

Forward Physics Facility

CF-7 Day - Snowmass 2021

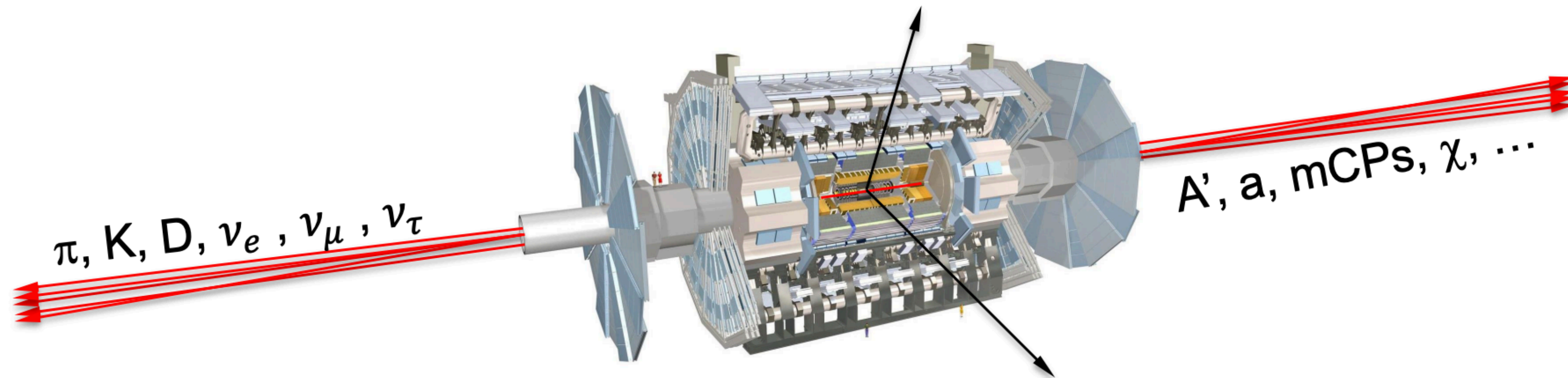
D. Soldin, J. Feng, F. Kling, M. H. Reno, J. Rojo



UNIVERSITY OF DELAWARE
**BARTOL RESEARCH
INSTITUTE**

Overview

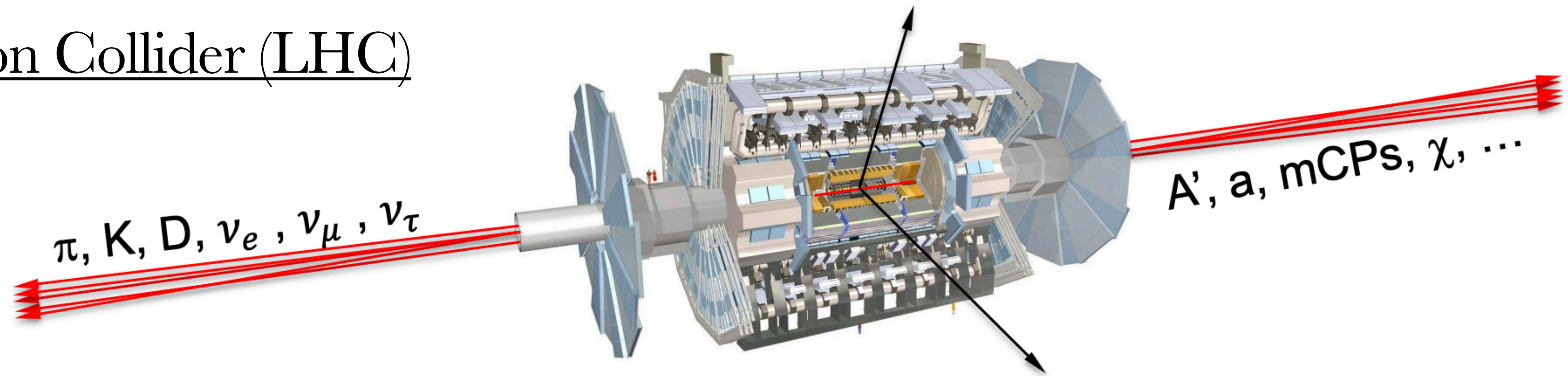
- Question: What opportunities are we currently missing from a lack of coverage of far-forward physics at the LHC?



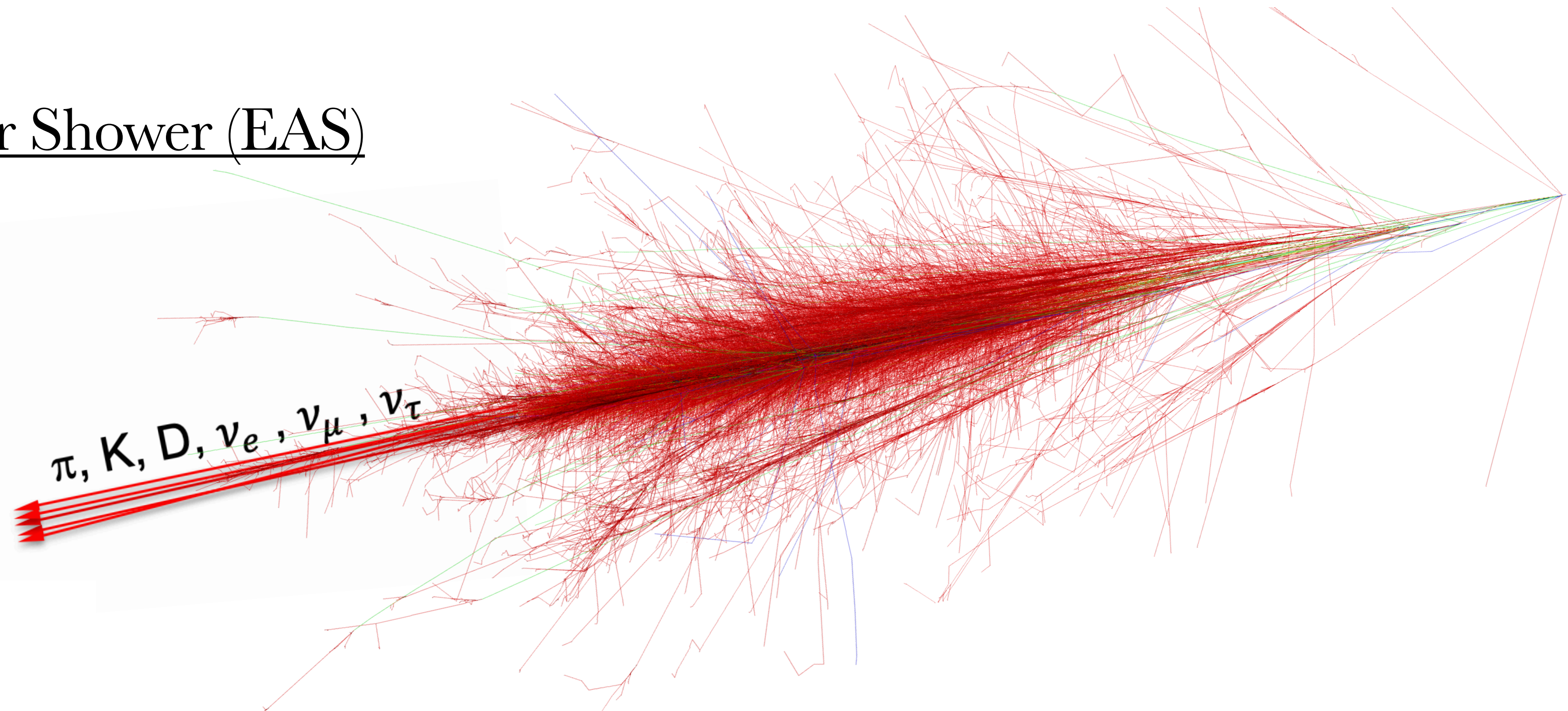
- By far the largest flux of energetic light particles is in the far-forward direction (mesons, neutrinos, and maybe also dark photons, ALPs, mCPs, DM, ...)
- Proposal: Forward Physics Facility (FPF) at LHC ($\eta \gtrsim 7$)
- Synergies between FPF physics and astroparticle physics!

FPF and CF-7

- Large Hadron Collider (LHC)



- Extensive Air Shower (EAS)



FAR FORWARD EXPERIMENTS AT LHC RUN 3

There are currently 3 detectors underway to exploit forward physics potential in the upcoming LHC Run 3

UJ18

ATLAS

SPS

UJ12

LHC

SND@LHC: approved March 2021

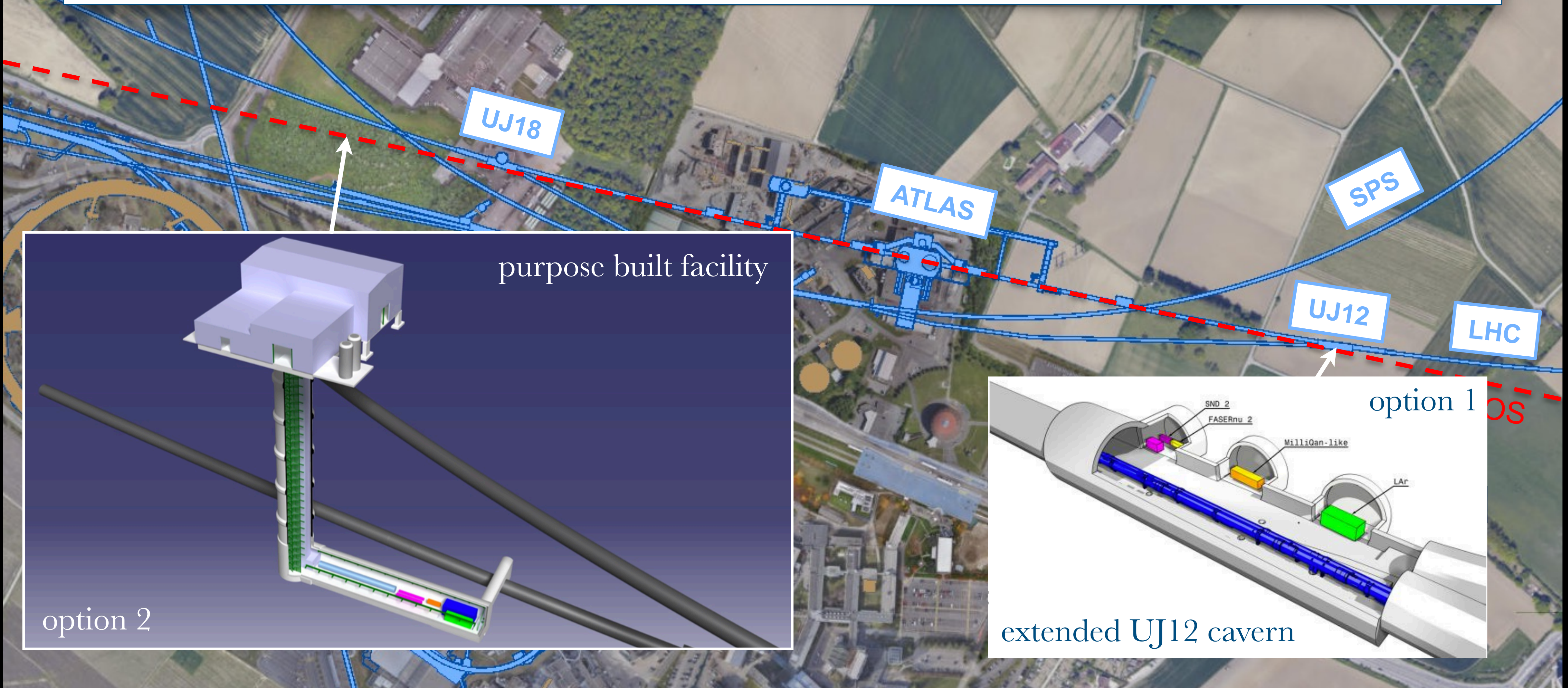
FASER: approved March 2019
FASERv: approved December 2019

LOS

- ▶ Experiments shielded from interaction point by more than 100 m of rock
- ▶ Extremely low background!
- ▶ Ideal to measure rare processes, e.g. exotic physics, neutrino physics, ...

FAR FORWARD EXPERIMENTS AT LHC RUN 3

The FPF is proposed to extend this program into the HL-LHC era!

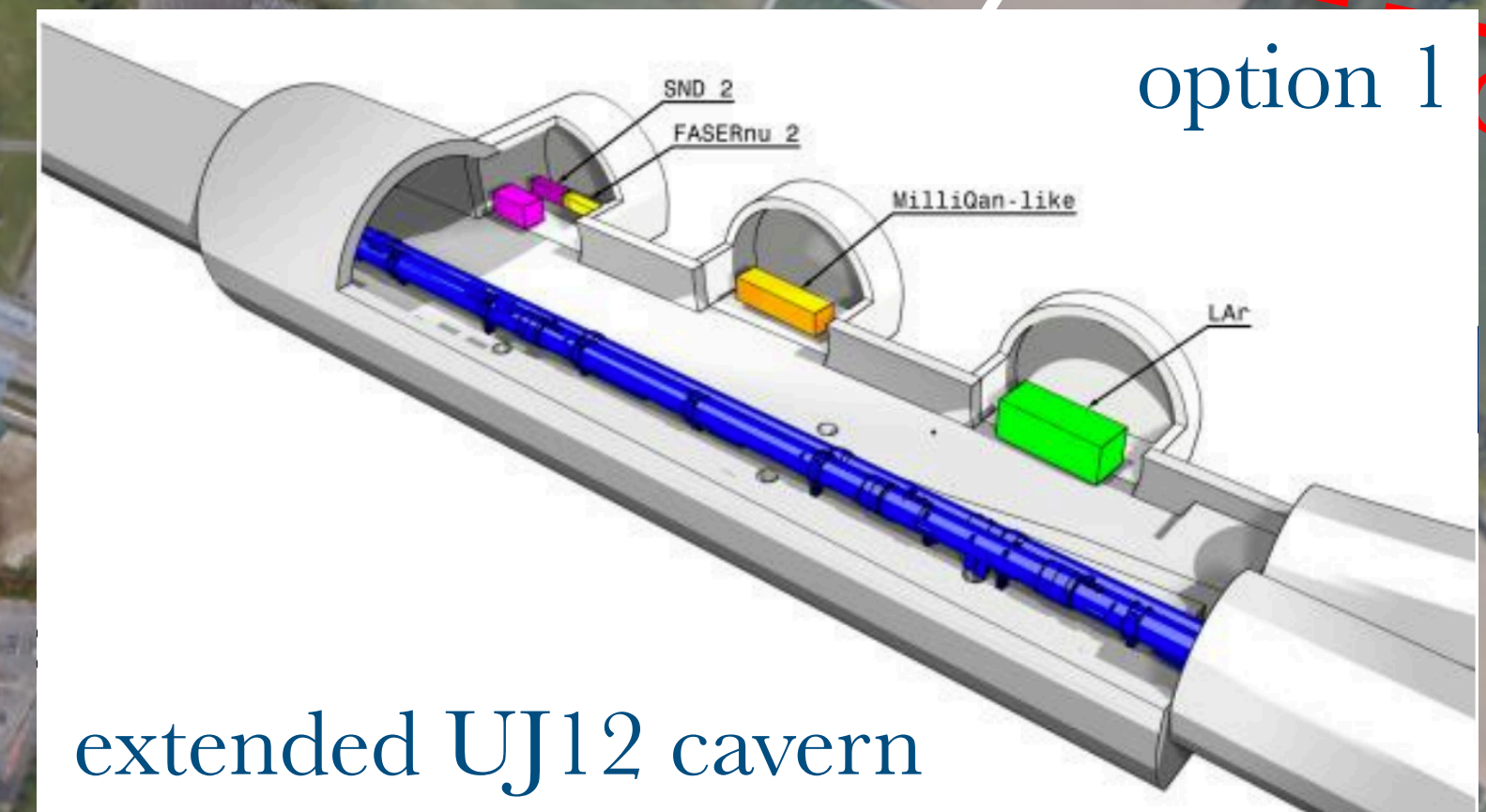


purpose built facility

option 2

option 1

extended UJ12 cavern



FPF Physics Potential

► Example:

FASER ν pilot detector

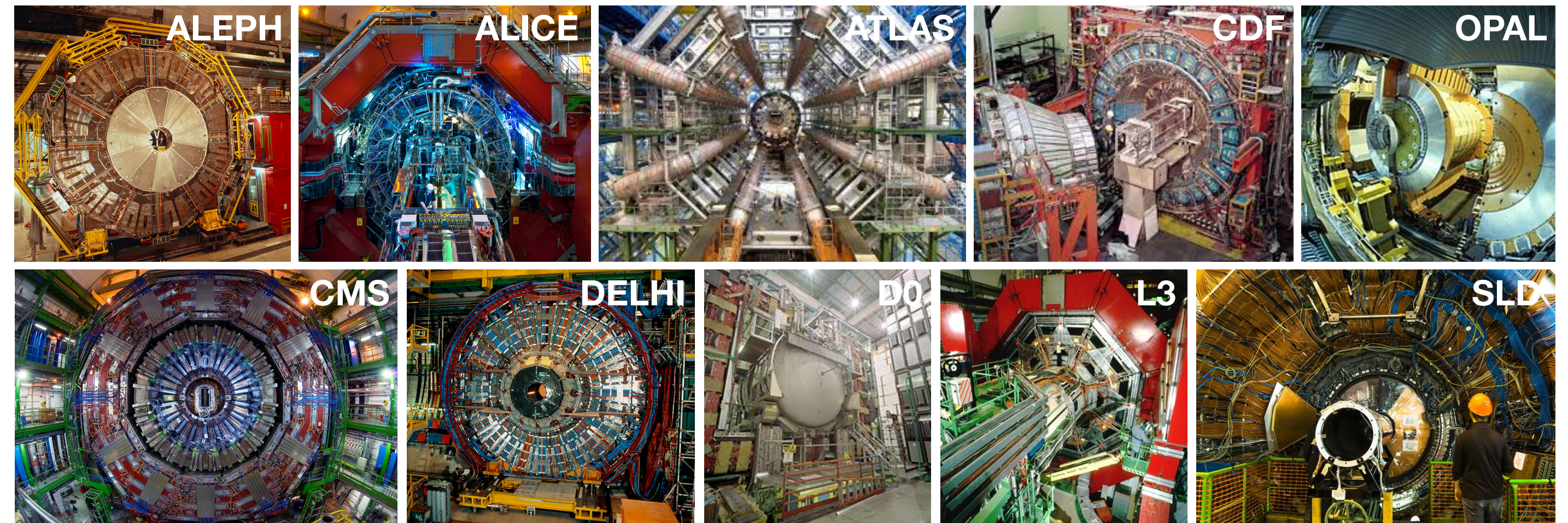
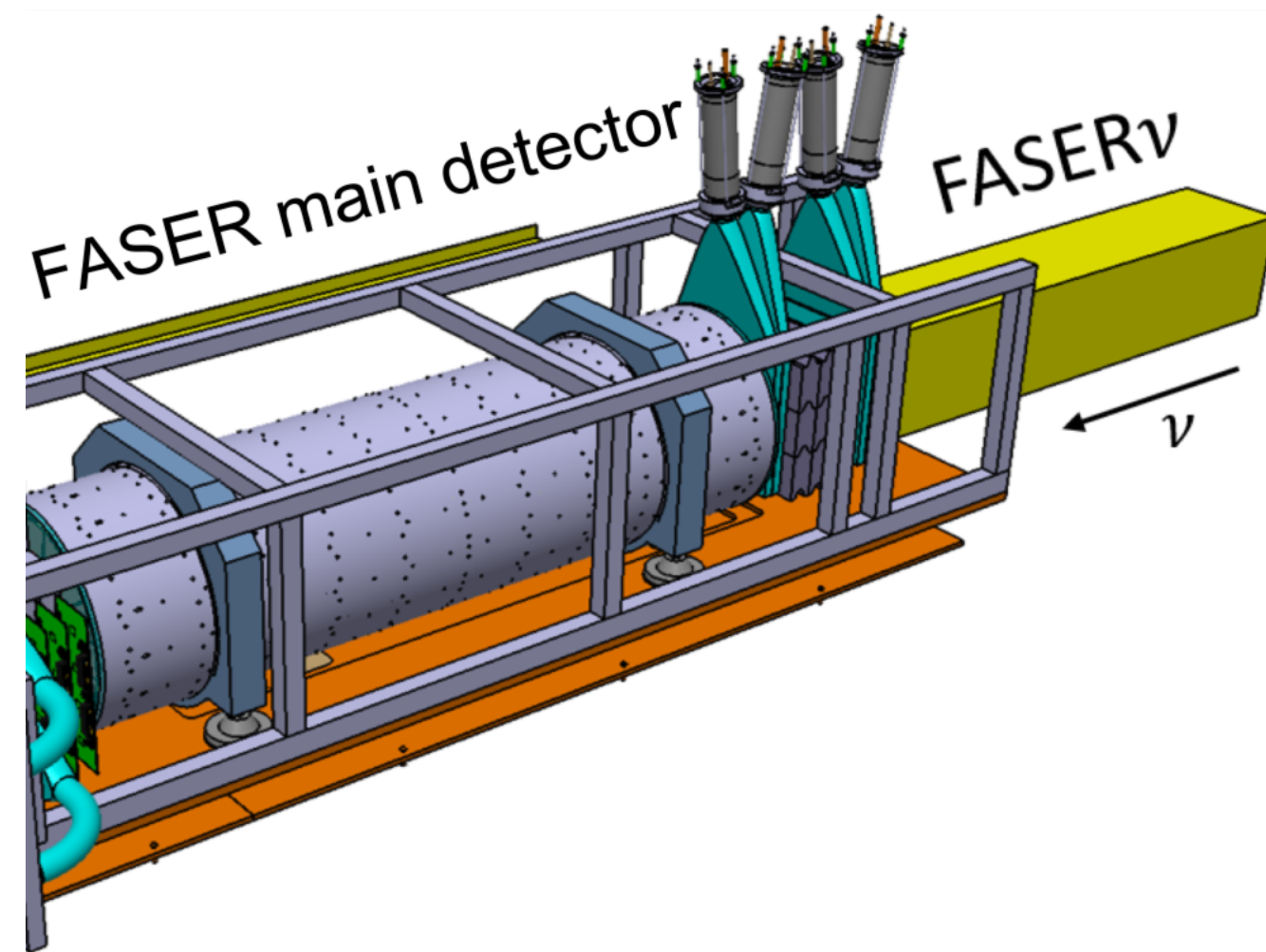
vs.

All previous collider experiments

- Suitcase size, 4 weeks of data
- Costs: \$0 (recycled parts)
- 6 TeV-neutrino candidates

[[arXiv:2105.06197](https://arxiv.org/abs/2105.06197)]

- Building size, decades of data
- Costs: $\sim \$10^9$
- 0 TeV-neutrino candidates



FPF Physics Potential

- ▶ Example:

FASER ν pilot detector

vs.

All previous collider experiments

- ▶ Suitcase size, 4 weeks of data
- ▶ Costs: \$0 (recycled parts)
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[[arXiv:2105.06197](#)]

- ▶ Building size, decades of data
- ▶ Costs: $\sim \$10^9$
- ▶ 0 TeV-neutrino candidates

- ▶ Years 2022-2024:

- ▶ ~ 10000 ν candidates expected
($\sim 10^9$ muons*)

- ▶ Forward Physics Facility:

- ▶ $\sim 10^6$ ν candidates expected!
($\sim 10^{12}$ muons*)

- ▶ Obvious synergies with astro-particle physics, e.g. IceCube...
- ▶ Scientific exchange between FPF and astroparticle community

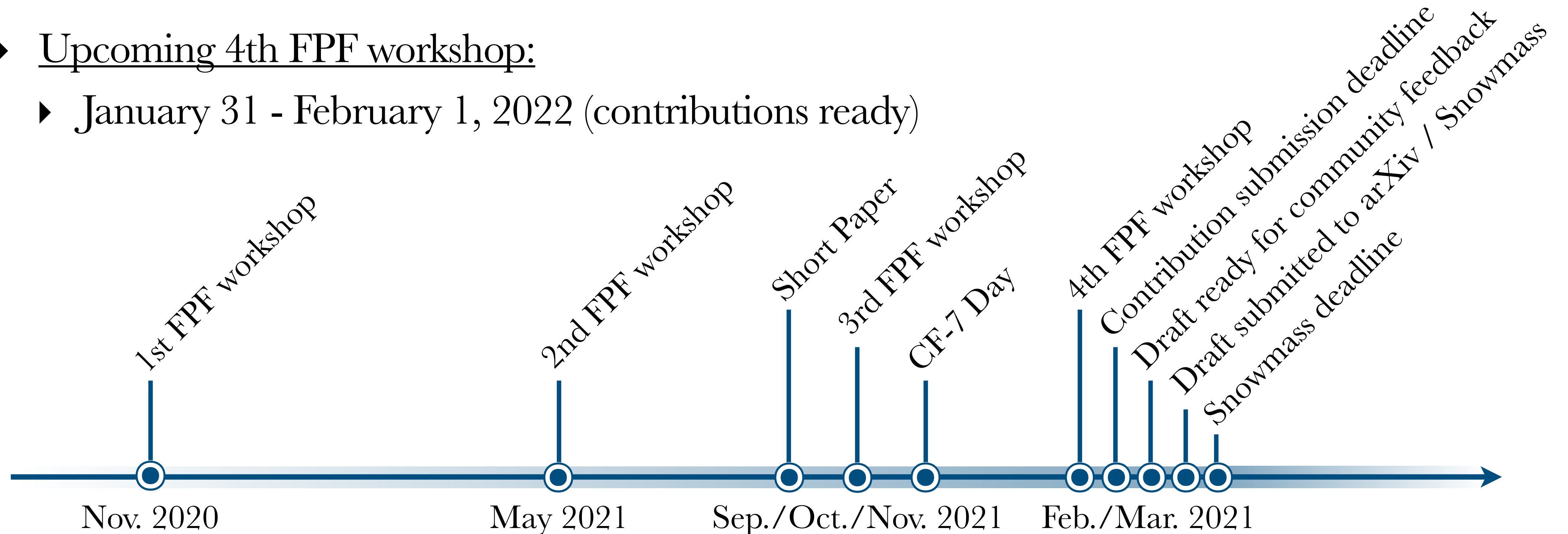
Timeline

- ▶ 3 dedicated FPF workshops:

- ▶ November 2020: <https://indico.cern.ch/event/955956/>
- ▶ May 2021: <https://indico.cern.ch/event/1022352/>
- ▶ October 2021: <https://indico.cern.ch/event/1076733/>

- ▶ Upcoming 4th FPF workshop:

- ▶ January 31 - February 1, 2022 (contributions ready)



Short Paper

- ▶ FPF Short Paper:
 - ▶ First "real" paper on FPF
 - ▶ About 80 authors
 - ▶ About 75 pages
 - ▶ Submitted to Physics Reports in September 2021
 - ▶ Pre-print: [arXiv:2109.10905](https://arxiv.org/abs/2109.10905)
 - ▶ Overview of ideas
 - ▶ Reference for future work
 - ▶ Basis for this White Paper...

BNL-222142-2021-FORE, CERN-PBC-Notes-2021-025, DESY-21-142, FERMILAB-CONF-21-452-AE-E-ND-PPD-T
KYUSHU-RCAPP-2021-01, LU TP 21-36, PITT-PACC-2118, SMU-HEP-21-10, UCI-TR-2021-22

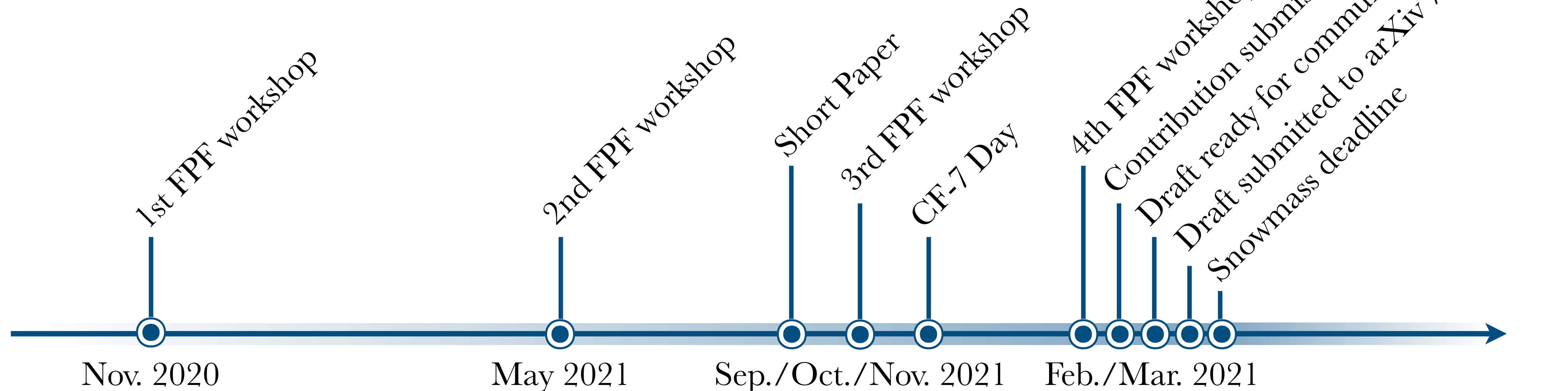
The Forward Physics Facility: Sites, Experiments, and Physics Potential

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The Forward Physics Facility (FPF) is a proposal to create a cavern with the space and infrastructure to support a suite of far-forward experiments at the Large Hadron Collider during the High Luminosity era. Located along the beam collision axis and shielded from the interaction point by at least 100 m of concrete and rock, the FPF will house experiments that will detect particles outside the acceptance of the existing large LHC experiments and will observe rare and exotic processes in an extremely low-background environment. In this work, we summarize the current status of plans for the FPF, including recent progress in civil engineering in identifying promising sites for the FPF and the experiments currently envisioned to realize the FPF's physics potential. We then review the many Standard Model and new physics topics that will be advanced by the FPF, including searches for long-lived particles, probes of dark matter and dark sectors, high-statistics studies of TeV neutrinos of all three flavors, aspects of perturbative and non-perturbative QCD, and high-energy astroparticle physics.

Timeline

- ▶ Today: Call for White Paper contributions!
- ▶ White Paper (~100-200 pages):
 - ▶ February 7, 2022: Final submission deadline for contributions
 - ▶ February 21, 2022: Draft sent for community feedback
 - ▶ March 5, 2022: Draft submitted to arXiv / Snowmass
 - ▶ March 15, 2022: Snowmass White Paper deadline



White Paper

- ▶ 5 lead conveners:
 - ▶ Jonathan Feng
 - ▶ Felix Kling
 - ▶ Juan Rojo
 - ▶ Mary Hall Reno
 - ▶ Dennis Soldin
- ▶ 5 topical sections:
 - ▶ Facility / Experiments
 - ▶ BSM Physics
 - ▶ QCD
 - ▶ Neutrino Physics
 - ▶ Astroparticle Physics
- ▶ Additional topical co-conveners (most confirmed)
- ▶ Snowmass Slack channel: #fpf-whitepaper
- ▶ We will also contact potential contributors (based on Short Paper authors)
- ▶ Contributions: contact conveners / google form via email

White Paper Outline

I. Executive Summary (Lead conveners)



Forward Physics Facility Whitepaper

A. Alpha, B. Beta, ..., and Z. Omega

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II. Introduction (Lead conveners)



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III. The Facility and Experiments (J. Feng)

- ▶ Facility
- ▶ FASER 2
- ▶ FASER ν 2
- ▶ AdvSND
- ▶ FLArE
- ▶ FORMOSA
- ▶ ...and more ideas!

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IV. Tools (All)

- ▶ Hadronic Generators
- ▶ Particle Transport Codes
- ▶ MC Tools for Neutrino Interactions
- ▶ MC Tools for BSM

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V. BSM Physics (F. Kling, TBC)

- ▶ Long-lived Particle Decays at the FPF
- ▶ Dark Matter Scattering at the FPF
- ▶ Milli-charged Particles at the FPF
- ▶ Others...

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VI. QCD (J. Rojo, TBC)

- ▶ Forward charm production
- ▶ Forward neutrino production (non-charm)
- ▶ BFKL/small-x physics
- ▶ Neutrino interactions and cross-sections at TeV
- ▶ Testing low-energy QCD with neutrino scattering
- ▶ Neutrino DIS: implications for proton/nuclear PDFs
- ▶ Far-forward hadronic physics
- ▶ Opportunities for FPF physics in the pA runs
- ▶ Key observables for QCD measurements at FPF
- ▶ ...

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VII. Neutrino Physics (H. Reno, TBC)

- ▶ Neutrino fluxes
- ▶ Neutrino cross sections
- ▶ BSM physics with neutrinos

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VIII. Astroparticle Physics (D. Soldin, L. Anchordoqui)

- ▶ Cosmic ray physics
- ▶ The Muon Puzzle
- ▶ Atmospheric neutrino fluxes
- ▶ Other applications...

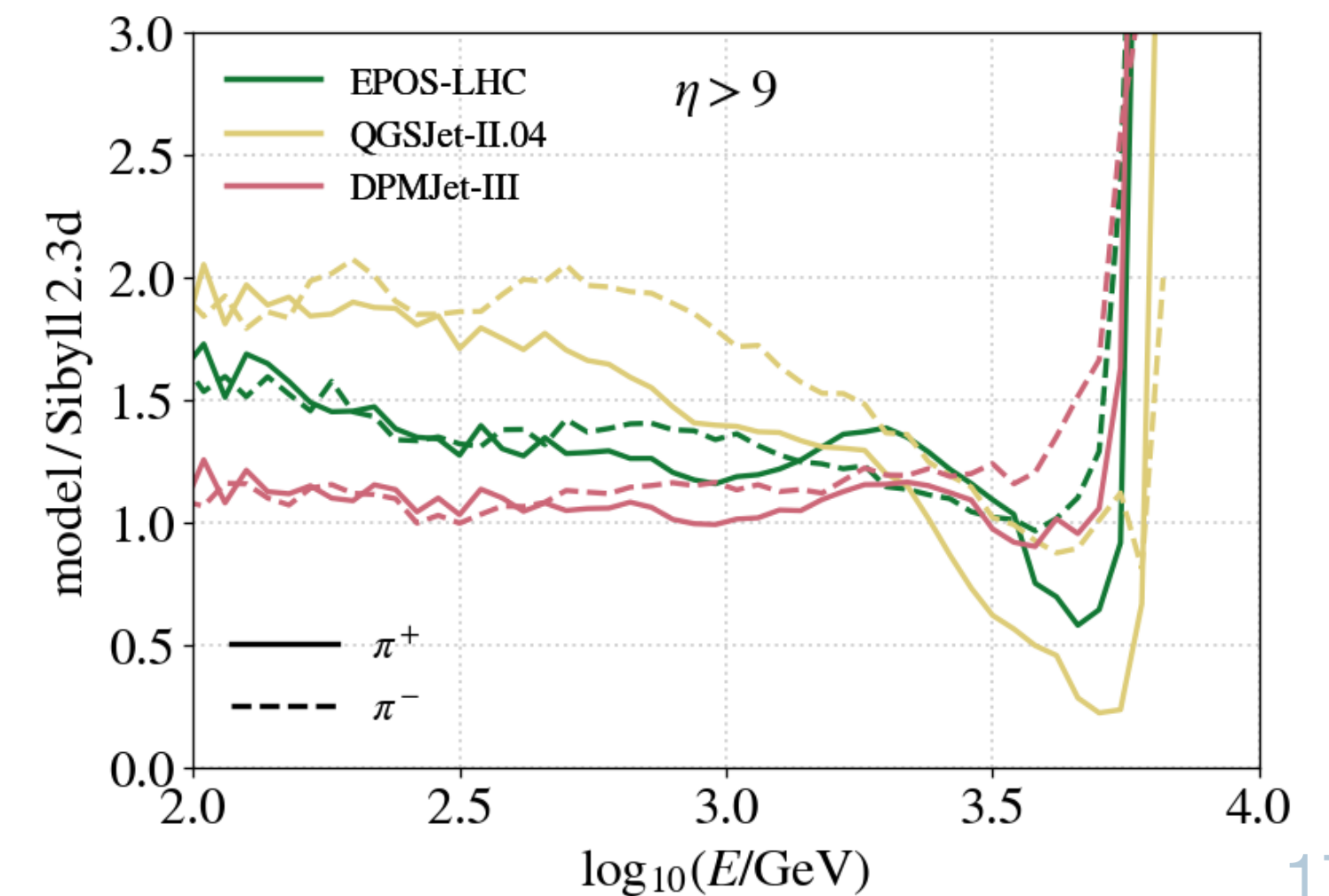
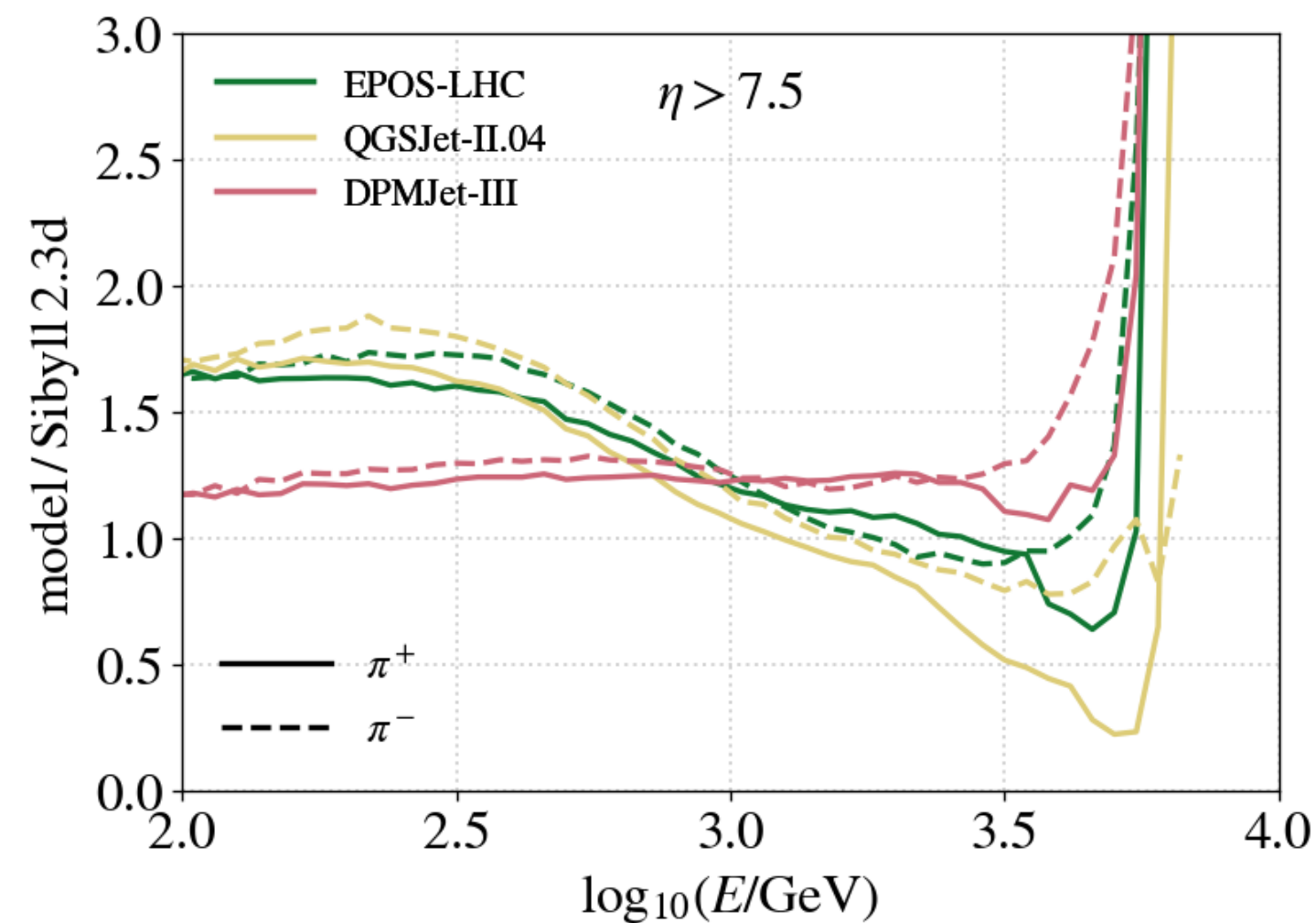
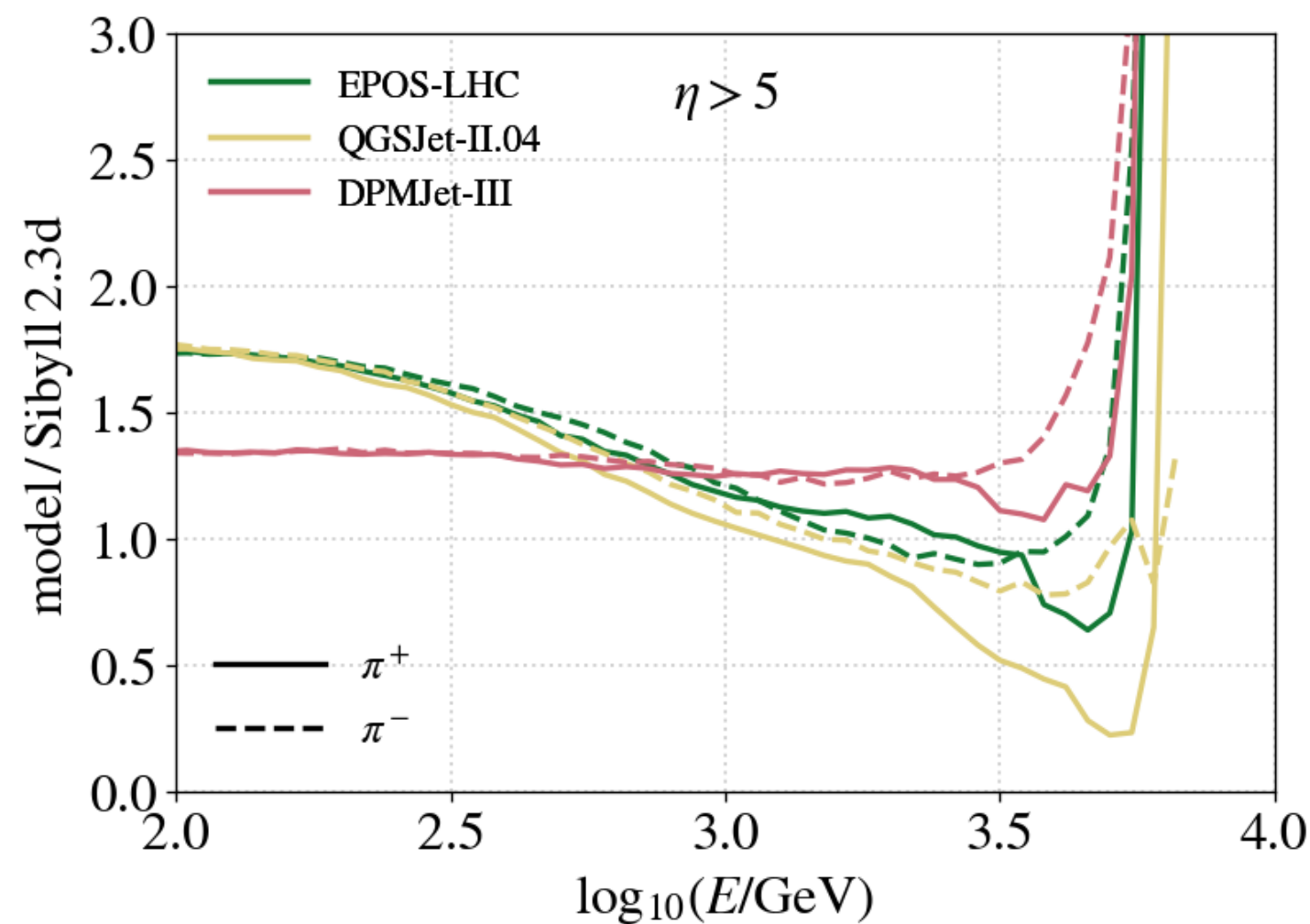
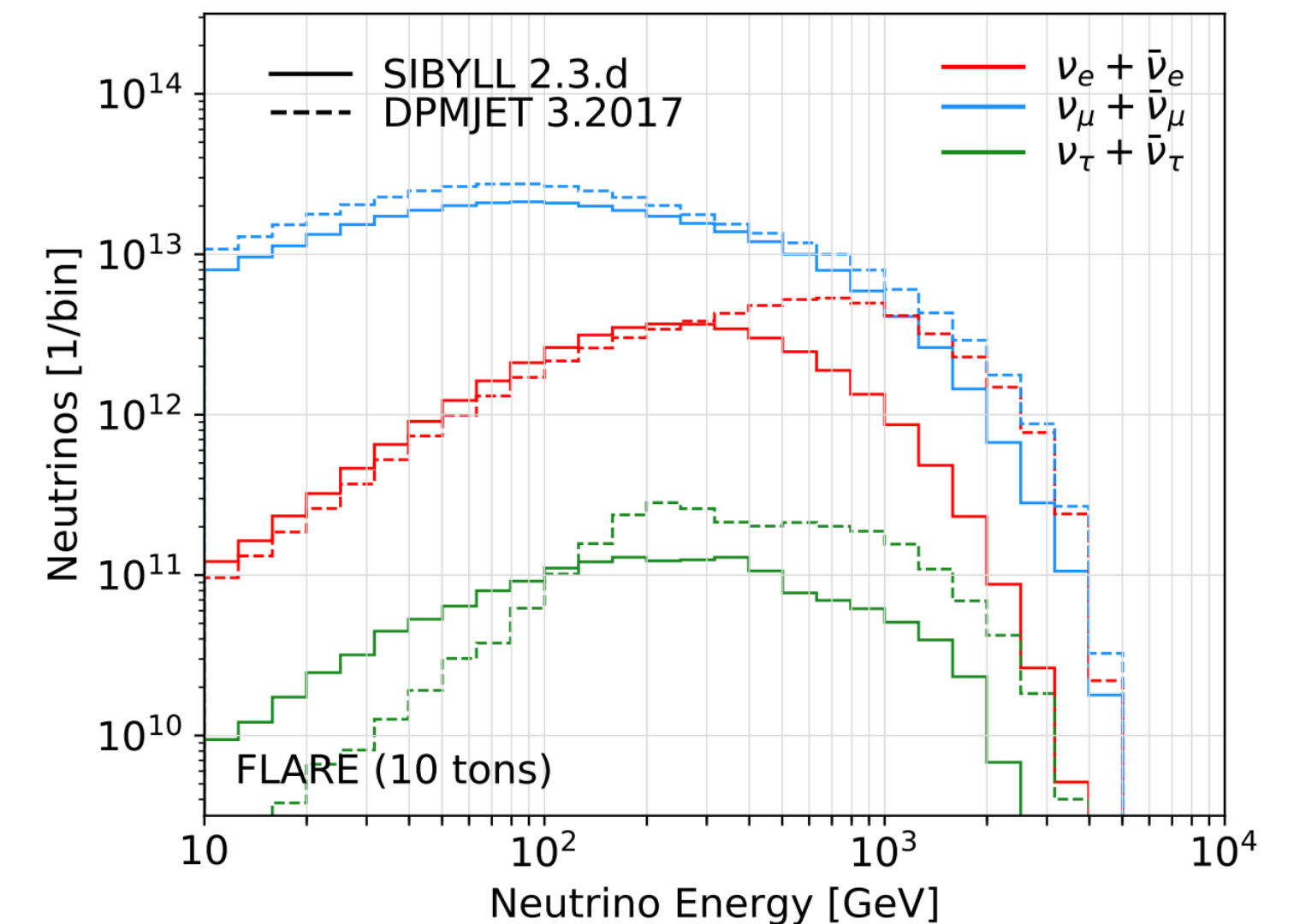
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VIII. Astroparticle Physics

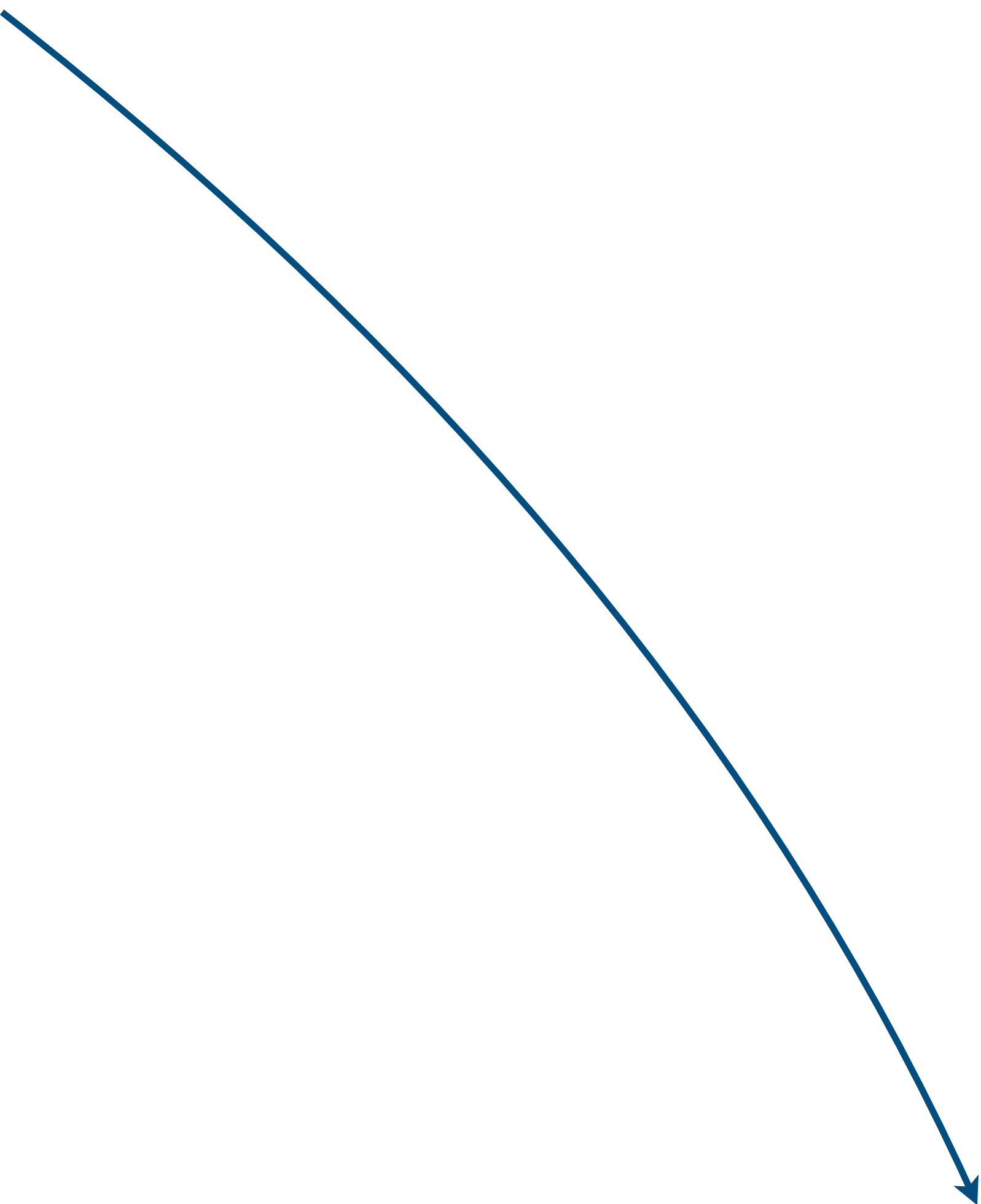
Many contributions to FPF workshops / Short Paper

- ▶ Atmospheric neutrino fluxes (I. Sarcevic, M.V. Garzelli, F. Halzen, D. Soldin)
- ▶ Neutrino MC generators (H. Reno, A. Garcia, V. Pandey, L. Pickering, U. Mosel, P. Sala, J. Sobczyk, ...)
- ▶ Hadronic MC generators (T. Pierog, S. Ostapchenko, F. Riehn, A. Fedynitch, J. Soriano, L. Anchordoqui, R. Engel)
- ▶ Atmospheric muon fluxes (H. Dembinski, D. Soldin)



White Paper Outline

IX. Conclusions (Lead conveners)



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Synergies

Topical overlap with other Snowmass White Papers:

- ▶ "Ultra-High-Energy Cosmic Rays" (see F. Sarazin's talk)
 - ▶ Synergies between UHECR and FPF
- ▶ "Event Generators for High-Energy Physics Experiments"
 - ▶ Common hadronic / neutrino event generators
- ▶ Others, e.g. neutrino White Paper?

Coordination required! (D. Soldin, S. Hoeche, ...?)

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Status & Outlook

- ▶ All contributions very welcome!

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- ▶ Dennis Soldin: soldin@udel.edu
- ▶ Most topical co-conveners confirmed
- ▶ We will reach out to potential contributors asap
- ▶ 4th FPF Workshop: January 31 - February 1, 2022
- ▶ Deadline for contributions: February 7, 2022



FPF Short Paper:
[arXiv:2109.10905](https://arxiv.org/abs/2109.10905)

We are looking forward
to your contributions!

Thanks!