Air shower simulations and hadronic interactions with CORSIKA 8

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for the CORSIKA 8 collaboration

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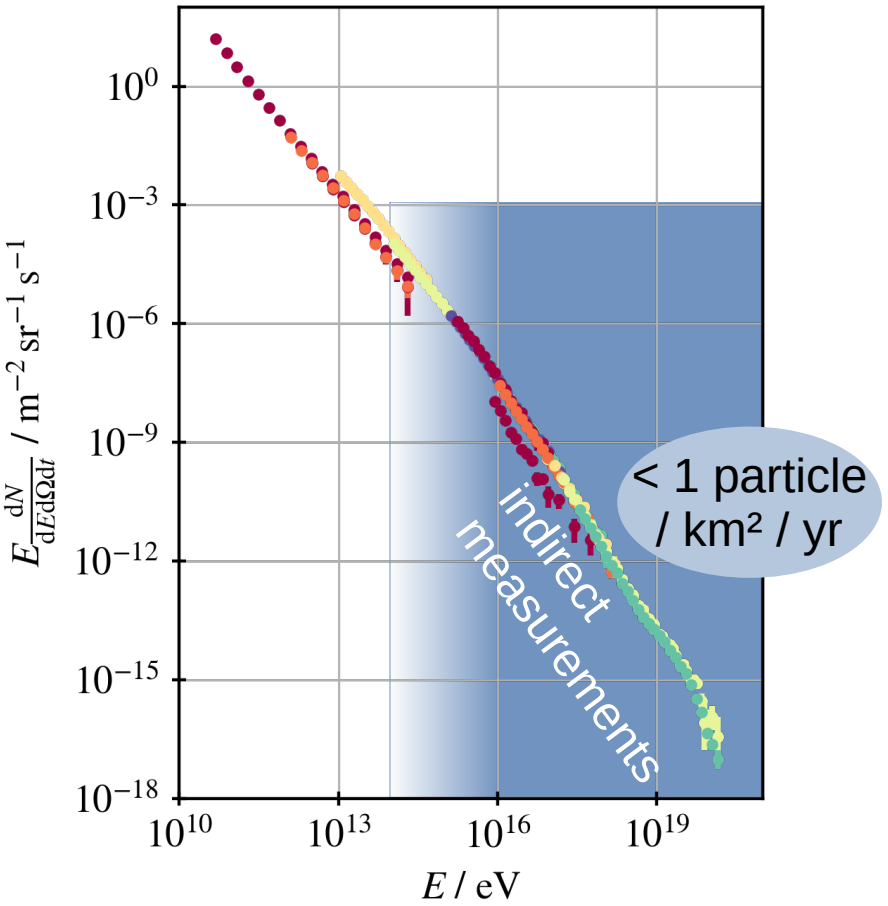
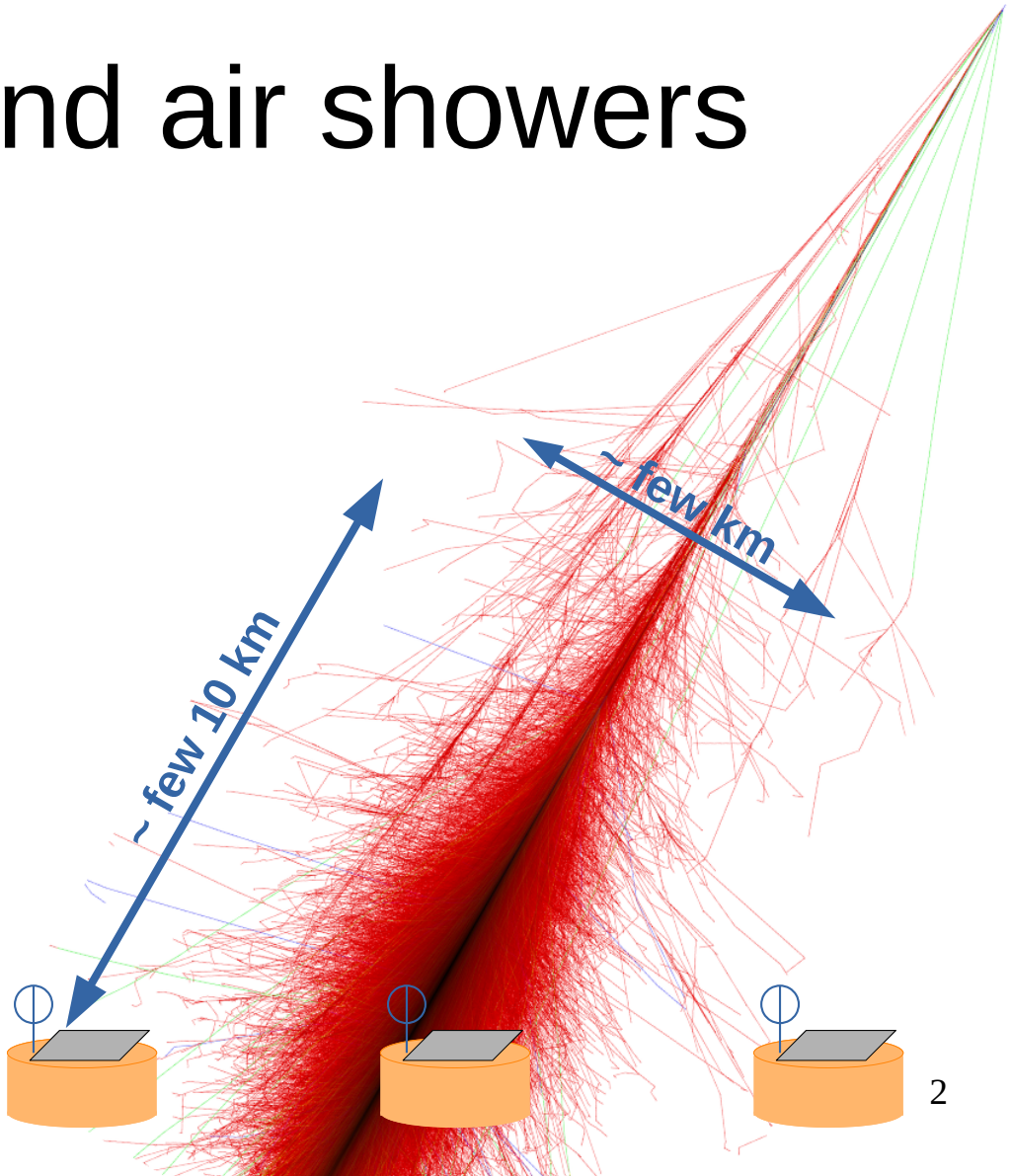
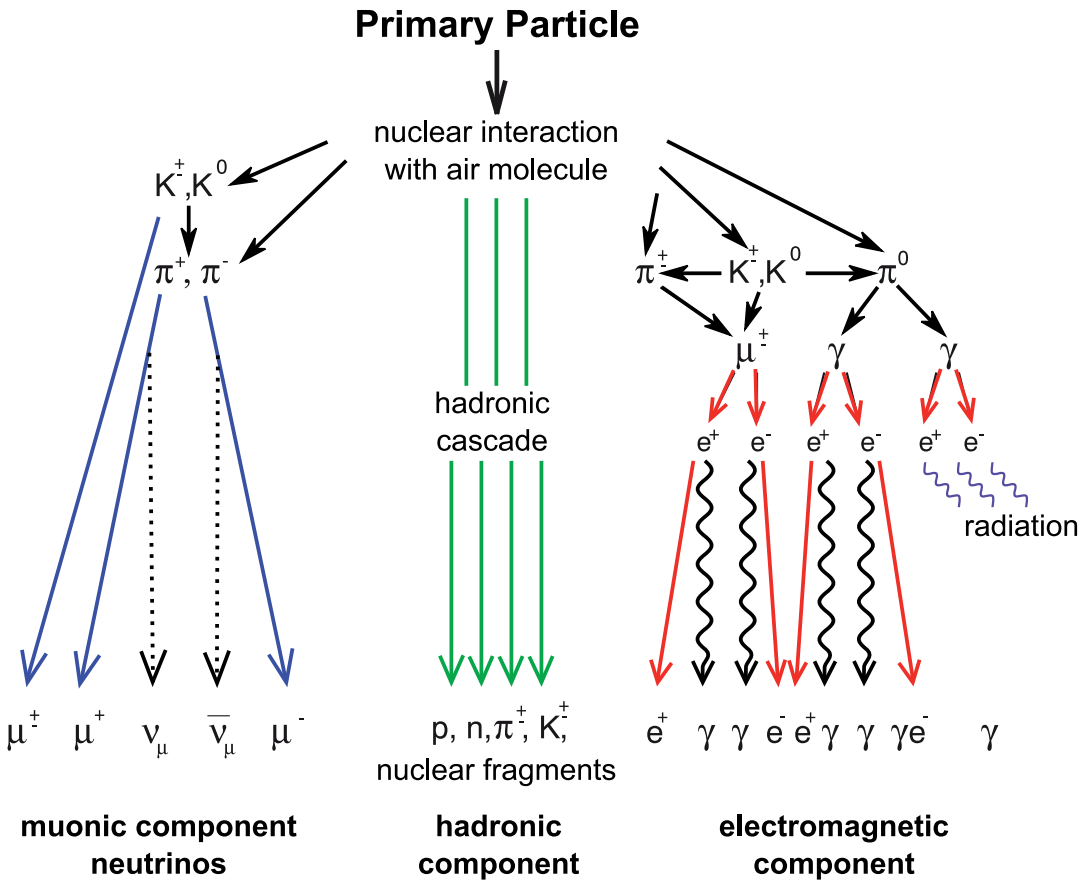
bw HPC

Cosmic rays and air showers





Air shower physics

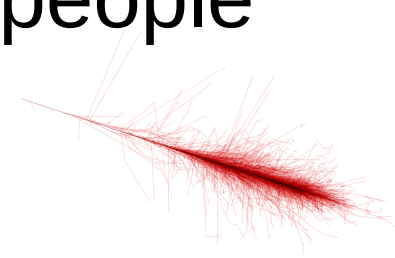


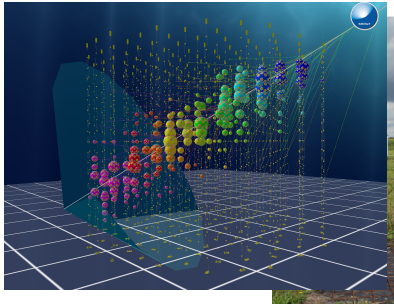
- > 30 particle species involved
- interactions from MeV to ZeV
- accurate simulations and physics models crucial
- reliable tools are a must-have

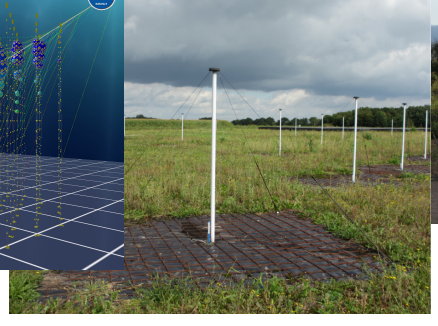
Haungs, Rebel, Roth, Rept. Prog. Phys. 66 (2003) 1145

CORSIKA

- *the* work horse for EAS simulations for ≥ 30 years
- but code is ageing, only two people know it well…
- hard to keep up with growing needs

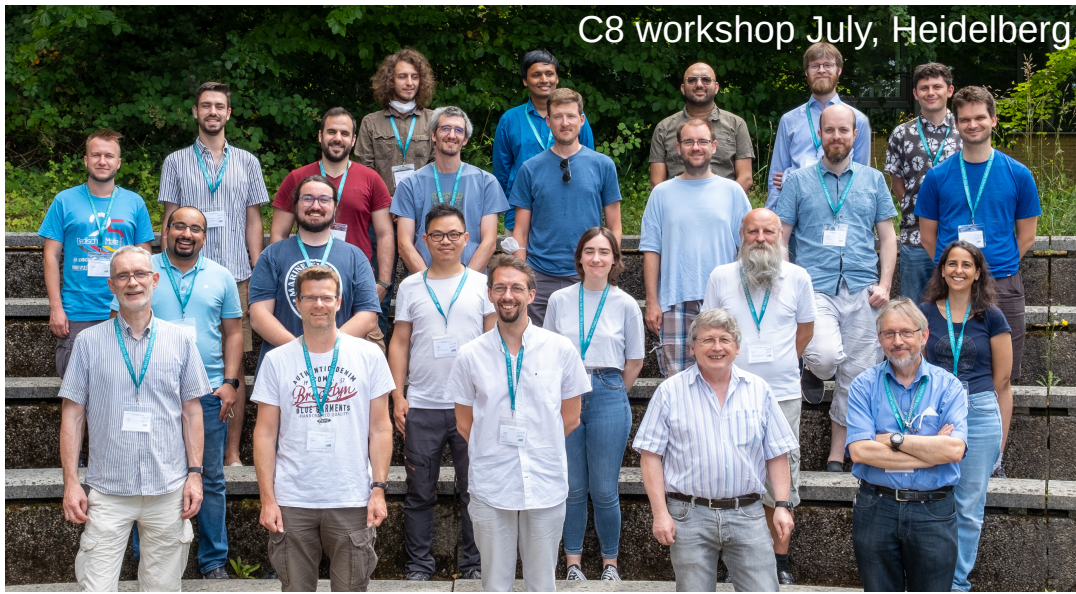






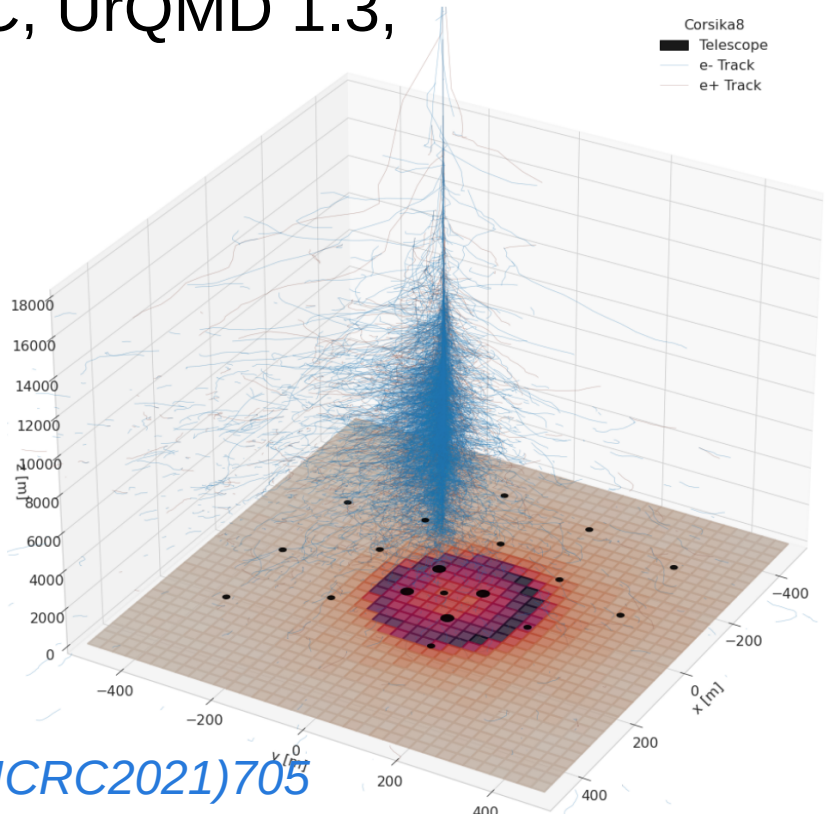
CORSIKA 8

- C++ framework for (air) shower simulations
- open source project, collaborative effort (link)
- modularity, flexibility:
  - physics models
  - geometry, media (e.g. air/ice showers)



Available physics modules

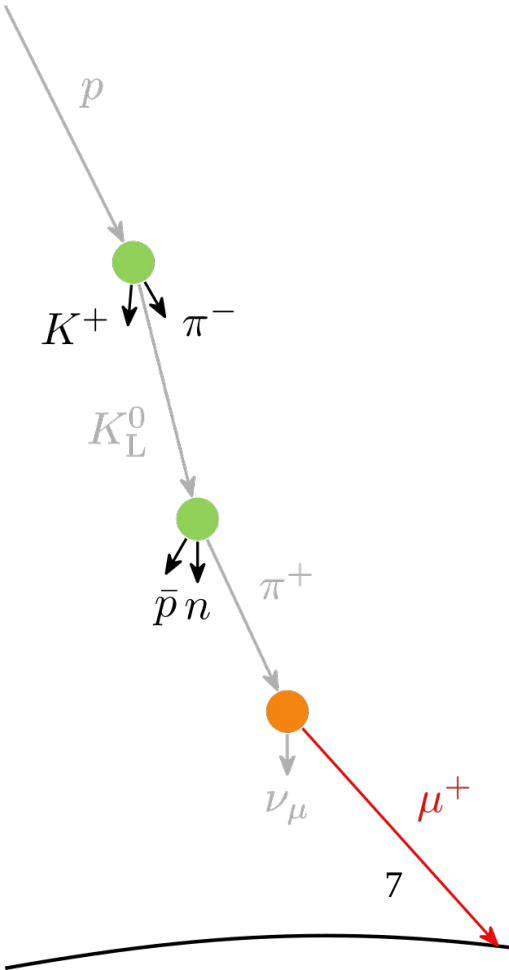
- hadronic interactions:
  SIBYLL 2.3d, QGSJetII-04, EPOS-LHC, UrQMD 1.3,
  Pythia 8.307
- EM interactions: PROPOSAL
- Cherenkov emission
  (GPU-computed)
- radio emission



Baack et al., PoS(ICRC2021)705

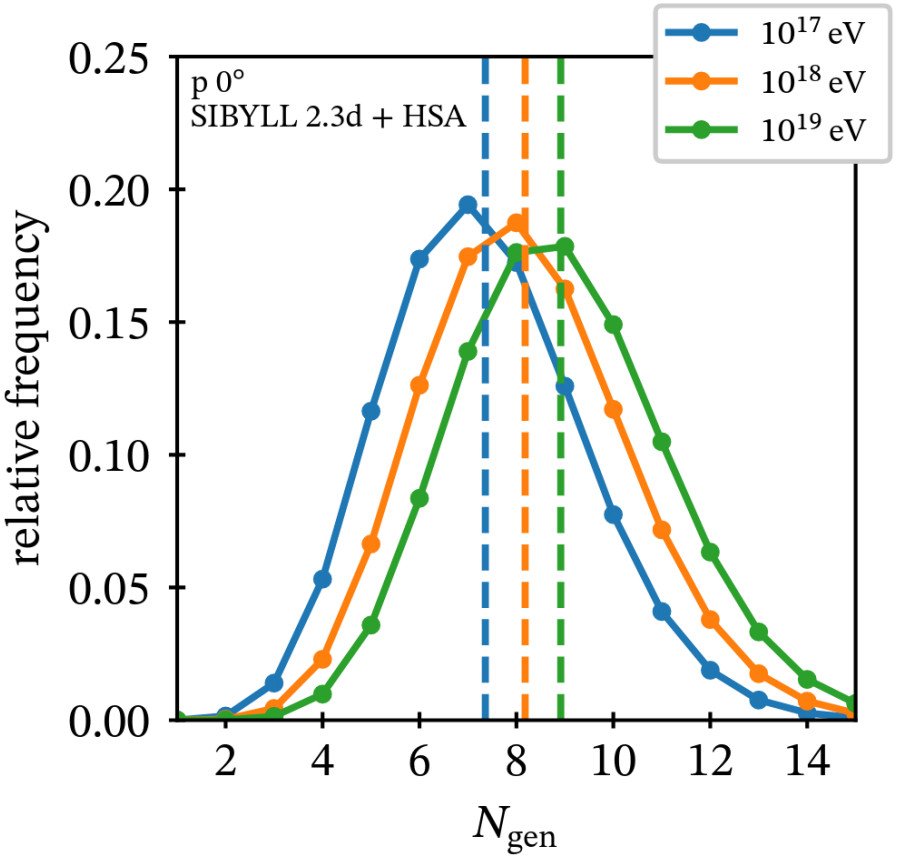
Shower *genealogy*

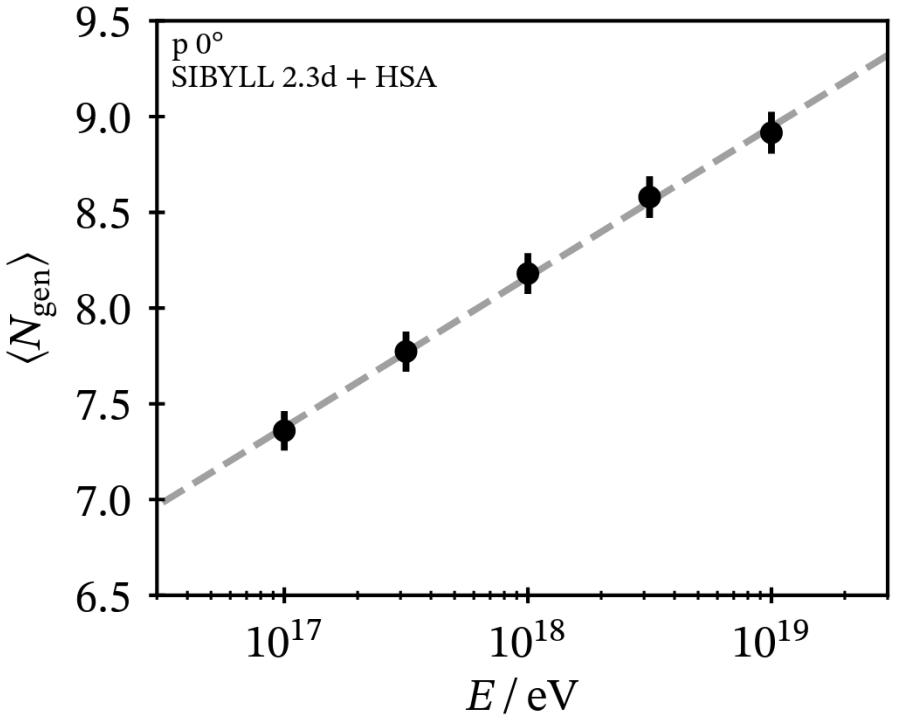
- motivation: *muon puzzle*
- inspect muons' ancestry, identify interesting phase-space
- shower evolution algorithm adapted to keep information in memory



MR, Pierog, Ulrich, 2108.03266

Number of generations



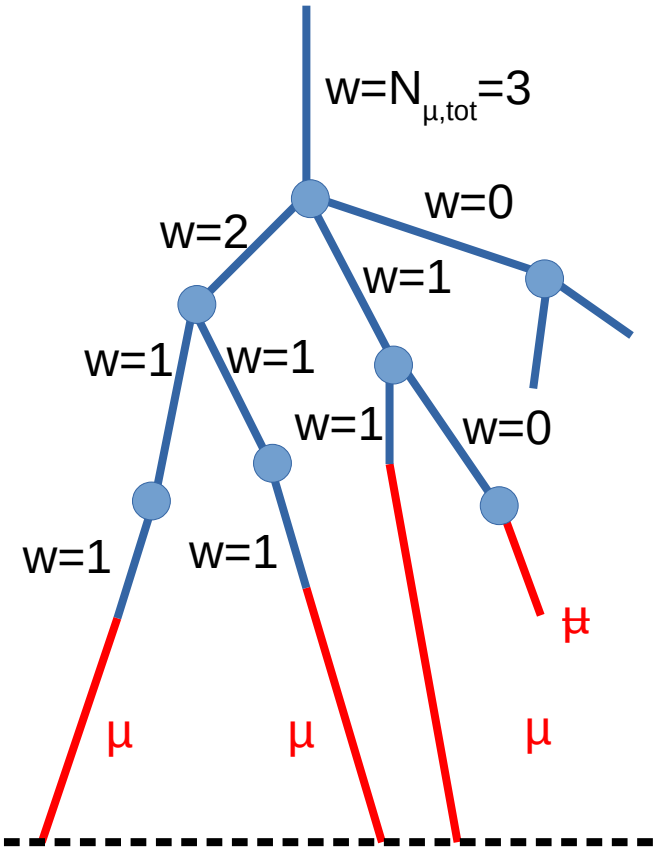


→ confirms toy-model expectations

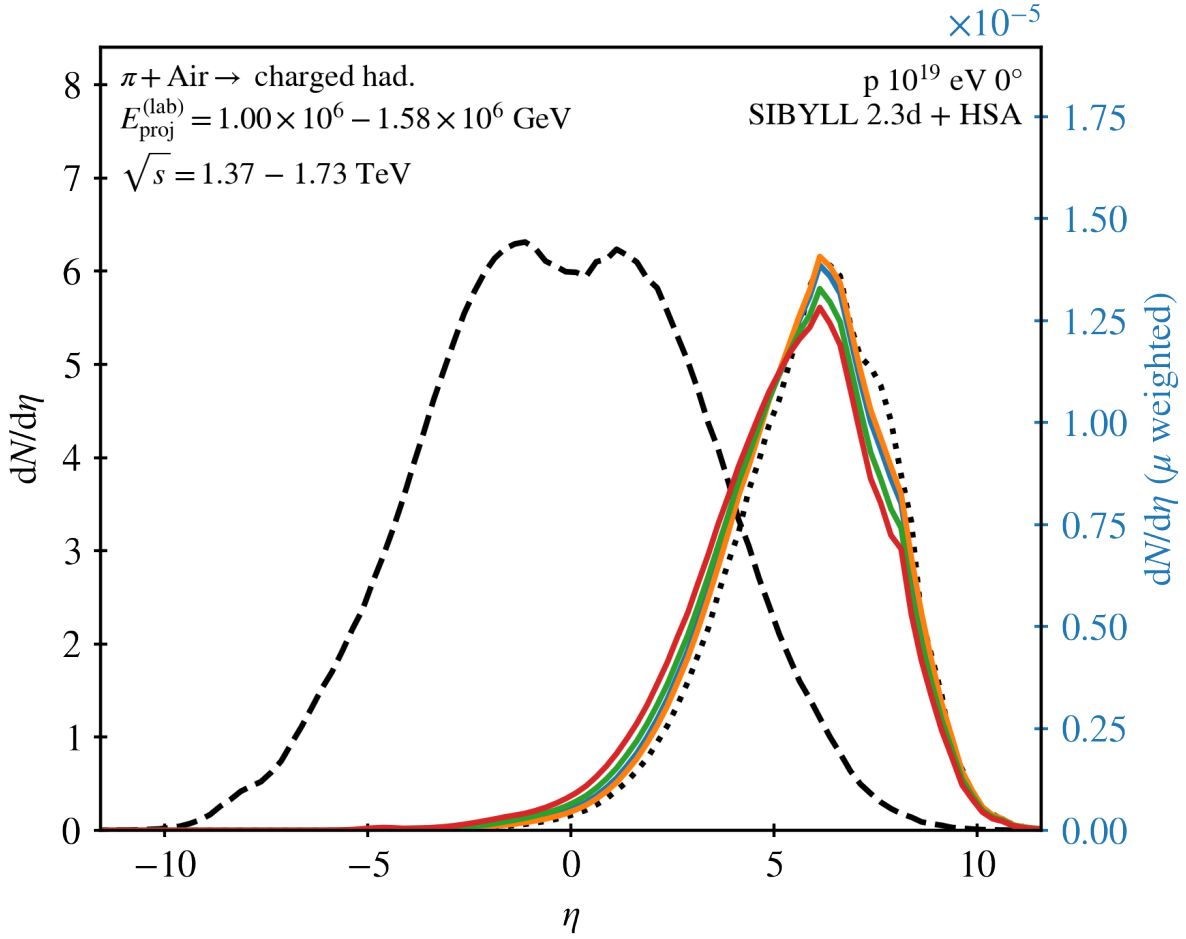
"muon weighted" phase space

How to quantify relevance / importance of individual particles for muon production?

→ assign weight given by number of (observed) muon descendants



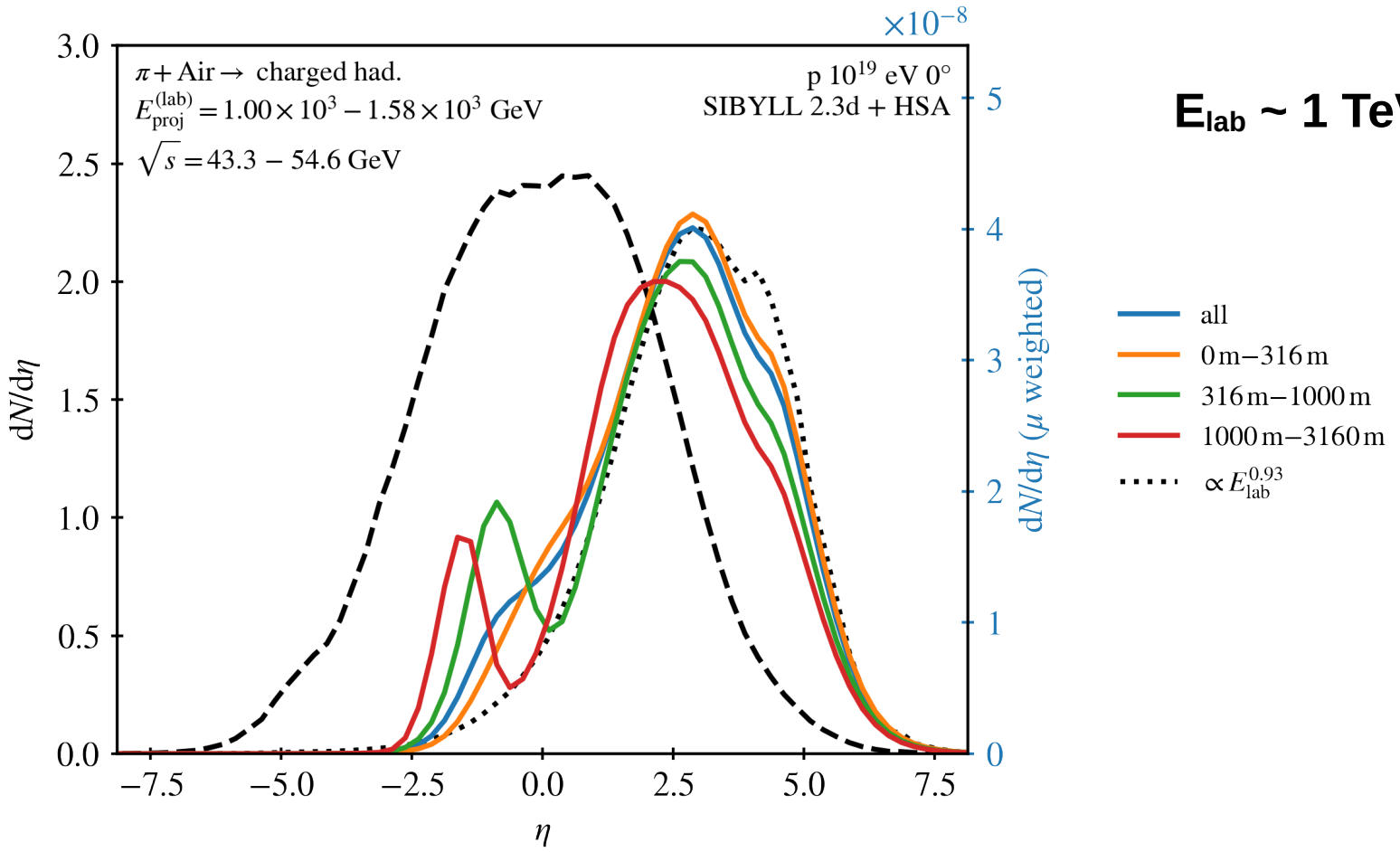
Pseudorapidity



E_{lab} ~ 1 PeV

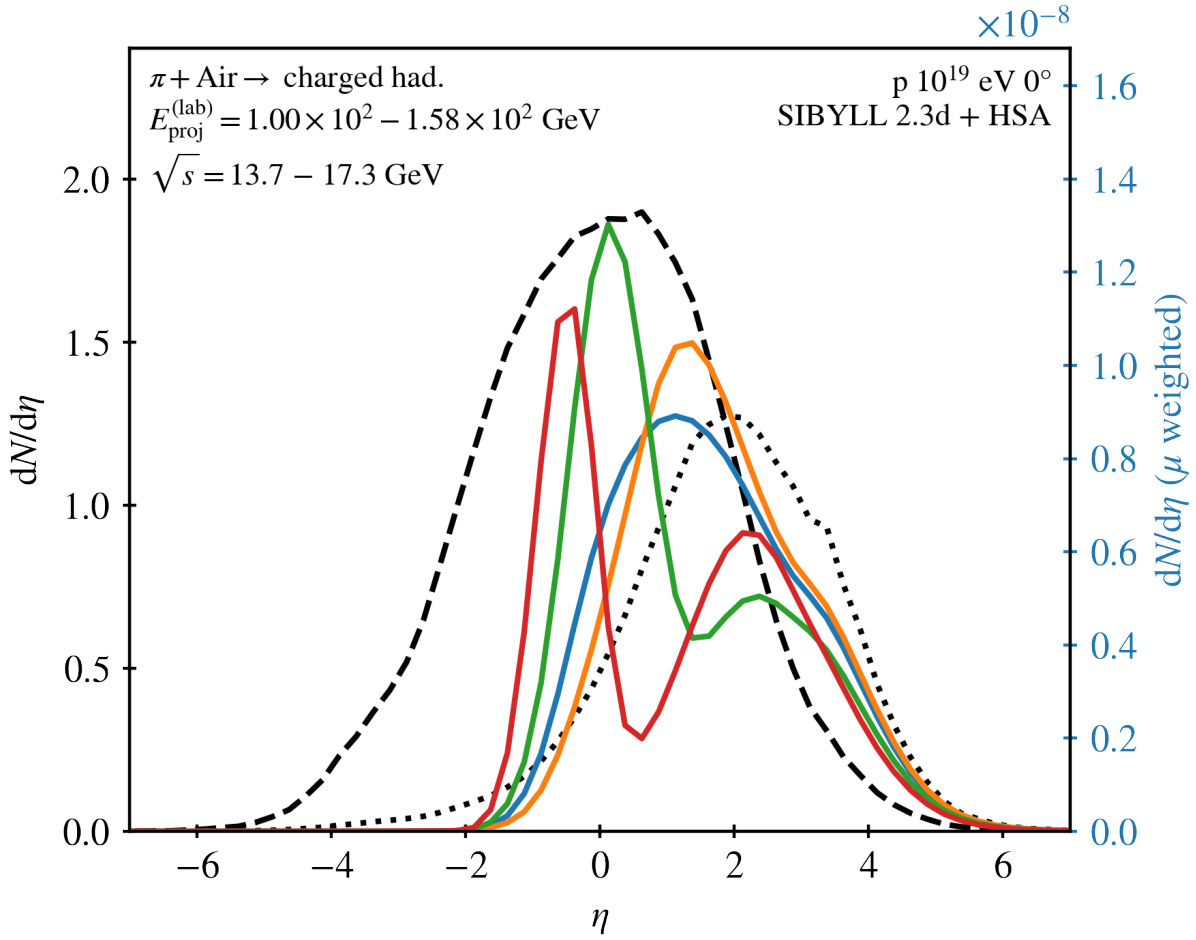
- toy-model estimation valid at high/intermediate energies
- barely dependent on lateral distance

Pseudorapidity



E_{lab} ~ 1 TeV

Pseudorapidity

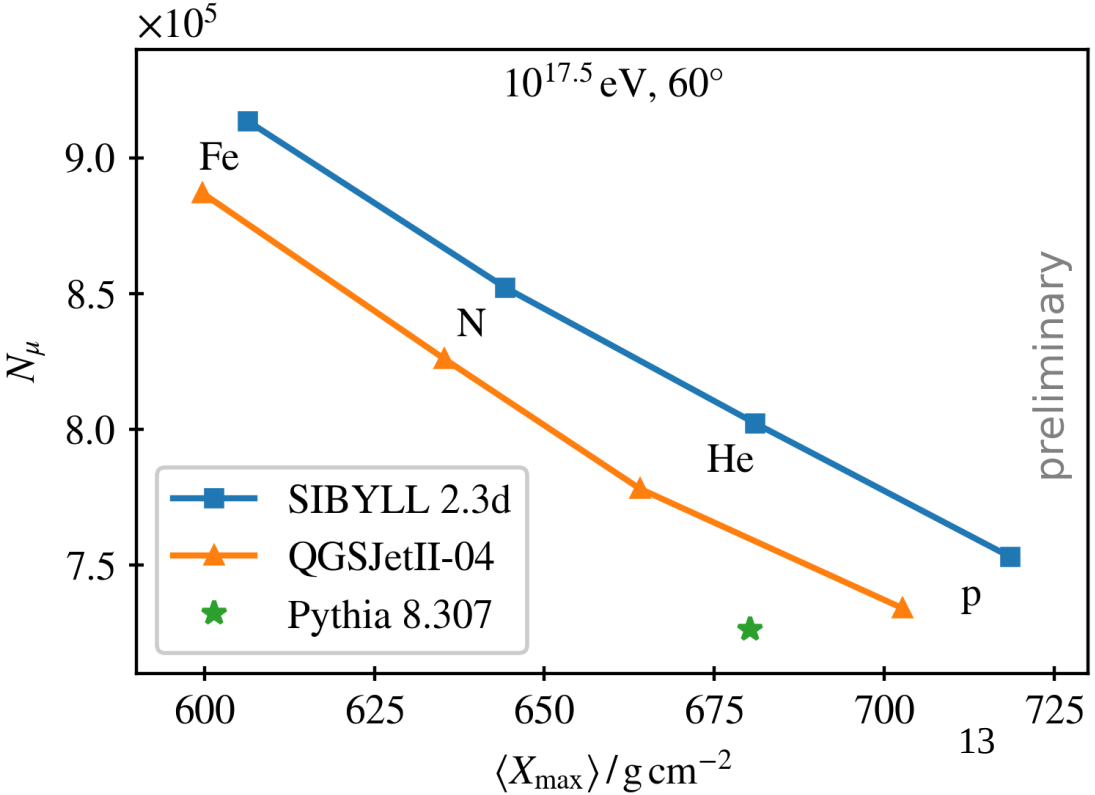


E_{lab} ~ 100 GeV

- last-generation π/K, no re-interaction
- relevance of mid-rapidity region

Pythia 8 in CORSIKA 8

- now usable as low- and high-energy interaction model
- kudos to Torbjörn Sjöstrand & Marius Utheim!
- results preliminary! (no μ from photohadronic int.; validation ongoing)
- so far only proton primaries possible

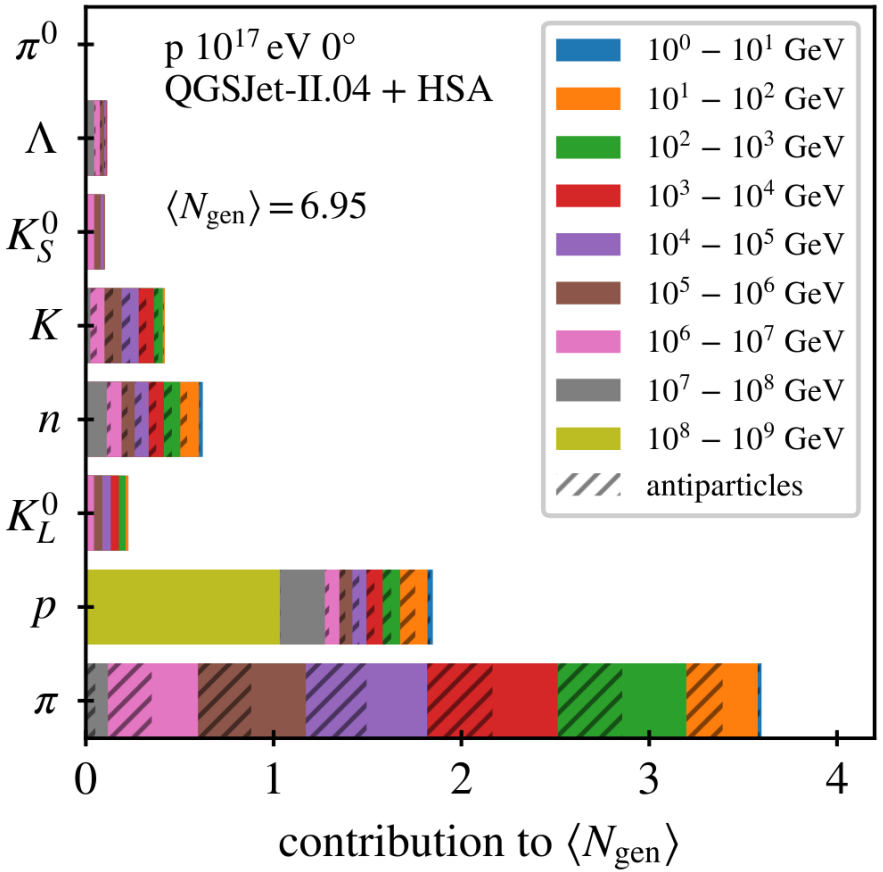


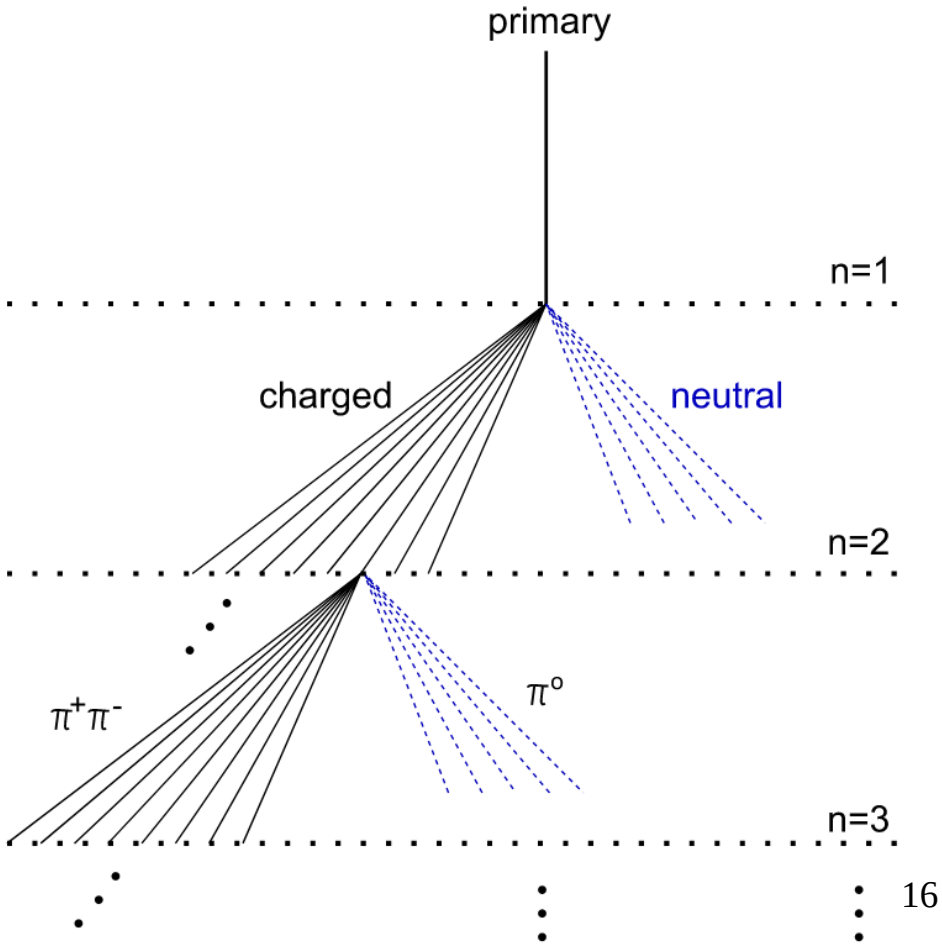
Conclusions

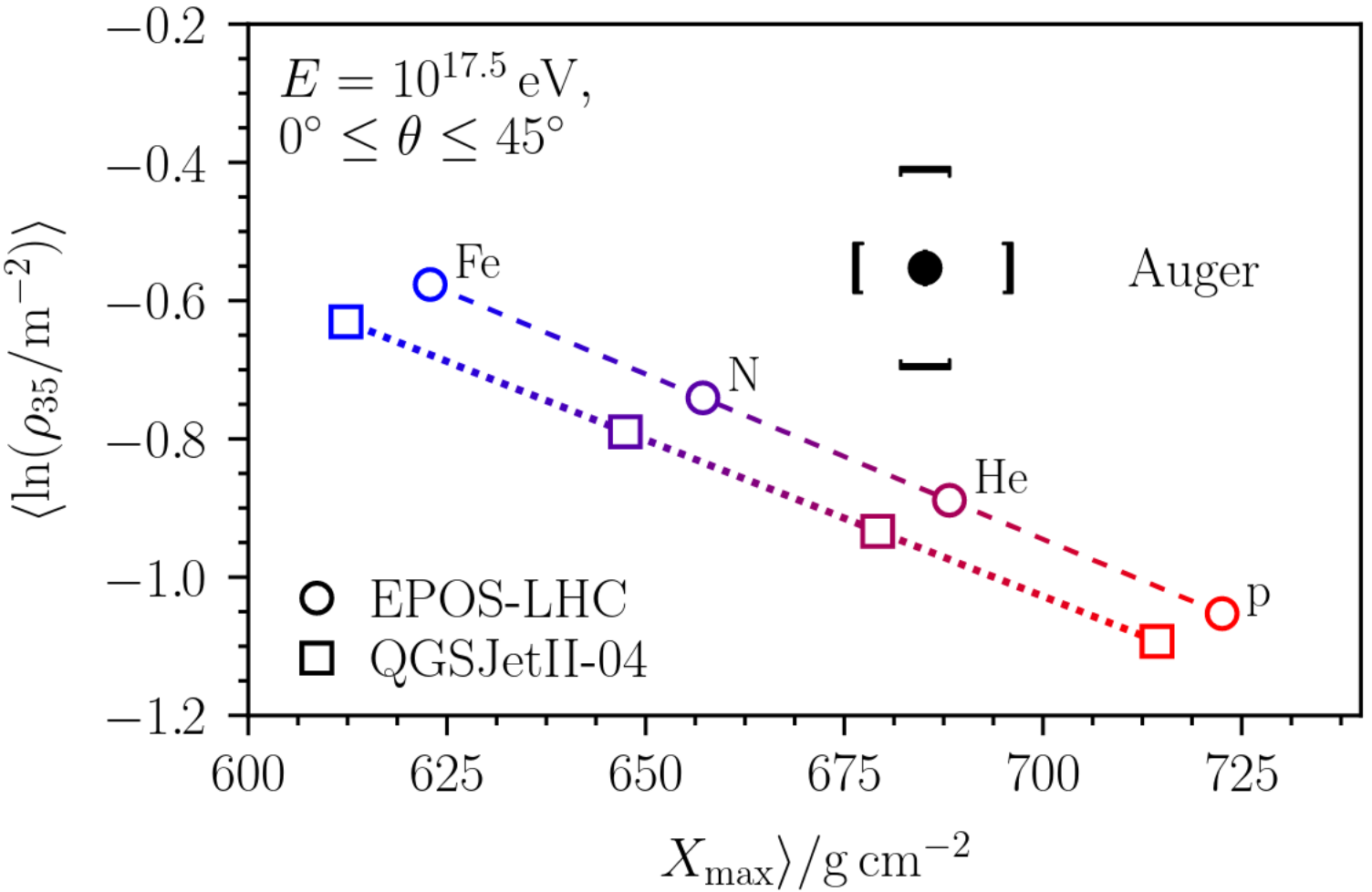
- CORSIKA 8 versatile tool, some unique features
- air shower genealogy: allows detailed studies of muon production
- Pythia 8 as interaction model, ongoing work
- get in touch with us:
  corsika.slack.com, corsika-devel@lists.kit.edu,
  regular meetings via zoom

Supplementary material

Number of generations







Pierre Auger Collaboration, EPJ C (2020) 80:751