Stopped Heavy Particles

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Stopped HSCP

- We plan to run a calorimeter trigger in periods where there is no beam in the LHC, and/or using gaps in LHC bunch structure to look for long-lived particles (e.g. split SUSY gluinos) which have become stopped in the detector and decay subsequently (mikroseconds, minutes, hours, months) later
- The heavy particles must stop in the CMS calorimeter for them to be detected. Heavy particles produced in p-p collisions will come to rest in the calorimeter either by ionization energy loss or by interactions with the nuclei constituting the calorimeter.
- The stopping power of the CMS detector for a particular class of particles is somewhat model dependent.
- The OBSERVATION of decaying particles in CMS is model independent

Historical Presentations

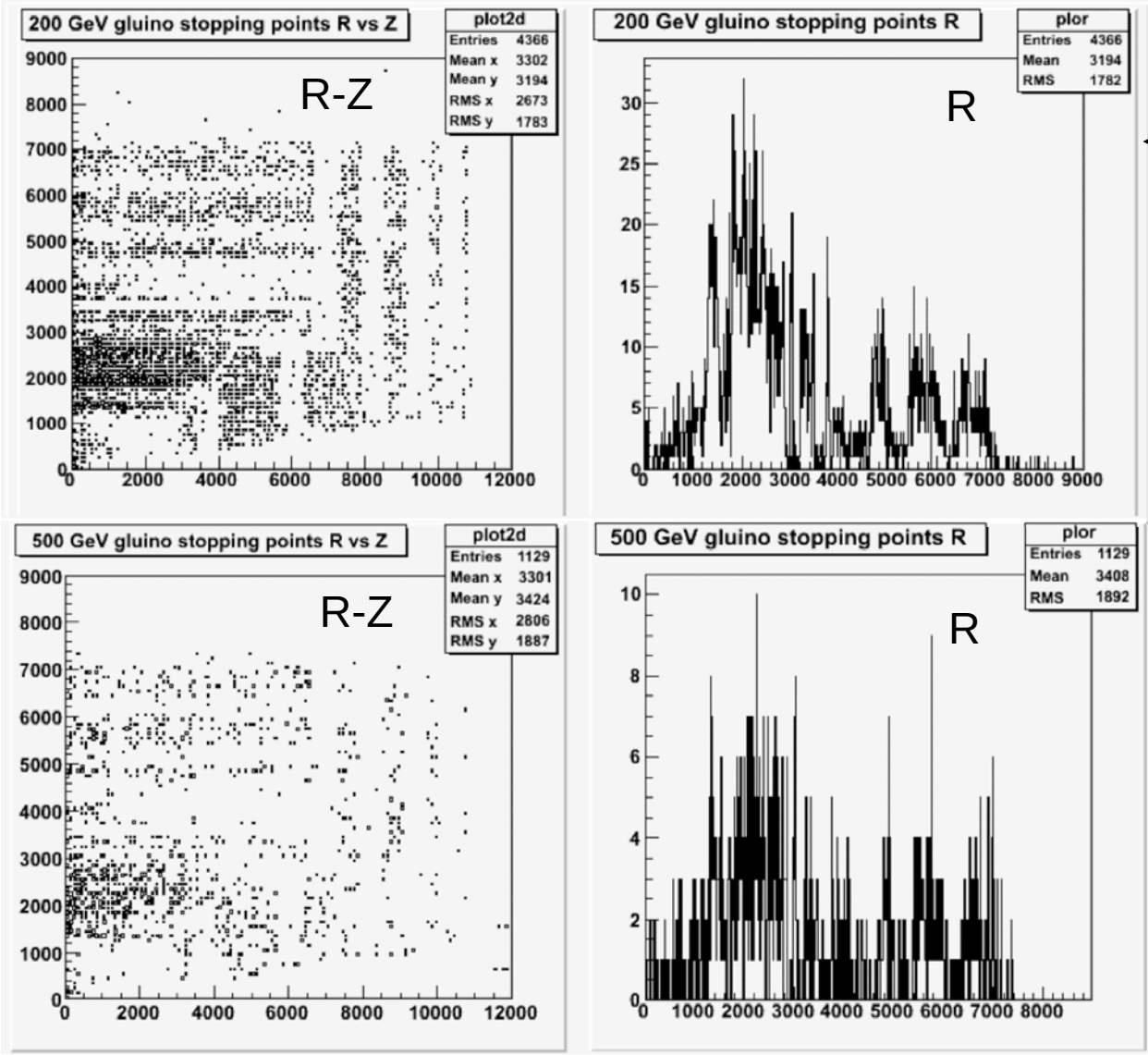
- A.Skuja, May 4, 2007
- C.Hill, July 27, 2007
- C.Hill, October 5, 2007
- C.Hill, February 27, 2008

- We concentrate on study of long-living gluinos predicted by split SUSY, thus we are searching for decays of gluinos compounded with hadrons - R-hadrons
- However, measurable value is model independent:
  - σ(production in pp collision)$\times$W(stopping in calorimeter)

HSCP Production Simulation

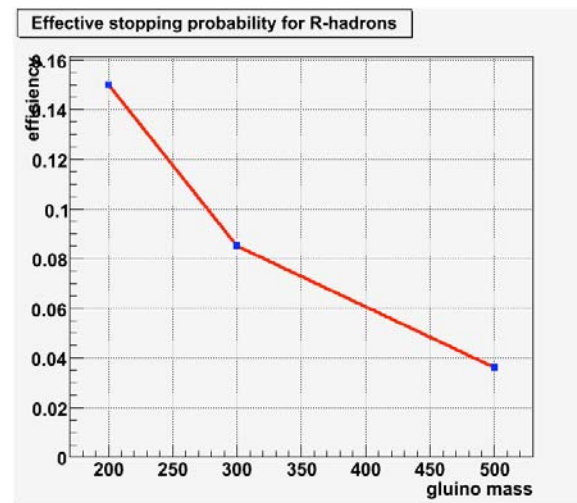
- Use PYTHIA to produce $\tilde{g}\tilde{g}$ hadronized to R-hadrons
  - Set $\tilde{g}$ stable
  - Let PYTHIA to combine gluino into colorless hadron
- Propagate R-hadron through detector
  - Use CustomPhysics package to produce specific elastic and inelastic nuclear interactions
    - R-hadrons quickly convert to R-baryons
  - Store R-hadron stopping point for further use
    - Most stopped states are $\Delta^{++}_{\tilde{g}}$
- Drop all other particles immediately to save CPU time

Stopping Points Distribution



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

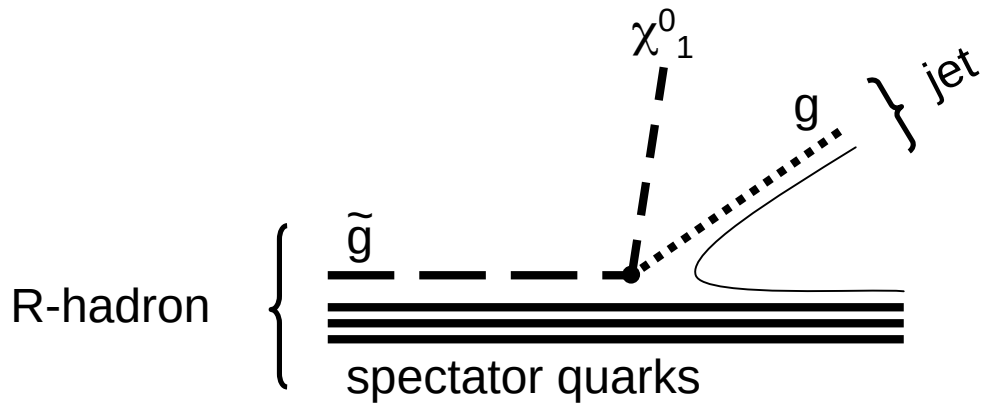
← 22% of R-hardrons stopped in the detector



$$M(\tilde{g}) = 500 GeV/c^2$$

← 5.6% of R-hardrons stopped in the detector

HSCP Decay Simulation



R-hadron → $\tilde{g}$ q (qq)
↳ g χ^0_1

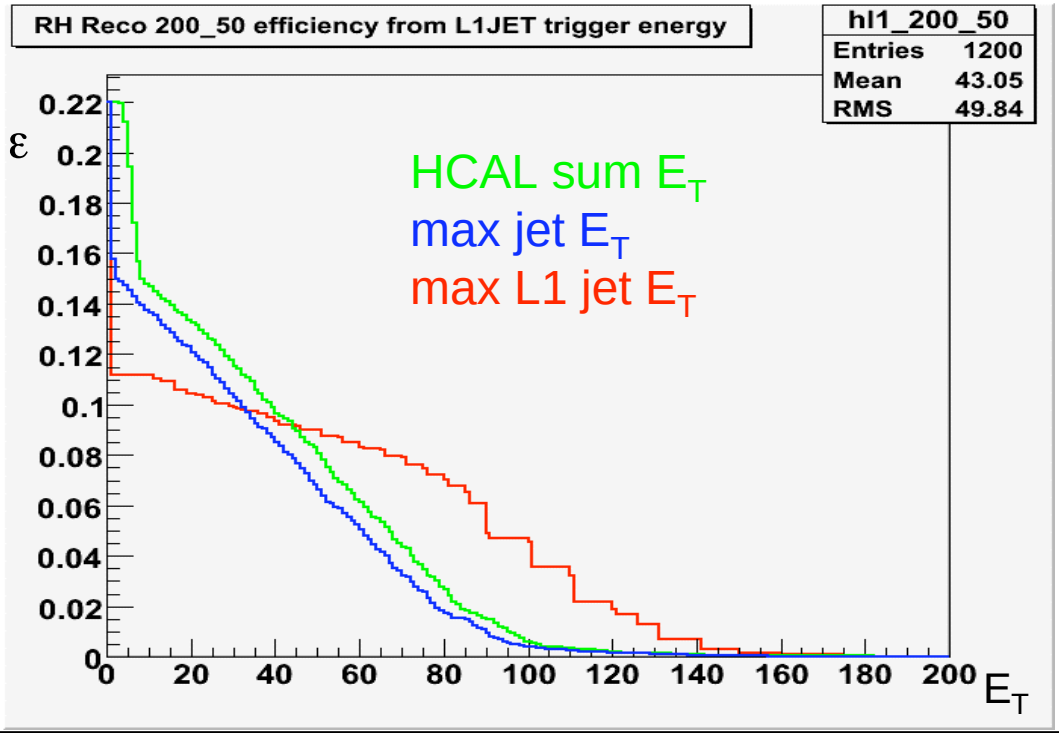
- Customized decay tables
- Customized masses
  - $M(\chi^0_1)$ = 50, 100, 200 GeV/c²
  - $M(\tilde{g})$ = M(R-hadron) - 2 GeV/c²
- As a result PYTHIA does what we need:
  - White (gluino+quark+diquark) system
  - Spectator quarks are essentially in rest
  - Two-body (3-body for di-jet mode) gluino decay with correct masses
  - Jet(s) development according to color structure of gluino products and spectator quarks

R-hadron Decay Reconstruction

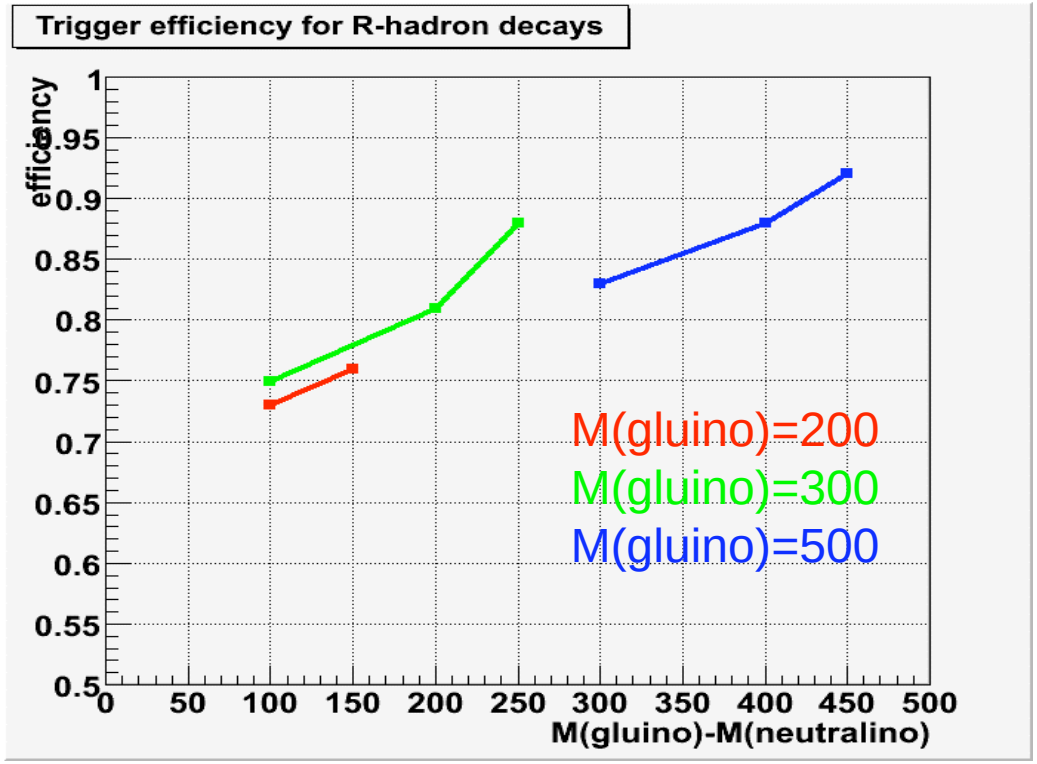
- Regular calorimetry reconstruction
  - Produce CalorecHits, CaloTowers, Jets
- Regular L1 trigger emulation
  - Produce ECAL and HCAL trigger primitives
  - Emulate L1 jet triggers objects

Trigger Simulation

- Three measures of trigger signal:
  - Total energy deposited in HCAL
  - Maximum energy of reconstructed IterativeCone R=0.7 jet
  - Maximum energy of any of L1 Central jet or L1 Tau jet



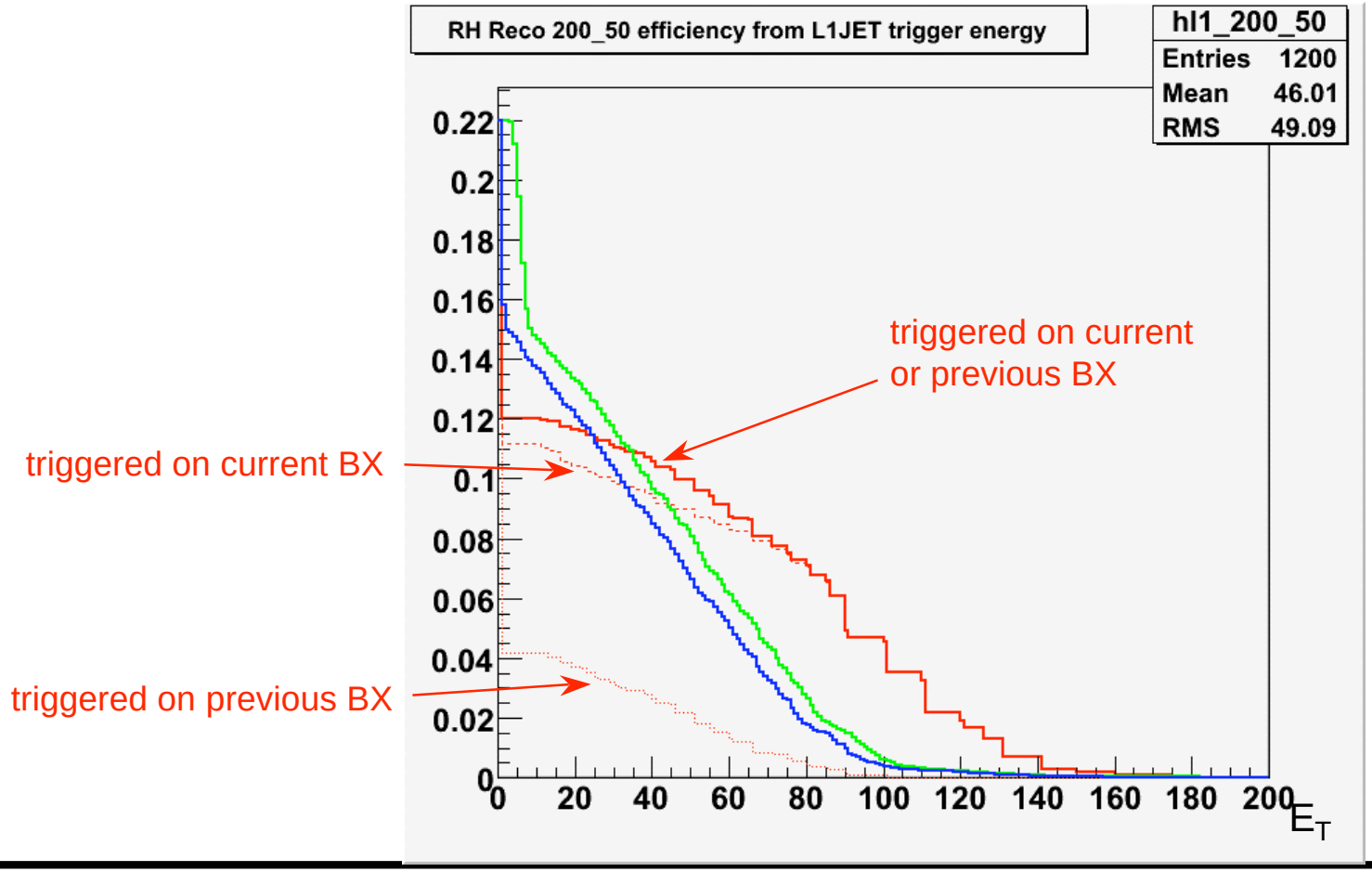
Relative Trigger Efficiency



- L1 efficiency providing decay does hit calorimeter
  - Is high
  - Mostly independent from gluino mass

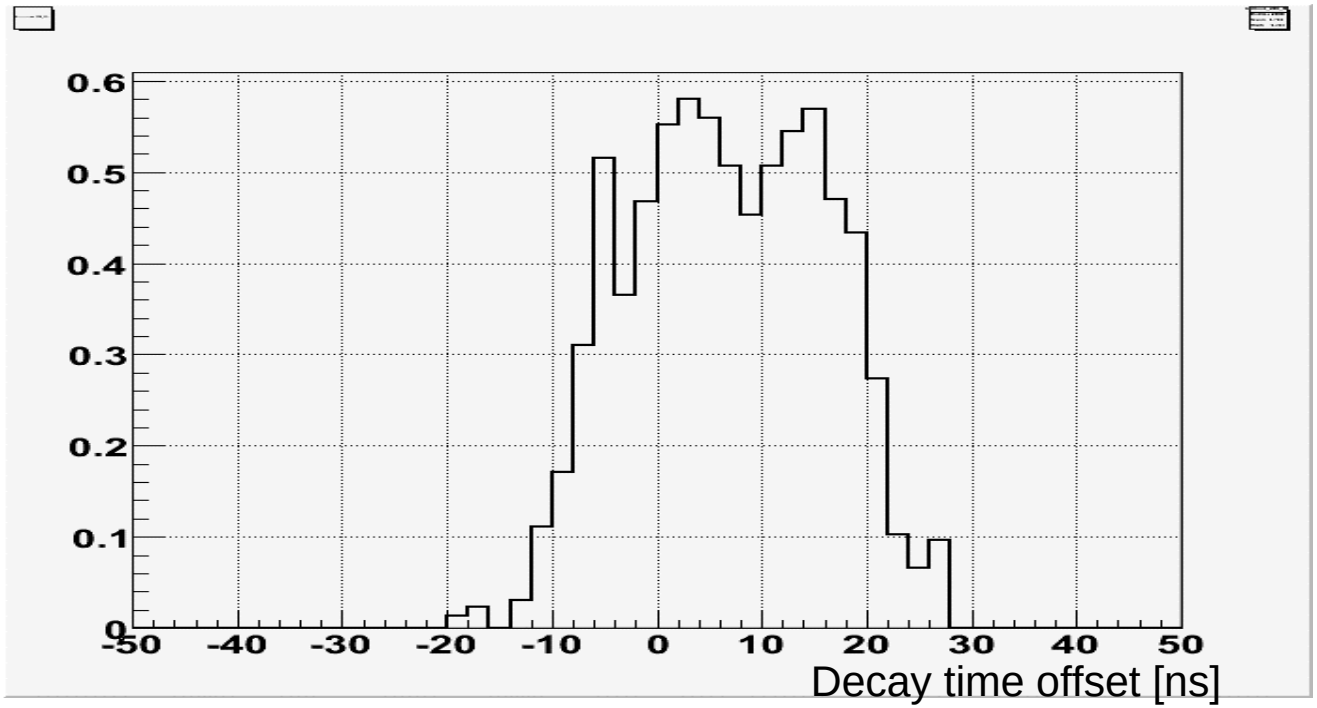
Timing Effect

- Some not triggered events are triggered if L1 is emulated for previous (25 ns) bunch crossing:



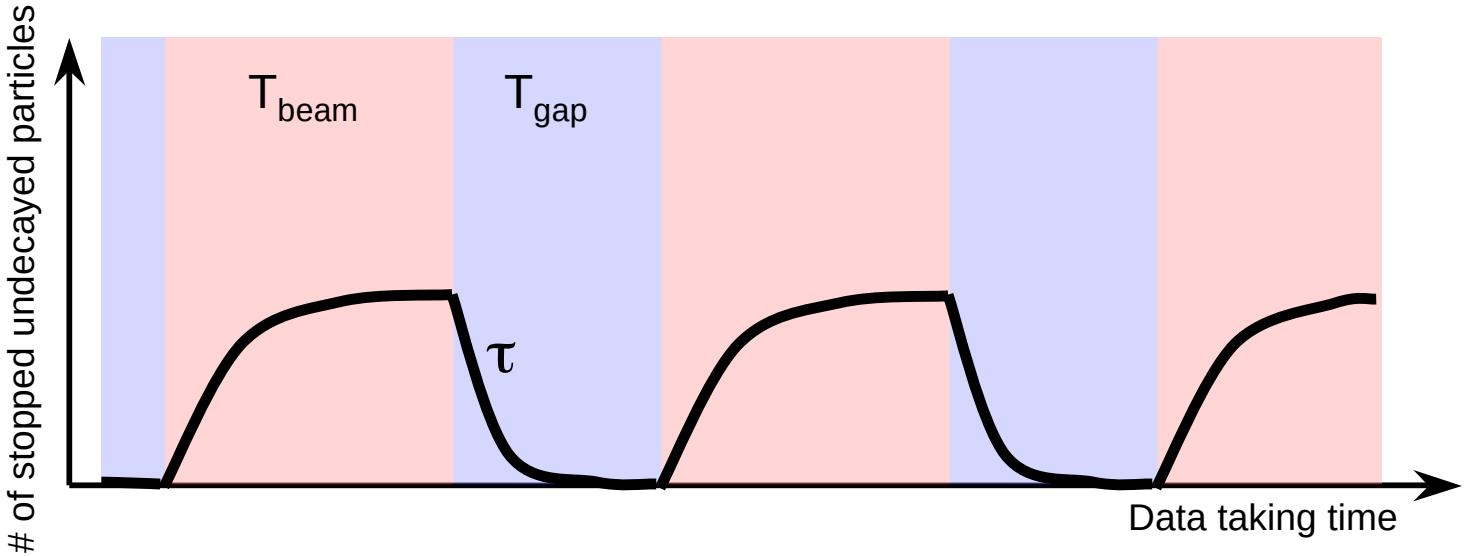
Trigger Synchronization

- Decay is actually uncorrelated with trigger clock
- Smear decay time uniformly [-50ns, 50ns]



- No significant efficiency degradation due to time smearing

Decays Timing Structure



If $\tau << T_{beam}$

$$\sigma_{effective} = [\sigma_{production} \bullet \varepsilon_{stop}] \bullet \varepsilon_{reco} \bullet \frac{\tau}{T_{beam} + T_{gap}} \bullet \left(1 - e^{-\frac{T_{gap}}{\tau}}\right)$$

Example: Beam Downtime

If $\tau << T_{gap}$

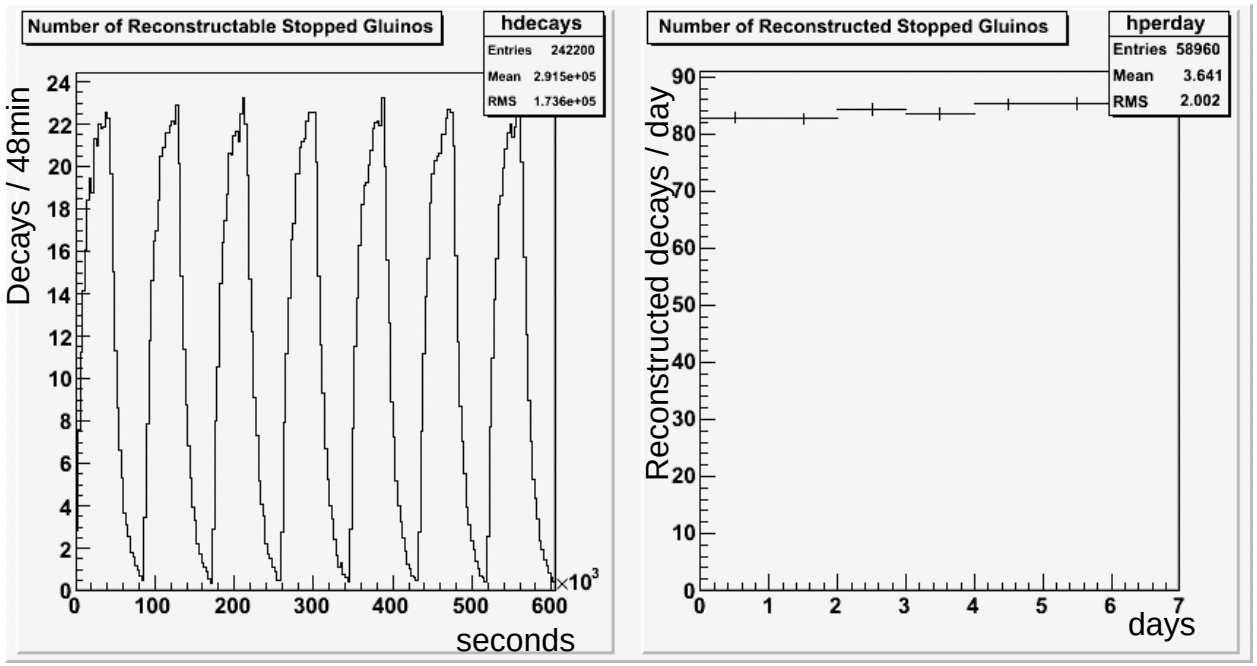
$$\sigma_{effective} = [\sigma_{production} \bullet \varepsilon_{stop}] \bullet \varepsilon_{reco} \bullet \frac{\tau}{T_{beam} + T_{gap}}$$

85 reconstructed decays / day

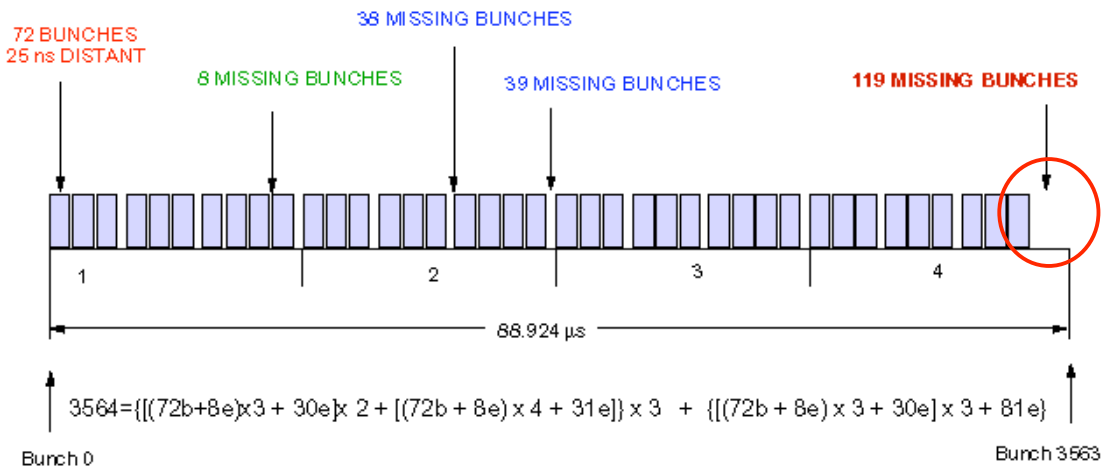
$\tau = 3h$

$T_{beam} = T_{gap} = 12h$

M(gluino) = 300 GeV
M(neutralino) = 50 GeV
σ(pp→gluino,gluino) = 1 nb
L = 10^{32}



Example: Beam Abort Gap



$$\sigma_{effective} = [\sigma_{production} \bullet \varepsilon_{stop}] \bullet \varepsilon_{reco} \bullet \frac{\tau}{T_{beam} + T_{gap}}$$

$\tau = 1\mu s$

$T_{beam} = 86\mu s$

$T_{gap} = 3\mu s$

M(gluino) = 300 GeV

M(neutralino) = 50 GeV

$\sigma(pp \rightarrow gluino,gluino) = 1$ nb

$L = 10^{32}$

1 reconstructed decay / 3h

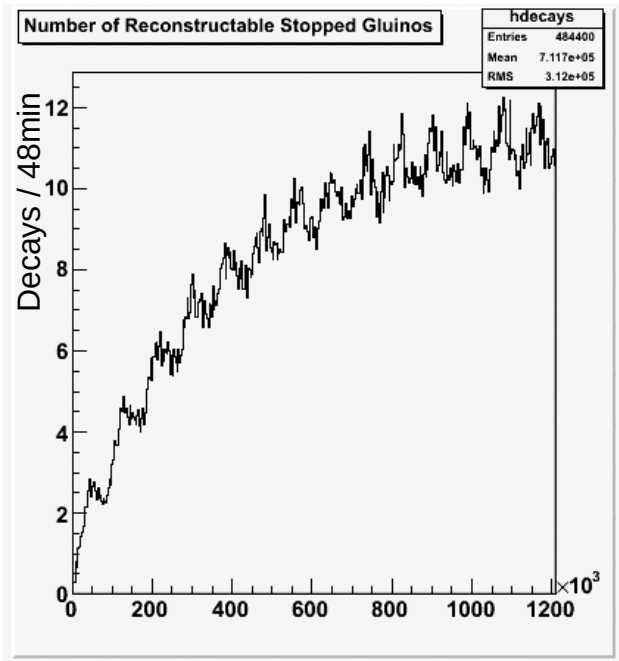
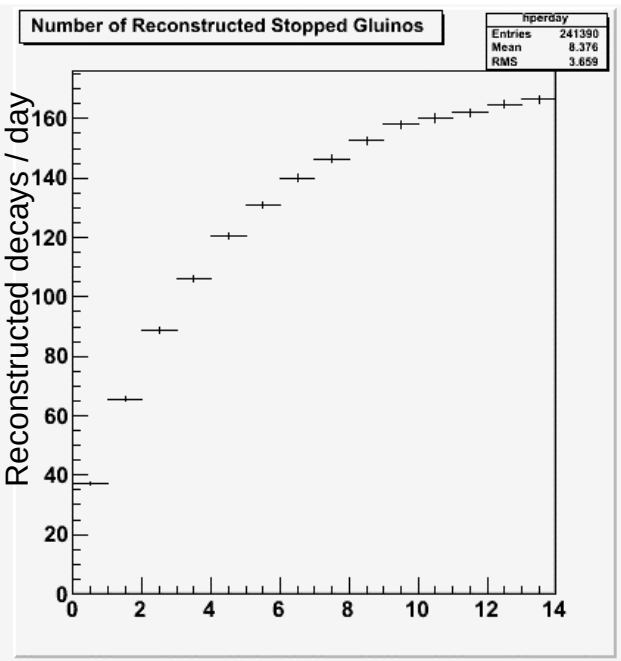
Example: Very Long Living Particles

If $\tau >> T_{gap}$, $\forall T_{beam}$

$$\sigma_{effective} = [\sigma_{production} \bullet \varepsilon_{stop}] \bullet \varepsilon_{reco} \bullet \frac{T_{beam} \bullet T_{gap}}{(T_{beam} + T_{gap})^2}$$

170 reconstructed decays / day

τ = 100h

$T_{beam} = T_{gap}$ = 12h

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