Detecção de bosões W no LHC

Detecção de bosões Z no LHC

Câmaras de bolhas:
medir a massa de uma partícula

Câmaras de bolhas:
Análise detalhada de uma imagem

Neutrinos

O tempo de vida do muão

Detecção de raios cósmicos em Auger

Detecção de raios cósmicos em AMS

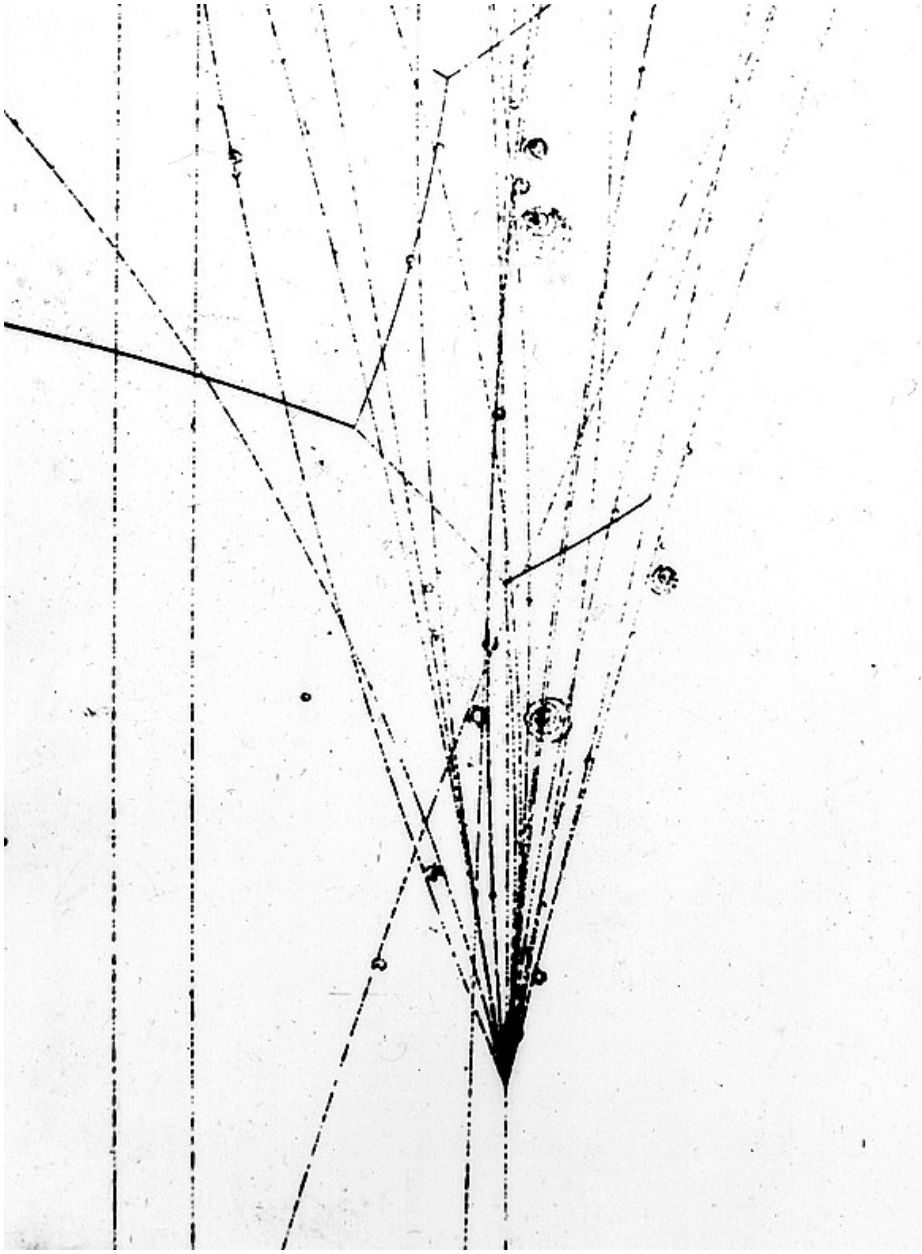
Algumas perguntas

O que é uma partícula elementar?

Onde andam as partículas?
Como “aparecem” e “desaparecem”?

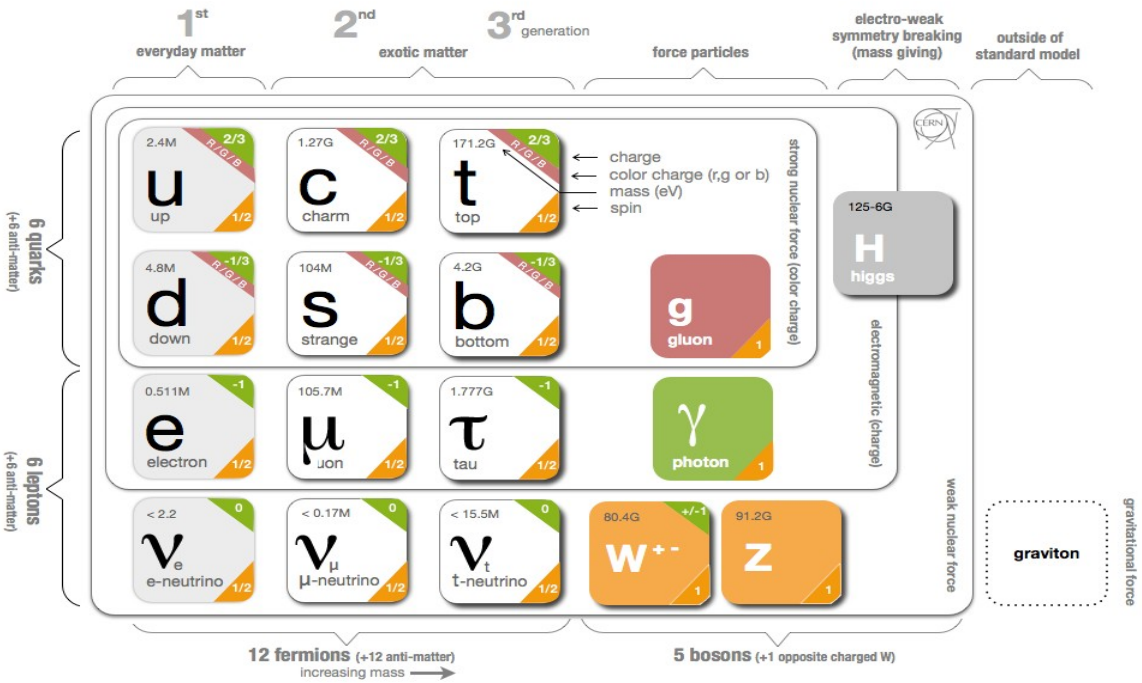
Como se detectam as partículas?

Que experiências de física de partículas existem hoje e a que perguntas procuram responder?



O que é uma partícula elementar?

As partículas elementares são “indivisíveis” e caracterizadas pela sua massa, carga, ...



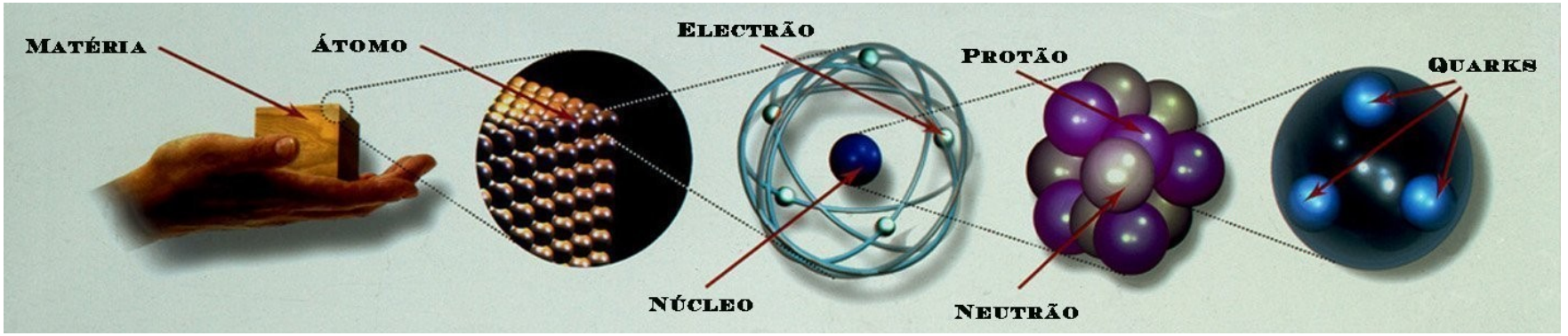
Em cada instante, o seu estado dinâmico é caracterizado por algumas outras grandezas:

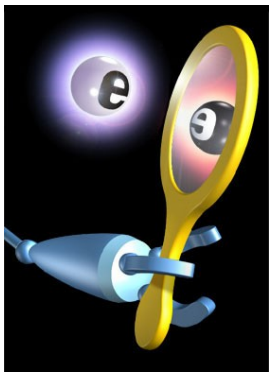
Energia $E=mc^2$

Momento linear $\vec{p}=m\vec{v}$

... E têm um comprimento de onda associado: $\lambda = h/p$

A “matéria”





Leptões:

$$\begin{pmatrix} \nu_e \\ e^- \end{pmatrix} \quad \begin{pmatrix} \nu_\mu \\ \mu^- \end{pmatrix} \quad \begin{pmatrix} \nu_\tau \\ \tau^- \end{pmatrix}$$

Quarks:

$$\begin{pmatrix} u \\ d \end{pmatrix} \quad \begin{pmatrix} c \\ s \end{pmatrix} \quad \begin{pmatrix} t \\ b \end{pmatrix}$$

As “Forças”

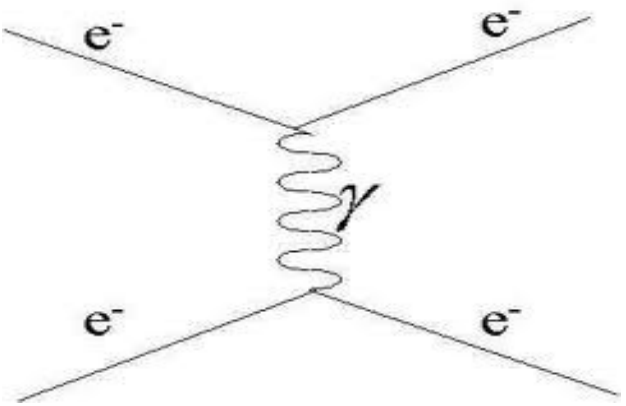
Interacção electrofraca:

γ, W^+,W^-, Z^0

Interacção forte:

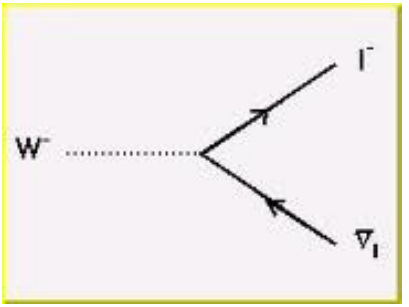
G_1, …., G_8

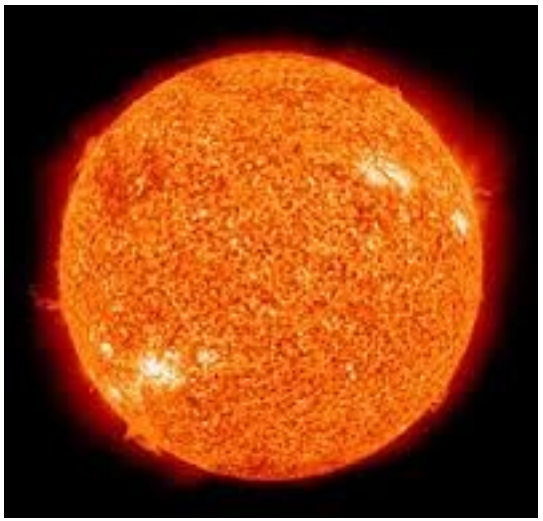
A interacção electromagnética

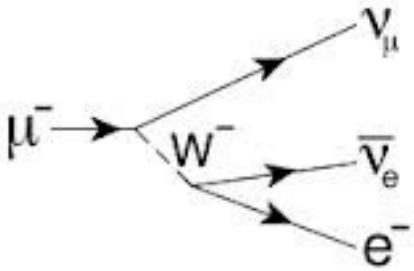


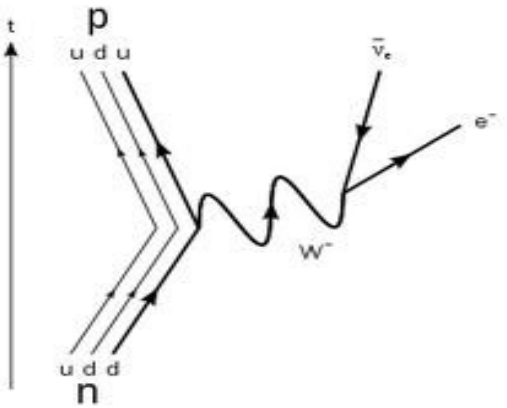
A interacção fraca

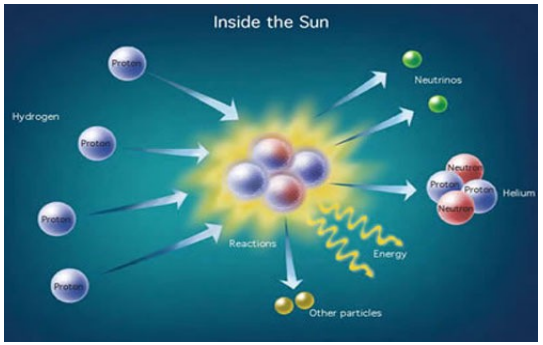
W

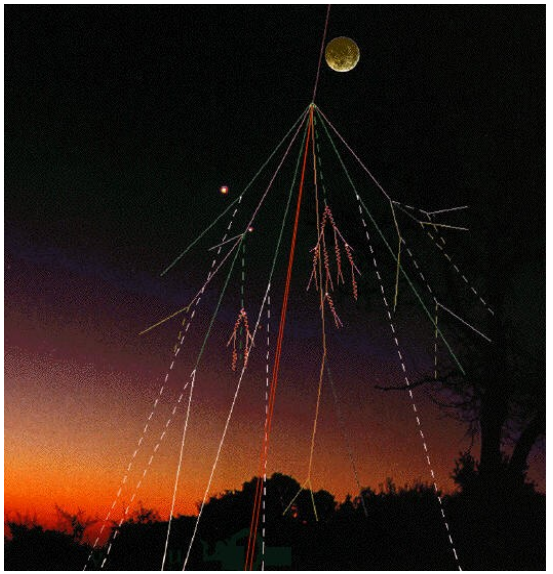


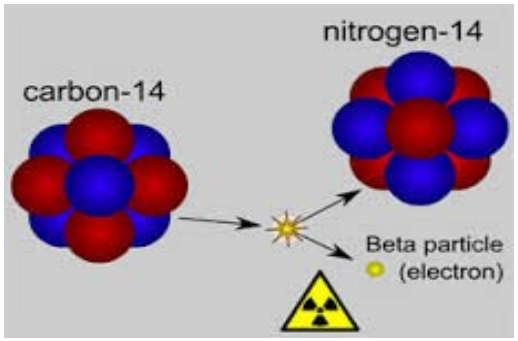




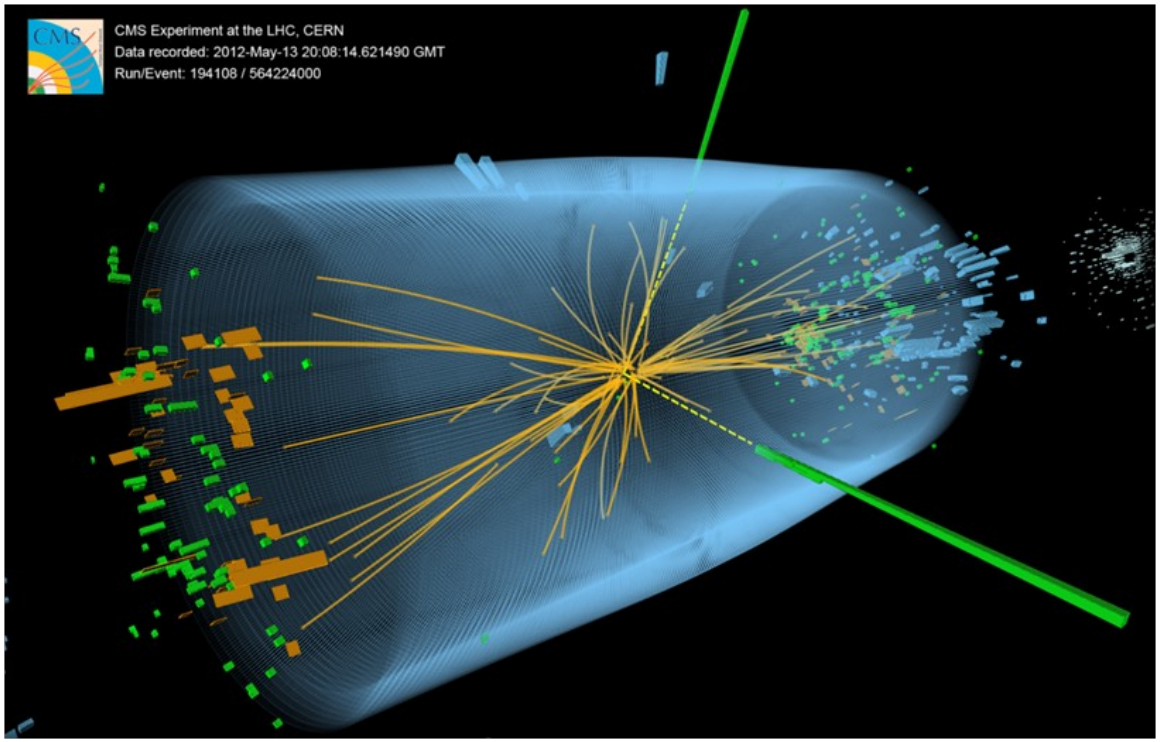


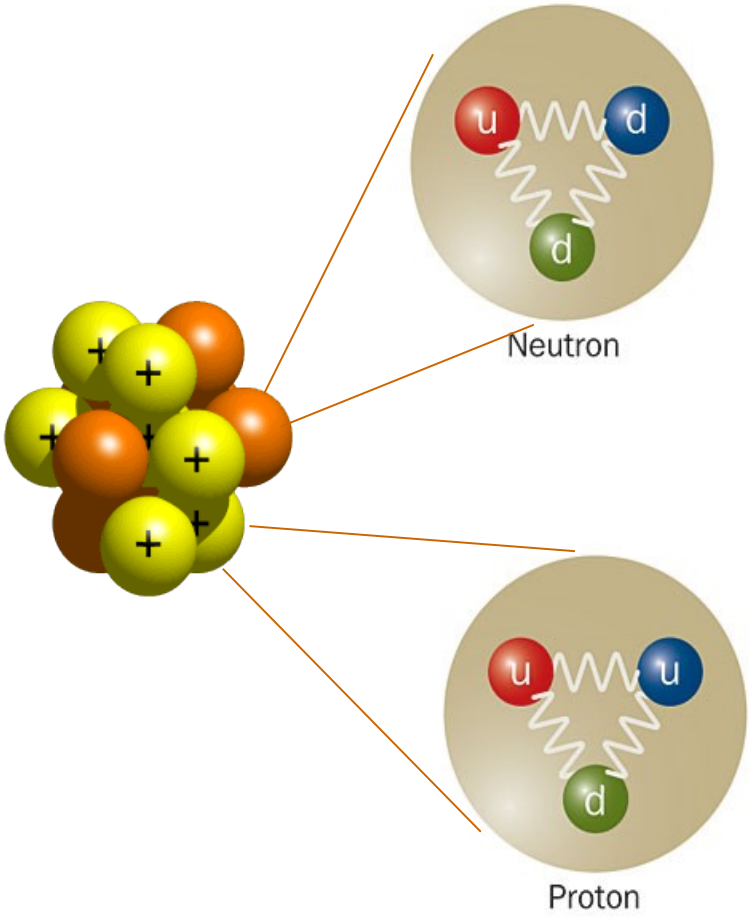






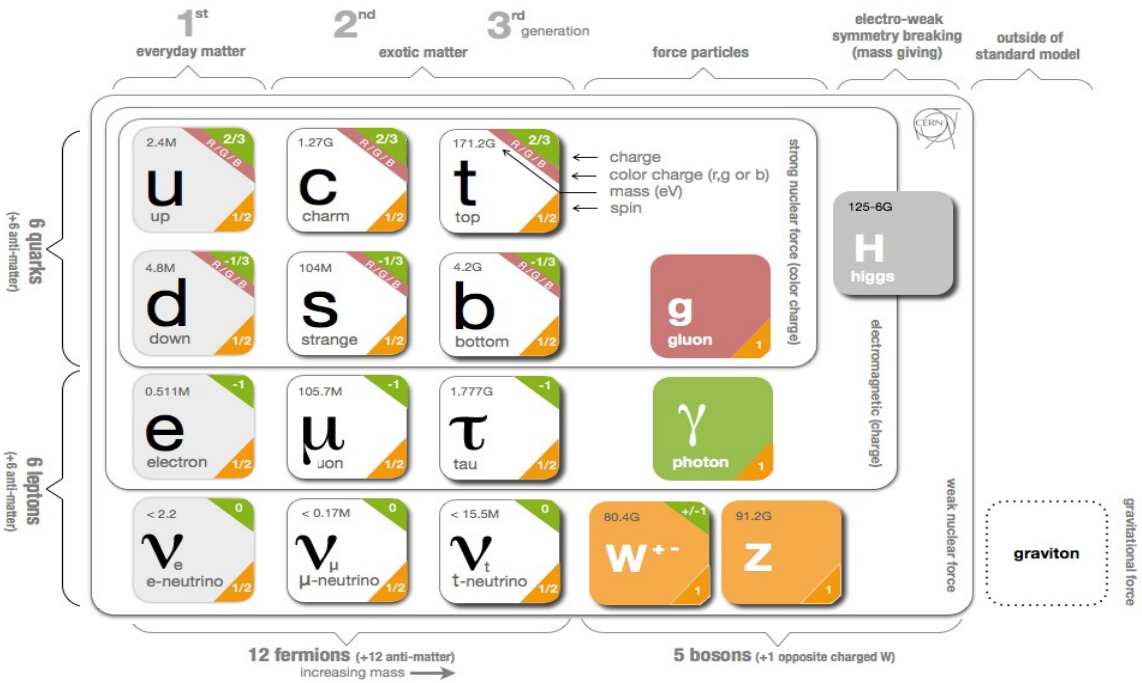
A interacção forte





O que é uma partícula elementar?

As partículas elementares são “indivisíveis” e caracterizadas pela sua massa, carga, ...



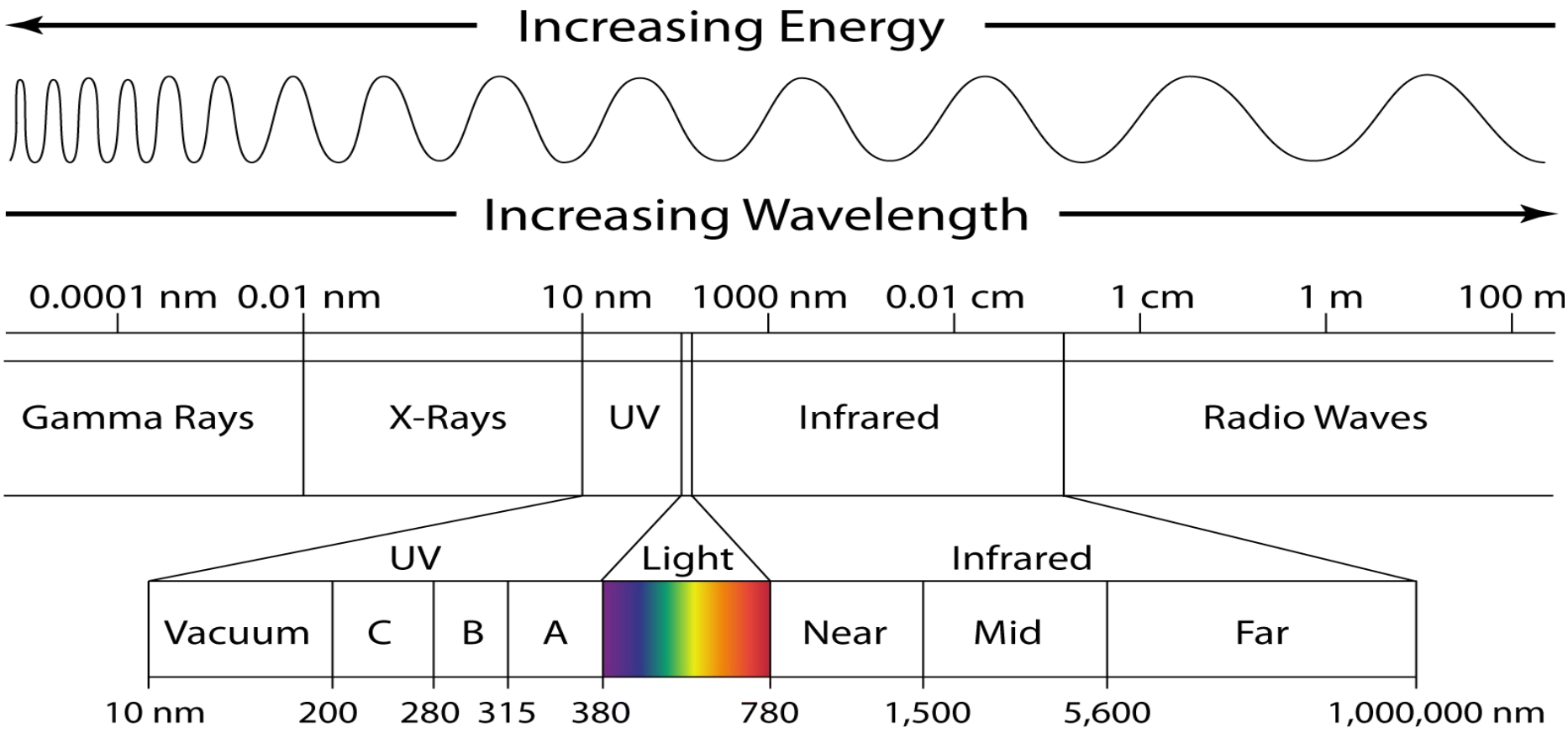
Em cada instante, o seu estado dinâmico é caracterizado por algumas outras grandezas:

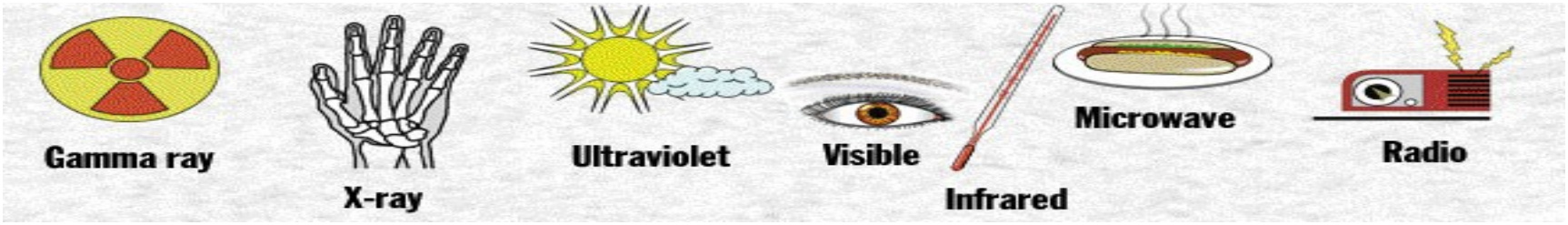
Energia $E=mc^2$

Momento linear $\vec{p}=m\vec{v}$

... E têm um comprimento de onda associado: $\lambda = h/p$

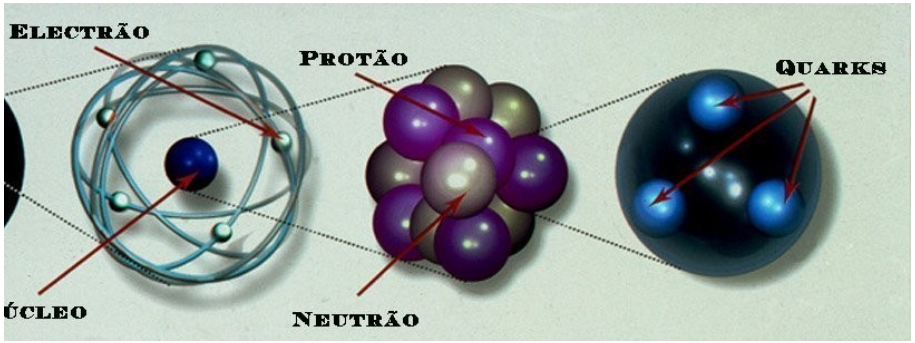
Há fotões e fotões...

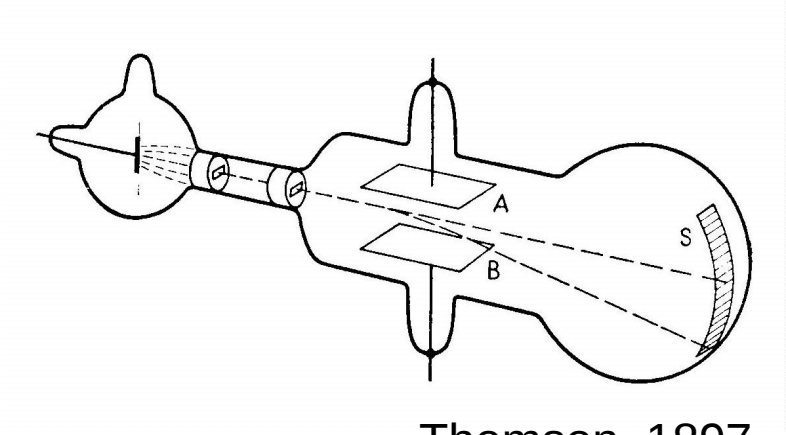




Onde andam as partículas?

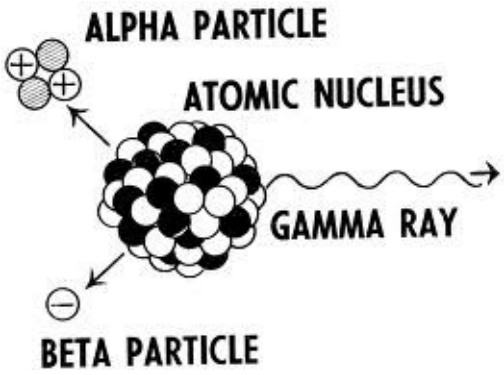
A matéria comum é feita de átomos constituidos por electrões, protões e neutrões.
Os protões e os neutrões não são elementares – são feitos de quarks

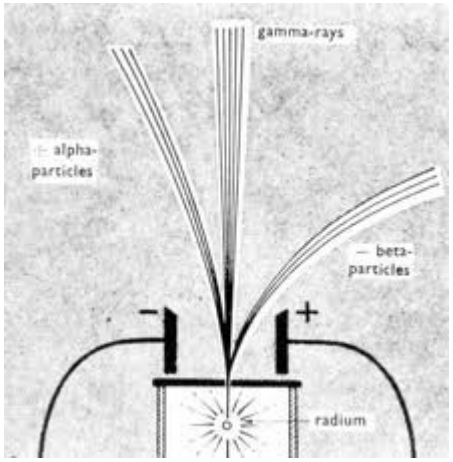




Thomson, 1897

Radioactividade natural:
Há núcleos que são instáveis, desintegrando-se com emissão de partículas

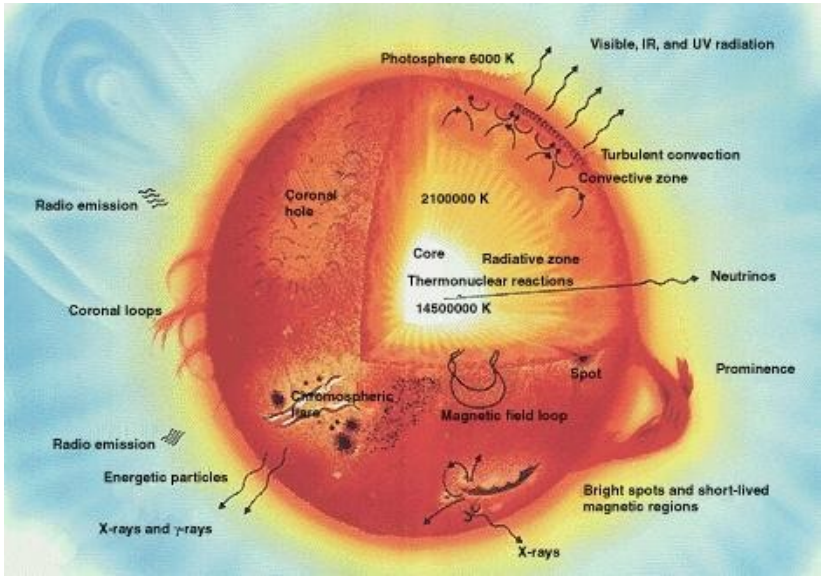




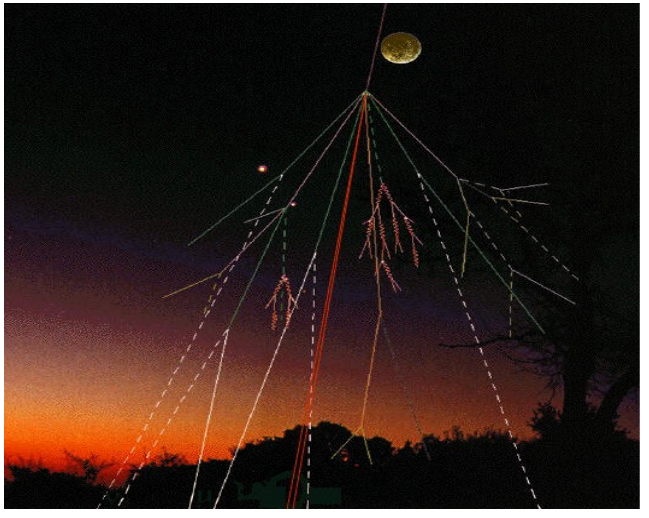
Becquerel, 1896
Curie

Onde andam as partículas?

As partículas são produzidas em reacções nucleares no interior das estrelas e outros objectos celestes

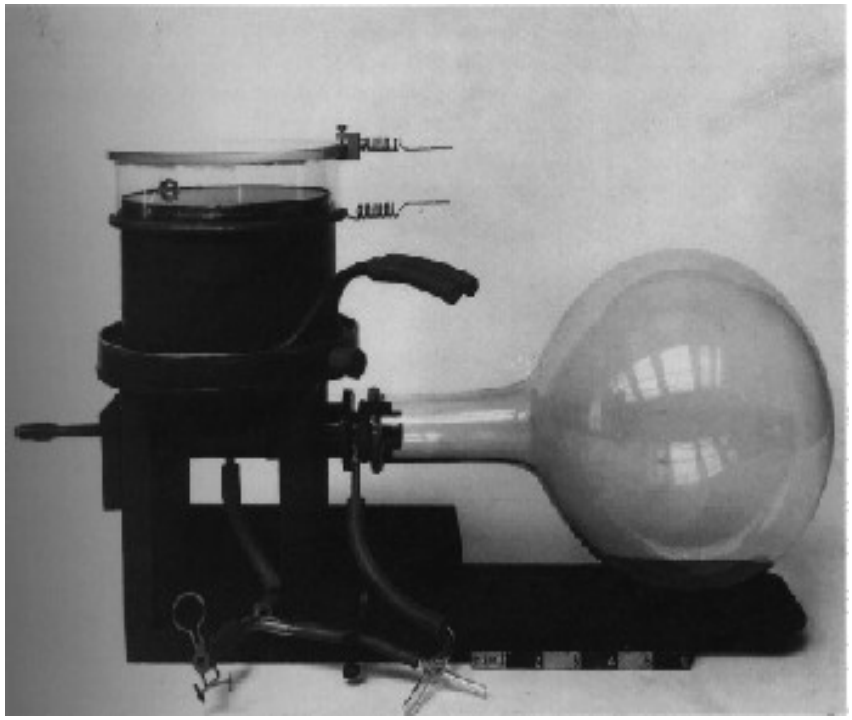


E algumas chegam até nós, podendo produzir novas partículas na atmosfera



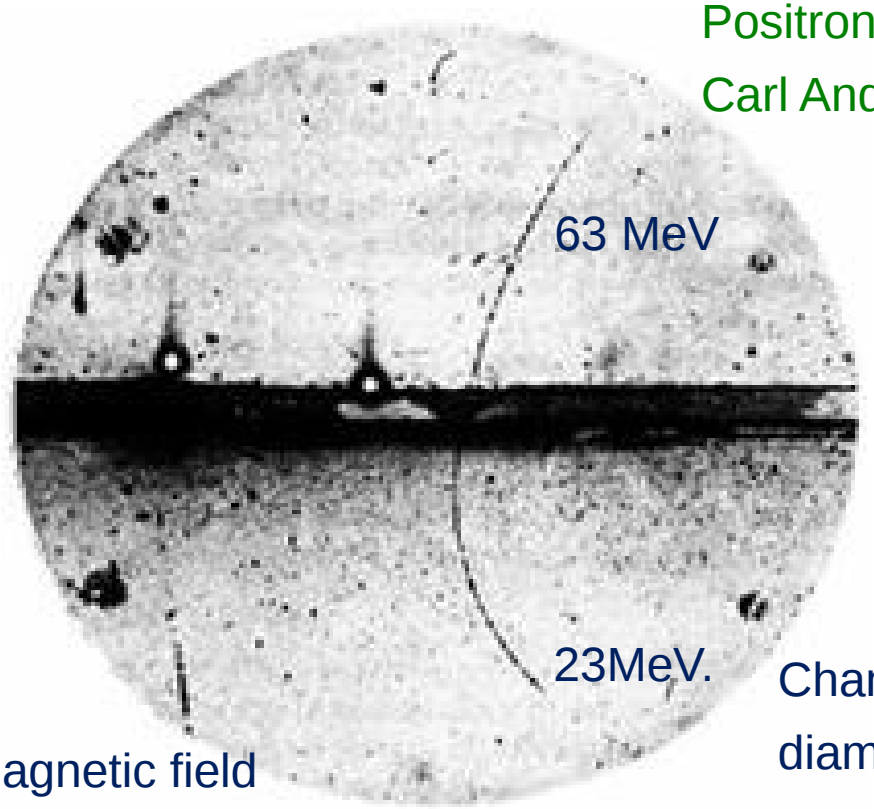
Onde andam as partículas?

Muitas partículas, como o positrão e o muão, foram descobertas nos raios cósmicos



Wilson Cloud Chamber 1911

Positron discovery,
Carl Andersen 1933



6mm
lead plate

Chamber
diameter 15 cm

Magnetic field
15000 Gauss

Como “aparecem” e “desaparecem”?

As partículas “aparecem” em reacções a partir de outras partículas e de energia

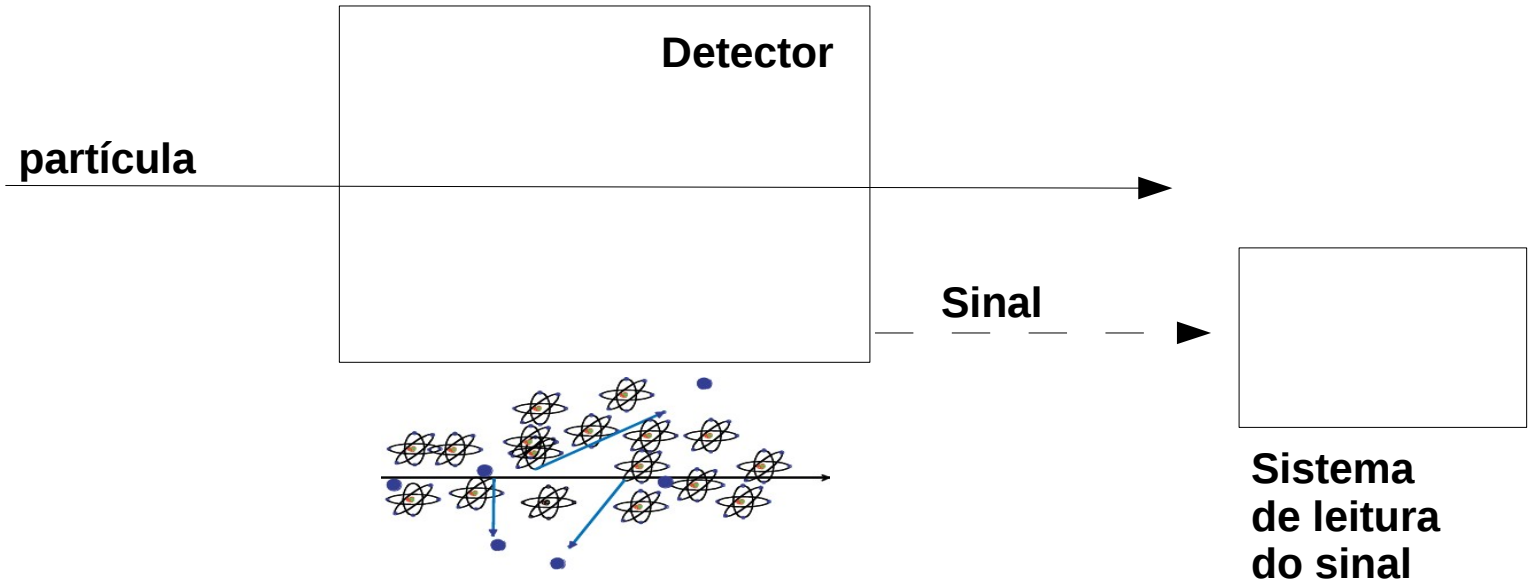
As partículas desaparecem:

> Porque têm um tempo de vida curto (são instáveis) dando origem a outras partículas

> Em reacções em que Interagem com a matéria (outras partículas)

Detectar partículas

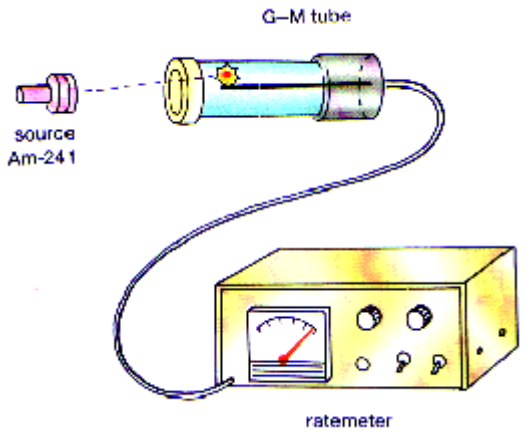
Detectamos as partículas pela sua interacção com a matéria

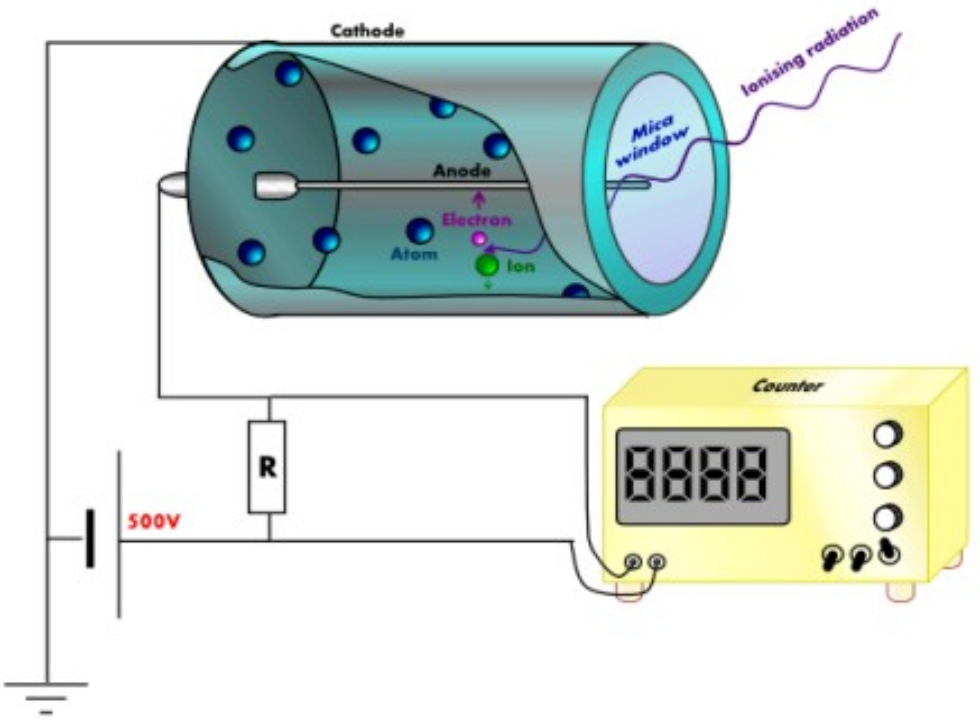


- Alguma da energia da partícula vai ser depositada no detector
- É produzido um sinal – eléctrico, luminoso, ...
- Conforme o tipo de detector, medimos propriedades diferentes:
- Energia, trajectória, momento linear, carga, massa, ...

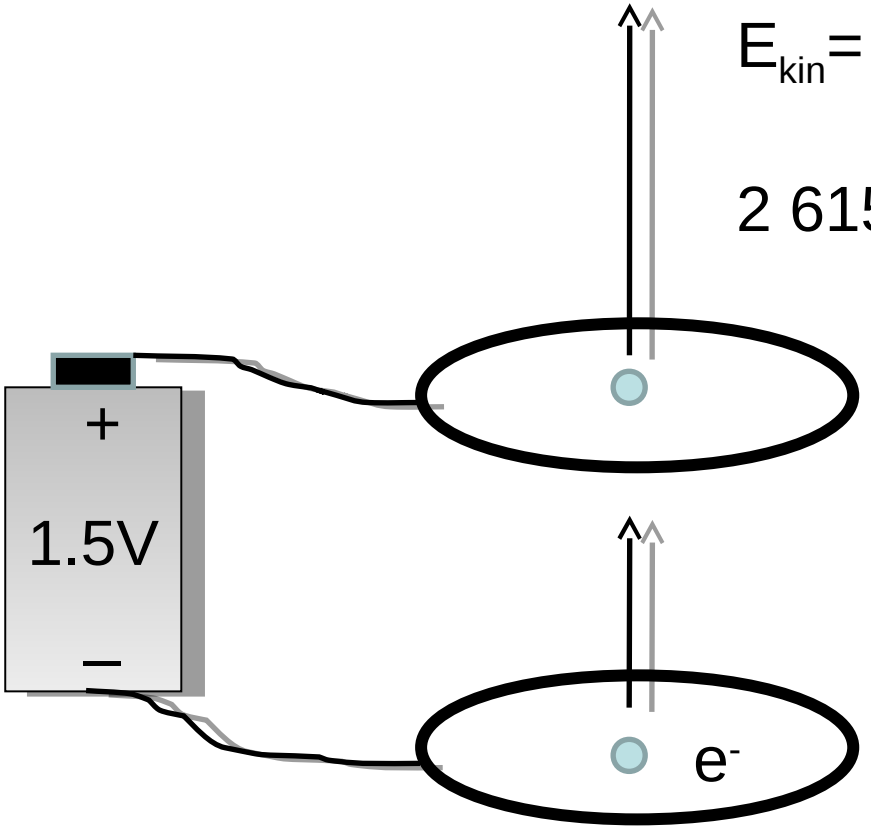
O detector Geiger

Um contador de partículas





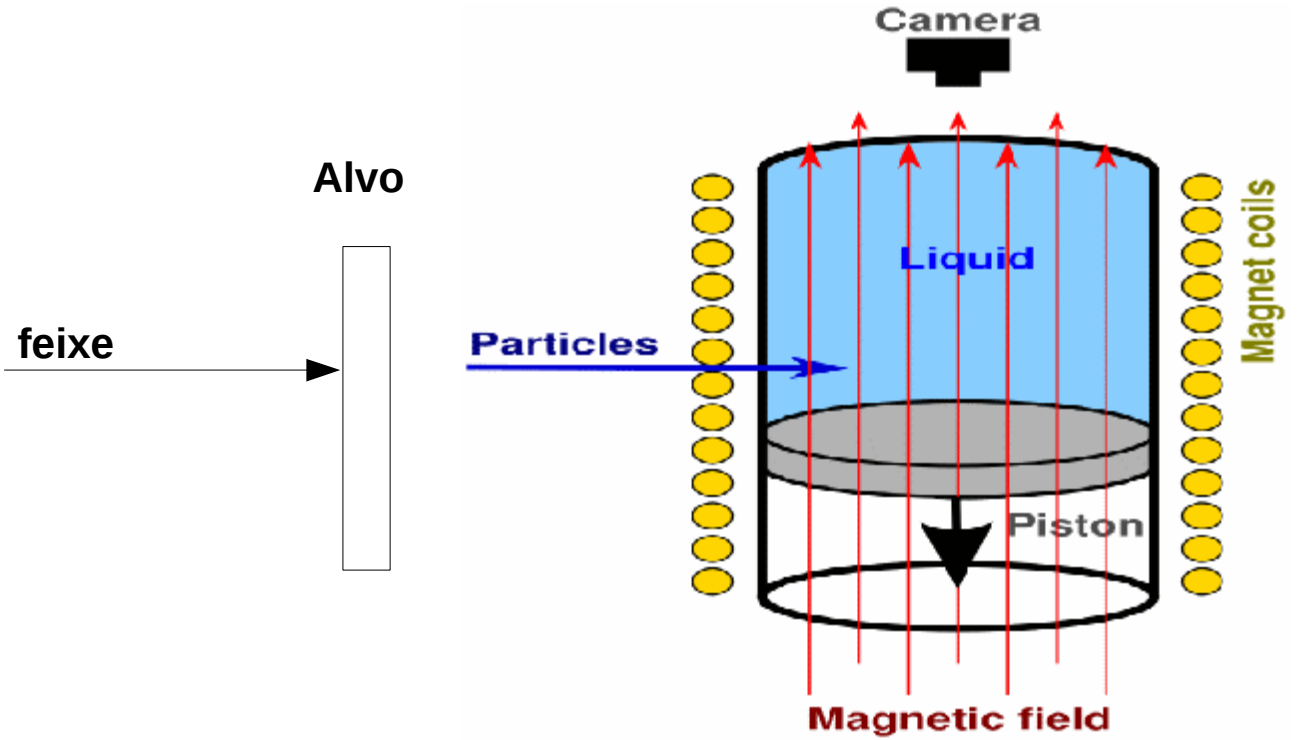
Como se aceleram as partículas?

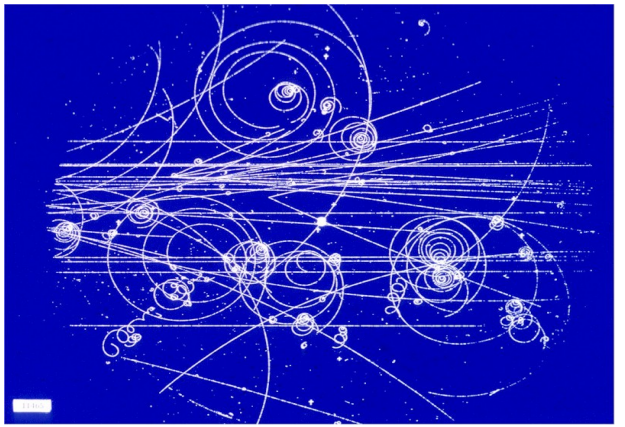


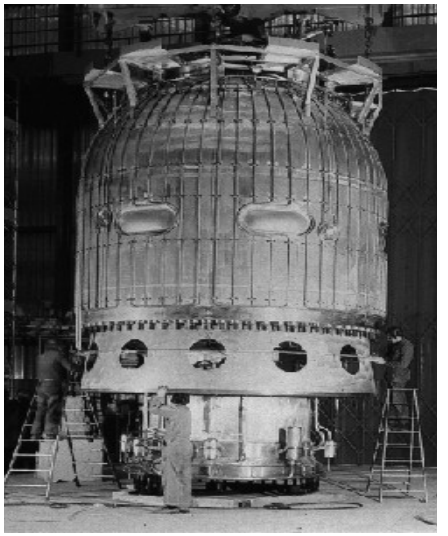
... Depois, fazem-se colidir as partículas com um alvo, ou com outro feixe de partículas...

Câmaras de bolhas

"Rastos" de bolhas indicam a trajectória das partículas, e são fotografados



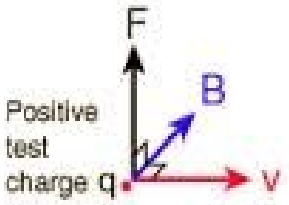




Campo magnético no interior da câmara

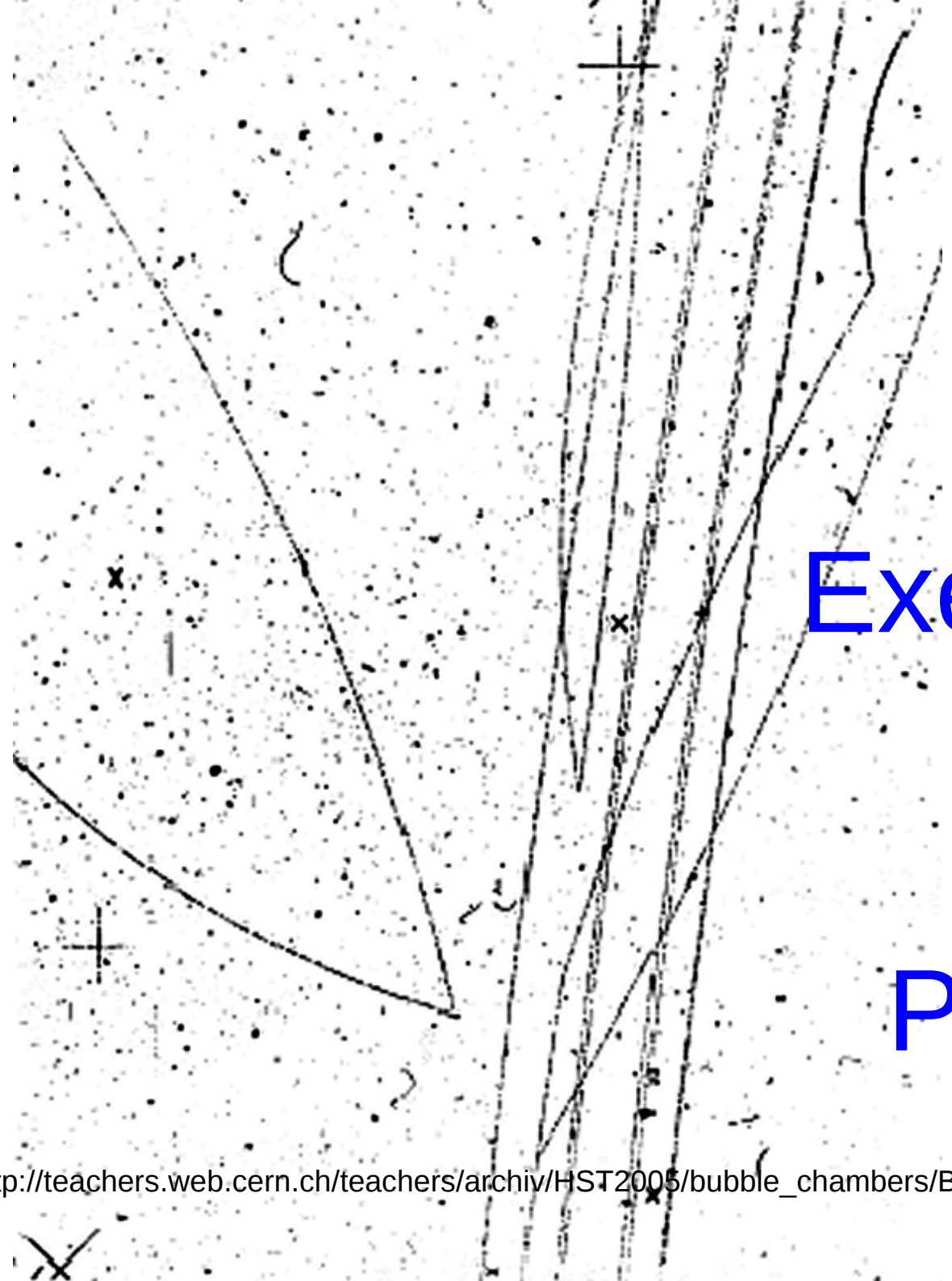
$$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$$

Electric force — *Magnetic force*



p=q.r.B

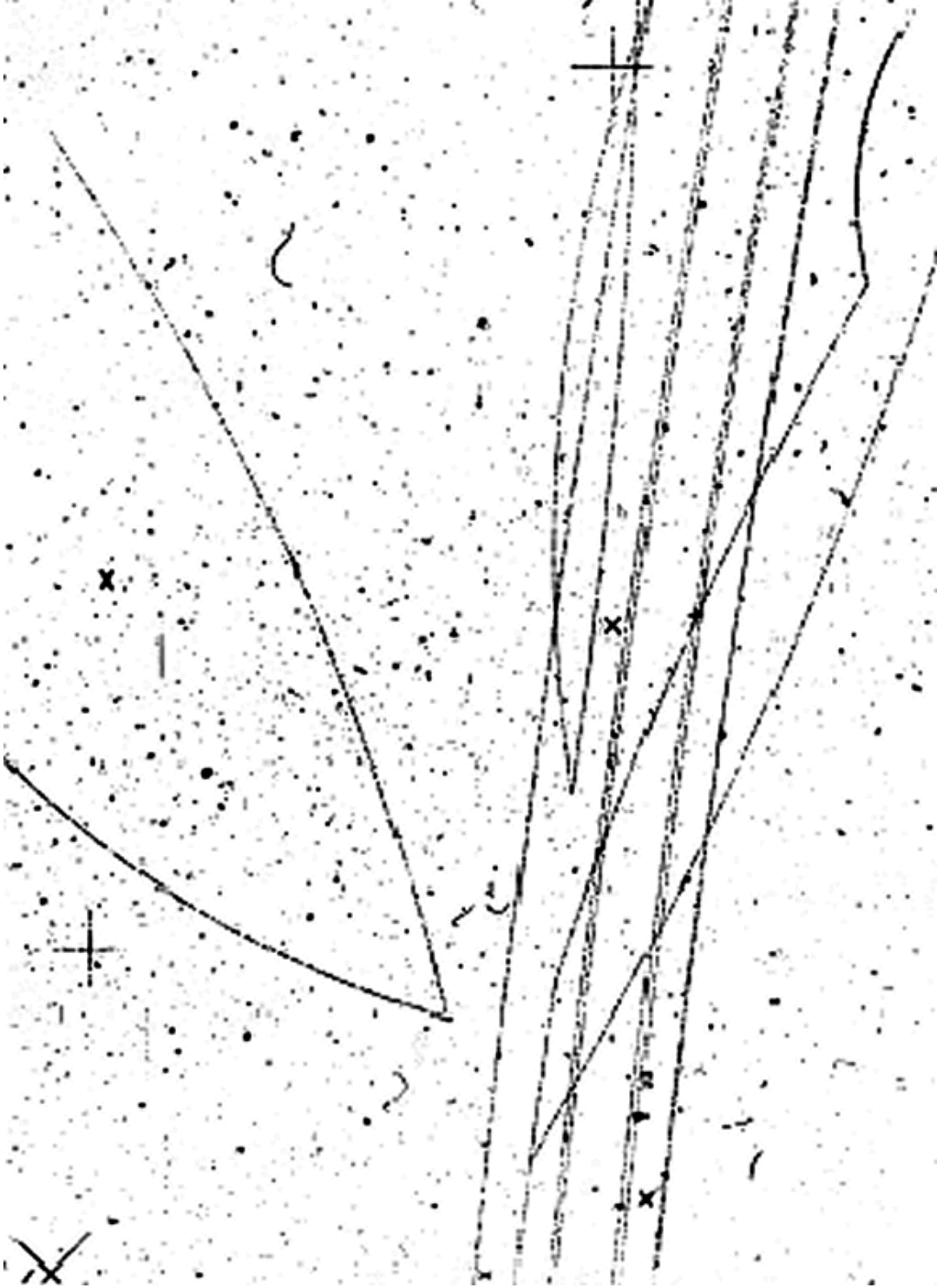
Sabemos o campo magnético e medimos o raio de curvatura
Podemos relacionar entre si o momento e a carga



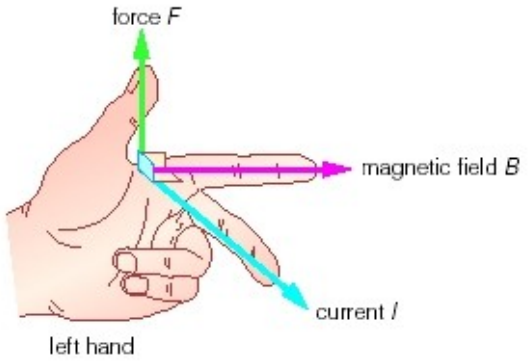
Exercises Using Bubble Chamber Photographs

http://teachers.web.cern.ch/teachers/archiv/HST2005/bubble_chambers/BCwebsite/index.htm

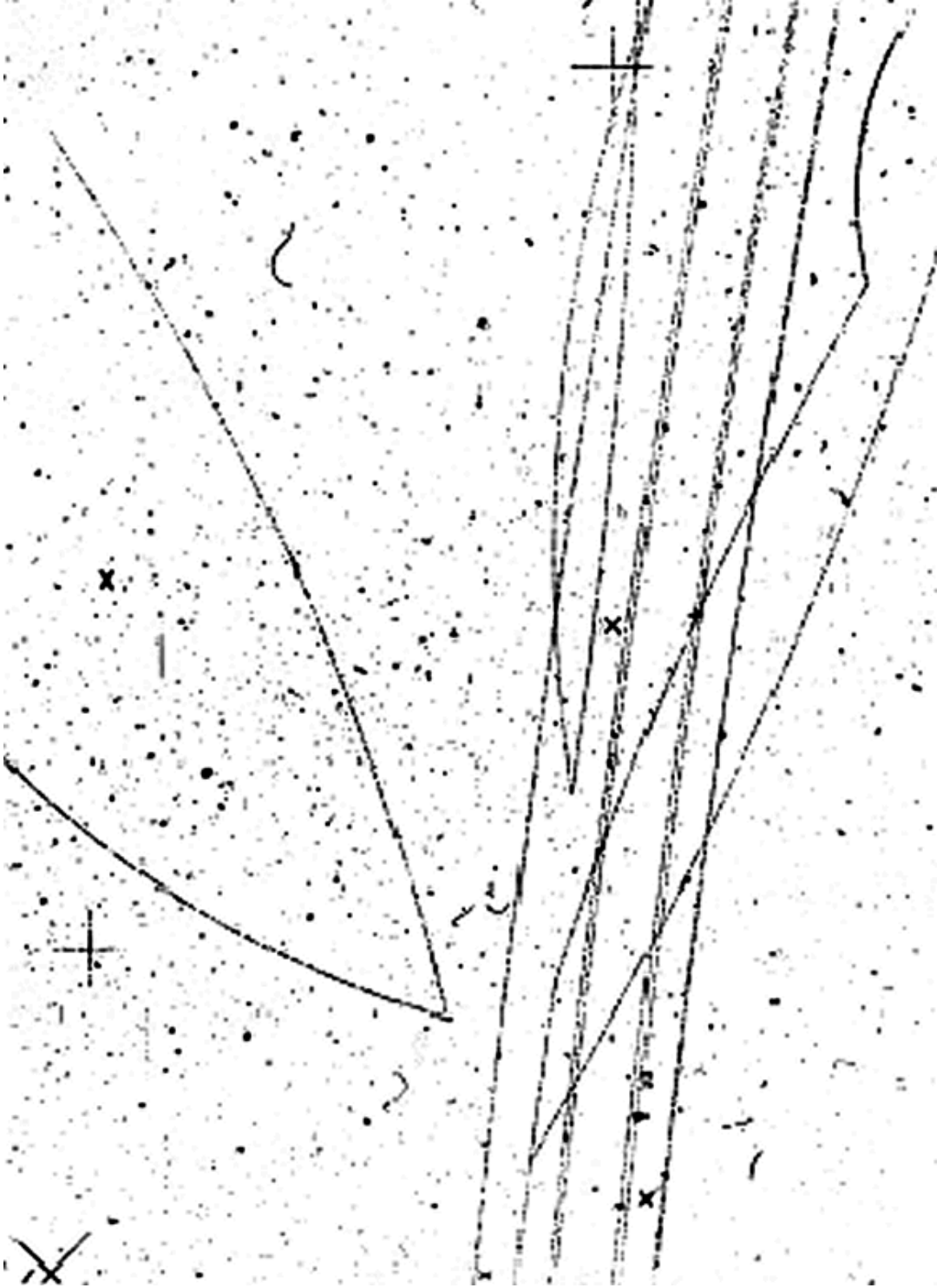
1. What is the direction of the magnetic field if the incoming beam is of K^- particles?

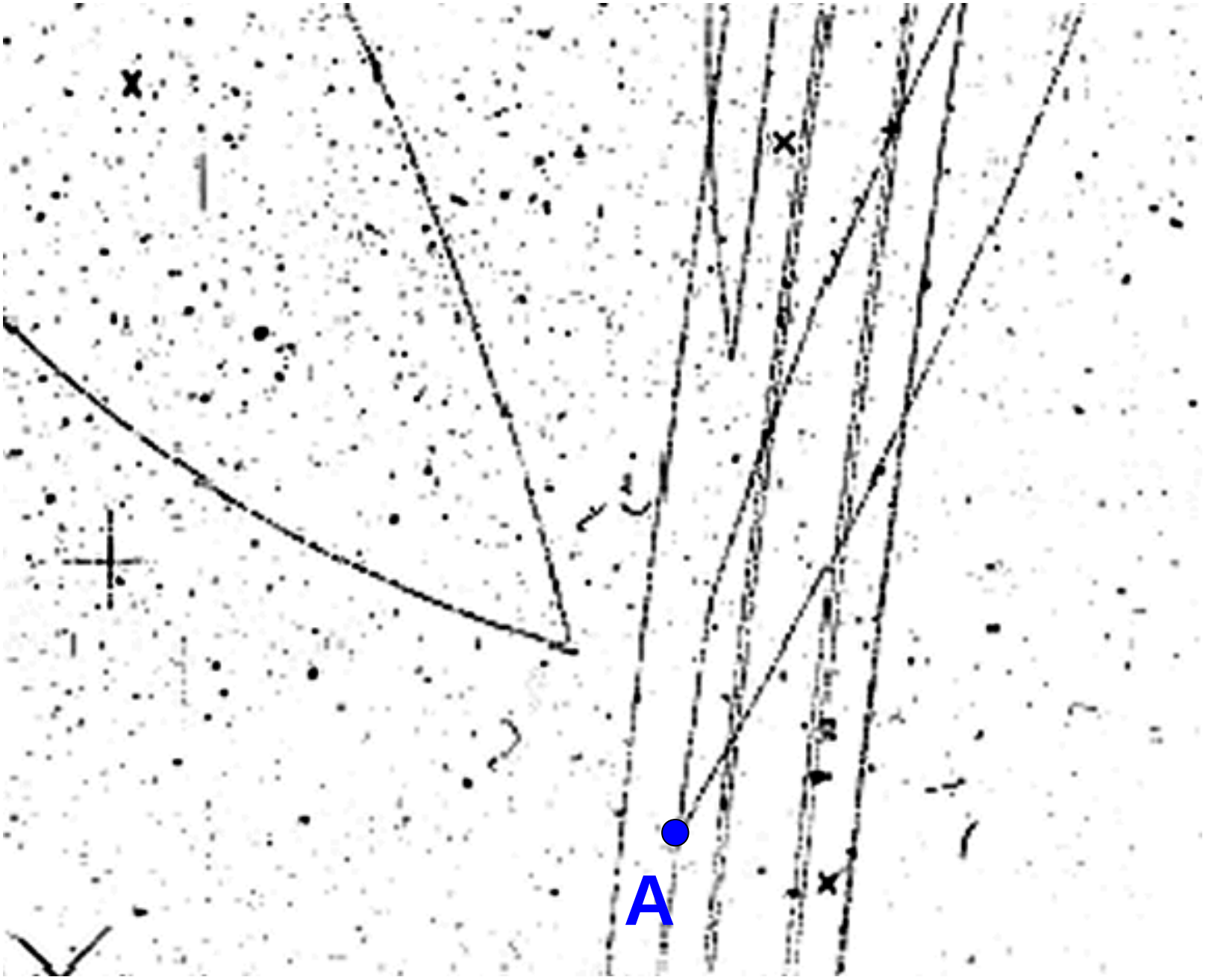


1. What is the direction of the magnetic field if the incoming beam is of K^- particles?

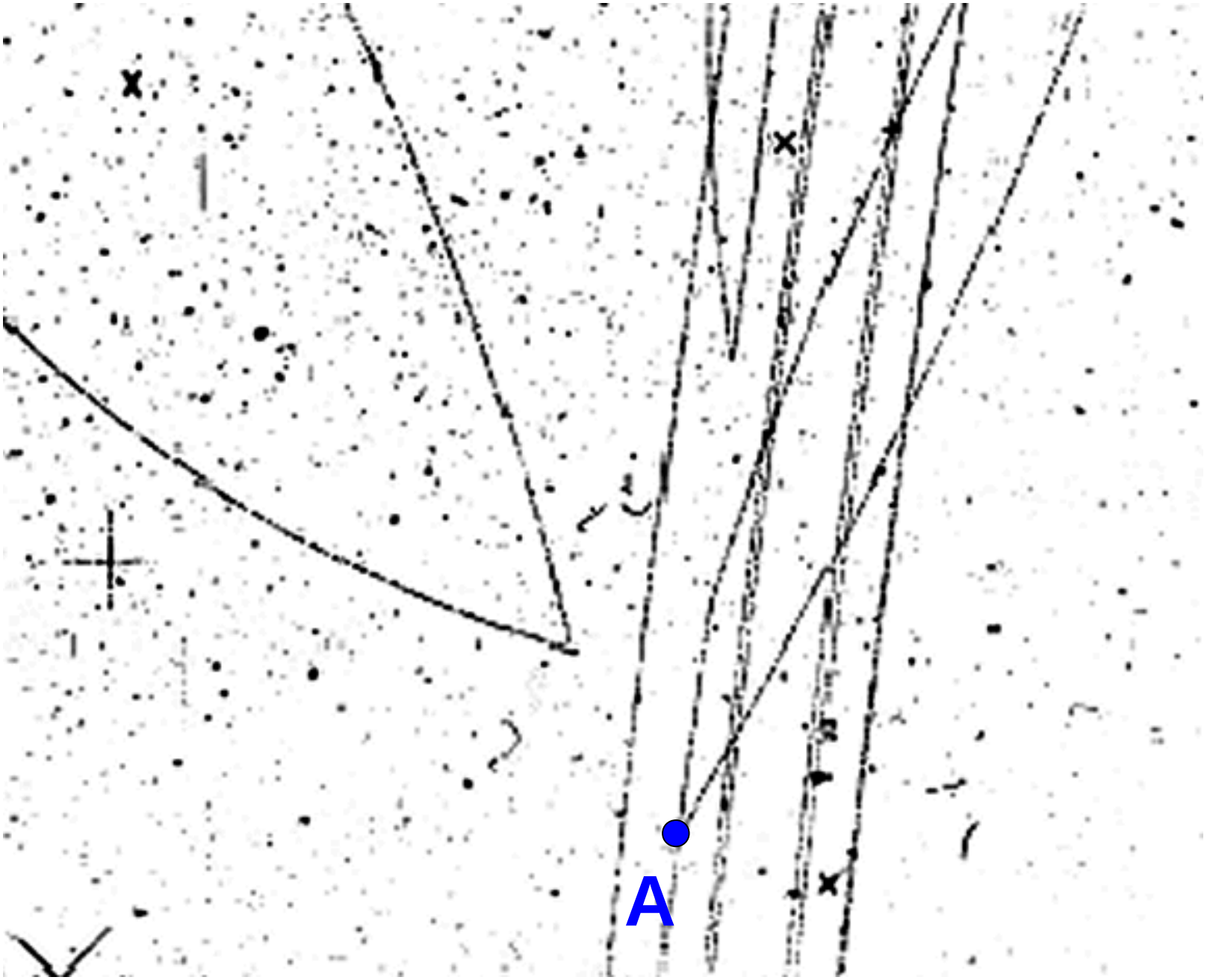


$\vec{B}$ ⊗



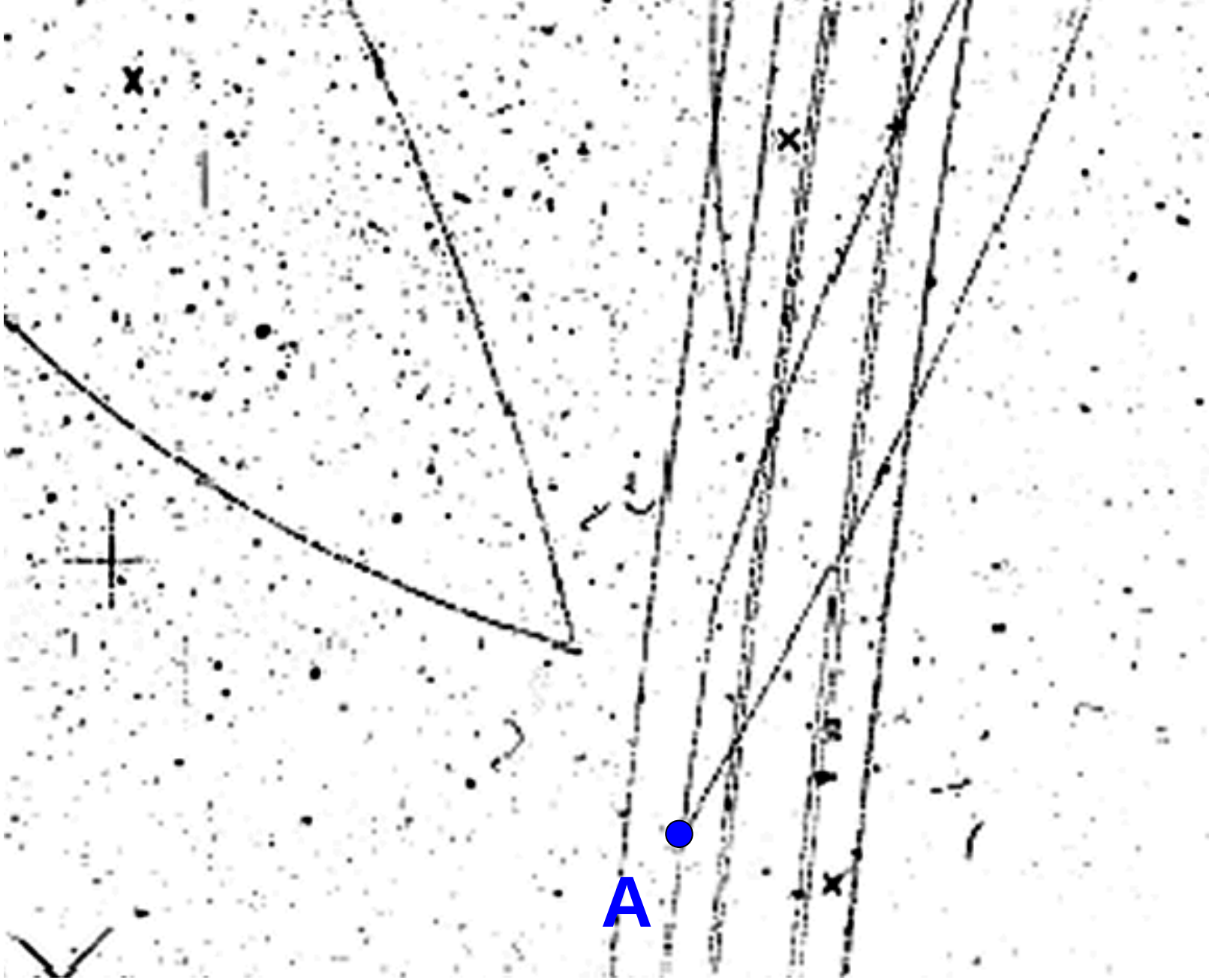


2. How many charged particles leave point A ?

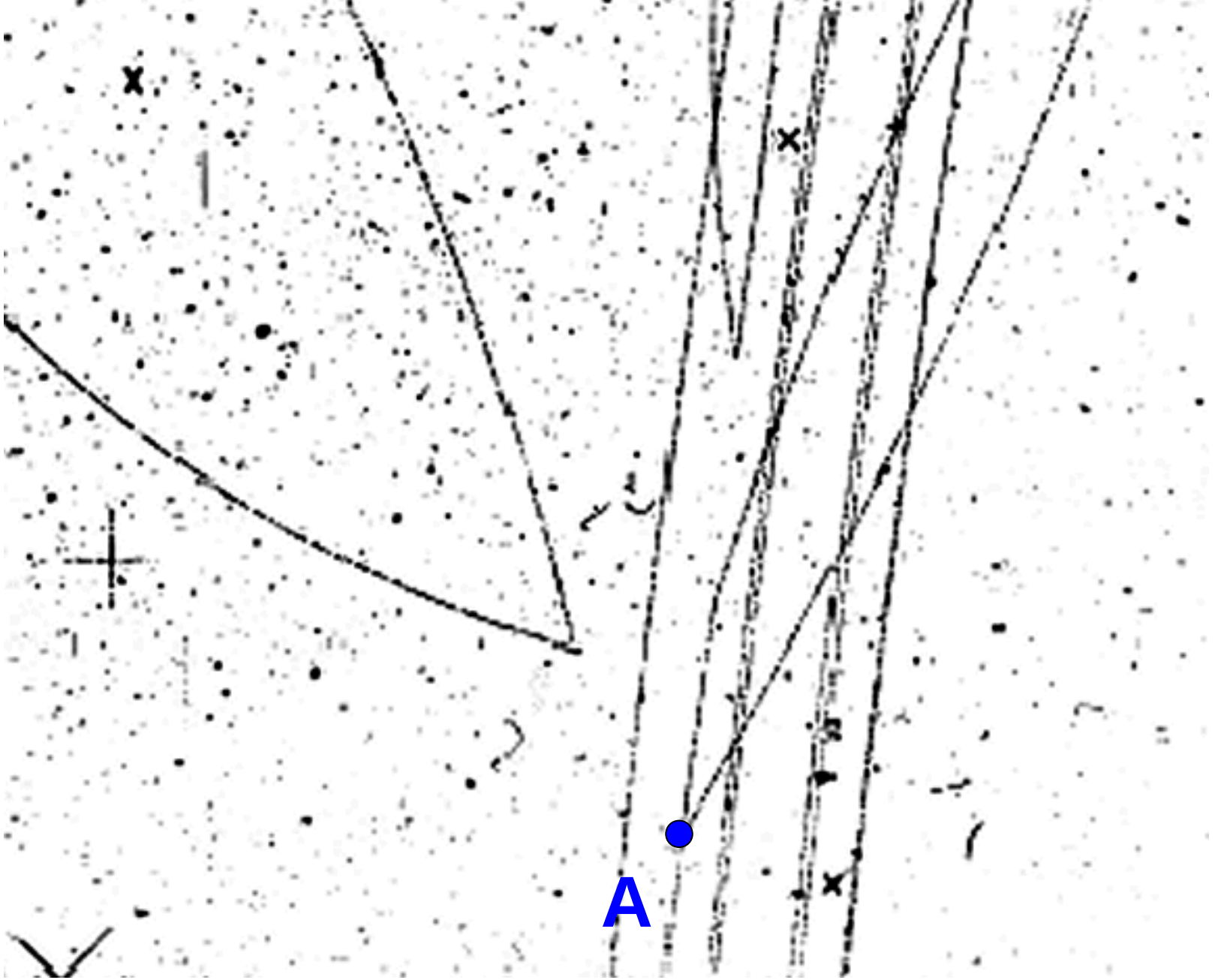


2. How many charged particles leave point A ?

2

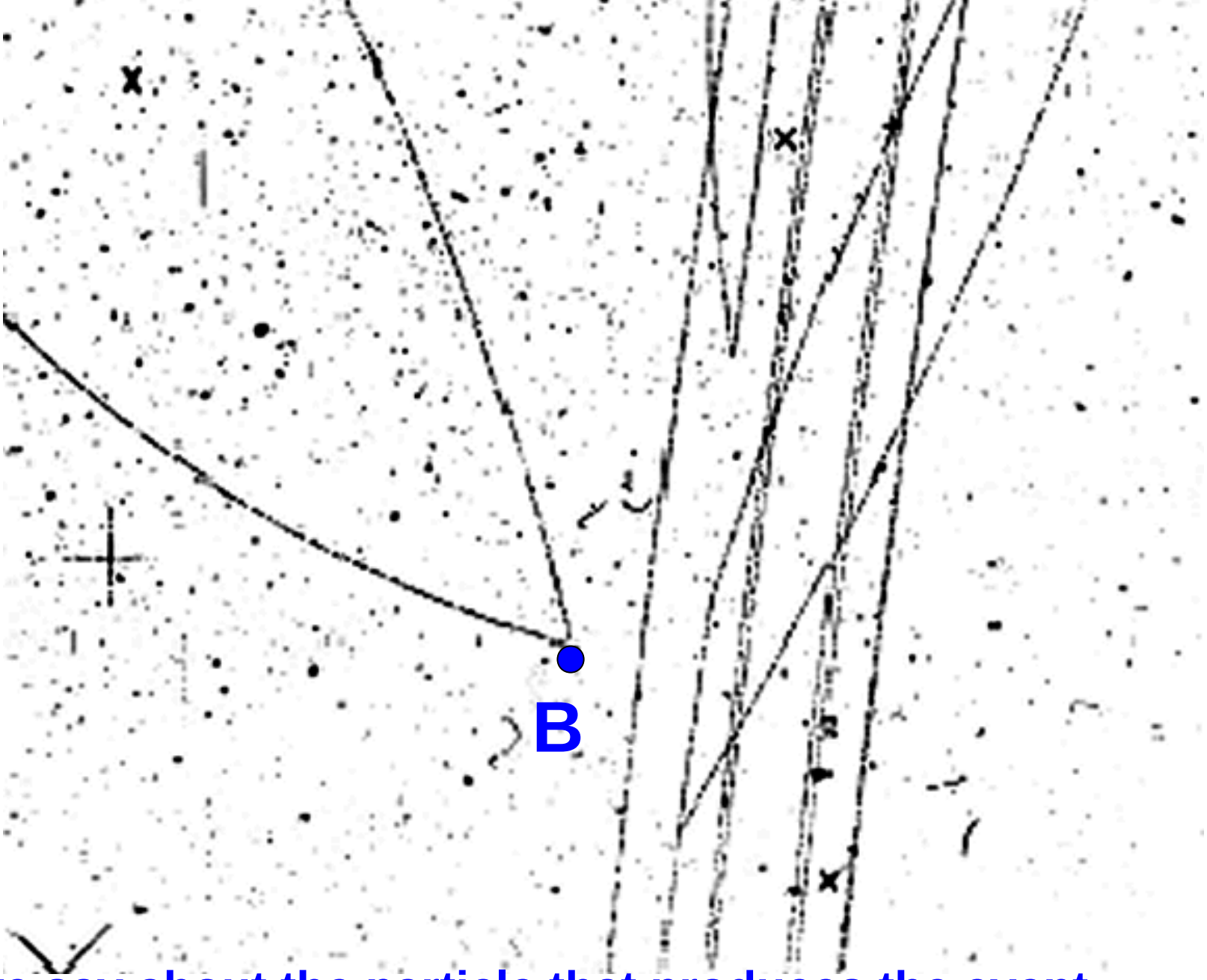


3. Is the event at point A, a decay or a collision ?

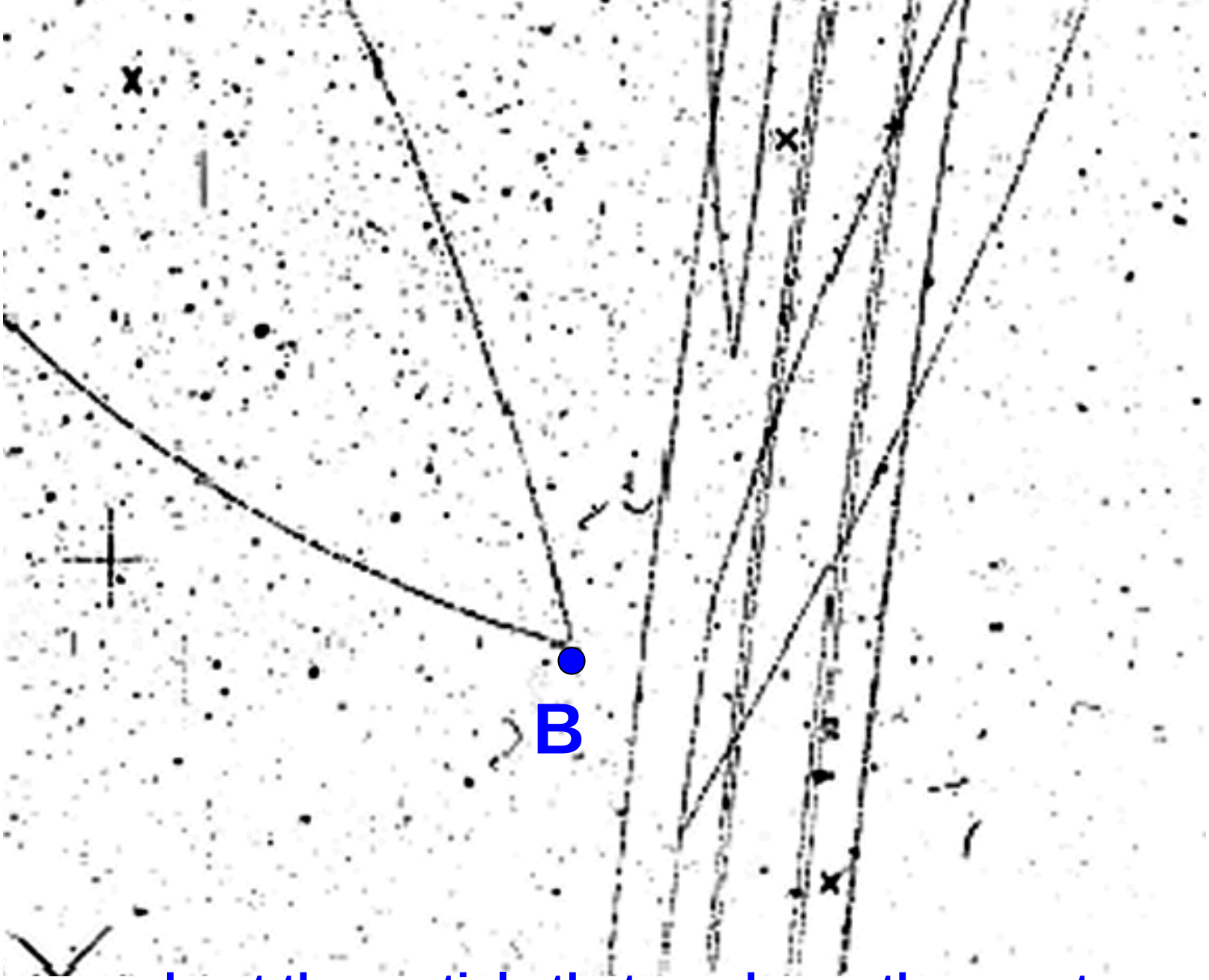


3. Is the event at point A, a decay or a collision ?

a collision

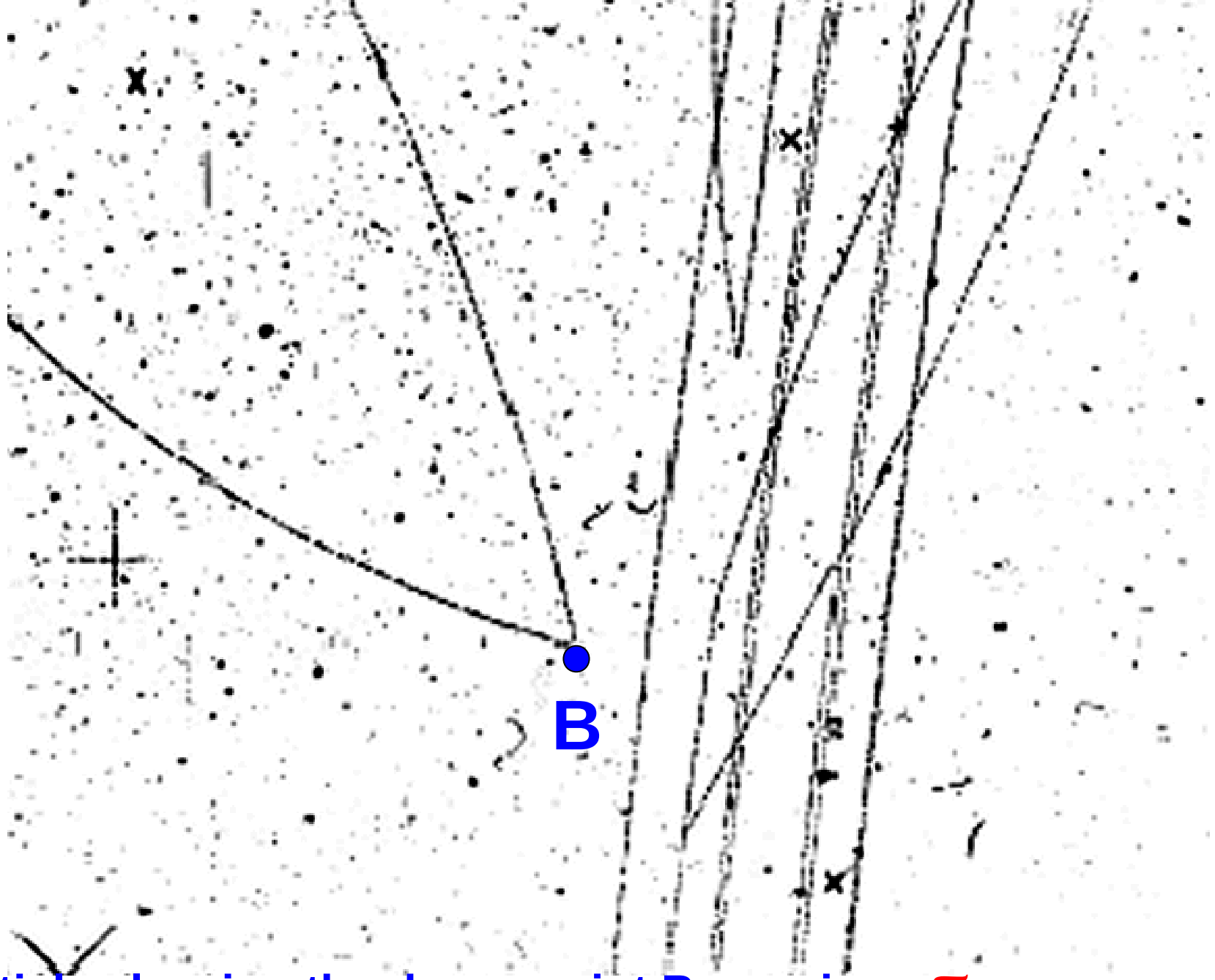


4. What can we say about the particle that produces the event at point B; what is it's charge?

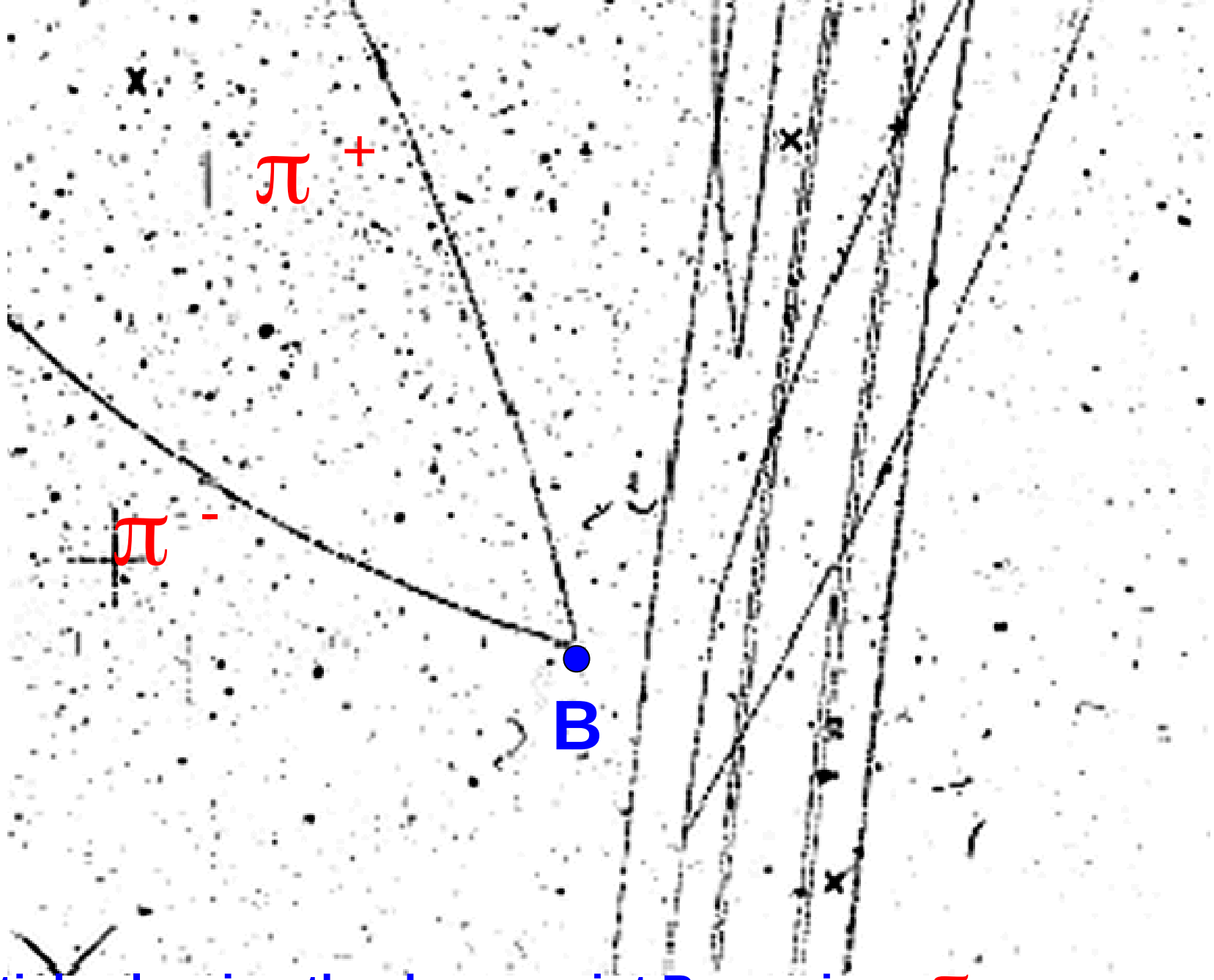


4. What can we say about the particle that produces the event at point B; what is it's charge?

It is a neutral particle

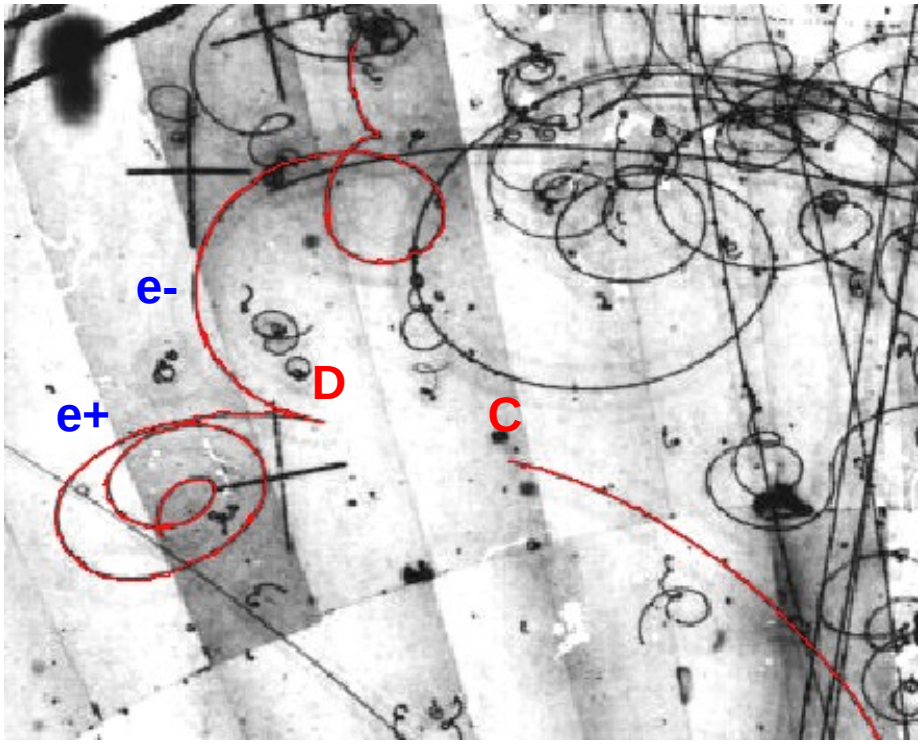


5. The particles leaving the decay point B are pions π .
What are their charges?



5. The particles leaving the decay point B are pions π . What are their charges?

$E=mc^2$



$\beta = v/c$

$\gamma = 1/\sqrt{(1-\beta^2)}$

$m = \gamma . m_0$

$E = m.c^2 = \gamma \ .m_0.c^2 \ = \sqrt{(m^2.c^4 + p^2.c^2)}$

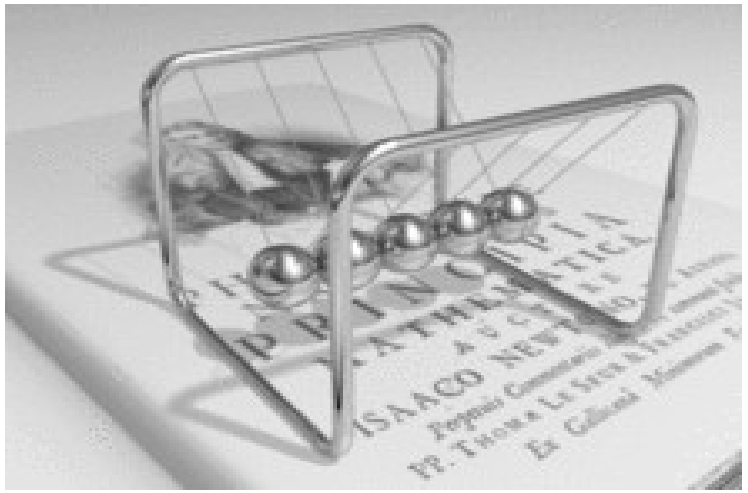
$\vec{p} = m.\vec{v} = \gamma . m_0 . \vec{v}$

(m_e = 0.511 MeV/c2)

Qual a energia mínima do fotão para que possa haver produção de um par e-/e+?

Sabendo que o momento do fotão é 265 ± 31 MeV/c, qual a energia cinética do par e-/e+ ?

Conservação da energia e do momento linear

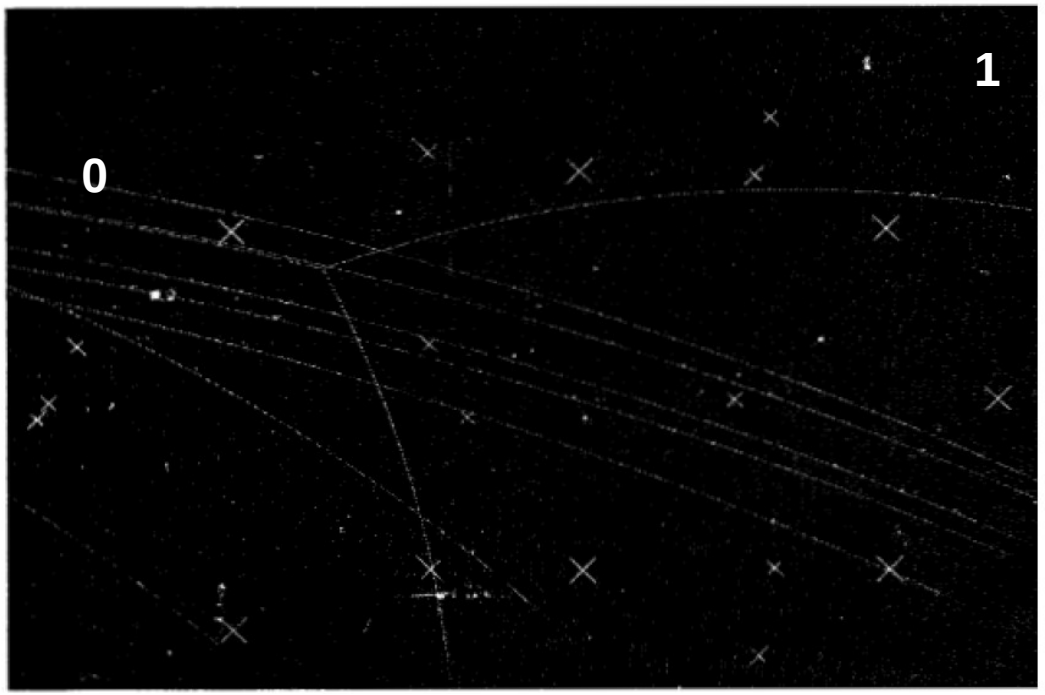


$$E_1 = E_5$$

$$m \vec{v}_1 = m \vec{v}_5$$

Colisão elástica: também há conservação da energia cinética

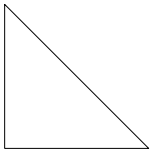
$$1/2\ m\ v_1^2 = 1/2\ m_5\ v_5^2$$



$$p\ p \longrightarrow p\ p$$

$$m_p \vec{v}_0 = m_p \vec{v}_1 + m_p \vec{v}_2$$

$$v_0^2 = v_1^2 + v_2^2$$

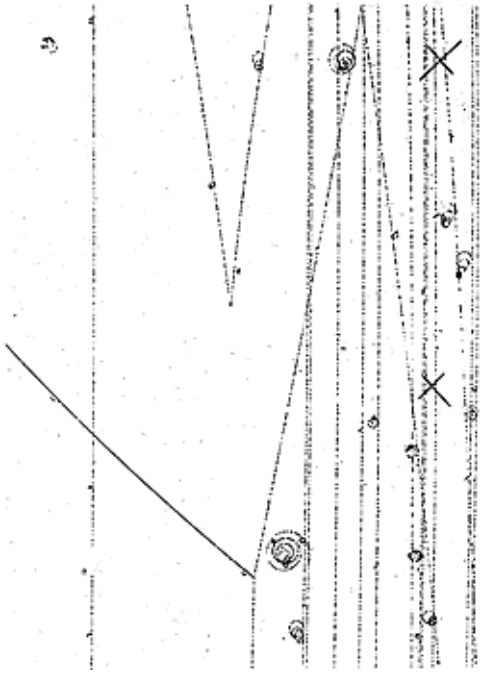


(não relativista)

$p_0 = 2$ GeV/c

Qual a velocidade do protão inicial?

Determinação da massa de uma partícula



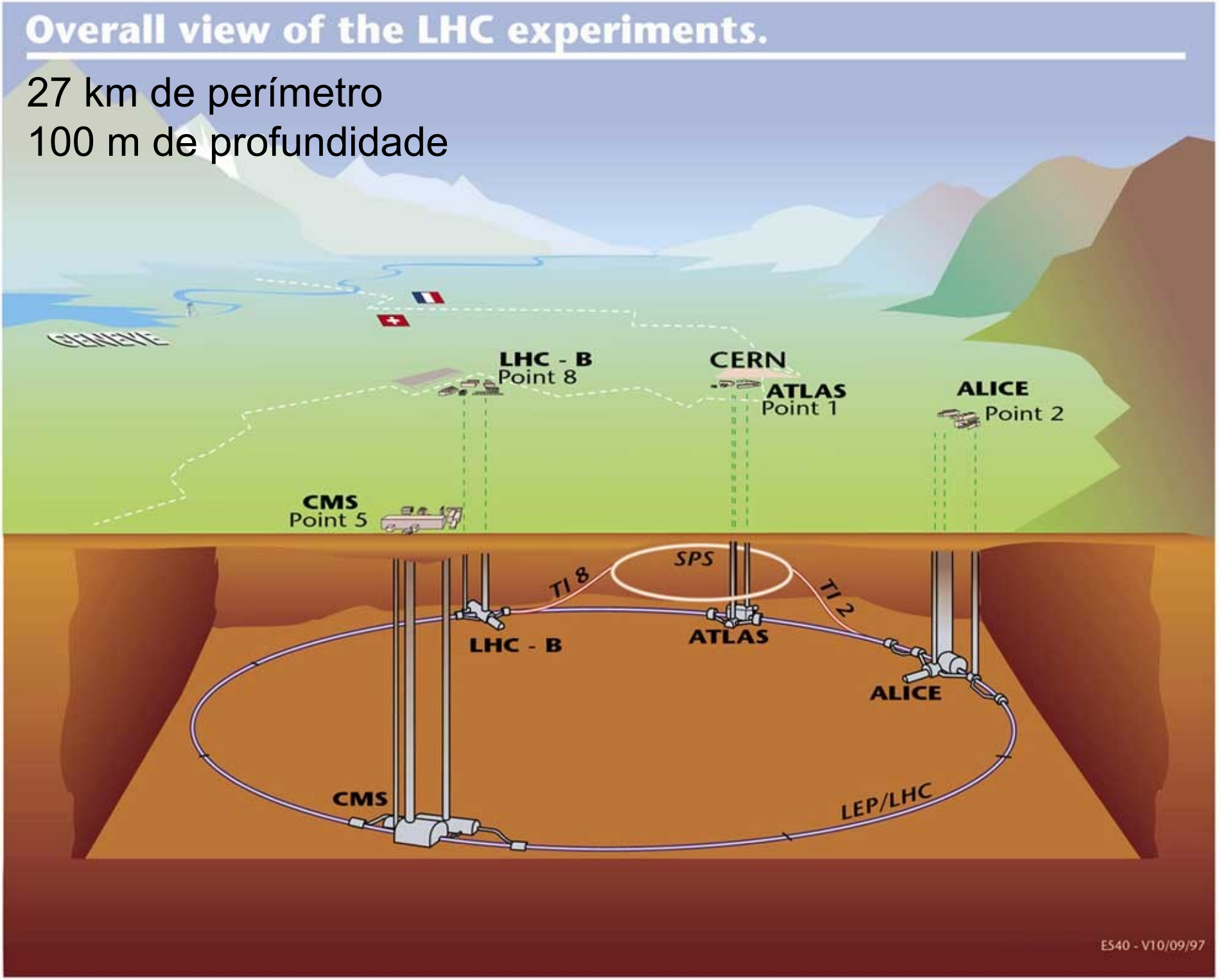
$$m^2c^4 = E^2 - p^2c^2$$

$$K^o\ (497\ MeV/c^2) \rightarrow \pi^+\ (139.6\ MeV/c^2) + \pi^-\ (139.6\ MeV/c^2)$$

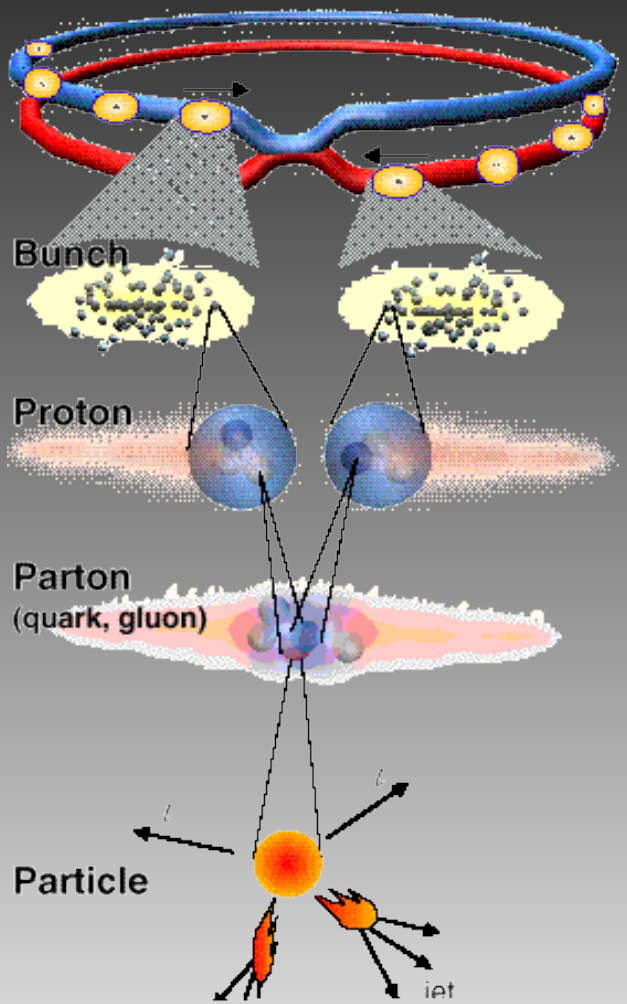
Track	**p_x (GeV/c)**	**p_y (GeV/c)**	**p_z (GeV/c)**
Negative	2.80879	-0.51130	0.45166
Positive	0.7638	0.04410	0.04419

$m = (E^2 - p_x^2 - p_y^2 - p_z^2)^{0.5}$

$= (3.67277^2 - 3.57259^2 - (-0.46720)^2 - 0.49579^2)^{0.5}.$


Overall view of the LHC experiments.
27 km de perímetro
100 m de profundidade
GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC
ES40 - V10/09/97

Colisões de feixes de partículas



$E = (\gamma)\, m_{NOVO} c^2$

LHC:

E = 7 TeV/protão

Nº pacotes = 2808

Protões / pacote = 10^{11}

E = 2 x 2808 x 10^{11} x 7 TeV ~ **0,6 GJ**

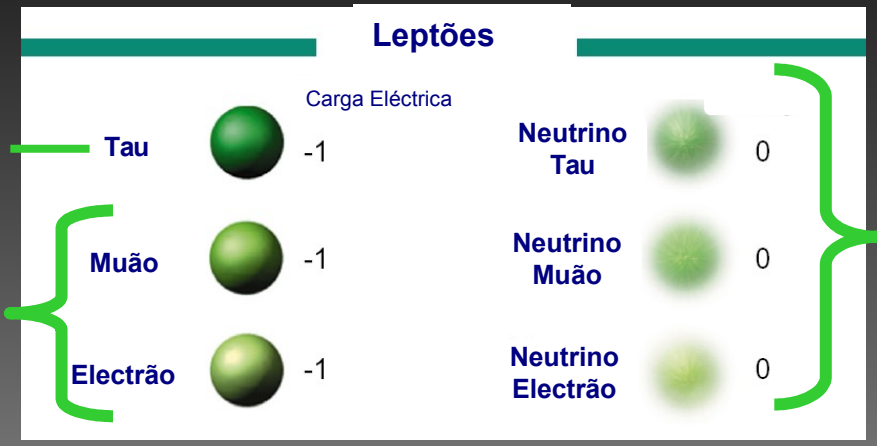
0,6 GJ é a energia cinética de um TGV à velocidade de **200 km/h** !

...ou de um carro a 3000 km/h !

Que partículas detectamos?

Detecção de forma indireta

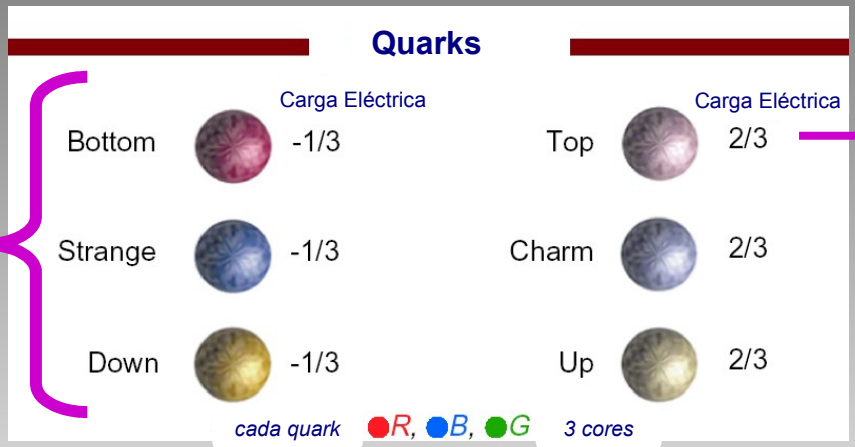
Detecção de forma direta



Interação muito fraca. Muitíssimo difíceis de detectar

Detecção indireta a partir de partículas ou jactos de partículas

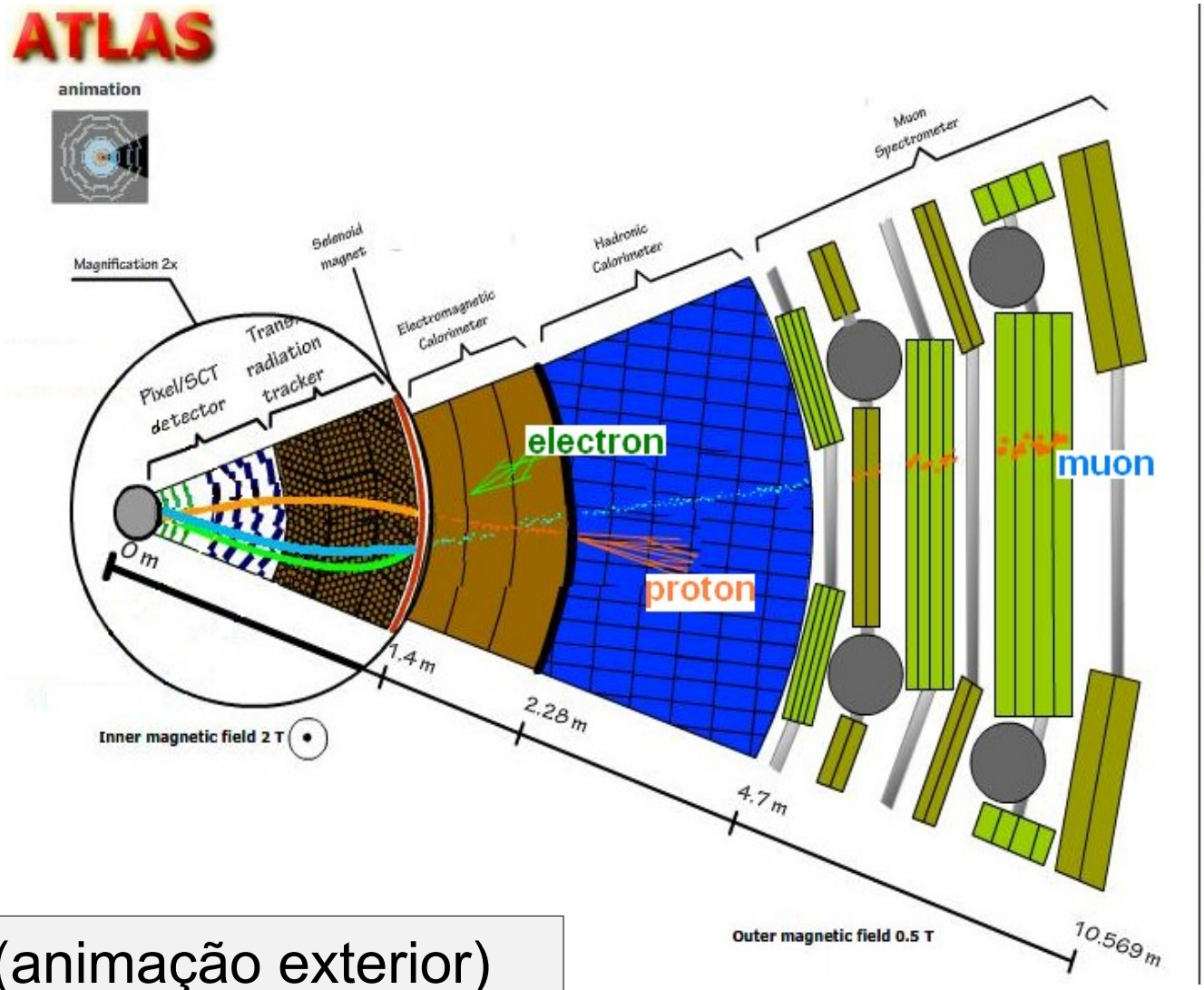
(formam hadrões, partículas com interação forte)

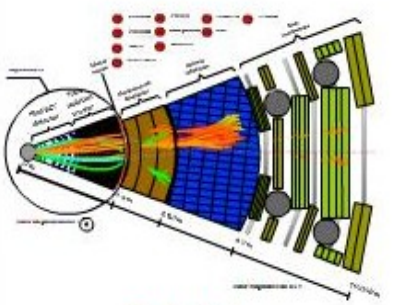


Muito pesado, mas produzido em LHC

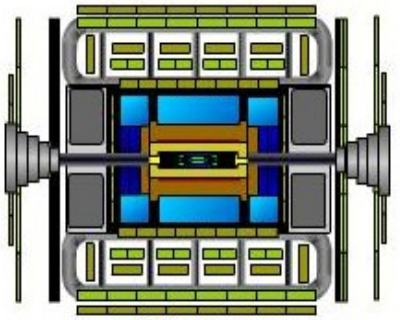
(detectado de forma indireta)

Detector ATLAS





End view



Side view

Created by Jeřábek, Jende 2010

(animação exterior)