Close-out

James Frost
(james.frost@physics.ox.ac.uk)

Friday 17th May 2024

Roadmaps for Run-3

LHC Run-2 was a rich environment for collider dark matter searches. Huge broadening of programme (exp. and theory), 'leave no stone unturned'.
Successful targeting of benchmarks $\rightarrow$ need to evaluate, update, innovate for Run-3.
Roadmap of Dark Matter models for Run 3

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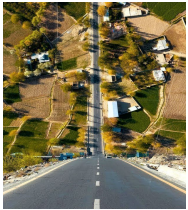

over-simplified

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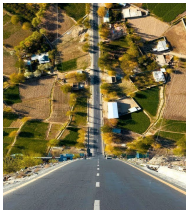

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worryingly wide resonances

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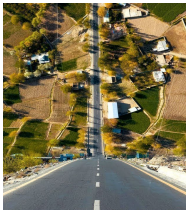


over-simplified

worryingly wide resonances

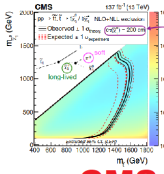
bad projection choice

- What new signatures, what new models, complementarity, perspectives

Monday - LLP - thanks Louie, Juliette & Dean

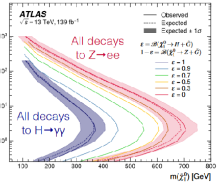
1. Freeze-in DM
2. Inelastic DM
3. Asymmetric DM
4. Draining the hidden sector
5. Composite/Rich Hidden Sectors
6. DM from Baryogenesis

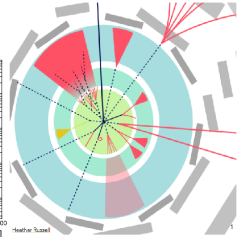
LLP searches are intimately connected to DM



CMS

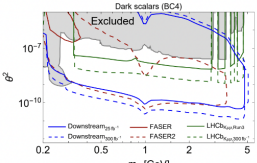
ATLAS

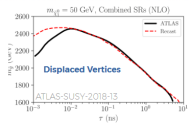


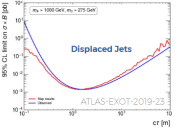


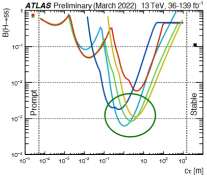
LHCb

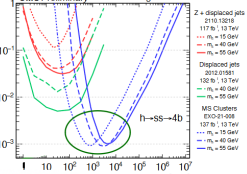
FASER





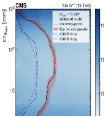


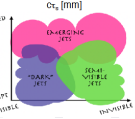




- *Recasting is an essential tool for finding gaps in coverage!*
- *For feebly coupled models the LHC may be the main tool for discovery!*

Emerging jets in CMS

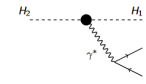




⇨ **Friday**

Tuesday am - Wildcards and New Ideas - thanks Giuliano, Alex & Monika

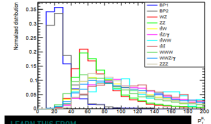
A smoking gun signature of 3HDM

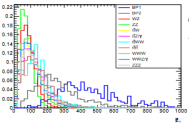


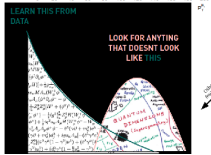
$gg \to h \to H_2 H_2 \to H_1 H_1 \gamma^* \to H_1 H_1 l^+ l^- l^+ l^-$.

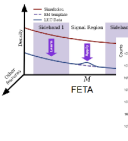
- We are looking for Benchmarks with small mass gap (Δm) between H_2 and H_1

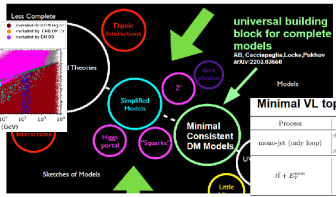
BPs	m_{H_1}	m_{H_2}	Δm	n	$\mathcal{B}_{H_2 H_1 h}$	θ_k	$\sigma(pp \to H_1 H_1 2\mu^+ 2\mu^-)$
$BP1: \frac{H_2}{H_1}$	50	55	5	0.83	0.01	0.105	6.923 *fb*
$BP2: \frac{H_2}{H_1}$	50	60	10	0.70	0.01	0.103	4.0 *fb*

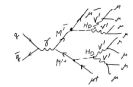




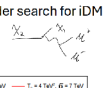




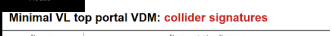
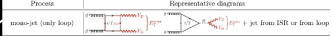
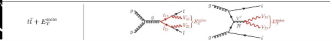


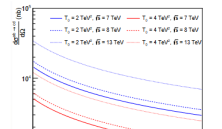


CMS did the first dedicated collider search for iDM

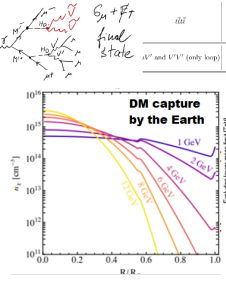


Minimal VL top portal VDM: collider signatures

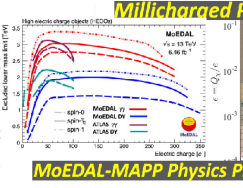
Process	Representative diagrams
mono-jet (only loop)	
$t\bar{t} + E_T^{miss}$	
$t\bar{t}t\bar{t}$	
$\mathcal{N}'$ and $V'V'$ (only loop)	

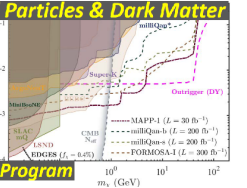


We considered production of Kaluza-Klein states from S^1 compactification of a $D-5$ theory.
The differential cross section exhibits forward peak.We devised bounds on cross section starting from general properties of S-matrix.



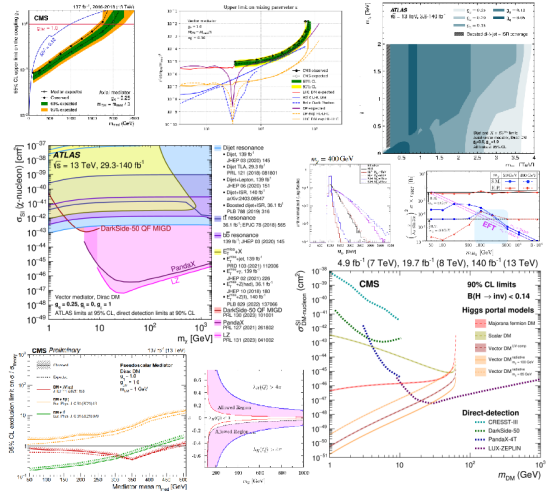
Millicharged Particles & Dark Matter



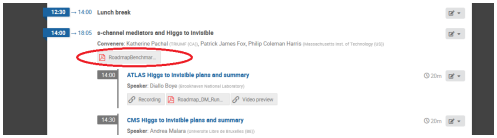


MoEDAL-MAPP Physics Program

Tuesday PM - S-channel Simplified Models - thanks Kate, Phil & Paddy

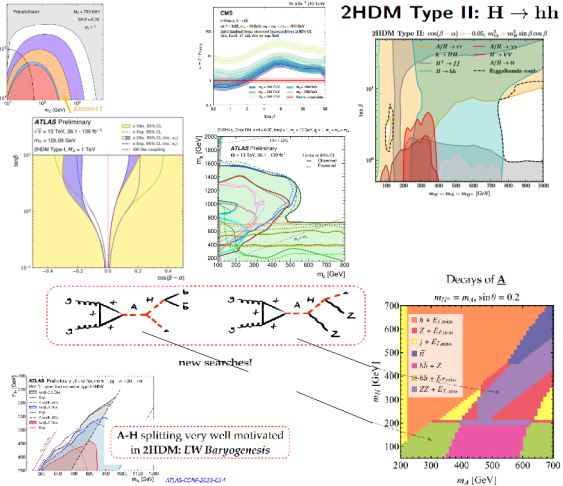


- Agenda: slides with discussion



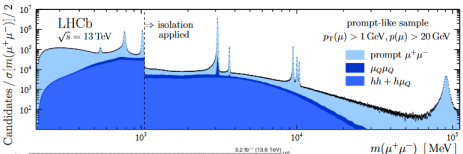
- Run-2 simplified models constrained → update
- Improved tools for coupling variation aid presentation.
- Complementarity with detection exp., light DM.
- Codify $h \to$ invisible completions.
- Discussion in future LHCDMWG meeting.
- Set of recommendations (benchmark parameters, interpretations)

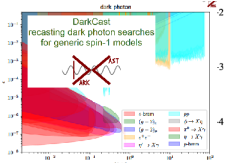
Wednesday am - Extended Higgs Sectors - thanks Priscilla & Uli

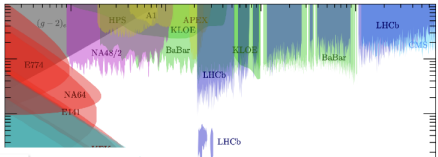


- General interest in looking beyond the assumptions/simplifications of the Run-2 WP benchmarks
- Type-I (Uli/Spyros/Ilia), mass degeneracies, alignment, low mass.
- Many additional signatures.
- Doc on agenda - to collate thoughts/questions ahead of a dedicated LHCDMWG meeting on this topic soon
- Scope for a WP effort - phenomenology work required.

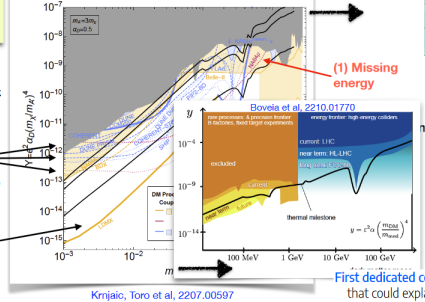
Wednesday pm - ~~Excursion~~ Dark Photon Models - thanks Zirui, Mike & Phil

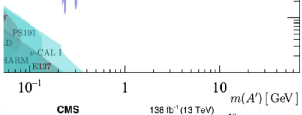




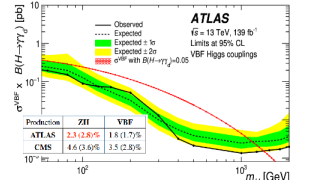


If $m_{A'} > 2m_{DM}$, the dark photon decays invisibly





- **Invisible** signatures can be interpreted in terms of invisible ALPs or invisible dark scalars
- Additional **visible** signatures coming from ALP, scalar, or sterile neutrino models



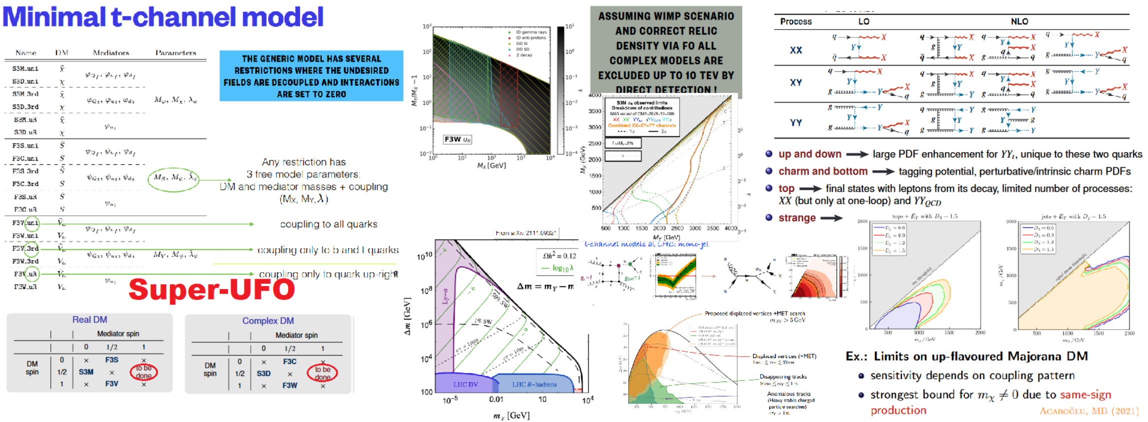
(2) Re-scattering (beam-dump)

(1) Missing momentum (fixed target)

Krnjaic, Toro et al, 2207.00597

First dedicated collider search for inelastic dark matter using Run 2 data that could explain the observed thermal-relic DM abundance in the universe

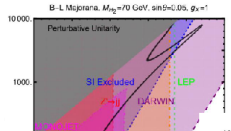
Thursday am - t-channel models - thanks Ben & Ben

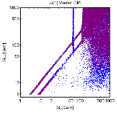


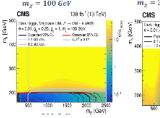
Minimal t-channel model
THE GENERIC MODEL HAS SEVERAL RESTRICTIONS WHERE THE UNDESIRED FIELDS ARE DECOUPLED AND INTERACTIONS ARE SET TO ZERO
Any restriction has 3 free model parameters: DM and mediator masses + coupling (Mx, MY, λ)
coupling to all quarks
coupling only to b and t quarks
coupling only to quark up-right
Super-UFO
Real DM
Complex DM
Mediator spin
DM spin
to be done
ASSUMING WIMP SCENARIO AND CORRECT RELIC DENSITY VIA FO ALL COMPLEX MODELS ARE EXCLUDED UP TO 10 TEV BY DIRECT DETECTION !
Process
LO
NLO
XX
XY
YY
up and down → large PDF enhancement for YY_t, unique to these two quarks
charm and bottom → tagging potential, perturbative/intrinsic charm PDFs
top → final states with leptons from its decay, limited number of processes: XX (but only at one-loop) and YY_{QCD}
strange →
Ex.: Limits on up-flavoured Majorana DM
sensitivity depends on coupling pattern
strongest bound for $m_\chi \neq 0$ due to same-sign production
Acaroğlu, MB (2021)
LHC DV
LHC R-hadrons
$\Delta m = m_Y - m$
m_χ [GeV]
Δm [GeV]

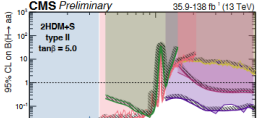
- DD bounds strong
- Ongoing white paper progressing (contributions mid-July), comprehensive signature set, extended scope - space for experimental contributors.
- Future ideas beyond WP in its outlook?

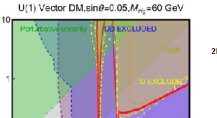
Thursday pm - dark Higgs models thanks Matteo & Felix

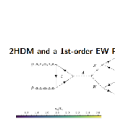


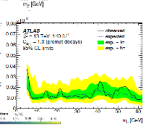


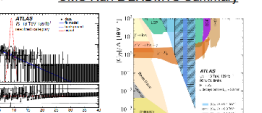


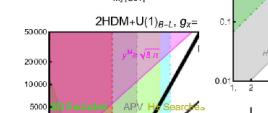


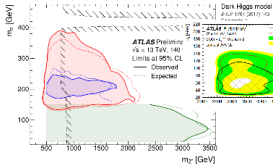


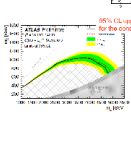


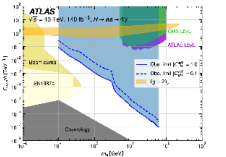






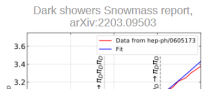




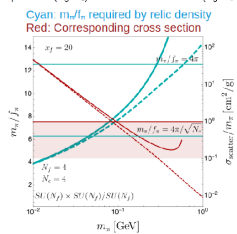


Understand signatures, constraints ($Z' \to qq, \ell\ell$).
higher m_χ, meet RD, m_S range, inelastic DM.
Short benchmark study/WP.

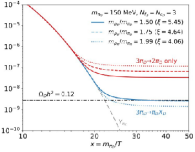
Friday am - strongly interacting dark sectors - thanks Sukanya, Suchita & Annapaola

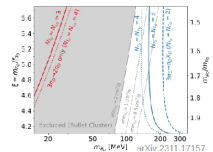


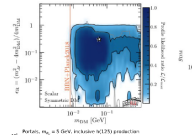
Low-energy pheno determined by one dimensionful parameter (e.g. m_π) and one dimensionless ratio (e.g. $m_{\rm inel}/m_\pi$)

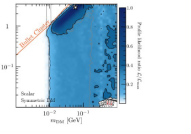


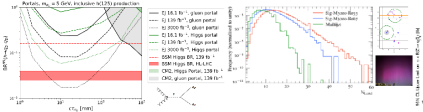
Including the process $3\pi_d \to \pi_d + \rho_d$ enhances annihilation rate by orders of magnitude
Freeze-out delayed, larger masses viable, Bullet Cluster constraint can be evaded

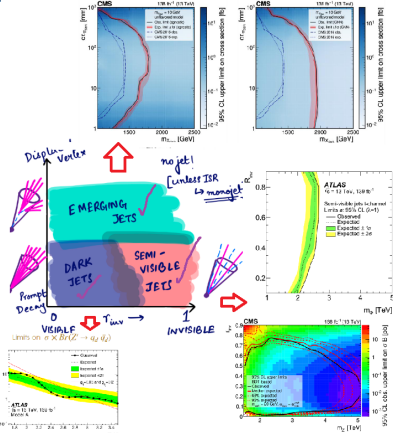












- Huge interest and range of theoretical and phenomenological questions.

Thank you all for coming/listening, Safe Journeys Home

- **Thankyou all for coming, presenting, discussing dark matter with us!**
- Thanks Zirui (CERN resident, cameraman, access card supremo, dinner organiser, many more roles)
- Hope everyone found the meeting enjoyable and interesting.
- Stay tuned for further LHCDMWG meetings/discussion and opportunities!
- To coverge into Run-3 benchmarks/recommendations - meetings & dedicated WP kick-offs to come (for Run-3).