

particelle conosciute: γ , e^- , p, n

Interazioni interessate

EM.

debole

forte

p, n : adroni: interazioni forte forte.

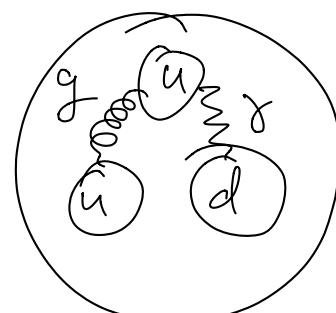
bannion: mesoni
 $(q\bar{q}_1 q_3)$ $q_1 \bar{q}_2$ carica elettrica

$(\begin{matrix} up \\ down \end{matrix})$ charm strange top bottom beauty $+2/3$
 $-1/3$

$-2/3$ (\bar{u}) (\bar{c}) (\bar{t}) fermioni:
 $+1/3$ (\bar{d}) (\bar{s}) (\bar{b})

$\begin{pmatrix} u & +\frac{2}{3} \\ u & +\frac{2}{3} \\ d & -\frac{1}{3} \end{pmatrix} = p$

$\begin{pmatrix} u \\ d \\ d \end{pmatrix} = n$



$$uuu = 3 \times \frac{2}{3} = +2$$

Banioni 9.9.29

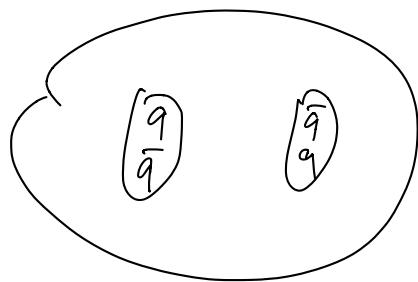
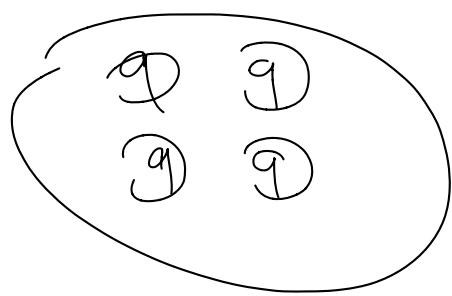
$$\bar{P} = (\bar{u}\bar{u}\bar{d})$$

Meson: $\bar{q}_1\bar{q}_2$ $\left(\frac{u}{d}\right)$ $q = +\frac{2}{3} + (+\frac{1}{3}) = +1$
 π^+ $m \approx 140 \text{ MeV}$

$$\left(\frac{\bar{u}}{d}\right) \pi^-$$

$-\frac{2}{3}$ $\left(\frac{\bar{u}}{s}\right) K^-$ $\left(\frac{\bar{d}}{s}\right) = \bar{K}^0$ $\left(\frac{d}{s}\right) \Xi K^0$
 $-\frac{1}{3}$ $\approx 500 \text{ MeV}$

meson:
hadron: ———
baryon:



tetraquark

In nature non esistono quark liberi
hadroni: forte EM (970), debole
lepton: interazioni debole e EM.

$$q_{\text{elec}} = -1 \quad \begin{pmatrix} e^- \\ 0.511 \text{ MeV} \\ \nu_e \end{pmatrix} \begin{pmatrix} \mu^- \\ 106 \text{ MeV} \\ \nu_\mu \end{pmatrix} \begin{pmatrix} \tau^- \\ 1.8 \text{ GeV} \\ \nu_\tau \end{pmatrix}$$

$$q=+1 \quad \begin{pmatrix} e^+ \\ \bar{\nu}_e \end{pmatrix} \quad \begin{pmatrix} \mu^+ \\ \bar{\nu}_\mu \end{pmatrix} \quad \begin{pmatrix} \tau^+ \\ \bar{\nu}_\tau \end{pmatrix} \quad \text{fermioni:}$$

$$q=0$$

$$M_{e^-} \equiv M_{e^+} \quad \begin{matrix} \mu^+ \ g^- \\ M \equiv m \\ \tau \equiv \tau \end{matrix}$$

γ^0 spin = 1 bosone.

Portatore di forte

bosoni di gauge vettori: ($S=1$) intermedi

$$m_\gamma = 0.$$

media le forte
EM

gluoni g^0 portatori di forte

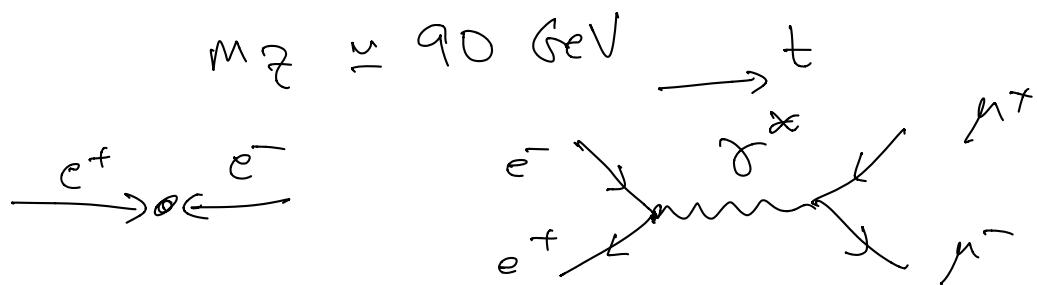
forte.

$$m_g = 0.$$

W^\pm, Z^0 mediatori di forte debole

$$M_W \approx 80 \text{ GeV}$$

$$M_Z \approx 90 \text{ GeV}$$



$$e^+ + e^- \rightarrow \mu^+ + \mu^-$$

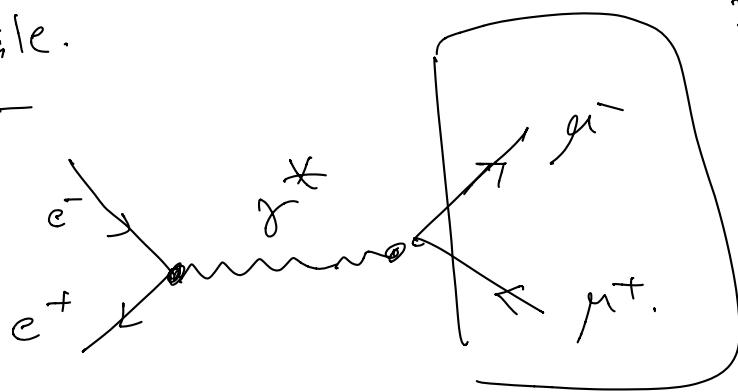
$$m_e = 0.511 \text{ MeV}$$

$$m_\mu = 106 \text{ MeV}$$

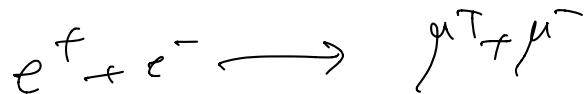
$$E_f = 212 \text{ MeV.} \Rightarrow P_{e^+} \approx 106 \text{ MeV.}$$

iniziale.

$e^+ e^-$



Finale.



In tutte le reazioni note, si osservano:

- # barioniico.

~~#~~ # leptonico.

L_e

$$\begin{array}{ccc} L_e & & \\ +1 & \left(\begin{array}{c} e^- \\ \nu_e \end{array} \right) & \left(\begin{array}{c} e^+ \\ \bar{\nu}_e \end{array} \right) -1 \\ +1 & & -1 \end{array}$$

$$P \quad B = +1. \quad \bar{P} \quad B = -1$$

$$L_e|_{in} - L_e|_{fin.} = DL_e = 0.$$

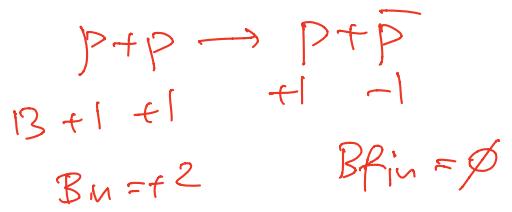
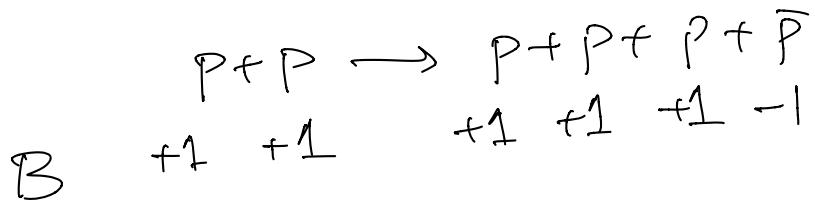
$$DB = 0. \quad \leftrightarrow \quad B_{fin} = B_{in}.$$

$$L_e \quad \begin{matrix} e^+ & +e^- \\ -1 & +1 \end{matrix} \quad \begin{matrix} \mu^+ & +\mu^- \\ 0 & 0 \end{matrix}$$

$$L_\mu \quad \begin{matrix} 0 & 0 \end{matrix} \quad \begin{matrix} -1 & +1 \end{matrix}$$

$$L_\tau \quad \begin{matrix} 0 & 0 \end{matrix} \quad \begin{matrix} 0 & 0 \end{matrix}$$

$$B \quad \begin{matrix} 0 & 0 \end{matrix} \quad \begin{matrix} 0 & 0 \end{matrix}$$



$$B_{in} = 2$$

$$B_{fin} = 2$$



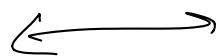
mecc. leg. di inv. sotto one trasf \Rightarrow conservazione di una quantità

$$L = L(r, \theta)$$

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

Teorema Nöther

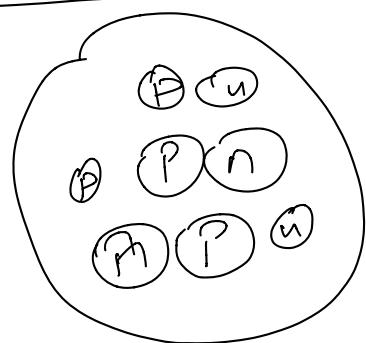
quantità
conservate



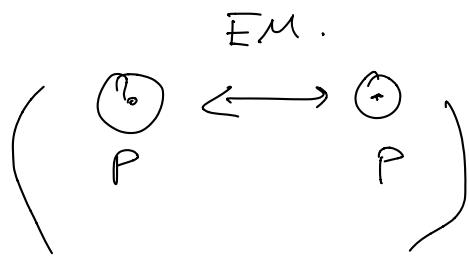
simmetria.
(inv. sotto una
trasf.)

B, L_e, L_n, L_T \Rightarrow esiste una simmetria.
Si conservano

Fisica nucleare



nucleo.



Forze

A, Z

$Z_1 \#$ protoni

carica elettrica = Ze

A : numero di massa.

$$A = Z + N$$

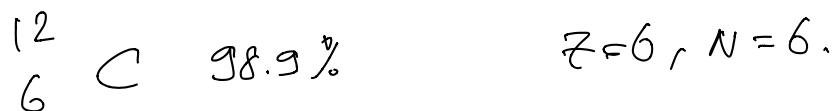
proton: ↓
 neutron:

nuclidi: (A, Z)

nuclone: } proton
 } neutrone.

$$\begin{aligned} A &= \text{nucloni} \\ Z &= \text{protoni} \\ A - Z &= \text{neutroni} \end{aligned}$$

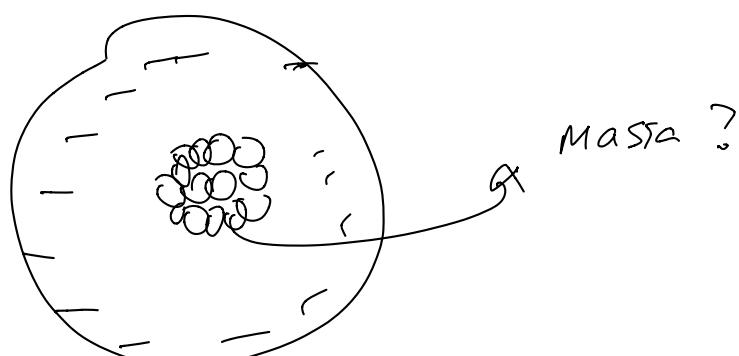
isotopi: nuclidi con lo stesso Z
 diverso A .



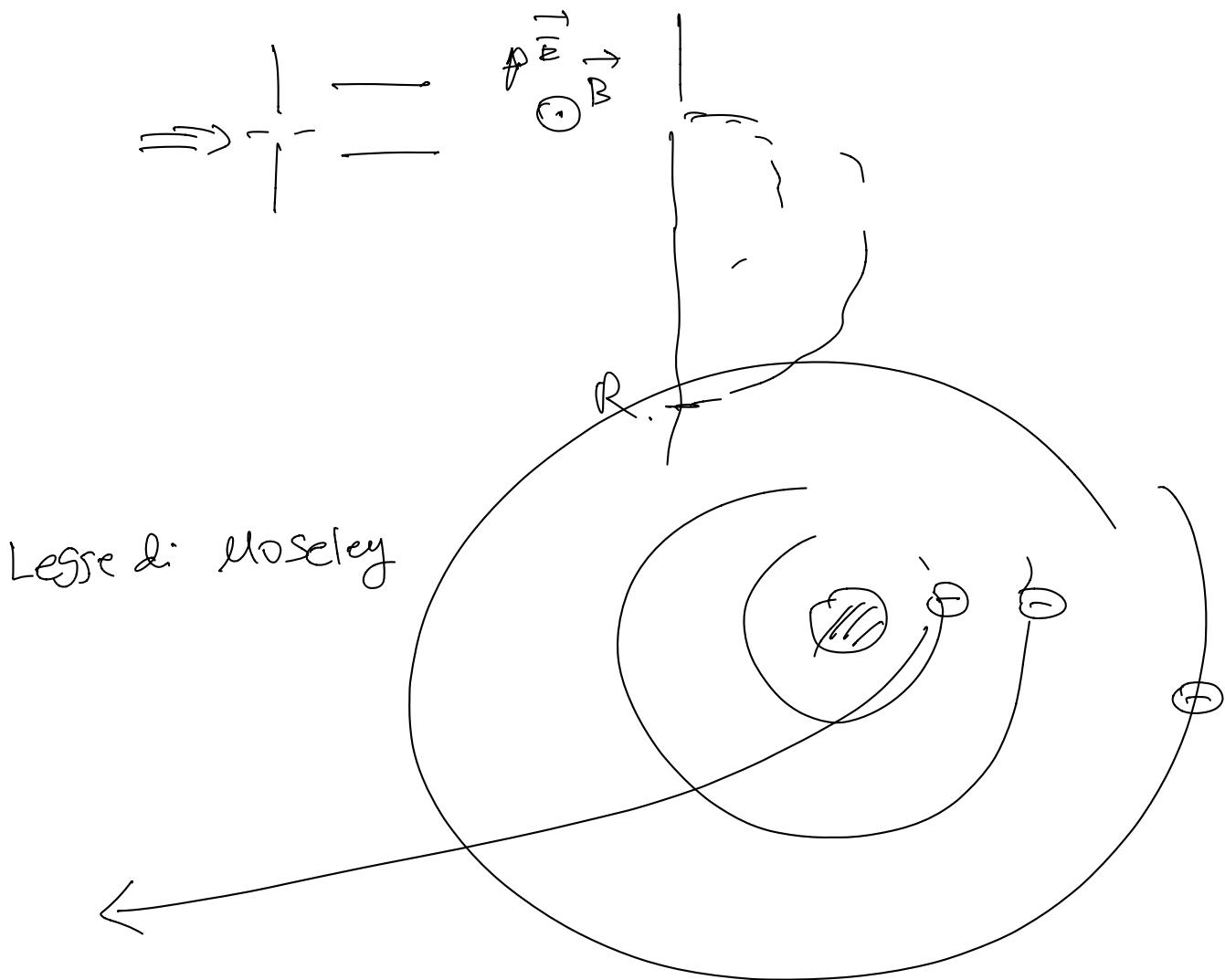
isobari: nuclidi con lo stesso A .
 diverso Z

A → massa del nucleo

Z → carica

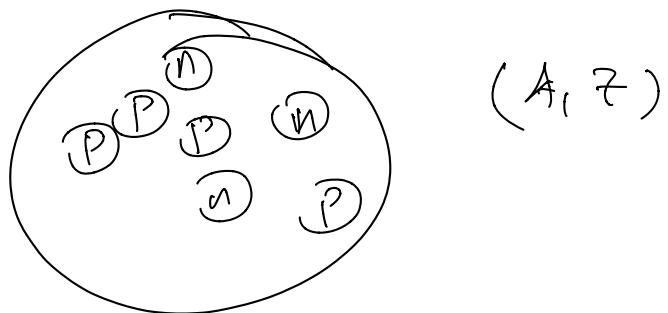


massa: spettrometro di massa.



$$E_c \approx \frac{3}{4} R_y (Z-1)^2$$
$$\approx 10 \text{ eV} (Z-1)^2$$
$$R_y = 13.6 \text{ eV.}$$

spettro rassi X \Rightarrow stime di Z .



$M(A, Z)$: massa di nuclioide (A, Z) .

$$M(A, Z) < Z \cdot m_p + (A - Z) m_n$$

nei sistemi legati: energia di legame.

$$B(Z, A) = \underbrace{Z M(^1H)}_{\text{energia di legame}} + (A - Z) m_n - \underbrace{M(Z, A)}_{\text{massa nucleide.}}$$

$$M(^1H) = m_p + m_e + B_e$$

$$\begin{array}{ccc} & \downarrow & \downarrow & \downarrow \\ m_p & 939. & 0.511 & 13.6 \text{ eV} \end{array}$$

$$\approx m_p.$$

Per definizione $B(Z, A) > 0$

$$M(^1H) = 938.9 \text{ MeV} = 1.008 \text{ uA}$$

$$1 \text{ uA} = \frac{1}{12} \underbrace{M(^{12}C)}_{\text{massa atomica.}} = 931.494 \text{ MeV.}$$

$$m_p \approx 939 \text{ MeV.}$$

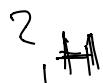
$$m_n \approx 938 \text{ MeV.}$$

$$B(Z, A) = ? \quad \text{energia di legame nucleare.}$$

$$^1H \quad (A=1, Z=1)$$

$$B(1, 1) = 0$$

deuteron.



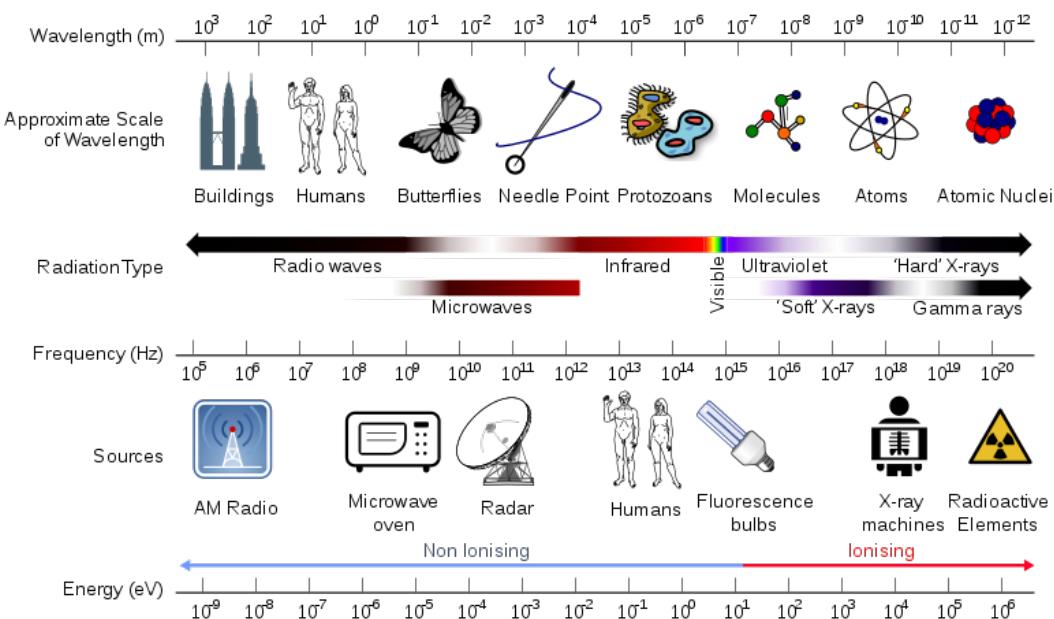
nuovo di deutone

$$\begin{aligned} B(Z=1, A=2) &= M(^2H) - m_n - m(^1H) \\ &= 2.225 \text{ MeV.} \end{aligned}$$

Ry = 13.6 eV.

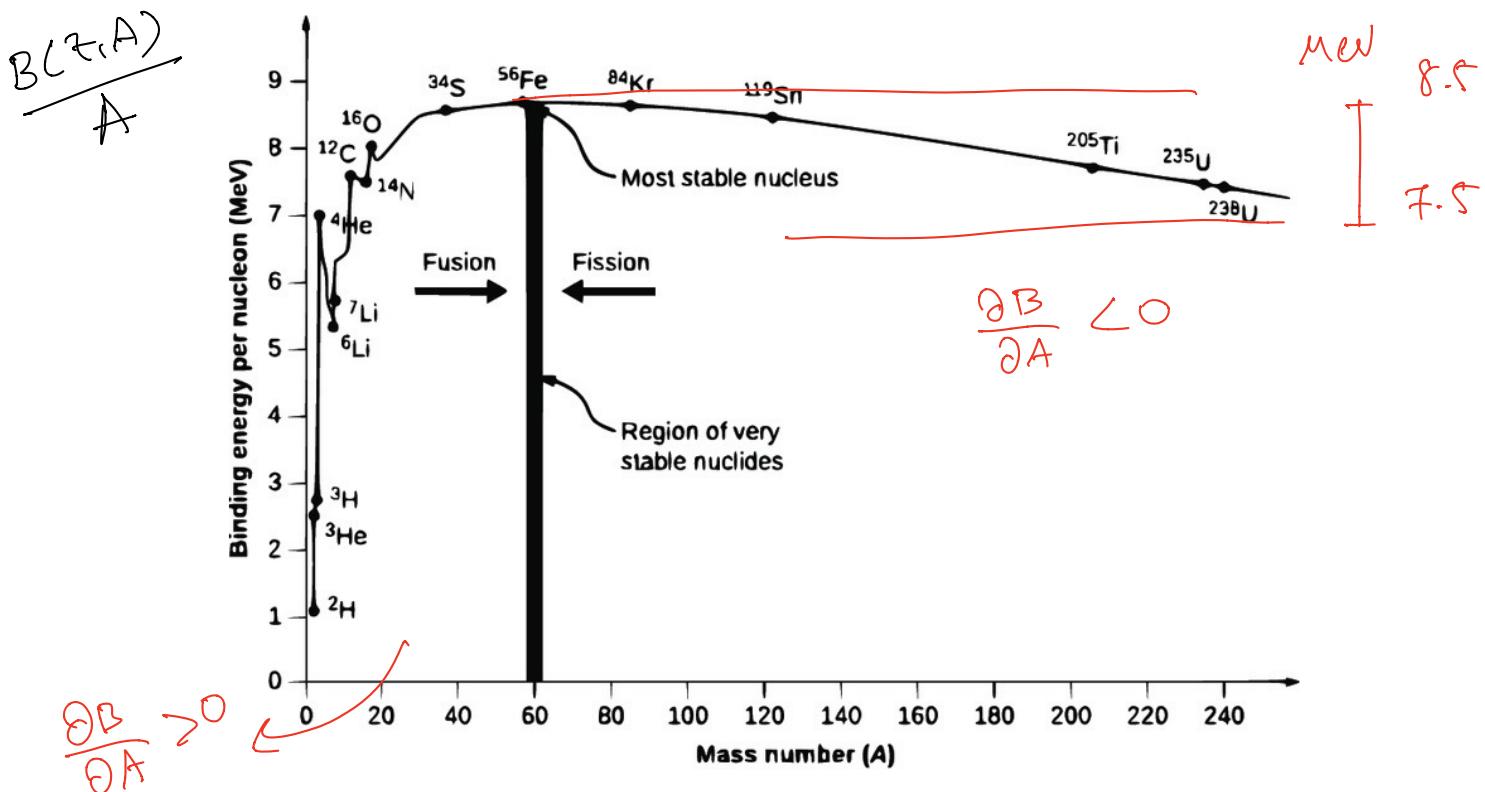
en. di legame atomico.

10^5 più grande, energia di legame.



$B(Z, A)$ dipendente da Z, A ,

si considera misura $\frac{B(Z, A)}{A}$: energia di legame medio per nucleone.



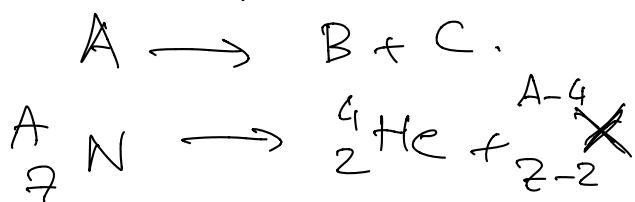
$$\alpha \equiv {}_2^4\text{He} \quad \frac{B(4,2)}{c} \approx 7 \text{ MeV}$$

Fissione: $A > 60$ possibile.
avviene soprattutto per $A > 200$

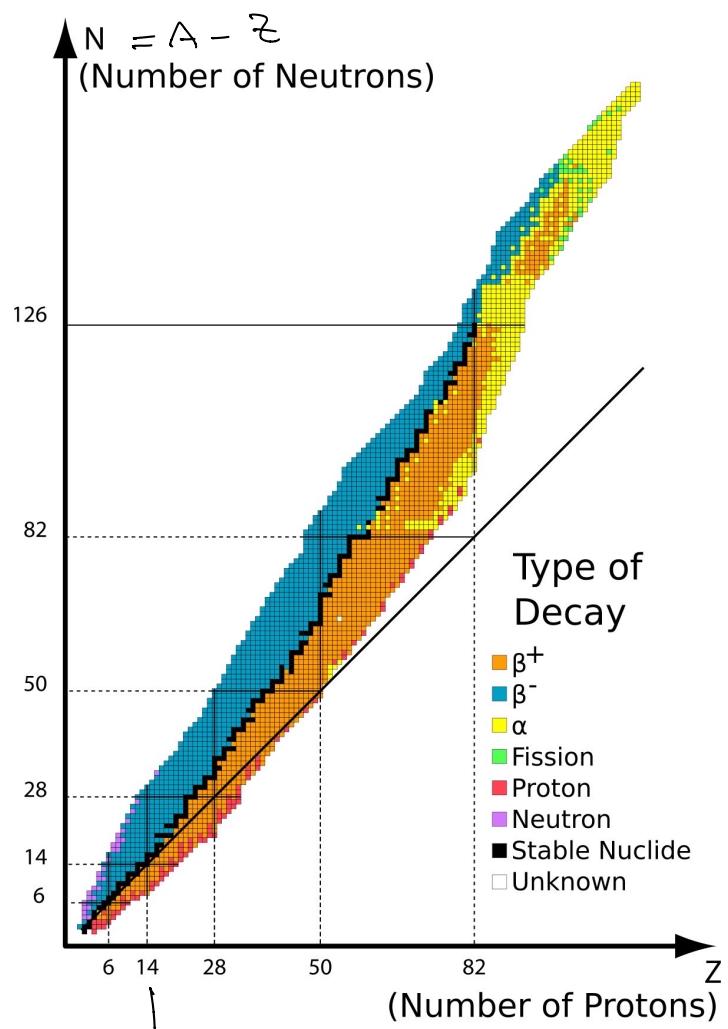
$A < 60$: Fusione

1 H Hydrogen 1.008	3 Li Lithium 6.94	4 Be Beryllium 9.012	6 C Carbon 12.011	5 B Boron 10.81	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305	19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845
37 Rb Rubidium 85.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium [97]	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.908	46 Pd Palladium 106.42
55 Cs Cesium 132.905	56 Ba Barium 137.327	* 57 - 70	71 Lu Lutetium 174.967	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217
87 Fr Francium [223]	88 Ra Radium [226]	** 89 - 102	103 Lr Lawrencium [262]	104 Rf Rutherfordium [267]	105 Db Dubnium [270]	106 Sg Seaborgium [269]	107 Bh Bohrium [270]	108 Hs Hassium [270]	109 Mt Meitnerium [278]
*Lanthanide series									
57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.242	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500
**Actinide series									
89 Ac Actinium [227]	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]
99 Es Einsteinium [252]	100 Fm Fermium [257]	111 Rg Roentgenium [281]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [293]	118 Og Oganesson [294]

nuclidi: now saw tutti stabili:
alcuni decadono spontaneamente.



$$B_{in} = A. \quad B_{fin} = 4 + A - 4 = A.$$



$Z = 14$ si

$Z < 14$

$$N = A - Z > Z$$

$$A > 2Z$$

eccesso di neutron:
 nei nuclei stabili.

$$Z \approx A - Z$$

$$\Rightarrow A \approx 2Z$$