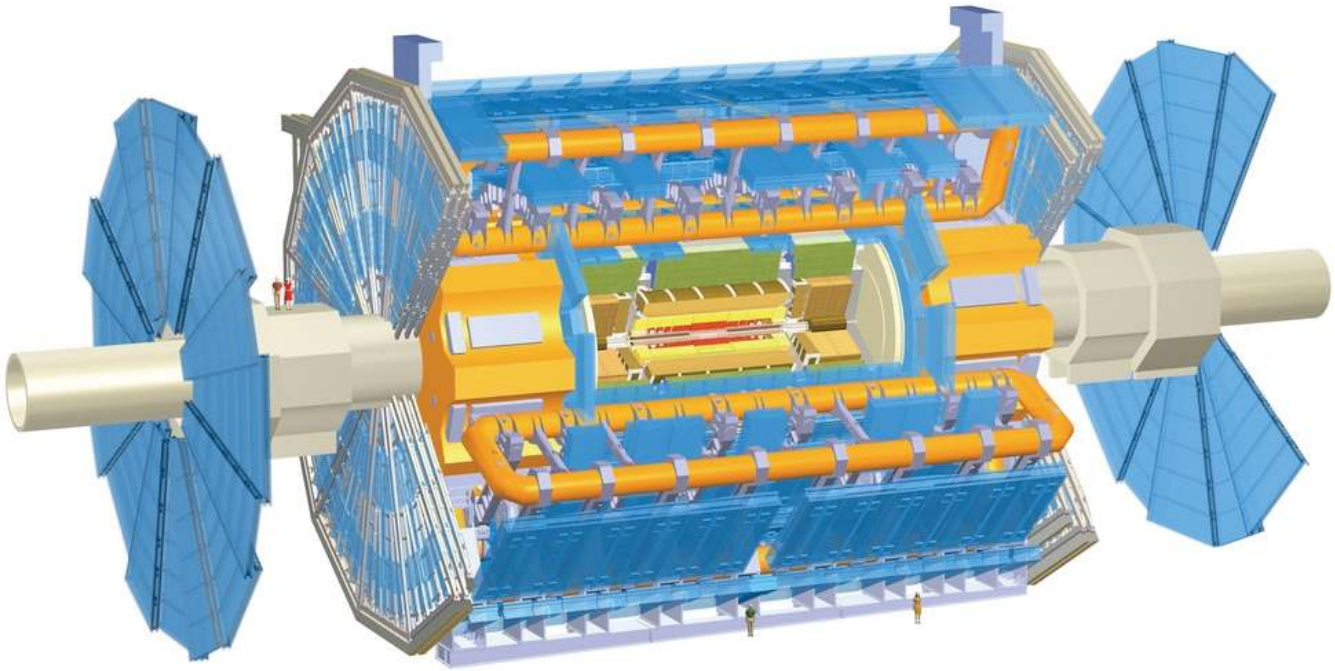
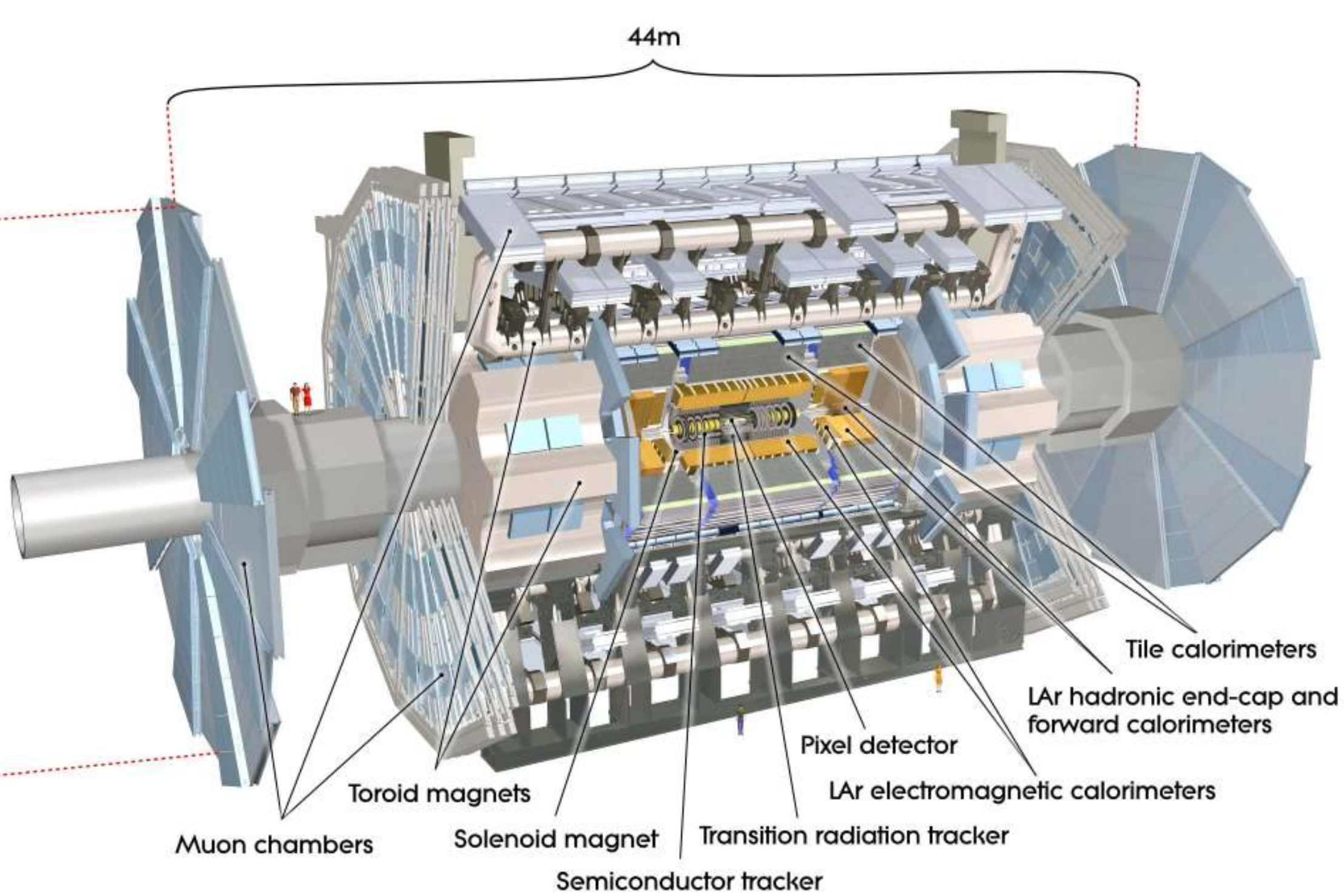
# for $\sigma_{t\bar{t}}$ at 10 TeV pp collisions at ATLAS

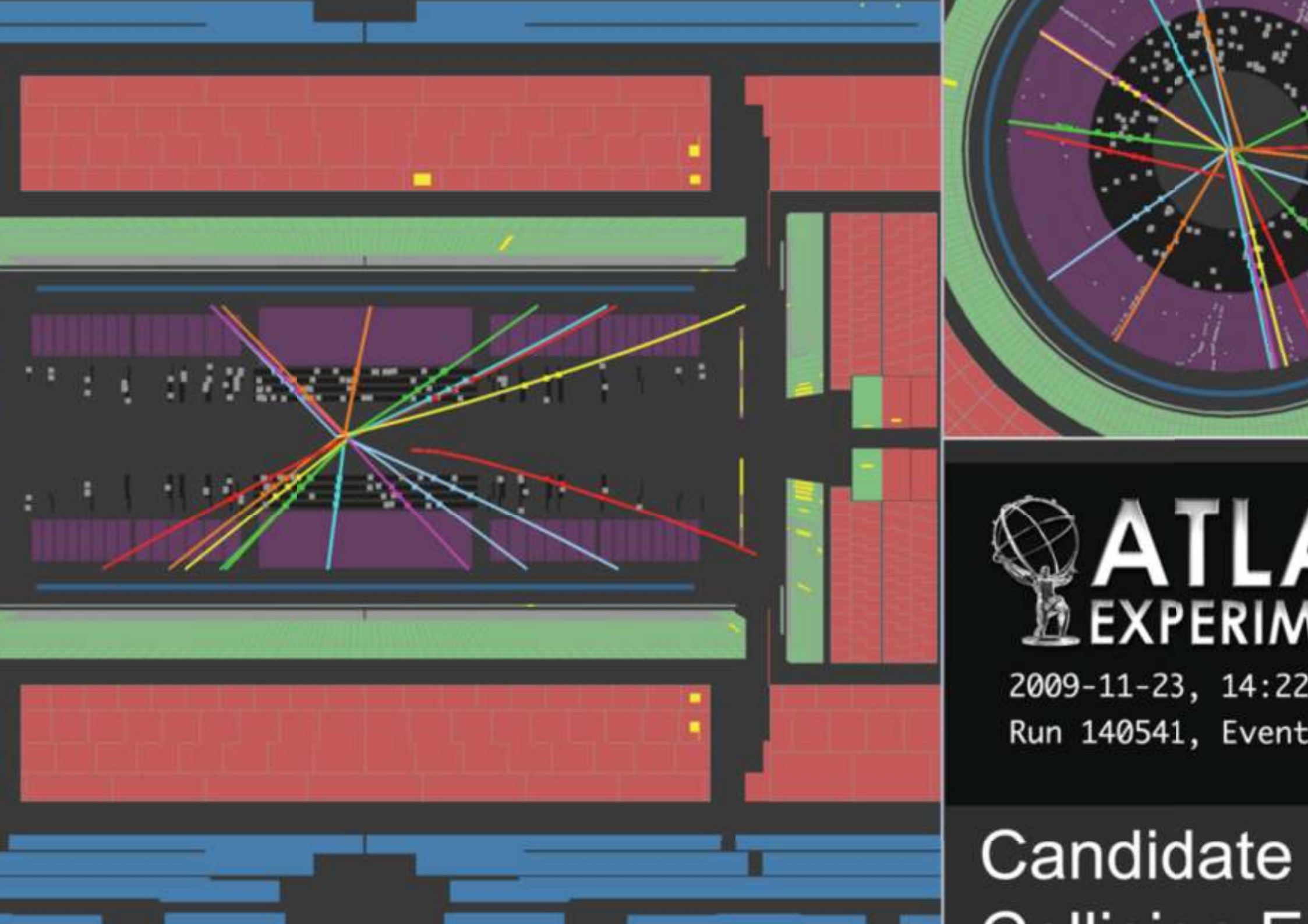
B.Radics (on behalf of the ATLAS collaboration)
*University of Bonn*

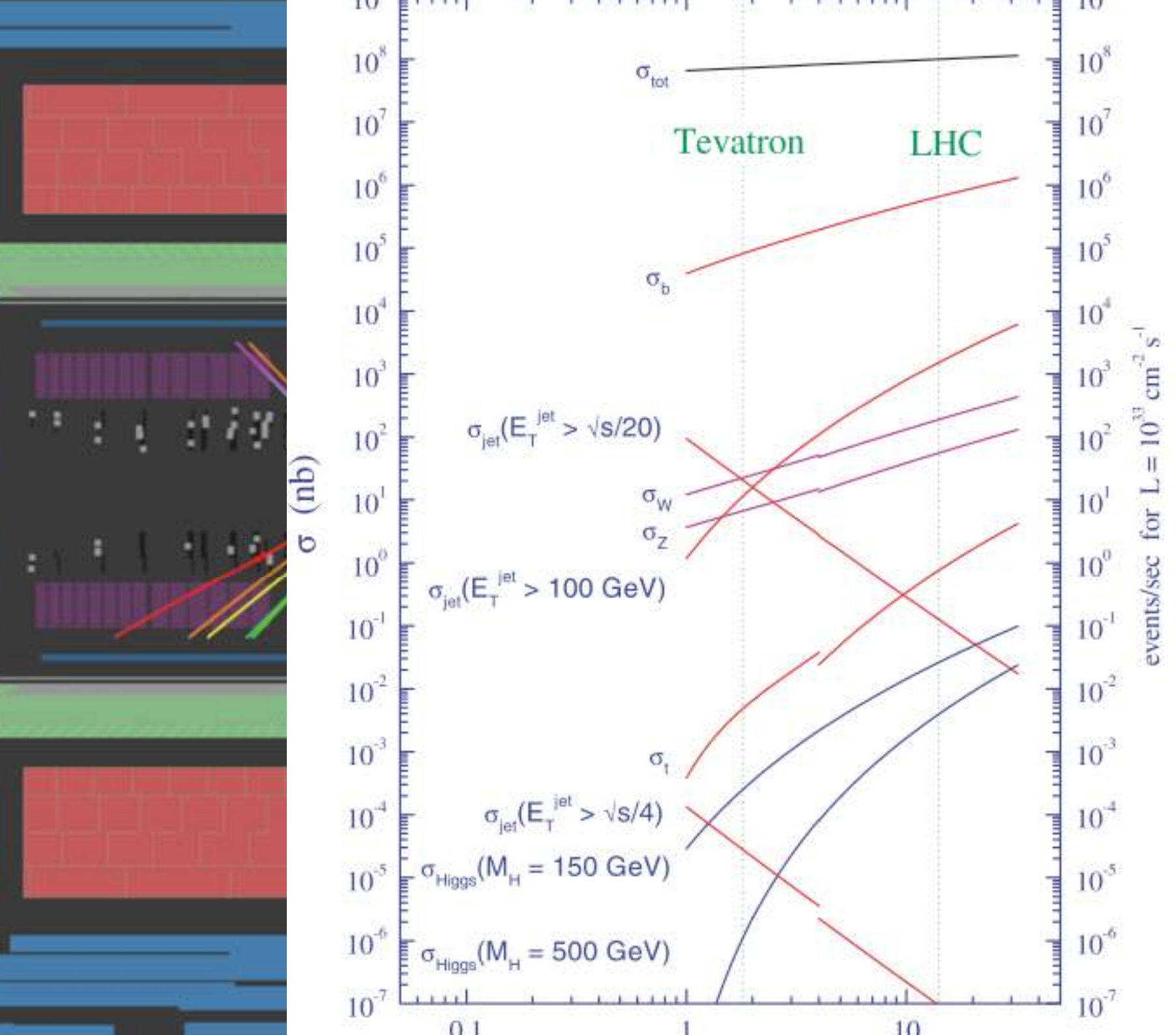


universitätbonn




**AS Experiment at the CERN Large Hadron Collider**

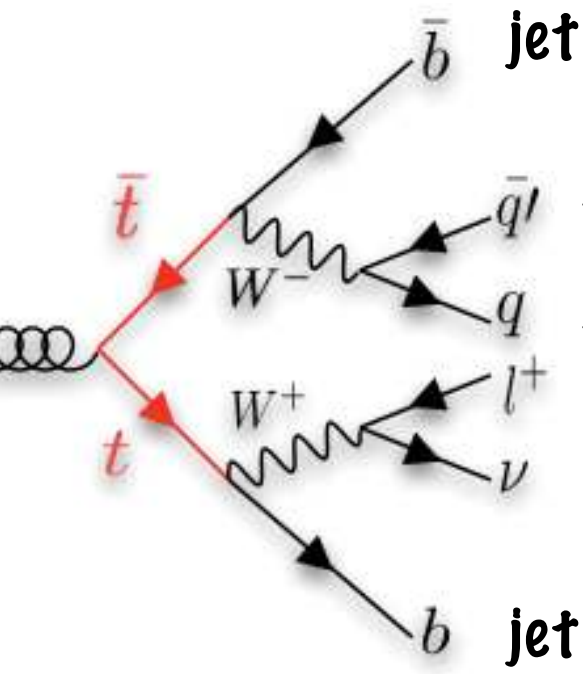

ATLA
EXPERIM
2009-11-23, 14:22
Run 140541, Event
Candidate


σ_tot
Tevatron
LHC
σ_b
σ_jet(E_T^jet > √s/20)
σ_W
σ_Z
σ_jet(E_T^jet > 100 GeV)
σ_t
σ_jet(E_T^jet > √s/4)
σ_Higgs(M_H = 150 GeV)
σ_Higgs(M_H = 500 GeV)
σ (nb)
events/sec for L = 10^33 cm^-2 s^-1
0.1
1
10

# Motivation

- Goal: Estimate uncertainty on a top pair production cross section at 10 TeV proton-proton collisions for 200 $pb^{-1}$ at ATLAS
- Major backgrounds: W+jets and QCD
- Problem: predictions on W+N jets (N >= 4) has large uncertainty
- Fortunately: W+jets/Z+jets ratio is predicted with much smaller uncertainty and Z+jets events can be selected from data with high purity
- Bonus: Taking ratios of jet multiplicites partially cancels uncertainties

# nal:

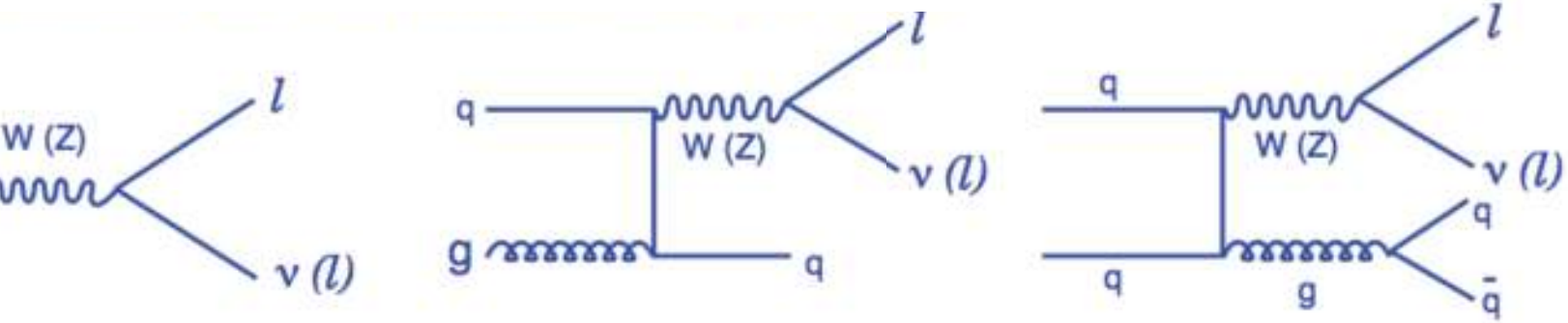



$$\sigma_{t\bar{t}}^{\text{approx. NNLO + NNLL}} = 401.6\,\text{pb}\,^{+3.6\%}_{-4.3\%}\,(\text{scales})\,^{+4.6\%}_{-4.5\%}\,($$

$$\sigma_{t\bar{t}}^{\text{NLO + NLL}} = 396.9\,\text{pb}\,^{+8.6\%}_{-9.2\%}\,(\text{scales})\,^{+4.9\%}_{-6.5\%}\,($$

$m_t$ = 172.5 GeV, CTEQ6.6 PDF

# W+jets background:




$$\sigma^{LO}_{W\to e\nu+0p} = 1018$$

$$\sigma^{LO}_{W\to e\nu+1p} = 211$$

$$\sigma^{LO}_{W\to e\nu+2p} = 67$$

$$\sigma^{LO}_{W\to e\nu+3p} = 20$$

$$\sigma^{LO}_{W\to e\nu+4p} = 5$$

$$\sigma^{LO}_{W\to e\nu+5p} = 1$$

selection:

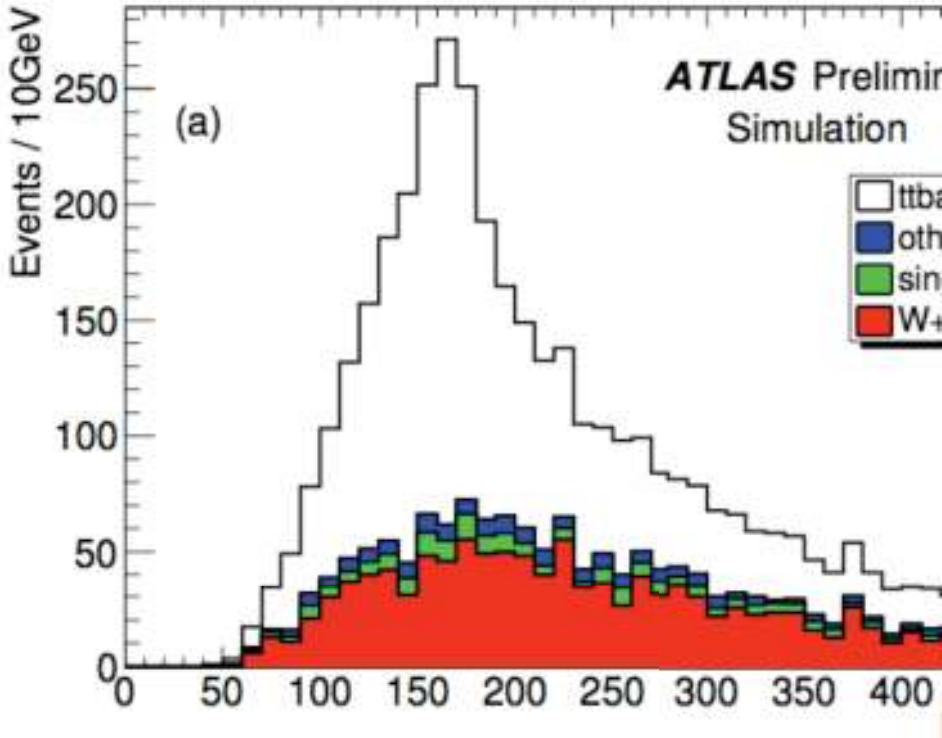
igger: single lepton with $p_T$ > 15 GeV

actly 1 lepton with $p_T$ > 20 GeV

ssing $E_T$ > 20 GeV

least 4 jets with $p_T$ > 20 GeV

which at least 3 jets have $p_T$ > 40 GeV




| Numbers of Selected Events | | | | |
|---|---|---|---|---|
| | Electron Analysis | | Muon Analysis | |
| mple | default | +$M_W$-cut | default | +$M_W$-cut |
| | 2600 | 1286 | 3144 | 1584 |
| +jets | 1305 | 448 | 1766 | 628 |
| ngle top | 210 | 81 | 227 | 98 |
| $\rightarrow ll$ +jets | 148 | 43 | 144 | 49 |
| dronic $t\bar{t}$ | 16 | 10 | 11 | 5 |
| $b\bar{b}$ | 21 | 7 | 32 | 10 |
| W | 11 | 6 | 14 | 7 |
| Z | 3 | 1 | 5 | 2 |
| Z | 0.4 | 0.2 | 0.5 | 0.2 |
| gnal | 2600 | 1286 | 3144 | 1584 |
| ackground | 1715 | 598 | 2199 | 799 |

Cut and count method:

$$\sigma = \frac{N_{\text{sig}}}{\mathcal{L} \times \varepsilon} = \frac{N_{\text{obs}} - N_{\text{bkg}}}{\mathcal{L} \times \varepsilon}$$

W+jets background: data dr

QCD background: data driv

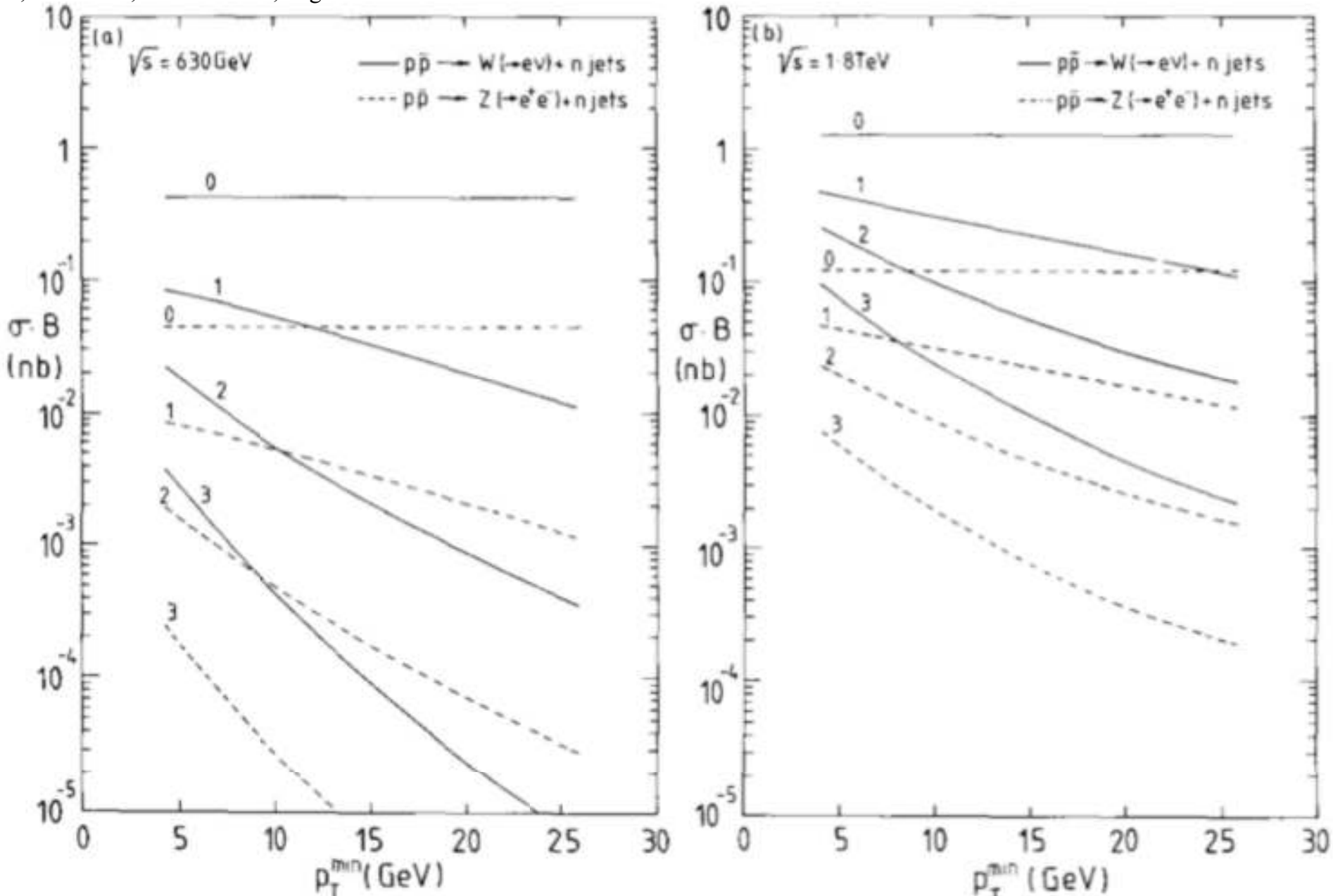
Other background: MC bas

# for W and Z + n jets

**production in W, Z events at p colliders**

, W. T. Giele, H. Kuijf, R. Kleiss, W. J. Stirling

rs B,Volume 224, Issues 1-2, 22 June 1989, Pages 237-242



# Jet multiplicity for W and Z + n jets

**production in W, Z events at p colliders**

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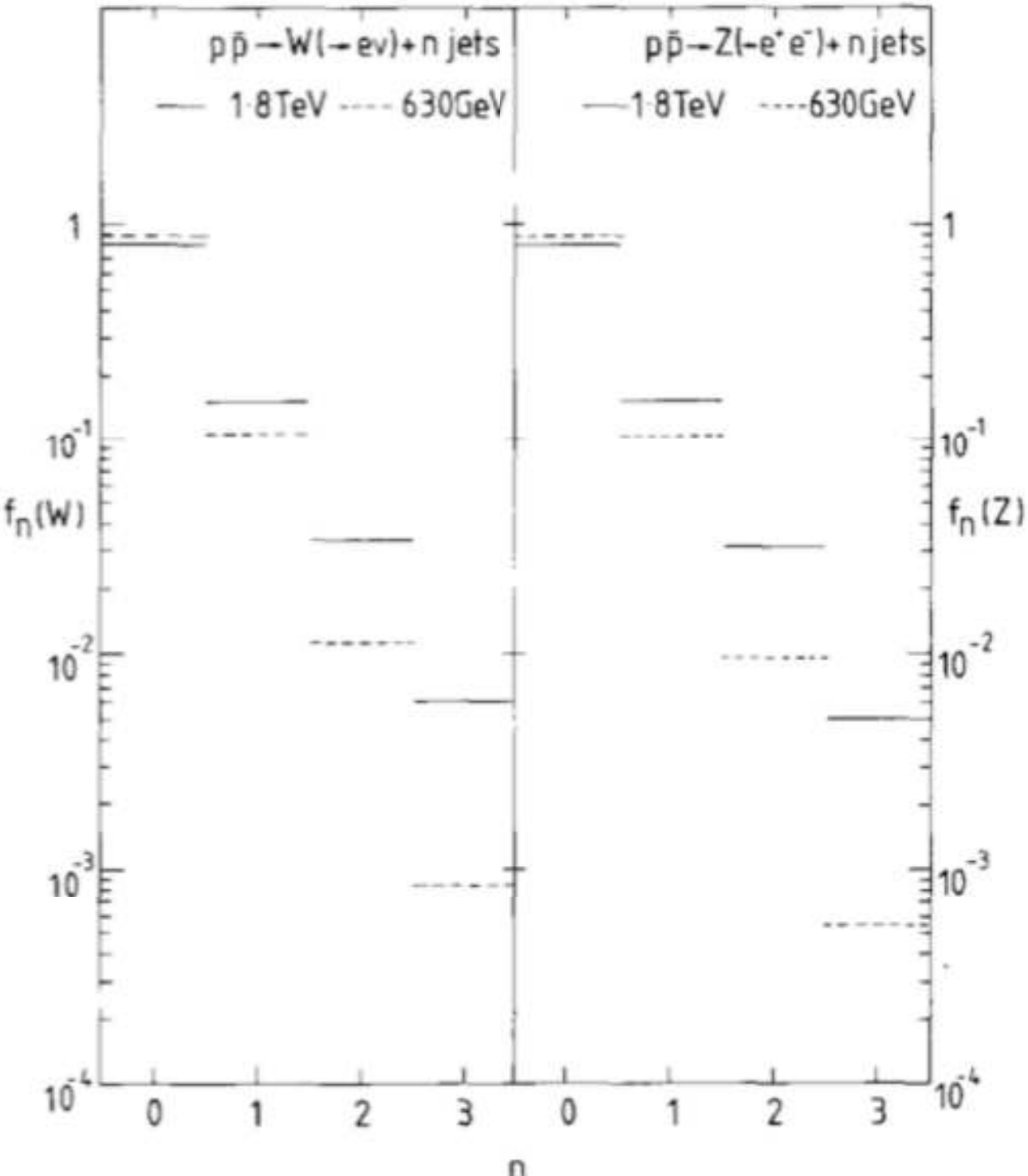
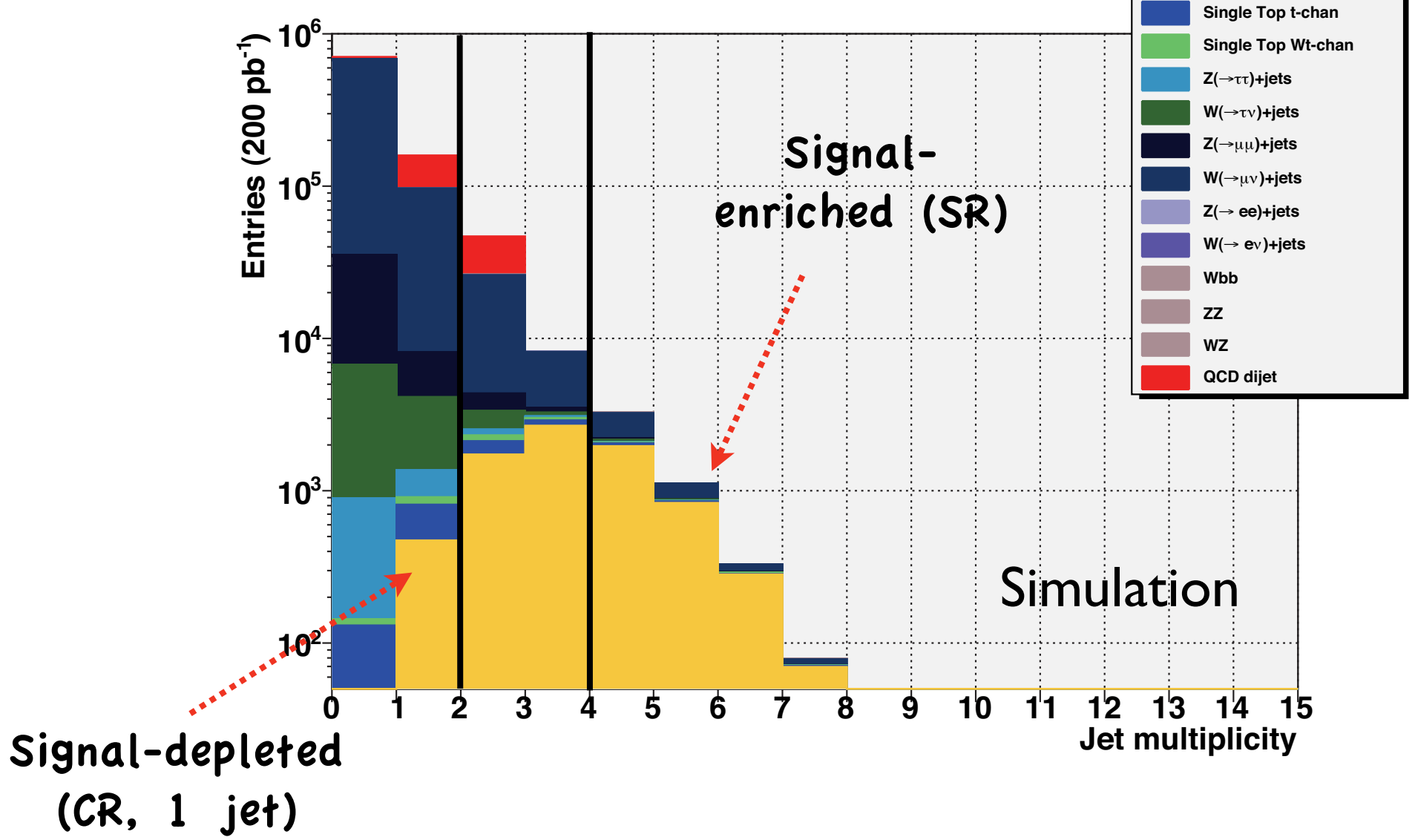





$$(W^{SR}/W^{CR})_{data} = (Z^{SR}/Z^{CR})_{data} \cdot C_{MC}, \qquad C_{MC} = \frac{(W^{SR}/W^{CR})_{MC}}{(Z^{SR}/Z^{CR})_{MC}}$$

# Control Region

- trigger: single electron (muon) $p_T$ > 15 GeV
- exactly 1 offline reconstructed electron (muon)
- veto on any reconstructed muon (electron)
- missing $E_T$ > 20 GeV
- CR: 1 jet $p_T$ > 20 GeV, SR: >= 4 jets, 3 jets $p_T$ > 40 GeV

| Process | $W \to e\nu$ | $W \to \mu\nu$ |
|---|---|---|
| $W(e\nu)$ | $148700 \pm 600$ | 0.0 |
| $W(\mu\nu)$ | $43 \pm 8$ | $190300 \pm 600$ |
| $W(\tau\nu)$ | $5570 \pm 110$ | $6820 \pm 110$ |
| $Z(ee)$ | $1197 \pm 39$ | 0.0 |
| $Z(\mu\mu)$ | $1.0 \pm 0.4$ | $8066 \pm 200$ |
| $Z(\tau\tau)$ | $879 \pm 25$ | $1130 \pm 30$ |
| $t\bar{t}$ | $203 \pm 6$ | $241 \pm 4$ |
| single top | $272 \pm 10$ | $308 \pm 10$ |
| $Wbb$ | $97 \pm 3$ | $119 \pm 3$ |
| Diboson | $427 \pm 11$ | $557 \pm 2$ |
| QCD | $42000 \pm 4000$ | $31000 \pm 15500$ |

# Control Region and Signal Region

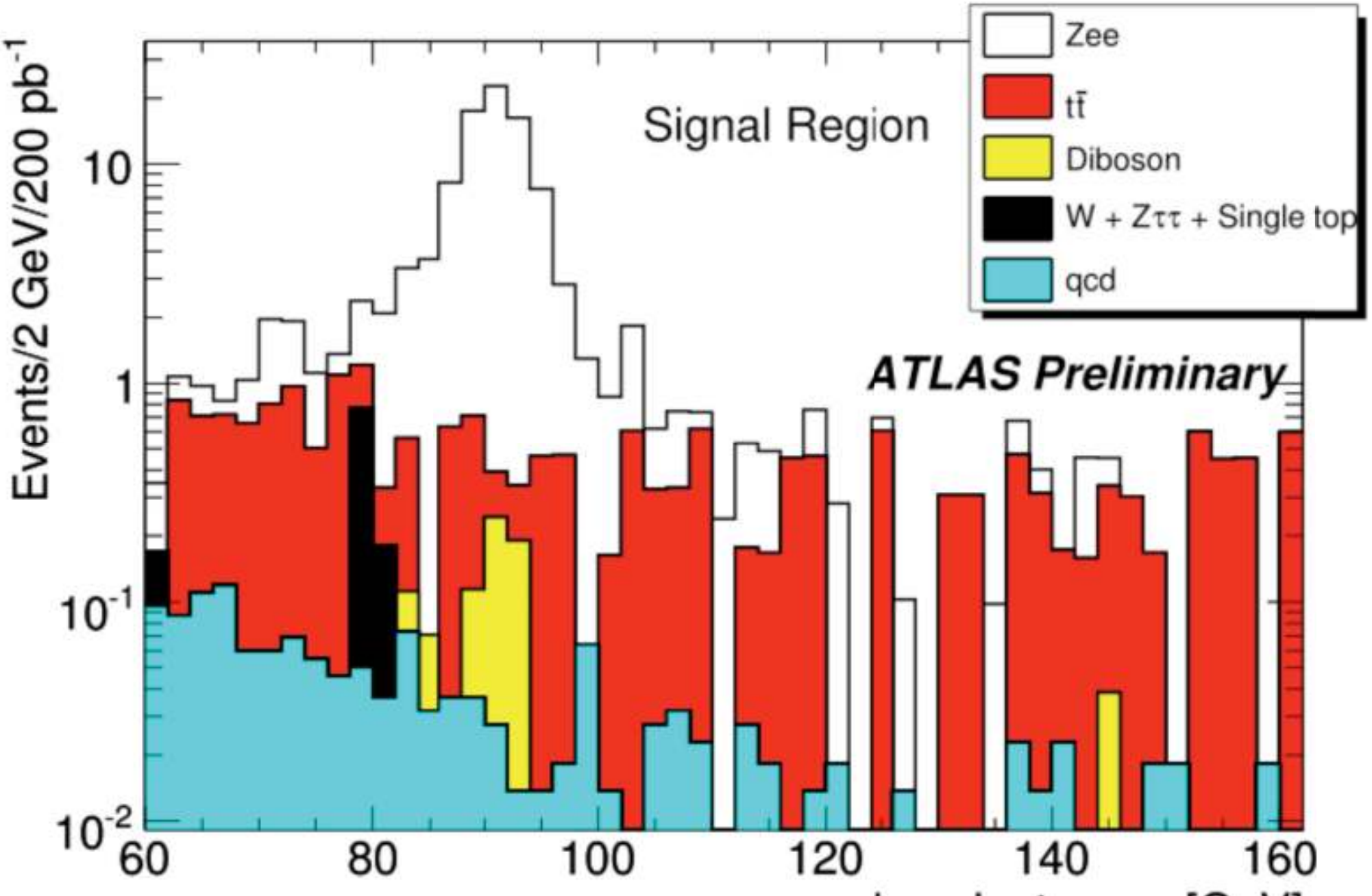
trigger: single electron (muon) $p_T$ > 15 GeV

exactly 2 offline reconstructed electrons (muons) with opposite charge, and invariant mass between 80 and 100 GeV

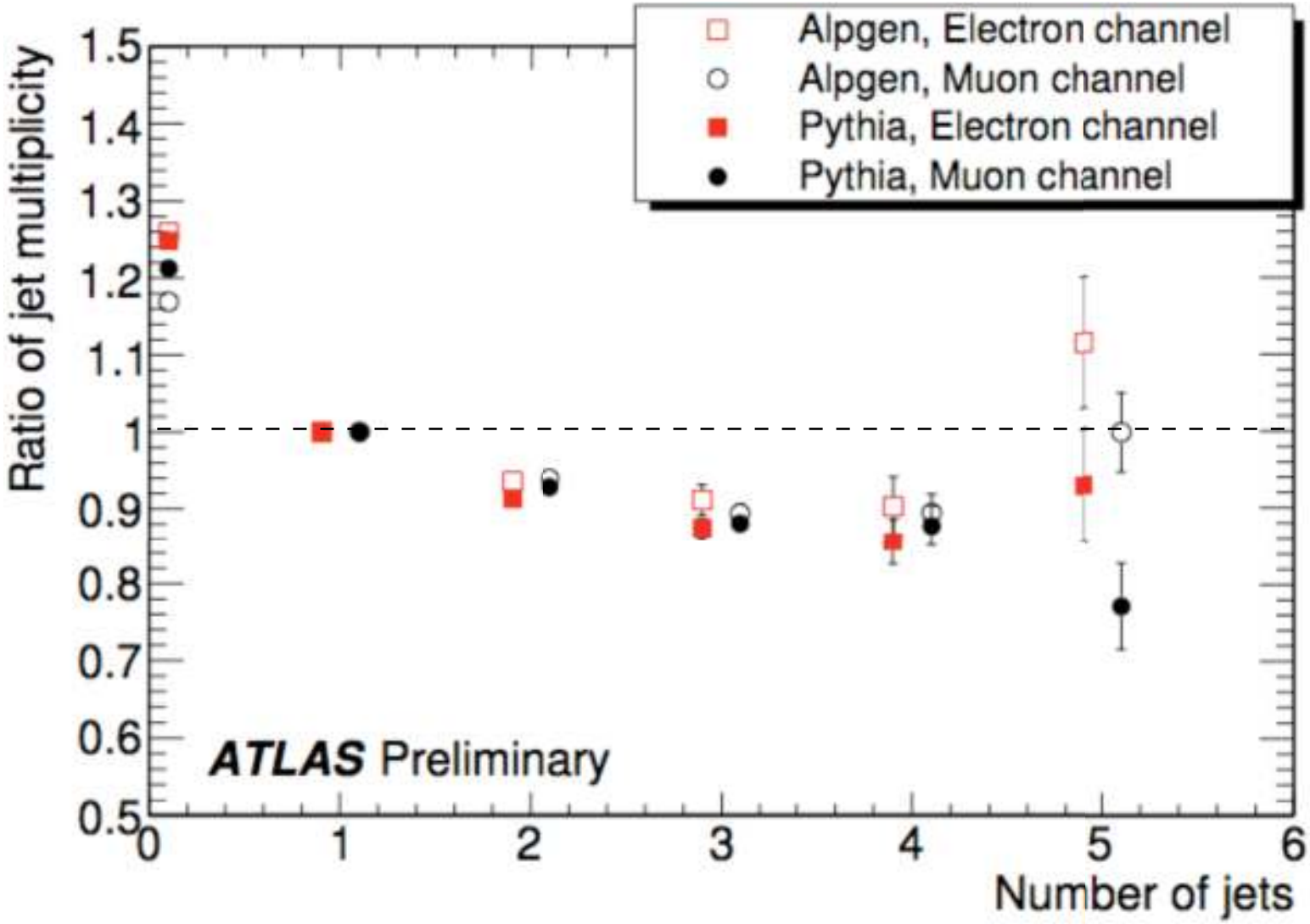
CR: 1 jet $p_T$ > 20 GeV, SR: >= 4 jets, 3 jets $p_T$ > 40 GeV

| Process | $Z \to ee$ | | $Z \to \mu\mu$ | |
|---|---|---|---|---|
| | + 1 jet | signal-like | + 1 jet | signal-like |
| Z(ee) | $10210 \pm 90$ | $82 \pm 3$ | 0.0 | 0.0 |
| $Z(\mu\mu)$ | 0.0 | 0.0 | $15750 \pm 270$ | $150 \pm 8$ |
| $Z(\tau\tau)$ | $0.1 \pm 0.1$ | $0.1 \pm 0.1$ | $0.9 \pm 0.9$ | 0.0 |
| W | $6.0 \pm 1.5$ | 0.0 | 0.0 | 0.0 |
| $t\bar{t}$ | $8.4 \pm 1.1$ | $2.8 \pm 0.6$ | $10.5 \pm 0.9$ | $5.0 \pm 0.7$ |
| single top | $2.9 \pm 1.4$ | 0.0 | $2.3 \pm 0.8$ | 0.0 |
| Wbb | 0.0 | 0.0 | 0.0 | 0.0 |
| Diboson | $24.9 \pm 1.9$ | $0.5 \pm 0.3$ | $40.0 \pm 2.4$ | $1.0 \pm 0.4$ |
| QCD | $110 \pm 80$ | $0.4 \pm 0.4$ | $< 50.0$ | $< 0.5$ |

# Event selection: Z(->ee)+jets, Signal Region



# Comparison of Alpgen and Pythia: Ratio of W to Z jet multiplicites




$$(\mathrm{W}^{\mathrm{SR}}/\mathrm{W}^{\mathrm{CR}})_{\mathrm{data}} = (\mathrm{Z}^{\mathrm{SR}}/\mathrm{Z}^{\mathrm{CR}})_{\mathrm{data}} \cdot C_{\mathrm{MC}}, \qquad C_{\mathrm{MC}} = \frac{(\mathrm{W}^{\mathrm{SR}}/\mathrm{W}^{\mathrm{CR}})_{\mathrm{MC}}}{(\mathrm{Z}^{\mathrm{SR}}/\mathrm{Z}^{\mathrm{CR}})_{\mathrm{MC}}}$$

# Systematic uncertainties

$$(W^{SR}/W^{CR})_{data} = (Z^{SR}/Z^{CR})_{data} \cdot C_{MC}, \qquad C_{MC} = \frac{(W^{SR}/W^{CR})_{MC}}{(Z^{SR}/Z^{CR})_{MC}}$$

| | Electron analysis | Muon analysis |
|---|---|---|
| Statistical for 200 $pb^{-1}$ | 11.3% | 8.3% |
| Purity of control samples | 17.0% | 12.7% |
| Monte Carlo correction factor | 12.1% | 12.1% |
| JES (±10%) | 3.6% | 2.3% |
| JES (±5%) | 3.0% | 0.7% |
| Lepton energy scale | 0.4% | 0.7% |
| total error | 23.9% | 19.6% |

Statistical uncertainty: Z candidates in signal region

Purity of control samples: assumption of 50% uncertainty on QCD

this dominates,and was extracted from Monte Carlo with limited statistics (multijet production cross section sets a limit)

trigger: single electron (muon) $p_T$ > 15 GeV

exactly 1 offline reconstructed electron (muon)

veto on any reconstructed muon (electron)

missing $E_T$ > 20 GeV

SR: >= 4 jets, 3 jets $p_T$ > 40 GeV

| Muon analysis | | | | | | |
|---|---|---|---|---|---|---|
| | 10TeV (200 pb$^{-1}$) | | | 14TeV (100 pb$^{-1}$) | | |
| Sample | default | +$M_W$ cut | +$m_t$ cut | default | +$M_W$ cut | +$m_t$ cut |
| ttbar | 3144 ± 17 | 1584 ± 12 | 712 ± 8 | 3274 | 1606 | 755 |
| W+jets | 1766 ± 44 | 628 ± 27 | 148 ± 13 | 1052 | 319 | 98 |
| single top | 227 ± 9 | 98 ± 6 | 33 ± 4 | 227 | 99 | 25 |
| Z→ *ll* +jets | 144 ± 4 | 49 ± 2 | 13 ± 1 | 84 | 23 | 3 |
| hadronic $t\bar{t}$ | 11 ± 2 | 5 ± 1 | 2 ± 1 | 35 | 17 | 7 |
| W $b\bar{b}$ | 32 ± 2 | 10 ± 1 | 3 ± 1 | 64 | 19 | 4 |
| W $c\bar{c}$ | | | | 26 | 9 | 3 |
| WW | 14 ± 2 | 7 ± 1 | 2 ± 1 | 7 | 3 | 0.7 |
| WZ | 5 ± 1 | 2 ± 1 | 0.2 ± 0.2 | 7 | 3 | 0.8 |
| ZZ | 0.5 ± 0.1 | 0.2 ± 0.1 | 0.1 ± 0.0 | 0.7 | 0.3 | 0.1 |

# measurement

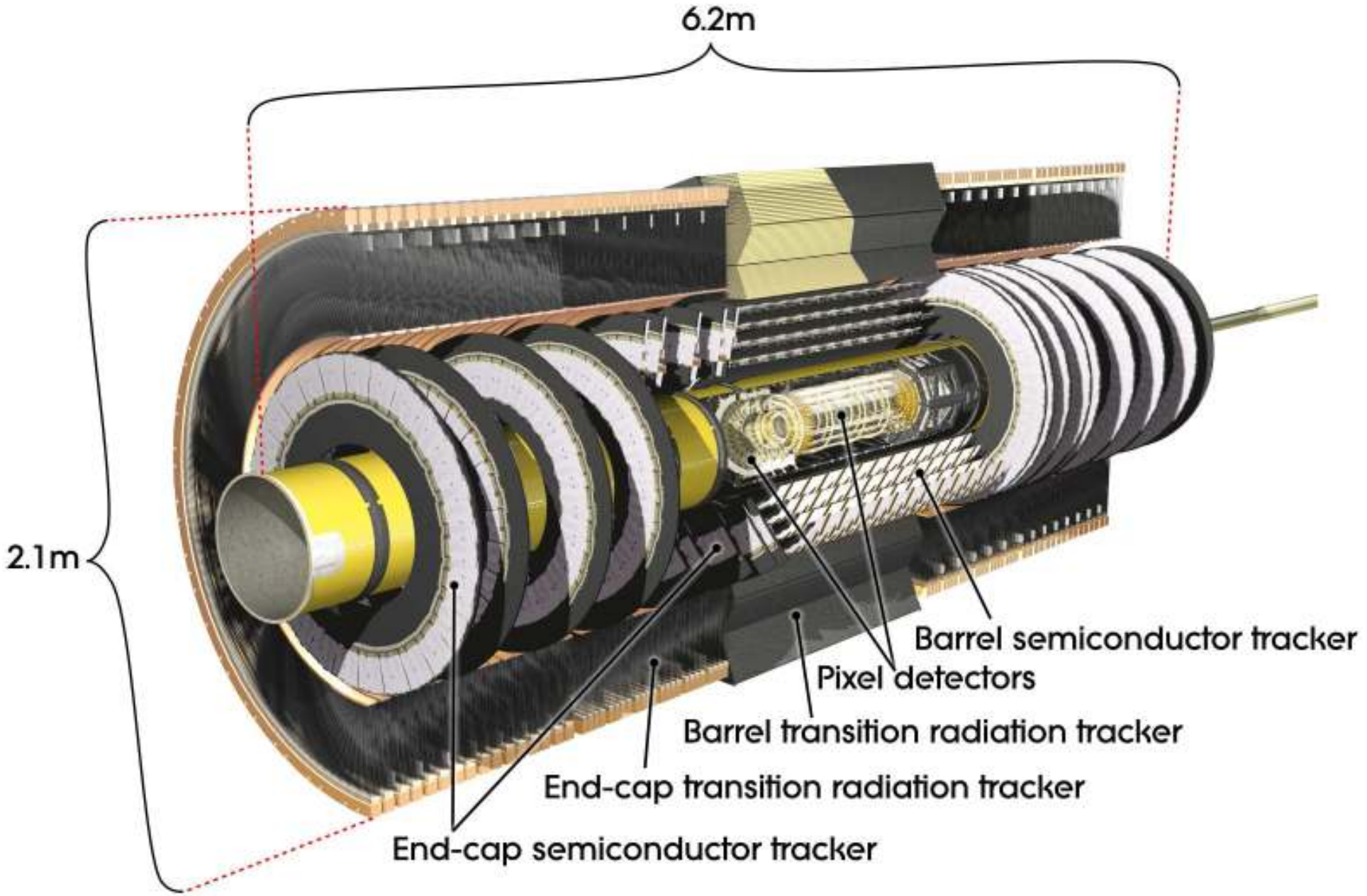
| | Cut and Count method | | | | Fit method | |
|---|---|---|---|---|---|---|
| Source | *e*-analysis | | $\mu$-analysis | | *e*-analysis | $\mu$-analysis |
| | default (%) | +$M_W$ cut (%) | default (%) | +$M_W$ cut (%) | +$M_W$ cut (%) | +$M_W$ cut (%) |
| Stat. | ± 2.5 | ± 3.4 | ±2.3 | ±3.1 | ± 14.1 | ± 15.2 |
| Lepton ID eff. | ±1.0 | ±**1.0** | ±1.0 | ±**1.0** | ± **1.0** | ± **1.0** |
| Lepton trig. eff. | ±1.0 | ±**1.0** | ±1.0 | ±**1.0** | ± **1.0** | ± **1.0** |
| 50% W+jets | ±25.1 | ±17.4 | ±28.1 | ±19.8 | ± 3.3 | ± 5.6 |
| 20% W+jets | ±10.0 | ±**7.0** | ±11.2 | ±**7.9** | ± **1.5** | ± **2.6** |
| JES (10%,-10%) | +24.8-23.4 | +15.9-19.1 | +20.5-22.3 | +11.9-17.9 | -14.4 | -15.4 |
| JES (5%,-5%) | +12.3-11.9 | **+8.6-9.3** | +10.4-10.9 | **+6.1-8.4** | **-3.7** | **-3.9** |
| PDFs | ±1.6 | ± **1.9** | ±1.2 | ± **1.4** | ± **1.9** | ± **1.4** |
| ISR/FSR | +9.1-9.1 | **+7.6-8.2** | +8.2-8.2 | **+5.2-8.3** | **-12.9** | **-12.9** |
| Signal MC | ±3.3 | ±**4.4** | ±0.3 | ±**2.8** | ± **4.5** | ± **1.4** |
| Back. Uncertainty | ±0.6 | ±**0.4** | ±0.5 | ±**0.4** | - | - |
| Fitting Model | - | - | - | - | ± **3.3** | ± **4.7** |
| 10% Lumi. | ±11.6 | ±11.2 | ±11.4 | ±11.1 | ±10 | ±10 |
| 20% Lumi. | ±23.2 | ±**22.3** | ±22.8 | ±**22.2** | ±**20** | ± **20** |
| Tot. without Lumi. | +18.8-18.5 | **+14.4-15.2** | +17.5-17.7 | **+11.9-14.7** | **+6.4 -14.9** | **+6.0 - 14.7** |

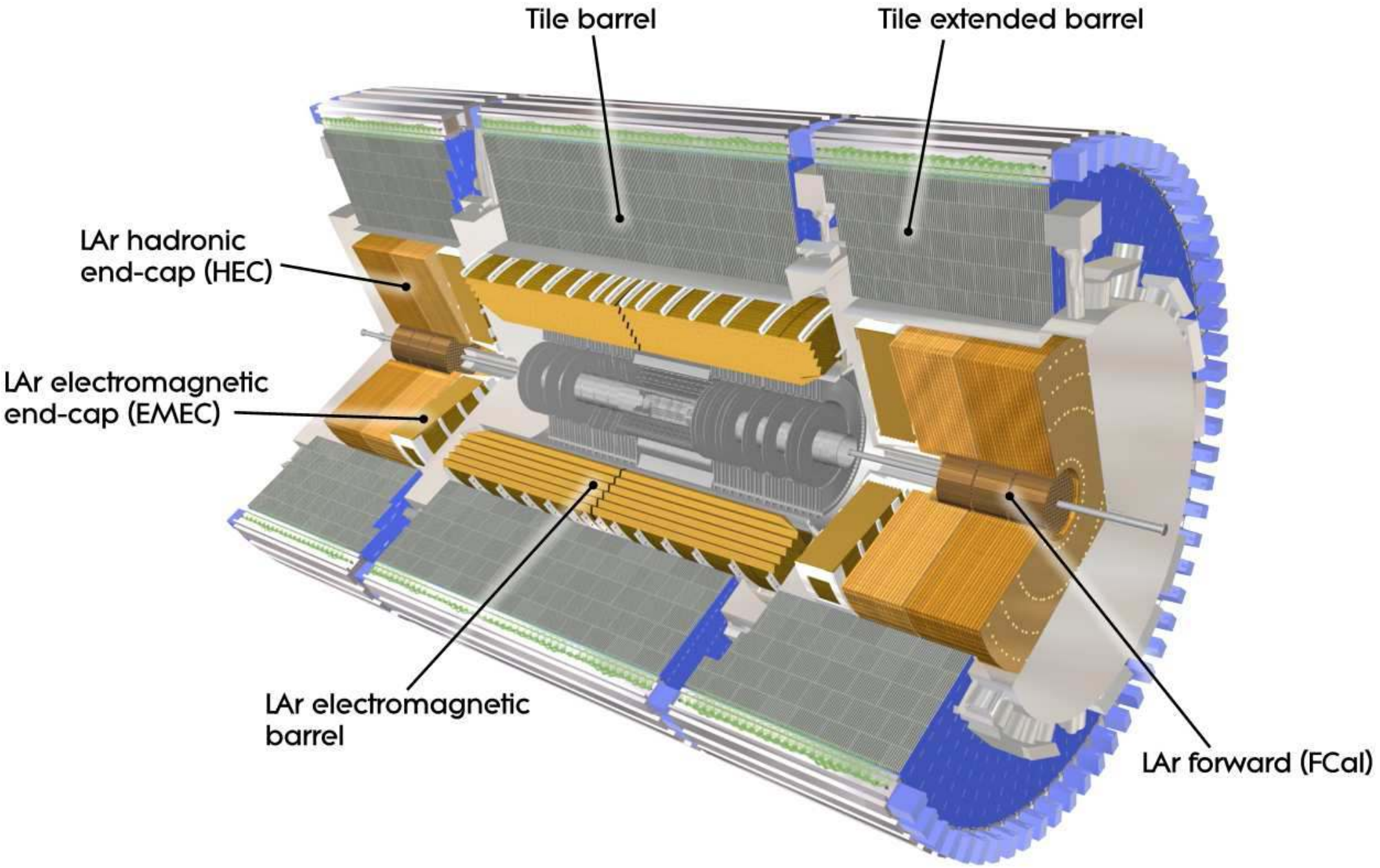
$$\texttt{ElectronCutandcount}\frac{\Delta\sigma}{\sigma} = (3.4(\texttt{stat})^{+14.4}_{-15.2}(\texttt{syst}) \pm 22.3(\texttt{lumi}))\%$$

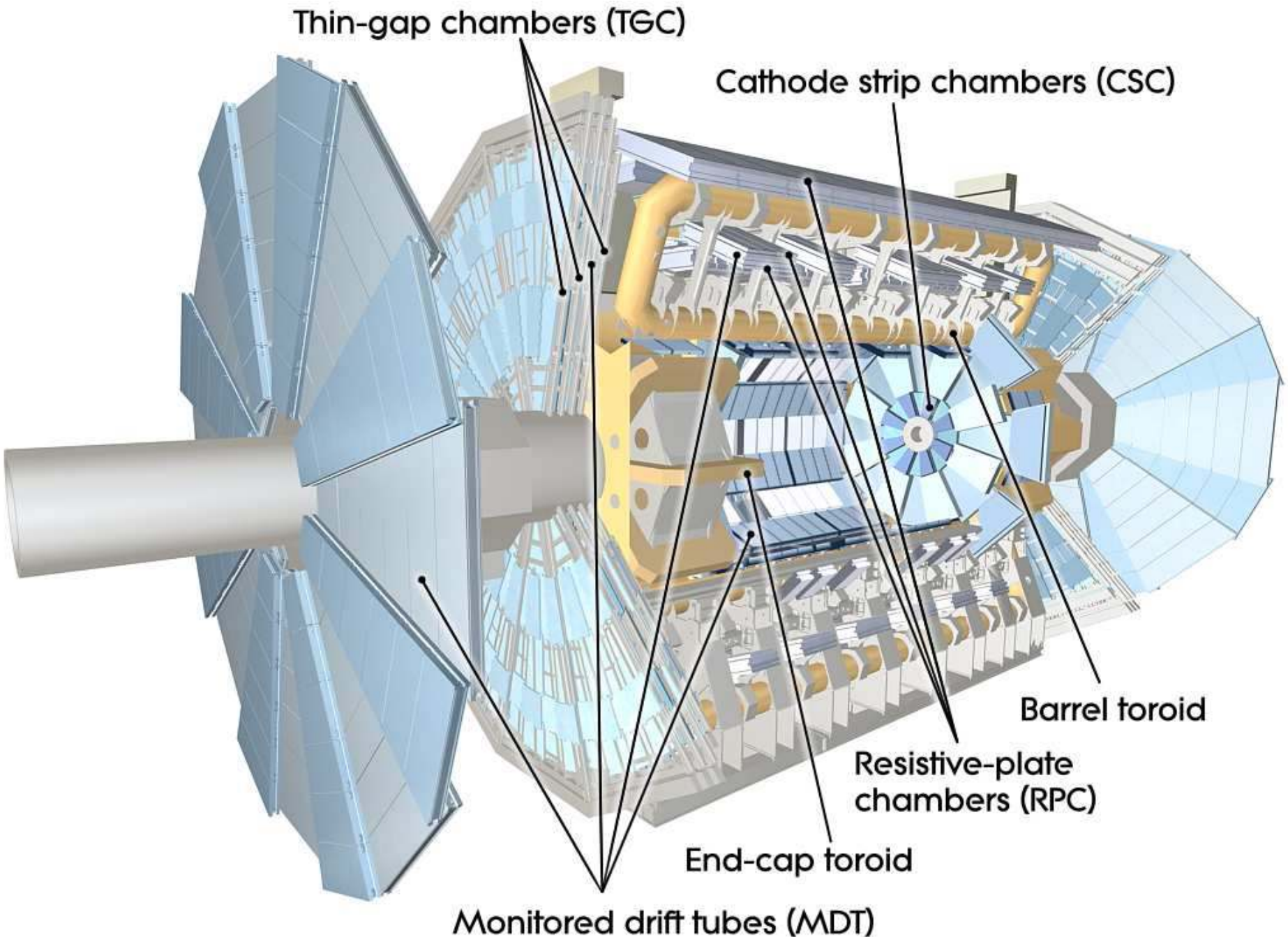
# Summary

- Estimation of uncertainty of $\sigma_{tt}$ @ 10 TeV
- Data-driven W+jets background estimation in signal region
- Ratios of jet mutliplicities cancel many uncertainties
- Major stat. uncertainty: number of Z events in signal region...
- Major systematics I.: QCD multiparton (light/heavy) production
- Major systematics II.: Monte Carlo predictions for W/Z ratio
  - compare with other Monte Carlo predictions (Pythia, Sherpa)
  - vary Monte Carlo parameters (being done for Alpgen)
- ATLAS Public note:
  http://cdsweb.cern.ch/record/1200436/files/ATL-PHYS-PUB-2009-087.pdf

# Backup slides


6.2m
2.1m
Barrel semiconductor tracker
Pixel detectors
Barrel transition radiation tracker
End-cap transition radiation tracker
End-cap semiconductor tracker


Tile barrel
Tile extended barrel
LAr hadronic
end-cap (HEC)
LAr electromagnetic
end-cap (EMEC)
LAr electromagnetic
barrel
LAr forward (FCal)


Thin-gap chambers (TGC)
Cathode strip chambers (CSC)
Barrel toroid
Resistive-plate
chambers (RPC)
End-cap toroid
Monitored drift tubes (MDT)

# Object definition

ectrons:

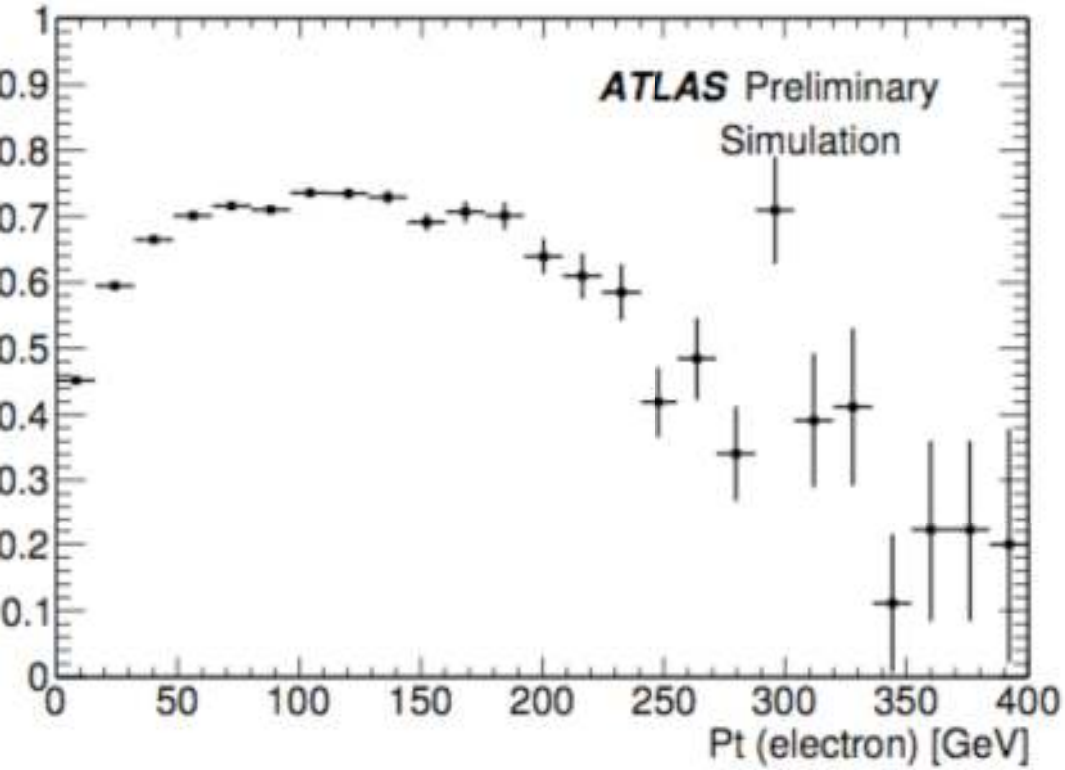
- calorimeter clusters and inner detector tracks
- identification: combined likelihood discriminants (shower shape, deposited energy in EMCal and HCal separate compartments, etc.)
- $p_T$ > 20 GeV, $\eta$ < 2.47, exclude $\eta$=[1.37-1.52]

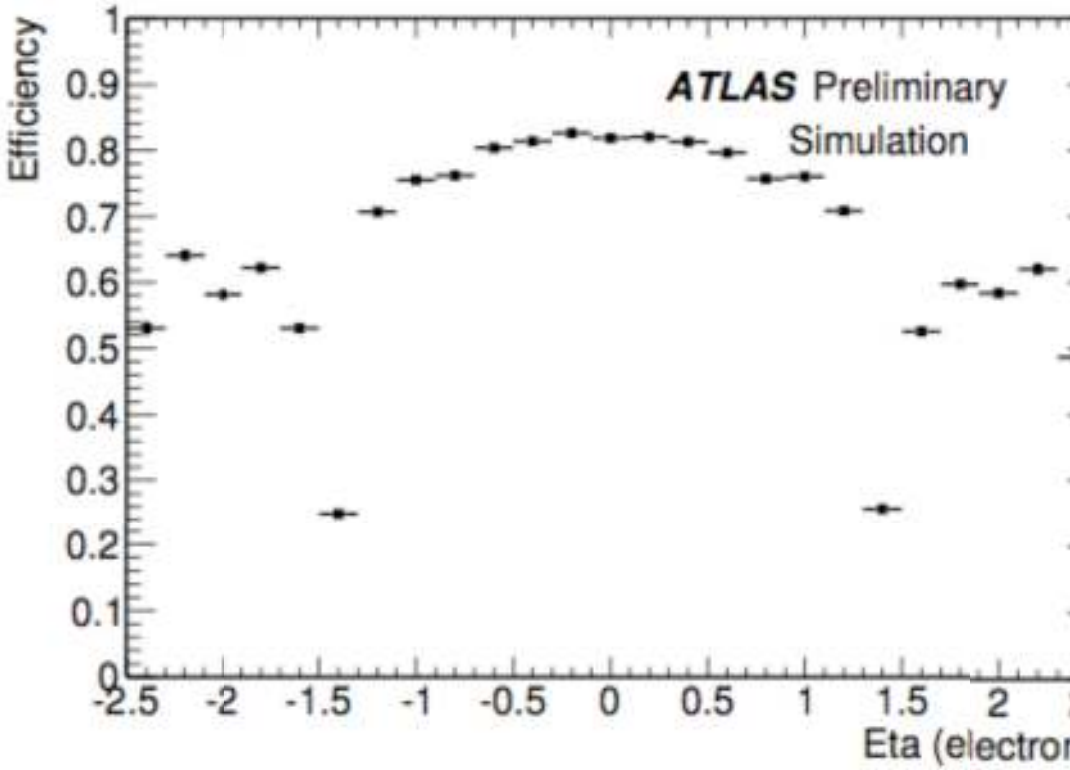
ts: seeded Cone algorithm, R=0.4, H1 calibration, $p_T$ > 20 GeV, $\eta$ < 5

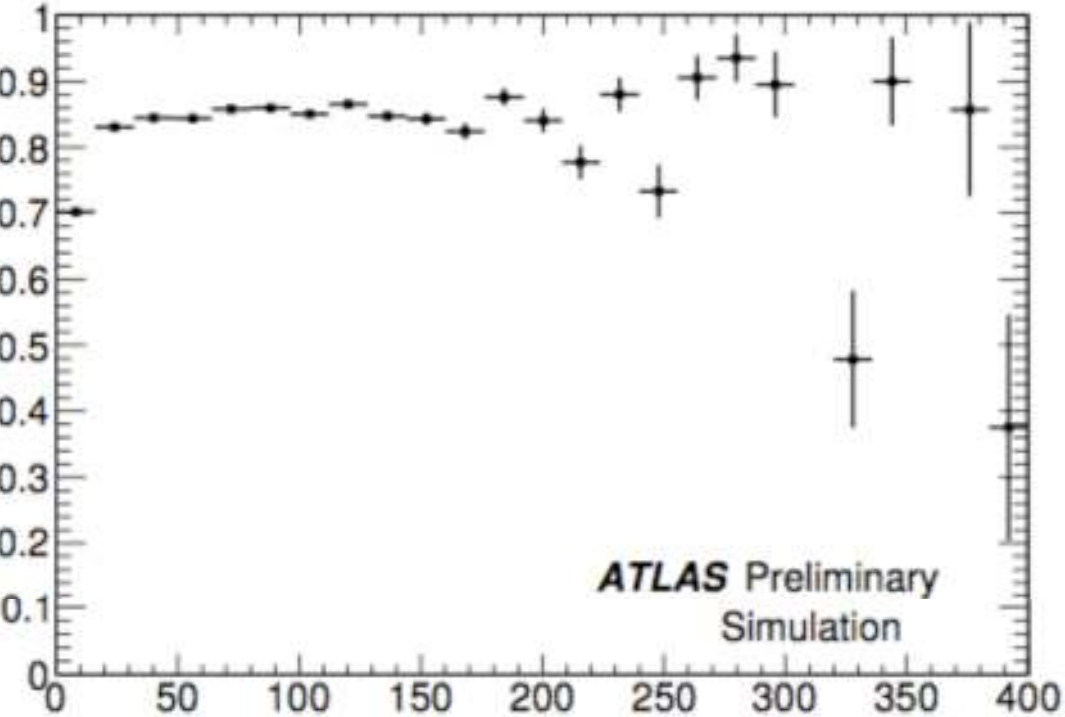
ons:

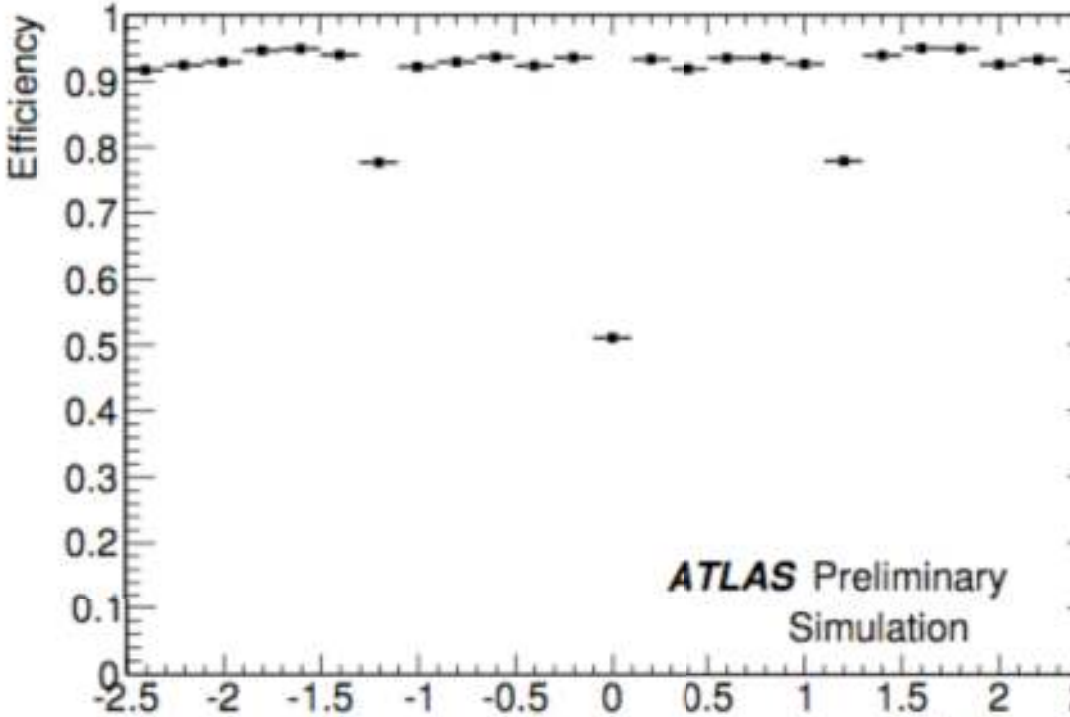
- combined muon spectrometer and inner detector tracks, possible correction for Calorimeter energy loss
- $p_T$ > 20 GeV, $\eta$ < 2.5

ssing $E_T$: Standard missing transverse energy reconstruction (sum of ansverse energies of all EM/Hadron Calorimeter activities + muons) th additional corrections from offline reconstructed objects


ATLAS Preliminary
Simulation
Pt (electron) [GeV]


Efficiency
ATLAS Preliminary
Simulation


ATLAS Preliminary
Simulation


Efficiency
ATLAS Preliminary
Simulation