Search for long-lived particles decaying to displaced jets

NNV Annual Meeting

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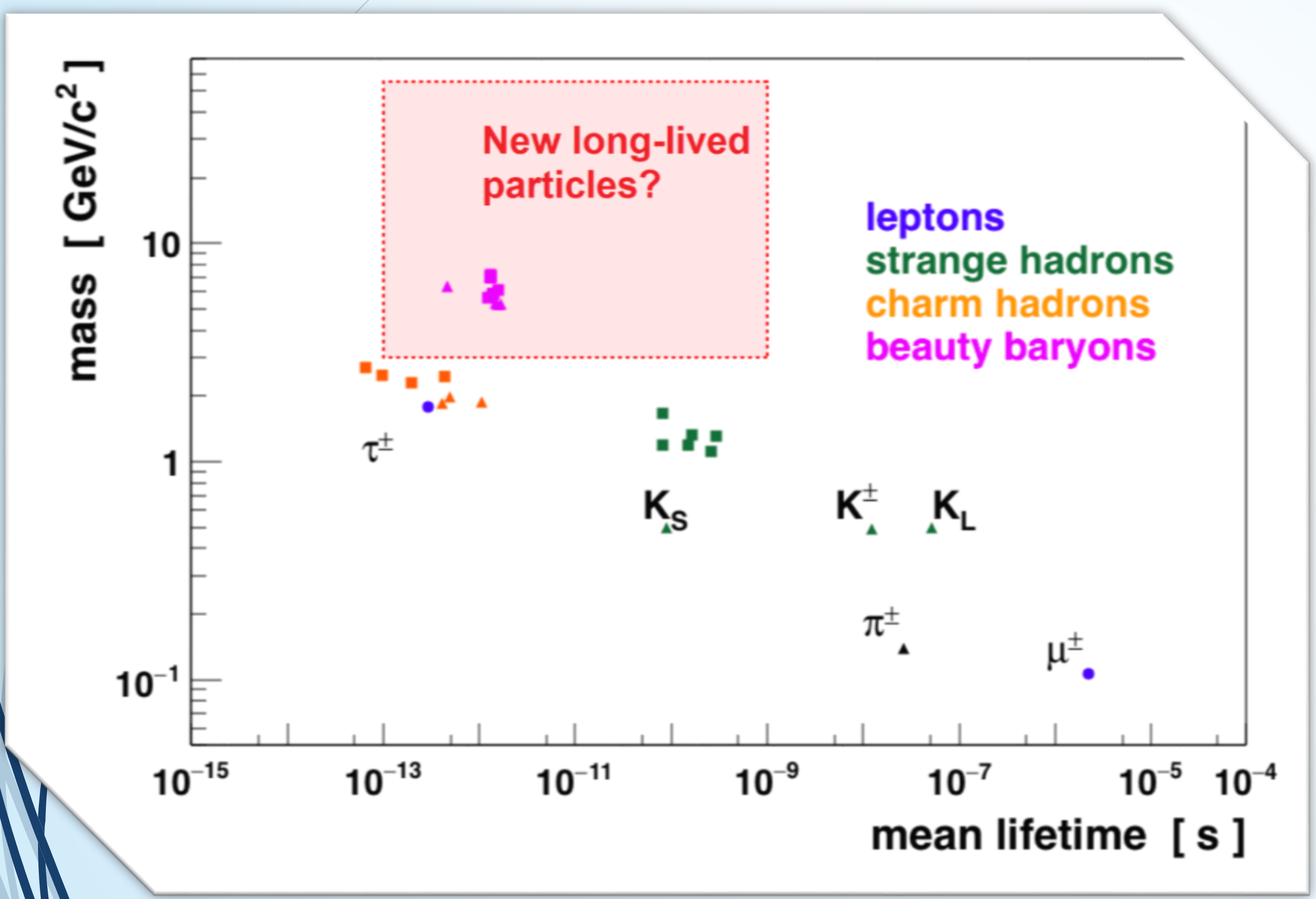
Long-lived particle. What is it?



Why long-lived?

- heavy messenger
- phase space (small mass splitting)

Same principles apply to BSM particles!

BSM Theories

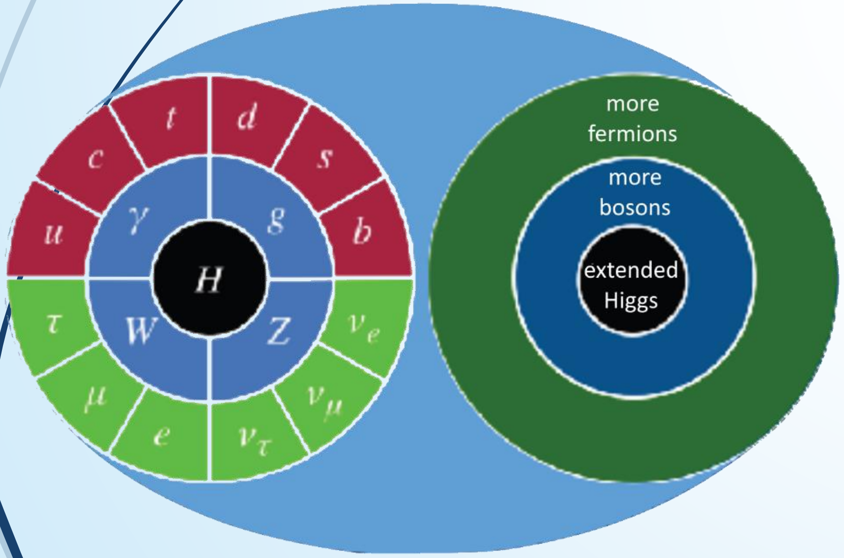
LLPs are motivated in many BSM models

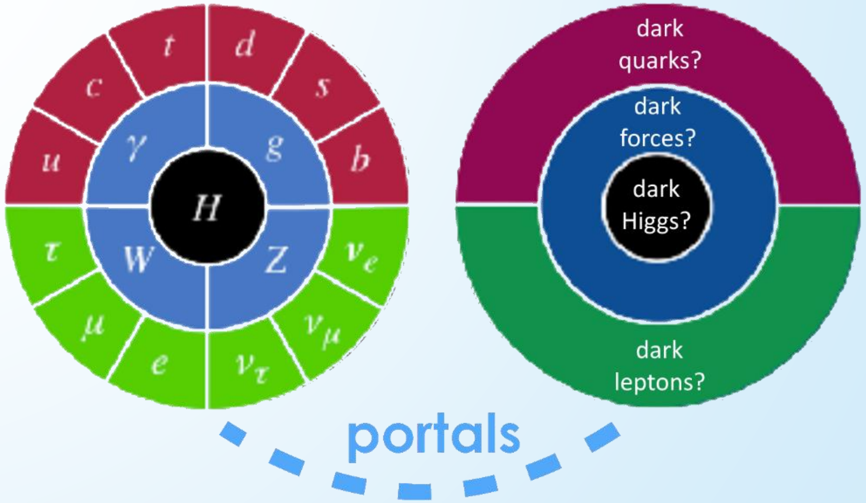
SUSY models

- Production through new particles charged under SM gauge interaction
- New particles are typically heavy because of constraints

Dark sector models

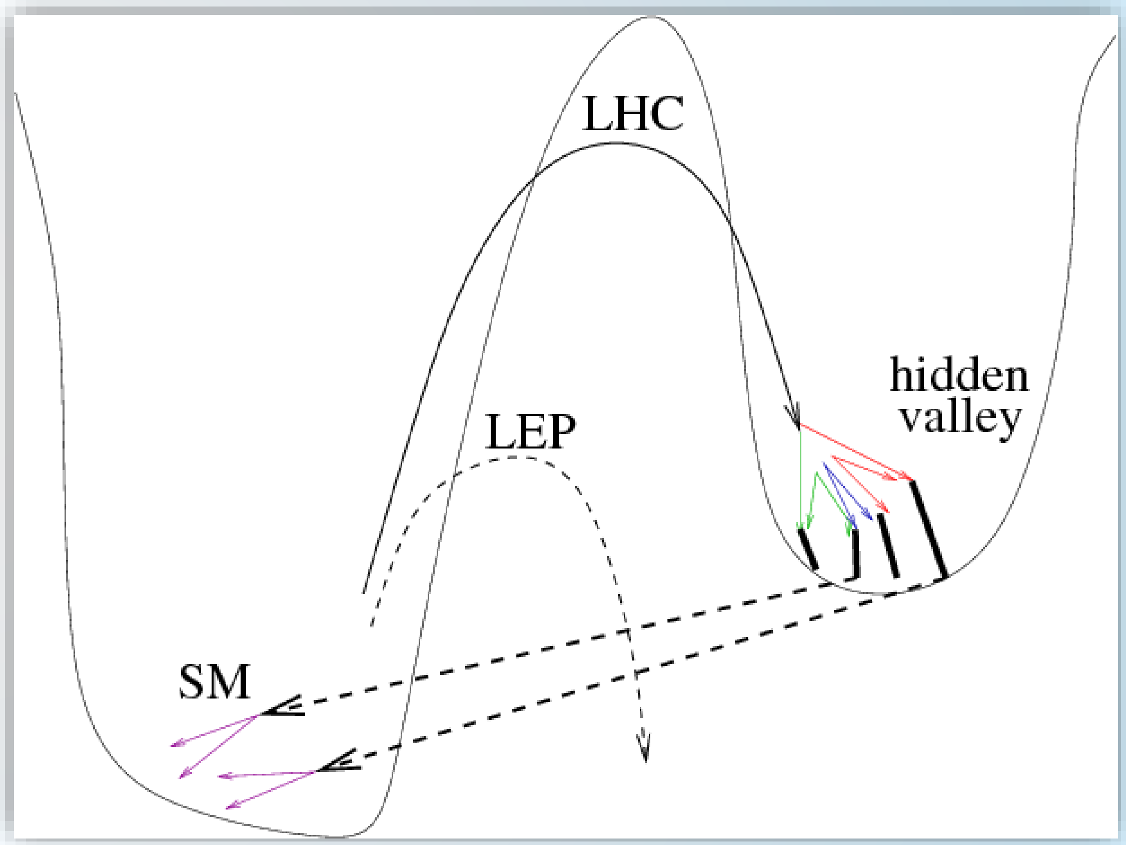
- Separated dark matter sector with portals to SM
- New particles must be SM singlet
- Could be any mass
- Could have own hidden sector confinement



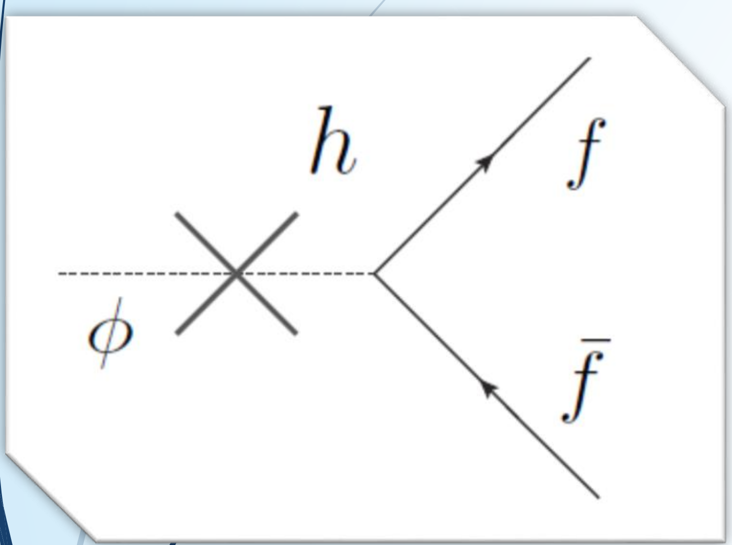


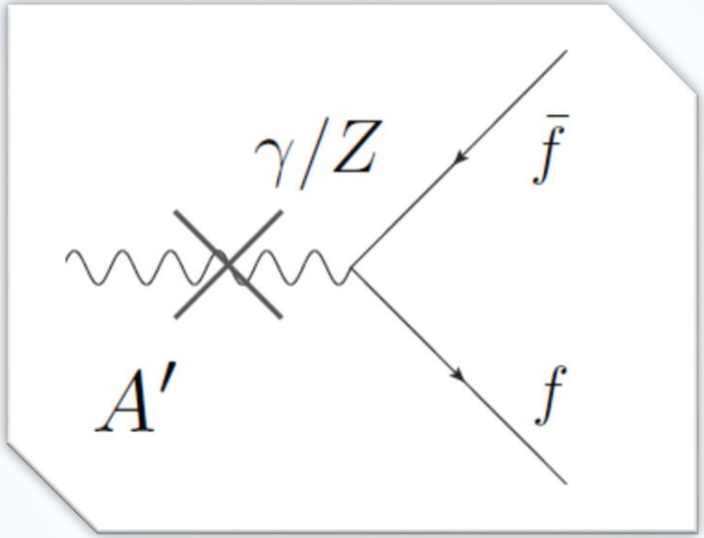
Hidden Valley models

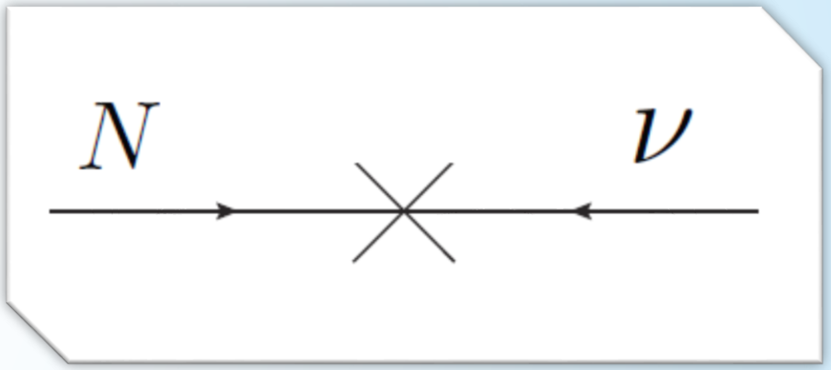
- new v-particles are charged under the new gauge group but not under SM
- lightest particle with nonzero v-charge cannot decay into SM particles → DM candidate
- lightest uncharged particle (π_v) can decay back to light SM particles by tunnelling back through portals → typically long-lived



Portals to the Dark Sector







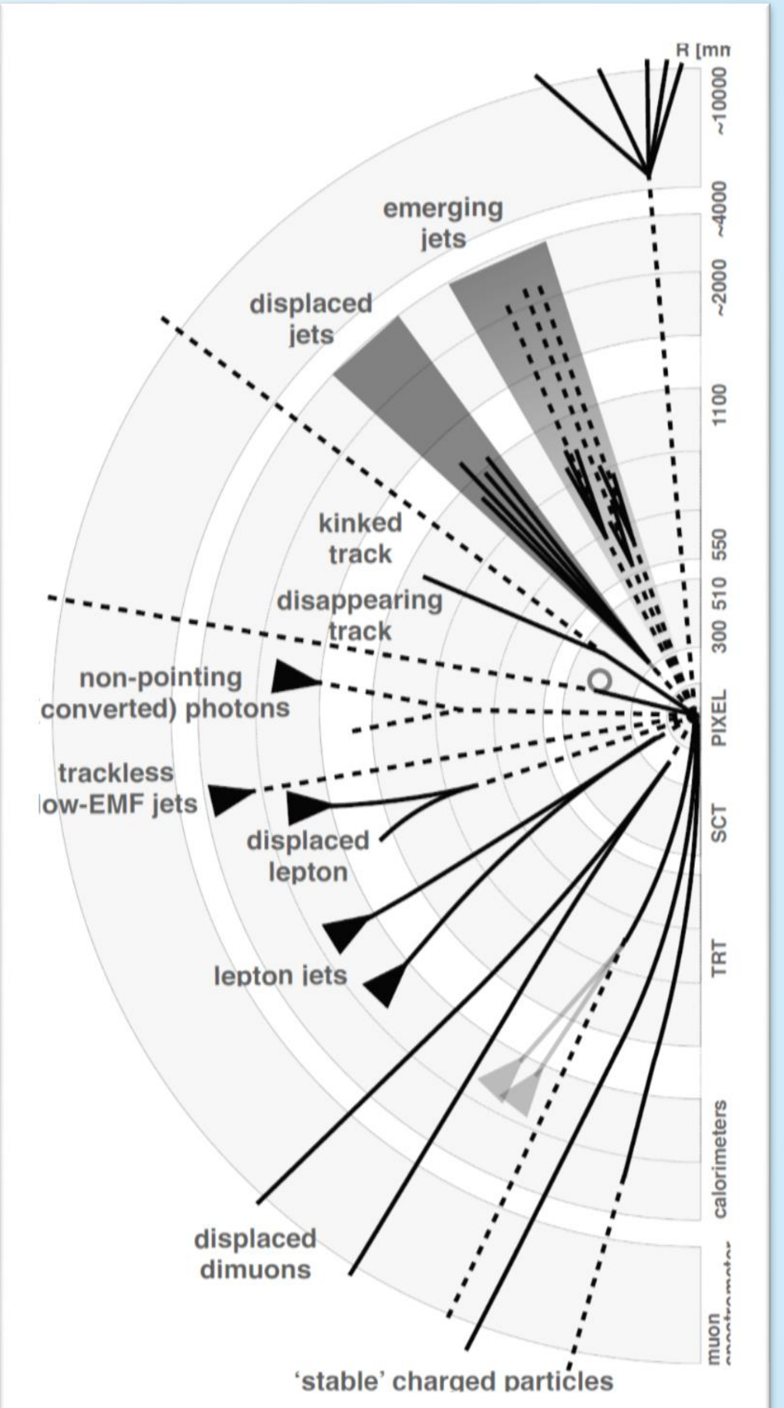
Higgs portal
- Hidden valley

Vector portal
- Dark photon
- Hidden valley
- Z' models

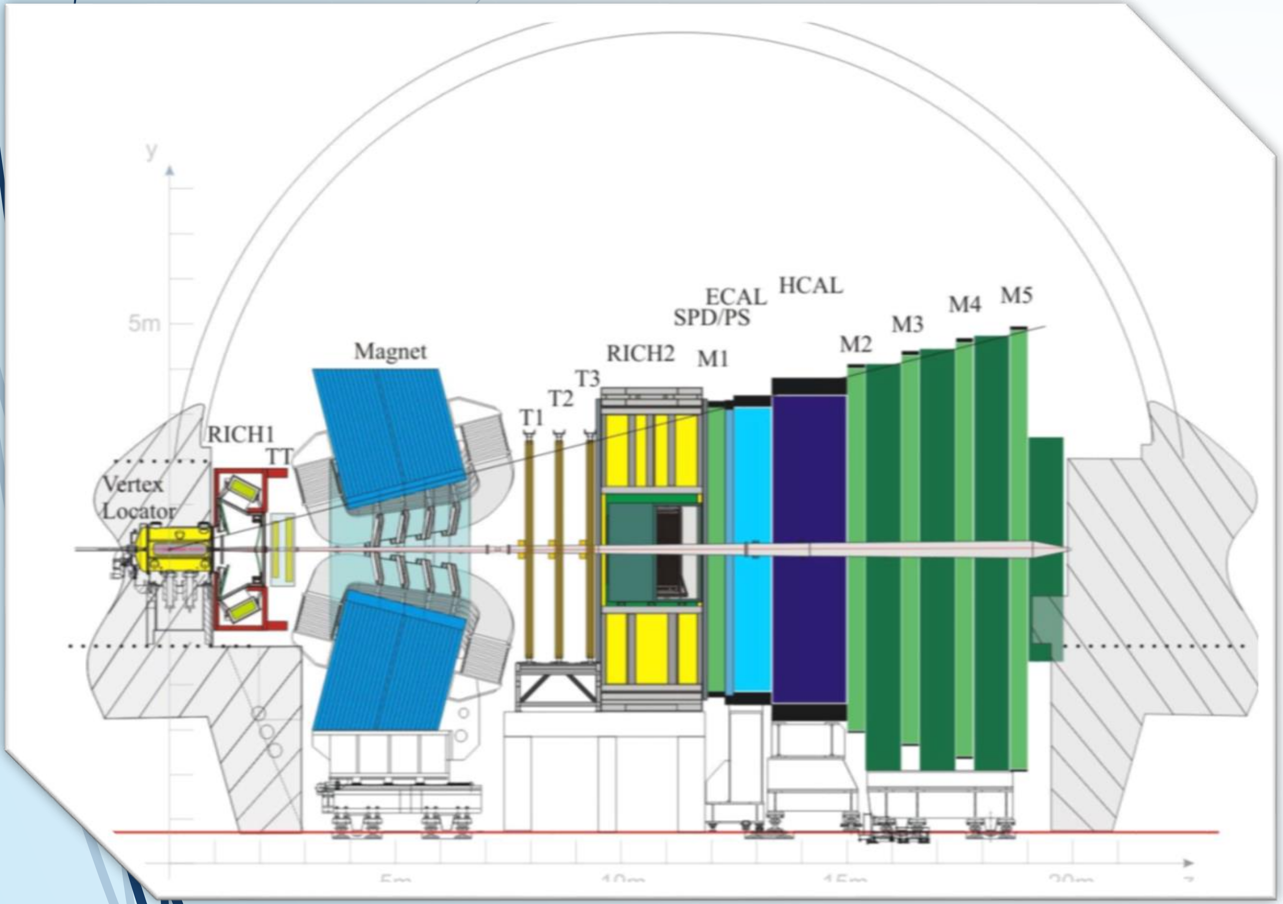
Neutrino portal
- Right handed neutrino

LLP Signatures

- All kinds of unusual signatures are possible
- Model-independent approach may be preferable
- Multiple search strategies can be applied to one signature



LHCb detector

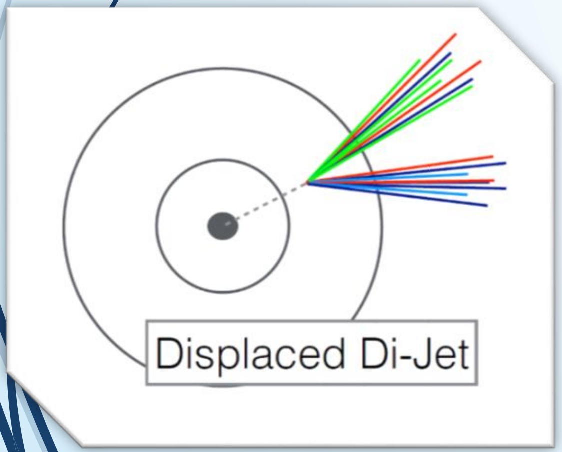


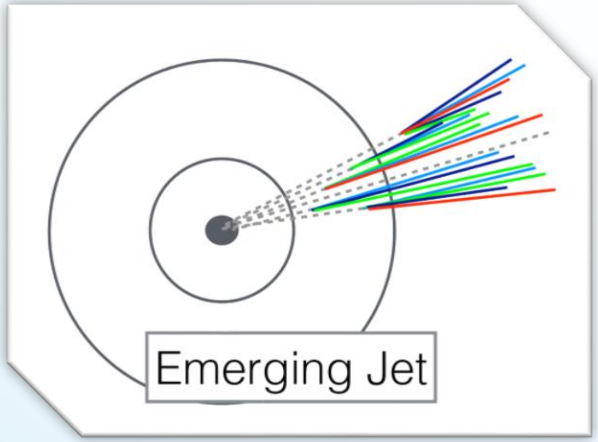
jet reconstruction:

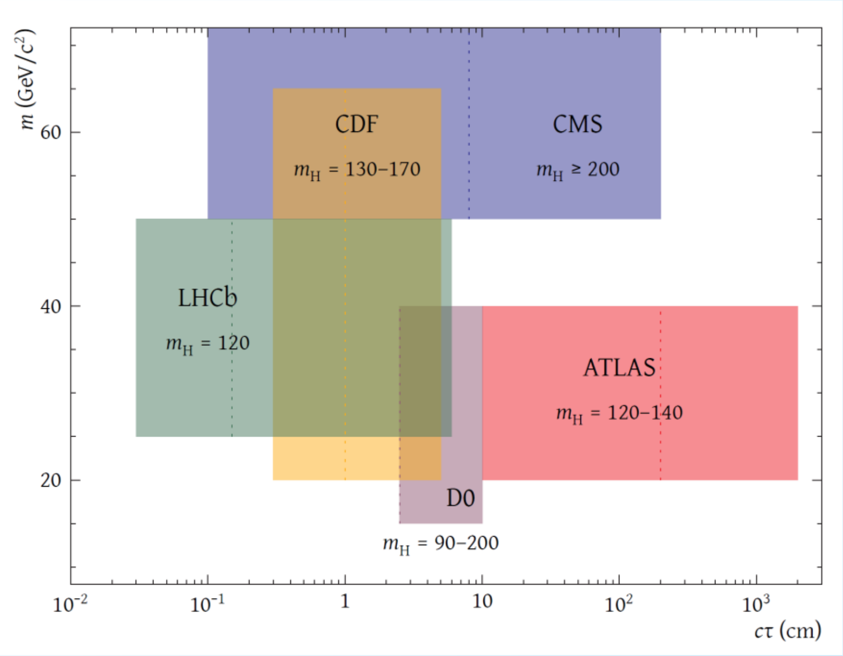
- efficiency > 80% (with p_T >15 GeV)
- energy resolution ~10% (with p_T >10 GeV)
- b(c) tagging efficiency ~65%(25%)

Past and present

- Jet is a collimated bundle of hadrons
- Previous analysis focused on displaced jets and set some limits
- This analysis - jets emerge in the detector → dark sector particle decays into dark parton showers: the lightest dark particles can then decay to SM ones
- Very distinctive signature: many displaced tracks and different vertices in the jet cone – needs dedicated trigger selection

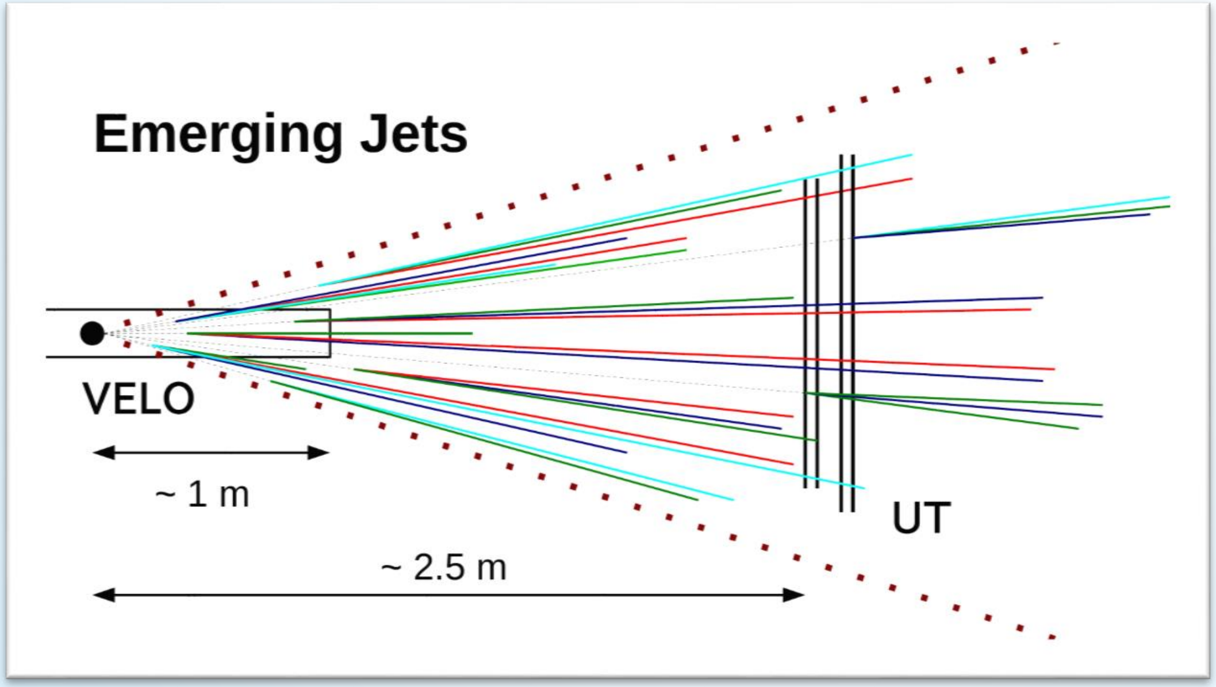






Simulation samples

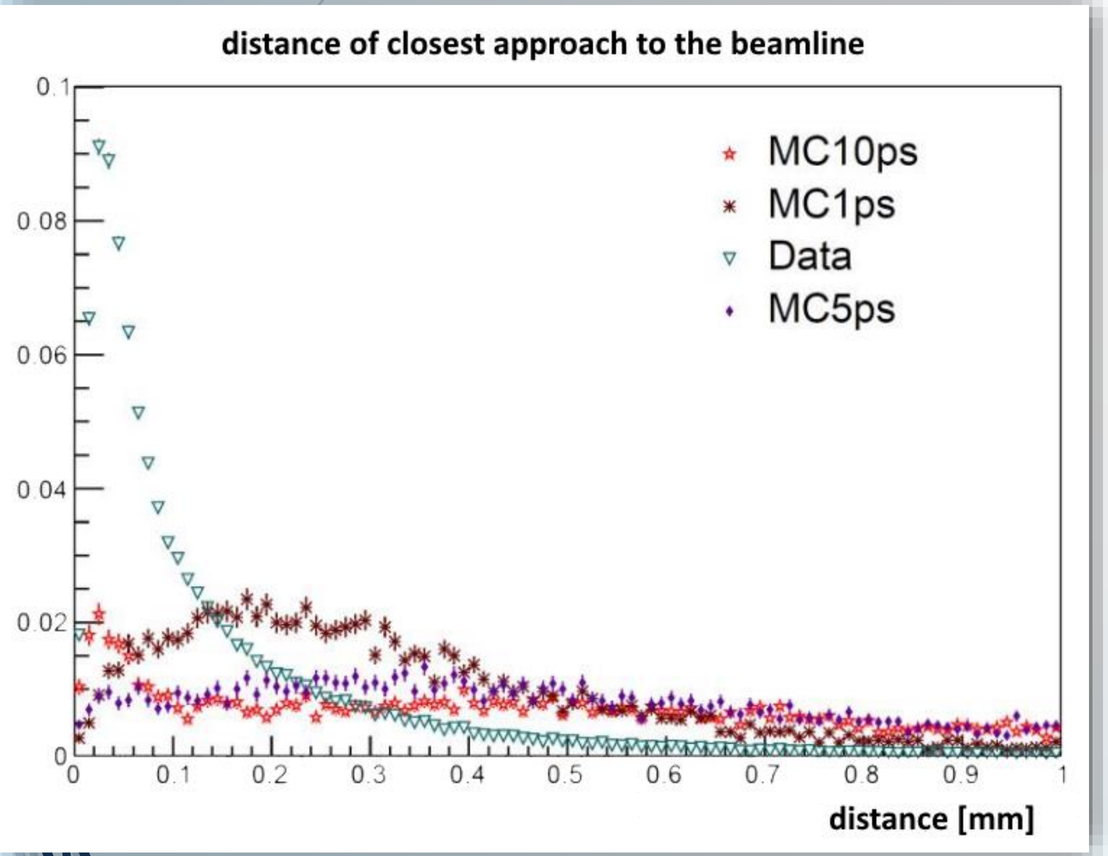
- Simulation samples (2016 conditions):
  - Produced 11, 20, 25, 35 GeV/c^2 for 1, 5, 10 ps
  - For all the cases, the π_v decays into two b-jets ($\pi_v \rightarrow b\bar{b}$)
- Emerging jet signature ($Z'(200) \rightarrow q_v\bar{q}_v \rightarrow$ multiple π_v)
- High multiplicity of π_v in the final state (between 5 and 6 per event)

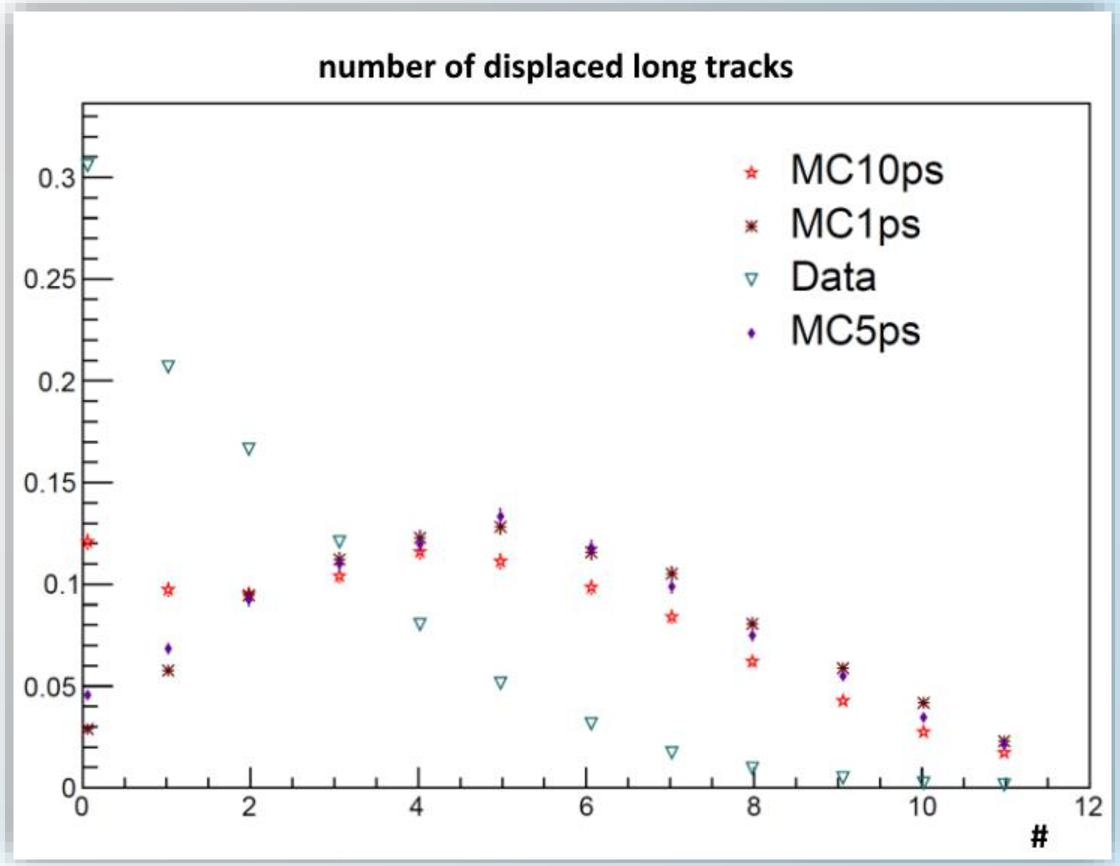


Trigger selections

- p_T-weighted distance of closest approach to the beamline
- Number of displaced long tracks
- Secondary vertex (SV) tag
- Other variables were considered too, i.e.:
  - fraction of p_T of prompt long tracks
  - p_T-weighted IP and χ^2_{IP} distributions
  - redefining the "displaced" condition that we are using

Distributions of the main variables





Trigger selection efficiencies

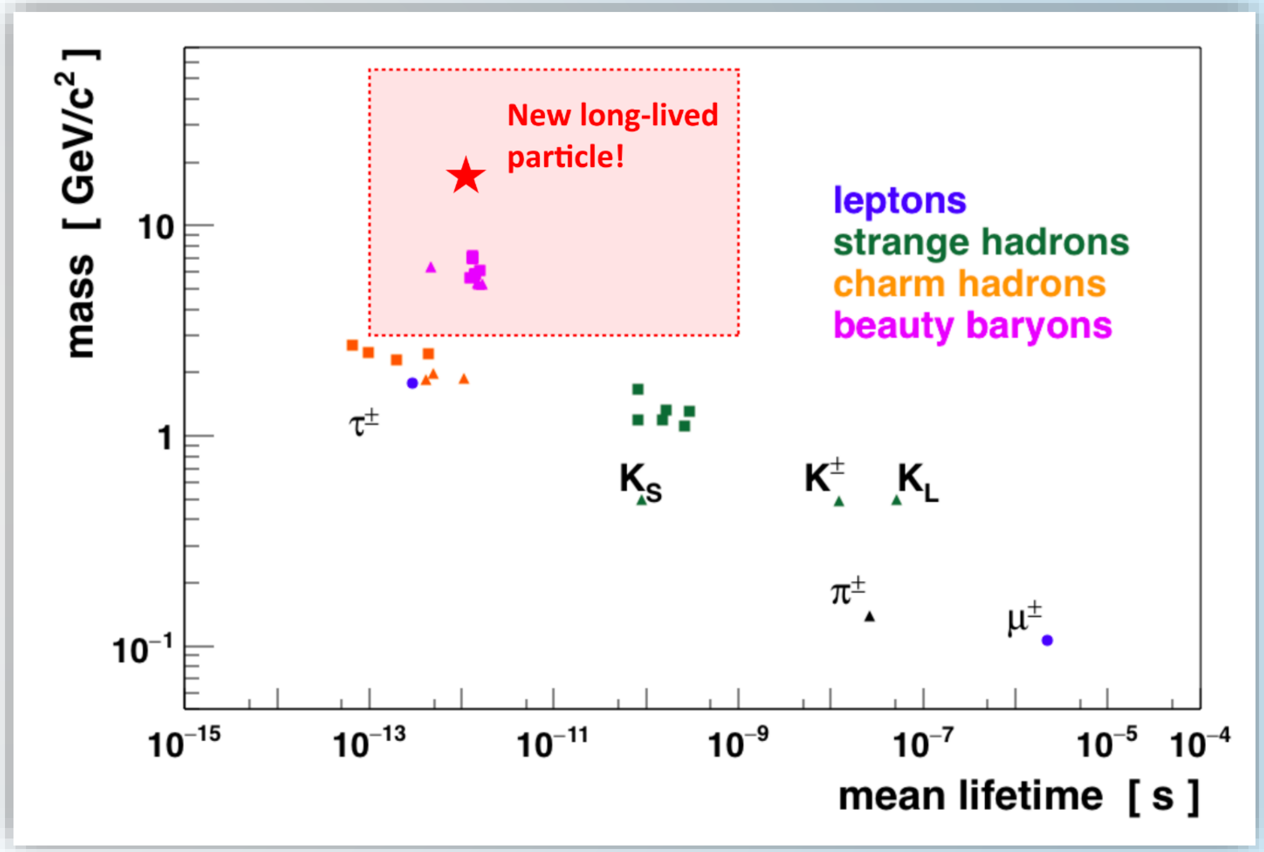
Dark showers $Z' \rightarrow q_v q_v$	1 ps	5 ps	10 ps
35 GeV/c²	8.50 ± 0.51 %	8.11 ± 0.50 %	7.65 ± 0.49 %
25 GeV/c²	11.39 ± 0.59 %	10.99 ± 0.58 %	10.13 ± 0.56 %
20 GeV/c²	11.85 ± 0.59 %	12.29 ± 0.60 %	10.98 ± 0.58 %
11 GeV/c²	15.40 ± 0.67 %	16.93 ± 0.69 %	14.83 ± 0.65 %

Next steps

- The amount of data is too big to process efficiently
- Developing a data filtering selection
- Need to retain about 0.5% of current sample
- Filter over the whole Run2 data
- Include code for finding subvertices in individual jets
- Expand the search to include lower masses of π_v

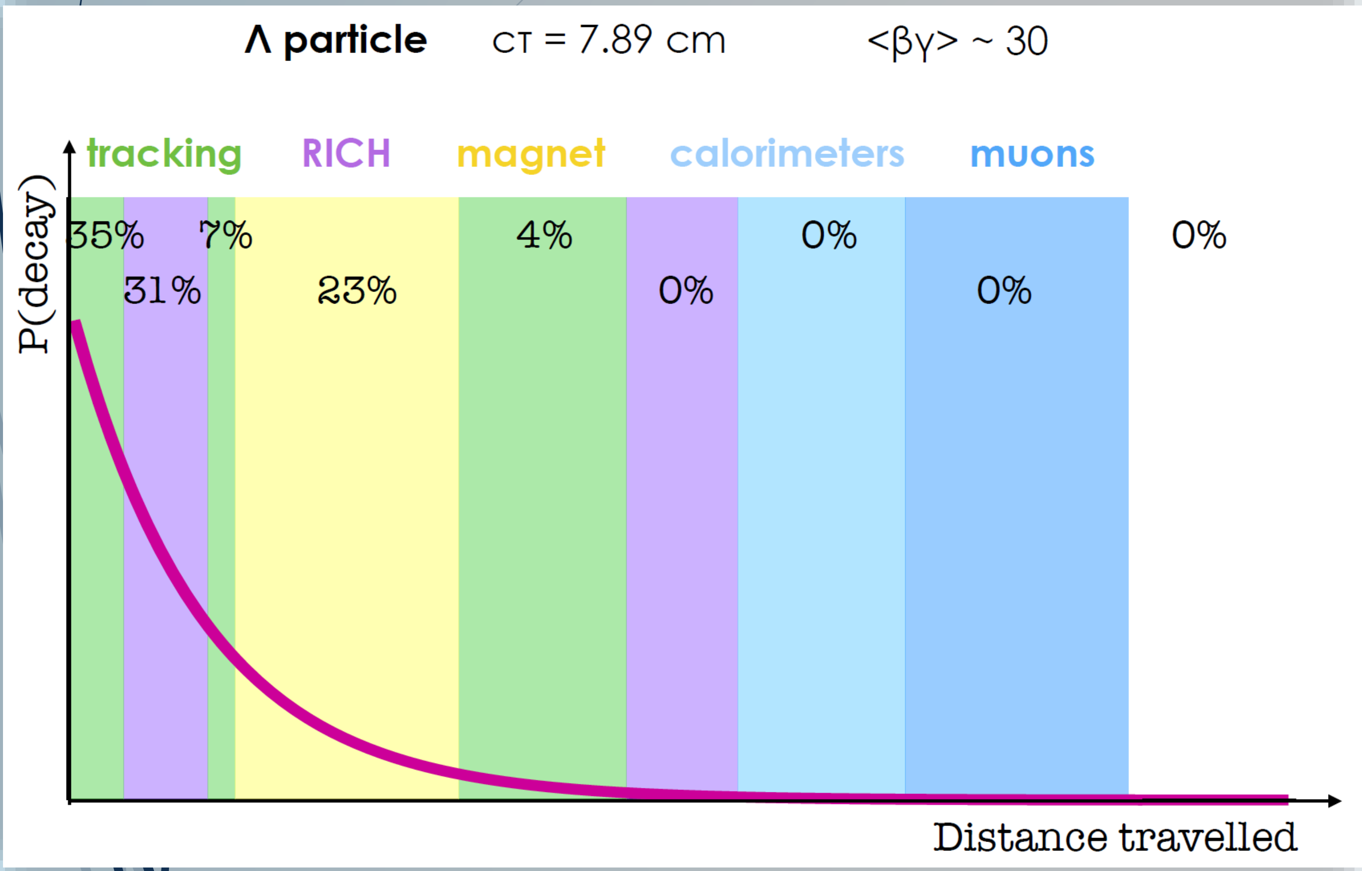
Conclusions

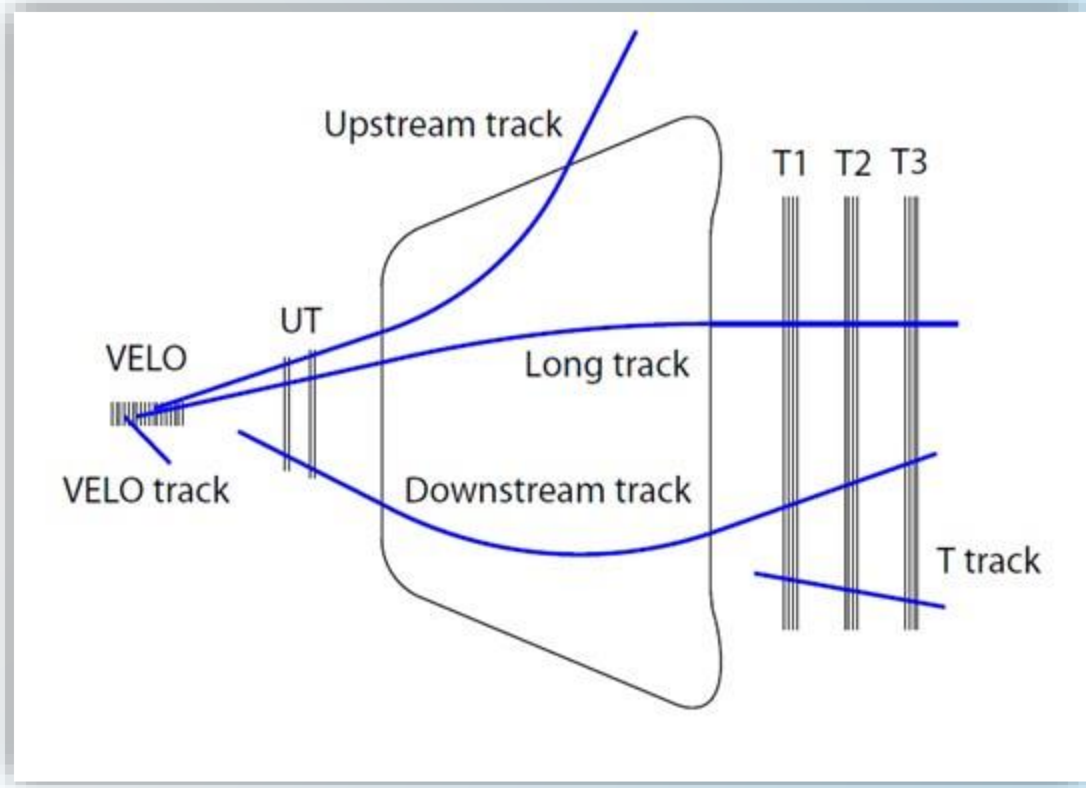
- Trigger selection was implemented for the emerging jets signature (the Run2 pp data taking was finished on the 24th of October)
- Data filtering selection is being developed taking into account jet daughter vertices (for the full Run2 data sample)
- Hopefully new LLP next year!



Thank you for attention!

LLPs in LHCb





Elena Dall'Occo