Recent Results On Searches From CMS

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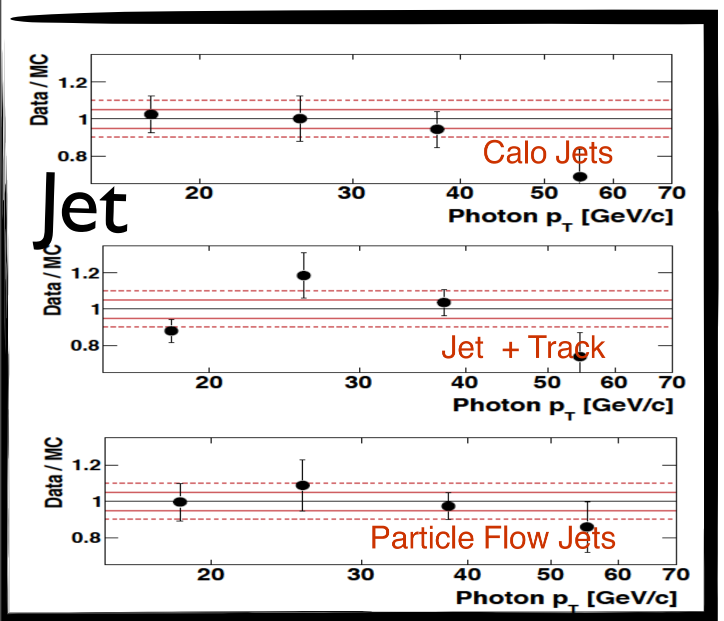
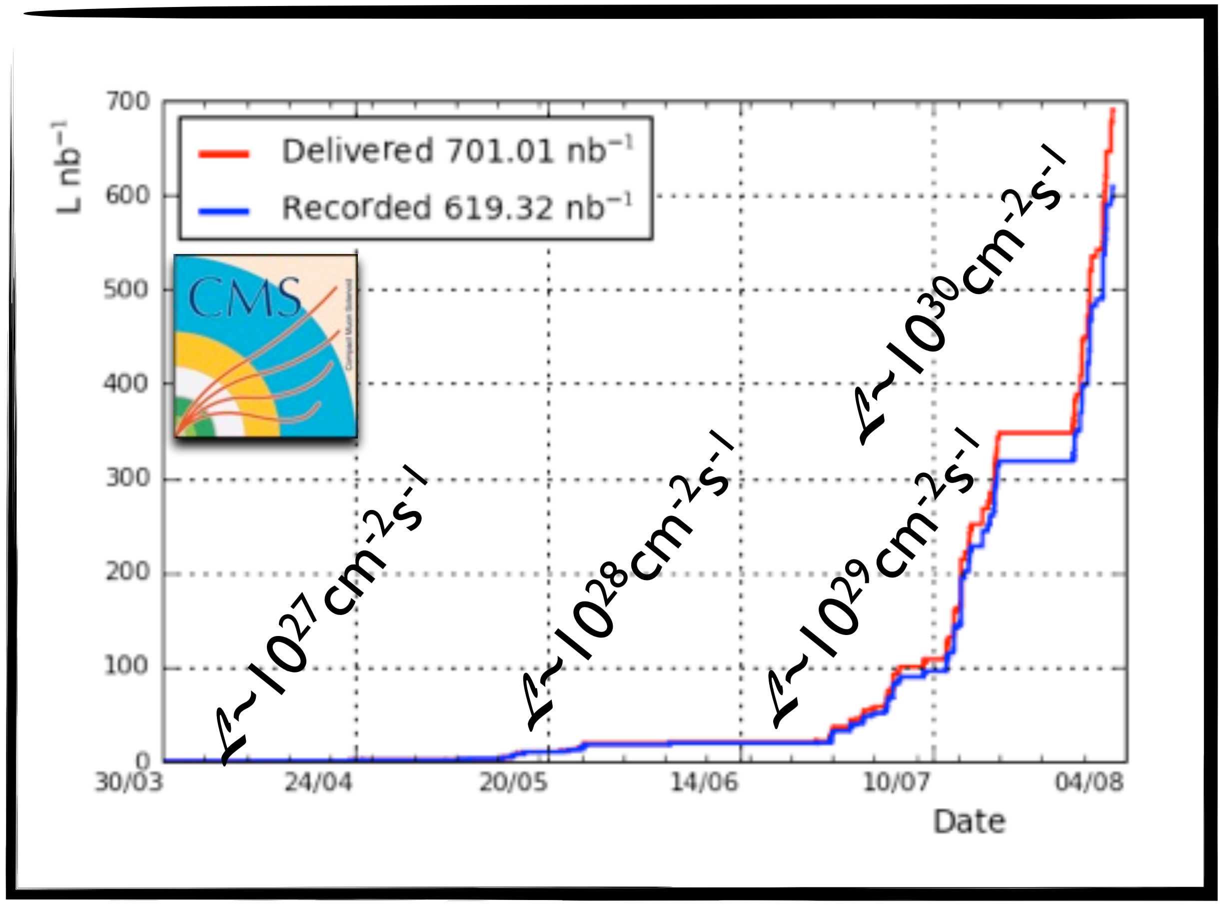
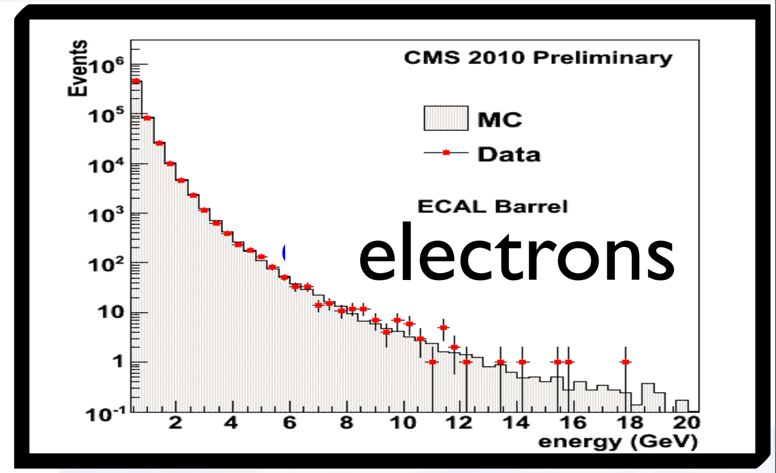
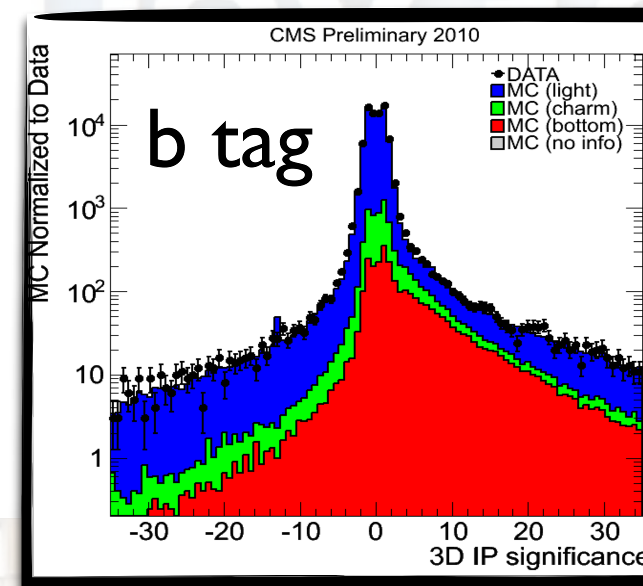
CERN

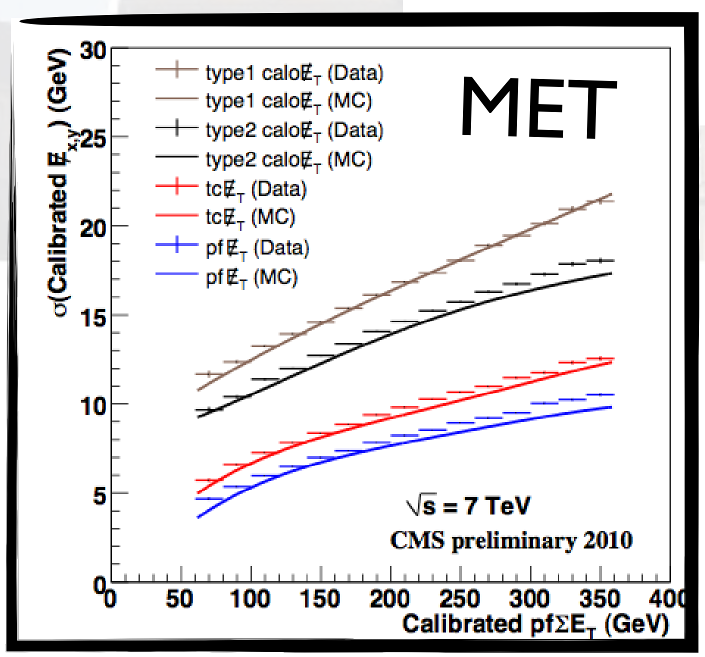
CMS is happening



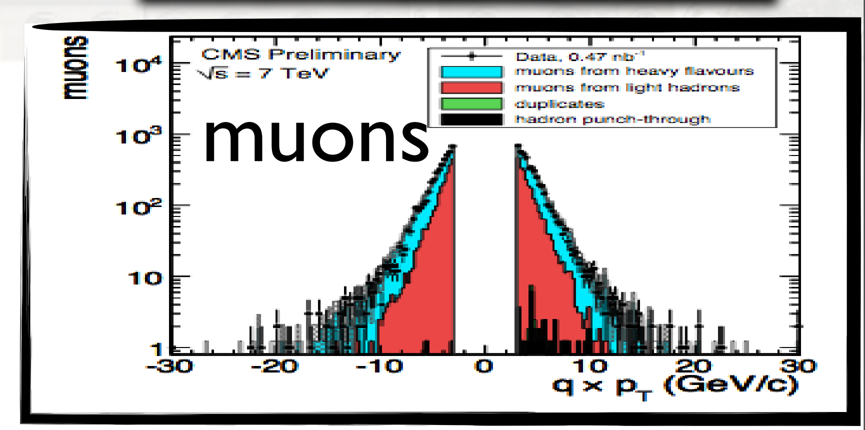








- Luminosity Increasing weekly
- Detector behaving as expected
- All ingredients already in place for searches to start



In This Talk

NEW!!!

<u>*Parallel Talk Speaker*</u>

New Physics Search with Dijet events

- DiJet Mass spectrum [836 nb^{-1}] *(J. Hirschauer)*
- Jet Centrality study [120 nb^{-1}] *(J. Hirschauer)*

Long-Lived Heavy Particles

- Anomalous dE/dx [198 nb^{-1}] *(P. Traczyk)*
- Stopped Particles Search [~200 nb^{-1}] *(F. Ratnikov)*

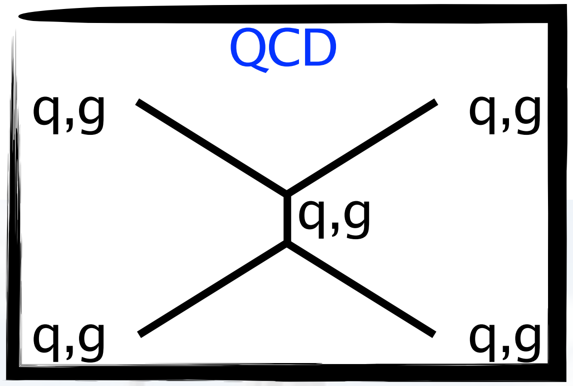
Commissioning of SUSY searches

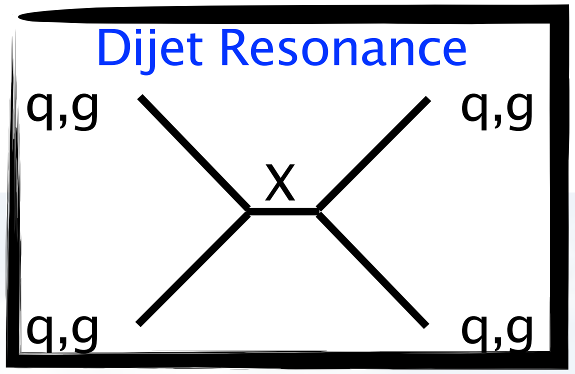
- Hadronic Analyses *(C. Auterman, C. Rogan)*
- Leptonic Analyses *(Y. Pakhotin)*
- MET commissioning ***(Plenary Talk by C. Sander+** C. Rogan**)***
- Model-Unspecified Searches *(H. Pieta)*
- Di-Photon Searches *(B. Heyburn)*

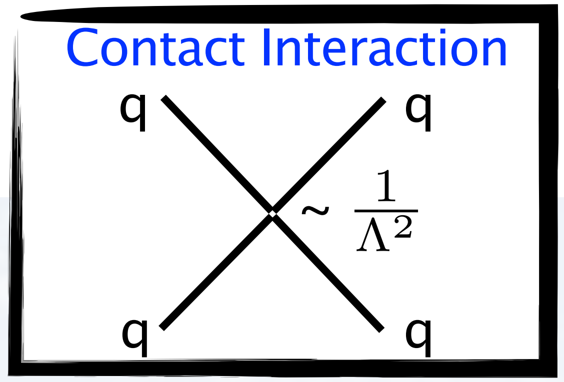
New Physics Search With DiJet

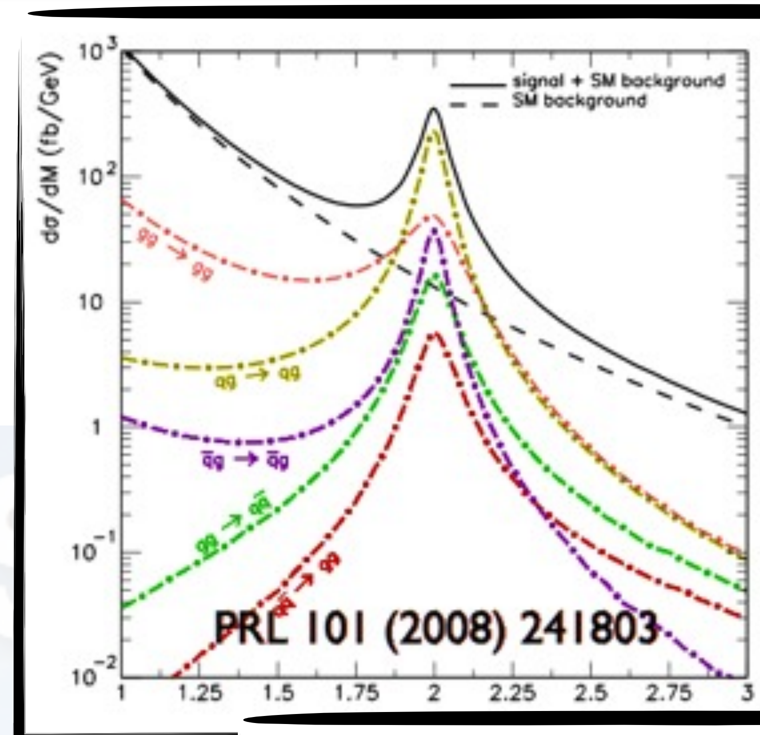
New Physics Search with Dijet events

- New Physics can modify DiJet production mainly in two ways







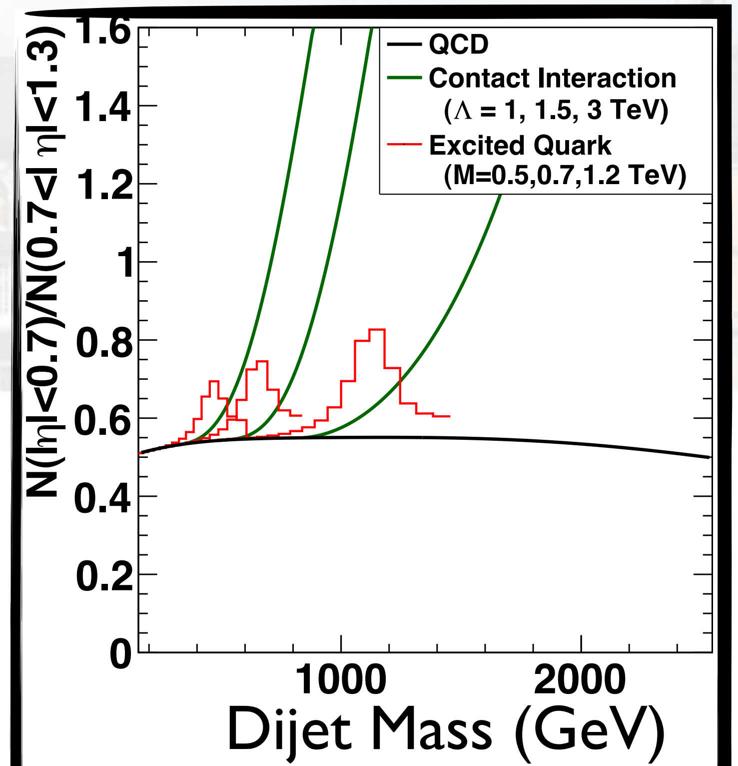


Large rate predicted e.g. for di-quark production in string models

- New DiJet resonances probed by Dijet mass distribution

- New Operators in the theory can be probed testing QCD properties vs Standard Model expectations, e.g.. centrality R vs DiJet Mass

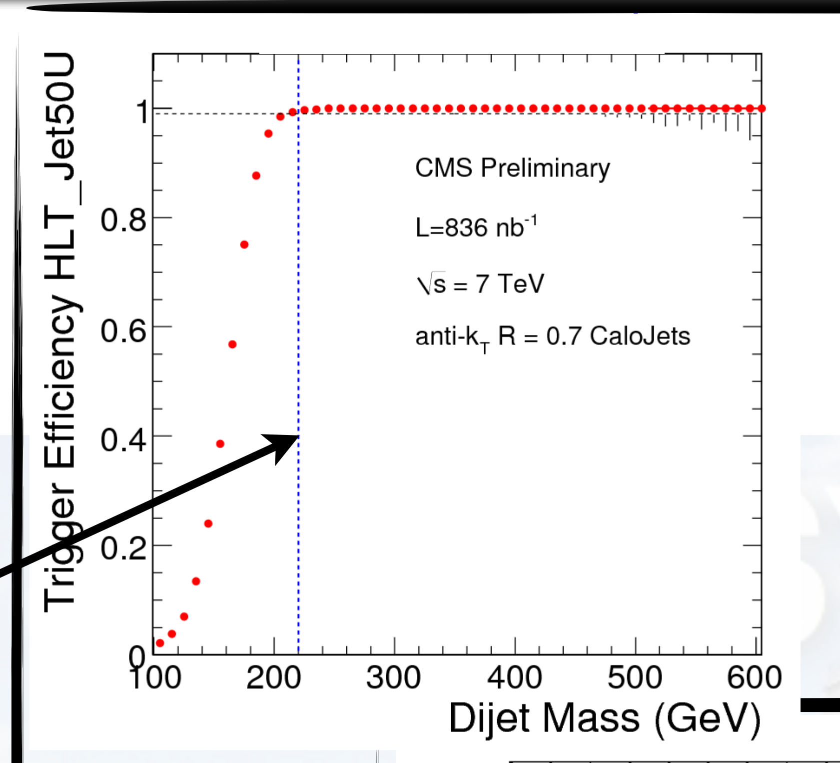
$$R = \frac{N(|\eta| < 0.7)}{N(0.7 < |\eta| < 1.3)}$$



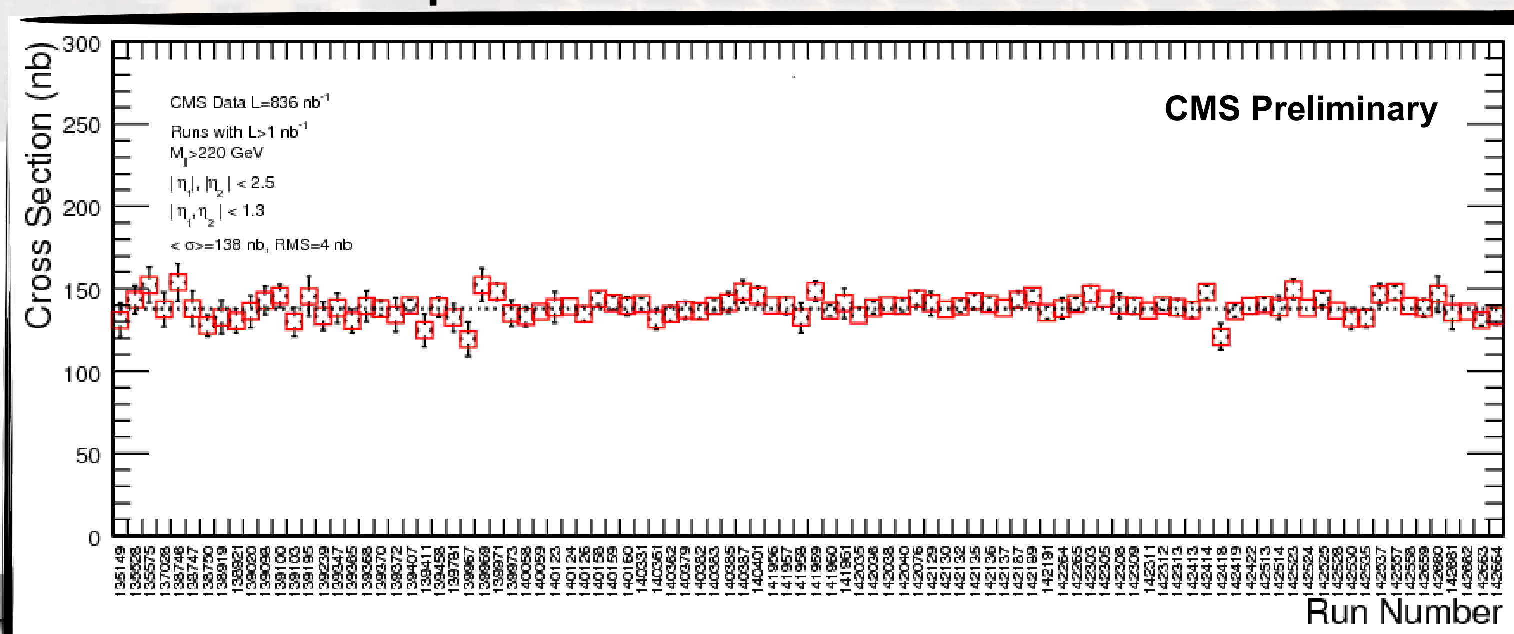
Dijet Mass Spectrum

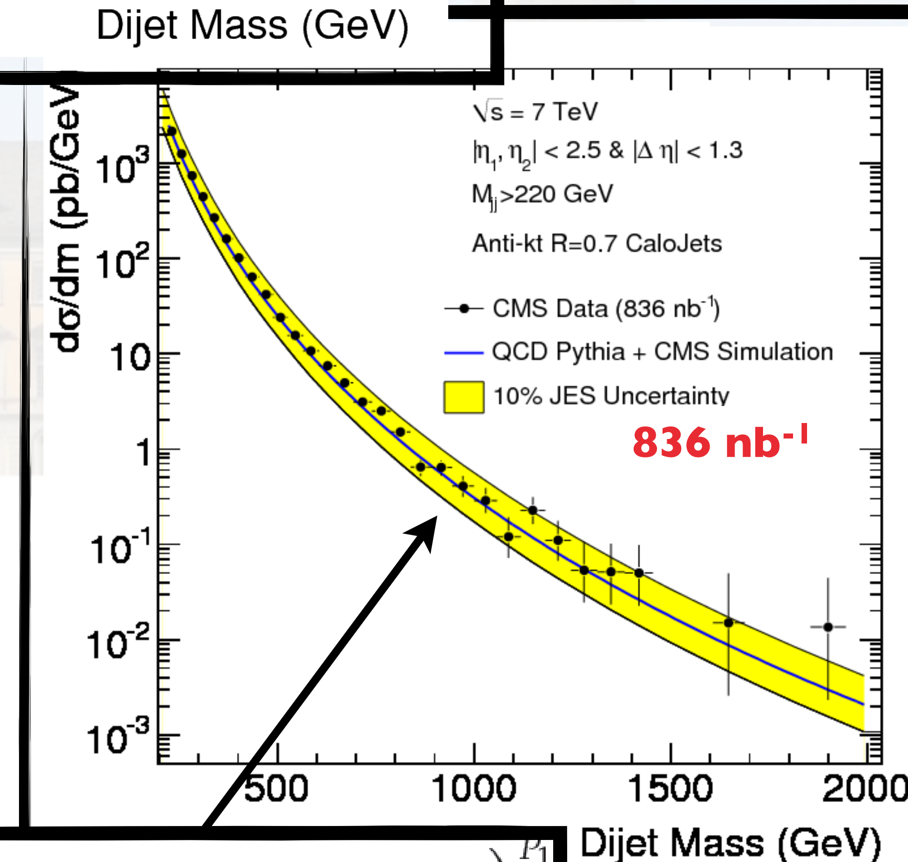
NEW!!!

- Events accepted by SingleJet HLTrigger
  - Jets clustered as cone with $\Delta R > 0.5$
  - One jet with raw E_T > 50 GeV
- Two Anti-Kt jets ($\Delta R = 0.7$) with $|\eta| < 2.5$ $|\eta_1 - \eta_2| < 1.3$ m(DiJet)>220 GeV/c^2
  - Jet energy corrected for detector effects (from Monte Carlo) + 10% systematics
  - Trigger fully efficient at this value



- Data in good agreement with PYTHIA
- Continuum spectrum described analytically
- Rate of accepted events stable vs time



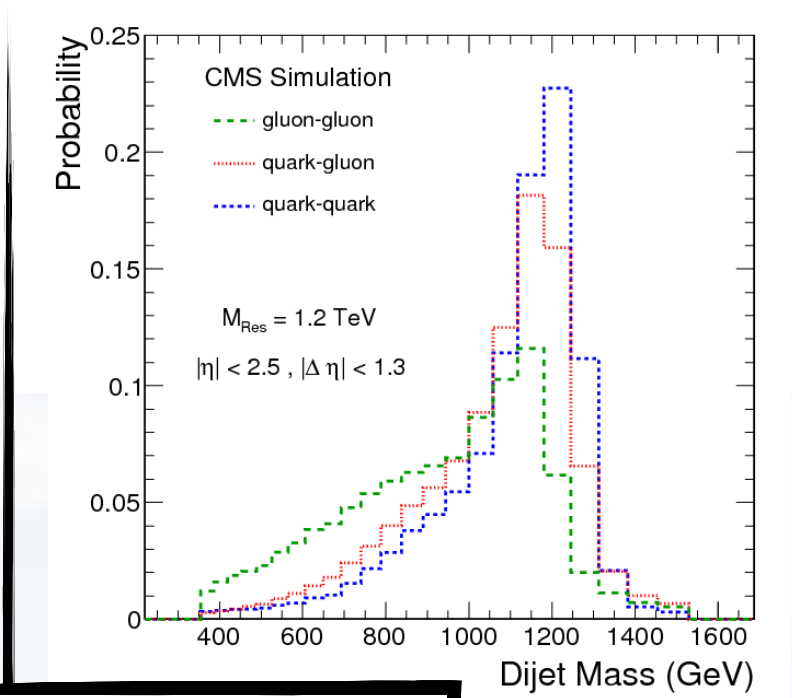


$$\frac{P_0 \cdot \left(1 - m/\sqrt{s} + P_3 \cdot (m/\sqrt{s})^2\right)^{P_1}}{m^{P_2}}$$

6

NEW!!!

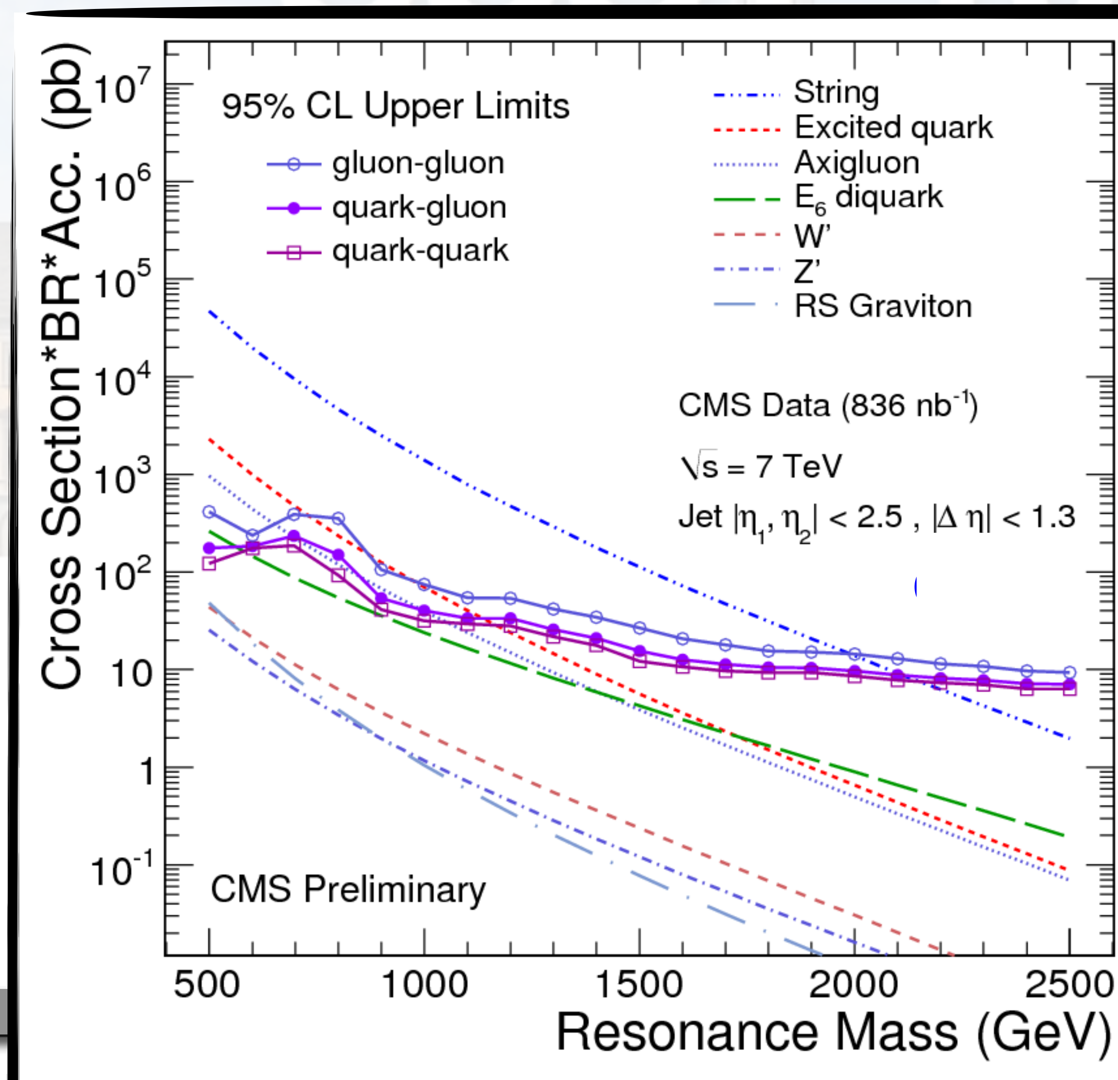
Limit on Heavy Resonances



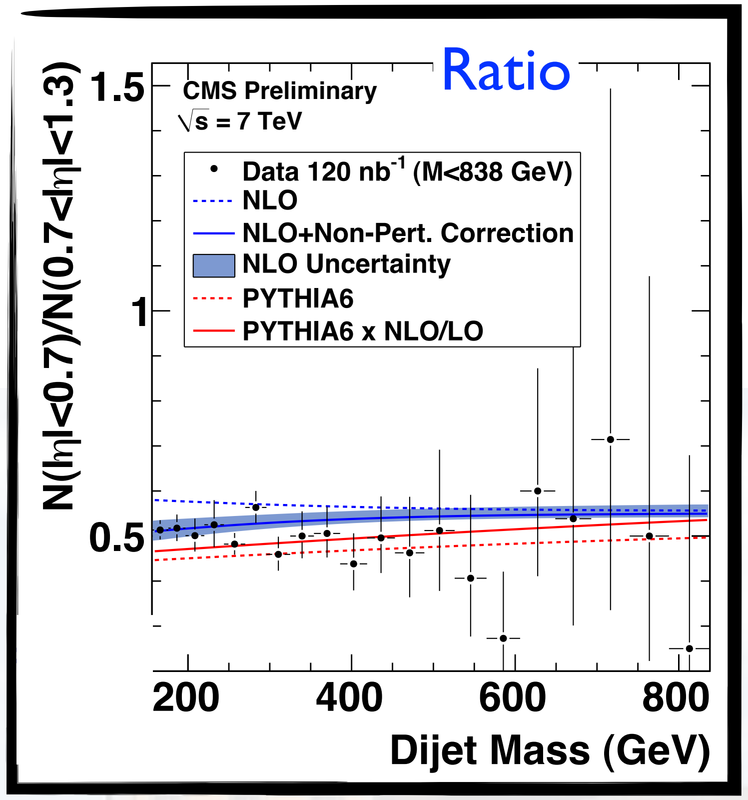
- Resonance shapes produced with PYTHIA
- Gaussian core of Dijet mass resolution varies from 11% at 0.5 TeV to 6% at 2.5 TeV
- Shape depends on final state (qq vs gq vs gg) more gluons → more radiation → broader peak
- We search for the three final states. No excess is seen, resulting into limits

95% CL Lower Limits on mass(in TeV)

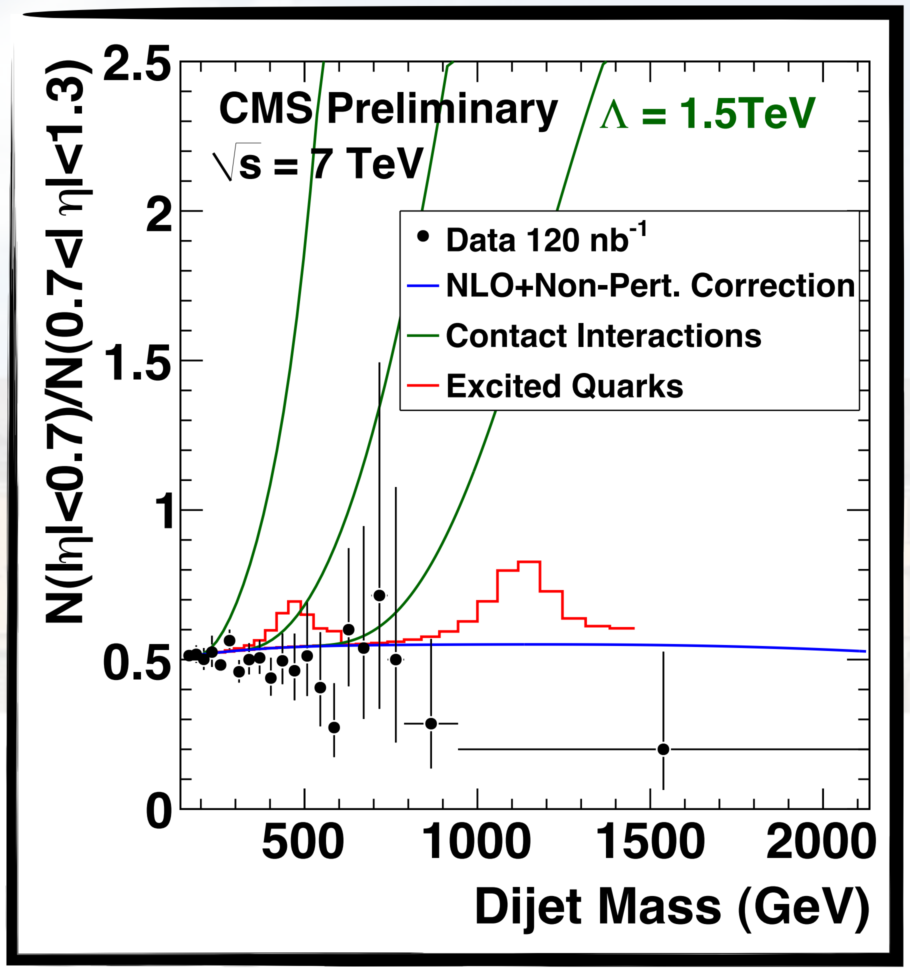
Model	Final State	CMS [836 nb^{-1}]	CDF [1.13 fb^{-1}]	ATLAS [315 nb^{-1}]
String	$q\bar{q}$, gq, gg	2.10	1.4	-
q*	gq	1.14	0.87	1.20
Axigluon/ Coloron	$q\bar{q}$	1.06	1.25	-
E6	qq	0.58	0.63	-



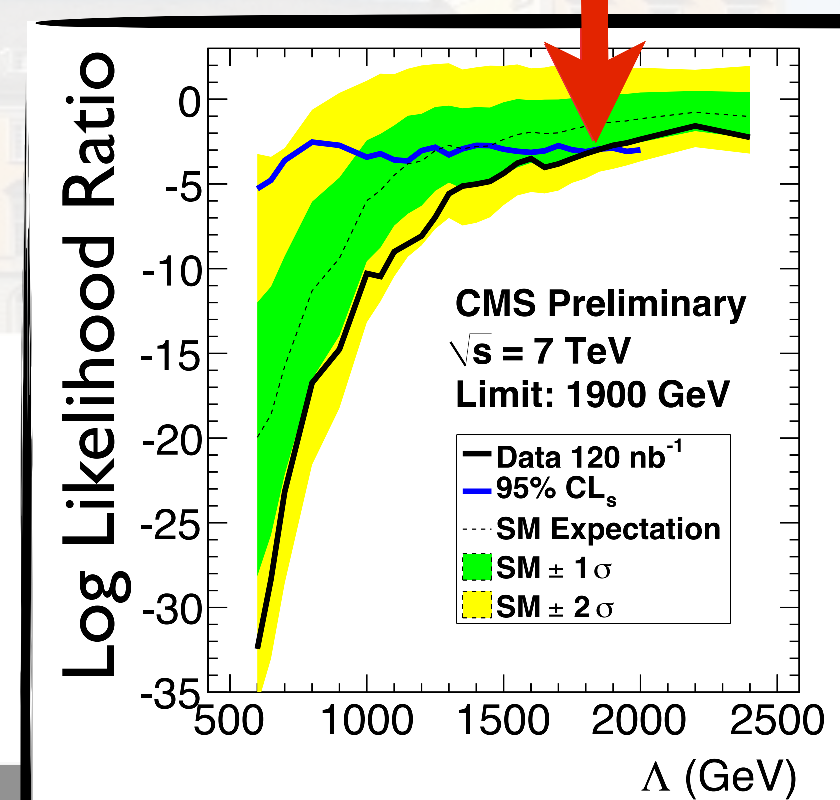
Centrality Ratio



- Complimentary to the spectrum analysis.
- Many experimental uncertainties cancel in the ratio (absolute jet energy scale, luminosity)
- The data agree well with NLO+non pert. corrections



- Ratio is flat, no sign of new physics.
- Contact interaction scale excluded for **Λ<1.9 TeV** at 95% CL.
  - Tevatron excludes Λ<2.8 TeV



- approximately flat vs dijet mass for QCD.
- rises vs dijet mass for contact interactions.
- “bumps” in dijet mass for dijet resonances.

Long-Lived Heavy Particles

LLH Signatures @CMS

Long-Lived Heavy particles in many NP scenarios:

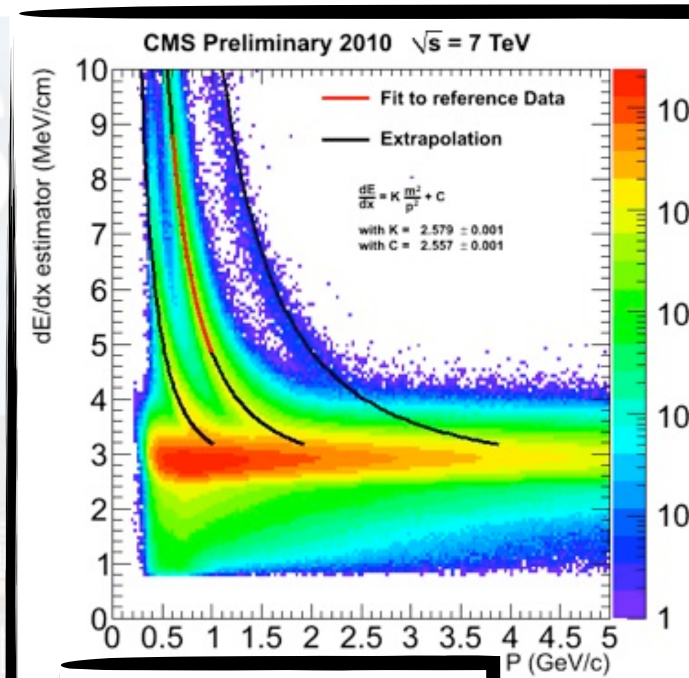
- Stau, gluinos, or stop in SUSY
- Hidden valley models
- (If strongly interacting) bound states with quark/gluons → R-hadrons

If charged, two main signatures in CMS

- Slow moving particles have energy loss in material > MIP
- Some of them will stop in the detector and decay out of time wrt beam crossing

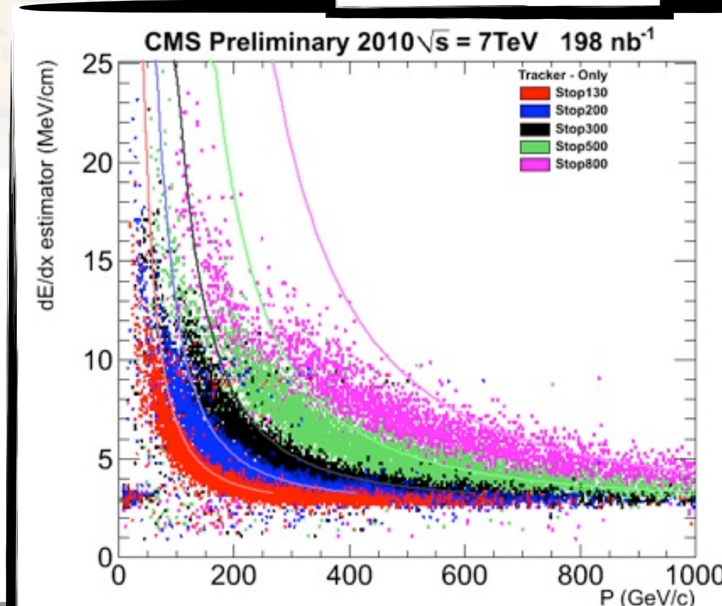
Two Analysis

- Search for charged tracks with anomalously high dE/dx (β<0.3)
- Search for stopped particles (sensitive to β>0.3)



Min. Bias Data

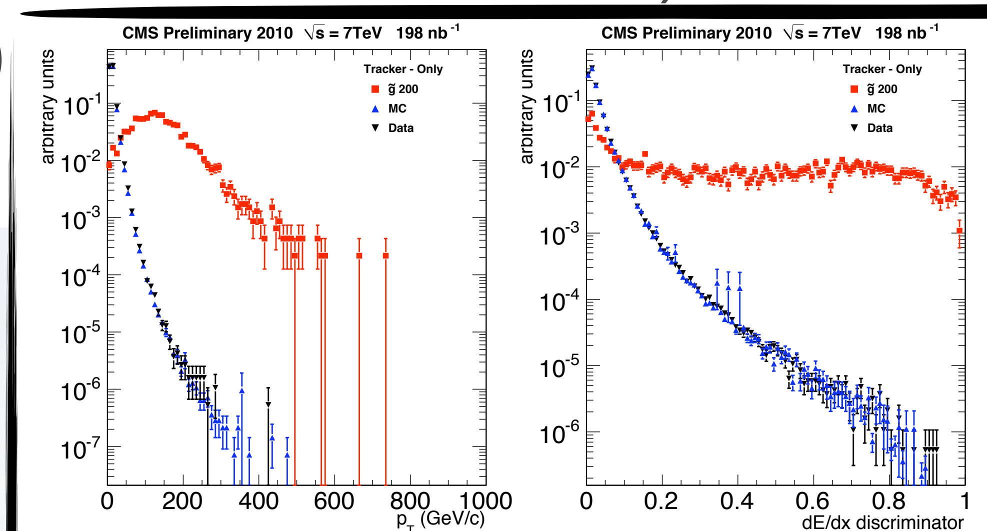
$\tilde{t}$ Monte Carlo



dE/dx Search Strategy

Highly penetrating particles

- track+muon (muon-like signature, e.g. 100-300 GeV mGMSB stau)
- track-only (e.g. 130-900 GeV gluino R-hadron)



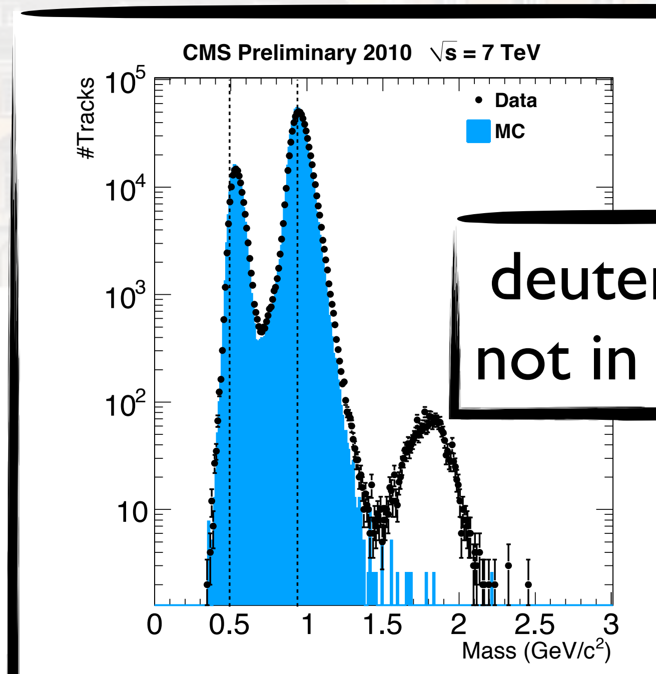
p_t distribution　　*dE/dx discriminator*

Trigger strategy:

- track+muon: Muon pT>3 GeV, DoubleMuon
- track-only: Jet pT>50 GeV, MET>45 GeV

Selection:

- Select Tracks on pT and dE/dx tails
- Tight selection for signal box
- Loose selection to cross-check bkg estimate
- Count events in bins of η and Nhits



deuteron not in MC

Mass determination

- Approximate Bethe-Bloch formula
- Parameters fixed by fit to protons

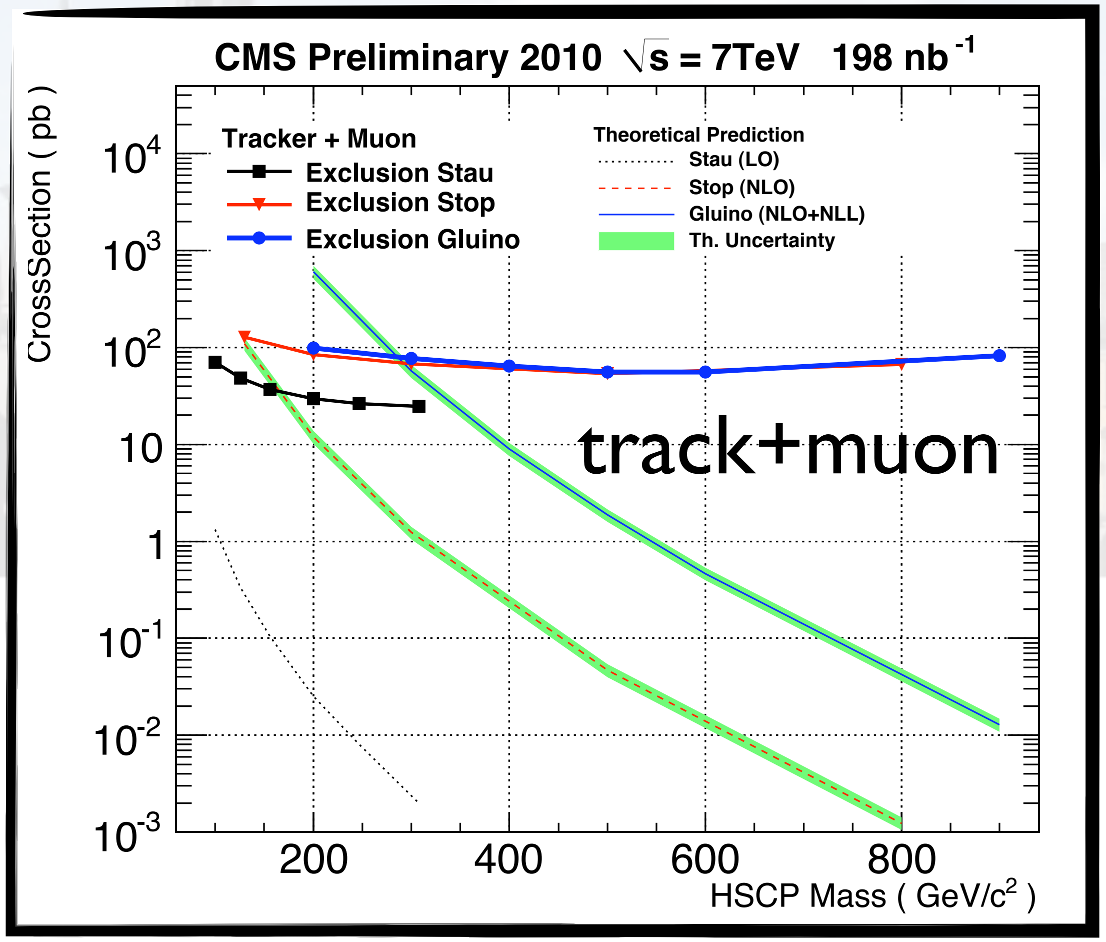
$$I_h = K\frac{m^2}{p^2} + C$$

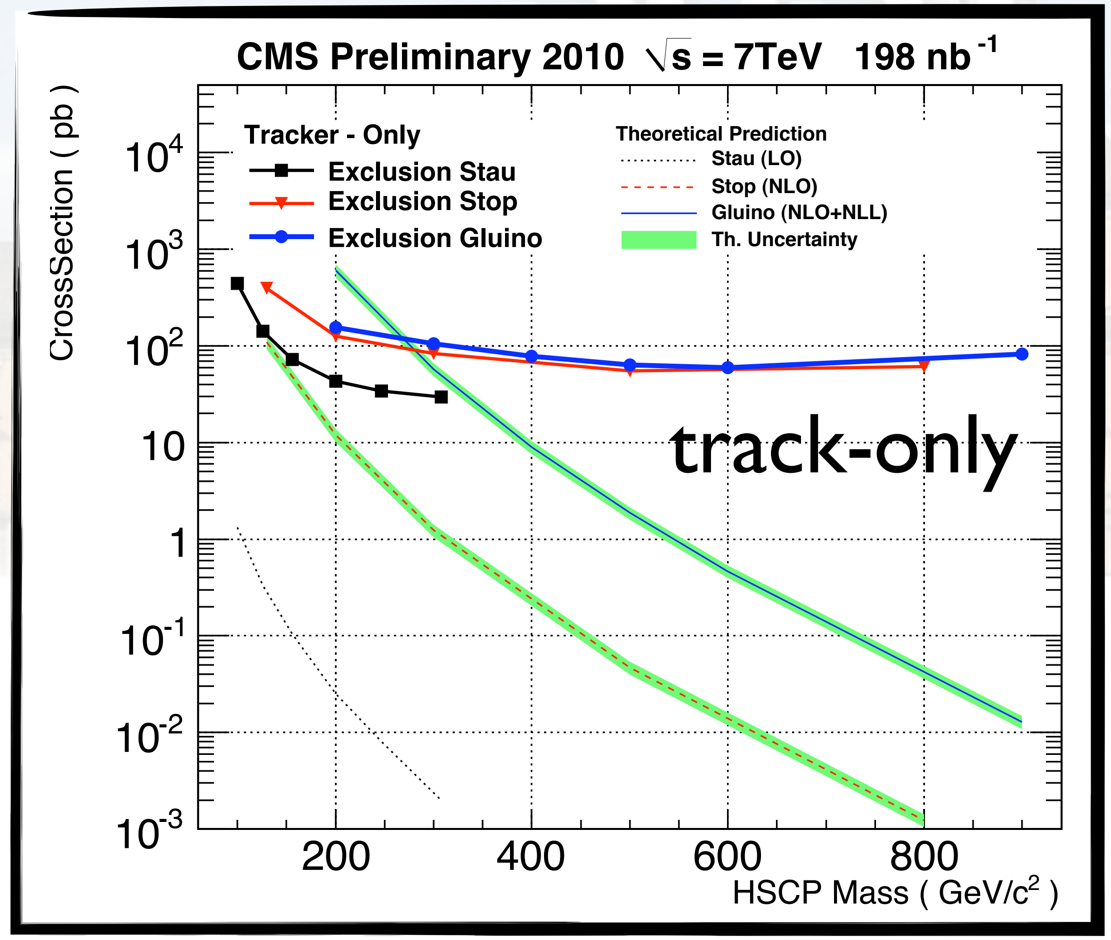
dE/dx Results

- 198 nb^{-1} analyzed
- No Signal found
- 95% CL limit on production cross-section for stau, stop, and gluinos

TIGHT	Exp.	Obs.	Exp. in full spectrum	Obs. in full spectrum
Muon-like	0.153 ± 0.061	0	0.249 ± 0.050	0
Tk-only	0.060 ± 0.021	0	0.060 ± 0.011	0

- Track-only analysis => **exclude $m_{\tilde{g}} < 271$ GeV/c^2**
- Track+muon analysis => **exclude $m_{\tilde{g}} < 284$ GeV/c^2**

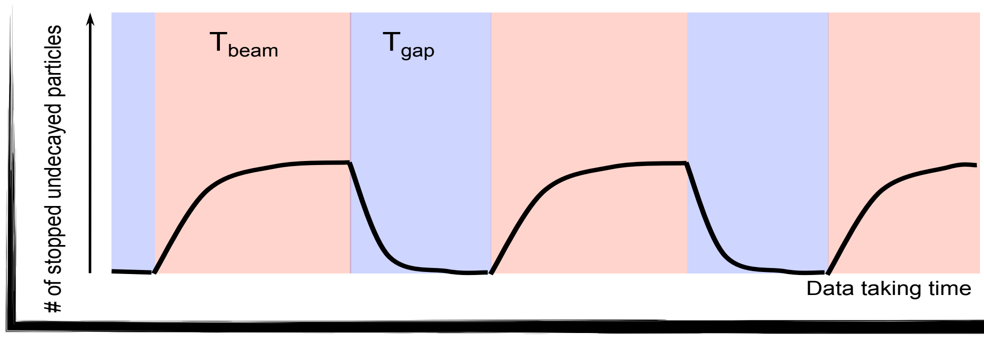




Stopping Particles Strategy

Dedicated calorimetry trigger for no-collision

- Gaps between filled bunches during LHC fills
- Beam presence vetoed at HLT (BPTX/BX veto)



Detailed study of background

- Cosmics & Noise rejection defined during 2008/2009 Cosmics runs
- Beam background study during 900 GeV and 7 TeV (low lumi)
- 17% efficient on signal (R-hadrons)

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

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

Counting Experiment in lifetime bins
No Signal observed

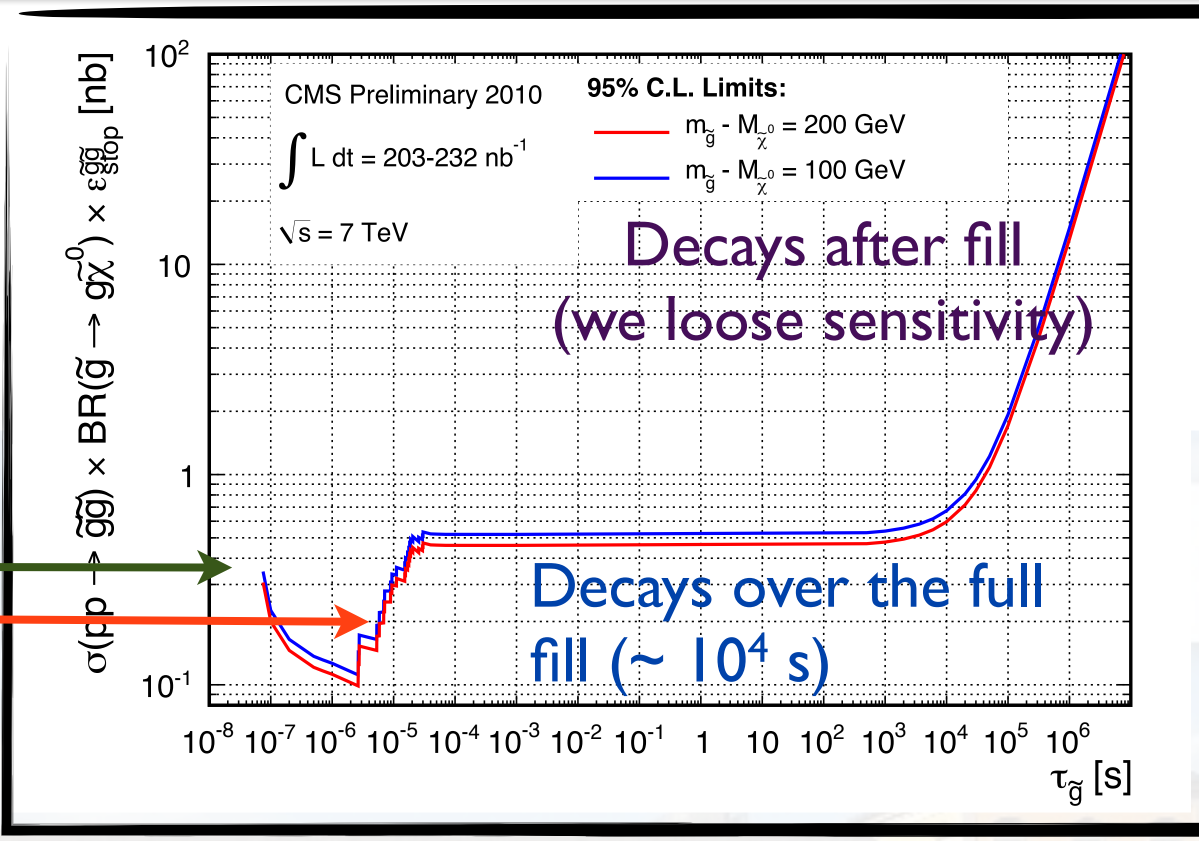
Model-Independent Results

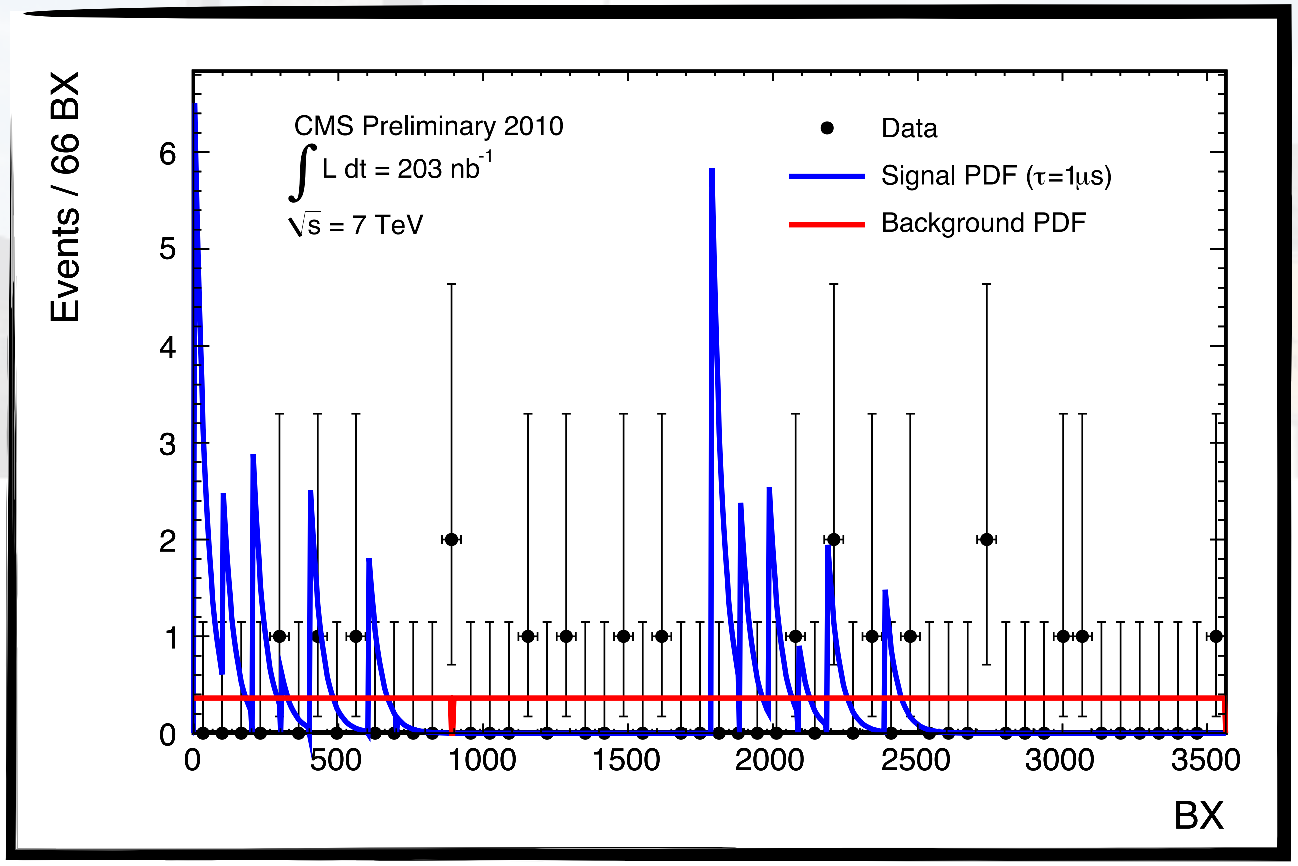
Limit on xsec vs stopping probability

- Independent on the model of interaction with matter
- 14 orders of magnitude covered

Decays during BX veto (~ 100 ns)

Decays within the orbit (~ 10-4 s)





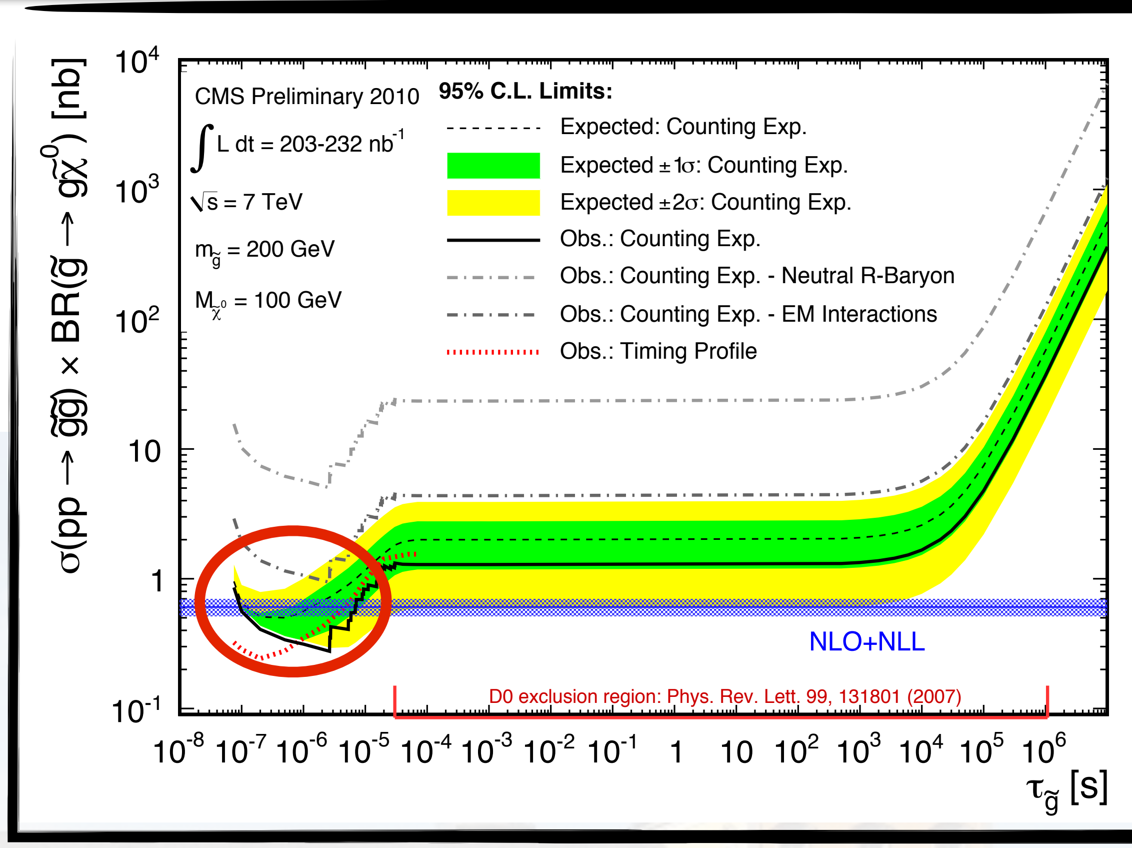
Time Profile analysis

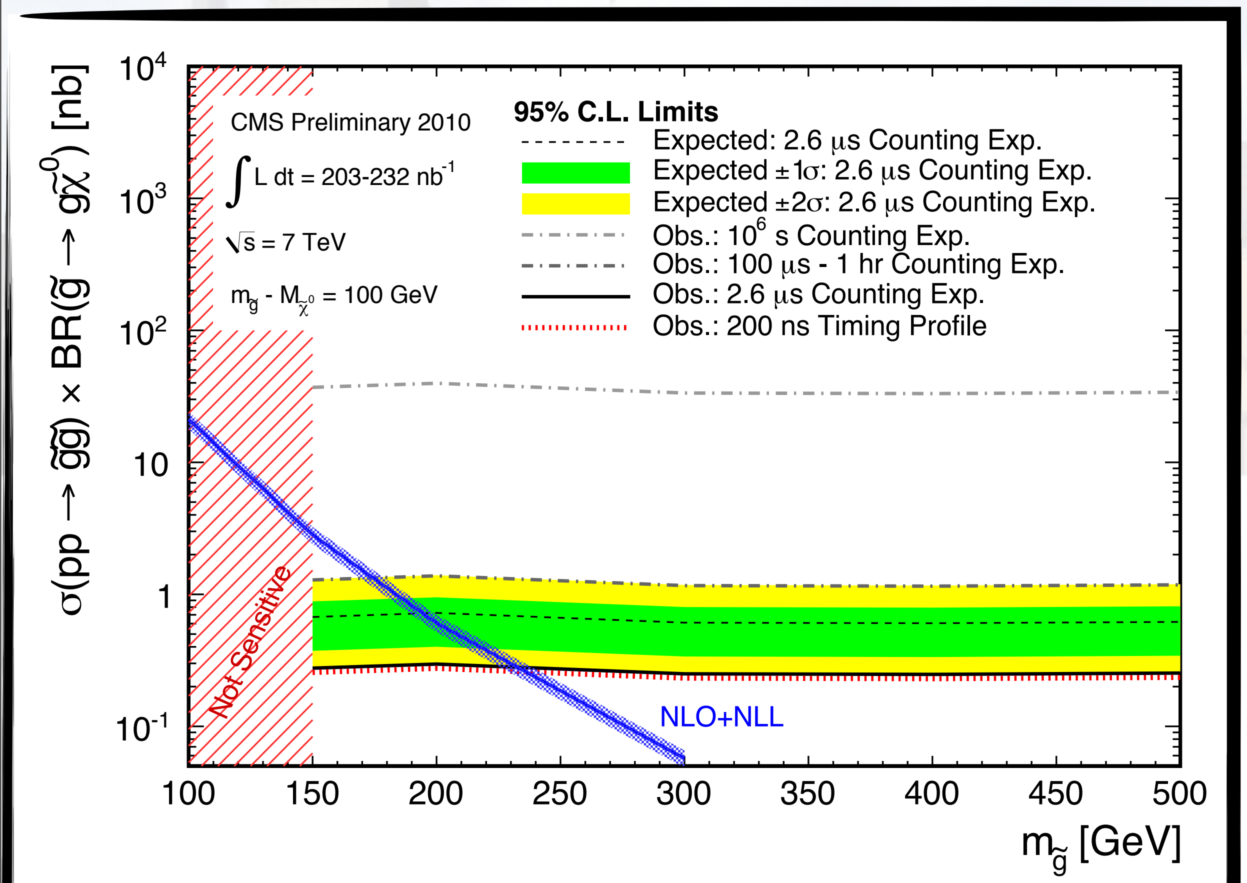
- Take the event time within the orbit
- Assuming a lifetime (<100 μs), compute PDF given the lumi profile
- Bkg flat. Signal peaks at bunch xings
- Fit the data → 95% CL

Model-Dependent Limits

Result translated into a **xsection limit**

- Assumed models for stopping probability ("cloud model," "EM only", "Neutral R-Hadron")
- Used $m_{\tilde{g}}$ = 200 GeV and $m_{\tilde{\chi}^0}$ = 100 GeV
- Included time-profile analysis (dot lines) to improve the sensitivity for $\tau_{\tilde{g}}$<100 ns
- Excluded lifetime range 120 ns <$\tau_{\tilde{g}}$< 6 μs





Result translated into a **mass limit**

- Fixed $m_{\tilde{g}}$-$m_{\tilde{\chi}^0}$ = 100 GeV
- Fixing lifetime
- No sensitivity below 150 GeV (efficiency drop) where LEP limits on m_{χ^0} applies
- Time profile (τ = 200 ns): $m_{\tilde{g}}$ > 229 GeV
- Counting (τ = 2.6 μs): $m_{\tilde{g}}$ > 225 GeV

Commissioning of SUSY Searches

Strategy

Physics Objects (MET, Jets, leptons) commissioned for general CMS use (see plenary talk by C. Sander)

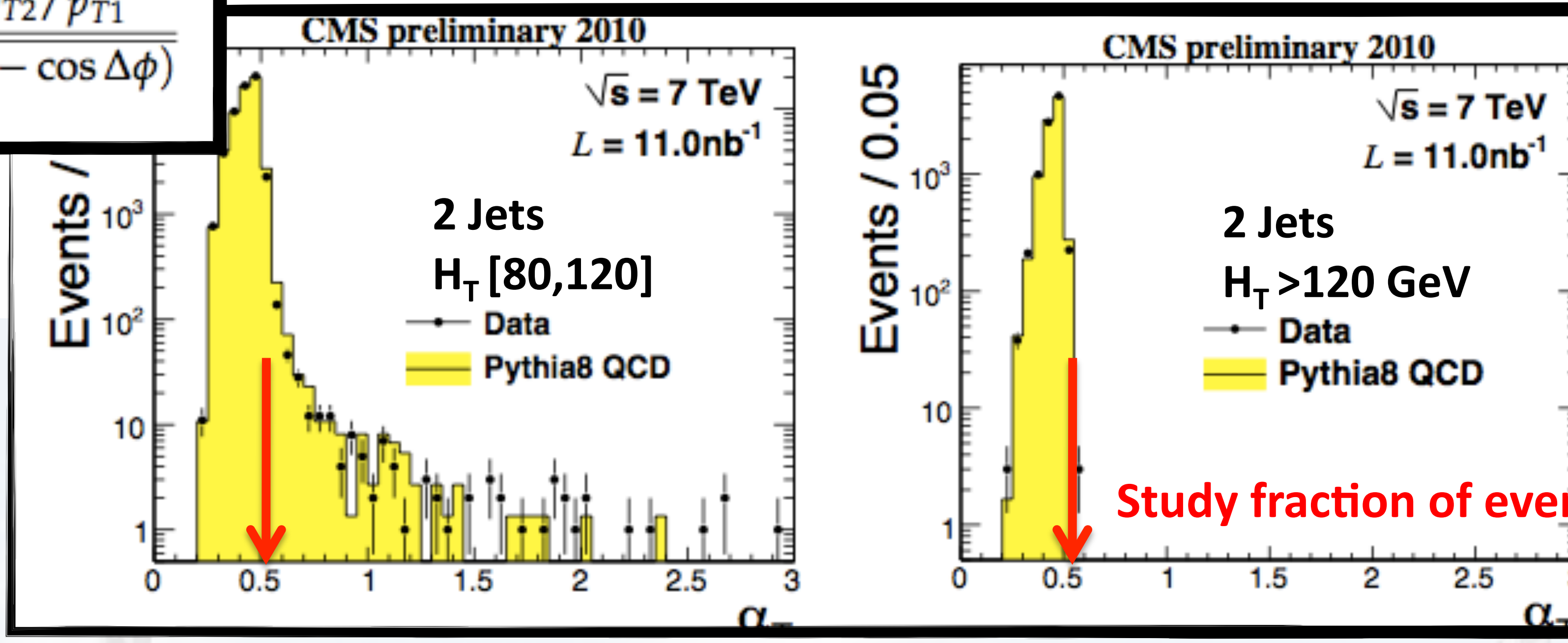
SUSY commissioning focused on specific tools for searches
- Bkg discriminating variables (e.g. α_T, $\Delta\Phi$(MHT, MPT))
- Data-driven strategies for QCD background estimate

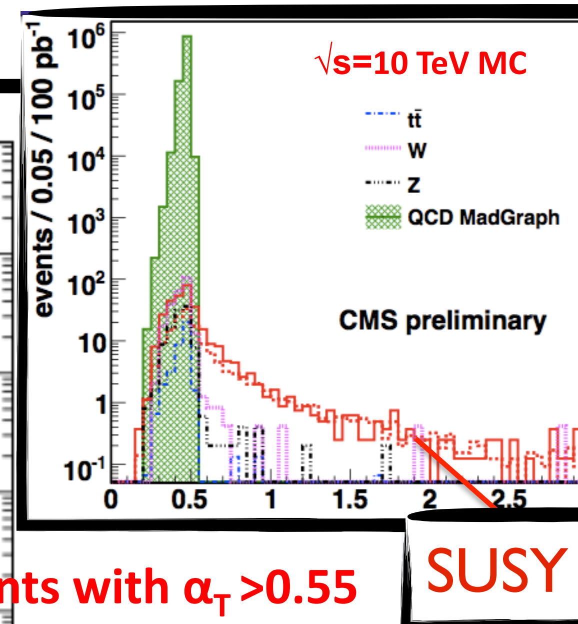
Use the first data as a QCD control sample

Huge effort ongoing to understand the SM backgrounds with data.
- A few highlights in the next slides

Hadronic Analyses

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



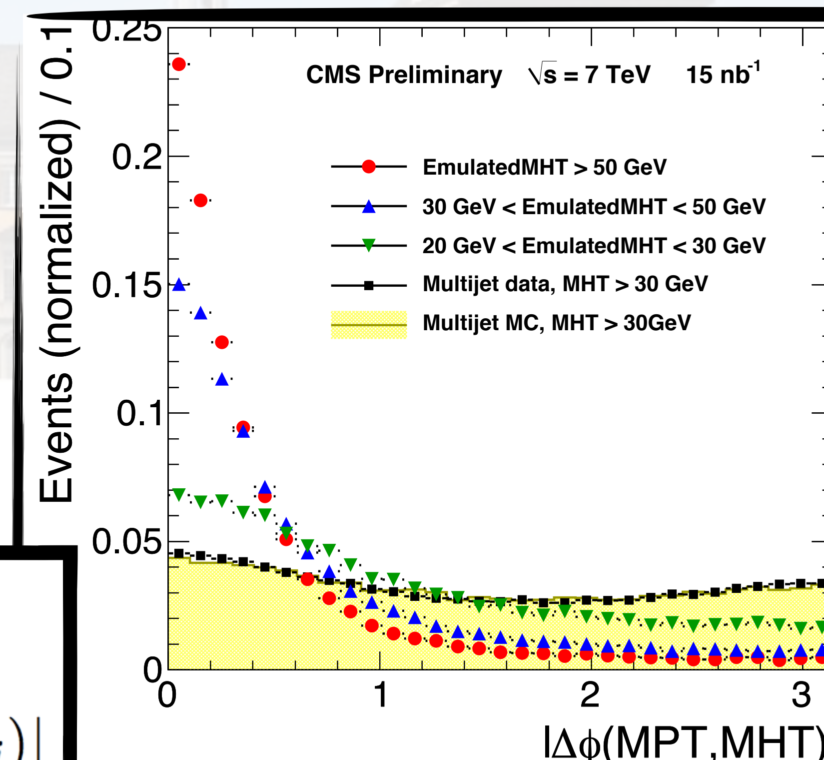


Use low-lumi data to check data-MC agreement

- Check performed in sidebands (far from tails of MET distribution). Reasonable agreement observed
- When possible, extrapolation performed to the tails (e.g. cutting on HT). Agreement preserved, i.e. Monte Carlo predicts correlations

$$\mathrm{MHT} = |-\sum_i \vec{p_T}(\mathrm{jet}_i)|$$

$$\mathrm{MPT} \equiv |-\sum_i \vec{p_T}(\mathrm{track}_i)|$$



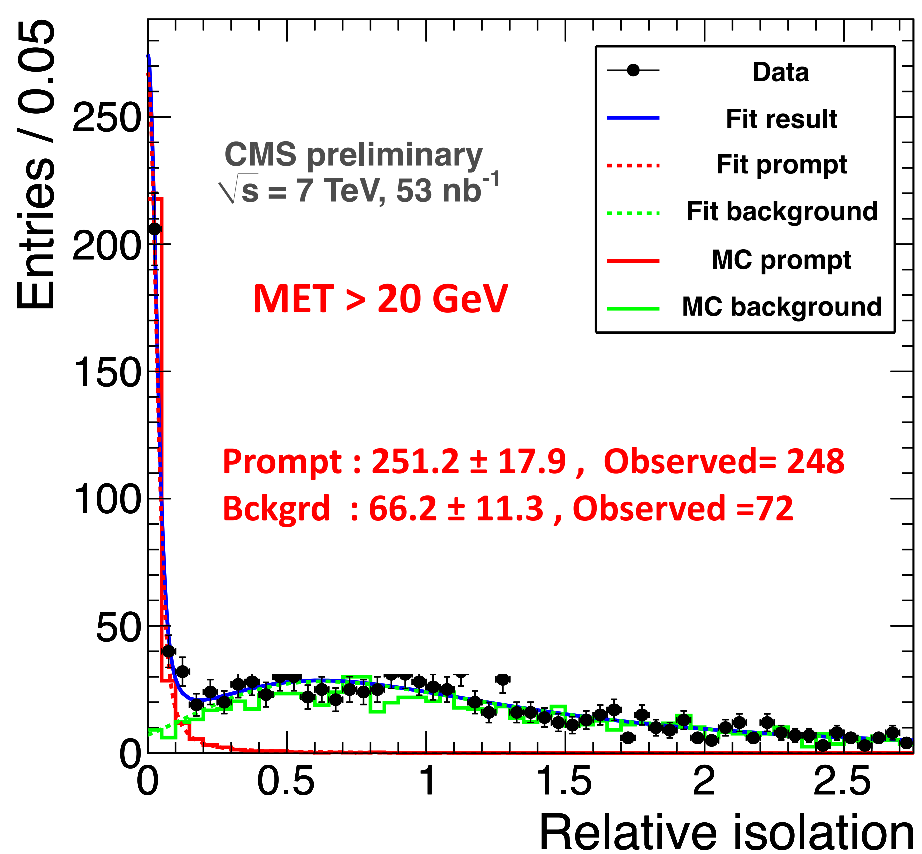
Lepton+Jets+MET

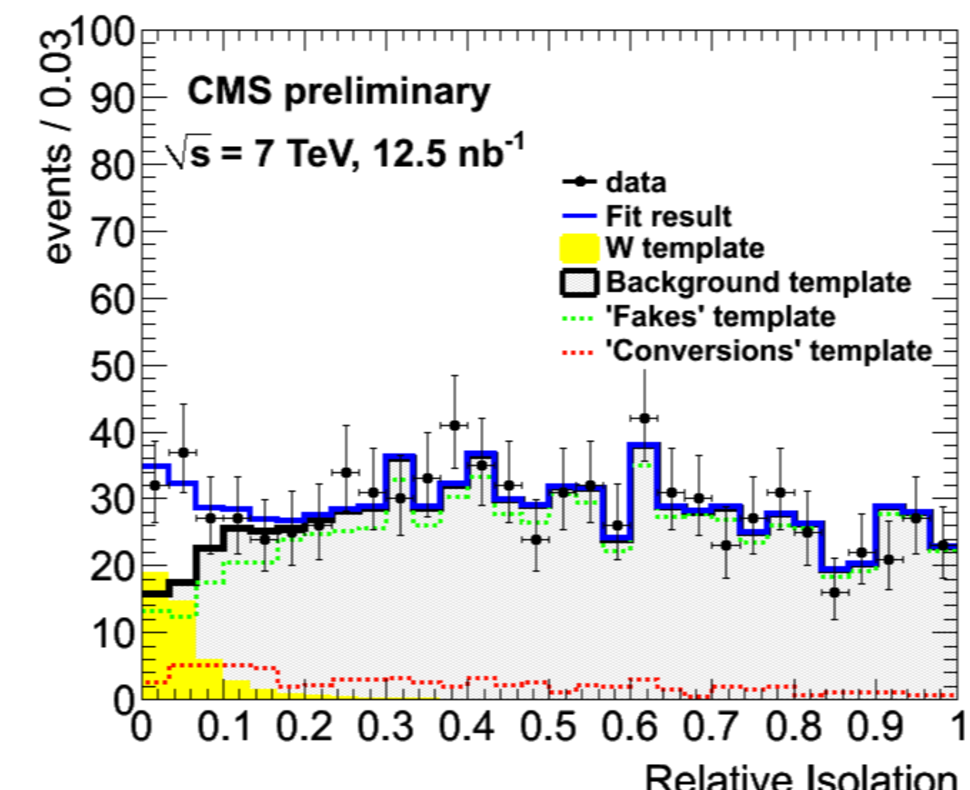
Test background estimate strategy with W

- Invert analysis cuts & fit Relative Isolation
- Prediction bkg events vs observed

$$\mathrm{RI} = \frac{\sum(p_T^{Calo+Trk})_{R<0.3}}{p_T(e)}$$

μ+Jets+MET	Fit Result	Observed
Prompt Muons MET<20	251 +- 18	248
Background MET<20	66 +/- 11	72



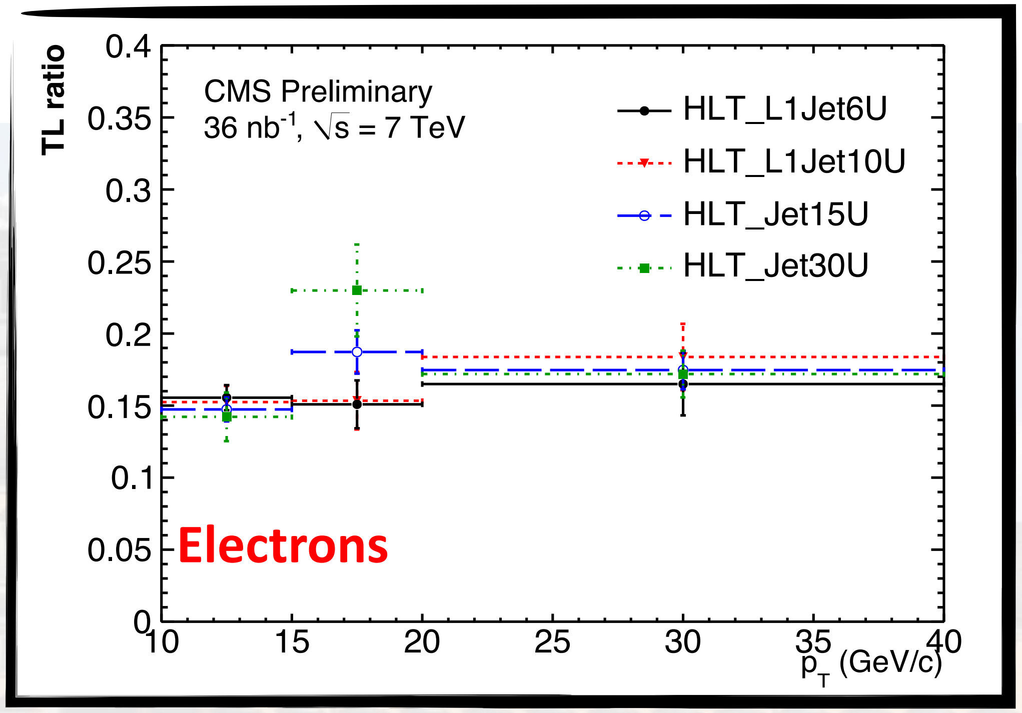


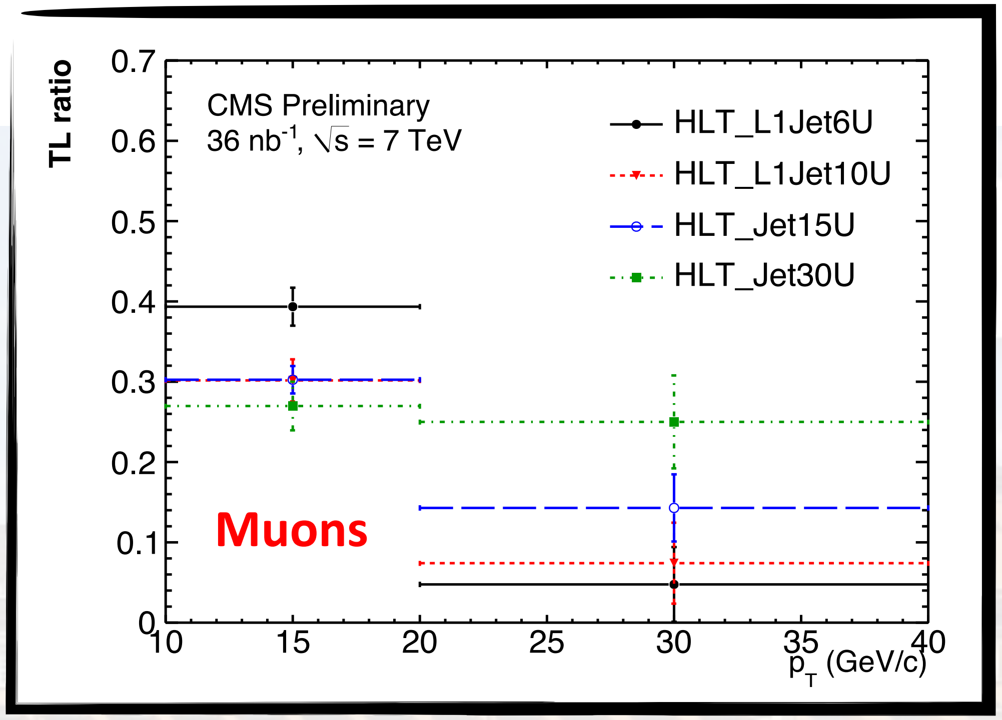
e+Jets+MET	Fit Result	Observed
RI<0.3	224 +- 13	263
RI<0.3 && MET<20	215 +/- 13	215

Same-Sign Dilepton

Control sample (loose lepton ID and isolation) → efficiency other requirements

Monitor Tight-to-Loose efficiency ratio using different jet samples vs pT (lepton)





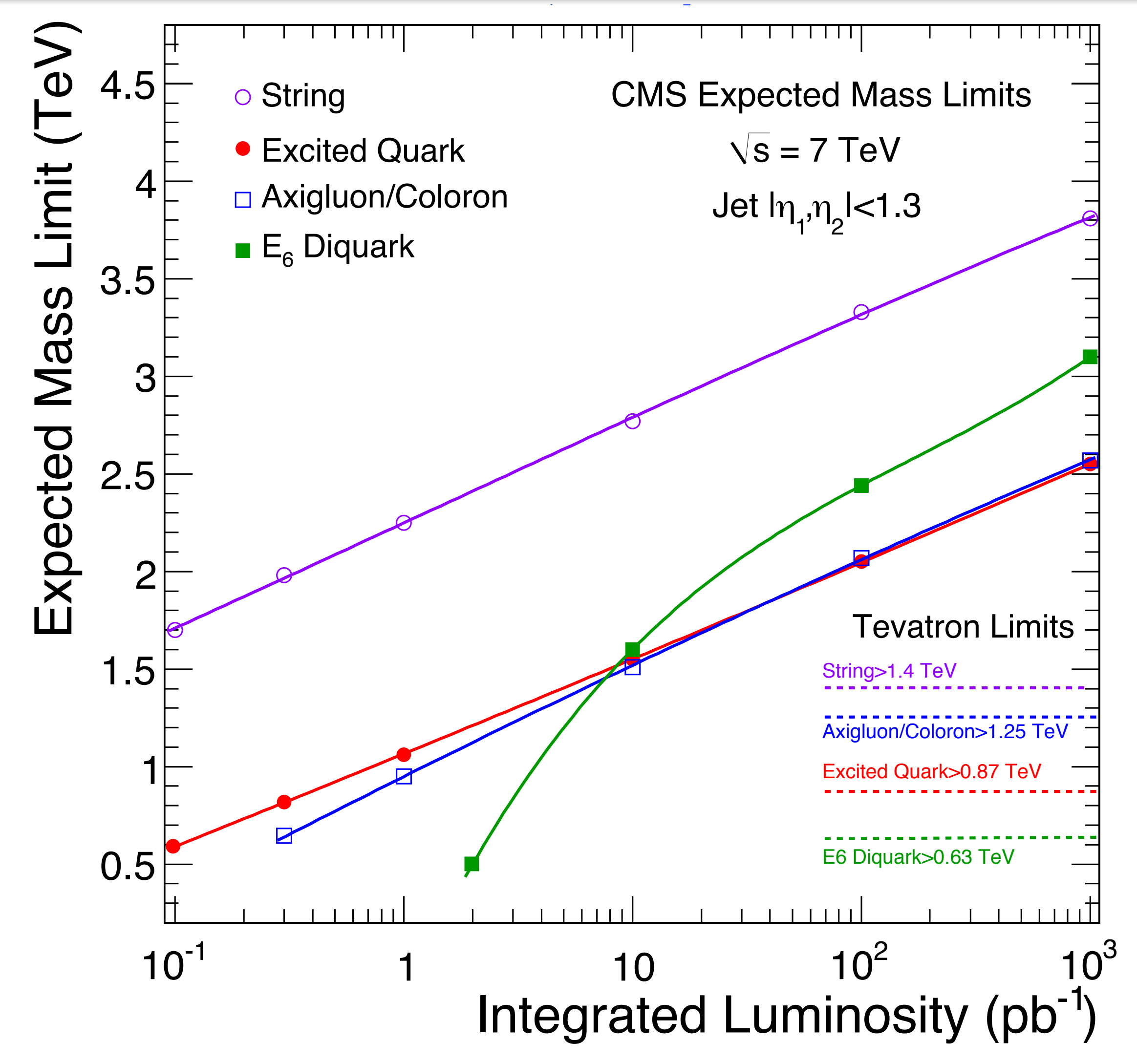
Predictions obtained using HLT_Jet15U

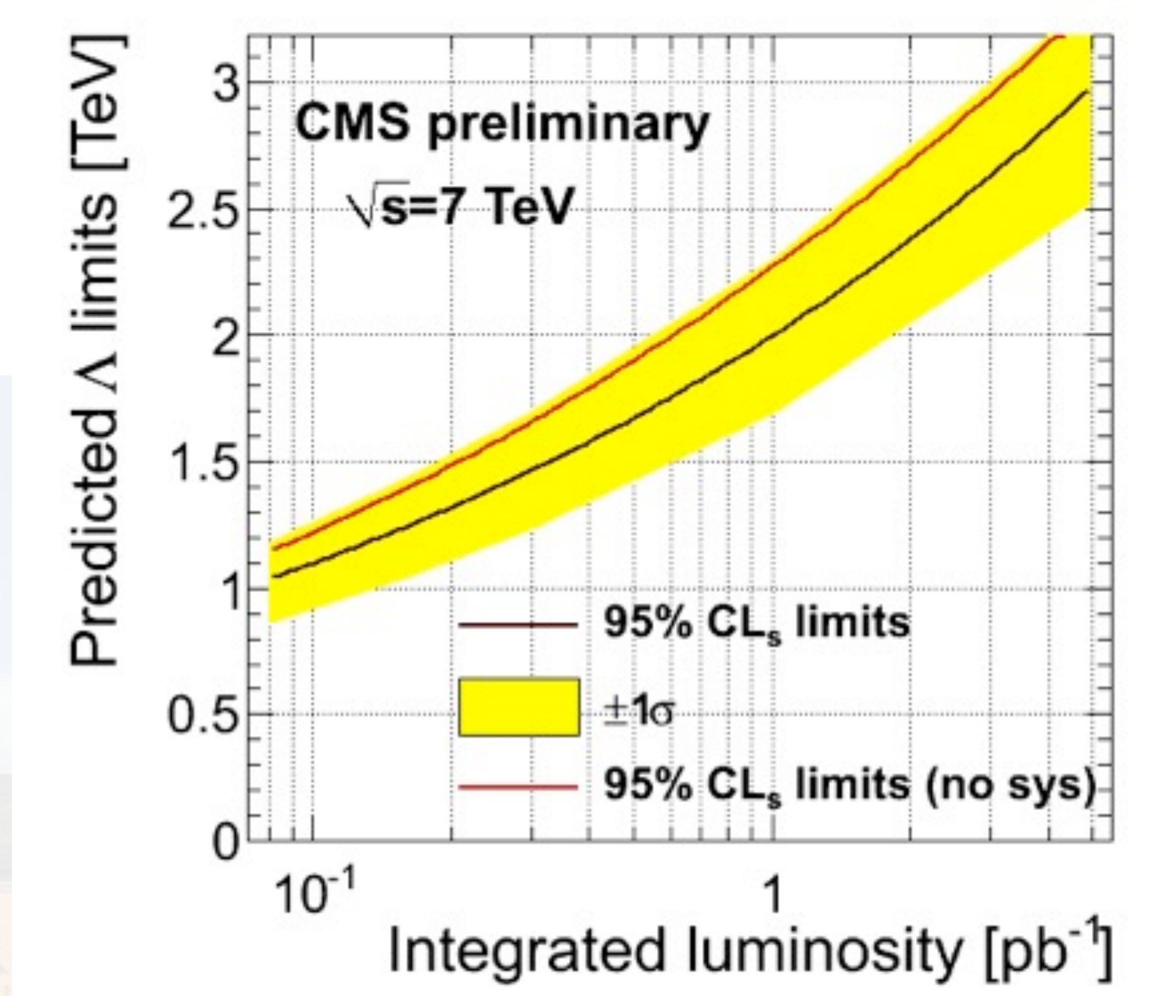
Channel	Predicted	Observed
ee	$0.43^{+0.18}_{-0.14}$	0
$e\mu$	$0.14^{+0.18}_{-0.09}$	1
$\mu\mu$	$0.22^{+0.51}_{-0.18}$	0

- No discrepancy observed
- Method in place, more statistics to come

Future prospects (three examples)

DiJet Analysis

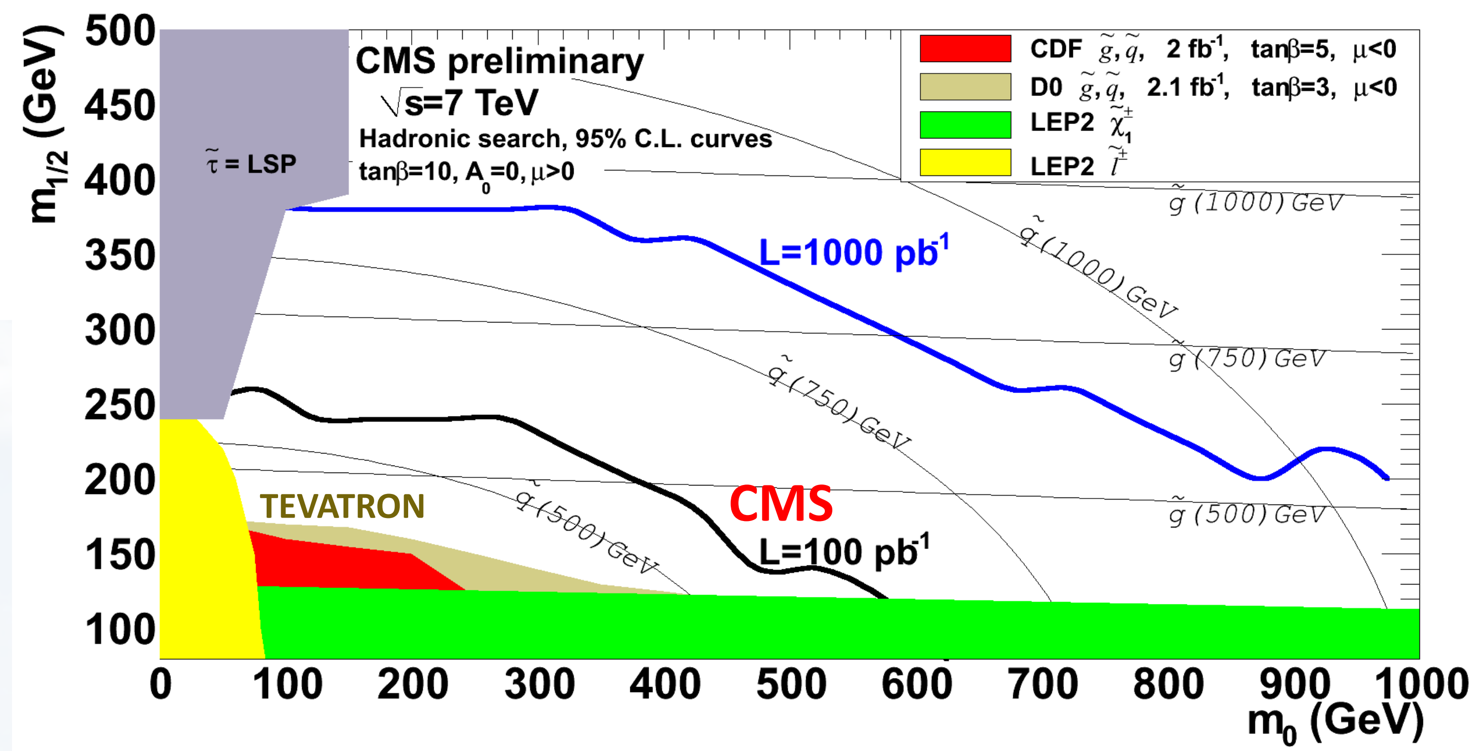




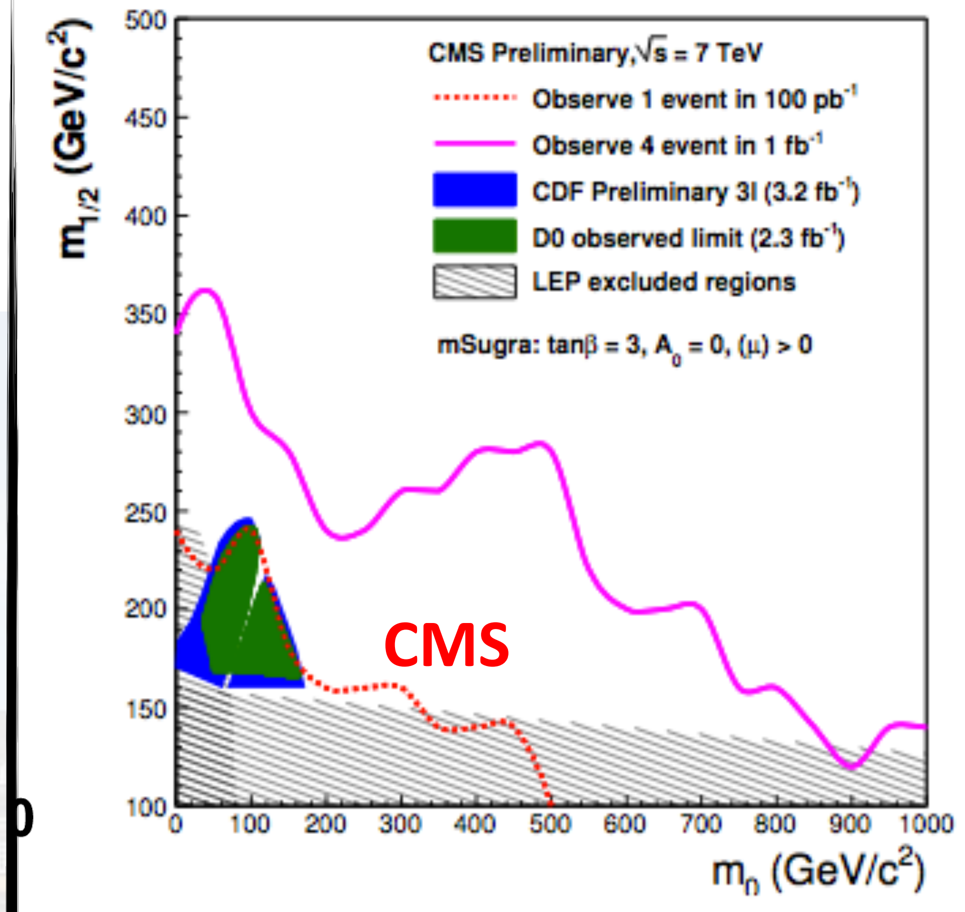
- CMS is already exploring new territory beyond the Tevatron
- Already competitive/better than Tevatron. Further improvements with more data
- The Tevatron limit of Λ > 2.8 TeV (D0, 1fb $^{-1}$) is expected to be surpassed with 4 pb $^{-1}$.
- Hopefully, more than exclusions in the future...

SUSY Searches

sensitivity to mSUGRA with fully hadronic signaure



Sensitivity with Same-Sign di-lepton



With 100 pb^{-1} of 7TeV data (end of the year?)

CMS will enter an unexplored territory, beyond what Tevatron could test.

Sensitivity depends on SM background understanding

- improvements on data-driven method will reduce the errors and will boost our sensitivity beyond what shown in the plot

Conclusions

CMS is happening
- Detector behaving as expected (good data-MC agreement)
- First Results on searches presented here

DiJet mass spectrum and centrality analyses
- First limits on Resonances and contact interactions
- Improved Tevatron limits on DiJet Resonances with 0.8 pb^{-1}
- Expect to extend Tevatron limits on Contact Interactions with O(4 pb^{-1})

Long-Lived Heavy particles
- Track-only analysis => exclude gluino below 271 GeV
- Track+muon analysis => exclude gluino below 284 GeV
- Stopped Particles for 120 ns < τ < 6 μs, exclude gluinos of mass up to 200 GeV
- Stopped Particles for lifetimes of 2.6 μs, exclude gluinos of mass up to 225 GeV
- Stopped Particles for lifetimes of 200 ns, exclude gluinos of mass up to 229 GeV

SUSY Commissioning started
- QCD Bkg estimates and data-MC agreement tested on data

References

- Search for Dijet Resonances in the Dijet Mass Distribution in pp Collisions at $\sqrt{s} = 7$ TeV

  http://cdsweb.cern.ch/record/1280687/files/EXO-10-001-pas.pdf

- Search for New Physics with the Dijet Centrality Ratio

  http://cdsweb.cern.ch/record/1280688/files/EXO-10-002-pas.pdf

- First Results on the Search for Stopped Gluinos in pp collisions at $\sqrt{s} = 7$ TeV

  http://cdsweb.cern.ch/record/1280689/files/EXO-10-003-pas.pdf

- Search for Heavy Stable Charged Particles in pp collisions at $\sqrt{s} = 7$ TeV

  http://cdsweb.cern.ch/record/1280690/files/EXO-10-004-pas.pdf

- Performance of Methods for Data-Driven Background Estimation in SUSY Searches

  http://cdsweb.cern.ch/record/1279147/files/SUS-10-001-pas.pdf

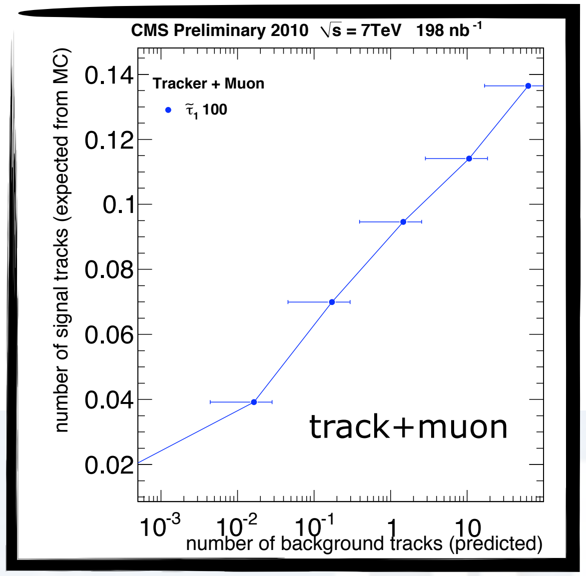
...and a Dedication

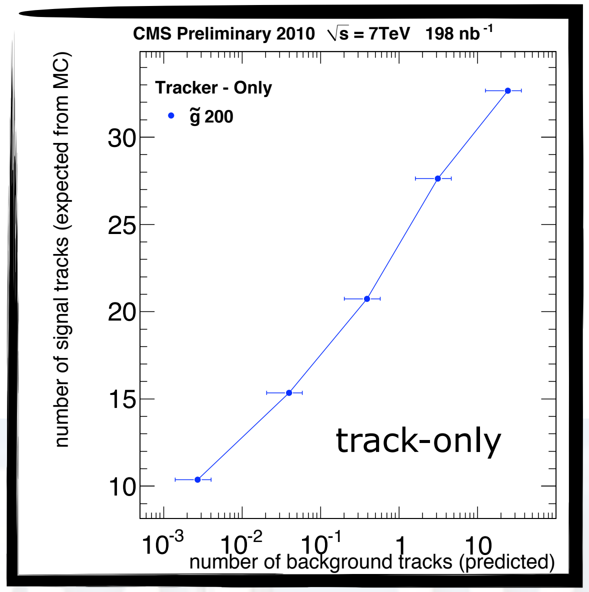
Nicola Cabibbo: 1935–2010

Backup Slides

dE/dx Tight&Loose

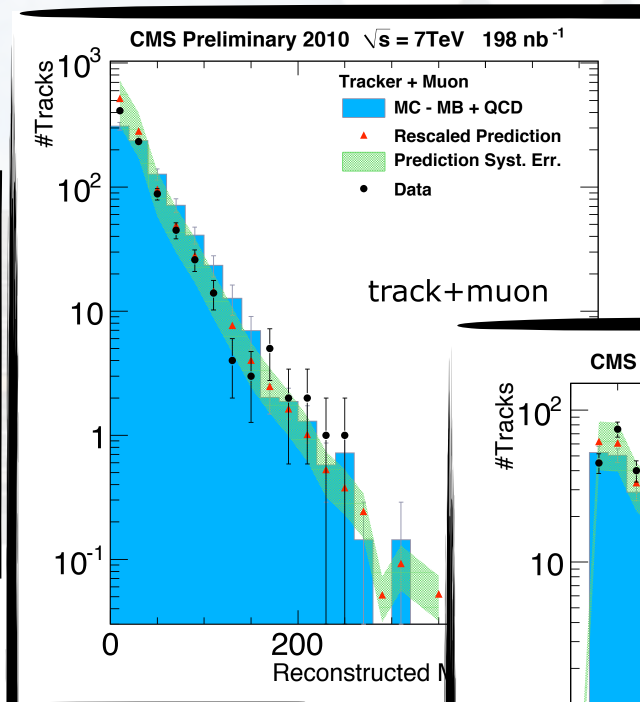
- Perform a counting experiment in the mass range 75-1200 GeV/c2 using 198 nb^{-1} data
  - Summing over bins in η, N_{hits}
  - Background for each bin determined from data using an "ABCD" method + (data-determined) correction
- Signal efficiency does not depend strongly on threshold (see right)
  - Optimise thresholds to yield desired background

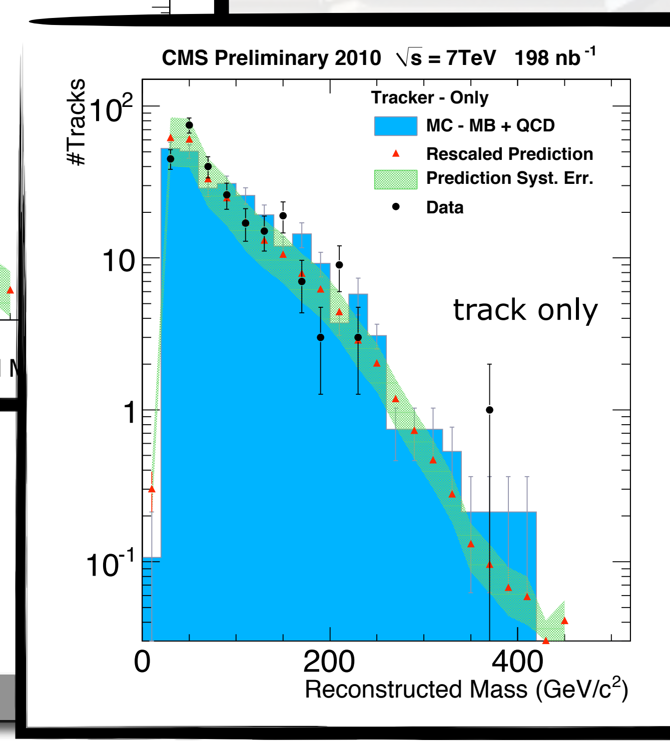




- Define a tight selection for the search
- And a background enriched selection for cross-checks

LOOSE	ϵ_{p_T}	p_T^{cut}	ϵ_I	I_{as}^{cut}
Tracker+Muon	$10^{-1.0}$	7.7 - 25.9	$10^{-1.5}$	0.0036 - 0.4521
Tracker only	$10^{-2.0}$	7.9 - 67.4	$10^{-2.0}$	0.0037 - 0.5293
TIGHT	ϵ_{p_T}	p_T^{cut}	ϵ_I	I_{as}^{cut}
Tracker+Muon	$10^{-3.0}$	7.7 - 125.9	$10^{-3.0}$	0.0036 - 0.6526
Tracker only	$10^{-4.0}$	7.9 - 259.0	$10^{-3.5}$	0.0037- 0.8901

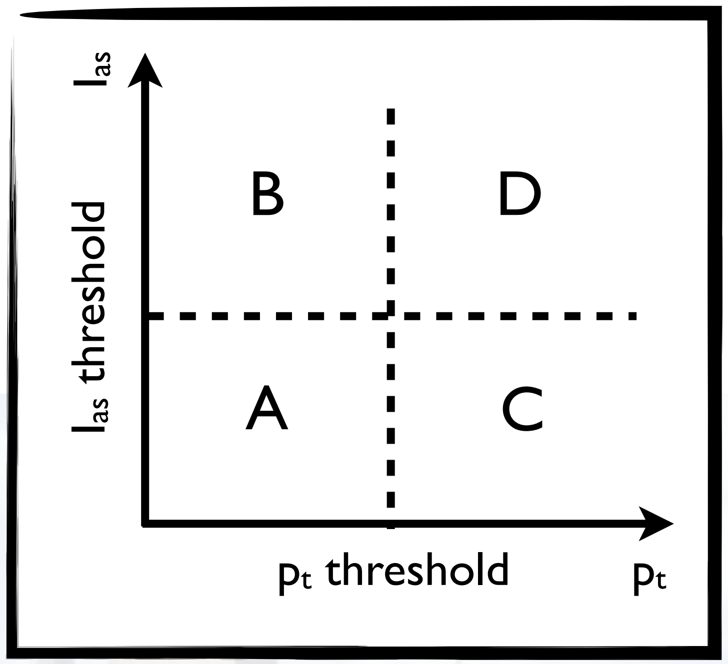


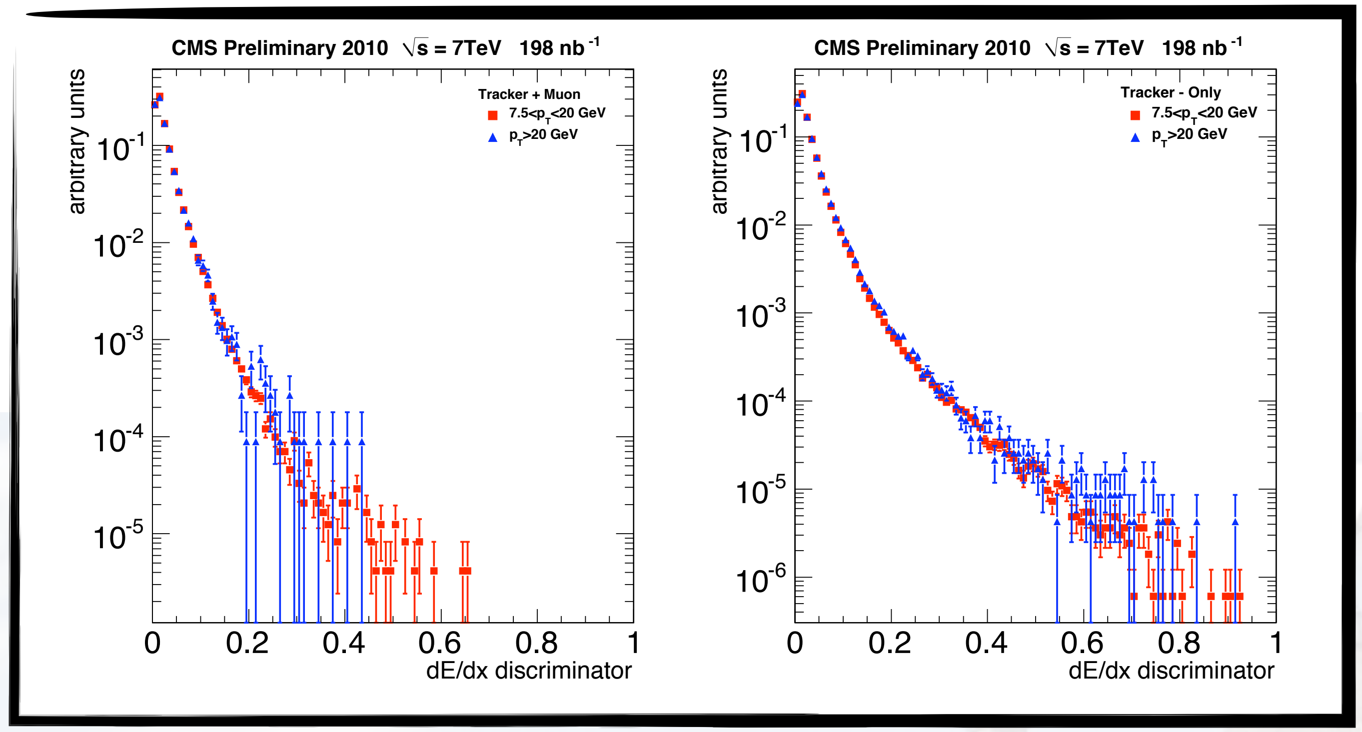


- Good agreement between expected background and observation

LOOSE	Exp.	Obs.	Exp. in full spectrum	Obs. in full spectrum
Tracker+Muon	82 ± 33	77	1007 ± 200	838
Tracker Only	108 ± 38	122	184 ± 250	260

dE/dx BKG ABCD

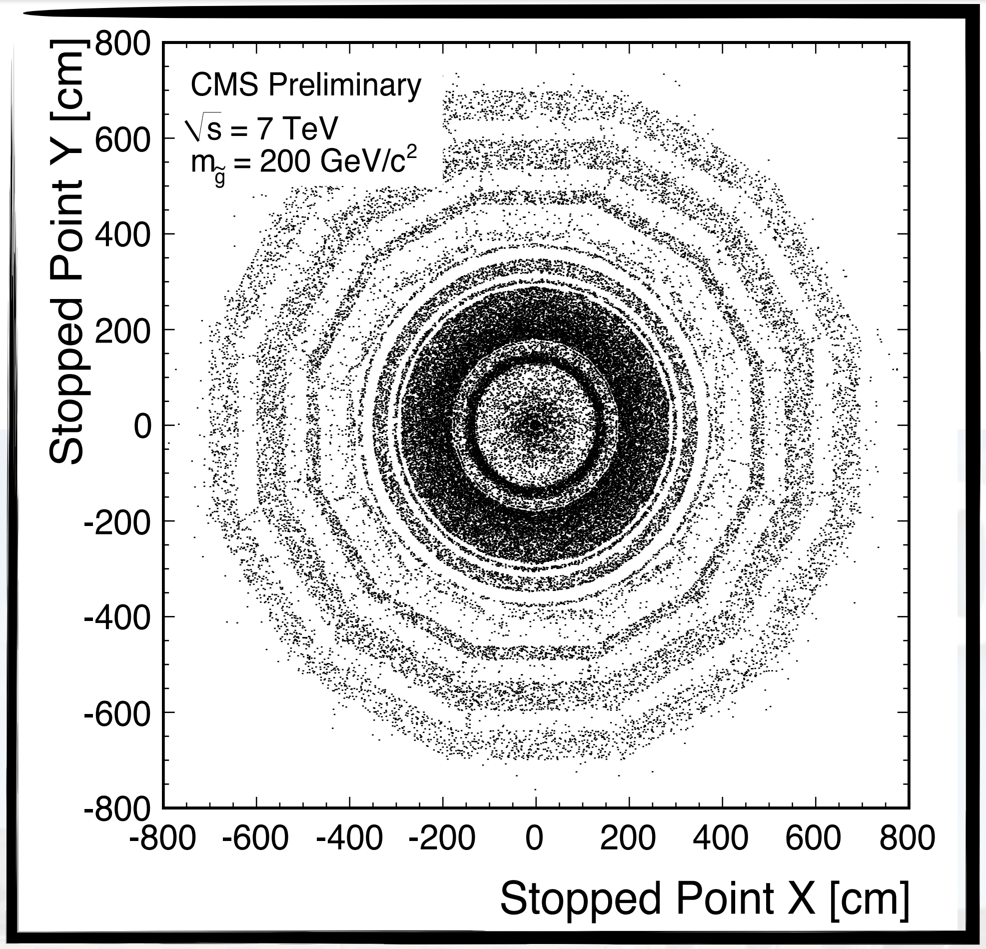


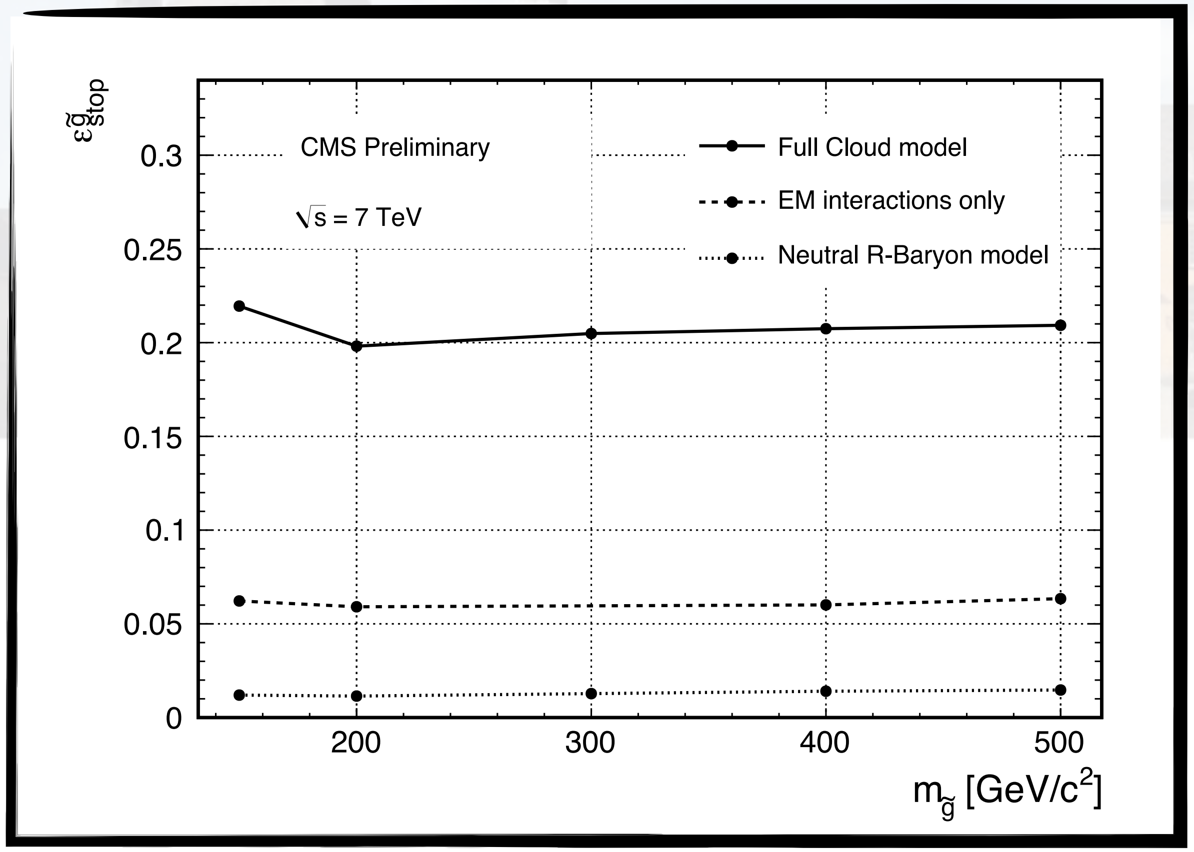


- Background for each (N_{hits}, η) bin is determined using an "ABCD" method
  - Background in signal region, D = BC/A
  - This relies on non-correlation of p_t and dE/dx measurements
  - Shown above, I_{as} distribution for two pt ranges
  - This method is extended to also predict the expected background mass spectrum
- Cross-check the background determination by comparing observed with expected background counts for a control region (mass < 75 GeV/c^2)
  - Find that a correction is required, average factor 1.32 (tk+muon), 1.36 (tk only)
  - Also use this to determine the systematic uncertainty on the background

Stopping Particles Simulation

- Solve the problem of simulating long lifetimes by factorising into 3 phases :
  1. R-hadron production, interaction with detector, and map stopping points
  2. Decay stopped R-hadron and simulate interaction of decay products with detector
  3. Simulate time of production (based on *delivered* luminosity profile), time of decay and calculate "time acceptance"





- 20% of particles stop somewhere in CMS
- Search performed in HCAL (highest probability)