

WG3: Working Group for Light Hadron Production

FPF6 Meeting, CERN

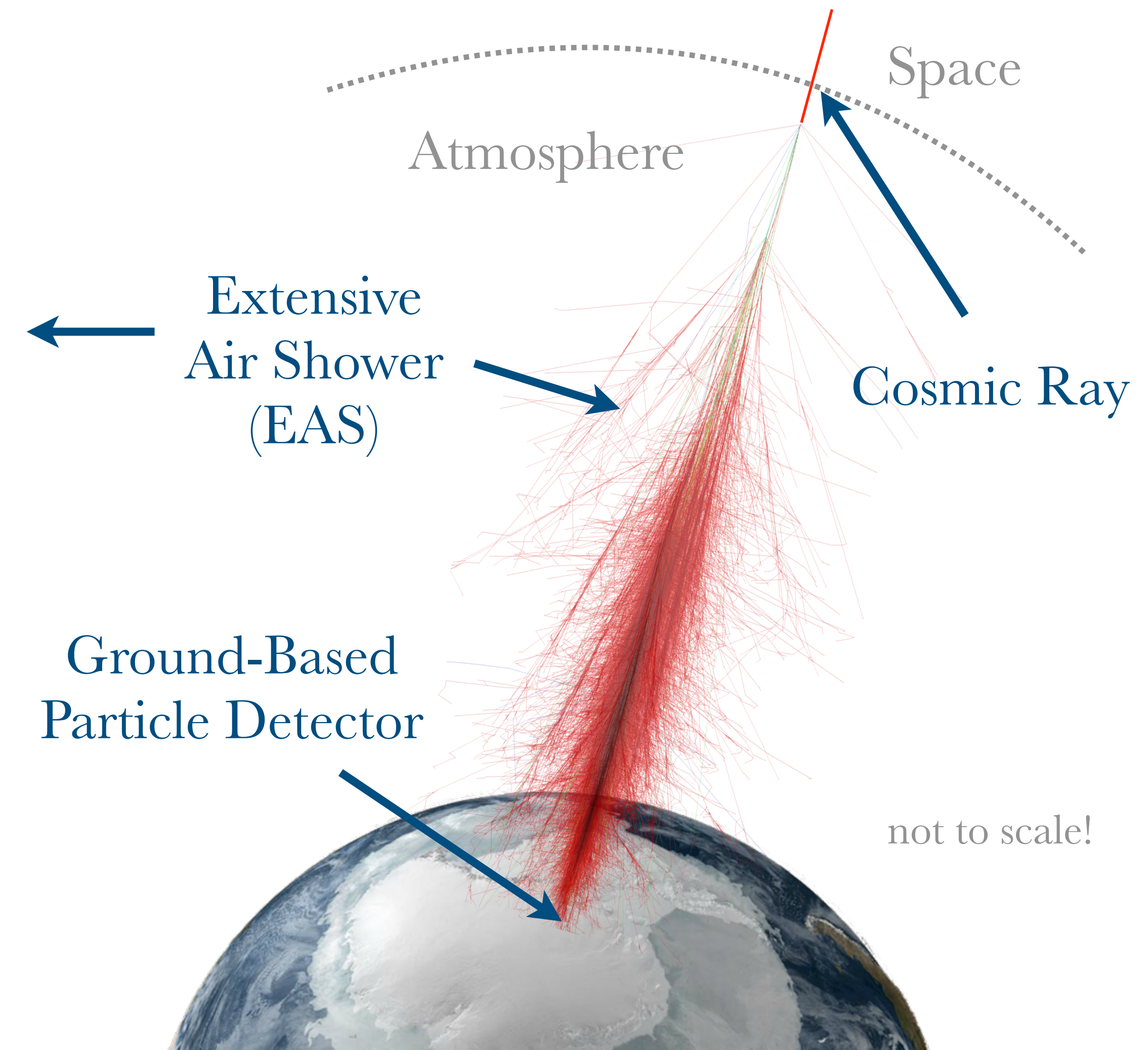
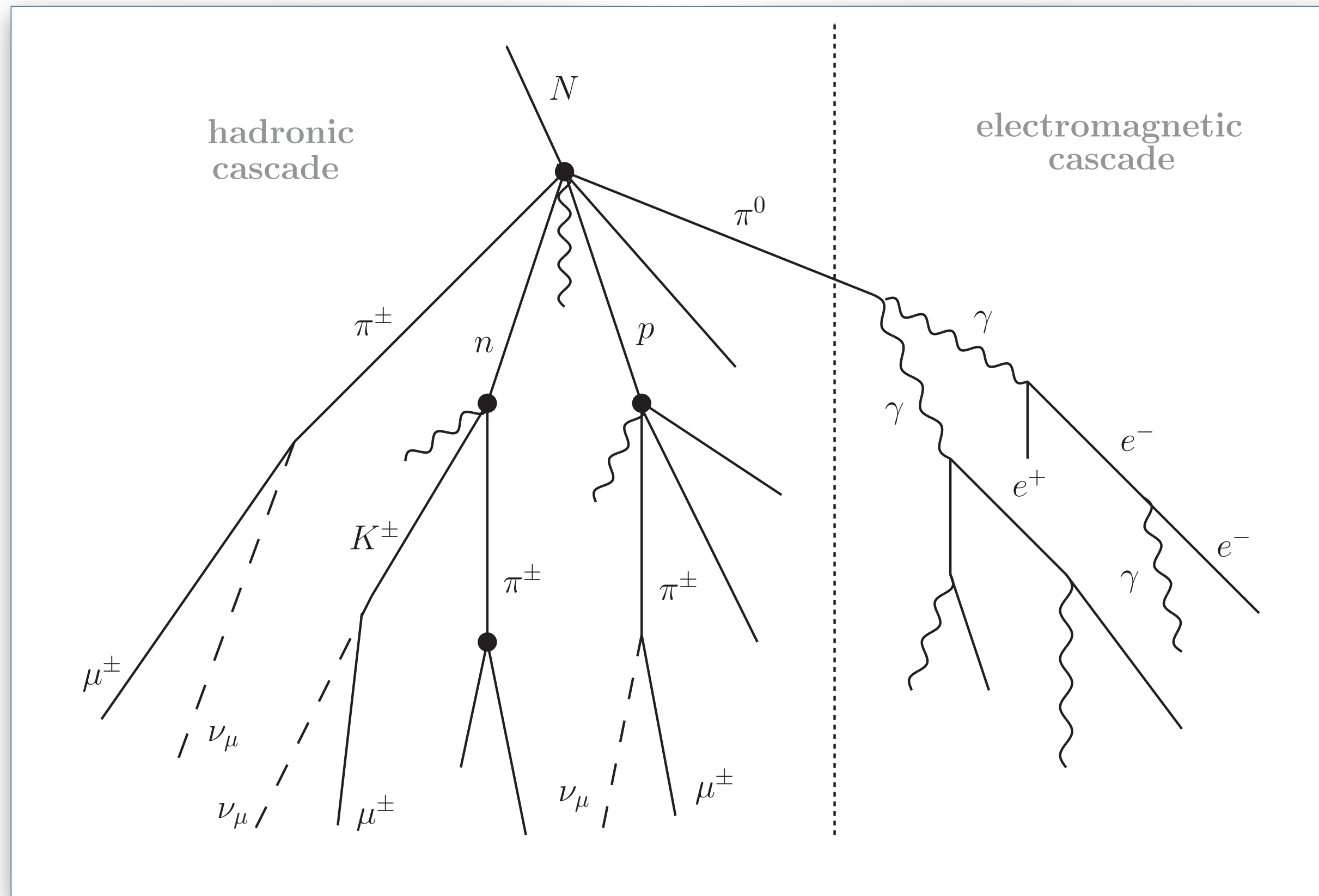
Dennis Soldin, Luis Anchordoqui



Motivation I



- ▶ Large motivation to study light hadron production at the FPF arises from observations of extensive air showers (EAS)

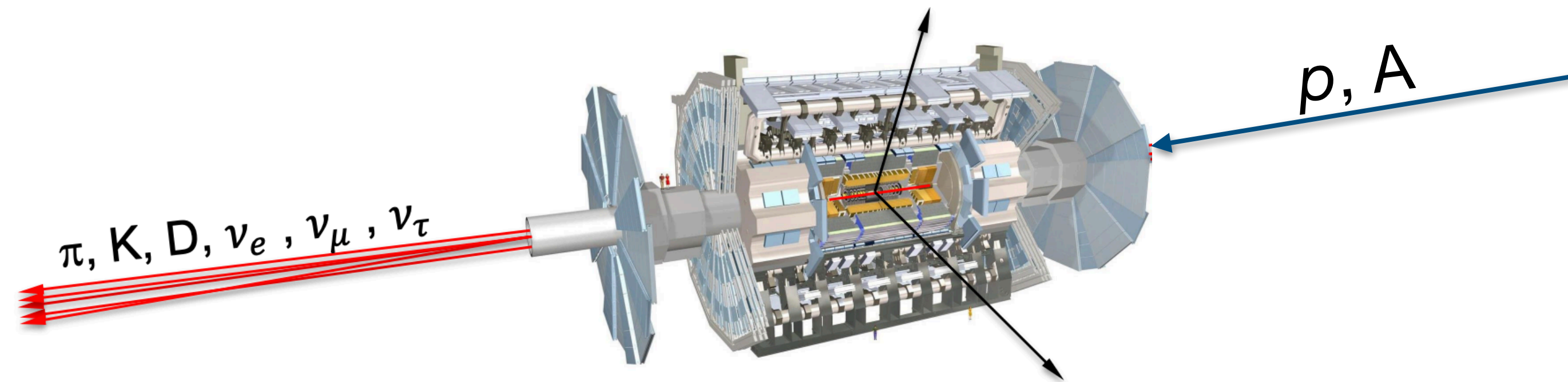


Motivation I

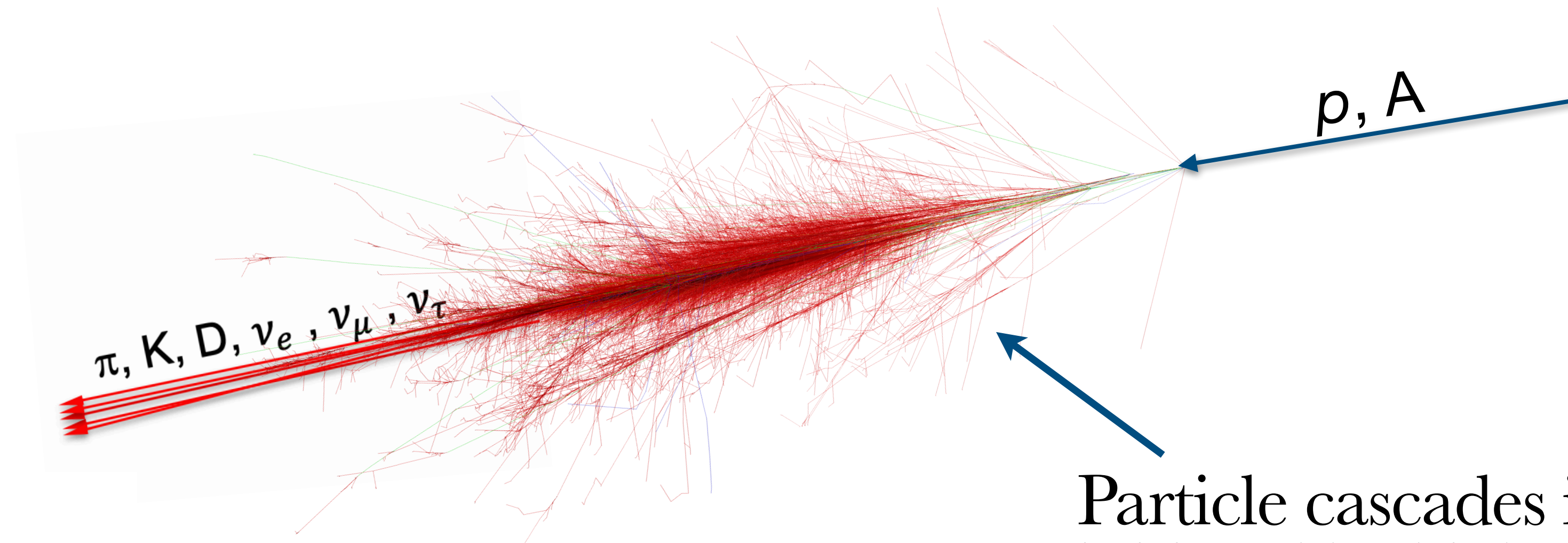


- ▶ Large motivation to study light hadron production at the FPF arises from observations of extensive air showers (EAS)

- ▶ LHC:



- ▶ EAS:



Particle cascades in the atmosphere initiated by high-energy cosmic rays

Motivation I



- ▶ Extensive air showers:

- ▶ Particle production in the far-forward region

- ▶ Low momentum transfer

- ▶ Non-perturbative regime

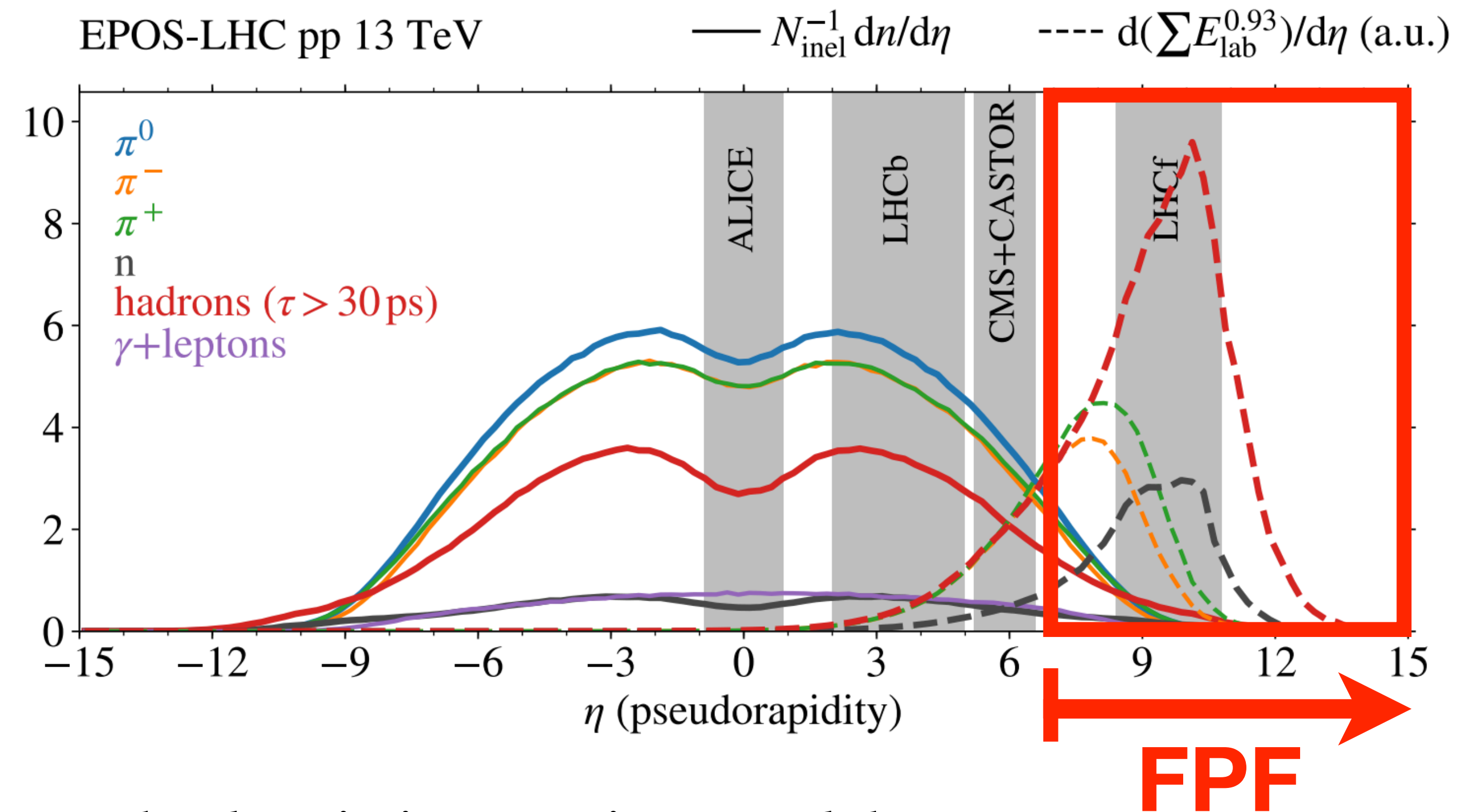
- ▶ Complex particle composition

- ▶ Energies range over many orders of magnitude

- ▶ Modeling of particle interactions based on phenomenological models developed for EAS simulations

- ▶ FPF will provide unique opportunities to test hadronic interaction models

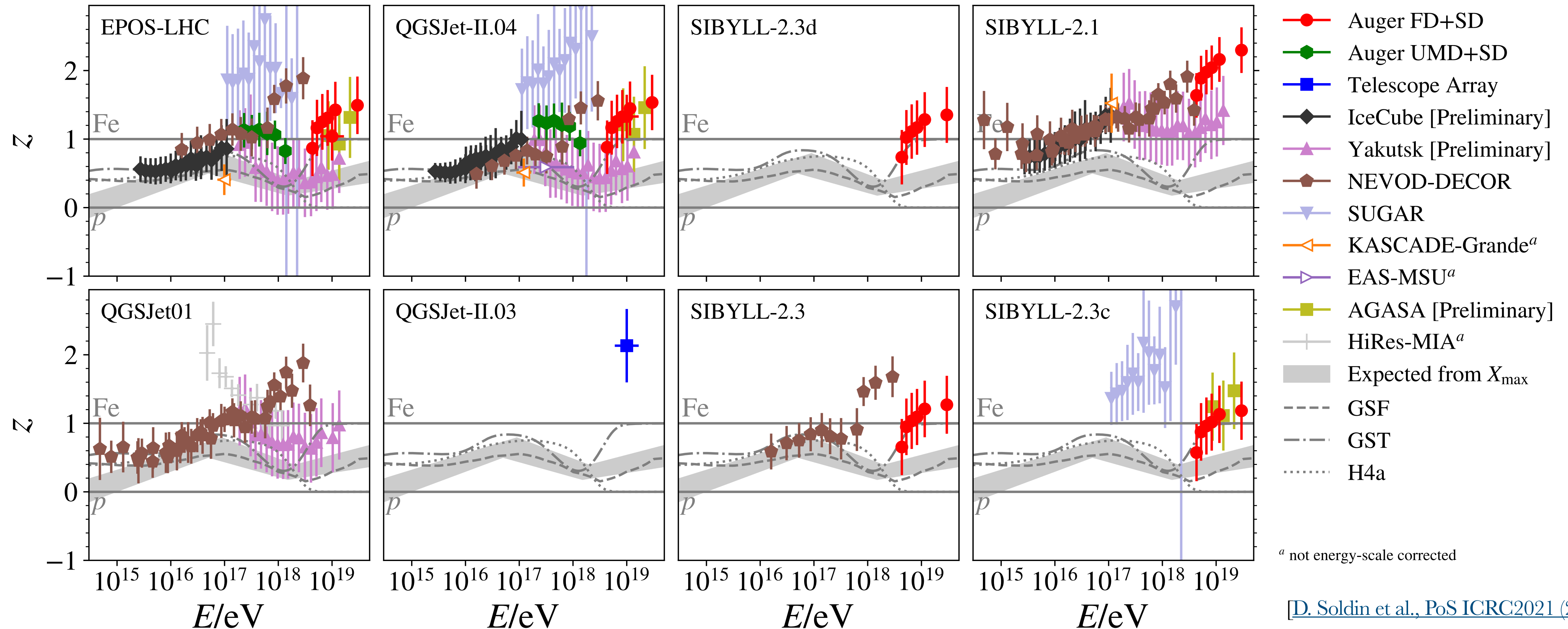
[J. Albrecht et al., *Astrophys. Space Sci.* 367 (2022)]



Motivation I



- ▶ Large discrepancies between data and MC observed in extensive air showers (EAS)



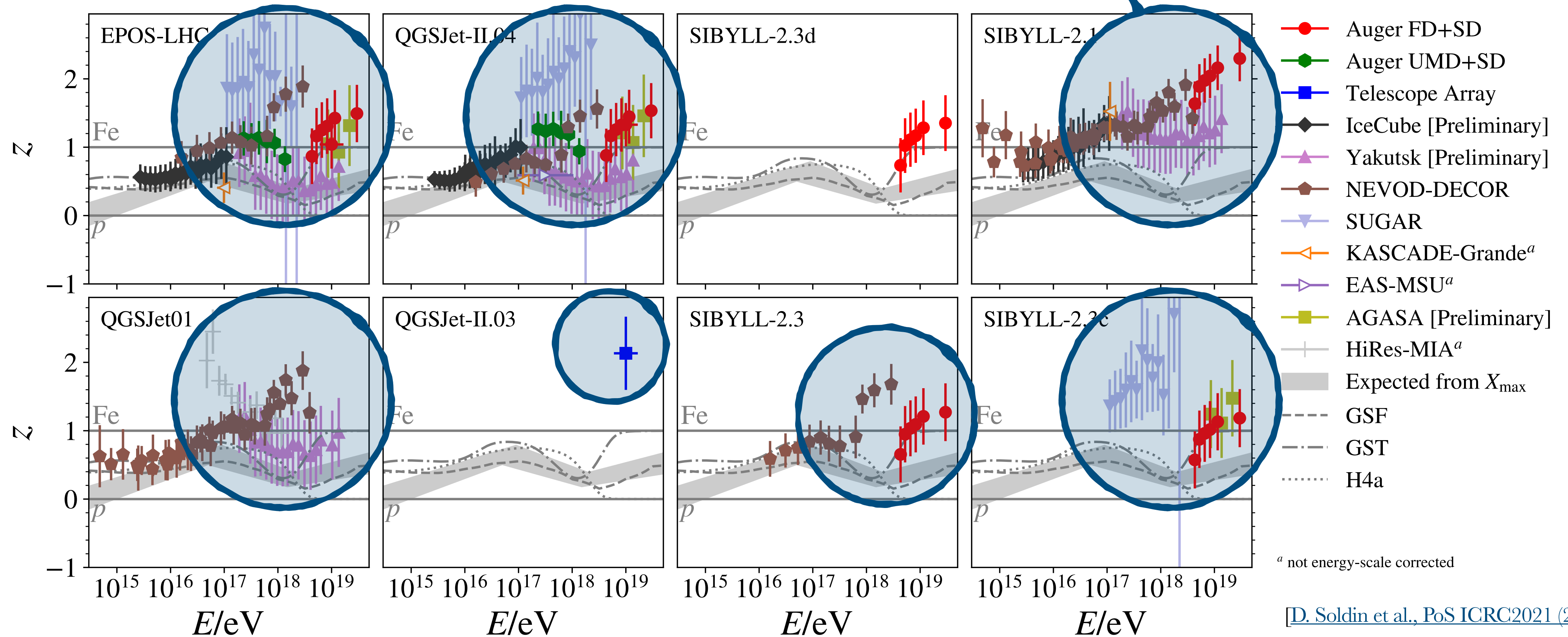
- ▶ Muon measurements and models indicate composition heavier than iron at high energies!

Motivation I

Muon Puzzle



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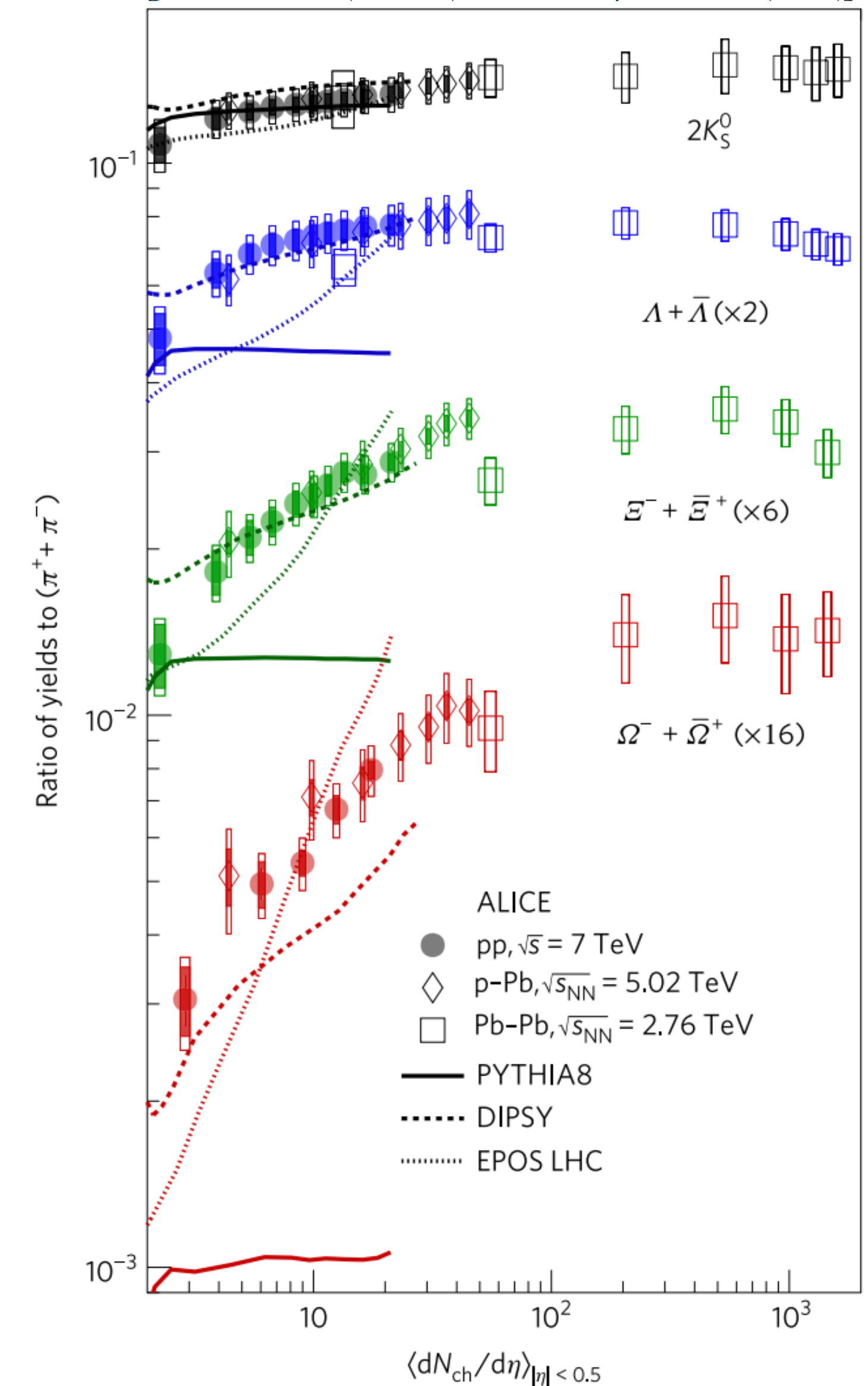
- ▶ Muon measurements and models indicate composition heavier than iron at high energies!

Motivation II

- ▶ Evidence for strangeness enhancement reported by ALICE
- ▶ Universal enhancement of strangeness production in high-multiplicity events at mid-rapidity ($|y| < 2$)
- ▶ Depends on the multiplicity of the event at mid-rapidity, not on the details of the collision system!
- ▶ Can this effect also be seen in hadrons produced at forward rapidities?
- ▶ Possible explanation for the Muon Puzzle in EAS...
- ▶ FPF provides unique opportunities for testing the forward rapidity region!



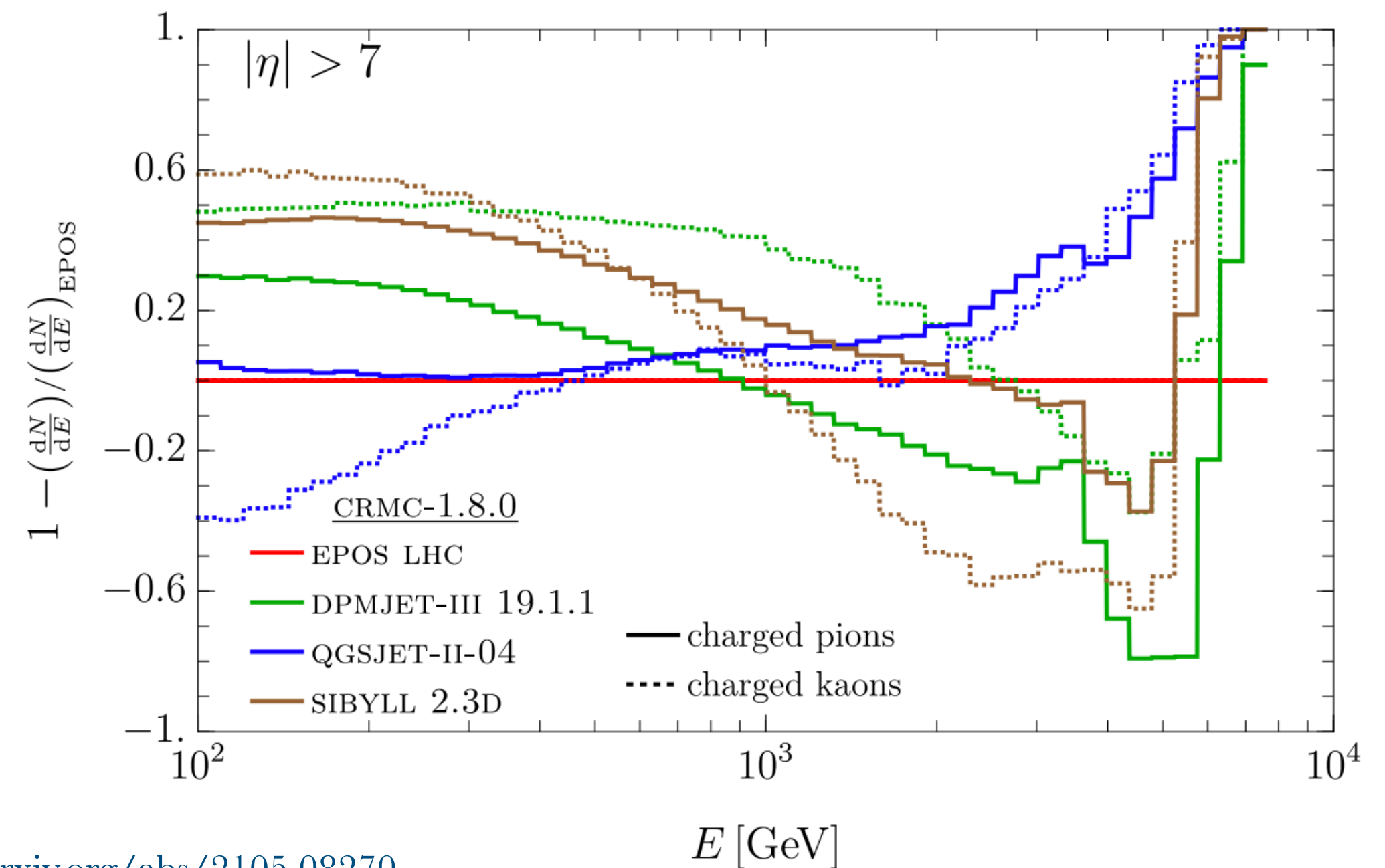
[J. Adam et al. (ALICE), Nature Phys. 13, 535 (2017)]



WG3 Science Topics I



- ▶ Neutrino fluxes at the FPF:
 - ▶ Ratio of electron and muon neutrinos is a proxy for the ratio of charged pions and kaons
 - ▶ Electron and muon neutrino fluxes populate different energy regions which will help to disentangle them
 - ▶ Neutrinos from pion and kaon decays have different rapidity distributions which will help to disentangle them
 - ▶ Fast simulation package* available (F. Kling)
 - ▶ Further studies needed:
 - ▶ MC based on different generators
 - ▶ Neutrino fluxes in different detectors
 - ▶ Tests of dedicated muon (e.g. strangeness) enhancement models



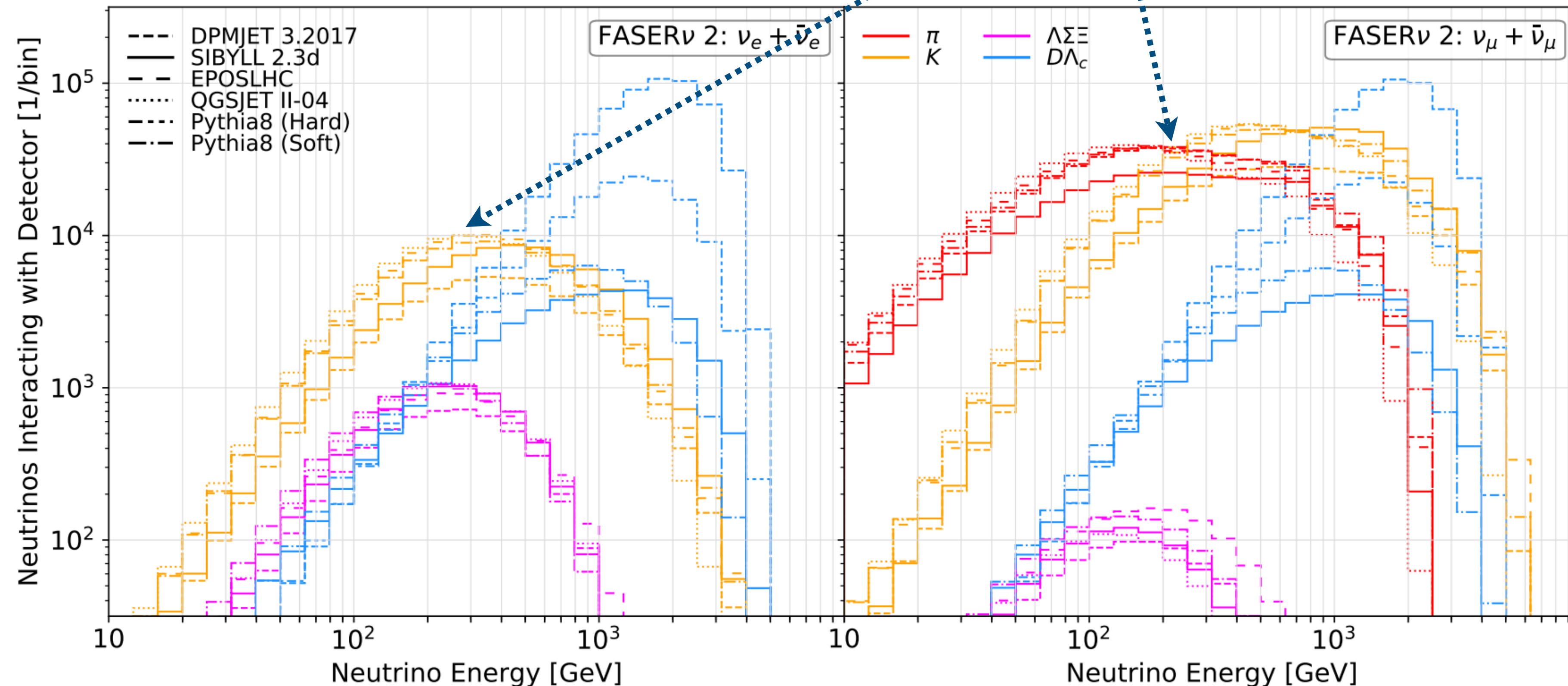
* Simulation code available at: <https://github.com/KlingFelix/FastNeutrinoFluxSimulation>, see also <https://arxiv.org/abs/2105.08270>

WG3 Science Topics I



► Neutrino fluxes at FASER ν 2:

low energy region relevant!

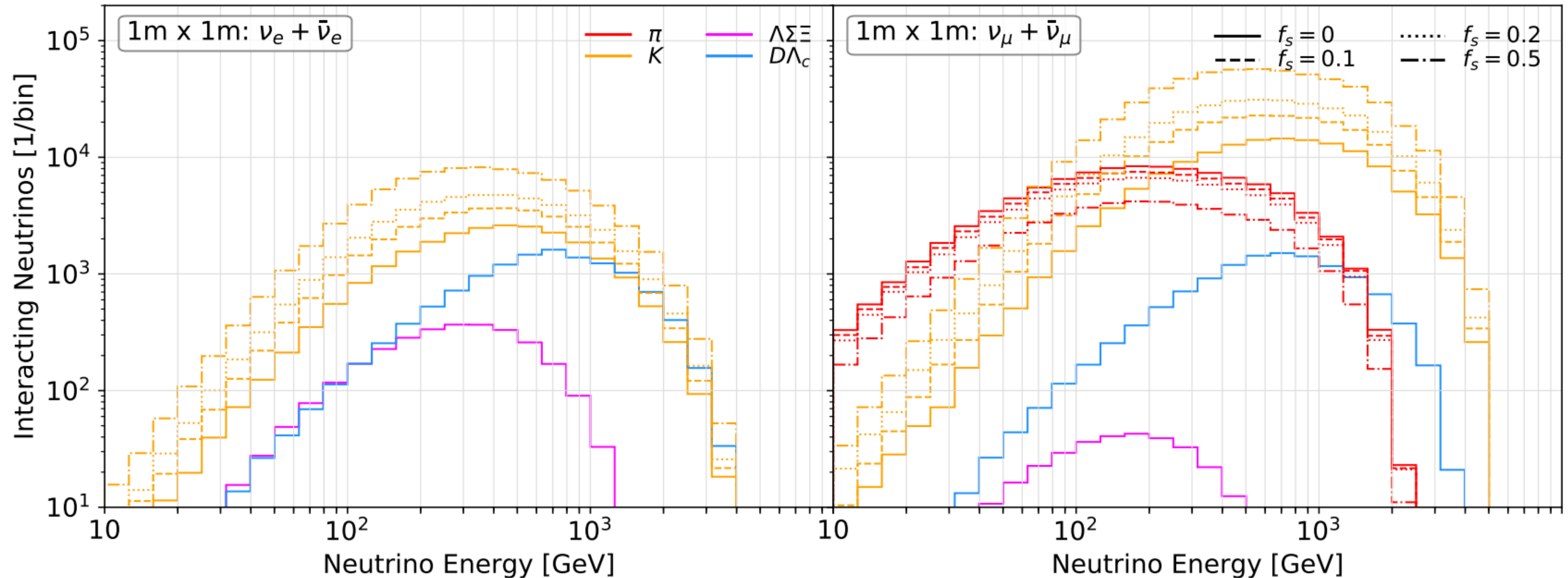


► Predictions differ by a factor of up to 2, much bigger than the anticipated FPF uncertainties

WG3 Science Topics I



► Neutrino fluxes at FLArE:



► Example: strangeness enhancement toy model [[L. Anchordoqui et al., JHEAp 34 \(2022\)](https://arxiv.org/abs/2105.08270)]

WG3 Plans



▶ Comprehensive MC library of event generators / models to be tested:

▶ PYTHIA

- ▶ Monash tune
- ▶ Forward physics tune

▶ HERWIG/SHERPA

▶ DIPSY

▶ DPMJet

- ▶ DPMJet-II
- ▶ DPMJet-III

▶ QGSJet

- ▶ QGSJet-II.04
- ▶ QGSJet-III (?)

▶ EPOS

- ▶ EPOS-LHC
- ▶ EPOS-LHCr (?)
- ▶ ~~EPOS 3~~
- ▶ EPOS 4 (?)

▶ Sibyll

- ▶ Sibyll-2.1
- ▶ Sibyll-2.3
 - ▶ ρ^0 -enhancement
 - ▶ Baryon enhancement
 - ▶ Strangeness enhancement (Luis et al.)
 - ▶ Manshanden et al. model

WG3 Plans



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▶ QGSJet-II.04

▶ QGSJet-III (?)

▶ EPOS

▶ EPOS-LHC

▶ EPOS-LHCr (?)

If you want additional models to be tested, please let us know!

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WG3 Plans

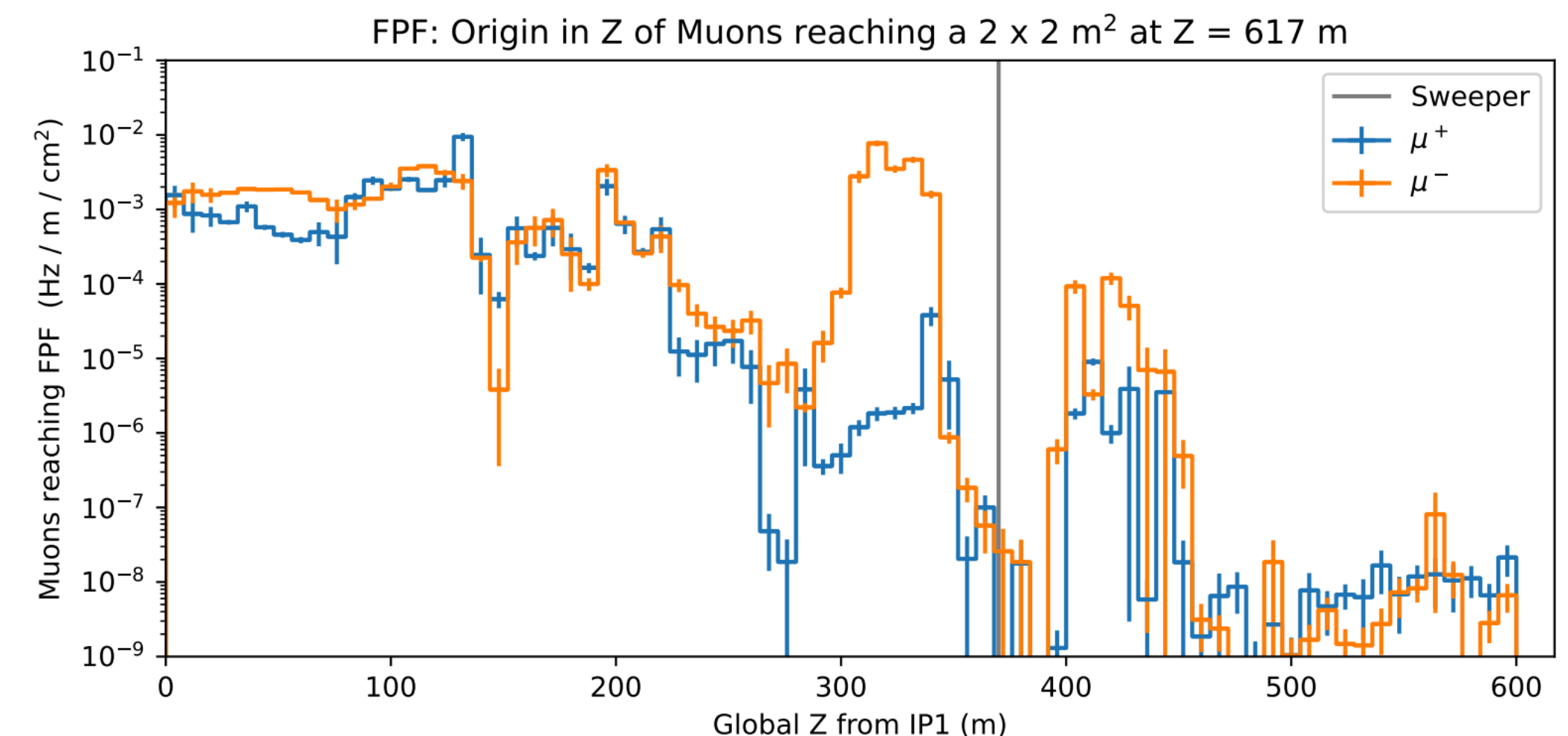


- ▶ Current status:
 - ▶ We're in the process of contacting all model authors at the moment
 - ▶ Production of comprehensive MC library (partially) in progress
 - ▶ WG3 report to be prepared (journal paper?):
 - ▶ Detailed model comparisons
 - ▶ Energy spectra
 - ▶ Rapidity spectra
 - ▶ K/pi ratios (?)
 - ▶ More..?
 - ▶ Recommendations / benchmark models for FPF science
 - ▶ Discussion: How to treat model uncertainties for FPF measurements (yesterday's talks)?
 - ▶ This effort needs some coordination with WG2 (e.g. some models include charm)

WG3 Science Topics II



- ▶ Muon fluxes at the FPF:
 - ▶ Large muon flux at the FPF, e.g. ~ 1 Hz per cm^2 in FASER
 - ▶ Challenging to study as the origin of production is uncertain...
 - ▶ BDSIM/Geant4 simulations available, including full muon history (L. Nevay)
- ▶ Open questions:
 - ▶ Can we use muons to study light hadron production?
 - ▶ Can we measure the muon charge ratio?
 - ▶ Can we measure muon cross-sections?
 - ▶ What can we learn from muon fluxes measured at FASER and SND@LHC?
- ▶ Dedicated studies of the muon yield at the FPF (incl. full muon history) needed!



Summary



- ▶ Studies of light hadron production in the forward region important!
- ▶ Goal:
 - ▶ Quantify how well we can test/constrain certain models/generators
- ▶ Plan:
 - ▶ Produce comprehensive MC library with large variety of models
 - ▶ Study particle distributions at the FPF in close collaboration with model builders
 - ▶ Recommendations for FPF benchmark models and systematics
- ▶ Status:
 - ▶ We're reaching out to all model builders at the moment
 - ▶ Production of HepMC files for all models (where to store them?)

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**If you want to contribute,
please get in touch with us!**

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Thanks!

