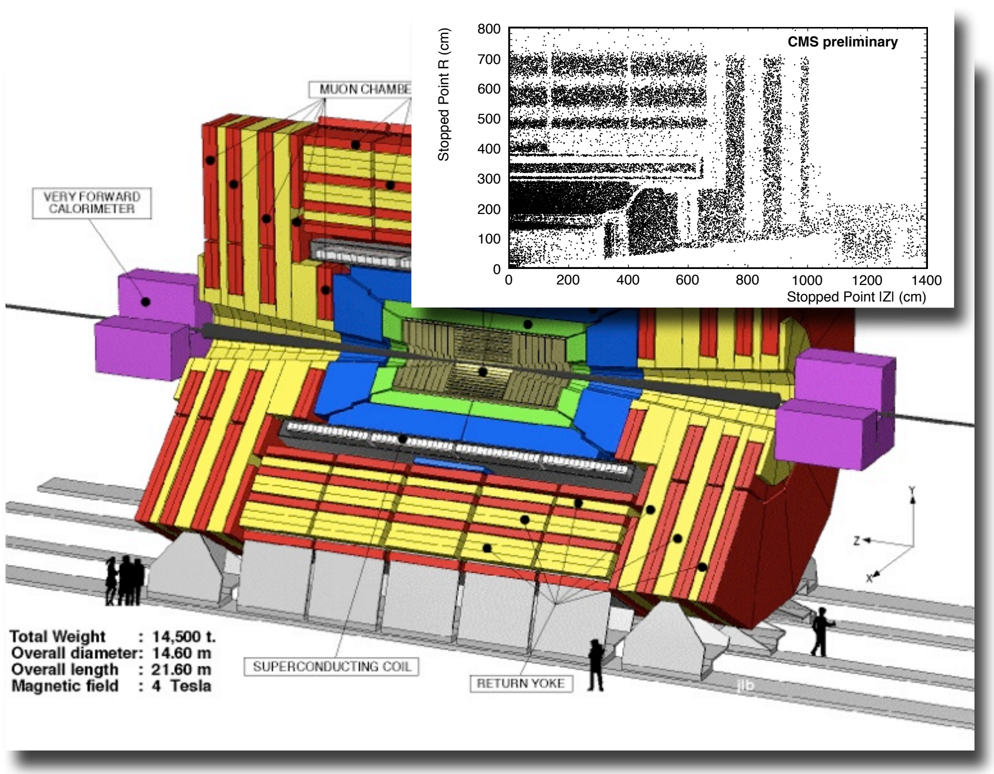
Stopped Gluino at CMS
First Direct Search Results



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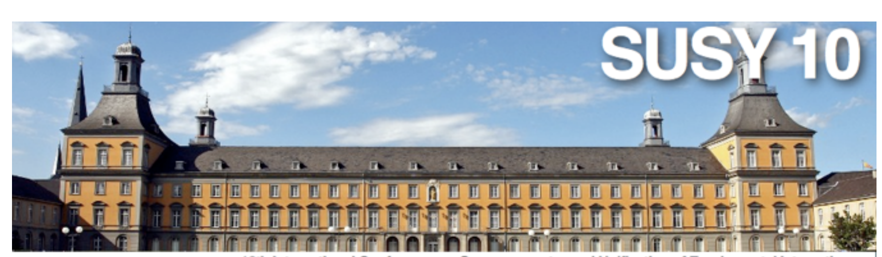
for the **CMS** collaboration

SUSY'10
Bonn, Aug. 23-28, 2010

Karlsruhe Institute of Technology



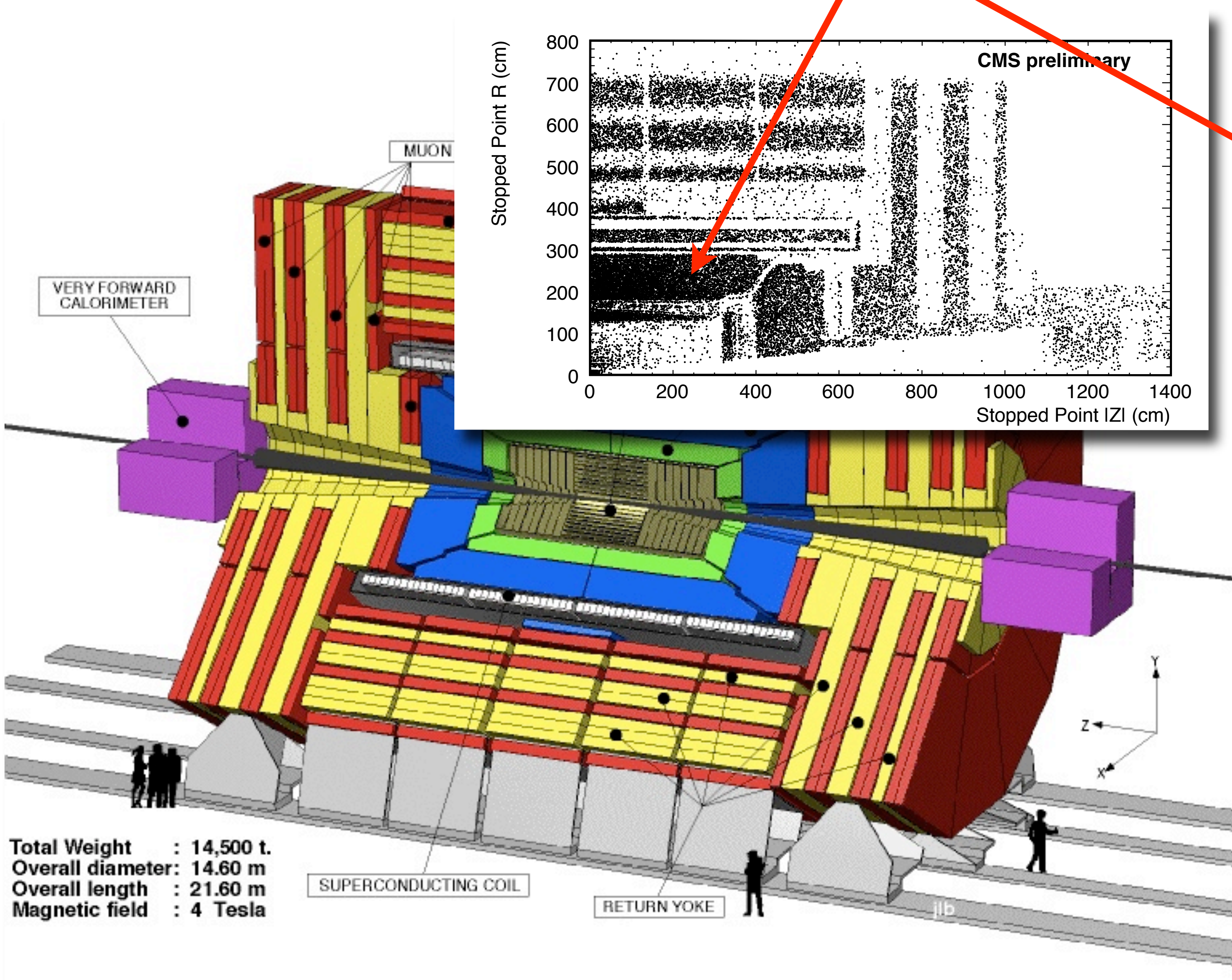
Compact Muon Solenoid

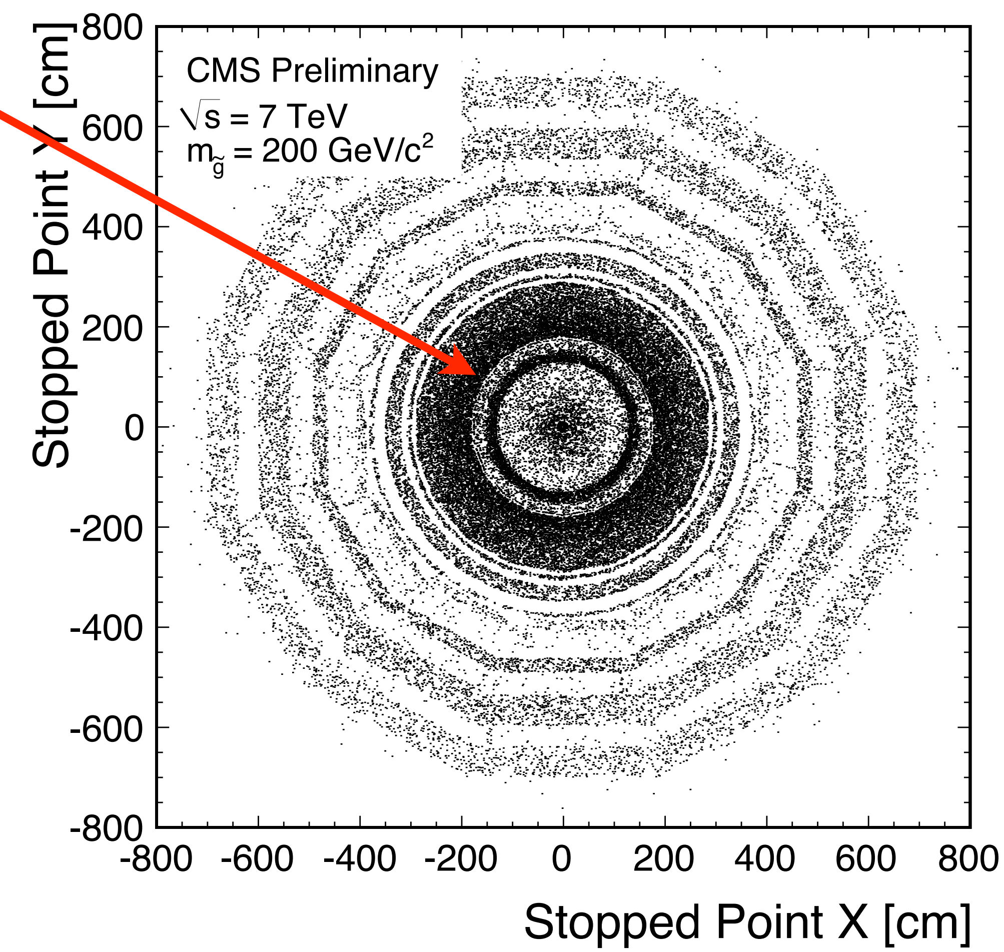
Motivation

- Inspired by physics scenarios predicting long living heavy particles
  - some SUSY flavors predict long living gluino, stop, stau...
  - Hidden valley models, certain GUTs
  - Lifetimes $10^2..10^3$ s are of particular interest by cosmology
    - may explain ^{7}Li and ^{6}Li abundance discrepancy between measurement and conventional nucleosynthesis
- Strongly interacting particles form stable states with quarks/gluons
  - R-Hadrons
- Being charged, particles lose energy when traversing the detector
  - fraction of them eventually stop in the detector.
  - They will eventually decay: μs, minutes, hours,days, months after their production
- We will run a calorimeter trigger in periods when there are no collisions in the LHC, and look for energy released in these decays
- An observation of such a decay with no beam in the machine will be an unambiguous sign of physics beyond the SM

R-Hadrons Stopping in the Detector

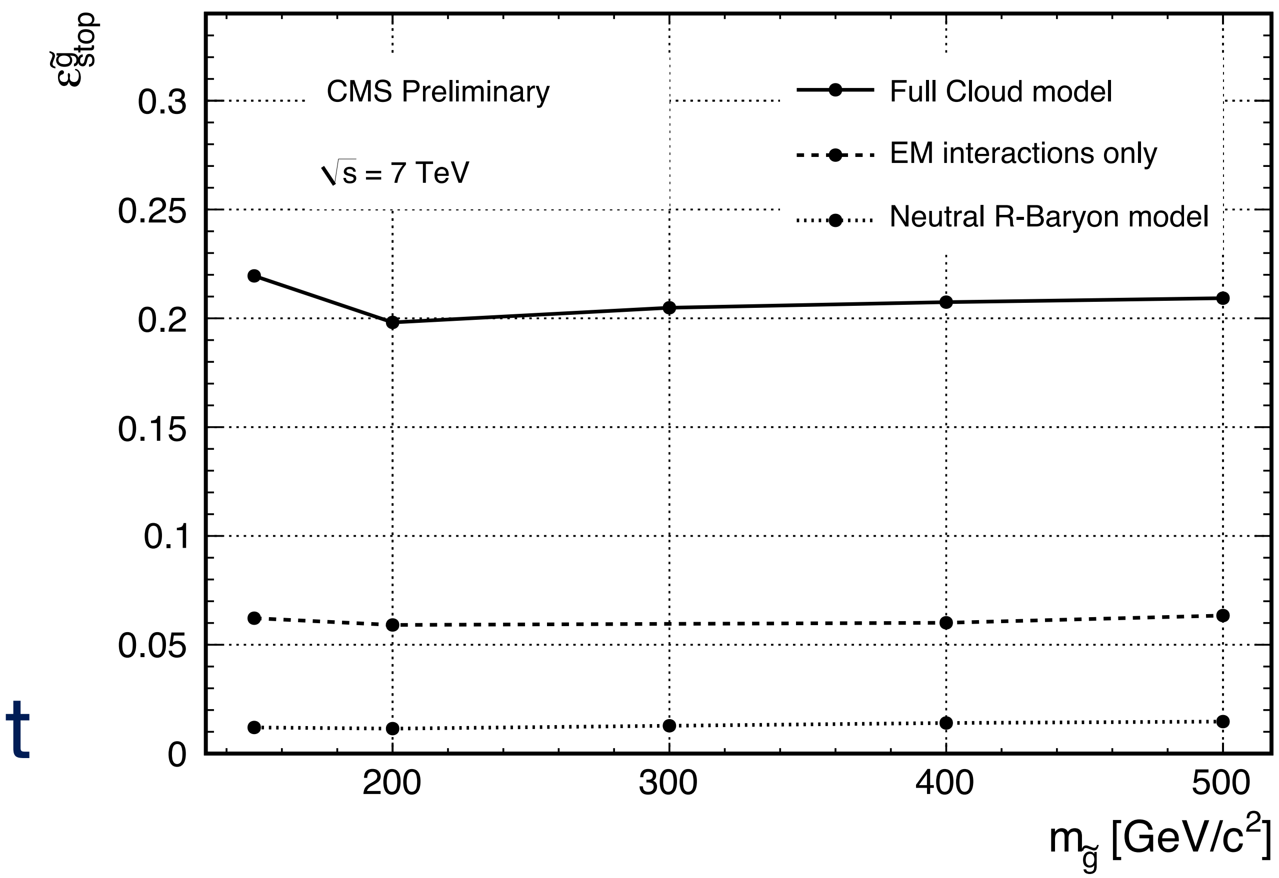
- This search is concentrated on long living gluinos
- Significant amount of them being produced, are stopping in the calorimeter





Stopping Power

- Stopping power essentially depends from details of interaction of the R-hadrons with detector material
  - It is the biggest uncertainty for the cross section measurement

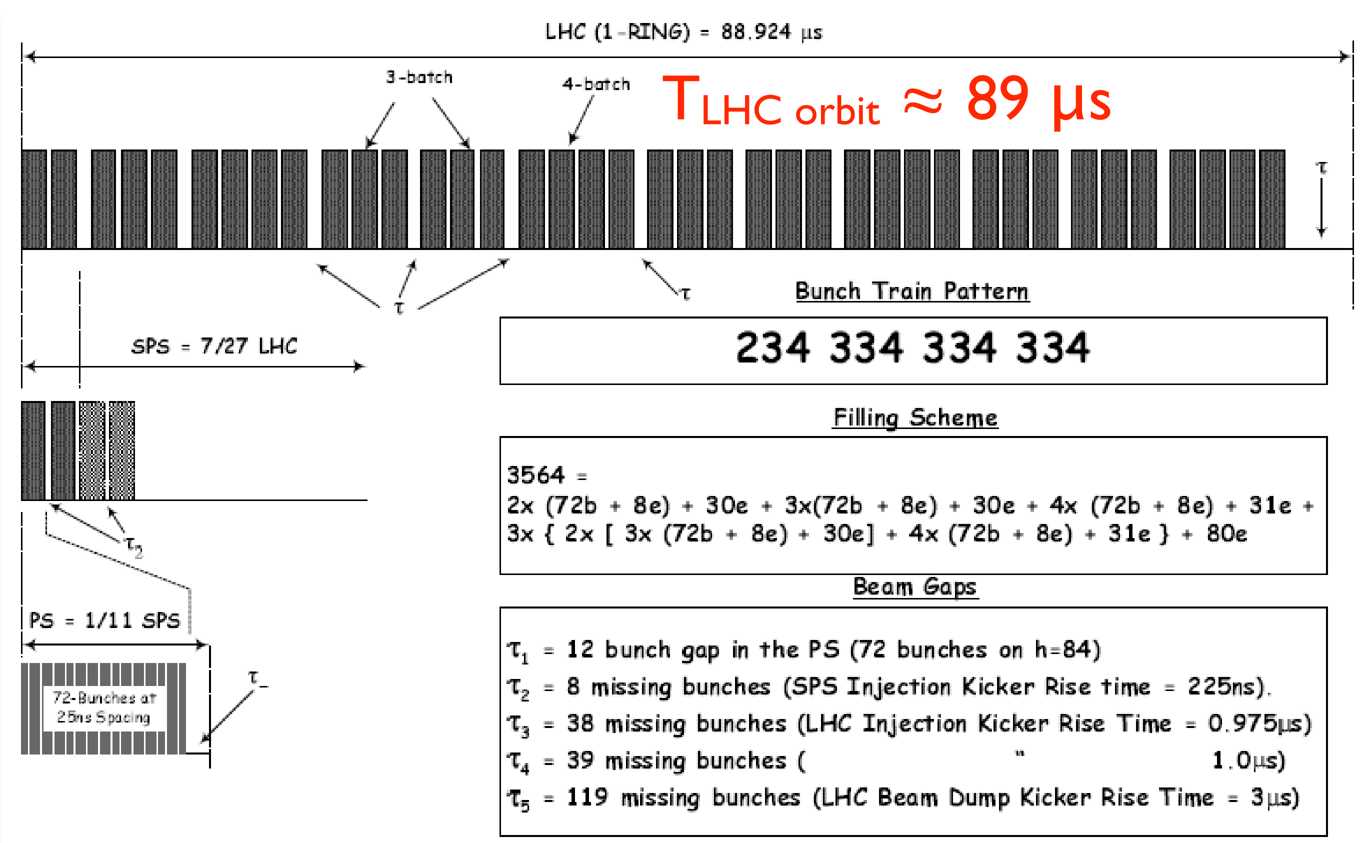


- Calculate it using customized physics processes in GEANT
  - Use “cloud model” as a baseline
  - Another model with the lightest R-baryon being neutral, thus escaping the detector

Two Trigger Scenarios

- Run after a fill has been dumped - inter-fill periods
- Trigger during normal run time in gaps in the beam structure

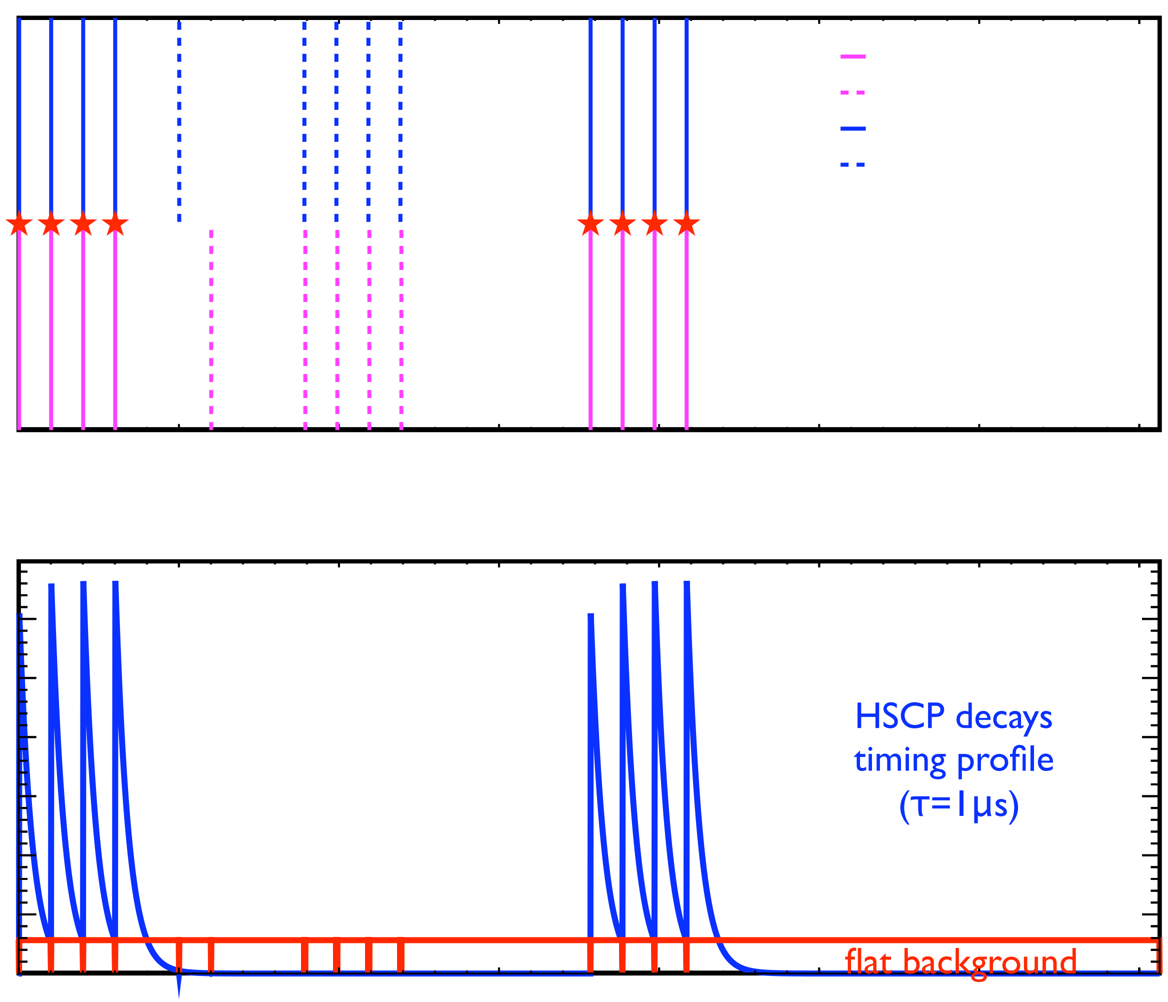
baseline LHC beam structure



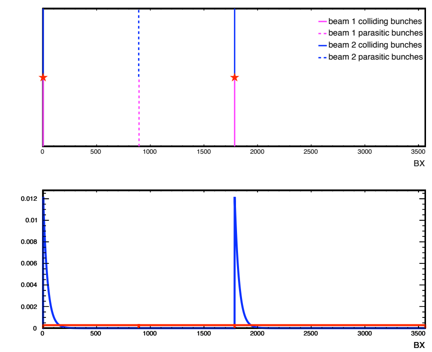
- Use beam gaps for this search

(Early) 2010 LHC Beam Structures

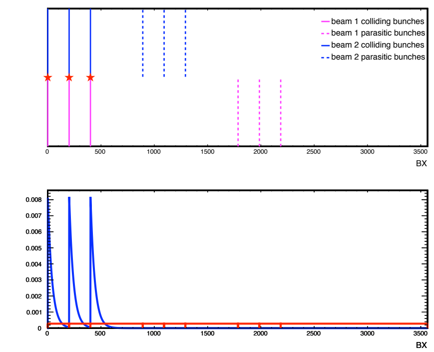
Single_13_8_8_8 LHC Fill Structure



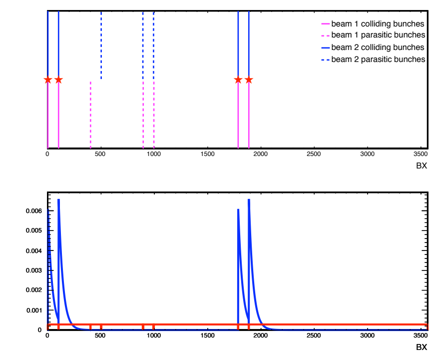
Single_3_2_2_2



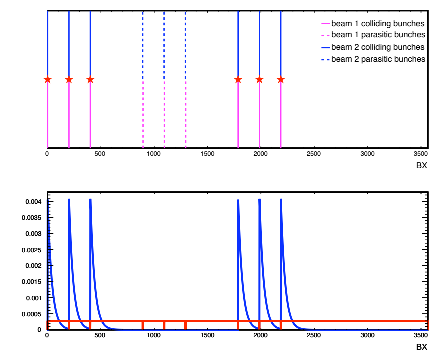
Single_6_3_3_3



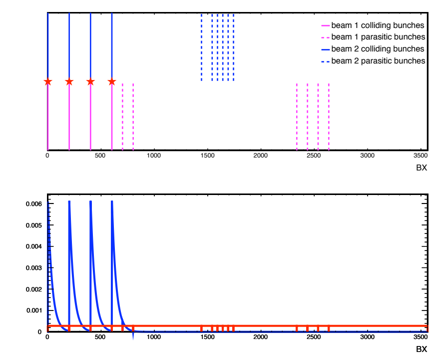
Single_7_4_4_4



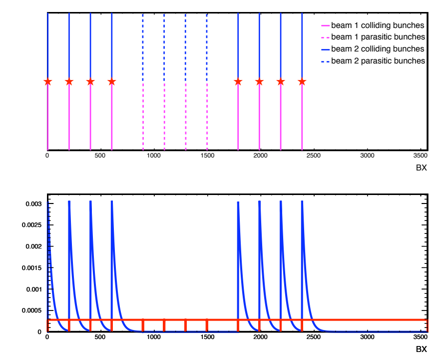
Single_9_6_6_6



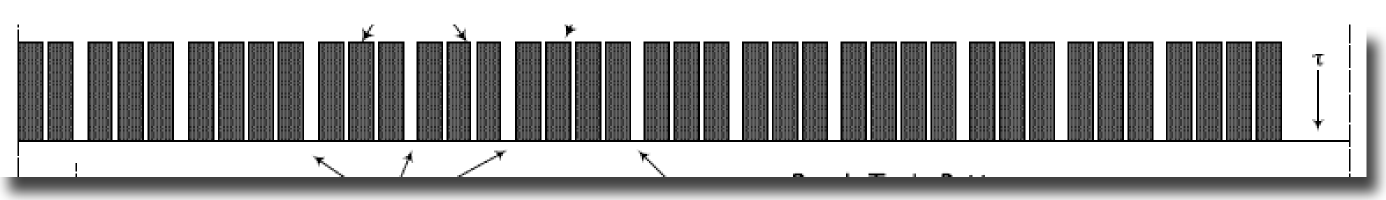
Single_10_4_2_4



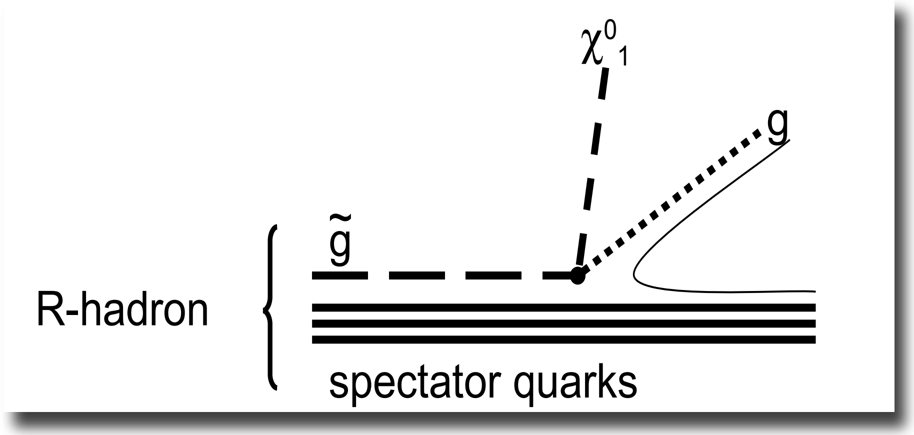
Single_12_8_8_8

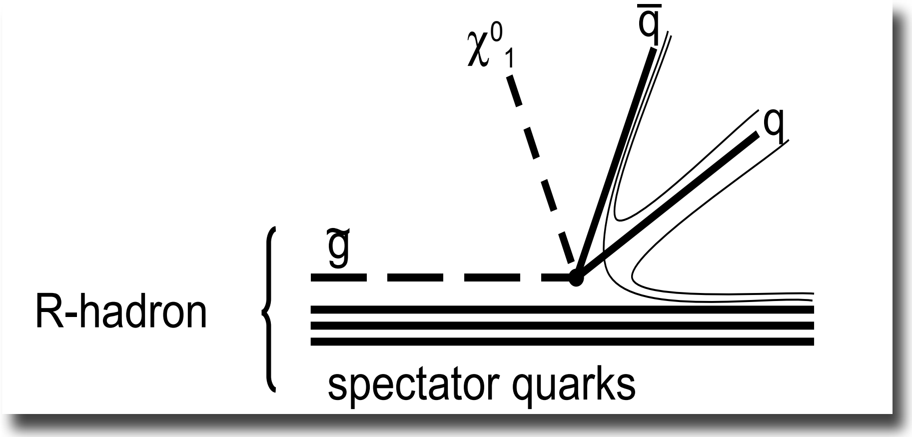


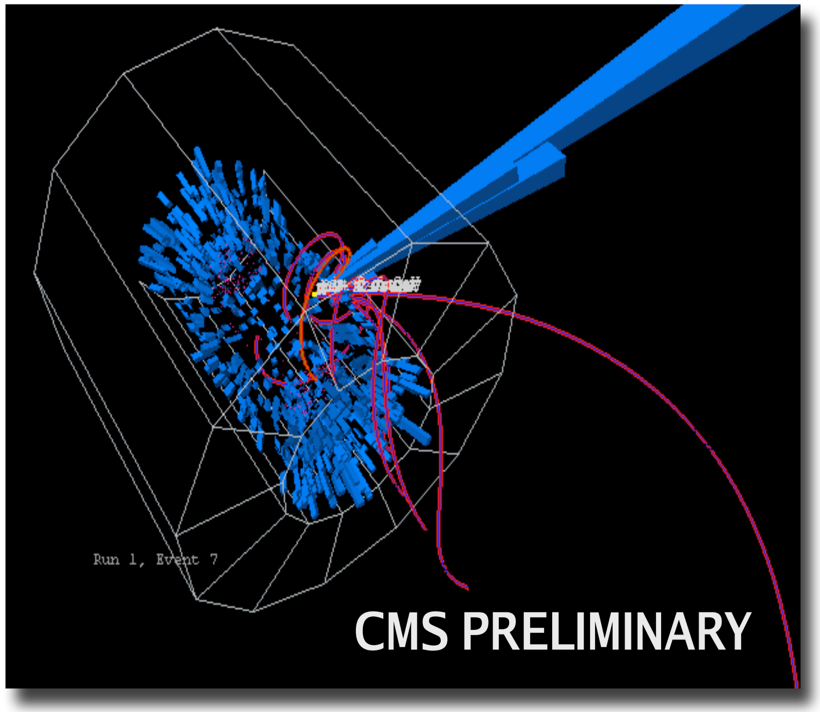
Baseline LHC Fill Structure



Signal Behaviors







- Energy cluster in the calorimeter
  - Signals from single- and two-jet decays are very similar
  - Time profile of the deposited energy is the same as for signals from regular interactions, but with arbitrary offset
  - Amount of deposited energy mostly depends from the difference between gluino and neutralino masses
- No other activity in the detector

Backgrounds

- Cosmics interacting in the calorimeter
  - veto events with track in muon system
- Instrumental noise
  - sophisticated analysis of spatial and time profiles of the energy deposition
- Both cosmics contribution and instrumental noises were measured in 2008/2009 cosmics runs and confirmed in 2009/2010 collision runs
- Beam related: early triggers, beam halo, beam-gas, parasitic bunches
  - suppress events within ±1 BX around collision/parasitic bunches

Data Selection

reject beam backgrounds

reject cosmics

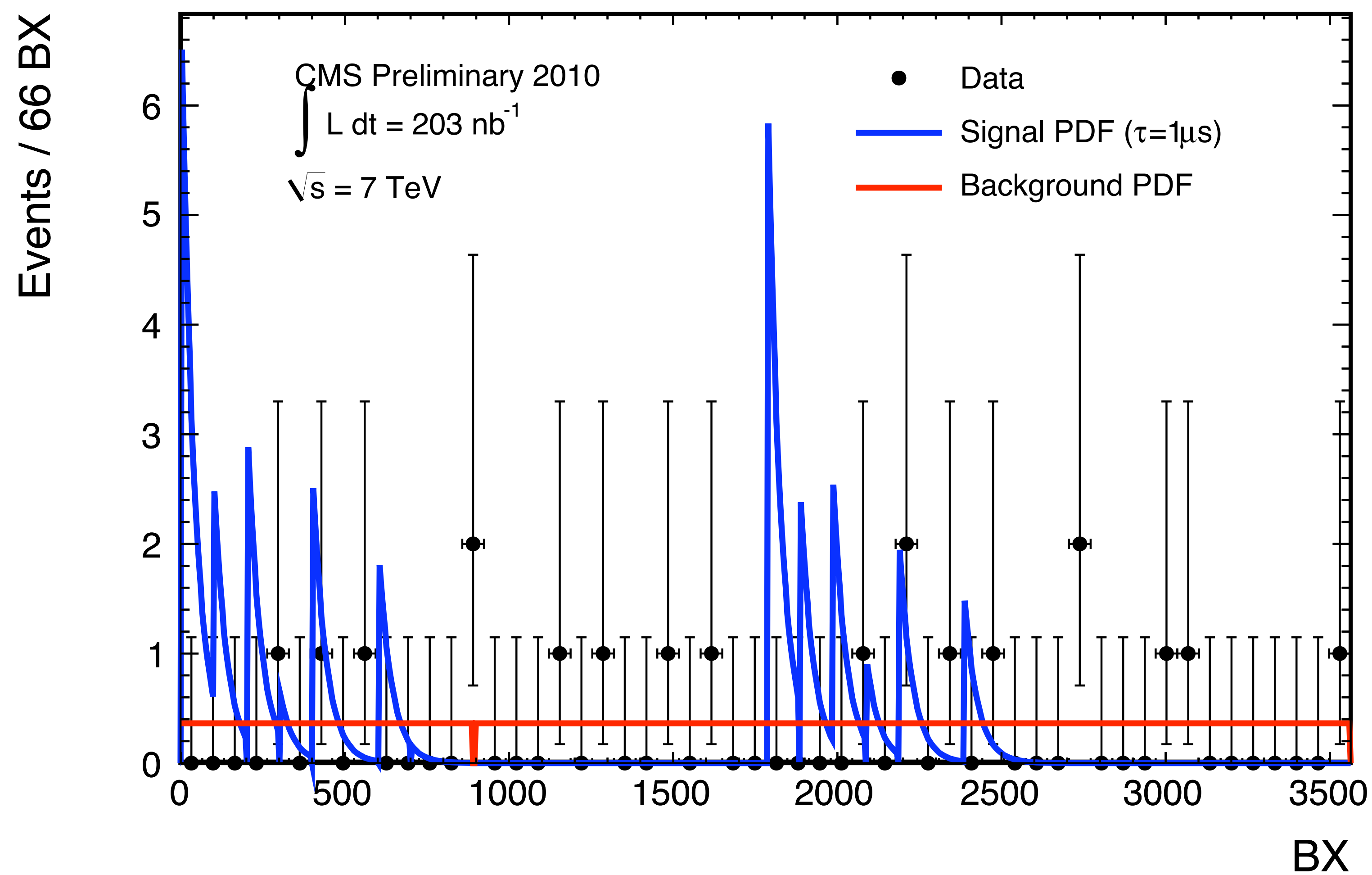
select signal spatial profile

select signal time shape

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}
$R_{outer} < 0.1$	$\boxed{6.9 \times 10^{-5}}$

Signal efficiency ~17% of all R-Hadrons stopped anywhere in the CMS

Selection Results



- 19 events selected from runs with different filling schemas
- Consistent with absence of the stopped gluino decays
  - Set 95% C.L. upper limit

Counting Experiment

- Perform counting experiment as a function of expected gluino lifetime τ
- For $\tau < T_{\text{LHC orbit}}$ select events in a window of $1.26\times\tau$ after the closest collision
- Extract expected background rate from low instantaneous luminosity runs

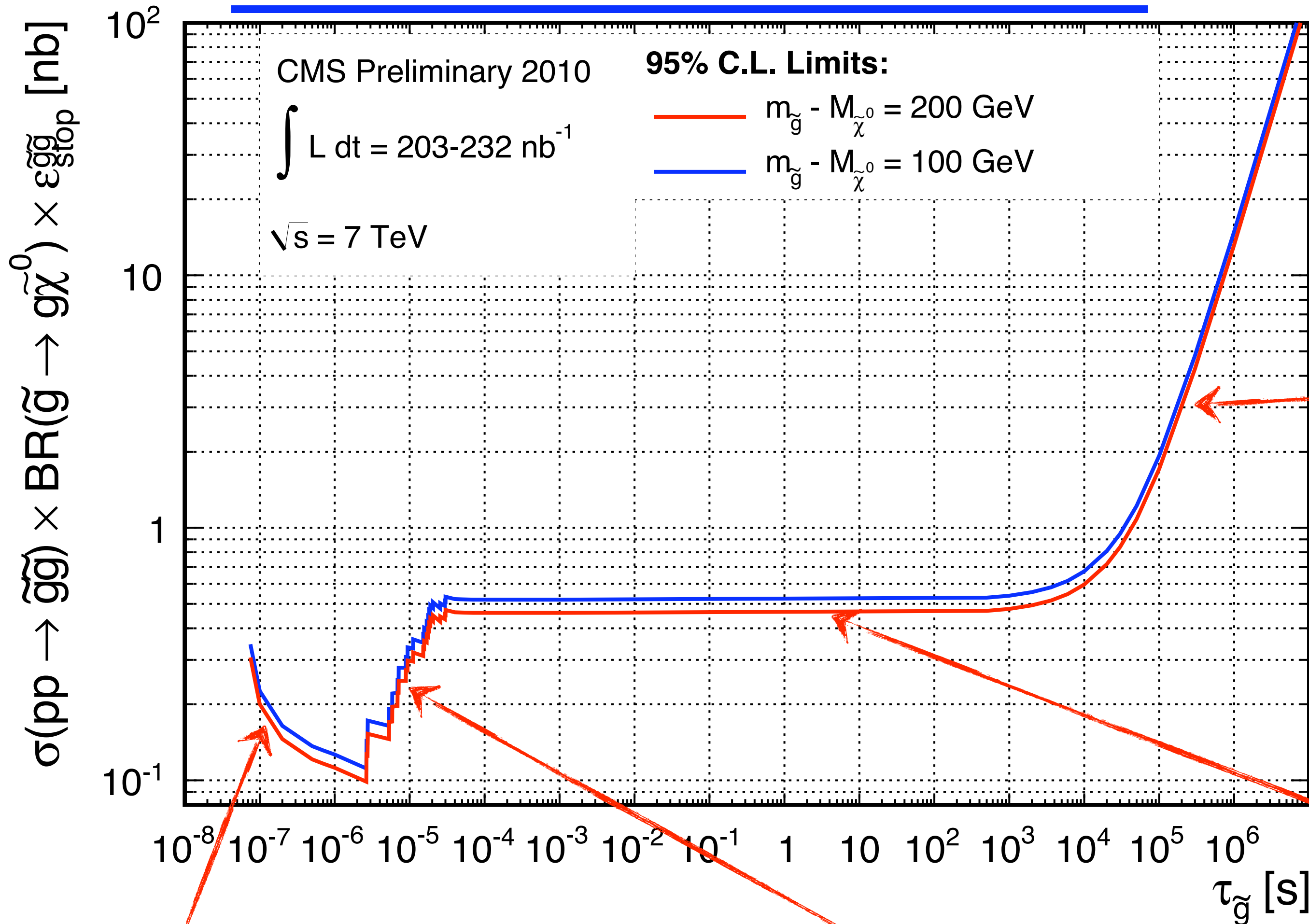
Lifetime [s]	Expected Background ($\pm$ stat $\pm$ syst)	Observed
1e-07	$0.15 \pm 0.04 \pm 0.05$	0
1e-06	$1.8 \pm 0.5 \pm 0.5$	0
1e-05	$11.7 \pm 3.2 \pm 3.5$	8
1e-04	$28.3 \pm 7.8 \pm 8.5$	19
1e-03	$28.3 \pm 7.8 \pm 8.5$	19
1e+03	$28.3 \pm 7.8 \pm 8.5$	19
1e+04	$28.3 \pm 7.8 \pm 8.5$	19
1e+05	$28.3 \pm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

- Set Bayesian limit taking into account systematics
  - 30% background uncertainty, 11% luminosity uncertainty, 10% jet energy scale uncertainty

Cross Section × Stopping Probability

- Independent from the assumptions about R-Hadrons interaction with material

$m(\tilde{g}) - m(\chi_1^0) = 100, 200\ \mathrm{GeV}/c^2$



$\tau > T_{fill}$:
slow decays
beyond fill

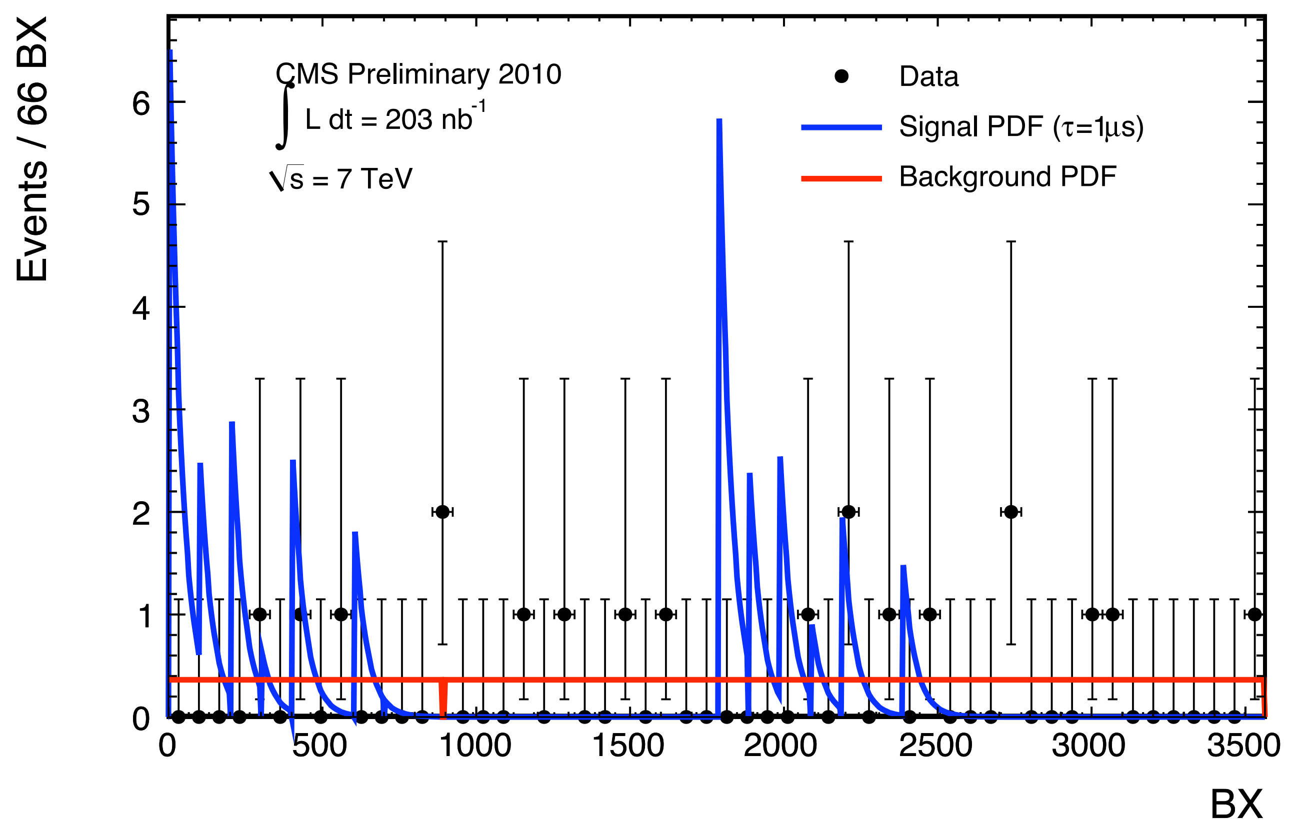
$\tau < 200$ ns:
quick decays
during vetoed BXs

$\tau < T_{LHC\ orbit}$:
getting more events
in the time window

$T_{LHC\ orbit} < \tau < T_{fill} \sim 10^4$ s:
accept all events
sensitivity plateau

Time Profile Fit

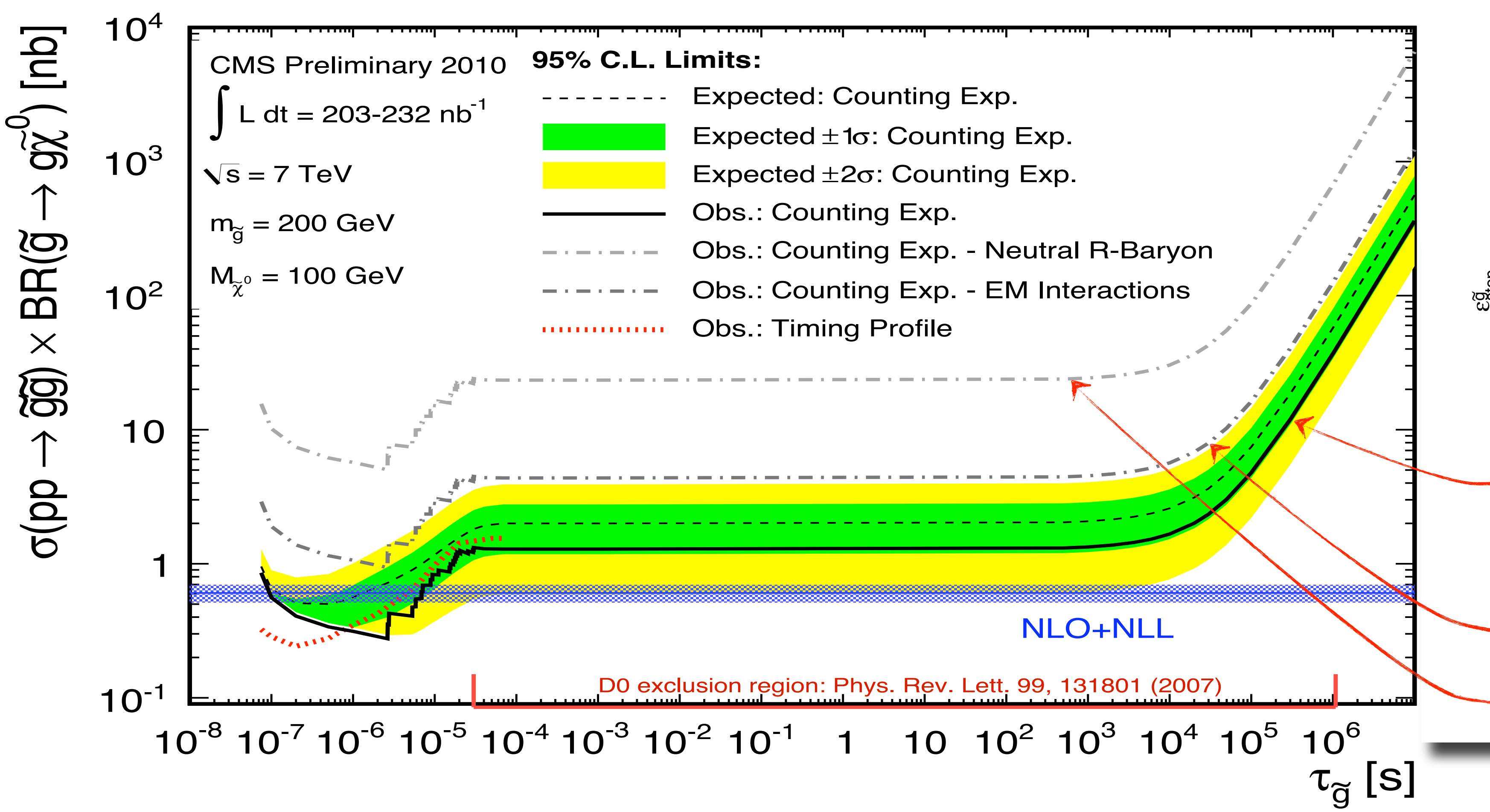
- Fit expected decay timing profile + flat background to data for every expected lifetime
  - Intrinsic background evaluation
    - free from background systematics
  - Is sensitive to $\tau < T_{\text{LHC orbit}}$



- Set Bayesian limit taking into account systematics

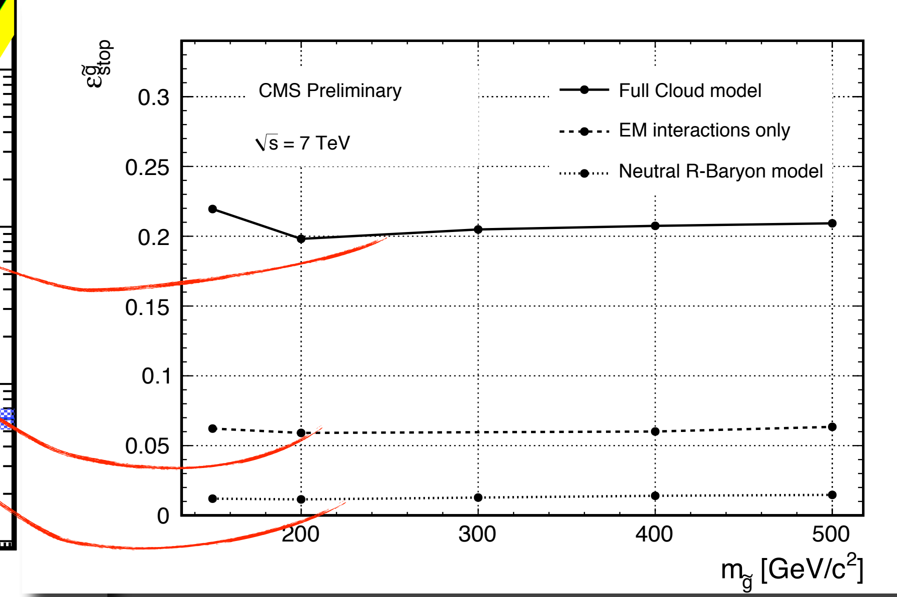
Cross Section Limit

- Use R-Hadrons stopping probability for specific models



$$m(\tilde{g}) = 200\ \mathrm{GeV}/c^2$$

$$m(\tilde{g}) - m(\chi_1^0) = 100\ \mathrm{GeV}/c^2$$



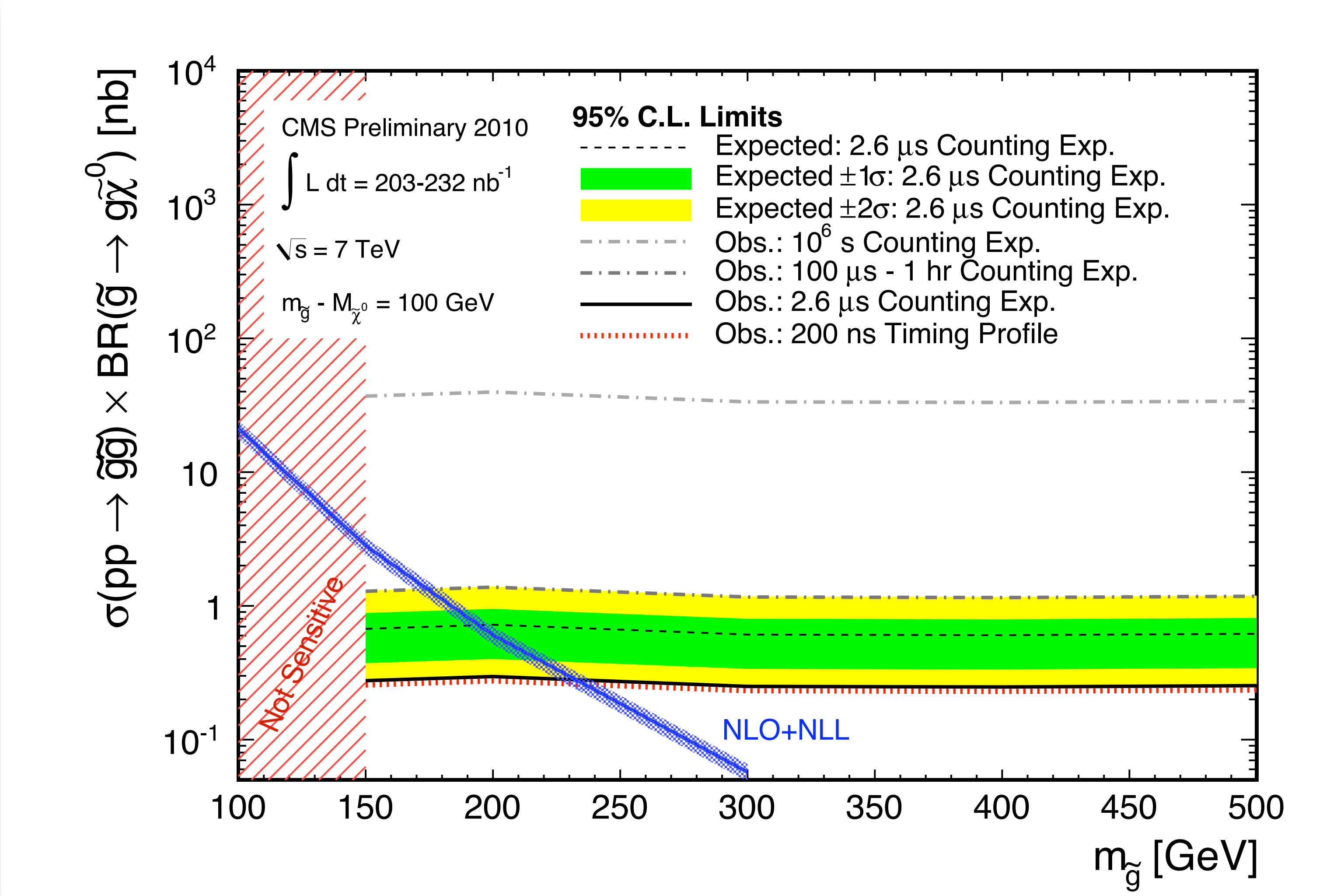
- Extend D0 result below 30 μs
- Exclude lifetimes 120 ns $< \tau <$ 6 μs for $m_{\tilde{g}}$=200 GeV/c^2

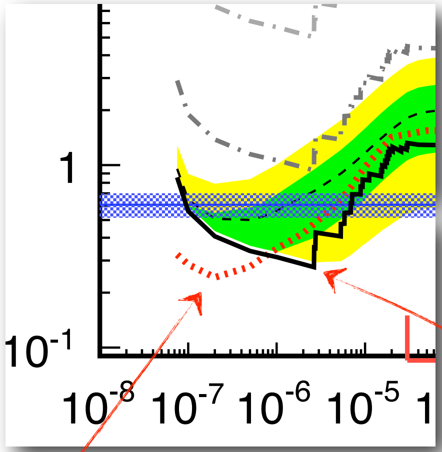
Gluino Mass Limit

- Convert gluino production cross section limit into gluino mass limit for different lifetimes

$\mathrm{m}(\tilde{g}) - \mathrm{m}(\chi_1^0) = 100\,\mathrm{GeV/c^2}$

$\tau(\tilde{g}) = 200\,\mathrm{ns}, 2.6\,\mu\mathrm{s}, 100\,\mathrm{ms}$ - $1\,\mathrm{hr}, 30\,\mathrm{hrs}$





$m_{\tilde{g}} < 229$ GeV/c^2, τ=200 ns

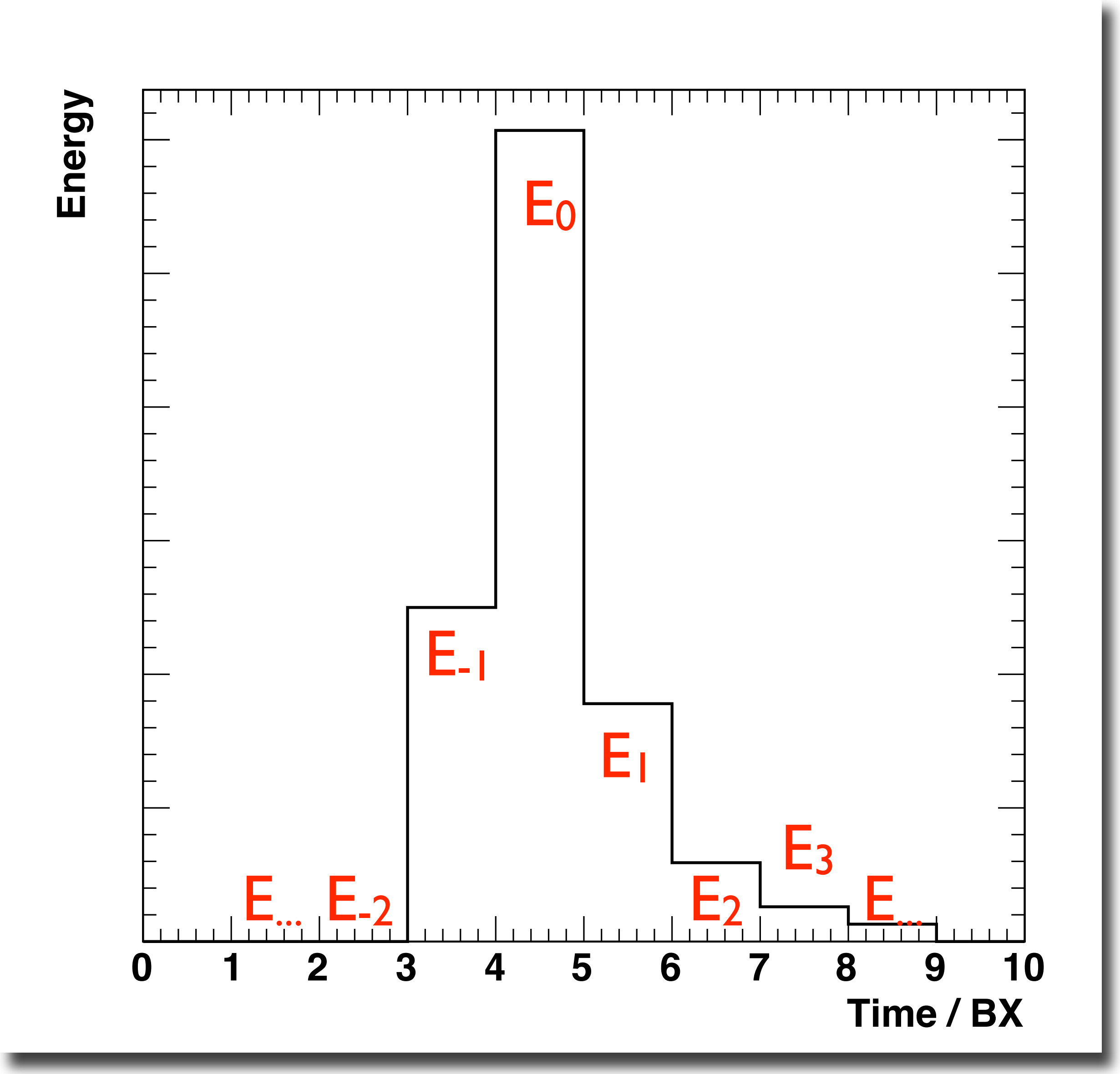
$m_{\tilde{g}} < 225$ GeV/c^2, τ=2.6 μs

Conclusions

- Direct search for particles stopped in CMS in 203-232 nb^{-1} of data at $\sqrt{s}$=7 TeV
  - For 120 ns < τ < 6 μs, exclude gluinos of mass up to 200 GeV/c^2
  - For lifetimes of 2.6 μs, exclude gluinos of mass up to 225 GeV/c^2
  - For lifetimes of 200 ns, exclude gluinos of mass up to 229 GeV/c^2
- Extend D0 limit to lifetimes below 30 μs
  - One of two first LHC search results extending Tevatron limit
- More details in the CMS public analysis summary CMS-PAS-EXO-10-003
  - http://cdsweb.cern.ch/record/1280689

Backup Slides

HCAL Timing Profile Cuts



time profile for signal shape

$R_1 = E_1/E_0$ $\quad R_1 > 0.15$

$R_2 = E_2/E_1$ $\quad 0.1 < R_2 < 0.5$

$R_{peak} = E_0/\sum E_i$ $\quad 0.4 < R_{peak} < 0.7$

$R_{outer} = 1 - (E_{-1} + E_0 + E_1 + E_2)/\sum E_i$

$R_{outer} < 0.1$

Noise Events from 2009 Cosmic Runs