Searches for New Physics in ATLAS

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on Behalf of the ATLAS Collaboration

Aspen, January 20, 2010

- Supersymmetry
  - "Classic" searches: sensitivity at 10 TeV
  - Gauge mediated SUSY signatures with τ's
- String balls
- High-p_T hadronic decays
  - Tops
  - R-parity violating SUSY

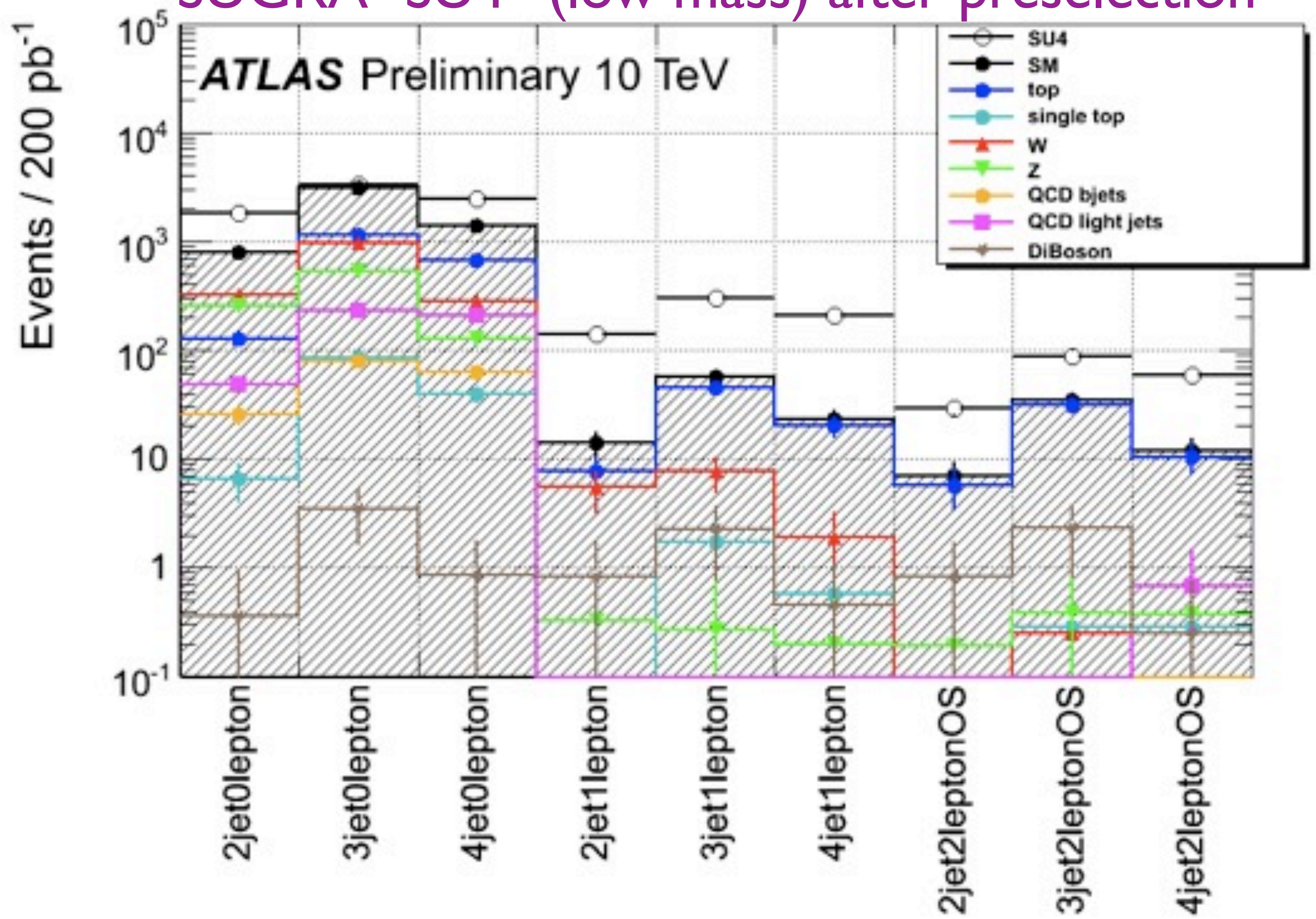
“Classic” SUSY Searches

- Main production mode: squarks and gluinos
- Decay chains lead to
  - Hard jets
  - MET (R-parity assumed to be conserved)
  - Leptons (maybe)
- SUGRA or pMSSM

pMSSM = MSSM
+ no new CP-violation
+ minimal flavor violation
+ first 2 sfermion generations degenerate

⇒ 19 parameters left
(**JHEP 0902:023,2009**)

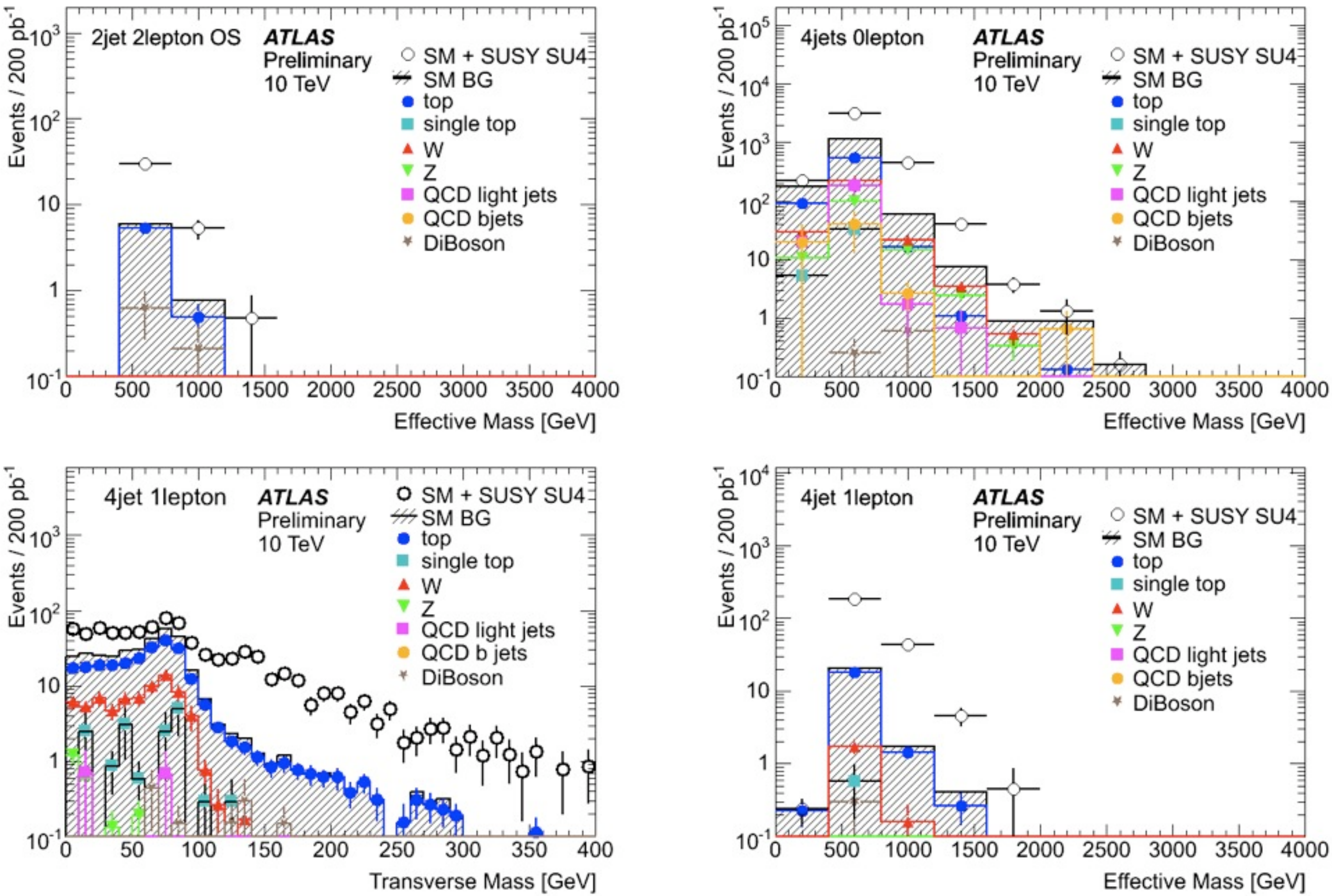
SUGRA “SU4” (low mass) after preselection



Inclusive Search

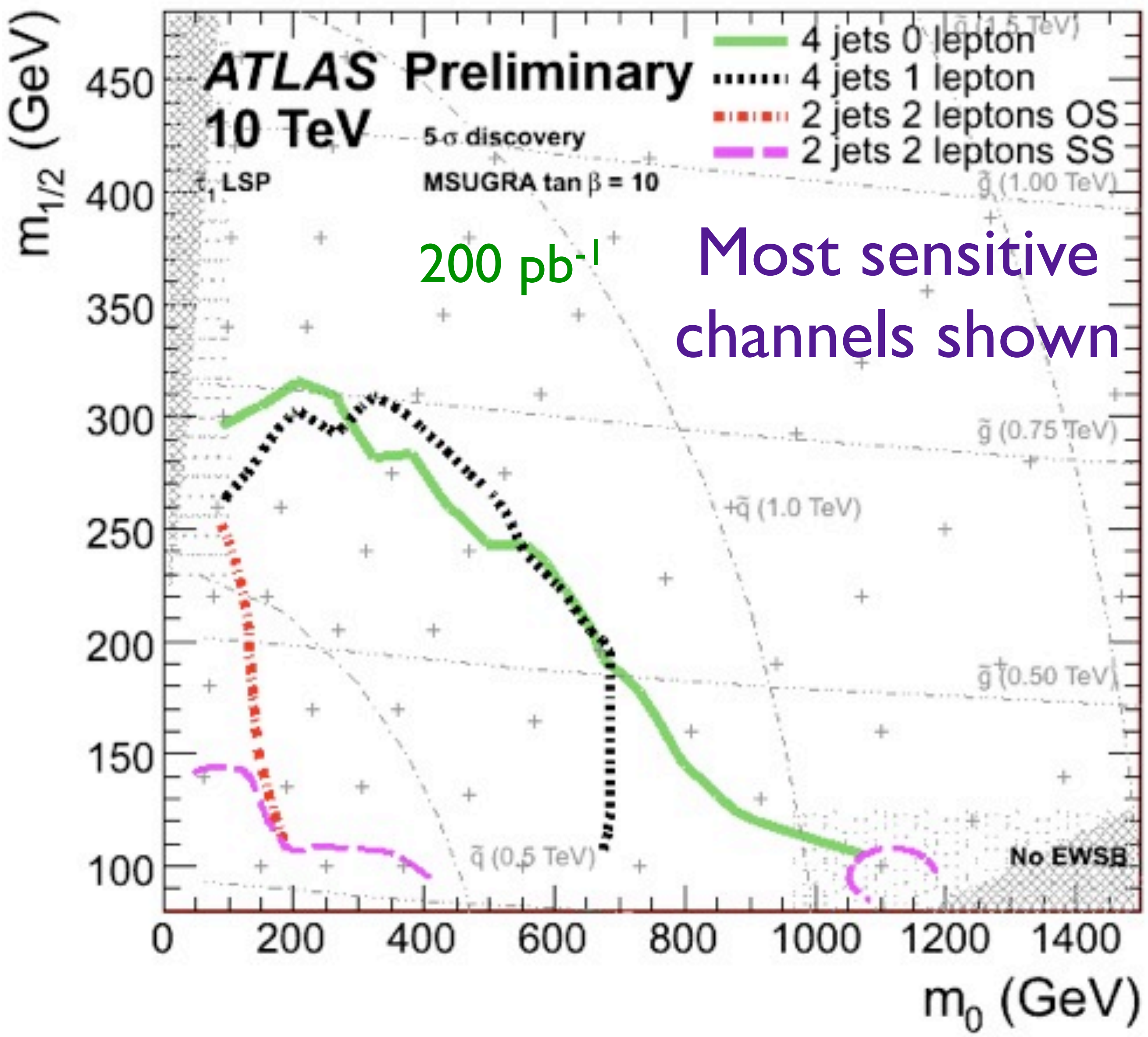
- Classify events according to #jets & #leptons
- Selections:
  - Leading jet $p_T > 100$ GeV (180 GeV if 2 jets)
  - Other jets $p_T > 40$ GeV (50 GeV if 2 jets)
  - MET > 80 GeV; if no leptons: MET > 0.3/0.25/0.2 x M_{eff} (for 2/3/4+ jets)
    - $M_{eff} = \Sigma$ (jet,lepton p_T's) + MET
  - Cuts on $\Delta\phi$(jets, MET) & transverse sphericity
- Use a cut on M_{eff} distribution to set limits
  - + M_T cut in the single lepton channel

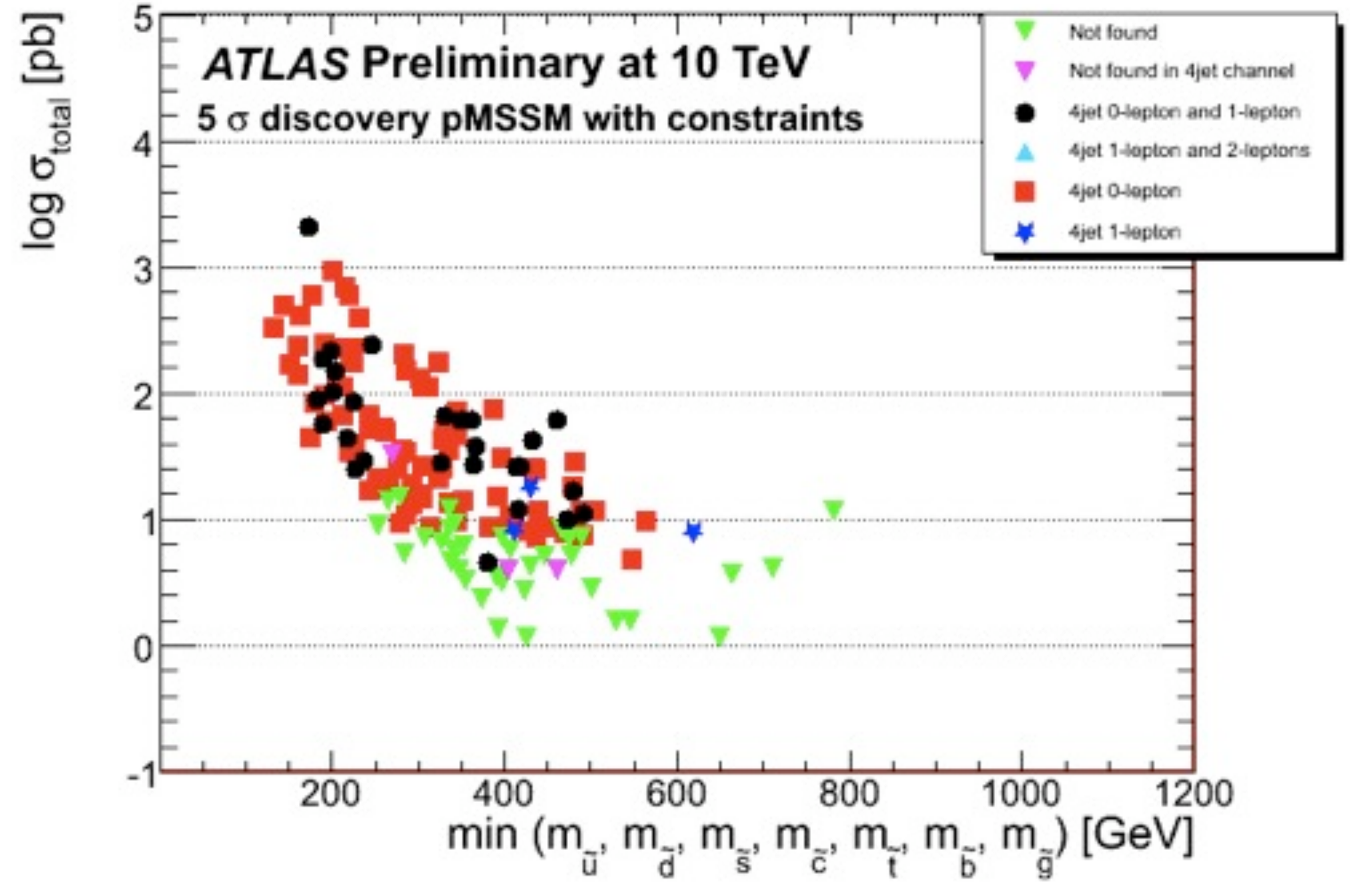
• Sample distributions

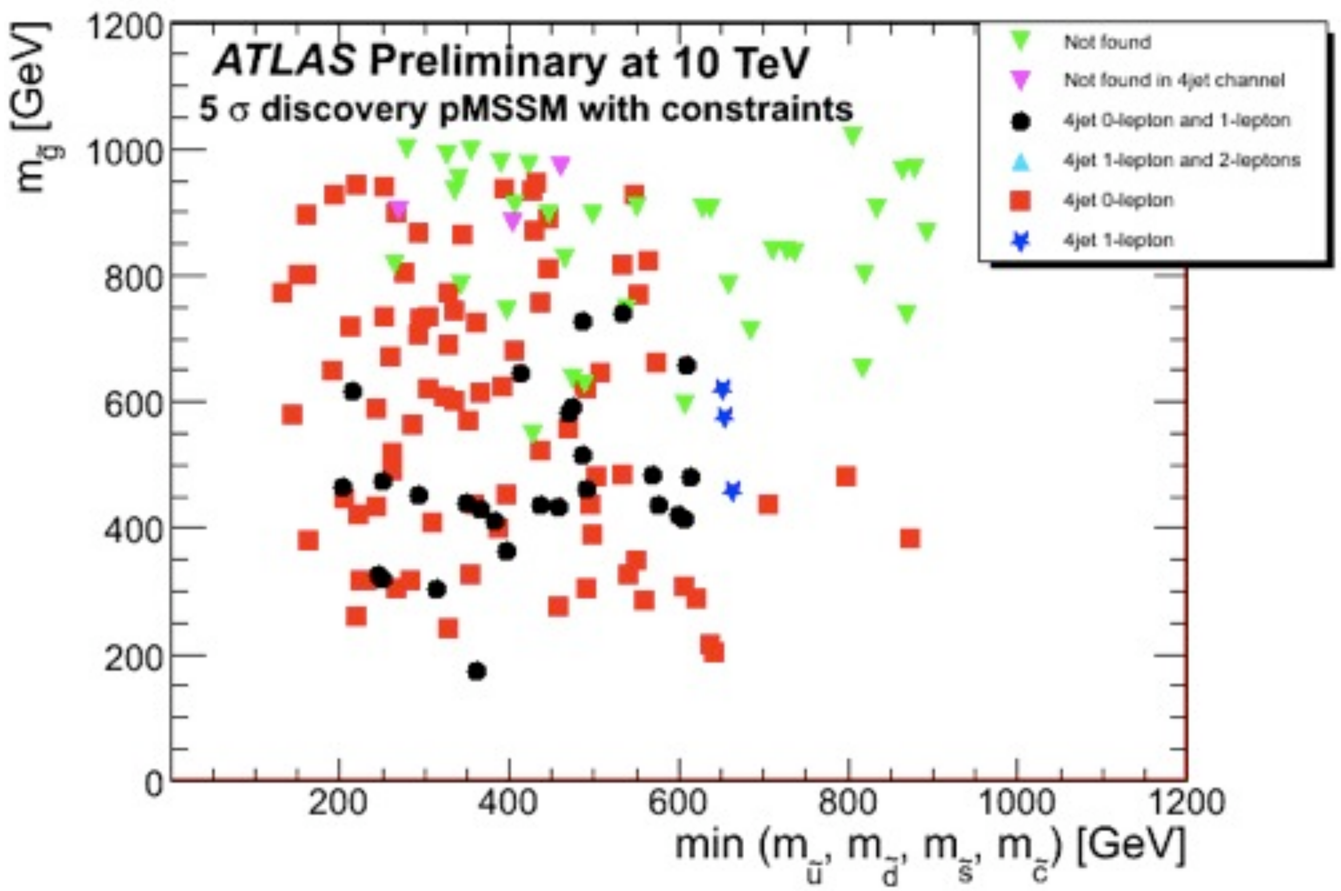


Results

50% uncertainty on backgrounds in sensitivity calculation

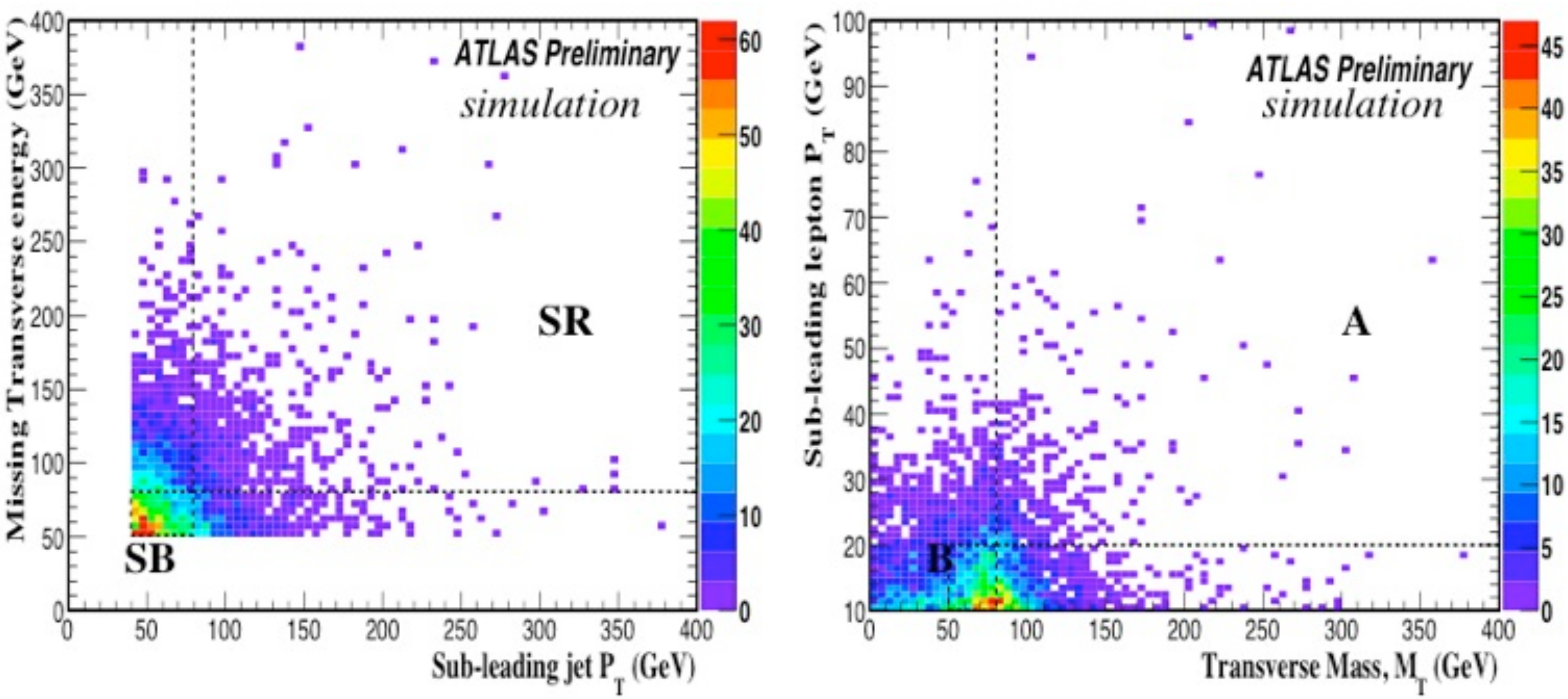






Same-Sign Dileptons

- Low backgrounds → good early search
- Require two jets ($p_T > 40$ GeV), two SS leptons (20/10 GeV), MET > 50 GeV
- Backgrounds from data using signal & control regions

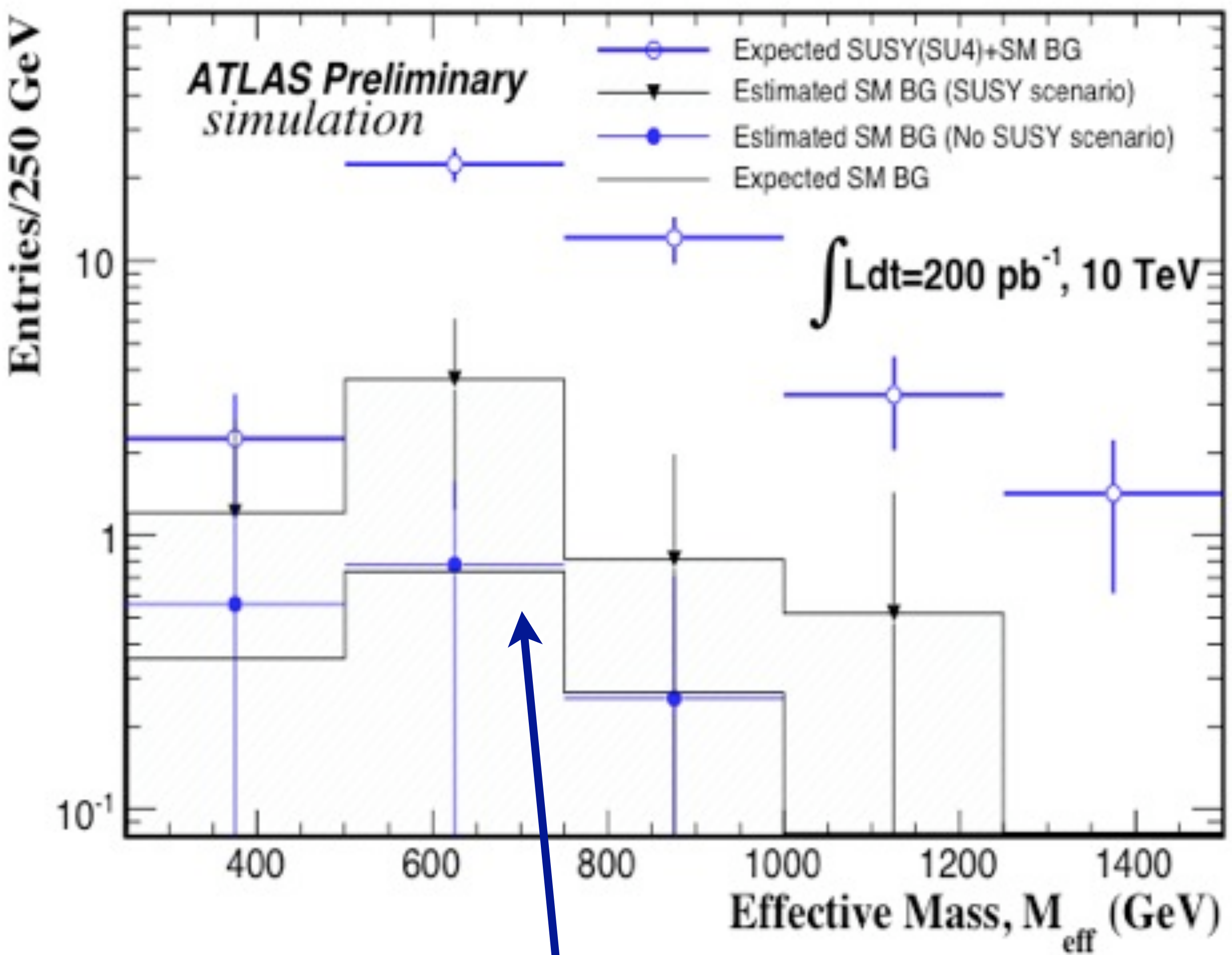


$$A'_{SR} \simeq \left(\frac{A_{SB}}{B_{SB}}\right) \times B_{SR}$$

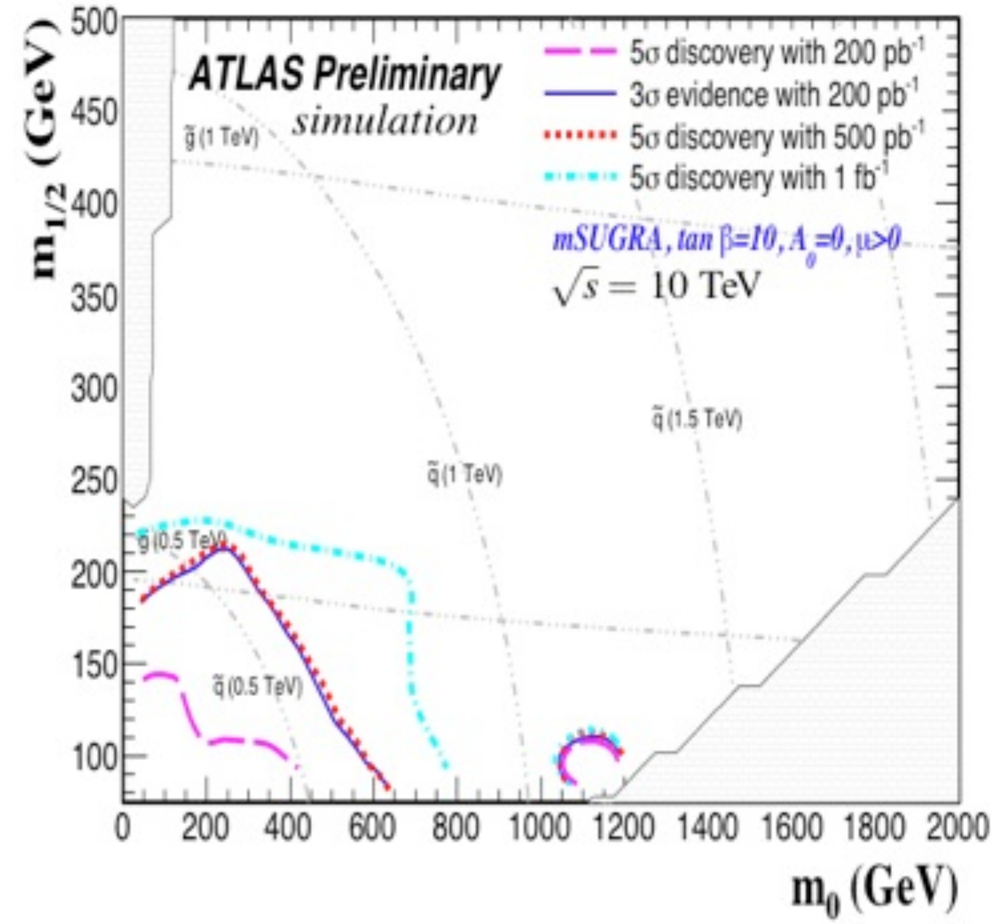
$$\Downarrow$$

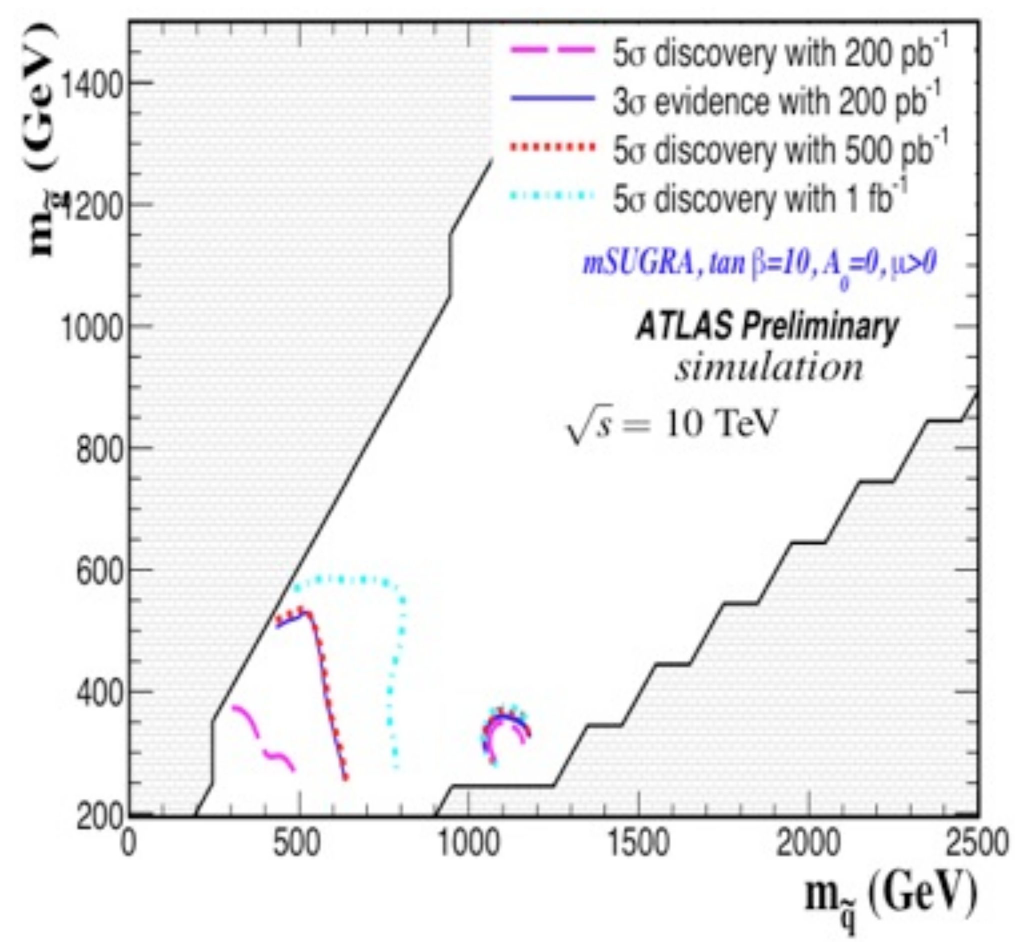
Not corrected for signal contamination...

- Results:



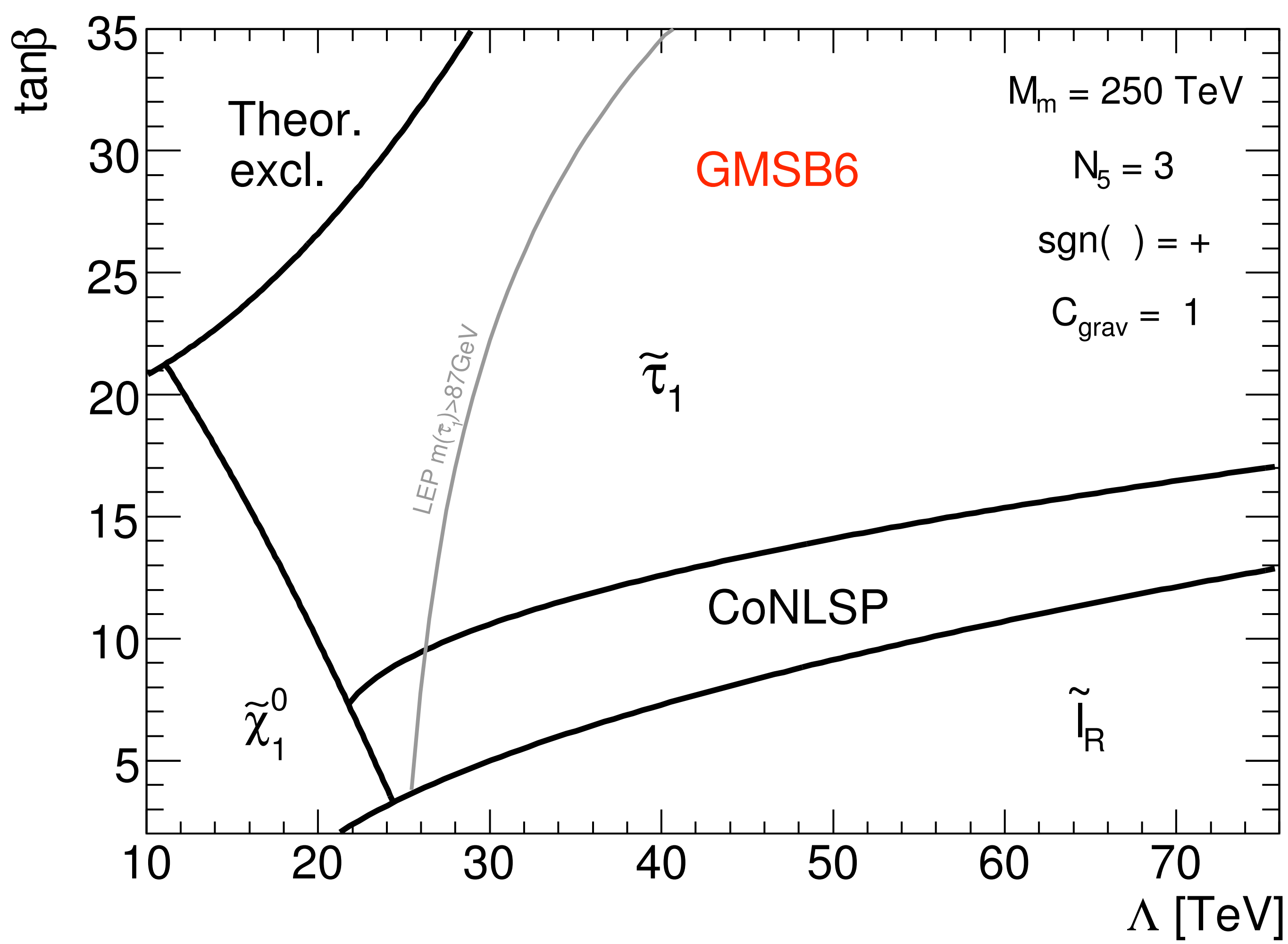
For large SUSY cross-section, background overestimation

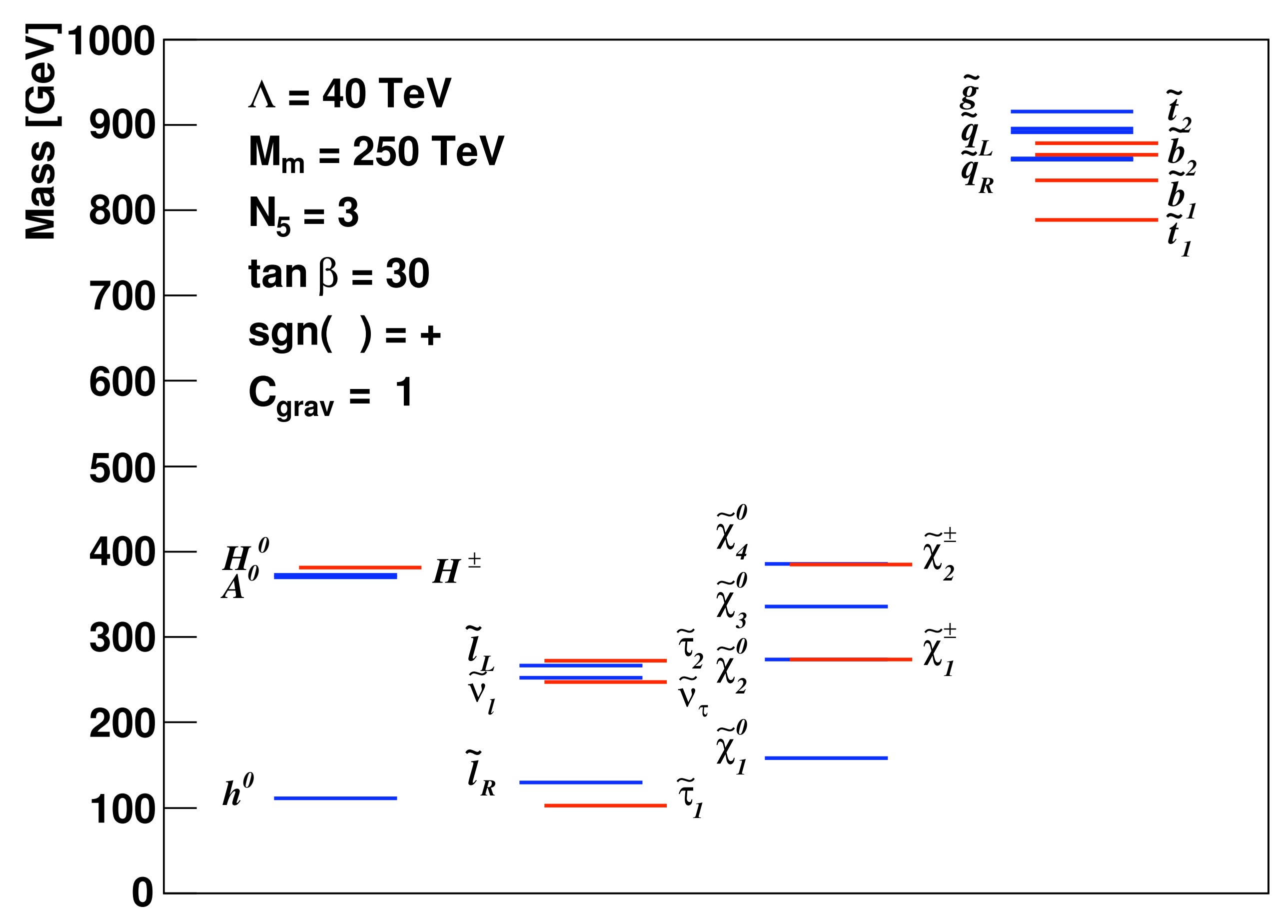




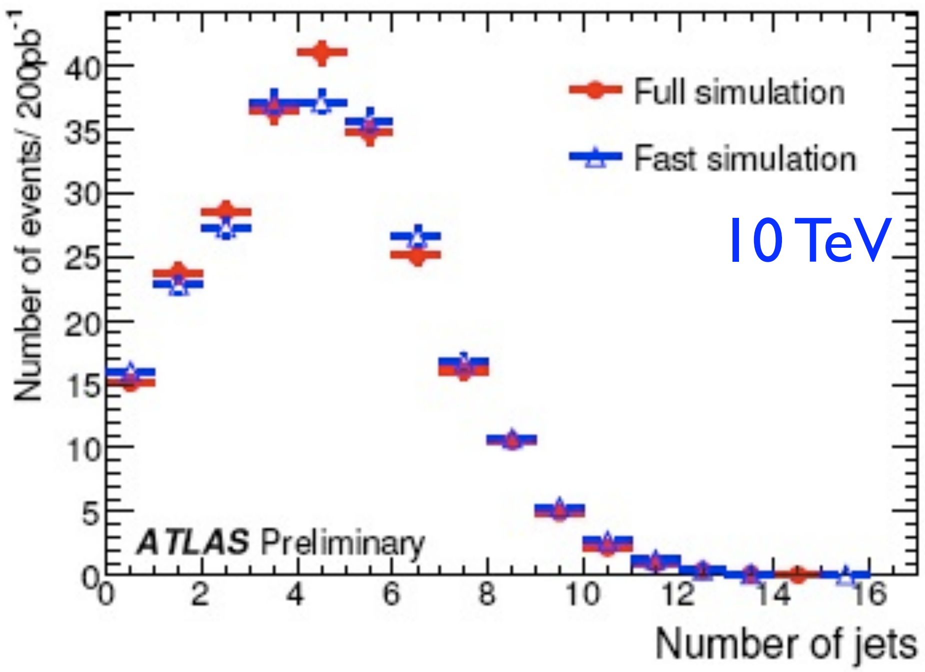
Gauge-Mediated SUSY Breaking

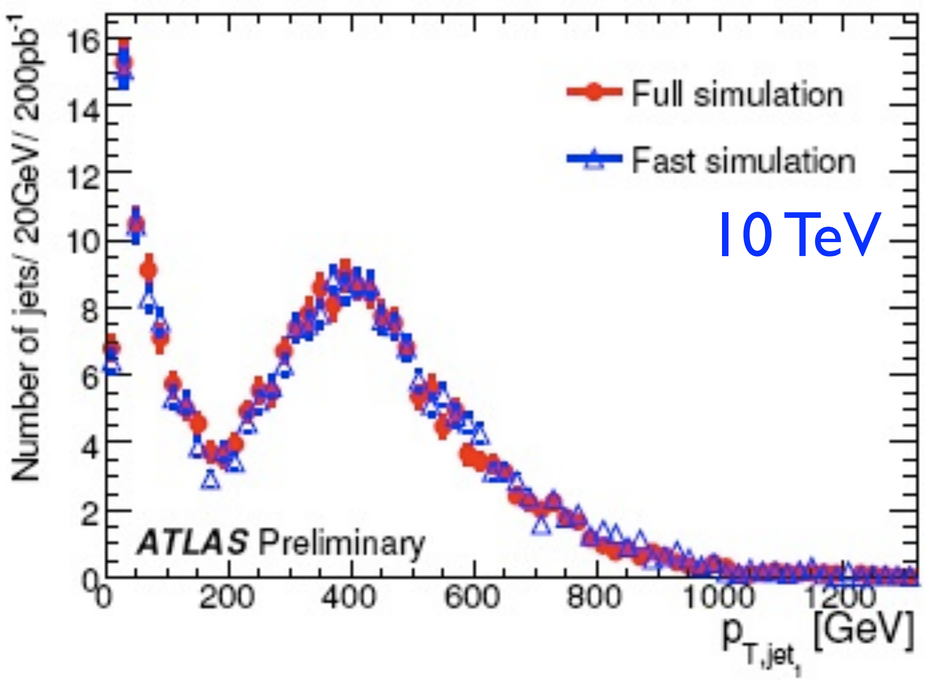
- Originally boosted by CDF eeγγMET event
  - Now more popular again, often nLSP not "bino"
  - Can lead to Z's, h's, but also τ's (and lifetimes could be long)



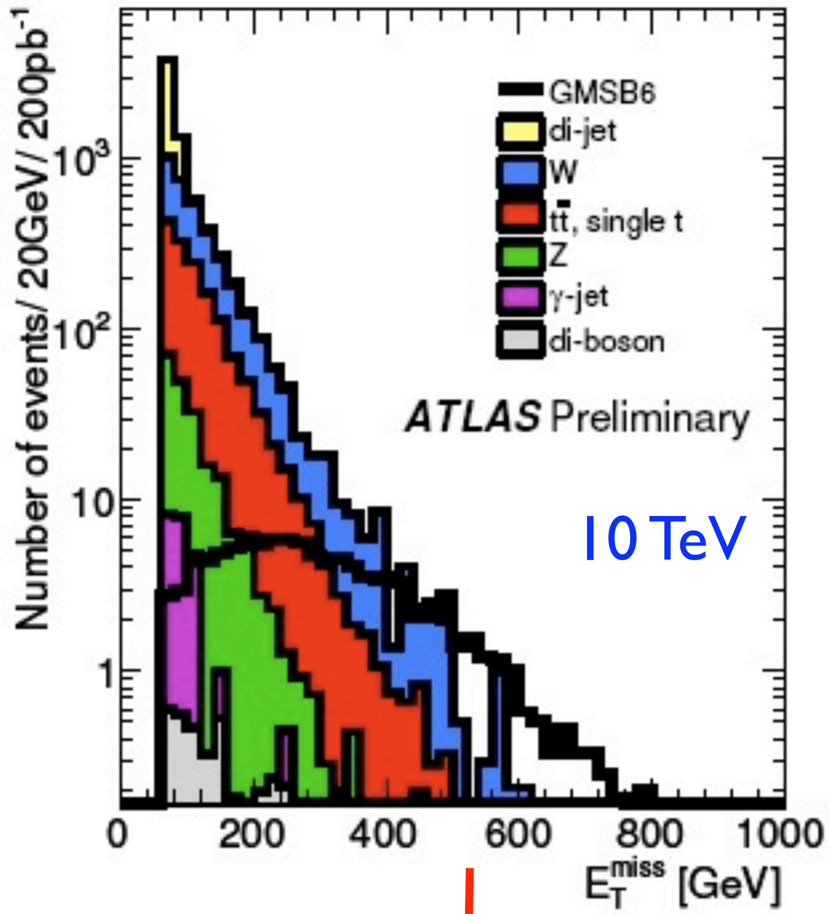


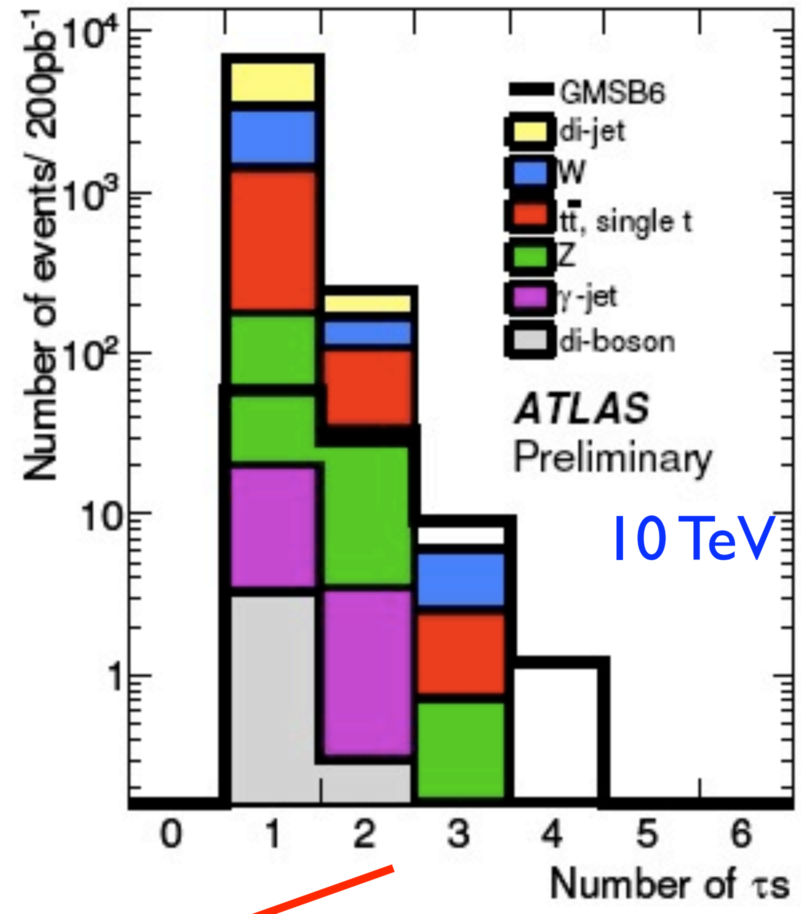
- Selection:
  - Again, many jets expected (production of squarks and gluinos)

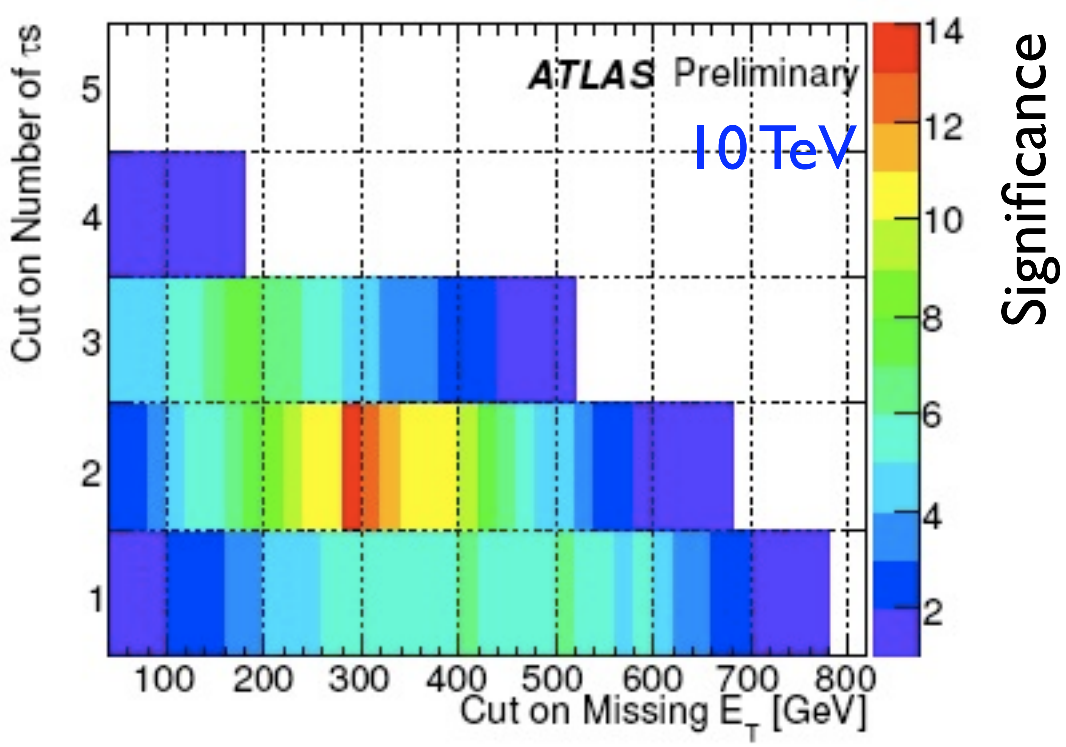




  - Two jets with $p_T > 100/50$ GeV
  - At least one hadronic tau $p_T > 20$ GeV
    - Likelihood based on calorimeter & tracking variables (incl. IP)
  - MET > 60 GeV
  - $\Delta\phi$(leading jet, MET) > 0.2





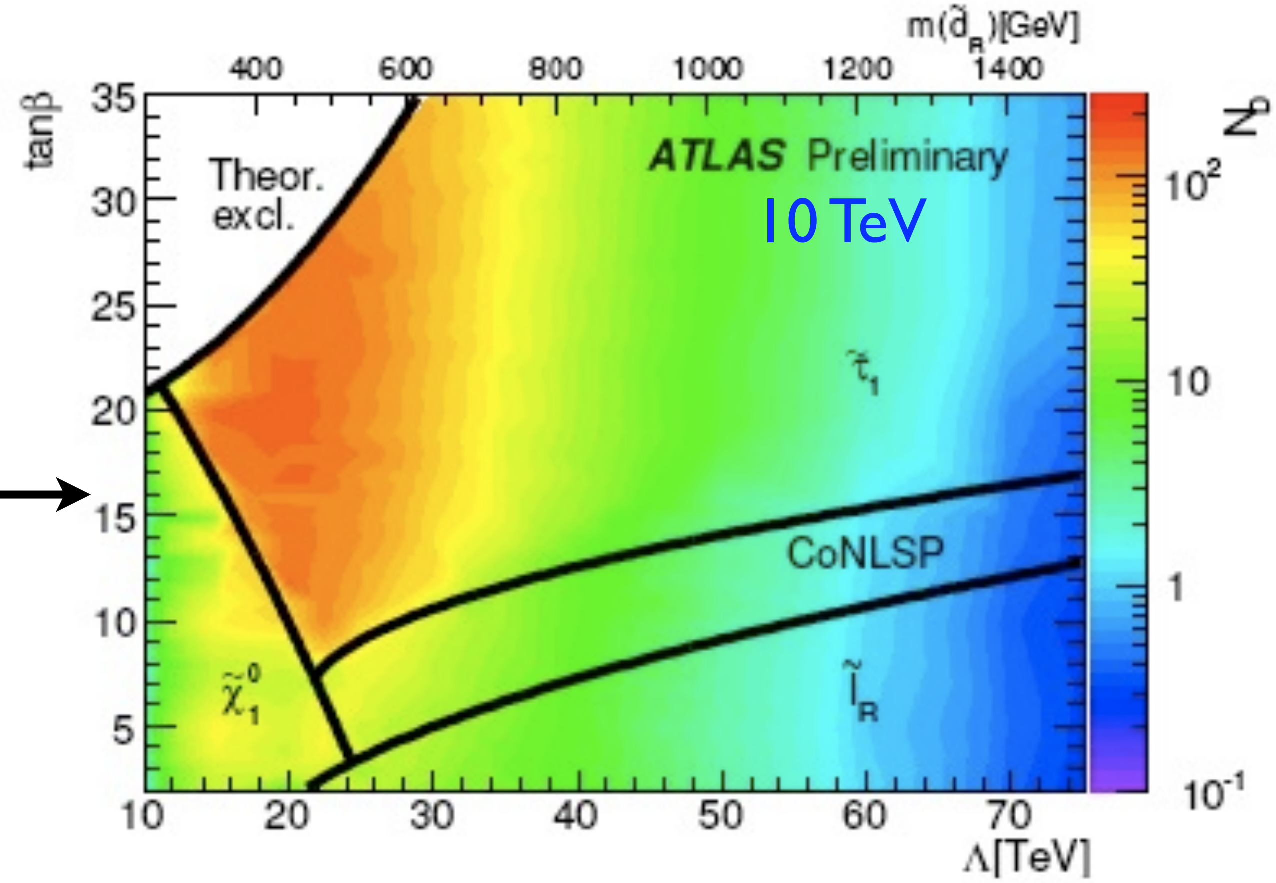


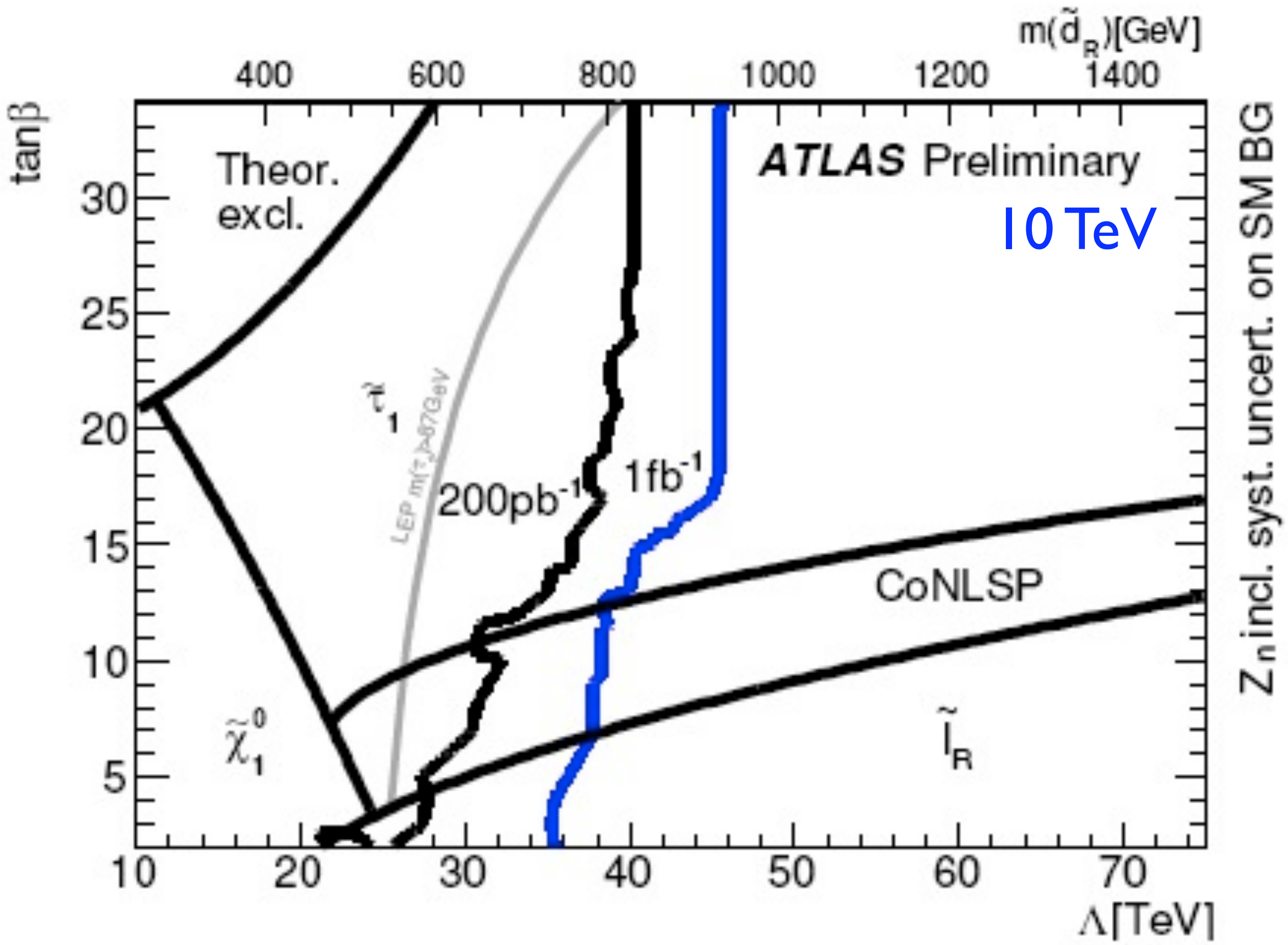
MET > 280 GeV

$N_\tau > 1$

- Result:

Number of expected signal events in 200 pb^{-1} (N_b = 2.5)



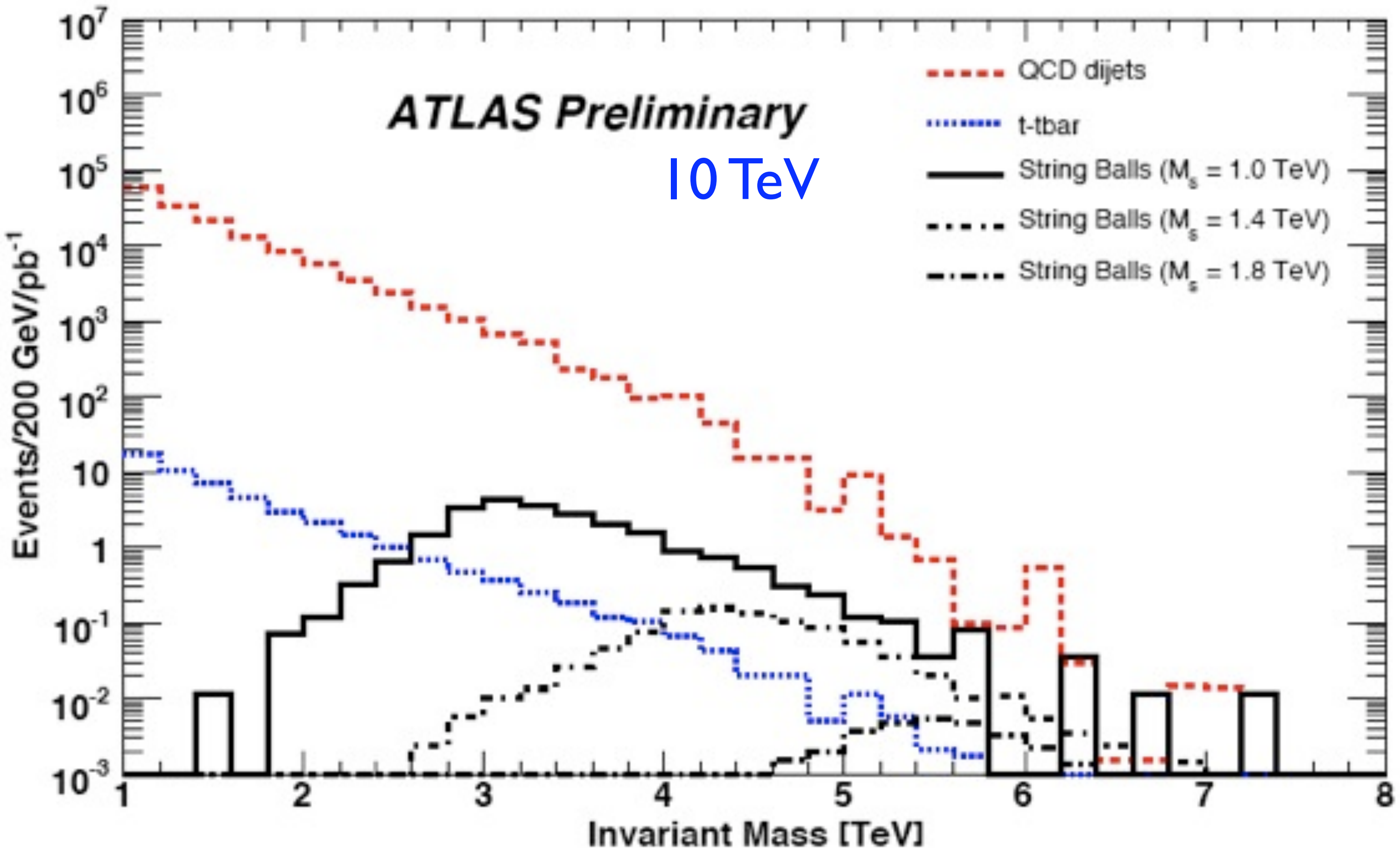


50% (20%) uncertainty on backgrounds in sensitivity calculation for 200 pb^{-1} (1fb^{-1})

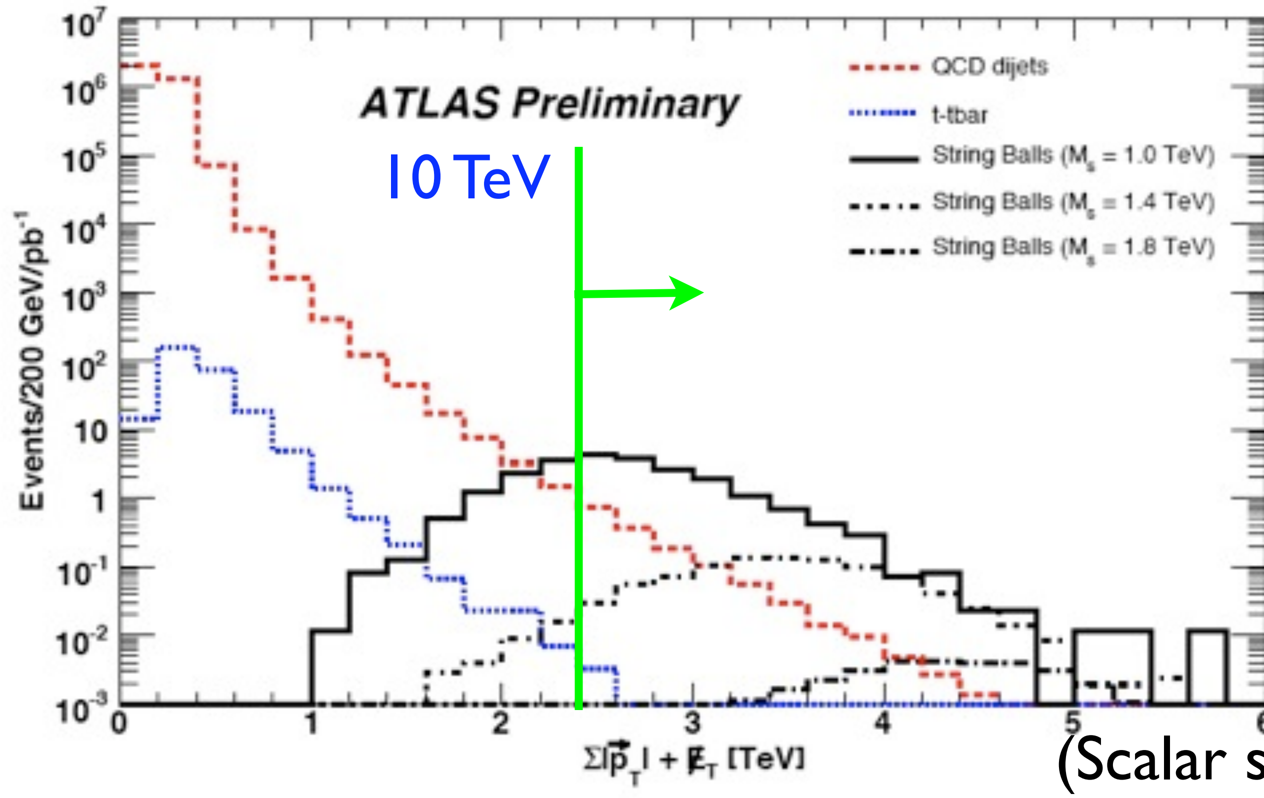
String Balls

- Below the threshold for black holes, can produce highly excited string states, "string balls"
  - "Evaporate" by thermal emission like black holes → multiple high p_T jets, leptons, photons, ...
  - Build M from $\vec{p} = \Sigma\, \vec{p}_i$ (all objects) + MET

Before cuts:



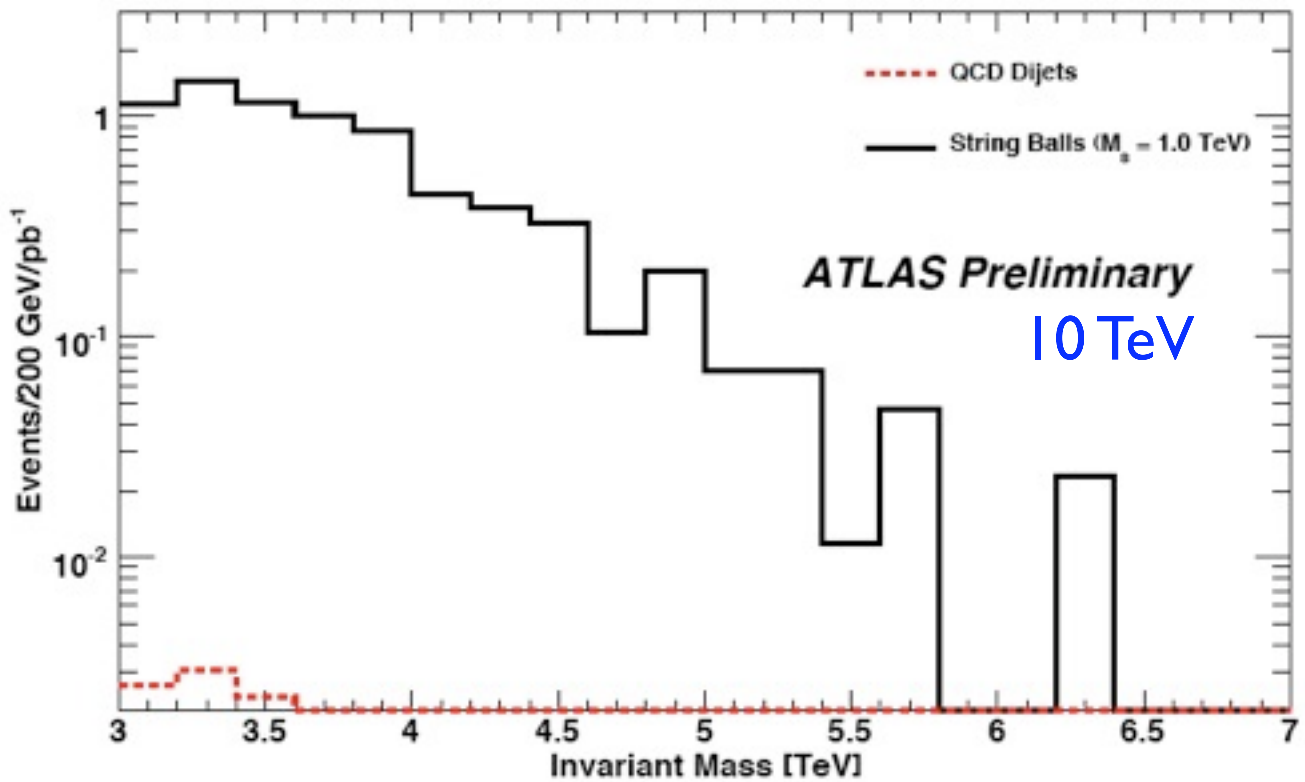
- Require $M > M_{thr} = 3\ M_S$ (for different choices of M_S)



Cut optimized for each M_S

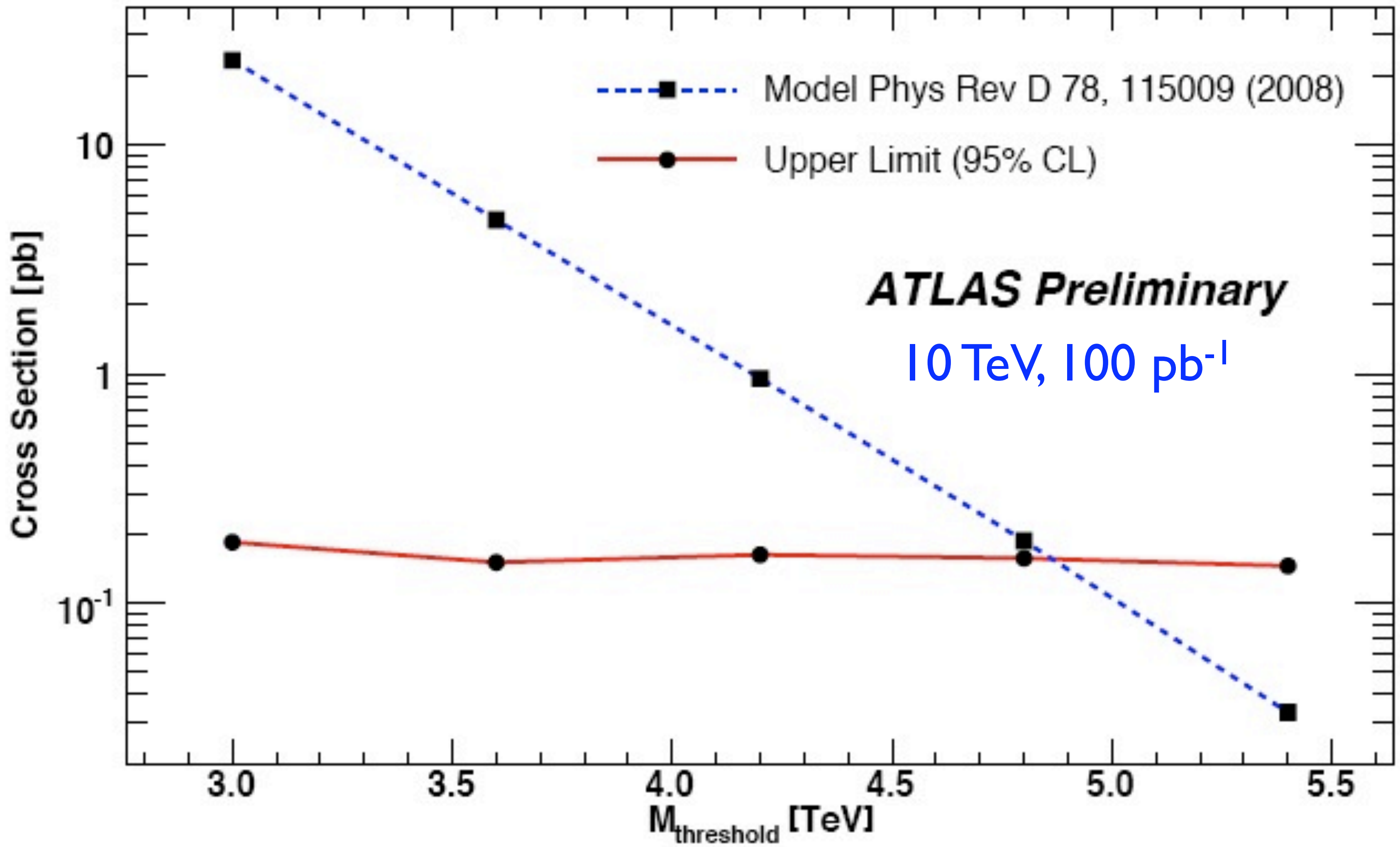
(Scalar sum: H_T)

- Then ask for a high p_T lepton (100/50 GeV):



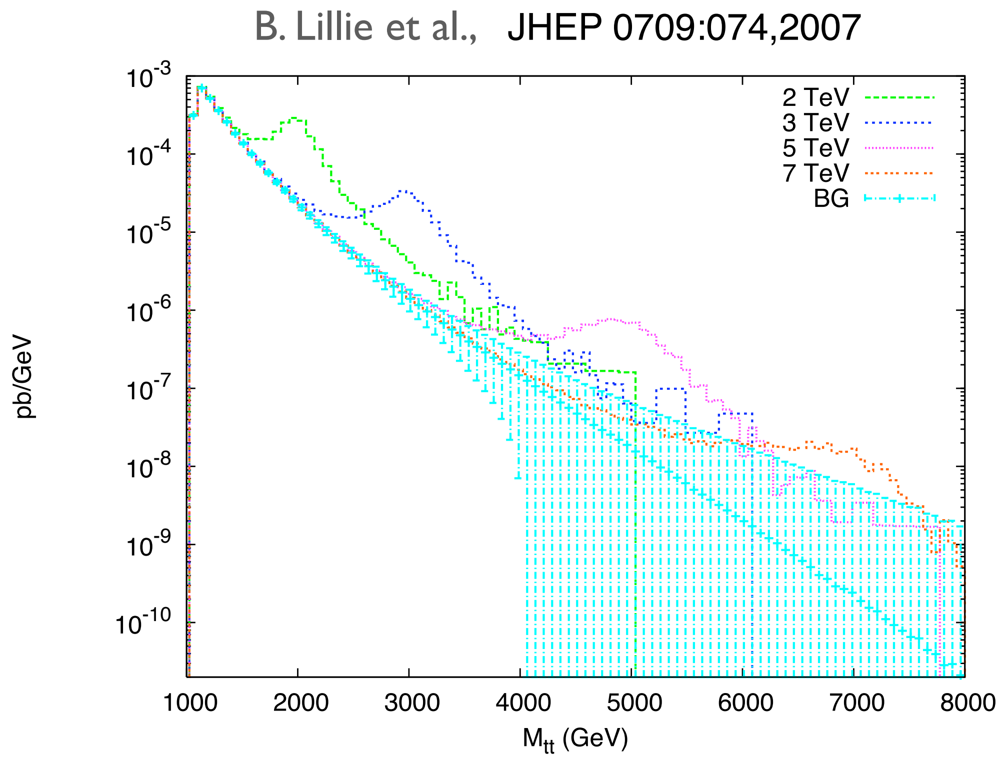
Results

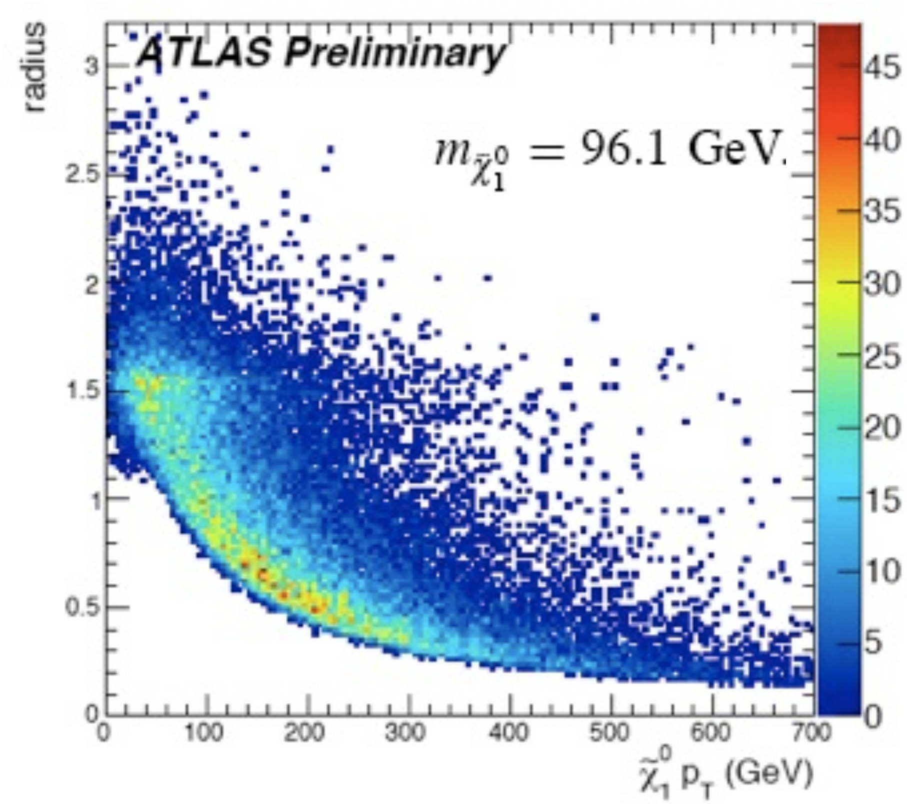
- Optimize cuts on H_T, lepton p_T for each threshold



New Resonances

- In Randall-Sundrum models with all particles in the bulk, excitations of the gauge bosons are very promising channels for discovery
  - Couplings to light fermions are small, but large coupling to top, W_L, Z_L which are produced with p >> m
- In RPV SUSY, high-p_T LSP can decay to collimated quarks
- High mass WW scattering, ...

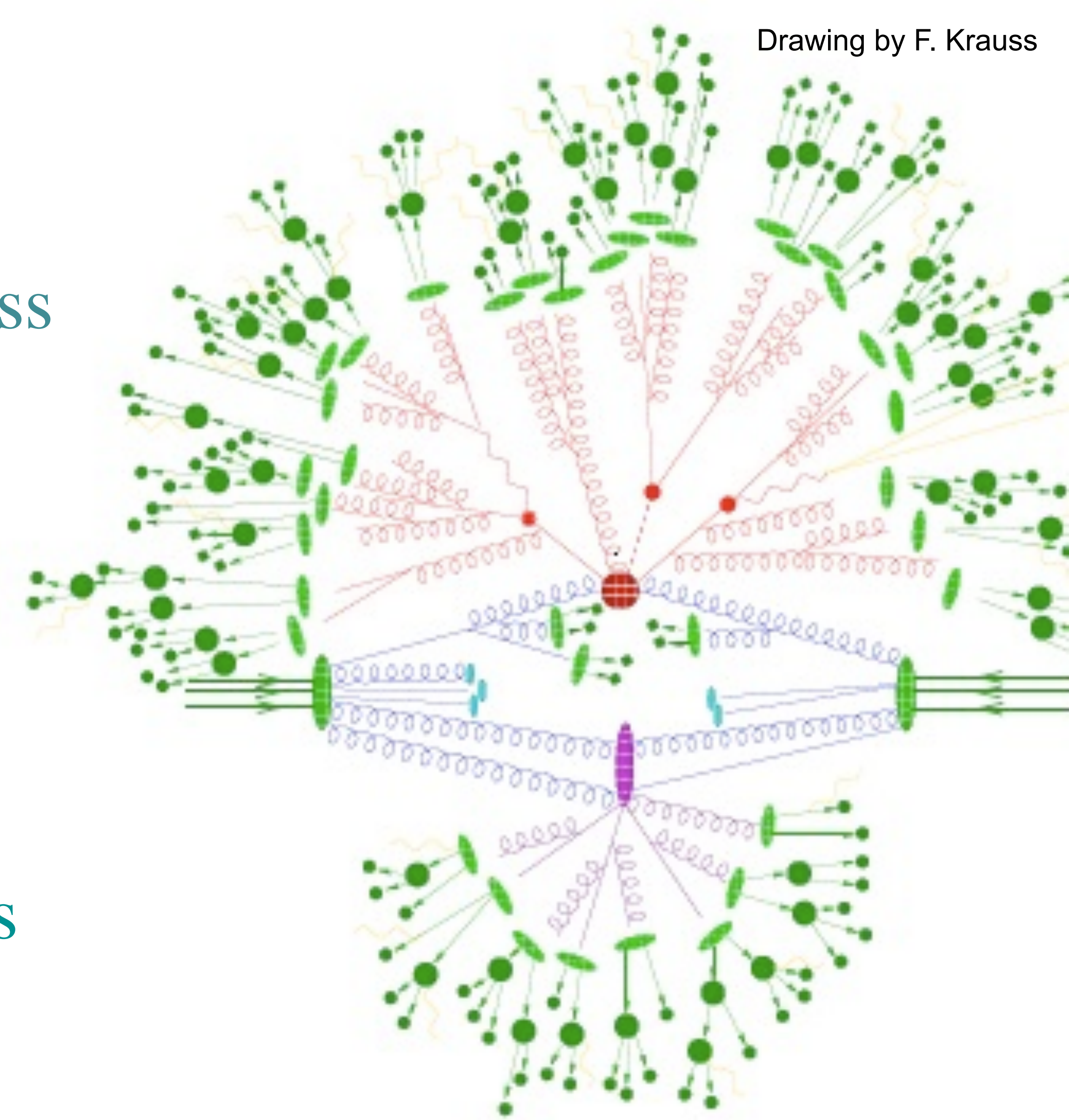




Hadronic Decays

- Decay hadrons reconstructed as a single jet
  - But even if it looks like a single jet, it originates from a massive particle decaying to three hard partons, not one
- If measure each of the partons in the jet perfectly, would be able to:
  - Reconstruct the "originator's" invariant mass
  - Reconstruct the direct daughter partons
- But
  - Quarks hadronize → cross-talk
  - Detector can't resolve all individual hadrons
    - LHC calorimeters have fine granularity

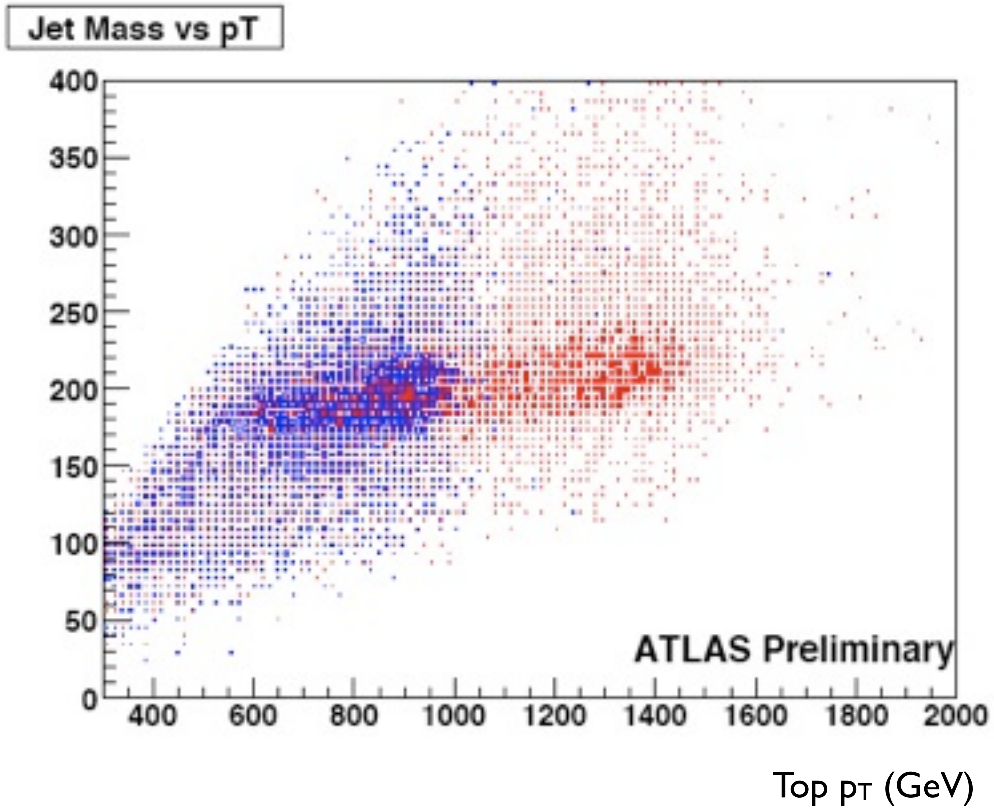
Drawing by F. Krauss



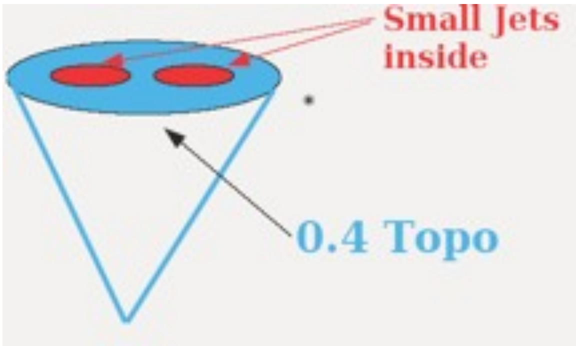
Jet Mass

- Jet mass: invariant mass of all jet constituents

High p_T top quarks from Z' (m=2,3 TeV) decays



- Jet mass not sensitive to jet structure
  - Multiple techniques to exploit this
  - Here use $k_\perp$ splitting scales



J. M. Butterworth, B. E. Cox, and J. R. Forshaw, *Phys. Rev.* **D65** (2002) 096014

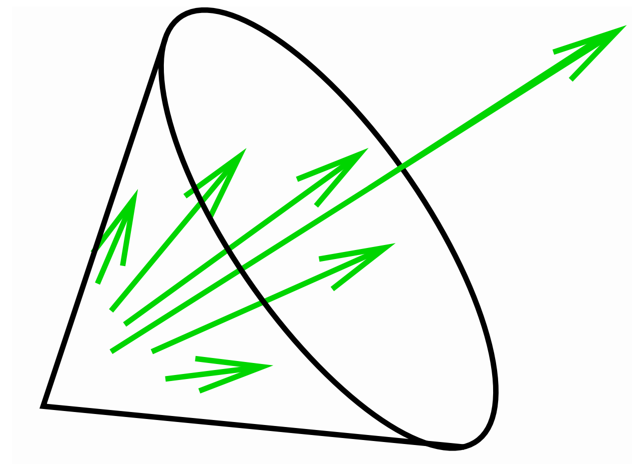
k_T Splitting Scales

- k_T jet algorithm is much better suited to understand jet substructure than cone:
  - Cone maximizes energy in an η x ϕ cone
  - k_T is a "nearest neighbor" clusterer

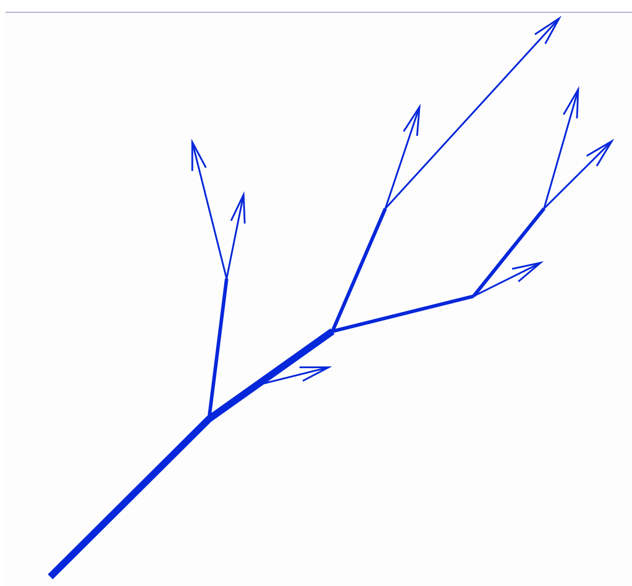
$$y_2 = \min\left(E_a^2, E_b^2\right) \bullet \theta_{ab}^2 \Big/ p_{T(jet)}^2$$

$$Y \text{ scale } = \sqrt{p_{T(jet)}^2 \bullet y_2}$$

- Can use the k_T algorithm on jet constituents and get the (y-)scale at which one switches from 1 → 2 (→ 3 etc.) jets
  - Scale is related to mass of the decaying particle



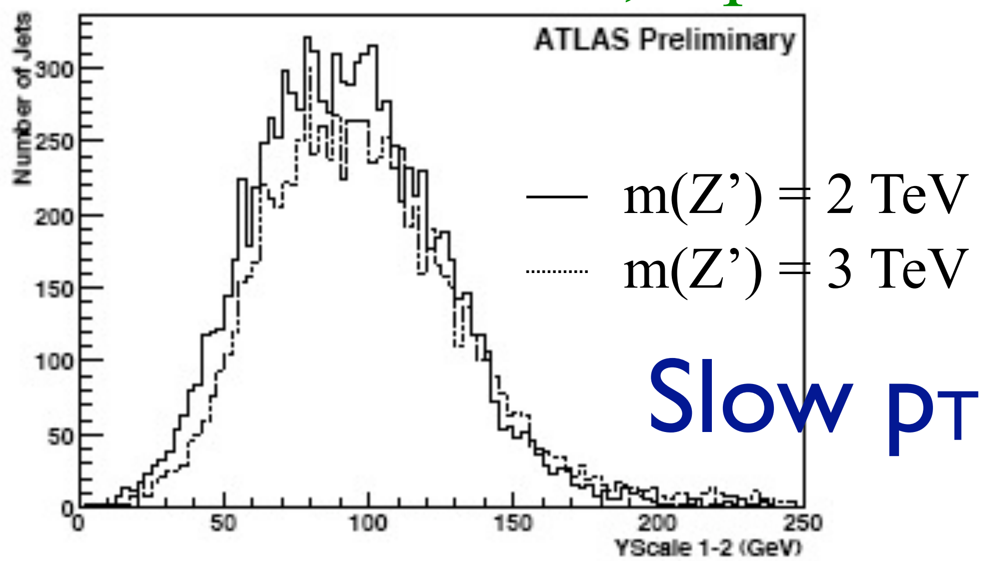
Cone



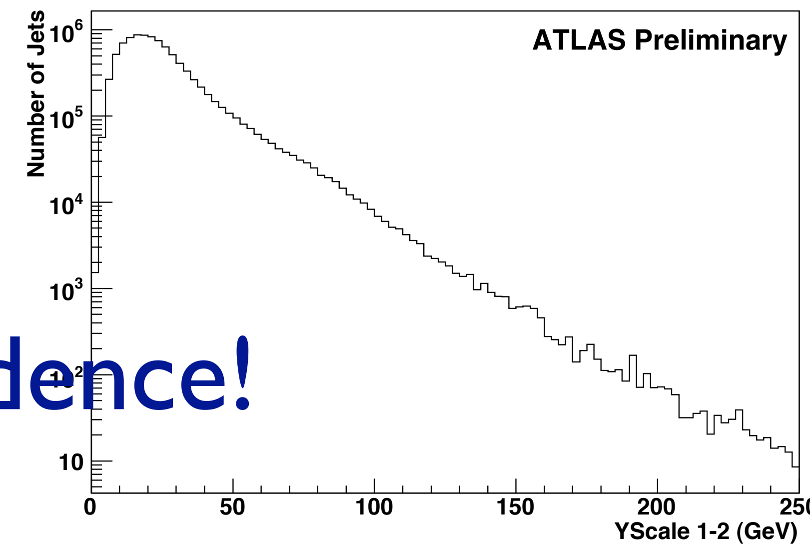
k_T

Variables

1 → 2 Jet Scale, top

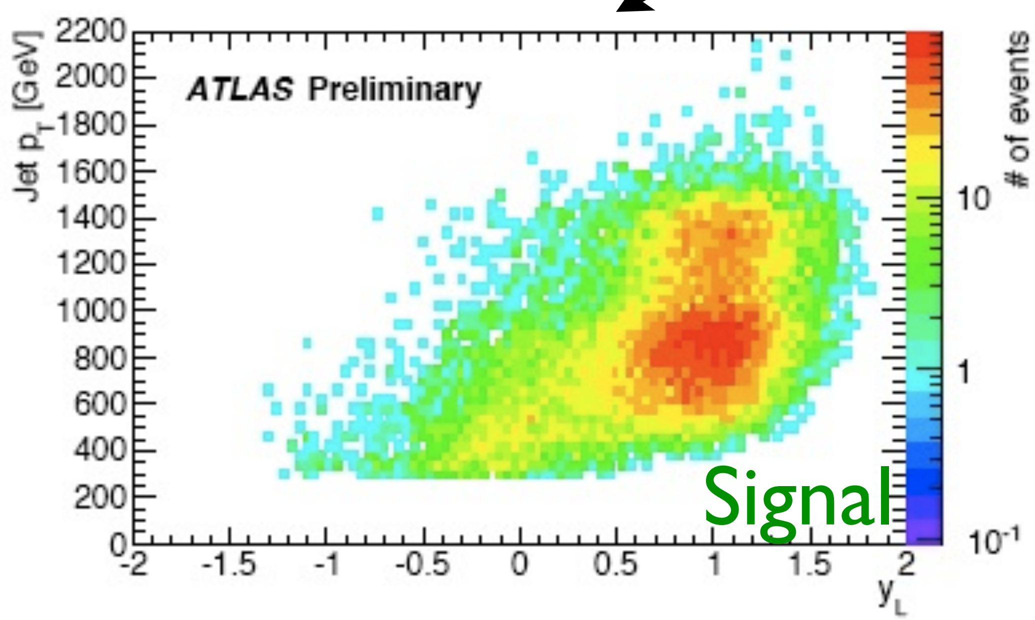


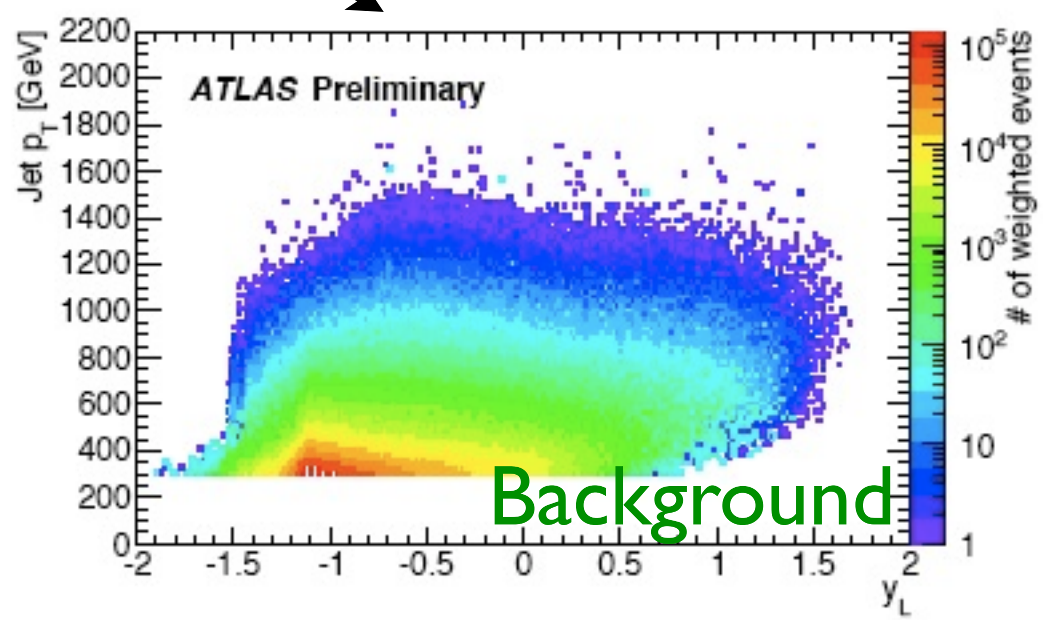
1 → 2 Jet Scale, light jets



Slow p_T Dependence!

Build likelihood from
jet mass + first 3 splitting scales:



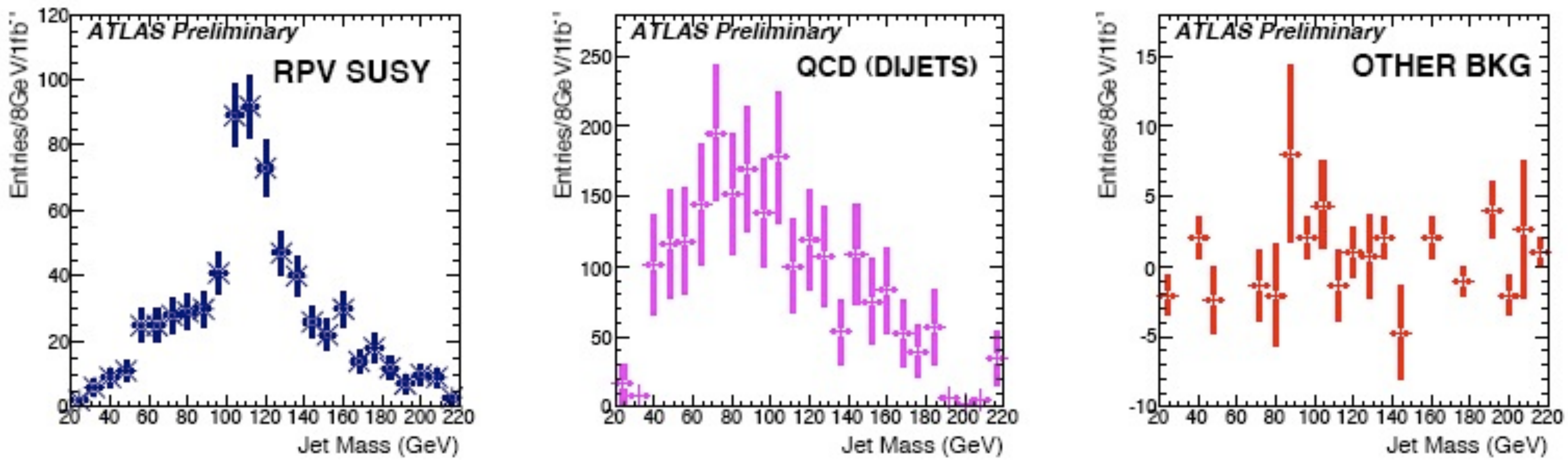


Results

- Background estimate in search for tt resonance
  - ℓ+jets, 1 fb^{-1} at 14 TeV: QCD well below irreducible tt!

$m = 2$ TeV	$y_L > 0.6$	$y_L > 0.9$	$y_L > 1.2$
QCD multijet (J5 + J6 + J7)	1.9 ± 0.5	0.7 ± 0.2	0.16 ± 0.04
SM $t\bar{t}$	$17.1 \pm 0.8 \pm 2.6$	$11.1 \pm 0.7 \pm 1.7$	$3.1 \pm 0.4 \pm 0.5$
Total	19 ± 2.8	11.8 ± 1.9	3.3 ± 0.6
$m = 3$ TeV	$y_L > 0.6$	$y_L > 0.9$	$y_L > 1.2$
QCD multijet (J5 + J6 + J7)	0.5 ± 0.2	0.2 ± 0.1	0.07 ± 0.03
SM $t\bar{t}$	$2.3 \pm 0.1 \pm 0.3$	$1.4 \pm 0.1 \pm 0.2$	$0.52 \pm 0.07 \pm 0.08$
Total	2.8 ± 0.4	1.6 ± 0.2	0.6 ± 0.1

- Search for RPV SUSY (10 TeV): after 2D cut in y_{12} vs y_{23}



Conclusions

- We know something is on the horizon
  - Hopefully more than just a Higgs boson
- ATLAS gearing up for
  - "Classic" searches, but also
  - New signatures
  - Only small sampling given here
- LHC will start exploring uncharted territory soon
  - Does not need much data to extend Tevatron reach, at least in some areas

SUSY Benchmark Points

Point	m_0 (GeV)	m1/2 (GeV)	A0(GeV)	tan(β)	sgn(μ)	x-sec (pb)	DC1	Rome	CSC
Coannihilation (SU1)	70	350	0	10	+	7.43 (a)		Y	Y
Focus Point (SU2)	3550	300	0	10	+	4.86 (a)		Y	Y
Bulk (SU3)	100	300	-300	6	+	18.59 (a)	Y	Y	Y
Low Mass (SU4)	200	160	-400	10	+	262 (b)		Y	
Scan (SU5.1)	130	600	0	10	+	0.44 (b)		Y	
Scan (SU5.2)	250	600	0	10	+	0.40 (b)		Y	
Scan (SU5.3)	500	600	0	10	+	0.31 (b)		Y	
Funnel (SU6)	320	375	0	50	+			Y	Y
Coannihilation (SU8.1)	210	360	0	40	+	6.44 (a)			Y
Coannihilation (SU8.2)	215	360	0	40	+	6.40 (a)			Y
Coannihilation (SU8.3)	225	360	0	40	+	6.32 (a)			Y

Some references

- ATLAS "CSC" book (14 TeV), January 2009
  - http://cdsweb.cern.ch/record/1125884?ln=en
- Other studies, incl. more recent 10 TeV:
  - https://twiki.cern.ch/twiki/bin/view/Atlas/AtlasResults