Neutrino Cross-Section Opportunities at FPF

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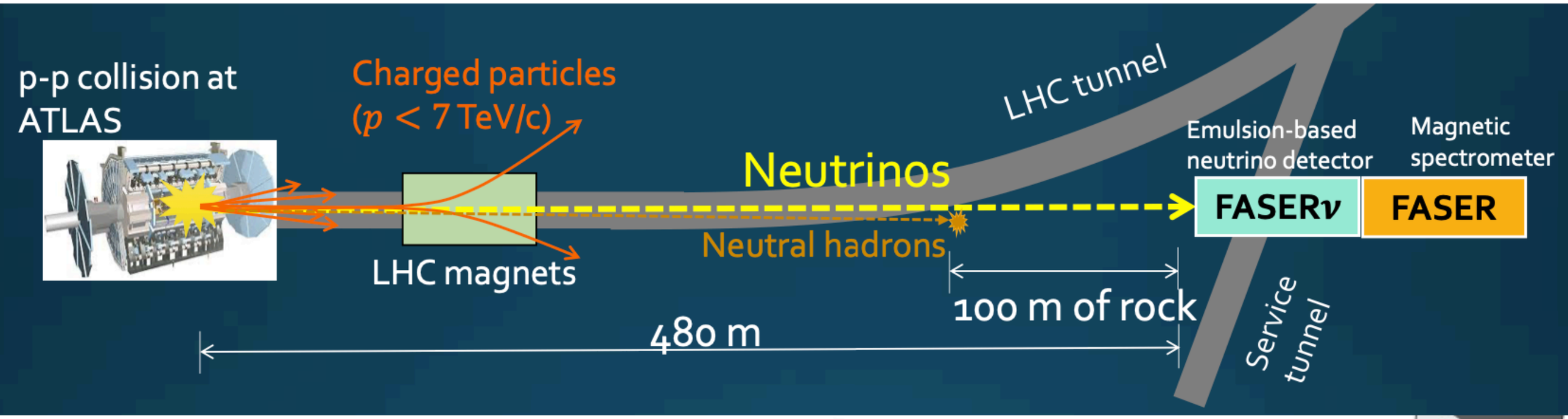
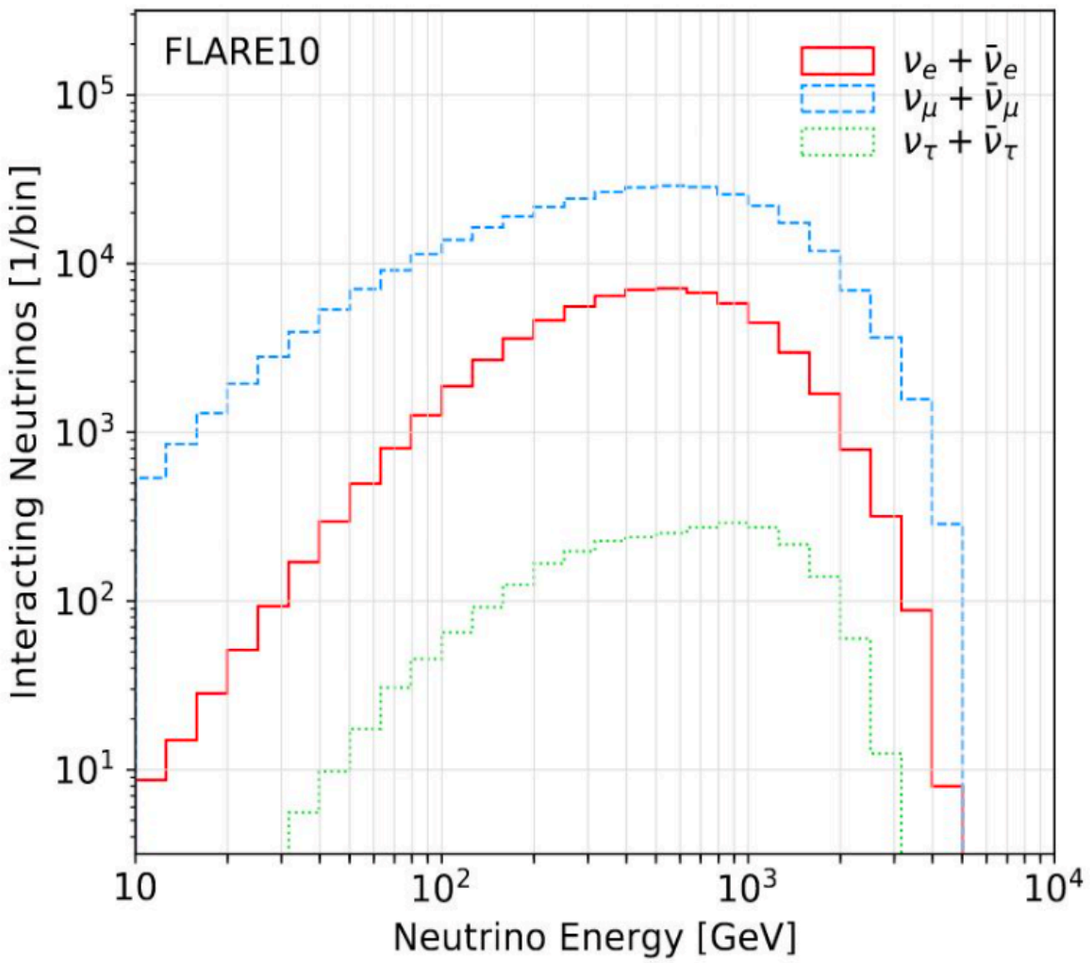
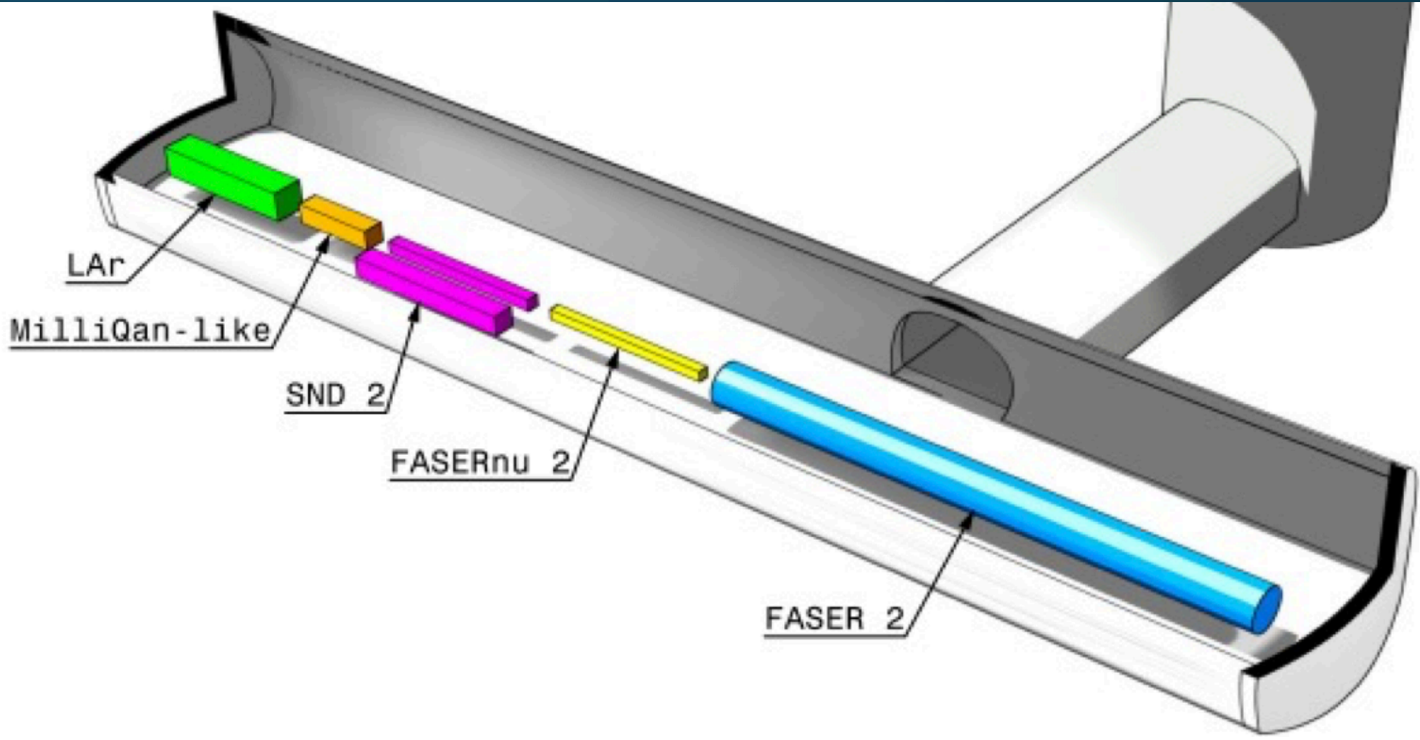
with Jonathan Feng (UCI), Maria Vittoria Garzelli (UHamburg),
Felix Kling (SLAC), Yu-Dai Tsai (FNAL)

2nd Forward Physics Facility Meeting, May 27-28, 2021

Neutrinos at the Forward Physics Facility



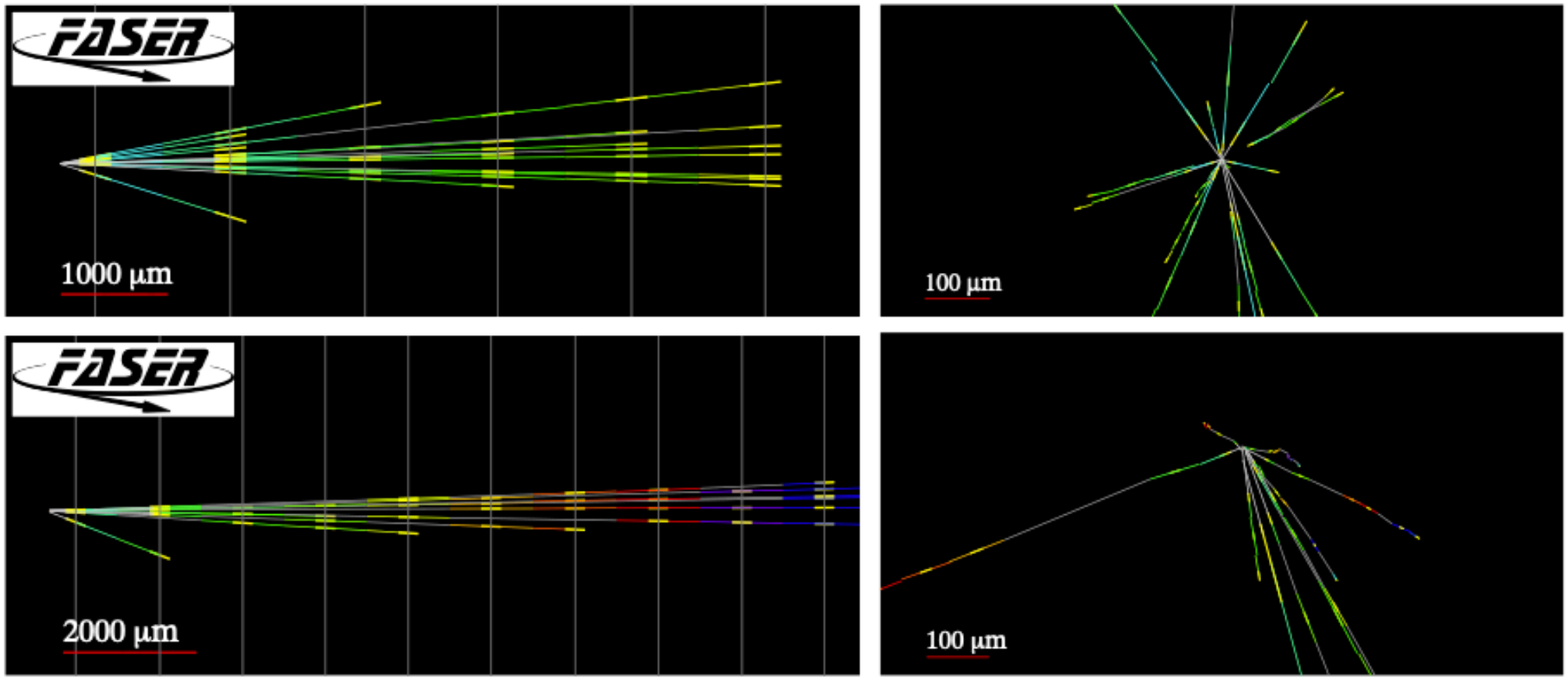


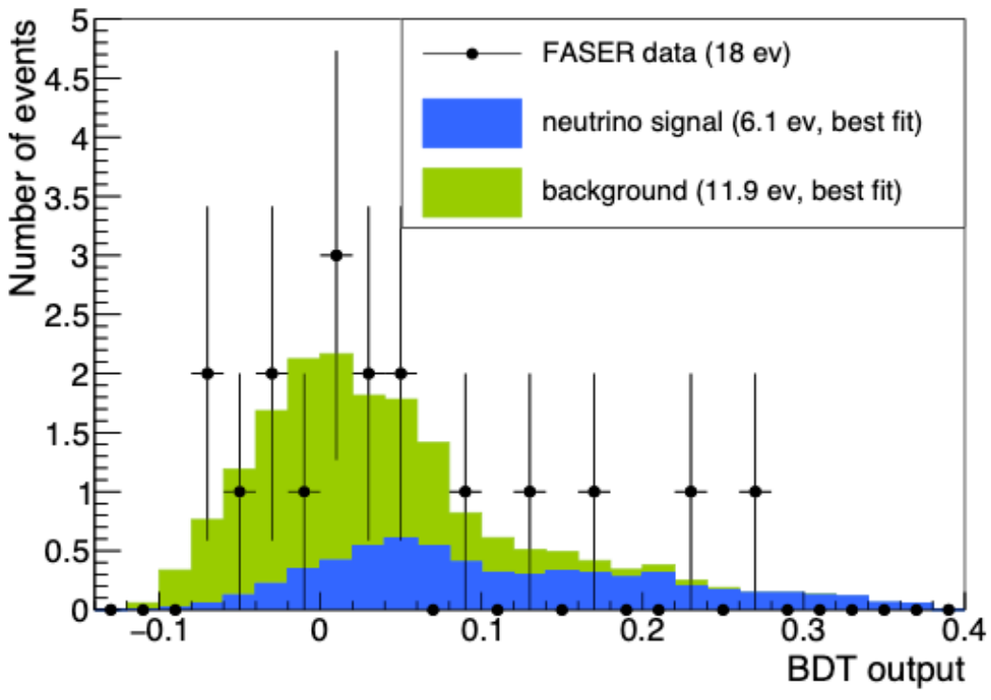


- Intense, strongly collimated beam of highly energetic neutrinos of all three flavors in the far-forward region around the beam collision axis.

Neutrinos at the Forward Physics Facility

- First neutrino interaction candidates at FASERν

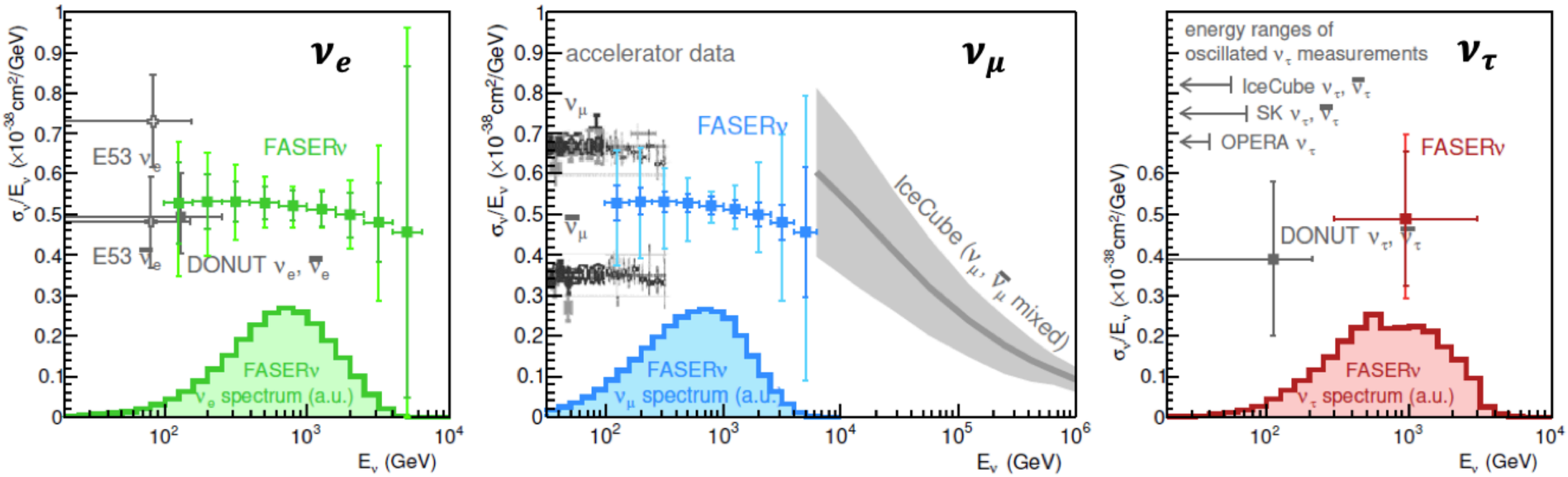




arXiv:2105.06197 [hep-ex]

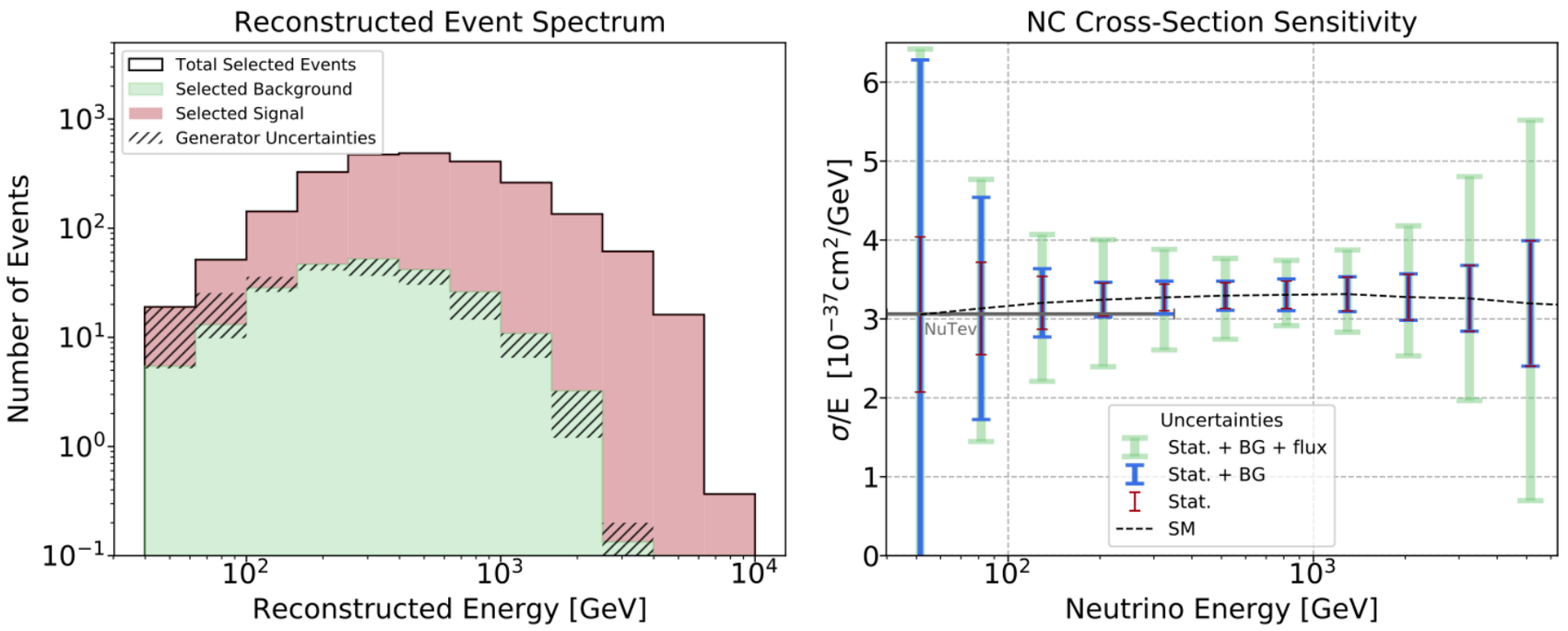
Neutrinos Cross Sections at FPF: Total Cross Section

- CC total cross sections at FASERν



[FASER Collaboration] arXiv:1908.02310 [hep-ex]

- NC total cross sections at FASERν

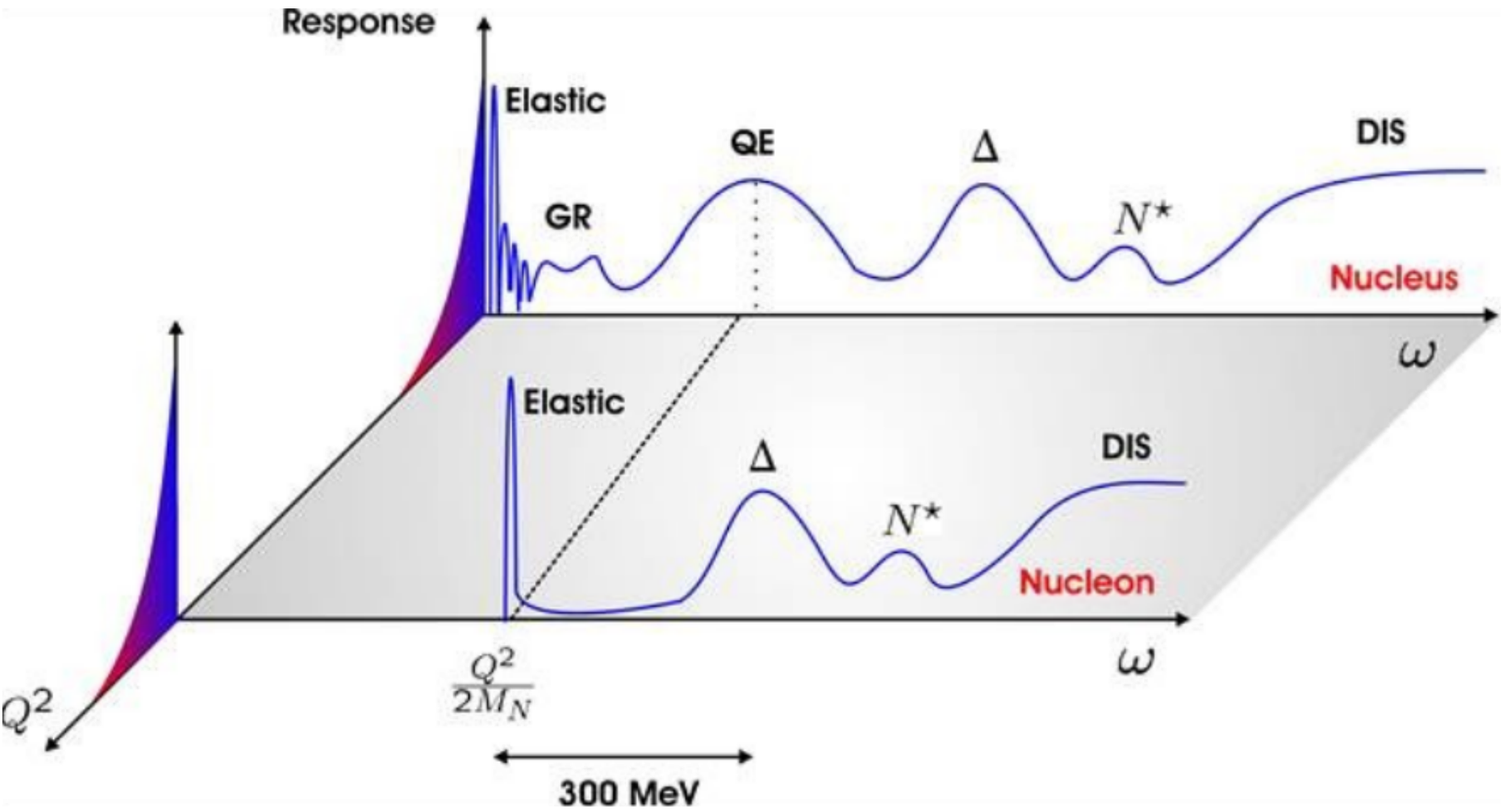


A. Ismail, R. M. Abraham and F. Kling, arXiv:2012.10500 [hep-ph]

Neutrinos Cross Sections Opportunities at FPF

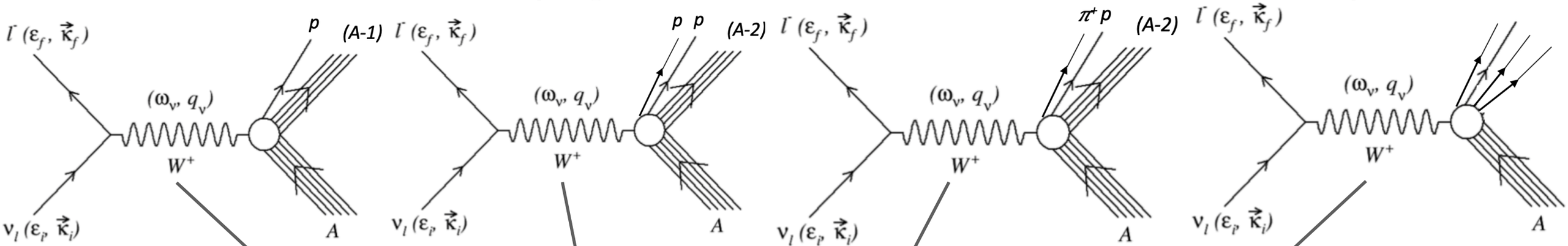
- Is there a potential to build a detailed neutrino-nucleon/nucleus cross section program at FPF to maximize the physics potential of the FPF in the HL-LHC era.

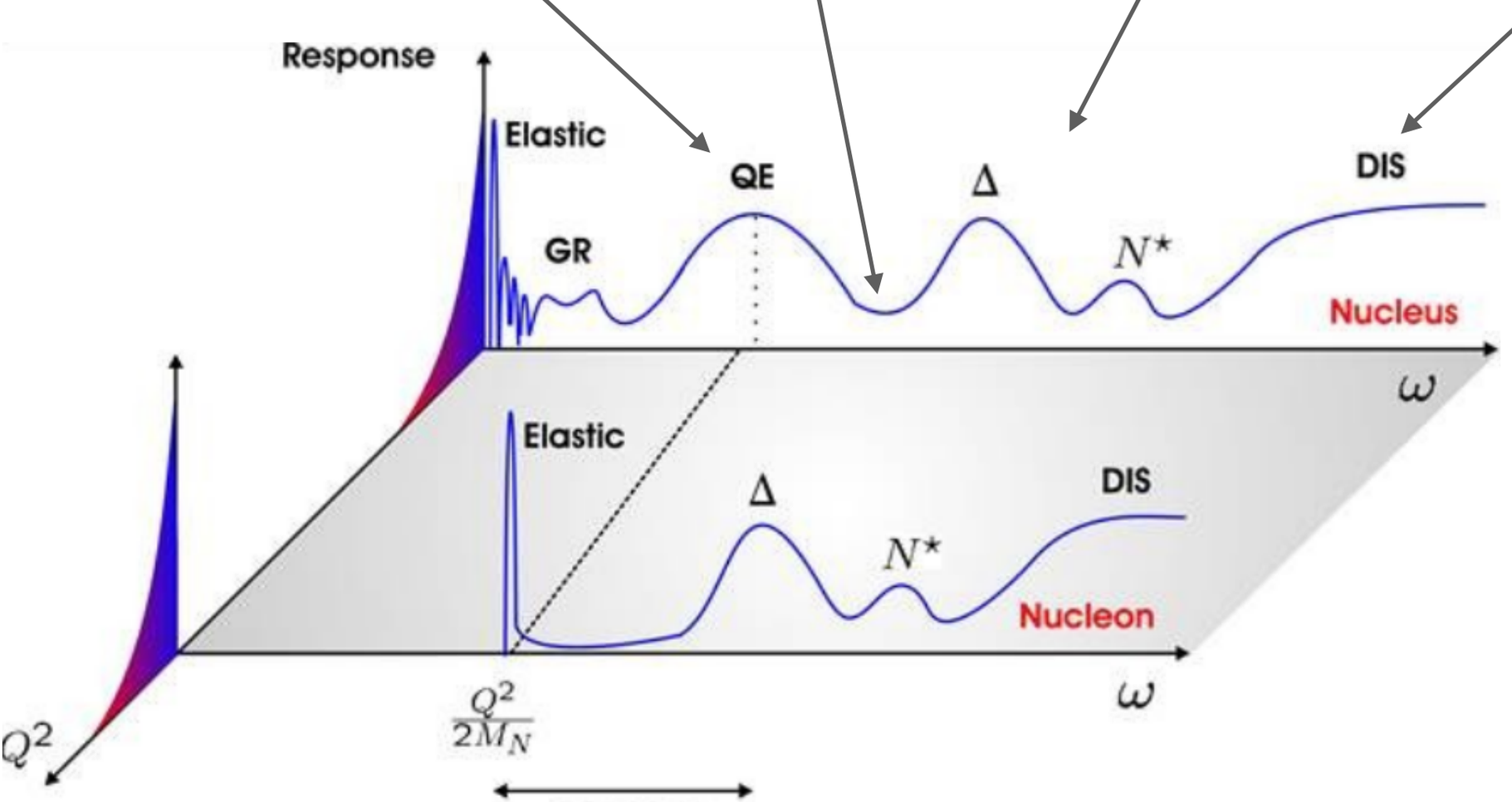
- If yes, what are the outstanding questions that can be tackled?



Neutrino Cross Sections Across Energies

Quasi Elastic | **Dip-region** | **Resonance** | **Deep Inelastic**





Neutrinos Cross Sections Opportunities at FPF

>10^3 expected quasi-elastic and resonant events (estimated with GENIE)

at FLArE	CCQE				CCRES				NCEL	NCRES
	ν_e	ν_μ	$\bar{\nu}_e$	$\bar{\nu}_\mu$	ν_e	ν_μ	$\bar{\nu}_e$	$\bar{\nu}_\mu$	all	all
Event Rate	58	590	47	366	167	1673	184	1219	175	1206

Sebastian Trojanowski

QCD and Neutrino: Parallel Session

- **Semi-hard reactions at the Forward Physics Facility** *Michael Fucilla*
- **Hadronic structure at a Forward Physics Facility** *Dr Francesco Giovanni Celib...*
- **Probing PDFs via Neutrino Scattering with FASERν** *Jason Arakawa*
- **LEvEL: Low-Energy Neutrino Experiment at the LHC** *Kevin Kelly*
- **Addressing the cosmic ray muon excess by probing a "fi..** *Julien Manshanden*
- **Dark Sectors via Proton Bremsstrahlung** *Saeid Foroughi-Abari*

- Neutrino cross sections are poorly known, no unified theoretical description. Largest source of systematic uncertainty in accelerator neutrino physics (MicroBooNE, DUNE, T2K, etc.).

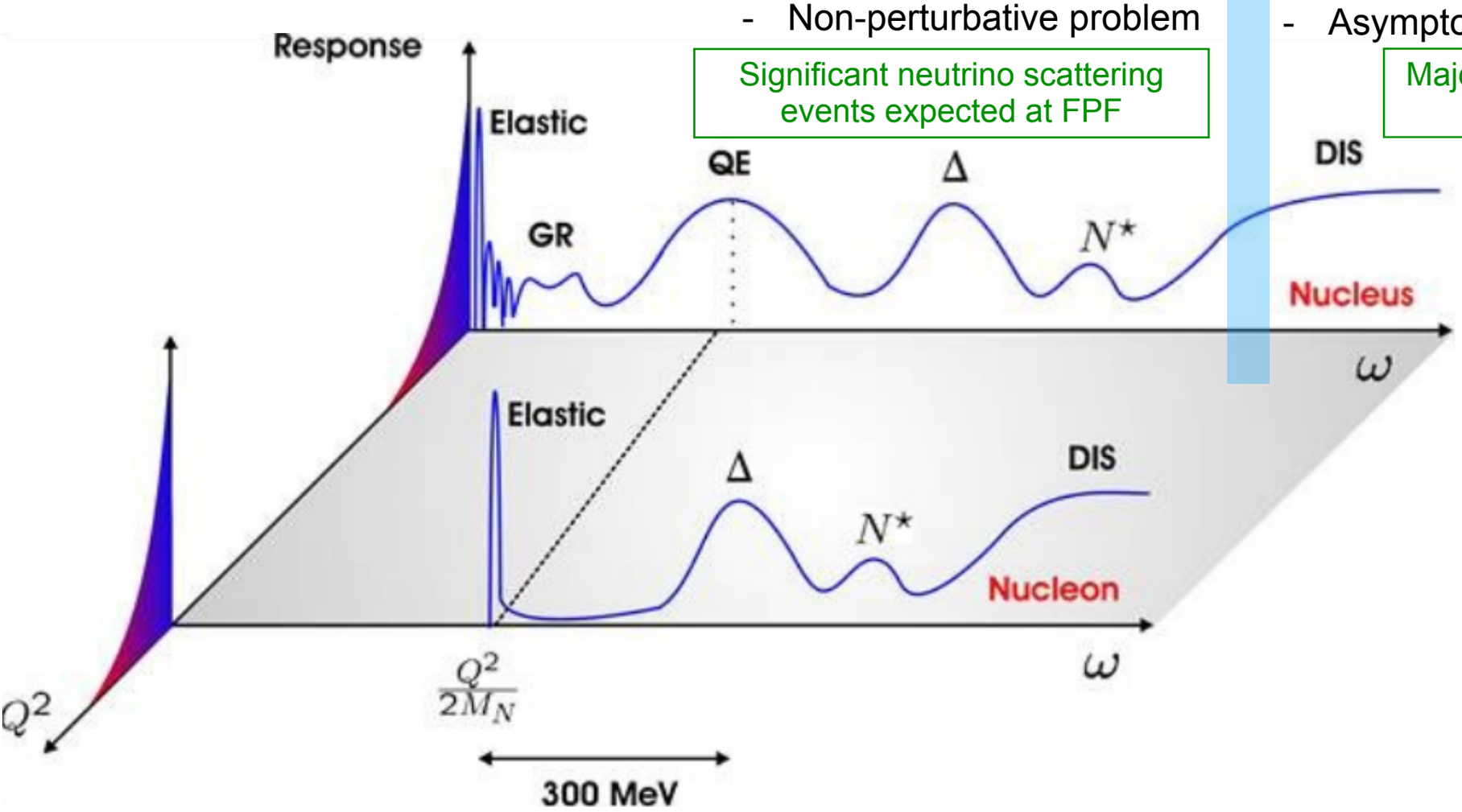
Nuclear/Hadronic Physics ⟵ | ⟶ **QCD**

- d.o.f.:hadrons and pions
- Non-perturbative problem

Significant neutrino scattering events expected at FPF

- d.o.f.:quarks and gluons
- Asymptotic freedom, confinement

Majority of the expected neutrino scattering events at FPF



Neutrinos Cross Sections Opportunities at FPF

- **SIS-DIS Region/Quark-Hadron Duality**: transition from interactions described in terms of hadronic degrees of freedom to quarks and gluons degrees of freedom. Neither well studied theoretically nor are there experimental measurements in the weak sector.

Nuclear/Hadronic Physics

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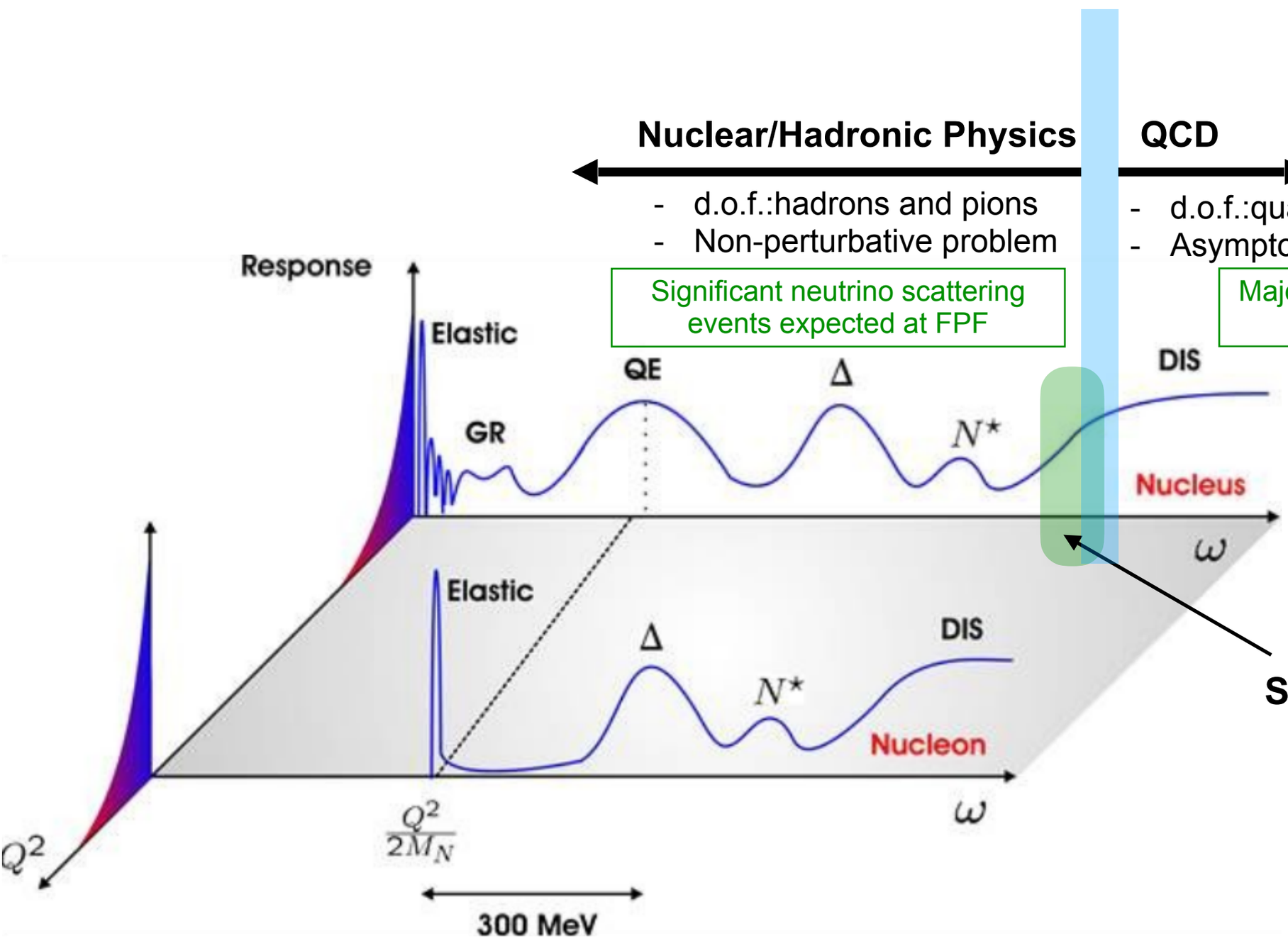

SIS: Shallow Inelastic Scattering

Neutrinos Cross Sections Opportunities at FPF

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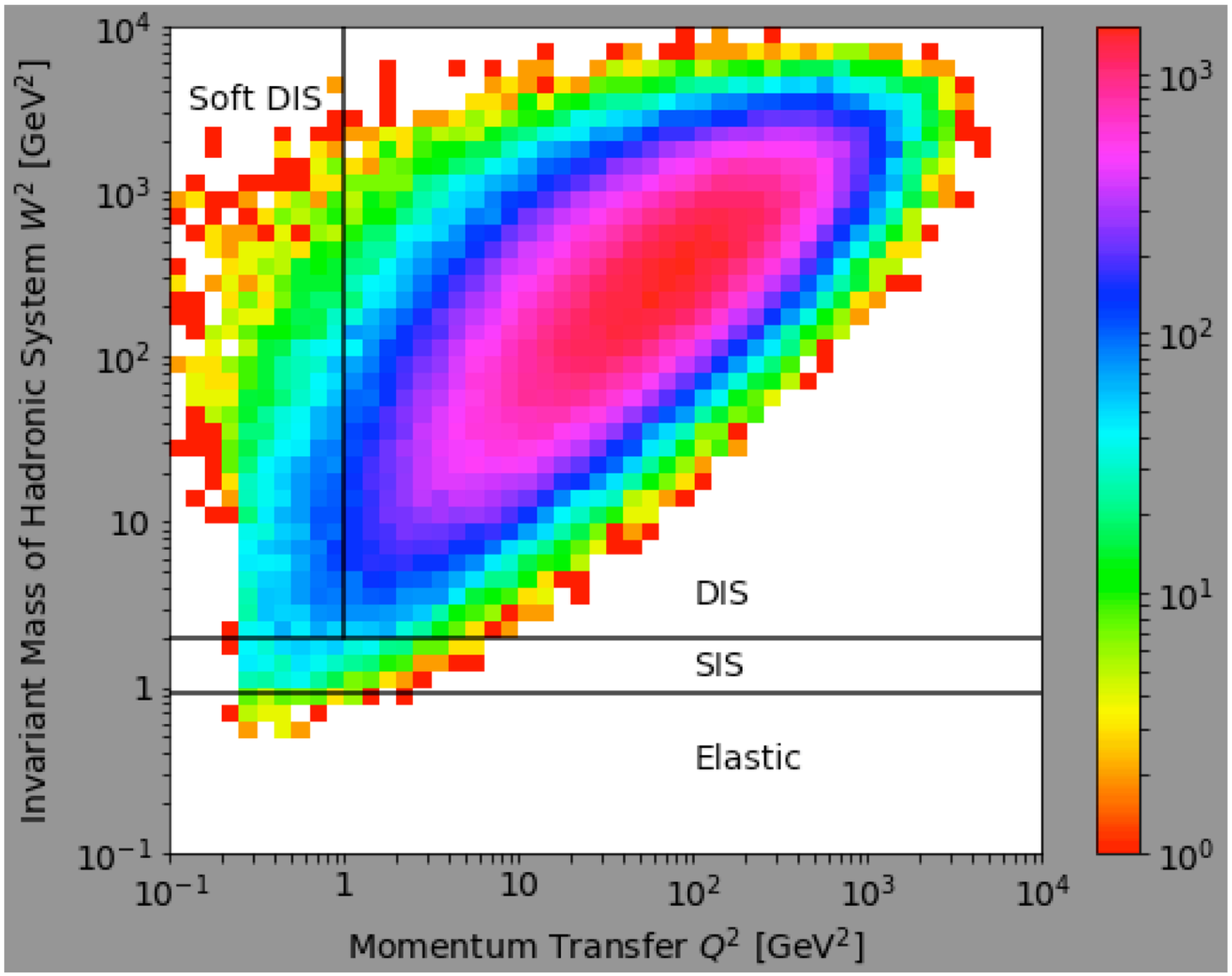
  - Expected events for CC $\nu_\mu - {}^{40}Ar$ scattering in FLArE-10 during HL-LHC exposure.



Plot by Felix Kling. Events generated using Pythia8.

- Expected $\mathcal{O}(1000)$ SIS events (according to Pythia8).

- Detailed exclusive measurements of hadron production, multiplicities, angular and momentum distributions are more informative.

- $W > 2\ GeV$ and $Q^2 > 1\ GeV^2$ is usually defined as DIS region

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- **Multi-dimensional Cross Sections**: Measure differential cross section in leptonic and hadronic kinematics. Differential cross-sections are more informative in order to explore underlying nuclear/nucleonic physics.

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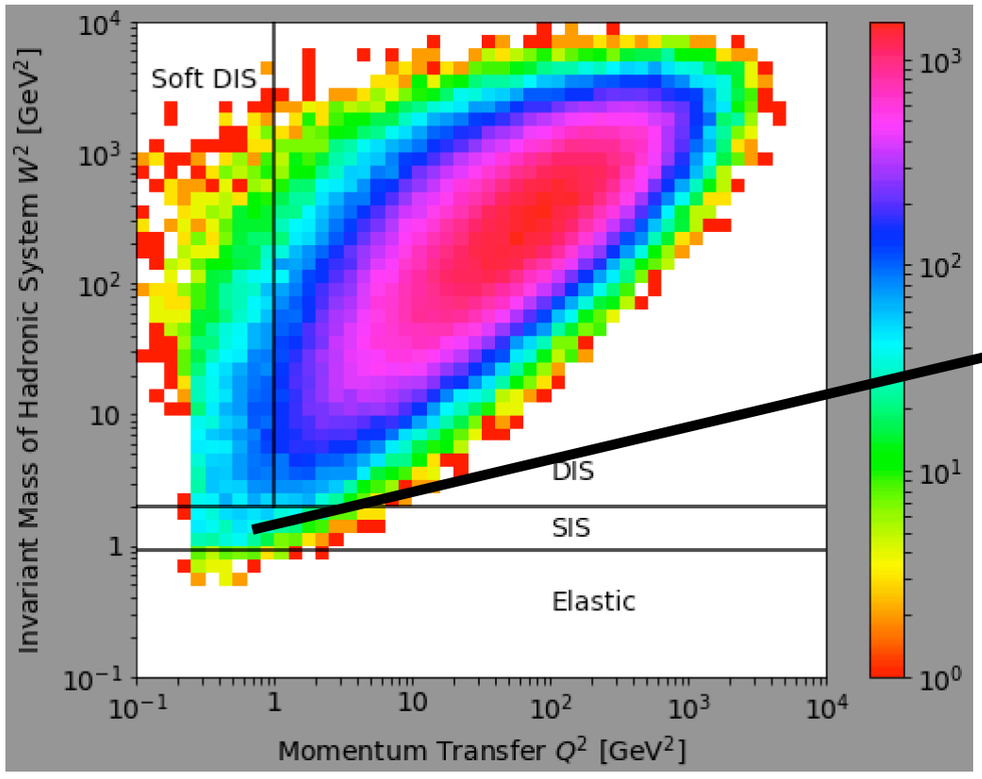

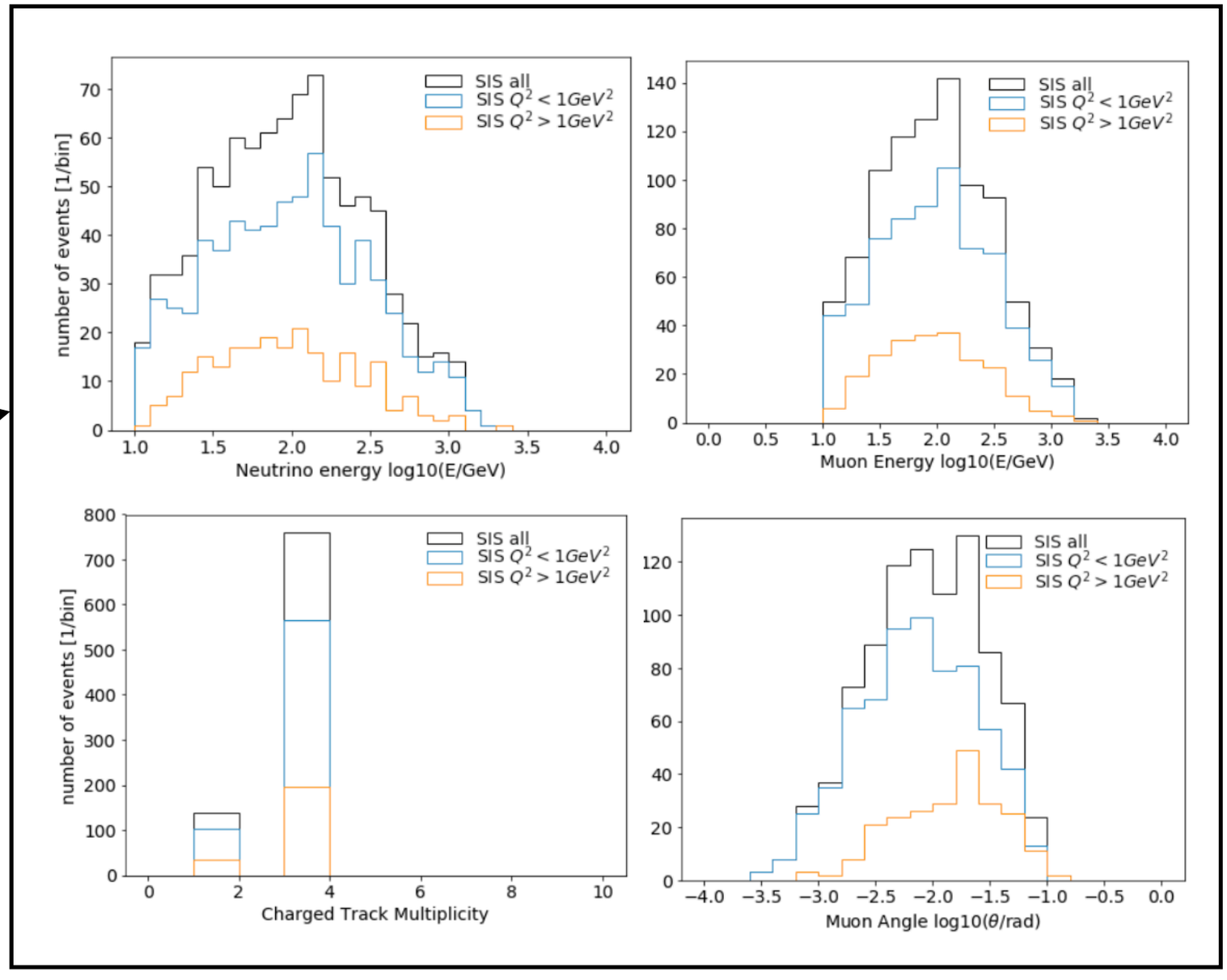

Plots by Felix Kling. Events generated using Pythia8.

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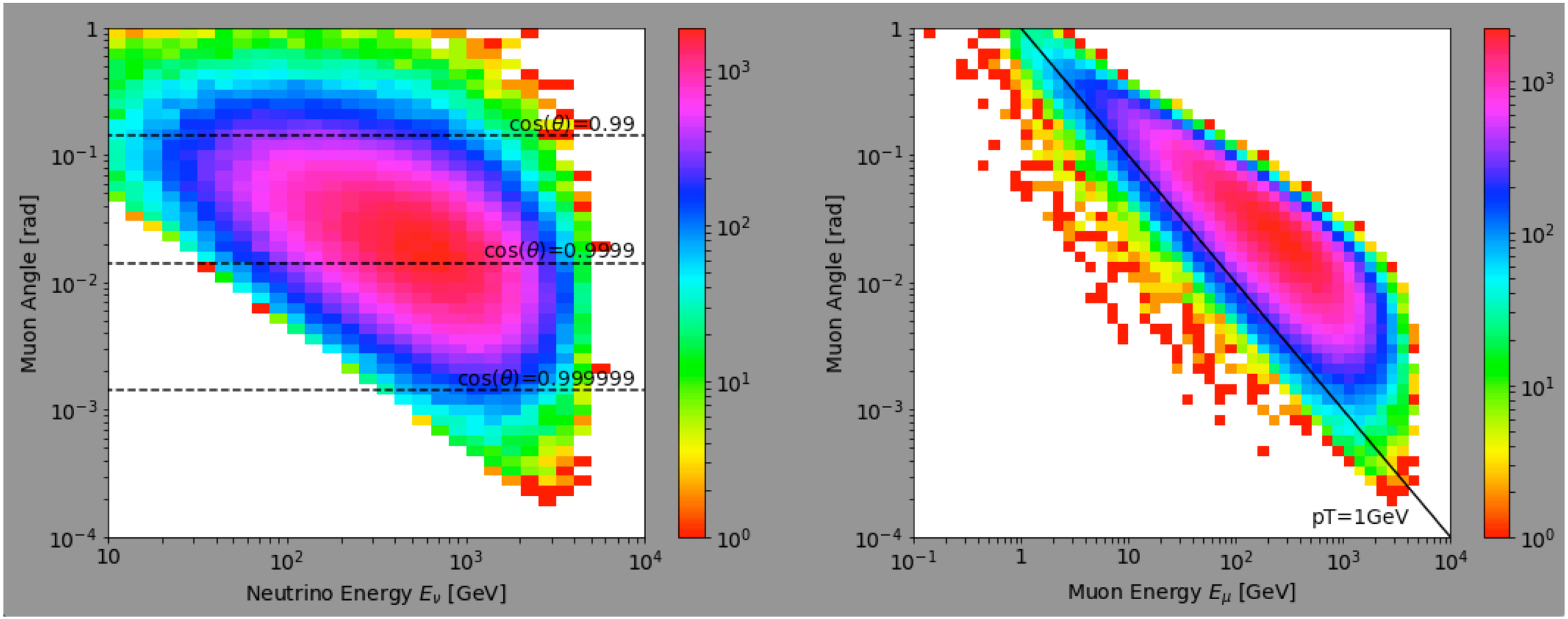

- Significant events across range of kinematics.

Plots by Felix Kling. Events generated using Pythia8.

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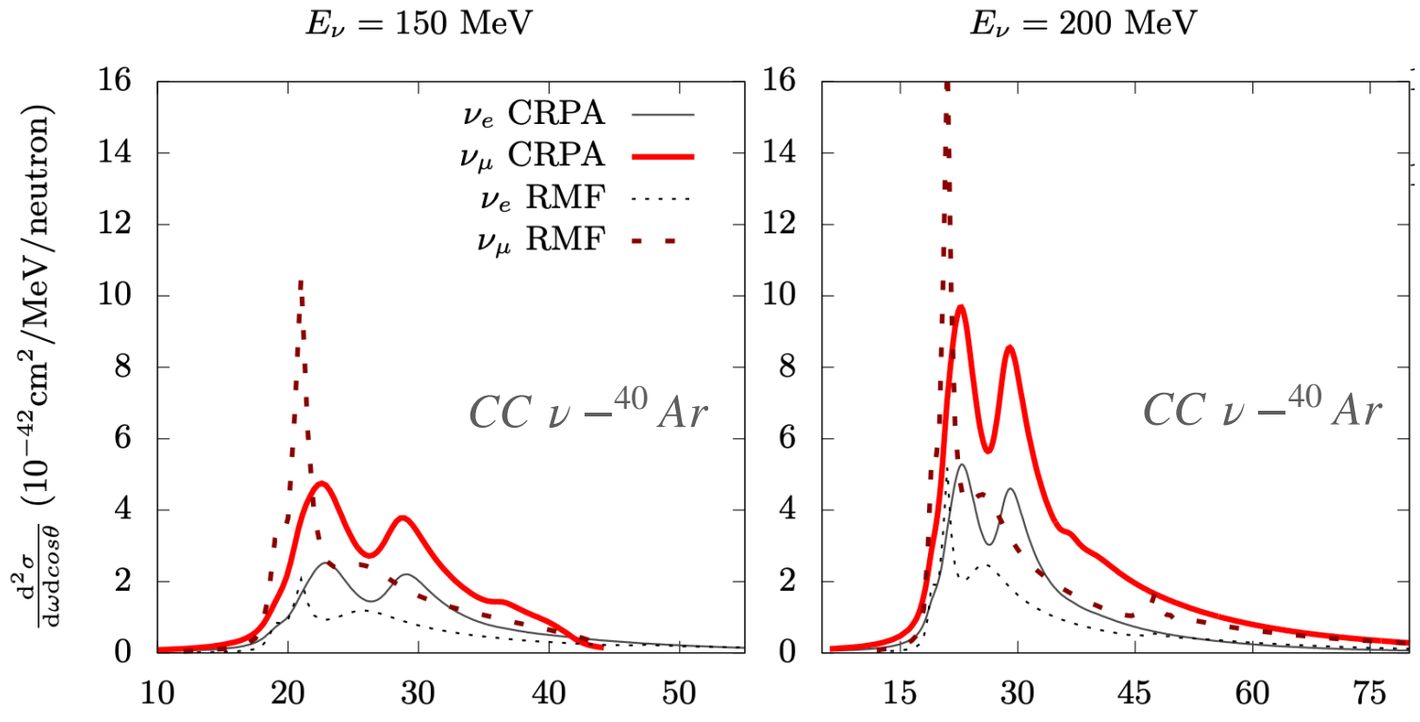
- **Test of Lepton Flavor Universality**: Measure ν_e CC vs. ν_μ CC vs. ν_τ CC scatterings, different lepton mass in the final state may affect CC cross sections.

- An example of lepton mass affecting ν_e to ν_μ cross sections at low energies.



A. Nikolakopoulos, N. Jachowicz, N. Van Dessel, K. Niewczas, R. González-Jiménez, J. M. Udías, VP, Phys. Rev. Lett. 123, 052501 (2019)

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- **Neutrino vs Antineutrino Scattering:** In an isospin asymmetric nuclei (e.g. argon), neutrino and antineutrino may behold different nuclear/nucleonic effects. Need Magnetized detectors (e.g. magnetized LArTPC).

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- Expected events for CC $\nu_\mu - {}^{40}Ar$ scattering in FLArE-10 during HL-LHC exposure.

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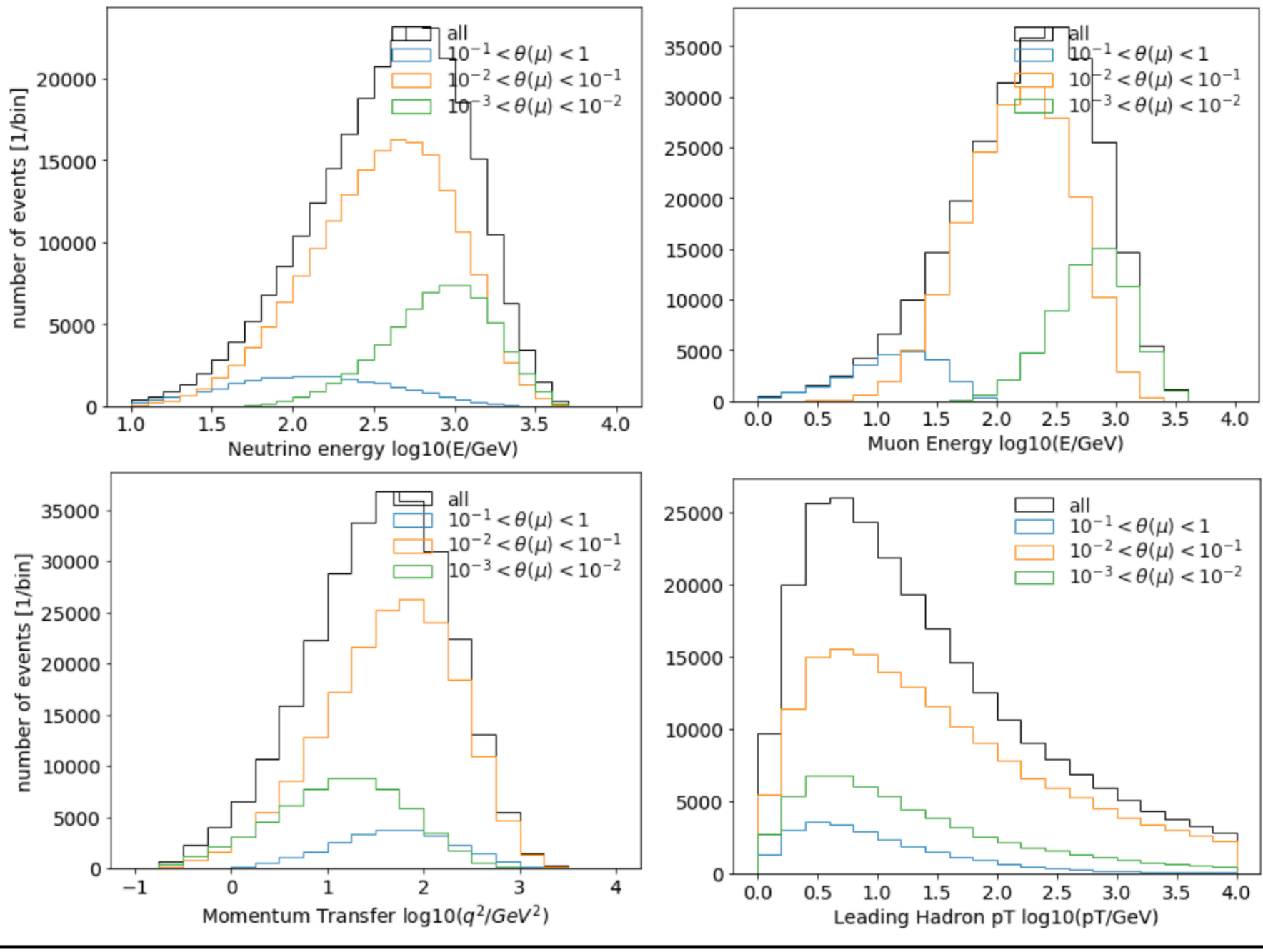

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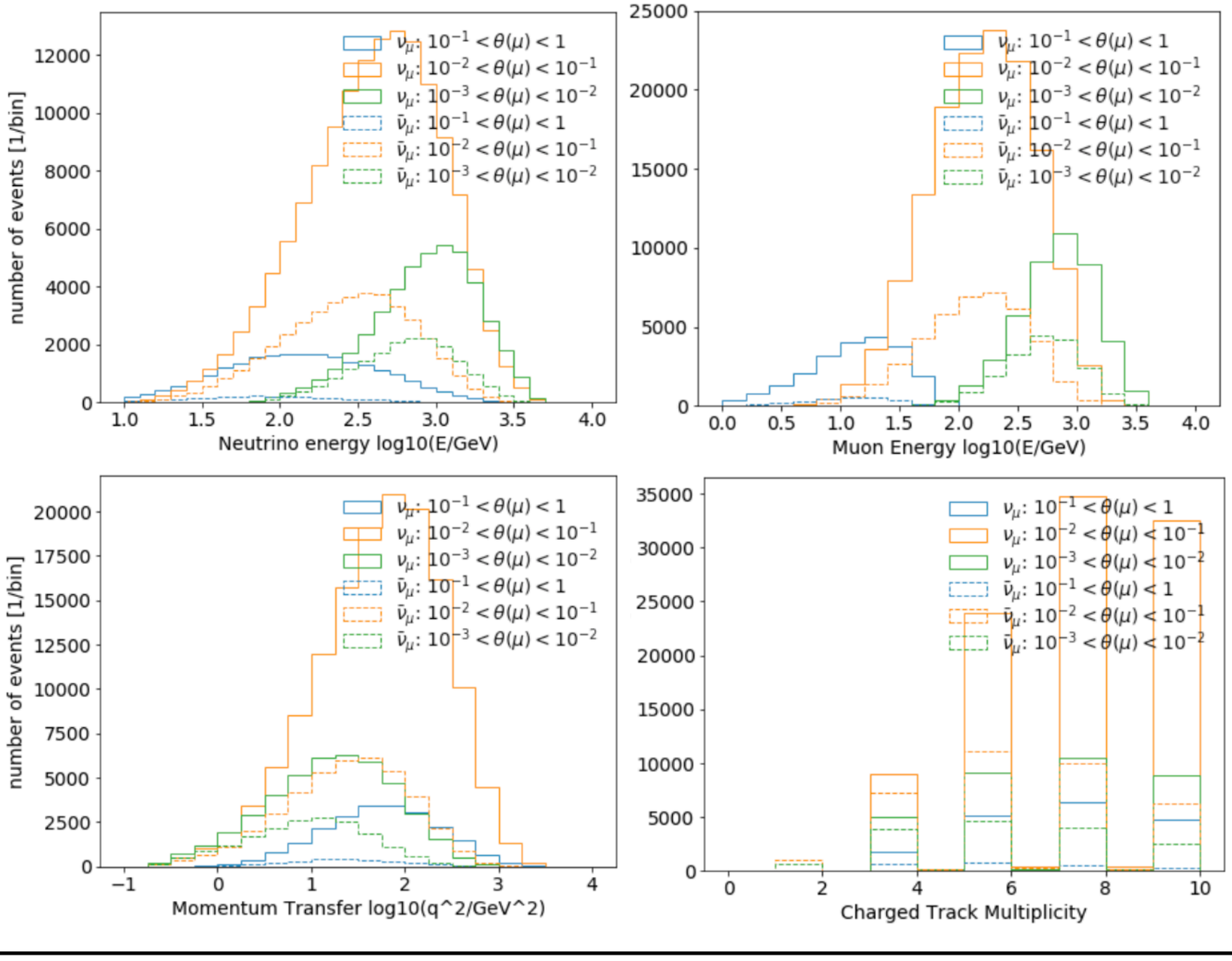

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Summary

✦ Forward Physics Facility provides a unique opportunity to develop a detailed neutrino-nucleus/nucleon program that covers a broad range of kinematic. Such a program greatly enhances and compliments the overall physics potential of the FPF in the HL-LHC era.

- **SIS-DIS Region/Quark-Hadron Duality:** transition from interactions described in terms of hadronic degrees of freedom to quarks and gluons degrees of freedom. Neither well studied theoretically nor are there experimental measurements in the weak sector.

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