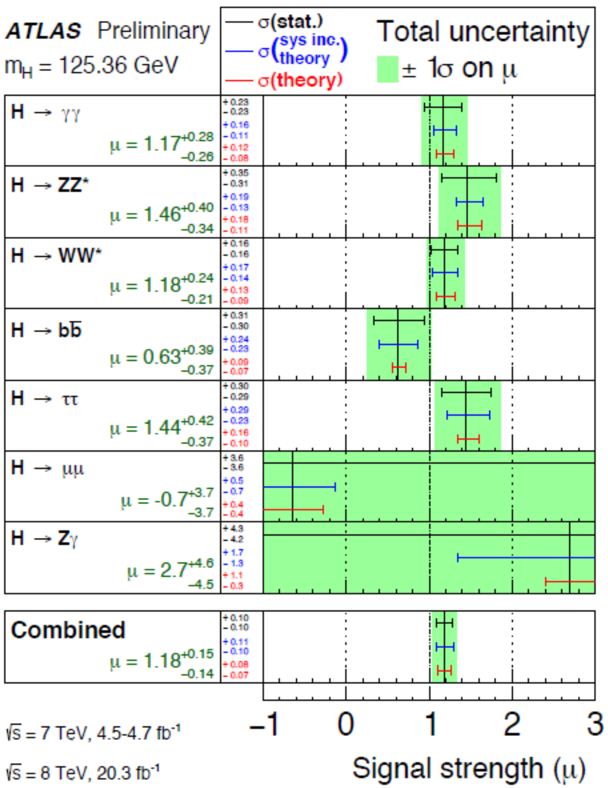
observed (expected) 95% CL upper limit on the Higgs boson total width of 22.7 (33.0) MeV.



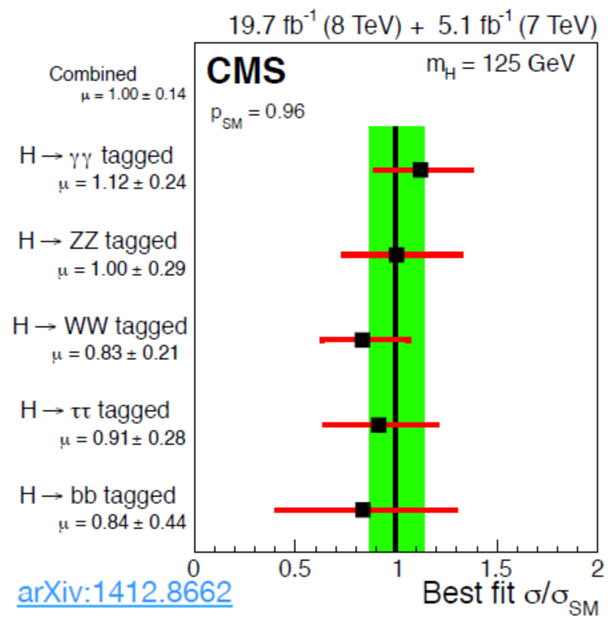
Higgs couplings measurements at CMS and ATLAS
Nick Edwards

Conclusions

- Observed couplings and signal-strengths in agreement with SM at level of 2σ or better.
- Evidence from ττ for couplings to fermions, and suggestions from bb.
- VBF observed at >3σ
- See next talk for couplings combinations & interpretations!



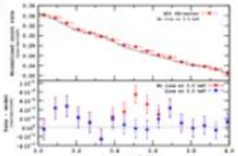
ATLAS-CONF-2015-007

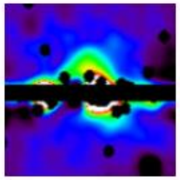


arXiv:1412.8662

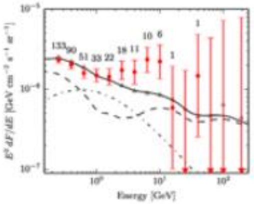
Outline

- Current anomalies: what is their observational status? What are the alternative (non-DM) interpretations? How do we move forward?
  - The 3.5 keV line
  - The inner Galaxy GeV gamma-ray excess

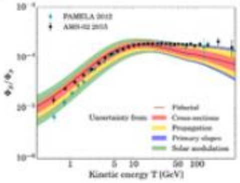




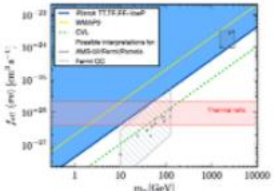
- Fermi dwarf galaxy searches



- Cosmic rays from AMS-02

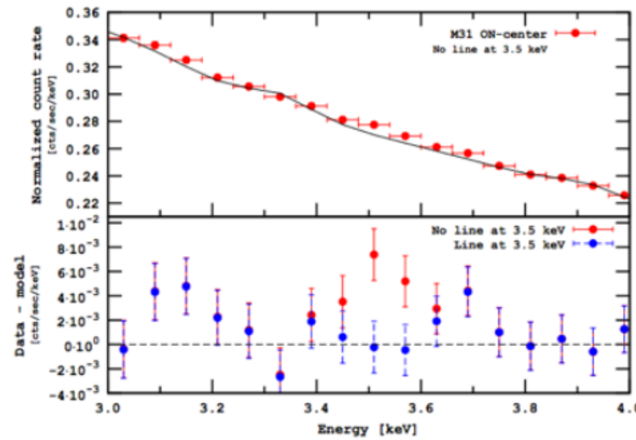


- Dark matter constraints from the CMB with Planck



The 3.5 keV line

- 3.5 keV X-ray spectral line: initial discovery in XMM-Newton data by Bulbul et al (1402.2301) and Boyarsky et al (1402.4119), at ~4σ significance.



- Follow-up observational studies by:

Riemer-Sorenson (1405.7943, MW with Chandra data)
Jeltema & Profumo (1408.1699, MW)
Boyarsky et al (1408.2503, MW center)
Malyshev et al (1408.3531, dwarf spheroidal galaxies)
Anderson et al (1408.4115, stacked galaxies with Chandra and XMM-Newton)
Urban et al (1411.0050, Suzaku)
Tamura et al (1412.1869, Suzaku)

	XMM-Newton	Chandra	Suzaku
Milky Way center	✓	✗	
Andromeda galaxy	?		
Perseus cluster	✓	✓	?
Coma, Virgo, Ophiuchus	✓	✗ studied Virgo only	✗
Stacked clusters	✓		
Stacked galaxies	✗	✗	
Milky Way dwarfs	✗		

✓ Claimed detection
✗ No detection, upper limit
? Conflicting claims

DM interpretations

- Simplest DM explanation is decaying sterile neutrino at a mass around 7 keV - long-standing DM candidate.
- However, simple DM decay models appear ruled out (at 12σ) by non-detection in dwarfs and stacked galaxies (1411.1758 also claims Perseus morphology is incompatible with DM decay).
- DM alternatives include exciting dark matter (see yesterday's talk by N. Weiner): (Finkbeiner & Weiner 1402.6671, Cline & Frey 1410.7766)
  - DM has a metastable excited state 3.5 keV above the ground state.
  - This state is excited by DM-DM collisions, and subsequently decays producing a photon.
  - Rate of excitation scales as density^2 x velocity dependence - much less constrained than just DM density, seems to allow compatibility with data.
- Another possibility is conversion of an axion-like particle to an X-ray photon in the presence of magnetic fields (e.g. 1404.7741) - can lead to widely varying signals from different systems (e.g. 1410.1867).

The GeV gamma-ray excess

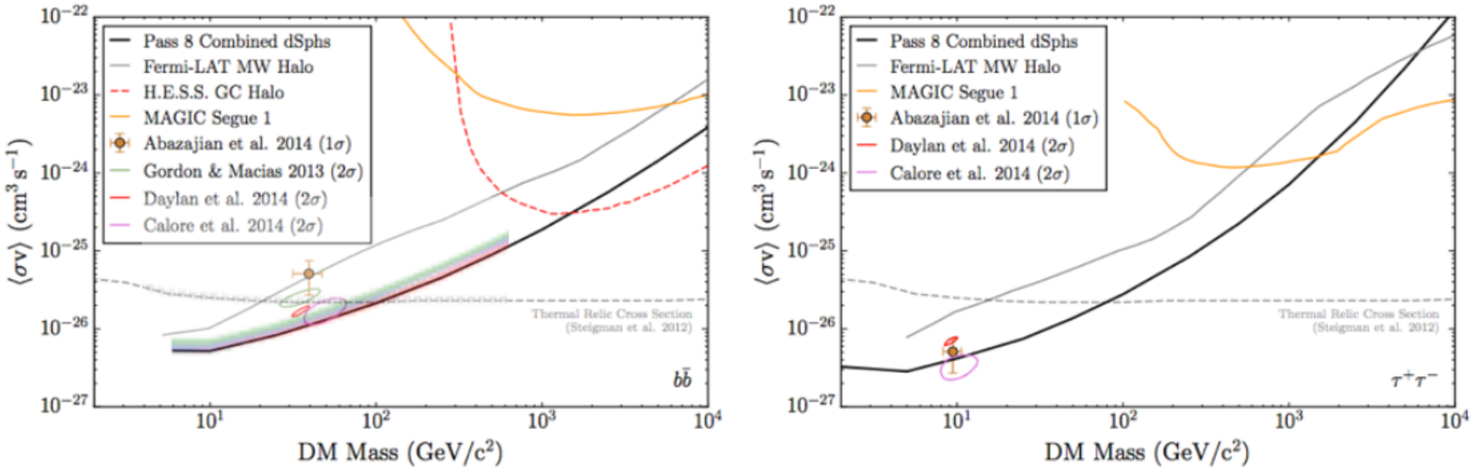
- Discovered in public data from the Fermi Gamma-Ray Space Telescope, first in the Galactic Center (Goodenough & Hooper 09) and later extending to higher latitudes (Hooper & TRS 13). Highly significant (test statistic, similar to $\Delta\chi^2$, is O(1000)) - not a statistical fluctuation.
- Spectral properties:
  - Rises at energies below 1 GeV, peaks around ~2 GeV (in $E^2 dN/dE$, power per logarithmic interval), falls off above ~5 GeV.
- Spatial properties:
  - Generally consistent with spherical symmetry around the Galactic Center (can exclude stretches by more than ~20% along the Galactic plane).
  - Small-r power-law slope of power/volume ~ $r^{-2.2\text{-}2.8}$ (corresponds to dark matter density profile with inner slope γ~1.1-1.4).
  - Appears centered on Sgr A*, the black hole at the center of the Milky Way.
  - Extends out to at least 10 degrees (~1.5 kpc) from the GC.

Dark Matter Indirect Detection: Tracy Slatyer

Dark matter…

- Naturally explains:
  - The invariance of the spectrum with position.
  - The ~spherical morphology of the signal.
  - The profile: steeply peaked at the Galactic Center but extending out to (at least) 10 degrees.
- Required annihilation cross section lines up with long-standing predictions for the “thermal relic” scenario.
- Spectrum can be easily produced by annihilation of light DM.
- But no detection yet in other channels - constraints from direct, indirect & collider searches limit model space.

Dwarf galaxies



- Dwarf galaxies: DM-dominated systems, provide a clean independent test of DM-annihilation hypothesis.
- Currently provide best current limits on sub-TeV DM annihilating through most channels (Fermi Collaboration, 1503.02641).
- See parallel session talk by Keith Bechtol tomorrow for more details - I will give a quick summary here.

Reticulum II

- Recently discovered in DES data, ~30 kpc away. A gamma-ray excess is consistently seen, in the 2-10 GeV energy range.
- Significance debated, various groups find 2.2-3.7σ local significance depending on background modeling. (See talk by K. Bechtol for detailed discussion.)
- Global significance depends on J-factors for dwarves, and whether one scans over DM mass + annihilation channel.
- Within uncertainties, consistent with Galactic Center excess - but uncertainties are large.

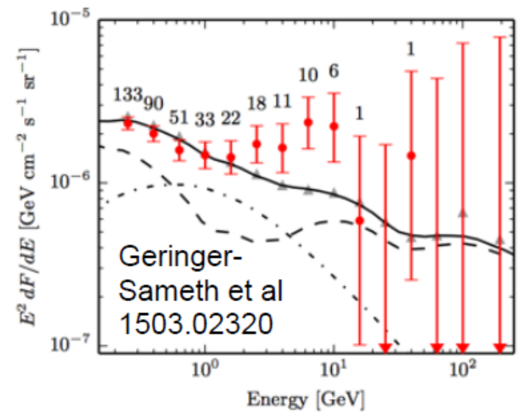
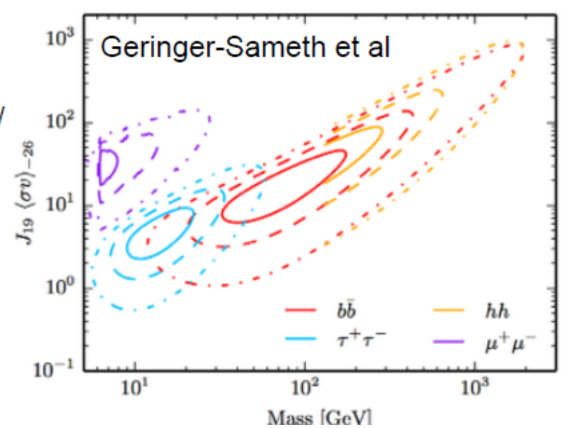
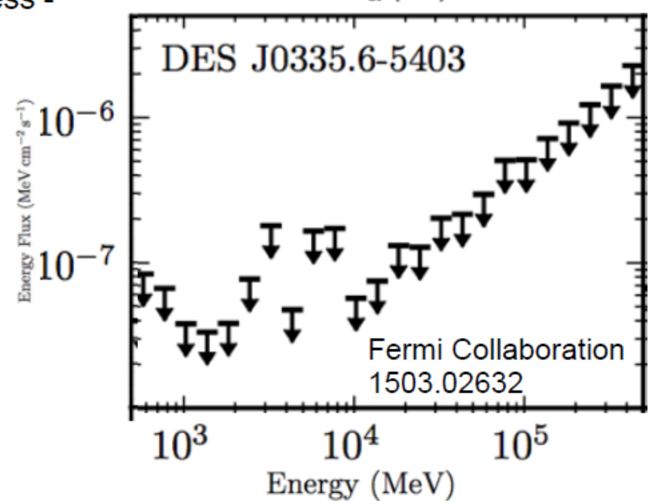


Figure takes a J-factor of $10^{19.5}$ GeV^2/cm^5 as found by 1504.03309*.

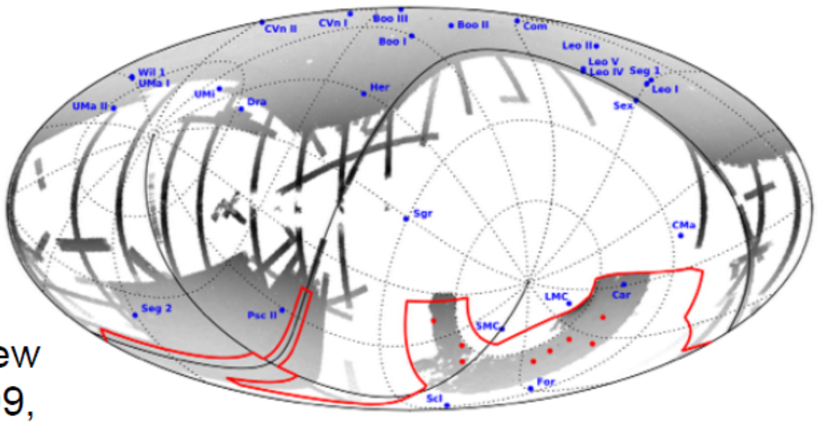
*Note however that this value has a 1-order-of-magnitude error bar.

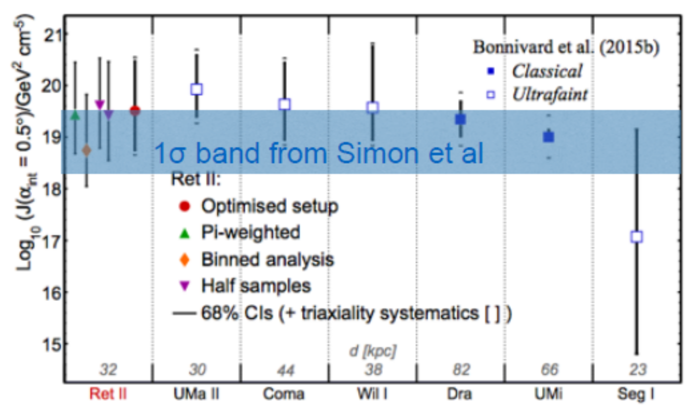


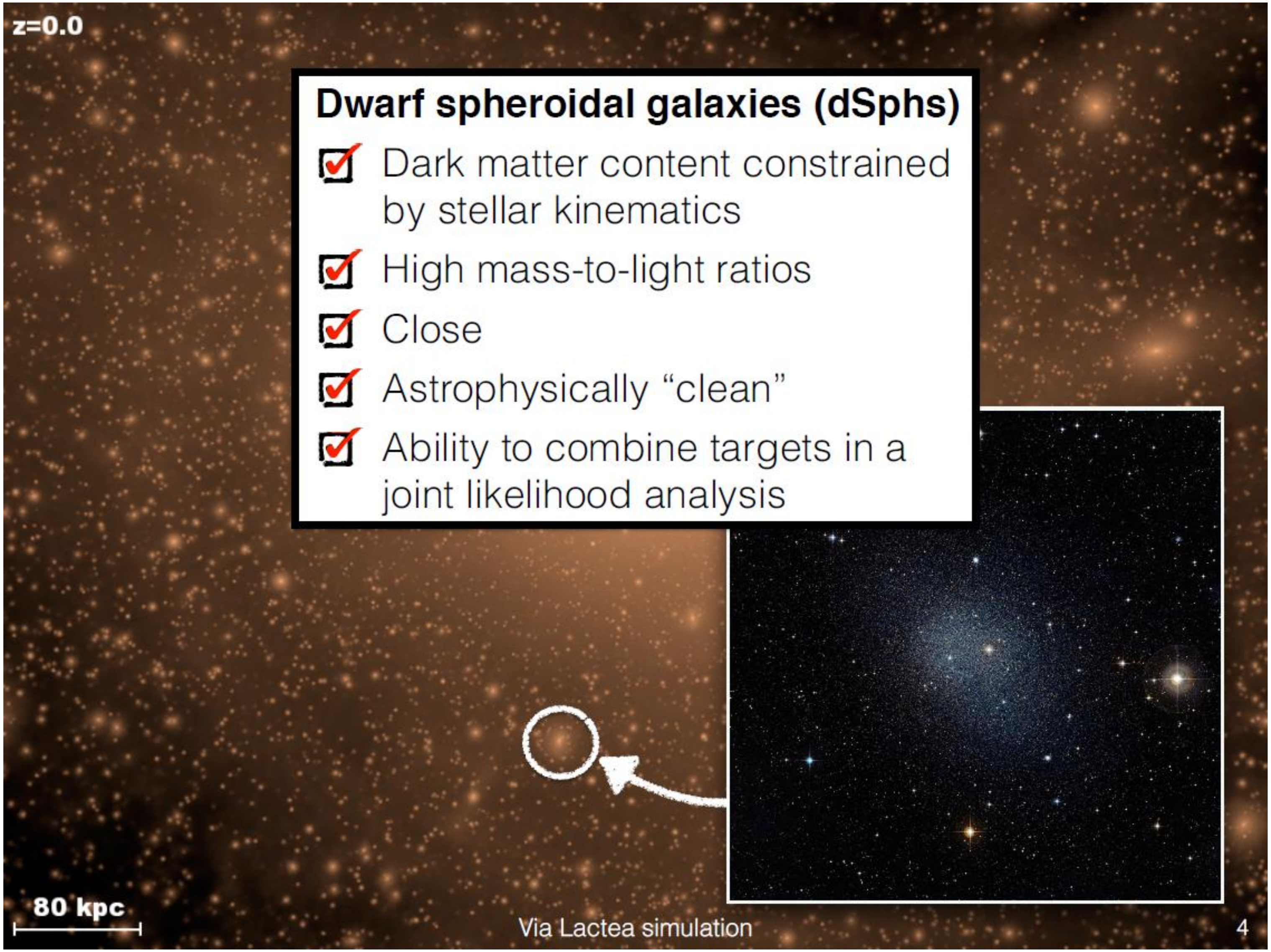


DES discovers new dwarf galaxies

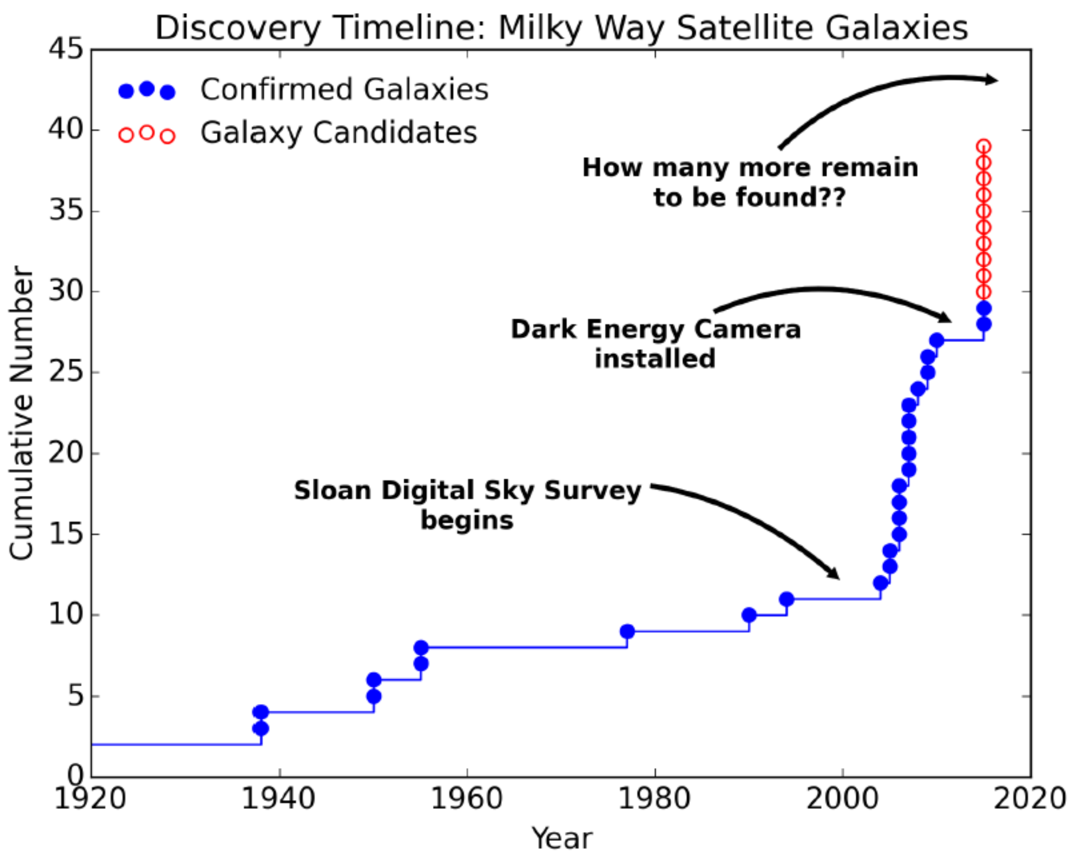
- Discovery of 8-9 new dwarf candidates in DES data in March (1503.02079, 1503.02584).
- More recently, kinematic studies were made of the DM content of "Reticulum II", the closest of the new dwarfs (Bonnivard et al 1504.03309, Simon et al 1504.02889).
- Want to estimate "J-factor", figure of merit for DM annihilation.
- Results are consistent within the (large) error bars, but Simon et al prefer a somewhat smaller value.






z=0.0
Dwarf spheroidal galaxies (dSphs)
Dark matter content constrained by stellar kinematics
High mass-to-light ratios
Close
Astrophysically "clean"
Ability to combine targets in a joint likelihood analysis
80 kpc
Via Lactea simulation
4

A Recent Flurry of Discoveries



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AMS-02 cosmic ray data

- AMS-02: high-precision measurements of cosmic rays, located on the International Space Station.
- New data presented last month at “AMS Days @ CERN” workshop.
- Protons, helium, lithium show consistent hardening of spectrum above ~ 200 GV rigidity - point to new CR source or propagation effects?
- Antiproton/proton ratio flattens to a constant at high energies.

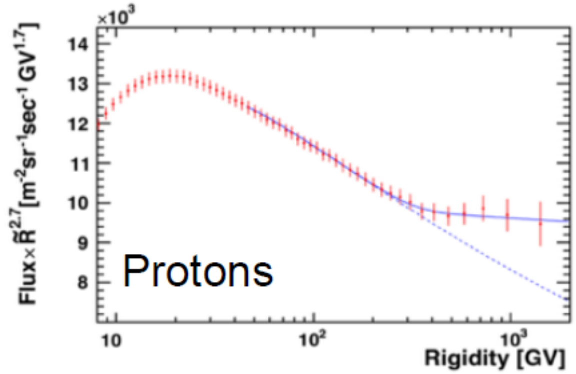
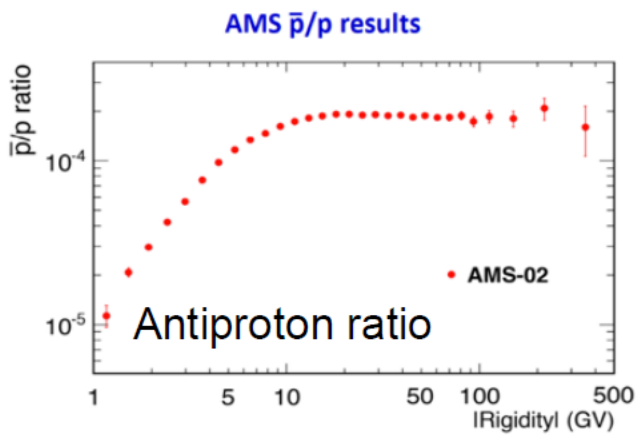
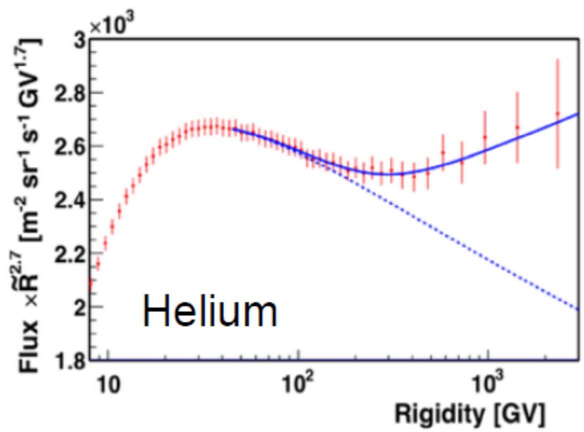
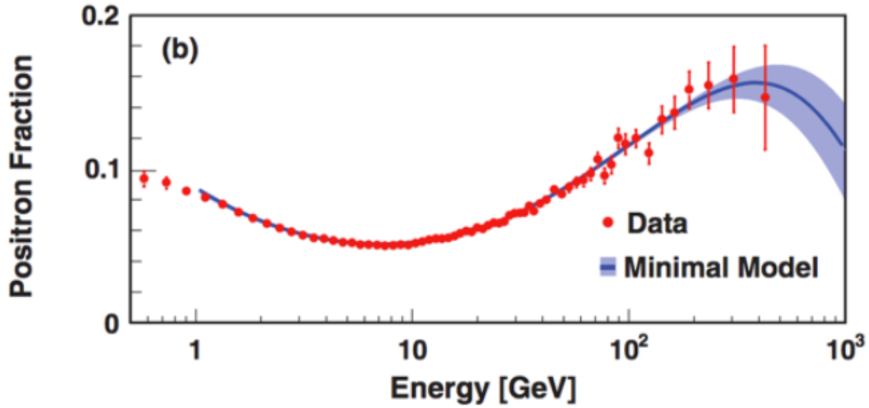


Figure 2: Measured proton fluxes as a function of rigidity.





An older anomaly: the AMS-02/PAMELA positron excess



Accardo et al (AMS-02 Collaboration), PRL 113, 121101 (2014)

- Rise in positron fraction above 10 GeV observed by PAMELA experiment in 2008, confirmed to extend up to at least 500 GeV by AMS-02.
- Possible signal of DM annihilation, producing additional primary positrons. (Other possibilities: pulsars, supernova remnants, modified cosmic-ray production and/or propagation.)

Outlook

- Indirect searches are rich, rapidly evolving, and have revealed several candidate dark matter signals - might be the first non-gravitational hints of dark matter physics.
- BUT - astrophysical backgrounds are complex; any dark matter detection will require confirmation in multiple channels.
- Simultaneously, powerful limits from new measurements of cosmic rays, cosmic microwave background, dwarf galaxies, etc.

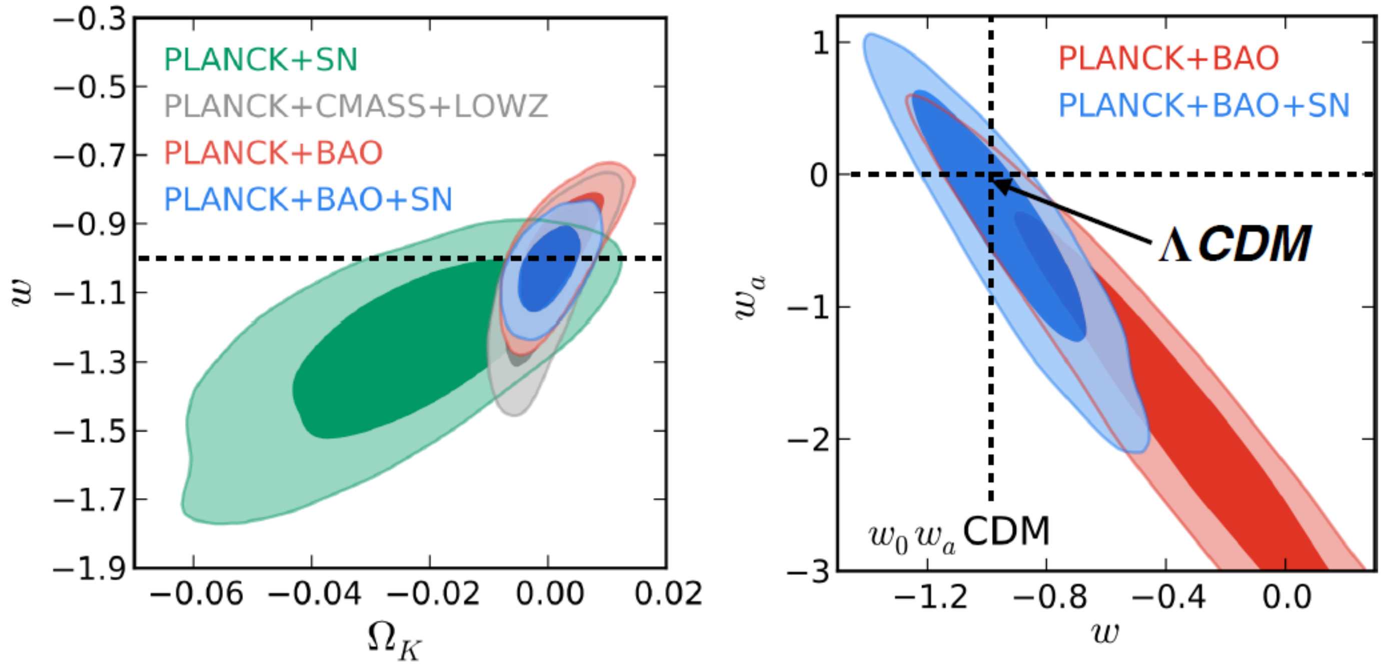
STATUS OF ANOMALIES

	3.5 keV X-ray line	GeV gamma-ray excess
Where?	Multiple experiments, multiple target systems	Only Fermi data, GC + inner Galaxy (perhaps a hint in Reticulum II?)
DM explanation?	Exciting DM, ALP conversion - simplest decaying-DM models in strong tension with other limits	Thermal-relic annihilating DM explains properties well
Non-DM explanation?	Contamination from plasma lines	Pulsars, Galactic outflows
Where next?	Astro-H observations	Further dwarf studies, new dwarfs? Improved analyses of GC + inner Galaxy? Direct detection / LHC?

CONSTRAINING DARK ENERGY WITH THE BARYON OSCILLATION SPECTROSCOPIC SURVEY (BOSS)

MARIANA VARGAS-MAGANA (compiled by Bradford Benson)

Dark Energy: Expansion History Constraints



- Constraints consistent with a **Λ*CDM*** cosmology (i.e., a constant dark energy equation of state, w=-1), even after allowing for a non-zero curvature (Ω_K) or evolving dark energy (w_a)

Talk by M. Vargas

W/Z measurements at LHC

ATL-PHYS-SLIDE-2015-277

https://cds.cern.ch/record/2018497

Pavel Staroba

for

ATLAS and CMS Collaborations

Outline

- Introduction
- ATLAS + CMS : Summary of Run1 results
- Selected Run 1 results:
  - W/Z cross sections
  - Differential Drell-Yan cross section
  - Z differential distributions: transverse momentum, rapidity
  - W/Z + jets
  - Z + b
- Run1 - summary
- Expectations for Run 2

Why W/Z Boson Physics?

Inclusive cross sections of W/Z

testing of QCD predictions

Differential cross-sections as a function of P_T and rapidity

constraints on PDFs, testing of parton emission calculations and resummation models

More exclusive final states: W/Z+jets, W/Z+b

stronger and more stringent tests of QCD

Low Mass Drell-Yan

constraints on PDFs, testing of parton emission calculations and resummation models

Why W/Z Boson Physics?

High Mass Drell-Yan

precision test of pQCD, constraints on PDFs, new physics

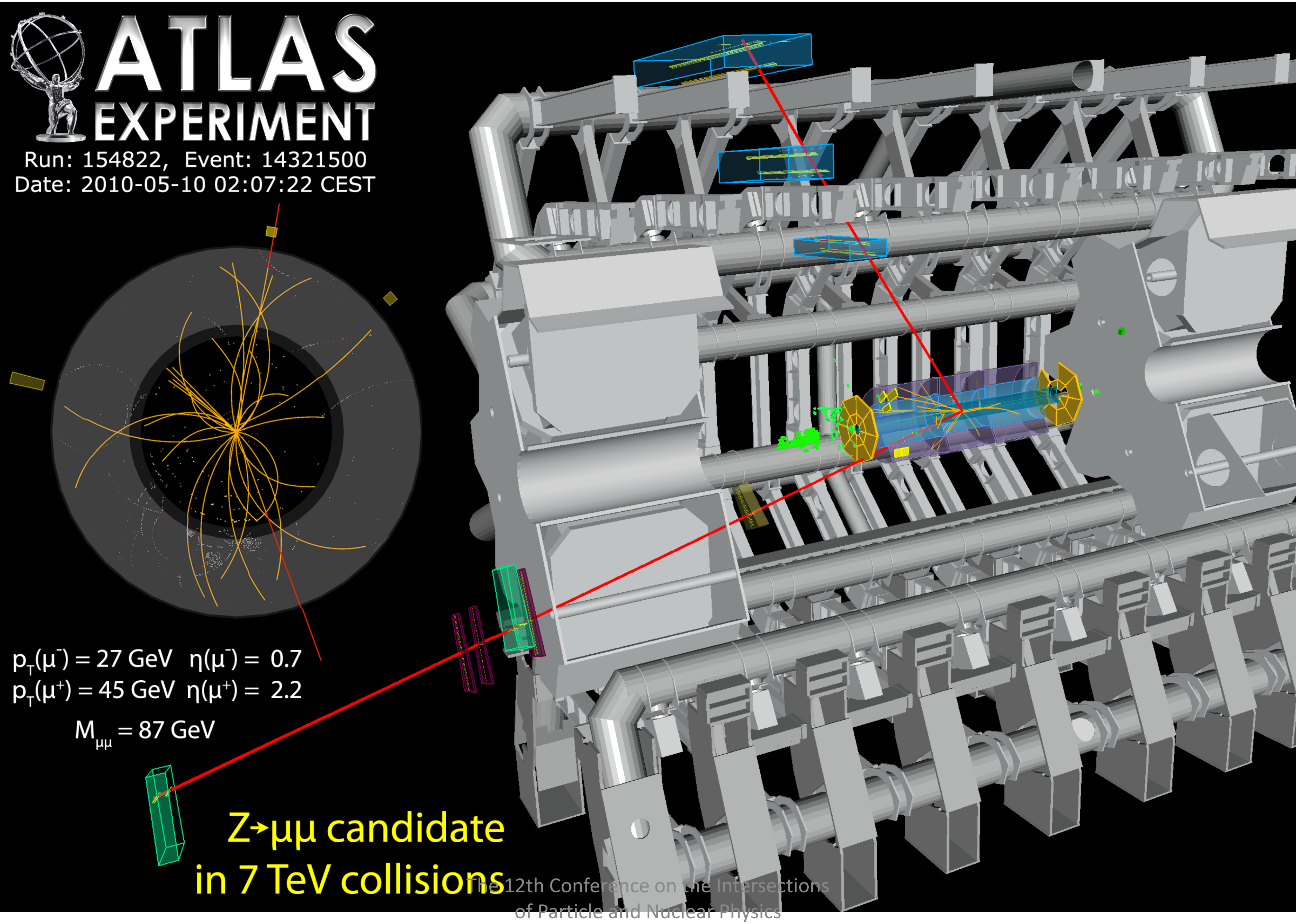
Forward Backward Asymmetry of Drell-Yan pairs

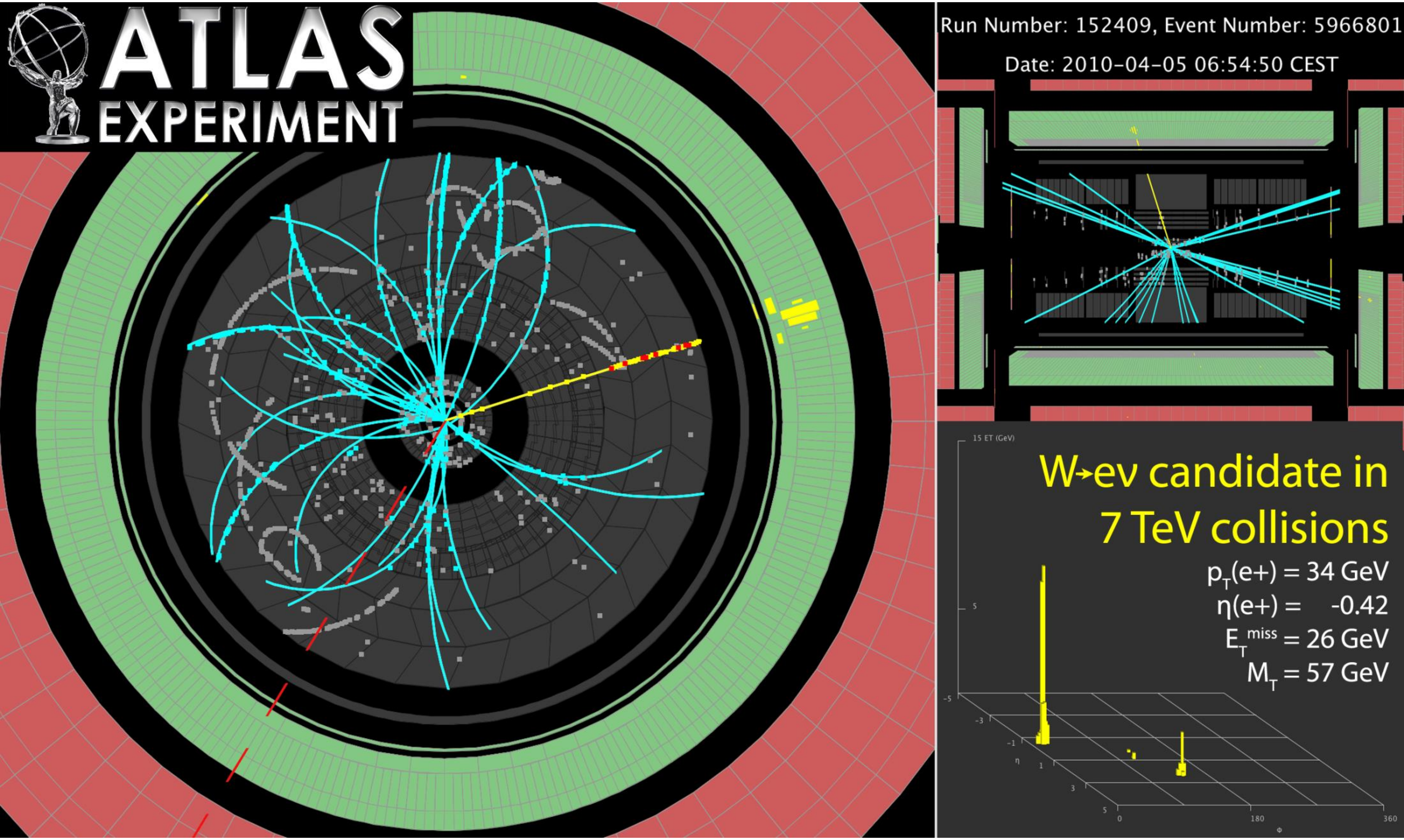
on-shell region: sensitive to the value of $\sin^2 \theta_W$

off-shell region: sensitive to the new physics

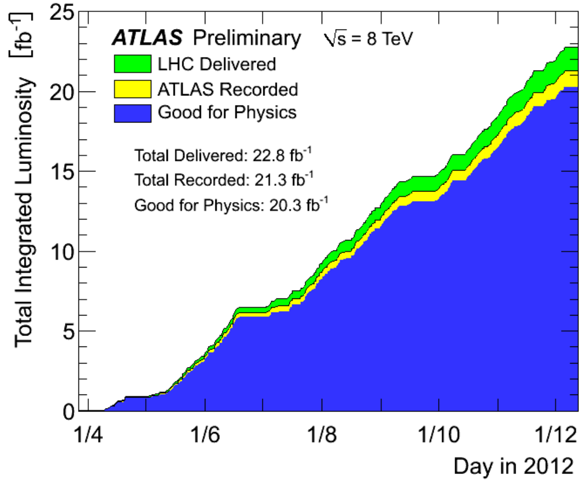
Charge Asymmetry in Inclusive W production

constraints to the PDFs


ATLAS EXPERIMENT
Run: 154822, Event: 14321500
Date: 2010-05-10 02:07:22 CEST
$p_T(\mu^-) = 27$ GeV $\eta(\mu^-) = 0.7$
$p_T(\mu^+) = 45$ GeV $\eta(\mu^+) = 2.2$
$M_{\mu\mu} = 87$ GeV
Z→μμ candidate
in 7 TeV collisions


ATLAS
EXPERIMENT
Run Number: 152409, Event Number: 5966801
Date: 2010-04-05 06:54:50 CEST
W→eν candidate in
7 TeV collisions
$p_T(e+) = 34$ GeV
$\eta(e+) = -0.42$
$E_T^{miss} = 26$ GeV
$M_T = 57$ GeV

Integrated luminosities collected during Run 1 by ATLAS



Period	$\sqrt{s}[TeV]$	$L_{\text{int}}[fb^{-1}]$
2010	7	≈ 0. 035
2011	7	≈ 4.57
2012	8	≈ 20.3

270k W, 24k Z dec. into e, μ

W/Z measurements at **ATLAS** and **CMS** LHC Run-1

More than 60 publications in total. Wide range of topics is covered:

- **production cross section of inclusive W and Z decaying into e, μ**, τ and b channels
- **differential Drell-Yan cross section**
- **differential cross section of W and Z as a function of boson transverse momentum, Φ* and rapidity**
- **production of W and Z in association with light jets**
- **production of W and Z in association with** c and **b quark**
- **the ratio of the W and Z cross sections in association with jets**
- forward-backward asymmetry of Drell-Yan lepton pairs
- lepton charge asymmetry in inclusive W production
- measurement of weak mixing angle with the Drell-yan process
- angular distributions in the decay of W and Z
- electroweak production of dijets in association with a Z boson

Production cross-section of W and Z decaying to leptons (7 TeV)

ATLAS

[Phys. Rev. D85, 072004 (2012)]

2010 7 TeV ∫Ldt = 35 pb^{-1}

CMS

[JHEP10 (2011) 132]

2010 7 TeV ∫Ldt = 36 pb^{-1}

$$\sigma(pp \to W^{\pm}X) \times B(W^{\pm} \to l^{\pm}\nu) = 10.207 \pm 0.021(stat) \pm 0.121(syst) \pm 0.347(lumi) \pm 0.164(acc) nb$$

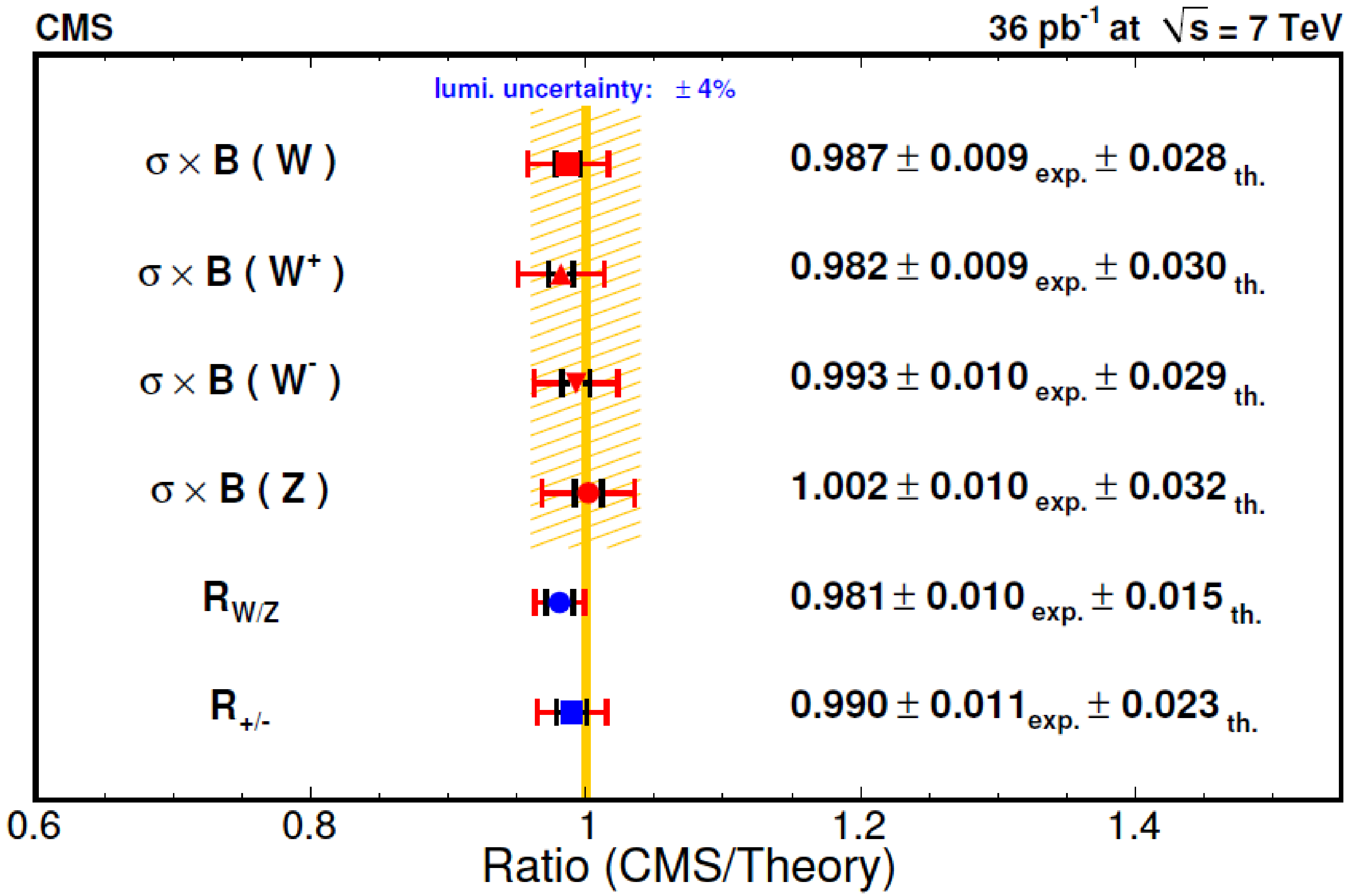
$$\sigma(pp \to W^{\pm}X) \times B(W^{\pm} \to l^{\pm}\nu) = 10.31 \pm 0.02(stat) \pm 0.09(syst) \pm 0.10(th) \pm 0.41(lumi) nb$$

$$\sigma(pp \to ZX) \times B(Z \to l^{+}l^{-}) = 0.937 \pm 0.006(stat) \pm 0.009(syst) \pm 0.032(lumi) \pm 0.016(acc) nb$$

$$\sigma(pp \to ZX) \times B(Z \to l^{+}l^{-}) = 0.974 \pm 0.007(stat) \pm 0.007(syst) \pm 0.018(th) \pm 0.039(lumi) nb$$

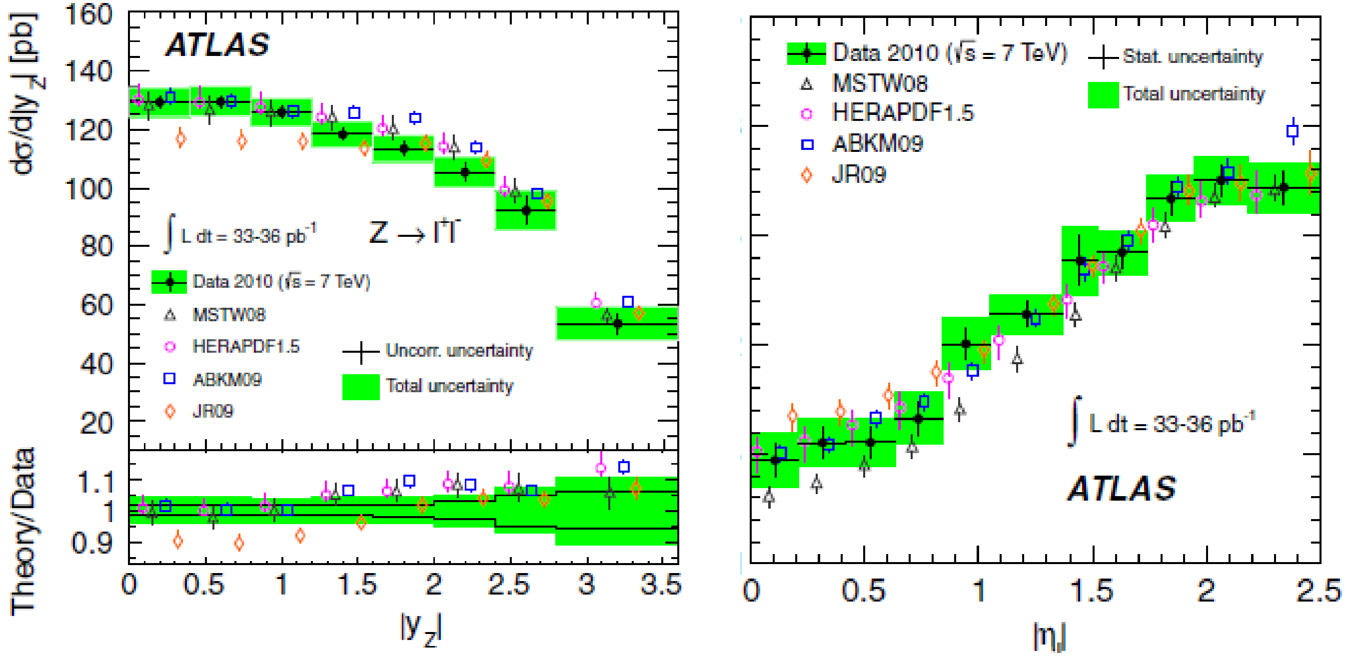
CMS Collaboration: [JHEP10 (2011) 132]

2010 7 TeV $\int Ldt = 36\ pb^{-1}$



ATLAS Collaboration: [Phys. Rev. D85, 072004 (2012)]

2010 7 TeV ∫Ldt = 35 pb^{-1}



Production cross-section of W and Z decaying to leptons (8 TeV)

CMS
[Phys. Rev. Lett. 112, 191802 (2014)]
2012 8 TeV $\int Ldt$ = 18.2 pb^{-1}

$$\sigma(pp \rightarrow W^{+}X) \times B(W^{+} \rightarrow l^{+}\nu) = 7.11 \pm 0.03(stat) \pm 0.14(syst) \pm 0.18(lumi) nb$$

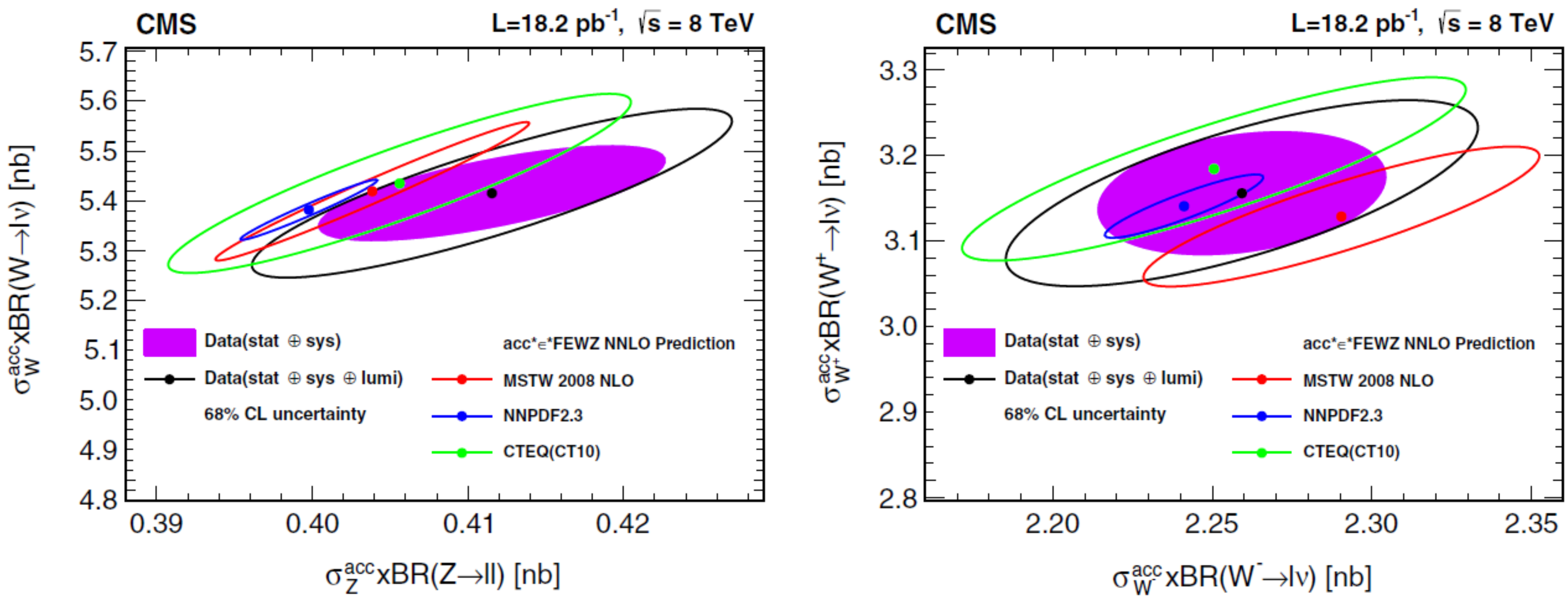
$$\sigma(pp \rightarrow W^{-}X) \times B(W^{-} \rightarrow l^{-}\nu) = 5.09 \pm 0.02(stat) \pm 0.11(syst) \pm 0.13(lumi) nb$$

$$\sigma(pp \rightarrow W^{\pm}X) \times B(W^{\pm} \rightarrow l^{\pm}\nu) = 12.21 \pm 0.03(stat) \pm 0.24(syst) \pm 0.32(lumi) nb$$

$$\sigma(pp \rightarrow ZX) \times B(Z \rightarrow l^{+}l^{-}) = 1.15 \pm 0.01(stat) \pm 0.02(syst) \pm 0.03(lumi) nb$$

CMS Collaboration: [Phys. Rev. Lett. 112, 191802 (2014)]
2012 8 TeV $\int Ldt = 18.2\ pb^{-1}$

Measured and predicted fiducial cross sections of W versus Z and W^{+} versus W^{-} are shown. This measurement has discriminating power between PDF sets.



Differential Drell-Yan cross section

ATLAS

[Phys. Lett. B725 (2013) 223-242]
2011 7 TeV $\int Ldt = 4.9\ fb^{-1}$
high mass

[JHEP06 (2014) 112]
2010 7 TeV $\int Ldt = 35\ pb^{-1}$
2011 7 TeV $\int Ldt = 1.6\ fb^{-1}$
low mass

CMS

[JHEP10 (2011) 007]
2010 7 TeV $\int Ldt = 36\ pb^{-1}$

[JHEP12 (2013) 030]
2011 7 TeV $\int Ldt = 4.8\ fb^{-1}$ (dielectron)
2011 7 TeV $\int Ldt = 4.5\ fb^{-1}$ (dimuon)

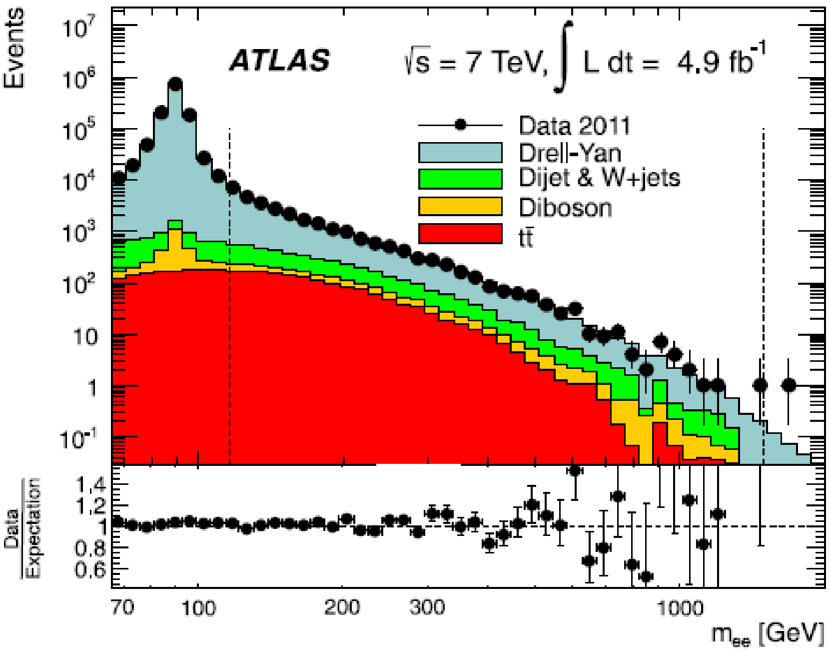
[Eur. Phys. J. C (2015) 75:147]
2012 8 TeV $\int Ldt = 19.7\ fb^{-1}$

ATLAS Collaboration: [Phys. Lett. B725 (2013) 223-242]

2011 7 TeV $\int L dt = 4.9\ fb^{-1}$

$$116 < m_{ee}[GeV] < 1500$$

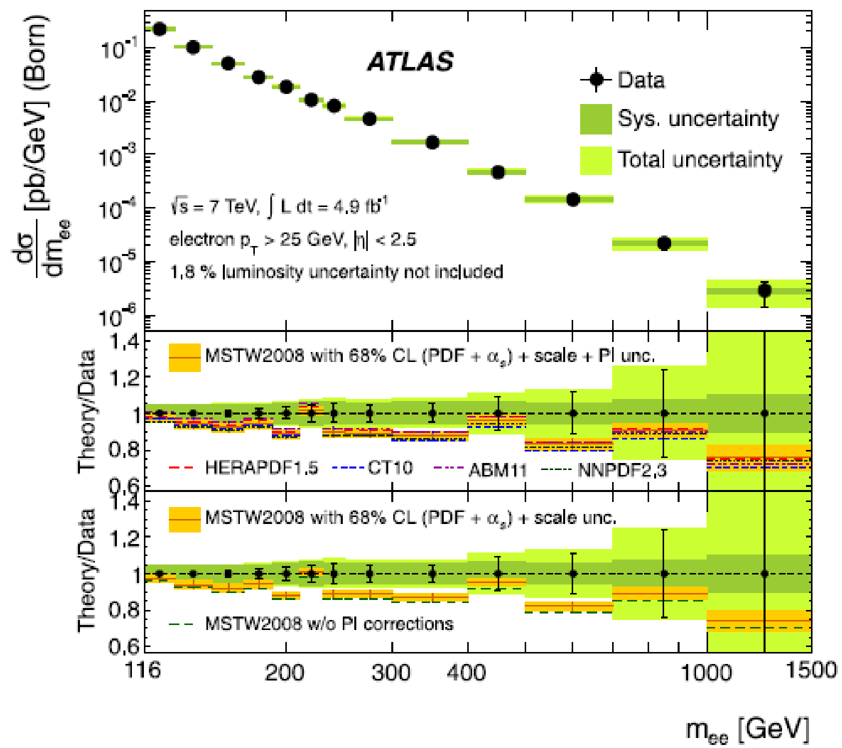
Shape of background extracted fiducial cross section at the particle level was compared to the predictions of **PYTHIA6**, **MC@NLO** and **SHERPA** generators and predictions of **FEWZ 3.1** framework using five NNLO PDF sets.

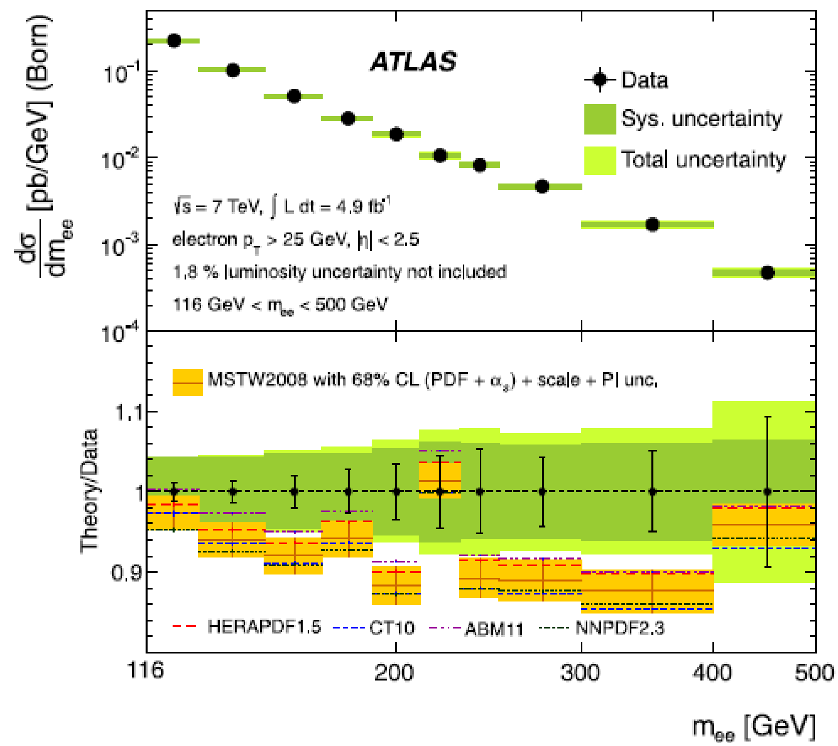


ATLAS Collaboration: [Phys. Lett. B725 (2013) 223-242]

2011 7 TeV ∫Ldt = 4.9 fb^{-1}

Data are compared to the prediction of **FEWZ** (NNLO QCD, NLO EW) with NNLO PDFs MSTW2008, HERAPDF1.5, CT10, ABM11 and NNPDF2.3 . Deviations between the MSTW2008 and all remaining PDFs are all covered in the MSTW2008 uncertainty band. All predictions lie below data.





ATLAS Collaboration: [JHEP06 (2014) 112]

2010 7 TeV $\int Ldt = 35\ pb^{-1}$

2011 7 TeV $\int Ldt = 1.6\ fb^{-1}$

Measurement done both in e and μ channels, results combined. Fiducial differential cross sections are compared to **FEWZ** predictions at NLO and NNLO as well as NLO calculations matched to LL resumed parton shower calculation from **POWHEG**. QCD analysis of the data is performed.

Combined analysis: $26 < m_{ll}[GeV] < 66$

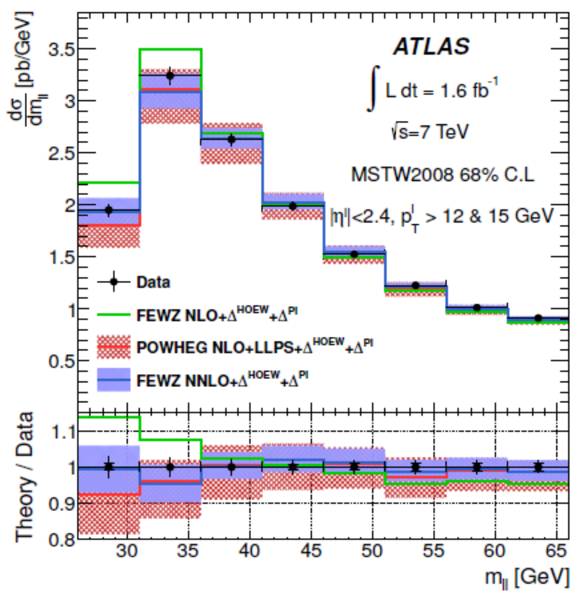
Extended analysis
(muon data from 2010 only) : $12 < m_{ll}[GeV] < 66$

ATLAS Collaboration: [JHEP06 (2014) 112]

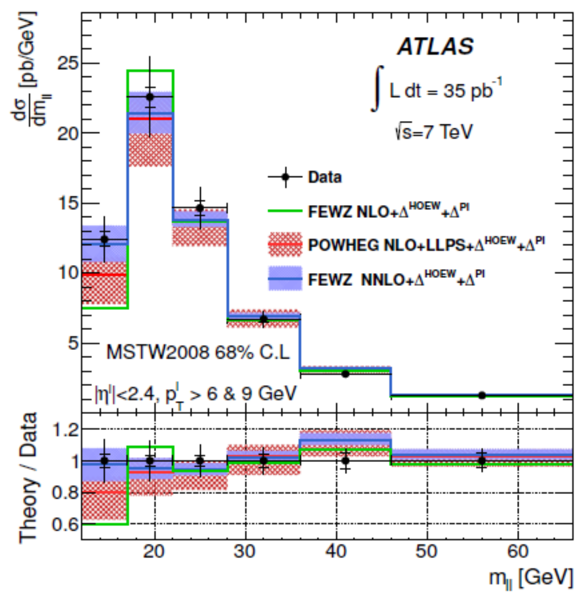
2010 7 TeV ∫Ldt = 35 pb^{-1}

2011 7 TeV ∫Ldt = 1.6 fb^{-1}

Measured fiducial differential cross section is compared to NLO (**FEWZ**), NLO + Leading Logarithm resumed Parton Shower (**POWHEG**) and NNLO (**FEWZ**). predictions. Only NNLO prediction reproduces data. Left plot shows results of combined analysis , the right one results of extended analysis.



(a)



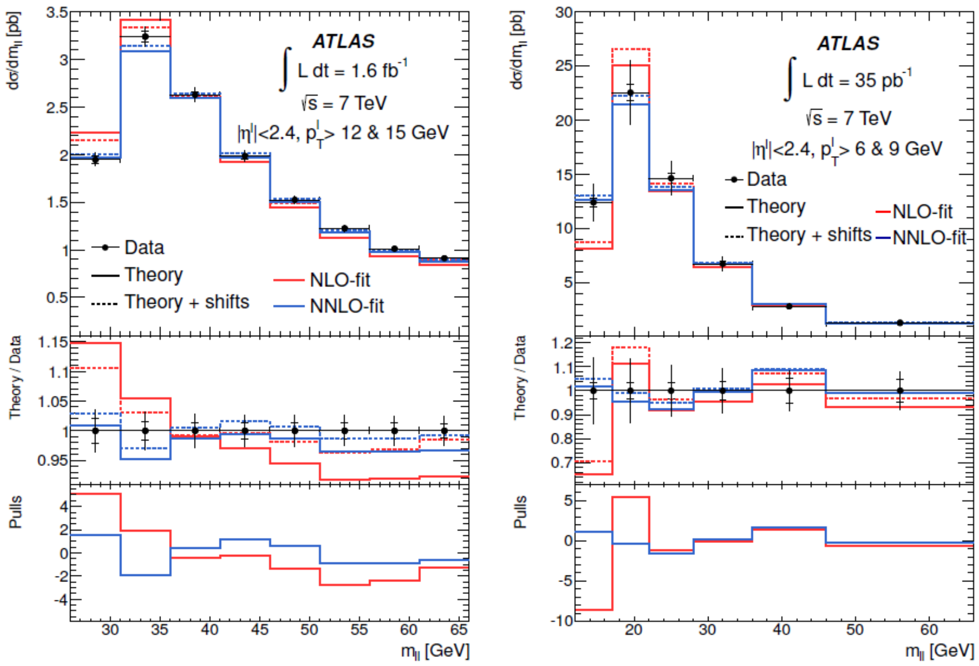
(b)

ATLAS Collaboration: [JHEP06 (2014) 112]

2010 7 TeV ∫Ldt = 35 pb^{-1}

2011 7 TeV ∫Ldt = 1.6 fb^{-1}

To investigate to what extent the disagreement with a pure NLO calculation is dependent on the PDF used, a QCD analysis of data is performed. In this analysis, the QCD fit and theoretical prediction were created using PDFs including DIS data from HERA and the new measurement presented here. Necessity of using NNLO prediction was confirmed.



(a) (b)

CMS Collaboration: [JHEP12 (2013) 030]

2011 7 TeV $\int Ldt = 4.8\ fb^{-1}$ (dielectron)

2011 7 TeV $\int Ldt = 4.5\ fb^{-1}$ (dimuon)

$\frac{d\sigma}{dm}$:

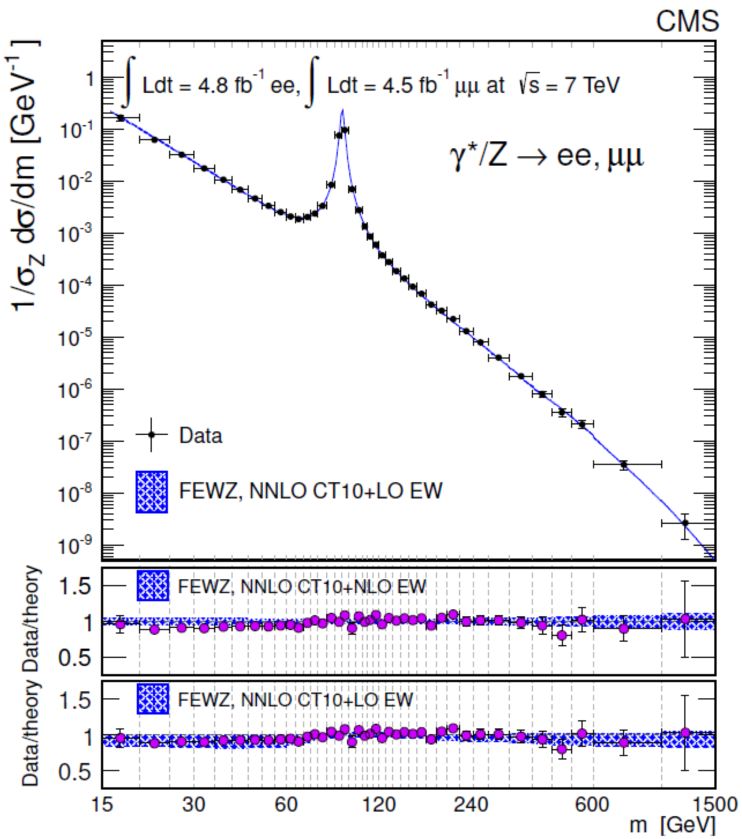
$15 < m_{ll}[GeV] < 2000$

dielectron,
dimuon and
combined channel

$\frac{d^2\sigma}{dmd|y|}$:

$20 < m_{ll}[GeV] < 1500$

dimuon channel



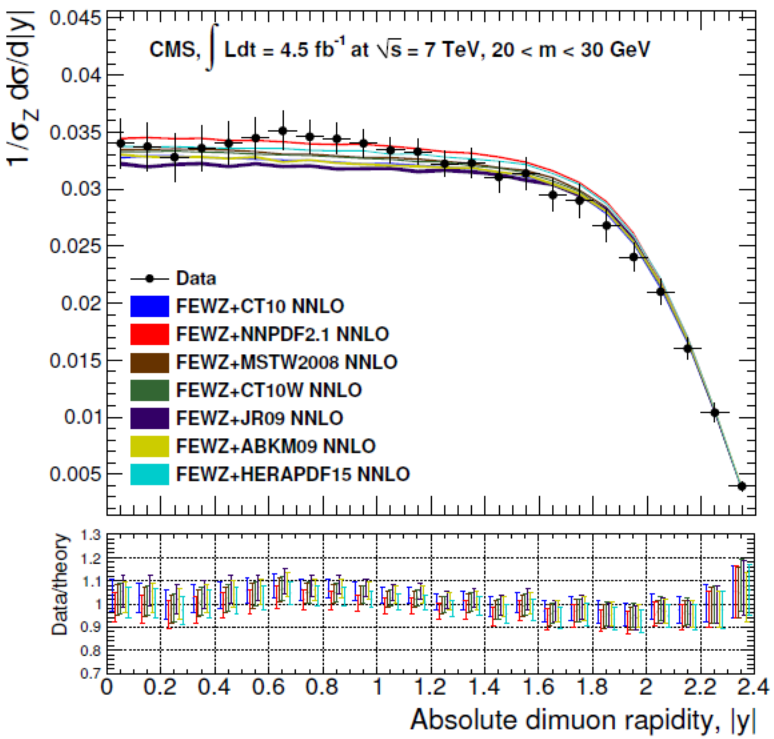
Results are compared with NLO and NNLO pQCD predictions using various sets of PDFs.

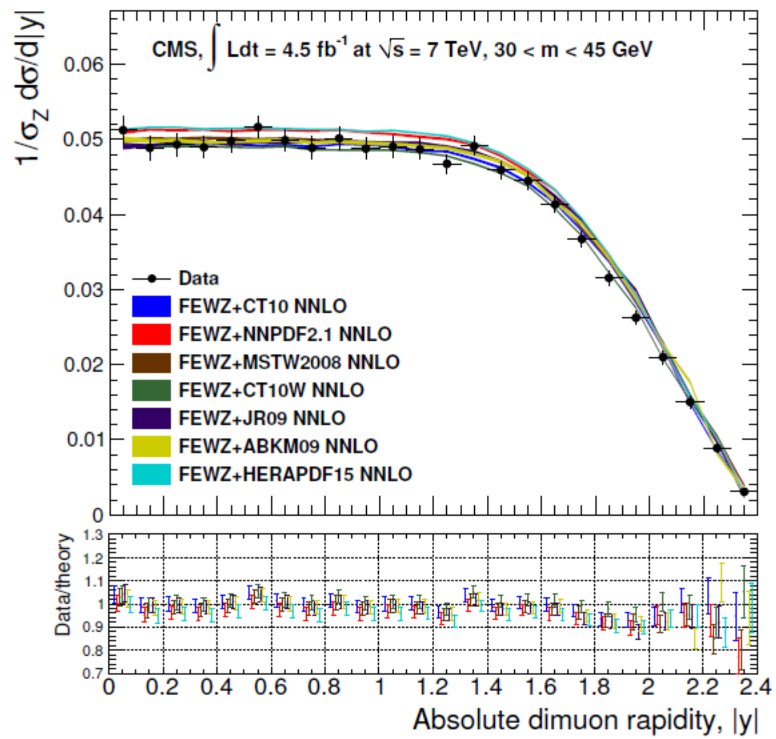
CMS Collaboration: [JHEP12 (2013) 030]

2011 7 TeV ∫Ldt = 4.8 fb^{-1} (dielectron)

2011 7 TeV ∫Ldt = 4.5 fb^{-1} (dimuon)

This is the first double differential Drell-Yan cross section measurement with a hadron collider and will provide precise inputs to update PDF sets.





CMS Collaboration: [Eur. Phys. J. C (2015) 75:147]
2012 8 TeV $\int Ldt = 19.7\ fb^{-1}$

Measurement done both in e and μ channels, results combined.

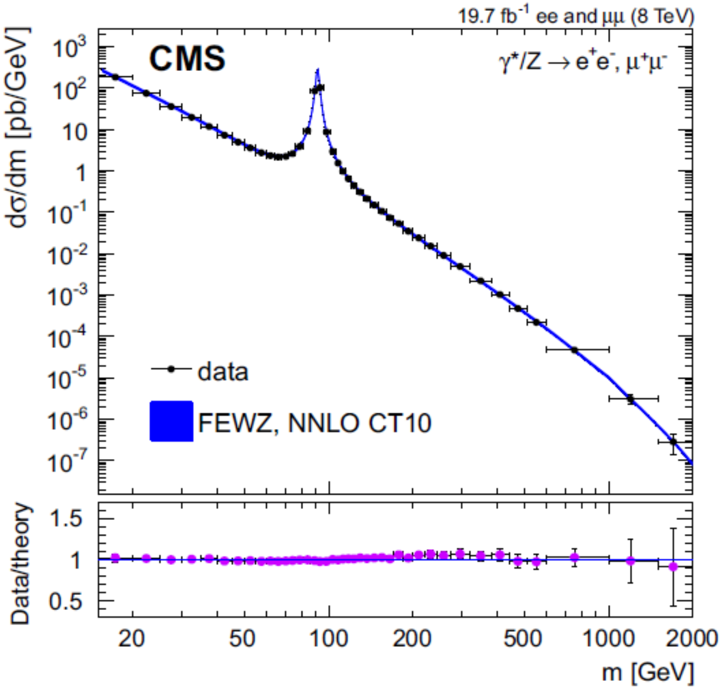
$\frac{d\sigma}{dm}$:

$15 < m_{ll}[GeV] < 2000$

$\frac{d^2\sigma}{dm d|y|}$:

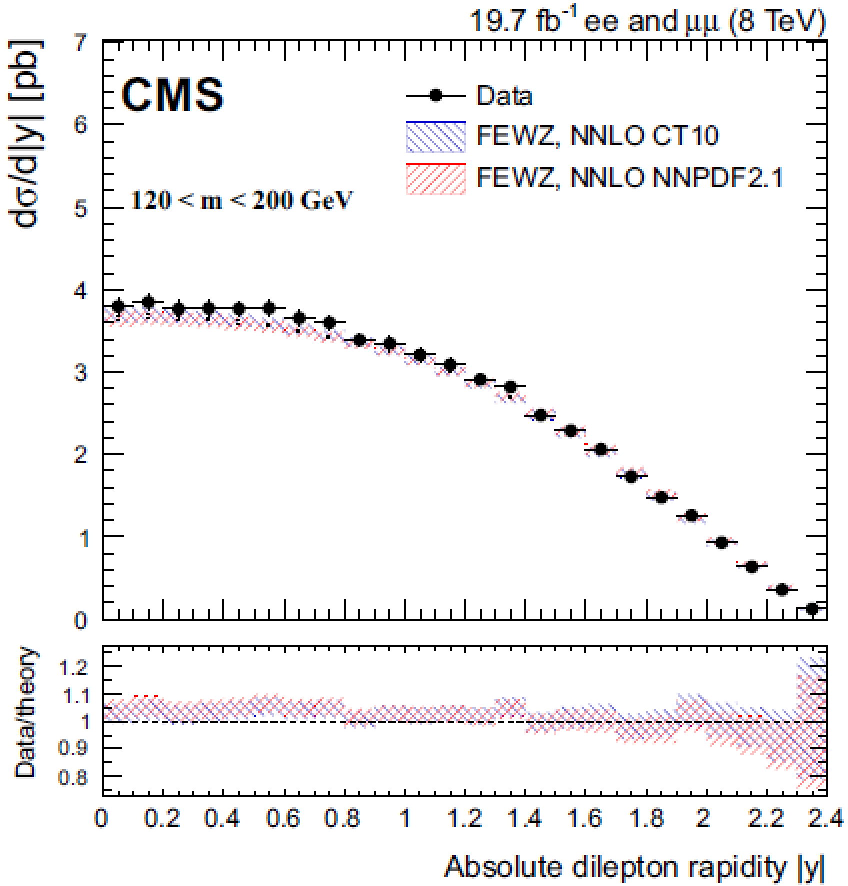
$20 < m_{ll}[GeV] < 1500$

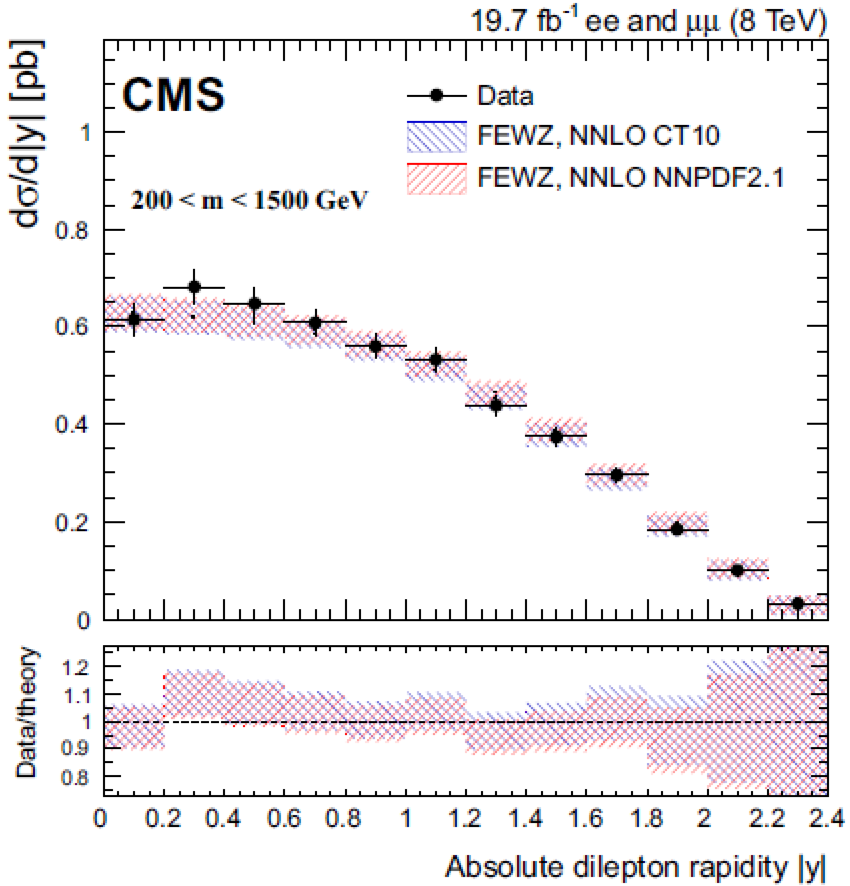
Results compared with NNLO QCD and NLO EW predictions using CT10 NNLO and NNPDF2.1 PDFs.



CMS Collaboration: [Eur. Phys. J. C (2015) 75:147]
2012 8 TeV $\int Ldt = 19.7\ fb^{-1}$

The measured double differential cross section is compared to the NNLO prediction with two PDFs. Both predictions agree with data within uncertainties





Pt , Φ* and rapidity distribution of Z boson

ATLAS

[Phys. Lett. B720 (2013) 32-51]
2011 7 TeV ∫Ldt = 4.6 fb^{-1}

[JHEP09 (2014) 145]
2011 7 TeV ∫Ldt = 4.7 fb^{-1}

CMS

[Phys. Rev. D85, 032002 (2012)]
2010 7 TeV ∫Ldt = 36 pb^{-1}

[CMS PAS SMP-12-025]
2012 8 TeV ∫Ldt = 18.4 pb^{-1}

[arXiv:1504.03511v1]
2012 8 TeV ∫Ldt = 19.7 fb^{-1}

ATLAS Collaboration: [JHEP09 (2014) 145] 2011
7 TeV $\int Ldt = 4.7\ fb^{-1}$

Channels $Z/\gamma^* \to e^+e^-,\ Z/\gamma^* \to \mu^+\mu^-$ and combined

Normalized differential cross sections as a function of Z/γ^* transverse momentum and Φ^*_η measured at rapidity bins

$|y_Z| < 1,\ 1 < |y_Z| < 2$ and $2 < |y_Z| < 2.4$

Data are compared with FEWZ, DDYNLO, RESBOS, NNLO+NNLL, PYTHIA6-AUET2B, POWHEG+PYTHIA6-AUET2B, MC@NLO, ALPGEN and SHERPA
The P_T^Z and Φ^*_η measurements were used to tune PYTHIA8 and POWHEG+PYTHIA8 generators. Here

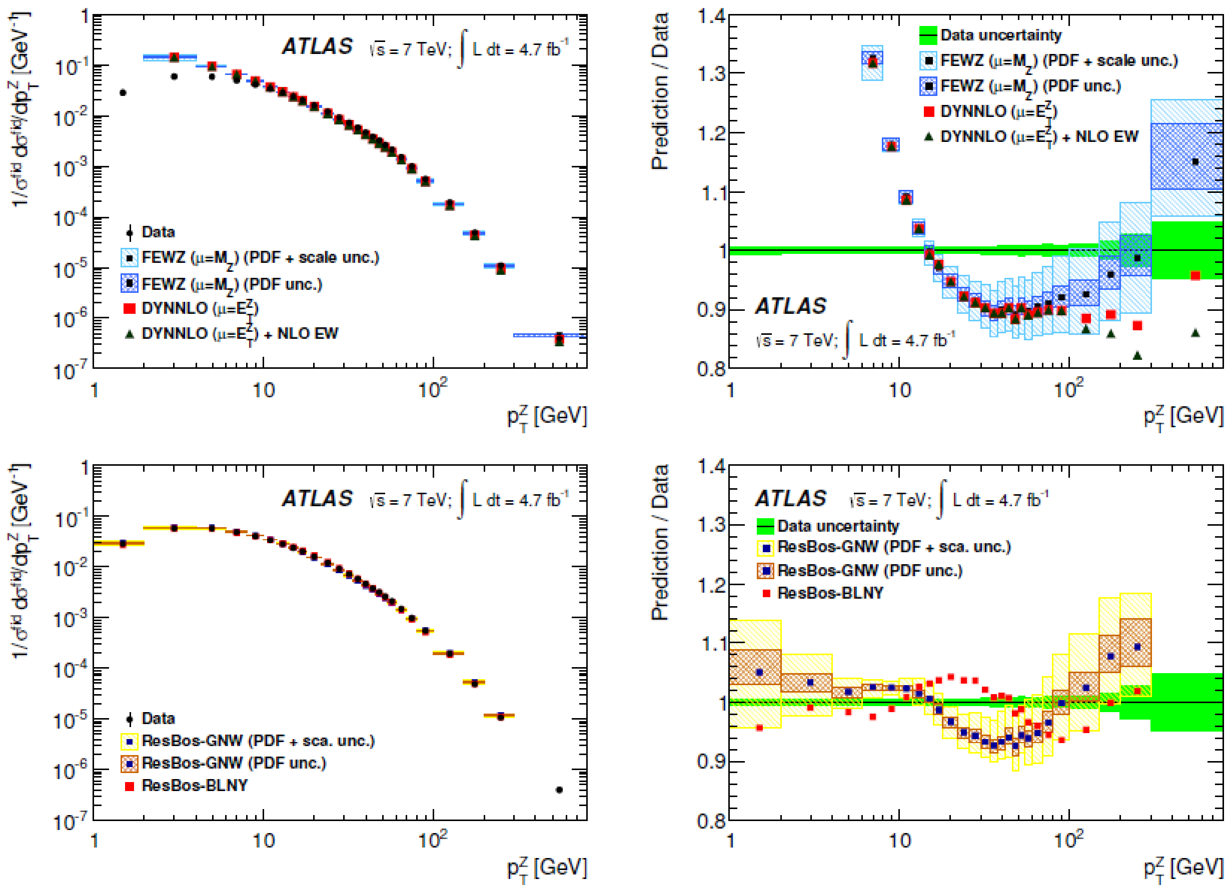
$$\Phi^*_\eta \equiv \tan\left(\frac{\pi - \Delta\Phi}{2}\right).\sin(\theta^*_\eta)$$

$$\cos(\theta^*_\eta) = \tanh((\eta^- - \eta^+)/2)$$

$\Delta\Phi$: azimuthal opening angle between the two leptons

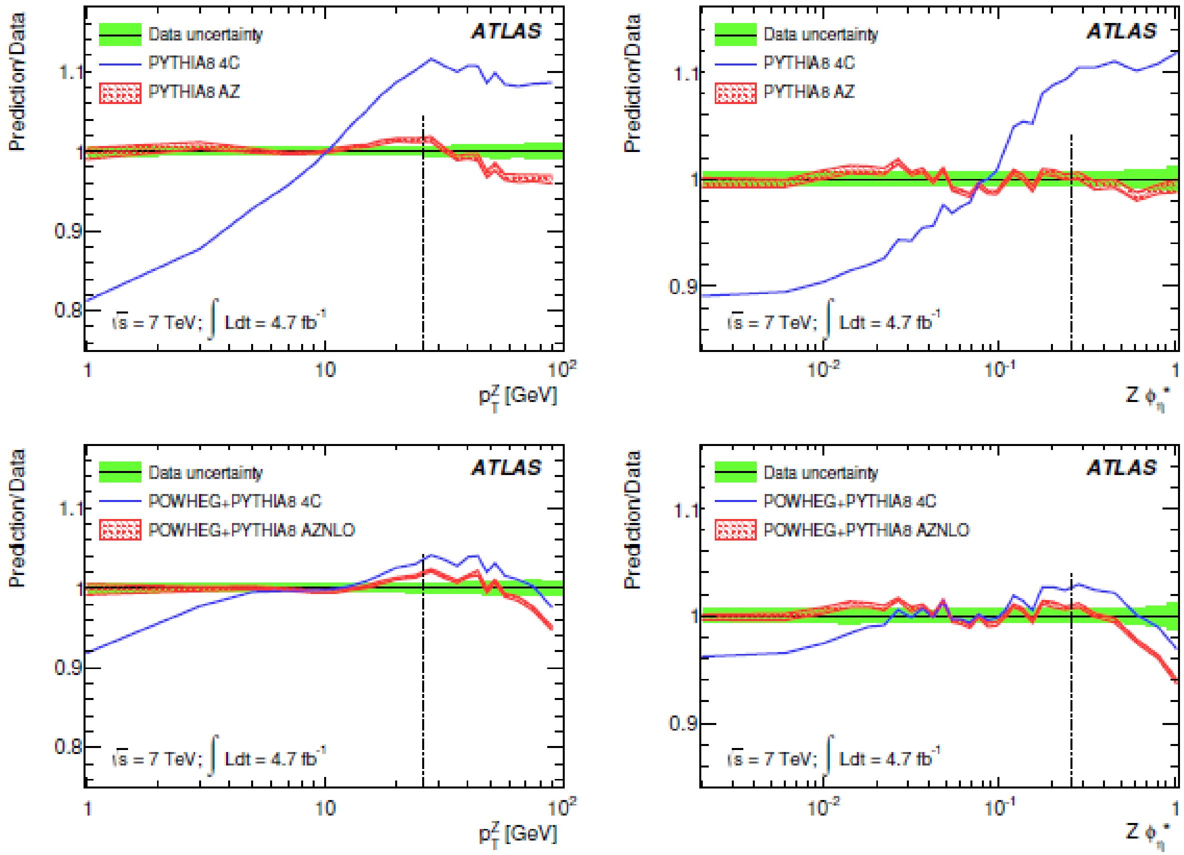
ATLAS Collaboration: [JHEP09 (2014) 145] 2011
7 TeV $\int Ldt = 4.7\ fb^{-1}$

Fixed order NNLO predictions **FEWZ** and **DYNNLO** can describe data only at large transverse momenta where radiation of high Pt gluons dominates. Low Pt region is dominated by soft gluon emission modeled by soft gluon resummation included in **RESBOS**.



ATLAS Collaboration: [JHEP09 (2014) 145] 2011
7 TeV ∫Ldt = 4.7 fb^{-1}

Comparison of tuned predictions of **PYTHIA8** and **POWHEG + PYTHIA8** to the P_T^Z and Φ_η^* differential cross sections. Prediction of base tune is always shown by the blue line.



CMS Collaboration: [arXiv:1504.03511v1]
2012 8 TeV $\int Ldt = 19.7\ fb^{-1}$

Channel $Z/\gamma^* \to \mu^+\mu^-$

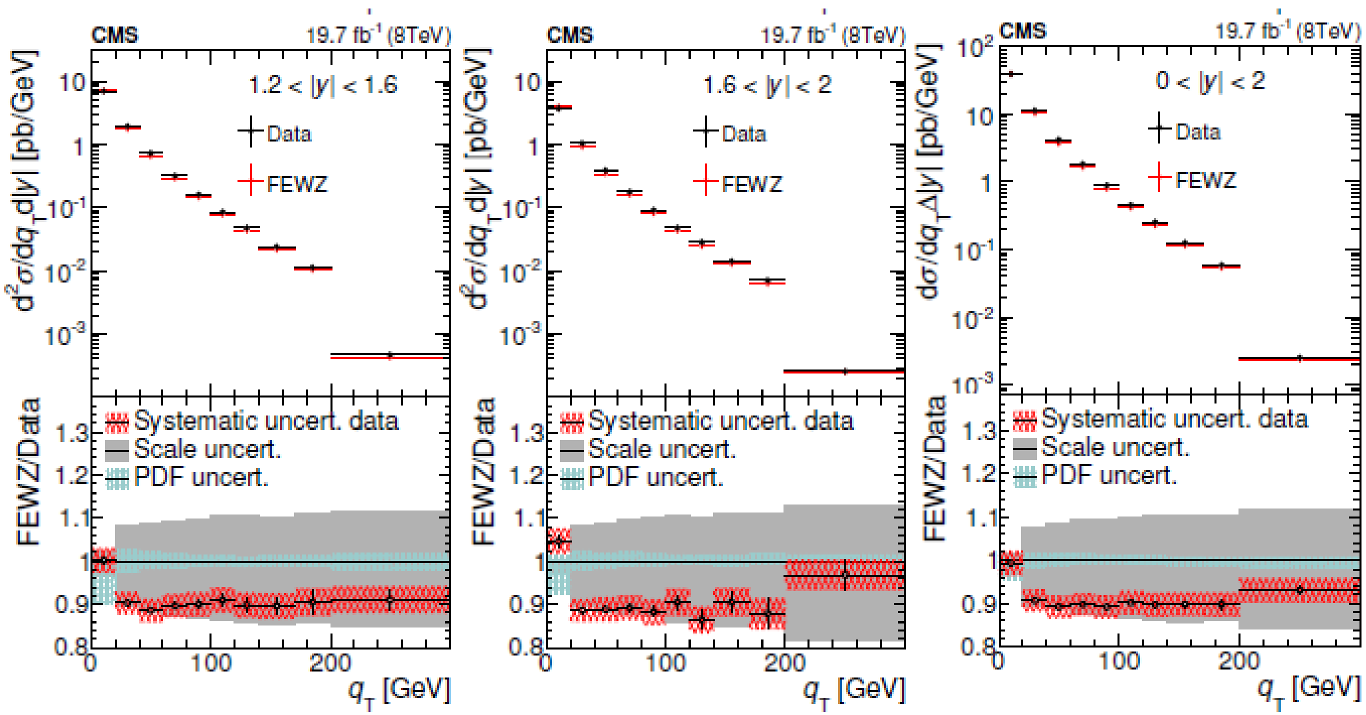
Differential cross section as a function of the Z transverse momentum measured at six rapidity bins

$|y_Z| < 0.4$ $0.4 < |y_Z| < 0.8$ $0.8 < |y_Z| < 1.2$
$1.2 |y_Z| < 1.6$ $1.6 < |y_Z| < 2$ $|y_Z| < 2$

Data are compared to FEWZ with NNLO PDF NNPDF23, MADGRAPH with CTEQ6L1(LO) and POWHEG with CT10(NLO)

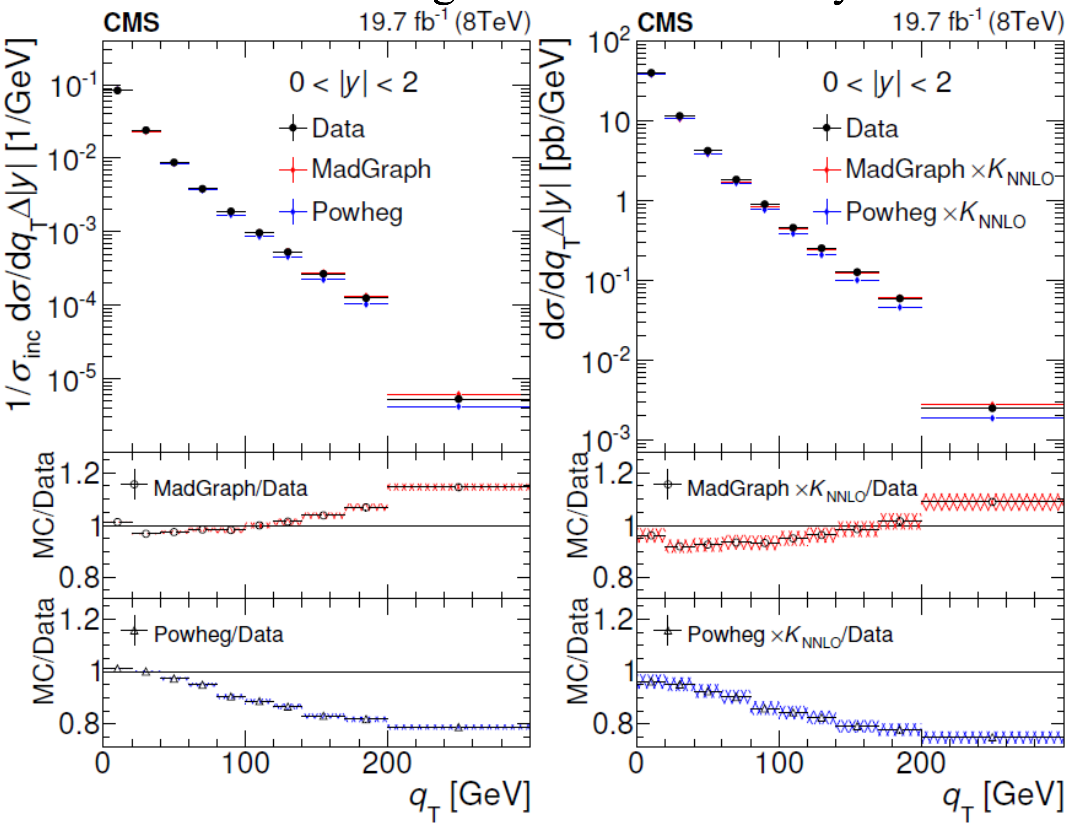
CMS Collaboration: [arXiv:1504.03511v1]
2012 8 TeV $\int Ldt = 19.7\ fb^{-1}$

The measured absolute fiducial Z boson differential cross section as a function of Z transverse momentum q_T compared to the NNLO prediction of **FEWZ**. Prediction agrees with data within the scale uncertainties. The shape is predicted correctly. For the lowest Pt bin, the ratio **FEWZ**/Data is different from the high Pt bins – as expected for the fixed order prediction.



CMS Collaboration: [arXiv:1504.03511v1]
2012 8 TeV $\int L dt = 19.7\ fb^{-1}$

The measured fiducial Z boson differential cross section as a function of Z transverse momentum q_T compared to the LO prediction of **MADGRAPH** and NLO prediction of **POWHEG**. Left plot shows normalised distributions, right plot shows absolute cross sections. MC cross sections in the right plot are corrected to NNLO level using K factors created by **FEWZ**.



Production of W and Z in association with jets

ATLAS

[JHEP07 (2011) 032]
2011 7 TeV $\int Ldt = 4.6\ fb^{-1}$

[Eur. Phys. J. C (2014) 74:3168]
2011 7 TeV $\int Ldt = 4.6\ fb^{-1}$

[Eur. Phys. J. C (2015) 75:82]
2011 7 TeV $\int Ldt = 4.6\ fb^{-1}$

CMS

[JHEP01 (2012) 010]
2010 7 TeV $\int Ldt = 36\ pb^{-1}$

[Phys. Rev. D91, 052008 (2015)]
2011 7 TeV $\int Ldt = 4.9\ fb^{-1}$

[Phys. Lett. B 741 (2015) 12 - 37]
2011 7 TeV $\int Ldt = 5\ fb^{-1}$

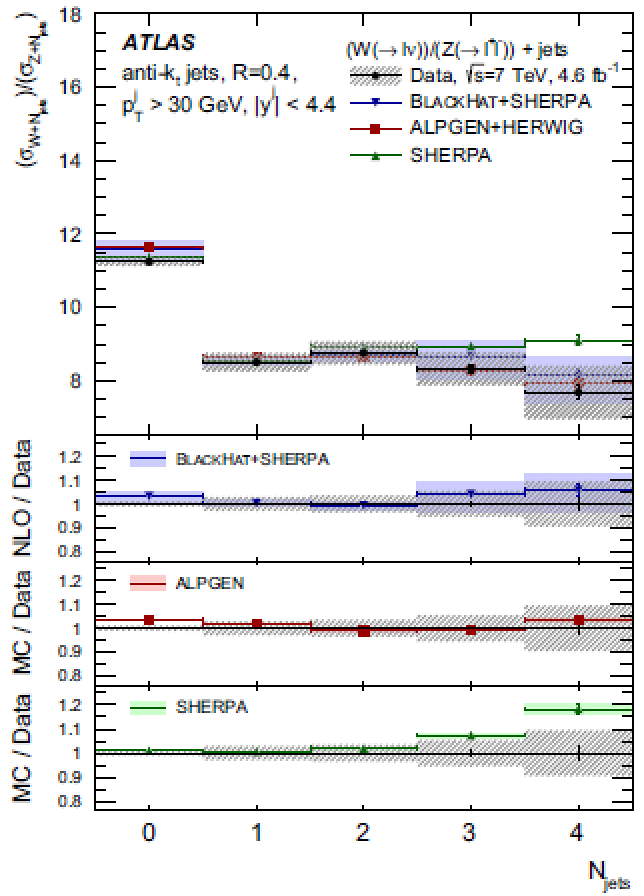
[CMS PAS SMP-13-007]
2012 8 TeV $\int Ldt = 19.6\ fb^{-1}$

[CMS PAS SMP-14-009]
2012 8 TeV $\int Ldt = 19.6\ fb^{-1}$

ATLAS Collaboration: [Eur. Phys. J. C (2014) 74:3168]
2011 7 TeV $\int Ldt = 4.6\ fb^{-1}$

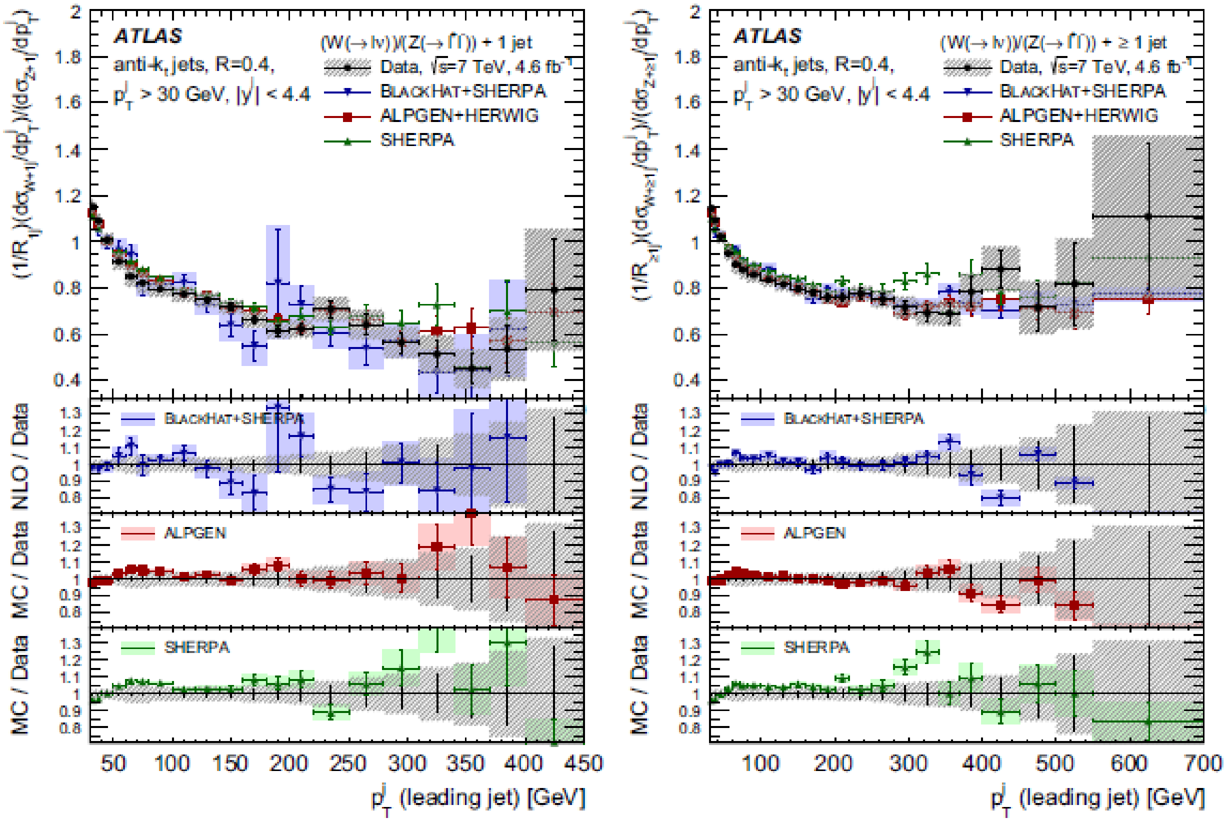
A measurement of the ratio of the production cross sections for *W* and *Z* bosons in association with jets with the ATLAS detector

Measurement of ratios of cross sections of W and Z provides more precise test of pQCD with respect the W/Z + jets measurement because of the cancelations of experimental uncertainties (luminosity, jet energy scale) and effects from non-perturbative processes (hadronization and multiparton interactions).



ATLAS Collaboration: [Eur. Phys. J. C (2014) 74:3168]
2011 7 TeV $\int Ldt = 4.6\ fb^{-1}$

Fall of the ratio in the low Pt region is due to the W and Z boson mass difference, which affects the scale of parton radiation, and due to the different vector boson polarization affecting kinematics of their decay products. ALPGEN provides best description of data.



SUMMARY RUN 1

- Both Collaborations produced nearly 60 publications dealing with W/Z Physics in total
- Wide range of topics is covered
- Typical achieved precision of published values of integrated W and Z cross sections is at the level of few %, both for 7 TeV and 8 TeV data
- Analysis of data taken in the years 2010 and 2011 is nearly completed
- Analysis of 8 TeV data from the year 2012 is still ongoing
- Predictions of Standard model were tested in most cases at NLO accuracy or higher

Summary
Run 2 Expectations

- New kinematic regime: $\sqrt{s}$: 8 TeV → 13 TeV (factor ≈ 1.6)
- Expected luminosities: $L_{\text{int}}^{2015} \geq 10\, fb^{-1}$, $L_{\text{int}}^{2018} \geq 100\, fb^{-1}$
- Short term (using 2015 data) : benchmark integrated and differential cross sections. Basic tests of Standard Model in the new kinematic region.
- 14 millions of W^-, 20 millions of W^+ and 4 millions of Z expected in full 2015 data