Looking forward to neutrinos at the LHC

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Neutrinos at the LHC

- neutrinos detected from many sources, but not from colliders

- many neutrinos at LHC produced in π, K, D meson decay
  → provides intense energetic collimated neutrino beam in forward direction
  * ~$10^{12}$ neutrino in LHC Run 3    * E~TeV.    * $\theta \sim \text{mrad}$

- 480m downstream from ATLAS, the FASER experiment is placed directly into this beam
  * proposed to search for long-lived particles
  * approved and funded, currently under construction
  * contains dedicated FASERv neutrino detector

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Neutrinos at the LHC

- dedicated FASERν neutrino detector in front of FASER
  * 25cm x 25cm x 1.3m emulsion detector
  * tungsten target with 1.2 ton mass
  * ~ 20000 $\nu_\mu$, ~ 2000 $\nu_e$, ~ 20 $\nu_\tau$

- TeV energy range currently unconstrained
  * this allows to probe neutrino cross sections at TeV for all 3 flavors
**FASERv Detector**

**FASERv: Detecting and Studying High-Energy Collider Neutrinos**

[FASER Collaboration, 1708.09389], [FASER Collaboration, 2001.03073]

- **FASERv**: 1000 emulsion films interleaved with 1mm tungsten plates
  
  * sensitive to neutrino interactions

- Emulsion detectors are 3D tracking devices with 50 nm spatial precision
  
  * used by many other neutrino experiments: CHORUS, DONUT, OPERA,

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**Emulsion film**  
**Cross-sectional view**  
**AgBr crystal**  
**Track in emulsion film**
Looking forward to neutrinos at the LHC

example: tau neutrino event in OPERA
- detector performance has been studied
  * flavor identification
  * vertex finding efficiency: $\sim 80\%$
  * energy resolution: $\sim 30\%$

- global reconstruction with the FASER detector
  * distinguish neutrino / anti-neutrino
  * improve neutrino energy reconstruction
  * background rejection

- pilot detector data is currently analyzed
  * 30 kg detector was installed in TI18, 12.5 fb$^{-1}$ of data collected 2018
  * goal: first neutrino detection at the LHC
Collider Neutrino Physics Potential

neutrino production
validation of hadronic interaction models
parton distribution functions
atmospheric neutrino background at neutrino telescopes

neutrino propagation
sterile neutrino oscillations

neutrino interactions
neutrino cross section measurements
events shapes and kinematics
heavy flavor associated neutrino interactions

Physics potential studies have just started.

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Neutrino Flux Estimates

- cross section measurements are limited by neutrino flux uncertainty
  * we need to quantify and reduce these uncertainties

- forward particle production is not described by perturbative QCD, but soft physics
  * use hadronic interaction models

- simulators are based on sophisticated modeling of microscopic physics
  * phenomenological parameters need to be tuned
  * include tuning uncertainties (similar to PDFs)

→ develop dedicated forward physics tune using forward data

[Graphs showing neutrino flux estimates and comparisons with different models]

[LHCf: 2003.02192]  
[LHCf: 1703.07678]
Summary and Outlook

**Neutrinos at the LHC**
- LHC produces intense high energy neutrino beam
- no neutrino detected so far
- all 3 flavors, E∼TeV

**FASERν**
- emulsion based detector
- 25cm x 25cm x 1m with 1.2 ton target mass
- take data during Run 3 (2021-23, 150 fb⁻¹)
- expect ~ 20000 ν_µ, 2000 ν_e and 20 ν_τ

**Physics Applications**
- neutrino cross section measurement at TeV energies
- neutrino production rate measurements
- flavor physics, neutrino oscillations, …
- many more unexplored opportunities!

For more information, see [faser.web.cern.ch](http://faser.web.cern.ch)

We look forward to feedback and suggestions