

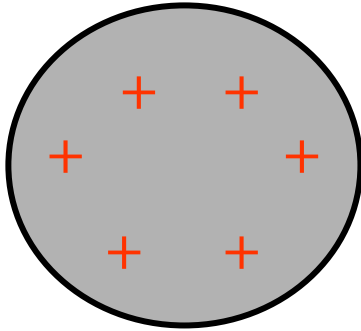
TRC 0/07

Introdução aos Raios cósmicos

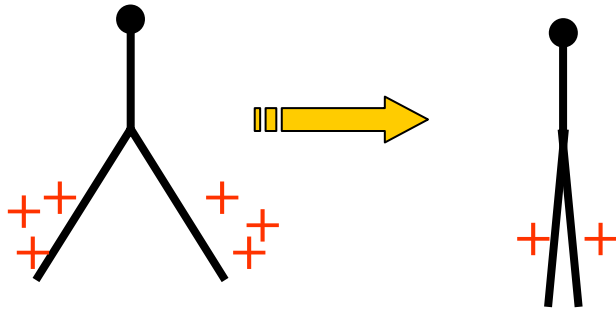


Mário Pimenta
Janeiro 2007

Uma história já longa...



As esferas descarregam-se...
Coulomb, 1785

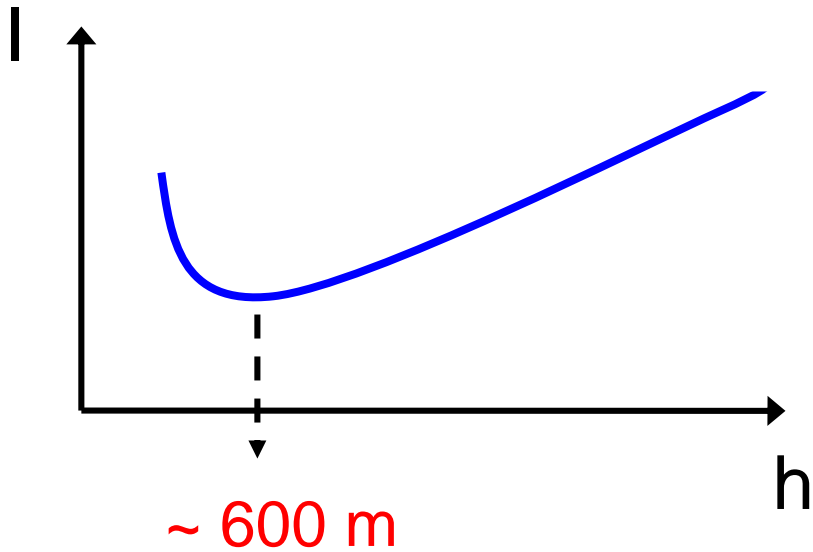


Finais do século XIX

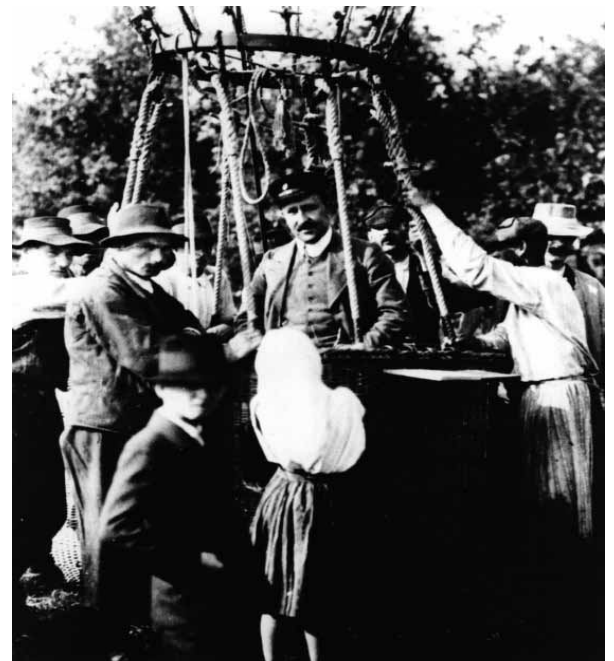
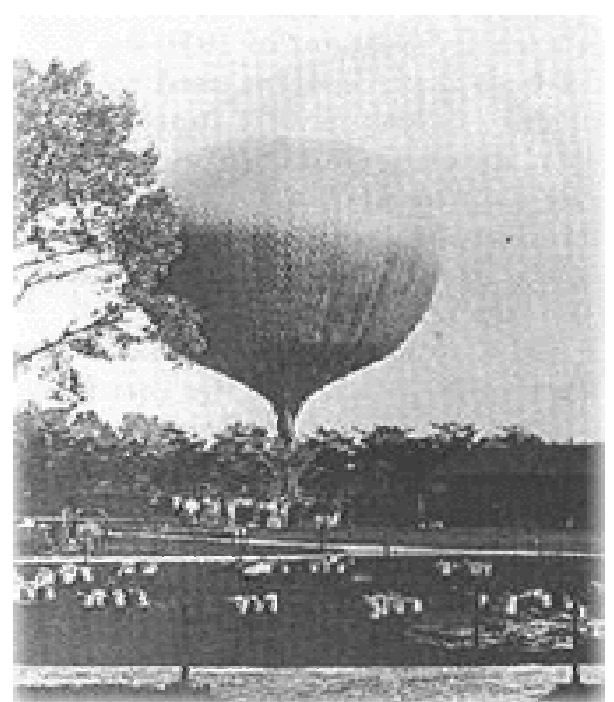
Radioactividade ?

Viktor Hess, 1912

Diversos vôos até 6 Km
Dia/noite, eclipse, ...



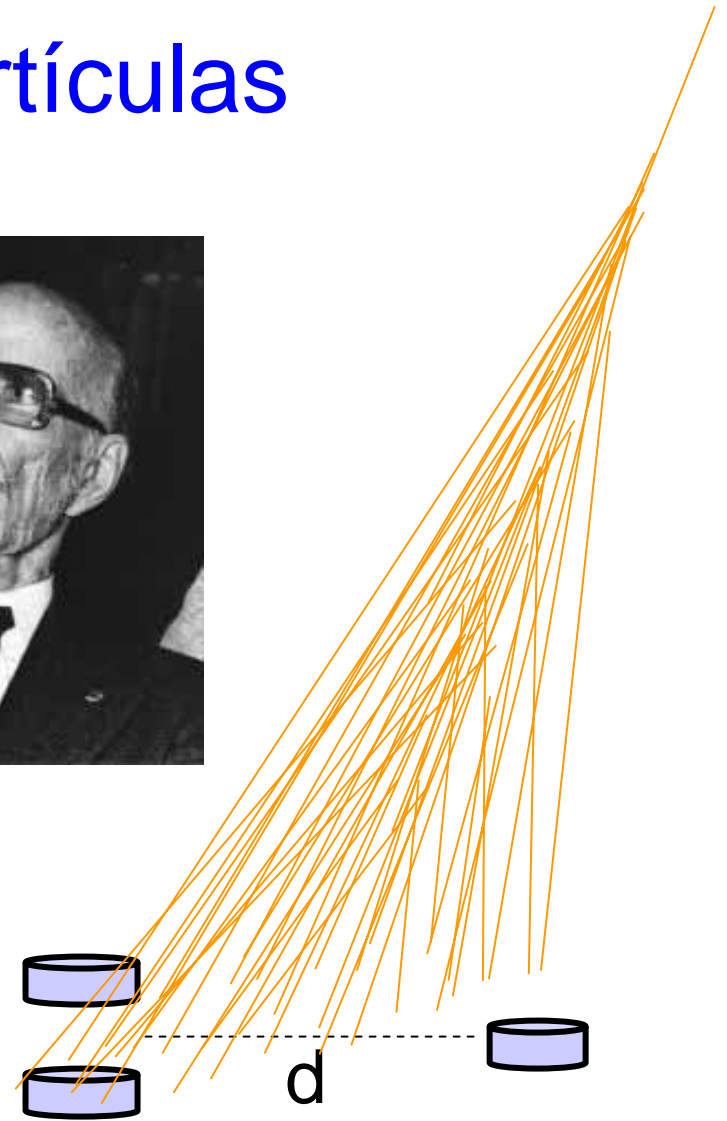
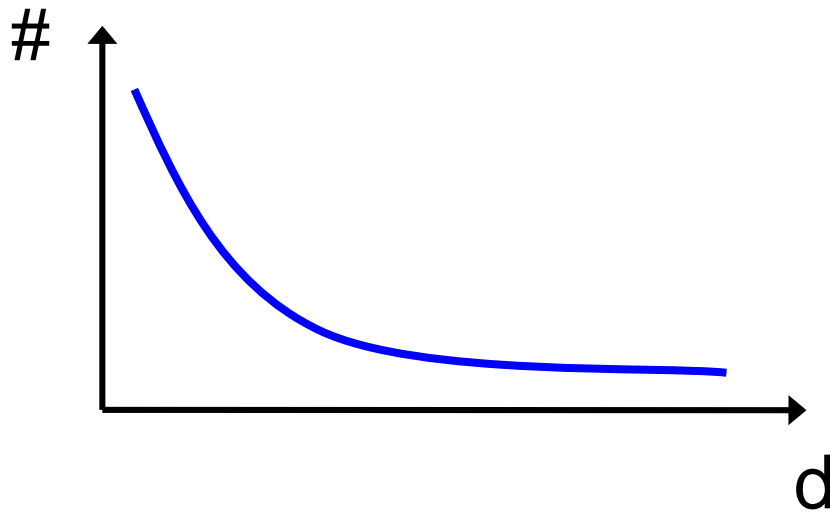
“Raios C3smicos” ! (Milikan)



Cascatas de partículas

Pierre Auger, 1938

Coincidências



Primeiras estimativas da energia das cascatas!

Na Origem da física de partículas

Positrão (Anderson, 1932)

Antimatéria! (Dirac)

$\gamma \rightarrow e^+e^-$ (Einstein)

μ (Anderson, 1937)

Rossi, 1940:

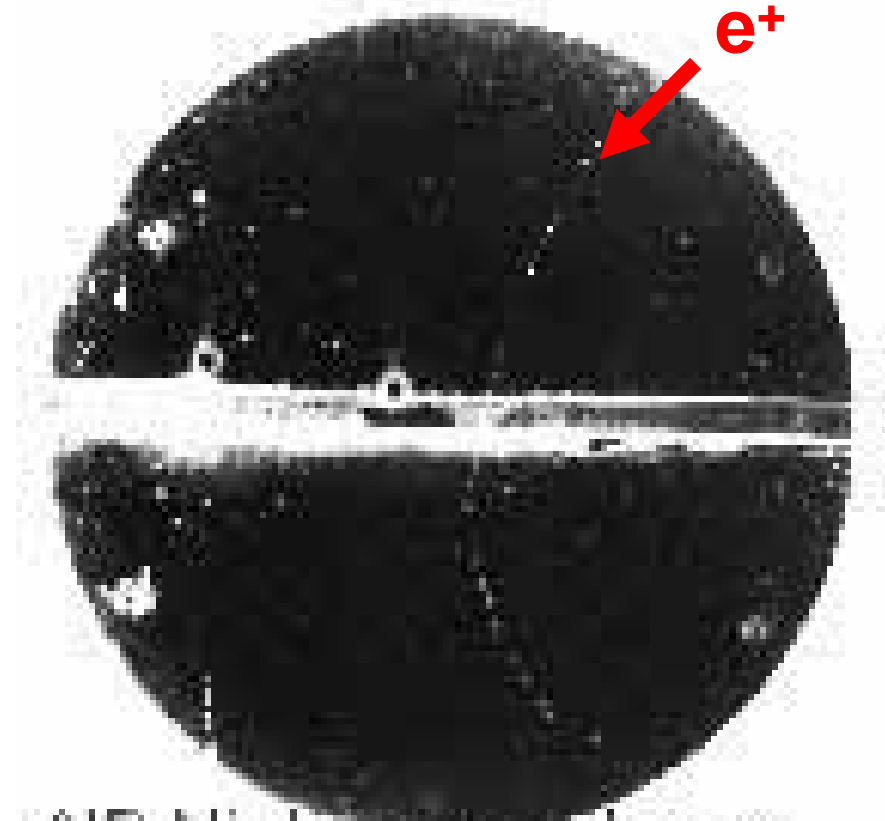
Tempo de vida do muão.

Dilatação do tempo!

π (Latter, 1947)

Interações fortes (Yukawa)

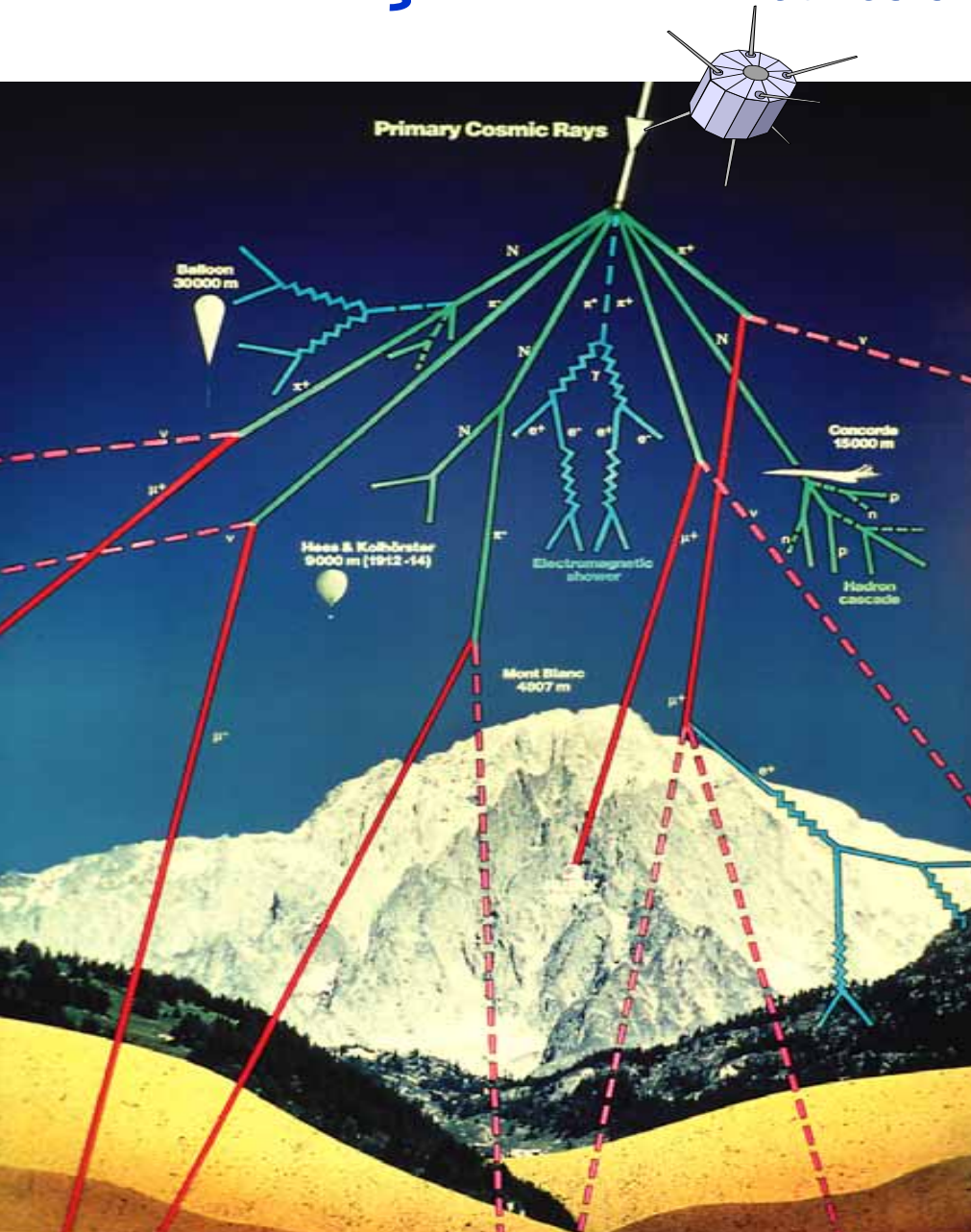
Anos 50: K , Λ , Σ , Ξ , Ω ...



AIP Niels Bohr Library
Cloud Chamber picture

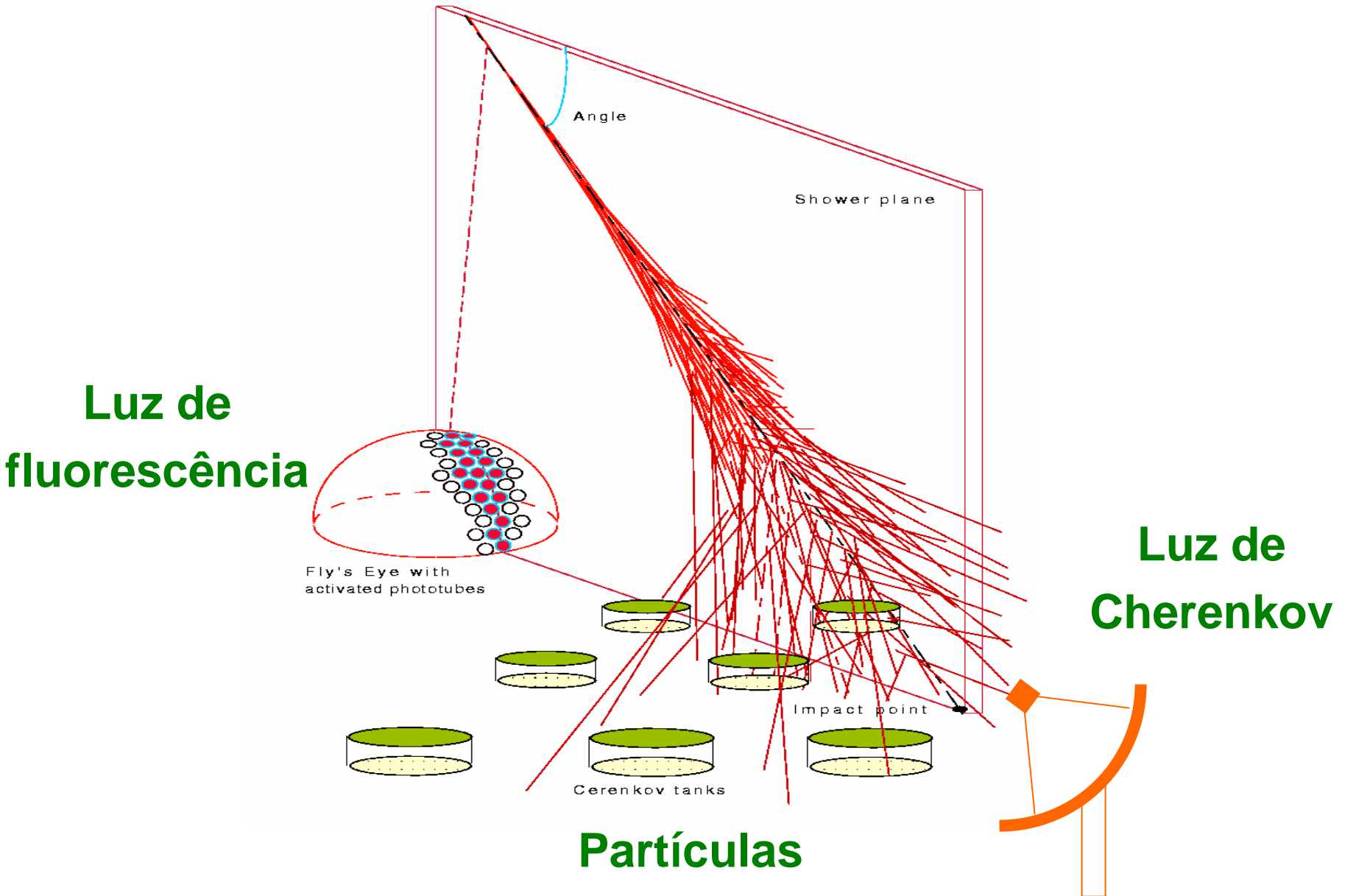
Detecção

Os raios cósmicos primários interagem com a atmosfera originando cascatas de partículas

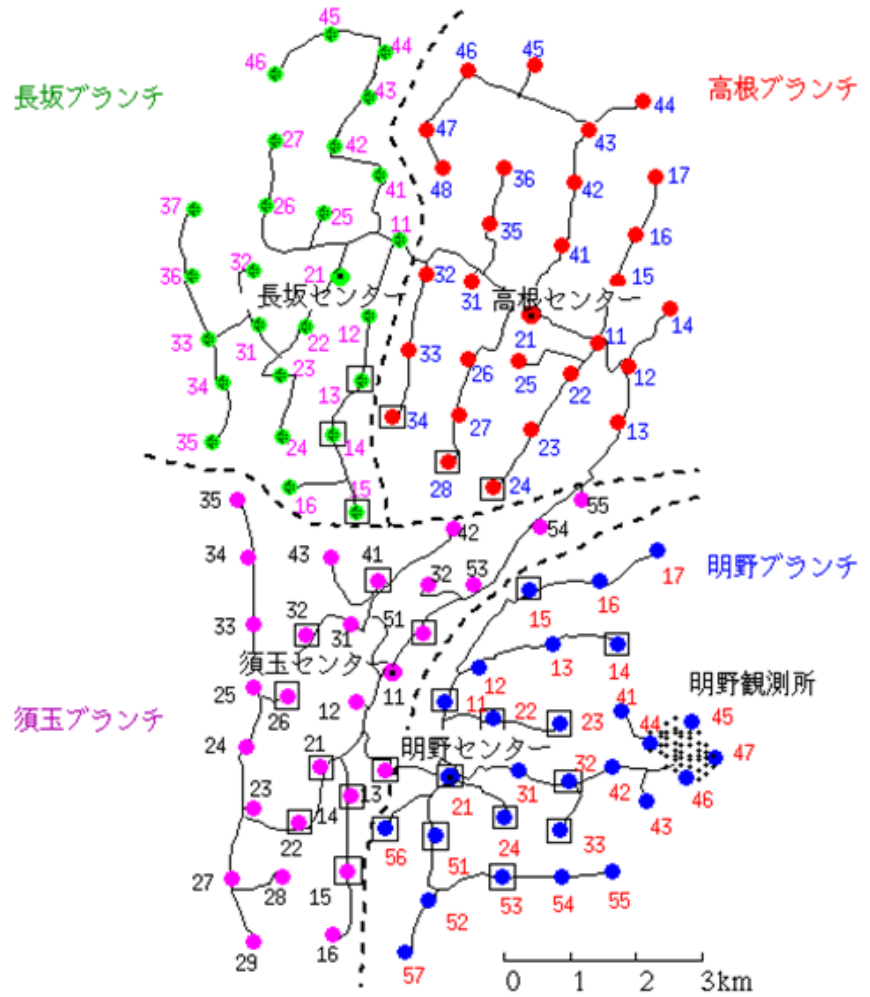
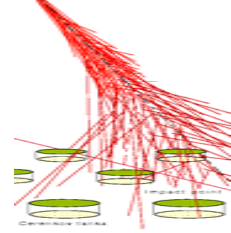


- Baixas energias:
detecção no Espaço!
- Energias mais altas:
baixo fluxo...

Cascatas de partículas: detecção



AGASA



Matrizes de detectores no solo

(n_i , t_i) nos diferentes detectores

Perfil lateral da cascata

$$\rho(r) = c(s)N_e / r_0^2 (r/r_0)^{s-2} (1+r/r_0)^{s-4.5}$$

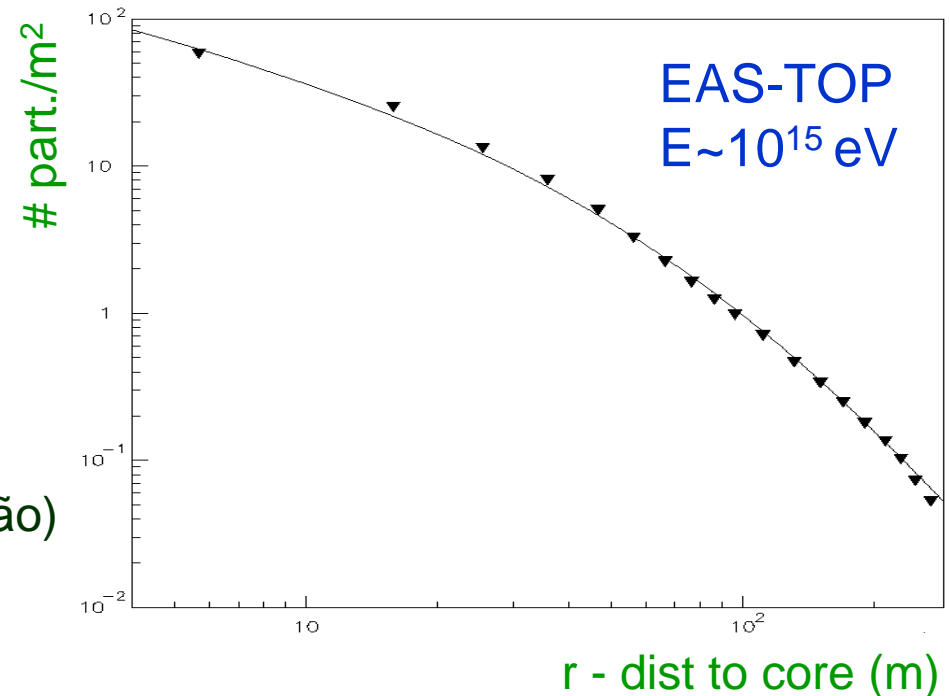
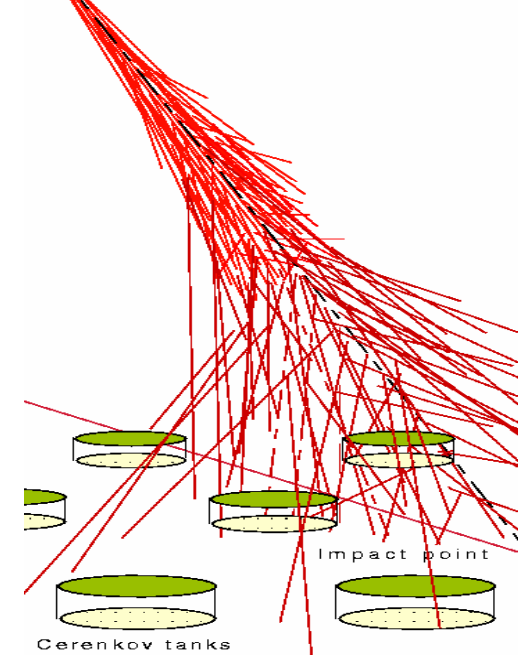
N_e : Tamanho da cascata
(# total de partículas)

s : Idade da cascata $s = \frac{3t}{t + 2\beta_0}$

t : profundidade (comprimentos de radiação)

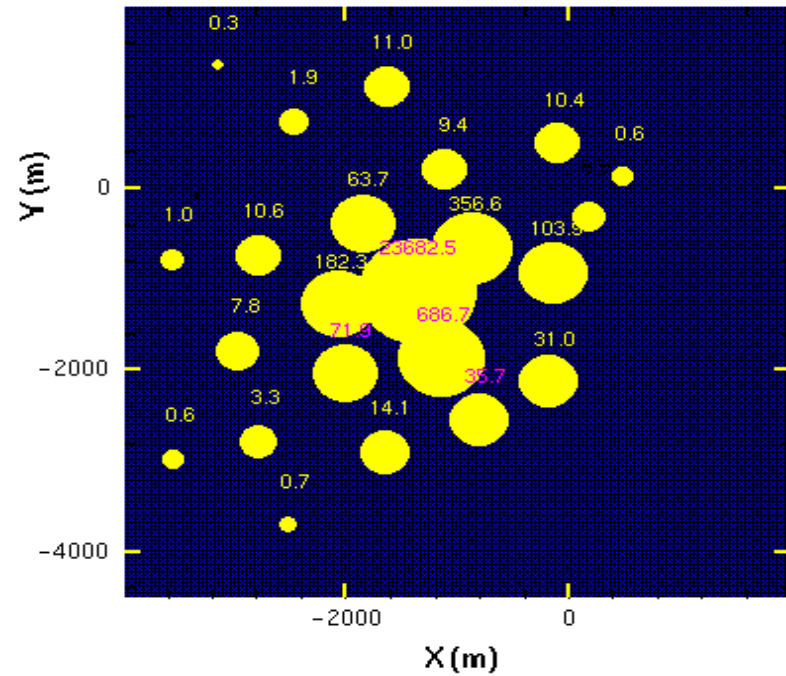
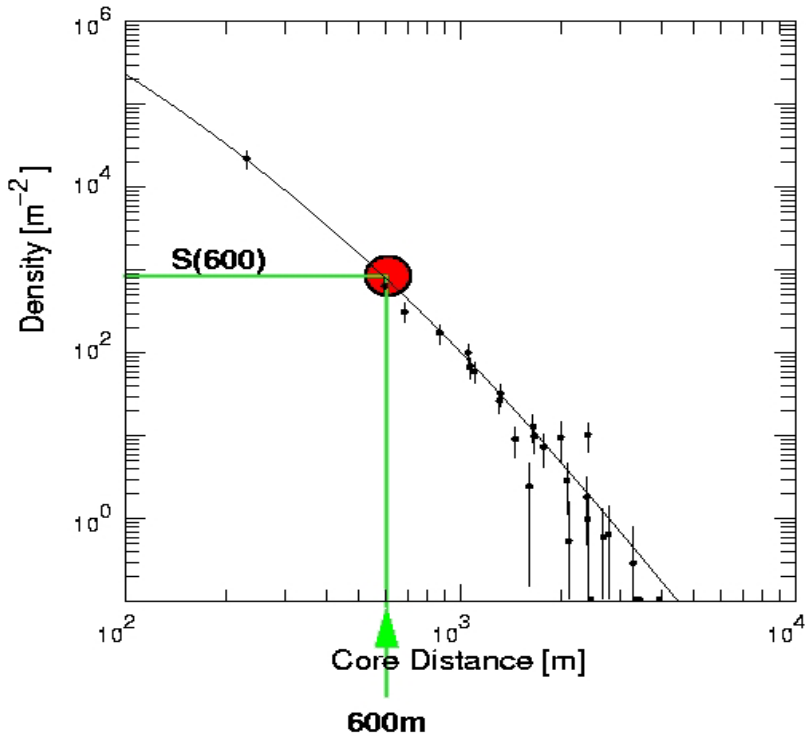
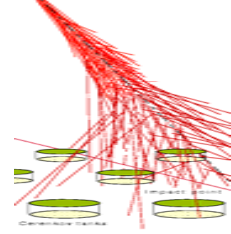
β_0 : $\ln(E/\epsilon_c)$

r_0 : raio de Molière

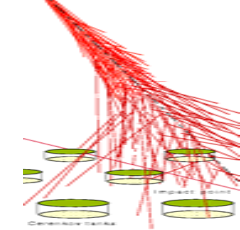


Energia

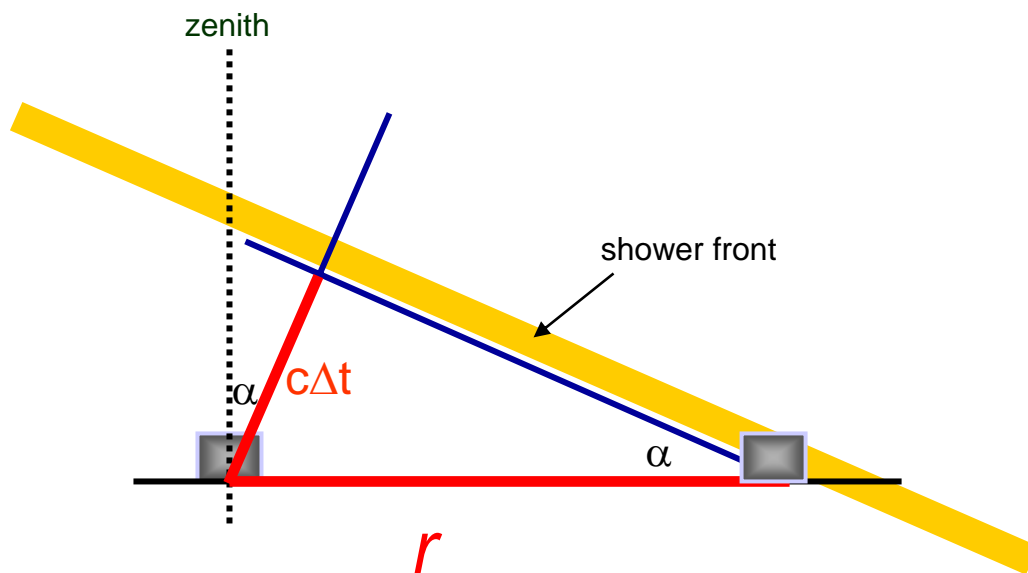
... Proporcional ao tamanho da cascata N_e



Direcção



... diferenças temporais na detecção da frente da cascata



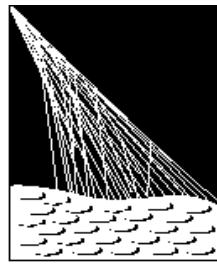
$$\sin(\alpha) = \frac{c \cdot \Delta t}{r}$$

$$\Delta\alpha < 8^\circ \quad \longrightarrow \quad \Delta t < 10 \text{ ns}$$

Auger

Área ~ 3000 km²

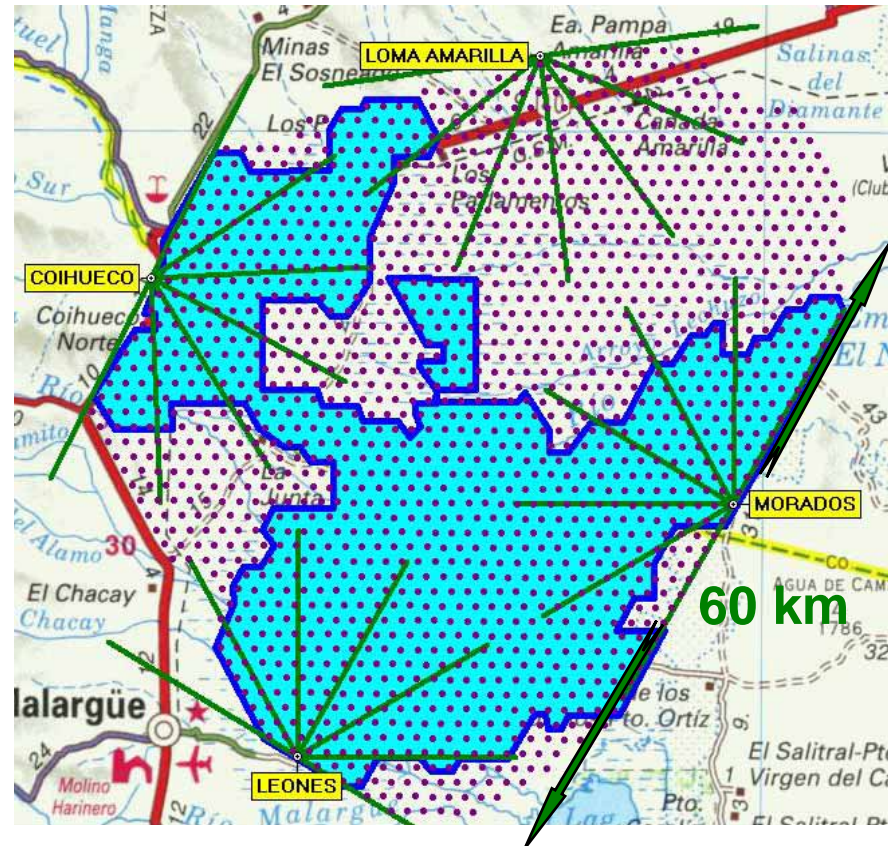
~ 100 acontecimientos de muito alta energia por ano!



**PIERRE
AUGER**
OBSERVATORY



Malargüe, Argentina

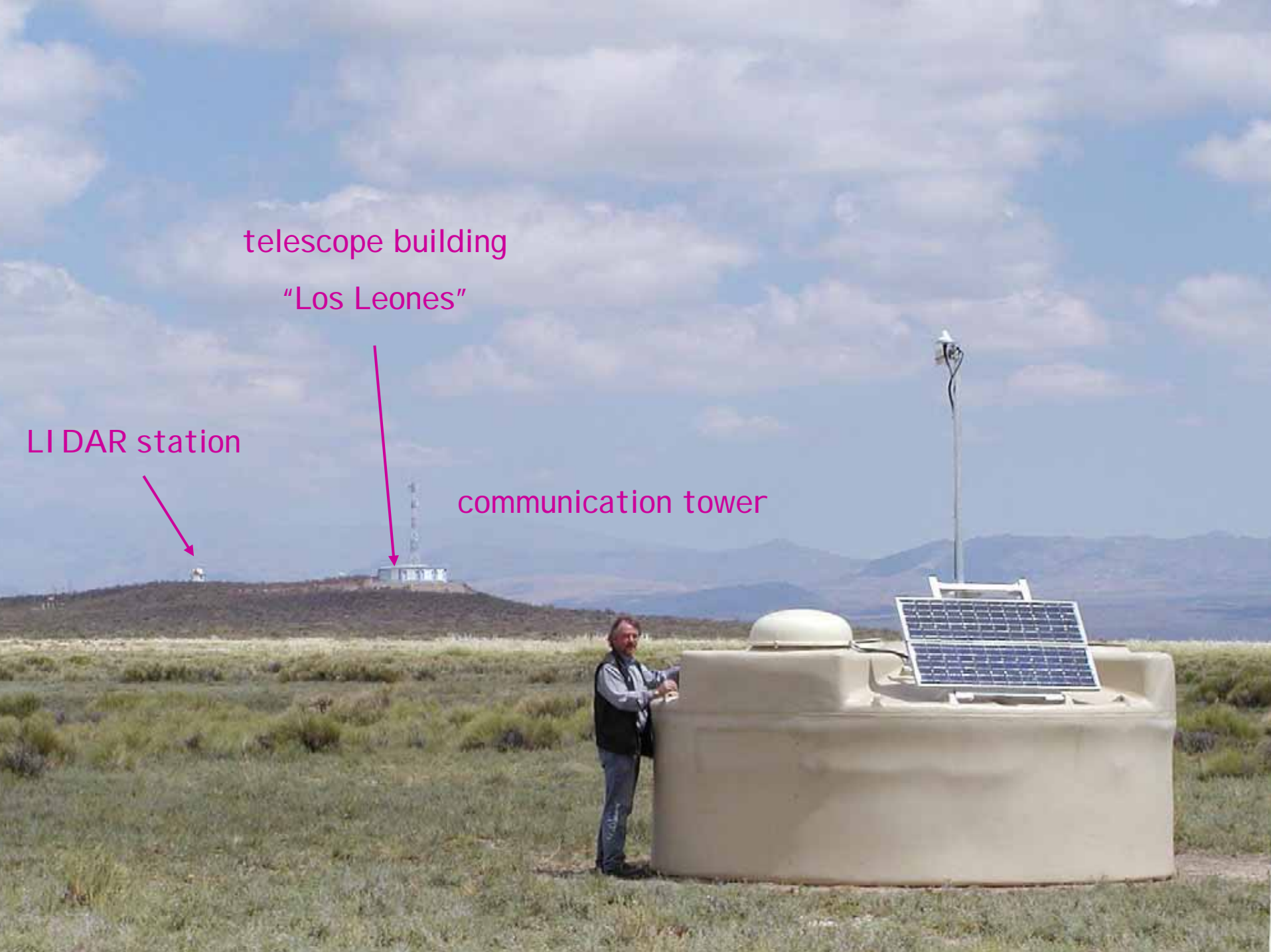


telescope building

"Los Leones"

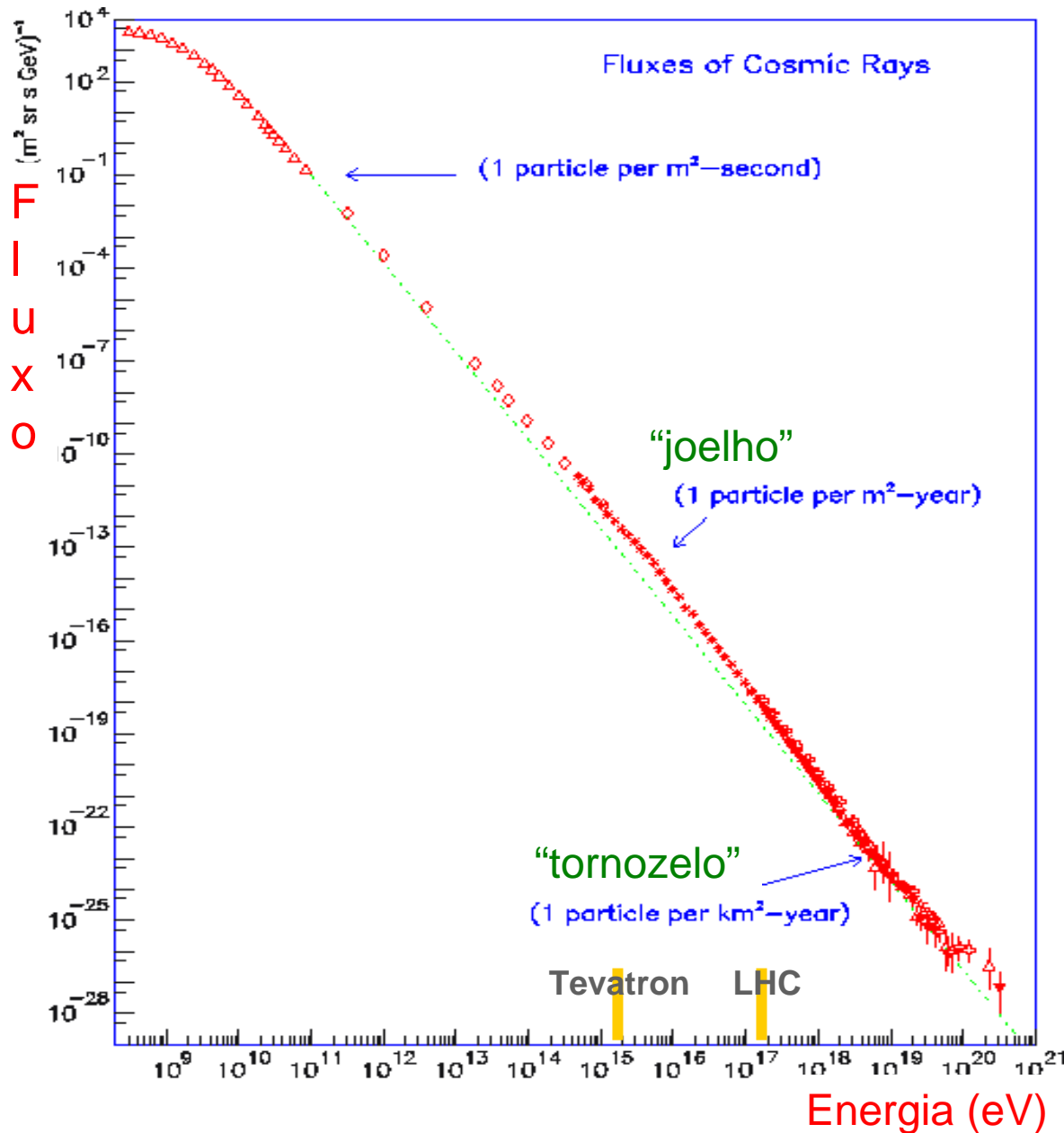
LI DAR station

communication tower





O Espectro de energia

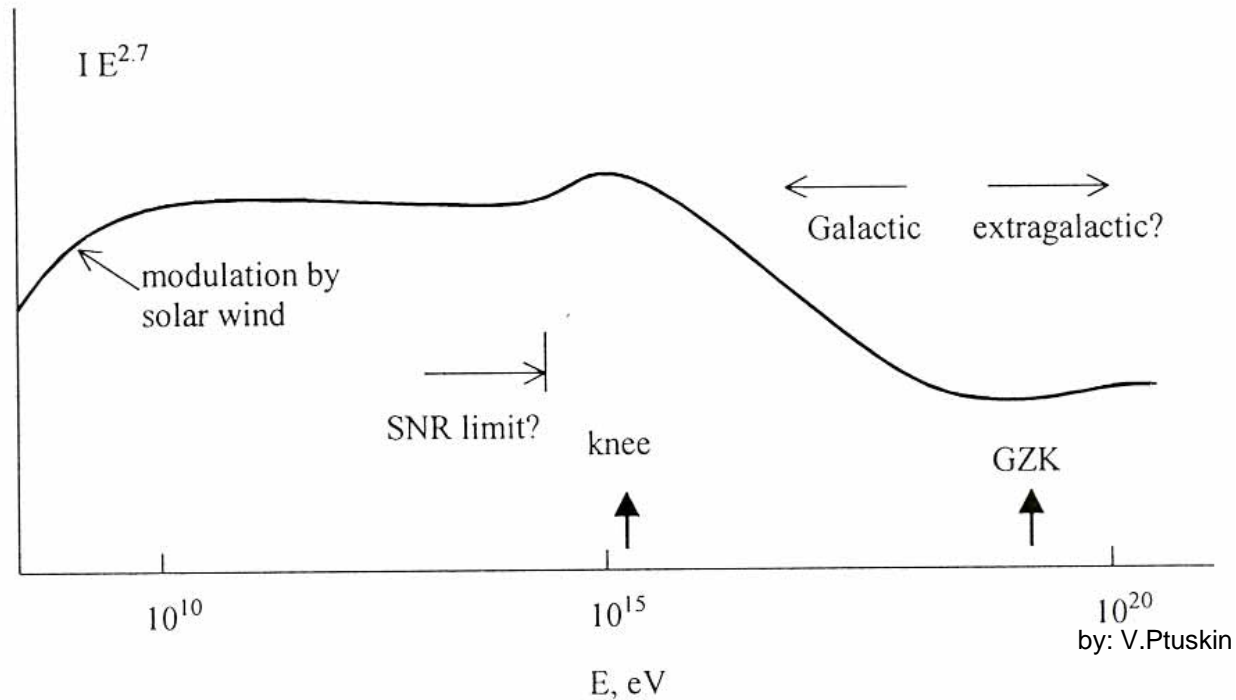


$$\frac{dN}{dE} \propto E^{-\alpha}$$

$$\alpha = \begin{cases} 2.7 & E < 10^{16} \\ 3.0 & 10^{16} < E < 10^{18} \\ 2.7? & E > 10^{18} \end{cases}$$

$$N(E > E_0) = \int_{E_0}^{\infty} E^{-\alpha} dE \propto E_0^{-\alpha+1}$$

O espectro de energia II



10^9 eV

Sol

10^9 a 10^{15} eV

Origem Galáctica (SNR)

10^{15} a $\sim 5 \times 10^{18}$ eV

Situação confusa

10^{19} eV

Origem desconhecida (Extragaláctica)

O espectro de energia III

Composição

p , He, ..., Fe, ...

γ , e , ν

