7th Patras Workshop on
Axions, WIMPs and WISPs

ATLAS results on SUSY

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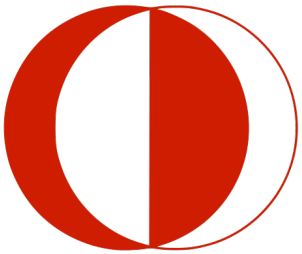
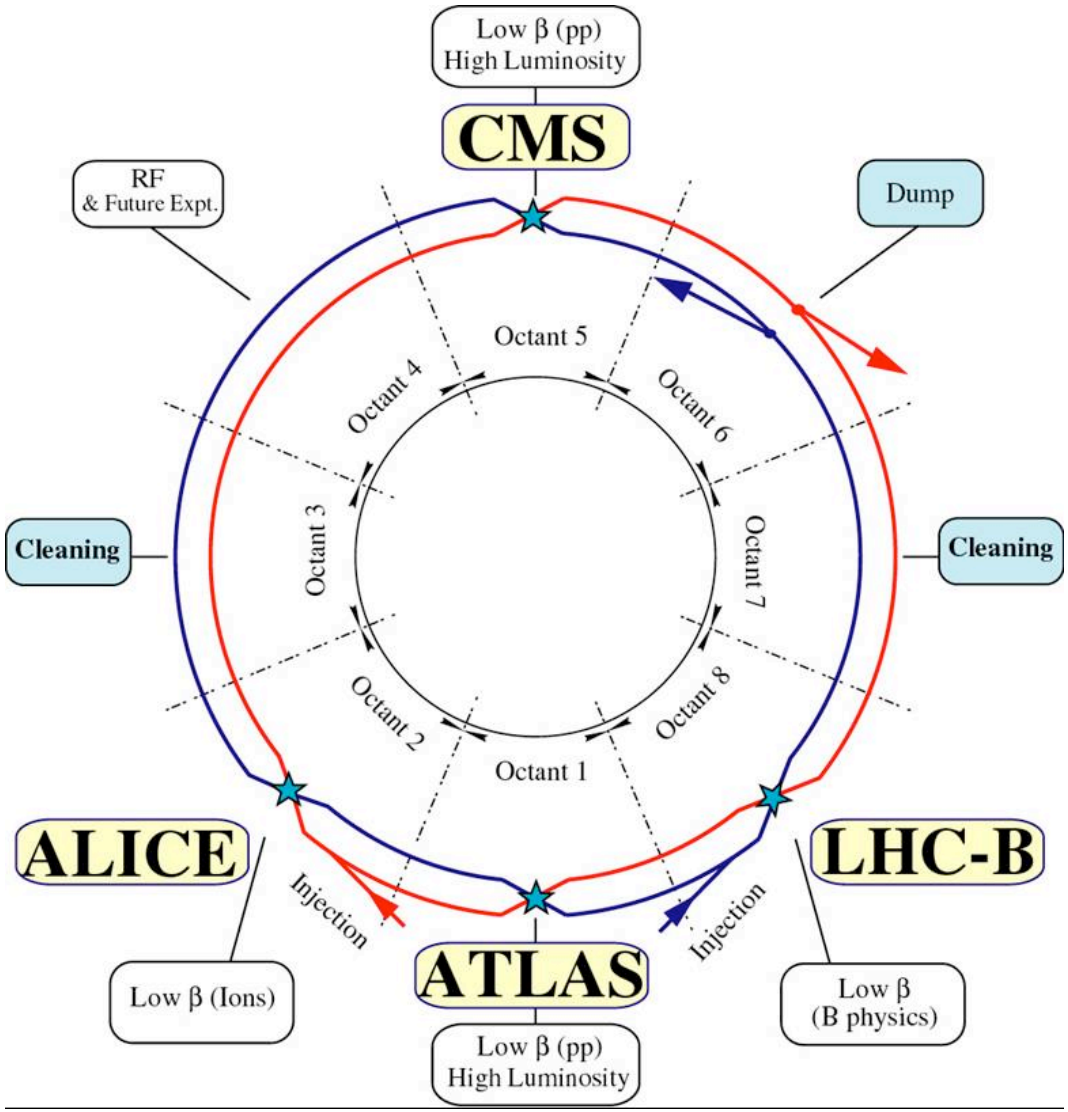
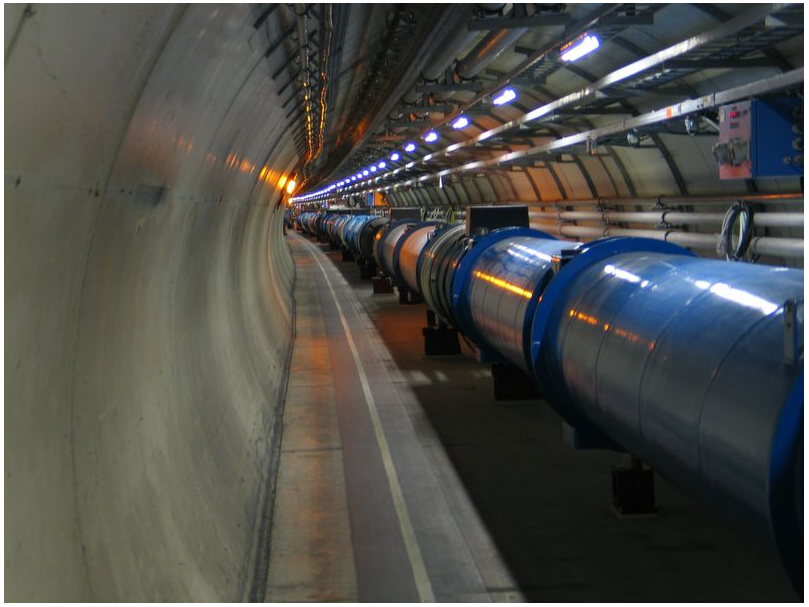
For the ATLAS Collaboration



Mykonos, 01/07/2011

Large Hadron Collider

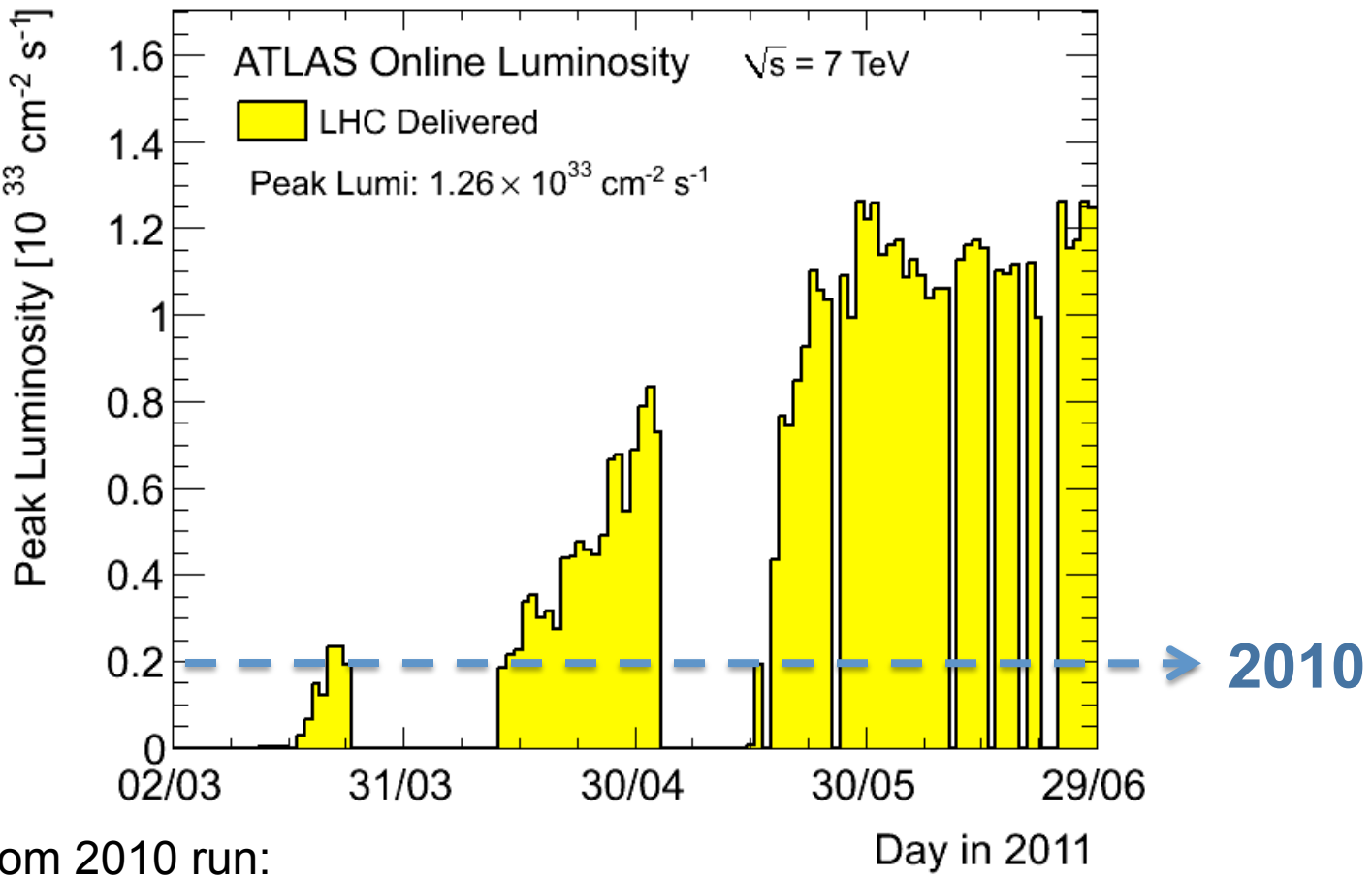




LHC Commissioning:
First 900 GeV center-of-mass collisions, end of 2009
Then 2.36 TeV collisions.
Since March 2010, 7TeV collisions

Energy limited by the safety of the magnets → can only go to 14TeV after ~1 year shutdown and upgrade

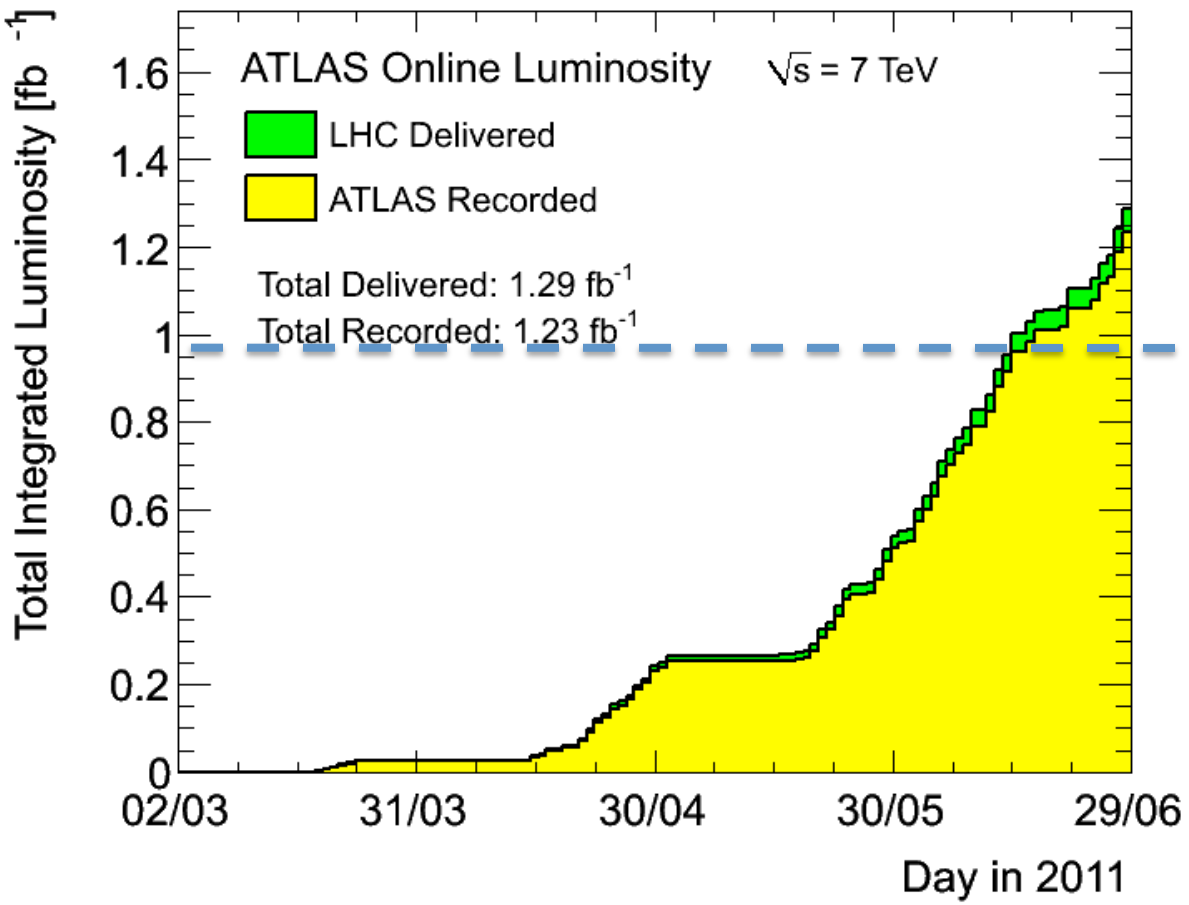
LHC Performance: Instantaneous Luminositv



Changes from 2010 run:

- Reduction of β* from 3.5 to 1.5 → Gain: 2.3
- Increase # of bunches with 50ns spacing. Max: 1400b, now: 1236b → Gain: ~ 3
- Increase bunch charge to 1.4 x 10^{11} or higher → Gain > 1.4

LHC Performance: Integrated Luminosity



17/06/2011

☺

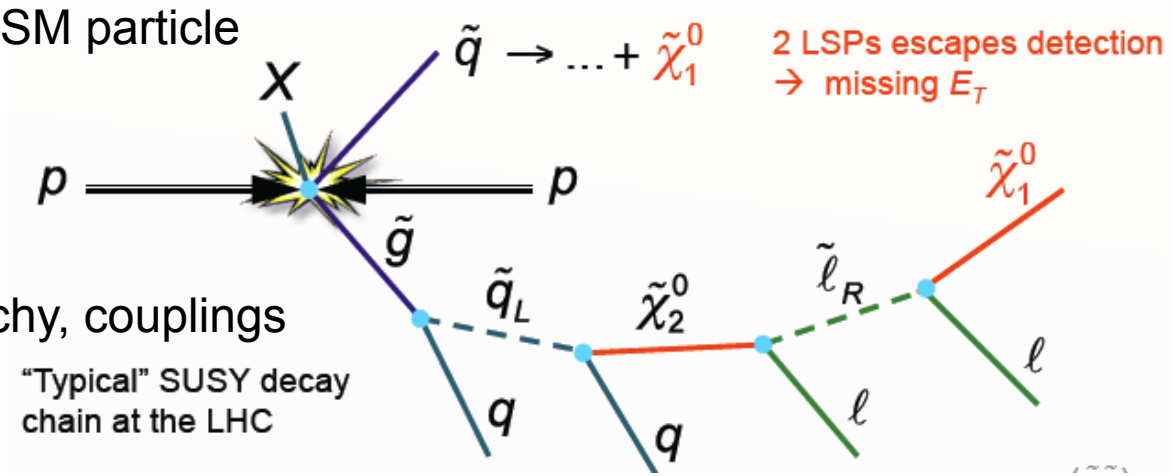
Data taking efficiency for ATLAS > 95 %

Searching for SUSY at the LHC

SUSY = superpartners of each SM particle

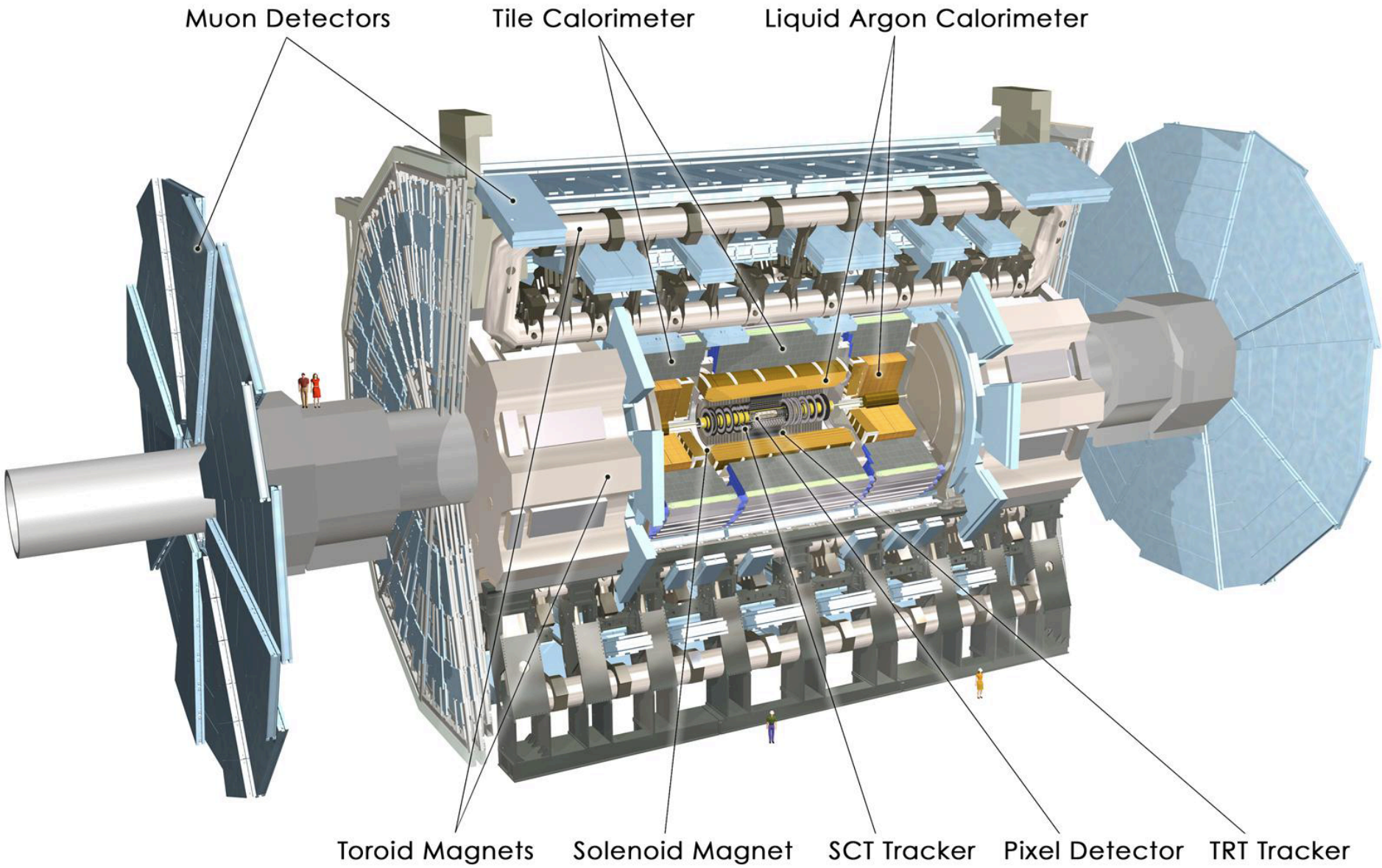
If R-parity is conserved,
sparticles are pair-produced.

Lots of unknowns: mass hierarchy, couplings
→ lifetimes, decays chains



- Have to search for SUSY in many different final states
- If R-parity is conserved: Lightest SUSY Particle (LSP) is stable
  - Dark Matter candidate
  - will produce MET (Missing Transverse Energy)
- Jets + MET (+ lepton)
- Di-leptons /Multi-leptons + MET
- B-jets + MET (+lepton)
- e+mu resonance and slow meta-stable particle search

ATLAS


Muon Detectors
Tile Calorimeter
Liquid Argon Calorimeter
Toroid Magnets
Solenoid Magnet
SCT Tracker
Pixel Detector
TRT Tracker

Jets + MET

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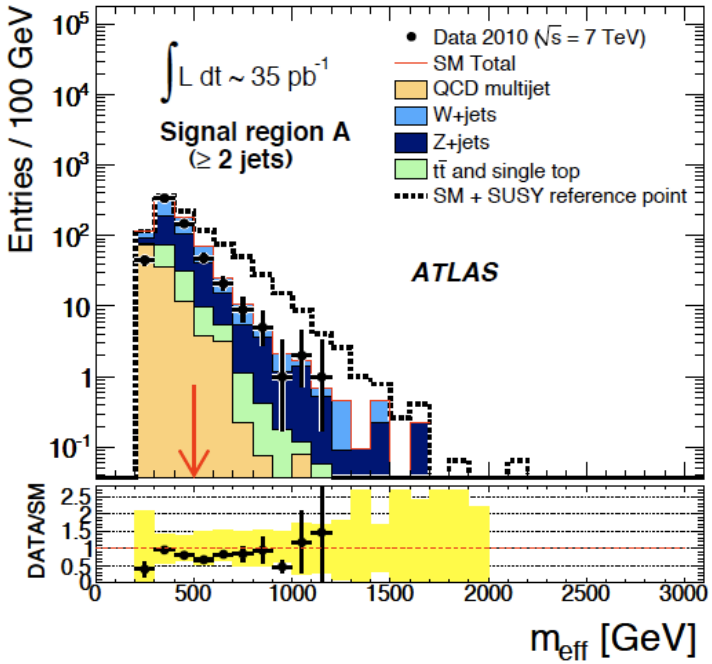
		A	B	C	D
Pre-selection	Number of required jets	≥ 2	≥ 2	≥ 3	≥ 3
	Leading jet p_T [GeV]	> 120	> 120	> 120	> 120
	Other jet(s) p_T [GeV]	> 40	> 40	> 40	> 40
	E_T^{miss} [GeV]	> 100	> 100	> 100	> 100
Final selection	$\Delta\phi(\text{jet}, \vec{p}_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
	E_T^{miss}/m_{eff}	> 0.3	–	> 0.25	> 0.25
	m_{eff} [GeV]	> 500	–	> 500	> 1000
	m_{T2} [GeV]	–	> 300	–	–



Optimization of cuts:

A: light squark pairs, B: heavy squark pairs, C: gluino pairs, D: squark+gluino

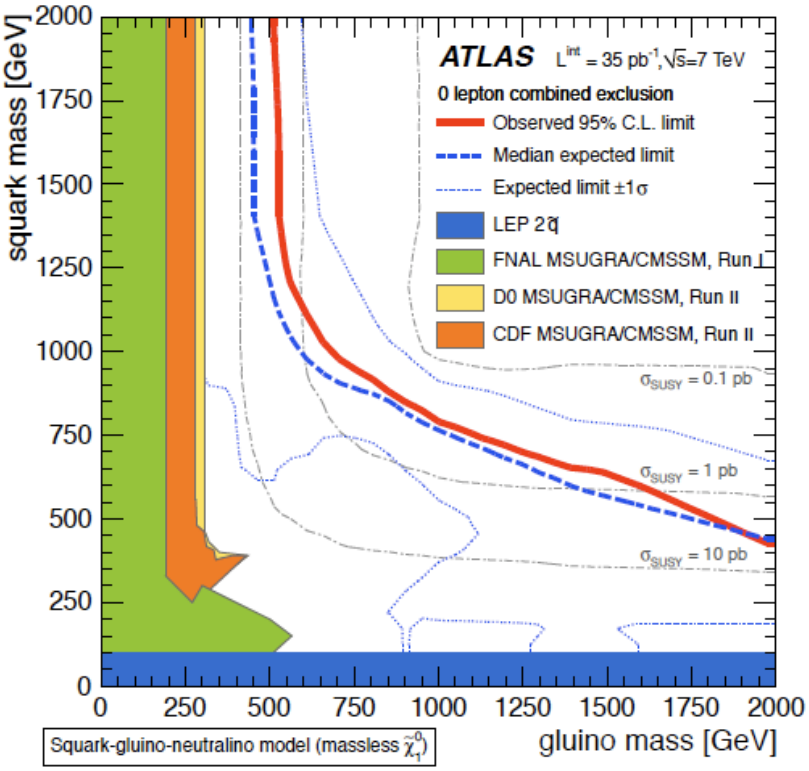
QCD background from data control sample

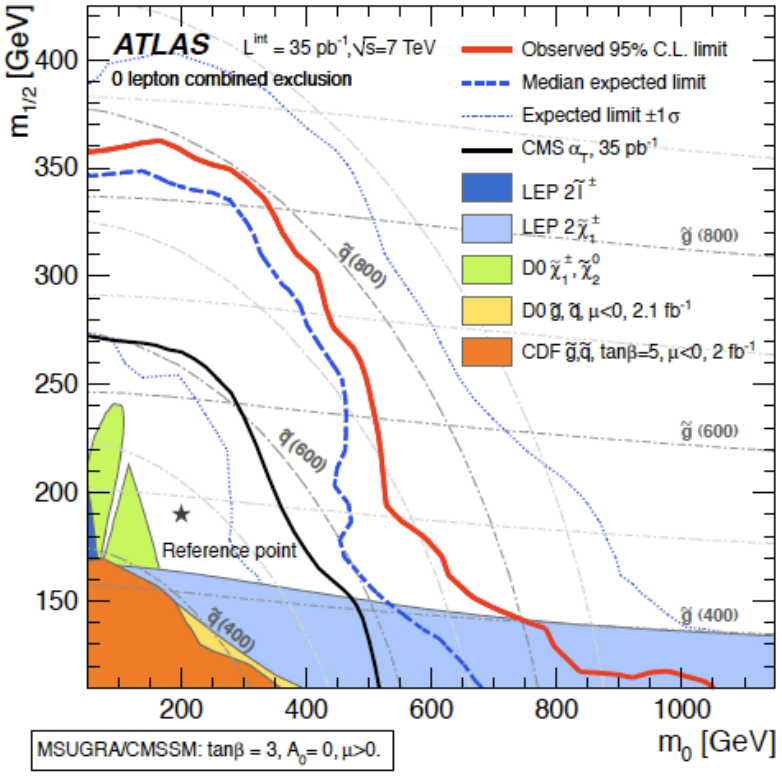
W+jets, Z+jets + top backgrounds from a mix of MC and data-driven techniques

	Signal region A	Signal region B	Signal region C	Signal region D
QCD	$7\ ^{+8}_{-7}$[u+j]	$0.6\ ^{+0.7}_{-0.6}$[u+j]	$9\ ^{+10}_{-9}$[u+j]	$0.2\ ^{+0.4}_{-0.2}$[u+j]
W+jets	50 ± 11[u] $^{+14}_{-10}$[j] $\pm$ 5[$\mathcal{L}$]	4.4 ± 3.2[u] $^{+1.5}_{-0.8}$[j] ± 0.5[$\mathcal{L}$]	35 ± 9[u] $^{+10}_{-8}$[j] ± 4[$\mathcal{L}$]	1.1 ± 0.7[u] $^{+0.2}_{-0.3}$[j] ± 0.1[$\mathcal{L}$]
Z+jets	52 ± 21[u] $^{+15}_{-11}$[j] $\pm$ 6[$\mathcal{L}$]	4.1 ± 2.9[u] $^{+2.1}_{-0.8}$[j] ± 0.5[$\mathcal{L}$]	27 ± 12[u] $^{+10}_{-6}$[j] ± 3[$\mathcal{L}$]	0.8 ± 0.7[u] $^{+0.6}_{-0.0}$[j] ± 0.1[$\mathcal{L}$]
$t\bar{t}$ and t	10 ± 0[u] $^{+3}_{-2}$[j] $\pm$ 1[$\mathcal{L}$]	0.9 ± 0.1[u] $^{+0.4}_{-0.3}$[j] ± 0.1[$\mathcal{L}$]	17 ± 1[u] $^{+6}_{-4}$[j] ± 2[$\mathcal{L}$]	0.3 ± 0.1[u] $^{+0.2}_{-0.1}$[j] ± 0.0[$\mathcal{L}$]
Total SM	118 ± 25[u] $^{+32}_{-23}$[j] ± 12[$\mathcal{L}$]	10.0 ± 4.3[u] $^{+4.0}_{-1.9}$[j] ± 1.0[$\mathcal{L}$]	88 ± 18[u] $^{+26}_{-18}$[j] ± 9[$\mathcal{L}$]	2.5 ± 1.0[u] $^{+1.0}_{-0.4}$[j] ± 0.2[$\mathcal{L}$]
Data	87	11	66	2

Arxiv:1102.5290

Jets+MET: interpretation





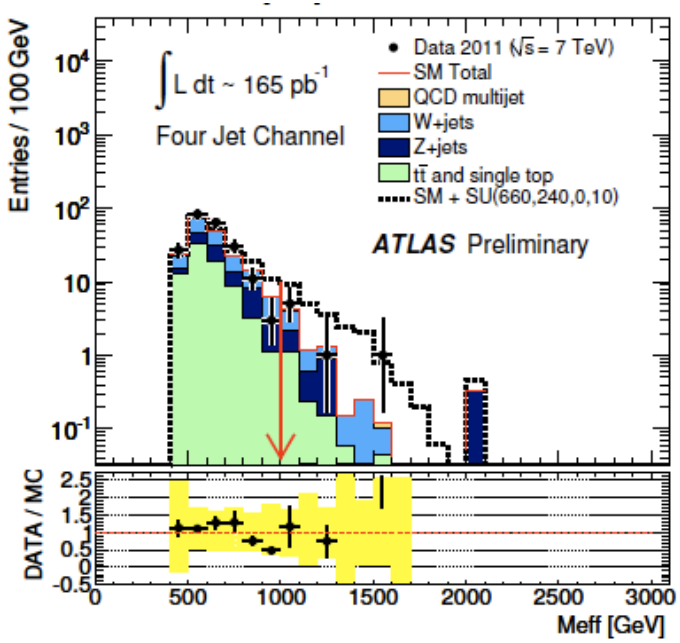
Using a simplified MSSM model.

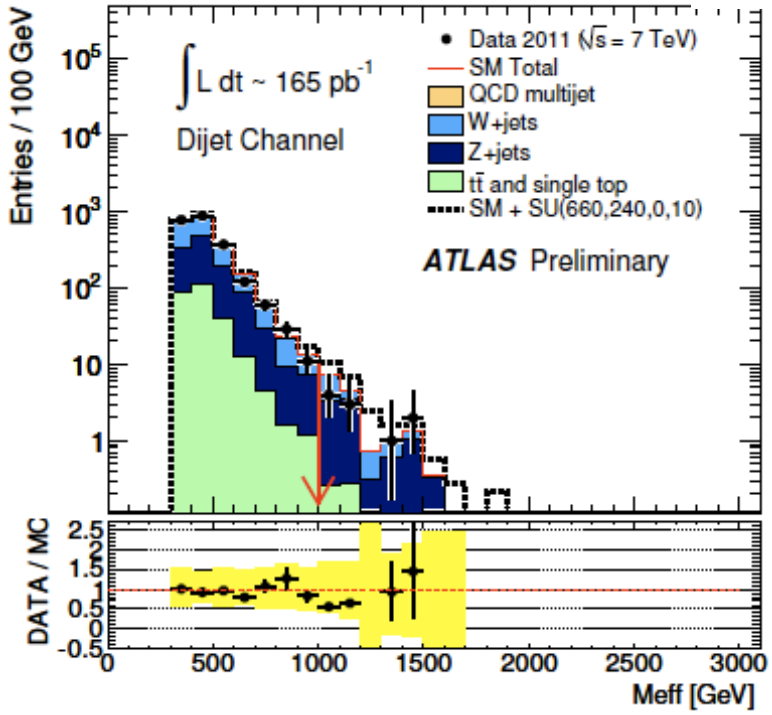
Show how powerful 7TeV searches are, even with just 35 pb^{-1}

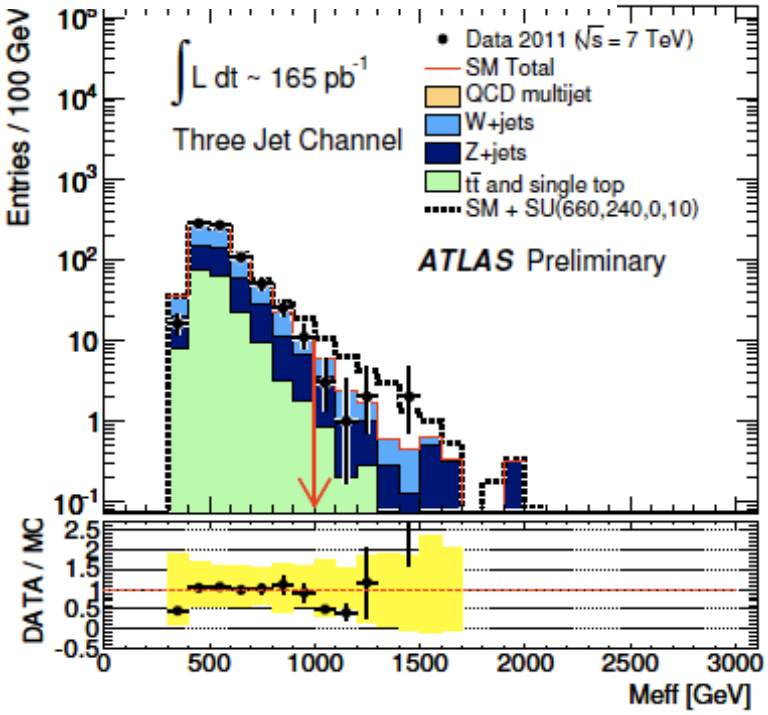
ATLAS-CONF-2011-086

Jets+MET (NEW!)

Signal Region	≥ 2 jets	≥ 3 jets	≥ 4 jets
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 130	> 130	> 130
Leading jet p_{T} [GeV]	> 130	> 130	> 130
Second jet p_{T} [GeV]	> 40	> 40	> 40
Third jet p_{T} [GeV]	–	> 40	> 40
Fourth jet p_{T} [GeV]	–	–	> 40
$\Delta\phi(\mathrm{jet}_i, E_{\mathrm{T}}^{\mathrm{miss}})_{\mathrm{min}}$ $(i = 1, 2, 3)$	> 0.4	> 0.4	> 0.4
$E_{\mathrm{T}}^{\mathrm{miss}}/m_{\mathrm{eff}}$	> 0.3	> 0.25	> 0.25
m_{eff} [GeV]	> 1000	> 1000	> 1000

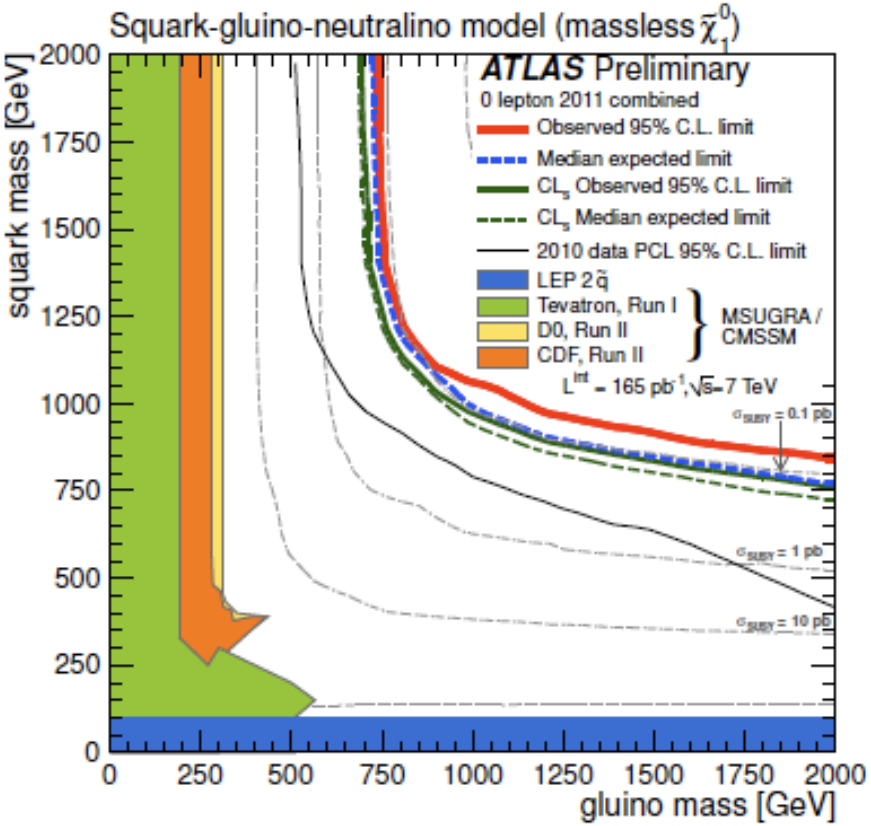


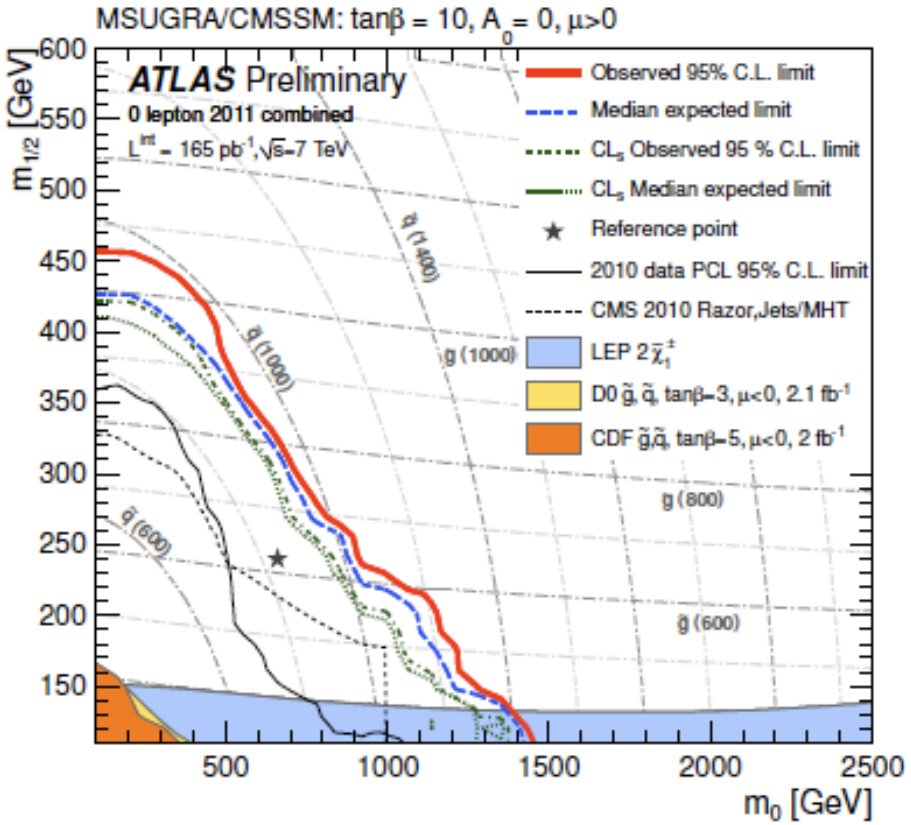




ATLAS-CONF-2011-086

MET + Jets: interpretation (new!)





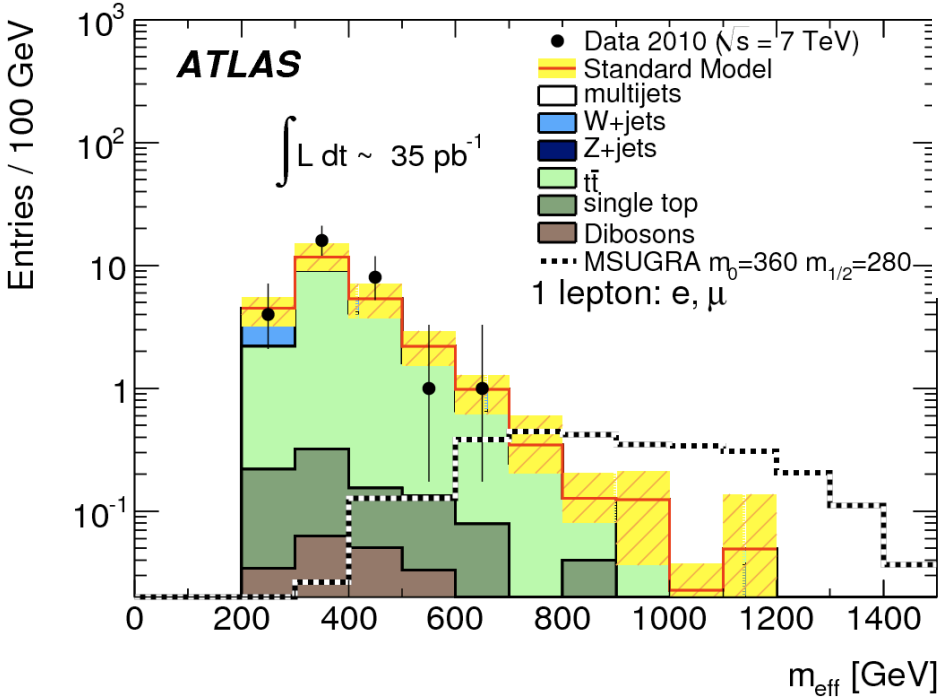
With only 165 pb^{-1} of 2011 data.
Now, we have more than 1 fb^{-1} – very exciting results soon to come!

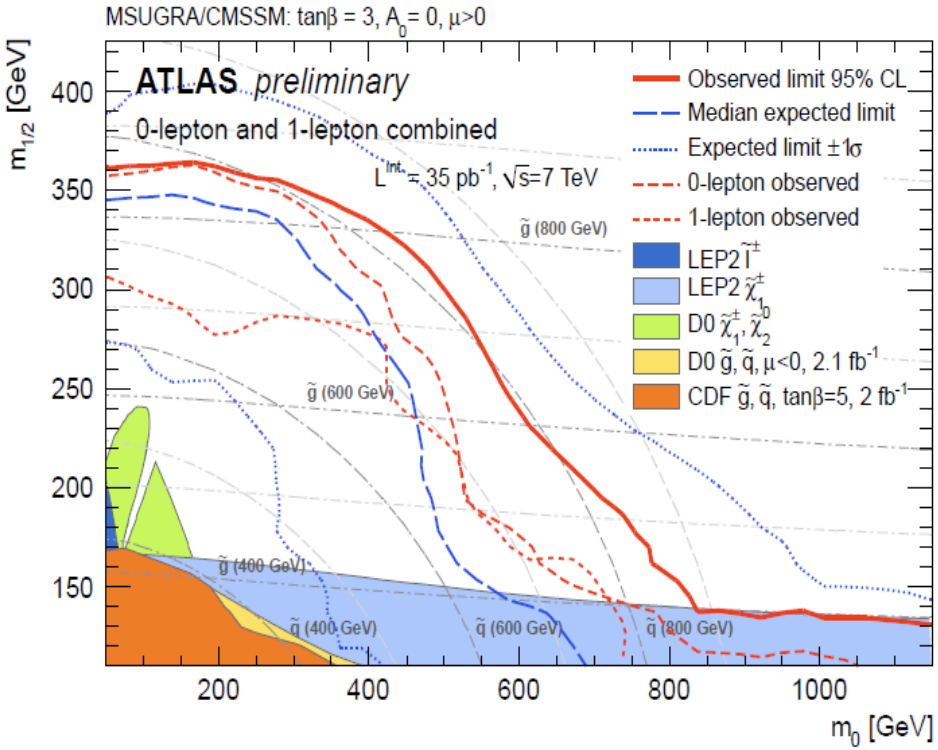
Jets + MET + 1 lepton

PRL 106, 131802
ATLAS-CONF-2011-064

Event selection:

- One lepton (e or μ)
  with p_T > 20 GeV
- ≥ 3 jets (p_T > 60, 30, 30 GeV)
- MET > 125 GeV
- M_{eff} > 500 GeV

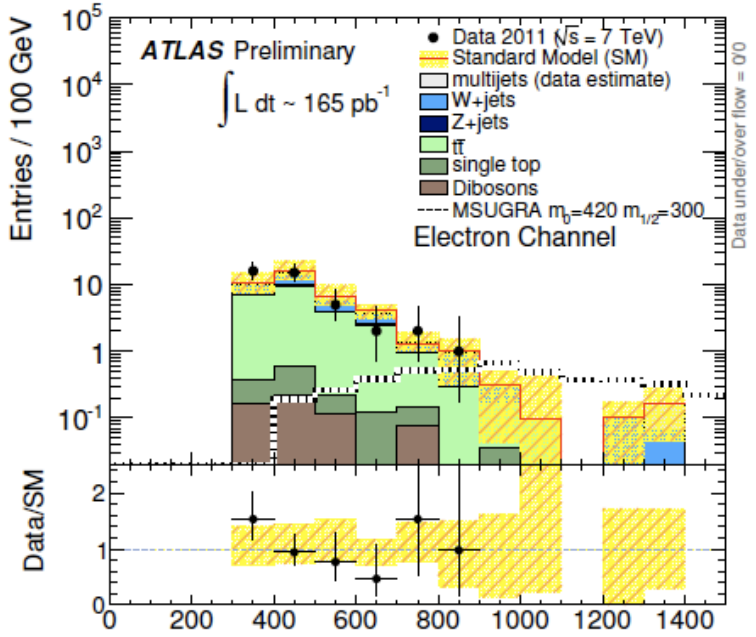


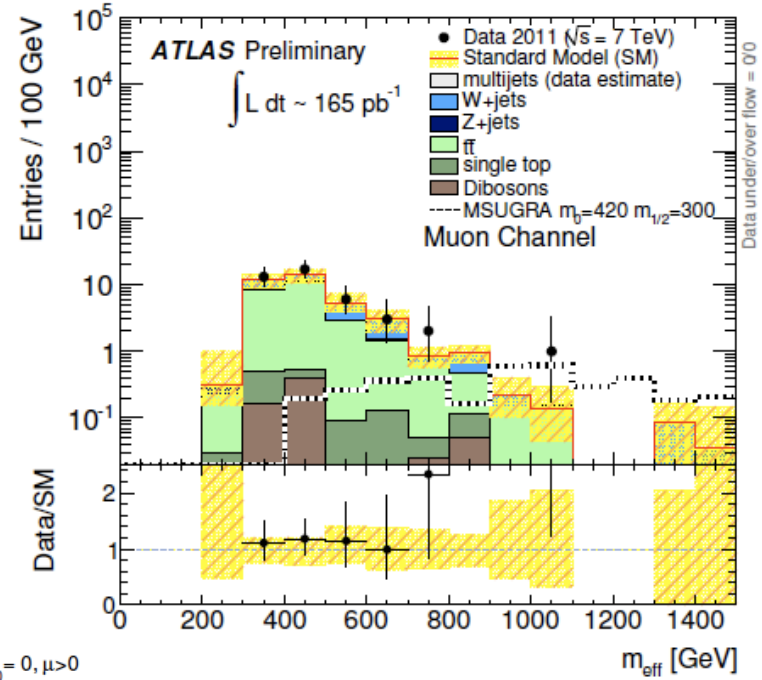


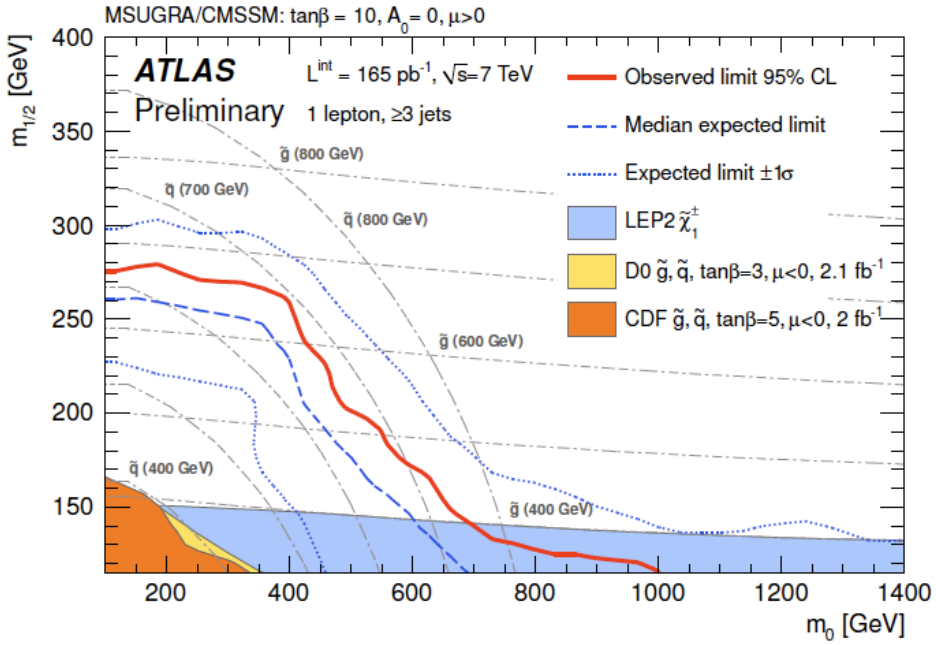
Combination of 0 and 1 lepton searches
Dominated by 0 lepton, except at low $m_{1/2}$
PCL statistical method (arxiv:1105.3166)

Jets+MET+1lepton (NEW!)

ATLAS-CONF-2011-090





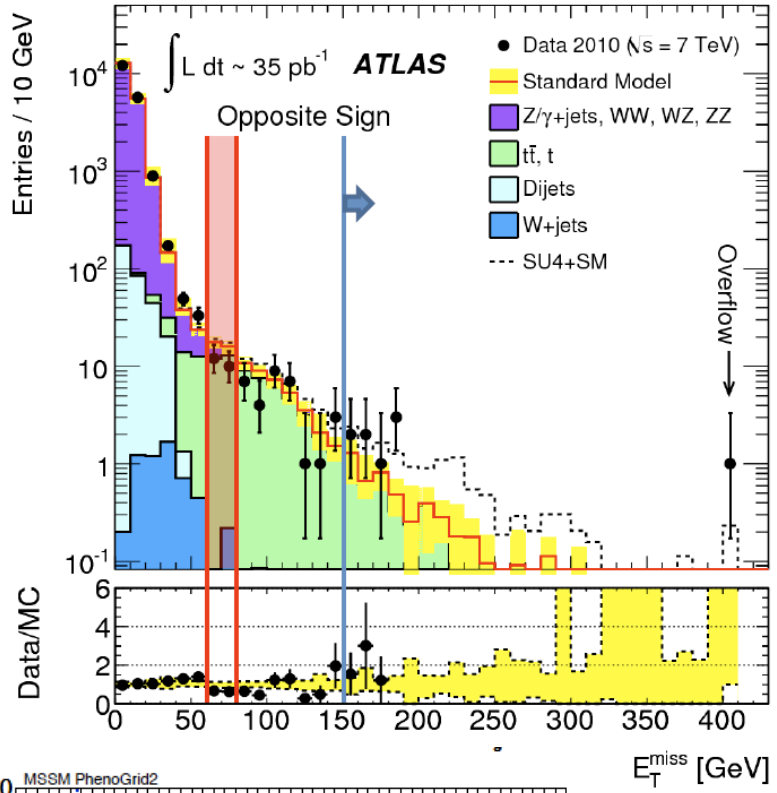


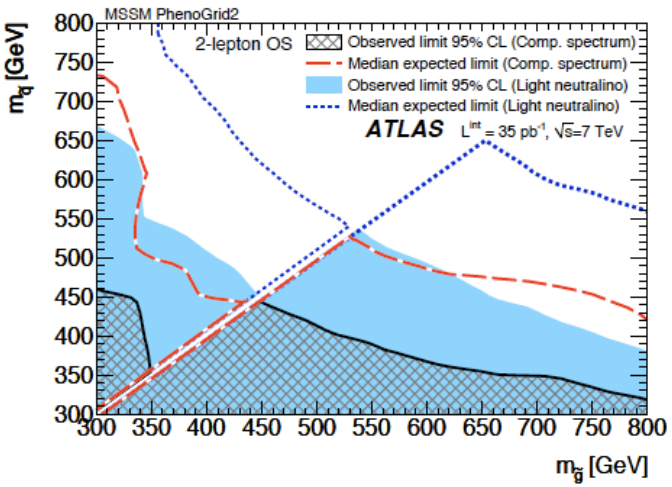
MET + 2 leptons

Arxiv:1103.6208
Arxiv:1103.6214

- Event selection
  - Two leptons, pT > 20GeV
  - MET >100 (150) GeV, for same (opposite) sign
- Count same sign and opposite-sign events
- Flavor subtraction of opposite-sign events
- Main background: top-quark decays
  - Control sample: 60<MET<80 GeV

	$e^{\pm}e^{\mp}$	$e^{\pm}\mu^{\mp}$	$\mu^{\pm}\mu^{\mp}$
Data	4	13	13
Z/γ^*+jets	0.40±0.46	0.36±0.20	0.91±0.67
Dibosons	0.30±0.11	0.36±0.10	0.61±0.10
$t\bar{t}$	2.50±1.02	6.61±2.68	4.71±1.91
Single top	0.13±0.09	0.76±0.25	0.67±0.33
Fakes	0.31±0.21	-0.15±0.08	0.01±0.01
Total SM	3.64±1.24	8.08±2.78	6.91±2.20





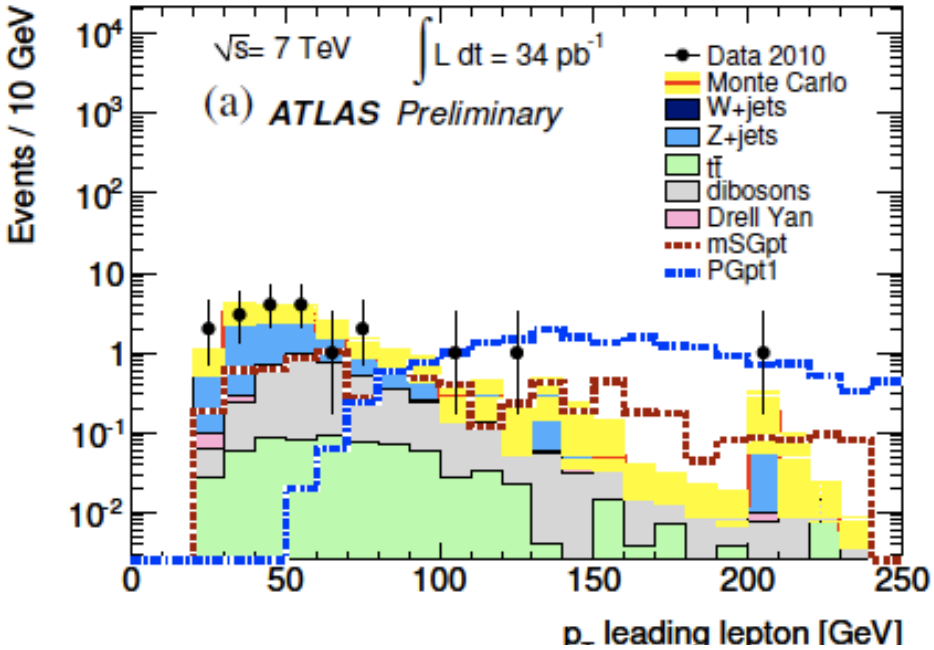
ATLAS-CONF-2011-039

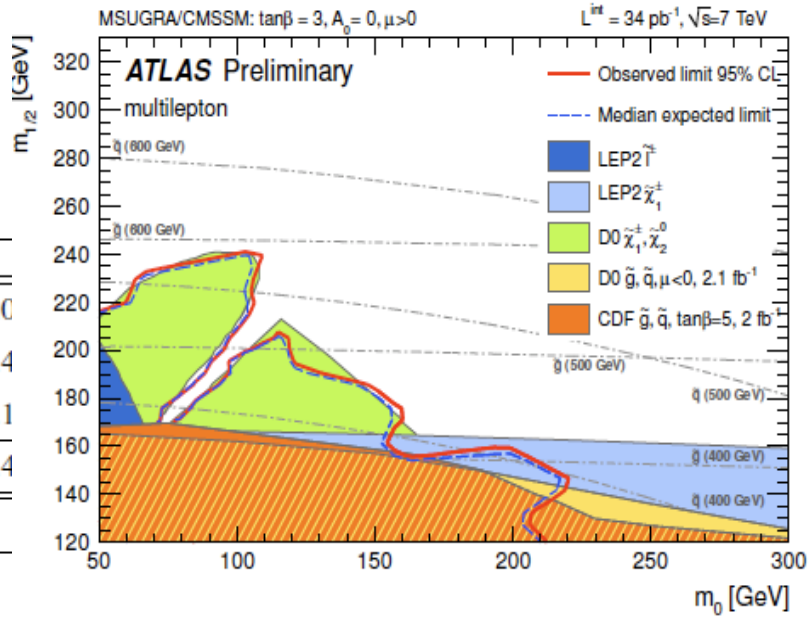
MET + multi-leptons

If gauginos & neutralinos are abundent…

Event selection:

- ≥ 3 leptons, pT > 20 (10) GeV
- ≥ 2 jets, pT > 50 GeV
- MET > 50 GeV
- Same Flavor Opposite Sign m(ll) > 20GeV and a Z-veto



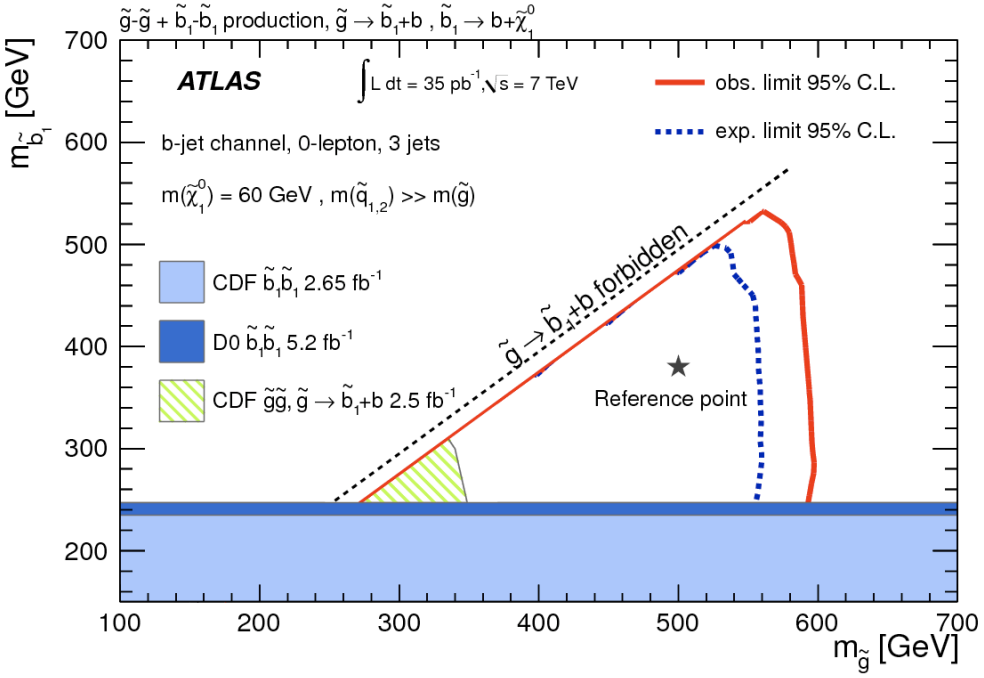


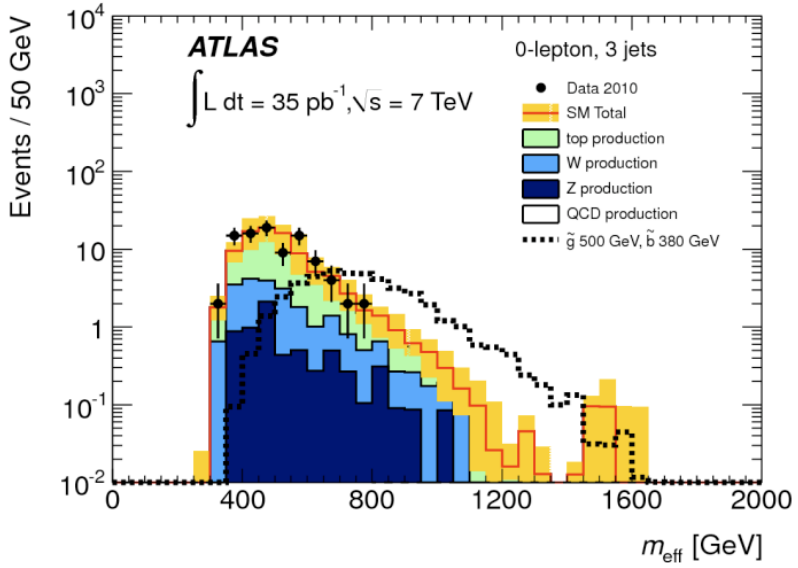
Multilep. events	All	*eee*	*eeμ*	*eμμ*	*μμμ*
$t\bar{t}$	0.68±0.16	0.032±0.016	0.24±0.07	0.31±0.08	0.096±0.0
Z backgrounds	15.6±1.3	3.8±0.8	1.60±0.34	7.9±1.0	2.4±0.4
Other backgrounds	0.28±0.13	0.02±0.14	0.03±0.06	0.21±0.09	0.01±0.1
Total SM	16.6±1.3	3.8±0.8	1.9±0.4	8.4±1.0	2.5±0.4
Data	19	2	1	10	6

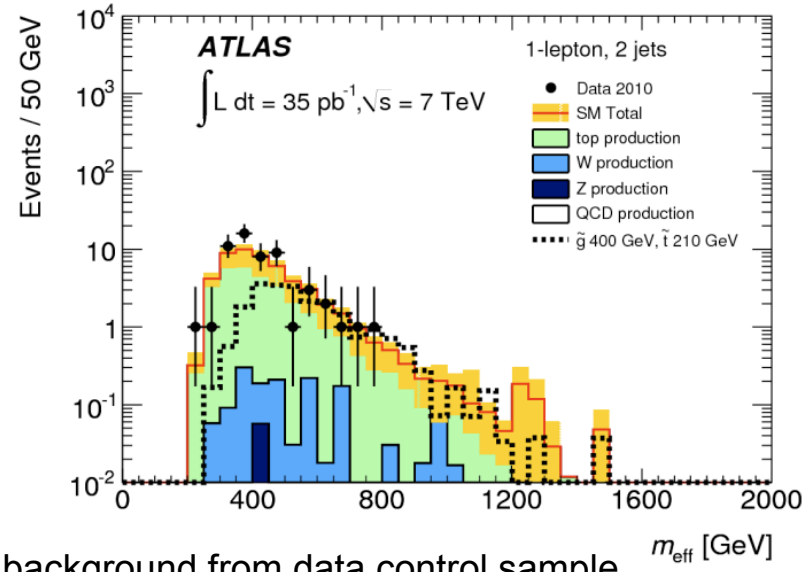
B-jets + MET + 0/1 lepton

Arxiv:1103.4344

- Event selection:
  - MET>100 GeV
  - ≥ 1 b-jet(s)
- 0-lepton selection
  - Lepton veto and ≥ 3 jets, p_T > 120, 30, 30 GeV
  - M_{eff} > 600 GeV and MET/M_{eff} >0.2
- 1-lepton selection
  - ≥ 1 Lepton, p_T > 20 GeV
  - ≥ 2 jets, p_T > 60, 30 GeV
  - M_T > 100 GeV and M_{eff} > 500 GeV







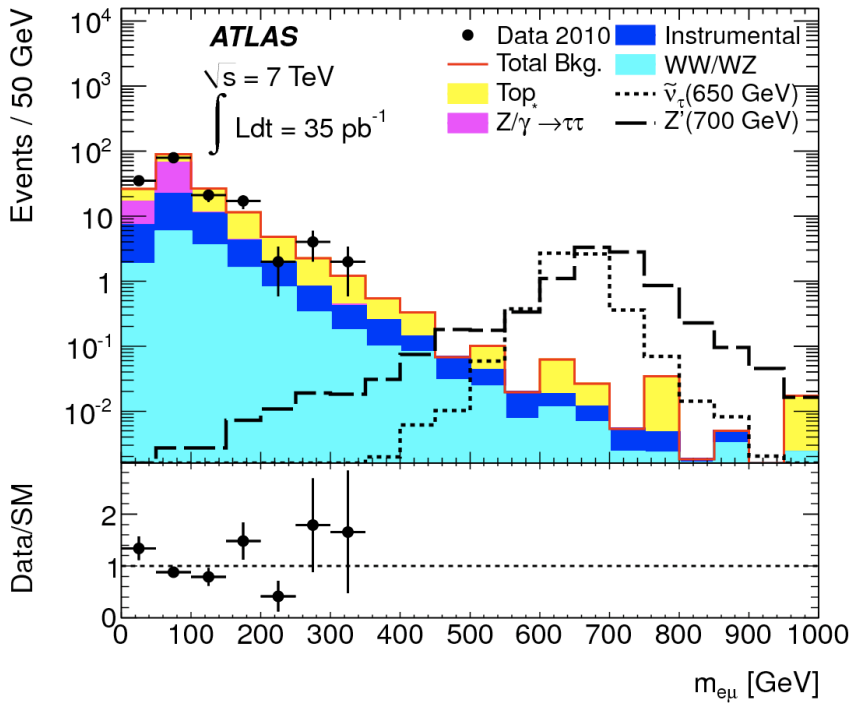
QCD background from data control sample
W, Z and Top: 0-lepton case: from simulation
1-lepton case: from data driven method.

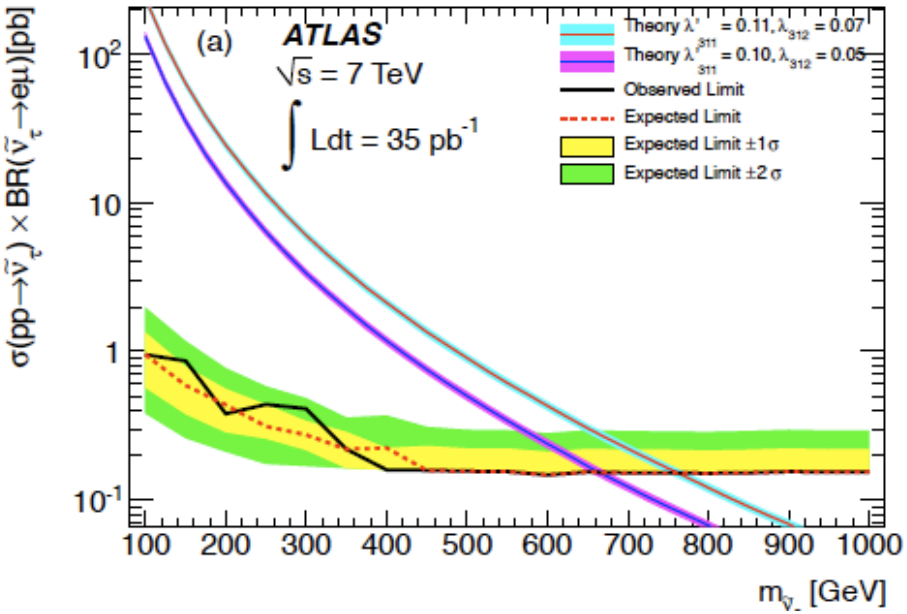
e+mu resonance

Arxiv:1103.5559

- If R-parity violating
  $\tilde{\nu}_\tau \rightarrow e\mu$
- Event selection:
- Only 1 e and 1 μ of opposite sign with pT > 20GeV + isolation

Process	Number of events
$Z/\gamma^* \rightarrow \tau\tau$	54±7
$t\bar{t}$	57±9
WW	13.4±1.7
Single top	4.6±0.9
WZ	0.79±0.11
Instrumental background	33^{+30}_{-10}
Total background	163^{+34}_{-18}
Data	160

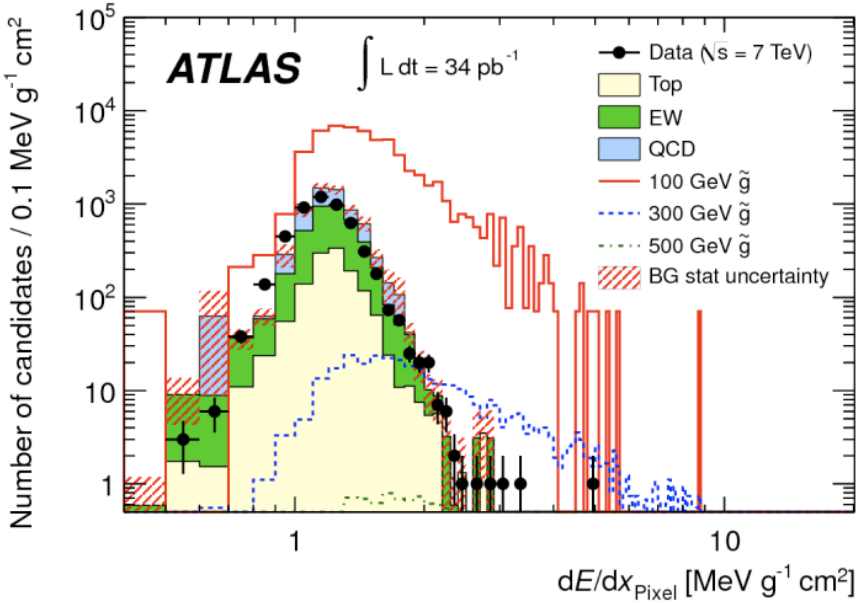


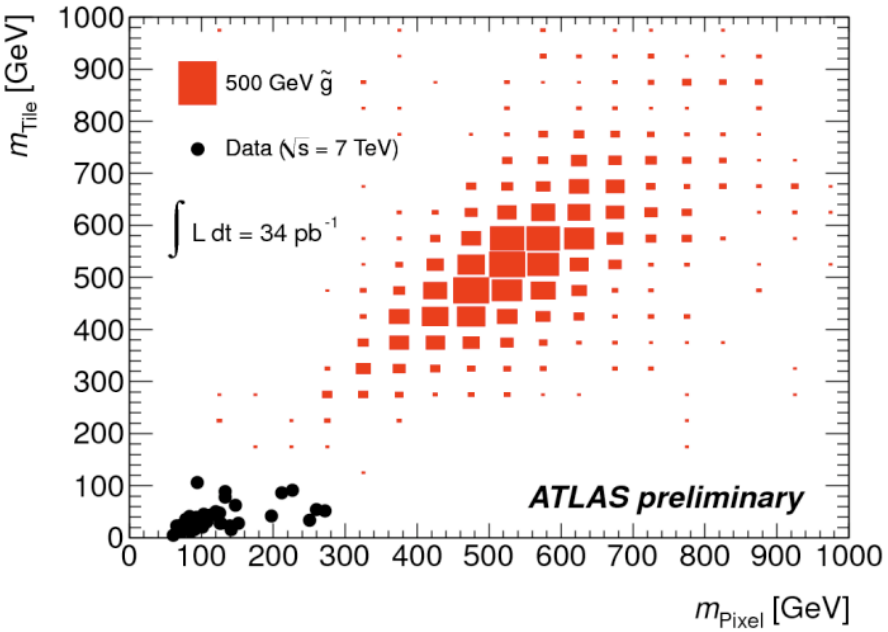


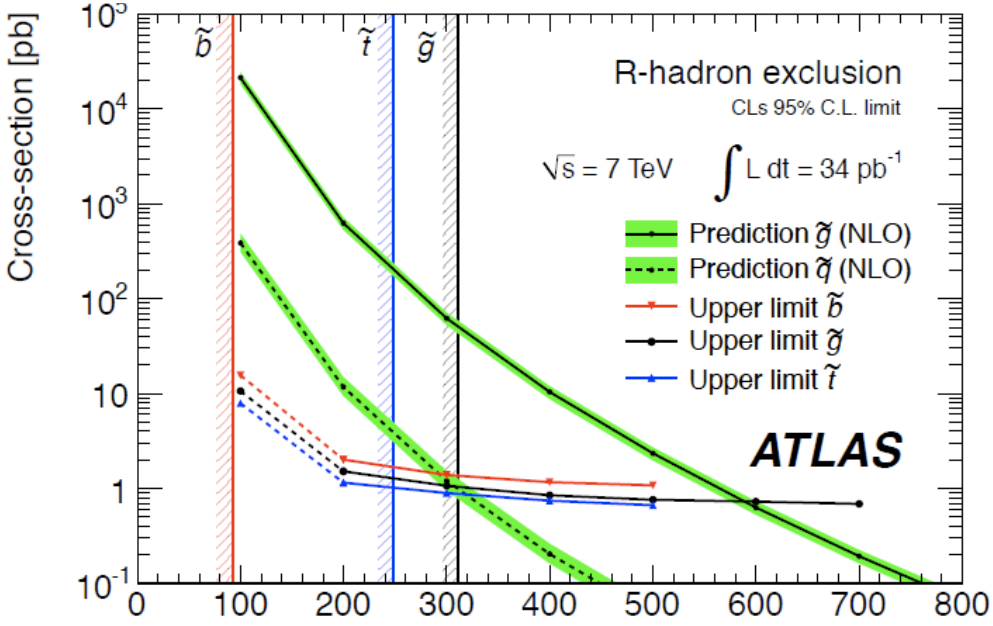
PLB 701 (2011) 1

Search for slow meta-stable particles

- Colored sparticles can hadronise into long-lived bound hadronic states, called R-hadrons
- Event selection
  - Trigger on MET
  - Require isolation, dR>0.5 to all jets
  - Large dE/dx in pixel detector
  - Long time-of-flight in Tile calorimeter
- Background : instrumental



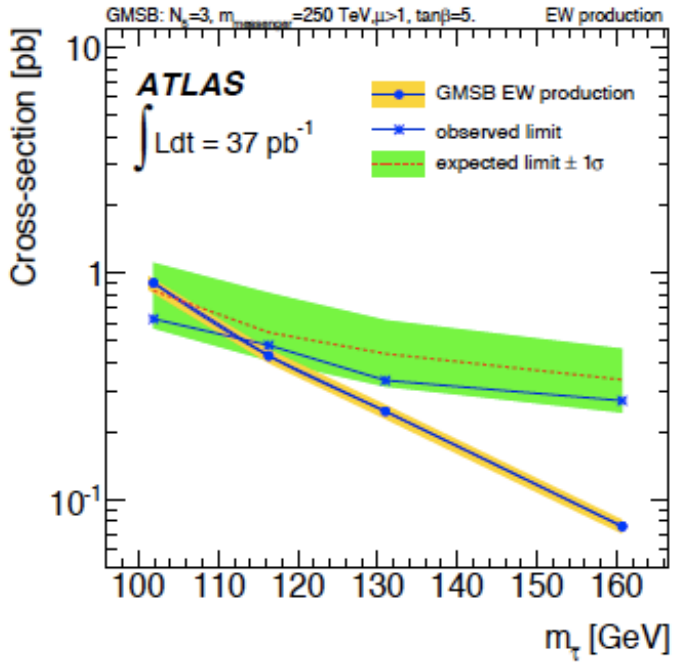


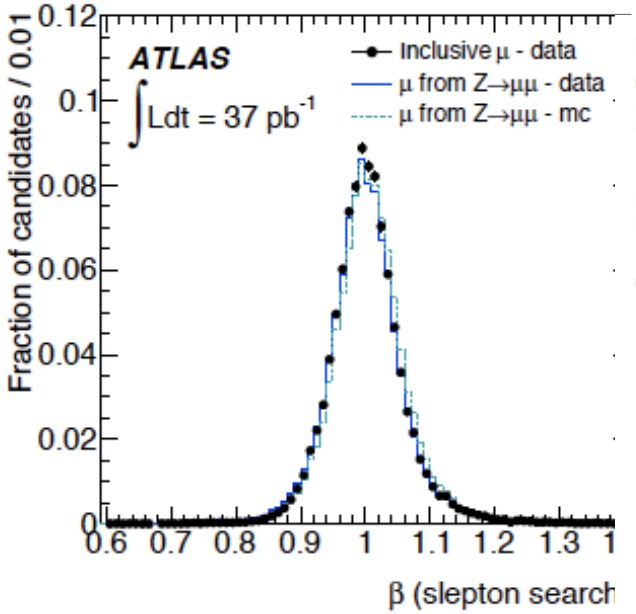


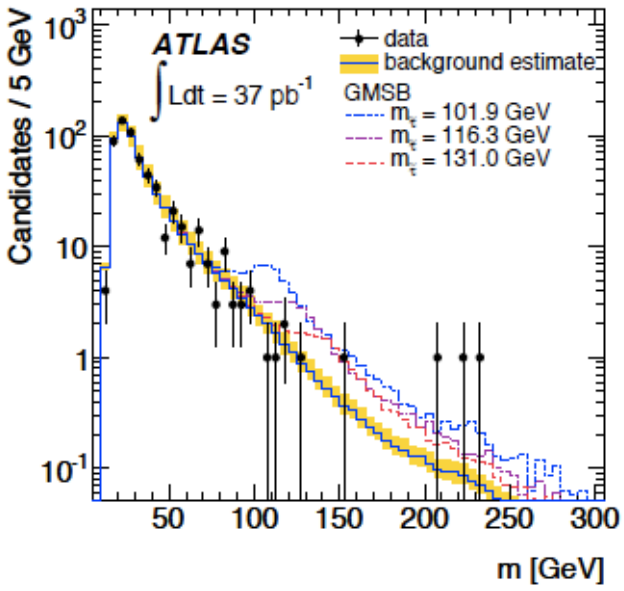
Search for Long-Lived Charged Particles

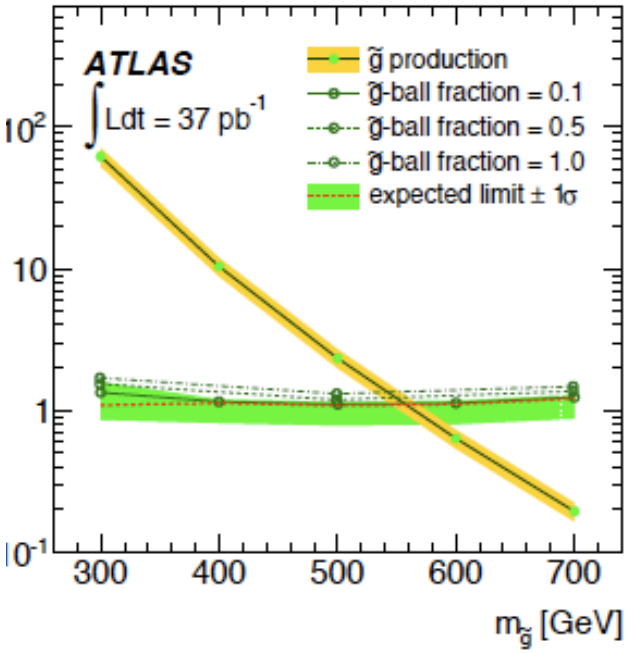
Arxiv:1106.4495

- Muon spectrometer: late arrival time
- Select $\beta < 0.95$









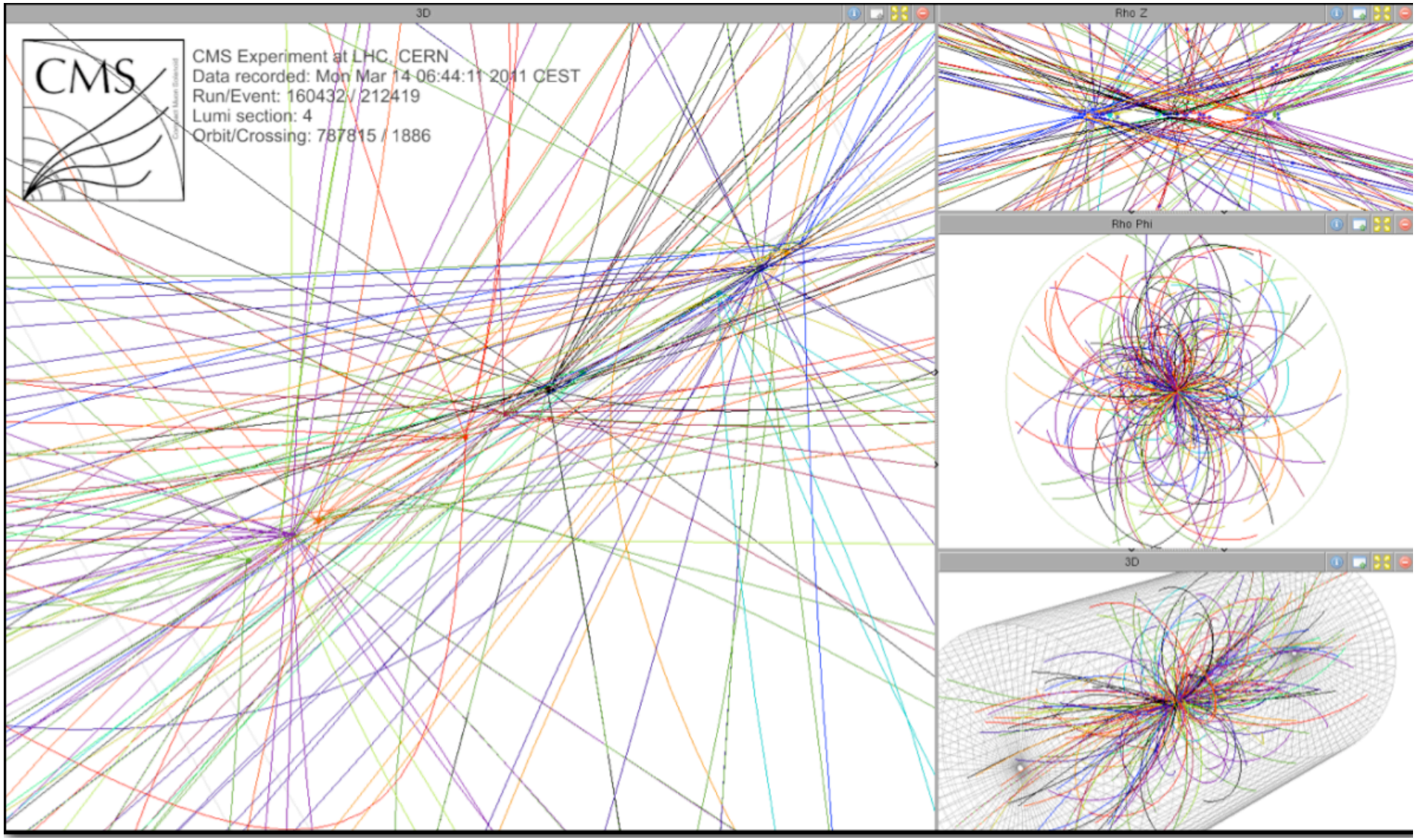
Conclusions and Outlook

- 2 analyses updated with 2011 data so far
- More are being prepared for EPS
- Already surpassed Tevatron sensitivity
- No sign of new physics yet
- Very exciting time to be doing physics at the LHC and elsewhere!

- *A big thanks to the LHC teams and Grid computing teams for the excellent performance!*

BACKUP

Challenge of the LHC environment



LHC Time-line

2009 — Start of LHC

Run 1: 7 TeV centre of mass energy, luminosity ramping up to few 10^{33} cm^{-2} s^{-1}, few fb^{-1} delivered

2013/14 — LHC shut-down to prepare machine for design energy and nominal luminosity

Run 2: Ramp up luminosity to nominal (10^{34} cm^{-2} s^{-1}), ~50 to 100 fb^{-1}

2017 or 18 — Injector and LHC Phase-I upgrades to go to ultimate luminosity

Run 3: Ramp up luminosity to 2.2 x nominal, reaching ~100 fb^{-1} / year accumulate few hundred fb^{-1}

~2021/22 — Phase-II: High-luminosity LHC. New focussing magnets and CRAB cavities for very high luminosity with levelling

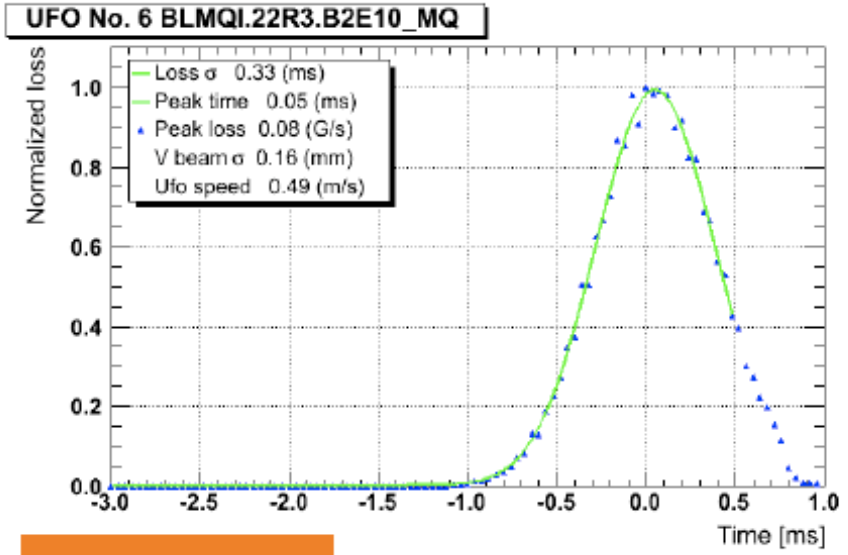
Run 4: Collect data until > 3000 fb^{-1}

2030 — ILC, High energy LHC, ... ?

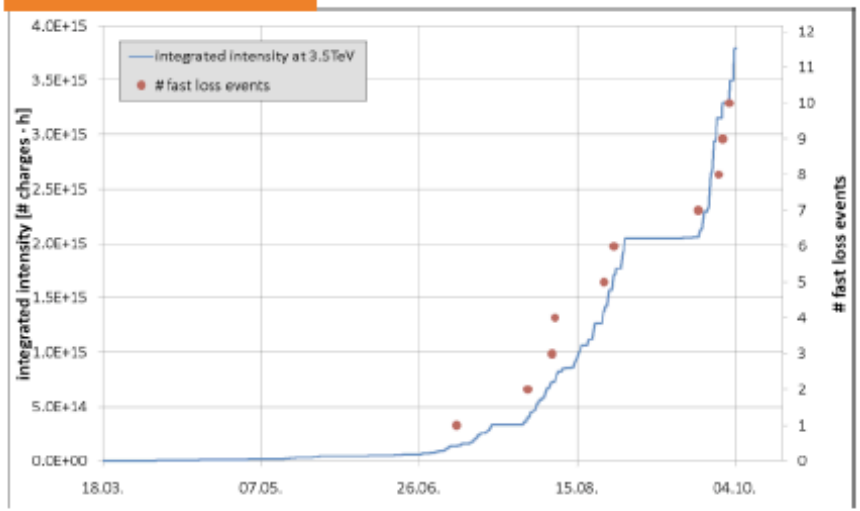
CERN status and plans, Sergio Bertolucci's talk at the PLHC, 6/6/2011

UFOs - Unidentified Falling Objects

- Sudden fast local losses recorded: most likely: dust (10's μm) particles falling into beam creating losses propagating downstream
- **18 beam dumps** due to UFOs
- 113 UFOs below threshold found in logging database in 2010
- UFO rate proportional to intensity
- No dependency of peak signal on intensity
- Loss duration (~ms) has tendency to become faster with higher intensity.



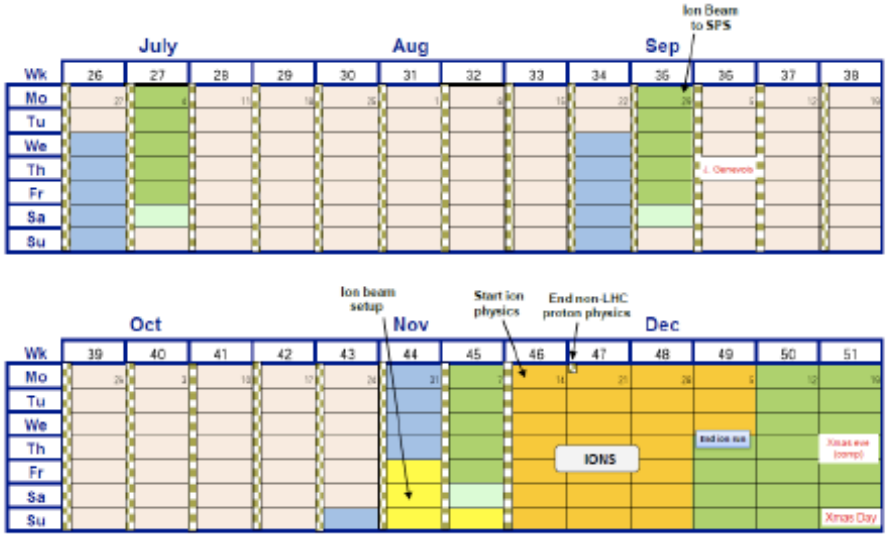
J. Wenninger



From the PLHC

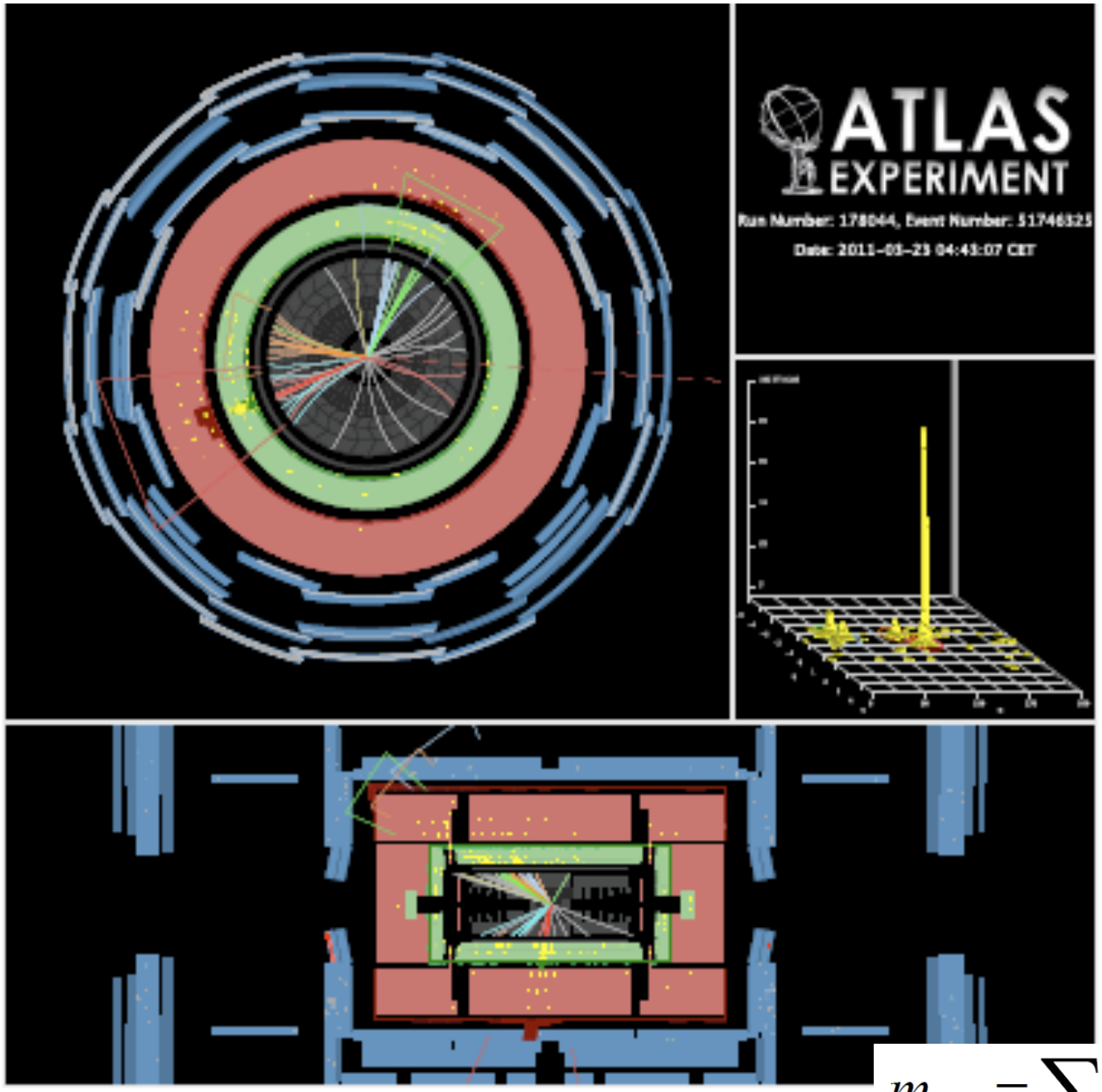
Outlook for 2011 (protons)

- Length and frequency of the technical stops optimized to maximize periods of steady production
- 115 days at >10^{33} $cm^{-2}s^{-1}$ and an efficiency for Physics (Hubner factor) of 0.2 gives >2.3 fb^{-1}
- Main unknown: UFOs and SEU but we are working on that!



- 25 ns studies to come during MDs (to sort out injection and beam stability issues) and possibly an operational development period to validate scrubbing and future operation scenarii

From the PLHC



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$$m_{Eff} \equiv \sum p_T^{jet} + E_T^{miss} + \left(p_T^{\ell}\right)$$

Figure 9: A display of the reconstructed event with the highest m_{eff} found in the data sample used for this note. This event possesses four jets with $p_{\text{T}} > 40$ GeV ($p_{\text{T}} = 636$, 189, 96 and 81 GeV respectively), $E_{\text{T}}^{\text{miss}} = 547$ GeV and $m_{\text{eff}} = 1548$ GeV (calculated using the leading four jets).