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Collider phenomenology of Hidden Valley models with semivisible jets

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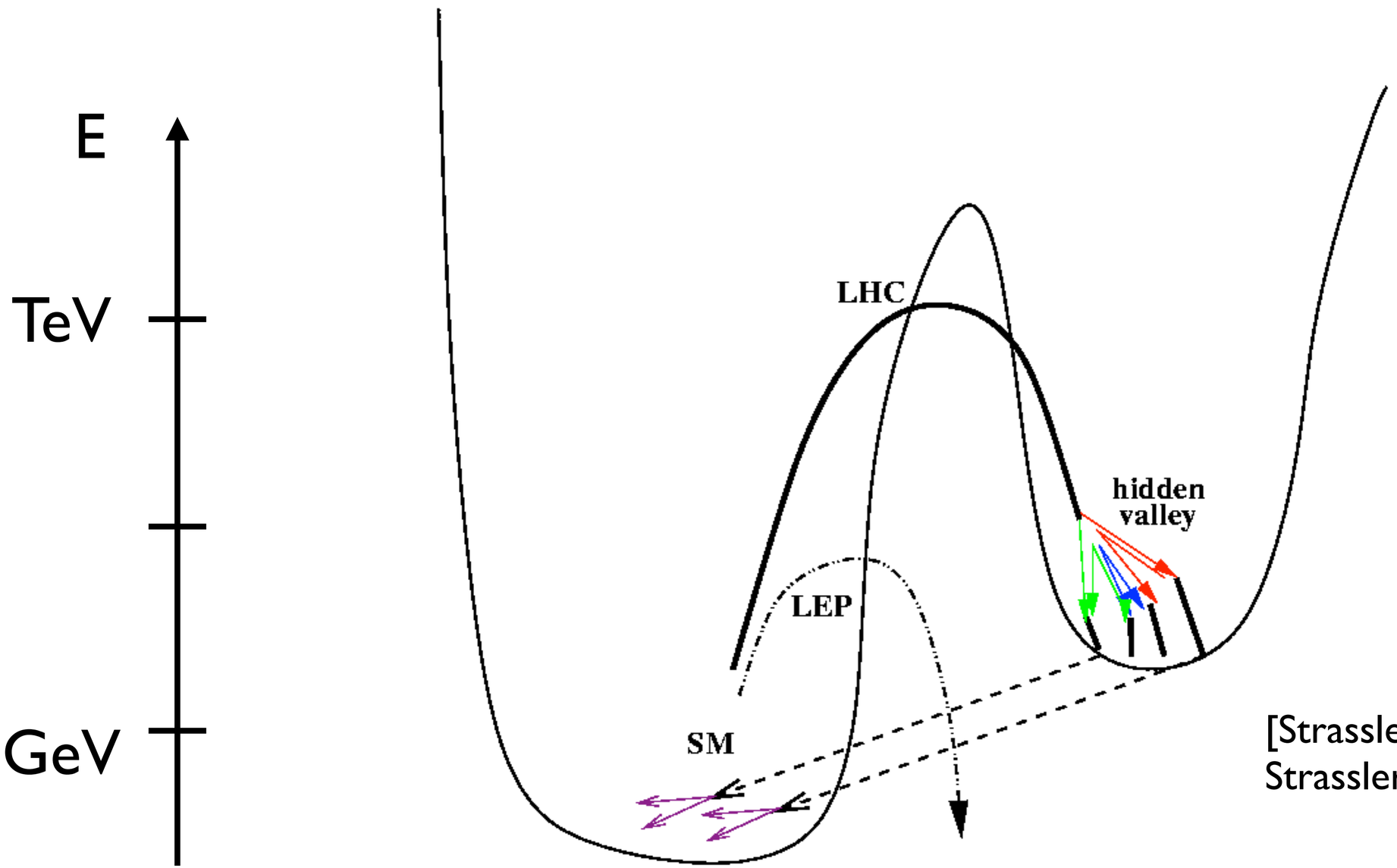
based on: H. Beauchesne, E. Bertuzzo, GGdC and Z. Tabrizi
arXiv:1712.07160, accepted by JHEP

SUSY - 26/07/2018

Motivation



[Strassler, Zurek '06, Strassler '08]

Motivation

Spin one mediators are very well studied.

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Chan et al. '11, …,
Cohen et al. '15, '17, …]

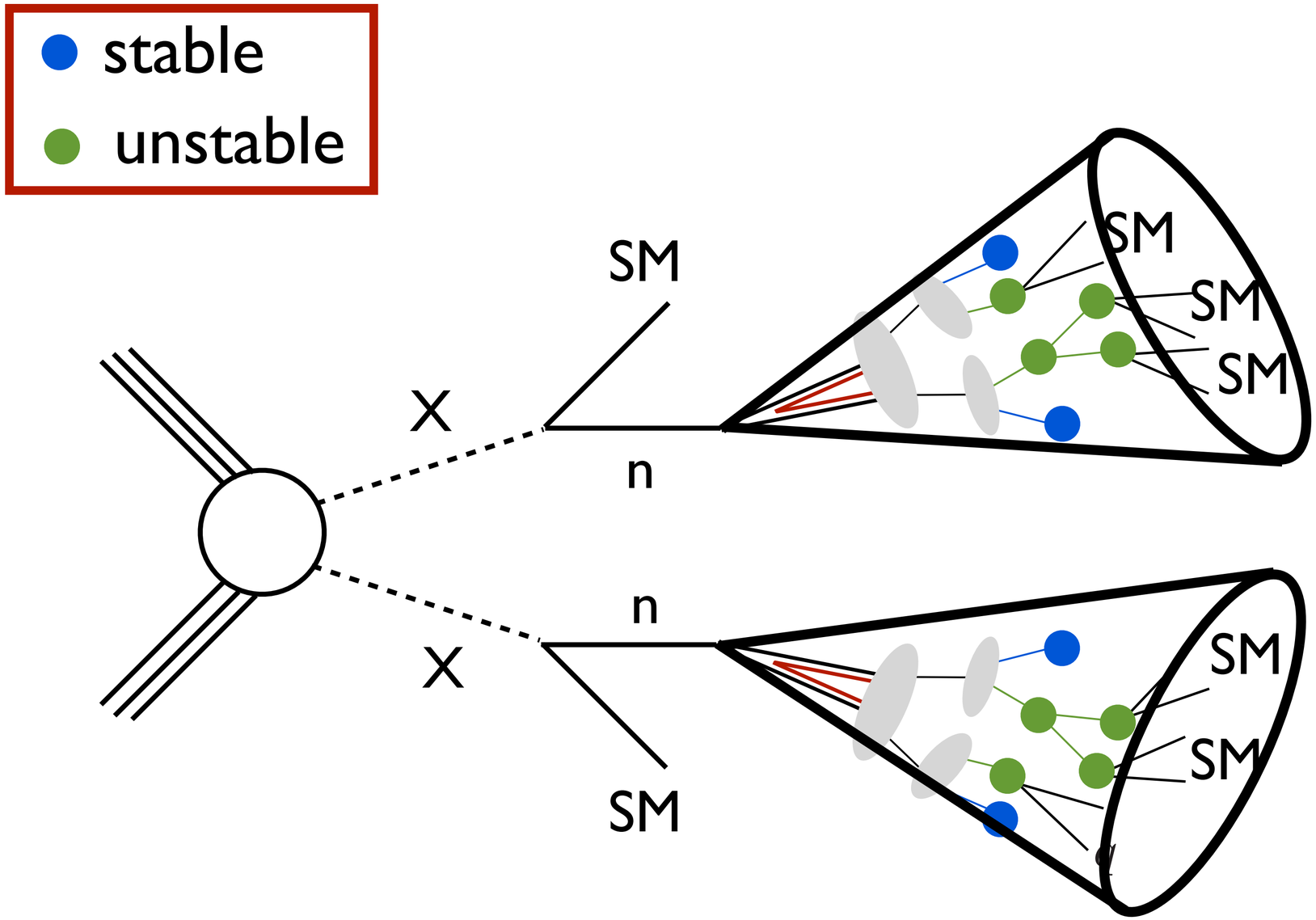
Spin 0 and 1/2 mediators well motivated:

Twin Higgs UV completions [Chacko et al. '05]

Folded SUSY [Burdman et al. '06]

Relaxion [Graham et al. '15]

Signatures



Signatures

Stable dark hadrons on collider scales

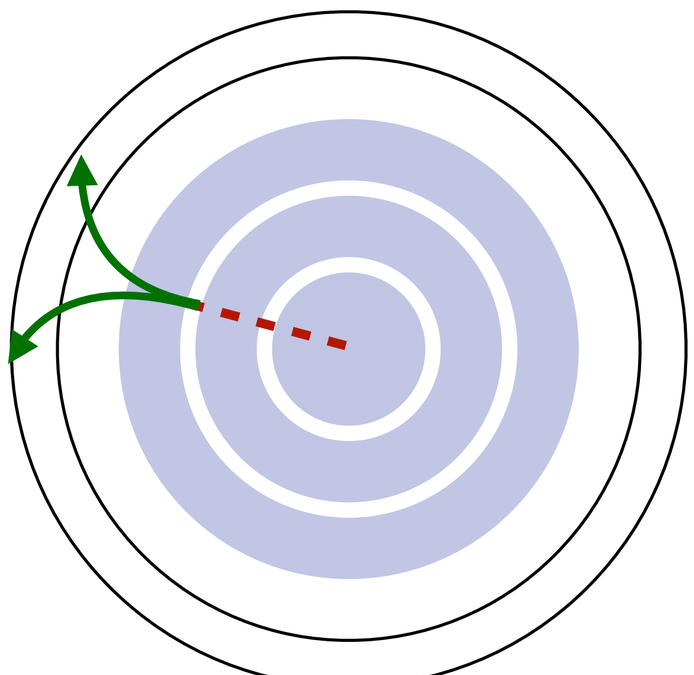
Dark hadrons leads to MET:
SUSY with R-parity searches

Signatures

Dark hadrons decaying inside the detector

[CMS-EXO-16-003, CMS-PAS-EXO-17-018,
ATLAS-SUSY-2016-08, ATLAS-PUB-2017-014]

Displaced vertices



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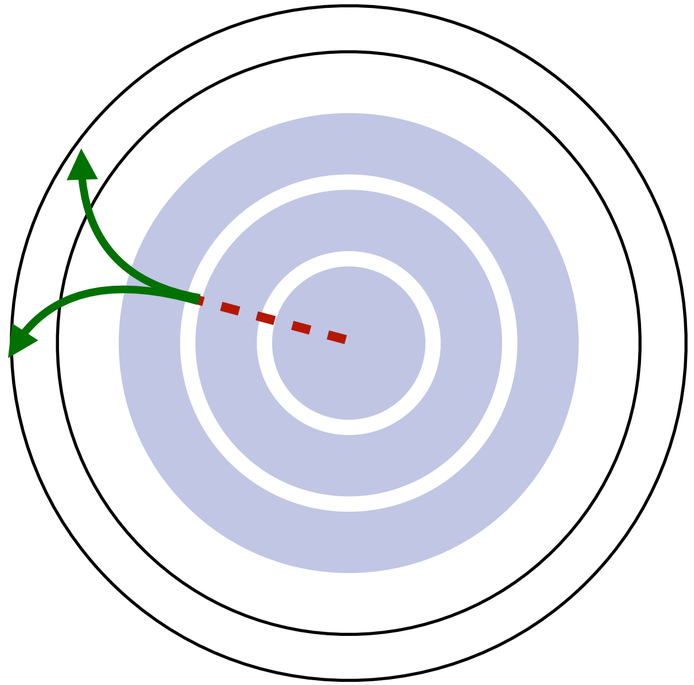
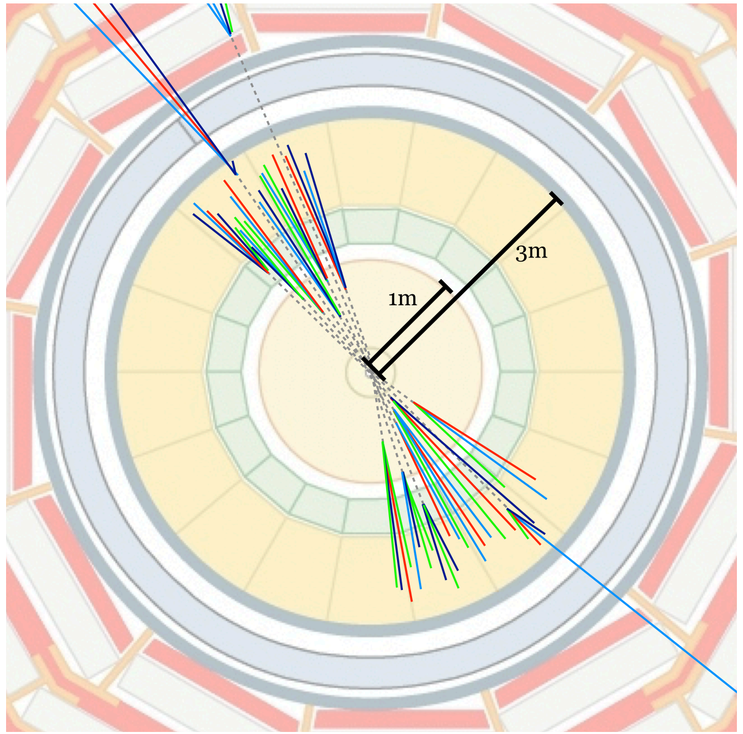


[Schwaller et al. '15, CMS-EXO-18-001]

Emerging jets

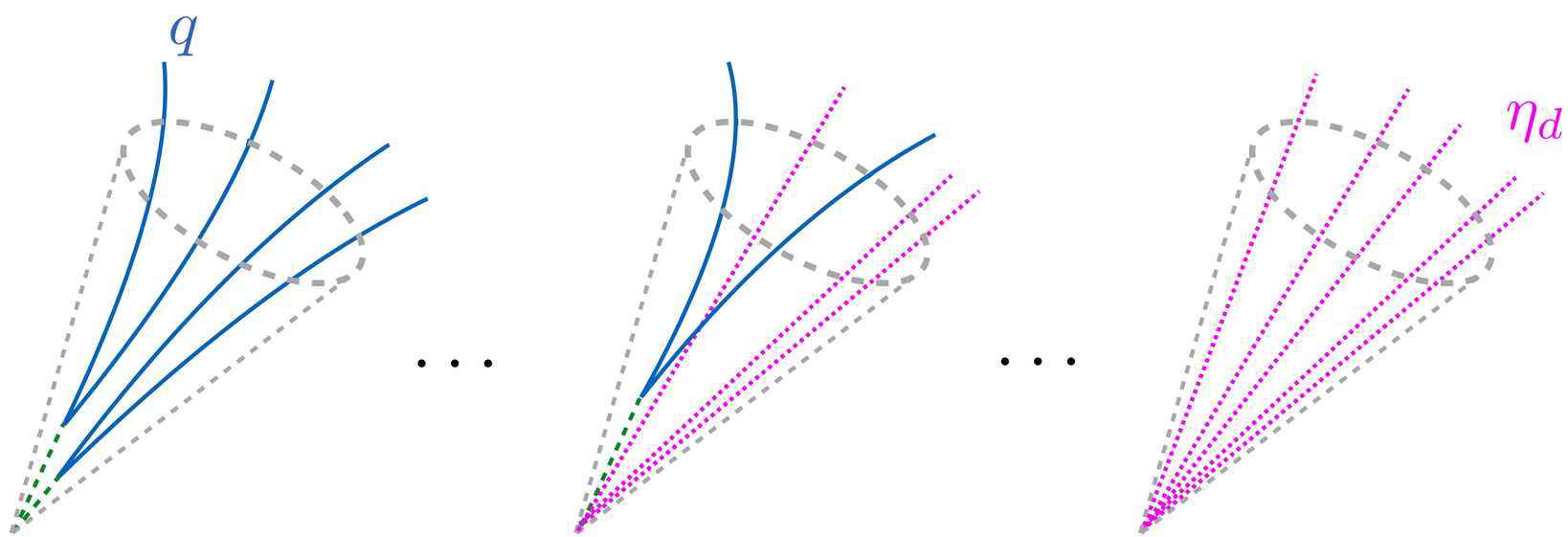


Signatures

Dark hadrons decaying promptly

[Cohen et al. '15, Cohen et al. '17]

Semivisible jets



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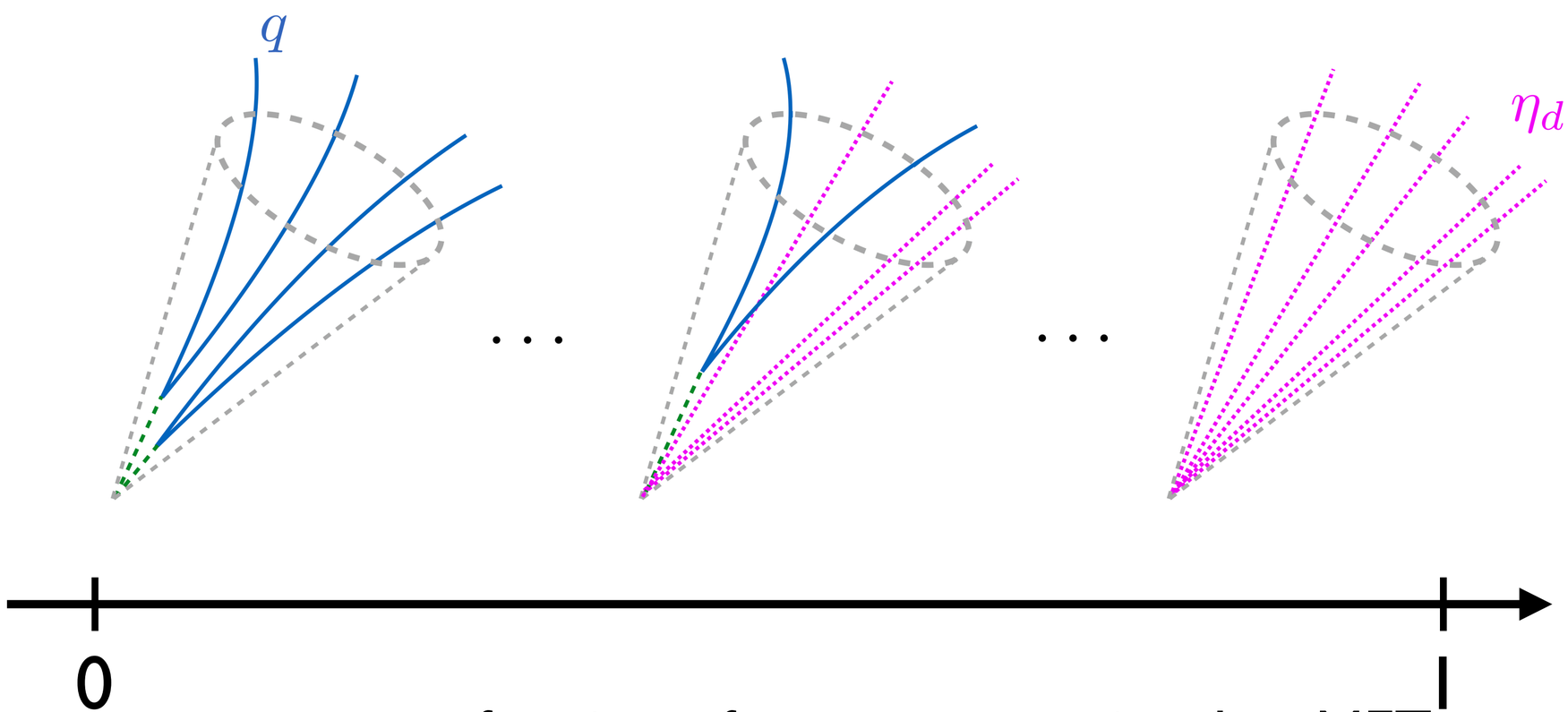
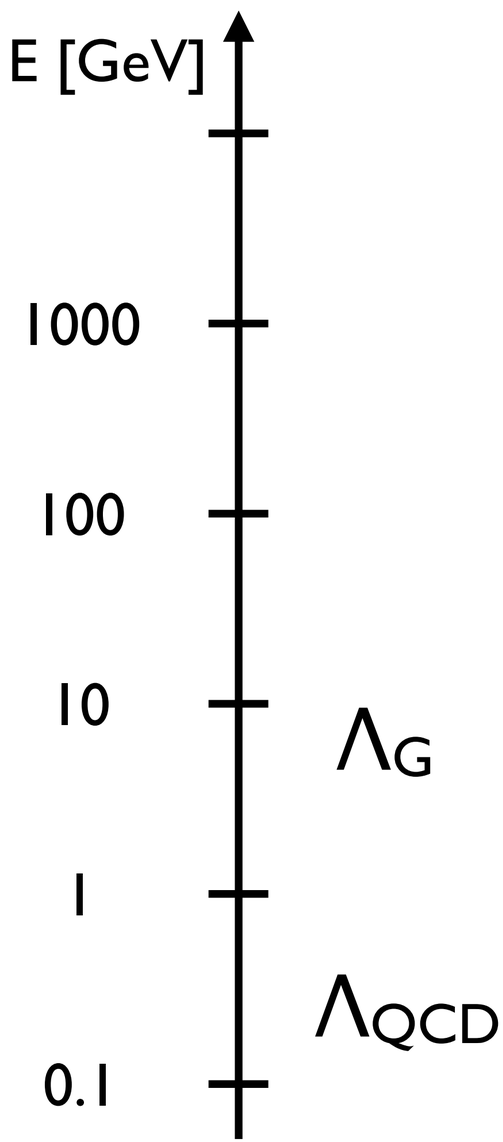
Semivisible jets



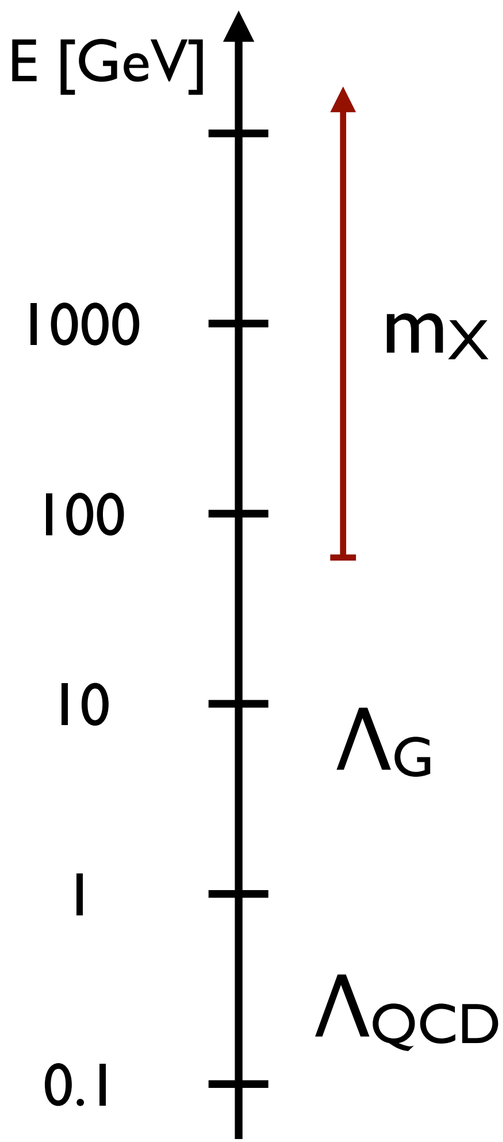
General setup



Assumptions:

1) new confining group G with confinement scale $\Lambda_G > \Lambda_{QCD}$;

General setup



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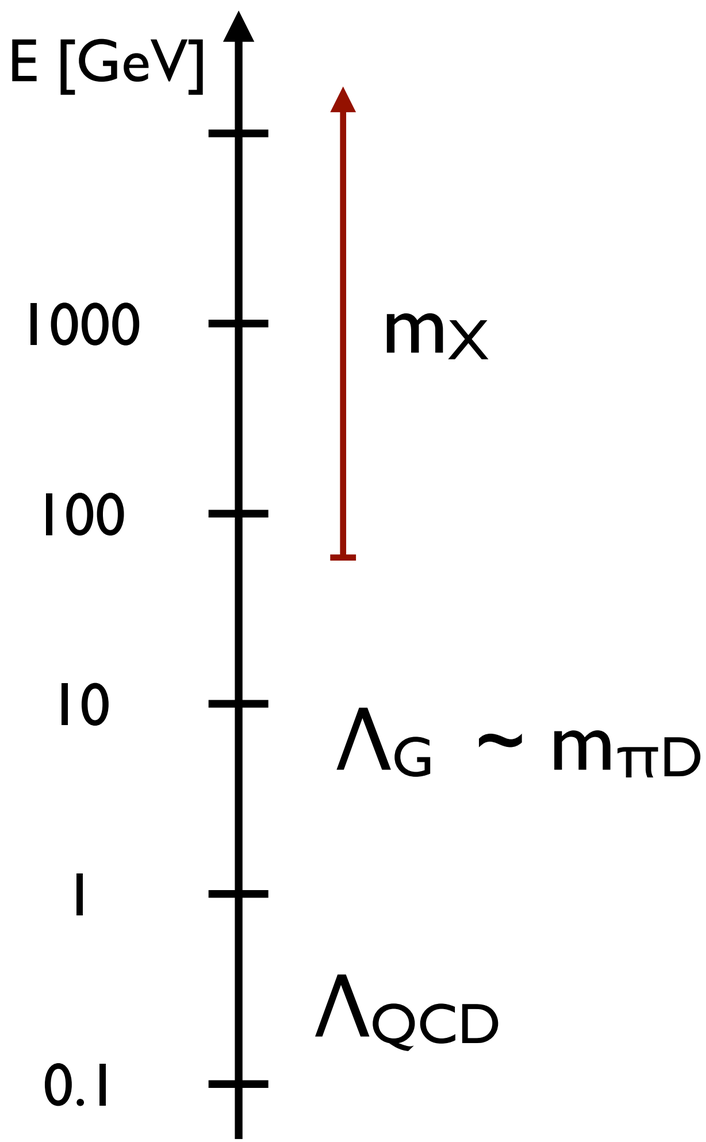


Assumptions:

1) new confining group G with confinement scale $\Lambda_G > \Lambda_{QCD}$;

2) one mediator X (scalar or fermion), charged under G and G_{SM};

3) dark (s)quark n charged only under G.

Explicit breaking operators

scalar or fermion

L_i, E_i

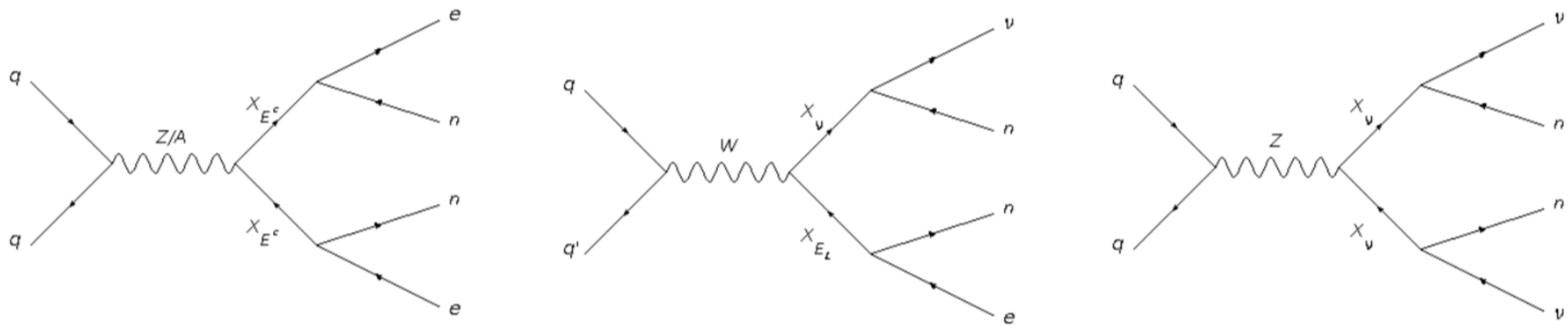
dark quark

$$\lambda\, n^\dagger \bar{X} P_{L/R} \Psi + \text{h.c.}$$

coupling **mediator**

fermion or scalar

Phenomenology

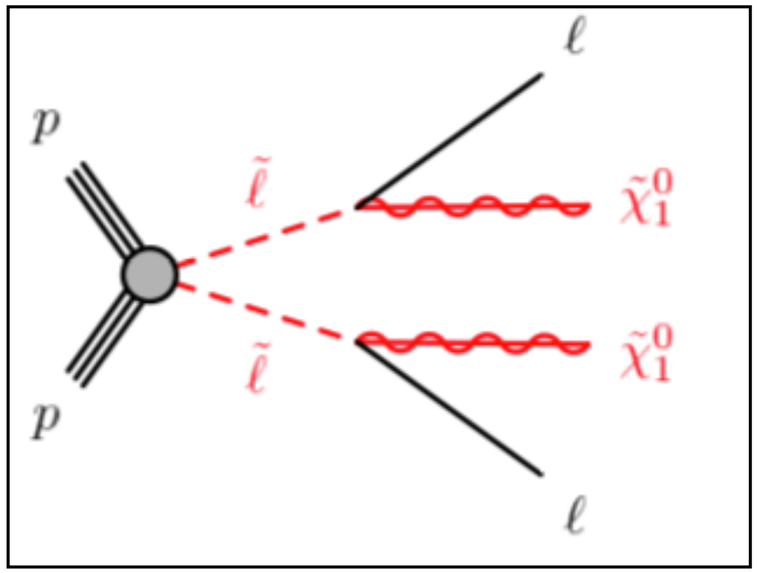


Possible signatures:

1) 2 charged leptons, 2 semivisible jets and MET
2) 1 charged lepton, 2 semivisible jets and more MET
3) 0 charged leptons, 2 semivisible jets and even more MET

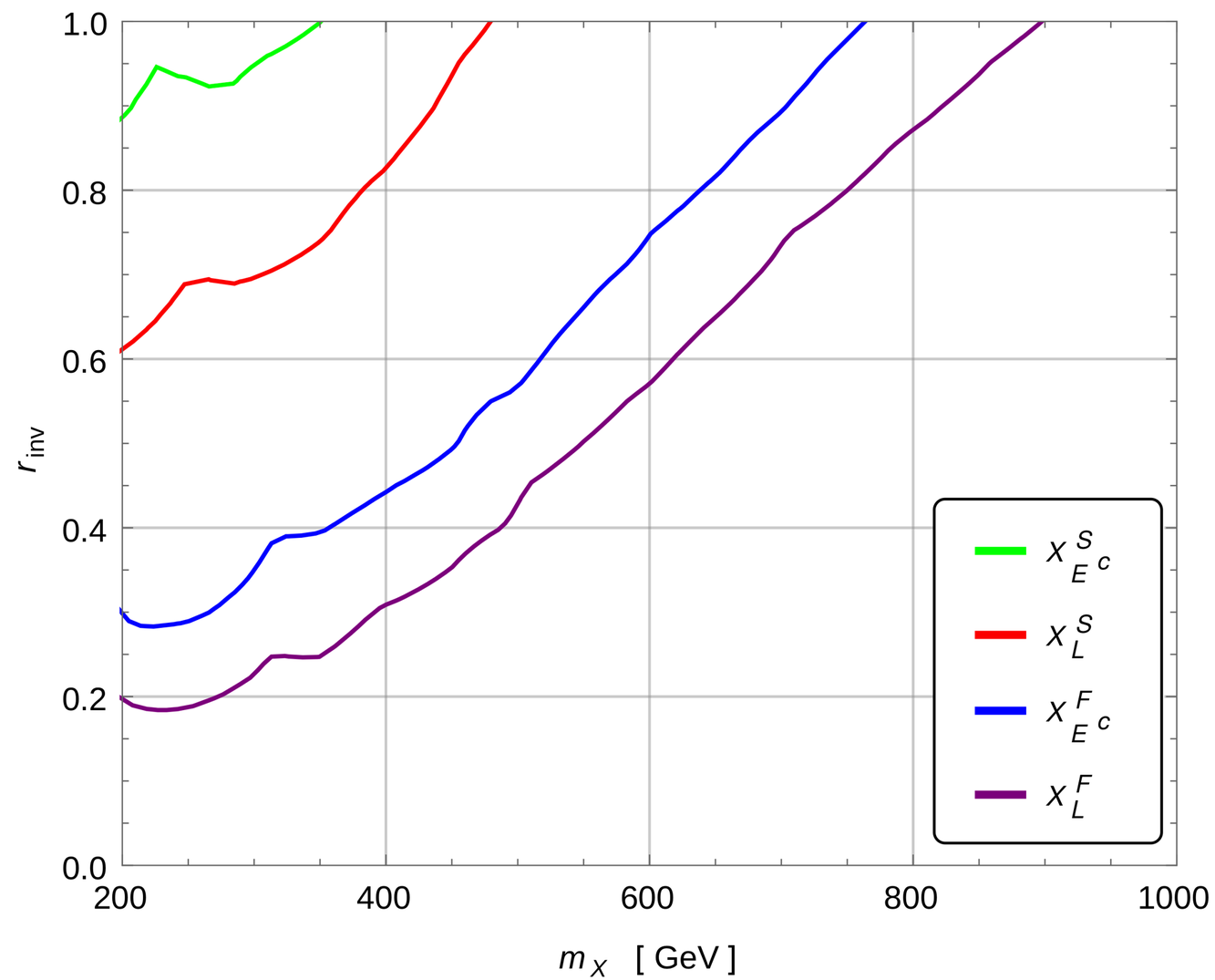
Phenomenology

Large r_{inv}: first two generations



[ATLAS-CONF-2017-039] 13 TeV, 36 fb^{-1}

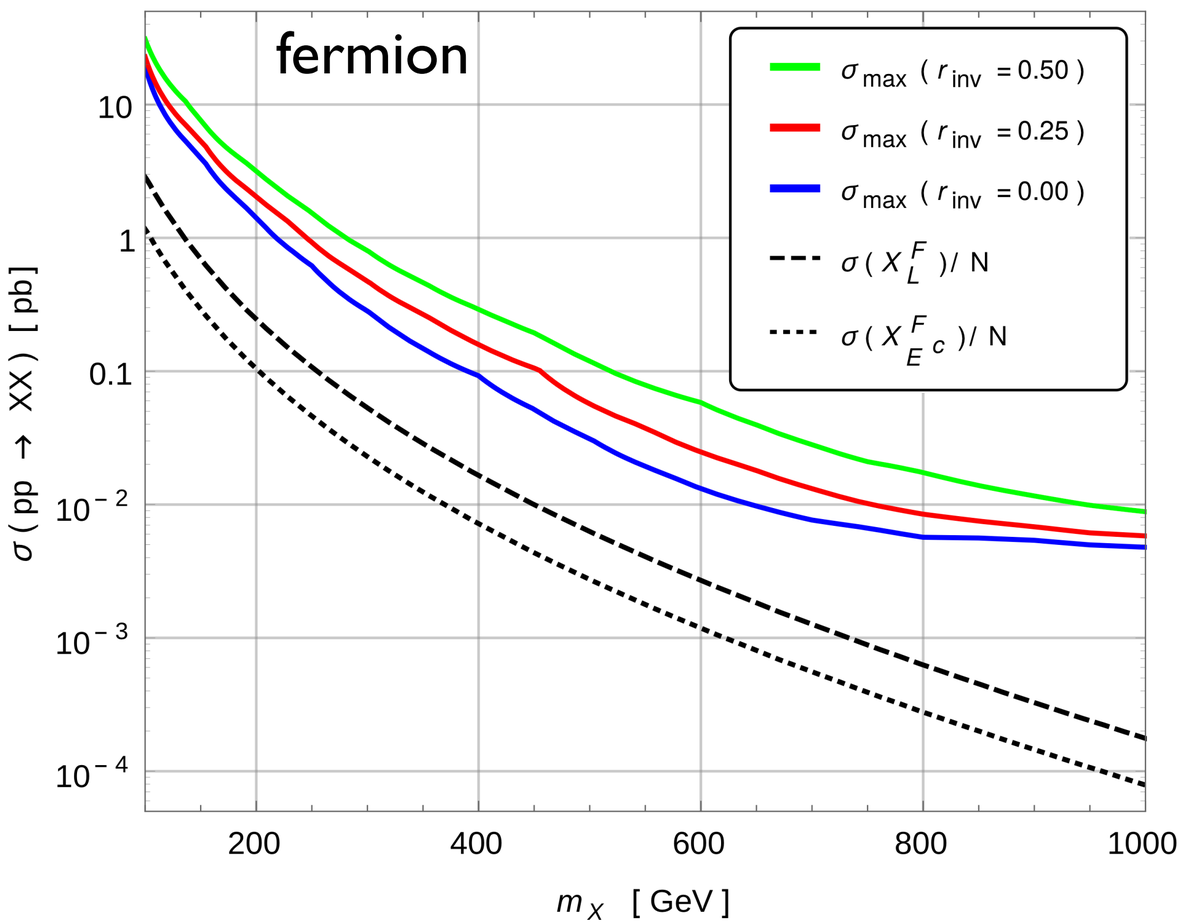
2 same flavour leptons + jet veto

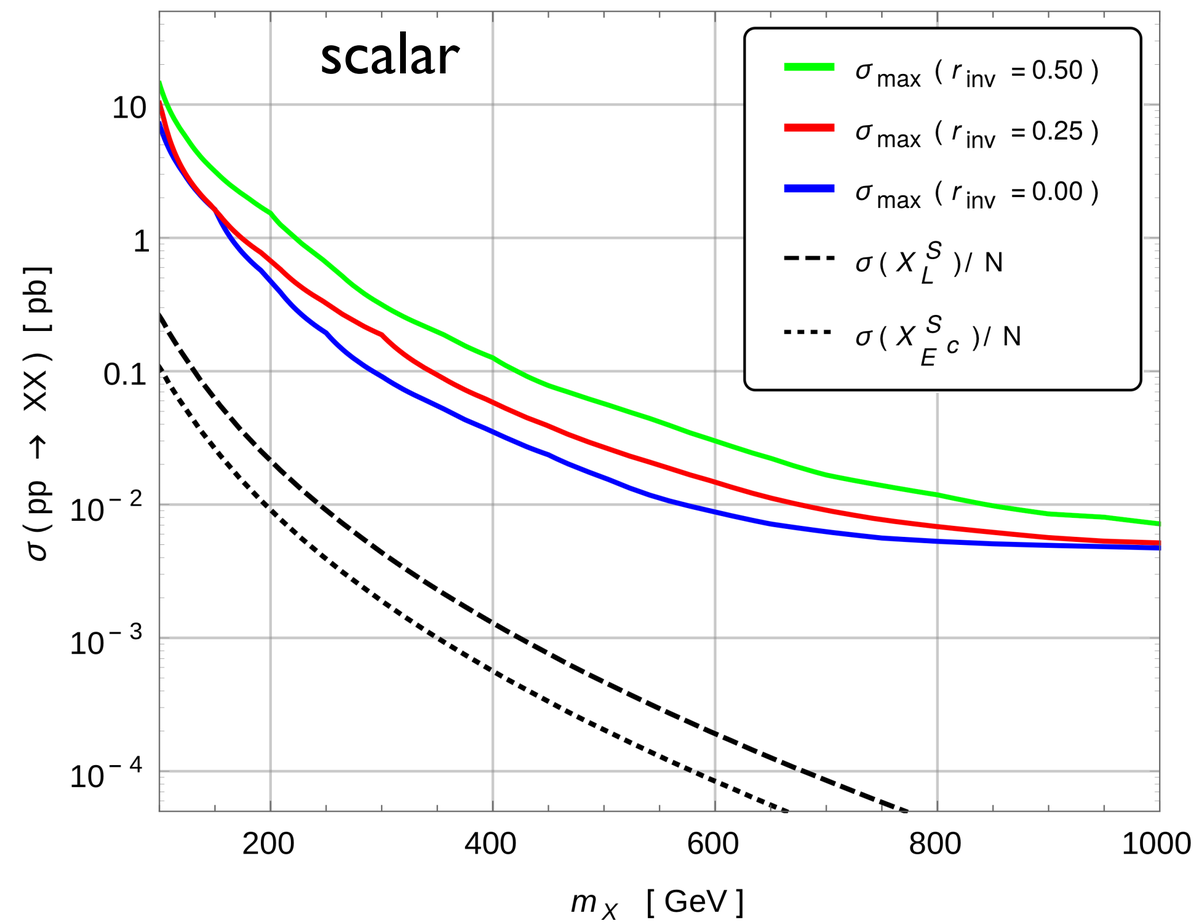


Phenomenology

Small r_{inv}

[CMS-PAS-EXO-16-043], 13 TeV, 2.6 fb^{-1}, requires 2 electrons and > 1 jet





Phenomenology

Small r_{inv}

[Opal collaboration, hep-ex/0305053], 595 pb^{-1} at (189-208) GeV

$r_{inv}=0$

Mediator	Generation	$SU(2)$ [GeV]	$SU(3)$ [GeV]	$SU(4)$ [GeV]
X_L^F	1	104	104	104
	2	104	104	104
	3	103	104	104
$X_{E^c}^F$	1	103	104	104
	2	104	104	104
	3	103	103	104
X_L^S	1	93	95	96
	2	98	99	100
	3	91	93	95
$X_{E^c}^S$	1	93	95	96
	2	98	99	100
	3	90	93	94

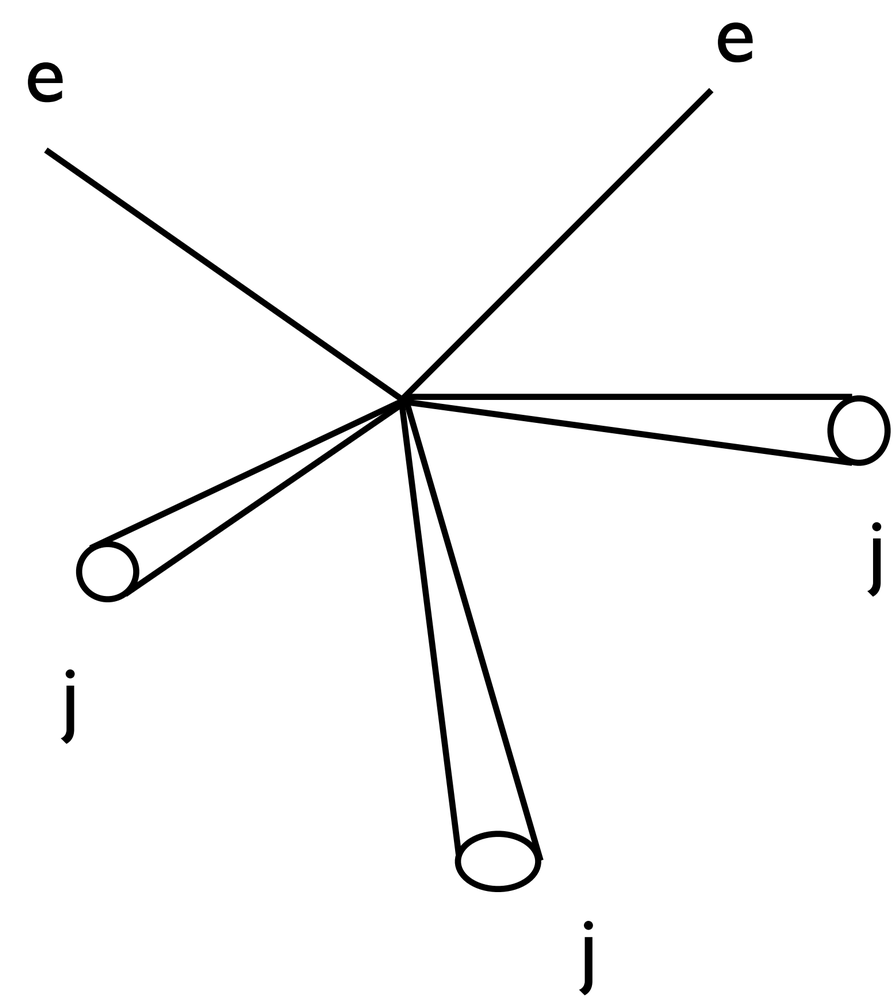
New strategy

Intermediate r_{inv}

Modify [ATLAS-CONF-2017-039]* and require:

1) presence of exactly 2 leptons;
2) presence of at least 2 jets;
3) minimum values for m_{ll}, m_{T2} and MET;

Main background: $t\bar{t}$ production

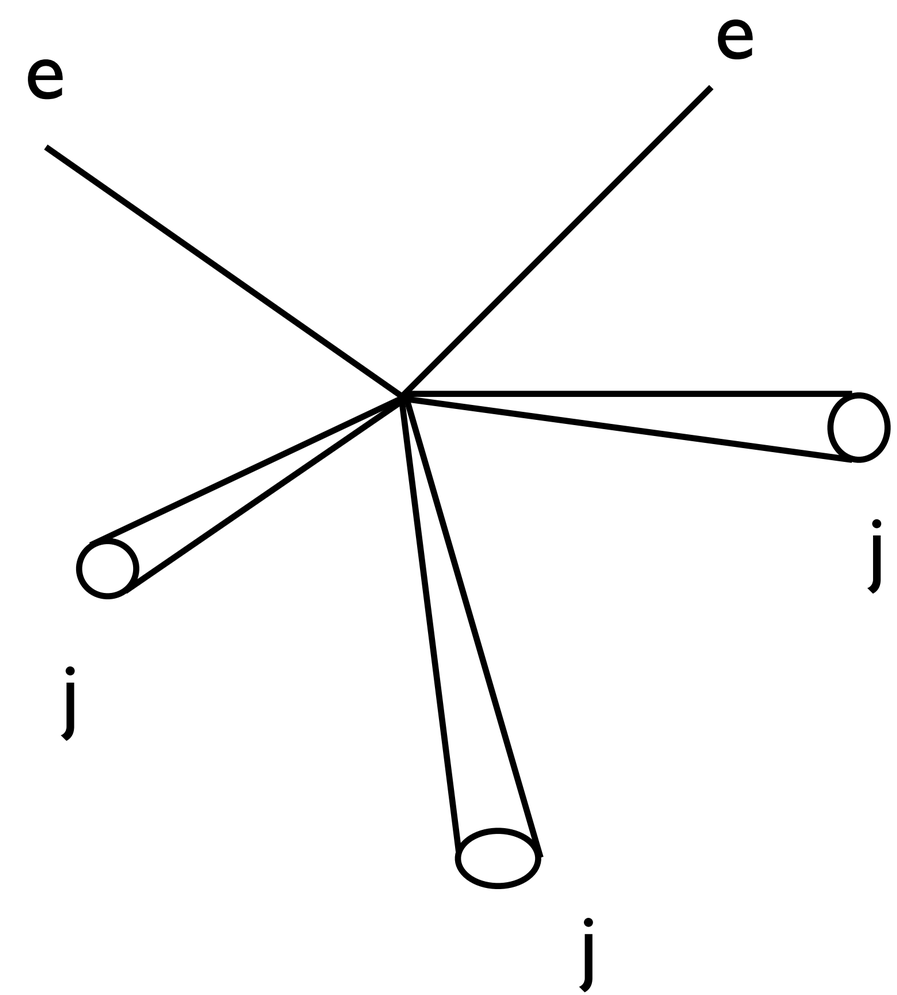


* slepton search

New strategy

Intermediate r_{inv}

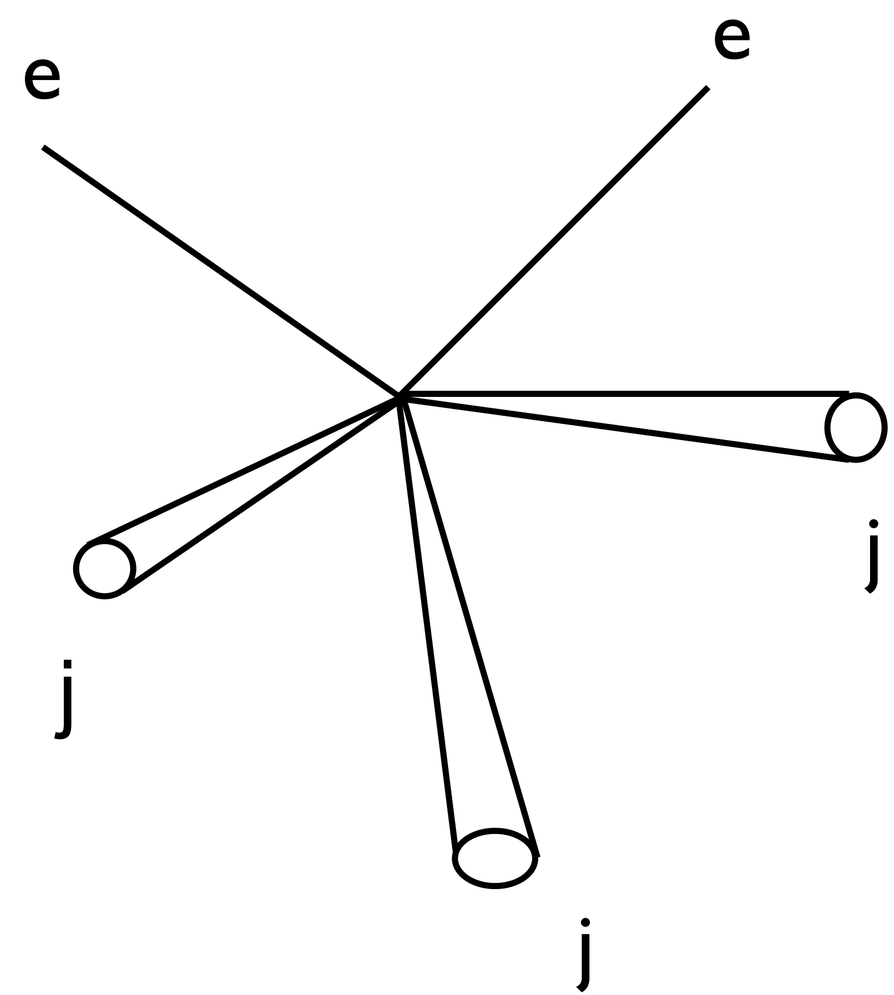
1) pair every lepton with a jet;



New strategy

Intermediate r_{inv}

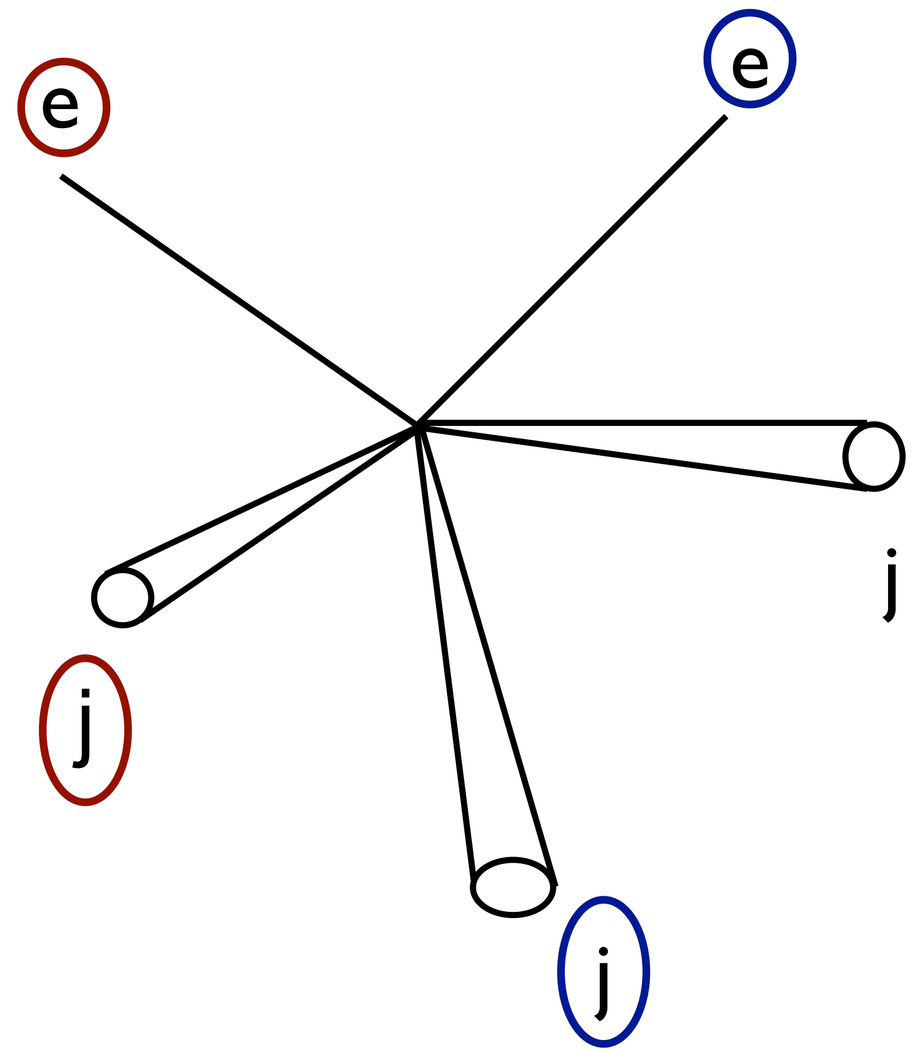
1) pair every lepton with a jet;
2) calculate the invariant mass of each pair;



New strategy

Intermediate r_{inv}

1) pair every lepton with a jet;
2) calculate the invariant mass of each pair;
3) select the pairing that minimizes the mass difference;



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1) pair every lepton with a jet;
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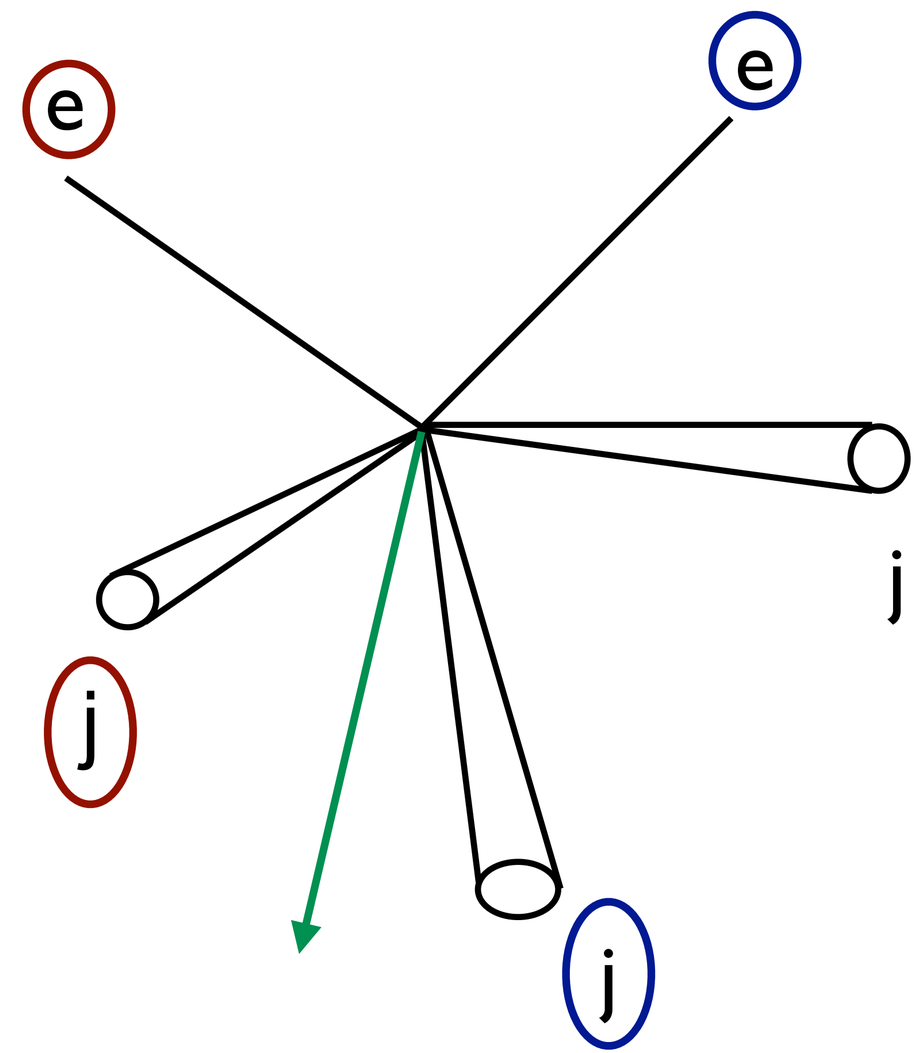
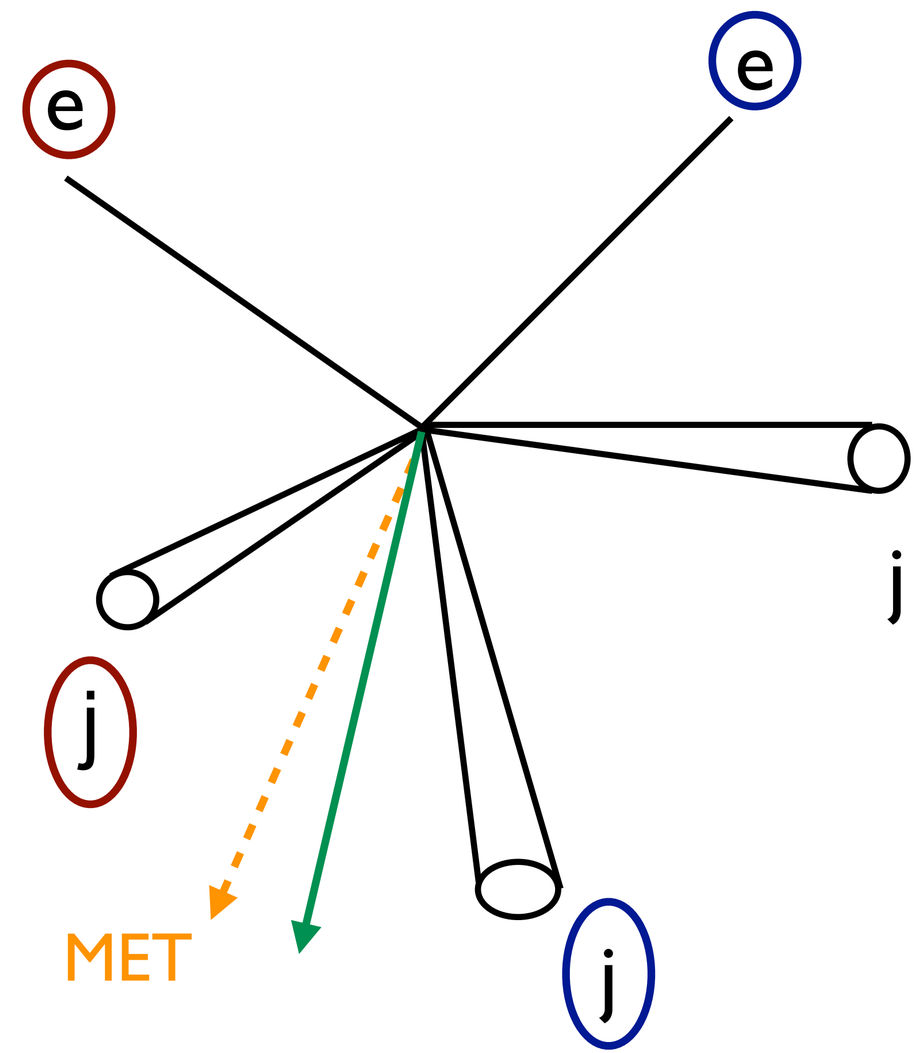
4) add the $\vec{p}_T$ of the two selected jets;



New strategy

Intermediate r_{inv}

1) pair every lepton with a jet;
2) calculate the invariant mass of each pair;
3) select the pairing that minimizes the mass difference;
4) add the $\vec{p}_T$ of the two selected jets;
5) define $\Delta\Phi^{j}_{MET}$ the difference between the azimuthal angle of the $\vec{p}_T$ and the direction of the MET;



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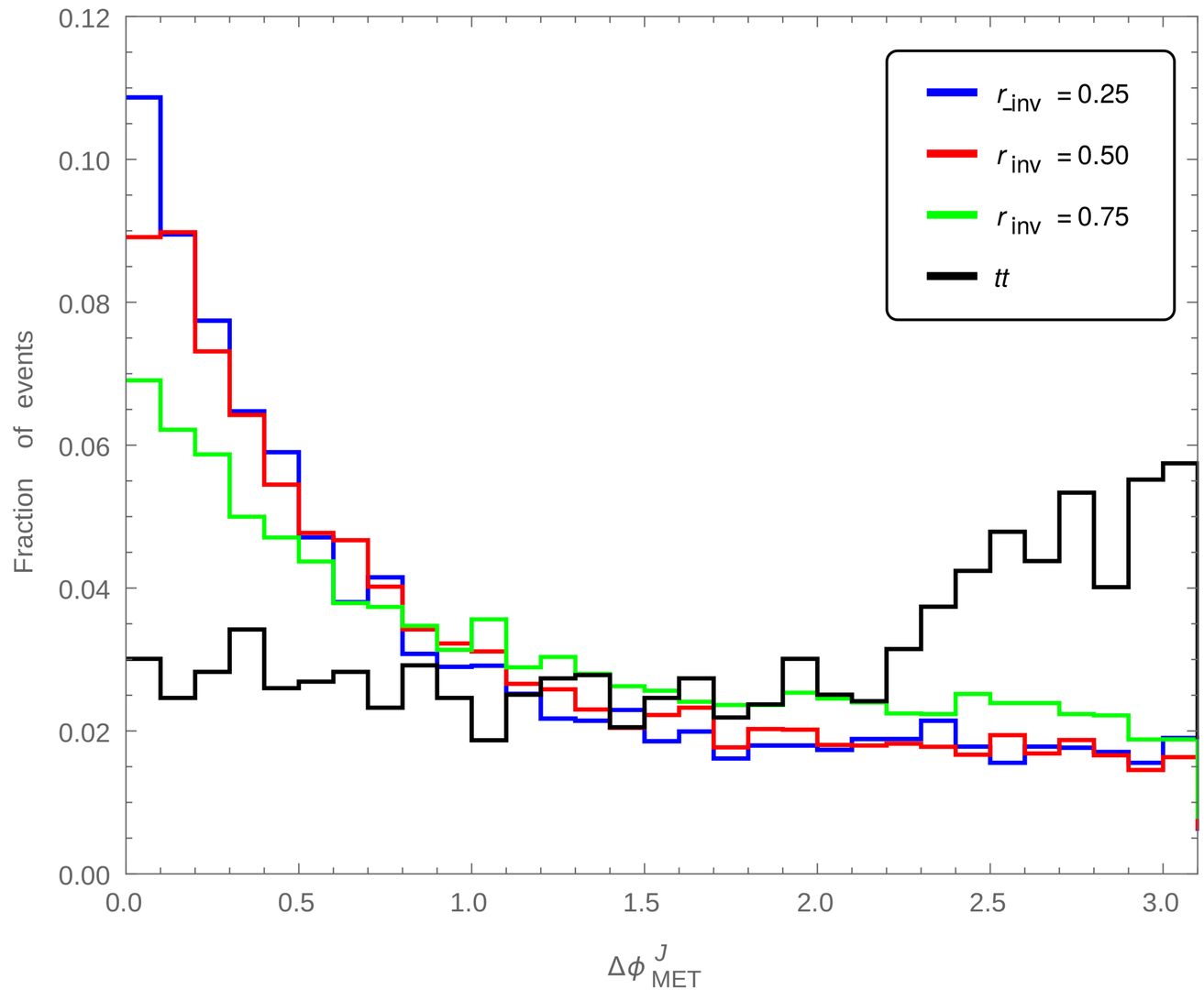

Conclusions

- Hidden dark sectors arise in many new physics models (Twin Higgs, Folded SUSY, Relaxion, DM) and lead to interesting collider signatures, such as semivisible jets.

- Current collider searches are not optimised to look for semivisible jets, leaving large part of the parameter space unconstrained.

- Our categorisation of Hidden sectors that lead to semivisible jets is a first step to cover the wide possibilities for dark sector physics with such a signature.

- OUTLOOK: missing dedicated studies on EWPT, flavour physics and DM for these classes of Hidden Valley models.