Reverse Direct Detection:

Cosmic Rays Scattering With Light Dark Matter

Kenny, Chun Yu Ng (吳震宇)

Weizmann Institute of Science

Soon:
GRAPPA, U of Amsterdam

Reverse Direct Detection:

Cosmic Rays Scattering With Light Dark Matter

- arXiv:1810.07705
- Christopher Cappiello (OSU), KCYN, John Beacom (OSU)

- Related works:
  - Cappiello, Beacom (arxiv: 1906.11283)
  - + others

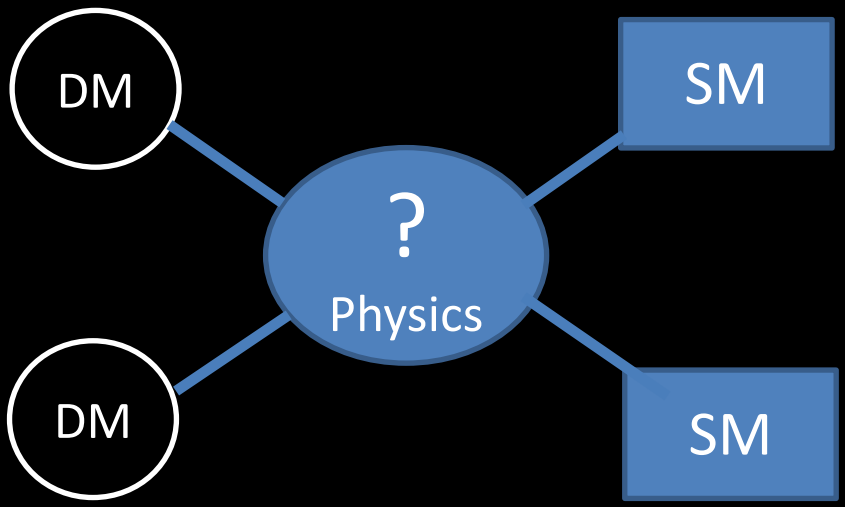
Finding Dark Matter

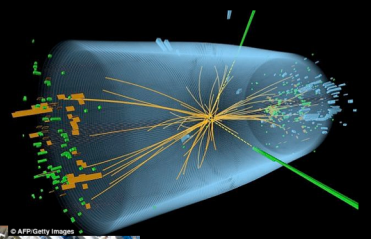
Indirect Detection(ann. + decay)

$\gamma, \bar{p}, \bar{\mathrm{d}}, \nu$ .....

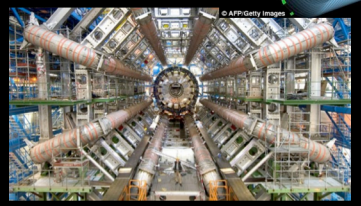
Direct Detection

$\chi + N \rightarrow \chi + N'$





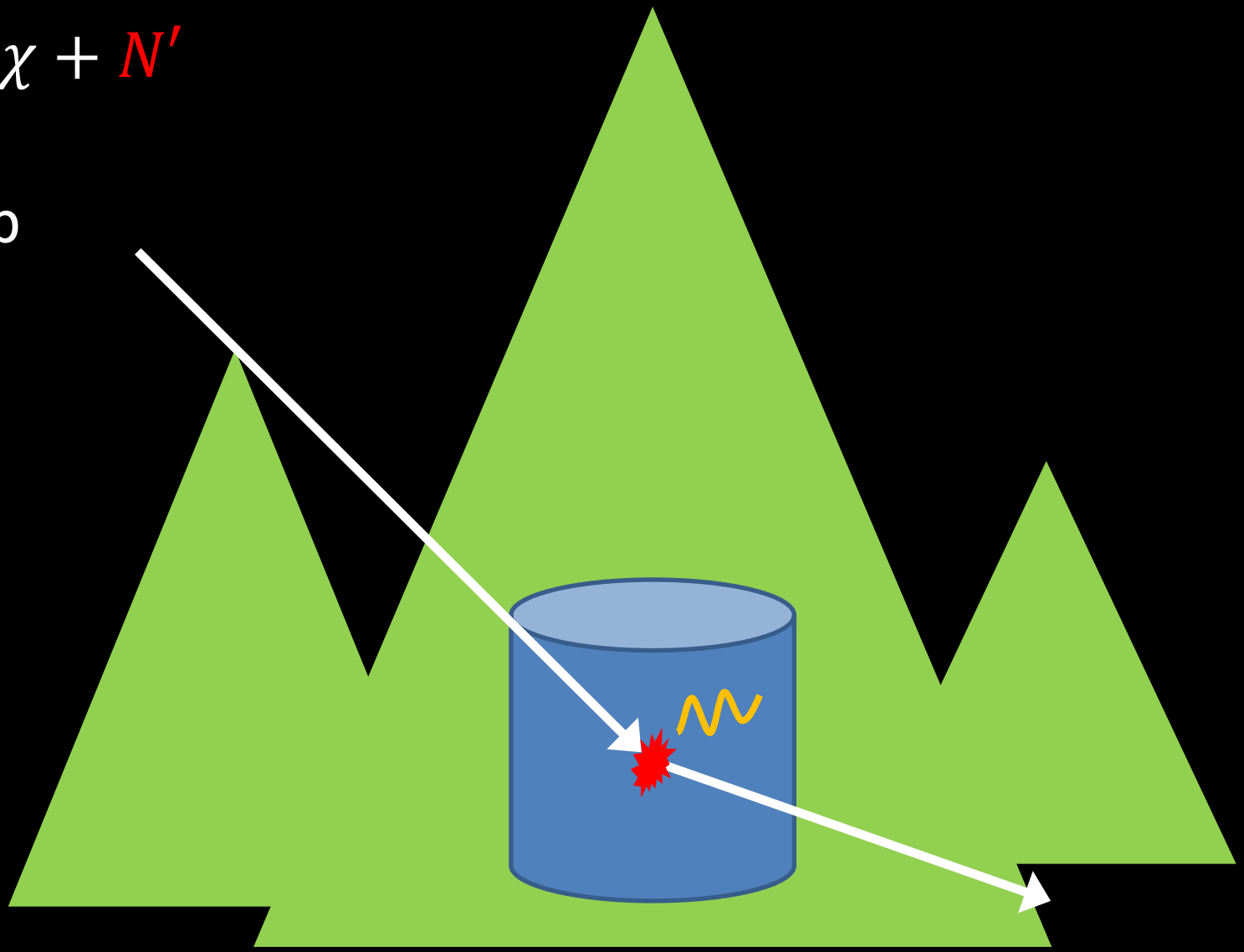
Collider Search



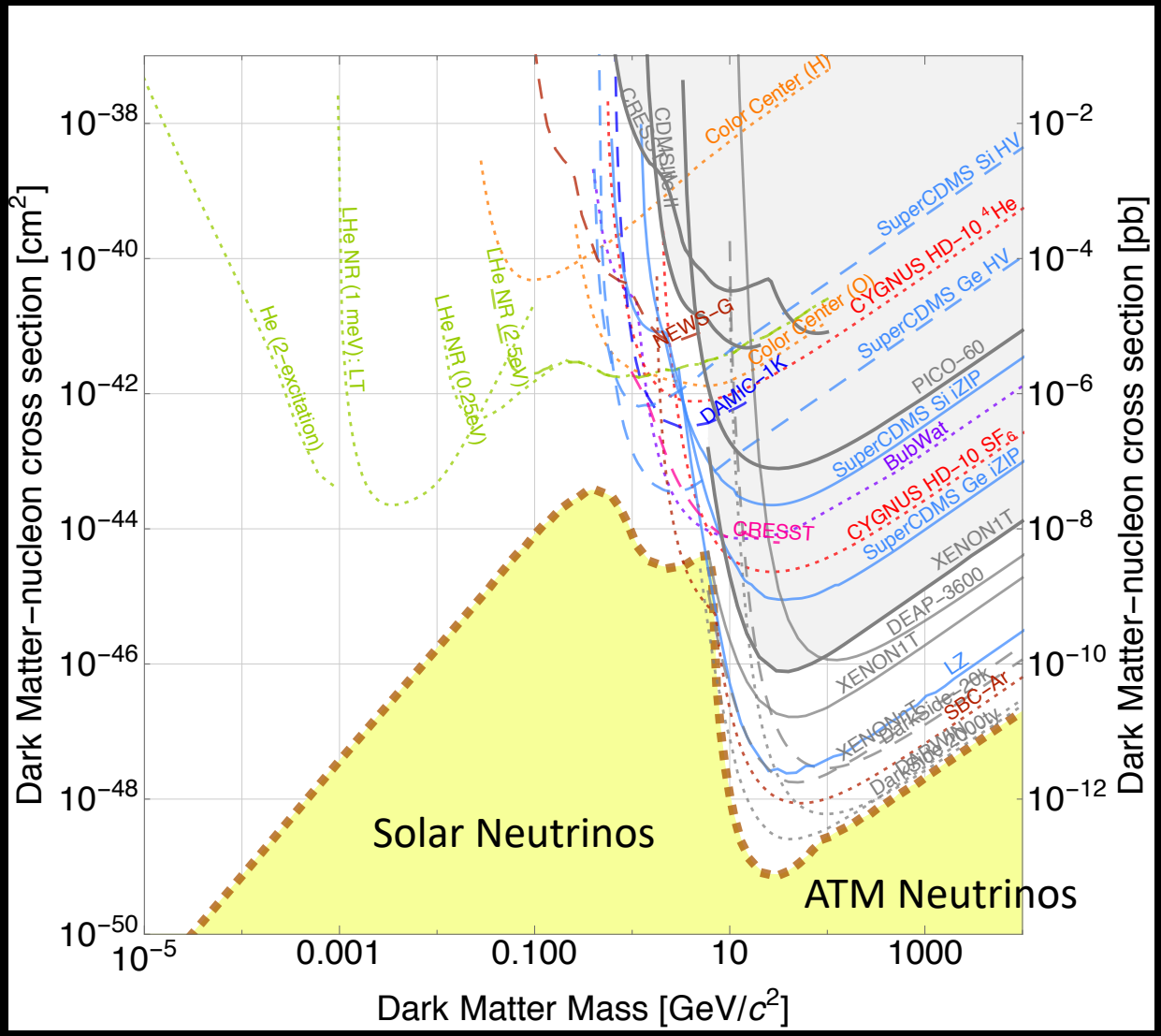
Direct Detection

- $\chi + N \rightarrow \chi + N'$
- JinPing lab
  - 2400m

X 8



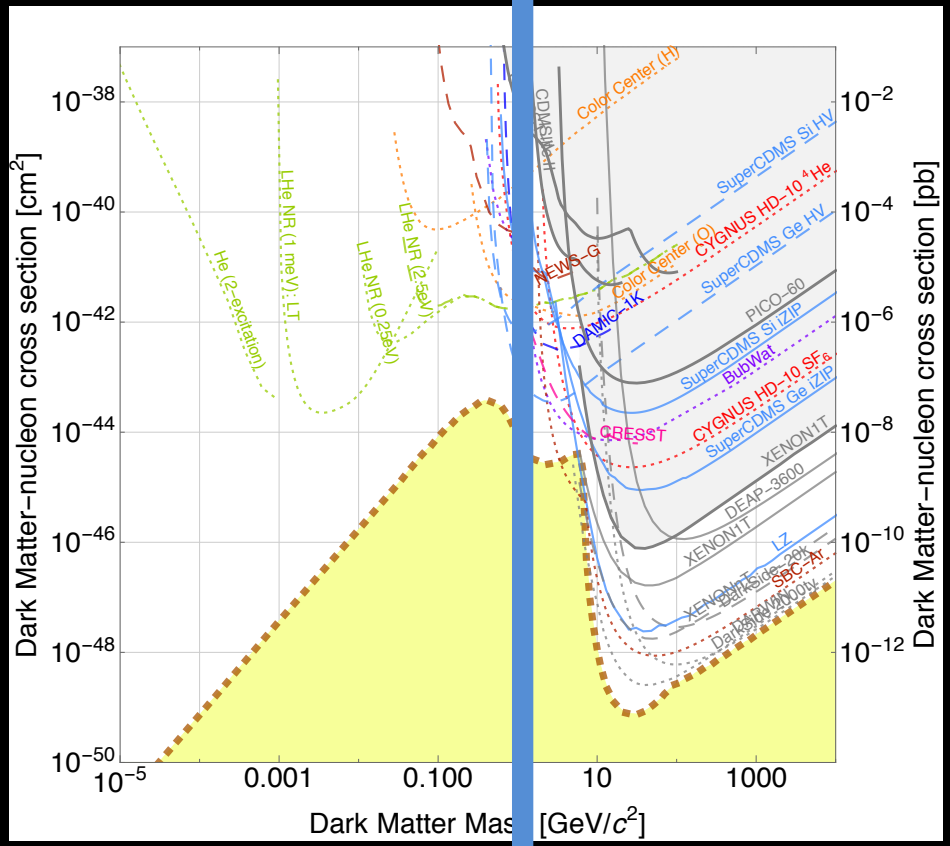
Direct Detection



Next generation experiments will reach the neutrino floor

US Cosmic Visions: New Ideas in Dark Matter 2017 : Community Report [1707.04591]

Direct Detection



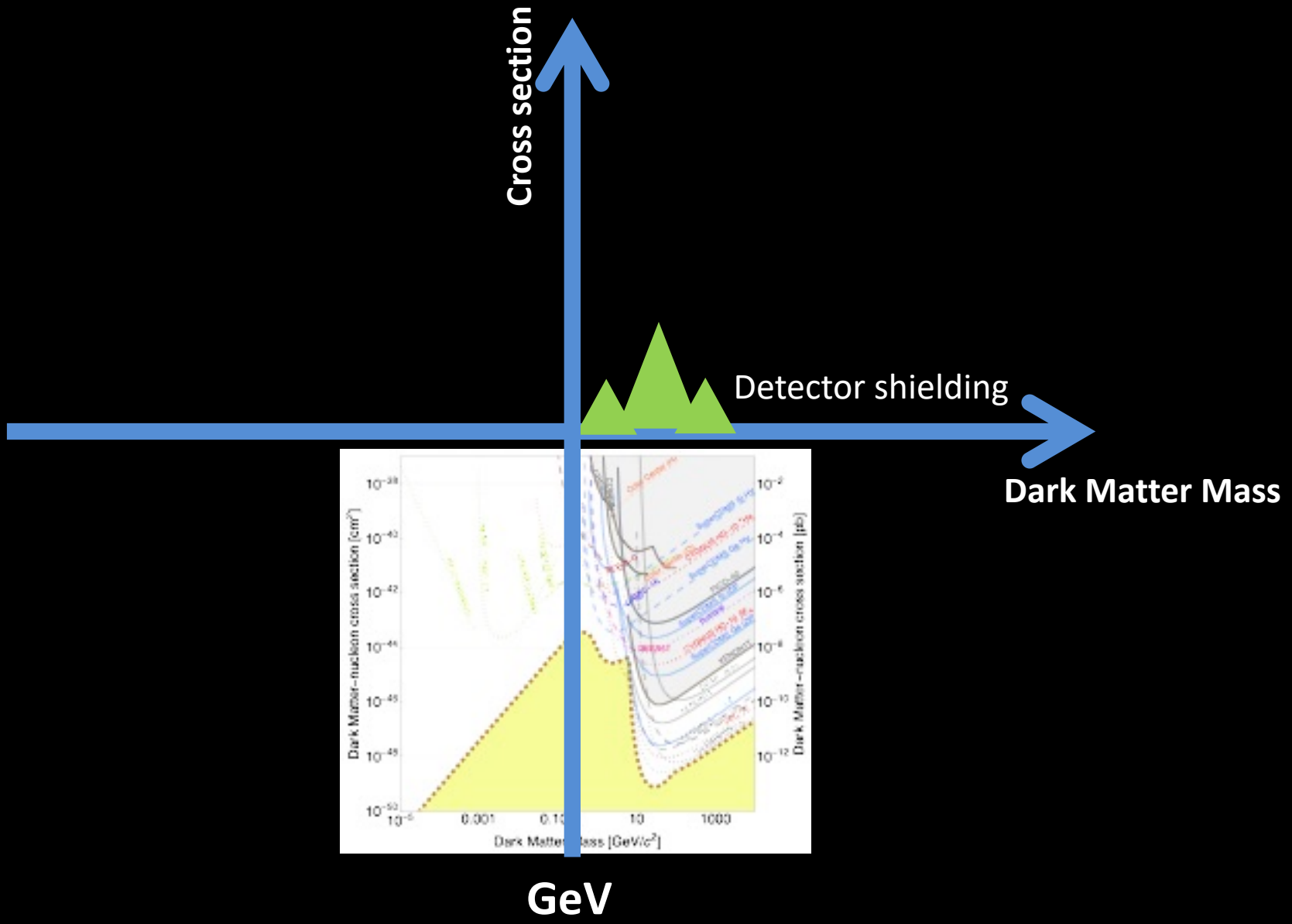
Detector Threshold ~ keV

Energy transfer ~ $m_\chi v^2$

$v \sim 10^{-3}$c

New detection ideas needed for light DM

Direct Detection Full landscape



Direct Detection Full landscape

Large Cross Section
Low Mass

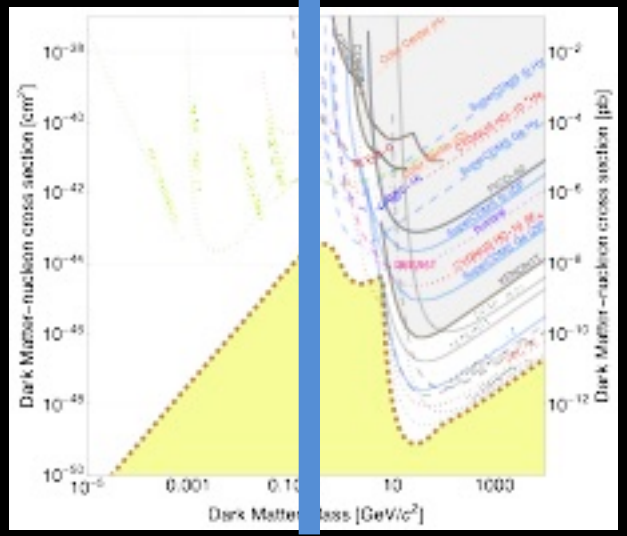
-> Astrophysical Probes
- CMB/structure formation
- Cosmic rays

Cross section

Surface experiments
Space experiments

Detector shielding

Dark Matter Mass



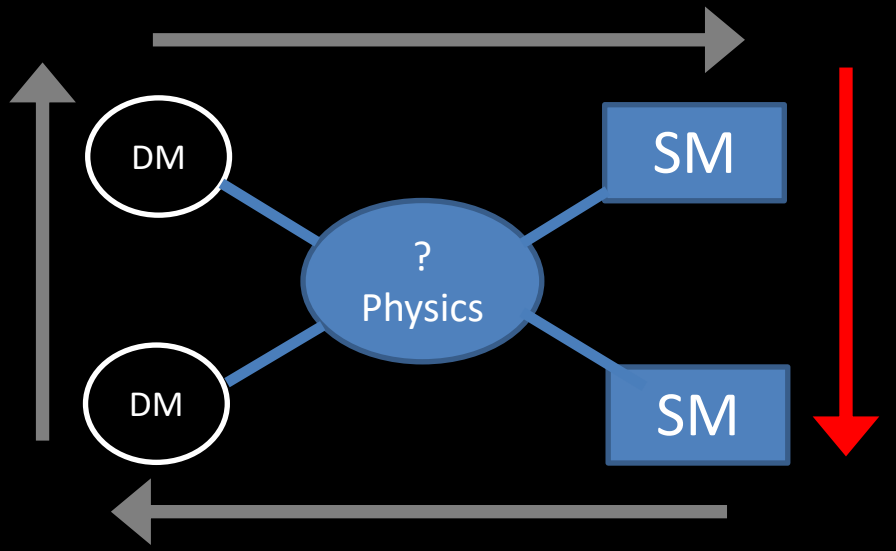
GeV

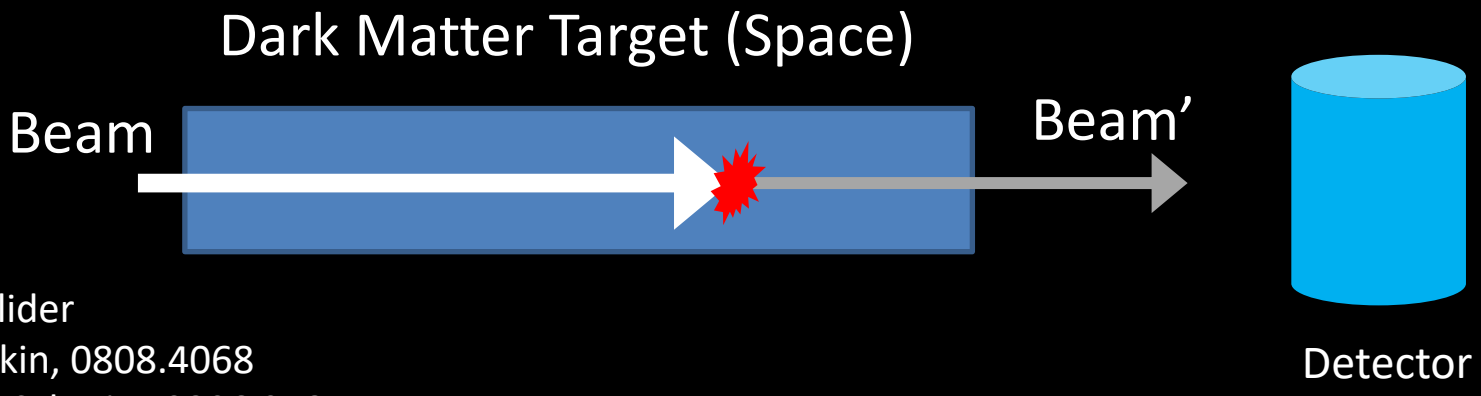
New detection ideas
- Dirac Materials
- Polar Materials
- Super-Fluid He
- Super-Cond. Al
- Color Center/defects
- Graphene
- ……

Neutrino floor
Imminent

Reverse Direct Detection

- Direct detection
  - $\chi + N \rightarrow \chi + N'$
- Reverse Direct Detection
  - $N + \chi \rightarrow N' + \chi$



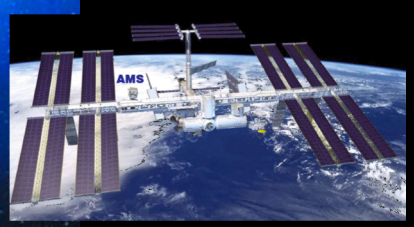


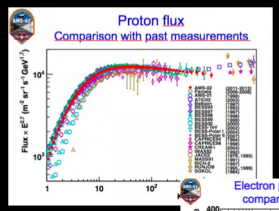
In collider
Kryshkin, 0808.4068
Kahn, Schmitt, 0806.2487

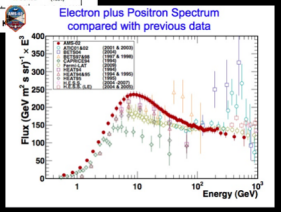
Cosmic Ray Scattering with DM

Cappiello, ***KCYN***, Beacom 1810.07705

- Beam: Cosmic Rays
- Target: MW DM halo (path length ~ Mpc)
- Effect: excessive energy loss to the cosmic rays
- Light DM: More target! $n_\chi = \rho_\chi / m_\chi$







Leaky Box model

$$\frac{N(E)}{T_{esc}(E)} + \frac{d}{dE}\left(\frac{E\,N(E)}{T_{loss}(E)}\right) = Q(E)$$

- Cross section:
  - energy independent
- Tesc:
  - power law
  - Norm. set by CR lifetime
- Injection spectrum:
  - Double broken power law
  - Norm. ~ supernova energy budget

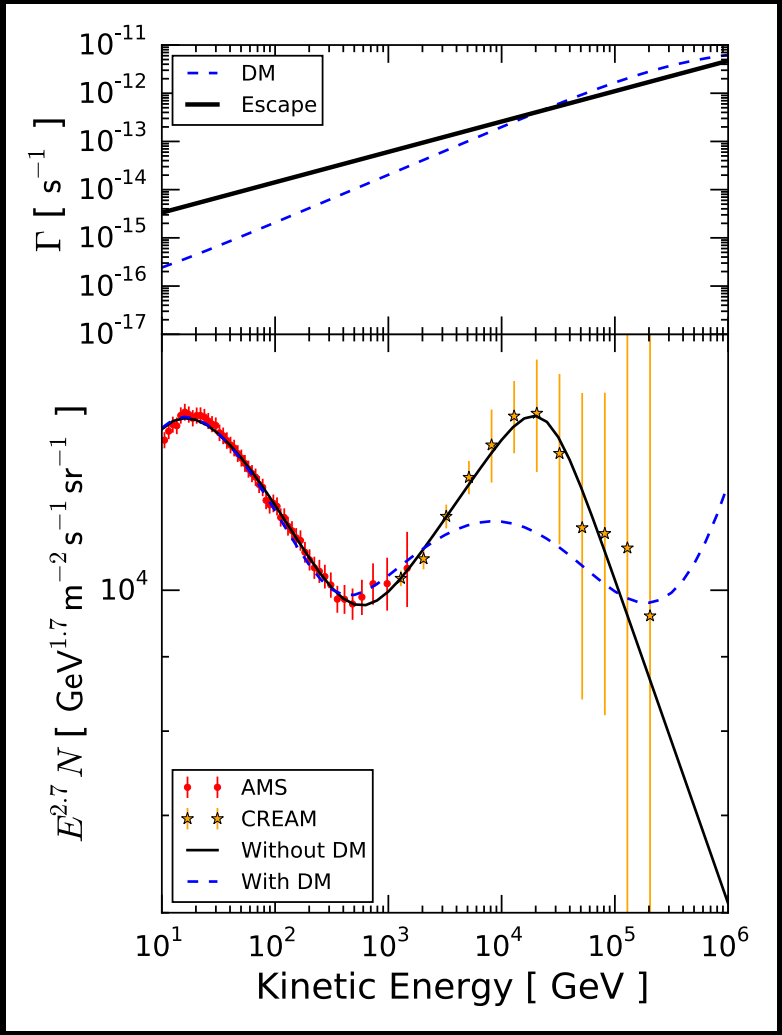
Proton scattering

1keV
~ 10^{-27} cm^2

$$\frac{N(E)}{T_{esc}(E)} + \frac{d}{dE}\left(\frac{E\,N(E)}{T_{loss}(E)}\right) = Q(E)$$

- Spectrum distortion
- Energy budget (conservative)

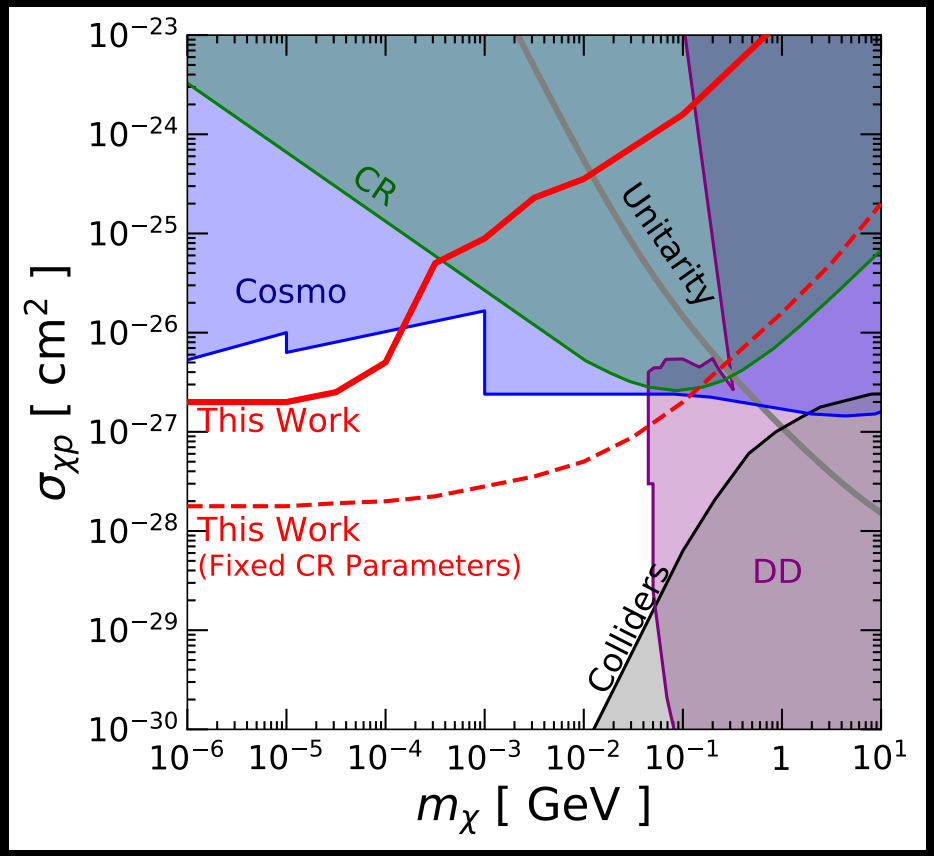
- Electrons
  - Add Syn+IC energy loss



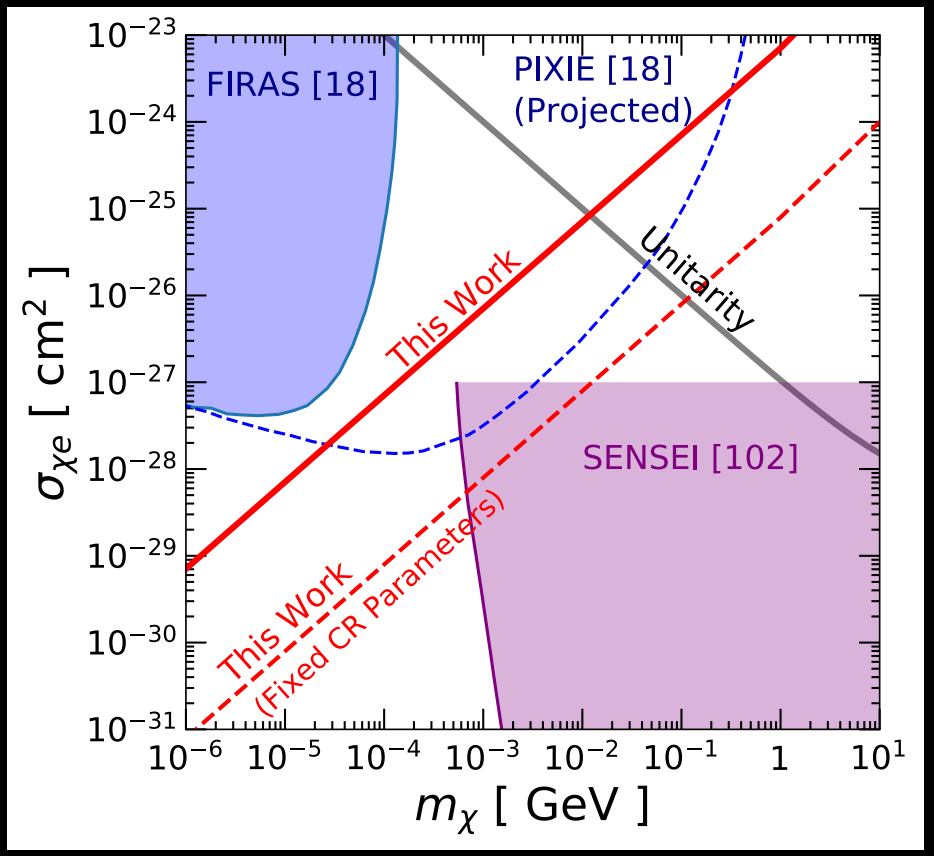
Cappiello, ***KCYN***, Beacom 1810.07705

Cosmic Ray Scattering with DM

Proton Scattering

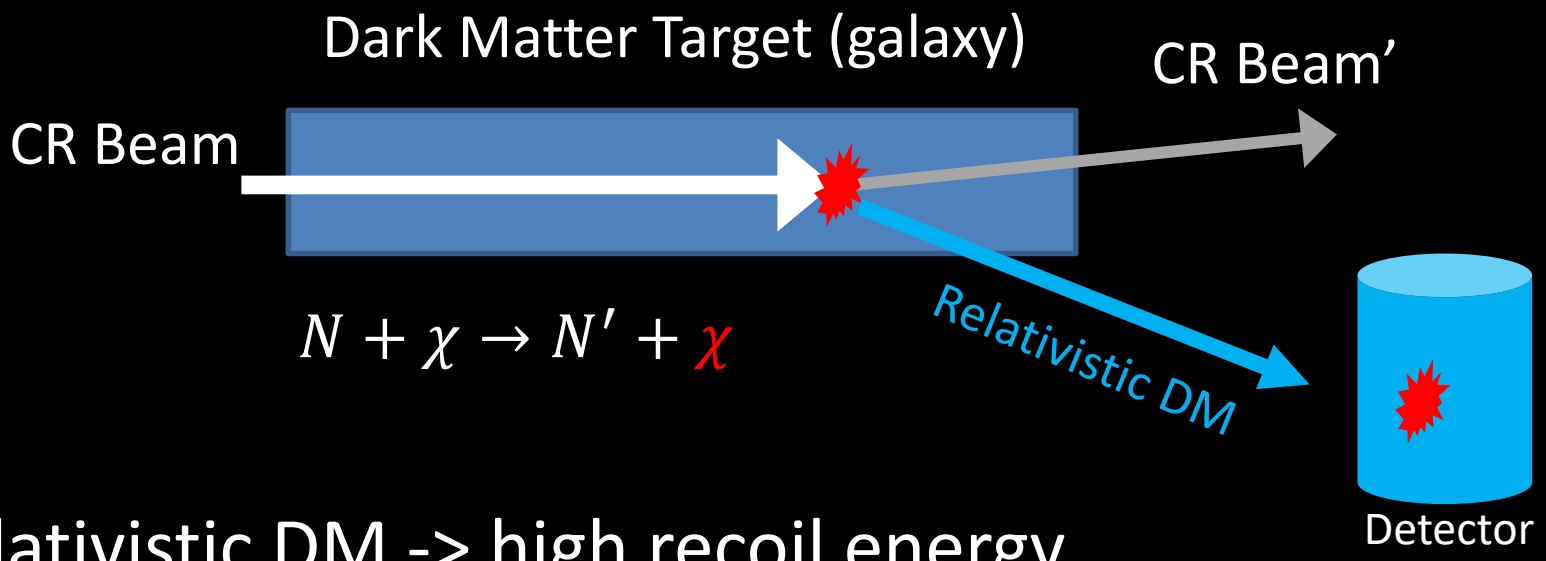


Electron Scattering



Cappiello, ***KCYN***, Beacom
1810.07705

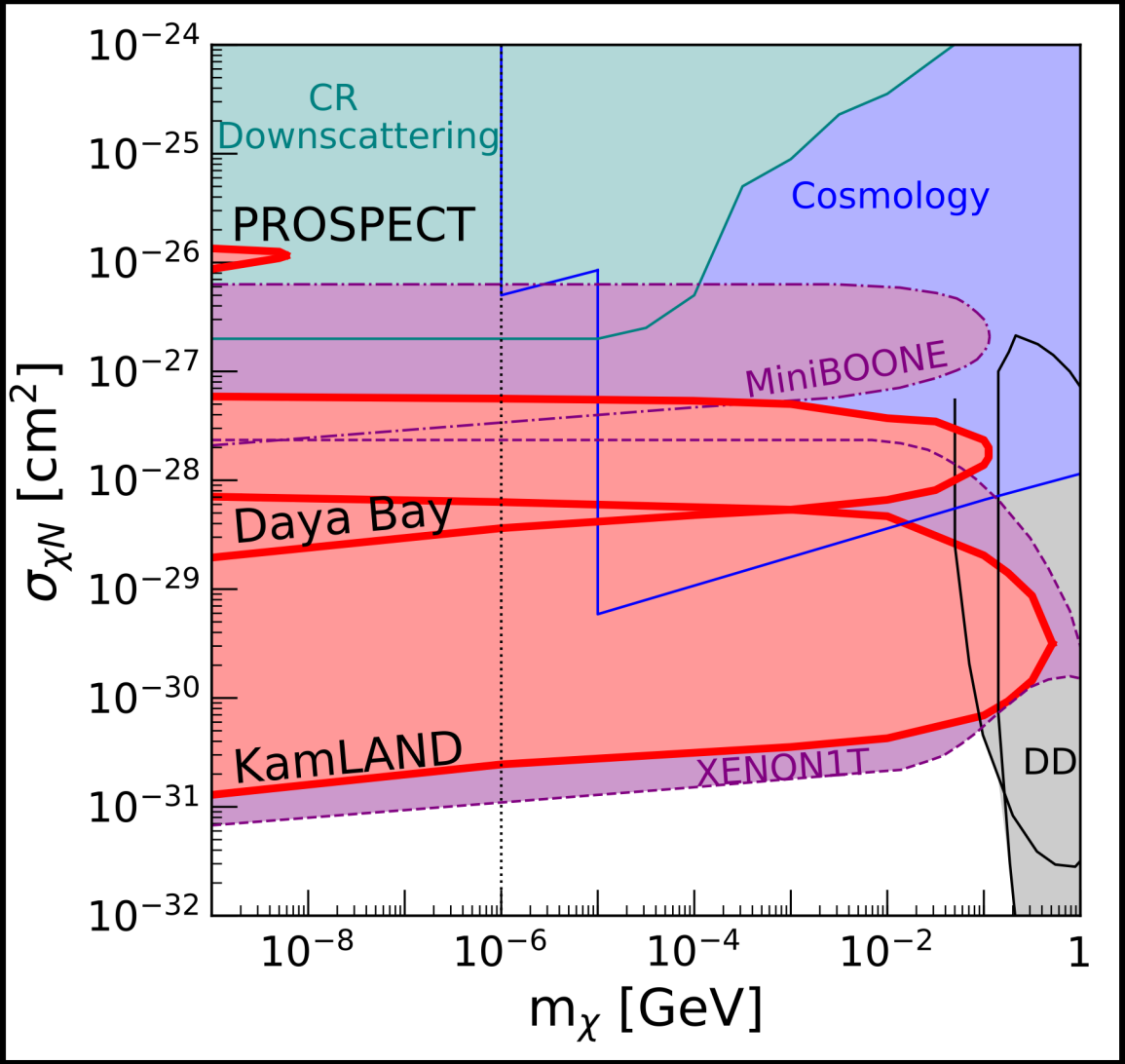
Dark Matter up-scattering



- Relativistic DM -> high recoil energy
  - kton neutrino detectors!
- Detection rate -> (cross section)^2

- Bringmann, Pospelov 1810.10543
- Ema, Sala, Sato 1811.00520
- Cappiello Beacom 1906.11283

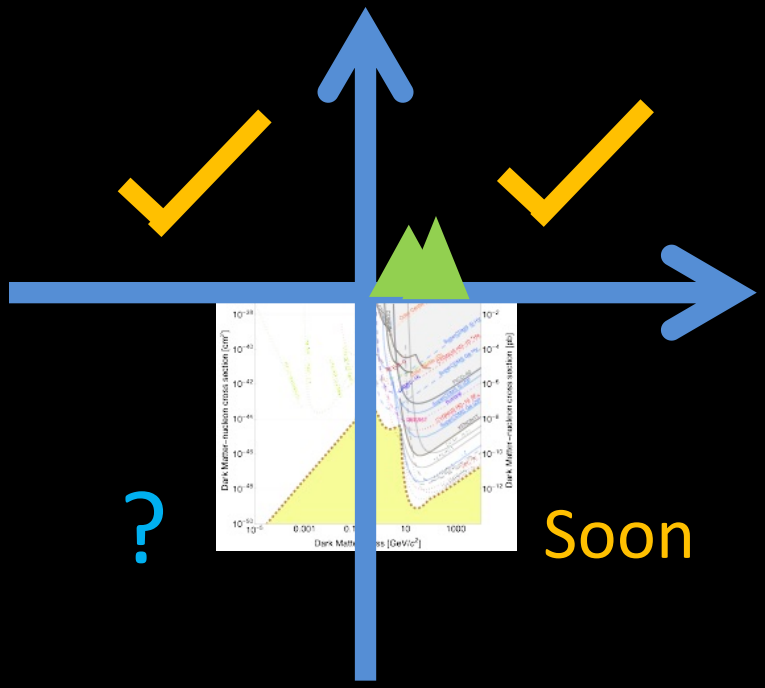
Dark Matter up-scattering



- Cappiello, Beacom 1906.11283

Conclusion

- Light dark matter has become increasingly popular
- Astrophysical and cosmological probes are complementary to (future) direct detection experiments
- Low-mass high cross section window closed



Backup

Electron scattering