# Comparison of the ground-state properties of $^{24}$Mg generated with soft-core Gaussian and Yukawa like NN-potentials

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## Introduction

Heavy-ion collision calculations in classical microscopic approaches require an NN-potential and the configuration of the nucleon positions in the ground-state of the colliding nuclei as initial conditions [1-7]. Thus, a proper ground-state configuration of the colliding nuclei and the form of the NN-Potential is very important in heavy-ion collision studies. The study of the dependence of the ground-state properties of the nuclear configurations generated using the "STATIC" code [1] on the soft-core Gaussian form and the Yukawa form of the NN-potential is presented [8].

## Calculational Details

A soft-core Gaussian form of NN potential given by

$$V_{ij}(r_{ij}) = -V_0\left(1-\frac{C}{r_{ij}}\right)\exp\left(-\frac{r_{ij}^2}{r_0^2}\right) \qquad \ldots (1)$$

along with the usual Coulomb interaction has been extensively used in heavy-ion fusion studies [2-6].

We now consider a Yukawa like potential which has an exponential form rather than the Gaussian form. This potential is given by eq. (2),

$$V_{ij}(r_{ij}) = -V_0\left(1-\frac{c}{r_{ij}}\right)\frac{\exp\left(-r_{ij}/r_0\right)}{r_{ij}} \qquad \ldots (2)$$

Soft-core Gaussian potential (eq.1) approaches zero very fast at large nucleon-nucleon separations, while the Yukawa like potential (eq.2) goes to zero slowly at large distances. For the sake of a comparison between the soft-core Gaussian potential (eq. 1) and the Yukawa potential (eq. 2), we chose the parameter set P4 [4] of the soft-core Gaussian potential as a reference. We adjust the parameters of the Yukawa type potential (eq. 2) to match the over all features of the potential P4 (eq. 1).

## Results and Discussion

Choosing the value of the range parameter of the Yukawa like potential to be about 0.3 fm, value of $V_0$ and C is adjusted such that depth of the potential minimum, and the location of this minimum matches with that of the potential P4 of the soft-core Gaussian potential. The values of these potential parameters for the two potentials are given in Table 1.

**Table 1:** Potential parameters set P4 for soft-core Gaussian potential & Y03 for Yukawa type potential.

| parameter set | $V_0$ (MeV) | C (fm) | $r_0$ (fm) |
|---|---|---|---|
| P4 | 1155.0 | 2.07 | 1.2 |
| Y03 | 167690.0 | 2.103 | 0.3 |

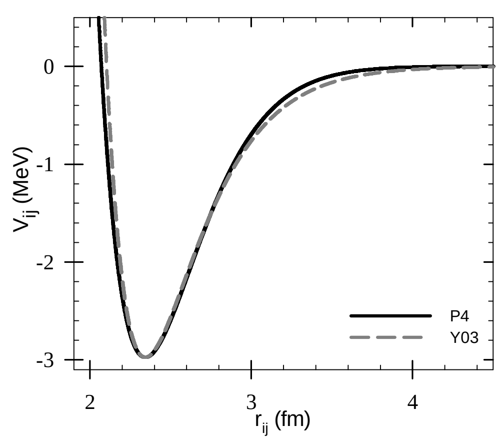


**Fig. 1:** Comparison of the two NN-potentials.

Yukawa-type potential with parameters given in Table 1 is compared with the soft-core Gaussian potential with parameters P4 in fig. 1. Using the above potentials we generate ground-state configurations of $^{24}$Mg, as an example, with a large number of initially random configurations using the STATIC program [1]. Calculated ground-state properties of $^{24}Mg$ for these configurations with Yukawa-type potential (Y03) are shown in figs. (2-4) (as grey points) and are compared with those obtained with the soft-core Gaussian potential P4 (shown as black points). Fig. 2 shows the comparison of the distribution of binding energy (BE) versus rms radius ($R_{rms}$) obtained with both the potentials with the parameter given in the Table 1.

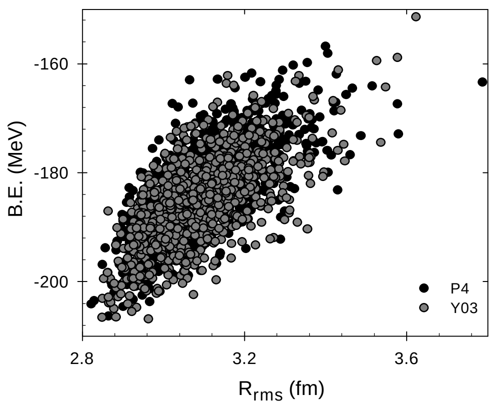


**Fig. 2:** Calculated BE and rms radius for $^{24}Mg$.

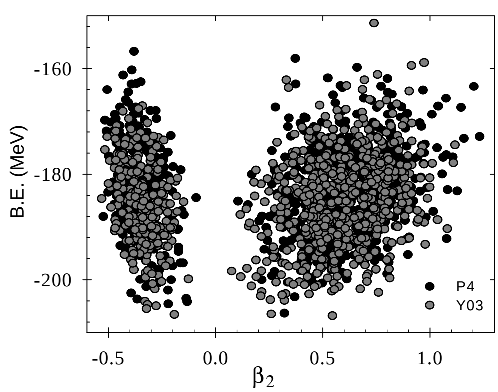


**Fig. 3:** Calculated BE and $ß_2$ for $^{24}Mg$.

Fig. 3 shows the comparison of distribution of binding energy (BE) versus deformation parameter ($ß_2$) obtained in the case of the two potentials. Fig. 4 shows the comparison of rms radius ($R_{rms}$) versus deformation parameter ($ß_2$) with the two potentials.

The distributions of the ground-state properties calculated with both the potentials almost match with each other. The two potentials match at distances near the core-radius; at the location of potential minimum, and at small distances larger than $r_{min}$. The two potentials are only slightly different from each other for 3.0 fm = $r_{ij}$ = 4.0 fm (fig. 1) because of the form of the potential. We can, therefore, conclude that so far as the values of the NN-potential in the vicinity of the potential minimum match with each other, the form of the NN-potential whether it is exponential or Gaussian does not seem to be important for the calculated ground-state properties like binding energy, rms radius and deformation parameter $ß_2$.

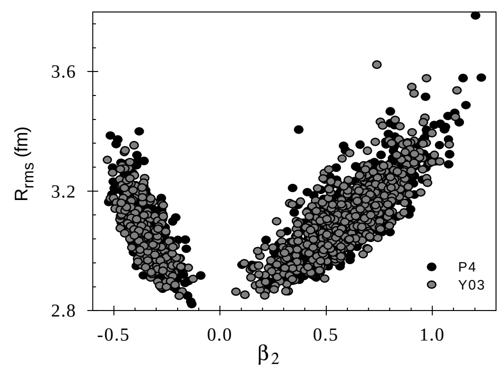


**Fig. 4:** Calculated rms radius and $ß_2$ for $^{24}Mg$.

## References

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