
# Supersymmetry prospects for 0.5-1fb$^{-1}$ with the LHC

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on behalf of ATLAS and CMS collaboration


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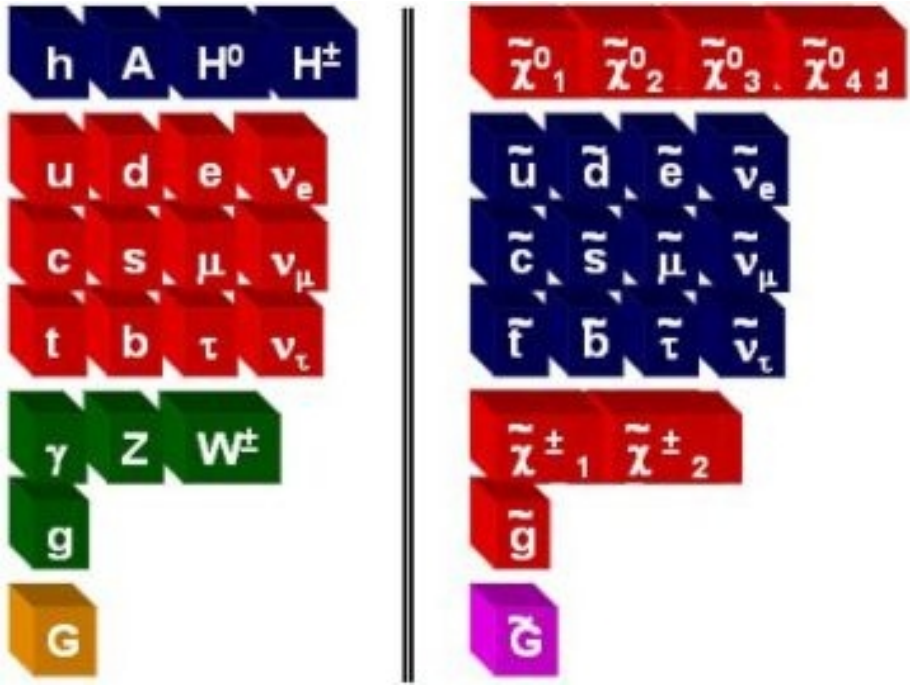
# Outline

- SUSY reminder
- ATLAS & CMS
- Searches for SUSY with missing transverse momentum (MET)
  (first data results & MC prospects for L=1fb$^{-1}$)
- Searches for SUSY with long-lived particle signatures
  (first data results & MC prospects for L=1fb$^{-1}$)

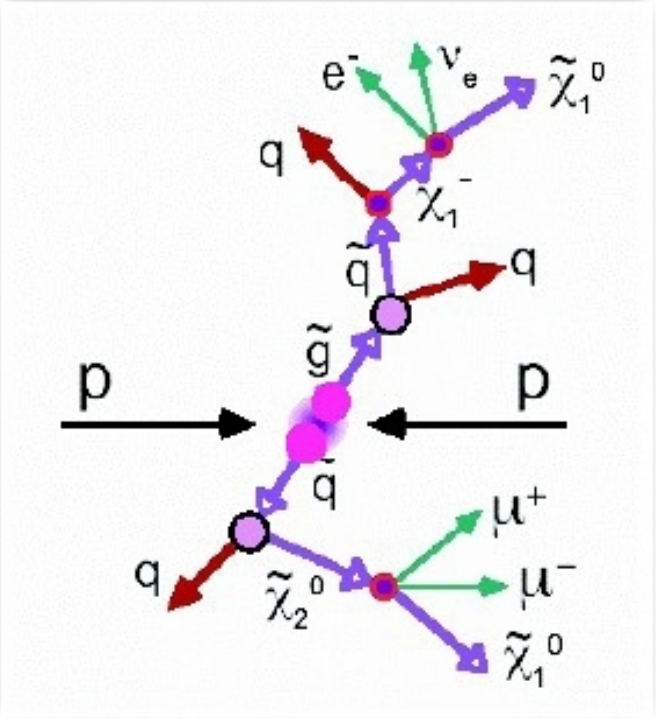
# What's SUSY

- **SUSY:** extension of the Standard Model with additional symmetry between spin $\frac{1}{2}$ fermions and integer spin bosons
- it's a broken symmetry (SUSY particles must have larger mass than the SM particles O(0.2-1TeV))



# SUSY signal at LHC

- at LHC SUSY production dominated by strongly interacting squarks and gluinos
- if R-parity is conserved SUSY particles are always produced in pairs
- **long cascade decays** with the lightest stable SUSY particle (LSP) at the end of the decay chain
- **Typical event signature:** MET, multiple jets and possibly leptons

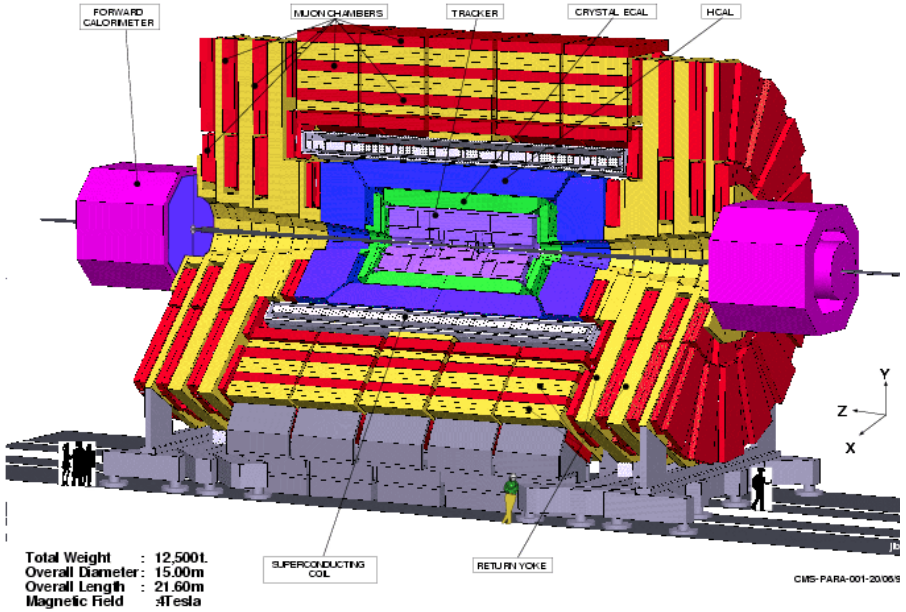


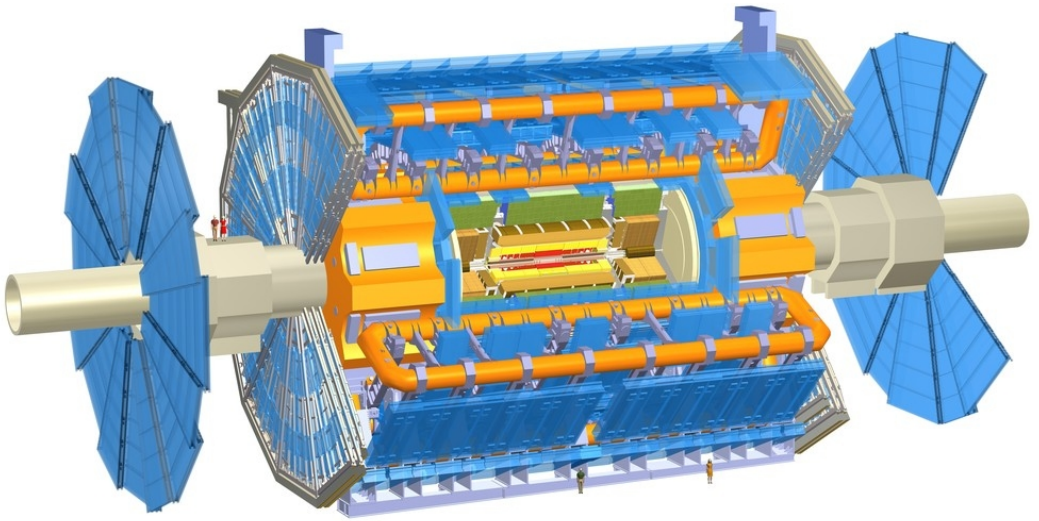
# SUSY models

- MSSM model: more than 100 free parameters
- Sub-models with less parameters: mSUGRA, GMSB, AMSB, ...
- **Depending on the parameters SUSY can have a huge variety of signals:**
  - **Standard signatures:** MET, jets, maybe leptons, maybe photons
  - **Non-standard signatures:** long lived heavy particles, non-pointing photons, events without MET

**Searches need to be quite general and model/parameter independent**

# CMS and ATLAS detectors



## CMS:

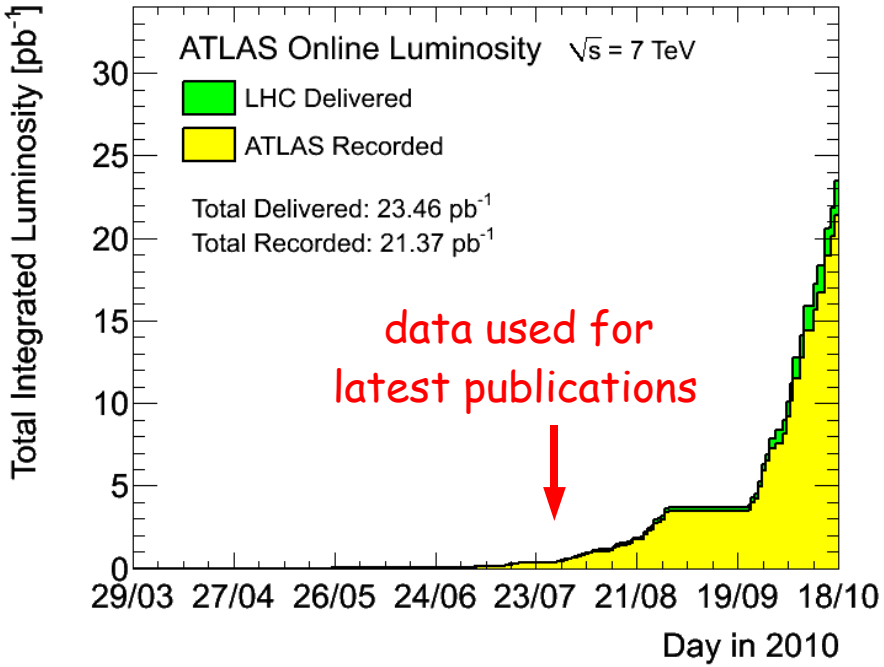
- silicon det. (pixel, strips)
- 4T solenoid magnet
- crystal EM calorimeter $\sigma(E)/E \sim 3\%/\sqrt{E} + 0.003$, brass and scintillator had. calorimeter $\sigma(E)/E \sim 100\%/\sqrt{E} + 0.05$
- muon chambers $\sigma(p)/p < 10\%$ at 1TeV

## ATLAS:

- silicon det. (pixel, strips) +TRT
- 2T solenoid + toroid magnets
- LAr EM calorimeter $\sigma(E)/E \sim 10\%/\sqrt{E} + 0.007$, tile+ scintillator had. calorimeter $\sigma(E)/E \sim 50\%/\sqrt{E} + 0.03$
- muon chambers $\sigma(p)/p < 10\%$ at 1TeV

# 2010-2011 LHC run

Up to now roughly 20pb$^{-1}$ of data collected




- 2010-2011 LHC run at √s=7TeV - plan to collect luminosity of 1fb$^{-1}$
- I will show:
  - latest ATLAS/CMS data analysis with luminosity up to 300 nb$^{-1}$
  - Monte Carlo studies showing SUSY discovery reach / exclusion limits for 2010-2011 run

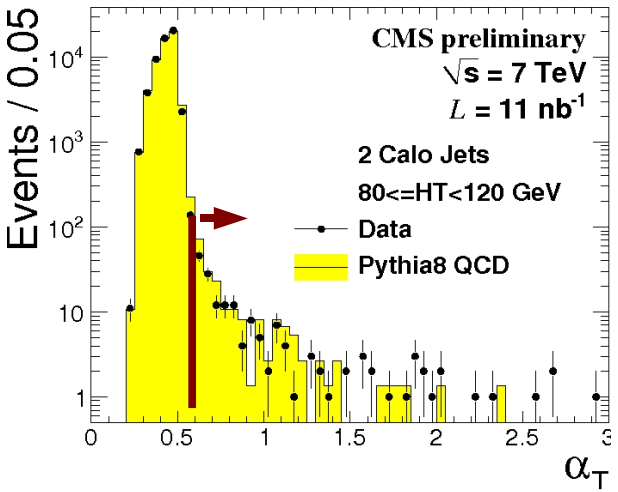
# Search for SUSY with MET signatures

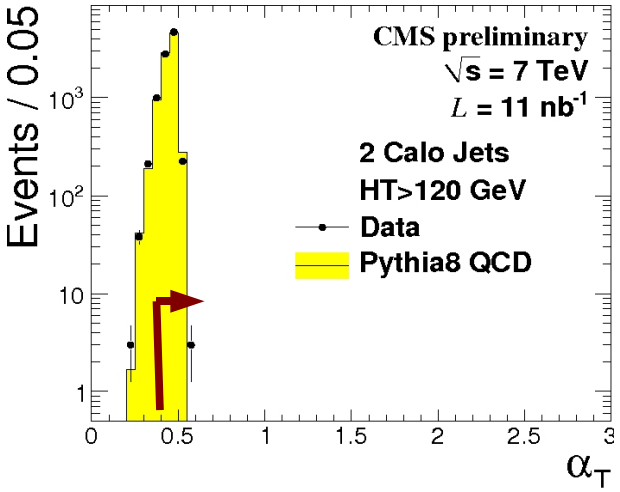
# SM background estimates

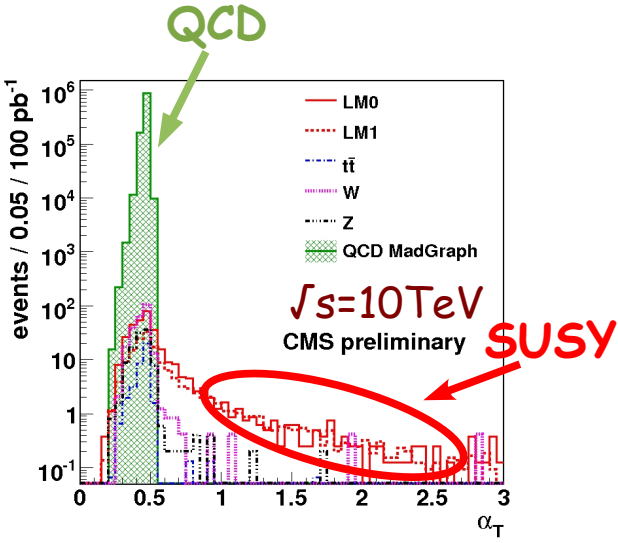
- Before claiming any discovery one needs to understand our SM expectations (MC, detector response)
- Two ways how to ensure control over SM backgrounds:
  1.) suppressing the background
  2.) provide background estimate using control samples
- QCD rejection power of $\alpha_T$>0.55 studied as a function of $H_T$=$\sum$Pt(jet)

(low lumi data used to x-check data<->MC agreement in control sample far from high MET tail)

$$\alpha_T \equiv \frac{p_{T2}}{M_T} = \frac{\sqrt{p_{T2}/p_{T1}}}{\sqrt{2(1-\cos\Delta\phi)}}$$

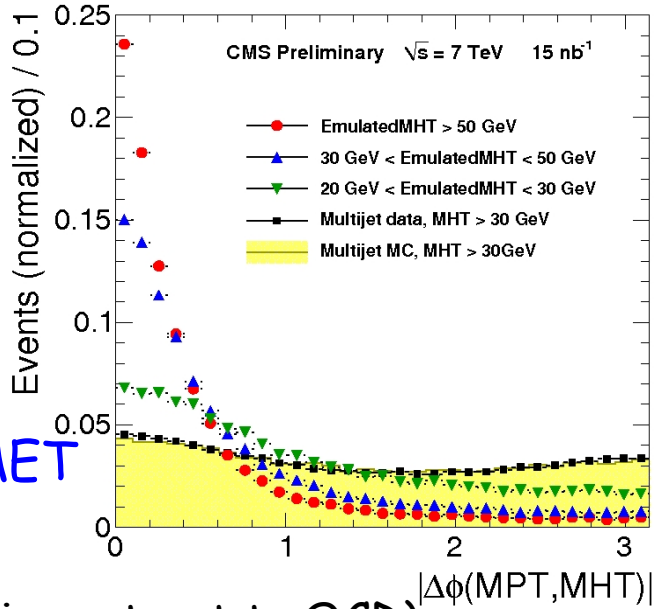


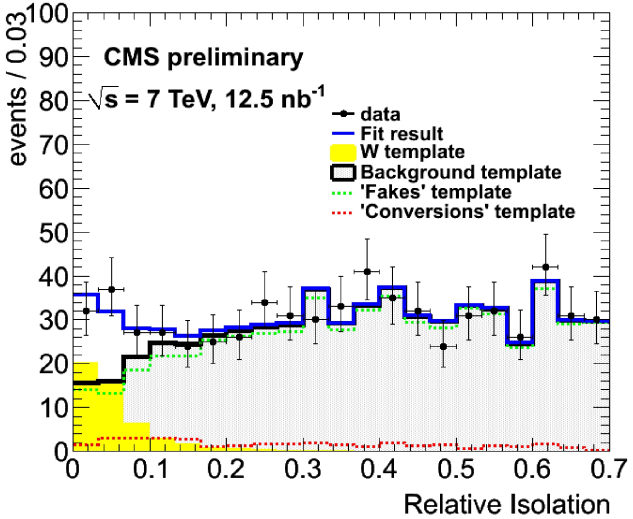



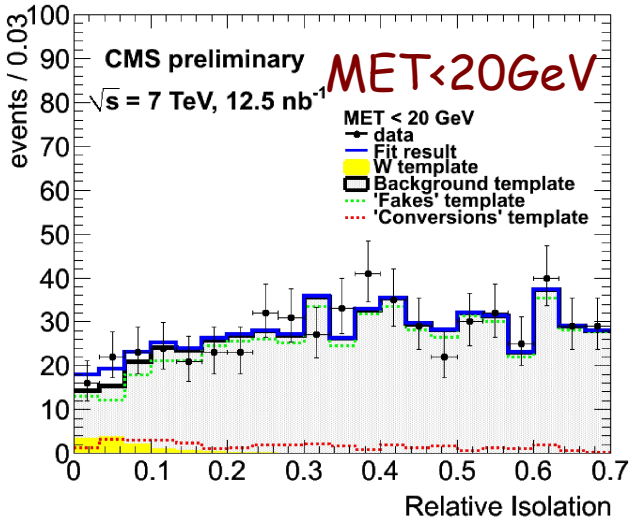
# SM background estimates

- suppressing QCD with ΔΦ(MET_track,MET_jet) cut
  - events with real MET peak at ΔΦ~0, whereas events with fake MET (mainly QCD) uniformly distributed in ΔΦ




- QCD estimate in channels with leptons +jets+ MET
  - relative isolation RI= $\sum Pt_{\Delta R<0.3}$/Pt_lepton of electron/muon studied (SUSY and W well isolated in contrast to QCD)
  - define control samples (γ->ee, and jets faking e by inverting analysis cuts)
  - templates fitted to the data, predicted and observed yields in good agreement



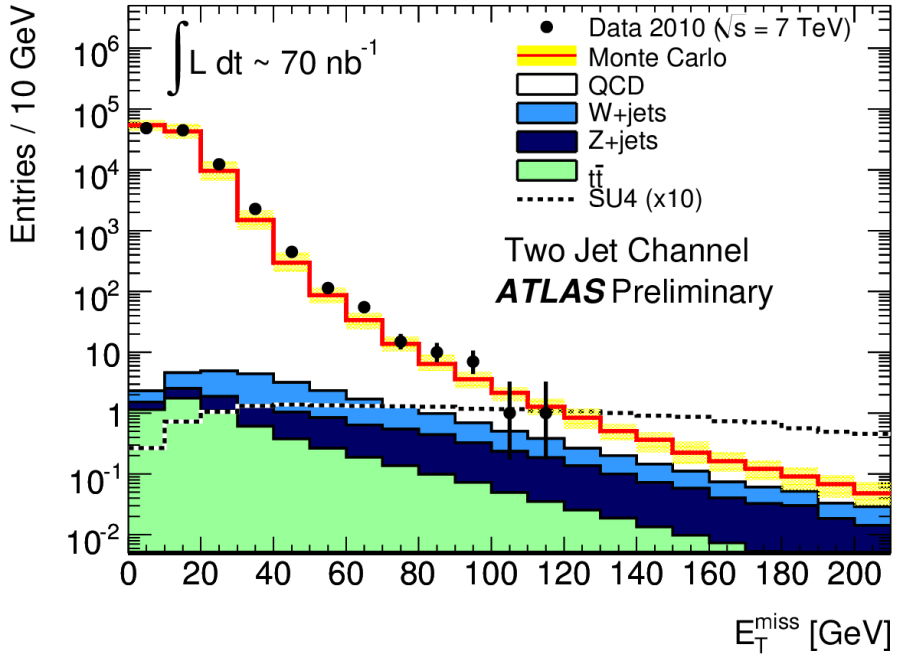



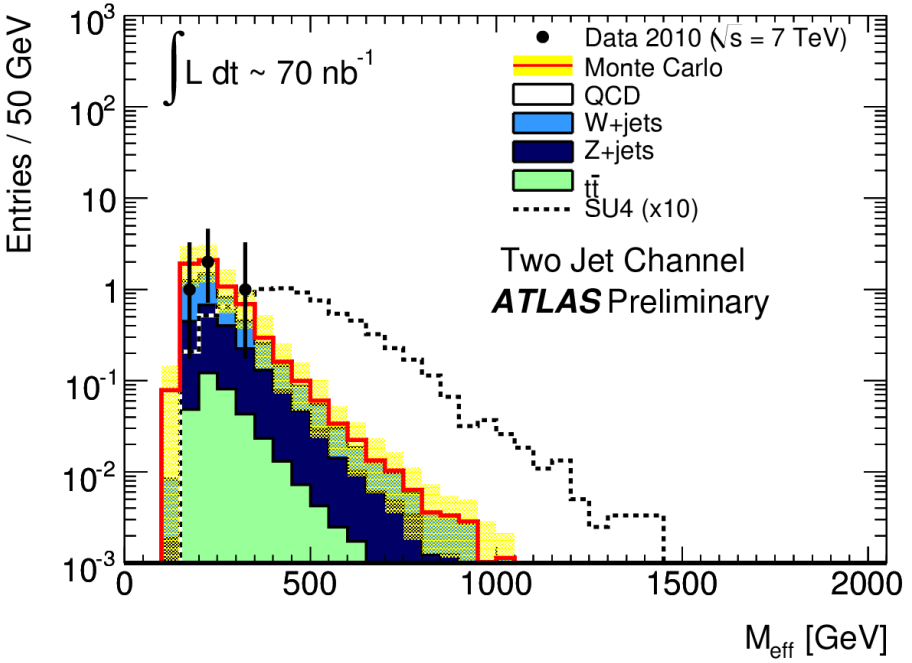
# Data analysis (0-lepton channel)

- Analyzed data with luminosity ~70nb$^{-1}$ (1jet, 2jet, 3jet and 4jet channels)
- All distributions well described by SM MC (QCD MC normalized to the data before MET cut)
- for the future analysis data driven methods will be used to determine the SM background

**Effective mass:** $$M_{\text{eff}} \equiv \sum_{i=1}^{N_{jets}} P_T^{\text{jet},i} + \sum_{i=1}^{N_{lep}} P_T^{\text{lep},i} + E_{\text{T}}^{\text{miss}}$$

SU4 - SUSY benchmark point close to the Tevatron bound m($\tilde{q}$,$\tilde{g}$)~410GeV



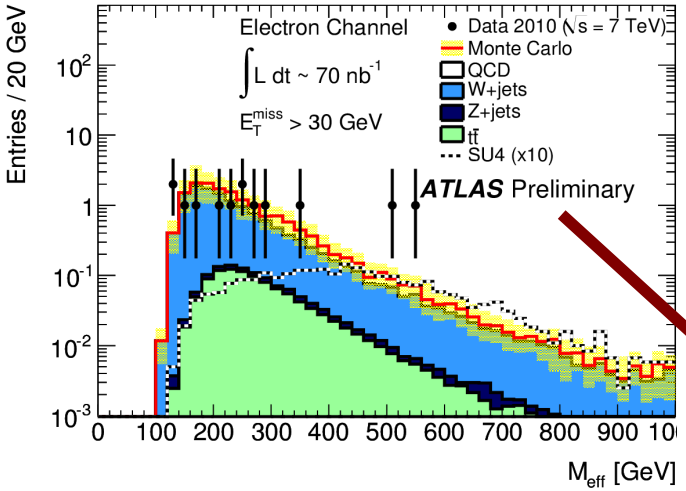



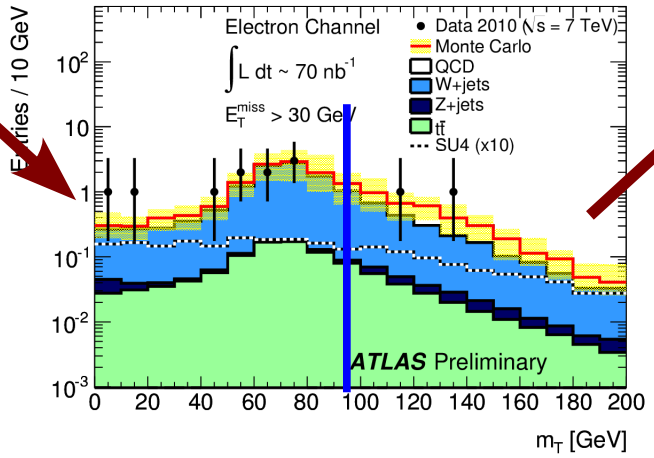

**0-lepton 2jet channel Pt(jet)>[70,30]GeV, MET>40GeV**

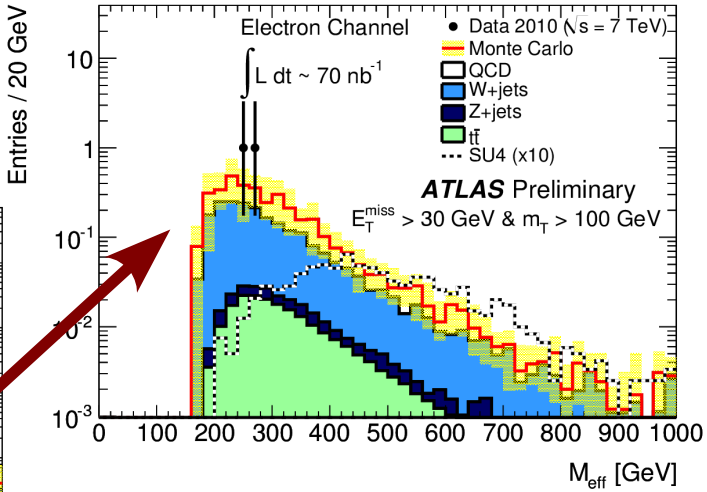
# Data analysis (1-lepton channel)

- Analyzed data with luminosity ~70nb$^{-1}$
- electron and muon channels analyzed, good agreement Data<--> MC found
- Selection cuts:

**Pt(lepton)>20GeV (no further lepton with Pt>10GeV)**
**Pt(jets)>30GeV (at least two jets)**
**MET>30GeV**



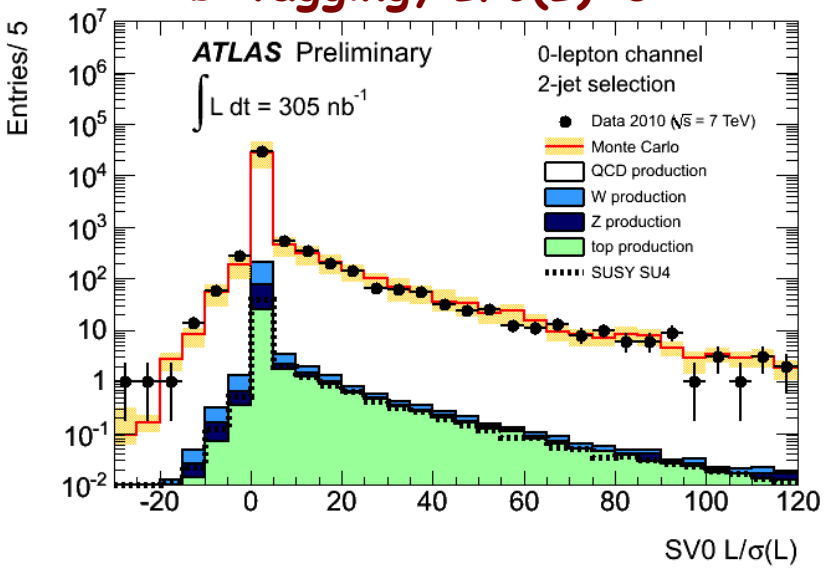

transverse mass>100GeV
(W,top background suppression)

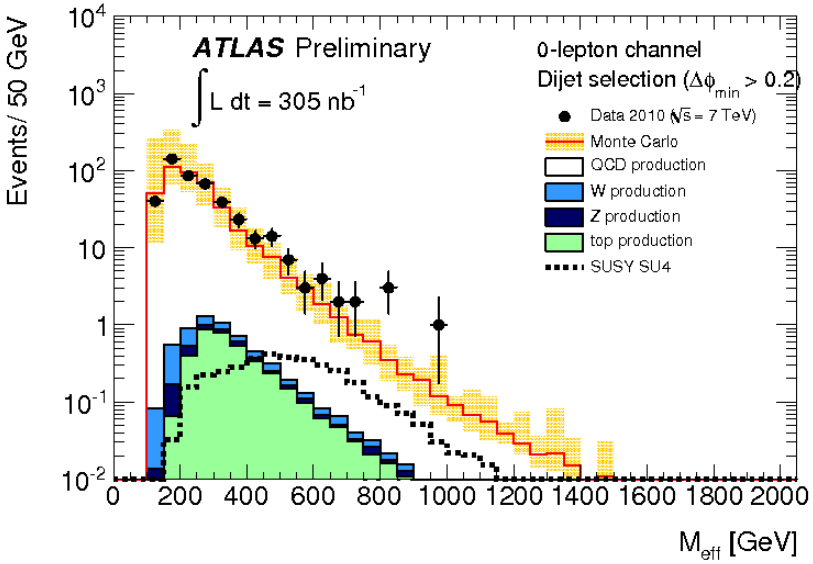
# Data analysis (b-jets)

- 0-lepton and lepton(e,μ) channels with b-jets, data luminosity~305nb$^{-1}$
- at least one b-tagged jet with Pt>30GeV

| No lepton ($p_T > 10$ GeV) | $\geq 1$ electron ($p_T > 20$ GeV) | $\geq 1$ muon ($p_T > 20$ GeV) |
|---|---|---|
| 2-jet: jet $p_T > (70,30)$ GeV | jet $p_T > (30,30)$ GeV | jet $p_T > (30,30)$ GeV |
| 3-jet: 3rd jet $p_T > 30$ GeV | - | - |

**b-tagging, L/σ(L)>6**

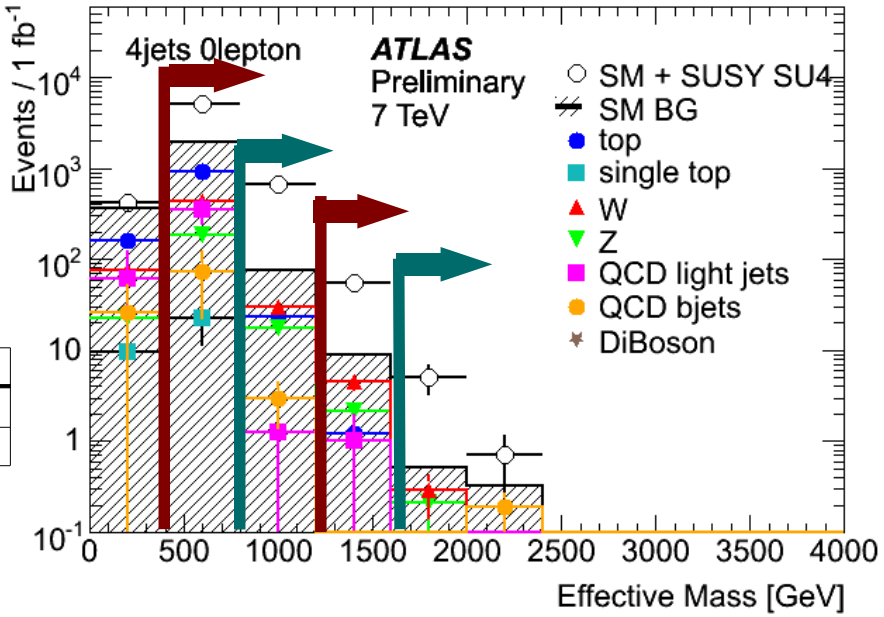



**good agreement found between data and SM expectation**

# Prospects for 1fb$^{-1}$

- MC study assuming L=1fb$^{-1}$
  (0,1 and 2 lepton channels with various jets multiplicities analyzed)




Cuts:

| | 2 jets | 3 jets | 4jets |
|---|---|---|---|
| **Pt jet cuts** | [180,50] | [100,40,40] | [100,40,40,40] |
| **MET** | 80 | 80 | 80 |

**Pt(e,μ)>20GeV (1,and 2 lepton SS)**
**Pt(e,μ)>10GeV (2 lepton OS)**

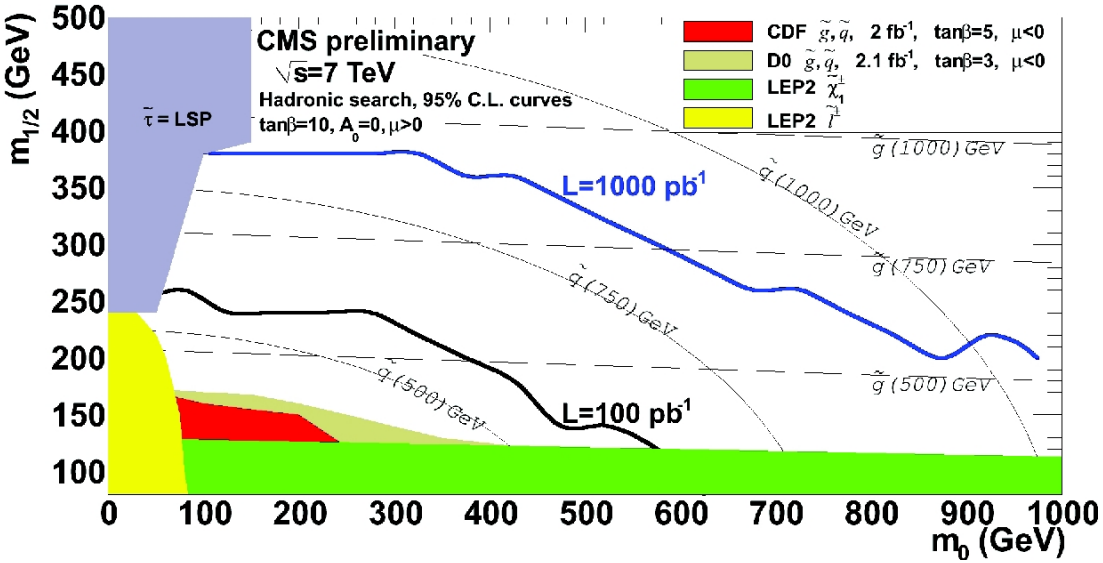
- SM background dominated by Top, W and Z production
- Cuts on effective mass optimized to obtain the best significance (significance then corrected for multiple tests)
- 50% sys. error assumed on the SM background estimate

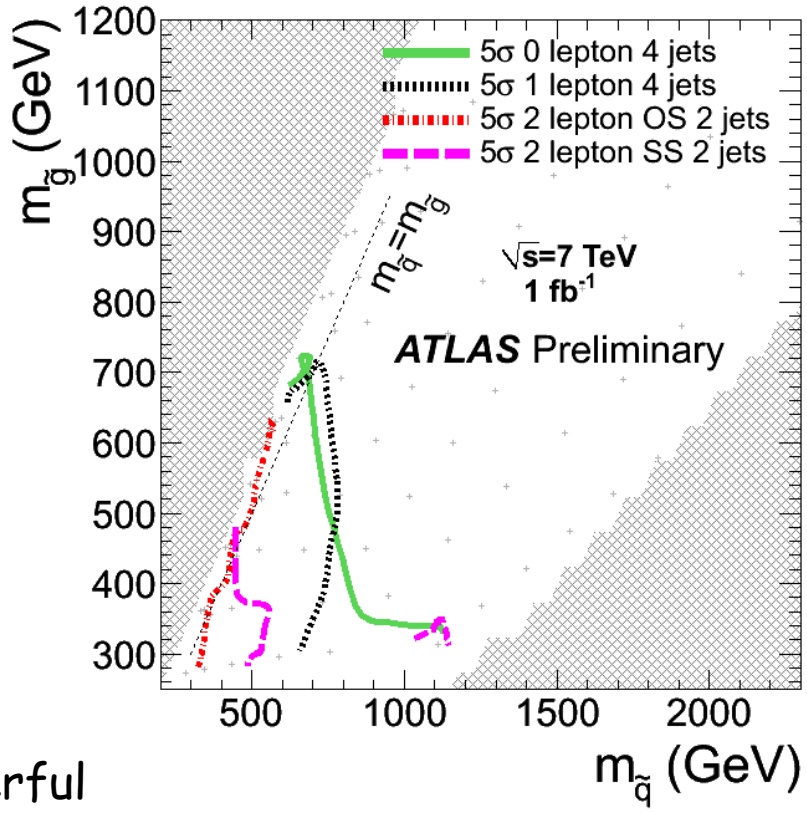
# Discovery reach & exclusion limits (MC study)

mSUGRA grid $A_0$=0, tanβ=10, μ>0

Discovery reach for 0,1 and 2 lepton channels:

All hadronic channel 95% exclusion limits:




## Conclusions:

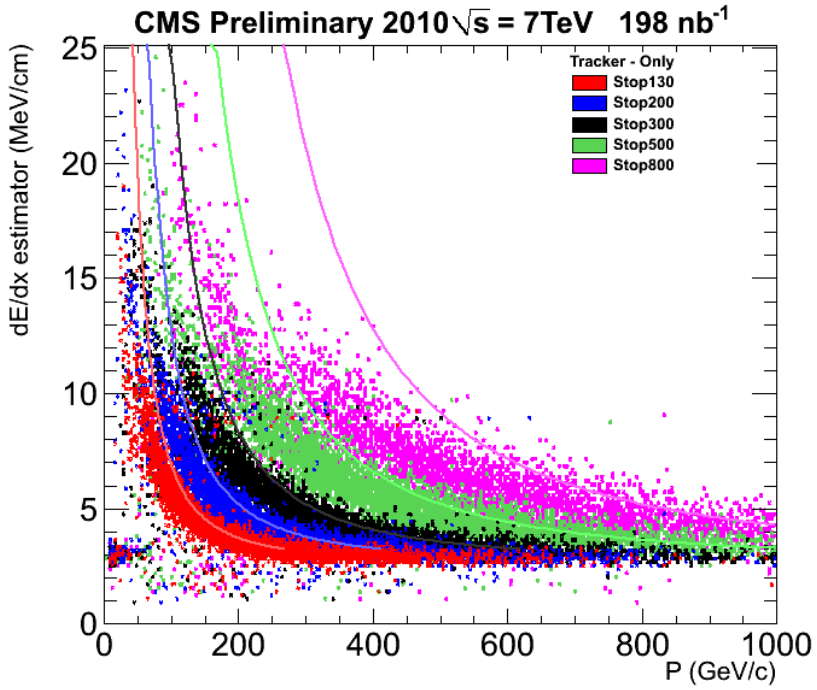
- 0-lepton and 1-lepton channels most powerful
- even with 100pb$^{-1}$ ATLAS and CMS can significantly surpass the current Tevatron and LEP exclusion limits
- with L=1fb$^{-1}$ squark and gluino masses up to 600-700 GeV can be discovered

# Search for SUSY with long lived particle signatures

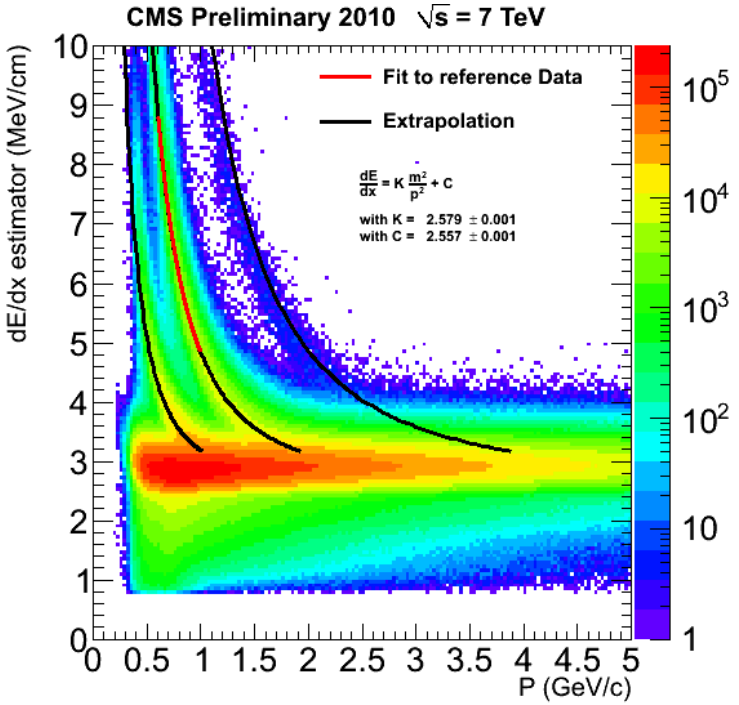
# Search for heavy stable charged particles (HSCP)

- HSCP (stop, gluinos, sleptons) predicted by many models (GMSB, Split-SUSY,....)
- HSCP with strong charge hadronize and form bounded states R-hadrons
- **Signature:** slowly moving high momentum particles ==> direct observation through anomalously large dE/dx possible

**Stop Monte Carlo**



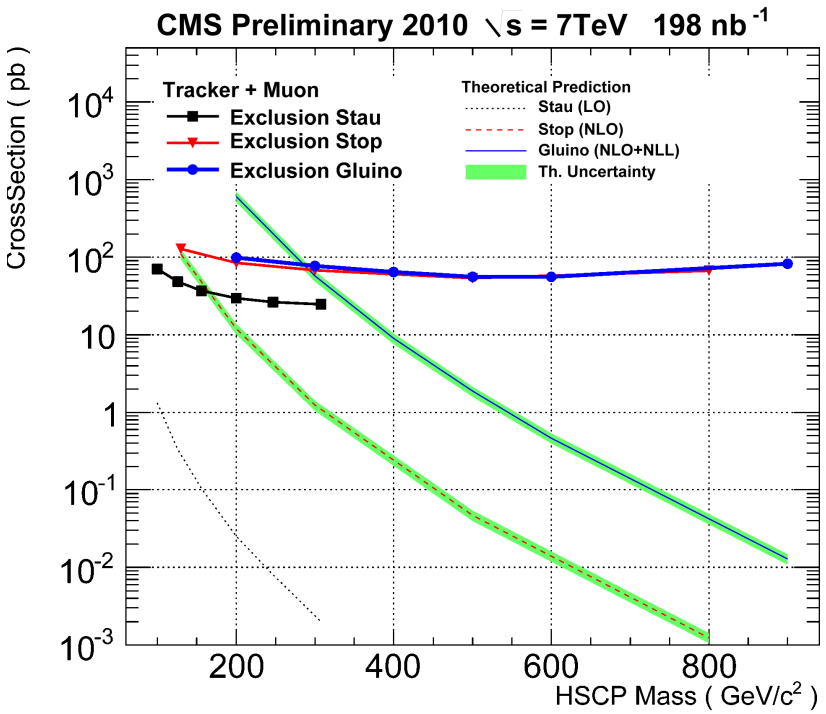

**Data**



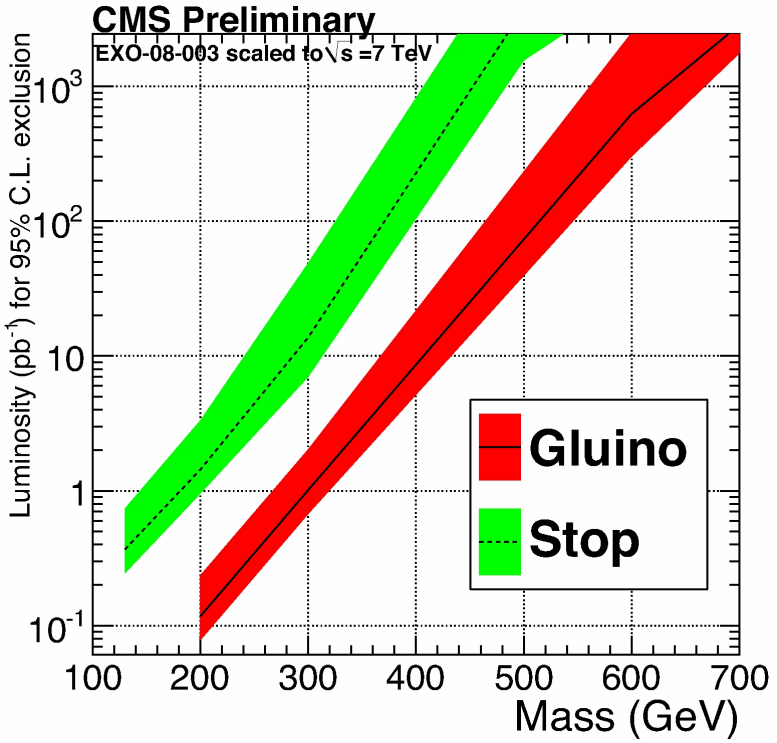
# HSCP - exclusion limits

- Two selections: tracker + muon identification (muon trigger)
  tracker only (jet and MET trigger)
- tracks with high pt and dE/dx tails selected
- data consistent with expected background determined from MIPs.
- with ~200nb$^{-1}$ CMS can exclude gluino masses below 284GeV

## Data exclusion limits



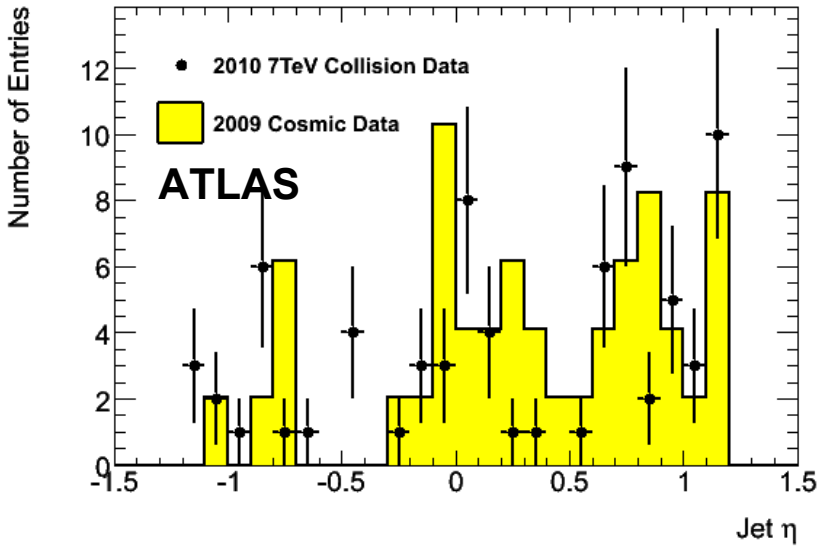

## MC exclusion limits

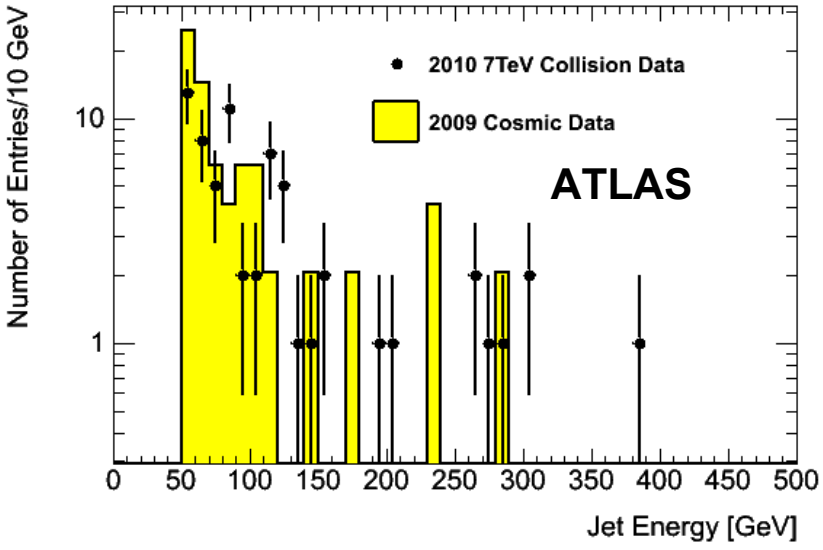


# Search for stopped gluinos

- study focused on gluino R-hadrons within the scope of split-SUSY scenario
- gluinos R-hadrons can get captured in detector volume and decay later (lifetime $10^{-8}$-$10^{6}$s)
- **strategy**: select events triggered in empty bunch-crossings
- ATLAS analyzed early data L~2.7nb$^{-1}$

Cuts: $E_{jet}$>50GeV, |η|<1.2, veto events with reconstructed muon segments



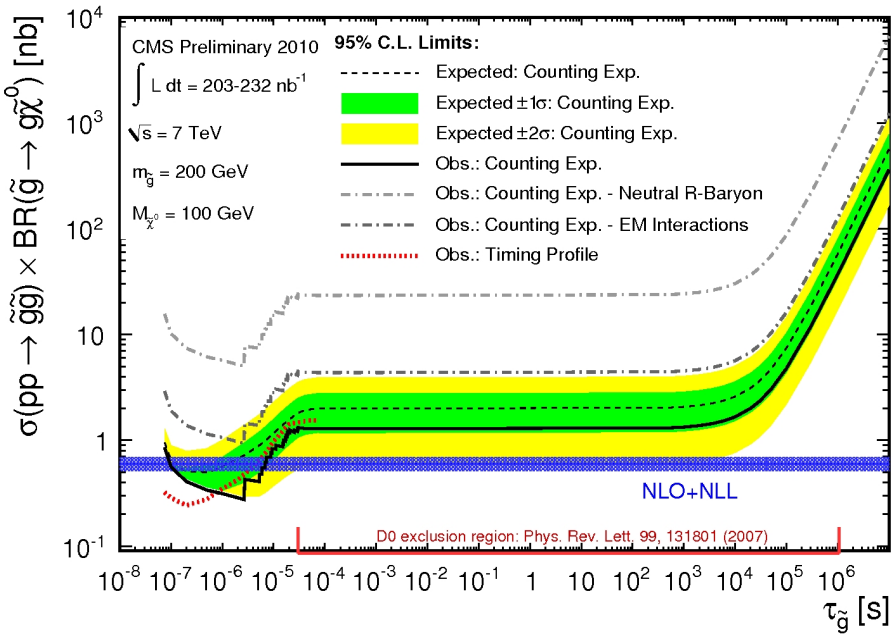




**Data consistent with the cosmic background expectation.**

# Exclusion/discovery limits for stopped gluinos

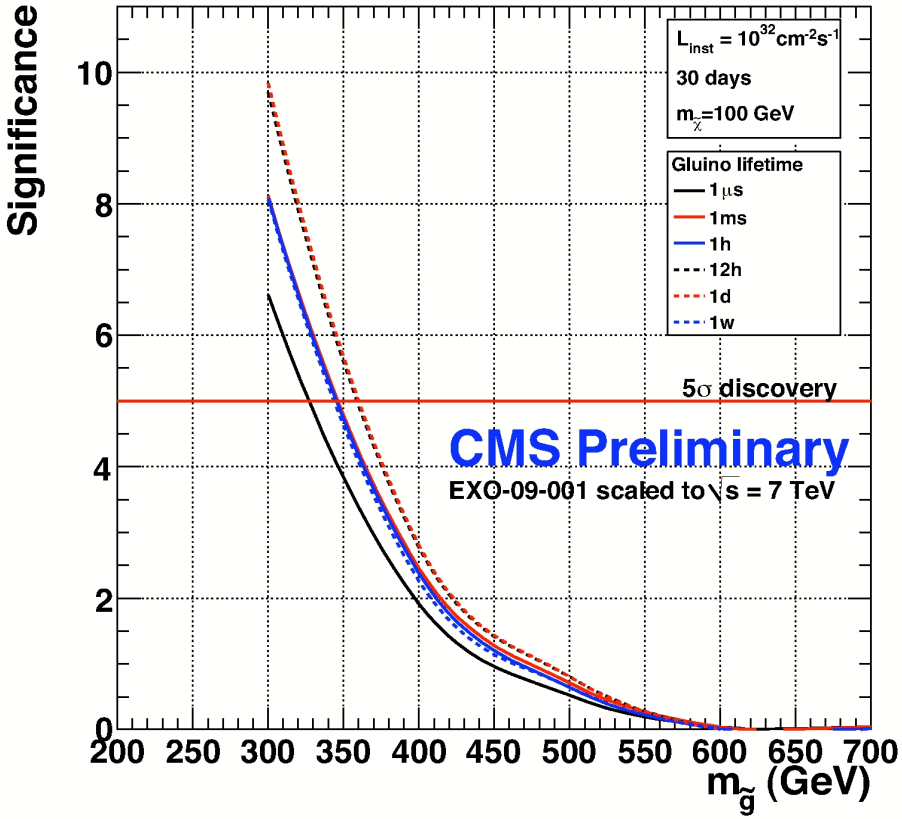
## 95% exclusion limits derived from data (L~200nb$^{-1}$):

- counting analysis (time profile analysis used to improve the sensitivity an $\tau$<100ns)
- for $M\tilde{g}$=200GeV and $M\tilde{\chi}$=100GeV gluino lifetimes 75ns-6μs excluded




## Discovery reach (MC study):

- discovery potential in a 30 day-long run at instantaneous luminosity of $10^{32}cm^{-2}s^{-1}$



# Summary

- ATLAS and CMS performed first analysis with luminosity up to 300 $nb^{-1}$
  - good understanding of detector performance
  - no significant deviations from SM seen so far (first exclusion limits derived)
- new results competing with Tevatron can be obtained this year (currently 100x more data on tape)
- Monte Carlo studies for L=1$fb^{-1}$ show that LHC has sensitivity to SUSY parameter space well beyond the Tevatron limits (SUSY with squark, gluino masses up to 600GeV can be discovered)