Mesonic Super Čerenkov-like effects in hadronic and nuclear media

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Abstract: Generalized mesonic Super-Čerenkov Radiations (SČR), as well as their SČR-signatures are investigated. Two general SČR-coherence conditions are found as two natural extremes of the same spontaneous particles decays in (nuclear or subnuclear) media. The positions of the pionic SČR-bands in the mesonic and baryonic SČR-sectors are estimated. The interpretation of the observed (at RHIC) two bump structure of the azimuthal distributions near the away-side jets as experimental evidence for the two SČR-mesonic components, is suggested.
Key words: Pionic Super-Čerenkov radiation, Nuclear pionic Čerenkov-like radiation (NPIČR), SČR-mesonic sectors.

We recall here that idea that meson production in nuclear interactions may be described as a process similar to the Čerenkov radiation has been considered by Wada (1949), Ivanenko (1949) Blohintev and Indenbom (1950), Čzyz, Ericson, Glashow (1959), Smrz (1962) and D. B. Ion (1969-1970). For the many detailed results on mesonic Čerenkov-like effect see Refs. [1-3,5,9-13] presented in Fig.1 while for the generalized Super-Cerenkov see Refs. [14-15]. In Ref. [1] from Fig.1 D.B. Ion developed a general classical and quantum theory of the mesonic Čerenkov-like radiation in hadronic and nuclear media. Moreover, the vector-mesonic Cerenkov-like radiation as well as baryonic Cerenkov-like effects in nuclear and hadronic media were also introduced for the first time in Ref. [1-2,Fig.1]. Then, there were predicted completely the properties of the mesonic Čerenkov-like radiation in the case when the mesonic refractive index is given by a single pole approximation. Then, they obtained a good agreement with the integrated cross section of the single meson production in the hadronic collisions (see Fig.9 from Ref. [1]).

In 1990-1995, we have extended [1-7] these ideas to the nuclear media where the pionic (NPIČR) and gamma Čerenkov radiation (NGČR) should be possible to be emitted from charged particles moving through nuclei with a velocity larger than the phase velocity of photons or/and pions in the nuclear media. The refractive indices of the gamma (n_γ), meson (n_π), nucleon (n_N), was calculated by using Foldy-Lax formula [8] and the experimental pion-nucleon cross sections combined with the dispersion relations predictions, the refractive index of pions in the nuclear media have been calculated (see Fig.2a,b). Then, the detailed predictions for the spontaneous pion emission as *nuclear pionic Čerenkov radiation* (NPIČR) inside the nuclear medium are obtained and published in Refs. [3-4]. These main predictions and conclusions obtained in this way for the low-energy SČR-pionic sector can be summarized as follow (see also Fig.4):

(i) The energy behavior of the pionic refractive index is presented in Fig. 2a;

(ii) The true coherent pion emission as *nuclear pionic Čerenkov-like radiation* (NPIČR) is possible in the following three energy bands (see Fig. 2b):

ČB1-NPIČR band for: $190\,MeV \leq \omega \leq 315\,MeV$ for all $\pi^{\pm,0}$

ČB2-NPIČR band for: $910\,MeV \leq \omega \leq 960\,MeV$ only for π^+, and

ČB3-NPIČR band for : $80\,GeV \leq \omega \leq 1000\,GeV$ for all $\pi^{\pm,0}$

in the nuclear reactions such as: $N +^{208} Pb \Rightarrow \pi N +^{208} Pb$.

Here, it is important to note that, for the nucleon laboratory momenta $p_{LAB} \geq 80\,GeV/c$, we predict that the all above SČR-pionic bands will be enlarged since the physical domain is given by

$$v_{\pi ph}(\omega)/v_1 \,\mathrm{Re}\, n_1(E_1) \leq \cos\theta_{N\pi} \leq 1$$

and $\mathrm{Re}\, n_N(E_N) \geq 1$ (see the results from Fig. 4).

(iii) The NPIČR-pions must be coplanar with the incoming and outgoing projectile possessing a strong correlation between the angle of emission (θ, ω_m) and the pion (ω) and projectile (T_p) energies (see Fig.3).

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(iv) For the ČB1 the NPIČR-differential cross section are peaked (see Ref. [4]) at the energy $\omega_m = 260$ MeV for ČB1 band and $\omega_m = 930$ MeV for ČB2 band when the absorption is neglected and the peak position is shifted up to $\omega_m = 240$ MeV for ČB1-band when the absorption is taken into account. As we already mentioned in Ref. [1], these predictions were experimentally confirmed (see Fig. 10 in [1]) by the Dubna group (see E.K. Sarkisyan et al. Phys. Lett. B471 (1999) 257). So, they obtained a good agreement with the position and width of the first pionic Cerenkov-like band predicted in Ref. [4].

Bibliography for Introduction in Super-Cerenkov Radiation

[1] D. B. Ion, *Mesonic Čerenkov-like Effect as Possible Mechanism of Meson Production in Hadronic Interactions*, DSc Thesis, Bucharest University, 1971.

[2] D. B. Ion, *The classical theory of mesonic Čerenkov radiation in nuclear media*, St. Cerc. Fiz. **22** (1970) 125.

[3] D. B. Ion and F. Nichitiu, *A possible Čerenkov mechanism for single pion production in hadron-hadron interactions at high energy*, Nucl. Phys. B **29** (1971) 547.

[4] D. B. Ion and W. Stocker, *Possibility of coherent gamma-Čerenkov radiation*, Phys. Lett. B **258** (1991) 262

[5] D. B. Ion and W. Stocker, *Coherent pion production via a mesonic Čerenkov mechanism in relativistic proton-nucleus collisions*, Phys. Lett. B **273** (1991) 20.

[6] D. B. Ion and W. Stocker, *Nuclear gamma Cherenkov radiation from charged projectiles as a coherent effect in nuclear media*, Ann. Phys.(N.Y.) **213** (1992) 355.

[7] D. B. Ion and W. Stocker, *High energy nuclear gamma-Čerenkov radiation*, Phys. Lett. B **311** (1993) 339.

[8] D. B. Ion and W. Stocker, *Nuclear gamma Čerenkov radiation from charged leptons*, Phys. Lett. B **323** (1994) 446.

[9] D. B. Ion and W. Stocker, *Quantum theoretical approach to meson production in nuclear media via Čerenkov mechanisms*, Phys.Rev. C **48** (1993) 1172.

[10] W. Stocker and D. B. Ion, *Electromagnetic and mesonic Čerenkov effects in nuclear media*, In "Topics in Atomic and Nuclear Collisions, edited by B. Remaud, A. Calboreanu and V. Zoran, NATO ASI Series B Vol. **321**, Plenum Press,New York, 1994, p.443.

[11] D. B. Ion and W. Stocker, *Nuclear pionic Čerenkov-like radiation from high energy nucleons in nuclear media*, Phys. Lett. B **346** (1995) 172.

[12] D. B. Ion and W. Stocker, *Nuclear mesonic Čerenkov-like radiation from high energy nucleons in nuclear media*, Phys.Rev. C **52** (1995) 3332.

[13] D. B. Ion and W. Stocker, *VHEGR/UHEGR produced by Čerenkov mechanisms in cosmic sources*, Astropart. Phys. **2** (1994) 21.

[14] D. B. Ion and M. L. D. Ion, *Super-Čerenkov Radiation a new phenomenon useful for RICH detectors*, Rom. Journ. Phys. **51** (2006) 867(2006).

[15] D. B. Ion, *Generalized Super-Čerenkov Radiations in Nuclear and Hadronic Media*, Romanian Reports in Physics Vol **59** , No 4 (2007) 1033-1044.

Fig.1: Selected bibliography for introduction in the generalized Super-Čerenkov-like radiations.
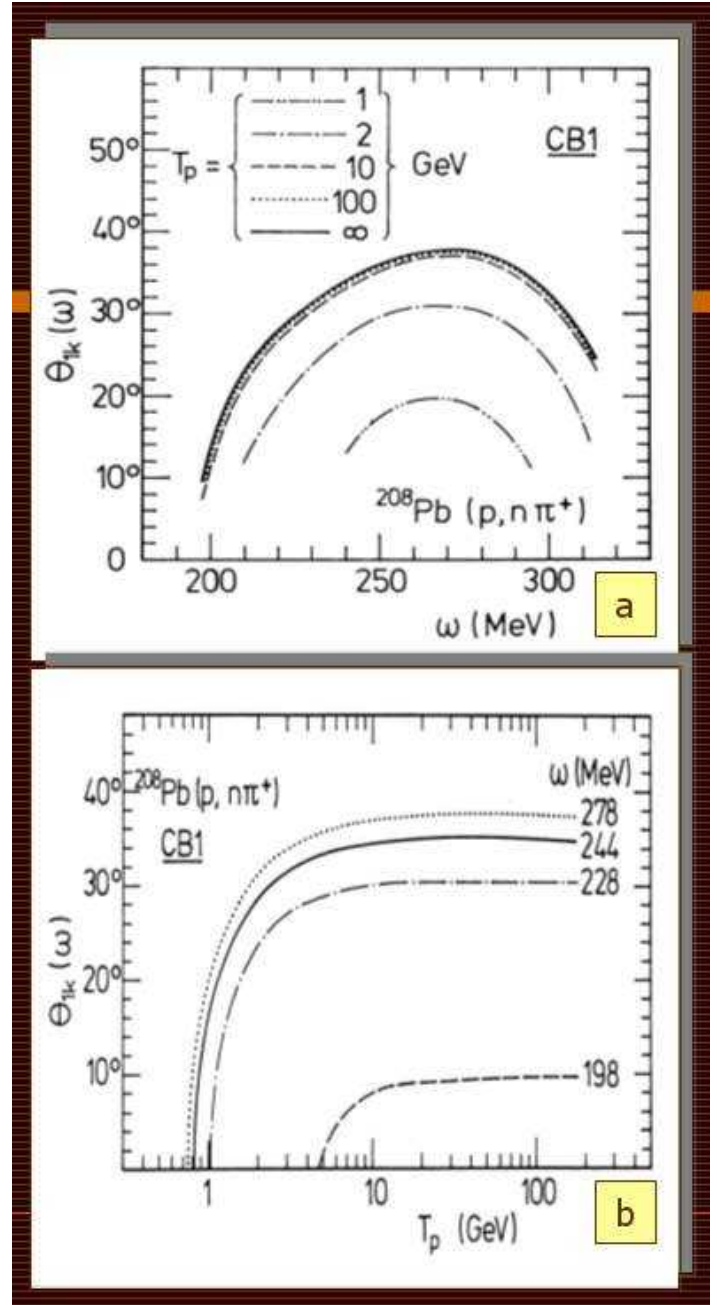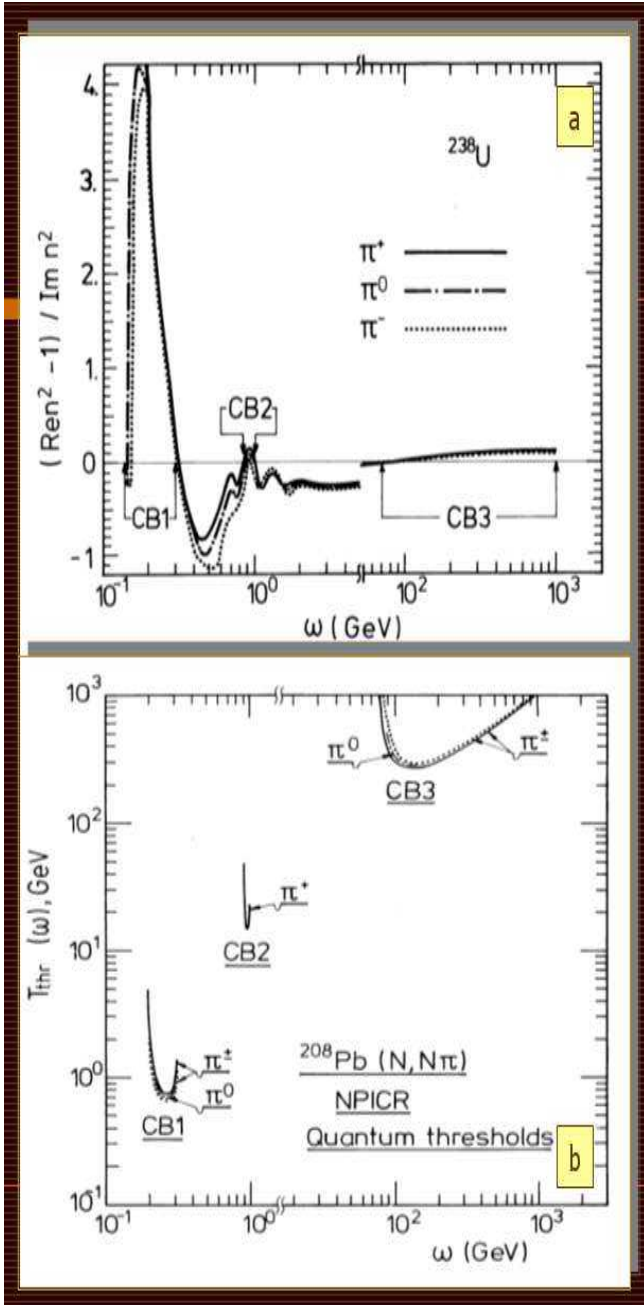
Fig. 2: (a) Pionic refractive index, (b) The SČR-energy thresholds.

Fig. **3**: $[(\theta_{1k}, \omega)$ and $(\theta_{1k}, T_p)] -$ angle-energy correlations.

(v) A summary of the theoretical results on pionic Super-Čerenkov-like radiation in (hadronic or nuclear) media is presented in Fig.4. The factor S is the spin factor while $\Theta(1-\cos\theta_{SC})$ is the Heaviside step function. In fact the entire quantum theory of the exotic decay: $B_1(\vec{p_1}, E_1) \to \pi(\vec{k}, \omega) B_2(\vec{p_2}, E_2)$, where B_1 and B_2 are spin ½ baryons, can be developed just as in Ref. [4]. So, by using the inequality: $\cos\theta_{SC} \approx v_{\pi ph} v_{Bph} \leq 1$, two general SČR-coherence conditions corresponding to the (mesonic and baryonic)- Čerenkov-like effects, are found (see Fig.4) as two natural extremes of the same spontaneous particles decays in medium.

(vi) Next, it is important to remark that the baryonic SČR-sector will appear especially for incident nucleons with p_{LAB} higher than 100 GeV/c where we found that the baryonic SČR-conditions: and $R\, v_{N\,ph}(E_2)/v_1\,\mathrm{Re}\,n_1(E_1) \leq \cos\theta_{12} \leq 1$ and $\mathrm{Re}\,n_N(E_N) \geq 1$, are satisfied with high accuracy.
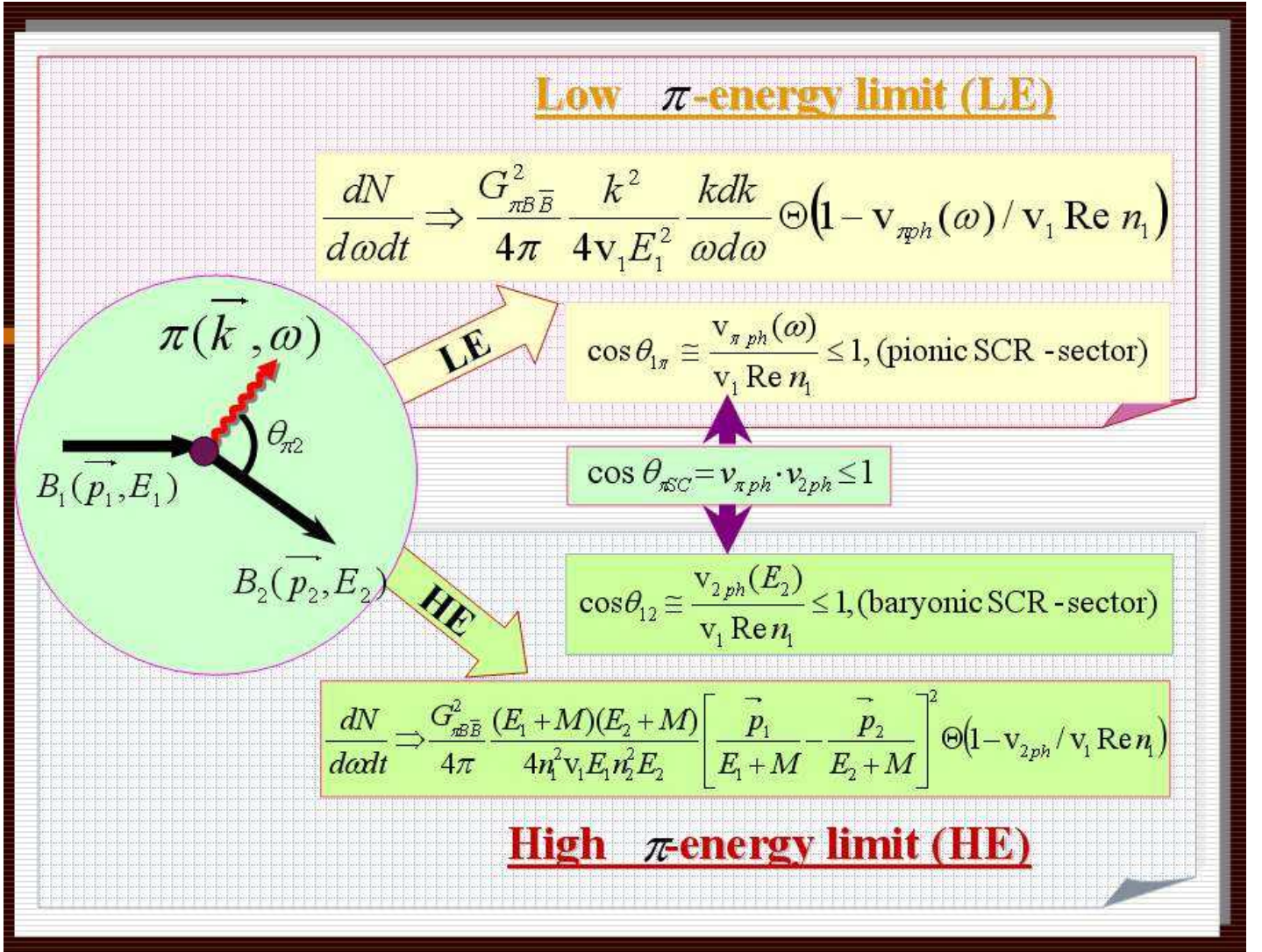
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Fig. 4: Summary of the theoretical results on pionic Super-Čerenkov-like radiation in (hadronic, nuclear) media.

(vii) It is well known that the recent RHIC experiments [6, 7] have shown two bump structure of the azimuthal distributions near the away-side jets. This structure was interpreted by Dremin [8] as being the signature of the Čerenkov gluons. But, it is easy to see that , these two bump distributions can be interpreted in more exact way: as signature of the two components of the SČR-gluons. However, the more realistic interpretation of these experimental results as signature of the generalized mesonic SČR-effects cannot be avoided. Of course more theoretical and experimental investigations are necessary to clarify the problems of the generalized SČR-gluons emissions in hadronic media.

References
[1] D.B. Ion and M.L. Ion, Rom. J. Phys. **55,** No. 5-6 (2010).
[2] D.B. Ion and M.L. Ion, Annals of Academy of Romanian Scientist, Physics, **1**, 47 (2009).
[3] D.B. Ion and W. Stocker, Phys. Lett. **B 273,** 20 (1991); Phys.Rev. **C 48,** 1172 (1993); Lett. **B 346**, 172 (1995).
[4] D.B. Ion and W. Stocker, Phys.Rev. **C 52,** 3332(1995).
[5] M. Lax, Rev. Mod. Phys. **23**, 287 (1951); L.L. Foldy, Phys. Rev. **67,** 107 (1945).
[6] J. Adams et al.(STAR Collaboration), Phys. Rev. Lett. **95**, 152301 (2005).

[7] S.S. Adler et al. (PHENIX Collaboration), Phys. Rev. Lett. **97**, 052301 (2005).

[8] I.M. Dremin, Nucl. Phys. **A767**, 233 (2006).

[9] D.B. Ion, Rom. Rep. Phys. **59**, 1033 (2007).