Neutron-induced showers in TAN → a new source of millicharged particles

Implications for FORMOSA at the Forward Physics Facility (FPF)

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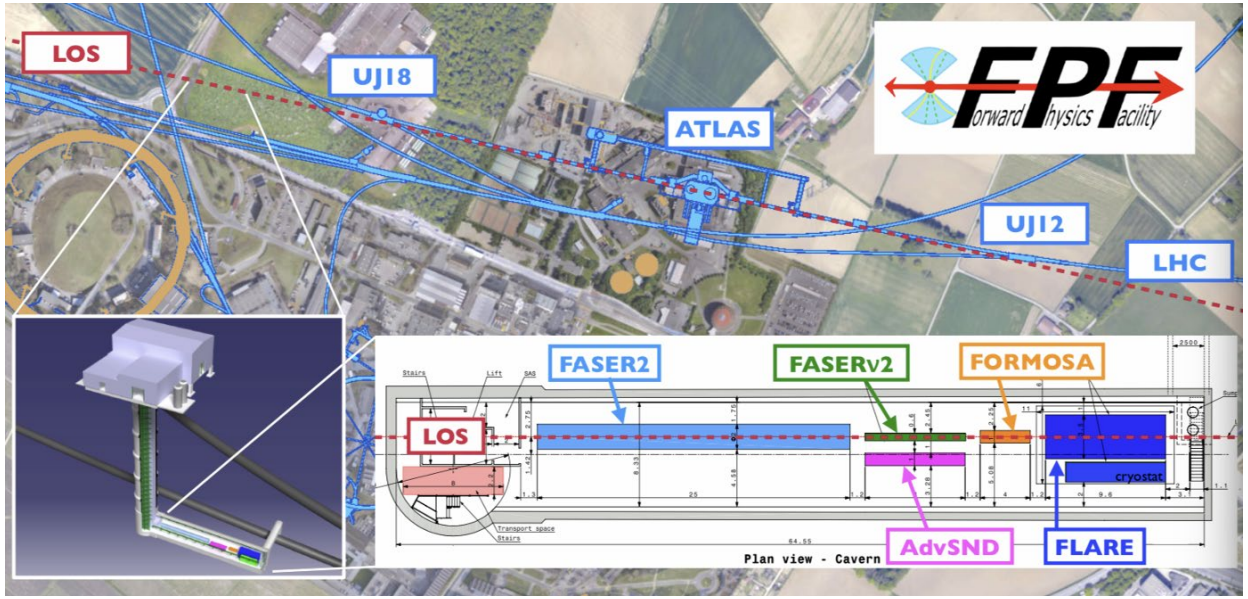
Collaboration with Jyotismita Adhikary, Zhen Liu, Sebastian Trojanowski, Azam Zabihi

Why far-forward? Why FPF?

Low backgrounds + huge forward fluxes → unique reach for weakly coupled physics

- A dedicated cavern on the LHC line-of-sight (LoS) for far-forward experiments
- Programs span neutrinos, forward hadron production, and new physics (LLPs, dark sector)
- Examples of BSM targets: dark photons, ALPs, HNLs, millicharged particles (mCP), etc.



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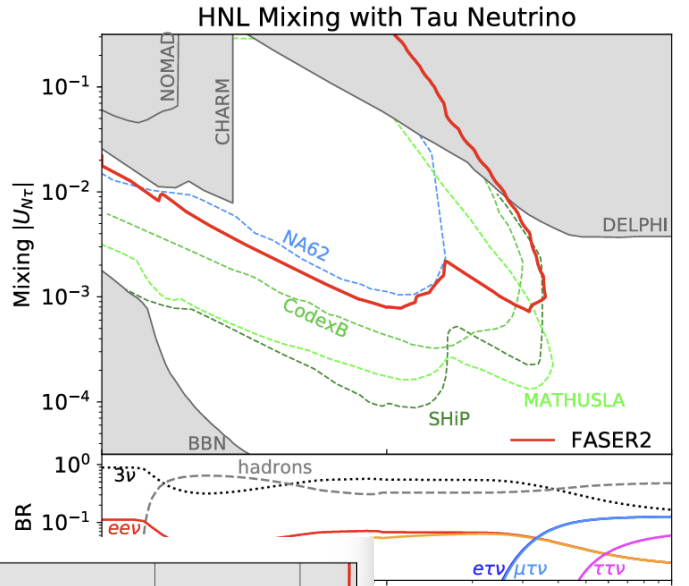
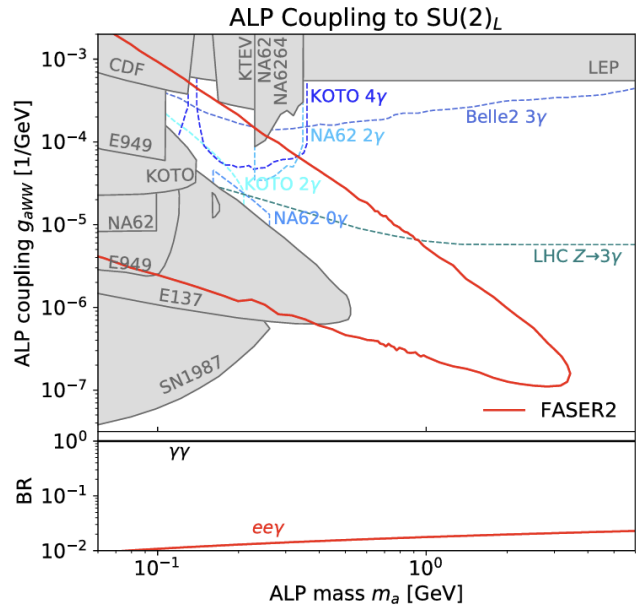
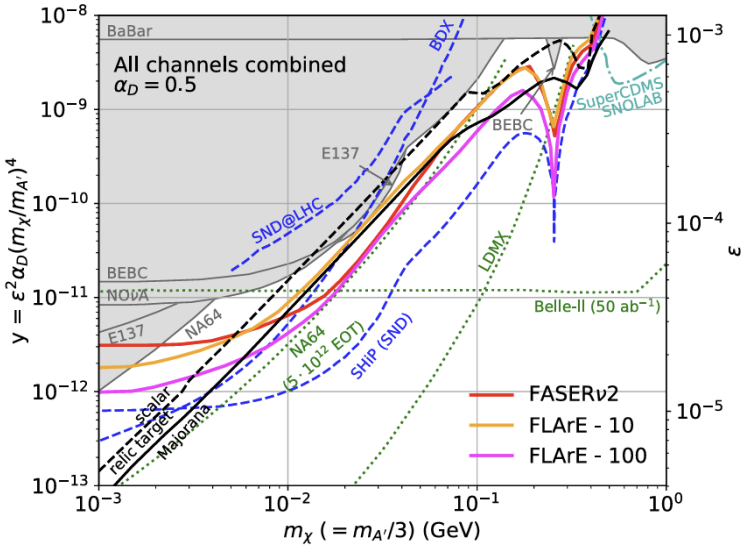
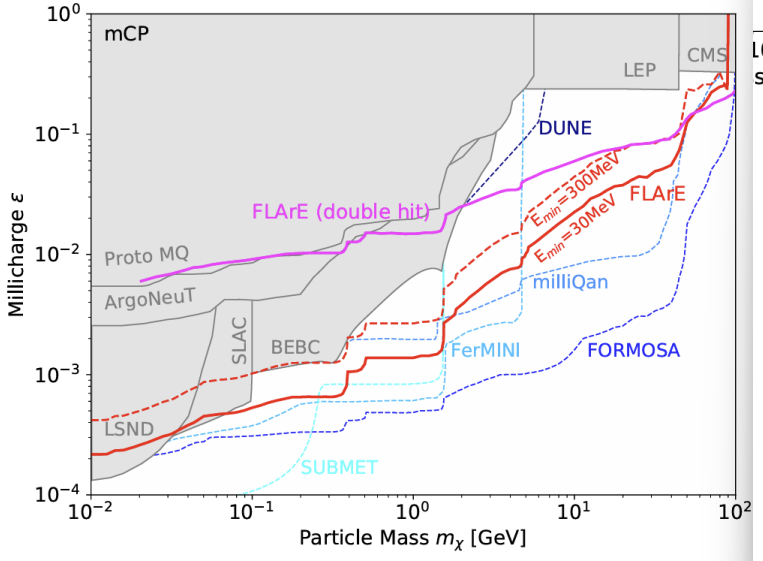


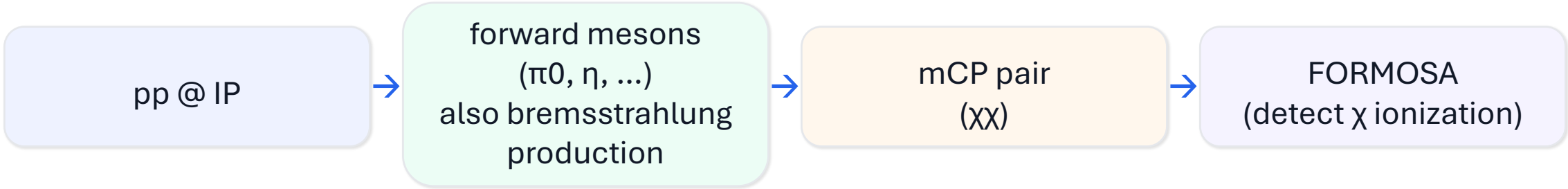






Baseline: mCP from forward mesons in pp collisions

What most LHC/FPF mCP sensitivity studies considered



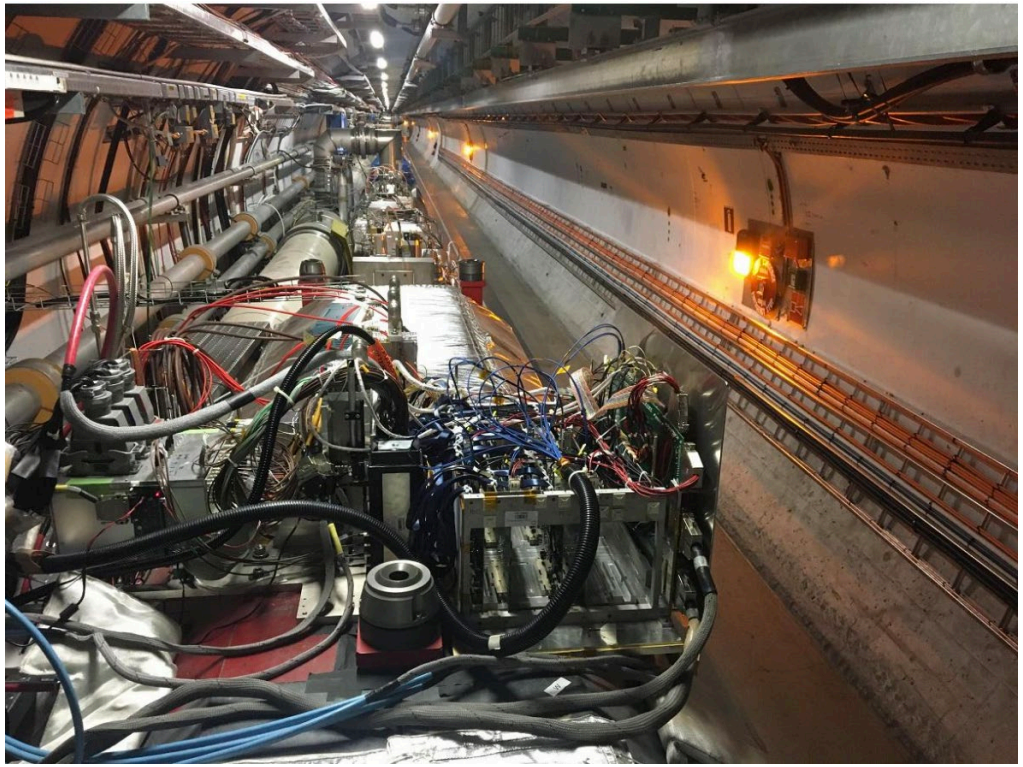
Takeaway: sensitivity is driven by how many forward mesons you produce at the IP and how often they decay to χχ.
Question: are there additional “secondary production” sites downstream that act like a beam dump?

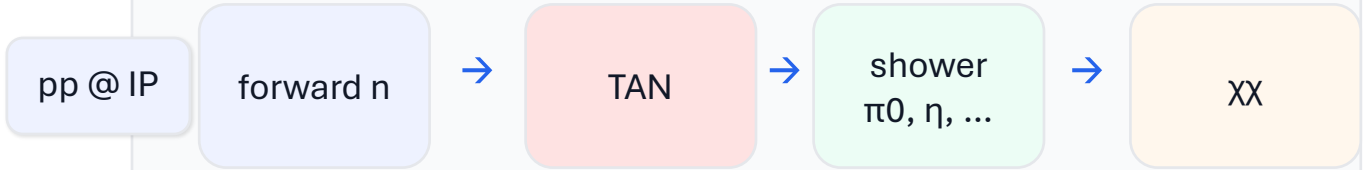
New source: forward neutrons showering in TAN (Target Absorber Neutral)

A “built-in beam dump” that regenerates mesons → χχ

Observation

- pp collisions produce a large flux of very forward neutrons at TeV energies (10^{16} n with $\theta < 3$mrad)
- These neutrons hit the neutral absorber TAN (~140 m) and initiate hadronic showers
- The shower produces secondary neutral mesons (π0, η, …) that can decay to mCPs

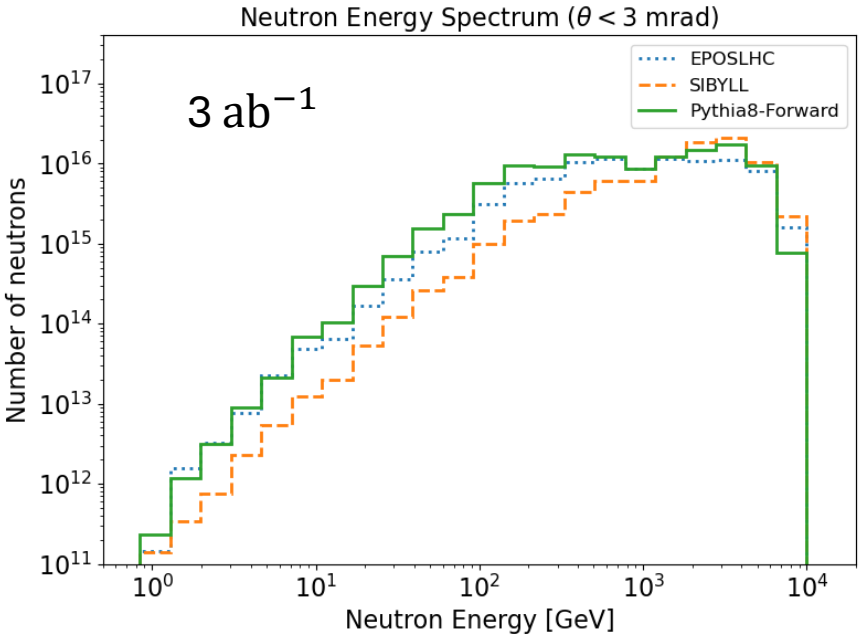




Beam-dump analogy: primary hadrons → absorber → secondary mesons → new particles

Key question for FORMOSA:
How much does neutron-induced meson production increase the χ flux at the detector?

Neutron beam-dump

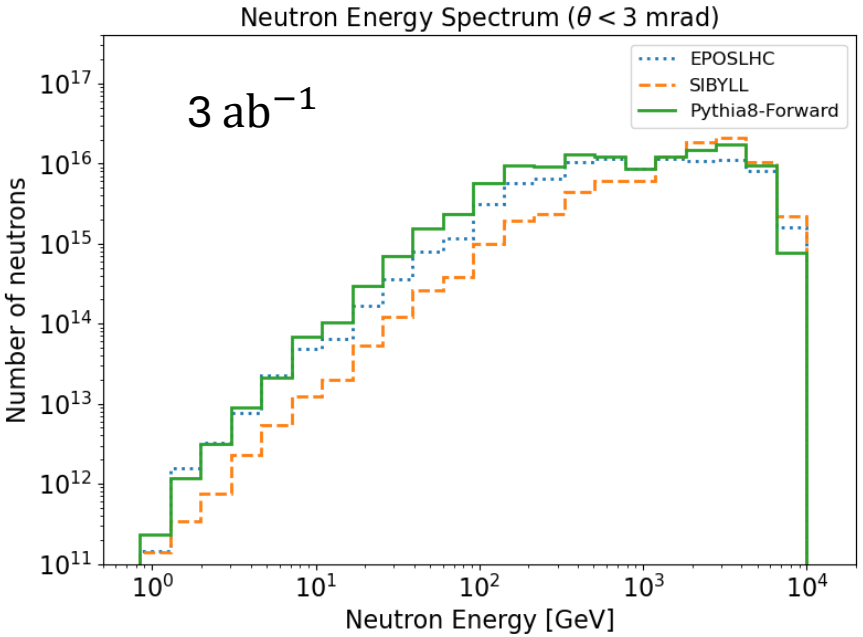


1 neutron → How many pion will be produced?

Setup: simulate forward neutrons from pp → propagate to TAN → hadronic shower → meson decays → χ reaching FORMOSA.

Deliverable: correction factor on meson production rate.

Neutron beam-dump



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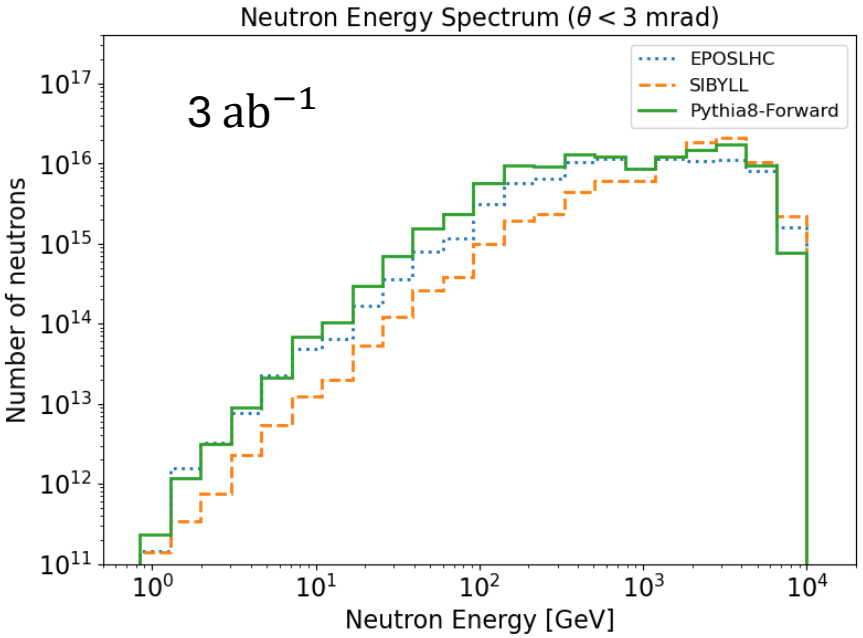

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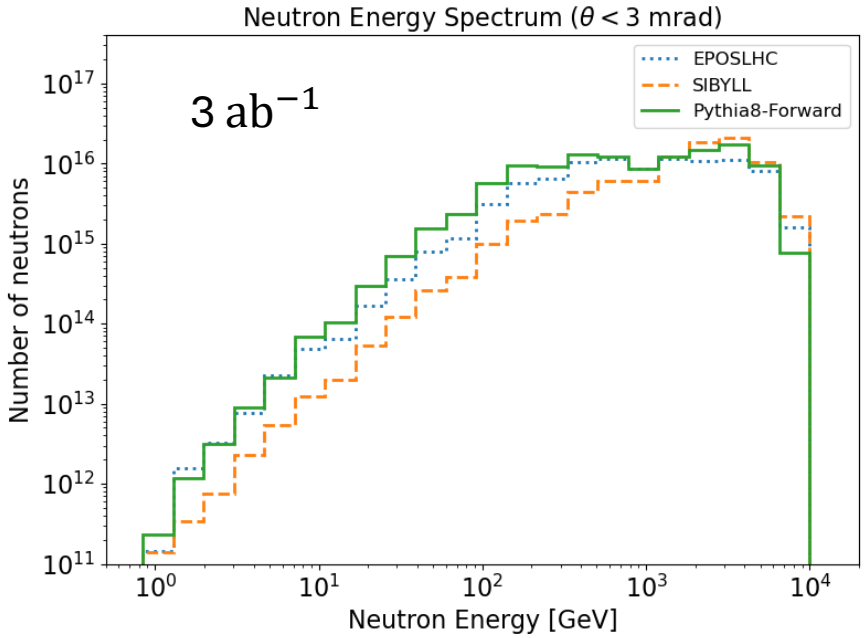
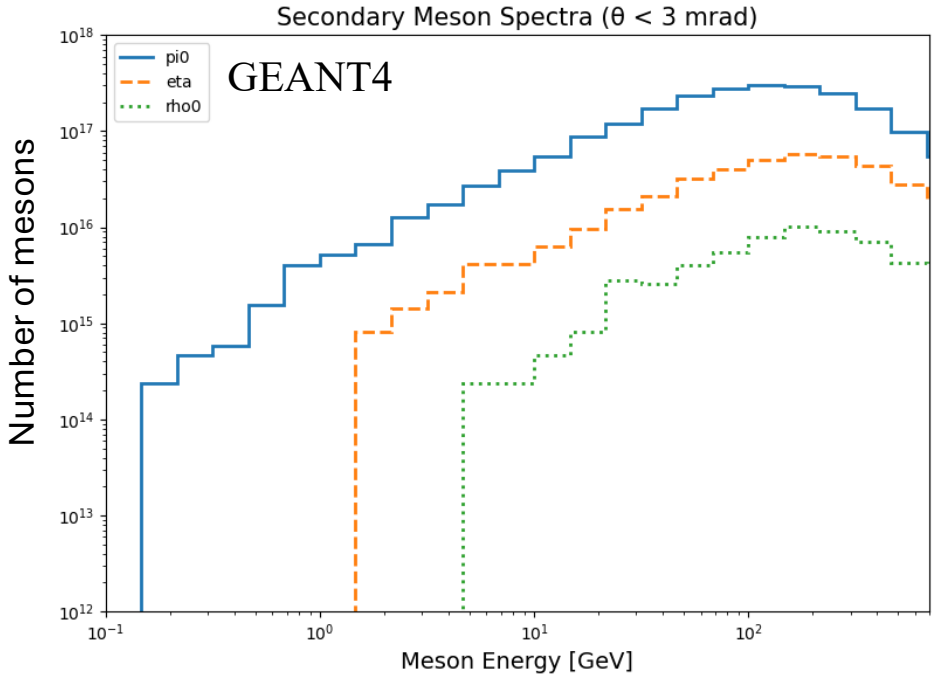


1 neutron → How many pion will be produced?

~O(100) π^0 GEANT4

At pp collision, there will be ~10^{18} π^0 with $\theta < 3$mrad



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Deliverable: correction factor on meson production rate.

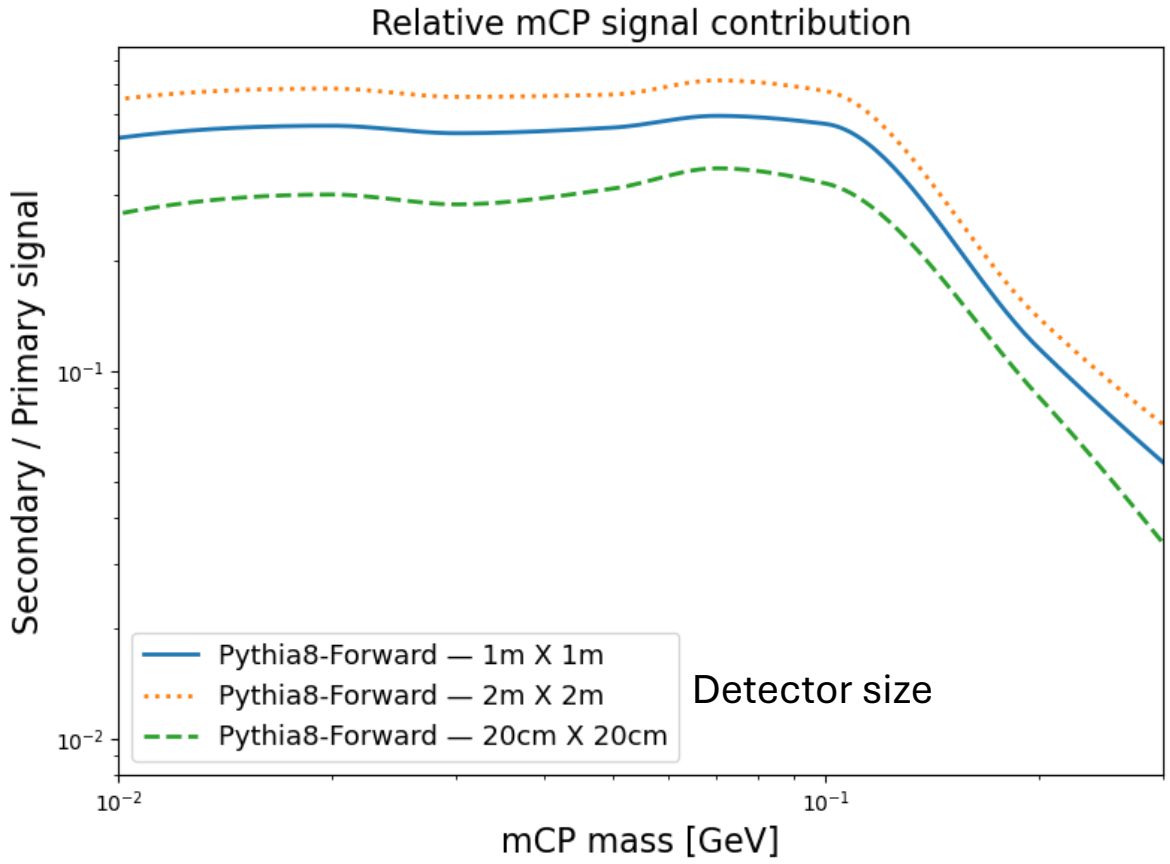
Main result: TAN showers improve χ production

Neutron-induced mesons add a sizable, previously neglected contribution

~+40%

increase in mCP production
(relative to production from IP)

- This is a new “secondary production” source, analogous to beam-dump searches
- Contribution is non-negligible, but not double-counted with, prompt pp mesons
- Impacts FORMOSA sensitivity projections (rate-limited regime)



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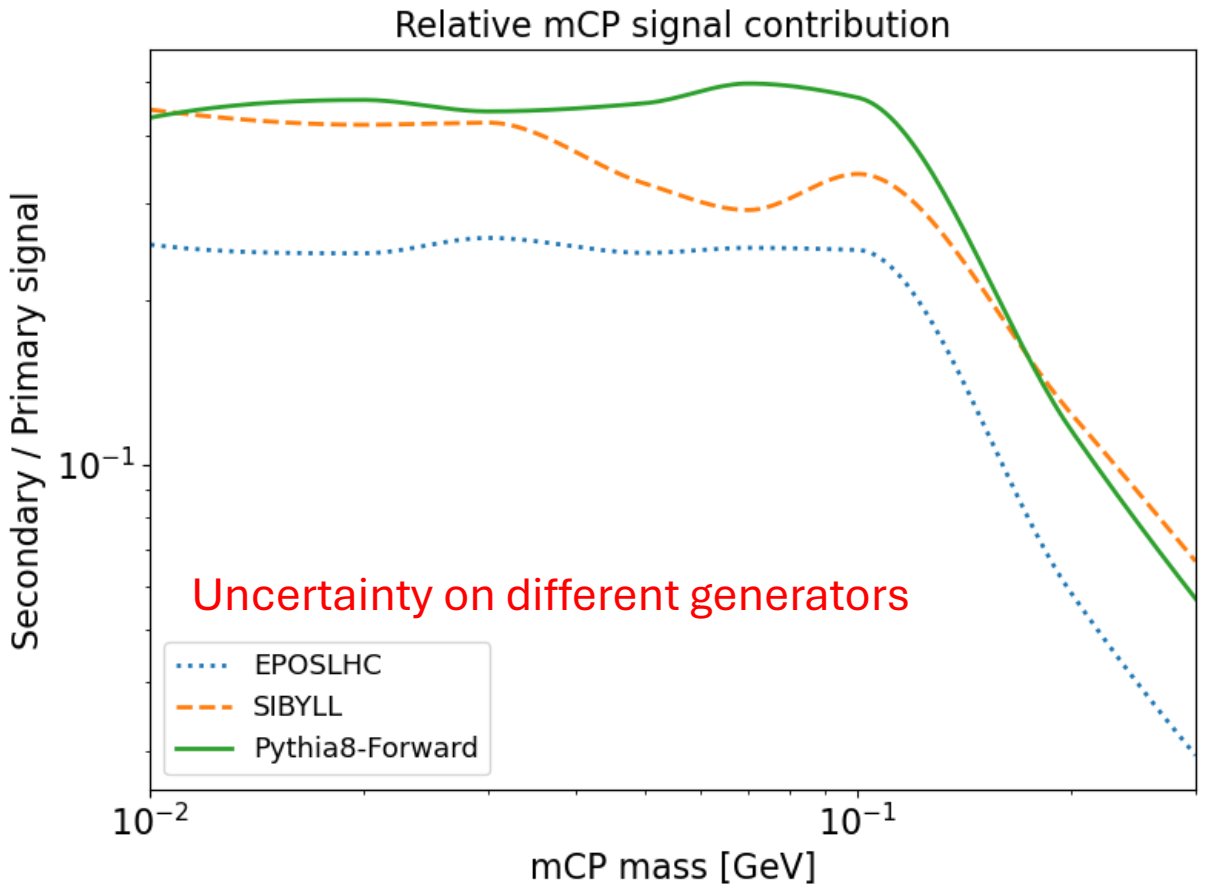
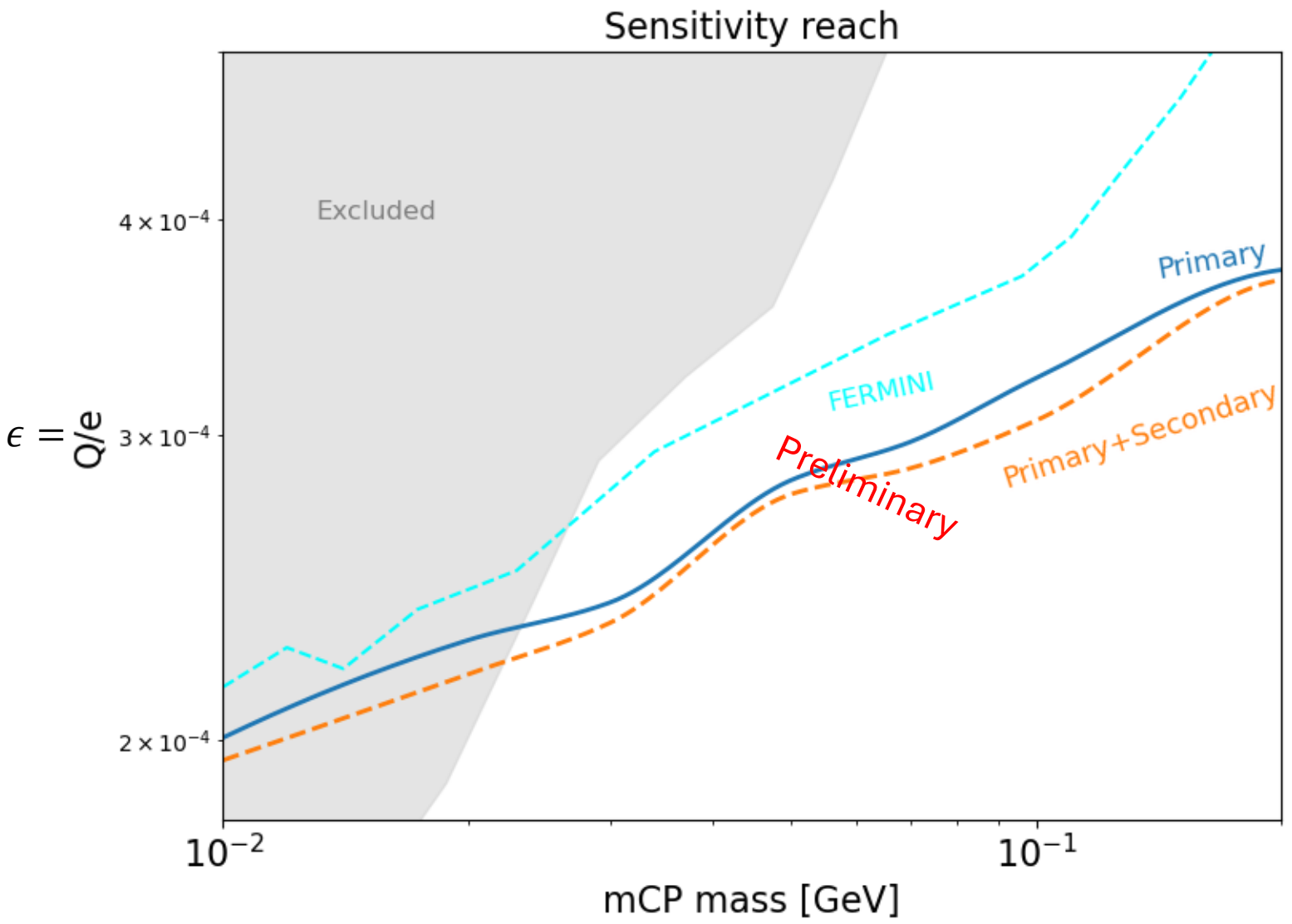
- The uncertainty between different generators also need to be counted.



Millicharged Particle Sensitivity



Implications for FORMOSA (and next steps)

Implications

- There is a TeV neutron beam-dump around FPF.
- Improve mCP flux at FORMOSA around 20%~40%
- Motivates careful treatment of downstream “secondary production” sites
- Potentially relevant for other far-forward dark-sector searches (not only mCP)

Next steps

- There will be also many high-energy photon produced from pp collision. Photon will directly induce EM shower and produce millicharged particles.
- Pile-up effect may also improve the hadron production
- We will public our showered mCP flux

Thanks!

Backup: absorber facts you can quote

Useful numbers for the audience Q&A

Quick facts

- TAS/TAXS: copper absorber ~19 m from IP
- TAN: neutral absorber ~140 m from IP; inner absorber is copper with steel + marble shielding
- TAN flange-to-flange length ~4.9 m; max width ~1.15 m
- Total length between IP and Formosa is roughly ~400 m