

Tipi di radiazione

fine 800

4 tipi di radiazione note

- X raggi X Röntgen 1895

molti penetraenti

definiscono le materie → le stesse fotografie impressionate dalla radiazione.

fotoni di "alta" energia

$$E \sim 10^2 \rightarrow 10^9 - 10^{15} \text{ eV} \quad \text{keV}$$

Radiosensibilità naturale

in alcuni materiali fluorescenti
salvi di zec. pesanti
RdBrz Bromuro di Radio

} questa radiazione
che interagisce con
la materia

- α
- β
- γ

} non sono penetranti quanto raggi X

γ : fotoni con energie più alte di raggi X $E \sim 10^{15} \text{ eV} \rightarrow$

β : elettroni (scoperto da Thompson 1897)



α : particelle massive, cariche. nucleo di ${}^4_2\text{He}$

emesse da materiali con $A \gg 1$.

A : numero di massa

Metodo sperimentale

\vec{E} per accelerare particelle cariche.

\vec{B} per deviare

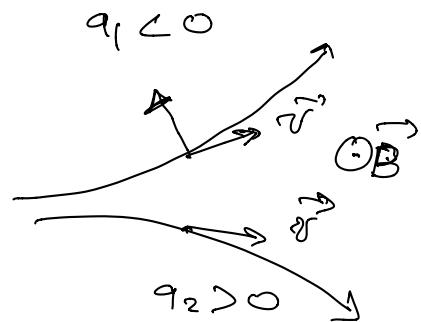
$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$\vec{a} = \frac{\vec{F}}{m} \Rightarrow \text{misura de } |\vec{a}| \propto \frac{q}{m}$$

$q = 0 \rightarrow$ non c'è deviazione.

$q \neq 0 \rightarrow$ raggio di curvatura $\rightarrow \frac{q}{m}$.

verso di deviazione \Rightarrow segno di q



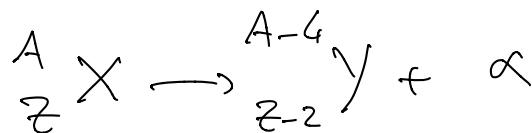
Esercizi di diffusione (scattering)

Rutherford - Geiger - Marsden.

proiettili α contro bersaglio fisso

a: particelle caricate massive

$$d \equiv {}^4_2 \text{He} \quad m \approx 3.7 \text{ MeV} \quad q = +2$$



Fatto sperimentalmente: $K_\alpha \approx 3-7 \text{ MeV}$ per tutti i materiali.



$$K_\alpha = 5 \text{ MeV} \quad K = E_{\text{kin}} = (\gamma - 1)m \Rightarrow \gamma - 1 = \frac{K}{m}$$

$$m = 3.7 \times 10^{-3} \text{ MeV.} \quad \Rightarrow \quad \gamma - 1 \approx \frac{5}{3.7} \times 10^{-3} \approx 1 \times 10^{-3}$$

$$K \approx 5 \text{ MeV}$$

$$\gamma \approx 1 + \frac{S}{m} 10^{-3}$$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \approx 1 + \frac{1}{2} \beta^2$$

$$\Rightarrow \beta \ll 1$$

$$\text{Non relativistica.} \Rightarrow K = \frac{P^2}{2m} \Rightarrow P = \sqrt{2mK} \approx 200 \text{ MeV.}$$

$$m = 3.7 \text{ GeV.}$$

$$P = 200 \text{ MeV} \ll m.$$

Materiali radioattivi più comuni:

Uranio $Z = 92$

U_{238} 99% in natura

U_{235} 1% naturale

$T_{1/2}$	$A = 2$
4.5×10^9 anni	$n \approx 145$
700×10^6 anni	143

$$T_{\text{SS}} \approx 5 \times 10^9 \text{ anni}$$

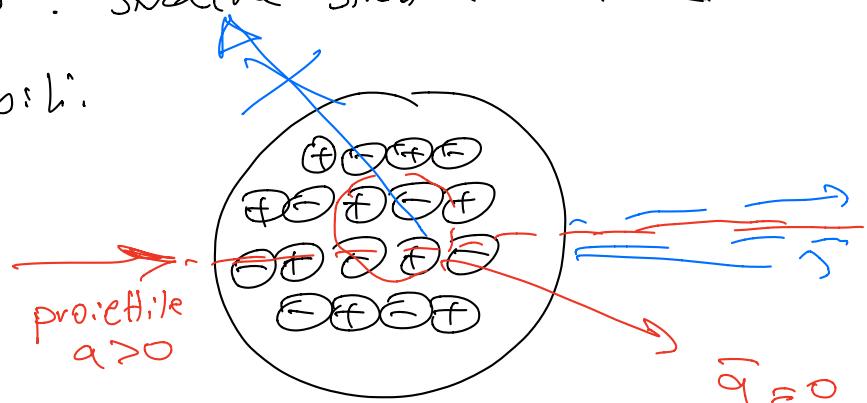
Radio	$Z = 88$	$T_{1/2}$
		11.4 ggs
	223	
	224	3.6 gg
	226	1600 anni

Rutherford ha usato il prodotto di Radio (RbBr_2)

$\alpha + \text{Bessilio} : \text{struttura nucleare}$

Due modelli teorici possibili:

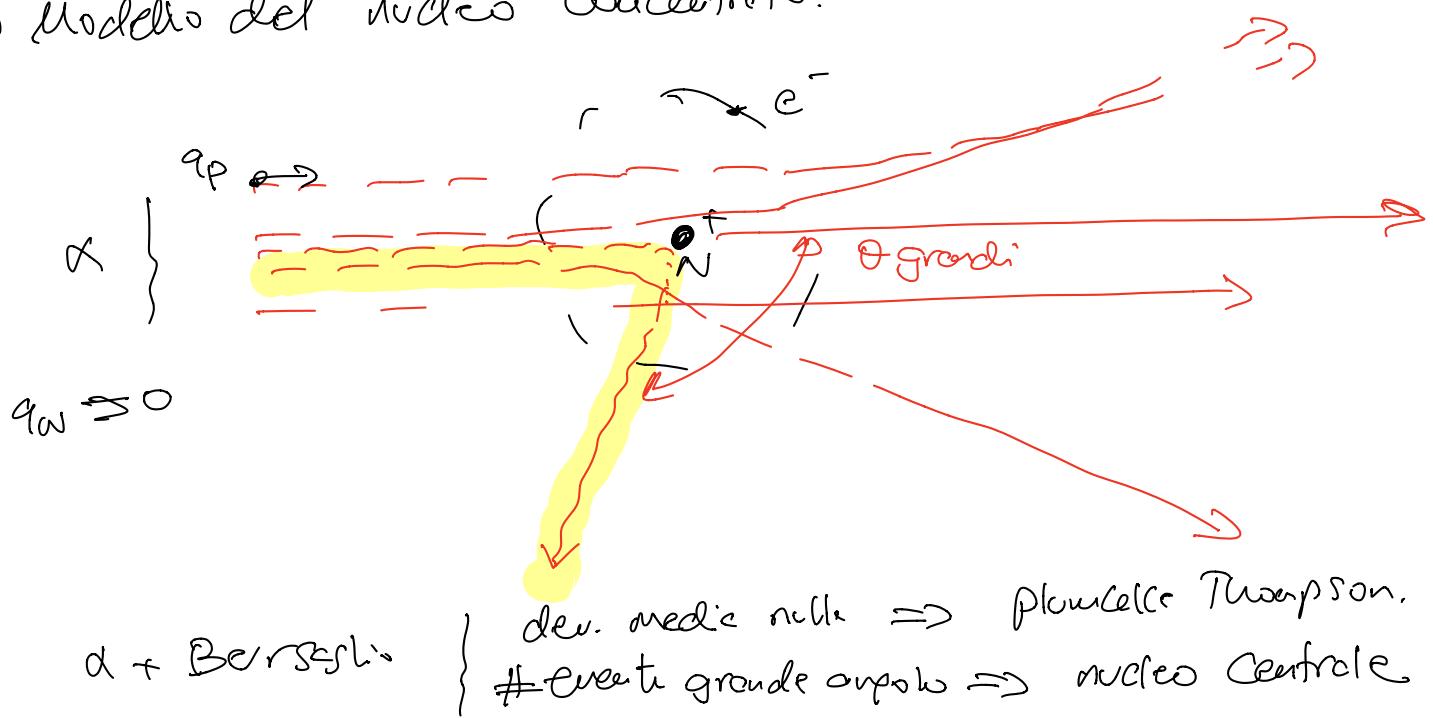
- 1) plumecke di Thompson.
atomo neutro.

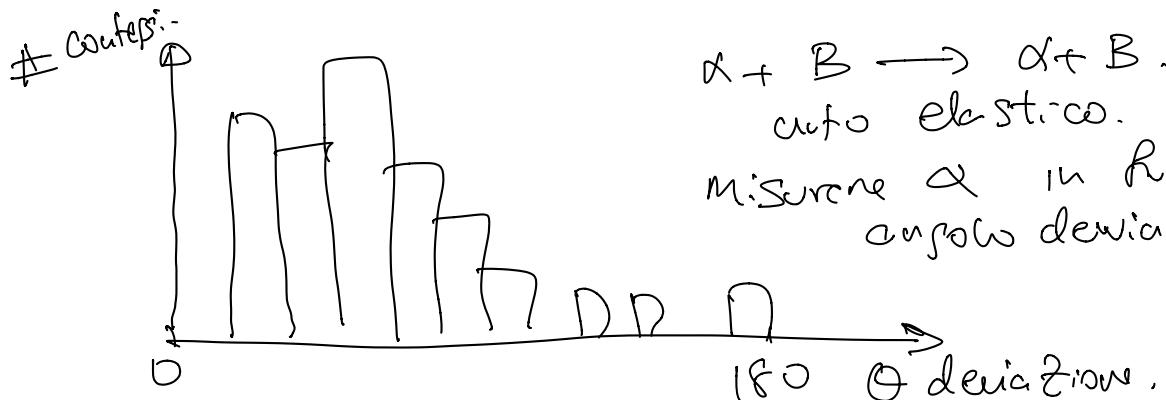
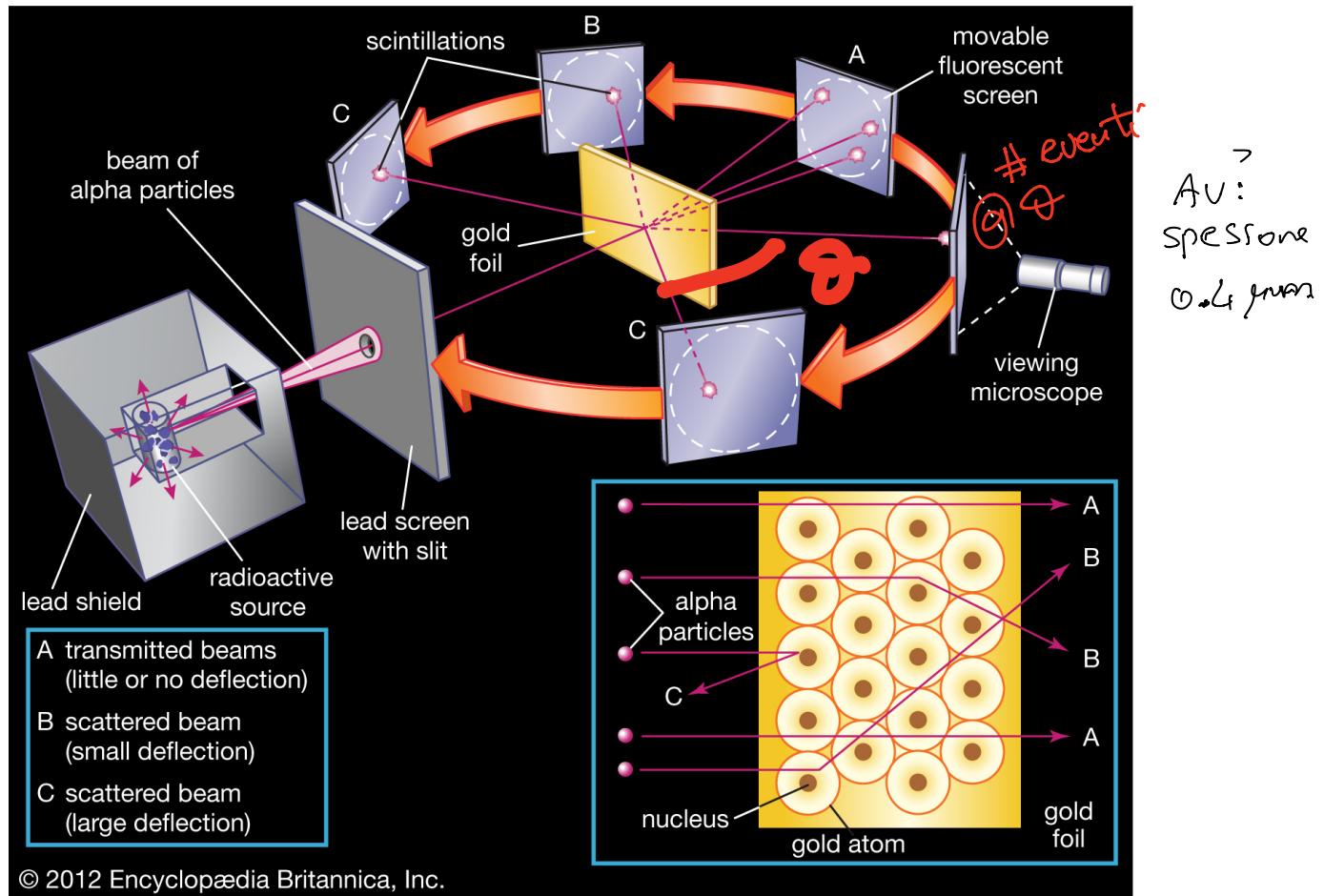


Interazione Coulomb: $\langle q \rangle_B \approx 0 \Rightarrow$ deviazione media = 0.

$$F = \frac{1}{4\pi\epsilon_0} \frac{q_p q_B}{r^2} \quad \langle q_B \rangle \approx 0 \Rightarrow \langle F \rangle \approx 0.$$

- 2) Modello del nucleo concentrato.





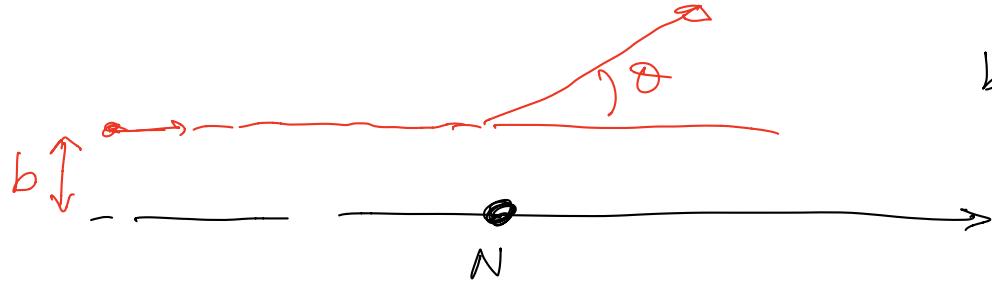
Esperimento: # α impresse su nivellatore.
in funzione di: angolo θ del nivellatore.

$$\Rightarrow \frac{d\sigma}{d\Omega} (\theta)$$

Interpretazione # contessi: in θ \Rightarrow Stimone $\frac{d\sigma}{d\Omega}$.

Calcolo di $\frac{d\sigma}{d\Omega}$.

mettere in relazione parametri d'urto b con θ .



$$b \leftrightarrow \theta.$$

Sezione d'urto di Rutherford: $\alpha + N \rightarrow \alpha + N$

Intrazione particella carica α con campo centrale N .

- trovare legge del moto
- trovare traiettoria del proiettile.
- relazione $b \leftrightarrow \theta$.

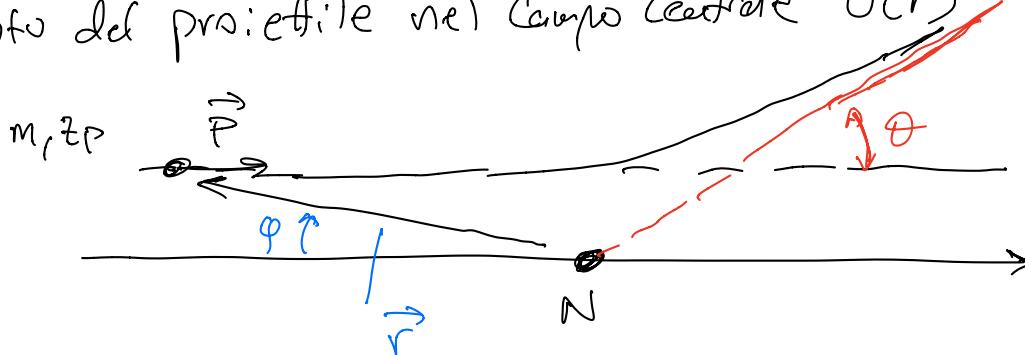
- Calcolare $\frac{d\theta}{db} = \frac{b}{\sin \theta} \left| \frac{db}{d\theta} \right|$

$$U(r) = \frac{A}{r} = \frac{e^2}{4\pi\epsilon_0} \frac{Z_p Z_n}{r} = \alpha \frac{Z_p Z_n}{r} \quad \alpha = \frac{1}{137}$$

$$Z_p = 2$$

$$Z_n = Z_{Au} = 79$$

Moto del proiettile nel campo centrale $U(r)$



\vec{r} : posizione
proiettile
rispetto
al nucleo.

θ : ang. deviazione.

urto elastico $\Rightarrow |\vec{P}| = \text{costante}$.

Cambia solo direzione e verso.

Campo centrale - energia E
- momento angolare $\vec{L} \quad \} \Rightarrow$ moto puro.

$$L = \frac{1}{2} m (\dot{r}^2 + r^2 \dot{\phi}^2) - U(r)$$

$$\frac{\partial L}{\partial \phi} = 0 \Rightarrow \frac{d}{dt} \frac{\partial L}{\partial \dot{\phi}} = 0 \Rightarrow \frac{\partial L}{\partial \dot{\phi}} = P_\phi = \text{cost.}$$

$$P_\phi = \frac{\partial L}{\partial \dot{\phi}} = \frac{m}{2} r^2 \dot{\phi} = m r^2 \dot{\phi} \stackrel{!}{=} M = \text{cost.}$$

$$\vec{M} = \vec{r} \times \vec{P}$$

$$\begin{array}{c} M \perp r \\ \vec{M} \perp \vec{P} \end{array}$$

E s: Conserva.

$$\begin{aligned} E &= \frac{m}{2} (\dot{r}^2 + r^2 \dot{\theta}^2) + U(r) = \frac{m}{2} \dot{r}^2 + \frac{m}{2} r^2 \dot{\theta}^2 + U(r) \\ &= \frac{m}{2} \dot{r}^2 + \frac{M^2}{2mr^2} + U(r) \end{aligned}$$

E s: Conserva $\Rightarrow E = \text{cost.}$

$$\underbrace{\frac{m \dot{r}^2}{2}}_{\frac{dr}{dt}} = E - \underbrace{\frac{M^2}{2mr^2} - U(r)}_{\text{dep. da } r}. \quad \dot{r} = \frac{dr}{dt}.$$

$$\left(\frac{dr}{dt} \right)^2 = \frac{2}{m} \left(E - \frac{M^2}{2mr^2} - U(r) \right)$$

$$\frac{dr}{dt} = \sqrt{\left(\dots \right)}$$

$$dt = \frac{dr}{\sqrt{\frac{2}{m} \left(E - \frac{M^2}{2mr^2} - U(r) \right)}}$$

$$M = mr^2 \dot{\phi} = mr^2 \frac{d\phi}{dt} = \text{cost.}$$

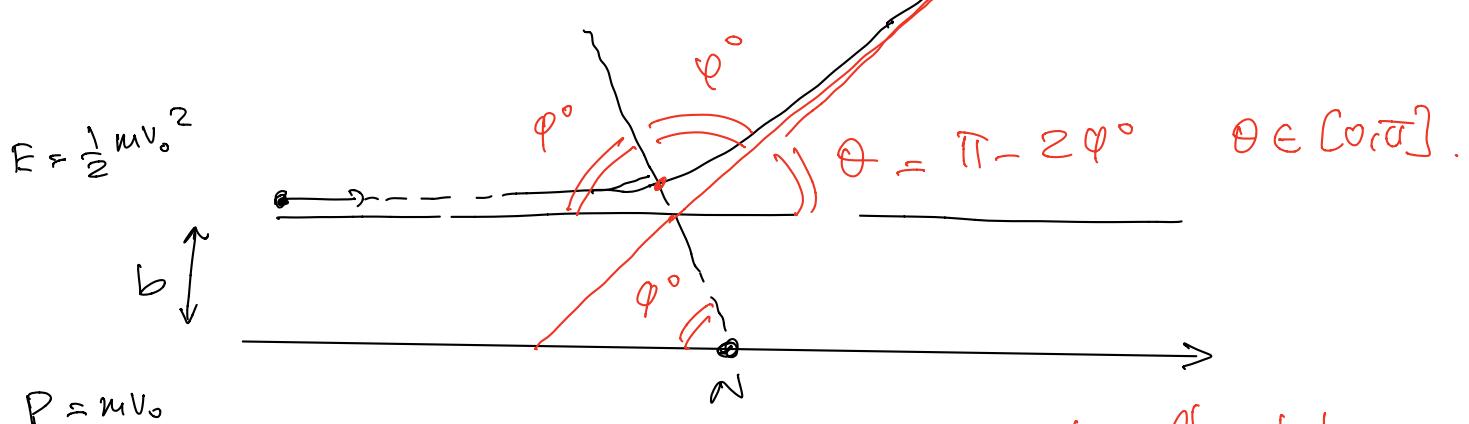
$$M dt = mr^2 d\phi \Rightarrow \boxed{d\phi = \frac{M}{mr^2} dt}$$

eliminare $dt \Rightarrow$ mettere in relazione ϕ con r

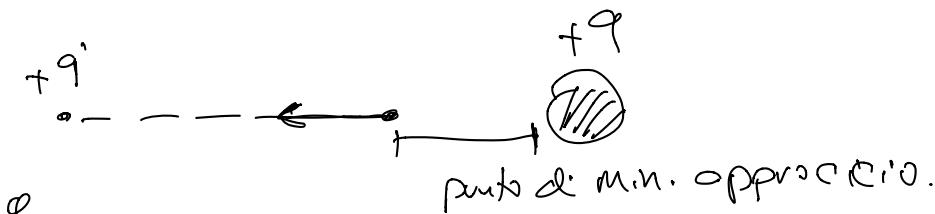
$$\frac{mr^2}{M} d\varphi = \frac{dr}{\sqrt{c - \dots}}$$

$$d\varphi = \frac{dr}{\frac{mv^2}{M} \sqrt{\frac{2}{m} \left(E - \frac{M^2}{2mr^2} - U(r) \right)}}$$

$$\varphi = \varphi(r)$$



φ_0 : angolo fra l'asintoto
passante per punto di
minima approssimazione.
e direzione del
proiettile.



φ_{\max}

$$\int_{\varphi_{\min}}^{\varphi_{\max}} d\varphi = \int_{r_{\infty}}^{r_{\min}} \frac{dr}{\sqrt{c - \dots}}$$

iniziale: $\varphi = 0$
 $r = \infty$.

$$f_{\min}: \frac{r_{\min}}{\varphi_0}$$

$$\varphi_0 = \varphi(r=\infty) + \int_{\infty}^{r_{\min}} \frac{1}{\sqrt{c - \dots}} dr.$$

$$E = E_0 = \frac{1}{2} mv_0^2 = K. \quad M = |\vec{r}_0 \times \vec{p}_0| = bmv_0.$$



Potential energy of particle: $\underline{U_0}$, b

$$\varphi_0 = \int_{r_{\min}}^{\infty} \frac{\frac{bmv_0}{r^2}}{\sqrt{2m(\frac{1}{2}mv_0^2 - U(r)) - \frac{b^2 m^2 v_0^2}{r^2}}} dr$$

fix one for v_0 : mv_0^2

$$\varphi_0 = \int_{r_{\min}}^{\infty} \frac{\frac{b/r^2}{\sqrt{1 - \frac{b^2}{r^2} - \frac{A}{E_0} \frac{1}{r}}}}{dr}$$

$$U(r) = \frac{A}{r} = \frac{dZPE}{r}$$

$$= \arccos \frac{\frac{A}{ZE_0 b}}{\sqrt{1 + (\frac{A}{ZE_0 b})^2}}$$

$$\Rightarrow \varphi_0 = \varphi_0(b)$$

$$\Theta = \pi - 2\varphi_0 \Rightarrow \Theta = \Theta(b)$$

$$b^2 = \frac{A^2}{4E_0^2} \operatorname{tg}^2 \varphi_0$$

$$\Theta = \pi - 2\varphi_0.$$

$$\operatorname{tg} \varphi_0 = \frac{\sin \varphi_0}{\cos \varphi_0}$$

$$b = \frac{A}{2E_0} \frac{1}{\operatorname{tg} \frac{\Theta}{2}}$$



$$\frac{d\sigma}{d\Omega} = \frac{b}{\sin \theta} \left| \frac{db}{d\theta} \right|$$

$$\begin{aligned} \sin \theta &= \sin(2 \frac{\theta}{2}) \\ &= 2 \sin \frac{\theta}{2} \cos \frac{\theta}{2}. \end{aligned}$$

$$\frac{d\sigma}{d\Omega} = \left(\frac{A}{4E_0} \right)^2 \frac{1}{\sin^4 \frac{\theta}{2}}$$

$$A = d Z_p Z_N.$$

$$E_0 = \frac{1}{2} m V_0^2$$

$$\Rightarrow \frac{A}{4E_0} = \frac{d Z_N}{2 K_A} \quad K_A = \text{SMW.}$$

$$d = \frac{1}{137}$$

$$\frac{A}{4E_0} \approx \frac{1}{1370} Z_N \text{ MeV}^{-1}$$

$$\frac{d\sigma}{d\Omega} \propto \frac{Z_N^2}{E_0^2} \frac{1}{\sin^4 \frac{\theta}{2}} \quad \begin{matrix} Z_p \\ \rightarrow \end{matrix}$$

$\textcircled{1}$
 Z_N

1) $\frac{d\sigma}{d\Omega} \propto A^2 \quad A = d Z_N Z_p.$

Sezione d'urto non dipende dal segno
del num. carica del bersaglio.
proiettile.

c) $\frac{d\sigma}{d\Omega} \propto Z_N^2$ al crescere di Z_N .
avendo numero di interazioni.

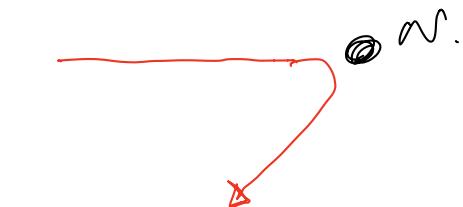
esempi:



3) $\frac{d\sigma}{d\Omega} \propto \frac{1}{E_0^2}$

$E_0 \uparrow \quad \frac{d\sigma}{d\Omega} \rightarrow$

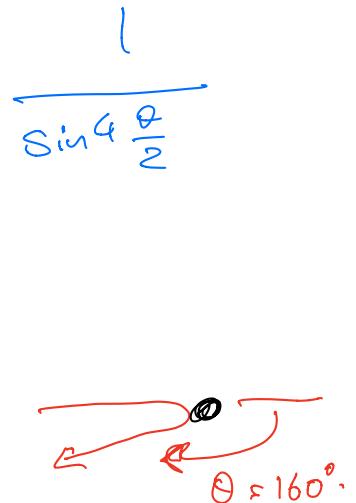
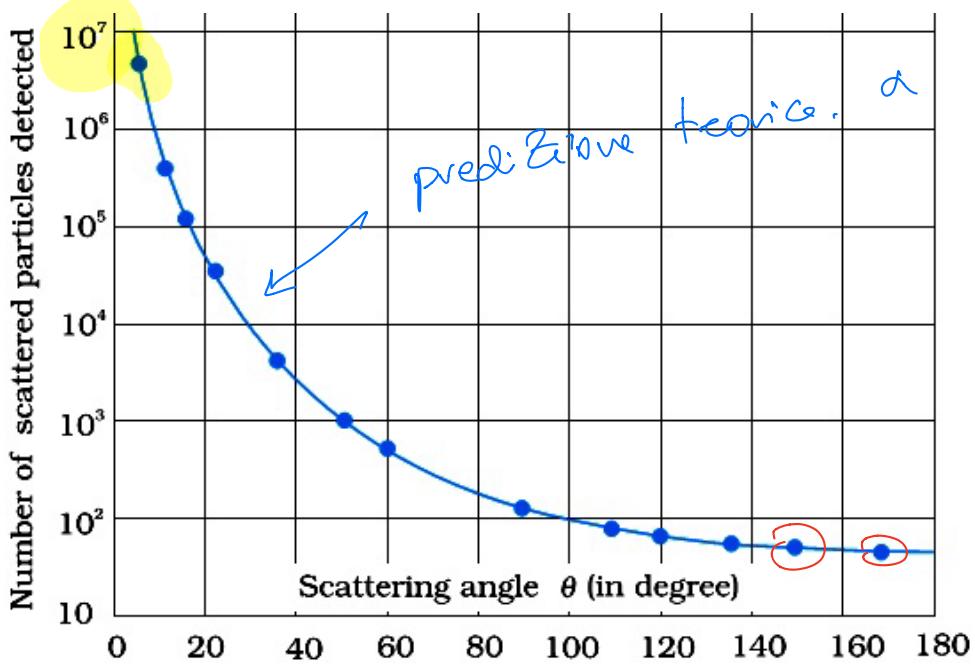
4) $\theta \in [0, \pi]$ possible where $\theta > \frac{\pi}{2}$.



Eservation

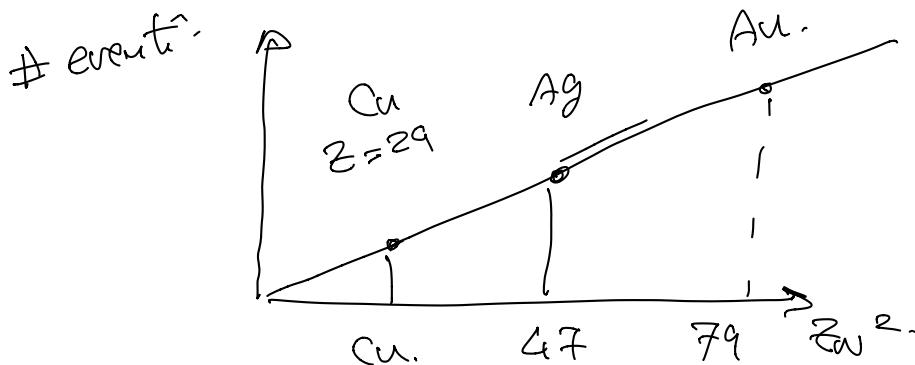
$$\int_{\frac{\pi}{2}}^{\pi} \frac{d\sigma}{d\theta} d\theta > 0$$

$$N \propto \sigma$$



θ deviation.

$\theta \approx 0^\circ$ # events $\sim 90^7$
 $\theta \approx 180^\circ$ # events < 100 . Event's rati.



Conclusione:

- conica positiva concentrica al centro.
non distrib. uniformemente

$$K = \frac{1}{2} mv_0^2 \leq 5 \text{ MeV.} \quad \begin{matrix} \text{punto di inversione} \\ K = U(v_0). \end{matrix}$$

$$U(r_0) = \alpha \frac{Z_p Z_n}{r_0} = K.$$

$$\Rightarrow r_0 = \alpha \frac{Z_p Z_n}{K} = \frac{2 \times 79}{137} \frac{1}{5 \text{ MeV.}} \\ = 0.23 \text{ MeV}^{-1}.$$

$$1 = 200 \text{ Mev. fm.}$$

$$\text{MeV}^{-1} \approx 200 \text{ fm.}$$

$$\Rightarrow r_0 \approx 46 \text{ fm.}$$

Rutherford: $r_N < 30 \text{ fm.}$

$$30 \text{ fm} \ll \text{Rutherford.} \approx 1 \text{ \AA} \approx 10^{-10} \text{ m.}$$

