

Vector/Axial-vector

Technical stuff:

- use POWHEG-BOX process of $pp \rightarrow DM DM$ | j at NLO (need to check how sufficient this will be for multijet+Met processes)
- use generation cut of 30 GeV, 50000 events each model. (previously used 20k events with a cut of 80 GeV, this was sufficient for monojets, but likely not sufficient for multijet analyses)

- vector coupling to both SM and DM
- axial vector coupling to both SM and DM
- no mixed coupling case yet (we can add later)

Width is calculated from couplings from using following formulas

$$\Gamma(Z' \rightarrow \bar{\chi}\chi)_{\text{vector}} = \frac{g_{\text{DM}}^2 M_{\text{med}}}{12\pi} \left(1 + \frac{2m_{\text{DM}}^2}{M_{\text{med}}^2}\right) \sqrt{1 - \frac{4m_{\text{DM}}^2}{M_{\text{med}}^2}}$$

$$\Gamma(Z' \rightarrow \bar{q}q)_{\text{vector}} = \frac{3g_q^2 M_{\text{med}}}{12\pi} \left(1 + \frac{2m_q^2}{M_{\text{med}}^2}\right) \sqrt{1 - \frac{4m_q^2}{M_{\text{med}}^2}}$$

$$\Gamma(Z' \rightarrow \bar{\chi}\chi)_{\text{axial}} = \frac{g_{\text{DM}}^2 M_{\text{med}}}{12\pi} \left(1 - \frac{4m_{\text{DM}}^2}{M_{\text{med}}^2}\right)^{3/2}$$

$$\Gamma(Z' \rightarrow \bar{q}q)_{\text{axial}} = \frac{3g_q^2 M_{\text{med}}}{12\pi} \left(1 - \frac{4m_q^2}{M_{\text{med}}^2}\right)^{3/2} .$$

g_q	g_{DM}
M_{med}	M_{DM}

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Proposal for scans:

- Vary M_{med} and M_{DM} and keep g_q and g_{DM} fixed to 0.3, 0.5, 1.0, 1.45 (weak coupling, semi-weak coupling, strong coupling, max coupling based on width~mass)
- Ranges depend on values of couplings

g_q	g_{DM}
M_{med}	M_{DM}

$g_q = g_{\text{DM}} = 0.3$ $M_{\text{DM}} = 25, 50, 75, 100, 125, 150, 175, 200$ $M_{\text{MED}} = 50, 100, 200, 300, 400, 500, 600, 700, 800$
$g_q = g_{\text{DM}} = 0.5$ $M_{\text{DM}} = 25, 50, 100, 150, 200, 250, 300$ $M_{\text{MED}} = 50, 100, 200, 400, 600, 800, 1000, 1100, 1200$
$g_q = g_{\text{DM}} = 1.0$ $M_{\text{DM}} = 25, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500$ $M_{\text{MED}} = 50, 100, 200, 400, 600, 800, 1000, 1100, 1200, 1300, 1400, 1500$
$g_q = g_{\text{DM}} = 1.45$ $M_{\text{DM}} = 25, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650$ $M_{\text{MED}} = 50, 100, 200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000, 2200, 2400, 2600$

Scalar/Pseudoscalar

- use MCFM
- yukawa coupling to quarks ONLY, not to DM.
- 50k events each with generation cut of 30 GeV

$$\mathcal{L} \supset g_{\text{DM}}^S (\bar{\chi}\chi) S + g_{\text{SM}}^S \sum_q \frac{m_q}{v} (\bar{q}q) S + ig_{\text{DM}}^P (\bar{\chi}\gamma_5\chi) P + ig_{\text{SM}}^P \sum_q \frac{m_q}{v} (\bar{q}\gamma_5q) P,$$

$g_q = g_{\text{DM}} = 0.1$
$M_{\text{DM}} = 25, 50, 75, 100, 125, 150, 175, 200$ $M_{\text{MED}} = 50, 125, 200, 300, 400, 500, 600, 700, 800$
$g_q = g_{\text{DM}} = 1.0$
$M_{\text{DM}} = 25, 50, 100, 150, 200, 250, 300, 350$ $M_{\text{MED}} = 50, 100, 200, 400, 600, 800, 1000, 1100, 1200$
Higgs invisible scan, $g_q = 1.0$, $g_{\text{DM}} = x$ (value of coupling which gives width of Higgs) $M_{\text{MED}} = 125$, $M_{\text{DM}} = 50$
$g_q = g_{\text{DM}} = 2.0$
$M_{\text{DM}} = 25, 50, 100, 150, 200, 250, 300, 350, 400$ $M_{\text{MED}} = 50, 100, 200, 400, 600, 800, 1000, 1100, 1200, 1400$
$g_q = g_{\text{DM}} = 3.2$ (max coupling for which mass \sim width)
$M_{\text{DM}} = 25, 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550$ $M_{\text{MED}} = 50, 125, 200, 400, 600, 800, 1000, 1200, 1400, 1600, 1800, 2000$

Implementation of scalar model in POWHEG

$$\mathcal{L} \supset g_{\text{DM}}^S (\bar{\chi}\chi) S + g_{\text{SM}}^S \sum_q \frac{m_q}{v} (\bar{q}q) S + ig_{\text{DM}}^P (\bar{\chi}\gamma_5\chi) P + ig_{\text{SM}}^P \sum_q \frac{m_q}{v} (\bar{q}\gamma_5q) P ,$$

No yukawa coupling to DM