

# DAMA and non standard halo models

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Aravind Natarajan

Pheno 2011,  
U. Wisconsin, Madison.

# Outline -

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## Introduction

annual modulation, DAMA, self similar halo model.

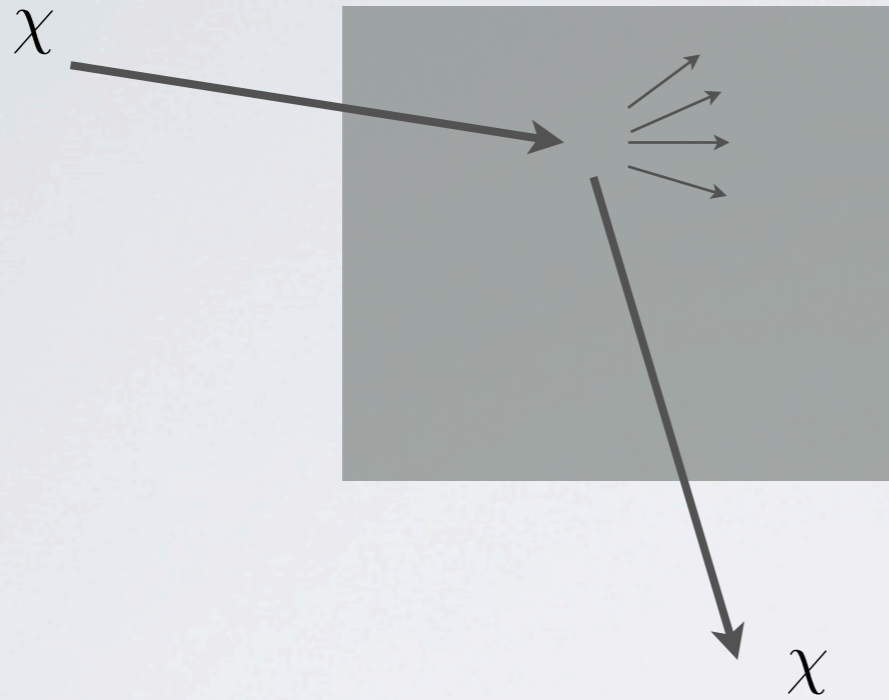
## Results

prediction match the observations.

## Testing the theory.

Experiments in the near future can confirm/falsify the theory.

# WIMP - nucleus scattering



See:

Goodman & Witten 1985  
Griest 1988  
Engel 1991

**Cross section:**      **Scalar (spin independent)**  
                                 **Axial (spin dependent)**

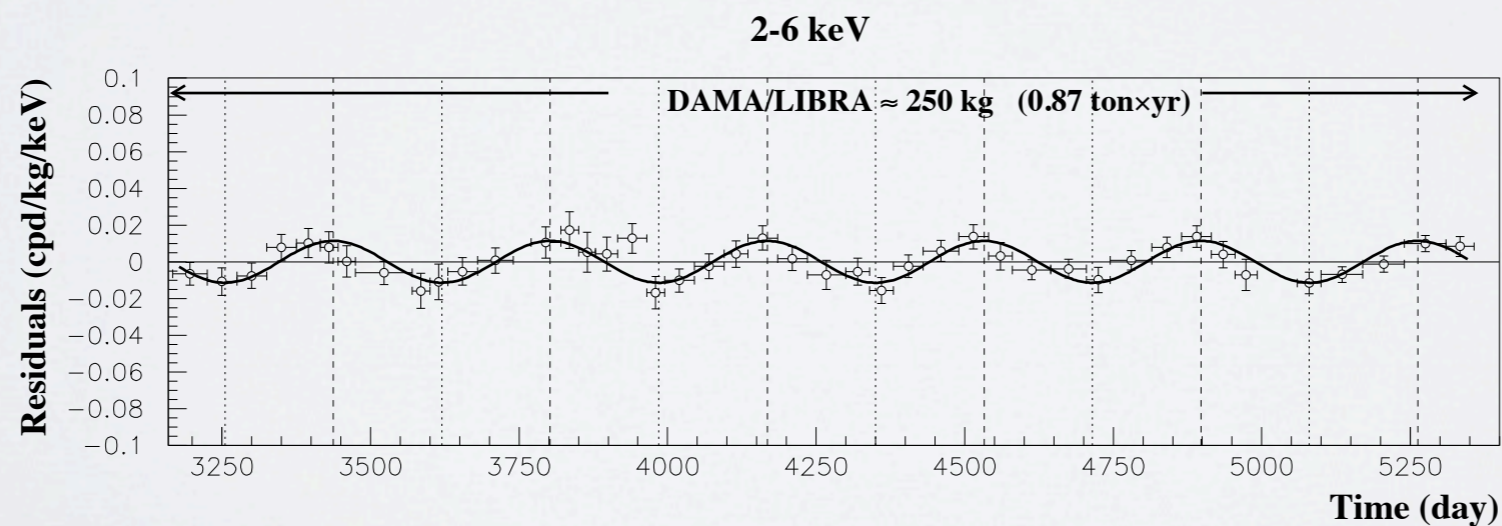
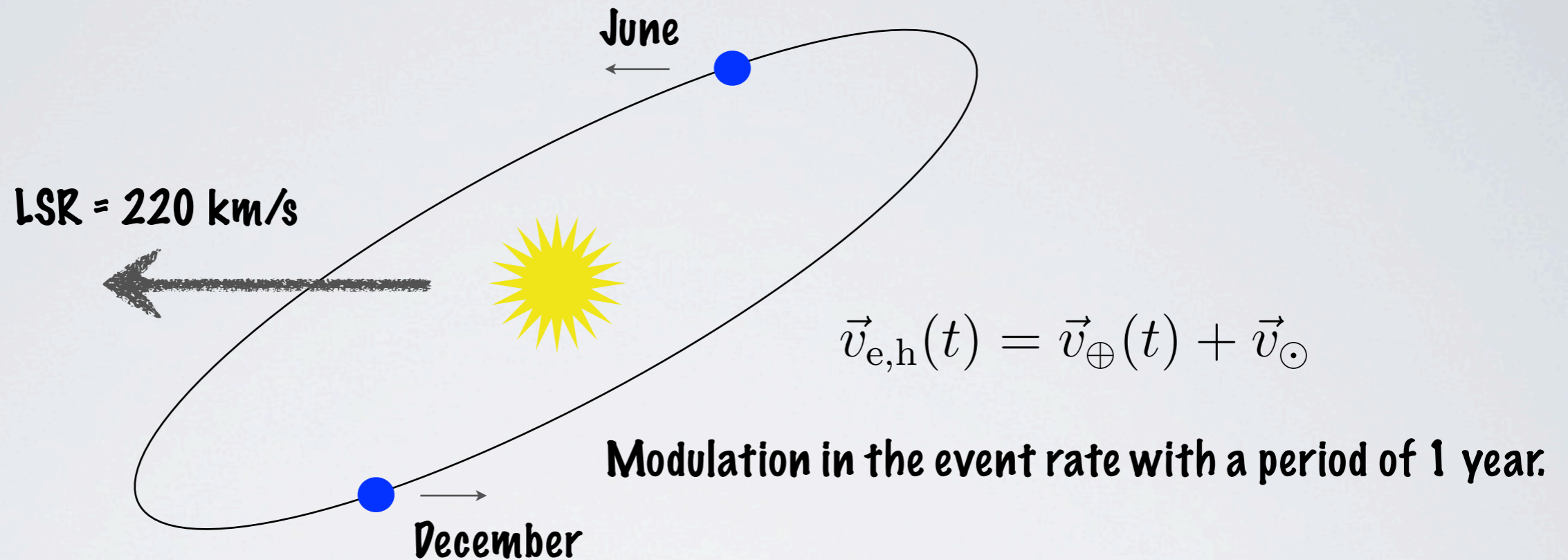
**Scattering:**            **Elastic**  
                                 **Inelastic**

How do we distinguish WIMPS from background events ?

By looking for an **annual modulation** in the scattering rate

Drukier, Freese, and Spergel 1986  
Freese, Frieman, and Gould 1988

# How do we distinguish WIMPS from background events ?



DAMA collab.  
2008, 2010

Such a modulation is claimed by DAMA at 8.9 sigma significance.

# A closer look at DAMA/LIBRA

25 pure NaI (TI) crystals, with a mass 9.70 kg each, taking data at Gran Sasso.

Looks for scintillation light using PMTs.

Total exposure is 0.87 ton-year (6 annual cycles).

DAMA collab. 2010

With earlier DAMA/NaI, exposure is 1.17 ton-year (13 annual cycles).

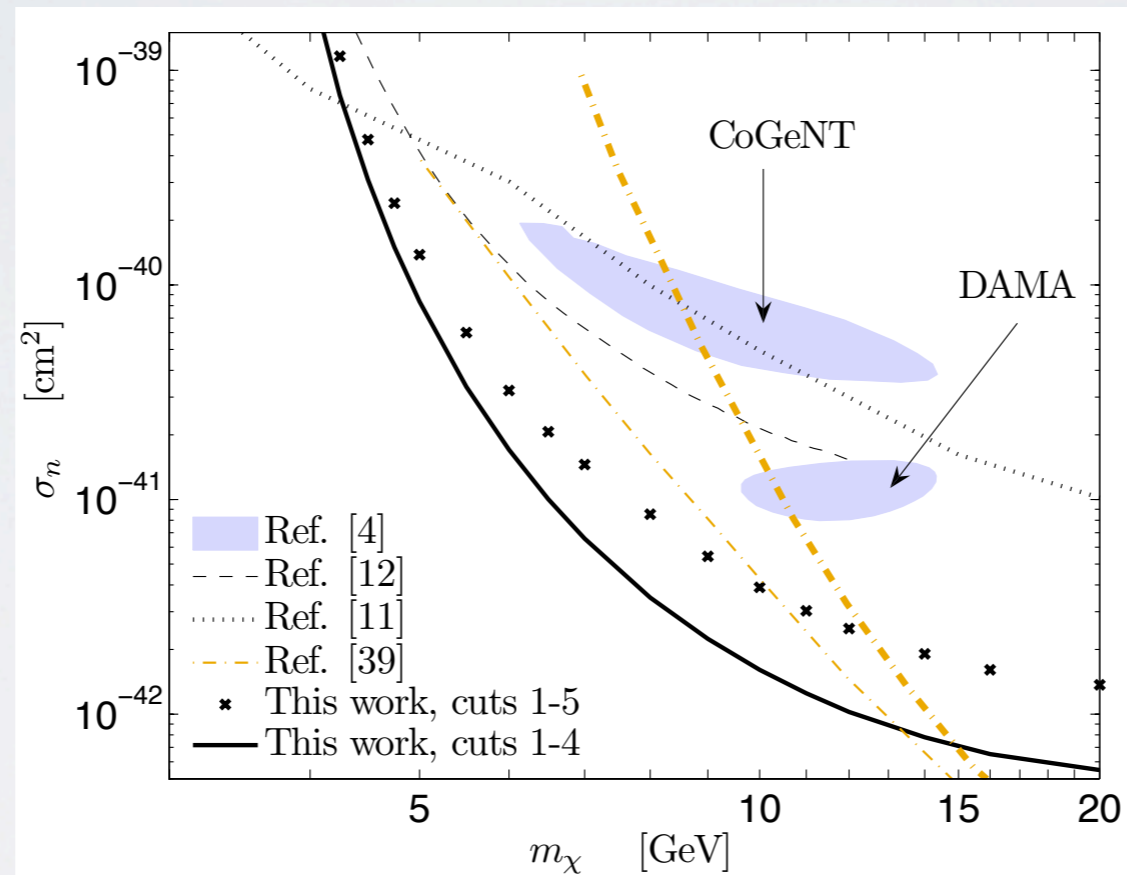
Single hit events can be distinguished from multiple hit events.

Single hit events modulate with  $> 8$  sigma confidence.

Multiple hit events consistent with zero modulation.

# Inconsistency with other experiments:

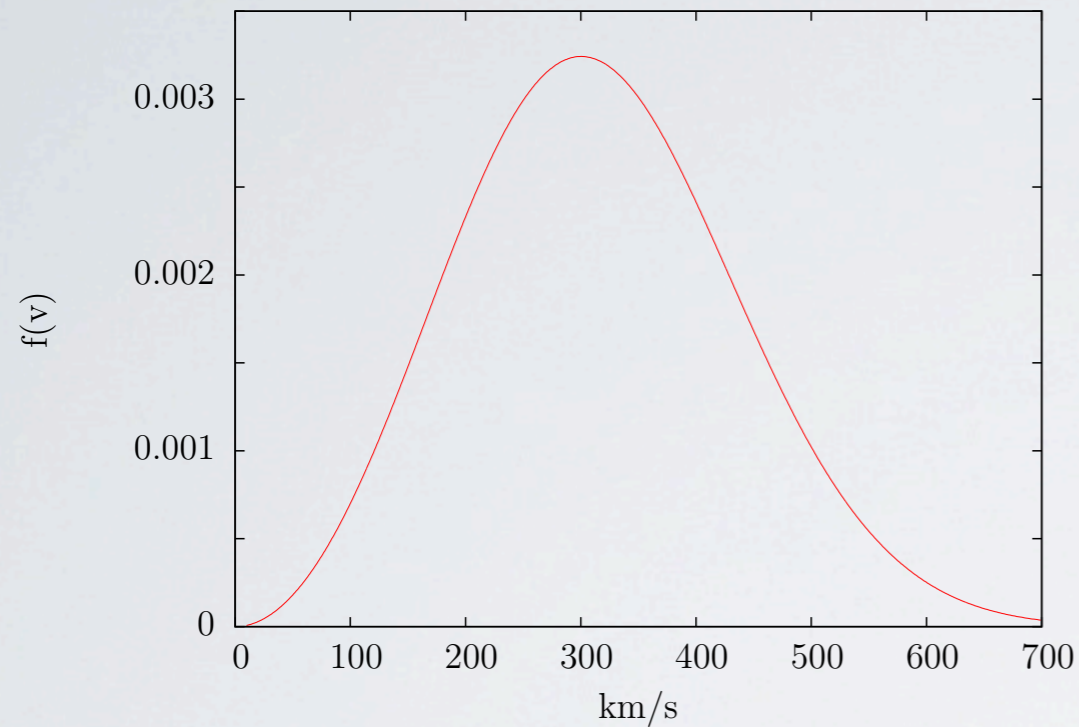
**DAMA allowed region disfavored by recent Xenon results!**



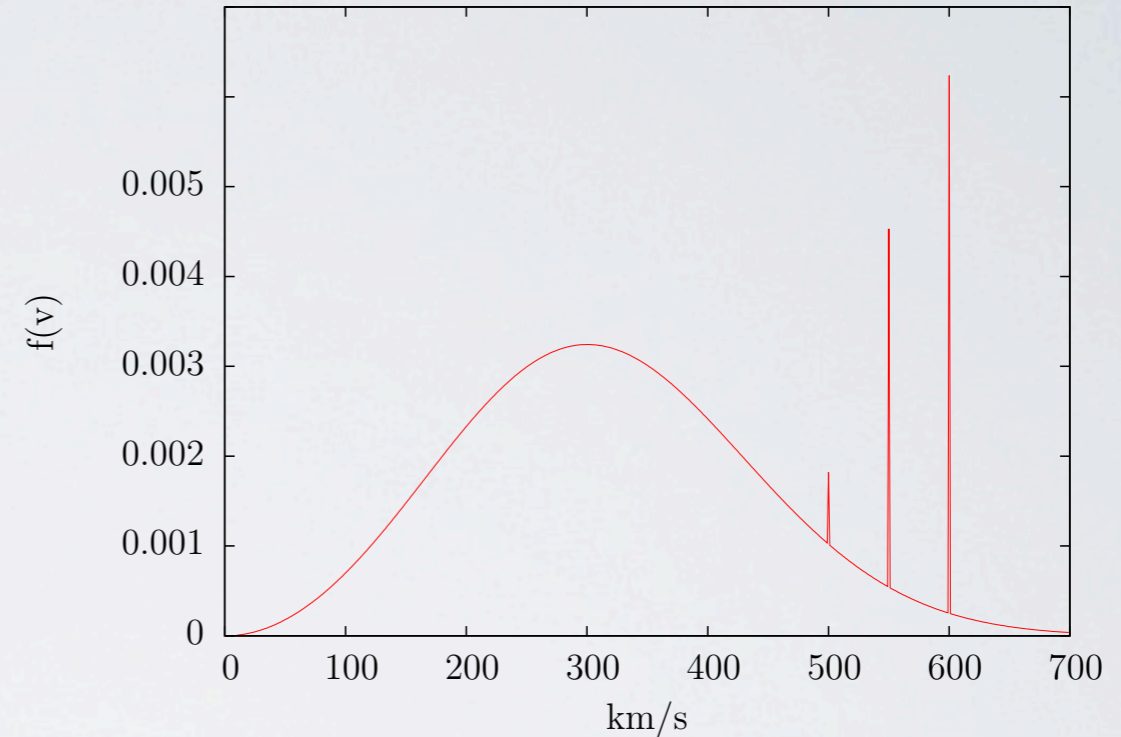
Xenon 2011

# Non-standard halo models:

## Maxwellian



## Maxwellian + streams



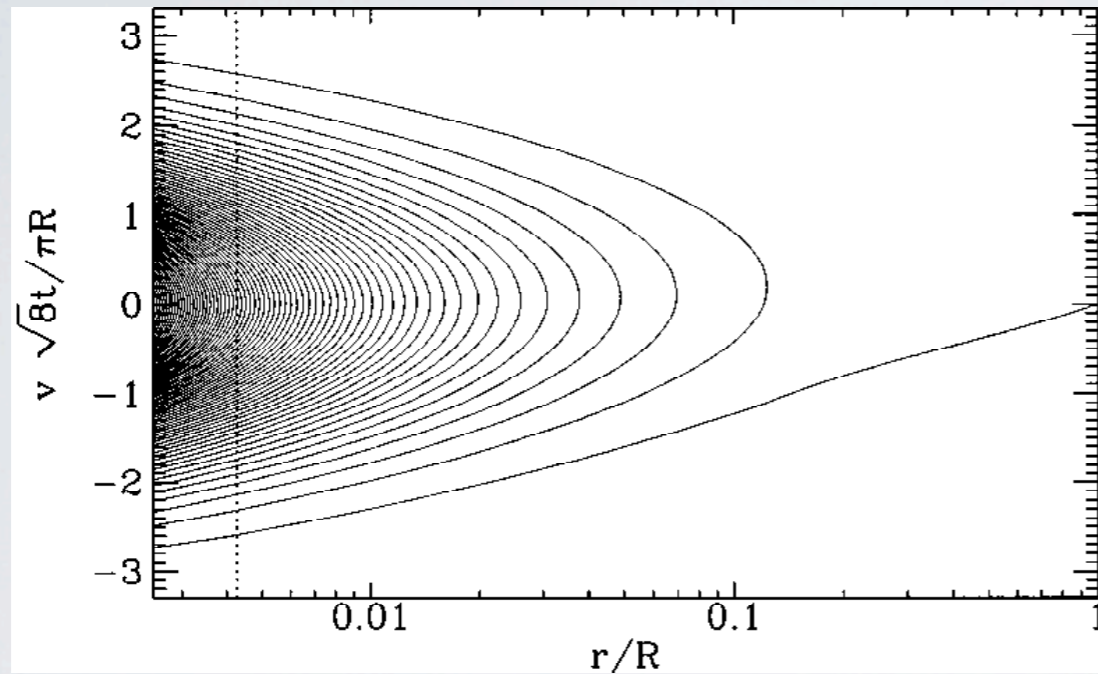
**Streams are expected due to:**

- (i) Late infall of DM onto a virialized halo.**
- (ii) Tidal disruption of dwarf galaxies.**



# Self-similar infall:

$$f(\vec{r}, \vec{v}; t) = A(t) F\left(\frac{\vec{r}}{R(t)}, \frac{\vec{v}}{V(t)}\right)$$



See:

Fillmore & Goldreich 1984

Bertschinger 1985

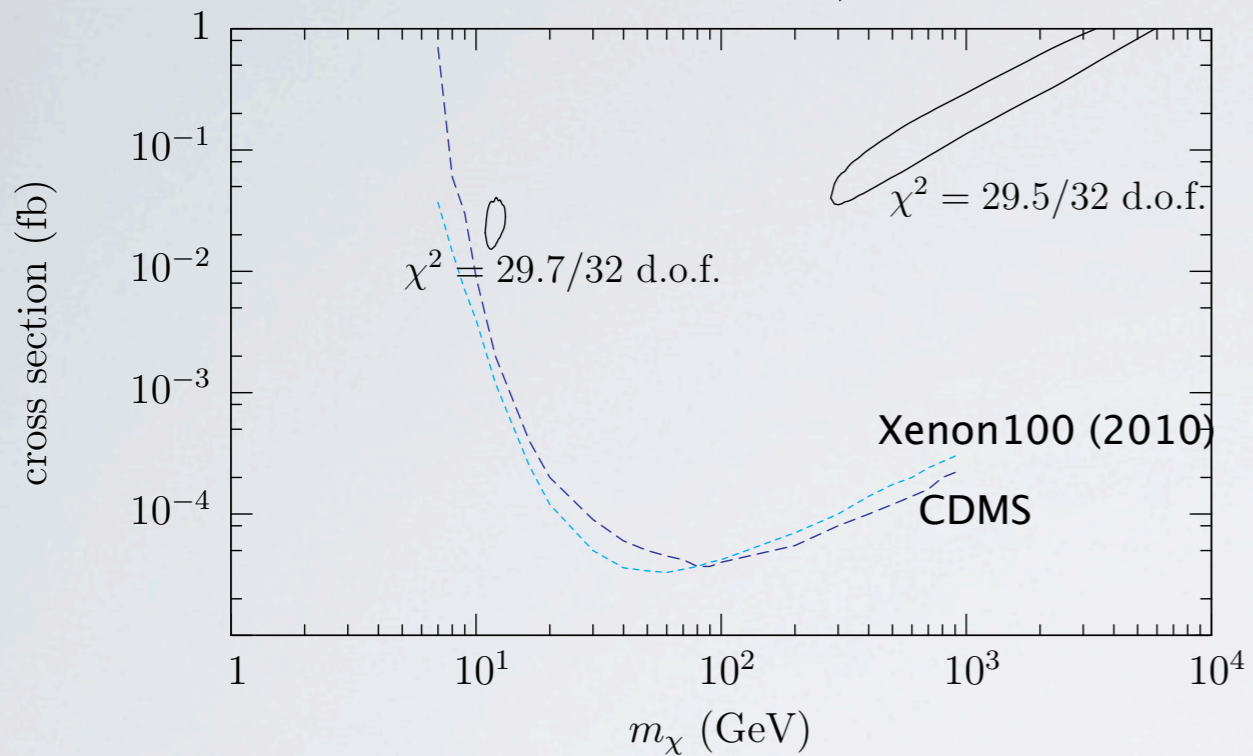
Sikivie, Tkachev, & Wang 1997

Duffy and Sikivie 2008

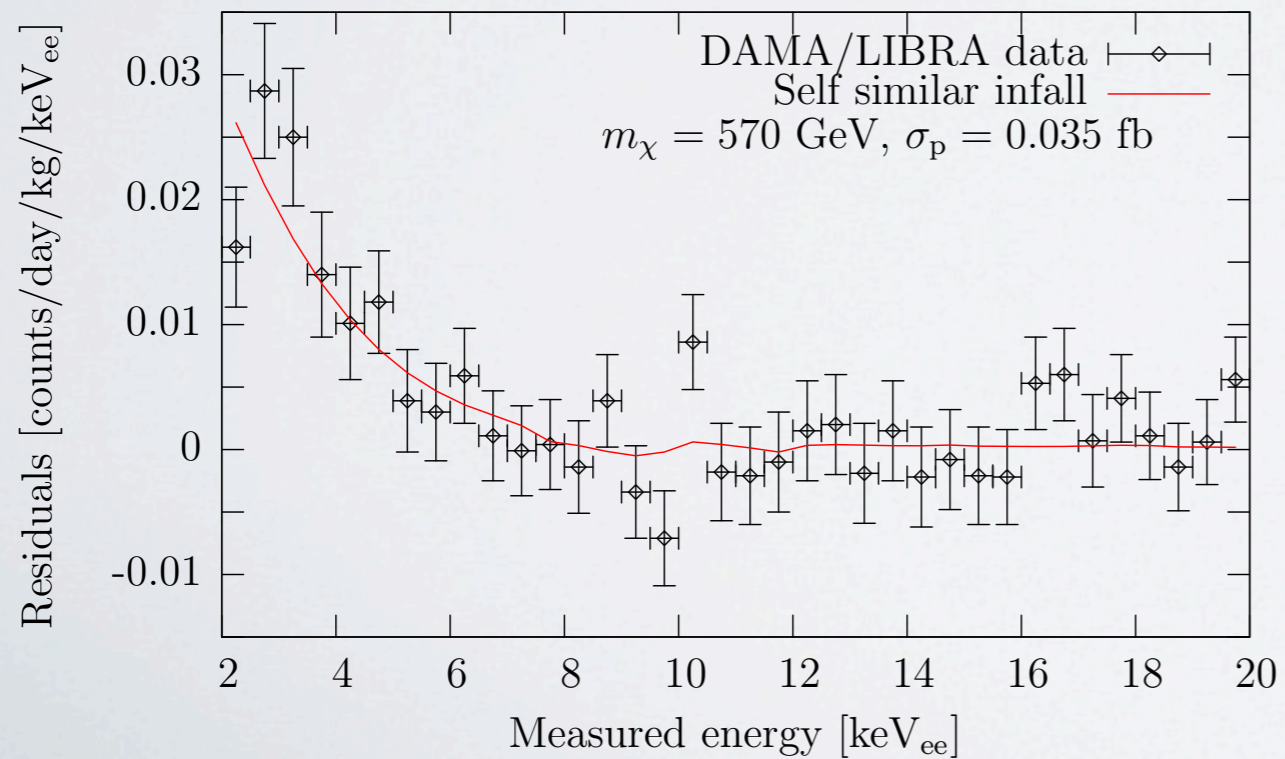
- **Velocity distribution is discrete, i.e. a sum over dark matter streams.**
- **$f(v)$  is different from a Maxwellian. Different annual modulation signature.**
- **The model predicts the densities and velocities of DM particles at the earth's location. Hence the recoil spectrum is predicted.**

# Results

50% streams, 50% thermal



**$m > 300$  GeV for correct modulation phase.**



# Testing the theory

## 1. With detectors that have directional sensitivity.

See:

Gelmini and Gondolo 2001

Copi and Krauss 2001

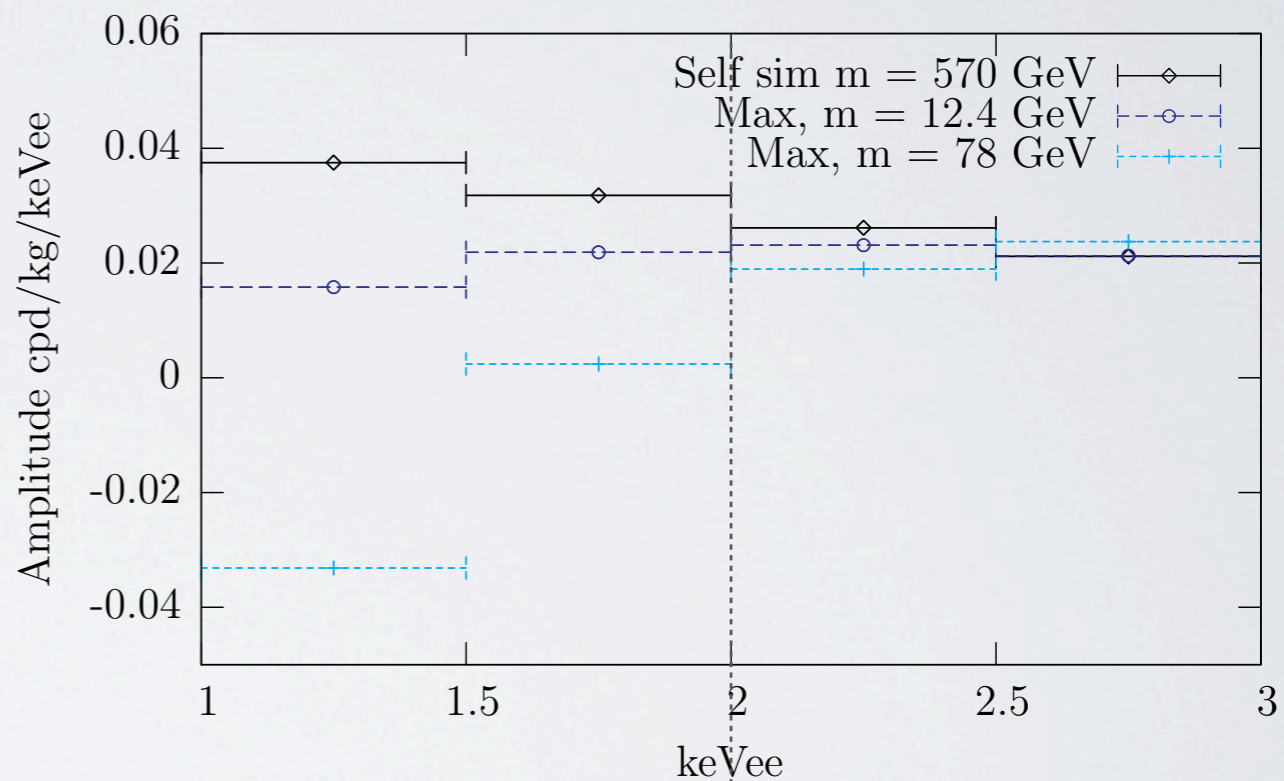
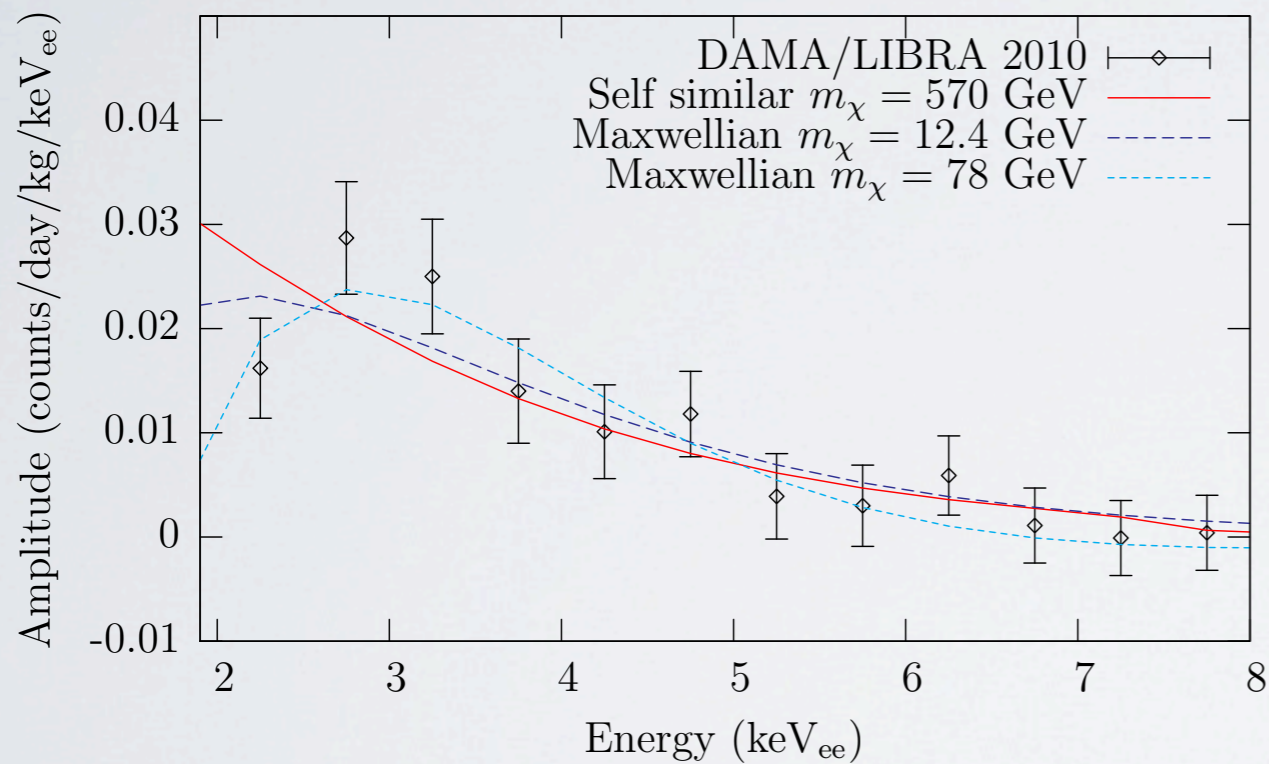
Green 2001

Vergados 2001

Ling, Wick, and Sikivie 2004

# Testing the theory

## 2. By measuring the amplitude at lower energies.



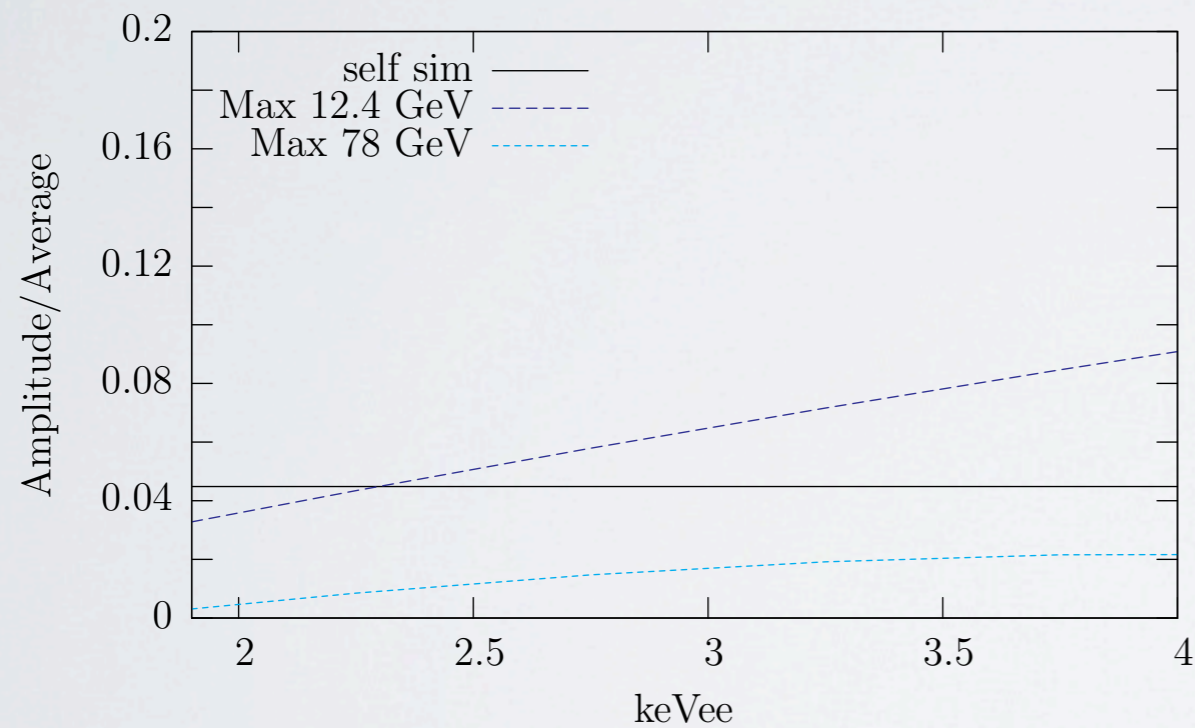
**New PMT's to reduce the threshold in the near future**  
DAMA collab. 2010

DAMA energy threshold

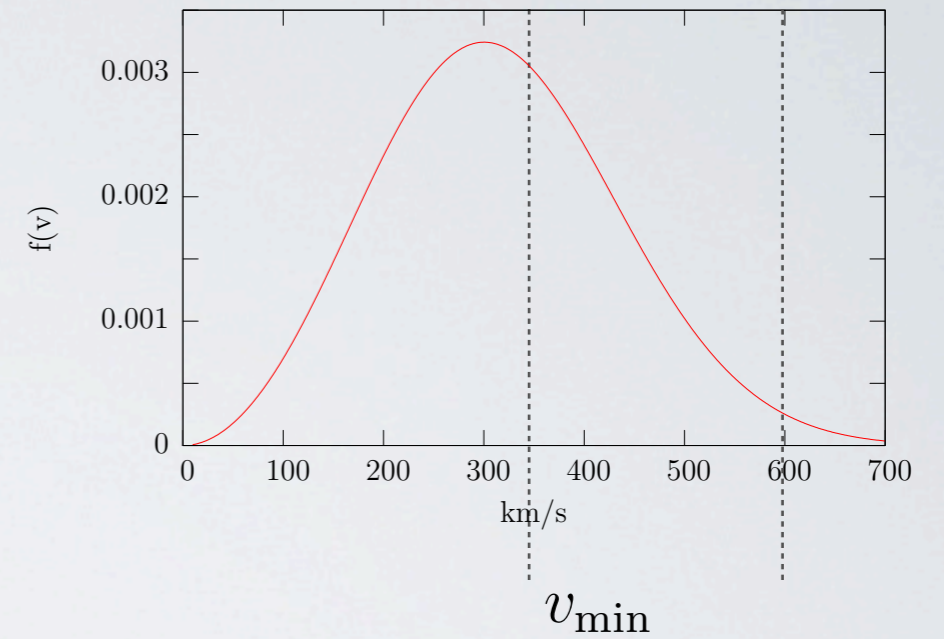
# Testing the theory

## 3. By measuring the average recoil rate.

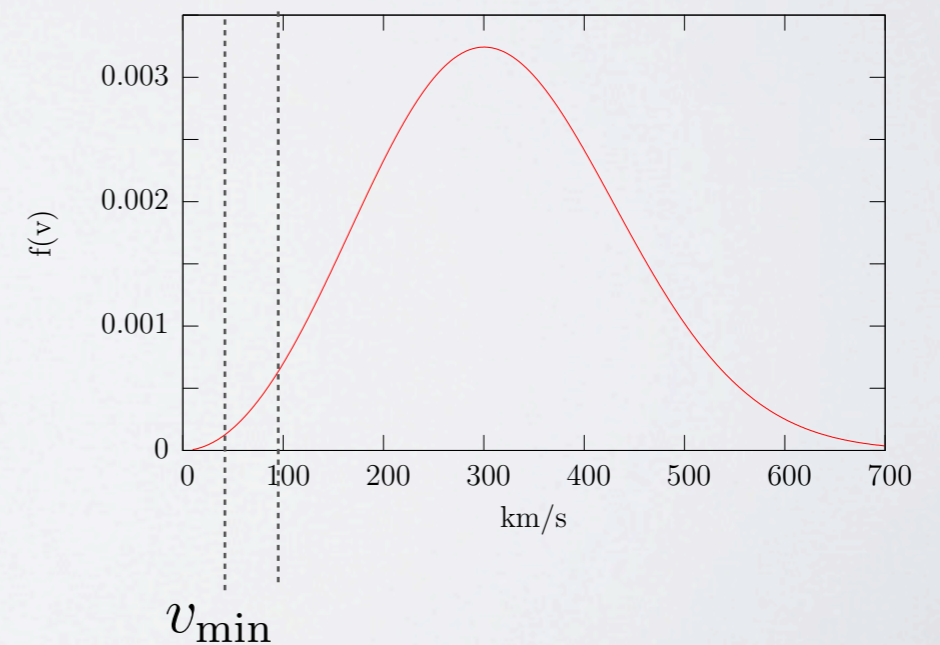
$$\frac{\text{Amplitude}}{\text{Average}} = \frac{\text{Max} - \text{Min}}{\text{Max} + \text{Min}}$$



Small mass

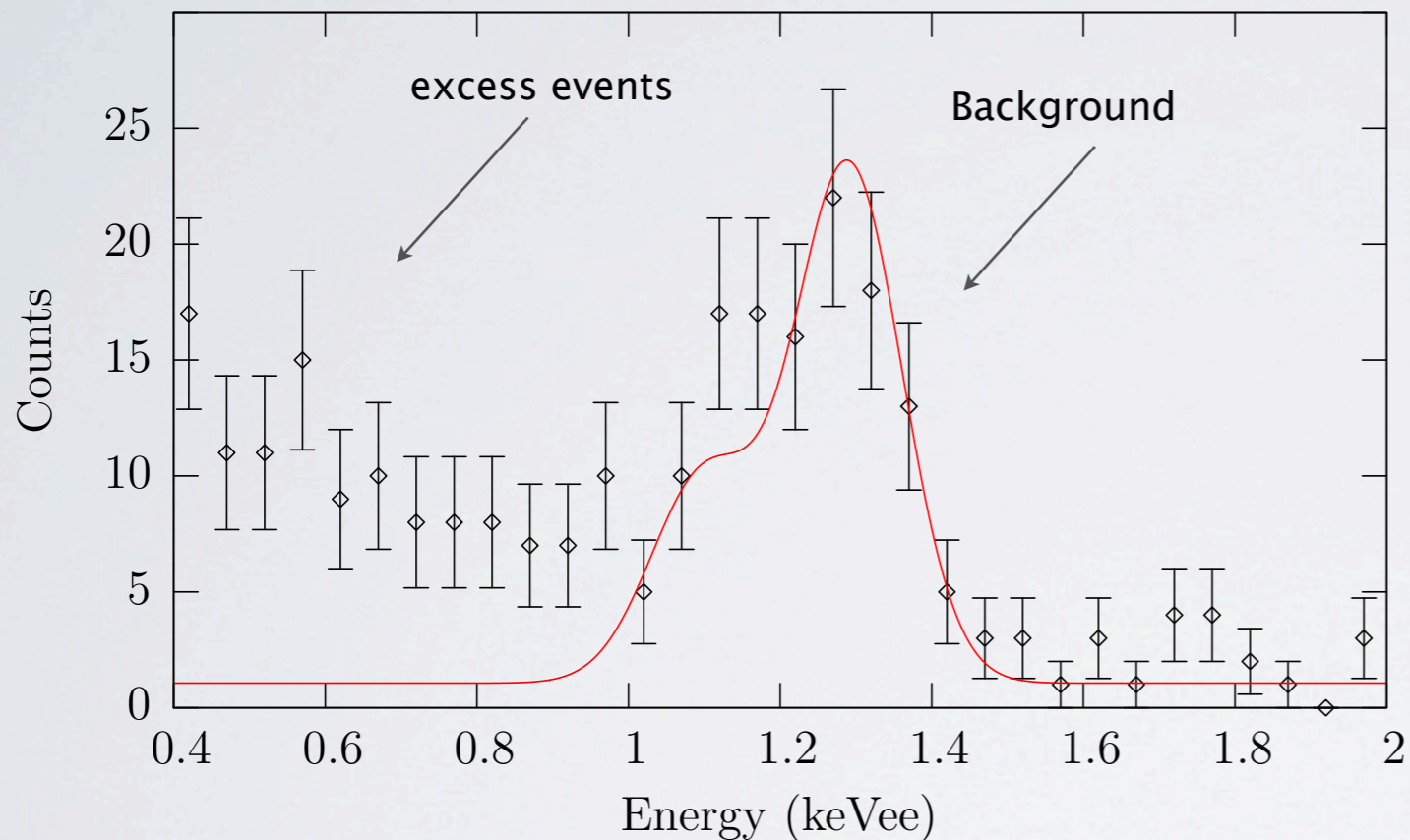


Large mass



# The CoGeNT experiment

Aalseth et al 2010, for CoGeNT



**Low threshold: 0.42 keVee**  
**Good resolution: 0.05 keVee**

See also:

Kelso, Hooper 2011

Hooper, Collar, Hall, McKinsey, Kelso 2010

Chang, Liu, Pierce, Weiner, Yavin 2010

Belikov, Gunion, Hooper, Tait 2010

See talks by  
Chris Kelso and Alexander Belikov  
in this session!

## Conclusions:

- The self similar infall model is an alternative to the isothermal halo model. In this model, there are several cold streams in addition to a thermal component.
- The self similar infall model is consistent with the DAMA modulation amplitudes, modulation phase, and the measured background.
- There are 2 allowed regions:
  - $m = 12 \text{ GeV}$ ,  $0.03 \text{ fb}$  (channeling) for 50% thermal component and  $m > 300 \text{ GeV}$ .  $c/s = 0.1 \text{ fb}$  at  $m = 500 \text{ GeV}$ , for 50% streams.
- More sensitive experiments can test the halo model.