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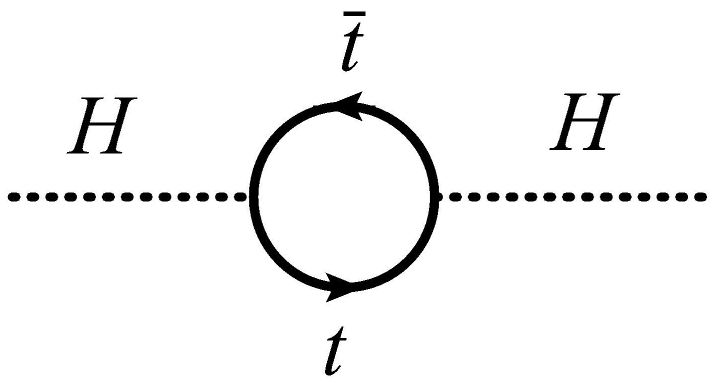
Search for squarks and gluinos with the ATLAS detector in final states with jets and missing transverse momentum using 4.7 fb^{-1} of $\sqrt{s}$ = 7 TeV proton-proton collision data

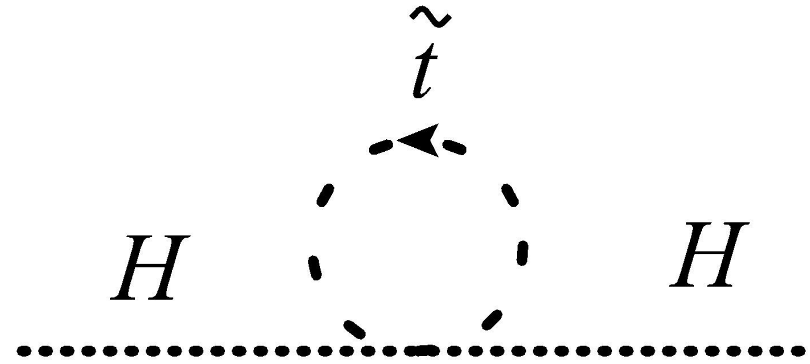
http://arxiv.org/pdf/1208.0949v3.pdf

K. Bozek and S. Blot
HASCO Presentations - 2013

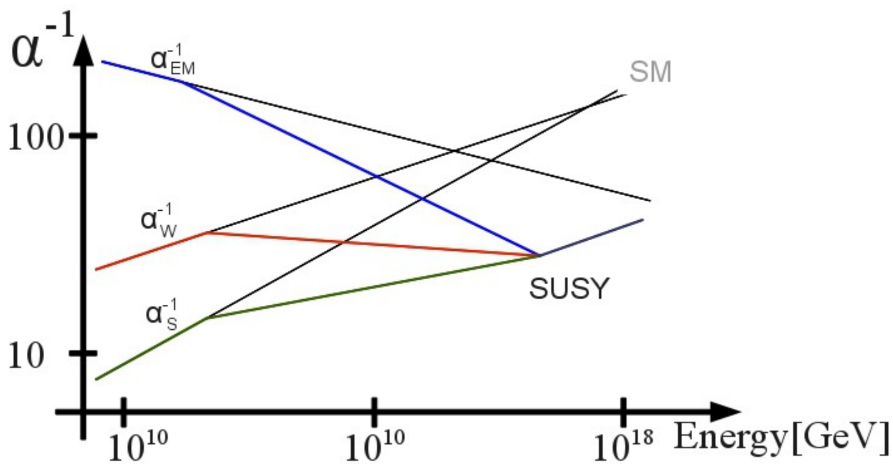
Motivation of SUSY

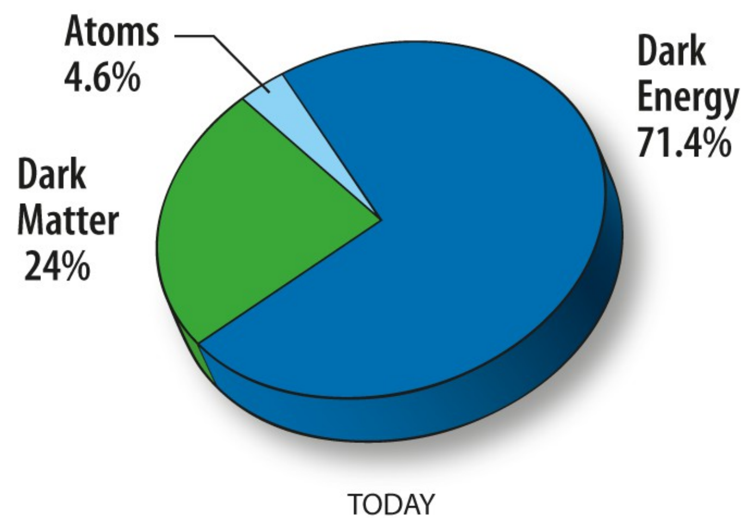
- Higgs mass corrections





- Dark matter candidates



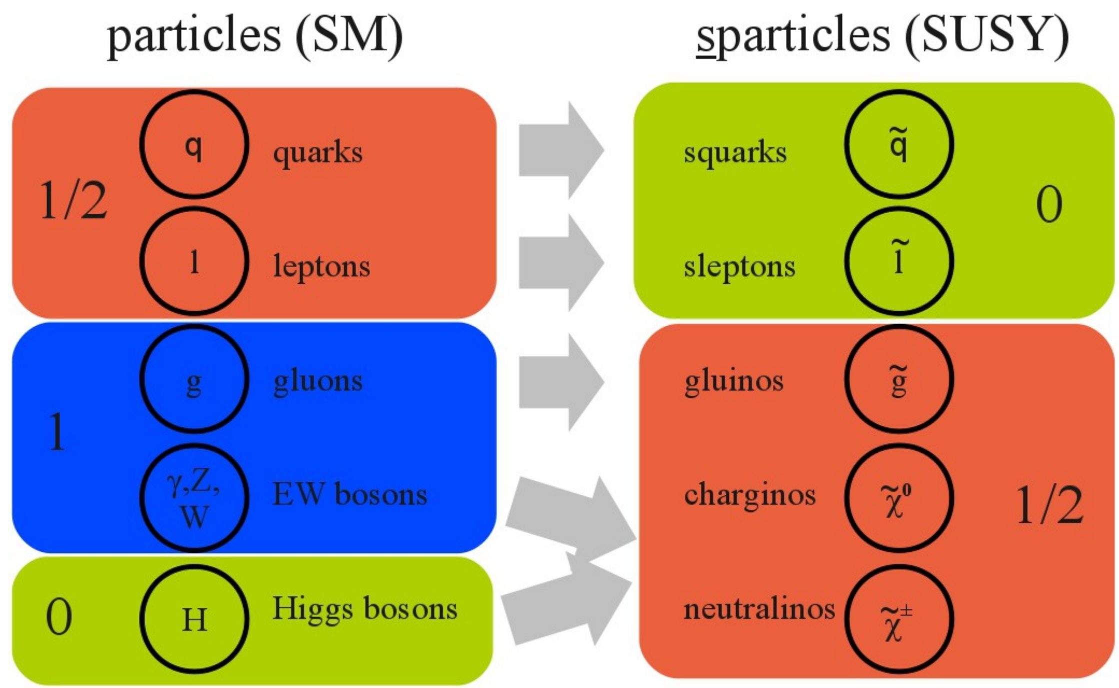


nasa.gov

- Running coupling constants?

SUSY

- New (s)particles



- Bunch of models ⟶ need to simplify

The goal: discovery!

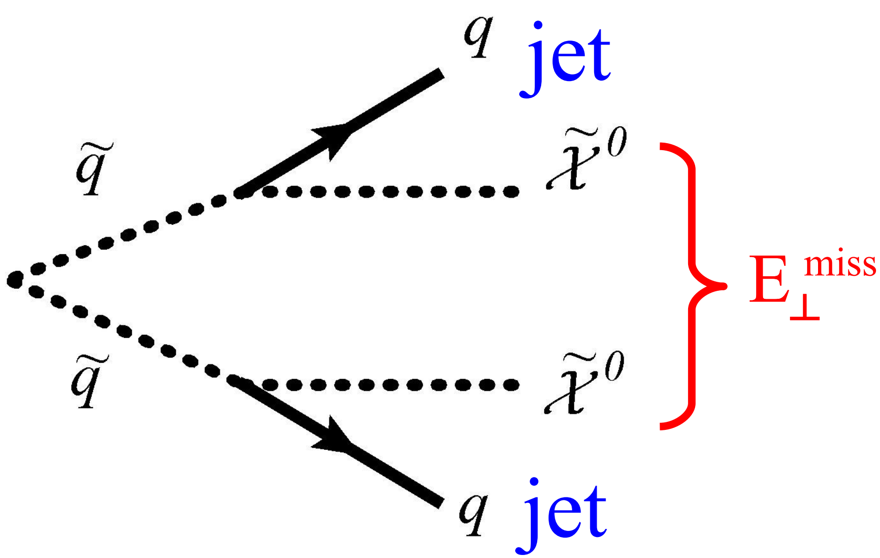
3 particles: $\tilde{q}$ $\tilde{g}$ $\tilde{\chi}^0$ others too heavy

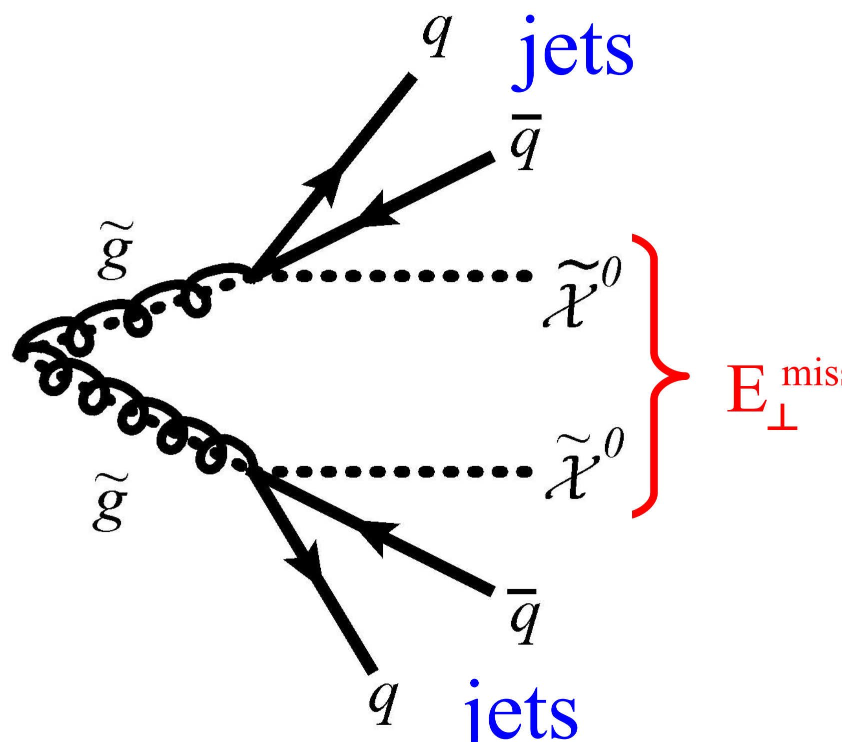
- R-parity (conservation)

SM R=1 = SUSY R= -1 • SUSY R= -1

Expected signal

- Jets + missing $E_\perp$

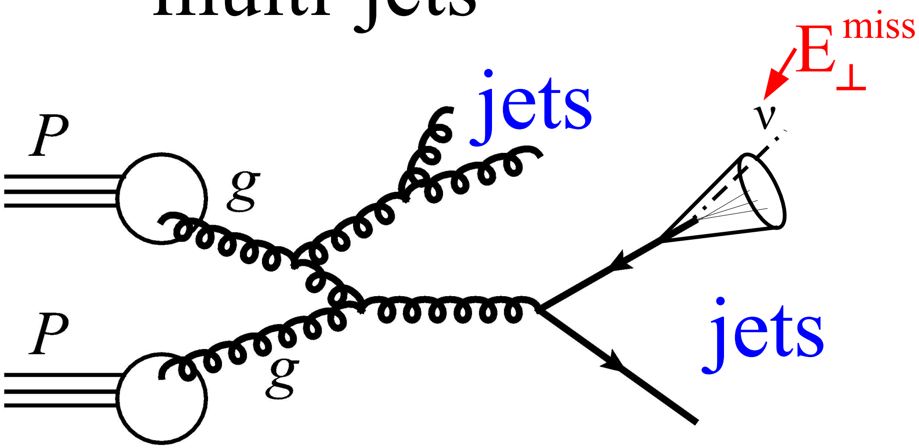




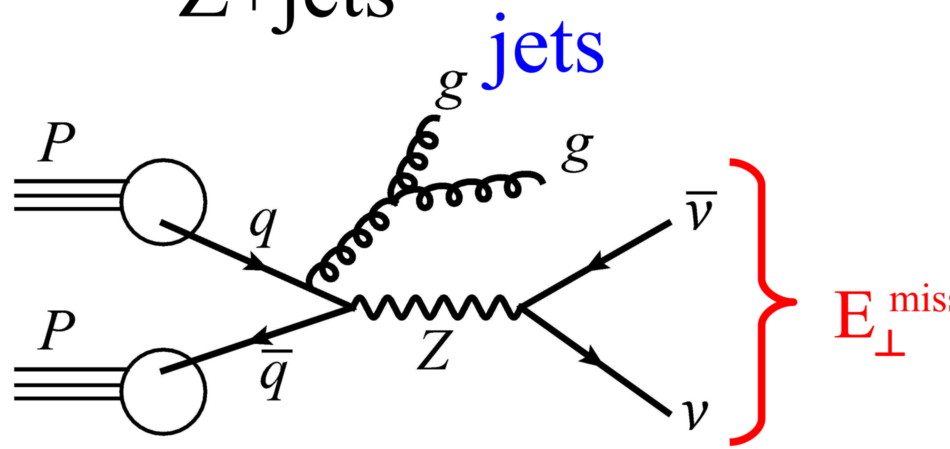
- The analysis focuses on jets in the final state
- Possible cascade decays – multi-jets final state.

Possible background

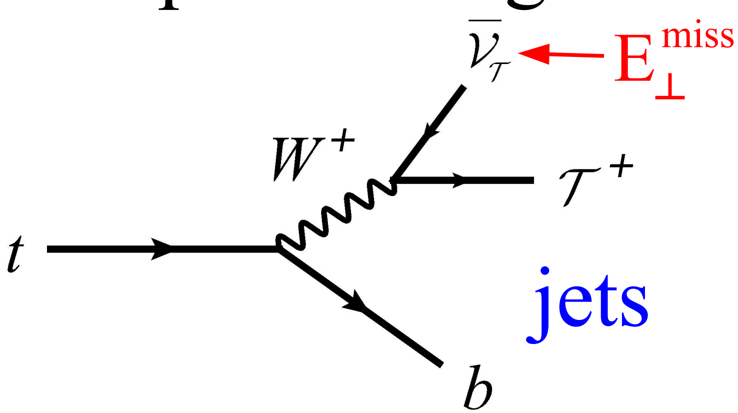
- multi-jets



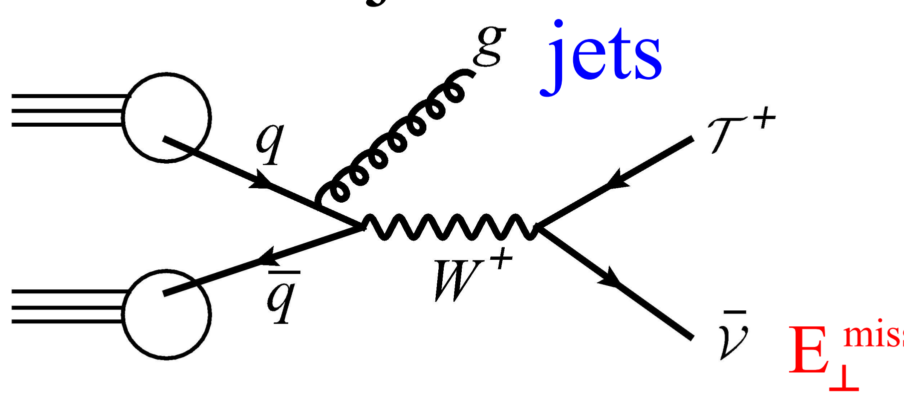
- Z+jets



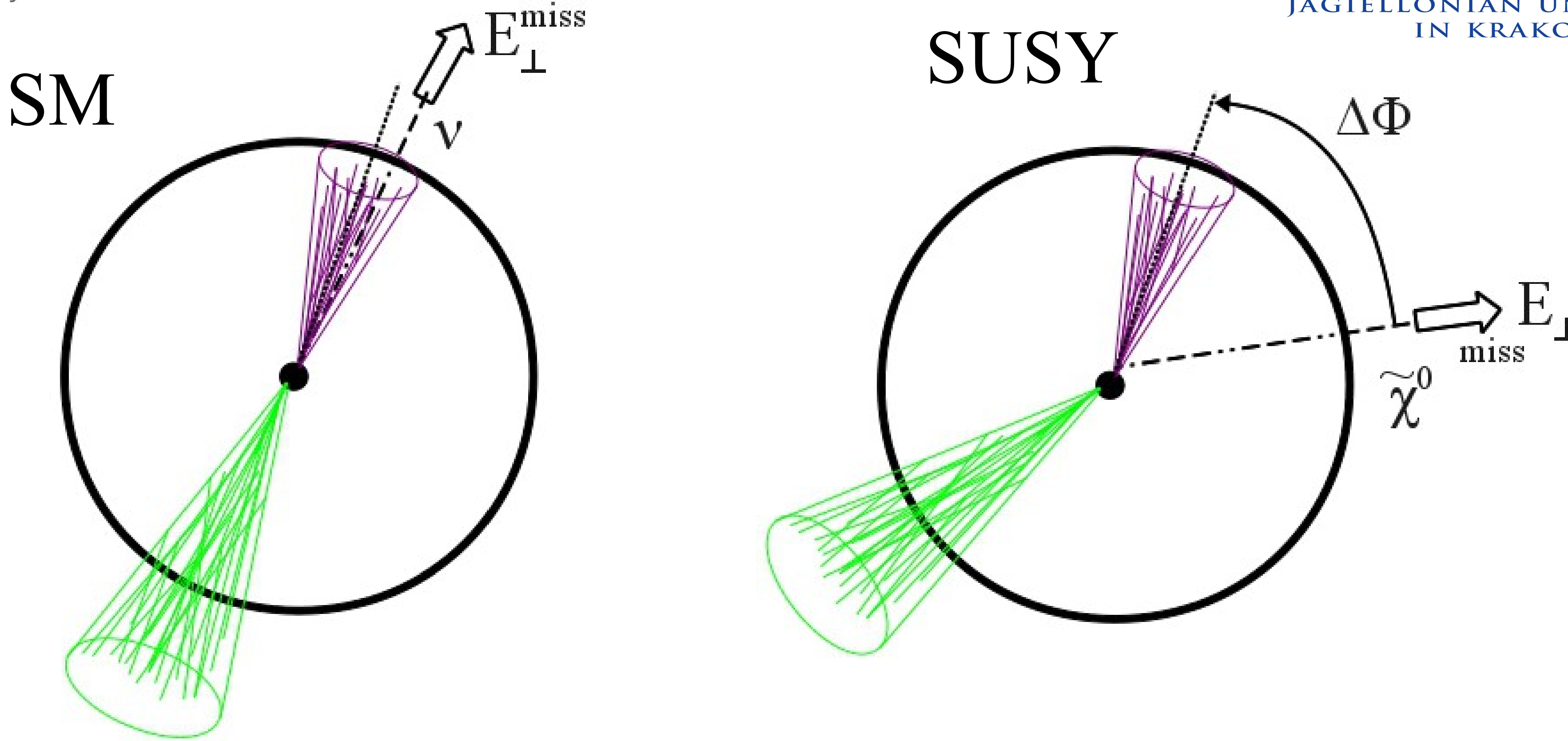
- tt–pair or single-t



- W+jets



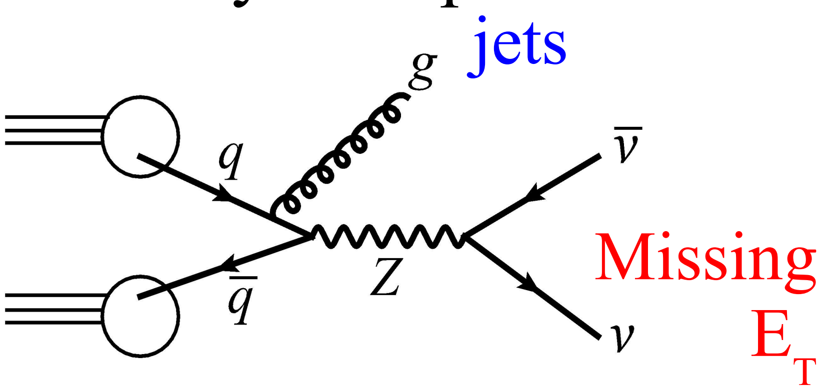
Multi-jets background



- Reducible background = SM background process is kinematically different from the SUSY signal process
  – For example, we can cut events where $E_\perp^{miss}$ and the jet direction have a small angular separation ($\Delta\Phi$)

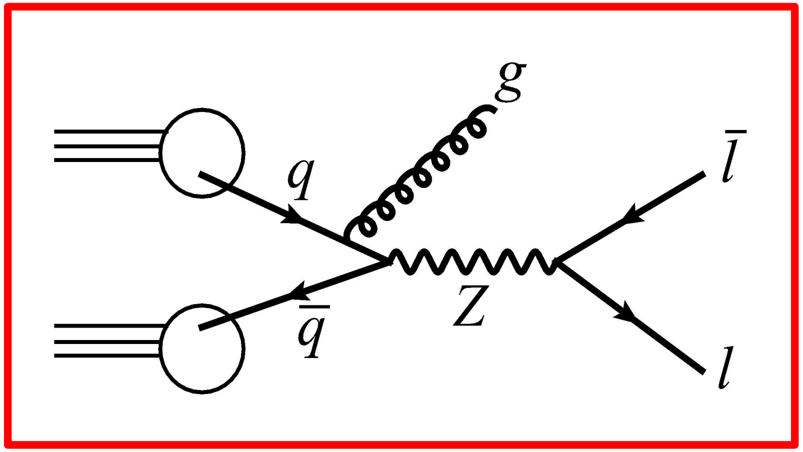
Irreducible Backgrounds

- Irreducible backgrounds produce events with the same topology and kinematics as your signal
- Because of this, all events will pass any kinematic/acceptance cuts that you impose on the data set



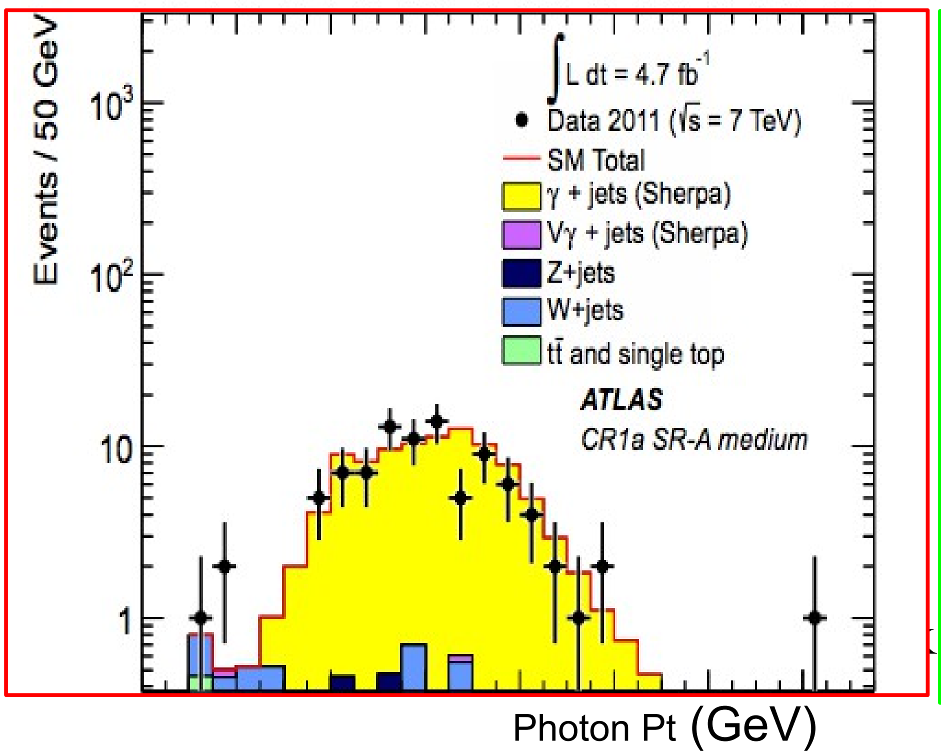
- Therefore, we just have to know how many of these events we expect in the signal region <u>as precisely as possible</u>

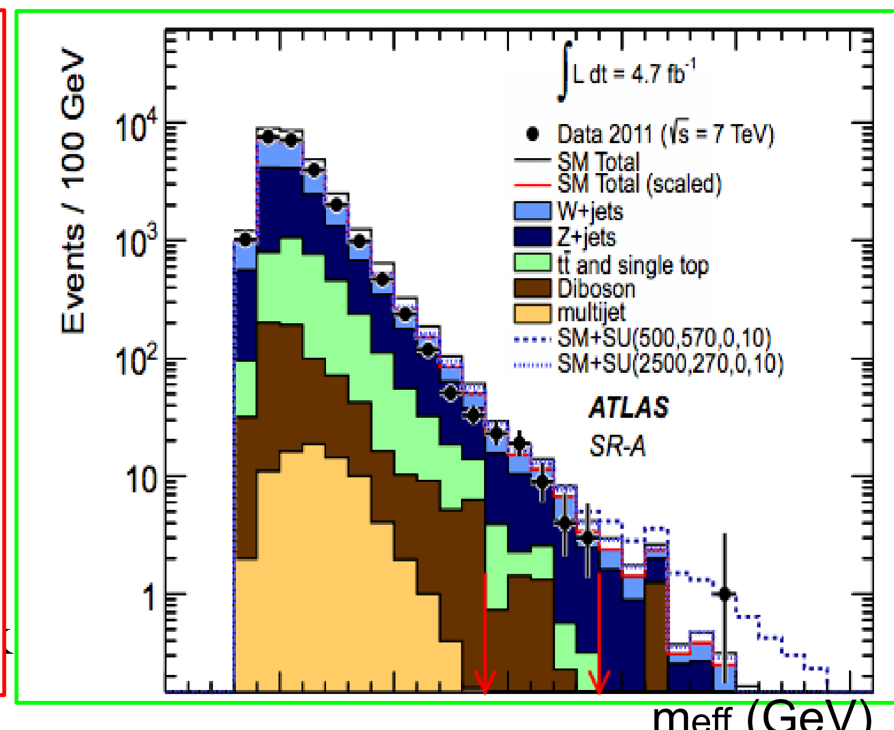
Control Region Process



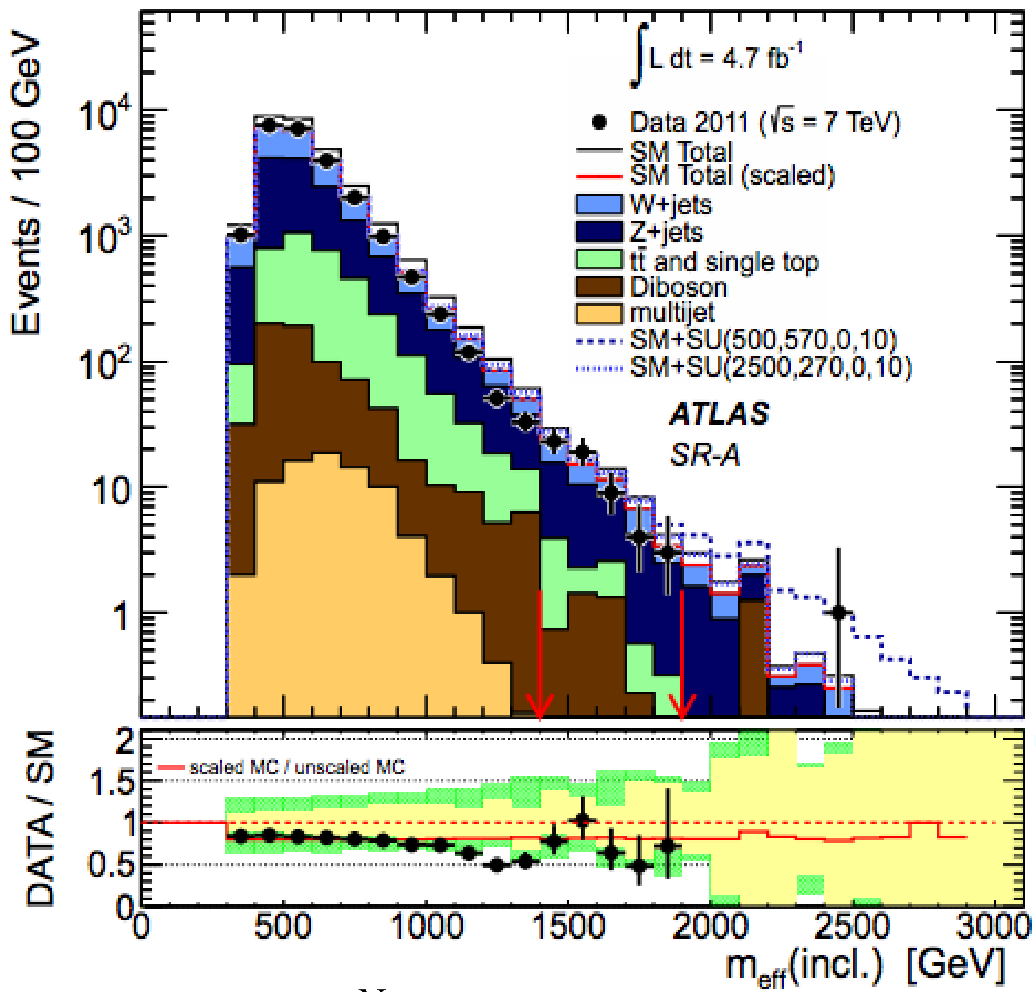
Background Estimates in Signal Region

- Measure each individual background rate in "control regions", where you do not expect any contamination from signal
- Once you have calculated the number of background events in each CONTROL region, you must translate that into an estimation of the background in the SIGNAL region
- The translation of the N_{bkg} as measured in the control region → signal region is never perfect ==> log likelihood fit





Results for 2 jets channel



$$m_{eff} = \sum_{i=1}^{N} p_T^i + E_T^{miss}$$

- m_eff (top plot) for 2 jet events
- Red arrows indicate the lower limits on the two signal regions defined in this analysis channel
- SM + SUSY expectation shown in dashed lines
- DATA/MC (Bottom plot)
  - Yellow band is total experimental uncertainty
  - Green band includes theoretical uncertainties

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Search Results

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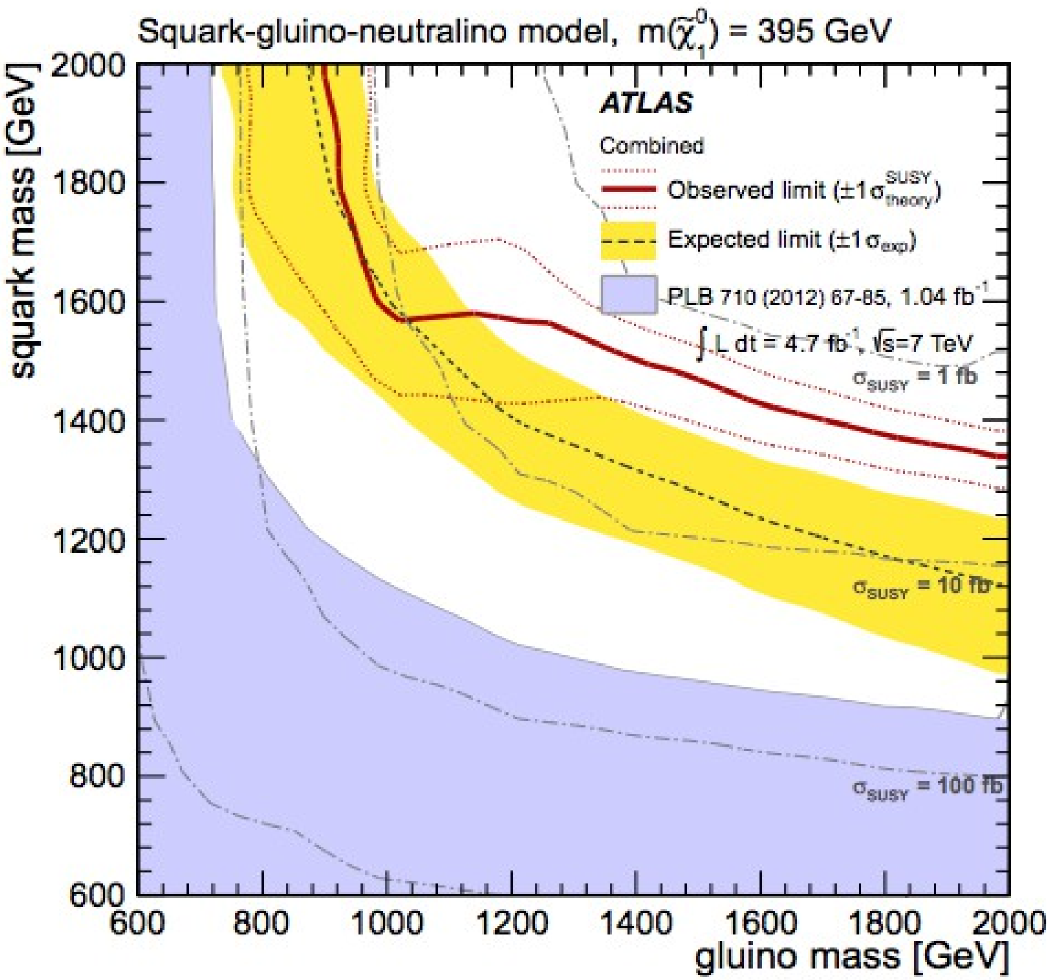
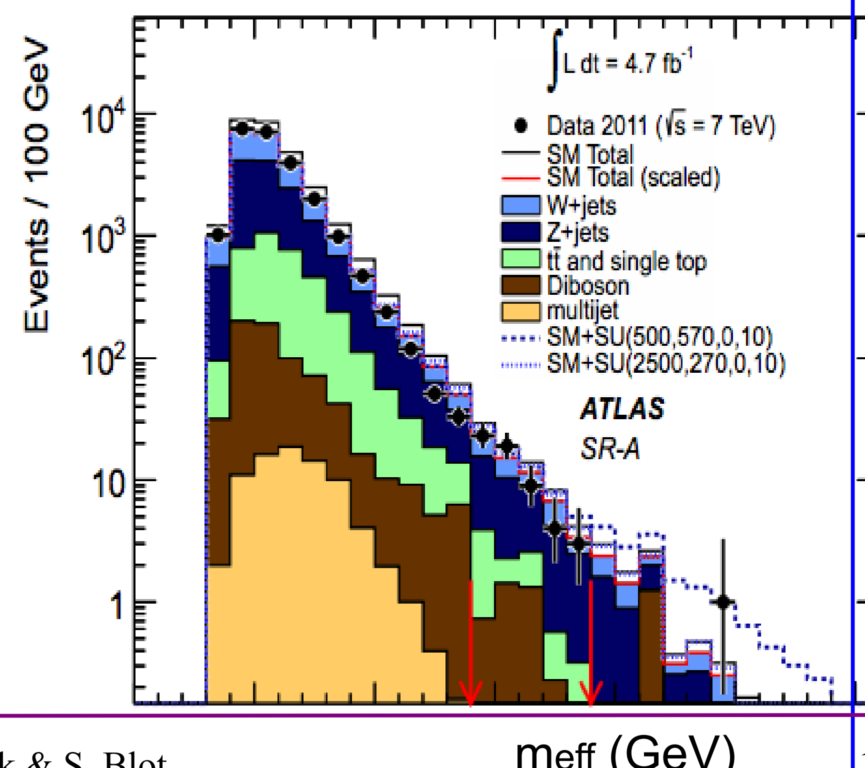
- No excess above background is observed in any of the signal regions
- Thus, exclusion limits are set for specific SUSY models taking into account uncertainties, different cross sections and branching ratios
- Put more simply, *if* SUSY particles existed with a certain mass/cross section/etc (model parameters), then we *would* have seen an excess of events
- Because we don't, we can exclude SUSY in the phase space available to these models

Results

- 95% CLs exclusion limits for squark and gluino masses in MSSM models with neutralino mass non-zero





Conclusions

- Search for squarks and gluinos was performed using the ATLAS detector
- Done by looking for events with multiple (≥ 2) jets and missing E_T
- Must know your backgrounds REALLY well, so that you can say with some *confidence* whether or not you see an excess in the data
  - Use many different "control regions" to measure backgrounds
  - Final likelihood fit to simultaneously fit the background in the control & signal regions
- No excess is seen, so results can be used to exclude some SUSY models

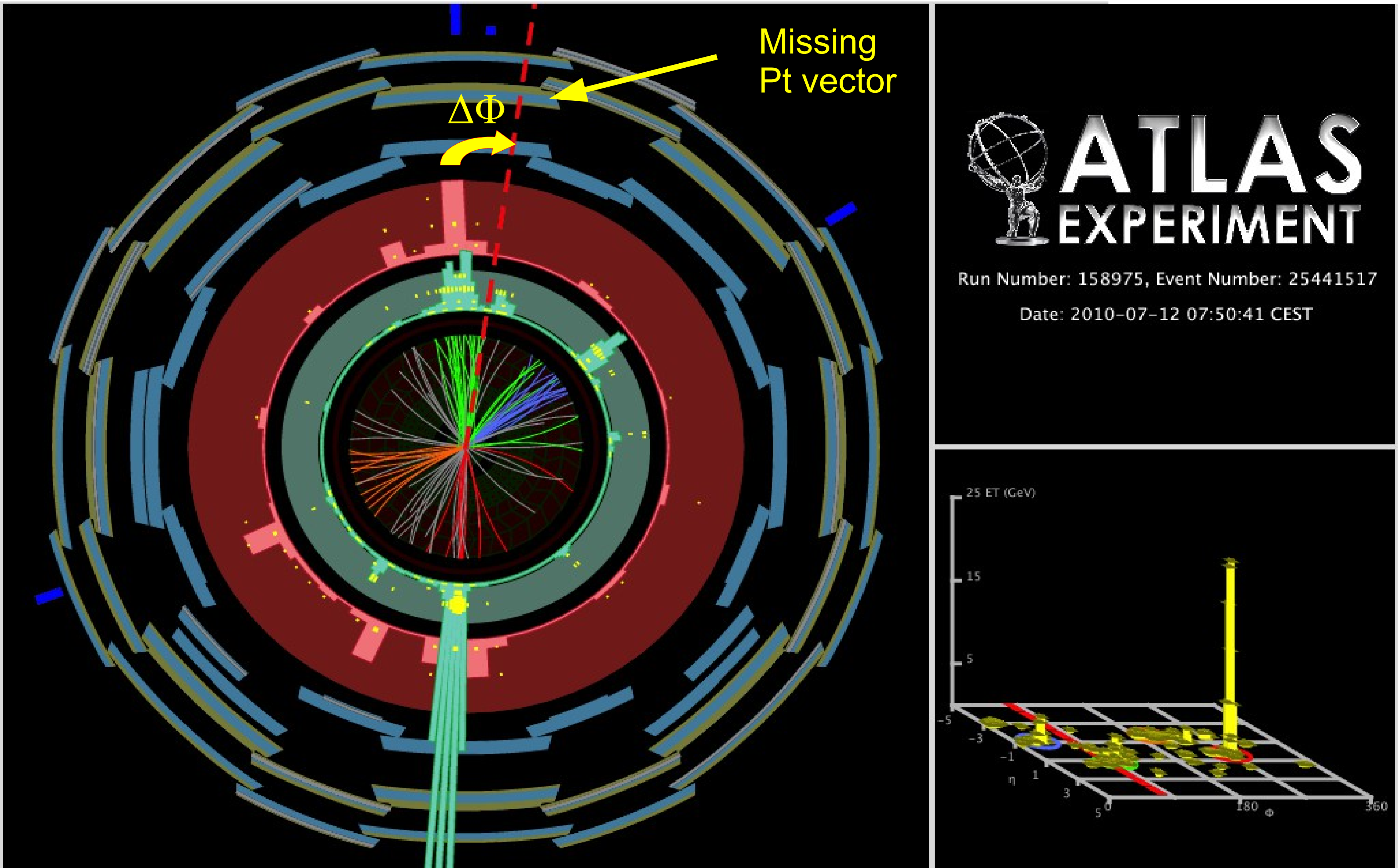
References

Early supersymmetry searches in events with missing transverse energy and b-jets with the ATLAS detector (ATLAS-CONF-2010-079, 20 August 2010)

Figure 14:

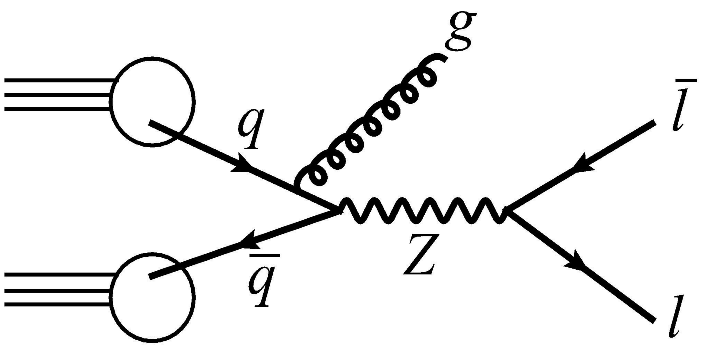
Transverse (top left), longitudinal (bottom) and lego plot (top right) views of the event EV1 (see Table in the text), with 3 b-tagged jets. The energy deposited in the electromagnetic (hadronic) calorimeter is shown in green (red). The direction of the ETmiss is along the dotted red line. Same colour is applied to all the tracks associated to a particular jet. Muon segments are also shown.Â

Sample Event Display



Irreducible Background: $Z(\rightarrow \nu\bar{\nu}) + \text{jets}$

- This particular background is very difficult to detect directly
- Easier to measure the rate in cleaner channels, and then translate the rate from those channels into the $Z \rightarrow \nu\bar{\nu}$ + jets rate
- For this particular analysis, they use
  - $Z \rightarrow l\bar{l}$ + jets; and
  - γ + jets



- For example, the number of $Z \rightarrow \nu\bar{\nu}$ + jets can be estimated from γ + jets via the relationship

$$N^{Z(\rightarrow\nu\bar{\nu})}(p_{\mathrm{T}}) = N^{\gamma}(p_{\mathrm{T}}) \cdot \left[\frac{(1-f_{\mathrm{bkg}})}{\varepsilon^{\gamma}(p_{\mathrm{T}}) \cdot A^{\gamma}(p_{\mathrm{T}})} \cdot R_{Z/\gamma}(p_{\mathrm{T}}) \cdot Br(Z \rightarrow \nu\bar{\nu})\right].$$

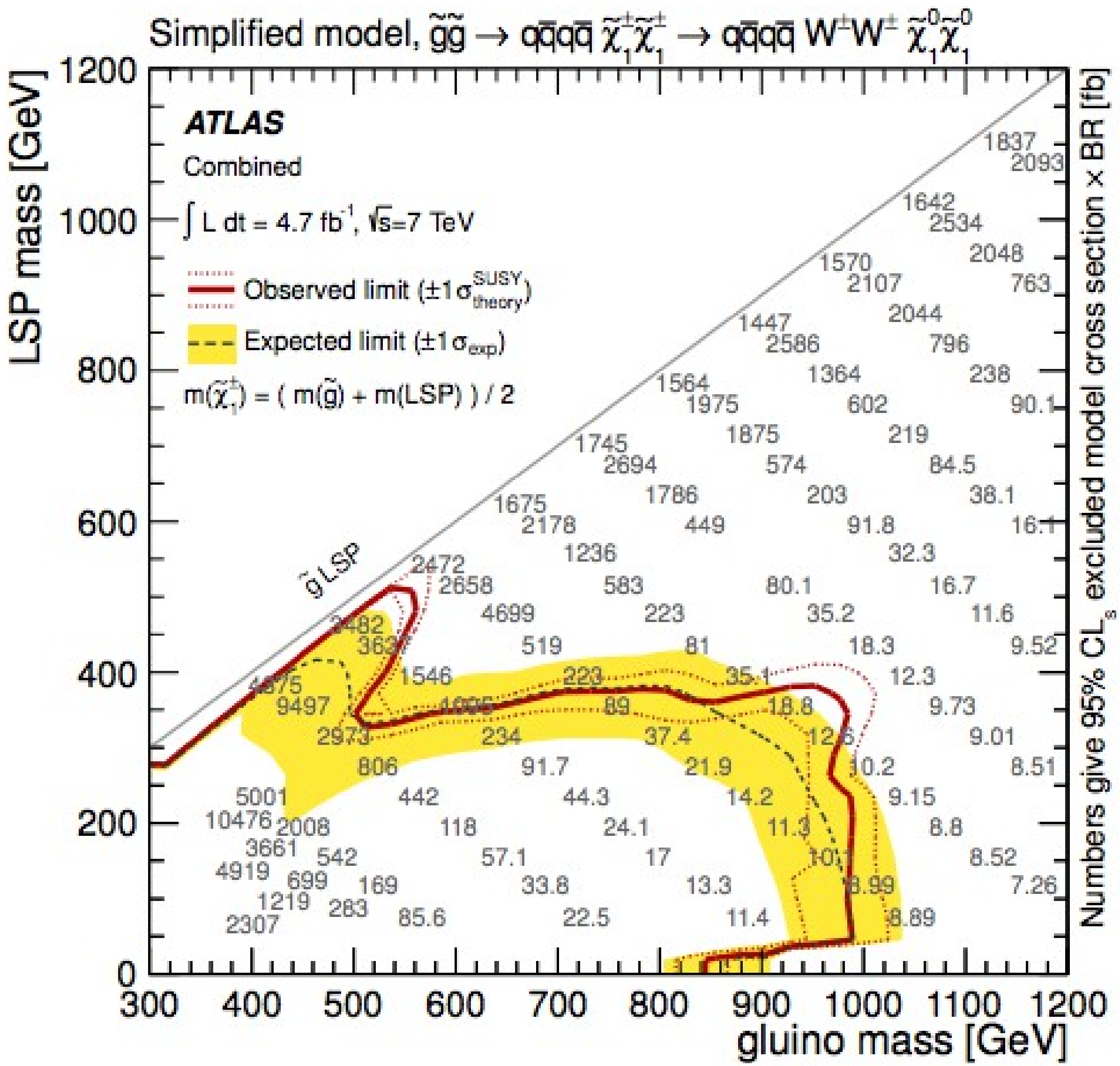
Background Estimates in Signal Region

- Once you have calculated the number of observed background events in each CONTROL region, you must translate that into an estimation of the background in the SIGNAL region
- This is done using a "transfer factor" (TF), defined as

$$N(SR, scaled) = N(CR, obs) \times \left[\frac{N(SR, unscaled)}{N(CR, unscaled)} \right]$$

- The translation of the N_{bkg} as measured in the control region → signal region is never perfect
- So, there is a final step where we perform a likelihood fit on the backgrounds in the signal and corresponding control regions.
  - See ROOT and statistics introduction talks for more details of log likelihood fitting

Results


Simplified model, $\tilde{g}\tilde{g} \rightarrow q\bar{q}q\bar{q}\,\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm} \rightarrow q\bar{q}q\bar{q}\,W^{\pm}W^{\pm}\,\tilde{\chi}_1^0\tilde{\chi}_1^0$
ATLAS
Combined
$\int L\,dt = 4.7\ fb^{-1}$, $\sqrt{s}$=7 TeV
Observed limit ($\pm 1\sigma^{SUSY}_{theory}$)
Expected limit ($\pm 1\sigma_{exp}$)
$m(\tilde{\chi}_1^{\pm}) = (\,m(\tilde{g}) + m(LSP)\,)/2$
$\tilde{g}$ LSP
LSP mass [GeV]
gluino mass [GeV]
Numbers give 95% CL_s excluded model cross section × BR [fb]