

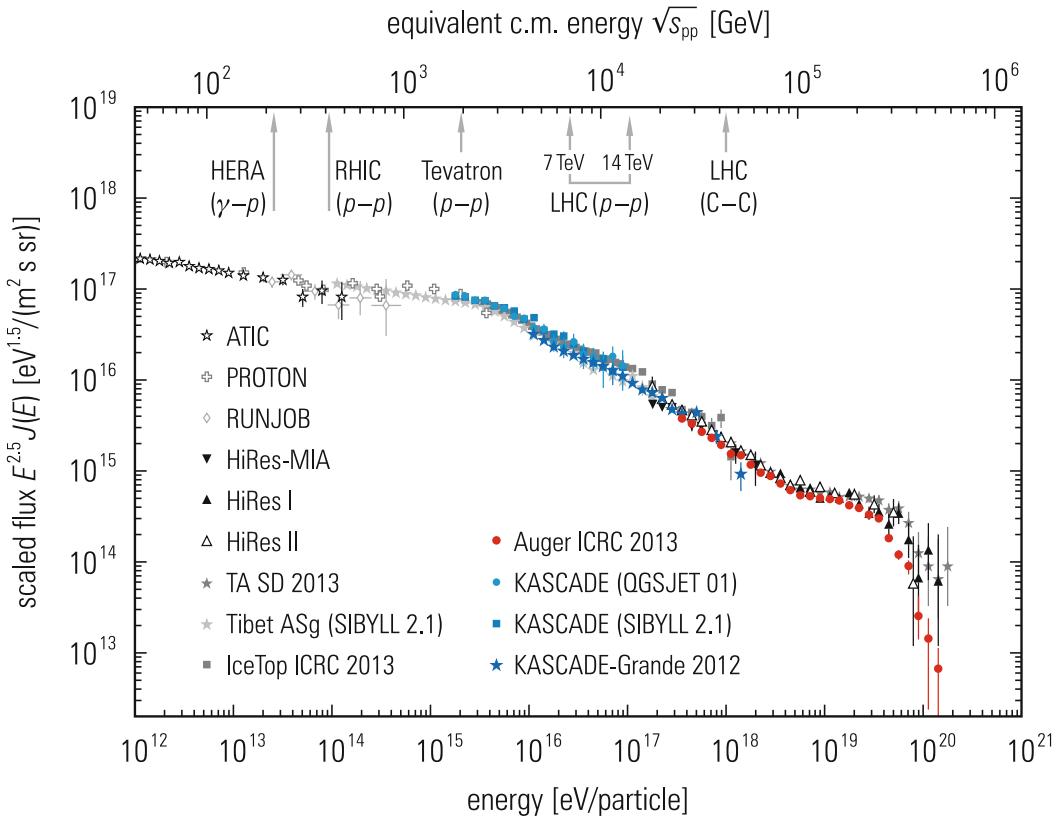
# Introduction to astroparticle physics

## Part 2, Exercises 1

April 11, 2025

### 1 Equivalent center-of-mass energy

Find the center-of-mass energy of a cosmic proton with energy  $E_1 = 10^{17}$  eV impinging on a proton at rest.



### 2 Maximum proton energy at LHC

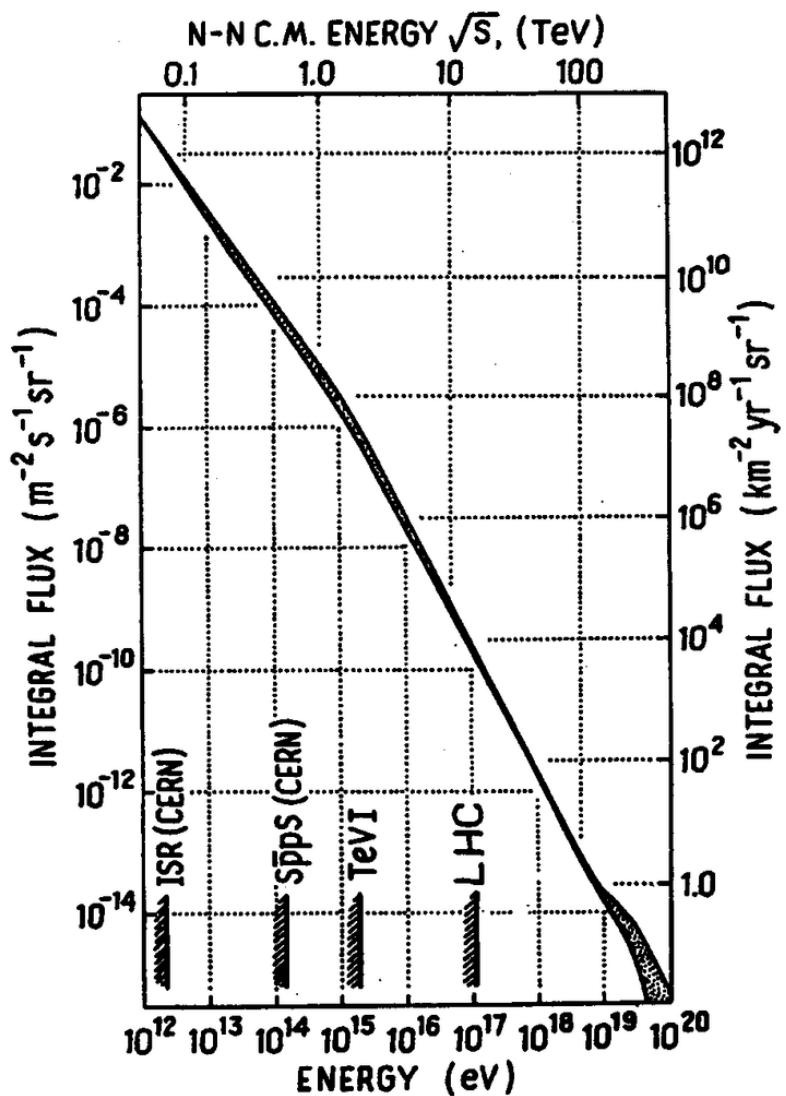
Calculate the maximum energy attainable by protons in a tunnel with a circumference of 27 km and a magnetic field of 8.36 T.

### 3 Differential energy flux of protons

Relativistic cosmic protons are accelerated by a shock front. Deduce the form of the differential energy flux of the protons, assuming that the probability that the proton escapes the acceleration process is 20% and the fractional increase in energy per crossing is 20%.

### 4 Integral flux

Show that the number of cosmic rays  $\frac{N(E>E_0)}{dA dt d\Omega}$  above a certain energy ( $E_0$ ) is also a power law.



## 5 Cosmic-ray rate per unit area

How many cosmic particles of energy between  $E_0 = 100$  GeV and  $E_1 = 101$  GeV do we expect per square meter and per second?