Nucleon polarizability and long range strong force from $\sigma_{I=2}$ meson exchange potential

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Abstract

We present a theory for how nucleon polarizability may be used to extract energy from nucleons by means of special electromagnetic conditions. Also a new theory for a long-range strong force is introduced by enhancing the role of the $\sigma_{I=2}$ meson in nucleon-nucleon potential obtained through isospin mixed σ mesons. The novelty in the idea is to let an imaginary mass exchange particle be enhanced by absorbing only one particle in an entangled state of two particles. The imaginary mass particle is not intendent to be free and contravene the laws of physics; it is merely included as a binding exchange particle in a system with total positive invariant mass. In order to validate part of the theory, we introduce an experiment that in many ways has motivated this study.

Introduction

A theory on the possibility that nuclear effects can occur at energies lower than expected comes with two problems:

- How to extract energy without strong radiation.

- How to effect this over a long range, i.e. ranges found by atomic separation of nuclides instead of separation of nucleons in a nuclide.

Two important assumptions are made in this paper to answer these questions. The first is that a special electromagnetic field can create a substitute for the meson exchange potentials created by nucleon-nucleon interaction inside nuclides. This is motivated, f.i., by the meson-photon couplings found in hadronic light by light scattering. The second assumption is that the same special EM fields are capable of creating an environment where nucleons may be transferred between nuclides

To match the theoretical predictions, links to experimental results should be established. Such possible experimental results are listed in the appendix.

There are two relevant experimental results worth mentioning. The first is that energy is released in the form of heat and kinetic energy of heavy ions.

The second result is that during the process nucleons are transferred between nuclides causing chemical and isotopic shifts.

Our proposed theory consists of four parts. The first is an interpretation of nucleon polarizability on how energy is extracted from theoretical formulas and parameters of polarizability. The purpose of this theory is to find which special electromagnetic field conditions correspond to the extraction of energy out of the nucleon. The second part is a short summary of the links between polarizability and nucleon-nucleon (N-N) interaction indicating how polarizability interaction sets the nucleon in a state that is found in nuclides.

The third part contains a new idea developed to answer the second question, i.e. how to conduct nucleon transfer over a long-range. The idea is that in meson exchange potential-based nucleon-nucleon interaction there is a degenerated state between two scalar mesons differing only in their isospin state. From $\pi\pi$ scattering, two resonances at $36.77m_\pi^2$ and $-21.62m_\pi^2$ are found(henceforth referred to as $\sigma_{I=0}$ and $\sigma_{I=2}$). The second resonance does not correspond to a real particle (because of its negative energy) and is only a parameter used in formulas for interaction. In N-N interaction these states are mixed at a resonance mass of 550 MeV. The idea is that, by enhancing interaction with isospin 0 particles (electrons and photons), the exchange meson changes its mass parameter to a value close to zero, giving it the same interaction length as the photon. The process is similar to that of enhancing the K_L over K_s meson parts of K_0 by performing measurements a long time after the creation of the meson, or choosing a proton over a neutron by defining a specific charge in a strong force calculation which would otherwise be charge-independent.

The fourth part describes possible atomic sources for the special electromagnetic field conditions found from polarizability. Unfortunately the available experimental data is not precise enough to draw any definite conclusions here, hence only suggestions are made.

To solve the two main problems listed above, the first thing to do is to set the low energy scale. Low energy means that there is not enough energy to push nucleons close enough together to interact strongly with one another. The residual interaction is the electromagnetic interaction with photons and electrons. For a single nucleon, the theory resorted to here is nucleon polarizability, i.e. how the internal structure of the nucleon changes with the interaction of photons. From the standpoint of polarizability the first question may be answered in two ways. Spin polarizability does not correspond to a classic electromagnetic field, and therefore all momentum transfers from the interaction should be released as kinetic energy of the nucleon. The other solution is that there is a magnetic quadrupole state in the nucleon with an energy level lower than zero. The full transition to this state is not possible through energy conservation, yet it is possible to extract parts of the energy over a limited time. The solution to the long-range question is also twofold. The first solution is the one described in the third part of the theory. The second is a less plausible idea that is assisted by the special electromagnetic field. The e-N interaction strength is in the same range as N-N, since the electron replaces the full attractive potential corresponding to a nuclide.

Nucleon Polarizability

The main theory for nucleon polarizability resorted to here is the baryon chiral perturbation theory [1]. Other extant theories are the heavy baryon chiral perturbation theory and the fixed-t dispersion theory, both of which have polarizability constants within the same ranges as those of the baryon ChPT. For a review, see for instance [6]. The theory of polarizability is carried out by first taking the ground state E_0 of the nucleon and then perturbing the N-γ interaction with an effective Hamiltonian(H_{eff}):

$$H = E_0 - H_{eff}$$

If the condition $H_{eff} < 0$ is fulfilled, the new state is an excitation and $H_{eff} > 0$ corresponds to a binding energy which could be used to extract energy out of the nucleon. The effective Hamiltonian admits an expansion of the form $H_{eff} = \sum H_{eff}^{(i)}$, where i denotes the number of space time derivatives of the electromagnetic field $A_\mu(x)$. According to reference [5], to the fourth derivative $H_{eff}^{(i)}$ is given by:

$$H_{eff}^{(2)} = -\tfrac{1}{2} 4\pi \left(\alpha_{E1} \bar{E}^2 + \beta_{M1} \bar{H}^2 \right)$$
$$H_{eff}^{(3)} = -\tfrac{1}{2} 4\pi \left(\gamma_{E1E1} \bar{\sigma} \cdot \left(\bar{E} \times \dot{\bar{E}} \right) + \gamma_{M1M1} \bar{\sigma} \cdot \left(\bar{H} \times \dot{\bar{H}} \right) - 2\gamma_{M1E2} E_{ij} \sigma_i H_j + 2\gamma_{E1M2} H_{ij} \sigma_i E_j \right)$$
$$H_{eff}^{(4)} = -\tfrac{1}{2} 4\pi \left(\alpha_{E1\nu} \dot{\bar{E}}^2 + \beta_{M1\nu} \dot{\bar{H}}^2 \right) - \tfrac{1}{12} 4\pi \left(\alpha_{E2} E_{ij}^2 + \beta_{M2} H_{ij}^2 \right)$$

$$(1)$$

where α_x, β_x, γ_x are polarizability constants, E and H are components of the electromagnetic fields. σ is the Pauli spin matrices of the nucleon and E_{ij} is given by $E_{ij} = \tfrac{1}{2} \left(\nabla_i E_j + \nabla_j E_i \right)$ with the same relation for H_{ij} where i and j stand for space indexes. For the polarizability constants with an even number of perturbations, the experimental values and theoretical predictions are shown in table 1. For the effective hamiltonians with an even number of space time derivates every part of the EM field is a square; there the only time the condition $H_{eff} > 0$ is fulfilled is when the polarizability constant is negative. In this case only theoretical values exist: the polarizability constant of the magnetic quadrupole and the electric dispersive polarizability constant.

The odd number of perturbation is called spin polarizability and has no meaning in a classic EM field. This means that the interaction is due to the non standard electromagnetic parts of the nucleon, i.e. the strong force. The situation is a bit more complicated if one wants to find the conditions for $H_{eff} > 0$. Since the field includes the nucleon spin, the positive value condition depends on the alignment of the nucleon spin with the EM field parts. An interesting and experimentally easily accessible part of the polarizability is the case of forward and backward scattering. These polarizability constants are labeled γ_0 and γ_π. They are related to the spin polarizability constants by:

$$\gamma_0 = -\gamma_{E1E1} - \gamma_{E1M2} - \gamma_{M1M1} - \gamma_{M1E2}$$

	α_{E1}	β_{M1}	α_{E2}	β_{M2}	$\alpha_{E1\nu}$	$\beta_{M1\nu}$
Proton						
BχPT Theory[1]	11.2 ± 0.7	3.9 ± 0.7	17.3 ± 3.9	-15.5 ± 3.5	-1.3 ± 1.0	7.1 ± 2.5
Experiment(PDG[9])	11.2 ± 0.4	2.5 ± 0.4				
Neutron						
BχPT Theory[1]	13.7 ± 3.1	4.6 ± 2.7	16.2 ± 3.7	-15.8 ± 3.6	0.1 ± 1.0	7.2 ± 2.5
Experiment(PDG[9])	11.8 ± 1.1	3.7 ± 1.2				

Table 1: Theoretical and experimental values of the proton and neutron static dipole, quadrupole and dispersive polarizabilities. The units are 10^{-4} fm^3 (dipole) and 10^{-4} fm^5 (quadrupole and dispersive).

	γ_{E1E1}	γ_{M1M1}	γ_{E1M2}	γ_{M1E2}	γ_0	γ_π
Proton						
BχPTTheory[1]	-3.3 ± 0.8	2.9 ± 1.5	0.2 ± 0.2	1.1 ± 0.3	-0.9 ± 1.4	7.2 ± 1.7
MAMI 2015[7]	-3.5 ± 1.2	3.16 ± 0.85	-0.7 ± 1.2	1.99 ± 0.29	-1.01 ± 0.13	8.0 ± 1.8
Neutron						
BχPT Theory[1]	-4.7 ± 1.1	2.9 ± 1.5	0.2 ± 0.2	1.6 ± 0.4	0.03 ± 1.4	9.0 ± 2.0

Table 2: Theoretical and experimental values of the proton and neutron static spin polarizabilities. The units are 10^{-4} fm^4.

$$\gamma_\pi = -\gamma_{E1E1} - \gamma_{E1M2} + \gamma_{M1M1} + \gamma_{M1E2}$$

The spin polarizability experiment and theoretical values are displayed in table 2. The binding conditions are fulfilled for the proton, for example by the γ_0 constants; and there is a possibility to define regions where $H_{eff} > 0$ when the four spin polarizability constants are known.

Discussion of the condition $H_{eff} > 0$

The polarizability condition $H_{eff} > 0$ is strange from the wiev of energy conservation. The condition needs some special attention to explain why it does not violate any basic law of physics. To understand the states with positive values of H_{eff} a thermodynamic view could be implemented. Start with the first law of thermodynamic:

$$dU = dQ + dW$$

where dU is the change in interanal energy, dQ the thermal flow(assumed to be 0 here) and dW the internal work of the system. For the groundstate particles, the proton and photon the internal energy U would be defined as 0 if there is no internal kinetic energy. In the case when $E_\gamma \sim 0$ which is the level where the static polarizability constant is defined the condition $dU > 0$ has

to be fullfilled. With a large E_γ the polarizability interaction would be called dynamic and the equation 1 would no longer be valid. For small magnetization and electric polarizability, the dW is defined by:

$$dW = -\mu_0 V H d\left(\chi H\right)$$

$$dW = -\varepsilon_0 V E d\left(\left(\varepsilon_r - 1\right) E\right)$$

where V is the volume of the system. The condition $\chi > 0$ and $\varepsilon_r > 1$ would be forbidden by the $dU > 0$ condition. This would correspond to the situation $H_{eff} > 0$ in polarizability calculations. The solution to the $H_{eff} > 0$ problem is the definition of $U = 0$. If the proton is considered the ground state, then the internal energy is 0; but if the bound nucleon in a nuclide is considered the G.S., then there is an internal energy that is defined by the mass difference. This gives a second problem, i.e. why is there no spontaneous de-excitation of the nucleon. A basic example is why the process $p + n \rightarrow d + \gamma$ is allowed but not $p \rightarrow p*(d) + \gamma$. The solution is different for the spin polarizability and quadrupole polarizability. For spin polarizability, a solution is that the interaction is due to non-classic EM fields. The basic interpretation of this is that the interaction cannot form real photons. Virtual photons are still possible, but the reaction $p \rightarrow p* + \gamma*$ is a normal interaction found for particles, which is a source for a static EM field. For the quadrupole polarizability the solution to the forced forbidden spontaneous de-excitation is different. The only solution would be that the hypothetical ground state have negative energy, i.e. the full reaction $p \rightarrow p* + \gamma$ is forbidden by energy conservation. This is an expected property of the nucleons as long as they not decay. The upper limit of proton decay is of the order of 10^{31} years, according to one of the best-measured upper limits on Earth. The reason this is expected comes from the properties of the internal structure of the proton. The internal structure through EM interaction consists of three charged quarks with no electric dipole moment. The electric structure then consist of two perfect aligned opposite dipoles. The opposite dipoles are capable of forming two photons, so that spontaneous de-excitation $p \rightarrow e^+ + 2\gamma$ would be possible if one assumes that lepton and baryon number could be exchanged.

A state with energy lower than zero is also found when expanding the instance of spontaneous de-excitation from photons only to photons plus mesons. The $\sigma_{I=2}$ meson has a mass square below 0. The spontaneous de-excitation would then be $p \rightarrow p* + \sigma$ instead of $p \rightarrow p* + \gamma$ but the σ would stay in place by the absence of energy available for kinetic energy separation of the meson and proton.

Identifying the Special EM Field

In this section we give criteria for the spin polarizability and the magnetic quadrupole polarizability to meet the condition $H_{eff} > 0$. In order to do so the

Nucleon	$\bar{\sigma} \cdot \left(\bar{E} \times \dot{\bar{E}} \right)$	$x = \dot{\bar{E}}/\bar{E}$ range (fm)
p	+	$x_T < -2 \; x_T > 4.5$
p	-	$x_T < -4.5 \; x_T > 2$
p	0	$x_L^2 > 0.11$
n	+	$3.1 < x_T < 44$
n	-	$-44 < x_T < -3.1$
n	0	-

Table 3: Ranges of $\dot{\bar{E}}/\bar{E}$ where the condition H_{eff} is fullfilled for the nucleons.

EM field condition may be divided in two parts. The first is when the system is an isolated $\gamma - N$ system. This is the case in which the polarizability constants are theoretically calculated: here, limits on the EM fields are dictated by the symmetry condition of the total wave function. The second part is when there exists at the same time an extra particle/ weak-coupled EM field, which would allow the full range and direction of each parameter. With the allowed full parameter range, there is one more important condition that has to be fulfilled. The $H_{eff} > 0$ condition has to be set for the full interaction, not just parts of the field.

Starting with the interaction with $\bar{E}$ and $\dot{\bar{E}}$ the full H_{eff} could be divided in two parts, either with $\dot{\bar{E}}$ aligned longitudinally or transversally to $\bar{E}$. Introducing the new paramter $x_{L,T} = \dot{\bar{E}}_{L,T}/\bar{E} \cdot \hat{\bar{E}}/\hat{\dot{\bar{E}}}$, two second order equation arise:

$$\alpha_{E1} \pm \gamma_{E1E1} x_T + \alpha_{E1\nu} x_T^2 \qquad (2)$$

$$\alpha_{E1} + \alpha_{E1\nu} x_L^2 \qquad (3)$$

where the $\pm$ sign depends on the direction of the nucleon spin vector compared to $\left(\bar{E} \times \dot{\bar{E}} \right)$. By solving the two second order equations, ranges of x where $H_{eff} > 0$ is fulfilled could be defined. The ranges are displayed in table 3 for the theoretical values of the polarizability constants.

For the magnetic field components $\bar{B}$ and $\dot{\bar{B}}$ the $H_{eff} > 0$ condition is never fullfilled. The condition on the polarizability constants to allow for this situation would be(with positive β_{M1}):

$$\frac{\gamma_{M1M1}^2}{4\beta_{M1\nu}} > \beta_{M1} \qquad (4)$$

which is not supported by the theoretical values from BχPT.

In the case of spin polarizability combined with electric quadrupoles, there is also no region where H_{eff} is larger than 0. The x parameter introduced here for a second order equation would be $x = \sigma_i H_j/E_{ij}$(with E and H changed for

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magnetic quadrupole), with the maximum for the spin polarizability part occuring when the magnetic field is completely in space dimension j. The condition for negative values is now:

$$\frac{6\gamma_{E2M1}^2}{\alpha_{E2}} > \beta_{M1} \tag{5}$$

which is not fullfilled for the theoretical values. For the magnetic quadrupole the negative sign of the magnetic polarizability constant changes the condition to allow for a large region. Defining E_j as $Esin\theta$(with θ the angle between dimension j and the plane defined by i and k) gives the second order equation:

$$\beta_{M2}/6 + 2sin\theta\gamma_{E1M2}x + x^2\alpha_1 \tag{6}$$

The condition for having H_{eff}=0 values are fullfilled by:

$$\frac{6\gamma_{E1M2}^2}{\beta_{M2}}sin\theta = \alpha_{E1} \tag{7}$$

For θ above this value, an unwanted $H_{eff} < 0$ region exist within the solutions to the second order equation.

The three conditions for $H_{eff} > 0$ is therefore a center of a magnetic quadrupole(eq. 6) which also allows for a weak electric field and two ranges from the parameter $\dot{\bar{E}}_{L,T}/\bar{E}$(eq. 2 and 3).
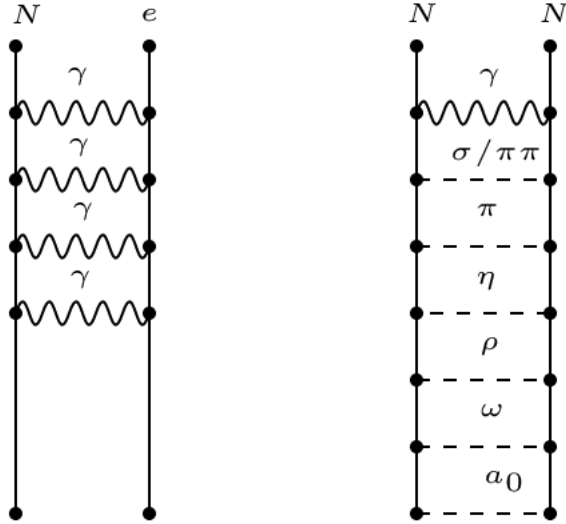
Figure 1: Left: The polarizability is the interaction of a nucleon with one or many, real or virtual photons. Here with an electron as the source of the photons. Right: Besides the photon nucleon-nucleon interaction also includes mesons.

Polarizability and nucleon-nucleon interactions

Since polarizability is a temporary interaction state extracting energy out of the nucleon, the state is therefore also temporary. Permanent energy extraction out of nucleons could be found in fusion of nucleons into nuclides (and transfer of nucleon between nuclides). Therefore, to make the temporary energy extraction permanent, one needs to move the polarizability interaction into nucleon-nucleon interaction. To do this, a link between nucleon- nucleon interaction and γ/e-nucleon interaction has to be established, to see that the polarizability interaction sets the nucleon in the same state it has when it is bound in a nuclide.

Figure 1 visualizes the difference between polarizability and nucleon-nucleon interaction in terms of exchange particles. To establish a link between the two, one has to introduce meson-photon couplings. This is, for example, used in hadronic light by light scattering and Primakoff effect. However, since the goal is the binding interaction, the interaction particle with a source in the nucleon should not be a photon but a σ. Figure 2 shows a comparision of Primakoff and $\gamma - \sigma - N$ interaction. The link is established by finding an alignment in the two types of interaction due to states with the same quantum numbers, i.e. parity, spin and charge should be conserved. Nucleon-nucleon interaction is suppressed or enhanced compared to polarizability, depending on the extra coupling constants between the mesons and the photon.
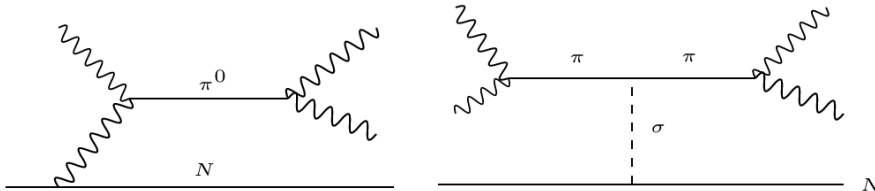
Figure 2: Left: Primakoff effect. Right: Instead of having a photon from the nucleon, a σ meson is between the nucleon and the photons. Here with pions in-between, even if direct photon σ interaction exist.

A second motivation for the link is to establish a space range of polarizability. If polarizability uses the exchange particles of the strong force(which is motivated by the absence of spin polarizability in a classical EM field), one would expect the interaction range to be similar to that of the strong force.

From the first attempt to accomplish the Yukawa nucleon-nucleon interaction [11] using a pion as a heavy exchange particle, the best known today nucleon-nucleon interactions are obtained by using quantum Monte Carlo methods [12]. The operators used there are not only meson exchange but also Δ baryons. 2N and 3N forces with more than one exchange particle are included and fitting is done by the Monte Carlo method. Each term in the Hamiltonian is a multiplication of operators including space, spin, isospin, and orbits of the nucleons with a fitted coupling strength. The polarizability binding link for these operators is found; it is equal to the one corresponding to the exchange that gives $H_{eff} > 0$ for polarizability and a binding term in the Hamiltonian of the N-N interaction. Other interaction models exist, for example the Bonn model[13] is further described with one boson exchange, and links each operator with a meson exchange. In this model the fitted parameters are coupling constants for each meson instead of each operator set.

The condition $H_{eff} > 0$ from polarizability is met for the magnetic quadrupole polarizability when magnets are opposite and separated on the z axis. In operator form this means that $\bar{s} \cdot \bar{r}$ is nonzero. A match for the binding polarizability constants are the tensor and spin orbit operators. In the tensor operator the scalar product of space and total spin is non zero. The operator used is $S_{12} = 2 \left(\frac{3(\bar{s} \cdot \bar{r})}{r^2} - \bar{s} \cdot \bar{s} \right)$ which in a one boson exchange model corresponds to η exchange. S_{12} is non zero only when the spin-spin couplings are in triplet state; a magnetic quadrupole is then only present when s_z is opposite. The second operator is the spin orbit coupling L*S which corresponds to σ meson exchange. This operator could have a back-to-back magnet with one of the magnets coming from the spin and the other from the orbit. It is notable that the σ meson is not a well-established particle, and that this interaction is usually described as an s-wave scattering of two pions. For the binding terms of dispersive polarizability the operator needs to include a time operator. That is also found in

spin orbit coupling since the L terms include a time derivative.

Long-range strong force

Putting a nucleon in the special EM condition $H_{eff} > 0$ could extract energy out of it but the effect is only temporary. When the nucleon gets out of place in a normal neutral EM environment, polarizability would absorb energy by scalar polarizability up to the ground state. To transfer nucleons over a long-range, a long-range potential of the strong force has to be established.

A less probable alternative to the long-range potential is if the e-N coupling in the special EM field environment would create a strong enough binding to compare an electron with a full nuclide. In this hypothesis, no constraints on the target nuclide are set, and nucleon transition to excited states in the target nuclide should be possible.

In other words these two views deals with the electrons role. One is as a carrier of the nucleon and the other is as a trigger for a long-range potential of the nucleon. The motivation for the second case is visualized in figure 3. A de-exitation $N* \rightarrow N + \gamma$ would require an internal EM oscillation motion in N*. This oscillation would only occure if the transfered nucleon would hit the target nuclide outside the center of mass. Examples of the special potential are found in figure 4 where the example potential with a $\bar{s} \cdot \bar{r}$ term enhances the chance for a central hit, while the example potential x=0 and y=0 only allows for a direct hit. A line potential is formed from when a dot and crossproduct is combined like in the case $\sigma \cdot \left(\bar{E} \times \dot{E} \right)$ and $\sigma \cdot \left(\bar{B} \times \dot{B} \right)$ that could be found in polarizability.

The nucleon-nucleon interaction is short-ranged because of massive exchange particles. The basic short range from Yukawa one-pion exchange potential[11] is given(without spin and isospin dependency) by:

$$\frac{g}{4\pi} \frac{e^{-m_\pi r}}{r}$$

where m_π is the pion mass and g is a Yukawa coupling. This is to be compared to the electromagnetic potential:

$$\frac{q}{4\pi} \frac{e^{-m_\gamma r}}{r}$$

where q is the charge of the source particle and $m_\gamma = 0$ gives the Coulomb potential with space dependency of $1/r$.

A long-range strong force is found if an exchange particle has a mass, or rather a squared mass, equal or less than the photon mass:

$$m^2 \leq m_\gamma^2$$

Notable here is that the mass should only be used in a system where the total mass is positive, i.e. as a particle exchange term in a total two particle
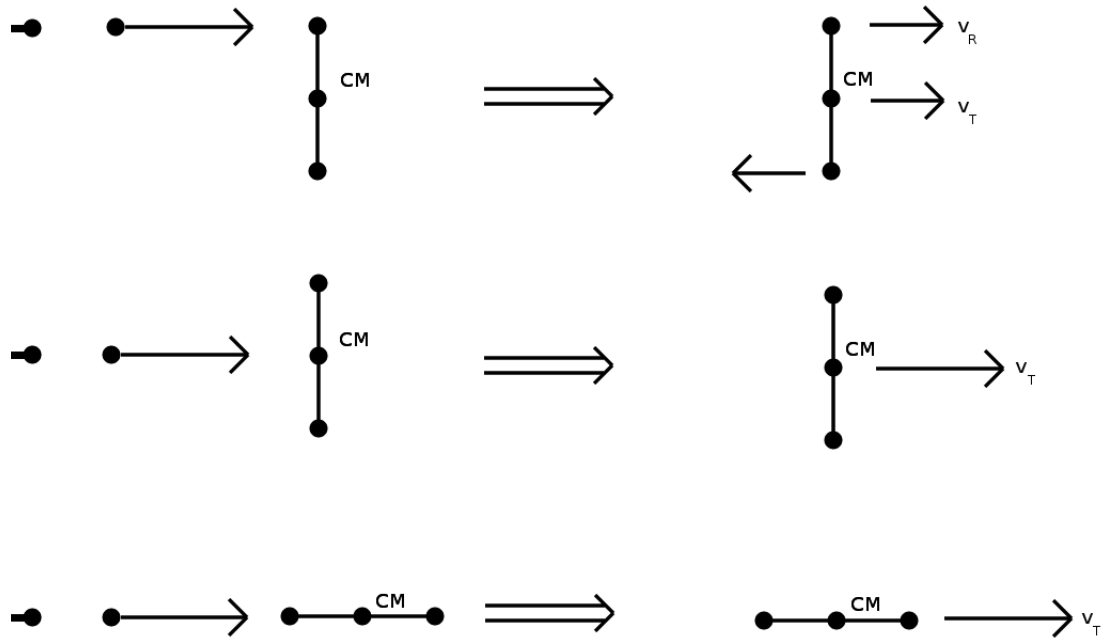
Figure 3: When two particles fuse to one, and the target has internal structure, a hit at the center of mass would create translation motion only, while a not direct hit would create both translation and circular motion. Note that in order to conserve energy and momentum a source particle must be present to avoid the creation of a new particle.
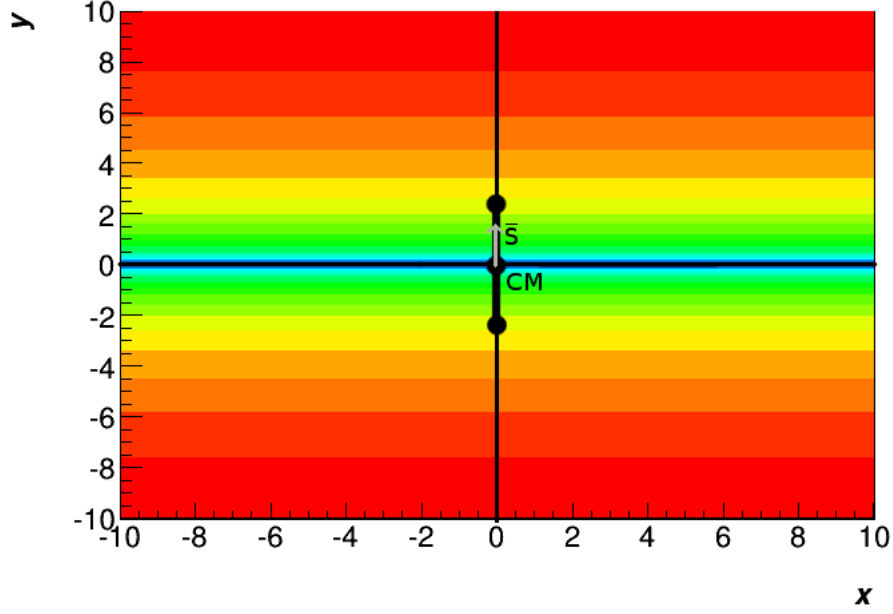
Figure 4: x-y view of a potential formed by $\bar{s} \cdot \bar{r}$ with $\bar{s}$ on the y axis together with line potentials x=0 and y=0(black lines).

system. Such a meson is found in $\pi\pi$ s-wave scattering in the isospin 2 channel. In nucleon-nucleon interaction $\pi\pi$ s-waves are found in 3N forces. The pion s-wave from the Illinois model is not accurate and only a plausible 1MeV size strength is included, but it is needed to explain energy levels of light nuclides. To move to the one boson exchange Bonn model the σ exchange potential is there given by:

$$V_{NN}^{(\sigma)}(r) = \int \frac{d^3q}{(2\pi)^3} e^{iqr} \frac{g_{\sigma NN}^2}{-q^2 - m_\sigma^2} = -\frac{g_{\sigma NN}^2}{4\pi} \frac{e^{-m_\sigma r}}{r}$$

The theory of $\pi\pi$ scattering may be found in [14]. This paper uses both fixed-t dispersion and χPT as seen in $B\chi$PT polarizability theory. In $\pi\pi$ scattering the σ mass is related to scattering phase shifts. The phase shift equation is [15]:

$$tan\delta_l^I = \sqrt{1 - \frac{4m_\pi^2}{s}} q^{2l} \left\{ A_l^I + B_l^I q^2 + C_l^I q^4 + D_l^{\hat{I}} q^6 \right\} \left(\frac{4m_\pi^2 - s_l^I}{s - s_l^I} \right)$$

where q is the momentum transfer of the scattering pion, A...D are constants, l gives spin and I isospin channel. The kinematic variable s is given by $s = 4m_\pi^2 + q^2$ and s_l^I specifies where δ passes through 90°. At lowest order the A constants equal the s-wave scattering length $a_0^0 = 0.22$ and $a_0^2 = -0.044$ [15]. The negative sign of a_0^2 is what gives the necessary $m^2 \le m_\gamma^2$ relation. The parameter s_l^I is given by $s_0^0 = 36.77m_\pi^2$, $s_1^1 = 30.72m_\pi^2$ and $s_0^2 = -21.62m_\pi^2$.

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The isospin 1 channel is isolated in a L=1 state by Dirac motivation of a total antisymmetric wave function, and this pole corresponds to the ρ meson. Since isospin is not a perfect symmetry the L=0 channel is mixed and σ exchange in nucleon nucleon interaction includes both I=0 and I=2 σ mesons. The m_σ used in the Bonn model is 550 MeV while s_0^0 gives a mass at 844 MeV. Assuming an equal mix of $\sigma_{I=2}$ and $\sigma_{I=0}$ in $NN\sigma$ coupling gives the more correct mass of m_σ =543 MeV.

To create a pure potential with $\sigma_{I=2}$ meson only the $\sigma_{I=0}$ has to be absorbed. Since the electron does not have an isospin component, e-N binding through nucleon polarizability is reducing the $\sigma_{I=0}$ part of the mixed σ exchange meson. To get a size of the free $\sigma_{I=2}$ interaction one could start with γ-vector meson couplings. In the quark model the coupling ratio is given by $g_{\omega\gamma} = 3g_{\rho\gamma}$ and $g_{\phi\gamma} = -\frac{3}{\sqrt{2}}g_{\rho\gamma}$. Assuming that two vector mesons are the strongest part of pion coupling, one gets a factor of two, while σ from $\pi\pi$ scattering is also a factor of 2. The total enhancement of $\sigma_{I=2}$ potential in e-N coupling is a factor of $(g_{\omega\gamma}/g_{\rho\gamma})^4$, i.e. $3^4 = 81$. Using this suppression and assuming equal mix of isospin states, the σ mass becomes virtual with the value $-im_\sigma = 642$ MeV. The σ exchange s-wave scattering then changes the exponential term to an oscillating one. Since the mass(square) of $\sigma_{I=2}$ is negative and the total mass of the nucleon should be positive and given by the sum of scalar particles, the potential is directed straight into the center of mass of the nucleon.

Since isospin comes with direction I_z that equals charge($q = 1/2 - I_Z$), the type of $\sigma_{I=2}$ matters for the potential. Proton has $I_Z = +1/2$ and neutron $I_Z = -1/2$ while Δ has $I_z = \pm 3/2$ and $I_z = \pm 1/2$ depending on the charge . From opposite attract properties of the potentials, protons are attracted to potentials created by neutrons and neutrons to potentials created by protons. To create a full $\sigma_{I=2}$ meson $N\Delta e$ is enhanced, compared to NNe where the Δ comes from the 3N force i.e. 3N-e interaction is most probable needed. In full 4N ground state clusters the N-N potential fulfills the binding polarizability conditions and e/γ-N interaction can not extract energy. This leaves 1 hole nuclides as the only source of $\sigma_{I=2}$ long range potentials. Examples of isotopes are ^7Li, ^{27}Al and in the case of attractive 3 neutron cluster ^{61}Ni. Since most free 3N states have 2 neutrons and 1 proton (except ^3He) the majority of $\sigma_{I=2}$ potentials are attractive to protons. Neutron attractive $\sigma_{I=2}$ potentials could be formed if a proton transfer does not form a perfect 4N state. For example the reaction Ni+p* with p* from manganese or lithium would give a copper isotope below the ground state. Such a reaction would still be possible as a temporary unstable state with the aid of a proton attractive $\sigma_{I=2}$ potential from for example a 3N cluster in ^{27}Al. Neutron transfer should be stronger compared to proton transfer since there is no Coulomb repulsion between the proton and the target nuclide.

Energy distribution between electron and nuclides

The ideas for energy release in this paper are so far two. Polarizability interaction requires kinetic energy to be shared between an electron (or more) and a nuclide i.e. $E_{rel} = E_k\left(e^-\right) + E_k\left(N_{source}\right)$, while nucleon transfer between nuclide N_1 and N_2 to nuclide N_3 and N_4, suggests that the mass difference between the start and final nuclides are shared between the two nuclides. From the center of mass source of the long range potential only kinetic energy is created i.e. $E_{rel} = E_k\left(N_3\right) + E_k\left(N_4\right)$. A mix between the two are expected i.e.:

$$E_{rel} = E\left(N_1 + N_2\right) - E\left(N_3 + N_4\right) = E_k\left(e^-\right) + E_k\left(N_3\right) + E_k\left(N_4\right) \qquad (8)$$

There is no experimental data to set any numbers into this equation. In the case that the electron works as a pure trigger the condition $E_k\left(e^-\right) = 0$ is fullfilled. The condition $E_k\left(N_1\right) + E_k\left(N_2\right) = 0$ is less probable since this would require a spot on energy release from the electron nuclide polarizability interaction.

Creating the special EM field

Before the $\sigma_{I=2}$ potential has been established the special EM fields has to come from short range interaction by the link to nucleon-nucleon interaction. The source of the fields is then enhanced by atomic sources over external fields. The best source are S-state electrons since they have an non-zero component of the wave function at r=0.

The two polarizability conditions have various sources. The ranges from $x_T = \dot{\bar{E}}_T/\bar{E}$ are fullfilled for an electron orbiting the nucleon in an circular motion. This is because in a perfect circular motion $\dot{\bar{E}}_T$ is constant and always perpendicular compared to $\bar{E}$. However the x_T ranges are above 1 fm(approximately the radius of the circular motion), and atomic sources would have a radius of 1Å. Here we propose three theoretical ideas to overcome this problem. The first one is to use high pressure to shrink the atoms to a small enough size. The second is to use a current. For a nuclide with a nucleon that has a stable distance to the charge center, the S-state electrons would temporarily be viewed as a part of a rotation when passed through the charge center. However, the part circular motion is opposite when the electron passes through the next time in the oscillating motion. But if the electron motion were a current following the S-state path, the return part of the oscillation would never be fulfilled. The third option is when the relative direction between the nucleon and the charge center of the nuclide oscillates with the same speed as the S-state oscillation.

For magnetic quadrupole polarizability, the electron alone can not form a quadrupole, which means that an external magnetic field would be needed. To

have a quadrupole would require that the magnetic moment of the electrons were opposite to the magnetic field. But since this is a higher energy state that is less probable. To enhance this state, two solutions exist. The first is to set the temperature to an energy where the upper energy state would be more probable. The second solution is to set the the atom in an external magnetic quadrupole. By placing the nuclide just outside the center, the electron would set the lower state in the opposite magnetic field in the far point, and be in the higher energy state when close to the nuclide. Another condition for energy extraction by magnetic quadrupole polarizability is that the electron must be in a single state to be able to spin flip. Suitable elements that are naturally in 1S states are the alkali and coin metals. In addition, other metals could be in 1S states, including nickel, platinum, niobium, molybdenum, ruthenium, rhodium, and chromium.

Comparision between theory and experiment

The experiment described in appendix has both weak and strong links to the theory. The weaker links are basically the atomic source theory. Since no detailed study in varying the atomic structure properties has been carried out, only arguments drawn by the electrical current, and chemical composition may be drawn.

The single S-state condition motivates the presence of the elements nickel, lithium and hydrogen. The current solution of $\left(\bar{E} \times \dot{\bar{E}}\right)$ matches the required presence of current in the experiment. It also matches the charge-neutral plasma observation. This is because the $\sigma \cdot \left(\bar{E} \times \dot{\bar{E}}\right)$ condition would be positive at half the time if σ alignment was random thus enhancing 50% of the current to induce kinetic energy for the heavy ions. The stronger links are found for the isotopic shifts. The proposed mechanism has already been presented in the long-range strong force part.

Also the existance of a plasma indicates that the positive ions should have a sizeable kinetic energy to overcome the air gap barrier in the starting phase. This requires a non zero part of the nuclide kinetic energy in 8 and motivates the existance of the $\sigma_{I=2}$ potentiall.

Summary and discussion

The aim of the theoretical parts of this paper was to answer two questions:

- How to extract energy without strong radiation.

- How to effect this over a long range.

The answer was done in brief, first comparing photon-meson interaction in polarizability with nucleon-nucleon interaction; secondly to use a process similar to the Primakoff effect with a σ meson replacing the pion. The advantage with the σ meson over the pion is that the scalar meson is included in the strongest

part of the strong force. The idea is no stranger than that of Cooper pairs in superconductivity, where a pair of electrons, which initially would repel each other, display an attractive interaction due to the special EM-field conditions that are created by the lattice between them.

For the polarizability part, ranges where the free nucleon is transformed into a special state with the energy of a bound one were found by searching for the condition $H_{eff} > 0$ for theoretical and experimental polarizability constants. The polarizability interaction only answers the first question and for the second question two special electron nucleon interaction where introduced. Either the special EM fields could create an enviroment where the electron could carry a nucleon or one where the electron triggered a special long range potential of the strong force from the nucleon. The second solution is favourable due to the fact that the first would still create some radiation and hence not be able to answer the first question.

Discussion The polarizabilty parameters needed are not known from experiment except for the spin polarizability constants. The long-range strong force that arises from the $\sigma_{I=2}$ meson is an interesting new part of the strong force that seems to be necessary to explain the experimental data but is not completely needed for the polarizability part. This long range potential is also unknown, both in detailed theory and experiment. To extract those constants experimentally, a theoretical means would be to use $\pi\pi$-lepton scattering with a measurement of nucleon properties in a nearby region. Practically, whether a pion beam with high enough luminosity as well as the means to construct it are possible is questionable. It is also plausible that the isospin mixing of the σ is a property only found in baryons, as a cause or a consequence of baryon number conservation.

Open questions that calls for future experimentation are:

- Is the main source spin polarizability, magnetic quadrupole polarizability or both?

- Is the long-range problem solved by e-N meson interaction or $\sigma_{I=2}$ enhanced exchange potential?

- What is the neccesary atomic states for creating the special EM fields?

- What is the relation $E_k(e^-)$ vs. $\sum E_k(N)$?

Experimental methods that could be used to solve those questions are:

- An isotopic analysis of silicon and chromium isotopes in the ash, in order to obtain a solid confirmation of proton transfer.

- Measuring helium output.

- Energy output variation by changing current and pressure.

- A beta spectrum probed inside the nickel.

- More probable chemical elements in the fuel for example all alkli metals.

Appendix

Experiment

The experimental inputs have two sources: one is isotopic shifts observed in the experiments performed in Lugano[2] and by Parkhomov[3]; the other source is the observation of an energy emitting charge-neutral plasma with current running through it observed in two different experimental setups, one with energy measured from the spectral maximum of the plasma and the other from a fluid heat exchange measuring system.
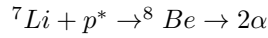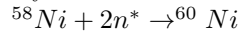
Isotopic shifts

Starting with the isotopic shifts, what is noteworthy is that most stable nucleons have a ground state of 0^+, and that all seen final state nucleons are of this state. The main reaction observed are:
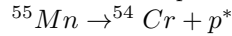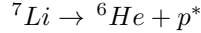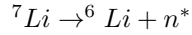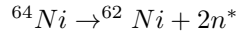
$^{62-x}Ni + xn^* \rightarrow^{62} Ni$

$^{27}Al + p^* \rightarrow^{28} Si$
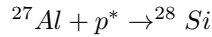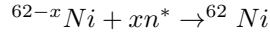
where p^* and n^* mean a bound nucleon, the source of which is in another nuclide. Noteable are that the $^{27}Al + p^*$ reaction only is validated by chemical observation. Other possible reactions that would be feasable within the same theory are:

$^{58}Ni + 2n^* \rightarrow^{60} Ni$

$^7Li + p^* \rightarrow^8 Be \rightarrow 2\alpha$

The main sources of the bound nucleons are:

$^{64}Ni \rightarrow^{62} Ni + 2n^*$

$^7Li \rightarrow^6 Li + n^*$

$^7Li \rightarrow {}^6He + p^*$

$^{55}Mn \rightarrow^{54} Cr + p^*$

The last reaction has only been observed by chemical identification.

Experiment with energy measurement done with a spectrometer

Description of the apparatus:

The circuit of the apparatus consists of a power source supplying direct current, a 1-Ohm resistor load, and a reactor containing two nickel rods with LiAlH4 separated by 1.5 cm of space.

Measurements:

During the test, a direct current was switched on and off. When the current was switched on, a plasma was seen flowing between the two nickel rods. The current was running through the plasma but the plasma was found to be charge-neutral from a Van de Graaff test. This implies that the plasma has an equal amount of positive ions flying in the direction of the current and negative ions(electrons) in the opposite direction.

Input: 0.105 V of direct current over a 1 Ohm resistance.

Energy output: The wavelength of the radiations from the reactor was measured with a spectrometer (Stellar Net spectrometer 350-1150 nm) and was integrated with the value of 1100 nm (1.1 microns).

The temperature of the surface of the reactor (a perfect black body) was calculated with Wien's equation: $2900/\lambda$ (micron) $= 2900/1.1 = 2636$ K

As per Boltzmann's equation, the effect is: $W = \sigma \times \epsilon \times T^4 \times A$

A $= 1.0 \; cm^2$

$\epsilon = 0.9$

By substitution: $W = 5,67 \times 10^{12} \times 0.9 \times 4.8 \times 10^{13} = 244.9$

Experiment with energy measurement done with a heat exchanger

The system is displayed in figure 5. In the figure, the yellow thermometer measures the temperature of the oil inside the heat exchanger. In the left in the figure there are two voltmeters that measure the mV of the current passing through the 1 Ohm brown resistance. In order to not burn the equipmet, the experiment was set in a state with lower output power.

Calculations of the calorimetry made by the heat exchanger:

efficiency of the heat exchanger:90%

Primary heat exchange fluid: lubricant oil (Shell mineral oil)

Characteristics of the lubricant oil: D = 0.9 Specific Heat: 0.5

Calorimetric data of the fluid: 0,5 Kcal/h = 0.57 Wh/h

Flow heating: 1.58 C / 1.8" x 11 g

Resulting rating: 20 Wh/h
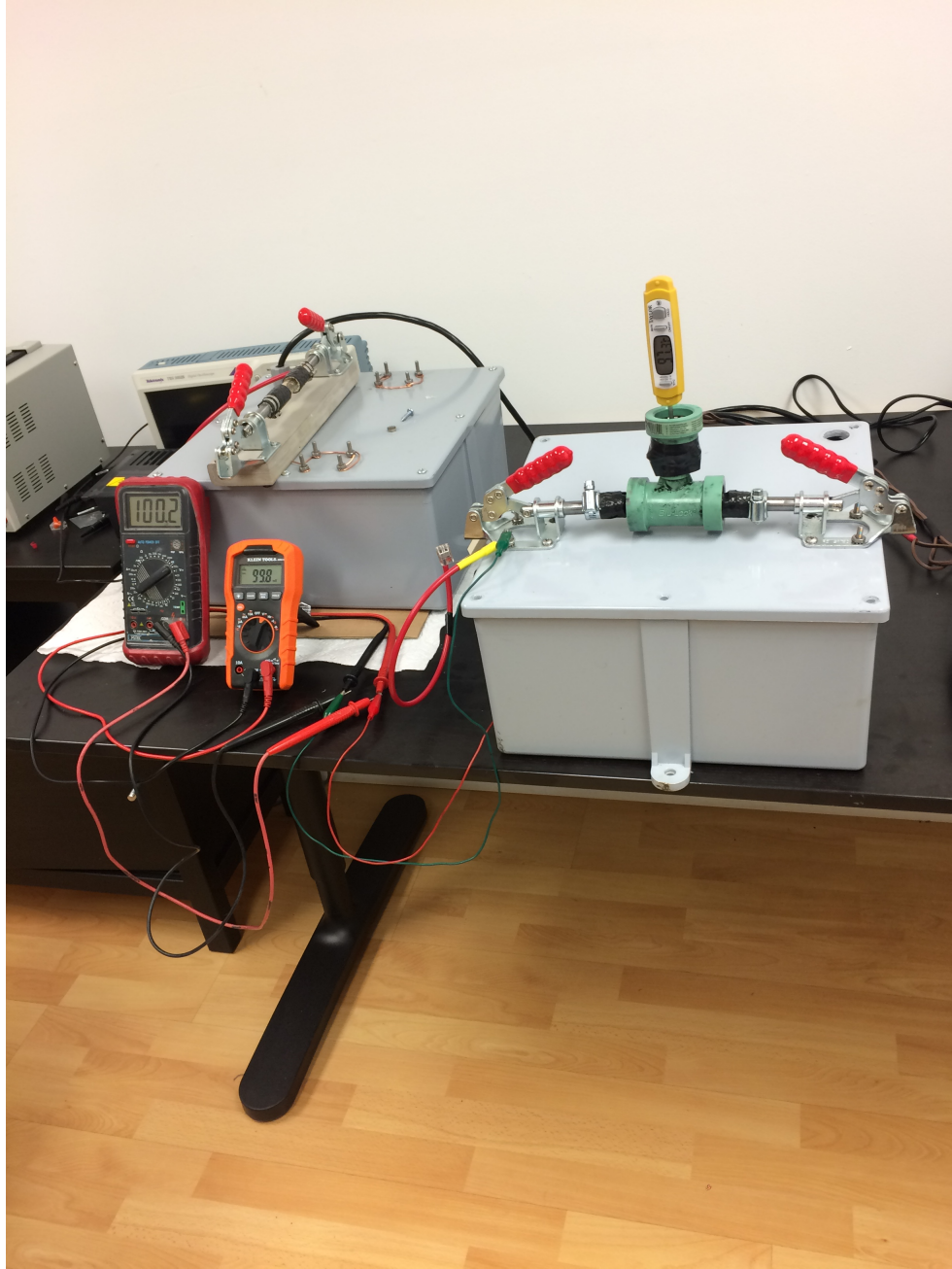
Energy input: V=0.1 R=1 Ohm $\rightarrow$ W=0.01

Figure 5: Experimental setup with energy measured by a heat exchanger.

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