Measuring Dark Matter Distribution in Directional Direct Detection

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Collaboration with

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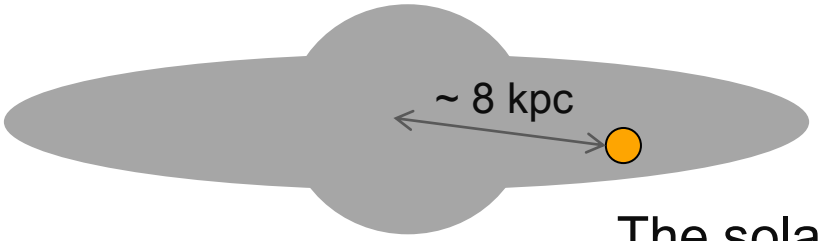
Introduction

- Dark matter distribution in the galaxy



The solar system

✓ Is it Maxwell distribution?

- Many distribution models have been proposed.

✓ Is there a way to observe it?

- I will discuss the possibility with the directional detector in this talk (taking the nuclear emulsion for example).

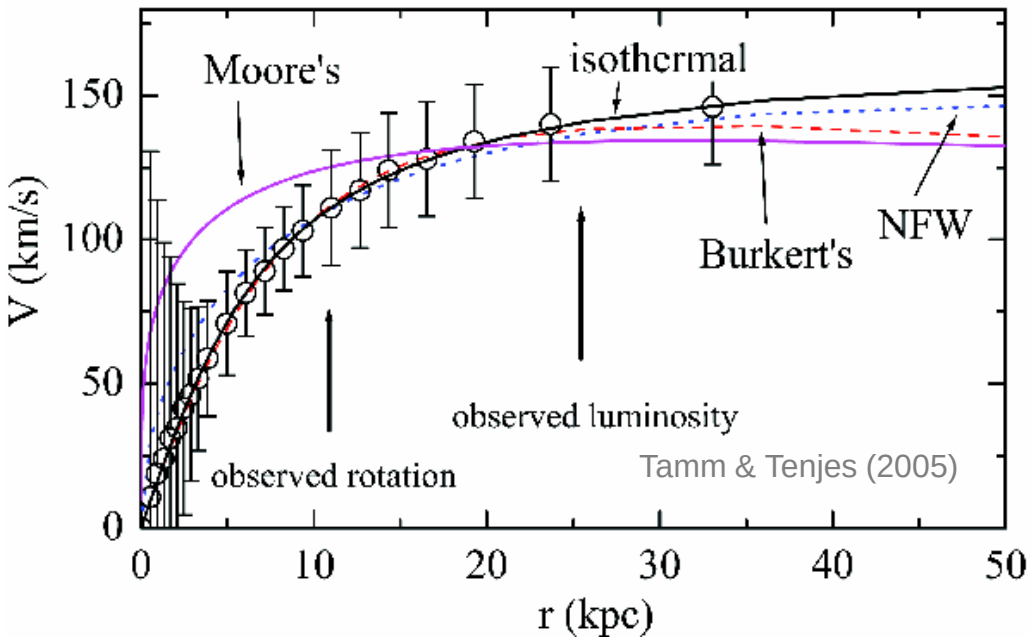
Outline

1. ~~Introduction~~
2. Why is the DM distribution important?
3. Non-standard distributions
4. Nuclear Emulsion Detector
5. Numerical results
6. Summary

Why is the DM distribution important for us?

1. Astronomical interest (Of course!)

   There are many distribution models,
   and which one agrees with the observation?



Tamm & Tenjes (2005)

Why is the DM distribution important for us?

2. Interest from particle physics

- Constraint from direct detections depends on DM distribution

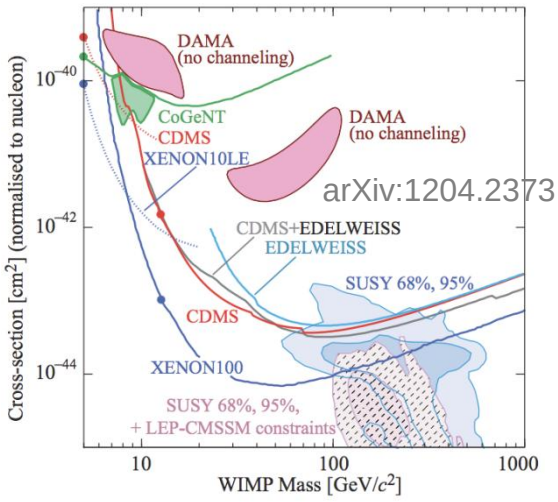
-Calculation of σ from event rate

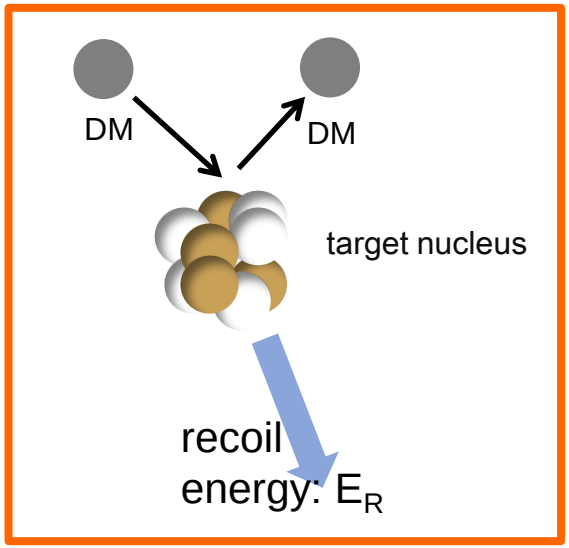
$$R = N_T n_\chi \int_{E_{R,\min}} dE_R \int_{v_{\min}}^{v_{\max}} d^3v \; f(v) \frac{\tilde{\sigma}_A m_A}{2v\mu_A^2}$$

Experiment

Astronomy

Particle + nuclear phys.



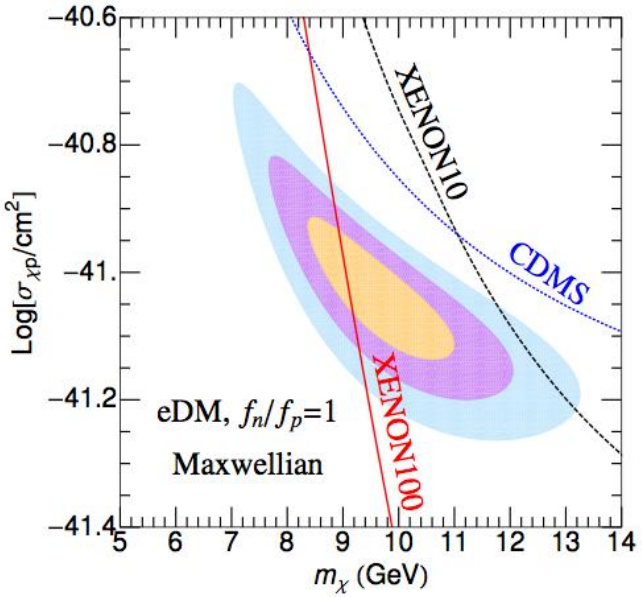


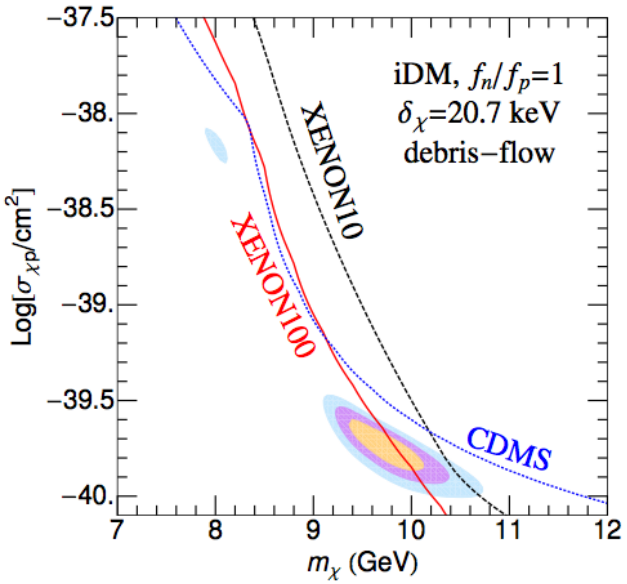
- We should know correct DM distribution to derive correct constraints for interaction of DM.

Why is the DM distribution important for us?

2’. Interest from particle physics

- Supposing non-standard distribution (with other factors, like isospin violating, inelastic scattering…) improves the situation to explain the discrepancy between positive and negative results of direct searches.





Cline,Liu, Xue (2012)

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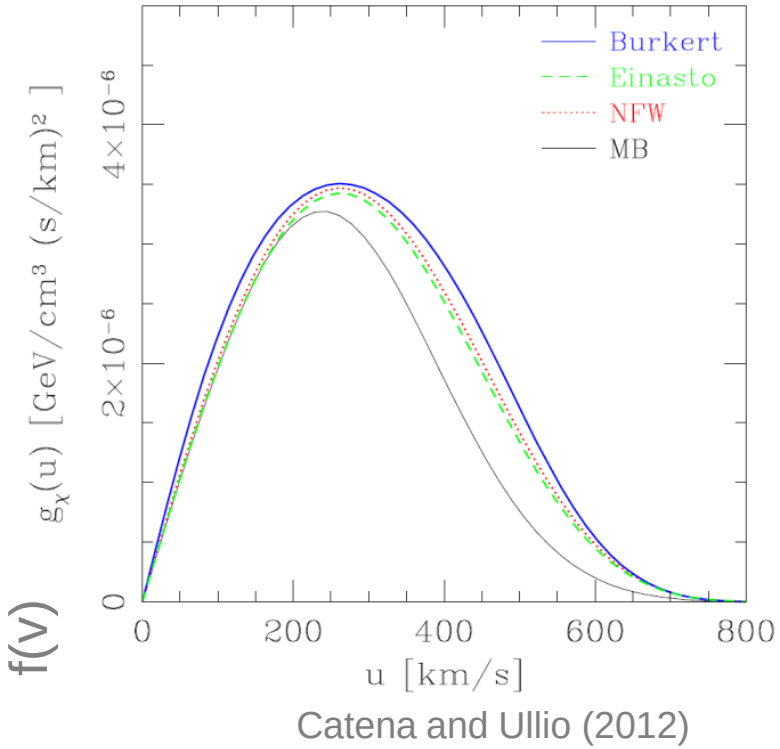
DM Velocity Distribution -Standard Distribution-



Catena and Ullio (2012)

- Maxwell distribution

$$f(v) = \frac{1}{(\pi v_0^2)^{3/2}} e^{-(v+v_E)^2/v_0^2}$$

v_0: velocity of the Solar system
v_E: Earth's velocity relative to DM

- Isothermal profile

density distribution: $\rho \sim 1/r^2$

- Cored isothermal (Bahcall et.al,1980)
- Burkert pofile (1995)
- Navaro-Frenk-White profile (1996)
- …

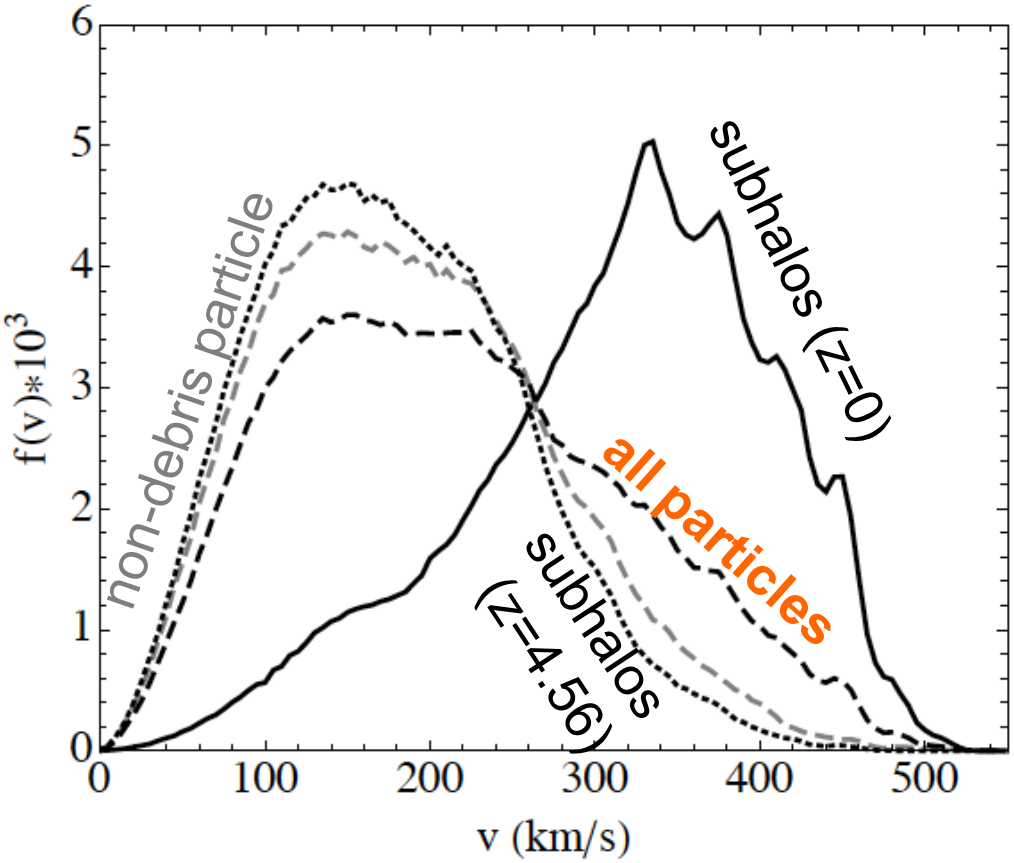
- DM distribution is surely this kind of shape?

-we don't know the answer yet…

Tidal Streams

- N-body simulation in which subhalos falling into the Milky Way

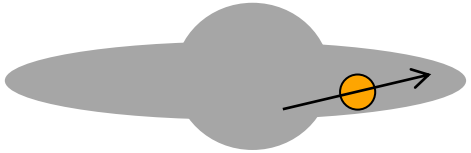
• **Smaller velocity** than that for Maxwell distribution

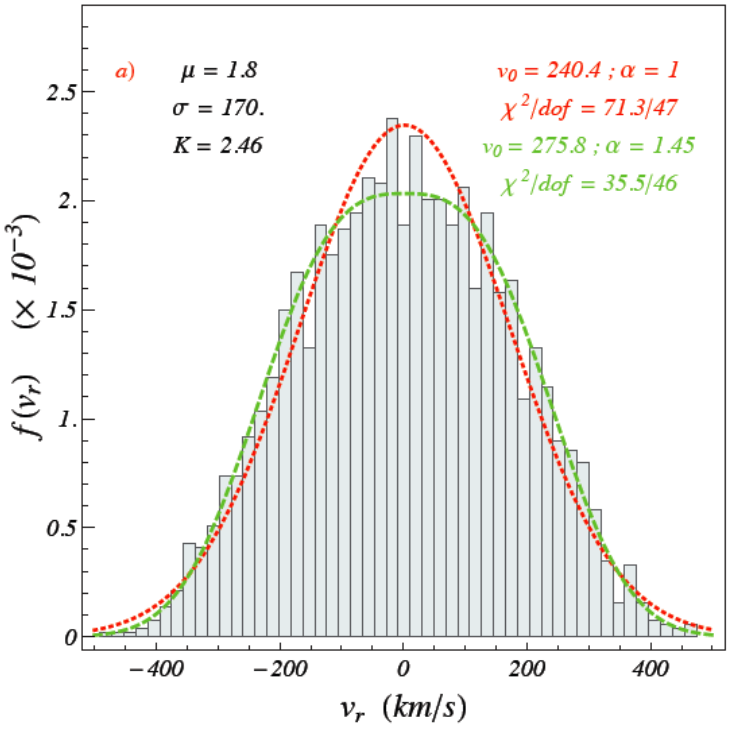


Kulen, Lisanti & Spergel (2012)

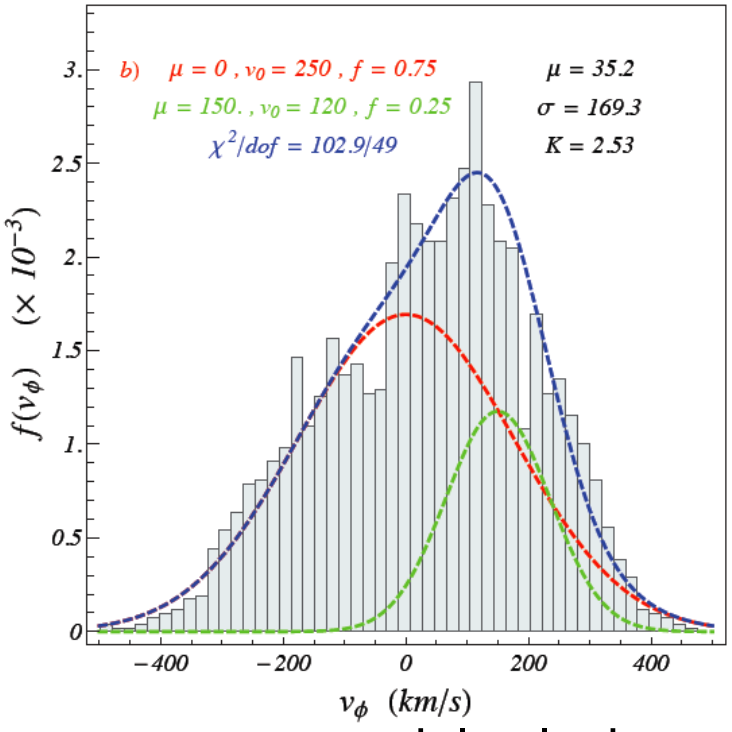
Debris Flow

- N-body simulation with baryons and gas
  - DM rotates following baryons
  - Distribution is not isotropic





radial velocity



tangential velocity

Ling Nezri Athanassoulab & Teyssierc (2009)

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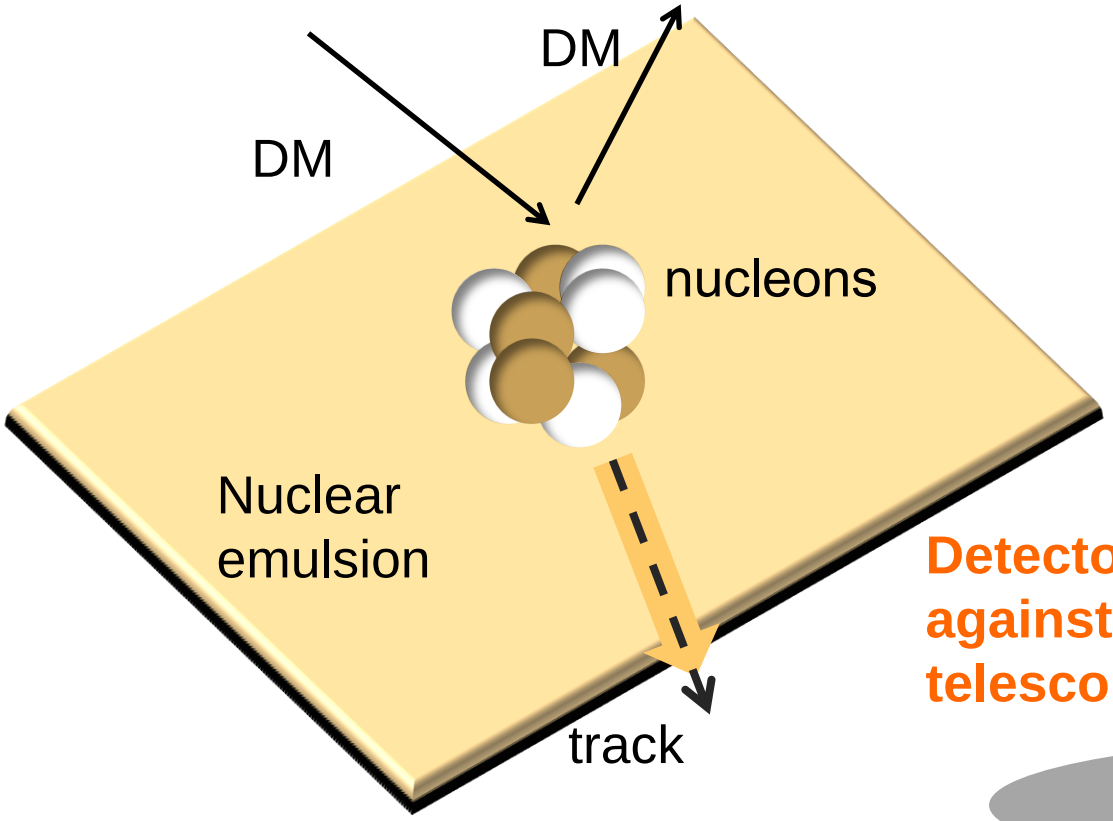
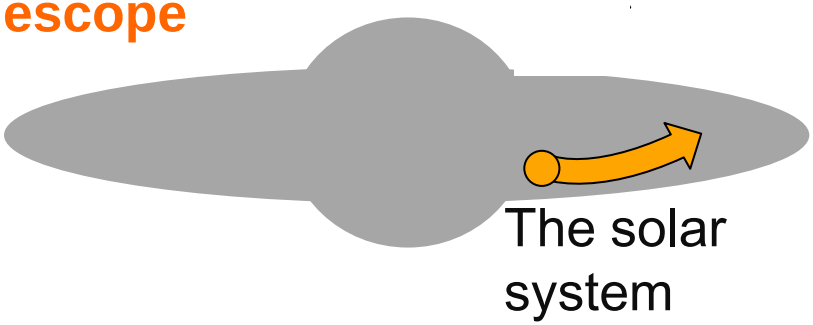
Concept of DM detection with nuclear emulsion

- Detection of **recoiled nucleus** from DM-nucleon scattering



Detector direction is kept to be against DM wind by an equatorial telescope



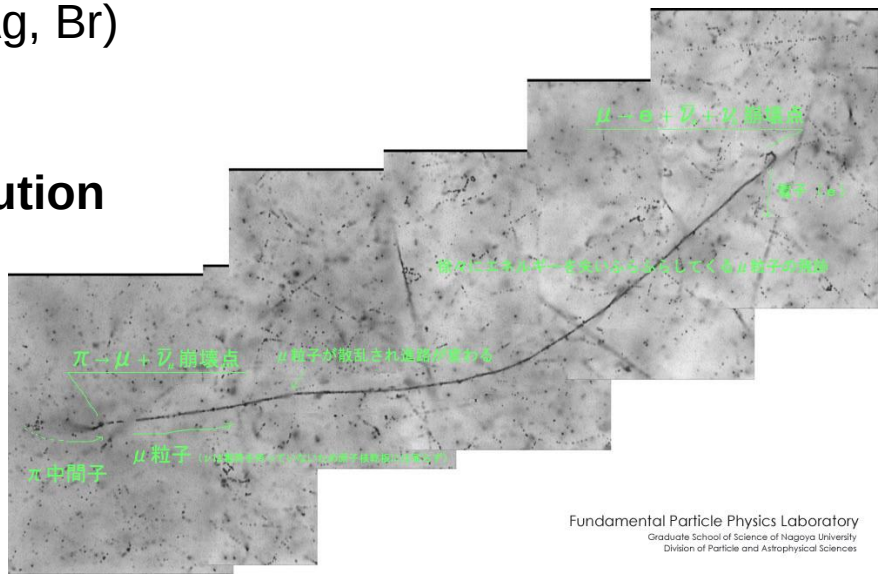
Direct detection with nuclear emulsion

- Sensitivity
  - Targets: Ag, Br, C, N, O
  - Energy threshold : depends on target

    (~33 keV for C, N, O and ~150 keV for Ag, Br)
- Advantage
  - **Directional sensitivity with high resolution**

    Angular resolution: 15-20°

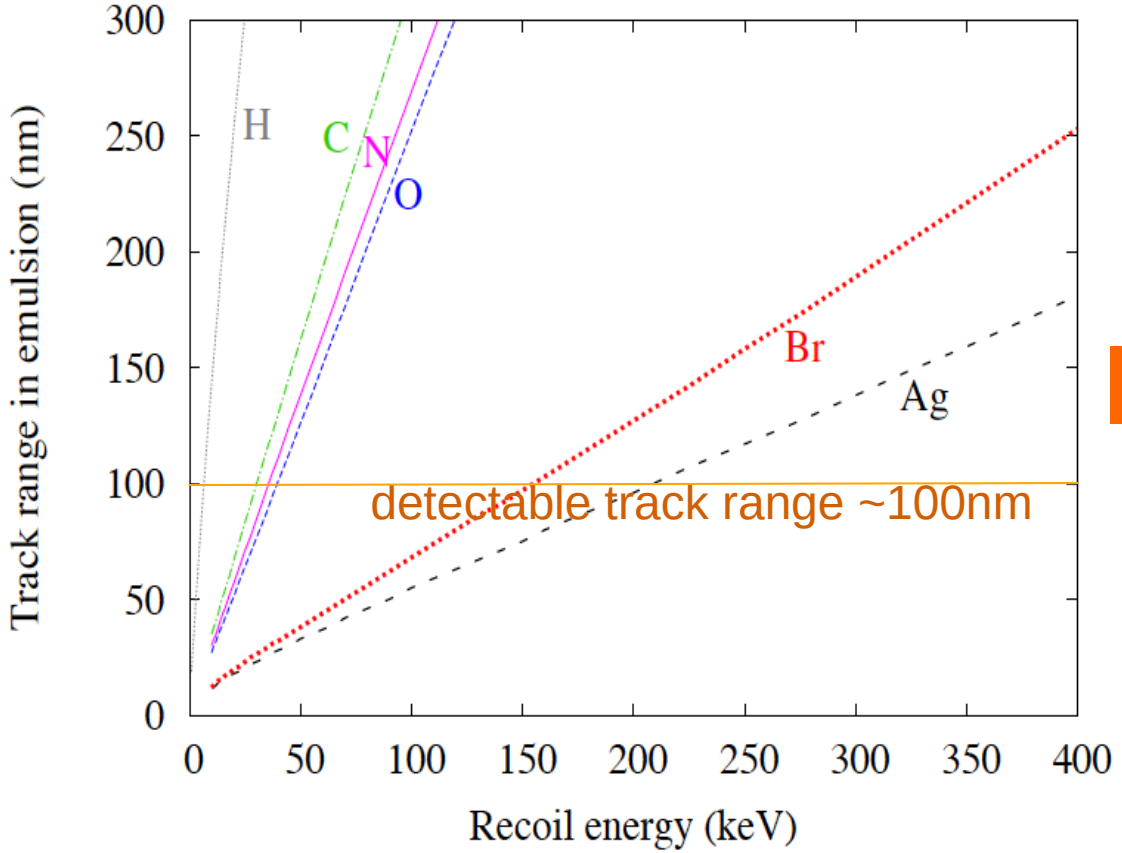
    Spatial resolution: 100 nm
  - **Large mass**: O(100) - 1000 kg
- Status
  - R&D

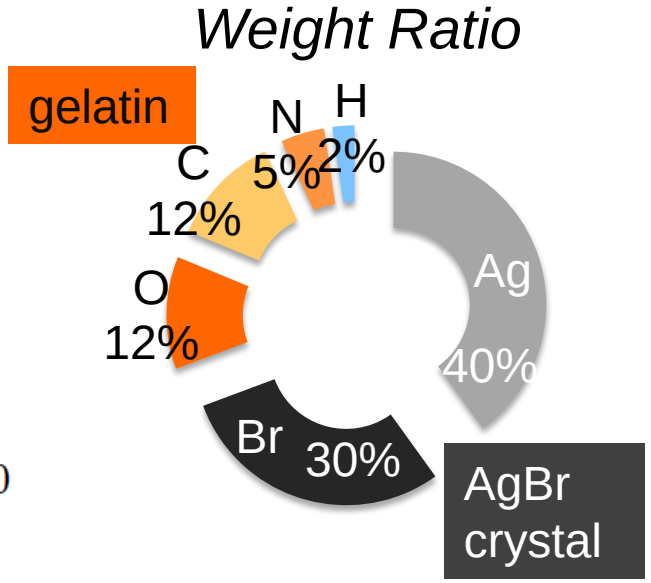


➡ See Takayoshi's (10P3) and Takashi's (11A6) talks for details

Energy threshold?

- O(10)-O(1000)GeV mass DM
  - Typical recoil energy :O(1)-O(100)keV
  - **Required resolution is submicron** (~O(100)nm) track length





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OK, we understand the distribution is important for our physics!

Non-standard distributions are suggested by N-body simulation…

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OK, we understand the distribution is important for our physics!

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Non-standard distributions are suggested by N-body simulation…

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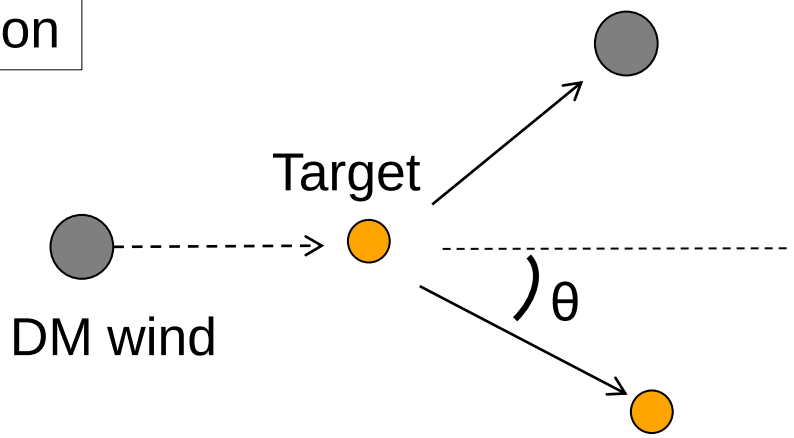
Can we distinguish the distribution?

Can we distinguish the distribution?

- No. (in the ordinary direct search)
- How about in the directional direct search? Then we can see both the scattering angle and the recoil energy.

Calculation



- Monte Carlo simulation
- Simple elastic scattering
- Scattering angle– Recoil energy (track length) distribution

Summary & Discussion

- I discussed the possibility to distinguish the distribution models of dark matter in the direct detection, focusing on the nuclear emulsions.
- Distribution of the scattering angle and the energy density is surely affected by the distribution model.
- Since we do not include the detector efficiency, the tendency of the angle-track distribution would be similar for gas detector case.