INDIVIDUAL DIPOLE TOROIDAL STATES IN ^{58}NI

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Introduction

In early $(e, e^{'})$ DALINAC experiments for spherical ^{58}Ni [1,2], there were observed 8.24-MeV and 10.04-MeV states with enhanced transversal form factors. These states were initially assigned as magnetic 1^{+} and 2^{-} excitations. However, later 1^{-} states in this energy range were discovered.

Our goal: to investigate low-energy states in Ni at the microscopic level

Calculation scheme

The calculation was made as part of a self-consistent QRPA (quasiparticle random phase approximation) [3]. Skyrme forces [4-6] ($SVmas10$, $SVbas$, $SLy6$, $SkM*$) were used. E1-transition is defined as:

$$B_X(E1,\nu) = \sum_{\mu=0,\pm1} |<\nu|\hat{M}_X(E1\mu)|0>|^2$$

where $X = IV$ isovector dipole, $X = tor$ vortical toroidal, $X = com$ compressional transitions.

The matrix elements read [7]

$$<\nu|\hat{M}_{IV}(E1\mu)|0> = e\sum_{q=p,n} e^{IV,q}_{eff}\int d^3r r Y_{1\mu}\delta\rho^{\nu}_q,$$

$$<\nu|\hat{M}_{tor}(E1\mu)|0> = \frac{-e}{10\sqrt{2}c}\int d^3r r[r^2+d^s]Y_{11\mu}\cdot(\nabla\times\delta j^{\nu}(\mathbf{r})),$$

$$<\nu|\hat{M}_{com}(E1\mu)|0> = \frac{-ie}{10c}\int d^3r r[r^2+d^s]Y_{1\mu}\cdot(\nabla\cdot\delta j^{\nu}(\mathbf{r})).$$

Coulumb and transverse form factors read

$$F^C_{E\lambda} = \sqrt{2\lambda+1}\int_0^{\infty} dr r^2\delta\rho^{\nu}_{\lambda}j_{\lambda}(qr)$$

$$F^T_{E\lambda} = \frac{1}{c}\int_0^{\infty} dr r^2[\sqrt{\lambda+1}\delta J^{\nu}_{\lambda,\lambda-1}(r)j_{\lambda-1}(qr) - \sqrt{\lambda}\delta J^{\nu}_{\lambda,\lambda+1}(r)j_{\lambda+1}(qr)$$

where $j_l(qr)$ are spherical Bessel functions and $\delta J^{\nu}_{\lambda,\lambda+1}$ are radial components of the CTD currents.

Result and discussion

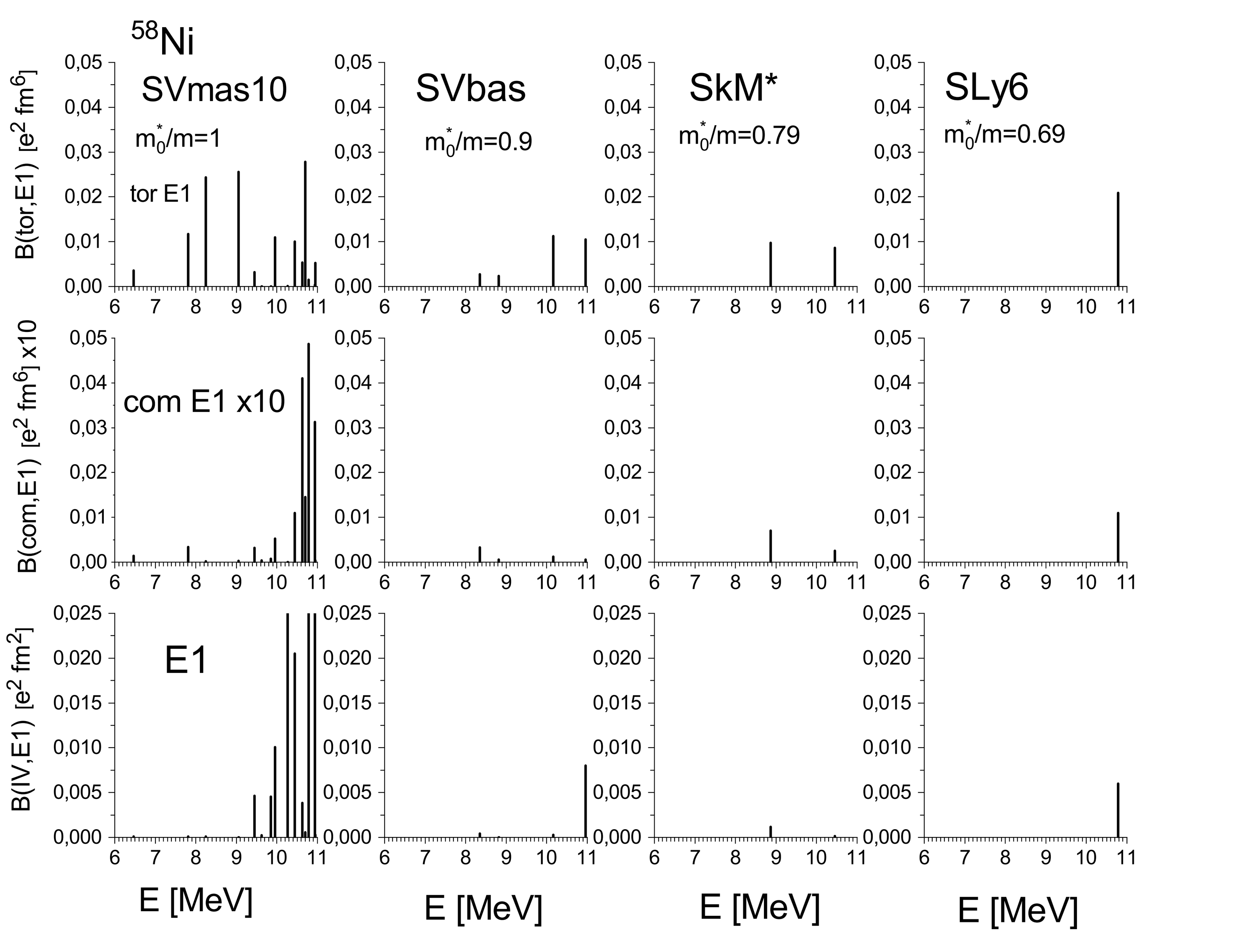

Figure 1. IS toroidal (upper plots), IS compression (middle plots) and IV (bottom plots) E1 strengths for separate QRPA states in ^{58}Ni, calculated with the Skyrme forces

In the upper and middle panels of Fig. 1, we show IS QRPA toroidal and compression dipole strengths for the separate QRPA states at 6-11 MeV. For all four Skyrme forces, Fig. 1 shows the strong dominance of the toroidal response over the compression one.

Form factors and Cross sections

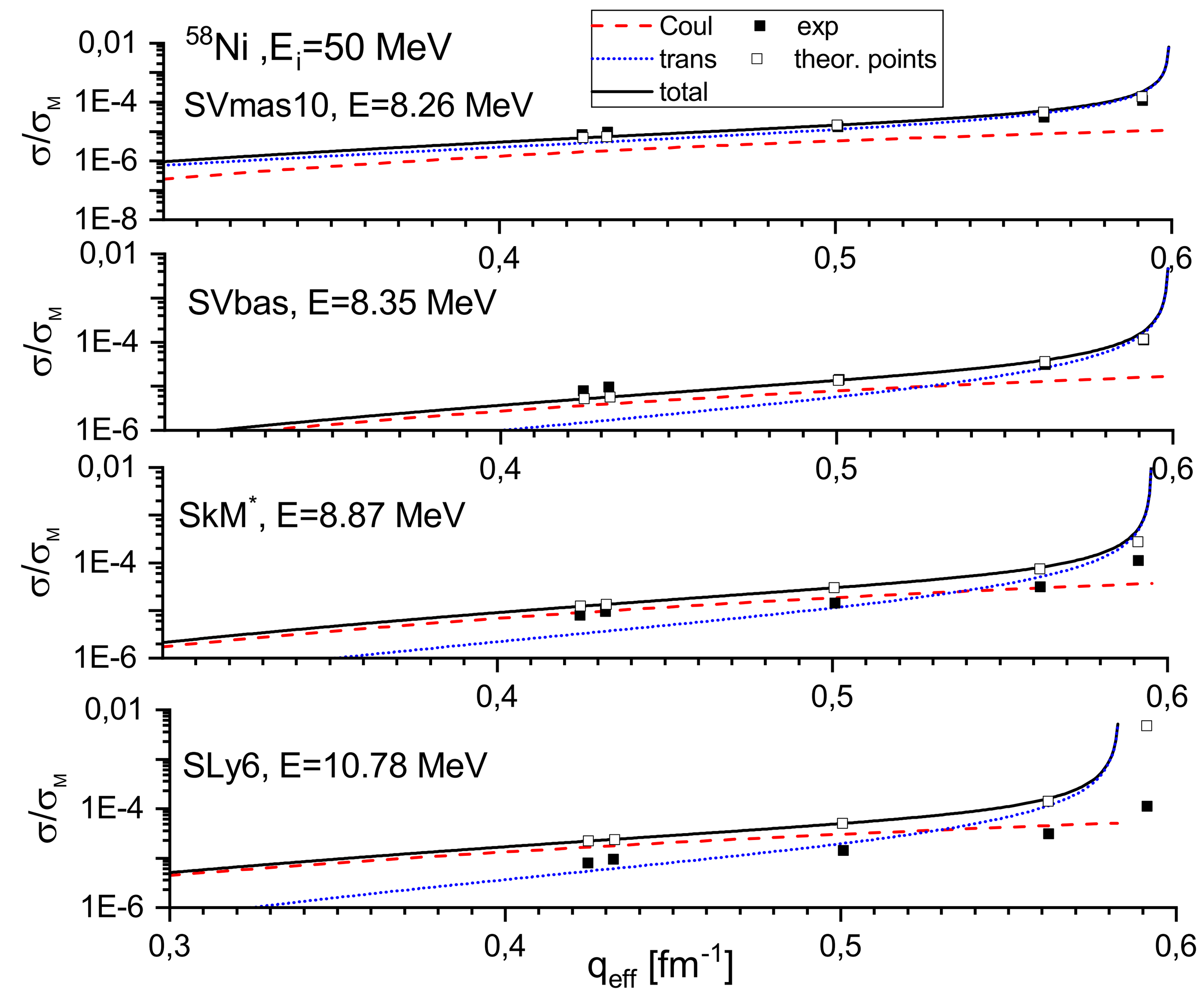

Figure 2. The normalized cross section for the lowest dipole state in ^{58}Ni, calculated with the forces $SVmas10$, $SVbas$, SkM^* and $SLy6$.

The Fig. 2 shows that the best agreement with the experiment is obtained for $SVmas10$ and $SVbas$. In particular, the increasing grow of cross section at large q_{eff} is well reproduced. The force SkM^* gives a bit worse but generally reasonable description. The worst result is obtained for $SLy6$.

Conclusion

This study is the first prediction of separate toroidal states in spherical nuclei, confirmed by detailed calculations. Namely, 1^{-} state at 6.18, 8.24 and 10.04 MeV in ^{58}Ni can be toroidal. The present result supplements prediction of individual toroidal states in light deformed nuclei

References

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