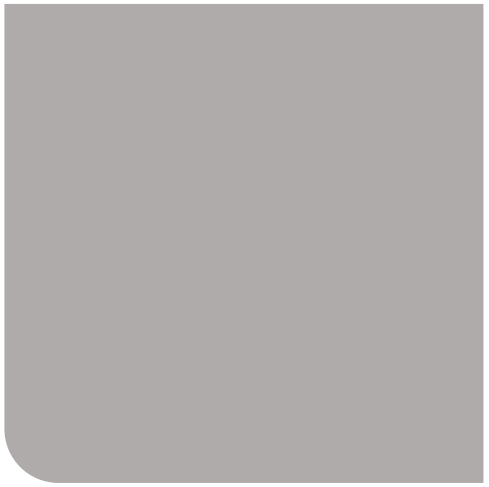


Other Exotica – Summary and Discussion of Critical Points

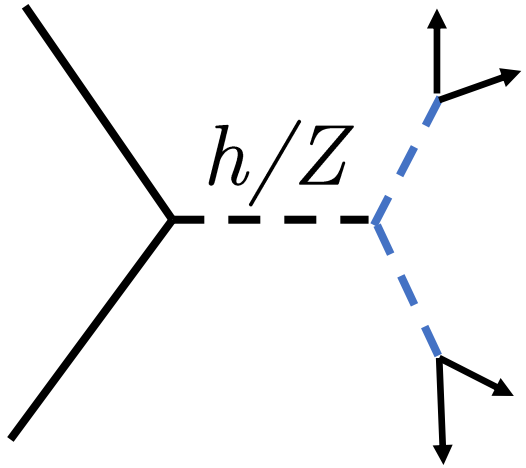
Lingfeng Li
Brown University
Mar. 30, 2022
Snowmass Energy Frontier WS

Other Exotica ≃ (Exotic)^{2}a ?

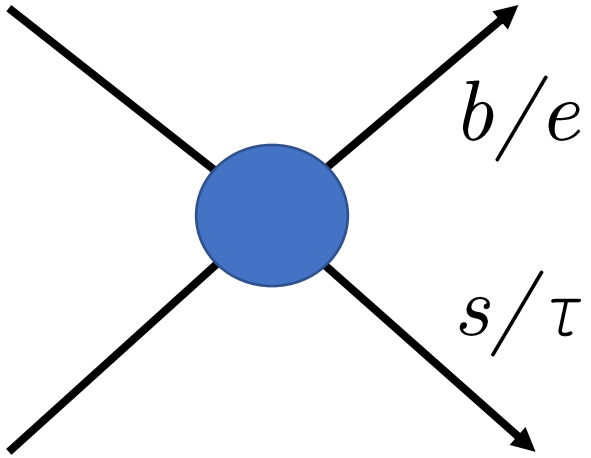
Ideas that are not covered in the previous summary:

- Light fermions/bosons (< m_h) , prompt or elusive.
- Operators with non-trivial BSM pattern (FCNC, LNV, etc.)
- Extraordinary dynamics (dark shower, “soft bombs”, etc.)

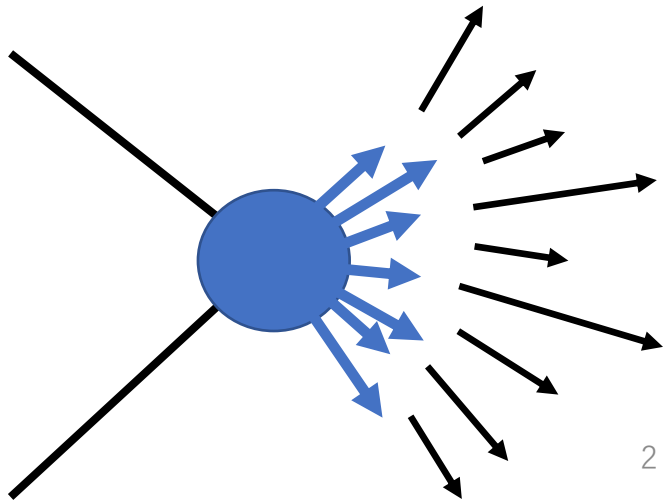
Marcela Carena et al., 2203.08206
Tania Robens, 2203.08210



W. Altmannshofer, S. A. Gadam, and S. Profumo, 2203.07495



Guillaume Albouy et al., 2203.09503



Other Exotica ≃ (Exotic)^{2}a ?

- Often with **STRONG** physical motivation (e.g. electroweak phase transition/ flavor anomalies/ neutral naturalness…)
- Not necessarily hard to search (e.g. bump hunting)
- Topics crossover outside EF09 (e.g., in EF10 with invisible dark particles T. G. Rizzo et al., 2202.02222 ; in EF02 with Higgs portal light exotics Tania Robens, 2203.08210 etc.)
- Expect the unexpected!

Smoke detectors for the (exotic)$^{2\cdots N}$a smoking guns?

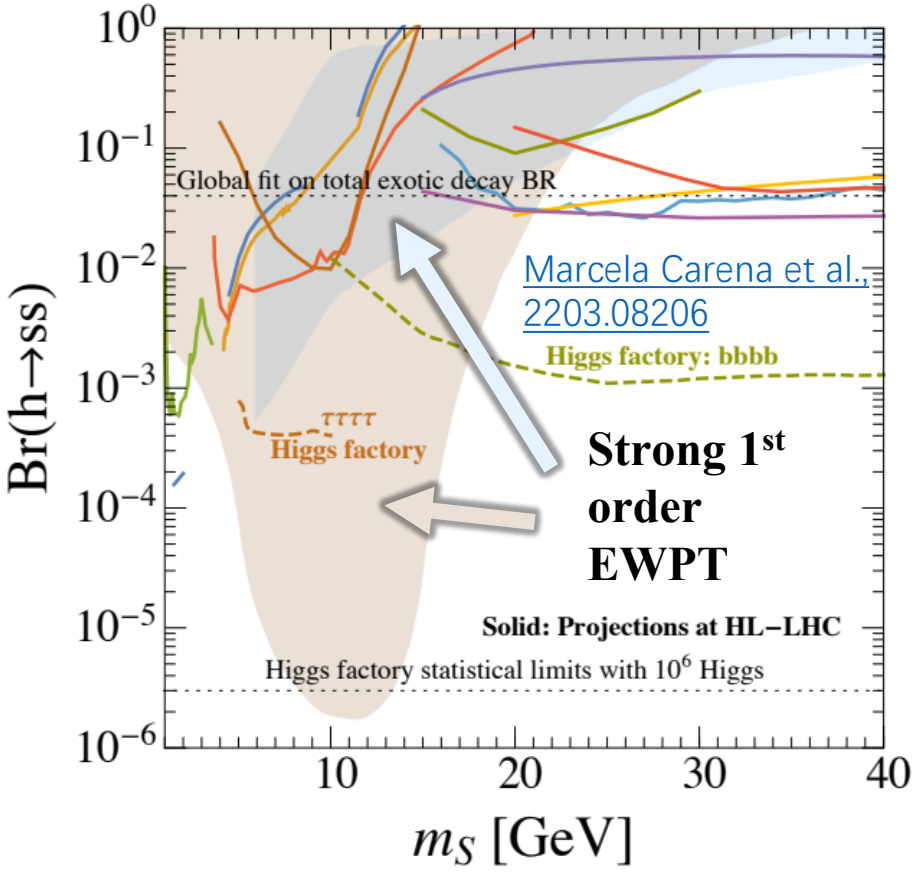
G. Kasieczka et al., 2101.08320, etc.

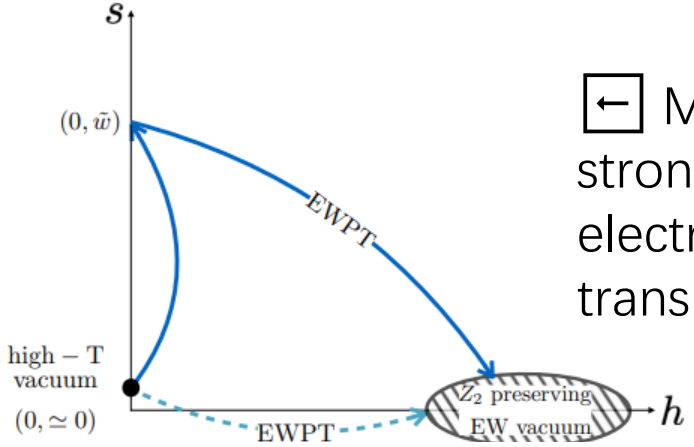
Machine Learning techniques without having specific signal samples:

- Unsupervised Leaning (No labels)
- Weakly Supervised Learning (Noisy/blurred labels)
- Semi Supervised Learning (“Bkg only” labels)

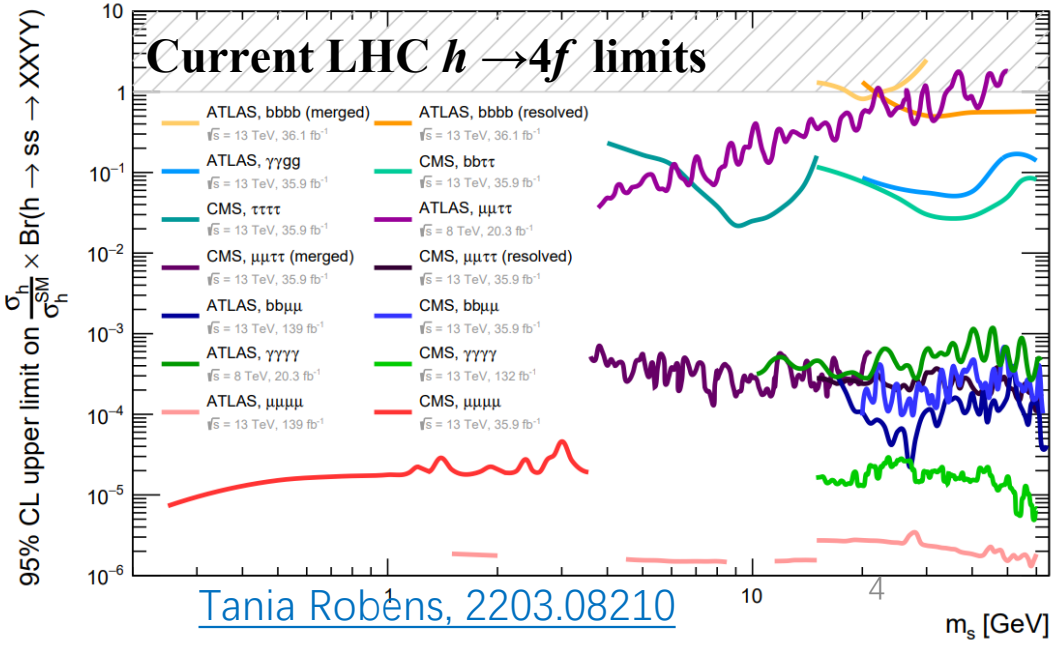
Interplay with CompF & TF…

Light Exotic Resonances



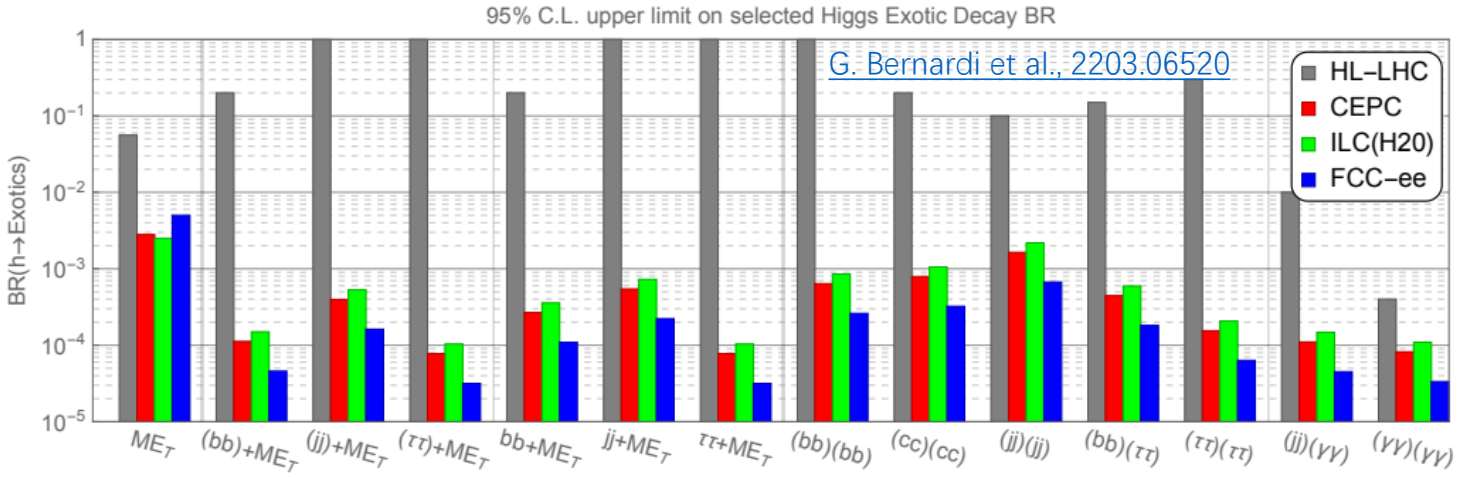


← Motivated by, e.g., strong first order electroweak phase transition/ 2HDM…

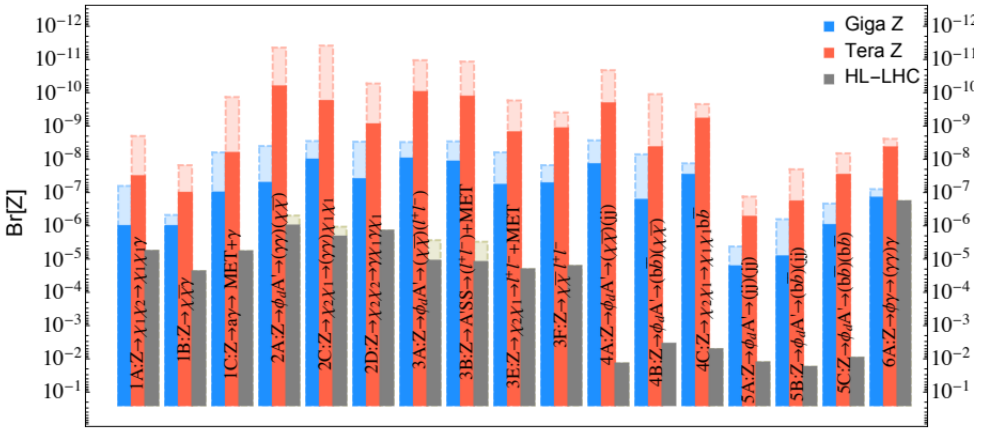


Tania Robens, 2203.08210

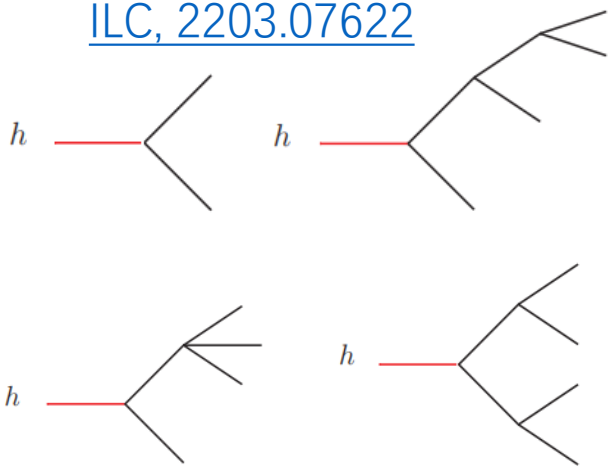
↑ Light scalar mix with Higgs, found in $h \rightarrow$ 2 scalar decays. When s is heavy, decays promptly.

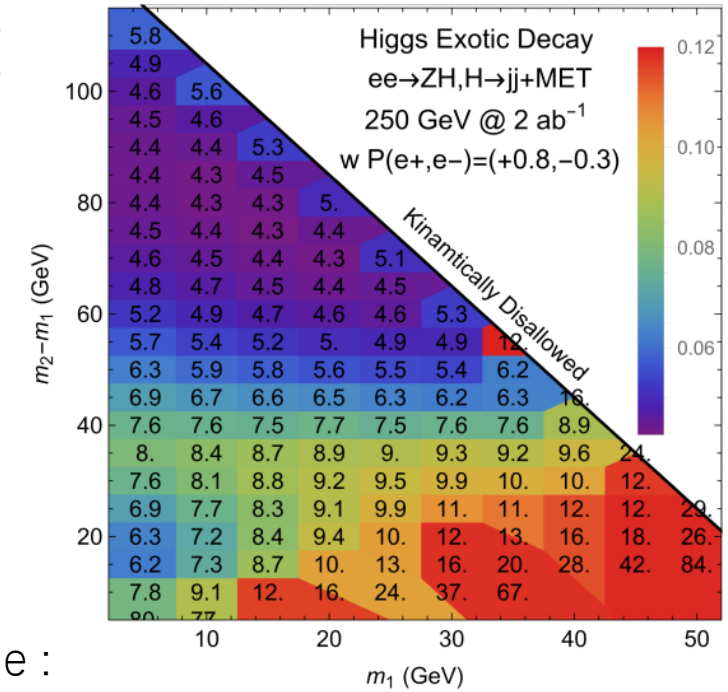


G. Bernardi et al., 2203.06520



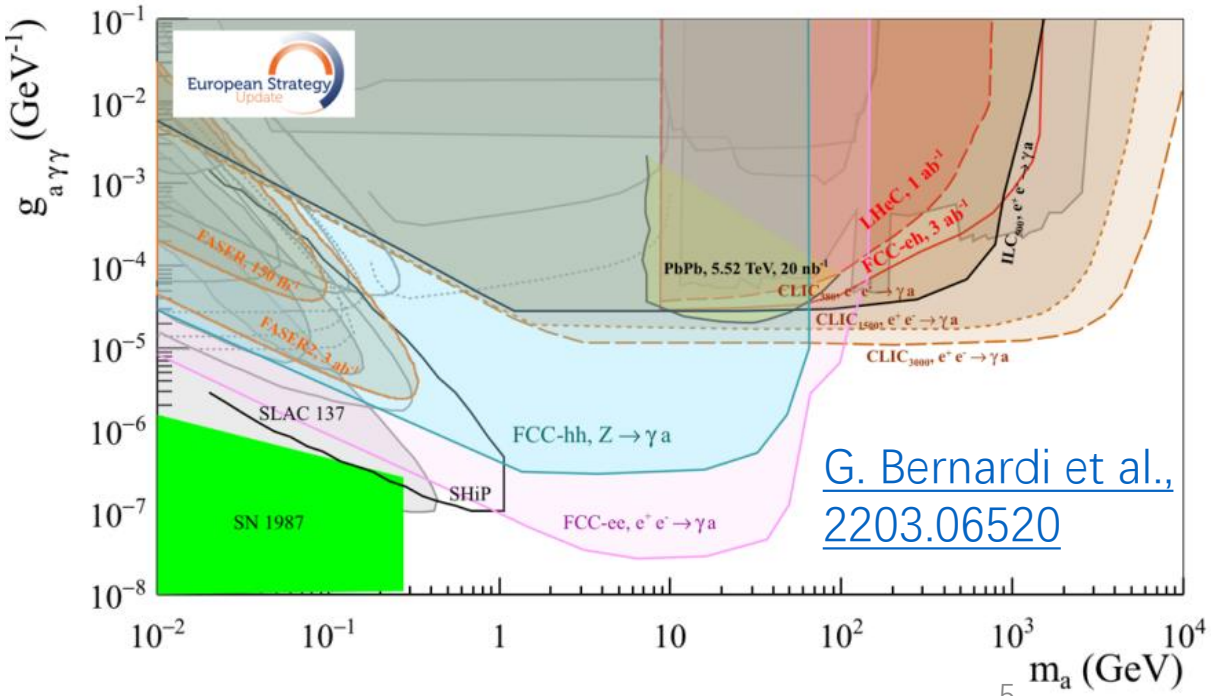
ILC, 2203.07622





↑ Power of the potential Z-pole run

J. Liu, L-T. Wang, X-P. Wang, W. Xue. 1712.07237

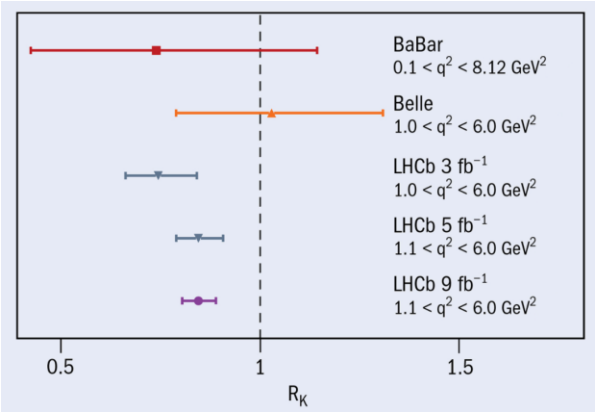


G. Bernardi et al., 2203.06520

↑ → Other models include :

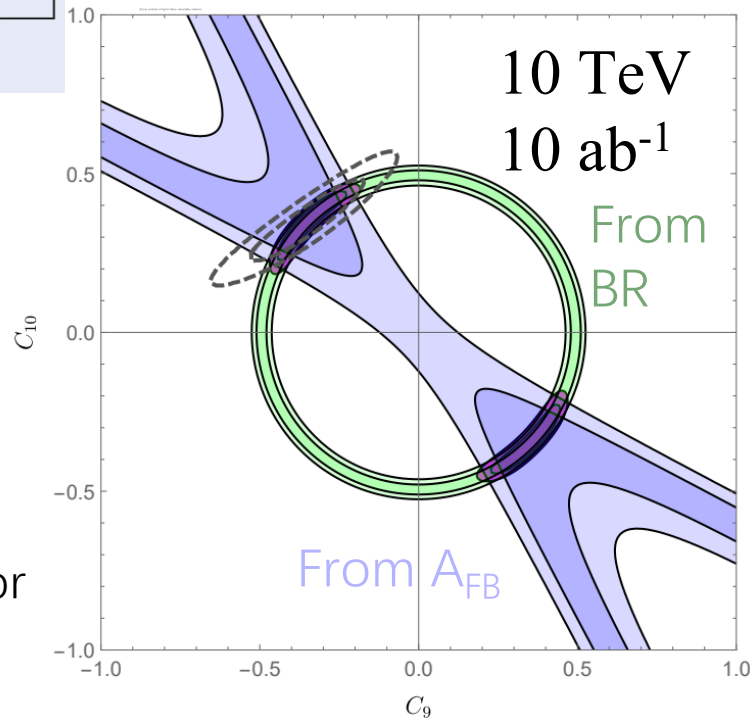
- Dark (thus missing) fermions…
- ALP, produced via $Z \to ya$, $h \to ya$, $h \to Za$, $h \to aa$, etc.
- Spin-1 (dark photon) models with mass>O(GeV).
- More complex topologies.

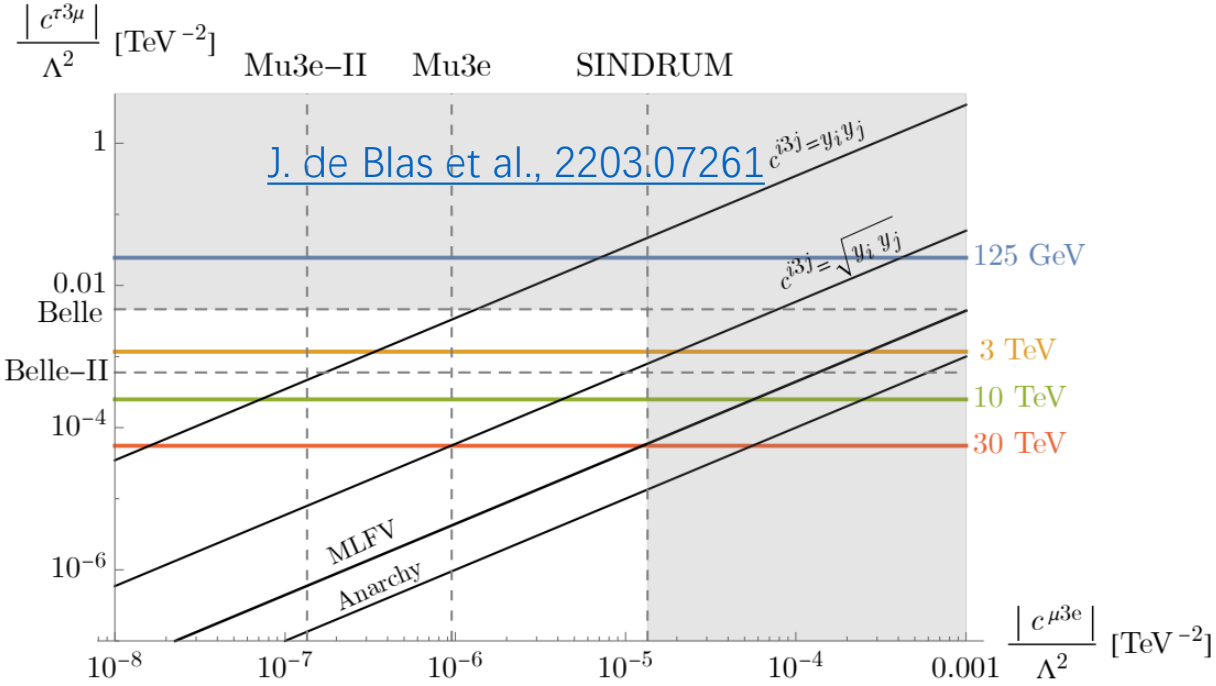
FCNC/LF(U)V/… Operators



$$R_{K^{(*)}} \equiv \frac{\mathrm{BR}(B \to K^{(*)}\mu^+\mu^-)}{\mathrm{BR}(B \to K^{(*)}e^+e^-)}$$

SM predicts $R_{K(*)} \approx 1$ in the low q^2 region.





→ "Direct" probe at high energy muon colliders via $\mu\mu \to bs$

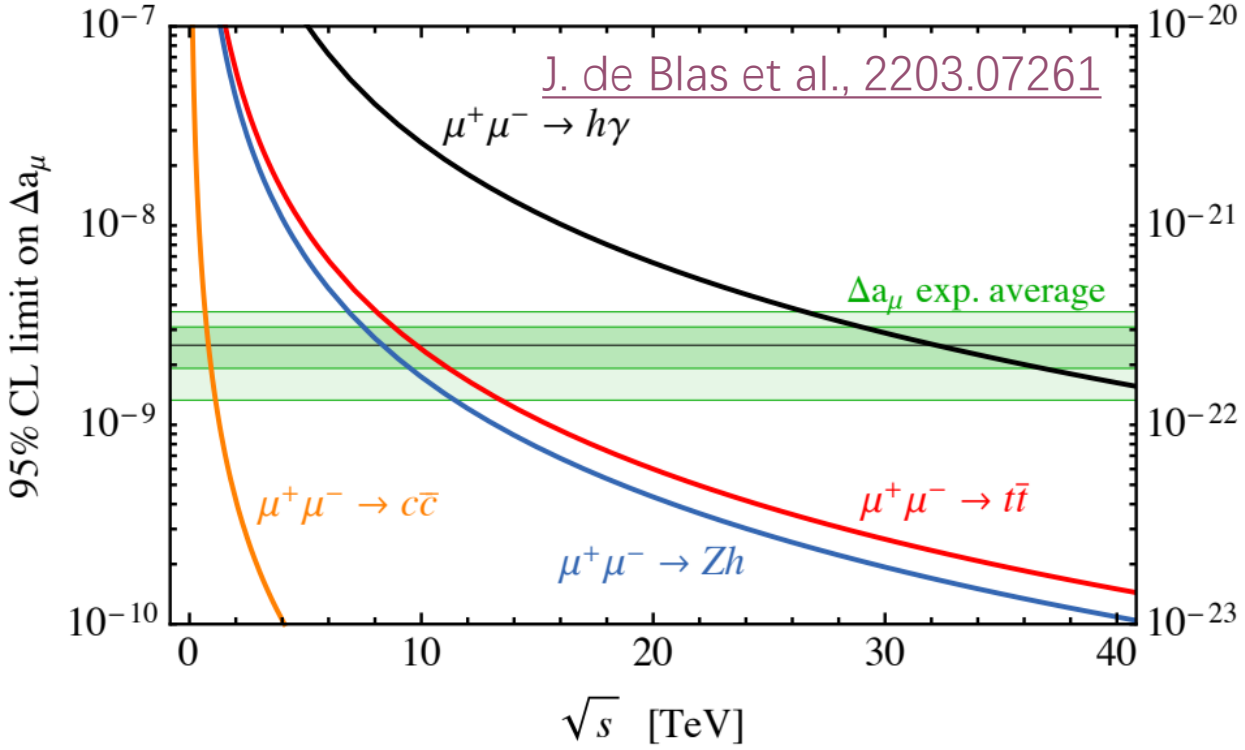
- Current limit relies on single b-tagging (eff.=70%).
- b-jet charge tagging for A_{FB} (eff.=70% as LEP)

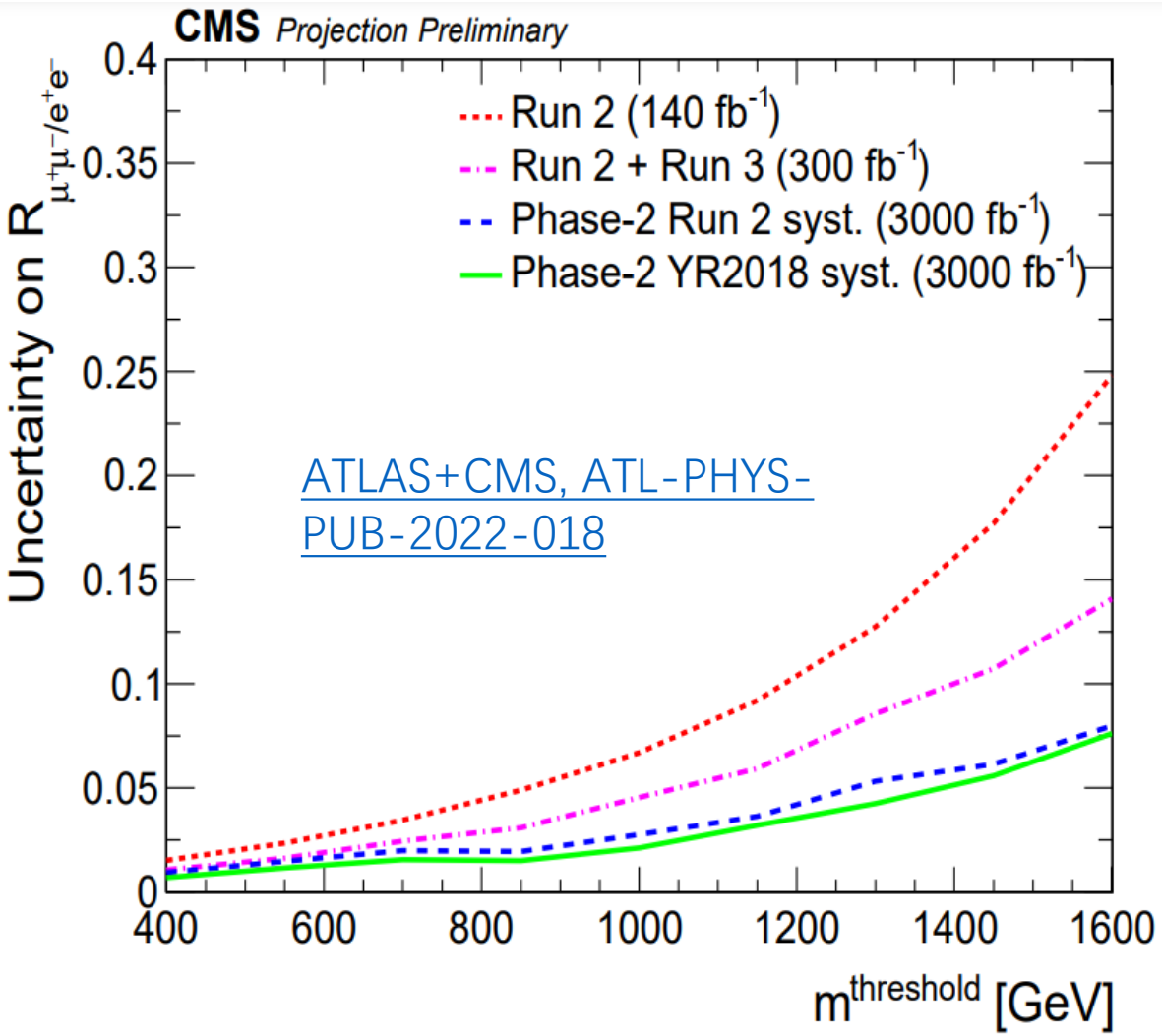
W. Altmannshofer, S. A. Gadam, and S. Profumo, 2203.07495

↑ The lepton flavor violation measured by $\mu\mu \to \mu\tau$.

Also probe other LFVs using $\mu\mu \to e\tau$ and $\mu\mu \to \mu e$ directly.

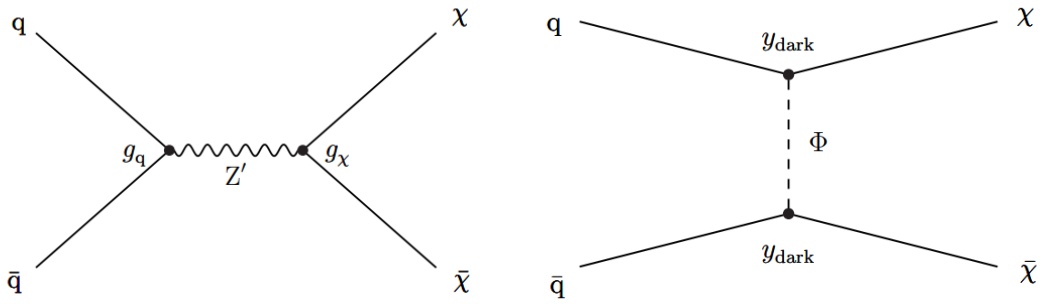
→ Monitoring LFUV interaction from lepton pair ratios above a certain threshold @ (HL-)LHC





← Dipole/four-fermion-tensoric interactions introducing $(g-2)_\mu$ will also be addressed

Exotic Dynamics: Models

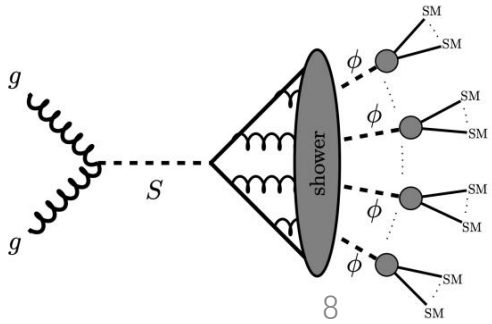


Dark showers: light particles charged under another confining gauge group.

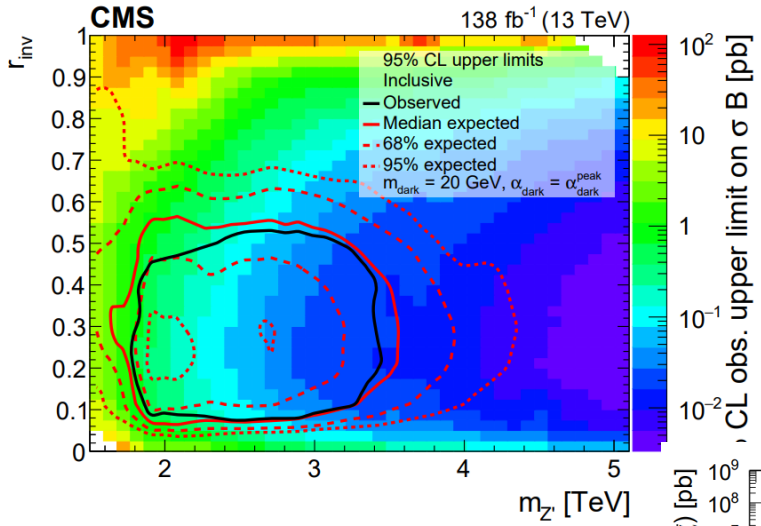
- QCD-like kinematics: significant angular correlation within a small scale, energy spreads.

Soft-unclustered-energy pattern (SUEP), or "soft bomb":

- Expected in a theory with $\alpha/N_c \gg 1 \gg \alpha$
- Quasi-isotropic, high-multiplicity of outgoing particles.

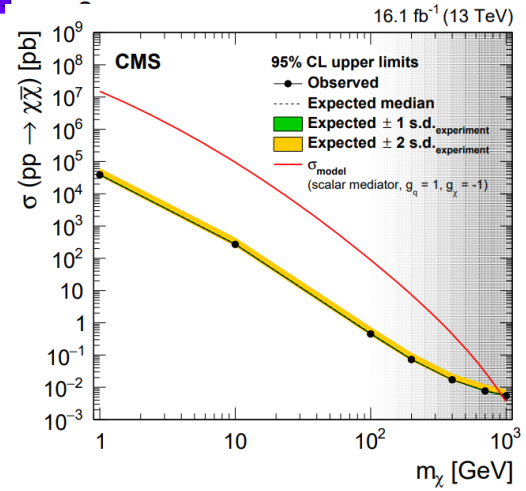


The dark particles can either be prompt, invisible or photon-philic to evade LLP bounds.



⟵: Limits on semivisible-jets: prompt + invisible invisible particles

⟶: Trackless jets, for neutron-like LLPs, but may also apply to photon-philic dark particles(?)

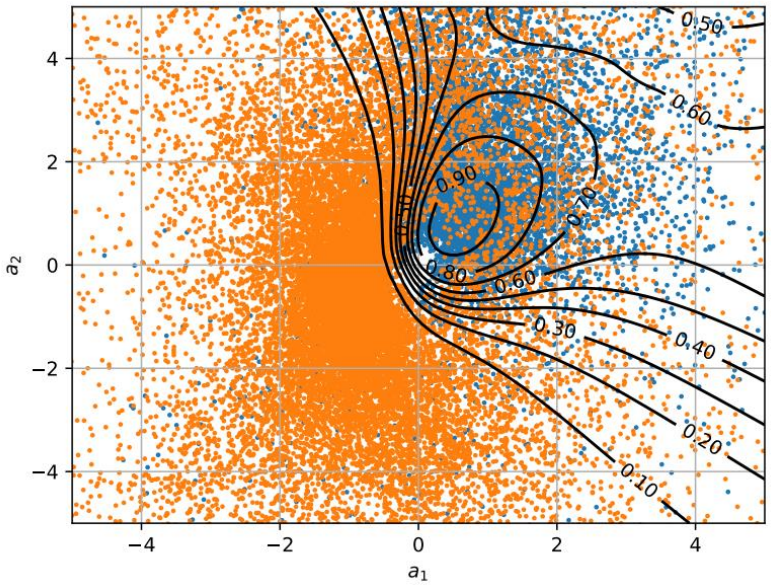


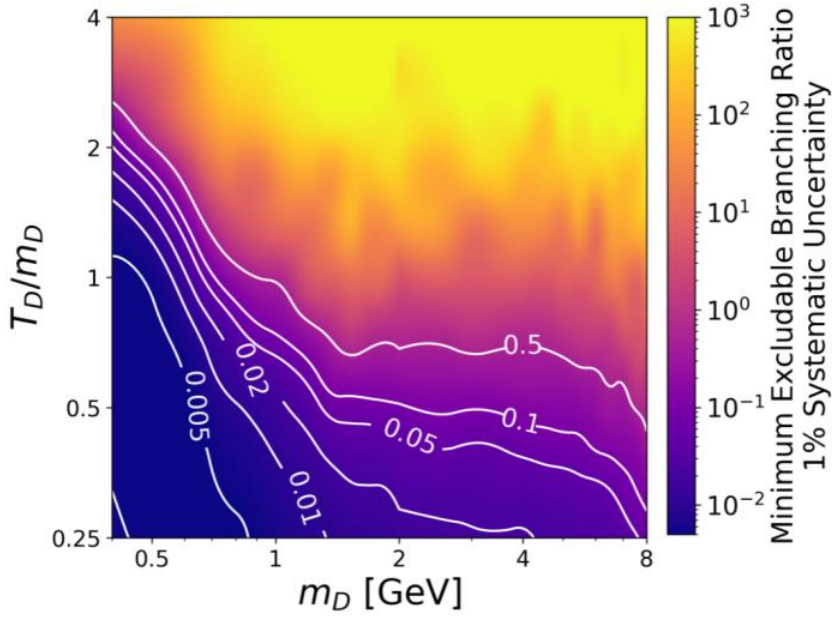
Guillaume Albouy et al., 2203.09503

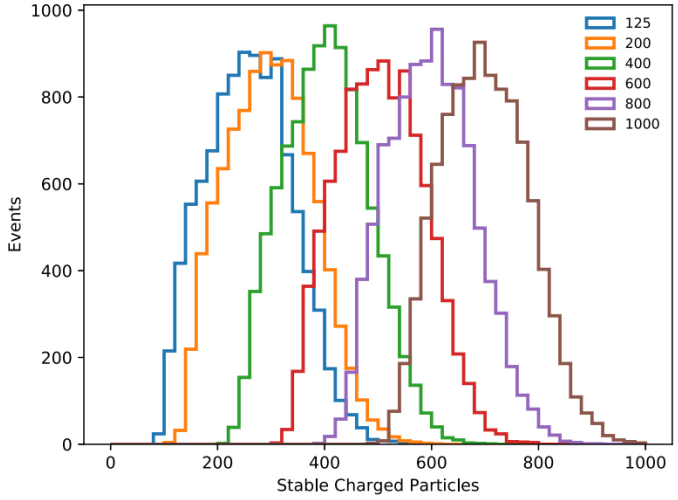
Exotic Dynamics: Phenomenology

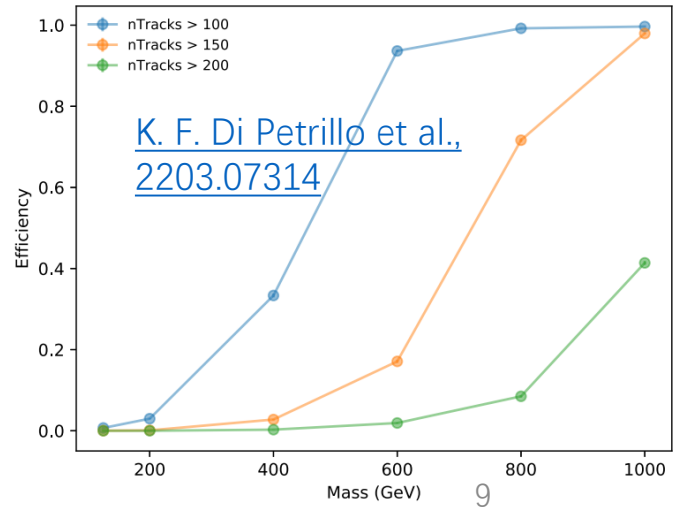
↓ ⤵: Sophisticated observables/algorithms are designed targeting various exotic dynamics Depending on kinematics instead of LLPs.

→ LHC triggers for the final states non-conventional and softer than average









H. Beauchesnea, G. di Cortona, 2111.12156

Gregor Kasieczka et al., 2101.08320

Anomaly/Novelty Detection

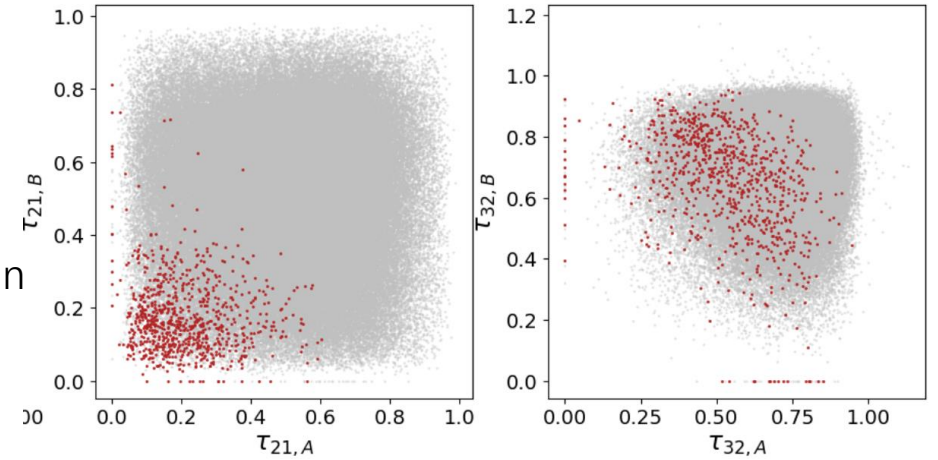
BSM may take the form that surprises all of us.
Real "data mining" from the collider data.

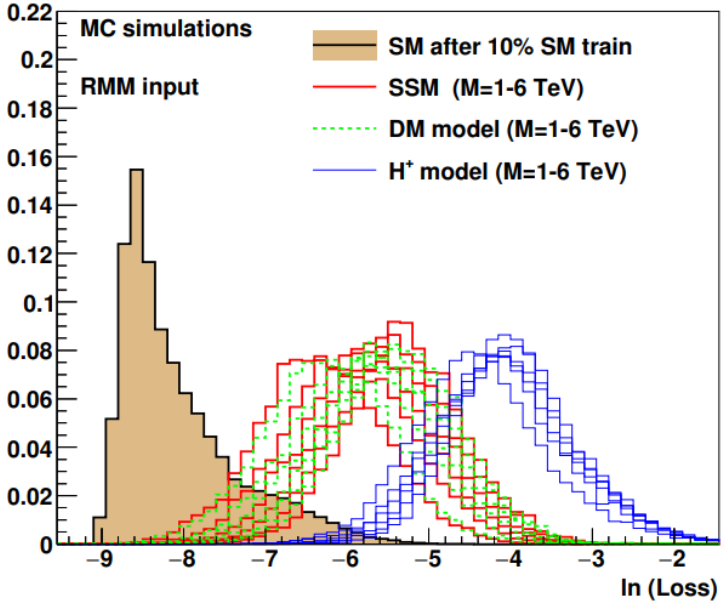
Section	Short Name	Method Type
3.1	VRNN	Unsupervised
3.2	ANODE	Unsupervised
3.3	BuHuLaSpa	Unsupervised
3.4	GAN-AE	Unsupervised
3.5	GIS	Unsupervised
3.6	LDA	Unsupervised
3.7	PGA	Unsupervised
3.8	Reg. Likelihoods	Unsupervised
3.9	UCluster	Unsupervised
4.1	CWoLa	Weakly Supervised
4.2	CWoLa AE Compare	Weakly/Unsupervised
4.3	Tag N' Train	Weakly Supervised
4.4	SALAD	Weakly Supervised
4.5	SA-CWoLa	Weakly Supervised
5.1	Deep Ensemble	Semisupervised
5.2	Factorized Topics	Semisupervised
5.3	QUAK	Semisupervised
5.4	LSTM	Semisupervised

G. Kasieczka et al., 2101.08320

(See also J. Gonski, J. Lai, B. Nachman, I. Ochoae, 2108.13451)

→ Novelty clustering in the feature space





← Autoencoder reconstruction error when trained with SM events only

S.V. Chekanova , W.Hopkins, 2111.12119

Although many activity focuses on heavy resonance decays, shall be extended to general signals.

- Difficulties in background estimation and other systematics

Summary

The “other exotica” may largely develop around four themes, three physics themes and another methodology:

- Light exotic states from Higgs(Z) decays.
- Anomalous EFT studies that reveal BSM features.
- Extraordinary dynamics other than QCD.
- Novelty detection techniques that are model-independent.

Exotic decays to light resonances seem best derived cross projects