From Superfluid Helium to Ultra-High-Energy Cosmic Rays

My journey through physics, countries, and collaborations

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From Quantum Fluids to Cosmic Particles

Different countries, different research topics — one curiosity.



Kharkiv, Ukraine

2012–2018

BSc and MSc in Physics

Condensed matter



DESY, Germany

2017

Summer research

Supernova remnants



Austria · Italy · Serbia

2017–2019

Erasmus Mundus MSc

Astrophysics



Karlsruhe, Germany

2019–2024

PhD at KIT

Ultra-high-energy cosmic rays



Prague, Czech Republic

Since 2024

Postdoctoral researcher

Pierre Auger Observatory



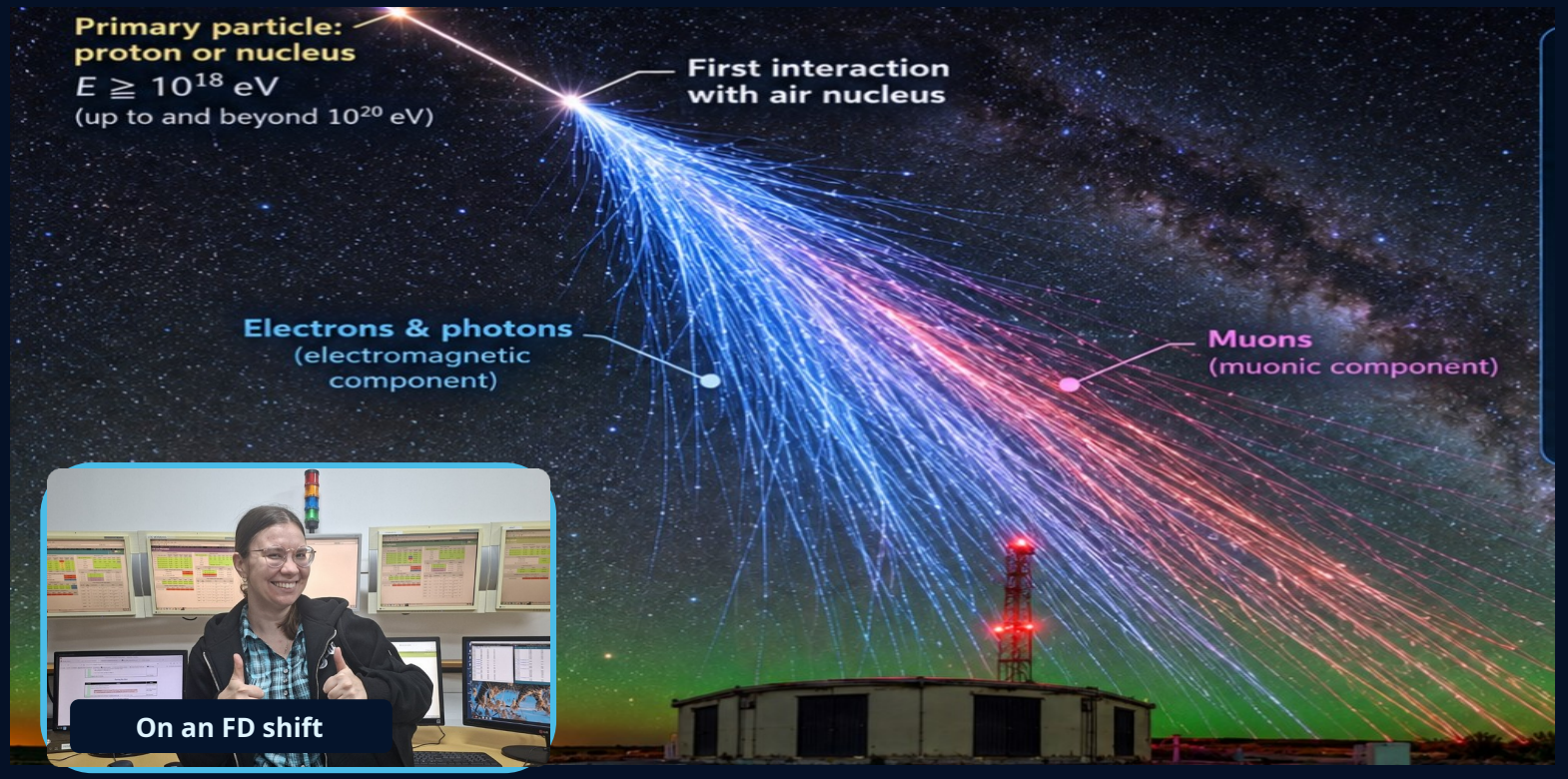
Jena, Germany — Max Planck Institute

Research internship · Cosmic dust

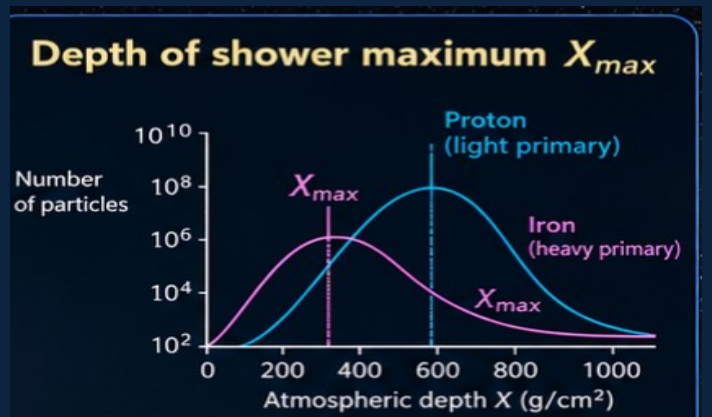
Different scales, different techniques — the same curiosity about how nature works.

Ultra-High-Energy Cosmic Rays

The highest-energy particles ever observed



SHOWER MAXIMUM



The depth at which the shower reaches its maximum size, X_{max}, carries information about the primary particle's mass and hadronic interactions.



Extreme energies

Up to and beyond 10^{20} eV

Millions of times more energetic than particles at the LHC.



Detected via air showers

Secondary particles from extensive air showers are measured at the Pierre Auger Observatory in Argentina.



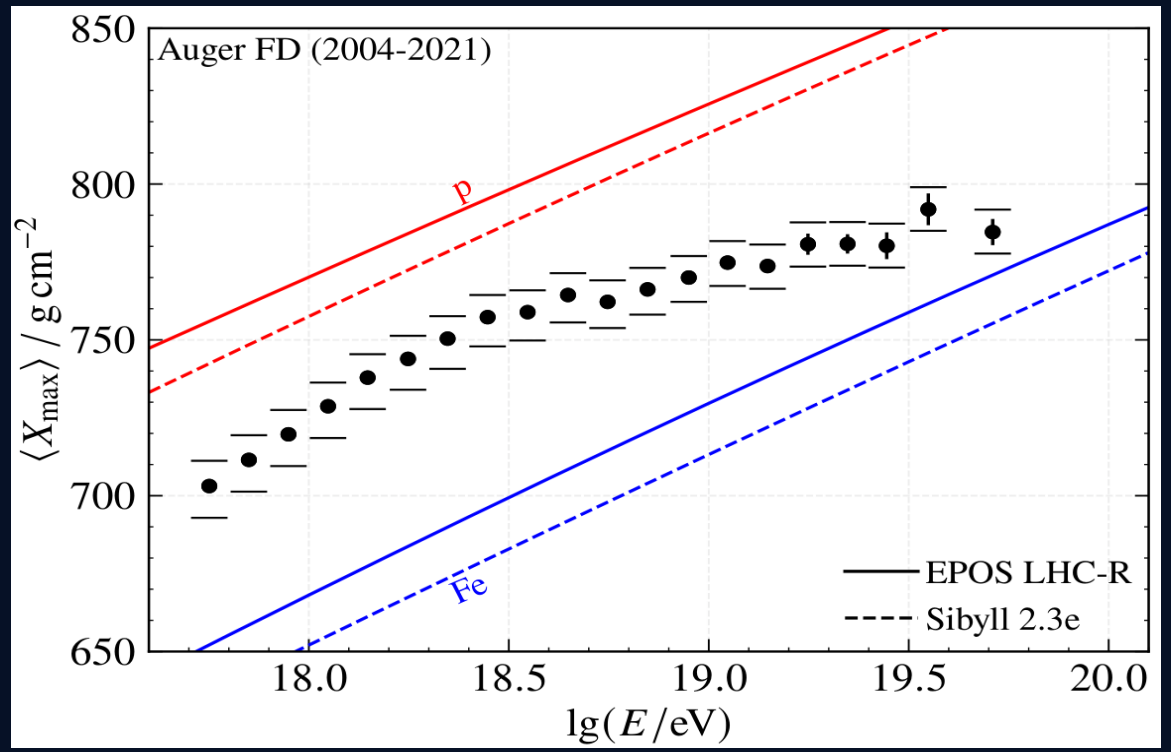
Key questions

- Where do they come from?
- What are they made of?
- How do they interact at extreme energies?

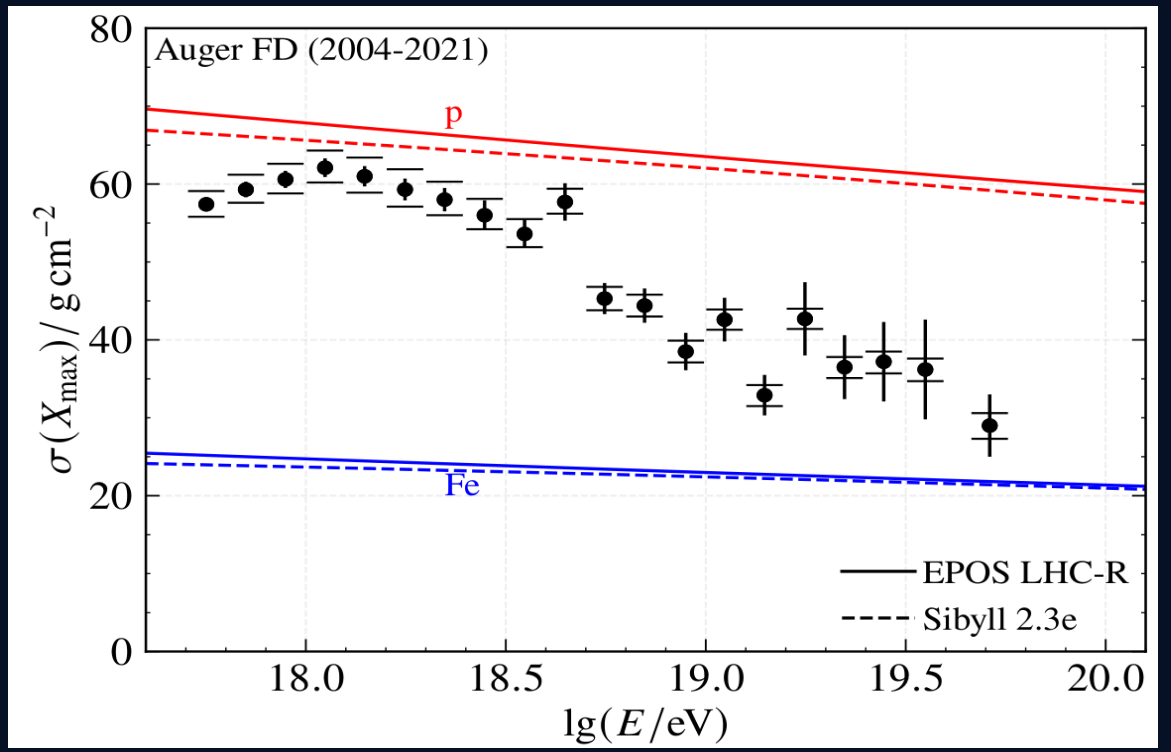
What Are Cosmic Rays Made Of?

The depth of shower maximum reveals information about primary mass.

AVERAGE SHOWER DEPTH



SHOWER-TO-SHOWER VARIATION

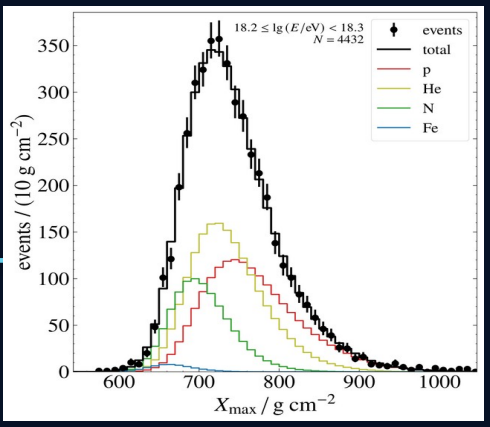


Protons: deeper and more variable · Heavier nuclei: shallower and less variable · Composition changes with energy

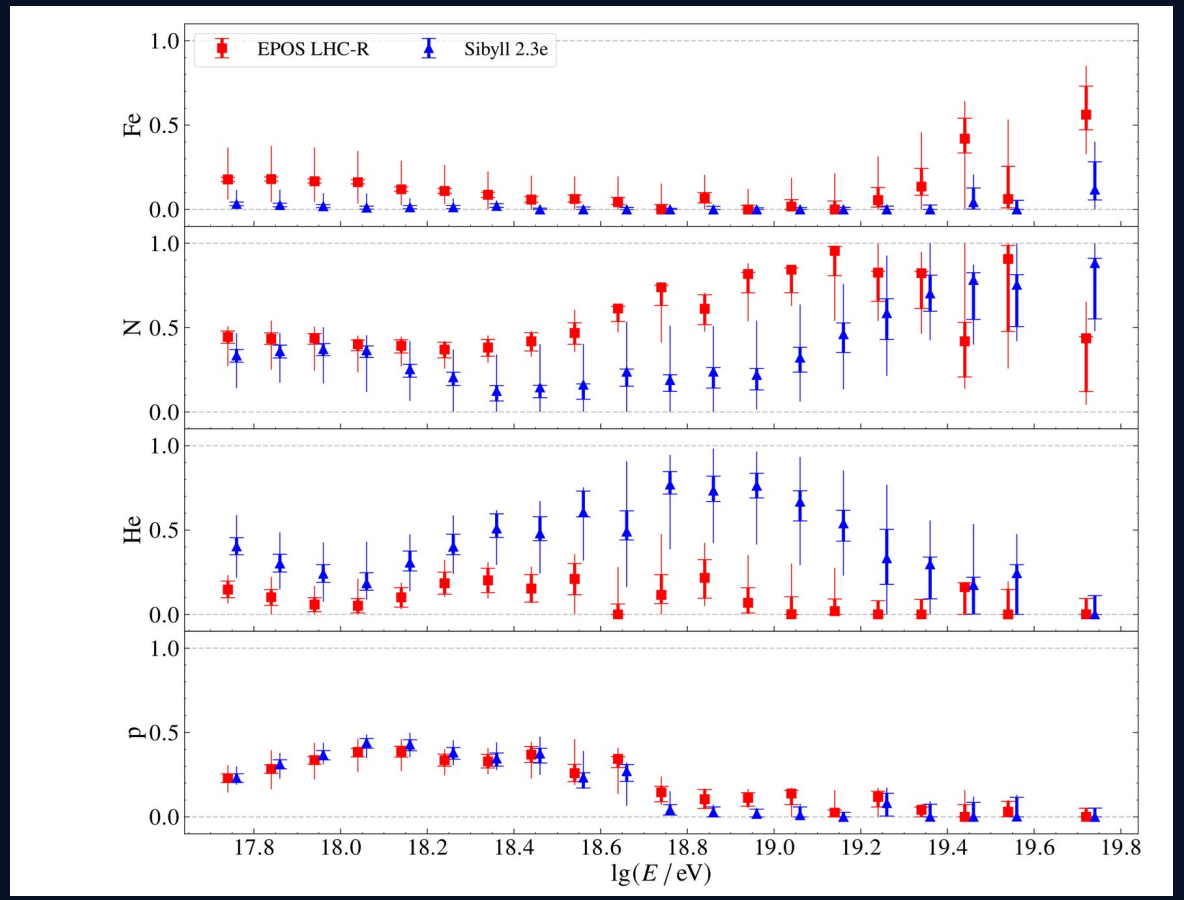
Source: Pierre Auger Collaboration, Phys. Rev. D 114, 043016 (2026), DOI: 10.1103/n616-15v5.

Bayesian Inference of Cosmic-Ray Mass

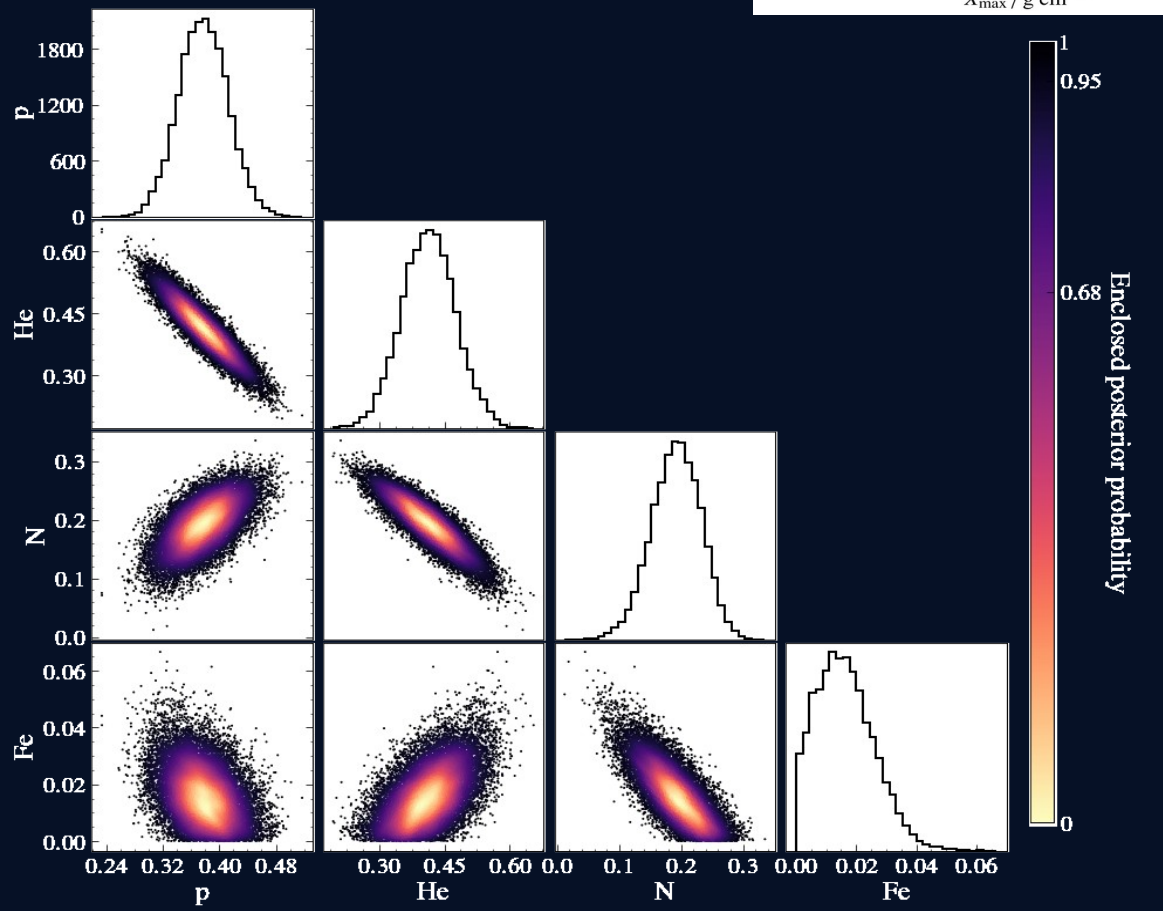
Four-component fit: protons · helium · nitrogen · iron



MASS FRACTIONS VS. ENERGY



BAYESIAN POSTERIORS

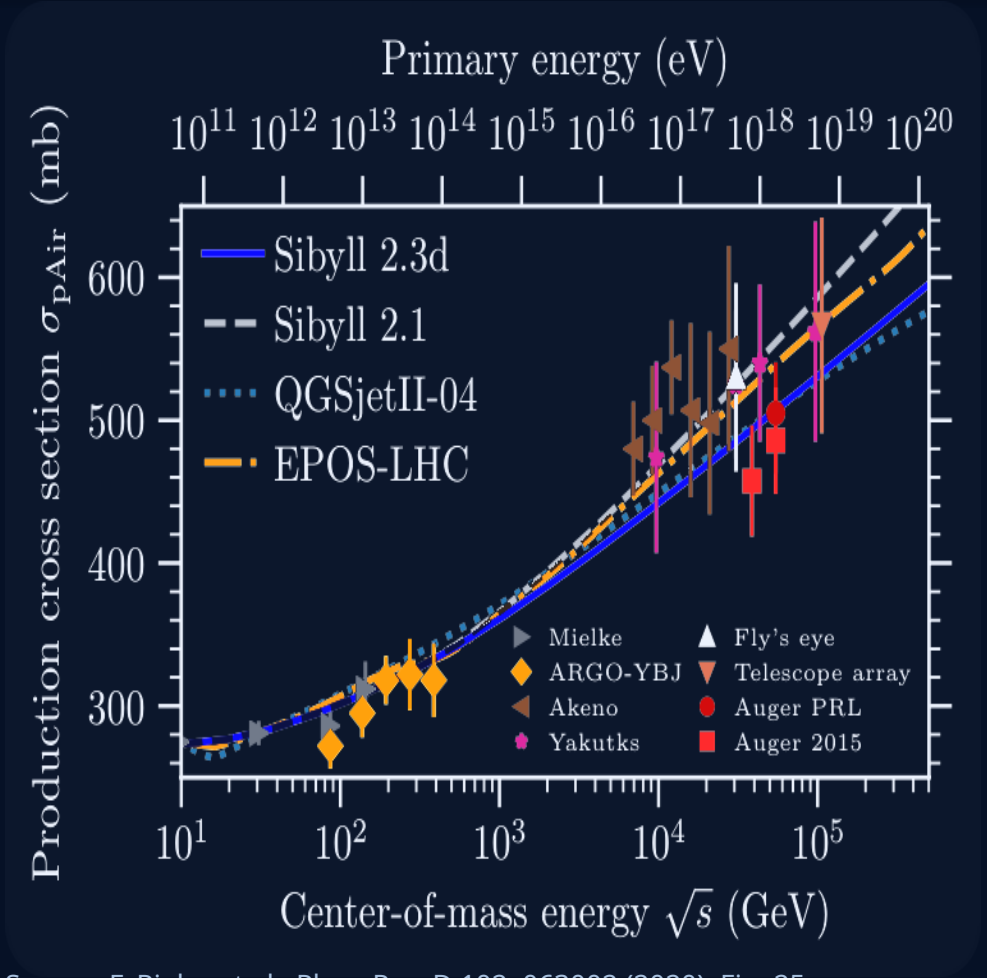


Source: Pierre Auger Collaboration, Phys. Rev. D 114, 043016 (2026).

From X_{max} distributions to posterior mass fractions and their evolution with energy

Interaction Cross Sections

Interaction cross sections and their role in air-shower interpretation



Source: F. Riehn et al., Phys. Rev. D 102, 063002 (2020), Fig. 25.

MY RESEARCH

Mass composition

+

Hadronic cross section

↓

Joint fit

Both primary mass and hadronic interactions shape the observed air shower.



Lessons from an Unexpected Journey

1 Changing fields is not starting over.

Knowledge and methods remain valuable even when you move into a new research area.

2 Research grows through exchange.

Working with different groups and institutions brings new perspectives, methods, and opportunities that can shape your scientific direction.

3 Big questions need shared effort.

The Pierre Auger Collaboration illustrates how individual contributions become part of a larger scientific project.



Thank you!