NEGLECTED SUSY; A PERSPECTIVE ON CURRENT SEARCHES

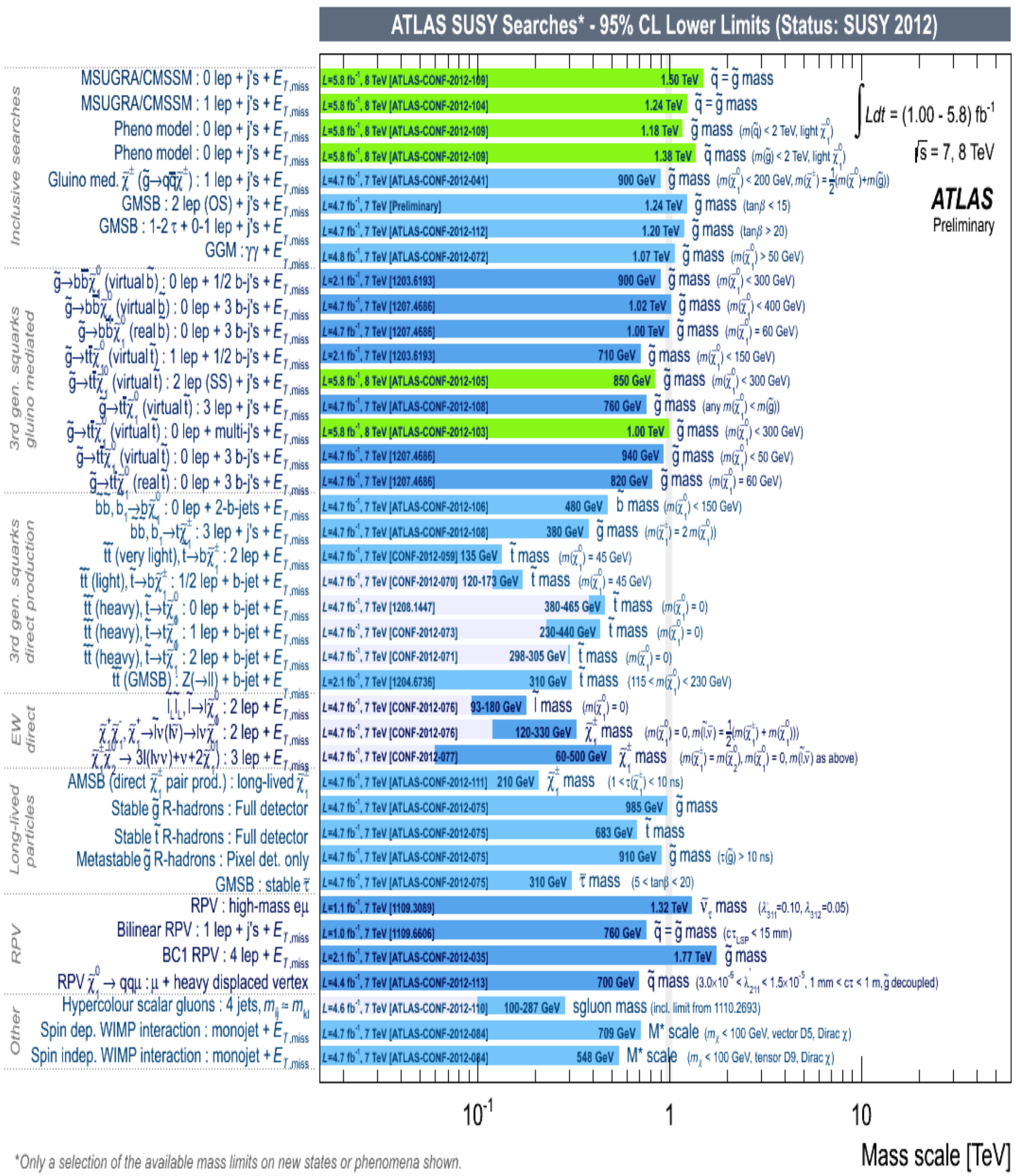
Based on unapproved CMS results, work and several conversations with M. Pierini, G. Rolandi, M. Lisanti, …

(I am the only one to blame)

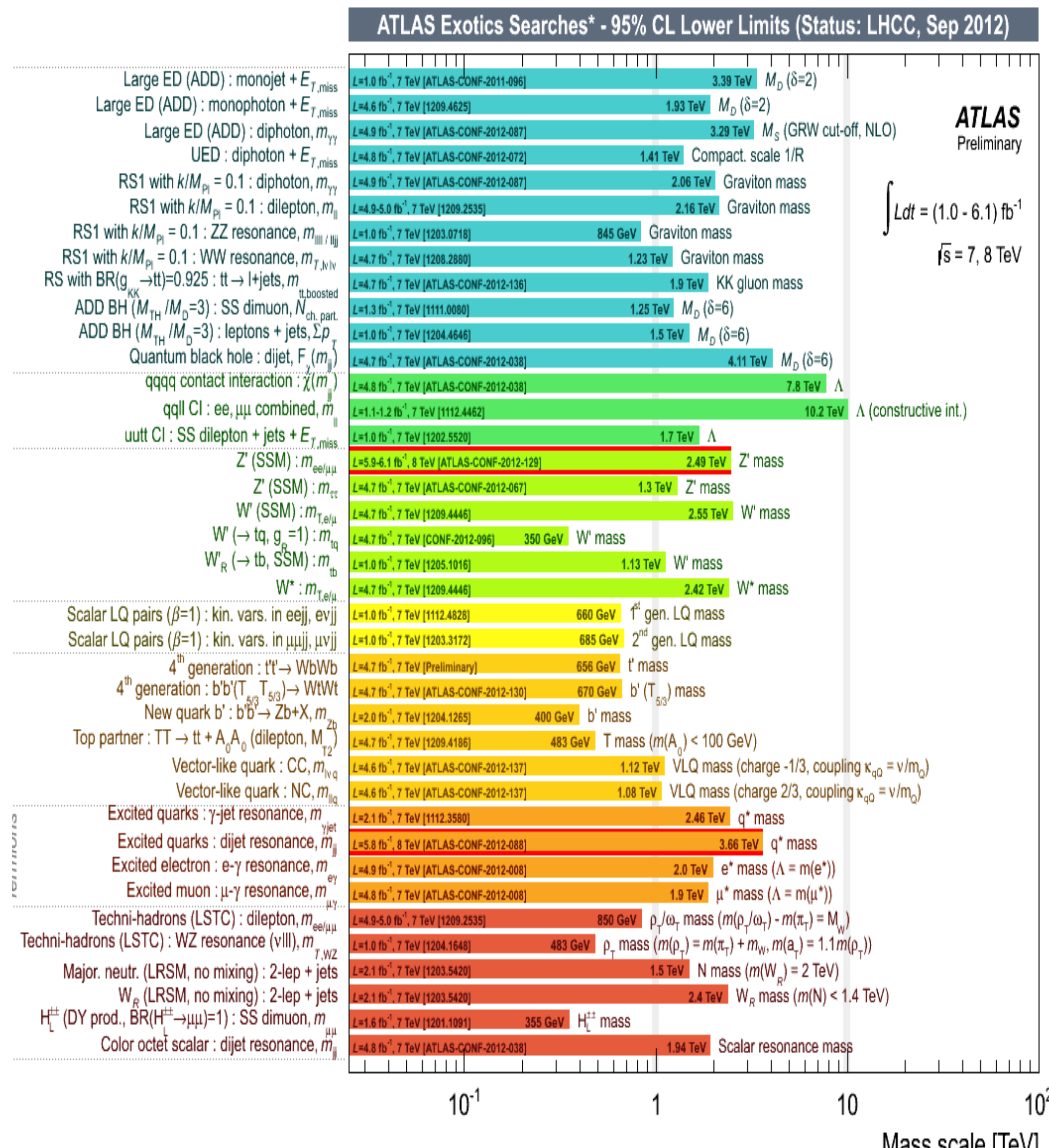
SUMMARY

- One loophole and one handle
  - Natural SUSY searches
- My view of the future

IS THAT EVEN POSSIBLE?



*Only a selection of the available mass limits on new states or phenomena shown.
All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.



nly a selection of the available mass limits on new states or phenomena shown

RELAXING ASSUMPTIONS

- SUSY = MET + X

  (with notable exceptions diphotons, SS dileptons and multileptons)

RELAXING ASSUMPTIONS

- SUSY = MET + X

  (with notable exceptions diphotons, SS dileptons and multileptons)

- New physics = high scale = hard objects

RELAXING ASSUMPTIONS

- SUSY = MET + X

Reminder: MET = p_T of the stable particle

- New physics ~ high scale ~ hard objects or many soft objects

SCUOLA NORMALE SUPERIORE PISA

NATURALNESS

gluino AND stops AND higgsinos

NATURALNESS

gluino AND stops AND higgsinos

$$M_3 \lesssim 1.3 \text{ TeV } \sin\beta \left(\frac{\log \Lambda/\text{TeV}}{3}\right)^{-1} \left(\frac{m_h}{125 \text{ GeV}}\right) \sqrt{\frac{10\%}{\Delta^{-1}}}$$

$$\frac{\sigma(m_{\tilde{g}}=1.5 \text{ TeV})}{\sigma(m_{\tilde{g}}=1 \text{ TeV})} \sim 10^{-2}$$

NATURALNESS

gluino AND stops AND higgsinos

$$t\bar{t}t\bar{t} + \chi^0\chi^0 \longleftrightarrow b\bar{b}b\bar{b} + \chi^0\chi^0$$

$$.., t\bar{b}\bar{t}b + X, ...$$

SCUOLA NORMALE SUPERIORE PISA

NATURALNESS

CMS Compact Muon Solenoid

gluino AND stops AND higgsinos

$$\bar{t}sb\bar{t}sb, qqqqqq, \ldots$$

OUT OF THE MET BOX

- SUSY configurations with low MET
  - RPV
  - Cascade decays or moderately squeezed spectrum
    - For very small mass splittings (for instance chargino-neutralino) p_T(mother) ~ p_T(daughter)
  - Partly visible decays of the lightest MSSM neutralino (NMSSM, gravitino LSP)

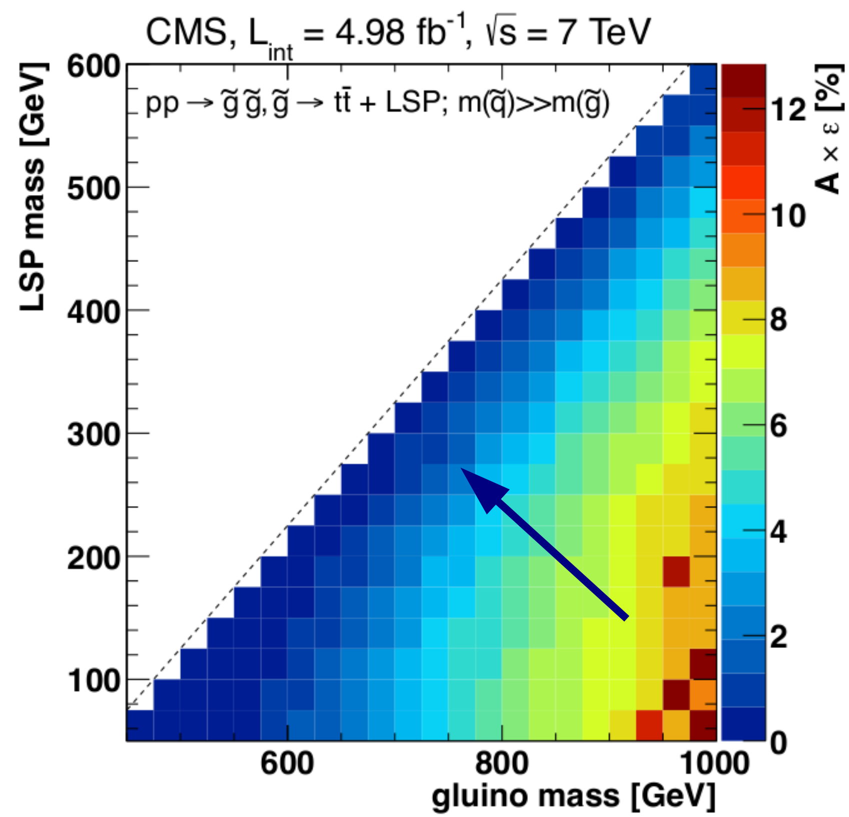
OUT OF THE MET BOX

- SUSY configurations with low MET
  - RPV
  - Cascade decays or moderately squeezed spectrum
  - Partly visible decays of the lightest MSSM neutralino (NMSSM, gravitino LSP)
- High multiplicities
  - Jets from RPV, extra W's, Z's, h's, extra steps in the cascades
- Rare objects: leptons (details of the spectrum are important), photons

IT IS SO TYPICAL (HADRONIC)

- We are not always doing our best, even before ISR becomes important

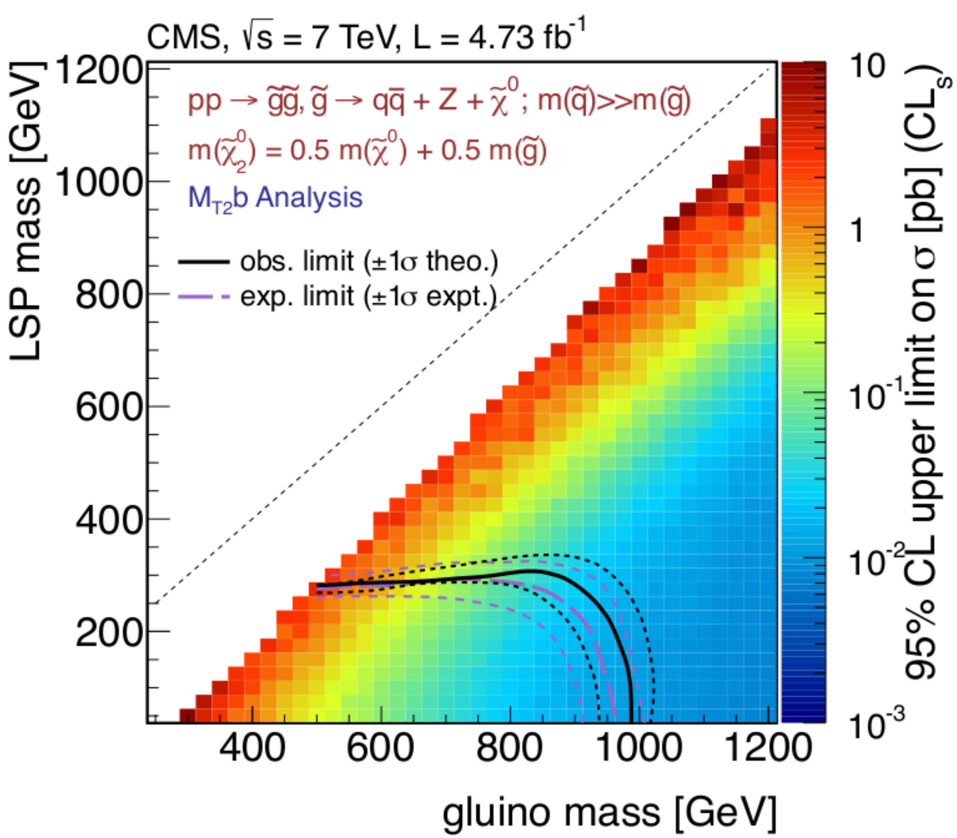
Signal region		H_T [GeV]	E_T^{miss} [GeV]	N_{bjets}
1b-loose	1BL	> 400	> 250	≥ 1
1b-tight	1BT	> 500	> 500	≥ 1
2b-loose	2BL	> 400	> 250	≥ 2
2b-tight	2BT	> 600	> 300	≥ 2
3b	3B	> 400	> 250	≥ 3

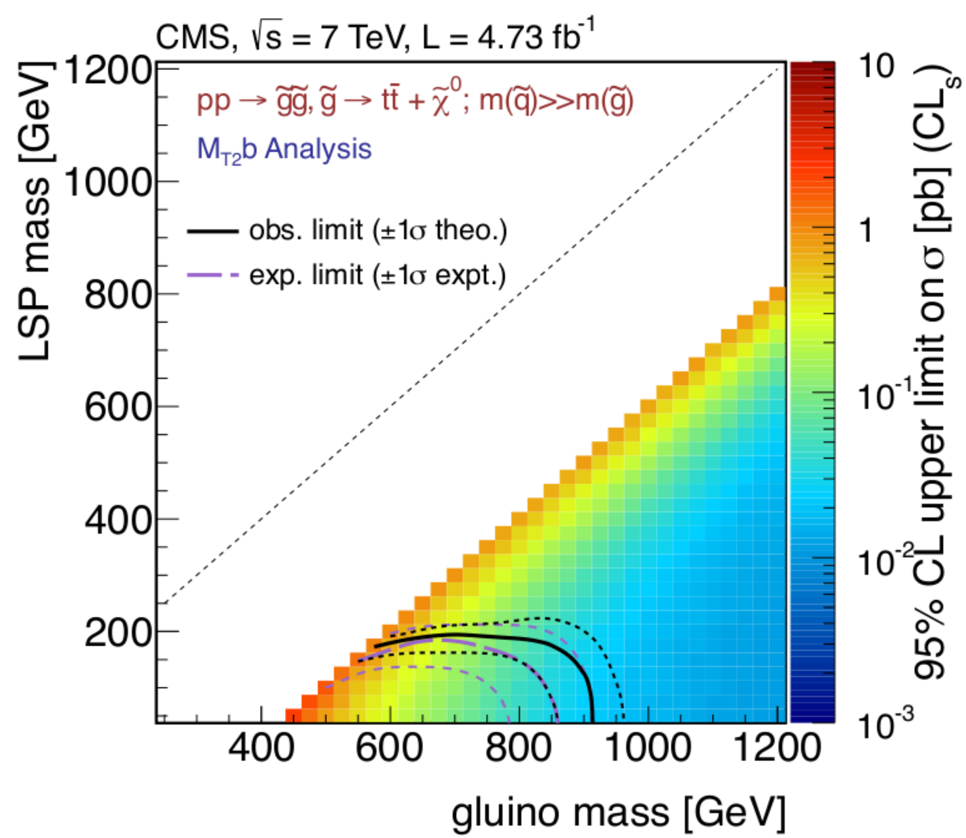


~ 1/10 in efficiency

IT IS SO TYPICAL (HADRONIC)

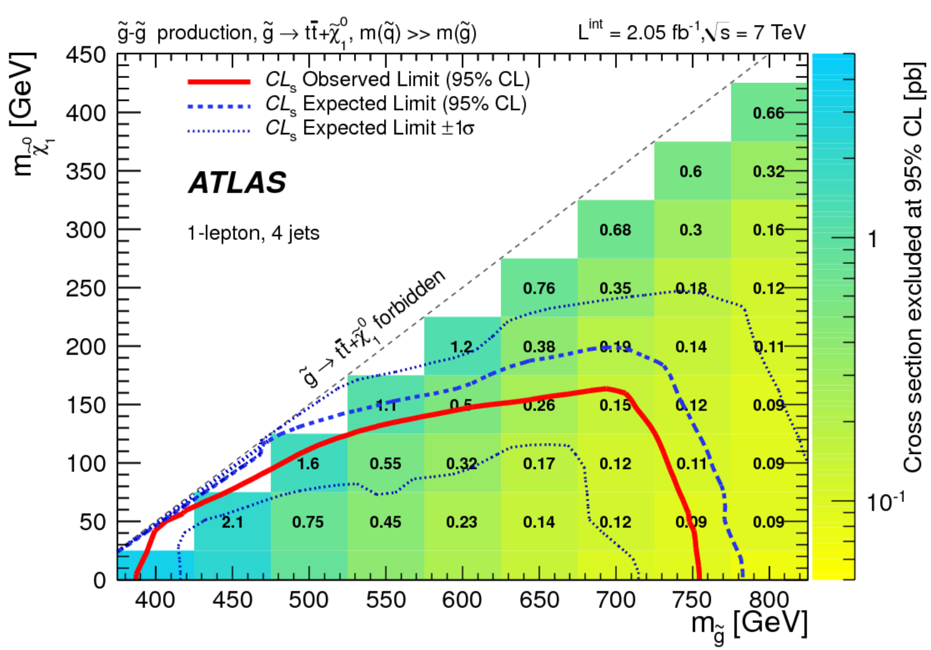
- We are not always doing our best, even before ISR becomes important

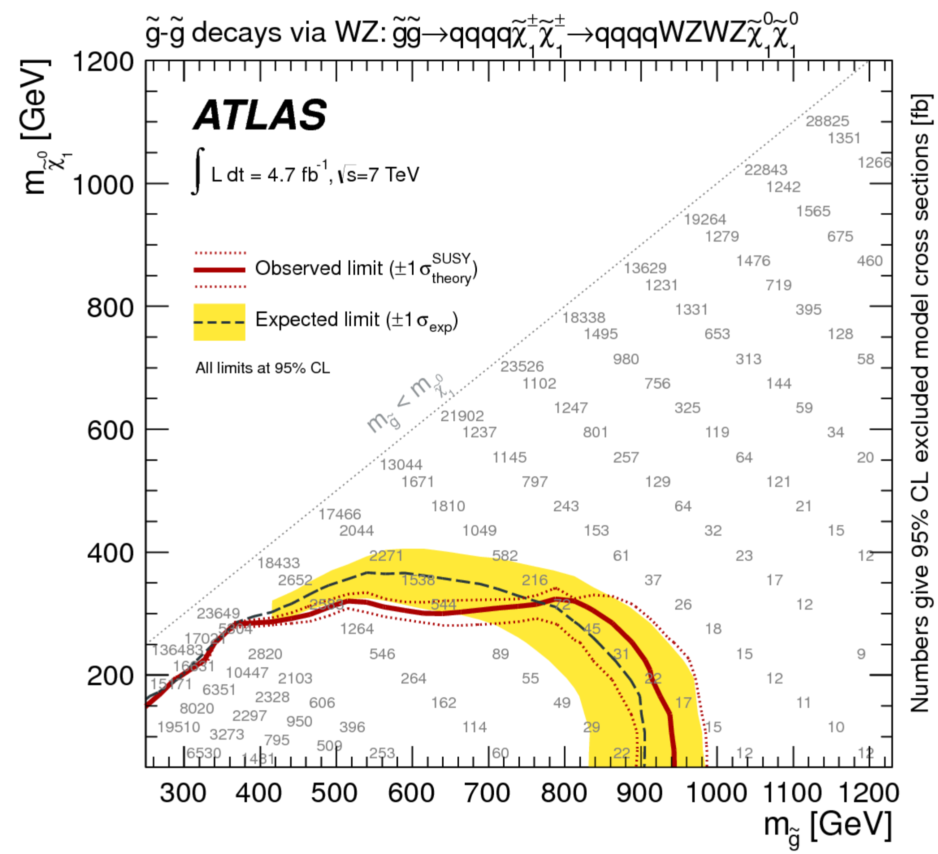




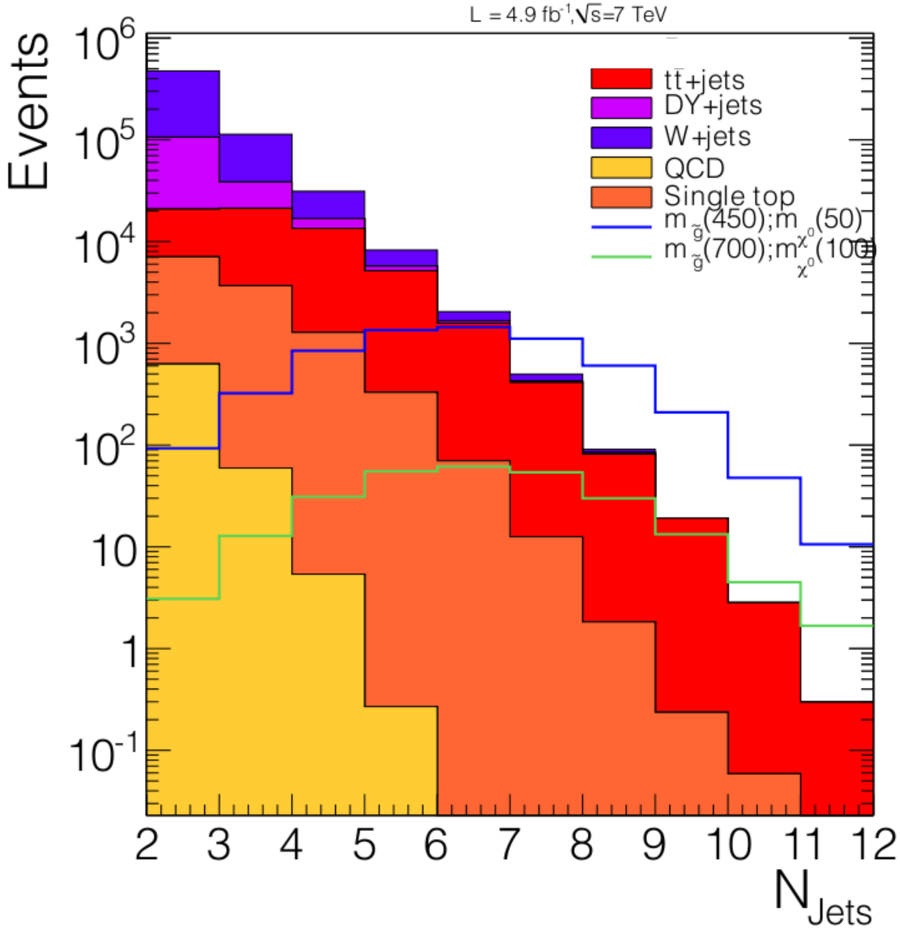
IT IS SO TYPICAL

- We are not always doing our best, even before ISR becomes important

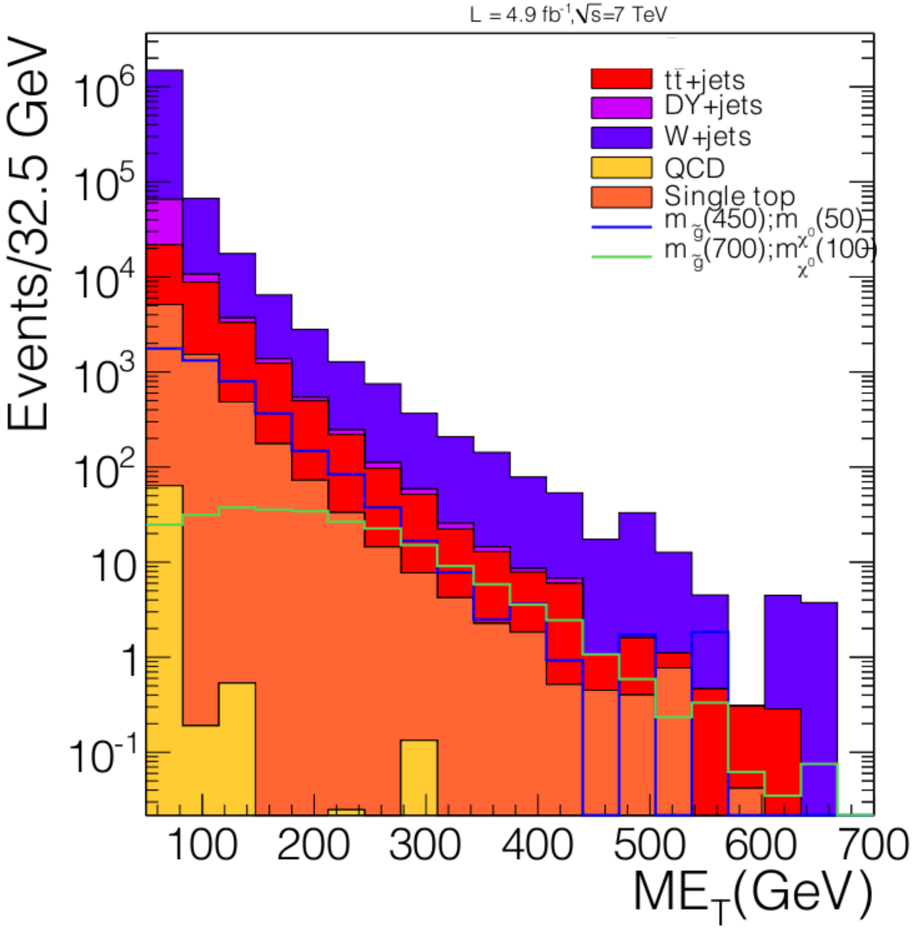




ONE HANDLE

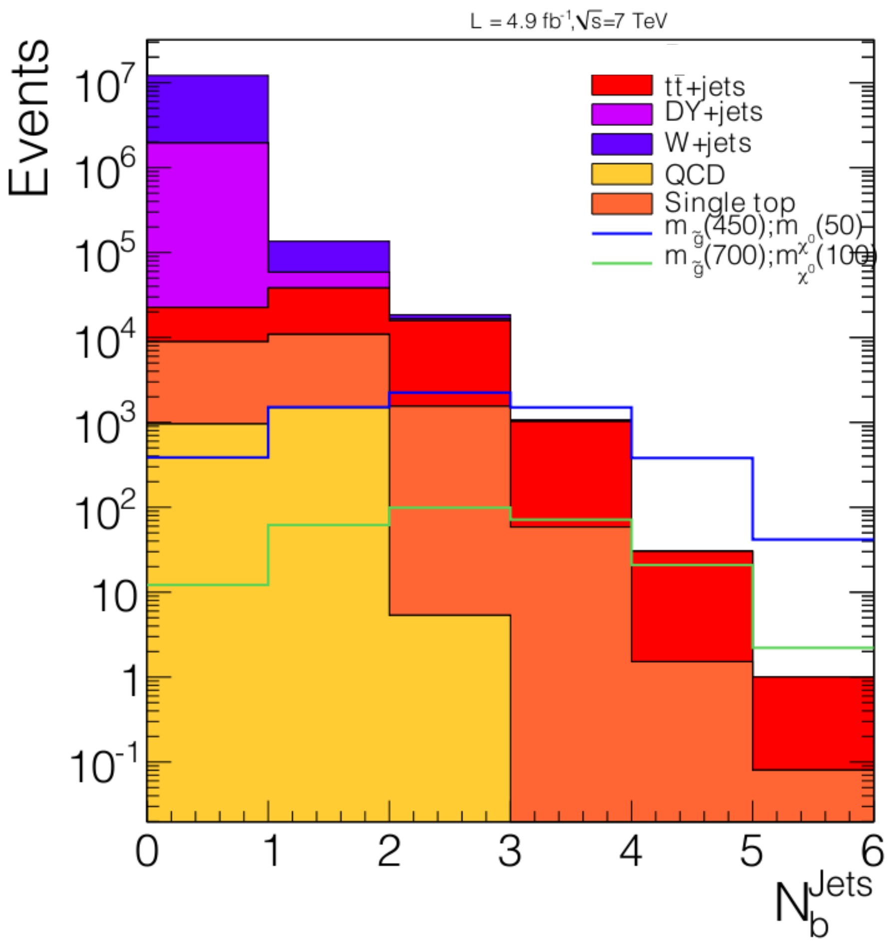


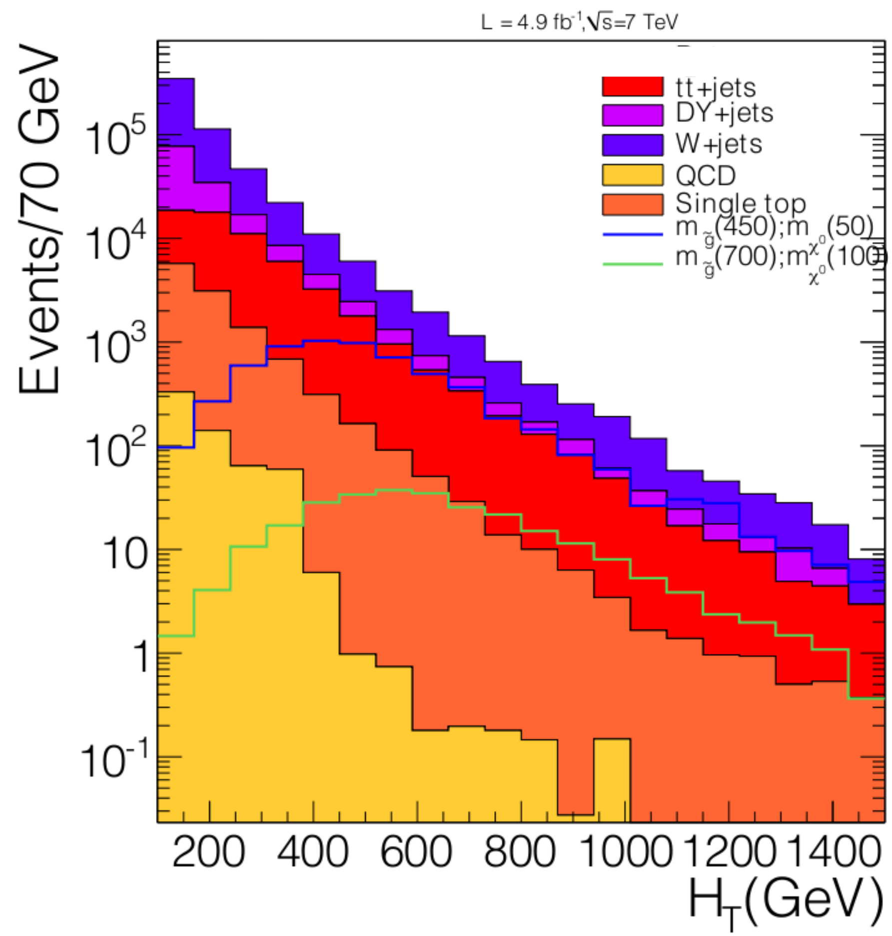
L = 4.9 fb^{-1},$\sqrt{s}$=7 TeV
Events
$t\bar{t}$+jets
DY+jets
W+jets
QCD
Single top
$m_{\tilde{g}}(450);m_{\chi^0}(50)$
$m_{\tilde{g}}(700);m_{\chi^0}(100)$
N_{Jets}



L = 4.9 fb^{-1},$\sqrt{s}$=7 TeV
Events/32.5 GeV
$t\bar{t}$+jets
DY+jets
W+jets
QCD
Single top
$m_{\tilde{g}}(450);m_{\chi^0}(50)$
$m_{\tilde{g}}(700);m_{\chi^0}(100)$
ME_T(GeV)

TWO HANDLES


L = 4.9 fb-1, √s=7 TeV
Events
tt̄+jets
DY+jets
W+jets
QCD
Single top
m g̃(450);m χ0(50)
m g̃(700);m χ0(100)
N_b^Jets


L = 4.9 fb-1, √s=7 TeV
Events/70 GeV
tt+jets
DY+jets
W+jets
QCD
Single top
m g̃(450);m χ0(50)
m g̃(700);m χ0(100)
H_T(GeV)

SCUOLA NORMALE SUPERIORE PISA

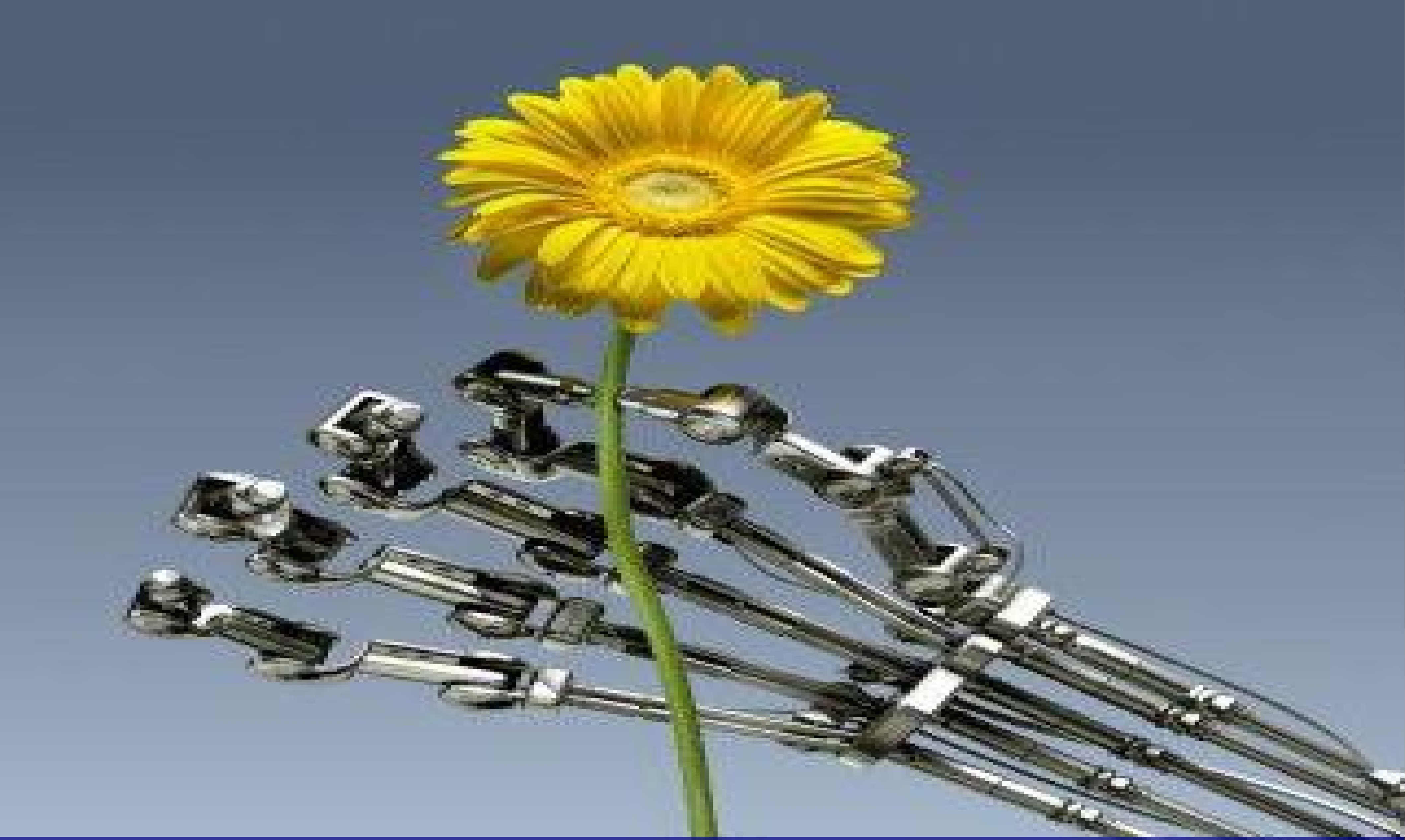
IN THE MATRIX

3 leptons	WHY NOT				
2 leptons					
1 lepton	IN PROGRESS				
0 lepton	NEED EXTRA DISCRIMINATION (b-tagging)				
	5 jets	6 jets	7 jets	8 jets	≥ 9 jets

$$(N_l, N_J, N_b)$$

CAN IT WORK?

- Multi-jet background
  - Berends-Giele scaling + phenomenological correction from the Tevatron (essentially a fit to the data)
  - Prerequisite: separate W from Z from tt from QCD
  - Byproduct: first measurement of the scaling for tt
- Multi-b background
  - Assume MC has the p_T and η of the jets (almost) right
  - Correct MC for efficiencies measured on data (p_T-rel template fit)



MY VIEW OF THE FUTURE

EDEN

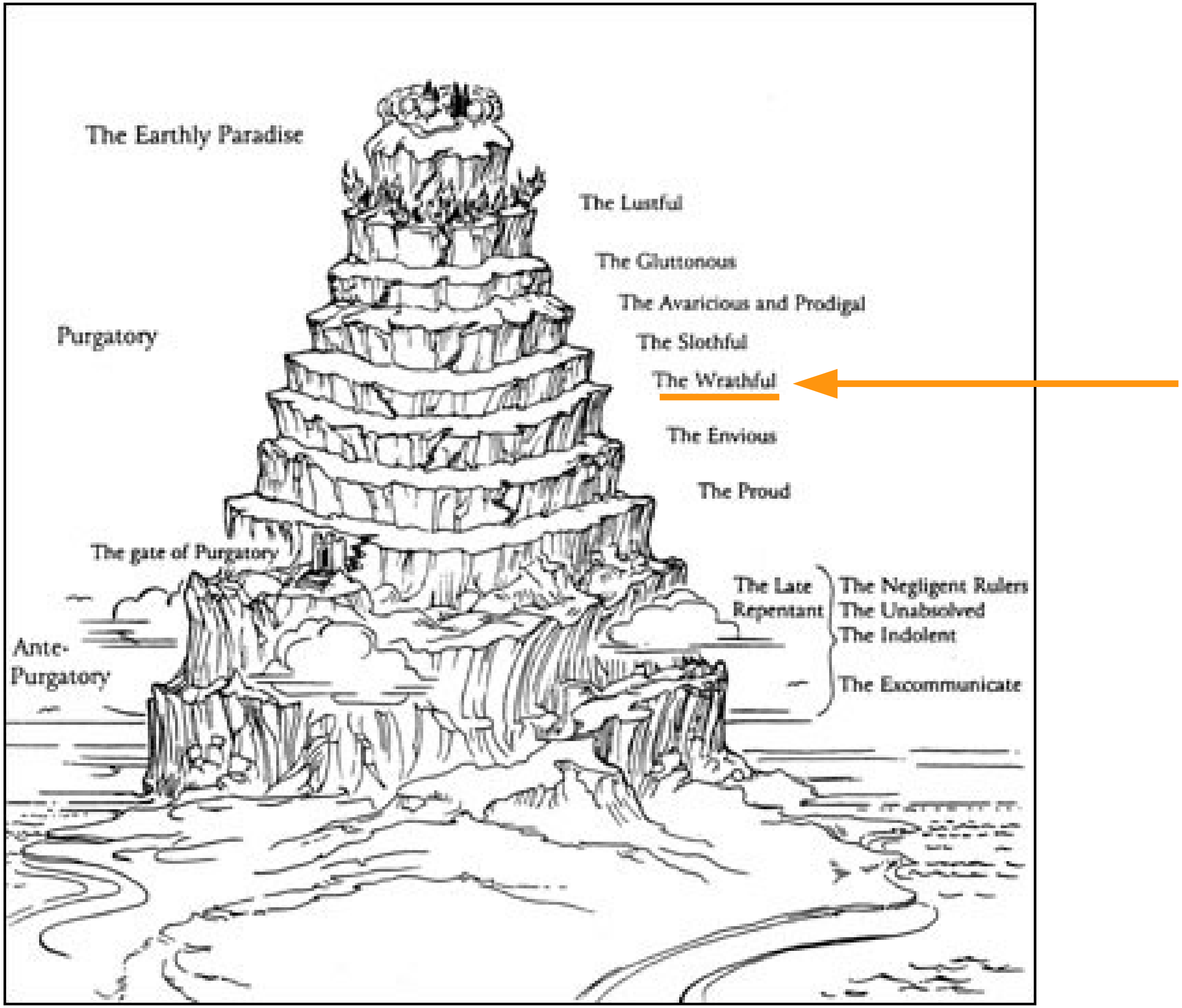
- Theory input
  - Dedicated searches to pursue outside of the grid
  - New dimensions for the grid
  - Simplified understanding of classes of models

EDEN

- Theory input
  - Dedicated searches to pursue outside of the grid
  - New dimensions for the grid
  - Simplified understanding of classes of models
- Experimental output
  - New physics discovery

EDEN

- Theory input
  - Dedicated searches to pursue outside of the grid
  - New dimensions for the grid
  - Simplified understanding of classes of models
- Experimental output
  - N_{bkg}, σ_{bkg}, N_{data} (for each point in the grid) + public simulation
  - Likelihood (where doable)


The Earthly Paradise
The Lustful
The Gluttonous
The Avaricious and Prodigal
Purgatory
The Slothful
The Wrathful
The Envious
The Proud
The gate of Purgatory
The Late Repentant
The Negligent Rulers
The Unabsolved
The Indolent
Ante-Purgatory
The Excommunicate

THE PURGATORY

- Theory input
  - Dedicated searches to pursue outside of the grid
    - Ok : stops, long lived, ...
  - New “dimensions” for the grid
    - Ok : α_T , jet substructure, ...
  - Simplified understanding of classes of models
    - Done for vanilla SUSY, but missing RPV, long lived and heavy colored objects travelling inside the detector

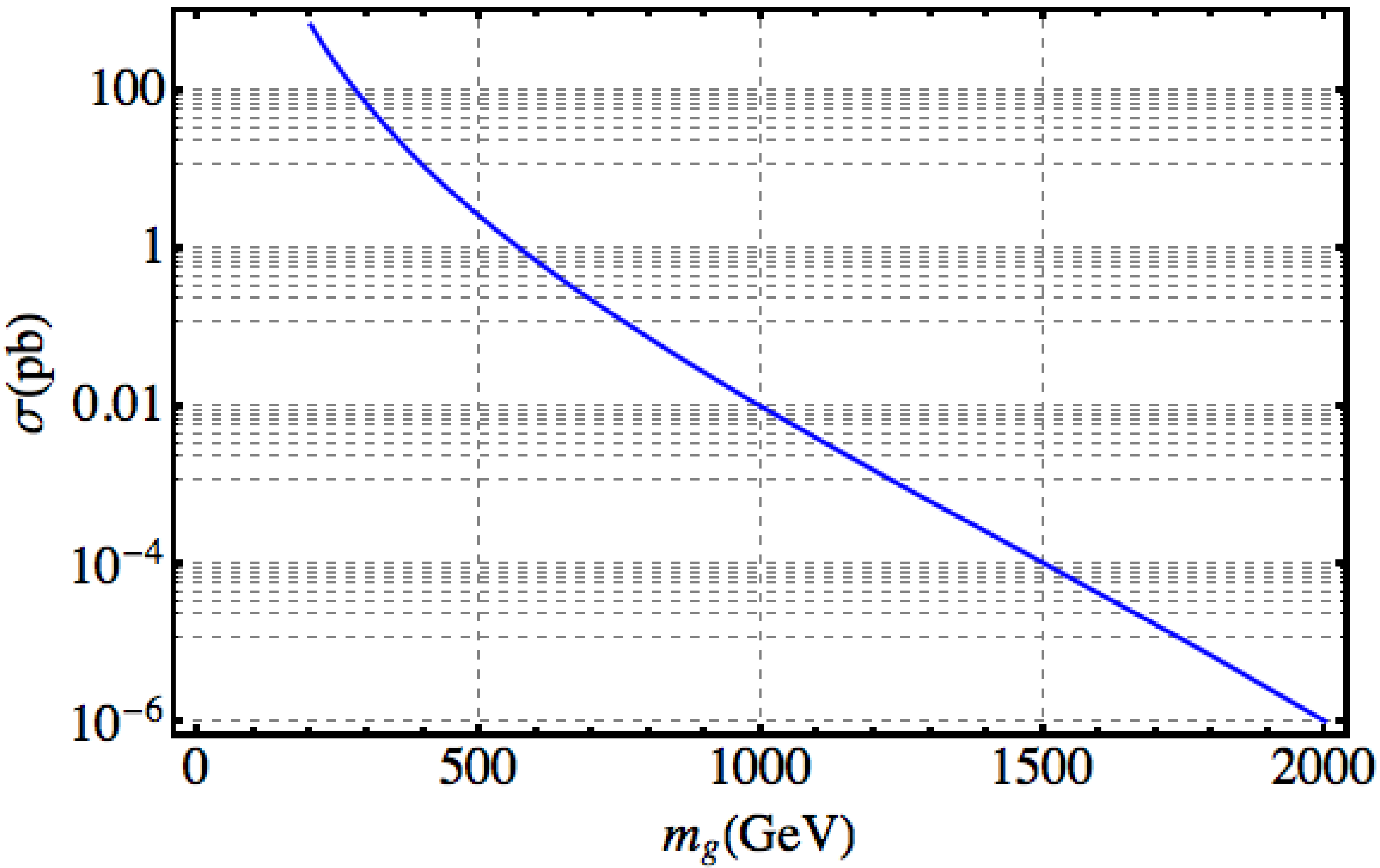
THE PURGATORY

- Experimental output
  - N_{bkg}, σ_{bkg}, N_{data} (for each point in the grid) + public simulation
    - Strong opposition inside the collaborations
    - Next-to-ideal: fill the grid (not even analyses, just counting experiments) and give detector to generator curves → Razor example
  - Likelihood (where doable)
    - “I'd be dead before [LHC experiment] releases a likelihood”. Anonymous

CONCLUSIONS

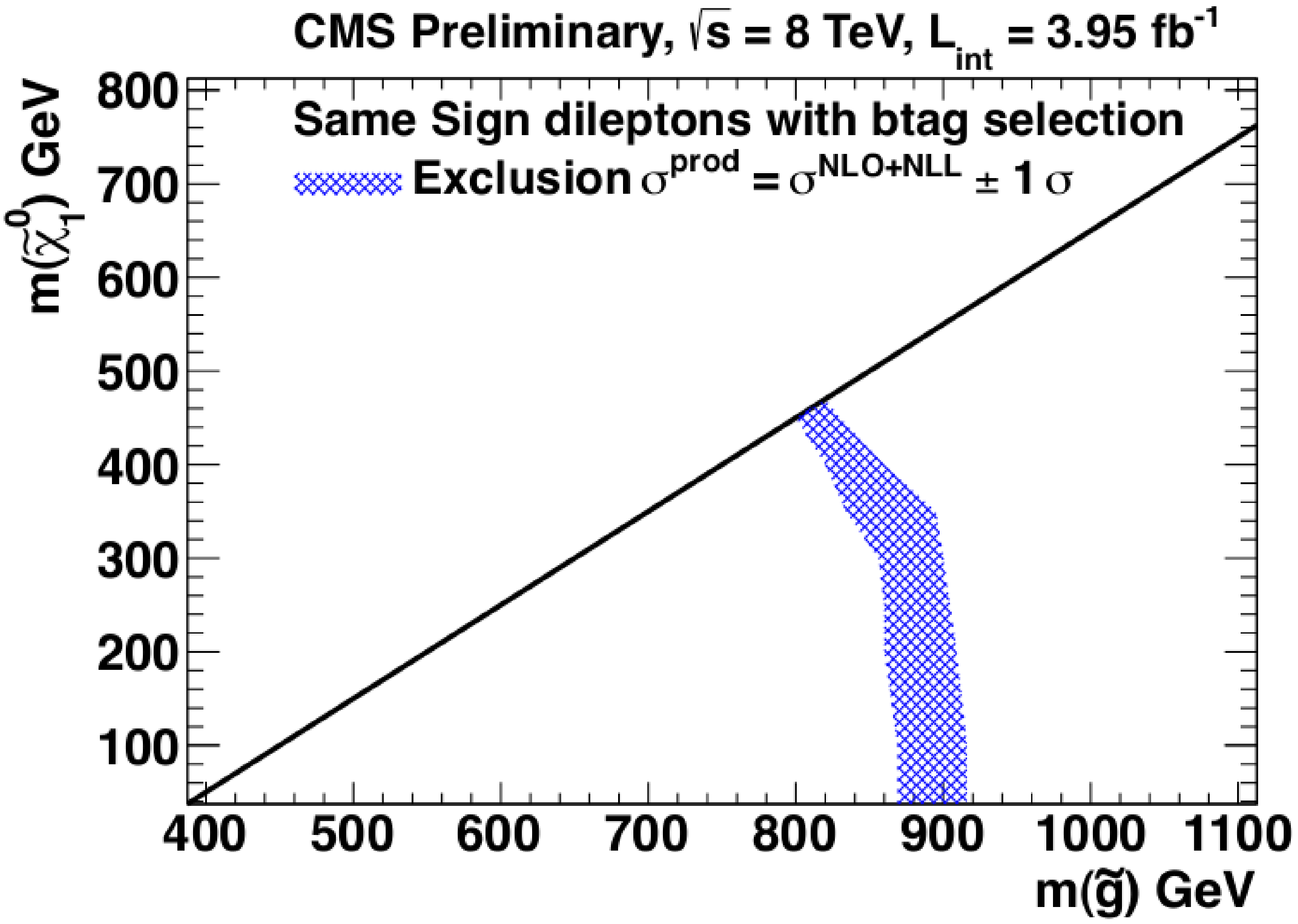
- There is a blind spot in our searches, but no fundamental obstacles (i.e. trigger) in front of us.
- In terms of discovery potential we are doing a great job, also thanks to cross feedback between theorists and experimentalists, but ...
- The future can be a much better place.

GLUINO 7 TeV



https://twiki.cern.ch/twiki/bin/view/LHCPhysics/SUSYCrossSections

SS DILEPTONS+b



SRs FOR THE EXAMPLE ANALYSES

CMS MT2

$750 \leq H_T < 950$
$M_{T2}[0,\infty]$
$M_{T2}[150,200]$
$M_{T2}[200,275]$
$M_{T2}[275,375]$
$M_{T2}[375,500]$
$M_{T2}[500,\infty]$
$H_T \geq 950$
$M_{T2}[0,\infty]$
$M_{T2}[150,200]$
$M_{T2}[200,275]$
$M_{T2}[275,375]$
$M_{T2}[375,500]$
$M_{T2}[500,\infty]$

ATLAS 1-2lepton

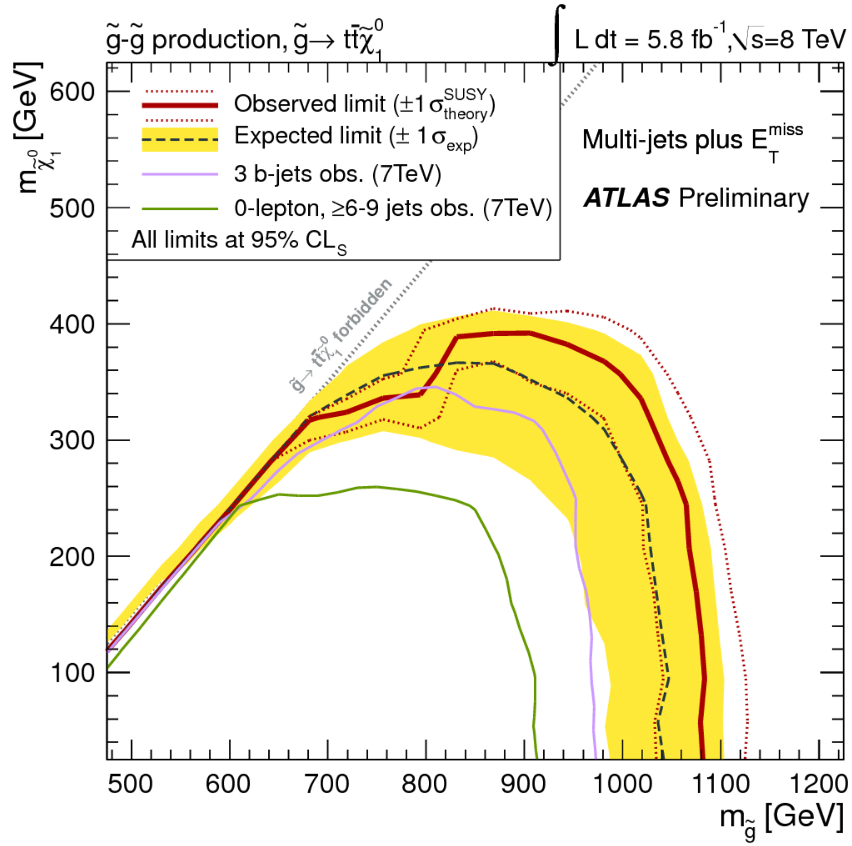
	single-lepton			multi-lepton	
	3-jet	4-jet	soft-lepton	2-jet	4-jet
Trigger	Single electron or muon (+jet)		Missing E_T	Single electron or muon (+jet)	
N_{lep}	1	1	1	≥ 2	≥ 2
p_T^{ℓ} (GeV)	> 25 (20)	> 25 (20)	7 to 25 (6 to 20)	25 (20)	25 (20)
$p_T^{\ell_2}$ (GeV)	< 10	< 10	< 7 (6)	> 10	> 10
N_{jet}	≥ 3	≥ 4	≥ 2	≥ 2	≥ 4
p_T^{jet} (GeV)	> 100, 25, 25	> 80, 80, 80, 80	> 130,25	> 200,200	> 50,50,50,50
$p_T^{add.jet}$ (GeV)	< 80	—	—	< 50	—
E_T^{miss} (GeV)	> 250	> 250	> 250	> 300	> 100
m_T (GeV)	> 100	> 100	> 100	—	—
E_T^{miss}/m_{eff}	> 0.3	> 0.2	> 0.3	—	0.2
m_{eff}^{inc} (GeV)	> 1200	> 800	—	—	> 650

ATLAS 1lepton+4jets

Pre-selection	Signal Region name	Selection
no leptons, at least three jets, $p_T(j1) > 130$ GeV, $p_T(j2, j3) > 50$ GeV, $E_T^{miss} > 130$ GeV, $E_T^{miss}/m_{eff} > 0.25$, $\Delta\phi_{min} > 0.4$	SR0-A1	at least one b-tag, $m_{eff} > 500$ GeV
	SR0-B1	at least one b-tag, $m_{eff} > 700$ GeV
	SR0-C1	at least one b-tag, $m_{eff} > 900$ GeV
	SR0-A2	at least two b-tags, $m_{eff} > 500$ GeV
	SR0-B2	at least two b-tags, $m_{eff} > 700$ GeV
	SR0-C2	at least two b-tags, $m_{eff} > 900$ GeV
one lepton, at least four jets $p_T(j1) > 60$ GeV, $p_T(j2, j3, j4) > 50$ GeV, $E_T^{miss} > 80$ GeV, $m_T > 100$ GeV, at least one b-tag	SR1-D	$m_{eff} > 700$ GeV
	SR1-E	$m_{eff} > 700$ GeV, $E_T^{miss} > 200$ GeV

SCUOLA NORMALE SUPERIORE PISA

ATLAS MULTIJET



Signal region	7j55	8j55	9j55	6j80	7j80	8j80
Number of isolated leptons (e, μ)	$= 0$					
Jet p_T	> 55 GeV			> 80 GeV		
Jet $\lvert\eta\rvert$	< 2.8					
Number of jets	≥ 7	≥ 8	≥ 9	≥ 6	≥ 7	≥ 8
$E_T^{miss}/\sqrt{H_T}$	> 4 GeV$^{1/2}$					