

Available simulation library and PEPS needs

Eva dos Santos

FZU - Institute of Physics of the Czech Academy of Sciences

2nd PEPS workshop

May 26 – 29 2026

Available air shower libraries

CORSIKA 7.* simulations: Standard shower libraries for multipurpose analyses



Mass Composition

X_{\max} from Fluorescence Detectors;
Surface Detector variables.



Air Shower Physics

Tests of hadronic interactions;
Estimation of the muon content of
air showers.



Neutral Particles

- **Photon searches**
- Neutrino searches (New libraries being designed)

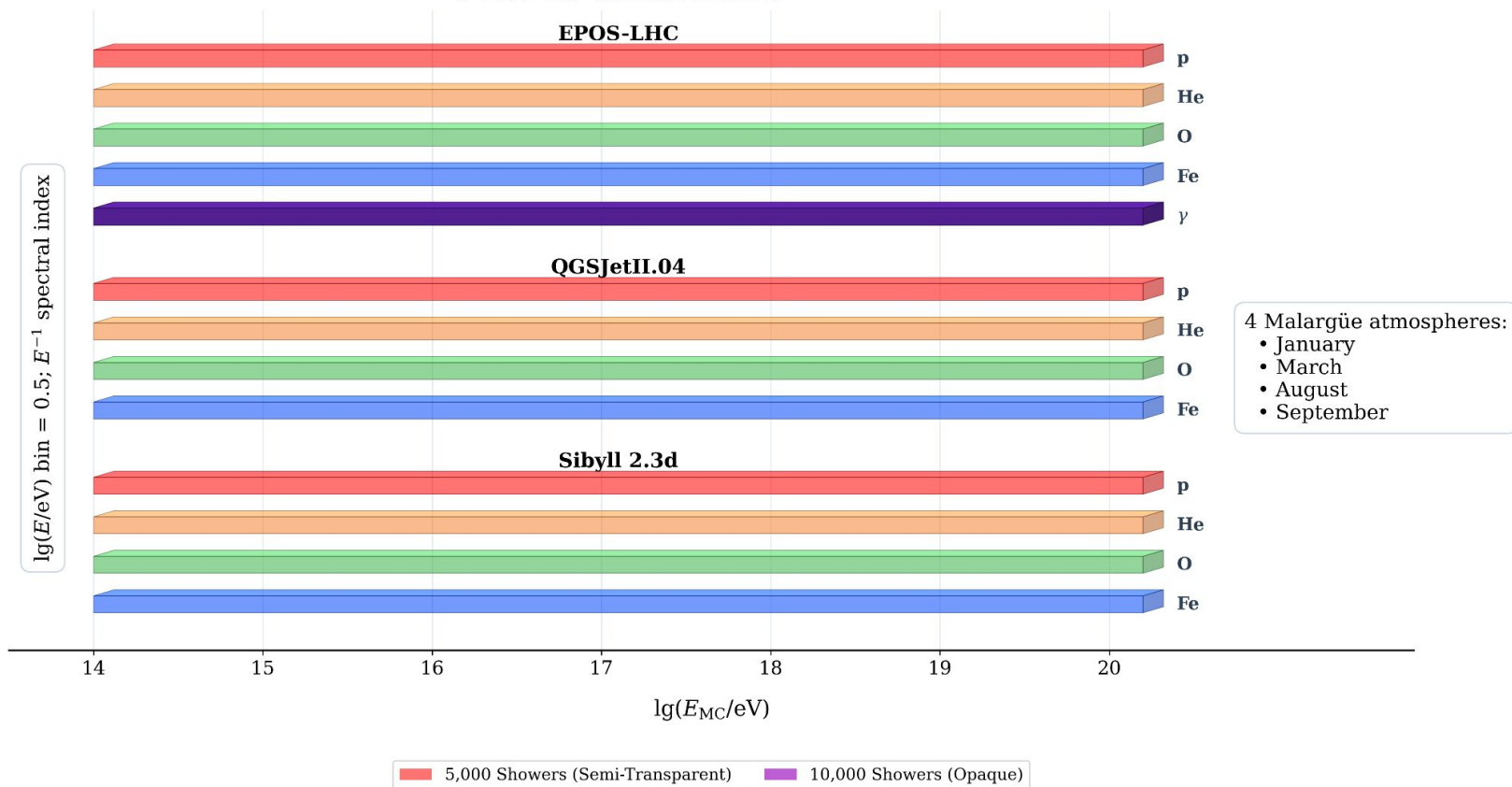
Full zenith angle range for hadronic primary species (0 - 89 deg)

Some subsets include the radio emission of air showers using CoREAS (specific analyses so far)

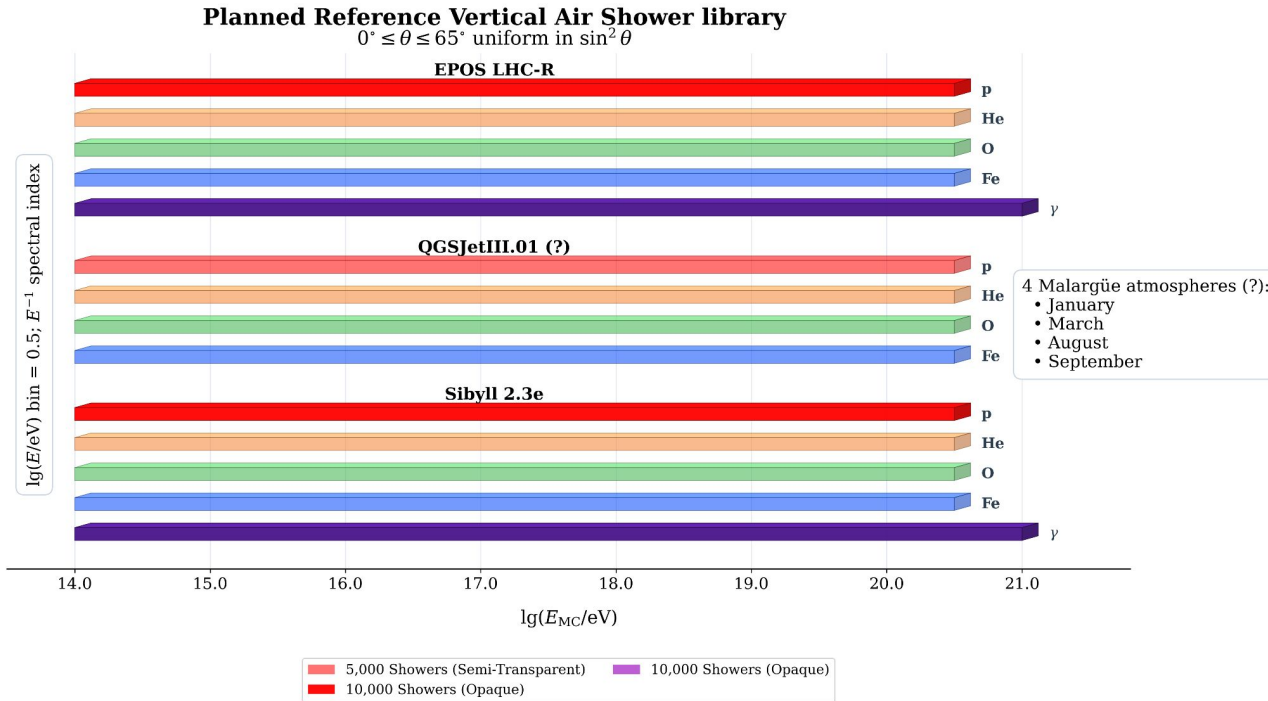
Library layout (old)

(Old) Reference Vertical Air Shower library

$0^\circ \leq \theta \leq 65^\circ$ uniform in $\sin^2 \theta$



Library layout - CORSIKA 7.8050 (planned)



NEW

Planned Updates



Photon Simulations

Extended reach up to 10^{21} eV.



Sibyll 2.3e Integration

Inclusion of the latest Sibyll version for comparative analysis.

Refer to following slides for Sibyll details.

Planned library – Some considerations (I)



EPOS LHC-R

Core considerations for the planned library update based on recent simulation data and experimental comparisons.

✓ Improvements

X_{\max} is 15 g cm⁻² deeper
Relative to EPOS-LHC

- Better agreement with Auger data
- Good description of p-O cross-section

⚠ Issues

Muon spectra are too hard

- Strong zenith angle dependence
- Muon LDF is too steep with respect to the other models
- Photon simulations are also affected

Planned library – Some considerations (II)



Sibyll 2.3e

Primary updates and version comparison

- Mostly the same as Sibyll 2.3d
- Only minor bug fixes



Suggestion: Photon Simulations

Conduct simulations with Sibyll 2.3e to ensure continuity:

- Provides similar outcome as EPOS-LHC for comparison with older simulations
- *Historically, the choice of hadronic model for photon simulations was not considered relevant*

Planned library - Some considerations (III)



QGSJetIII.01

Drop the production for now?

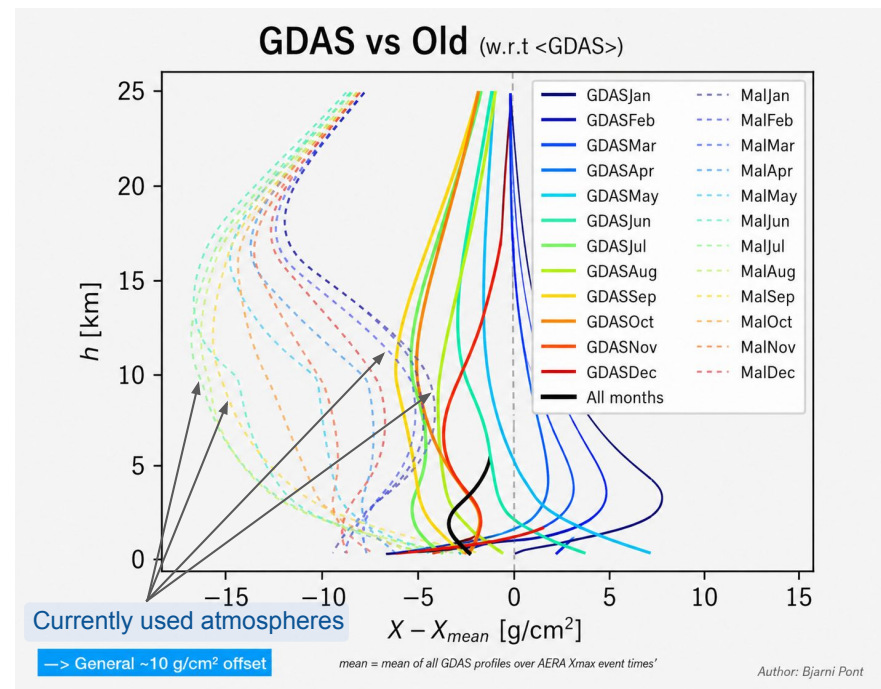
- Model has technical issues in the current implementation that affects nucleus-nucleus interactions

Planned library - Some considerations (IV)

Atmospheric Profiles

Request: Change profiles used

- Current choice is not well-performant for the KANE neural network
- GDAS profiles differ significantly from Malargüe atmospheres
- Uniformity would allow consistent CORSIKA/CoREAS comparisons
- Optimal number of atmospheric models is currently unknown
- May impact number of showers per bin
- **Main showstopper for now**



Time-dependent simulations?



Field Strength Weakening

Total Intensity

Rapidly decreasing, dropping from 24.623 μT (2004) to a projected 23.217 μT (2029).

~5.7% Loss

in magnetic shielding (25 years)



Magnetic North Drifting

Declination

Steady westward shift: from $+3.14^\circ$ (2004) to -0.83° (2029).

Westward Crossing

of geographic north by 2029



Steepening Angular Plunge

Inclination

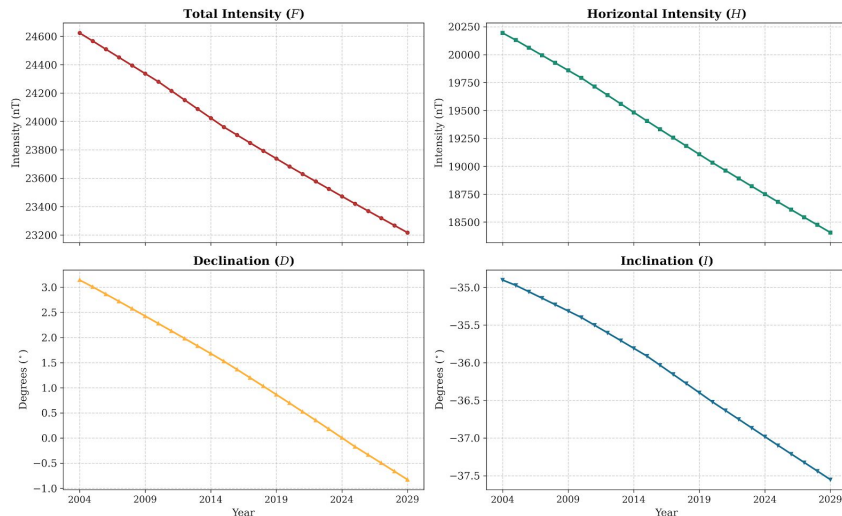
Becoming more negative, shifting from -34.90° to -37.55° .

Southern Hemisphere

Vectors pointing deeper into soil

Time-dependent simulations (II)?

Geomagnetic Field Evolution at Malargüe (2004-2029)
Pierre Auger Observatory Site Coordinates



Source: [Geomagnetic Field Evolution at Malargüe \(2004-2029\)](#)

Consistency

Maybe more relevant for **CoREAS** simulations, but simulations should be **consistent** across the library.

Should we update GCOORD?

```
GLONG = -69.585  
GLATI = -35.463  
GRFYEAR = 2013.  
IPREPR = 1  
IPRSTP = 0
```

 *Effect expected to be small*

Currently used values for the magnetic field: $B_x = 19.52 \mu\text{G}$; $B_z = -14.17 \mu\text{G}$

Estimated values in 2026: $B_x = 18.61 \mu\text{G}$; $B_z = -14.13 \mu\text{G}$

CORSIKA settings (I)

CORSIKA compilation options:

- **2a** - THINning version (includes LPM)
- **7** - SLANT depth instead of vertical depth for longi-distribution
- **7a** - CURVED atmosphere version
- **7b** - UPWARD particles version

+

 **3 - PRESHOWER version**
for EeV gammas (Photon simulations)

CORSIKA settings (II)



Thinning

- **Thinning level:** 10^{-6}
- **Optimal thinning:** $E_0 \times 10^{-6}$

Radial thinning:

50 m for $E < 10^{19}$ eV

- 100 m for $E \geq 10^{19}$ eV



Energy cuts

- **Hadrons:** 20 MeV
- **Muons:** 10 MeV
- **Electrons and gammas:** 0.25 MeV