- CINEMATICA / DECADIMENTI
- SEZ. D'URTO
- PERDITE DI ENERGIA

IL NUCLEO

- interazione a corto raggio
- Z protoni, A−Z neutroni

$$\underbrace{\text{protoni, } A-Z}_{\text{NUCLEONI}}$$

$A = 50$

$50!$ istanze

→ servono quantità collettive

- statiche R, E_L, M...
- dinamiche
  decadimenti
  α, β, γ

NUCLIDE (A, Z)

ISOTOPI "nuclidi con lo stesso Z"

^{12}C, ^{14}C

ISOBARI lo stesso A

$\boxed{\text{RAGGIO}}$

$$b \propto \frac{1}{\tan\theta/2}$$

$$V = \frac{4}{3}\pi R^3 \propto A$$

$$R = \underbrace{R_0}_{\sim 1.2\,fm} A^{1/3}$$

H   p

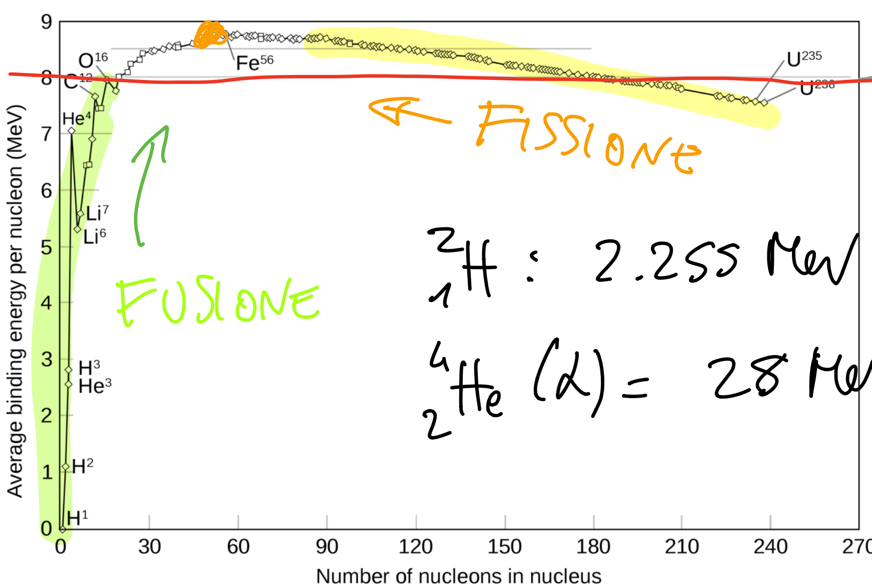
^{2}H p n

^{2386}H p n n n n ... n

(c = 1)

$$M(A, Z) = Z m_p + (A - Z) m_n - E_L$$

$\frac{E_L}{A}$ ↑



8 MeV

← FISSIONE

↑ FUSIONE

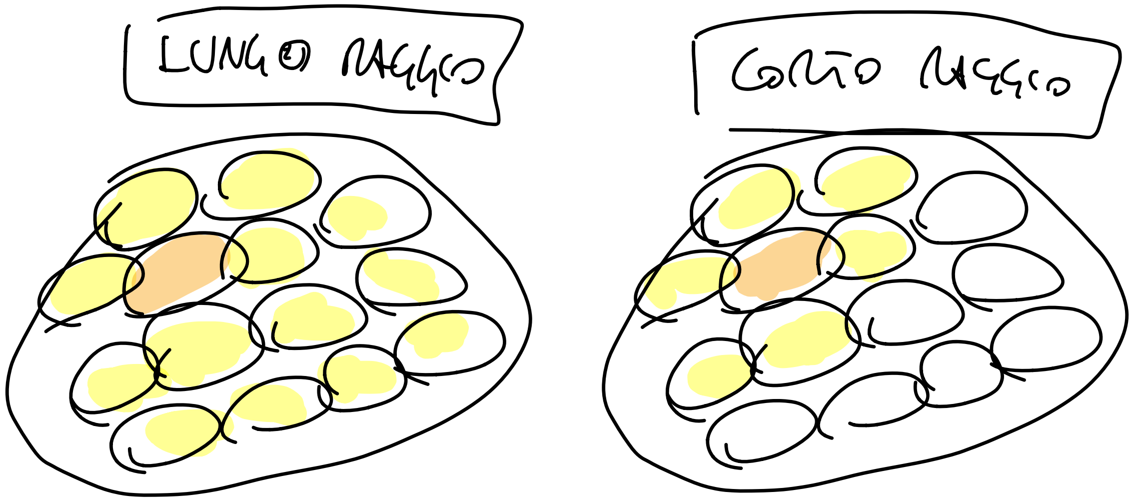
$^{2}_{1}H$: 2.255 MeV

$^{4}_{2}He$ (α) = 28 MeV

→ A

$E_L \propto A$

MODELLO NON MQ: a goccia



es. EM

es. FORTE

VOLUME $E_L \propto A(A-1) \propto A^2$ $E_L \propto A \equiv a_1 A$

SUPERFICIE $E_L \propto -R^2 = -A^{2/3} \equiv -a_2 A^{2/3}$

- i protoni si respingono

$$E_L \propto -\frac{3}{5} \frac{Q^2}{R \cdot 4\pi\varepsilon_0}$$

$$= -\frac{3}{5}\cdot\frac{Z^2 e^2}{R_0 A^{1/3}\cdot 4\pi\varepsilon_0}$$

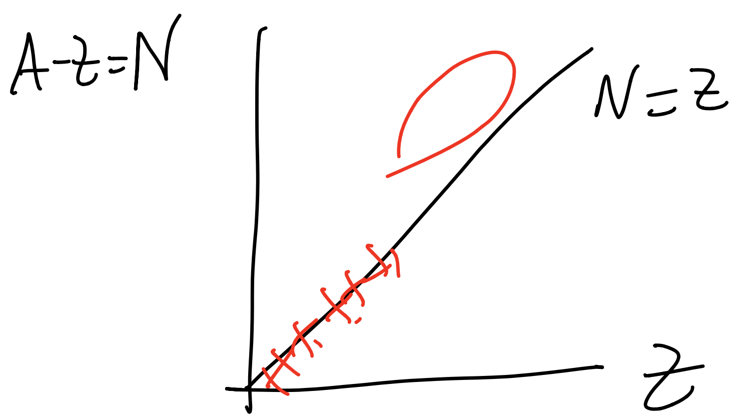
$$= -\frac{3}{5}\cdot\frac{(\alpha\hbar c)}{R_0}\,\frac{Z^2}{A^{1/3}}$$

$$\simeq -0.7\ \text{MeV}\cdot\frac{Z^2}{A^{1/3}}$$

$$\equiv -a_3\,\frac{Z^2}{A^{1/3}}$$

MODELLO A GOCCIA

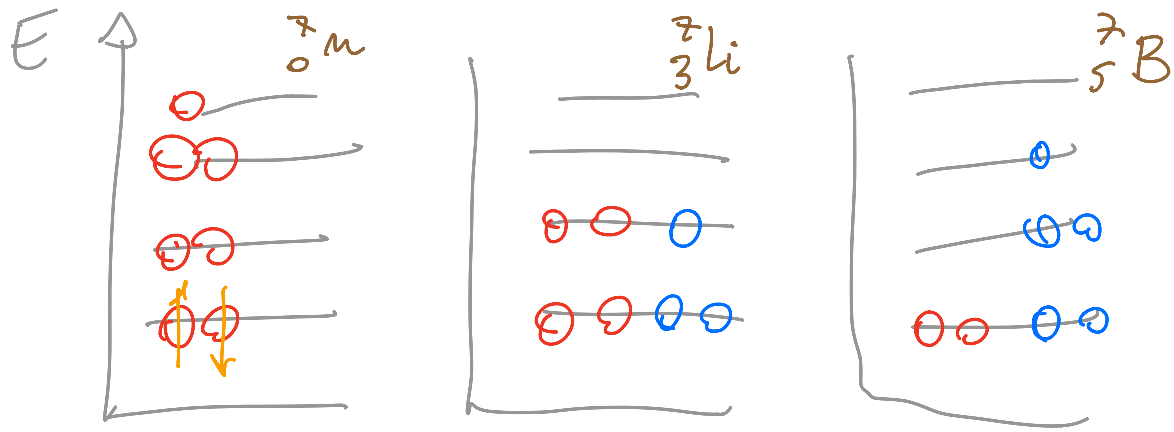
$$E_L = a_1 A - a_2 A^{2/3} - a_3\frac{Z^2}{A^{1/3}}$$



$N - Z = (A-Z) - Z$

termine di Pauli

$$E_L = -a_4\,\frac{(A-2Z)^2}{A}$$



○ = n

○ = p

$A = 7$

A	N	Z	NUCLEI STABILI
PARI	PARI	PARI	156
PARI	DISPARI	DISPARI	5
DISPARI	PARI	D	48
DISPARI	D	PARI	50

→ ODD - ODD è RARO

$$E_L = \pm a_s A^{-3/4}$$

$$\begin{cases} 0 & \text{per } A \text{ dispari} \\ -a_s & \text{ODD-ODD} \\ +a_s & \text{EVEN-EVEN} \end{cases}$$

BETHE-WEIZSÄCKER

$$E_L = a_1 A - a_2 \cdot A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a_4 \frac{(A-2Z)^2}{A} \pm a_5 A^{-3/4}$$

$a_1 = 16$ MeV

$a_2 = 17$ MeV

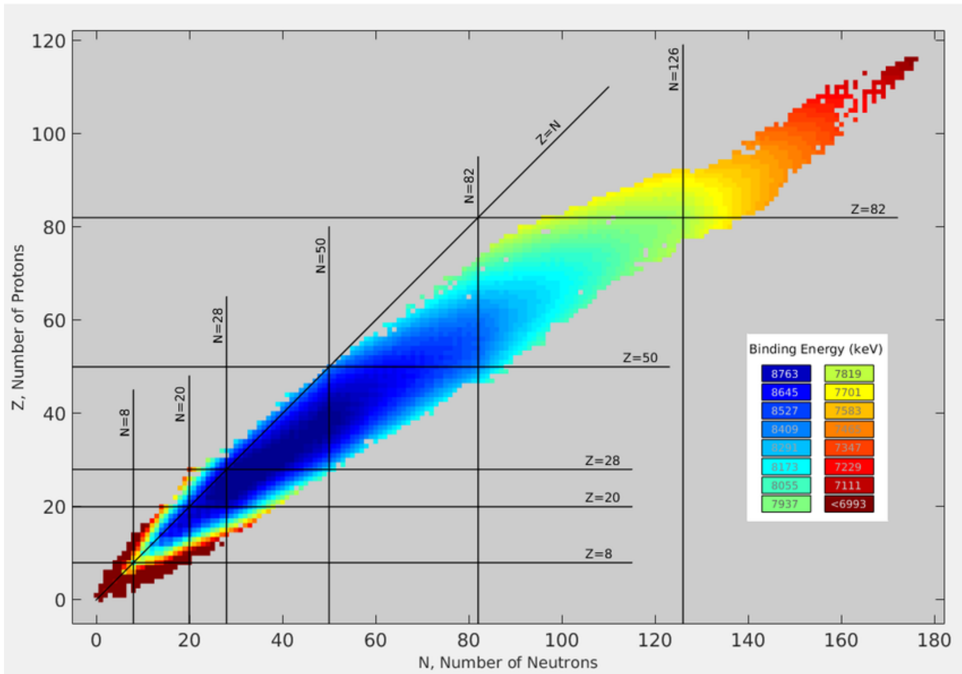
$a_3 = 0.7$ MeV

$a_4 = 24$ MeV

$a_5 = 34$ MeV

$$M(A,Z) = Z\, m_p + (A-Z)\, m_n - E_L(A,Z)$$

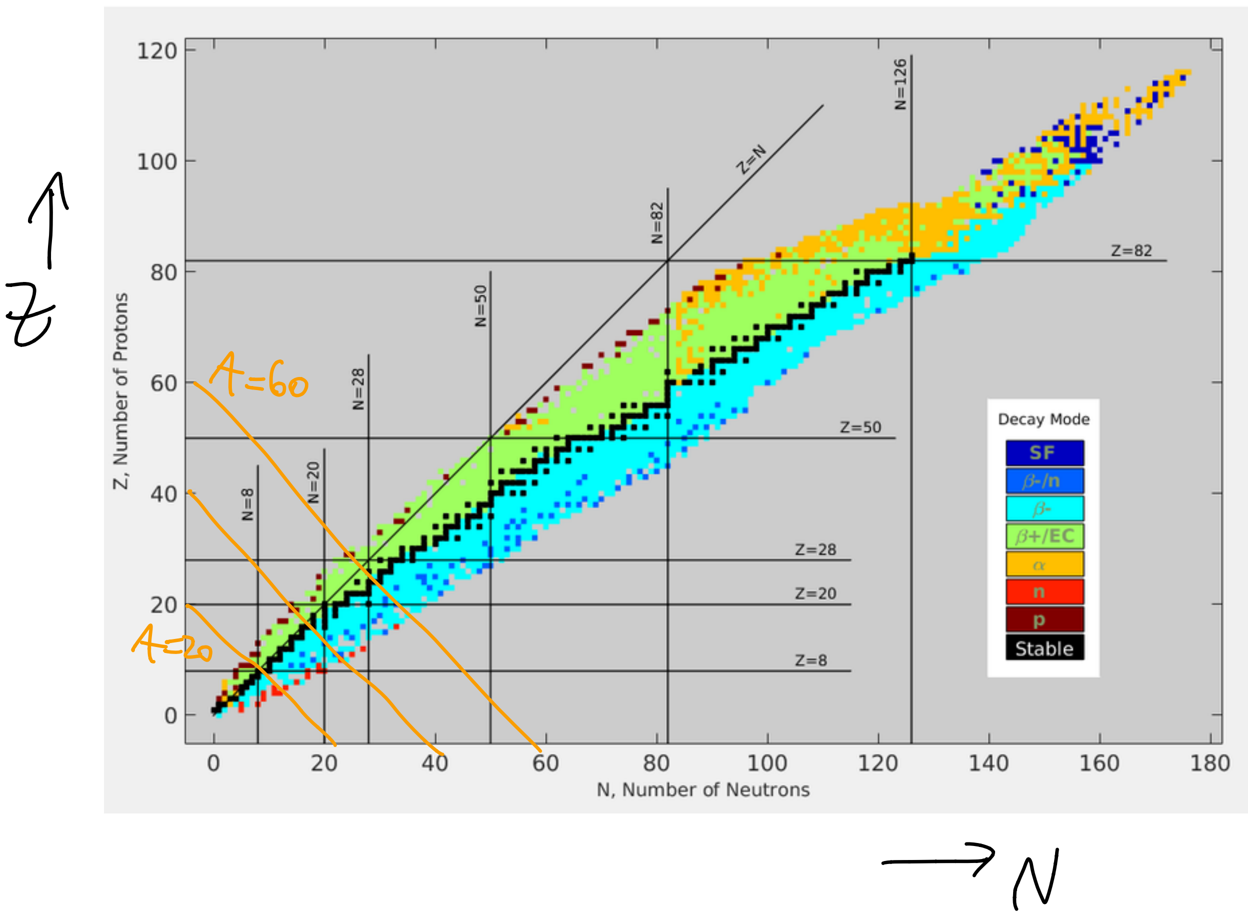
CARTA DI SEGRE'



asse z: EL

asse x: N

asse y: Z



A fissato $\rightarrow$ $Z+N = K$

$\beta^+ :\quad N(Z,A) \rightarrow N(Z-1,A) + e^+ + \nu_e$

$\quad\quad "p" \rightarrow n + e^+ + \nu_e$

$EC :\quad N(Z,A) + e^- \rightarrow N(Z-1,A) + \nu_e$

$\quad\quad p + e^- \rightarrow n + \nu_e$

β^- : $N(Z,A) \to N(Z+1,A) + e^- + \bar{\nu}_e$

stabilità : fissato A,

$$\left.\frac{\partial E_L}{\partial Z}\right|_{A=\text{cost}} = 0 = 2a_3 \frac{Z}{A^{1/3}} - 4a_4 \frac{(A-2Z)}{A}$$

$$Z = \frac{4a_4}{\frac{2a_3}{A^{1/3}} + 8\frac{a_4}{A}} = \frac{2a_4 A}{4a_4 + a_3 A^{2/3}}$$

per A piccolo

$$Z \cong \frac{A}{2}$$

per A grande

$$Z \simeq \frac{2a_4}{a_3} A^{1/3}$$

E_L è una parabola in Z
(fissato A)

$$E_L(A,Z) = a_1 A - a_2 A^{2/3} - a_3 \frac{Z^2}{A^{1/3}} - a_4 \frac{(A-2Z)^2}{A} \pm a_5 A^{-3/4}$$

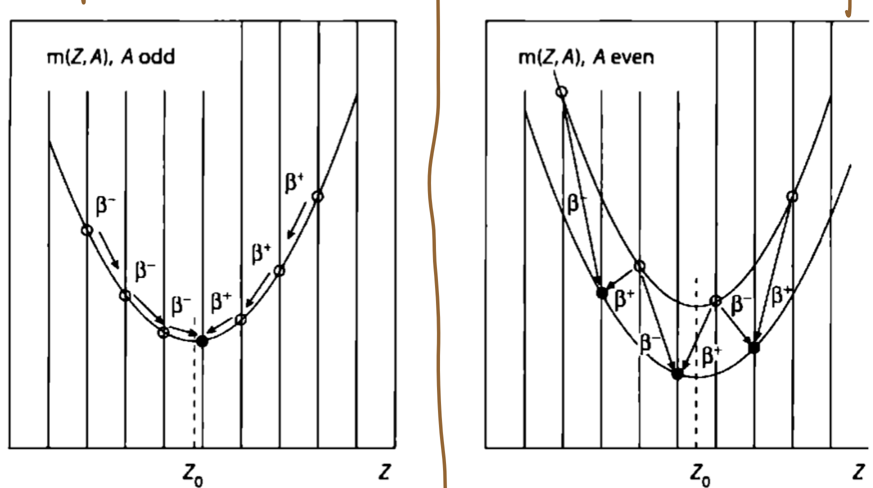
se plotto

$$M(A,Z) = Z m_p + (A-Z) m_n - E_L(A,Z)$$

A dispari

A pari

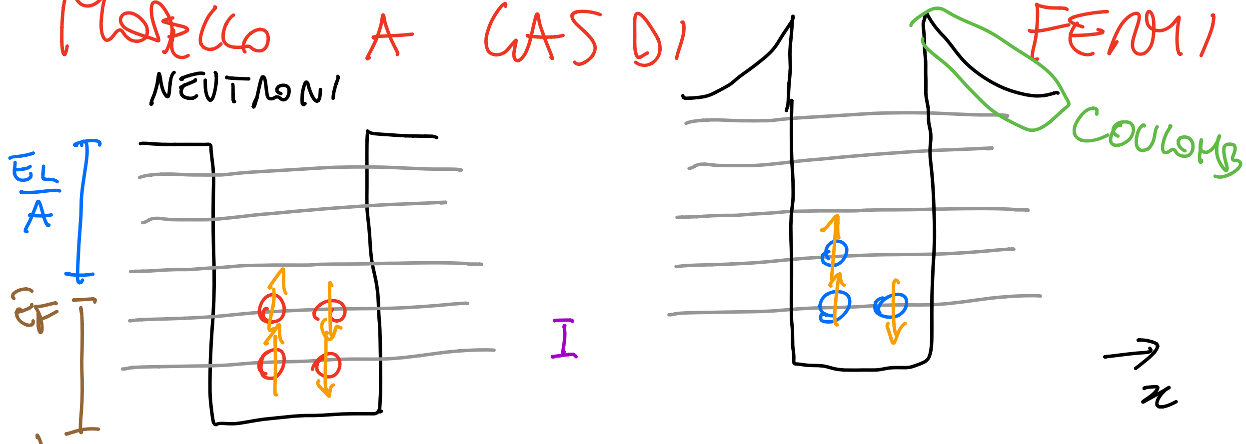
M



Z

Z

MODELLO A GAS DI FERMI



→ energia di Fermi

$E_L/A \sim 8\ \text{MeV}$

quantità ψ dentro il volume del nucleo

$$dn = \frac{d^3p}{\frac{(2\pi\hbar)^3}{V}}$$

$$= \frac{p^2\,dp\,d\Omega}{(2\pi\hbar)^3}\cdot V = \frac{p^2\,dp\cdot 4\pi}{(2\pi\hbar)^3}\,V$$

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A$$

assumiamo $A = Z + N = 2Z = 2N$

$\rightarrow Z = A/2 = N$

SPIN SU + SPIN GIÙ

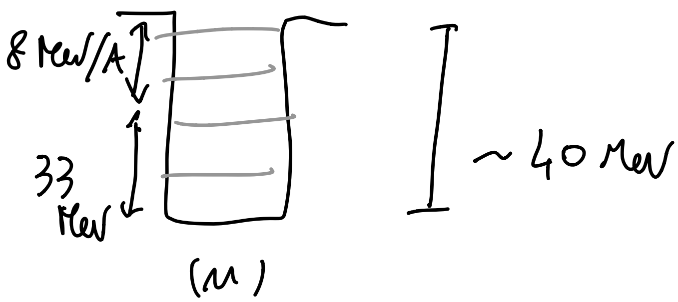
$$Z = N = \frac{A}{2} = 2\int_0^N dn = 2\int_0^{p_F} \frac{p^2\,dp\cdot 4\pi}{(2\pi\hbar)^3}\cdot\frac{4}{3}\pi R_0^3 A$$

$$= \frac{\cancel{32}^{\,4}\pi}{\cancel{8}_{\,1}} \frac{1}{(\pi\hbar)^3} \cdot \frac{1}{3} p_F^3 R_0^3 \cdot A\pi$$

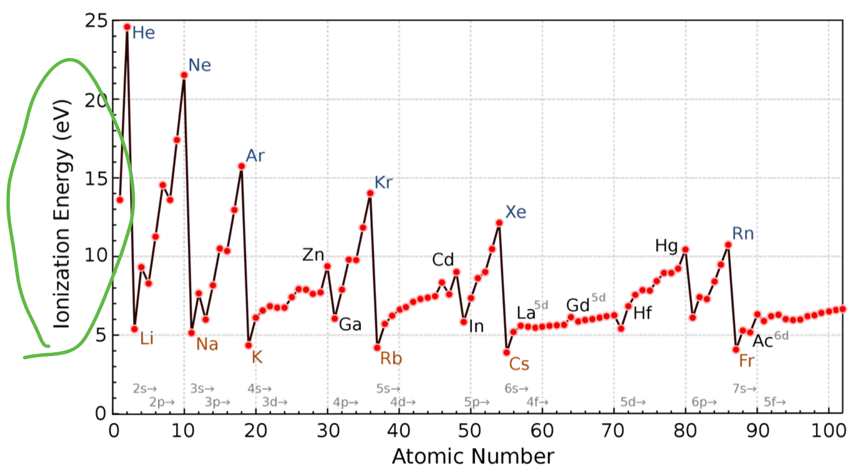
$$p_F = \left(\frac{\hbar}{R_0}\right)\left[\frac{9\pi}{8}\right]^{1/3} = 250 \text{ MeV}/c$$

$R_0 \to 1.2$ fm $\qquad \hbar c = 197$ MeV$\cdot$fm

$$E_F \simeq \frac{p_F^2}{2m_p} = 33 \text{ MeV}$$



MODELLO A SHELL



NUMERI MAGICI : valori di Z (o N) per cui E_L è particolarmente alta

o MEGLIO: è più stabile il nucleo

$N = 2, 8, 20, 28, 50, 82, 126$

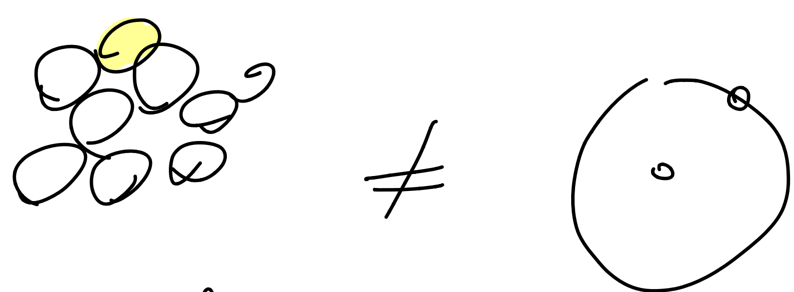
livelli energetici n $\quad l$ $\quad m$

$l \in (0, n-1)$ $\quad m \in (-l, l)$

$$2 \times \sum_{l=0}^{n-1} (2l+1)$$

$$= 2n^2$$

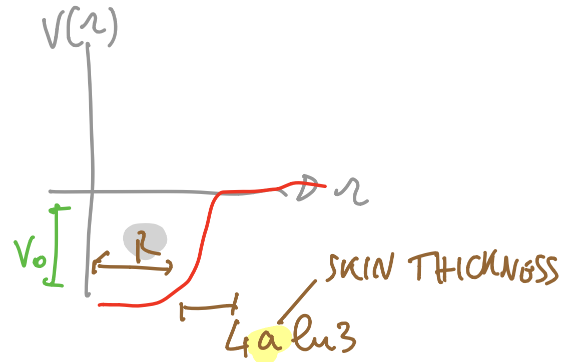
MA



difficile MA fattibile

→ serve V

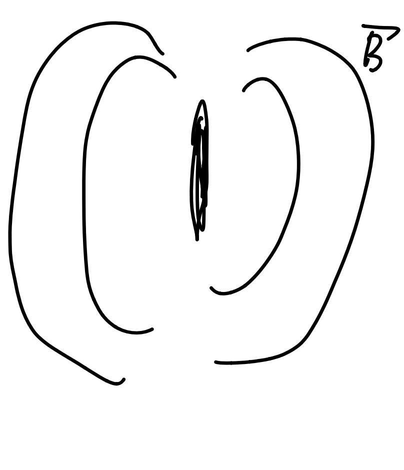
V	risultati
buca infinita	?
armonico	2, 8, 20, 40, 70, 112
Woods-Saxon	2, 8, 20, 40, 58, 92, 112 — NO!



$$V(r) = \frac{-V_0}{1+e^{\frac{r-R}{a}}}$$

→ serve spin-orbita

$$\Delta E \propto \vec{\mu}\cdot\vec{B} \propto \vec{L}\cdot\vec{S}$$



$$\vec{B} = \frac{\mu_0}{4\pi}\left[\frac{3\hat{r}(\vec{\mu}\cdot\hat{r})}{r^3} - \frac{\vec{\mu}}{r^3}\right]$$

$$U = -\vec{\mu}\cdot\vec{B}$$

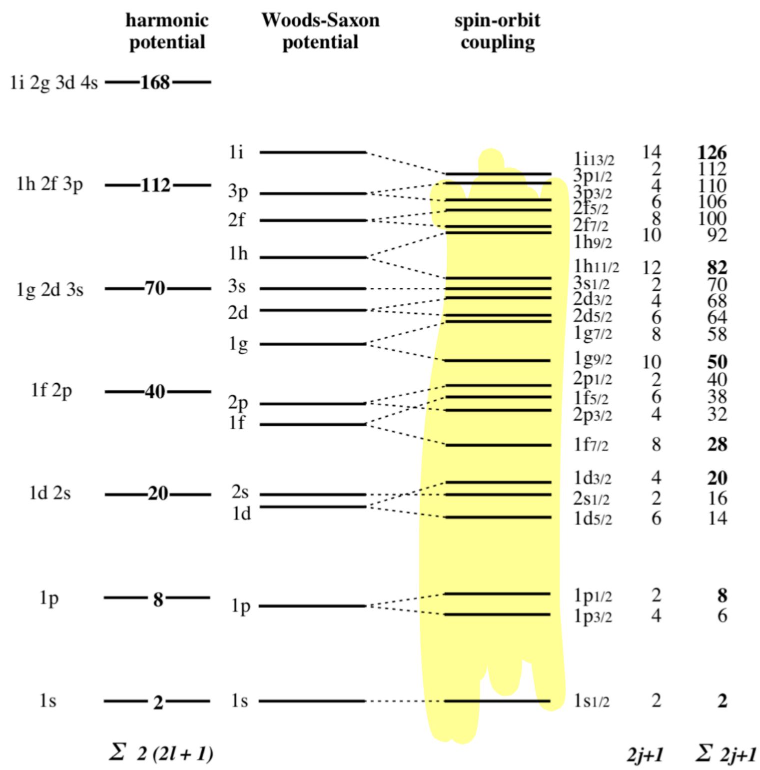
$= \sim keV$

perché $\ell^3 \sim R^3$

$\sim 1.2 fm^3$

in fisica atomica:

$\Delta E \sim meV$



lo splitting è (dispense)

$J = L + S$

$L \quad S = 1/2$

$\Delta E = \ell + 1/2$