

Detecting *Boosted* Dark Matter with Neutrino Experiments

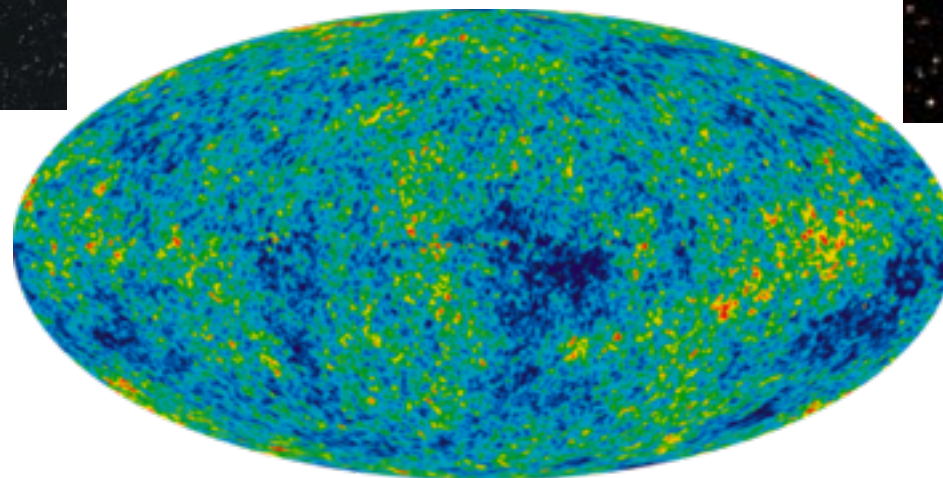
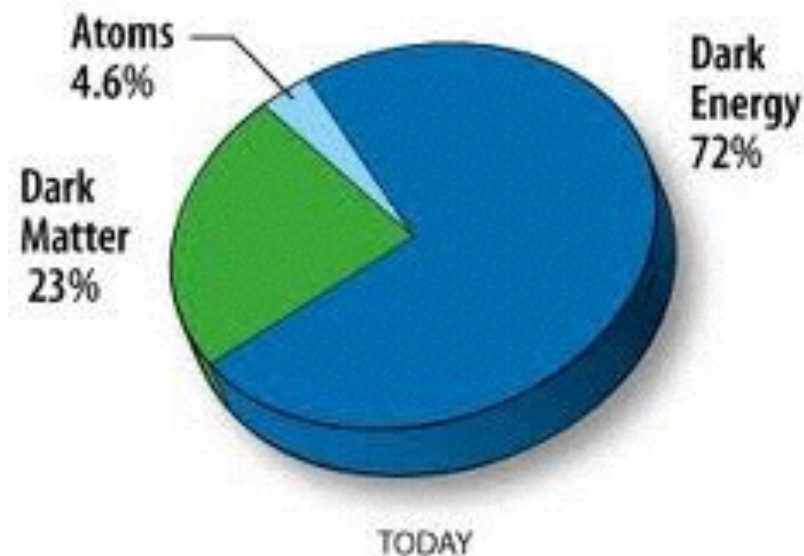
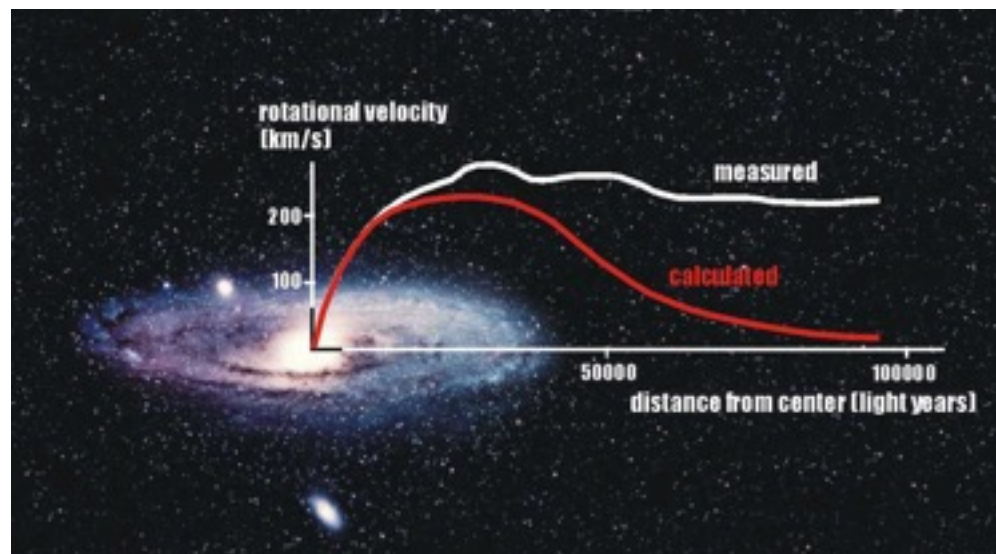
Yanou Cui

Perimeter Institute for Theoretical Physics

SN@DUNE workshop
Mar 12, 2016

What is Dark Matter ?

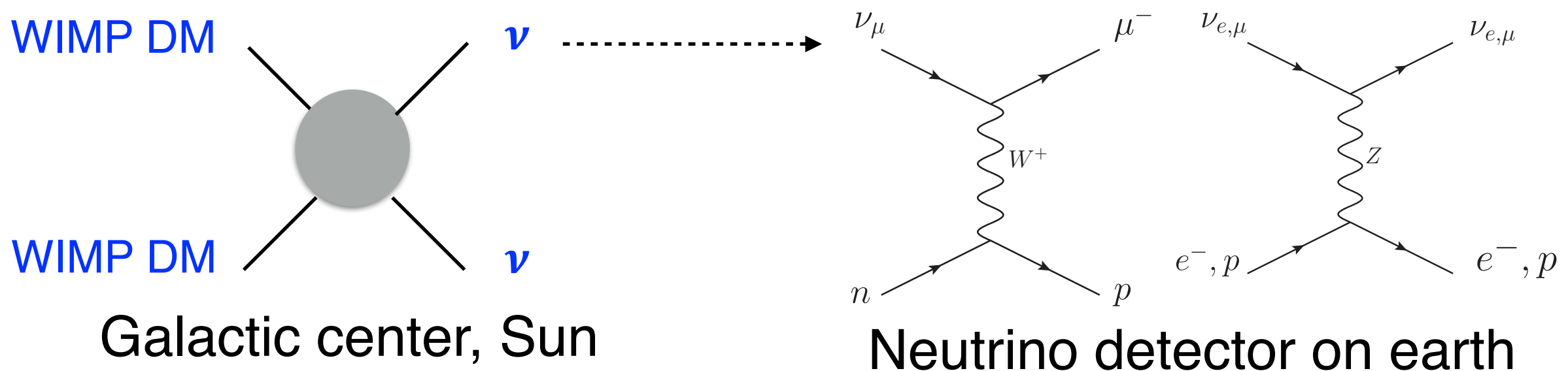
- **Dark Matter:** 85% of cosmic matter abundance!
Cold, non-relativistic



**Big mystery! Demand new particle physics
beyond the Standard Model !**

A **New** Opportunity of Probing Dark Matter with Neutrino Experiments

- It *is NOT* the familiar *indirect* detection



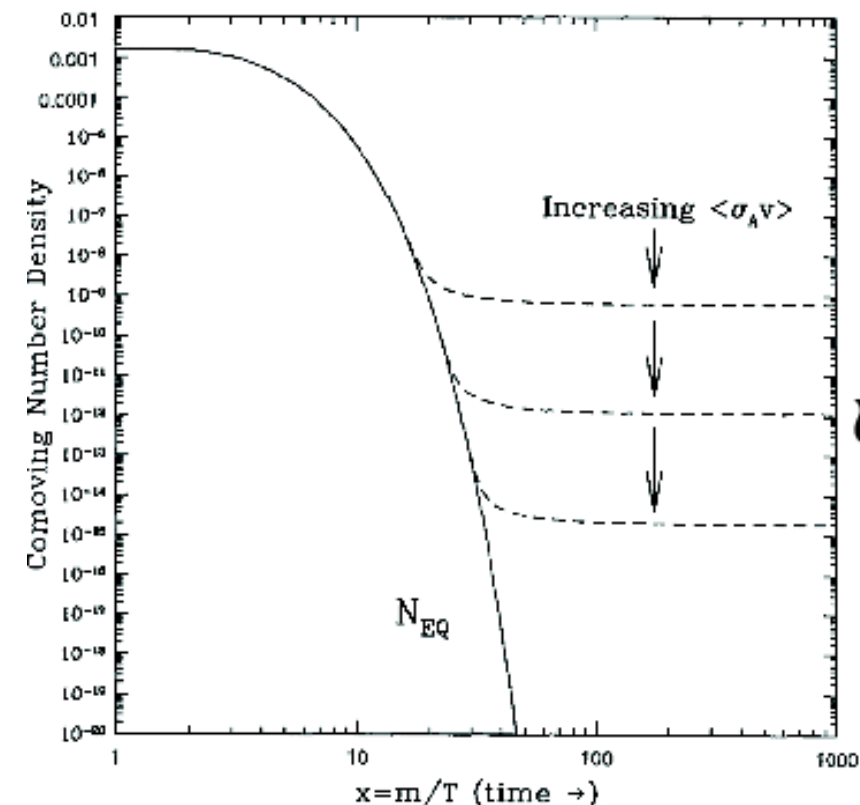
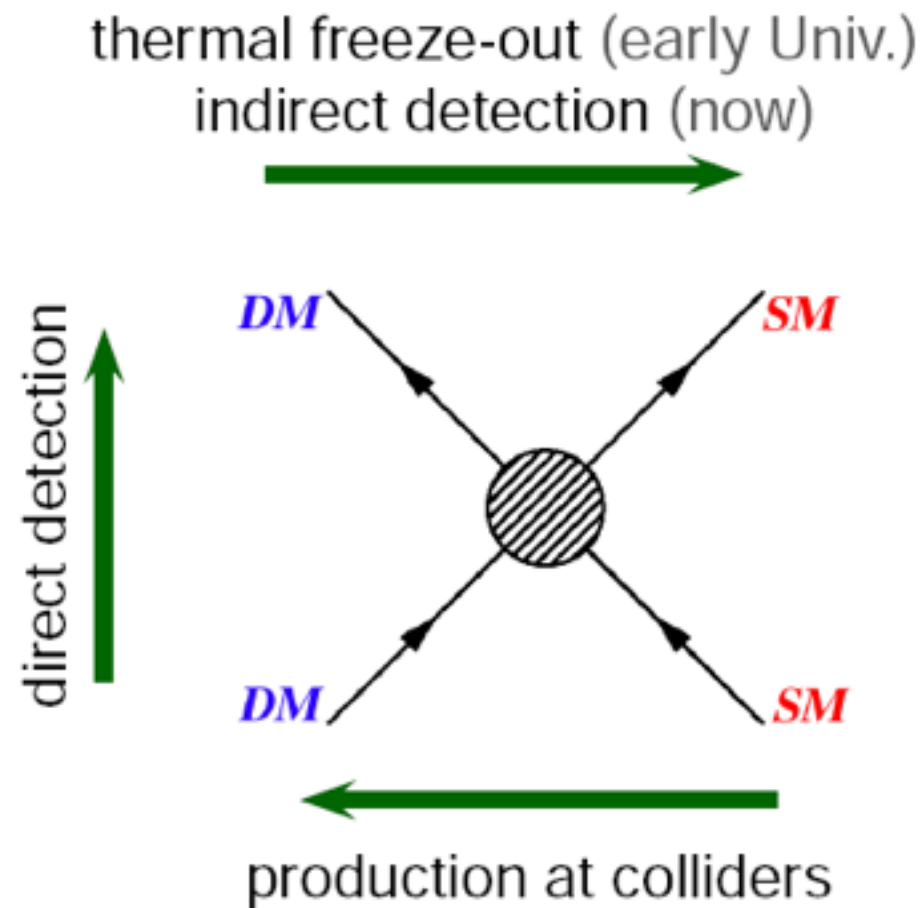
- It **IS**: **direct** detection of a (small) **relativistic** component of dark matter
 - **Boosted Dark Matter!** (NEW)
- May be the smoking gun signal for DM!



Motivations of Boosted Dark Matter:

e.g. Hidden dark matter sector with multiple components

WIMP DM miracle: merits and challenges



- But no convincing signal yet:
many years, many experiments...

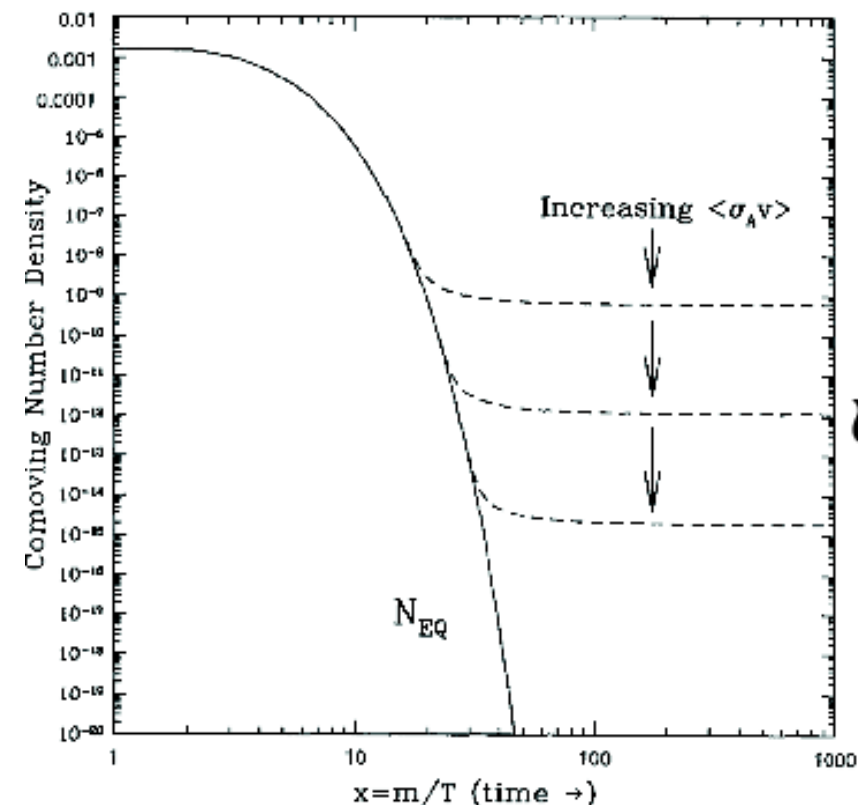
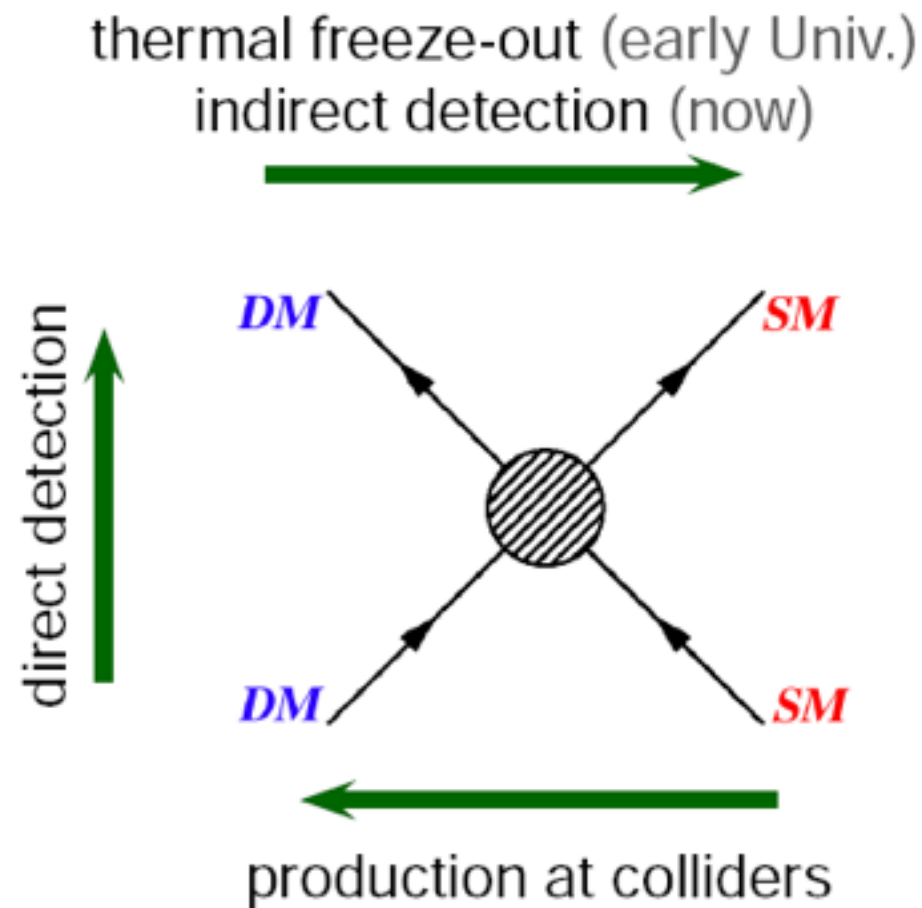
$$\Omega_\chi \propto \langle \sigma_{ann} v \rangle^{-1}$$

$$\sim 0.1 \left(\frac{G_{Fermi}}{G_\chi} \right)^2 \left(\frac{M_{weak}}{m_\chi} \right)^2$$

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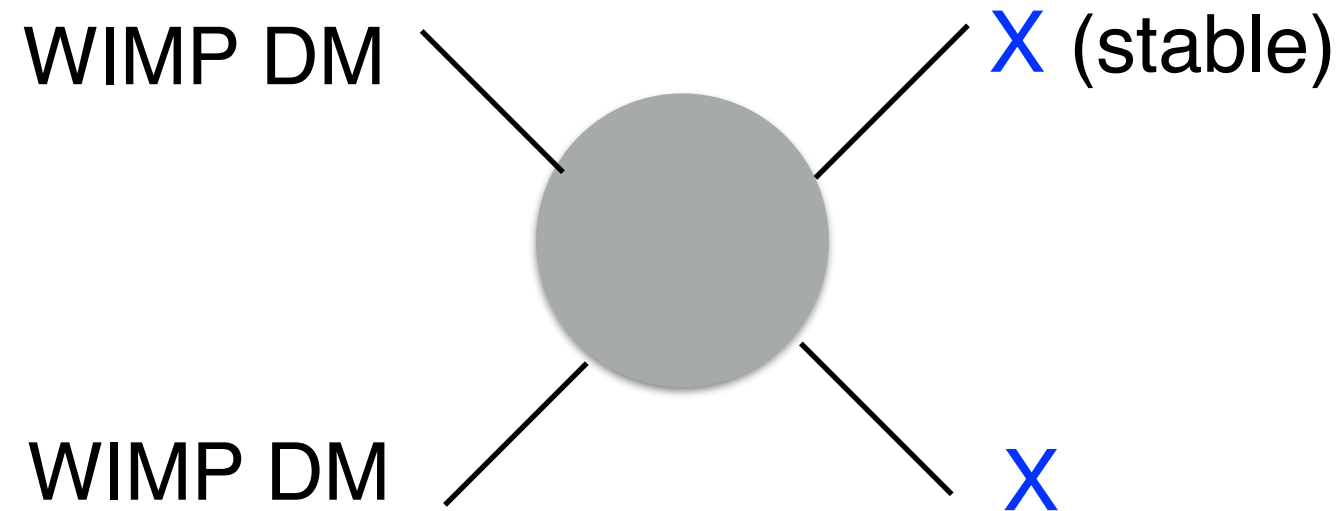
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Not looking at the right signal channel(s)?

Motivations of Boosted Dark Matter:

e.g. Extended dark matter sector with multiple components

A New Realization of WIMP Miracle

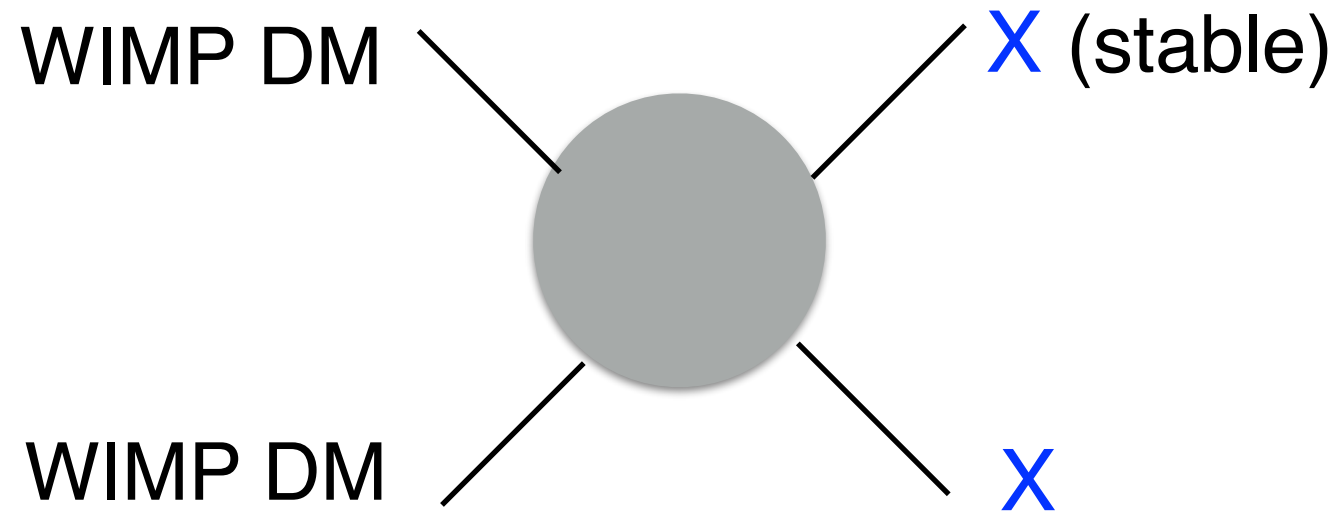


- **Determines Ω_{DM} !**
- Conventional signals absent/suppressed

Motivations of Boosted Dark Matter:

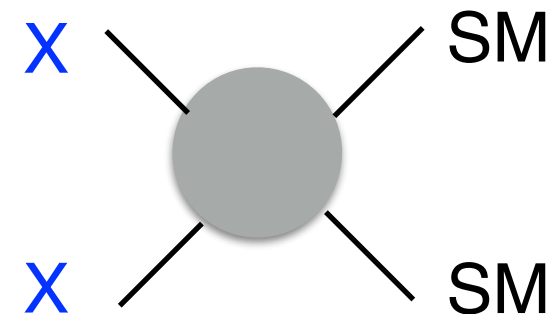
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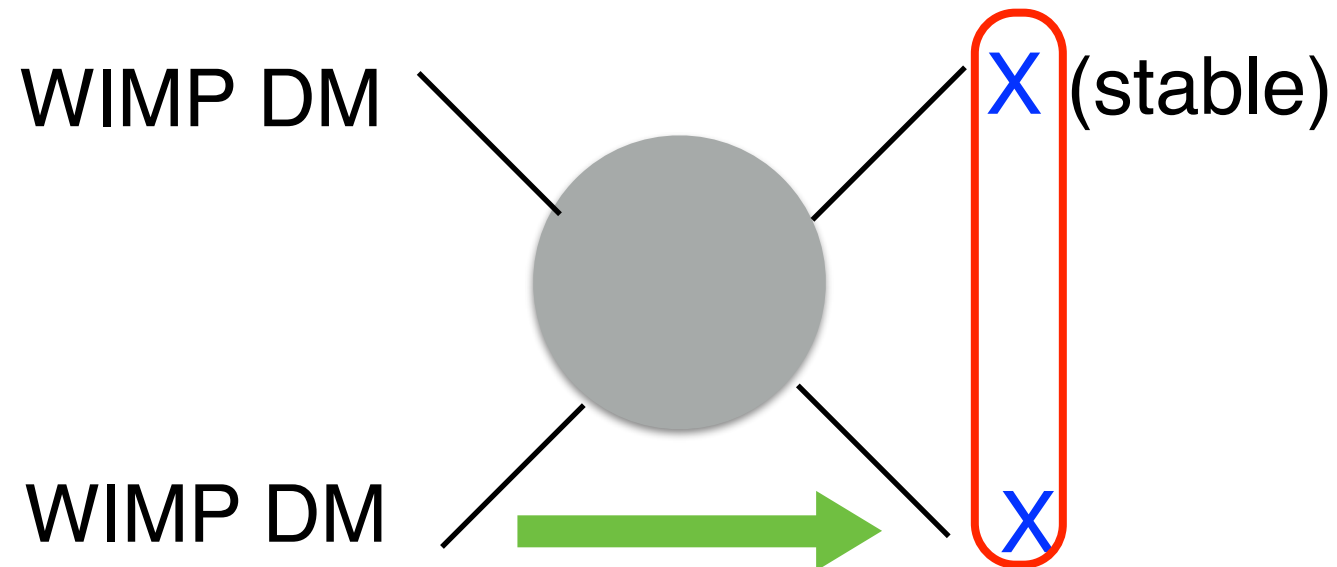
- Massive X ($m_X \gtrsim \text{eV}$): $\Omega_X > 1$
👉 deplete X via annihilation \rightarrow SM



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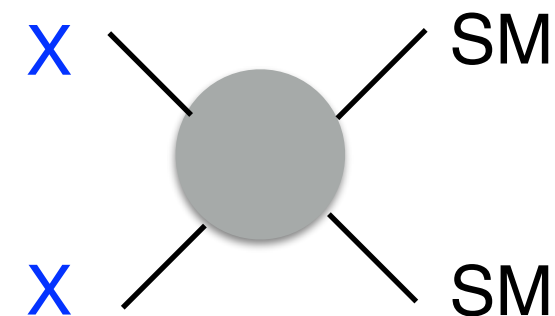
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Boosted X: $\gamma_X = m_{\text{WIMP}}/m_X$

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- **Novel signal: Boosted DM (X) (Vs. “slow” DM) !**

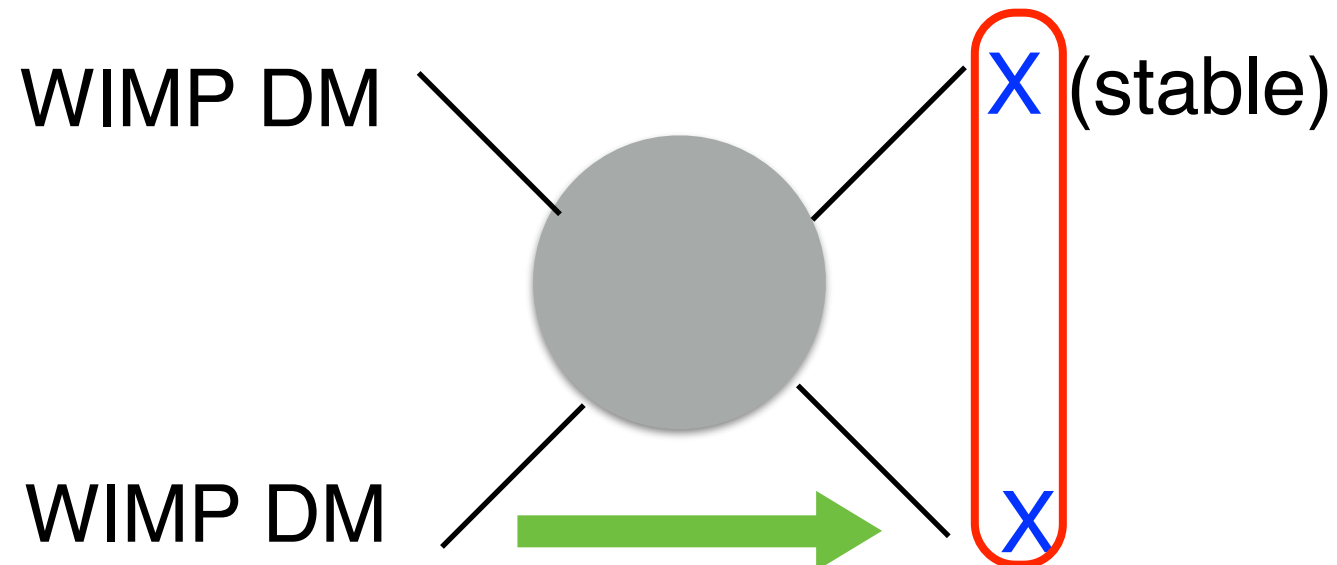


JCAP 1410 (2014) 062, **YC** w/Agashe, Necib, Thaler;
JCAP 1502 (2015) , **YC** w/Berger, Zhao

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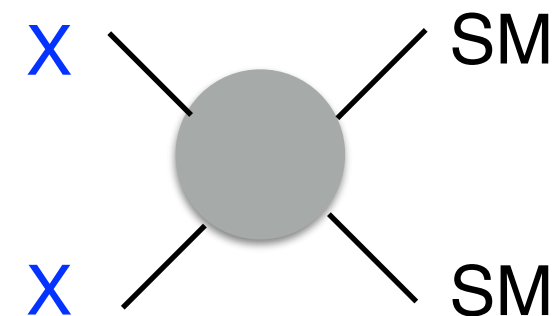
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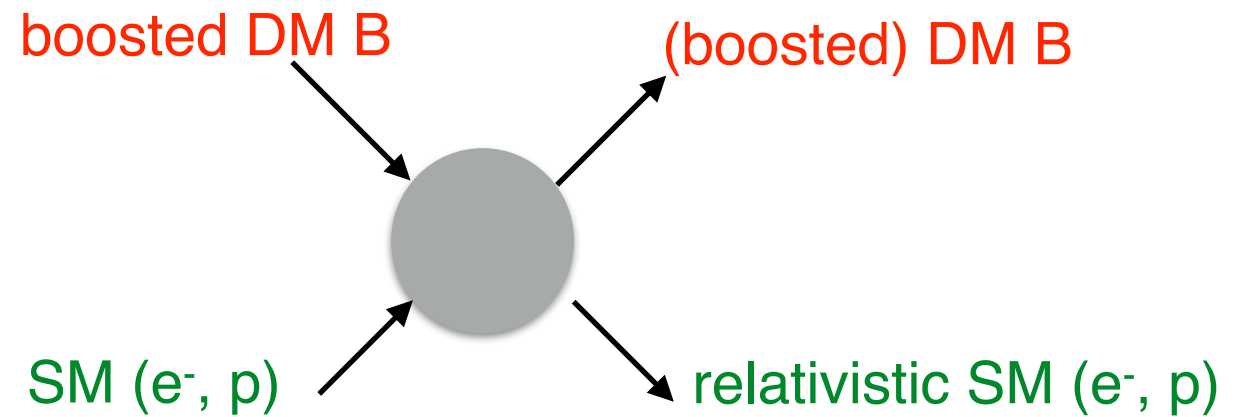
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- **Dark matter lives in a hidden sector! (DM, X, +...)**

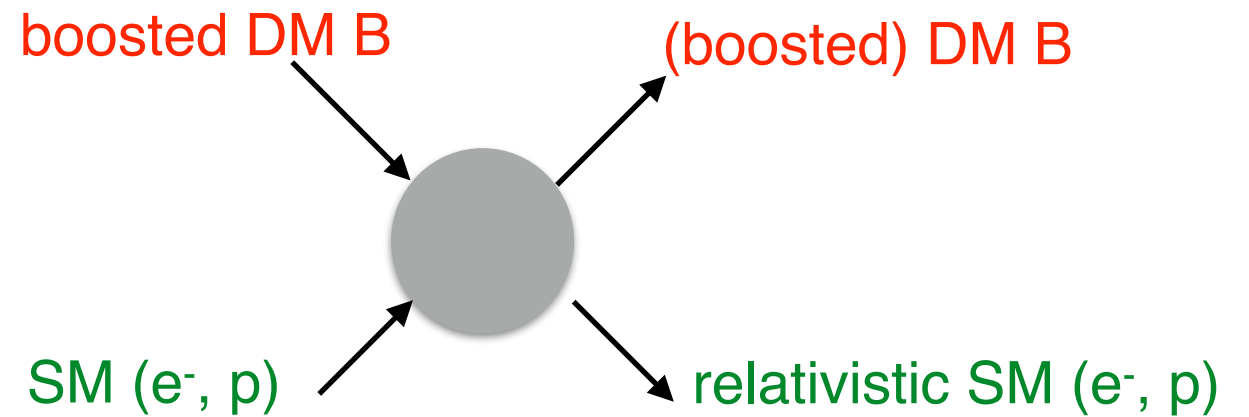
How to Search for Boosted DM?

- **Small flux** $\propto n_{\text{DM}-A}^2$
- Boosted incoming B
 \Rightarrow **Relativistic outgoing e^- , p**



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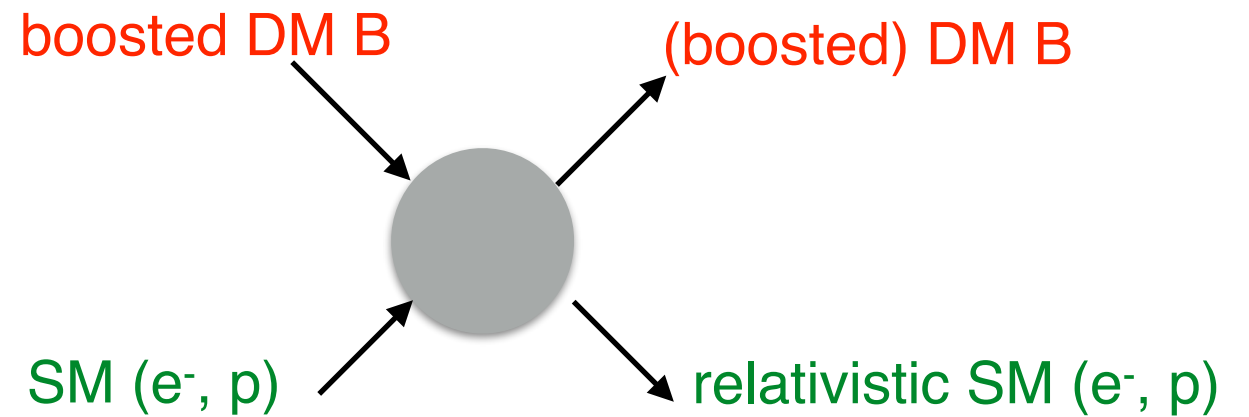


What experiments?

- ☞ **Large volume detector + sensitive to energetic e^- , p**
(Conventional DM direct detection 😞)

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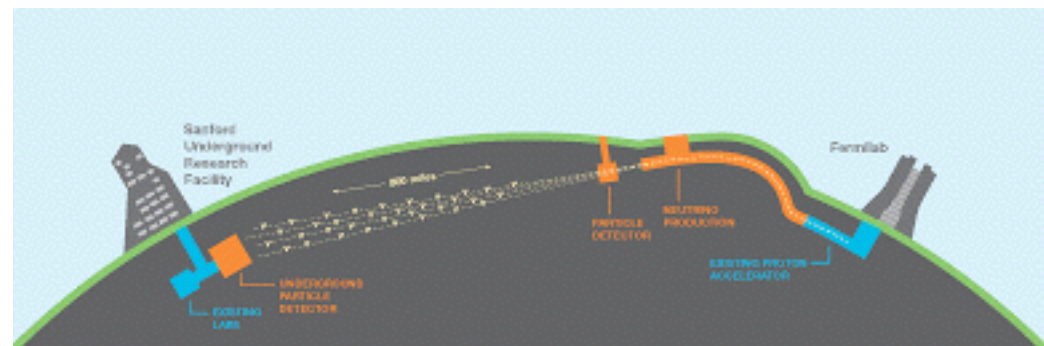


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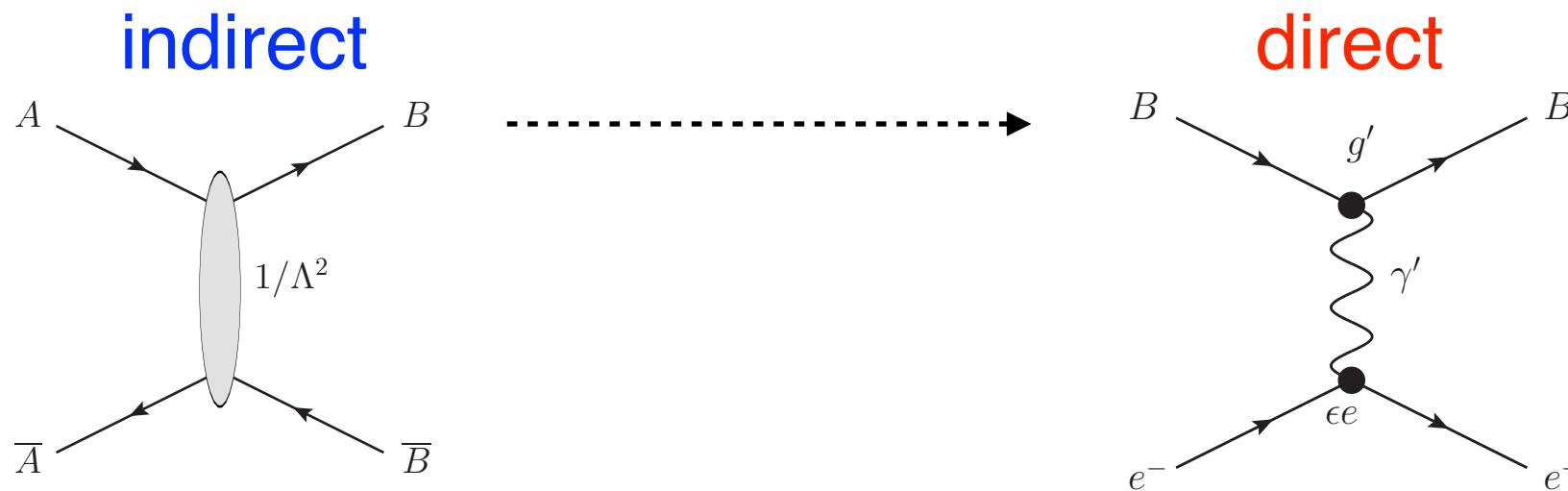
Experiments for neutrinos or proton decay!

- Cherenkov-radiation: *SuperK/HyperK, IceCube/PINGU...*
- Liquid scintillator: *Borexino, JUNO...*
- Liquid Argon: ***DUNE/LBNF!***

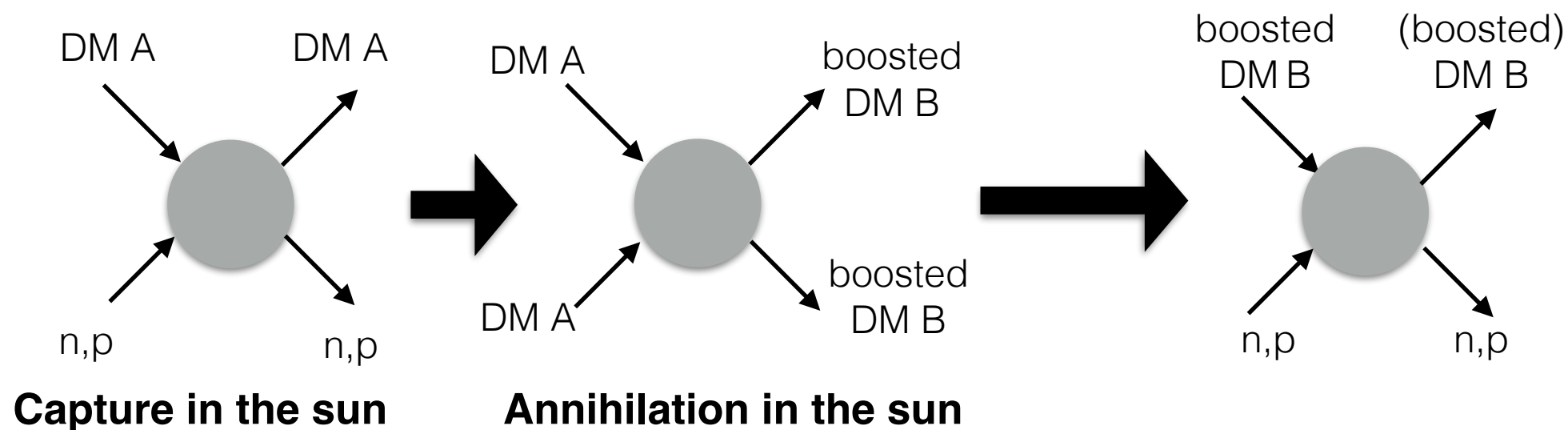


Search Strategies for Boosted DM

- A combination of conventional DM indirect & direct detections
- **Signals from the galactic center:**



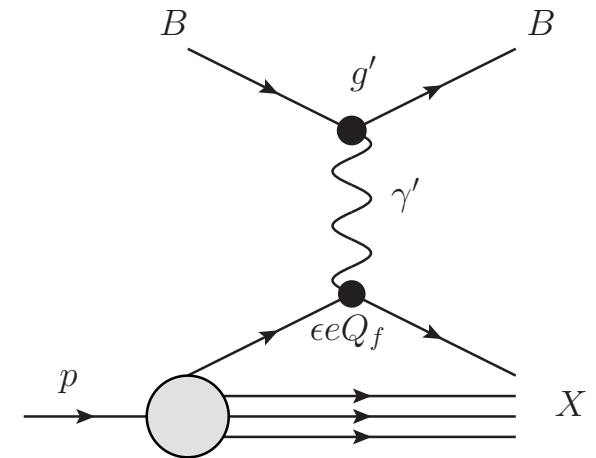
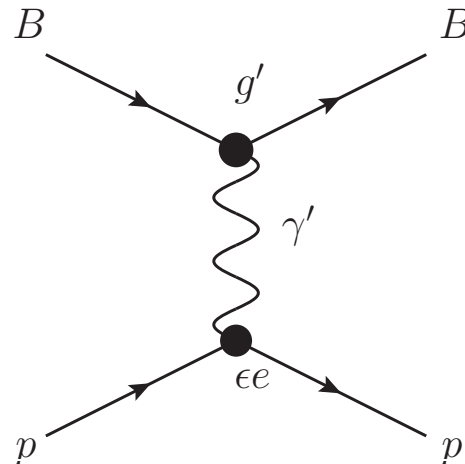
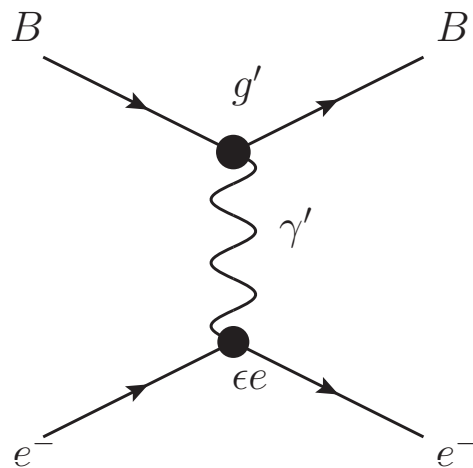
- **Signals from the Sun:**



**With
neutrino
detectors!**

Signals for Boosted DM

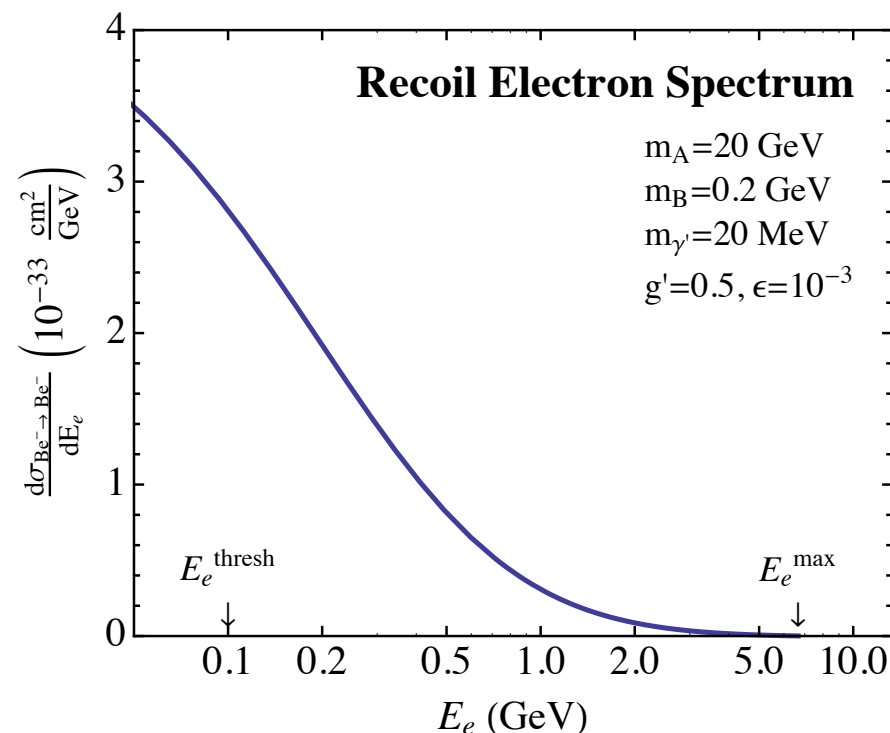
- Single e^- and/or single proton track (model dependence)



May only interact w/baryons!
Motivated, studied!

inelastic channel:
lack directionality...

- Signal spectrum
may peak at low E
($m_{\gamma'} \ll E_B$)



low E threshold
desirable
(both e^- and p)!

How to Distinguish Boosted DM from Neutrinos?

- **Directionality:**

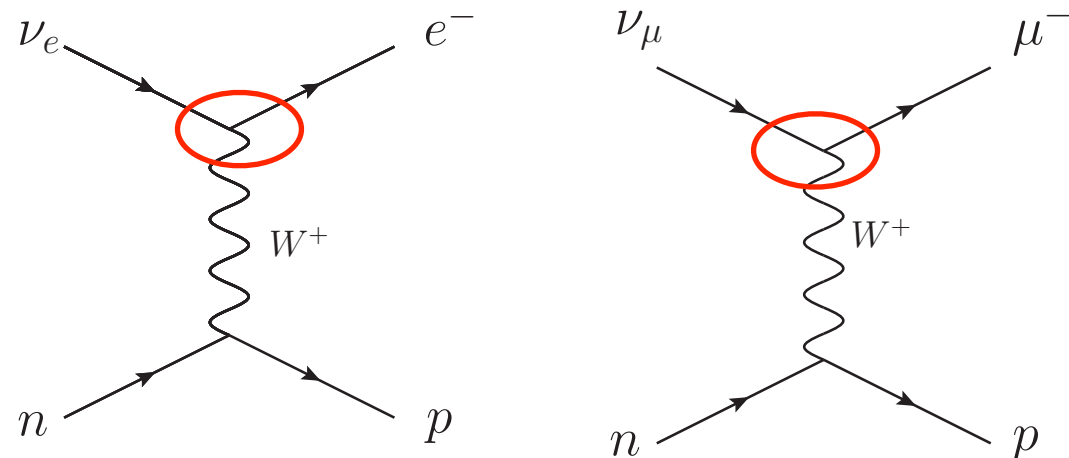
Boosted DM: from DM concentrated region,
e.g. GC, Sun...

Vs. (atmospheric) neutrino: isotropic

- **Interaction:**

Boosted DM interaction: neutral current-like only,

Vs. Neutrino: neutral current + charged current



No correlated muon,
muon veto

Outlook

- Great Opportunity at DUNE

Desirable Factors

- Large volume detector
- Good angular resolution (*directionality*)
- Low energy threshold: $E_k \sim O(\text{MeV})$ for both e^- and p ?
 - Spectrum peaks at low E : light γ '
 - Low mass dark matter (sub-GeV)
(work in progress: YC w/Pappadopulo, Ruderman, YC w/Pospelov, Pradler)
 - Benefit Supernova-, solar- neutrino studies as well!
(Super-K, IceCube: limited by Cherenkov threshold;
Borexino, JUNO: sensitive to $E \sim \text{MeV}$; DUNE?)

**We look forward to interactions
with neutrino physicists at DUNE!**

(Already substantial interests from
experimentalists at Super-K, Microboone)

Thank you!

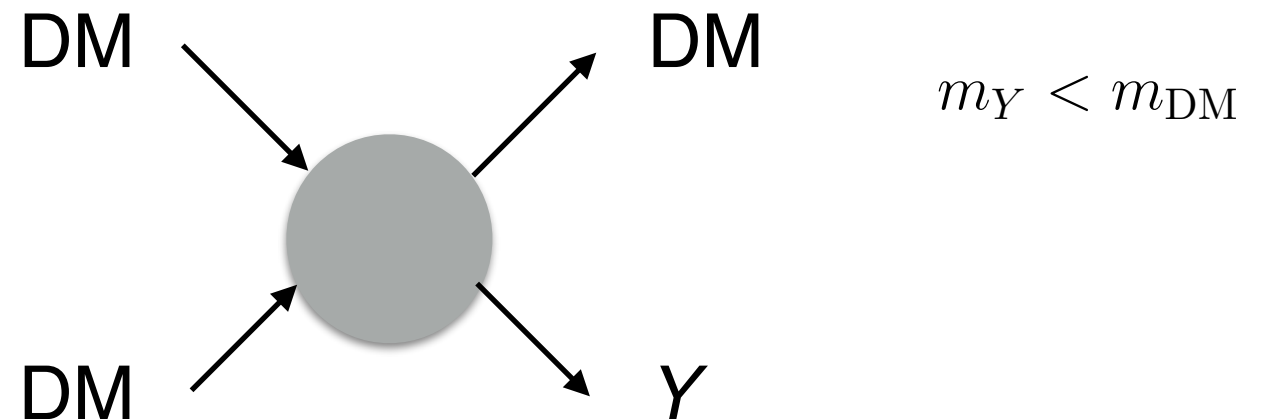
My email: ycui@perimeterinstitute.ca

Backup slides

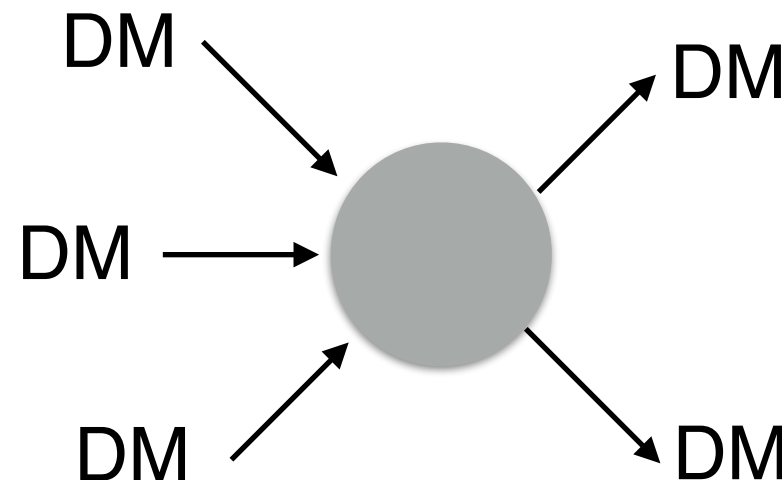
Motivation of Boosted Dark Matter

2. Other motivations

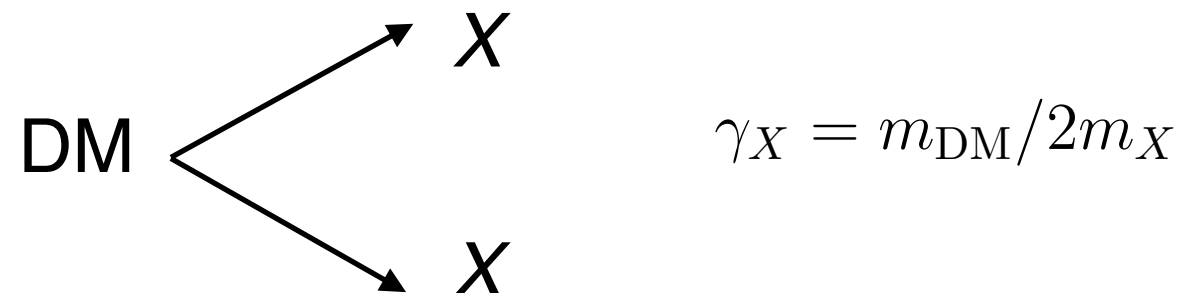
- Z_3 semi-annihilating dark matter:



- Self-annihilating dark matter:



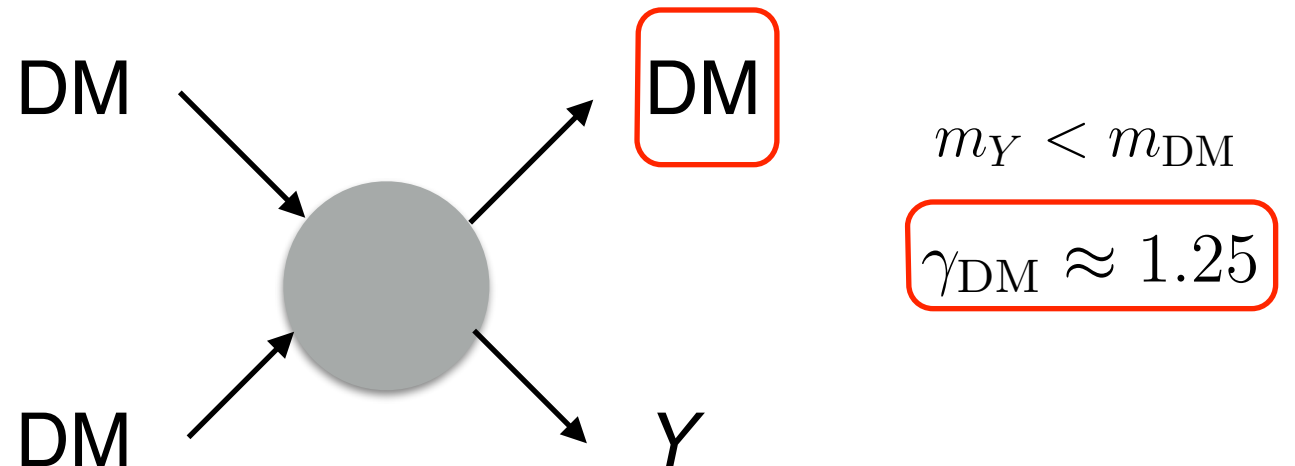
- Decaying dark matter:



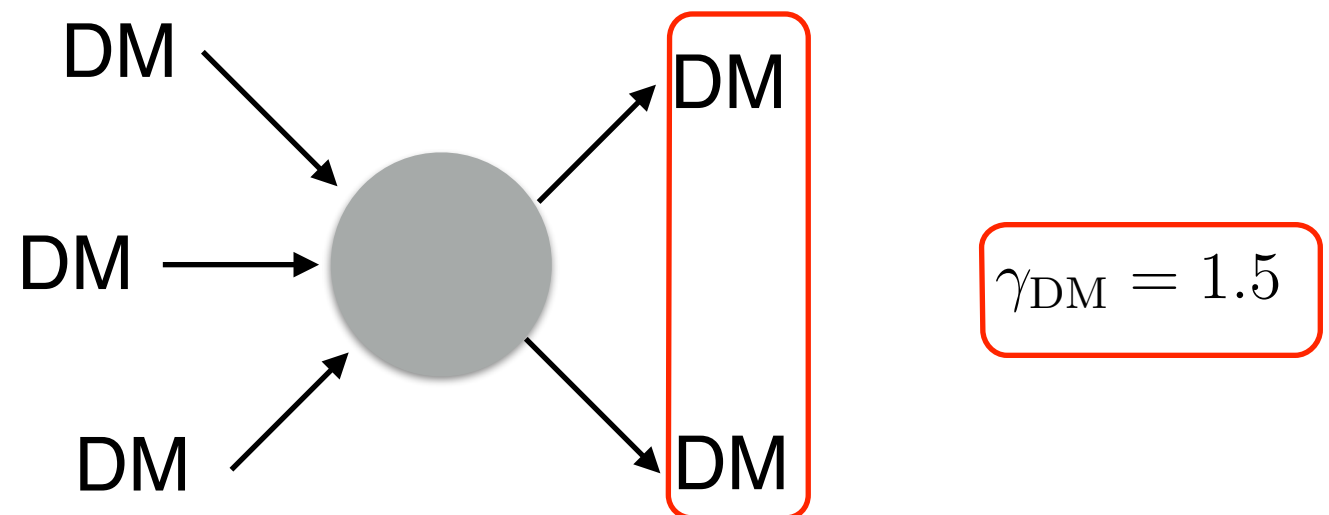
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