SENSITIVITY STUDY OF CYGNO

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Goal of The Work

- The work can be seen as split in two major branches

Sensitivity curve at 3 σ

It aims at finding the line in the cross section–WIMP mass plane, where the average result of the WIMP experiment will allow to claim for a 3 σ significance discovery

Confidence level curve at 90%

In case of no discovery, a confidence level region in the cross section–WIMP mass plane, must be addressed

Sensitivity to Discovery: Statistical Method

- After the experience gained in the SNDM–WIMP work, a very similar approach will be used based on **extended likelihood ratios**

- The extended likelihood ratio will be evaluated as follows

$$\lambda = \frac{L_{b+s}}{L_b}$$

$$L_{b+s} = \frac{(\mu_s+\mu_b)^{N_{evt}}}{N_{evt}!} e^{-(\mu_s+\mu_b)} \times N_{evt}! \times \prod_{i=1}^{N_{bin}} \left[\left(\frac{\mu_s}{\mu_s+\mu_b} P_{si} + \frac{\mu_b}{\mu_s+\mu_b} P_{bi}\right)\frac{1}{n!}\right]$$

Poissonian fluctuation of total events

Permutation term

Probability of the event to end up in bin i

Normalization of the probability to the expected total counts

$$L_b = L_{b+s}(\mu_s = 0)$$

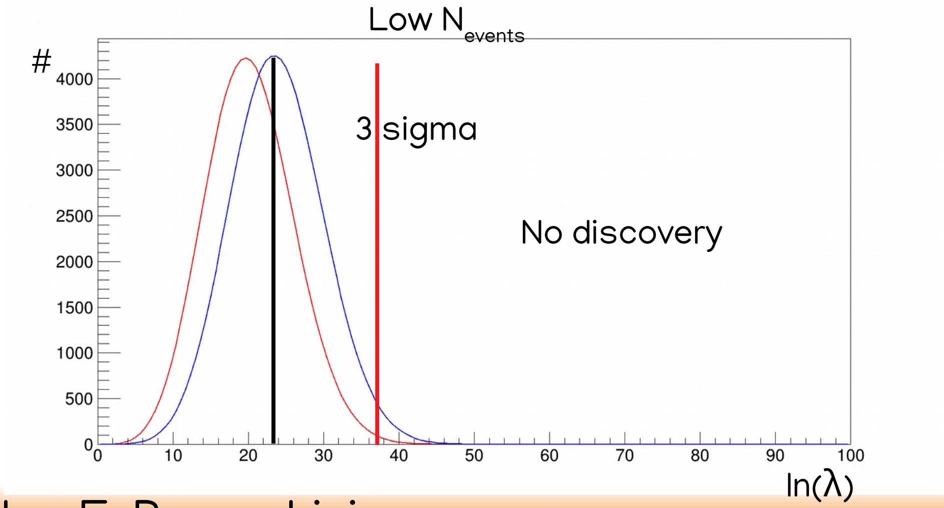
Sensitivity to Discovery: Statistical Method

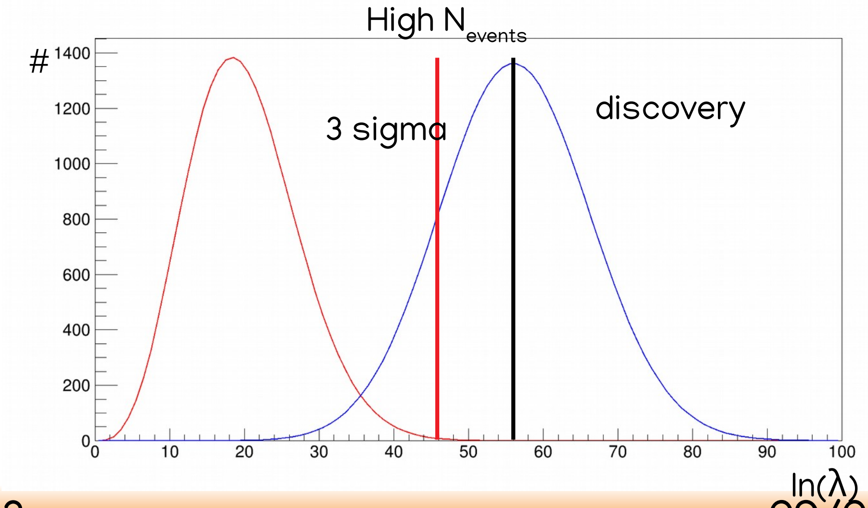
- Now, one chooses the μ_s (can later be translated into cross section) and WIMP mass (m) to put under test and simulates fake experiment.

- When simulating only background experiments, one builds the distribution of λ_b (red curve).

- When simulating experiments with background and signal, one builds the distribution of λ_{b+s} (blue curve)

- Sensitivity to discovery is considered when the mode of λ_{b+s} returns a p-value <3 σ





Confidence Level

- If no discovery can be claimed, then a confidence level must be calculated (90%)

- The Feldman–Cousins method will be used

Scans the μ_s–m plane and, running fake experiments, obtaines a secondary variable used to determine whether a point in that space is in the region or not

- More details in: arXiv:physics/9711021

Operative Conditions

- Before starting the analysis some working conditions should be discussed:
  - Which information of the possible spectra to use
  - Angular resolution to use
  - Energy resolution to use
  - High energy threshold
  - Low energy threshold and correponding expected background

Operative Conditions: Which information to use

- Both angular and energy spectra are available for the WIMP model, but the same cannot be said for the background

Real energy spectrum can be known only after some data taking

Real angular spectrum can be known only after some data taking, but should be well approximated by an isotropic distribution

Indeed, exploiting Galactic coordinates, even located sources of background would be diluted.

- From the experience in the SNDM–WIMP work, the angular information gives better discrimination power

Energy information could be added to the angular one, to reach even bettere performances

Operative Conditions: Angular Resolution

- Limitations on the angular resolution may come directly from straggling effect in the gas, other than readout configuration

Would it be possible to have a simulation of the angular resolution independent of the readout?

- From the experience in the SNDM–WIMP work, the angular resolution does not affect significantly the discrimination power

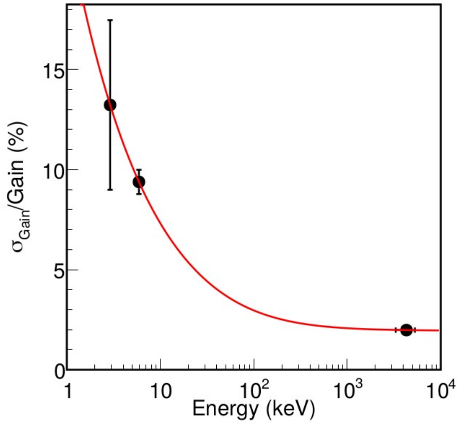
Spanning from 2x2 up to 40x40 deg^2, the discrimination required only O(2) events.

Operative Conditions: Energy Resolution

- When also energy information will be included, the energy resolution must be defined.

- A shape describing the energy resolution could be taken from Sven's paper arXiv:1407.7013v1

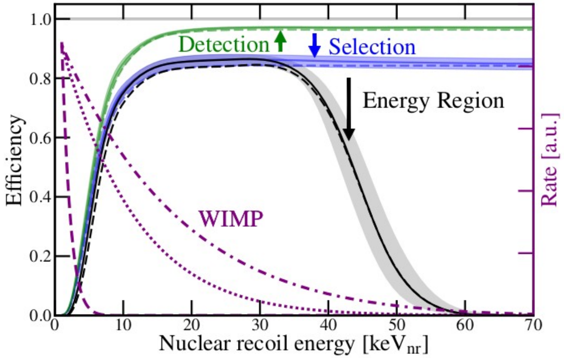
$$\sigma_G/G = \sqrt{d^2 + c^2/E},$$



- The parameters of the formual could be tune so that the resolution at 5.9 keV is of the order of 18%, while at 70 keV of the order of 2%

Operative Conditions: Upper Energy Threshold

- Experiment like Xenon set also a upper energy threshold: arXiv:1805.12562v2



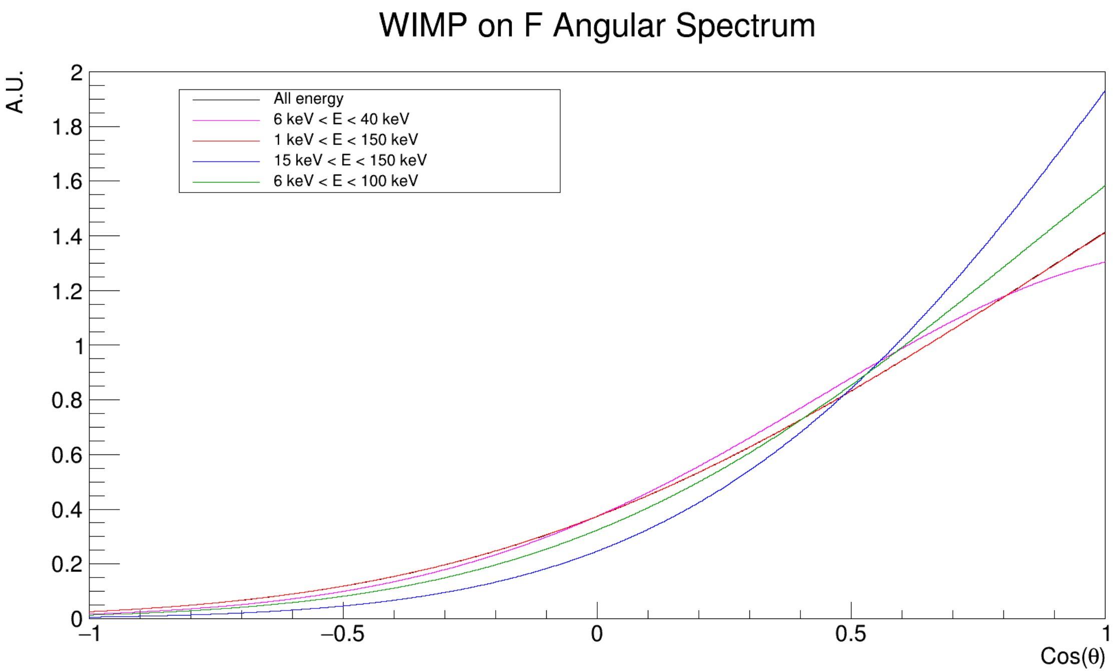
Based on theier selection ability and the probability of events occurence

- From study on the kinematics, the angular shape can differ significantly depending on energy range

High energy recoils are more peaked in the direction of the original particle

Low energy recoils have wider angular spread

Operative Conditions: Upper Energy Threshold



- Due to our background discrimination at high energy it could make sense to use a upper energy threshold that leaves the angular distribution unscated

Operative Conditions: Lower Energy Threshold

- Also the lower energy threshold affect the kinematics (even more than the upper one)

- However, the rejection factor at low energy also determines how many backgound one can expect.

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Direct relation between background events and low energy threshold

Putative Operative Conditions

- Only the angular information in Galactic coordinates will be used with an isotropic distributed background

- Angular resolution of the order of 30–40 deg^2

- Energy resolution of the shape of Sven's paper, normalized at CYGNO measurement

- Various configuration of low energy threshold and background could be considered:
  - Low energy threshold: 1, 5, 15 keV
  - expected events of background: 10, 100, 1000

- Upper energy threshold not affectin the angular spectrum