

Looking forward to neutrinos at the LHC

May 4th 2020

Pheno 2020

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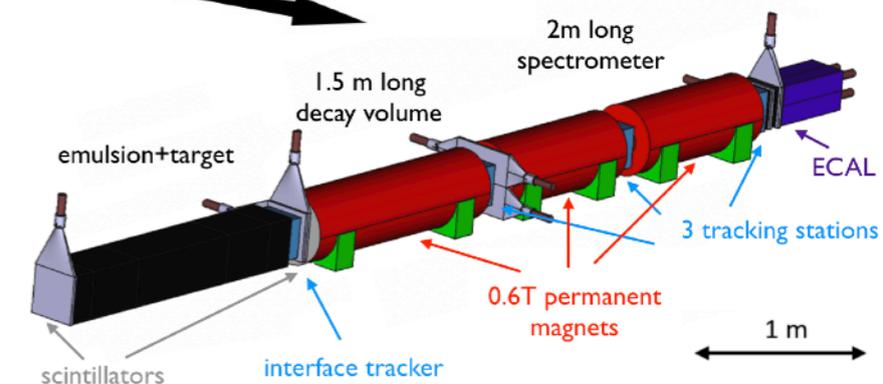
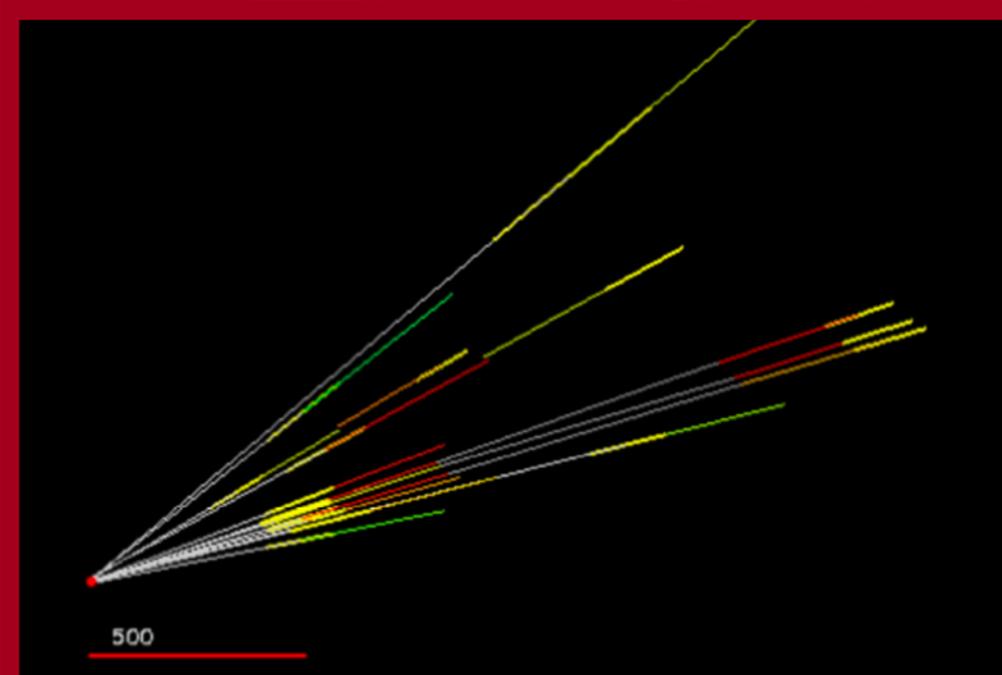
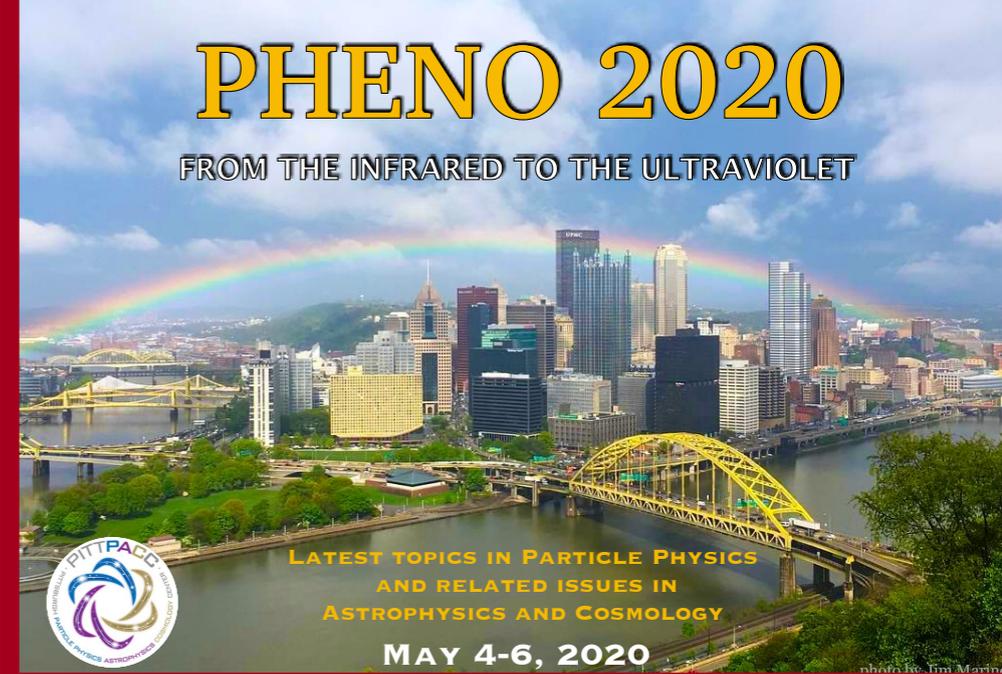
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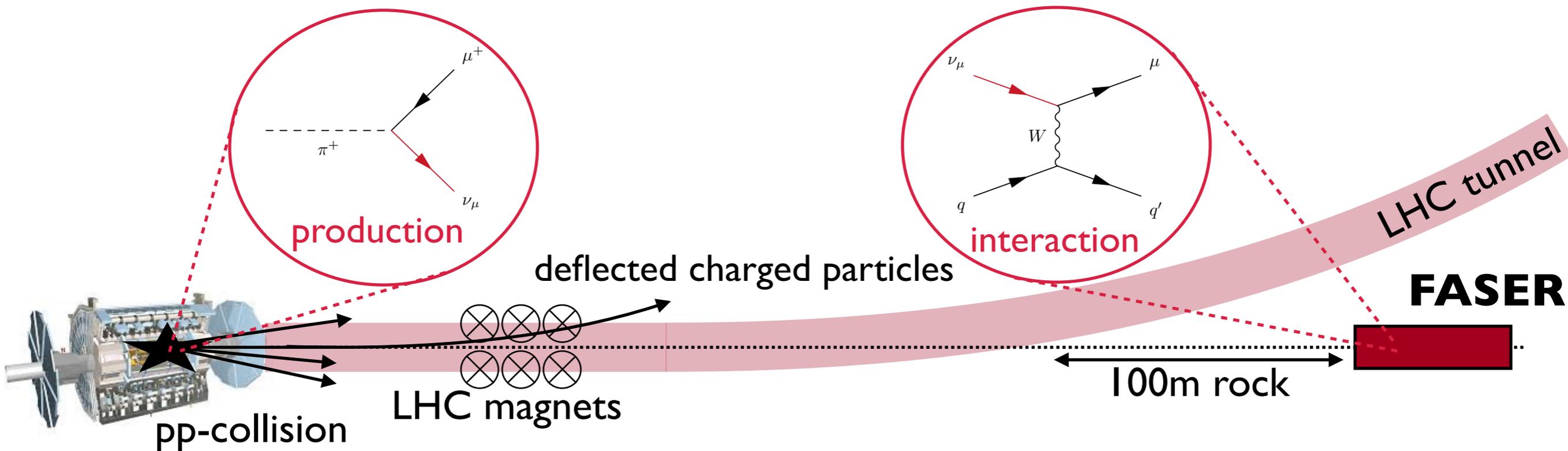


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Neutrinos at the LHC

- 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
 - * $\sim 10^{12}$ neutrino in LHC Run 3
 - * $E \sim \text{TeV}$.
 - * $\theta \sim \text{mrad}$
- 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



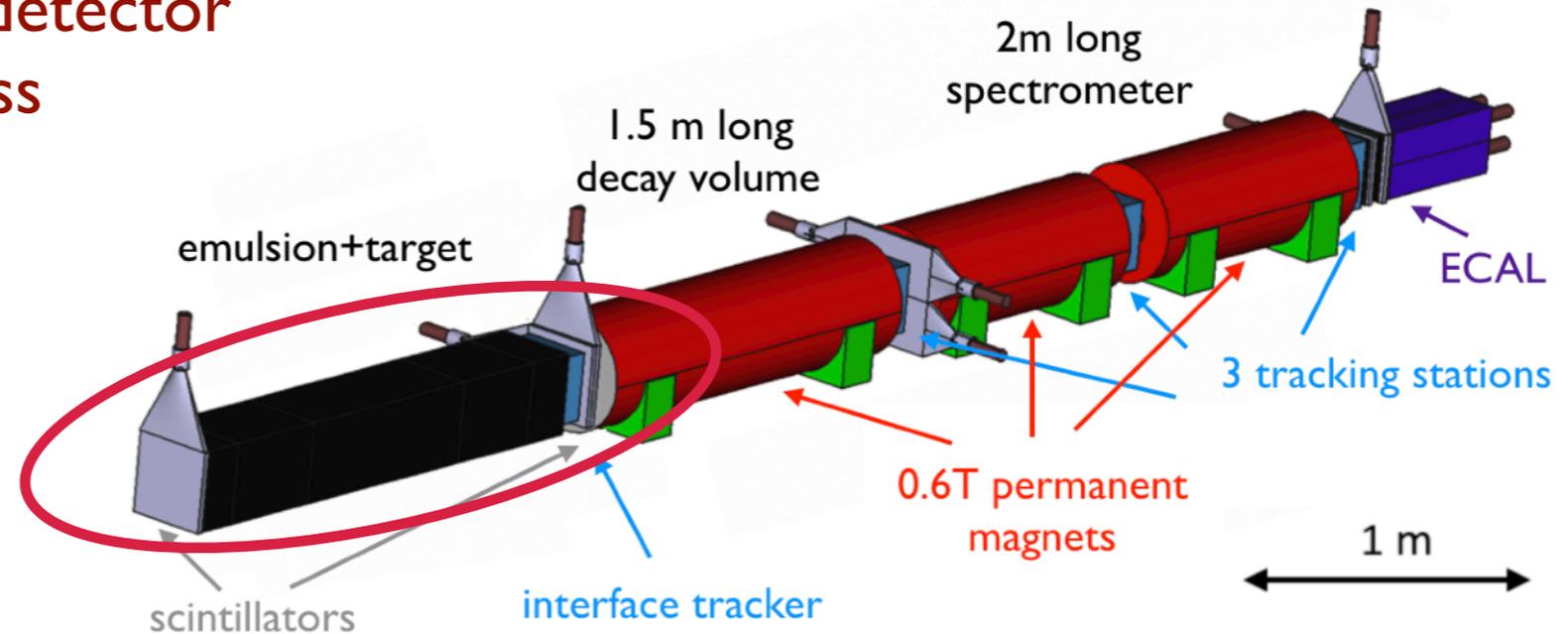
Neutrinos at the LHC

- dedicated FASERv neutrino detector in front of FASER

* 25cm x 25cm x 1.3m emulsion detector

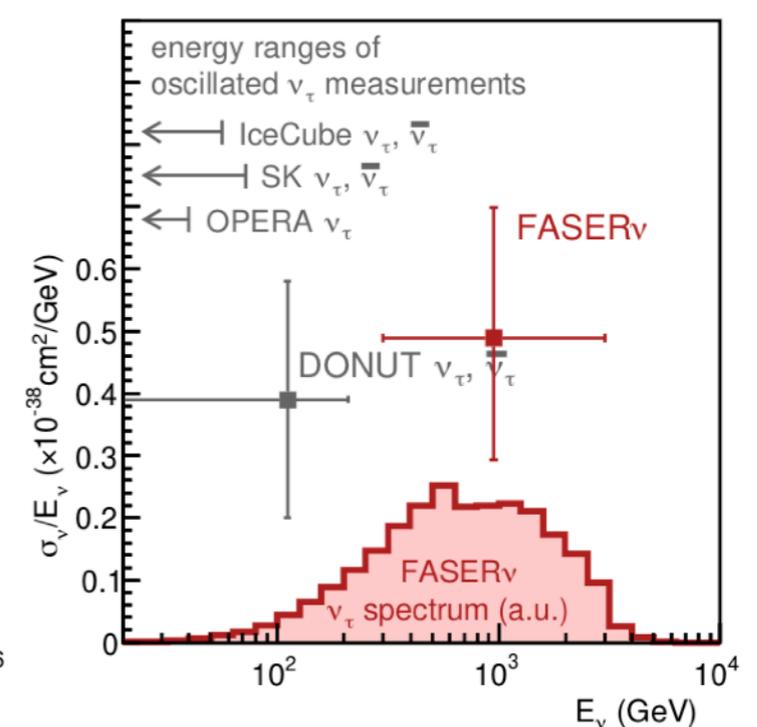
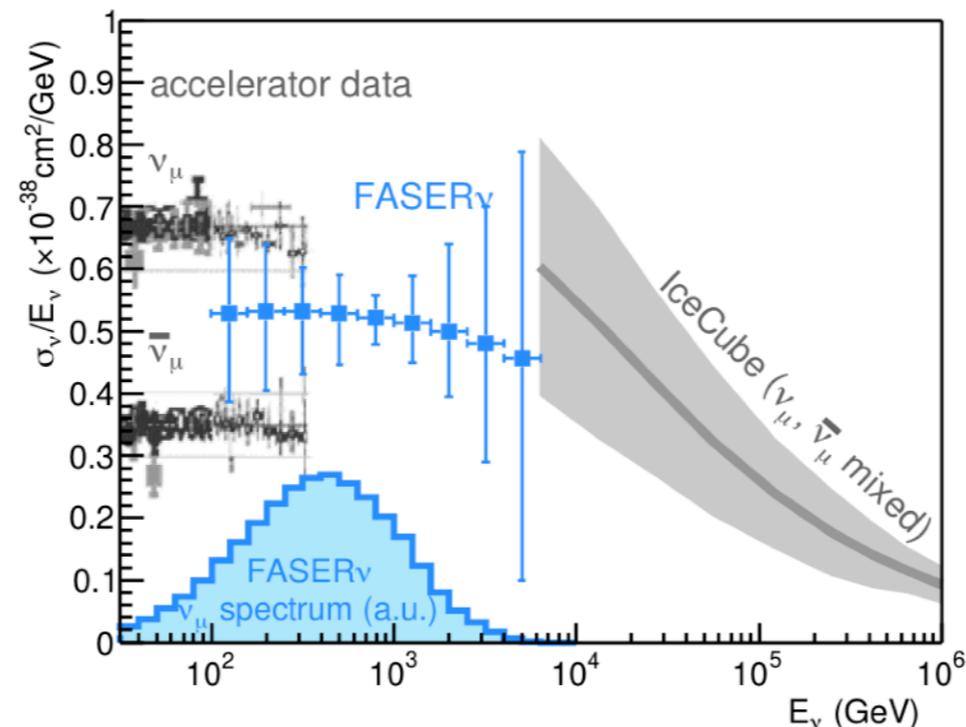
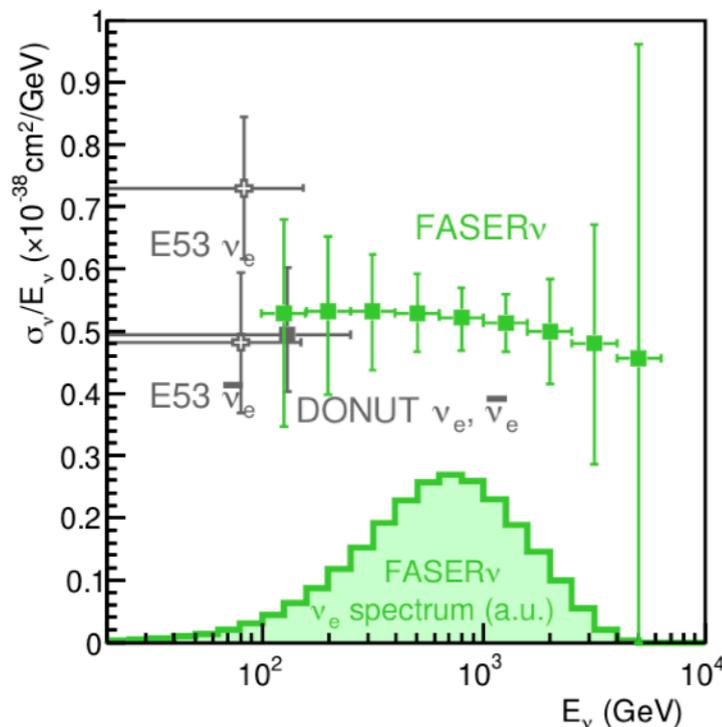
* tungsten target with 1.2 ton mass

* $\sim 20000 \nu_\mu, \sim 2000 \nu_e, \sim 20 \nu_\tau$



- TeV energy range currently unconstrained

* this allows to probe neutrino cross sections at TeV for all 3 flavors



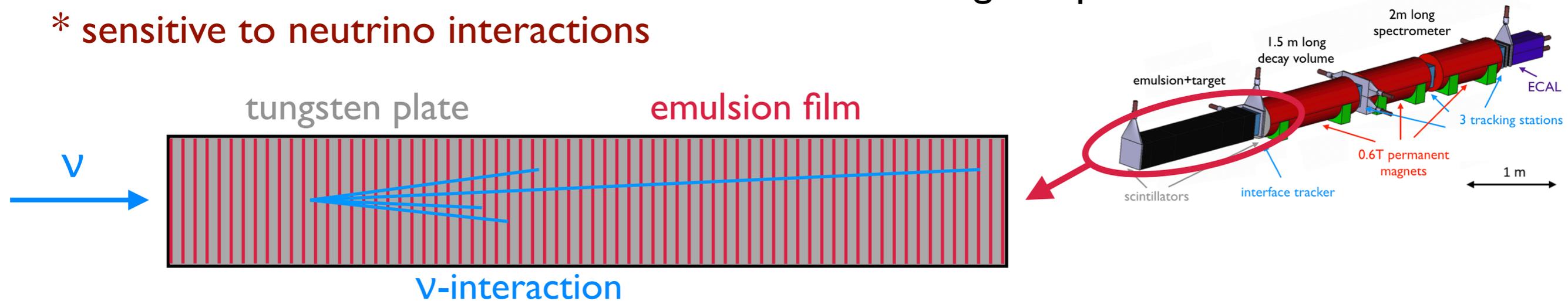
FASER ν Detector

FASER ν : Detecting and Studying High-Energy Collider Neutrinos

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

- FASER ν : 1000 emulsion films interleaved with 1mm tungsten plates

* sensitive to neutrino interactions



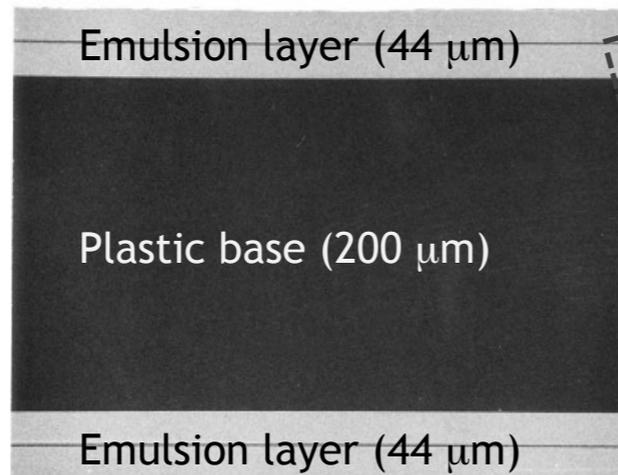
- emulsion detectors are 3D tracking devices with 50 nm spatial precision

* used by many other neutrino experiments: CHORUS, DONUT, OPERA,

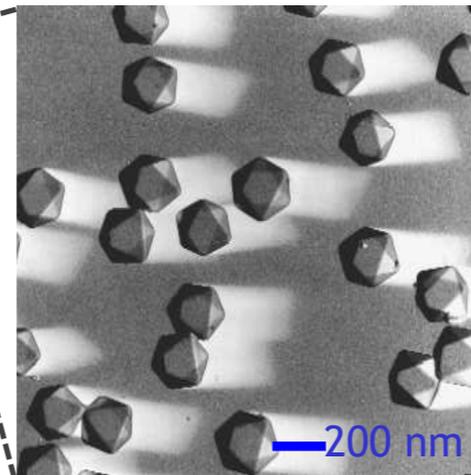
Emulsion film



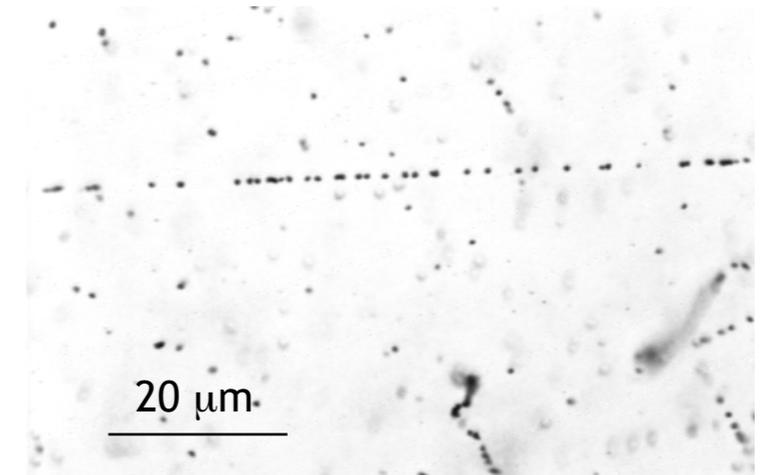
Cross-sectional view



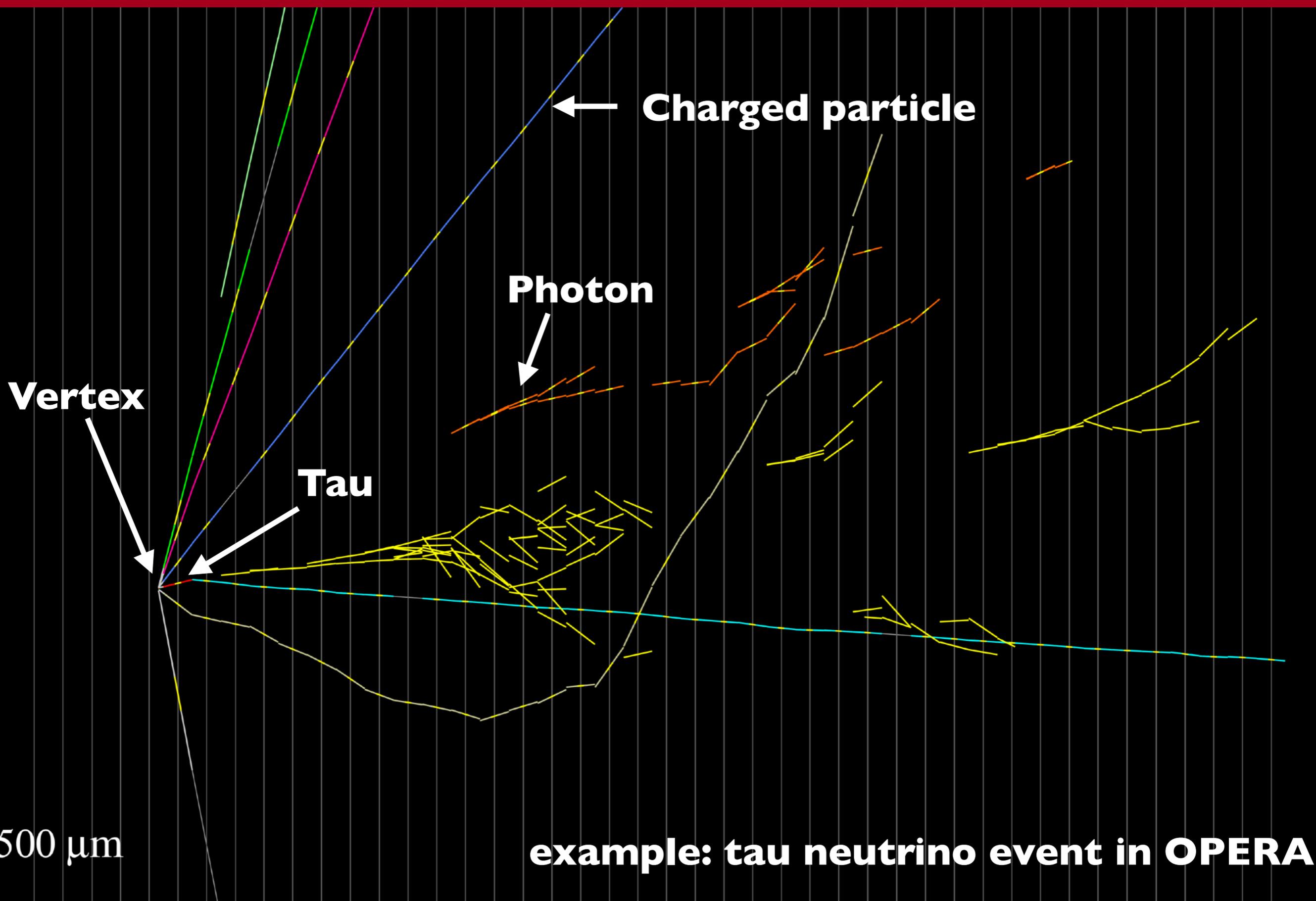
AgBr crystal



Track in emulsion film

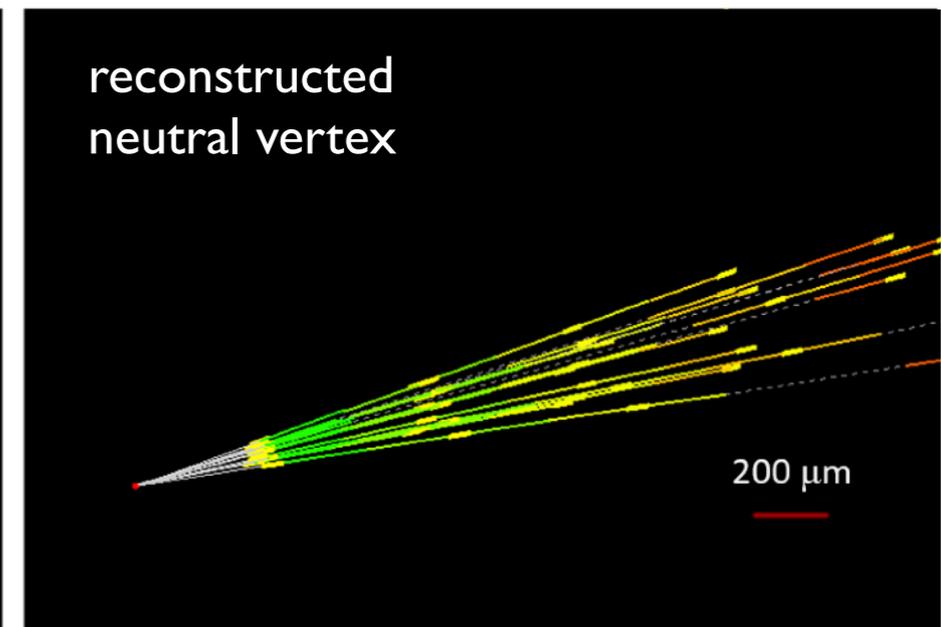
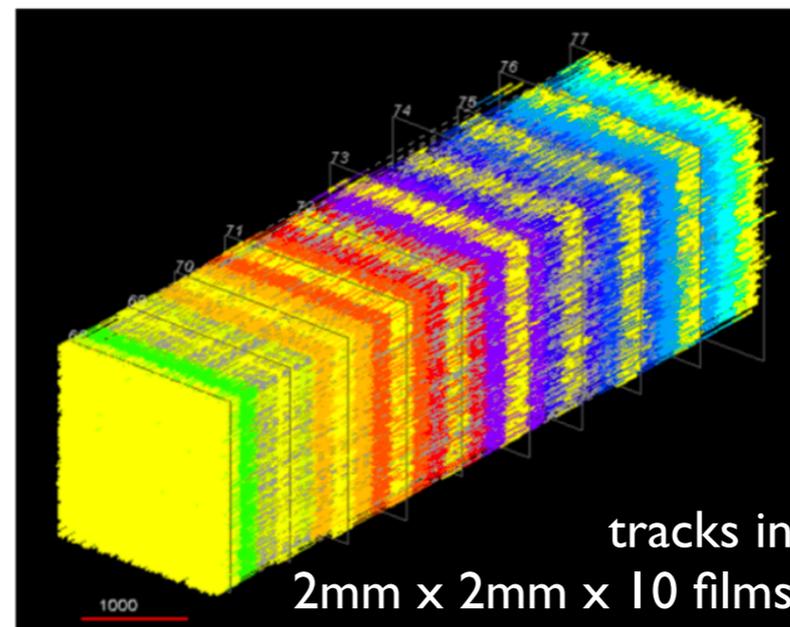
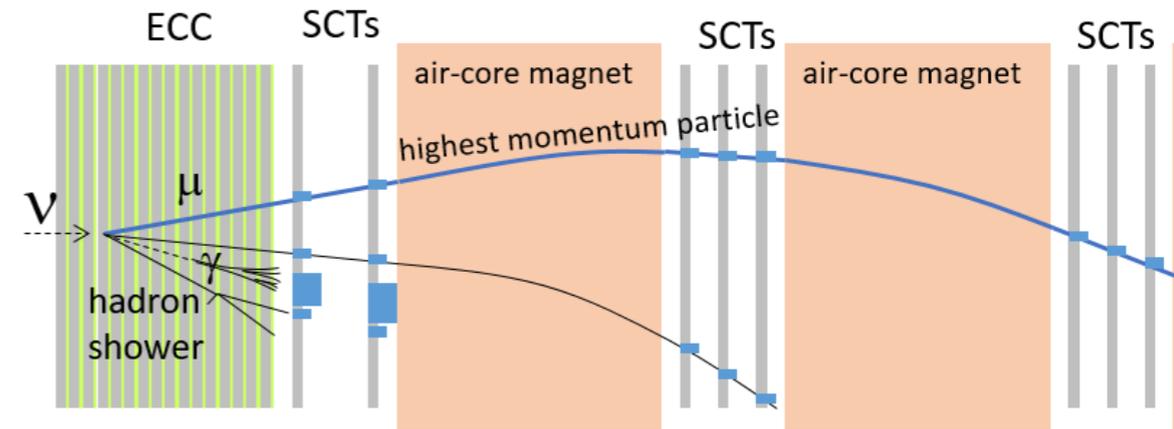


FASER ν Detector

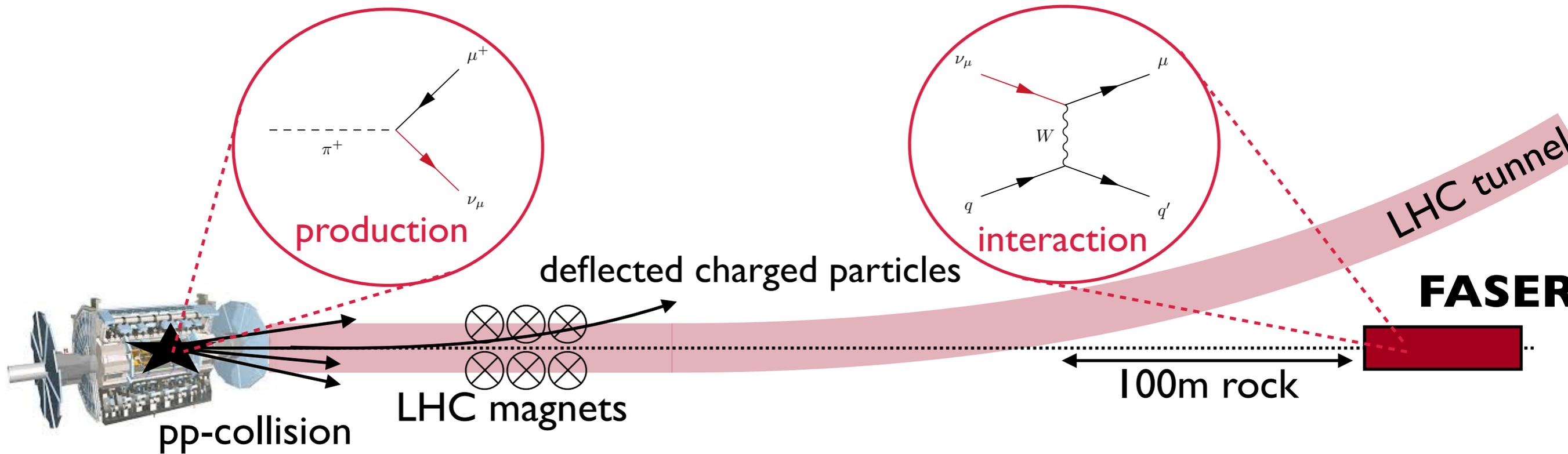


FASER ν Detector

- 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 T118, 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

Physics potential studies have just started.

neutrino interactions

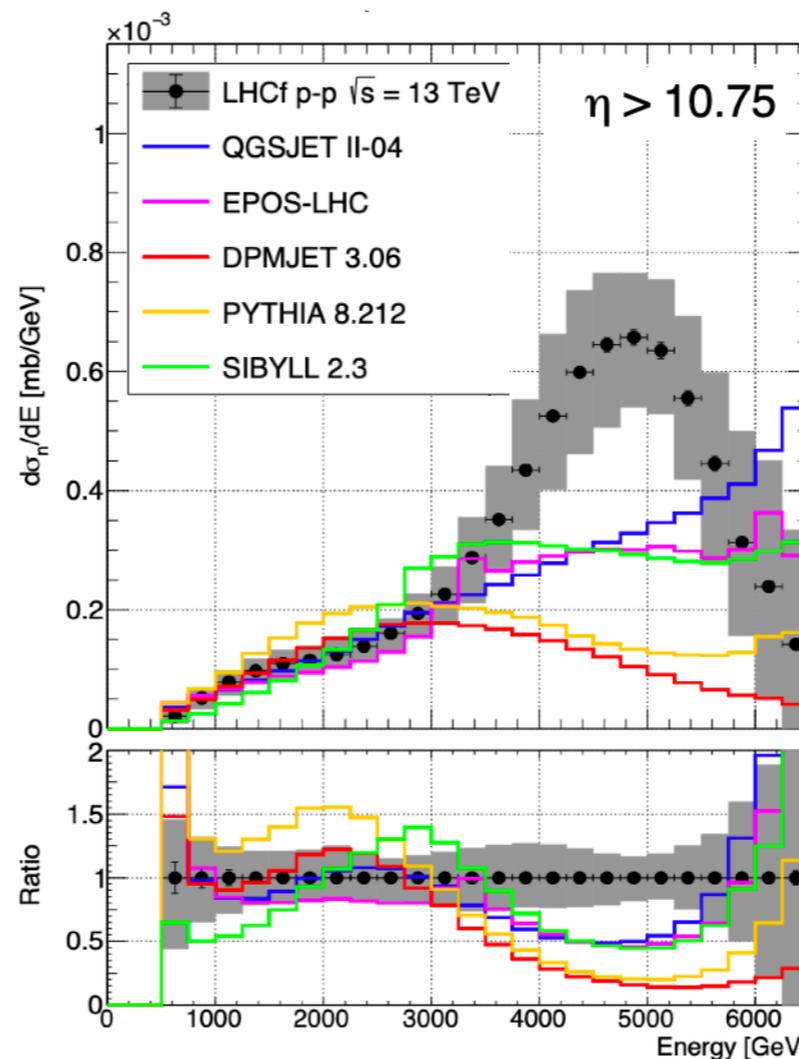
neutrino cross section measurements

events shapes and kinematics

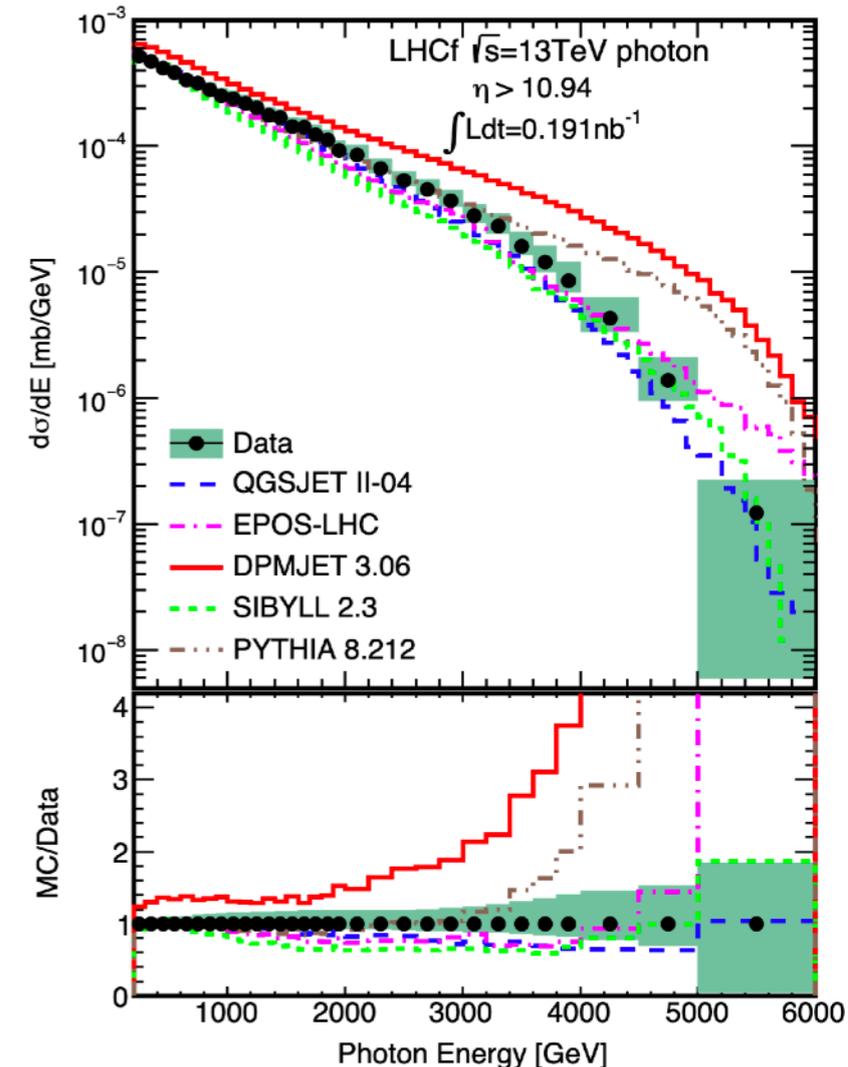
heavy flavor associated neutrino interactions

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



[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, $E \sim \text{TeV}$

FASER ν

- 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 $\sim 20000 \nu_{\mu}$, $2000 \nu_e$ and $20 \nu_{\tau}$

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

We look forward to feedback and suggestions

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