Searching for early lepton and photon signatures with ATLAS

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SLAC
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The path to discovery and exclusion

What to look for, and where we are now:

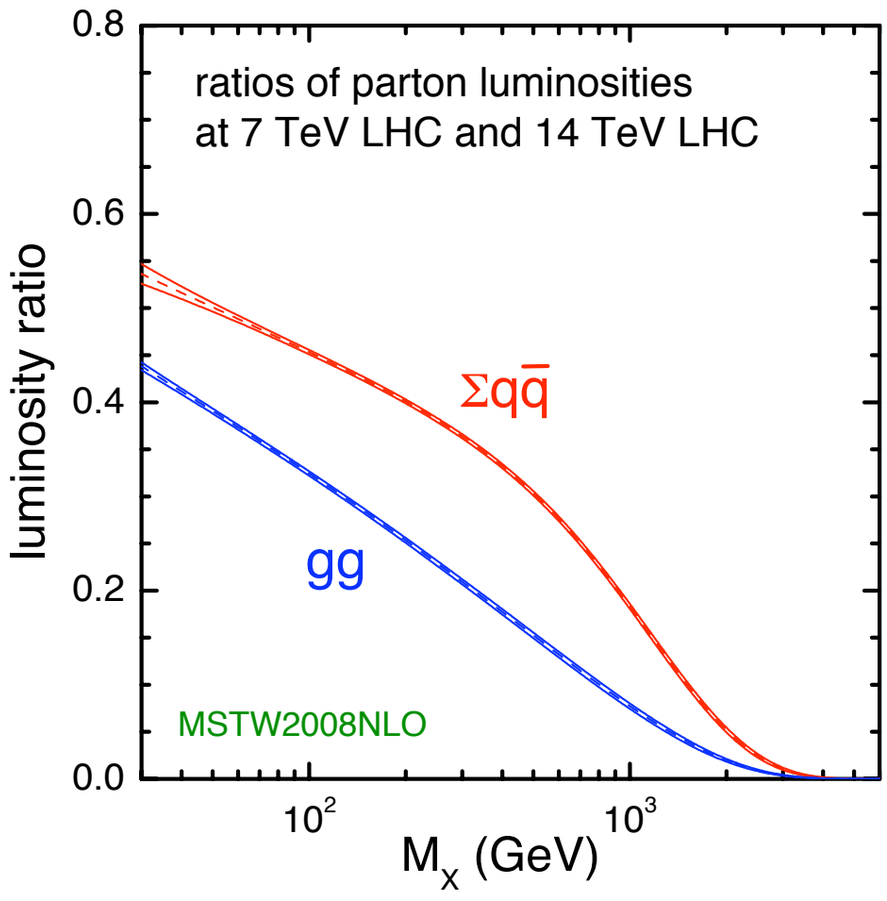
- Leptons and photons provide a distinct handle on new phenomena
  - From "*Z*-like", to "*t*-like", to "unlike anything else"
  - Resonances: $\gamma\gamma$, $\ell^+\ell^-$, $\ell + \not{E}_T$, ℓ + jet
  - Complex events: $\gamma\gamma + \not{E}_T$, $\ell^+\ell^- + \not{E}_T$, $\ell + \not{E}_T$ + jets, $\ell\ell + \not{E}_T$ + jets
- The entire ATLAS detector is required and ready
  - For triggering and reconstruction, require tracking, calorimetry, and muon identification
  - Cannot ignore jets and missing energy

Sensitivity to new phenomena is at hand.

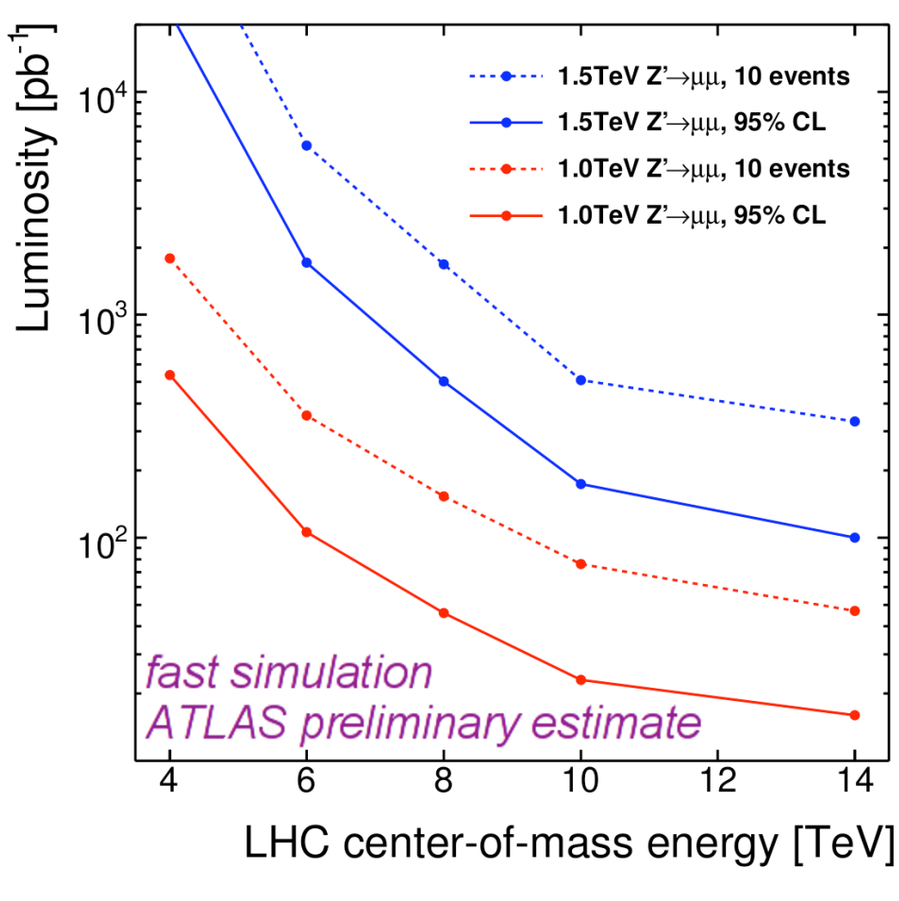
Collisions at 7 TeV

Studies looking forward to 14 TeV c.m. energy are valuable at 7 TeV

- 4th gen. quark ($m = 400$ GeV): $\sigma(7)/\sigma(14) \approx 0.15$
- W' ($m = 1.0$ TeV): $\sigma(7)/\sigma(14) \approx 0.2$
- 95% exclusions of Z' ($m = 1.0$ TeV) from 15 pb^{-1} to 70 pb^{-1}



J. Sterling, http://projects.hepforge.org/mstwpdf/plots/plots.html



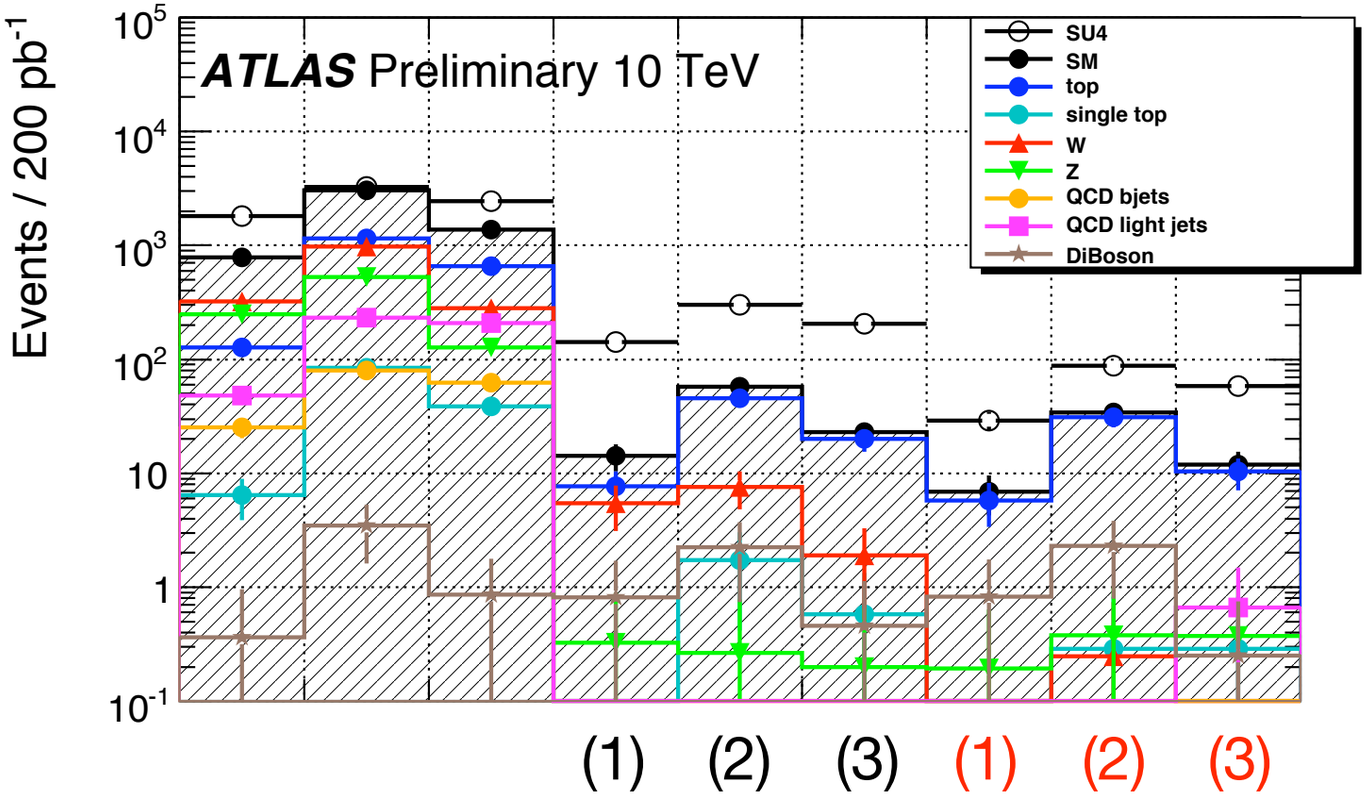
https://twiki.cern.ch/twiki/bin/view/Atlas/AtlasResultsEcmDependence

Lepton + jets + missing E_T

Many models generically produce signatures with at least one high p_T isolated lepton, with jets and missing energy

- Specifically considered R-conserving SUSY (mSUGRA, pMSSM) and universal extra dimensions (UED)
  ⇒ **At least one new particle is stable and escapes detection**

- Significant excess of events in many channels with few 100 pb^{-1}



200 pb^{-1} @ 10 TeV
→ 1 fb^{-1} @ 7 TeV

(1) 1 lepton, 2 jets

(2) 1 lepton, 3 jets

(3) 1 lepton, 4 jets

(1) 2 leptons, 2 jets

(2) 2 leptons, 3 jets

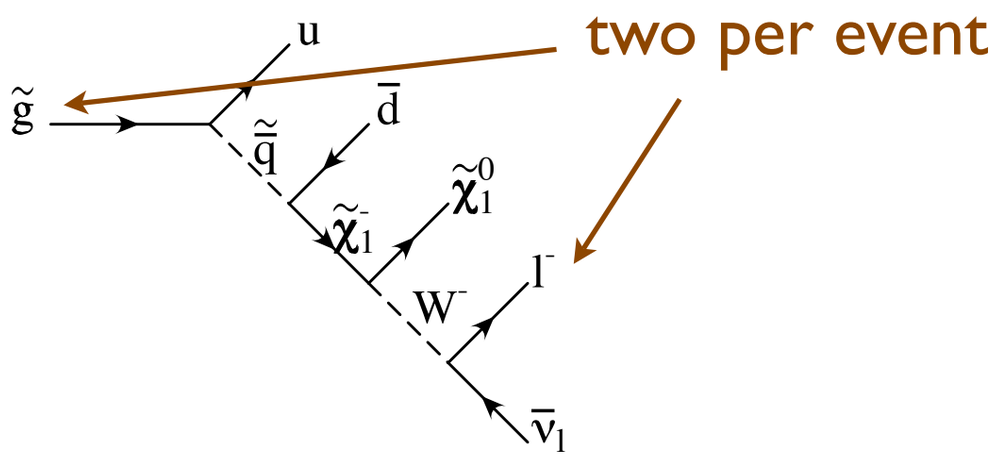
(3) 2 leptons, 4 jets

Same-sign dilepton + jets + missing E_T

Moderately high p_T leptons from intermediate *W* bosons:

- SM backgrounds are rare
- $\mathcal{B} \times \sigma$ could be > 0.1 pb^{-1}
- Challenge: $t\bar{t}$ and charge mis-ID background

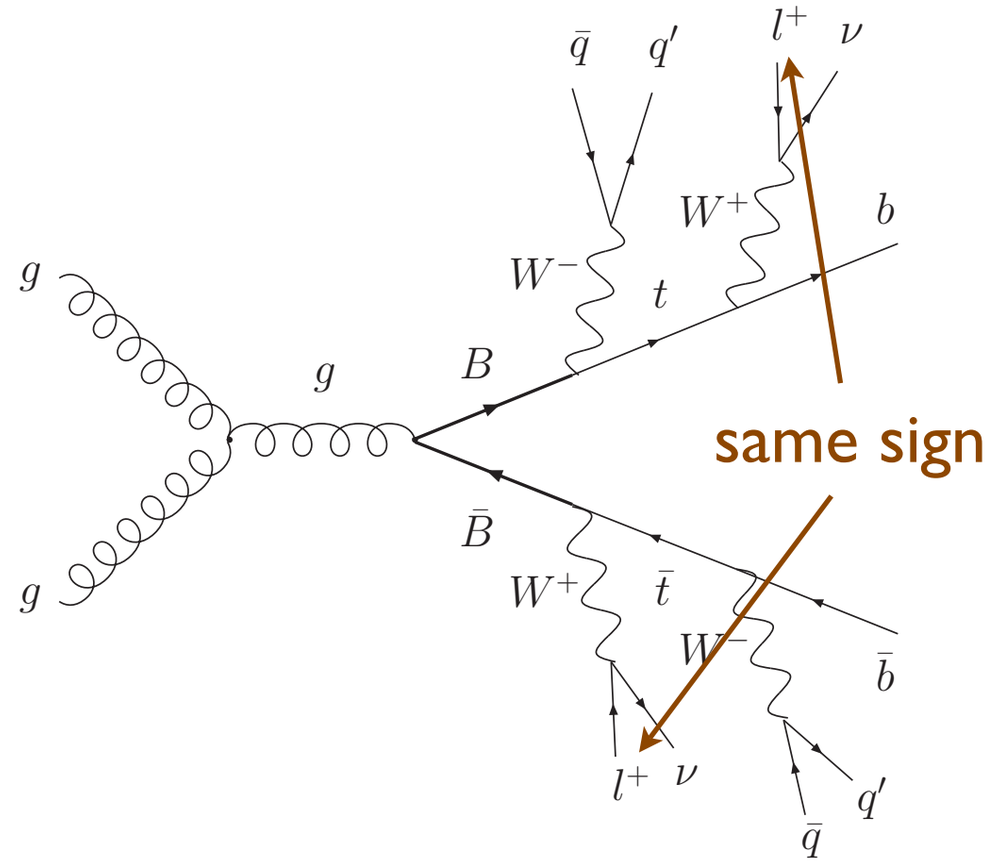
Gluino-pair production with same decay chains



High $\not{E}_T$

d-type fermion-pair production:

$$Q\bar{Q} \rightarrow (tW^{\mp})(\bar{t}W^{\pm})$$

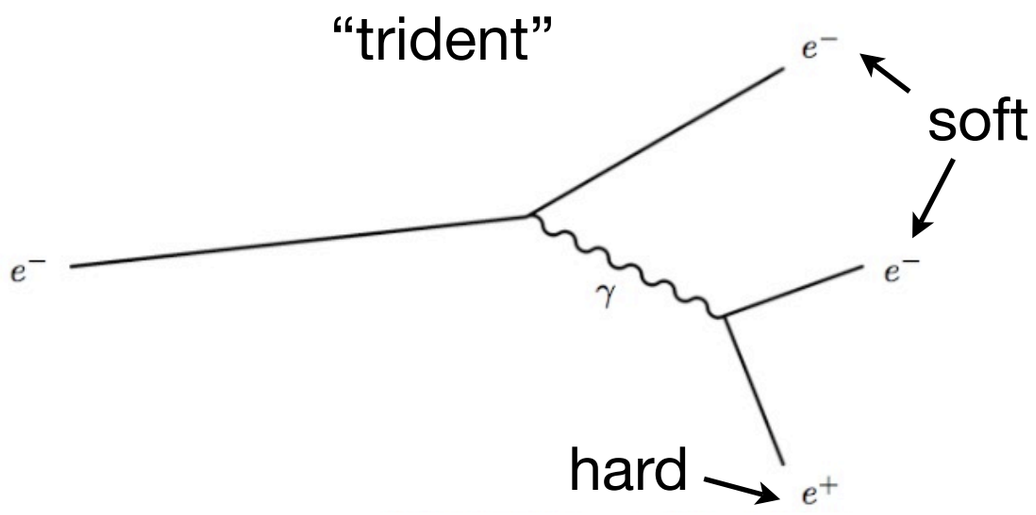


Many energetic jets

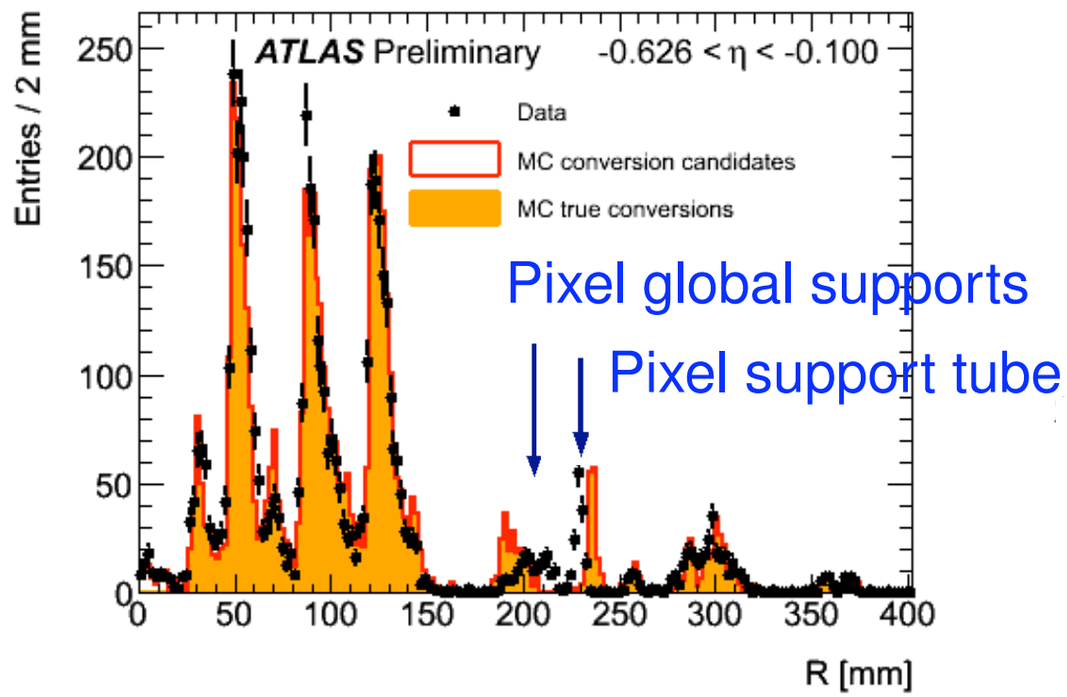
Status: material in the inner detector

Understanding the amount of material in the inner detector is crucial for reconstructing electron tracks and estimating properties of conversions.

- Estimates from material interactions agree well with expectations.
- “Charge mis-ID” for electrons mostly from highly asymmetric conversions



Material understood by photon conversions and K_S decays

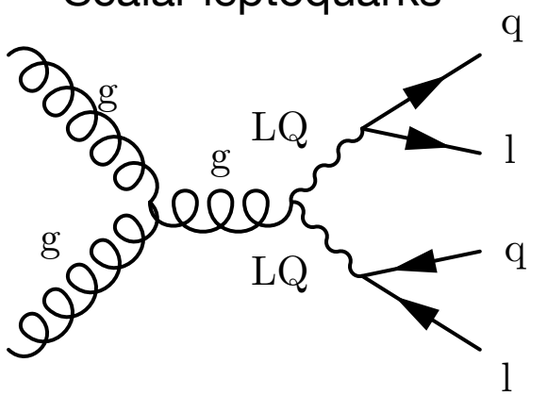


See K. Tackmann’s talk from Monday

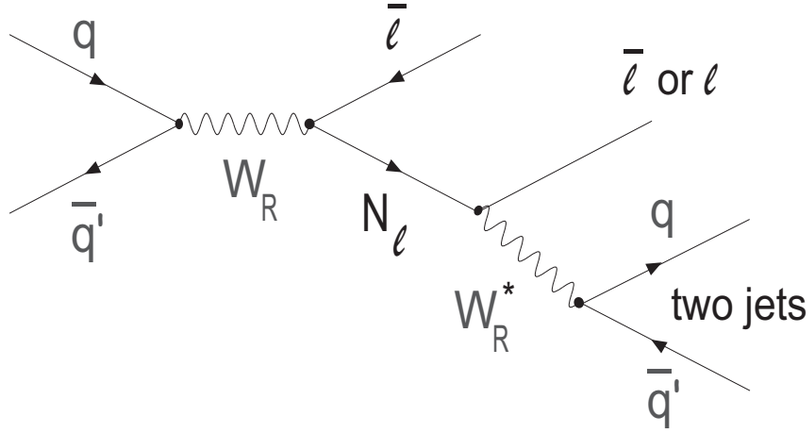
Dilepton + jets

Models predict lepton+jet resonances:

Scalar leptoquarks



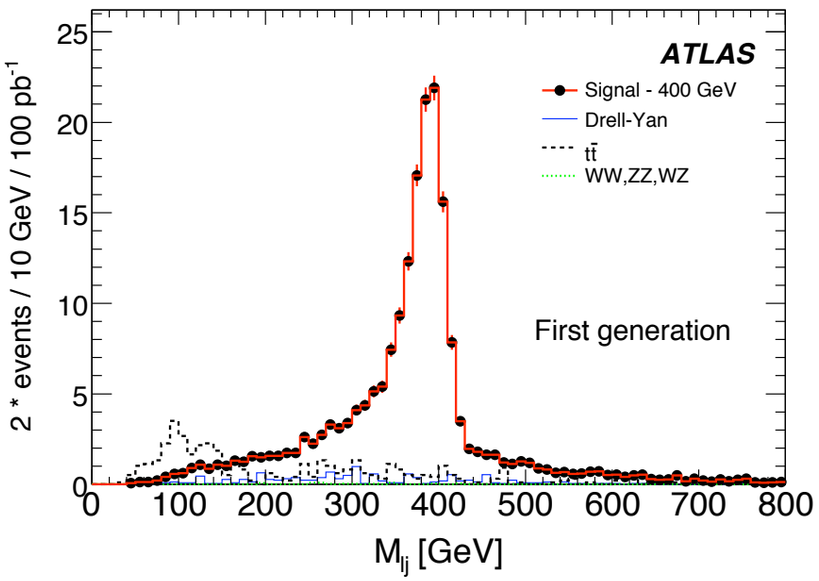
Left-right symmetric model



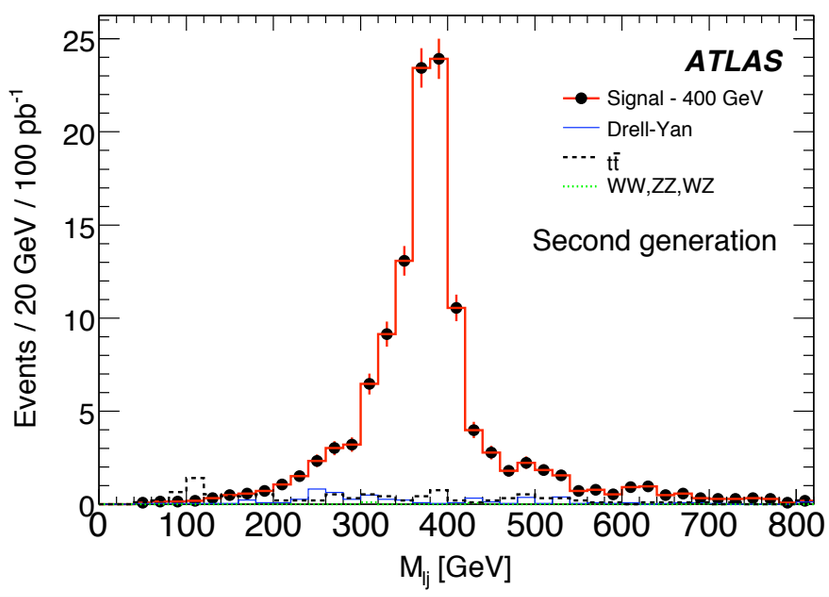
$\sigma \approx 1$ pb^{-1} at 7 TeV for $m_{LQ} \approx 350$ GeV

100 pb^{-1} @ 14 TeV c.m. energy

electron channel



muon channel



Diphoton

Search for diphoton resonances as well as diphoton events with missing energy:

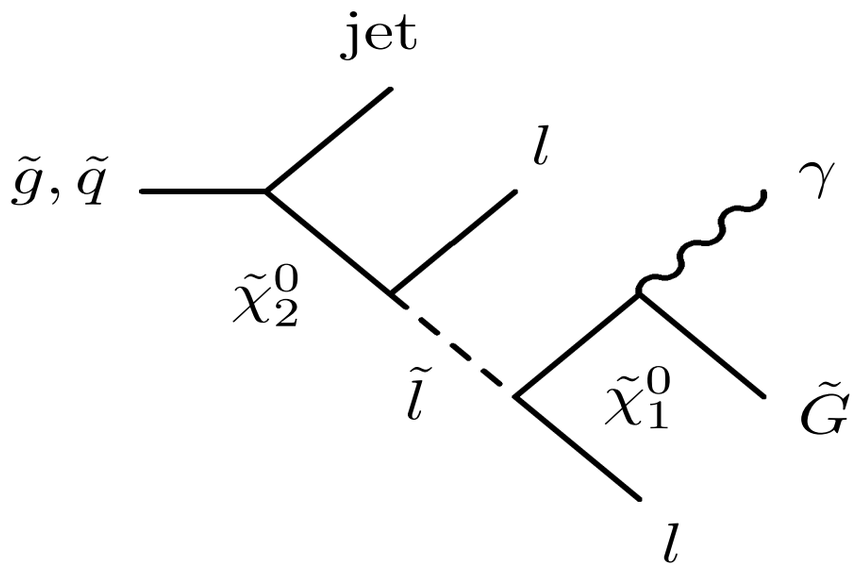
- Models with extra dimensions predict graviton decays

$$G \rightarrow \gamma\gamma$$

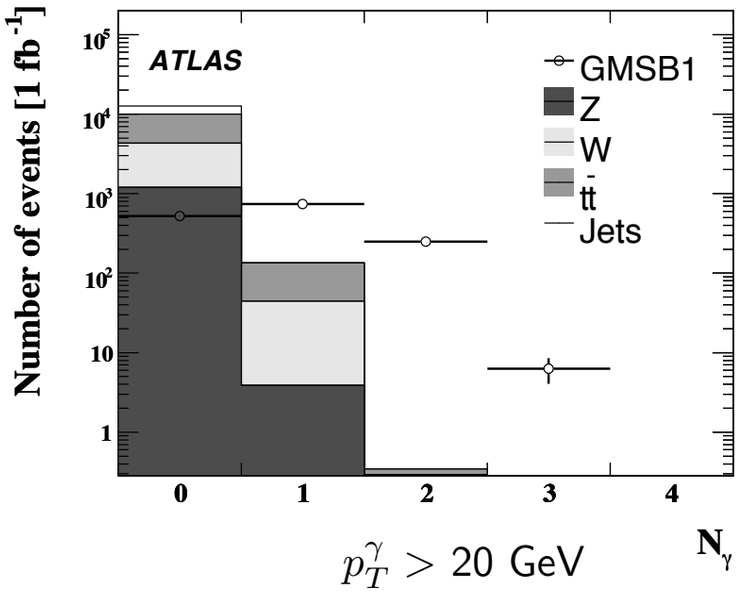
- Universal extra dimensions, with gravity mediation, or gravity-mediated SUSY, where graviton/gravitino does **not** decay

$$\gamma^*\gamma^* \rightarrow (\gamma G)(\gamma G)$$

- Backgrounds: direct diphoton production, fake photons



1 fb^{-1} @ 14 TeV c.m. energy;



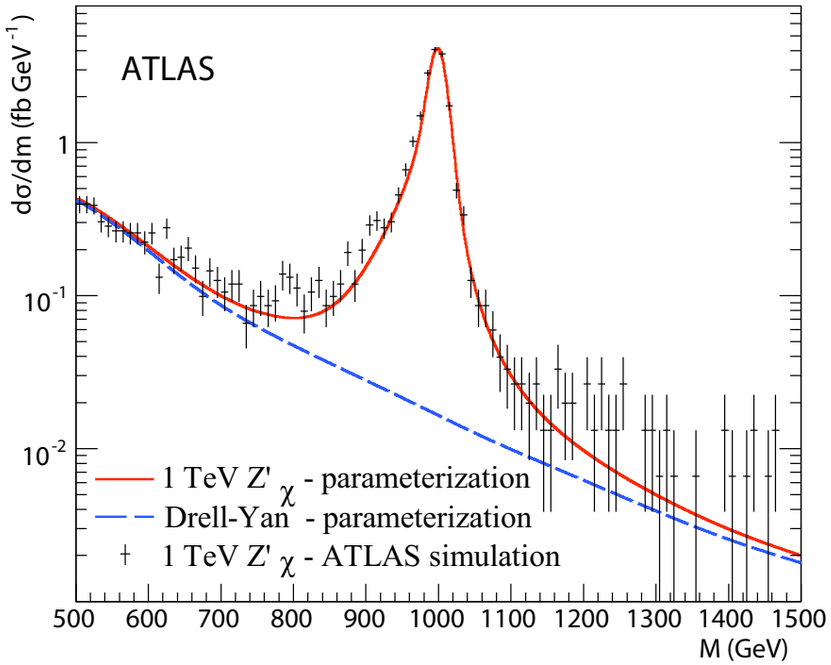
Dilepton resonance

Many models predict neutral resonances:

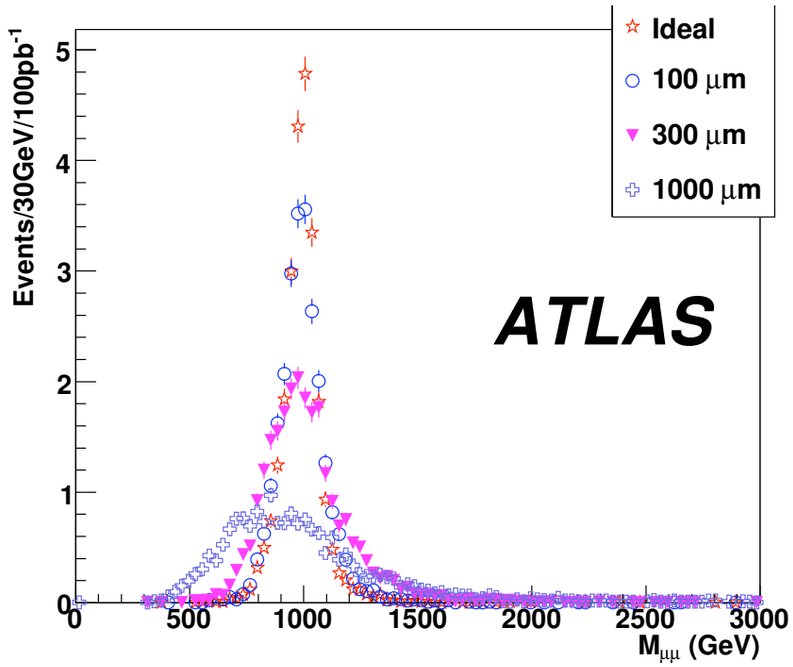
$$Z', G, \rho_T \rightarrow \ell^+\ell^-$$

- At 7 TeV, roughly 1 fb^{-1} needed for 5σ observation of *Z′* at *m* = 1.5 TeV
- Mass resolution expected to be 1% (10%) for electron (muon) channel

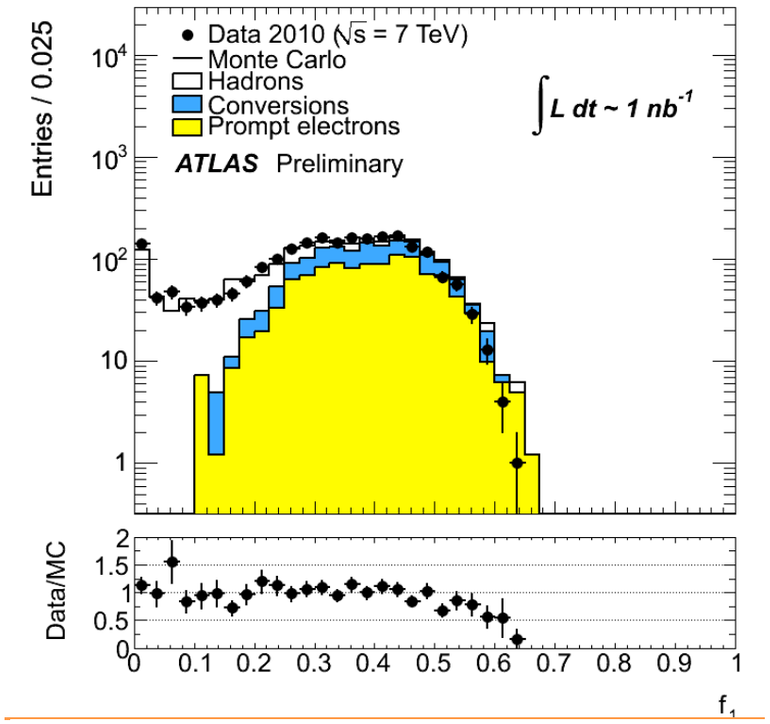
electron channel



muon signal: effect of misalignment shown

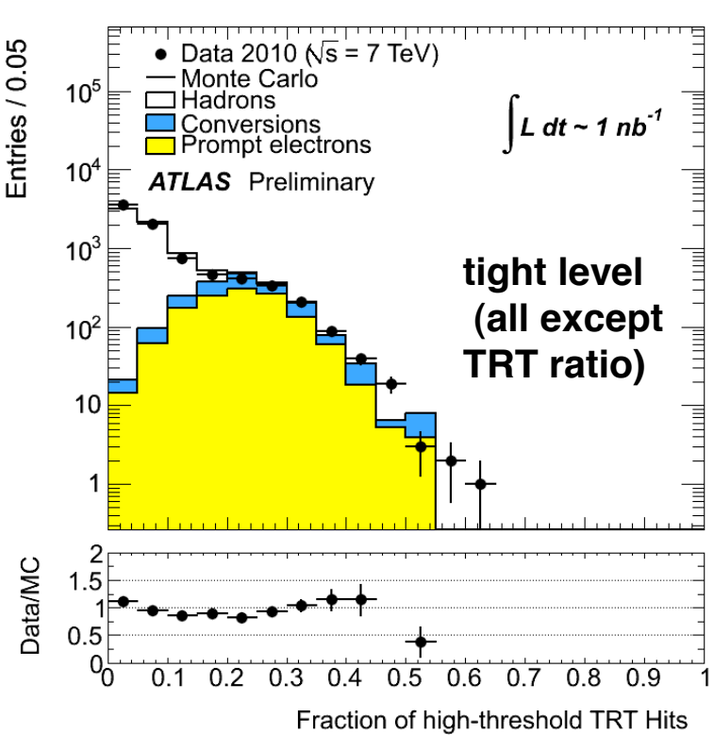


Status: electron identification



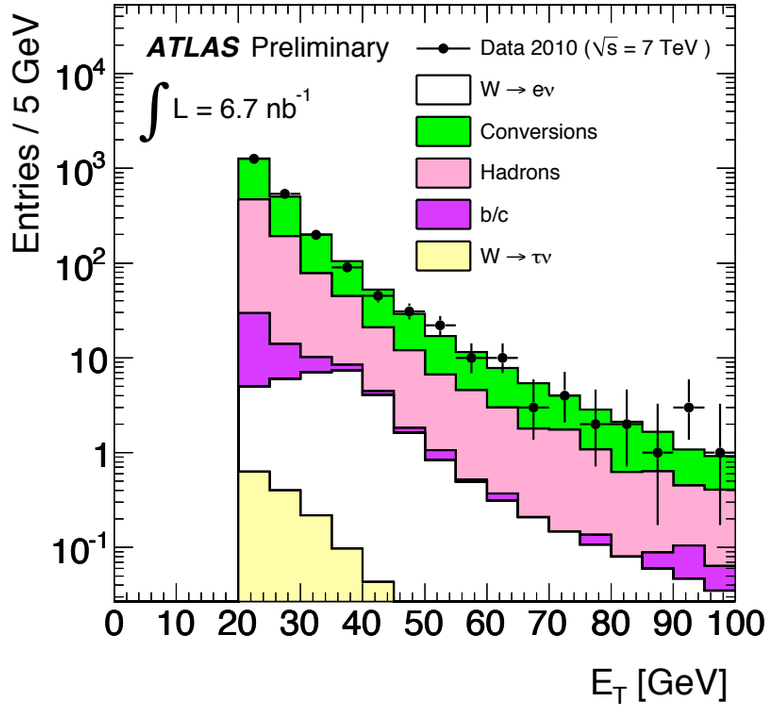
Energy fraction in first sampling

Electron identification is reasonably well understood with available statistics; awaiting data to estimate high-p_T fake rates



Fraction of high-threshold hits in TRT

cluster E_T, by category

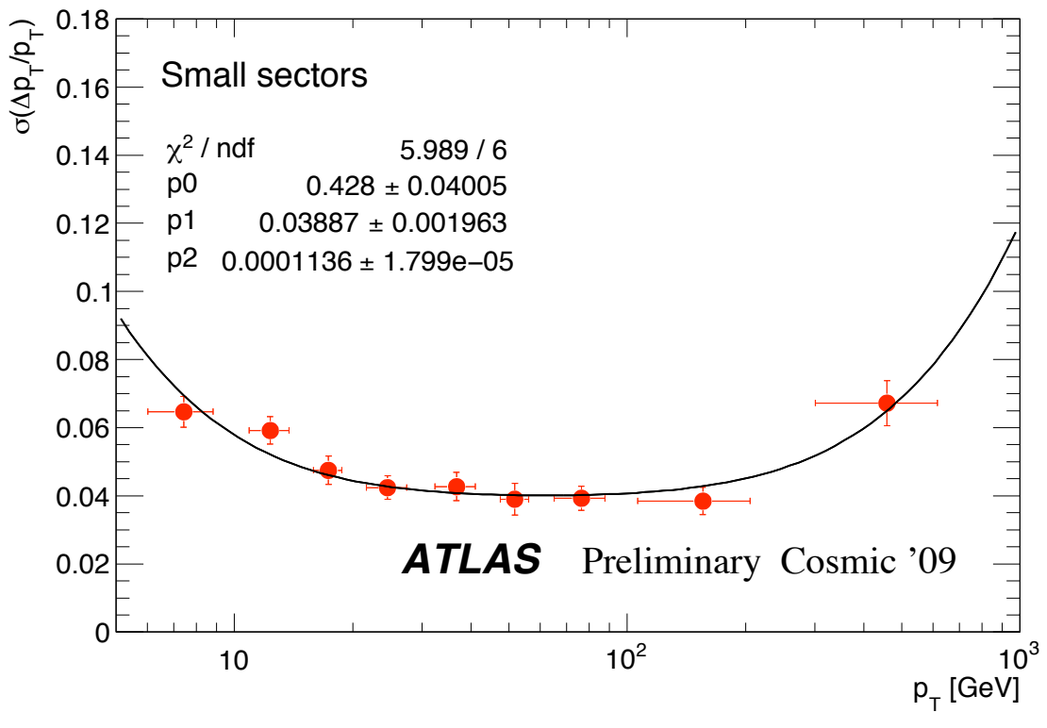


Status: Muon momentum resolution

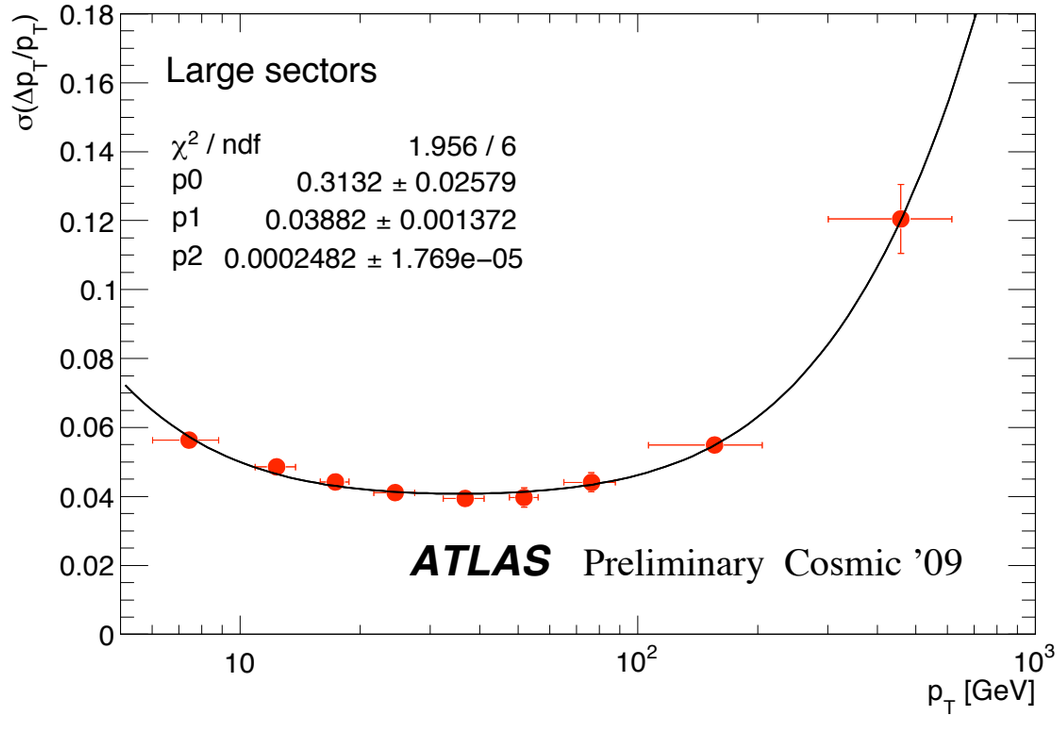
Resolution in the muon spectrometer near design for 100 GeV muons (from cosmic-ray data)

- Goal: 10% momentum resolution for muon p_T = 1 TeV
- Ready to finish calibrations as luminosity increases (need a dedicated, B-field off run)

Small Sectors



Large Sectors



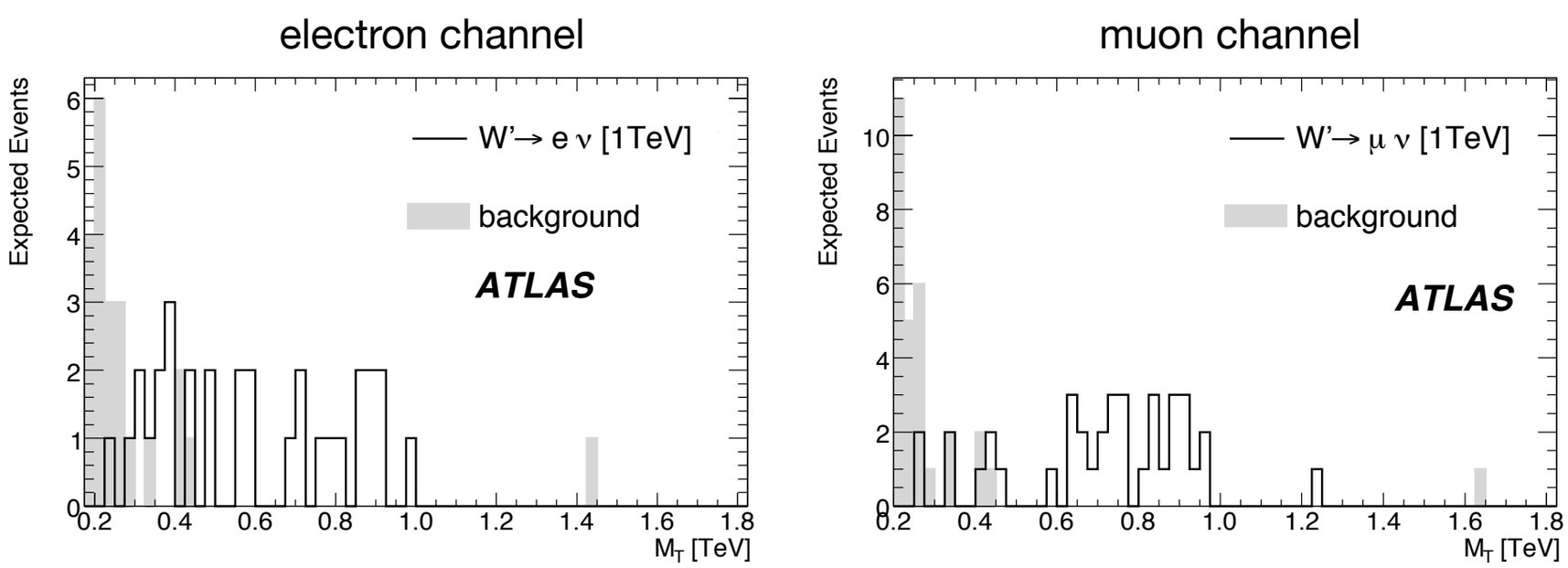
Lepton + missing energy

Many models predict a charged vector boson:

$$W' \rightarrow \ell\bar{\nu}$$

- At 7 TeV, roughly 1 fb^{-1} needed for 5σ observation of *W′* at *m* = 2 TeV
- High-energy version of current *W* observation exercise

Pseudo-experiments at 10 pb^{-1} @ 14 TeV c.m. energy



$$m_T = \sqrt{2 p_T \not{E}_T (1 - \cos\Delta\phi)}$$

Outlook

The 2010/2011 ATLAS physics run will yield new opportunities for discovery:

- 2010 (100 pb^{-1}, 7 TeV) — begin to probe strongly interacting particles with $m \approx$ 300–400 GeV
  - SUSY, UED, Leptoquarks, MCHM, 4th gen. quarks
  - **Lepton and Dilepton (opp. or same sign) with jets or missing E_T**
  - Interesting sensitivity in diphoton and lepton+missing energy
- 2011 (1 fb^{-1}, 7 TeV) — surpass Tevatron sensitivity on many fronts
  - Resonances with TeV-scale masses become visible
  - Generic SUSY models yield unexplainable excesses
  - SM 4th generation of quarks are discovered or excluded