1. Let's assume that the cross section x acceptance x efficiency for a simplified model of DM production passing the mono-jet analysis criteria (E_T^{miss}>500 GeV) is about σ x A x ε = 35 fb.

a) How many events do we expect to select in the 2015 dataset?

b) The Monte Carlo predicts 385 events from $Z(\nu\nu)$+jets in the signal region. In an ideal world, and assuming the Monte Carlo prediction is accurate, how many events would there be in a $Z(\mu\mu)$+jets control region and what would be the associated statistical uncertainty?

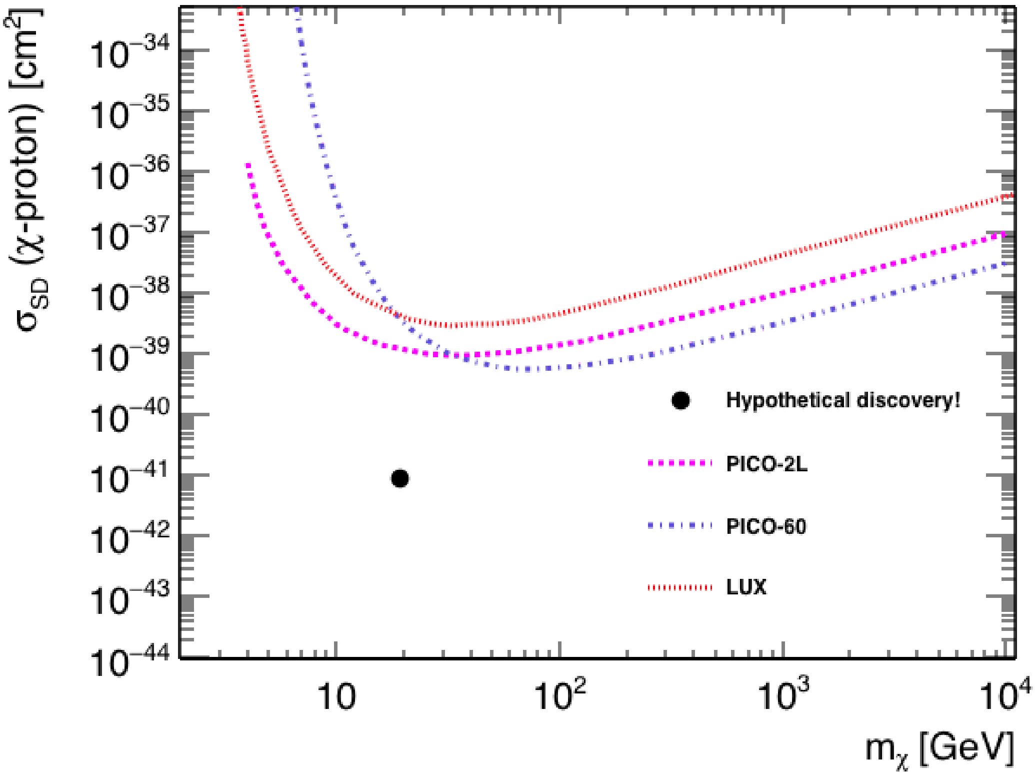
c) If the analysis uses this control region and sees 85 data events in it, how many events are then expected from $Z(\nu\nu)$+jets in the signal region?

d) What would be the expected statistical significance for the signal considered in a) if there is also 80 events of other BG processes expected (mainly $W(l\nu)$+jets)? Disregard uncertainties on the BG determination… (so use S/sqrt(B))

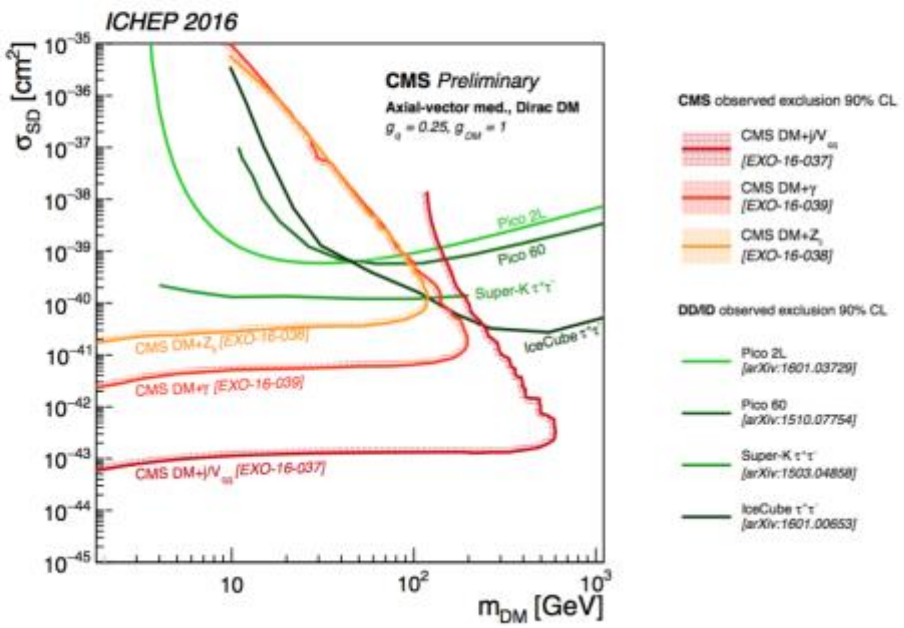
e) The harsher one cuts on E_T^{miss}, the less events remain… If the acceptance goes down by a factor of 2.5 for the signal considered when moving to a signal region with E_T^{miss} > 700 GeV while the expected background goes down to 80 events, what is the expected significance in this signal region?

f) So… in a more realistic scenario, would we necessarily gain by cutting harder?

2. Let's assume that in a near future, a direct detection experiment makes a discovery claim:



The CMS limits are recalled here:



a) What can we say about the direct detection claim?

b) Given the simplified model used by CMS to draw the limits, to what mediator mass would this correspond?

As a reminder,

$$\sigma_{\rm SD} = \frac{3 f^2(g_q) g_{\rm DM}^2 \mu_{n\chi}^2}{\pi M_{\rm med}^4} \quad \text{with} \quad \mu_{n\chi} = m_n m_{\rm DM}/(m_n + m_{\rm DM})$$

$f(g_q) = 0.32\ g_q$ for the spin-dependent interaction and $\hbar c \sim 197\ MeV\ fm$

c) To what mass would it correspond if instead the model considered would have couplings of g_q=0.2 an g_{DM}=2.0 instead?

d) What can we learn by comparing the hypothetical discovery with the limits from the LHC?

e) What if we see something at the LHC in the jet+E_T^{miss} channel and the direct detection experiments do not see any signal? Can we claim a dark matter discovery?

3. Given a model of dark matter production with the initial state radiation of an object, one can look in the jet+ E_T^{miss} or in the photon+ E_T^{miss} final states for example.
    a. Which one has the best sensitivity?

    b. Why is it interesting to look in both channels?

4. Say we want to look for a H(bb)+E_T^{miss} final state. “Normal” jets are reconstructed with a size parameter of ΔR=0.4 in ATLAS.

    a. Below which p_T of the Higgs boson would the b’s coming from its decay be reconstructed as two separated ‘normal’ jet?

    b. What information could we use to identify a fat jet as a Higgs candidate?

5. Suppose that the experiments are able to ultimately place a 5% limit on BF(H→inv).
    a. What would then be the limit on the DM-nucleon cross section for a fermionic DM mass (called m_f or m_χ below) of 1 GeV?

    Reminder:

$$\Gamma_H^{\rm inv} = \frac{\mathrm{BF}(H \to \text{invisible})}{1 - \mathrm{BF}(H \to \text{invisible})} \times \Gamma_H$$

Γ_H = 4 MeV

$$\Gamma_{H\to ff}^{\rm inv} = \frac{\lambda_{Hff}^2 v^2 m_H \beta_f^3}{32\pi\Lambda^2}$$

$$\beta_X = \sqrt{1 - 4m_X^2/m_H^2}$$

v = 246 GeV

$$\sigma_{fN}^{\rm SI} = \frac{\lambda_{Hff}^2}{4\pi\Lambda^2 m_H^4} \frac{m_N^4 m_f^2 f_N^2}{(m_f + m_N)^2}$$

m_N ~ 0.94 GeV is the nucleon mass

f_N = 0.33 is the Higgs-nucleon coupling

    b. Why is it particularly interesting?