ON THE BOSON'S RANGE OF THE WEAK NUCLEAR FORCE

Antonio PUCCINI
Neurophysiologist of Health Ministry, Naples –Italy

Abstract
As known the Weak Nuclear Force (WNF) acts between quarks (Qs) and leptons. The action of the WNF is mediated by highly massive gauge bosons. How does a Q emit such a massive particle, approximately 16.000 or 40.000 times its mass? Who provides so much energy to a up Q or a down Q? However, it must be considered that according to Quantum Mechanics it is possible to loan temporarily some energy, but to a precise and binding condition, established by the Uncertainty Principle: the higher the energy borrowed, the shorter the duration of the loan. Our calculations show that the maximum distance these bosons can travel, i.e. the upper limit of their range, corresponds to $1.543\cdot10^{-15}$ [cm] for particles W^+ and W^- and $1.36\cdot10^{-15}$[cm] for Z° particles.

Introduction
The Weak Nuclear Force (WNF) is a short-range force, which acts within the space of an atomic nucleus. The WNF acts between both Quarks (Qs) and leptons. As described by Heisemberg [1] and Majorana [2], particles interact with each other by continuously exchanging another type of particle, defined as *gauge boson*. This is the concept of *exchange forces*. Particles sensitive to WNF exchange the bosons W^+, W^- o Z°, discovered by Rubbia and Van der Meer in 1983. Bosoni W^+ and W^- have a mass about 80.385±0.015 GeV/c^2, whereas the particle Z° weighs about 91.1876±0.0021 GeV/c^2.
As regards the radius of action of the WNF we don't find unique data in literature: they mostly hover around 10^{-16} [cm]. Let's try to deepen this topic.

Discussion
According to Quantum Field Theory a particle generates a field, and the field acts on another particle. "Consider two particles rather close to each other: each of them surrounds itself with its field, which will have to act on the other. Get sourrounded by its field means emit *quanta* of this field" [3]. The quanta of action of the field are said *bosons*, which differ as the generated field vary, namely as the Fundamental Force taken into account vary. Thus a Q can emit a boson and interact with another Q. Qs which frequently interact with each other are up Q and down Q, wich literally weigh about 2MeV/c^2 and 5 MeV/c^2. To this point one wonders: how does a Q emit a particle so much heavier and so more energetic? For instance a boson W, emitted by the Q, is 40000 times heavier than the up Q and 16000 times heavier than the Q down. Saying heavier is as to say more energetic, along with the mass-energy equivalence principle (MEEP):

	$E = m c^2$	(1).

Then: who is giving so much energy (E) to the Q, so that it can emit a particle of so much E as the W boson? None. This E is borrowed from the Q. Quantum Mechanics (QM) allows it to do so, but at a precise and binding condicion: the higher E (Δ_E) loaned, the sooner the loan must be paid, that is the shorter the time (Δ_t) of the loan. This is required by one of the pillars of the QM, that is the Uncertainty Principle of Heisemberg (HUP), concerning the E and the (t) [4][5]:

	$\Delta_E \cdot \Delta_t \geq \text{h}$	(2).

Where h is Planck's constant equal to $6.626\cdot10^{-27}$ [erg·s]. Thus the duration of the energetic loan is given by Eq.(2), from which we get:

	$t = h/E$	(3).

The value of E in Eq.(3) can be substituted by the value $m\,c^2$ of Eq.(1):

$$t = h/mc^2 \quad (4).$$

Eq.(3) shows very clearly that the time (t) and E are inversely proportional. That's why the higher the E loaned, the lower the period of the loan. Eq.(3), thus, as Fermi reminds us "represents the time in which the boson issued can stay in the free space. If then it is assumed that its speed is the maximum speed at which a particle can move, that is the speed of light (c), it is seen that the maximum distance (d) to which it can arrive, before being recalled to weld the debt, is given, as order of magnitude, by the product of time (t) for the maximum speed at which the particle can move"[3]:

$$d = t\,c \quad (5).$$

Introducing in Eq.(5) the value of t expressed by (4), we get:

$$d = (h/\mathrm{m}c^2)\cdot c \quad (6),$$

that is:

$$d = h/mc \quad (7).$$

As Fermi says "Eq.(7), thus, unless some numerical coefficients, expresses the range of the *nuclear forces*"[3]. Therefore let's calculate the range of the EWF mediated by bosons W. At this point it is more convenient to consider the mass of the W boson in grams [g], then using the metric system *cgs*. As we know 1 GeV/c^2=1000 MeV/c^2, and as Feynman reminds us 1 MeV/c^2 = $1.782\cdot10^{-27}$ [g] [6]. Thus 1 GeV/c^2= $1.782\cdot10^{-24}$ [g]. Hence the mass of the boson W corresponds to:

$$m_\mathrm{w} = 80.385 \cdot (1.782\cdot10^{-24}\ [\mathrm{g}]) \quad (8),$$

that is:

$$m_\mathrm{w} = 1.4324607 \cdot10^{-22}\ [\mathrm{g}] \quad (9),$$

that is almost 100 times the mass of the proton. Let's substitute now this value to the m of Eq.(7):

$$d = \frac{6.626\cdot10^{-27}[erg\cdot s]}{(1.4324607\cdot10^{-22}[g])(2.9979\cdot10^{10}[cm/s])} \quad (10).$$

Since 1 erg = g·cm/s^2 ·cm, we can write:

$$d = \frac{6.626\cdot10^{-27}[g\cdot cm^2/s]}{(4.2943739\cdot10^{12}[g\cdot cm/s])} \quad (11),$$

$$d = 1.542949 \cdot10^{-15}[\mathrm{cm}] \quad (12),$$

which we round to:

$$d = 1.543\cdot10^{-15}[\mathrm{cm}] \quad (13).$$

This is the upper limit of the range of the W boson.
Let's consider the other boson that mediates the WNF, namely the Z ° particle, whose mass would correspond to ≈91.1876 GeV/c^2. Let's write this mass in [g]:

$$m_\mathrm{z} = 91.1876 \cdot (1.782\cdot10^{-24}\ [\mathrm{g}]) \quad (14),$$

that is:

$$m_\mathrm{z} = 1.624963 \cdot10^{-22}\ [\mathrm{g}] \quad (15).$$

Also in this case we can substitute this value with the *m* from Eq.(7):

	$d = \frac{6.626 \cdot 10^{-27}[erg \cdot s]}{(1.624963 \cdot 10^{-22}[g])(2.9979 \cdot 10^{10}[cm/s])}$	(16),

	$d = \frac{6.626 \cdot 10^{-27}[g \cdot cm^2/s]}{4.8714765 \cdot 10^{-12}[g \cdot cm/s]}$	(17),

that is:	$d = 1.3601625 \cdot 10^{-15}$[cm]	(18),

as to say:	$d = 1.36 \cdot 10^{-15}$[cm]	(19).

The latter equation delineates the upper limit of the range of the boson Z°.

Conclusions

With our work we tried to give a contribution to the literature on the measurement of the maximum distance gauge bosons of the WNF can travel before the time of paying back the energetic debt.
It is this short time to narrow their journey, it can not go beyond 10^{-15}[cm]. The small difference between the radius of the particle Z° and that of bosons W (slightly larger the latter) goes perfectly along with the known fact that the action range of a Fundamental Force is inversely proportional to the mass of the bosons the force conveys [7].

References

1) Heisemberg W., Zeitschrift fur Physik,Vol.77,1-11,1932.
2) Majorana E., Zeitschrift fur Physik,Vol.82,137-145,1933.
3) Fermi E., Atomi Nuclei Particelle, Boringhieri Ed. (Torino), 140-141,2009.
4) Heisemberg W., Zeitschrift fur Physik,Vol.43,184-185,1927.
5) Puccini A., Journal of Electromagnetic Waves and Applications,Vol.19,N°7,885-890,2005.
6) Feynman R.P., QED, The Strange Theory of Light and Matter, Adelphi Ed.(To),164,1989.
7) Yukava H., Proc. Phys. Math. Soc. Japan, 1935, 17, 48-57.