Cranked relativistic Hartree-Bogoliubov theory:
Superdeformation in the $A \sim 190$ mass region

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A systematic investigation of the yrast superdeformed (SD) rotational bands in even-even nuclei of the $A \sim 190$ mass region has been performed within the framework of the cranked relativistic Hartree-Bogoliubov theory. The particle-hole channel of this theory is treated fully relativistically, while a finite range two-body force of Gogny type is used in the particle-particle (pairing) channel. Using the well-established parameter sets NL1 for the Lagrangian and D1S for the Gogny force, very good description of experimental data is obtained with no adjustable parameters.

Despite the fact that superdeformation at high spin has been studied experimentally and theoretically for one and half decade a number of theoretical questions such as, for example, the underlying mechanism of identical bands and the role of pairing correlations in the regime of weak pairing in rotating nuclei, remains still not fully resolved and further development of theoretical tools is definitely required. During the last decade the relativistic mean field (RMF) theory became a standard microscopic tool of nuclear structure studies. Systematic investigation of SD rotating nuclei in the regime of weak pairing correlations in the $A \sim 150$, $A \sim 60$ (see Ref. and references therein), mass regions revealed that cranked relativistic mean field (CRMF) theory, in which pairing correlations are neglected, provides an astonishingly accurate description of the properties of SD bands, such as moments of inertia, transition quadrupole moments $Q_t$, effective alignments $i_{eff}$, single-particle properties at superdeformation etc. In particular we have to keep in mind that this theory has only seven free parameters fitted to the properties of few spherical nuclei.

One should clearly recognize that the neglect of pairing correlations used in CRMF theory is an approximation because pairing correlations being weak are still present even at the highest rotational frequencies. Moreover, the rotational properties of nuclei at low and medium spin are strongly affected by pairing correlations. In order to describe such properties within the relativistic framework, cranked relativistic Hartree-Bogoliubov theory has been developed. This theory is an extension of CRMF theory to the description of pair-
Figure 1: Experimental and calculated kinematic ($J^{(1)}$) and dynamic ($J^{(2)}$) moments of inertia of the yrast SD bands in even-even nuclei of the $A \sim 190$ mass region. Experimental $J^{(1)}$ and $J^{(2)}$ moments of inertia are shown by open and solid circles, respectively. Solid and dashed lines are used for the $J^{(1)}$ and $J^{(2)}$ moments obtained in the CRHB calculations.

The comparative study of pairing and rotational properties in the rare earth region performed within the frameworks of CRHB theory and non-relativistic cranked Hartree-
Fock-Bogoliubov theory based on the finite range force of the Gogny type indicates that APNP(LN) plays a more important role in the relativistic calculations most likely reflecting the lower effective mass.

In Refs. CRHB theory has been applied for a systematic investigation of the properties of SD bands in even-even nuclei of the $A \sim 190$ mass region. The calculations have been performed using the well established parameter sets NL1 for the RMF Lagrangian and D1S for the Gogny force. Fig. compares the experimental dynamic and kinematic moments of inertia with the ones obtained in the CRHB calculations. Since the SD bands in $^{190,192}$Hg, $^{196,198}$Pb and $^{198}$Po are not linked to the low spin level scheme, their ‘experimental’ spin values and thus kinematic moments of inertia have been established based on the comparison with calculated kinematic moments of inertia. Note that the analysis of experimental and calculated effective alignments $i_{eff}$ between the bands in different nuclei confirms the present assignment of the spin values for unlinked bands. One can see that very good agreement exists in all the cases with an exception of the yrast SD band in $^{198}$Pb. The investigation of the structure of the SD bands in neighboring odd nuclei is needed for a better understanding of the problems seen in this nucleus.

Proton and neutron scalar density distributions for the yrast SD band in $^{192}$Hg calculated at rotational frequency $\Omega_x = 0.1$ MeV are shown in Fig. Both distributions show considerable variations as a function of the coordinate. These variations are caused by shell effects. It is interesting to mention that the maximal density is reached along the symmetry axis at the distance of 6 – 8 fm from the center of nucleus. These density distributions correspond to a transition quadrupole moment $Q_t = 19.6$ e$\cdot$b. A detailed comparison presented in Ref. shows that the results of the CRHB calculations are within the error bars of available experimental data on transition quadrupole moments $Q_t$ for yrast SD bands of even-even nuclei in the $A \sim 190$ mass region.

In conclusion, cranked relativistic Hartree-Bogoliubov theory has been developed and applied for a systematic investigation of SD bands of even-even nuclei in the $A \sim 190$ mass region. Using well established parameter sets for the RMF Lagrangian and Gogny force the available experimental data is described very well without any new adjustable parameters. Further investigations of odd and odd-odd nuclei are needed for a deeper understanding of the properties of SD bands in CRHB theory. Such an investigation is in progress.

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Figure 2: The self-consistent scalar neutron density as a function of the $y$- and $z$-coordinates at the value $x = 0.308$ fm for the yrast SD band in $^{192}$Hg at rotational frequency $\Omega_x = 0.1$ MeV (top panel). The self-consistent scalar neutron and proton densities as a function of the $z$-coordinate at the values $x = y = 0.308$ fm (bottom panel). Note that the symmetry axis points in $z$-direction, while the $x$-axis is the axis of rotation.