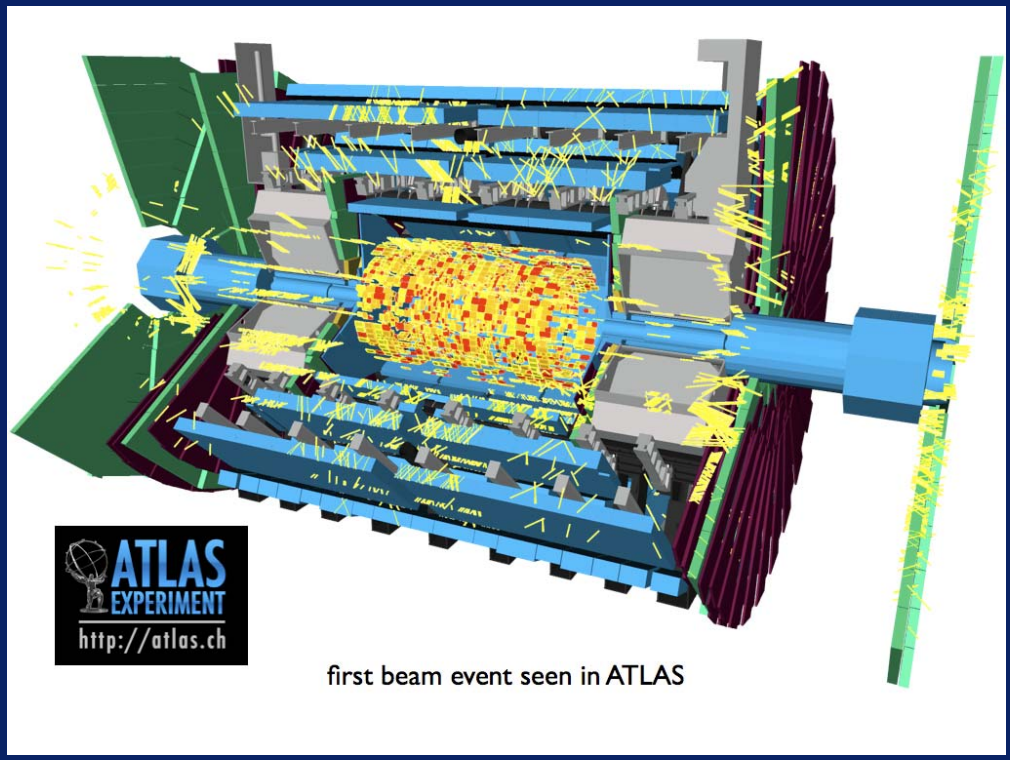


EARLY STANDARD MODEL MEASUREMENTS WITH ATLAS

Joost Vossebeld on behalf of the ATLAS collaboration.

PANIC08, 9-14 November, Eilat

UNIVERSITY OF LIVERPOOL

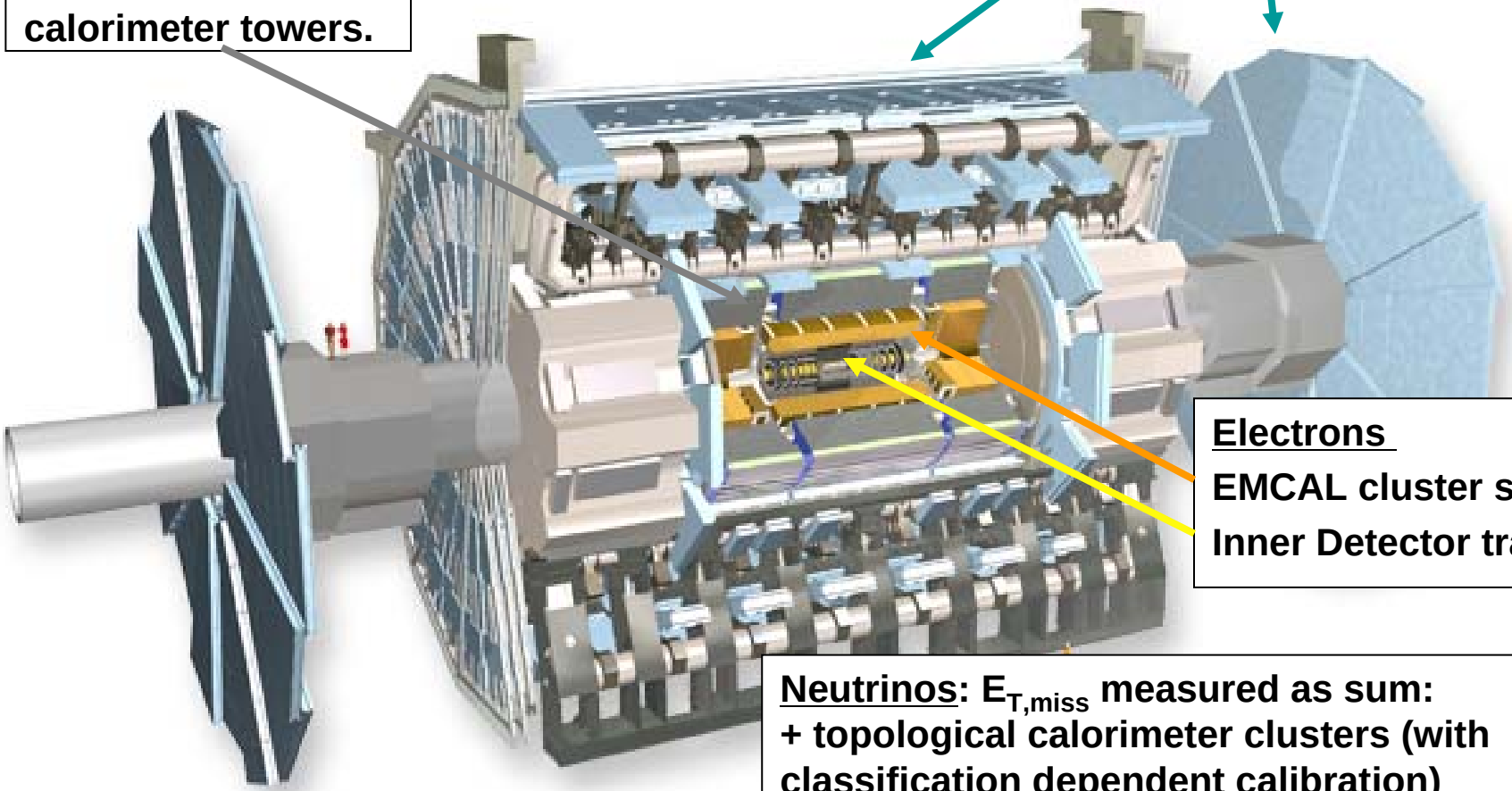
PANIC 2008 Eilat, ISRAEL

OUTLINE

- ATLAS current status and outlook 2009
- Motivation W,Z and top measurements
- Z & W: first measurements and commissioning
- Top pairs: first measurements and commissioning
- Summary

Unless stated otherwise results presented originate from:
ATLAS Collaboration, *Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics,* CERN-OPEN-2008-020, Geneva, 2008, to appear.

Physics object in ATLAS



Muons
Muon Spectrometer track

Jets (Cone, ΔR<0.4)
calorimeter towers.

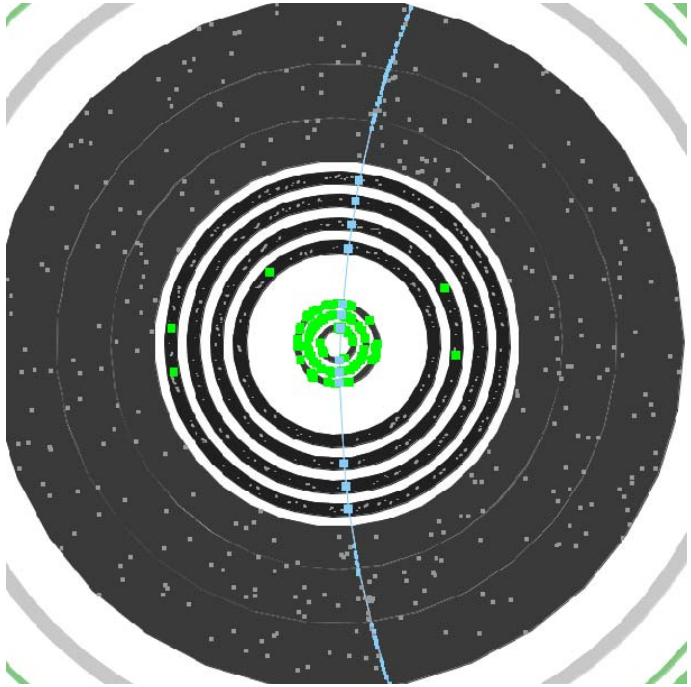
Electrons
EMCAL cluster shapes
Inner Detector track

Neutrinos: $E_{T,miss}$ measured as sum:
+ topological calorimeter clusters (with classification dependent calibration)
+ muons
+ correction for cryostat energy losses

Start up ATLAS

2008:

- **single beam and cosmic data (~1,000,000 cosmic tracks)** →
- **exercised data chain with all sub-detectors**
- **first calibrations, alignment, timing-in**



2009:

hope LHC will deliver about 100 pb^{-1} at 10 TeV.

- **Commissioning of lepton, jet, missing E_T reconstruction and triggers**
- **First physics measurements:**

  minimum bias, J/ψ, Υ, b-physics, jet cross sections, <u>W,Z, top</u> and some first BSM searches

Studies shown are for 50 pb^{-1} (W&Z) or 100 pb^{-1} (top) and 14 TeV.
At 10 TeV cross sections will be reduced by about 40%.

Z & W and top physics in ATLAS

Physics motivation:

- High precision cross sections to test QCD predictions
- Parton density functions proton
- EW parameters: M_{top}, M_W, Γ_W and $\sin^2\theta_W$, gauge couplings
- Direct sensitivity new physics (e.g. rare top decays ..)

Indirect motivation:

- commissioning of leptons, jets, b-jets, missing E_T
- Measure backgrounds BSM

Many measurements foreseen in ATLAS:

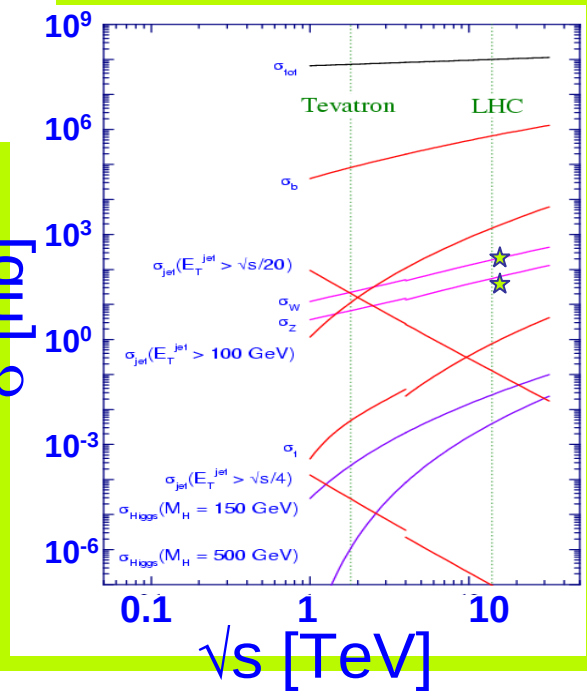
W/Z: Inclusive production cross sections, differential cross sections, cross section ratios, W/Z + jets, W^+/W^- asymmetry, Drell-Yan, Z + b-jets, Di-bosons, W mass and width, Forward-backward asymmetry, di-bosons, High mass di-leptons

Top: Pair production cross sections, Single top, High P_T top, Top mass, spin correlations, rare decays

Inclusive W,Z production in ATLAS

Electron and muon final states.

cross sections (FEWZ, Melnikov & Petriello)		
process	**σ at 14 TeV**	**N (50pb^{-1}, 14 TeV)**
Z→ee or μμ ($\sqrt{\hat{s}}$>60 GeV)	**2015 pb**	**~100,000**
W→eν or μν	**20510 pb**	**~1,000,000**



Simple cut-based analyses for early data

Z→μμ and Z→ee
TRIGGER: single muon/electron
OFFLINE: 2 opposite charge muons/electrons in mass window around the Z

W→μν and W→eν
TRIGGER: single muon/electron
OFFLINE: electron/muon and cuts on $E_{T,miss}$ and transverse mass (M_T)

For early data cannot rely fully on Monte Carlo simulations (MC) for correct estimation of detector effects.
Measure efficiencies and backgrounds from data where possible/needed.

Background estimation. (assuming 50 pb^{-1})

$Z \to \mu\mu$: Main backgrounds tt & bb (small). Estimated from MC ($\delta B/B = 0.4\%$)

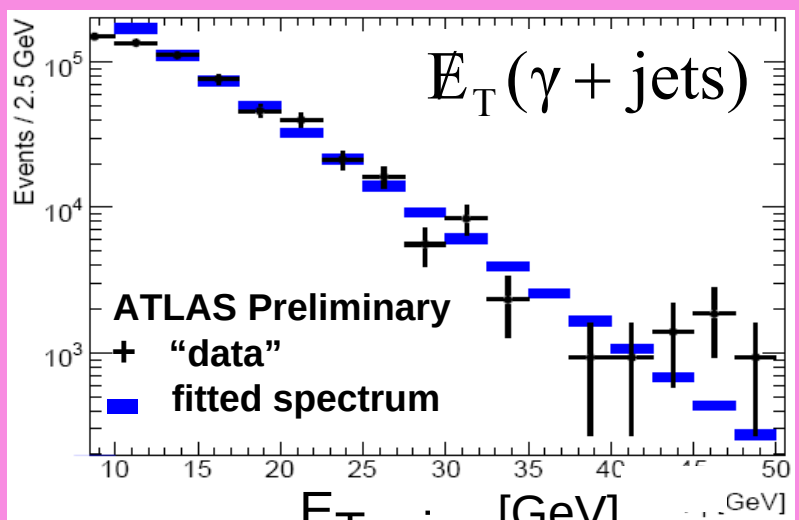
$W \to \mu\nu$: Main backgrounds $Z \to \mu\mu$ & $W \to \tau\nu$ (well-understood). Estimated from MC ($\delta B/B = 0.1\%$)

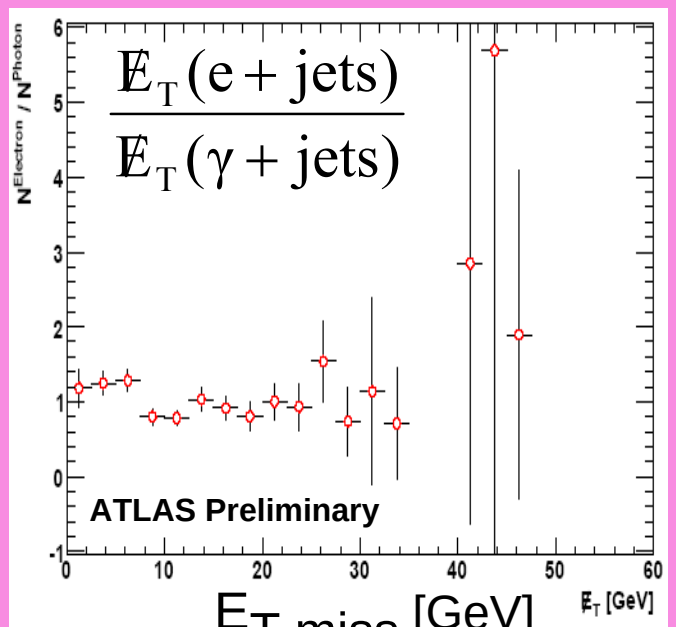
$Z \to ee$: Main backgrounds fake electrons from jets. Measure from data using fit to M_{ee} spectrum ($\delta B/B = 1.6\%$)

$W \to e\nu$: Main background fake electrons & $E_{T,miss}$ in jet events. Try to measure from data:

Signal sample: "e+jets", selection up to $E_{T,miss}$ cut

Control sample: "γ+jets", same selection without track (essentially pure jet events up to high $E_{T,miss}$) . Measure and parametrise $E_{T,miss}$ spectrum, then normalise to "e+jets"

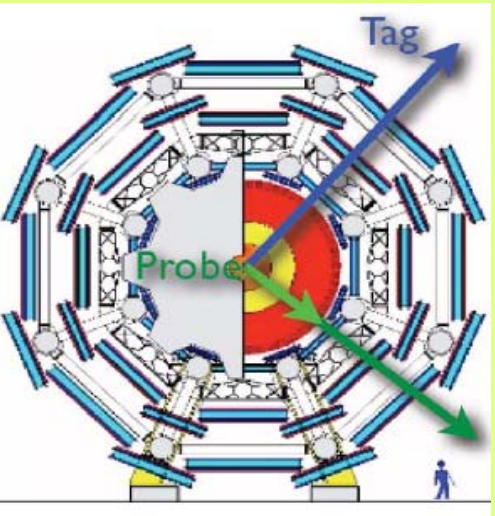




Verify "e+jets" and "γ+jets" spectra agree in MC ($\delta B/B = 4.2\%$)

Lepton efficiencies from data

Tag & Probe method:

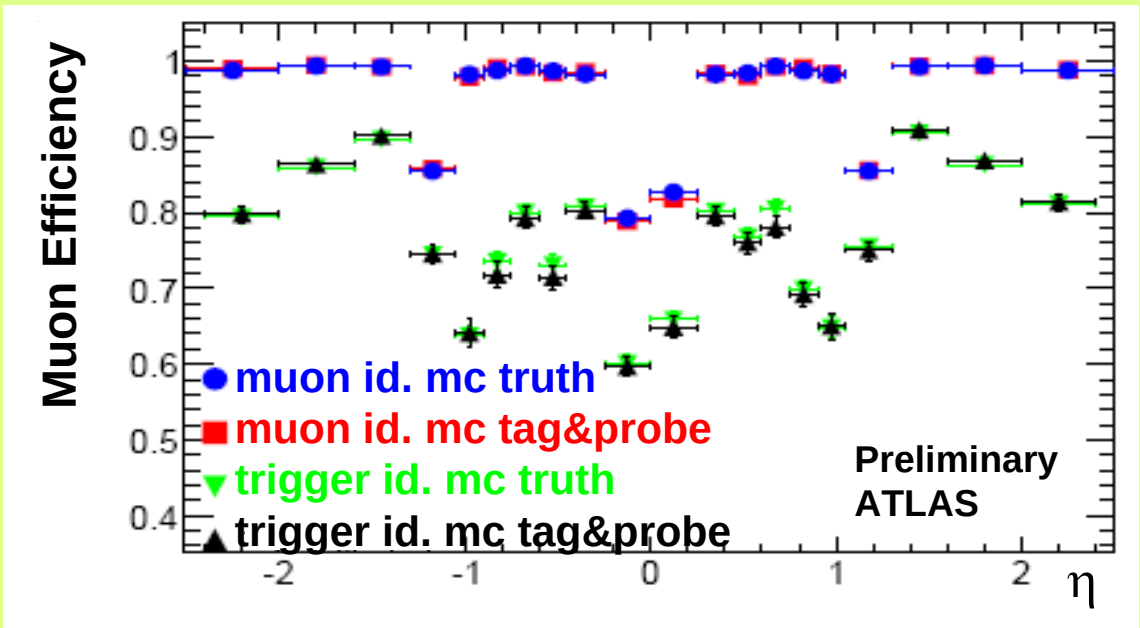


Tag object: tight lepton identification

Probe object: loose identification, independent lepton selection.

Tag and probe must be in M_Z mass window.

Measure efficiency lepton selection on probe object.



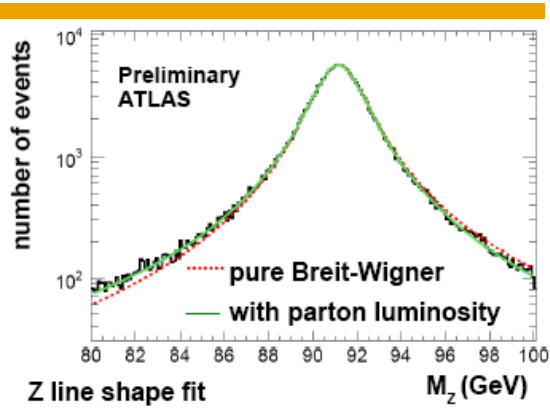
Compare Tag & Probe efficiencies and true efficiencies in Monte Carlo events to set systematic.

$\delta\varepsilon/\varepsilon$ **= 2%** (with 50 pb^{-1})

Lepton and $E_{T,miss}$ calibration from data

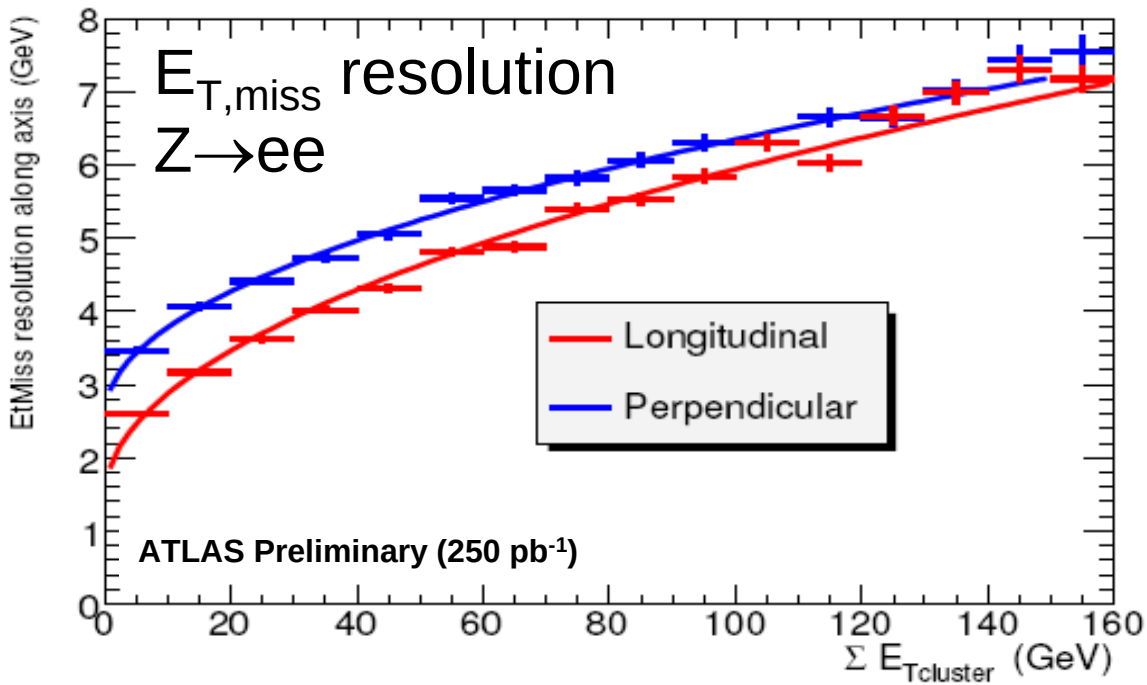
Electron/Muon calibration from data:

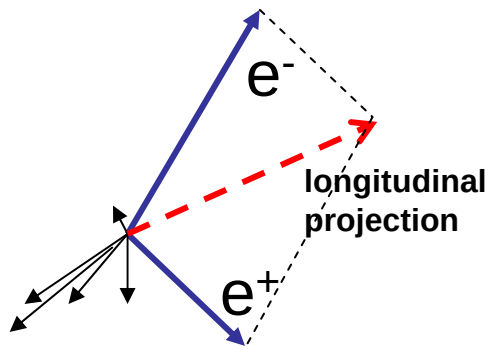
Use Z, J/ψ and Υ to achieve accurate calibration with limited luminosity.



Example: electron calibration to δE/E = 0.2% from Z→ee (200 pb^{-1})

$E_{T,miss}$ scale & resolution from data: Z→ll, Z→ττ, W→lν, top pairs





Longitudinal projection $E_{T,miss}$.
- **hadron vs lepton calibration**

Perpendicular projection $E_{T,miss}$
- **hadron resolution**

Accurate results with early data

Inclusive W/Z production: expected precision

$$\sigma = \frac{N - B}{LA\varepsilon}$$

$$\frac{\delta\sigma}{\sigma} = \frac{\delta N \oplus \delta B}{N - B} \oplus \frac{\delta L}{L} \oplus \frac{\delta A}{A} \oplus \frac{\delta \varepsilon}{\varepsilon}$$

N **observed events**

A **(acceptance) extrapolation to full kinematic range.**

ε (efficiency) efficiency lepton missing E_T and M_T selection.

L **(luminosity)**

B **(background)**

ATLAS Preliminary (50 pb^{-1})

Process	N	B	$\Delta\sigma/\sigma$(stat)	$\Delta\sigma/\sigma$(syst)	$\Delta\sigma/\sigma$(lumi)
W→eν	226,700	6,100	0.2%	5.2%	10%
W→μν	300,400	20,100	0.2%	3.1%	10%
Z→ee	27,100	2,300	0.8%	4.1%	10%
Z→μμ	27,700	100	0.8%	3.8%	10%

Luminosity:

Large uncertainty in earliest data but will come down to 2-3% in later years.

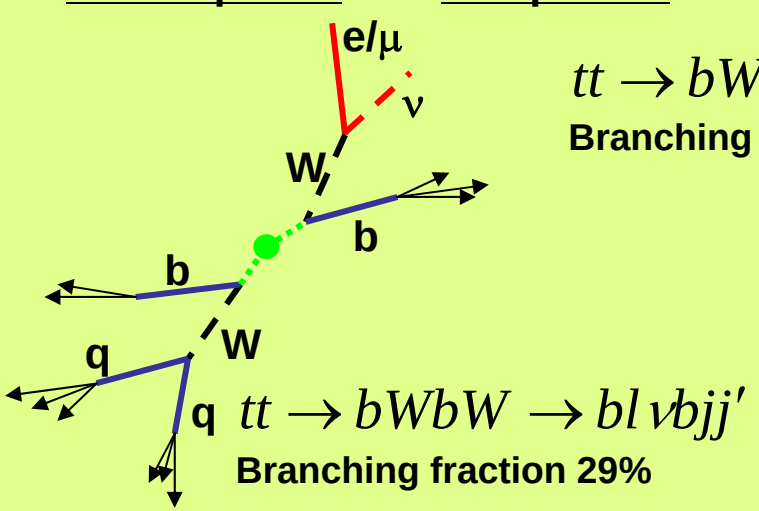
Systematic uncertainties:

- **Unfolding to full inclusive cross section (mainly PDF uncertainties & ISR)**
- **Lepton efficiencies**
- **Backgrounds**

Top pair production in ATLAS

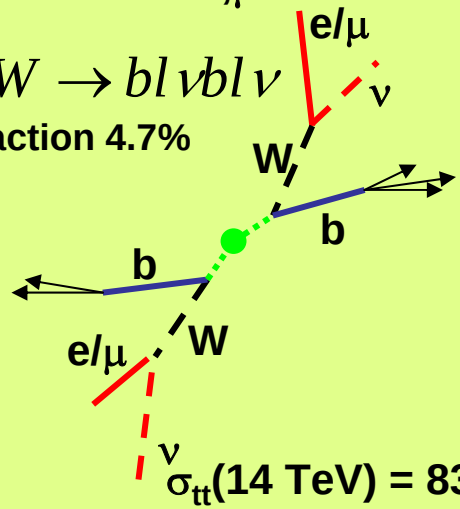
First ATLAS measurement: top pair cross section

In semi-leptonic and di-leptonic channels with l=e,μ



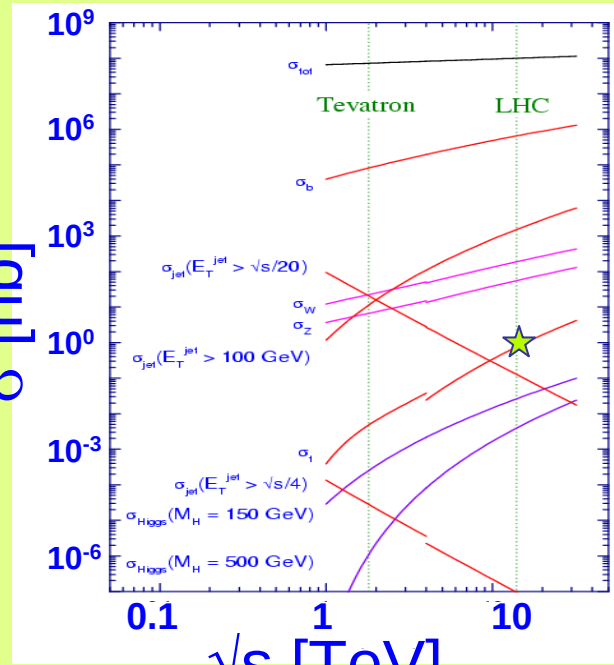
$$tt \to bWbW \to bl\nu bl\nu$$

Branching fraction 4.7%



$$tt \to bWbW \to bl\nu bjj'$$

Branching fraction 29%



MC@NLO (Frixione & Webber)

σ_{tt}(14 TeV) = 830 pb ⇒ 83,000 tt pairs (100pb^{-1})

Example: selection for semi-leptonic analysis:

Basic selection (no use of b-tagging)

TRIGGER: single isolated muon

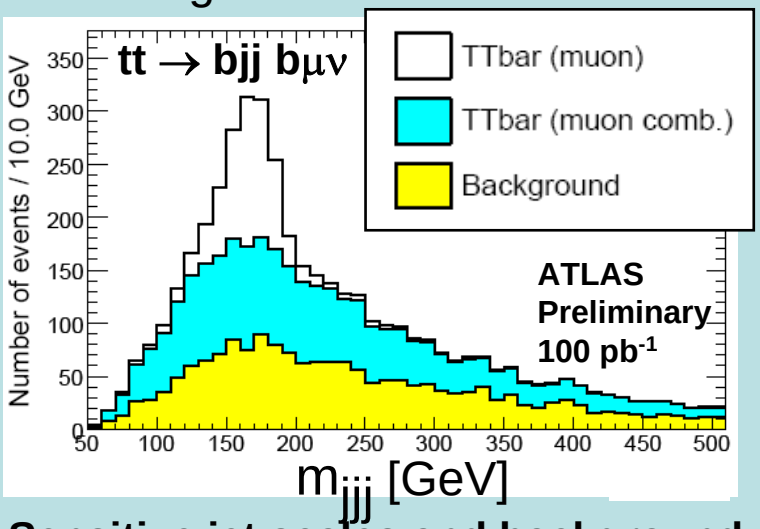
OFFLINE: 1 muon, 4 jets and cut on $E_{T,miss}$ cut and W mass constraint

Alternative selections include M_{top} constraint, b-tagging requirement.

Cross section extraction (example semi-muonic final state)

Use dIfferent methods with different (partially independent) systematics.

Counting method

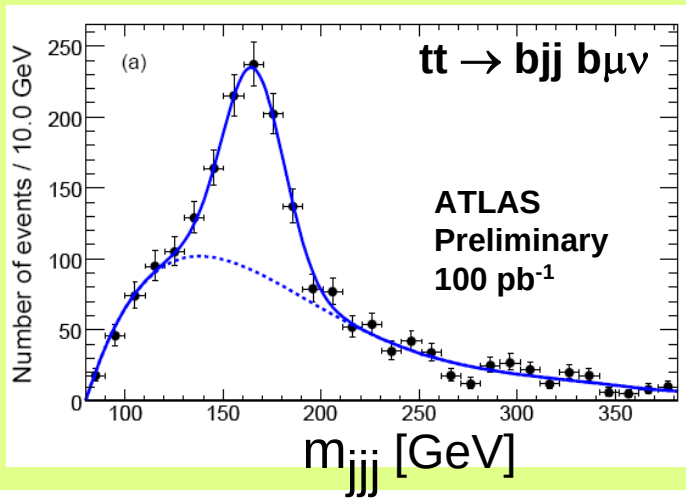


Sensitive jet scales and background

Fit signal and background shapes to M_{jjj} spectrum.

Reduced statistical power (only correct combinations)

Sensitive shape fit functions.



Expected precision with electron and muon final states (ATLAS Preliminary, 100 pb $^{-1}$)

Semi-leptonic top pairs:

$$\text{Likelihood method:}\quad \Delta\sigma/\sigma = (7(\text{stat}) \pm 15(\text{syst}) \pm 3(\text{pdf}) \pm 5(\text{lumi}))\%$$

$$\text{Counting method:}\quad \Delta\sigma/\sigma = (3(\text{stat}) \pm 16(\text{syst}) \pm 3(\text{pdf}) \pm 5(\text{lumi}))\%$$

Di-leptonic top pairs (not discussed here):

$$\text{Cut and Count method:}\quad \Delta\sigma/\sigma = (4(\text{stat})^{+5}_{-2}(\text{syst}) \pm 2(\text{pdf}) \pm 5(\text{lumi}))\%$$

$$\text{Template method:}\quad \Delta\sigma/\sigma = (4(\text{stat}) \pm 4(\text{syst}) \pm 2.(\text{pdf}) \pm 5(\text{lumi}))\%$$

$$\text{Likelihood method method:}\quad \Delta\sigma/\sigma = (5(\text{stat})^{+8}_{-5}(\text{syst}) \pm 0.2(\text{pdf}) \pm 5(\text{lumi}))\%$$

With 100 pb^{-1} systematics dominated.
Improve with better detector understanding: e.g. b-tagging, jet scale

Physics commissioning with top pairs

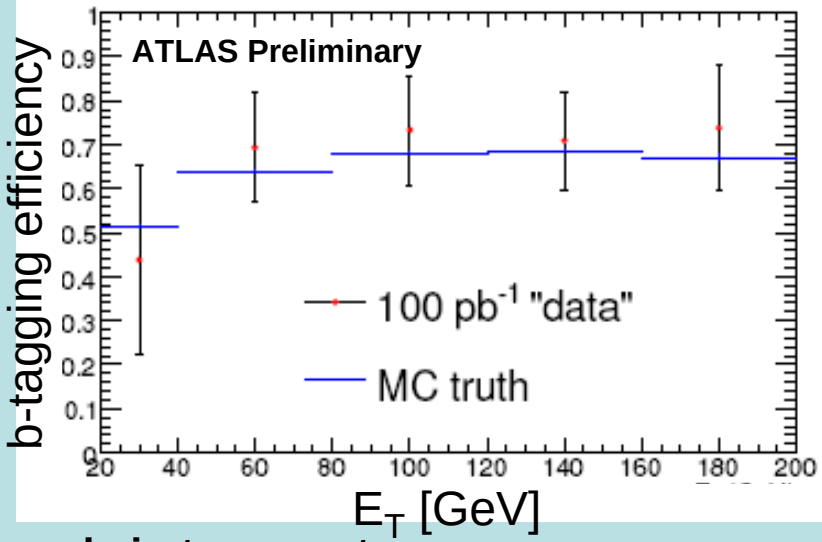
B-tagging efficiency:

In early data:

Select semi-leptonic top pairs and count number of events with 1,2 and 3 b-tags. (tag-counting)

Using flavour content from MC extract σ_{tt}, ε_b and ε_c from fit.

$\delta\varepsilon_b/\varepsilon_b$ = 2.7%(stat) $\oplus$ 3.4%(syst) (with 100 pb^{-1})



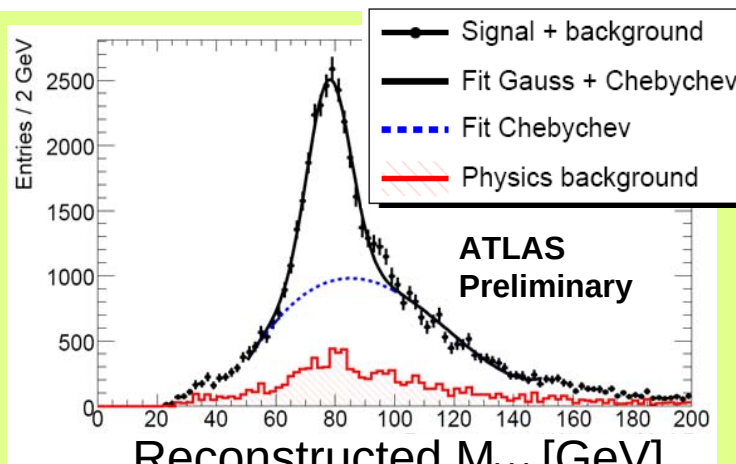
With more data:

Use stringent selection to obtain high purity b-jet sample in top events.

Light jet energy scale:

Select pure light jet sample from W decays in top events
And use M_W constraint to obtain energy scale.

$\delta E/E$ = 2% with 50 pb^{-1} (requires use of b-tagging!)



In parallel also use P_T balance in Z/γ + jet and QCD jet events.

Summary

Program 2009:

Extensive commissioning program leptons, $E_{T,miss}$, jets and b-tagging with W,Z and top events.

First W,Z and top cross section measurements (already systematics limited).

Priorities beyond 2009:

- Reduce systematic uncertainties with increasing luminosity
- Direct measurements of BSM backgrounds (W/Z+jets, tt+jets, ZZ, ..)
- Dedicated measurements to constrain proton PDFs
  - forward Z for low x
  - W^+/W^- ratios for flavour composition
  - ..
- Measurements EW parameters: M_{top}, M_W, $\Gamma_{W,}$ $\sin^2\theta_W$, gauge couplings,..