

Probes of light dark matter in relativistic regime

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Graduate physics seminar

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Dark matter evidences and candidates

The Redshift of Extragalactic Nebulae

by F. Zwicky.

(16.II.33.)

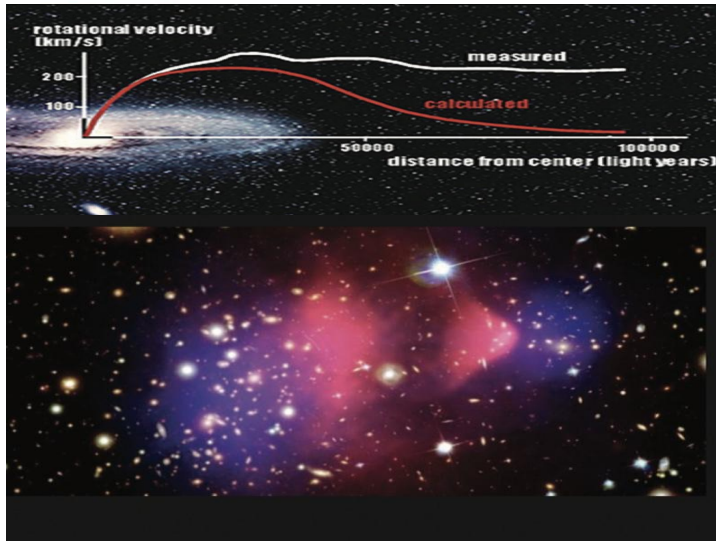
Contents. This paper gives a representation of the main characteristics of extragalactic nebulae and of the methods which served their exploration. In particular, the so called redshift of extragalactic nebulae is discussed in detail. Different theories which have been worked out in order to explain this important phenomenon will be discussed briefly. Finally it will be indicated to what degree the redshift promises to be important for the study of penetrating radiation.

ROTATION OF THE ANDROMEDA NEBULA FROM A SPECTROSCOPIC SURVEY OF EMISSION REGIONS*

VERA C. RUBIN† AND W. KENT FORD, JR.†

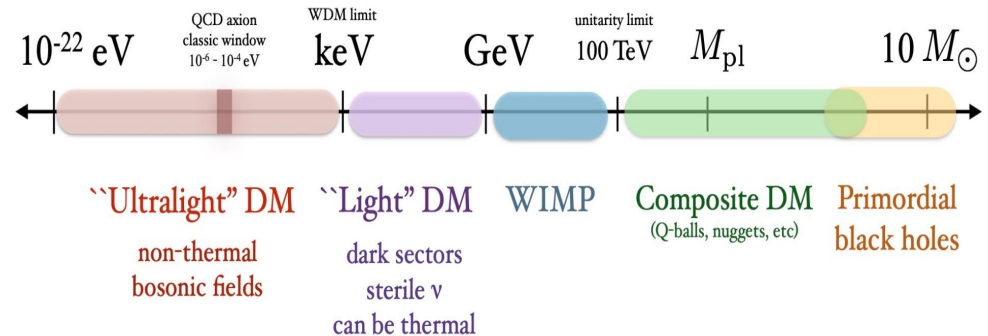
Department of Terrestrial Magnetism, Carnegie Institution of Washington and Lowell Observatory, and Kitt Peak National Observatory‡

Received 1969 July 7; revised 1969 August 21



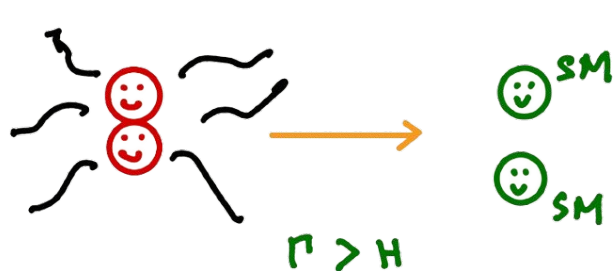
Mass scale of dark matter

(not to scale)



Credit: Tongyan Lin,
TASI lectures on DM models and direct detection

The freezeout mechanism and the “WIMP miracle”



$$\Gamma \lesssim H$$

$$\Omega_{\chi}^0 \approx 0.2 \frac{2.2 \times 10^{-26} \text{ cm}^3/\text{s}}{\langle \sigma v \rangle}.$$



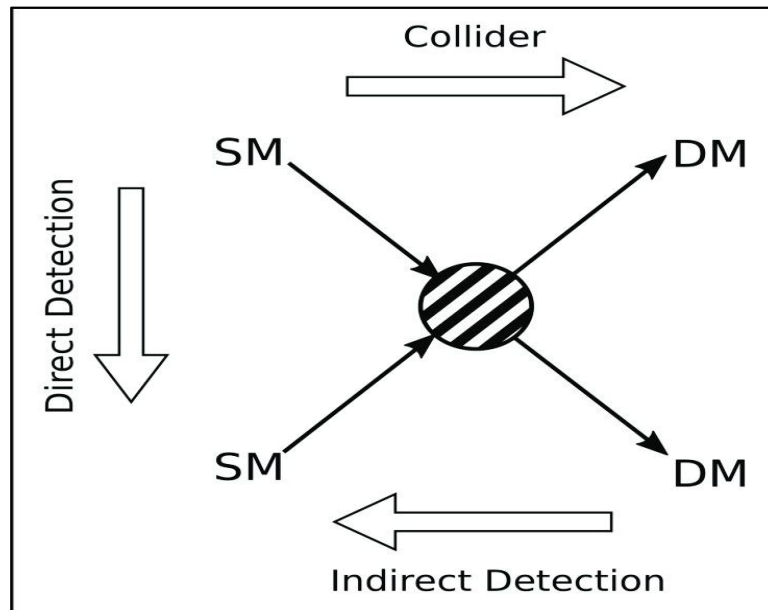
Cross section corresponds to
weak scale

$$\Omega_X^0 \propto \frac{1}{\langle \sigma v \rangle} \sim \frac{m_X^2}{g_X^4}$$



Freezeout is still possible without
WIMPs.

The hunt for dark matter



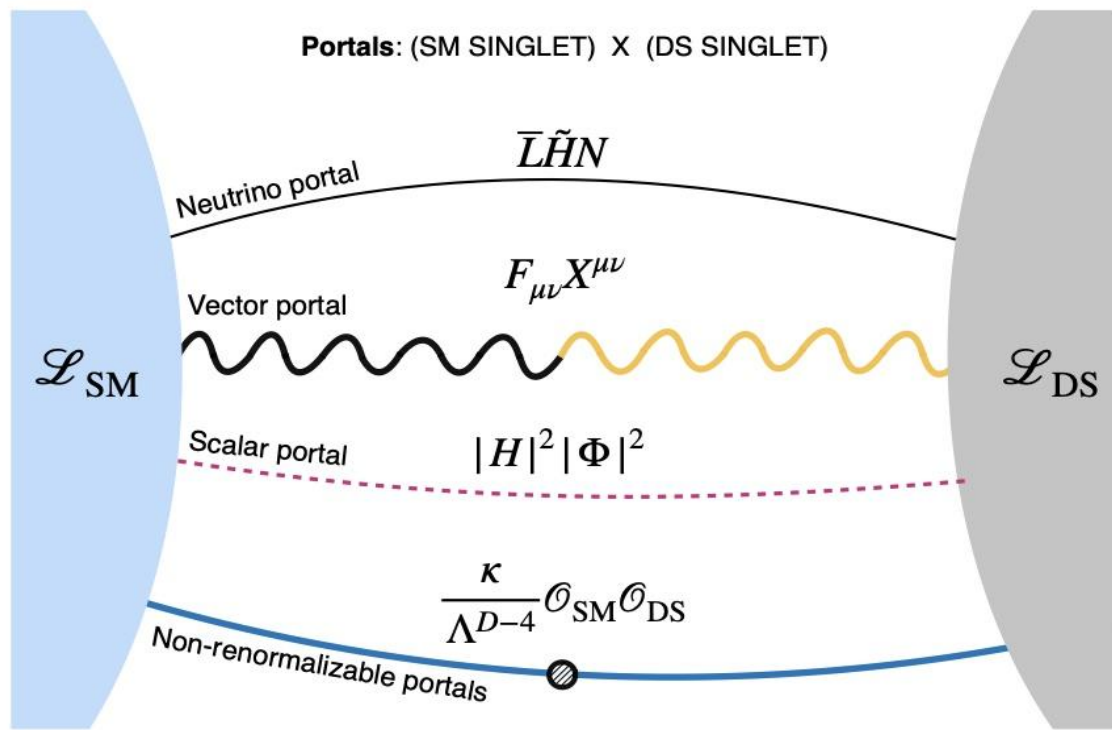
Credit: [Stefano Giagu](#)

WIMP like light dark matter through portals



Theory side

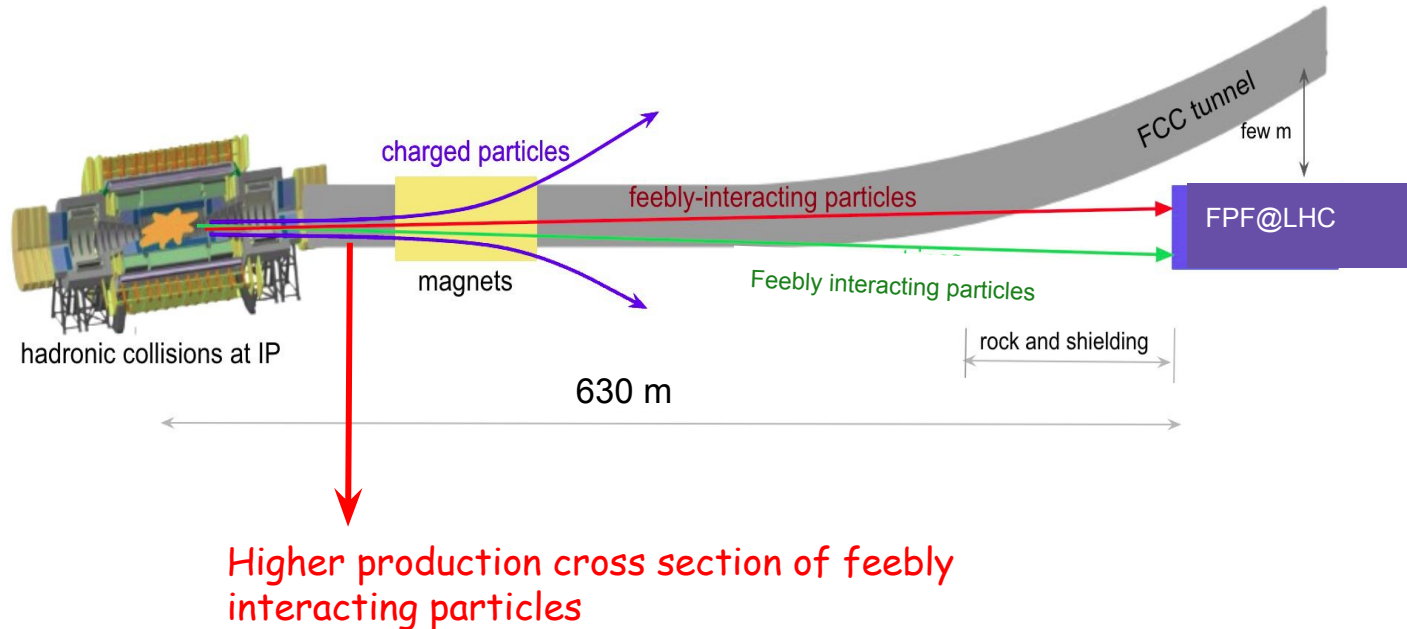
Light WIMP like dark matter through portals



Theory side

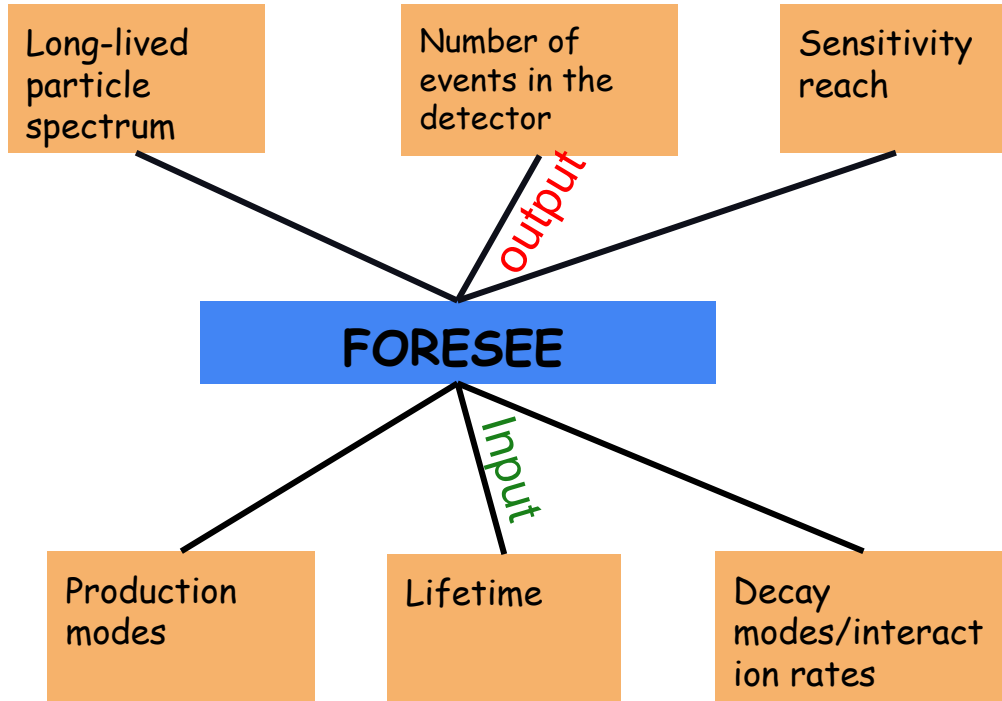
An idea to look for light dark matter at colliders

Forward physics facility at LHC

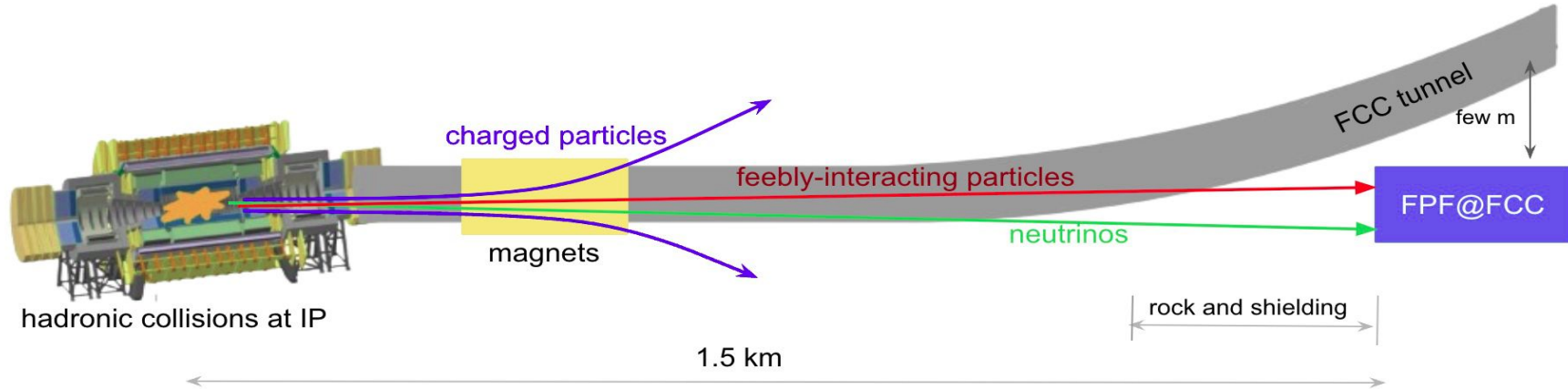


The FORESEE code

What is FORESEE: python based simulation tool for long lived particle searches at Forward physics facility
available on github: <https://github.com/KlingFelix/FORESEE>



Forward Physics facility@FCC



FCC-hh era

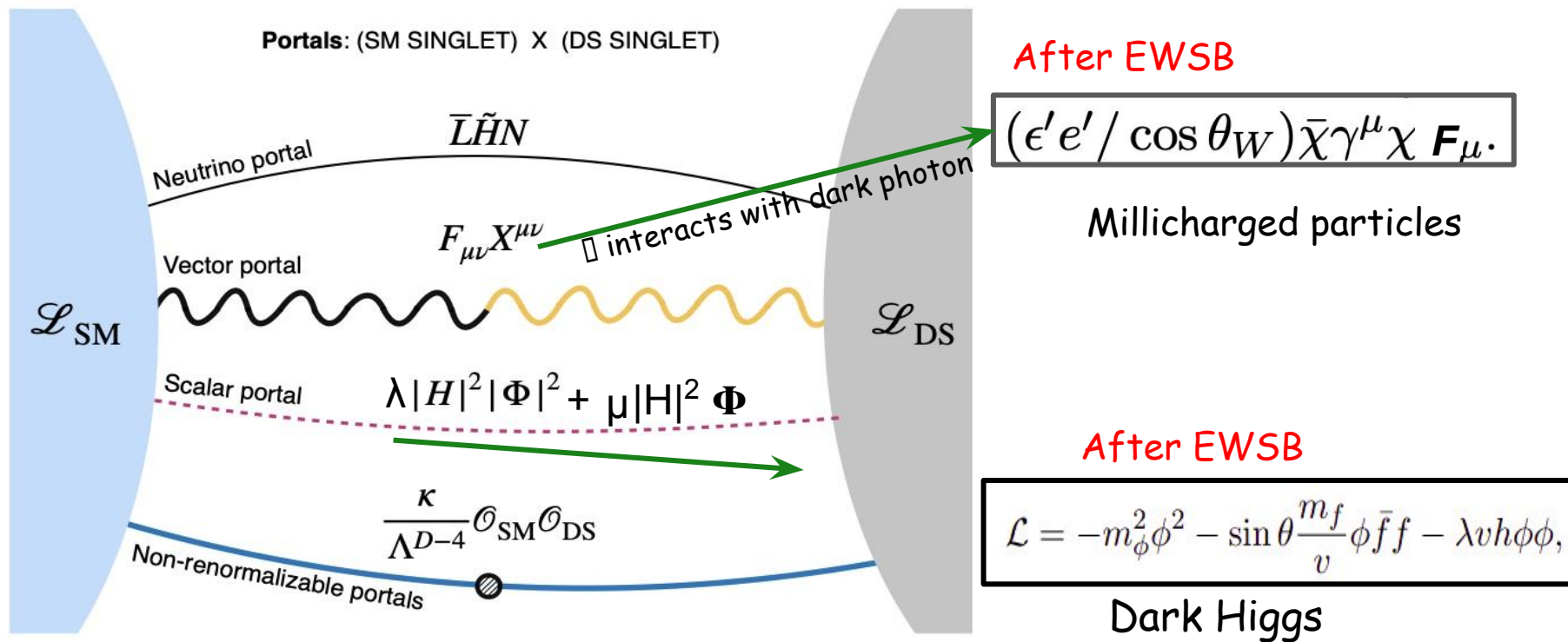
- ❑ COM energies upto 100 TeV
- ❑ Expected integrated luminosity of 30 ab^{-1}

arXiv:2409.02163v1

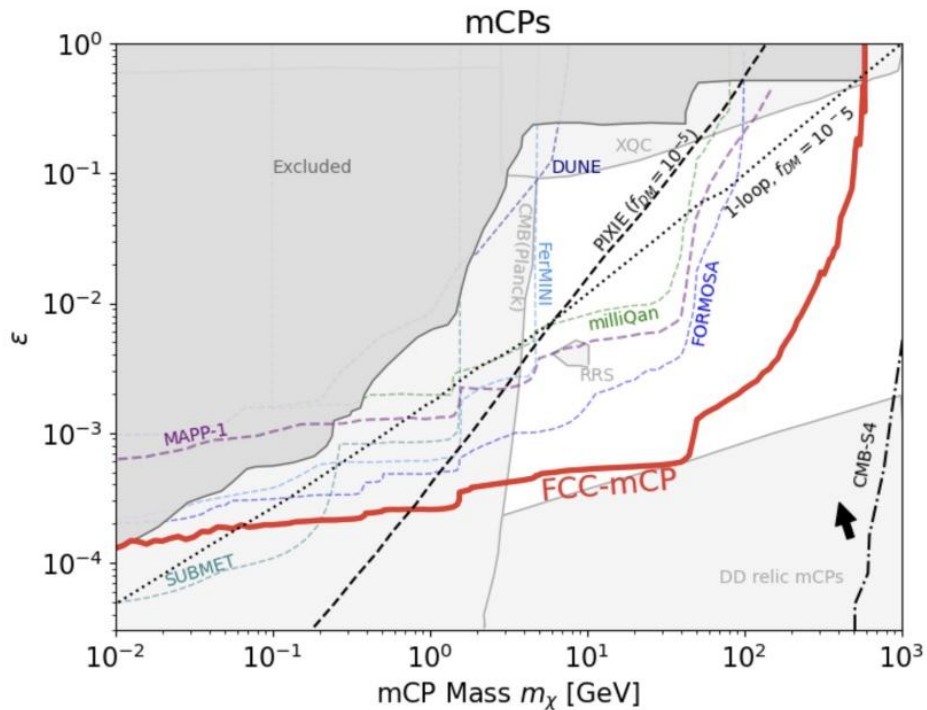
**FPF@FCC: Neutrino, QCD, and BSM Physics Opportunities with
Far-Forward Experiments at a 100 TeV Proton Collider**

Roshan Mammen Abraham¹, Jyotismita Adhikary², Jonathan L. Feng¹, Max Fieg¹,
Felix Kling³, Jinmian Li⁴, Junle Pei^{5,6}, Tanjona R. Rabemananjara^{7,8},
Juan Rojo^{7,8}, and Sebastian Trojanowski²

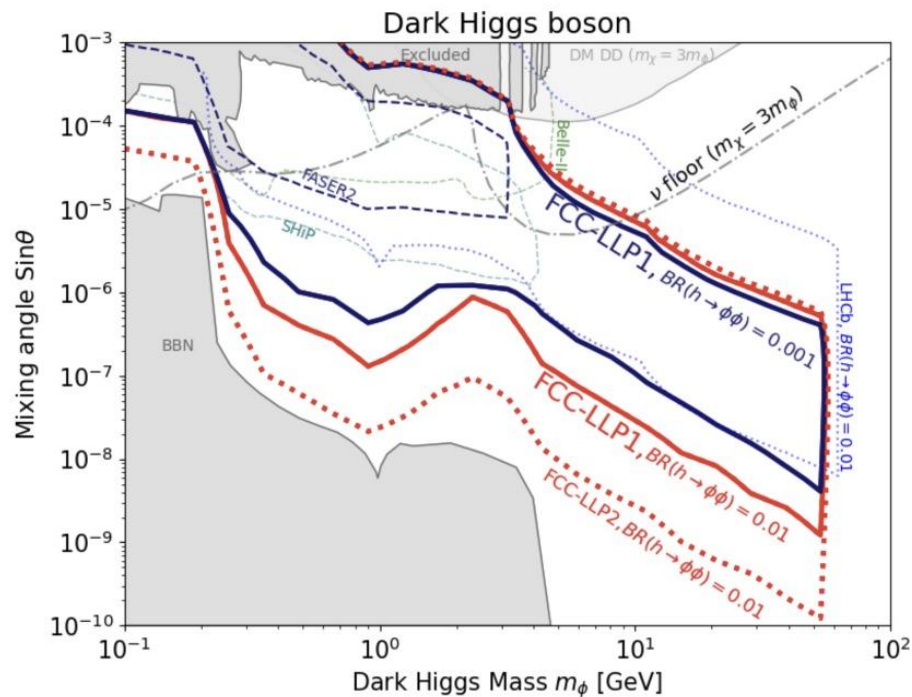
WIMP like light dark matter at FPF@FCC



Search for long lived particles at FPF@FCC

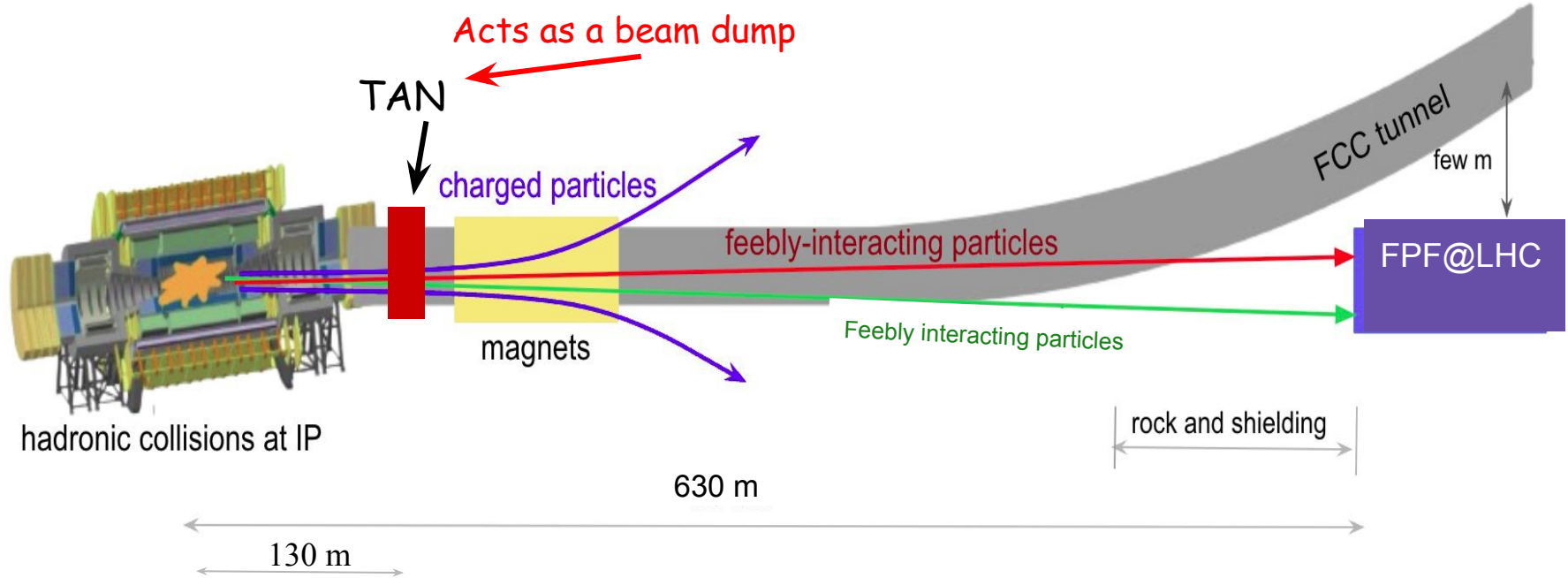


Ionisation Signature



Decay Signature

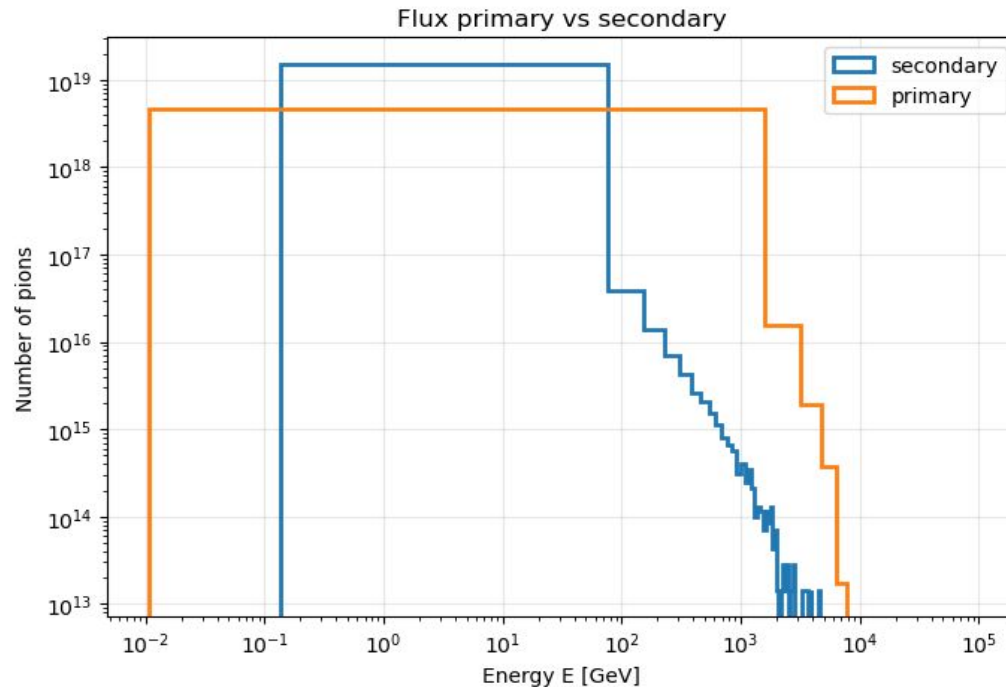
Target absorber neutral at LHC



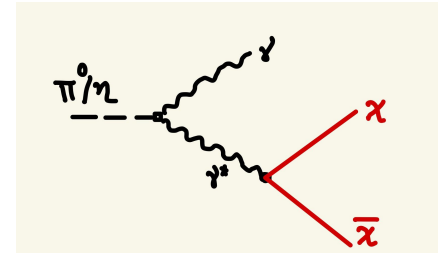
We want to evaluate whether **hadronic and electromagnetic (EM) showers in the TAN** can improve detector sensitivity to mCPs.

Flux of neutral pions produced from neutrons at TAN

Work in progress:
Azam Zabihi,
Sebastian
Trojanowski, Leszek
Roszkowski, Peiran
Li, Lei Zu, JA

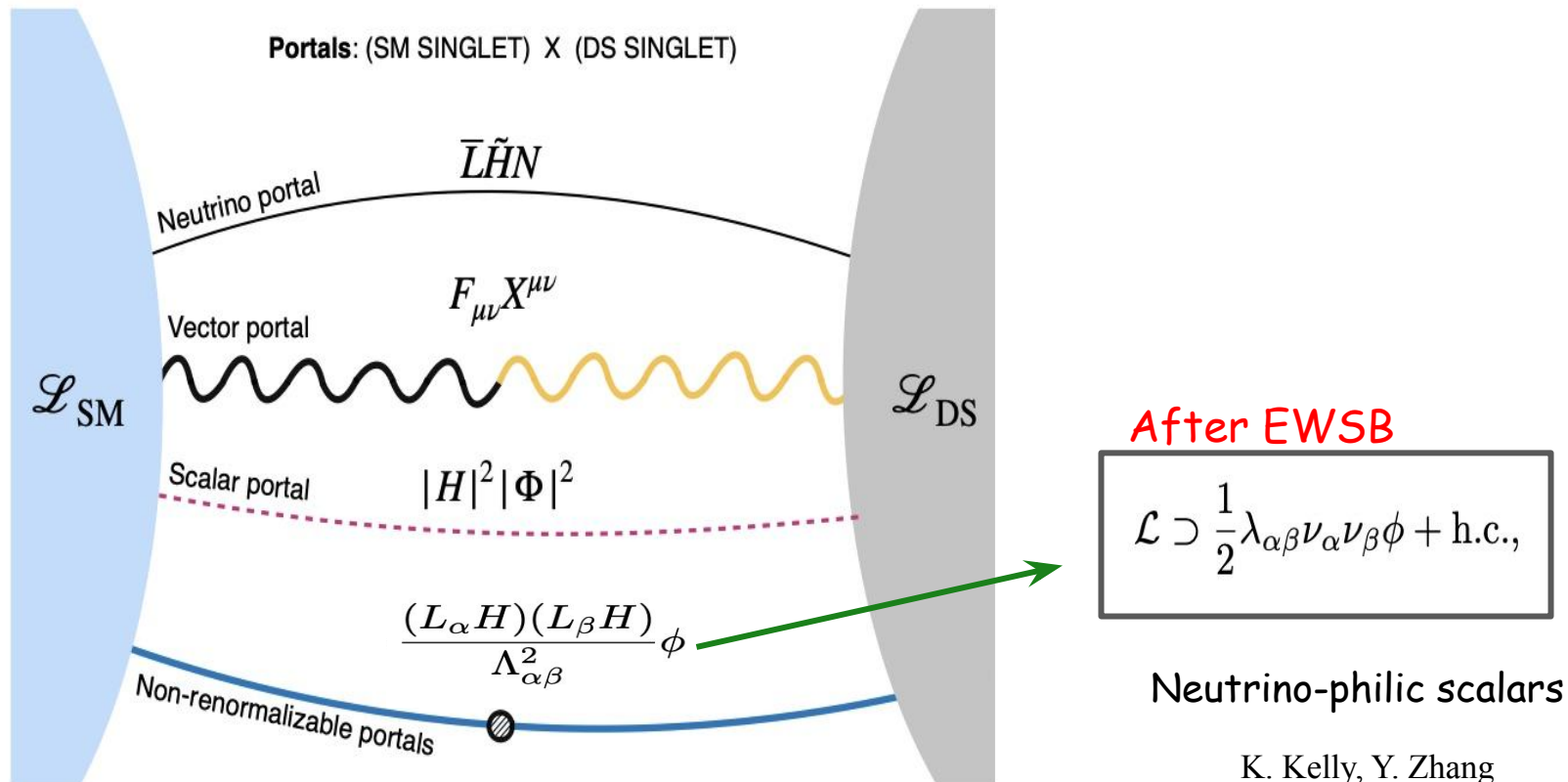


Flux of secondary
pions higher than
primary ones!

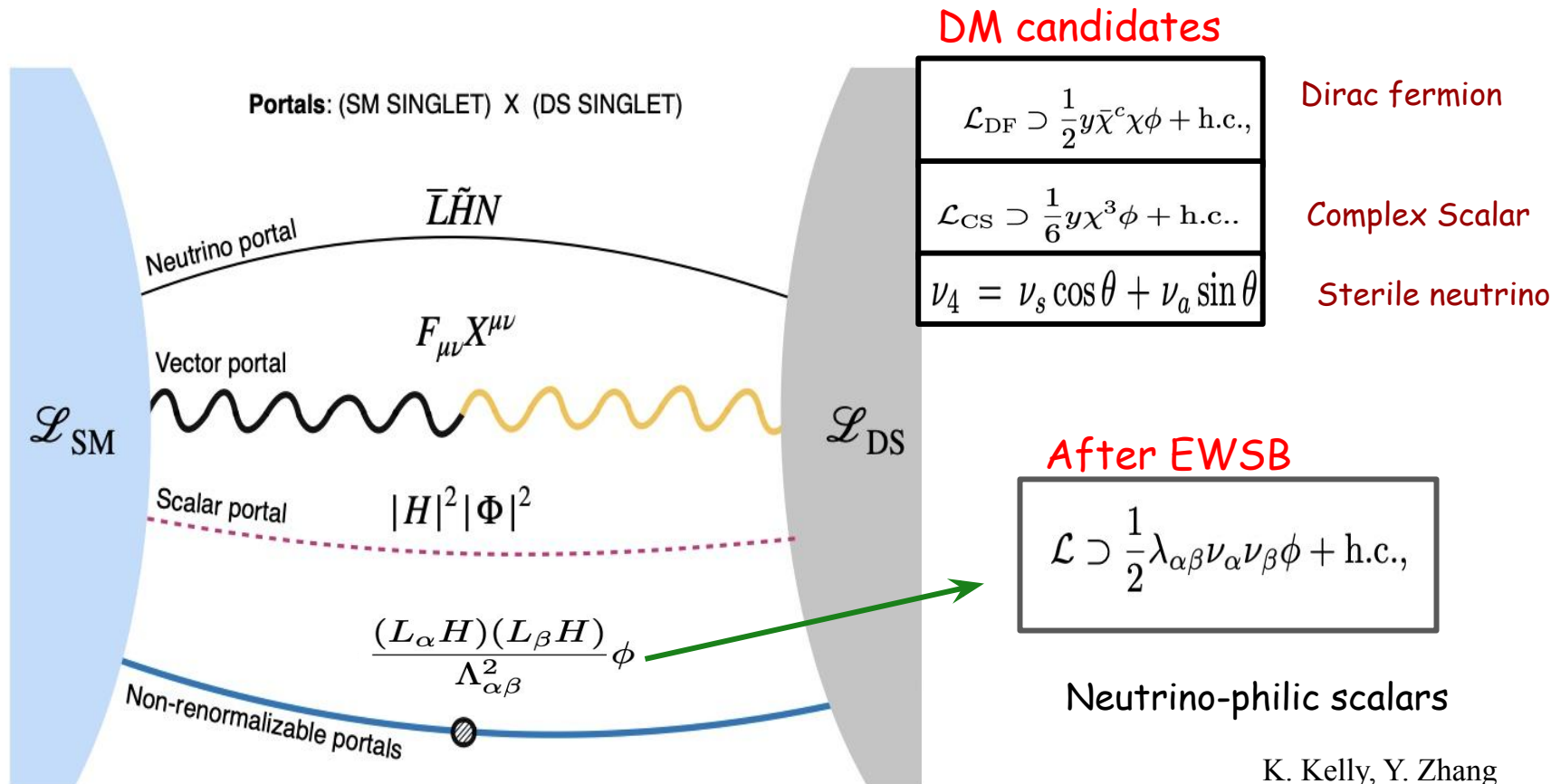


Next step: to check the flux of mCPs produced from meson decays and from EM shower

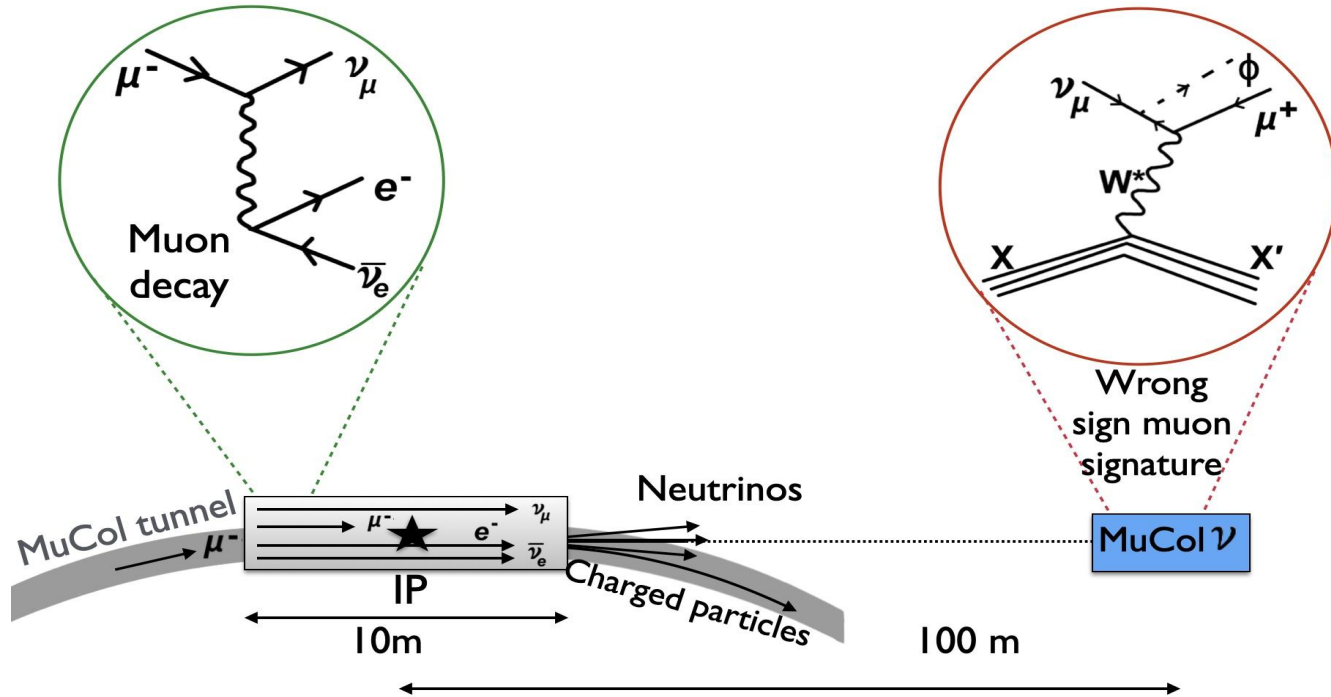
Neutrino-philic scalar mediator



Neutrino-philic scalar mediator



The wrong-sign muon signature

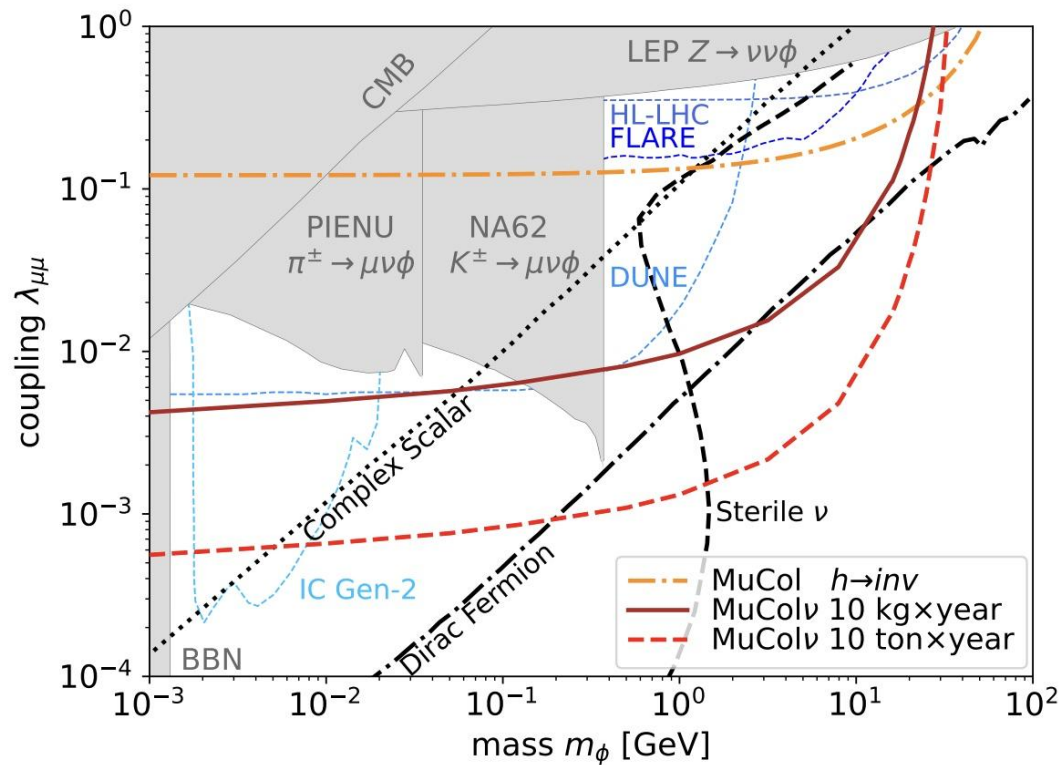


Note: One beam is enough to probe the signature

10^{13} muons will be injected each second.

resulting in about 10^{10} neutrinos per second

Sensitivity reach

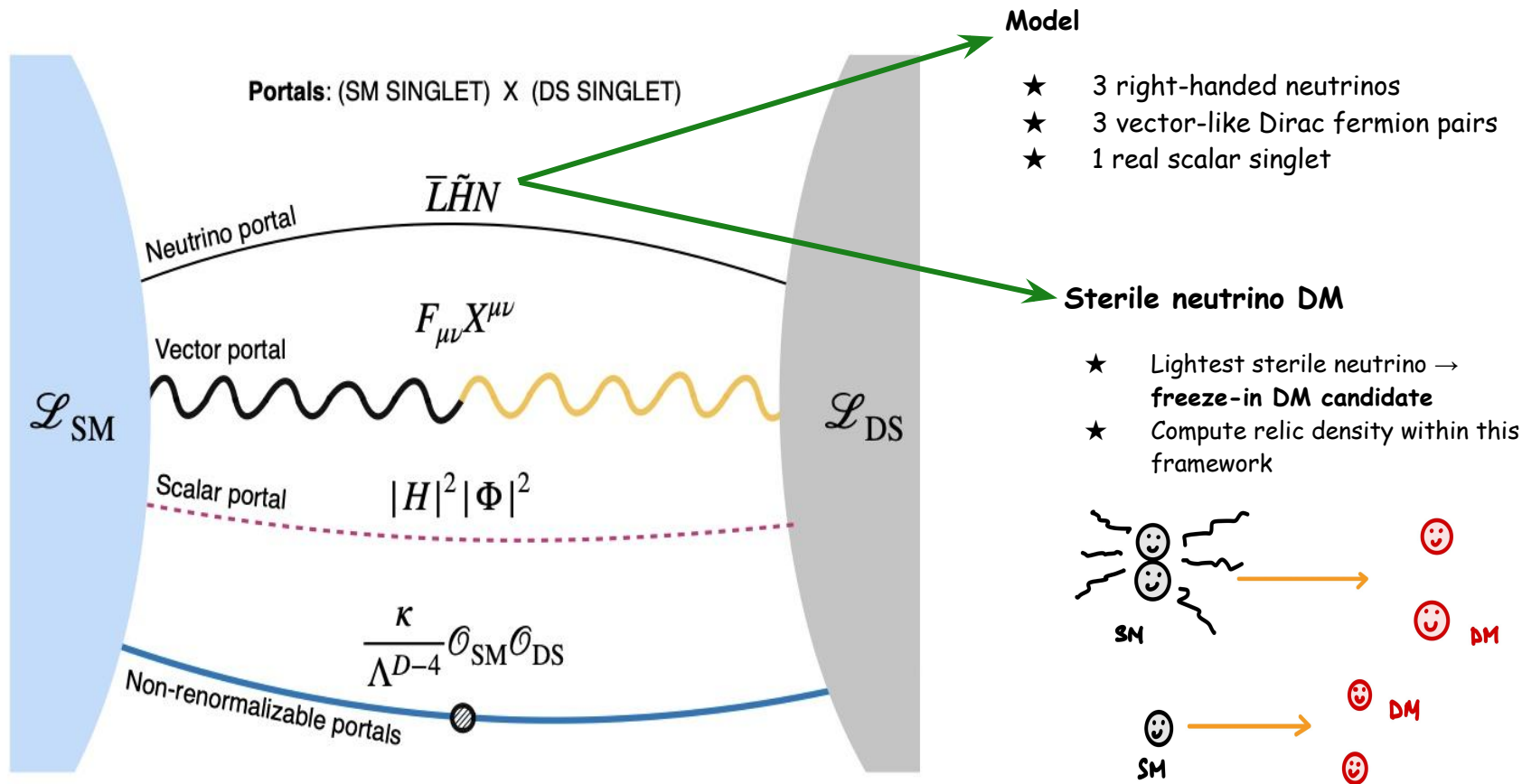


arXiv:2412.10315v2

Neutrino-Portal Dark Matter Detection Prospects
at a Future Muon Collider

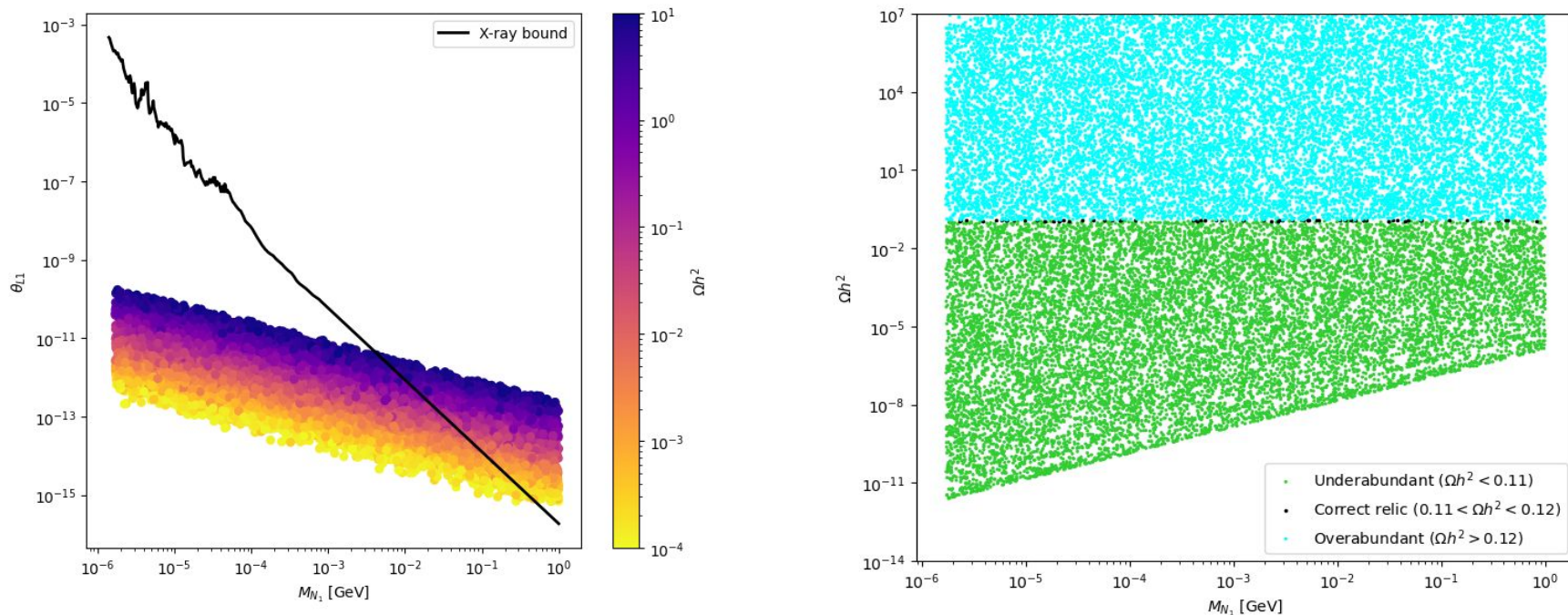
Jyotishmita Adhikary,^{1,*} Kevin J. Kelly,^{2,†} Felix Kling,^{3,‡} and Sebastian Trojanowski^{1,§}

Sterile neutrino dark matter in the minimal Dirac seesaw



Sterile neutrino Dark Matter in the minimal Dirac Seesaw

Preliminary!



Conclusions and future work

- DM interactions should be tested in the relativistic regime, which is a direct probe of the thermal production paradigm.

My research directions

- ★ Searched for dark matter and long lived particles at the forward kinematic region of FCC-hh.
- ★ Looked for neutrino-philic mediator at the future muon collider.
- ★ Contributed in calculating the relic target of the model that realize Dirac neutrino masses through discrete symmetries while providing viable dark matter candidates.
- ★ Aim to improve sensitivity of forward detectors to mCPs with introduction of hadron and electromagnetic showers at TAN/TAXN.
- **Beyond colliders:** It is also possible to look for complementary targets in astrophysics/cosmology in dark matter searches so currently looking for effect of up-scattering of inelastic dark matter having electric dipole moment with cosmic rays at the galactic centre on gamma ray spectra.

Jaime Zink, Sebastian Trojankowski, JA