Machine Learning Applications at the Pierre Auger Observatory

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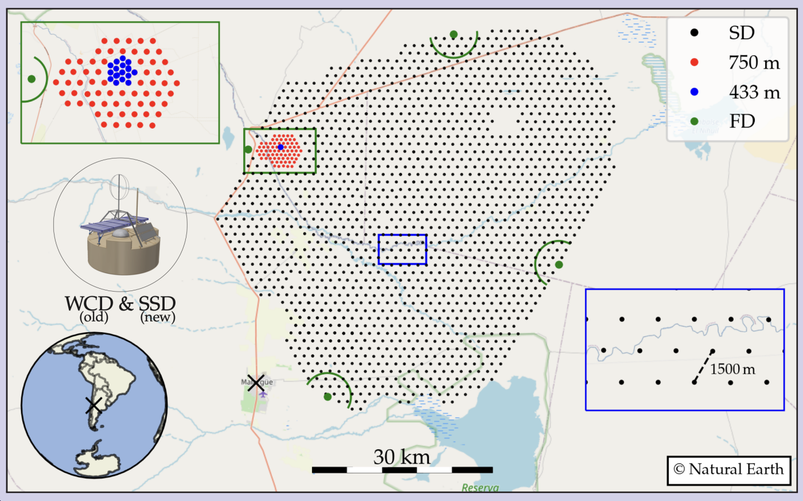
PIERRE AUGER OBSERVATORY

Surface detector (SD)

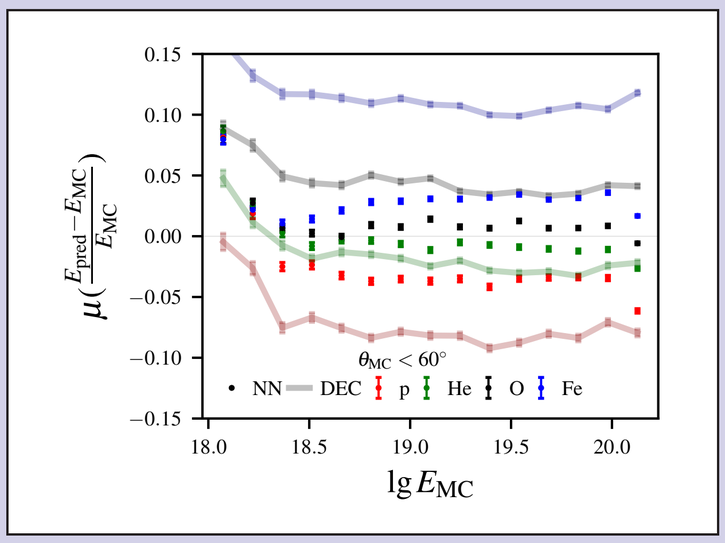


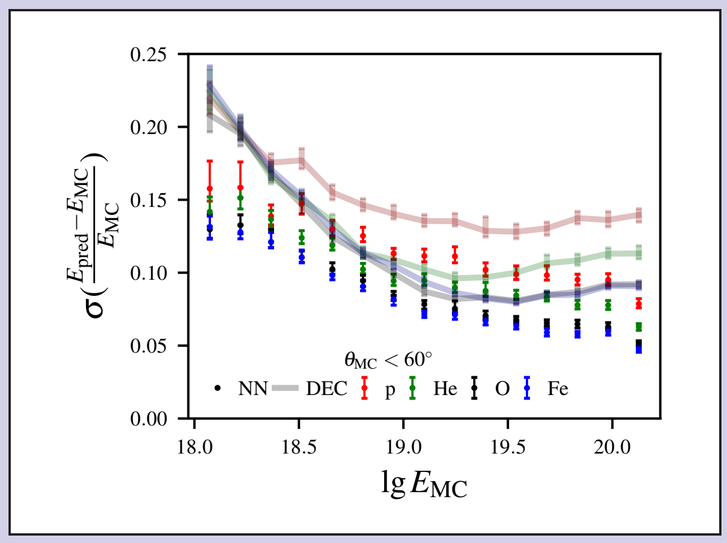
- Grid of 1660 water-Cherenkov detectors.
- AugerPrime upgrade:
  - New electronics
  - Scinillation detectors (SSD)
- **ML methods use the spatial and temporal information contained in the shower footprint that is measured by the SD stations.**
- **Goal: Mass composition from SD.**

Energy Estimator for the Surface Detector [1]

CNNs are used to reconstruct the energy of the impinging cosmic ray.

- Composition bias is reduced when compared to standard techniques.

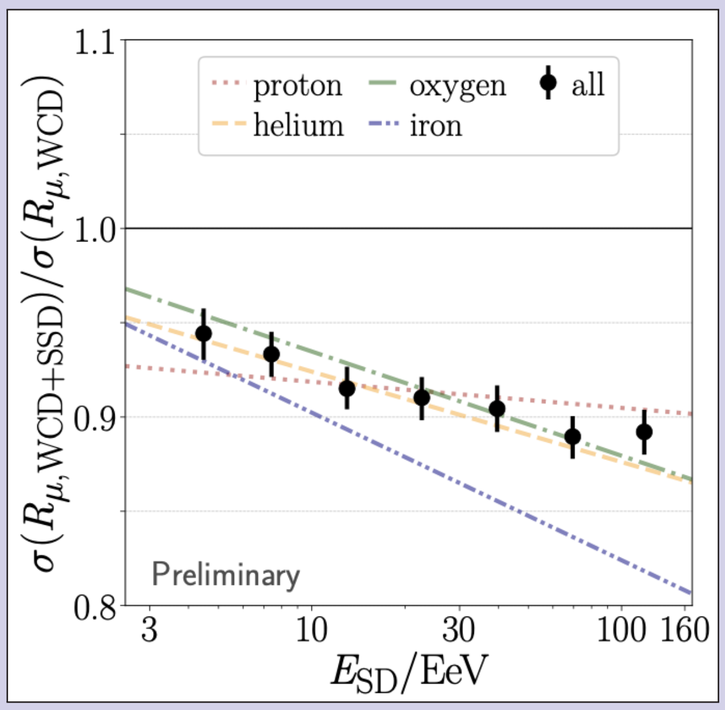


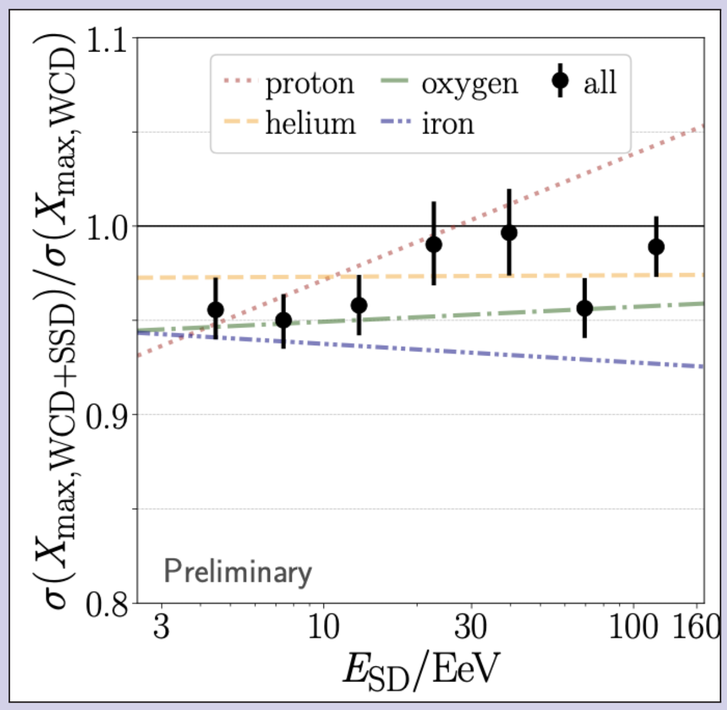


Using upgraded SD stations [3]

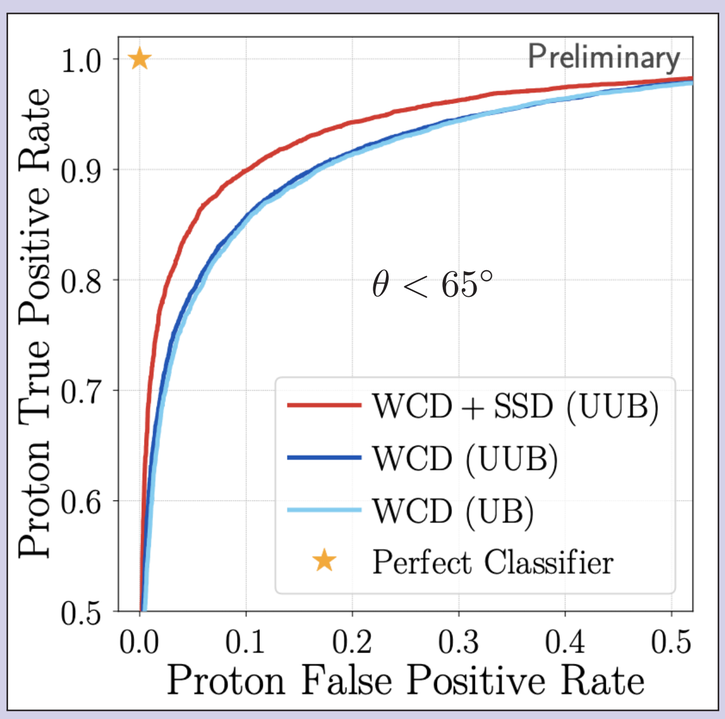
X_{max} and the number of muons R_μ in the air shower are estimated using simulations for the upgraded stations of the SD.

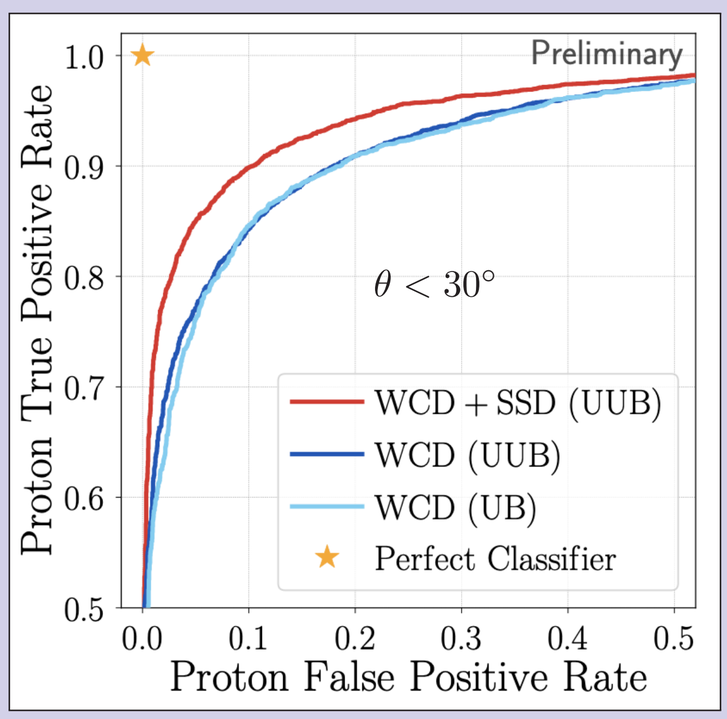
- Improvement in resolution ($\sim$10% for R_μ and $\sim$4% for X_{max}) for WCD + SSD.





- Proton-Iron ROC curves show improvement for WCD+SSD.

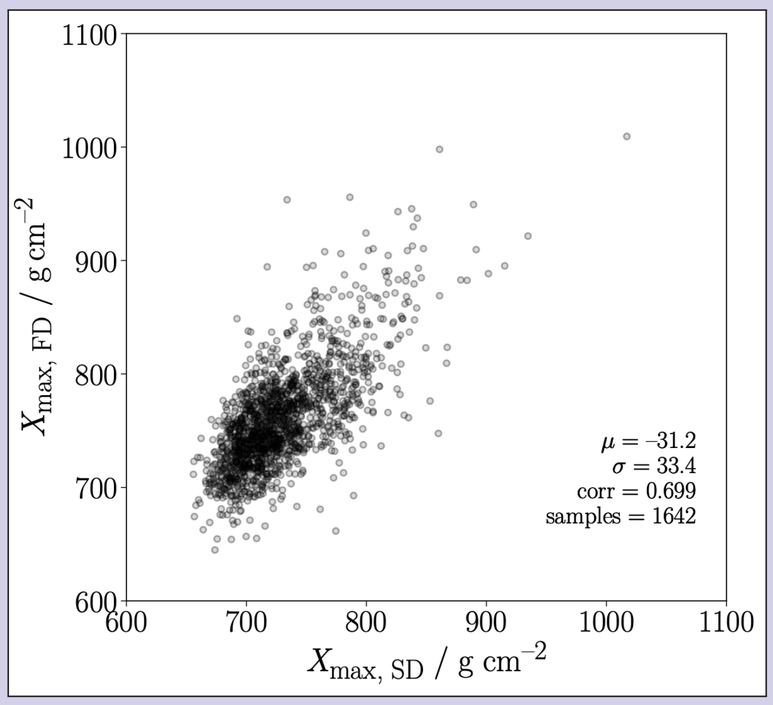




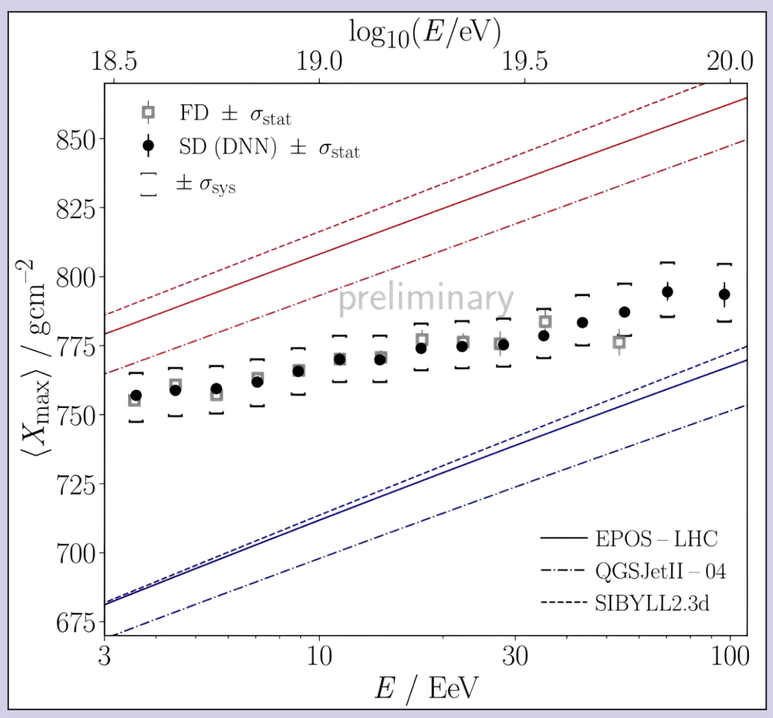
Mass Composition [2]

The depth of the maximum of air-shower profiles, X_{max} is estimated with the combination of CNNs and LSTMs.

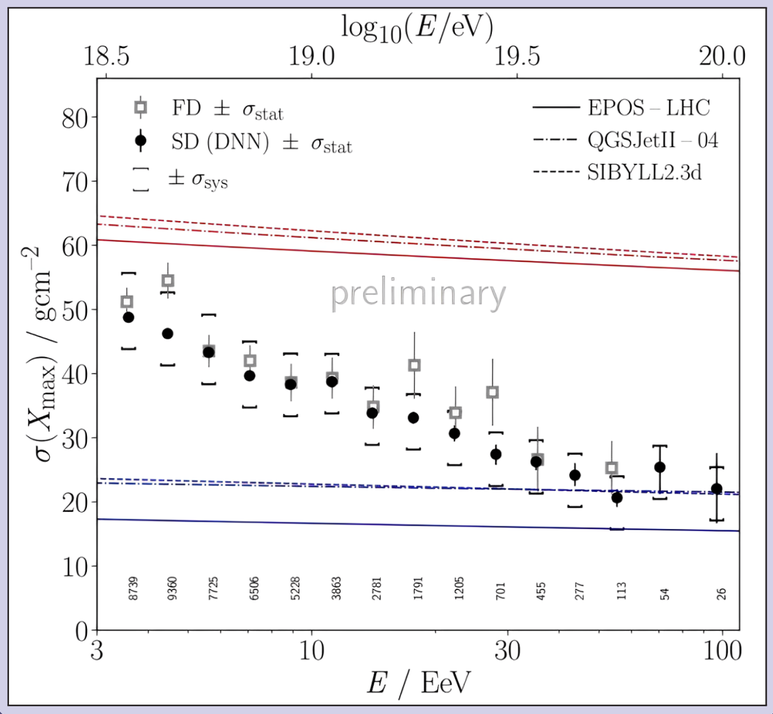
- Offset of ~ 31 g/cm^2 between the SD and FD reconstruction due to mismatches between data and simulation, removed by calibration with FD data.



- There is a clear transition from a lighter to heavier composition.
- Indication for 3 breaks in the elongation rate close to the energy spectrum features.



- $\sigma(X_{\text{max}})$ shows evolution from mixed to purer composition.



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[1] F. Ellwanger. PoS ICRC2023 (2023) 275.
[2] J. Glombitza. PoS ICRC2023 (2023) 278.
[3] N. Langner. PoS ICRC2023 (2023) 371.