



Searches for long-lived, weakly interacting particles

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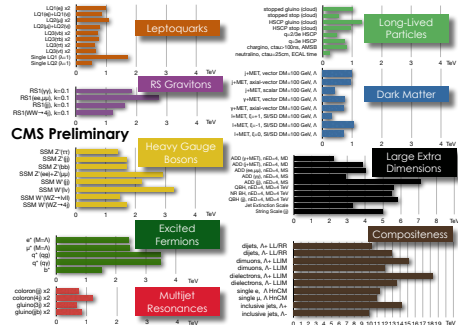
Status of new physics after LHC Run 1

- A lack of signs of new physics, despite extensive searches, is one of the most important results from Run 1.
- But we must keep in mind the assumptions we make in all these searches.
- One of the most common is that new particles will decay promptly.

ATLAS Exotics Searches* - 95% CL Exclusion

Model	\sqrt{s}	Ints	E_{cm}^{int}	$\mathcal{L} \times \mathcal{B} \times \mathcal{A}$	Limit	Reference
Scalar bosons						
ADD (m=1)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=2)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=3)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=4)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=5)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=6)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=7)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=8)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=9)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=10)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=11)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=12)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=13)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=14)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=15)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=16)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=17)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=18)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=19)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=20)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=21)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=22)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=23)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=24)	20.0	1.1	Yes	20.3	1.1	1407.014
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ADD (m=26)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=27)	20.0	1.1	Yes	20.3	1.1	1407.014
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ADD (m=66)	20.0	1.1	Yes	20.3	1.1	1407.014
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ADD (m=71)	20.0	1.1	Yes	20.3	1.1	1407.014
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ADD (m=82)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=83)	20.0	1.1	Yes	20.3	1.1	1407.014
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ADD (m=88)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=89)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=90)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=91)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=92)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=93)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=94)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=95)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=96)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=97)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=98)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=99)	20.0	1.1	Yes	20.3	1.1	1407.014
ADD (m=100)	20.0	1.1	Yes	20.3	1.1	1407.014

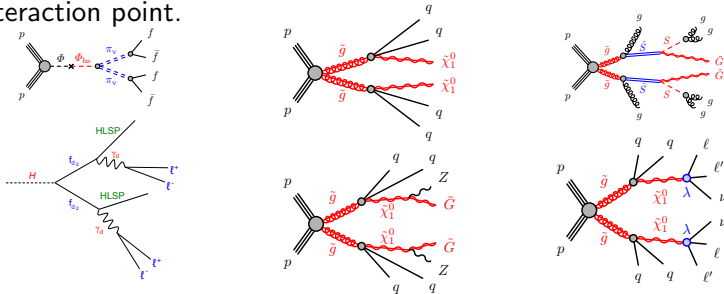
* Only a selection of the searches have been included; others are shown in the full report.



CMS Exotics Physics Group Summary - Moriond 2015

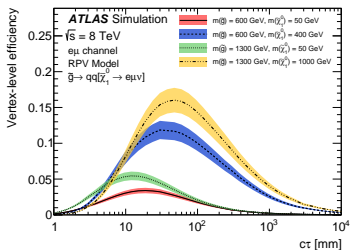
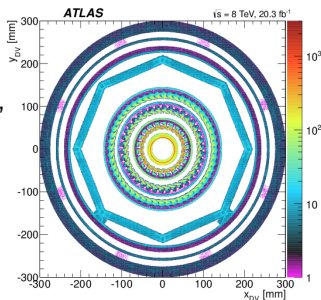
Motivations for long-lived particles

- Assuming new particles are long-lived (LL) complicates analysis strategies, background estimation, systematic uncertainties, etc.
- But there are several reasons this could be and a plethora of models that realize them:
 - heavy intermediate particles (hidden valley models, split SUSY, etc.)
 - weak couplings (couplings to \tilde{G} , RPV couplings, etc.)
 - very limited phase space (e.g. AMSB $\tilde{\chi}_1^\pm$ decays)
- This talk summarizes searches for weakly interacting, LL particles; i.e., searches for decay products displaced to various degrees from the interaction point.



Displaced vertices ($c\tau \sim 1$ cm)

- Displaced vertices (DV) formed from clusters of ≥ 5 tracks.
- Dilepton vertices formed from $e^\pm e^\mp$, $\mu^\pm \mu^\mp$, $e^\pm \mu^\mp$ pairs.
- Density map of ATLAS used to veto vertices in dense material.
- Backgrounds from accidental crossings and merged vertices taken from data.



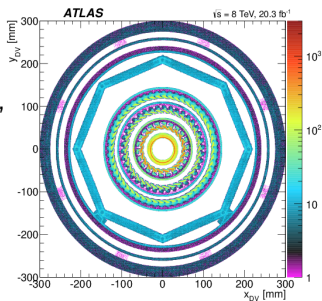
- No events observed in any of the seven signal regions.

Channel	No. of background vertices ($\times 10^{-3}$)
DV+jet	$410 \pm 7 \pm 60$
DV+ E_T^{miss}	$10.9 \pm 0.2 \pm 1.5$
DV+muon	$1.5 \pm 0.1 \pm 0.2$
DV+electron	$207 \pm 9 \pm 29$

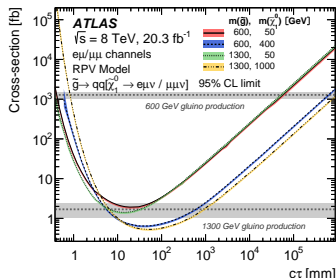
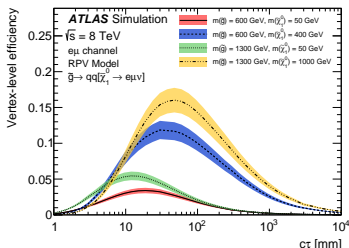
Channel	No. of background vertices ($\times 10^{-3}$)
$e^+ e^-$	1.0 ± 0.2 ^{+0.3} _{-0.6}
$e^\pm \mu^\mp$	2.4 ± 0.9 ^{+0.8} _{-1.5}
$\mu^+ \mu^-$	2.0 ± 0.5 ^{+0.3} _{-1.4}

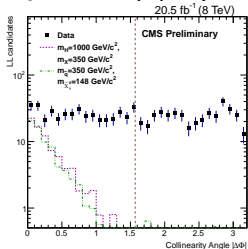
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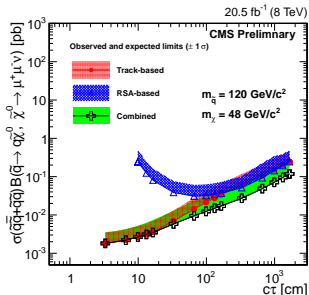
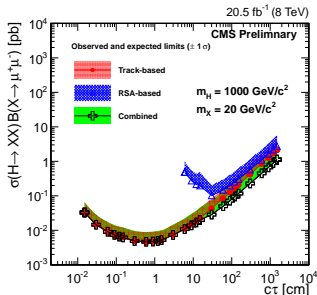
- Limits set on several SUSY models.



Displaced $\mu\mu$ (muon chambers only) ($c\tau \sim 100$ cm)

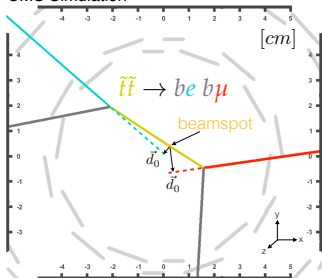
- CMS also looked for dimuon vertices with only muon chambers, vetoing muons matching tracks from the inner tracker.
- Background estimated from candidates in data with anti-aligned momentum and position vectors.

- Zero events predicted and observed; combined with results using inner tracker to set limits on hidden valley scalars (X) and RPV $\tilde{\chi}^0$.



Displaced SUSY ($c\tau \sim 1$ cm)

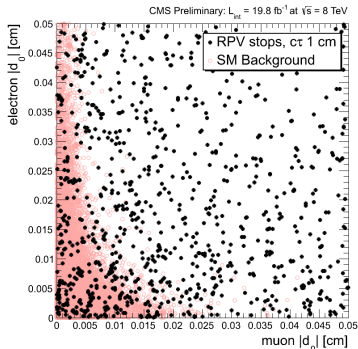
CMS Simulation



- Isolated $e^\pm \mu^\mp$ pairs searched for with large transverse impact parameters ($|d_0|$).
- Leptons from LL particle decays have broad $|d_0|$ distributions.
- No common vertex required.

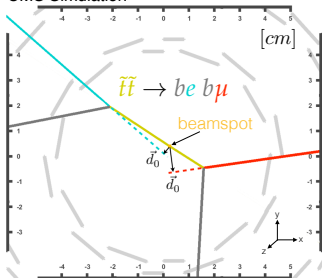
- No excess observed in any of the three signal regions.

Signal region	Expected	Observed
$ d_0 \in (0.02, 0.05)$ cm	$18.0 \pm 0.5 \pm 3.8$	19
$ d_0 \in (0.05, 0.1)$ cm	$1.01 \pm 0.06 \pm 0.30$	0
$ d_0 \in (0.1, 2)$ cm	$0.051 \pm 0.015 \pm 0.010$	0



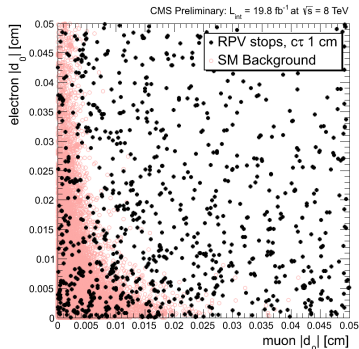
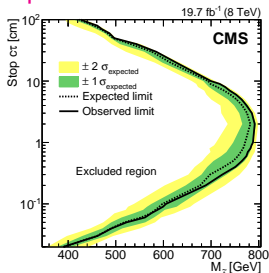
Displaced SUSY ($c\tau \sim 1$ cm)

CMS Simulation



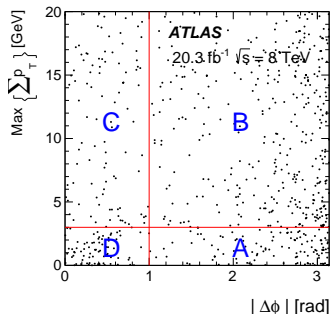
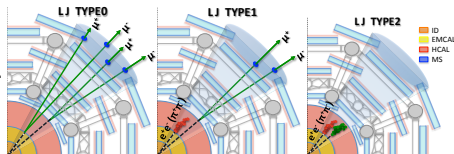
- Isolated $e^\pm\mu^\mp$ pairs searched for with large transverse impact parameters ($|d_0|$).
- Leptons from LL particle decays have broad $|d_0|$ distributions.
- No common vertex required.

- Limits set on RPV stop pair production in a “displaced SUSY” model.



Displaced lepton jets (LJ) ($c\tau \sim 10$ cm)

- Displaced LJs formed by clustering muons and calo. deposits isolated from ID tracks.
- Cosmic background estimated from empty bunch crossing data.
- Multijets estimated with data-driven ABCD method.

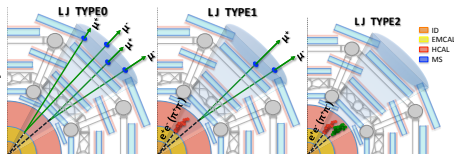


- Data well-described by backgrounds.

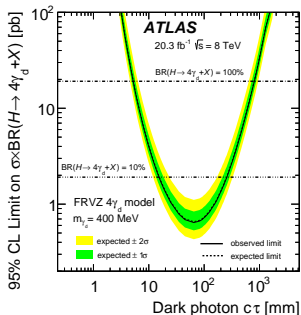
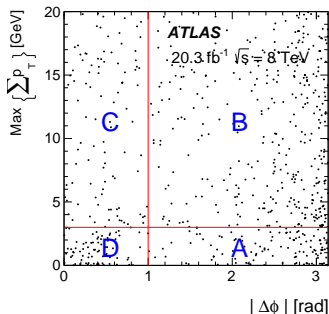
	All LJ pair types	TYPE2-TYPE2 LJs excluded
Data	119	29
Cosmic rays	$40 \pm 11 \pm 9$	$29 \pm 9 \pm 29$
Multi-jets (ABCD)	$70 \pm 58 \pm 11$	$12 \pm 9 \pm 2$
Total background	$110 \pm 59 \pm 14$	$41 \pm 12 \pm 29$

Displaced lepton jets (LJ) ($c\tau \sim 10$ cm)

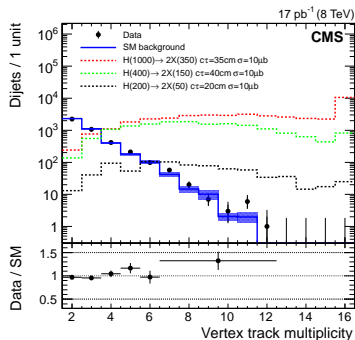
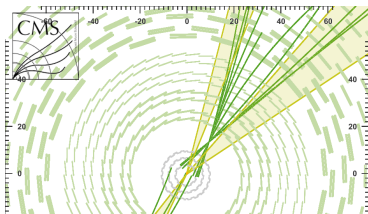
- Displaced LJs formed by clustering muons and calo. deposits isolated from ID tracks.
- Cosmic background estimated from empty bunch crossing data.
- Multijets estimated with data-driven ABCD method.



- Limits set on dark photons (γ_d).



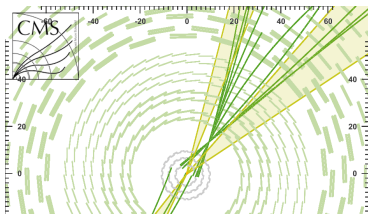
Displaced dijets ($c\tau \sim 10$ cm)



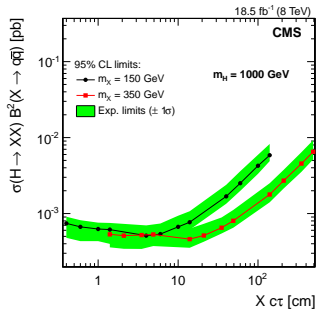
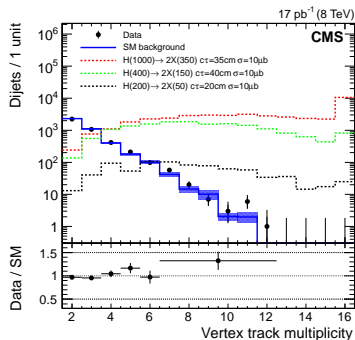
- Displaced vertices formed from tracks in pairs of jets.
- Several variables used to select vertices compatible with signal.
- Multijet background estimated from data with ABCDEFGH method.
- Two sets of selections considered; background describes the data well for both.

	Loose selection	Tight selection
Expected	$1.56 \pm 0.25 \pm 0.47$	$1.13 \pm 0.15 \pm 0.50$
Observed	2	1

Displaced dijets ($c\tau \sim 10$ cm)



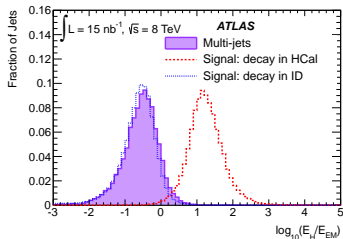
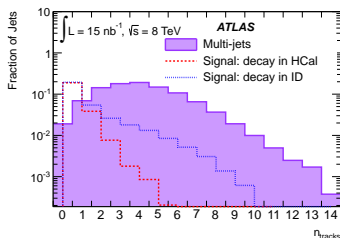
- Displaced vertices formed from tracks in pairs of jets.
- Several variables used to select vertices compatible with signal.
- Multijet background estimated from data with ABCDEFGH method.
- Limits set on hidden valley scalars (X).



Trackless jets ($c\tau \sim 100$ cm)

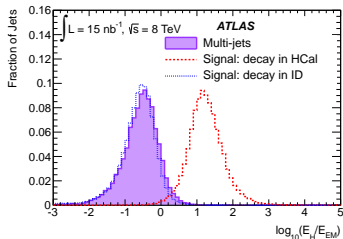
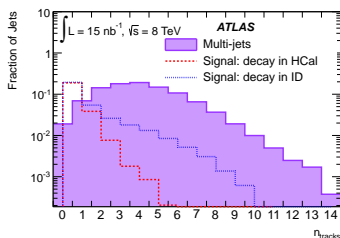
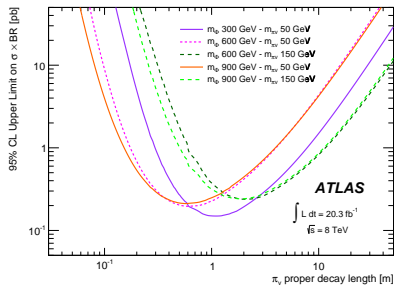
- Pairs of trackless jets are used to search for particles decaying in the HCAL.
- No tracks in the ID and little energy in the ECAL.
- Multijet and cosmic backgrounds estimated from data.
- No excess of events observed.

Background	Expected events
SM Multi-jets	23.2 ± 8.0
Cosmic rays	0.3 ± 0.2
Total Expected Background	23.5 ± 8.0
Data	24



Trackless jets ($c\tau \sim 100$ cm)

- Pairs of trackless jets are used to search for particles decaying in the HCAL.
- No tracks in the ID and little energy in the ECAL.
- Multijet and cosmic backgrounds estimated from data.
- Limits set on hidden valley pions (π_V).



Conclusion

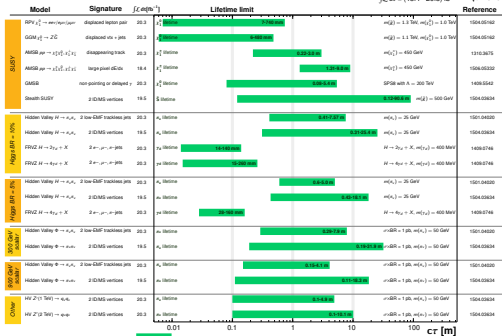
- ATLAS and CMS have performed several searches for new weakly interacting, LL particles.
- These searches help fill important gaps in coverage left by more traditional searches where new physics could hide.
- Conversely, a future discovery by one of these searches would be a striking sign of new physics.

- Stay tuned for even more exciting results during Run 2!

ATLAS Long-lived Particle Searches* - 95% CL Exclusion

Statist. July 2015

ATLAS Preliminary
 $\int \mathcal{L} dt = (18.4 - 20.3) \text{ fb}^{-1}$
 $\sqrt{s} = 8 \text{ TeV}$



*Only a selection of the available lifetime limits on new states is shown.

ATLAS Preliminary

$\sqrt{s} = 13 \text{ TeV}, 78 \text{ pb}^{-1}$

MS vertex ϕ - pre-isolation

