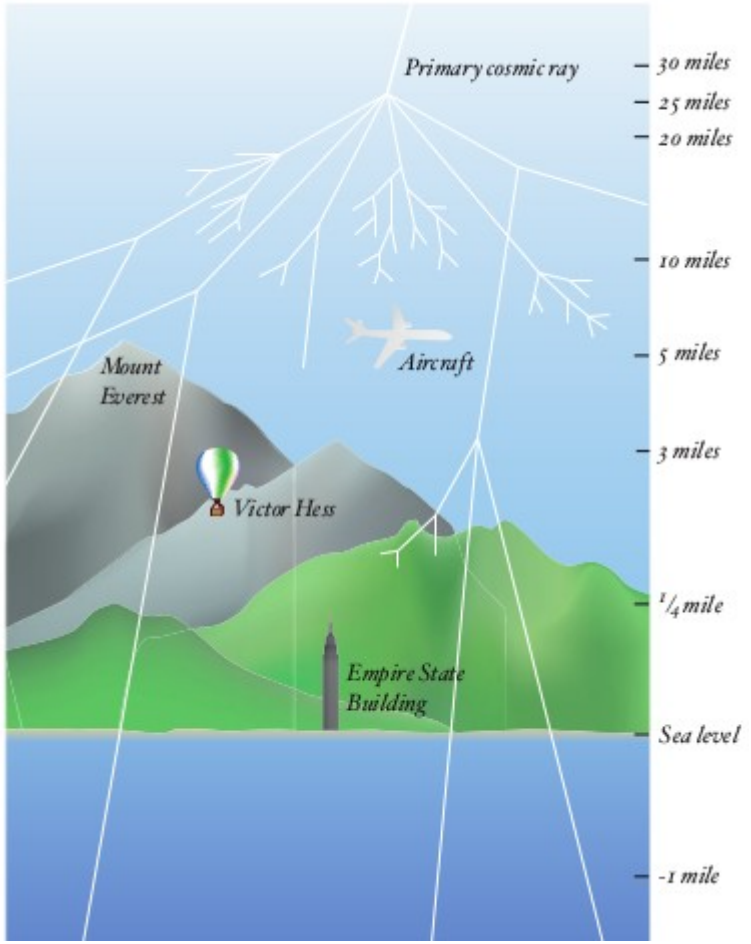
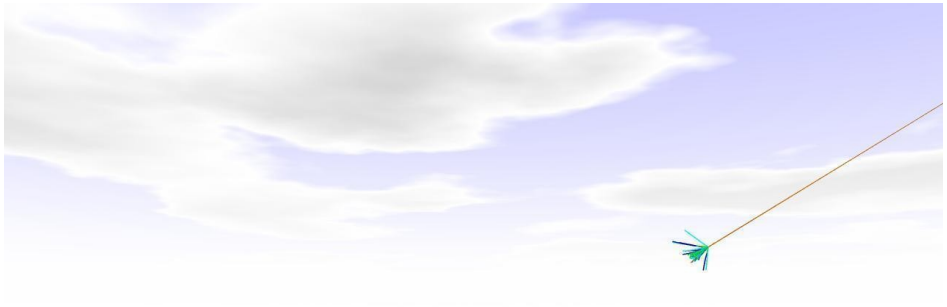
Cosmic Rays, high energy particles coming from space



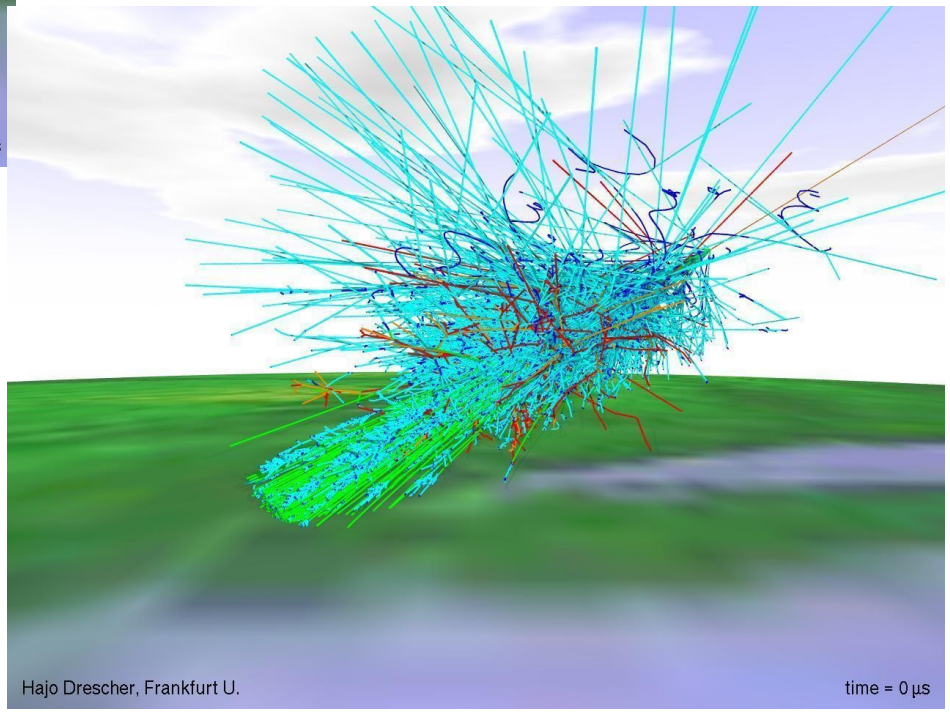
The particles that hit our atmosphere:

- 90% protons (hydrogen nuclei)
- 9% alpha particles (helium nuclei)
- remainder are solar wind particles, big nuclei, and their *debris,* low energy

Ref:Cosmic Extremes



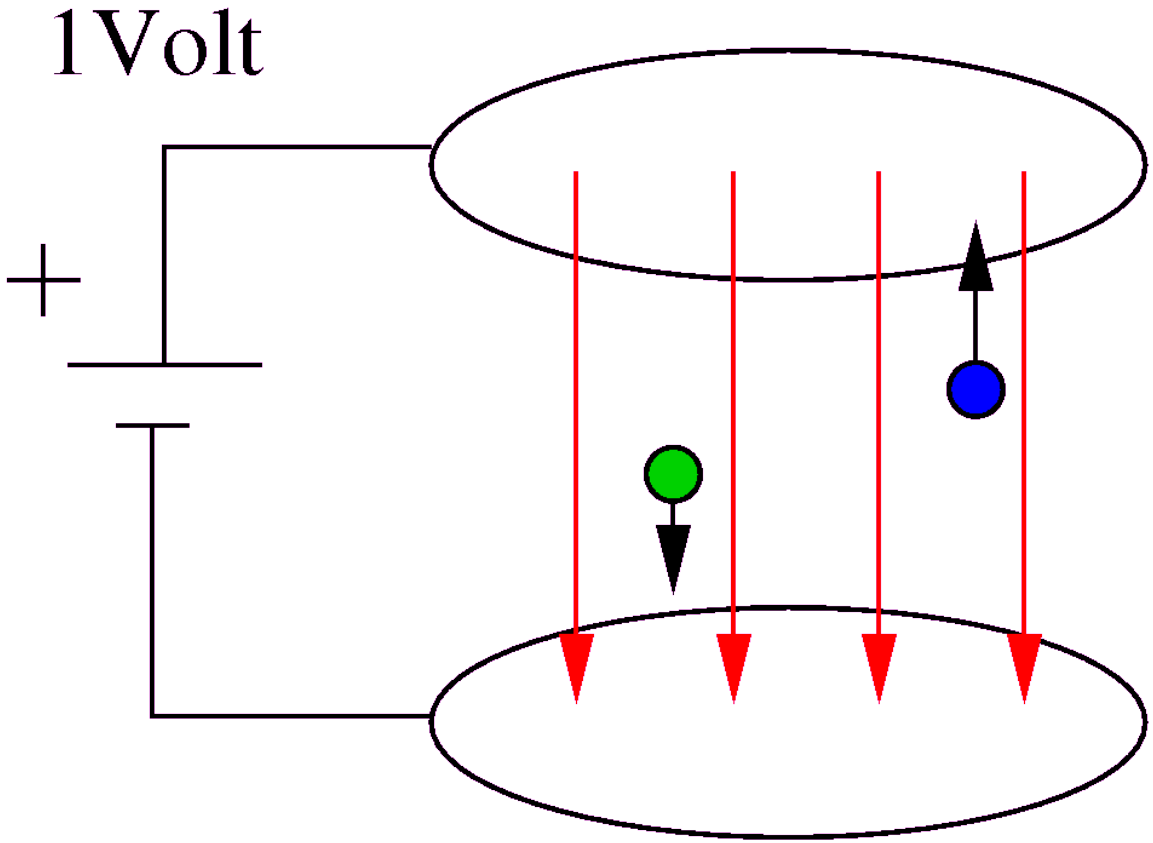

Hajo Drescher, Frankfurt U.
time = -300 µs


Hajo Drescher, Frankfurt U.
time = 0 µs

Animation

- Victor Hess on Cosmos, Episode 13, ts=7m13s, YouTube, https://youtu.be/XGKvX83iM4g?t=433 (low quality) https://youtu.be/cgSSXEqUnEE?t=466 (high quality, purchase, 7:46 to 10:47 Hess, then to 12:40 Zwicky and Supernovae)
- aa

Units?



- Proton, heavy, +e
- Electron, light, –e

Earth's Surface

The particles that hit our atmosphere clobber the nuclei of the atoms and molecules:

- create a shower of x-rays, gamma rays, and light

- also make a lot of muons (like an electron but heavier), with mass 106 MeV (compare to an electron with mass 0.511 MeV).

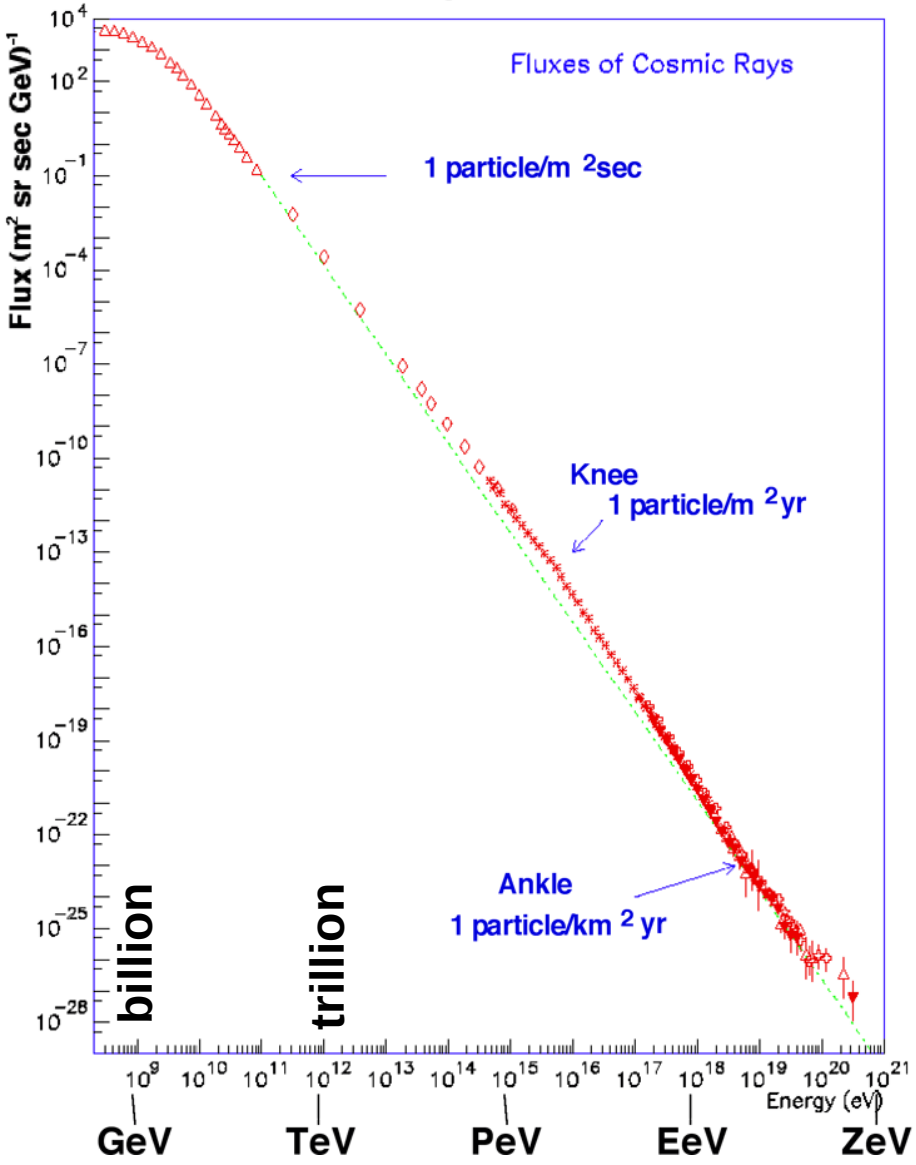
Energy and Quantity

eV is short for electron-Volt, and gives the energy of an object...or its mass!

$$E = m\,c^2$$

Energy equals **mass** times **speed of light squared** (just some constant, but a big one)

proton mass 0.924 GeV
electron mass 0.511 MeV
muon mass 106 MeV
my mass 4.3×10^{37} eV



Sources of Cosmic Rays

Sun	10 MeV,	0.01 GeV
Supernovae	10 TeV,	10,000 GeV
??	10 EeV,	10e9 GeV

Detection of Cosmic Rays

Air Shower

Measuring the charged particles hitting the Earth/Our Detector (like CRMDs).

Air Fluorescence

Charged particles moving through the atmosphere excites molecules and some decay by emission of a UV photon.

Pierre Auger Detector uses both:

https://www.auger.org/ .

Speed of Light

Fastest possible speed is the speed of light in vacuum.

Defined as $299792458\,\mathrm{m/s}$

$3.0 \times 10^8\,\mathrm{m/s}$

$30\,cm/ns$

$300\,m/\mu s$

$300\,\mu m/ps$

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SI Prefixes

Table 5. SI prefixes

Factor	Name	Symbol	Factor	Name	Symbol
10^{24}	yotta	Y	10^{-1}	deci	d
10^{21}	zetta	Z	10^{-2}	centi	c
10^{18}	exa	E	10^{-3}	milli	m
10^{15}	peta	P	10^{-6}	micro	μ
10^{12}	tera	T	10^{-9}	nano	n
10^{9}	giga	G	10^{-12}	pico	p
10^{6}	mega	M	10^{-15}	femto	f
10^{3}	kilo	k	10^{-18}	atto	a
10^{2}	hecto	h	10^{-21}	zepto	z
10^{1}	deka	da	10^{-24}	yocto	y