

New constraints on HNLs from the BEBC beam dump experiment

Giacomo Marocco
University of Oxford

FITs 2022

Introduction

- How do we find new, light, weakly coupled states?

↳ Go to intensity frontier!

- What can upcoming forward physics experiments (@ CERN, FNAL, etc.) discover?

↳ Look for HNLs (+ other dark states) at past beam dump experiments e.g. BEBC

Heavy Neutral Leptons

- New SM singlet N

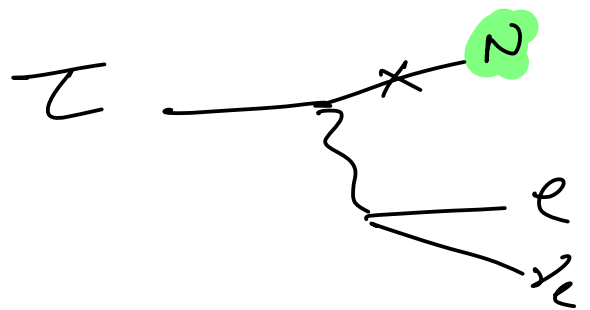
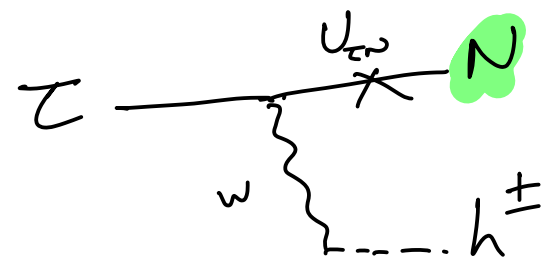
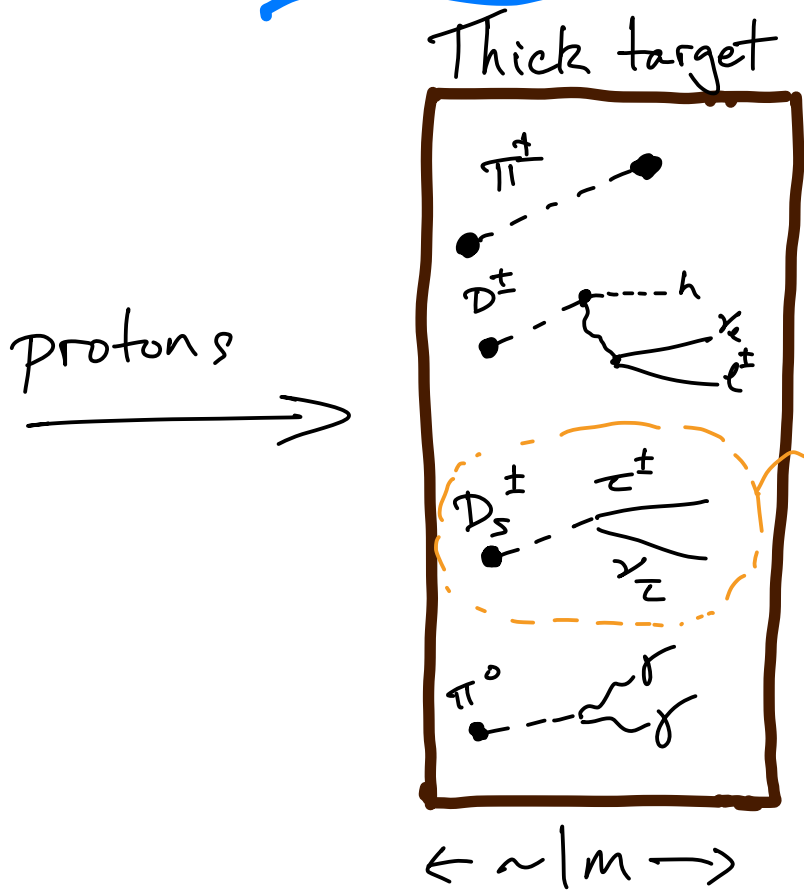
↳ One of few SM - BSM renormalisable

portals: $(L \tilde{\Phi}) N$ — neutrino masses?

- Mixing with 3rd generation least constrained

$$\nu_{\tau} = \sum_{i=1}^3 U_{\tau i} \nu_i + U_{\tau N} N$$

Beam dump production



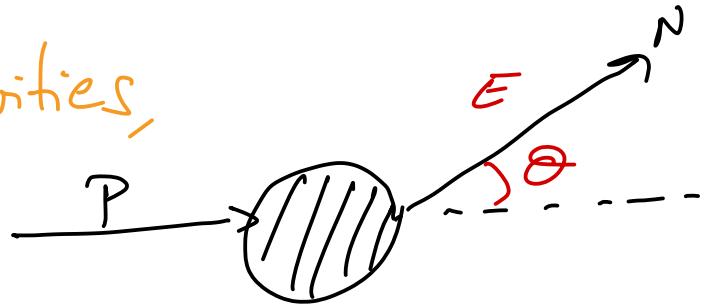
[1805.08567; 2107.14685]

HNL Spectrum

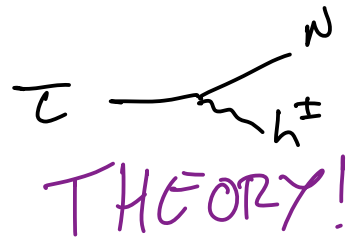
- To calculate sensitivities,

need

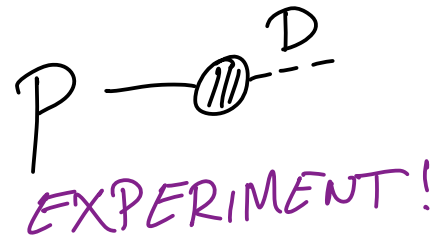
$$\frac{d^2 \sigma_s}{dE d\theta}$$



↳ Decay distributions →



↳ Parent distributions →



- Reduce systematic uncertainty in total Λ flux

inferred from
measured
 ν_e flux

$$\frac{dN_p}{dN_{\nu_e}} = \frac{\sigma(pX \rightarrow \nu X)}{\sigma(pX \rightarrow \nu_e X)}$$

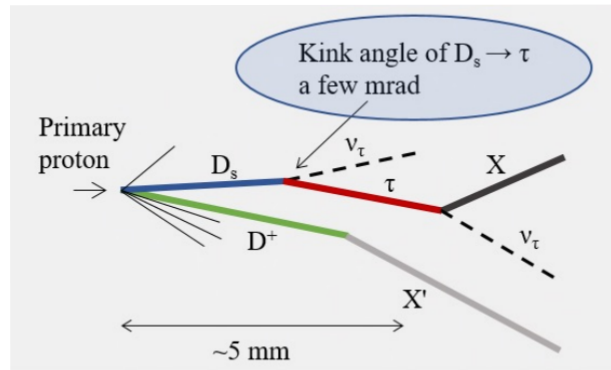
- Experimentally fit parent D distribution

$$\frac{d^2 \sigma_D}{dP_T^2 dx_F} \sim e^{-b P_T^2} (1 - |x_F|)^n$$

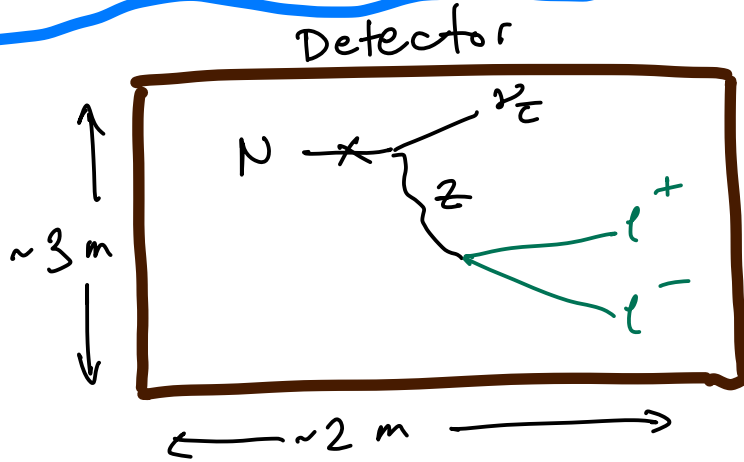
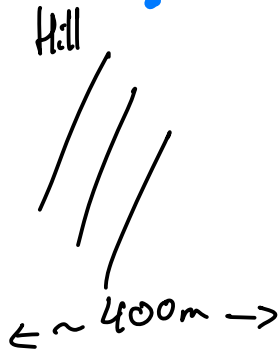
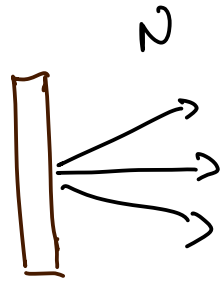
b, n for $pCu \rightarrow D_s$

assumed same as for $pCu \rightarrow D^\pm$.

NA65
DsTau



HNL detection



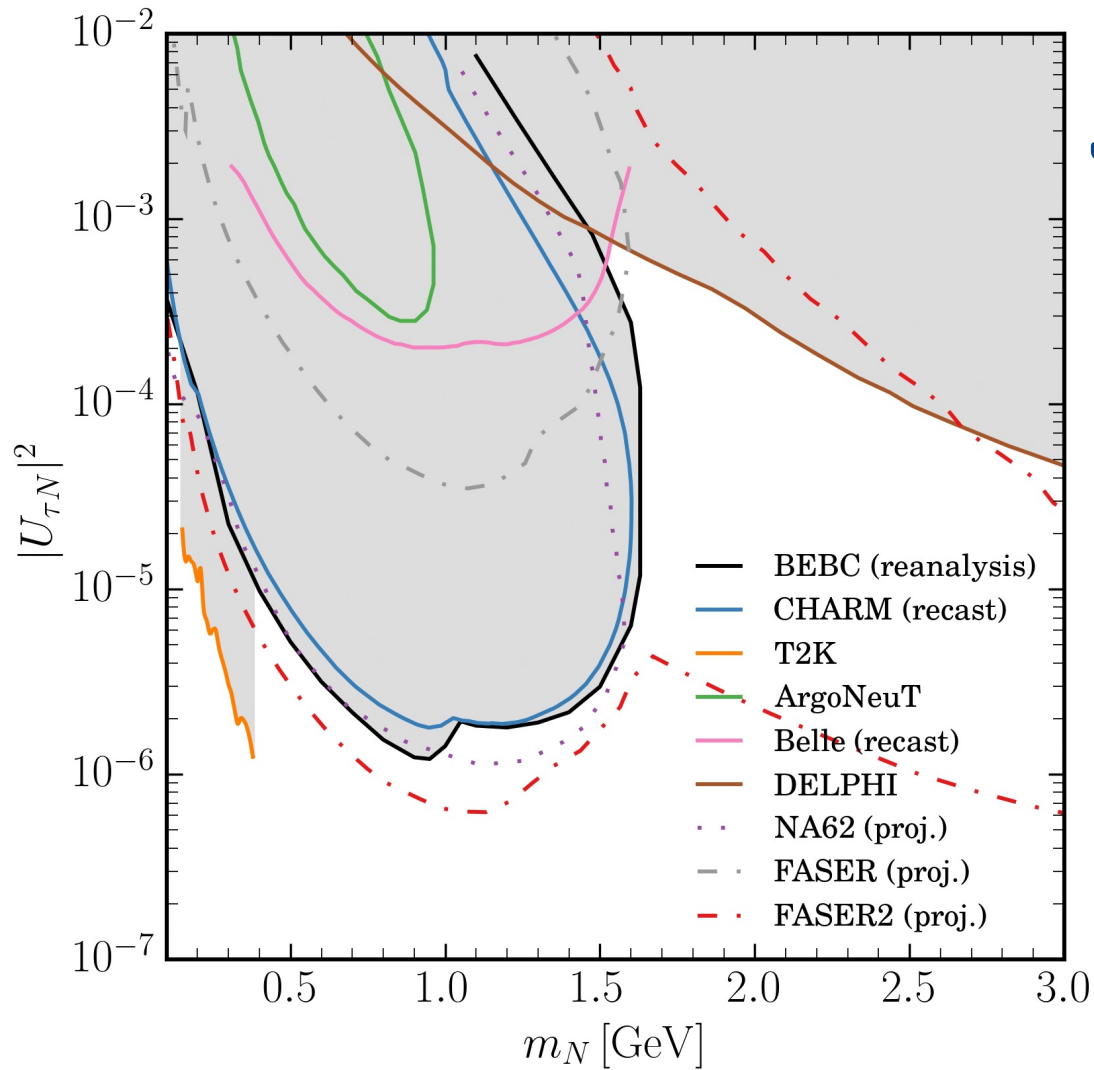
$$P_{\text{det}} = P_{\text{survival}} \cdot E_{\text{geom}} \cdot P_{\text{decay}} \cdot \Sigma_{\text{det}}$$

very model-dependent — new z' ?
decay to dark states?

Big European Bubble Chamber CERN SPS beam dump (1982)

- 11.5 tonnes of H_2-Ne mix
- 2.72×10^{18} POT @400 GeV on Cu
- On-axis (406m from dump)
- Dedicated new physics analyses — excellent background rejection + detector efficiencies

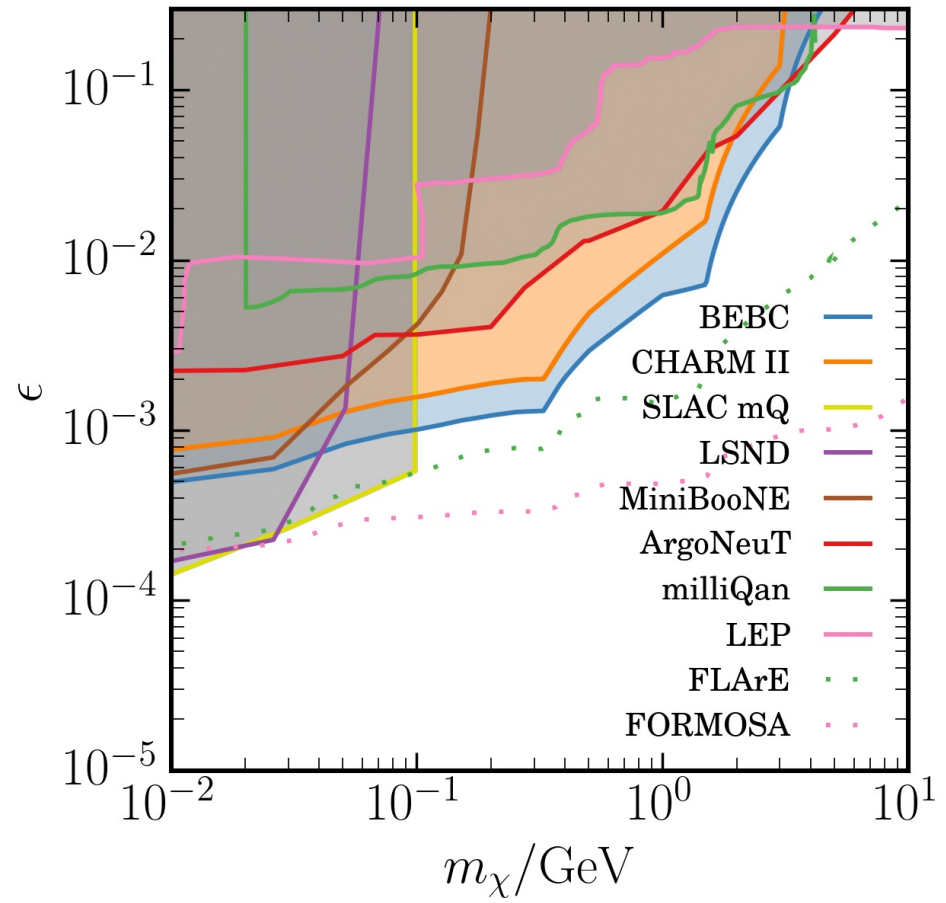




[2208.00416]
w/ Ryan Barouki
+ Subir Sarkar

Other FIPs

e.g.
Millicharged
particles
 $Q = \epsilon e$
[2011.08153]



Conclusions

- Leading bounds on HNLs (+ other FIPs)
- Need new experiments (NA65! FASER2!) to thoroughly probe open $U_{\tau\nu}$ - m_{ν} space.