Long-Lived Particles (LLP) Working Group and Community

José Francisco Zurita

Institut für Theoretische Teilchenphysik

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

Karlsruhe Institute of Technology

On behalf of the Long-Lived Particle Working Group

Based on:

J. Alimena et al, arXiv 1903.04497 [LLP@LHC White Paper, accepted by J.Phys.G]

Ongoing discussions within LLP WG and LLP Community

DM WG Meeting, CERN, 28.04.2020

LLP:WG and Community

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What is the LLP WG?

The goals of the working group are to:

- Facilitate communication between the experimental and theoretical LLP communities.
- Provide recommendations for benchmark models to be used in LLP interpretations.
- Develop and/or validate MC tools for event generation (e.g. dark sector showers, library of models).
- Provide recommendations to experiments on result presentation to facilitate reinterpretation of LLP searches.
- Discuss possible new search directions based on new input from theory and/or experiment.

Convenors:

ATLAS: James Beacham, Sascha Mehlhase

CMS: Juliette Alimena, Albert de Roeck

LHCb: Federico Leo Redi, Carlos Vázquez Sierra

MoEDAL: James Pinfold

FASER: Dave Casper

TH: Nishita Desai, José Zurita

The WG builds on the experience of the LLP LHC Community and, preserving its main scientific objectives, it serves as a formal bridge with the internal analysis groups of the LHC experiments, to streamline the official endorsement of its recommendations.

https://lpcc.web.cern.ch/lhc-llp-wg ⟶ subscribe to mailing list for news and updates!!!

What is the LLP "Community"?

- Group of scientists generically interested in the exploration of long-lived signatures at colliders (not only LHC!) and beyond. Operating since 2015.
- Holds two yearly workshops (May@CERN, November: elsewhere)
- Milestone: LLP@LHC White Paper:
  - Simplified models based on signatures (prod x decay factorization)
  - Assessment of the coverage of current searches, making the gaps explicit.
  - Recasting of LLP studies (recommendations for presentation)
  - Explored capabilities of detector upgrades, future dedicated experiments (FASER, MATHUSLA, CODEX-B, AL3X, ANUBIS, MoEDAL, MilliQan, NA62, SHiP, …) and also future colliders.
  - LLP frontier: dark showers, emerging and semi-visible jets, etc.

https://longlivedparticles.web.cern.ch → subscribe to mailing list for news and updates!!!

LLPs: Motivation

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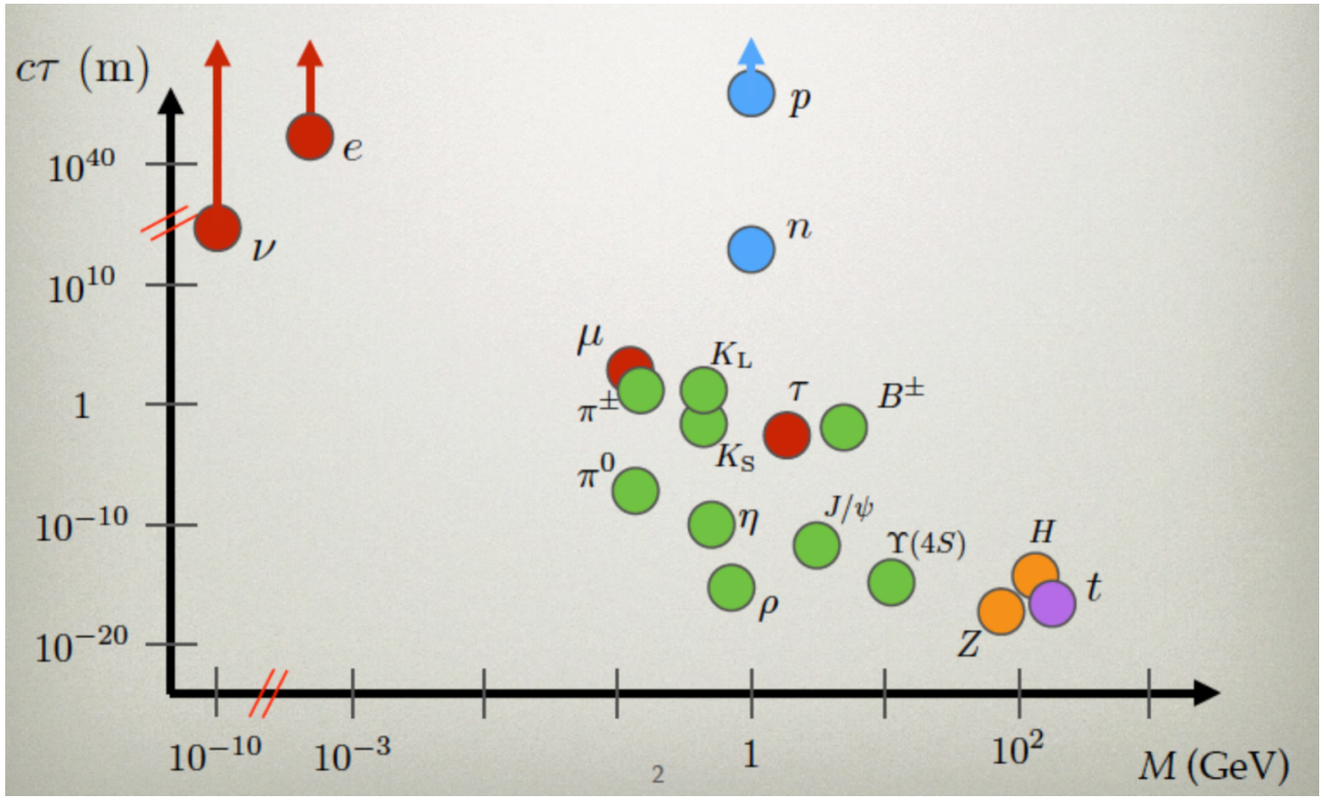
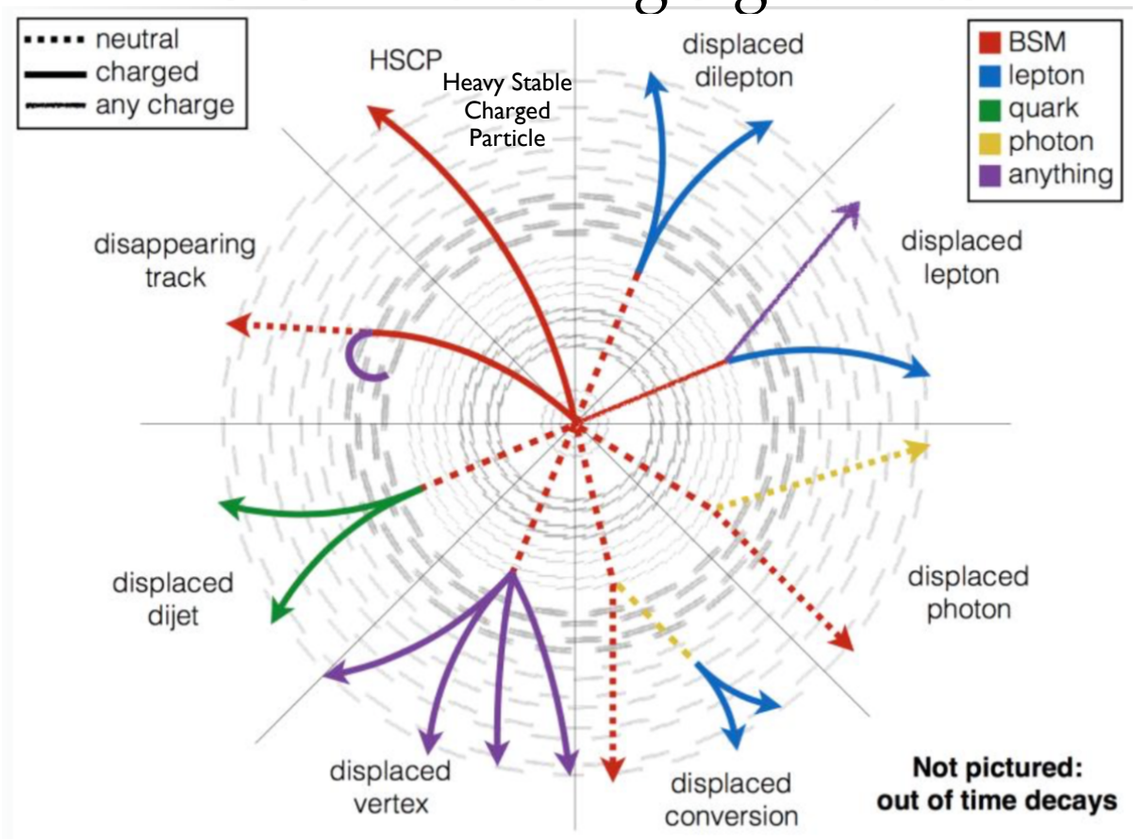
Long-Lived Particles

- LLPs: BSM states with macroscopic lifetimes (ns), theoretically well motivated.

Exist in the SM!



A lot of interesting signatures!



large cτ, small Γ

- Large mass hierarchies
- Compressed spectra
- Small couplings

EW Baryogenesis
Dark Matter
Hierarchy Problem
Neutrino Masses

BSM Models: RH neutrinos, dark QCD, stealth SUSY, Neutral Naturalness, Higgs Portal, Z' Portal, Hidden Valleys, …

LLP signatures-> arXiv:1903.04497 ; LLP theory motivations-> arXiv 1806.07396

LLP >>>> "displaced vertices": disappearing tracks, HSCP, displaced leptons, emerging jets…

LLP lessons from the SM

3 ways to get large cτ / small Γ (correlated with LHC limitations)

- Large mass hierarchies / off-shell mediator ⟶ heavy E scale

$$c\tau(\mu \to e\nu) = \frac{1.2\ \text{fm}}{g_X^4}\left(\frac{m_e}{m_\mu}\right)^4\left(\frac{1\ \text{TeV}}{m_\mu}\right) \sim 1\ \text{cm}$$

$m_e = 10\text{GeV}, \mathrm{m}_\mu = 100\ \text{GeV}, \mathrm{g}_\mathrm{X}^4 = 10^{-7}$ RH neutrinos

$m_e = 10\ \text{GeV}, \mathrm{m}_\mu = 1\ \text{TeV}, \mathrm{g}_\mathrm{X}^4 = 10^{-3}$ Hidden Valleys

- Compressed spectra ⟶ Object reconstruction, thresholds

$$c\tau(n \to pe\nu) \sim \frac{1.2\ \text{fm}}{g_X^4}\left(\frac{m_p}{m_n - m_p}\right)^4\left(\frac{1\ \text{TeV}}{m_n - m_p}\right) \sim 1\ \text{cm}$$

SUSY

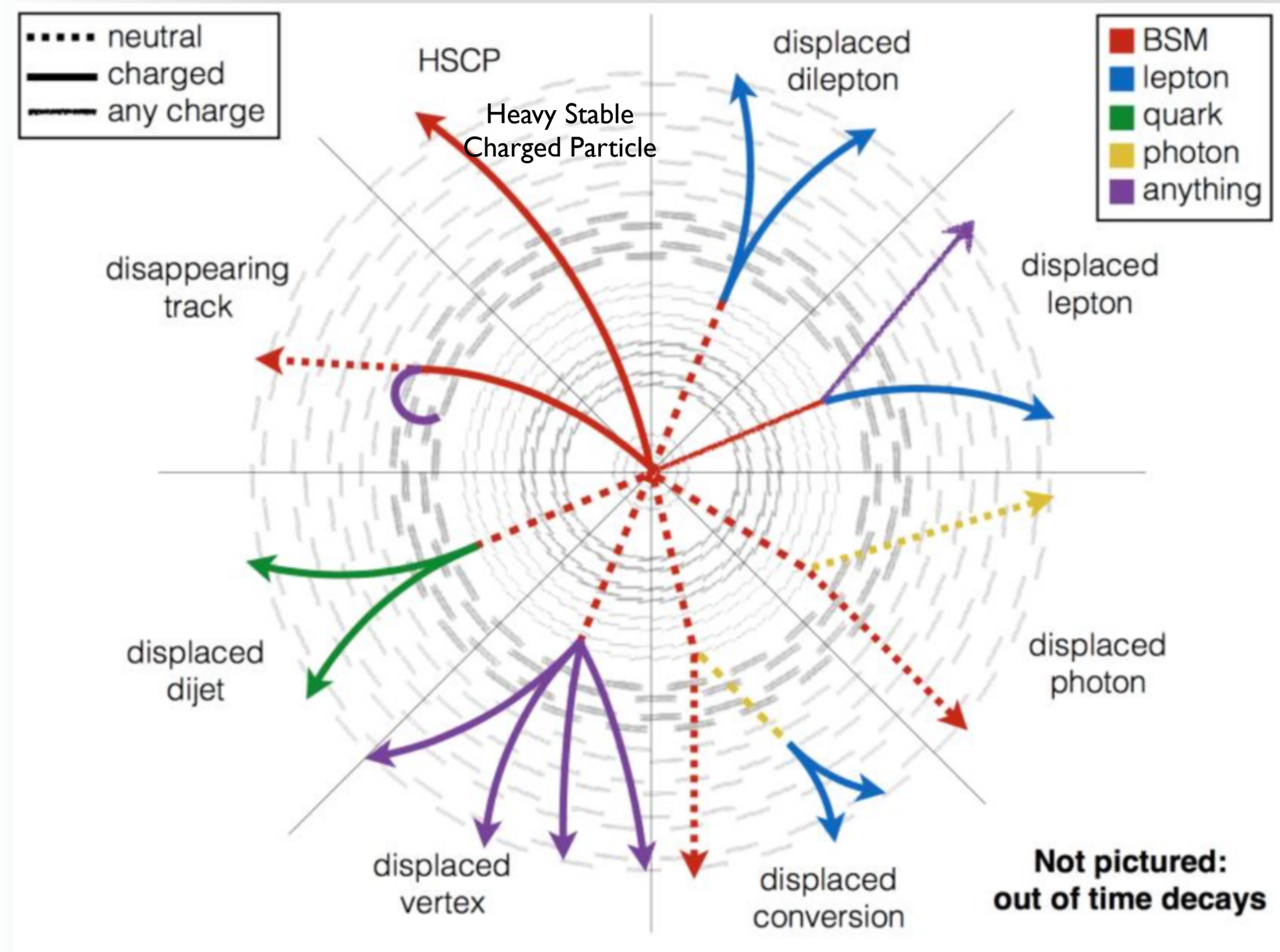
$m_n = 101\ \text{GeV}, \mathrm{m_p} = 100\ \text{GeV}, \mathrm{g}_\mathrm{X}^4 = 10^{-2}$

- Small coupling ⟶ Low rates

$$c\tau(Z \to \nu\nu) \sim \frac{0.02\ \text{fm}}{g_Z^4}\left(\frac{1\ \text{TeV}}{m_Z}\right) \sim 1\ \text{cm}$$

$m_Z = 1\ \text{GeV}, \mathrm{g}_\mathrm{Z}^2 = 10^{-12}$ $\mathrm{Z_D}$ models

LLP >>>> DVs!



+ dark showers: emerging jets (1502.05409), semi visible jets (1503.00009), SUEPs (1612.00850)

LLP WG: Status

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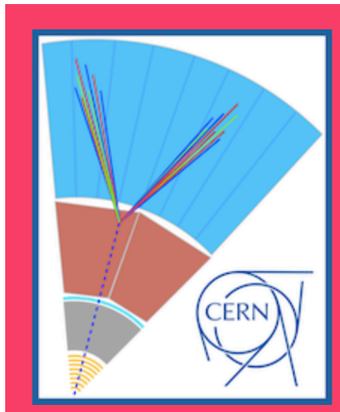
LLP WG's agenda

LLP WG will make its social debut on the LLP@LHC Community workshop 25-27 May, 2020 (fully virtual).



Searching for long-lived particles at the LHC: Seventh workshop of the LHC LLP Community

25-27 May 2020
Virtually, worldwide
Europe/Zurich timezone

Goals, structure, tasks, etc are being the subject of lively discussions, stemming from the Community's activity.

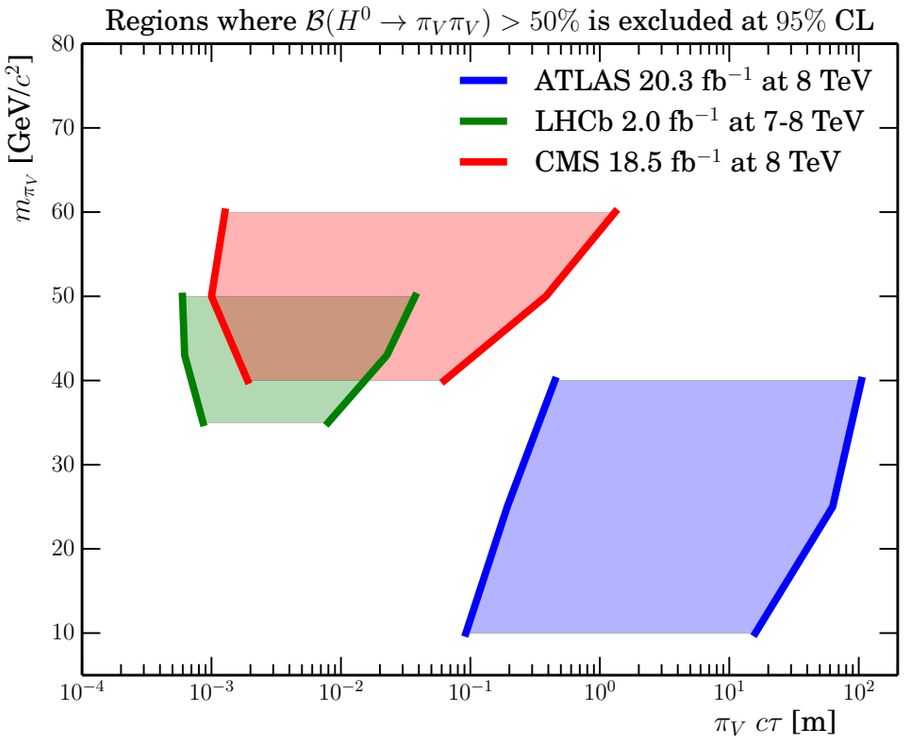
Key topics:

- Gaps in coverage: triggers (specially for Run-3), analysis strategies, detector limitations, overlooked signatures, …
- Reinterpretation: Benchmark models, result presentation, …

Gaps & Triggers

- LLP searches need to rely on existing triggers from the available menu.
- This is an important bottleneck in many searches.
  A fan's favourite: H (125) → LLP LLP → 4 b, for LLP masses in [10-35] GeV

<u>Hadronic DV searches in Hidden Valley Model: Comparison of ATLAS, CMS and LHC-b.</u>



1) For light LLP masses, jets become softer and more boosted. Trigger on H_T > "a lot" fails (ATLAS, CMS).

2) Coverage at low masses and large lifetimes occur because of decays inside muon chambers (clean signal, but can we actually reconstruct LLP mass? tag jet flavors?)

3) Analogous reasoning for LLP->ττ, $2\, m_\tau < m_{LLP} < 2\, m_b$

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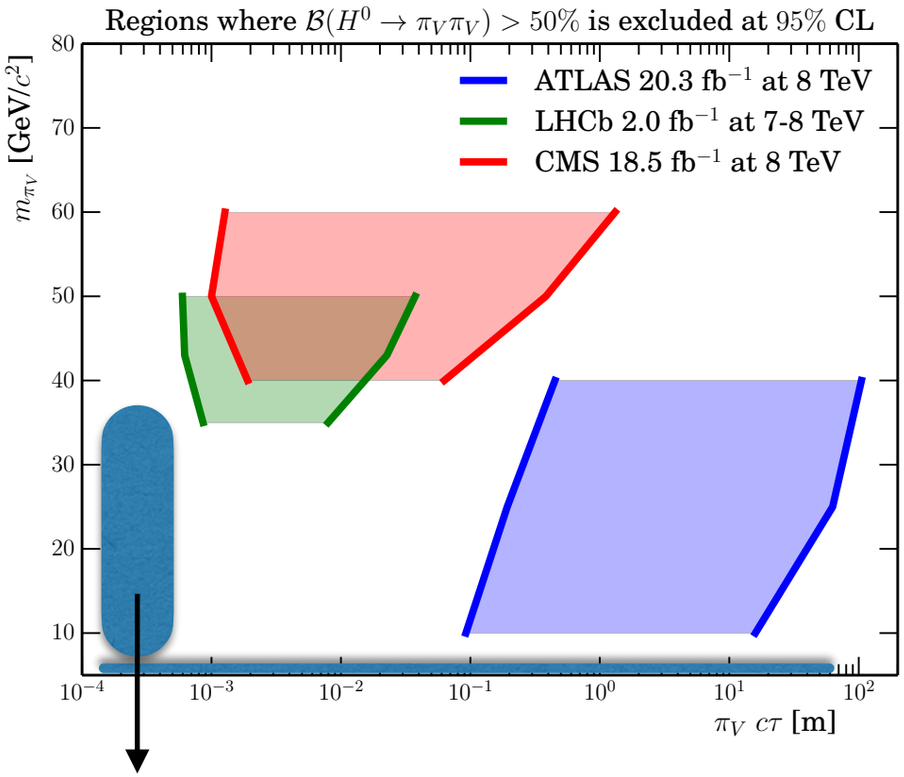

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Here B-mesons

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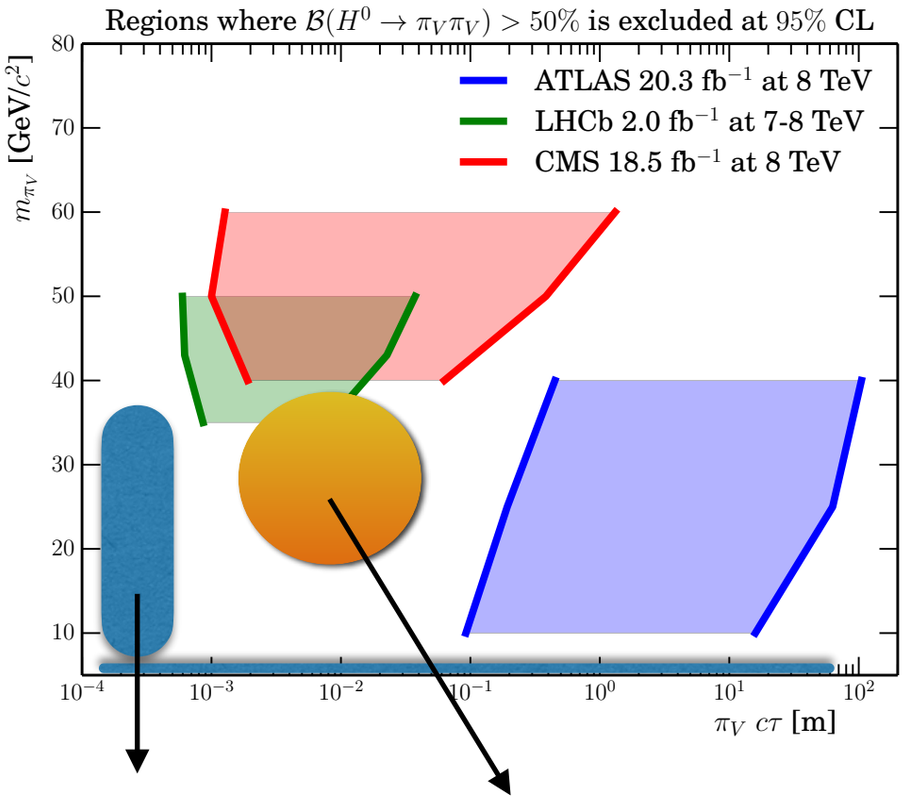

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Here B-mesons

BR(H^0->bb) ~ 90%. Bgd: non-b mesons.
How well can we reject light displaced jets?

Reinterpretation of LLP searches

- Currently (some) analysis provide efficiency maps for displaced objects.
  They are often presented only for one model, usual suspect SUSY: RPC or RPV.
  Are they truly model-independent?

- LLP studies require to add new variables to the prompt ones, e.g: $c\tau$, r, z, t.
  Is it too cumbersome to add these to the prompt object variables η, p_T, etc?
  (In other words: can we have LLP objects (e.g: displaced jet) in Delphes?)

- Is the public information provided in the analysis good enough to reproduce the published results (analysis validation) outside the collaboration?
  (e.g: cutflows, distributions, likelihoods, efficiency maps…)

- Key analysis steps, object definitions tend to be verbalized, e.g:
  Abuse of "Efficiency", "Acceptance": these are highly loaded words!
  "Missing energy […] is calculated using all calibrated objects as well as those reconstructed tracks not associated with these objects";
  "We request one good primary vertex…" , …
  Can analysis codes (or pseudocode in the worst case) be made public?

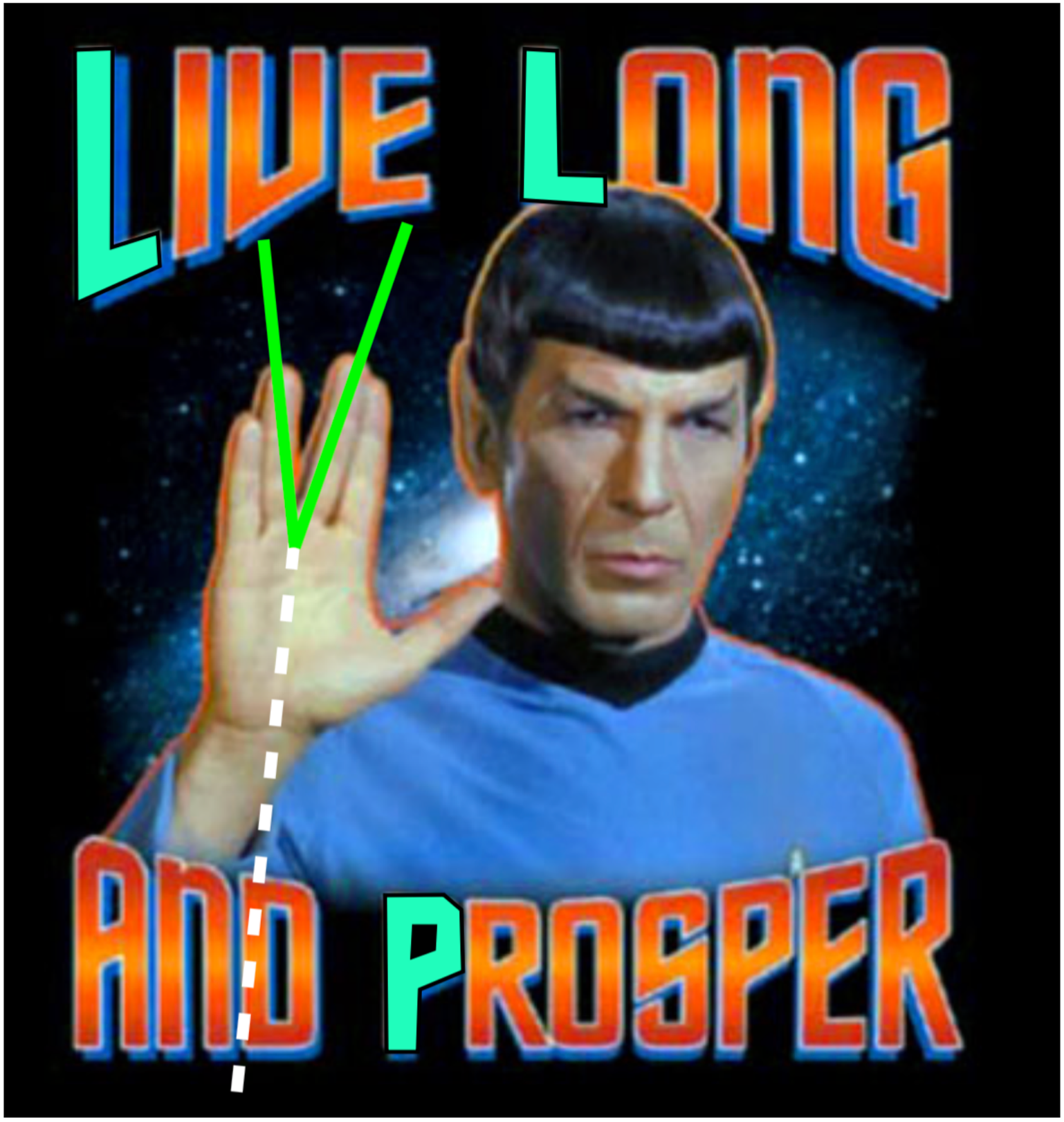
Other items…

- Unified simulation framework (for e.g: dark showers)
- UFO library of simplified models (topology / signature based) [first steps already taken in the LLP WP.]
- Benchmark points (across all LLP experiments!)
- Machine Learning for LLPs (e.g: anomaly detection)
- Impact of detector upgrades (e.g: timing@HL-LHC)
- LLPs from DM: FIMPs, co-annihilation/co-scattering, etc
- …

LLP - DMWG synergies

- A rich spectrum of long-lived signatures of DM arise in BSM scenarios.
- DM has been a leitmotiv of the LLP Community activities.
- The LLP-WG links the rich Community activities and discussion within with the physics program of LHC experiments.
- As we also have a natural link with the DM WG we are considering to nominate a "liason officer" between our WGs (TBD in next meeting).
- We look forward to a bright (dark?) interaction between our WGs!

Questions? Comments? Rotten Tomatoes?



Stolen from D. Curtin