FASER

Workshop on Forward Physics and QCD with EIC, LHC and cosmic rays

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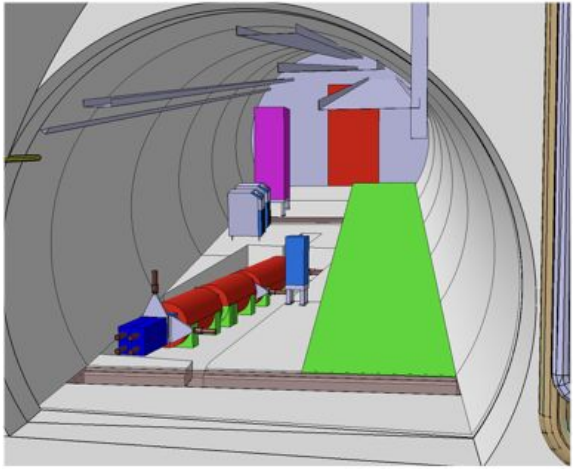
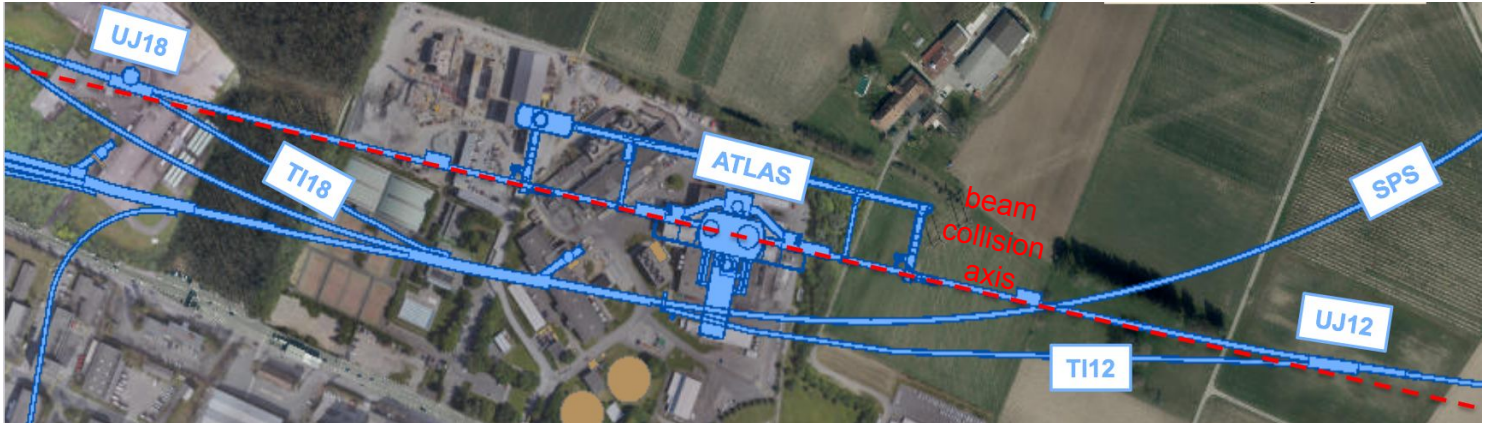
FASER

FASER, the ForwArd Search ExperRiment, is the newest experiment at the LHC.

It is placed along the beam collision axis, about ~500m downstream from the ATLAS interaction point in the previously unused service tunnel TI12. It covers region η>9.

FASER will search for new long-lived particles and probe neutrino interactions at TeV energies.





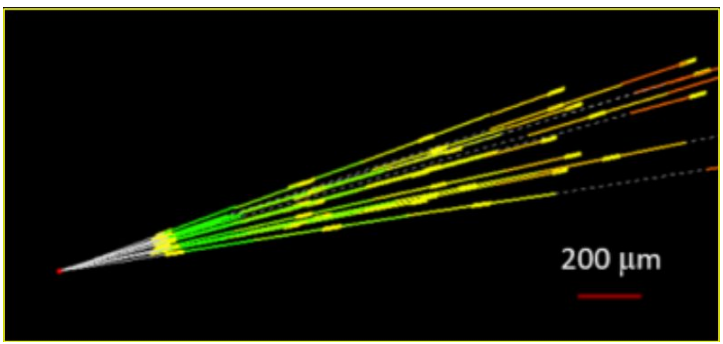
An Example: Neutrinos at the LHC

No collider neutrino has ever been detected.

But there is a huge flux of neutrinos in the forward direction. De Rujula et al. (1980s)

In 2018, the FASER collaboration placed ~30 kg pilot emulsion detectors in the far forward region for a few weeks.

Expect ~10 neutrino interactions. Several neutral vertices have been identified, likely to be neutrinos. Analysis ongoing.

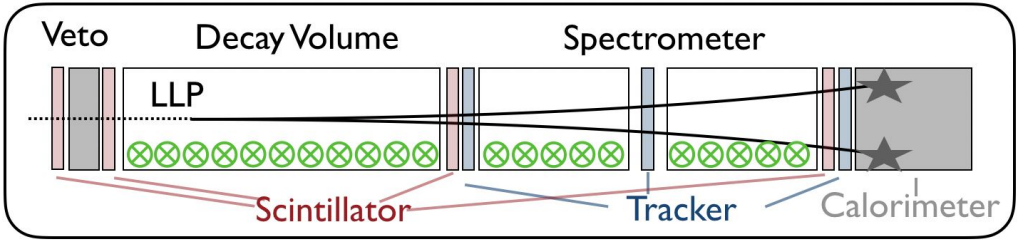


FASER Status

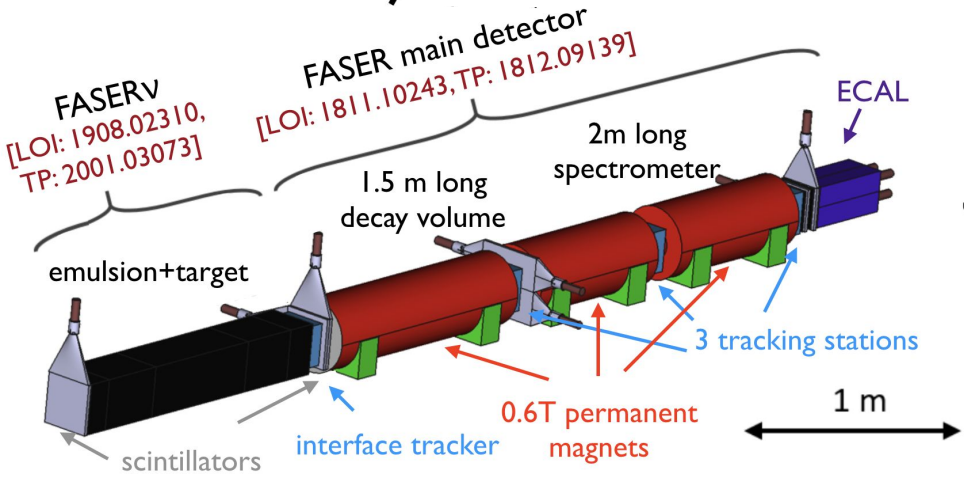
The FASER experiment is approved, funded and currently under construction. It will take data during LHC Run 3 (2022-2024).

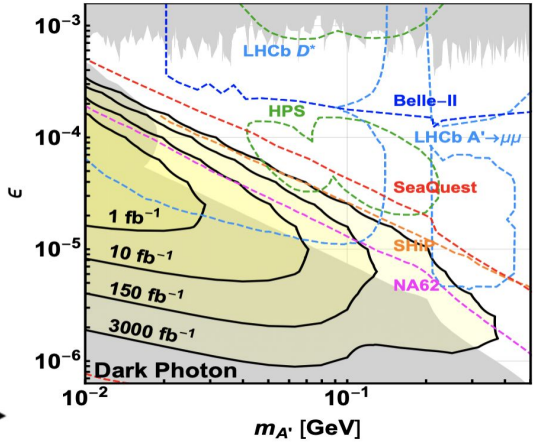
FASER experiment
(under construction)

FASER: LLP Searches

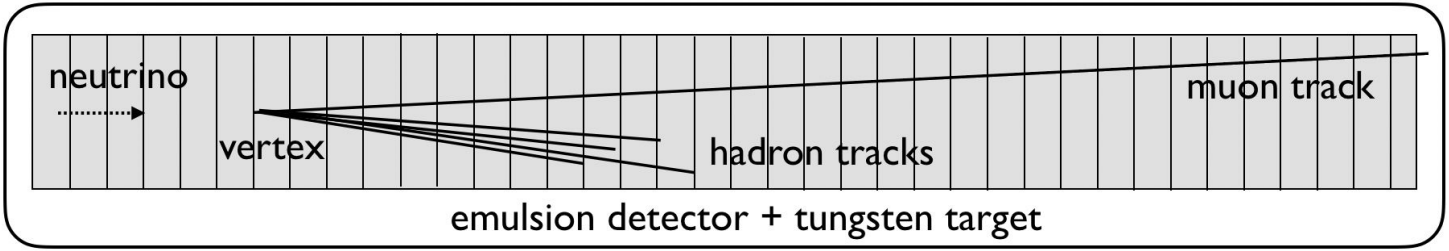


main goal: long-lived particle searches

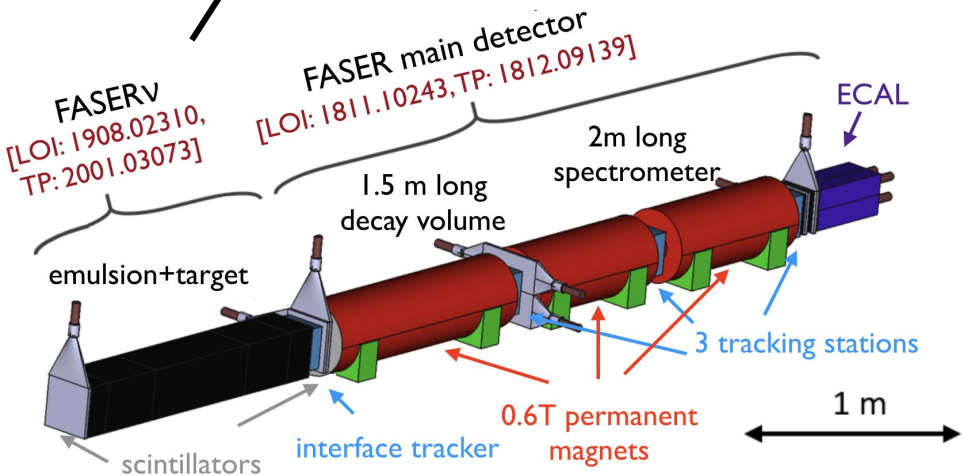


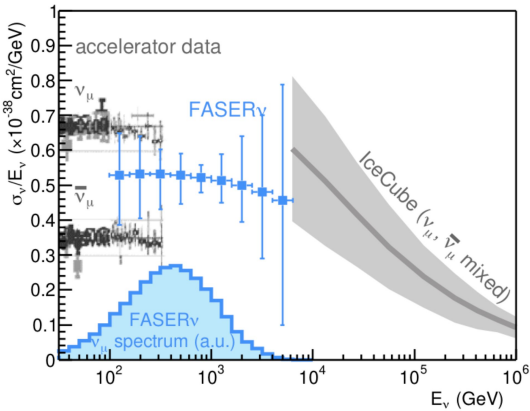


FASER: Neutrino Physics



main goal: neutrino physics at the LHC



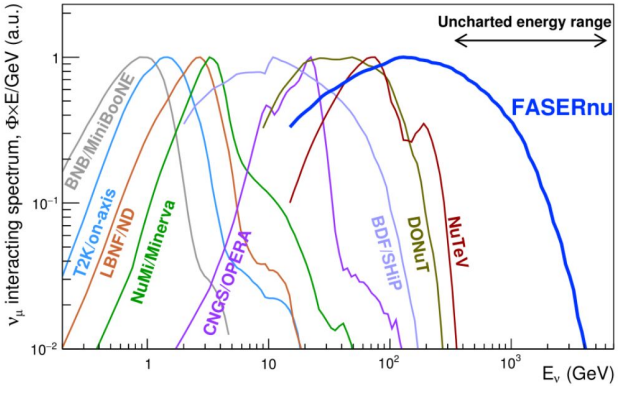


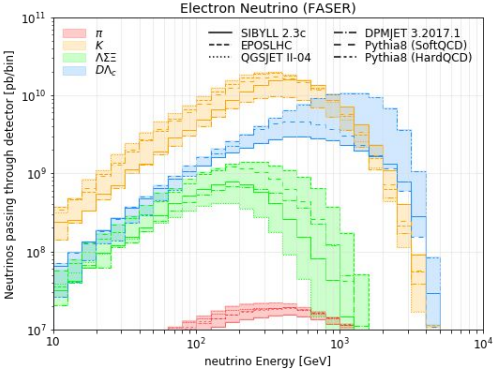
FASERν Neutrino Spectra

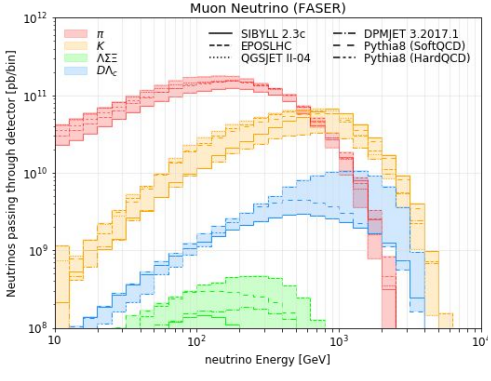
The LHC neutrino beam is broad, with mean energies around 1 TeV, exceeding the energies of all other artificial neutrino sources.

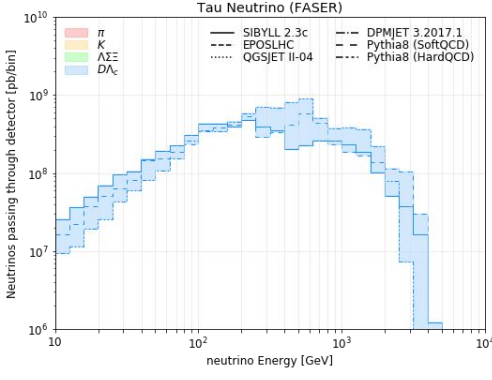
It originates from a variety of sources: pion, kaon, hyperon and charm decays.

About 1000 electron neutrinos, 10000 muon neutrinos and 10 tau neutrino interactions are expected to be identified.



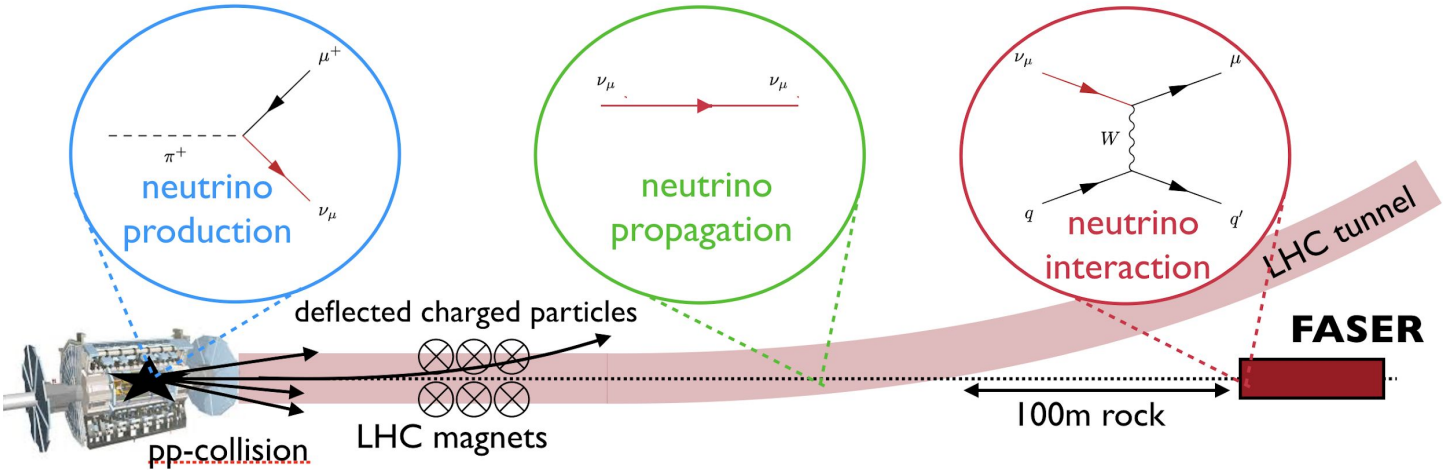






LHC Neutrino Physics Potential

What can we do learn from those neutrinos?

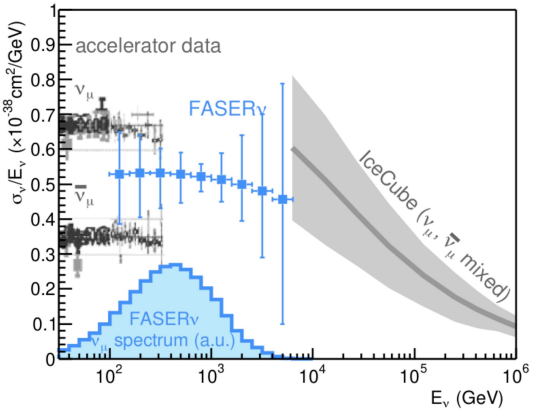


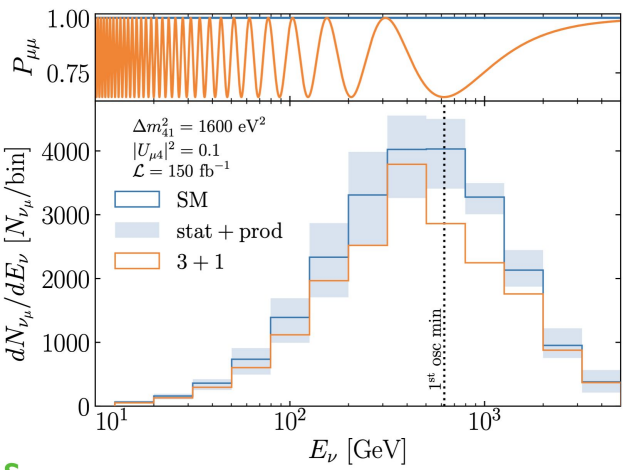
In the following, I will present some ideas.

Neutrino Physics

FASERν will measure neutrino cross section at unexplored TeV energies for all three flavors. Both CC and NC are possible.

FASERν will detect ~10 tau neutrino interactions, which is similar to DONuT and OPERA. Thousands of tau neutrino events possible at HL-LHC, allowing for precision studies of tau neutrino properties.



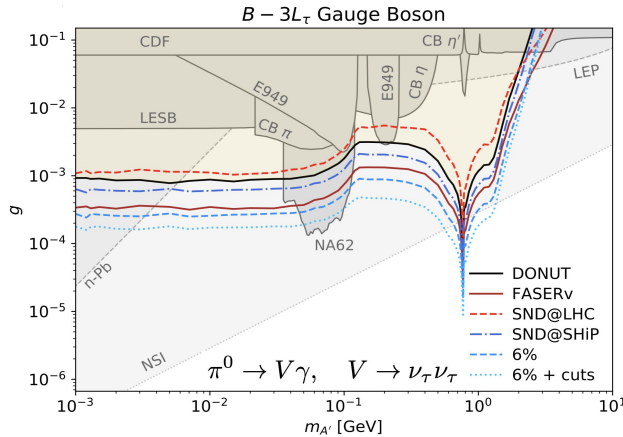


FASERν will record neutrino interaction event shapes with high precision. This could be useful for validation/tuning of neutrino event generators.

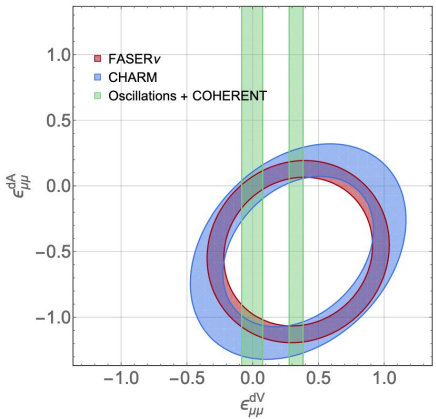
SM neutrino oscillations are expected to be negligible at FASERν. However, sterile neutrinos with mass ~40eV can cause oscillations. FASERν could act as a short-baseline neutrino experiment.

BSM Physics

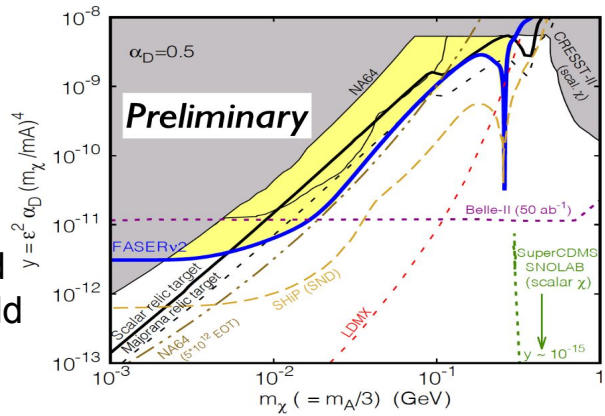
The tau neutrino flux small in SM. A new light weakly coupled gauge bosons decaying into tau neutrinos could significantly enhance the tau neutrino flux. Kling 2005.03594



NC measurements at FASERν could constrain neutrino non-standard interactions (NSI). Abraham, Ismail, Kling 2012.10500



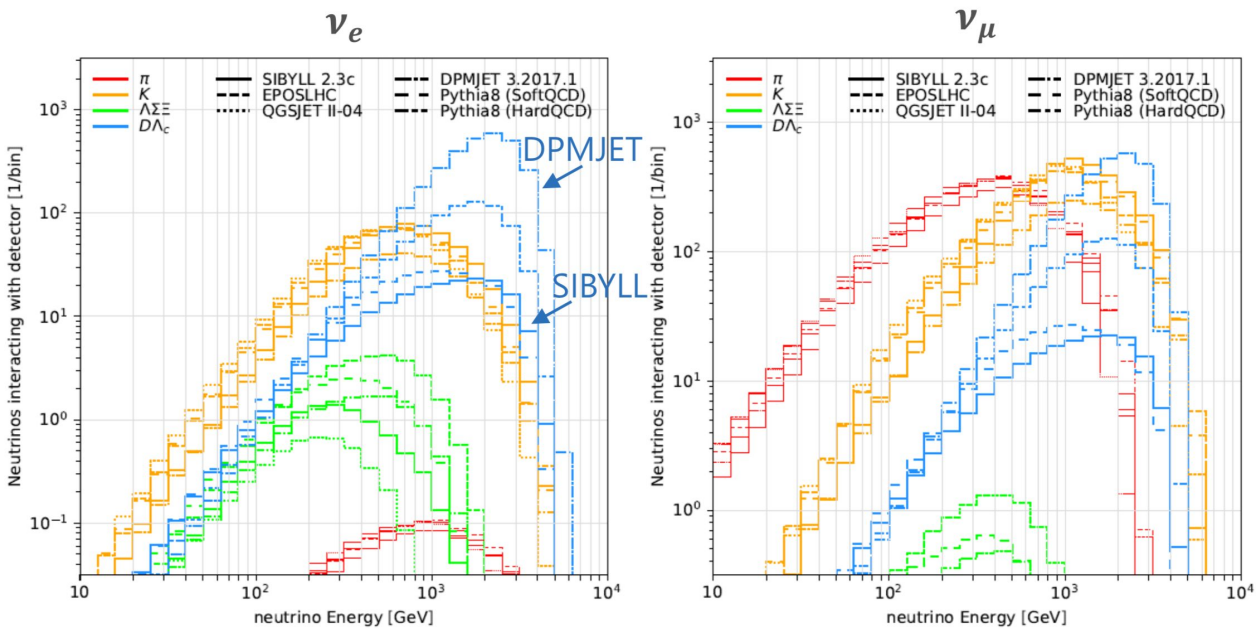
If DM is light, the LHC can produce an energetic and collimated DM beam towards FASERν. FASERν could therefore also search for DM scattering. Batell, Feng, Trojanowski 2020 (to appear)



QCD: Generators

Forward particle production is poorly constrained by other LHC experiments. FASERν's neutrinos flux measurements will provide novel complimentary constraints that can be used to validate/improve MC generators.

We need to quantify and reduce these uncertainties.

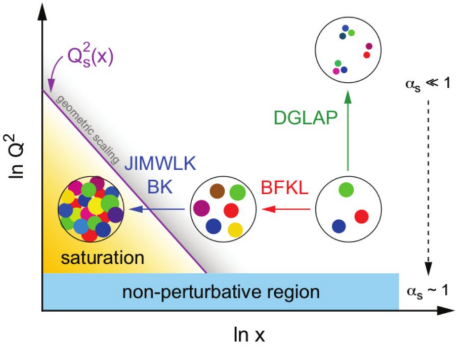


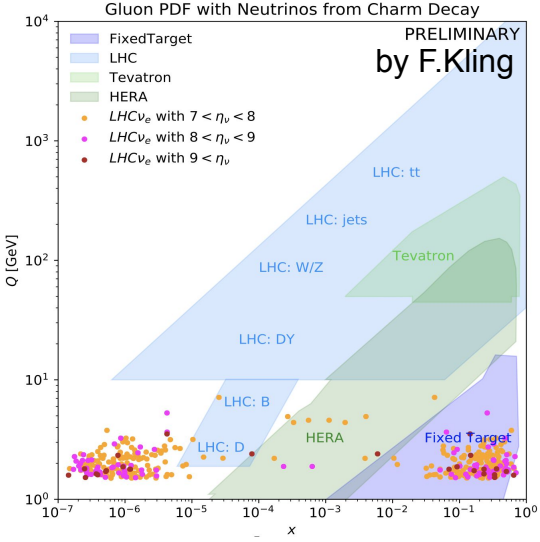
QCD and charm production

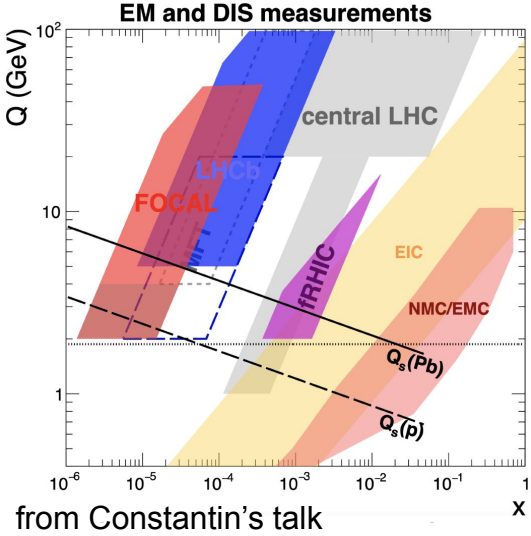
Electron neutrinos at high energy and tau neutrinos are mainly produced in charm decays:

$g\,g \rightarrow c\,c\,,\;\; c \rightarrow D,\quad D \rightarrow K\,l\,\nu$

Neutrinos from charm decay could allow to test transition to small-x factorization, constrain low-x gluon PDF and probe intrinsic charm.







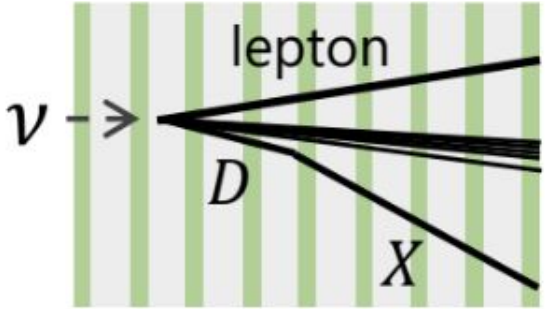
from Constantin's talk

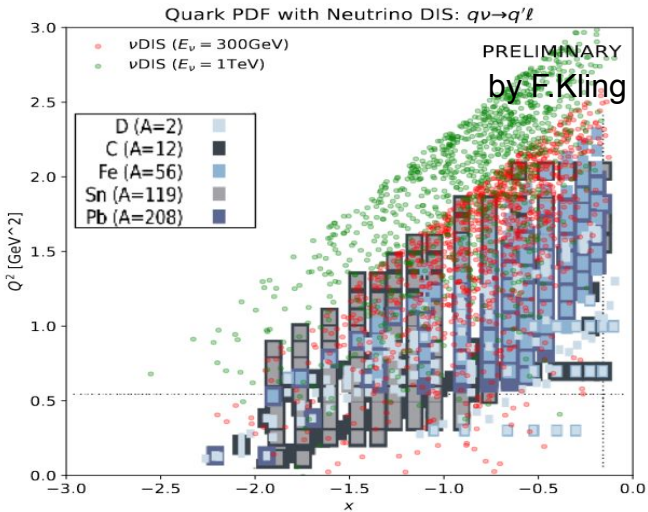
QCD in ν-scattering

It might also be possible to probe (nuclear) PDFs via DIS neutrino scattering.

In particular, charm associated neutrino events (ν s → l c) are sensitive to the poorly constrained strange quark PDF.

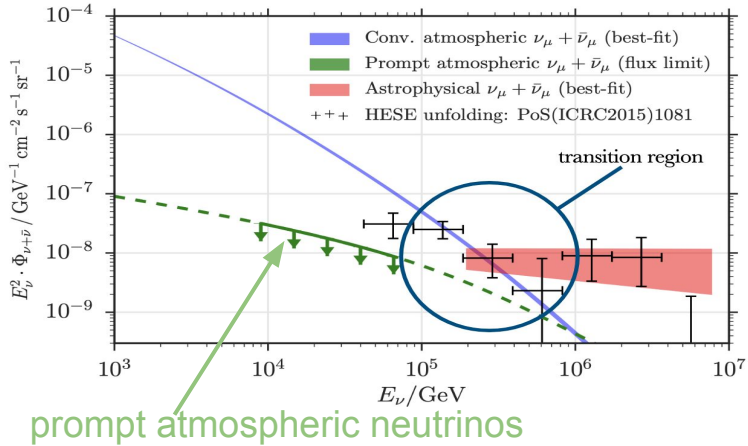
Various nuclear targets are possible.

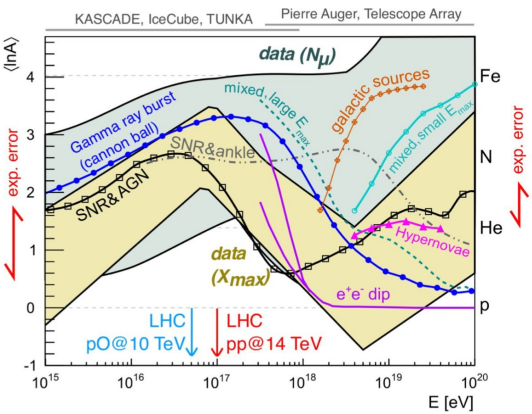




Cosmic Rays and Neutrinos

In order for IceCube to make precise measurements of the cosmic neutrino flux, we need accelerator measurements of high energy and large rapidity charm production.





Based on Kampert & Unger, Astropart. Phys. 35 (2012) 660

Muon problem in CR physics: Cosmic Ray experiments have reported an excess in the number of muons over expectations computed using extrapolations of hadronic interaction models tuned to LHC data at the few σ level.

New input from LHC is crucial to reproduce CR data consistently.

Summary

FASER is a new LHC experiment, currently under construction. It will soon measure the first neutrinos at the LHC.

FASER also paves the way for a forward search and neutrino program at the HL-LHC, opening up many many new opportunities for neutrino physics, new physics searches and QCD measurements, significantly extending the LHC's physics program.

There are many complementarities between EIC and FASER. A better understanding of SM physics will allow for more sensitive probes of new physics.

For Snowmass 2021, we propose FASERv2 with roughly ten times the mass of FASERv operating at the HL-LHC. Such a detector would collect roughly 100k electron neutrinos, ~1M muon neutrinos and ~1k tau neutrinos at TeV energies. It could be housed in a dedicated Forward Physics Facility.

We would like to invite the EIC community to help us better understand these complementaries, and explore the physics potential of this program.