Neutrinos in Lake Geneva

Measuring the LHCb Forward Neutrino Flux with Large-Scale Detectors

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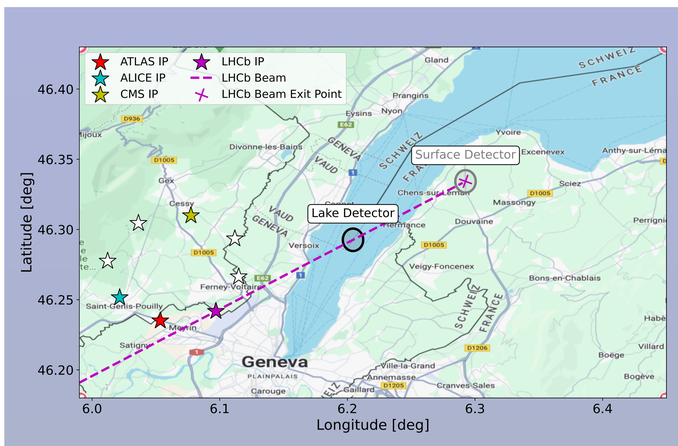
Introduction

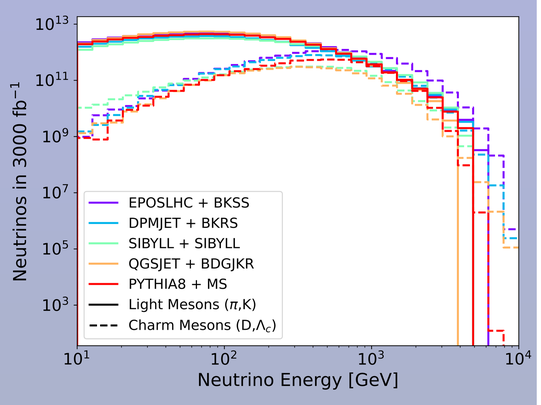
The era of collider neutrinos is upon us, ushered in by FASER's recent observation of the first neutrinos from proton-proton collisions at the LHC [1]. In this work, we propose two large-scale detectors along the LHCb forward flux beam line:

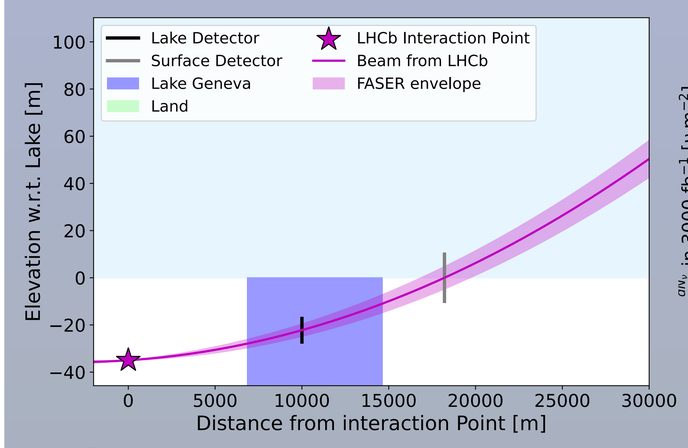
1. A 100-m-long, 5-m-radius Cherenkov detector deployed in Lake Geneva, sensitive to all-flavor neutrino interactions within the fiducial volume
2. A 10-m-radius scintillator panel detector deployed at the surface exit point of the beam, sensitive to charged-current muon neutrino interactions

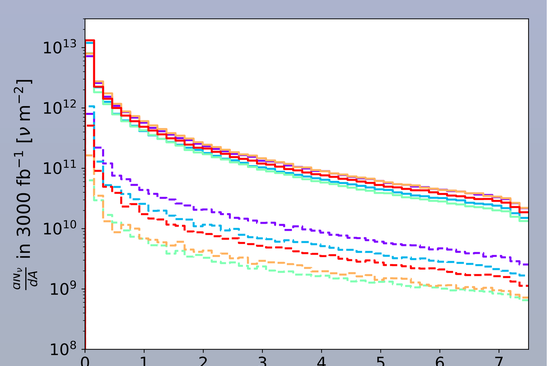
These detectors would record 1-10M neutrino interactions over the course of the high-luminosity Large Hadron Collider (HL-LHC) era, providing new insights into TeV-scale neutrino interactions and charm production in p-p collisions

Experimental Configuration



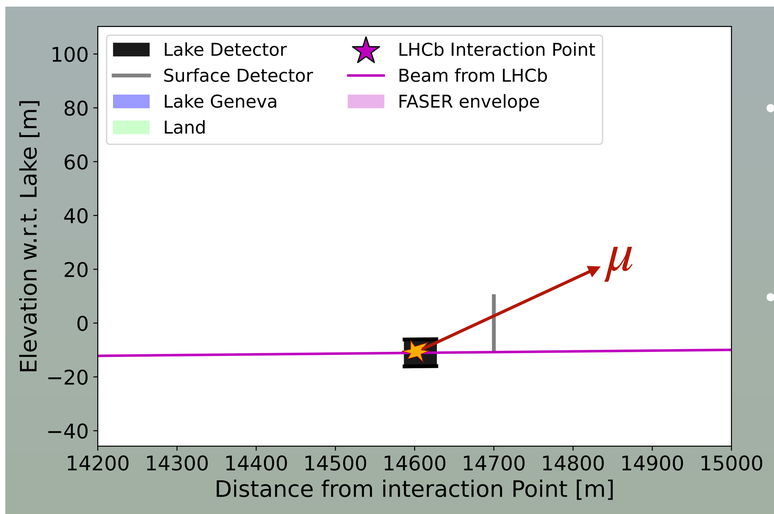




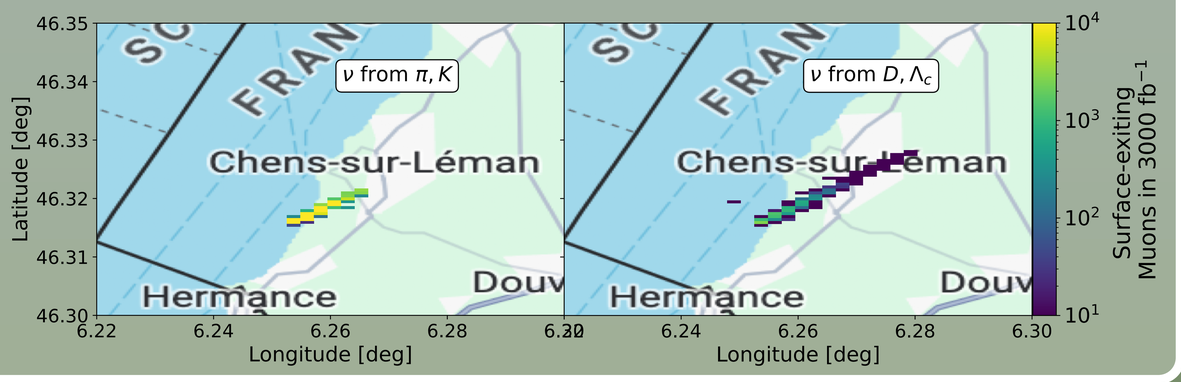


- **Surface detector:** scintillator panels measuring crossing muons from ν_μ interactions in the surrounding bedrock
- **Lake detector:** water-Cherenkov detector built in a modular fashion, using CHIPS-style sub-detectors [2]
- LHCb neutrino flux prediction from forward-nu-flux-fit [3]

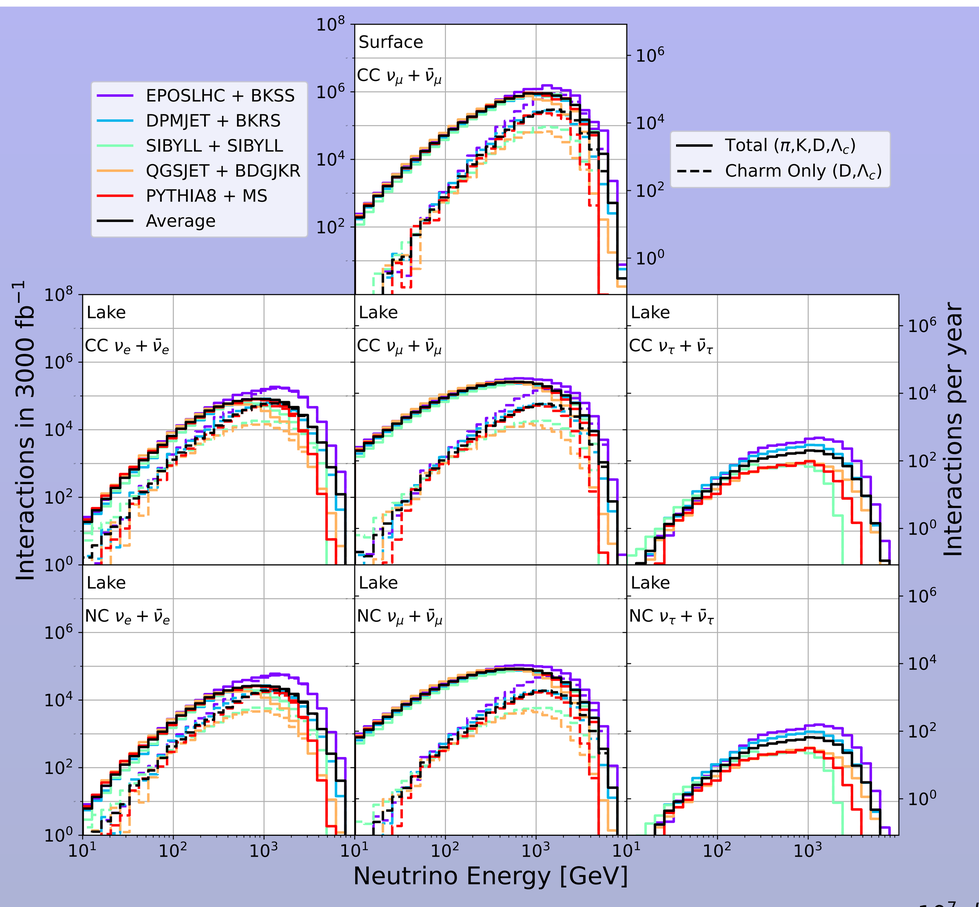
Correlated Lake-Surface Measurement

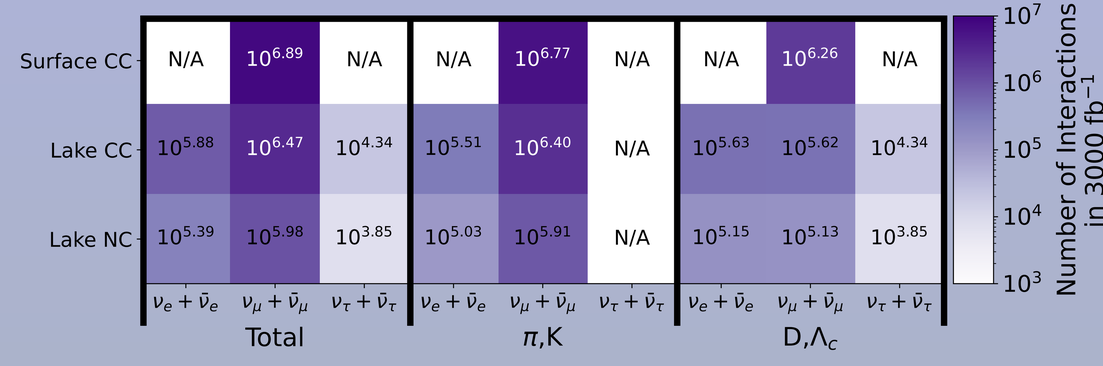


- A ν_μ CC interaction with high Q^2 could be visible in both the lake and surface detectors
- Requires closer proximity between detectors to maximize muon survival probability



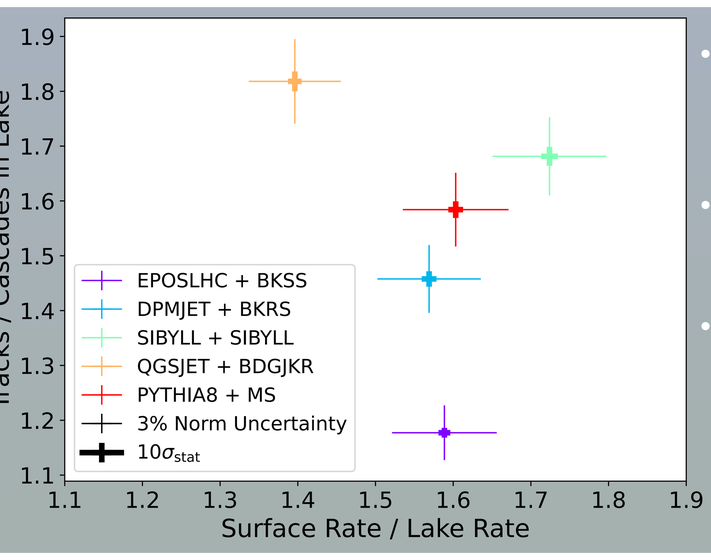
HL-LHC Event Rates





- Event rates assume the nominal HL-LHC luminosity (3000 fb^{-1}), DIS cross sections from [4], and account for muon survival probabilities
- **Surface detector:** ~10 million muons from neutrino interactions during the 12 years of HL-LHC operation
- **Lake detector:** ~5 million contained neutrino interactions over HL-LHC

Flux Model Sensitivity



- Ratio measurements can differentiate between flux models
- Track $\equiv \{\nu_\mu \text{ CC}\}$
  Cascade $\equiv \{\nu_{e,\tau} \text{ CC}, \nu_\alpha \text{ NC}\}$
- This measurement constrains forward charm production in p-p collisions and, in turn, the prompt atmospheric neutrino flux [5]

Conclusion

1. Large-scale lake and surface-based detectors can observe 1-10M neutrinos interactions from LHCb throughout the HL-LHC
2. These high-stats samples can constrain forward charm production in p-p collisions and the prompt atmospheric flux
3. Coincidence measurements between the lake and surface detectors are potentially sensitive to the high Q^2 region of the ν_μ CC cross section

References

[1] FASER Collab. 2023
[2] CHIPS Collab. 2024
[3] github/makelat/forward-nu-flux-fit
[4] Cooper-Sarkar+ 2011
[5] Bai+ 2022

Acknowledgments

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