UNIVERSITÄT BERN

AEC
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FOR FUNDAMENTAL PHYSICS

Search for SUSY in events with resonances or long-lived particles in ATLAS

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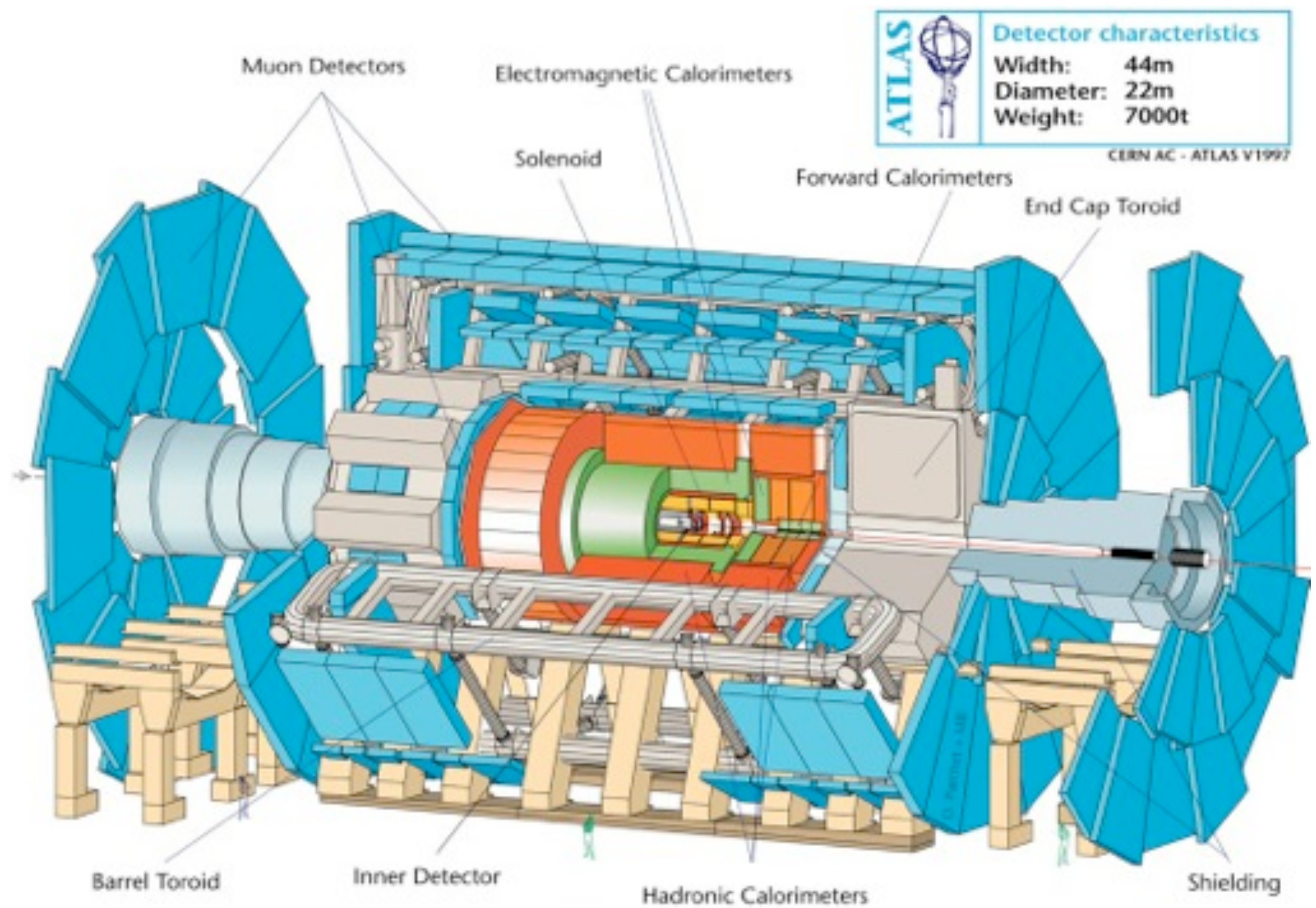
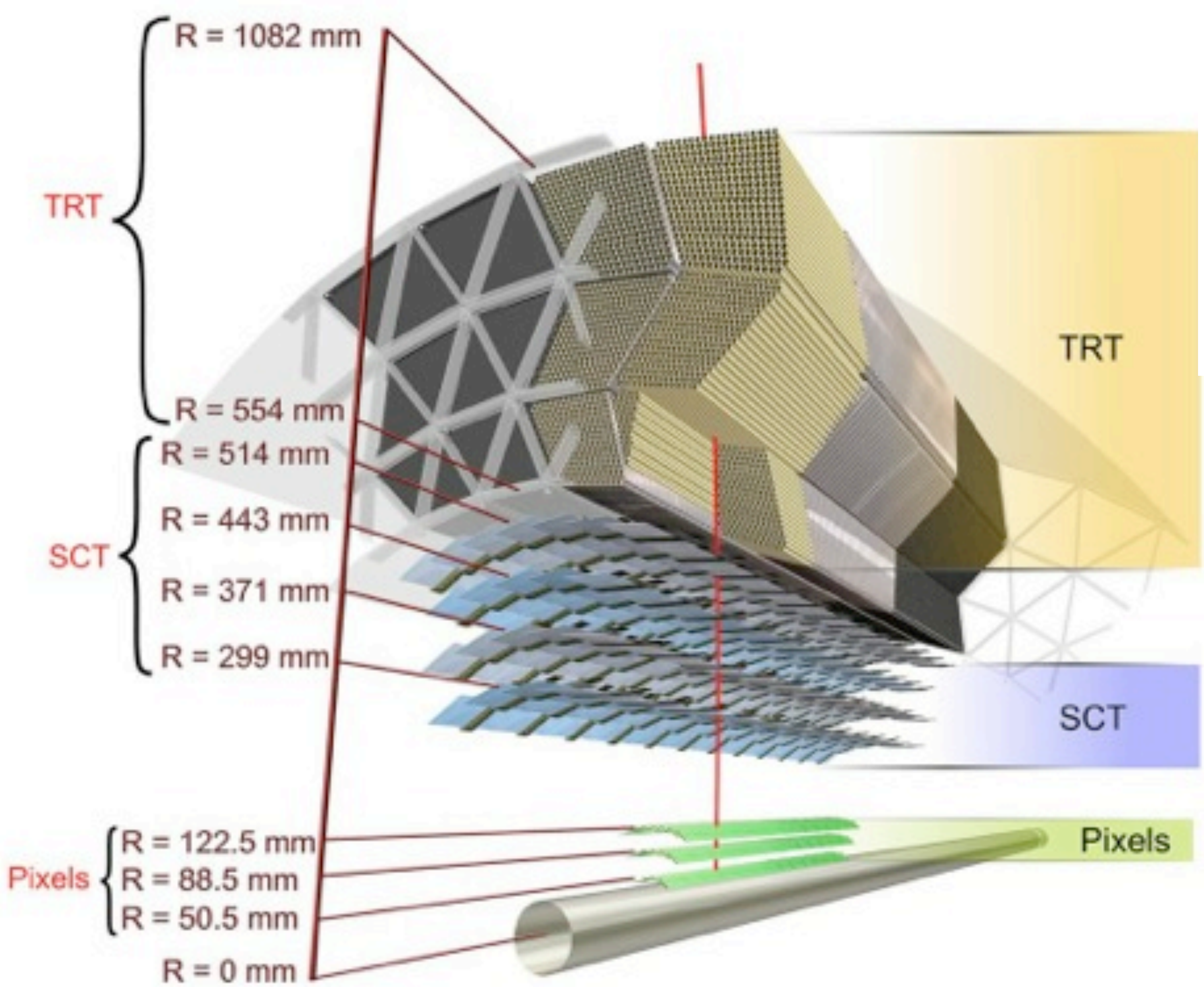
on behalf of the ATLAS collaboration

2012 LHC Days in Split

The ATLAS detector

- Many SUSY models have long lived particles and resonances
- ATLAS well suited for their detections via: disappearing tracks, displaced vertices, ionizing heavy particles





- Reporting on SUSY searches of long lived particles and resonances in up to 4.7fb^{-1} collected at $\sqrt{s}$=7TeV.

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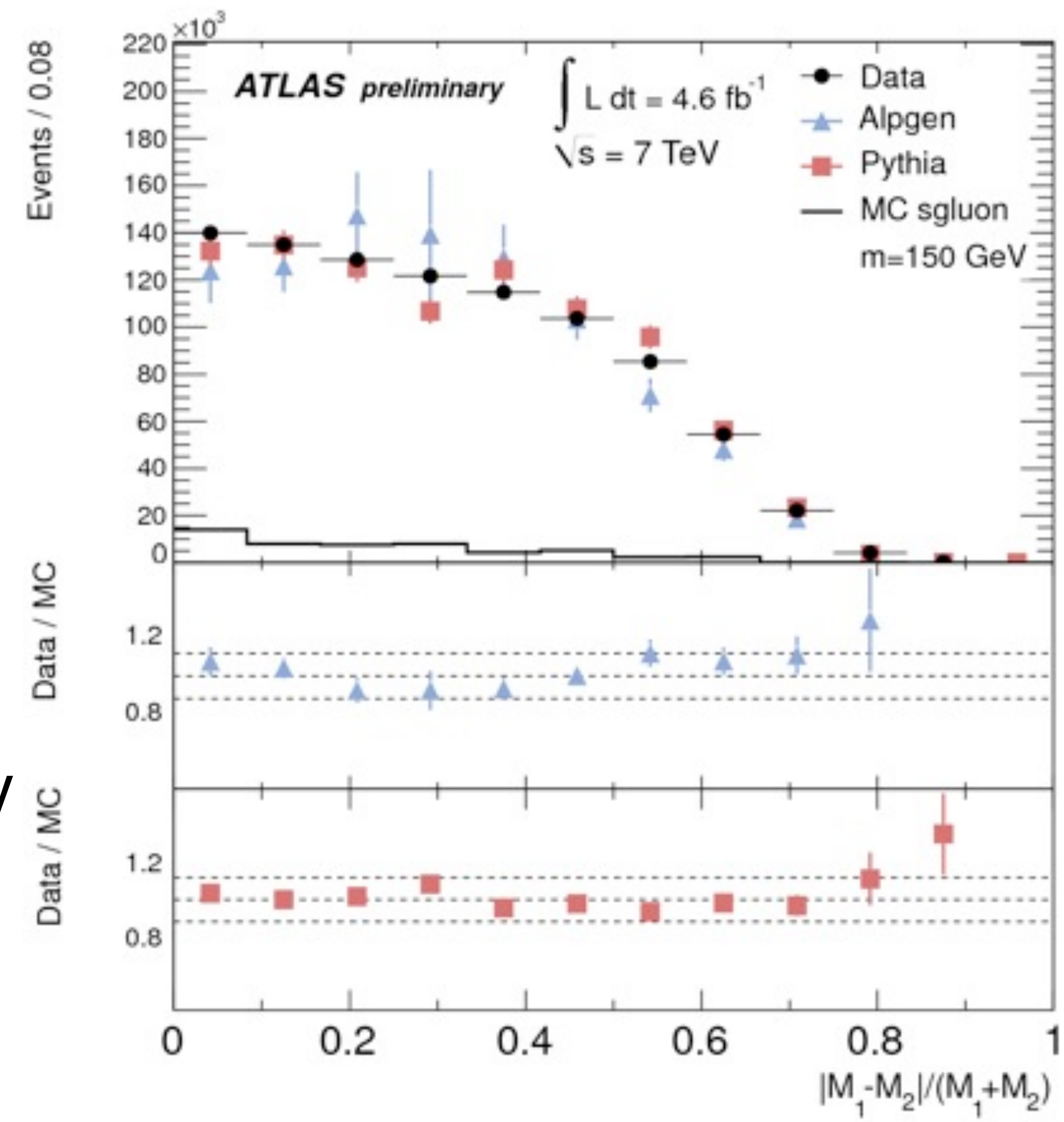
Massive colored scalar particles

- Sgluons (R=+1) predicted in many models (extended SUSY N=1/2 hybrid, R-symmetric MSSM, compositness models)
  - Consider pair production
    - LO cross section ~M_{sgluon}
    - 4 jet final state+ MET: $\sigma\sigma^* \rightarrow gggg$
  - Trigger: 4 jets above 45 GeV (EM scale) →allows probing sgluon masses > 150 GeV
  - Selection :
      - at least 4 jets with p_T>80 GeV
      - pT(4th jet) = f(M_{sgluon})
    - Main background SM multijet



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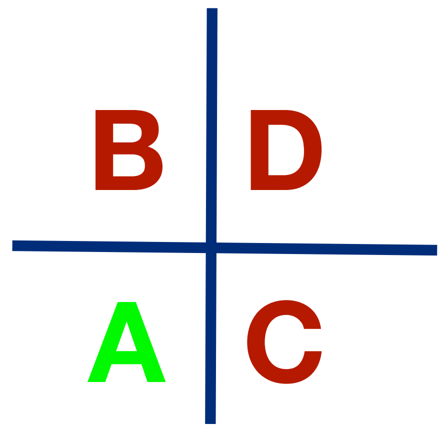
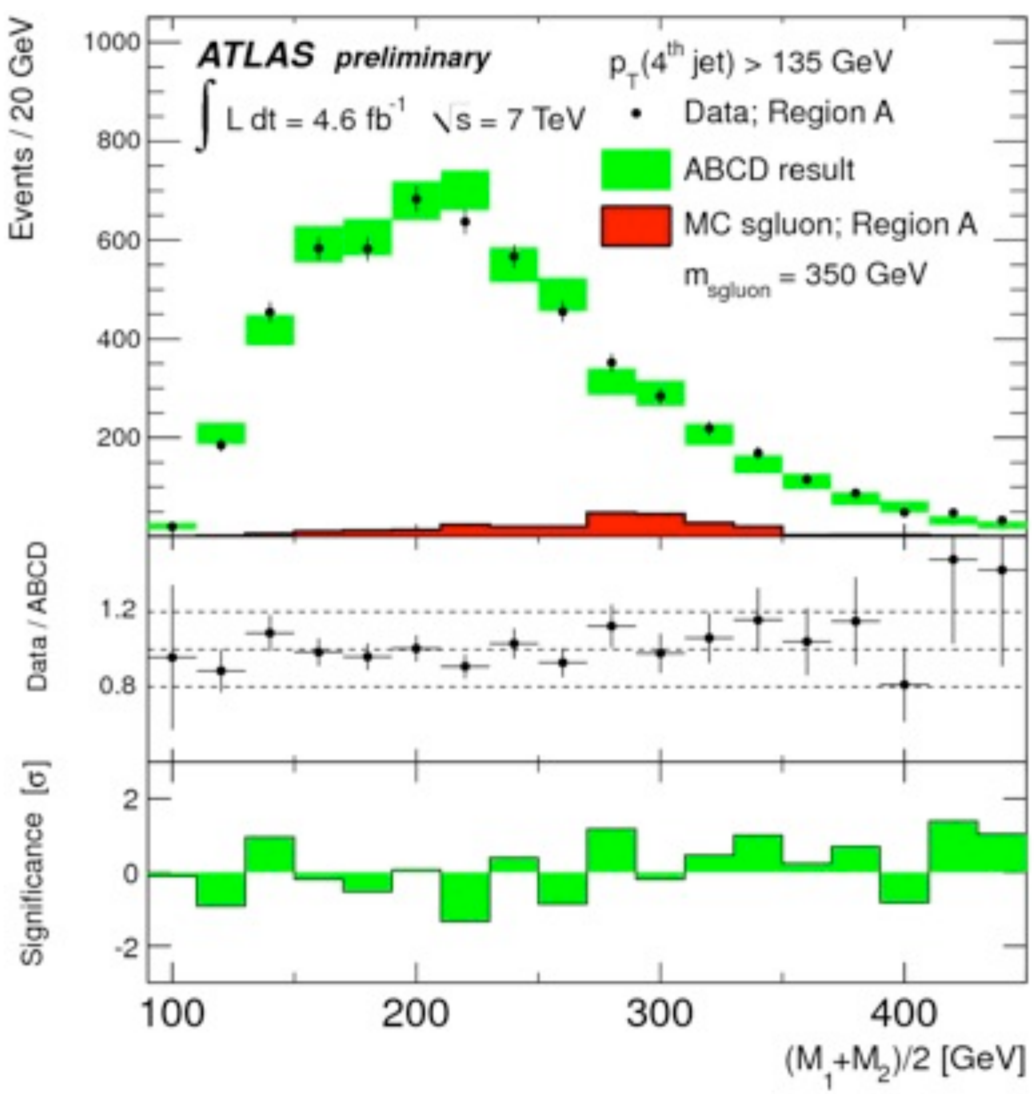
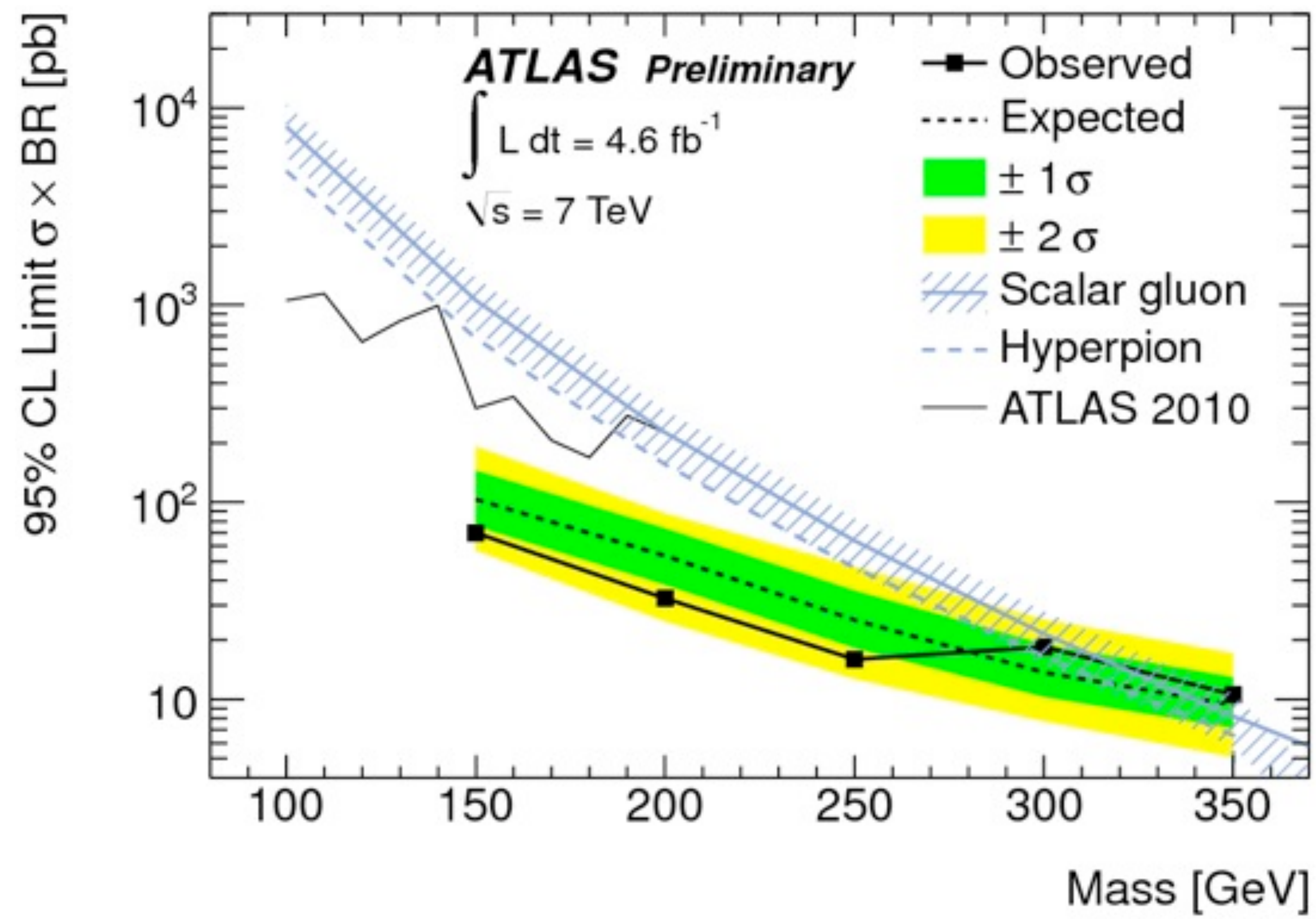
Data driven background estimation

$|cos(\theta^*)| = 0.5$



$$\frac{|M_1 - M_2|}{M_1 + M_2} = 0.15$$





Sgluons excluded in [150,287] GeV @95%CL

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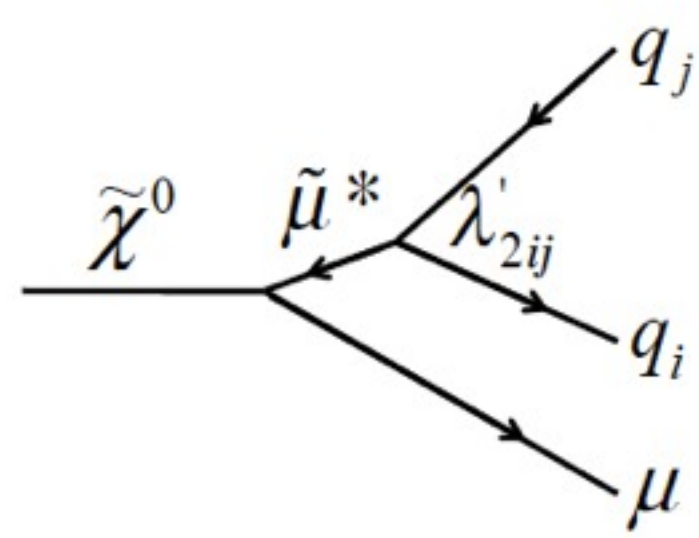
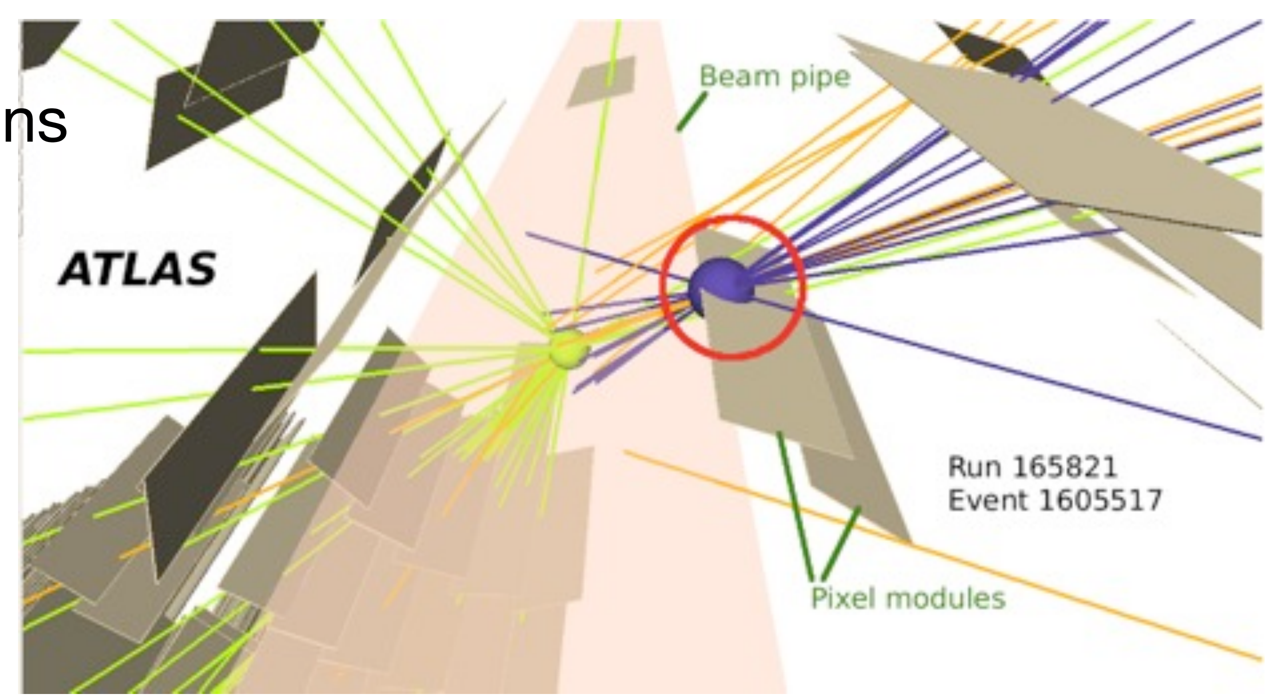
Muon and displaced vertex

- R-parity violating :
    - LSP can decay to SM
    - allows for long lived particles
- Generic search for long lived particles (LLP) decaying to muon+jets:
    - Require a high p_T muon and a displaced vertex in the pixel detector volume
    - Background: combinatorics of independent tracks, material interactions
- Signal vertex :
    - $N_{tracks} \geq 5$ having d_0>2mm
    - m_{vertex}>10 GeV
    - veto areas of high material density





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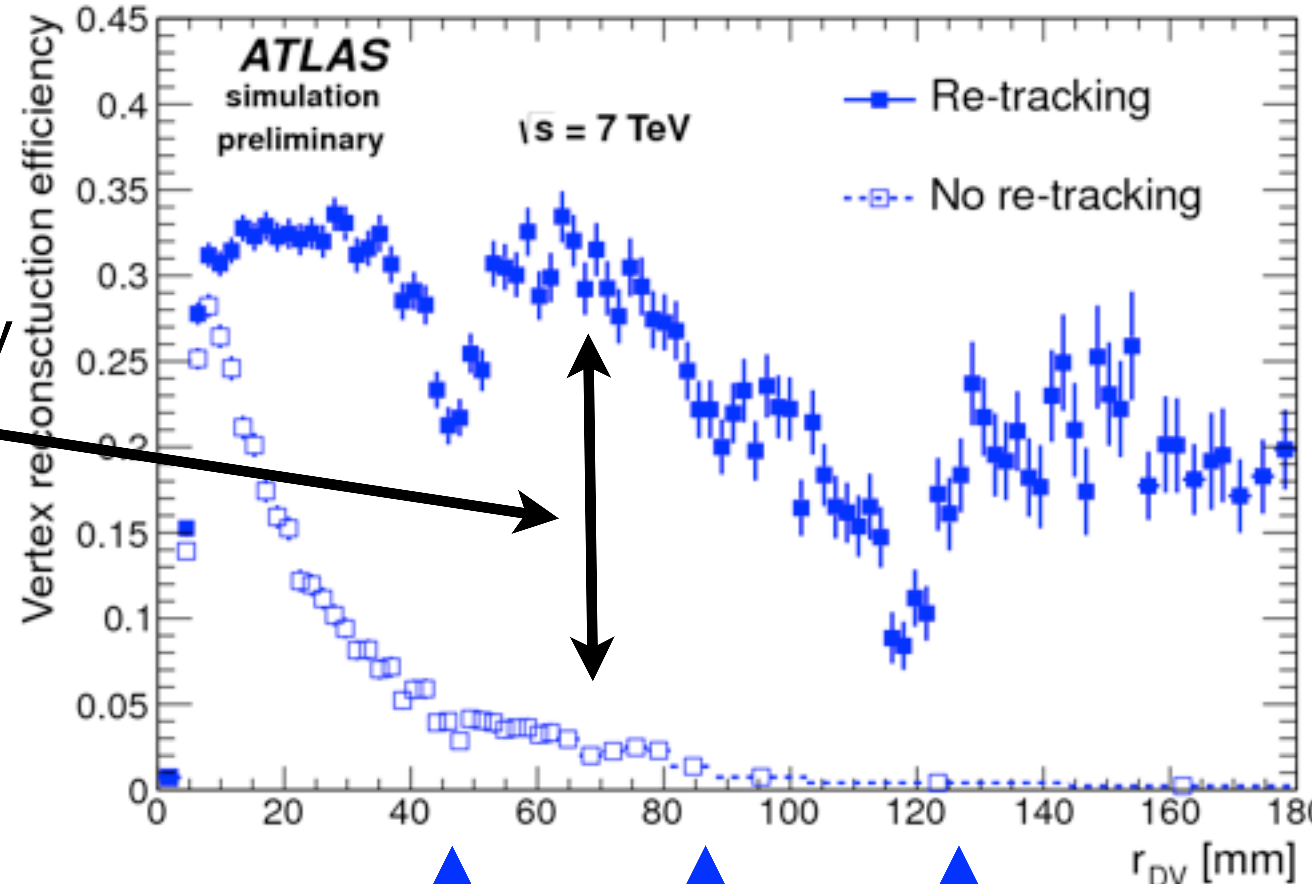
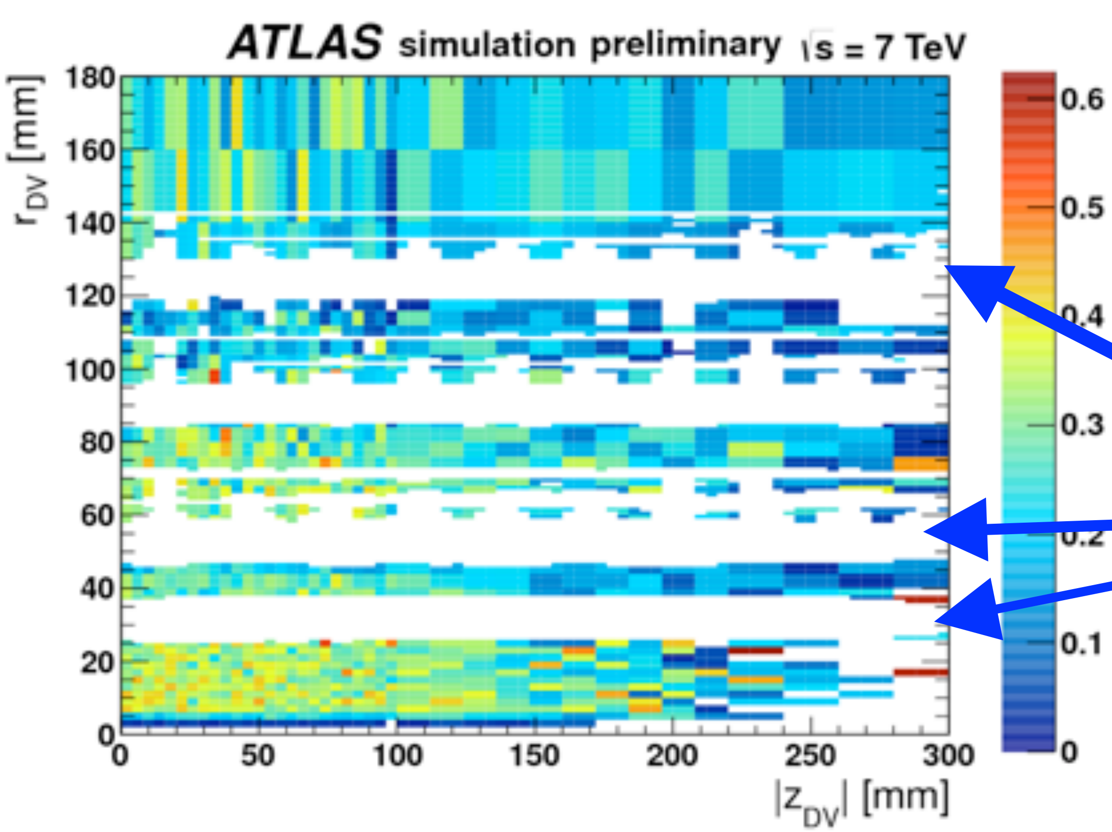
Signal Efficiency

Depends on neutralino mass, boost, decay position relative to pixel layer

Tracking rerun to improve the efficiency for finding displaced vertices

$$m_{\tilde{q}} = 700 GeV \text{ and } m_{\tilde{\chi}_1^0} = 494 GeV$$





Pixel detector layers

High material density veto

"Zero" background analysis ($B=4^{+60}_{-4} \times 10^{-3}$)

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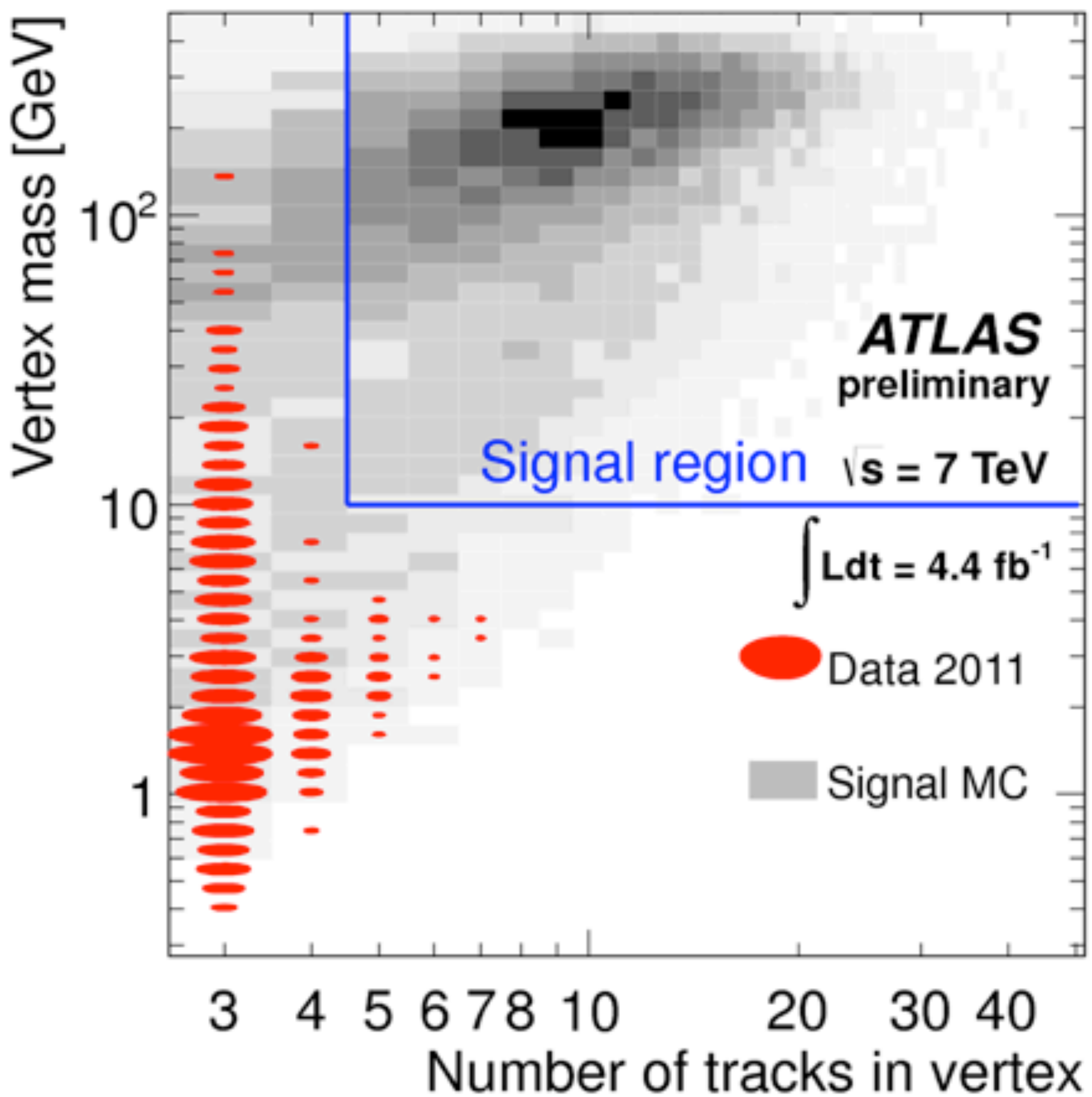
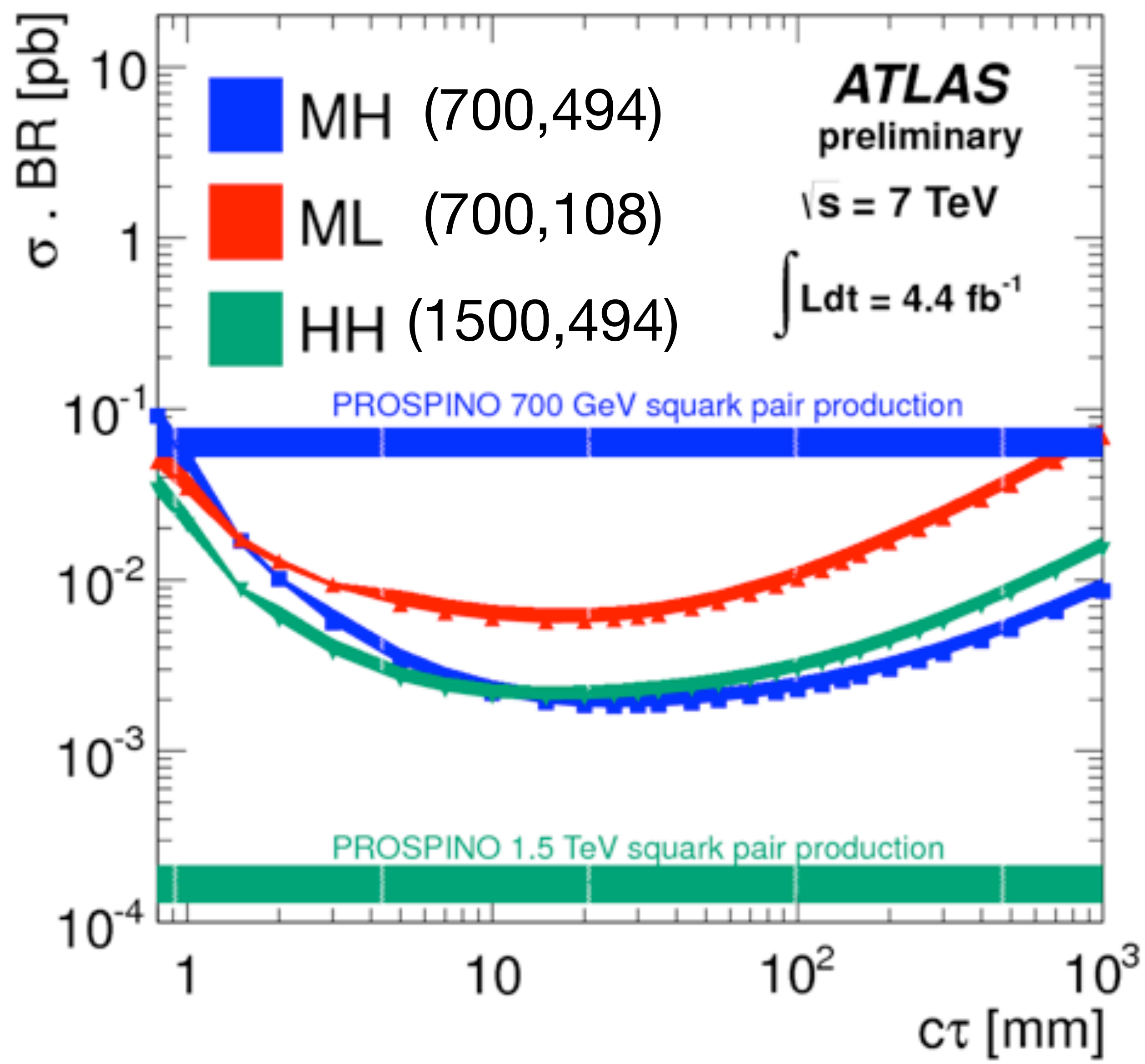
Results





No events observed in data → 95% CL upper limits are set

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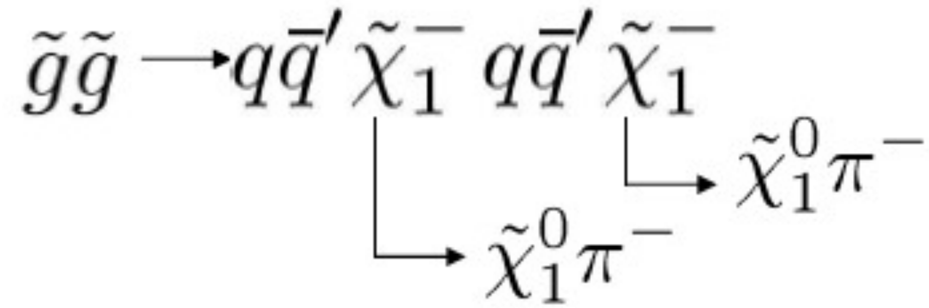
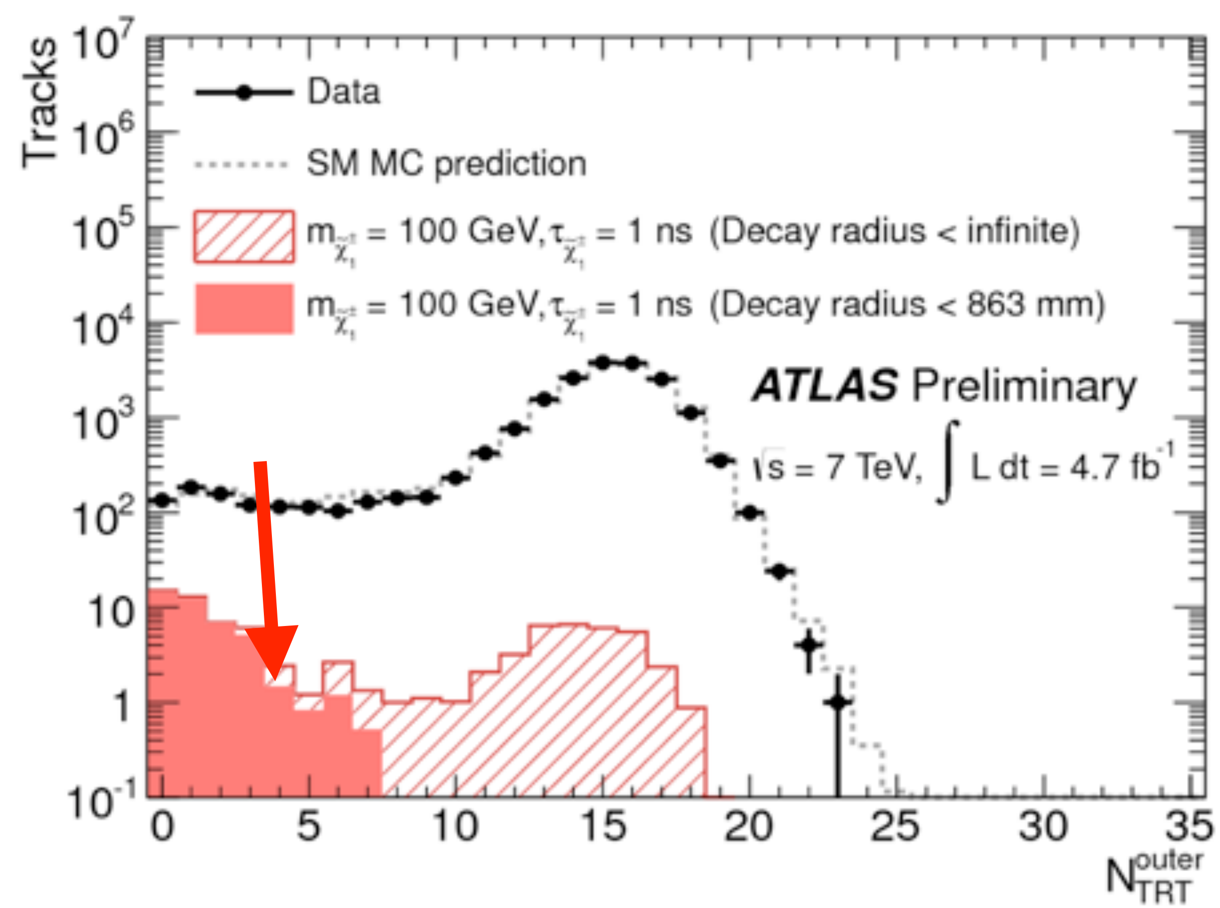
Disappearing track chargino searches

- AMSB gluino pair production
  - breaking due to loop corrections
  - $m_{Bino}:m_{Wino}:m_{gluino} \approx 3:1:7$
  - spectrum highly degenerate - chargino heavier only due to loop corrections Δm_{NLSP} typically 160-170 MeV
  - charginos could have cτ>1cm and decay inside the tracking detector
- Signature: high p_T disappearing track + MET +high p_T jets



- Selection:
  - MET > 90 GeV, 1st jet p_T>90 GeV other jet p_T>50 GeV, Δø(1-2jet, MET) >1.5
  - leading isolated track pT>10GeV and N_{TRT}(outer)<5



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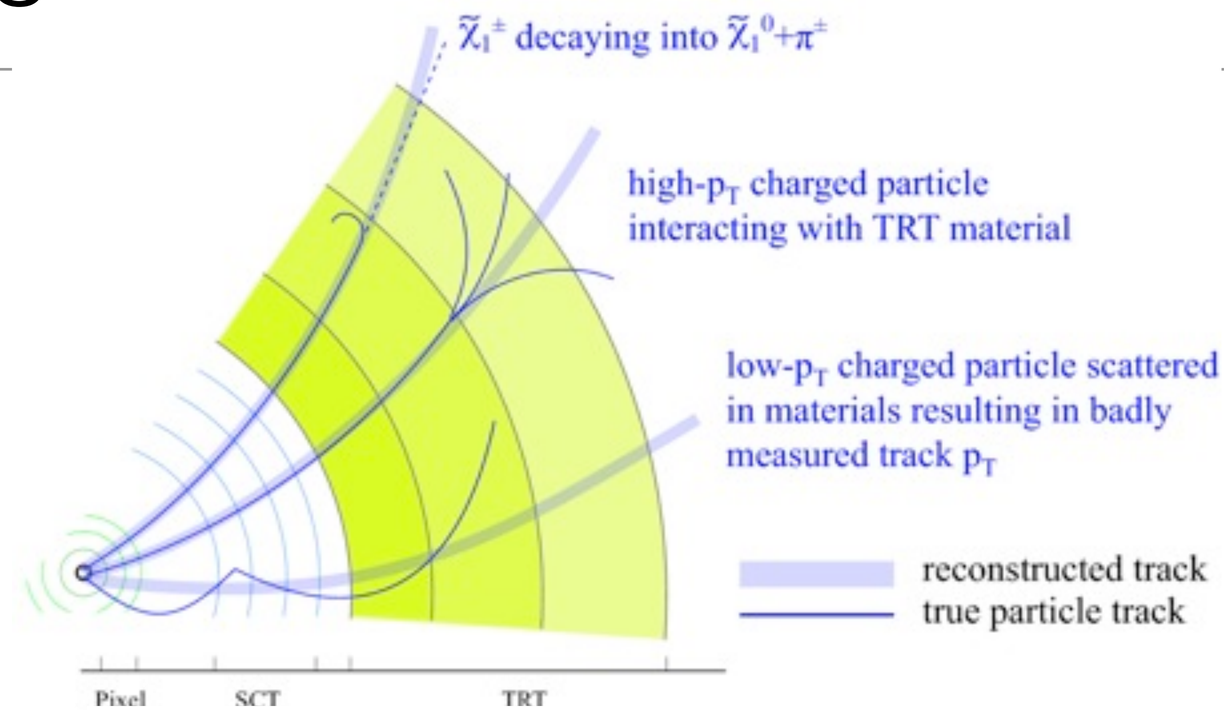
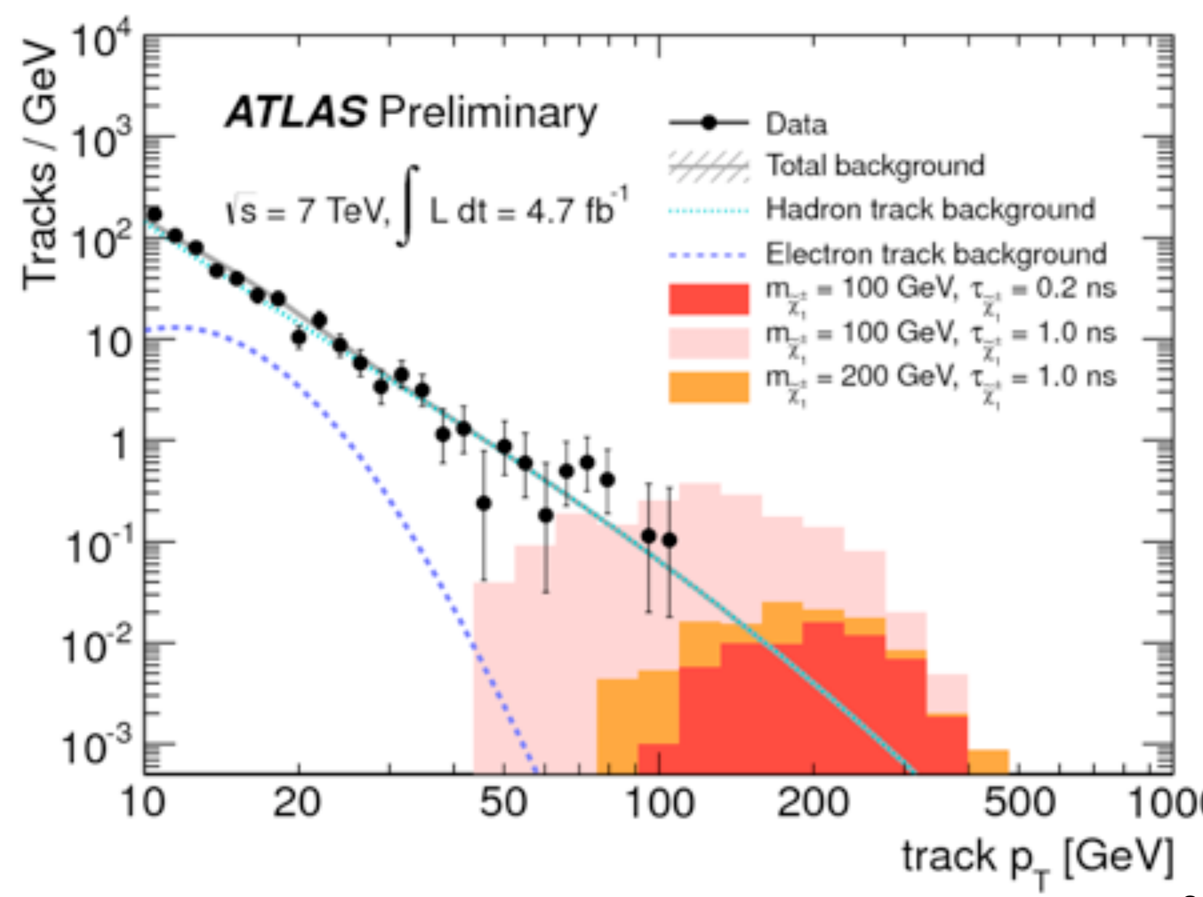
Disappearing track chargino searches

- Background estimation:
  - W main background (W→τν)
  - Background tracks:
    - interacting hadrons
    - badly measured tracks (with no activity in calorimeter)
    - leptons from W decays (mostly e)
- background shapes are determined in control regions
- a simultaneous fit is performed in the signal region





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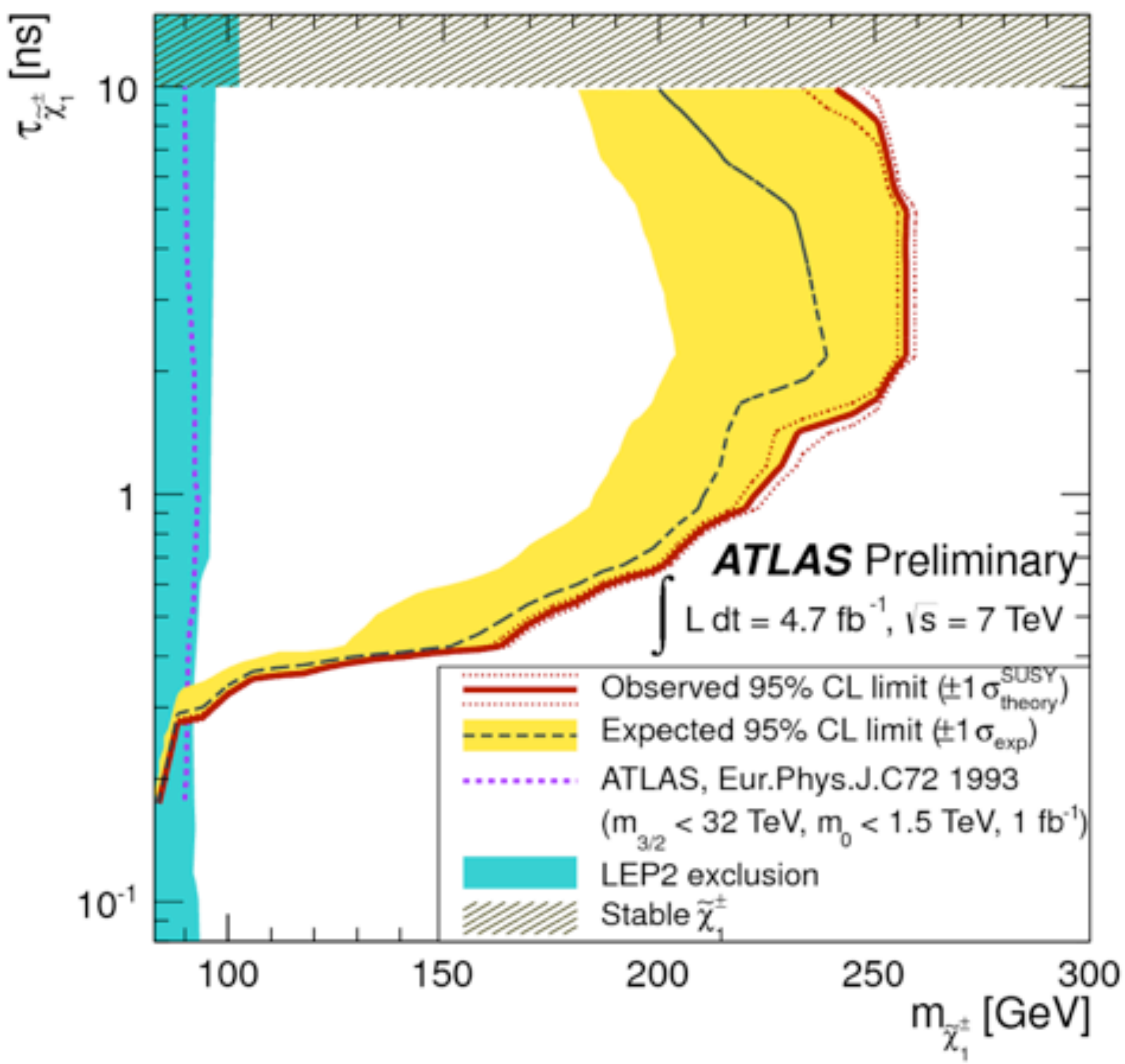
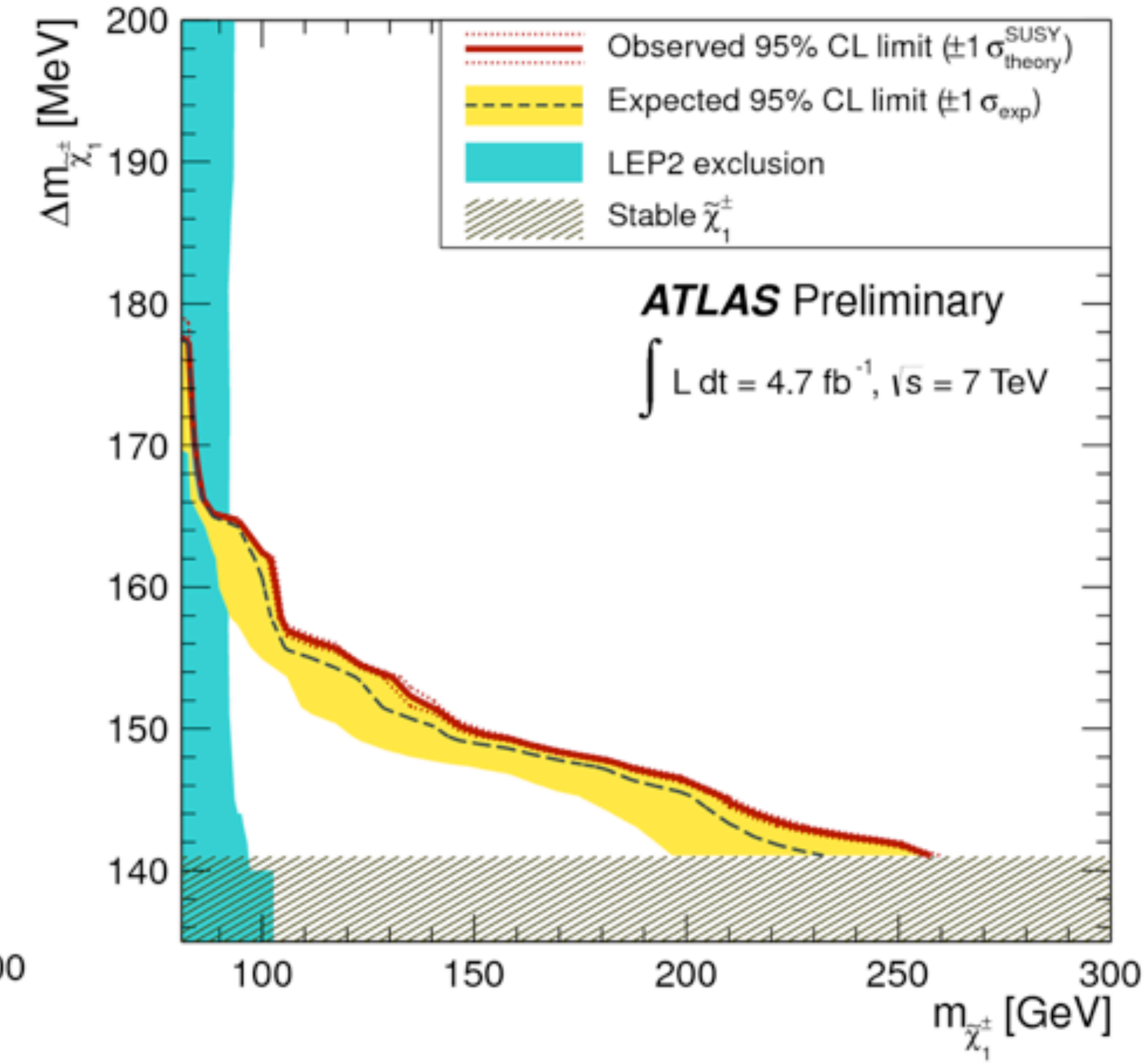
Disappearing track chargino searches

- Data consistent with background → 95% CL upper limits set





- For Δm_{NLSP} =160(170) MeV new limit on chargino mass 103(85) GeV

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Heavy long lived sleptons and R-hadrons

- GMSB can accommodate massive charged sleptons:
  - would interact like “heavy muons” and have β<1 producing high ionization
  - N_5=3, $M_{messenger}$=250 TeV, sign(μ)=+1, C_{grav}=5000, tanβ=5-40

NLSP does not decay in the detector

- R-hadrons:
  - SUSY particles with color charge hadronizing with a SM quark
  - can arrive neutral, or single/double charged at MS

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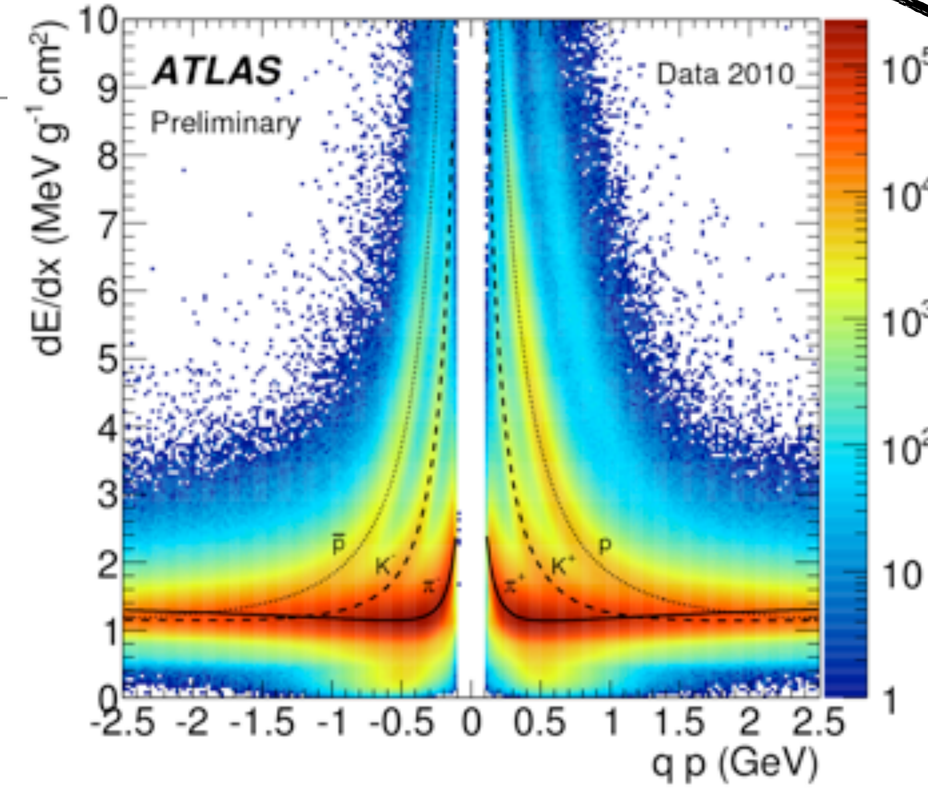
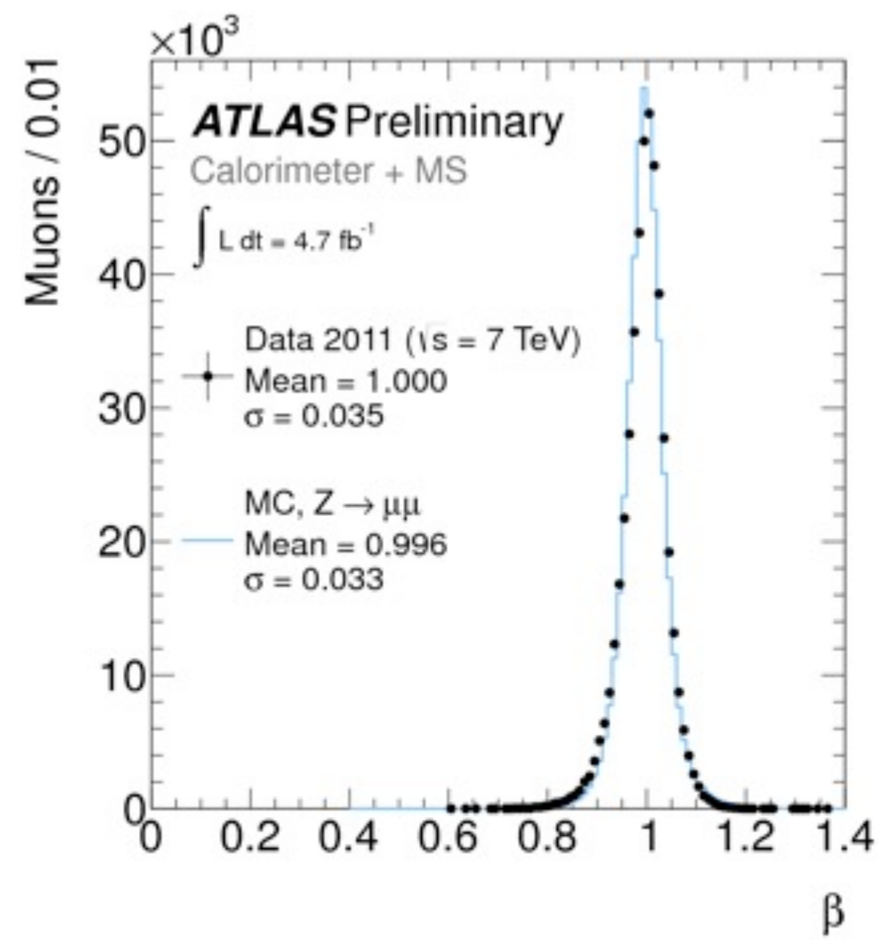
β and βγ determination

- βγ :using pixel detector
  - specific energy loss ~ average dE/dx from all clusters (after removing the highest clusters (1-2)
  - $m_{\beta\gamma}$ extracted from the dependence of the most probable value of dE/dx on βγ
- β: Time of flight based measurements in calorimeter and muon spectrometer (MS):
  - MS reconstruction of muons without β=1 requirement
  - MS measurement both based on drift-tube chambers and resistive plate chambers
- Detector timing calibrated using muons





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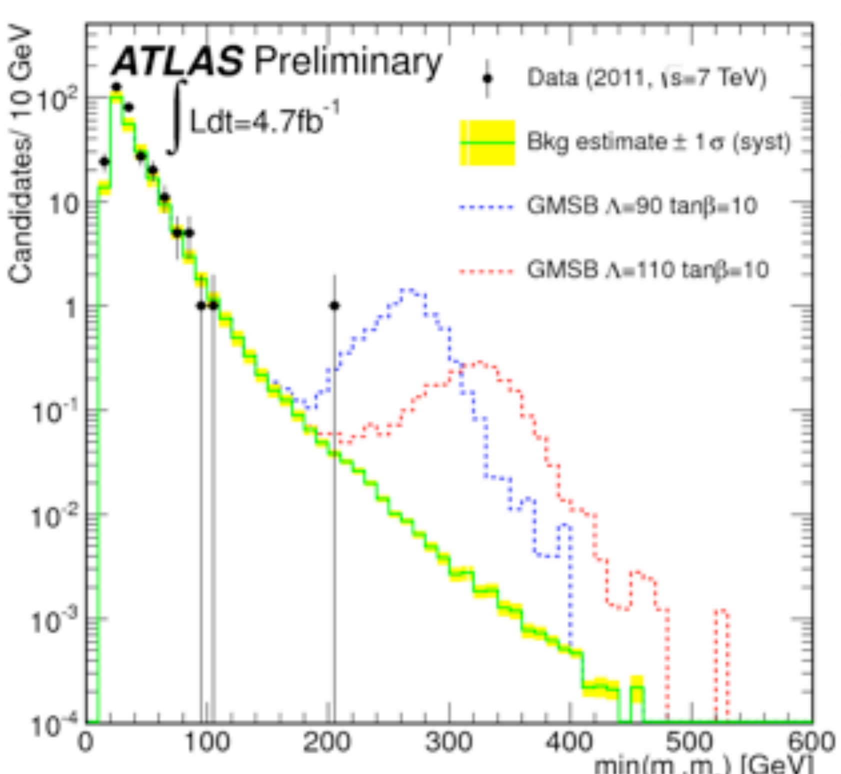
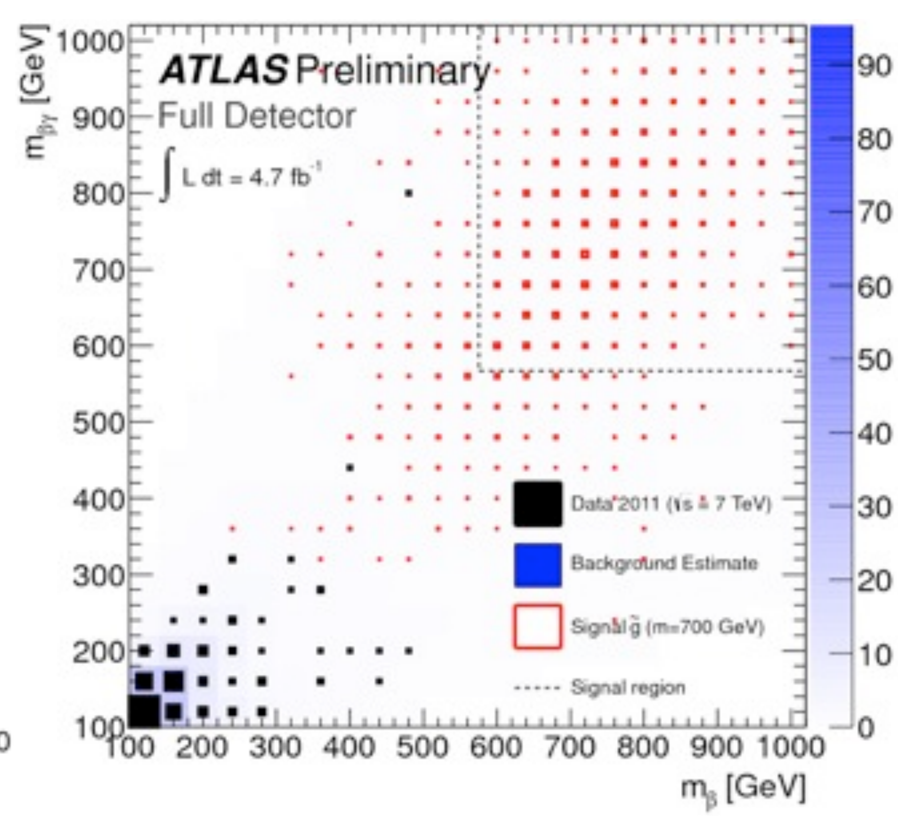
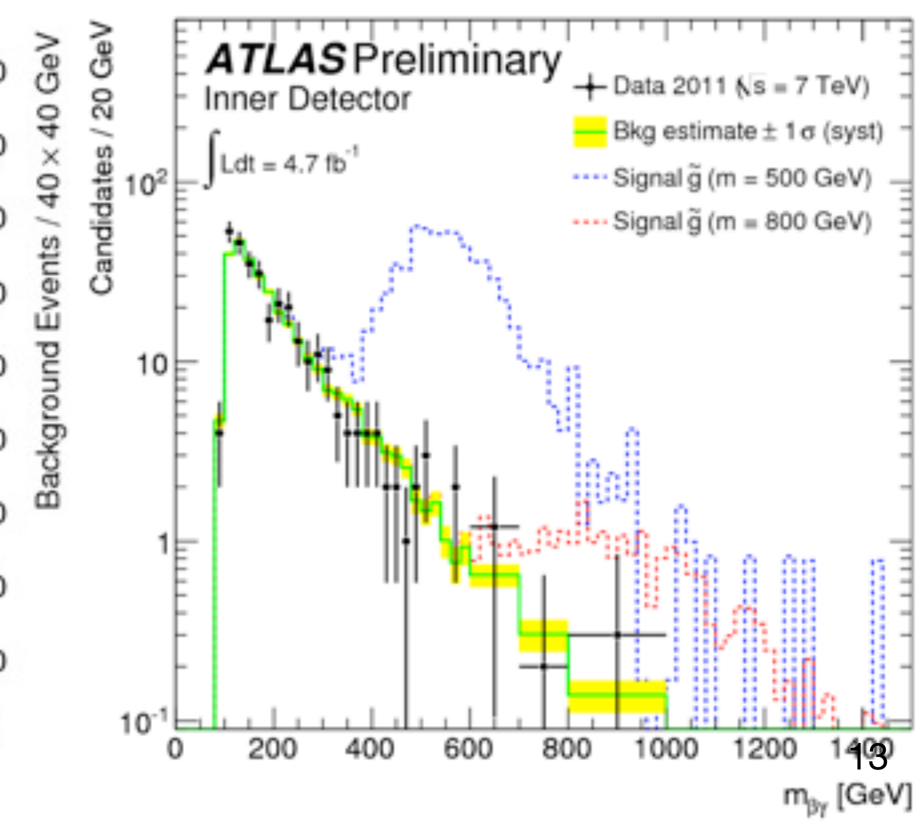
Heavy long lived sleptons and R-hadrons

- Sleptons :
  - muon trigger, muons are common in events (eff~75-80%)
  - 2(1) muon from a primary vertex with loose(tight) selection, Z-veto, β & $\beta\gamma$ -consistent across subdetectors
  - discriminant on m_β optimized for 2(1) SR and mass hypothesis
- R-hadrons:
  - MET trigger (small deposits of energy due to R-hadrons) (eff~15-20%)
  - discriminant on β,$\beta\gamma$,m_β,$m_{\beta\gamma}$ -depending on full det, MS agnostic,ID only
- Background data driven estimated from control regions of selections







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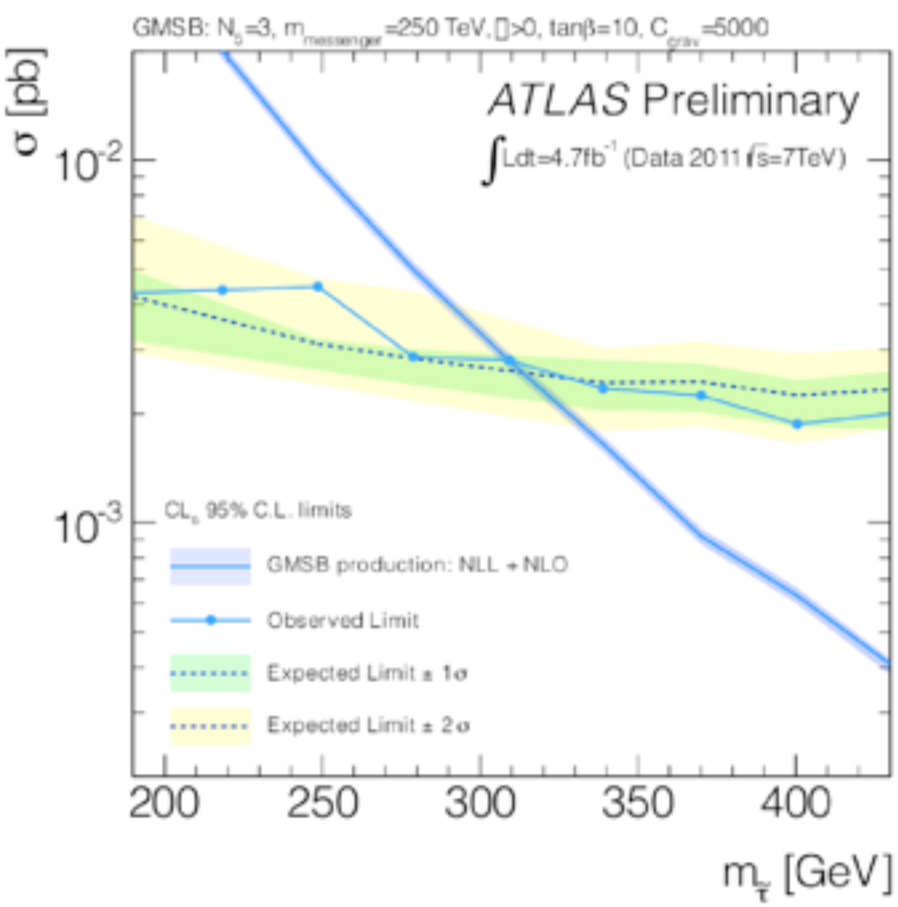
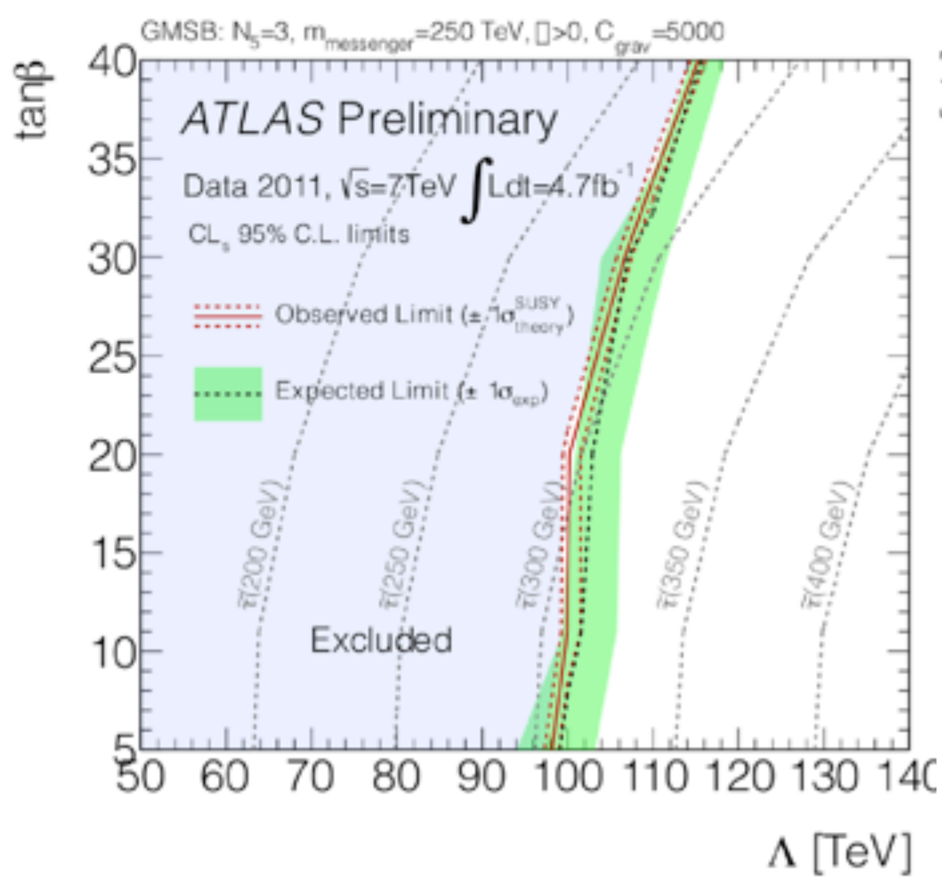
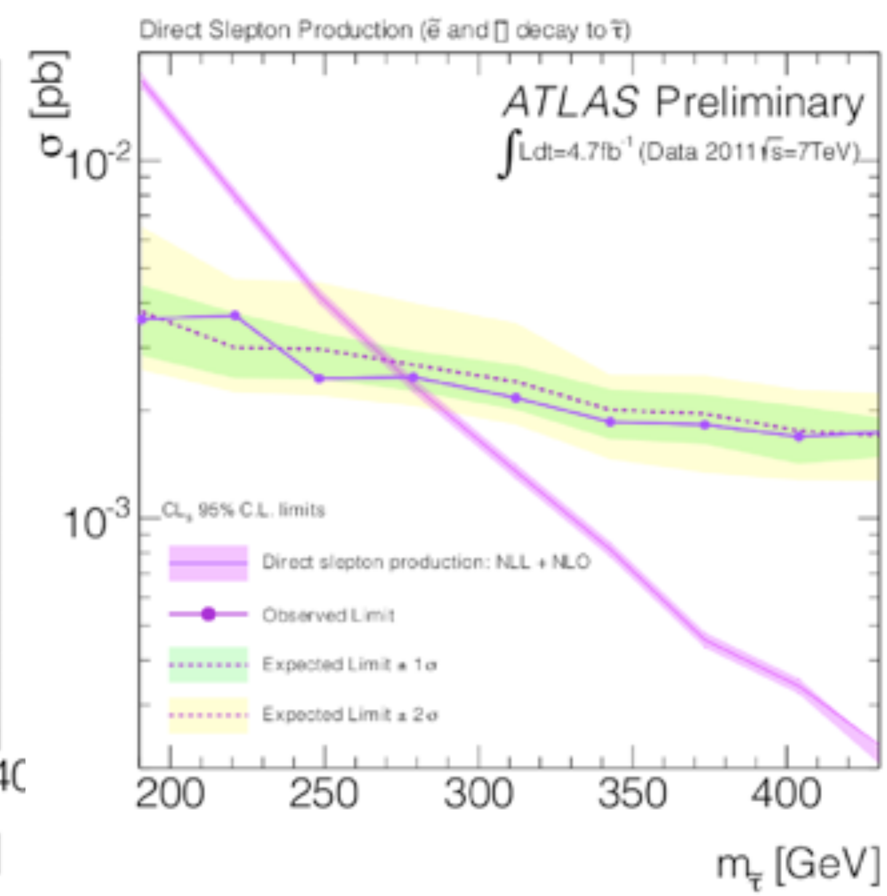
Slepton limits

- No excess over background

→ limits computed







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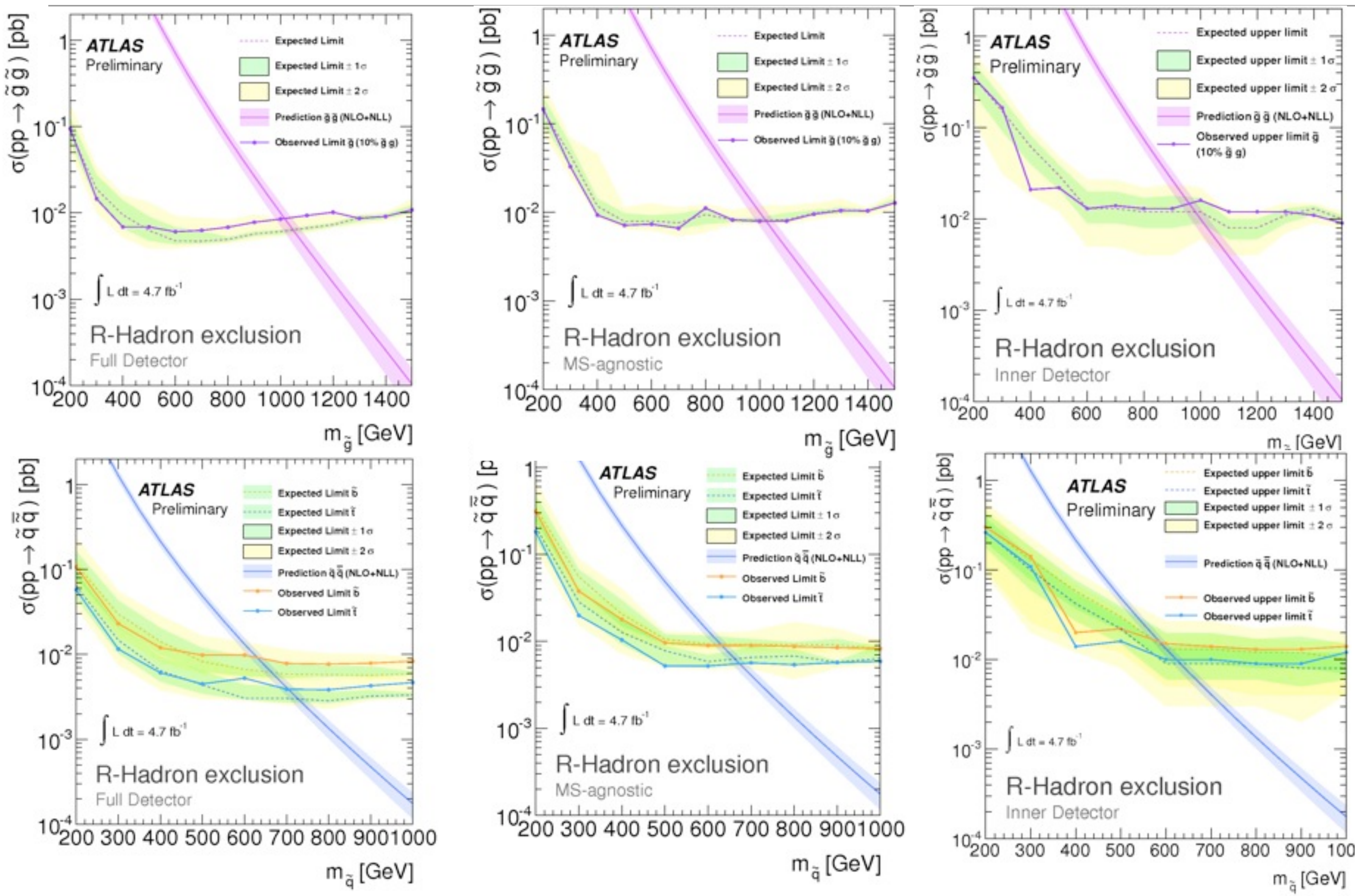
R-hadron limits



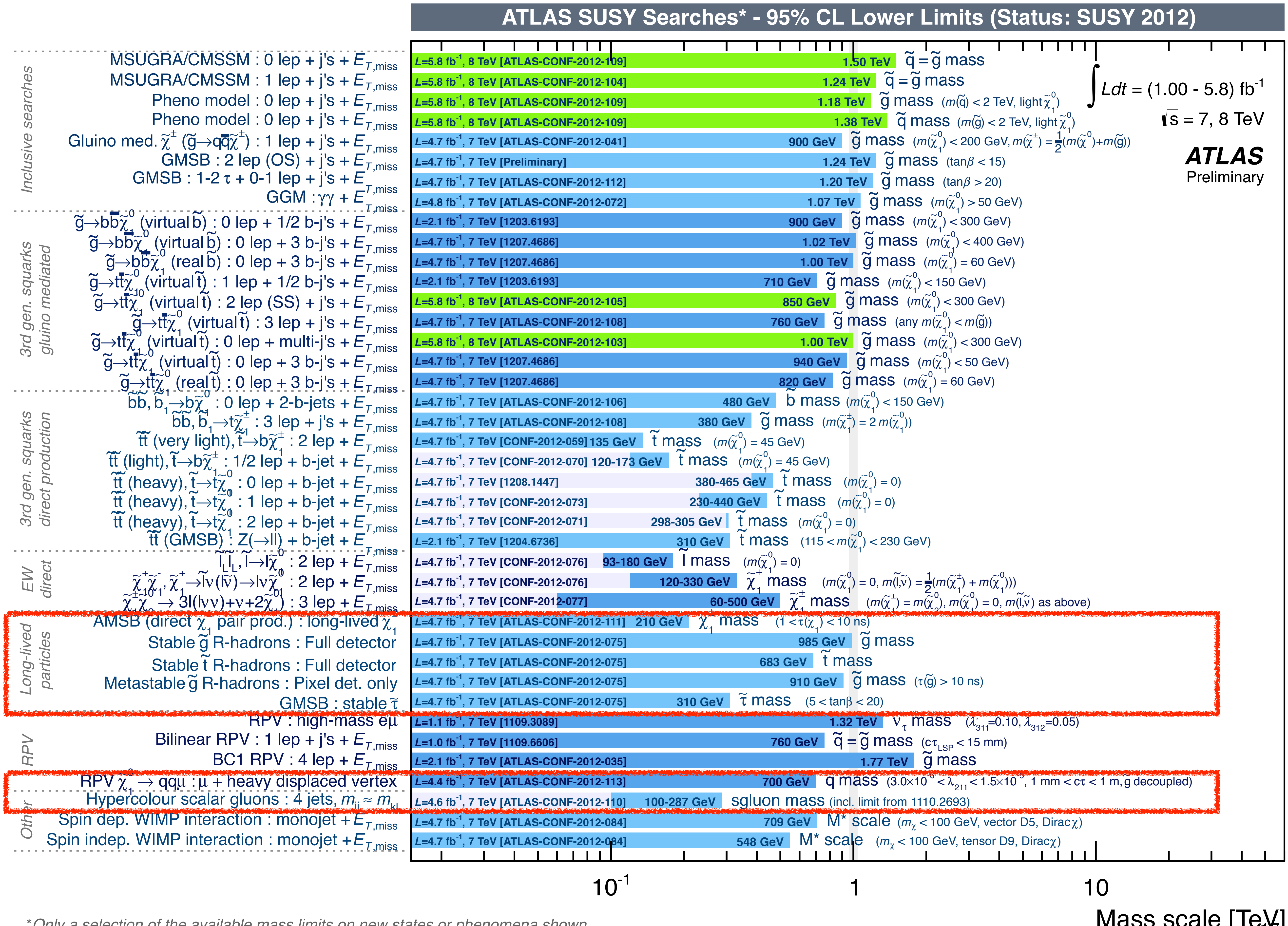
Summary

Based on up to 4.7 fb^{-1} of data at 7TeV the following 95% CL exclusions have been made

- AMSB: $m_{\tilde{\chi}_1^\pm} \leq 100GeV$ for $\delta m_{\tilde{\chi}_1^\pm} \approx 160MeV$
- GMSB: $m_{\tilde{\tau}} < 300GeV$ for tanβ =5-10
  $m_{\tilde{\tau}} < 285GeV$ for tanβ =30
  $m_{\tilde{\tau}} < 268GeV$ for tanβ =40
- R-hadrons

Full-detector	MS-agnostic	ID-only
$m_{\tilde{g}} < 985GeV$	$m_{\tilde{g}} < 989GeV$	$m_{\tilde{g}} < 940GeV$
$m_{\tilde{t}} < 683GeV$	$m_{\tilde{t}} < 657GeV$	$m_{\tilde{t}} < 576GeV$
$m_{\tilde{b}} < 612GeV$	$m_{\tilde{b}} < 618GeV$	$m_{\tilde{b}} < 606GeV$

- RPV SUGRA $m_{\tilde{q}} < 700GeV$ for $c\tau \in (1, 10^3)mm$ $\lambda'_{211} \in (3.0 \times 10^{-6}, 1.5 \times 10^{-5}$
- Extended SUSY $m_{\text{sgluons}} \in (150, 287)GeV$



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

Backup

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Backup

Sgluon Mass [GeV]	p_T^{min} [GeV]	Data	ABCD prediction	Shape p-value(A,B)
150	80	102162	101100 ± 800 ± 2000	0.22
200	90	55194	54500 ± 600 ± 1100	0.10
250	105	23404	22500 ± 340 ± 500	0.28
300	120	11082	10640 ± 230 ± 210	0.24
350	135	5571	5330 ± 180 ± 110	0.70

Systematic	A	B	C	D	Correlation ABCD
JES	+10%,-10%	+11%,-11%	+11%,-13%	+15%,-10%	100%
JER	+0%,-2%	+0%,-7%	+0%,-1%	+0%,-2%	100%
ISR/FSR	+3.5%,-3.5%	+3.5%,-3.5%	+3.5%,-3.5%	+3.5%,-3.5%	100%
Trigger	±1%	±1%	±1%	±1%	100%
MC Statistics	±4%	±11%	±5%	±8%	0%
PDF	±3%	±3%	±3%	±2%	0%
Luminosity	±1.8%	±1.8%	±1.8%	±1.8%	100%

ATLAS-CONF-2012-075

Backup

Source	GMSB sleptons one-cand.	GMSB sleptons two-cand.	R-hadrons ID-only	R-hadrons other
Theoretical systematic uncertainty on signal size	5	5	15–30	
Uncertainty on signal efficiency				
Signal trigger efficiency	1.8	1.8	4.5	4.5
QCD uncertainties (ISR, FSR)			8.5	8.5
Signal pre-selection efficiency				1.5
Momentum resolution	0.5	0.5	1.3	1.3
Pixel dE/dx calibration			5.8–0.2	5
Combined β timing calibration	4	6		
Calo β timing calibration				1.0
MS β timing calibration				3.6
Offline E_T^{miss} scale			7.3–4.5	
Total uncertainty on signal efficiency	4.4	6.3	13.4–10.6	11.6
Luminosity	3.9	3.9	3.9	3.9
Experimental uncertainty on background estimate	11	13	3–20	15

Table 1: Summary of systematic uncertainties (given in percent). Ranges indicate a mass dependence for the given uncertainty.

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Backup

Sample	$m_{\tilde{q}}$ [GeV]	σ [fb]	$m_{\tilde{\chi}_1^0}$ [GeV]	$\langle\gamma\beta\rangle_{\tilde{\chi}_1^0}$	$c\tau_{MC}$ [mm]	λ'_{211}
MH	700	66.4	494	1.0	78	3.0×10^{-6}
ML	700	66.4	108	3.1	101	1.5×10^{-5}
HH	1500	0.2	494	1.9	82	1.5×10^{-5}

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Backup

Source	$m_{\tilde{\chi}_1^\pm} = 100$ GeV	$m_{\tilde{\chi}_1^\pm} = 200$ GeV
(Theoretical uncertainty)		
Cross section	±7	±7
(Uncertainty on the acceptance)		
Modeling of initial/final state radiation	±10	±13
JES/JER	±10	±6
Trigger efficiency	±3	±3
Pile-up modeling	±0.5	±0.5
Track reconstruction efficiency	±2	±2
Luminosity	±3.9	±3.9
Sub-total	±15	±15

Table 2: Summary of systematic uncertainties [%] on the expectation of signal events.

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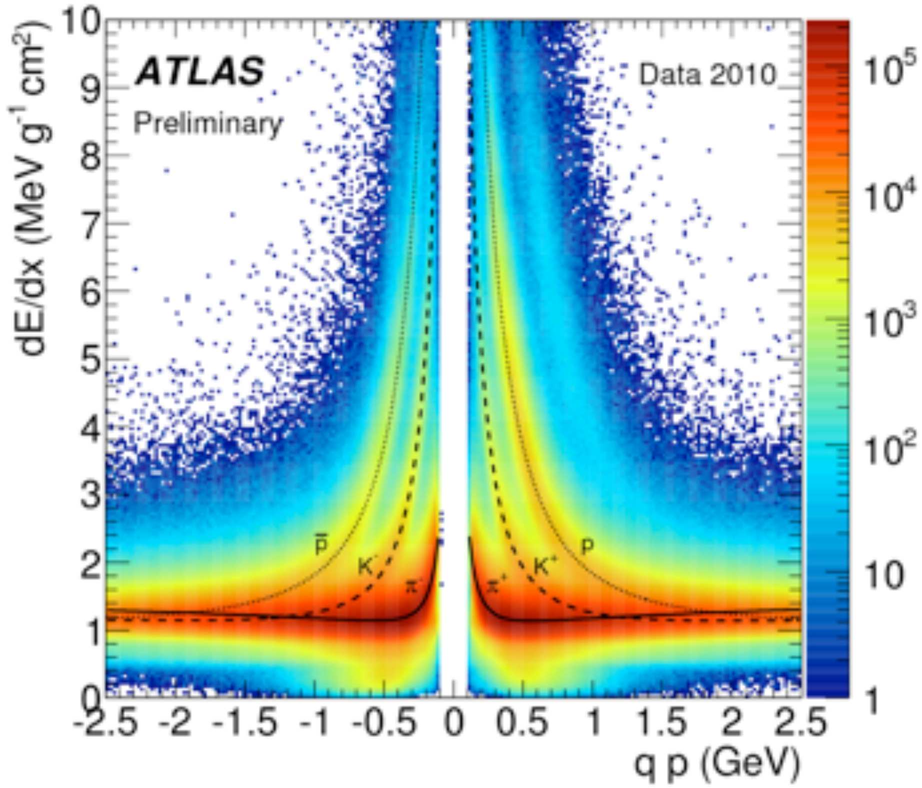
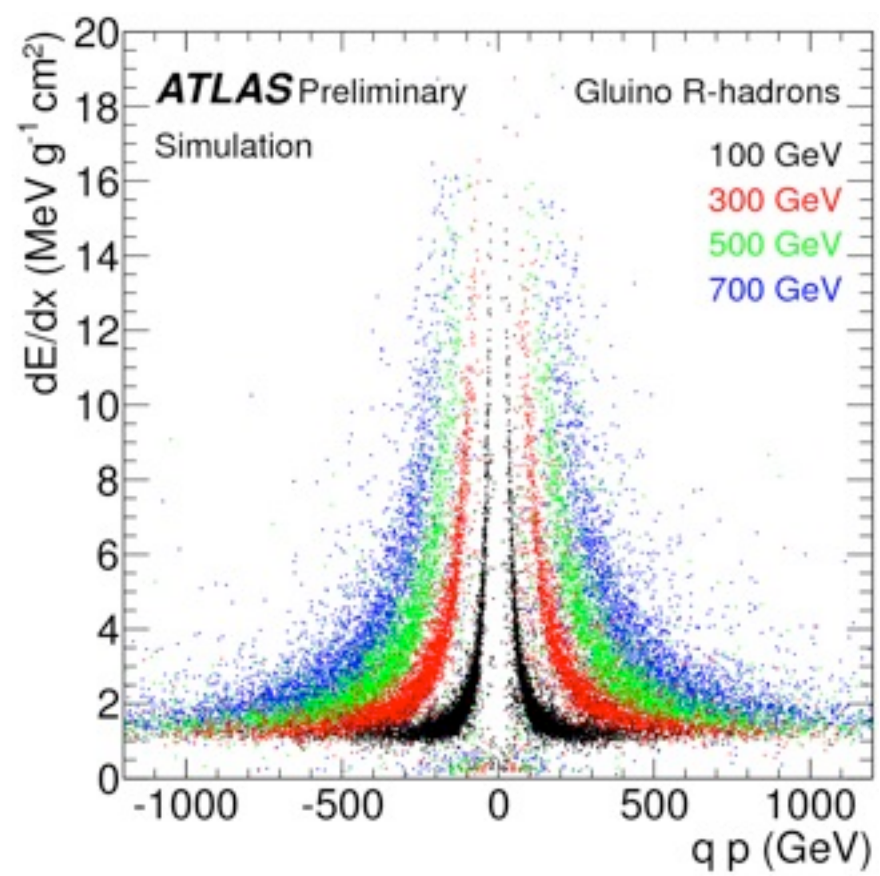
βγ determination

- using pixel detector
- specific energy loss ~ average dE/dx from all clusters (after removing the highest clusters (1-2)
- $m_{\beta\gamma}$ extracted from the dependence of the most probable value of dE/dx on β

$$\mathrm{MPV}_{dE/dx}(p/m_{\beta\gamma}) = dE/dx$$





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β determination

- ToF (time of flight) based measurements in calorimeter and muon spectrometer (MS):
    - MS reconstruction of muons without β=1 requirement
    - MS measurement both based on drift-tube chambers and resistive plate chambers
- Detector timing calibrated using muons