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D-Dimensional Dirac Fermions BEC-BCS Crossover Thermodynamics

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Abstract: An effective relativistic continuum massive Proca Lagrangian action is used to account for the Lorentz vector condensation effects on the equation of state of the strongly interacting fermions system. The interior quantum fluctuation effects are incorporated as an external field approximation indirectly through a fictive generalized Thomson problem counterterm background. The general analytical formulas for the d-dimensional thermodynamics are given near the unitary limit region. In the non-relativistic limit for d=3, the universal dimensionless coefficient ξ=4/9 and energy gap Δ/ε_f=5/18 are reasonably consistent with the existing theoretical and experimental results. In the unitary limit for d=2 and T=0, the universal coefficient can even approach the extreme occasion ξ=0 corresponding to the infinite effective fermion mass $m^*=\infty$, which can be mapped to the strongly coupled two-dimensional electrons and is quite similar to the three-dimensional Bose-Einstein condensation of ideal boson gas. Instead, for d=1, the universal coefficient ξ is negative, implying the non-existence of phase transition from superfluidity to normal state. The solutions manifest the quantum Ising universal class characteristic of the strongly coupled unitary fermions gas.

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Key words: unitary fermions thermodynamics, BEC-BCS crossover, statistical methods

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