First Results of Searches for New Physics at 7 TeV with the CMS detector

First LHC Data: Implications of First LHC Data: a joint Berkeley-MIT workshop

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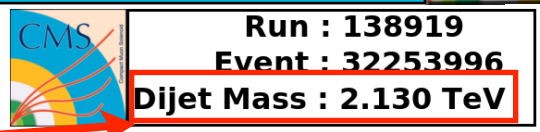
for the CMS Collaboration

Analyses Sensitive in First Data

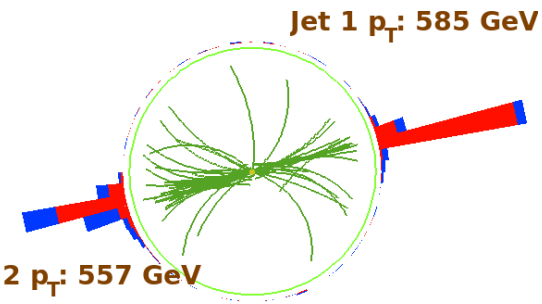
- New physics with dijets
  - Dijet resonances (CMS-PAS-JME-10-001)
  - Dijet centrality (CMS-PAS-JME-10-002)
- New physics with long-lived particles
  - Stopped gluinos (CMS-PAS-JME-10-004)
  - Heavy stable charged particles (CMS-PAS-JME-10-003)

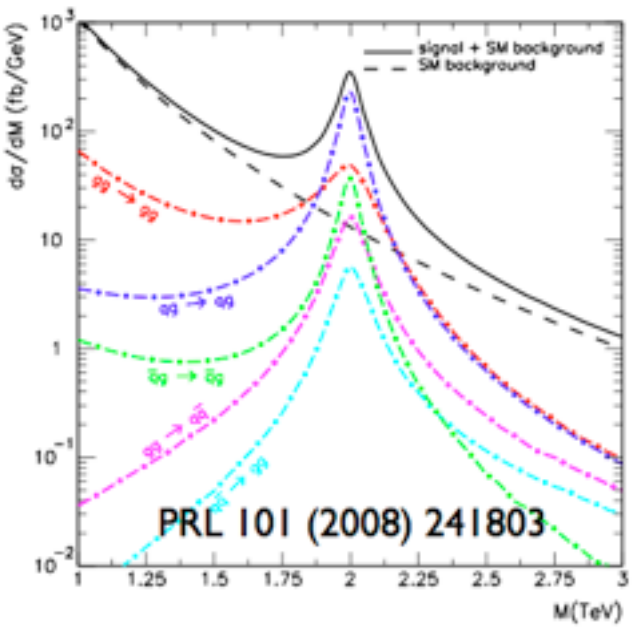
Let's start to chip away at new physics!

New Physics With Dijets

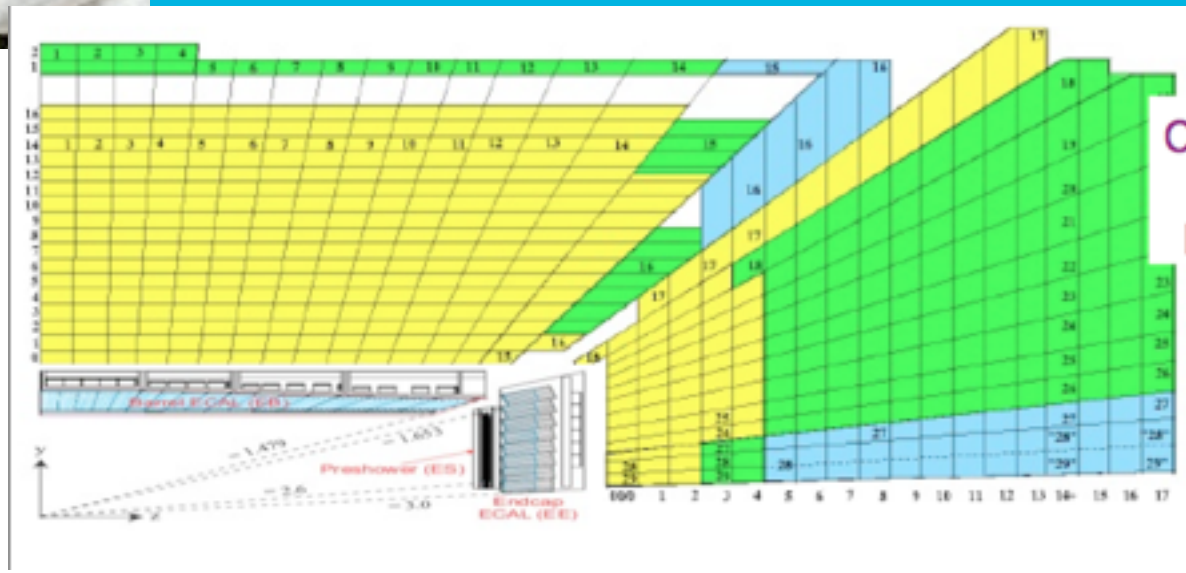


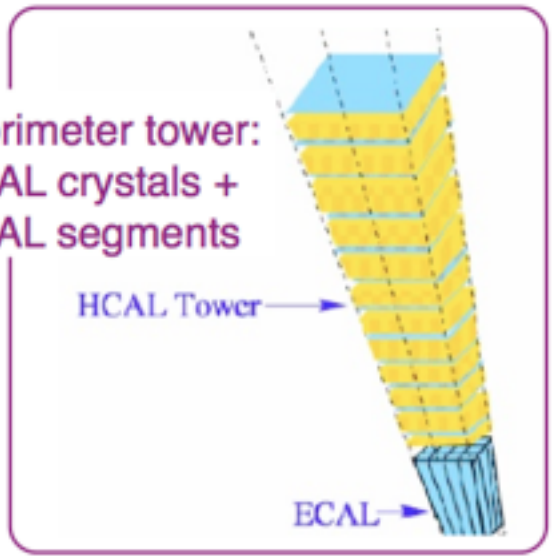
- New physics sensitivity due to higher COM energy and the pp (rather than ppbar) collisions
- Search for narrow resonances in dijet spectrum



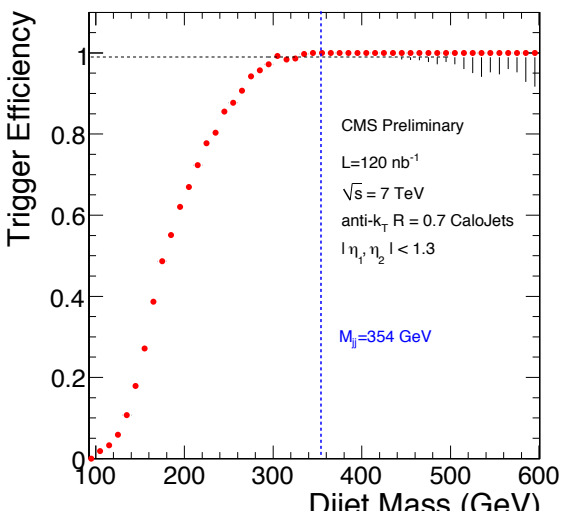


New Physics With Dijets





- Events in 120 nb^{-1} of pp data at 7 TeV
  - Trigger : Jet pt > 50 GeV (uncorr)



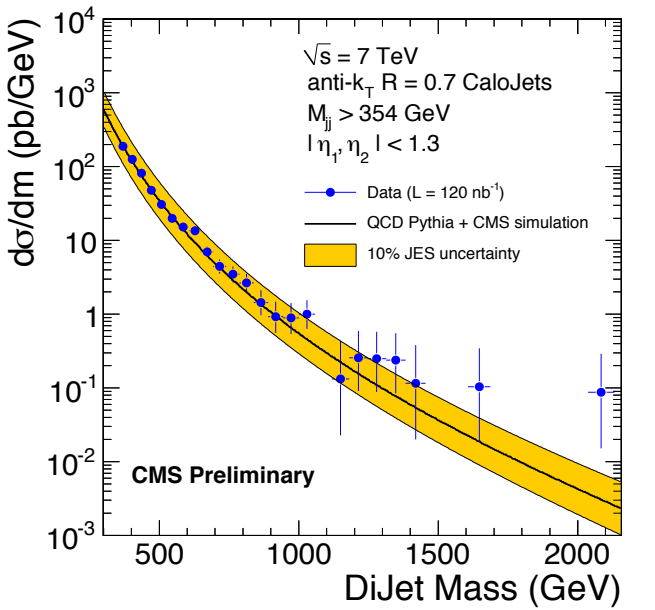
- Require 2 calorimeter jets:
  - anti-k_T algorithm, D = 0.7, $|\eta| < 1.3$
  - Noise cleanup
    - Electromagnetic fraction > 1%
    - >= 2 calorimeter cells in readout
    - <= 98% of energy from leading hybrid photodiode (HPD) detection device
  - Nonlinearity correction : **10% uncertainty**
    - From simulation
    - Correct for nonlinearity in eta and p_T

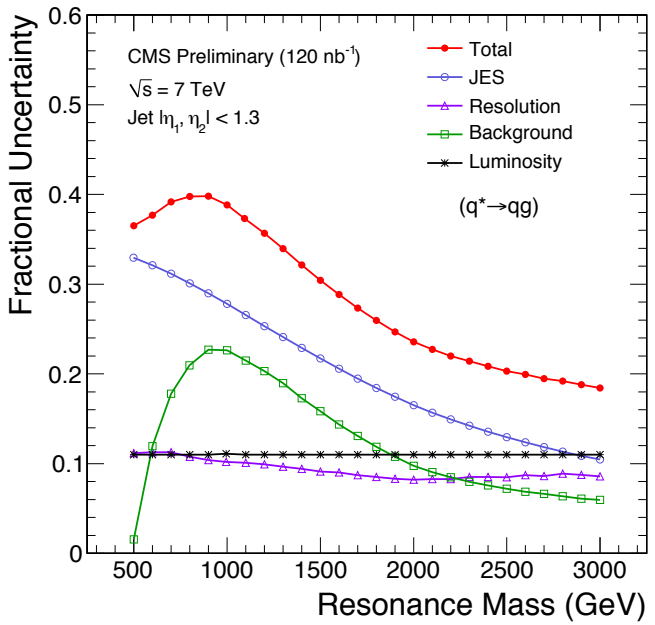
Dijet Resonances

- Fit to falling spectrum

$$\frac{d\sigma}{dm} = \frac{P_0 \cdot (1 - m/\sqrt{s})^{P_1}}{m^{P_2}}$$

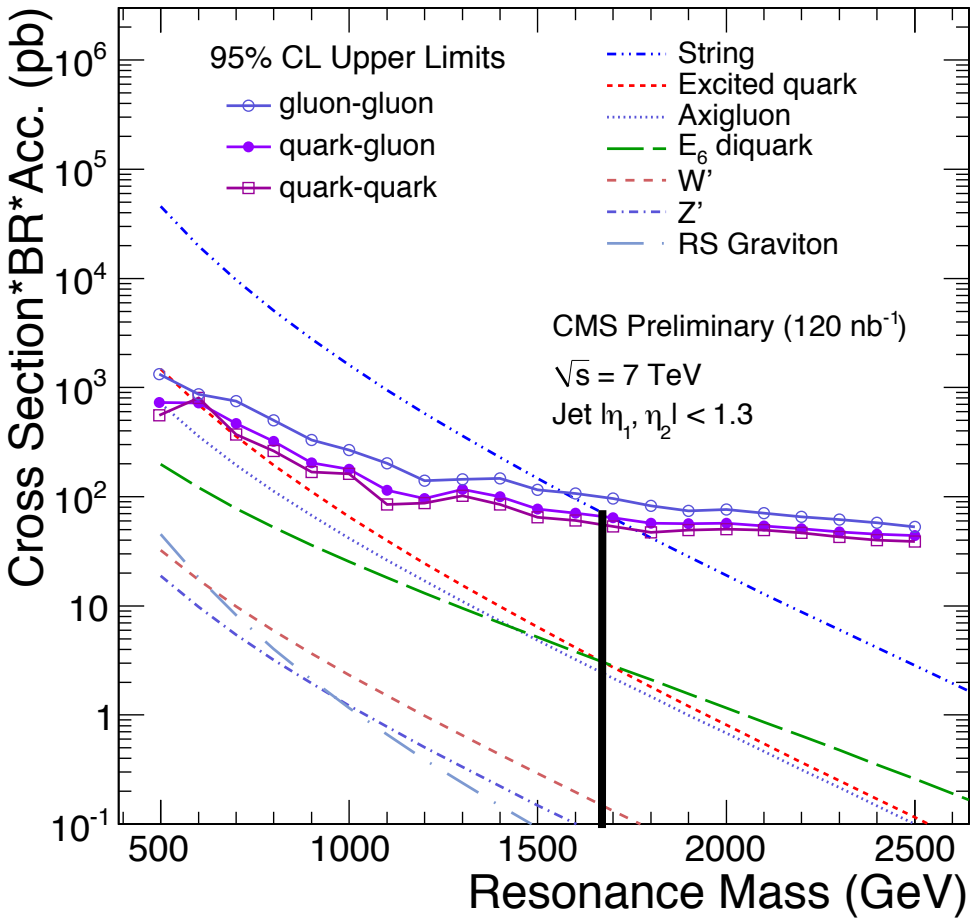
- Search for excess
  - Require $m_{jj} > 354$ GeV/c^2
- Hybrid Bayesian technique for limit setting
  - Convolute likelihood with a Gaussian for uncertainty
- Uncertainties:
  - Jet energy scale
  - Jet energy resolution
  - Background parameterization
  - Luminosity





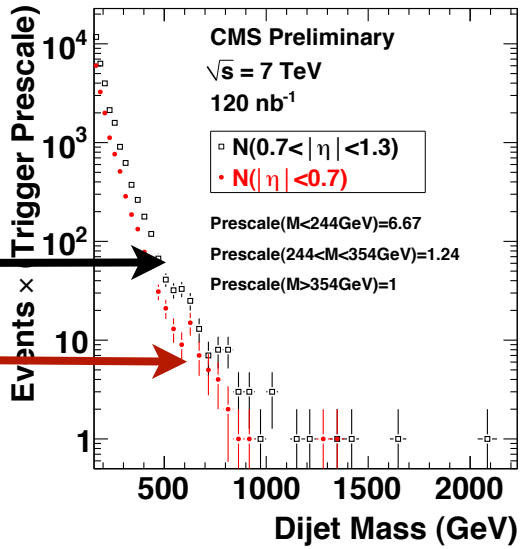
Dijet Resonances

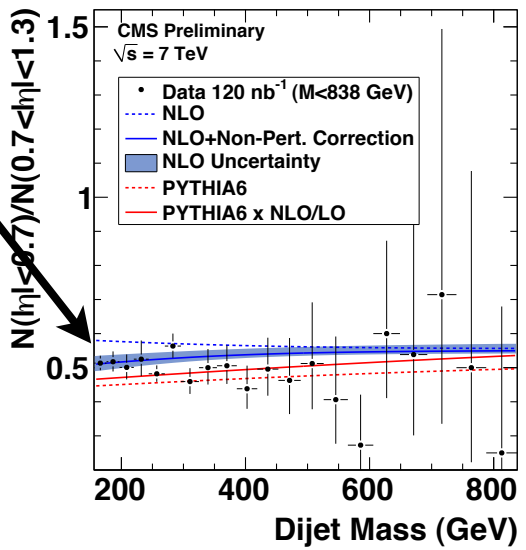
- Results
- No significant excess observed
- Limits set on various models
  - e.g. Regge string resonances : M < 1.67 TeV
    - **More stringent than Tevatron (1.4 TeV)!**



Dijet Centrality

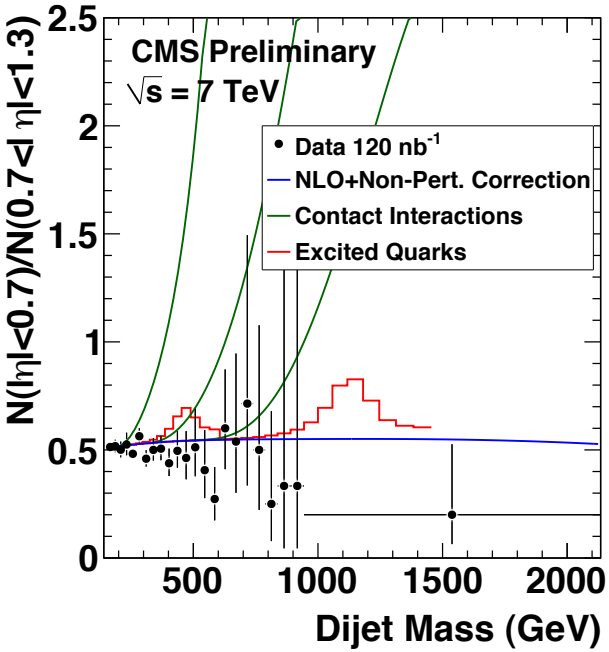
- Examine ratio of dijet events from “inner” versus “outer” regions
  - Inner : $|\eta|$ = 0 - 0.7
  - Outer : $|\eta|$ = 0.7 - 1.3
  - Nearly flat in the Standard Model case
- **Complimentary** analysis to the dijet resonance search
- Event selection is the same
- Uses lower pt mass bins (and triggers) also
  - Jet pt > 15 GeV (uncorr): m_{jj} = 154-244 GeV/c^2
  - Jet pt > 30 GeV (uncorr): m_{jj} = 244-354 GeV/c^2
  - Jet pt > 50 GeV (uncorr): m_{jj} > 354 GeV/c^2





Dijet Centrality

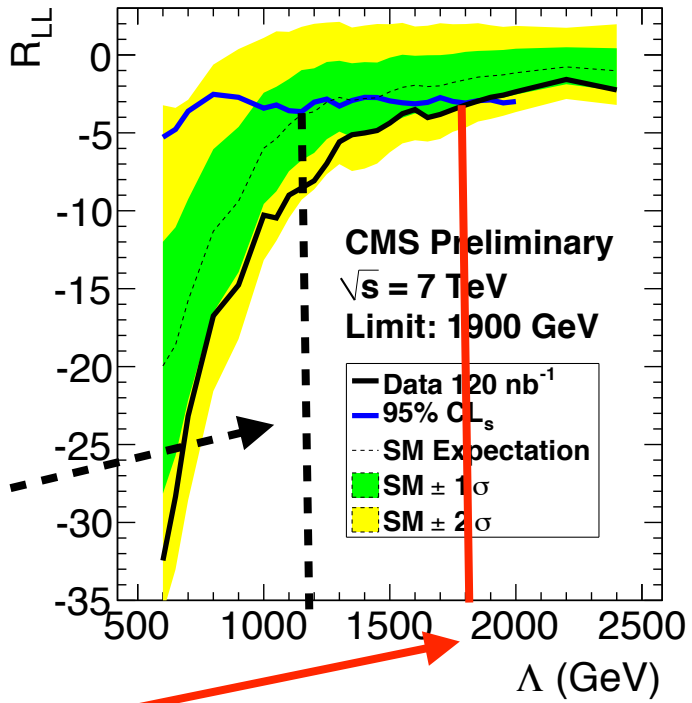
- Compute log-likelihood ratio, compare to "null" hypothesis
- Null hypothesis: shape from NLO calculations, scaled to low-m_{jj} data
  - Normalize to $m_{jj} < 270$ GeV/c^2
  - Offset consistent with zero (-0.013 ± 0.012)



Source of Uncertainty	NLO QCD (Units of Ratio)	NLO QCD (%)	Contact Interactions (%)
Detector Uncertainty			
Absolute JES	0.002 - 0.004	0.3 - 0.8	5 - 30
Relative JES	0.02 - 0.03	3.9 - 5.3	2
Other	0.01	2.0	–
Jet Energy Resolution	0.003	0.6	–
Total Detector	0.02 - 0.03	4.5 - 5.8	5 - 30
Model Uncertainty			
Scale	+(0.014 - 0.023) −(0.005 - 0.008)	+(2.7 - 4.4) −(0.9 - 1.6)	–
Offset	0.02	3.9	–
Fit	0.005	1.0	2 - 5
PDF	0.002	0.3	–
Total Model	+(0.024 - 0.030) −(0.021 - 0.022)	+(4.8 - 5.9) −(4.0 - 4.3)	2 - 5
Total	+(0.034 - 0.042) −(0.031 - 0.037)	+(6.6 - 8.3) −(6.1 - 7.2)	6 - 30

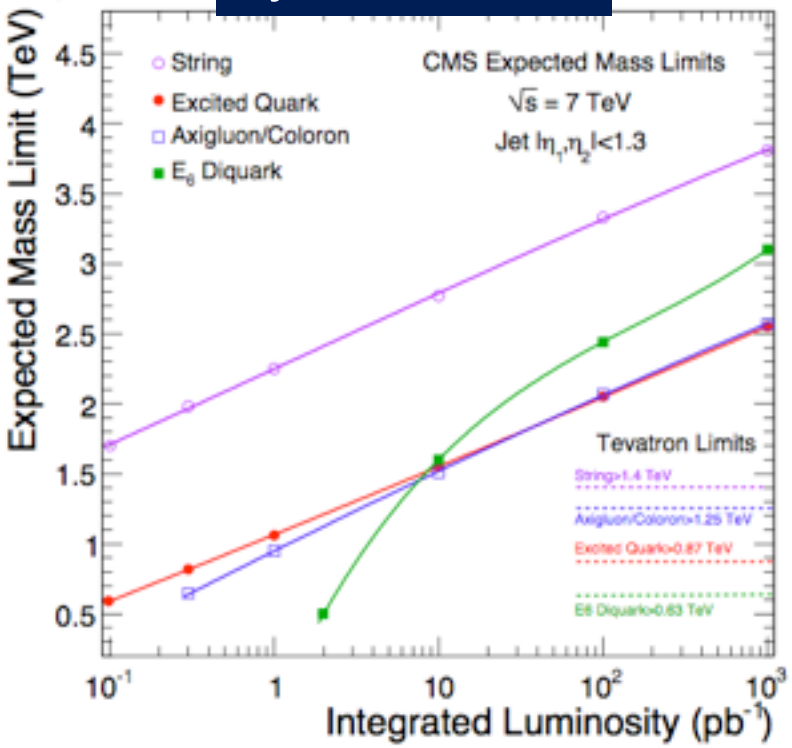
Dijet Centrality

- For exclusion, use frequentist-like CL_s method
- Systematics included via Cousins-Highland method (hybrid Bayesian smearing of parameters)
- Expected limit:
  - 1.2 TeV
- Observed limit:
  - 1.8 TeV

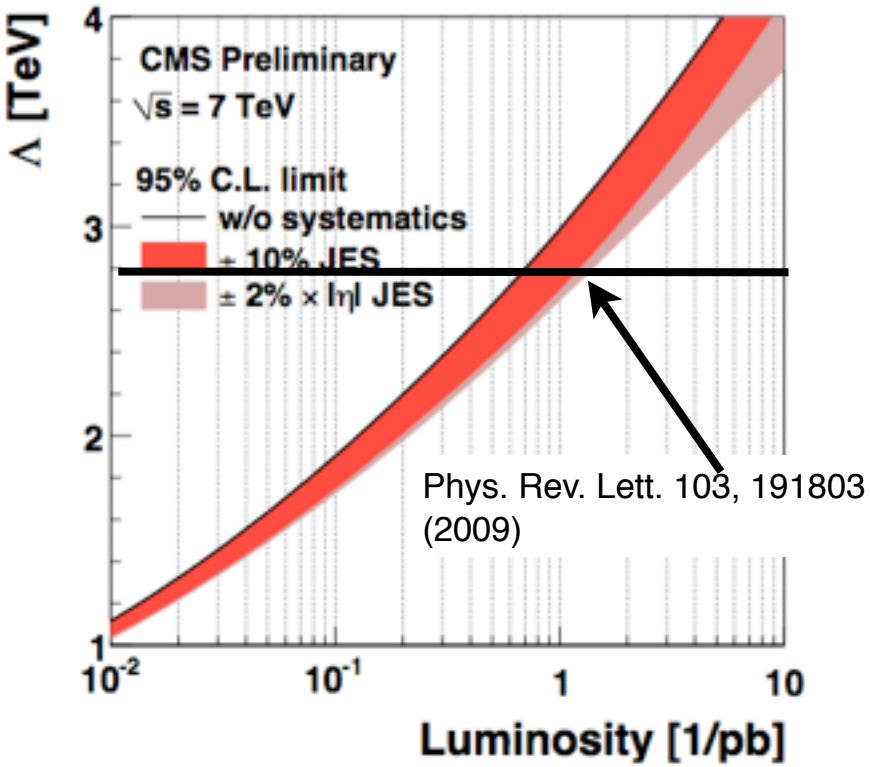


Expected Limits

Dijet resonances



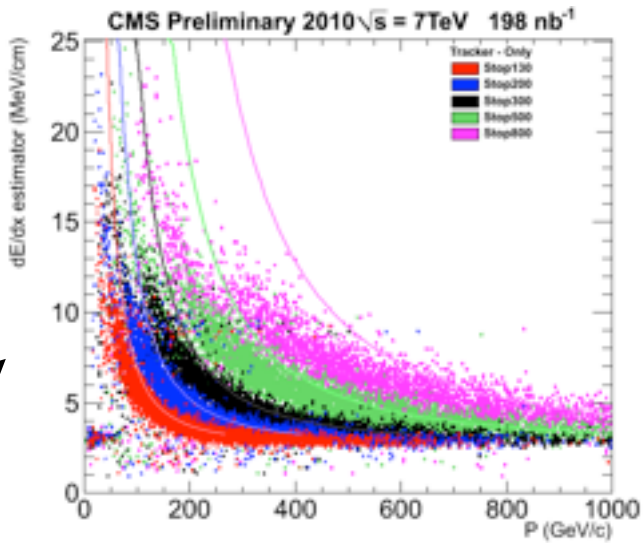
Compositeness with angular analysis

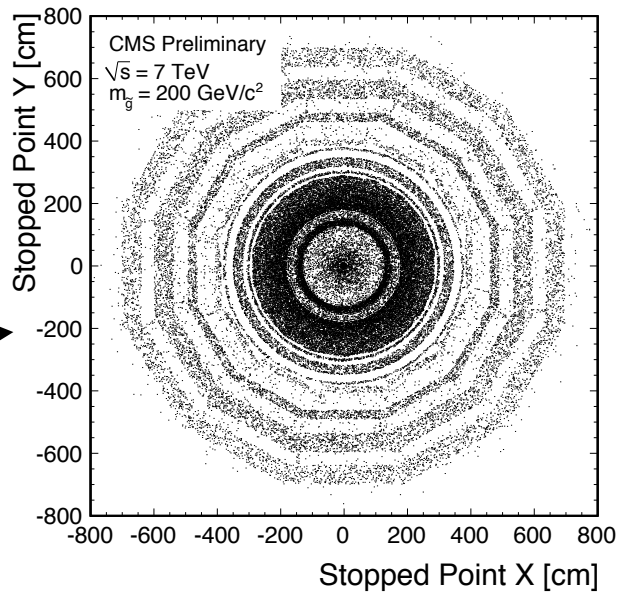


- Expect to exceed Tevatron limits with ~ 10 pb^{-1}!
  - In a few cases, already have!

New Physics With Long-Lived Particles

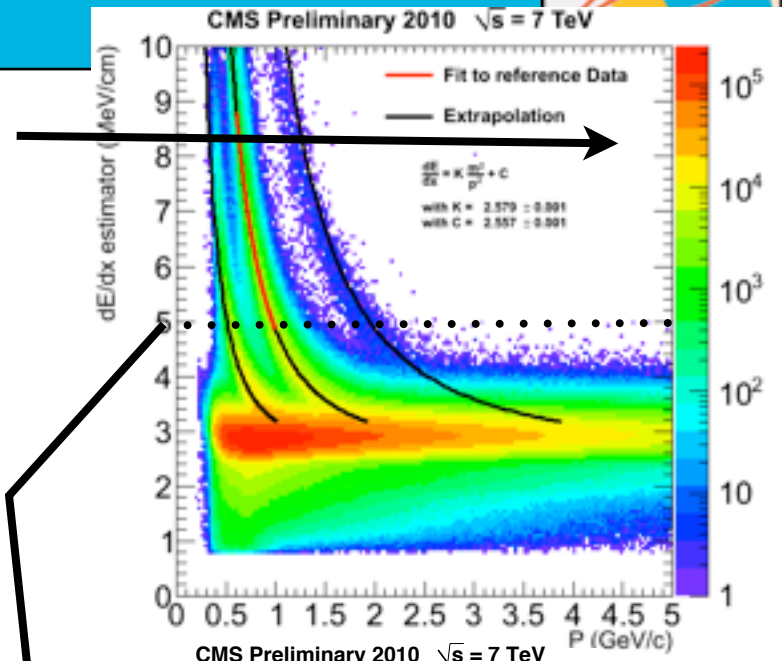
- New physics scenarios often predict heavy long-lived particles
  - Some SUSY models, hidden valley models, some GUT's
- Can form bound states with quarks/gluons to form R-hadrons
- Charged states will deposit energy through dE/dx
- Some will stop altogether, then decay

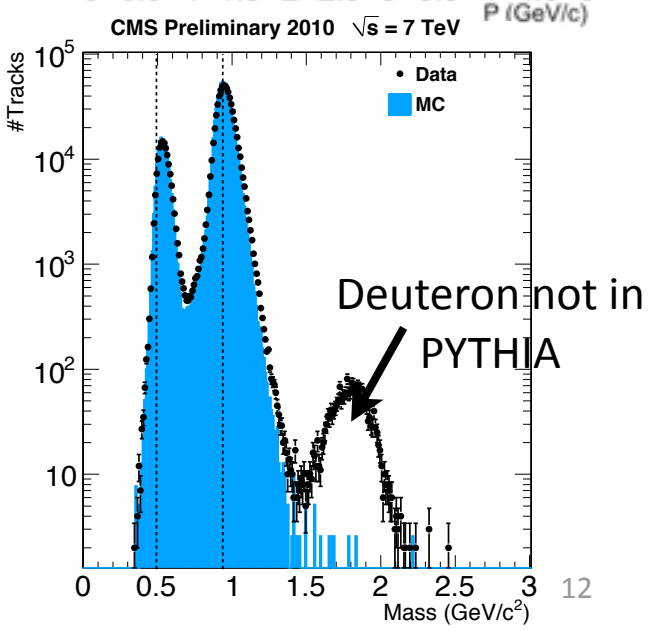




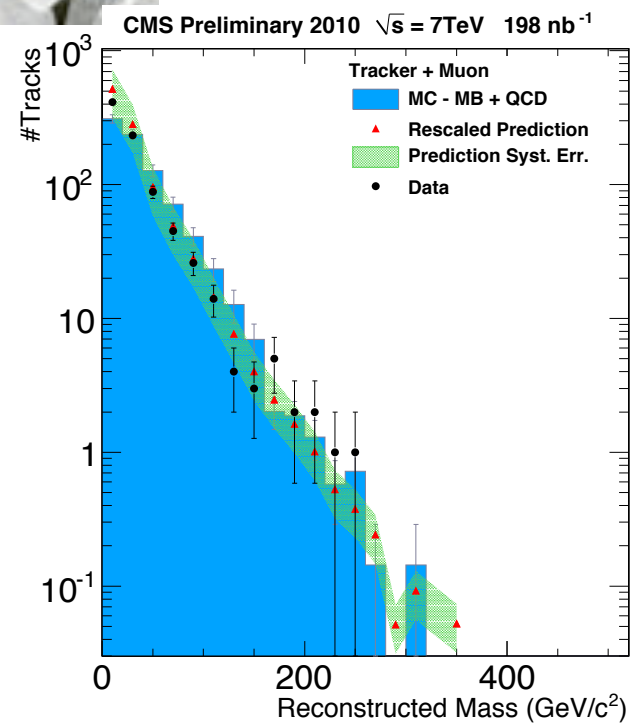
Heavy Stable Charged Particles

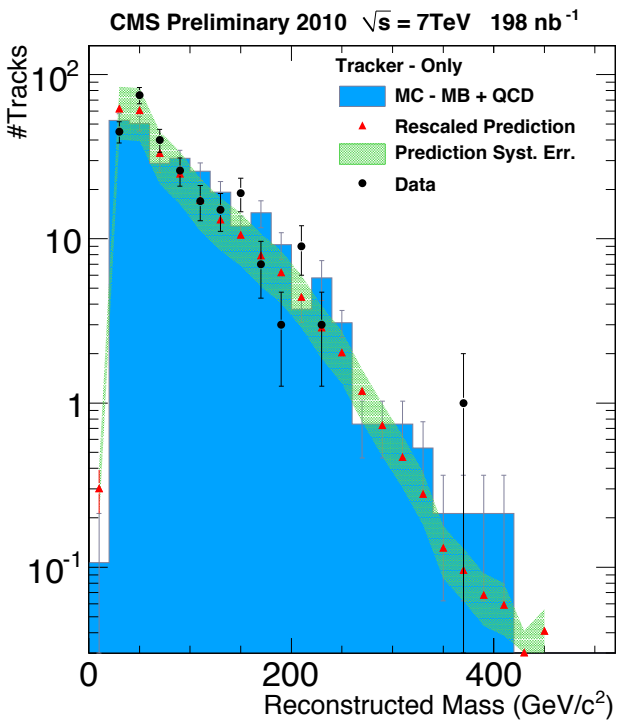
- Look for tracks with high p_T, high dE/dx
- Charged R-hadrons will escape, and be identified as a muon
  - Some models predict R-hadrons can become neutral
- Two counting experiment analyses:
  - Track+muon : muon-like HSCP
    - Trigger: muon pt > 3 GeV, double muon pt > 0 GeV
  - Track-only : non-muon-like HSCP
    - Jet pt > 50 GeV (uncorr), Missing E_T > 45 GeV
- Data-driven background technique:
  - dE/dx uncorrelated with pT measurement
  - Estimate background using sideband technique





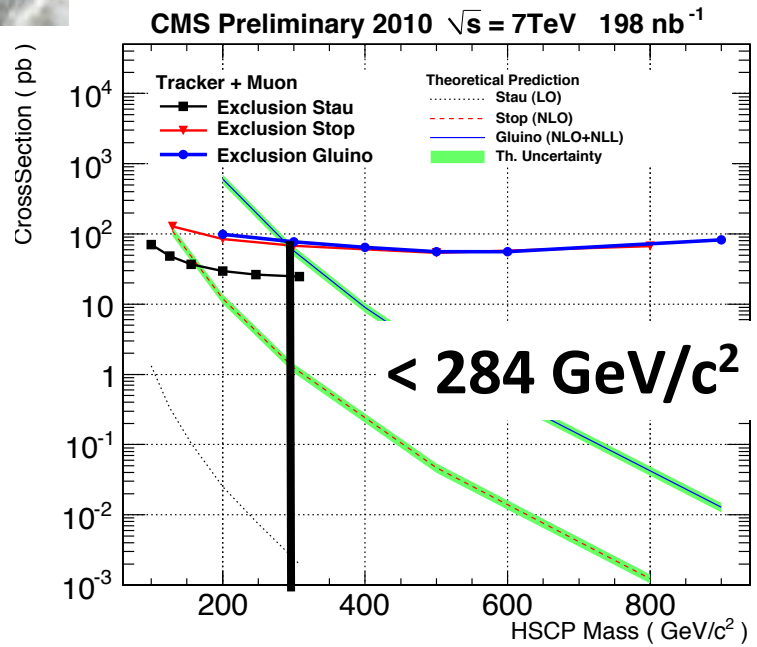
Heavy Stable Charged Particles

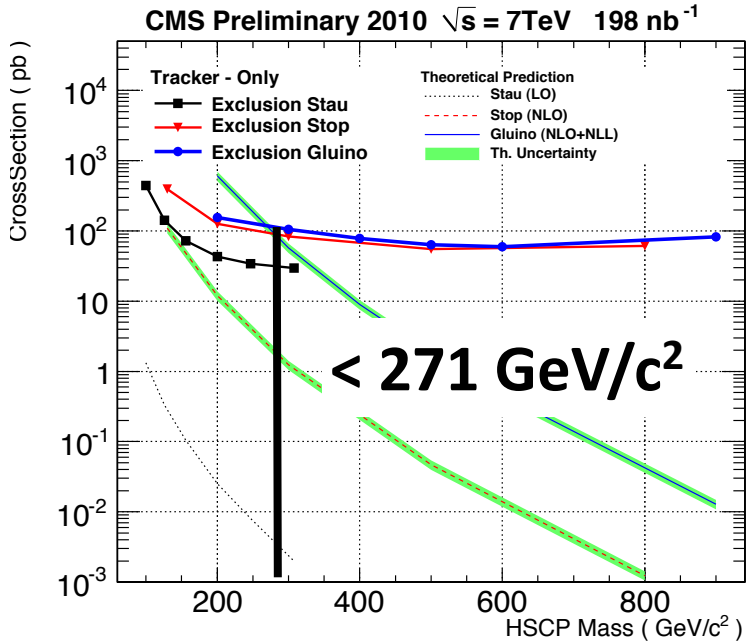




- Good agreement seen between data, scaled data-driven background, and simulated background
- No excess observed

Heavy Stable Charged Particles

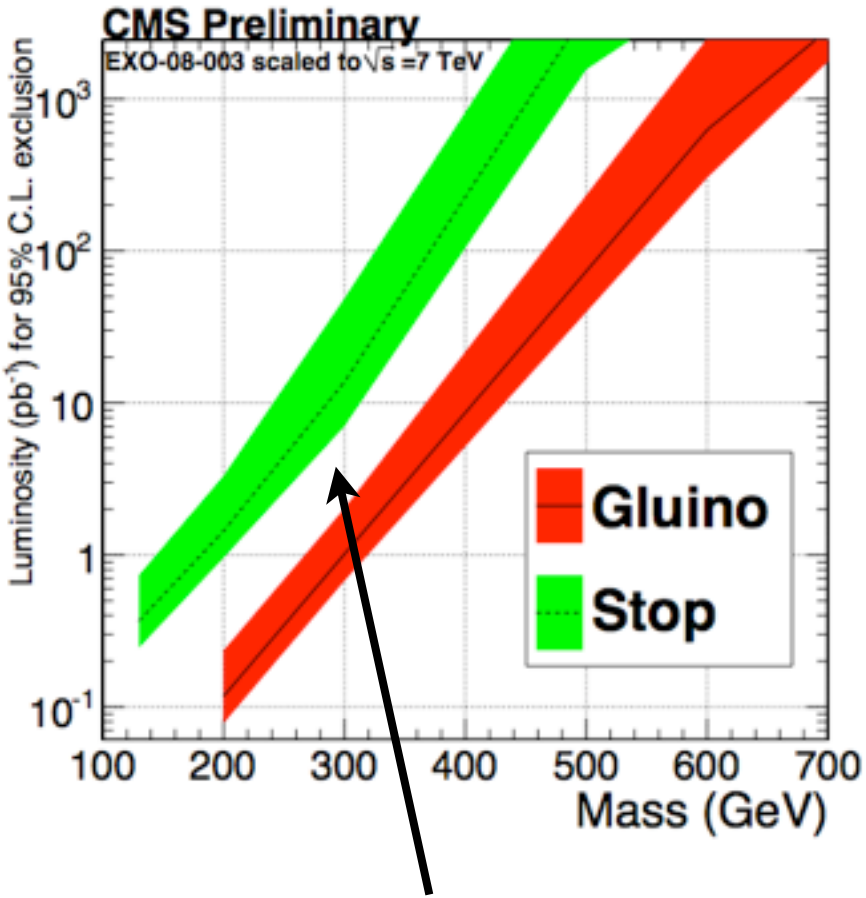


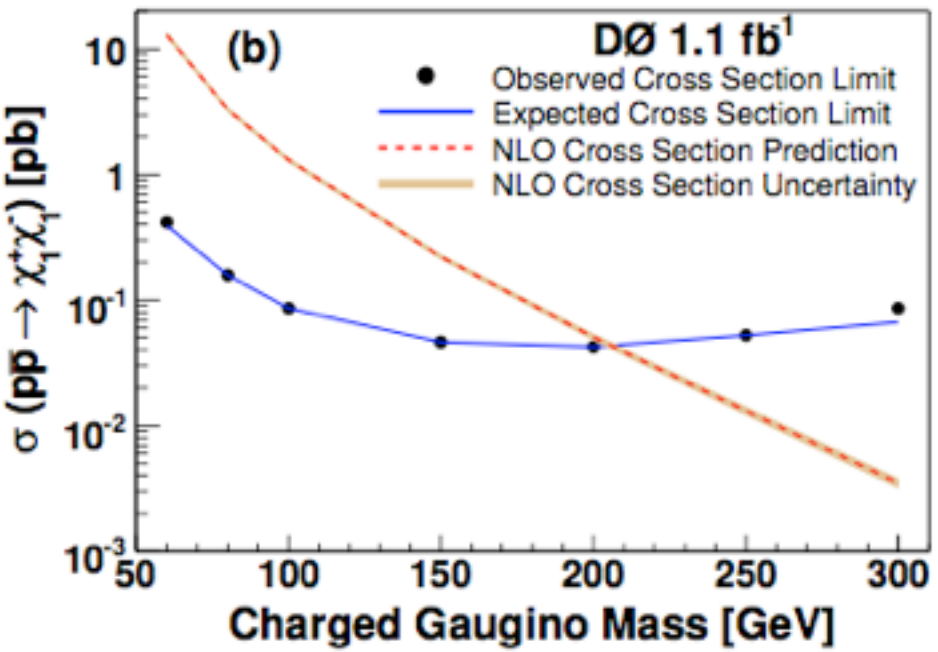


- Full Bayesian limit
  - Log-normal prior
  - Integrate over nuisance parameters

Source of Systematic Error	Relative Uncertainty (%)
Theoretical cross section	15 ($\tilde{t}_1$and $\tilde{g}$)
Expected background	36(Tk) ; 40 (Tk+Mu)
Integrated luminosity	11
Trigger efficiency	15
Muon reconstruction efficiency	5
Track reconstruction efficiency	< 5
Momentum scale	< 5
Ionization energy loss scale	< 3 (8 for 100 GeV/c^2 $\tilde{\tau}_1$)
Total uncertainty on signal acceptance	20

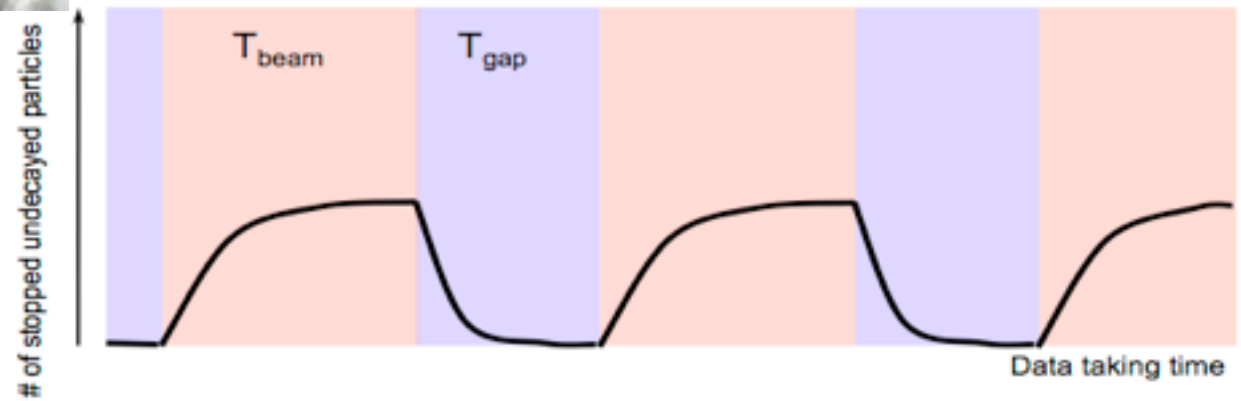
Expected Limits





- Need only a few pb^{-1} to exceed Tevatron limits!

Stopped Gluinos



- Stopped R-hadrons (like gluinos) produced during collisions, but decay **at any time!**
  - Can look during "gap" periods!
- Event selection is conservative, mostly removes beam and noise backgrounds
  - Noise and cosmics backgrounds are measured from data during cosmic data taking
  - Beam-related backgrounds are reduced by looking far from triggered bunch crossings

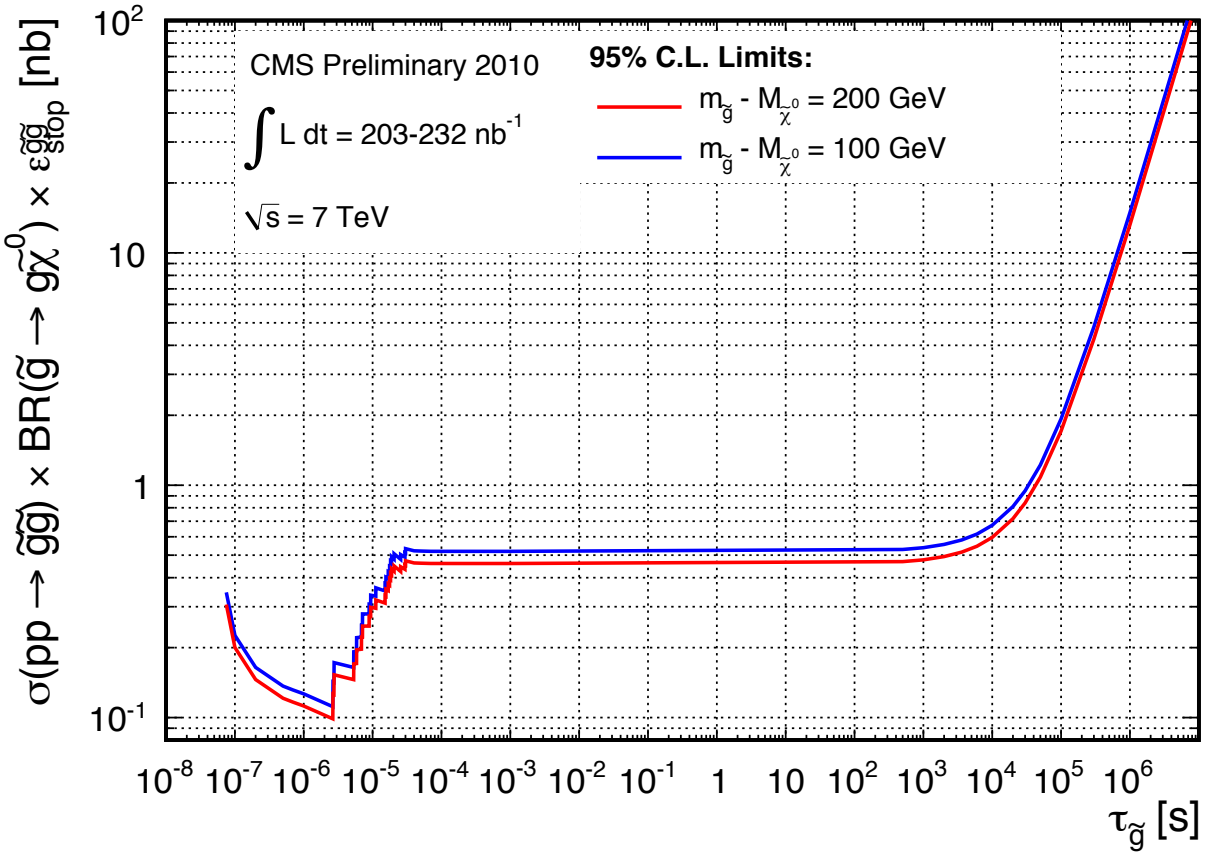
Selection Criteria	Background Rate (Hz)	Signal Efficiency %
L1+HLT (HB+HE)	3.27	30.5
Calorimeter noise filters	1.12	29.9
BPTX/BX veto	1.11	29.9
muon veto	6.6×10^{-1}	26.4
$E_{jet} > 50$ GeV, $\lvert\eta_{jet}\rvert < 1.3$	7.6×10^{-2}	20.5
$n_{60} < 6$	7.6×10^{-2}	20.2
$n_{90} > 3$	3.1×10^{-3}	18.6
$n_{phi} < 5$	1.3×10^{-4}	18.5
$R_1 > 0.15$	1.1×10^{-4}	18.5
$0.1 < R_2 < 0.5$	8.5×10^{-5}	17.5
$0.4 < R_{peak} < 0.7$	7.9×10^{-5}	17.3
$R_{outer} < 0.1$	6.9×10^{-5}	17.2

Stopped Gluinos

Lifetime [s]	Expected Background ($\pm$ stat $\pm$ syst)	Observed
1e-07	$0.15 \pm 0.04 \pm 0.05$	0
1e-06	$1.8 \pm 0.5 \pm 0.5$	0
1e-05	$11.7 \pm 3.2 \pm 3.5$	8
1e-04	$28.3 \pm 7.8 \pm 8.5$	19
1e-03	$28.3 \pm 7.8 \pm 8.5$	19
1e+03	$28.3 \pm 7.8 \pm 8.5$	19
1e+04	$28.3 \pm 7.8 \pm 8.5$	19
1e+05	$28.3 \pm 7.8 \pm 8.5$	19
1e+06	$28.3 \pm 7.8 \pm 8.5$	19

- Perform simple counting experiment in “off” cycles
- Results consistent with null hypothesis

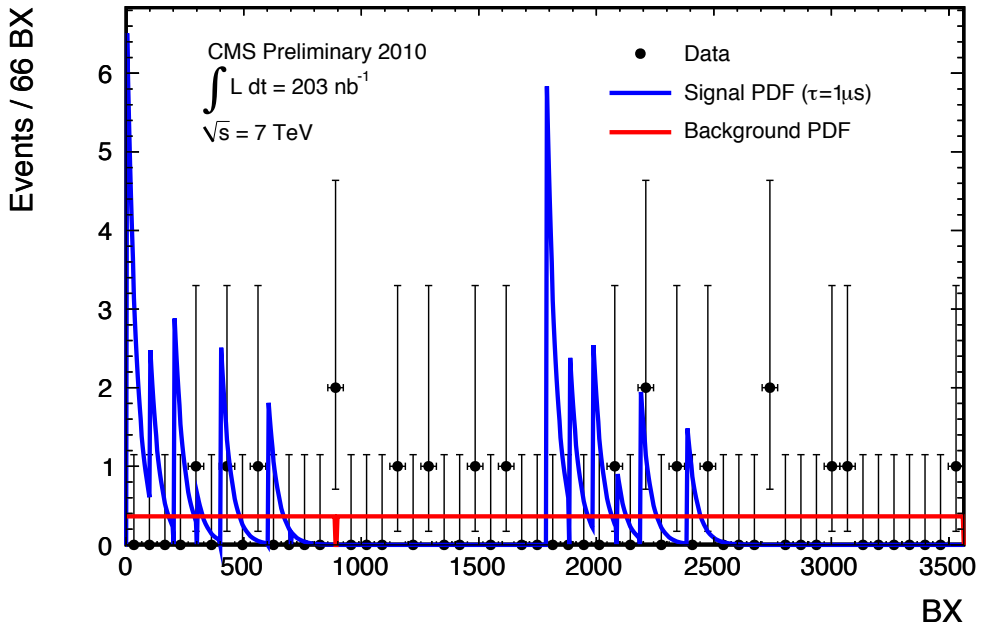
Stopped Gluinos

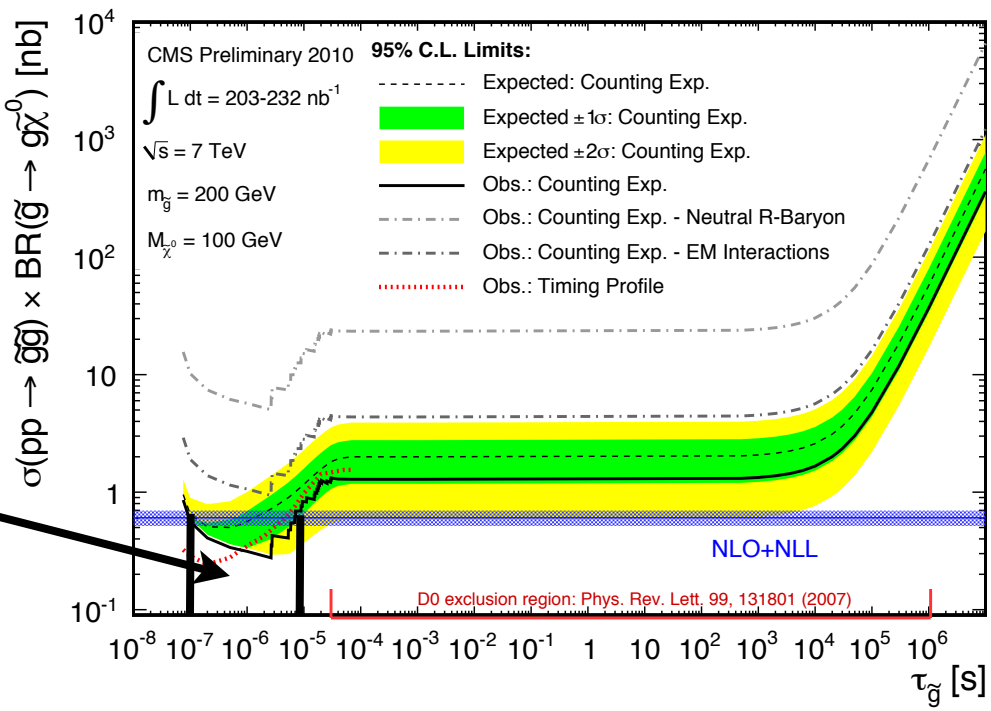


- Model independent limit
- Structure seen due to different time windows in analysis, based on hypothesized gluino lifetime

Stopped Gluinos

- Time profile analysis
  - Signal PDF based on beam profile
  - Background PDF is flat
- Model-dependent exclusion
  - Consistent with null hypothesis
- Extends current Tevatron limits!
  - 120 ns < t < 6 μs





Conclusions

- The LHC era of new physics has started!
  - We're chipping away at the available phase space already!

- Several new analyses even with a trickle of data that probe new physics scenarios

Every block of stone has a statue inside it and it is the task of the sculptor to discover it.

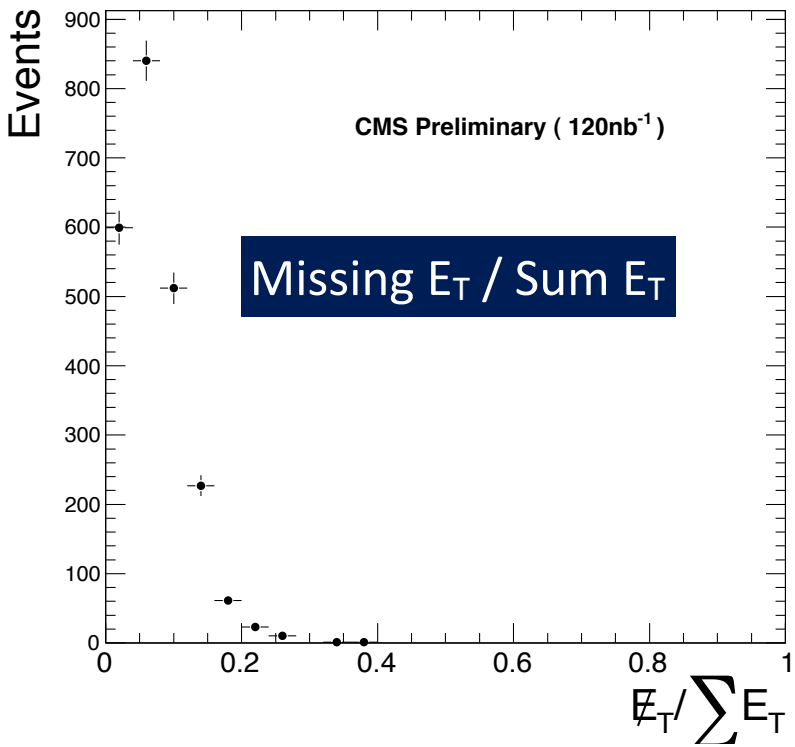
-- Michelangelo*

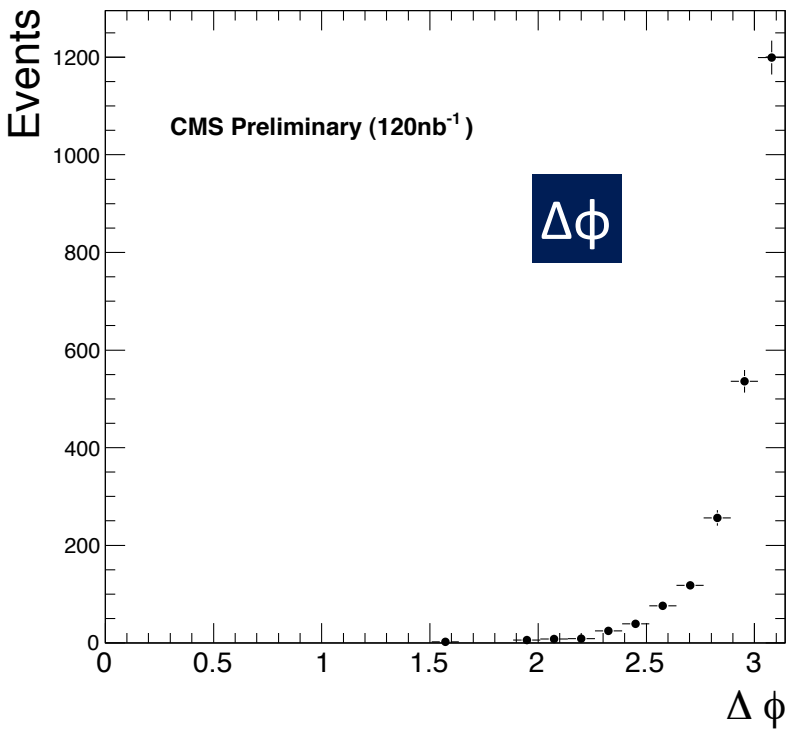
*Buonarroti, not Mangano

Sober reminder for patience

- Michelangelo's floor

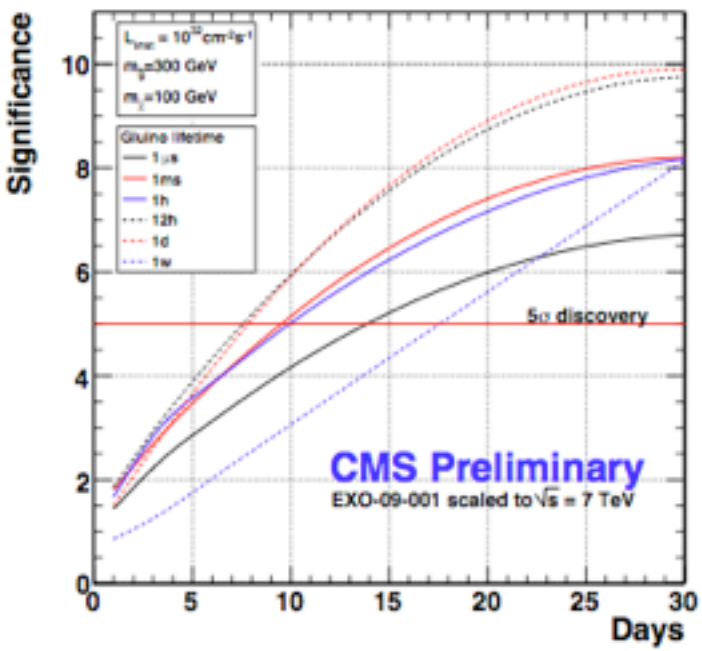
New Physics With Dijets

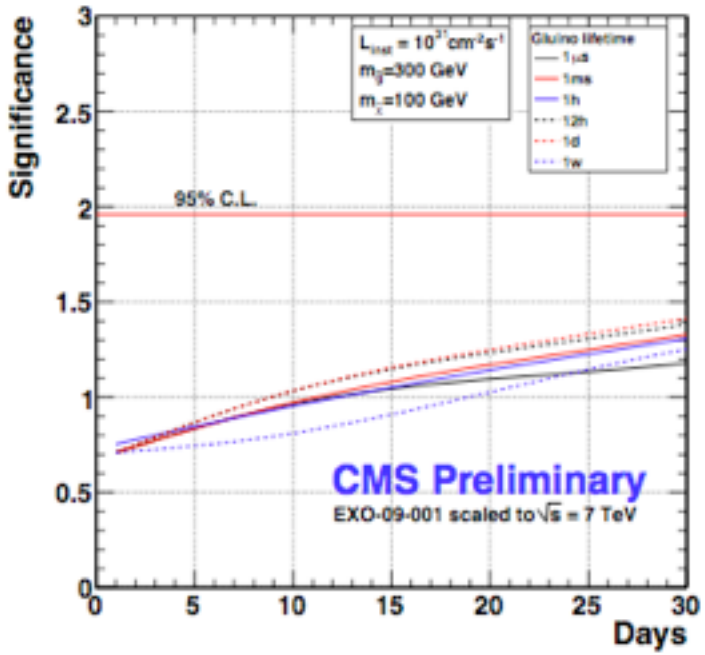




Very clean dijet sample!

Expected Limits





- CAVEAT: Makes assumptions based on beam performance and parameters