The SHiP experiment at the CERN SPS

Richard Brenner- Uppsala University

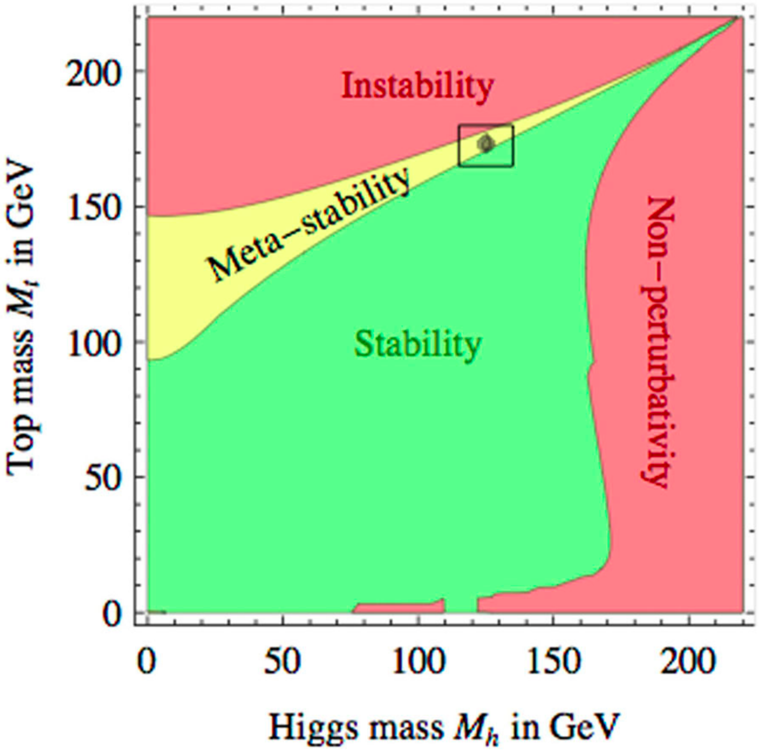
Why (to) Search for Hidden Particles?

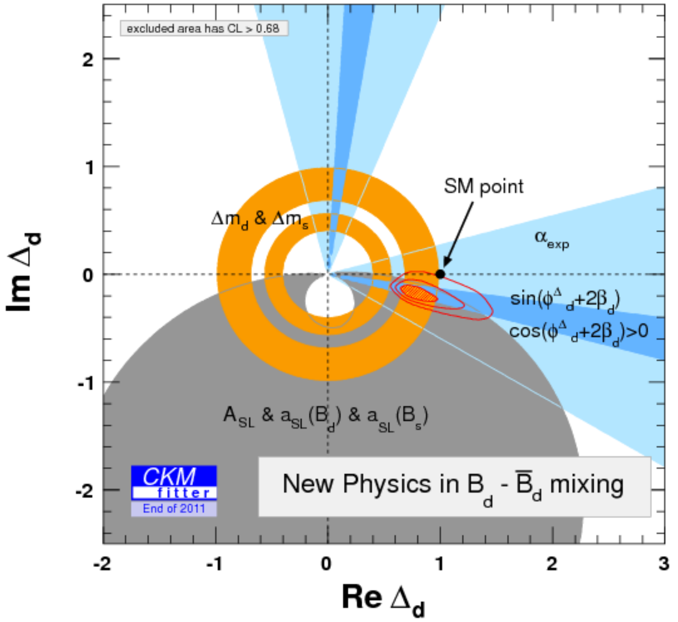
- Higgs boson found and consistent with SM Higgs (so far)
- Higgs mass located in a meta-stability wedge:

  →Vacuum might be stable or has τ >> τ (universe)

  → SM may work successfully up to the Planck scale

  i.e. no need for a new mass scale.
- Flavor Physics consistent with SM predictions (so far).
- No new particles found at LHC (so far).



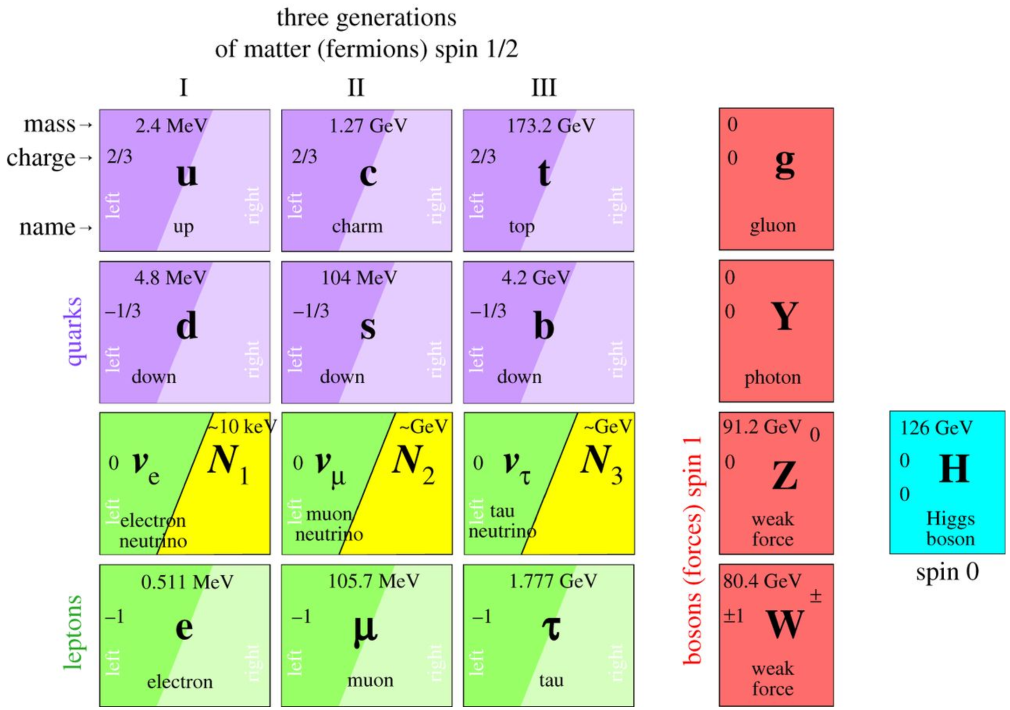


Shortcomings in SM

- matter anti-matter asymmetry in universe
- neutrino mixing → masses
- Non-baryonic dark matter

How many new particles are needed to fix the above?

vMSM: T. Asaka, M. Shaposhnikov PL B620 (2005) 17



- Adding three right-handed Majorana Heavy Neutral Leptons (HNL): N_1 , N_2 and N_3

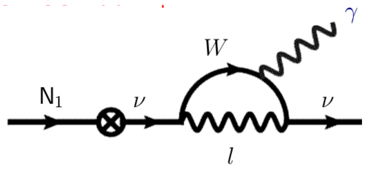
- N_1 can provide dark matter candidate

- $N_{2,3}$ can provide neutrino masses via Seesaw mechanism

- $N_{2,3}$ can induce leptogenesis → baryogenesis

SHiP

N_1 : the Dark Matter candidate

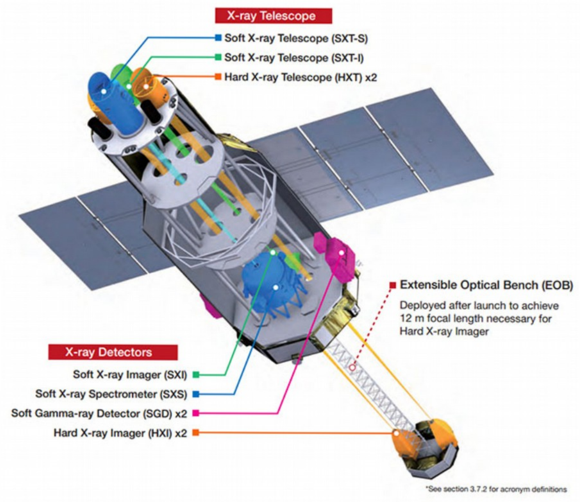


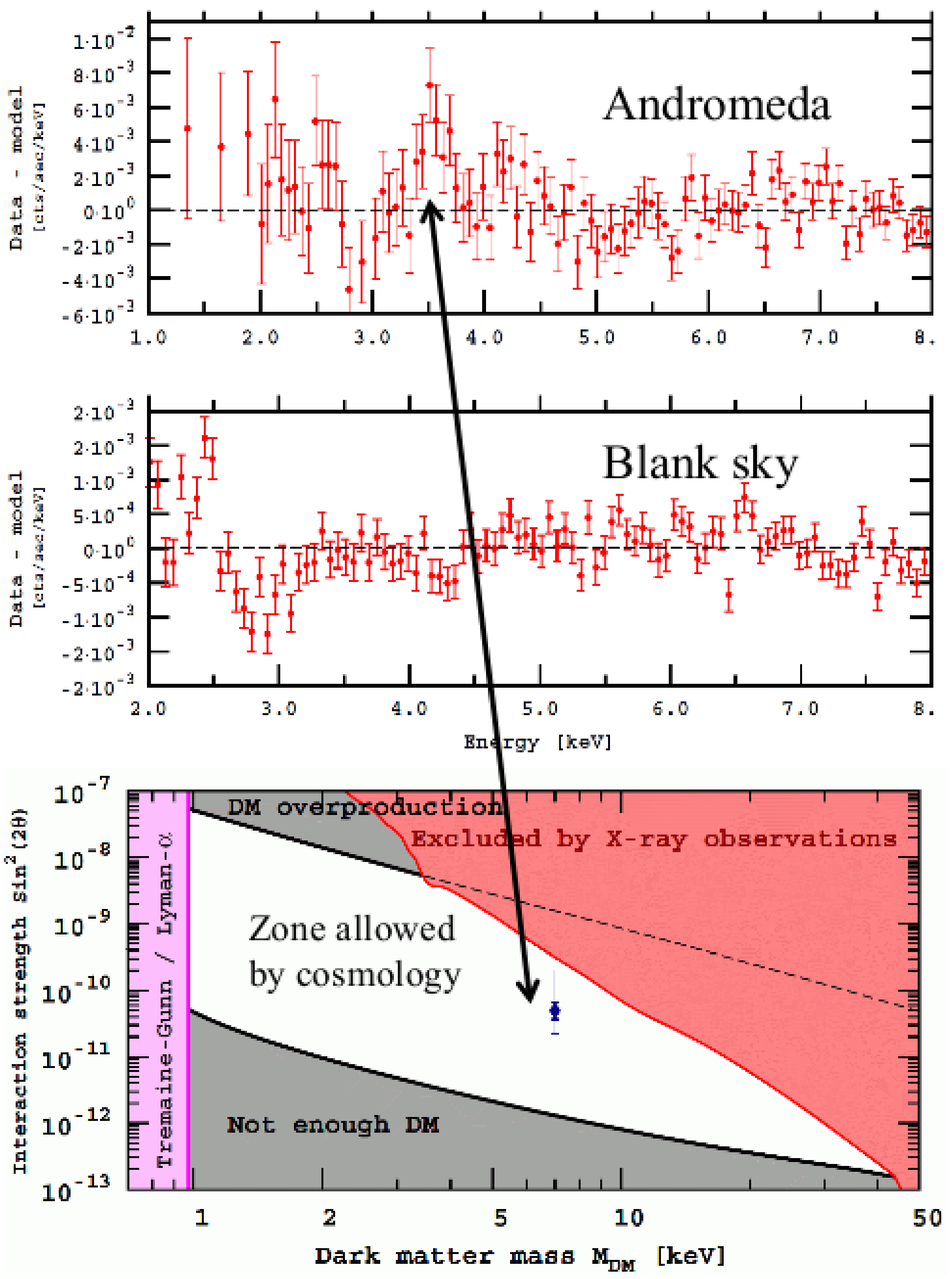
Signature: $N_1 \to \nu\, \gamma$

3.5 keV photon line originally observed in several galaxy clusters and Andromeda (M31) at 4–5σ (Bulbul et al1402.2301, Boyarsky et al 1402.4119).

Many papers on arXiv

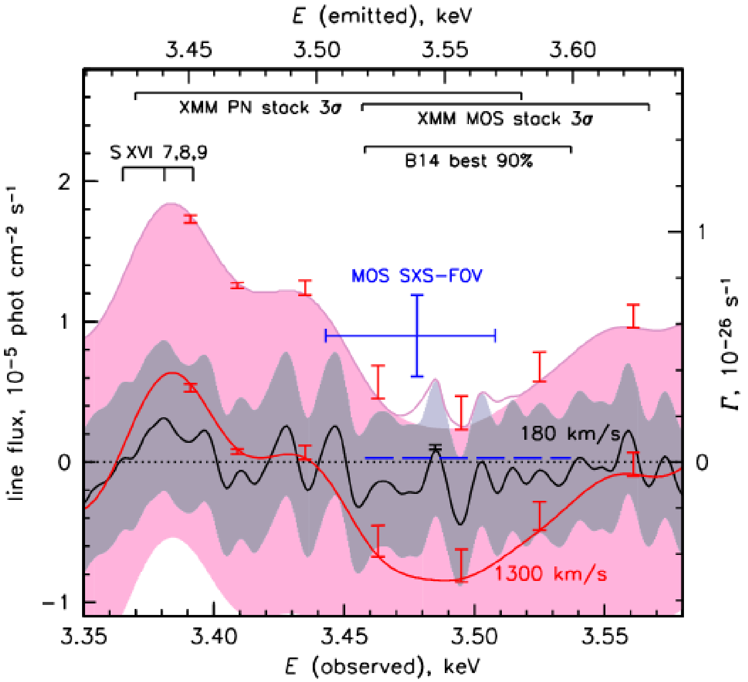
Expected to improve understanding with the Hitomi satellite equipped with a superb Soft X-Ray Spectrometer





Hitomi

- Hitomi (Astro-H) launched February 17, lost March 26, 2016;
- Hitomi can distinguish between atomic line broadening (thermal velocities ~ 10^2 km/sec) and decaying dark matter line broadening (virial velocity ~ 10^3 km/sec)
- Before its loss, observed Perseus cluster core in calibration phase



- Hitomi constraints on the 3.5 keV line in the Perseus galaxy cluster (arXiv:1607.07420)
- Bounds much weaker for a broad (dark matter) line → not at tension with previous detections
- "The inconsistency with Hitomi is at a 99% significance for a broad dark-matter line and at 99.7% for a narrow line from the gas."

Next X-ray missions

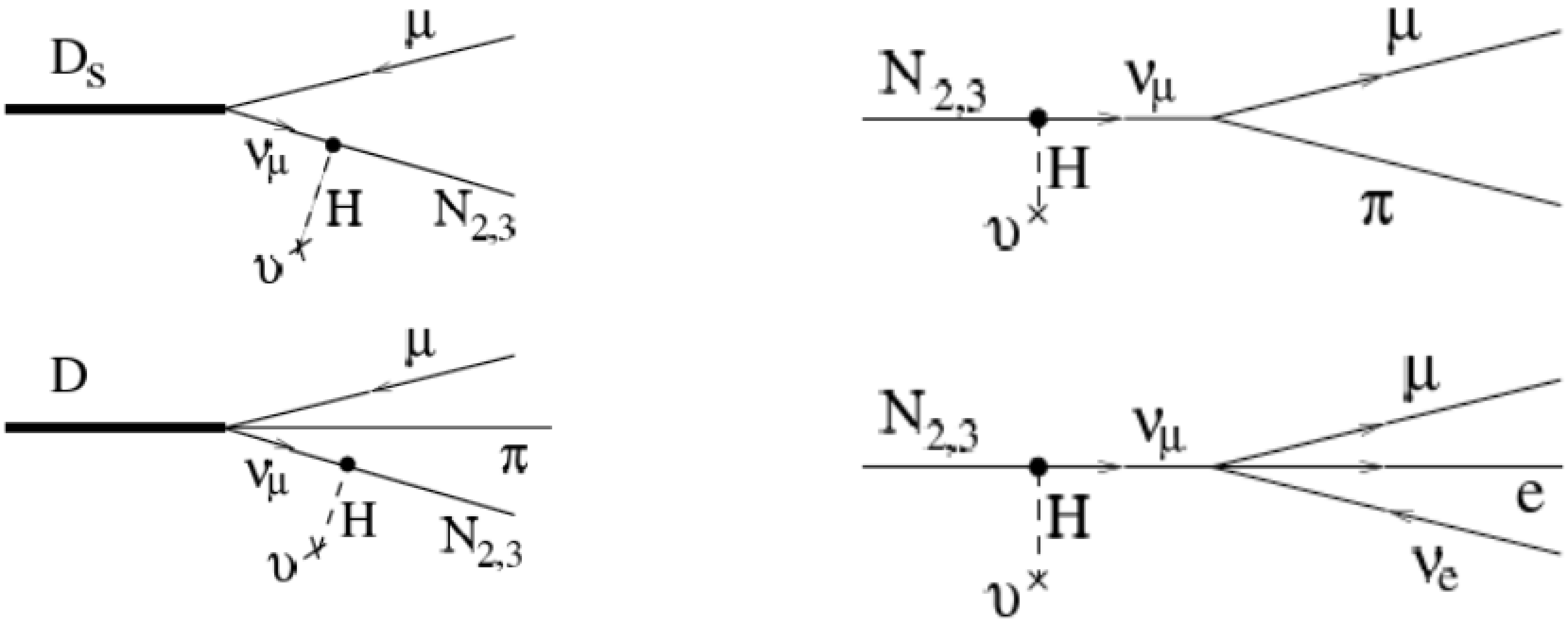
- Micro-X sounding rocket experiment (2019+) – large field-of-view, large energy resolution, very small exposure – will probe Galacticc Center+Bulge region (ApJ’15 [1506.05519]);
- Hitomi-2 – planned to launch by NASA during 2020-2021;
- Athena – large ESA mission (2028+), very large resolution and collecting area (each 10×XMM-Newton) – will probe individual DM haloes (e.g. galaxy clusters).

$N_{2,3}$ production and decay

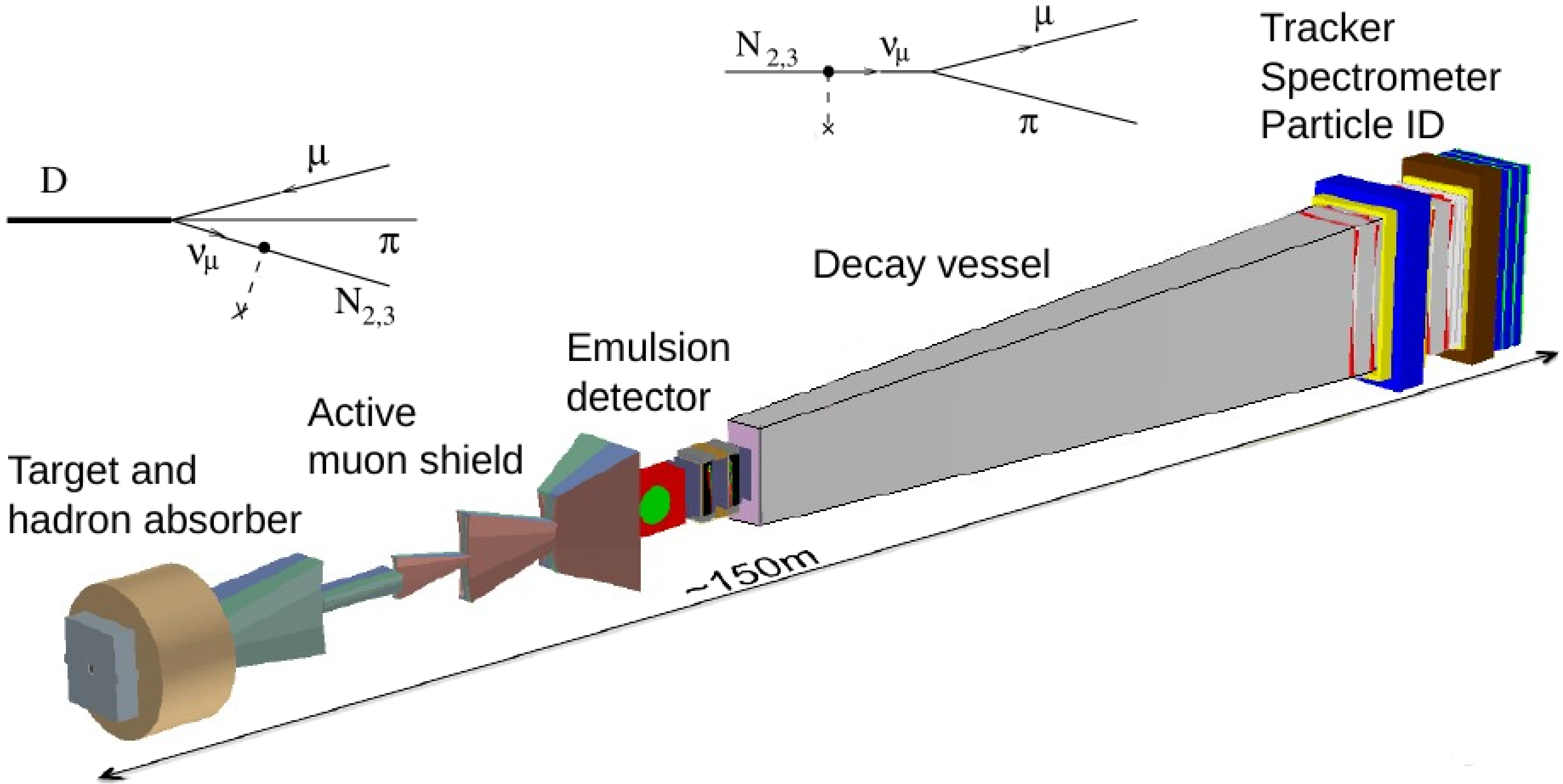
- $N_{2,3}$ mix with active neutrinos:

- produced in semileptonic decays of K, D, B (low mass) mesons and from Z decays (high mass)

- Decays in $N \to \mu/e\ \pi$, μ/e rho, $\nu\ \mu\ e$, etc.)



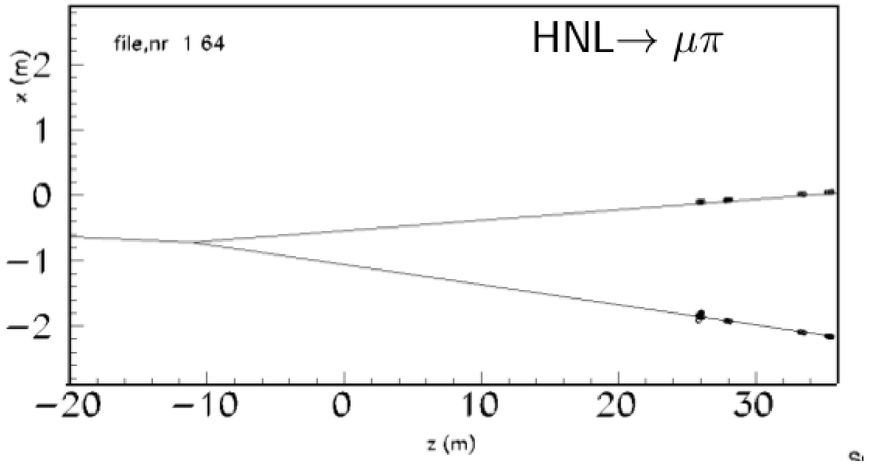
The SHIP experiment



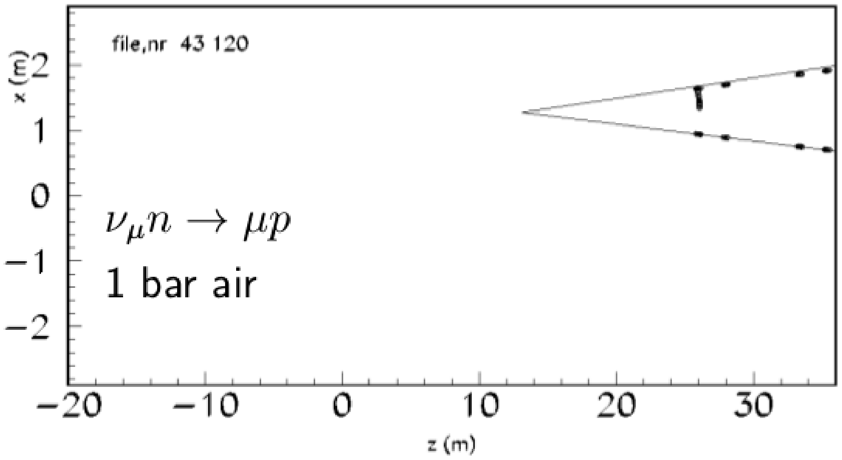
400 GeV p-beam:
- 2 × 10 20 pot in 5 years
- Peak power: 2.6 MW

HNL detection

- 5 × 10 m 2 straw chambers
- Low-field magnet: σ(M HNL) ≈ 15 MeV
- γ/e/π/μ: Calorimetry+μ-detector



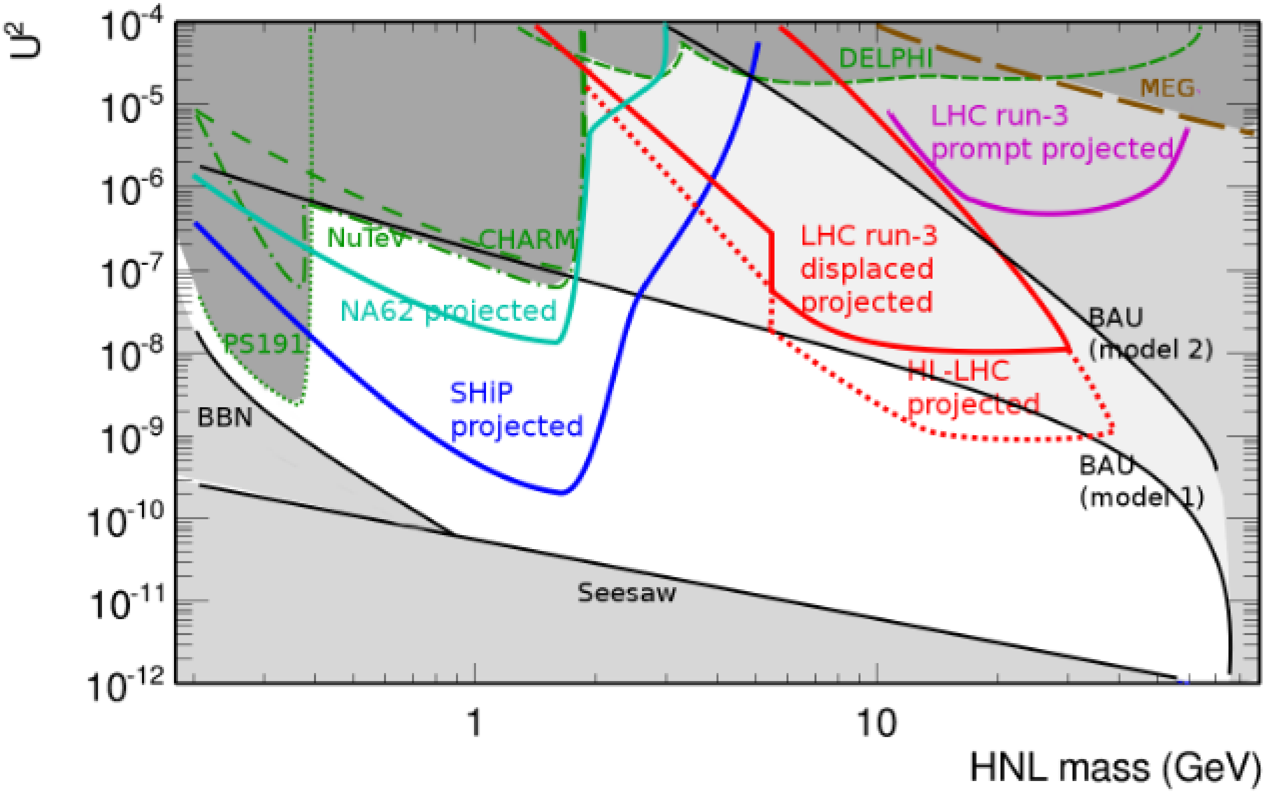
Signal



Background

- Low pressure
- Sourounding scintillatords
- 100 ps timimng

Sensitivity



P. Mermod: https://arxiv.org/pdf/1712.01768.pdf

SHIP roadmap

SHiP Collaboration:

- 49 institutes (UU, SU)
- 17 countries (Sweden)
- ~ 200 members

- 2018: SHiP Comprehensive Design Reports

– Optimized SHiP detector. R&D on crucial elements.

– New background studies, new (improved!) sensitivities.

- 2019-2020: European Strategy Meeting → SHiP Approval….
- 2026: First data taking.