BSM Physics Opportunities with Far-Forward Experiments at a 100 TeV Proton Collider

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ISAPP 2024: Particle Candidates for Dark Matter

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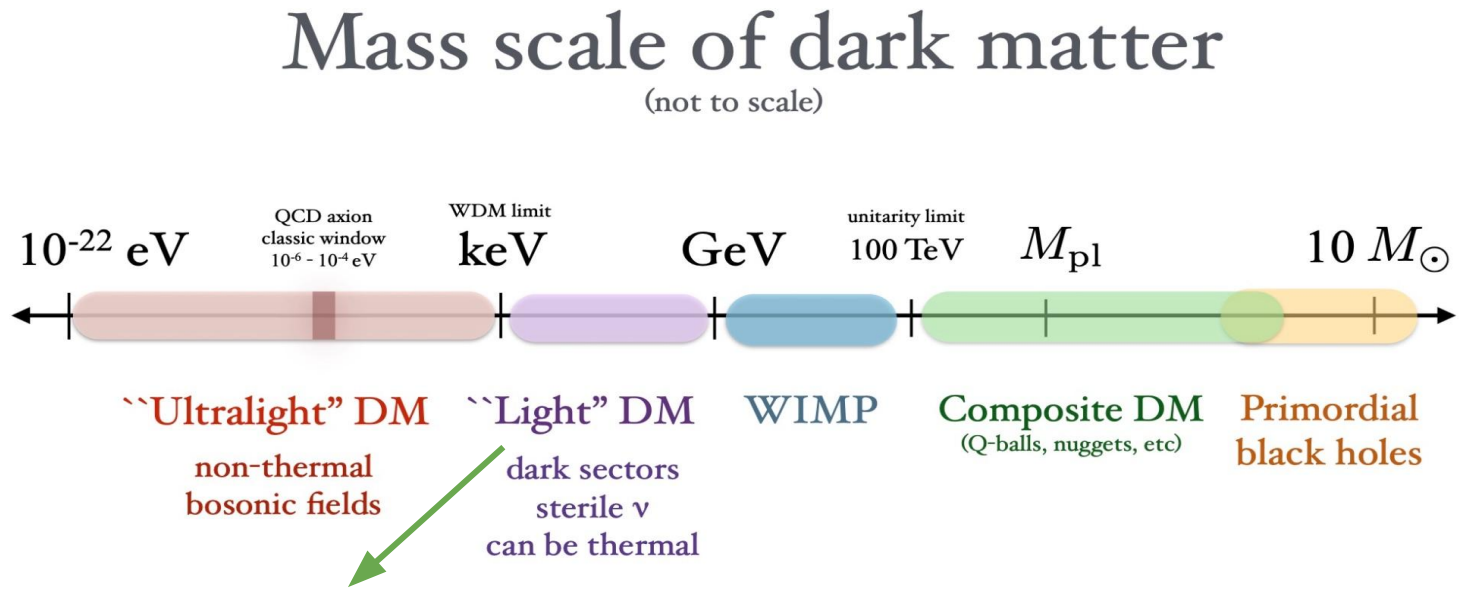
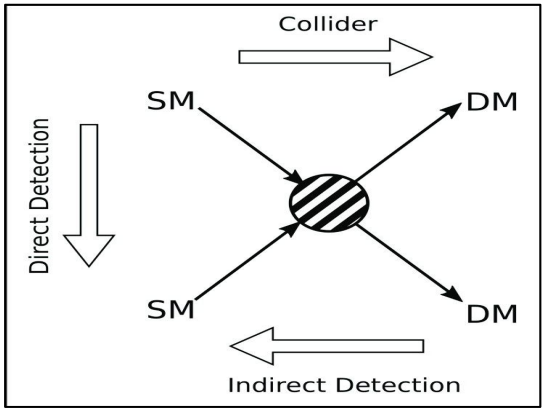
Possible dark matter candidates

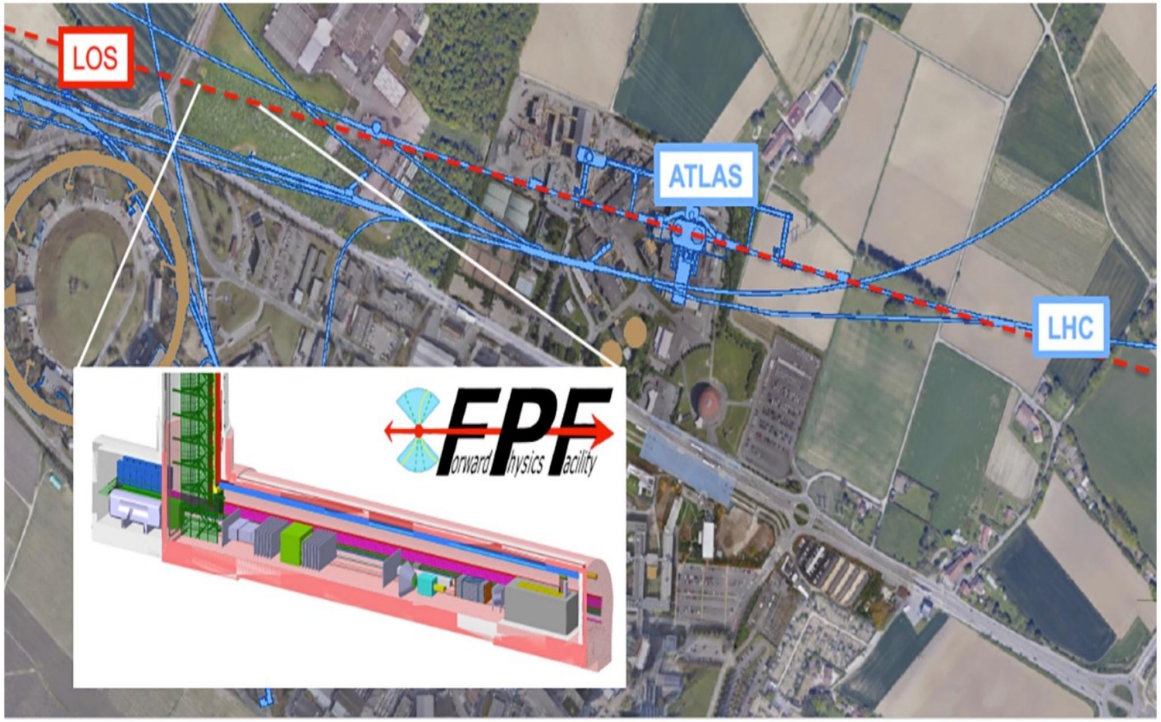


Credit:Tongyan Lin,
TASI lectures on DM models and direct detection

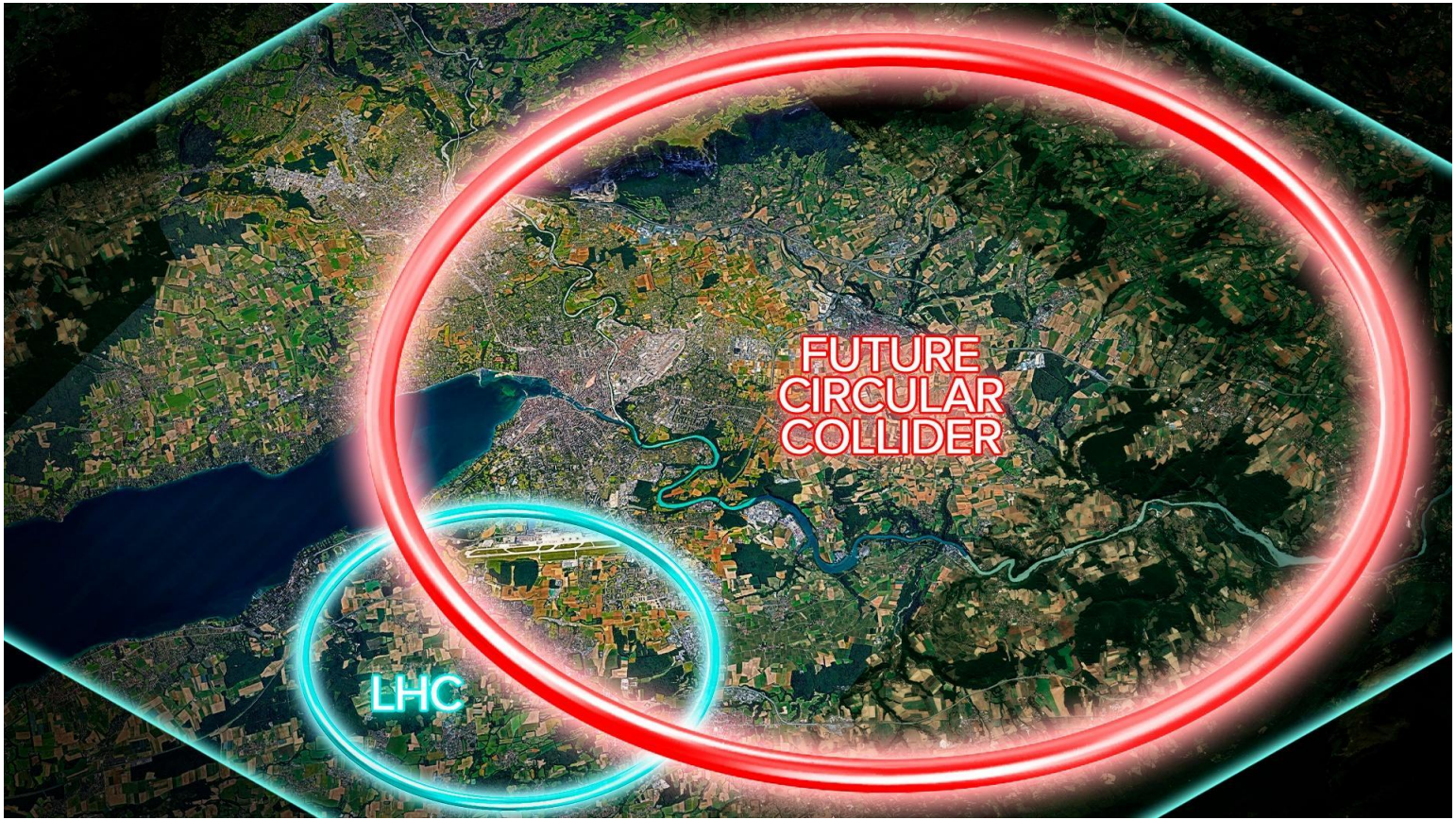
The hunt for dark matter



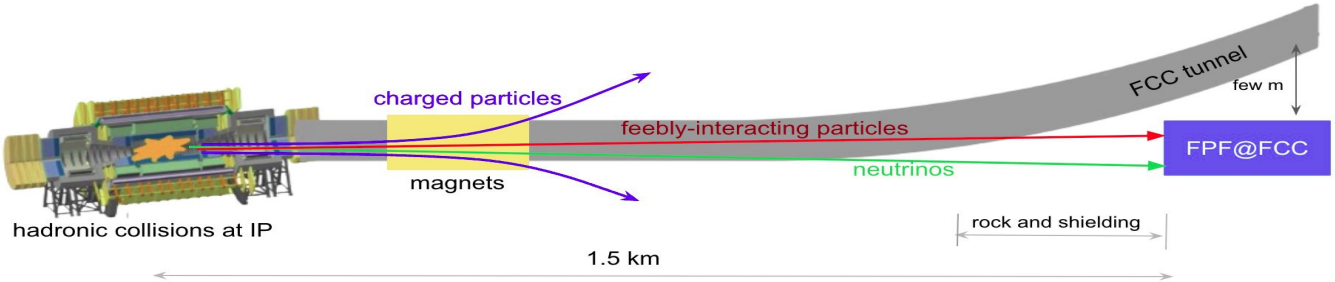
Credit: Stefano Giagu



The hunt for dark matter@FCC

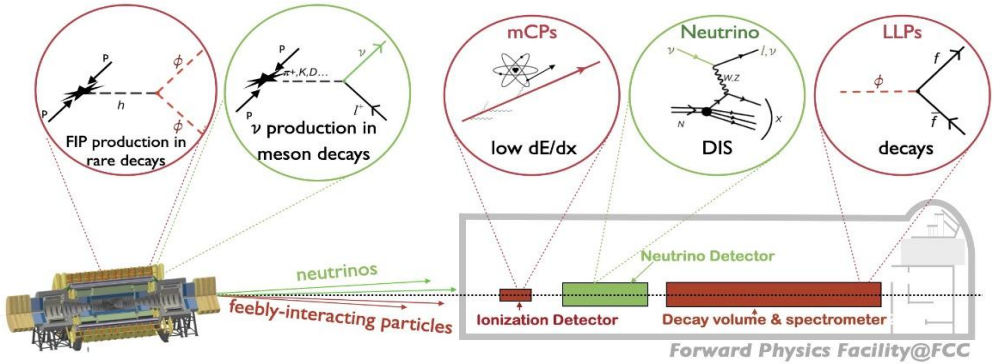


Forward Physics facility@FCC



FCC-hh era

- COM energies of 100 TeV and beyond
- Expected integrated luminosity of 30 ab^{-1}



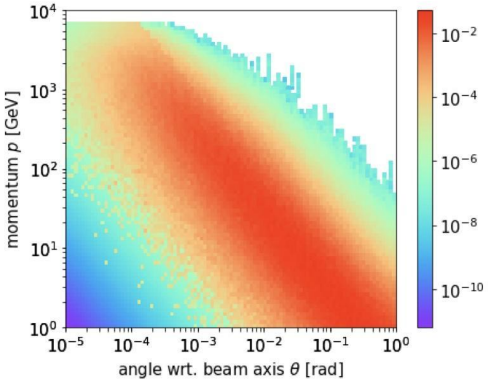
How do we get to know what to expect in the detectors at FPF@FCC?

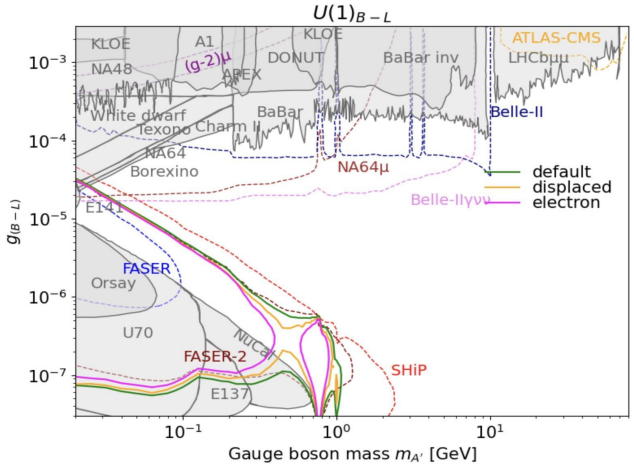
FORESEE

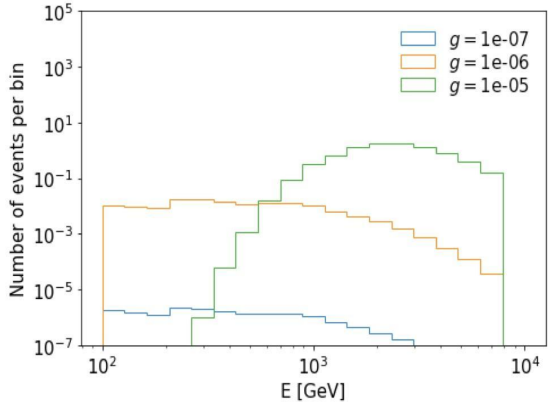
What is FORESEE: python based simulation tool for long lived particle searches at FASER
available on github: https://github.com/KlingFelix/FORESEE

How does it work:

1. Define the model with production, lifetime and decay modes.
2. Obtain the long lived particle spectrum.
3. Define detector specifics.
4. Obtain the number of events expected in the detector.
5. Obtain parameter space available for exploring the model in specific detector.





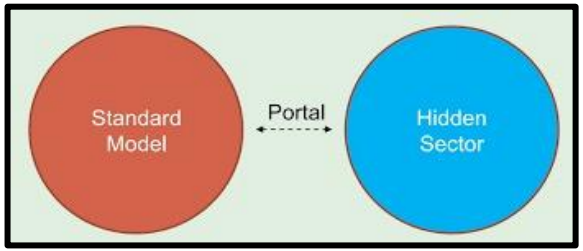


F. Kling, S. Trojanowski:
arXiv:2105.07077v1

BSM physics Cases

Dark Higgs Boson

The model



Dark Higgs, S $(\mu S + \lambda S^2) H^\dagger H$

New scalar mixing with the SM Higgs

Dark higgs also inherits couplings to SM fermions

$$\mathcal{L} = -m_\phi^2 \phi^2 - \sin\theta \frac{m_f}{v} \phi \bar{f} f - \lambda v h \phi \phi,$$

Production and decay

Production:

- Heavy meson decays ($B \to X_s \phi$) , ($B \to X_s \phi\phi$)
- SM Higgs decay $h \to \phi\phi$ @ FCC

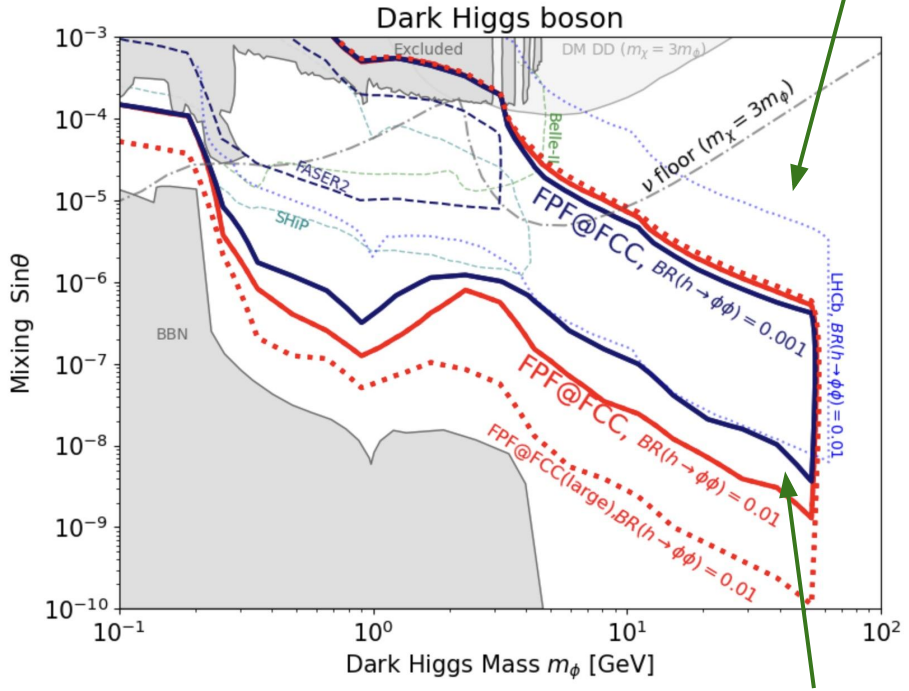
Decay:

- mostly bb, $\tau^+\tau^-$, … final states

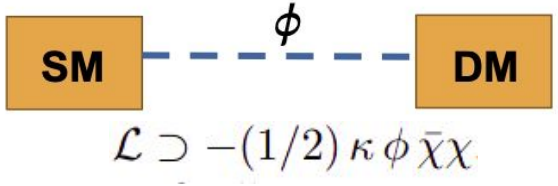
Large lifetime: TeV-energy $m_\phi = 10$ GeV, $\theta \sim 10^{-7} \to \tau_\phi \sim 100$ km

Dark Higgs sensitivity reach without or with trilinear coupling

complementarity:
central detectors
(displaced vertices)



Advantage of high COM energy



Relic density, $\chi\chi \to \phi\phi$ (driven by κ)

complementarity:
DM direct detection

Millicharged particles

- Possible result of new unbroken gauge symmetries.
- Massless dark vector boson A' kinetically mixes with hypercharge boson.

$$(\epsilon'/2\cos\theta_W)B^{\mu\nu}X_{\mu\nu}$$

If dark fermion χ couples to A'

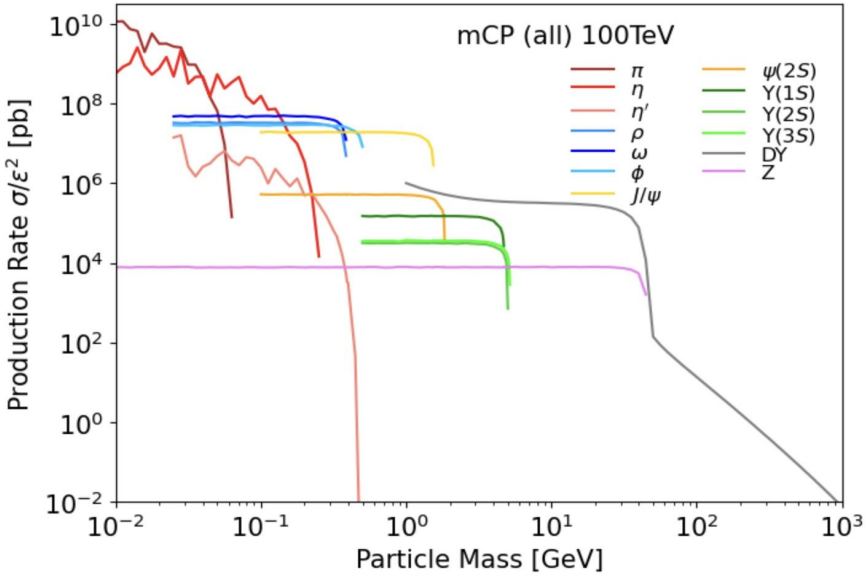
↓

- can also interact with hypercharge boson

$$(\epsilon' e'/\cos\theta_W)\bar{\chi}\gamma^{\mu}\chi B_{\mu}.$$

↓

After EWSB, χ couples to photon and Z boson and hence gains millicharge

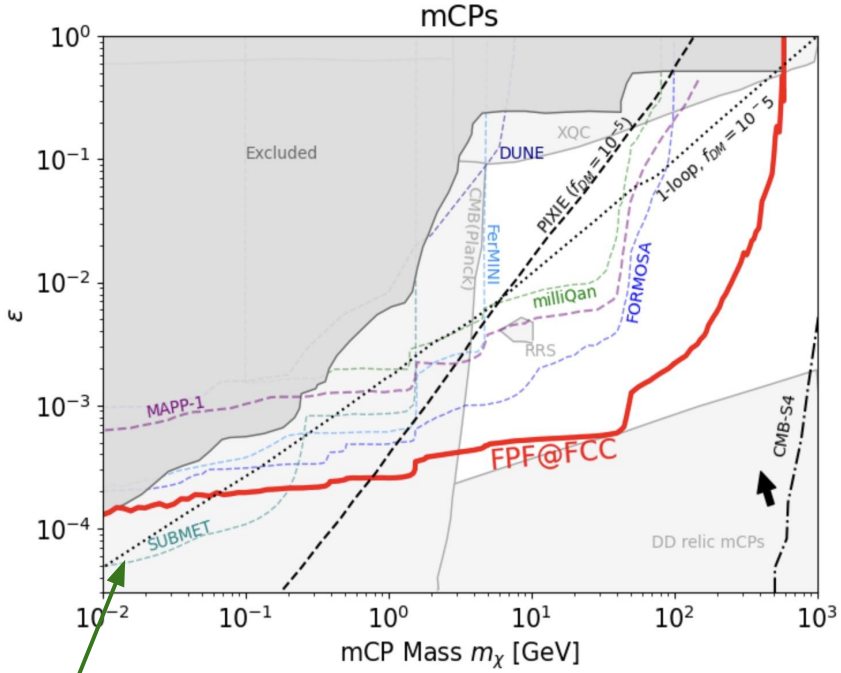


Stable particle

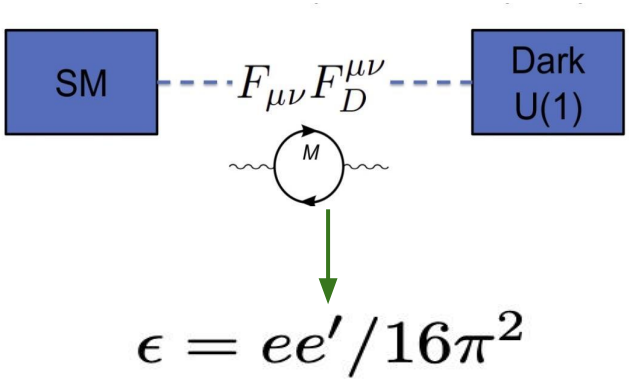
↓

possibility of detection with ionization signals

Millicharged particles sensitivity reach



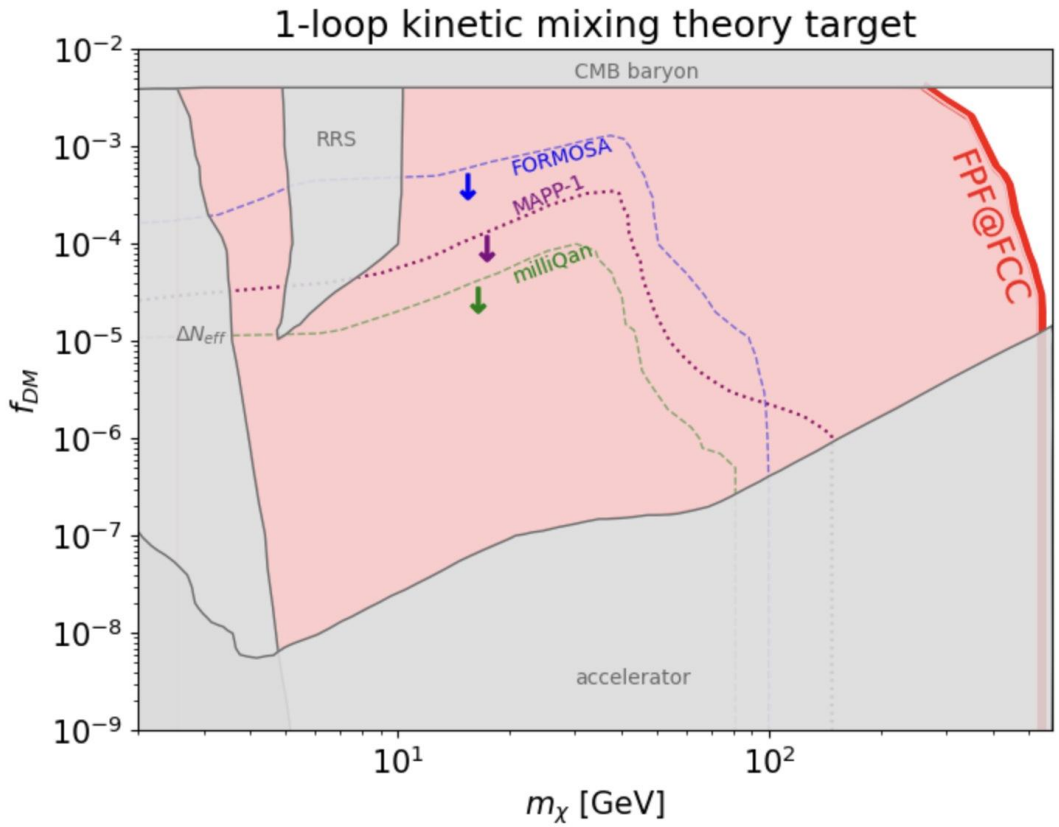
Theory target



- mCP relic abundance is set by annihilation $\chi\chi \longrightarrow A'A'$
- e' is fixed by relic density of mCPs set to be equal to $f_{DM} = 10^{-5}$

Complementarity:
Direct probe for mCPs only tested by indirect cosmological constraints

Millicharged particles sensitivity reach



Conclusions

- FPF@FCC – out-of-the-box studies but updated for higher energies
- Long-lived particles with masses up to tens or hundreds of GeV can be probed (examples: dark Higgs, mCPs)
- **Convenient simulation tool FORESEE**
  (initial forward BSM studies for FCC-hh, HE-LHC, SppC)


THANK YOU FOR YOUR ATTENTION
ANY QUESTIONS?