QCD properties of wfs of a hadron, of a nucleus and coherent high energy phenomena

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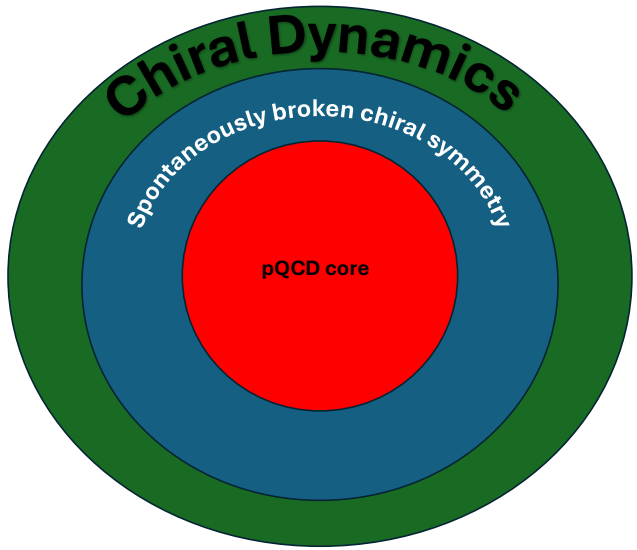
- Important properties of wfs of a hadron and nucleus follow from the general principles of quantum mechanics , from the gauge invariance asymptotic freedom, formation time. Some of these properties are absent in the standard phenomenological nuclear theory, but they resolves longstanding problems of particle and nuclear physics. Wf of a hadron in QCD see Fig 1.



- pQCD predicts the radius of pQCD core of a hadron : r_c \gg 1/Q. Q is the scale of the proper hard process. The radiation of soft gluons from the core is suppressed by the formation time, the radiation of hard gluons by power of \alpha_s. r_c is restricted from above by the interaction of bare quarks with the chiral condensate . r_c\approx 0.3 Fm is extracted from the FNAL data on the process: \pi+A\to 2 jets +A(A'). (D. Ashery). Factorization theorems of J.Collins, L.Frankfurt, M.Strikman ( ) is sufficient to calculate amplitudes of hard diffractive processes. Coherent photo production of heavy Quarkoniums: \gamma+A\to Y,Y'+A was observed in the AA ultra-peripheral collisions at LHC by several detectors. By product CT was observed.

Blue circle at Fig1 describes the region where spontaneously broken chiral symmetry(SPB) dominates. The narrow region between two regimes is not described at Fig1 is relevant for the local phase transition to SPB. M.Gell Mann,Leutwiller calculated successfully mass of pion in terms of interaction of bare quarks with chiral condensate Method of dispersion sum rules of A. Vainstein, V.Zakharov, M.Schifman allowed to expand this result to other mesons and for a nucleon by B.Ioffe. This evident success suggests that the dominant non-perturbativeQCD phenomenon is the scattering of bare quarks off the chiral condensate. The exploration of this idea allows to derive that the dominate physics in the blue regionis the kind of constituent quark model. In this model constituent quarks have color and are accompanied by the field of pseudoGoldston meson- pion

- The pQCD core within a nucleon resolves the fundamental puzzle characteristic for a preQCD field theory . L.Landau(1954) explained that coupling constant in such a theory is zero after account of radiative corrections. This result means that popular in the nuclear test books assumption on the dominance in the short-range inter-nucleon forces by strongly virtual meson exchanges is inadequate in QCD. There should be no significant short-range meson currents within a heavy nucleus, in the core of a heavy neutron star.

- QCD phenomena impossible within the standard nuclear theory.
- The similarity between repulsive core in NN interactions (relevant for the stability of a heavy nucleus) with QED phenomenon-repulsive core in the collision of many electron atoms did not found explanation in the nuclear theory(Bohr,Mottelson)
- Fig 1 suggests that the short-range NN repulsion is due to Pauli principle between quarks belonging to different nucleons . Repulsion between two atoms results from Pauli principle between electrons. Suggested by (Ya. Zeldovich 1965) before advent of QCD. On the contrary, a nuclear model starts from a structuraless nucleon.

- Hard coherent processes: \pi+A\to 2jet+A(A'). \gamma^*+A\to V+A. V =\rho,\omega; J/\psi.\psi' Another group is the production of heavy Quarkoniums in ultra-peripheral AA collisions \gamma+A\to Y(Y') +A are calculable in QCD in terms of minimal Fock component(MFC) of hadron wf as the consequence of derived before QCD factorization theorem which triggers for MFC. One of straightforward predictions is the color transparency phenomenon. Observed at LHC at several detectors.

- The challenge is the search for the deformation of a bound nucleon. Since the EMC effect is dominated by the contribution of SRC so SRC can be used as the trigger to increase the relative contribution of the deformation of a bound nucleon. cf. talk of E.Piasetsky

- Challenging process is e(h)+A\to e'(h') +2N+(A-2) and the Quenching of the yield of S and P levels.

  - Quenching of nuclear levels should disappear for Q>1 GeV. This is the property of quantum mechanics. Final state interaction is minimal for P level. In QCD the fsi of S level should disappear due to formation time.

- Wave function of a hadron in QCD.
- Wave function of a hadron is the evolution from initial state to the final state.(Feynman). We choose hard QCD as the initial condition for the evolution to the soft QCD state in the form of hard QCD which is well understood and well tested. In QCD wf of a bound state is the Fock column containing varying number of constituents
- \psi = 1/(E-P_z)\int V d\tau \psi_{initial}
- This is Lippman-Scwinger equation for a bound state. d\tau is the phase volume. The form of initial condition is unambigos and it is restricted by asymptotic freedom. In the case of light quark it is necessary to add the interaction of bare quarks with condensate.

- To suppress production of vacuum q\bar q pairs we consider light-cone wf where this effect is absent. Production of of vacuum heavy quark pairs is tiny. So description of heavy Quarkonia is resembles the experience in the non-relativistic mechanics.

Conclusion

- New particle production at LHC will be masked by QCD effects neglected in the current Monte Carlo programs.
- It is necessary to investigate QCD environment accompanying new particles production.
- Small x QCD physics can be investigated in ultraperipheral processes which is feasible at ATLAS.

Small x physics:From HERA to LHC and beyound.
L.Frankfurt, M.Strikman, C.Weiss
Ann.Rev.Nuc.Part.Phys.2005

- The causality and/or energy-momentum conservation constraints on QCD amplitudes in small x region. L.Frankfurt and B.Blok Phys.Rev.D75 2007