Discrimination of Dark Matter Velocity Distribution by Directional Detection

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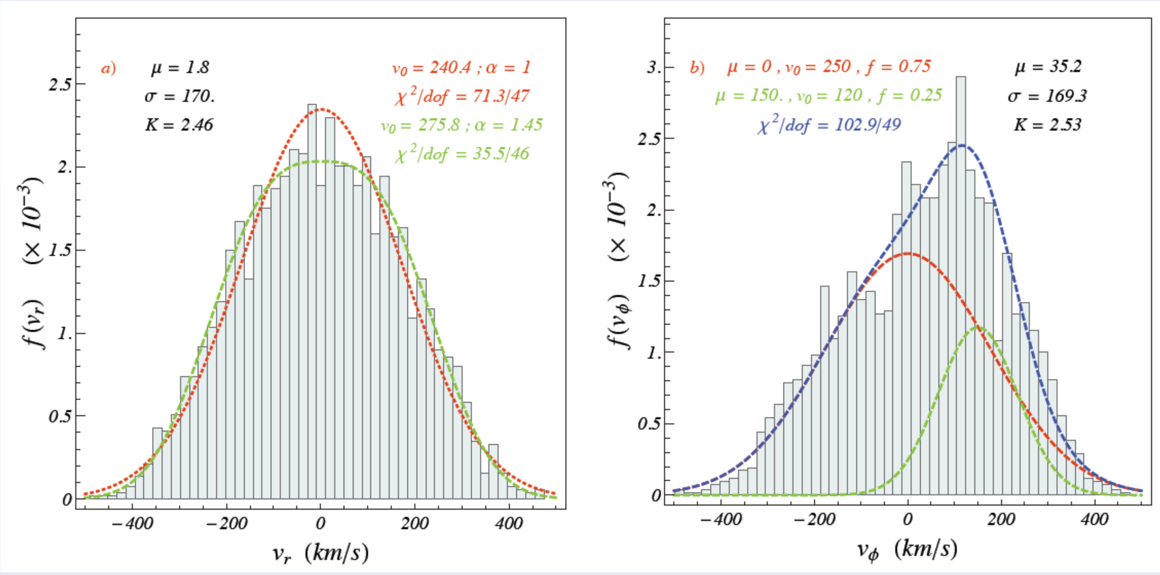
INTRODUCTION

>> Velocity distribution of dark matter

In direct detection experiment of dark matter, velocity distribution f(v) need to be supposed to convert event rate R in the experiment to constraints for dark matter mass mχ and cross section σ

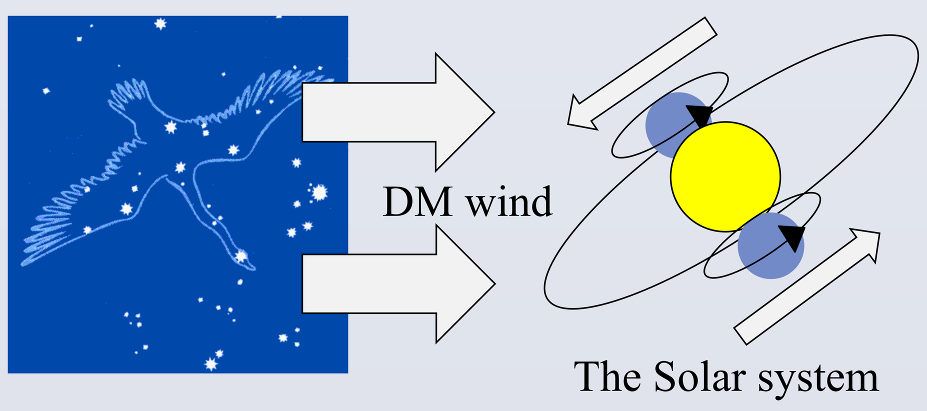
$$\frac{dR}{dE_R} = \frac{N_T \rho_0}{m_\chi} \int^{v_{\max}} d\vec{v}\, f(\vec{v})|\vec{v}| \frac{d\sigma(\vec{v})}{dE_R}.$$

Isotropic Maxwell-Boltzmann distribution is commonly adopted as the velocity distribution f(v), however, some observations and simulations have pointed out that this approximation is too simplified. In this study, we focus on the possibility that the distribution is anisotropic, especially the following distribution [1],



where v_r and v_φ represent radial and tangential velocities in the Galactic frame, respectively. The distribution is obtained by N-body simulation of dark matter with baryons and gasses and the tangential velocity suggests that the dark matter follows the motion of the baryons and gasses around the Galactic center. Afterwards, this distribution model is refereed as **"anisotropic distribution" with anisotropic parameter r=0.25 or 0.3** in the study.

>> Directional detection for dark matter search



Taking into account the Sun's movement around the Galactic center, the Solar system receives dark matter wind from direction of the Cygnus. In directional detection of dark matter, direction of coming dark matter from the Universe can be detected as well as the recoil energy of nuclear recoil, and most of the signal is presumed to come from the direction of Cygnus. In order to discriminate the anisotropy of velocity distribution, the directional detection is considered as most hopeful experiment.

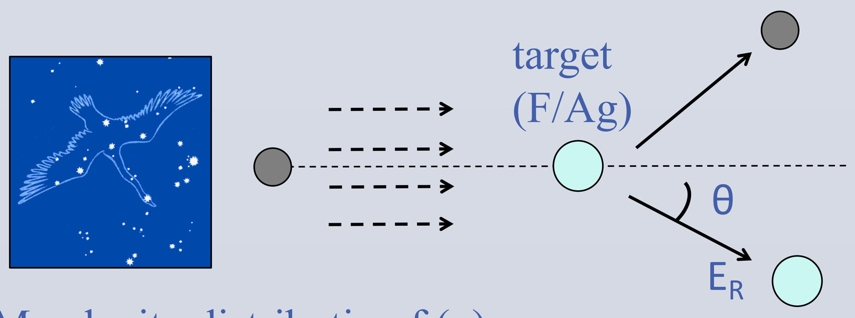
†A. MONTE-CARLO SIMULATION of DIRECT DETECTION

>>Target of scattering

In directional detection, currently CF_4, CS_2, CHF_3 are typical target of gas detector (DRIFT, DM-TPC, MIMAC, NEWAGE, D³, …) and Ag, Br, C, N, O are target of solid detector (NEWSdm). In this study we suppose **two typical target atoms fluorine (F) and silver (Ag)**.

>>Monte-Carlo simulation

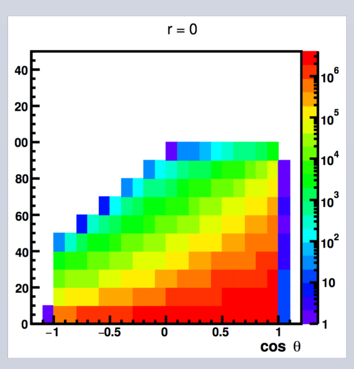
Supposing isotropic and anisotropic velocity distribution f(v), we generate scattering events by Monte-Carlo simulation. As a result, **the recoil energy E_R and scattering angle θ** are obtained. For simplicity, elastic scattering and zero back ground are assumed. Also the energy threshold of detectors are optimized for the discrimination.

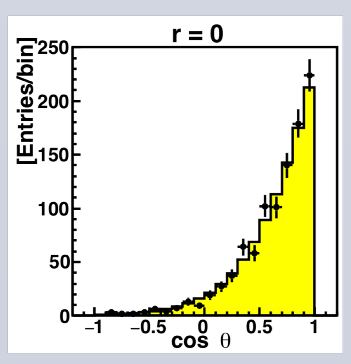


>>Data plot

Depending on energy and angular resolution of the detector, two kinds of distribution can be analyzed.

- Energy-angular distribution
- Angular histogram





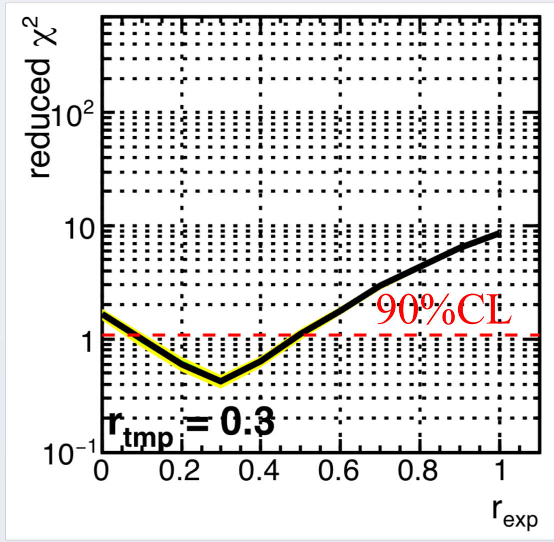
CONCLUSIONS

By Monte-Carlo simulation† of directional detection supposing isotropic and anisotropic velocity distribution, following conclusions* are obtained.

†**A. MONTE-CARLO SIMULATION of DIRECT DETECTION** for details.
***B. DATA ANALYSIS** for details.

1. **If we obtain dark matter mass from other experiment such as LHC, O(1000)-O(10000) events[2] are required to discriminate anisotropic distribution from isotropic Maxwell-Boltzmann distribution.** If anisotropic distribution is realized, isotropic case can be excluded at 90% confidence level by chi-squared test with the number of events.

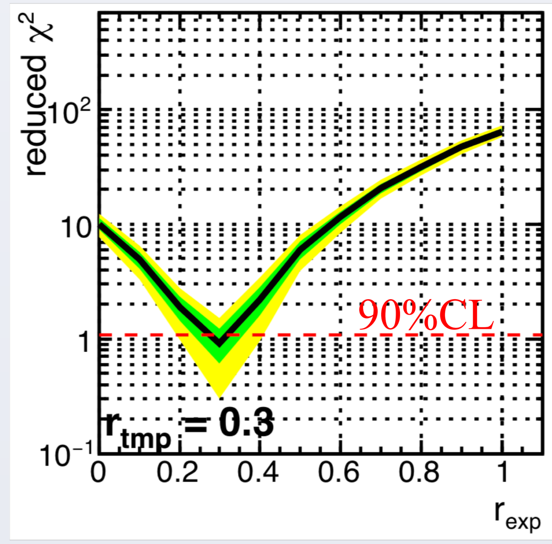
Using energy-angular distribution



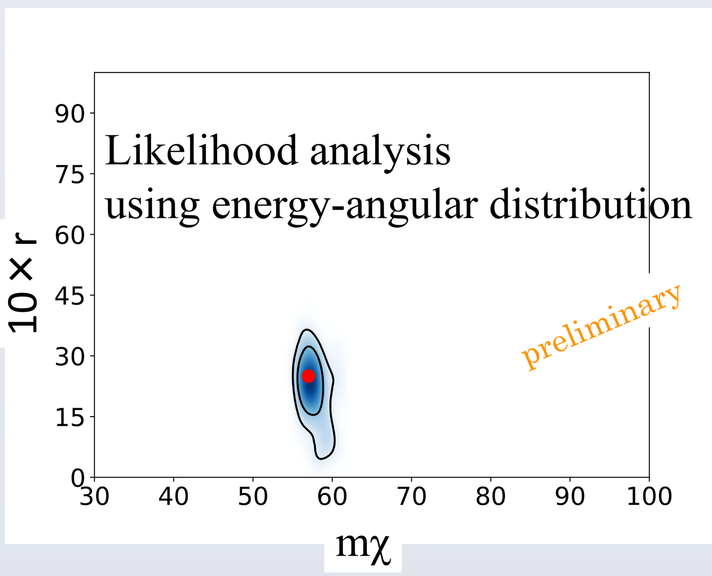
◂ target Ag
#exp.=6*10⁴
Ethr=50keV
mχ=302GeV

▸ target Ag
#exp.=2*10⁴
Ethr=50keV
mχ=302GeV

Using angular histogram



2. **Even if the dark matter mass is not knows, constraints for both mass and anisotropy can be obtained with energy-angular distribution.** Note that ambiguity of the constraint increases in case only one of the data, i.e., only ER or only cosθ, is used for the discrimination[3].



◂ target F
Ethr=50keV
#event: 1000
mχ=57GeV
anisotropy r = 0.25

B. DATA ANALYSIS

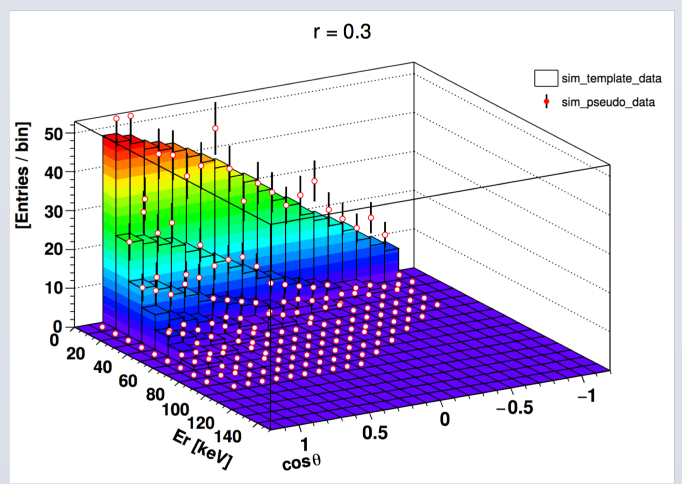
>>Strategy for the discrimination

Two data sets are generated by Monte-Carlo simulation supposing anisotropy parameter r and dark matter mass mχ.

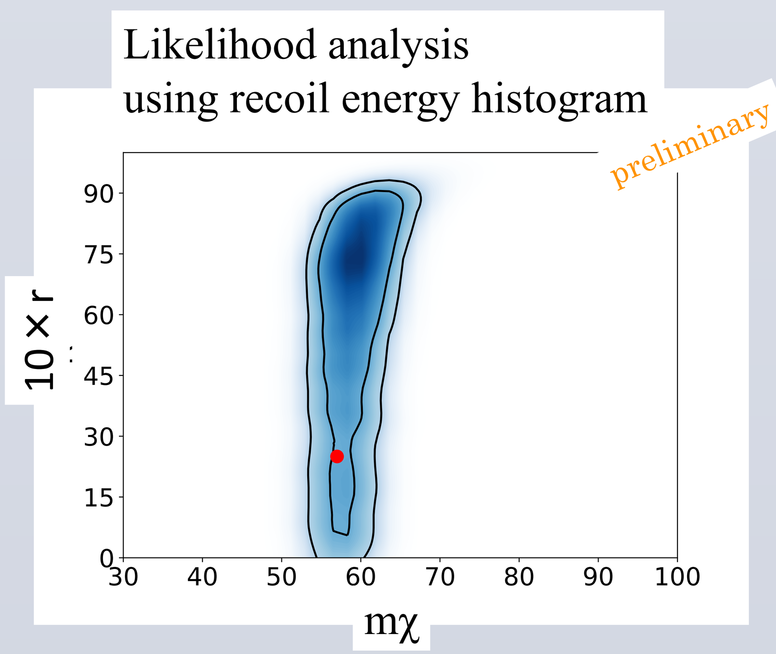
(1) ideal template data with $O(10^6\text{-}10^8)$ events

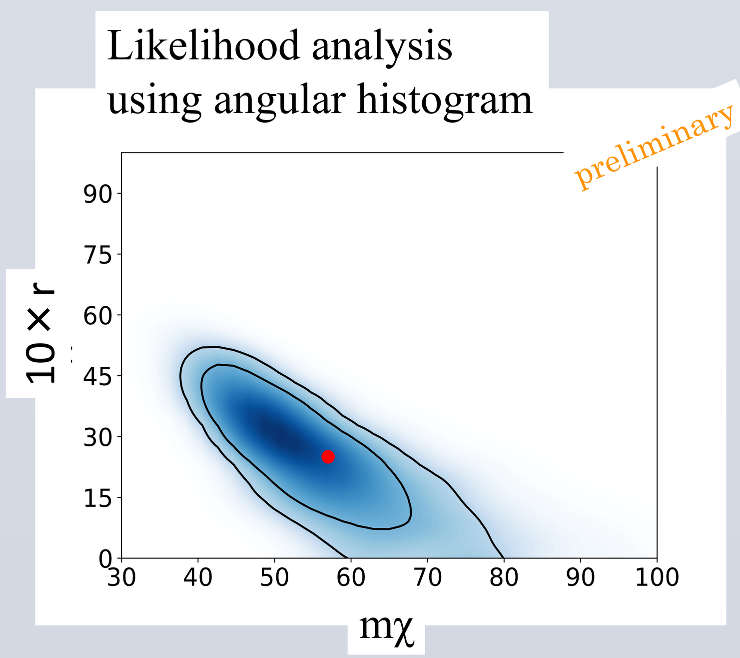
(2) pseudo-experimental data with $O(10^3\text{-}10^4)$ events

Comparing (1) and (2) by chi-squared test and/or likelihood analysis, conditions for the discrimination can be obtained.



>>Comparing three types of distribution





References

[1] Ling, Nezri, Athanassoula and Teyssier, JCAP 1002:012,2010

[2] See also astro-ph/0408047, arXiv:0704.2909, arXiv:0911.4086 arXiv:1012.3960 arXiv:1202.5035 for gas detector case.

[3] Consistent with previous study by Samuel K. Lee, Annika H. G. Peter, JCAP04(2012)029.

CONTACT

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