

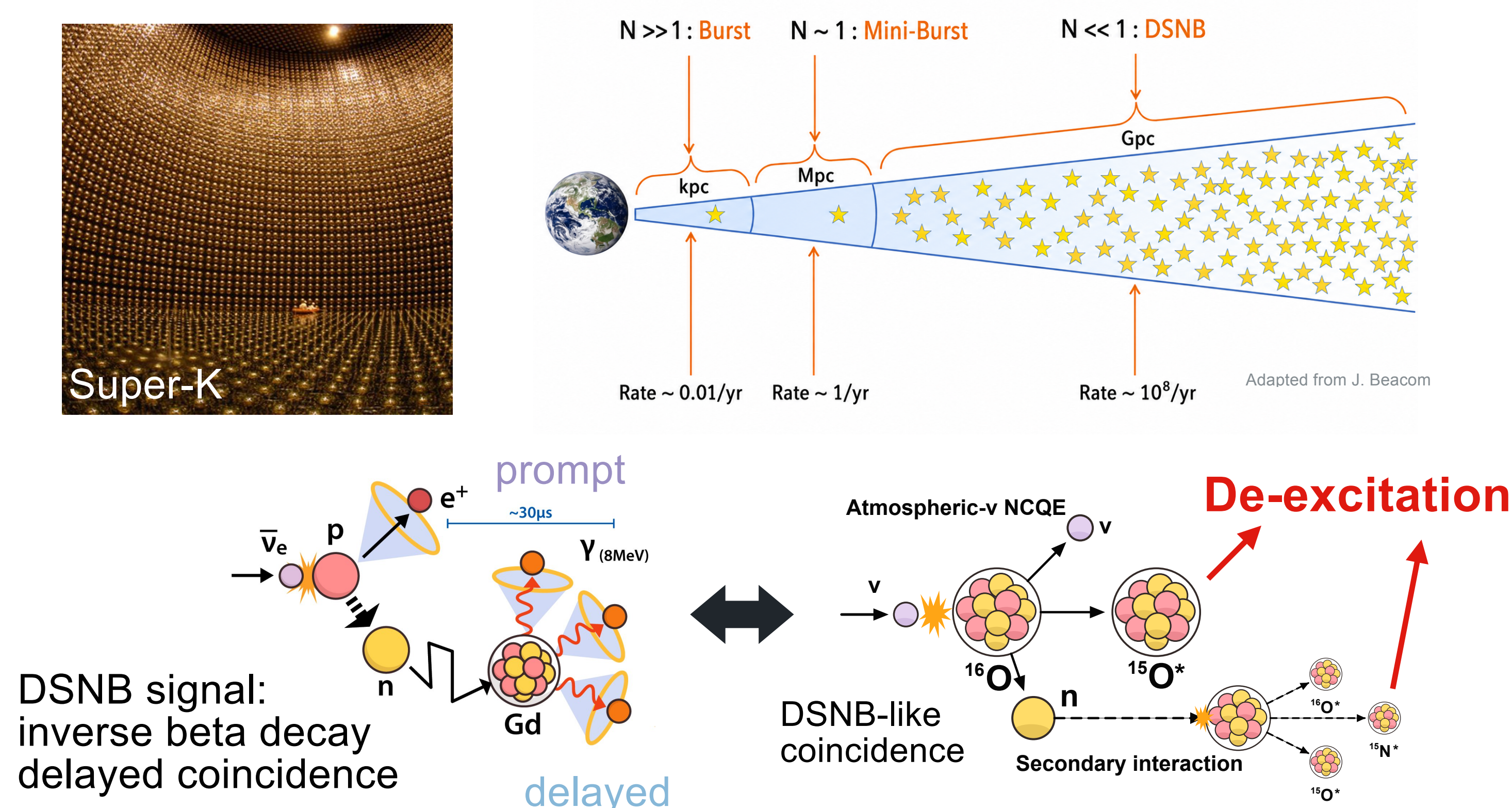
Toward Nuclear De-Excitation Measurements with Oxygen-Ion Beams for Improved DSNB Searches at Super-Kamiokande

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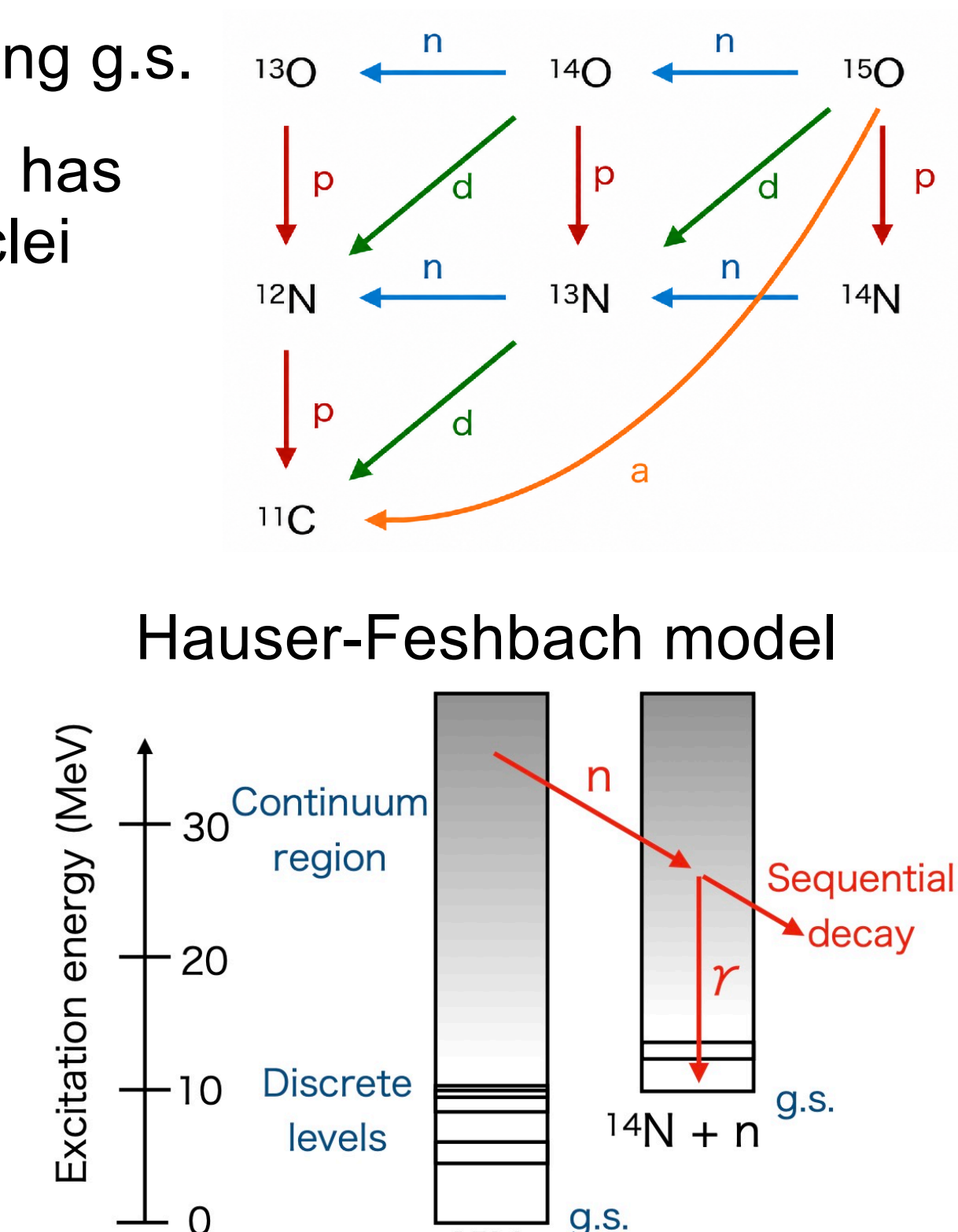
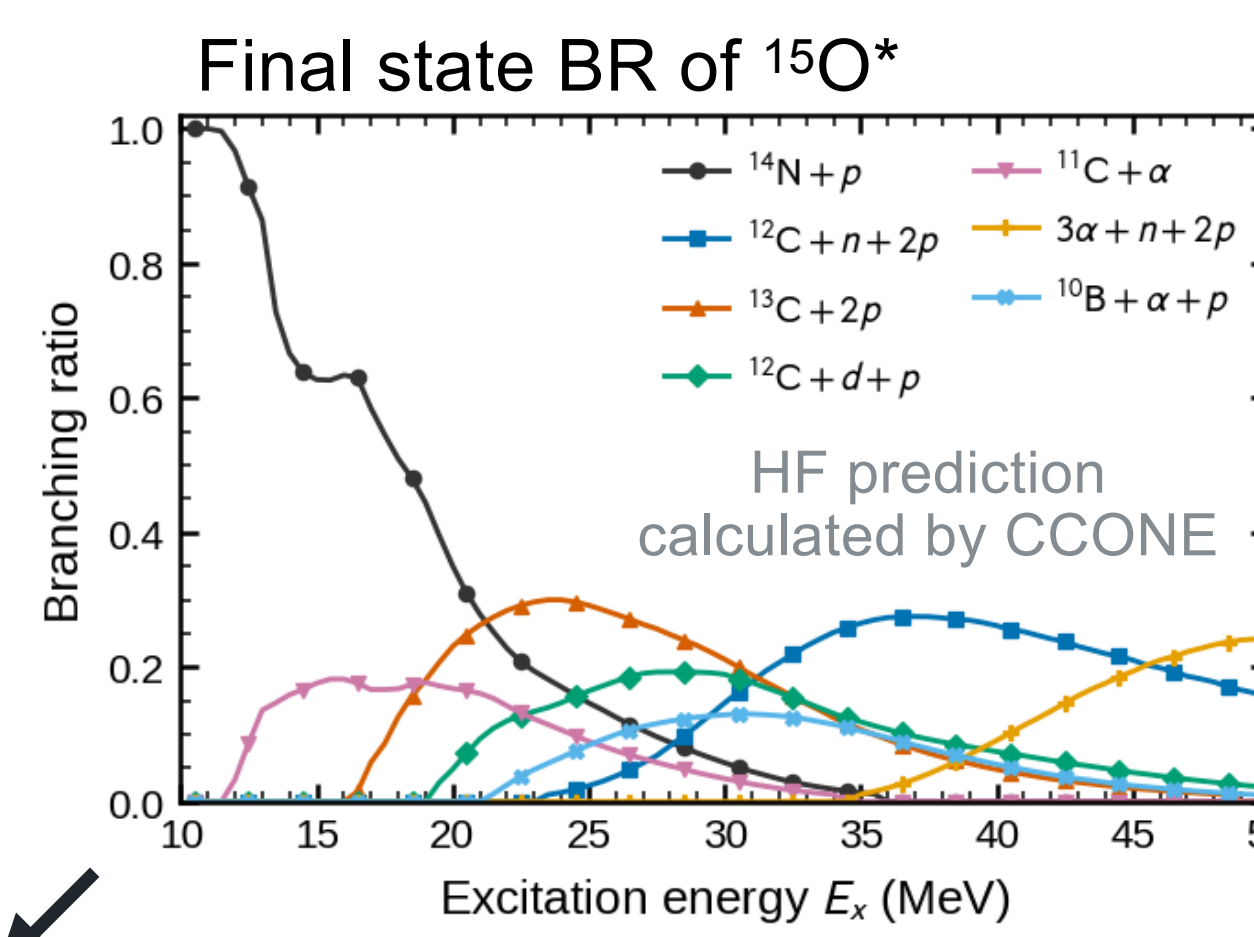


Diffuse Supernova Neutrino Background (DSNB)

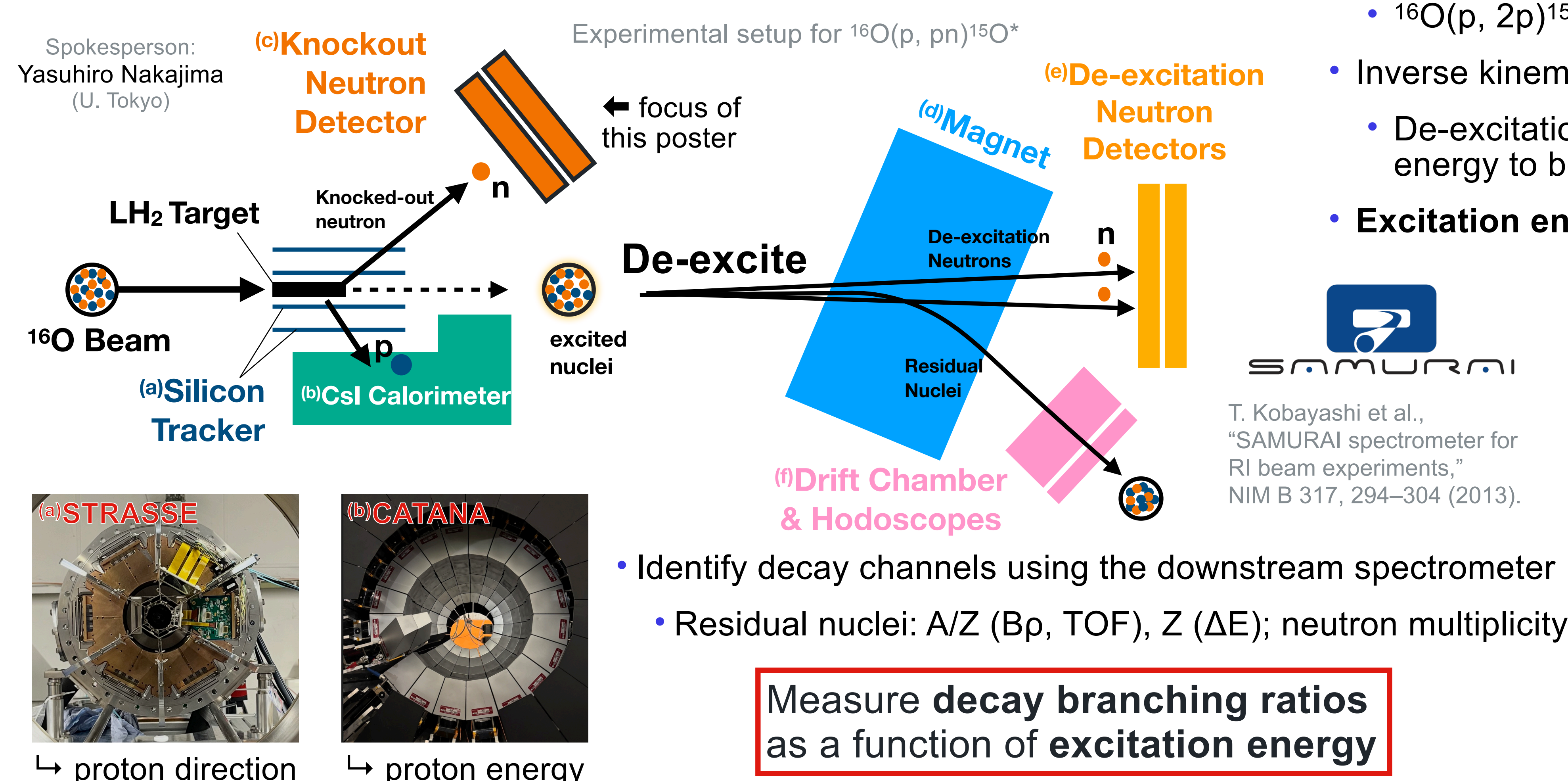


Nuclear De-excitation via Particle Emission

- Excited nuclei emit γ , n , p , d , α until reaching g.s.
- Hauser-Feshbach statistical model (HF)** has made successful predictions for heavy nuclei
- But needs experimental validation and parameter tuning for the light nuclei



SAMURAI-79 Experiment at RIBF (Radioactive Isotope Beam Factory)



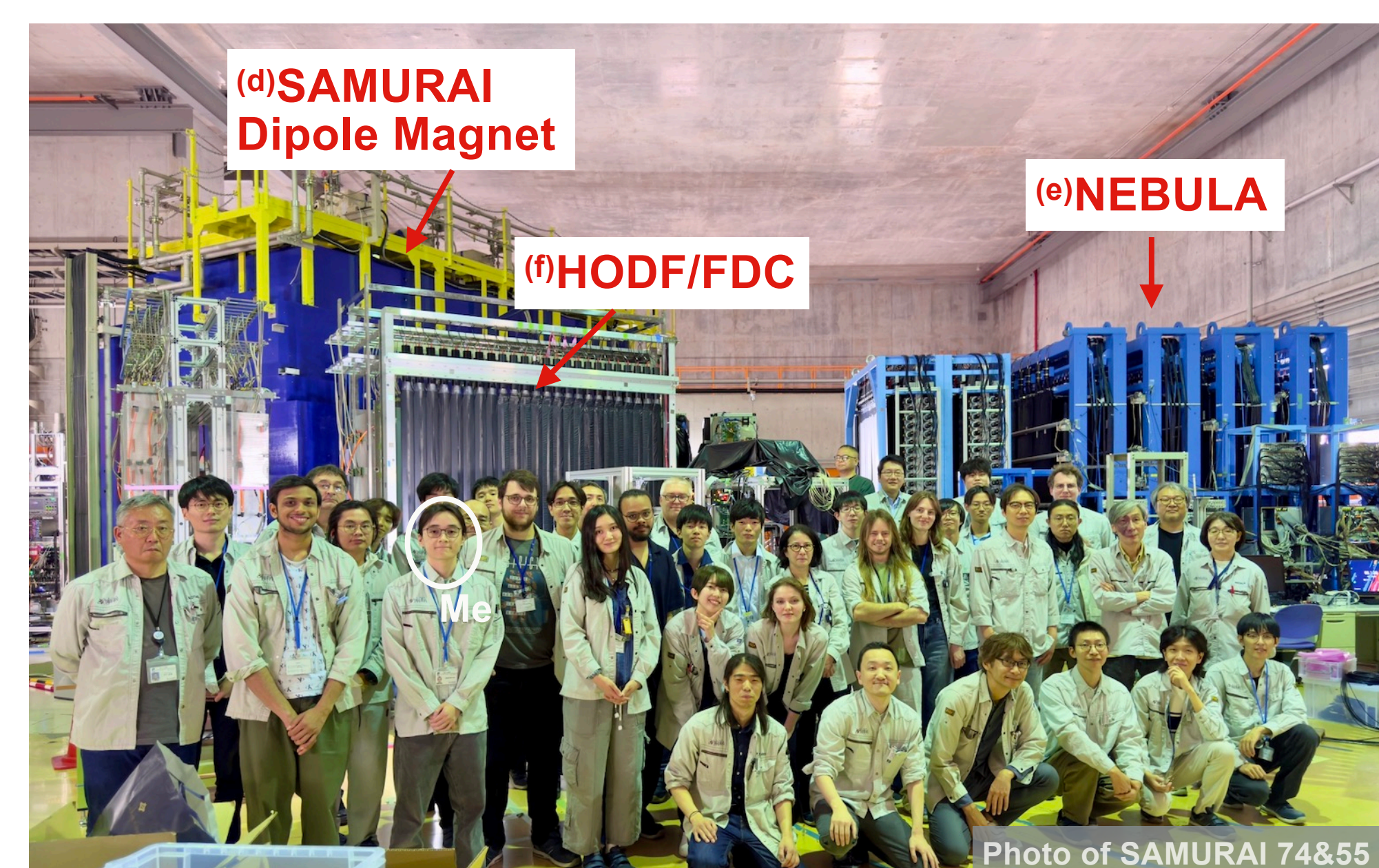
- Produce excited nuclei via **strong** interactions ($\sigma \sim 6\text{mb}$):

- $^{16}\text{O}(p, 2p)^{15}\text{N}^*$, $^{16}\text{O}(p, pn)^{15}\text{O}^*$, $^{17}\text{O}(p, pn)^{16}\text{O}^*$

- Inverse kinematics with a 200 MeV/u ¹⁶/¹⁷O beam

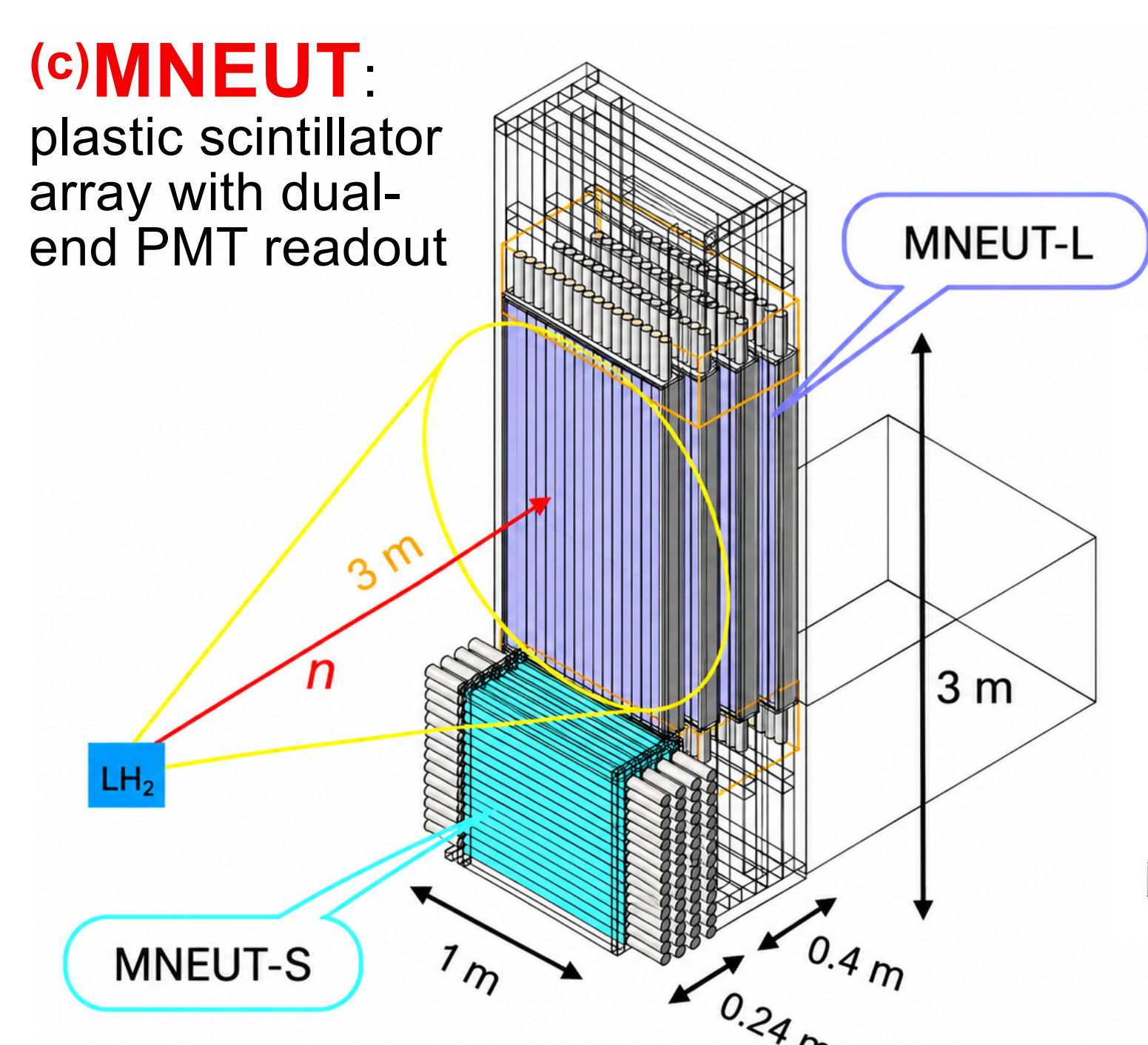
- De-excitation products are **forward-boosted** with sufficient energy to be detected

- Excitation energy (E_x) is reconstructed from missing mass



Developing the Neutron Detector: MNEUT

- (c) **MNEUT**: plastic scintillator array with dual-end PMT readout



missing-mass reconstruction:

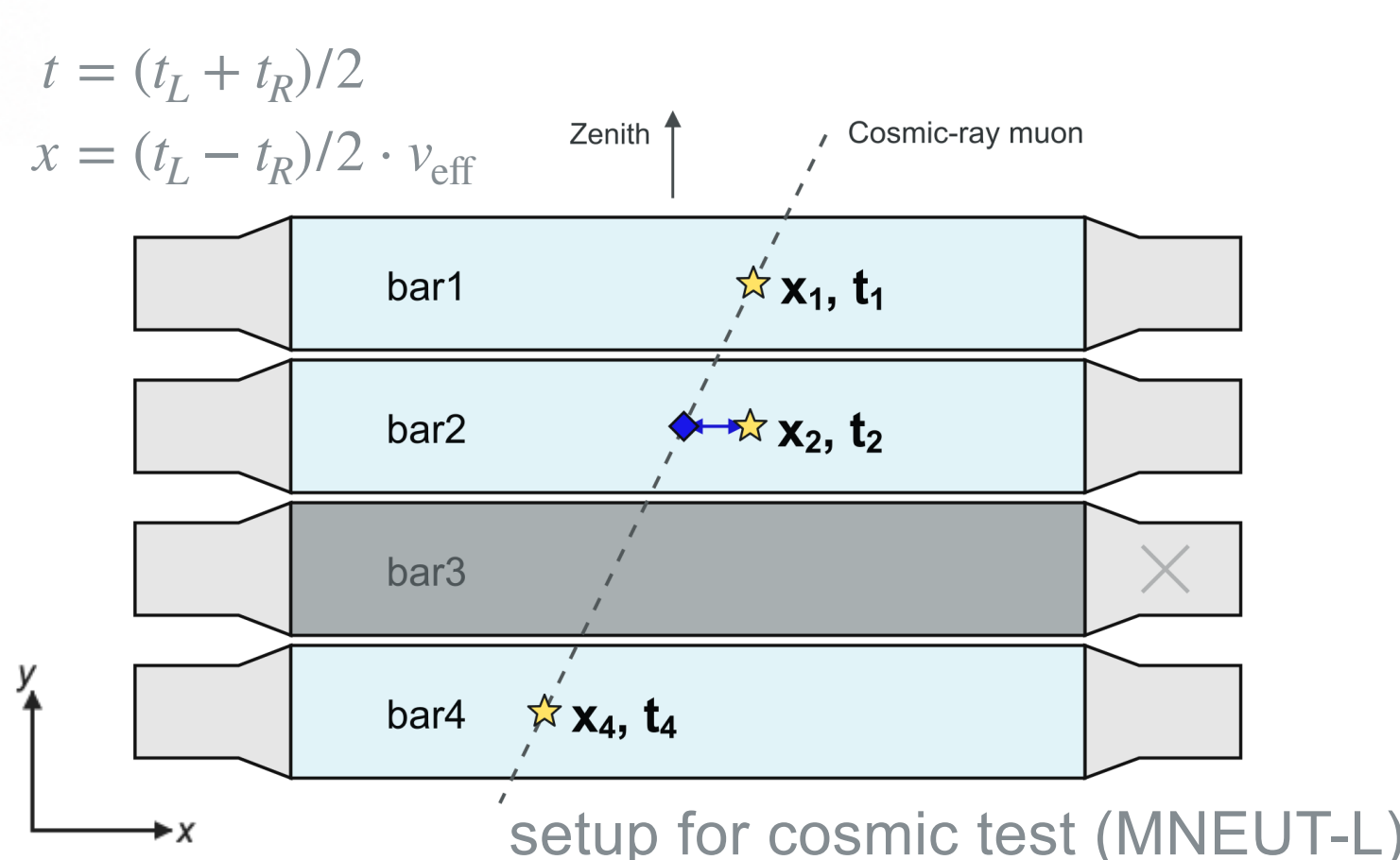
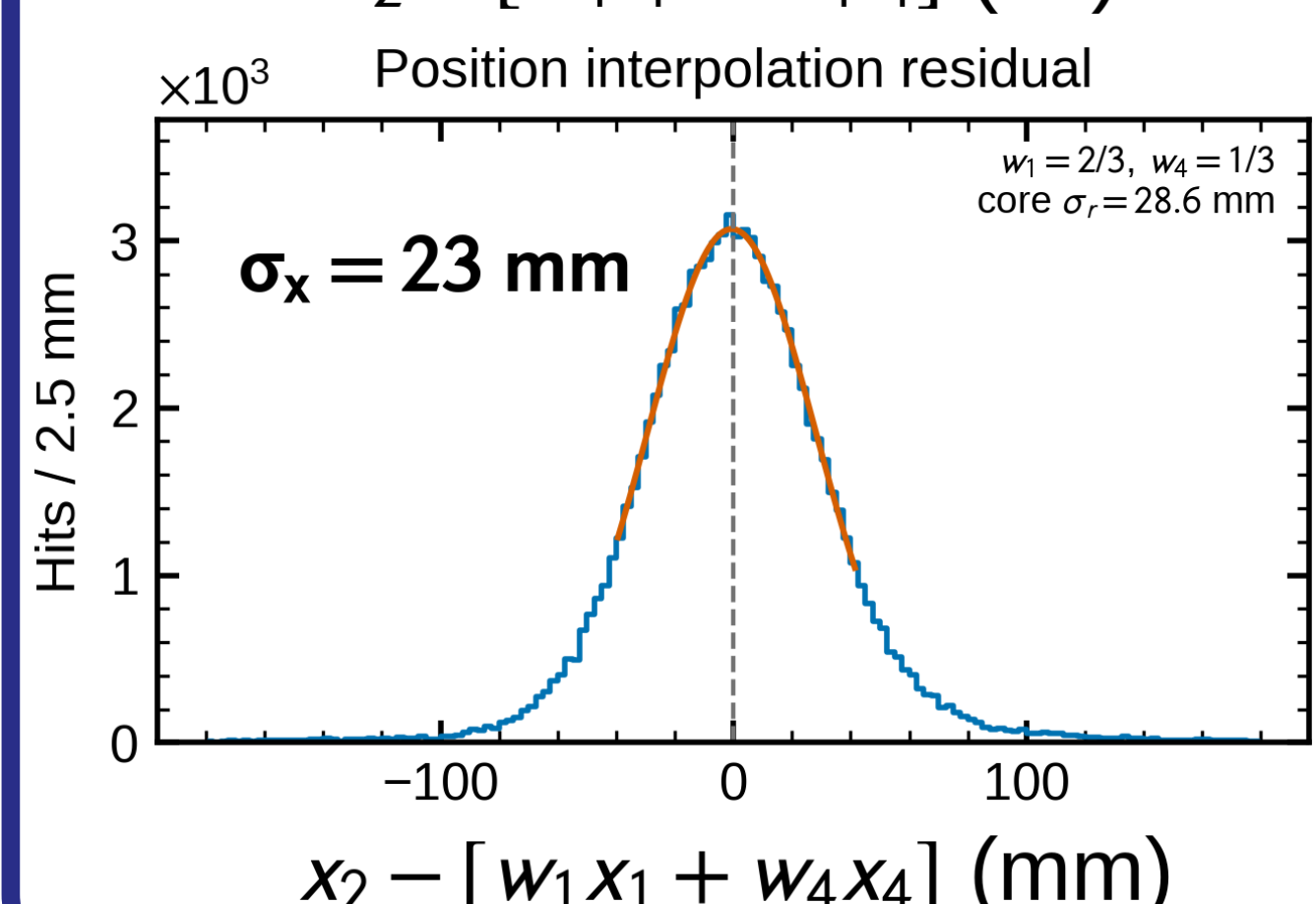
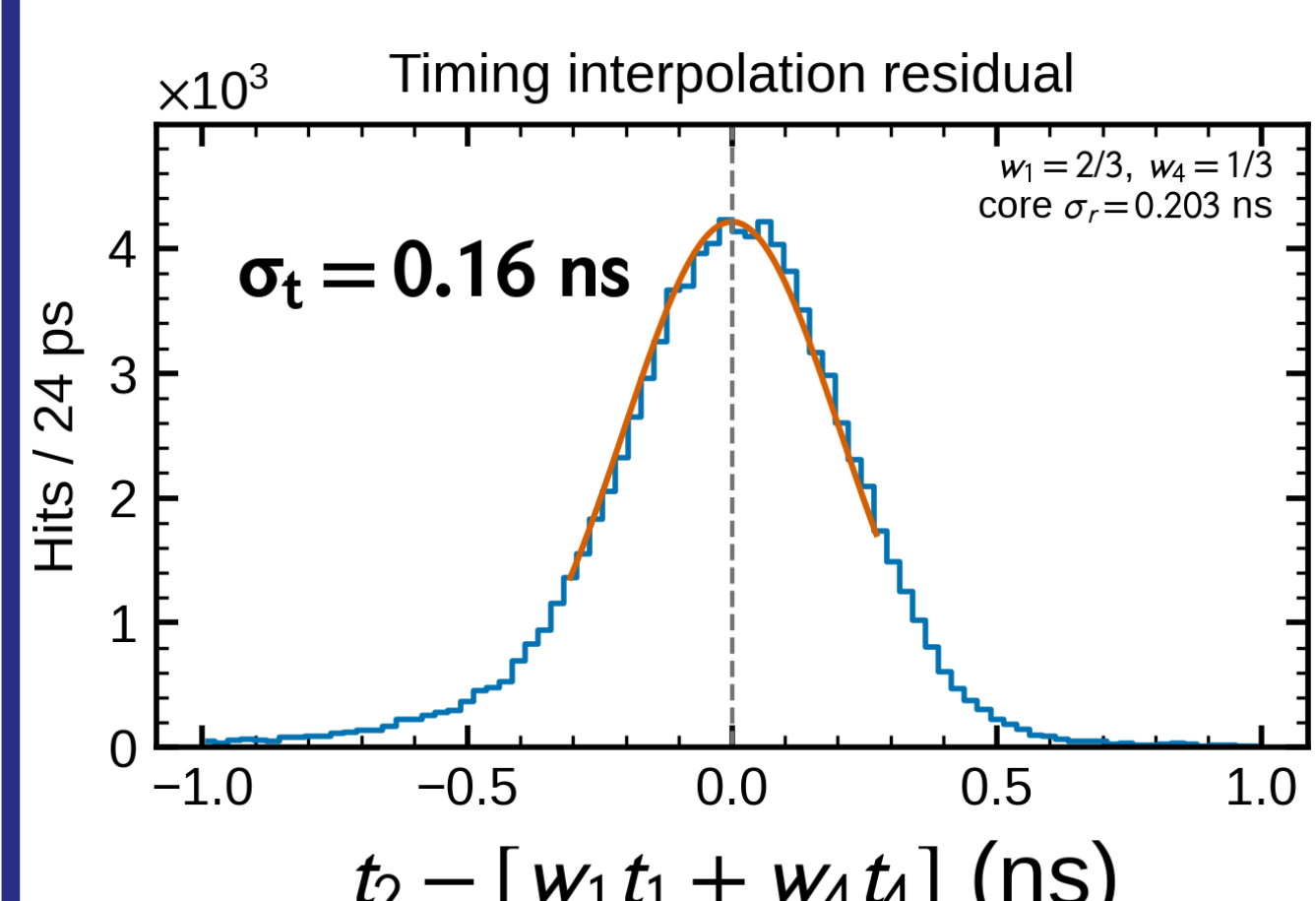
$$P_{\text{miss}} = P_{\text{initial}} - P_p - P_n$$

$$E_x = \sqrt{P_{\text{miss}}^2} - M_{\text{g.s.}}$$

New readout electronics based on the **MDPP-32**:

- QDC & TDC in one module
- Programmable parameters
- Built-in CFD for precise timing

Performance test with cosmic-ray muons



knockout neutron @3m, KE=50 MeV
ref. recoil proton STRASSE + CATANA

$$\sigma_{|p|} \sim 1.8\text{ MeV/c} \sim 1\text{ MeV/c}$$

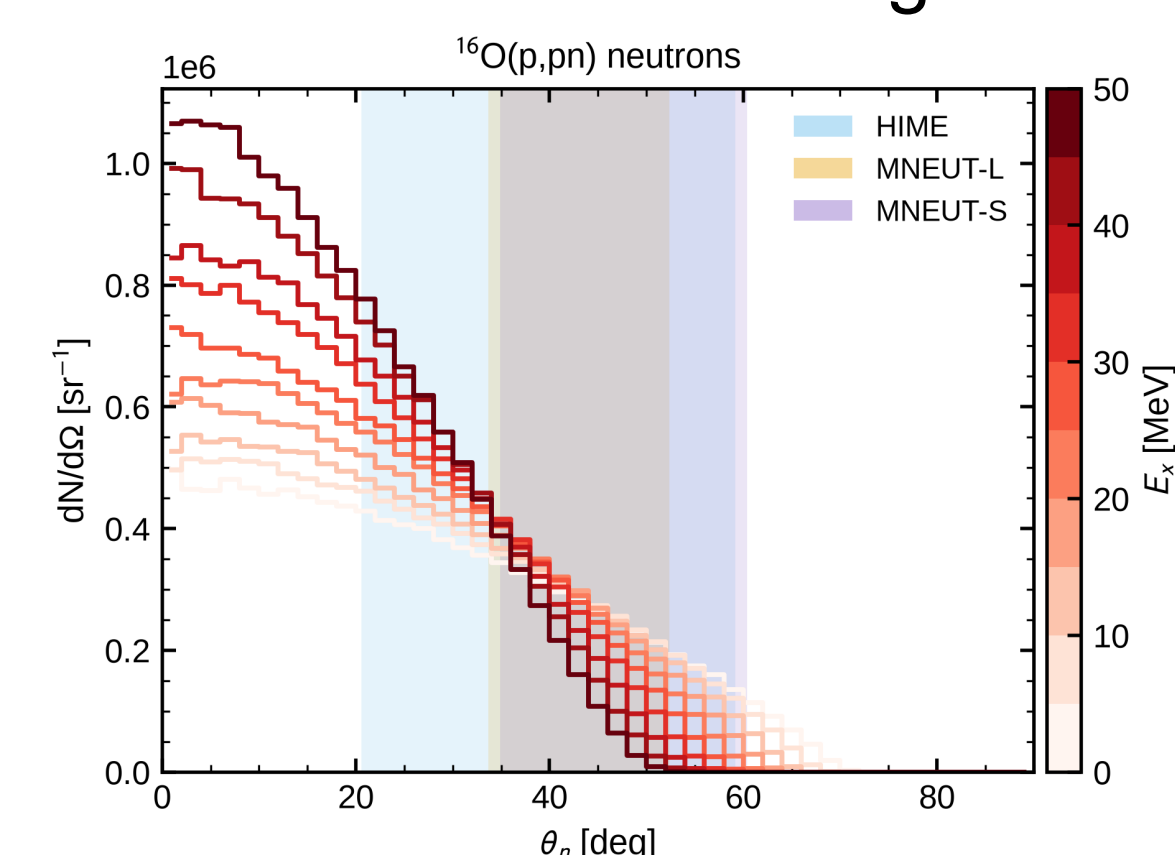
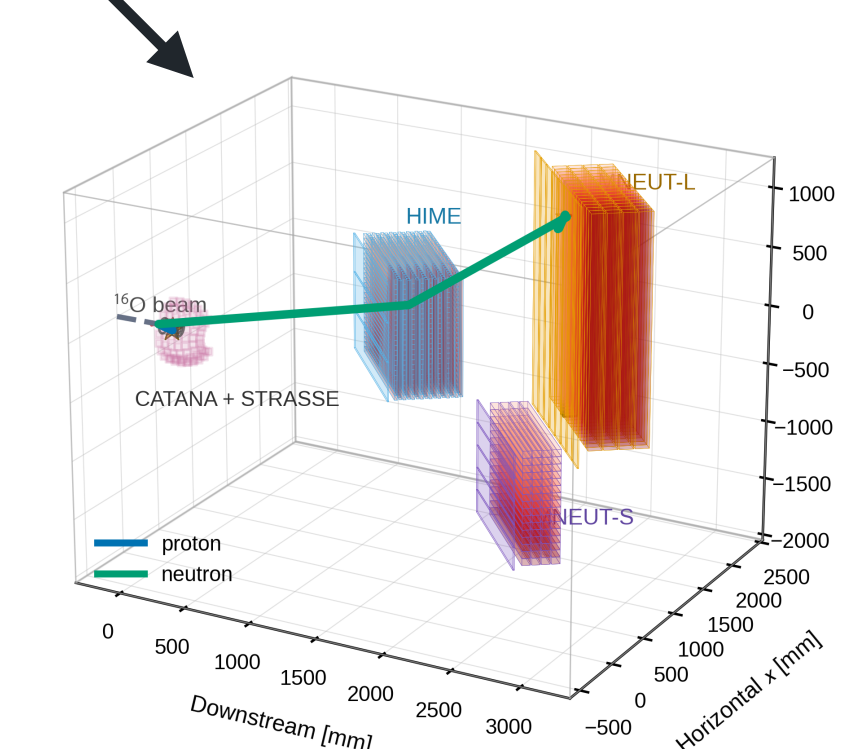
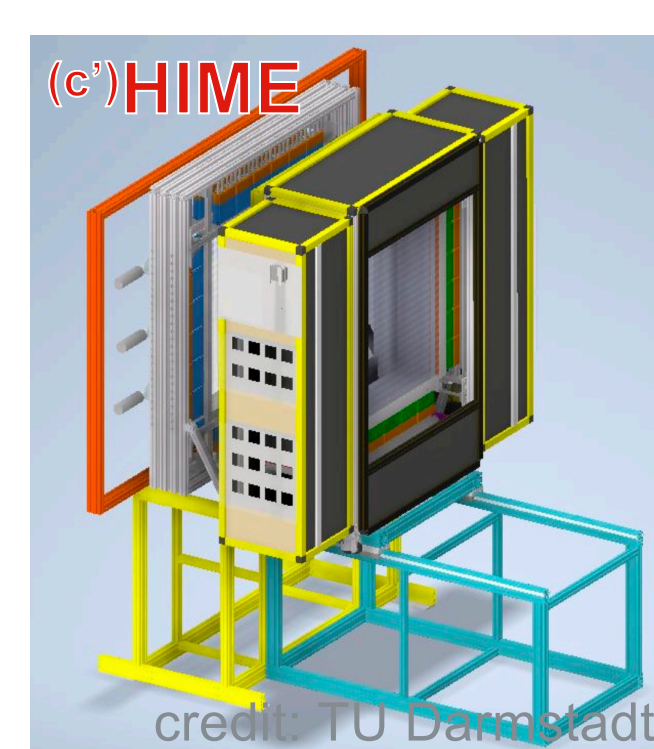
$$\sigma_{\hat{p}} \sim 8\text{ mrad} \sim 5\text{--}10\text{ mrad}$$

- Comparable precision to the proton track
- Neutron contribution to E_x resolution: ~1 MeV (estimate)

MNEUT enables precise missing-mass reconstruction

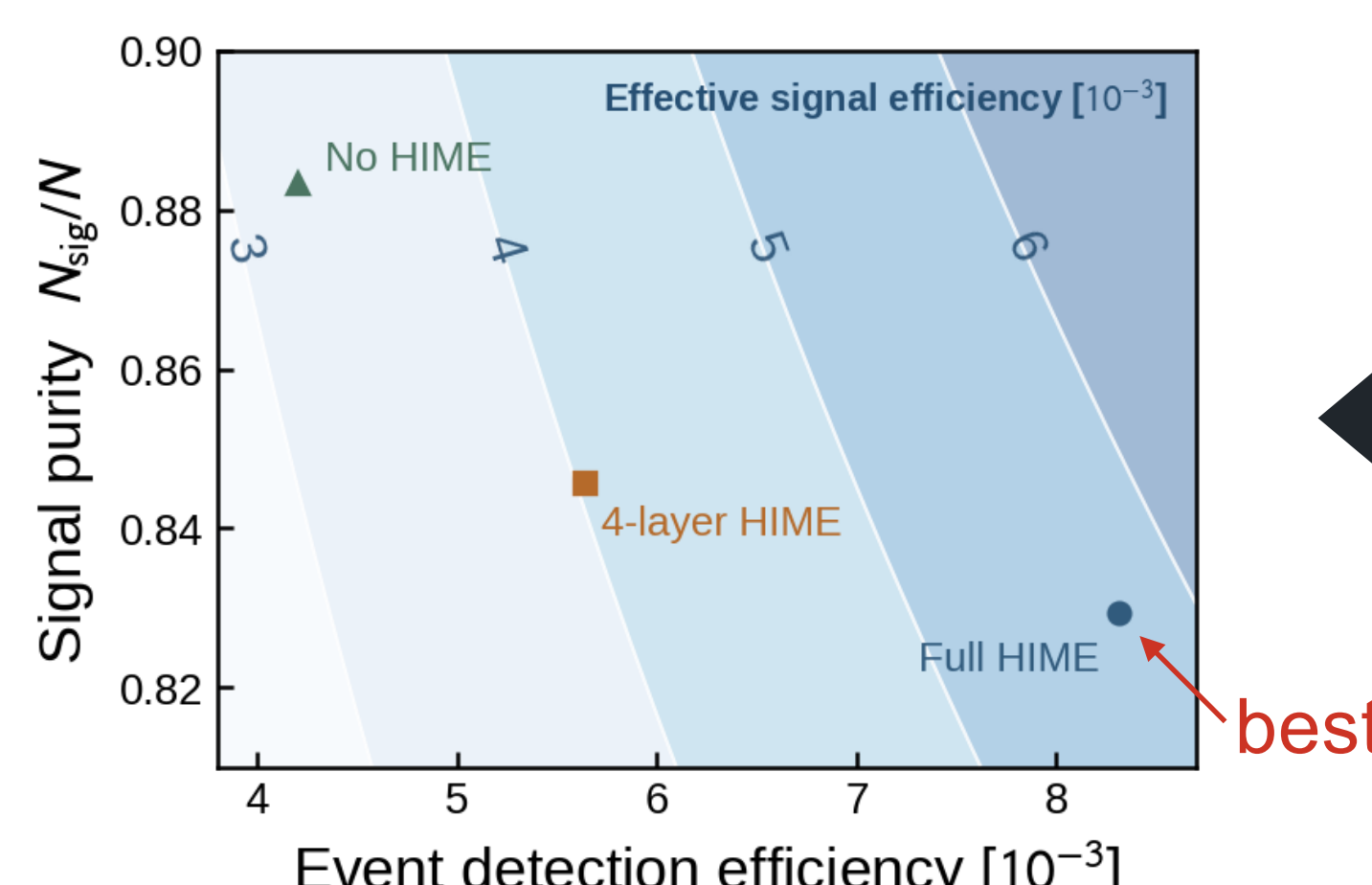
MC Optimization of Detector Configuration

- Planning to introduce another neutron detector HIME for **more statistics**
- However, it **degrades data purity** due to invisible neutron scattering

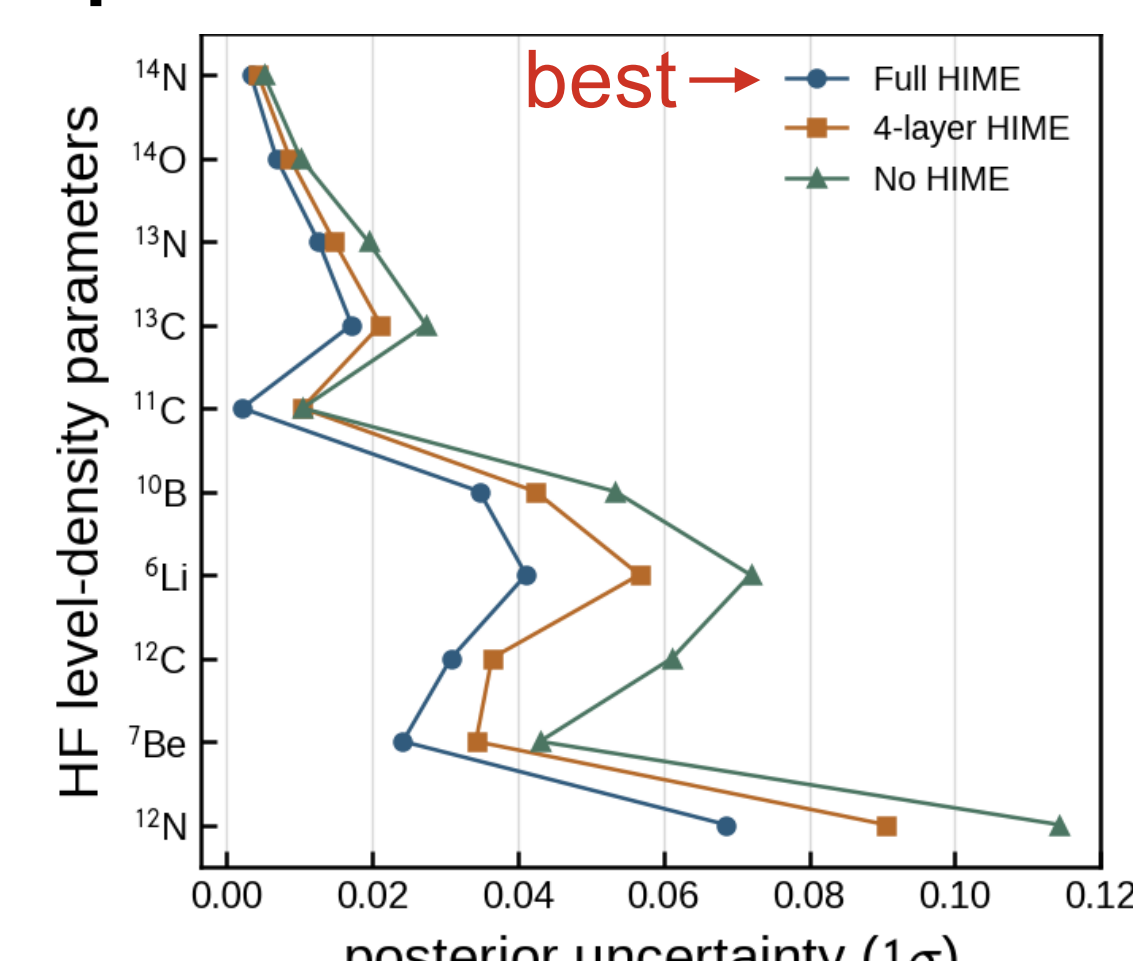


Is the gain in statistics worth the loss in purity?

balancing data purity & statistics by maximizing effective signal (N_{sig}^2/N)



comparing model-constraining power with Asimov datasets



- Two optimization approaches yield consistent configuration preferences
- Both support **adding the additional HIME detector**

Outlook

- Collect the first ¹⁶O(p, 2p)¹⁵N* data in early 2027
- Assemble and commission MNEUT before ¹⁶O(p, pn)¹⁵O* beam time
- Constrain atmospheric-ν NCQE uncertainty from ~70% to ~10%
- Enable **3σ observation of DSNB** at Super-K