Discovery Potential for Di-lepton and Lepton+Etmiss Resonances at High Mass with ATLAS

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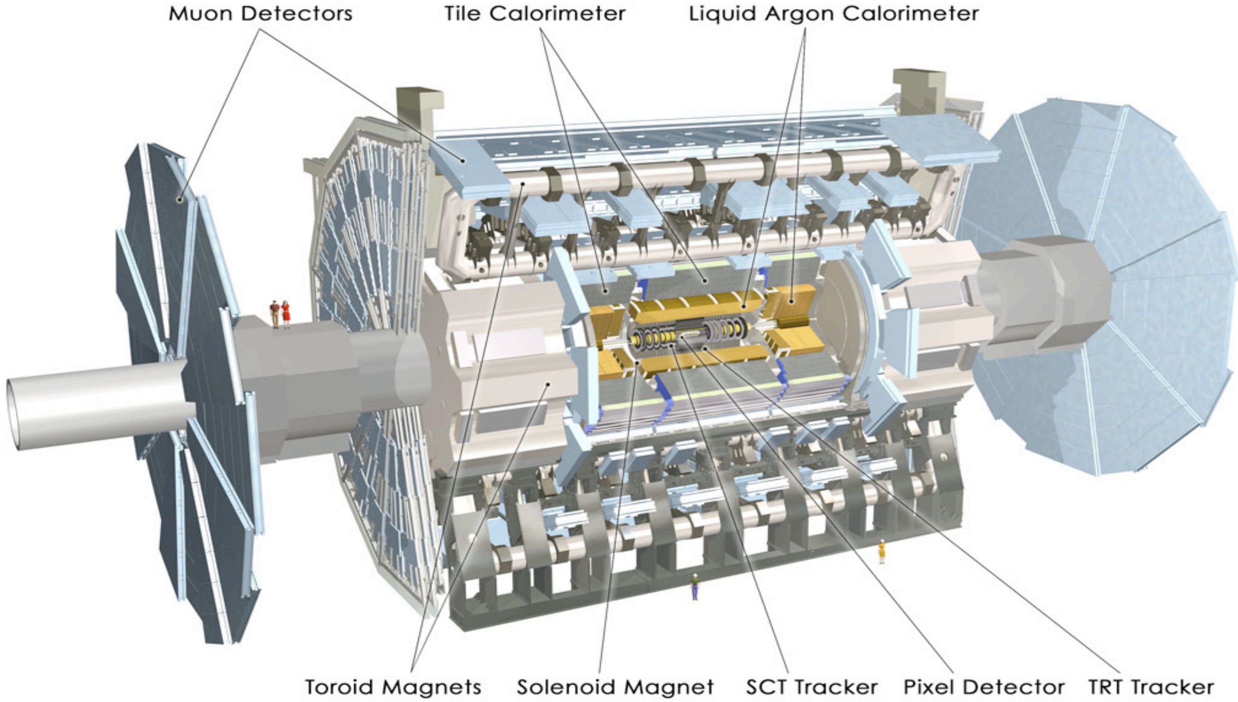
Prelude

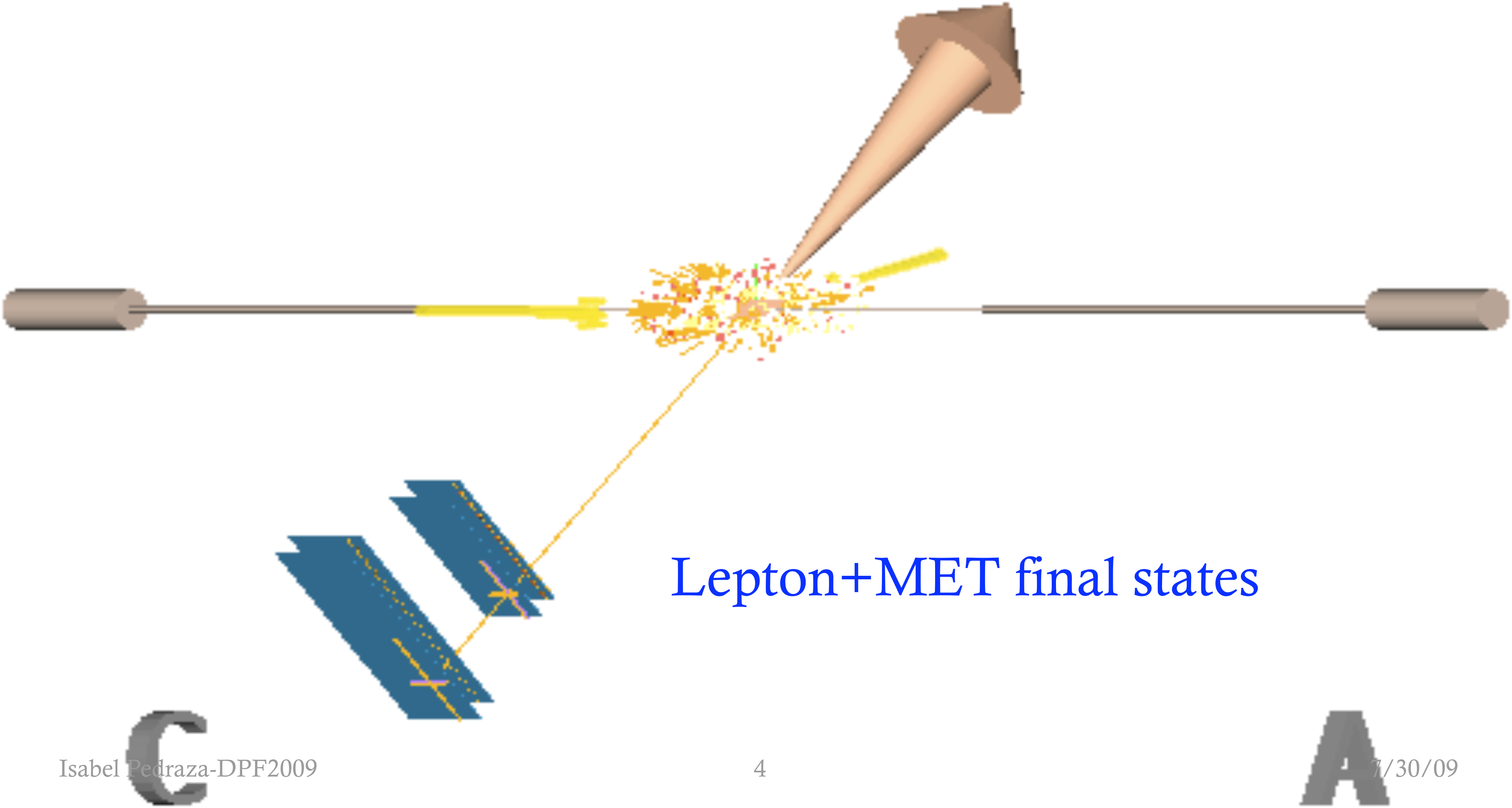
- Fact: We are looking for new physics. Why?
  - Necessity to explain the origin of the hierarchy problem, the mechanism of electroweak symmetry breaking…
  - Standard Model is low energy effective theory.
- Many models of new physics predict new heavy resonances decaying into di-leptons (e, μ , τ , ν).
  - String inspired models
  - Extended gauge symmetries
  - Left-right symmetric models
  - Extra dimensions
  - Technicolor
  - Etc…
- ATLAS is sensitive to a broad array of new physics. We will address the discovery potential of some of these new physics final states.

ATLAS Detector

	ATLAS
Weight	7000 tons
Diameter	22m
Length	46m
Peak B Field	2T solenoid 3.9T (peak) BA toroid 4.1T (peak) EC toroids



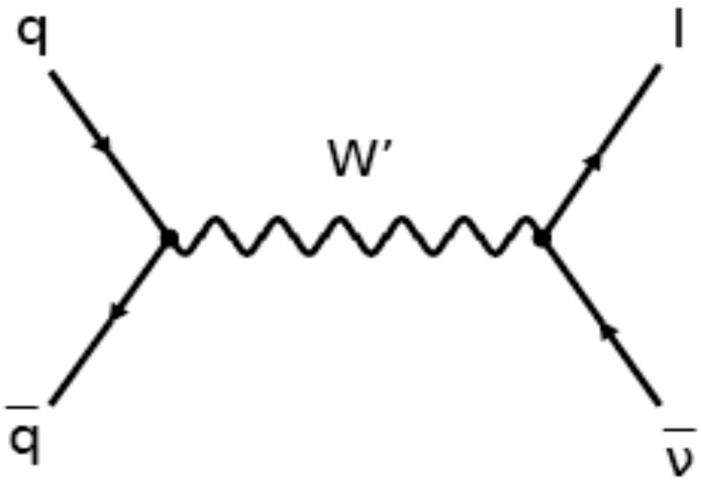
PERFORMANCE		
Tracker	Si pixels, strips + TRT (pid)	$\sigma/p_T \approx 5x10^{-4} p_T \oplus 0.01$
EM calorimeter	Pb + LAr	$\sigma/E \approx 10\%/\sqrt{E} \oplus 0.007$
Hadronic calorimeter	Fe+scintillator / Cu + LAr	$\sigma/E \approx 50\%/\sqrt{E} \oplus 0.03$
Combined Muons (ID+MS)	2%@50GeV to	10%@1TeV



Lepton+MET final states

W'

- W' in the Sequential Standard Model:
  - W' is an additional heavy gauge boson
  - W' has the same couplings as W to left-handed fermions; no interaction with other heavy gauge bosons (W, Z, Z')
  - Lower bound on W' mass (direct searches): ~1TeV



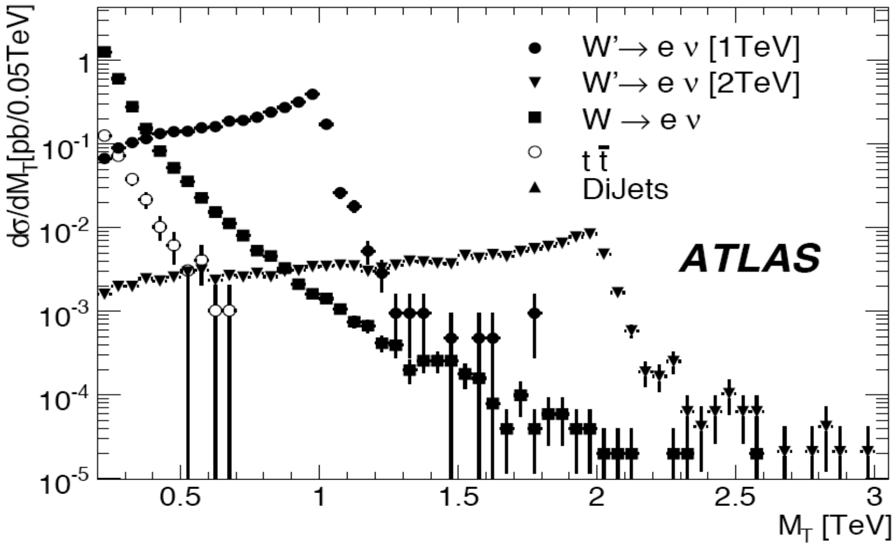
- Standard Model backgrounds:
  - $W \rightarrow l\nu$ (l: e, μ, τ)
  - QCD (dijets processes)
  - ttbar

- W' signature:
  - High energy lepton accompanied by missing energy coming from the undetected neutrino.

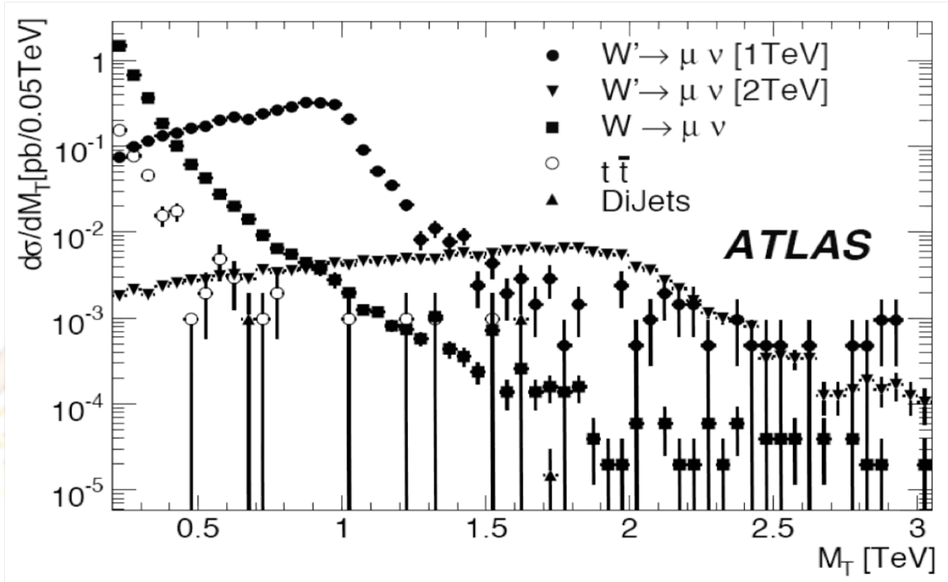
W'

Decay channels

- W' → e ν



W' → μ ν

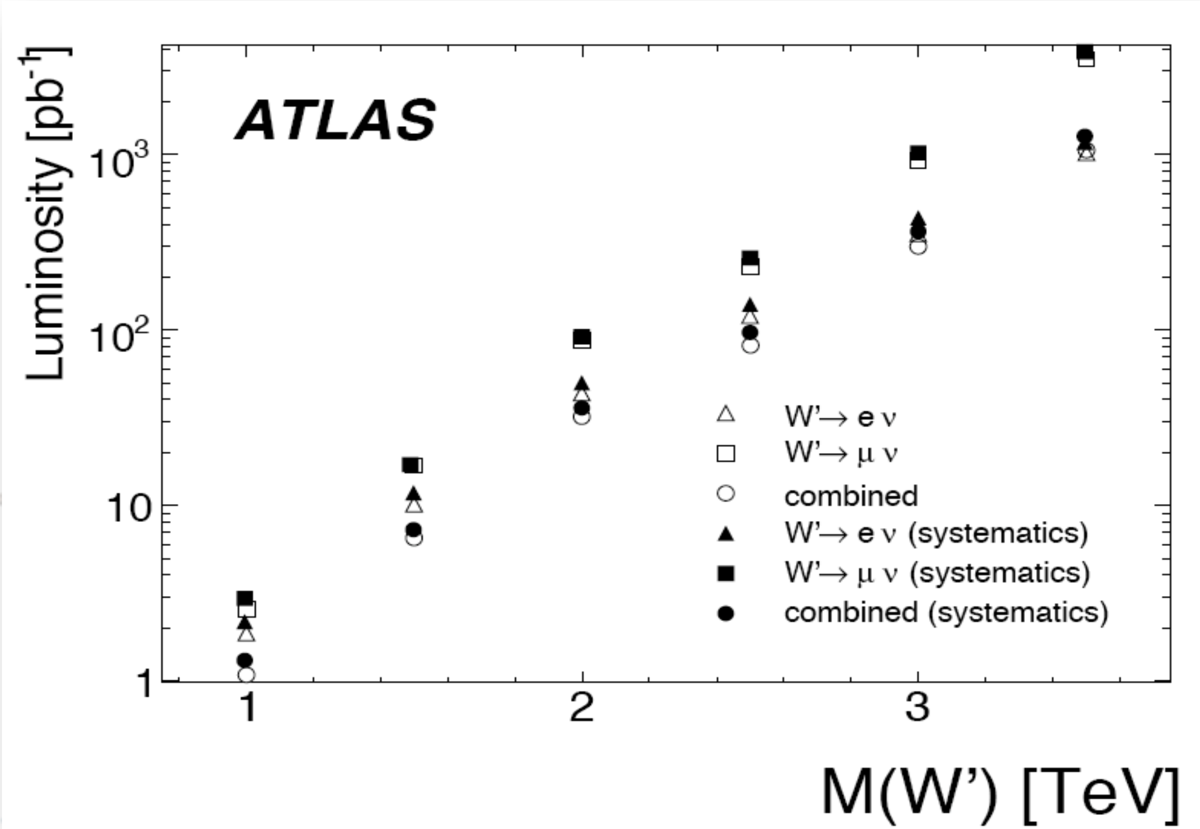


Event Selection

- Good reconstructed electron/muon
- Just one lepton with p_T>50GeV
- E_T^{Miss}>50GeV
- $\sum p_T^{leptons} / (\sum p_T^{leptons} + \sum E_T^{Miss}) > 0.5$

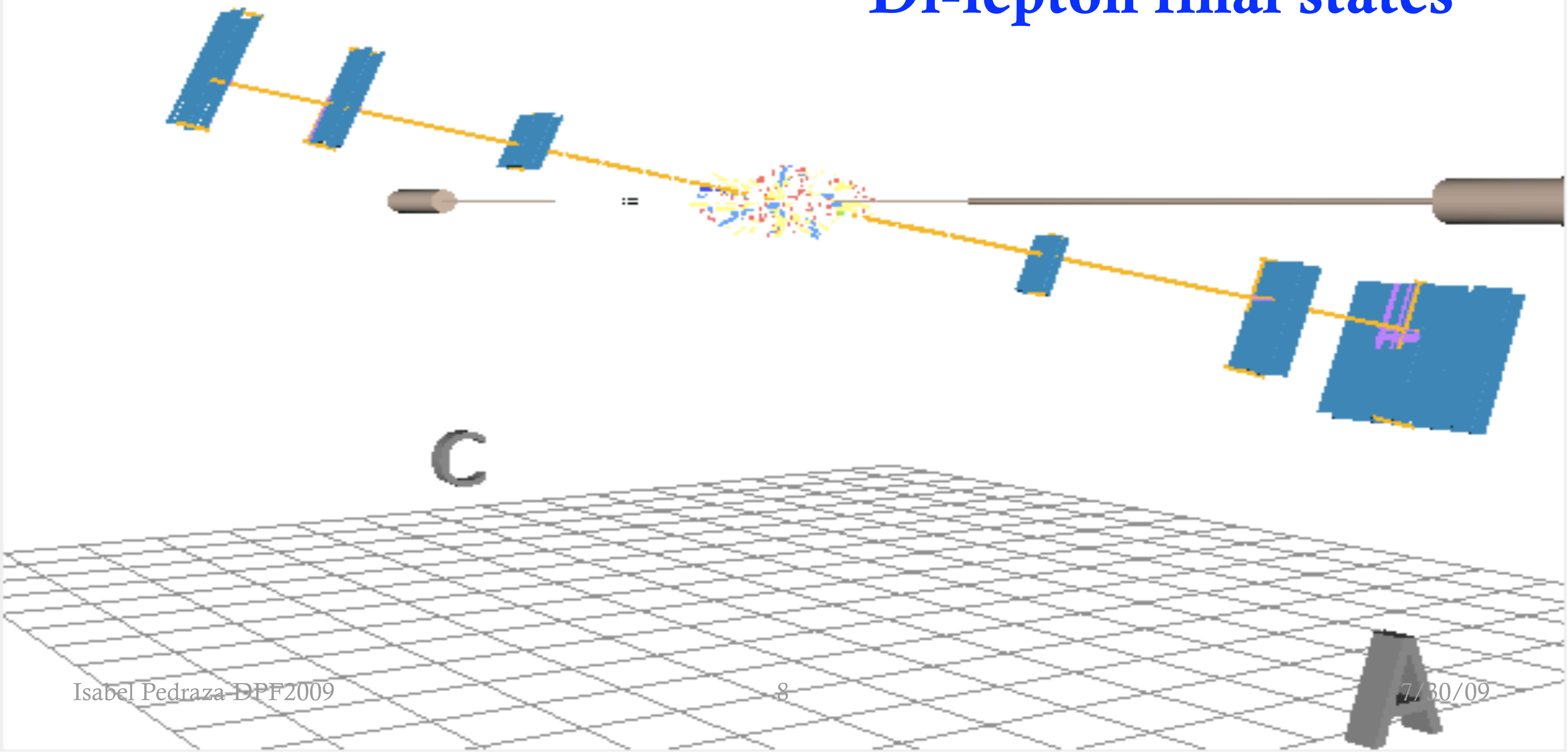
W'

- Expected luminosity for a 5 σ discovery (number counting)



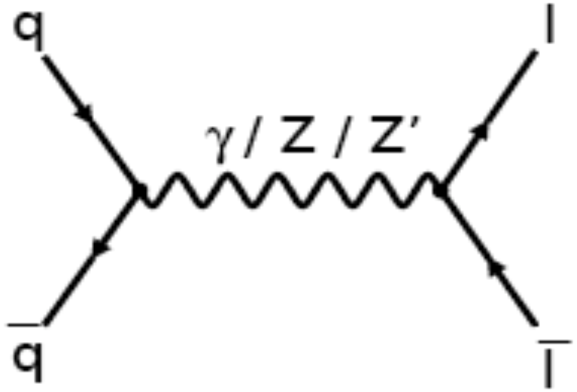
- •Electron, muon channels studied
- •Worse muon resolution at high p_T
- •Possible discovery above TeV limits (1TeV) with O(10pb^{-1})

Di-lepton final states



Z'

- Z' in some representative models:
  - Sequential Standard Model Z'_{ssm}
  - E_6 (Z'_{ψ}, Z'_{η}, Z'_{χ})
  - Left-Right Symmetric models (Z'_{LRM}, Z'_{ALRM})



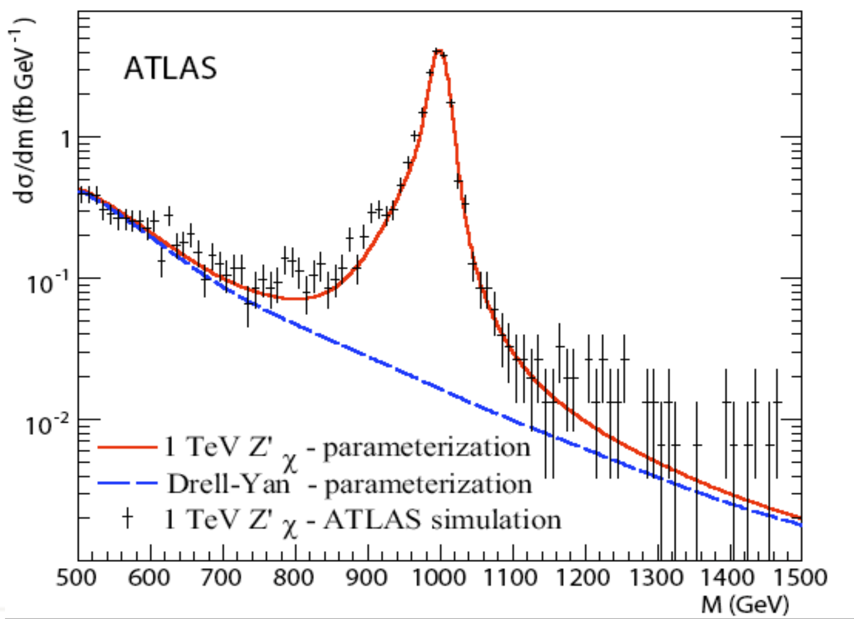
Z' Model	Indirect Searches (GeV)	Direct Searches (GeV)	
		e^+e^- Colliders	p^+p^- Colliders
Z'_{χ}	680	781	864
Z'_{ψ}	481	366	853
Z'_{η}	619	515	933
Z'_{LRSM}	804	518	–
Z'_{SSM}	1787	1018	966

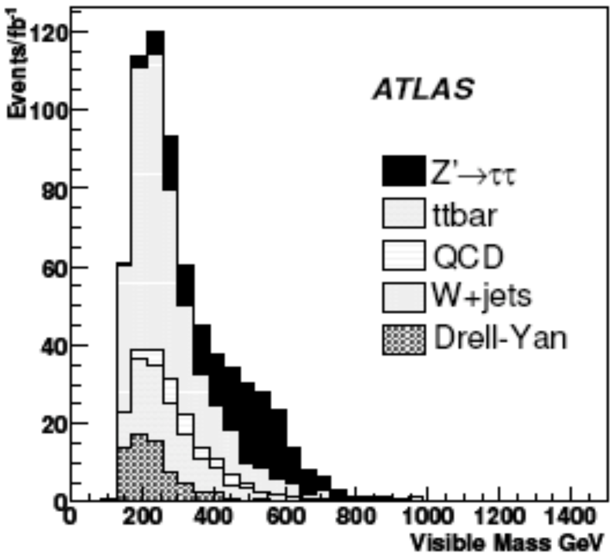
Table 1: 95% C.L. limits on various Z' models.

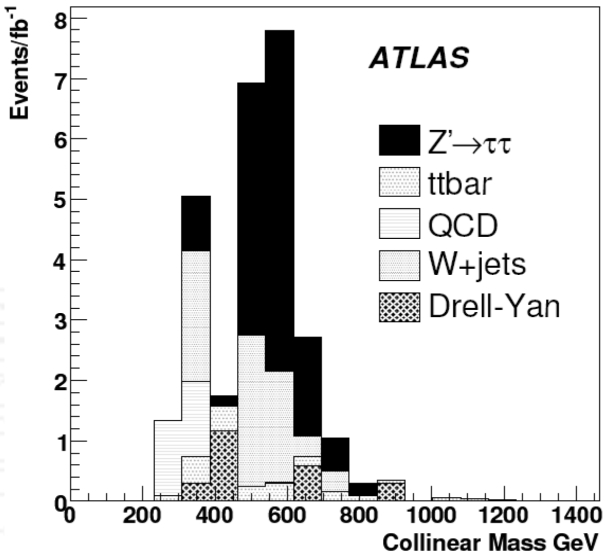
- Standard Model backgrounds
  - For Z' → ee, $\mu\ \mu$
    - Drell-Yan
  - For Z' → $\tau\ \tau$
    - ttbar
    - QCD
    - W+jets

Z'

- Event Selection
  - $Z' \rightarrow \mu\ \mu$
    - Two muons with p_T>30GeV
    - Opposite charge
  - $Z' \rightarrow$ ee
    - 2 electrons
    - At least one with p_T>65GeV
    - Opposite charge





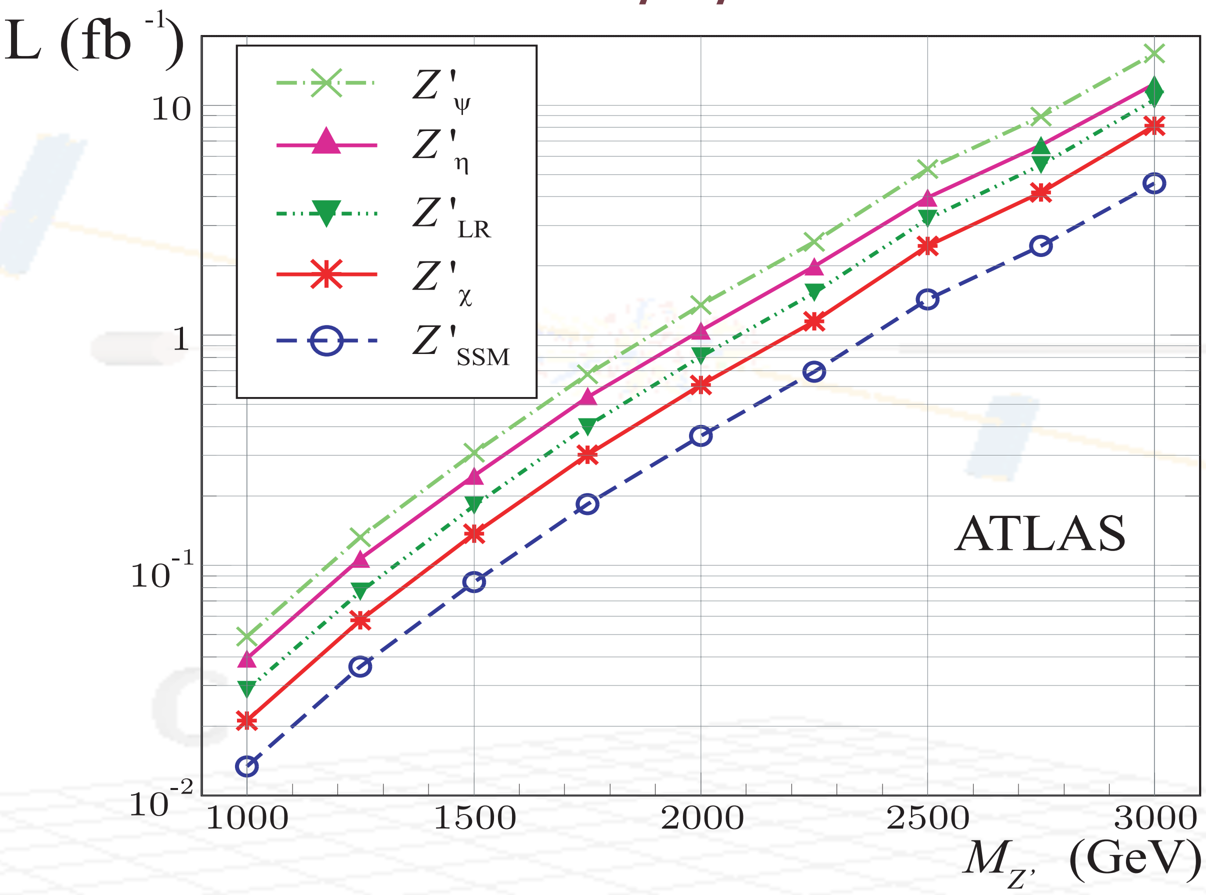


- $Z' \rightarrow \tau\ \tau$
  - τ selection
  - Opposite charge
  - E_t^{miss}>30GeV
  - m_T>300GeV
  - p_T^{tot}<70GeV
  - m_{vis}>300GeV
  - $\cos\Delta\phi_{lh}$>-0.99

Z'

- Expected luminosity for a 5 σ discovery

$Z' \rightarrow \mu\ \mu$



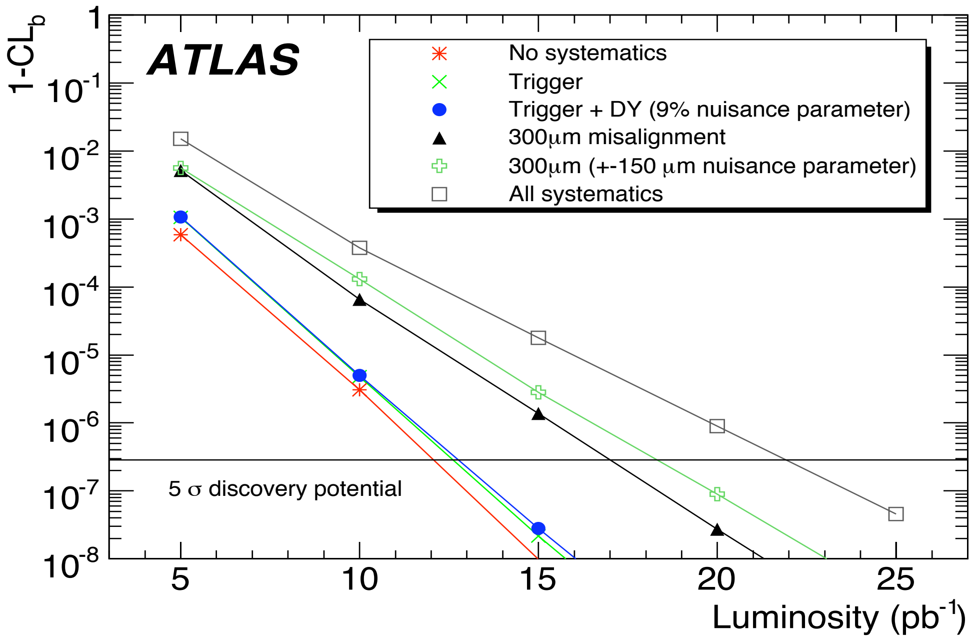
As little as 100pb^{-1} of physics data could yield a 5σ discovery.

Z’

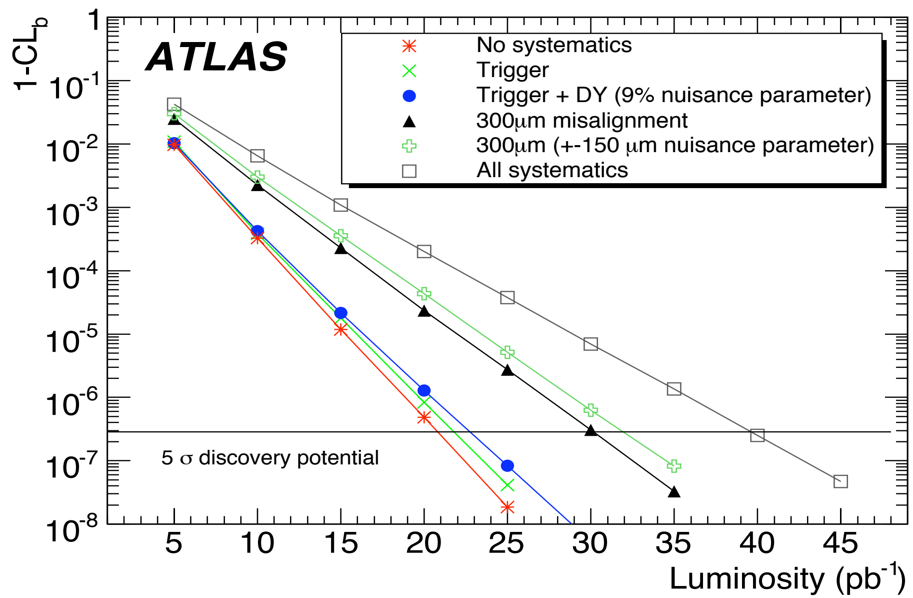
- Expected luminosity for a 5 σ discovery

$Z' \rightarrow ee$, m=1TeV

Z'_{SMM}



Z'_{χ}



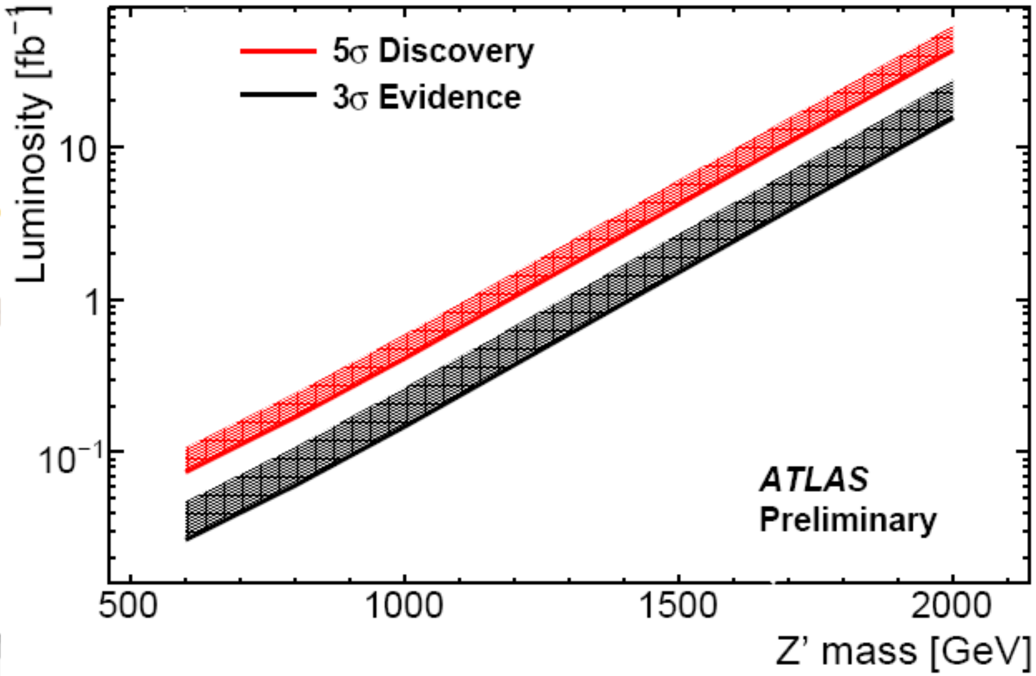
•Different systematic errors were applied for two benchmark models.

•As little as 50pb^{-1} of physics data could yield a 5σ discovery.

Z'

- Expected luminosity for a 5 σ discovery

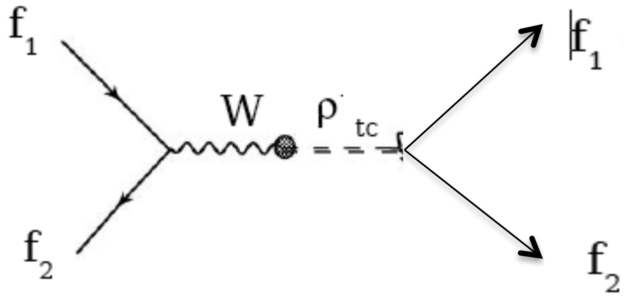
$Z'_{SMM} \rightarrow \tau\ \tau$



•Z'_{SSM} with a mass up to 1.2 TeV could yield a 5 sigma significance with ~1fb^{-1} of data

ρ_{TC} and ω_{TC}

- One of the most promising search channels is the dilepton decay of the ρ_{TC} and ω_{TC}.
- The "Technicolor Strawman Model" or TCSM is used as a benchmark model for generic strongly interacting theories.
- The limits set by CDF rule out ρ_{TC} and ω_{TC} masses below 280GeV for a particular choice of the TCSM parameters.



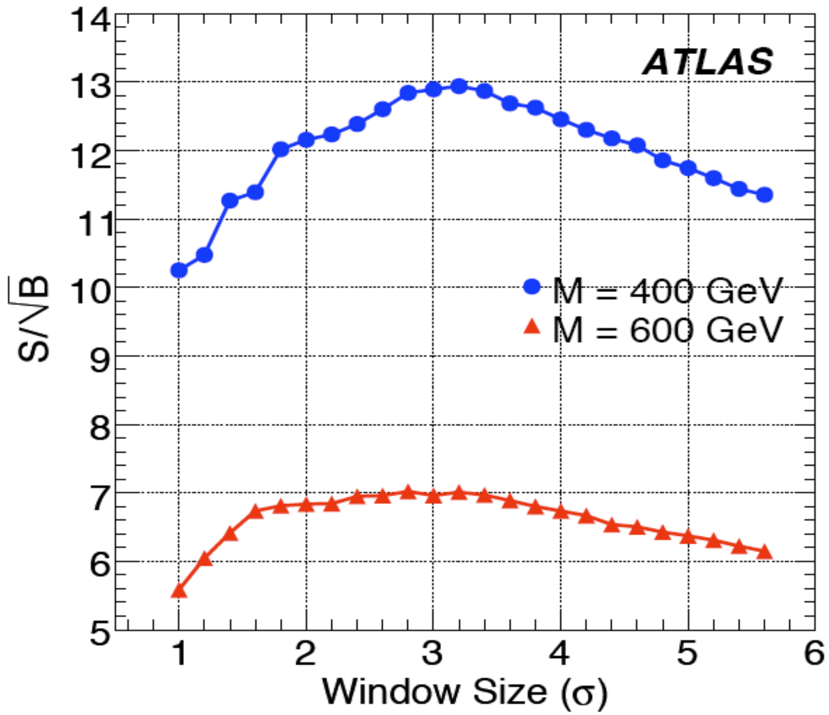
m_{ρ_T,ω_T} (GeV)	400	600	800	1000
Peak mass (GeV)	403	603	804	1004
$\sigma(m)$ (GeV)	13	22	34	46

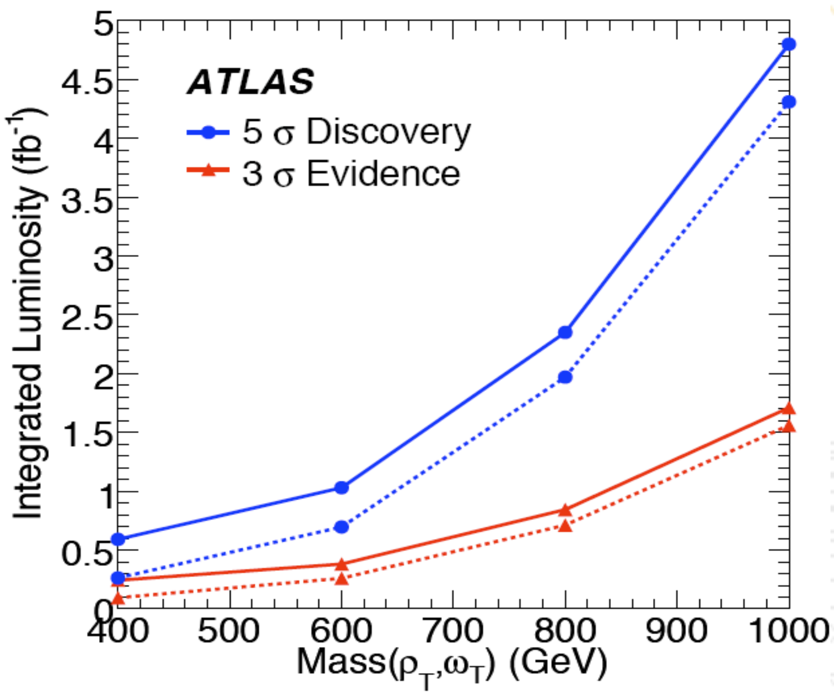
The meson natural widths are less than a GeV, so the observed width $\sigma(m)$ is entirely due to detector resolution.

- Standard model background
  - Drell-Yan

ρ_{TC} and ω_{TC}

- Event Selection for muon channel
  - p_T>30GeV
  - Trigger selection
  - Well reconstructed muons
  - Opposite charge
  - Mass window ±1.5 σ

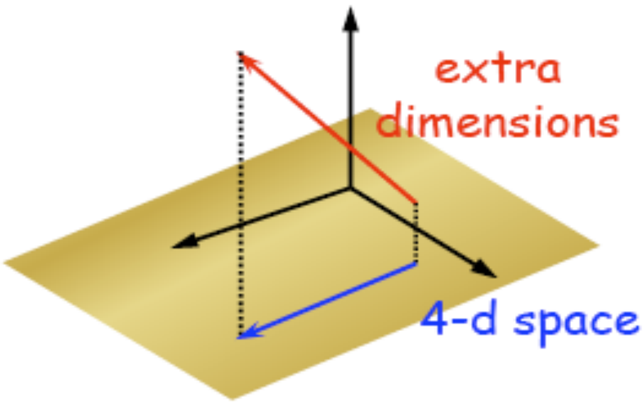




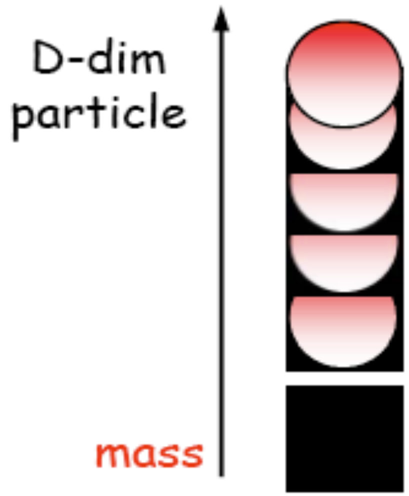
- Discovery Potential
  - Including estimated early alignment: +50% luminosity needed

Graviton

- Randall-Sundrum model addresses the hierarchy problem by adding one extra-dimension. It predicts the existence of a tower of Kaluza-Klein exitations of the graviton.



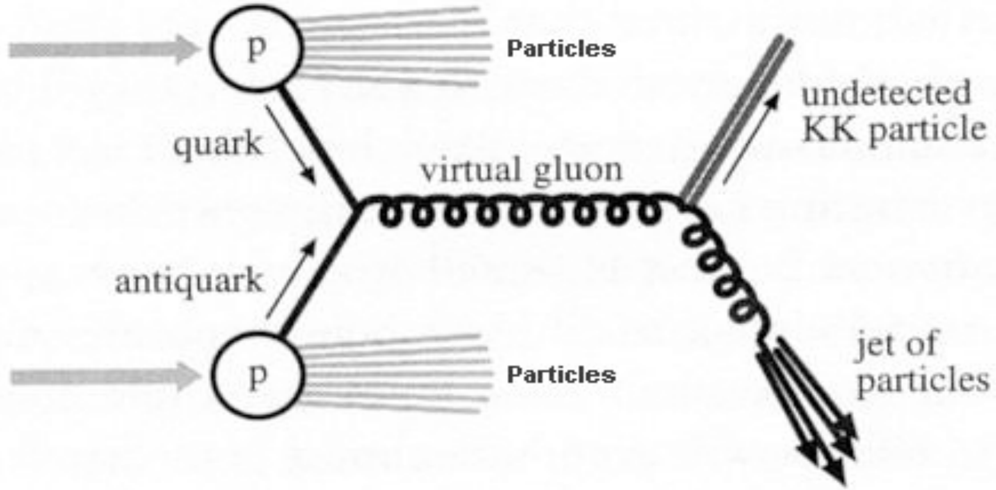
$$E^2 = \vec{p}^{\,2} + \underbrace{p^2_{extra} + m^2}_{\text{KK mass}}$$



Graviton

- These graviton should be observable as resonances which decay into lepton pairs at LHC.

- The current limits depend on the parameters of the model, and range from several hundreds GeV to one TeV



Model Parameters		Γ_G	σ_m	$\sigma \cdot BR(G \to e^+e^-)$
m_G	$k/\bar{M}_{pl}$	[GeV]	[GeV]	[fb]
500 GeV	0.01	0.08	4.6	187.4
750 GeV	0.01	0.10	6.4	27.7
1.0 TeV	0.02	0.57	7.9	26.0
1.2 TeV	0.03	1.62	10.3	22.4
1.3 TeV	0.04	2.98	11.4	25.3
1.4 TeV	0.05	5.02	13.1	26.8

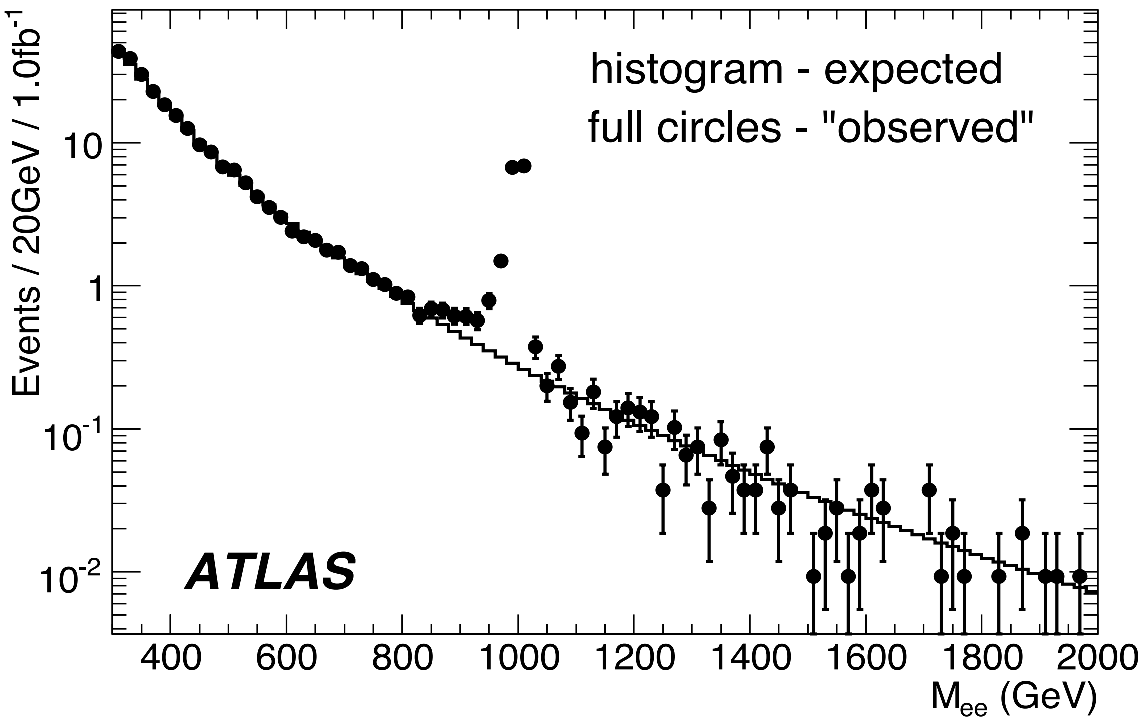
- Standard Model backgrounds
  - For G →ee
    - Drell-Yan
    - All other backgrounds are expected to be small.

Graviton

G→ee

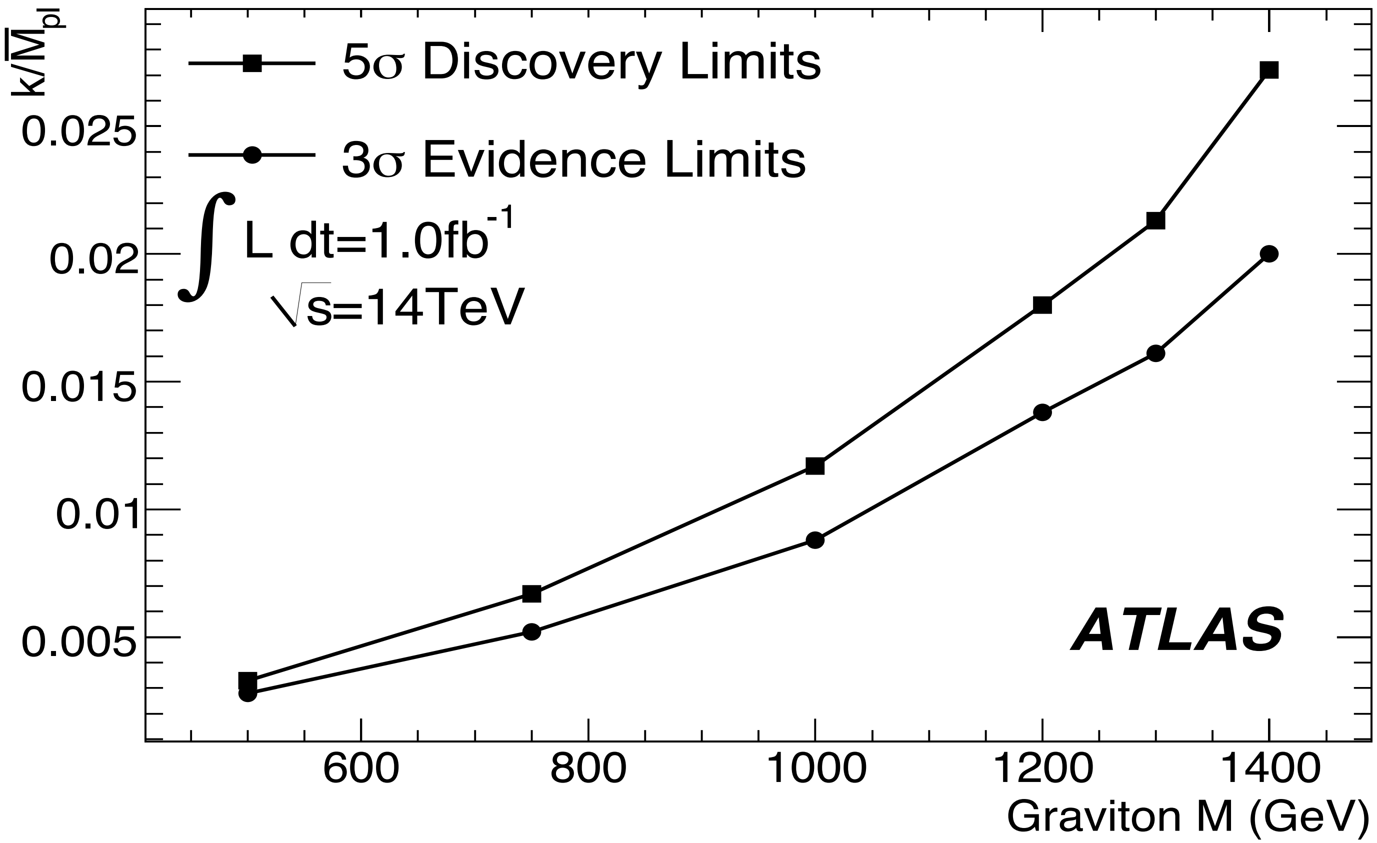
•The observed distribution includes a graviton with mass 1 TeV and coupling $\kappa/M_{pl}=0.02$.

- Event selection
  - Two electrons
  - $p_T >= 65$ GeV
  - $\cos\Delta\phi_{ee}<0$



Graviton

- Discovery potential as a function of the graviton mass.



For some values of k/M_{pl}, possible discovery with $O(100pb^{-1})$

Example of the potential of the early data of LHC $W' \rightarrow e\nu, \mu\nu$

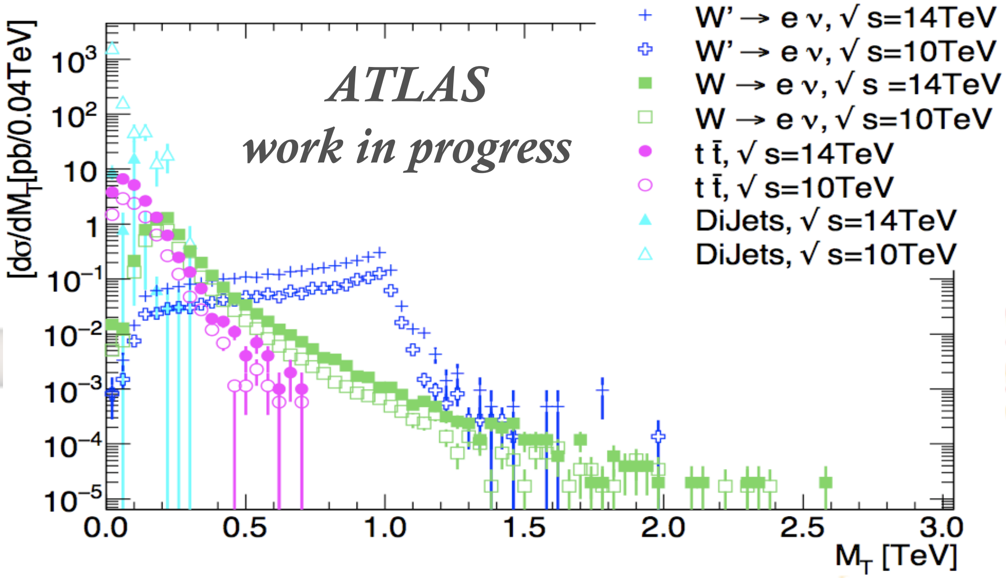
- The early run of the LHC is expected to be at $\sqrt{s}$=10TeV.
- With this we can have new physics showing up.
- The lowered center-of-mass energy, at 10TeV, degrades the production cross section, thus the sensitivity. In the case of the $W' \rightarrow l\nu$ the fraction left for the cross sections for signal and background are:

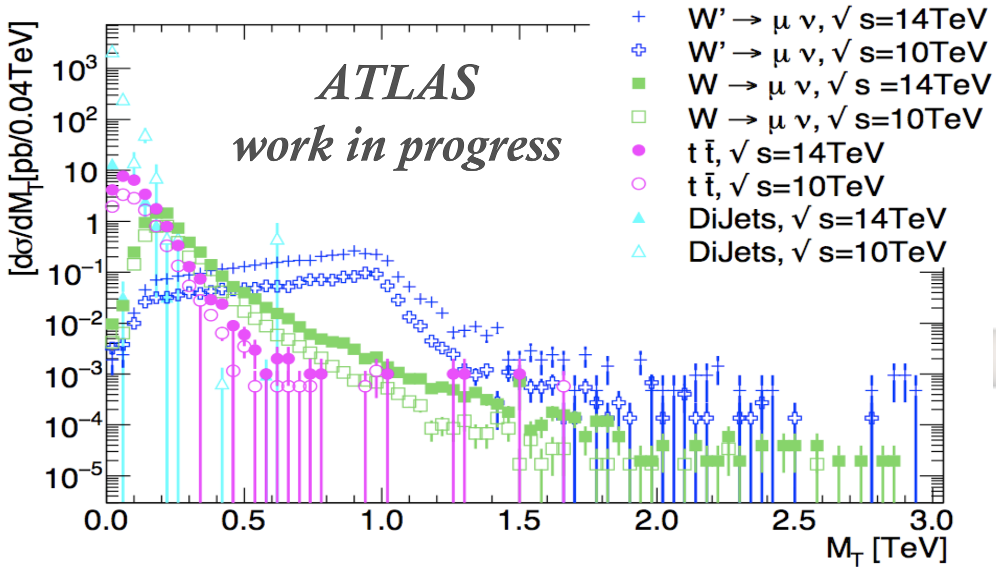
W' m=1 TeV	W' m=1.5 TeV	W' m=2 TeV	W' m=2.5 TeV
51.54%	40.37%	34.50%	27.40%

W	tt	DiJet's
62.60%	56.43%	63.08%

Example of the potential of the early data of LHC

W' → $e\nu$, $\mu\ \nu$



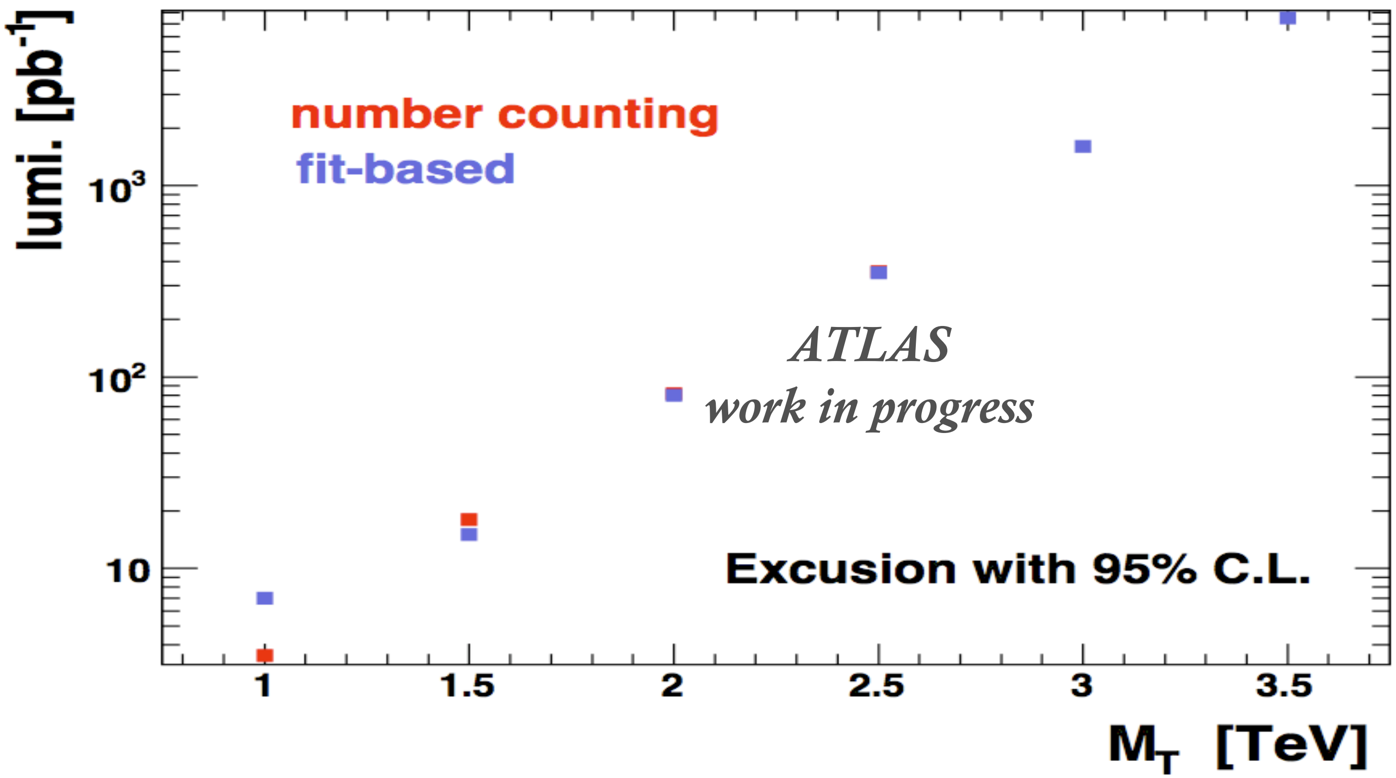


- The signal and background remain without significant modifications on their shape for √s=10TeV.

Example of the potential of the early data of LHC

W' $\longrightarrow e\nu, \mu\nu$

- Exclusion limits W' $\longrightarrow e\nu$



W' is one of the searches that can be done in the first run of the LHC. With O(50pb^{-1}) of well understood data we can either discover it or exclude it beyond the current limit.

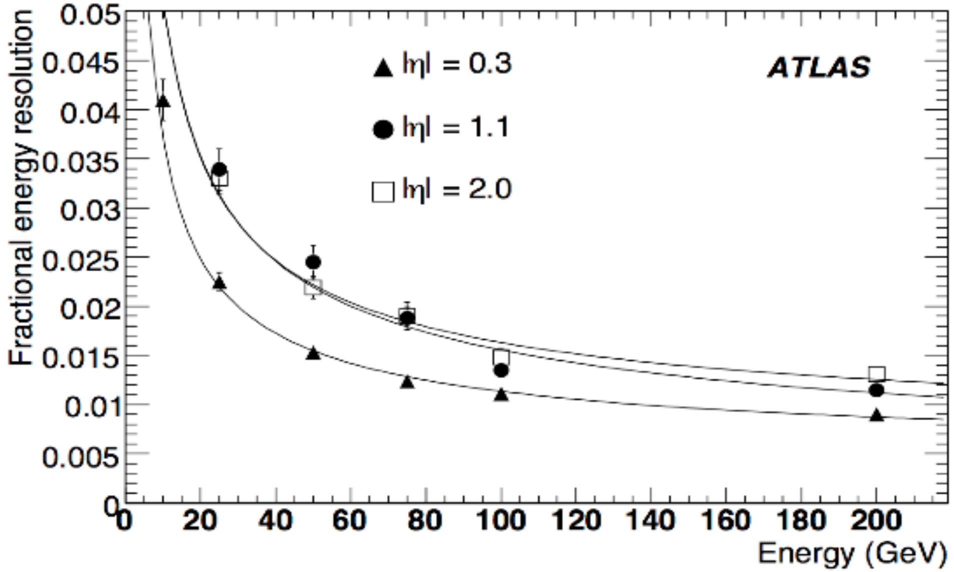
Conclusions

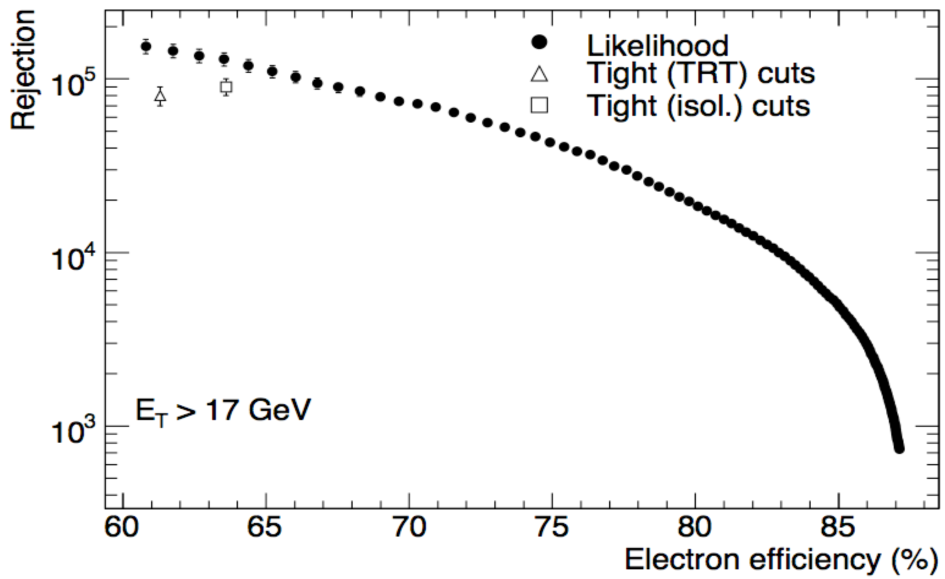
- A selection of analyses on new predicted particles with Di-lepton and Lepton+MET final states was presented.
- LHC and ATLAS constitute a powerful tool to discover or exclude new particles.
- 14TeV studies have shown that the existence of a W' and Z' could be established at the 5 sigma level even with O(100pb^{-1}) of integrated luminosity
- The initial run of few tens of pb^{-1} at 10TeV would be enough to go beyond Tevatron limits in most of these models.

BACKUP

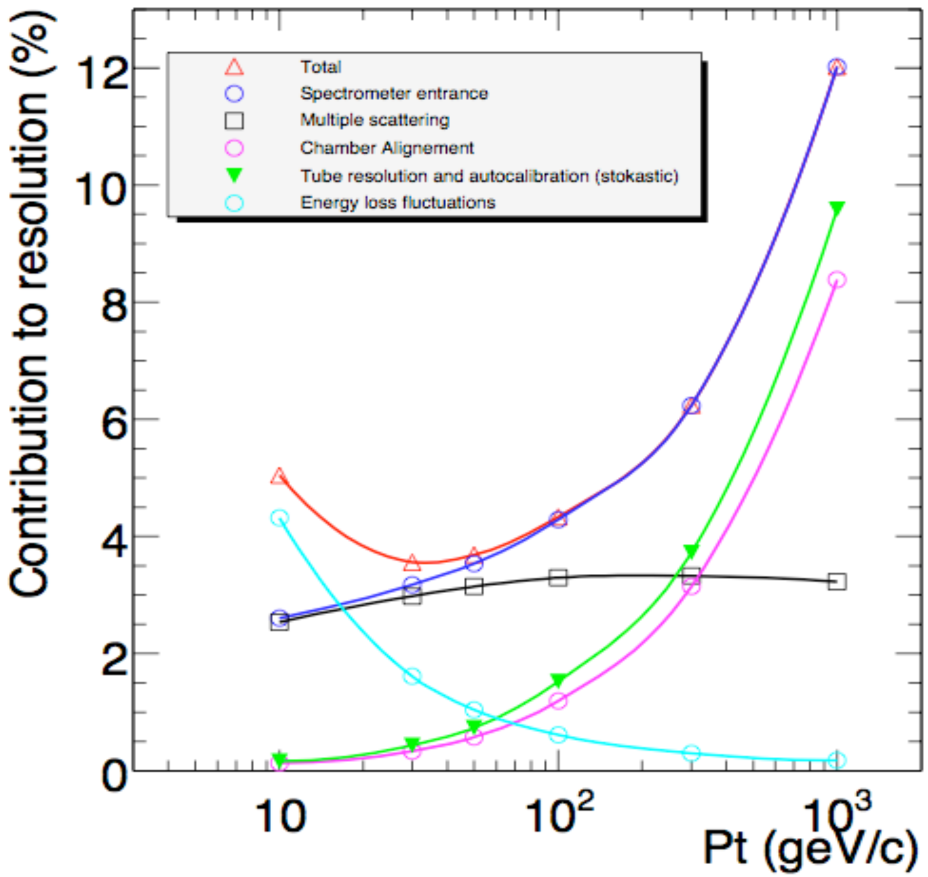
Electrons

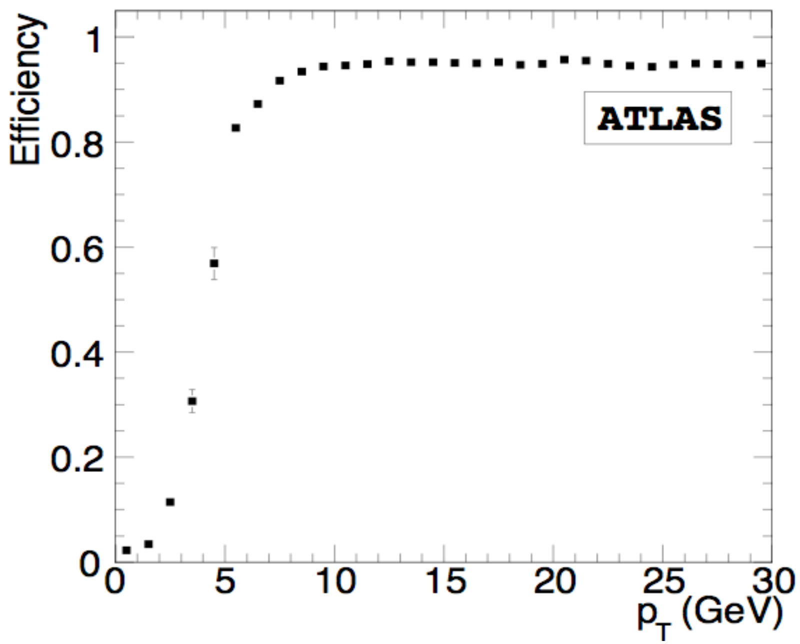
- The QCD cross sections at LHC are 10 to 100 times higher than at the Tevatron





Muons


Total
Spectrometer entrance
Multiple scattering
Chamber Alignement
Tube resolution and autocalibration (stokastic)
Energy loss fluctuations
Contribution to resolution (%)
Pt (geV/c)


Efficiency
ATLAS
p_T (GeV)

Tau leptons

- With 100 pb-1, clear signals for W and Z in τ channels
- $Z \rightarrow \tau\ \tau$ can then be used to set the ET miss scale to a few %
- τ reconstruction is tricky and relies (not for very first data but soon after) on multivariate techniques.