Early searches for supersymmetry with jets and missing transverse energy with ATLAS

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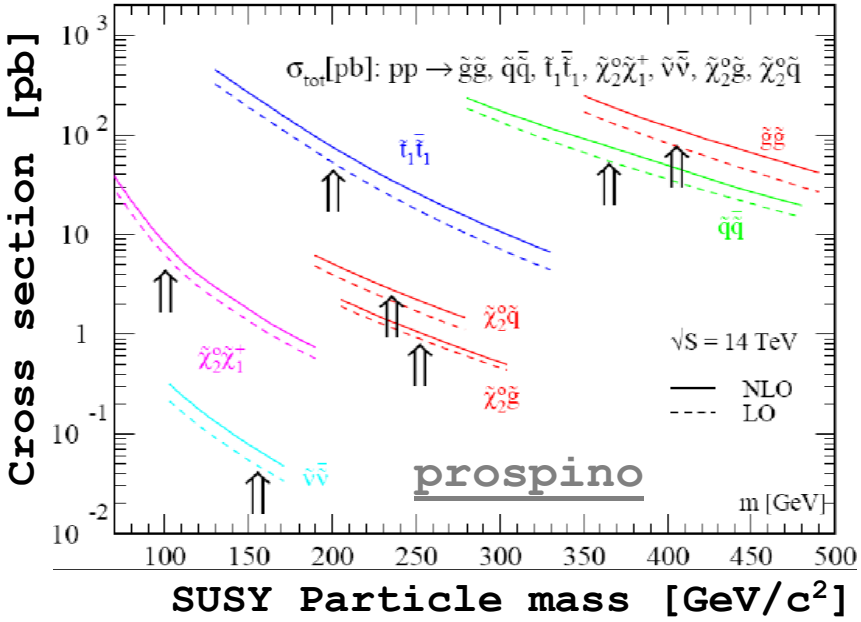
On behalf of ATLAS Collaboration

Outline

- Motivations
- MC samples
- Object selection
- Systematic uncertainties
- Event selection
- Results
- Prospects & Summary

Motivations

Production at LHC of SUSY particles dominated by squarks and gluinos.



✓ Look for an excess of events with high P_T jets and missing transverse momentum

✓ True for any model with strongly interacting particles decaying semi-invisibly

Today:

✓ 7 TeV, L=70±8 nb^{-1} !!

✓ First comparison data/MC for this topology

✓ Look at SUSY discriminating variables

Monte Carlo samples

- **QCD jet production: PYTHIA 6.4.21**
  - ✓ Normalized to data in 2-jets channel (Pt(jet1)>70 GeV, Pt(jet2)>30 GeV, prior to Missing E_T cut)
  - ✓ QCD scaling factor = 0.61
  - ✓ Compared to ALPGEN (2->5 Matrix elements)
- **W/Z+jets: ALPGEN + HERWIG + JIMMY**
  - ✓ Normalized to integrated luminosity
  - ✓ Overall W inclusive cross-section taken from NNLO
- **Top: MCAtNLO + HERWIG + JIMMY**
  - ✓ Normalized to integrated luminosity
  - ✓ Overall cross-section taken from approximate NNLO
- **Supersymmetry: SU4 (m_0=200 GeV, $m_{1/2}$=160 GeV, A_0=-400 GeV, tan(β)=10, μ>0), HERWIG++ 2.4.2**
  - ✓ Normalized to integrated luminosity
  - ✓ Overall cross-section taken from NLO (prospino)
  - ✓ x10 in all the following plots

Object selection

- **Jets**
  - Algorithm: Anti-Kt R=0.4, topological clusters as inputs
  - P_T>20 GeV, |η|<2.5
- **Electrons (used to veto events)**
  - P_T>10 GeV, |η|<2.47, excluding 1.37<|η|<1.52
  - identification with "medium"-purity cuts
  - Calorimeter isolation E_T(cone,ΔR<0.2)<10 GeV
- **Muons (used to veto events)**
  - Algorithm combining inner detector and muon spectrometer tracks
  - P_T>10 GeV, |η|<2.5
  - Calorimeter isolation E_T(cone,ΔR<0.2)<10 GeV
- **Missing transverse energy**:
  - Cells belonging to topological clusters at electromagnetic-scale
  - $E_T^{miss} = \sqrt{(E_x^{miss})^2 + (E_y^{miss})^2}$
- **Overlap removal**:
  - ΔR(jet,electron) < 0.2 => reject jet
  - 0.2 < ΔR(jet,electron) < 0.4 => veto electron
  - ΔR(jet,muon) < 0.4 => veto muon

Event cleaning cuts

Expect a small fraction of fake jets coming from:

- Calorimeter noise
- Non-collision backgrounds: cosmic rays, beam halo muons

=> Reject any event with a jet satisfying:

1. Noise bursts in hadronic endcap calorimeter (HEC):
   - ✓ n90≤5 AND HECf>0.8
   - ✓ HECf≥1-|jetQuality|
2. Electromagnetic calorimeter (EM) noise:
   - ✓ |jetQuality|>0.8 AND EMf>0.95
3. Out-of-time jets (from e.g. cosmics)
   - ✓ |time|>50 ns
4. Cosmic ray or beam-halo muons energy deposits for monojet channel
   - ✓ n90≤5 AND EMf<0.05

- n90 = number of cells containing 90% of the energy
- HEFf (EMf) = fraction of energy in hadronic endcap (electromagnetic) calorimeters
- jetQuality = how good calorimeter pulse shape is

Main systematic uncertainties

- **Jet energy scale uncertainty**
  - Dominant uncertainty for this study
  - ~10% is $20<p_T<50$ GeV, ~7% higher values
  - Propagated to Missing transverse momenta
  - Resulting uncertainty on N_{events}:
    - ~25% for 1 and ≥2 jets,
    - ~40% for ≥3 jets,
    - ~50% for ≥4 jets.
  - Conservative estimate as of summer 2010. Will improve with more data.

- **Uncertainty on the integrated luminosity**
  - 11% uncertainty propagated to W,Z,top MC samples
  - Not applied to QCD dijets since data-driven

- **Other systematic uncertainties are smaller**

Event selection

Preselection:

1. Calorimeter jet trigger of the first trigger level
2. Jet event cleaning
3. ≥1 primary vertex with N(Tracks)>4
4. Reject events with an electron in crack region
5. Reject events with ≥1 isolated electron or muon

Final selection based on event topology:

N(Jets)	Monojets	≥ 2 jets	≥ 3 jets	≥ 4 jets
Leading jet P_T (GeV)	> 70	> 70	> 70	> 70
Subsequent jet P_T (GeV)	Veto if > 30	> 30	> 30 (jets 2 and 3)	> 30 (jets 2 to 4)
E_T^{miss} (GeV)	> 40	> 40	> 40	> 40
$\|\Delta\varphi(jet, E_T^{miss})\|$	No cut	[>0.2,>0.2]	[>0.2,>0.2,>0.2]	[>0.2,>0.2,>0.2,>0]
$E_T^{miss} > f * M_{eff}$	No cut	f=0.3	f=0.25	f=0.2
Physics	Split SUSY, VB+jets	Squark production, QCD dominant	Standard SUSY seaches, Dominated by top,W,Z	

Reminder: Effective mass = $M_{eff} = E_T^{miss} + \Sigma\, p_T(jet)$

Cut flow

Reminder: L=70±8 nb^{-1}

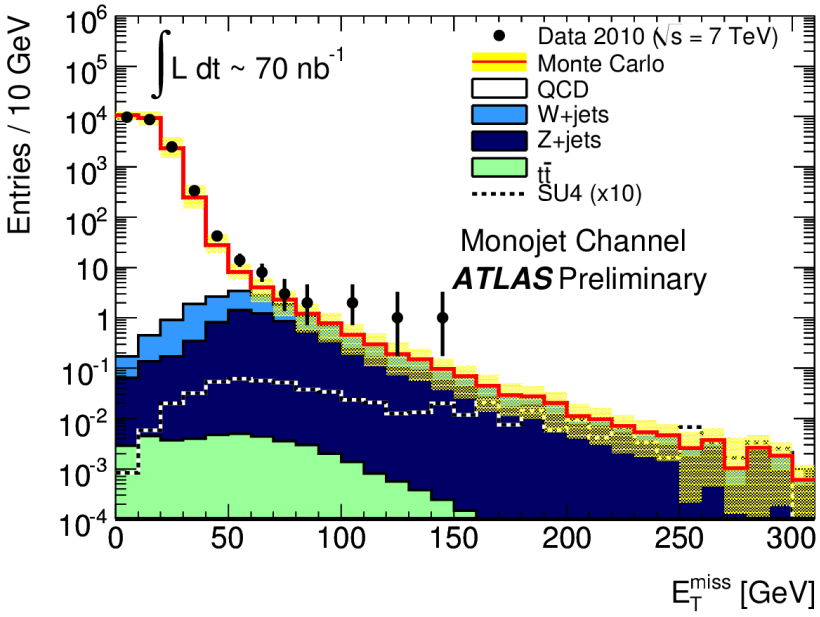
	Monojet		≥ 2 jets		≥ 3 jets		≥ 4 jets	
	Data	Monte Carlo	Data	Monte Carlo	Data	Monte Carlo	Data	Monte Carlo
After jet cuts	21 227	$23\,000^{+7000}_{-6000}$	108 239	$108\,000^{+31\,000}_{-25\,000}$	28 697	$31\,000^{+10000}_{-8000}$	5329	5600^{+2300}_{-1600}
$\cap$ E_T^{miss} cut	73	46^{+22}_{-14}	650	450^{+190}_{-120}	325	230^{+100}_{-70}	116	84^{+45}_{-30}
$\cap$ $\Delta\phi$ and E_T^{miss} cuts	–	–	280	200^{+110}_{-65}	136	100^{+55}_{-30}	54	43^{+26}_{-16}
$\cap$ E_T^{miss}/M_{eff}, $\Delta\phi$ and E_T^{miss} cuts	–	–	4	6.6 ± 3	0	1.9 ± 0.9	1	1.0 ± 0.6

✓ **E_T^{miss} > 40 GeV**

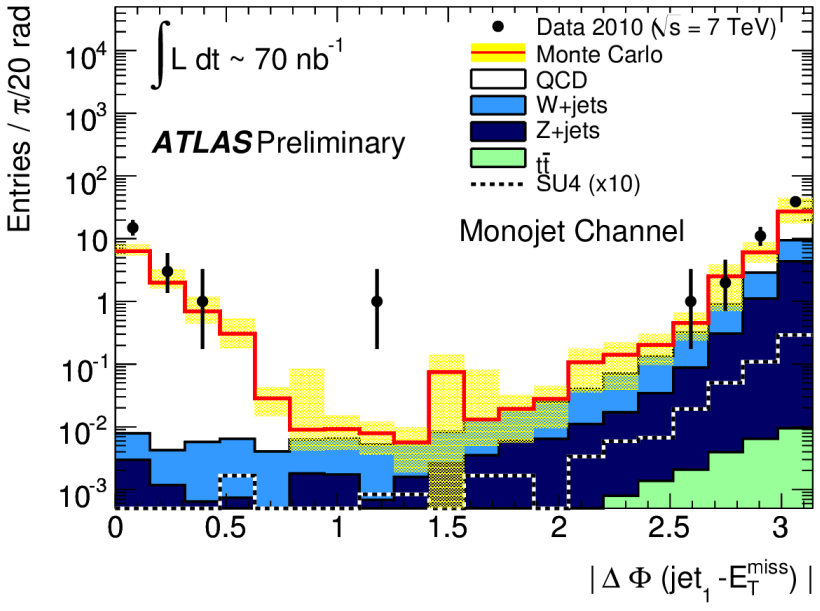
✓ **Overall very good agreement between data and MC**

Monojet channel

✓ jet P_T > 70 GeV



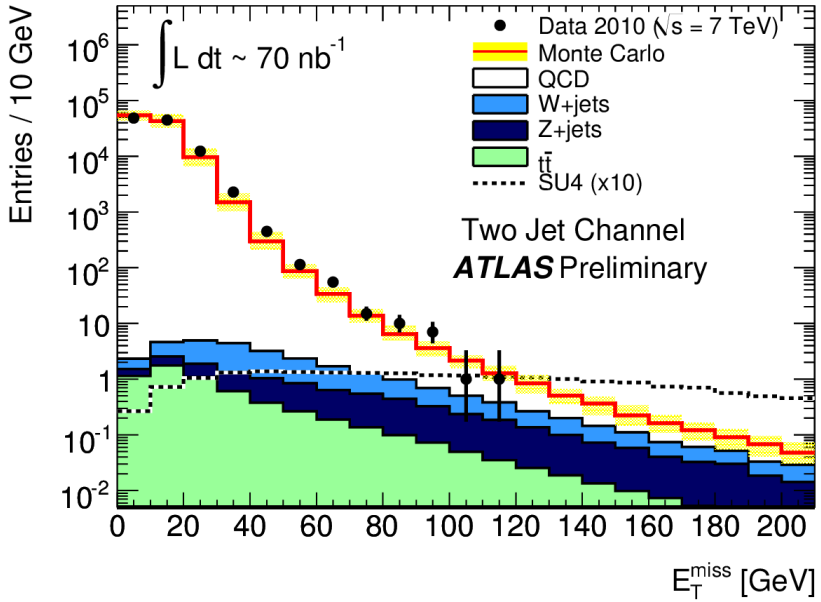
✓ jet P_T > 70 GeV
✓ E_T^{miss} > 40 GeV

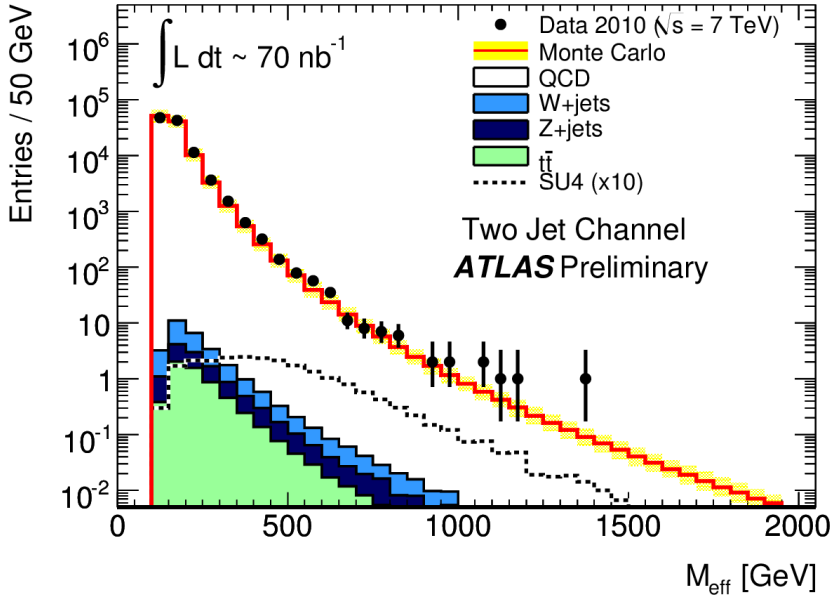


- After applying cosmics and beam halo cuts, good agreement seen
- Soon sensitive to Vector Boson(Zνν/Wτν) + Jets !

Dijet channel – QCD control sample region

Reminder: MC QCD normalized to data before E_T^{miss} cut





✓ **jet P_T > [70,30] GeV**

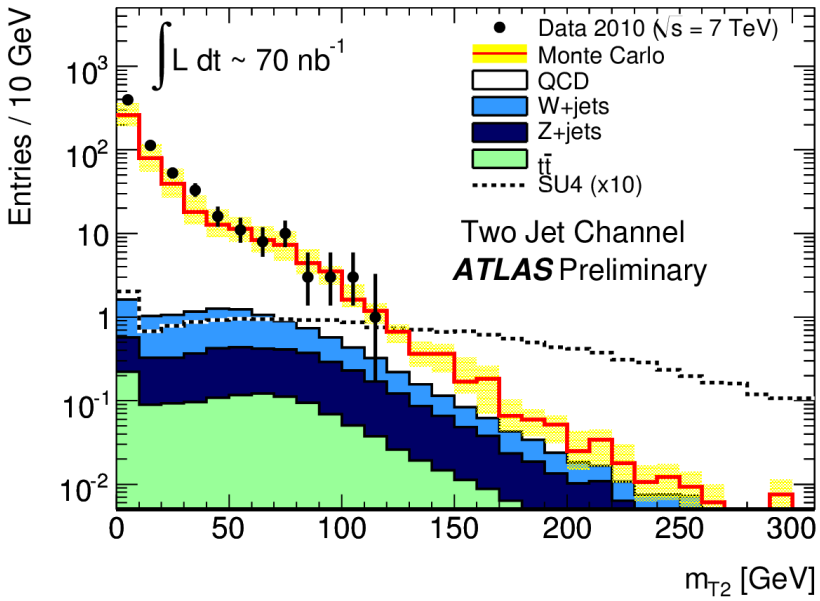
✓ **jet P_T > [70,30] GeV**

✓ E_T^{miss} shape currently described by MC given our current systematics

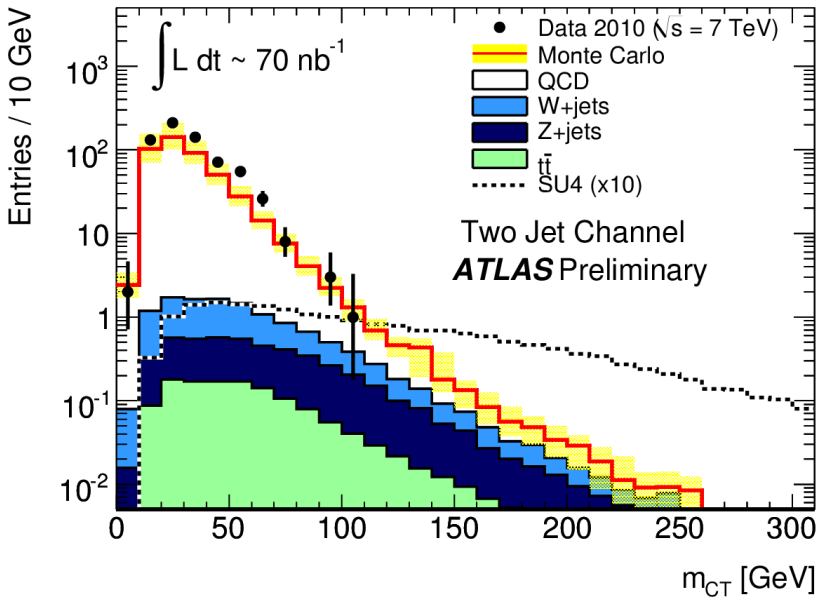
✓ More work needed

Dijet channel – SUSY mass variables

- m_{T2} = generalization of the transverse mass to pair decays
- m_{CT} = variable for pair of identical parents decaying semi-invisibly
- See backup slides for exact formula



✓ jet P_T > [70,30] GeV
✓ E_T^{miss} > 40 GeV

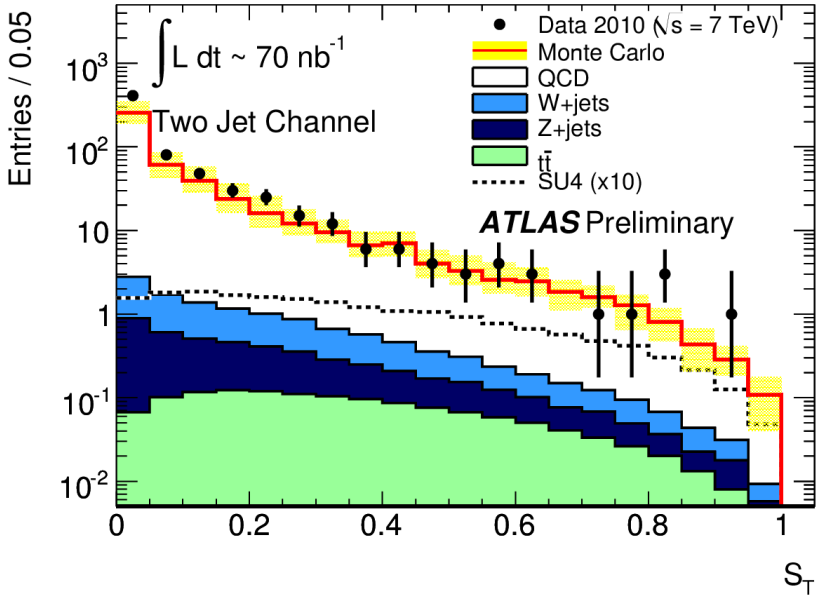


✓ jet P_T > [70,30] GeV
✓ E_T^{miss} > 40 GeV

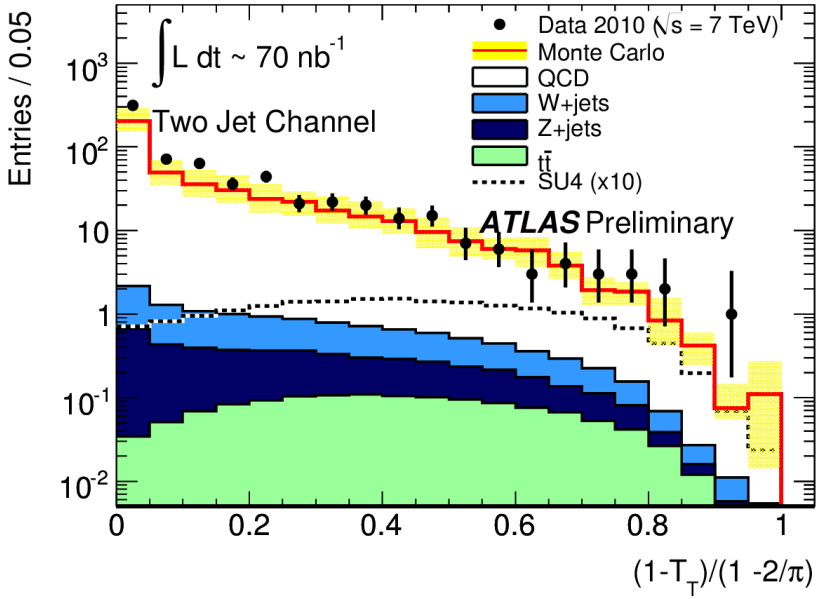
Dijet channel – Event shape variables

- QCD, VB+jets : expect back-to-back topology
- SUSY : expect uniform events

=> Look at event shape variables transverse sphericity (S_T) and transverse thrust (T_T)

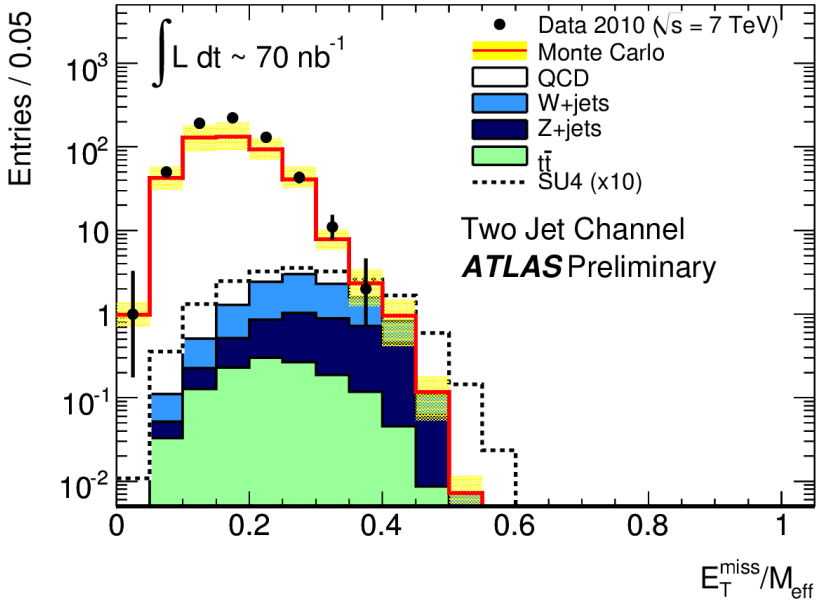


✓ jet P_T > [70,30] GeV
✓ E_T^{miss} > 40 GeV

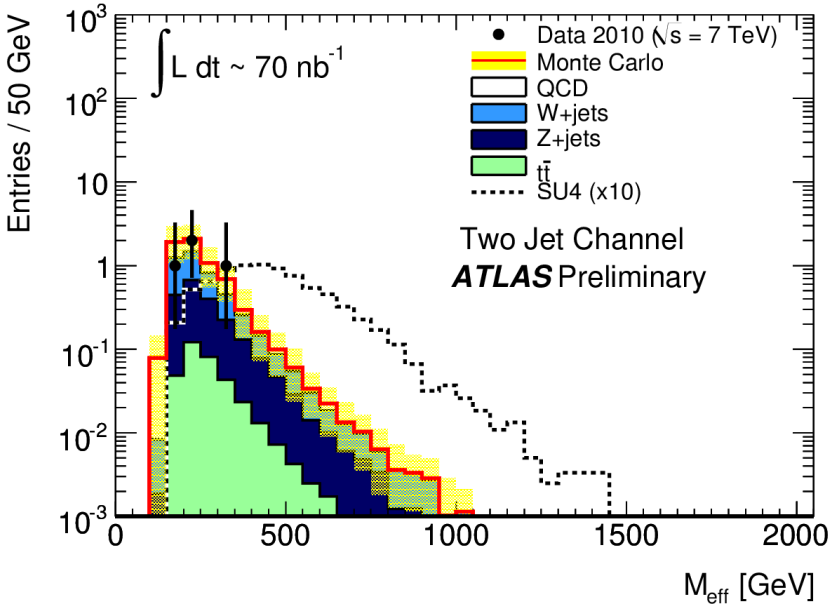


✓ jet P_T > [70,30] GeV
✓ E_T^{miss} > 40 GeV

Dijet channel - Effective mass after SUSY cuts



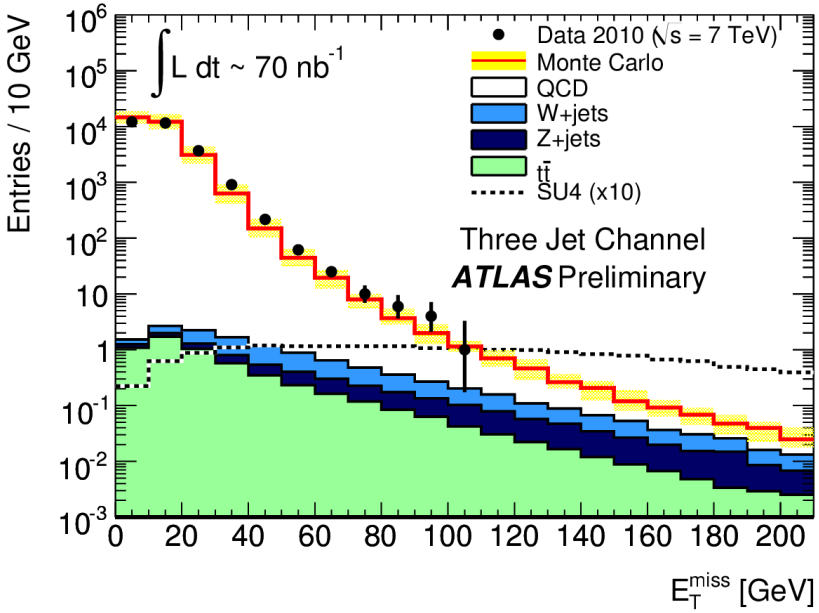
✓ **jet P_T > [70,30] GeV**
✓ **E_T^{miss} > 40 GeV**

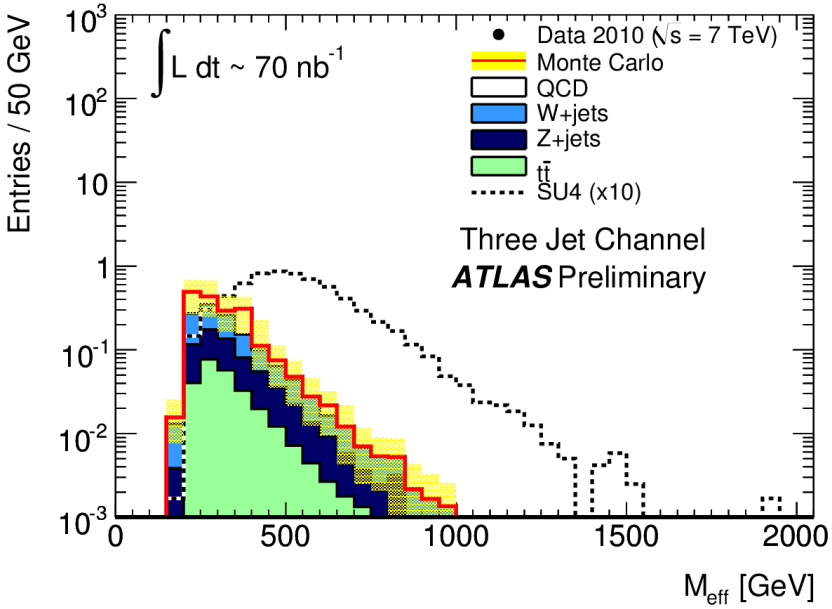


✓ **jet P_T > [70,30] GeV**
✓ **E_T^{miss} > 40 GeV**
✓ **$\Delta\varphi(\text{jet},E_T^{miss})$ > [0.2,0.2]**
✓ **E_T^{miss}/M_{eff} cut > 0.3**

- ~ 6.6 events expected, 4 events observed !
- QCD jet production reduced by $\Delta\varphi$ and E_T^{miss}/M_{eff} cuts

Three jet channel



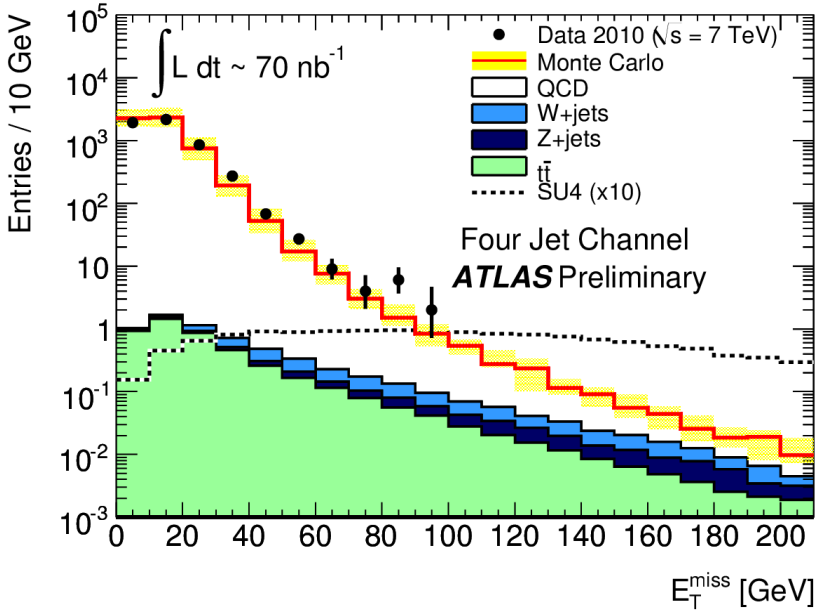


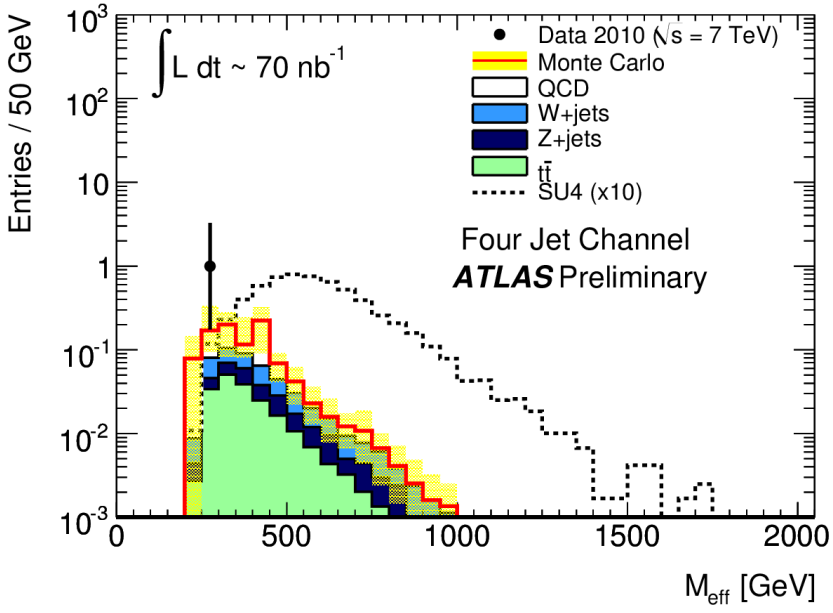
Before susy cuts:
- ✓ **jet P_T > [70,30,30] GeV**

After susy cuts:
- ✓ **jet P_T > [70,30,30] GeV**
- ✓ **E_T^{miss} > 40 GeV**
- ✓ **$\Delta\varphi$(jet,E_T^{miss}) > [0.2,0.2,0.2]**
- ✓ **E_T^{miss}/M_{eff} cut > 0.25**

~ 1.9 events expected, 0 event observed !

Four jet channel





Before susy cuts:
- ✓ **jet P_T > [70,30,30,30] GeV**

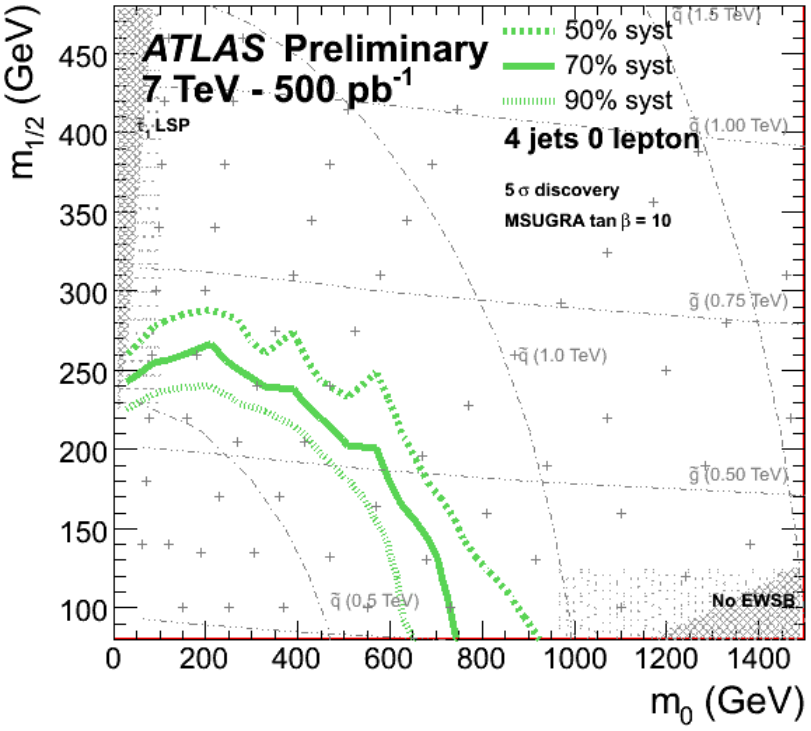
After susy cuts:
- ✓ **jet P_T > [70,30,30,30] GeV**
- ✓ **E_T^{miss} > 40 GeV**
- ✓ **$\Delta\varphi$(jet,E_T^{miss}) > [0.2,0.2,0.2]**
- ✓ **E_T^{miss}/M_{eff} cut > 0.2**

~ 1.0 events expected, 1 event observed !

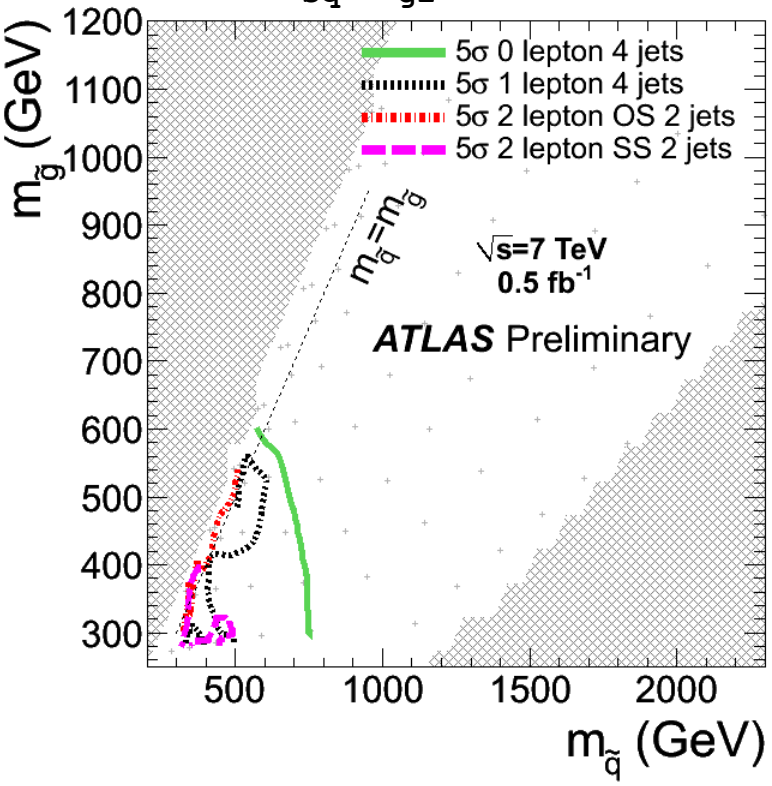
Prospects

- ✓ jet P_T > [100,40,40,40] GeV
- ✓ E_T^{miss} > 80 GeV
- ✓ $\Delta\varphi$(jet,E_T^{miss}) > [0.2,0.2,0.2]
- ✓ E_T^{miss}/M_{eff} cut > 0.2

$(m_0, m_{1/2})$ plane



(m_{sq}, m_{gl}) plane



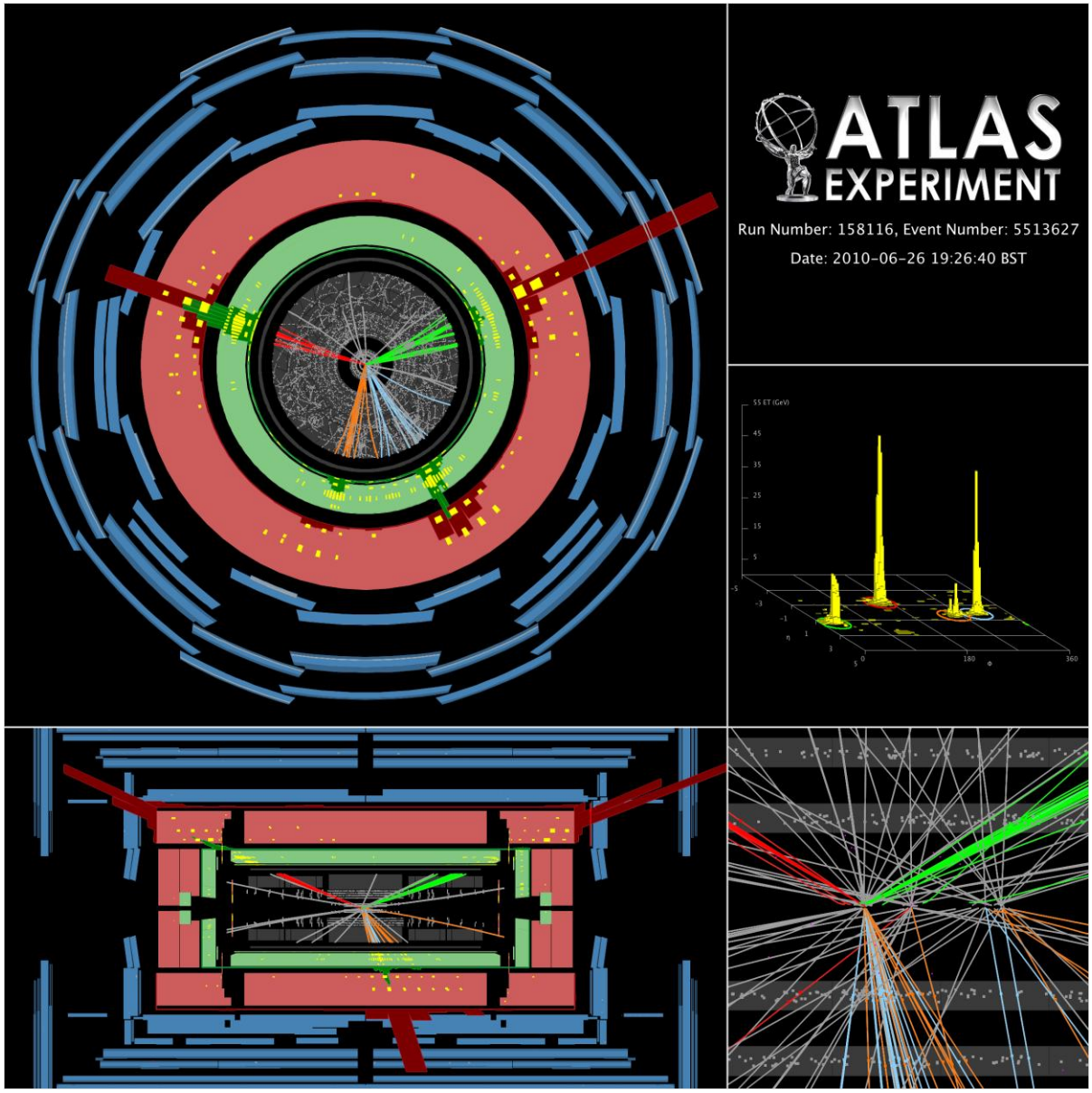
With 500 pb^{-1}:

- ✓ could exclude up to m_{squark} ~ 700 GeV, m_{gluino} ~ 600 GeV
- ✓ improve limits of Tevatron(m_{gluino}>390 GeV) on mSUGRA

Summary

- Performed analysis of first 70 nb^{-1} of integrated luminosity
- First look within ATLAS at events with jets and missing transverse momentum
- No significant deviations from the SM predictions observed so far
- Now concentrating on data/MC comparison, but with higher statistics, data-driven background estimations will become possible/necessary to reduce dependence on MC
- LHC collider and ATLAS detector are performing very well. Expect very soon to already improve existing exclusion limits !

MANY THANKS TO SUSY10 ORGANIZERS !!!!



- Run 158116
- Evt 5513627
- M_{eff}=1.5 TeV
- E_T^{miss}=100 GeV
- discarded

from 3jets search by $\Delta\varphi(j, E_T^{miss})$ cut

BACKUP

Event shape variables

- **Effective mass**

$$M_{\mathrm{Eff}} \equiv \sum_{i=1}^{n} |\mathbf{p}_T^{(i)}| + E_{\mathrm{T}}^{\mathrm{miss}}$$

- **Stransverse mass**

$$m_{T2}\left(j^{(1)}, j^{(2)}, \not{\mathbf{p}}_T\right) \equiv \min_{\not{\mathbf{q}}_T^{(1)} + \not{\mathbf{q}}_T^{(2)} = \vec{E}_{\mathrm{T}}^{\mathrm{miss}}} \left\{ \max\left(m_T\left(j^{(1)}, \not{\mathbf{q}}_T^{(1)}\right), m_T\left(j^{(2)}, \not{\mathbf{q}}_T^{(2)}\right)\right)\right\}$$

$$m_T^2\left(j^{(i)}, \not{\mathbf{q}}_T^{(i)}\right) \equiv 2E_T^{(i)}|\not{\mathbf{q}}_T^{(i)}| - 2\mathbf{p}_T^{(i)} \cdot \not{\mathbf{q}}_T^{(i)}$$

- **Contransverse mass**

$$m_{CT}^2\left(j^{(1)}, j^{(2)}\right) \equiv 2E_T^{(1)}E_T^{(2)} + 2\mathbf{p}_T^{(1)} \cdot \mathbf{p}_T^{(2)}$$

Event shape variables

- **Transverse thrust**

$$T_T = \frac{\max(\sum_i |p_i \cdot n|)}{(\sum_i |p_i|)}$$

- **Transverse sphericity. λ_i=eigenvalues of S_{ij}**

$$S_T \equiv \frac{2\lambda_2}{(\lambda_1 + \lambda_2)} \qquad S_{ij} = \sum_k p_{ki} p^{kj}$$