Collaborative Research Center TRR 257

Particle Physics Phenomenology after the Higgs Discovery

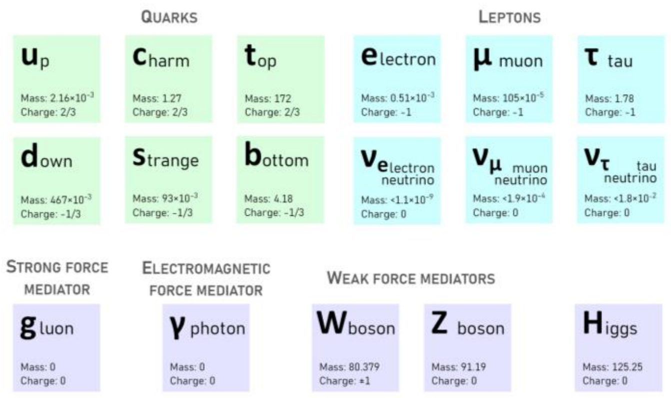
Strongly-interacting Dark Sector Phenomenology

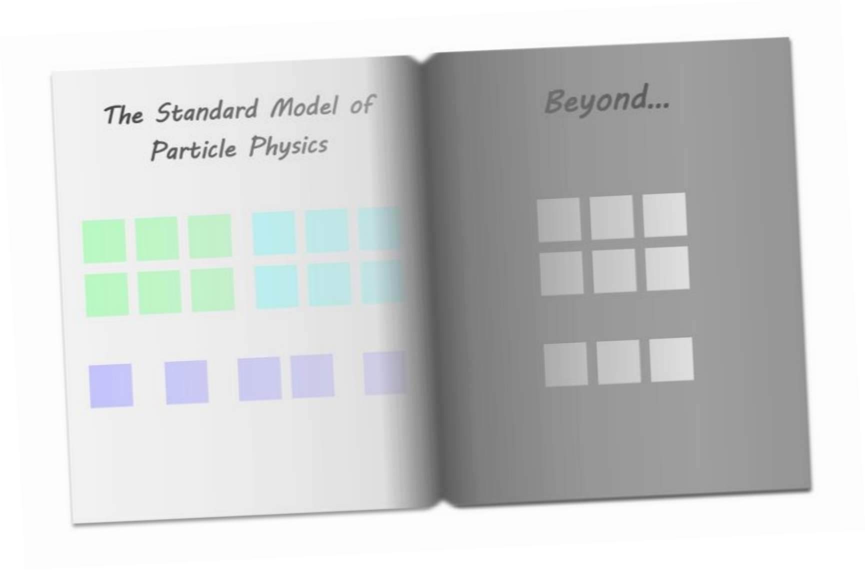
Nicoline Hemme

Collaborators: Elias Bernreuther, Felix Kahlhoefer and Suchita Kulkarni

Karlsruher Institut für Technologie

Strongly-interacting Dark Sector Phenomenology





The Standard Model consists of several elementary particles and types of interactions

→ It seems natural that **dark matter** may originate from a complex **dark sector**

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References: E. Bernreuther, F. Kahlhoefer, M. Krämer and P. Tunney (2020) and Snowmass 2021: E. Bernreuther, C. Doglioni, NH, S. Kulkarni et al

Invisibles23 Workshop, Göttingen University, August 28th - September 1st 2023

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Extend the Standard Model by an SU(N_d) gauge group

$$\mathcal{L} \supset -\frac{1}{4} F^a_{\mu\nu} F^{\mu\nu a} + \bar{q}_d i \not{D} q_d - \bar{q}_d M_q q_d$$

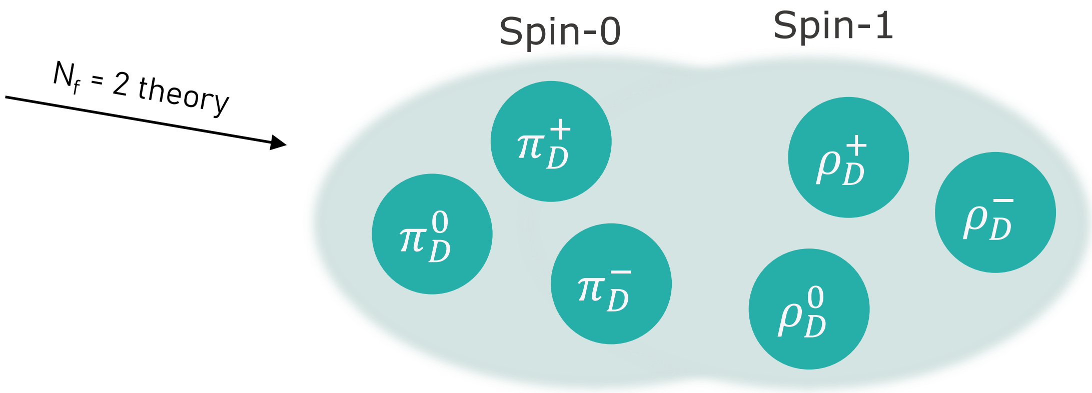
← You can consider other gauge groups, but make sure it exhibits asymptotic freedom and confinement

+ Add a portal to the Standard Model

$$\mathcal{L} \supset -g_d Z'_d \bar{q}_d Q \gamma^\mu q_d - Z'_d g_q \sum_{q_{SM}} \bar{q}_{SM} \gamma^\mu q_{SM}$$

← We consider a vector portal, but dark photon and Higgs portals among others are also very interesting

Ref: S. Knapen, J. Shelton and D. Xu (2021)



→ Dark hadrons (DM candidate) and dark showers (collider signatures)

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Collider Phenomenology – Dark Showers

What happens when we create a Z' boson in high-energy collisions?

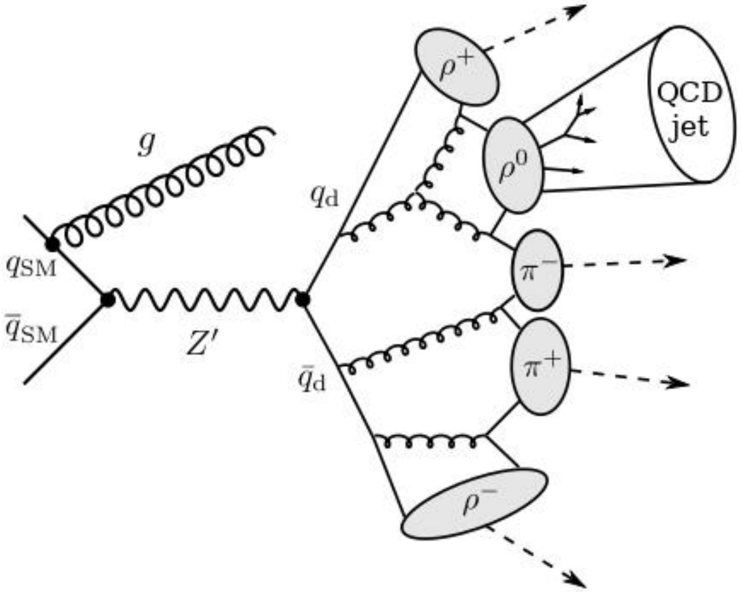
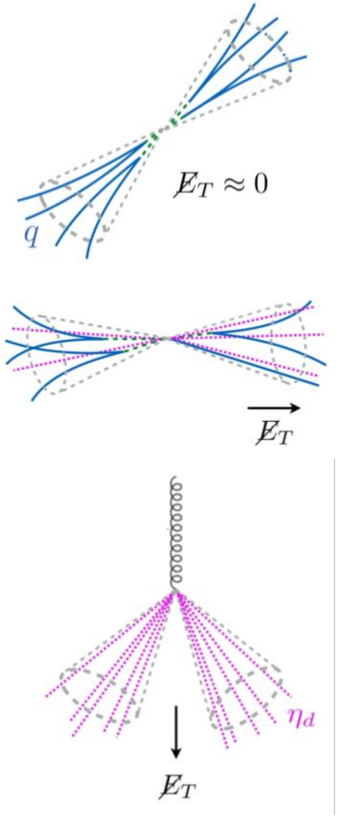


Figure: E. Bernreuther, F. Kahlhoefer, M. Krämer and P. Tunney (2020)



Visible shower
→ All dark hadrons decay to the SM
$r_{inv} \sim 0$

Semi-visible shower
→ Some dark hadrons decay to the SM
$0 < r_{inv} < 1$

Invisible shower
→ No dark hadrons decay to the SM
$r_{inv} \sim 1$

Figure: T. Cohen, M. Lisanti, H. K. Lou and S. Mishra-Sharma (2017)

$$r_{inv} = \frac{\#\ \text{Stable dark hadrons}}{\#\ \text{All dark hadrons}}$$

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Current work: **Study of a simplified strongly-interacting dark matter model that is consistent with cosmology and with the theoretical framework that has been established in the community**

Consistent with cosmology

We require that our model is able to reproduce the dark matter relic abundance (via thermal freeze-out)

A lot of the theory/work is based on Bernreuthers and Kahlhoefers previous work on this topic (arXiv:1907.04346)

Strongly interacting dark sectors in the early Universe and at the LHC through a simplified portal

Elias Bernreuther, Felix Kahlhoefer, Michael Krämer and Patrick Tunney

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Consistent with the community

This is a young field, and the community is making efforts towards benchmark models that can help motivate and guide experimental searches in the future

The Snowmass 2021 report was a large, joint community effort and we want to follow and promote the framework established in the report (arXiv:2203.09503)

Theory, phenomenology, and experimental avenues for dark showers: a Snowmass 2021 report

Guillaume Albouy[a], Jared Barron[h], Hugues Beauchesne[b], Elias Bernreuther[c], Marcella Bona[d], Cesare Cazzaniga[e], Cari Cesarotti[o], Timothy Cohen[f], Annapaola de Cosa[e], David Curtin[h], Zeynep Demiragli[aa], Caterina Doglioni[v,y], Alison Elliot[d], Karri Folan DiPetrillo[c], Florian Eble[e], Carlos Erice[aa], Chad Freer[z], Aran Garcia-Bellido[g], Caleb Gemmell[h], Marie-Hélène Genest[a,*], Giovanni Grilli di Cortona[i], Giuliano Gustavino[j], Nicoline Hemme[v], Tova Holmes[bb], Deepak Kar[x], Simon Knapen[k], Suchita Kulkarni[l,*], Luca Lavezzo[z], Steven Lowette[r], Benedikt Maier[j], Seán Mee[l], Stephen Mrenna[c], Jeremi Niedziela[e], Christos Papageorgakis[cc], Nukulsinh Parmar[g], Christoph Paus[z], Kevin Pedro[c], Ana Peixoto[a], Alexx Perloff[dd], Tilman Plehn[w], Christiane Scherb[m], Pedro Schwaller[m], Jessie Shelton[ee], Akanksha Singh[u], Sukanya Sinha[x], Torbjörn Sjöstrand[t], Aris G.B. Spourdalakis[h], Daniel Stolarski[n], Matthew J. Strassler[o], Andrii Usachov[p], Carlos Vázquez Sierra[j], Christopher B. Verhaaren[q] and Long Wang[cc]

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Thank you!

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