

# PERTURBATIVE BENCHMARKS FOR DARK SHOWERS

SM, S. SHELTON, D. XU: 2013.01238

"SIMPLIFIED MODELS" FOR

DARK SHOWERS? IS IT POSSIBLE?

STEP 1: DEFINE SCOPE

STEP 2: WHAT IS THE "SIGNATURE SPACE"?

STEP 3: DEFINE MINIMAL SET OF MODELS

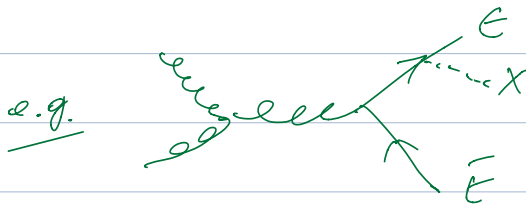
EXAMPLE: DARK MATTER

STEP 1: MUST CONTAIN SOMETHING DARK  
(MET)

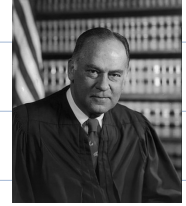
STEP 2: MET + ASSOCIATED OBJECT(S)  
( $\chi, Z, W, \text{JETS}, h, \dots$ )  
 $\Rightarrow P_T$

TRIGGER ON MET OR OTHER OBJECT

STEP 3: CLASSIFY ACCORDING TO PRODUCTION



# FOR DARK SHOWERS

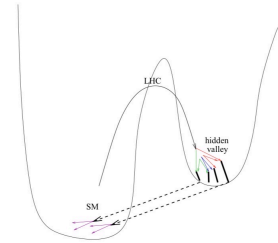


## STEP 1: WHAT IS IT?

- 1) "I KNOW IT WHEN I SEE IT!" @ STEWARD 1964
- 2) HIGH MULTIPLICITY? HOW MUCH IS "HIGH"?
- 3) HIDDEN VALLEY MODELS

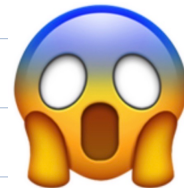
(STRASSLER & ZUREK 0604261)

SOME TYPE OF STRONG DYNAMICS GOING ON.



## STEP 2: SIGNATURE SPACE

- DISPLACEMENT? MULTIPLE DISPLACED SPECIES?
- MULTIPLICITY?
- $R_F$ ? WHOSE  $R_T$ ?
- MET FRACTION?
- ISOLATION, JET SHAPES?
- FLAVOR COMPOSITION?
- ASSOCIATED OBJECTS?



## STEP 3: MODELS



→ ONLY HANDFUL ARE CALCULABLE

→ ONLY 2 MC IMPLEMENTATIONS

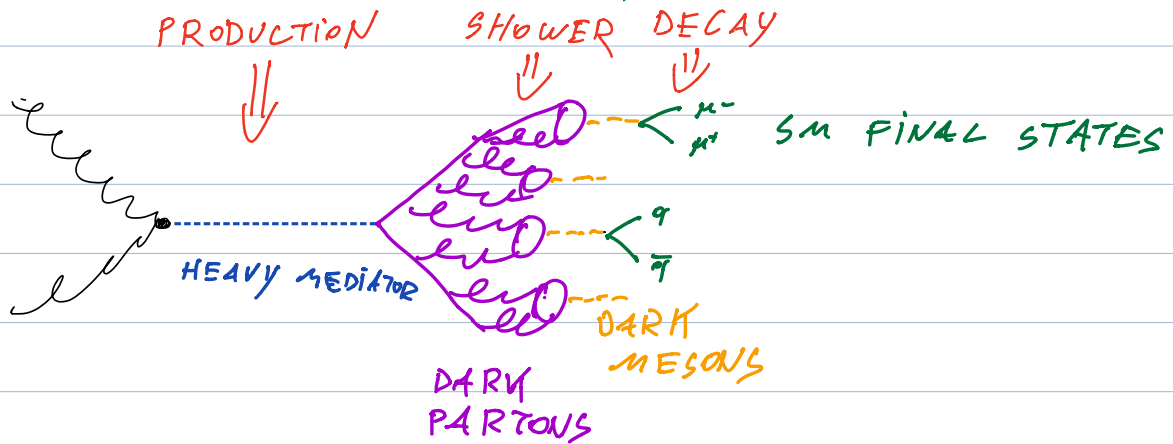
VERY DIFFERENT FROM e.g. SUSY!

ATM, I DON'T THINK THIS IS REALISTIC...

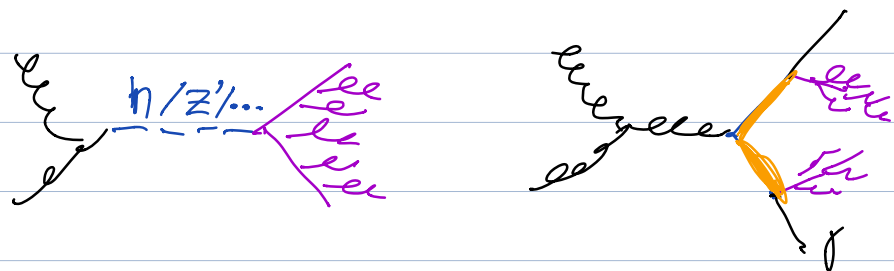
ALTERNATIVE : INCOMPLETE BUT EXTENDABLE  
 SET OF BENCHMARKS WHICH  
 COVER QUALITATIVELY DIFFERENT  
 PHENO

⇒ INJECT SOME THEORY  
 PRIORS

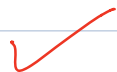
DARK SHOWER TOPOLOGY

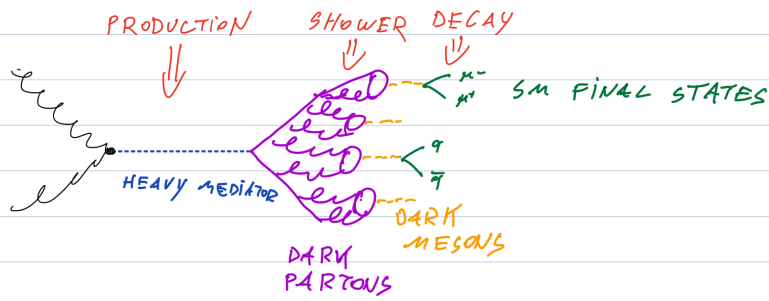


PRODUCTION : S-CHANNEL ASSOCIATED OBJECTS



MOST "INCLUSIVE"

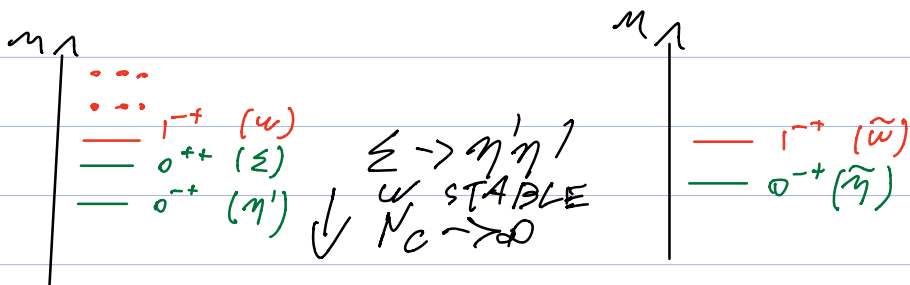




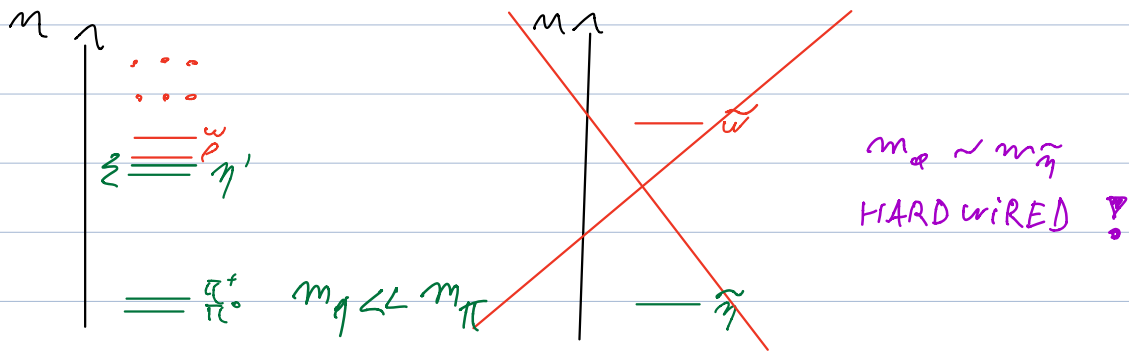
SHOWER: USE PYTHIA 8 MODULE  
 ⇒ NOT REPRESENTATIVE OF REAL MODEL.

EXAMPLE 1:  $N_F = 1$  QCD

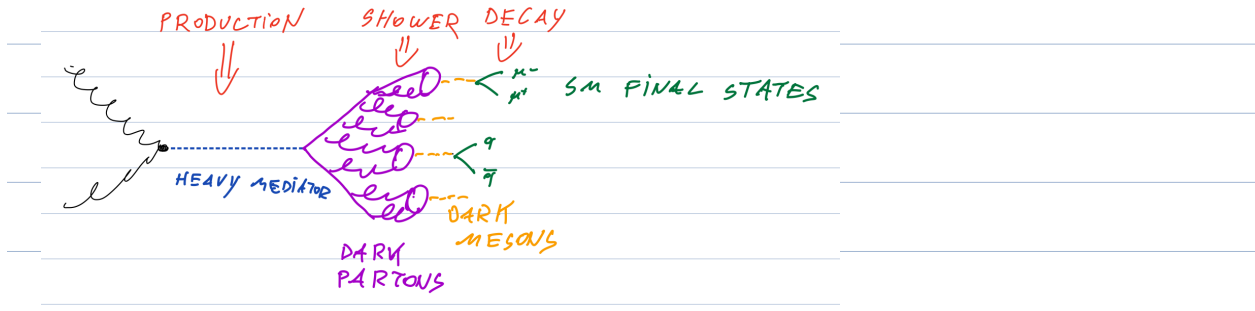
PYTHIA



EXAMPLE 2:  $N_F = 2$  QCD



WE ASSUME :  $m_{\eta'} \sim m_{\omega}$   
 AND ALLOW  $W \rightarrow 2\eta'$



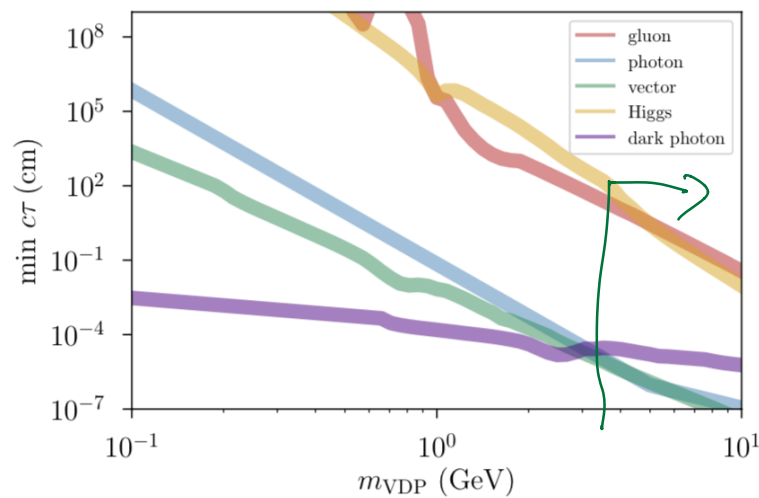
DECAY:

- AVOID FLAVOR VIOLATION
- AVOID ANOMALOUS GAUGE BOSONS

Decay portal	decay operator	VDP	other dark hadron	features	section
A. gluon portal	$\tilde{\eta} G^{\mu\nu} \tilde{G}_{\mu\nu}$	$\tilde{\eta}$	$\tilde{\omega}$ stable or $\tilde{\omega} \rightarrow \tilde{\eta}\tilde{\eta}$	hadron-rich shower	III A
B. photon portal	$\tilde{\eta} F^{\mu\nu} \tilde{F}_{\mu\nu}$	$\tilde{\eta}$	$\tilde{\omega}$ stable or $\tilde{\omega} \rightarrow \tilde{\eta}\tilde{\eta}$	photon shower	III B
C. vector portal	$\tilde{\omega}^{\mu\nu} F_{\mu\nu}$	$\tilde{\omega}$	$\tilde{\eta}$ stable	semi-visible jet	III C
D. Higgs portal	$\tilde{\eta} H^\dagger H$	$\tilde{\eta}$	$\tilde{\omega}$ stable or $\tilde{\omega} \rightarrow \tilde{\eta}\tilde{\eta}$	heavy flavor-rich shower	III D
E. dark photon portal	$\tilde{\eta} F'^{\mu\nu} \tilde{F}'_{\mu\nu} + \epsilon F'^{\mu\nu} F_{\mu\nu}$	$A'$	$\tilde{\omega}$ stable or $\tilde{\omega} \rightarrow \tilde{\eta}\tilde{\eta}$	lepton-rich shower	III E

- PAY ATTENTION TO LIFETIME

$\Rightarrow$  ALMOST ALWAYS NEW MEDIATOR NEEDED.  $\Rightarrow$  LOWER BOUND ON  $c\tau$



EXAMPLE: HIGGS PORTAL

$\mathcal{L} \supset A \tilde{\eta} \dagger H \Rightarrow$  CONSISTENT MODEL,  $H^\dagger H$  WILL ALSO GIVE MASS TO QUARKS

$\Rightarrow$  EITHER TUNE OR ACCEPT UPPER BOUND ON  $A$

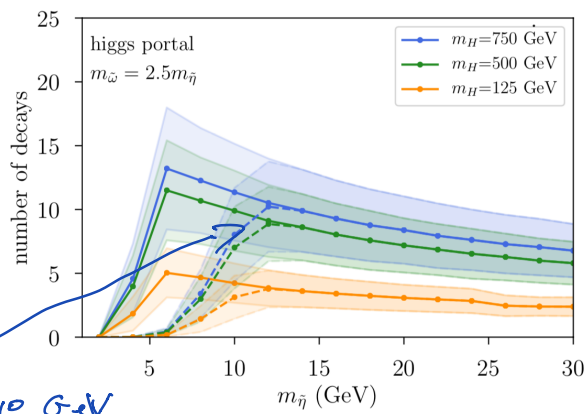
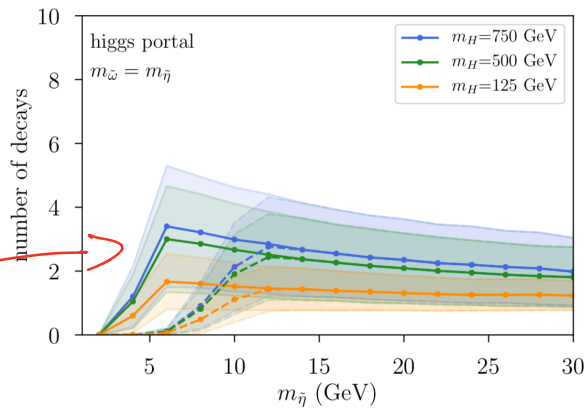
$\Rightarrow$  UPPER BOUND ON  $c\tau_{\tilde{\eta}}$

$c\tau \gg 1m$

$\Downarrow$

SINGLE DV SEARCH MORE APPROPRIATE

No "PROMPT" DARK SHOWER FOR  $m_{\tilde{\eta}} \ll 10$  GeV (UNLESS you TUNE)



# TOOL TO WRITE PYTHIA CARDS:

The screenshot shows the GitLab interface for the repository 'dark\_showers\_tool'. The repository is located at 'Project ID: 24119940' and has 10 commits, 1 branch, 0 tags, 758 KB files, and 758 KB storage. The description is 'tool to generate pythia 8 configuration cards for dark shower models'. The current branch is 'master' and the repository is named 'dark\_showers\_tool'. There are buttons for 'History', 'Find file', 'Download', and 'Clone'. A comment by Simon Knapien is visible, mentioning a typo in comments. The repository has a README file and no license. A table lists the files and their last commit details. The README content is also visible, including the title 'dark\_showers\_tool', a description, requirements (python 3.6 or higher, scipy, numpy), and included files (dark\_shower.py, data, dark\_showers\_demo.ipynb, test.cmnd).

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**dark\_showers\_tool** Project ID: 24119940 ★ Star 0

10 Commits 1 Branch 0 Tags 758 KB Files 758 KB Storage

tool to generate pythia 8 configuration cards for dark shower models

master dark\_showers\_tool History Find file Download Clone

**typo in comments** Simon Knapien authored 3 weeks ago 8b9779f3

README No license. All rights reserved

Name	Last commit	Last update
data	data folders	1 month ago
.gitignore	add example output	1 month ago
README.md	Update README.md	1 month ago
dark_shower.py	typo in comments	3 weeks ago
dark_showers_demo.ipynb	initial commit	1 month ago
test.cmnd	add example output	1 month ago

README.md

## dark\_showers\_tool

Tool to generate pythia 8 configuration cards for dark shower models. See arXiv xxxx.xxxx for a description of the models and assumptions.

### Requirements

- python 3.6 or higher
- scipy
- numpy

### Included

- dark\_shower.py : python package
- data: folder containing lifetime grids which are interpolated by dark\_shower.py
- dark\_showers\_demo.ipynb: example jupyter notebook, which serves as a short tutorial
- test.cmnd: example pythia 8 configuration file as generated with dark\_shower.py

### functionality

QUESTIONS ?

