UNIVERSITY OF OSLO

Inclusive SUSY searches with early ATLAS data

Studies of fully simulated ATLAS data with as-installed geometry, covering two specific final states

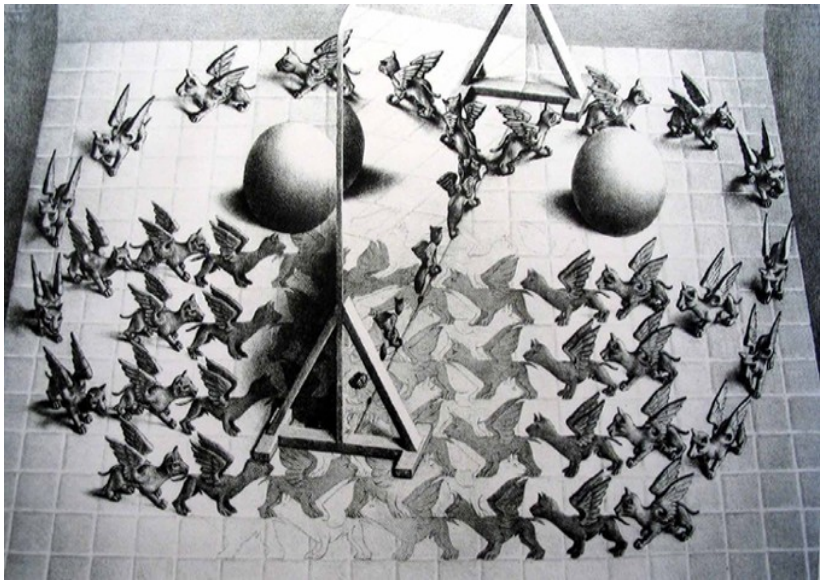
Gunn K. Larsen, Maiken Pedersen, Bjørn H. Samset

Supervisor: Farid Ould-Saada

Dept. of Physics, University of Oslo

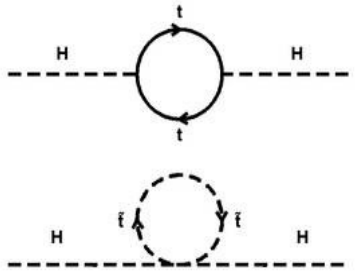
- Two jets, no leptons
- Two leptons, some jets
- 1fb^{-1} integrated luminosity (i.e. Year 2...)

Supersymmetry: Nature's Next Big Thing?
(In any case, it's good guidance)

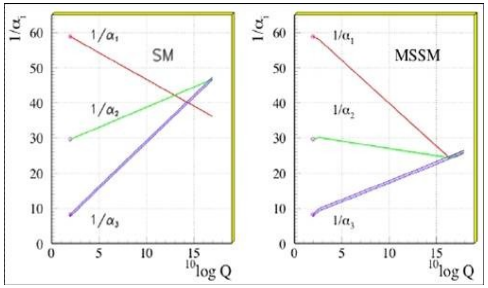


For every SM particle...
...a super-partner (and more).

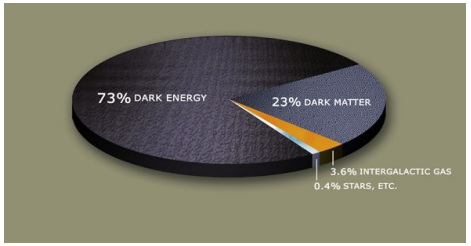
But does it exist?



Taming the Higgs mass...



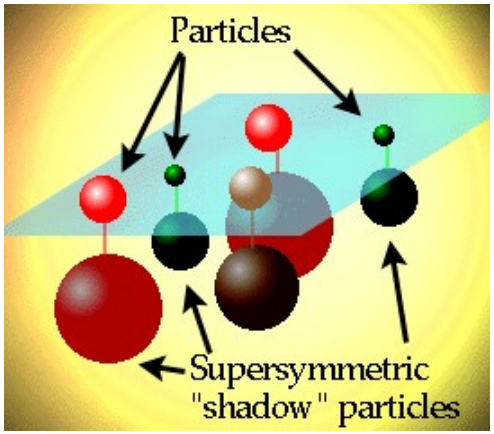
...uniting the forces...

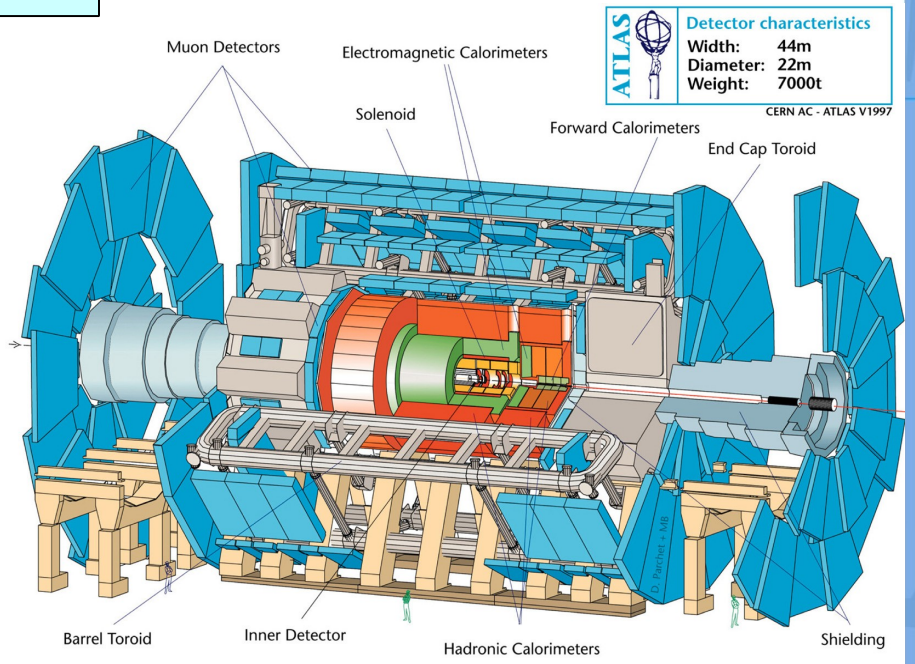


...yielding Dark Matter.

ATLAS:
A Tool for Locating Any Supersymmetry

- General purpose LHC detector
- Currently in final testing
- Will take data when LHC starts up during summer 2008

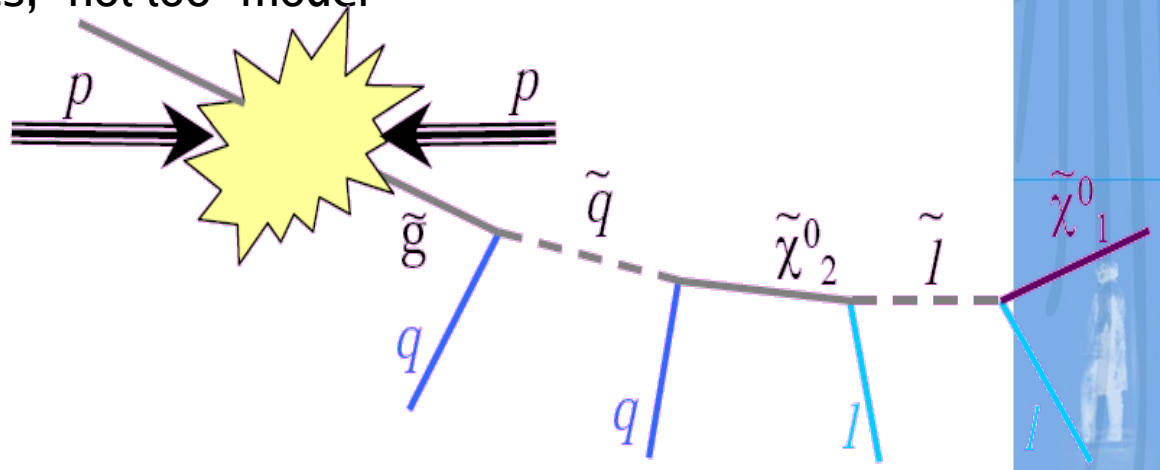




ATLAS early search strategies

- Early studies will require good understanding of detector.
- Prepare by looking at various SUSY breaking scenarios. ....

- Will use "golden discovery channels": multi-jets + leptons + missing transverse energy
- General SUSY characteristics, "not too" model dependent

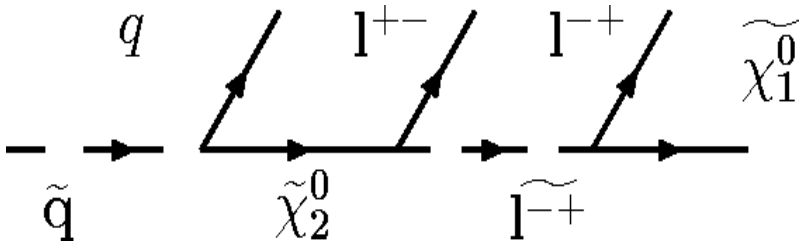


· Decay of squarks -> jets,
· Decay of charginos/neutralinos -> leptons and missing transverse energy (MET)

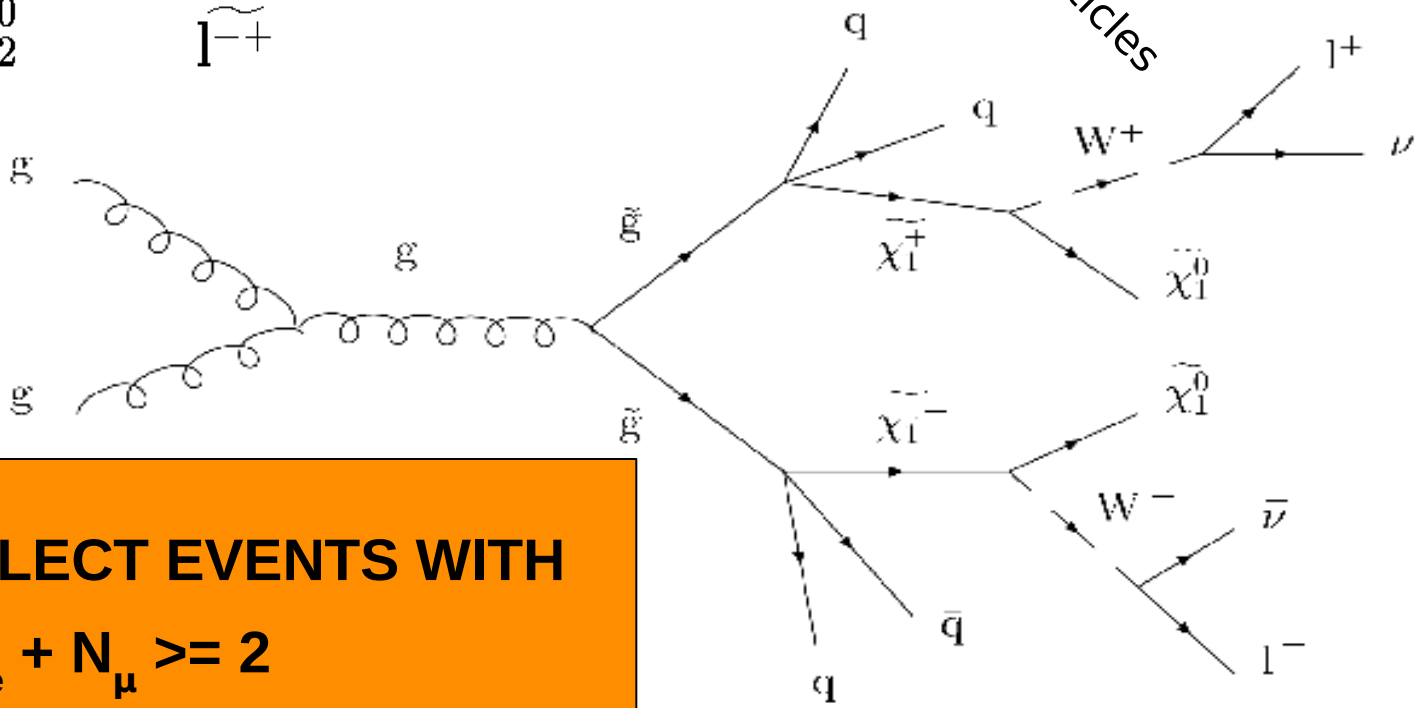
We will now present studies of 2 specific event topologies

Case 1: Di-lepton OS search

"Classic" signature topology in many SUSY realizations. (Good topic for master students....)



Example decay of sparticles



SELECT EVENTS WITH

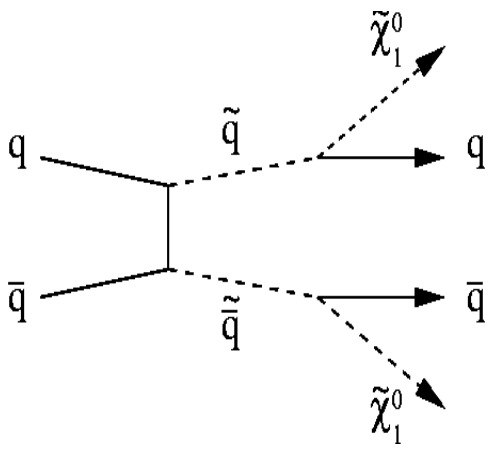
$N_e + N_\mu >= 2$

Case 2: Two jets, no leptons

For the slightly more advanced :

Expect high jet cross section.
Relevant for early data, may have other interesting properties.

Example decay chain

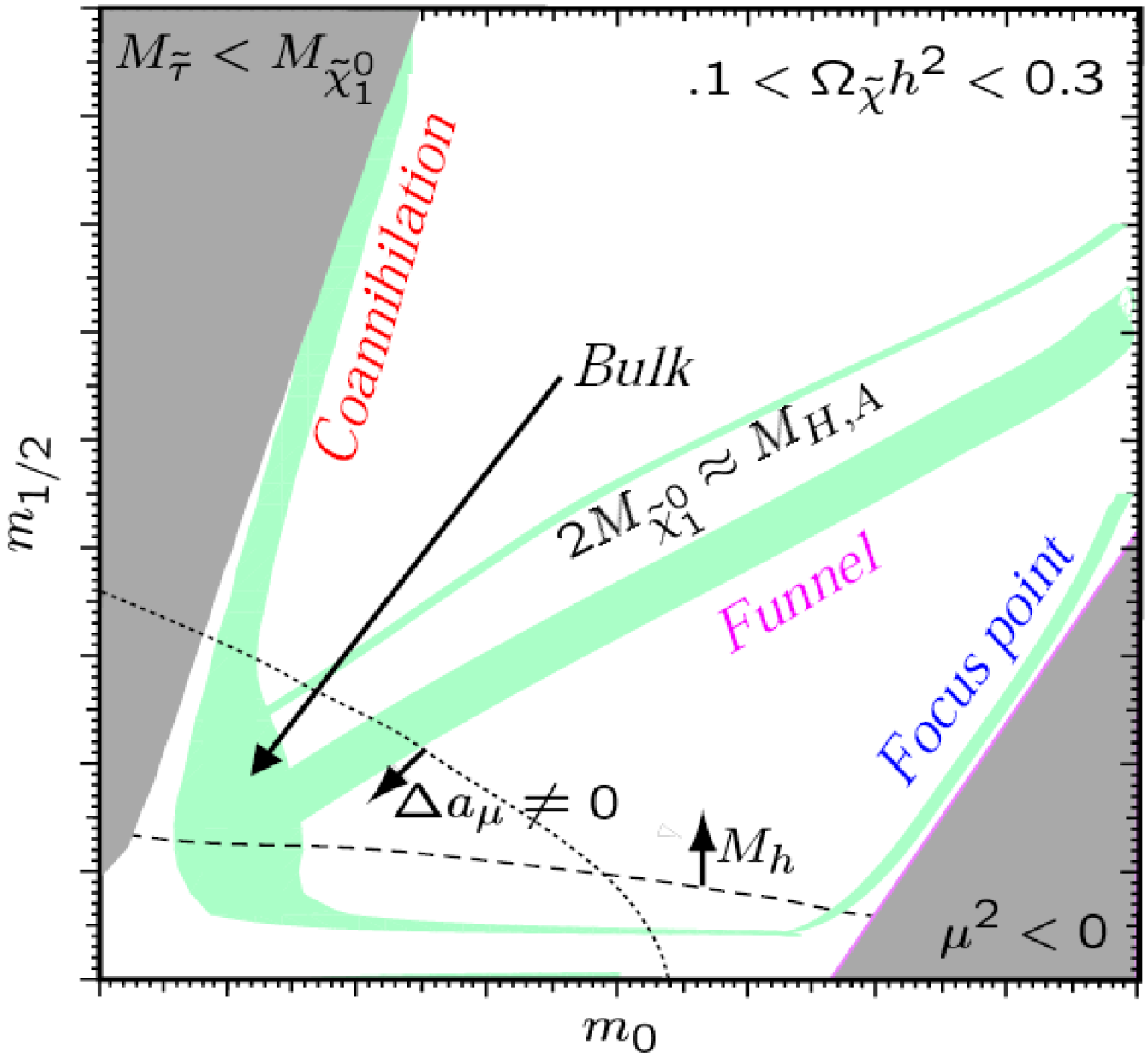


SELECT EVENTS WITH

$N_e + N_\mu = 0$

ATLAS has chosen some mSUGRA points as benchmarks during preparations

	SU1	SU2	SU3	SU4	SU6
	Coannihilation	Focus Point	Bulk	Low Mass	Funnel
m_0	70	3550	100	200	320
$m_{1/2}$	350	300	300	160	375
$\tan\beta$	10	10	6	10	50
A_0	0	0	-300	-400	0
signμ+	+	+	+	+	+
crossection[pb]	7.43	4.85	18.59	262	4.48
$\tilde{g}$	831	856	722	413	894
$\tilde{q}$	758	3576	662	445	862
$\tilde{\chi}_4^0$	479	294	478	327	493
$\tilde{\chi}_2^0$	262	160	223	113	287
$\tilde{\chi}_1^0$	136	103	116	59	149
$\tilde{\chi}^{\pm}$	478	286	476	326	493
$\tilde{l}$	254	3547	233	236	410

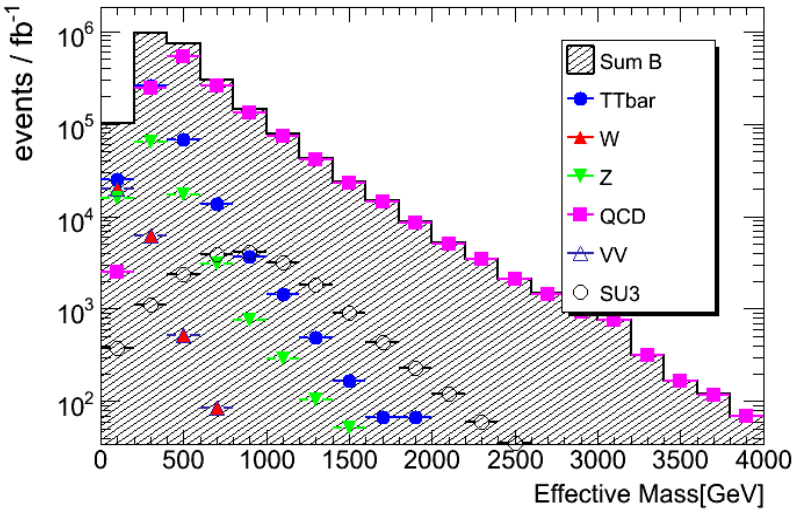

$M_{\tilde{\tau}} < M_{\tilde{\chi}_1^0}$
$.1 < \Omega_{\tilde{\chi}} h^2 < 0.3$
Coannihilation
Bulk
$2M_{\tilde{\chi}_1^0} \approx M_{H,A}$
Funnel
Focus point
$\Delta a_\mu \neq 0$
M_h
$\mu^2 < 0$
$m_{1/2}$
m_0

STRATEGY: CUT AND COUNT

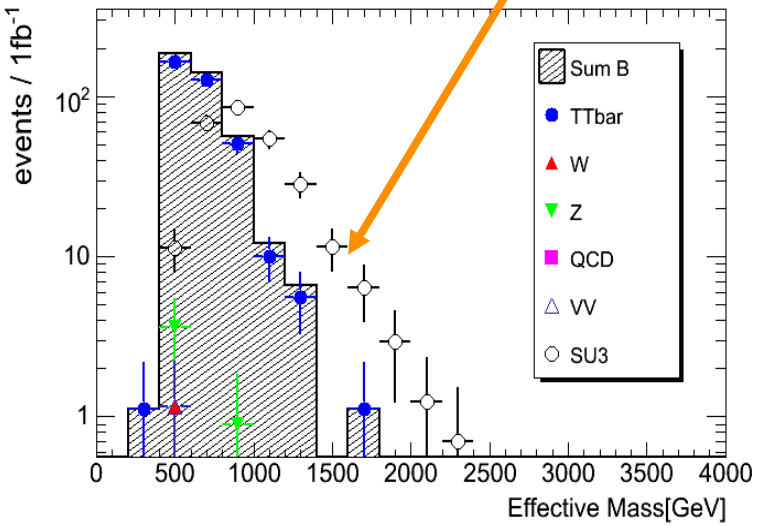
- After defining a final state of interest: select events which fulfil the criteria
- Plot variable of interest and see what you are left with
- What requirements (cuts) can we place on our events to enhance the total signal relative to the background?
- Is it possible to separate the SUSY signal from the SM background?

Good signal separation

WANT TO GET FROM THIS



TO THIS



Select events by setting requirements on jet momenta, missing transverse energy, event topology

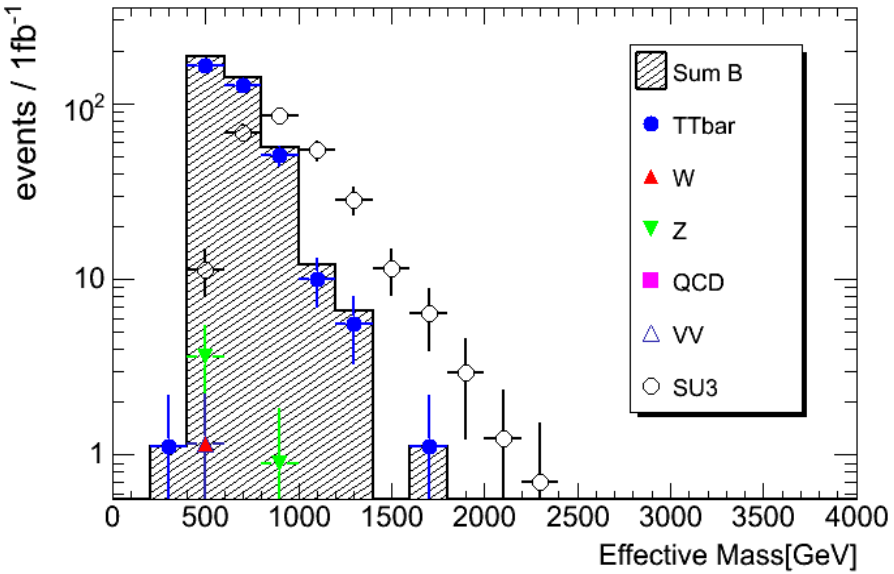
- **jet_pt_1 > 150 GeV**
- **jet_pt_2 > 100 GeV**
- **EtMiss > 100 GeV**
- **EtMiss/Meff > 0.25**
- **Dphi1 > 0.2**
- **Dphi2 > 0.2**

Jet_pt : Transverse momentum of jets
EtMiss: Missing Transverse momentum
EtMiss/Meff: Ratio of Missing Transverse momentum over Effective mass.
Dphi: phi_etmiss – phi_jetpt. Expected to be larger for SUSY events than for SM events.

After selecting events / cutting away the ones we don't want, we plot a variable that we expect will look different for respectively SUSY and pure SM events.

Strategy 1: Effective mass analysis
(Both dijet and dilepton topologies)

- Effective mass (Meff) indicates mass scale of the event
- SUSY particles are expected to be much heavier than SM particles -> larger mass scale.
- Will (hopefully) show as excess above SM background

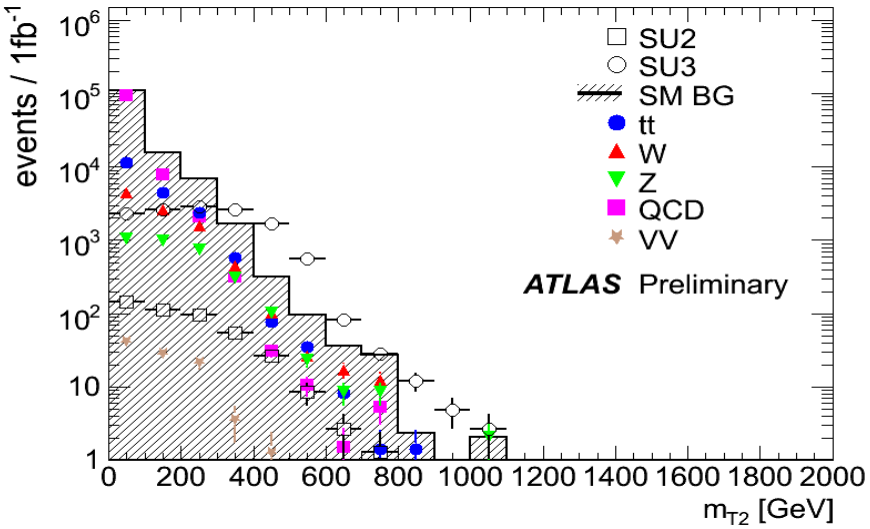


Meff=Missing transverse energy (MET) + $\sum jet\, p_T$ + $\sum lepton\, p_T$

Definition depends on event topology

Strategy 2: Stransverse mass analysis
(Here used for dijet topology only)

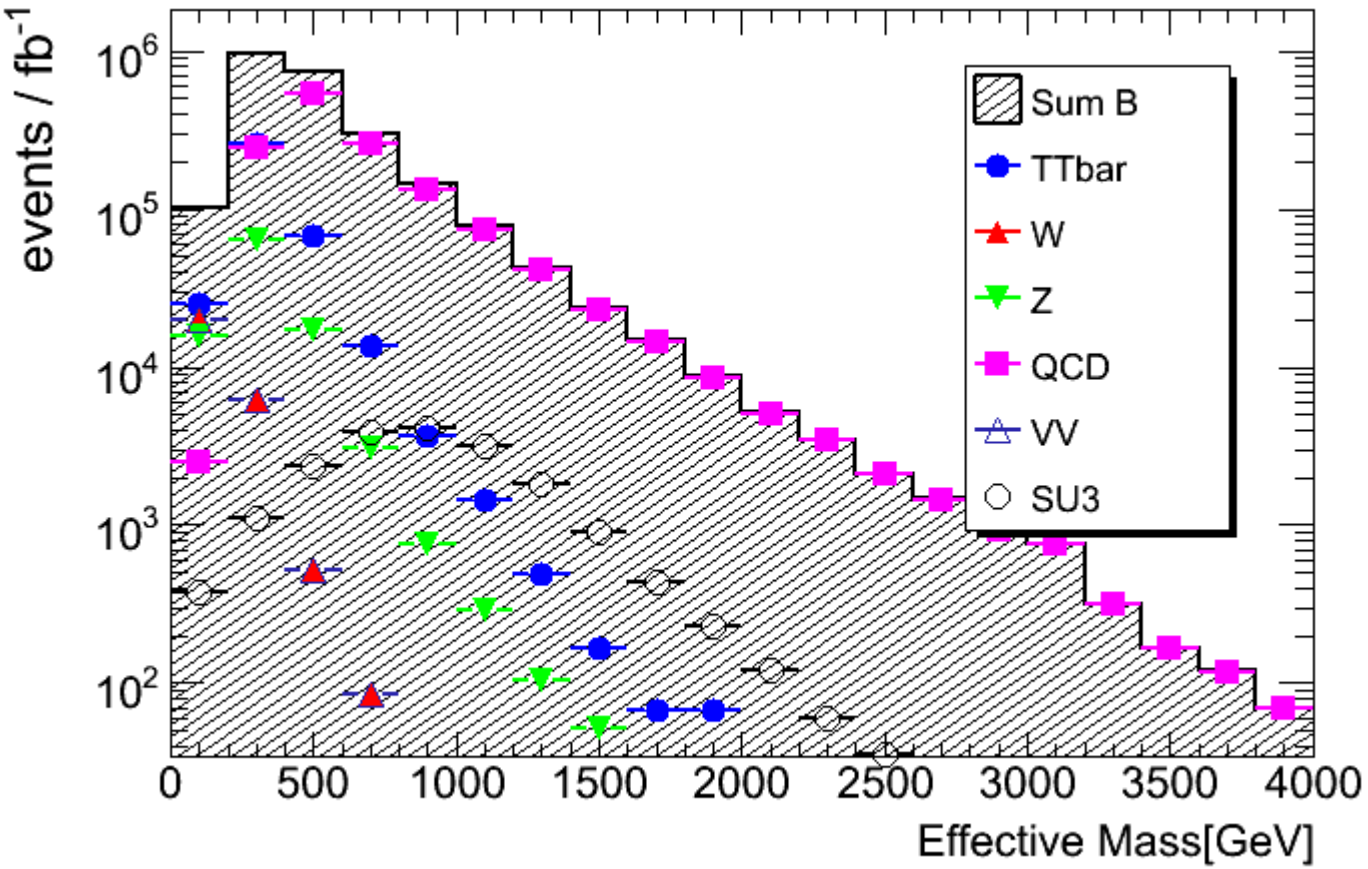
- Stransverse mass (MT2) works as a SUSY selector and end point mass analysis
- Expect small MT2 for SM backgrounds
- Explanation to come...



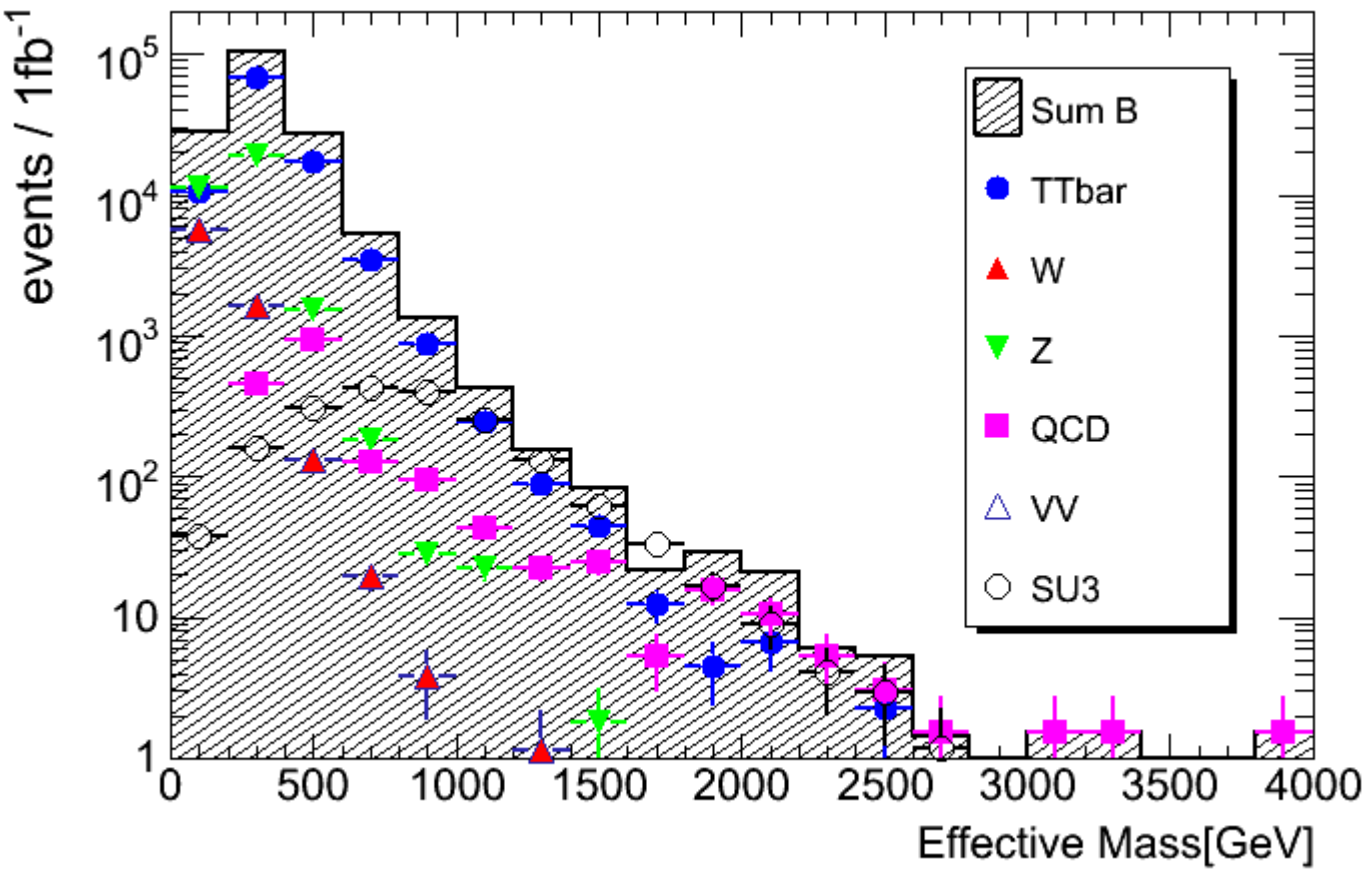
$$M_{\mathrm{T2}} \equiv \min_{p^{(1)}+p^{(2)}=\not{p}_T} \left[\max \left\{ m_T\left(p_T^{j(1)}, p^{(1)}\right), m_T\left(p_T^{j(2)}, p^{(2)}\right) \right\} \right]$$

J.Phys.G29:2343-2363,2003 Phys.Lett.B463:99-103,1999

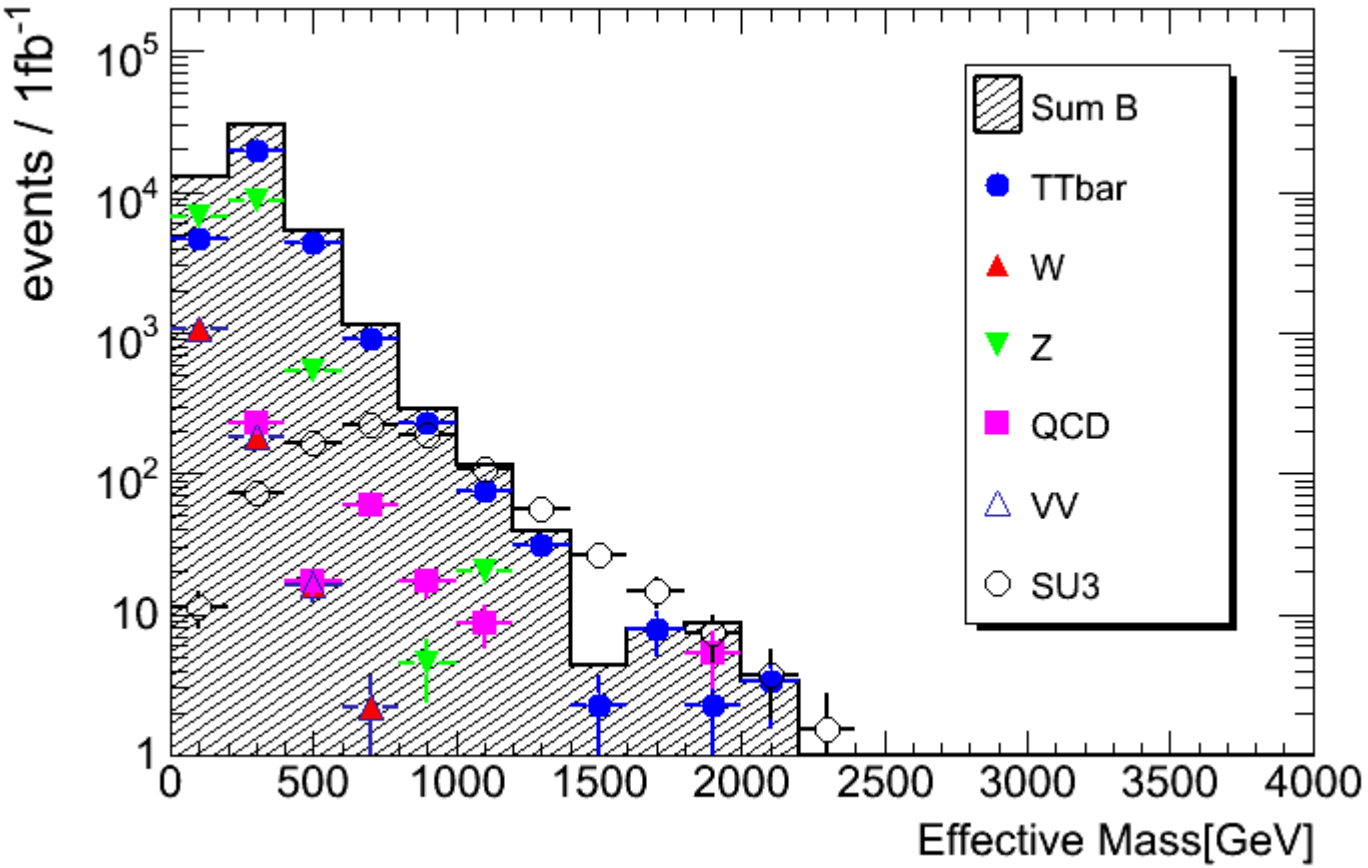
Effective mass distributions
before any cuts



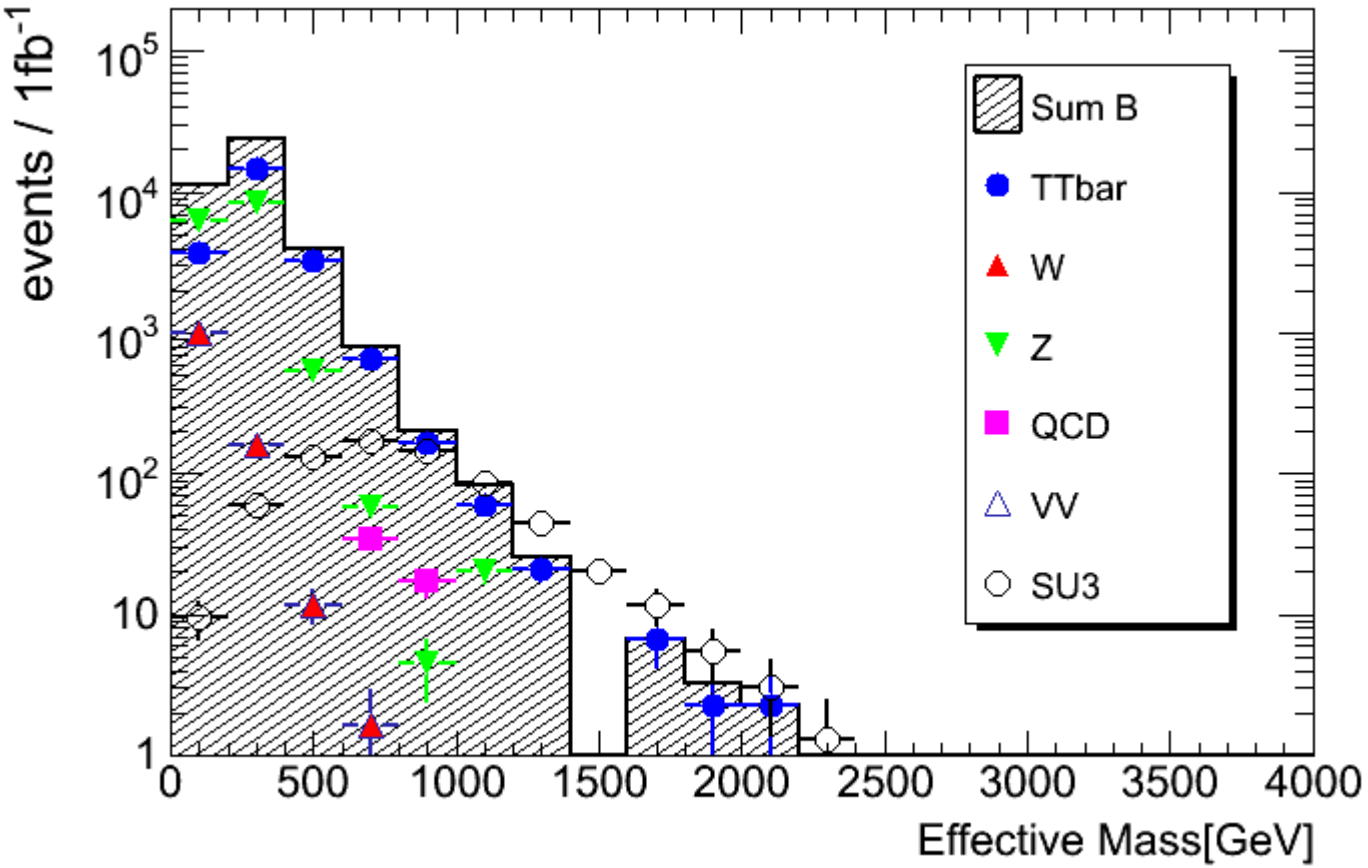
Effective mass distribution 1fb^{-1} requiring electron transverse momentum > 25GeV (approximates trigger requirement)



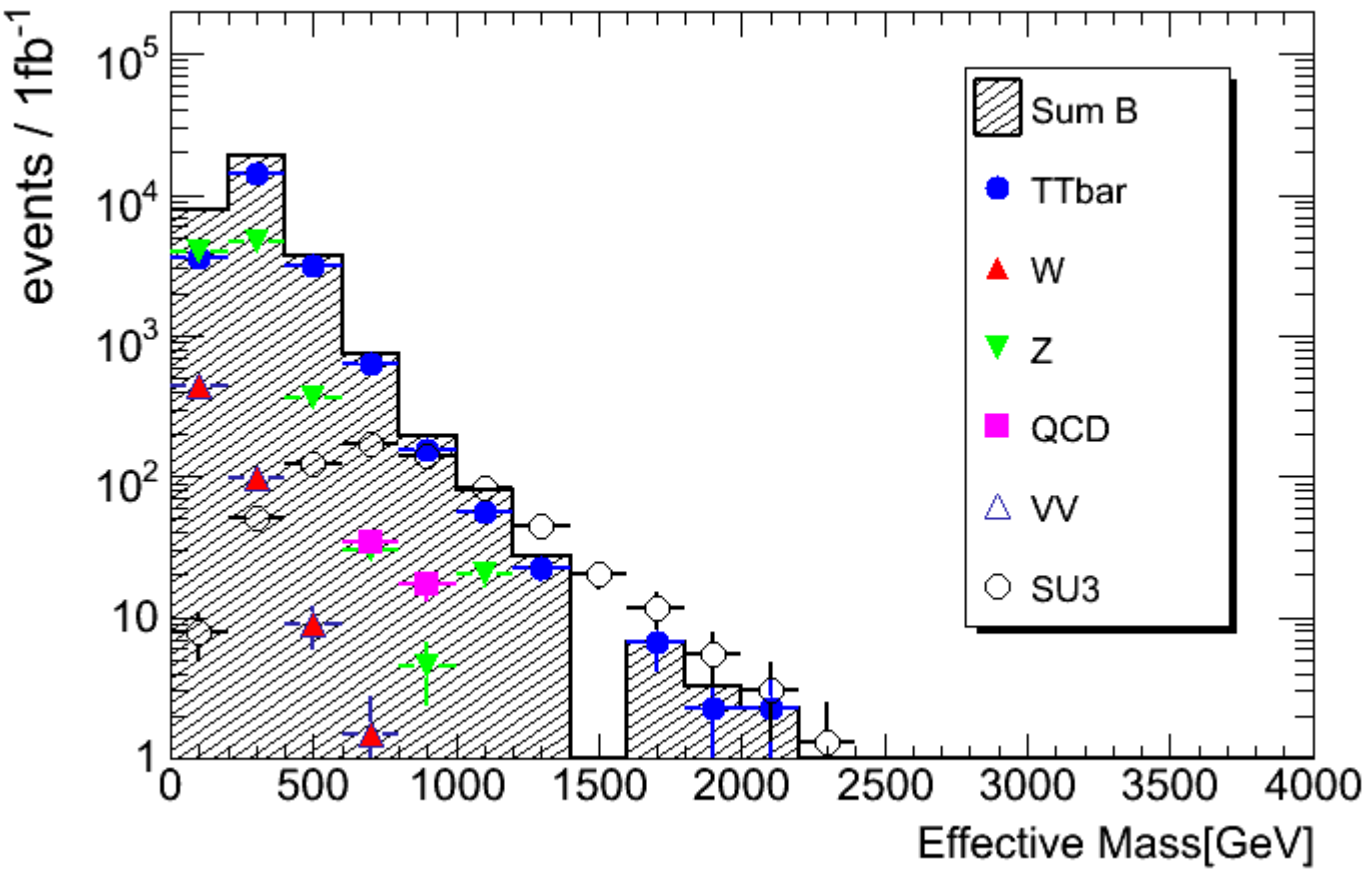
Effective mass distributions 1fb^{-1} selecting events with >= 2 leptons (lepton = electron or muon)



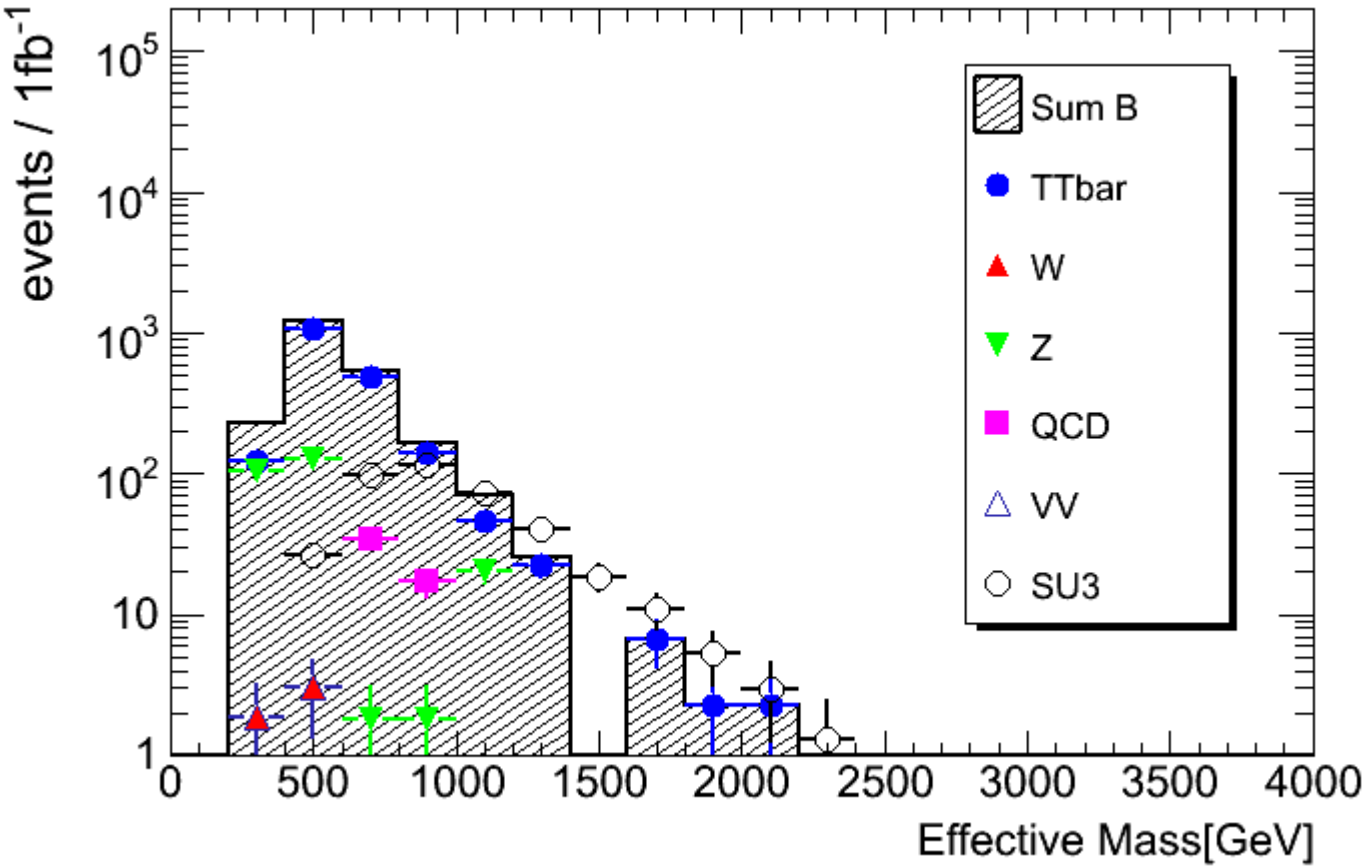
Effective mass distributions 1fb^{-1} selecting events with 2 leptons of opposite sign



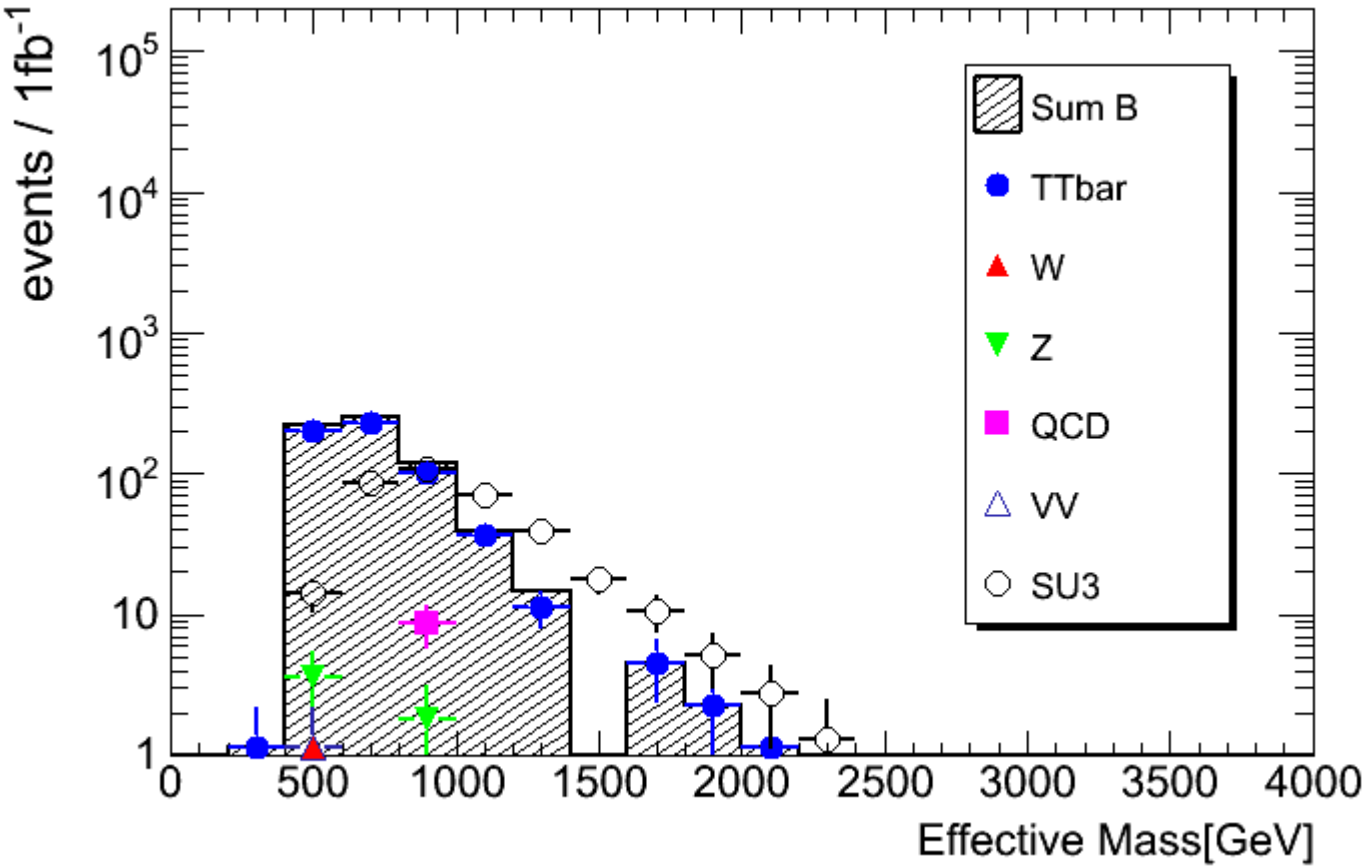
Effective mass distributions 1fb^{-1} selecting events with 2 or more jets



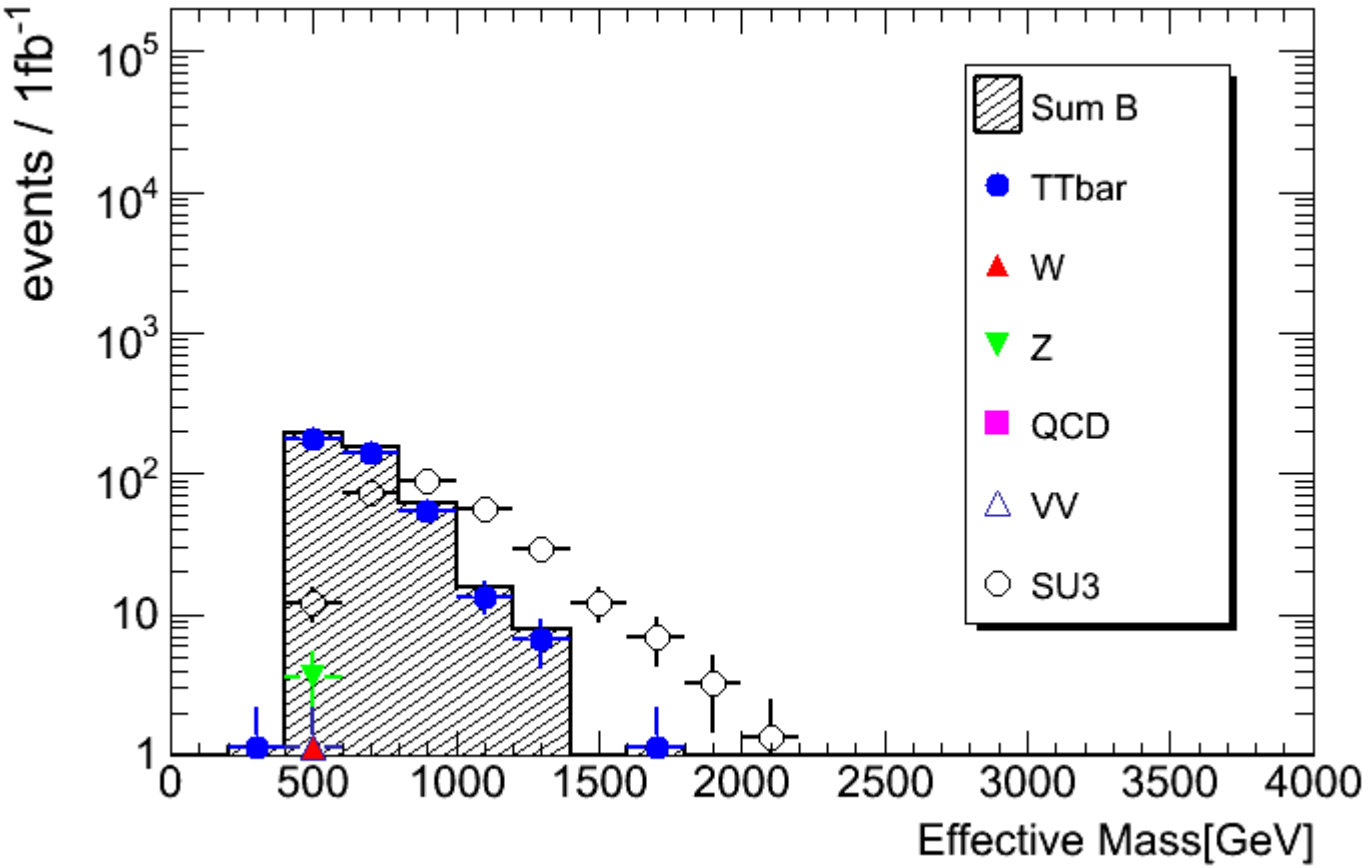
Effective mass distributions 1fb^{-1}
requiring first jet: transverse momentum > 150GeV, second jet: transverse momentum > 100GeV



Effective mass distributions 1fb^{-1}
selecting events with
missing transverse energy > 100GeV



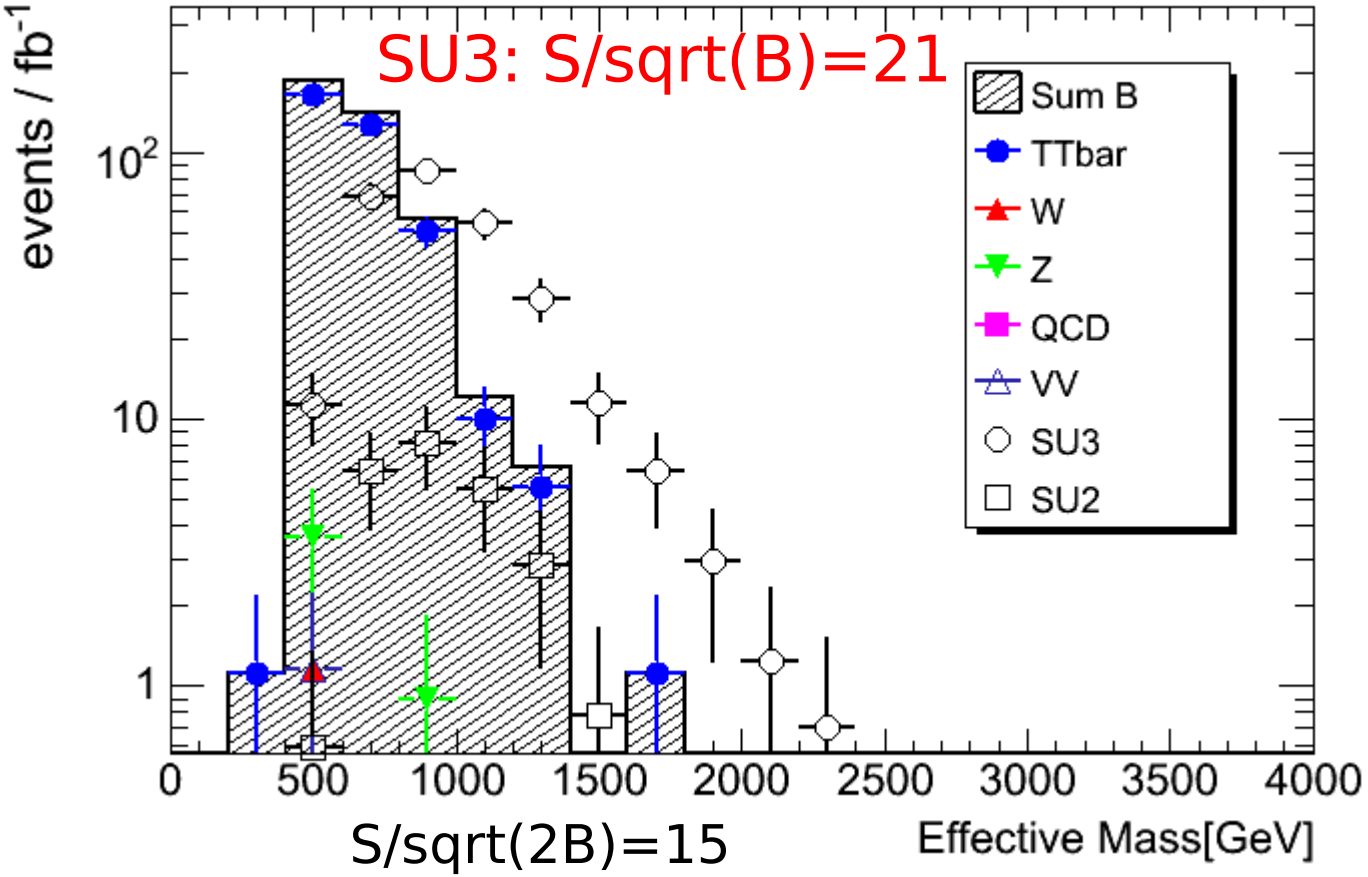
Effective mass distributions 1fb^{-1}
selecting events with MET/Meff > 0.2



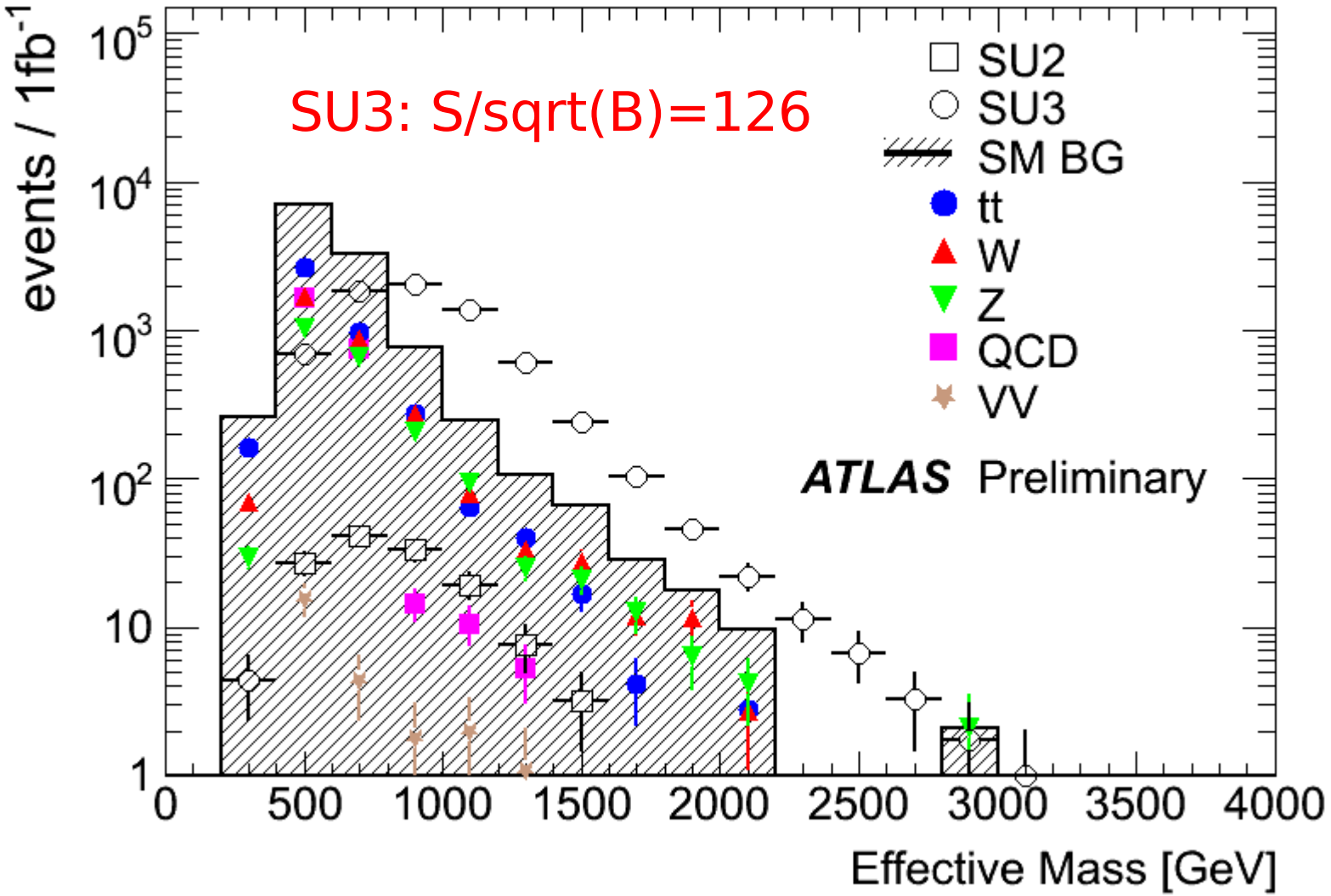
Opposite sign di-lepton Meff final plot, 1fb^{-1}

UNIVERSITY OF OSLO

Significance calculated from 800GeV for SU3
SU2 totally buried under background.



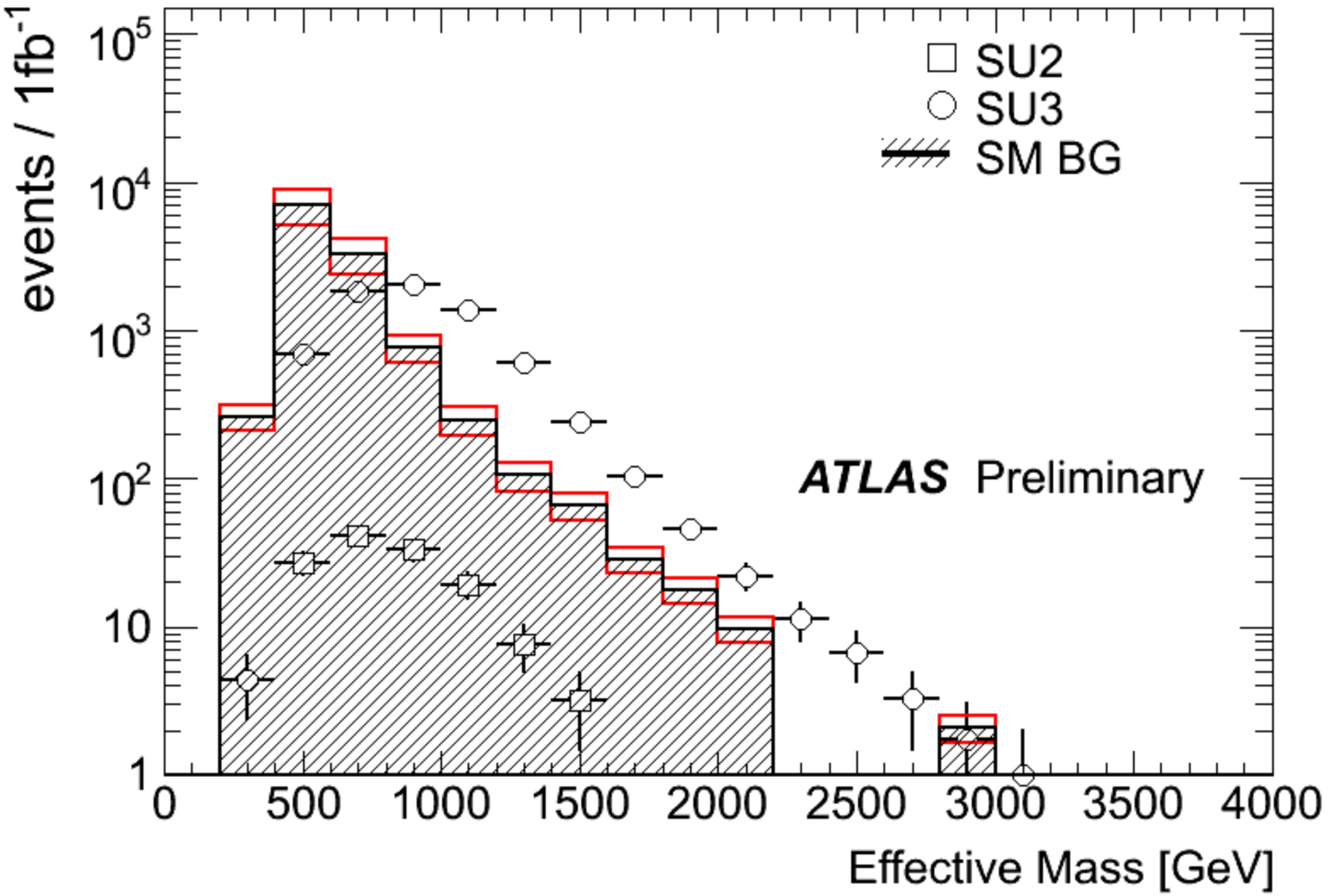
2-jet Meff final plot, 1fb^{-1}



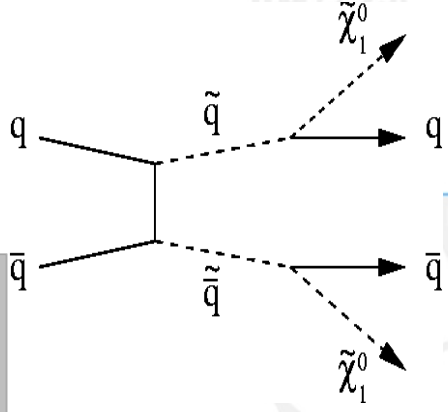
S/sqrt(2B)= 89

2-jet Meff final plot, 1fb^{-1}

Significance calculated from 800GeV



M_{T2} – what is it?



$$M_{\mathrm{T2}} \equiv \min_{p^{(1)}+p^{(2)}=\not{p}_T} \left[\max \left\{ m_T\left(p_T^{j(1)}, p^{(1)}\right), m_T\left(p_T^{j(2)}, p^{(2)}\right) \right\} \right]$$

J.Phys.G29:2343-2363,2003 Phys.Lett.B463:99-103,1999

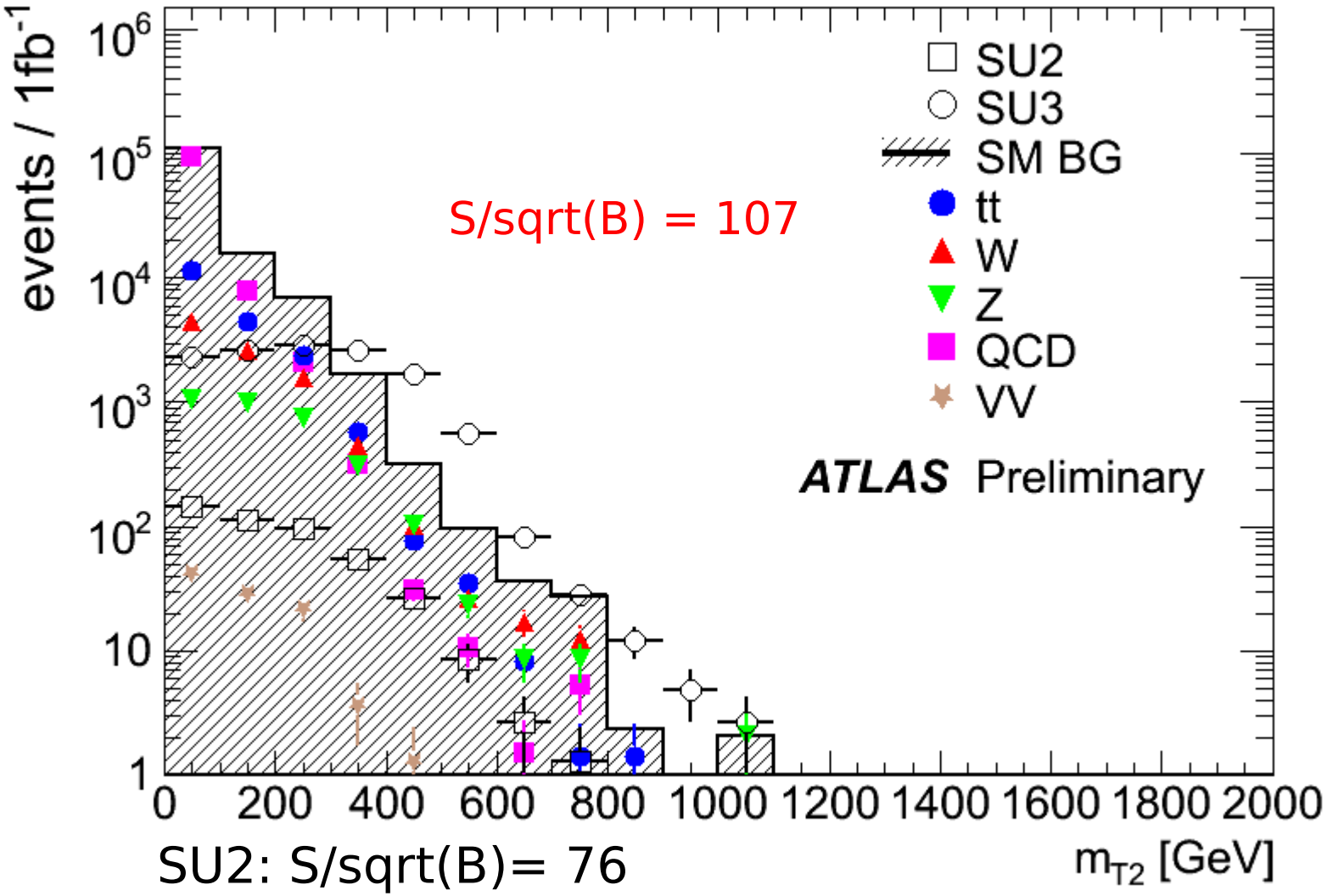
"Try all possible directions for the neutralinos and find the minimum heavy sparticle mass"

$M_{T2}(\chi=0) \rightarrow 0$ if

$E_T \rightarrow 0$, E_T parallel to either jet, Either jet $E_T \rightarrow 0$

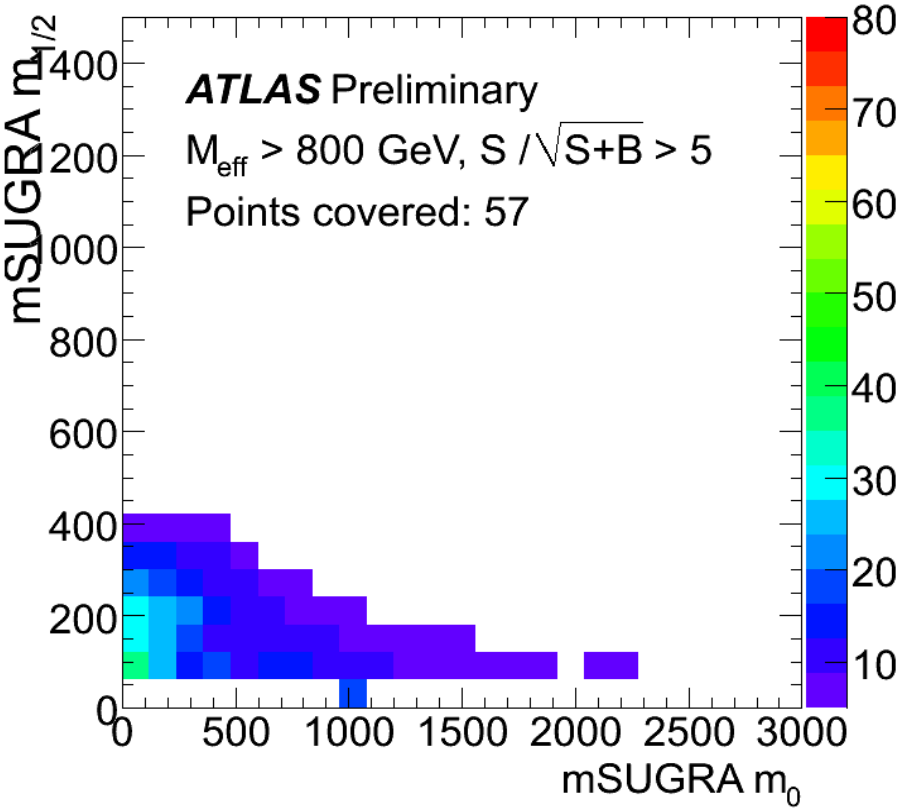
Cutting on this single variable does the work of the whole collection of cuts needed for the Meff analysis. Makes for a simpler analysis in total.

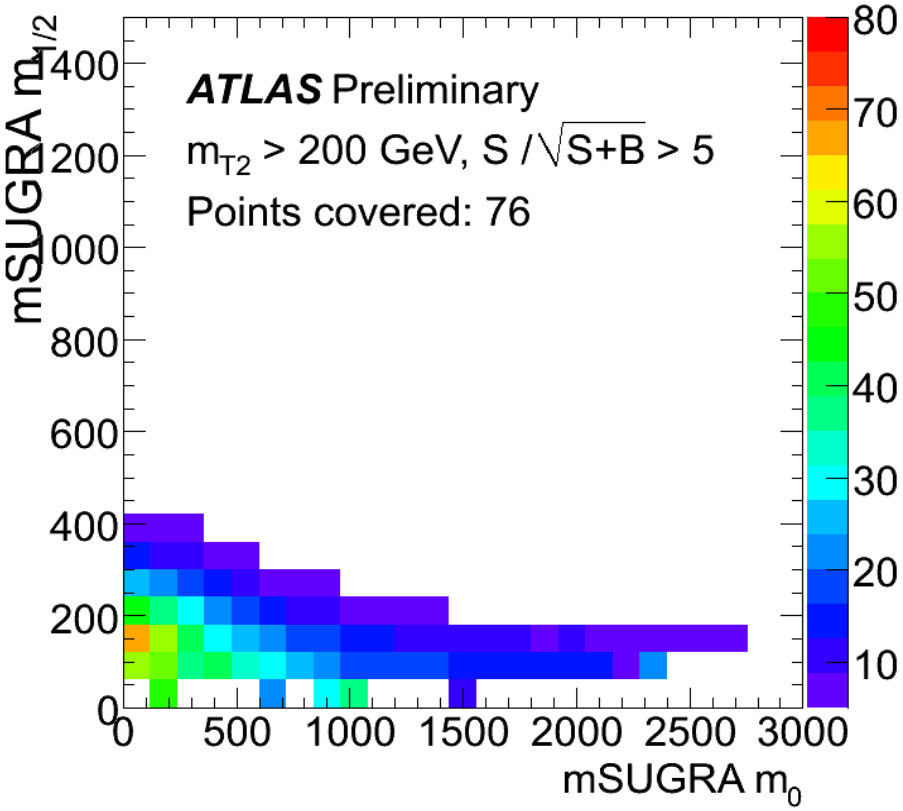
2-jet MT2 final plot, 1fb^{-1}



Scan over two mSUGRA parameters, find significance of dijet analyses

- $\tan(\beta)=10$, $A_0=0$, $\mathrm{sgn}(\mu)=+$
- No point-to-point optimization
- Fully simulated background, ATLFast simulated signal





- Both analyses have reasonable discovery potential
- Further study: Is MT2 more robust when missing ET is poorly known?

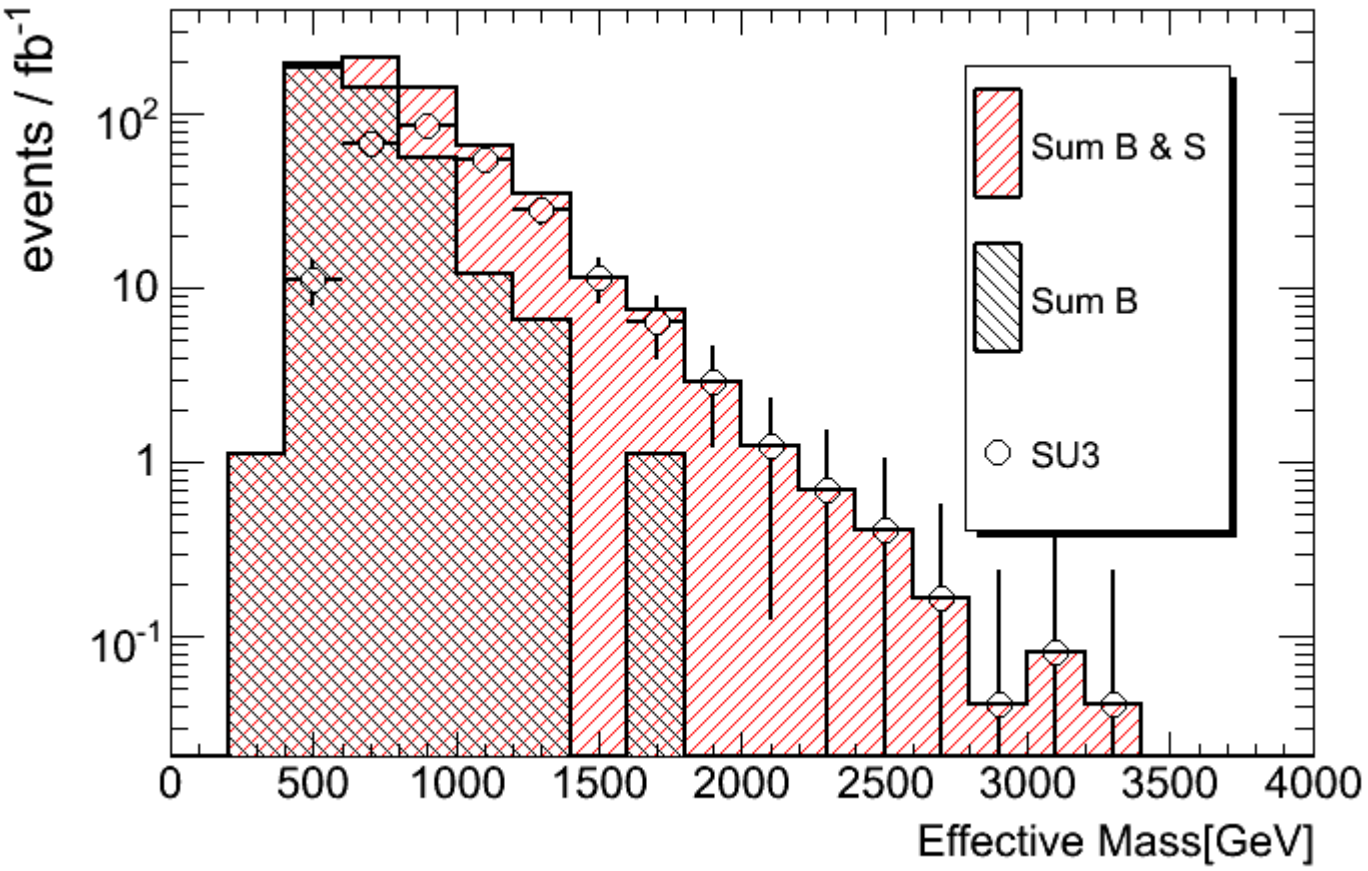
Conclusions and outlook

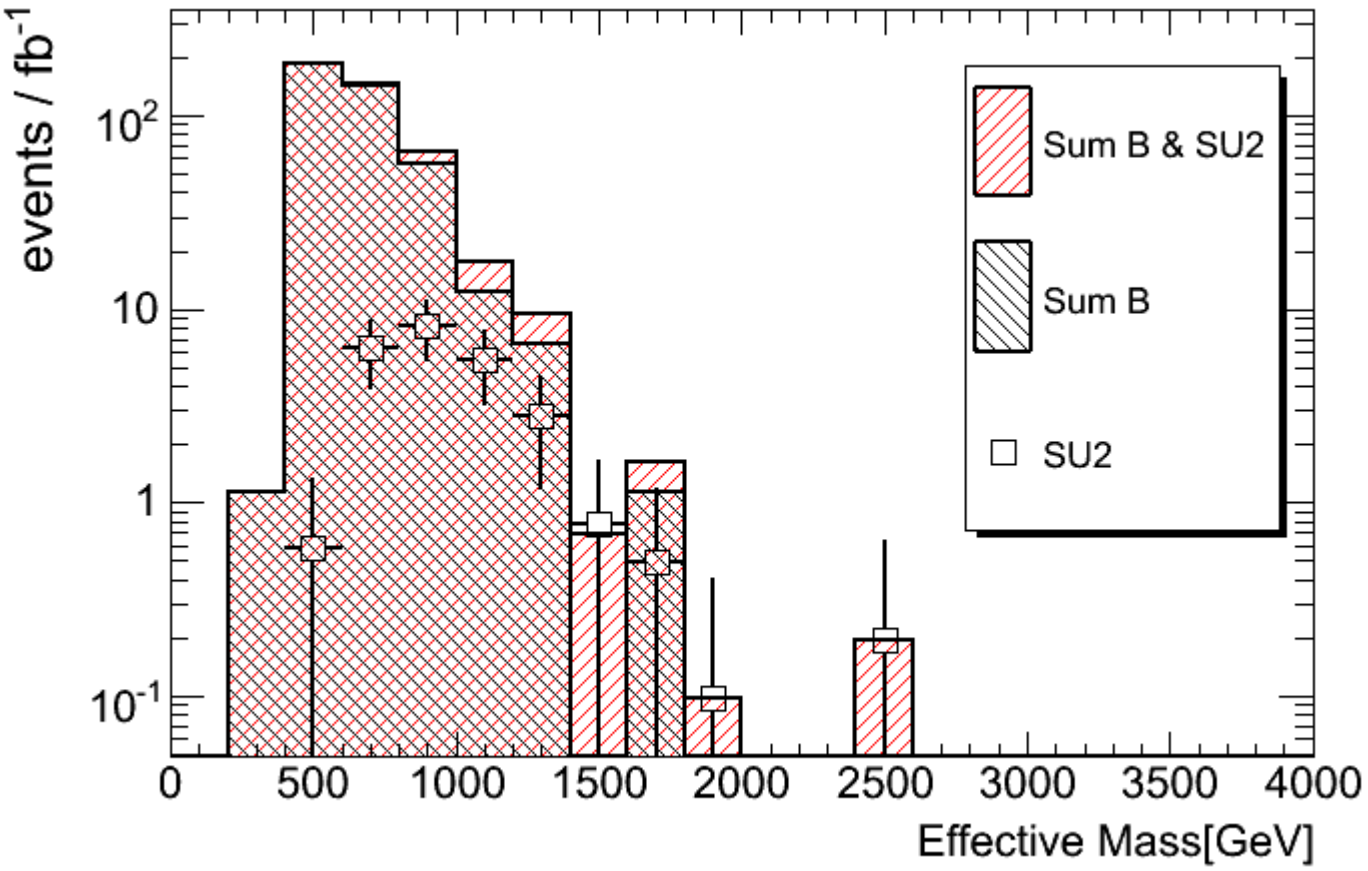
- We have illustrated the ATLAS strategy for early searches for “Susy-like” BSM physics.
- By “cutting and counting” we have shown that input from common SUSY benchmark scenarios can be reconstructed.
- Other SUSY realizations will require looking at other signatures (see e.g. talk by K. Pajchel yesterday)

- Effective mass and stransverse mass searches will be useful in searching for deviations from SM physics.
- Further studies in the OS and SS dilepton channels include mass reconstruction from edge analyses and cut optimization through multivariate analyses.
- In the dijet channel, effects of incomplete knowledge of missing transverse energy will be studied, and we will use the analysis to give lower limits on the squark mass.

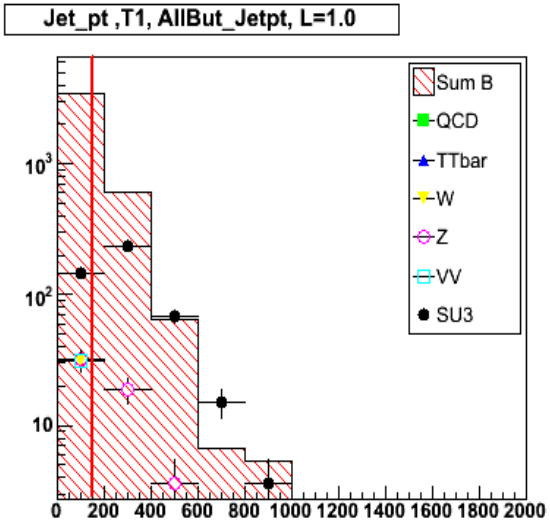
- ATLAS focus now shifts to understanding the detector.

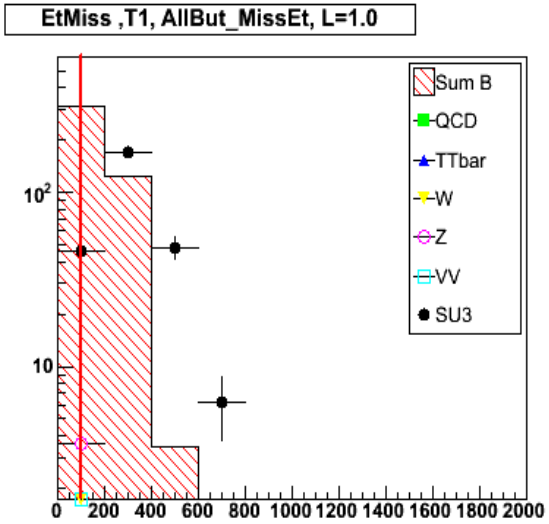
BACKUP

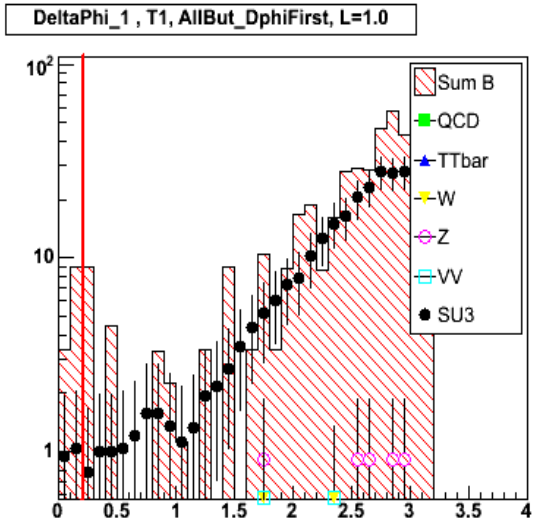

events / fb^{-1}
10^2
10
1
10^{-1}
0
500
1000
1500
2000
2500
3000
3500
4000
Effective Mass[GeV]
Sum B & S
Sum B
SU3

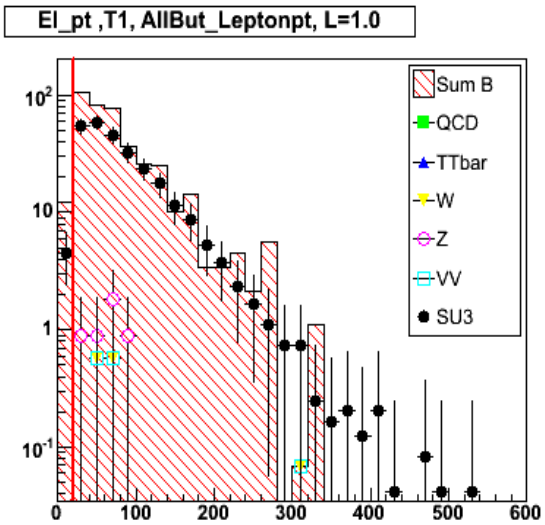

events / fb^{-1}
10^2
10
1
10^{-1}
0
500
1000
1500
2000
2500
3000
3500
4000
Effective Mass[GeV]
Sum B & SU2
Sum B
SU2

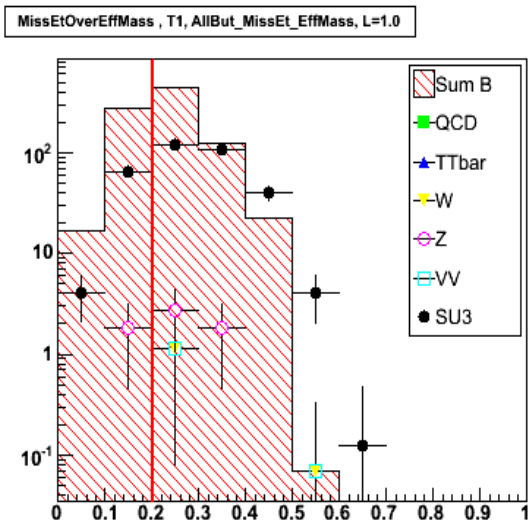
Di-lepton analysis all cuts except...

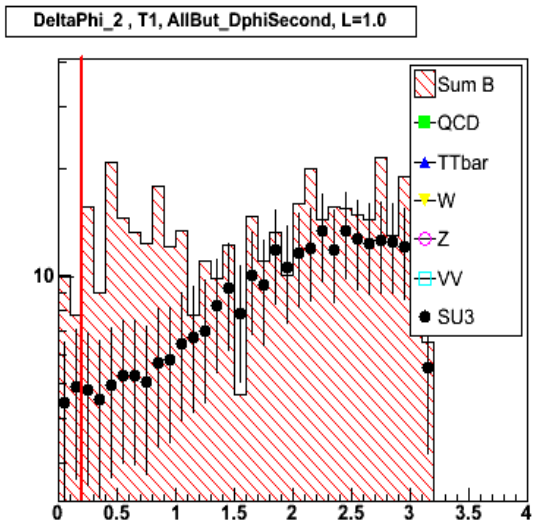








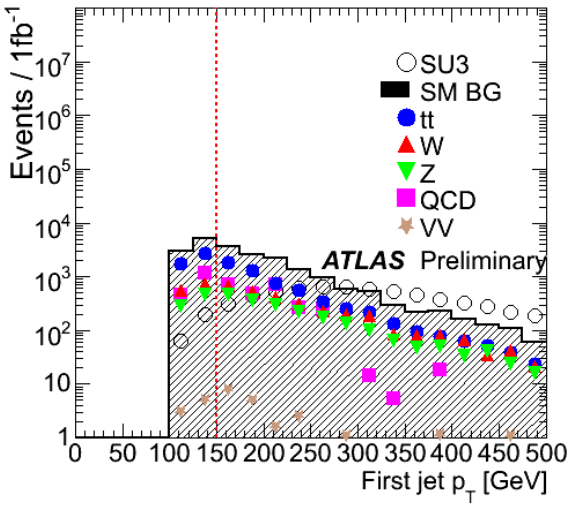


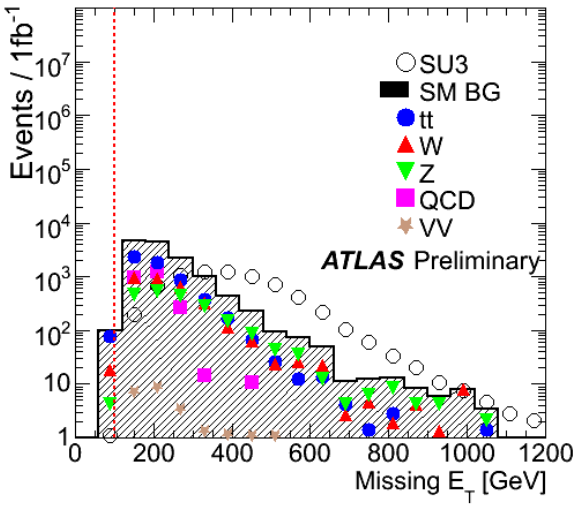


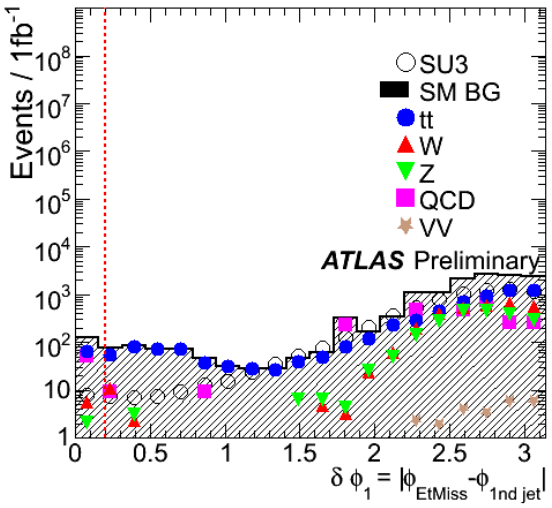
UNIVERSITY OF OSLO

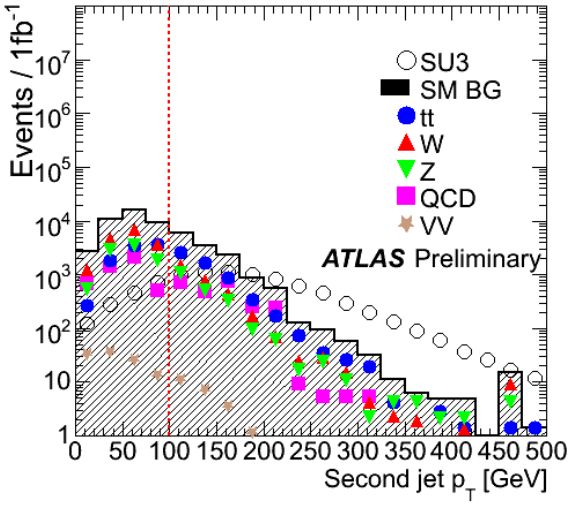
Cut efficiencies for 2-jet Meff analysis

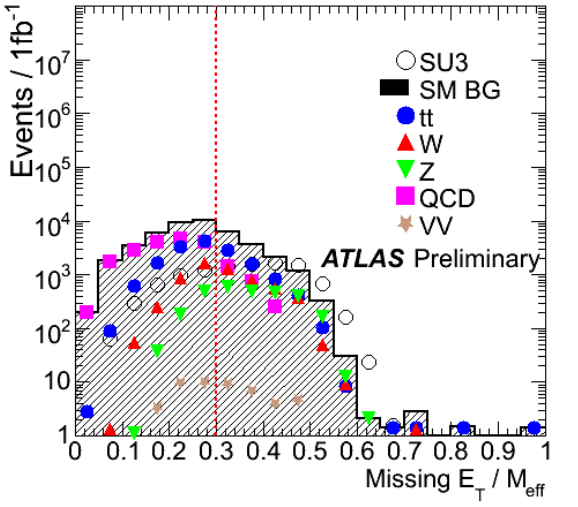
All cuts applied except the one plotted

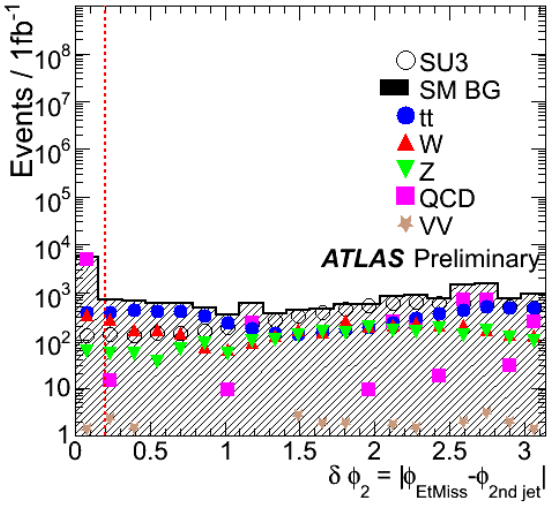


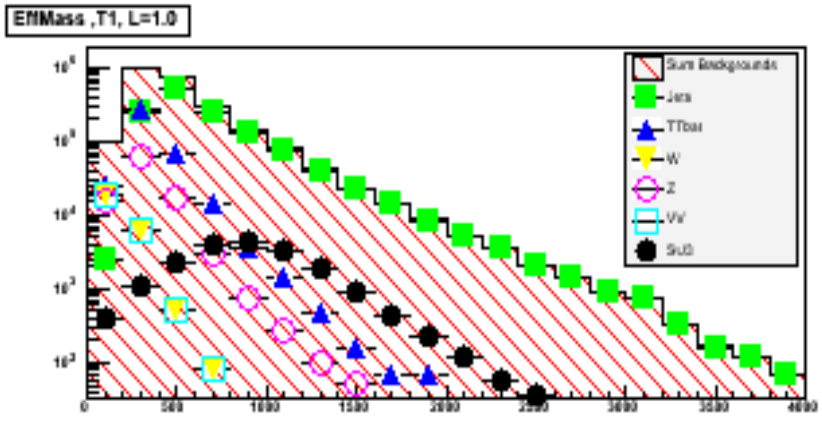


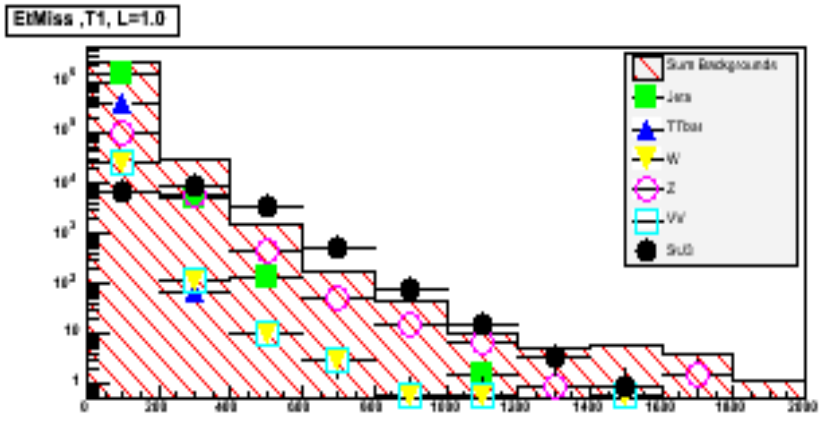


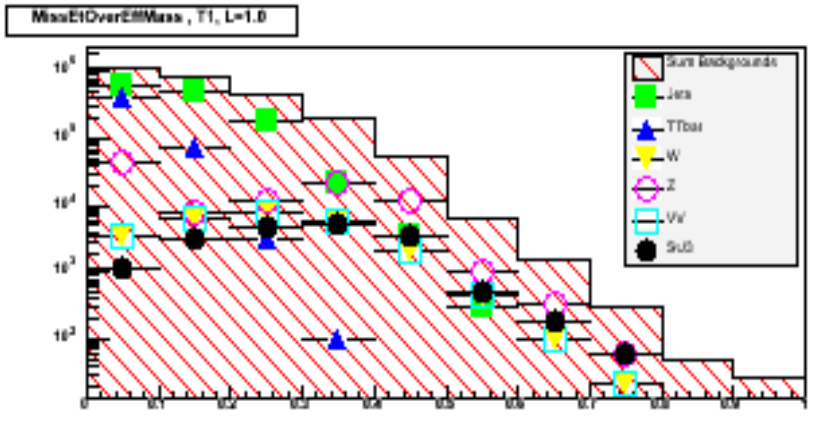


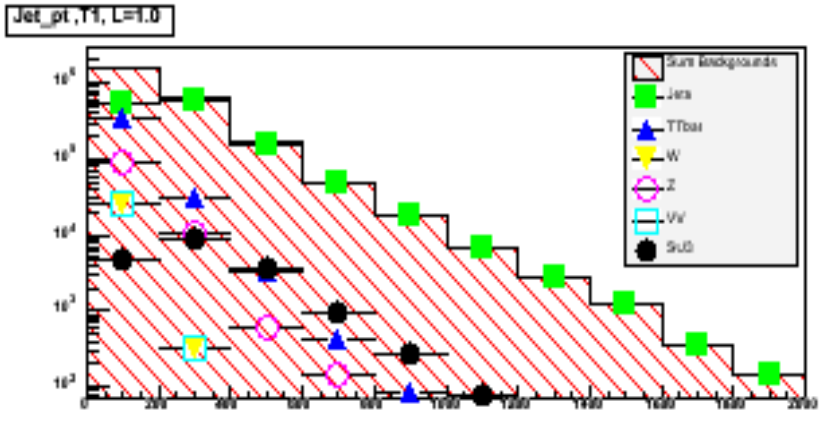


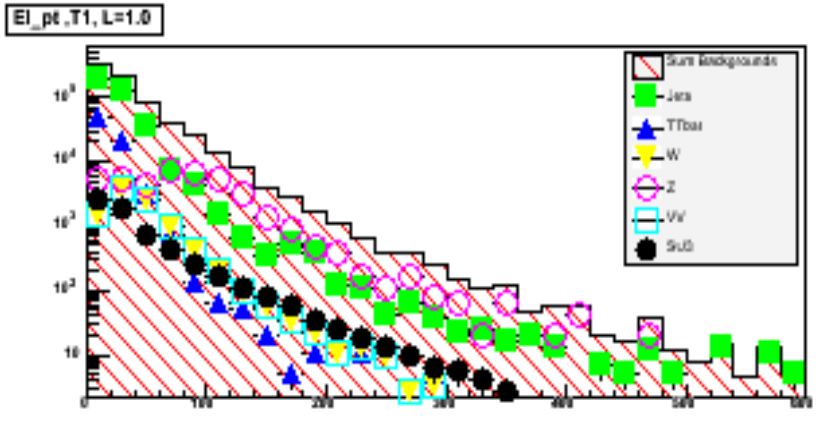



EffMass ,T1, L=1.0
Sum Backgrounds
Jets
TTbar
W
Z
Vv
SuSy


EtMiss ,T1, L=1.0
Sum Backgrounds
Jets
TTbar
W
Z
Vv
SuSy


MissEtOverEffMass , T1, L=1.0
Sum Backgrounds
Jets
TTbar
W
Z
Vv
SuSy

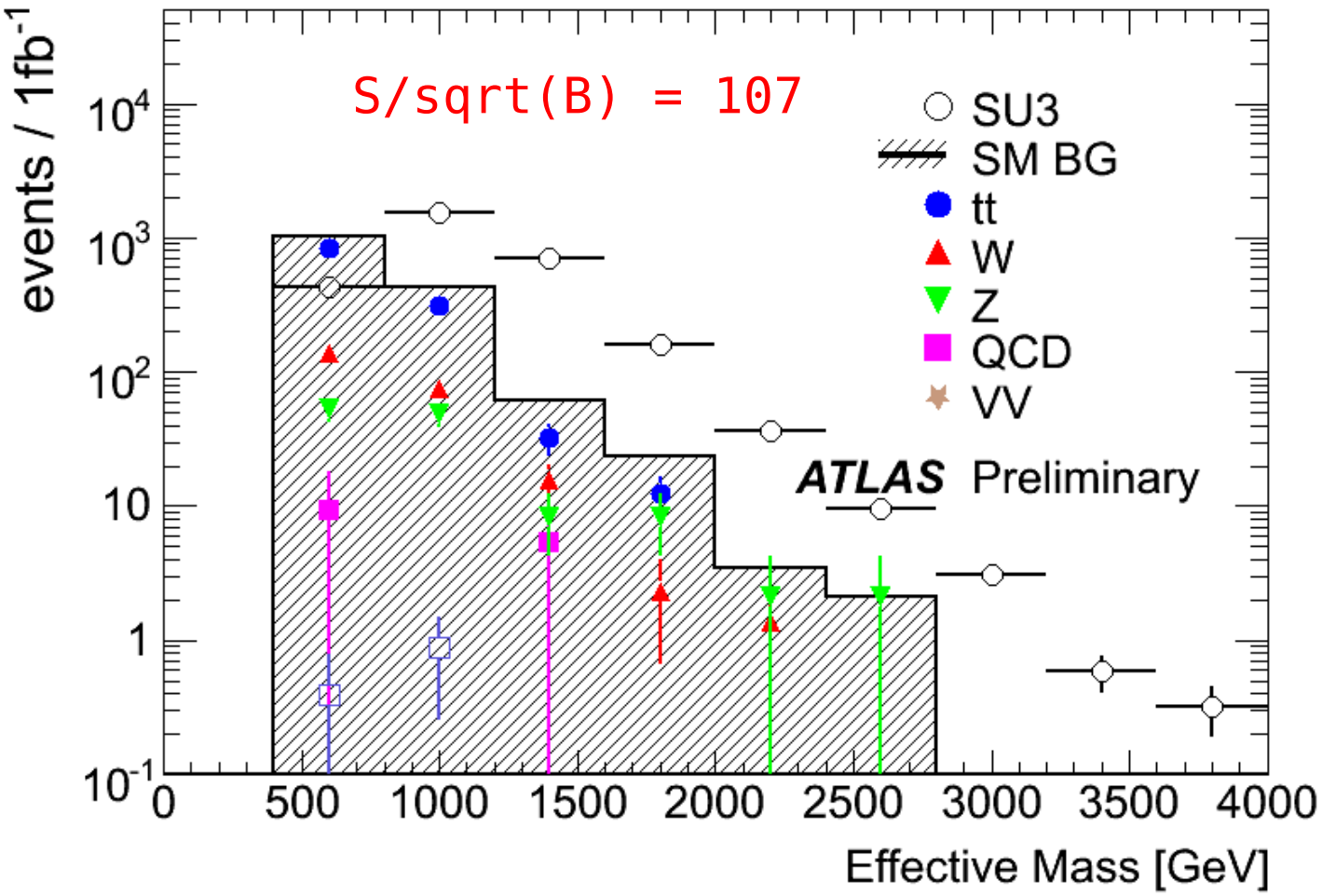

Jet_pt ,T1, L=1.0
Sum Backgrounds
Jets
TTbar
W
Z
Vv
SuSy


El_pt ,T1, L=1.0
Sum Backgrounds
Jets
TTbar
W
Z
Vv
SuSy

	SU1	SU2	SU3	SU6
NoCut	7430	4860	18590	4480
El pt >25GeV	968	380	1832	472
>2 Leptons	434	141	880	228
OS Dileptons	318	114	688	167
Lepton pt	317	113	685	166
> 2 jets	299	99	659	163
Jet pt	180	49	396	111
MET	166	42	355	101
MET/EffMass	139	27	283	83
dphi1 dphi2	134	25	271	79

	ttbar	WW	Z	QCD	VV	B
NoCut	820505	121189	64805	1284694	26622	2317815
El pt >25GeV	137783	25848	31792	1758	7489	204670
>2 Leptons	40513	2195	15758	337	1277	60080
OS Dileptons	30567	1240	15095	51	1184	48136
Lepton pt	30406	1230	15095	51	1182	47965
>2 jets	29342	681	8978	51	553	39605
Jet pt	2868	62	255	51	5	3242
MET	945	51	6	9	1	1013
MET/EffMass	601	39	5	0	1	646
dphi1 dphi2	543	38	5	0	1	587

3-jet Meff final plot, 1fb-1



3-jet MT2 final plot, 1fb-1