

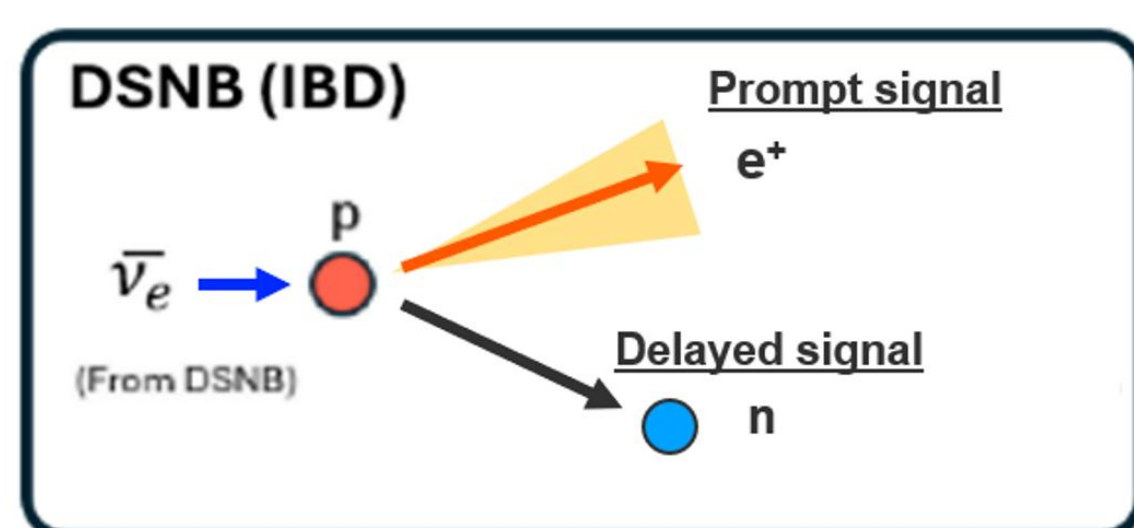
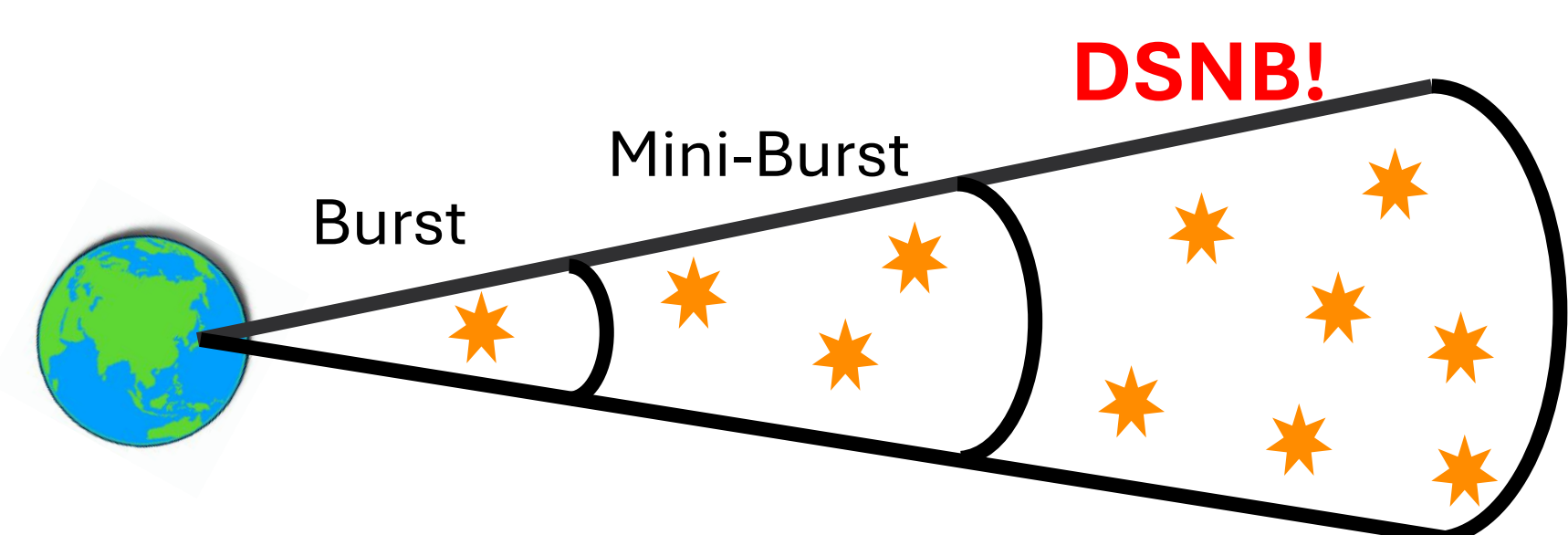
Constraining Atmospheric NCQE Backgrounds for Super-Kamiokande DSNB Searches using T2K Data

LiCheng Feng, Ashida Yosuke, Yota Hino
On behalf of the T2K Collaboration



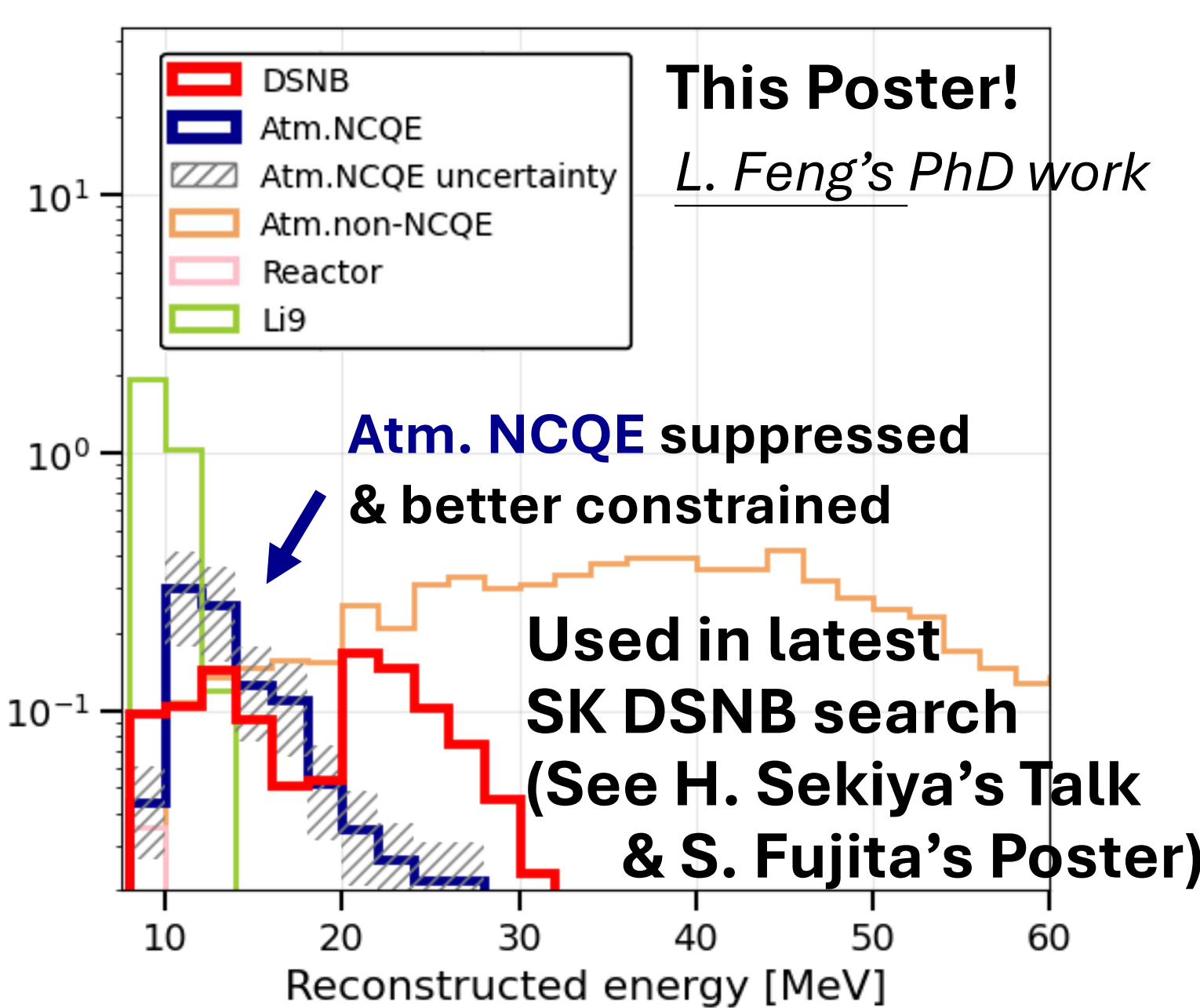
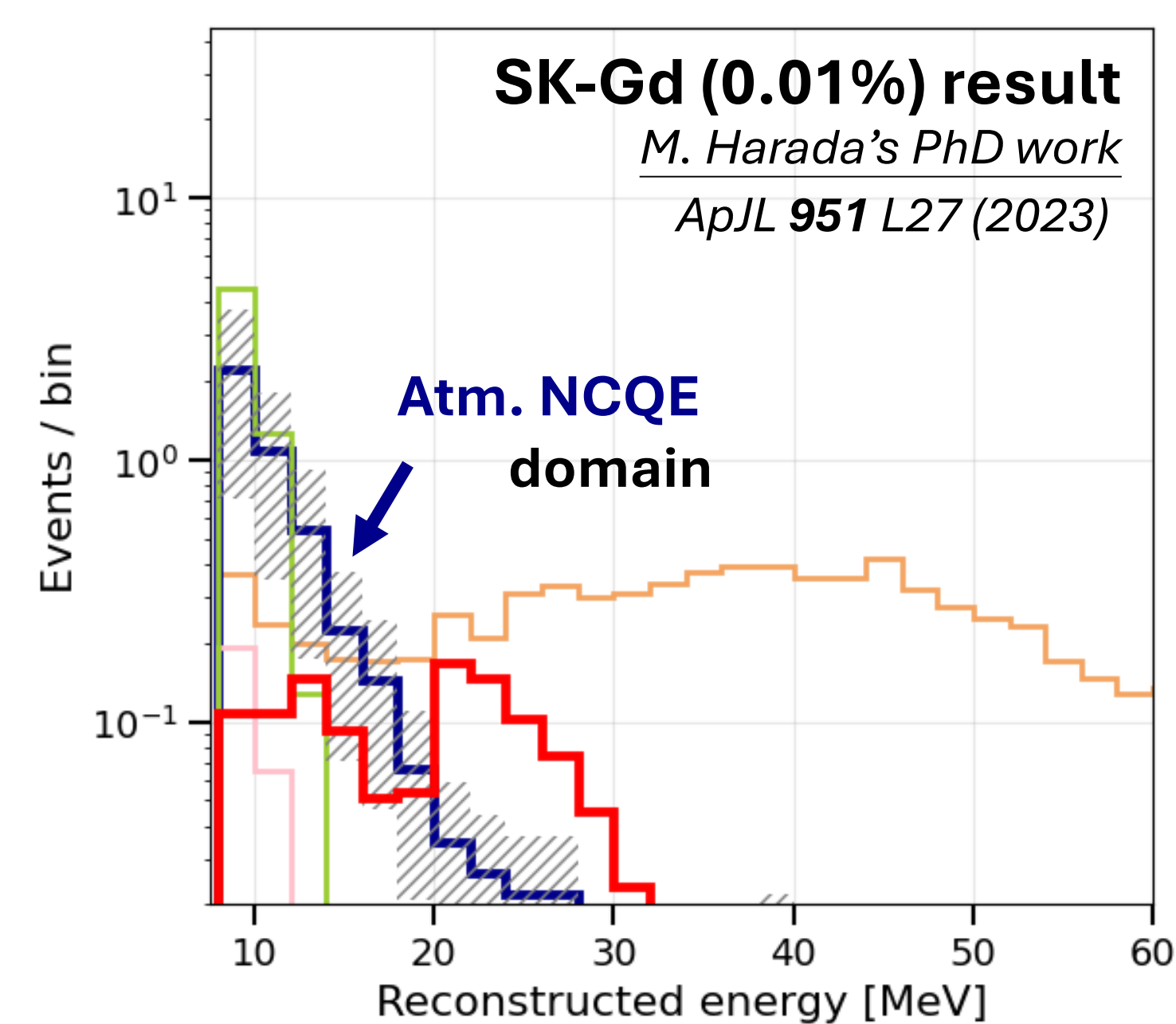
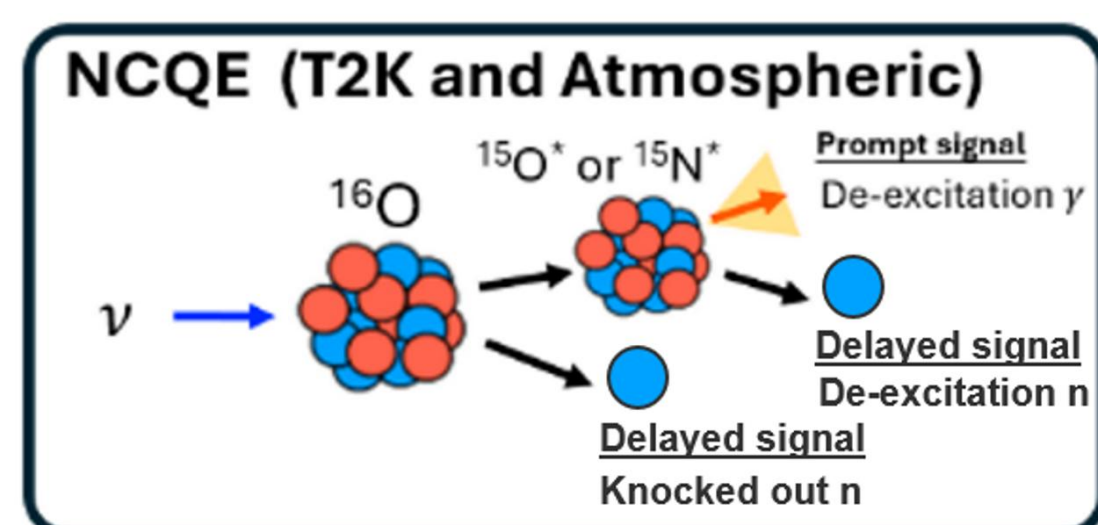
Diffuse Supernovae Neutrino Background

- Neutrinos from all past core-collapse supernovae in the Universe.
- Could be humanity's second-ever observation of supernova neutrinos.



Atmospheric NCQE background

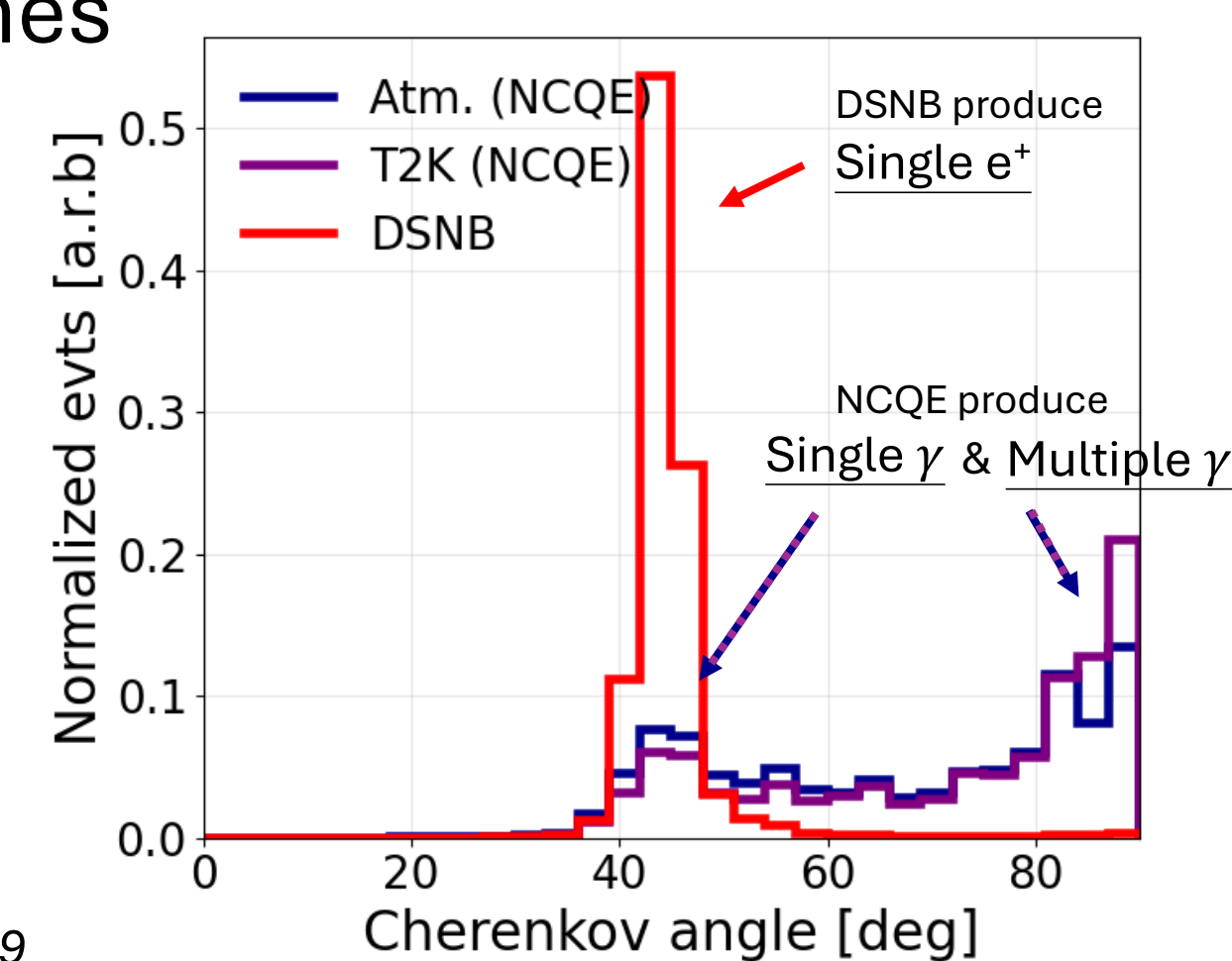
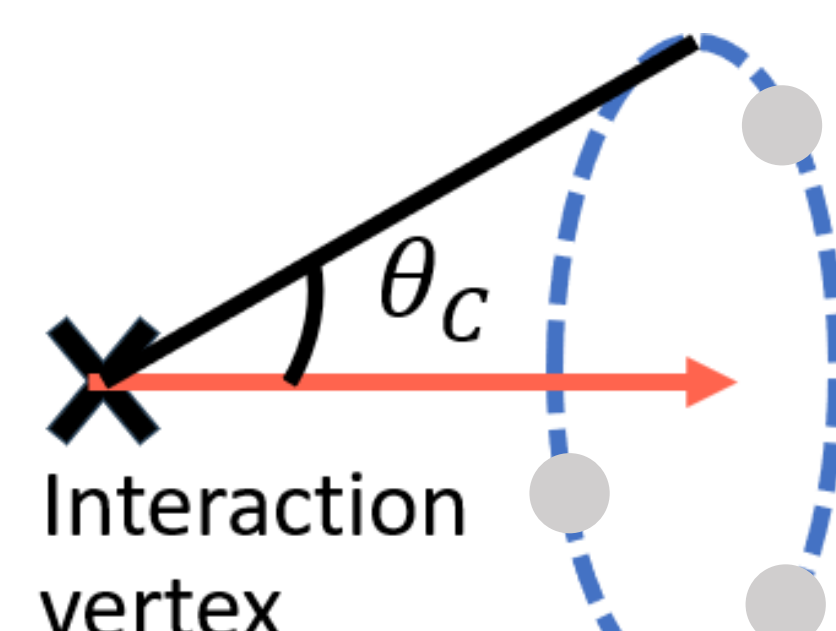
- Atmospheric Neutral Current Quasi-Elastic interactions are a major background.
- The nuclear de-excitation γ and accompanying neutron process mimic the DSNB signal



Cherenkov ring key features to suppress NCQE

Cherenkov angle (θ_C)

- Opening angle of the Cherenkov ring
- Used in all SK DSNB searches



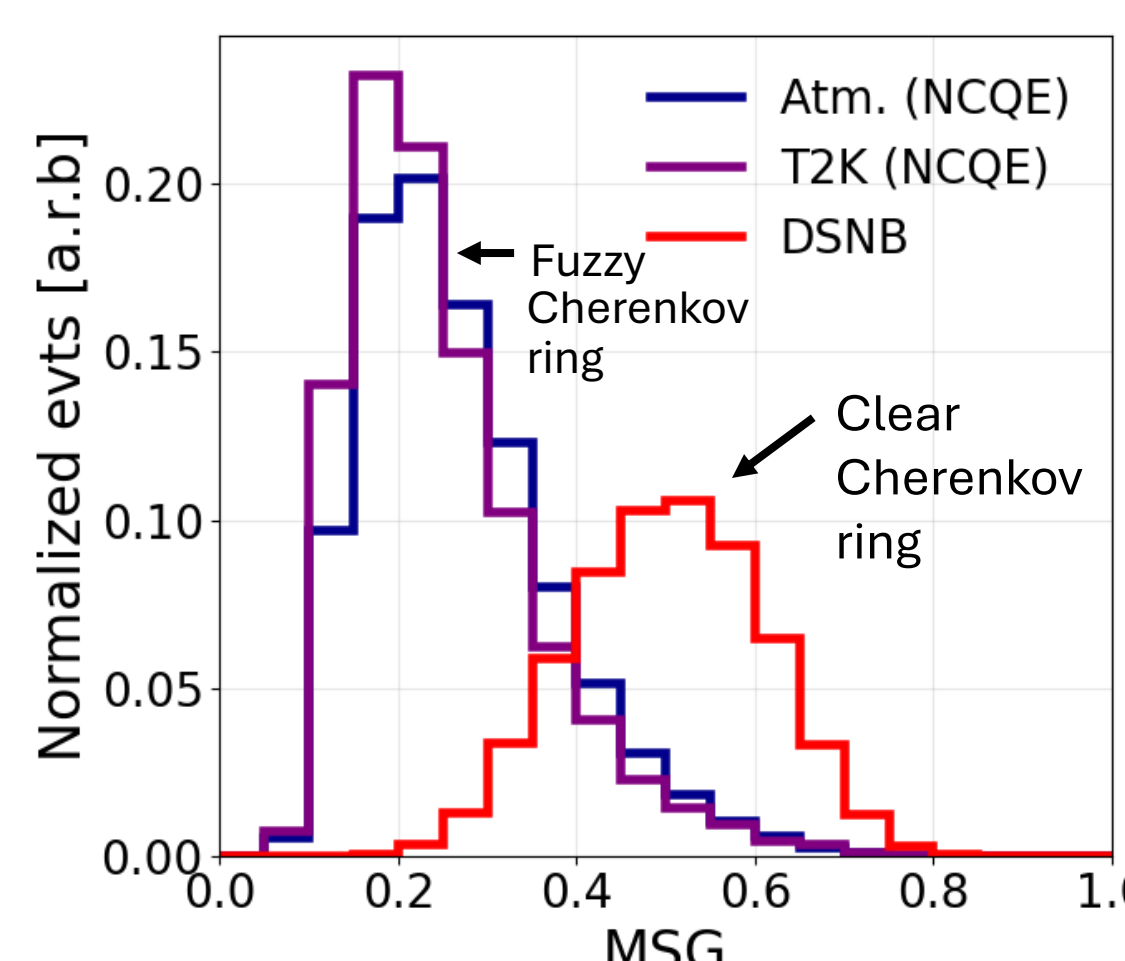
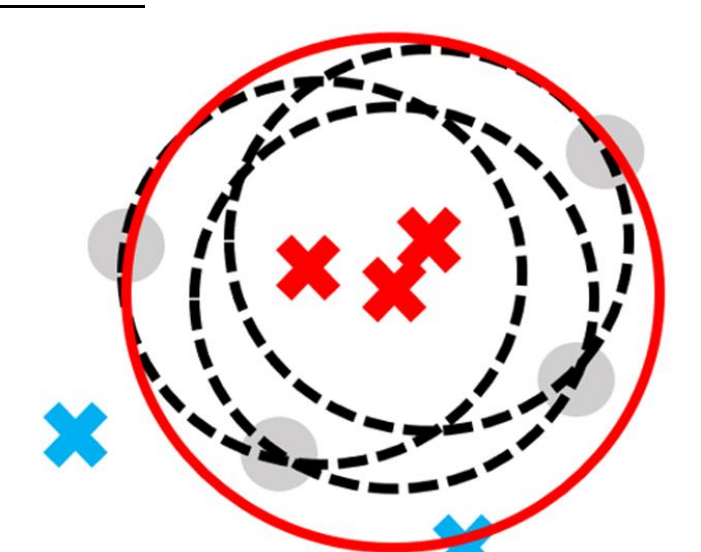
- Tested with T2K NCQE data

Y. Ashida's PhD work, PRD 100, 112009

Multiple Scattering Goodness (MSG)

- Fuzziness of the Cherenkov ring
- Proposed and used in SK DSNB search

A. Santos's PhD work, arXiv:2511.02222



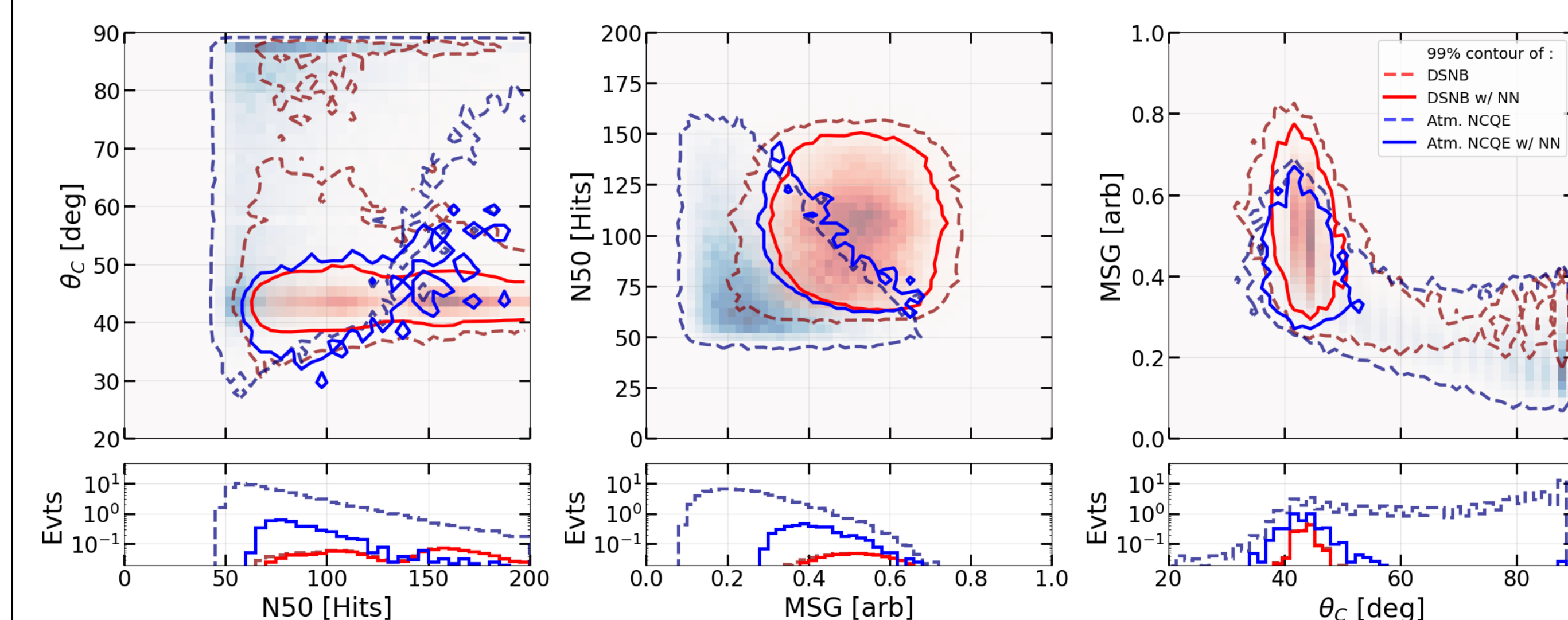
- Fully tested with T2K NCQE data in this Poster

Neural Network classifier

To optimize feature classification :

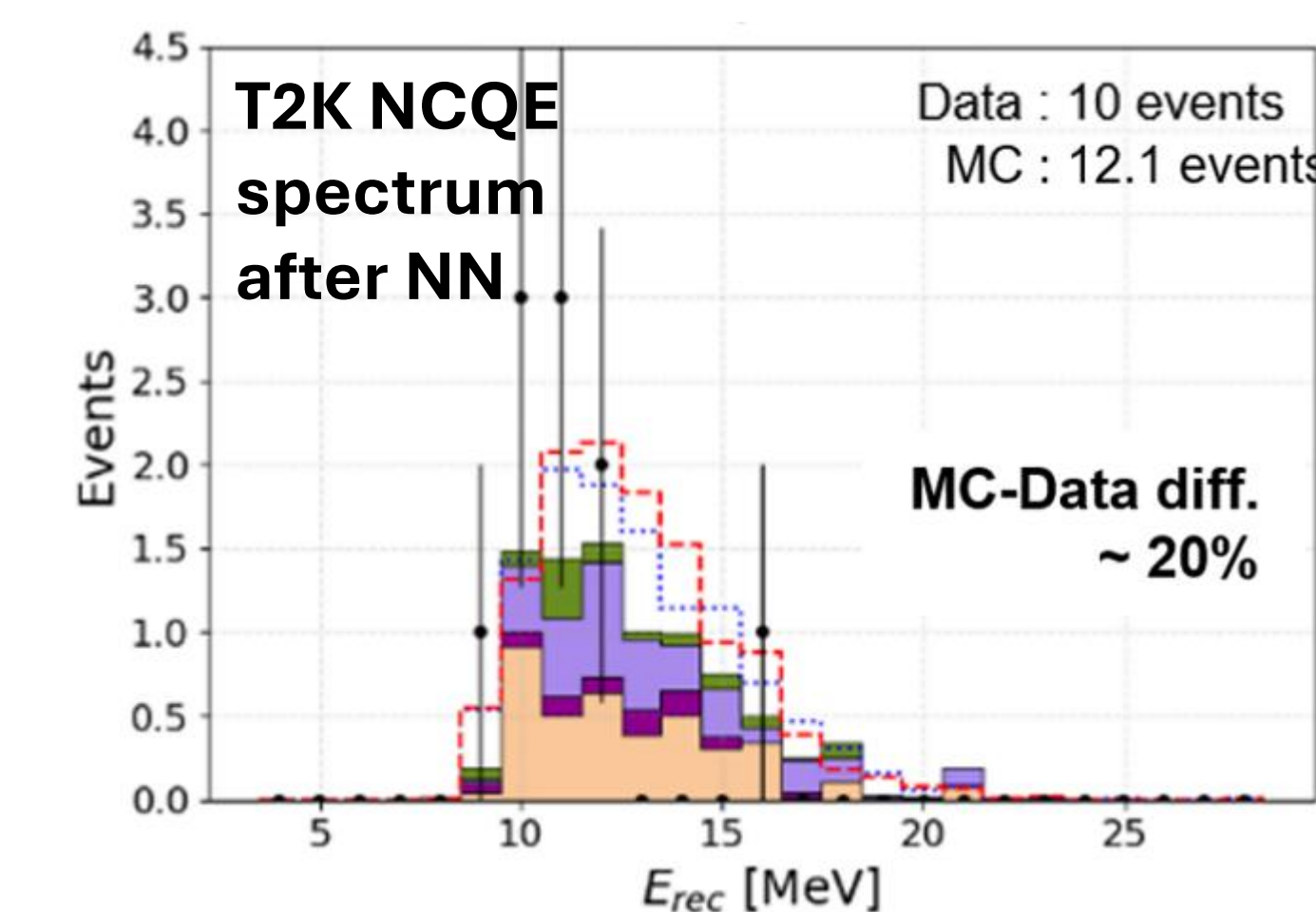
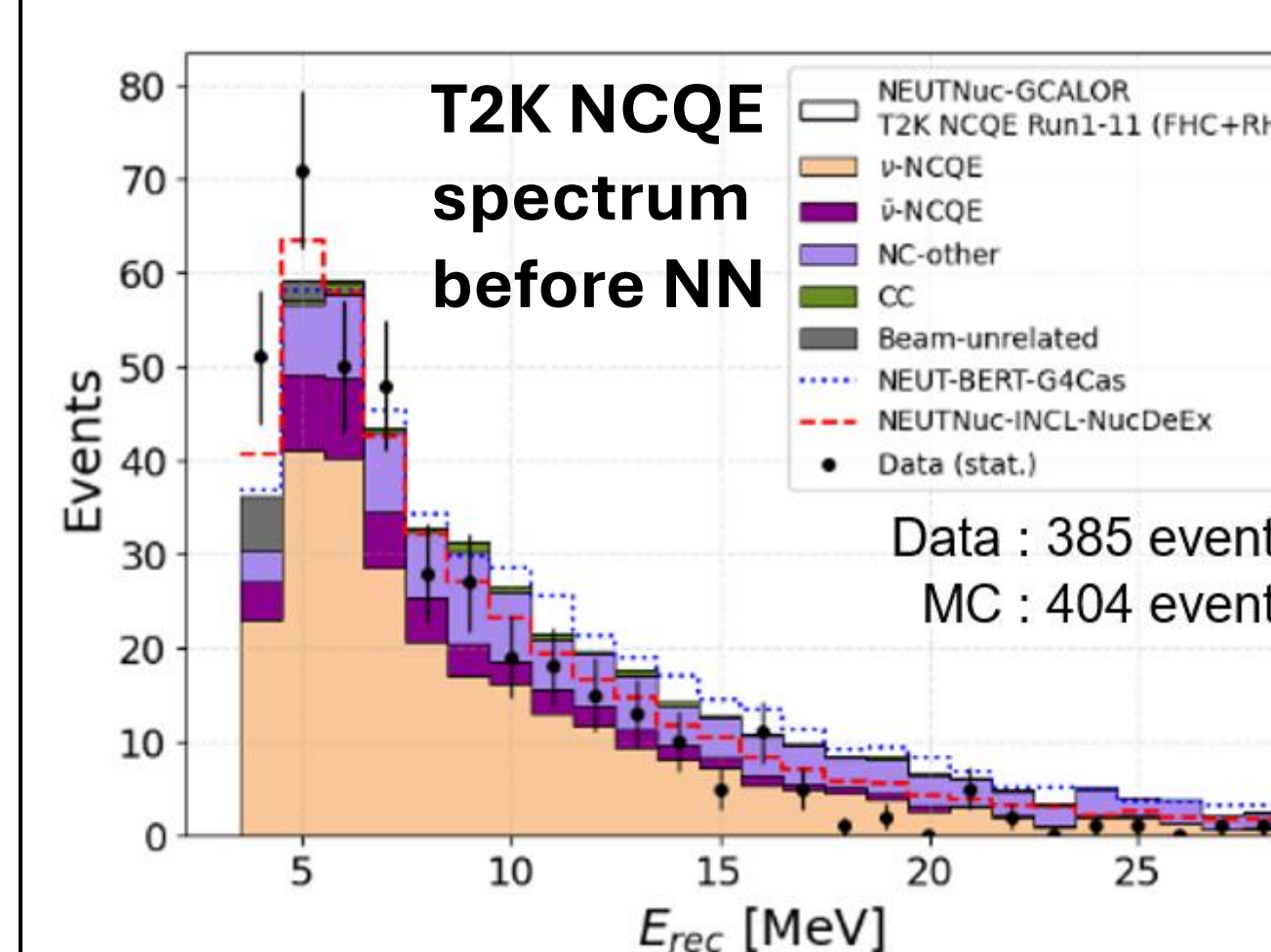
- We fed N_{50} , θ_C , and MSG into a 3-64-64-64-64-64-1 network,
- An explainable, feature-based non-linear cuts method.

[DSNB, Atm. NCQE] efficiency : [95%, 23%] (θ_C only) → [89%, 5%] (NN)



Test NN cut with T2K NCQE data

- Applied NN (trained on Atm. NCQE) on T2K NCQE data (2009-2021)



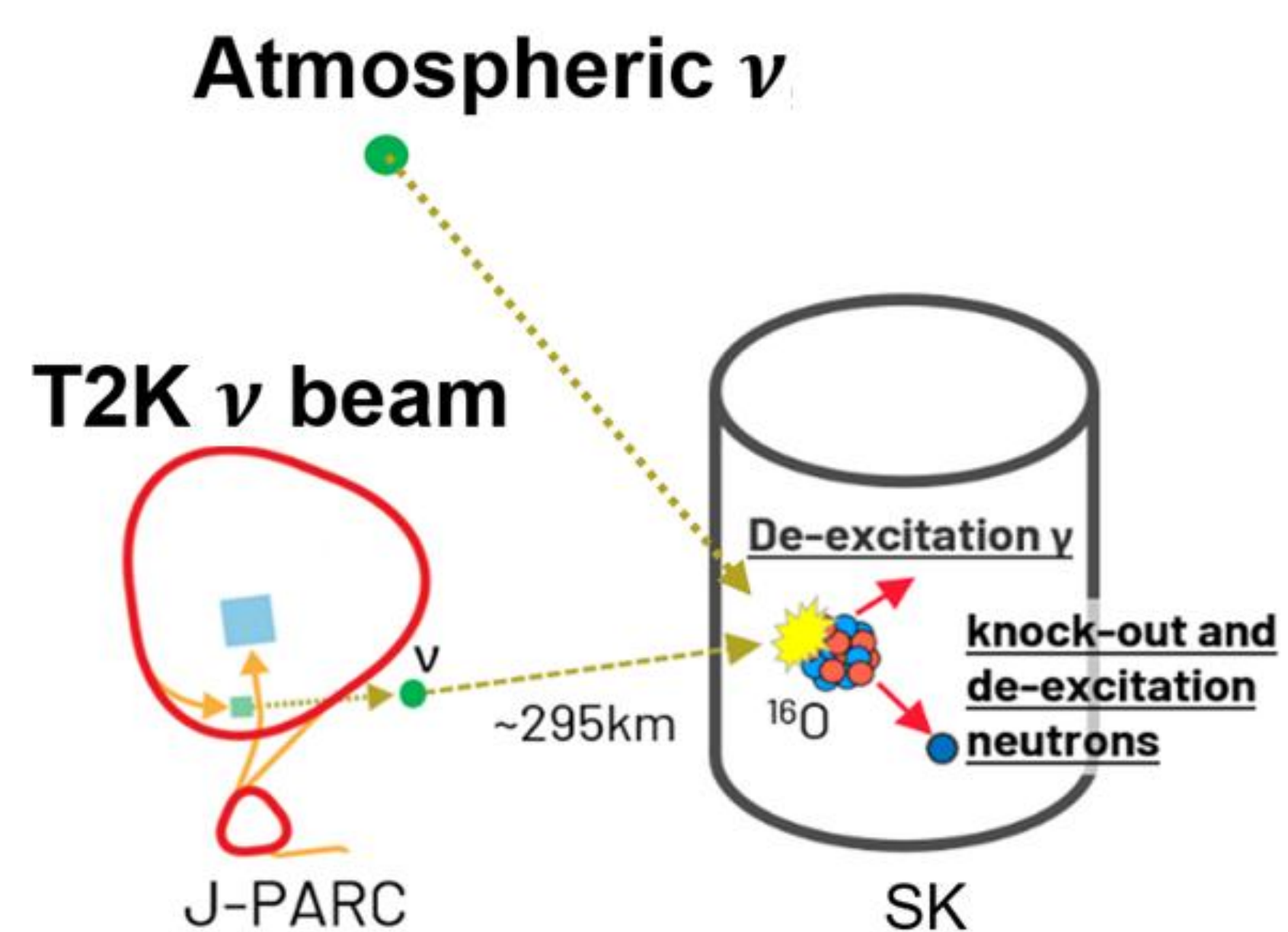
- MC and Data agree well

- T2K data is limited by strict NCQE rejection rate

Statistical error : ~32%

Atmospheric and T2K ν

- Syst. uncertainties for NN cut applied on Atm. NCQE: Estimated with T2K NCQE data as a reference.

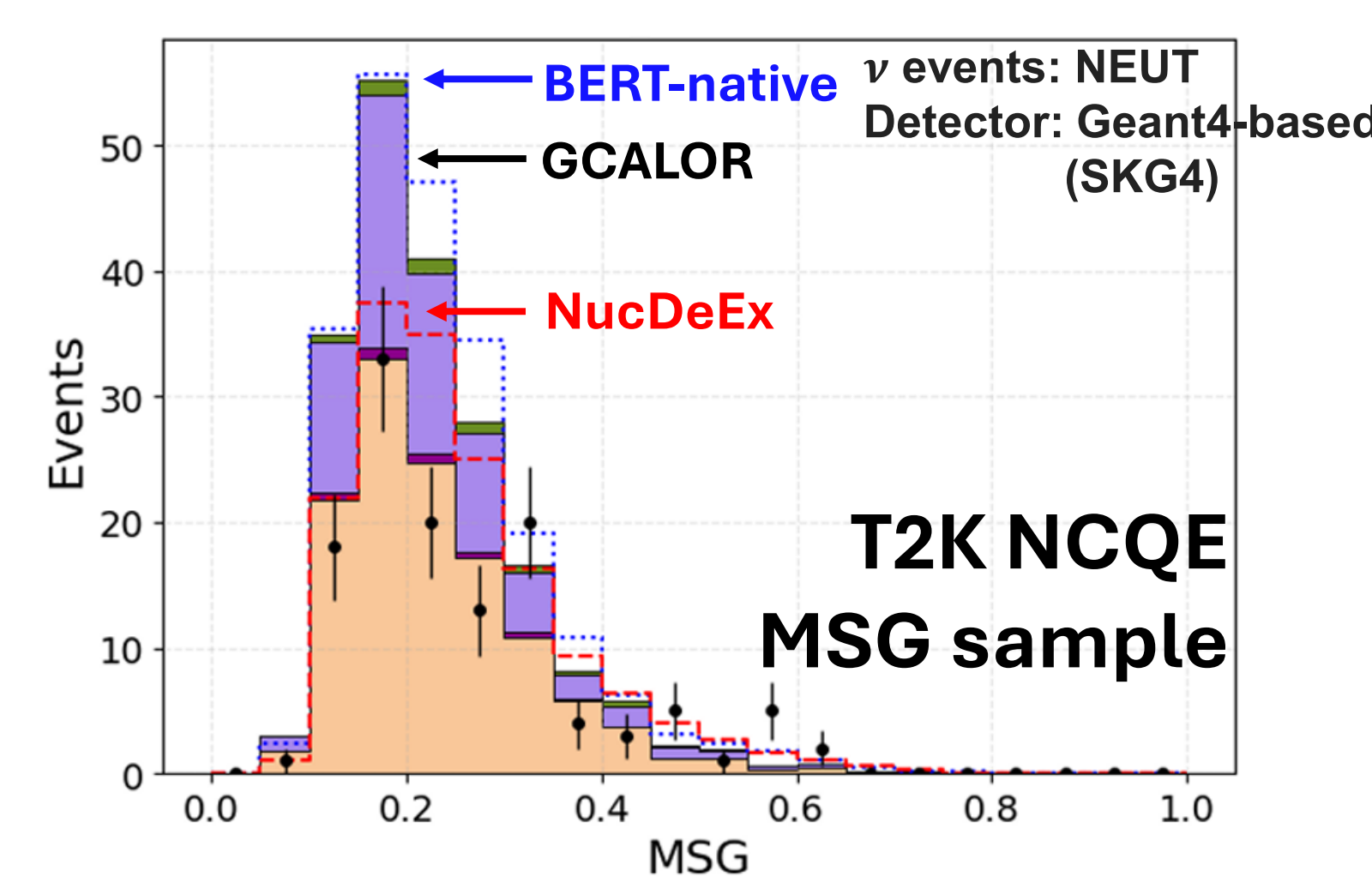
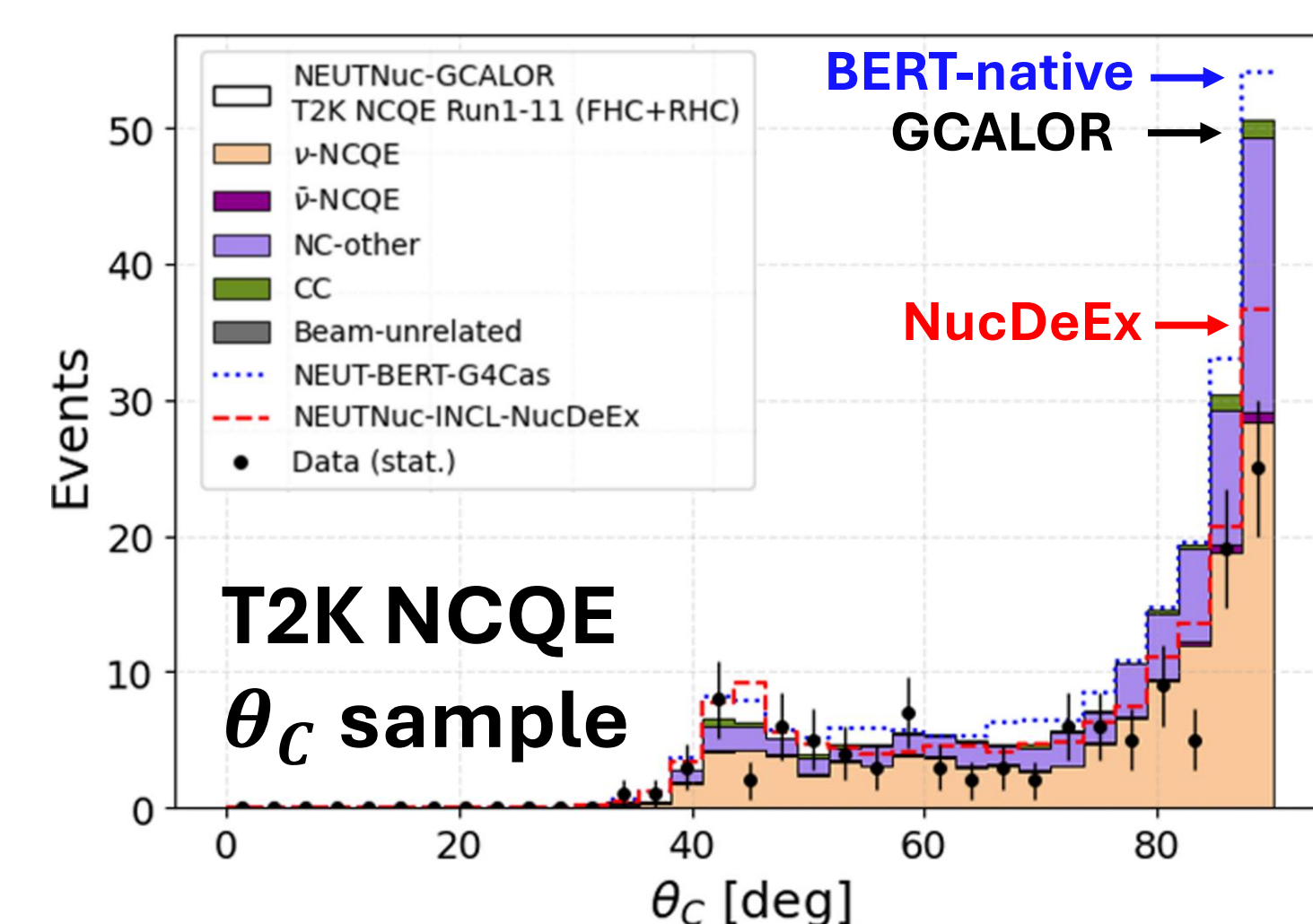


Pure (T2K) NCQE events in DSNB signal window (by using ν beam timing information)

Systematic error of the NN cut

- Upgraded MC to **NucDeEx** (.....) because **GCALOR** (▭) and **Bertini w/ native de-excitation** (.....) lack discrete γ emissions.

Poor γ multiplicity prediction → Data-MC diff. topology → A major syst. error in previous T2K study



Syst. =	Atm. flux	ν interaction	Intra-nuclear cascade	Neutron tag efficiency
~33% =	T2K flux	NCQE models	De-excitation (NucDeEx & G4PreCompound)	Neutron multiplicity
	Weight			
	~18%	~8%	~34% → ~13% (omit GCALOR & BERT-native)	~25%

Conclusion & Prospect

- Suppress Atm. NCQE to 5% level with Stat. \otimes Syst. ~45% error

Applied feature-based NN cut Applied T2K data & MC investigation

- Syst. will be improved by SAMURAI-79 exp. (See Y. Mizuno's Poster)
- Stat. will be improved by upcoming T2K data at SuperK & HyperK

