ATLAS Searches for SUSY and Other BSM Phenomena

(*) R-parity conserving

MAP winter meeting, 4-8 March 2012, SLAC

Till Eifert (SLAC)
for the ATLAS Collaboration

Outline

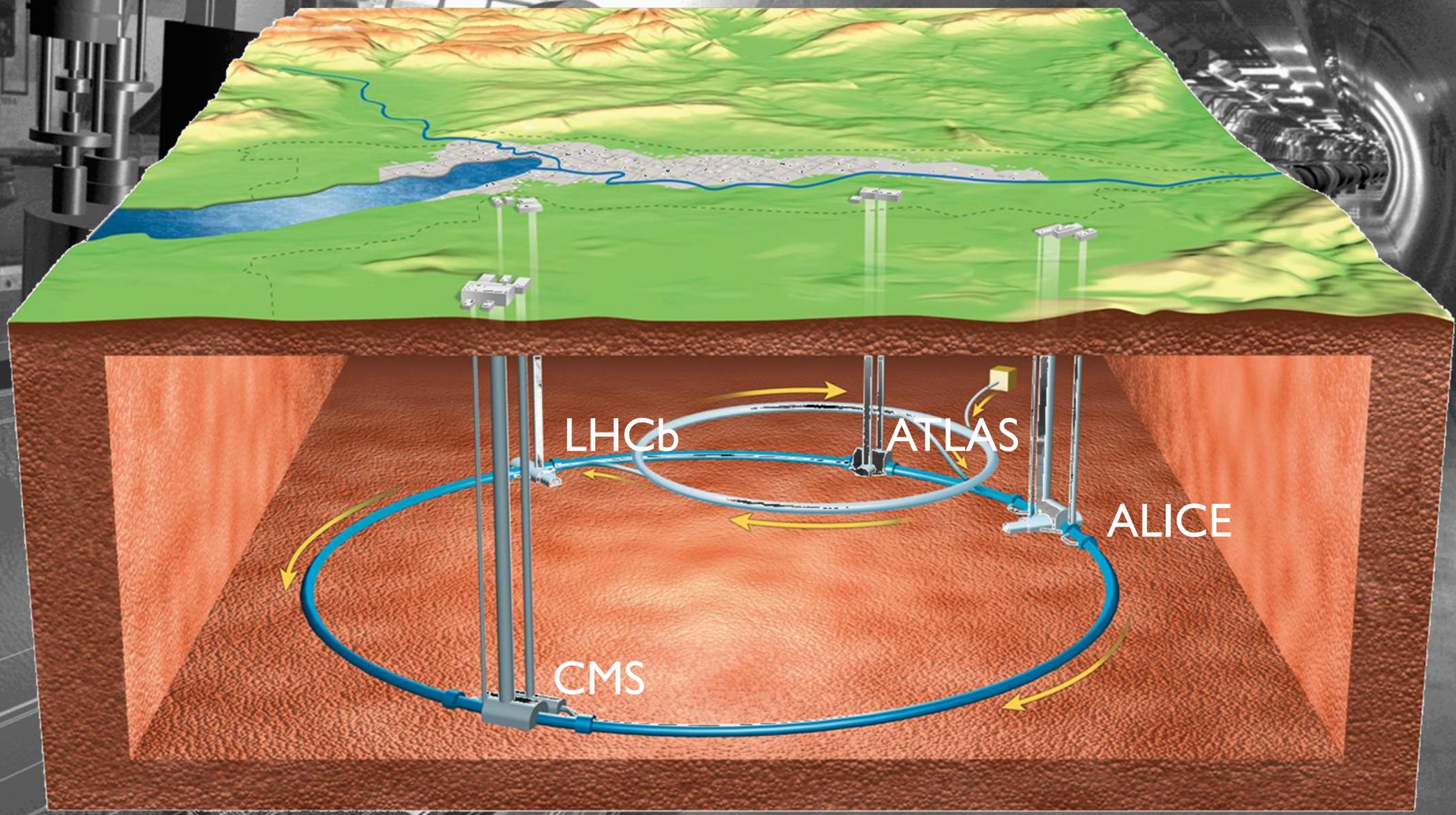
- Setting the Stage
  LHC, ATLAS, and the experimental challenges
- ATLAS SUSY Searches
  - Strong production
  - 3rd generation
  - weak production
- ATLAS Exotic Searches
  - Few selected results

Experimental Setup

AC/DI/MM

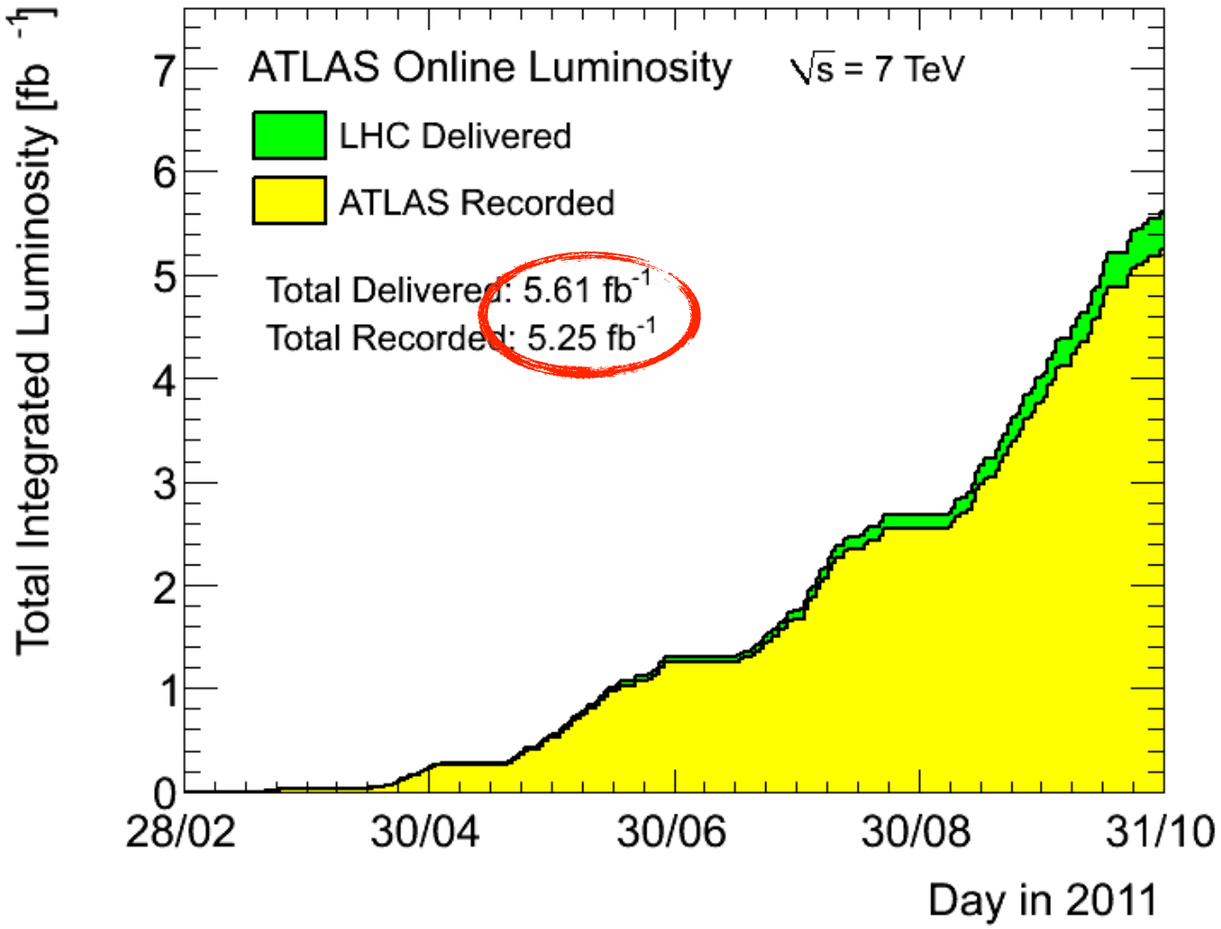
The **L**arge **H**adron **C**ollider (LHC) @ CERN

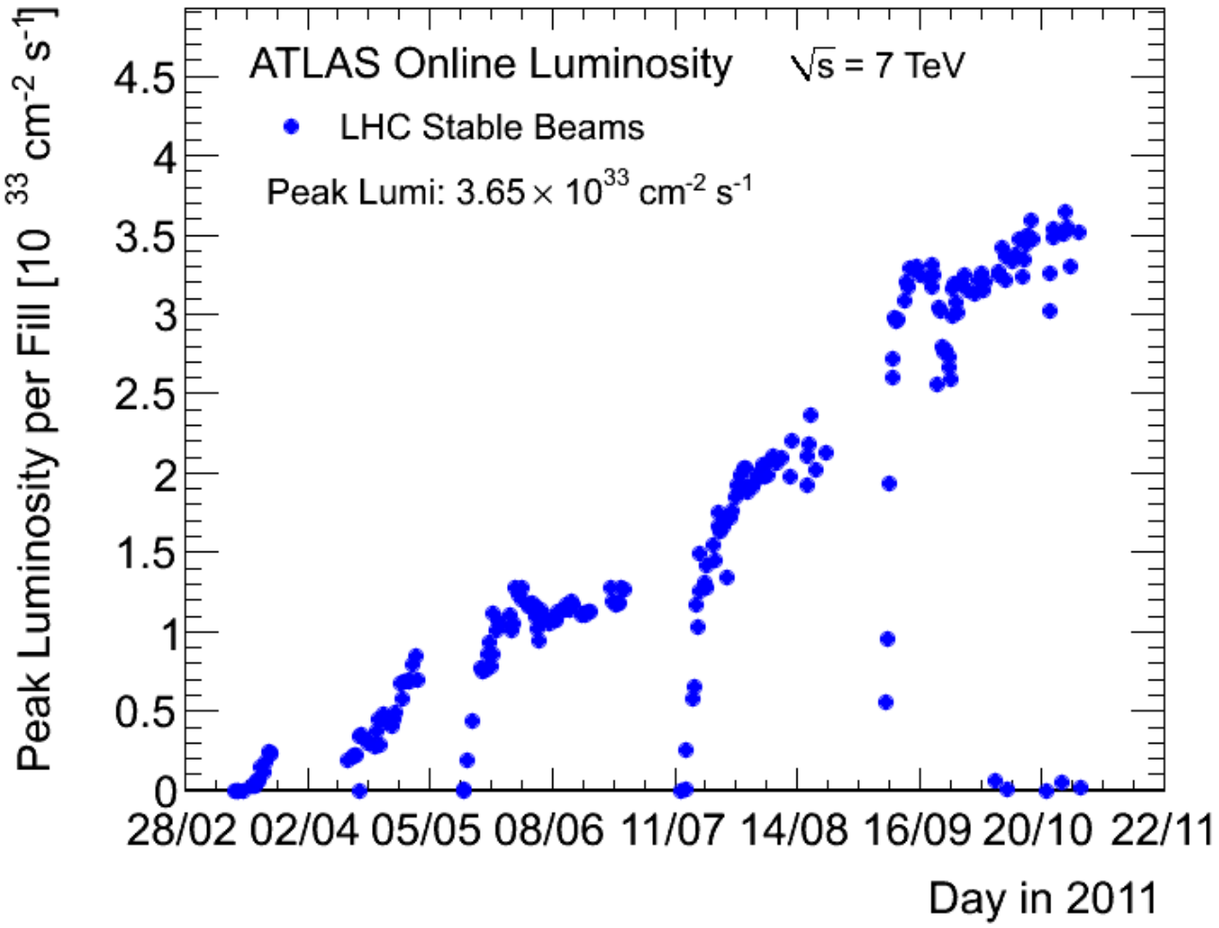
LHC has 4 large experiments: ATLAS, CMS, LHCb, ALICE



AC/DI/MM

2011 Luminosity and Data Taking



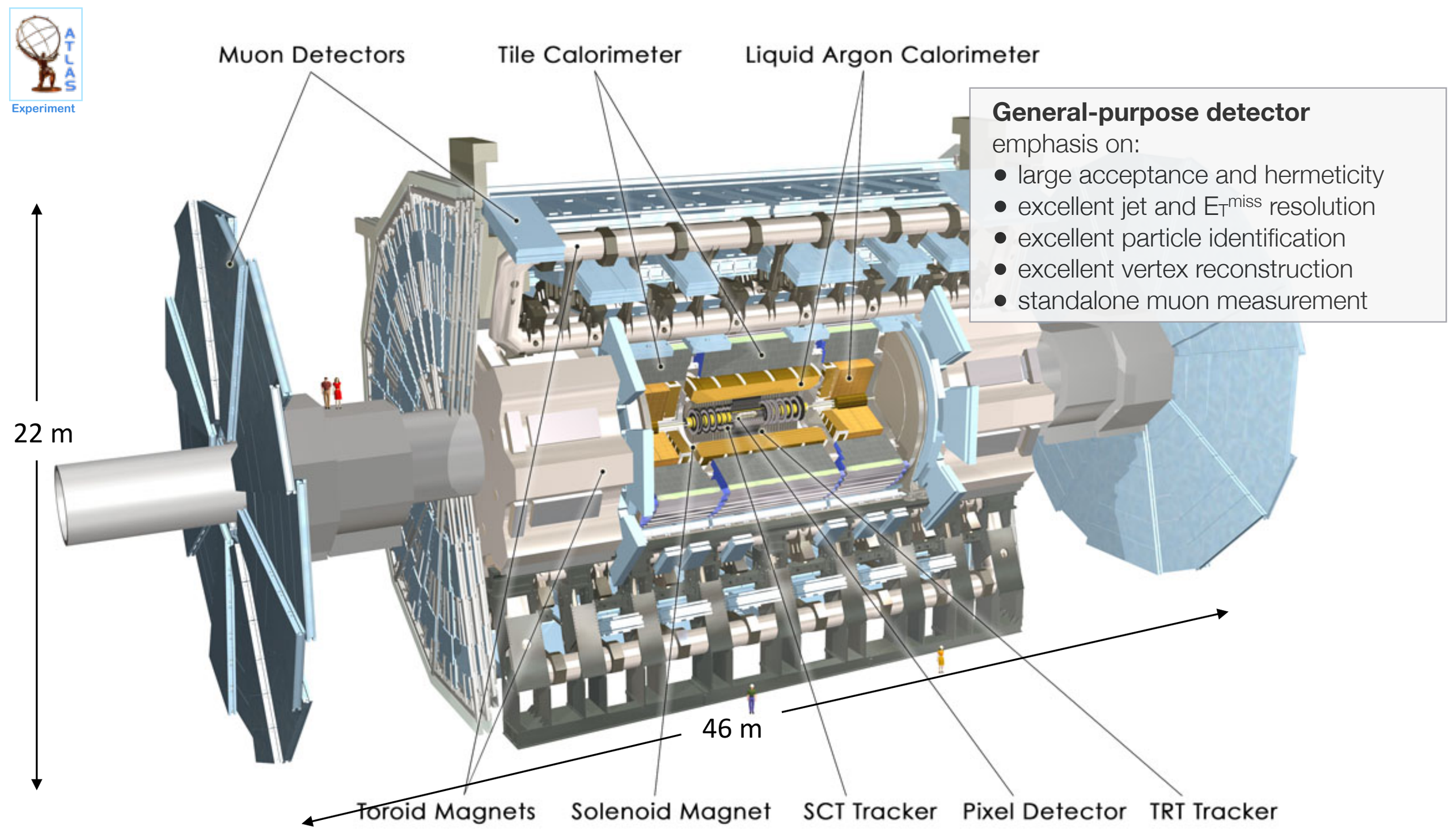


- More than 5.6 fb^{-1} of pp collisions delivered by LHC in 2011 @ 7 TeV CM energy
- Peak stable luminosity: $3.65 \times 10^{33} cm^{-2} s^{-1}$ (LHC design goal: 10^{34})
- Maximum recorded in one day: 135 pb^{-1} (about three times of full 2010 dataset)
- Total data taking efficiency in ATLAS: 93.5%

ATLAS Detector

A Toroidal LHC Apparatus

Experiment



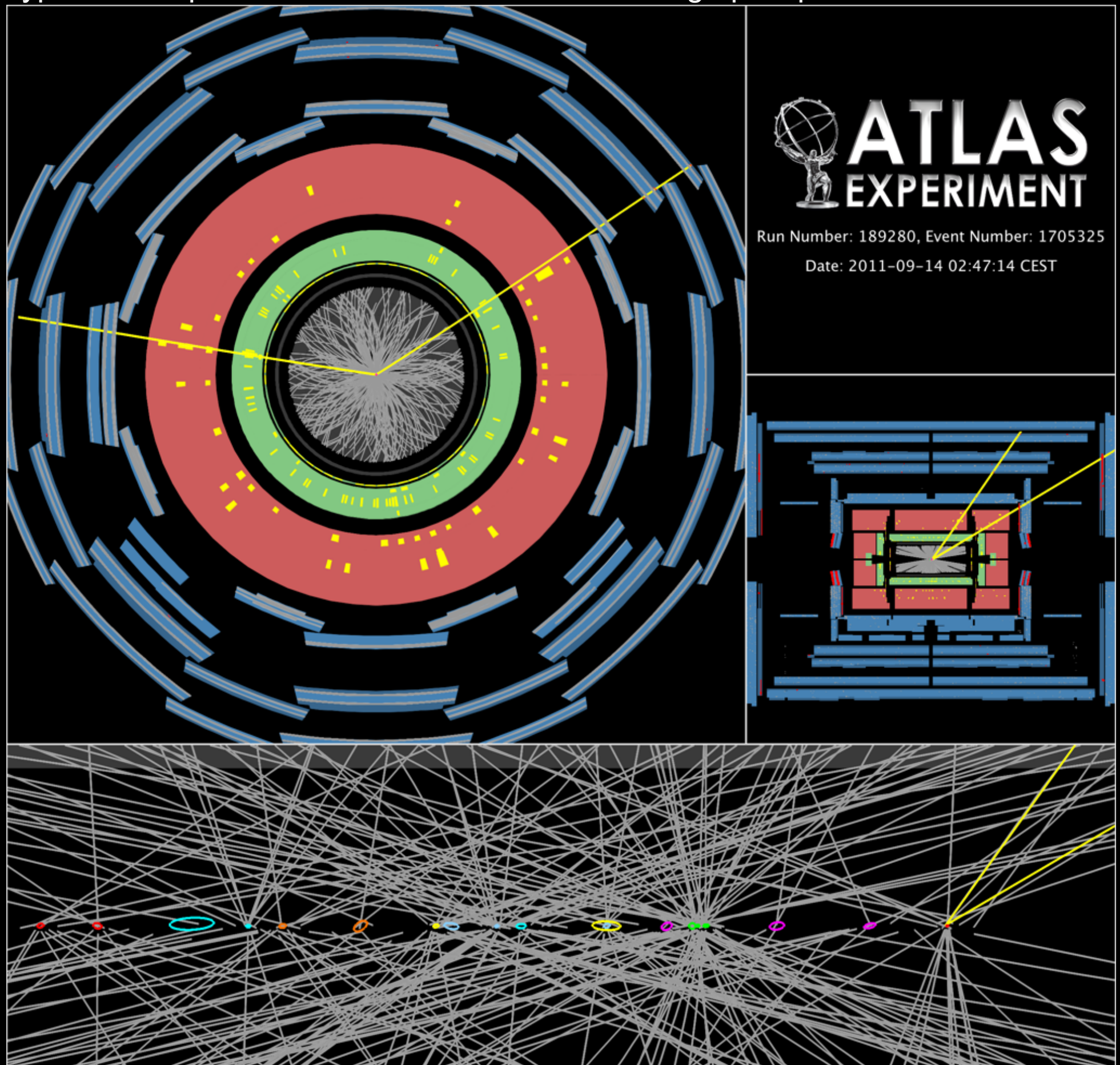
General-purpose detector

emphasis on:

- large acceptance and hermeticity
- excellent jet and E_T^{miss} resolution
- excellent particle identification
- excellent vertex reconstruction
- standalone muon measurement

Typical example for the 2011 environment with high pileup

Candidate Z boson event in the dimuon decay with **20 reconstructed vertices**.

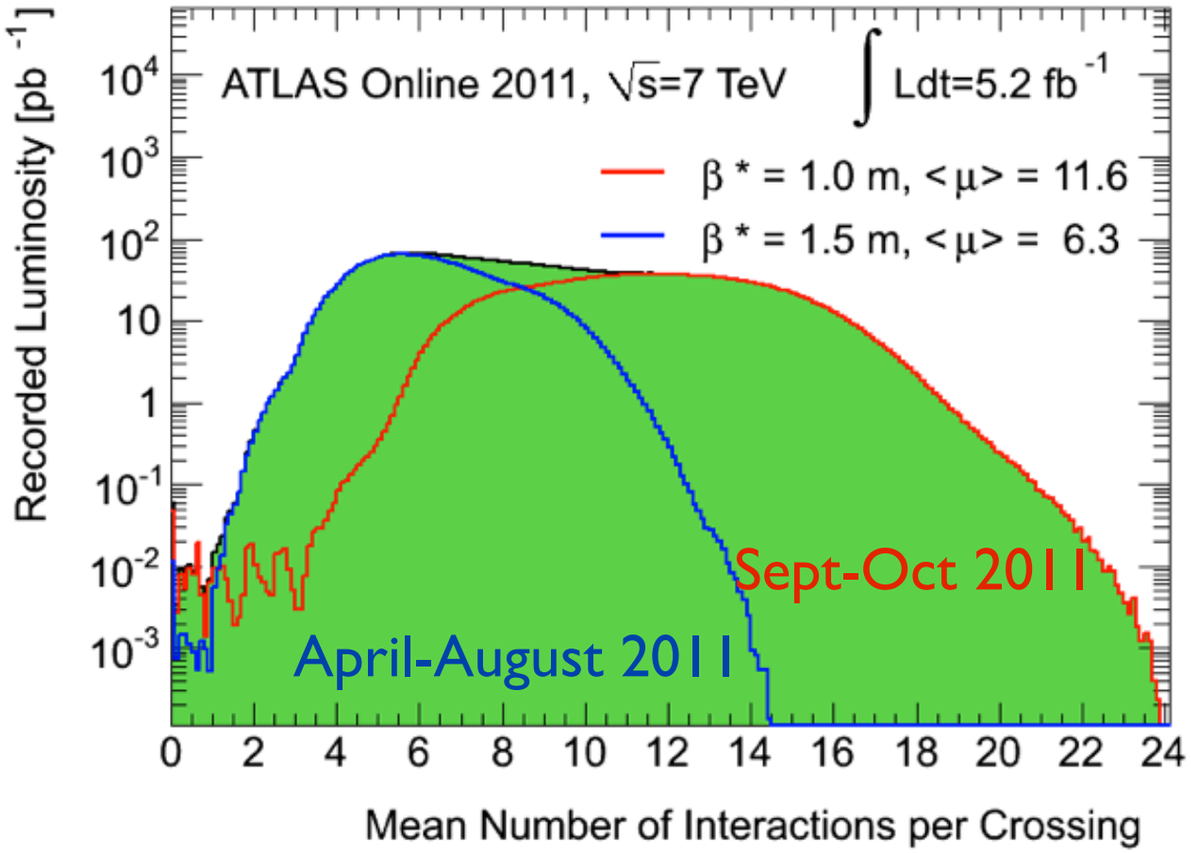


The vertices shown are reconstructed using tracks with pT greater than 0.4 GeV. The reconstructed vertex error ellipses are shown scaled up by a factor of 20 so that they are visible.

Pileup Effects

... the price for high luminosity

- **Pileup = number of interactions per crossing**
  - 2011 significantly higher than in 2010
  - tails up to 23
  - In-time pileup: many interactions in same bunch crossing
  - Out-of-time pileup: additional interactions in preceding bunch crossings
    - significant impact on ATLAS calorimeter reconstruction since LAr drift time is ~400 ns (bunch spacing Δt = 50 ns)
- **Challenging for physics analyses**
  - detailed simulation models <μ> and bunch train structure
  - reweight MC in analyses
  - Reconstruction s/w performance improved to accommodate Tier-0 resources
  - Detector performance reasonably unaffected
- **For Search analyses**
  - Affects mostly low p_T jets, low-medium E_T^{miss}, lepton isolation, triggering
  - Relatively small effect for most search analyses (control-regions are more affected than signal-regions)



For 2012, we expect a mean number of interactions (<μ>) ~35

2011 ATLAS Physics Proton Trigger Menu (end of run L = 3.3 10^{33} $cm^{-2}s^{-1}$) ... increasing thresholds

SUSY searches

SR: 1-lepton, multilept
CR for W/Z samples

SR: multilept

diphoton

0-lepton

monojet

multijet

	Offline Selection	Trigger Selection		L1 Rate (kHz) at 3e33	EF Rate (Hz) at 3e33
		L1	EF		
Single leptons	Single muon > 20GeV	11 GeV	18 GeV	8	100
	Single electron > 25GeV	16 GeV	22 GeV	9	55
Two leptons	2 muons > 17, 12GeV	11GeV	15,10GeV	8	4
	2 electrons, each > 15GeV	2x10GeV	2x12GeV	2	1.3
	2 taus > 45, 30GeV	15,11GeV	29,20GeV	7.5	15
Two photons	2 photons, each > 25GeV	2x12GeV	20GeV	3.5	5
Single jet plus MET	Jet pT > 130 GeV & MET > 140 GeV	50 GeV & 35 GeV	75GeV & 55GeV	0.8	18
MET	MET > 170 GeV	50 GeV	70GeV	0.6	5
Multi-jets	5 jets, each pT > 55 GeV	5x10GeV	5x30GeV	0.2	9
TOTAL				**<75**	**~400 (mean)**

from D. Strom, Dec. 7 2011, LHCC

- Trigger menu kept ~stable in 2011
  - primary (physics) triggers never prescaled
  - supplement by supporting and monitoring triggers
- Performance of trigger well understood

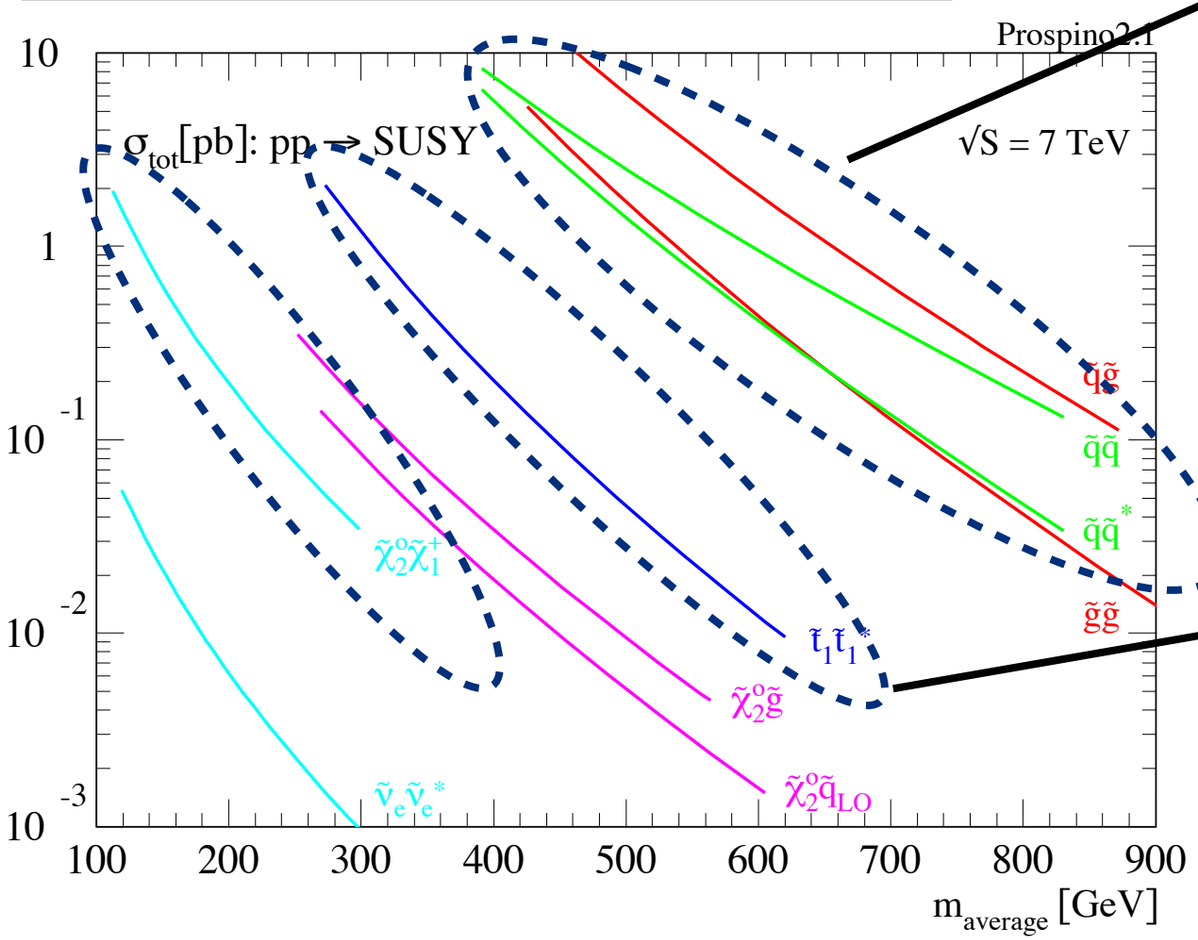
- With increasing lumi for 2012 run will need to control trigger rates:
  - multi-object triggers (lower thresholds)
  - move part of offline selection to trigger-level
  - dedicated triggers for signal, control region (prescaled?)

Supersymmetry Searches

also sensitive to many other new physics scenarios

ATLAS SUSY Search Strategy

Production cross-section @ 7 TeV



1. Strong production of SUSY particles

- Copious production at hadron colliders
- Inclusive E_T^{miss} based searches
- But also more "exotic" channels
  - Long-lived particles
  - Resonances

2. Third generation squarks

- Expected from naturalness to be O(<TeV)
- Expected lighter than other squarks due to mixing
- Dedicated searches for specific final states

3. Weak production of SUSY particles

- Production of charginos, neutrinos, sleptons
- Relevant when colored SUSY particles too heavy
- Dedicated searches based on multi-leptons

ATLAS SUSY Search Results using 2011 Data

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

2011 Data

Short Title of the Paper	Date	√s (TeV)	L (fb^{-1})	Document	Plots+Aux. Material	Journal
Disappering track (jets + Etmiss) NEW	02/2012	7	1.02	1202.4847	Link	Submitted to EPJC
Direct sbottom (2bjets + Etmiss)	12/2011	7	2.05	1112.3832	Link	Accepted by PRL
2photons + Etmiss	11/2011	7	1.07	1111.4116	Link	Accepted by PLB
2leptons + jets + Etmiss	10/2011	7	1.04	1110.6189	Link (inc. HEPData)	PLB 709 (2012) 137
0lepton + >=6jets + Etmiss	10/2011	7	1.34	1110.2299	Link (inc. HEPData)	JHEP 11 (2011) 99
1lepton + jets + Etmiss	09/2011	7	1.04	1109.6606	Link	PRD 85 (2012) 012006
0lepton + jets + Etmiss	09/2011	7	1.04	1109.6572	Link (inc. HEPData)	Accepted by PLB
Electron-muon resonance (RPV)	09/2011	7	1.07	1109.3089	Link (inc. HEPData)	EPJC 71 (2011) 1809

lepton denotes isolated electron or muon

Short Title of the CONF note	*Date*	*√s (TeV)*	*L (fb^{-1})*	*Document*	*Plots*
3leptons + Etmiss NEW	03/2012	7	2.05	*ATLAS-CONF-2012-023*	*Link*
Long lived Particle (Pixel-like) NEW	03/2012	7	2.05	*ATLAS-CONF-2012-022*	*Link*
>=1tau + jets + Etmiss NEW	02/2012	7	2.05	*ATLAS-CONF-2012-005*	*Link*
2 Same Sign Leptons + jets + Etmiss NEW	02/2012	7	2.05	*ATLAS-CONF-2012-004*	*Link*
bjets + 0-1lepton + jets + Etmiss NEW	02/2012	7	2.05	*ATLAS-CONF-2012-003*	*Link*
>=2taus + Etmiss NEW	02/2012	7	2.05	*ATLAS-CONF-2012-002*	*Link*
>=4leptons + Etmiss NEW	01/2012	7	2.05	*ATLAS-CONF-2012-001*	*Link*
Add. 2leptons + jets + Etmiss interpretation	11/2011	7	1.04	*ATLAS-CONF-2011-156*	*Link*
Add. 0lepton + jets + Etmiss interpretation	11/2011	7	1.04	*ATLAS-CONF-2011-155*	*Link (inc. HEPData)*
bjets + 1lepton + jets + Etmiss	08/2011	7	1.03	*ATLAS-CONF-2011-130*	*Link*
bjets + 0lepton + jets + Etmiss	07/2011	7	0.83	*ATLAS-CONF-2011-098*	*Link*
1lepton + jets + Etmiss	06/2011	7	0.16	*ATLAS-CONF-2011-090*	*Link*
0lepton + jets + Etmiss	06/2011	7	0.16	*ATLAS-CONF-2011-086*	*Link*

ATLAS SUSY Search Results using 2011 Data

lepton denotes isolated electron or muon

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/SupersymmetryPublicResults

2011 Data

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Disappearing track (jets + Etmiss) NEW	02/2012	7	1.02	1202.4847	Link	Sub
Direct sbottom (2bjets + Etmiss)	12/2011	7	2.05	1112.3832	Link	
2photons + Etmiss	11/2011	7	1.07	1111.4116	Link	
2leptons + jets + Etmiss	10/2011	7	1.04	1110.6189	Link	137
0lepton + >=6jets + Etmiss	10/2011	7	1.34	1110.2299		(2011) 99
1lepton + jets + Etmiss	09/2011	7	1.04	11		RD 85 (2012) 012006
0lepton + jets + Etmiss	09/2011	7	1.04		ata)	Accepted by PLB
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3leptons + Etmiss NEW				*ATLAS-CONF-2012-023*	*Link*
Long lived Particle (Pixel-like) NEW			2.05	*ATLAS-CONF-2012-022*	*Link*
>=1tau + jets + Etmiss NEW			2.05	*ATLAS-CONF-2012-005*	*Link*
2 Same Sign Lept		7	2.05	*ATLAS-CONF-2012-004*	*Link*
bjets + 0-1	02/2012	7	2.05	*ATLAS-CONF-2012-003*	*Link*
>=2	02/2012	7	2.05	*ATLAS-CONF-2012-002*	*Link*
	01/2012	7	2.05	*ATLAS-CONF-2012-001*	*Link*
Etmiss interpretation	11/2011	7	1.04	*ATLAS-CONF-2011-156*	*Link*
jets + Etmiss interpretation	11/2011	7	1.04	*ATLAS-CONF-2011-155*	*Link (inc. HEPData)*
1lepton + jets + Etmiss	08/2011	7	1.03	*ATLAS-CONF-2011-130*	*Link*
bjets + 0lepton + jets + Etmiss	07/2011	7	0.83	*ATLAS-CONF-2011-098*	*Link*
1lepton + jets + Etmiss	06/2011	7	0.16	*ATLAS-CONF-2011-090*	*Link*
0lepton + jets + Etmiss	06/2011	7	0.16	*ATLAS-CONF-2011-086*	*Link*

Expect several search results updated to full 2011 dataset in the coming weeks.

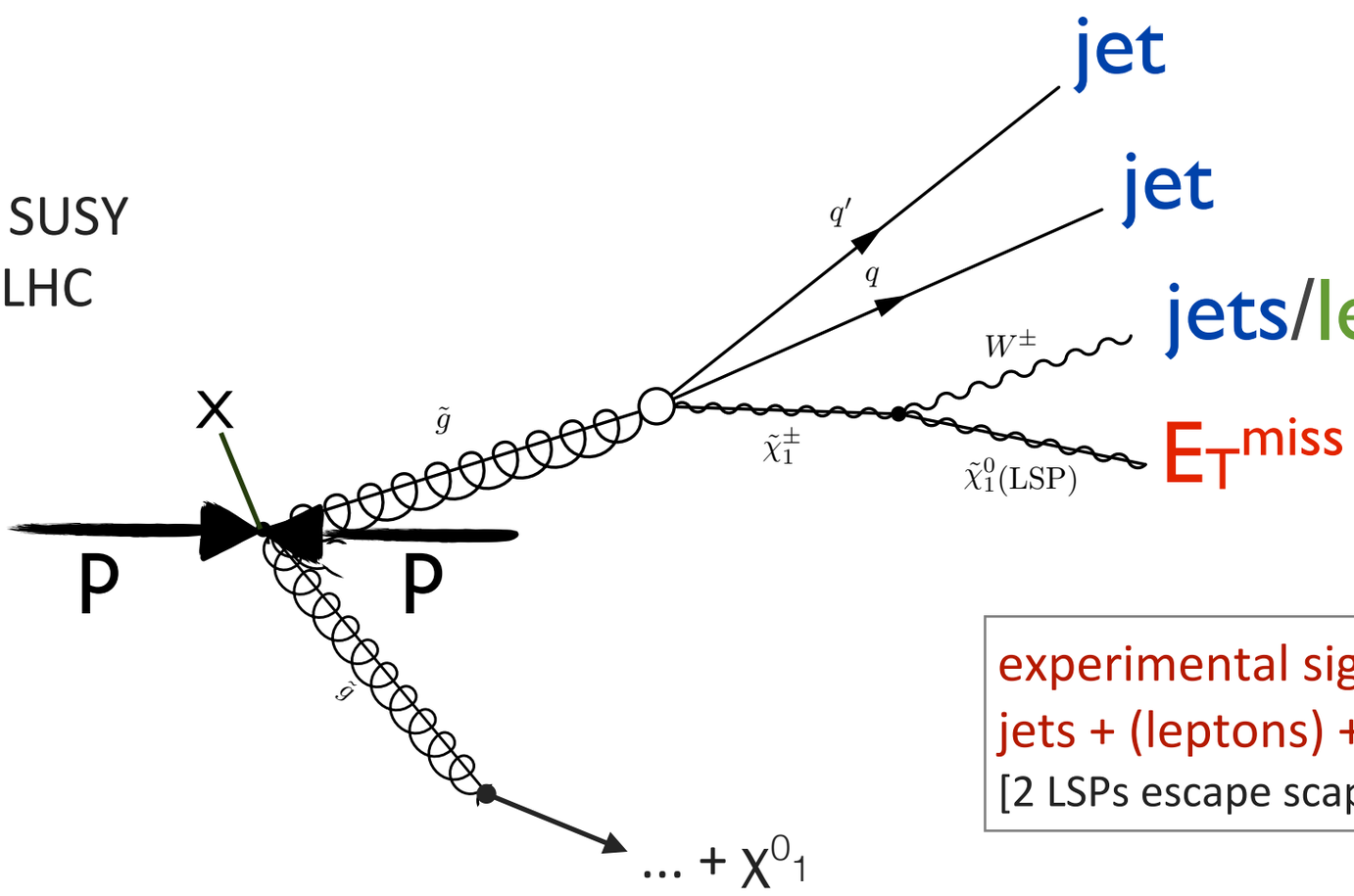
Expected SUSY Characteristics at LHC

R-parity conservation (RPC)

RPV & long-lived scenarios => different signatures! (see later)

- ★ lightest supersymmetric particle (LSP) must be stable => WIMP candidate
- ★ SUSY particles pair produced
- ★ Cascade decays down to LSP

Expected "**typical**" SUSY decay chain at the LHC



jet

jet

jets/lepton or photons

depends on nature of next-to-lightest SUSY particle

E_T^{miss}

experimental signature:
jets + (leptons) + (photons) + E_T^{miss}
[2 LSPs escape scape detection]

Squarks can be directly produced too.
If gluinos & squarks too heavy, then EW direct gaugino production becomes important.

R-parity = +1 (-1) SM (SUSY) particles

A typical SUSY search analysis

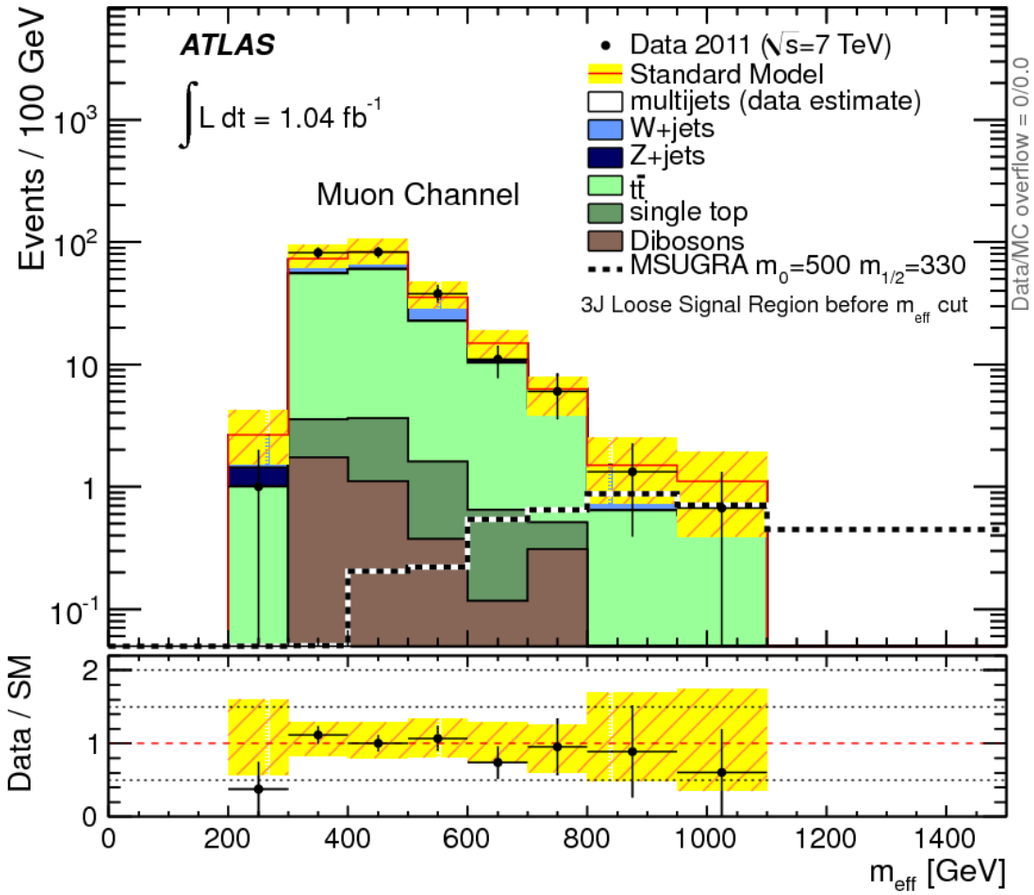
1. **Event selection** ("cut-and-count" approach)
   - Based on : jets + large E_T^{miss} + leptons/photons/bjets
     - coherent with trigger
   - Cut sufficiently hard to reduce difficult background processes (fake E_T^{miss}, fake leptons from QCD, pile-up)
   - Enhance signal / background by cutting on discriminating variables, e.g. "effective mass"
2. **Estimate remaining backgrounds**
   - fully data-driven for difficult processes, e.g. QCD fake leptons
   - semi data-driven for most major processes, e.g. W and ttbar (see next slide)
   - MC based for minor processes, e.g. dibosons
3. **Estimate all uncertainties**
   - Experimental uncertainties: jet energy scale calibration, b-tagging efficiency, etc.
   - Theoretical uncertainties: renomalization and factorization scales, PDF, etc.
4. **Look at the signal-region(s):** Any significant excess ? If not, derive exclusion limits
5. **Interpretation** of the results in a model-independent way or within specific scenarios (simplified models, MSSM, MSUGRA, GMSB, etc.)

transverse scalar mass (HT):

$$H_T = p_T^{\ell} + \sum_{i=1}^{3} p_T^{jet_i}$$

"effective" mass (Meff):

$$m_{\text{eff}} = H_T + E_{\text{T}}^{\text{miss}}$$

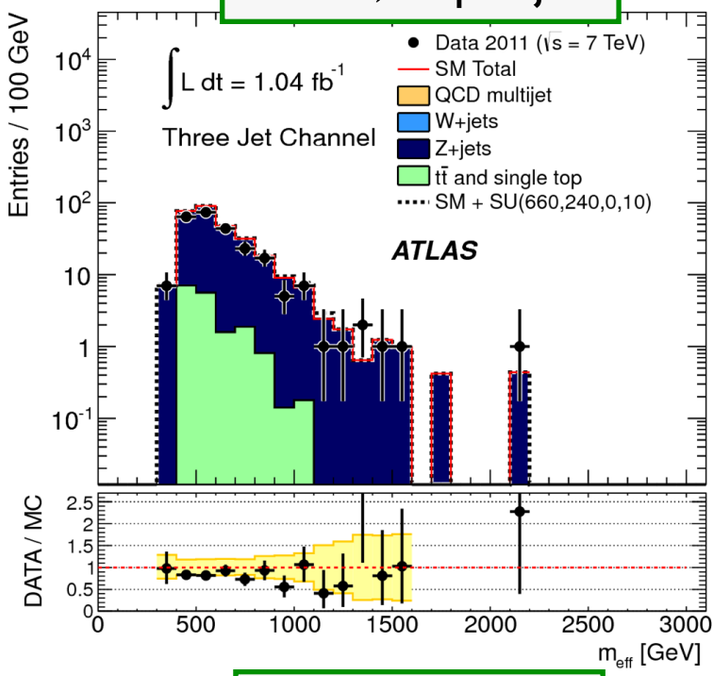


Example background estimates

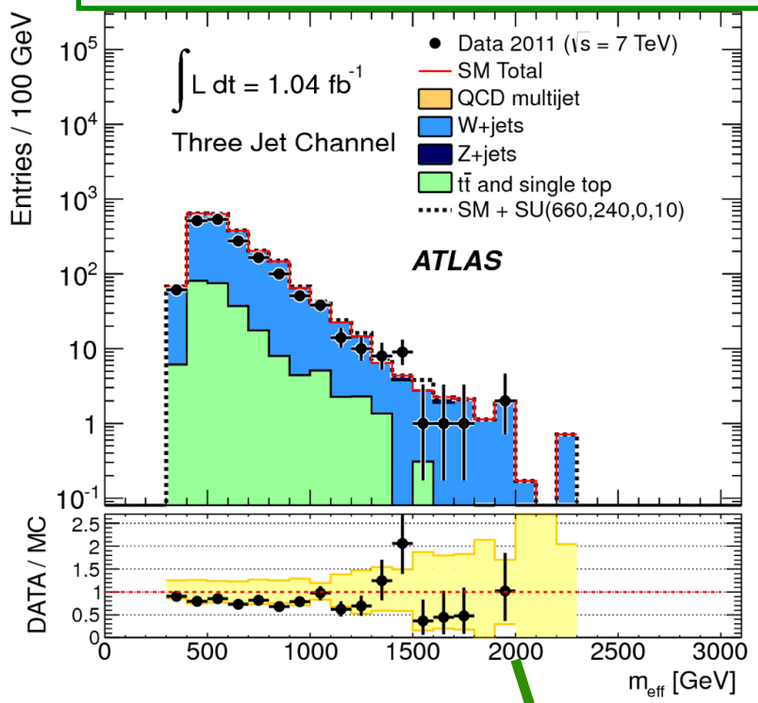
semi data-driven for most major processes

Extrapolation (green arrows) from control to signal region using simulation.

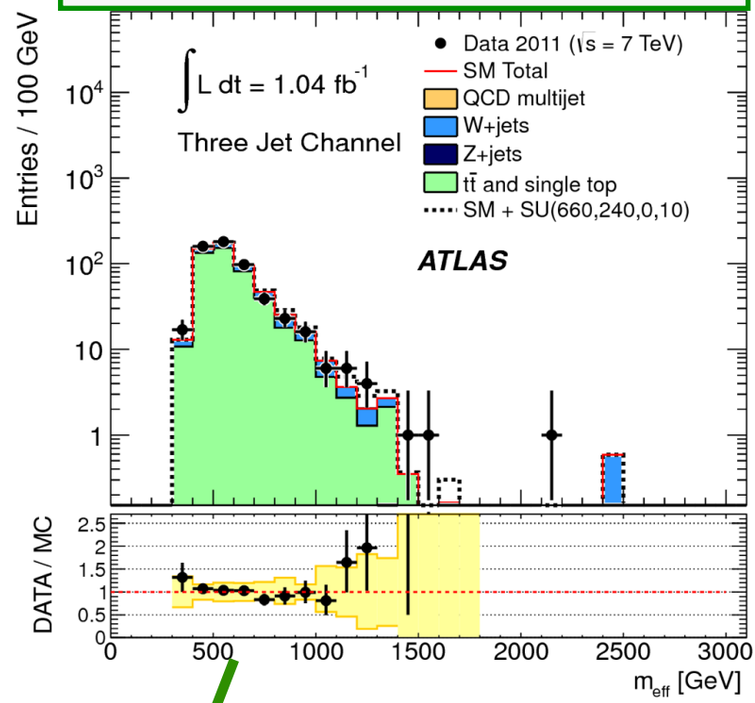
Z CR2, 2lep+3jets



W CR, 1lep+MET+3jets (no bjet)



Top CR, 1lep+MET+3jets (1bjet)



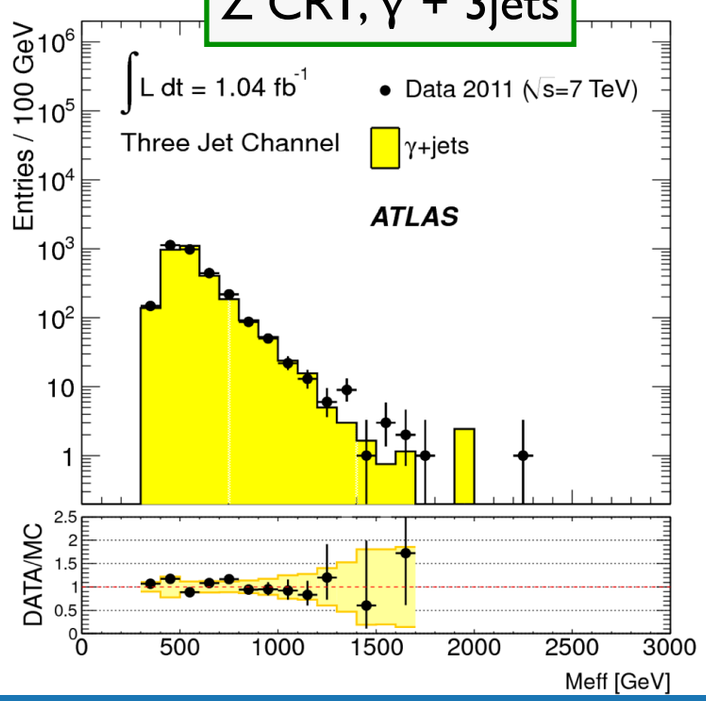
W→W

top→top

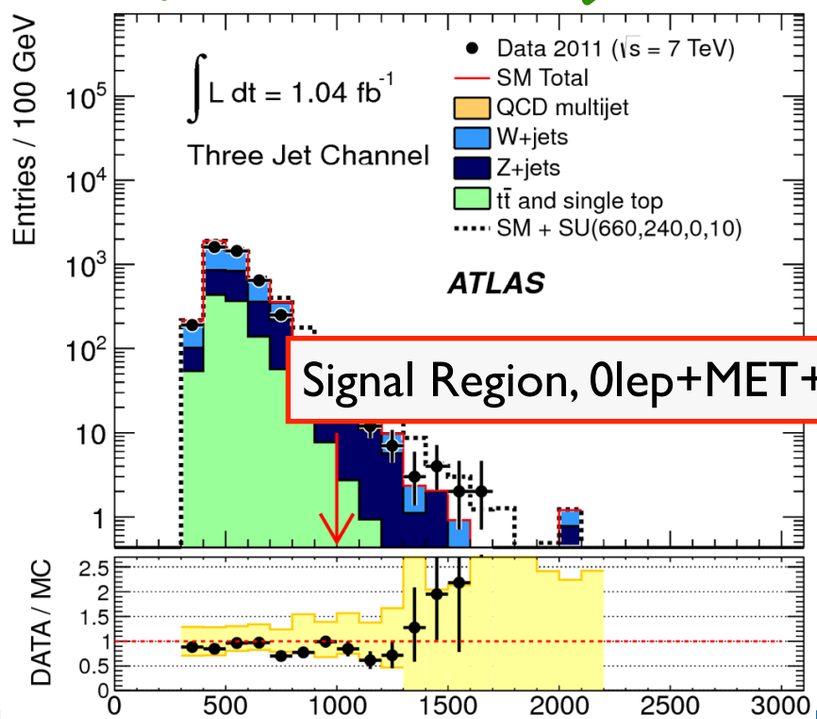
Zll→Zνν

γ→Zνν

Z CR1, γ + 3jets



Signal Region, 0lep+MET+3jets



strong prod

All-hadronic SUSY searches

5 fb^{-1} search results being approved these days.

squark + gluino production

==> MET + jets signature

SM backgrounds: MET with leptons, except for Znunu+jets

==> veto leptons

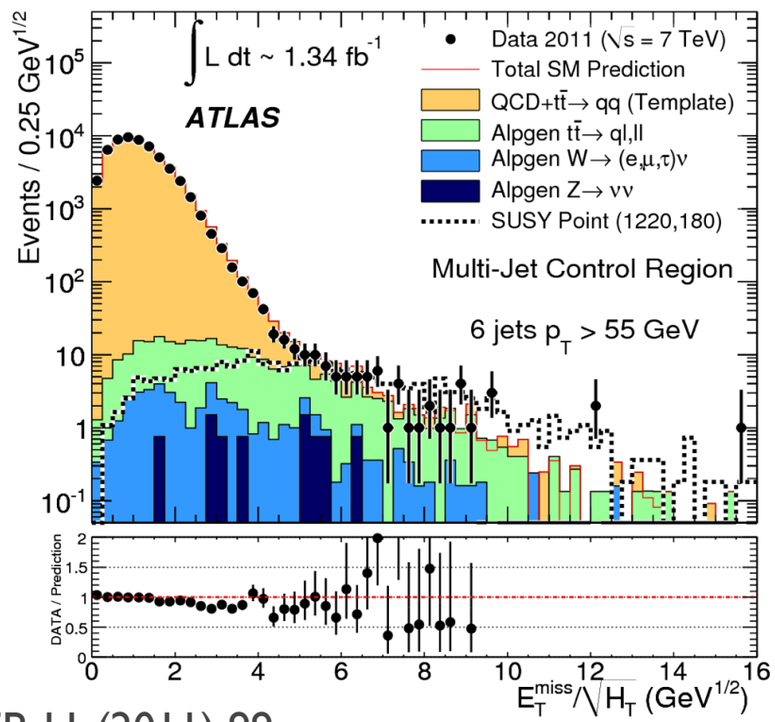
Searches:

1. no leptons + large E_T^{miss} + ≥ 2-4 jets
2. no leptons + medium E_T^{miss} + ≥ 6-8 jets

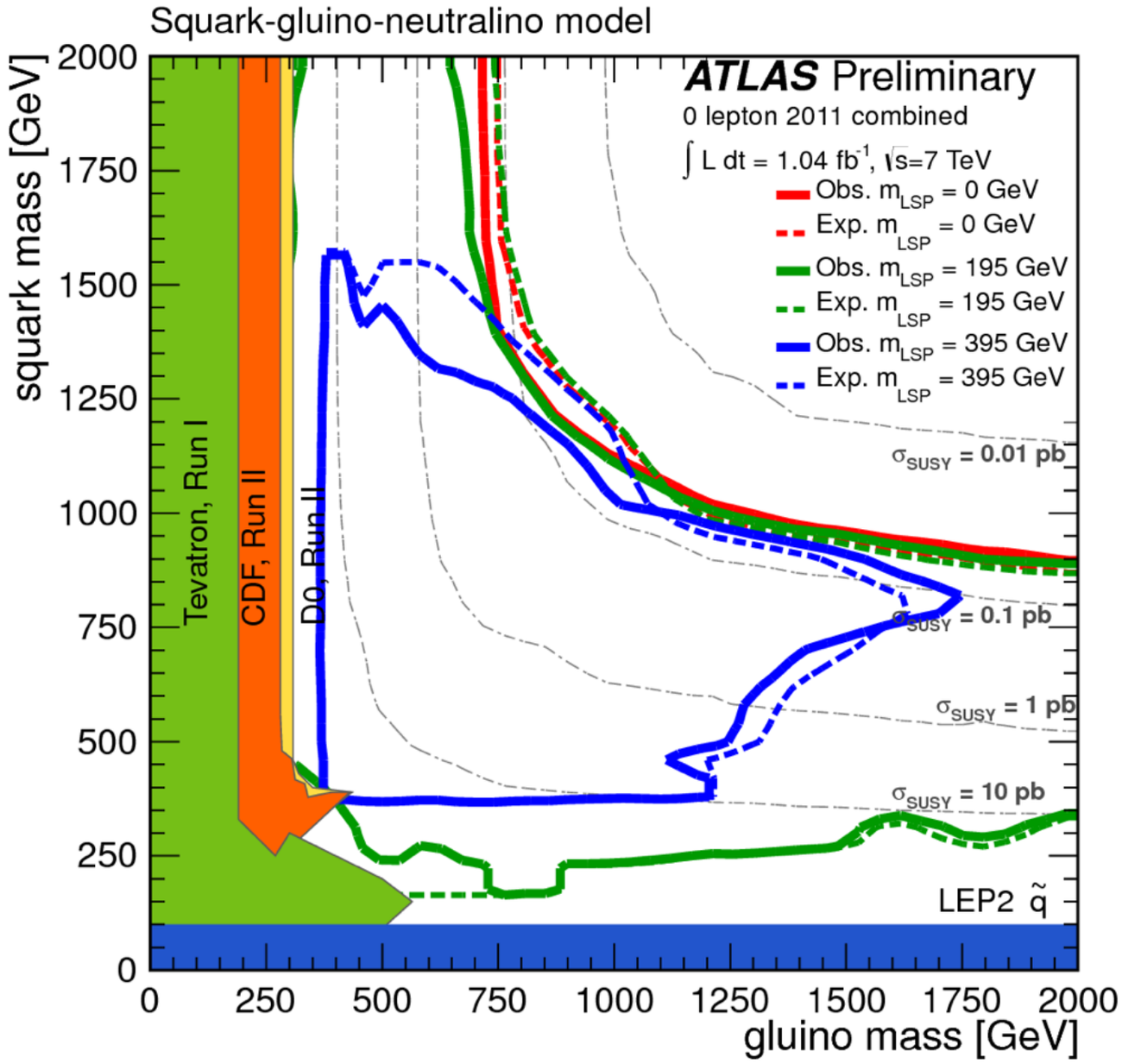
Results compatible with SM only.

Example interpretation in simplified model, which considers only gluino, squarks, and LSP.

$M_{sq} = M_{gl} \gtrsim 1$ TeV (LSP mass < 200 GeV)



JHEP 11 (2011) 99



Accepted by PLB (ArXiV:1109.6572) + ATLAS-CONF-2011-155

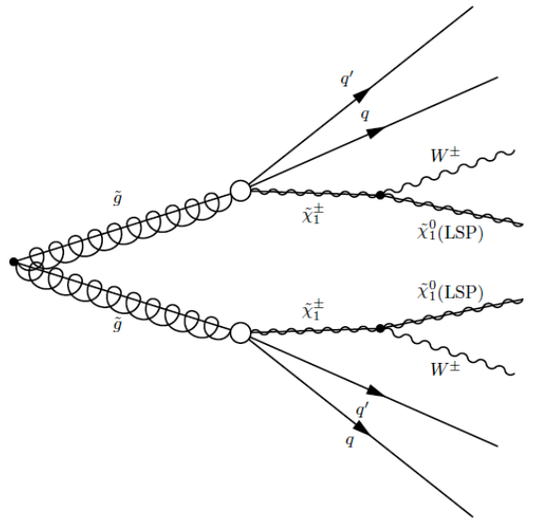
strong prod

PRD 85 (2012) 012006

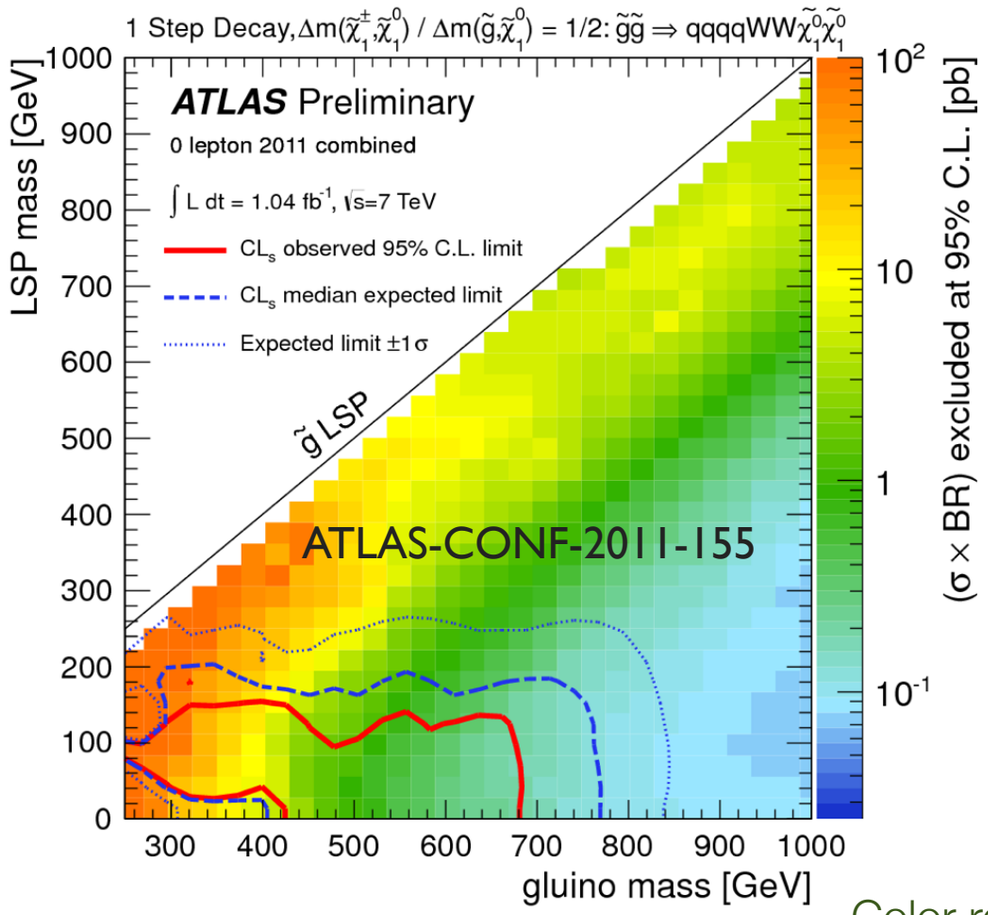
Lepton + MET + Jets

For strong production with longer decay chains, where leptons can be generated (e.g. a chargino emits a W boson, or via sleptons), leptonic searches complement the all-hadronic channels.

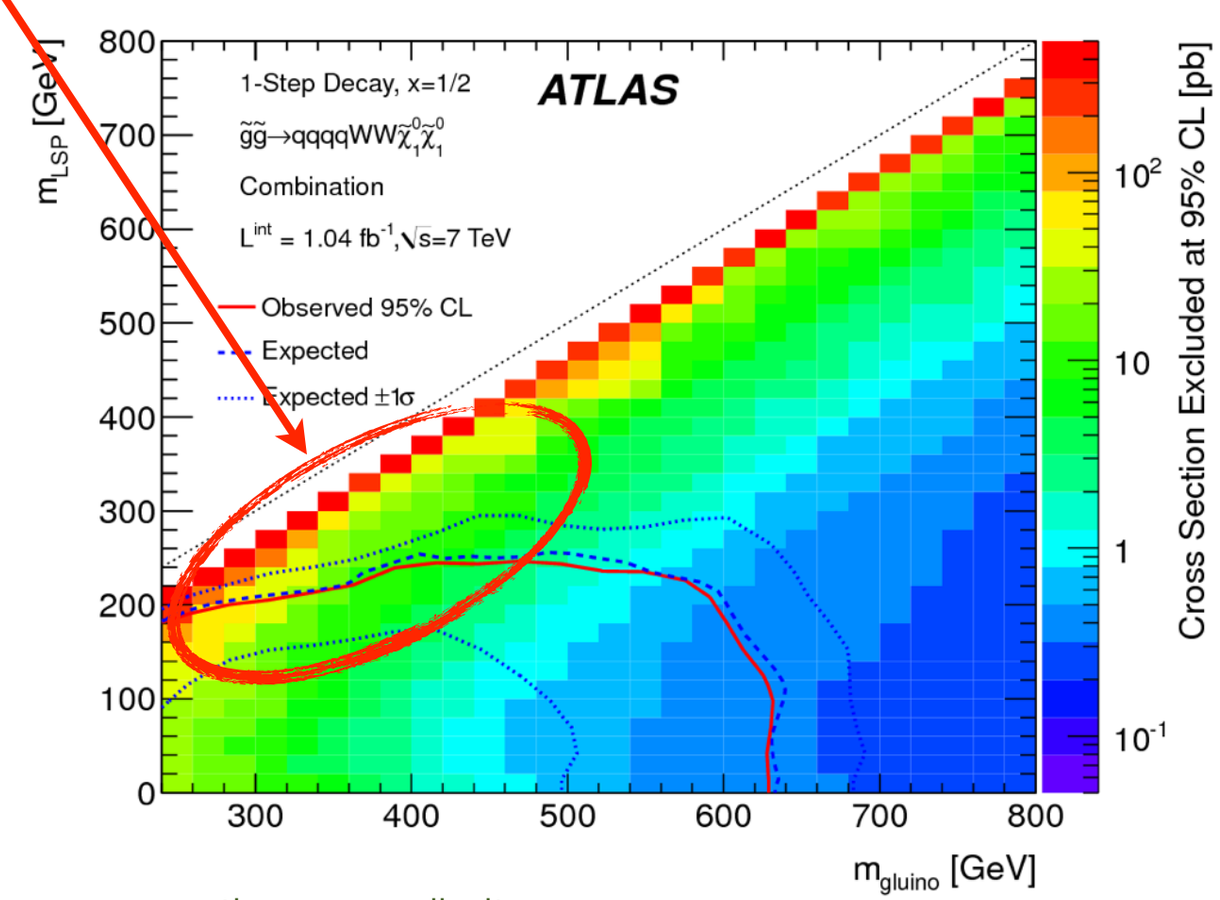
In particular, for "compressed" SUSY mass scenarios.



All-hadronic (0-lep): E_T^{miss} + ≥ 2-4 jets search



1-lepton + ≥ 3-4 jets + E_T^{miss} search



Color represents cross-section upper limit.

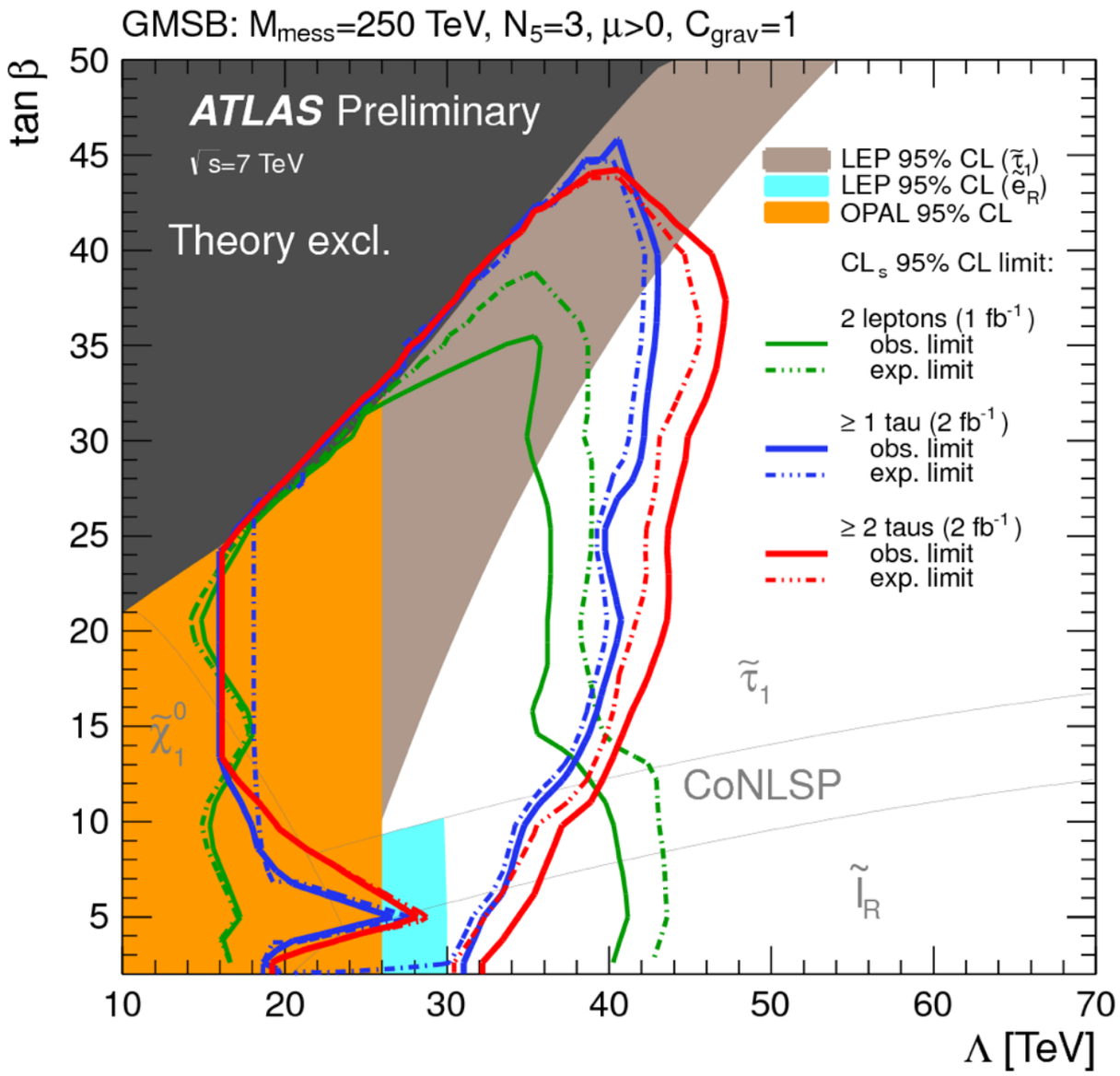
Tau Signatures

Signal scenario:
Strong production of squarks & gluinos in GMSB with stau NLSP.

ATLAS-CONF-2011-156, ATLAS-CONF-2012-005, ATLAS-CONF-2012-002

The Stau in each decay chain generates taus, which decay to:

- hadrons (65%)
- leptons (35%)



Search signatures:

✓ 2 opposite sign el/mu + jets + E_T^{miss}
✓ 1 hadronic-tau + Jets + E_T^{miss}
✓ 2 hadronic-taus + Jets + E_T^{miss}
1 hadronic-tau + 1 mu + jets + E_T^{miss} (on-going)

Exclude Λ < 40-46 TeV (tanβ=2-40),
~ M_{SUSY} < 900 - 1000 GeV

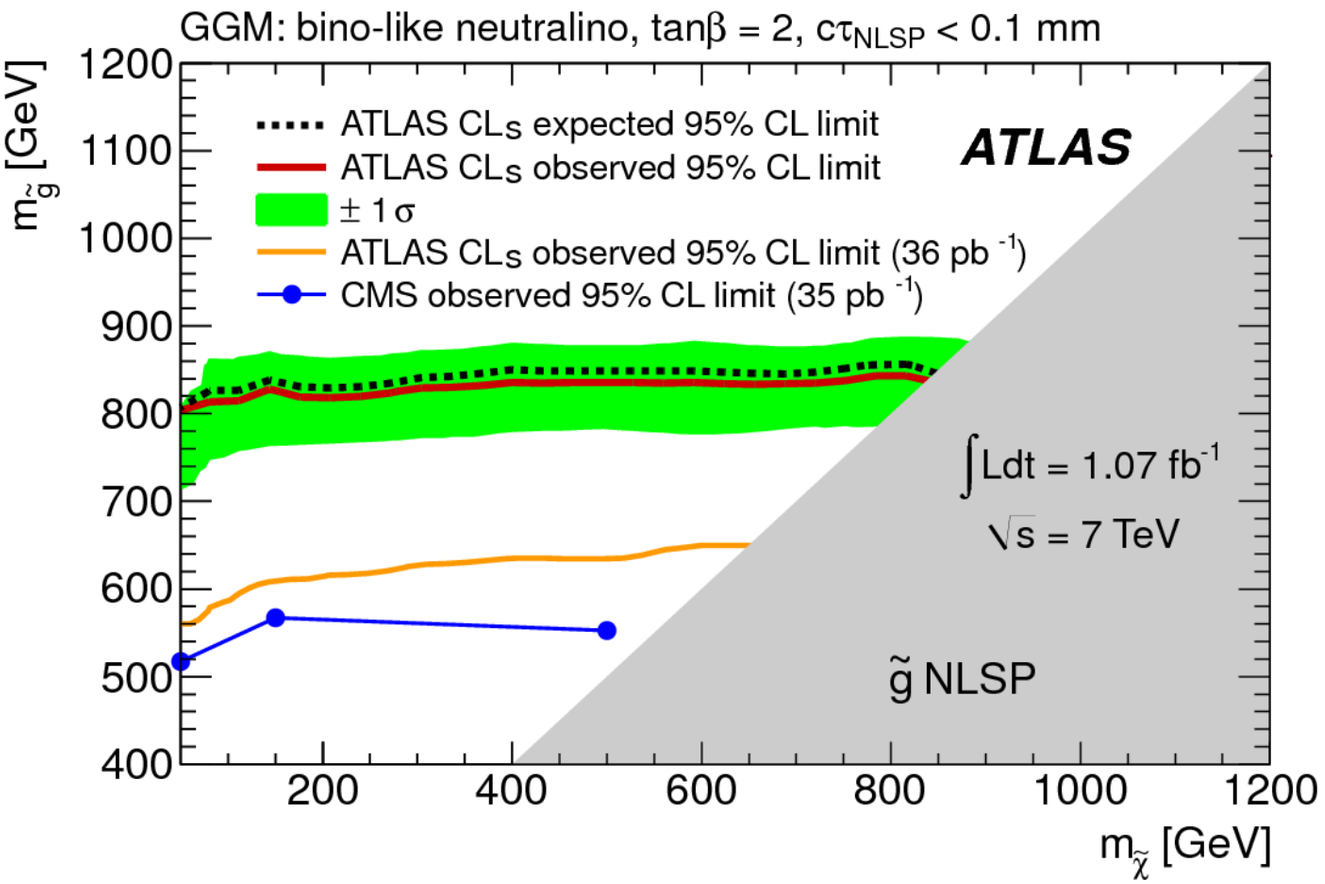
strong prod

Accepted by PLB (ArXiv:1111.4116)

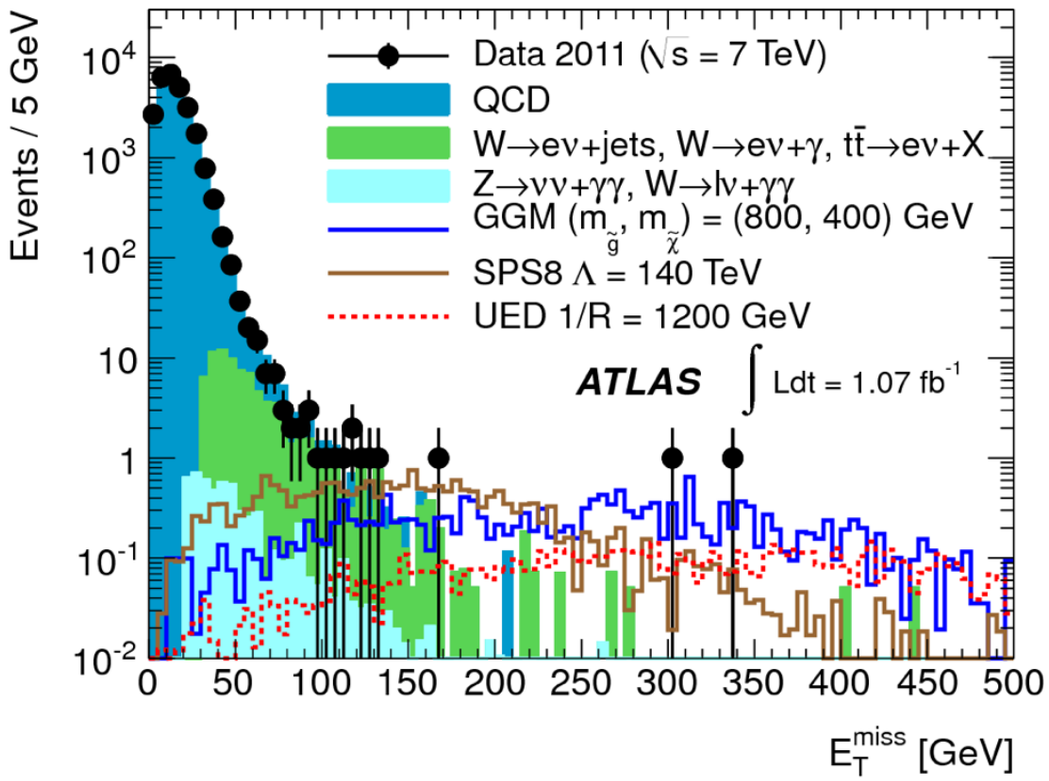
Search with 2 photons + E_T^{miss}

Signal scenario:
Strong production of squarks & gluinos in GMSB scenarios.

Cut E_T^{miss} > 125 GeV sets 95% CL_S limits:
exclude GGM gluino mass < 800 GeV



Observed and predicted E_T^{miss} spectrum

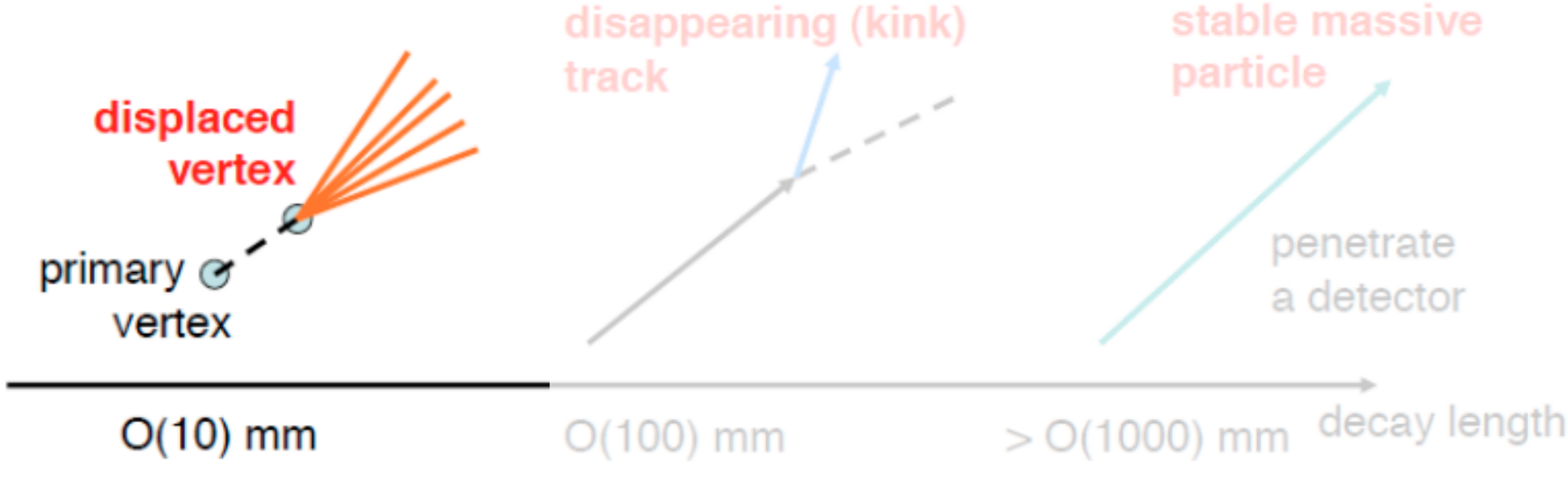


RPVLL

Displaced Vertex

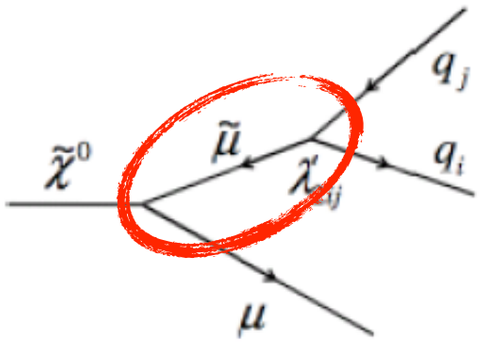
PLB 707 (2012) 478

strong production, but with long-lived SUSY particles (RPV, GMSB, AMSB models)



RPV, decay of LSP

- trigger on muon
- select vertices

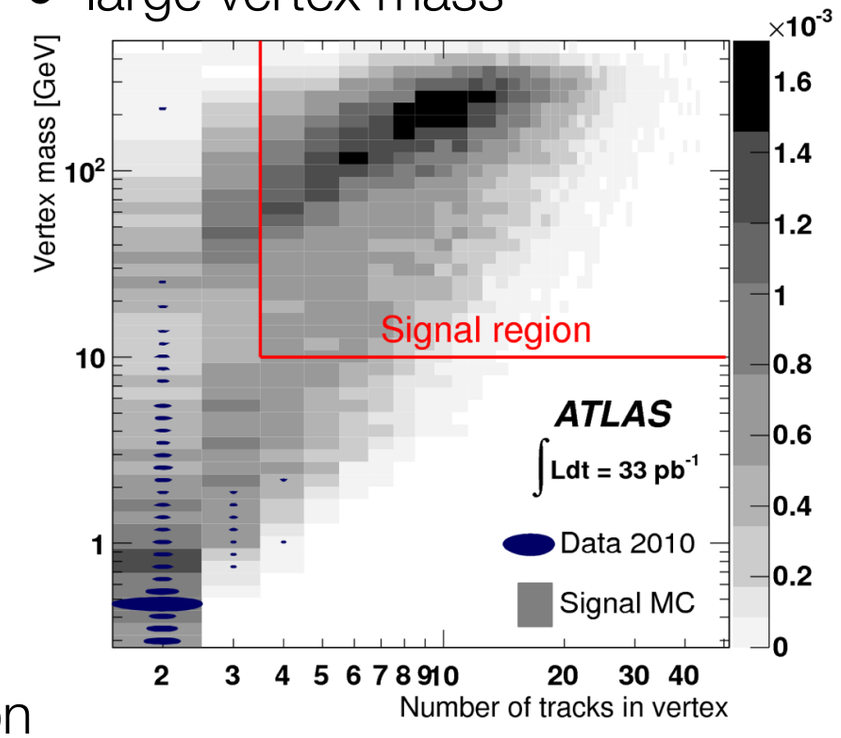


Main backgrounds:

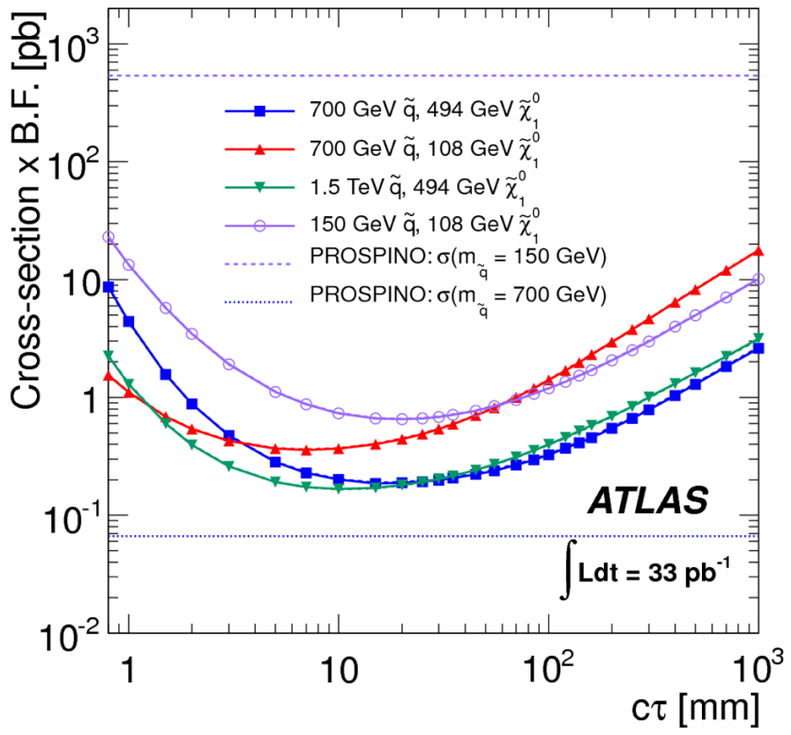
- hadronic interactions with detector material
- veto based on vertex position

Search for displaced vertices

- many tracks
- large vertex mass



Upper limit on σxBR, depends on neutralino lifetime.

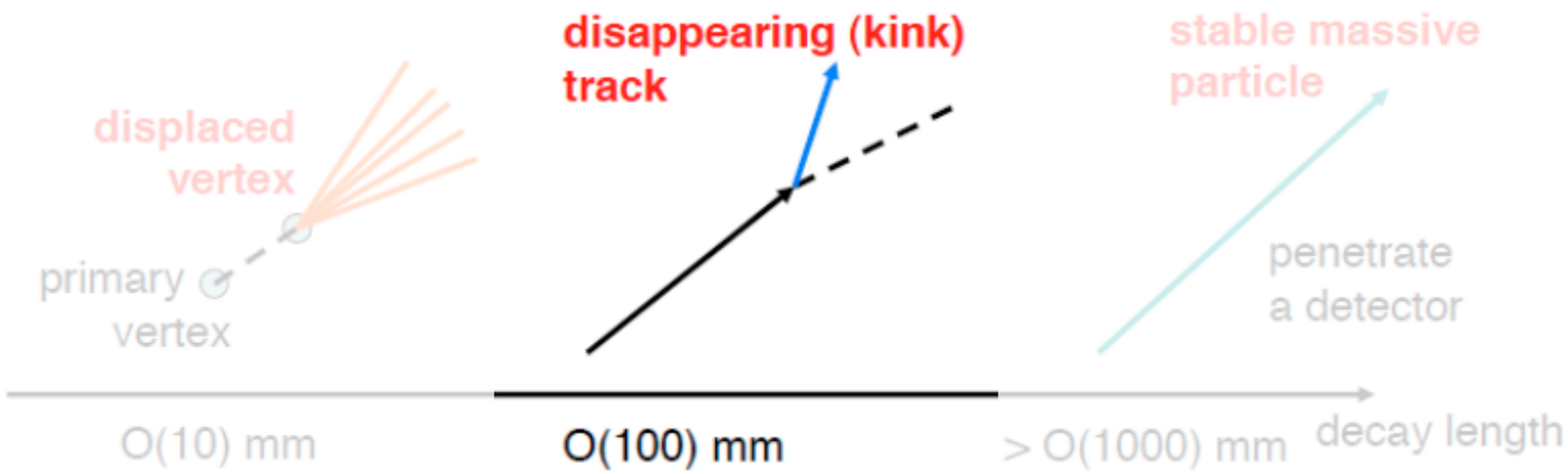


RPVLL

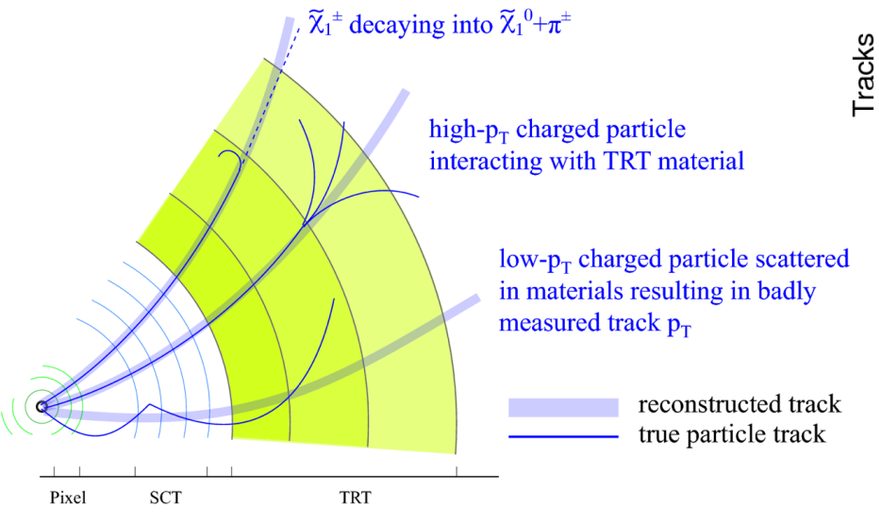
Disappearing Track

Submitted to EPJC (ArXiv:1202.4847)

strong production, but with long-lived SUSY particles (RPV, GMSB, AMSB models)

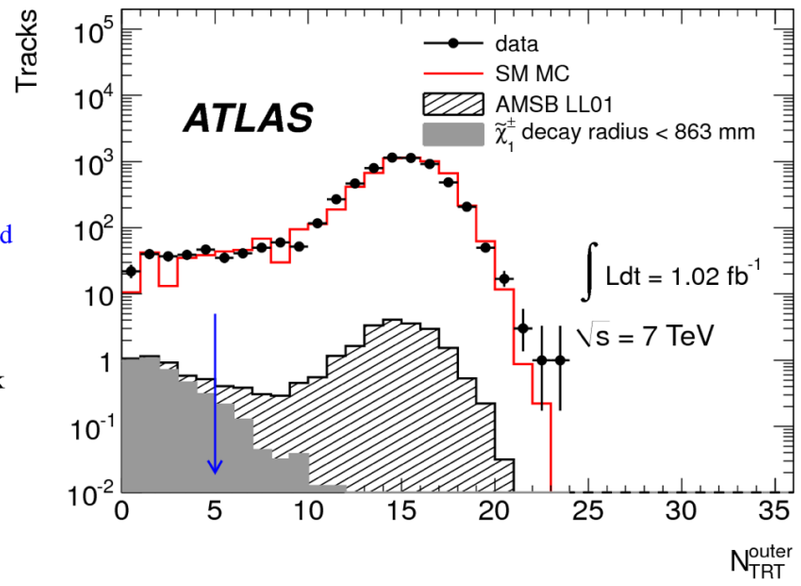


AMSB, neutralino and chargino are nearly mass degenerate

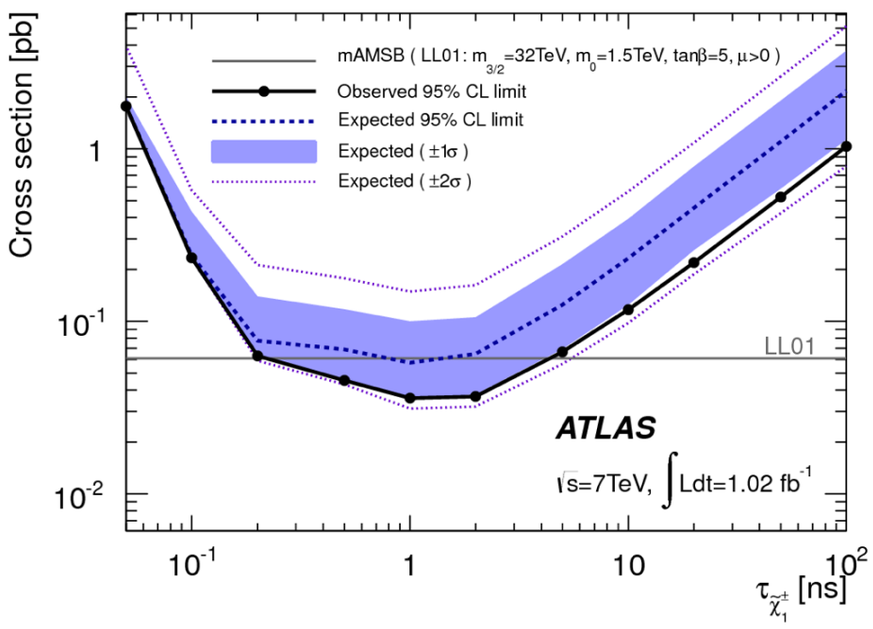


Search for disappearing track

- high pT track with a small number of TRT hits



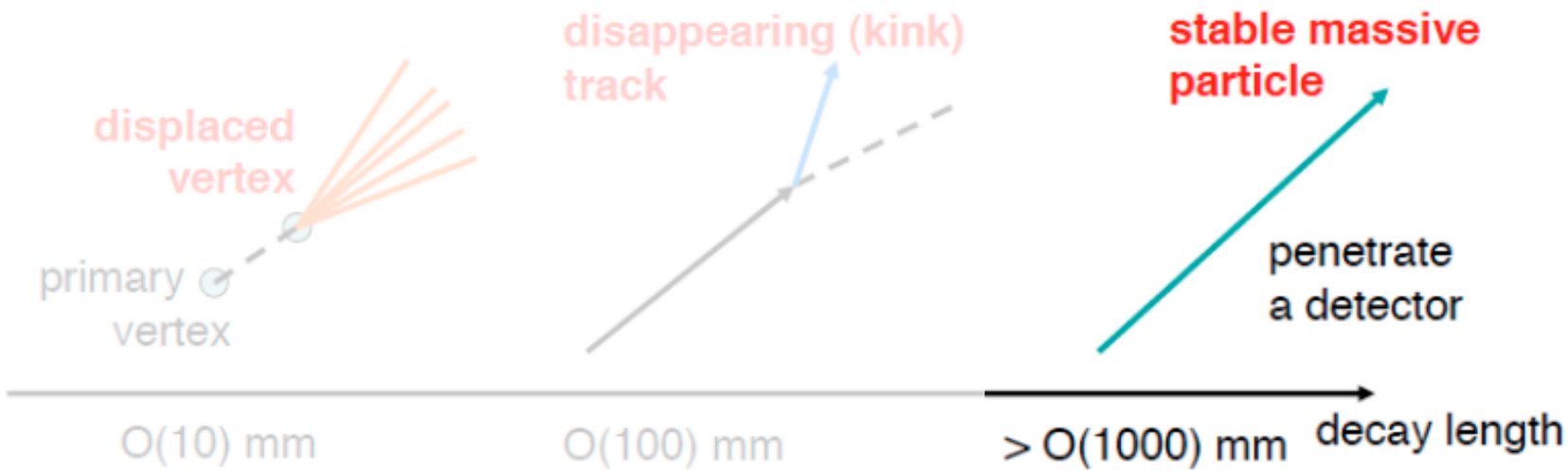
Exclude chargino mass < 90.2 GeV, for a lifetime 0.5-2 ns.



RPVLL

Stable Massive Particles

strong production, but with long-lived SUSY particles (RPV, GMSB, AMSB models)



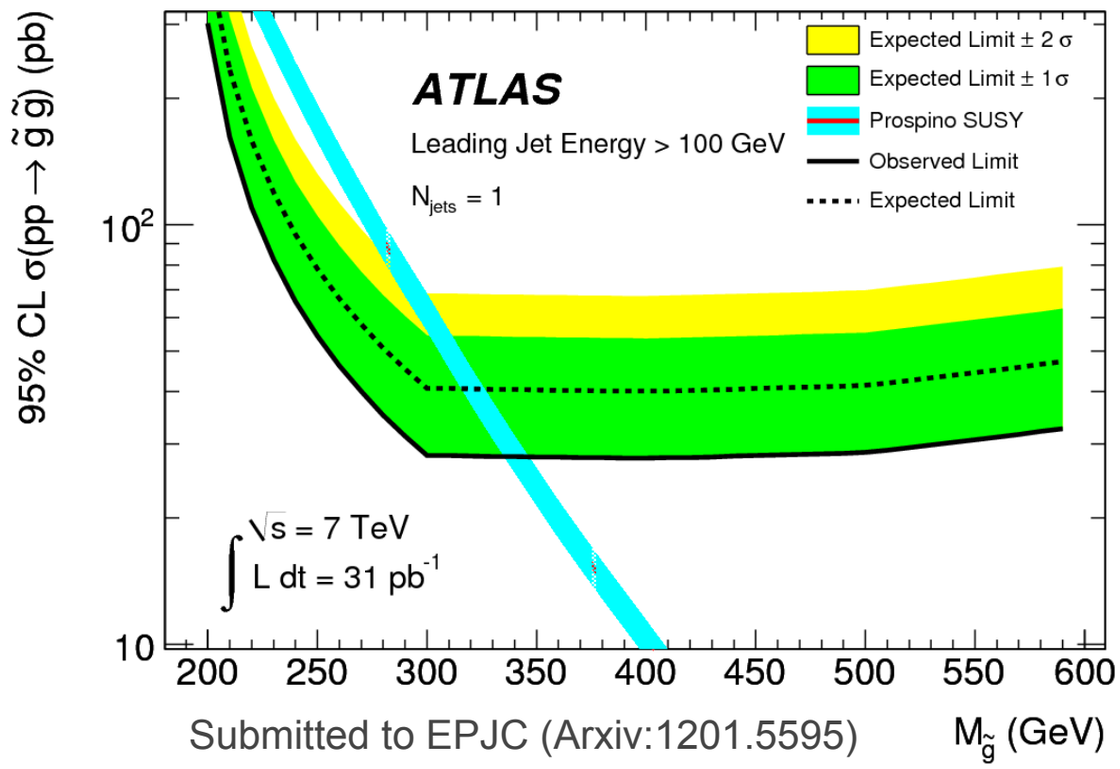
✓ Long-lived sleptons or R-hadrons (gluino or squark binding with other quarks).

✓ depending on nature/interaction/lifetime could produce

- large ionization loss in track detectors
- long time-of-flight in calorimeters
- heavy-like muons (staus) seen in muon spectrometer
- large calorimeter deposit in empty bunch crossings

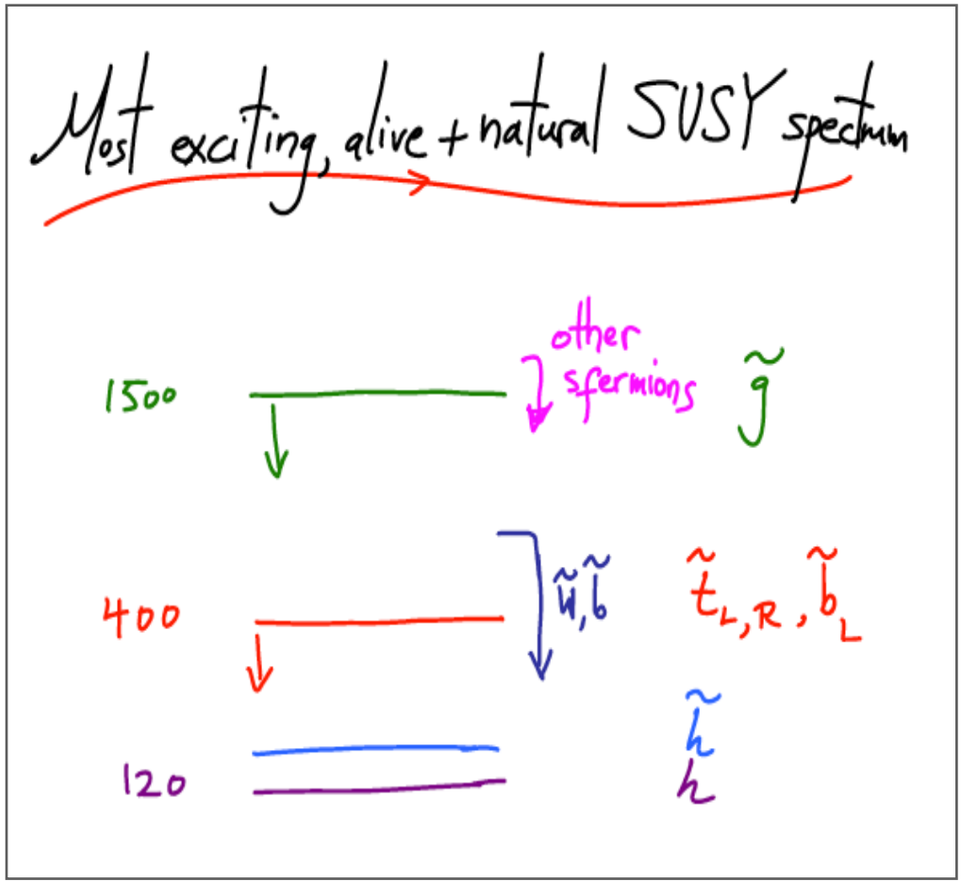
=> Many dedicated searches

Search for calorimeter energy deposits in empty bunches: Excluding gluino-based R-hadrons with masses less than 341 GeV.



strong prod., 3rd gen.

Searches for 3rd gen. squarks

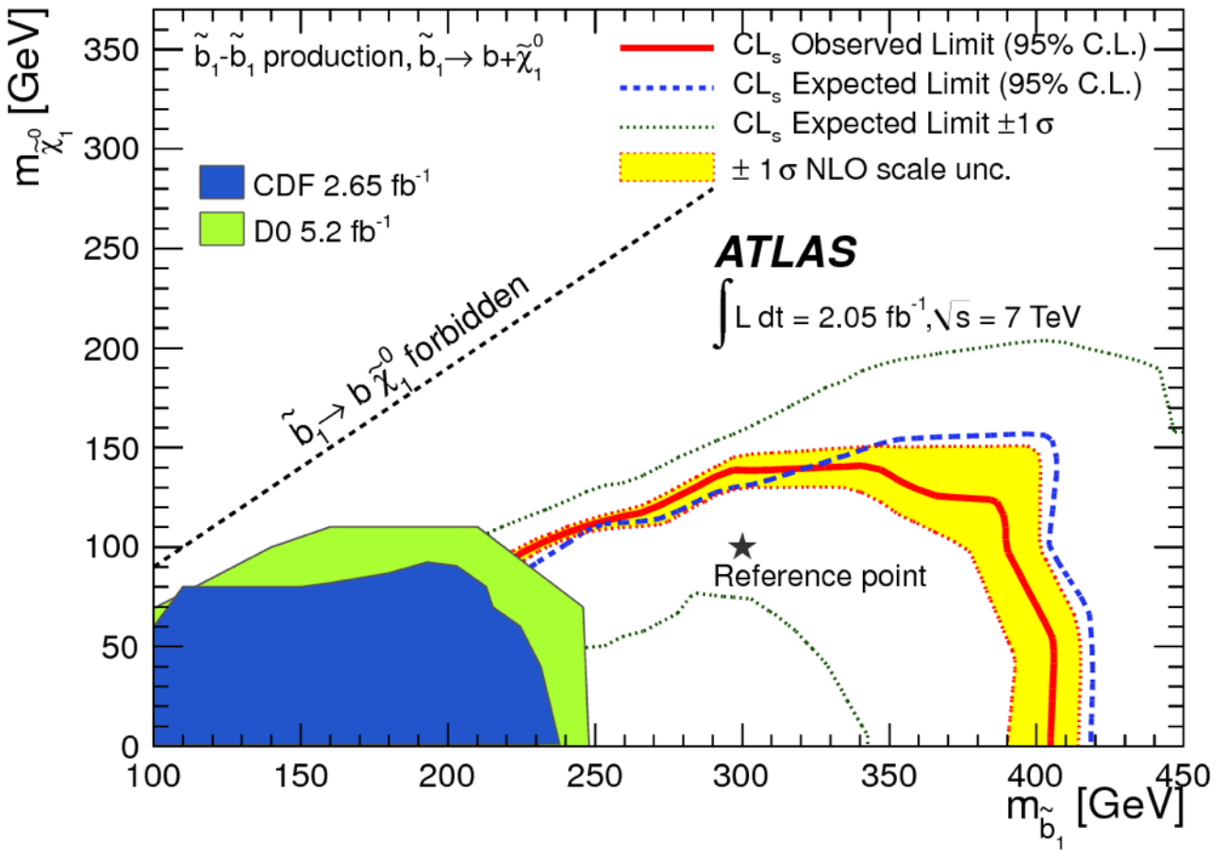


Taken from Nima Arkani-Hamed

3rd generation

- Main motivation for TeV-scale SUSY is solving hierarchy problem
- If SUSY solves the hierarchy problem naturally, then 3rd gen. squarks must be light

✓ Signature: exactly 2 b-jets + MET
=> make use of flavor tagging



Exclude sbottom mass < 380 GeV for neutralino masses up to ~ 100 GeV

Accepted by PRL (Arxiv:1112.3832)

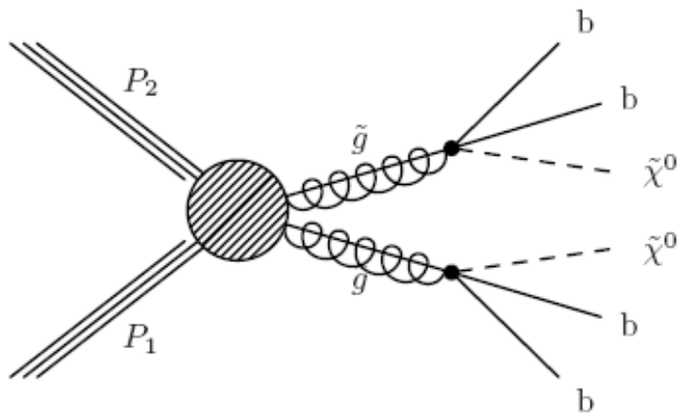
Search effort for direct stop pair production on-going, expect results soon.

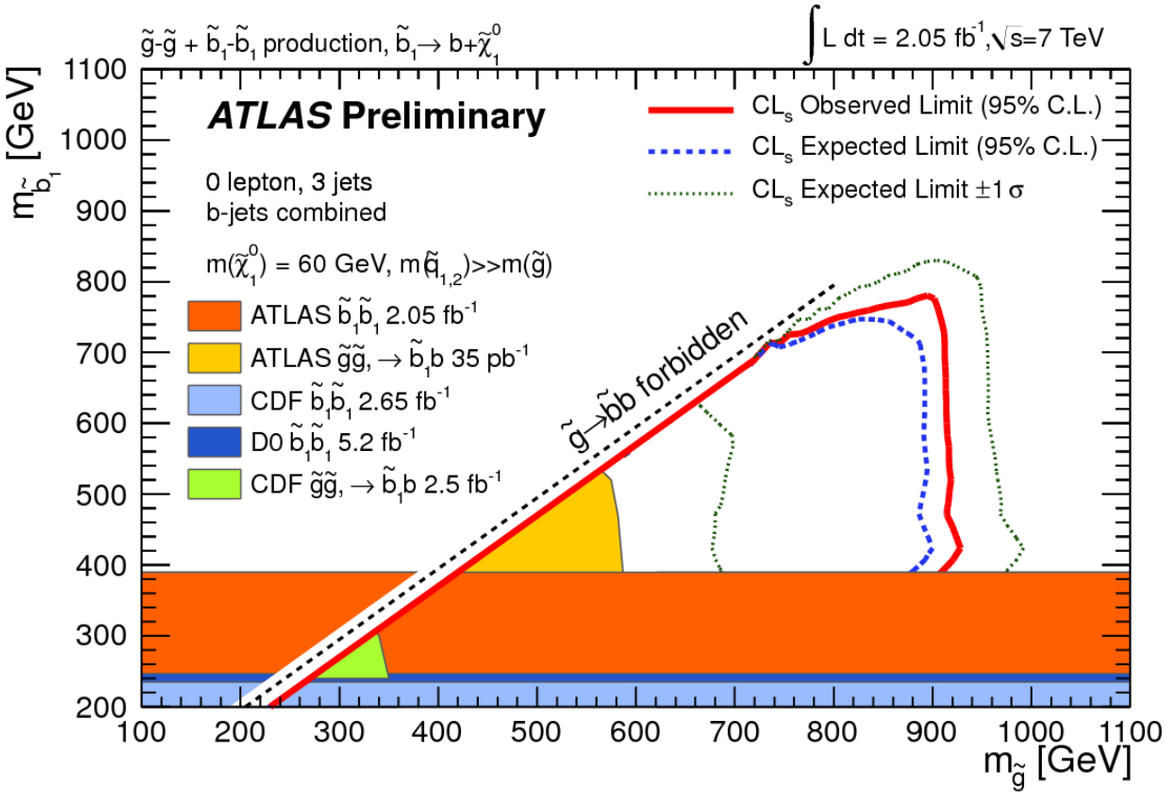
strong prod.,
3rd gen.

Gluino mediated 3rd gen. squarks

ATLAS-CONF-2012-003

Signature: 0-lepton + several b-jets + MET
=> make use of flavor tagging

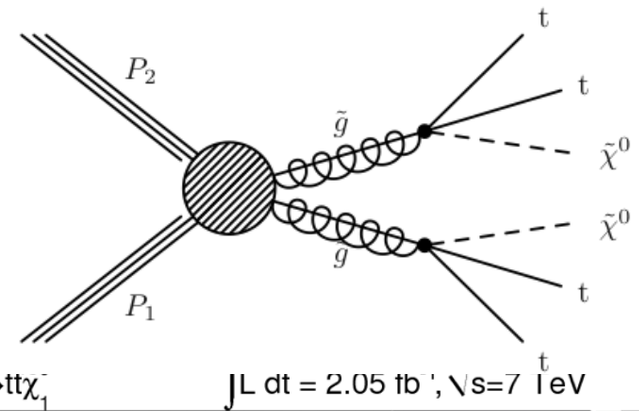


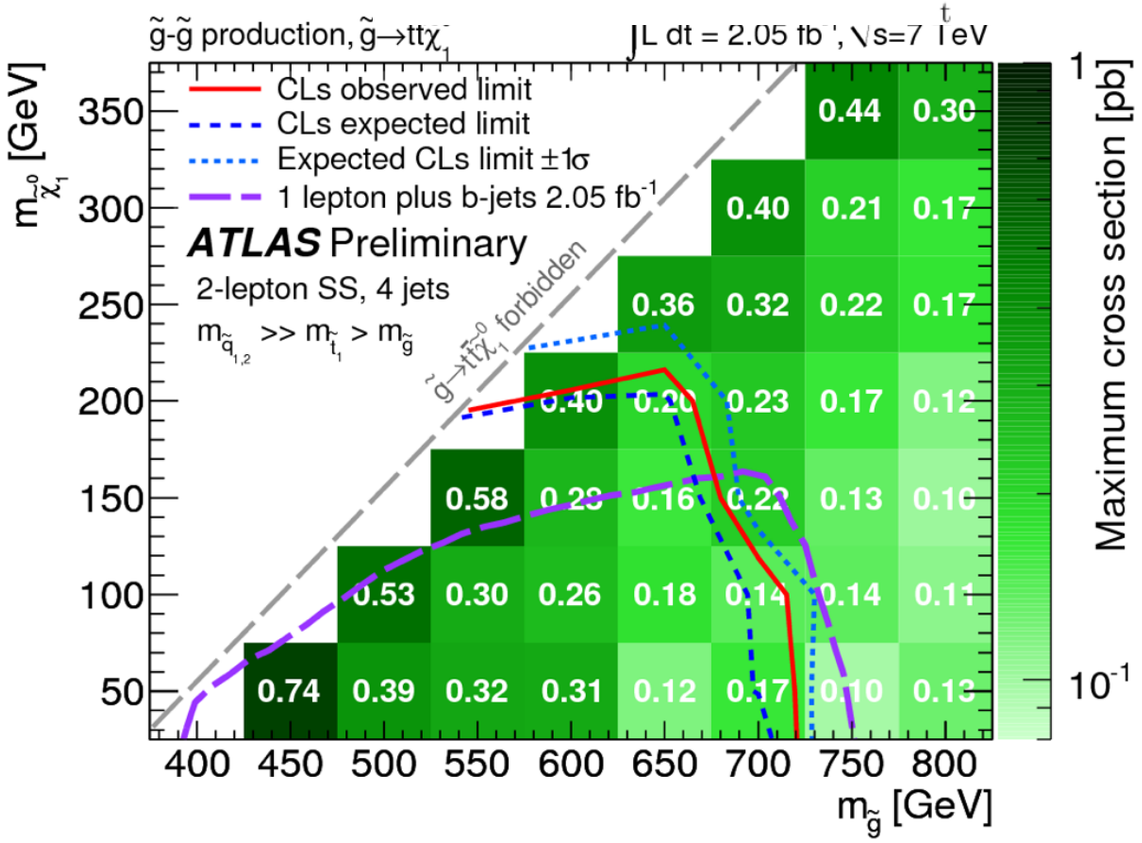


Exclude m(gluino)<900 GeV for m(sbottom) up to ~ 800 GeV

Signatures:

- ✓ 1-lepton + several b-jets + MET
- ✓ 2 same-sign leptons + several jets + MET





Exclude m(gluino)<700 GeV for m(stop) up to ~ 150 GeV

Searches for weakly produced SUSY

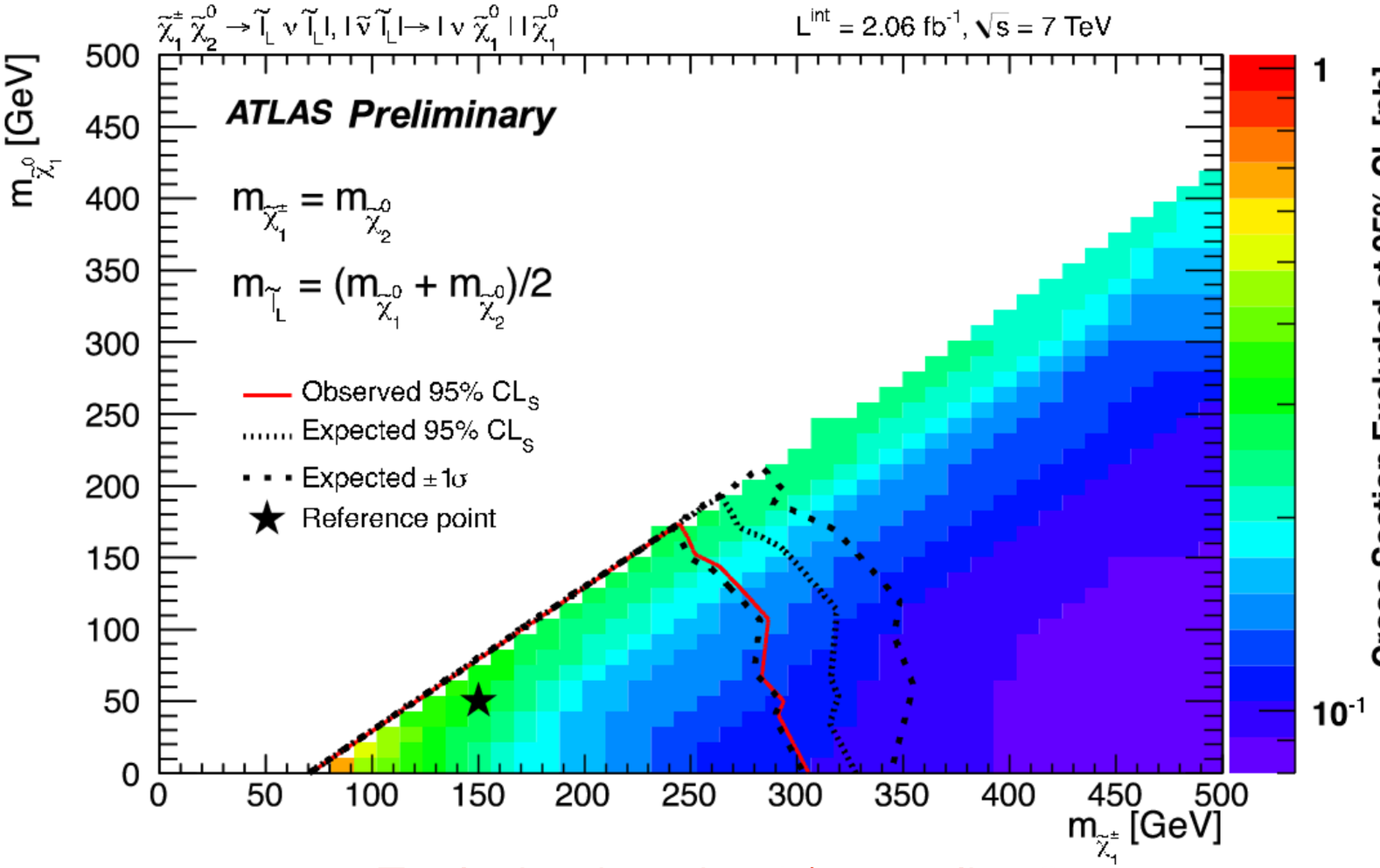
Signal scenario:
Weak production of charginos and neutrlinos. Assume decay proceeds via sleptons (=> leptons + MET signature).

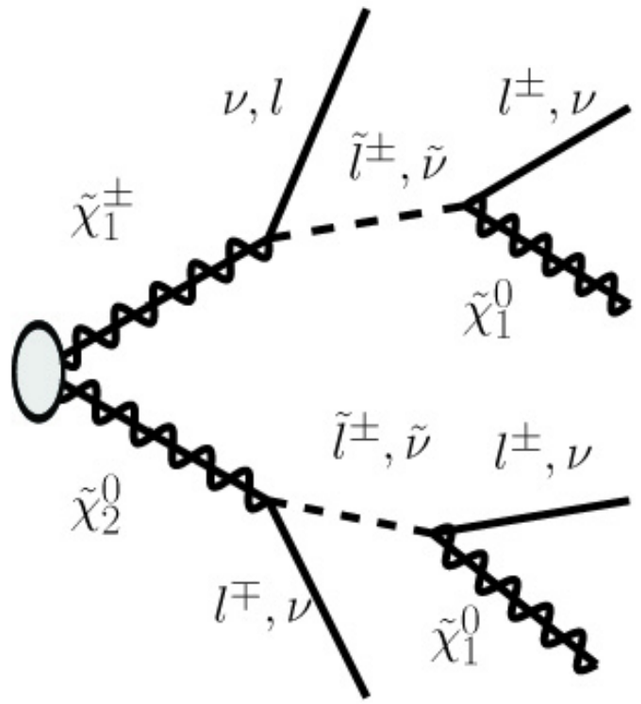
ATLAS-CONF-2012-001, ATLAS-CONF-2012-023, ATLAS-CONF-2012-004

Search signatures:

- ✓ ≥ 4 leptons (el/mu) + E_T^{miss} [+Z-veto]
- ✓ 3 leptons (el/mu) + E_T^{miss} [+Z-veto]
- ✓ 2 leptons (el/mu) + Jets + E_T^{miss}

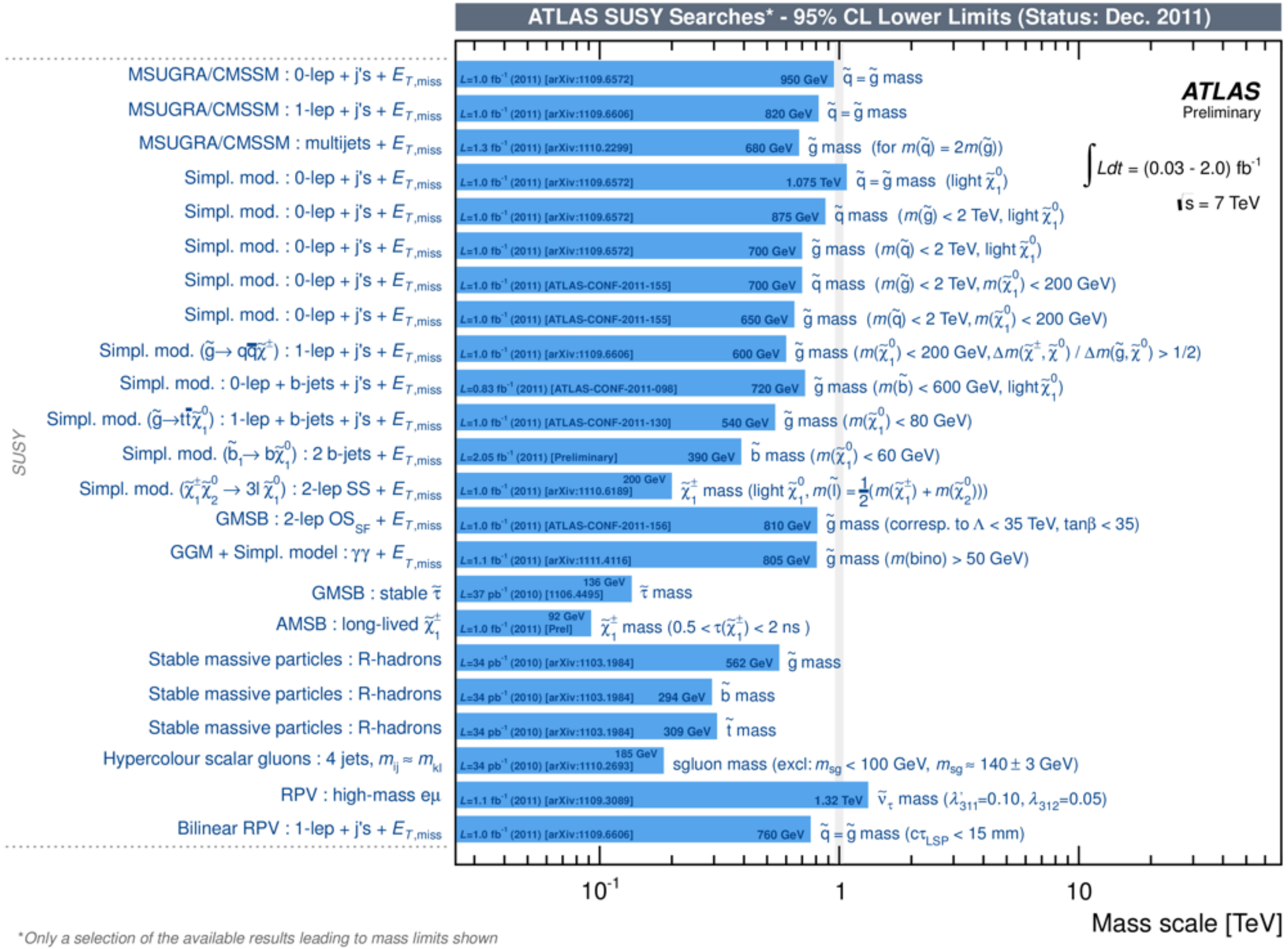
More dedicated gaugino/sleptons searches underway.





Exclude chargino1/neutralino2 masses up to ~250-300 GeV

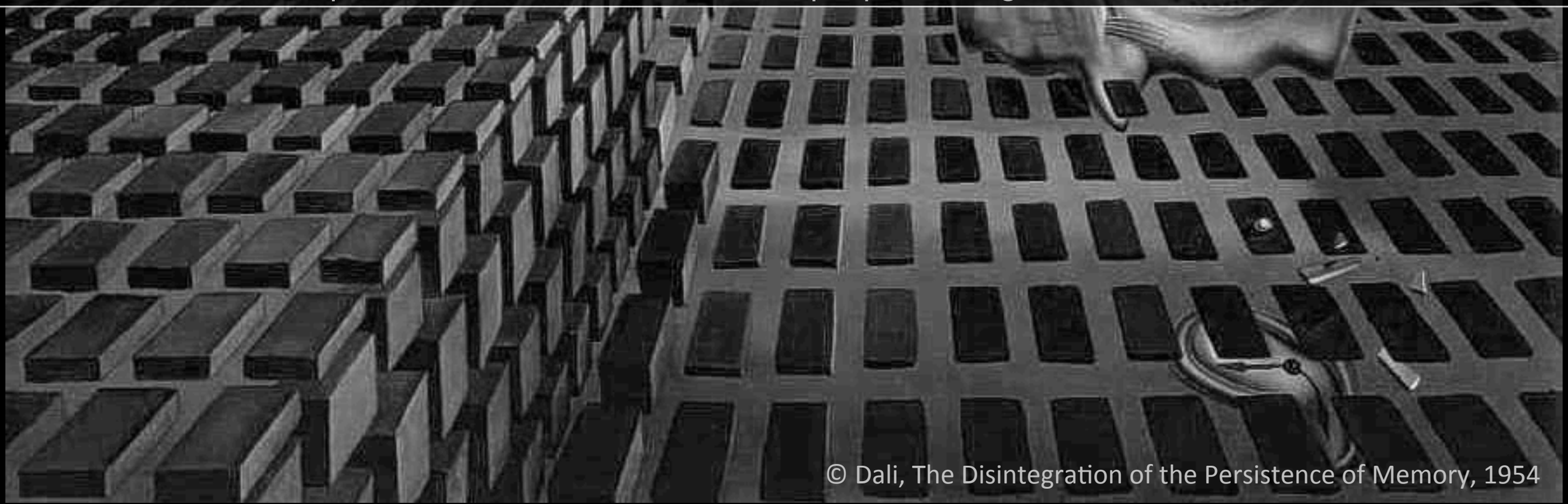
Mass limits approaching TeV-scale



*Only a selection of the available results leading to mass limits shown

Searches for Other BSM Phenomena

Excited quarks, contact interactions, Z'/W', Leptoquarks, 4th generation, extra dimensions, ...



© Dali, The Disintegration of the Persistence of Memory, 1954

ATLAS Exotics Search Results using 2011 Data

SUSY searches look at many final states that overlap with other BSM searches.

However, some final states not covered, for example:

- Monojets (Large extra dimensions)
- Resonances (ll, tt, γγ, jj)
- and more.

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

Papers with 2011 data

Title	Journal	Papers and Plots	Int. luminosity	Date
Search for a light Higgs boson decaying to long-lived weakly-interacting particles in proton-proton collisions at sqrt{s} = 7 TeV with the ATLAS detector NEW!	submitted to PRL	Plots and more Info;arXiv:1203.1303	1.94/fb	March 2012
Search for new particles decaying to ZZ using final states with leptons and jets with the ATLAS detector in sqrt(s) = 7 Tev proton-proton collisions NEW!	submitted to PLB	Plots and more Info;arXiv:1203.0718	1.02/fb	March 2012
Search for down-type fourth generation quarks with the ATLAS Detector in events with one lepton and high transverse momentum hadronically decaying W bosons in sqrt(s)=7 TeV pp collisions NEW!	submitted to PRL	Plots and more Info;arXiv:1202.6540	1.04/fb	February 2012
Search for same-sign top-quark production and fourth-generation down-type quarks in pp collisions at sqrt(s) = 7 TeV with the ATLAS detector NEW!	submitted to JHEP	Plots and more Info;arXiv:1202.5520	1.04/fb	February 2012
Search for pair-produced heavy quarks decaying to Wq in the two-lepton channel at sqrt(s) = 7 TeV with the ATLAS detector NEW!	submitted to PRD	Plots and more Info;arXiv:1202.3389	1.04/fb	February 2012
Search for Pair Production of a Heavy Quark Decaying to a W Boson and a b Quark in the Lepton+Jets Channel with the ATLAS Detector NEW!	submitted to PRL	Plots and more Info;arXiv:1202.3076	1.04/fb	February 2012
Search for excited leptons in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector	submitted to PRD	Plots and more Info;arXiv:1201.3293	2.05/fb	January 2012
Search for anomalous production of prompt like-sign muon pairs and constraints on physics beyond the Standard Model with the ATLAS detector	submitted to PRL	Plots and more Info;arXiv:1201.1091	1.6/fb	January 2012
Search for heavy vector-like quarks coupling to light quarks in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector	submitted to PLB	Plots and more Info;arXiv:1112.5755	1.04/fb	December 2011
Search for first generation scalar leptoquarks in pp collisions at sqrt(s)=7 TeV with the ATLAS detector	Published in PLB	Plots and more Info;arXiv:1112.4828;Phys. Lett. B709 (2012) pp 158-176	1.03/fb	December 2011
Search for contact interactions in dilepton events from pp collisions at sqrt(s)=7 TeV with the ATLAS detector	submitted to PLB	Plots and more Info;arXiv:1112.4462	1.08-1.21/fb	December 2011
Search for production of resonant states in the photon-jet mass distribution using pp collisions at sqrt(s) = 7 TeV collected by the ATLAS detector	submitted to PRL	Plots and more Info;arXiv:1112.3580	2.11/fb	December 2011
Search for Extra Dimensions using Diphoton events in 7 TeV proton-proton collisions with the ATLAS detector	Accepted by PLB	Plots and more Info;arXiv:1112.2194	2.12/fb	December 2011
Search for Strong Gravity Signatures in Same-sign Dimuon Final States using the ATLAS detector at the LHC	submitted to PLB	Plots and more Info;arXiv:1111.0080	1.3/fb	October 2011
Search for new phenomena in ttbar events with large missing transverse momentum in proton-proton collisions at √s= 7 TeV with the ATLAS detector	published in PRL	Plots and more Info;arXiv:1109.4725;Phys. Rev. Lett. 108, 041805 (2012)	1.0/fb	September 2011

Check webpage (see above) for complete list (!)

Monojet Search

ATLAS-CONF-2011-096

- Signature: 1-jet + E_T^{miss}
  (veto leptons, veto additional jets)

- Main background:

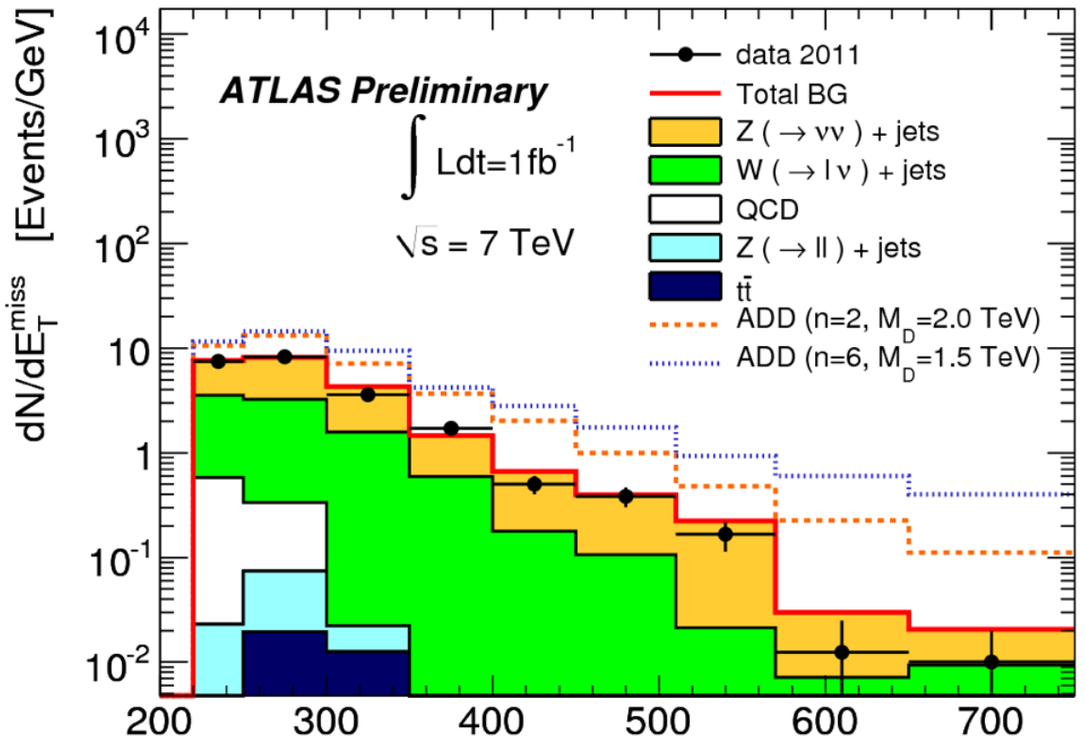
  - Znunu + jets: estimated with MC normalized to data in control region with identified leptons

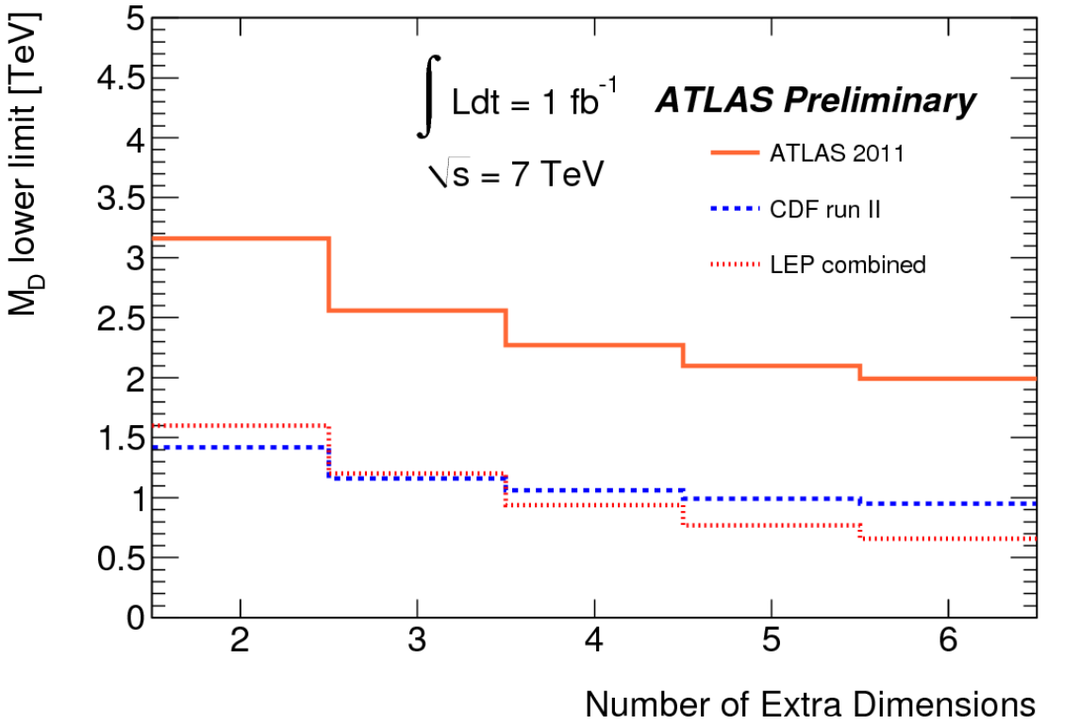
- LED (ADD):
  → Graviton escapes detector

- Split SUSY

- Model independent: pair production of WIMP DM particles + one ISR jet

ADD LED, exclude:
M_D between 3.2-2.0 TeV
for n from 2–6



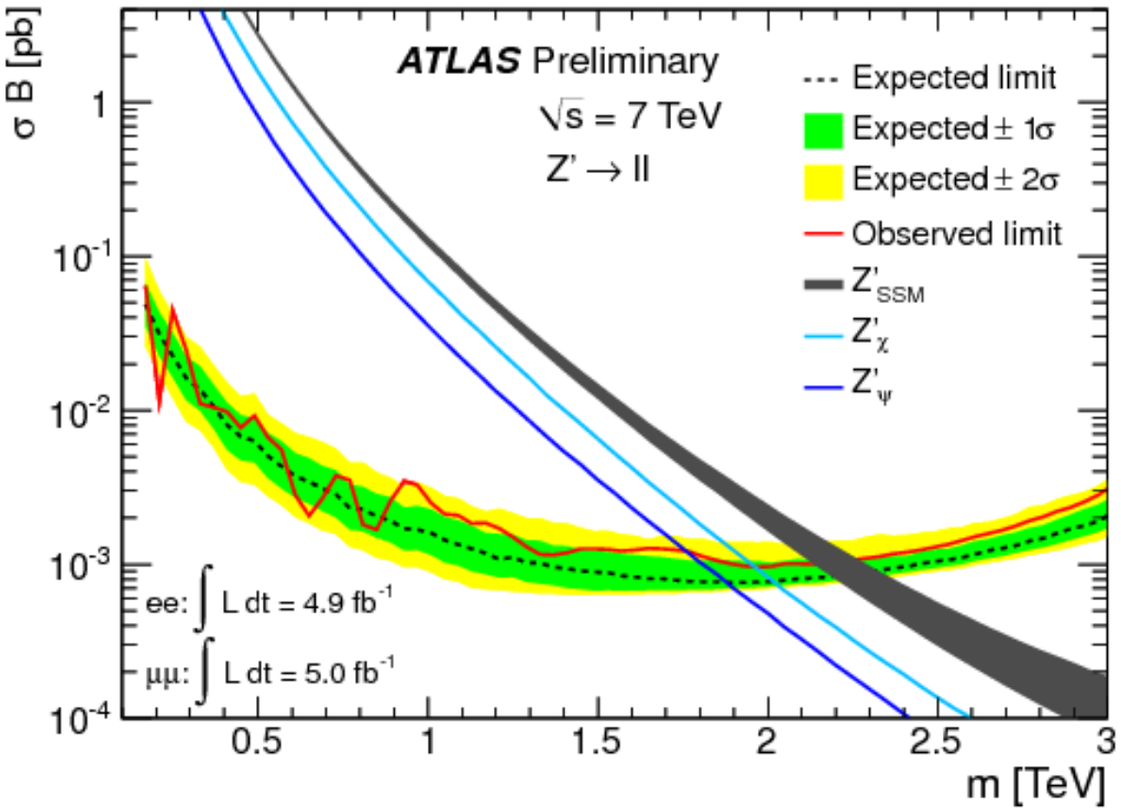


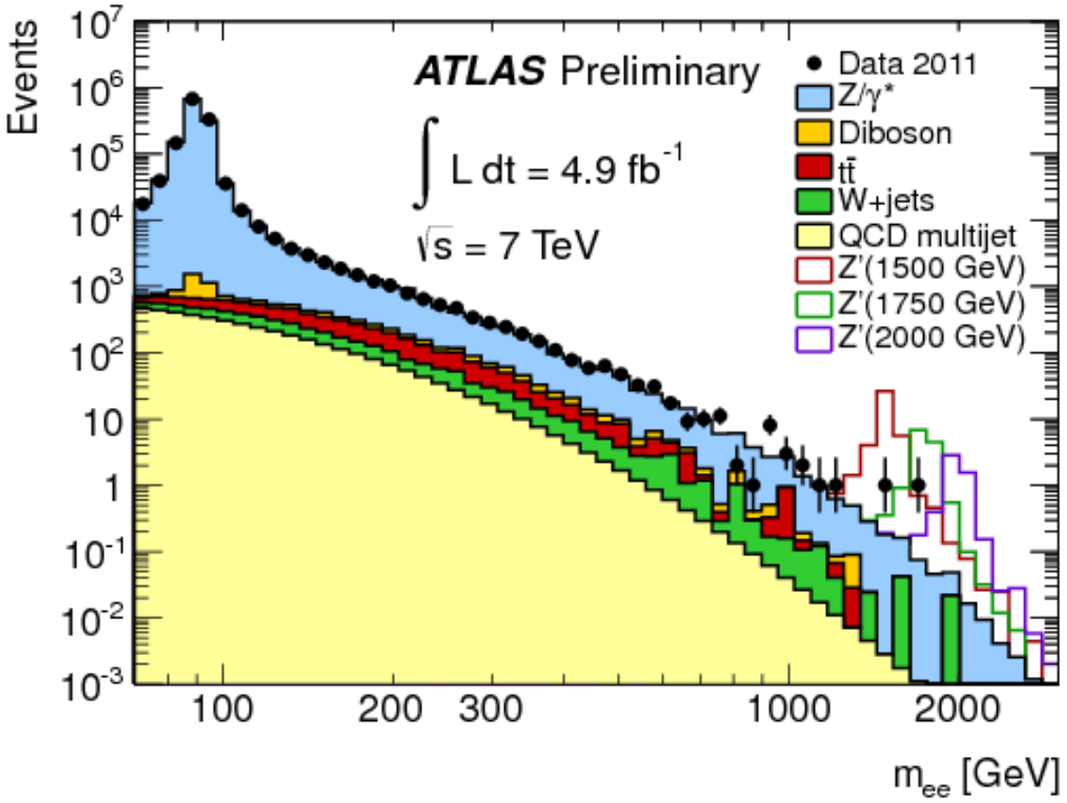
ATLAS-CONF-2012-007

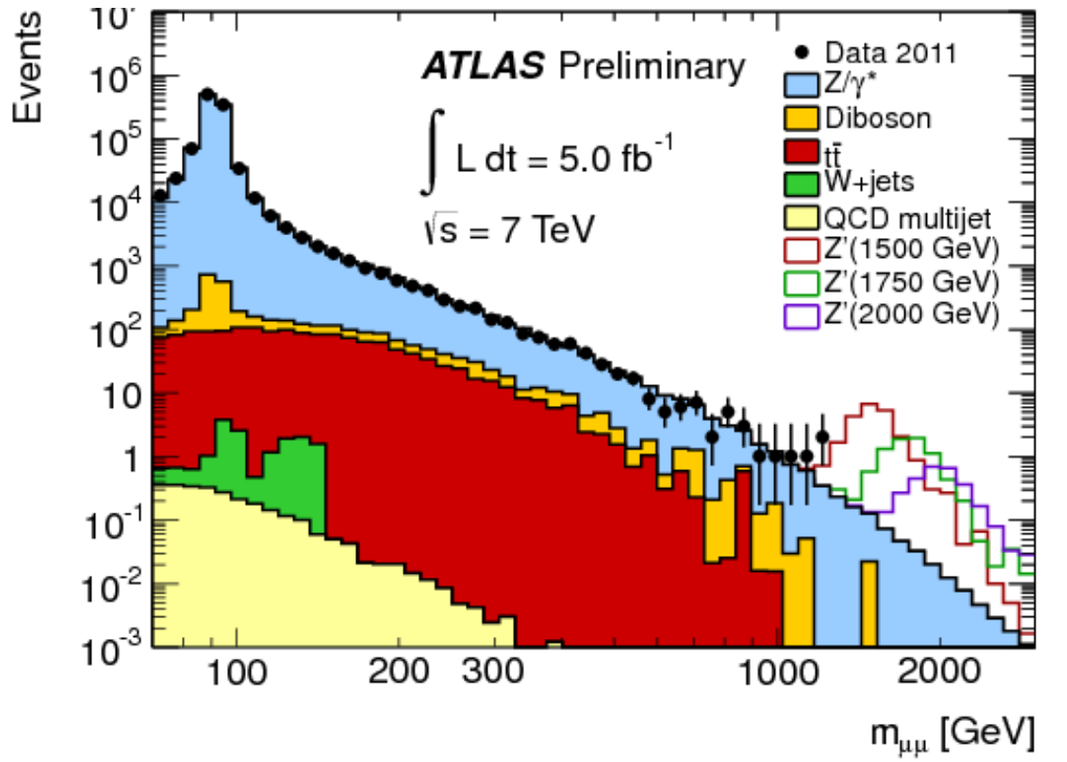
Dilepton Resonances (Z')

- Very clean signatures:
  2 isolated high pT ee or μμ
- Dominant background: Z/γ → ll
- Consistent with background only

$M_{Z'} > 2.2$ TeV







Lepton-Neutrino Resonances (W')

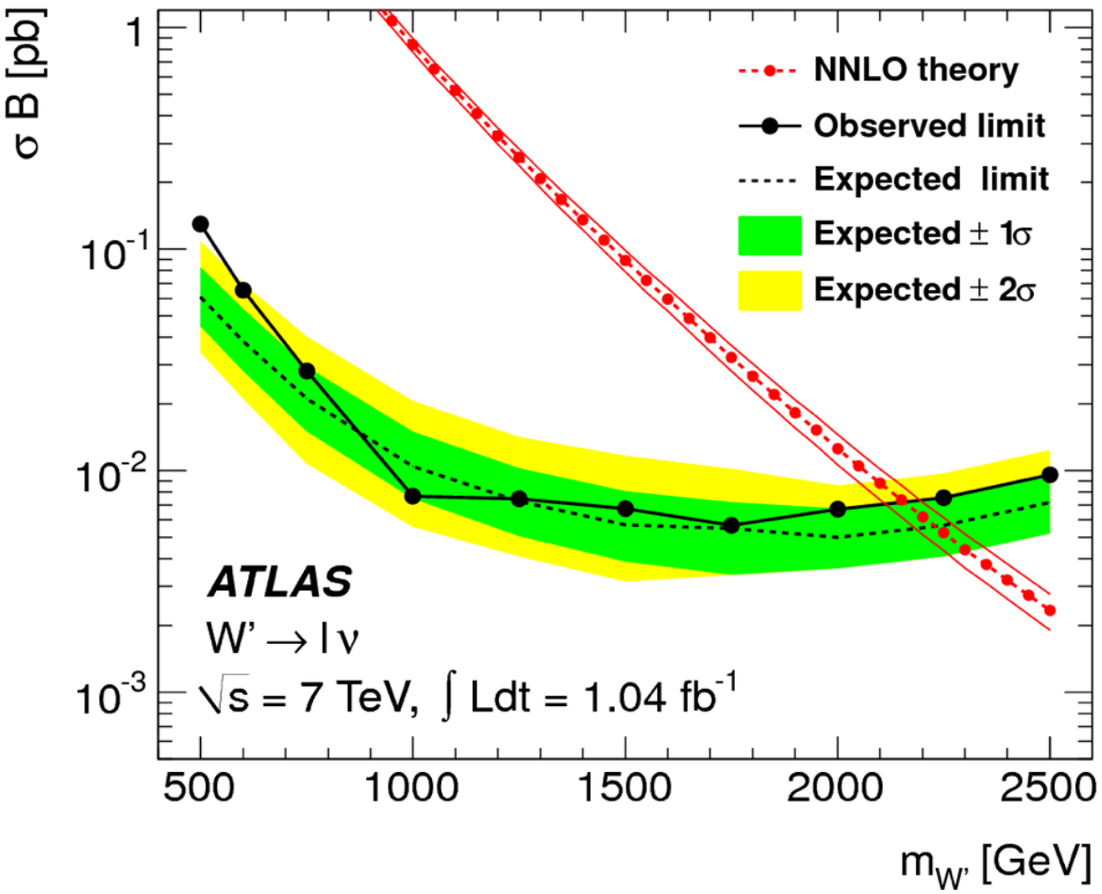
Phys.Lett.B 705 (2011) 28-46

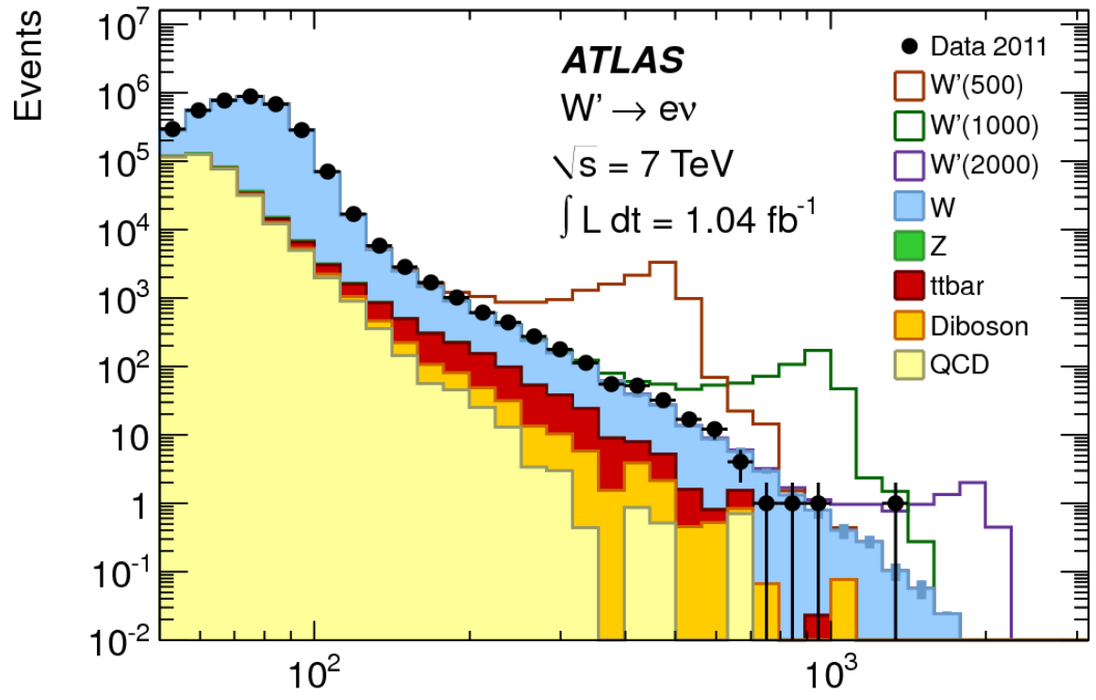
- Main backgrounds:
  SM W, QCD (estimated from data)

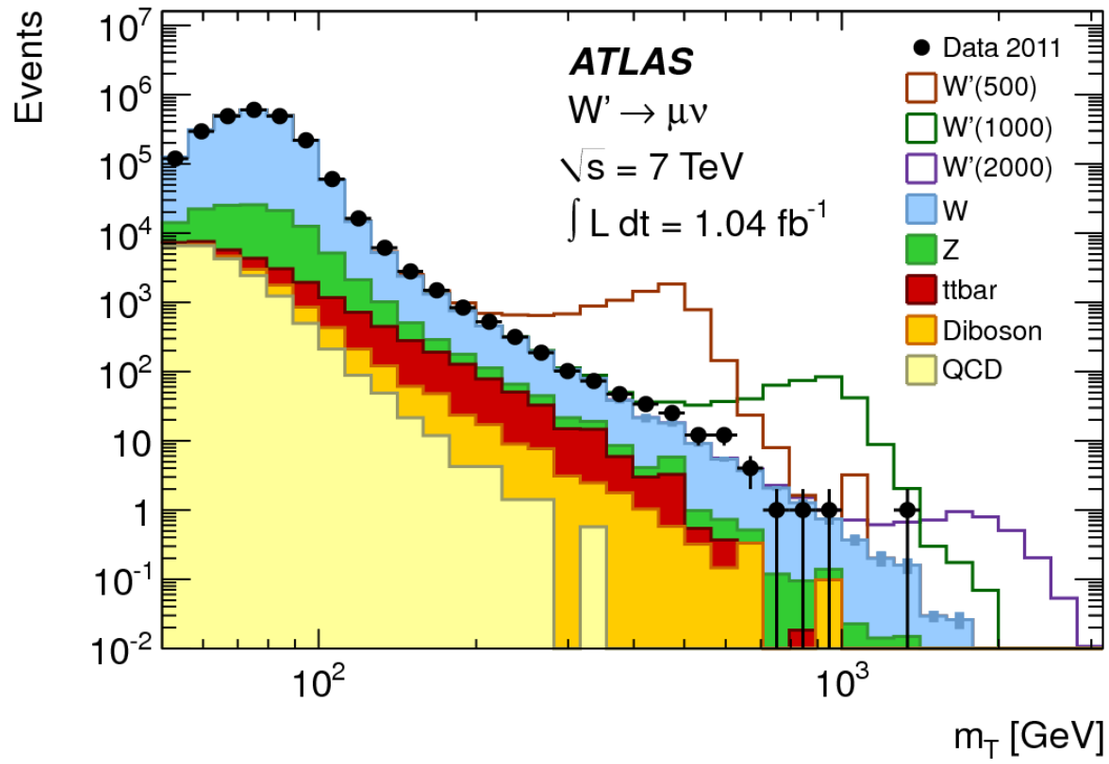
- Reconstruct transverse mass:

$$m_T = \sqrt{2 p_T \not{E}_T (1 - cos\Delta\phi_{\ell,\not{E}_T})}$$

$M_{W'} > 2.15$ TeV



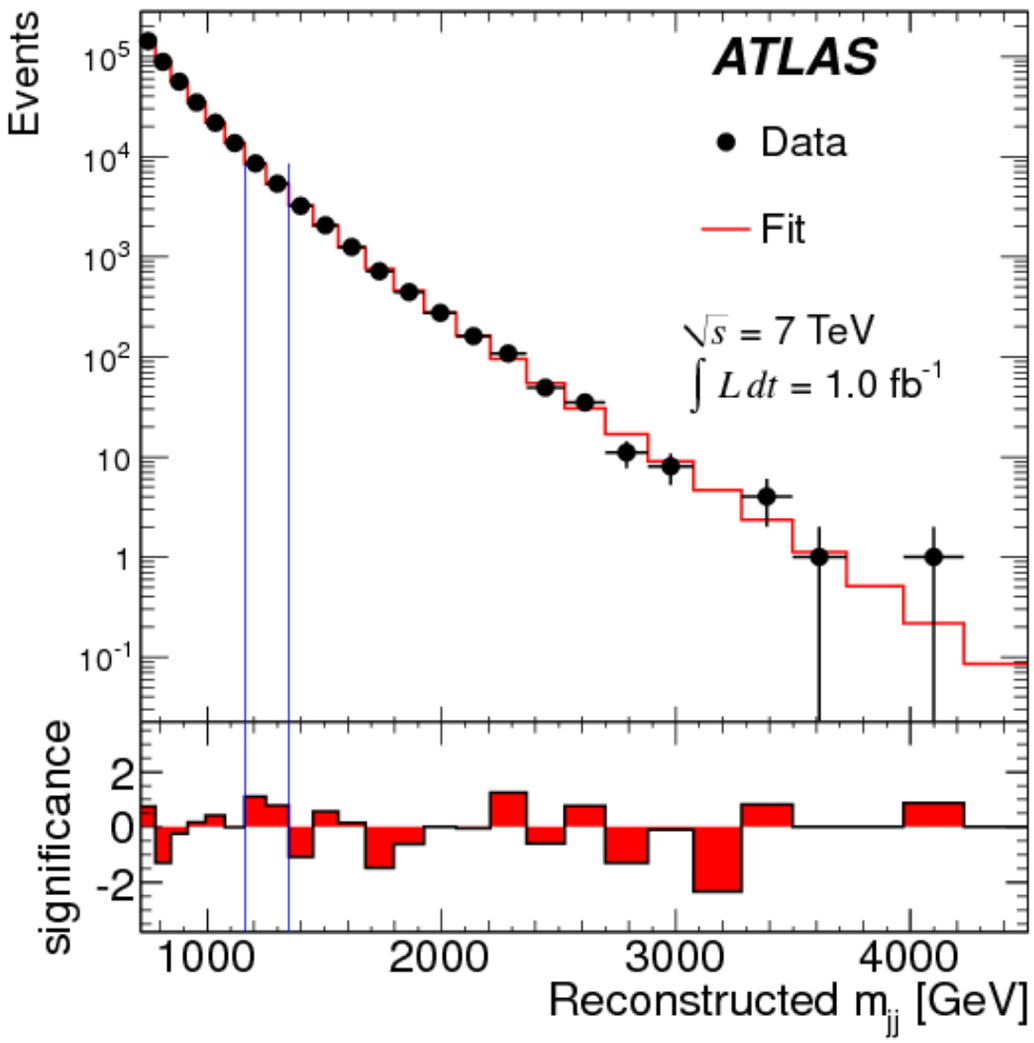




Dijet Resonances as Probes of NP

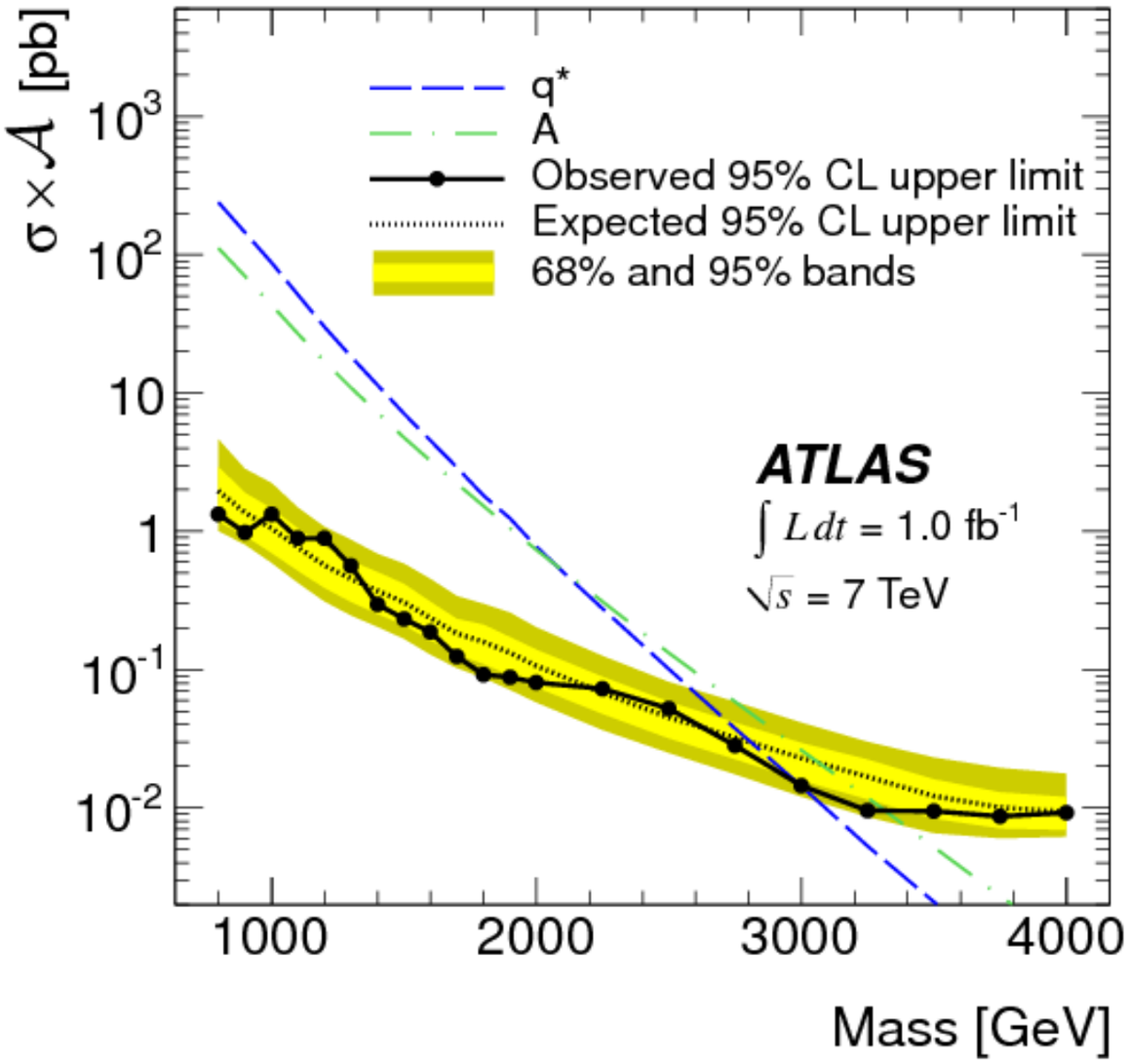
Phys.Lett.B 708 (2012) 37-54

Fit m_{jj} spectrum, data well described by smooth fit function



Limits set on models:

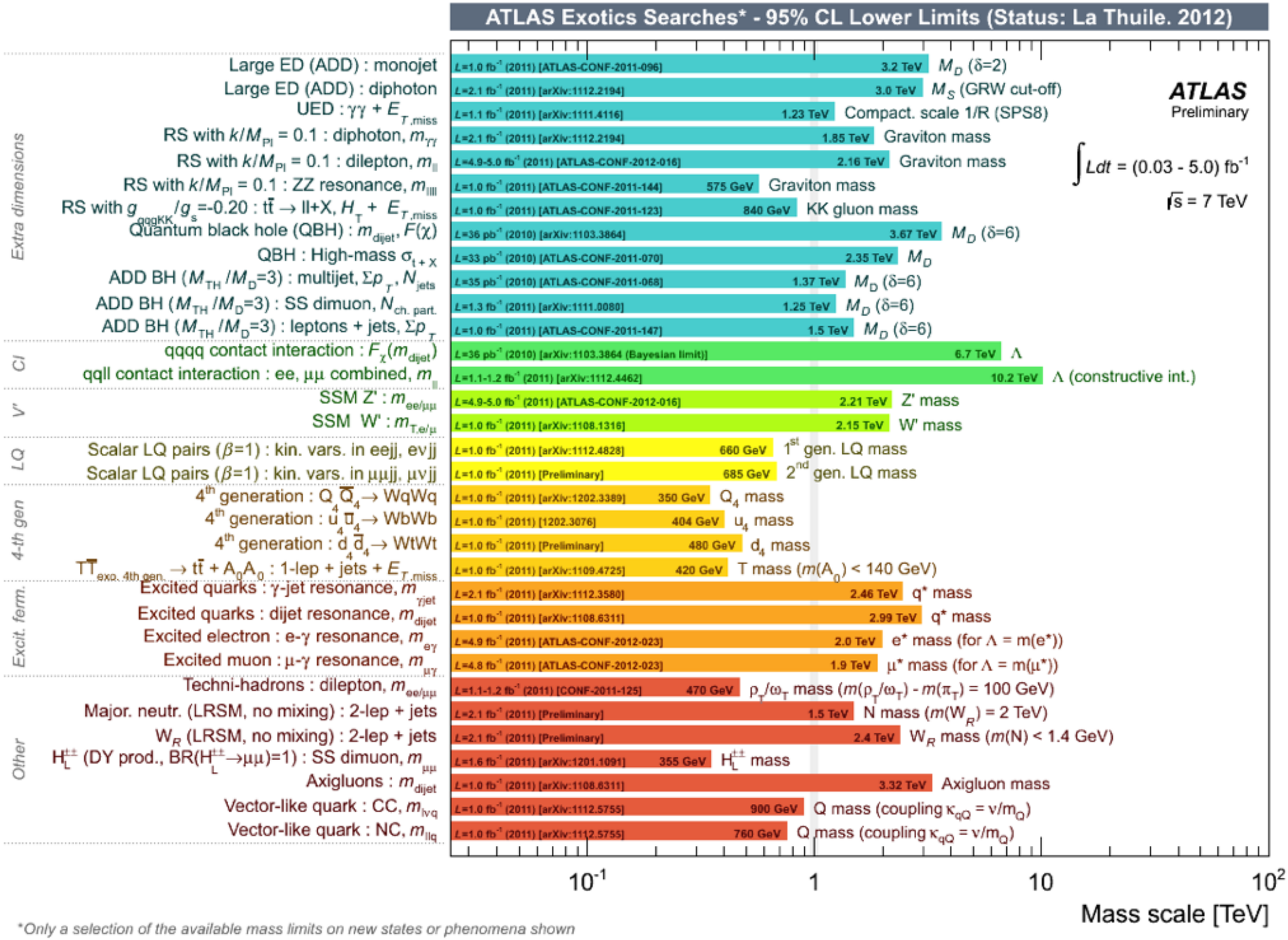
q*, axigluon , color octet scalar



Dijet masses up to ~4 TeV are observed in the data, and no evidence of resonance production over background is found.

Excited quarks (q*) are excluded for masses ≲ 3 TeV

ATLAS searches for new phenomena other than SUSY



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

Expected LHC Operation

2012

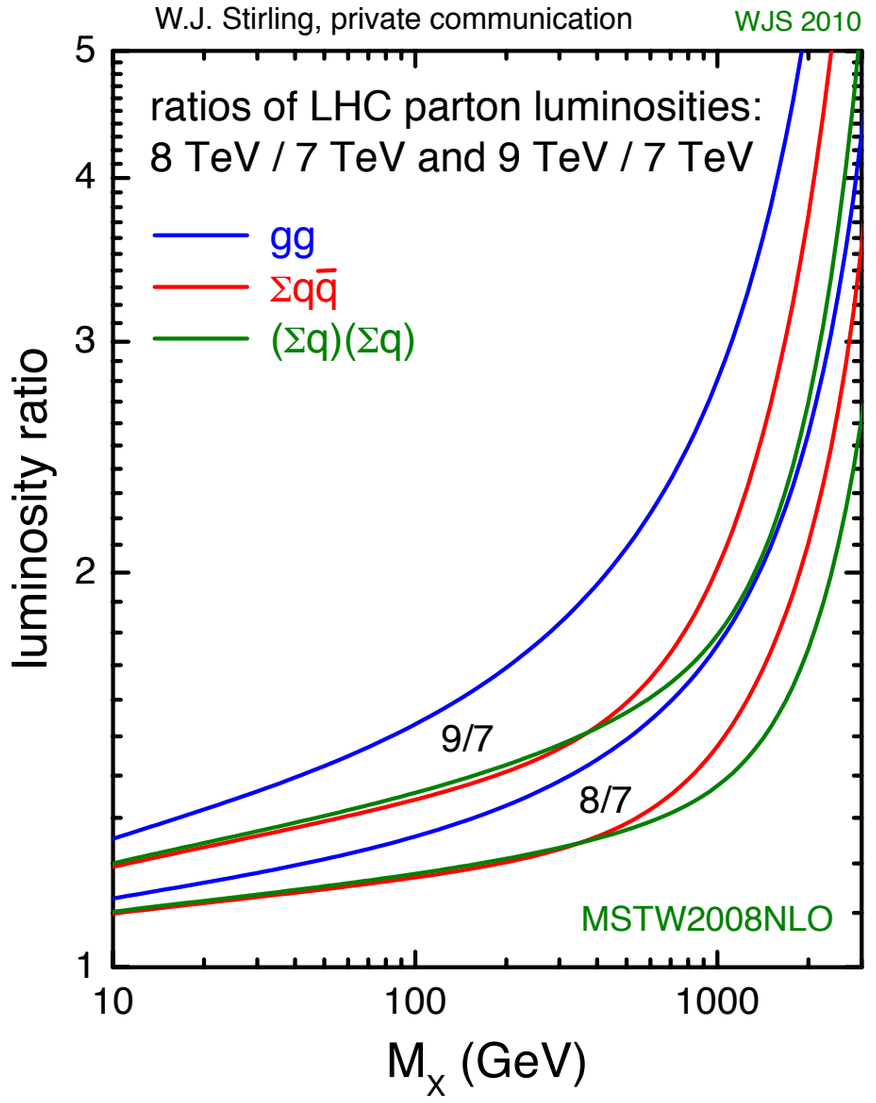
- Beam energy: 4 TeV ($\sqrt{s}$ = 8 TeV)
- luminosity goal: O(20 fb^{-1})
- Peak luminosity: up to $6x10^{33}$
- Pileup <mu> ~ 35 (!)

2013/2014

- long shutdown (~ 20 month)
- upgrade the LHC machine to reach (almost) the design collision energy and higher luminosity.

2015-2017

- Beam energy: ~6.5 TeV
- Peak luminosity: ~ $1x10^{34}$
- Pileup <mu> (?)



7->8 TeV energy increase will effectively increase gain for M_X = 2 TeV by a factor 2-3

Summary

ATLAS is mining its data for the expected and the unexpected

- summer 2011 dataset ~fully analyzed
- first full 2011 data results being published

Searches for Supersymmetry

- wide and complementary search coverage of SUSY signatures
- generic strong production (gluinos, squarks): mass limits at the TeV-scale
- 3rd generation squarks: sbottom mass > ~400 GeV, stop searches underway
- weakly produced SUSY particles (charginos, neutralinos, sleptons): first limits up to 300 GeV, dedicated searches on-going

Searches for Other New Phenomena

- large search effort to cover all possible signatures
- Exclusion reach between ~300 GeV and 10 TeV obtained
  - First full 2011 data results: $M_{Z'}$>2.2 TeV

No new physics yet, expect

- ~3-4 times more data in 2012,
- with 8 TeV collision energy (factor ~2 gain for M_X ~ TeV searches)
- challenging for triggering, and pileup

Backup

Brief SUSY Reminder

Standard Model (SM) of particle physics remarkably successful (!)

Why new physics then ?

- Gauge hierarchy problem (fine tuning of Higgs mass)
- Grand unification of forces
- Dark Matter

Supersymmetry (SUSY) adds a new fundamental **boson fermion symmetry**

✓ This solves the **Higgs fine tuning** problem of the SM

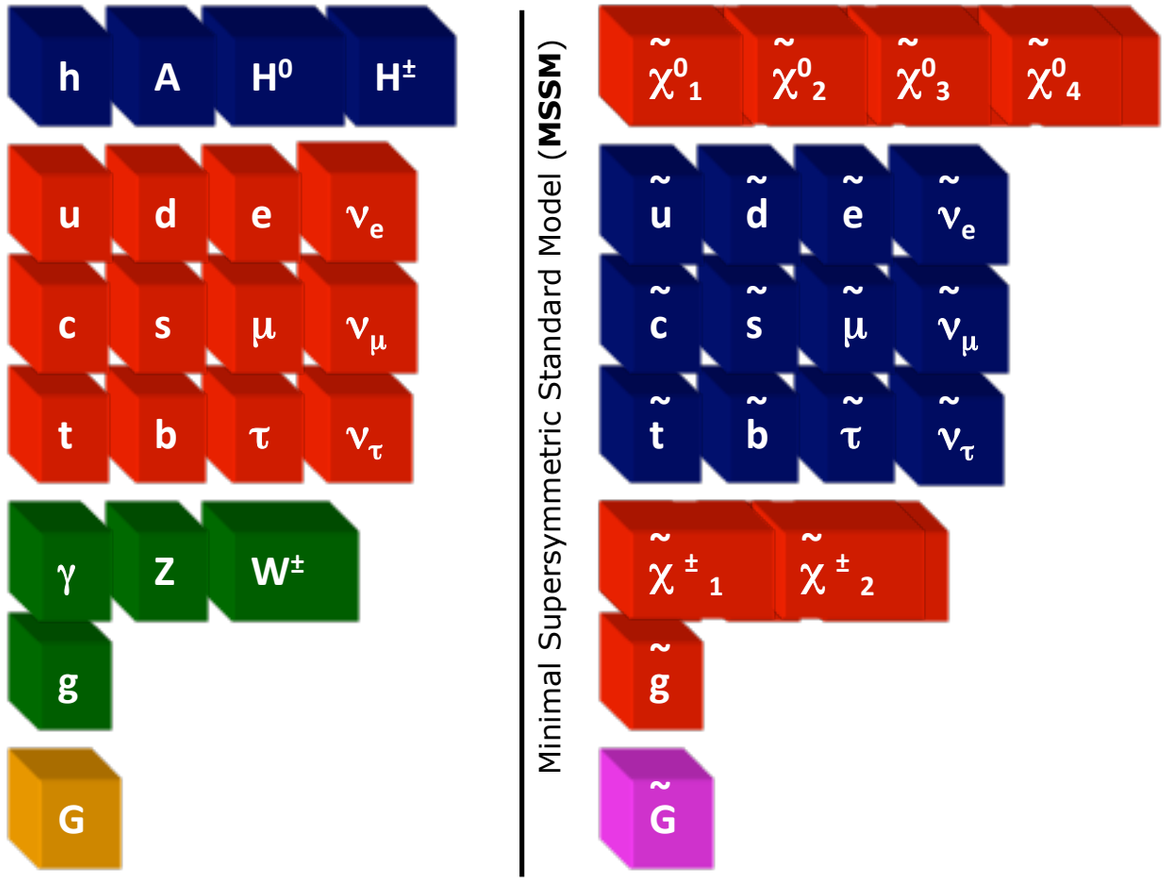
✓ Can **unify gauge couplings** at GUT scale

✓ can provide suitable **Dark Matter** candidate

SUSY mass scale should not exceed a few TeV

Minimal Supersymmetric Standard Model (MSSM) particle content

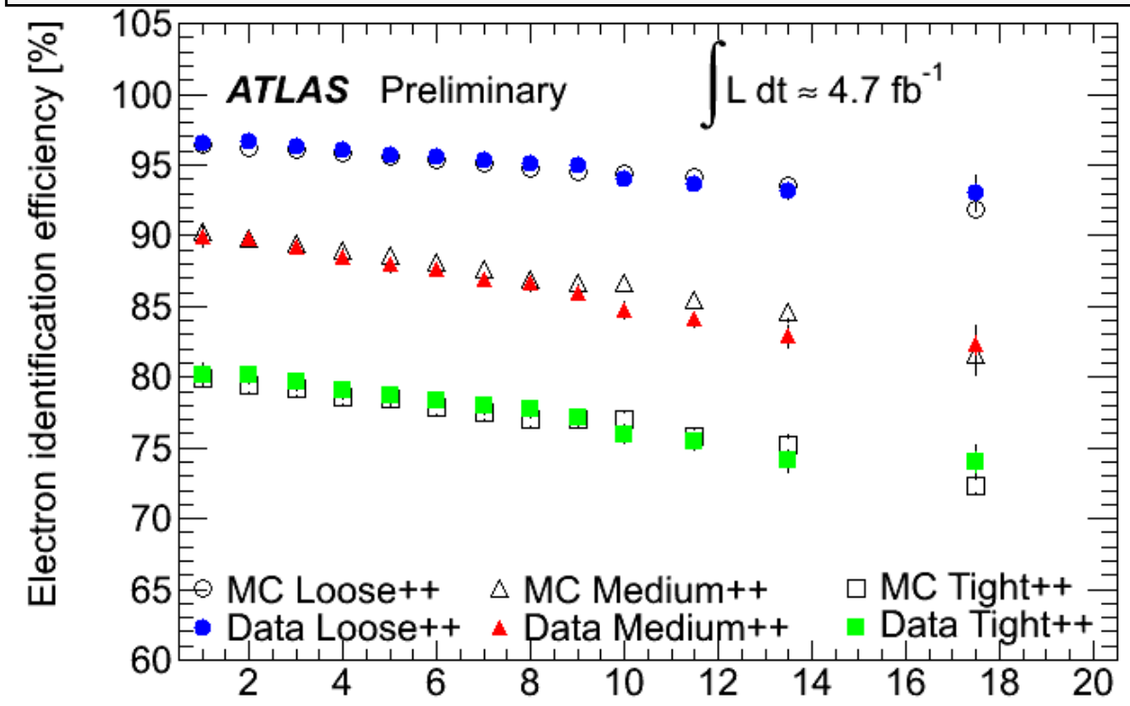
- SUSY particles with "~" on top
- blue: spin-0
- red: spin-1/2
- green: spin-1
- yellow: spin-2, pink: spin-3/2
- Higgs sector expanded
- all scalar particles with same e-charge, R-parity and colour quantum number can mix



A few examples of pileup effects in ATLAS

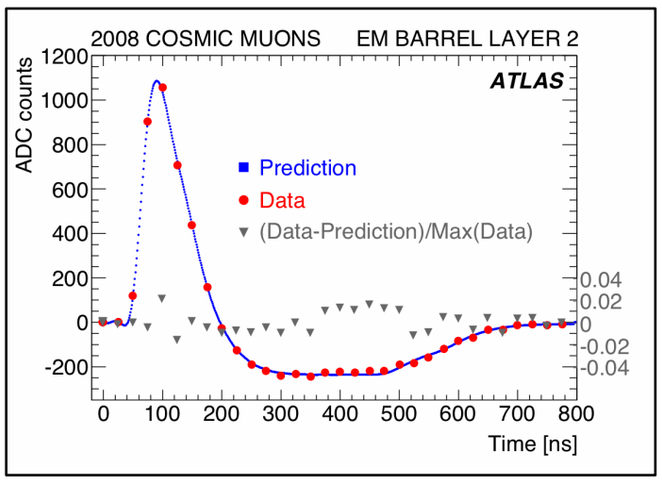
- Significant impact of pileup on electron ID
- Will re-tune cuts for 2012

Simulation doing good job modeling these effects



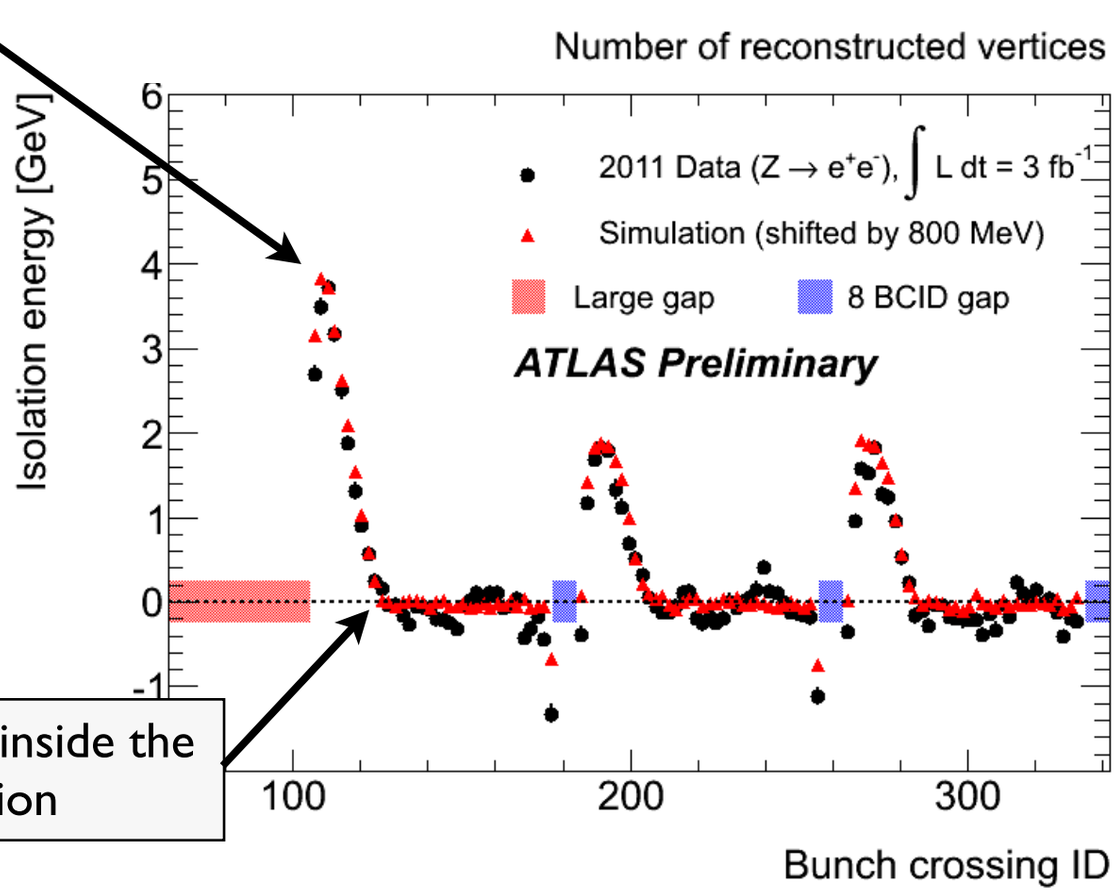
Effects will increase 2012 due to higher mu!

- Calorimeter isolation versus out-of-time pile-up



Beginning of the train: no cancellation from previous bunches

Calorimeter bipolar pulse shape: average pile-up is zero over ~ 600 ns (12 bunches).
Well described by MC (!)



From 12 bunches inside the train: full cancellation

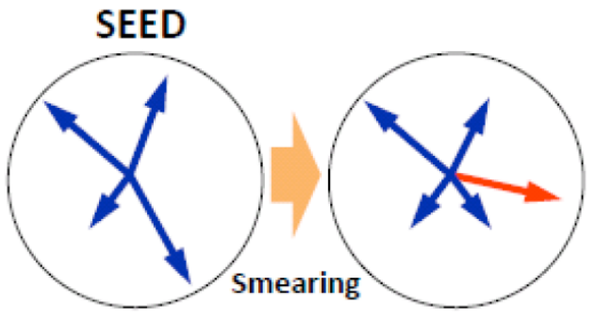
QCD Estimate in all hadronic SUSY Search

Fully data-driven method to estimate QCD multijet background

1. Determine the jet response function R from dijet balance and 3-jets mercedes events.

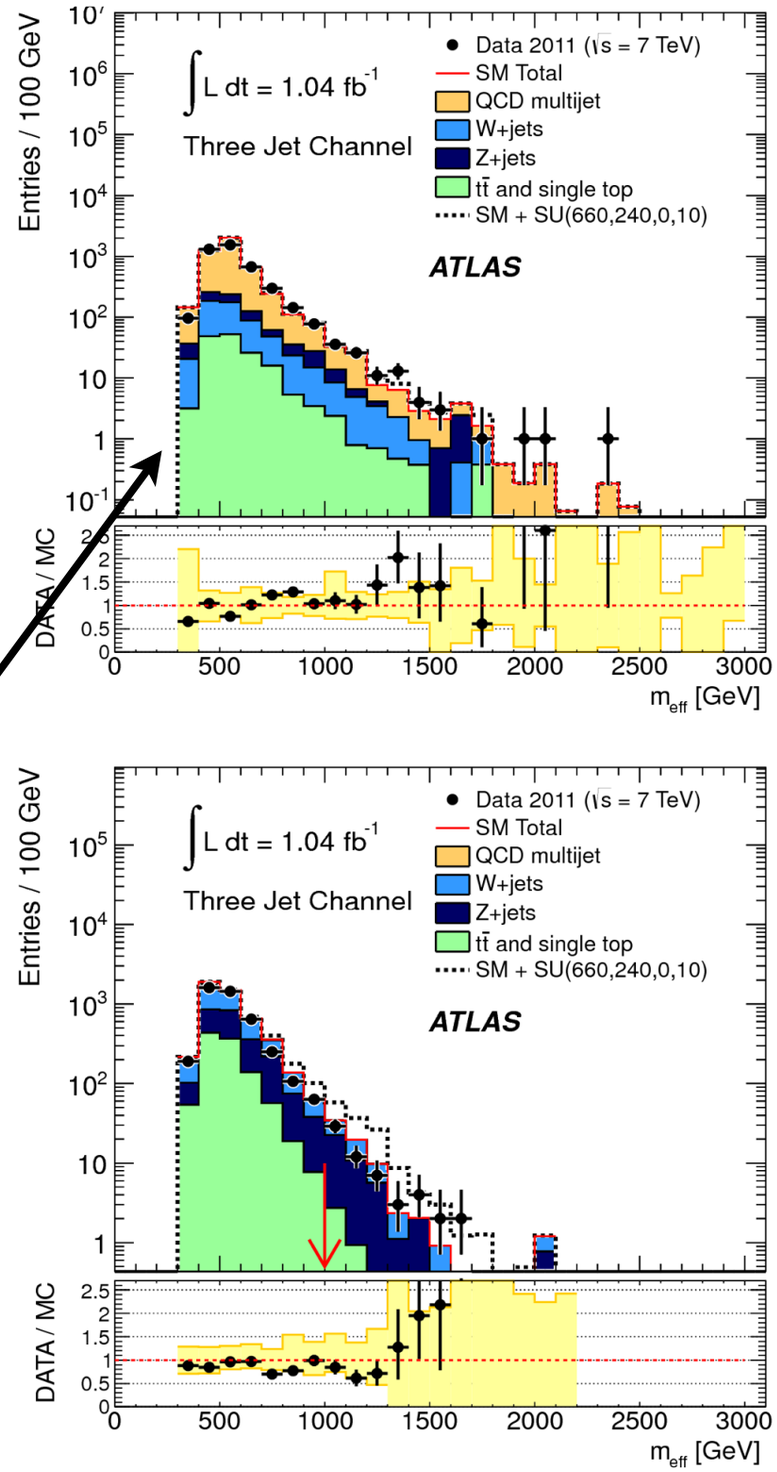
2. Take a control sample of multijets with small MET.

3. Smear each jet by its response R.



4. Normalize the shape obtained in a QCD enhanced region with low $\Delta\phi(\text{jet}, E_T^{\text{miss}}) < 0.4$

5. Propagate to signal region



Latest public SUSY E_T^{miss} search results

for various SUSY scenarios

Rel.16, (1-2) fb^{-1} results

lepton denotes isolated electron or muon

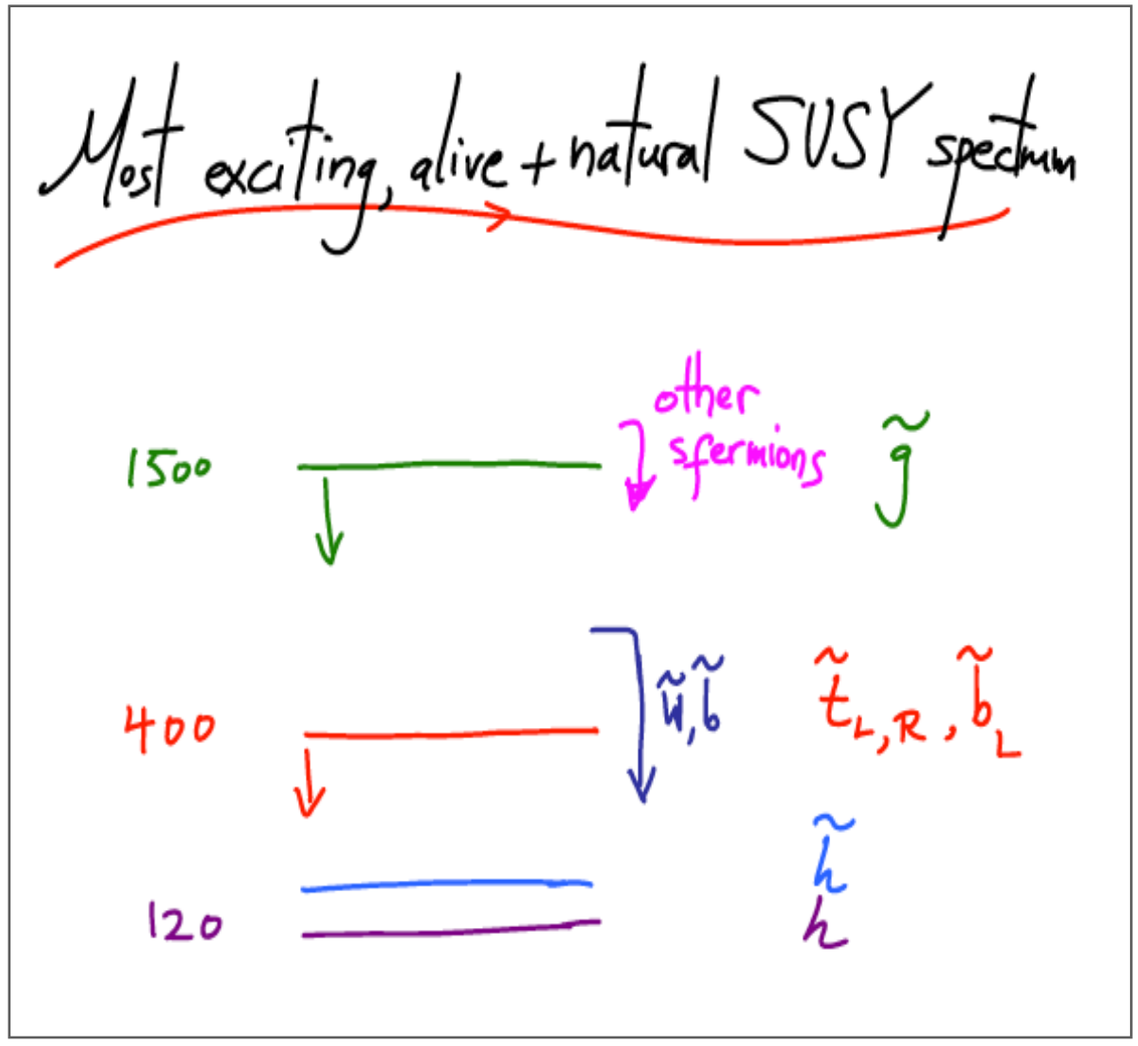
channel	search target	lumi	status
0 leptons + E_T^{miss} + ≥ 2-4 jets	heavy colored objects, decaying semi-invisibly w/ large mass splitting	1 fb^{-1}	Accepted by PLB (ArXiV:1109.6572) + ATLAS-CONF-2011-155
0 leptons + $E_T^{miss}/\sqrt{HT}$ + ≥6-8 jets	Long decay chains	1.3 fb^{-1}	JHEP 11 (2011) 99
1 lepton + E_T^{miss} + ≥ 3,4 jets	cascade decays with intermediate charginos/sleptons	1 fb^{-1}	PRD 85 (2012) 012006
2 leptons (SS/OS) + E_T^{miss}	intermediate charginos/sleptons; direct gaugino production	1 fb^{-1}	PLB 709 (2012) 137 + ATLAS-CONF-2011-156
multileptons (>=4) + E_T^{miss}	direct gaugino production	2 fb^{-1}	ATLAS-CONF-2012-001
0 (1) leptons + b-jets + E_T^{miss}	gluino mediated 3rd gen. (sbottom, stop)	0.8(1)fb^{-1}	ATLAS-CONF-2011-098, ATLAS-CONF-2011-130,
0 leptons + ETmiss + 2 bjets	direct sbottom production	2 fb^{-1}	Accepted by PRL (ArXiv:1112.3832)
2 γ + E_T^{miss}	GMSB with neutralino NLSP	1 fb^{-1}	Accepted by PLB (ArXiv:1111.4116)

incomplete list: RPV, long-lived, and exotics searches not shown.

SUSY Searches for 3rd gen. Squarks

3rd generation

- Main motivation for TeV-scale SUSY is solving hierarchy problem
- If SUSY solves the hierarchy problem naturally, then 3rd gen. squarks must be light



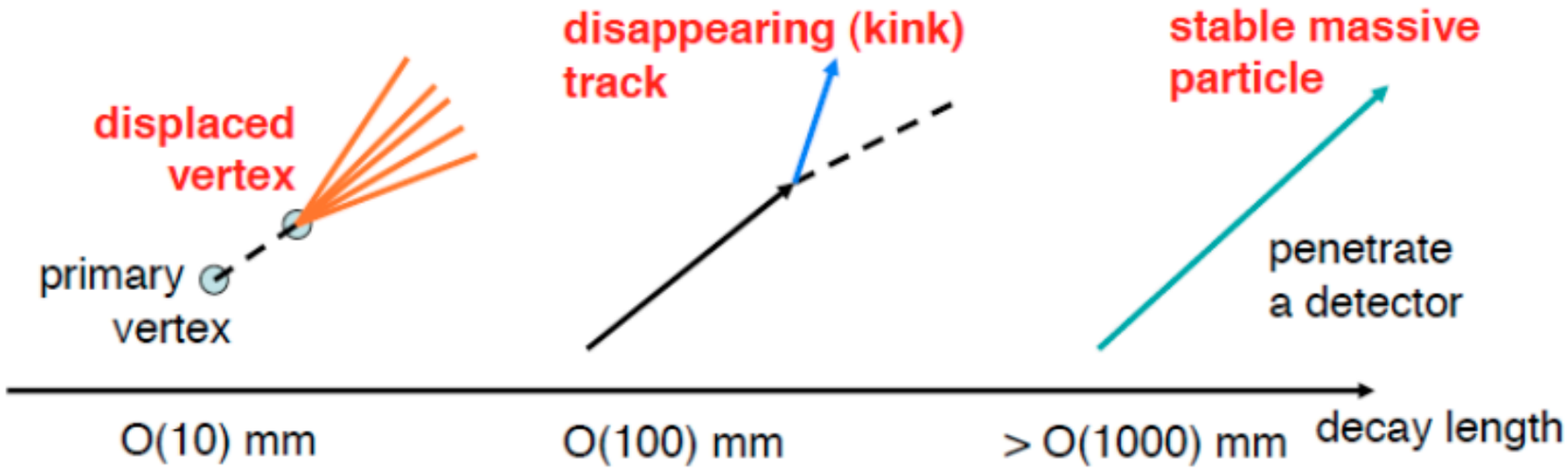
Taken from Nima Arkani-Hamed

Possible search strategies:

- If gluino is light enough => dominant process
  - gluino pair production
  - glu -> b+sbottom, glu -> t+stop
  - search for b-jets + ETmiss + jets
- If not and only 3rd gen. squarks are light
  - sbottom pair production => 2 b-jets + MET
  - stop pair production => several decay chains depending on mass hierarchy

More "exotic" final states ...

strong production, but with long-lived SUSY particles (RPV, GMSB, AMSB models)



Long-lived particles occur naturally in some models:

- very small mass splitting (AMSB)
- very small coupling (GMSB)
- 3-body decay via very heavy particle (split SUSY)
- RPV coupling $10^{-(5\text{-}7)}$ => long-lived LSP

What's next ?

Given that no new physics signal has been found yet.

- **2012**
  - Much more LHC data, and slight increase in collision energy
  - Maximize search coverage using:
    - dedicated analyses to target challenging signatures (thus more exclusive searches)
    - improve analysis techniques (inclusive & exclusive searches)
- **2014+**
  - LHC increase to design collision energy $\sqrt{s}$ ~ 14 TeV
  - opens sensitivity to discover new heavy particles
    - reach up to ~2.5 TeV squarks/gluinos with 100 fb^{-1}
  - Will repeat all searches, in particular inclusive channels