Synergy of astroparticle physics and collider physics: Measurement of the pp cross section at $\sqrt{s} \sim 100$ TeV

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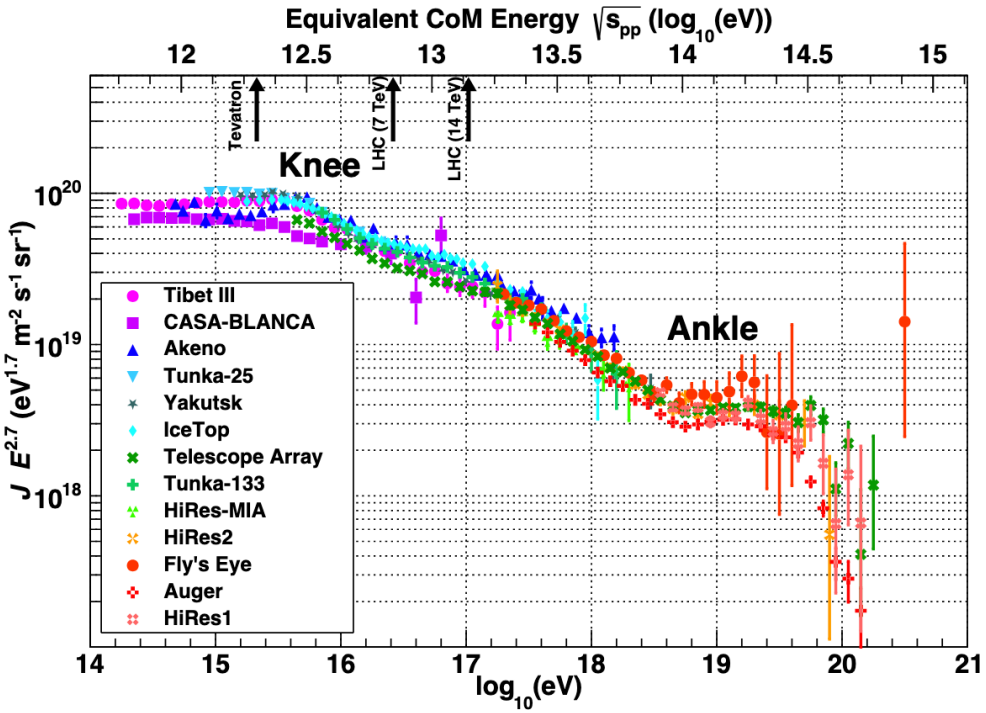
Cosmic accelerators



Cosmic ray spectrum

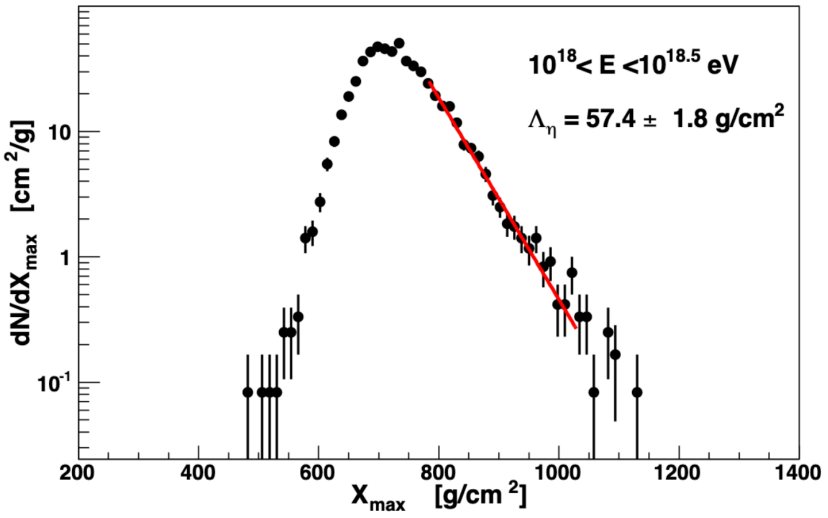
TA Collaboration, Abbassi et al.,
PRD 102 (2020) 6
arXiv:2006.05012

Highest energy hadron collisions
$10^{14}\ eV = 100\ TeV$

Opportunity to measure the inelastic scattering cross section with air targets.

Most penetrating particles are protons $\rightarrow \sigma_{p-air} \rightarrow \sigma_{pp}$.

X_{max} distribution – large X_{max} tail



Ulrich for Auger Collaboration, PoS (ICRC2015) 401

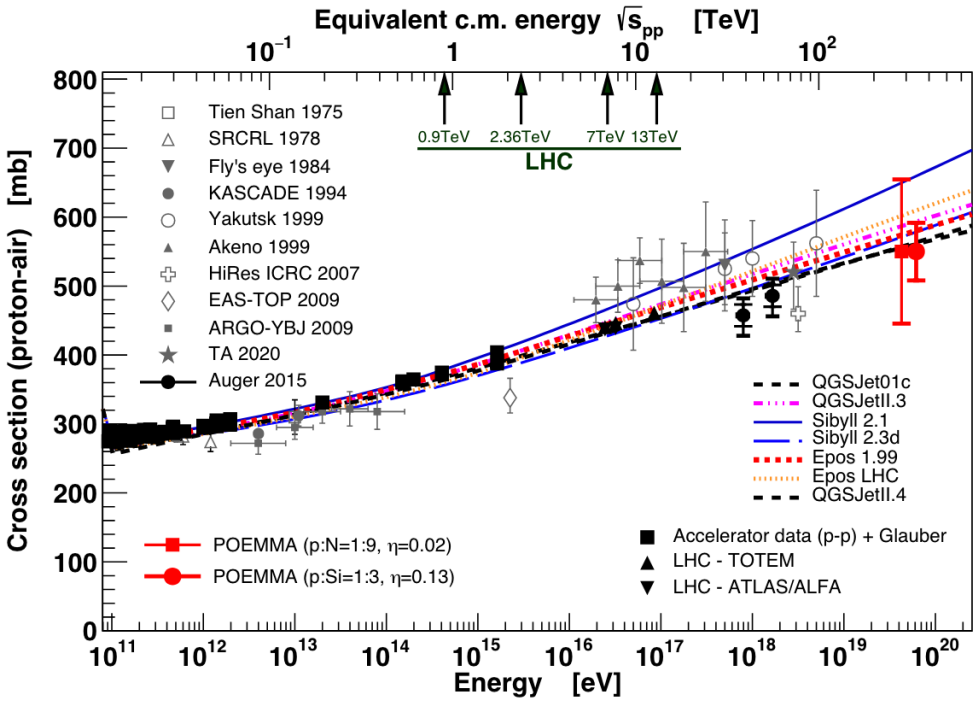
- X_{max} is a well-defined point in the shower development.
- It is related to the interaction length of the cosmic ray primary.
- The deepest showers have the highest proportion of protons.

$$\frac{dN}{dX_{\max}} \propto e^{-X_{\max}/\Lambda_\eta} \quad , \quad \Lambda_\eta \propto 1/\sigma_{p-air}$$

η: fraction of the deepest events

Use (several) MC to determine Λ_η^{MC} which depends on σ_{p-air} to make conversion.
Use the Glauber formalism to determine σ_{pp}.

Current and projected p-air cross section measurements



Olinto et al. (POEMMA), in preparation, Anchordoqui et al., PRD 101 (2020) 023012
TA Collaboration, Abbassi et al., PRD 102 (2020) 6
Auger Collaboration, Abreu et al., PRL 109(2012) 062002, Ulrich, PoS(ICRC2015)

- Projected measurement (arbitrary normalization) of POEMMA for two cosmic ray compositions.
  (Muzio, Unger & Farrar, PRD 100 (2020) 103008)
- Depends on the proton content of the highest energy cosmic rays (more protons, better projected measurement).
- Weak dependence on which MC is used for $\Lambda_\eta \rightarrow \sigma_{p-air}$.
- Another method for E>10^{20} eV: lunar orbit radio detection
  ZAP: Zettavolt Askaryan Polarimeter
  (see Romero-Wolf LoI)