Inclusive SUSY search at ATLAS

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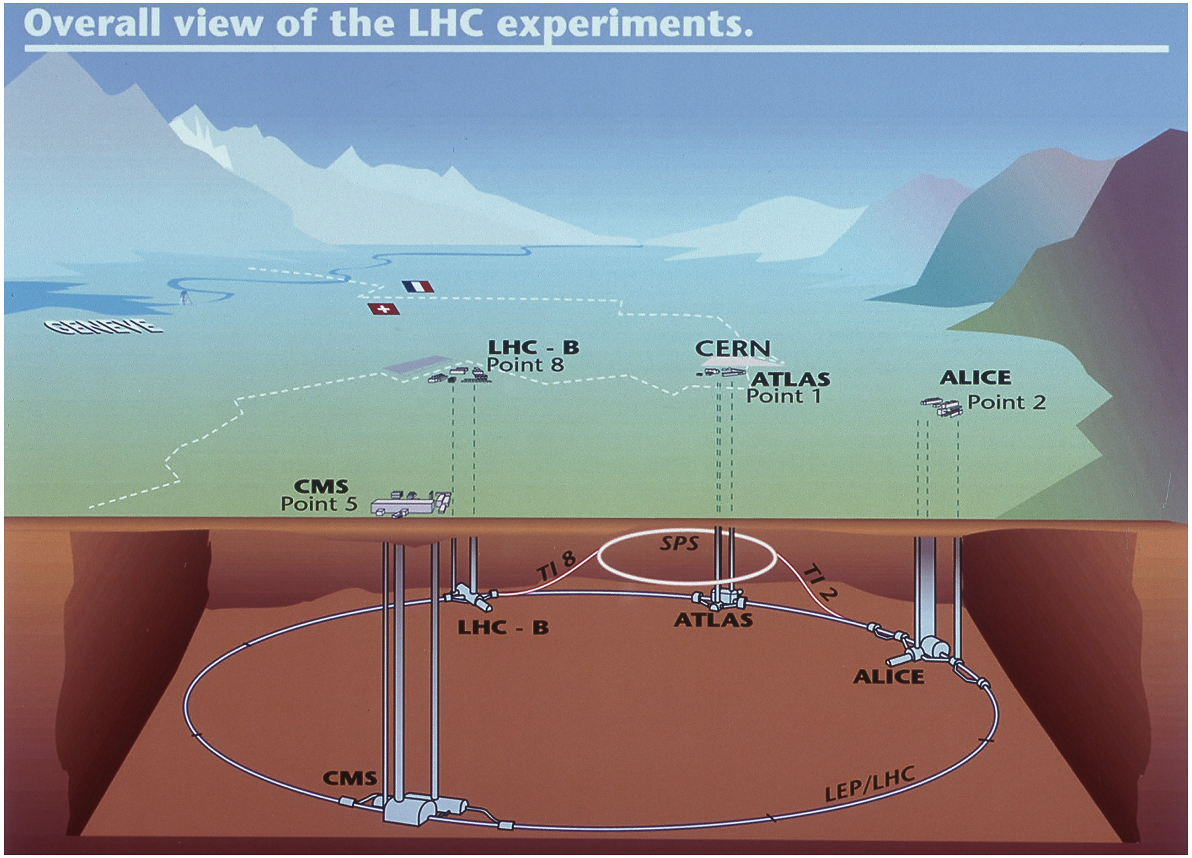
Large Hadron collider



27 km ring situated underground beneath Geneva,

High-energy protons (2*7 TeV) are circulated in the ring in two counter-rotating beams,

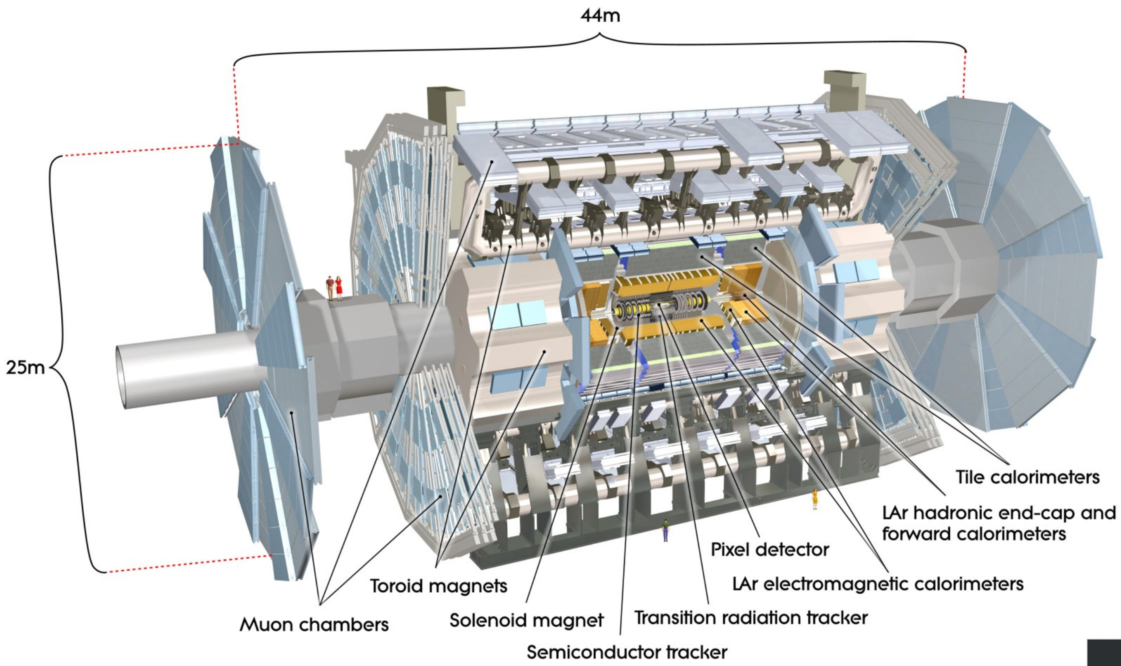
Four experimental caverns for ATLAS, CMS, ALICE and LHCb,

One year of running at 7 TeV and ~35pb^{-1} physics data collected at ATLAS!

Physics Program:

Higgs searches, Precise Top Physics, Susy searches, Extra Dimensions ...

The ATLAS Experiment



The mechanical installation of the detector was completed in July 2008

2008 – 2009: In-situ detector commissioning with cosmic runs,

Sept. 2008: First LHC beams at ATLAS cavern,
19th Sept. magnet accident,

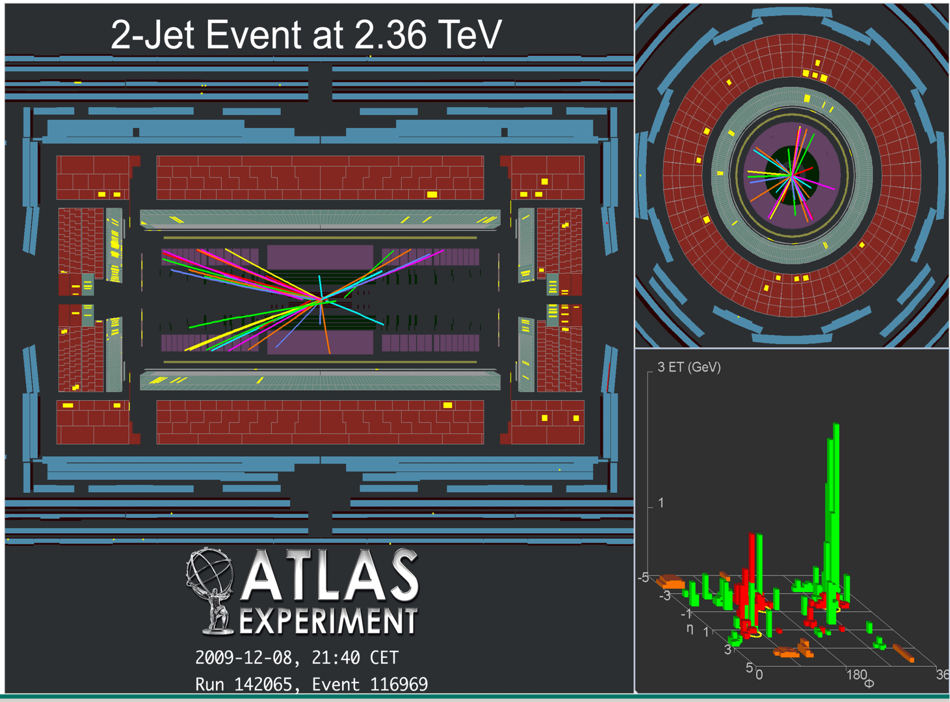
Nov. 2009: LHC operation at 900GeV, up to 2.36TeV,

2010 one year of successful running at 7TeV!

13th March 2011 LHC back with stable beam!

2011-2012 LHC deliver more data at 7TeV...

Very, very first Collision!!



Content

The search for SUSY

- ➢ Motivation
- ➢ Event Selection
- ➢ Fit based method
- ➢ Counting method
- ➢ Conclusion

Why SUSY?

Could solve:

1) The hierarchy problem, protects the Higgs mass from large quantum corrections,
2) the unification of gauge couplings,
3) a dark matter candidate.

SUSY preferably at TeV scale!!

The Minimal SuperSymmetric Standard Model (MSSM) at least 105 new parameters, not very predictive …

↓

Constrained MSSM (cMSSM)

↓

The minimal SuperGravity (mSUGRA) – gravity mediated SUSY breaking – only five parameters: m_0, $m_{1/2}$, A_0, tanβ and the sign of μ.

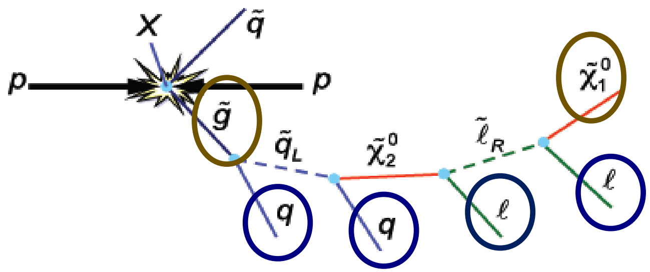
Note: at ATLAS SUSY searches A_0=0 GeV, tanβ =3, μ>0.

SUSY phenomenology and search strategies

In R-parity conserving scenarios, $R = (-1)^{3(B-L)+2s}$
(1 for SM, -1 for SUSY particles),
Lightest SuperSymetric Particle (LSP) is stable and escapes undetected...

Signature: High Missing Energy ...

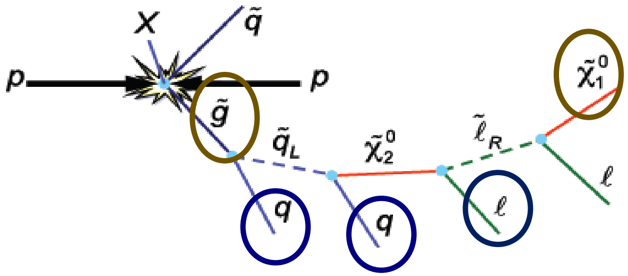
Exact decay chain depends on SUSY particle masses, but final state consists with SM quarks w/o leptons



Signatures: Missing Energy + jets + 0/1/2leptons.

Data sets and Selection

- **MC data sets, SM processes and mSUGRA,**
- **ATLAS Data, L = 35 ± 4 (11%) pb^{-1}**

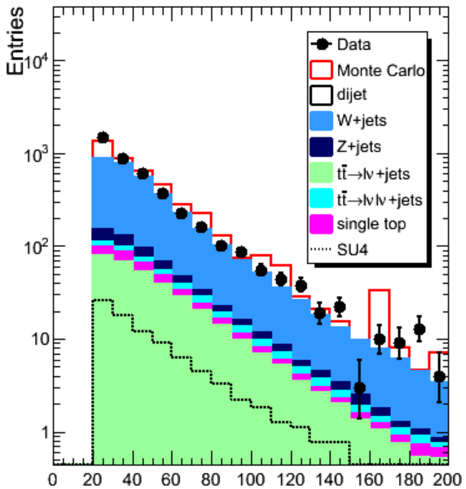


Event Selection:

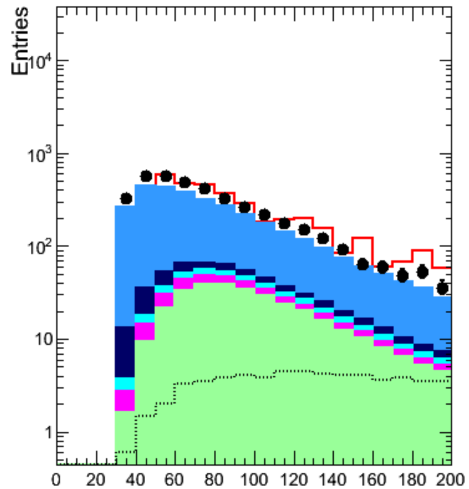
Data quality flags,
Trigger fired,
Calorimeter noise cleaning,
Good primary vertex,
Crack region cleaning,

1 Lepton channel	2 Lepton channel
Exactly one good lepton p_T>20 GeV, At least 2 good Jets with p_T>30 GeV, Missing energy (MET) > 30 GeV,	Exactly two good lepton p_T>20 GeV, No jet requirement, Missing energy > 100 GeV

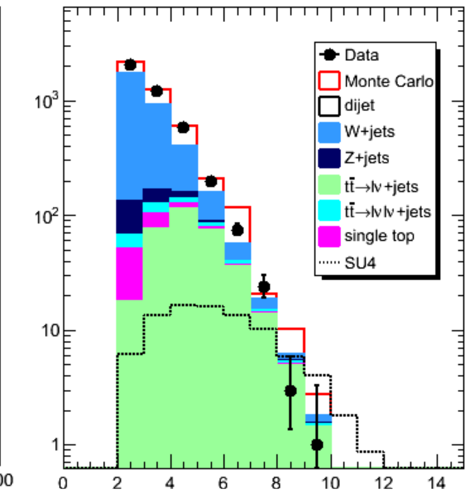
Data MC comparison lepton plus jets channel



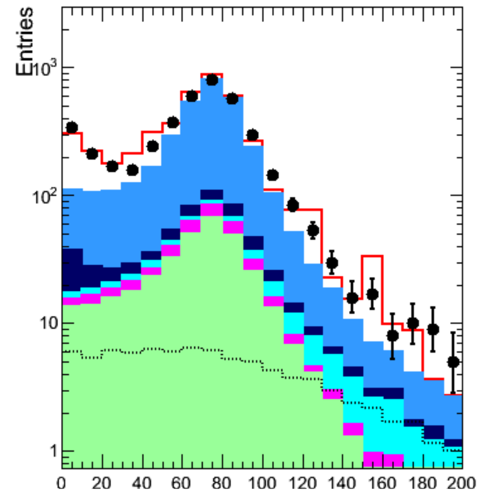
Lepton p_T



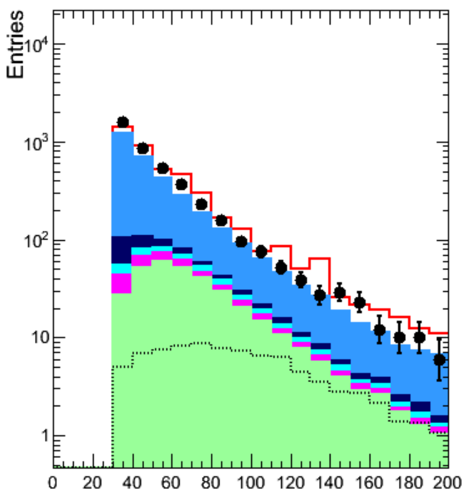
1^{st} Jet p_T



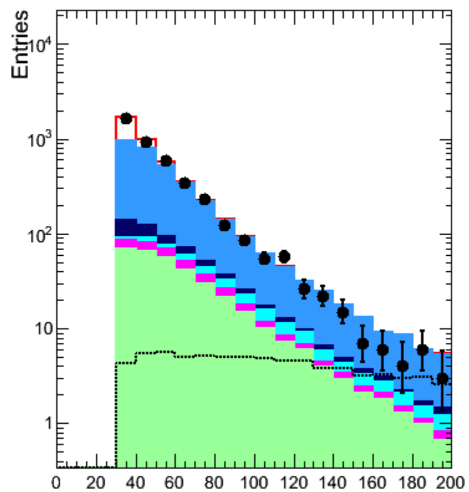
Num. of central jets



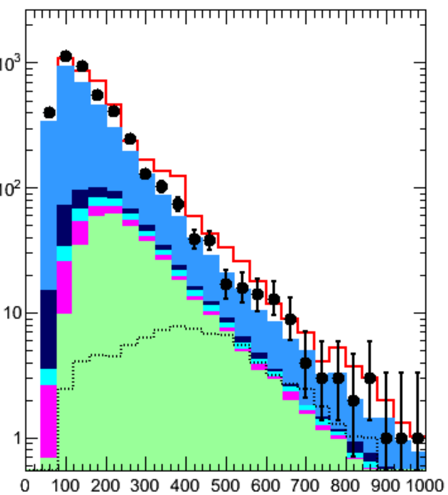
MET + Lepton p_T



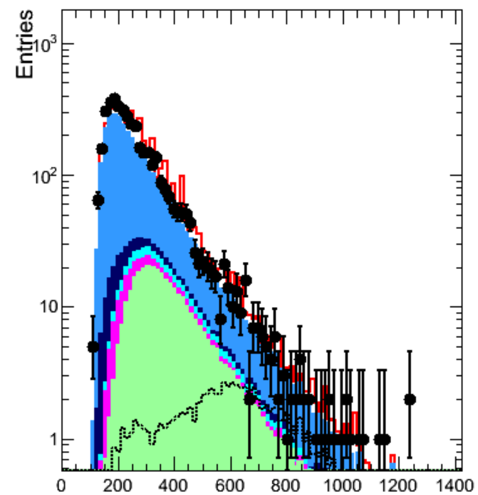
2^{nd} Jet p_T



Missing energy



Sum of all jet p_T



Sum of all p_T

SU4 corresponds to mSUGRA model with the parameters:
m_0 = 200 GeV, $m_{1/2}$ = 160 GeV, A_0 = -400 GeV, tanβ = 10 and $\mu > 0$.

Fit based method

After the pre-selection:

1) to reject dijet we veto events with:
p_T(lepton) < 30 GeV and MET < 40 GeV.

2) Electron is Tight instead,

1. Control sample **(CS)**:

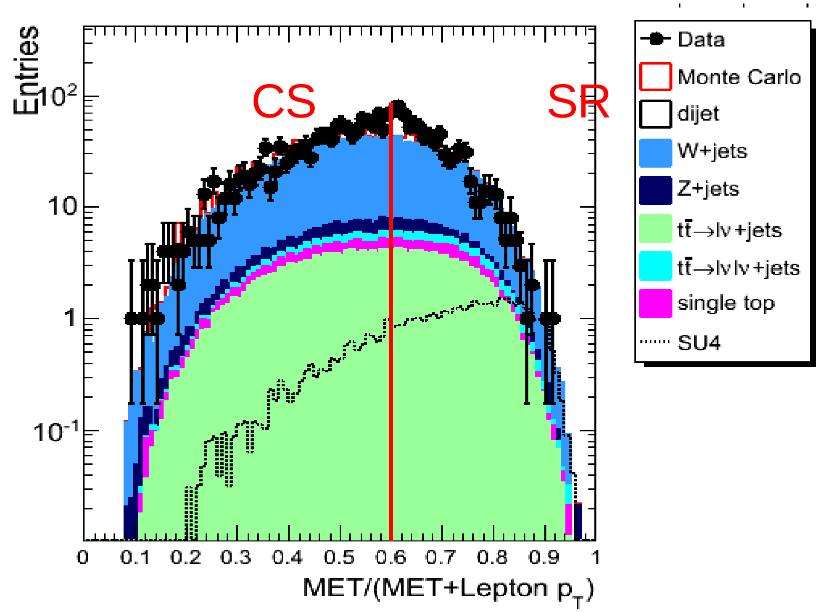
3 Jets (30, 30, 20)GeV and MET > 30 GeV;
MET/(MET+P_T(lepton)) <0.60;

2. Signal region **(SR):**

3 Jets (60, 30, 30)GeV and MET > 60 GeV;
MET/(MET+P_T(lepton)) >0.60;

	dijet	Wjets	AllTop	Zjets	SU4
CS	52.3	706.5	253.0	39.2	20.3
SR	22.8	445.5	187.6	24.9	65.6

This table corresponds to L= 20 pb^{-1}.

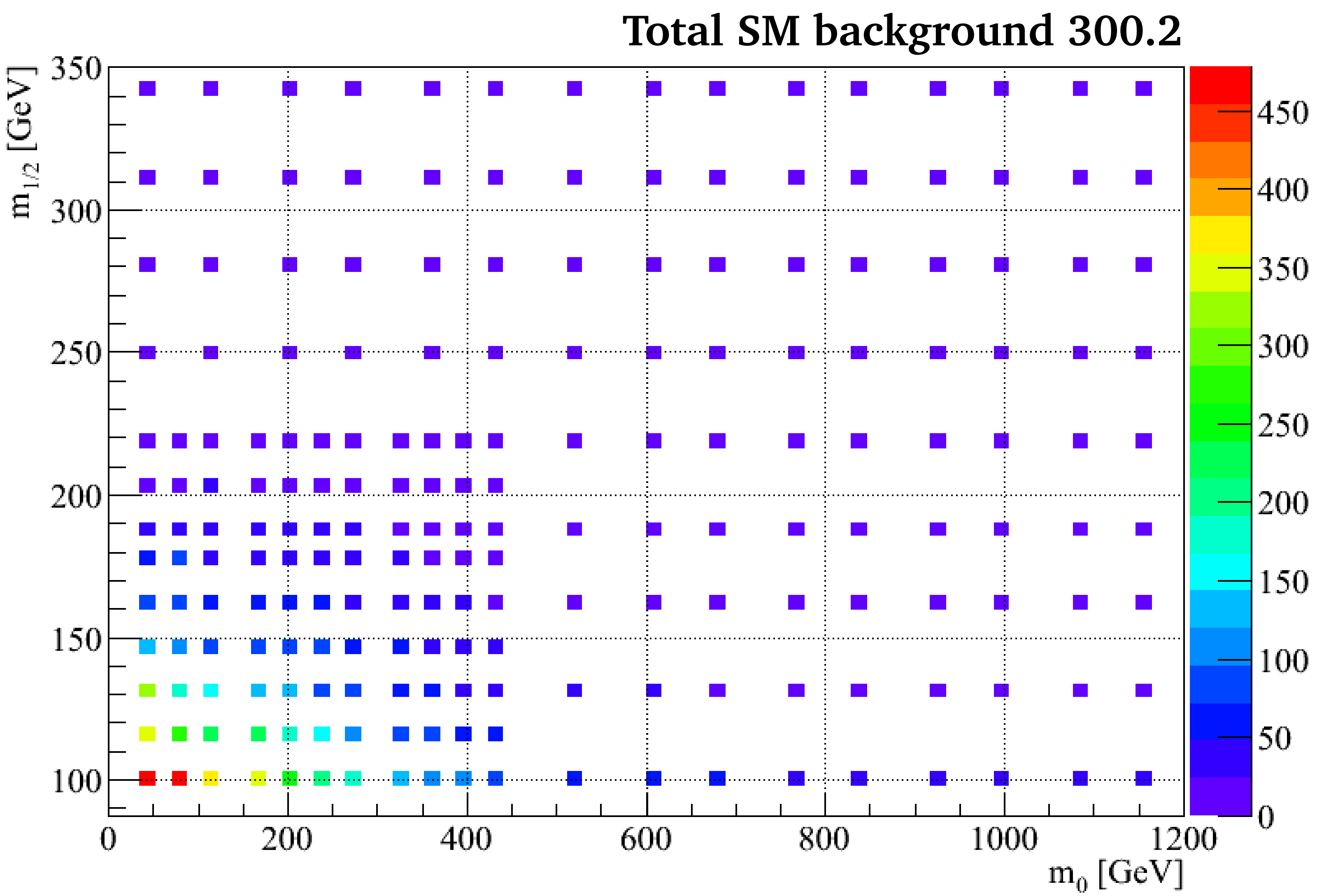


	0.30	0.45	0.60	0.75
2jets	0.51	0.54	0.61	0.59
3jets	0.59	0.61	0.66	0.61
4jets	0.54	0.55	0.59	0.52

The S/S_{min} of the mSUGRA point $(m_0, m_{1/2})$=(40,100), N^C_{jet} (rows) and MET/(MET+P_T(lepton)) (columns).

$S_{min} = a\sqrt{B} + b\sqrt{(B+S_{min})}$; (a=5;b=1.645)
$S > S_{min}$ signal either discovered with 5σ or excluded with 95% CL.

Expected number of events in SR for L = 20 pb^{-1}



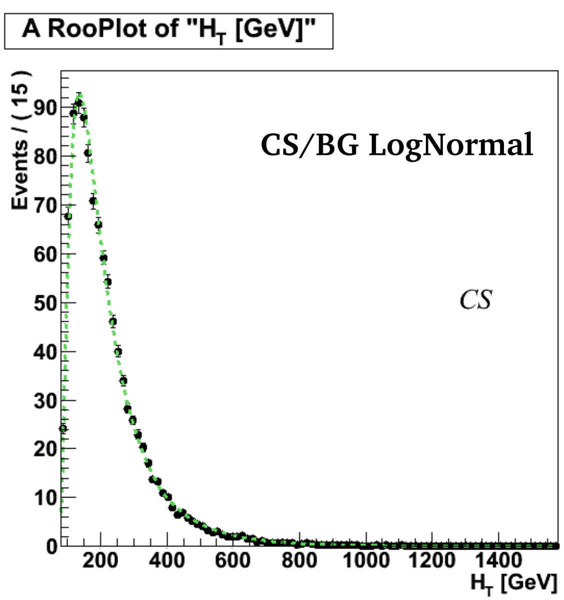
The mSUGRA plane in (m_0;$m_{1/2}$) with A_0 = 0 GeV, tanβ = 3 and μ > 0

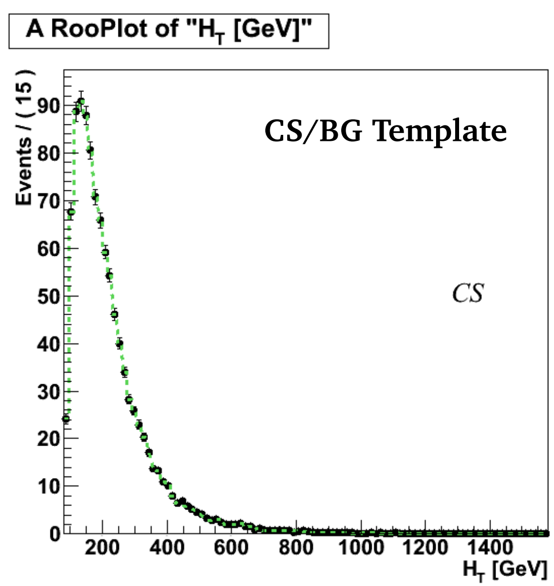
Fitting procedure for early measurement

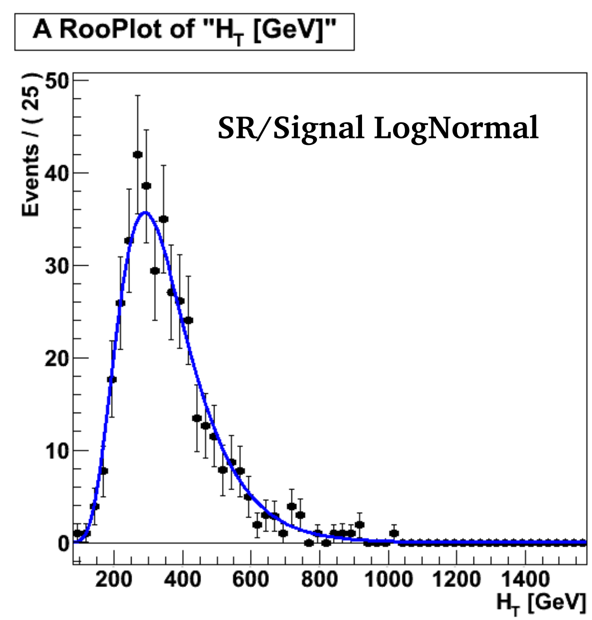
"LogNormal p.d.f" is used for the fits, also for the shape uncertainty studies MC templates were used:

H_T fitting scenario:

$H_T = \sum p_T (\text{Jets});$







un-binned fit to the mSUGRA point at m_0=40, $m_{1/2}$=100, and tanβ=3, MC.

Simultaneous fit to CS and SR

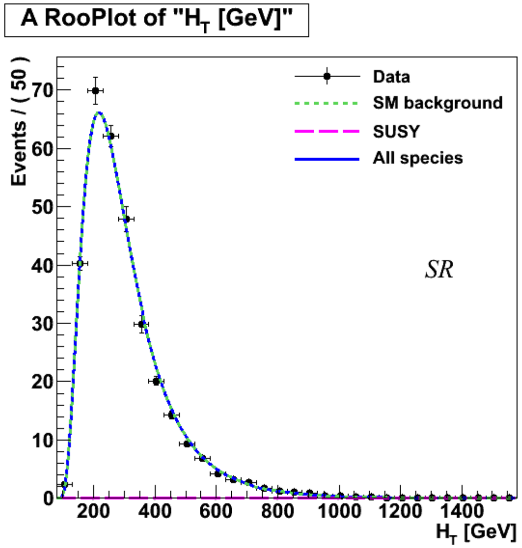
Simultaneous fit in CS and SR with LogNormal p.d.f.:

- 10% uncertainty on the Signal shape (JES+theory), the shape uncertainty is applied along the observable axis, which affects the sensitivity the most.

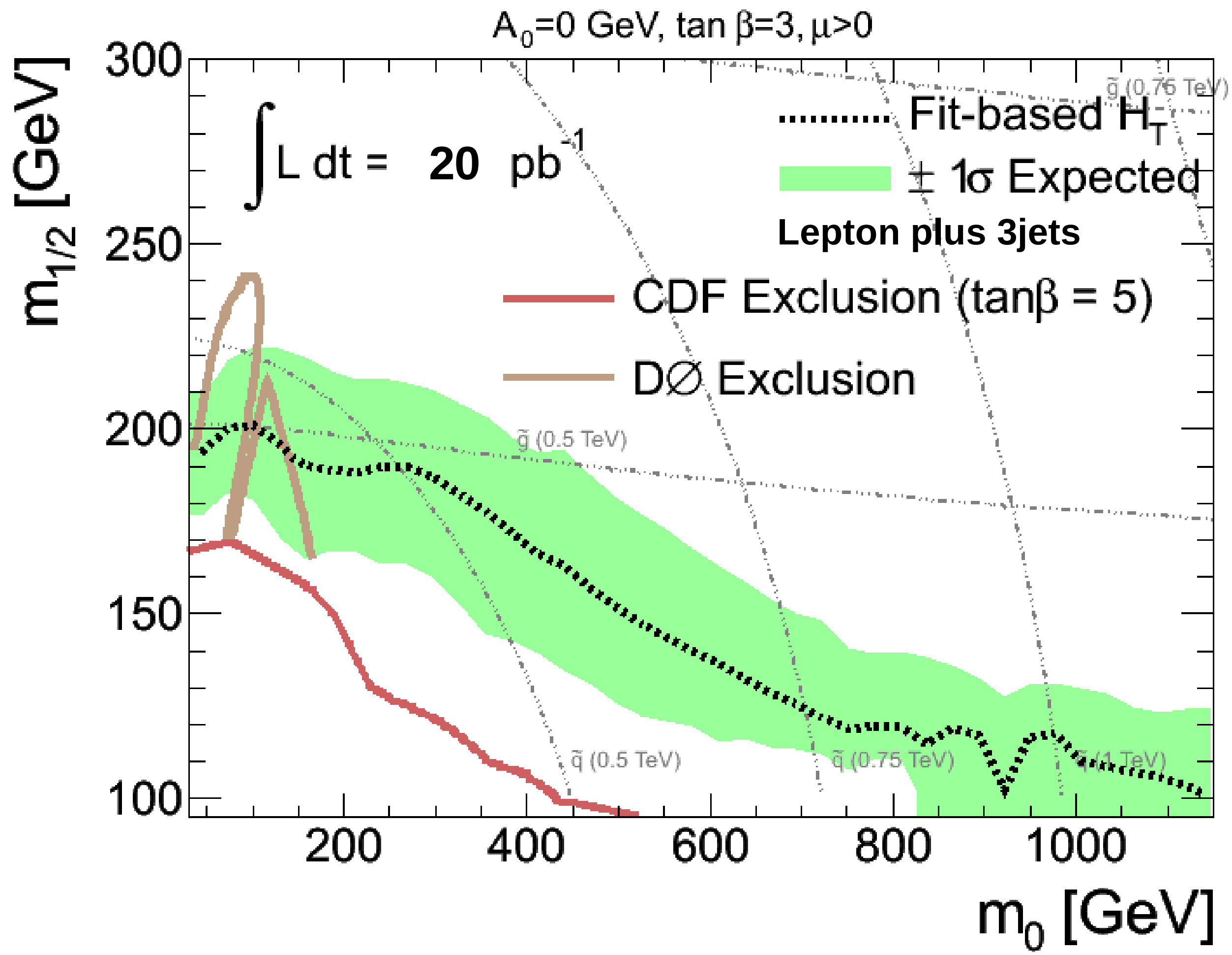
- The Background shape (k) is floated freely in the fit.

- The Ratio of the shape parameters (k) of the background in the Control Region and Signal Region is fixed parameter of the fit with 4% uncertainty assigned to it.

- The background and Signal normalizations in the SR region are free parameters in the fit.



Expected exclusion limits with L = 20 pb^{-1}



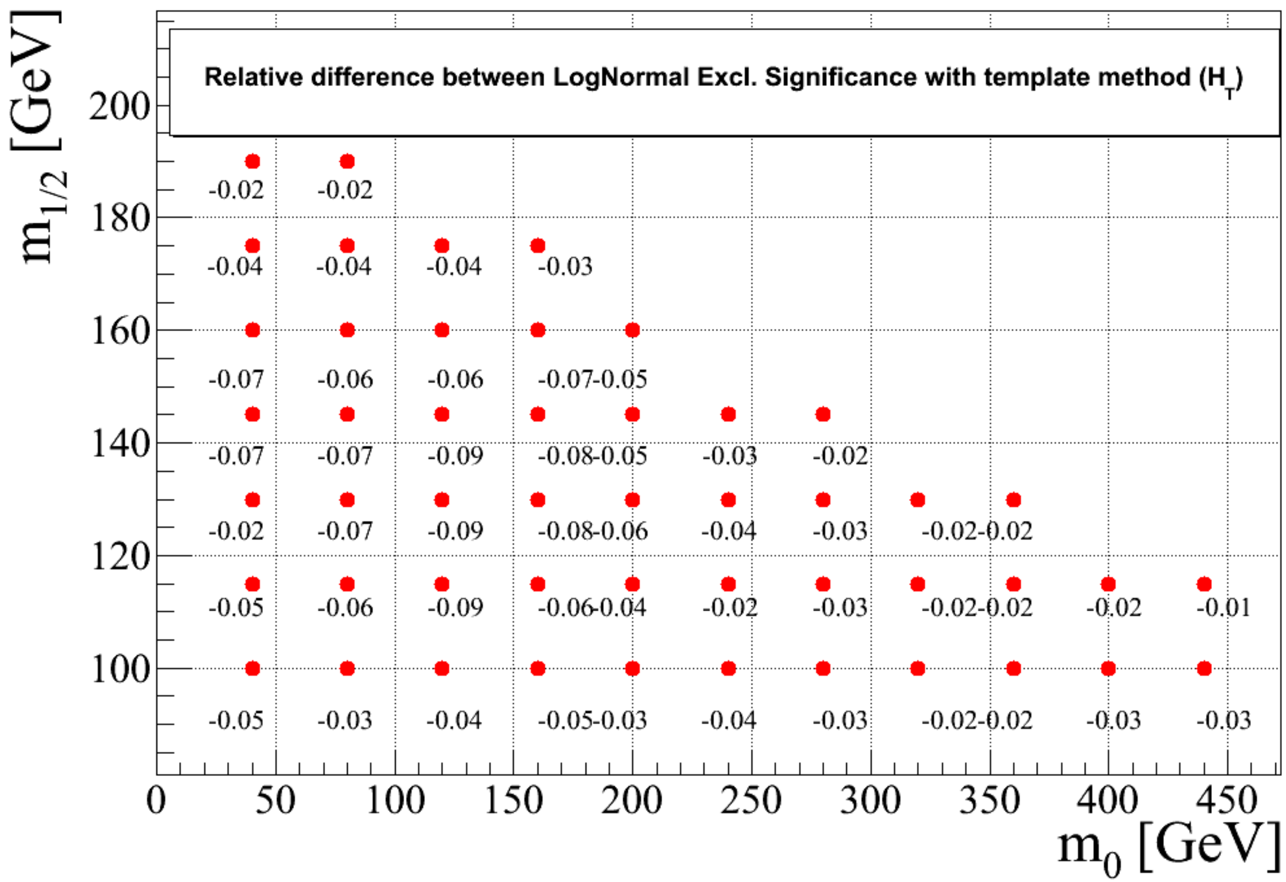
To obtain exclusion limit we used a likelihood ratio test statistics,

Signal contamination in CS were considered and in SR signal event counts were corrected.

Note: List of systematic uncertainties included in 1σ band on back up slide.

Systematic uncertainties due to different pdfs

For the shape uncertainty studies we compared MC templates with LogNormal distribution for the Background shapes



$$\frac{\text{Excl. significance (LogNormal pdf) - Excl. significance (MC template)}}{\text{Exclusion significance (LogNormal pdf)}}$$

Additional uncertainty due to the limited statistics ($L \sim 50pb^{-1}$) for the BG shape estimation with MC template method: ~10 %

W +Jets Shape Studies

W plus jets events are dominant background for lepton plus Jets channel (slide 9):

Following variations of W plus jets contributions were used to derive BG pdfs for the fitting procedure:

- Sherpa data sets, with alternative matrix-element generator,
- Variations of the functional form of the factorization scale in Alpgen (iqopt).

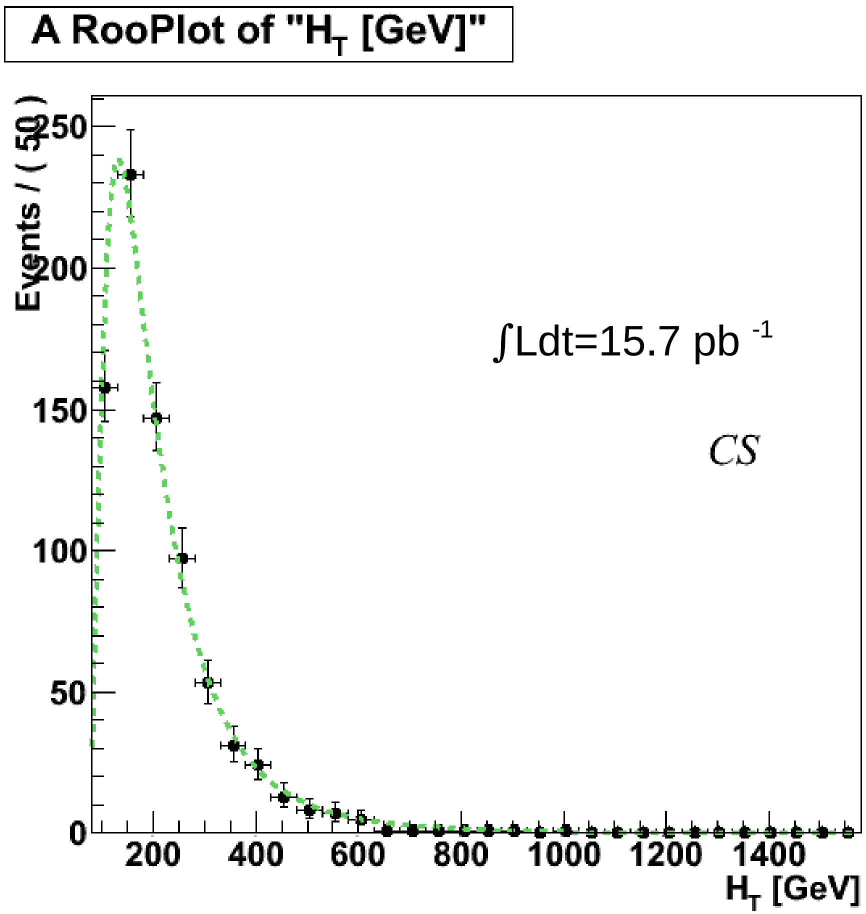
Those contributions are considered to be most significant because they effect jet kinematics and could change H_T distributions used for the fitting procedure.

The systematic errors were derived on the ratio $r = k_{sr}/k_{cs}$ which is fixed parameter in simultaneous fit (introduced on slide 12):

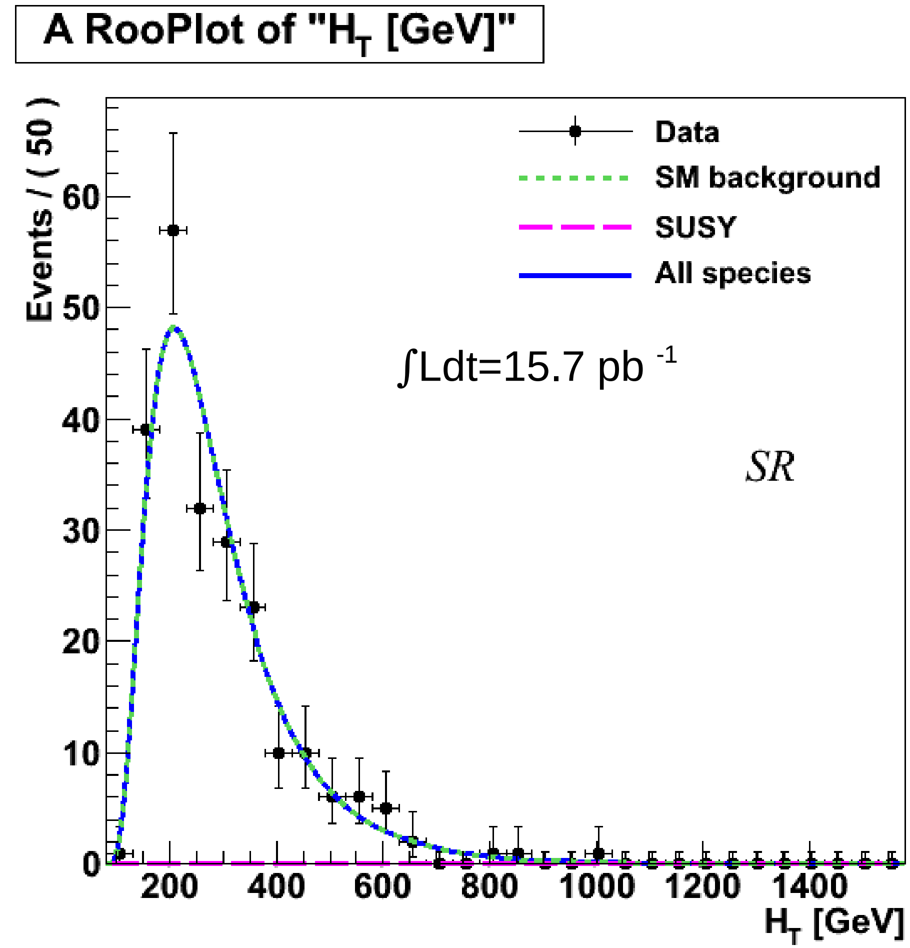
Sherpa: 0.8 %,
Iqopt2 (m^2_w): 1.2 %,
Iqopt3 ($m^2_w + p_T(W)^2$): 0.1 %.

Simultaneous H_T fit to data in CS and SR

Signal hypothesis mSUGRA point at m_0=40, $m_{1/2}$=100, and tanβ=3.

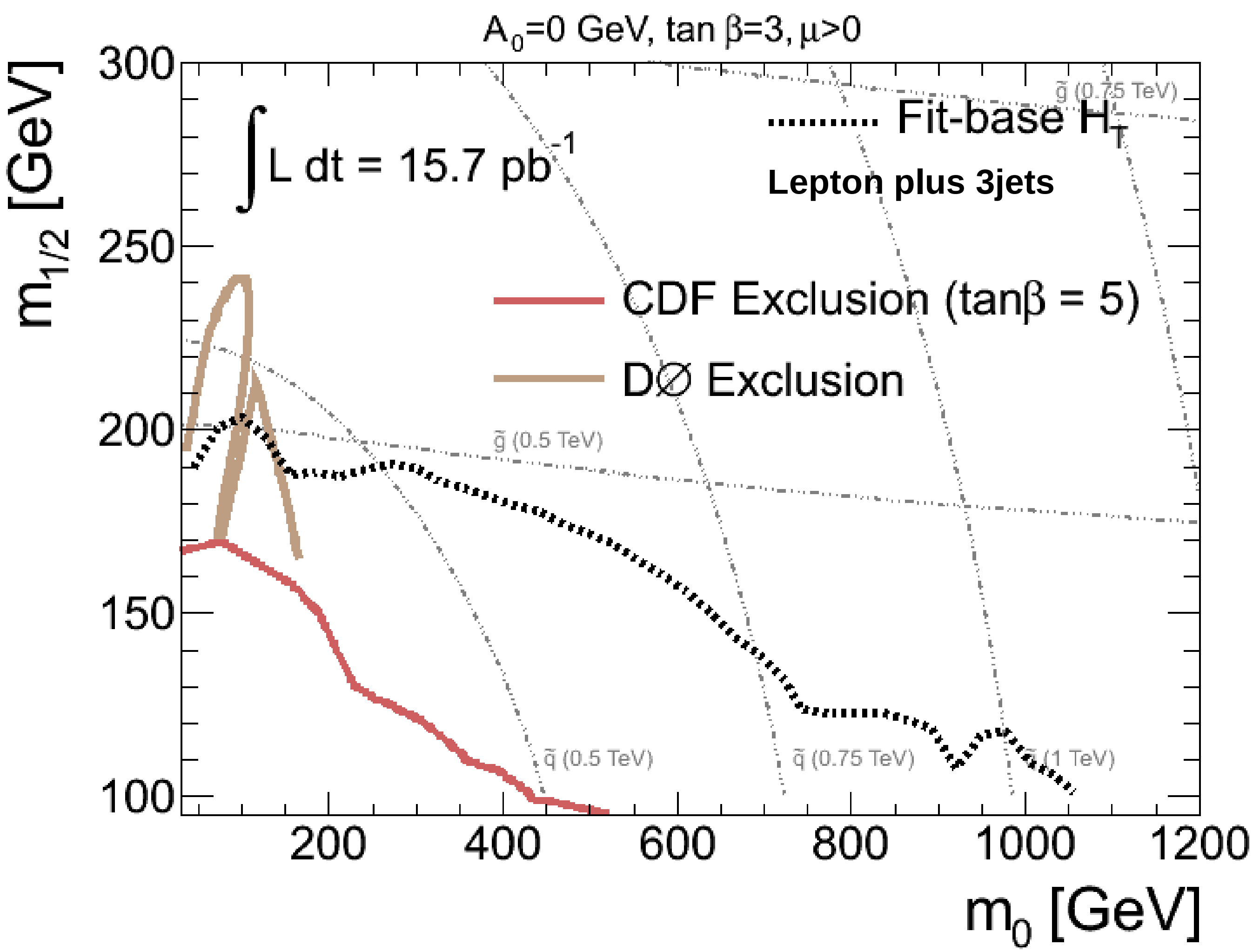


Fit to the data (e+μ channels) in CS.



Fit to the data (e+μ channels) in SR.

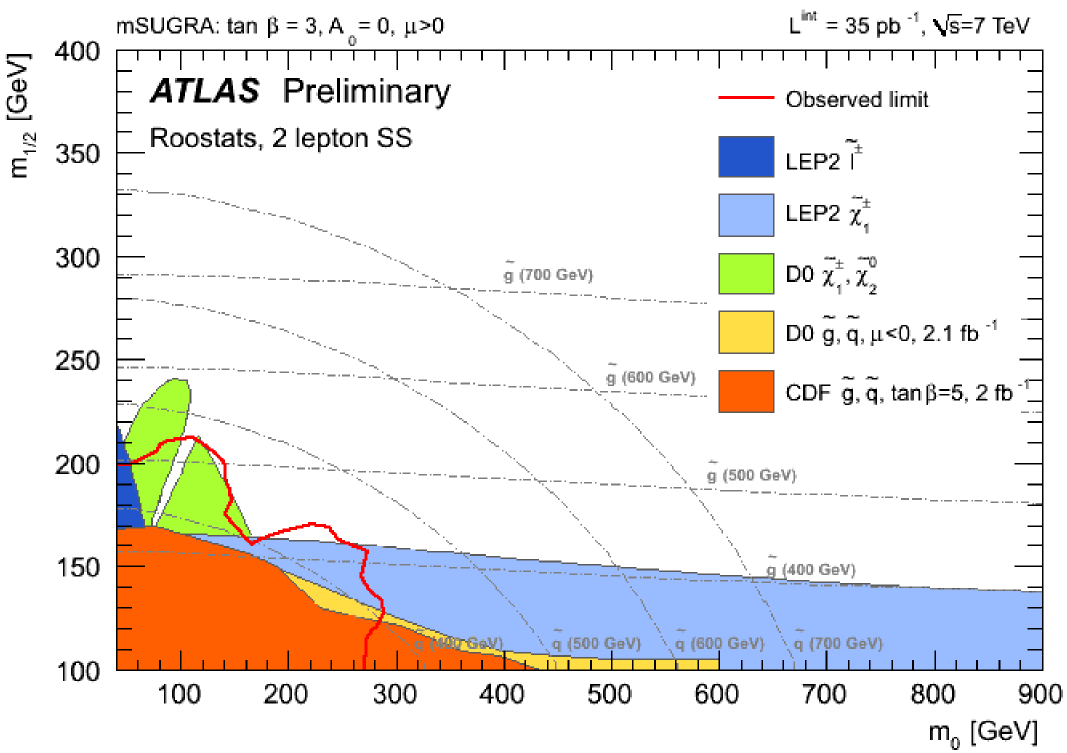
Observed exclusion limits with L = 15.7 pb^{-1}



The exclusion significance from data with likelihood ratio test statistics.
10% uncertainties signal shapes, and 30% uncertainty on the expected signal normalization. The background shape uncertainty is derived from Control Region.

Same Sign dilepton channel (cut &count method)

Event selection from slide 7,
2 good Same Sign lepton with pT > 20 GeV,
MET > 100 GeV.



Data	0^{+2}_{-0}
Z plus jets	0
W plus jets	0.10 ± 0.10
Drell Yan	0
ttbar	0.20 ± 0.01
Dibosons	0.06 ± 0.01
Dijets	0
Wbb	0.03 ± 0.03
Single Top	0
MC SM expected	0.39 ± 0.14
Data driven SM BG estimation	0.235 ± 0.123

To obtain exclusion limit we used Profile likelihood ratio test statistics.

The two-lepton signature typically suffers from lower statistics.

Conclusion

SUSY exclusion limits were obtained for lepton plus jets channel with fit based method,

- We had look to systematic uncertainties coming from the shape estimation.
- W plus jets shapes were studied looking at various MC generators, or parametrization.

SUSY exclusion limits were obtained for di-lepton channel for cut&count method.

Back up

Systematic errors on fit

source	H_T
W+jets normalization ± 50%	1%
tt normalization ± 10%	0%
W+⩾4jets normalization ± 50%	0%
tt+⩾2jets normalization ± 50%	1%
Dijet normalization ± 100%	3%
Other background normalization ± 50%	1%
Jet energy scale ± 7%	0%
MET scale ± 7%	2%
Electron reconstruction efficiency ±15%	$0.3*10^{-4}$%
total	4%

The systematic errors on the ratio $r = k_{sr}/k_{cs}$ which is fixed parameter in simultaneous fit with 4% error for H_T.

Note: additional systematic error 1.2% on r due to the different pdfs LogNormal vs. MC template