Early new physics searches with leptons at LHC

Claudio Gatti
Laboratori Nazionali di Frascati – INFN

On behalf of the ATLAS and CMS Collaborations

Outline

1. $pp \rightarrow Z' \rightarrow ee$
2. $pp \rightarrow Z' \rightarrow \mu\mu$
3. $pp \rightarrow W' \rightarrow l\nu$
4. $pp \rightarrow W_R \rightarrow lljj$

EPS HEP 2009, 16-22 July Krakow, Poland

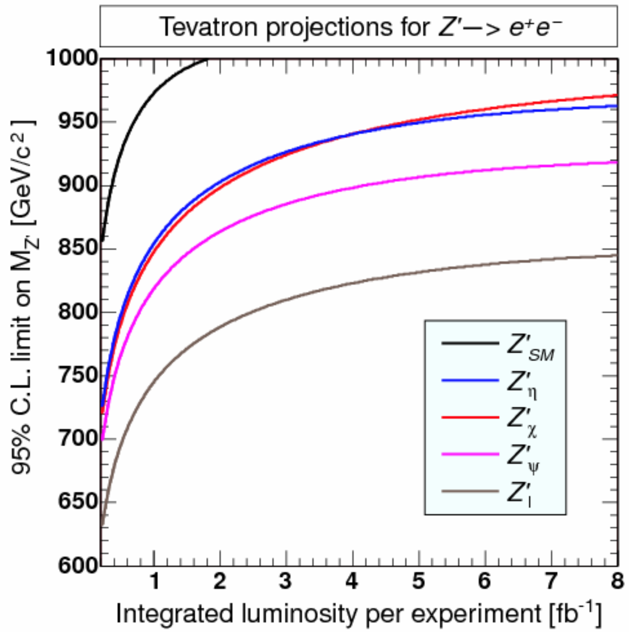
New heavy vector bosons

New bosons predicted as narrow resonances: $\Gamma/M \sim 1\text{-}2\%$

Direct searches

	Mass Limit (95%)	Cross section at LHC (14 TeV)
Z' (SM-like)	1 TeV	$\sigma(pp \to Z' \to ll) \sim 0.5$ pb (M(Z')=1 TeV)
W' (SM-like)	1 TeV	$\sigma(pp \to W' \to l\nu) \sim 5$ pb (M(W')=1 TeV)
W_R	750 GeV	$\sigma(pp \to W_R \to lljj) \sim 0.4$ pb ($M(W_R)$= 1.5 TeV)

Tevatron limited by CM energy →

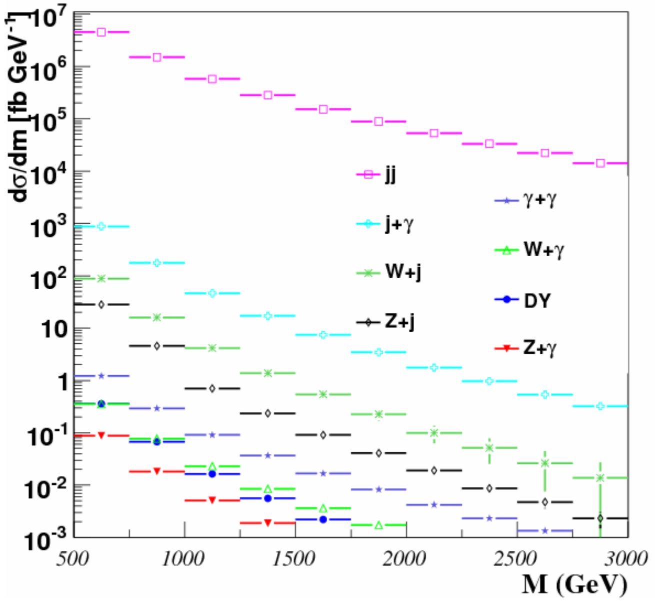


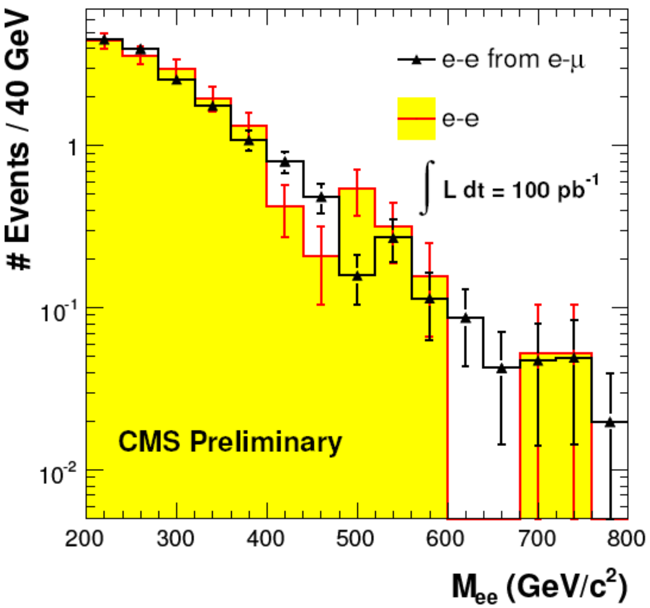
Larger CM energy at LHC will allow us to probe the mass region above 1 TeV

In the following, I'm assuming $\sqrt{s}$=14 TeV

I'll focus on discoveries with 100 pb^{-1}
(and a little bit more on Atlas)

Z'→ee





DY irreducible background

$\sigma(pp \rightarrow Z/\gamma \rightarrow ll)$= 0.1 pb for M>0.5 TeV

QCD: σ(dijet p_T*>280 GeV)=13 nb

Electron identification: E_{Had}/E_{em}; track association; E/p; shower shape.

e/jet rejection (ATLAS) E_T^{Jet} = 280-560 GeV

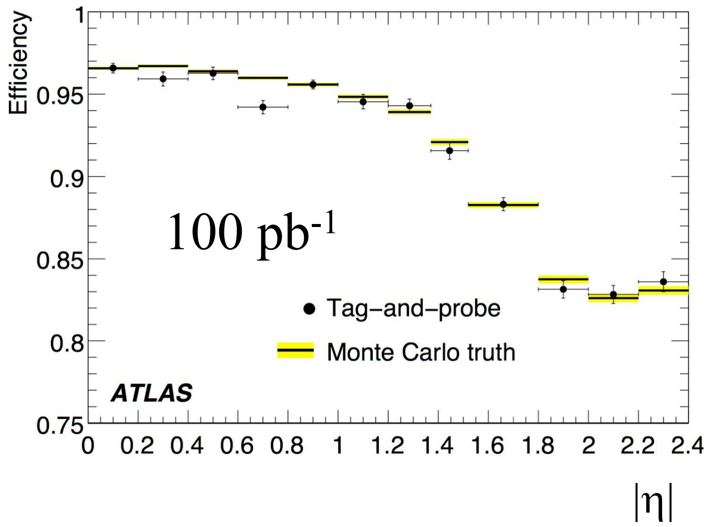
	Efficiency	Rejection
e-loose	90%	600
e-medium	85%	2300

ttbar→ee background estimated from data counting the number of ttbar→eμ (CMS)

$N_{\mu e} \approx 2N_{ee}$

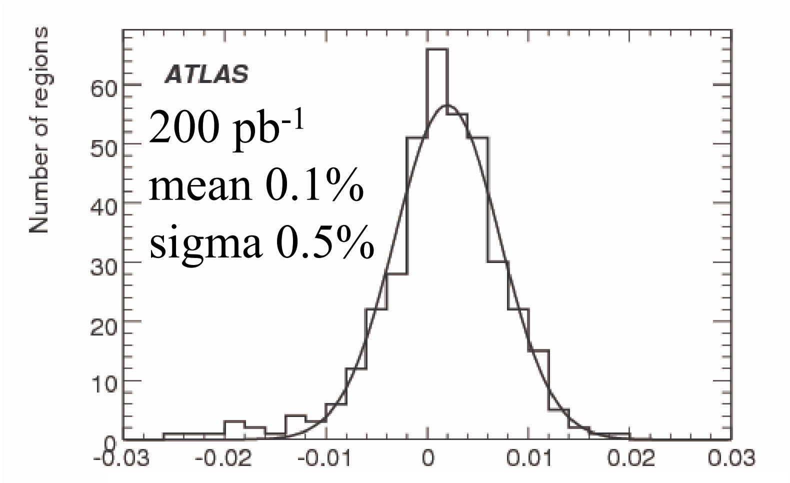
With 100 pb^{-1} expected 16 "ee" events and 43 "eμ" events with E_T> 80 GeV and M_{ll}>200 GeV

Performance studies with Z→ee



Z→ee events useful for several studies:
Efficiencies, calibration, material effects ...

Electron identification efficiency:
With 100 pb^{-1} with 1% error for p_T up to 100 GeV

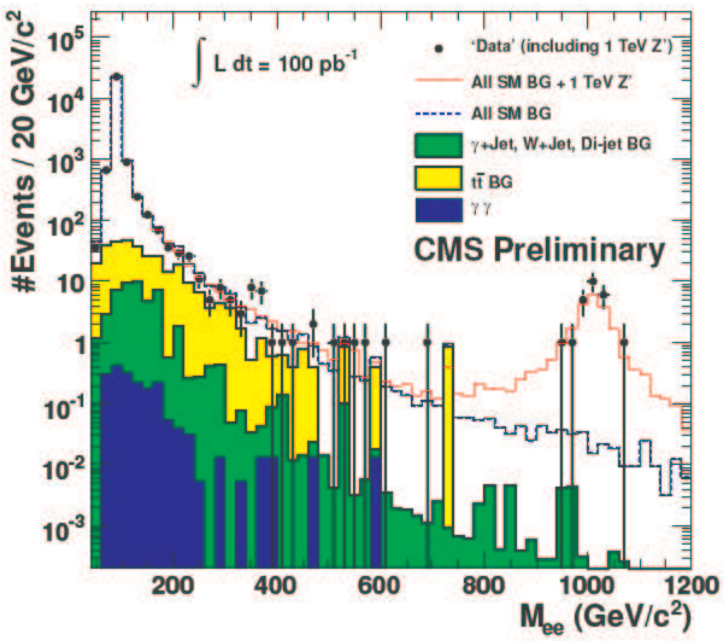


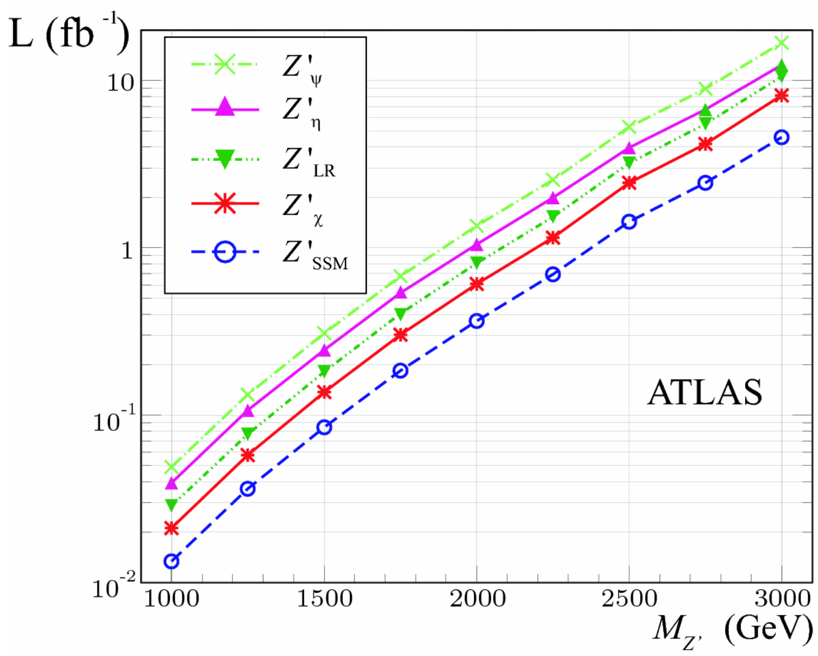
Energy scale: Fit result -Truth

In-situ calibration:
Atlas calorimeter response locally uniform within 0.5% (from test beam).
Understand detector material in ID studying conversions.
Use E/p from inclusive electrons (HeavyQ, W decays).
Mass constraint in Z→ee events used for intercalibration of different regions to keep constant term <0.7%.

Non trivial extrapolation to higher p_T

Z'→ee: discovery potential





Background: Drell-Yan 1% signal (QCD reduced to 0.3 DY)
Atlas mass resolution ~1% increased to 1.5% → 5% syst. error
CMS mass resolution ~2% assuming calibration available with 100 pb^{-1}
Theoretical uncertainties →10%

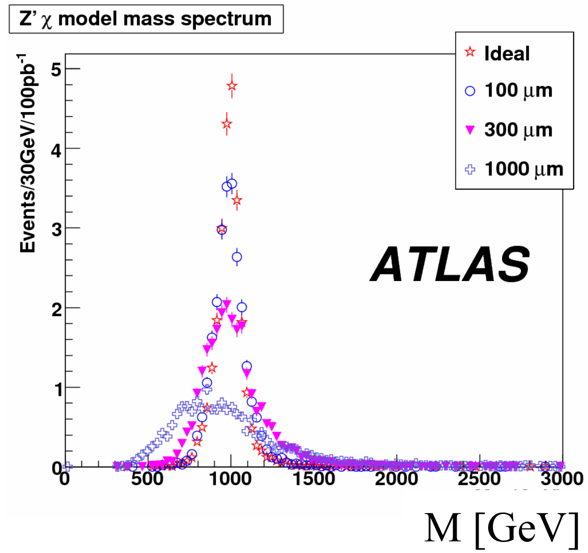
Z'→μμ

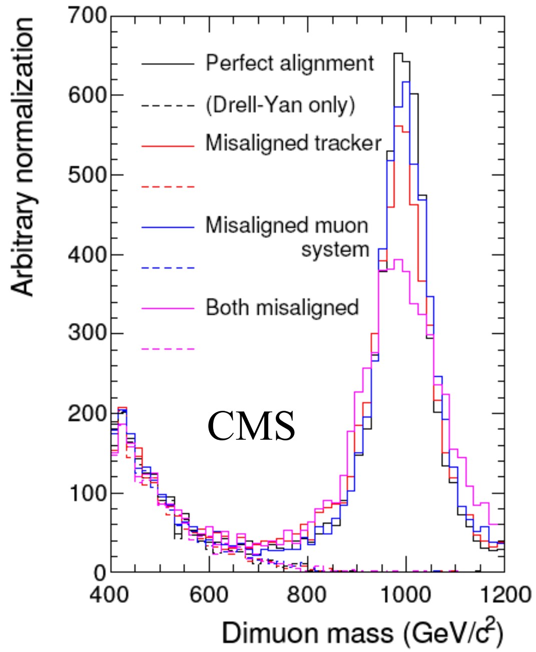
Reducible background (ttbar, jets) → loose cut on isolation and jet multiplicity (easier rejection than in electron case)

DY (irreducible) dominates.

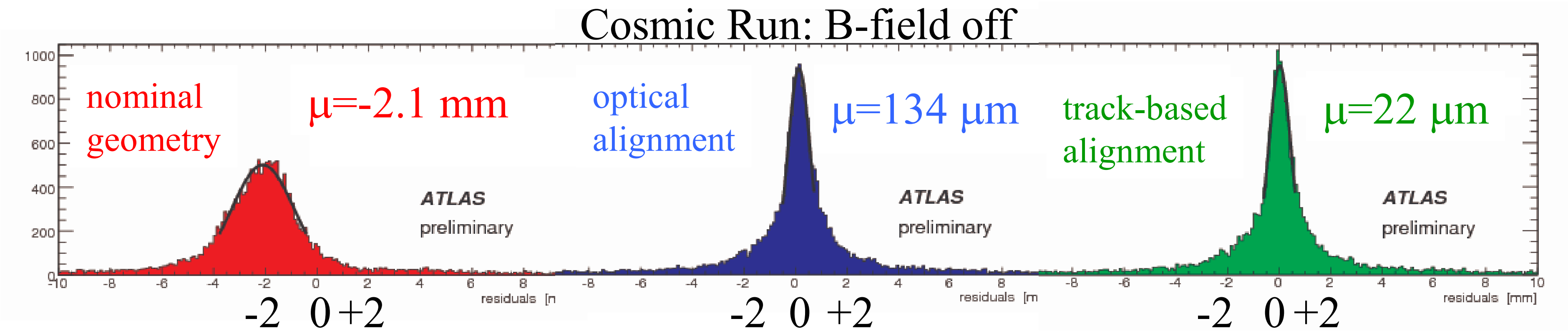
Atlas muon spectrometer at 500 GeV:
sagitta~1 mm
dp_T/p_T ~ 6% (>>Γ/M)
Inner detector:
sagitta~150 μm
dp_T/p_T~15%

For nominal performance of Atlas, we need alignment better than 30 μm in the muon spectrometer and better than 10 μm in ID (silicon modules).





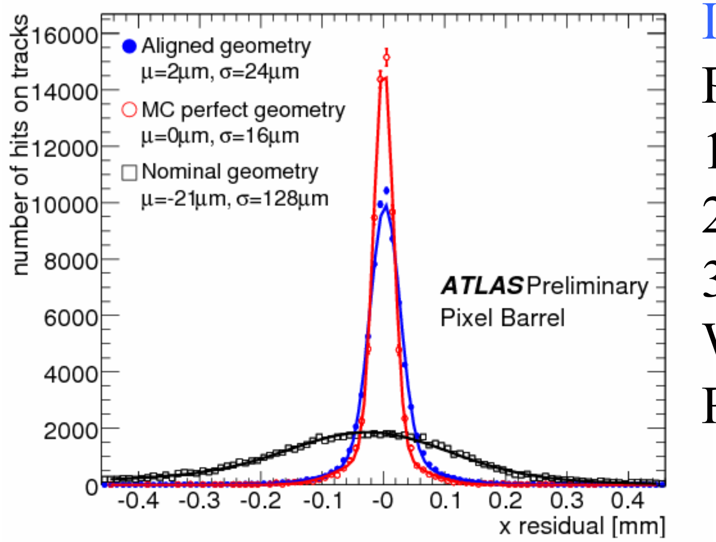
Alignment



Muon Spectrometer

Optical alignment: absolute alignment O(100 μm); relative changes O(20 μm)

Track-based alignment: final alignment 15,000 tracks/tower (30 pb^{-1})



Inner detector

Preliminary results with cosmics (residuals):

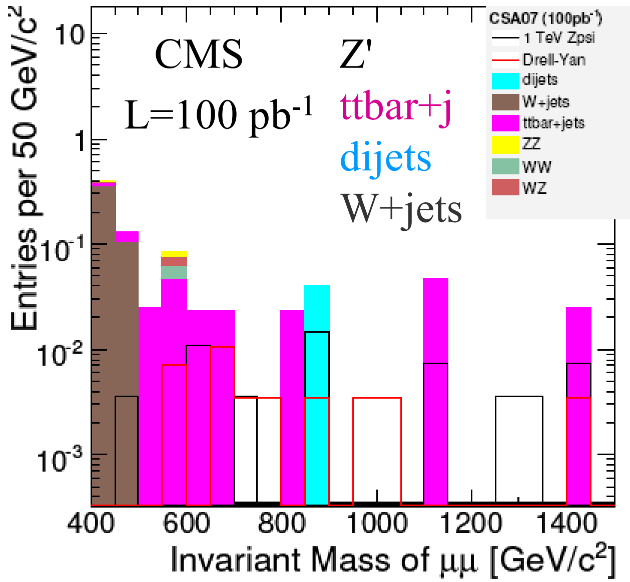
1. Pixel ~20 μm
2. SCT ~30 μm
3. TRT ~190 μm

With tracks: 10^6 tracks (dedicated stream)

Remove "weak modes": alignment with high statistics; E/p; cosmics and beam-halo events; resonances.

Performance and background estimate

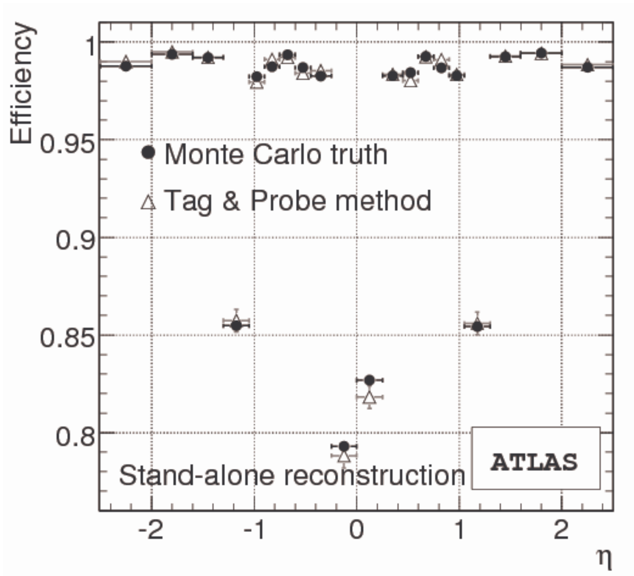
Contamination from sources other than DY (jets, ttbar+jet) are estimated from same-sign events.



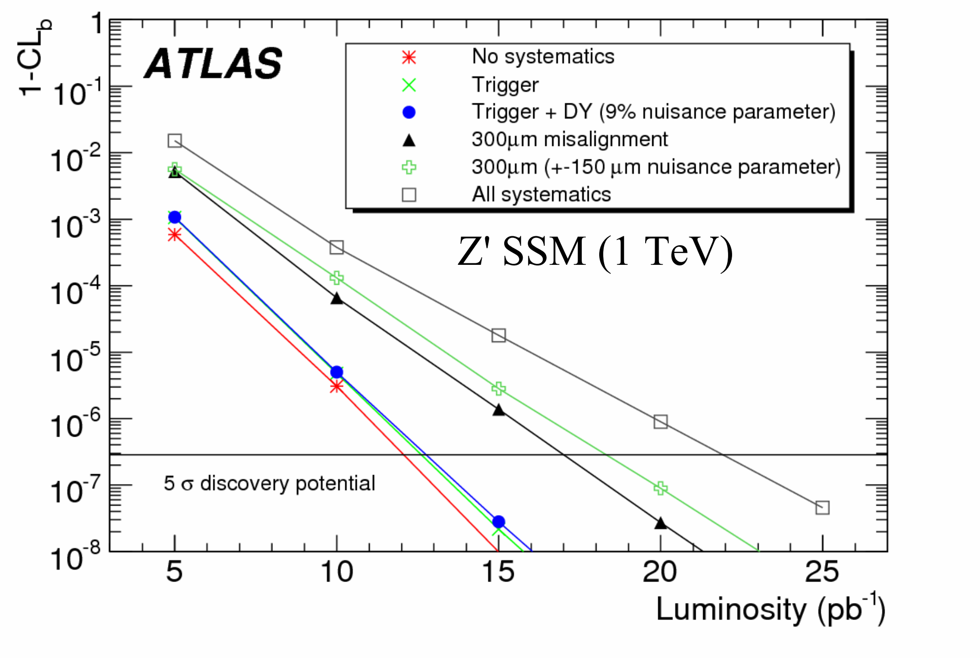
$Z \rightarrow \mu\mu$ events used to measure the reconstruction efficiency up to 100 GeV. Better than 1% (per $\eta \times \phi$ bin) accuracy with 100 pb^{-1}

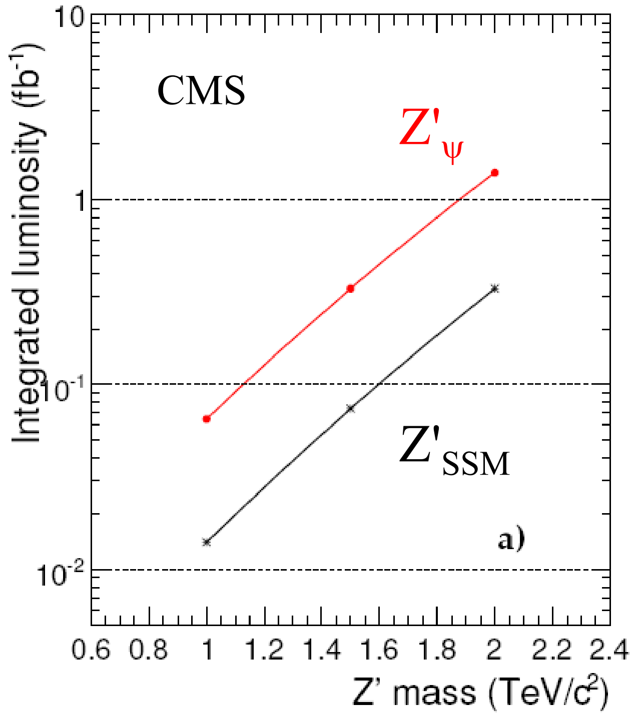
Momentum scale and resolution determined by fitting the Z lineshape. With about 50 pb^{-1} statistical errors of about 0.5% are obtained.

Non trivial extrapolation to higher p_T



Z'→μμ: discovery potential



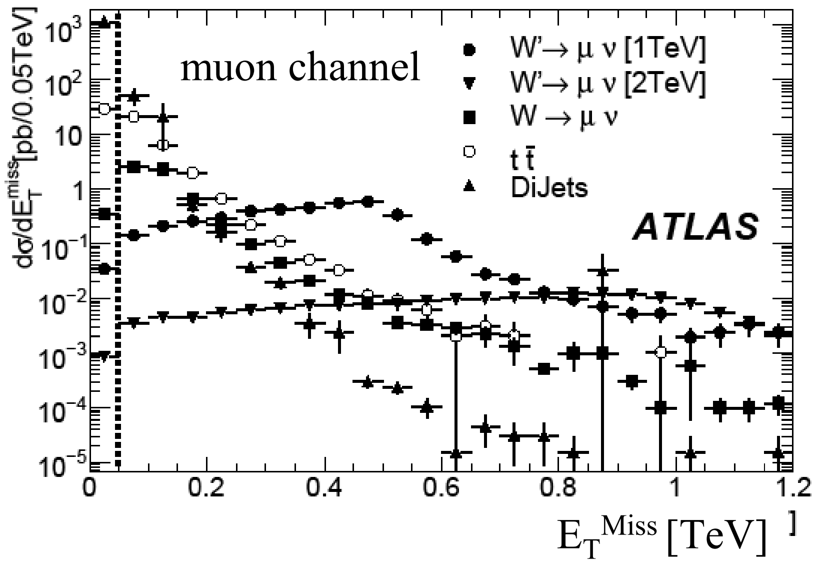


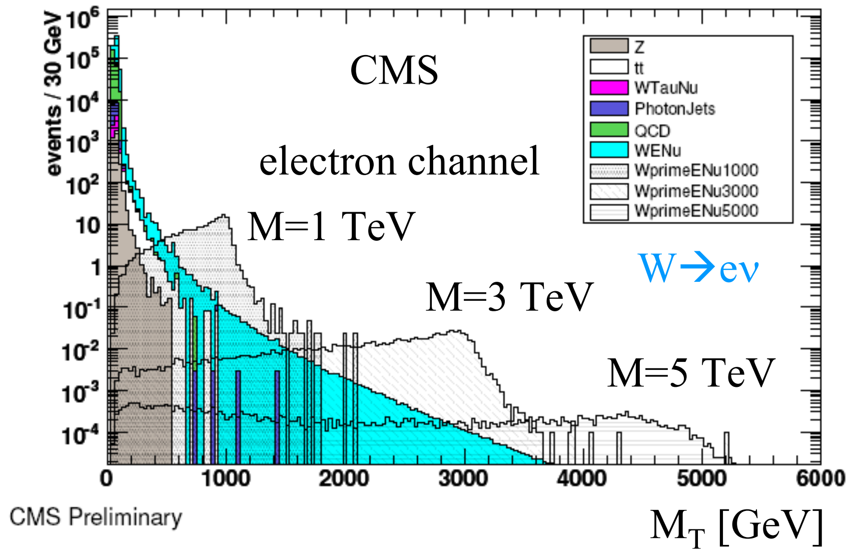
Competitive with electron channel (even if lower resolution).

Atlas considers a conservative 300 μm misalignment with 150 μm uncertainty.

Discovery still possible with less than 30 pb^{-1}.

W'→lν





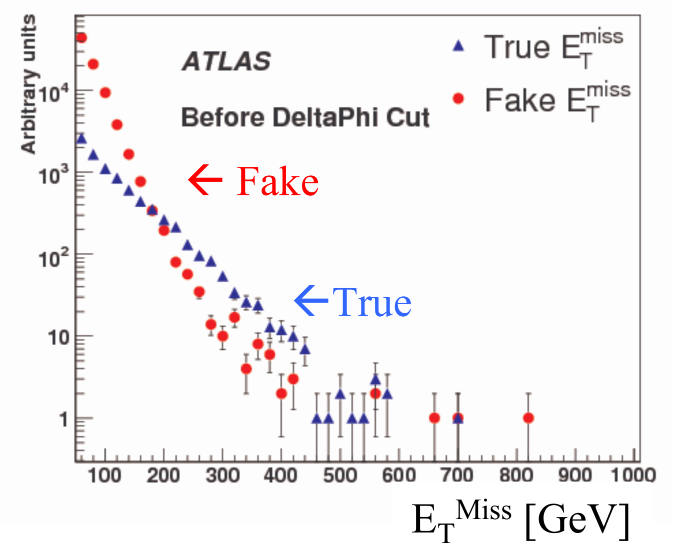
ATLAS: 1 lepton with p_T> 50 GeV and |η|<2.5; E_T^{Miss} > 50 GeV
CMS: 1 lepton with p_T> 30 GeV and |η|<2.5; 0.4< p_T/E_T^{Miss} <1.5 and Δϕ-cut

Irreducible background: W→lν
Reducible background: ttbar and jets

Further background rejection: isolation; jet-veto

Fake E_T^{Miss}

QCD sample $560<p_T<1120$ GeV

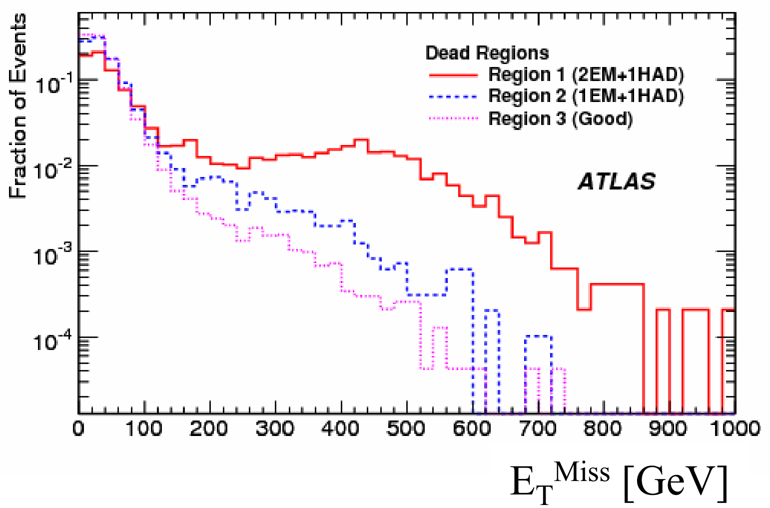


Fake E_T^{Miss} gives a large contribution to the measured missing energy in high-p_T jets.

Several sources of fake E_T^{Miss}:

1. Not reconstructed muons
2. Cracks and gaps in calorimeters
3. Instrumental effects (crucial in first data taking)

Simulation with dead regions in calorimeter



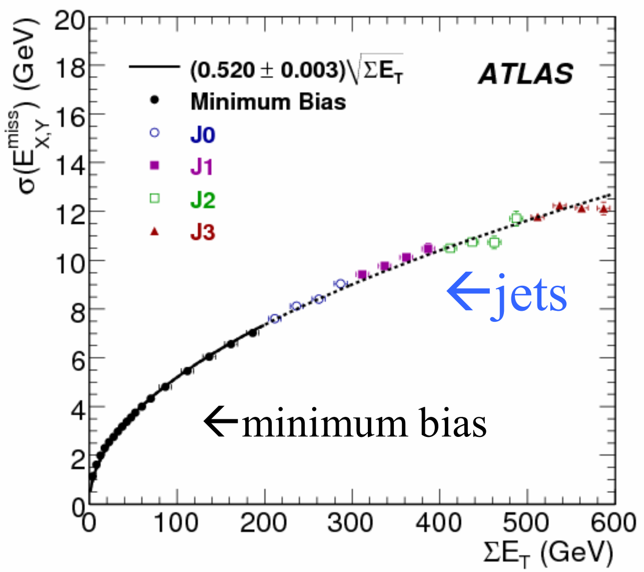
Region 1: two dead LArEM regions
one dead HEC region

Region 2: one dead LArEM region
one dead HEC region

Region 3: No dead regions

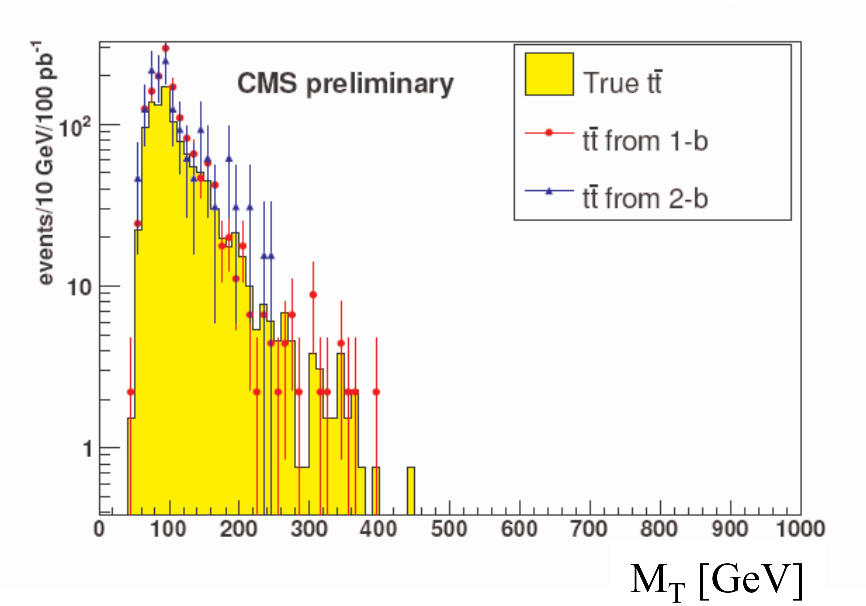
Large dead regions $\Delta R \sim 0.5 \div 1$

E_T^{Miss} performance and background estimate



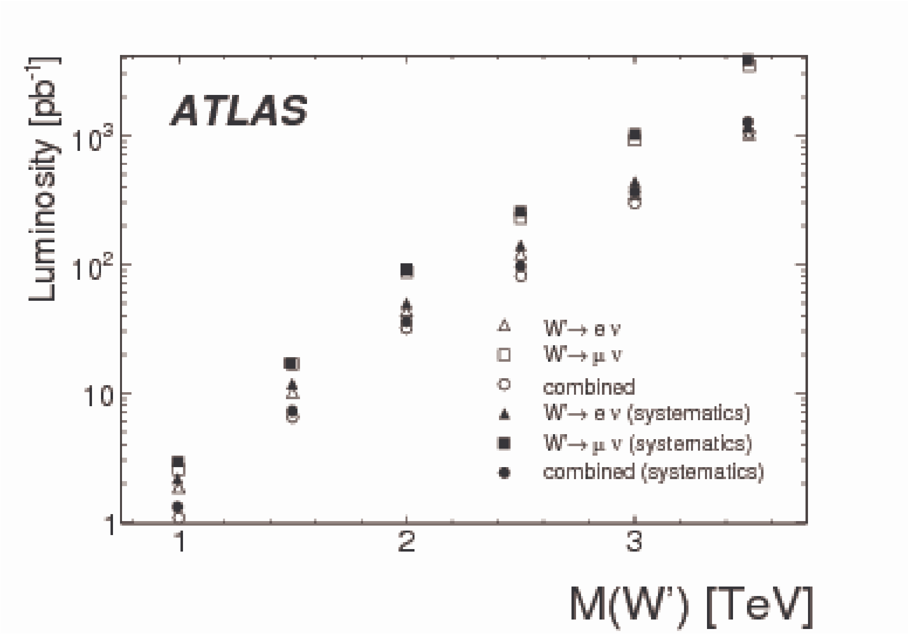
E_T^{Miss} commissioning with minimum-bias events.
Will provide first measurement of the resolution.
With 100 pb^{-1} from Z→ee, μμ, ττ and W→eν, μν and ttbar events:

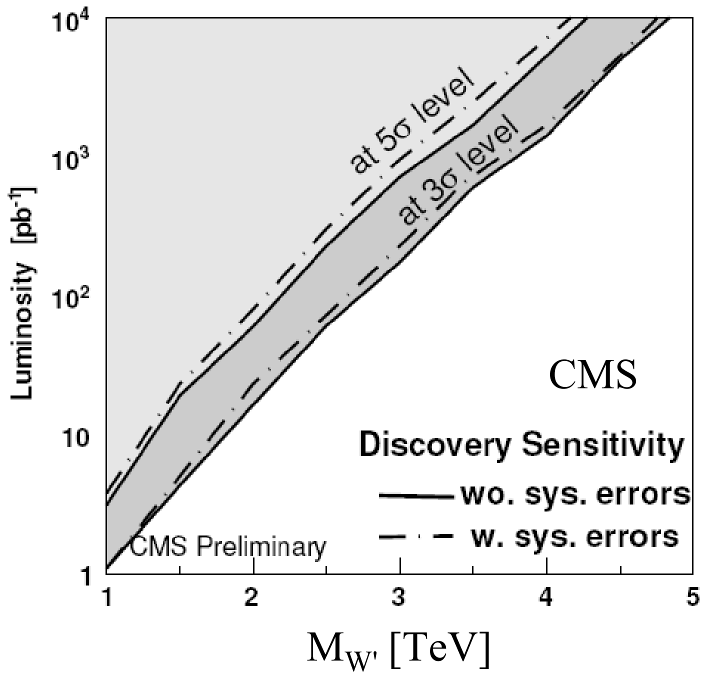
1. Scale
2. Resolution
3. Linearity



Estimate of ttbar background from data using b-tagging (single-double tag method)
With 100 pb^{-1} 30% statistical error.

W'→lν: discovery potential



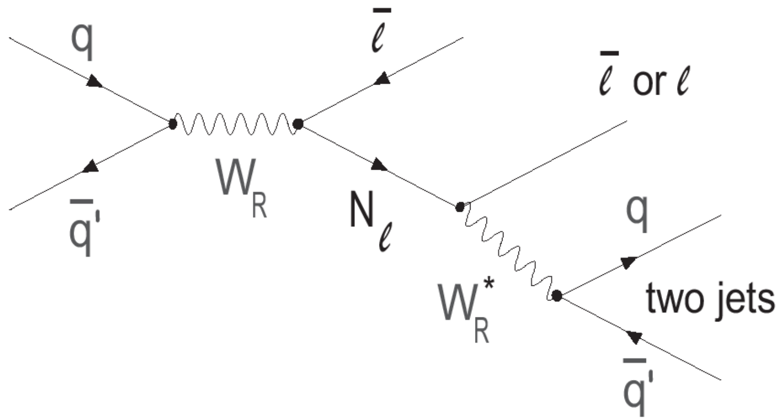


Theoretical uncertainties (PDF,NLO) → 8-9%
Experimental uncertainties (Atlas):

1. signal → 1.5% (electrons), 5% (muons)
2. background → 3% (electrons), 8% (muons)

Discovery in the 1 TeV region with less than 10 pb^{-1}

$W_R \rightarrow lljj$



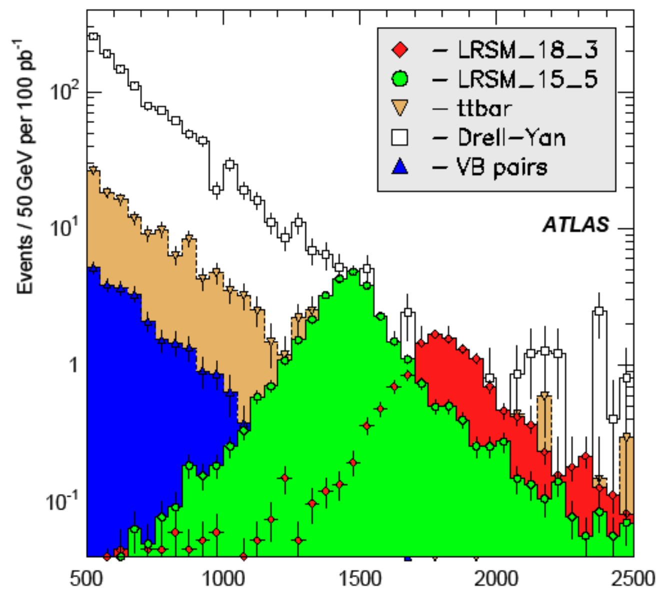
Left-Right symmetric models predict the production of a W_R boson decaying into lepton and right-handed Majorana neutrino.

Select 2 leptons and two jets
All objects with p_T> 20 GeV
Leptons with $|\eta|<2.5$
Jets with $|\eta|<4.5$
$M_{dilepton}$> 300 GeV
ΣE_T> 700 GeV

Main background: ttbar, DY, vector boson pairs.

M_{WR}=1800 GeV M_N=300 GeV
M_{WR}=1500 GeV M_N=500 GeV

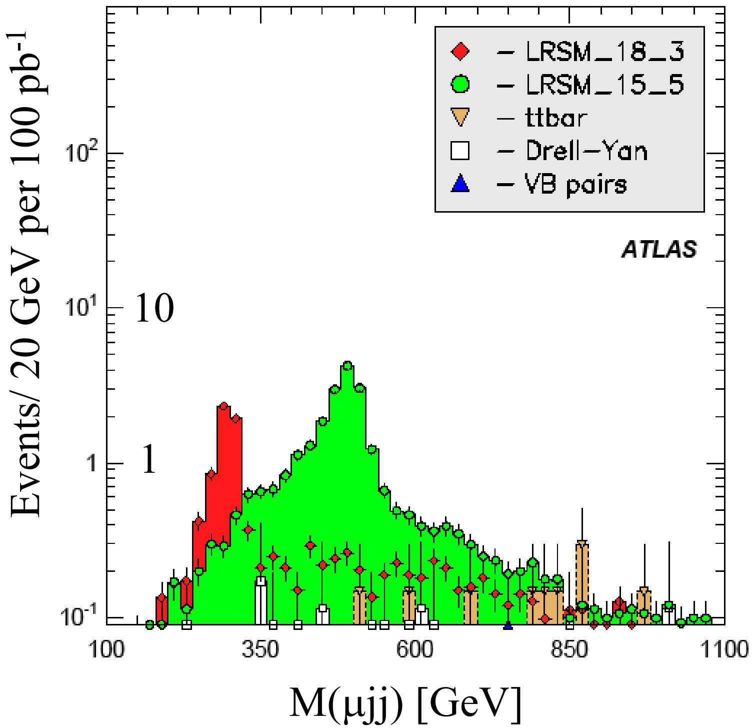
W_R mass before full selection



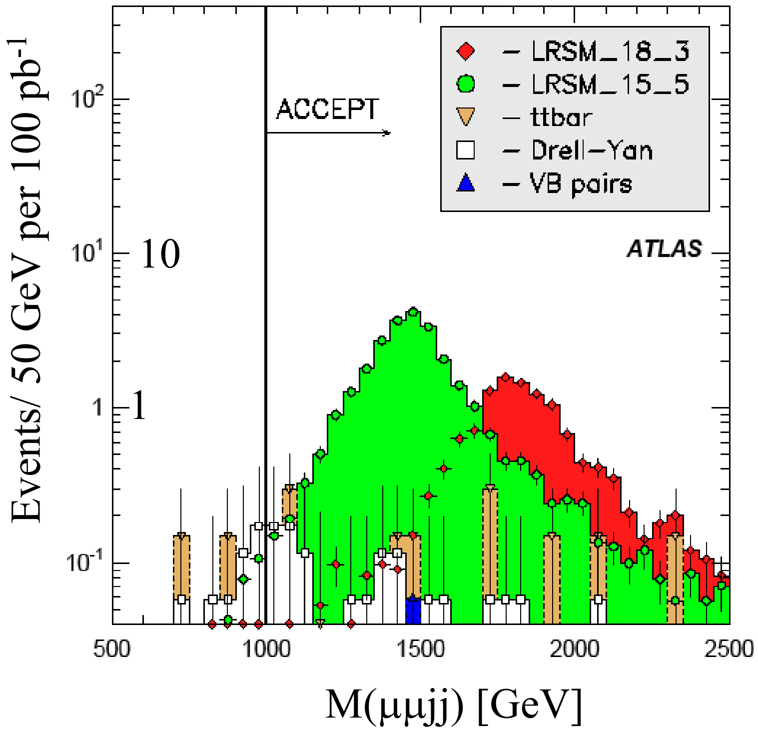
M(μμjj) [GeV]

$W_R \rightarrow lljj$

N mass after selection



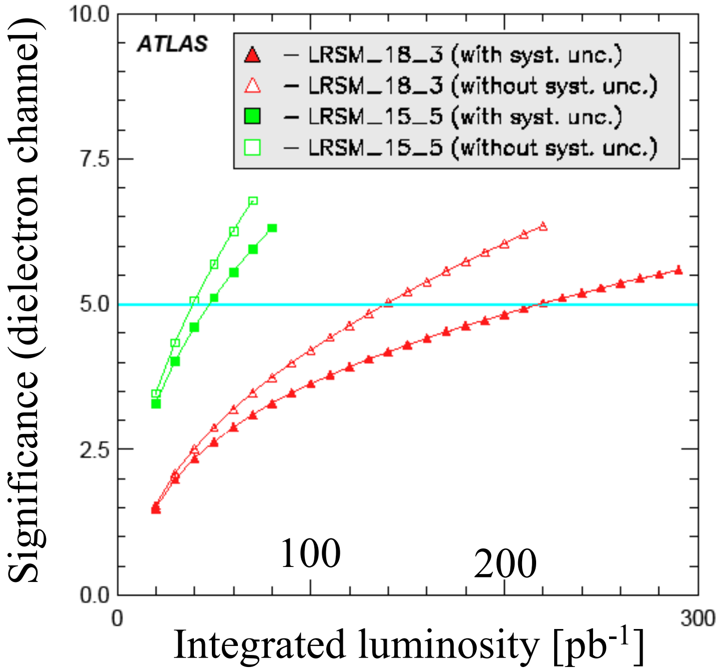
W_R mass after selection

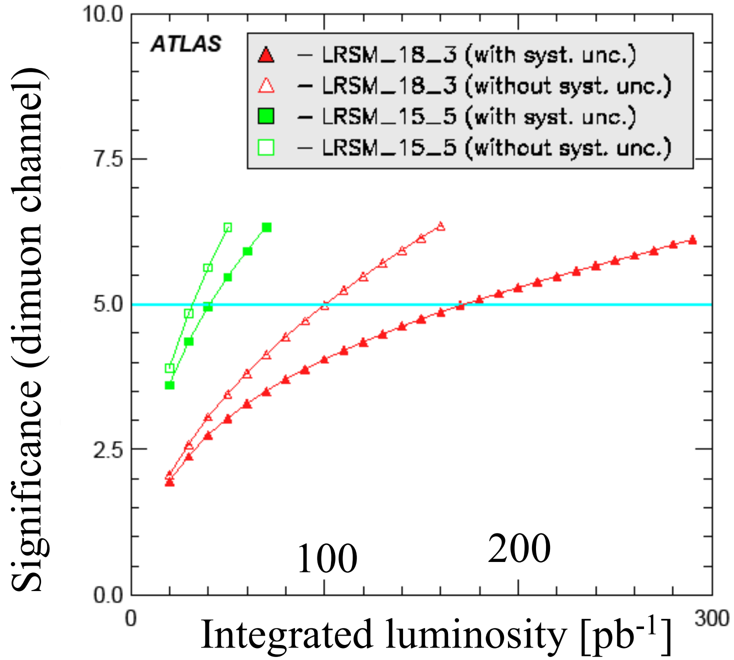


channel	efficiency
LRSM_18_3	52%
LRSM_15_5	58%
DY(M>60 GeV)	10^{-5}
ttbar	4×10^{-5}
VB pairs	2×10^{-5}

Similar results for electron channel

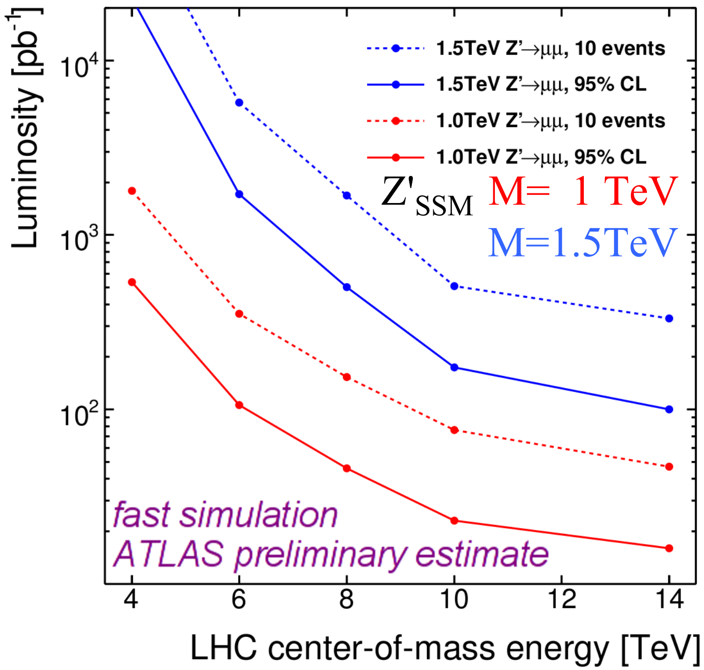
$W_R \rightarrow lljj$

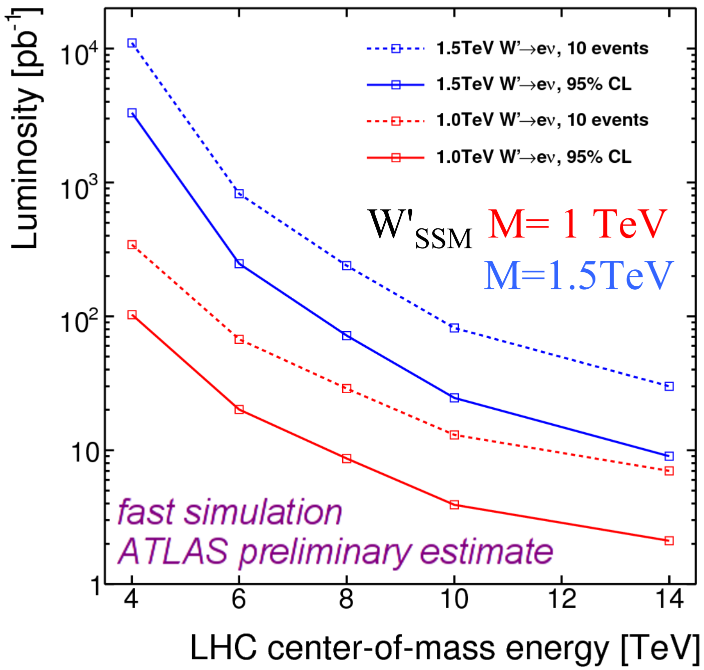




Uncertainty on luminosity → 20%
Jet energy scale (±10%)→15%-35%
Jet resolution (±30%)→ 5%-30%
MC statistics →15%-30%
Overall uncertainty on background →45%

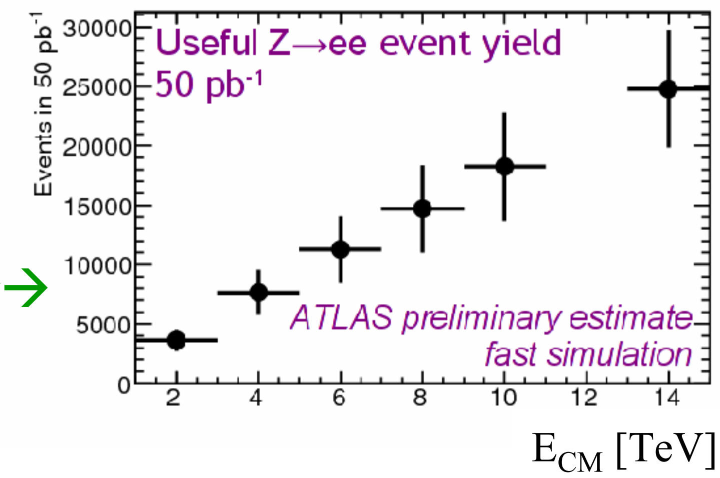
Extrapolation to lower √s





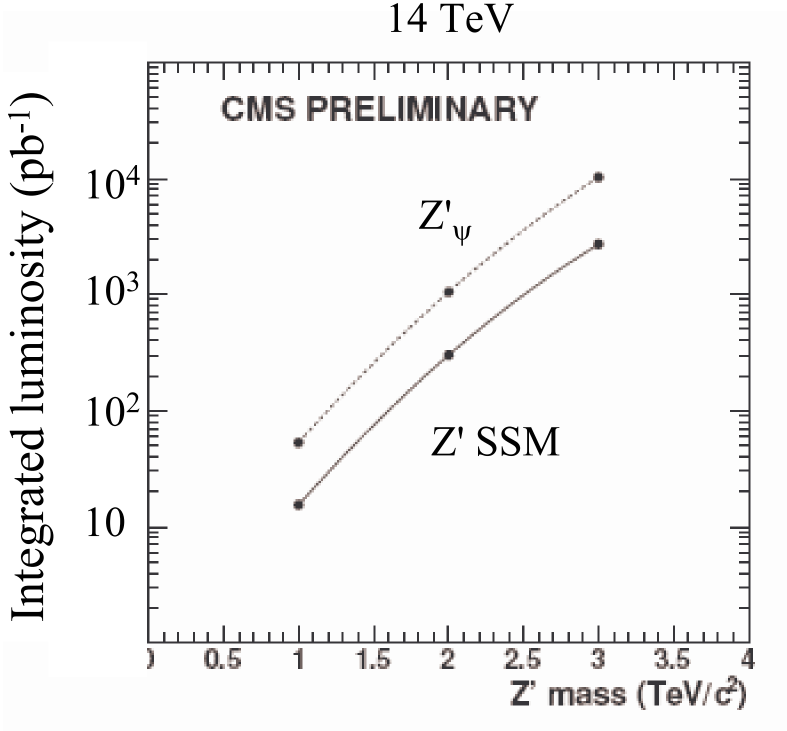
Loose a factor 2 from 14 to 10 TeV
and a factor 4 from 14 to 8 TeV

Z calibration samples decrease linearly→

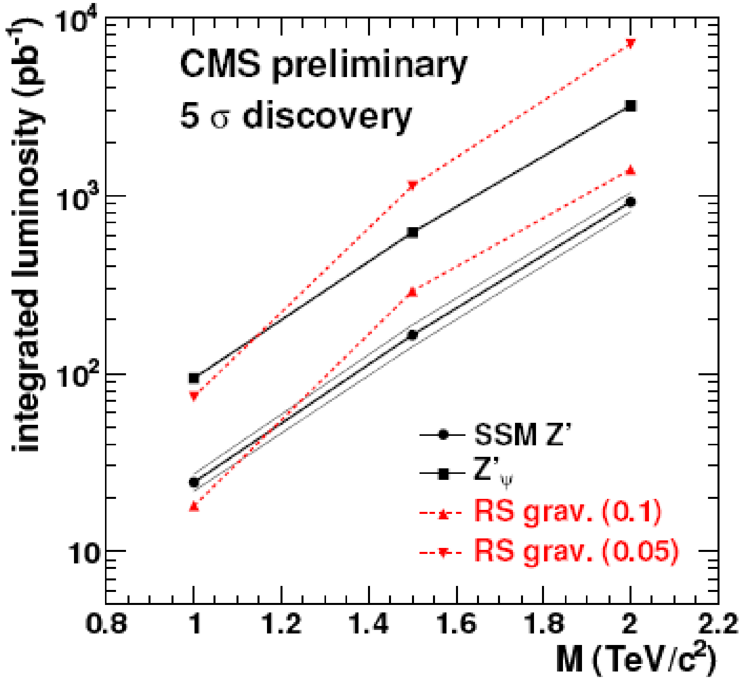


A complete study at √s=10 TeV

14 TeV



10 TeV



Complete study of Z'→ee with √s= 10 TeV taking into account efficiency determination and background estimate from data control-samples.

Z' SSM M=1 TeV

√s (TeV)	10	14
BR×σ(fb)	236	458

Summary

$L(pb^{-1})$

$W_R \to lljj$ (M=1.8 TeV) 10 events

Alignment: weak modes

E_T^{Miss} scale <8% (Atlas)

10^2

$W_R \to lljj$ (M=1.5 TeV) 10 events

Efficiencies energy scale and resolution with $Z \to \mu\mu$ and $Z \to ee$ ~1%

$Z' \to ll$ (M=1 TeV) 10 events

EmC const. term <1% with $Z \to ee$ (Atlas)

10

MS alignment 10^4 μ tracks/tower (Atlas)

ID alignment 10^6 μ tracks

$Z \to ll$ 10^3 events $W \to l\nu$ 10^4 events

$W' \to l\nu$ (M=1 TeV) 10 events

1

Commissioning with minimum bias: alignment; E_T^{Miss}; ID material studies

10^{-1}

Alignment (optical+cosmics): ID 20-50 μm MS 100-150 μm (Atlas)

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Bibliography

ATLAS

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2008 JINST 3 S08003 "The ATLAS Experiment at the CERN Large Hadron Collider"

CMS

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CMS PAS EXO-08-001 "Search for high mass resonance production decaying into an electron pair in the CMS experiment"

CMS PAS EXO-09-006 "Search for high mass resonance production decaying into an electron pair in CMS at 10 TeV with 100 pb^{-1}"

CMS PAS EXO-08-004 "Discovery Potential of $W' \rightarrow e\nu$ at CMS"

2008 JINST 3 S08004 "The CMS Experiment at the CERN LHC"