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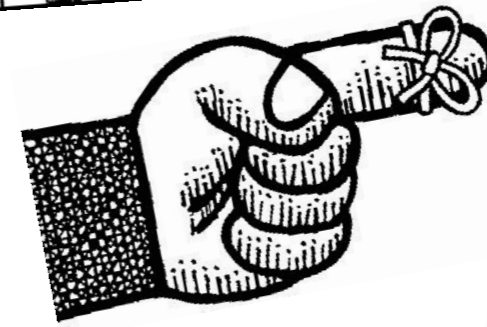
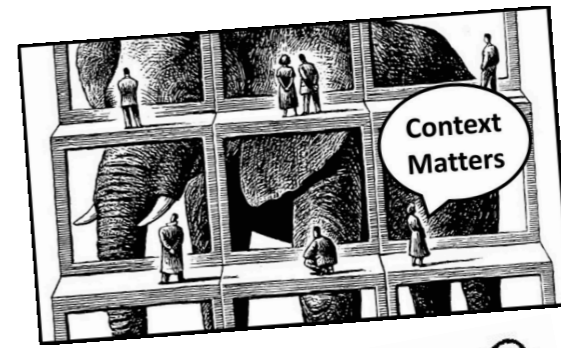
summary and taking stock

2nd LHC LLP Community Workshop - 20 October 2017

Sascha Mehlhase (LMU Munich)

quick summary

- ▶ providing context
 - ▶ experimental status quo
 - ▶ quick reminder of why we're here
 - ▶ first glimpse of how to reinterpret
-
- ▶ the complexity of simplification
 - ▶ reiteration on reinterpretation
 - ▶ mind the gap
-
- ▶ trigger upgrade and upgrade trigger ideas
 - ▶ taste the dark side
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- ▶ and of course lightning rounds



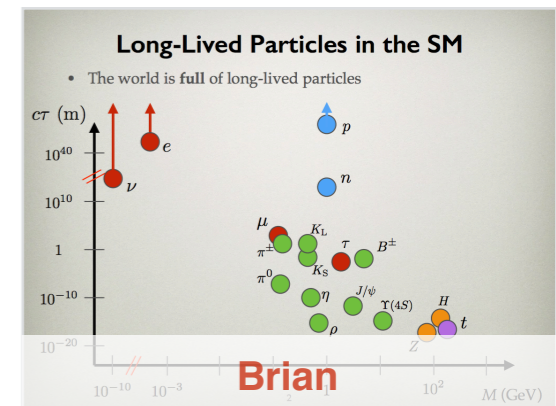
context and motivation

- ▶ theorists think it's interesting
 - ▶ it's something we can do
 - ▶ it addresses fundamental questions
 - ▶ it's challenging and fun
-
- ▶ LLPs exist in the Standard Model (SM), so why not in anything beyond the SM
-
- ▶ plethora of possibilities
 SUSY-like theories, Higgs-portal theories, gauge-portal theories, Dark Matter theories, heavy-neutrino theories (grouped as in white-paper draft)

Experimental LLP Search: Motivation

- Theorists think it's interesting 🤔
- It's something we can do 😊
- It addresses fundamental Q's 🙄

Michael



$$c\tau \approx \frac{1.2 \text{ fm}}{g_X^4} \left(\frac{M_X}{M_Y} \right)^4 \left(\frac{1 \text{ TeV}}{M_Y} \right)$$

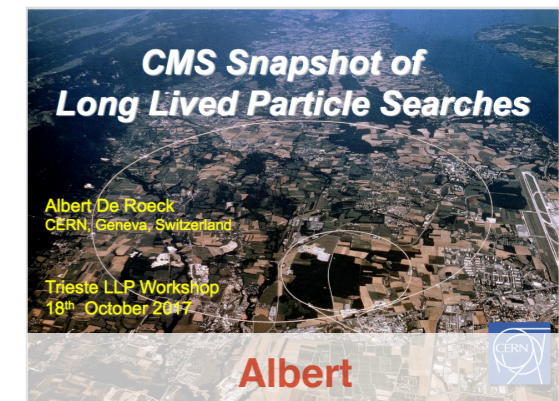
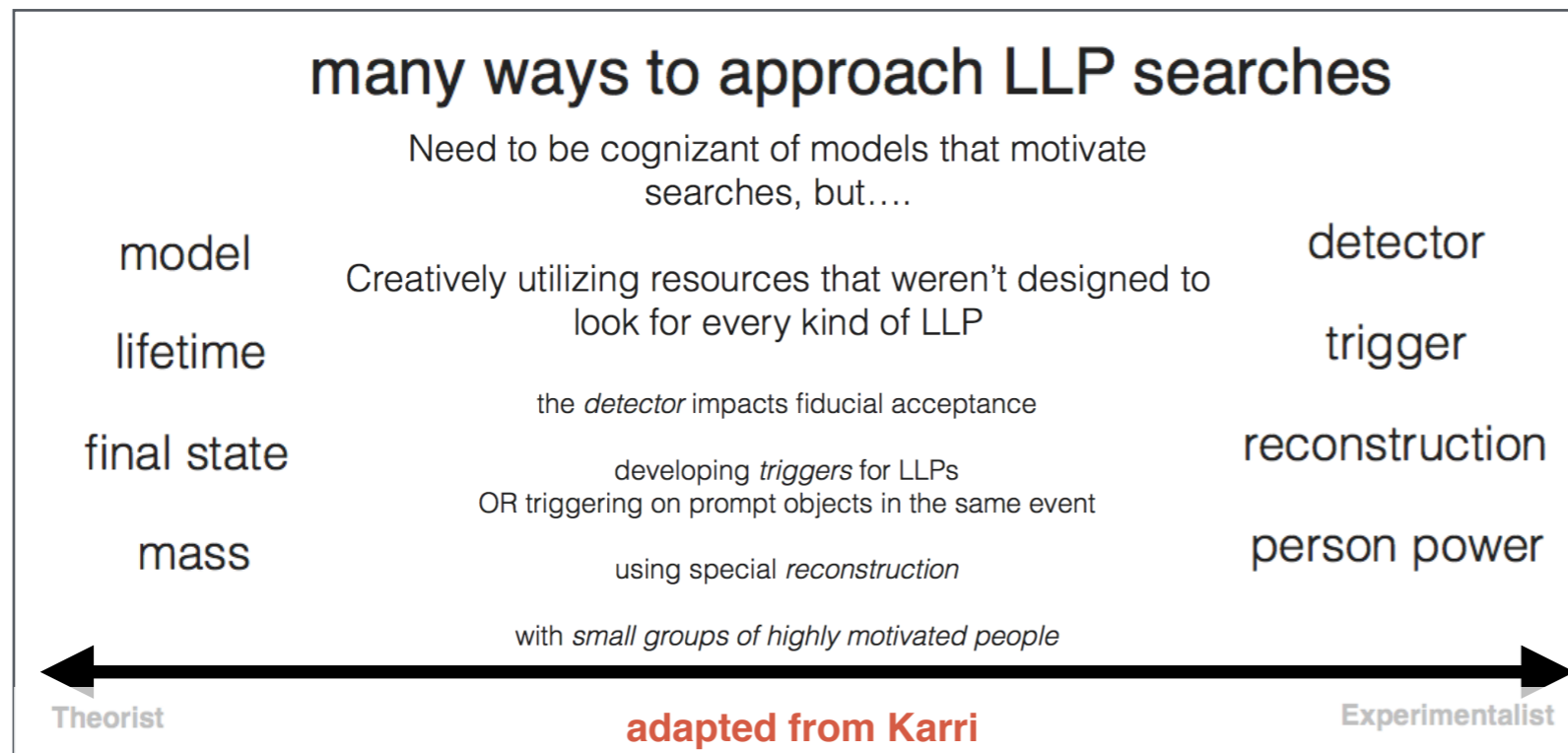
$$c\tau \approx \frac{1.2 \text{ fm}}{g_X^4} \left(\frac{M_X}{M_Y} \right)^4 \left(\frac{1 \text{ TeV}}{M_Y} \right)$$

$$c\tau \approx \frac{0.02 \text{ fm}}{g_Y^2} \left(\frac{1 \text{ TeV}}{M_Y} \right)$$

LLP Scenario	m_H	BAU	DM	m_ν
RH Neutrinos	✗	✓	✓	✓
WIMPY baryogenesis	✗	✓	?	✗
Dark QCD	✗	✓	✓	✗
Stealth SUSY	✓	✓	✓	✗
Neutral Naturalness	✓	✗	✗	✗
Dark U(1)	✗	✗	✓	✗

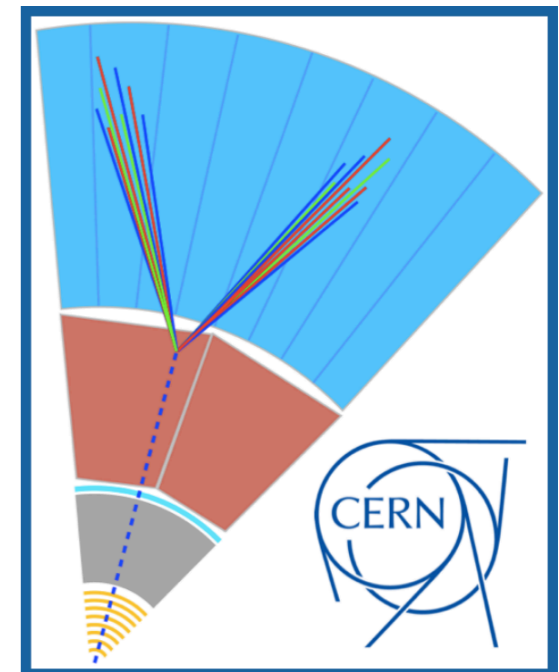
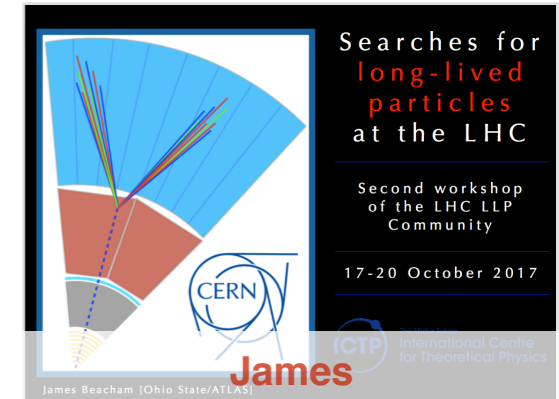
experimental status quo

- ▶ all three experiments ...
 - ▶ have a comprehensive (and growing) search programme
 - ▶ have updated and/or new searches in the pipelines
 - ▶ (will / plan to) have new detectors improving sensitivity for LLP searches
 - ▶ have and/or plan dedicated triggers for LLPs



quick reminder of why we're here

- ▶ simplified models
 - ▶ ready for use by experiments? what's missing?
- ▶ experimental coverage
 - ▶ map out what gaps exist that should motivate new, improved, and/or expanded searches?
- ▶ recasting and re-interpretation
 - ▶ provide recommendations
 - ▶ demonstrate usefulness and necessity of detector collaboration controlled frameworks like RECAST to work in conjunction with and in parallel to re-interpretation tools

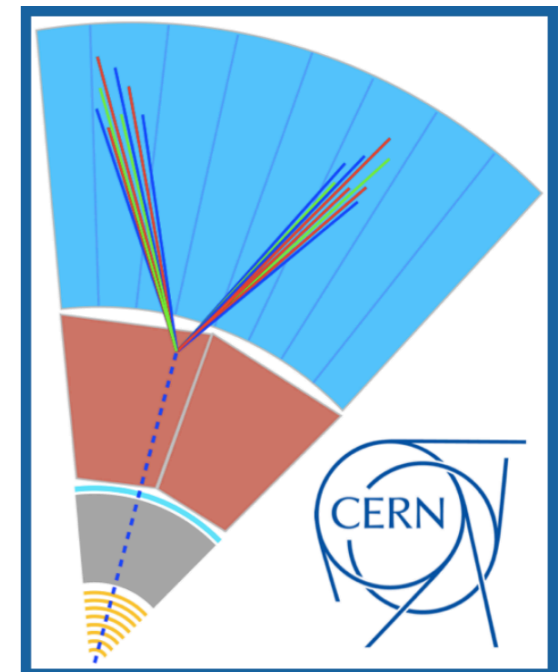
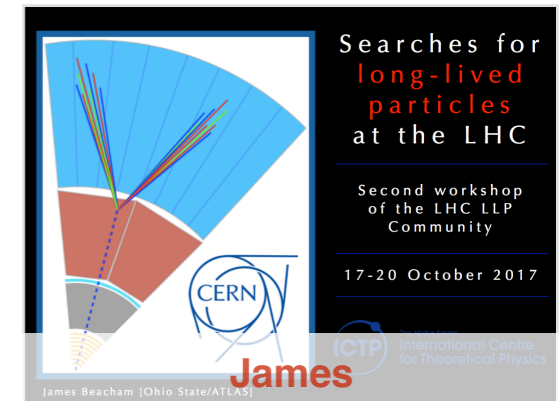


Workshop goal:

Map the future.
You're doing it
right now.

quick reminder of why we're here

- ▶ trigger, upgrades and beyond
 - ▶ what (type of) triggers are we missing?
 - ▶ what studies have been performed to support possible detector upgrades?
 - ▶ what are prospects, challenges, and opportunities of a high luminosity or high energy (~ 25 TeV) LHC?
- ▶ Dark showers
 - ▶ how do we know what we don't know?
 - ▶ how do we interpolate between pencil-like jet regime and soft radiation patterns, w.r.t. theory/pheno (generators, event shape variables, etc.) and in the detector (how do we trigger on these and ID them)?



Workshop goal:

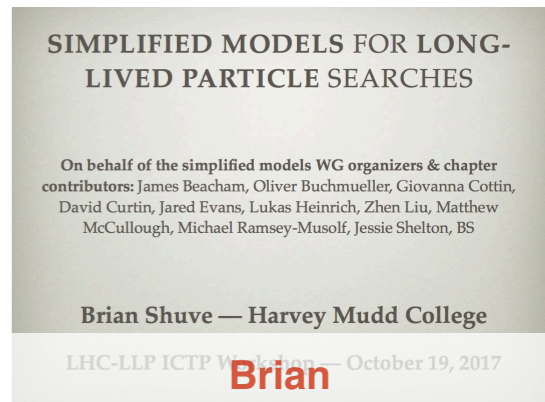
Map the future.
You're doing it
right now.

the complexity of simplification

- ▶ defining a framework of simplified models
 - ▶ compromise between minimal set and coverage
 - ▶ broadly applicable to different types of models
 - ▶ main focus on studies of coverage and generating search ideas, rather than utilising extensive reinterpretations
 - ▶ factorise production and decay (where possible)
 - ▶ theory-driven signatures
(one analysis might cover several channels)

- ▶ limited set of 'umbrella' UV models
 - ▶ SUSY-like theories, Higgs-portal theories, gauge-portal theories, Dark Matter theories, heavy-neutrino theories

- ▶ production and decay modes
 - ▶ direct pair production, heavy-parent production, Higgs production, resonance production, charged-current production
 - ▶ di-photon, single photon, fully hadronic, semi-leptonic, leptonic, flavoured leptonic (+ invisible)



Production \ Decay	Decay		
	$\gamma\gamma(+inv.)$	$\gamma + inv.$	$jj(+inv.)$
DPP: sneutrino pair		SUSY	SUSY
HP: squark pair, $\tilde{q} \rightarrow jX$ or gluino pair $\tilde{g} \rightarrow jjX$		SUSY	SUSY
HP: slepton pair, $\tilde{\ell} \rightarrow \ell X$ or chargino pair, $\tilde{\chi} \rightarrow WX$		SUSY	SUSY
HIG: $h \rightarrow XX$ or $\rightarrow XX + inv.$	Higgs, DM*		Higgs, DM*
HIG: $h \rightarrow X + inv.$	DM*		DM*
ZP: $Z(Z') \rightarrow XX$ or $\rightarrow XX + inv.$	Z', DM^*		Z', DM^*
ZP: $Z(Z') \rightarrow X + inv.$	DM		DM
CC: $W(W') \rightarrow \ell X$			$RH\nu^*$

Production \ Decay	Decay			
	$\ell + inv.$	$jj(+inv.)$	$jj\ell$	$\ell\gamma$
DPP: chargino pair or slepton pair	SUSY	SUSY	SUSY	
HP: $\tilde{q} \rightarrow jX$	SUSY	SUSY	SUSY	
ZP: $Z' \rightarrow XX$	Z', DM^*	Z', DM^*	Z'	
CC: $W' \rightarrow X + inv.$	DM*	DM*		

Production \ Decay	Decay			
	$j + inv.$	$jj(+inv.)$	$j\ell$	$j\gamma$
DPP: squark pair or gluino pair	SUSY	SUSY	SUSY	

the complexity of simplification

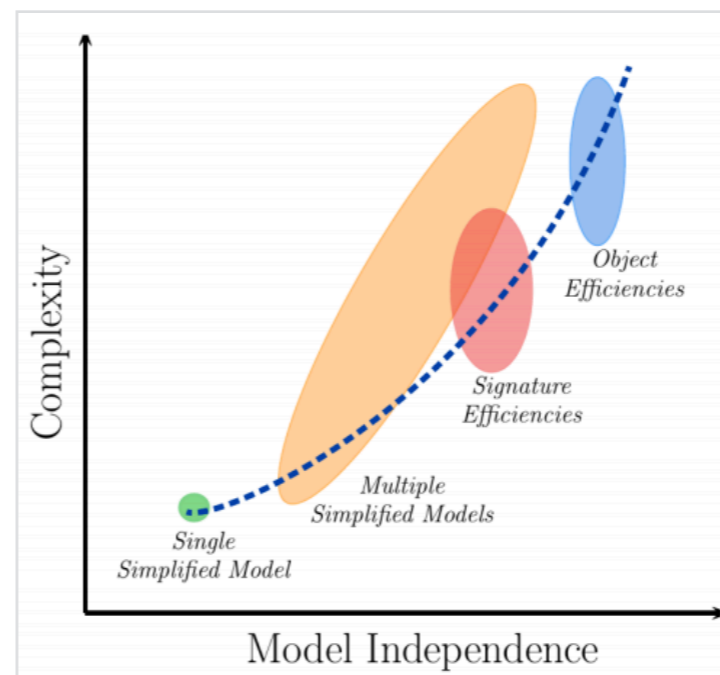
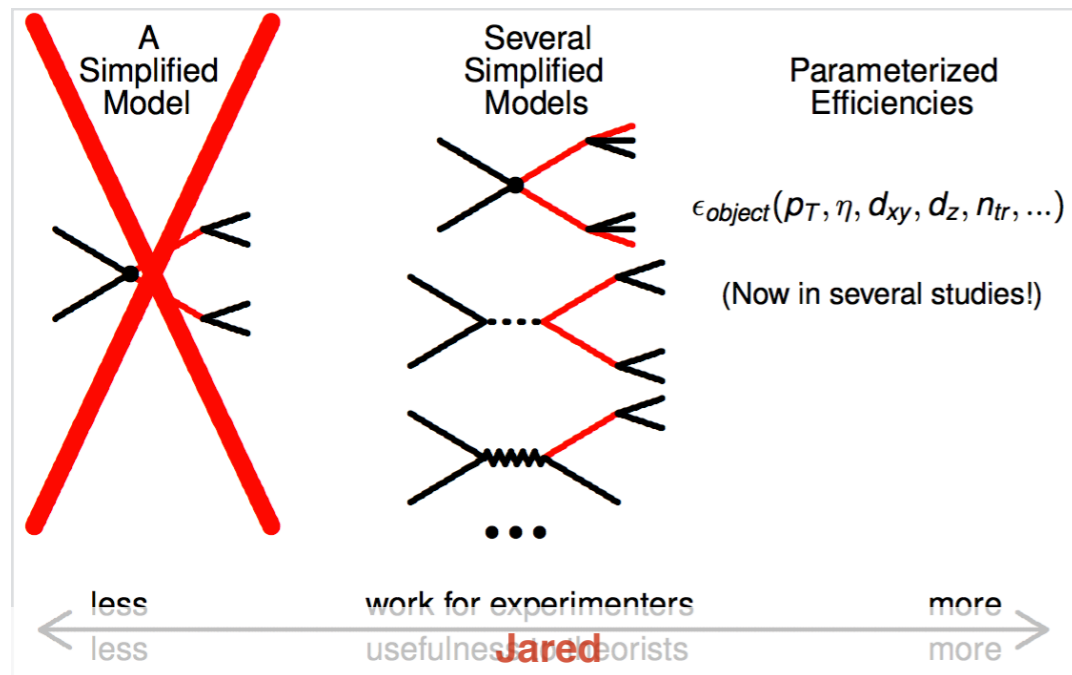
▸ discussion

- make sure tables are not misunderstood, not to discourage analysis efforts
 - empty cells might still be interesting and filled over time
- emphasise usefulness of prompt objects
 - will have an impact on sensitivity / trigger / ...
- technical issues with GEANT4 interfaces (e.g. R-Hadron decays in Pythia)
 - can we generalise this for any BSM particle?
 - is / should it implemented similar in all experiments?
- be cautious / honest
 - simplified-model results can be misleading and might suggest coverage we don't actually have looking at complete models
 - factorisation does not work for all cases (hadronisation)
- connection to trigger effort
 - which benchmark models can be triggered and how?
 - do we want it in this section? probably not!?
- connection to coverage / reinterpretation effort
 - which benchmark models are covered and/or to which extend or could be by reinterpretation?
 - do we want it in this section? probably not!?
- are we ready to use this *minimal* set?
 - maybe from the theory side (did we miss anything)!?
 - maybe not entirely on the technical side!?

▸ current version of the white-paper section

reiteration on reinterpretation

- ▶ difficulties in recasting / reinterpretation
 - ▶ changing the model can completely change the analysis (different lifetime/decay → different experimental signature)
 - ▶ high-level efficiencies (on top of standard ones)
 - ▶ hard/impossible to interpolate between models/analyses
 - ▶ risk of dangerously uncontrolled extrapolations
 - ▶ along what axes could searches lose sensitivity? (how to address this with our set of simplified models)
 - ▶ it can easily get very complex



Long-lived Particles:
some experimental perspective

1) Experimental challenges
2) Ways to present results
- efficiencies
- fastsim?
- RECAST

This is a workshop, we are here to discuss!

Reinterpretation and Recommendations for the Presentation of Search Results

Based on LLP Whitepaper Chapter 3

Gavin

October 19, 2017

Reinterpreting Long-Lived Particle Searches

Jared A. Evans
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Department of Physics
University of Cincinnati

Jared

LLP Reinterpretations

Reinterpretations and Recommendations Discussion

Juliette Alimena, Will Buttinger, Giovanna Cottin, Yanou Cui, Nishita Desai, Jared Evans, Lukas Heinrich, Jan Heisig, Gavin Hesketh, Sabine Kraml, Andre Lessa, Zhen Liu, David Morse, Brian Shuve

LLP Trieste Workshop

Juliette

reiteration on reinterpretation

- ▶ discussion
 - ▶ keeping extrapolations under control may sometimes require information that cannot realistically be acquired
 - ▶ maybe the ATLAS DV+MET exercise is a good compromise?
 - restrict results to some fiducial volume, evaluate efficiency dependencies, state numbers as function of relevant (three) variables, integrate over others (or adjust fiducial volume)!?
 - ▶ experiments should limit need to recast via judicious choice of benchmarks clearly illustrating where sensitivity will fail
 - ▶ clear information about limitations will spur innovation
 - ▶ prompt search sensitivity to LLPs should be illustrated
 - ▶ make it more obvious where to find data for reinterpretation
 - ▶ we do have links to auxiliaries and HEPdata on the arXiv page!?
 - ▶ connection to simplified-model effort
 - ▶ is it worth producing efficiency tables for one/two/many models?
 - ▶ how do we choose the one/two? need case-by-case input from theory!?
 - ▶ is it worth doing the exercise of fully processing one simplified models close to the complete model used in an existing analysis!?
- ▶ current version of the white-paper section

Long-lived Particles:
some experimental perspective

1) Experimental challenges
2) Ways to present results
- efficiencies
- fastsim?
- RECAST

This is a workshop, we are here to discuss!

Based on LLP Whitepaper Chapter 6

October 23, 2017

Gavin Hesketh, UCL

Gavin

Reinterpreting Long-Lived Particle Searches

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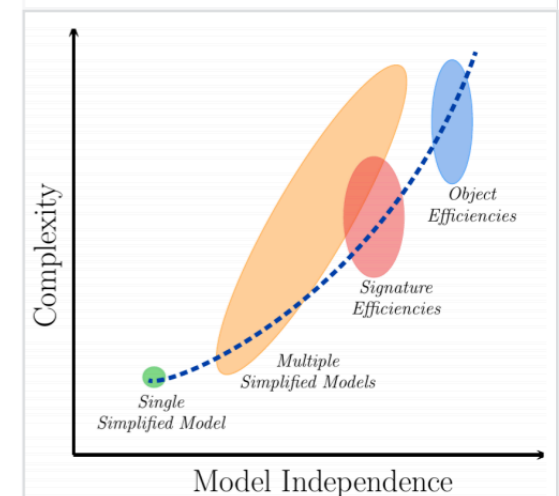
Jared

Reinterpretations and Recommendations Discussion

Juliette Alimena, Will Buttinger, Giovanna Cottin, Yanou Cui, Nishita Desai, Jared Evans, Lukas Heinrich, Jan Heisig, Gavin Hesketh, Sabine Kraml, Andre Lessa, Zhen Liu, David Morse, Brian Shuve

LLP Trieste Workshop

Juliette



mind the gap

- ▶ goals of the effort
 - ▶ identify most obvious coverage gaps of current searches
 - ▶ byproduct concise summary of searches, inviting to challenge the shortcomings and caveats
- ▶ classification of searches by final states
 - ▶ fully hadronic, leptonic, semi-leptonic, photonic
- ▶ current status
 - ▶ already broad overview of existing searches, providing essential information for the non-expert reader, and refer the avid one to the original publications
 - ▶ not the whole landscape covered here: heavy neutral leptons, magnetrons, kinked tracks, fractionally(milli) charged particles, emerging jets, ...
 - ▶ need to discriminate between intrinsic limitations and possible improvements: EXP feedback needed!

Experimental Coverage WG: Report

José Francisco Zurita

Institut für Kernphysik (IKP) and Institute für Theoretische Teilchen Physik (TTP),
Karlsruher Institut für Technologie (KIT).



WG: Xabier Cid Vidal, Heather Russell, Albert de Roeck, Jared Evans, David Curtin, JZ

Searches for long-lived particles **José** IC, ICTP Trieste 20.10.2017

mind the gap

▸ discussion

- why do/did we not consider hidden-valley signatures
 - did we find out yet? does it make sense not to discuss them here at all?
- what about searches *without weak points*
 - make sure not to send the wrong message
 - still worth pursuing/improving
- try to provide (more) overview/summary plots
 - both from within the experiments and merging those?!
 - comparisons between experiments using benchmark point!?
 - make sure all results are based on same/similar assumptions!
- connection to simplified-model effort
 - can/should we (try to) give examples or a list of simplified models are covered (to which extend)
- how to present this material
 - library/webpage/catalog with all searches linked (à la HXSWG)

- first public version of white-paper section after the workshop

Experimental Coverage WG: Report

José Francisco Zurita

Institut für Kernphysik (IKP) and Institute für Theoretische Teilchen Physik (TTP),
Karlsruher Institut für Technologie (KIT).



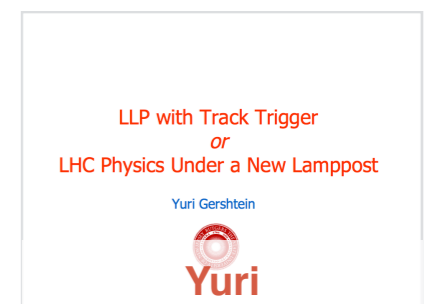
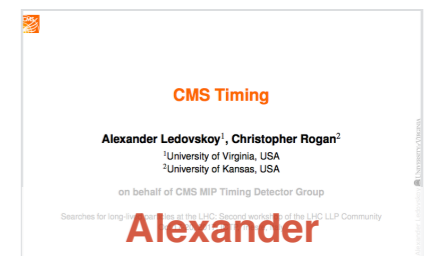
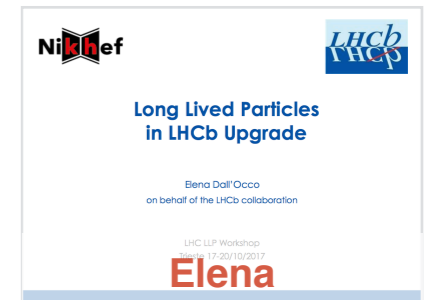
WG: Xabier Cid Vidal, Heather Russell, Albert de Roeck, Jared Evans, David Curtin, JZ

Searches for long-lived particles José, ICTP Trieste 20.10.2017

trigger upgrade and upgrade trigger ideas

- ▶ comprehensive overview of challenges and possibilities for HL-LHC from all three experiments
- ▶ some really nice ideas/applications in the pipeline
 - ▶ e.g. (downstream) track triggers, hit-count trigger, timing detectors, combined-calo-HGTD trigger, no trigger*, 4D-vertexing,
- ▶ discussion
 - ▶ make sure to give input to decision-making process

* at least not in hardware



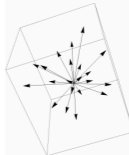
taste the dark side

- ▶ extreme cases (jetty and SUEPy) are *somewhat* under control using PythiaHV and *handmade* LHEs
- ▶ working on solutions for the transition region
 - ▶ how do we actually validate predictions?
- ▶ how about the experimental side?
 - ▶ still have a few open items from previous workshop :(

**Dark Showers
WG report**

Jakub Scholtz
on behalf of the Dark Showers working group:
Michael Adersberger, James Beacham, Malte Buschmann, Cari
Cesarotti, Jared Evans, Marat Freytsis, Simon Knapen, Dylan Linthorne,
Matt Reece, Sophie Renner, Jakub Scholtz, Pedro Schwaller, Jessie
Shelton, Daniel Stolarski, Yuhsin Tsai, Devin Walker and more ...

Jakub



**SUEPs* to Jets:
Parameterizing the Theory**

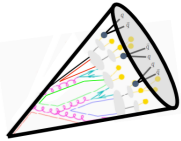
Cari Cesarotti
Harvard University
In Collaboration with Matt Reece, Matt Strassler
LLP Trieste, October 20 2017

Cari *Soft unclustered energy patterns

**Searching for dark sector parton
showers at the LHC**

Siddharth Mishra-Sharma
Princeton University

Based on work with:
T. Cohen, M. Lisanti and H.K. Lou
(1707.05326)



LHC LLP Workshop
October 20, 2017

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Siddharth

general discussion

- need to define and work on *overlap/interaction* between working groups
 - maybe it's worth compiling a current version of a complete draft for people to read
- what to do about backgrounds
 - several people mentioned it might be good to document something!?
- dedicated experiments
 - how, where and when to incorporate?

last but not least

- repeating and adding to what was said during the conference dinner
- thanks to everyone for joining / taking part / contributing, but especially to ICTP, Bobby, Albert, Brian and **James** for hosting, supporting and organising this workshop

