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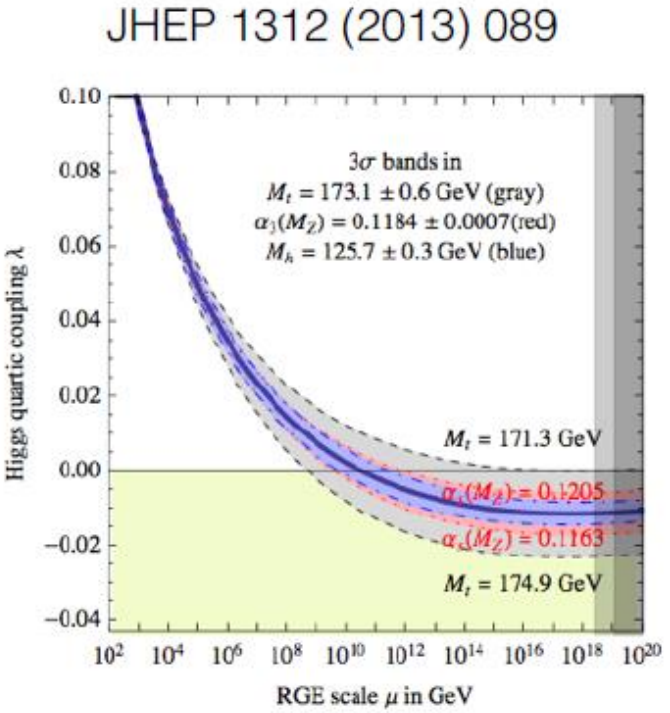
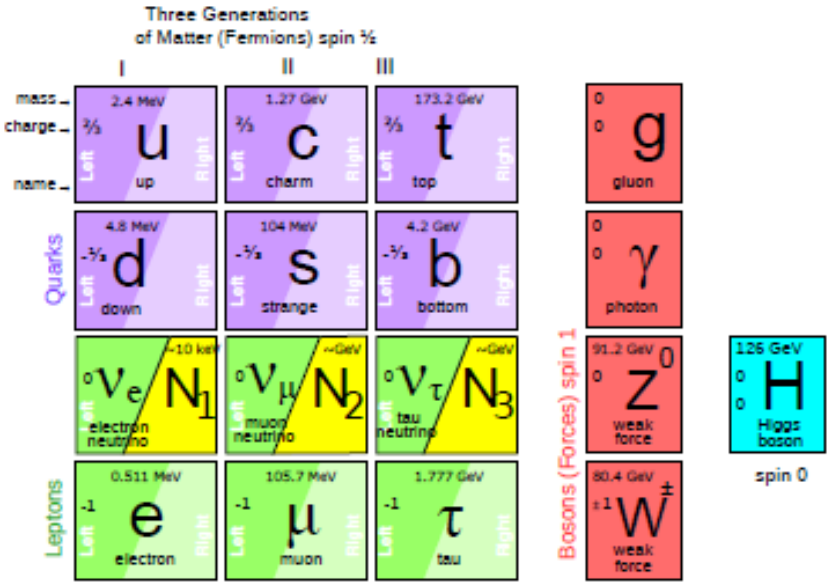
Physics motivations

- SM is very predictive and successful
  - No deviations observed so far
- With a mass of the Higgs boson of 125 GeV, SM may be a self-consistent weakly coupled **effective field theory** up to very high scales
- We know that cannot be the ultimate theory
  - Neutrino masses and oscillations
  - Baryon asymmetry of the Universe (BAU)
  - Dark Matter (bullet clusters, Planck etc)
  - Too boring…



Physics motivations

- Up to now NP searches were mostly oriented towards naturalness
- Now we are going at a 0.1% fine tuning, so we need to find a new paradigm
- Solutions of the three problems of the previous slide in one shot, w/o introducing new physics principles (SUSY or ED) or new energy scales:
  3 Majorana partners (RH and steriles) of active neutrinos (HNL = Heavy Neutral Leptons)



Shaposhnikov model

T. Asaka, M. Shaposhnikov / Physics Letters B 620 (2005) 17–26

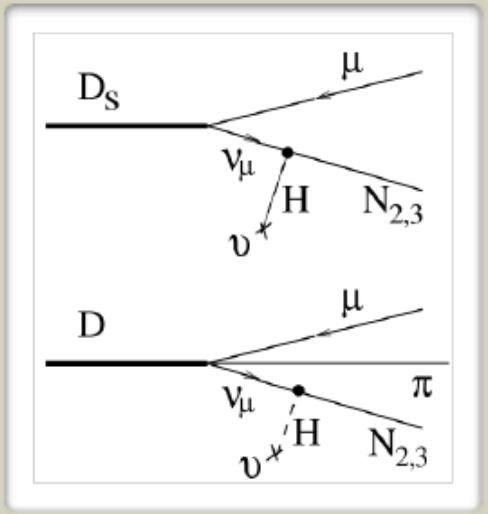
- Basically is the see-saw model with 3 RH fermions and require their mass to be of the order of the electroweak scale or below
- 18 new parameters w.r.t. SM (3 Majorana masses, 3 Yukawa couplings, 6 mixing angles and 6 CP-violating phases)
- N2 and N3 with masses >> eV and < EW scale
- N2 $\leftrightarrow$ N3 oscillations with CP violations induce baryon asymmetry via sphaleron generation (non-perturbative process which convert baryons to leptons and vice-versa)
- N1 could be at the level of O(keV), in the ballpark of wark dark matter.

$N_{2,3}$: Production and Decay

- Mass(N_2) ~ Mass(N_3) ~ few GeV
- Weak mixing with active neutrino
  - → very long lifetimes wrt SM particles >10 μs
  - → flight length ~ km

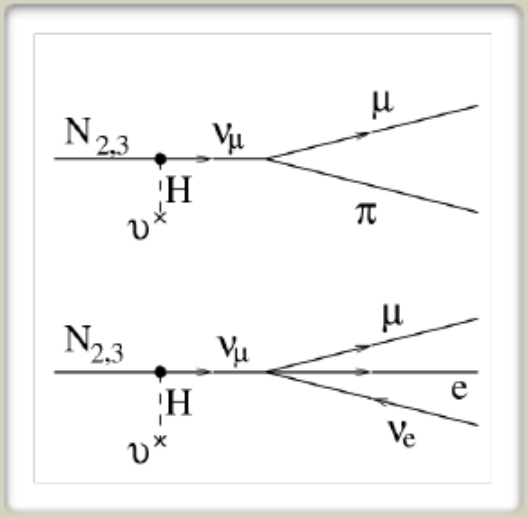
PRODUCTION

- Mixing with active neutrino
- Semi-leptonic decay



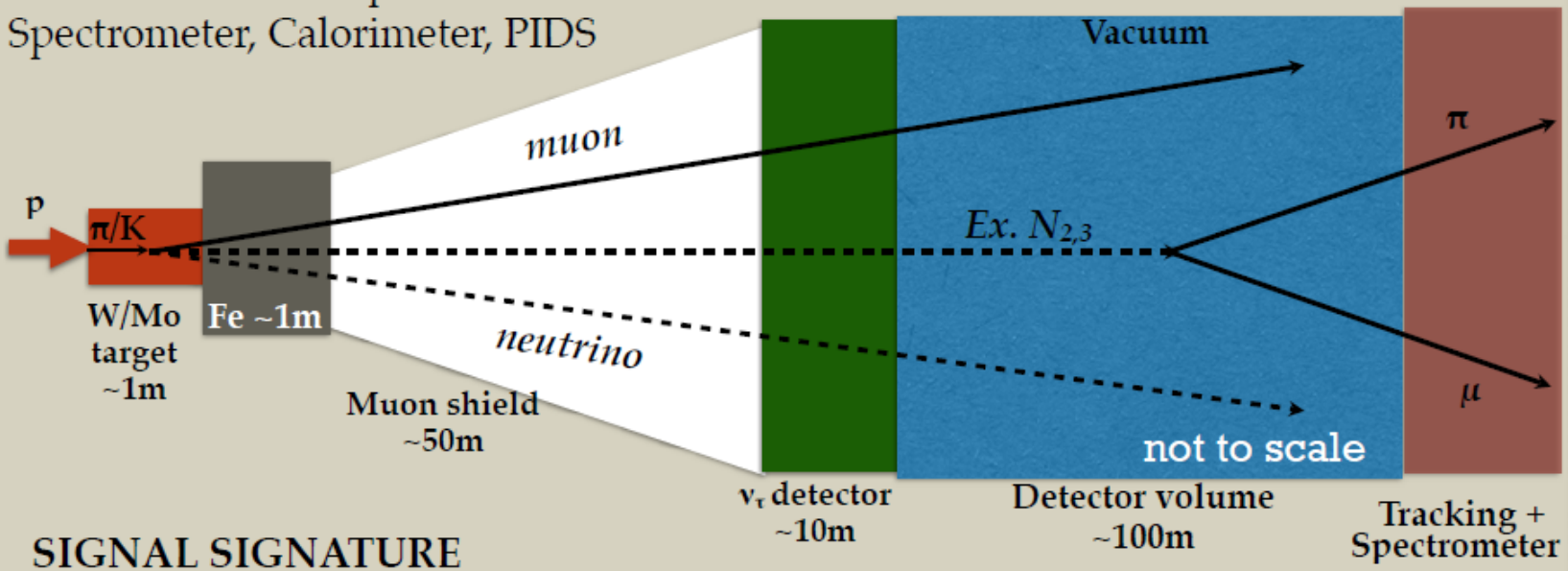
DECAY

- Br(N →μ / e π) ~ 0.1 - 50 %
- Br(N →μ / e ϱ) ~ 0.5 - 20%
- Br(N →νμe) ~ 1 - 10%



REQUIREMENTS

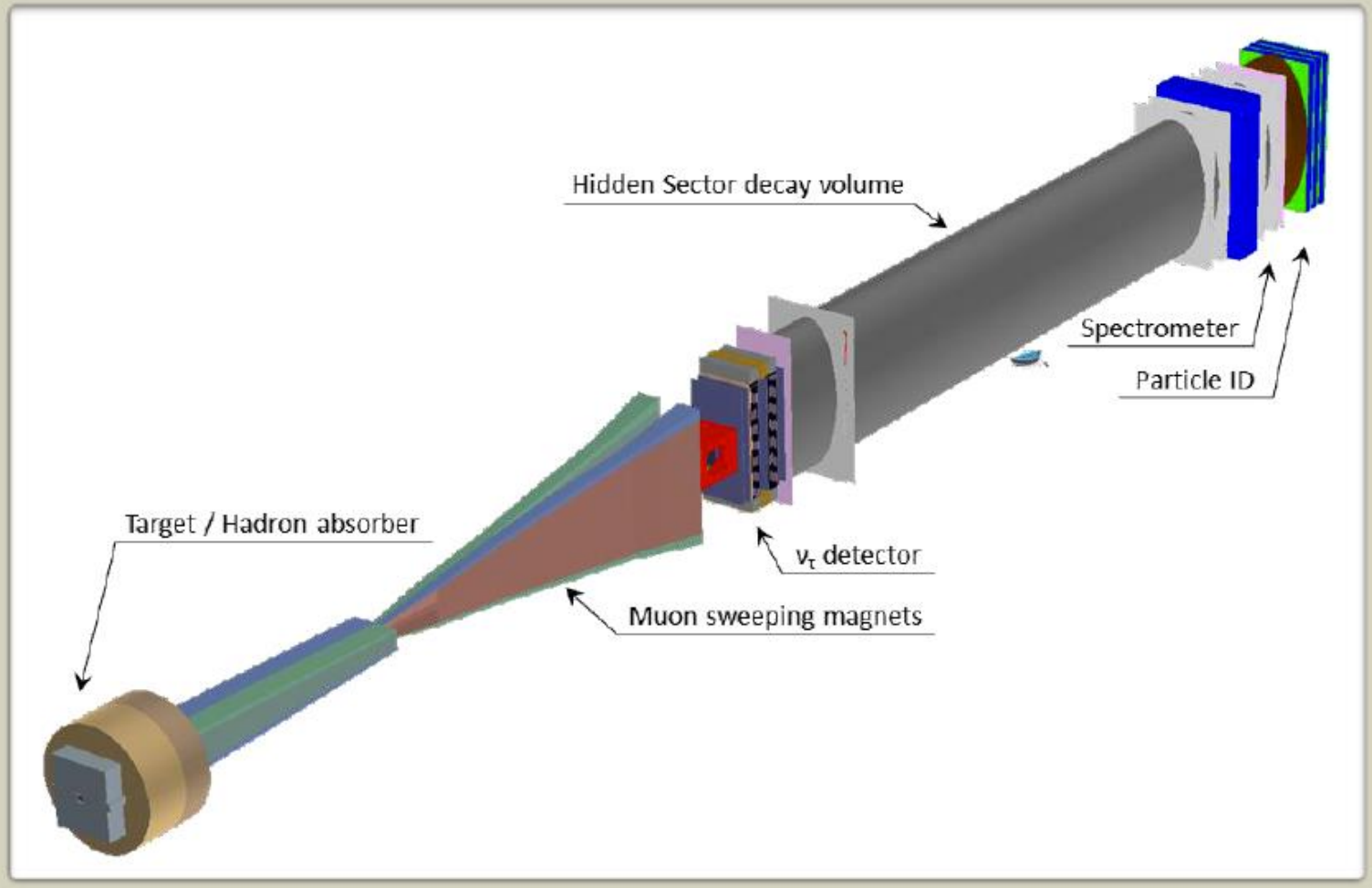
- High intensity beam dump experiment ⇒ K, D, B mesons
- Long-lived, weakly interacting particles require:
  - large decay volume
  - shielded from SM particles
- Spectrometer, Calorimeter, PIDS



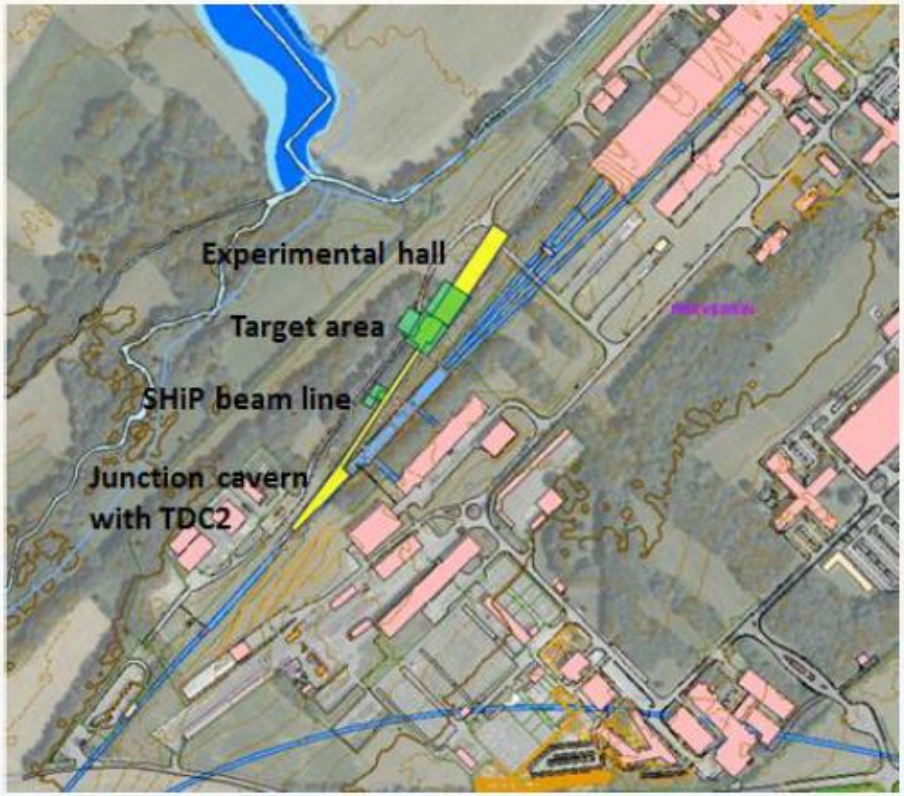
SIGNAL SIGNATURE

- charged tracks forming an isolated vertex inside the fiducial volume acceptance
- Candidate momentum pointing back to the target
- "silent" VETO detectors

Detector Layout

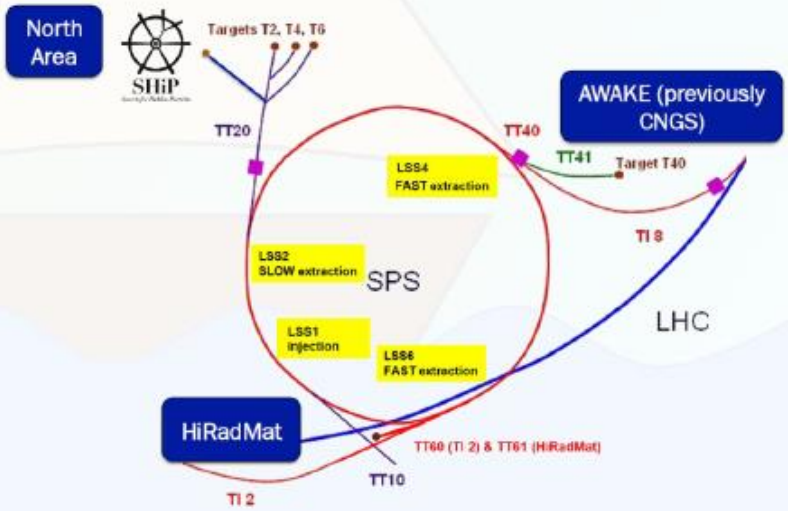


The SHiP facility at the SPS



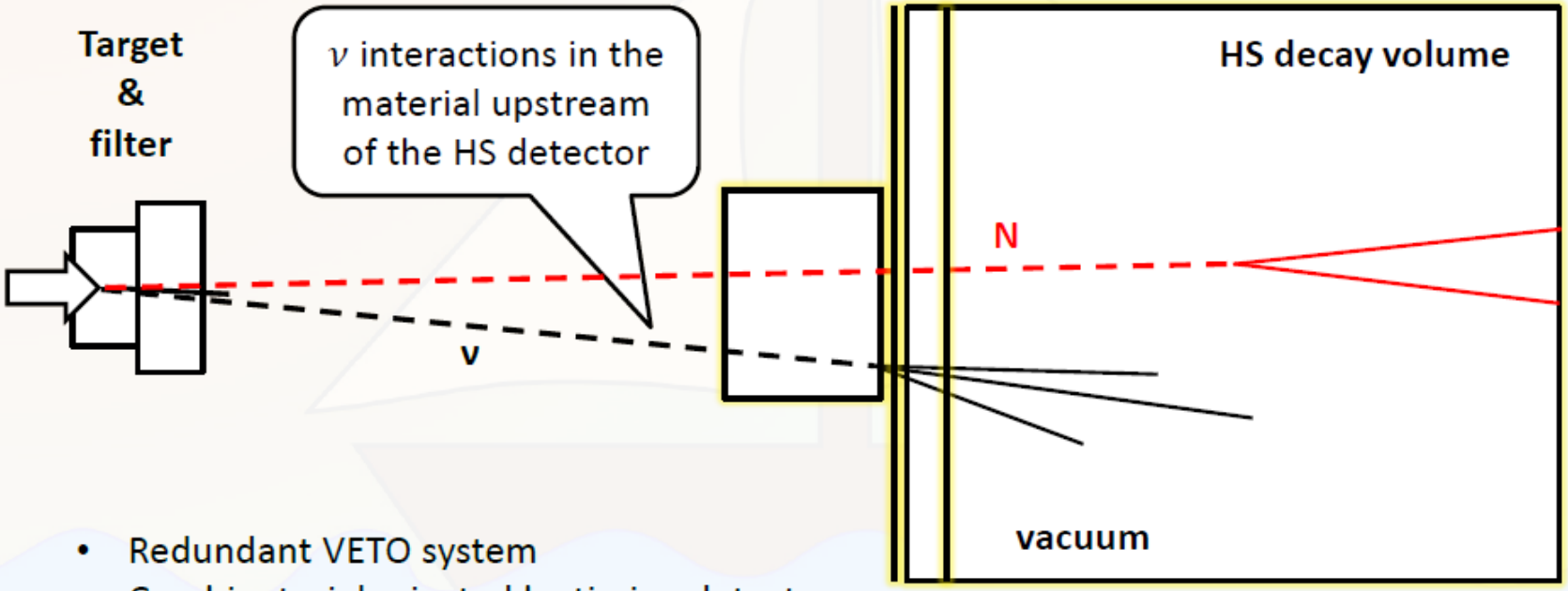
Proposed implementation is based on minimal modification to the SPS complex.

Share transfer line and slow extraction mode with existing facilities.



- 235 experimentalists from 45 institutes and 15 countries + CERN
- Physics Proposal signed by 80 theorists

Background rejection

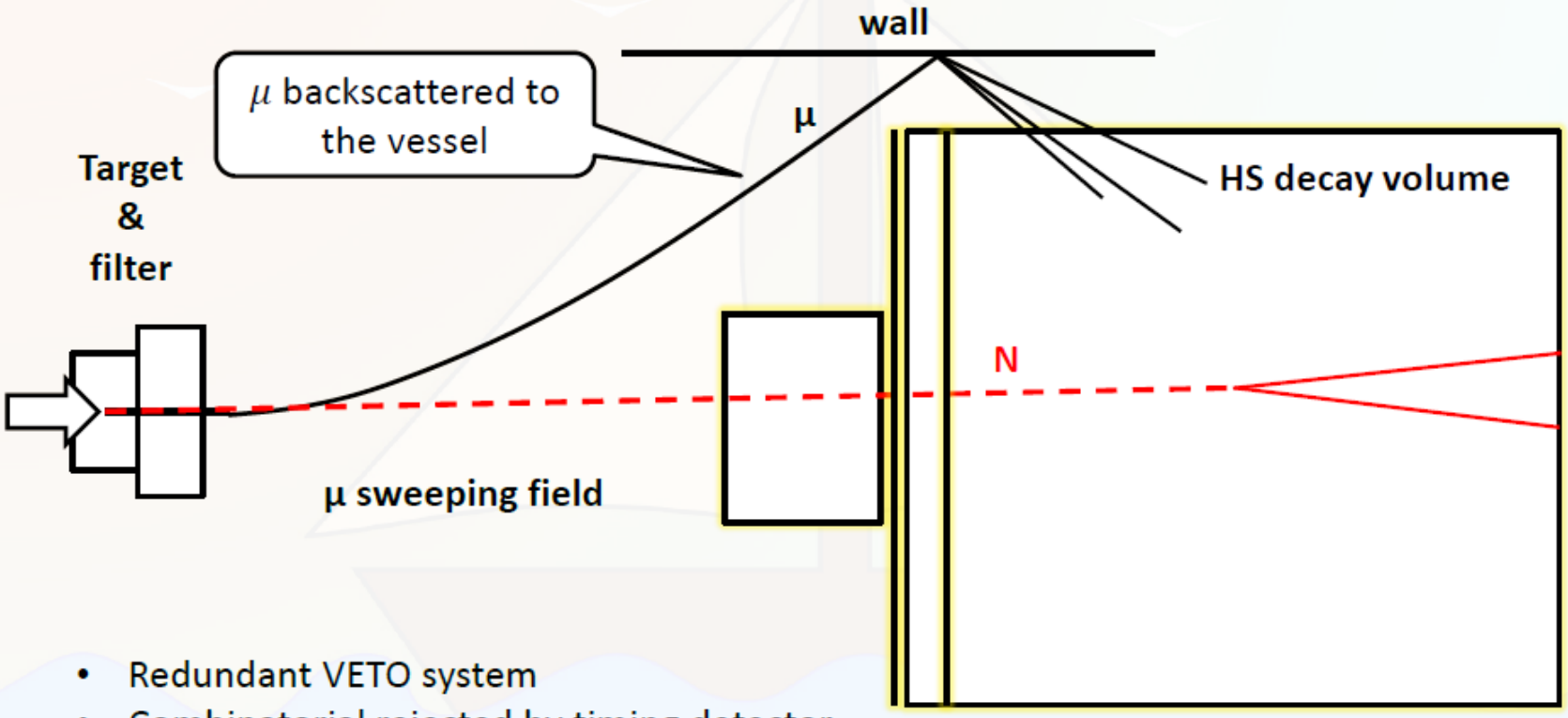


- Redundant VETO system
- Combinatorial rejected by timing detector
- Impact parameter to the target
- 75% selection efficiency for signal

After selections:

≤ 0.1 bkg / 5 y

Background rejection



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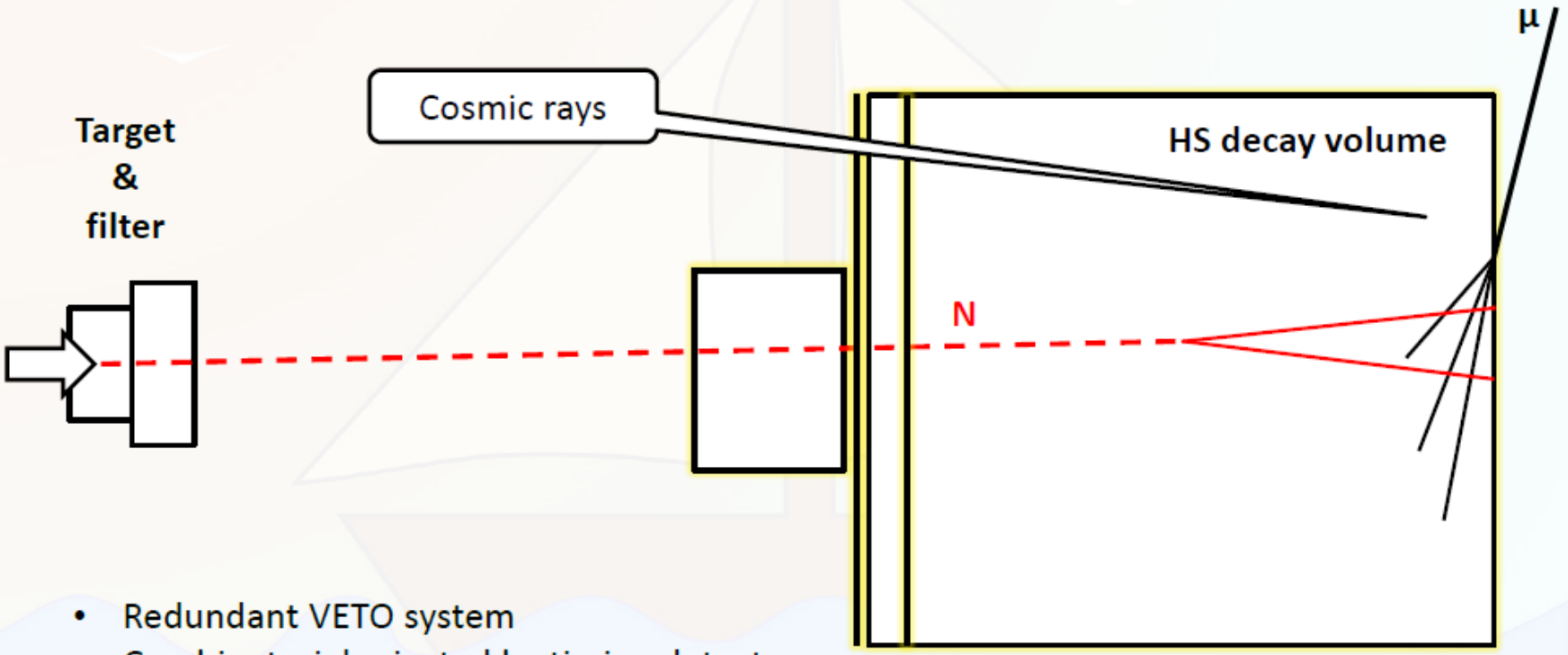

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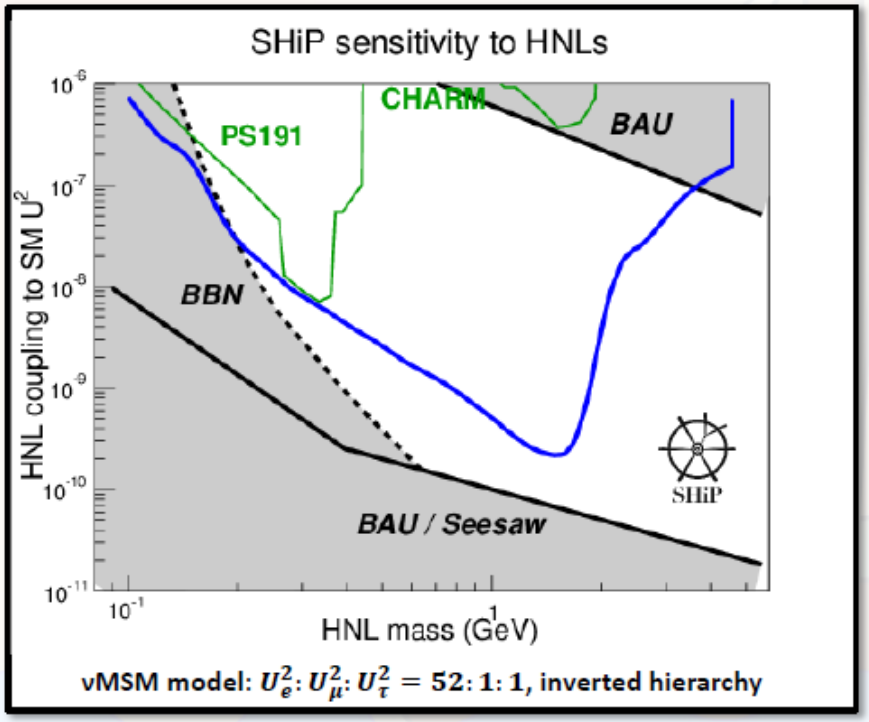
Sensitivity to HNLs



- Critically improving present limits in U^2
- Access masses up to m_B
- Probe region of special interest:
  - left open by cosmological observations (BBN)
  - explains ν masses (seesaw)
  - explains matter-antimatter asymmetry (BAU)
- Sensitivity in all U_e, U_μ, U_τ channels

- **but also much more…**

Theory bibliography:

- Gorbunov, Shaposhnikov hep-ph/0705.1729

Final remark

- How could you quantify the acceptable risk? Maybe a figure of merit could be:

Risk = Cost/(physics output)

- Here the cost is ~150 M€, and the potential physics output is extremely large
- So why not? Or there's something on the figure-of-merit formula which is missing?