



Long lived particles

Implications of LHC results for TeV-scale physics (WG3)

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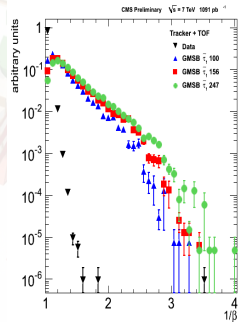
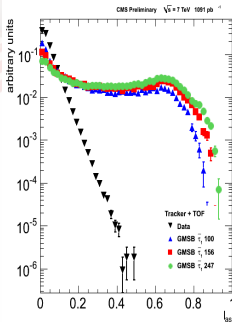
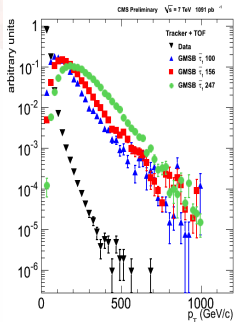
on behalf of the CMS collaboration

INFN Sezione di Roma "La Sapienza"

8th – 9th December 2011 (CERN, Geneva, Switzerland)

- **Exotic long lived particles predicted by extensions of SM**
 - eg. Hidden Valley, GUTs, Gauge mediated SUSY, BSM Higgs
 - In general search for heavy, stable particles which decay away from interaction point
 - Present model independent results using data-driven bkg estimation
- **September meeting [\[link\]](#) covered:**
 - Heavy stable charged particles, HSCPs (1.1 fb^{-1}) [\[PAS link\]](#)
 - Stopped heavy stable charged particles (886 pb^{-1}) [\[PAS link\]](#)
 - Displaced Leptons (1.1 fb^{-1}) [\[PAS link\]](#)
- **NEW: Displaced photons (2.1 fb^{-1})** [\[PAS link\]](#)

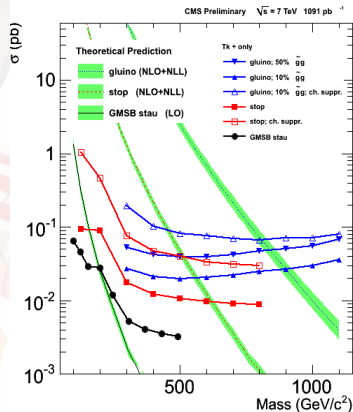
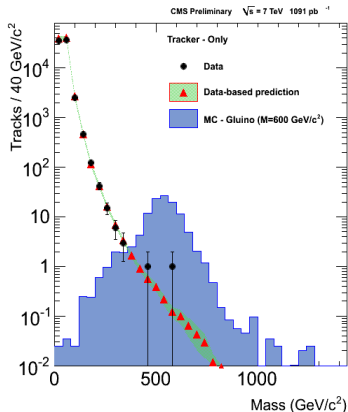
- HSCPs appear in various extensions of the SM
- **Signal MC:** Pair produced gluino (\tilde{g}), scalar top (\tilde{t}) into R-hadrons ($g\tilde{g}$, $gq\bar{q}$, $\tilde{g}qqq$, $\tilde{t}q$, $\tilde{t}q\bar{q}$), GMSB stau
- **Signature:** Particles with large p_T and low $\beta \rightarrow$ large Time-Of-Flight ($1/\beta$) and high energy loss (dE/dx)
- **Bkg:** Instr. noise with high dE/dx , overlapping tracks etc...



No significant excess observed

Limits set for mass and production \times -section for

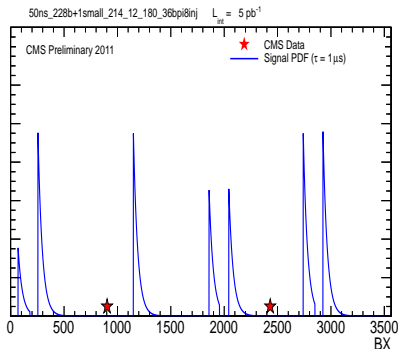
$m_{\tilde{g}} > 889 \text{ GeV}/c^2$ and $m_{\tilde{t}} > 620 \text{ GeV}/c^2$ (Trk only)
and **GMSB stau** $> 293 \text{ GeV}/c^2$ (Trk+TOF)



Stopped HSCP



- **HSCP may come to rest and decay later**
 - Signif. for particles with $\beta < 0.4$ (compliments HSCP search)
- **Signal MC:** Pair produced \tilde{g} and \tilde{t} hadronizing to R-hadrons
- **Signature:** Asynchronous HCAL activity (± 1 BX from pp collision)
- **Bkg:** Cosmics rays, beam-halo muons, instr. noise
- Est. bkg using data-driven methods (see constant rate since 2010)



Stopped HSCP

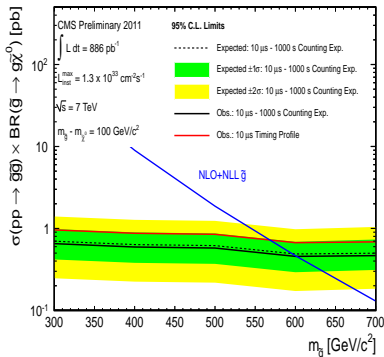
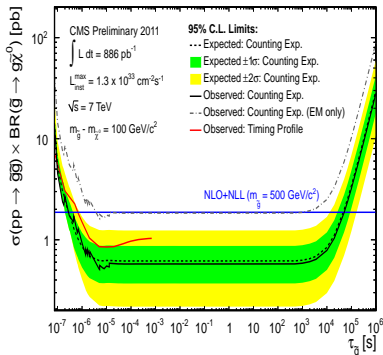
Glino limits



No significant excess observed

Limits as func. of mass on plateau of lifetime excl. ($10\mu\text{s}$ – 1000s)

Lower limits set: $m_{\tilde{g}} > 601 \text{ GeV}/c^2$ and $m_{\tilde{t}} > 337 \text{ GeV}/c^2$



Stopped HSCP

Stop Limits

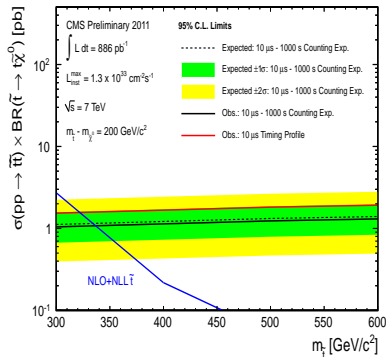
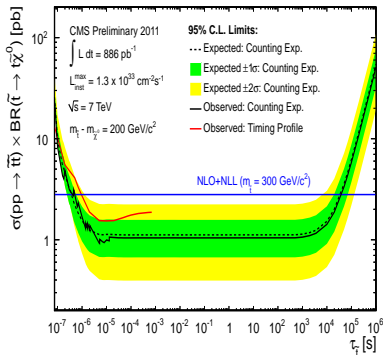


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No significant excess observed

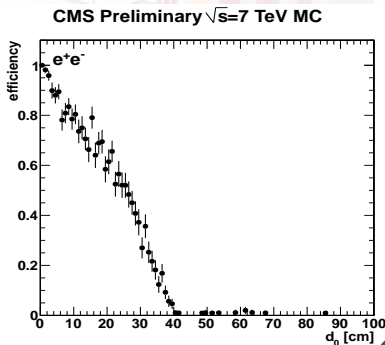
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Displaced leptons

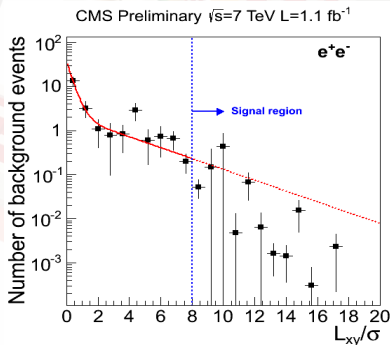
- Search for neutral LL particles decaying into leptons
- **Signal MC:** $H^0 \rightarrow 2X, X \rightarrow \ell^+ \ell^-$
- **Signature:** One or two displaced vertices from oppositely charged leptons
- **Bkg:** QCD, $t\bar{t}$, $Z/\gamma \rightarrow \ell^+ \ell^-$
- Eff. for single isol. particles $d_0 < 40$ cm
- Look for peak in inv. mass spec. of X
- Bkg. estimated with fit to decay length signif.



Displaced leptons



- Search for neutral LL particles decaying into leptons
- Signal MC: $H^0 \rightarrow 2X, X \rightarrow l^+l^-$
- Signature: One or two displaced vertices from oppositely charged leptons (use iterative tracking)
- Bkg: QCD, $t\bar{t}$, $Z/\gamma \rightarrow l^+l^-$
- Eff. for single isol. particles $d_0 < 40$ cm
- Look for peak in inv. mass spec. of X
- Background estimated with data-driven fit to decay length signif.



Displaced leptons

Limits



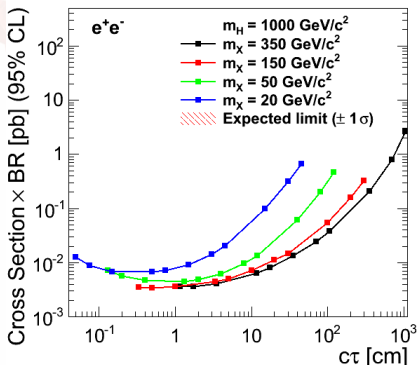
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No significant excess observed

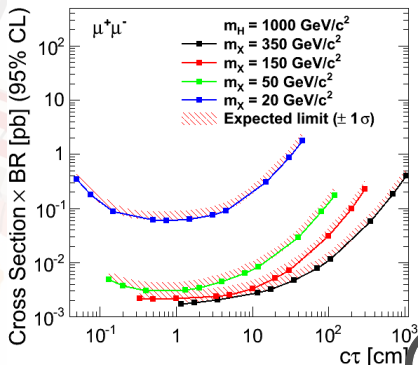
Limits set for range of m_{H^0} , m_X

For $200 < m_H < 1000 \text{ GeV}/c^2$ and $20 < X < 350 \text{ GeV}/c^2$
typically in range $0.003 - 0.03 \text{ pb}$

CMS Preliminary $\sqrt{s}=7 \text{ TeV } L=1.1 \text{ fb}^{-1}$

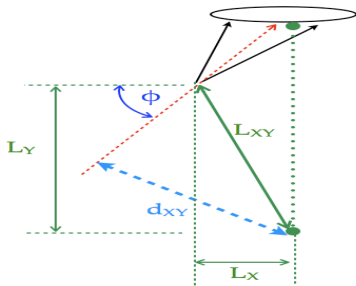


CMS Preliminary $\sqrt{s}=7 \text{ TeV } L=1.2 \text{ fb}^{-1}$



Displaced photons

- Search for long-lived neutral particles decaying into photons
- **Signal MC:** GMSB scenario ($\tilde{\chi}_1^0 \rightarrow \tilde{G}\gamma$) with Gravitino (\tilde{G}) as LSP and Neutralino ($\tilde{\chi}_1^0$) as NLSP
- **Signature:** Photon will be produced from displaced vtx. (will also see \cancel{E}_T from event from \tilde{G})
- Difficult to assign vertex to displaced photon
Use converted photons
- Transverse impact parameter (d_{XY}) as discriminating variable

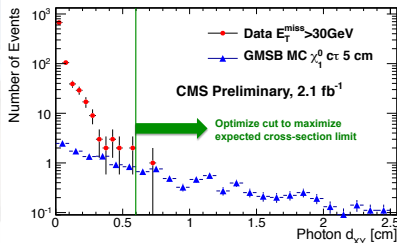


Displaced photons

Analysis



Selection	Events in MC
Total	45057
Di- γ trigger	39988
Di- γ $E_T > 45$ GeV and $E_T > 30$ GeV	37398
Barrel γ $E_T > 45$ GeV with photon ID	27766
Jets $p_T > 80$ GeV and $p_T > 50$ GeV	26229
Conversion selection	1602
$E_T^{miss} > 30$ GeV	1542
$d_{XY} > 0.6$ cm	711

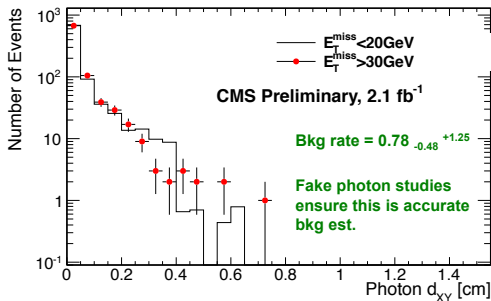


- Select γ conversions \rightarrow Able to reconstruct γ direction
- Select di-photon events (counting exp.) \rightarrow Use transverse IP (d_{XY}) to distinguish signal from SM bkg
- Expect 8 events of signal (after normalizing to lumi) \rightarrow Observe 1

Displaced photons

Background estimation

- Final state composed of γ and Jets \rightarrow No true \cancel{E}_T
- Use low \cancel{E}_T as control region for bkg estimation



- Lower \cancel{E}_T compared to other SUSY/EXO analyses using photons (eg. $\cancel{E}_T > 100 \text{ GeV}$)
- Compare d_{XY} distributions for $\cancel{E}_T < 20 \text{ GeV}$ and $\cancel{E}_T > 30 \text{ GeV}$
- Normalize bkg estimate to signal data using number of conversions

Displaced photons

Uncertainties



The overall uncertainty is 25% with the largest contribution from the conversion reconstruction efficiency

Systematics	Uncertainty (%)
Conversion reconstruction efficiency	20.6
Photon d_{XY} resolution	< 0.5
Integrated luminosity	4.5
Jet/ E_T^{miss} energy scale	< 0.5
Pile-up study	2.5
Photon Data/MC scale	2.6
Photon ID	0.5
Total	25

Table: Summary of experimental uncertainties

Displaced photons

Results

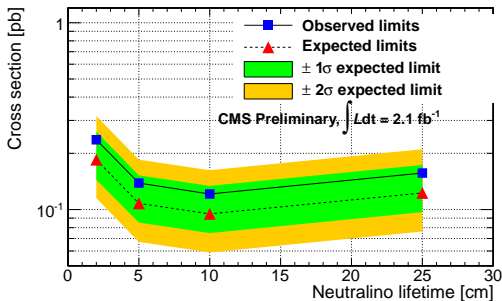


No significant excess observed

Set limits as a function of lifetime of long-lived particle

Sensitivity of analysis is $2 \text{ cm} < c\tau_{\tilde{\chi}_1^0} < 25 \text{ cm}$

- **At short lifetimes:**
Difficult to optimize sig/bkg eff. near PV
- **At long lifetimes:**
Low conversion reconstruction eff.



Summary



- **We search for long lived particles using a wide range of techniques**
 - Highly ionising tracks
 - Slow muon tracks (high TOF)
 - Decays from stopped particles
 - Displaced vertices
 - Photon conversions
- **No discoveries as of yet → Only limits**
 - Competitive world limits for stable \tilde{g} , \tilde{t} , GMSB (and pair-produced) stau
 - Competitive world limits for displaced ℓ in mass range presented
 - New results on LL particles using displaced photons
 - For all publicly available results from CMS see [\[here\]](#)



Thank You