

Latest 13 TeV results from ATLAS

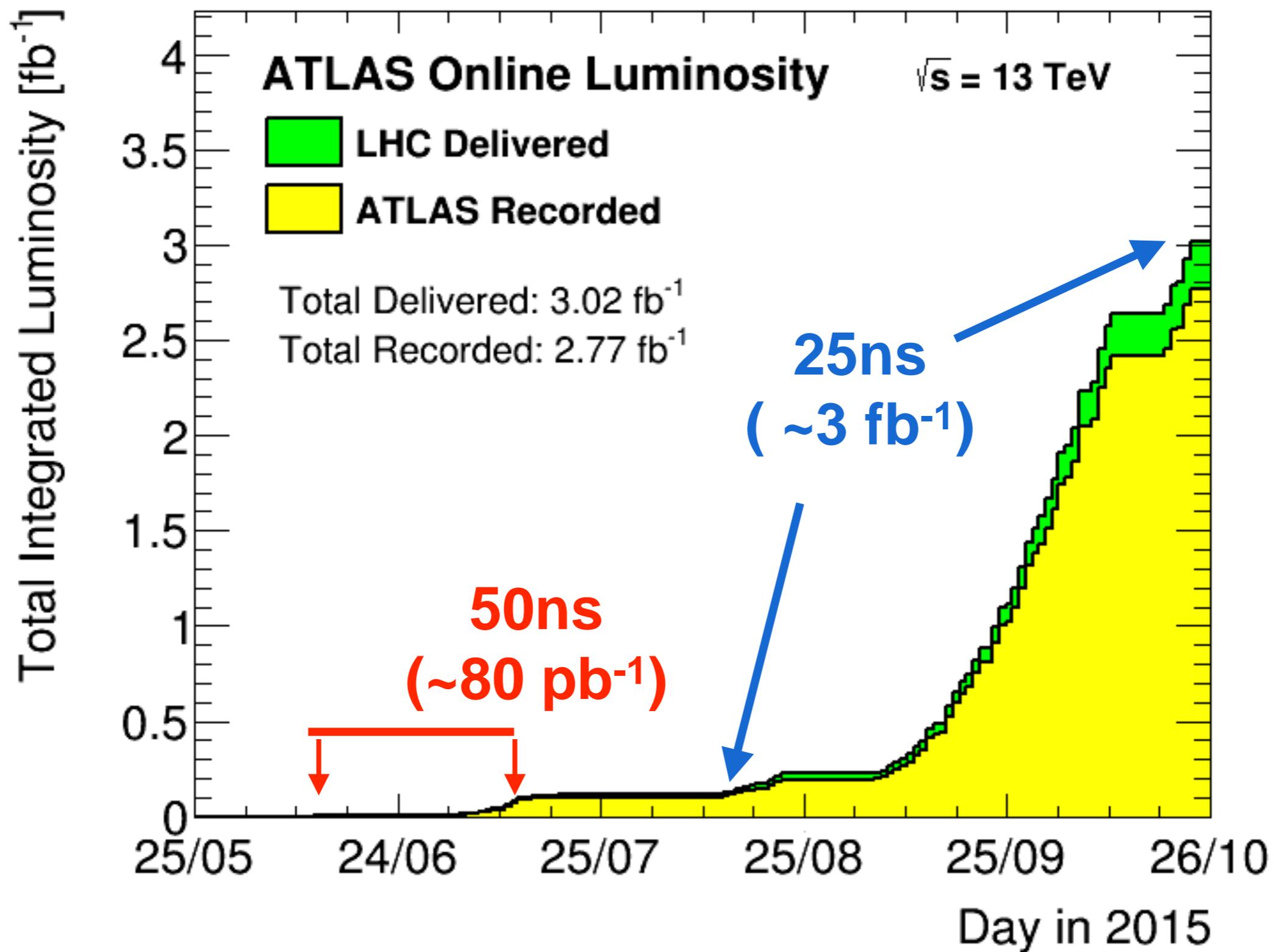


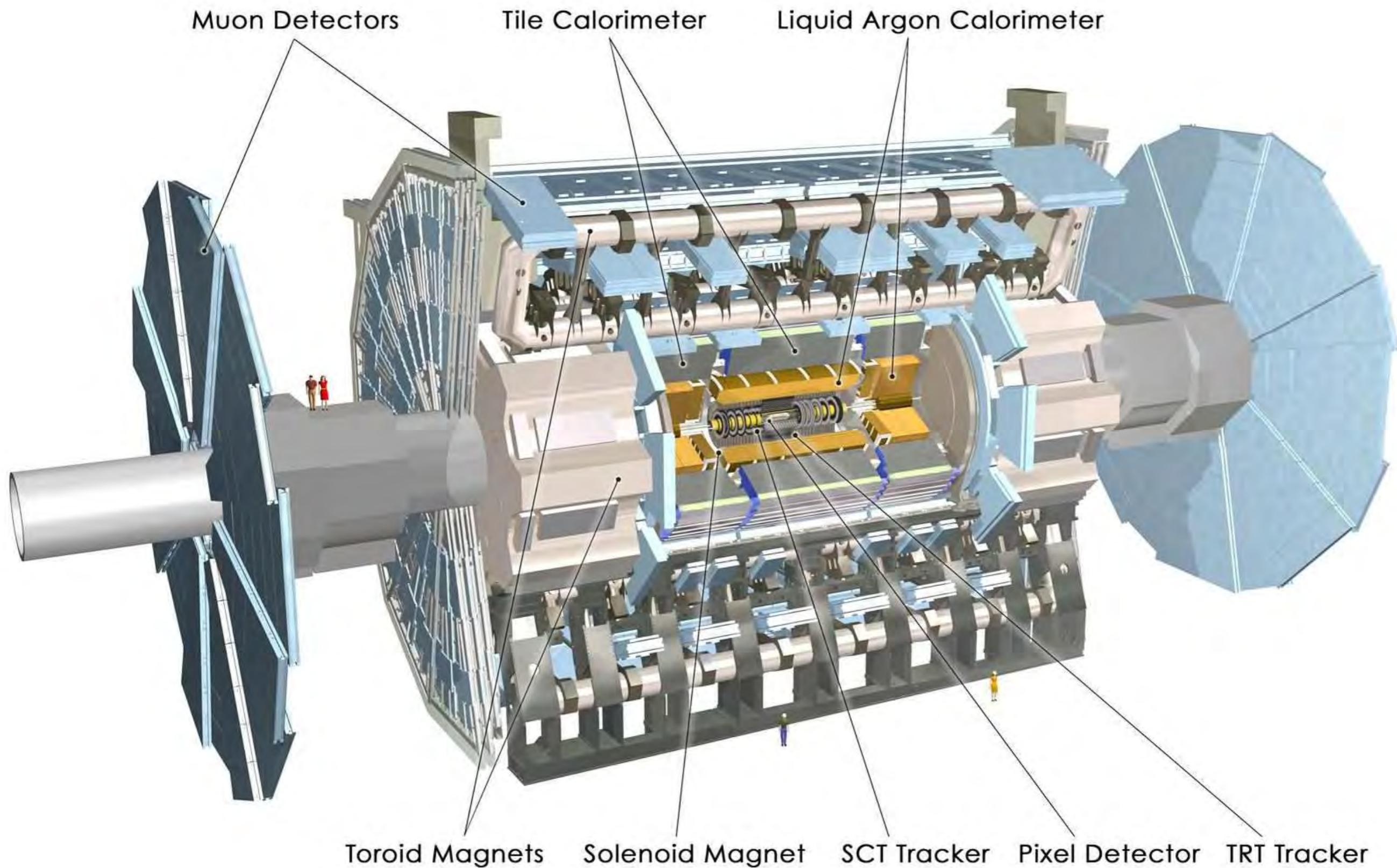
LHC New and Improved!

- **New Energy:** 6.5 TeV per beam
- Data taking starting in June 2015
- 80 pb⁻¹ at 50ns followed by short break.
- 4fb at 25ns, finishing **3rd November!**

| | | | | | | | Sep | | | | | | |
|----|-------------|-----------------------------------|--|------|--|-----------------------------------|------|-----|-----|---------|----|----|----|
| | | | | | | | 34 | 35 | 36 | 37 | 38 | 39 | |
| W | | | | | | | 17 | VdM | 24 | 31 | 7 | 14 | 21 |
| M | | | | | | | | | | | | | |
| Tu | | | | | | | | | | | | | |
| We | Leap second | | | MD 1 | | | | | TS2 | | | | |
| Th | | Intensity ramp-up with 50 ns beam | | | | Intensity ramp-up with 25 ns beam | | | | Jeune G | | | |
| Fr | | | | | | | MD 2 | | | | | | |
| Sa | | | | | | | | | | | | | |
| Su | | | | | | | | | | | | | |

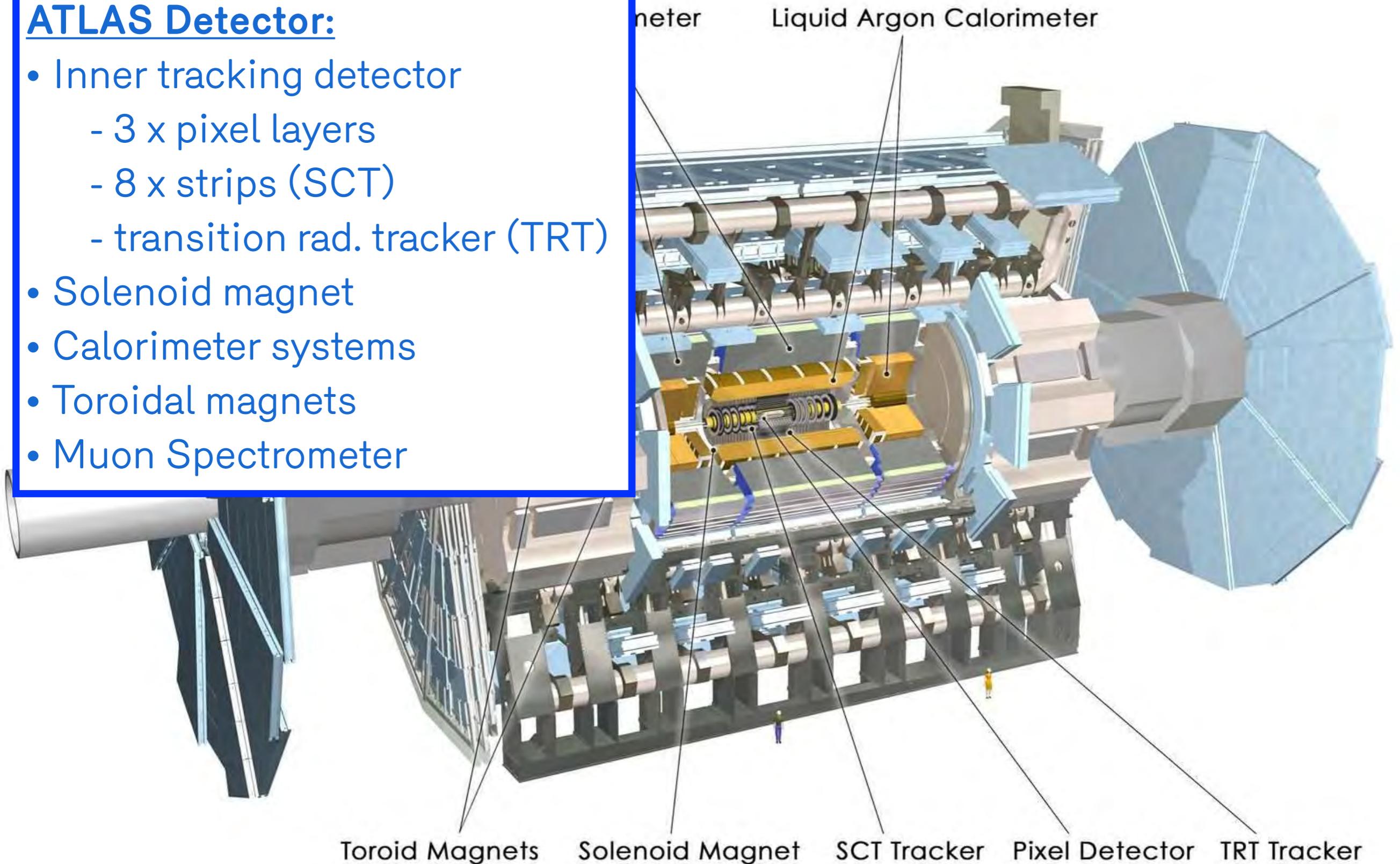
| Oct | | | | Nov | | | | Dec | | | | End physics [06:00] | |
|-----|----|----|--------------------|-----|----|------|-----|------------|----|--------|----|---------------------|------|
| Wk | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 |
| Mo | 28 | 5 | 12 | 19 | 26 | 2 | 9 | 16 | 23 | 30 | 7 | 14 | 21 |
| Tu | | | | | | | | Ions setup | | | | Technical stop | |
| We | | | Special physic run | | | | TS3 | | | low MD | | | |
| Th | | | | | | | | | | | | | |
| Fr | | | | | | MD 3 | | | | IONS | | | Xmas |
| Sa | | | | | | | | | | | | | |
| Su | | | | | | | | | | | | | |





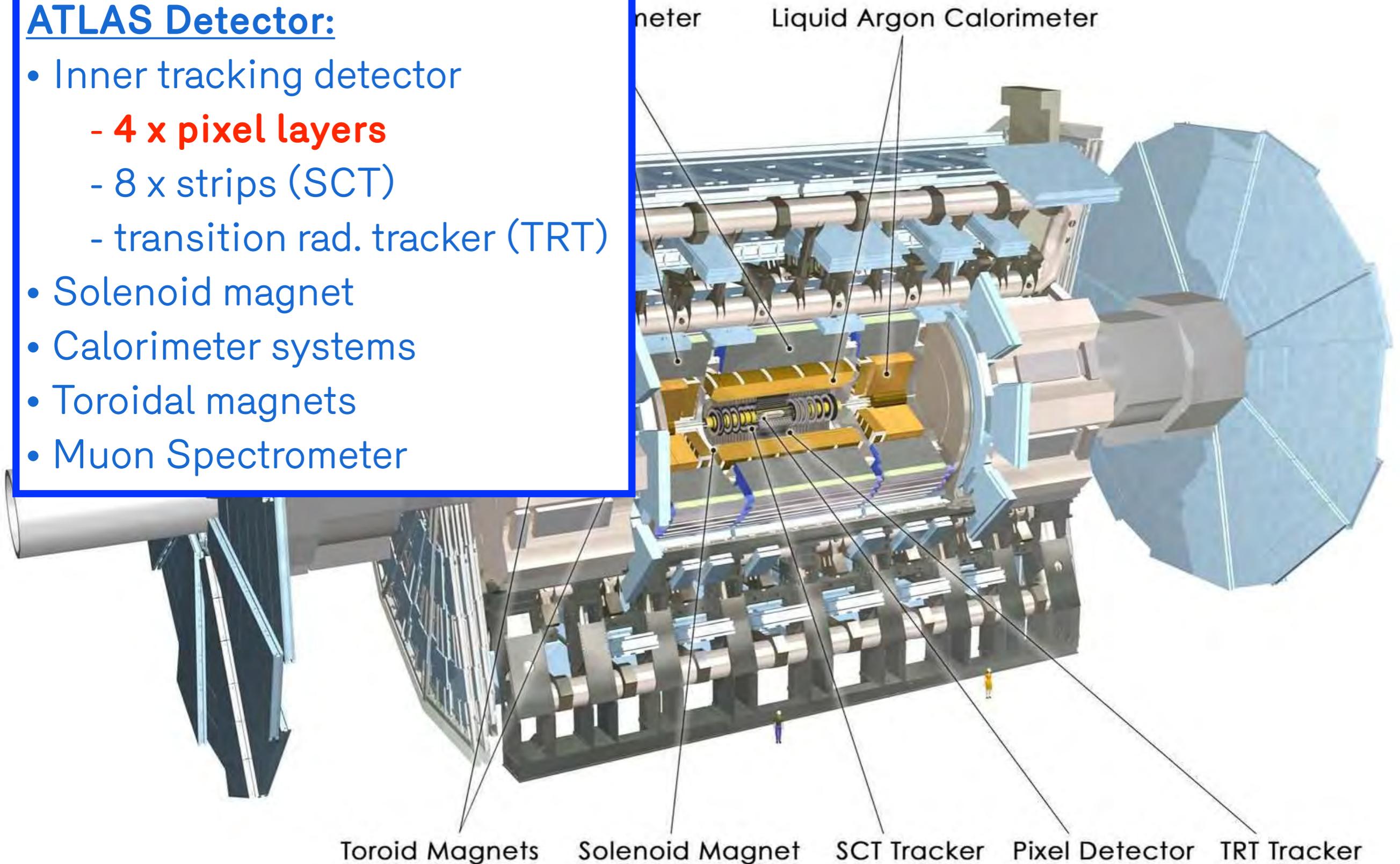
ATLAS Detector:

- Inner tracking detector
 - 3 x pixel layers
 - 8 x strips (SCT)
 - transition rad. tracker (TRT)
- Solenoid magnet
- Calorimeter systems
- Toroidal magnets
- Muon Spectrometer



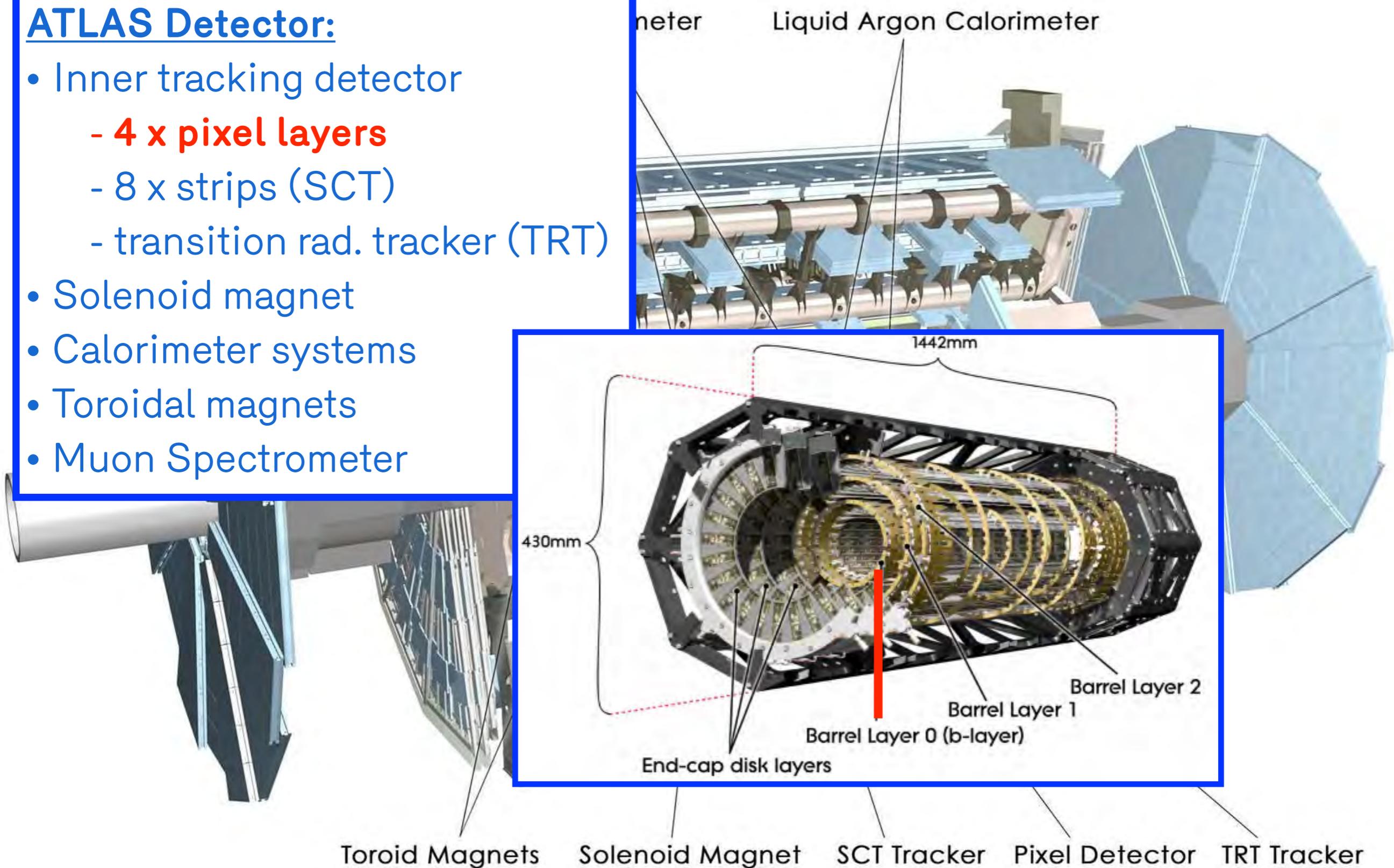
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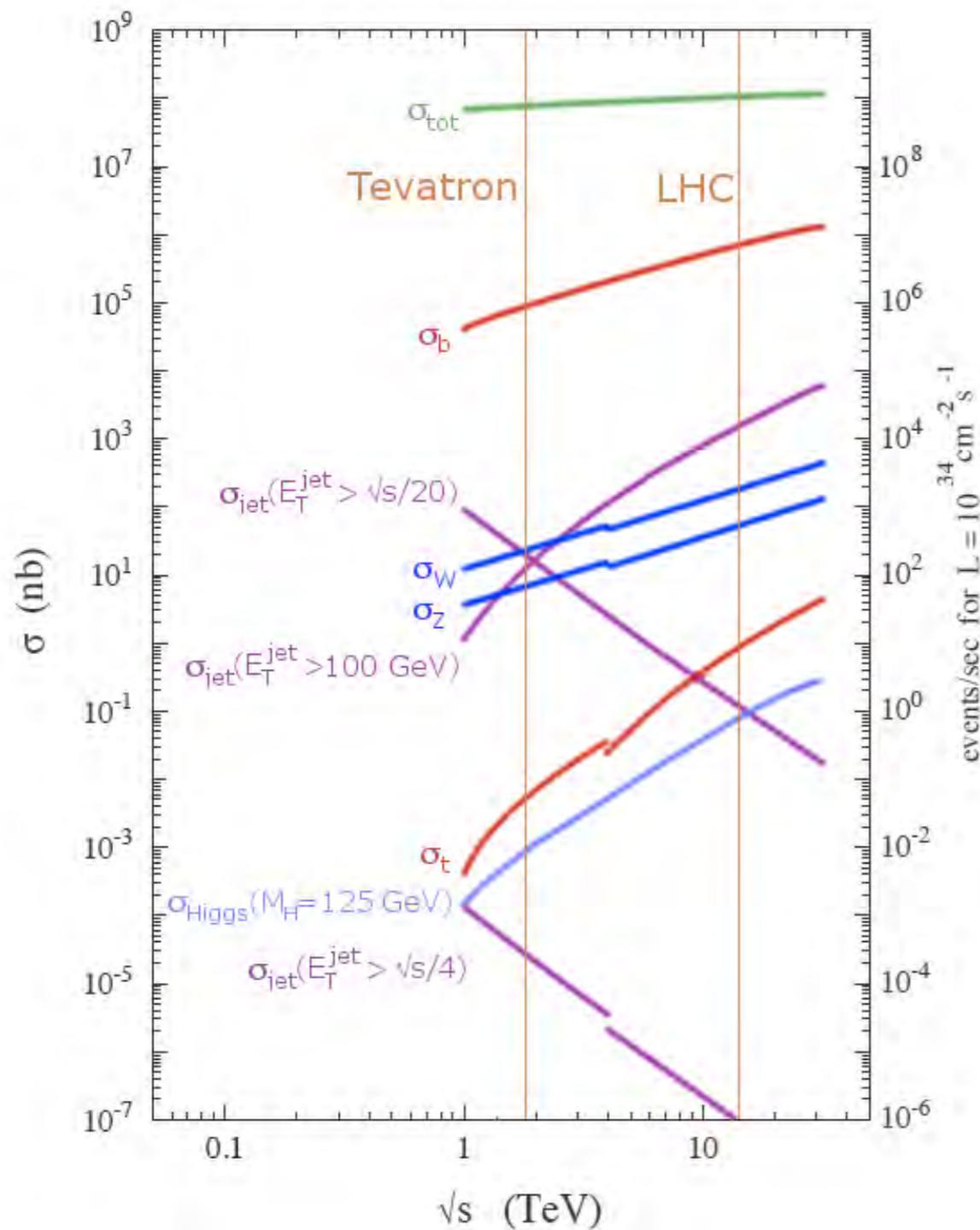
- Inner tracking detector
 - **4 x pixel layers**
 - 8 x strips (SCT)
 - transition rad. tracker (TRT)
- Solenoid magnet
- Calorimeter systems
- Toroidal magnets
- Muon Spectrometer



ATLAS Detector:

- Inner tracking detector
 - **4 x pixel layers**
 - 8 x strips (SCT)
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- Muon Spectrometer

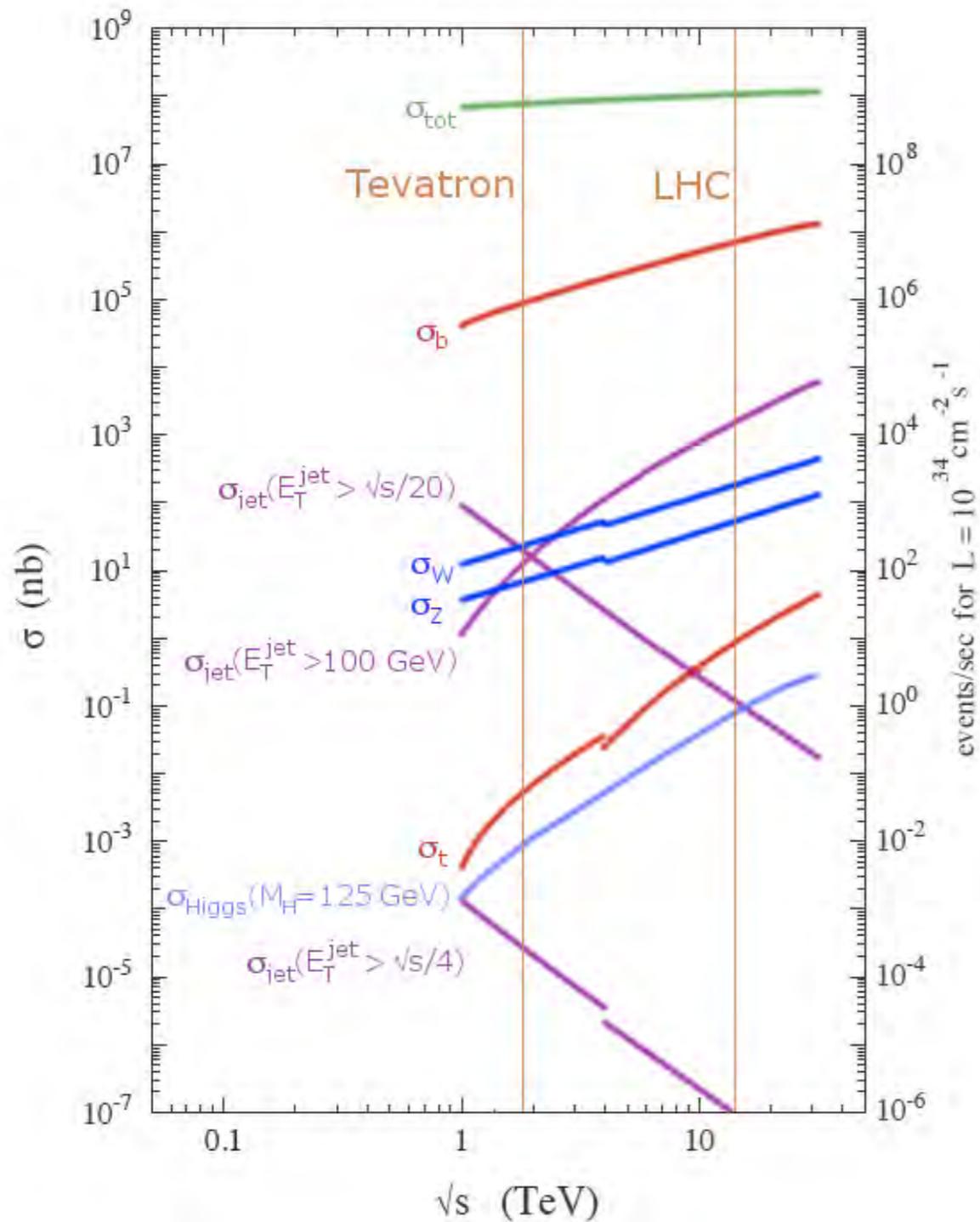




| Energy | 7 TeV | 8 TeV | 13 TeV |
|----------------------|-------|-------|--------|
| $\sigma(W-l\nu)$ | 10455 | 12087 | 20080 |
| $\sigma(Z-l\bar{l})$ | 964 | 1122 | 1906 |
| $\sigma(gg-H)$ | 15 | 19 | 44 |
| $\sigma(t\bar{t})$ | 177 | 253 | 832 |
| $\sigma(t\bar{t}H)$ | 0.09 | 0.13 | 0.5 |

*References in backup.

- New energy \rightarrow different cross-sections in many SM processes.
- Important to quickly test and understand as all of these processes are key backgrounds in searches.



| Ratio | 7 / 7 | 8 / 7 | 13 / 7 |
|----------------------|-------|-------|------------|
| $\sigma(W-l\nu)$ | - | 1.2 | 1.9 |
| $\sigma(Z-l\bar{l})$ | - | 1.2 | 2.0 |
| $\sigma(gg-H)$ | - | 1.3 | 3.0 |
| $\sigma(t\bar{t})$ | - | 1.4 | 4.7 |
| $\sigma(t\bar{t}H)$ | - | 1.4 | 5.6 |

*References in backup.

- Many new processes reach measurable rates at 13 TeV.
- Other SM processes (such as $t\bar{t}$) get significant increases in cross-section, relative to Run1.

| Topic | Title | Link | CONF |
|--------------|---|--|-------------|
| Heavy Ion | Two-particle correlations | arXiv: 1509.04776 | Paper |
| Heavy Ion | Forward-backward multiplicity correlations | ATLAS-CONF-2015-051 | QM 2015 |
| QCD / EW | Z + jets cross-section | ATLAS-CONF-2015-041 | LHCP 2015 |
| QCD / EW | Inelastic pp cross-section | ATLAS-CONF-2015-038 | LP 2015 |
| QCD / EW | W, Z cross-section | ATLAS-CONF-2015-039 | LP 2015 |
| QCD / EW | Charged particle multiplicity | ATLAS-CONF-2015-028 | EPS 2015 |
| QCD / EW | Jet cross-section measurement | ATLAS-CONF-2015-034 | EPS 2015 |
| B-Physics | J/Psi non-prompt fraction | ATLAS-CONF-2015-030 | EPS 2015 |
| Top | Top cross-section (l+jets, SF dilep, Z ratio) | ATLAS-CONF-2015-049 | Top 2015 |
| Top | Top cross-section ($e\mu$) | ATLAS-CONF-2015-033 | EPS |
| Exotics | Lepton + jets search | ATLAS-CONF-2015-046 | LHCP 2015 |
| Exotics | Dijet resonance and angular search | ATLAS-CONF-2015-042 | LHCP 2015 |
| Exotics | Multijet search | ATLAS-CONF-2015-043 | LHCP 2015 |

Full list here: <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Summer2015-13TeV>

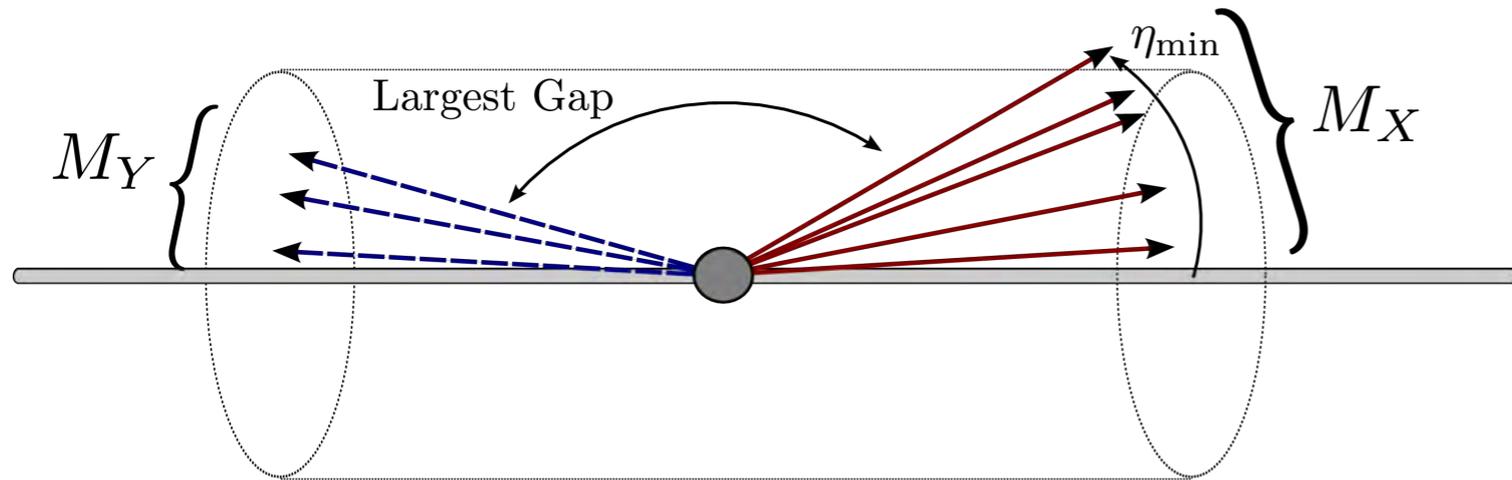
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Inelastic cross-section

$$\sigma_{\text{inel}} =$$

+ non-diffractive processes



$$\tilde{\xi} = \tilde{M}_X^2 / s$$

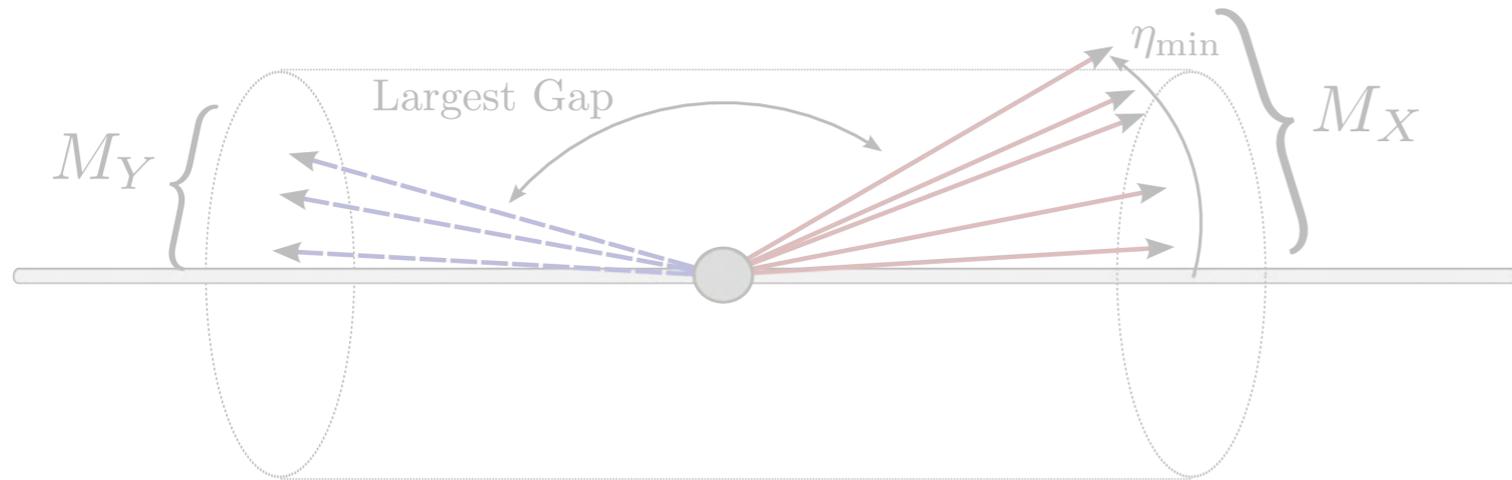
Bounded by $M_X = M_P$

Analysis Strategy:

- Events are triggered using MBTS (plastic scintillating tiles).
- Largest rapidity gap between two hadrons used to define hadron collections.

$$\sigma_{\text{inel}}(\tilde{\xi} > 10^{-6}) = \frac{N - N_{\text{BG}}}{\epsilon_{\text{trig}} \cdot L} \cdot \frac{1 - f_{\tilde{\xi} > 10^{-6}}}{\epsilon_{\text{sel}}}$$

- Fiducial volume defined where $\tilde{\xi}$ is $> 10^{-6}$ (50% offline selection eff.).
- Cross-section extracted using a simple counting strategy.



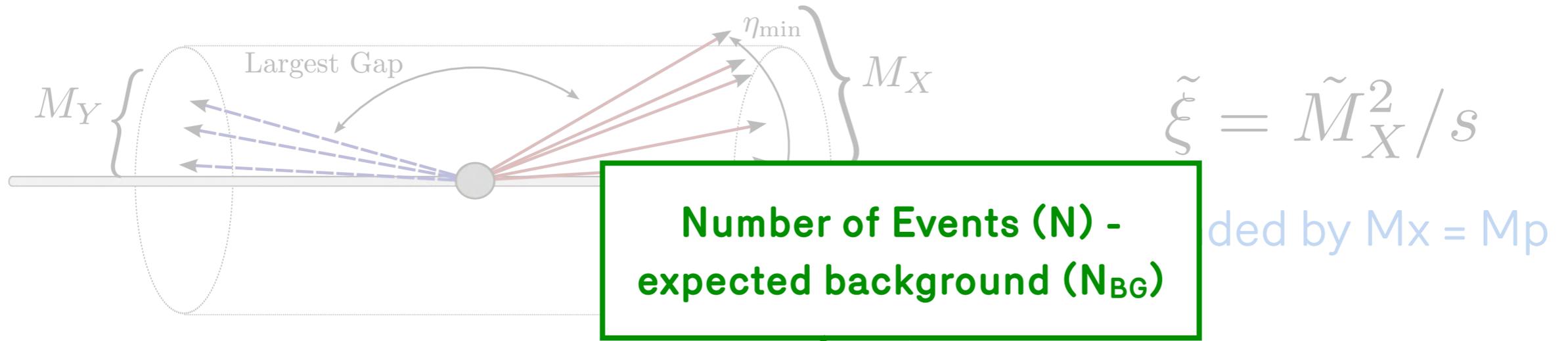
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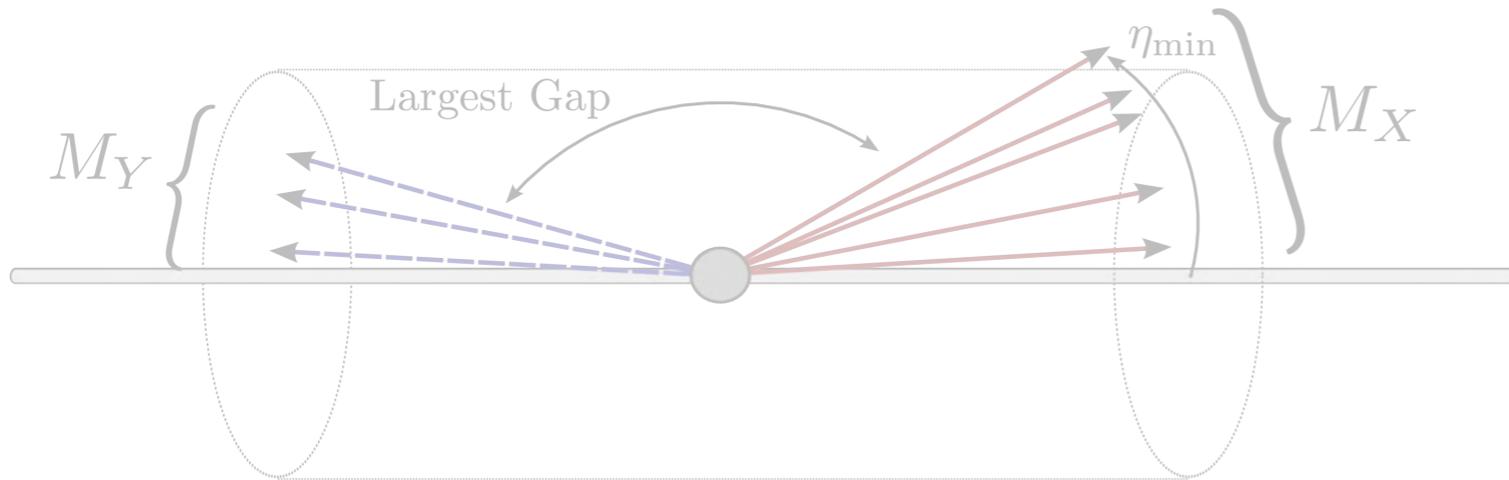
- Fiducial volume defined where
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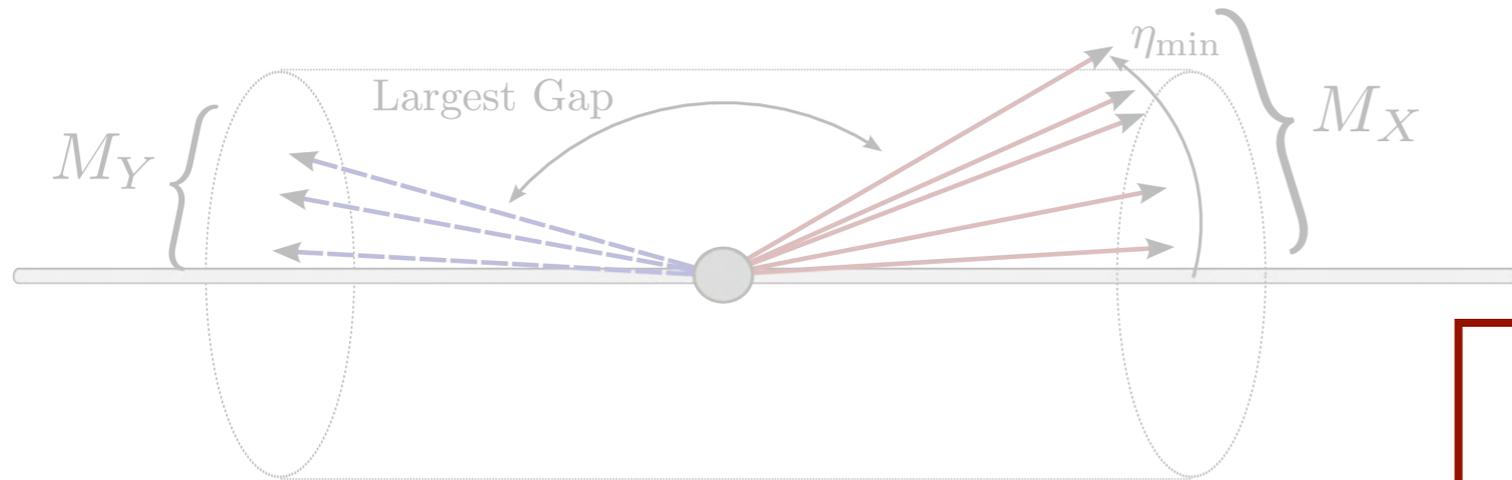
$$\sigma_{\text{inel}}(\tilde{\xi} > 10^{-6}) = \frac{N - N_{\text{BG}}}{\epsilon_{\text{trig}} \cdot L} \cdot \frac{1 - f_{\tilde{\xi} > 10^{-6}}}{\epsilon_{\text{sel}}}$$

- Fiducial volume defined
- Cross-section extracted

Trigger Efficiency

Integrated luminosity
(63 μb^{-1})

Offline selection efficiency



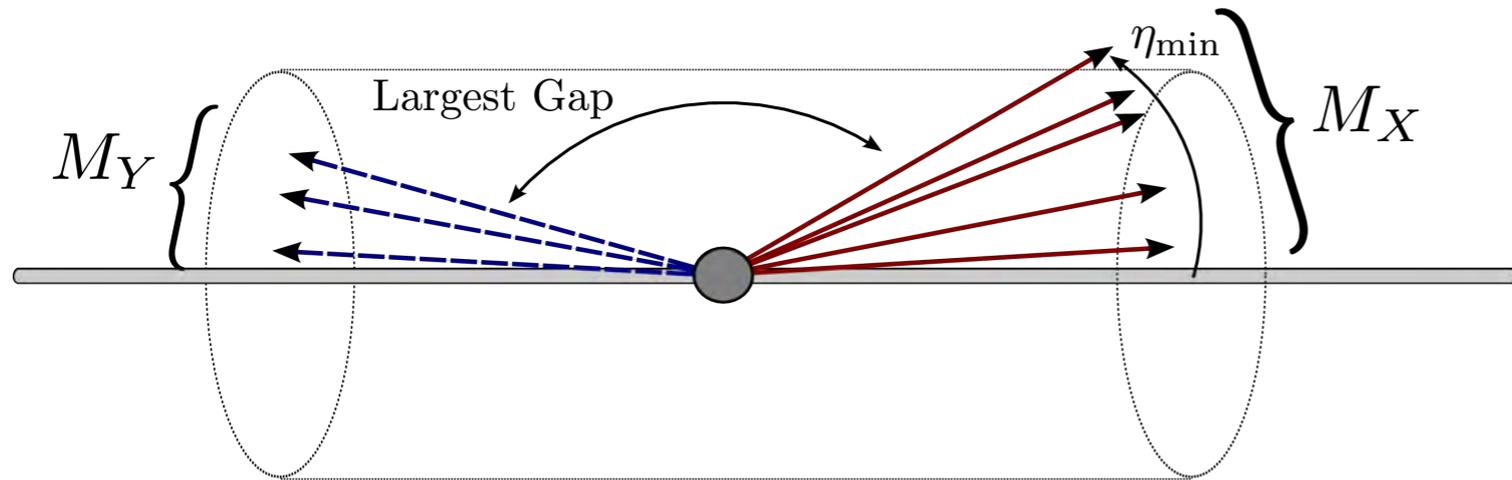
$$\tilde{\xi} = \tilde{M}_X^2 / s$$

**Fraction of events
contaminating fiducial region**

Analysis Strategy:

- $$\sigma_{\text{inel}}(\tilde{\xi} > 10^{-6}) = \frac{N - N_{\text{BG}}}{\epsilon_{\text{trig}} \cdot L} \cdot \frac{1 - f_{\tilde{\xi} > 10^{-6}}}{\epsilon_{\text{sel}}}$$

- Fiducial volume defined where
- Cross-section extracted using a simple counting strategy.



$$\tilde{\xi} = \tilde{M}_X^2 / s$$

Bounded by $M_X = M_P$

Analysis Strategy:

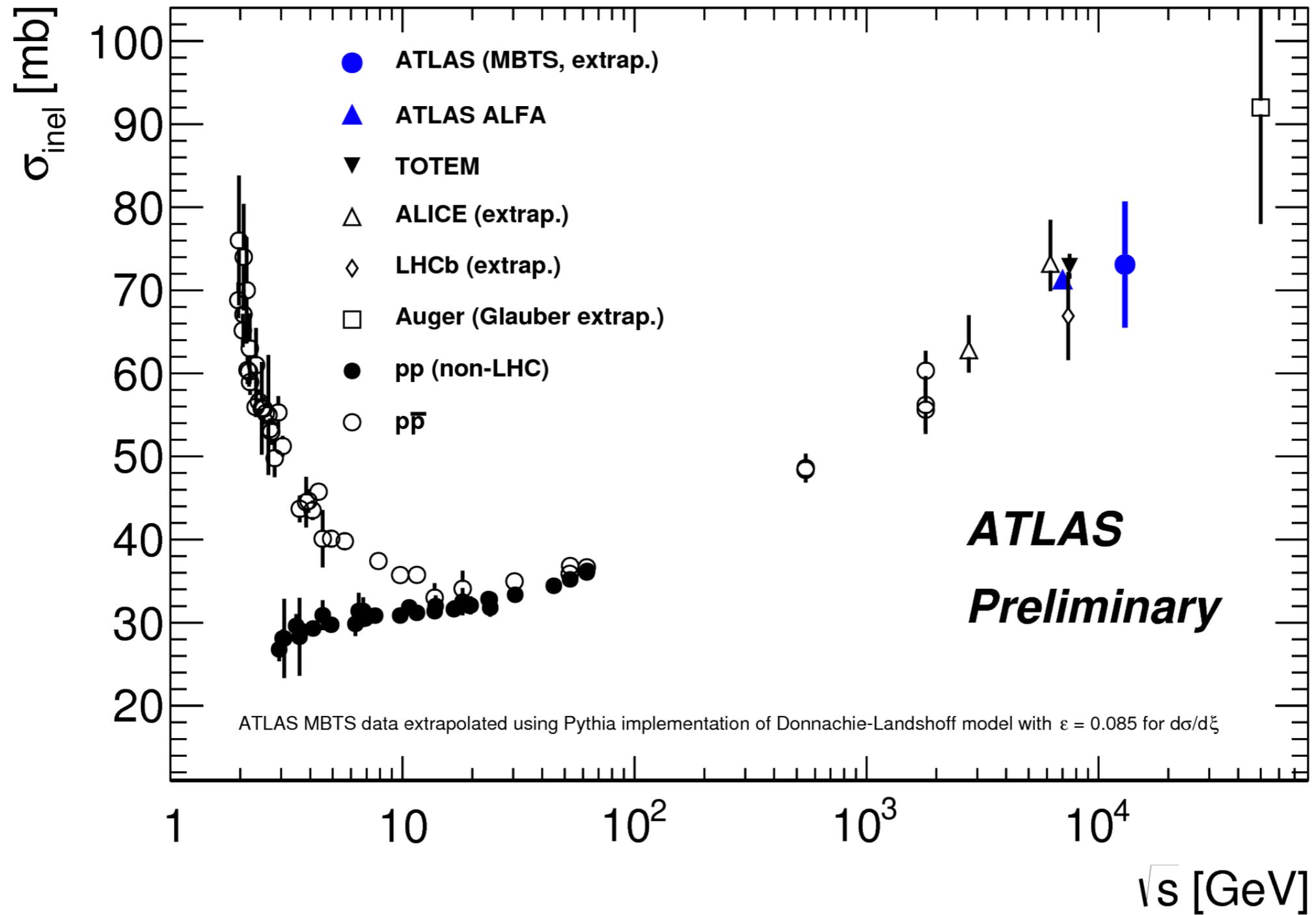
- Events are triggered using MBTS (plastic scintillating tiles) in low $\langle \mu \rangle$ events.
- Largest rapidity gap between two hadrons used to define hadron collections.

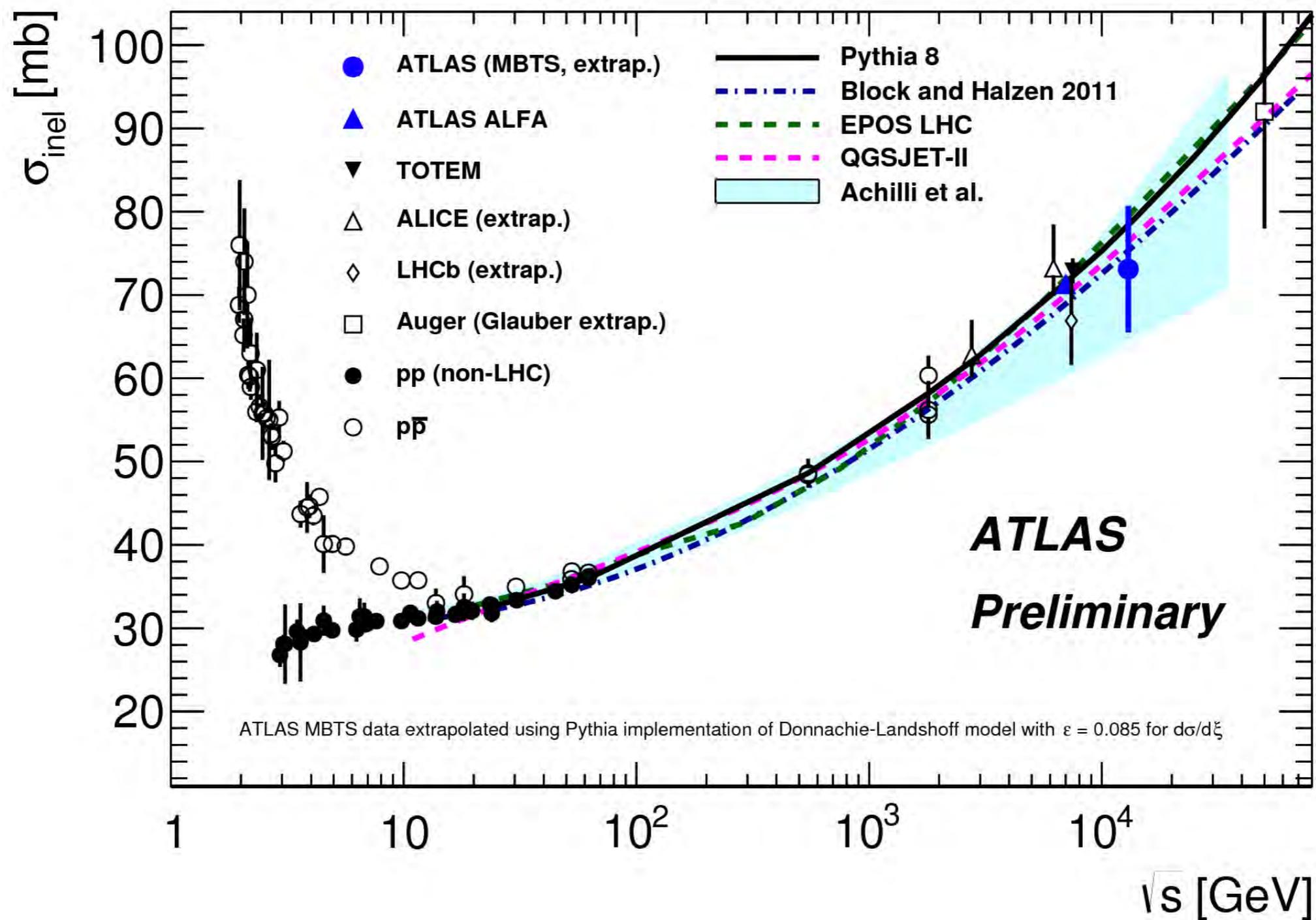
$$\sigma_{\text{inel}}(\tilde{\xi} > 10^{-6}) = \frac{N - N_{\text{BG}}}{\epsilon_{\text{trig}} \cdot L} \cdot \frac{1 - f_{\tilde{\xi} > 10^{-6}}}{\epsilon_{\text{sel}}}$$

- Fiducial volume defined where ξ is $> 10^{-6}$.
- Cross-section extracted using a simple counting strategy.

$$\sigma_{\text{inel}} = 73.1 \pm 0.9 \text{ (exp.)} \pm 6.6 \pm \text{(lumi.)} \pm 3.8 \pm \text{(extr.)} \text{ mb}$$

$$\sigma_{\text{pythia8}} = 78.4 \text{ mb}$$





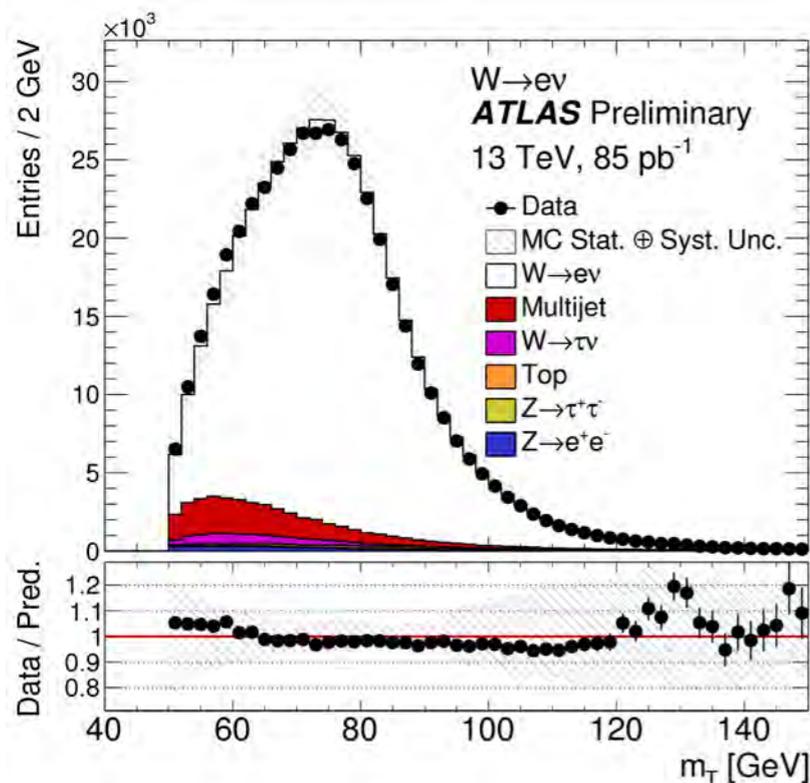
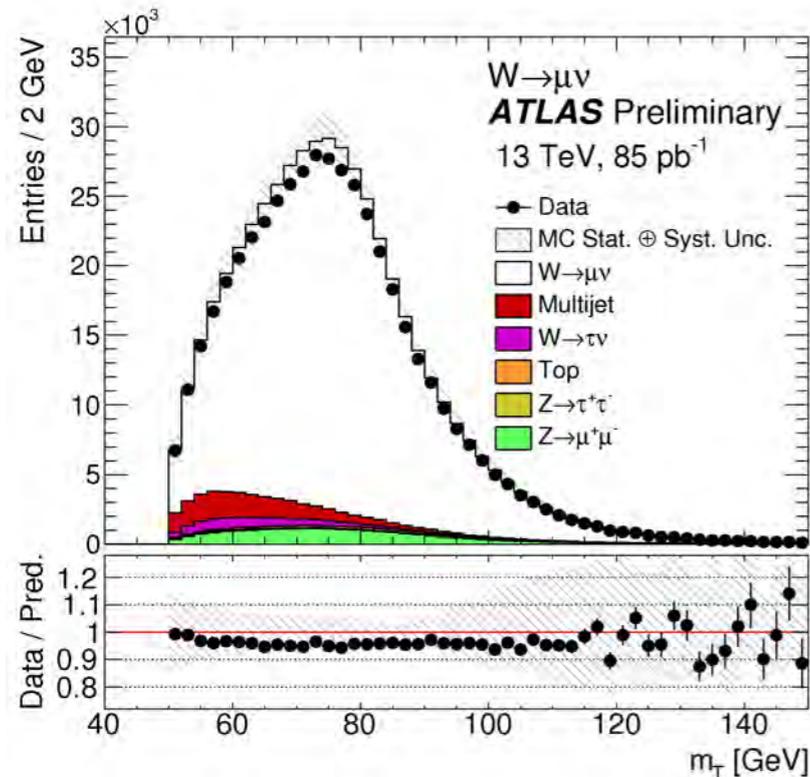
- ATLAS results agree well with theoretical predictions.

***W/Z* production**

Analysis Strategy:

- Cross section determined individually for W^+ and W^- as well as charge combined, for fiducial and full phase-space.

$$\sigma_{W^\pm}^{\text{tot}} = \frac{N_W^{\text{sig}}}{A_W \cdot C_W \cdot \mathcal{L}}$$



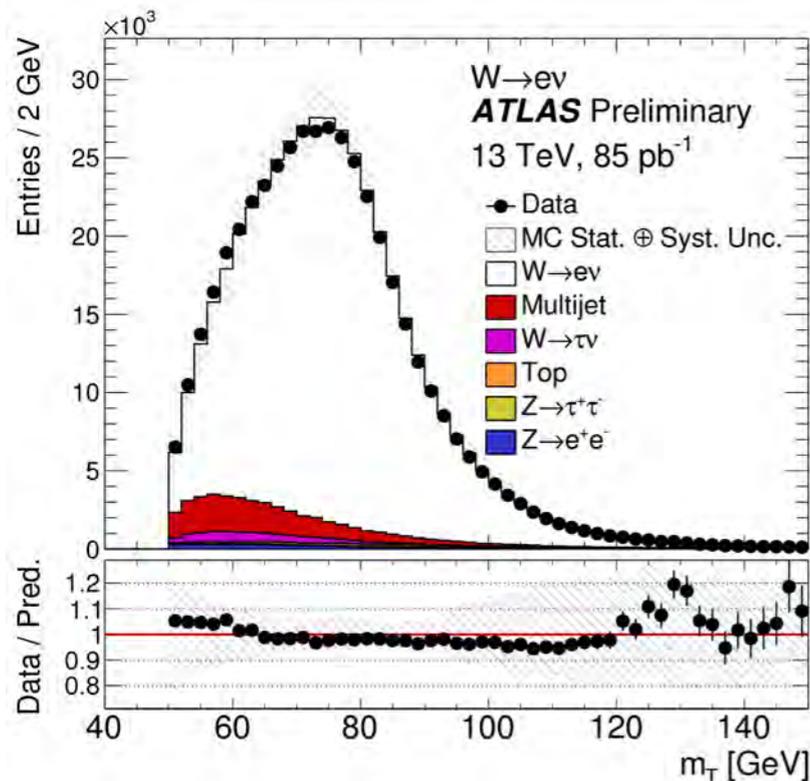
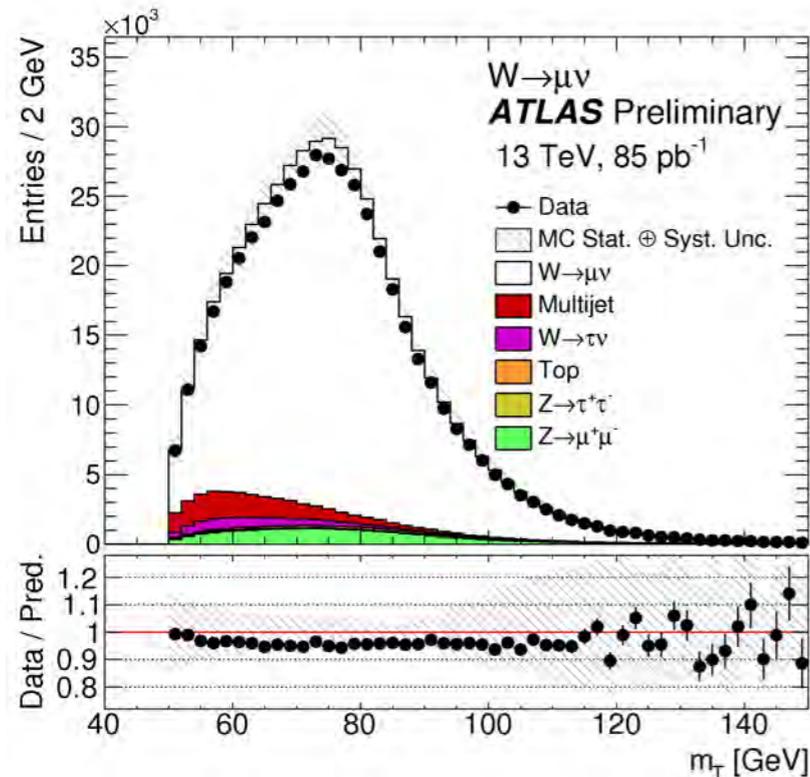
Analysis Strategy:

- Cross section determined individually for W^+ and W^- as well as charge combined, for fiducial and full phase-space.

$$\sigma_{W^\pm}^{\text{tot}} = \frac{N_W^{\text{sig}}}{A_W \cdot C_W \cdot \mathcal{L}}$$

- $p_T(e, \mu) > 25 \text{ GeV}$
- $|\eta(e)| < 2.47$
- $|\eta(\mu)| < 2.4$
- $\text{MET} > 25 \text{ GeV}$
- $p_T(\text{jet}) > 20 \text{ GeV}$
- $1.37 < |\eta(e)| < 1.52$
- $M_T(W) > 50 \text{ GeV}$

$$m_T = \sqrt{2 p_T^\ell p_T^\nu [1 - \cos(\phi_\ell - \phi_\nu)]}$$

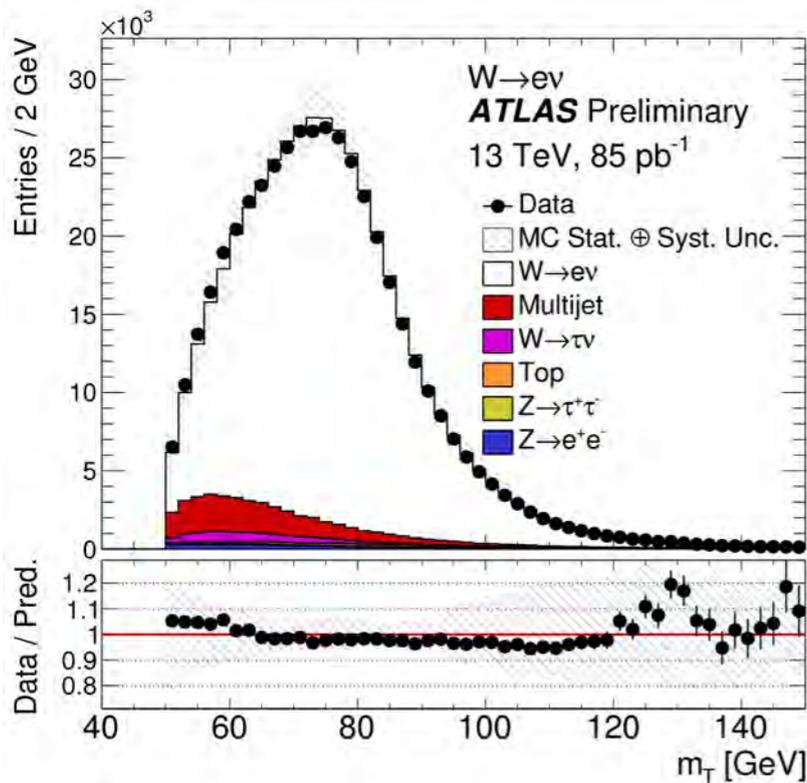
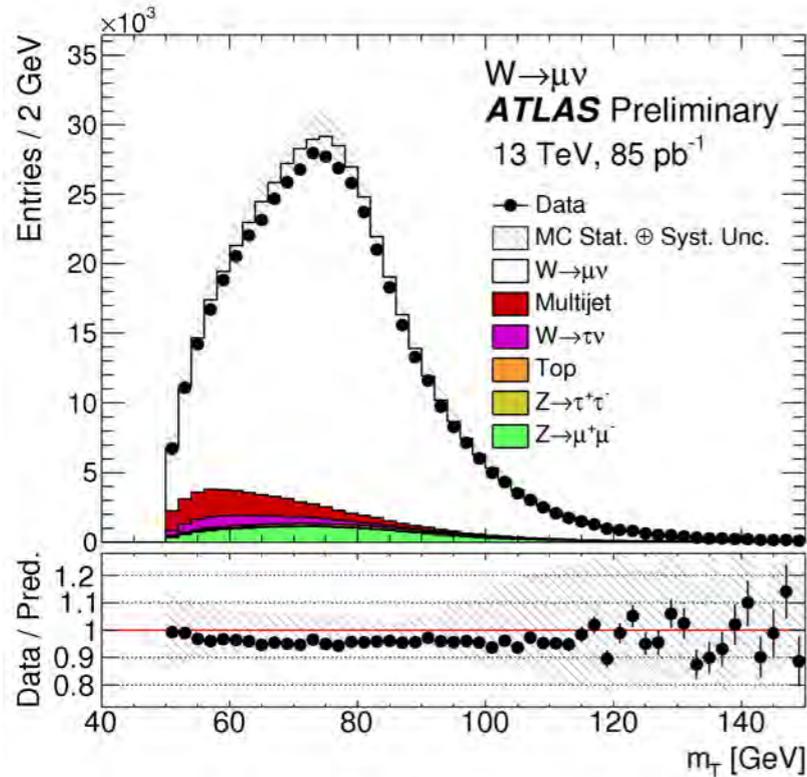


Analysis Strategy:

- Cross section determined individually for W^+ and W^- as well as charge combined, for fiducial and full phase-space.

$$\sigma_{W^\pm}^{\text{tot}} = \frac{N_W^{\text{sig}}}{A_W \cdot C_W \cdot \mathcal{L}}$$

Full phase space correction

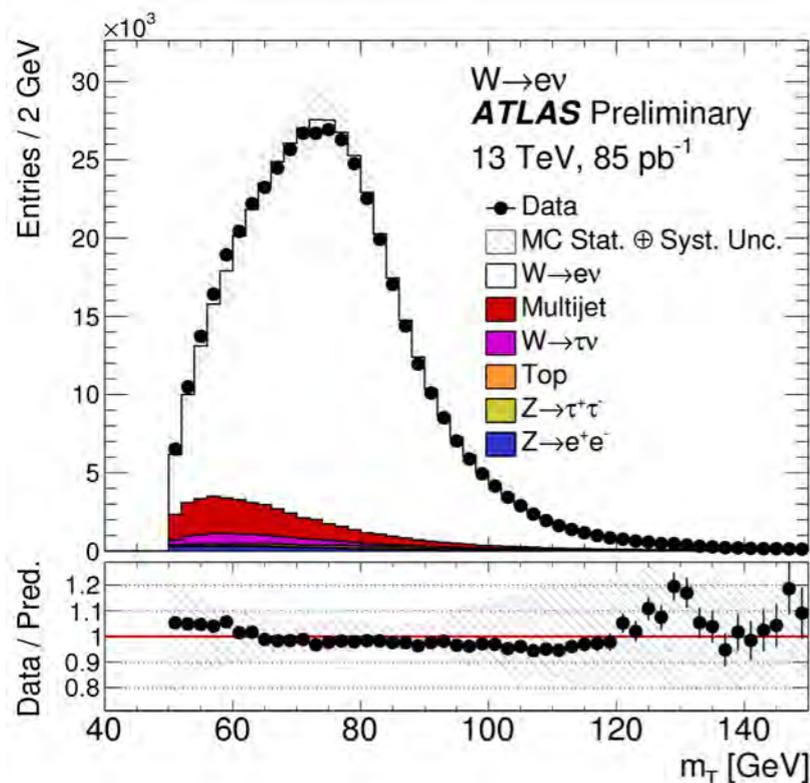
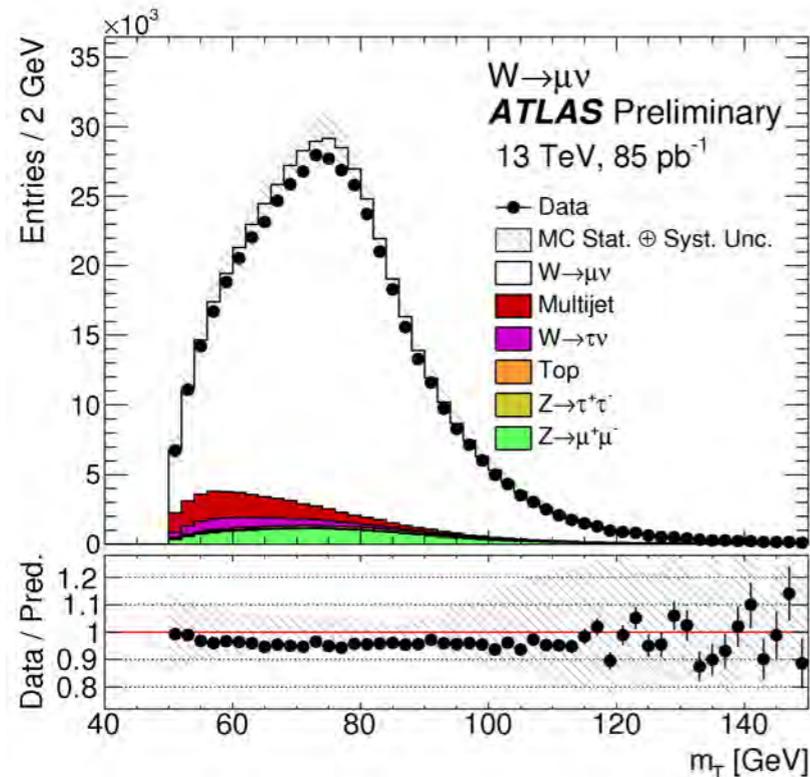


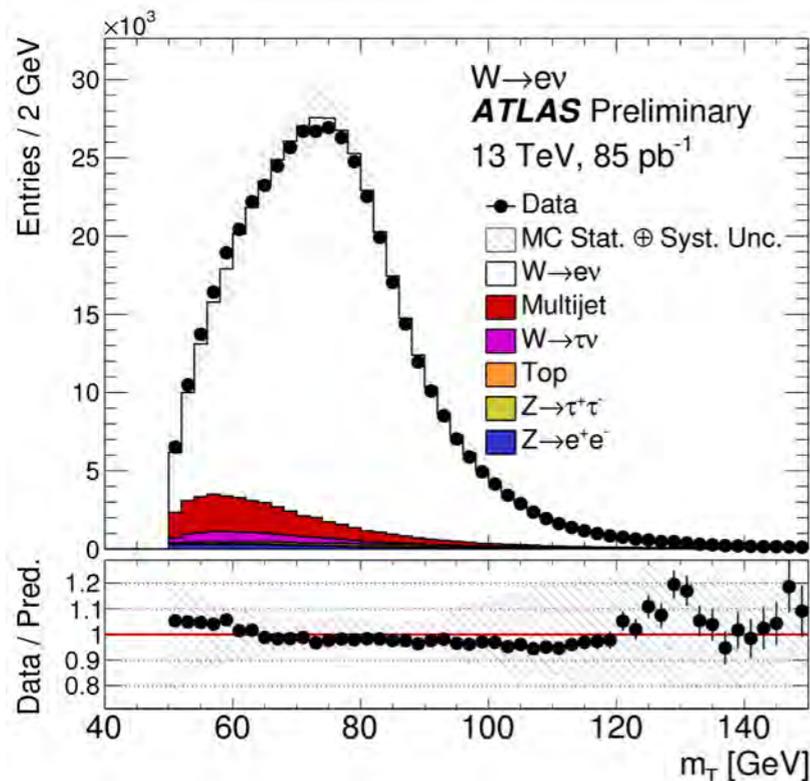
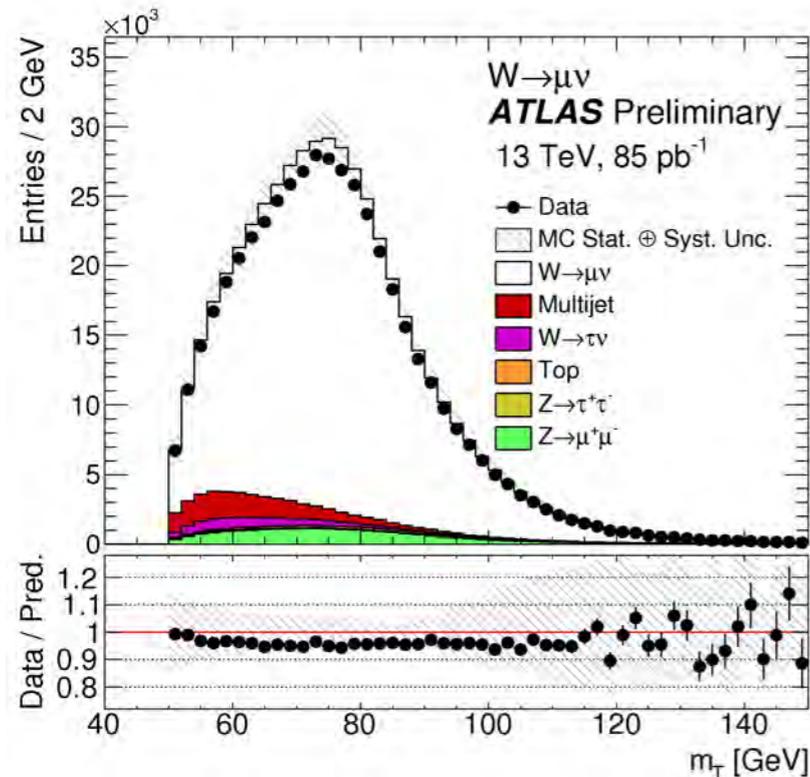
Analysis Strategy:

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$$\sigma_{W^\pm}^{\text{tot}} = \frac{N_W^{\text{sig}}}{A_W \cdot C_W \cdot \mathcal{L}}$$

Fraction of observed events to generator level.





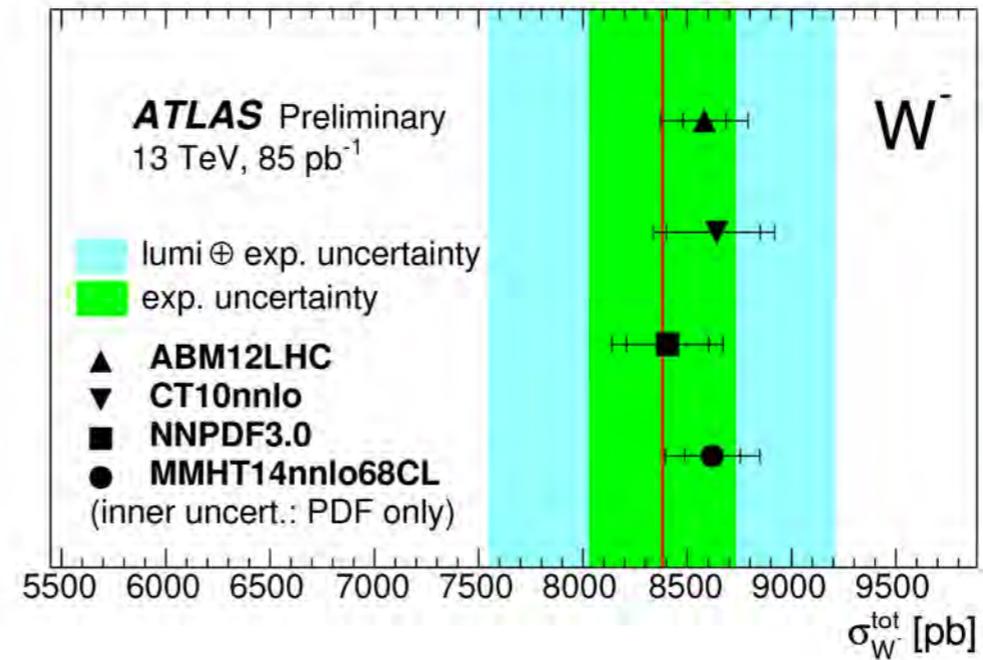
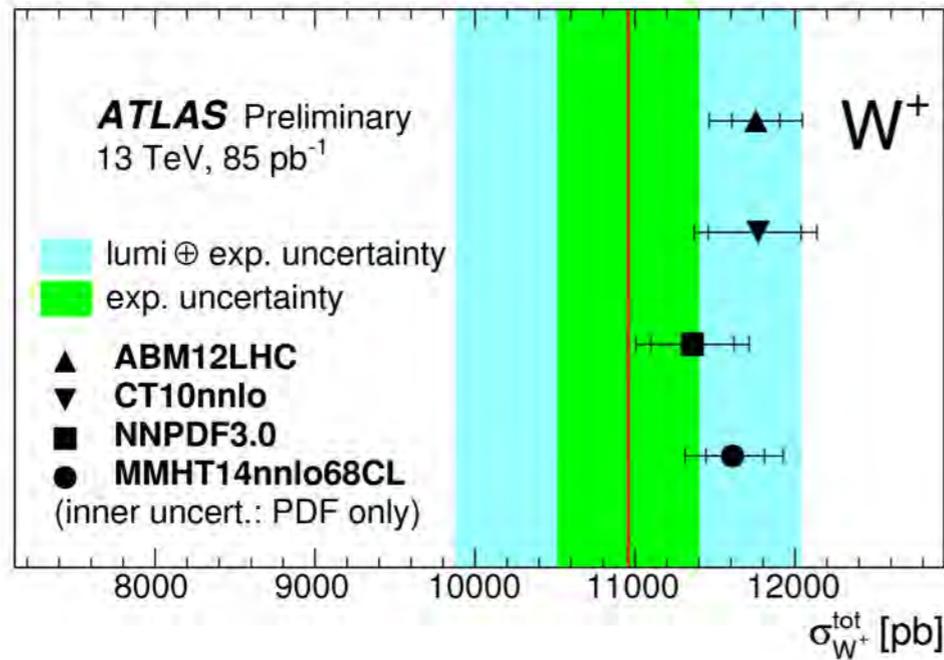
Analysis Strategy:

- Cross section determined individually for W^+ and W^- as well as charge combined, for fiducial and full phase-space.

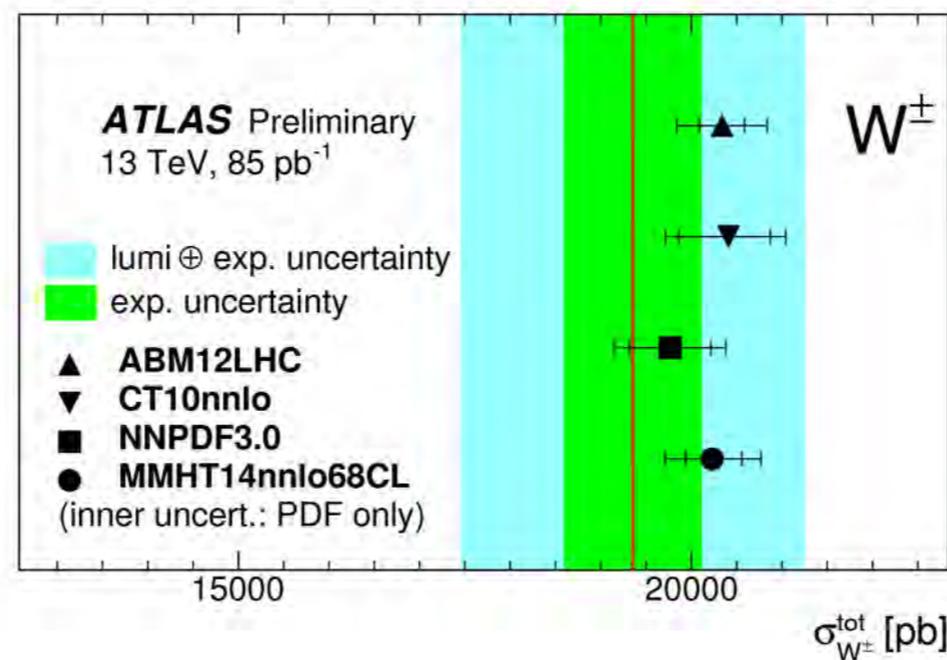
$$\sigma_{W^\pm}^{\text{tot}} = \frac{N_W^{\text{sig}}}{A_W \cdot C_W \cdot \mathcal{L}}$$

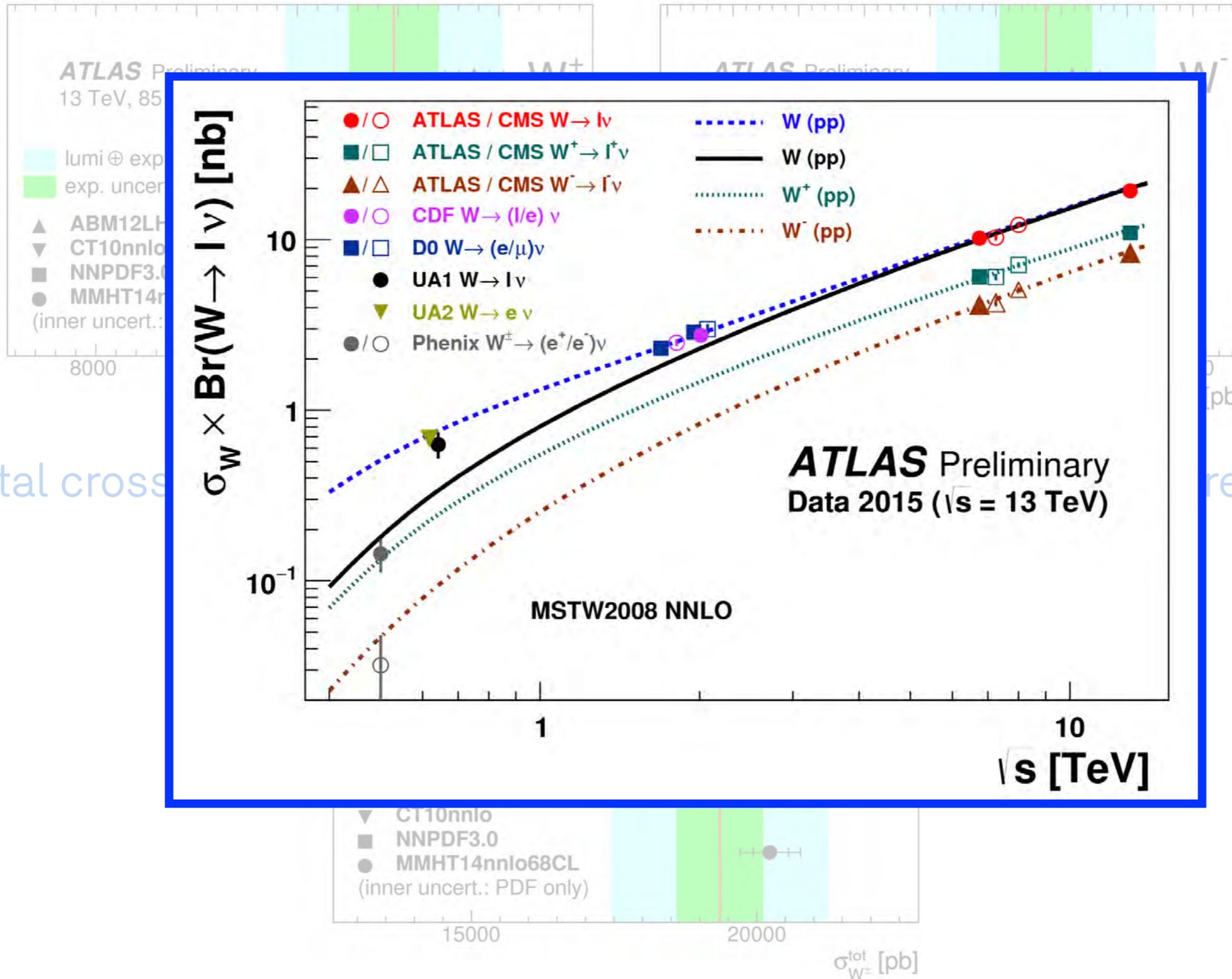
- Dominant backgrounds come from Multijet events.
- Electron identification and trigger uncertainties are large source of systematic uncertainty (mitigated by combination).

$$\sigma_{W^\pm}^{\text{tot}} = 19350 \pm 20 \text{ (stat)} \pm 760 \text{ (syst.)} \pm 1740 \text{ (lumi.) pb}$$



- Total cross-section measurements in good agreement with predictions.





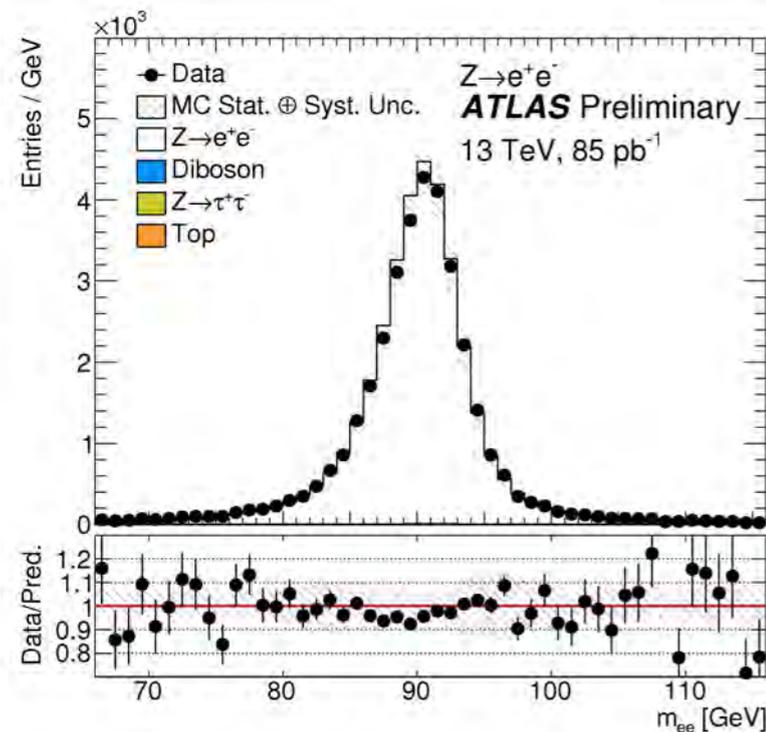
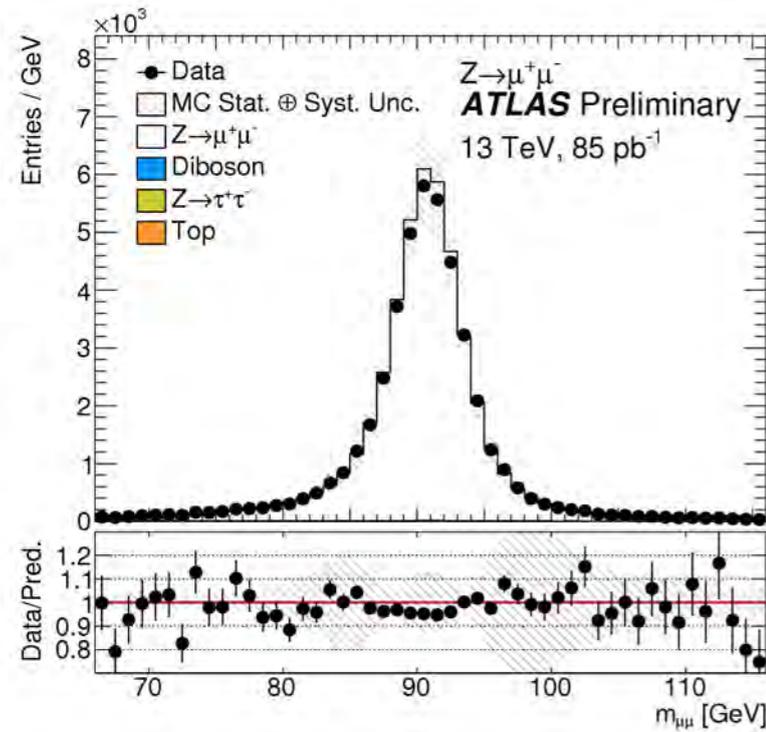
• Total cross

predictions.

Analysis Strategy:

- Fiducial definition requires that Z decay objects be inside the detector acceptance on MC truth level.

$$\sigma_Z^{\text{tot}} = \frac{N_Z^{\text{sig}}}{A_Z \cdot C_Z \cdot \mathcal{L}}$$



- $p_T(e, \mu) > 25 \text{ GeV}$
- $|\eta(e)| < 2.47, \quad 1.37 < |\eta(e)| < 1.52$
- $|\eta(\mu)| < 2.4$
- $66 \text{ GeV} < M_{ll} < 116 \text{ GeV}$

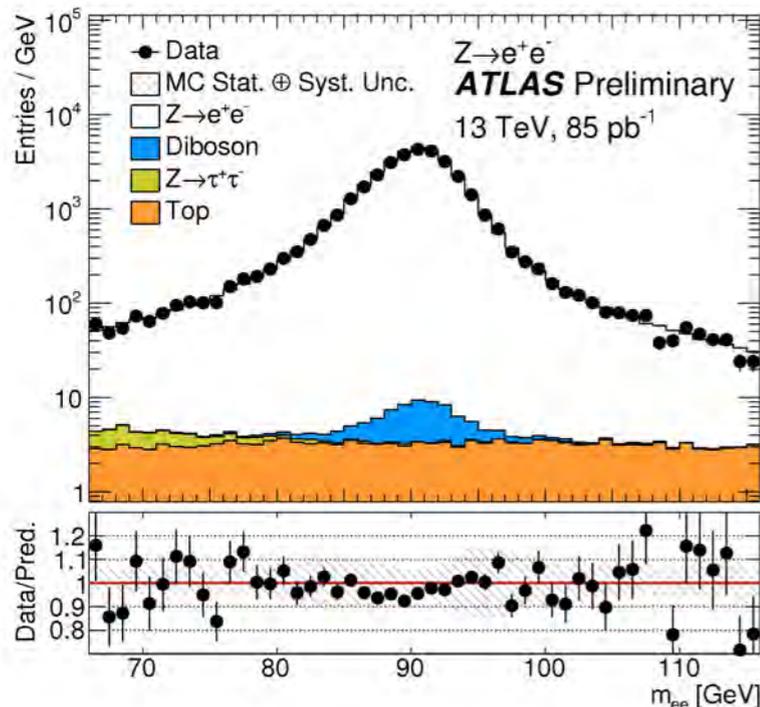
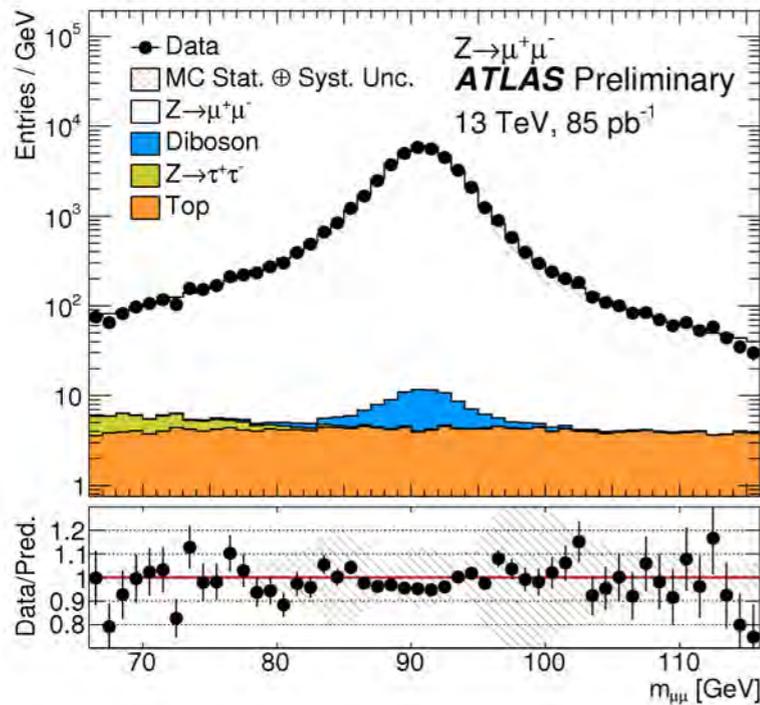
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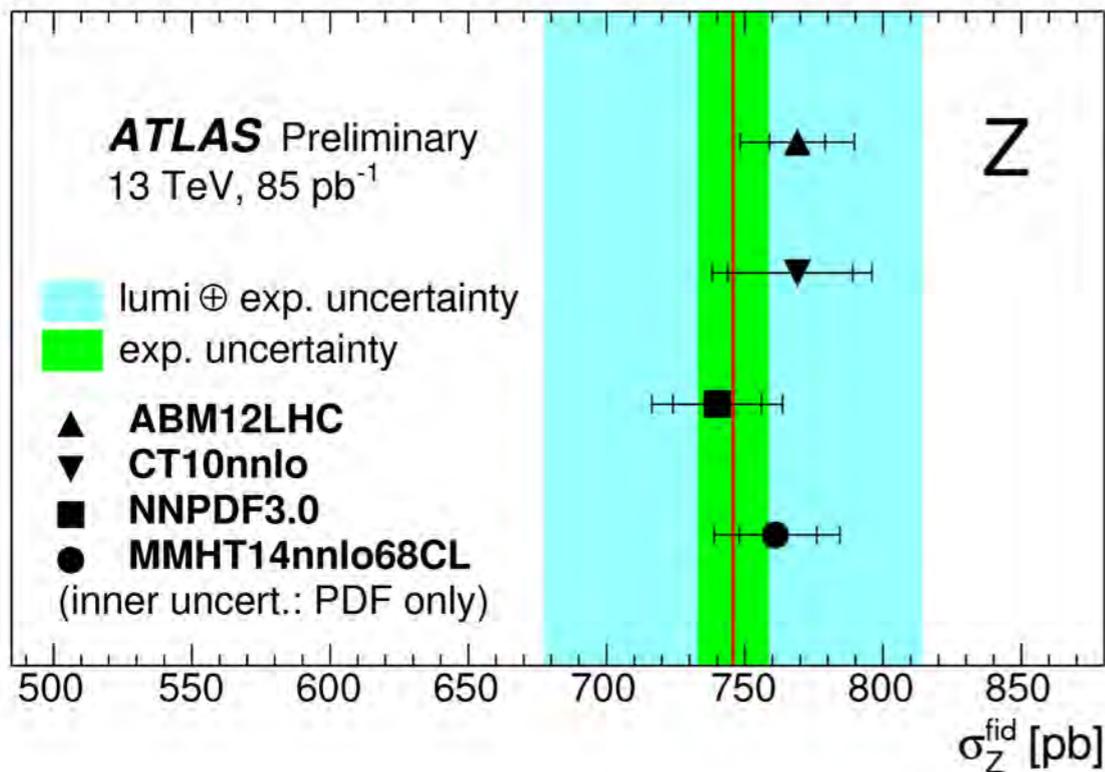
$$\sigma_Z^{\text{tot}} = \frac{N_Z^{\text{sig}}}{A_Z \cdot C_Z \cdot \mathcal{L}}$$

- Dominant uncertainties are from the understanding of integrated luminosity.
- Other significant systematics are electron reconstruction, ID, and trigger.

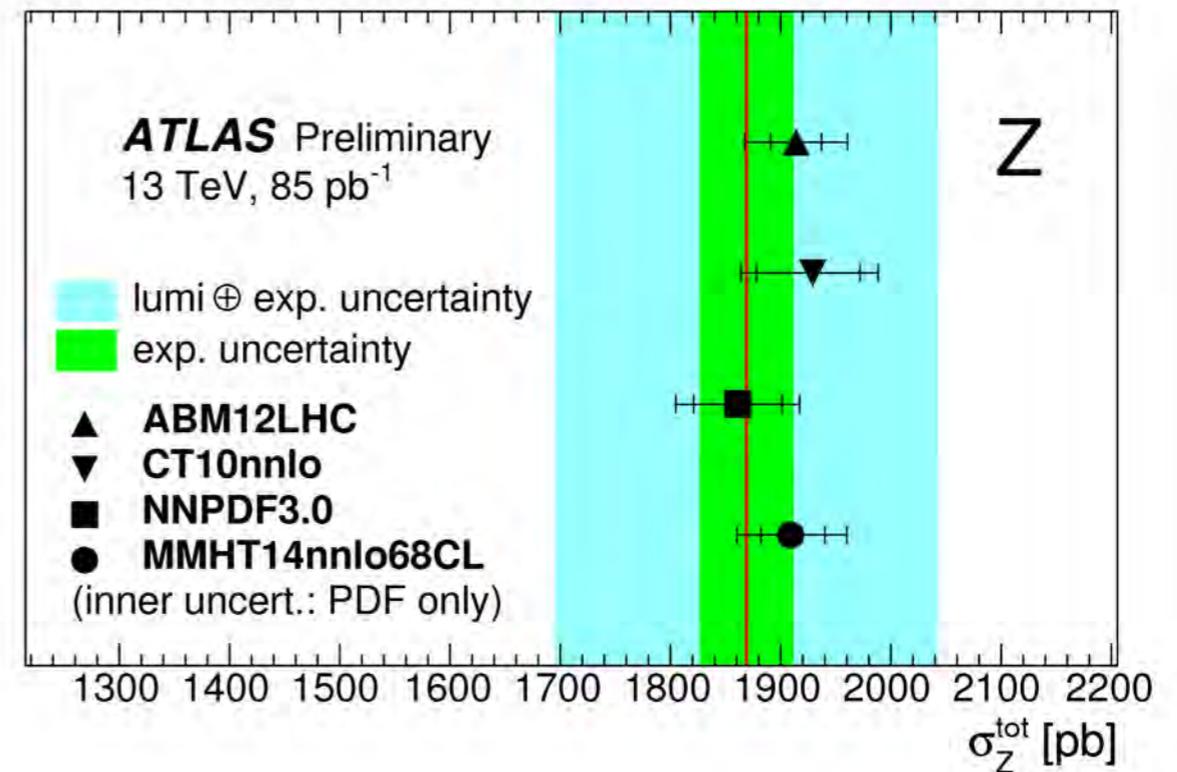
$$\sigma_Z^{\text{tot}} = 1869 \pm 7 \text{ (stat)} \pm 42 \text{ (syst.)} \pm 168 \text{ (lumi.) pb}$$



Fiducial



Full



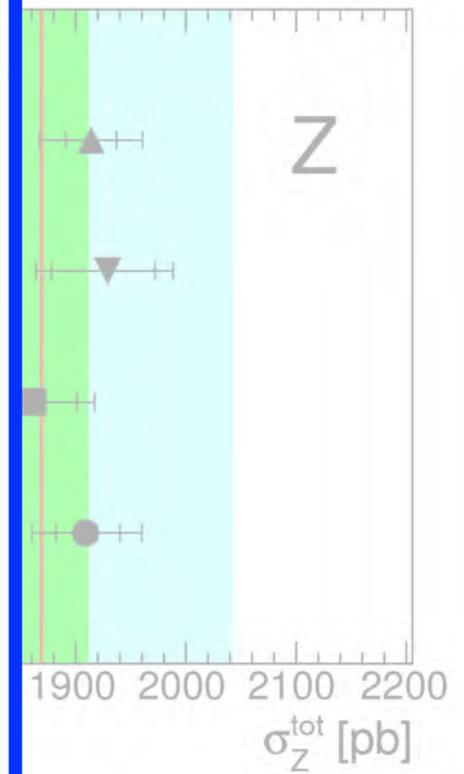
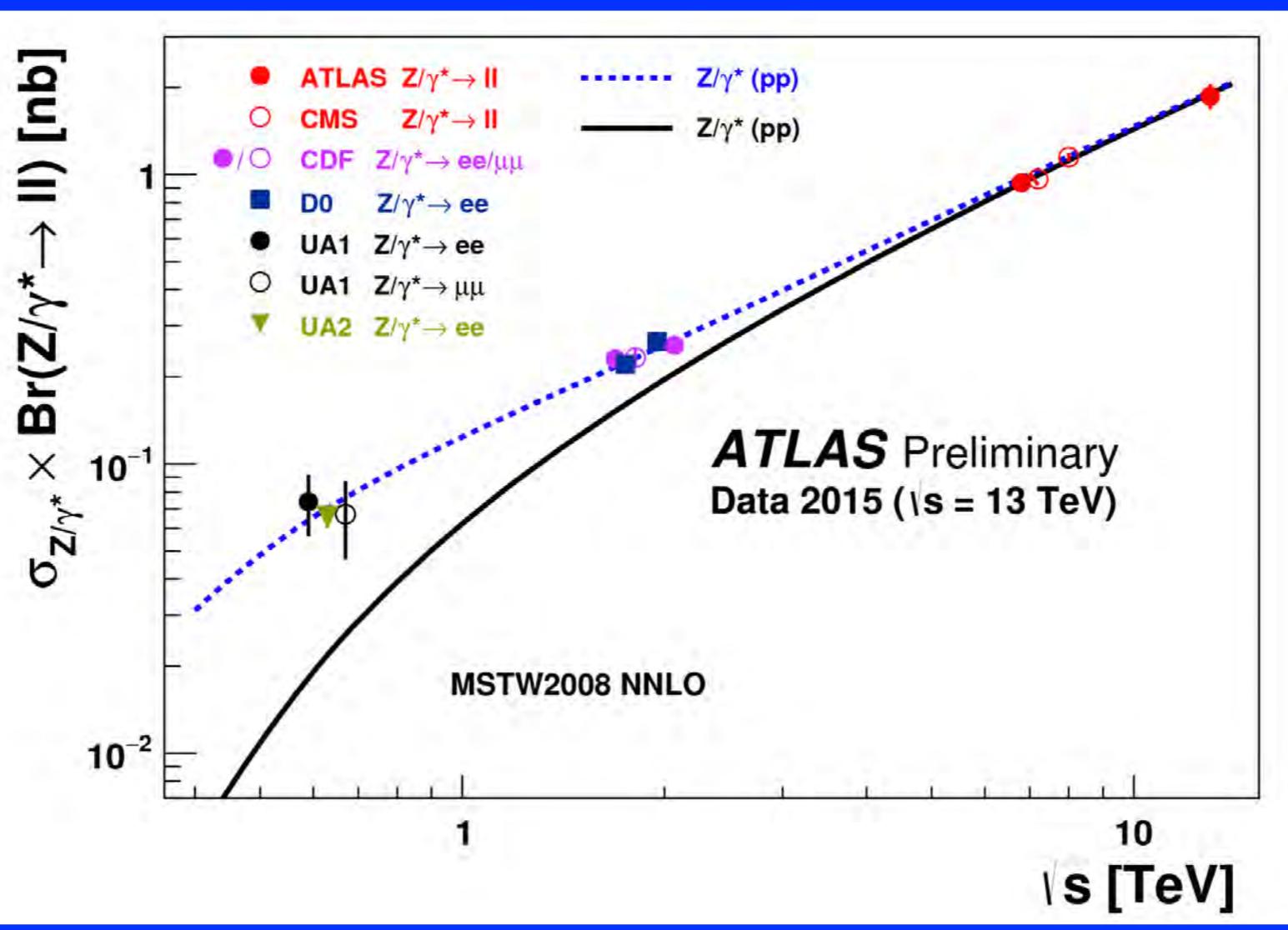
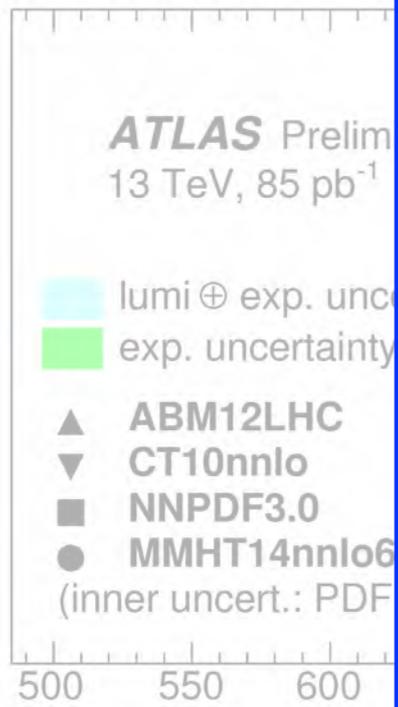
- Predictions describe both fiducial and full phase space very well.

| Channel | value ± stat. ± syst. ± lumi [pb] |
|---------|--------------------------------------|
| W^- | $3344 \pm 6 \pm 113 \pm 301$ |
| W^+ | $4340 \pm 7 \pm 138 \pm 391$ |
| W | $7684 \pm 9 \pm 232 \pm 692$ |
| Z | $746 \pm 3 \pm 13 \pm 67$ |

| Channel | value ± stat. ± syst. ± lumi [pb] |
|---------|--------------------------------------|
| W^- | $8380 \pm 20 \pm 350 \pm 750$ |
| W^+ | $10960 \pm 20 \pm 440 \pm 990$ |
| W | $19350 \pm 20 \pm 760 \pm 1740$ |
| Z | $1869 \pm 7 \pm 42 \pm 168$ |

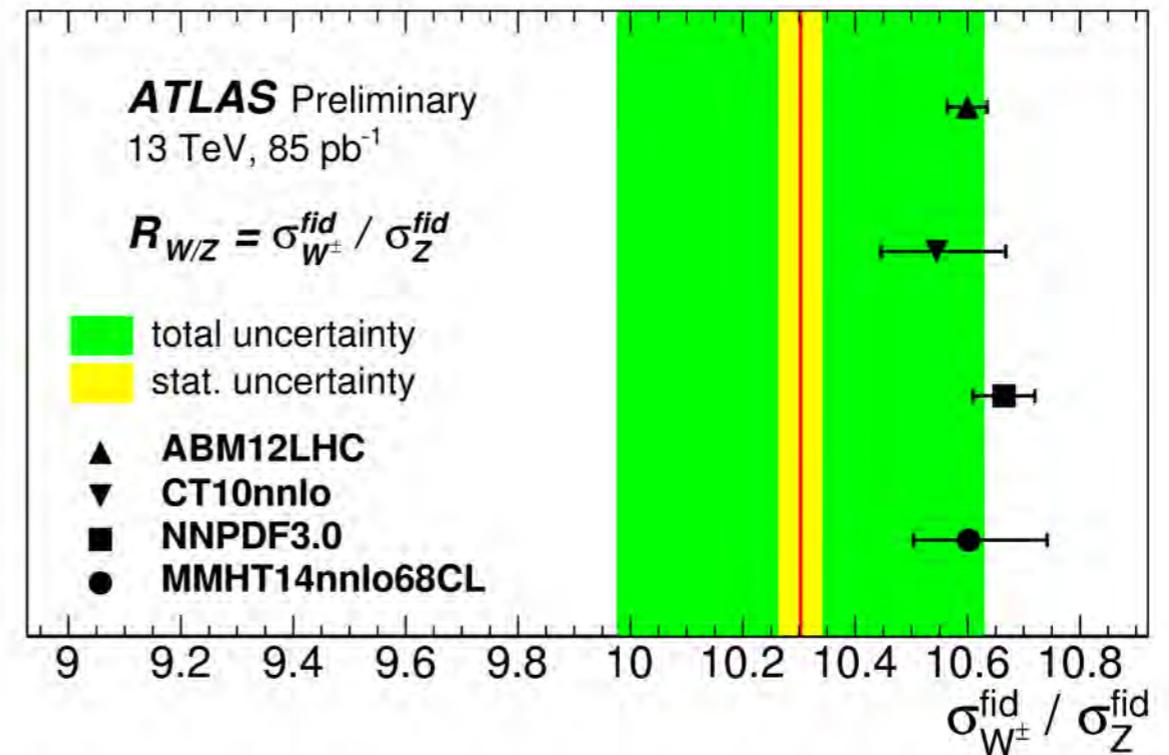
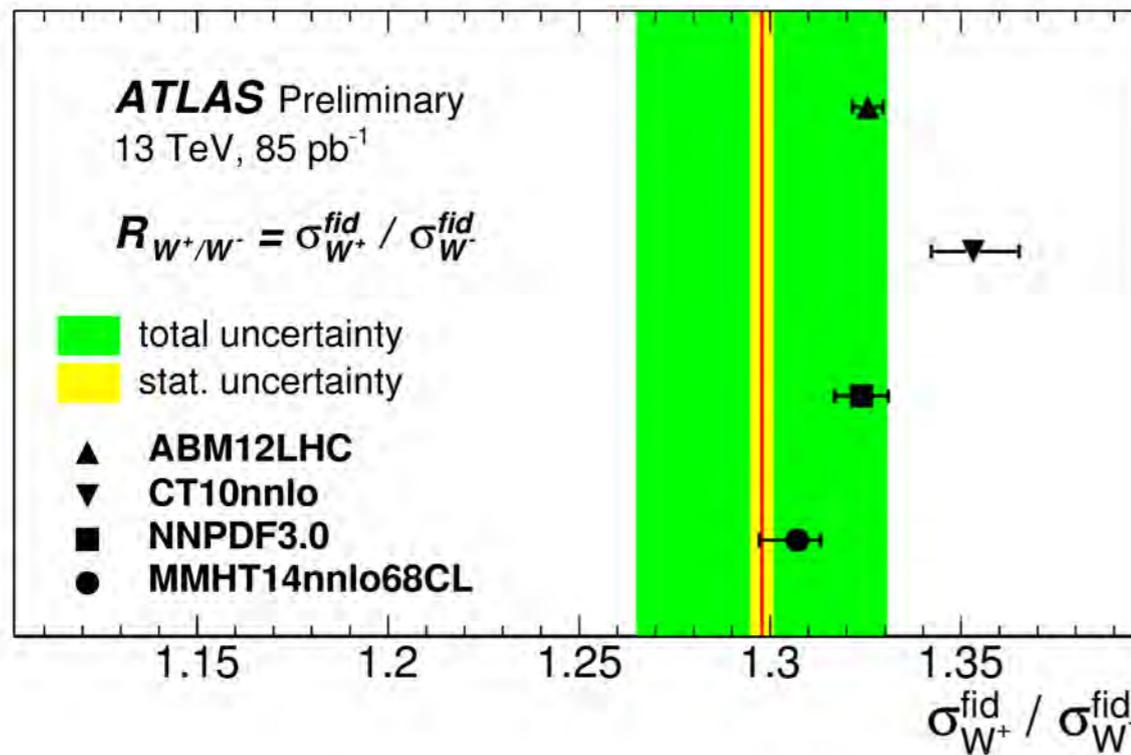
Fiducial

Full



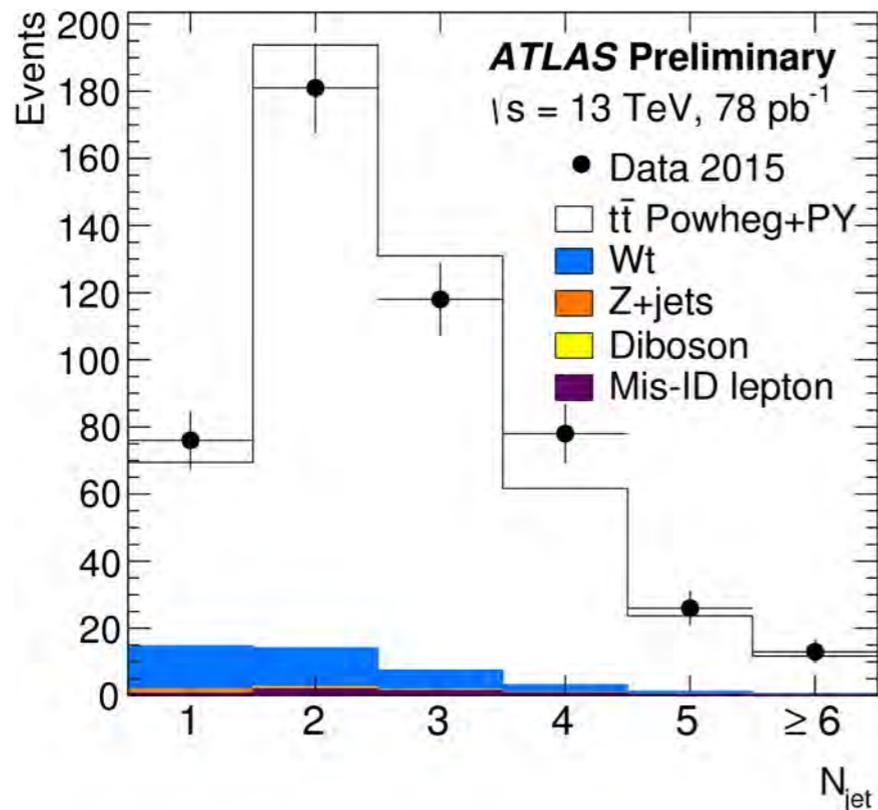
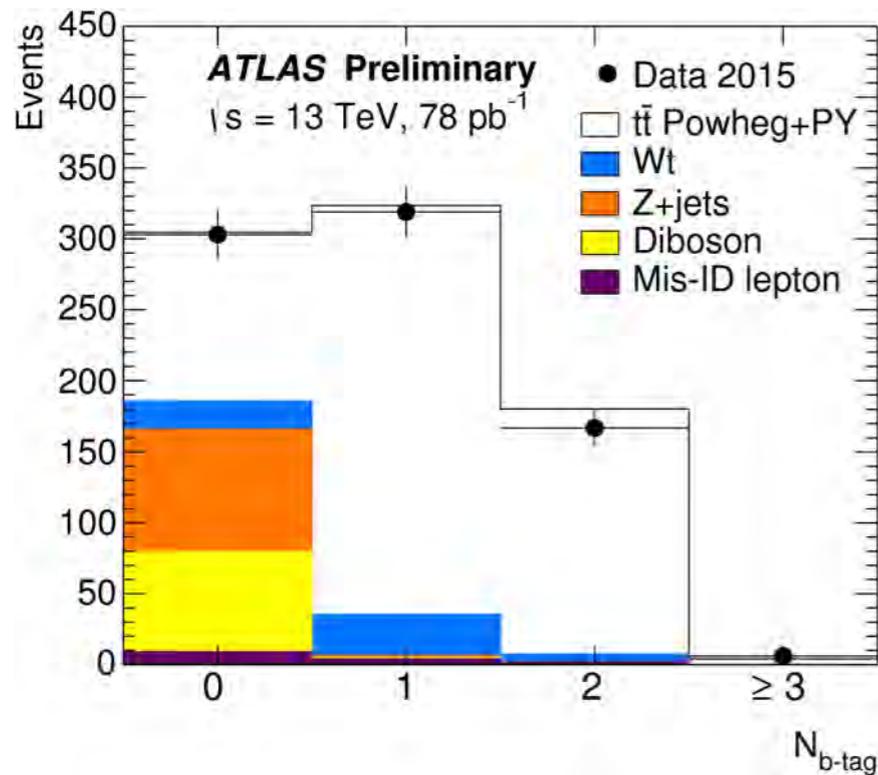
- Multi-pur
- Silicon in

on systems.



- Ratio of W^+ to W^- is sensitive to the u_v and d_v valence quark PDF at low x .
- Ratio of inclusive W^\pm to Z cross-sections is sensitive to the strange-quark PDF.
- Precision at $\sim 2.5\%$ level (2% needed to have significant PDF impact)
- Ratios agree with the predictions from PDF and are dominated by systematic uncertainties.

$t\bar{t}$ production



Analysis Strategy:

- Cross-section and b-tagging efficiency extracted using events with 1 or 2 b-tags.

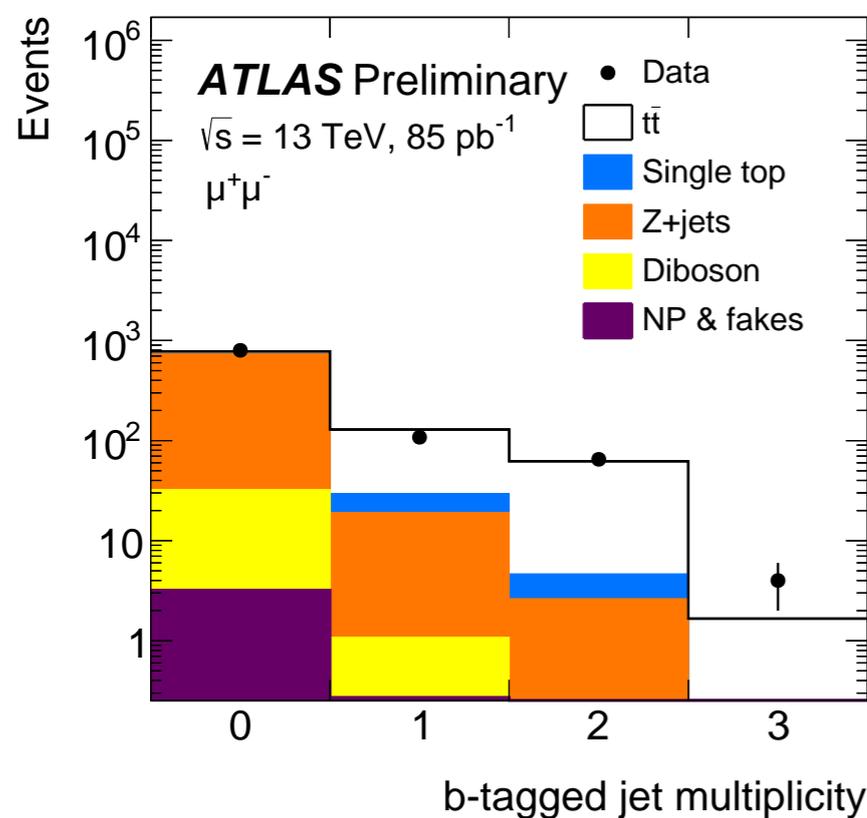
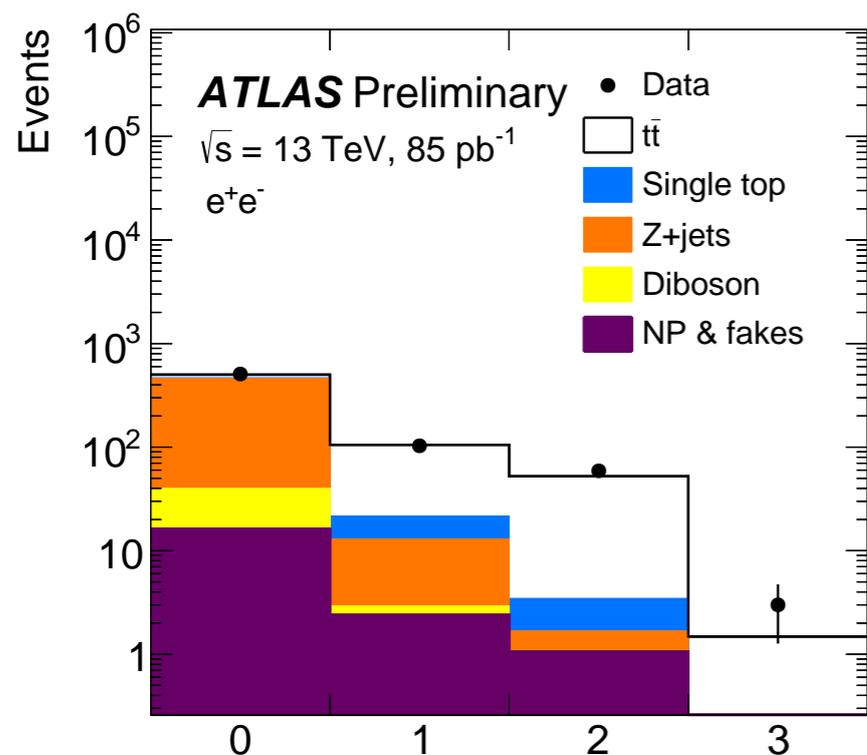
$$N_1 = \mathcal{L} \sigma_{t\bar{t}} \epsilon_{e\mu} 2 \epsilon_b (1 - C_b \epsilon_b) + N_1^{bkg}$$

$$N_2 = \mathcal{L} \sigma_{t\bar{t}} \epsilon_{e\mu} C_b \epsilon_b^2 + N_2^{bkg}$$

- Selection requires one electron, one muon and one or more b-tagged jets.
- B-tagging efficiency absorbs systematic uncertainties due to b-tagging and BJES.

$$\sigma_{e\mu} = 825 \pm 49 \text{ (stat.)} \pm 60 \text{ (syst.)} \pm 83 \text{ (lumi) pb}$$

$$\sigma_{SM} = 832^{+40}_{-46} \text{ pb}$$



Analysis Strategy:

- Same method as for the $e\mu$ analysis.
- B-tag eff independent in each channel.
- Tighter selection cuts required to suppress DY and low dilepton invariant mass resonances.

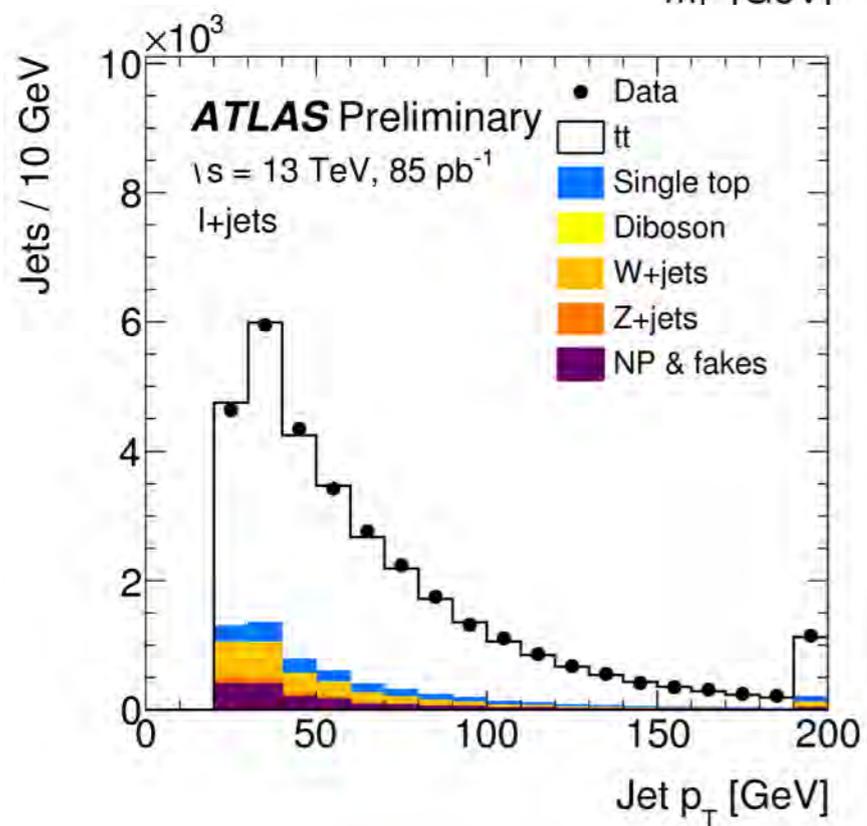
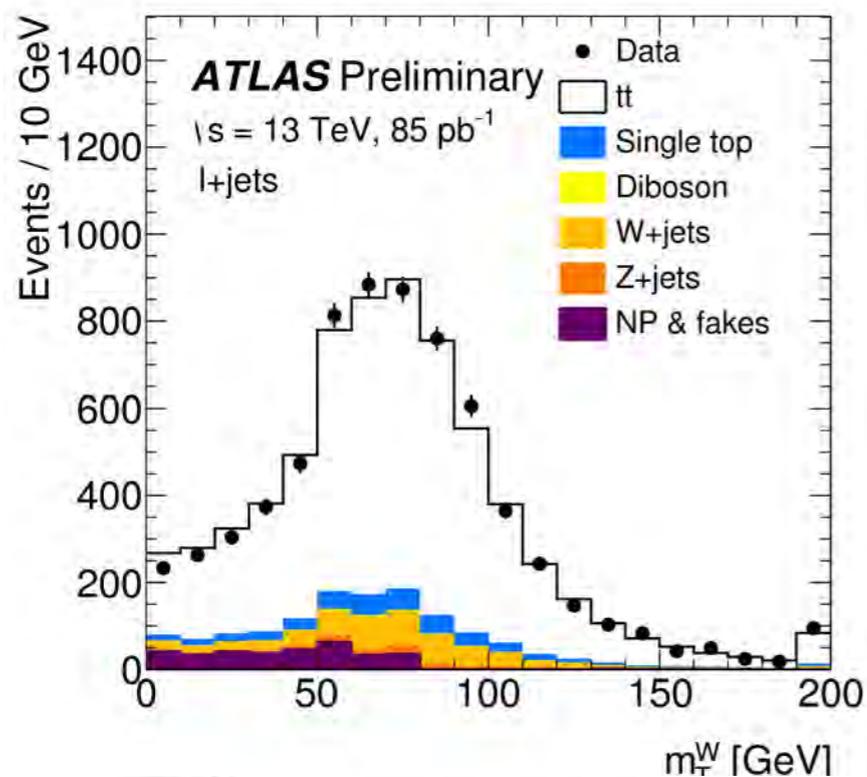
- $|m_{ll} - m_Z| > 10 \text{ GeV}$
- $m_{ll} > 60 \text{ GeV}$
- $\text{MET} > 30 \text{ GeV}$

$$\sigma_{ee} = 824 \pm 88 \text{ (stat)} \pm 91 \text{ (syst)} \pm 82 \text{ (lumi)} \text{ pb}$$

$$\sigma_{\mu\mu} = 683 \pm 74 \text{ (stat)} \pm 76 \text{ (syst)} \pm 68 \text{ (lumi)} \text{ pb}$$

$$\sigma_{comb} = 749 \pm 57 \text{ (stat)} \pm 79 \text{ (syst)} \pm 74 \text{ (lumi)} \text{ pb}$$

$$\sigma_{SM} = 832^{+40}_{-46} \text{ pb}$$



Analysis Strategy:

- Simpler strategy than for dilepton, simply counting events and measuring acceptance efficiency.
- More complex selection to suppress W-boson and QCD multi-jet background.

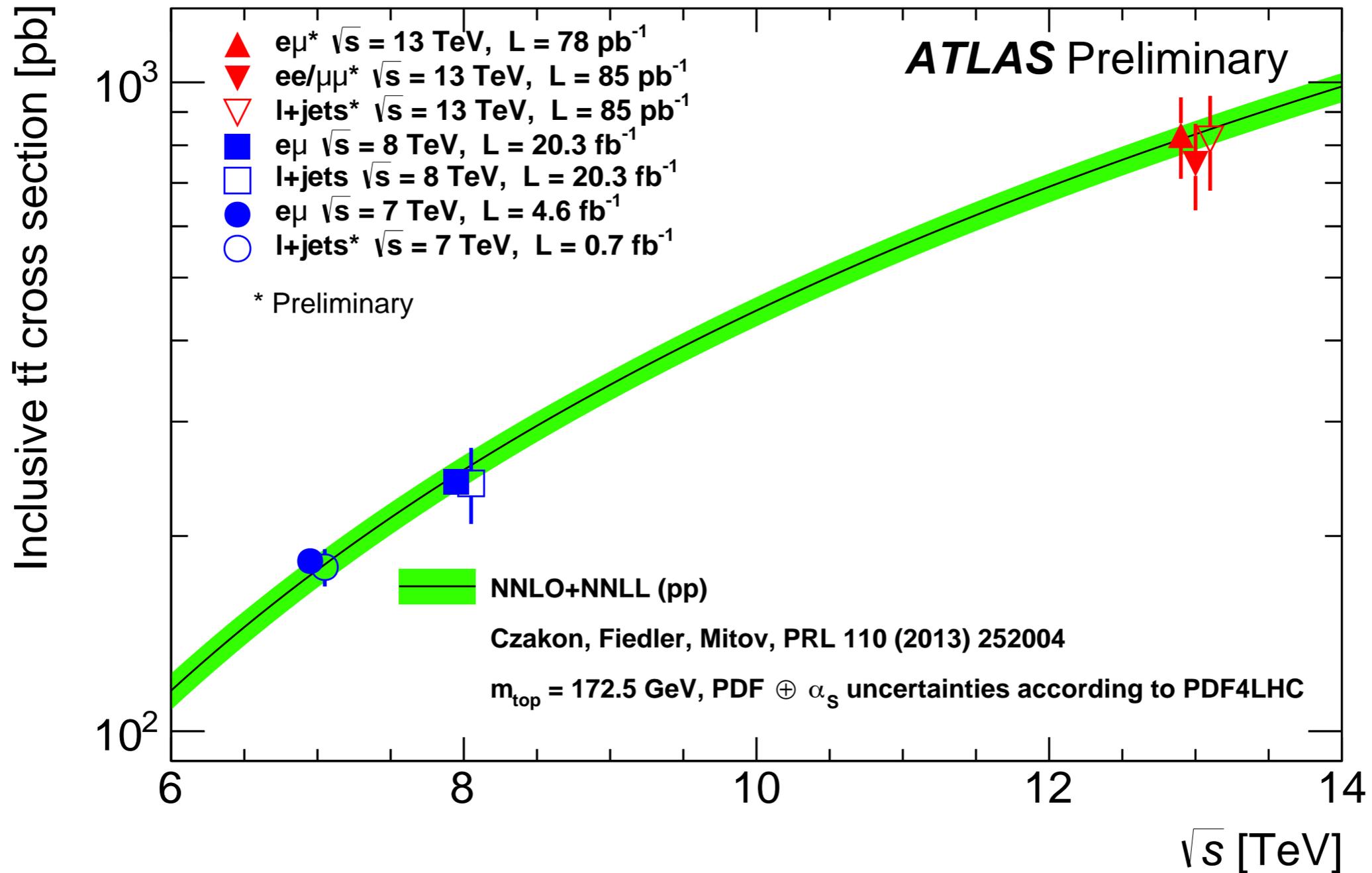
- e or μ + 4 or more jets (2 b-tagged)
- $m_T(W) > 50 \text{ GeV}$
- $\text{MET} > 50 \text{ GeV}$

$$\sigma_{e+\text{jets}} = 775 \pm 17 \text{ (stat.)} \pm 123 \text{ (syst.)} \pm 85 \text{ (lumi) pb}$$

$$\sigma_{\mu+\text{jets}} = 862 \pm 18 \text{ (stat.)} \pm 93 \text{ (syst.)} \pm 94 \text{ (lumi) pb}$$

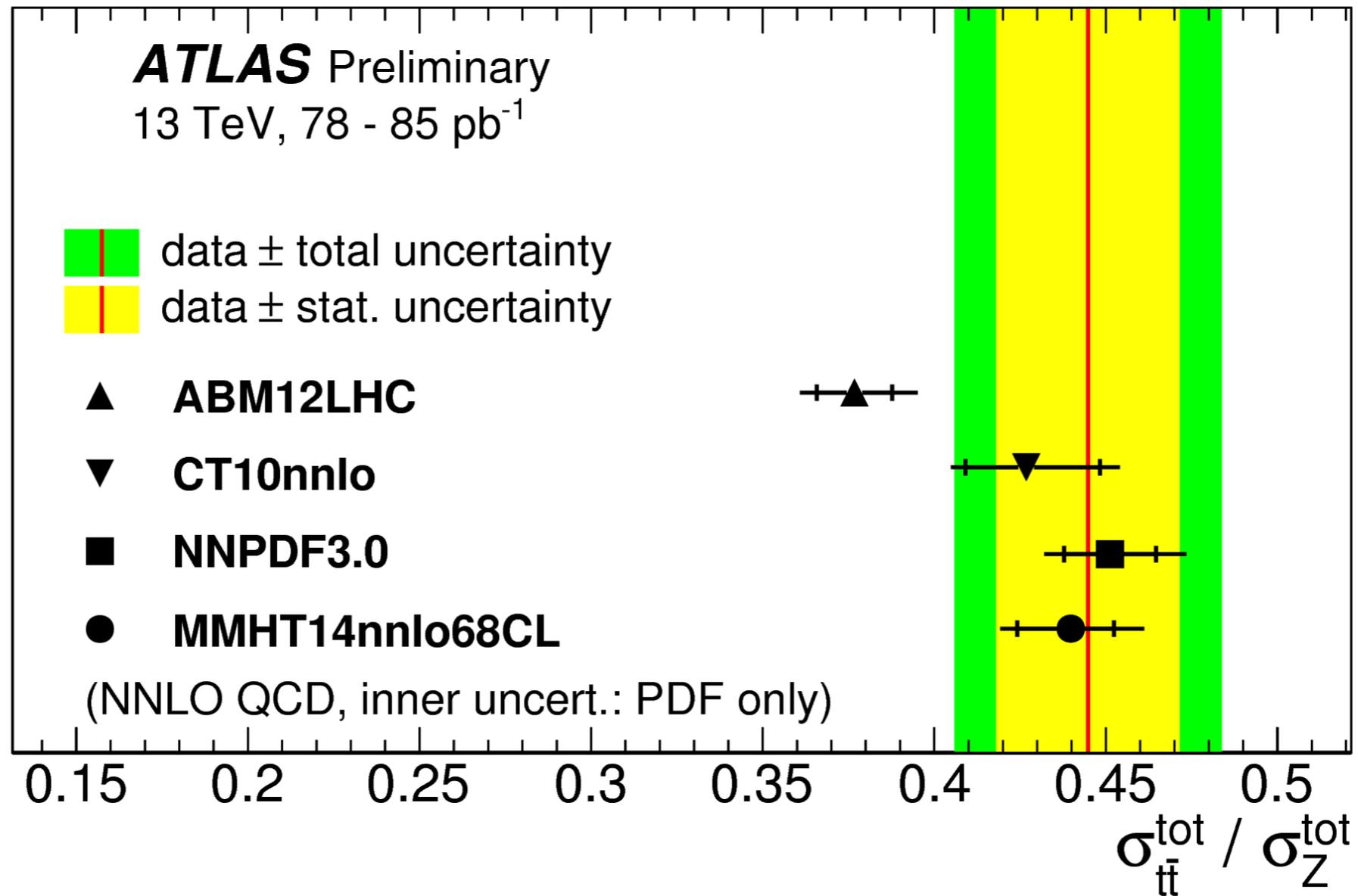
$$\sigma_{\text{comb}} = 817 \pm 13 \text{ (stat.)} \pm 103 \text{ (syst.)} \pm 88 \text{ (lumi) pb}$$

$$\sigma_{SM} = 832_{-46}^{+40} \text{ pb}$$



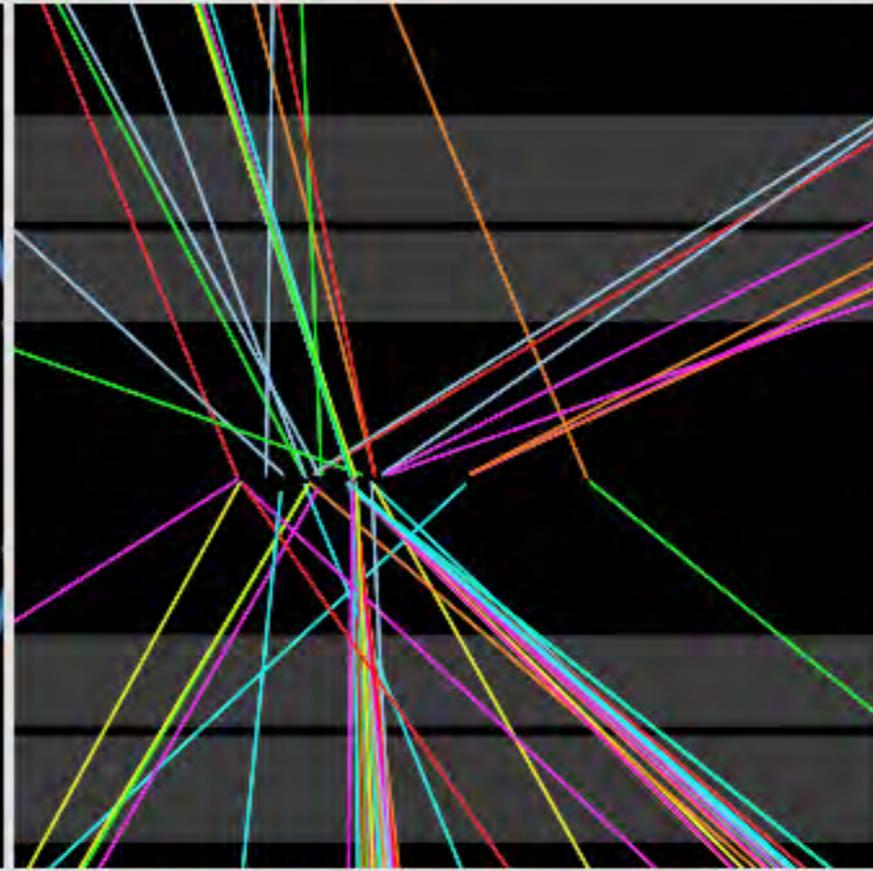
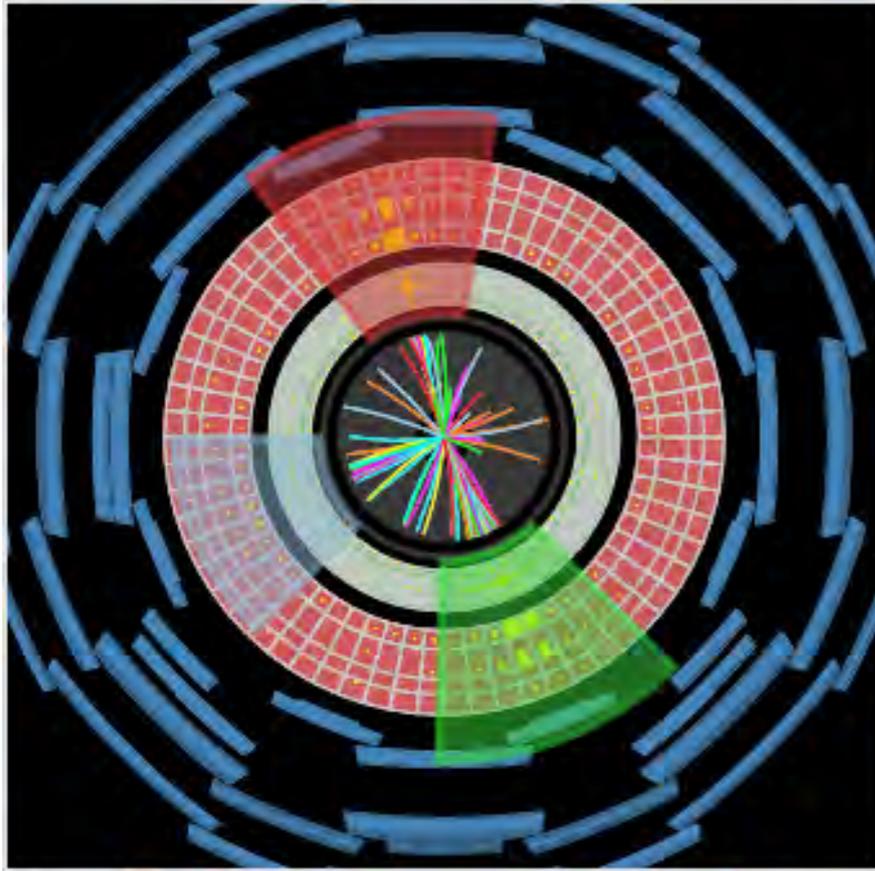
- Uncertainty dominated by luminosity (10%).
- Total uncertainty: $e\mu$ 14% $ee,\mu\mu$ 16% $l+jets$ 17%

$t\bar{t}$ / Z ratio



- Ratio of $t\bar{t}$ and Z cross-sections interesting for PDF fits.
- Experimental very nice as large luminosity uncertainties cancel.

Energetic dijets

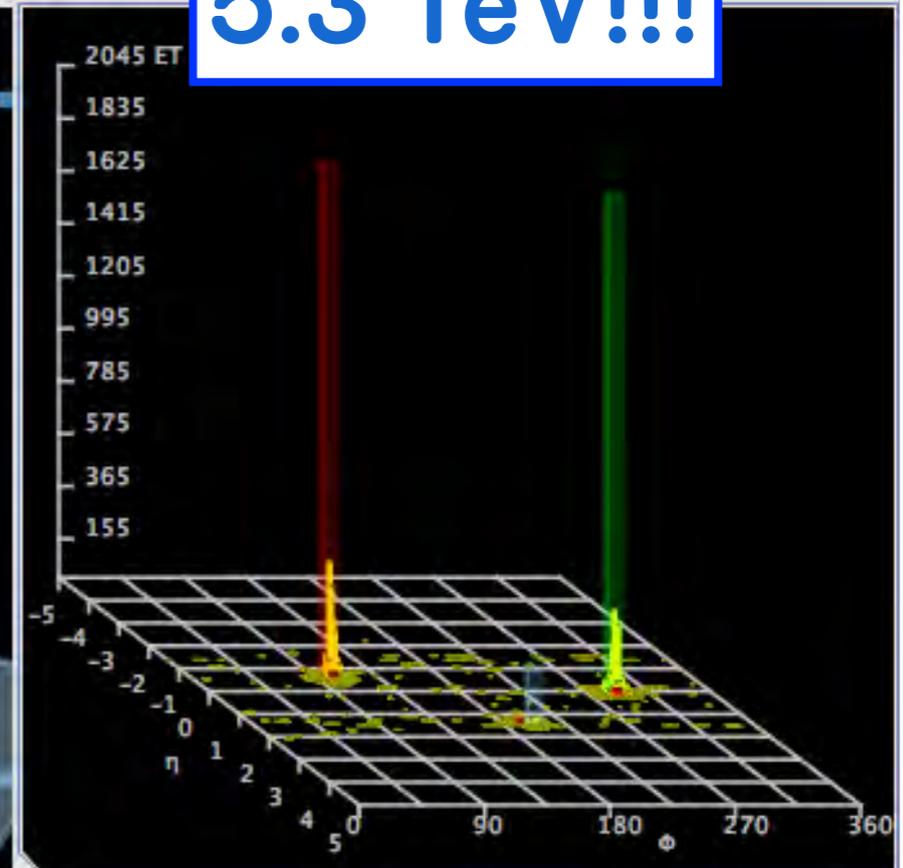
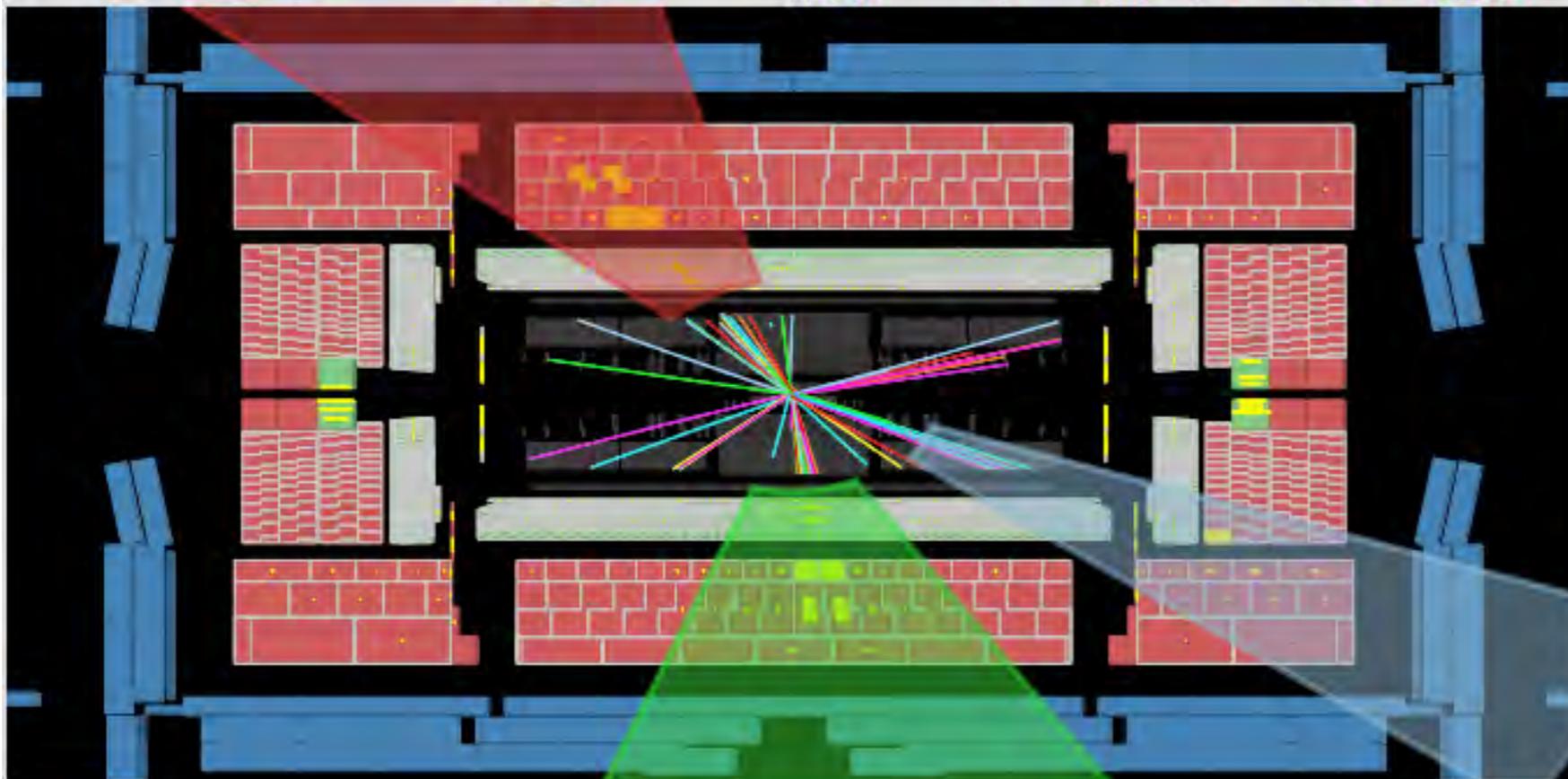


ATLAS
EXPERIMENT

Run Number: 276731, Event Number: 531676916

Date: 2015-08-22 04:20:10 CEST

5.3 TeV!!!

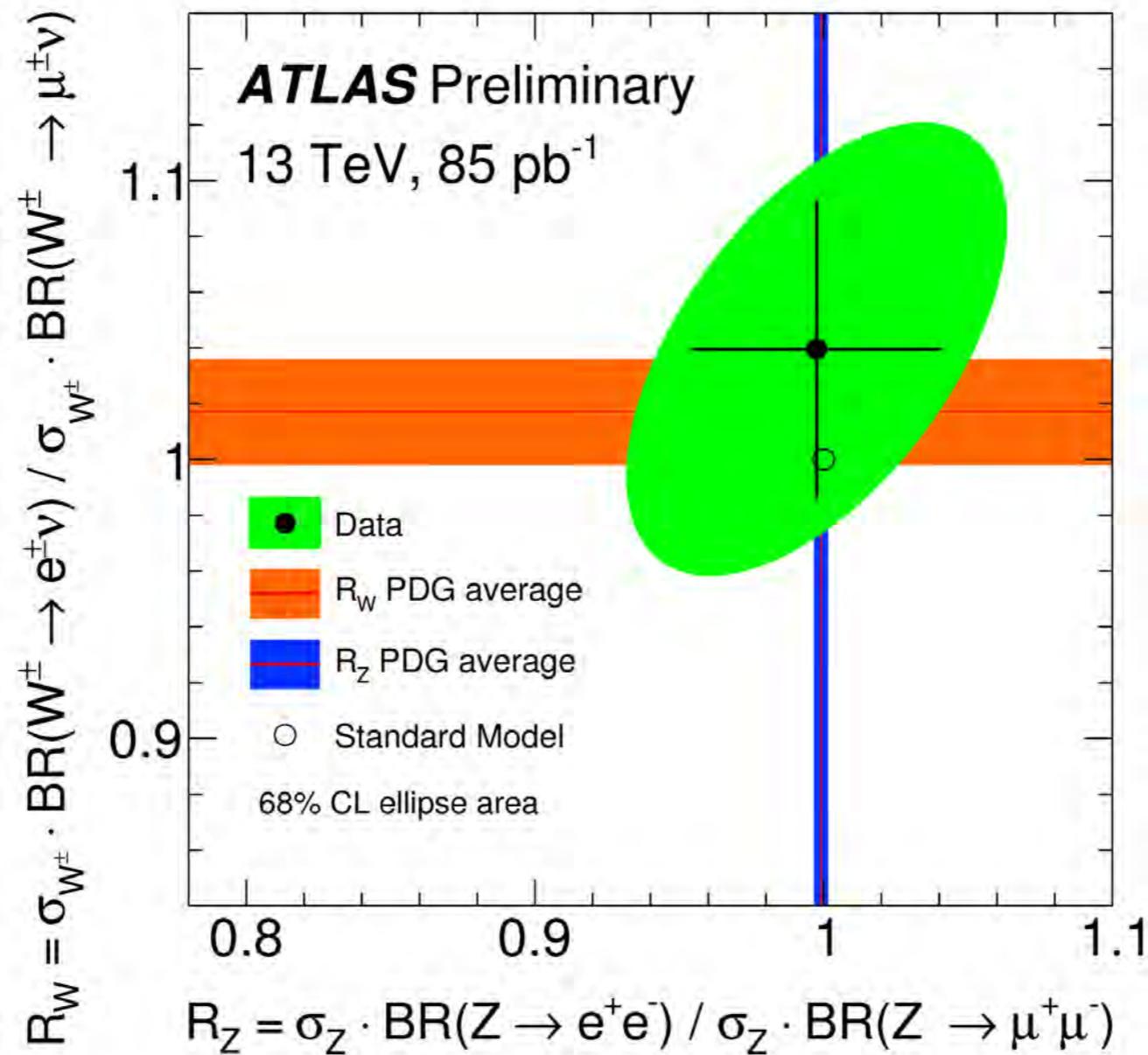


- SM validated a new energy of 13 TeV using a small fraction of the total 2015 Data.
- So far, all results appear to be consistent with the SM expectation.
- Many more interesting results than were shown today:

Full list here: <https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Summer2015-13TeV>

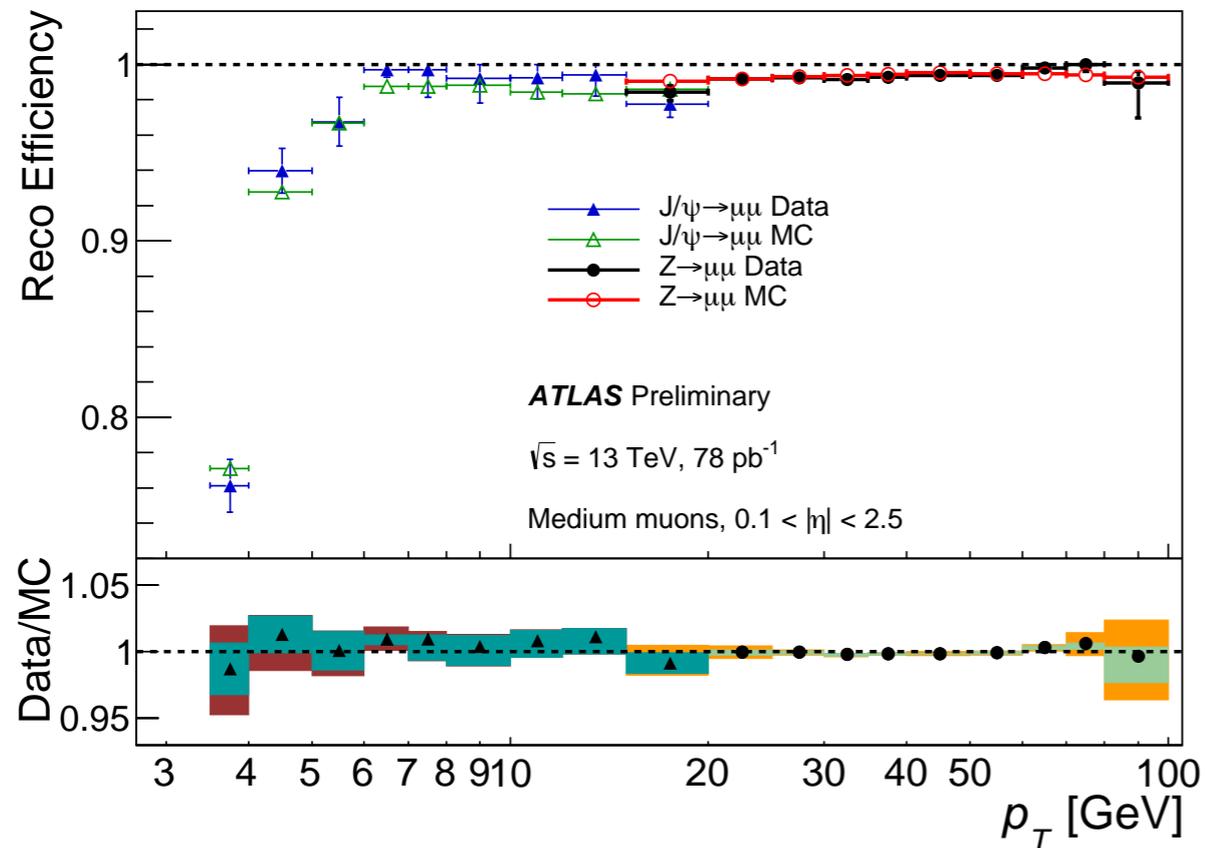
- Coming results will utilise much larger data sets, stay tuned for searches updates soon, and comprehensive results spring 2016.

Backup



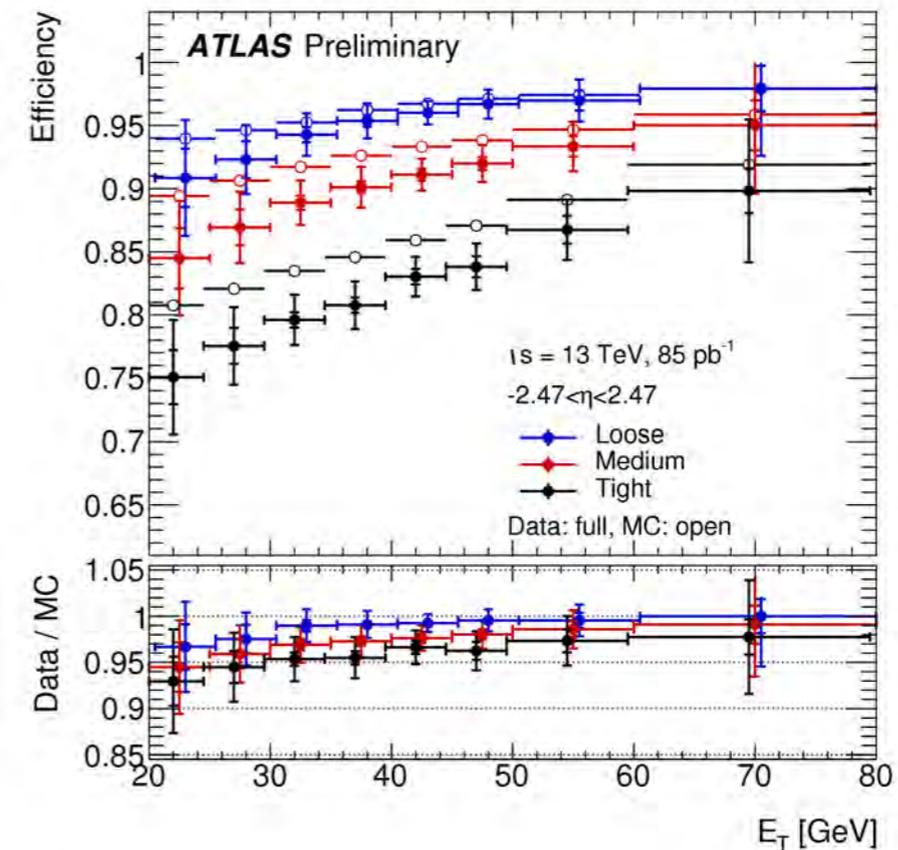
- Simultaneous check of the W and Z cross-section is a test of the SM and of lepton universality.
- Everything appears consistent with the SM.

Muon



- Trigger: 20 GeV + iso or 50 GeV
- Combined ID and MS tracks
- $p_T > 25 \text{ GeV}, |\eta| < 2.4$

Electron

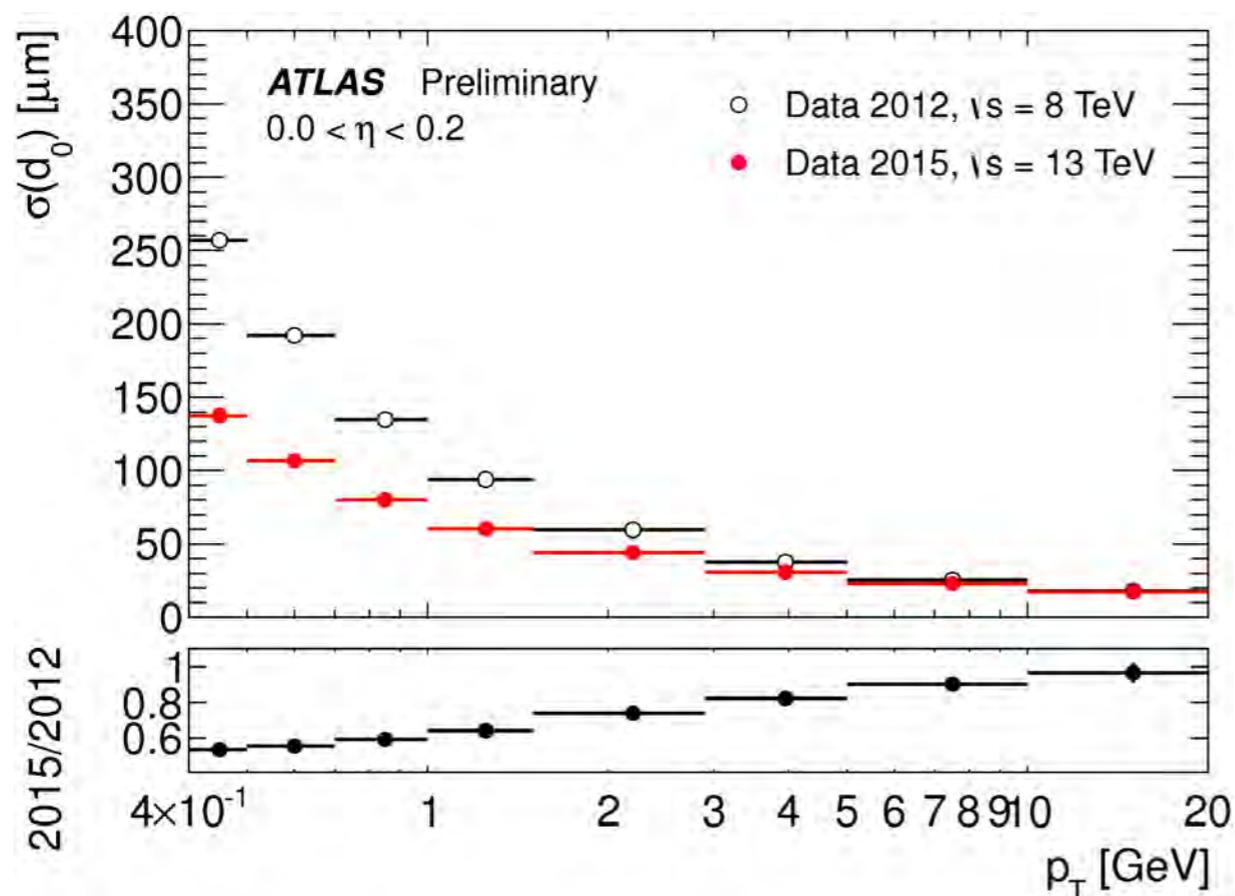


- Trigger: 24 + iso or 60 GeV
- Likelihood-based reco.
- $p_T > 25 \text{ GeV}, 1.37 < |\eta| < 1.52$

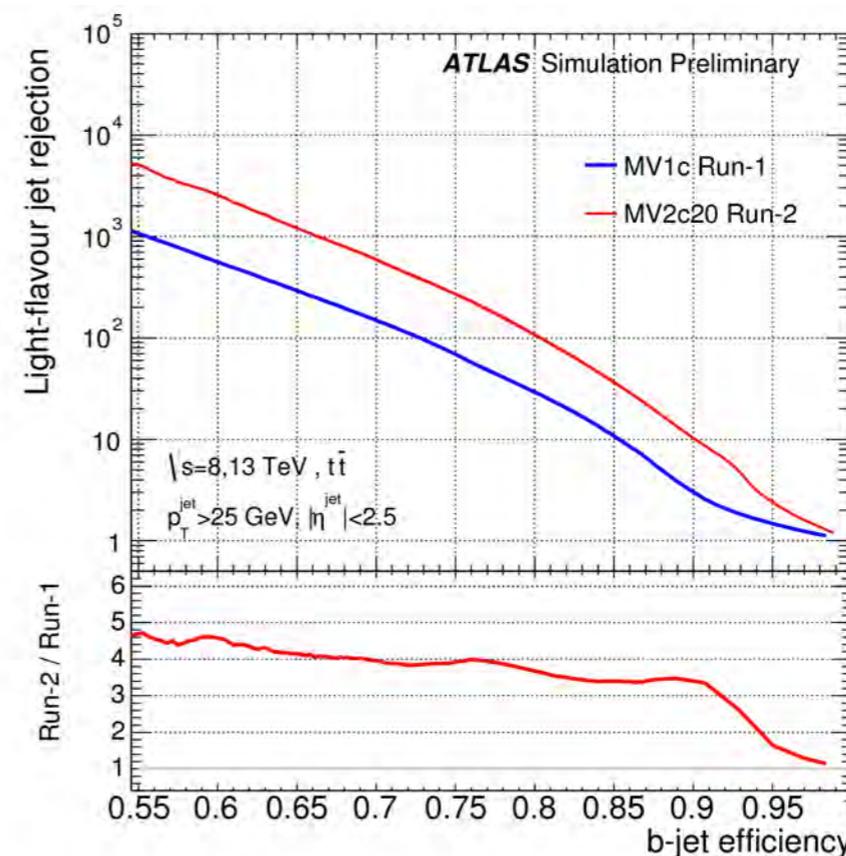
<https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-039/>

(Electron) <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PUBNOTES/ATL-PHYS-PUB-2015-041/>

Impact Parameter

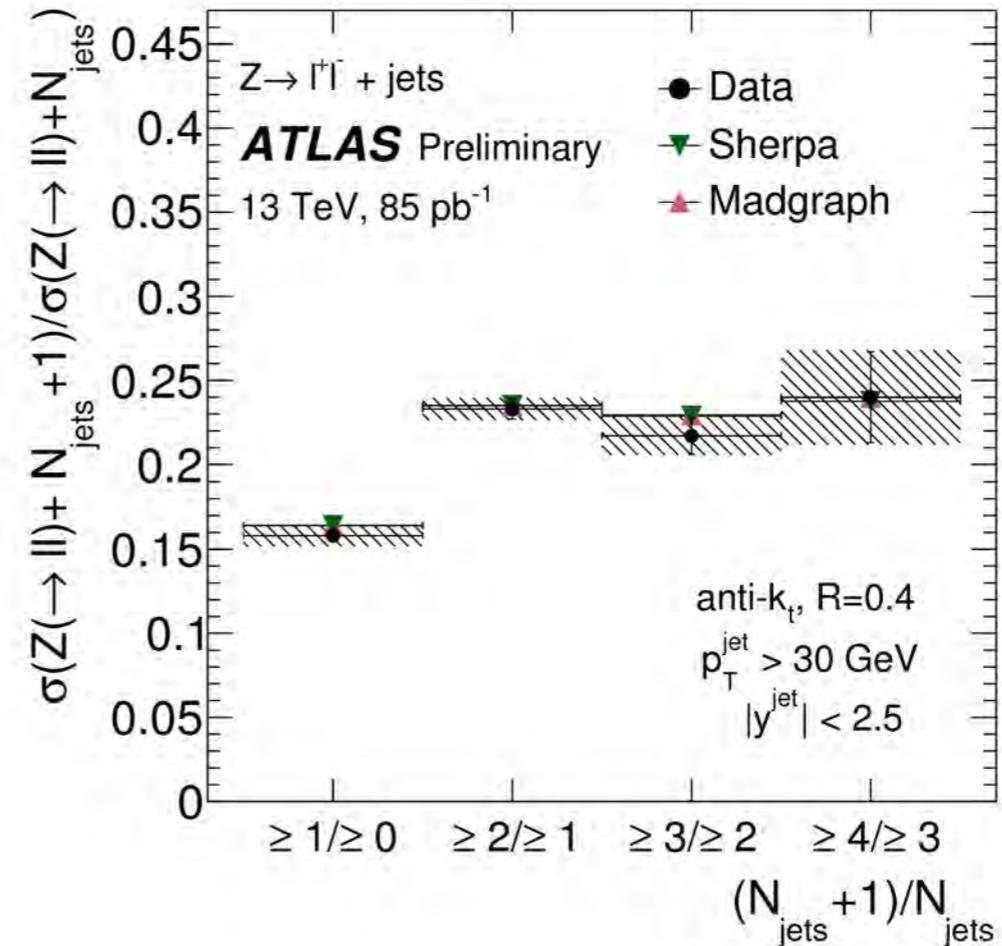
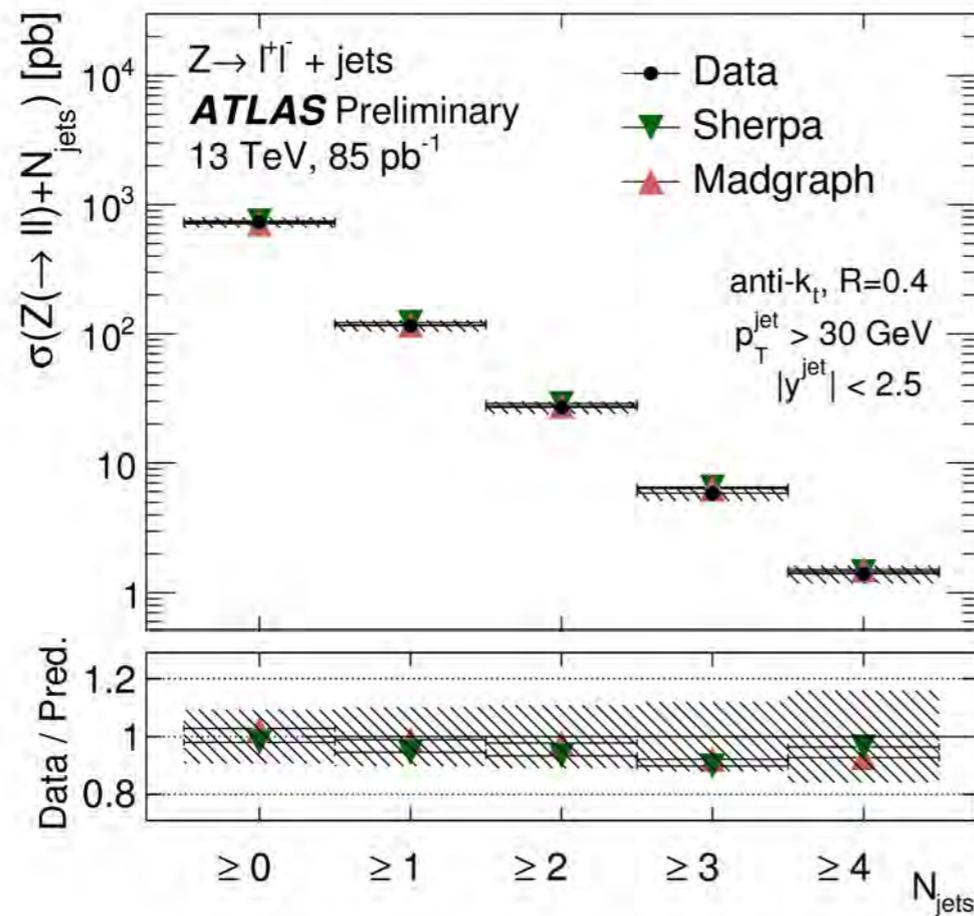


B-Tagging



[Performance Note]

- Impact parameters (d_0 and z_0) improve with the addition of the IBL.
- Multi-variate B-tagging algorithms (based on tracks) have improved rejection, relative to similar Run1 algorithms.



- Jet multiplicity distribution tests pQCD predictions.
- Very useful for tuning of parton showers and radiation parameters in MC.
- Madgraph and Sherpa giving consistent description of the data.

Cross-section calculations:

Higgs cross-sections:

- 7 TeV: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt7TeV>
- 8 TeV: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt8TeV>
- 13 TeV: <https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CERNYellowReportPageAt1314TeV>
- $m_H = 125.0$ GeV

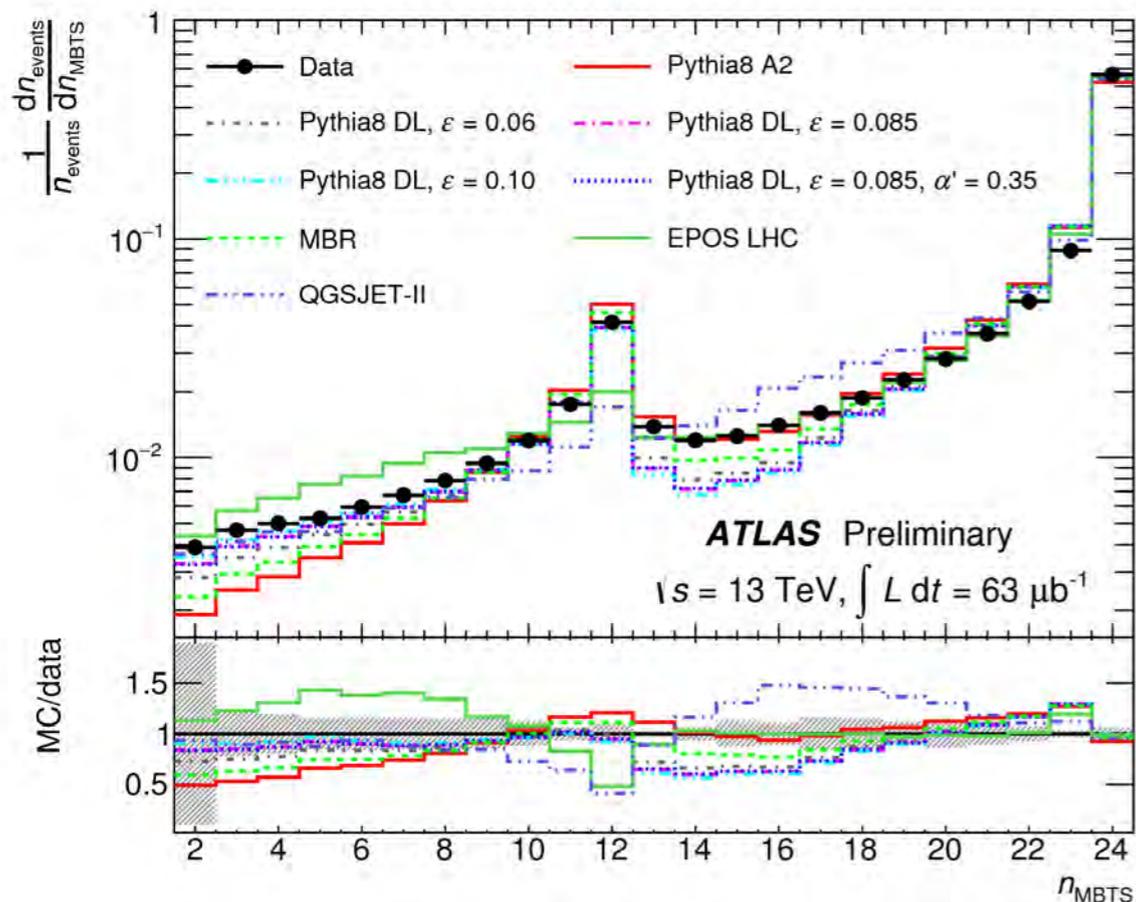
Top cross-sections:

- https://twiki.cern.ch/twiki/bin/view/LHCPhysics/TtbarNNLO#Top_quark_pair_cross_sections_at
- Calculated with top++2.0, NNLO + NNLL soft gluon resummation

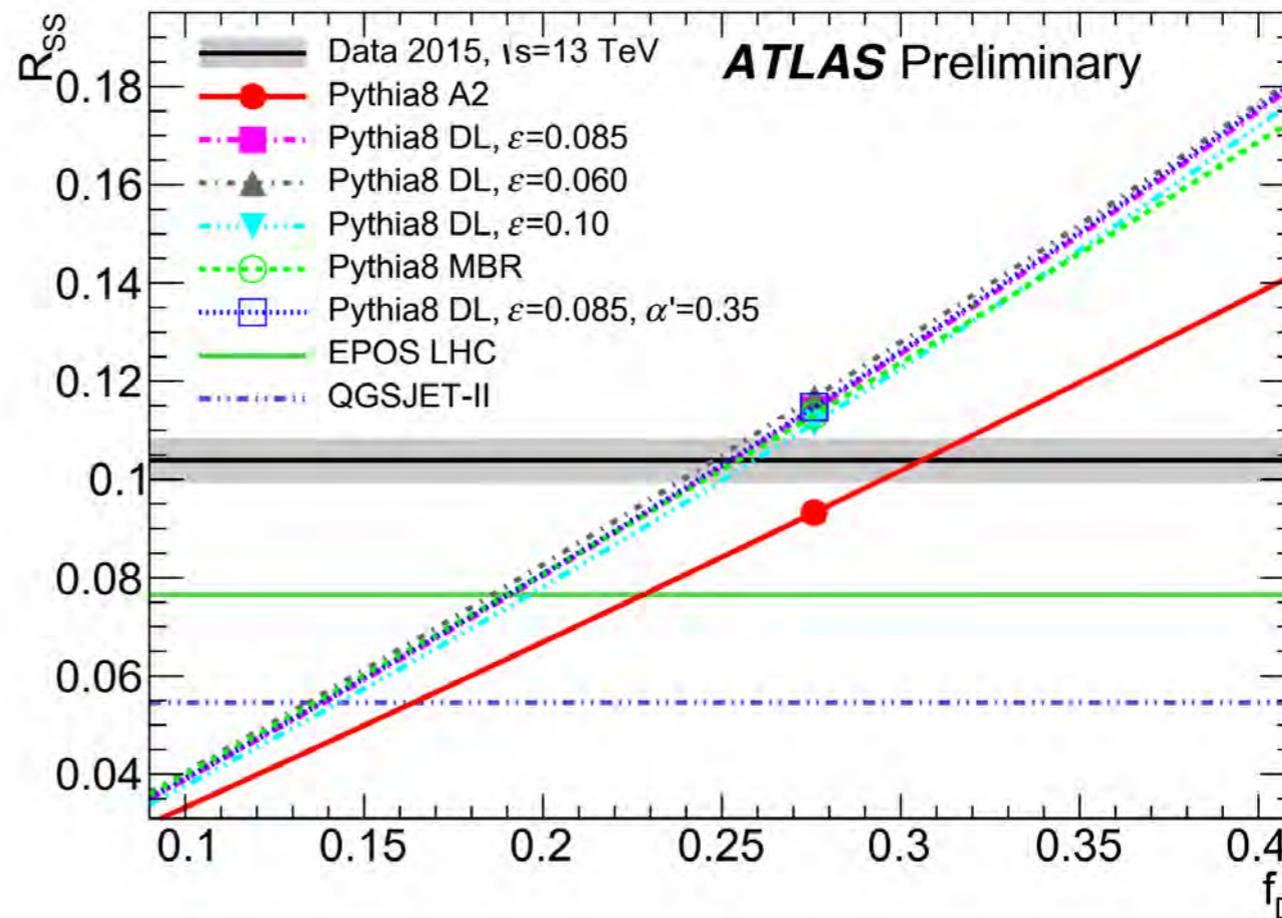
W/Z cross-sections:

- Calculated with FEWZ NNLO in QCD (not including the NLO EW corrections).
- $m_W = 80.403$ GeV
- $m_Z = 91.1876$ GeV

N_{MBTS} hits



Ratio SS/DS



Systematics

| Source | Value |
|-------------------------|---|
| This measurement | 73.1 ± 0.9 (exp.) ± 6.6 (lum.) ± 3.8 (extr.) mb |
| Pythia8 | 78.4 mb |
| Kopeliovich et al. [33] | 79.8 mb |
| Menon et al. [34] | 81.4 ± 2.0 mb |
| Khoze et al. [35] | 81.6 mb |
| Gotsman [36] | 81.0 mb |
| Fagundes [37] | 77.2 mb |

Fiducial

| Source | Value |
|--------------------------------|---|
| This measurement | 65.2 ± 0.8 (exp.) ± 5.9 (lum.) mb |
| Pythia8 DL, $\epsilon = 0.06$ | 71.0 mb |
| Pythia8 DL, $\epsilon = 0.085$ | 69.1 mb |
| Pythia8 DL, $\epsilon = 0.1$ | 68.1 mb |
| Pythia8 A2 | 74.4 mb |
| EPOS LHC | 71.2 mb |
| QGSJET-II | 72.7 mb |

Total cross-section

| Source | Value |
|-------------------------|---|
| This measurement | 73.1 ± 0.9 (exp.) ± 6.6 (lum.) ± 3.8 (extr.) mb |
| Pythia8 | 78.4 mb |
| Kopeliovich et al. [33] | 79.8 mb |
| Menon et al. [34] | 81.4 ± 2.0 mb |
| Khoze et al. [35] | 81.6 mb |
| Gotsman [36] | 81.0 mb |
| Fagundes [37] | 77.2 mb |

Systematics

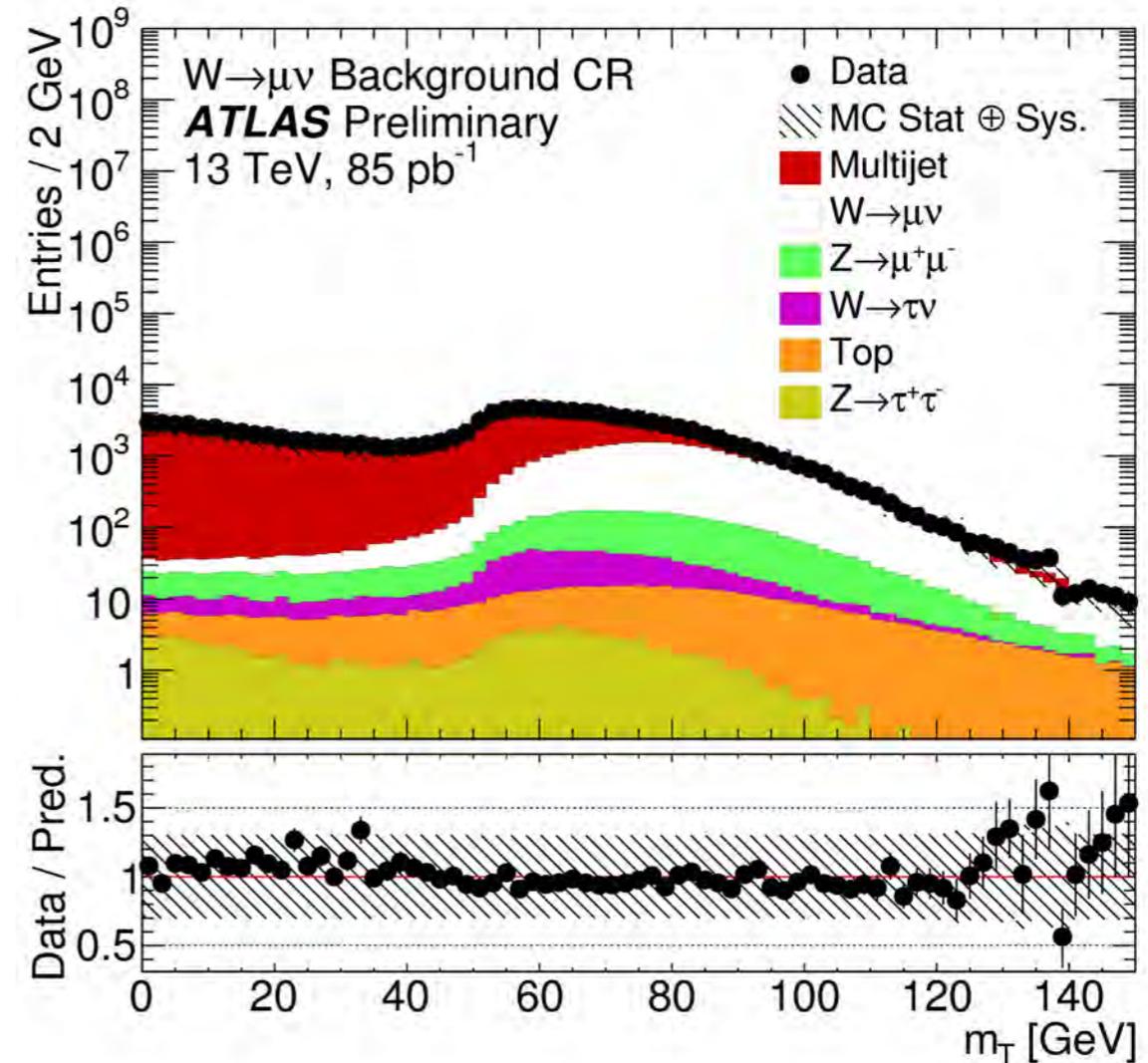
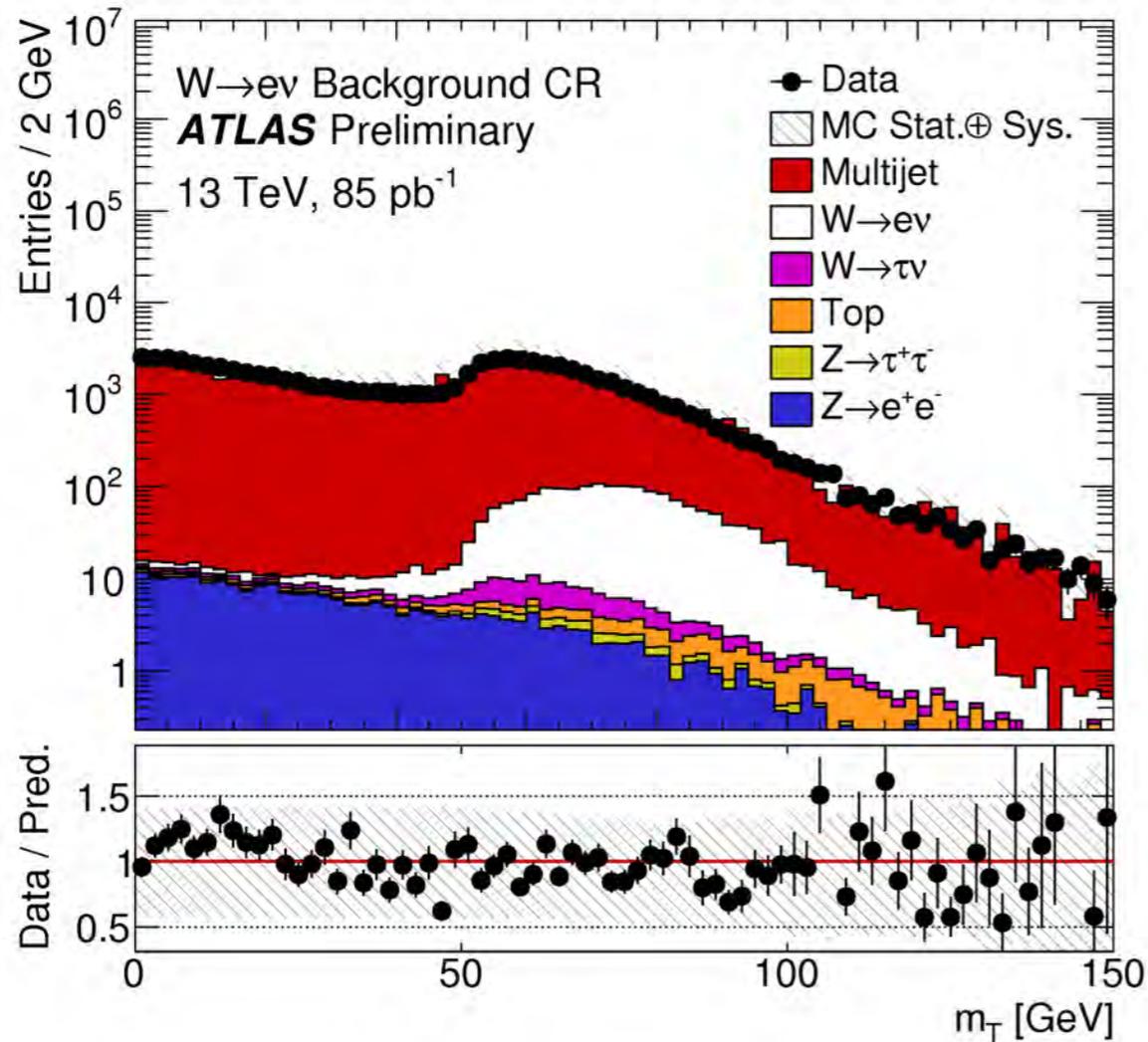
| Process $\delta C/C$ (%) | $Z \rightarrow \mu^+ \mu^-$ | $W^+ \rightarrow \mu^+ \nu$ | $W^- \rightarrow \mu^- \bar{\nu}$ | $Z \rightarrow e^+ e^-$ | $W^+ \rightarrow e^+ \nu$ | $W^- \rightarrow e^- \bar{\nu}$ |
|---|-----------------------------|-----------------------------|-----------------------------------|-------------------------|---------------------------|---------------------------------|
| Electron Trigger | – | – | – | 0.5 | 3.0 | 3.2 |
| Electron Reconstruction, Identification | – | – | – | 3.8 | 2.0 | 2.1 |
| Electron Isolation | – | – | – | 1.0 | 0.5 | 0.5 |
| Electron Scale and Resolution | – | – | – | 0.2 | 0.4 | 0.5 |
| Charge Identification | – | – | – | 0.8 | 0.1 | 0.1 |
| Muon Trigger | 1.0 | 2.0 | 2.0 | – | – | – |
| Muon Reconstruction, Identification | 0.9 | 0.4 | 0.4 | – | – | – |
| Muon Isolation | 0.5 | 0.3 | 0.3 | – | – | – |
| Muon Scale and Resolution | 0.1 | 0.1 | 0.1 | – | – | – |
| JES and JER | – | 1.5 | 1.5 | – | 1.9 | 1.8 |
| MET Soft Term | – | 0.1 | 0.1 | – | 0.1 | 0.1 |
| Pileup Modeling | 0.9 | 1.2 | 1.2 | 0.9 | 1.4 | 1.4 |
| Total | 1.7 | 2.8 | 2.8 | 4.1 | 4.4 | 4.5 |

Correlation

| | W^- | W^+ | Z |
|-------|-------|-------|------|
| W^- | 1 | 0.71 | 0.20 |
| W^+ | | 1 | 0.16 |
| Z | | | 1 |

Fraction of selection

| | Expected fraction in each channel | | | |
|-------------------------------|-----------------------------------|------------------------|-------------------------|-----------------------------|
| | $W \rightarrow e\nu$ | $W \rightarrow \mu\nu$ | $Z \rightarrow e^+ e^-$ | $Z \rightarrow \mu^+ \mu^-$ |
| $W \rightarrow \tau\nu$ | 1.8 | 2.0 | – | – |
| $Z \rightarrow \tau^- \tau^-$ | 0.2 | 0.2 | ¡0.1 | ¡0.1 |
| Diboson | – | – | 0.1 | 0.1 |
| $t\bar{t}$ | 1.2 | 1.1 | 0.5 | 0.5 |
| $W \rightarrow e\nu$ | 95.6 | – | ¡0.1 | – |
| $W \rightarrow \mu\nu$ | – | 92.0 | – | ¡0.1 |
| $Z \rightarrow e^+ e^-$ | 1.2 | – | 99.4 | – |
| $Z \rightarrow \mu^+ \mu^-$ | – | 4.7 | – | 99.4 |



Control region

- Inverted m_T cut.
- Inverted isolation requirement (and ID, in the case of electrons).

Same-flavour

| Uncertainty | $\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%) |
|---|---|
| Data statistics | 7.6 |
| $t\bar{t}$ NLO modelling | 2.6 |
| $t\bar{t}$ hadronisation | 7.9 |
| Initial/final state radiation | 1.5 |
| PDF | 3.7 |
| Single-top Wt cross-section | 0.6 |
| Single-top interference | <0.05 |
| Diboson cross-section | 0.4 |
| Z +jets $\rightarrow ee/\mu\mu$ modelling | 1.5 |
| Z +jets $\rightarrow \tau\tau$ modelling | 0.1 |
| Electron energy scale | 0.3 |
| Electron energy resolution | 0.2 |
| Electron identification | 3.6 |
| Electron trigger | 0.2 |
| Electron isolation | 1.0 |
| Muon momentum scale | 0.1 |
| Muon momentum resolution | 1.1 |
| Muon identification | 0.8 |
| Muon trigger | 0.6 |
| Muon isolation | 1.0 |
| Jet energy scale | 1.2 |
| Jet energy resolution | 0.2 |
| b -tagging efficiency | 0.8 |
| Missing transverse momentum | 0.3 |
| NP & fakes | 1.5 |
| Analysis systematics | 11 |
| Integrated luminosity | 10 |
| Total uncertainty | 16 |

l + jets

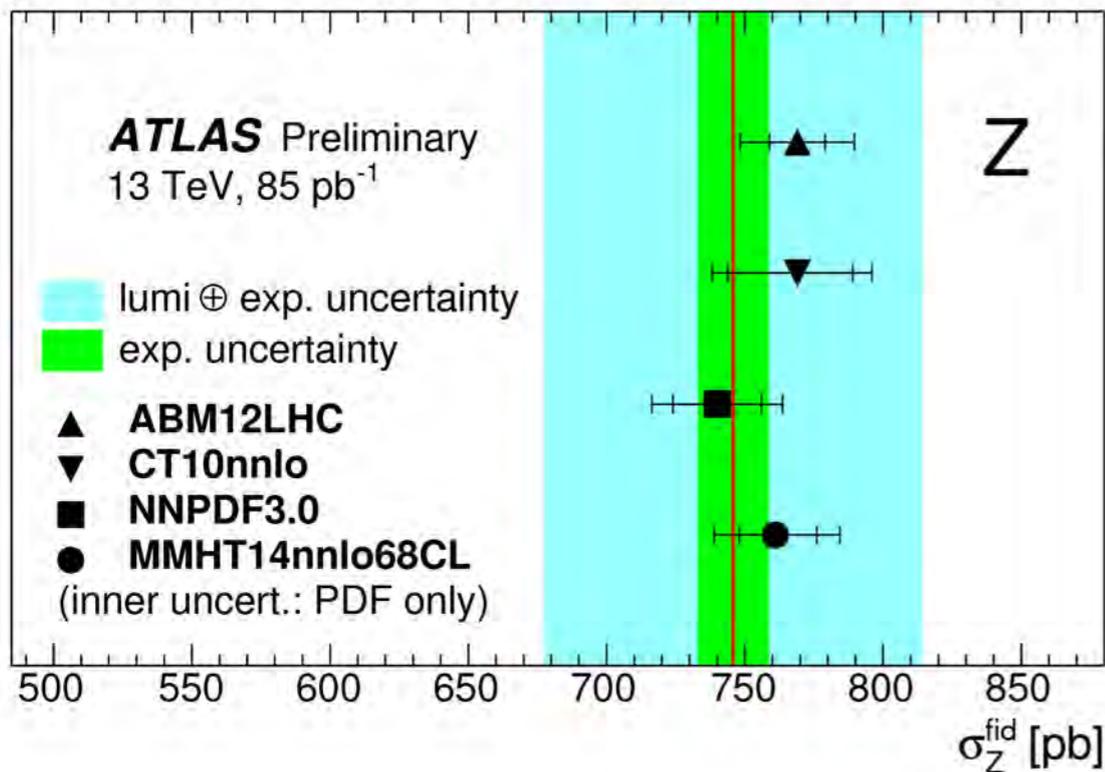
| Uncertainty | $\Delta\sigma_{t\bar{t}}/\sigma_{t\bar{t}}$ (%) |
|--------------------------------------|---|
| Data statistics | 1.5 |
| $t\bar{t}$ NLO modelling | 0.6 |
| $t\bar{t}$ hadronisation | 4.1 |
| Initial/final state radiation | 1.9 |
| PDF | 0.7 |
| Single top cross-section | 0.3 |
| Diboson cross-sections | 0.2 |
| Z +jets cross-section | 1.0 |
| W +jets method statistics | 1.7 |
| W +jets modelling | 1.0 |
| Electron energy scale/resolution | 0.1 |
| Electron identification | 2.1 |
| Electron isolation | 0.4 |
| Electron trigger | 2.8 |
| Muon momentum scale/resolution | 0.1 |
| Muon identification | 0.2 |
| Muon isolation | 0.3 |
| Muon trigger | 1.2 |
| E_T^{miss} scale/resolution | 0.4 |
| Jet energy scale | +10 -8 |
| Jet energy resolution | 0.6 |
| b -tagging | 4.1 |
| NP & fakes | 1.8 |
| Analysis systematics | +13 -11 |
| Integrated luminosity | +11 -9 |
| Total uncertainty | +17 -14 |

| Uncertainty (%) | $\sigma_{Z \rightarrow ee}$ | $\sigma_{Z \rightarrow \mu\mu}$ | $\sigma_{t\bar{t}}$ | $R_{t\bar{t}/Z}$ |
|---|-----------------------------|---------------------------------|---------------------|------------------|
| Data statistics | 0.5 | 0.5 | 6.0 | 6.0 |
| $t\bar{t}$ NLO modelling | - | - | 2.2 | 2.2 |
| $t\bar{t}$ hadronisation | - | - | 4.5 | 4.5 |
| Initial/final state radiation | - | - | 1.2 | 1.2 |
| Parton distribution functions ($t\bar{t}$, Wt) | - | - | 1.4 | 1.4 |
| Single-top modelling | - | - | 0.5 | 0.5 |
| Single-top/ $t\bar{t}$ interference | - | - | 0.1 | 0.1 |
| Single-top Wt cross-section | - | - | 0.5 | 0.5 |
| Diboson modelling | - | - | 0.1 | 0.1 |
| Diboson cross-sections | - | - | 0.0 | 0.0 |
| Z+jets extrapolation | - | - | 0.2 | 0.2 |
| Electron energy scale/resolution | 0.2 | - | 0.2 | 0.1 |
| Electron identification | 3.8 | - | 3.2 | 1.3 |
| Electron charge identification | 0.8 | - | - | 0.4 |
| Electron isolation | 1.0 | - | 1.1 | 1.2 |
| Muon momentum scale/resolution | - | 0.1 | 0.1 | 0.0 |
| Muon identification | - | 0.9 | 0.5 | 0.1 |
| Muon isolation | - | 0.5 | 1.1 | 1.1 |
| Lepton trigger | 0.5 | 1.1 | 0.8 | 0.7 |
| Jet energy scale | - | - | 0.3 | 0.3 |
| Jet energy resolution | - | - | 0.1 | 0.1 |
| b -tagging | - | - | 0.3 | 0.3 |
| Misidentified leptons | - | - | 1.4 | 1.4 |
| Pileup modelling | 0.9 | 0.9 | - | 0.9 |
| Z acceptance | 1.5 | 1.5 | - | 1.5 |
| Z backgrounds | 0.1 | 0.1 | - | 0.1 |
| Analysis systematics | 4.4 | 2.3 | 6.7 | 6.3 |
| Integrated luminosity | 9.0 | 9.0 | 10.0 | 1.0 |
| Total uncertainty | 10.0 | 9.3 | 13.5 | 8.8 |

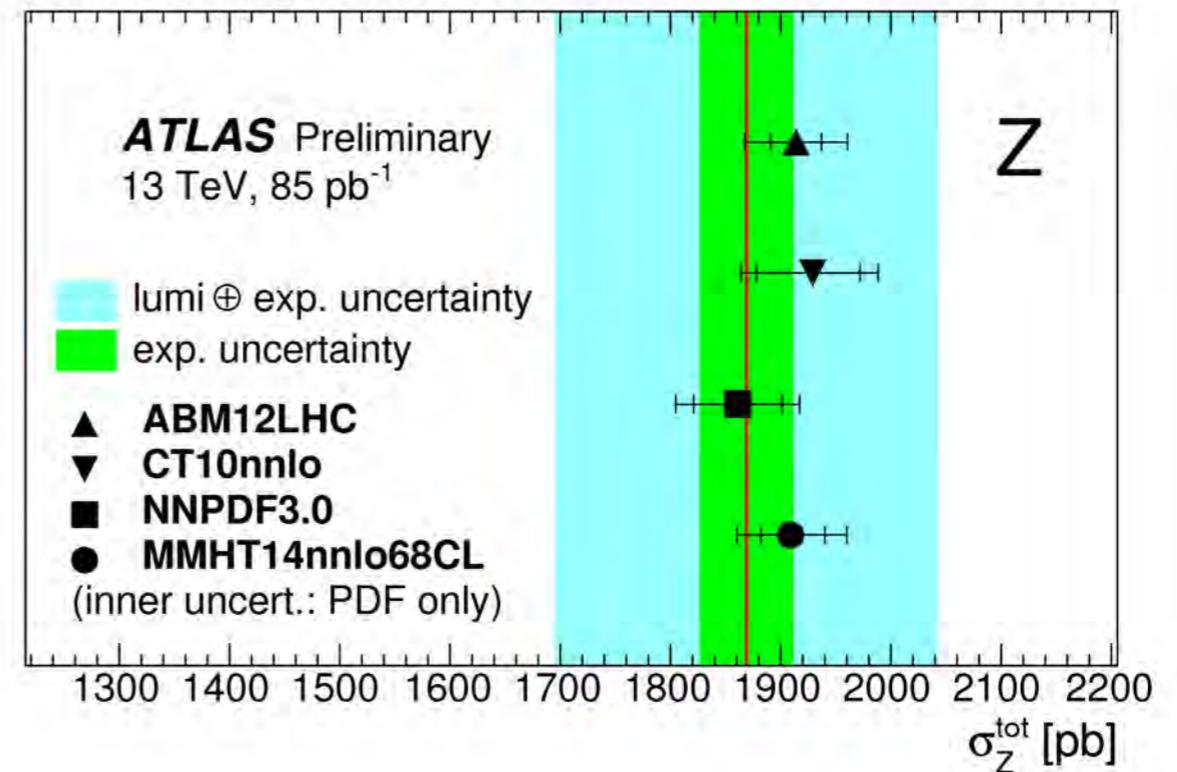
Constrained systematics

- Electron identification and reconstruction.
- Muon Momentum scale and resolution.
- Muon identification.
- Integrated Luminosity

Fiducial



Full



- Predictions describe both fiducial and full phase space very well.

| Channel | value ± stat. ± syst. ± lumi [pb %] |
|---------|--|
| W^- | $3344 \pm 0.2 \pm 3.4 \pm 9.0$ |
| W^+ | $4340 \pm 0.2 \pm 3.2 \pm 9.0$ |
| W | $7684 \pm 0.1 \pm 3.0 \pm 9.0$ |
| Z | $746 \pm 0.4 \pm 1.7 \pm 9.0$ |

| Channel | value ± stat. ± syst. ± lumi [pb %] |
|---------|--|
| W^- | $8380 \pm 0.2 \pm 4.0 \pm 9.0$ |
| W^+ | $10960 \pm 0.2 \pm 4.0 \pm 9.0$ |
| W | $19350 \pm 0.1 \pm 3.9 \pm 9.0$ |
| Z | $1869 \pm 0.4 \pm 2.2 \pm 9.0$ |