VBF DM searches within Simplified Models

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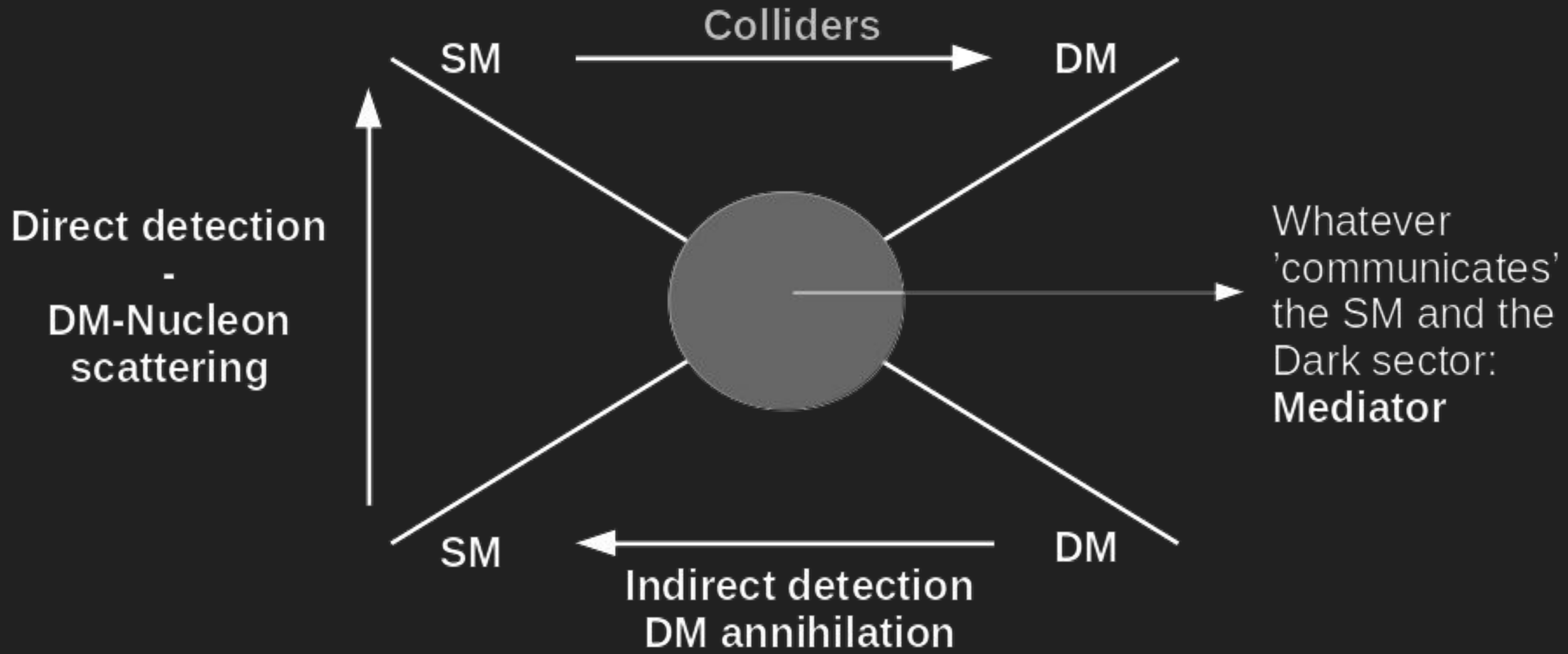
Dark matter

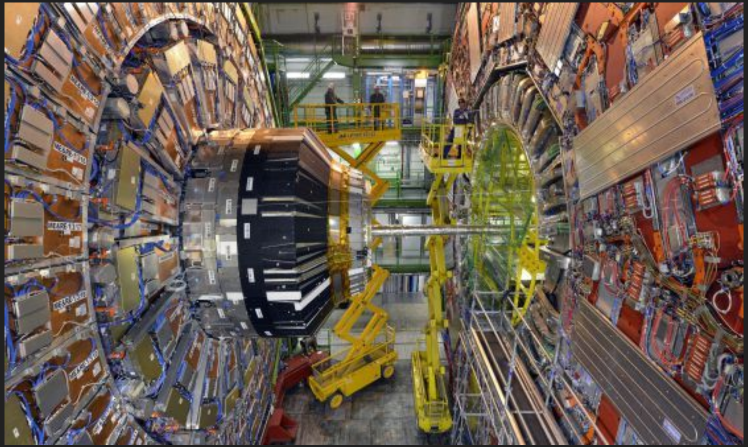
One of the main problems in contemporary physics

- Populates the universe (~25% universe's matter).
- Crucial for structure formation.
- Mainly cold.
- Very "invisible".

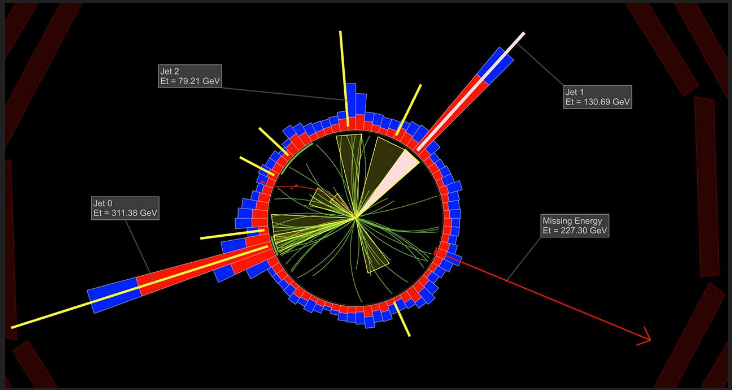
Dark Matter detection



LHC provides pp collisions



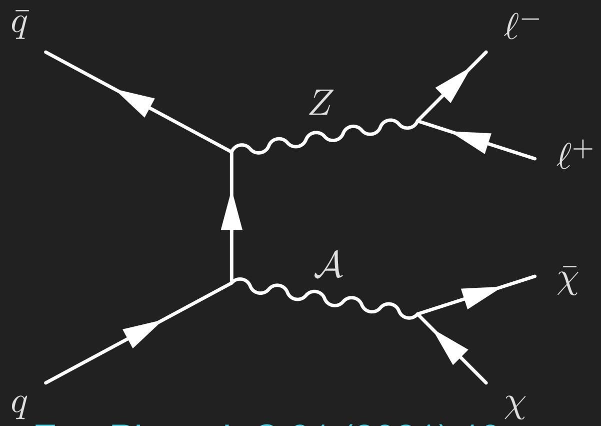
Experiments record the products of LHC collisions



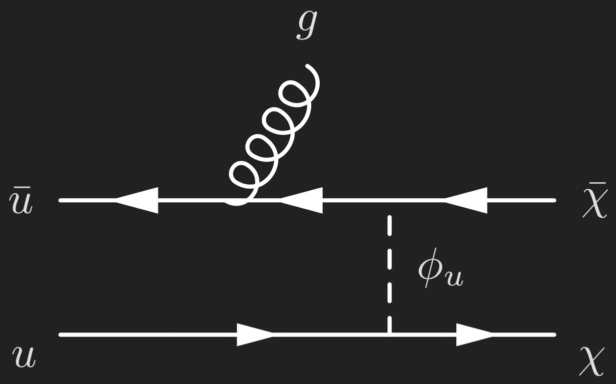
Non-interacting particles
cause momentum imbalance
in the transverse plane
of the beam

pT,miss → “Missing energy”

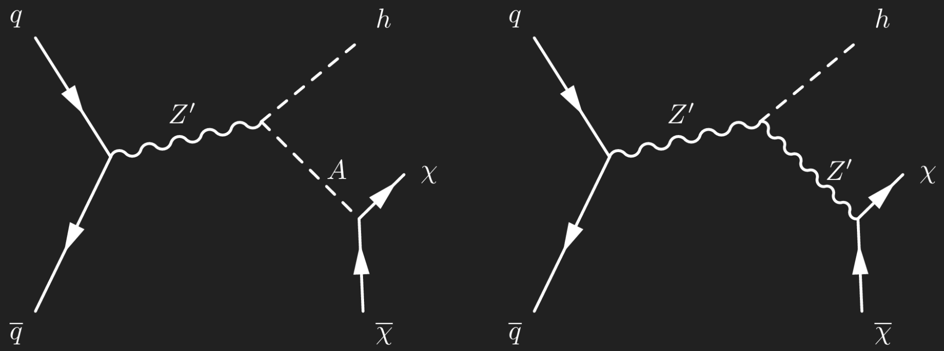
Many searches, many signatures



Eur. Phys. J. C 81 (2021) 13



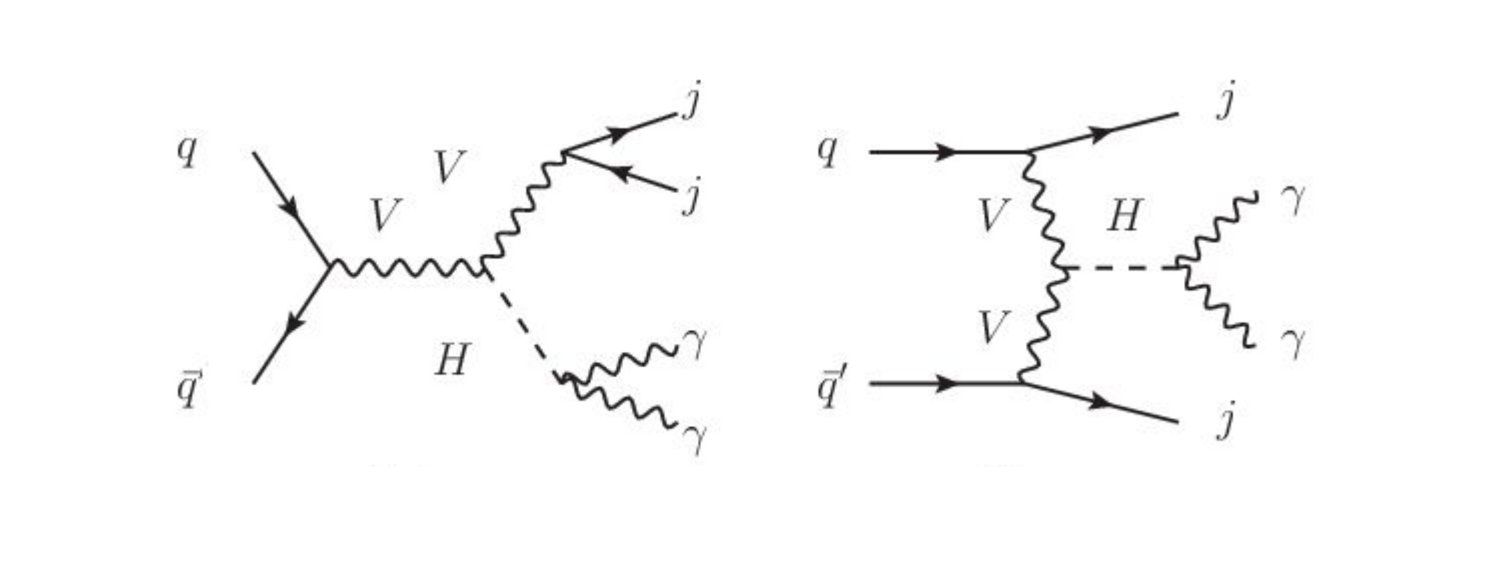
Phys. Rev. D 97 (2018) 092005



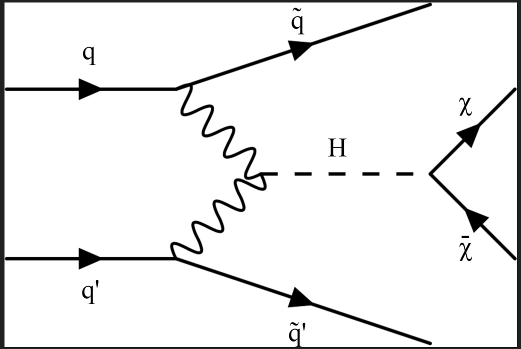
JHEP 09 (2018) 046

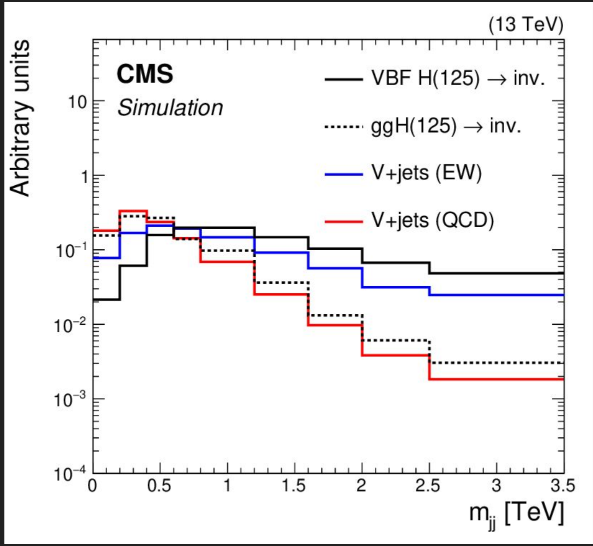
Vector Boson Fusion @ LHC

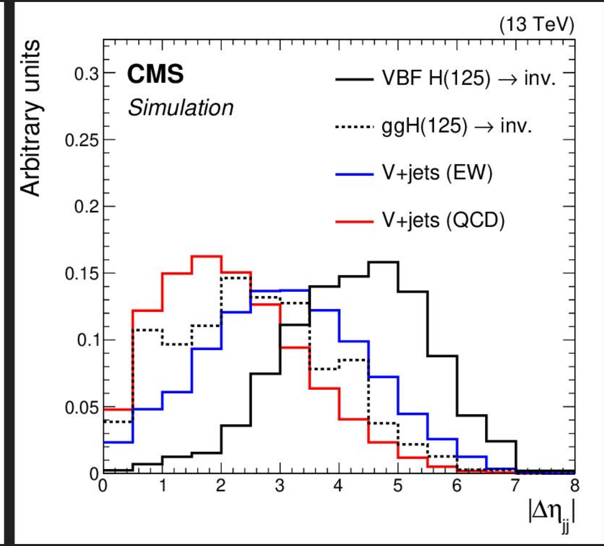
Higgs production

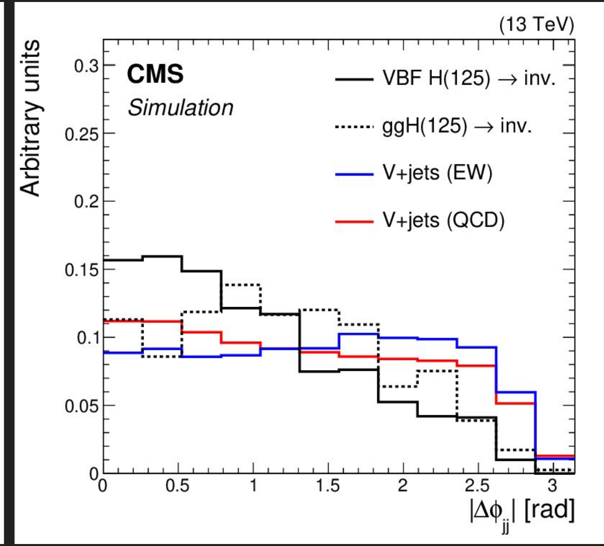


[Phys.Lett.B 793 (2019) 520-551]









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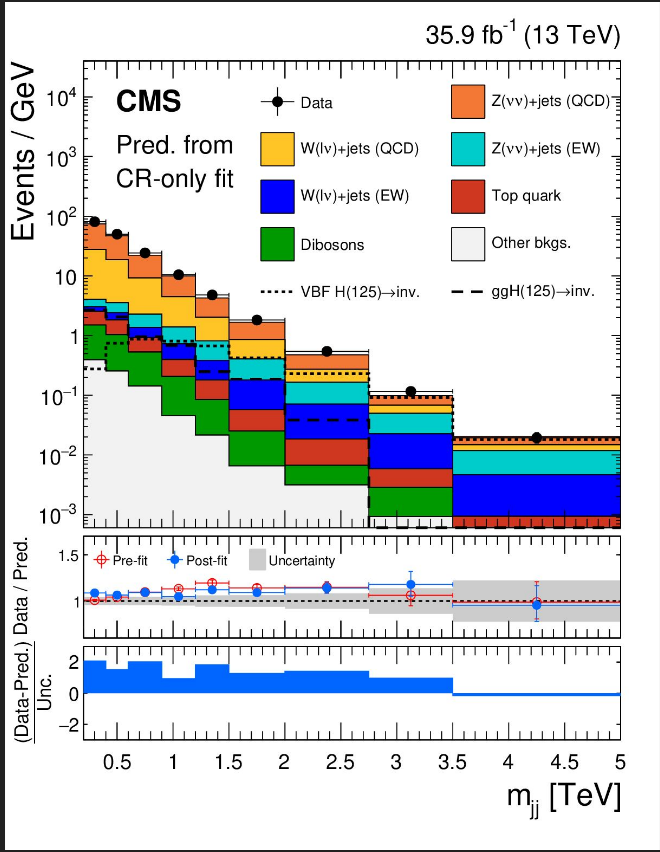
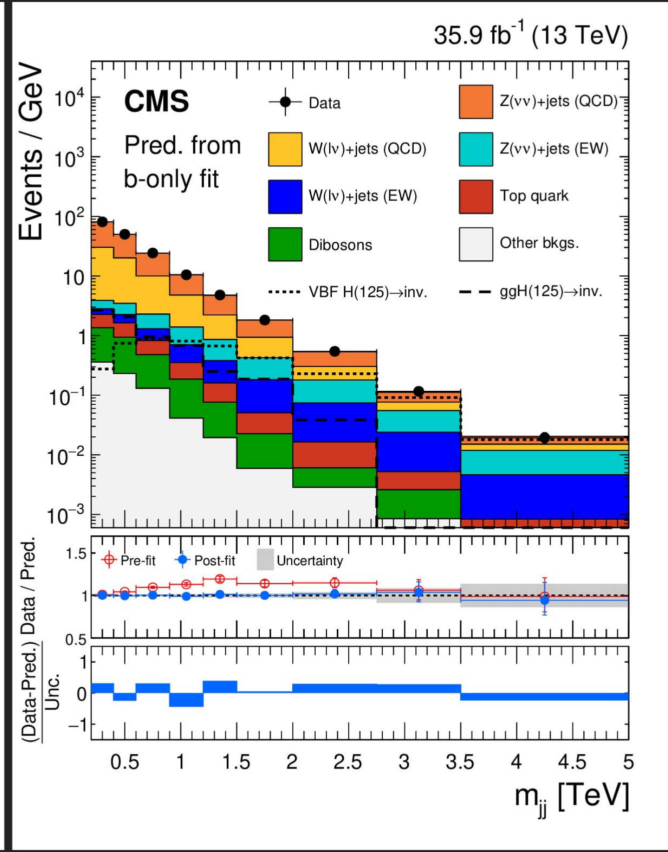
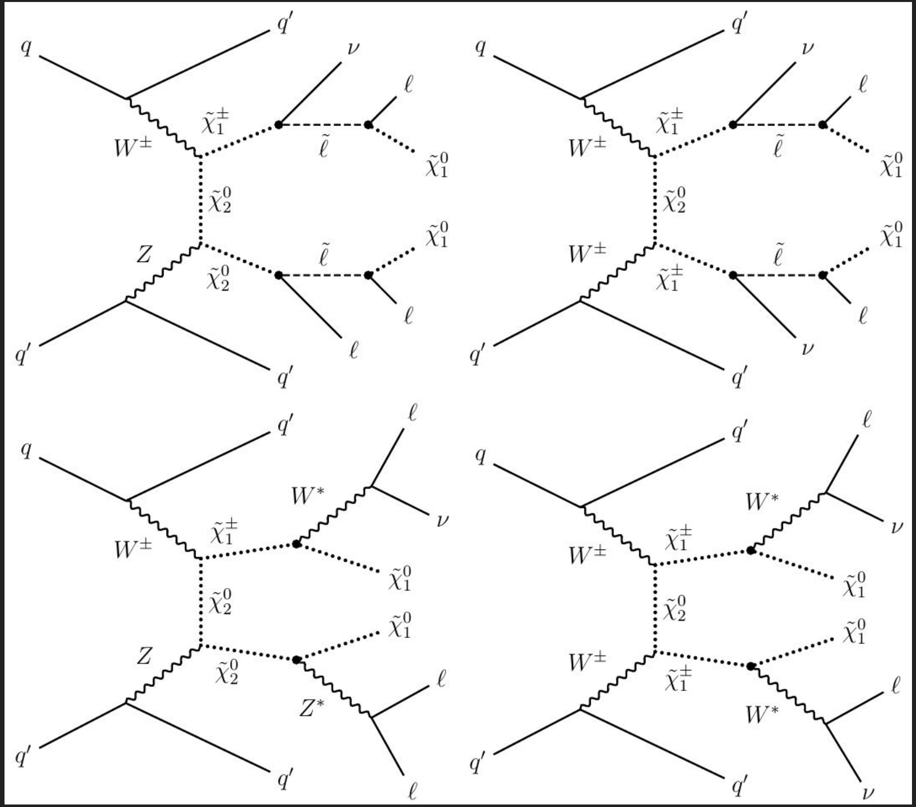




JHEP 08 (2019) 150



- Compressed mass spectra -> very likely to lose one or two leptons.
- Selection:
  - Leptons veto.
  - min(|Δφ(MET, j)|)>0.5
  - MET>250 GeV
  - VBF selections:
    - pT(j) > 60 GeV
    - |Δη(j,j)|>3.8
    - $\eta(j_1)\eta(j_2)<0$
    - m_{jj} > 1 TeV

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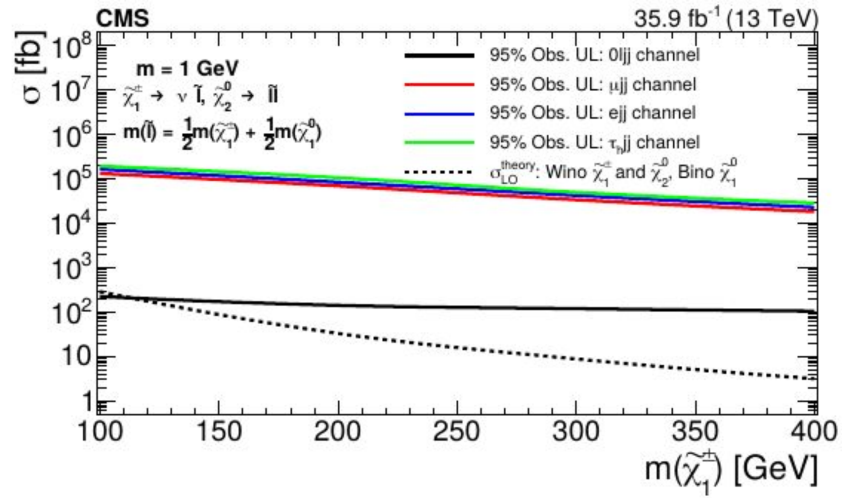

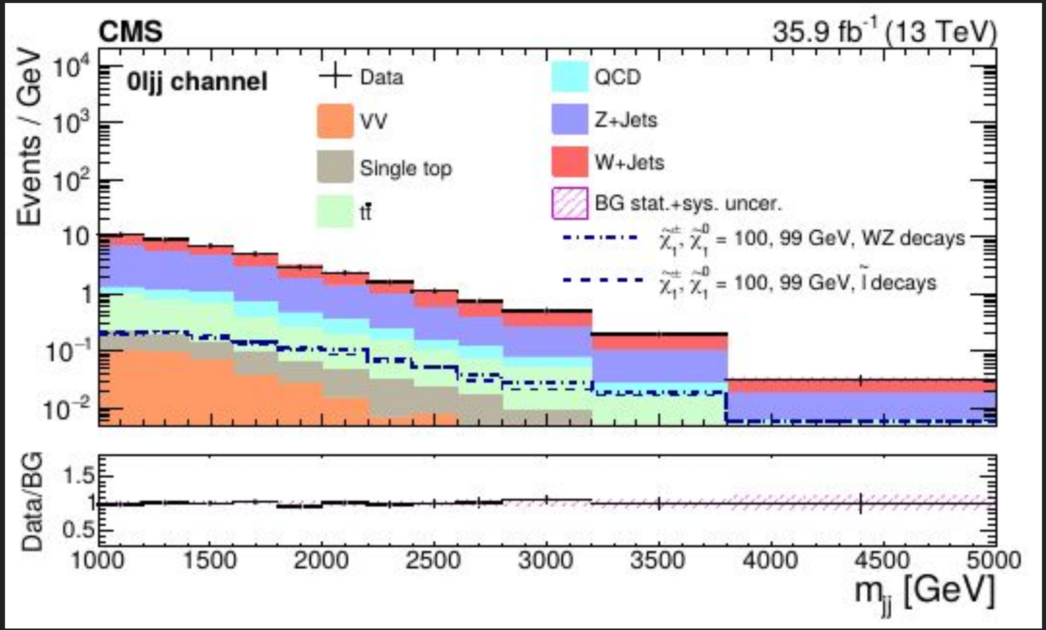

Process	μjj	ejj	$\tau_h$jj	0ℓjj
DY+jets	0.20 ± 0.07	0.10 ± 0.04	0.10 ± 0.04	3714 ± 760
W+jets	13 ± 3	6 ± 1	7 ± 2	2999 ± 620
VV	1.7 ± 0.7	1.5 ± 0.6	0.9 ± 0.9	77 ± 18
$t\bar{t}$	13 ± 4	11 ± 4	5 ± 3	577 ± 128
Single top quark	2.2 ± 0.9	0.2 ± 0.1	0.6 ± 0.3	104 ± 10
QCD	$0^{+0.2}_{-0}$	$0^{+1.2}_{-0}$	23 ± 5	546 ± 69
Total BG	31 ± 5	19 ± 5	37 ± 6	8017 ± 992
Data	36	29	38	8408

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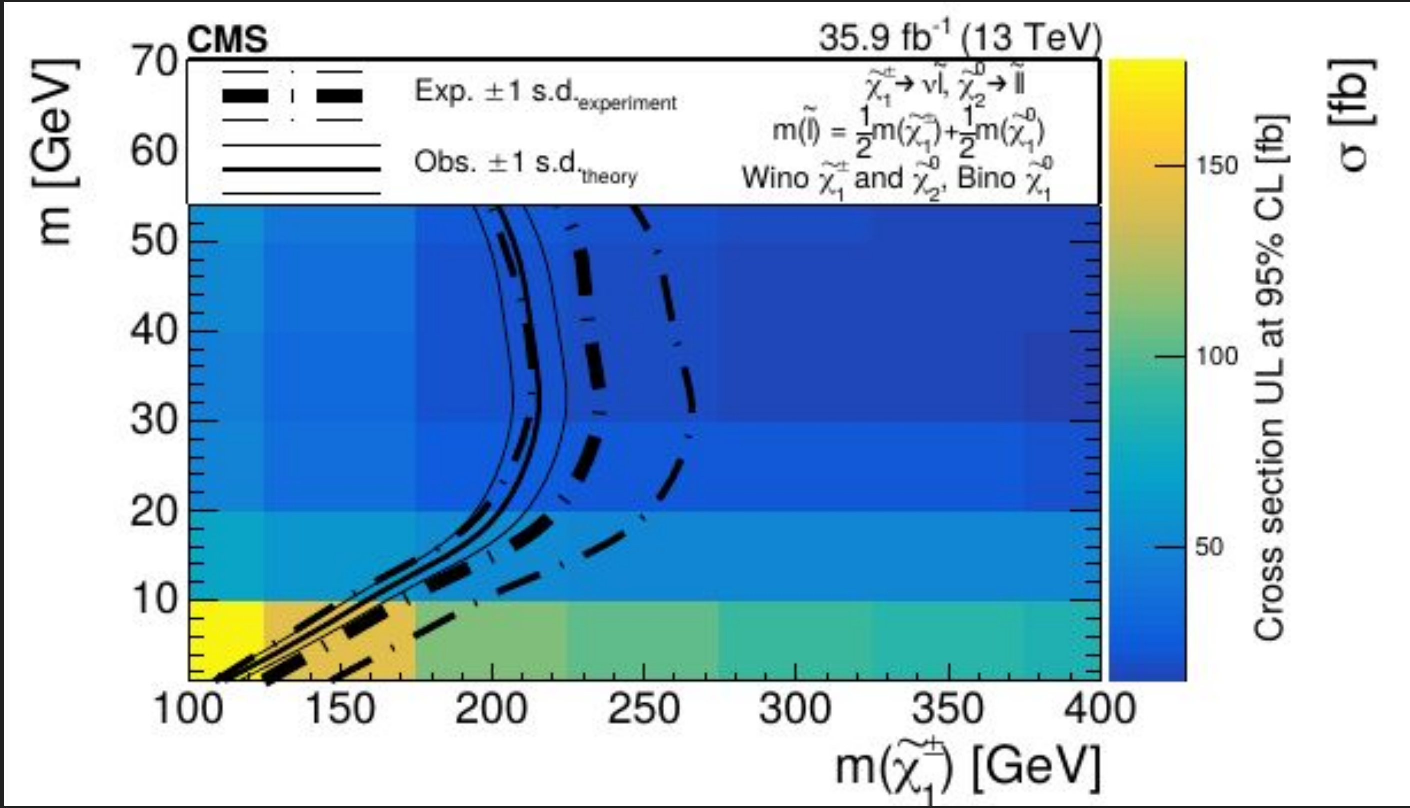
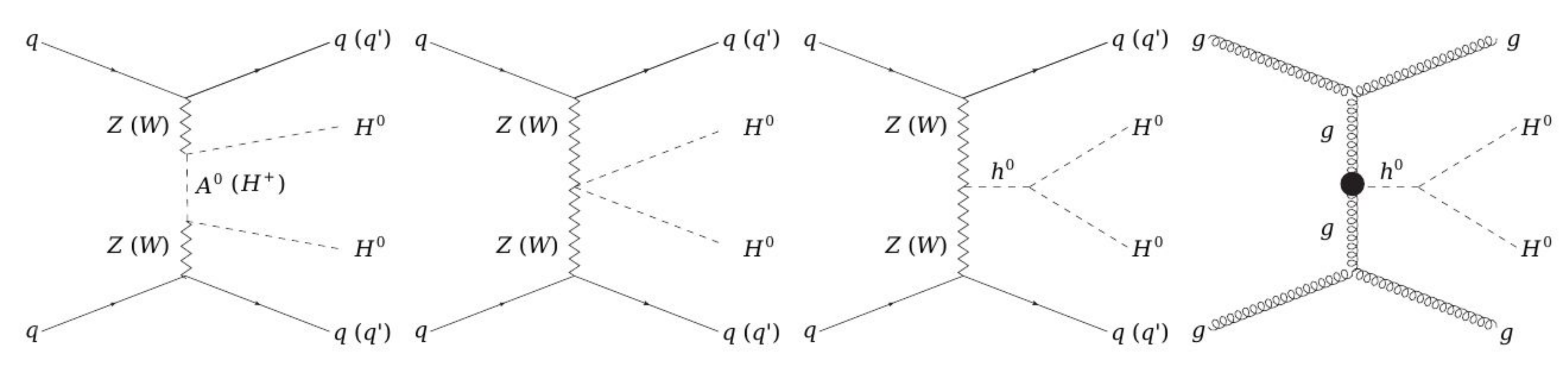


Phys.Rev.D 97 (2018) 5, 055045



	Efficiency per cut	
Process	Signal	Z+jets
Initial number of MC events	2447	30996944
Cut 1	$(23.38 \pm 0.86)\%$	$(0.22 \pm 8 \times 10^{-4})\%$
Cut 4	$(63.11 \pm 2.02)\%$	$(51.95 \pm 0.19)\%$
Cut 6	$(10.80 \pm 1.63)\%$	$(1.82 \pm 0.07)\%$
Cut 7	$(84.62 \pm 5.78)\%$	$(82.57 \pm 1.48)\%$

Cut 1 : $p_T^{\text{miss}} > 180$ GeV

Cut 2 : $N(j) \geq 2$

Cut 3 : $p_T(j_1) > 100$ GeV

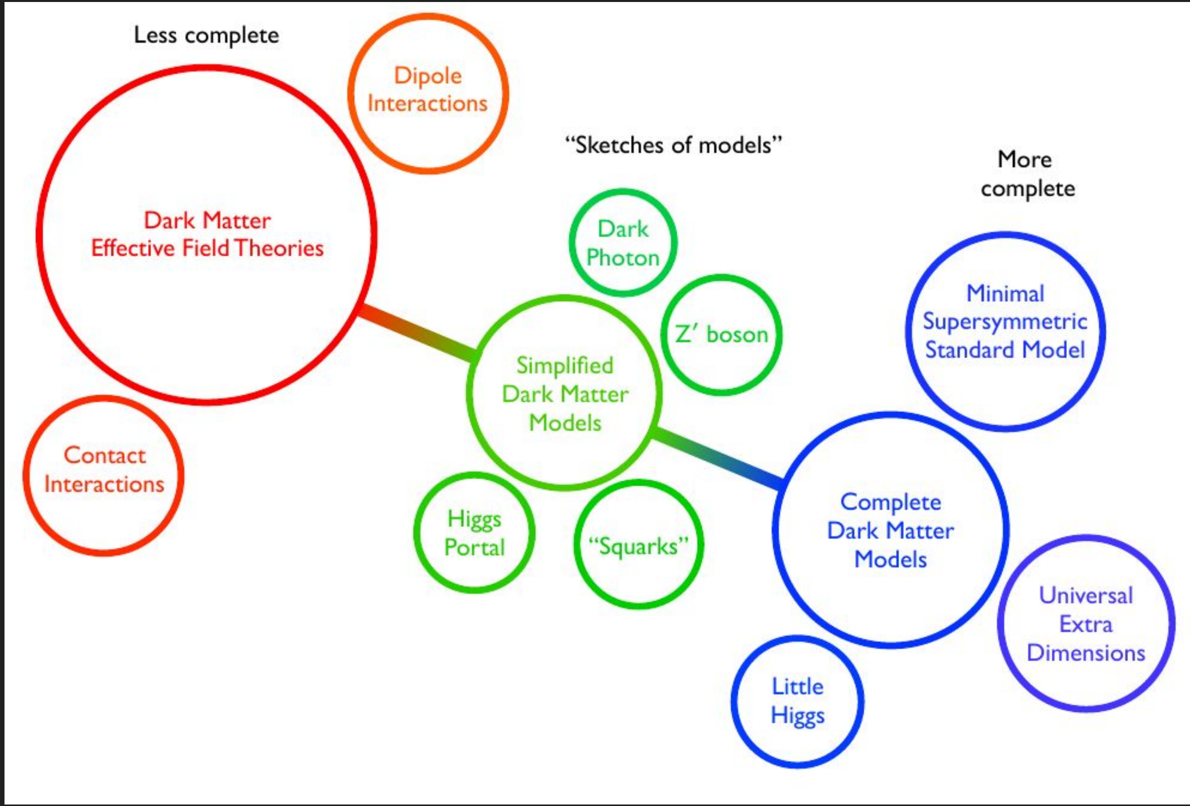
Cut 4 : $p_T(j_2) > 50$ GeV

Cut 5 : $\eta(j_1) \times \eta(j_2) < 0$

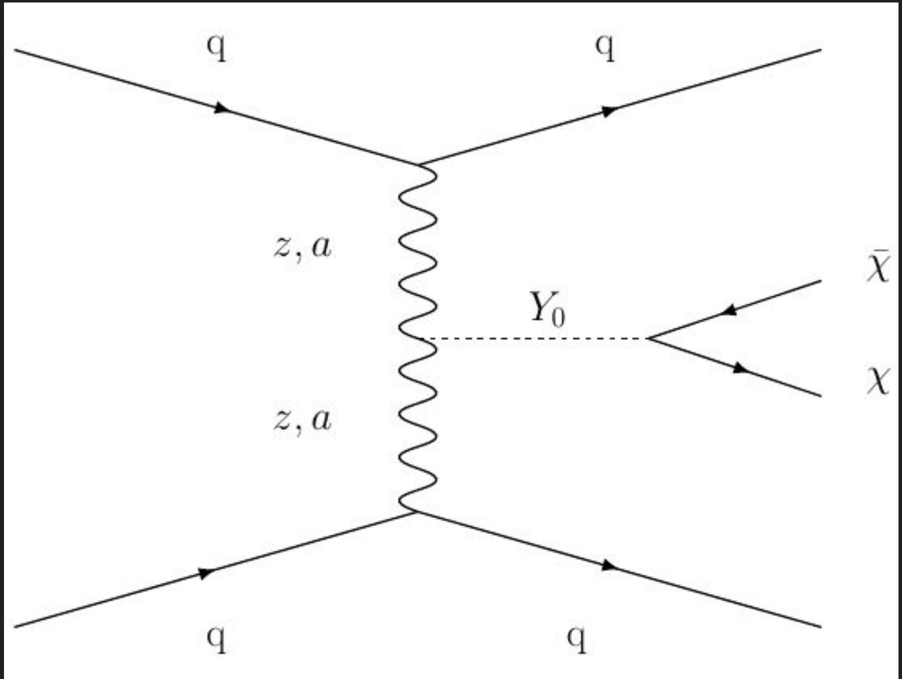
Cut 6 : $|\Delta\eta(j_1, j_2)| > 4.2$

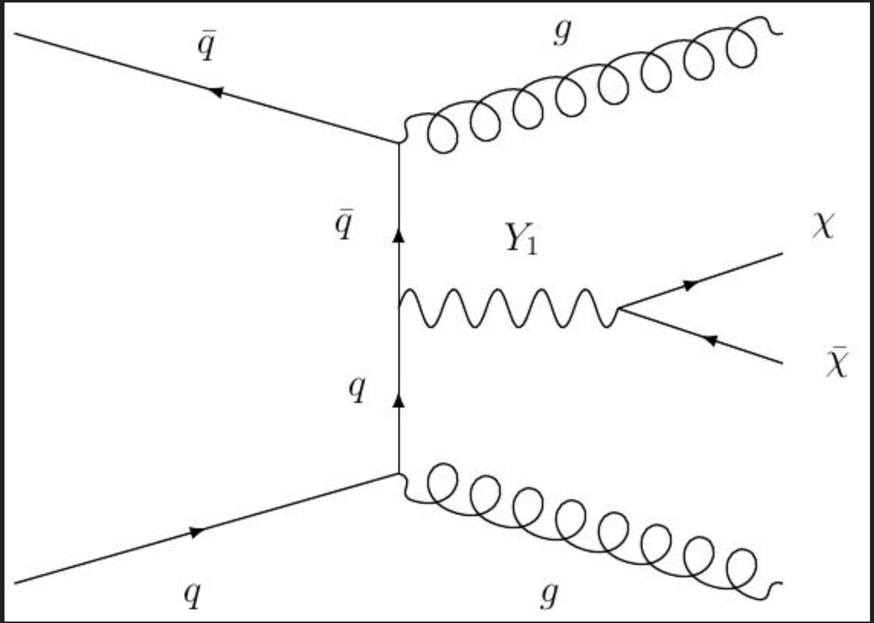
Cut 7 : $M(j_1, j_2) > 1$ TeV

Simplified models - [Phys.Dark Univ. 9-10 (2015) 8-23]



VBF topology in Simplified Models





Selection criteria

- $N(j) > 1$
- $\eta(j_1)\eta(j_2) < 0$
- $pT(j) > 30$ GeV
- $HT > 200$ GeV
- $|\Delta\varphi(j_1, j_2)| > 2.3$
- $\min(|\Delta\varphi(MET, j)|) > 0.5$
- $m_{jj} > 1$ TeV
    - Low Mediator Mass:
        - $|\Delta\eta(j,j)| > 3$
    - High Mediator Mass:
        - $|\Delta\eta(j,j)| < 3$

1. Two channels:
   Usual VBF selections are biased by Higgs mediator mass. Higher masses produce less separated jets in the pseudorapidity.
2. Specially low MET events, therefore we can't rely on this variable for the selection.
3. Selection optimized towards Z+jets background:
   a. W+jets has shown very similar behavior from other studies and analyses.
   b. QCD background controlled by min(|Δφ(MET, j)|) selection.
4. Main experimental challenge would be to estimate QCD contribution.

Conclusions

1. $|\Delta\eta(j,j)|$ cut is optimized for different mediator masses.

2. Competitive and complementary results with monojet searches (in progress).

3. VBF topology is a promising window for searching for DM at the LHC.

4. Simplified models provide a generic framework for DM searches at the LHC also for VBF searches.

Perspectives

1. Completing studies with other backgrounds and more signal points.

2. Parameter coverage compared with other searches.

Thanks!!!