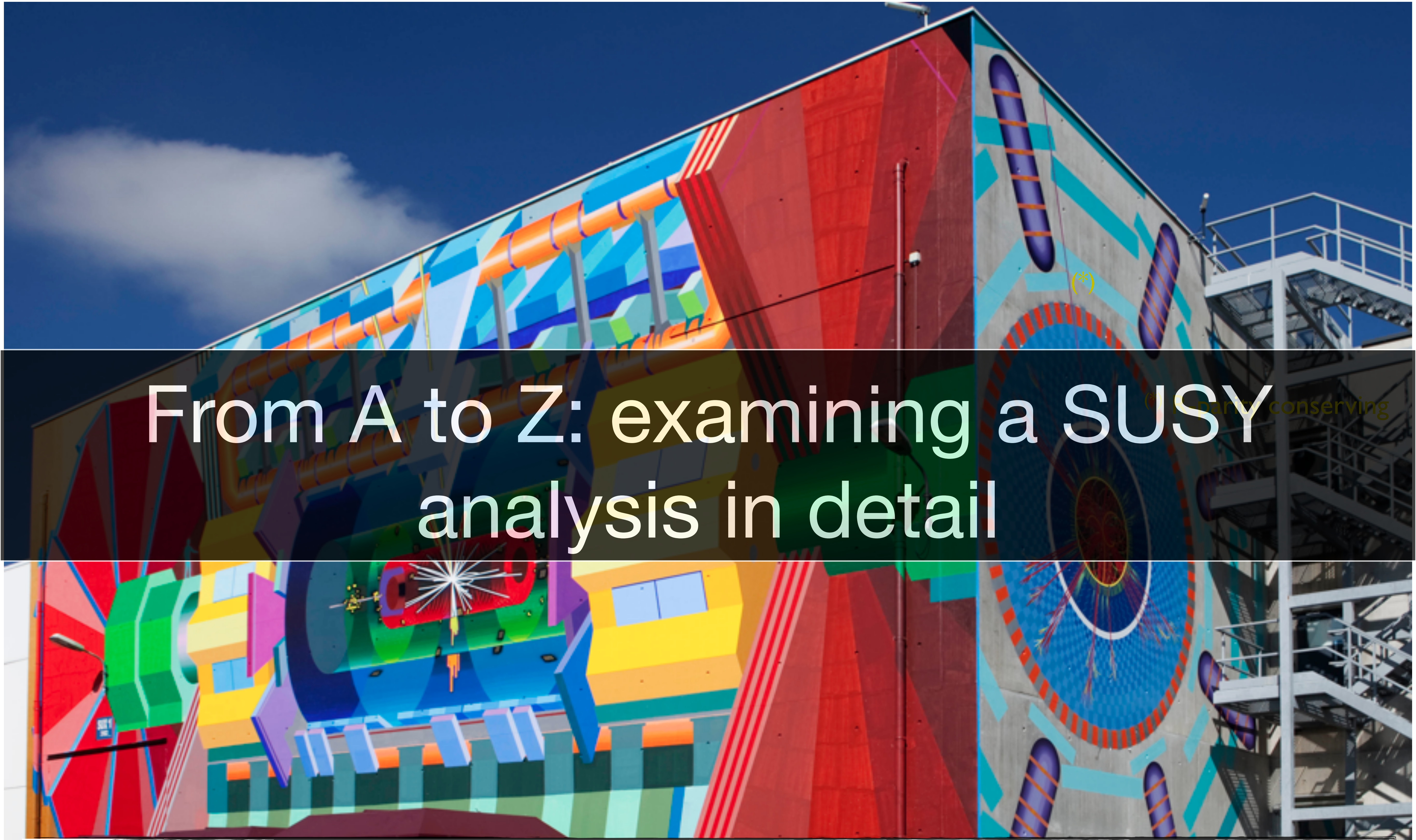


From A to Z: examining a SUSY analysis in detail

NATIONAL ACCELERATOR LABORATORY

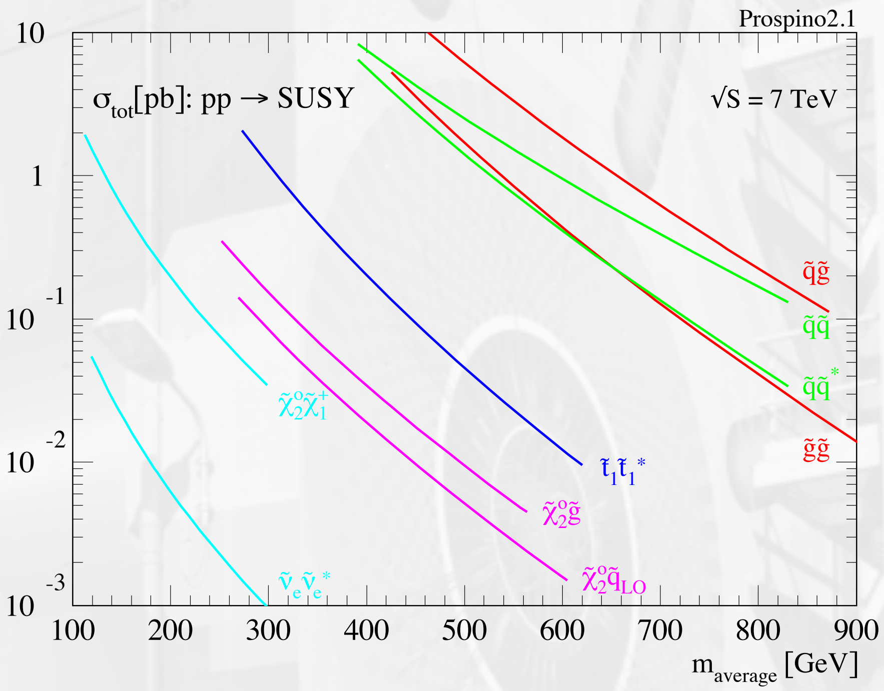
Physics at the Terascale, August 20-24, 2012, Bonn

Prejudice meets reality: setting limits at the LHC and global fits of LHC data and other measurements

Till Eifert (SLAC)

Outline

- Designing a SUSY Search
  - direct stop prod. in 1-lep + jets + ETmiss channel,
  - signal optimization,
  - background estimation,
  - statistical modeling
  - discovery & exclusion fits
- Making the results useful for externals
  - What is provided
  - How to use it



Stop search in the 1-lepton channel

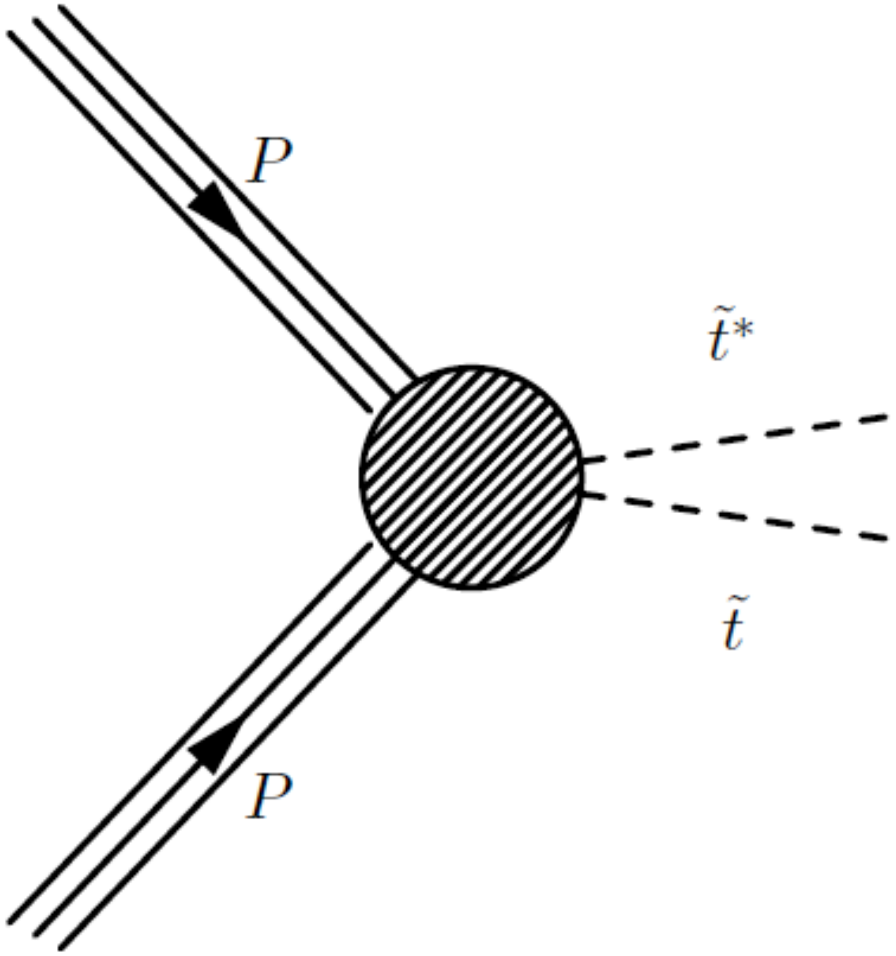
Example SUSY search:
pre-print: http://arxiv.org/abs/1208.2590
paper submitted to PRL

Signal

Direct stop pair prod.

stop means stop1 here

No top quark in proton, thus only s-channel prod. Hence stop-antistop pair.



Several decay possibilities for the stop:

1. stop to top + neutralino1
2. stop to b + chargino1
3. stop to top + neutralino2

etc.

Decay depends on M(stop), M(other SUSY particles), stop mixing (handedness).

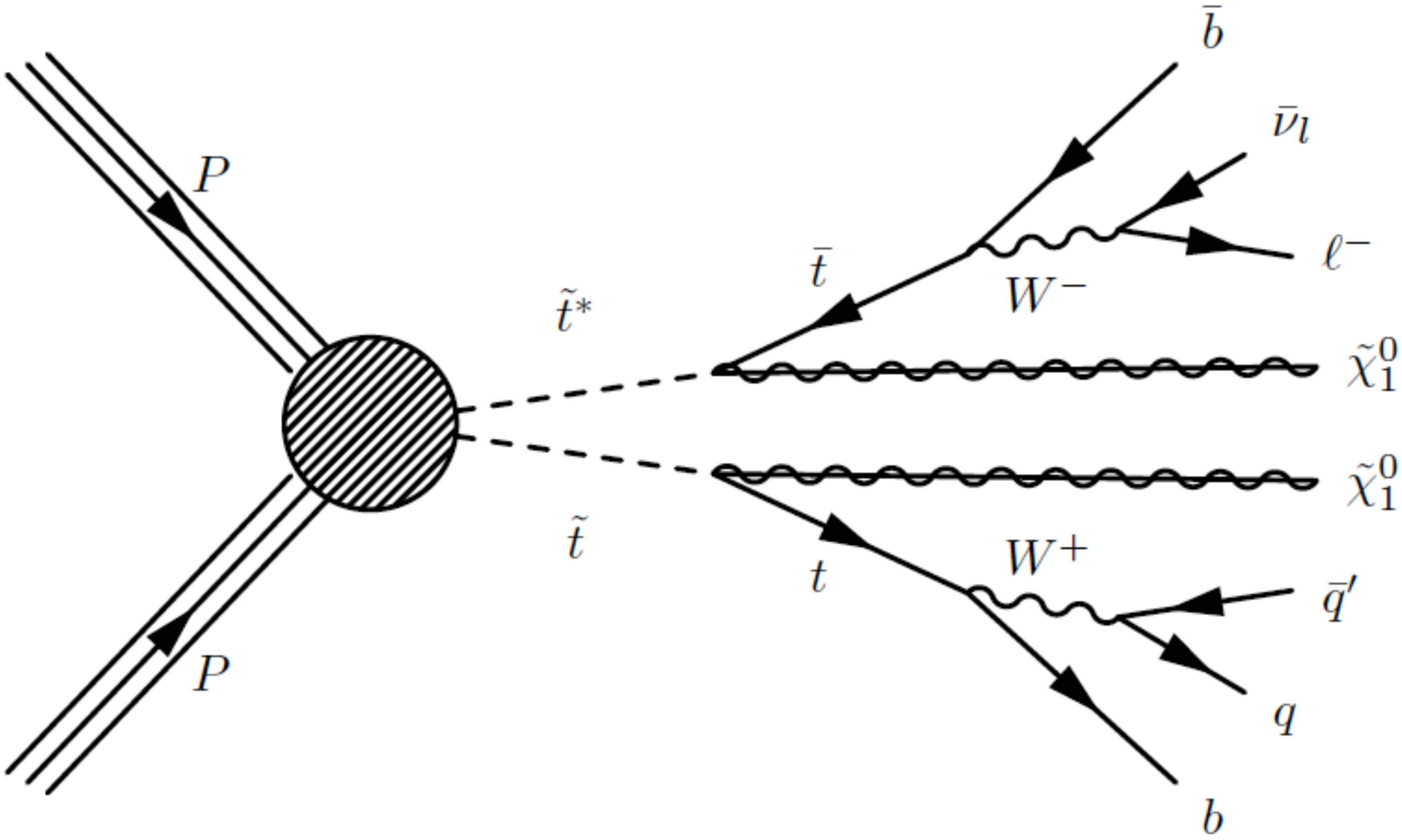
Assumptions of this search:

- M(stop) > M(top)
- stop1 mostly right-handed (i.e. large stop mixing)
- Decay to top + neutralino1

Direct stop pair prod.

stop means stop1 here

No top quark in proton, thus only s-channel prod. Hence stop-antistop pair.



Based on the number of isolated electrons+muons (leptons), the events are categorized in three independent channels:

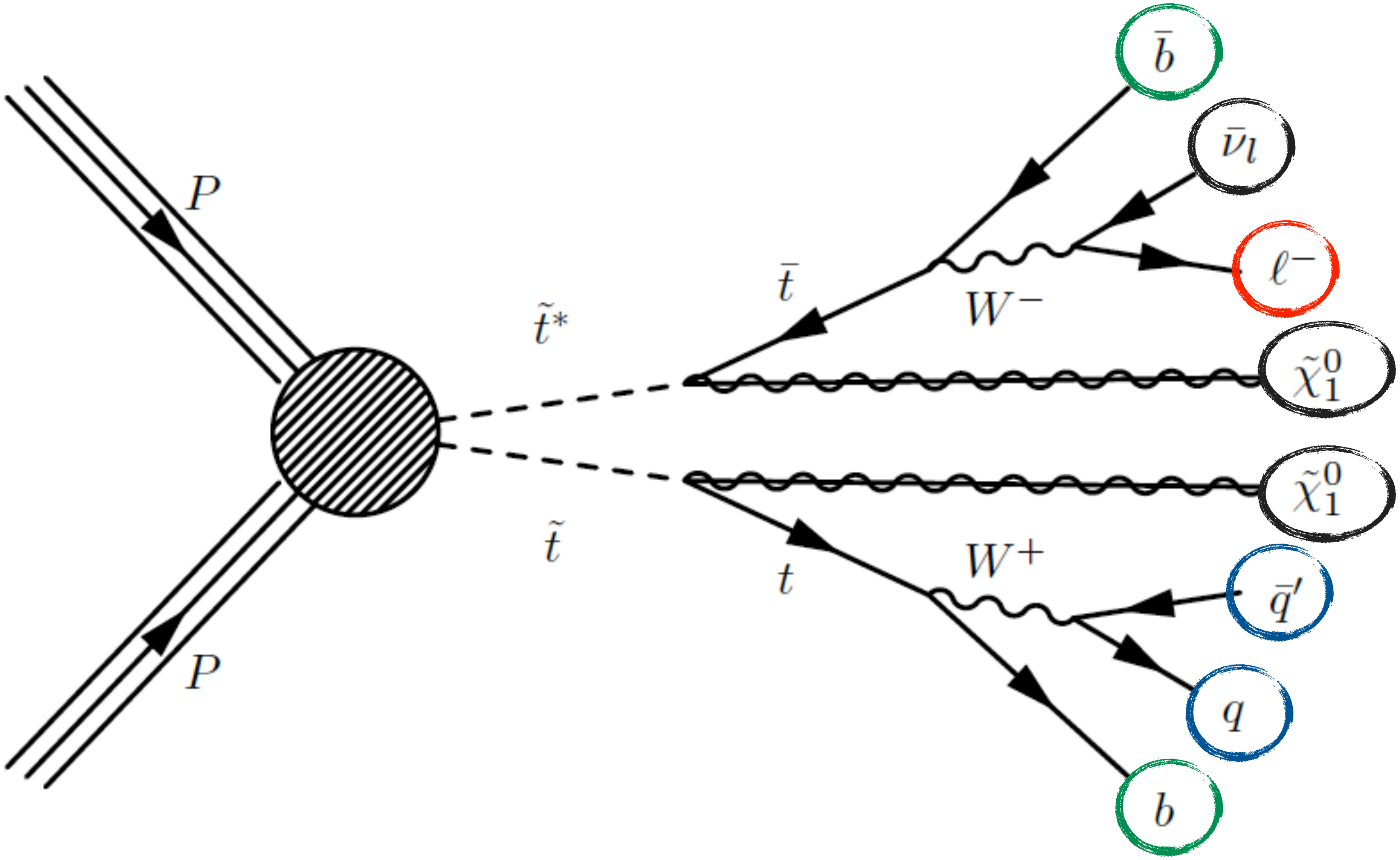
- zero-lepton (both Ws decay hadronically)
- one-lepton (shown above)
- two-lepton (both Ws decay leptonically)

The final results can be statistically combined again.

Direct stop pair prod.

stop means stop1 here

No top quark in proton, thus only s-channel prod. Hence stop-antistop pair.



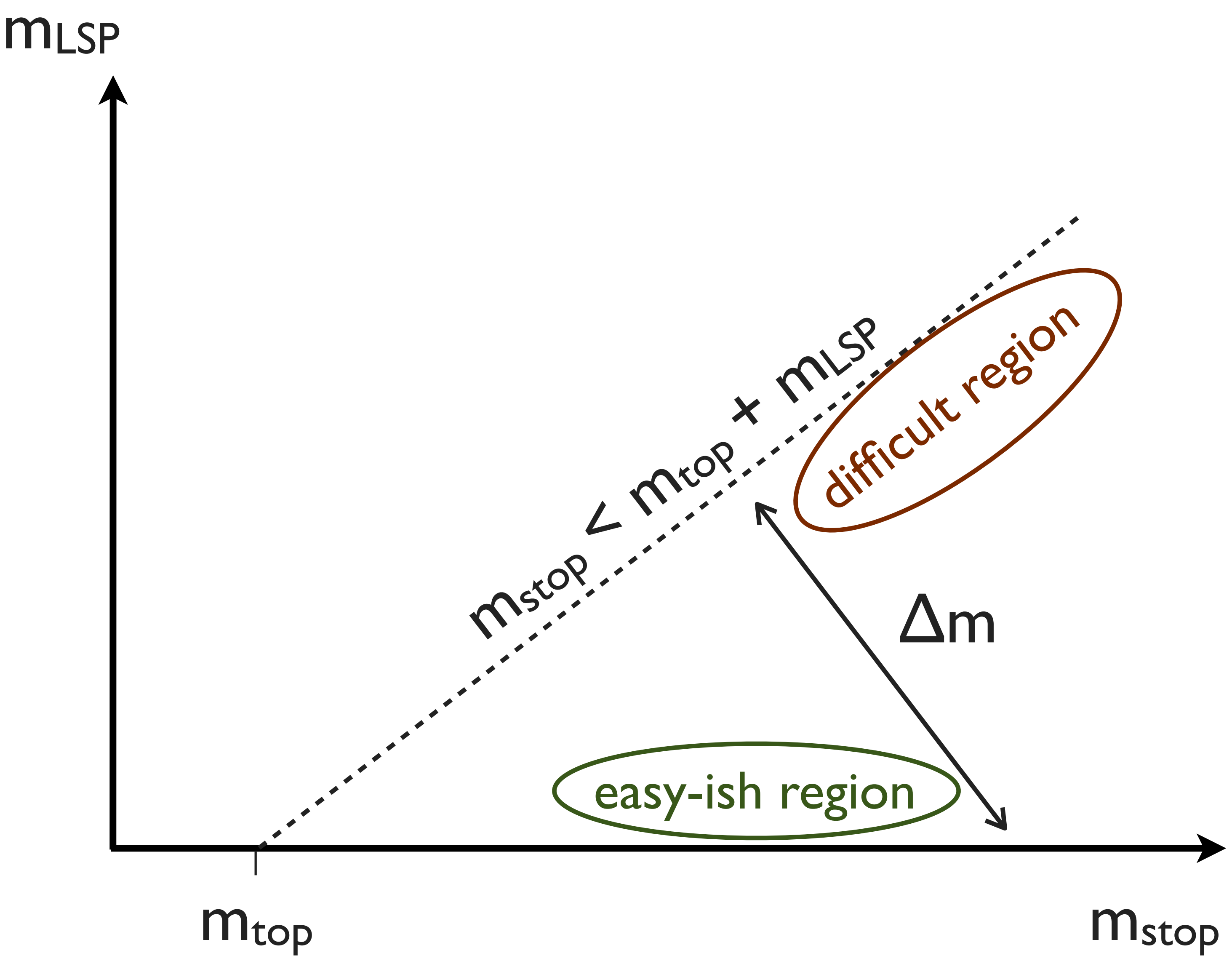
extra E_T^{miss}

Detector signature: ttbar + extra E_T^{miss}

here: 1-lepton + 4-jets (2-bjets) + E_T^{miss}

Signal characteristics

2 parameters: stop, LSP (neutralino1) masses



cross-section

~10pb @ m_{stop}=200GeV

~0.2pb @ m_{stop}=400GeV

~0.01pb @ m_{stop}=600GeV

Key characteristics:

- **small Δm** (close to diagonal)
  - small phase-space available
  - top and LSP have little momentum
  - less E_T^{miss}, less boosted jets, lepton
  - in limit of diagonal, looks identical to SM ttbar
- **big Δm**
  - all objects have more momentum
  - in particular higher E_T^{miss}

Discriminate Signal from background (1)

- Require exactly one isolated lepton (electron or muon)
    - pT threshold, isolation, PID

defines channel

- Require ≥4 jets
    - jet algorithm, pT threshold, eta acceptance, pileup,

lower Njet small S/B

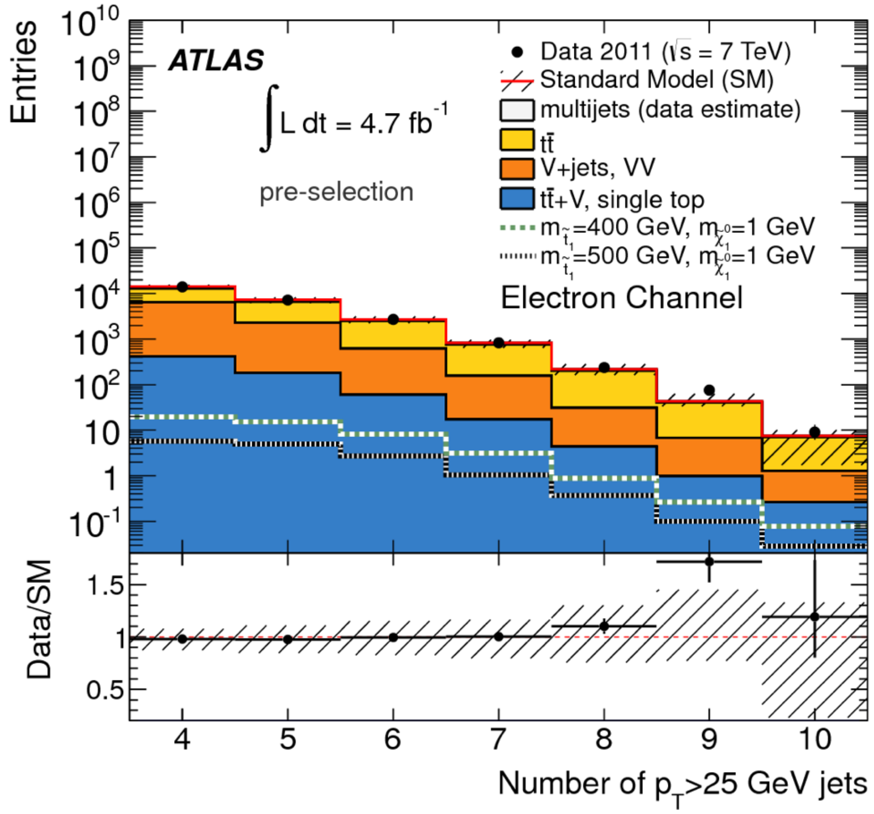
- Require ≥1 b-tagged jets (bjet)
    - tagging algorithm, working point, pT cut

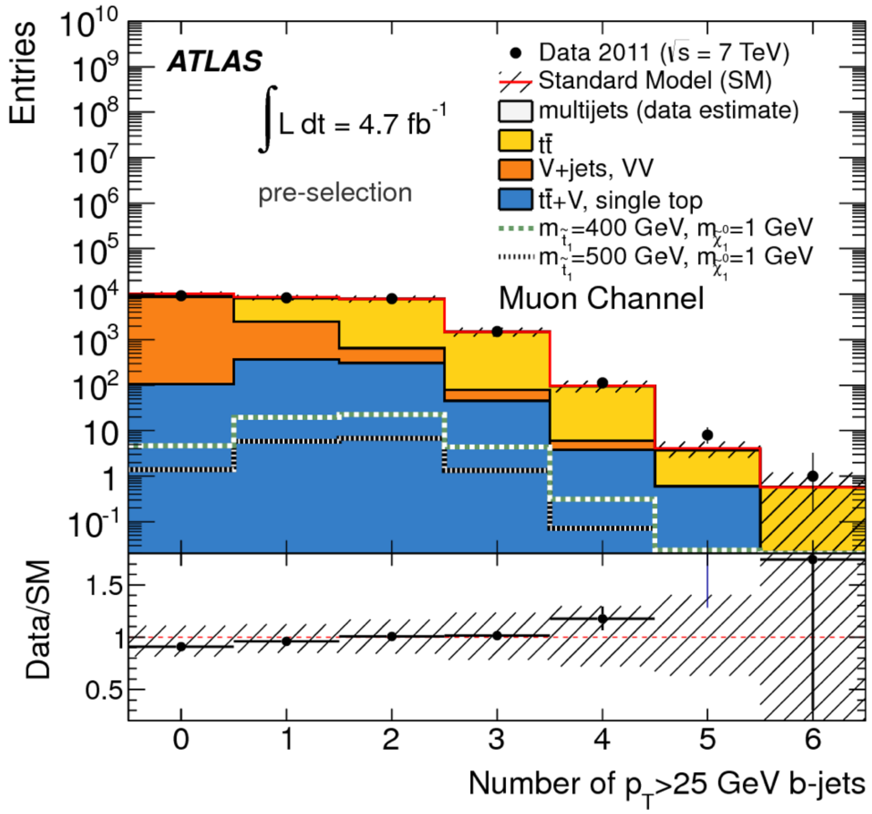
reject most W+jet

Dominant background ttbar (semi-lep)

Optimize search:

- **kinematic selection**
    - jet multiplicity (what jets)
    - bjet(s) -- suppress W+jets
    - more variables (next slide)
- MC backgrounds, signal models (grid)
- figure of merit: ~significance
    - with systematics



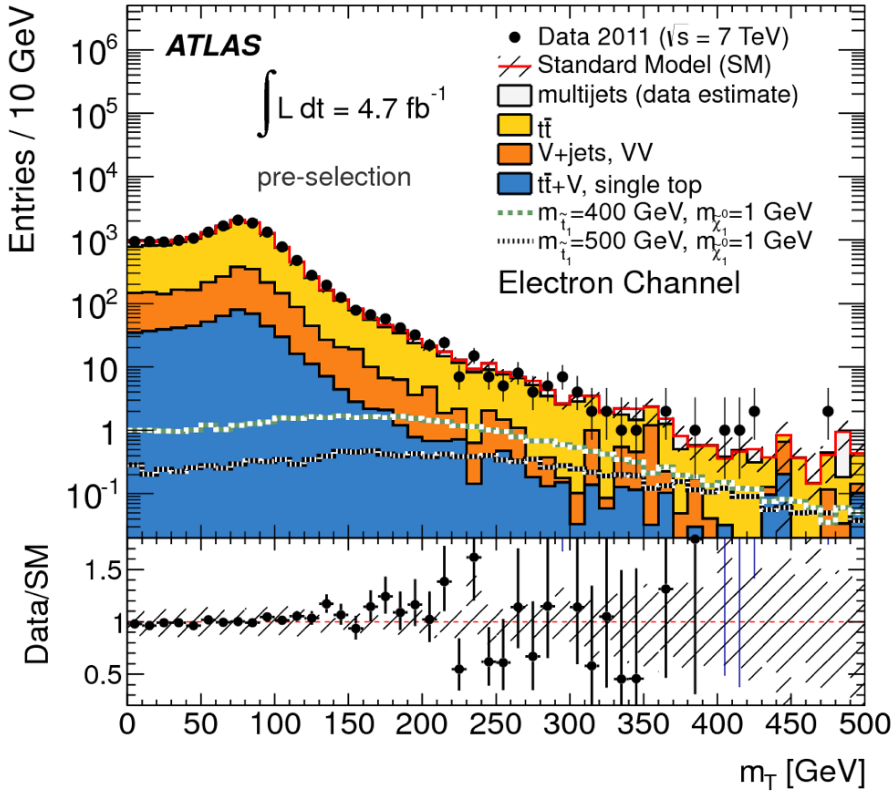


Discriminate Signal from background (II)

- Transverse mass (lepton, pTmiss) > 120 GeV

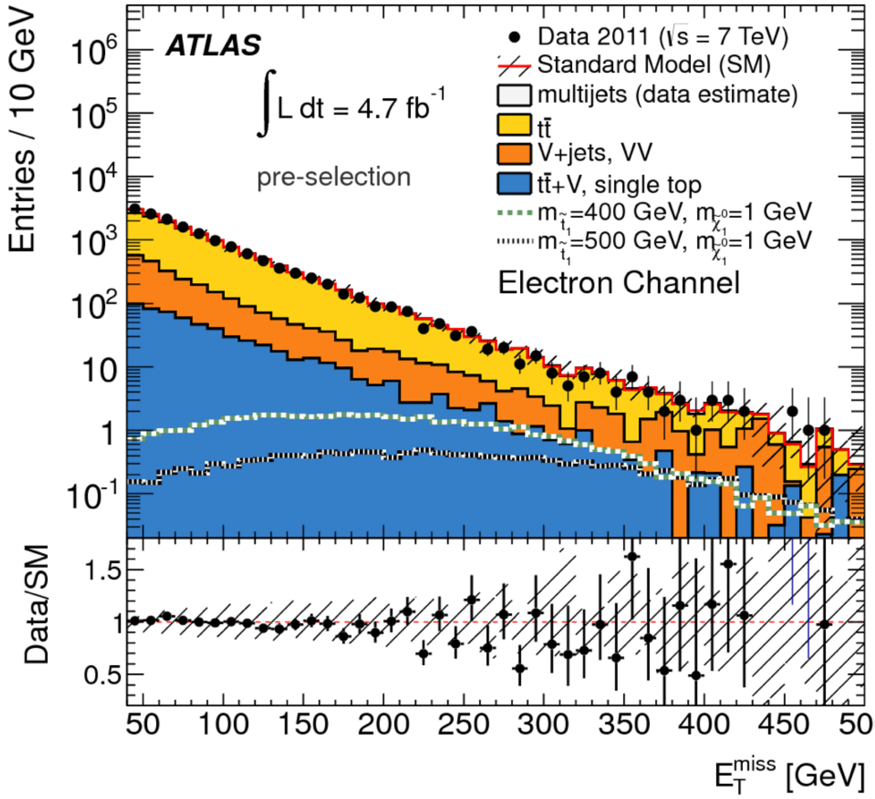
  Dominant background full-lep ttbar, where 2nd lepton is not identified, out of acceptance, or a hadronically decaying tau.

- Reconstruct hadronic top mass (Mjjj) to specifically reject full-lep ttbar background
- E_T^{miss}, $E_T^{miss}/\mathrm{sqrt}(HT)$
- Azimuthal angle between jets and pTmiss



Optimize search:

- **signal selection**
  - discrimination power,
  - correlations,
  - MC modeling (robustness)

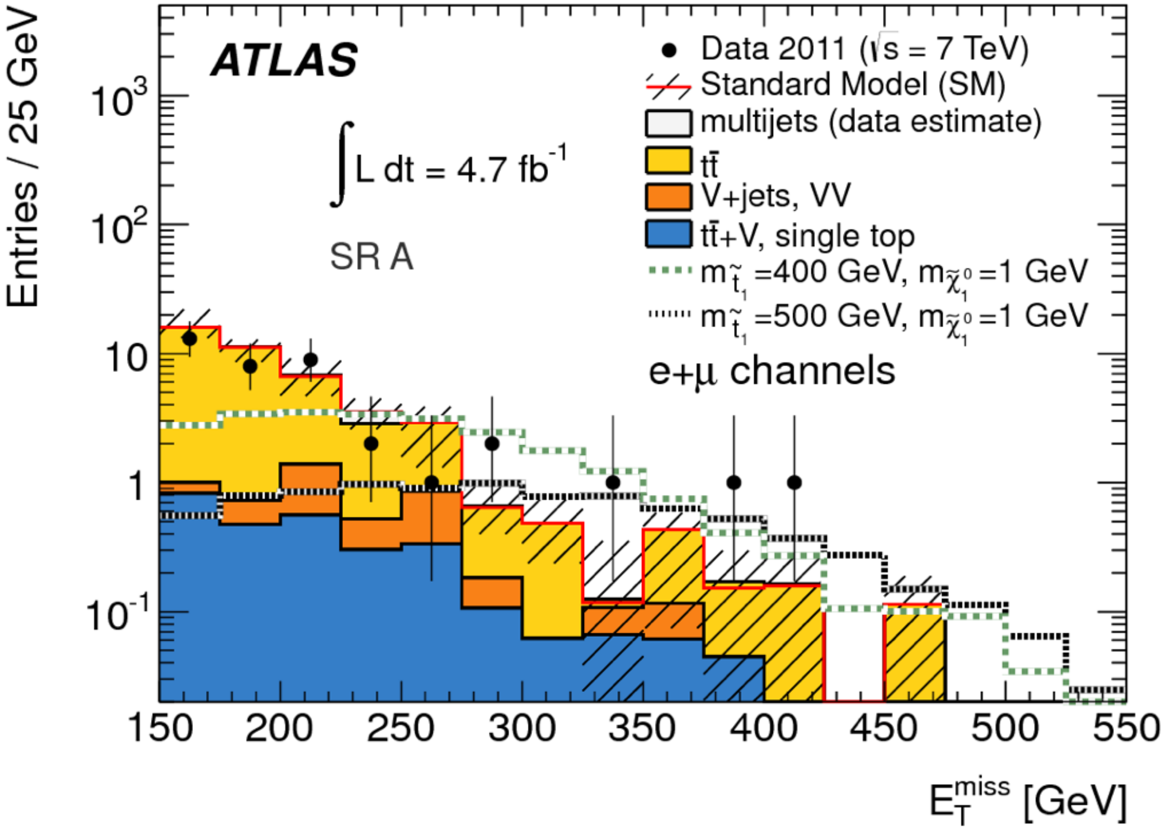


Optimization

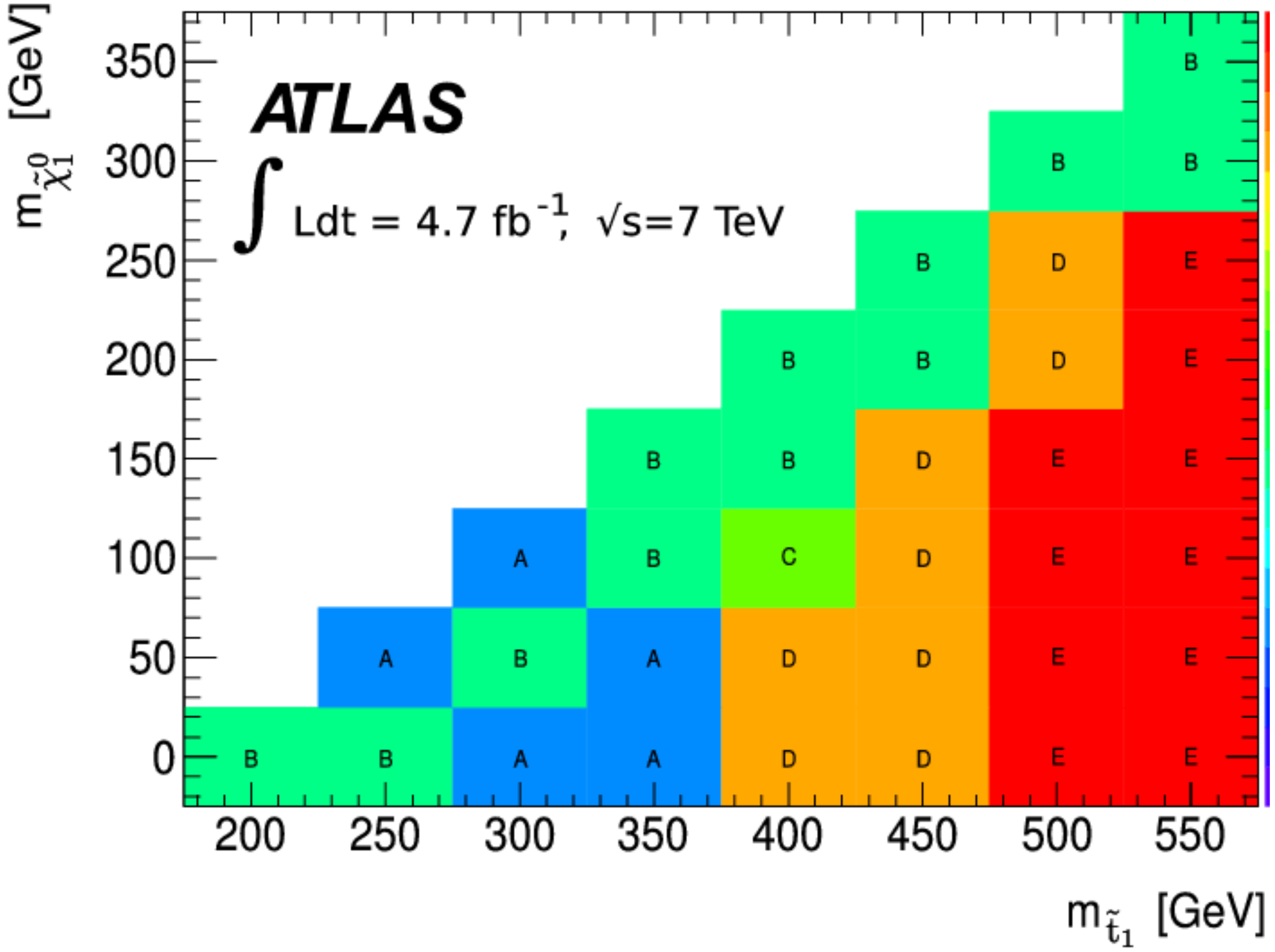
Optimize search:

- **cover various signal models (low and high stop mass, etc.)**
  - define several (overlapping) selections
  - Look-elsewhere-effect (discovery)
  - For exclusion limit: use best-expected selection for each signal model point

Requirement	SR A	SR B	SR C	SR D	SR E
E_T^{miss} [GeV] $>$	150	150	150	225	275
$E_T^{miss}/\sqrt{H_T}$ [GeV$^{1/2}$] $>$	7	9	11	11	11
m_T [GeV] $>$	120	120	120	130	140



Tightest selection (E) for largest Δm



simple cut-and-count experiment; shape information not (yet) used

Background estimation (1)

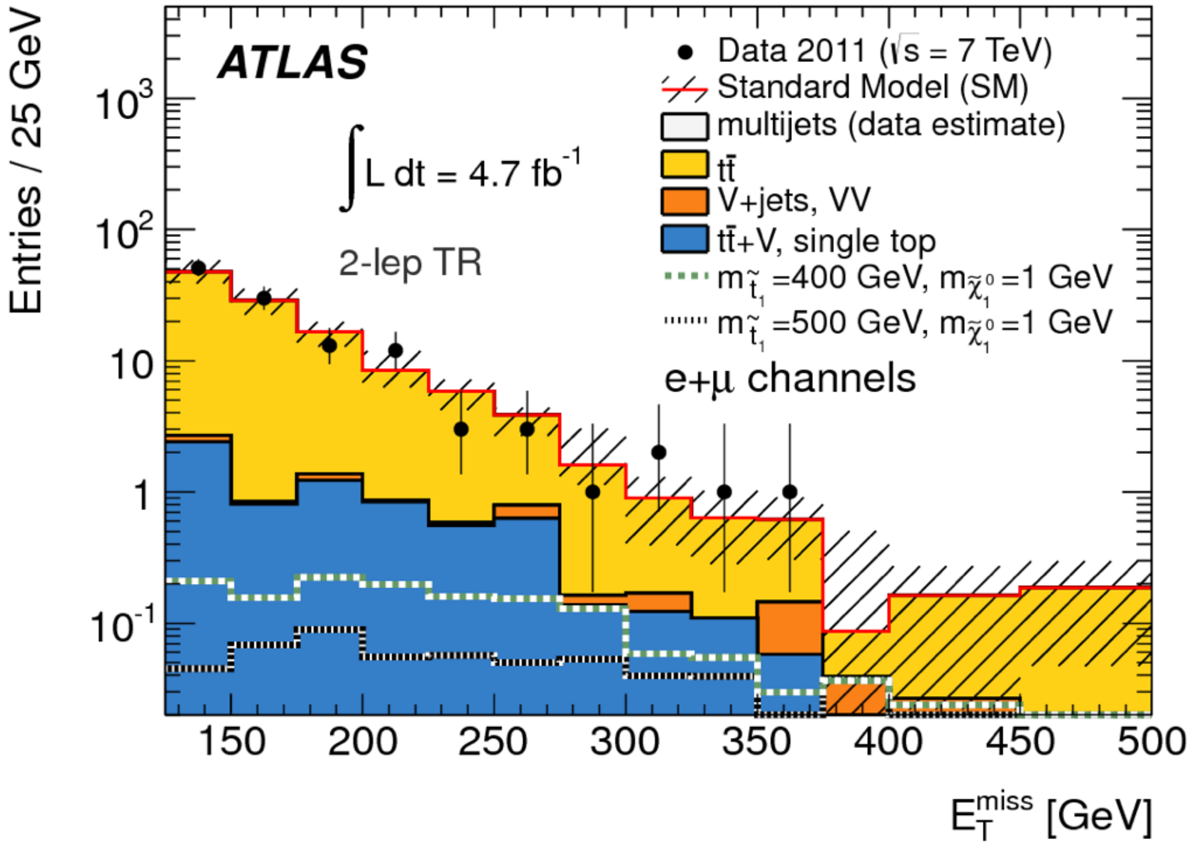
- Dominant background: ttbar
  - Normalize MC prediction in orthogonal control region(s);
  - rely on MC for extrapolating to signal region, i.e. MC “shape” is used;
  - significantly reduces those systematics which affect signal and control regions similarly.

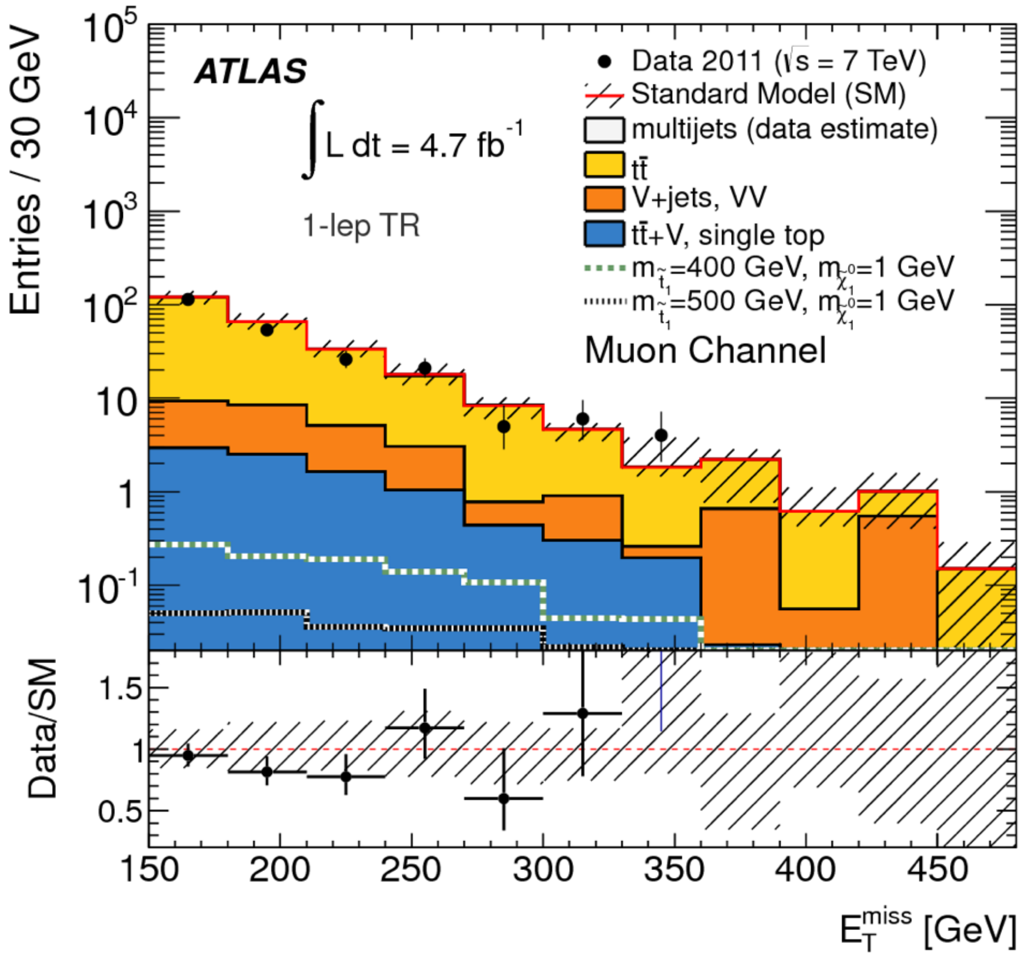
Trade off btw.:

- cancelation of systematics,
- number of events (stat. unc.),
- signal contamination

prefers CR close to (resembles) SR

prefers CR with looser cuts than SR



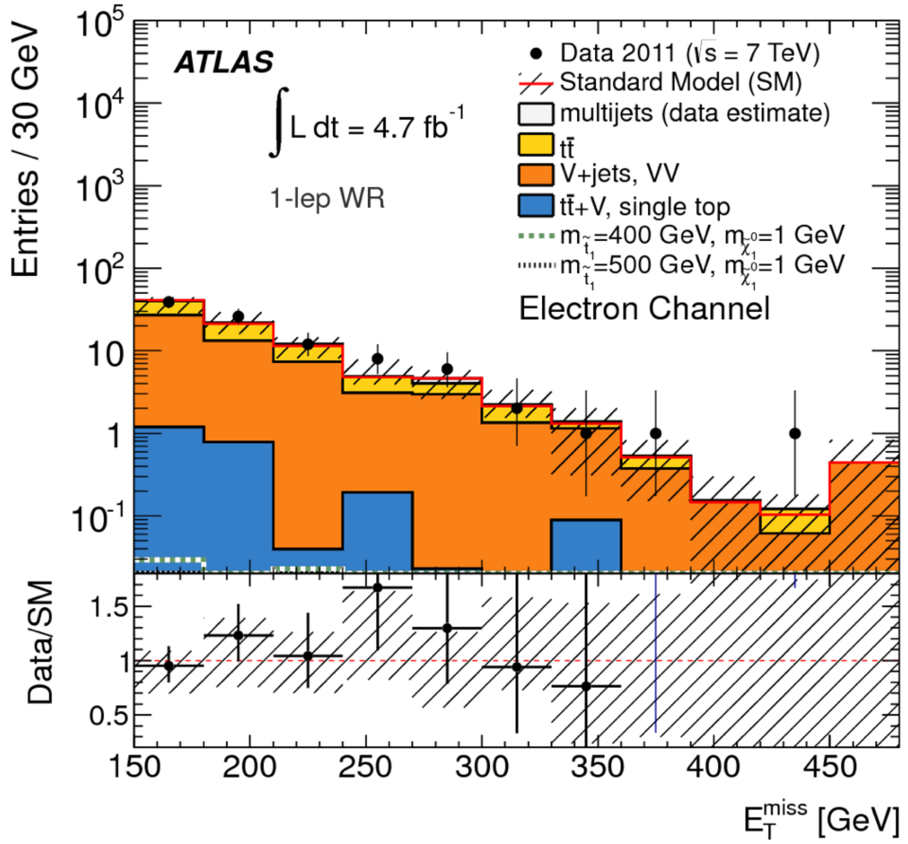


2-lepton ttbar control region:
exactly two leptons, same jet and bjet requirements,
no requirements on mT, ETmiss/sqrt(HT), and m_{jjj};
E_T^{miss} > 125 GeV.

1-lepton ttbar control region:
same as signal selection, but with 60 GeV < MT < 90 GeV;

Background estimation (2)

- Sub-dominant background: W+jets
  - Again, normalize MC prediction in orthogonal control region;
- Sub-dominant backgrounds: single top, dibosons (VV), W+b/c+jets
  - Relatively small backgrounds;
  - estimated using MC, normalized to NLO predictions
- Sub-dominant backgrounds: ttbar+Z, ttbar+W,
  - Small cross section (<1 pb), but relevant for tight cuts;
  - ttbar+Z(nunu) irreducible background, very similar signature to stop signal;
  - no control region could be defined;
  - estimated using MC, normalized to NLO prediction (larger uncertainties!)
- Fake lepton background: multijet (QCD)
  - jets mis-identified as isolated lepton
  - estimate using another data sample where lepton identification criteria are relaxed; thus with significantly more fake leptons.



1-lepton W+jets control region: same as signal selection, but with 60 GeV < MT < 90 GeV; b-jet veto;

Systematic Uncertainties

- detector related: e.g. jet energy scale (JES), electron identification efficiency, luminosity
- generator related: e.g. parton-density-function, renormalization & factorization scales, parton-shower
- both types above apply to MC samples
- Study by varying each uncertainty (typically one at a time), and re-run full analysis on MC samples
  - yields new MC shapes and numbers --> affects both normalization and extrapolation
  - when using CR to normalize MC samples to data, only the extrapolation uncertainty will enter

Example (numbers are made-up):

MC pred. ttbar	SR A	CR 1	CR 2
nominal	5.1	103.4	248.6
JES up	6.1 (+20%)	117.8 (+14%)	289.9 (+17%)
JES down	4.2 (-18%)	87.2 (-16%)	208.3 (-16%)

- Taking the MC prediction for ttbar in the SR would yield a JES uncertainty of +20%/-18%
- However, when normalizing ttbar in CR1 then what remains is the relative change:
  - nominal MC extrapolation factor = 5.1 / 103.4 = 0.049
  - JES up extrapolation factors = 6.1/117.8 = 0.052 (i.e. +6%)
- The effective JES uncertainty is +6% / -2%

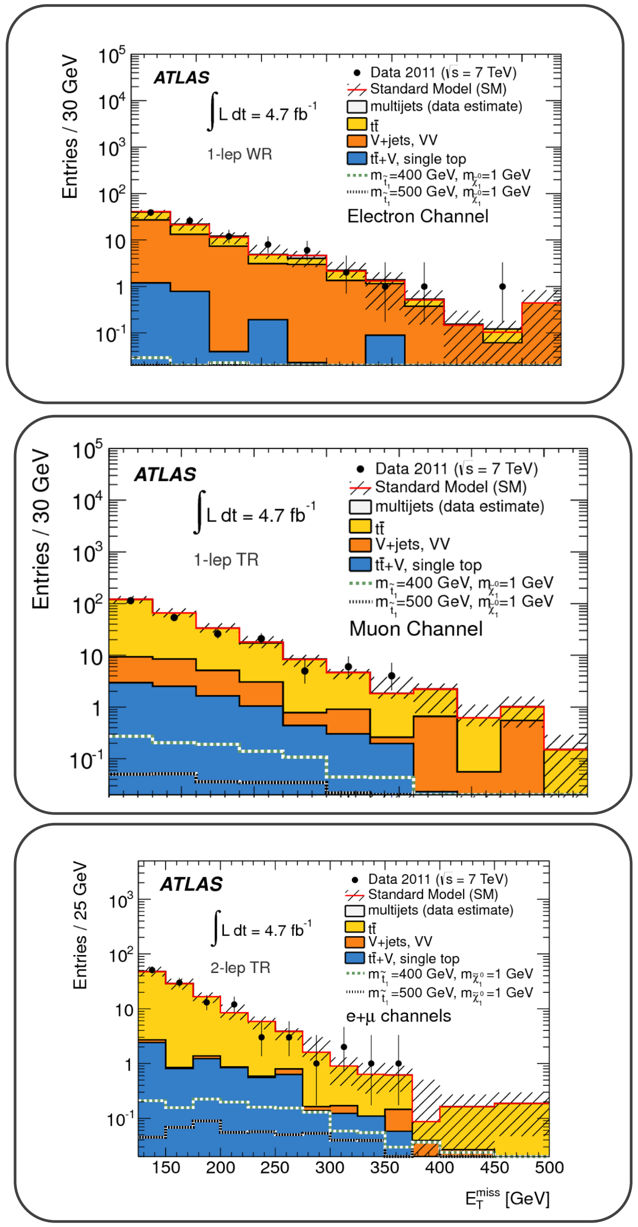
Statistical model (I)

Perform simultaneous fit of all control regions (and later signal regions).
Properly accounts for:

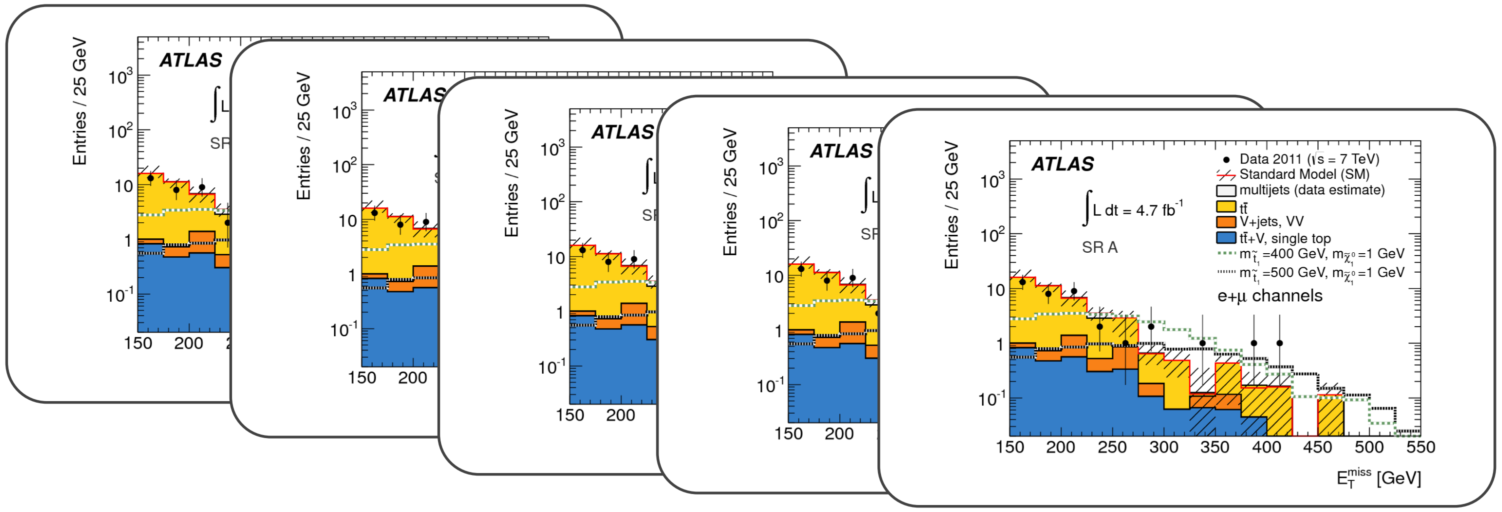
- cross contamination
  (some ttbar also in W+jet region, some signal in control regions, etc.),
- uncertainties can be correlated
  (e.g. JES is correlated btw. ttbar, W+jets, signal, etc.)

‣ Each control / signal region is taken as a single bin (could be more in principle, c.f. profiling of uncertainties)

3 orthogonal CRs



5 overlapping SRs



Statistical model (2)

- Consider control regions only
- Likelihood function is

bin-1..3

$$L = P_{2\text{-lep}} \times P_{1\text{-lep TR}} \times P_{1\text{-lep WR}} \times G_{syst}$$

where $P_{bin\text{-}j} = P_{bin\text{-}j}(N^{obs}_{bin\text{-}j}, N^{fit}_{bin\text{-}j})$ is the Poisson distribution, $N^{obs}_{bin\text{-}j}$ is the number of observed events in bin-j, $N^{fit}_{bin\text{-}j} = \sum N^{proc\text{-}i}_{bin\text{-}j}$ is the fitted number of events in the same bin, and G_{syst} is a product of Gaussians which describes the prior systematic uncertainties as follows.

$$N^{proc\text{-}i}_{bin\text{-}j} = \begin{cases} N^{fit,proc\text{-}i}_{bin\text{-}j} = N^{MC,proc\text{-}i}_{bin\text{-}j} \times \mu^{proc\text{-}i} \times \prod[1 + \lambda^{sys\text{-}k} \times \sigma^{sys\text{-}k,\ proc\text{-}i}_{bin\text{-}j}] & \text{normalization floating} \\ N^{MC,\ proc\text{-}i}_{bin\text{-}j} = N^{MC,proc\text{-}i}_{bin\text{-}j} \times \prod[1 + \lambda^{sys\text{-}k} \times \sigma^{sys\text{-}k,\ proc\text{-}i}_{bin\text{-}j}] & \text{normalization from MC} \end{cases}$$

where $N^{MC,proc\text{-}i}_{bin\text{-}j}$ is the MC predicted number of events for (bkg) process i, in bin j, $\mu^{bkg\ i}$ is a fitted (freely floating) fit parameter to scale process i, $\lambda^{sys\text{-}k}$ is a nuisance parameter for a systematic uncertainty k, and $\sigma^{sys\text{-}k,\ proc\text{-}i}_{bin\text{-}j}$ denotes the impact of applying a 1-sigma variation of systematic k on (bkg) process i in bin j.

Penalty terms describe the prior (Gaussian) probability distribution of the nuisance parameters:

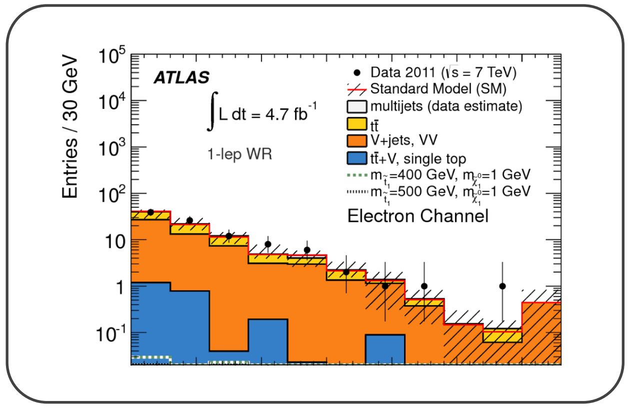
$G_{syst} = \prod G(\lambda^{sys\ k}, 0, 1)$

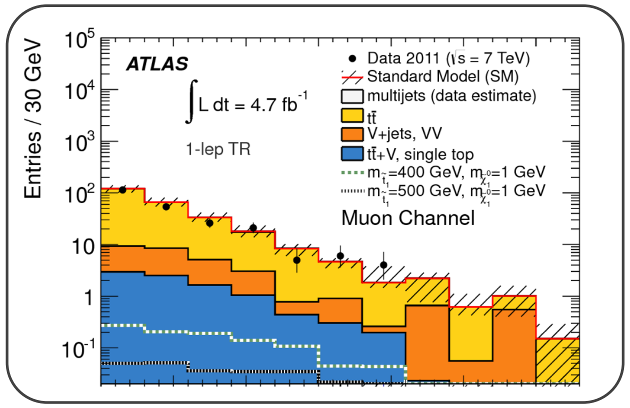
Statistical model (I)

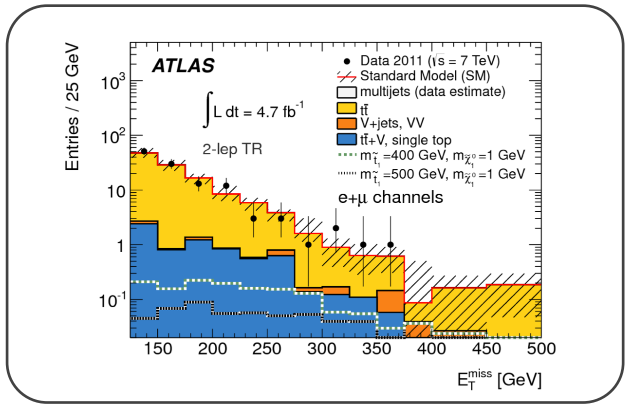
$$L = P_{2\text{-lep}} \times P_{1\text{-lep TR}} \times P_{1\text{-lep WR}} \times G_{syst}$$

- Each control / signal region is taken as a single bin (could be more in principle, c.f. profiling of uncertainties)
- Event counts are described by Poisson statistics
- Describe full system by its likelihood function,
- maximize it to find the "fitted" number of backgrounds and the associated uncertainties
- same likelihood is used to determine p-value (compatibility with background-only hypothesis), and CL$_s$ exclusion limits

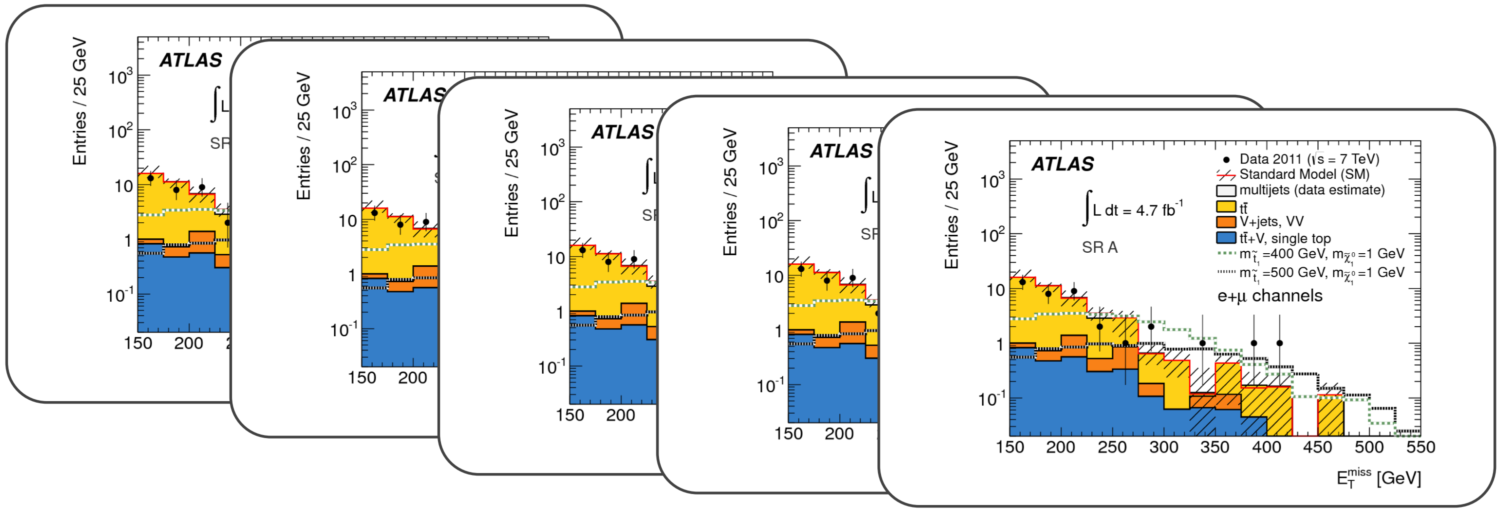
3 orthogonal CRs





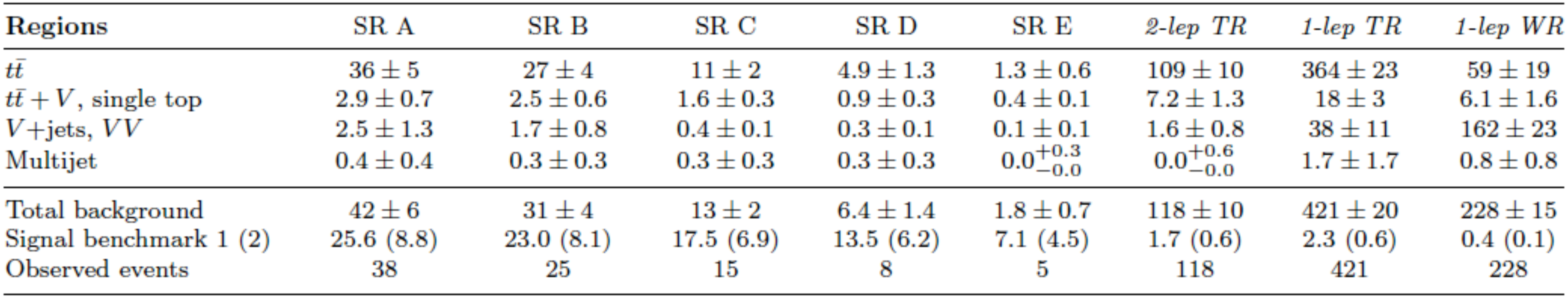


5 overlapping SRs



Background fit

- Consider the 3 CRs (observed events in SRs are not used here)
- Exact solution to maximize the likelihood.
- W+jets is fitted ($\mu^{\text{W+jets}}$), ttbar is fitted independently in the 2-lep TR ($\mu^{\text{ttbar, 2lep}}$) and 1-lep CRs ($\mu^{\text{ttbar, 1lep}}$). $\mu^{\text{ttbar, 1lep}}$ is for validation, while the ttbar estimate in all SRs is taken from 2-lep TR which minimizes the extrapolation systematics.

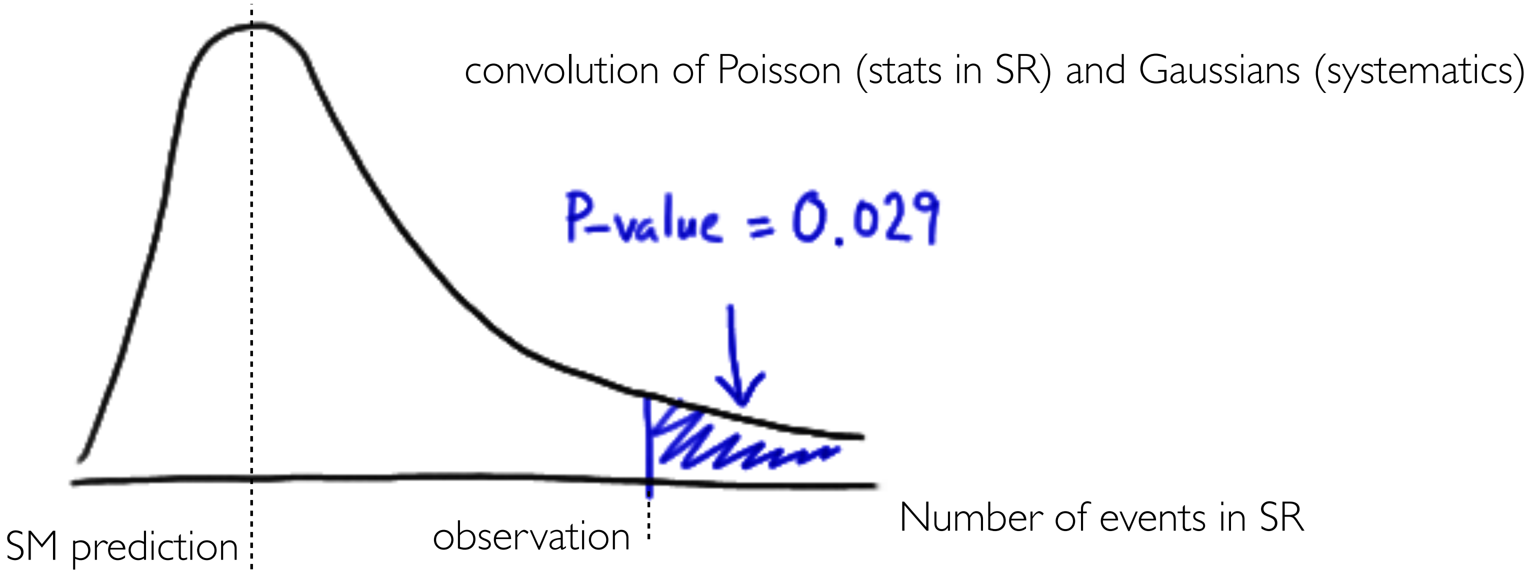


Regions	SR A	SR B	SR C	SR D	SR E	*2-lep TR*	*1-lep TR*	*1-lep WR*
$t\bar{t}$	36 ± 5	27 ± 4	11 ± 2	4.9 ± 1.3	1.3 ± 0.6	109 ± 10	364 ± 23	59 ± 19
$t\bar{t} + V$, single top	2.9 ± 0.7	2.5 ± 0.6	1.6 ± 0.3	0.9 ± 0.3	0.4 ± 0.1	7.2 ± 1.3	18 ± 3	6.1 ± 1.6
V+jets, VV	2.5 ± 1.3	1.7 ± 0.8	0.4 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	1.6 ± 0.8	38 ± 11	162 ± 23
Multijet	0.4 ± 0.4	0.3 ± 0.3	0.3 ± 0.3	0.3 ± 0.3	$0.0^{+0.3}_{-0.0}$	$0.0^{+0.6}_{-0.0}$	1.7 ± 1.7	0.8 ± 0.8
Total background	42 ± 6	31 ± 4	13 ± 2	6.4 ± 1.4	1.8 ± 0.7	118 ± 10	421 ± 20	228 ± 15
Signal benchmark 1 (2)	25.6 (8.8)	23.0 (8.1)	17.5 (6.9)	13.5 (6.2)	7.1 (4.5)	1.7 (0.6)	2.3 (0.6)	0.4 (0.1)
Observed events	38	25	15	8	5	118	421	228

- The sum of fitted background numbers in each CR agree with the observation by construction,
- The background in the SRs comes from an MC-based extrapolation, from the CRs
- All (statistical and systematics) uncertainties are included
- The fitted number of W+jets and ttbar events is compatible with the theory predictions. $\mu^{\text{W+jets}} \bumpeq 0.9$, $\mu^{\text{ttbar, 2lep}} \bumpeq 1.0$

Discovery Fit (1)

- Probe the compatibility of data with the SM-only hypothesis. The resulting compatibility is expressed as a probability and is called p_0-value (or just p-value).
- Test one signal-region (SR) at a time



p_0-value is the probability under the SM-only hypothesis to find an upwards fluctuation (one-sided hypothesis test) as high, or higher as observed.

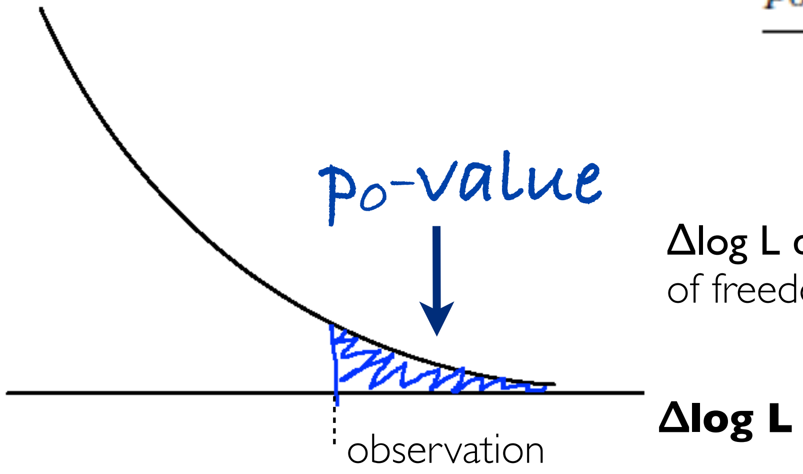
Discovery Fit (2)

- Probe the compatibility of data with the SM-only hypothesis. The resulting compatibility is expressed as a probability and is called p_0-value (or just p-value).
- Test one signal-region (SR) at a time, i.e. another Poisson is multiplied to the likelihood (L).
- Allow for a positive signal contribution in the SR (μ^{sig})
  This is ignoring a potential signal contamination in the CRs, which is conservative (background is over-estimated). Without a signal model, the signal contribution to CRs is unknown.
- maximize likelihood both for μ^{sig} = 0, and μ^{sig} floating. The ratio is used as the test statistic:
  $\Delta\log L = \log L^{max}(\mu^{sig}=0) - \log L^{max}(\mu^{sig}\ \mathrm{floating})$
- This can be directly used to get an approximative p_0-value [in units of std dev.] from
  `sqrt(-2 x Δlog L)` [Wilk's theorem]
- Exact result: generate pseudo (toy) experiments to gauge the Δlog L distribution for the SM-only scenario.

Final results from stop 1-lep search

Regions	SR A	SR B	SR C	SR D	SR E
p_0-values	0.50	0.50	0.32	0.24	0.015

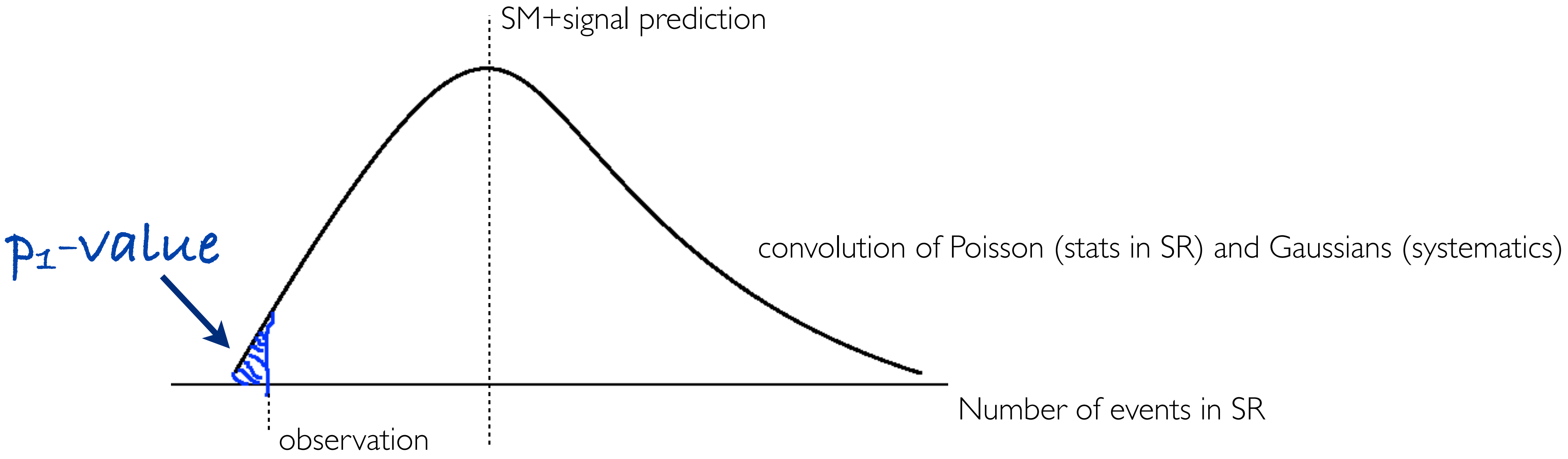
~2σ



Δlog L distribution follows a chi² distribution with one-degree of freedom.

Exclusion Fit (1)

- Probe the compatibility of data with the SM+signal hypothesis. The resulting compatibility is expressed as a probability and is called p_1-value. Note that we have to assume one signal model now.
- Test one signal-region (SR) at a time



p_1-value is the probability under the SM+signal hypothesis to find a downwards fluctuation (one-sided hypothesis test) as low, or lower as observed.

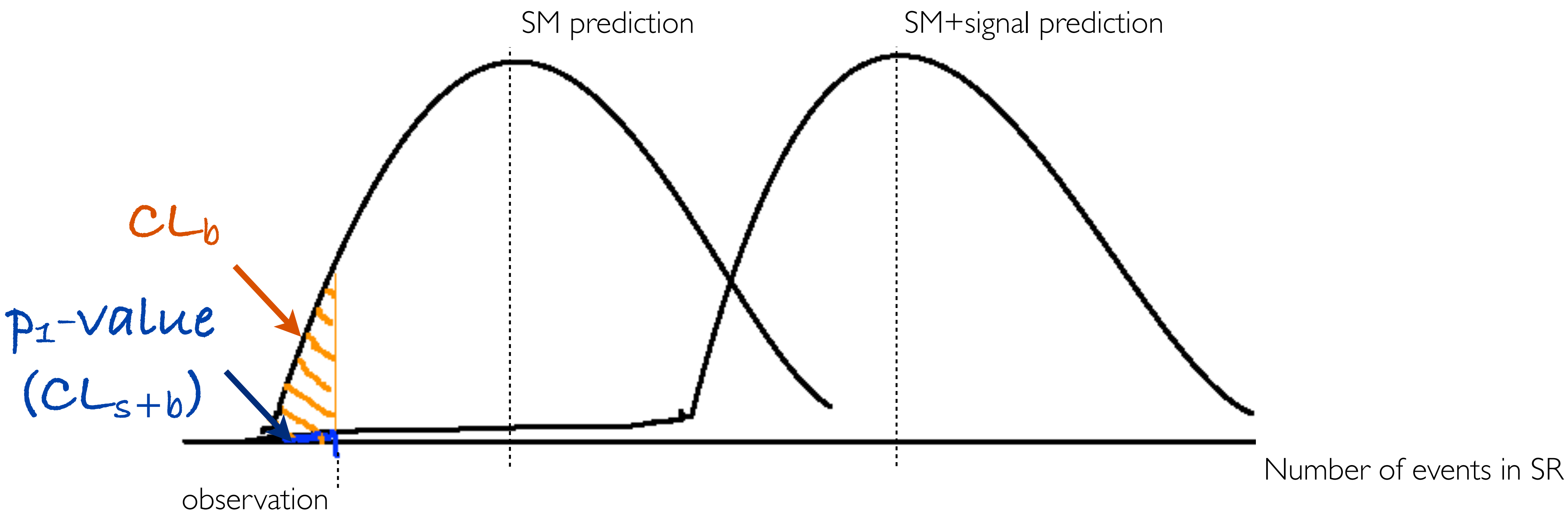
Exclusion Fit (2)

- Probe the compatibility of data with the SM+signal hypothesis. The resulting compatibility is expressed as a probability and is called p_1-value. Note that we have to assume one signal model now.
- Test one signal-region (SR) at a time, i.e. another Poisson is multiplied to the likelihood (L).
- Allow for a positive signal contribution (μ^{sig}), in all regions (SR and CRs).
- maximize likelihood both for $\mu^{sig} = 1$, and μ^{sig} floating. The ratio is used as the test statistic:
  $\Delta\log L = \log L^{max}(\mu^{sig}=1) - \log L^{max}(\mu^{sig}\ \text{floating})$
  [almost same as the difference in chi^2 of two fits]
- This can be directly used to get an approximative p_1-value [in units of std dev.] from
  $\text{sqrt}(-2 \times \Delta\log L)$ [Wilk's theorem]
- Exact result: generate pseudo (toy) experiments to gauge the $\Delta\log L$ distribution for the SM+signal scenario.
- This p_1-value is also called CL_{s+b} value. If it is below 0.05 (i.e. 5%), then we can say that the given signal model is excluded at 95% confidence level (CL).

As with discovery fit, but testing for signal (μ^{sig}=1)

Exclusion Fit (3)

- This p_1-value is also called CL_{s+b} value. If it is below 0.05 (i.e. 5%), then we can say that the given signal model is excluded at 95% confidence level (CL).
- Potential issue: in a situation where the observation is a significant down-fluctuates from the SM background, the CL_{s+b} method's exclusion power is over-aggressive (excluding more than expected).



- Way out: include penalty when observation is incompatible with SM-only hypothesis.
- CL_b similar to CL_{s+b} but obtained from toys around SM-only (see illustration)
- Define: $CL_s = CL_{s+b} / CL_b$ [strictly speaking, this is not a probability ...]
- For very small signal numbers CL_s approaches 1
- Exclusion is based on CL_s value. This is the convention agreed upon by the LHC experiments.

Exclusion Plot (1)

(1) Observed limit: Calculate CL_s values for each signal model, for a given signal-region (SR).

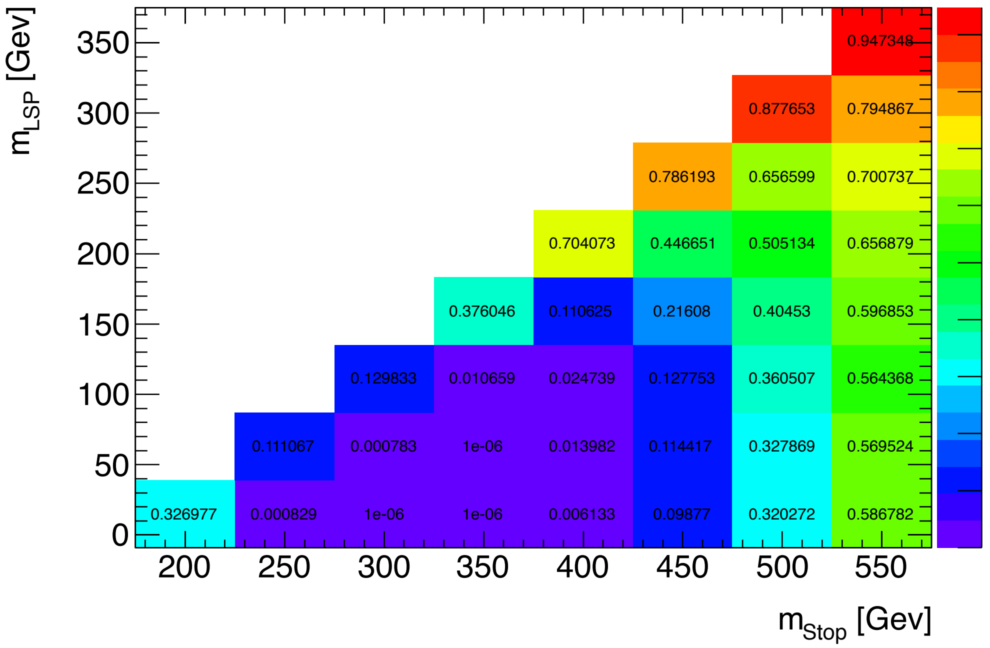
- All uncertainties are included in the fit as nuisance parameters, with the exception of the theoretical signal uncertainties (PDF, scales).
- The contour where $CL_s = 0.05$ is the observed exclusion limit at 95% CL . The finite signal grid is linearly smoothed.

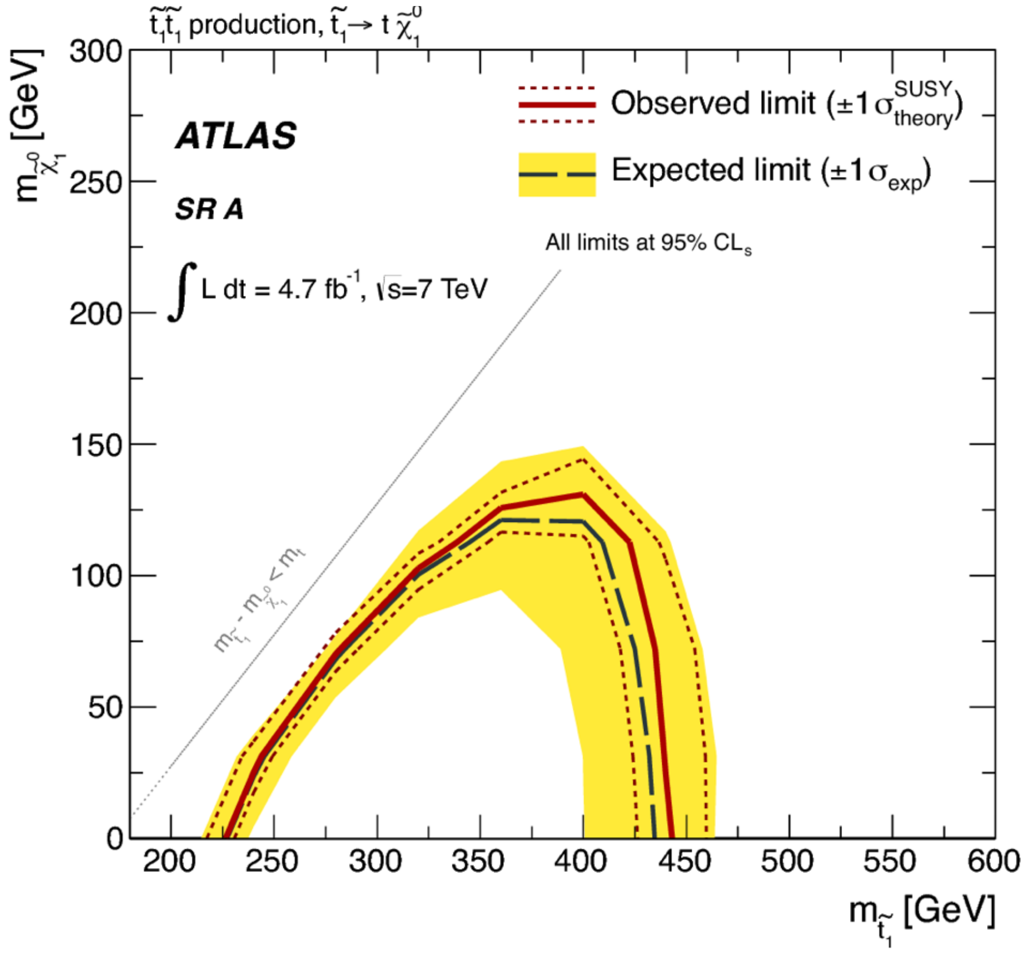
(2) Expected limit: repeat CL_s calculation, but with the observation in the SR set to the estimated background. This is the expected limit under the assumption of observing SM background only.

- Same treatment of uncertainties and CL_s contour as for observed limit

- ±1σ lines around observed limit (1): re-run limit calculation (1) while increasing or decreasing the signal cross section by the theoretical signal uncertainties (PDF, scales).
- ±1σ band around expected limit (2) "yellow band": the band contours are the ±1σ results of the fit (2).

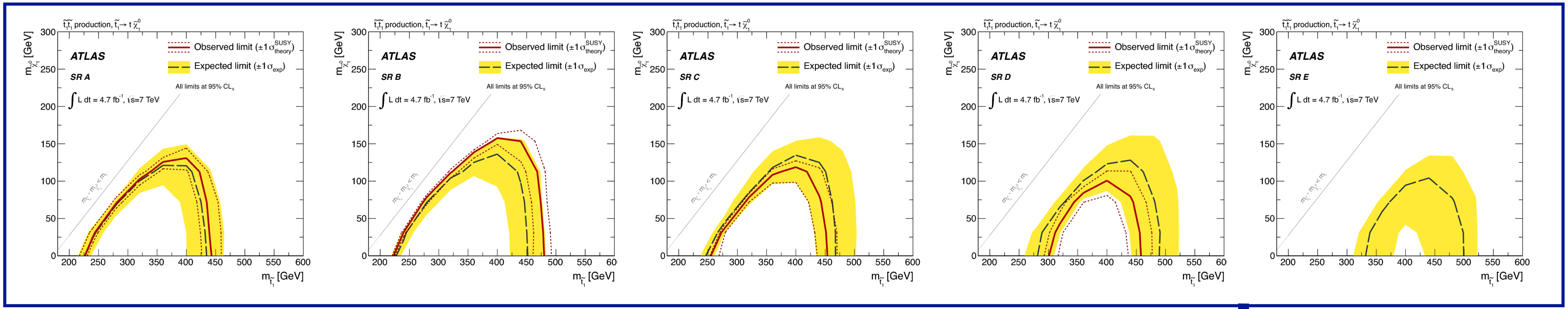
Obseverd CL_s values for SR A

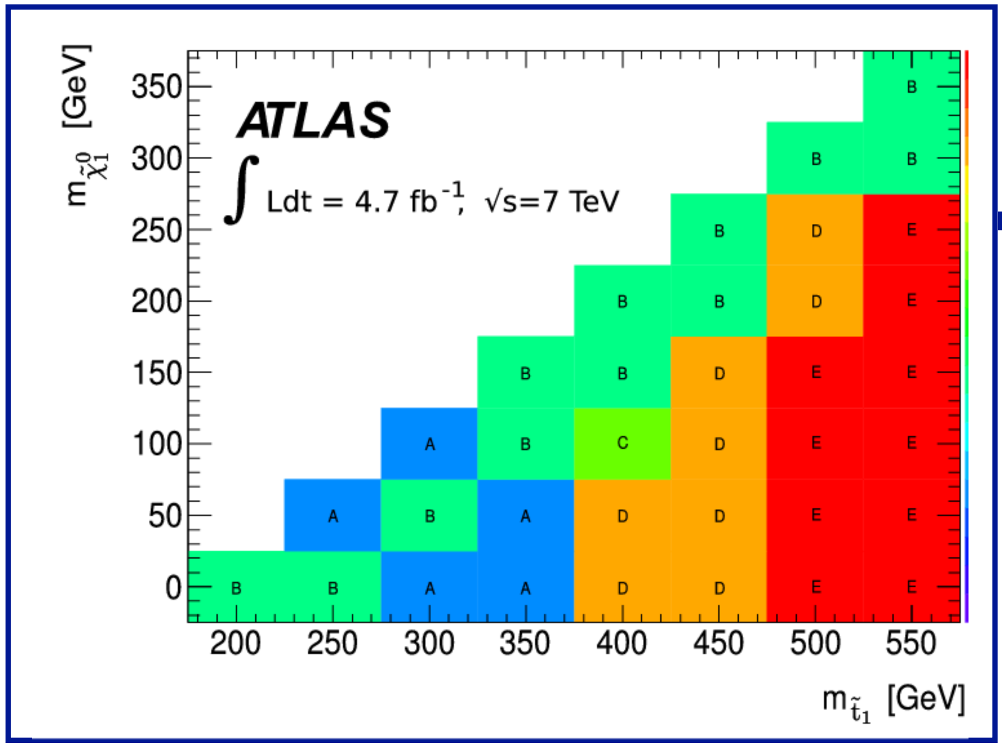


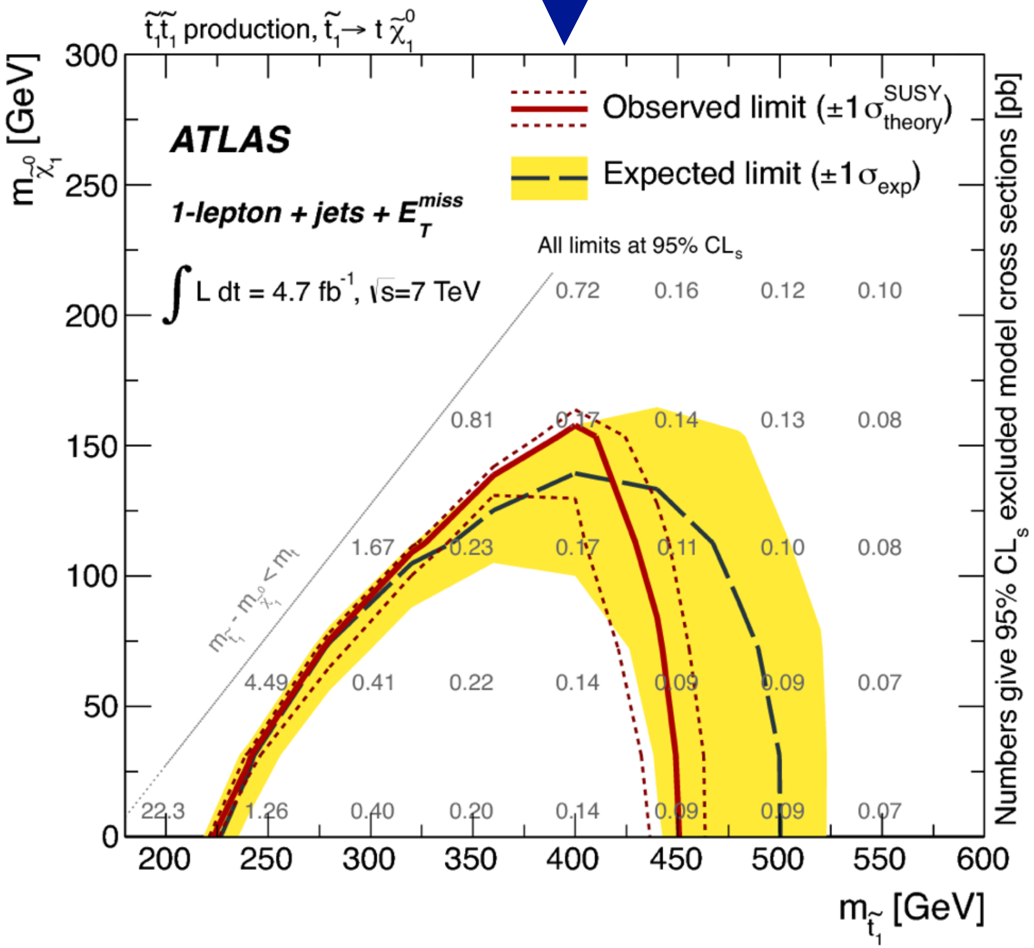


Exclusion Plot (2)

1. Make exclusion plot for each SR (A-E)







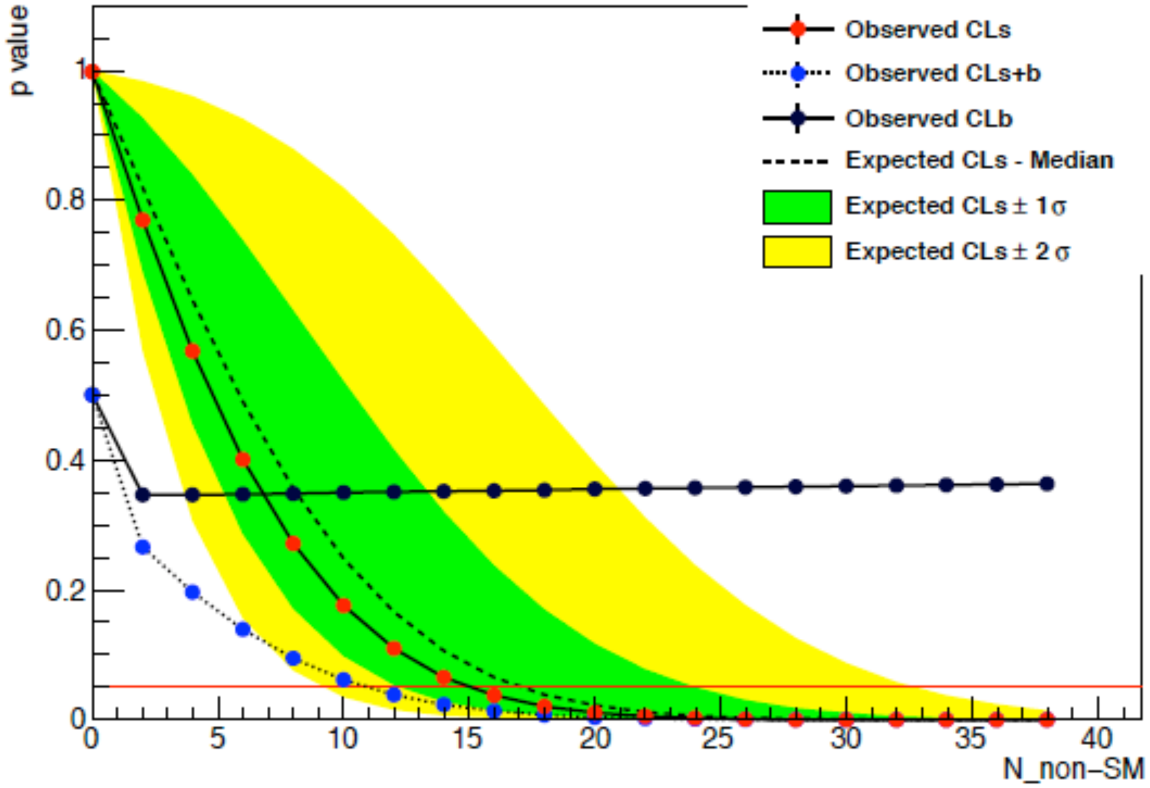
2. Combination according to best-expected SR per signal point.

The gray overlaid numbers show the upper limit on the production cross-section

Signal model independent upper limits

- Give an upper limit on the number of beyond-SM (BSM) events in each SR.
  In other words: what is the maximum number of events that can be added to the observation in a given SR, keeping it (just) compatible with the background-only hypothesis at 95% CL.
- Test one signal-region (SR) at a time

- Fit setup: include one SR, allow for signal contribution in the SR.
- Signal-model specific input is <u>not</u> included: i.e. signal contamination in the CRs is ignored, signal systematic uncertainties (e.g. JES) is ignored, etc.
- Varying the signal strength (in the SR), the CL_s calculation is performed
  - see illustration plot.
- The signal strength which corresponds to a CL_s value of 0.05 is the upper limit.



Regions	SR A	SR B	SR C	SR D	SR E
Obs. (exp.) $N_{\mathrm{BSM}} <$	15.1 (17.2)	10.1 (13.8)	10.8 (9.2)	8.4 (7.0)	8.2 (4.6)

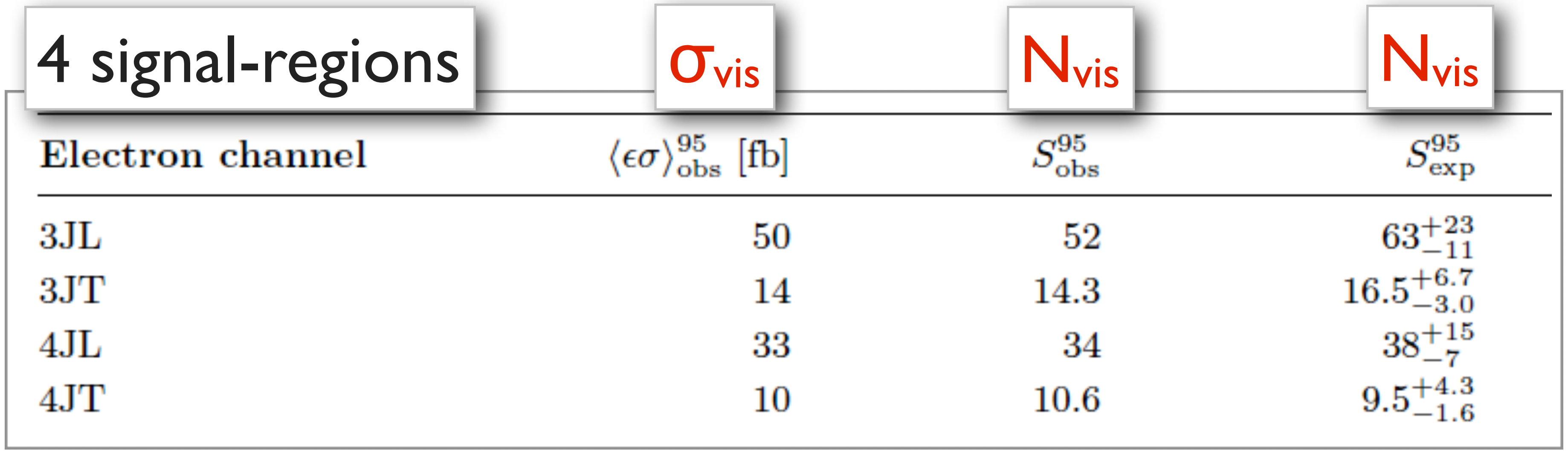
These limits are intended to be used by externals to test new/other signal models. This will be demonstrated in the tutorial session.

Presentation of ATLAS SUSY results

Disclaimer:
Current ATLAS SUSY guidelines on presenting results do not necessarily apply to previously published results, or non-SUSY results.

Results provided in paper/conf note

example **upper limits table**



4 signal-regions

σ_{vis}

N_{vis}

N_{vis}

Electron channel	$\langle\epsilon\sigma\rangle^{95}_{\rm obs}$ [fb]	$S^{95}_{\rm obs}$	$S^{95}_{\rm exp}$
3JL	50	52	63^{+23}_{-11}
3JT	14	14.3	$16.5^{+6.7}_{-3.0}$
4JL	33	34	38^{+15}_{-7}
4JT	10	10.6	$9.5^{+4.3}_{-1.6}$

Example from SUSY 1-lepton paper (arxiv 1109.6606)

For each signal-region (SR) provide

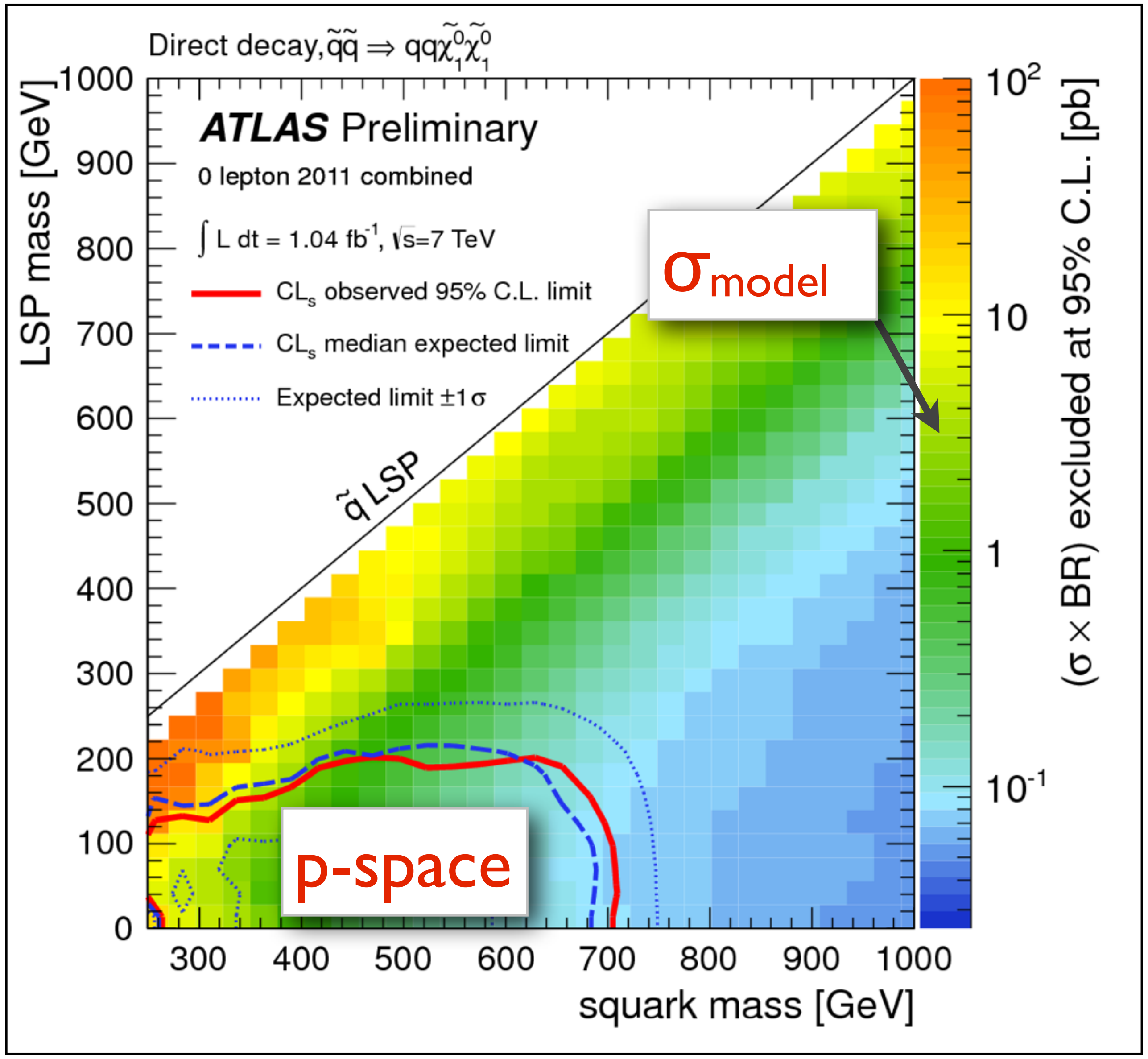
- upper limit on the number of visible signal events in SR:
  $N_{vis} = N_{vis}(N^{obs}, N^{bkg}, \Delta^{bkg})$
- upper limit on the visible signal cross-section in SR:
  $\sigma_{vis} = A \times \varepsilon \times \sigma = N_{vis} / L$
  $\sigma_{vis} (N^{obs}, N^{bkg}, \Delta^{bkg}, L, \Delta L)$
- Provide expected and observed limits.
- These limits are <u>signal</u> model independent, [but analysis and detector dependent]
  can be used to compare against prediction of any signal model (in the analysis' SR).

Blue: uncertainties (some complexity e.g. correlated unc. not shown here)

Default stats. method: CLs

Results provided in paper/conf note

example **interpretation**



Example from ATLAS-CONF-2011-155

- For multi-SR analyses:
  Check in the paper whether SR bins (channels) are combined, or only one is chosen. In the latter case, it's always the best expected SR per signal model point.

- Limits in the model parameter space
  $CLs(N^{obs}, N^{bkg}, \Delta^{bkg}, L, \Delta L, (A x \varepsilon)^{model}, \Delta(A x \varepsilon)^{model}, \sigma^{sig\ prod}, \Delta\sigma^{sig\ prod})$

  - Provide observed & expected p-space limits, and 1σ band around expectation.

- [optional] upper limit on the production cross-section:
  $\sigma_{model} = N_{vis} / [(A x \varepsilon)^{model} \times L]$
  $\sigma_{model} (N^{obs}, N^{bkg}, \Delta^{bkg}, L, \Delta L, (A x \varepsilon)^{model}, \Delta(A x \varepsilon)^{model})$

  - No dependence on $\sigma^{sig\ prod}$, $\Delta\sigma^{sig\ prod}$

  - So far provided for simplified models only.

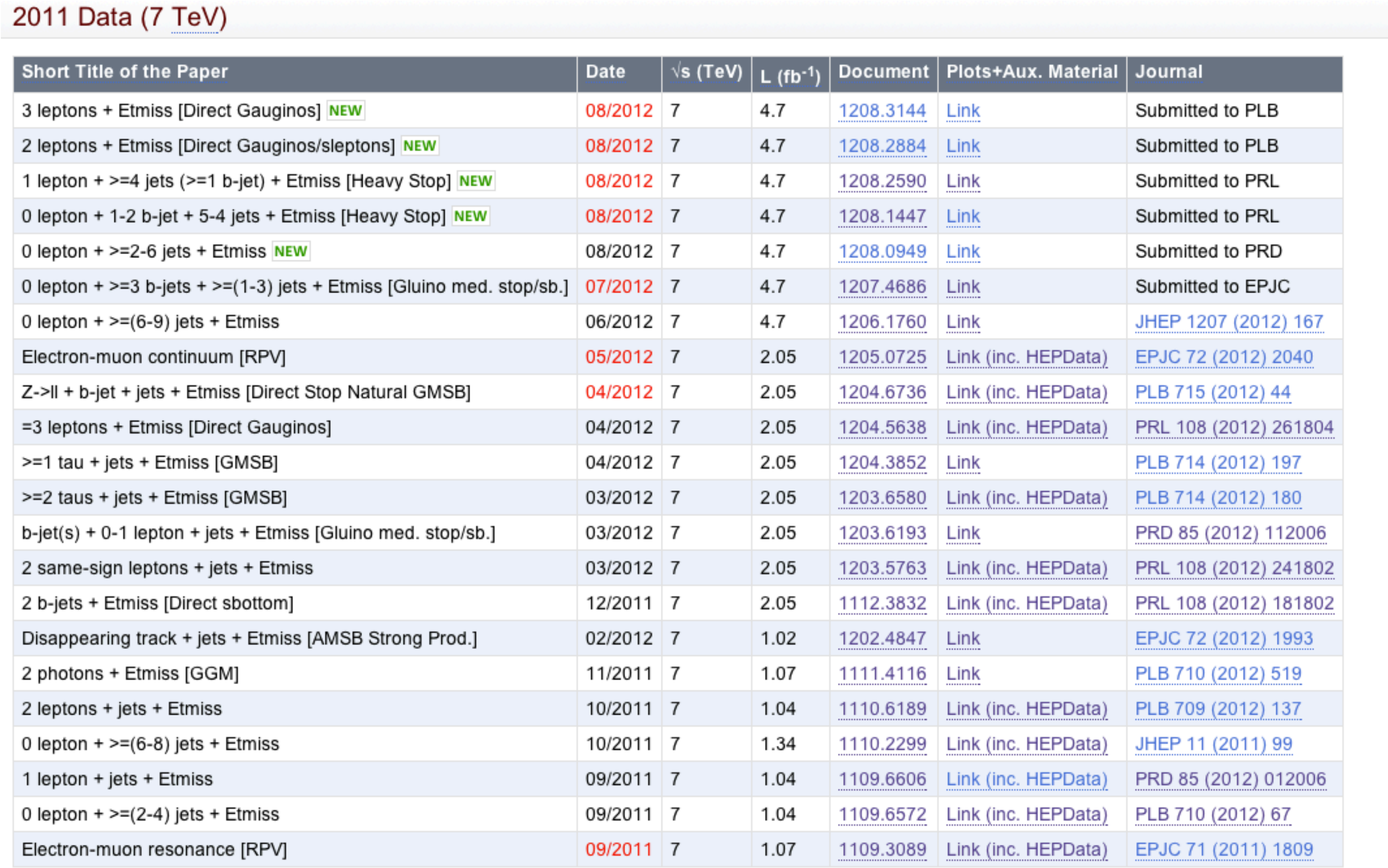
Blue: uncertainties (some complexity e.g. correlated unc. not shown here)

Default stats. method: CLs

Numerical results in HEPdata

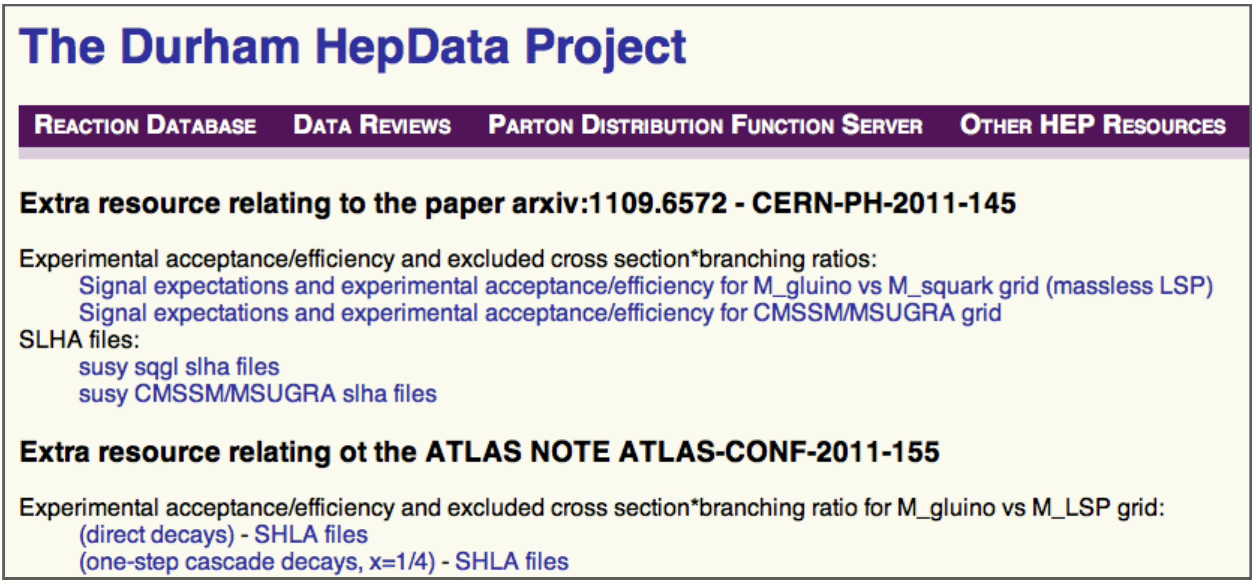
Published + auxiliary plots and interpretations are numerically available from HEPdata.

ATLAS SUSY results from https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults



2011 Data (7 TeV)

Short Title of the Paper	Date	√s (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
3 leptons + Etmiss [Direct Gauginos] NEW	08/2012	7	4.7	1208.3144	Link	Submitted to PLB
2 leptons + Etmiss [Direct Gauginos/sleptons] NEW	08/2012	7	4.7	1208.2884	Link	Submitted to PLB
1 lepton + >=4 jets (>=1 b-jet) + Etmiss [Heavy Stop] NEW	08/2012	7	4.7	1208.2590	Link	Submitted to PRL
0 lepton + 1-2 b-jet + 5-4 jets + Etmiss [Heavy Stop] NEW	08/2012	7	4.7	1208.1447	Link	Submitted to PRL
0 lepton + >=2-6 jets + Etmiss NEW	08/2012	7	4.7	1208.0949	Link	Submitted to PRD
0 lepton + >=3 b-jets + >=(1-3) jets + Etmiss [Gluino med. stop/sb.]	07/2012	7	4.7	1207.4686	Link	Submitted to EPJC
0 lepton + >=(6-9) jets + Etmiss	06/2012	7	4.7	1206.1760	Link	JHEP 1207 (2012) 167
Electron-muon continuum [RPV]	05/2012	7	2.05	1205.0725	Link (inc. HEPData)	EPJC 72 (2012) 2040
Z->ll + b-jet + jets + Etmiss [Direct Stop Natural GMSB]	04/2012	7	2.05	1204.6736	Link (inc. HEPData)	PLB 715 (2012) 44
=3 leptons + Etmiss [Direct Gauginos]	04/2012	7	2.05	1204.5638	Link (inc. HEPData)	PRL 108 (2012) 261804
>=1 tau + jets + Etmiss [GMSB]	04/2012	7	2.05	1204.3852	Link	PLB 714 (2012) 197
>=2 taus + jets + Etmiss [GMSB]	03/2012	7	2.05	1203.6580	Link (inc. HEPData)	PLB 714 (2012) 180
b-jet(s) + 0-1 lepton + jets + Etmiss [Gluino med. stop/sb.]	03/2012	7	2.05	1203.6193	Link	PRD 85 (2012) 112006
2 same-sign leptons + jets + Etmiss	03/2012	7	2.05	1203.5763	Link (inc. HEPData)	PRL 108 (2012) 241802
2 b-jets + Etmiss [Direct sbottom]	12/2011	7	2.05	1112.3832	Link (inc. HEPData)	PRL 108 (2012) 181802
Disappearing track + jets + Etmiss [AMSB Strong Prod.]	02/2012	7	1.02	1202.4847	Link	EPJC 72 (2012) 1993
2 photons + Etmiss [GGM]	11/2011	7	1.07	1111.4116	Link	PLB 710 (2012) 519
2 leptons + jets + Etmiss	10/2011	7	1.04	1110.6189	Link (inc. HEPData)	PLB 709 (2012) 137
0 lepton + >=(6-8) jets + Etmiss	10/2011	7	1.34	1110.2299	Link (inc. HEPData)	JHEP 11 (2011) 99
1 lepton + jets + Etmiss	09/2011	7	1.04	1109.6606	Link (inc. HEPData)	PRD 85 (2012) 012006
0 lepton + >=(2-4) jets + Etmiss	09/2011	7	1.04	1109.6572	Link (inc. HEPData)	PLB 710 (2012) 67
Electron-muon resonance [RPV]	09/2011	7	1.07	1109.3089	Link (inc. HEPData)	EPJC 71 (2011) 1809



The Durham HepData Project

Extra resource relating to the paper arxiv:1109.6572 - CERN-PH-2011-145

Experimental acceptance/efficiency and excluded cross section*branching ratios:
Signal expectations and experimental acceptance/efficiency for M_gluino vs M_squark grid (massless LSP)
Signal expectations and experimental acceptance/efficiency for CMSSM/MSUGRA grid
SLHA files:
susy sqgl slha files
susy CMSSM/MSUGRA slha files

Extra resource relating ot the ATLAS NOTE ATLAS-CONF-2011-155

Experimental acceptance/efficiency and excluded cross section*branching ratio for M_gluino vs M_LSP grid:
(direct decays) - SHLA files
(one-step cascade decays, x=1/4) - SHLA files

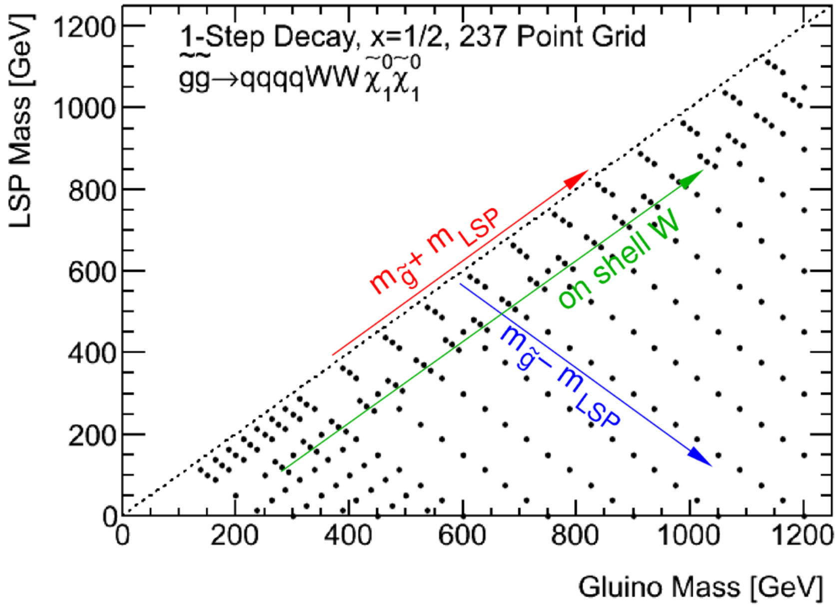
Example of extra resources from 0-lepton search (http://hepdata.cedar.ac.uk/view/p8106)

- Extra resources: $(A \times \varepsilon)^{\text{signal model}}$, SLHA files
- available for several publications

Input to HEPdata (starting with winter 2012 results)

Refined and extended list of input to HEPdata, starting with winter 2012 results.

- Plots, interpretation (CLs limits) from paper and auxiliary material
- For each signal region, and for all relevant models
  - acceptance (A), defined next page [$A=N_{\text{fiducial}}/N_{\text{total}}$]
  - efficiency (ε), defined next page [$\varepsilon=N_{\text{fiducial-reco}}/N_{\text{fiducial}}$]
  - Δ^{tot} total systematic and theoretical signal uncertainty, not including MC stat. unc.
  - CLs value
- For all relevant models
  - Number of generated MC events (can be used to derive all signal MC stat. unc.)
  - σ^{tot} total signal production cross section
  - SUSY Les Houches Accord (SLHA) files
- Relevant models:
  - E.g. small number of simplified models (easy kinematics)
  - no smoothing/interpolation between points


example "plane"

Definition of “fiducial” (or what’s A and ε)

Guiding idea for fiducial cuts:

- defined using truth and hadron level quantities
- can be implemented by externals (w/o detector simulation)

Use a **common definition** for all ATLAS SUSY public results !

A×ε is the full event selection efficiency at detector level.

Acceptance $A = N_{\text{fiducial}} / N_{\text{total}}$

where fiducial cuts are based on the following objects:

- truth electrons/muons/E_T^{miss} (non-interacting)
- hadron level jets
- heavy-flavor: b-quark matched to jet, at parton level

all above with analysis cuts on pT, eta.

Apply

- object overlap-removal (in eta-phi space)
- avoid leptons from b-jets: require mother’s mass above 10 GeV or mother being a tau.

Efficiency $\varepsilon = N_{\text{fiducial-reco}} / N_{\text{fiducial}}$

where fiducial-reco cuts are our nominal analysis cuts, applied to detector level variables.
Differences to Acceptance include:

- Reconstruction inefficiencies
- Full particle identification cuts
- Resolution effects
- trigger inefficiencies

Note that ε can be bigger or smaller than one.

ATLAS SM group uses b-hadrons to define fiducial cross-sections.

Re-interpreting Results

A user can probe his/her favorite model(s) by:

1. take our background estimate (per SR): $N^{tot} \pm \Delta^{tot}$ (numbers in publication)
2. implement event selection (per SR), validate against our acceptance numbers (in HEPdata)
3. implement a detector response, validate against our efficiency numbers (in HEPdata)
4. run on favorite model, and calculate sensitivity/limits using our visible upper limits (from publication)

The limit setting code (CLs, p-values, combination of channels/bins) used within the ATLAS SUSY group is based on the public ROOT / RooStats package. From this public package it is a small step to a standalone statistics tool to be used with our data input from HepData and some signal model (passed through $A \times \varepsilon$). The ATLAS SUSY group considers to provide such a standalone statistics tool.