R-hadrons at ATLAS

Discovery and Properties

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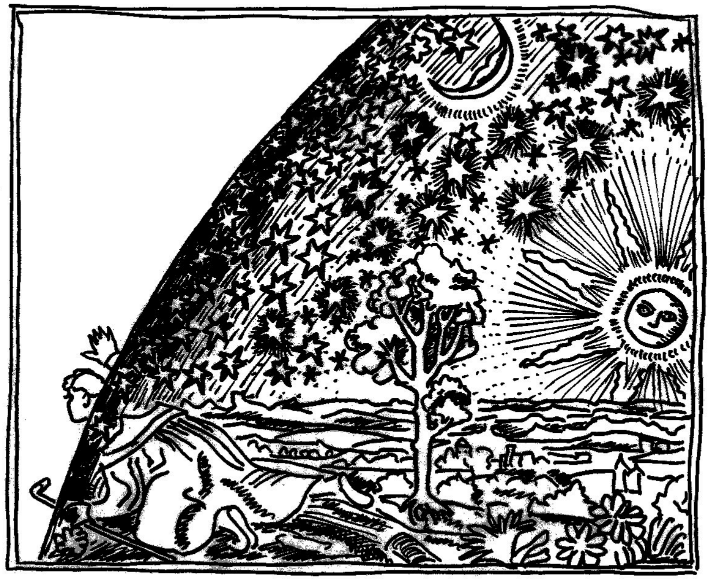
Outline

- Stable Massive Particles
- Gluino R-hadrons
- R-hadron interactions
- Experimental signatures
- R-hadrons at ATLAS
- Conclusion



Is there anything beyond the Standard Model?

Stable Massive Particles

Metastable -can traverse detectors without decaying, but not a dark matter candidate.

Commonly studied SUSY scenarios:

Particle	Scenario	Color
Gluino	Split-SUSY	8
Stop	SUSY 5D G-MSB	3
Chargino	AMSB	0
Stau	GMSB	0

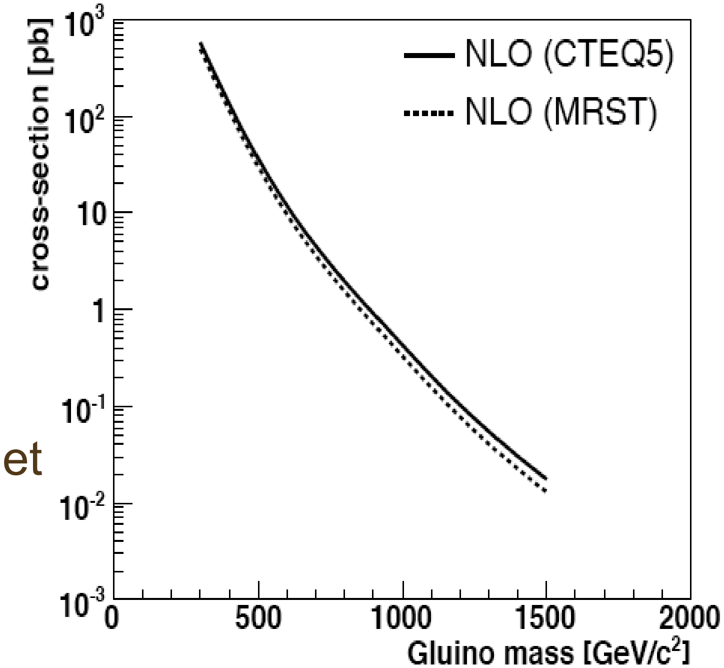
} **R-hadrons**

also RPV SUSY, UED, leptoquarks, exotic quarks…

Identification of SMPs important tool in exotic program, non-discovery (almost) equally important in model discrimination

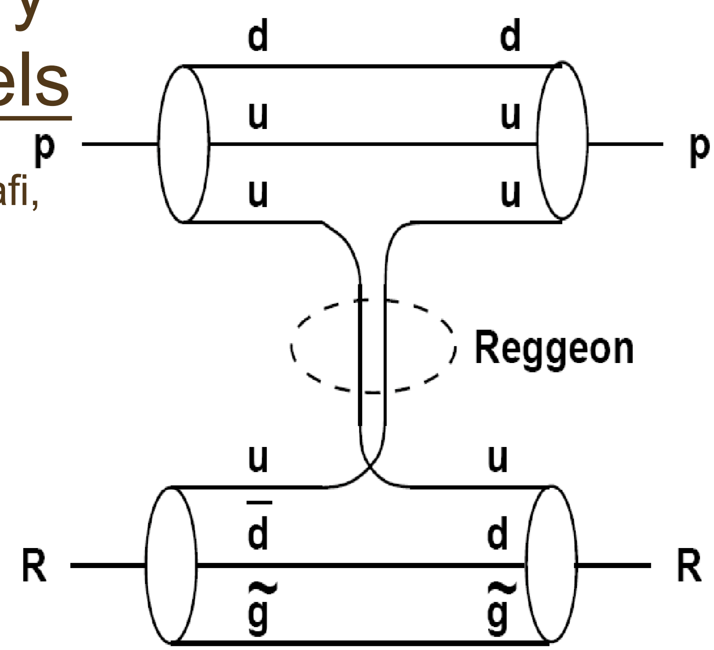
Gluino R-hadrons

- Studies done at ATLAS are all within the Split-SUSY scenario
- Split-SUSY -hierarchy problem abandonded, allows for SUSY-breaking at some high scale, can lead to heavy scalars and light fermions.
- Large cross section for gluino R-hadrons, for m=1 TeV, 1500 events ~ 1 fb^{-1}
- Gluino R-hadron mass splittings available T.Sjöstrand et al. (hep-ph/0603175).



R-hadron interactions

- Heavy constituent is a non-interacting spectator. Light constituents interact like ordinary hadrons → <u>interaction models very uncertain.</u> Kraan(hep-ex/0404001), Mafi, Raby (hep-ph/9912436), Baer, Cheung, Gunion(hep-ph/9806361)
- Expected energy loss; tens of GeV, collision length -10 cm.



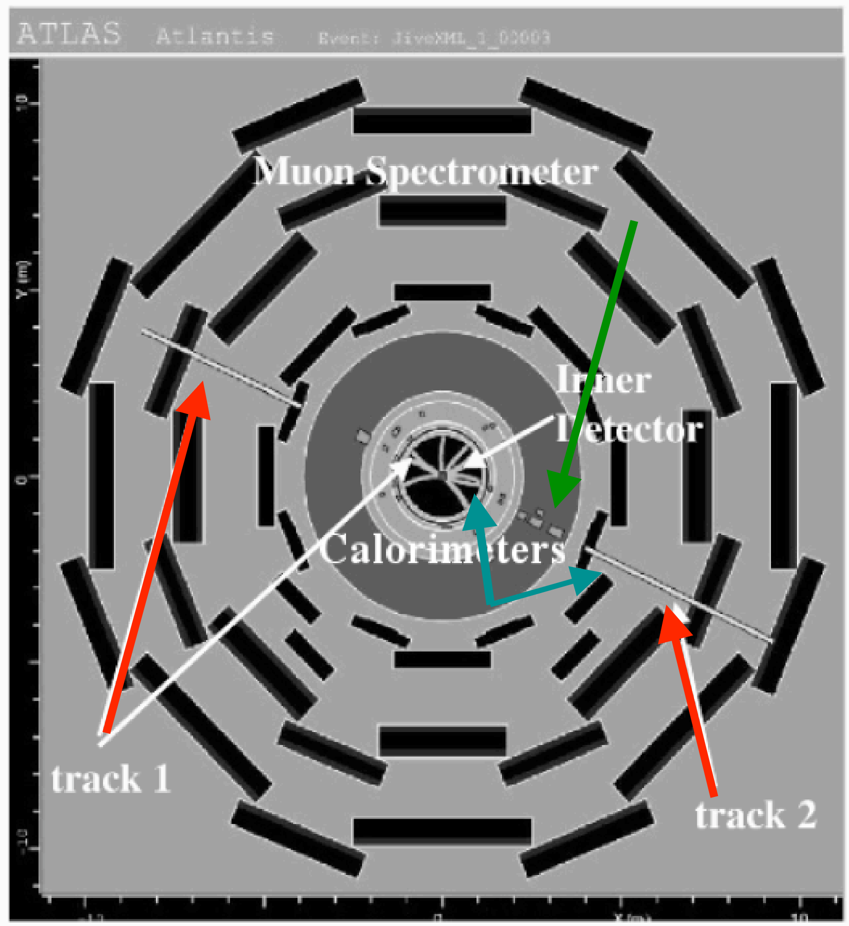
Experimental signatures

- Measured as delayed muon, timing resolution ~1ns
- Triggered as a high-pT muon
- Charge flippers

$$\tilde{g}d\bar{d} + uud \rightarrow \tilde{g}u\bar{d} + uud$$

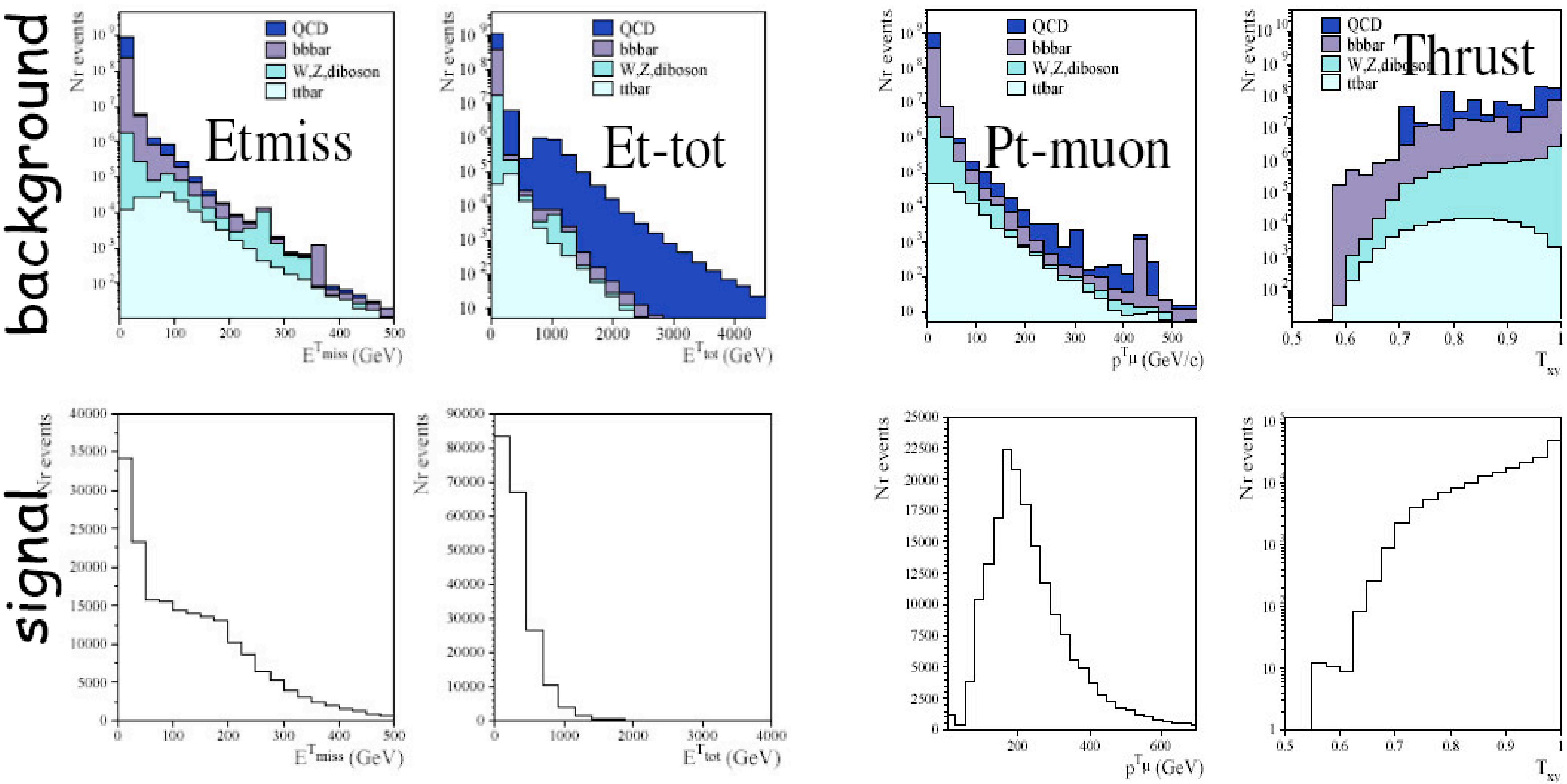
- Larger hadronic energy deposit than muons
- R-mesons convert to R-baryons

$$\tilde{g}d\bar{d} + uud \rightarrow \tilde{g}udd + u\bar{d}$$



R-hadrons at ATLAS

- **First search**, global variables, transverse momentum in the muon system, missing transverse energy, total energy and thrust.
- An excess > 5σ can be found by cutting on these variables (Kraan, Hansen, Nevski, hep-ex/0511014)



Results from global cuts

Background	$\frac{N_{trig}}{N_{gen}}$ (%)	σ (mb)	$N_{trig}(1\text{fb}^{-1})$	$N_{sel}(1\text{fb}^{-1})$
QCD $\hat{p}_T < 17\,\text{GeV}/c^2$	-	4.8×10^3	-	-
QCD $17\,\text{GeV}/c^2 < \hat{p}_T < 35\,\text{GeV}/c^2$	0.04	1.4	6.0×10^8	-
QCD $35\,\text{GeV}/c^2 < \hat{p}_T < 140\,\text{GeV}/c^2$	0.05	9.9×10^{-2}	5.2×10^7	-
QCD $140\,\text{GeV}/c^2 < \hat{p}_T < 560\,\text{GeV}/c^2$	0.8	3.2×10^{-4}	2.7×10^6	24
QCD $\hat{p}_T > 560\,\text{GeV}/c^2$	97.7	6.6×10^{-7}	5.5×10^5	168
bb $\hat{p}_T < 35\,\text{GeV}/c^2$	0.1	4.8×10^{-1}	4.9×10^8	-
$b\bar{b}$ $35\,\text{GeV}/c^2 < \hat{p}_T < 140\,\text{GeV}/c^2$	0.6	3.8×10^{-4}	2.3×10^6	-
$b\bar{b}$ $140\,\text{GeV}/c^2 < \hat{p}_T < 560\,\text{GeV}/c^2$	4.4	1.1×10^{-6}	5.1×10^4	4
$b\bar{b}$ $\hat{p}_T > 560\,\text{GeV}/c^2$	98.9	9.8×10^{-10}	9.7×10^2	10
$t\bar{t}$	29.8	4.9×10^{-7}	1.5×10^5	187
W	7.2	1.6×10^{-4}	1.1×10^7	47
Z	0.88	6.0×10^{-4}	5.3×10^6	4
diboson	6.2	2.5×10^{-6}	1.6×10^5	14
R-hadrons M=100 GeV/c^2	45.0	5.6×10^{-5}	2.5×10^7	393k
R-hadrons M=300 GeV/c^2	70.0	2.8×10^{-7}	1.97×10^5	54k
R-hadrons M=600 GeV/c^2	60.0	5.2×10^{-9}	3.1×10^3	1.2k

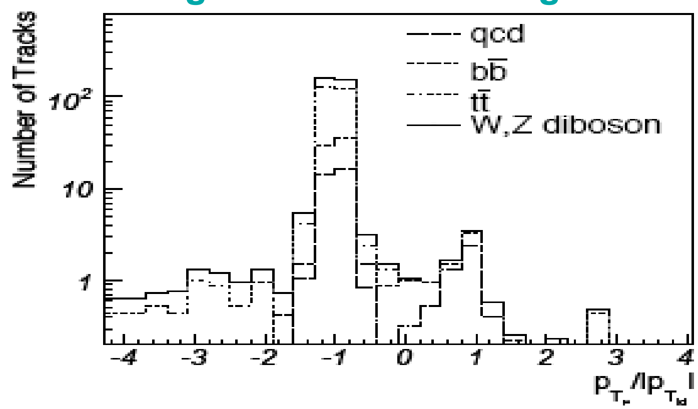
Charge flipping

- Strategy for detecting and identifying gluino R-hadrons
  Hellman, Milstead, Ramstedt (ATL-PHYS-PUB-2006-005)
- Three different selection criteria:
  1. Opposite charge tracks in Inner Detector (ID) and Muon System
  2. Two same sign, high pT-tracks in Muon System
  3. Two same sign, high pT-tracks in Muon System, and explicitly no tracks in ID.
- Selection criteria has a good discrimination rate up to gluino masses of 1 TeV $\longrightarrow$ a pure R-hadron sample can be extracted

Results from selection criteria 1.

Source		Number of tracks passed Scaled to 2fb^{-1}
Signal	300	21,598
Gluino mass	500	1,742
(GeV/c^2)	1000	16
Background	QCD	11
$p_T > 150$ GeV	$b\bar{b}$	4.0
	$t\bar{t}$	0.9
	W, Z, diboson	1.1
	total	17
Background	QCD	0.6
$p_T > 350$ GeV	$b\bar{b}$	0.7
	$t\bar{t}$	0
	W, Z, diboson	0.33
	total	1.6

Charge of ID tracks is negative!



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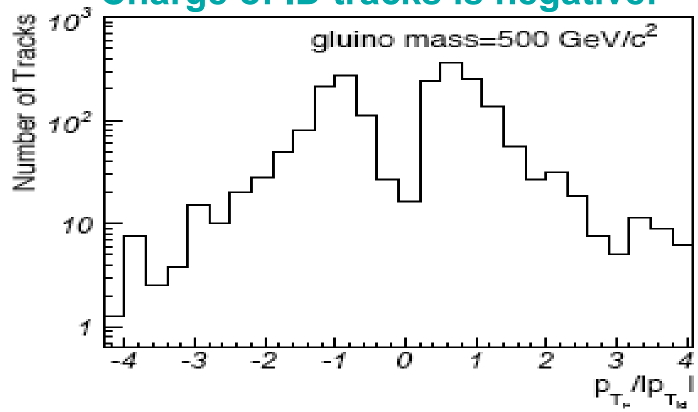
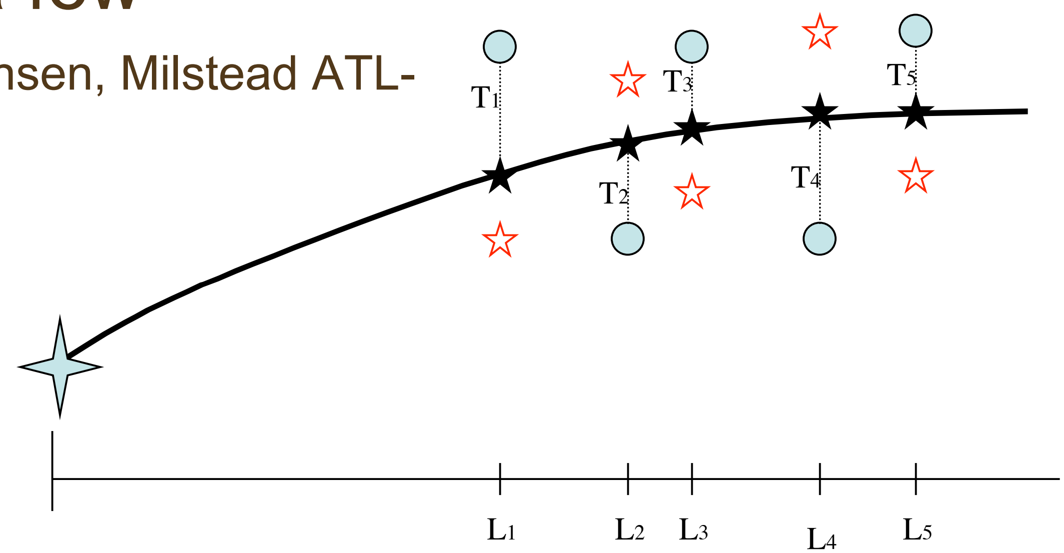
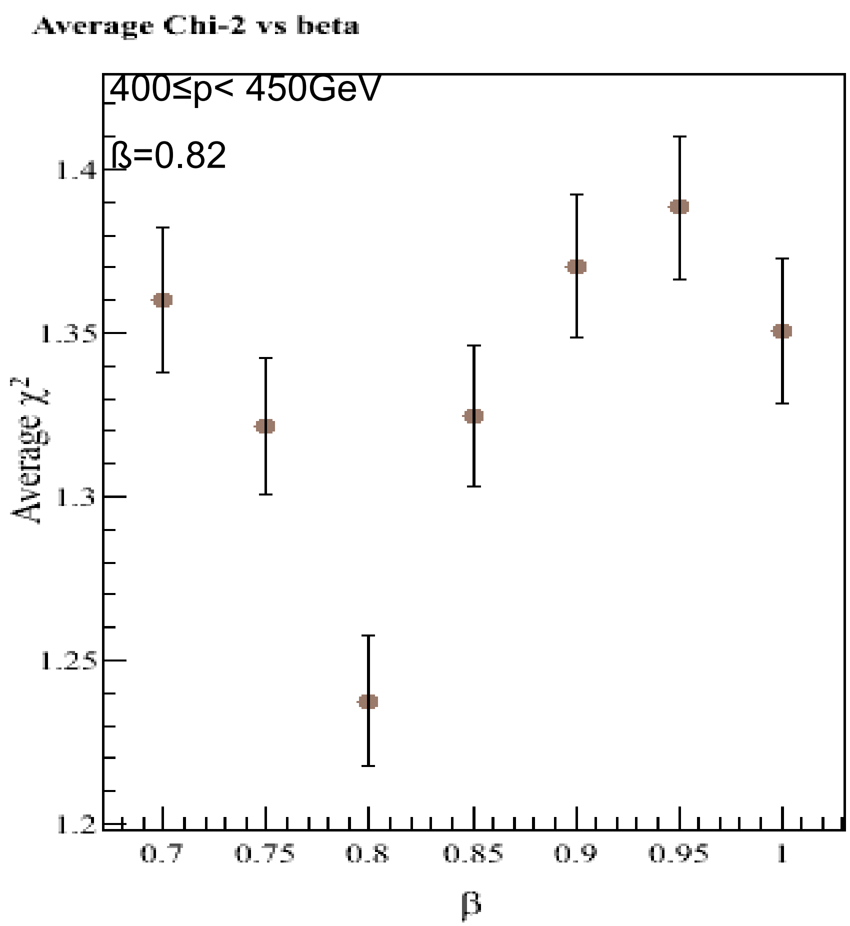


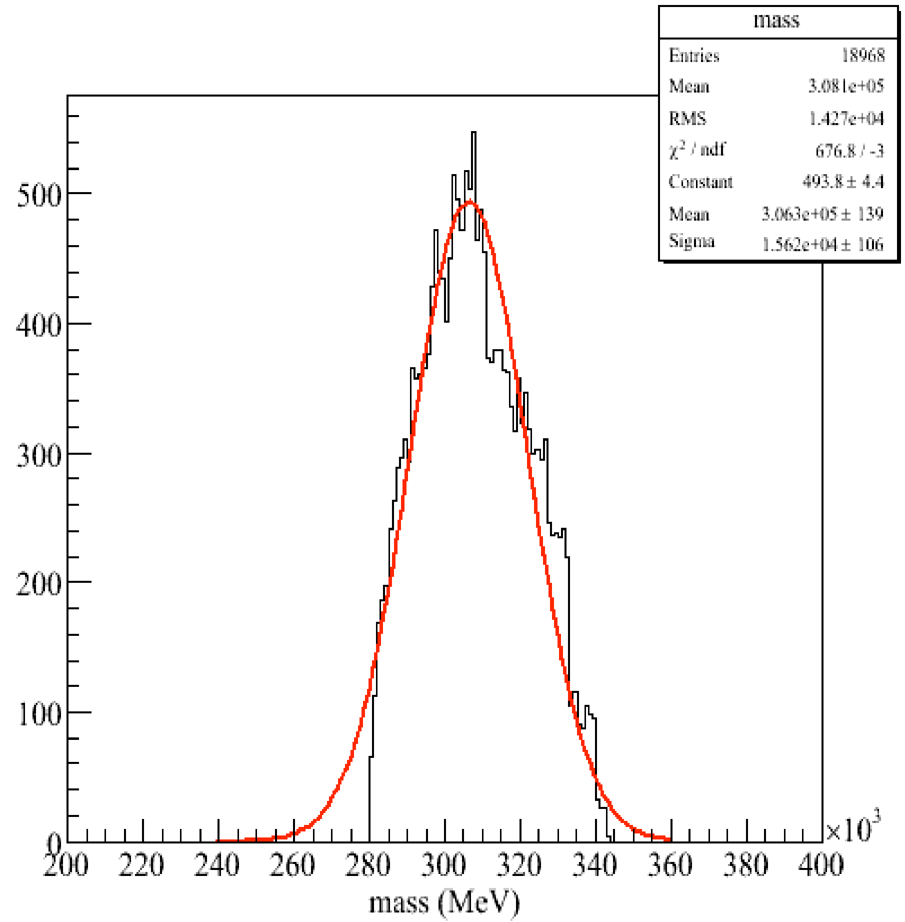
Mass determination

- Time-Of-Flight method, using Moore fits, (Polesello, Rimoldi ATL-MUON-99-006) used for mass determination.
- Masses can be determined up to an accuracy of a few percent. (Hellman, Johansen, Milstead ATL-PHYS-PUB-2006-01)



Mass determination





Conclusion

- SMPs are predicted in many scenarios of new physics
- Large cross-sections and distinct signatures for gluino R-hadrons allows for early discovery at LHC.
- Search strategies and mass resolution studied at ATLAS