Anapole Dark Matter via Vector Boson Fusion Processes at the LHC

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Anapole Dark Matter via Vector Boson Fusion Processes at the LHC - PRD

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$$\Phi(\vec{x}) = \int d^3x \frac{\rho(\vec{x}')}{4\pi|\vec{x} - \vec{x}'|}, \quad \vec{A}(\vec{x}) = \int d^3x \frac{\vec{j}(\vec{x}')}{4\pi|\vec{x} - \vec{x}'|}$$

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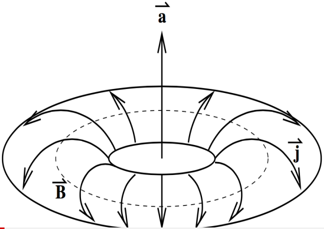

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- The study focuses on the so called anapole moment (AM).

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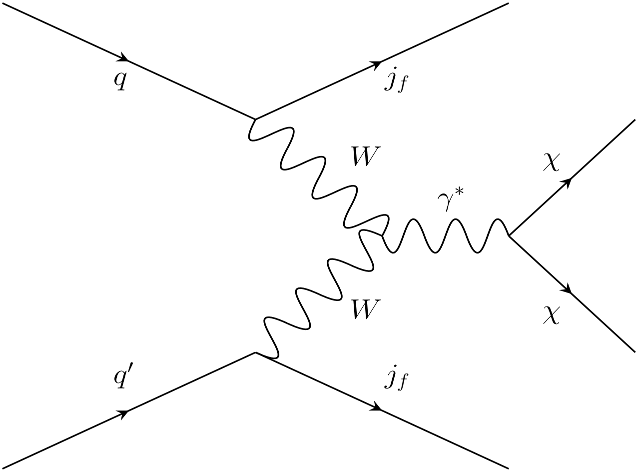
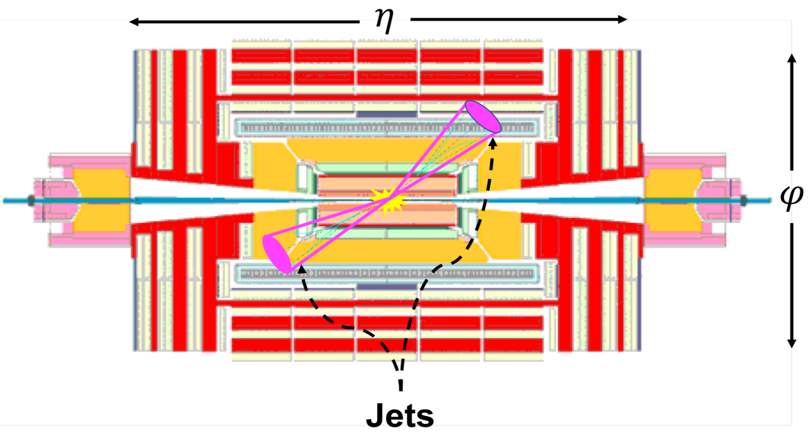
- where Λ is the cutoff scale and χ denotes the DM particle.
- Possible UV completions could be Bino DM coupling to sleptons in supersymmetry or DM that is a composite state of charged particles.

Anapole DM Through VBF



Vector Boson Fusion Topology



- The VBF topology is characterized by the presence of two highly energetic jets, with a large $\Delta\eta$ gap, located in opposite hemispheres of the detector, and with a large dijet reconstructed mass.

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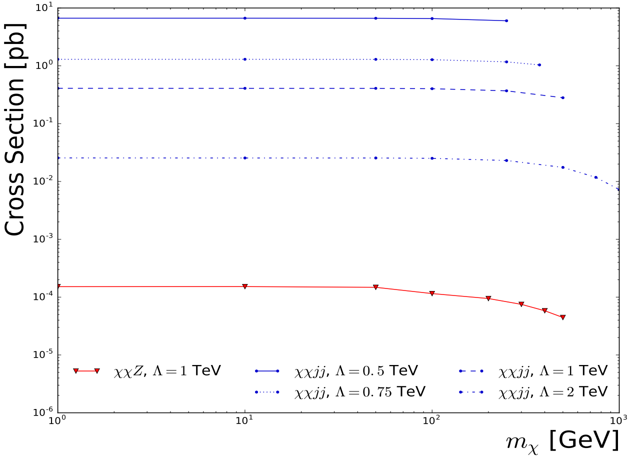
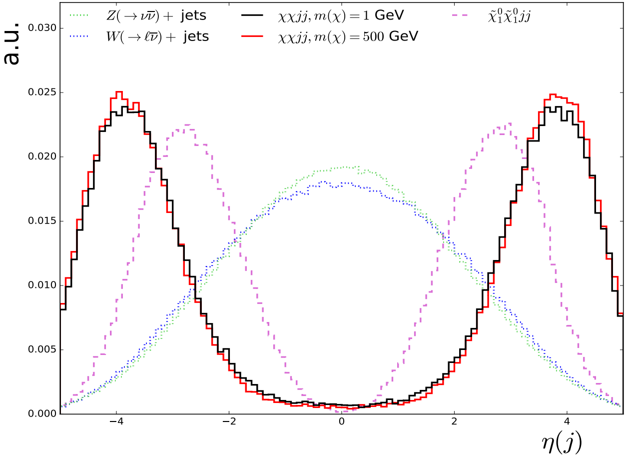
- The value of Λ was varied between 500 GeV to 3000 GeV, in steps of 10 GeV, for every ADM mass point considered.
- The signal samples were produced considering pure electroweak production of a $\chi\chi$ pair and two additional jets (i.e. $pp \rightarrow \chi\chi jj$ with suppressed QCD coupling α^0_{QCD}).

ADM Cross Sections



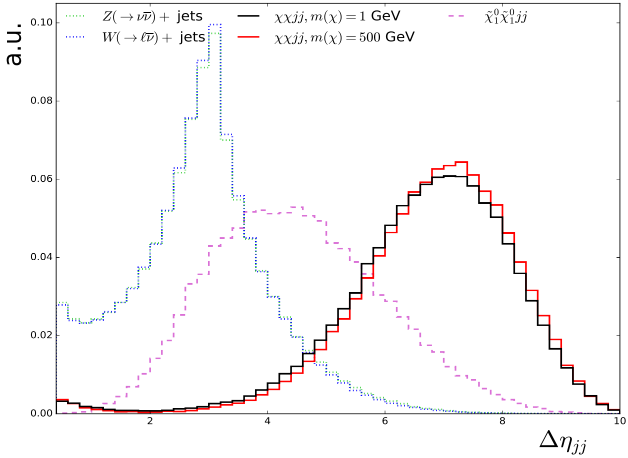
We find that the VBF ADM production cross sections dominate over those of the more traditional mono-Z and monojet processes (See Eq. 49.38).

Jet η Distribution



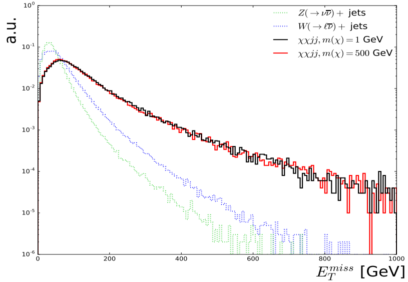
Since the minimum p_T of reconstructed jets is limited by experimental constraints, we select events with at least two jets with $p_T(j) > 30$ GeV.

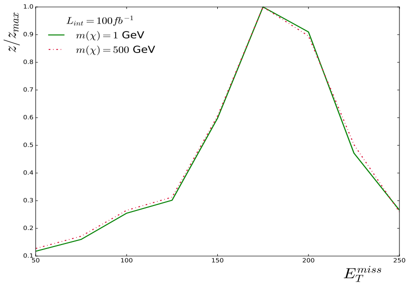
Jet $\Delta\eta$ Distribution



Comparison of the pseudorapidity difference $|\Delta\eta_{jj}|$ between the two leading jets.

Event Selection Criteria



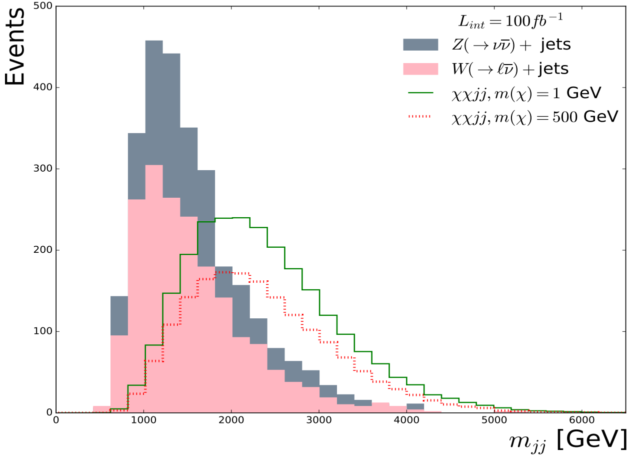


- Thresholds were selected using best signal significance:

$$z = \frac{S}{\sqrt{S+B+(0{,}25B)^2}}$$

Criterion	Selection
$\lvert\eta(j)\rvert$	$> 3{,}0$
$p_T(j)$	> 30 GeV
$N(j)$	≥ 2
$p_T(\ell)$	> 10 GeV
$\lvert\eta(\ell)\rvert$	$< 2{,}5$
$N(\ell)$	$= 0$
p_T(b-jet)	> 30 GeV
$\lvert\eta\rvert$(b-jet)	$< 2{,}4$
N(b-jet)	$= 0$
$\Delta\eta_{jj}$	$> 7{,}0$
E_T^{miss}	> 175 GeV

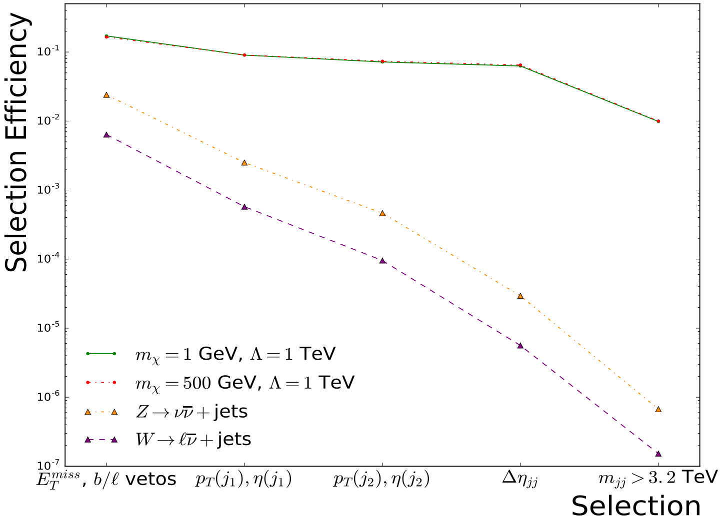
m_{jj} Distribution



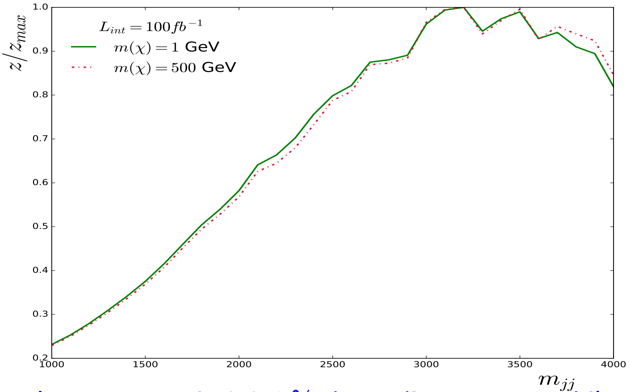
We used the m_{jj} Distribution as fitting variable.

$$m_{jj} = \sqrt{2p_T^{j_1} p_T^{j_2} cosh(\Delta\eta(jj))}$$

Selection Efficiency After Each Additional Criteria.

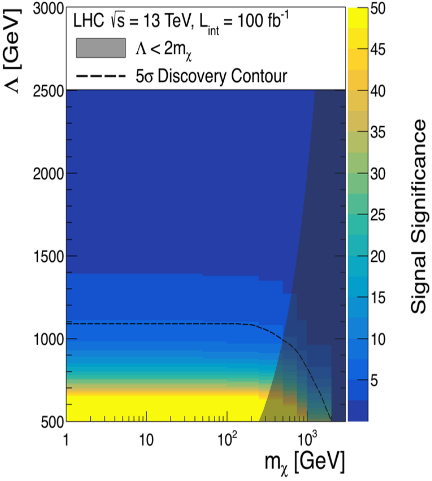


Normalized Signal Significance vs m_{jj}



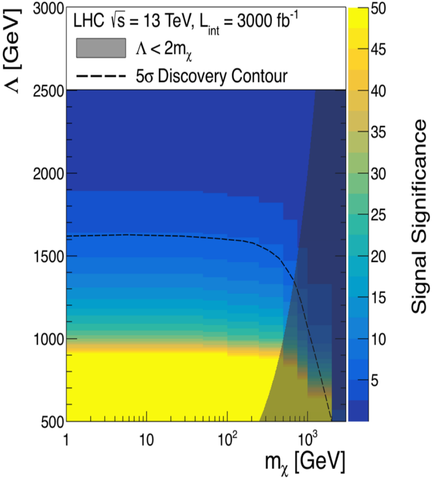
- The signal acceptance is 0.8-1 % depending on m_χ, while the $W/Z+$jets backgrounds are reduced by approximately 6-7 orders of magnitude.
- Additionally, we required that the momentum transfer (Q_{tr}) at the EFT vertex be lower than Λ (sets the validity of the EFT.).

Expected Signal Significance - $\mathcal{L} = 100 fb^{-1}$



- Expected signal significance as a function of the cutoff scale Λ and the ADM mass m_{χ}.
- The signal significance was calculated by performing a profile binned likelihood of the m_{jj} distribution, assuming a luminosity of 100 fb^{-1}.
- The 5σ discovery potential region is enclosed by the black dashed line, while the shaded grey area is the kinematically forbidden region $\Lambda < 2m_{\chi}$.

Expected Signal Significance - $\mathcal{L} = 3000 fb^{-1}$



- Expected signal significance as a function of the cutoff scale Λ and the ADM mass m_χ.
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- We find that s-channel WW fusion is the important VBF ADM production mechanism, with cross sections that dominate over those of the more traditional mono-X processes for TeV scale values of Λ and all relevant values of m_χ.
- A particularly interesting feature resulting from s-channel WW fusion events within the ADM EFT is that it leads to a VBF topology with significantly more forward jets and a larger dijet pseudorapidity gap compared to VBF DM production in other models such as SUSY, where t-channel WW/ZZ/WZ fusion diagrams dominate.

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