



To catch a long-lived particle

Rebeca Gonzalez Suarez

Uppsala University

Spaatind 2020 - Nordic conference on Particle Physics



The life of a particle



Particles in the SM have varying lifetimes, from the very short-lived Z boson $(2 \times 10^{-25} \text{s})$ through to the proton (10^{34} years) or the electron (stable)



Then why

• Do we assume that new particles have to die young?





Long-lived particles

- There could be new particles with lifetimes long enough to travel some distance inside the detector before decaying
 - Long enough to have **distinct experimental signatures**
 - There are many reasons why they would live long:
 - Small couplings, large mediator masses, or approximated symmetries
- Long-lived particles are not a prediction of a new theory
 - A feature of virtually all proposed frameworks for BSM physics
 - Their presence is strongly motivated



LLP are a Hallmark of Hidden sectors, with non-SM matter and forces, that can be connected to the SM via very small effective couplings called <u>portals</u>

Hidden sectors could explain big questions of the SM in a way that is compatible with the current lack of new particles



In a panorama

• In which searches for new physics in ATLAS and CMS are systematically coming back empty

	Model	S	ignatur	e ∫	` <i>L dt</i> [fb⁻	Ma	iss limit				Reference
6	$\tilde{q}\tilde{q}, \tilde{q} \rightarrow q \tilde{\chi}_1^0$	0 e, μ mono-jet	2-6 jets 1-3 jets	E_T^{miss} E_T^{miss}	36.1 36.1	$ ilde{q}$ [2×, 8× Degen.] $ ilde{q}$ [1×, 8× Degen.]	0.43	0.9	1.55	m(𝐉˜1)<100 GeV m(𝐉)-m(𝐉˜1)=5 GeV	1712.02332 1711.03301
Irche	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q \tilde{q} \tilde{\chi}_1^0$	0 <i>e</i> , <i>µ</i>	2-6 jets	$E_T^{ m miss}$	36.1	ĩg ĩg		Forbidden	0.95-1.6	.0 m($\tilde{\ell}_1^0$)<200 GeV m($\tilde{\ell}_1^0$)=900 GeV	1712.02332 1712.02332
e Seá	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow q\bar{q}(\ell \ell)\tilde{\chi}_1^0$	3 e, μ ee, μμ	4 jets 2 jets	E_T^{miss}	36.1 36.1	ĩġ			1.85	m(𝔅1) ⁰ <800 GeV m(𝔅)⋅m(𝔅1)=50 GeV	1706.03731 1805.11381
clusiv	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow qqWZ\tilde{\chi}_1^0$	0 e, μ SS e, μ	7-11 jets 6 jets	$E_T^{\rm miss}$	36.1 139	750 its			1.8 1.15	$m(\tilde{\chi}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{g})-m(\tilde{\chi}_{1}^{0})=200 \text{ GeV}$	1708.02794 ATLAS-CONF-2019-015
5	$\tilde{g}\tilde{g}, \tilde{g} \rightarrow t t \tilde{\chi}_1^0$	0-1 <i>e</i> , μ SS <i>e</i> , μ	3 <i>b</i> 6 jets	$E_T^{\rm miss}$	79.8 139	93° 93°			1.25	2.25 $m(\tilde{\chi}_1^0)$ <200 GeV $m(\tilde{g})$ - $m(\tilde{\chi}_1^0)$ =300 GeV	ATLAS-CONF-2018-041 ATLAS-CONF-2019-015
	$\tilde{b}_1\tilde{b}_1, \tilde{b}_1{\rightarrow}b\tilde{\chi}_1^0/t\tilde{\chi}_1^\pm$		Multiple Multiple Multiple		36.1 36.1 139	\$\bar{b}_1\$ Forbidden \$\bar{b}_1\$ \$\bar{b}_1\$	Forbidden Forbidden	0.9 0.58-0.82 0.74		$\begin{array}{c} m(\tilde{\chi}_{1}^{0}){=}300\text{GeV},BR(b\tilde{\chi}_{1}^{0}){=}1\\ m(\tilde{\chi}_{1}^{0}){=}300\text{GeV},BR(b\tilde{\chi}_{1}^{0}){=}BR(b\tilde{\chi}_{1}^{0}){=}0.5\\ m(\tilde{\chi}_{1}^{0}){=}200\text{GeV},m(\tilde{\chi}_{1}^{0}){=}300\text{GeV},BR(b\tilde{\chi}_{1}^{0}){=}1\end{array}$	1708.09266, 1711.03301 1708.09266 ATLAS-CONF-2019-015
ion	$\tilde{b}_1 \tilde{b}_1, \tilde{b}_1 \rightarrow b \tilde{\chi}^0_2 \rightarrow b h \tilde{\chi}^0_1$	0 <i>e</i> , <i>µ</i>	6 <i>b</i>	$E_T^{ m miss}$	139	$ar{b}_1$ Forbidden $ar{b}_1$	0.23-0.48		0.23-1.35	$\Delta m(\tilde{\chi}_{2}^{0}, \tilde{\chi}_{1}^{0}) = 130 \text{ GeV}, m(\tilde{\chi}_{1}^{0}) = 100 \text{ GeV}$ $\Delta m(\tilde{\chi}_{2}^{0}, \tilde{\chi}_{1}^{0}) = 130 \text{ GeV}, m(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}$	SUSY-2018-31 SUSY-2018-31
product	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow Wb \tilde{\chi}_1^0 \text{ or } t \tilde{\chi}_1^0$ $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow Wb \tilde{\chi}_1^0$	0-2 <i>e</i> , μ 1 <i>e</i> , μ	0-2 jets/1-2 3 jets/1 b	$b E_T^{miss} E_T^{miss}$	36.1 139	\tilde{t}_1 \tilde{t}_1	0.44-0	.59		$m(\tilde{\chi}_1^0)=1 \text{ GeV}$ $m(\tilde{\chi}_1^0)=400 \text{ GeV}$	1506.08616, 1709.04183, 1711.115 ATLAS-CONF-2019-017
direct p	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow \tilde{\tau}_1 bv, \tilde{\tau}_1 \rightarrow \tau \tilde{G}$ $\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow c \tilde{\chi}_1^0 / \tilde{c} \tilde{c}, \tilde{c} \rightarrow c \tilde{\chi}_1^0$	1 τ + 1 e,μ,τ 0 e, μ	2 jets/1 b 2 c	E_T^{miss} E_T^{miss}	36.1 36.1	τ̃ ₁ č	0.40	0.85	1.16	$m(\tilde{\tau}_1)=800 \text{ GeV}$ $m(\tilde{\chi}_1^0)=0 \text{ GeV}$	1803.10178 1805.01649
		0 <i>e</i> , <i>µ</i>	mono-jet	$E_T^{\rm miss}$	36.1	$t_1 \\ \tilde{t}_1$	0.46 0.43			$ m(\tilde{i}_1, \tilde{c}) \cdot m(\tilde{X}_1^0) = 50 \text{ GeV} \\ m(\tilde{i}_1, \tilde{c}) \cdot m(\tilde{X}_1^0) = 5 \text{ GeV} $	1805.01649 1711.03301
	$ \tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + h \tilde{t}_2 \tilde{t}_2, \tilde{t}_2 \rightarrow \tilde{t}_1 + Z $	1-2 e, μ 3 e, μ	4 b 1 b	E_T^{miss} E_T^{miss}	36.1 139	<i>ι</i> ₂ <i>ι</i> ₂	Forbidden	0.32-0.88 0.86		$m(\tilde{\chi}_{1}^{0})=0 \text{ GeV}, m(\tilde{\iota}_{1})-m(\tilde{\chi}_{1}^{0})=180 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0})=360 \text{ GeV}, m(\tilde{\iota}_{1})-m(\tilde{\chi}_{1}^{0})=40 \text{ GeV}$	1706.03986 ATLAS-CONF-2019-016
	$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ via WZ	2-3 e, μ ee, μμ	≥ 1	$E_T^{ m miss}$ $E_T^{ m miss}$	36.1 139	$\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ $\tilde{\chi}_{1}^{\pm}/\tilde{\chi}_{2}^{0}$ 0.205		0.6		$m(\tilde{\chi}_1^0)=0$ $m(\tilde{\chi}_1^\pm)-m(\tilde{\chi}_1^0)=5$ GeV	1403.5294, 1806.02293 ATLAS-CONF-2019-014
	$\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\mp}$ via WW $\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{0}$ via Wh	2 e, μ 0-1 e, μ	2 b/2 γ	E_T^{miss} E_T^{miss}	139 139	$\tilde{\chi}_{1}^{\pm}$ $\tilde{\chi}_{-}^{\pm} I \tilde{\chi}_{0}^{0}$ Forbidden	0.42	0.74		$m(\tilde{\chi}_1^0)=0$ $m(\tilde{\chi}_1^0)=70$ GeV	ATLAS-CONF-2019-008 ATLAS-CONF-2019-019, ATLAS-CONF-2
lirect	$\tilde{\chi}_{1}^{\pm}\tilde{\chi}_{1}^{\mp}$ via $\tilde{\ell}_{L}/\tilde{\nu}$ $\tilde{\tau}_{T}^{\mp}$ $\tilde{\tau}_{\to}\tau\tilde{\chi}_{-}^{0}$	2 e, μ 2 τ		E_T^{miss} E_T^{miss}	139 139	τ̃[τ̃ι, τ̃RI] 0.16-0.3	0.12-0.39	1.0		$m(\tilde{\ell},\tilde{v})=0.5(m(\tilde{\chi}_1^{\pm})+m(\tilde{\chi}_1^{0}))$ $m(\tilde{\chi}_2^{0})=0$	ATLAS-CONF-2019-008 ATLAS-CONF-2019-018
Ŭ	$\tilde{\ell}_{L,R}\tilde{\ell}_{L,R}, \tilde{\ell} \rightarrow \ell \tilde{\chi}_1^0$	2 e, μ 2 e, μ	0 jets ≥ 1	E_T^{miss} E_T^{miss}	139 139	ĩ ĩ 0.256		0.7		$m(\tilde{\ell}_1^0)=0$ $m(\tilde{\ell})\cdot m(\tilde{\ell}_1^0)=10 \text{ GeV}$	ATLAS-CONF-2019-008 ATLAS-CONF-2019-014
	$\tilde{H}\tilde{H}, \tilde{H} \rightarrow h\tilde{G}/Z\tilde{G}$	0 e, μ 4 e, μ	$\geq 3 b$ 0 jets	$E_T^{ m miss}$ $E_T^{ m miss}$	36.1 36.1	 <i>H</i> 0.13-0.23 <i>H</i> 0.3 		0.29-0.88		$BR(\tilde{\chi}_1^0 \rightarrow h\tilde{G})=1$ $BR(\tilde{\chi}_1^0 \rightarrow Z\tilde{G})=1$	1806.04030 1804.03602
sels	$\operatorname{Direct} \tilde{\chi}_1^{+} \tilde{\chi}_1^{-} \text{ prod., long-lived } \tilde{\chi}_1^{\pm}$	Disapp. trk	1 jet	$E_T^{\rm miss}$	36.1	$\tilde{\chi}_{1}^{\pm}$ 0.15	0.46			Pure Wino Pure Higgsino	1712.02118 ATL-PHYS-PUB-2017-019
parti	Stable \tilde{g} R-hadron Metastable \tilde{g} R-hadron, $\tilde{g} \rightarrow qq \tilde{\chi}_1^0$		Multiple Multiple		36.1 36.1				2	.0 05 2.4 m($\tilde{\chi}^0_1$)=100 GeV	1902.01636,1808.04095 1710.04901,1808.04095
	$LFV pp \rightarrow \tilde{v}_{\tau} + X, \tilde{v}_{\tau} \rightarrow e\mu/e\tau/\mu\tau$	εμ,ετ,μτ	0 inte	emiss	3.2	\tilde{v}_r			1.9	$\lambda'_{311}=0.11, \lambda_{132/133/233}=0.07$	1607.08079
>	$\begin{array}{l} \chi_1^-\chi_1^-/\chi_2^- \to WW/Z\ell\ell\ell\ell\nu\nu\\ \tilde{g}\tilde{g}, \tilde{g} \to qq\tilde{\chi}^0_1, \tilde{\chi}^0_1 \to qqq \end{array}$	4 e,μ 4	-5 large- <i>R</i> je Multiple	ts LT	36.1 36.1 36.1	$\begin{array}{l} \chi_1 / \chi_2 & [\lambda_{133} \neq 0, \lambda_{12k} \neq 0] \\ \tilde{g} & [m(\tilde{\chi}_1^0) = 200 \text{ GeV}, 1100 \text{ GeV}] \\ \tilde{g} & [\lambda_{112}' = 2e{-}4, 2e{-}5] \end{array}$		0.82	1.33 1.3 1.9 5 2	m(𝔅 ₁)=100 GeV Large 𝑋 ⁰ ₁₁₂ .0 m(𝔅 ₁ ⁰)=200 GeV. bino-like	1804.03602 1804.03568 ATLAS-CONF-2018-003
dH H	$\tilde{t}\tilde{t}, \tilde{t} \rightarrow t\tilde{\chi}_{1}^{0}, \tilde{\chi}_{1}^{0} \rightarrow tbs$ $\tilde{t}_{1}\tilde{t}_{1}, \tilde{t}_{1} \rightarrow bs$		Multiple 2 jets + 2 h		36.1 36.7	$\tilde{g} = [\lambda''_{323} = 2e-4, 1e-2]$ $\tilde{I}_1 = [aa, bs]$	0.42	5 1.0 0.61	5	$m(\tilde{\chi}_1^0)$ =200 GeV, bino-like	ATLAS-CONF-2018-003 1710.07171
	$\tilde{t}_1 \tilde{t}_1, \tilde{t}_1 \rightarrow q \ell$	2 e, μ 1 μ	2 b DV		36.1 136	\tilde{t}_1 \tilde{t}_1 [1e-10< λ'_{23k} <1e-8, 3e-10< λ'_{23k}	<3e·9]	1.0	0.4-1.45 1.6	$\begin{array}{l} BR(\tilde{t}_1 \rightarrow be/b\mu) > 20\% \\ BR(\tilde{t}_1 \rightarrow q\mu) = 100\%, \ \cos\theta_t = 1 \end{array}$	1710.05544 ATLAS-CONF-2019-006

LLP are looking like a very attractive alternative



They are nothing new

A Sta	TLAS Long-l atus: July 2019	ATLAS Preliminary $\int \mathcal{L} dt = (18.4 - 36.1) \text{ fb}^{-1} \sqrt{s} = 8, 13 \text{ TeV}$							
	Model	Signature	∫£ dt [fl	D ⁻¹]	Lifetime limit			ji di kana j	Reference
	$\operatorname{RPV}\chi_1^0 \to eev/e\mu v/\mu\mu v$	displaced lepton pair	20.3	χ_1^0 lifetime		7-740 mm		$m(ilde{g}){=}$ 1.3 TeV, $m(\chi_1^0){=}$ 1.0 TeV	1504.05162
	$\operatorname{GGM} \chi_1^0 \to Z \tilde{G}$	displaced vtx + jets	20.3	χ_1^0 lifetime		6-480 mm		$m(ilde{g}) = 1.1 \; { m TeV}, \; m(\chi^0_1) = 1.0 \; { m TeV}$	1504.05162
	$\operatorname{GGM} \chi_1^0 \to Z \tilde{G}$	displaced dimuon	32.9	χ_1^0 lifetime			0.029-18.0 r	$m(\tilde{g}) = 1.1 \text{ TeV}, m(\chi_1^0) = 1.0 \text{ TeV}$	1808.03057
	GMSB	non-pointing or delayed 3	v 20.3	χ_1^0 lifetime			0.08-5.4 m	SPS8 with $\Lambda{=}~200~\text{TeV}$	1409.5542
	AMSB $pp \rightarrow \chi_1^{\pm} \chi_1^0, \chi_1^+ \chi_1^-$	disappearing track	20.3	χ_1^{\pm} lifetime			0.22-3.0 m	$m(\chi_1^{\pm})=$ 450 GeV	1310.3675
SUSY	AMSB $pp \rightarrow \chi_1^{\pm} \chi_1^0, \chi_1^+ \chi_1^-$	disappearing track	36.1	χ_1^{\pm} lifetime		0.057-1	1.53 m	$m(\chi_1^{\pm})=$ 450 GeV	1712.02118
	AMSB $pp \rightarrow \chi_1^{\pm}\chi_1^0, \chi_1^+\chi_1^-$	large pixel dE/dx	18.4	χ_1^{\pm} lifetime			1.31-9.0 m	$m(\chi_1^{\pm})=$ 450 GeV	1506.05332
	Stealth SUSY	2 MS vertices	36.1	S lifetime		0.1-519 m	_	$\mathcal{B}(\tilde{g} \to \tilde{S}g) = 0.1, m(\tilde{g}) = 500 \text{ GeV}$	1811.07370
	Split SUSY	large pixel dE/dx	36.1	ğ lifetime			> 0.9 m	$m(ilde{g}) =$ 1.8 TeV, $m(\chi^0_1) =$ 100 GeV	1808.04095
	Split SUSY	displaced vtx + $E_{\rm T}^{\rm miss}$	32.8	ĝ lifetime			0.03-13.2 m	$m(ilde{g}){=}$ 1.8 TeV, $m(\chi^0_1){=}$ 100 GeV	1710.04901
	Split SUSY	0 ℓ , 2 – 6 jets + E_T^{miss}	36.1	ğ lifetime	-		0.0-2.1 m	$m(ilde{g}) =$ 1.8 TeV, $m(\chi_1^0) =$ 100 GeV	ATLAS-CONF-2018-003
%	$H \rightarrow s s$ lo	w-EMF trk-less jets, MS v	/tx 36.1	s lifetime				0.18-120 m m(s)= 25 GeV	1902.03094
	FRVZ $H \rightarrow 2\gamma_d + X$	2 <i>e</i> -, <i>µ</i> -jets	20.3	γ _d lifetime 0-3 mm				$m(\gamma_d) = 400 \text{ MeV}$	1511.05542
= 10	FRVZ $H \rightarrow 2\gamma_d + X$	2 <i>e</i> -, μ-, π-jets	36.1	γ _d <mark>lifetime</mark>	1	.5-284 mm		$m(\gamma_d)$ = 400 MeV	CERN-EP-2019-140
IS BH	FRVZ $H \rightarrow 4\gamma_d + X$	2 e-, μ-, π-jets	36.1	γ _d lifetime	3.7-17	8 mm		$m(\gamma_d) = 400 \text{ MeV}$	CERN-EP-2019-140
Higg	$H \rightarrow Z_d Z_d$	displaced dimuon	32.9	Z _d lifetime	_		0.009-24	0 m $m(Z_d) = 40 \text{ GeV}$	1808.03057
	$H \rightarrow ZZ_d$ 2	e, μ + low-EMF trackless	jet 36.1	Z _d lifetime			0.21-5.2 m	$m(Z_d)=$ 10 GeV	1811.02542
Scalar	VH with $H \rightarrow ss \rightarrow bbbb$	$1-2\ell$ + multi-b-jets	36.1	s lifetime 0-3 mm				$\mathcal{B}(H \rightarrow ss) = 1, m(s) = 60 \text{ GeV}$	1806.07355
	$\Phi(\text{200 GeV}) \rightarrow \textit{s s} \qquad \text{ low-EMF trk-less jets, MS vtx 36.1}$			s lifetime		-	-	0.41-51.5 m $\sigma \times \mathcal{B} = 1 \text{ pb}, m(s) = 50 \text{ GeV}$	1902.03094
	$\Phi(600 \text{ GeV}) \rightarrow s s$ lo	ow-EMF trk-less jets, MS v	/tx 36.1	s lifetime		_	0.04-21.5	$\sigma \times \mathcal{B} = 1 \text{ pb}, m(s) = 50 \text{ GeV}$	1902.03094
	$\Phi(1 \text{ TeV}) \rightarrow s s$ lo	ow-EMF trk-less jets, MS v	/tx 36.1	s lifetime	-		_	0.06-52.4 m <i>σ</i> × <i>B</i> = 1 pb, <i>m</i> (<i>s</i>)= 150 GeV	1902.03094
Other	${\rm HV} \; Z'(1 \; {\rm TeV}) \to q_{\rm v} q_{\rm v}$	2 ID/MS vertices	20.3	s lifetime			0.1-4.9 m	$\sigma \times \mathcal{B} = 1 \text{ pb, } m(s) = 50 \text{ GeV}$	1504.03634
	HV $Z'(2 \text{ TeV}) \rightarrow q_{ m v} q_{ m v}$	2 ID/MS vertices	20.3	s lifetime			0.1-10.1 m	$\sigma \times \mathcal{B} = 1 \text{ pb}, m(s) = 50 \text{ GeV}$	1504.03634
	√s = 8 [°]	TeV √s = 13 TeV			0.01 0	.1	1 10	¹⁰⁰ cτ [m]	
*Oni	y a selection of the av	ailable lifetime limits	is showr	0.01	0.1	1	10	100 τ [ns]	



But our detectors





Long-lived particles are not like that





Paradigm shift



- Looking for LLPs STILL represents a paradigm shift from the usual approach to hunting for new physics
- Implies exploiting the detectors in ways they were not designed for



Roadblocks

- Need for specialized algorithms
 - Dedicated Track and Vertex reconstruction
- Though they have very low background
 - instrumental effects, still not well-modelled in the simulation
- The clearest challenge:

TRIGGER





In the HL-LHC

• Neither track reconstruction or trigger are going to get any easier





Hardware Tracking for Trigger

- Charged particle reconstruction in high-pileup conditions → challenge to tackle
- To use of information from the tracking as early as possible in the trigger selection
 - Central to the future ATLAS TDAQ
 - Also present in the CMS Phase-II upgrade



The plan for ATLAS is a **hardware-based system (HTT)** based on custom AM ASICs for pattern recognition and FPGAs for track reconstruction/fitting → **on-demand**, **fast tracking done in hardware**



LLP at the HTT

- Our goal is to make sure that LLP with characteristic tracker signatures are taken into account for trigger purposes in ATLAS at the HL-LHC
 - For this we need to make the HTT aware of them





Work performed mainly by two Uppsala PhD students (now graduated): **Mikael Mårtensson and Max Isacson**

PUBLISHED BY IOP PUBLISHING FOR SISSA MEDIALAB

RECEIVED: July 25, 2019 REVISED: September 2, 2019 ACCEPTED: October 24, 2019 PUBLISHED: November 6, 2019

To catch a long-lived particle: hit selection towards a regional hardware track trigger implementation

M. Mårtensson, M. Isacson, H. Hahne, R. Gonzalez Suarez¹ and R. Brenner Uppsala universitet, Lägerhyddsvägen 1, 752 37 Uppsala, Sweden

E-mail: rebeca.gonzalez.suarez@physics.uu.se

ABSTRACT: Conventional searches for new phenomena at collider experiments tend to focus on prompt particles, produced at the interaction point and decaying rapidly. New physics models including long-lived particles that travel a substantial distance in the detectors before decaying provide an interesting alternative, especially in light of the lack of new phenomena at the current LHC experiments, and could solve unanswered questions of the Standard Model. Long-lived particles have characteristic experimental signatures that, while making them clearly distinct from other processes, also could make them potentially invisible to current data-acquisition methods. Specific trigger strategies need to be in place to target long-lived particles. In this paper, we investigate the use of tracker information at trigger level to identify displaced signatures. We propose two methods that can be implemented at hardware-level: one based on the Hough transform, and another based on pattern matching with patterns trained on displaced tracks.

KEYWORDS: Pattern recognition, cluster finding, calibration and fitting methods; Data reduction methods; Particle identification methods; Trigger algorithms

ArXiv ePrint: 1907.09846

inst

1Corresponding author.

© 2019 The Author(s). Published by IOP Publishing Lid on behalf of Sissa Medialab. Original content from this work may be used under the terms of the Creative Common Authoriton 3.0 licence. Any further distribution of this work mast maintain attribution to the author(s) and the title of the work, journal citation and DOI.

https://doi.org/10.1088/1748-0221/14/11/P11009



Displaced tracks

- Many interesting tracker signatures that we would like to identify at trigger level
- In this paper we start with the simplest
 - Displaced muons



Displaced µ tracks generated with a particle gun in Pythia Transverse coordinates of the position of the track vertex: 0–350mm



Custom simulation

- Generic tracker similar to that used in ATLAS and CMS is modelled with Geant4
 - Same geometry as in <u>arXiv:1709.01034</u>



5 pixel layers, in red, and 5 strip double layers, in blue, in the barrel (7/7 in the endcaps)

Study restricted to a single region, using only its outermost layers



Hit selection

- Two hardware-based hit collection methods:
 - One based on the Hough transform
 - Can be implemented un GPU/FPGAs
 - Used in computer vision applications
 - Can be constructed for any curve that can be described with a few parameters
 - One based on **pattern matching**
 - **Baseline HTT**, done in ASICs
 - Reserving 10% and 20% patterns trained with displaced muons from a prompt muon pattern bank



Hough transform

Efficiency of finding hits for the displaced-vertex sample The efficiency increases overall with respect to the default when tuned for displaced, though it is still hard to finding tracks with low p_T and high d_0





Pattern matching



The efficiency rises to $\sim 30\%$ with 10% and close to 40% with 20%

(SSW: superstrip width, proxy of the "resolution" of a pattern in a bank We use 16 for this exercise)

Rebeca Gonzalez Suarez (UU) - 5/1/20

Pattern matching



Rebeca Gonzalez Suarez (UU) - 5/1/20



Summary

- LLP are cool but we could be missing them, especially at trigger level
- Preliminary study: promising performance of dedicated trigger strategies for long-lived particles at the HL-LHC
 - With small additional resources, the sensitivity to these signals can be improved
- Both methods will increase the load on the data acquisition system because of additional hits from minimum bias
 - This effect can be kept small if only events of interest are kept, how this can be done is left for a future study
- We propose that resources are reserved in the design of the future tracker triggers for the HL-LHC