WOUNDED CONSTITUENTS

A.Bialas
(Cracow)
Acta Physica Polonica B43 (2012) 95.
ArXiv: 1202.4599

WOUNDED NUCLEONS

EXPERIMENTS OF BUSZA ET AL. (1975) SHOWED THAT THE OBSERVED MULTIPLICITY IN P-A COLLISIONS FOLLOW THE SIMPLE RULE

$$N_{pA} = \frac{1+\nu_A}{2} N_{pp} \tag{1}$$

WHICH CAN BE INTERPRETED AS AN EVIDENCE THAT THE COLLIDING PROTON EMITS A NUMBER OF PARTICLES (GETS "WOUNDED"), INDEPENDENTLY OF THE NUMBER OF COLLISIONS IN THE NUCLEUS (AB, W.Czyz & M.Bleszynski, 1976).

IT FOLLOWS THAT RAPIDITY DISTRIBUTION in AB COLLISION IS

$$\rho_{AB}(y) = w_A \rho_H(y) + w_B \rho_H(-y); \quad w_A = \frac{A\sigma_{pA}}{\sigma_{AB}}; \quad w_B = \frac{B\sigma_{pB}}{\sigma_{AB}} \tag{2}$$

FORMATION ZONE

EMISSION OF A PARTICLE REQUIRES TIME. IN THE FRAME WHERE ITS RAPIDITY $y = 0$, $\Delta t \approx 1/m_\perp$. THEREFORE FOR ARBITRARY y WE HAVE

$$\Delta t \approx \frac{E}{m_\perp^2} = \frac{\cosh(y)}{m_\perp}; \quad \Delta L \approx \frac{\sinh(y)}{m_\perp}. \tag{3}$$

FOR LARGE ENOUGH y, $\Delta L >> R_A$ AND THE EMITTED PARTICLE IS UNLIKELY TO BE SENSITIVE TO THE NUMBER OF COLLISIONS OF THE PROJECTILE.

BUT: THE MODEL DOES NOT WORK FOR $m_\perp$ GREATER THAN ~ 300 MeV (more particles are produced).

A (POSSIBLE) RECIPE: MORE CONSTITUENTS: AB, Czyz, & Furmanski, APP B8 (1977) 585 (3 quarks); AB & Bzdak, P.R. C77 (2008) 034908 (quark+diquark).

NUCLEON STRUCTURE: WOUNDED CONSTITUENTS

DEEP INELASTIC MEASUREMENTS SHOWED THAT NUCLEON IS COMPOSED OF *MANY* CONSTITUENTS OF VARIOUS RAPIDITIES AND SIZES. THUS THERE ARE MANY POTENTIAL "SOURCES" WHICH CAN RADIATE PARTICLES (GLUONS?) WHEN "WOUNDED" IN A COLLISION.

IDEA: $p_\perp$ DISTRIBUTION FROM A "SOURCE" DEPENDS ON ITS (TRANSVERSE) SIZE δ:

$$\rho_\delta(p_\perp; y) = I(\delta; y) e^{-p_\perp^2 \delta^2}. \quad (4)$$

For a collision of a nucleon at a nucleus A we thus have

$$\rho_{HA}(p_\perp; y) = \int dw_H(\delta; A)\rho_\delta(p_\perp; y) + \int dw_A(\delta; H)\rho_\delta(p_\perp; -y). \quad (5)$$

$$\sigma_{HH} dw_H(\delta; A) = dN_H(\delta)\sigma_{\delta A}; \quad \sigma_{HA} dw_A(\delta; H) = A dN_H(\delta)\sigma_{\delta H} \quad (6)$$

NUCLEON-NUCLEON COLLISIONS

FOR NUCLEON-NUCLEON COLLISIONS THE MODEL GIVES:

$$\sigma_{HH}\rho_{HH}(p_\perp;y) = \sigma_{HH}\int dw_H(\delta)[\rho_\delta(p_\perp,y)+\rho_\delta(p_\perp,-y)] =$$

$$= \int dN_H(\delta)\sigma_{\delta H}[I(\delta;y)+I(\delta,-y]e^{-p_\perp^2\delta^2} =$$

$$= \int d\delta^2\,[G(\delta;y)+G(\delta;-y)]\,e^{-p_\perp^2\delta^2};$$

$$G(\delta;y) \equiv I(\delta;y)\frac{dN_H(\delta)}{d\delta^2}\sigma_{\delta H} \tag{7}$$

One sees that at $y \approx 0$, the effective intensity $G(\delta;y)$ can be recovered from $p_\perp$ distribution in nucleon-nucleon collisions (by inverting the Laplace transform).

INPUT DISTRIBUTIONS

I TRIED THE TSALLIS DISTRIBUTION

$$\rho_H(p_\perp) = [1 + \beta m_\perp / k]^{-k} \,. \tag{8}$$

FOR $k \to \infty$**,**

$$[1 + \beta m_\perp / k]^{-k} \to e^{-\beta p_\perp} \tag{9}$$

EFFECTIVE INTENSITY

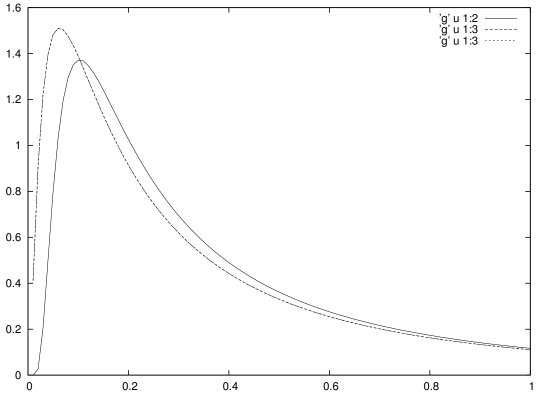

Figure: The effective intensity $G(\delta^2)$, plotted vs δ^2 (in fm^2), for (a) exponential distribution $\rho(p_\perp) = e^{-\beta p_\perp}$ (full line) and (b) Tsallis distribution $\rho(p_\perp) = [1 + \beta m_\perp / k]^{-k}$ with $k = 8$ (dotted line). $M = 141$ MeV, $\beta^{-1} = 250$ MeV.

NUCLEON-NUCLEUS COLLISIONS

$$\sigma_{HA} dw_H(\delta; A) = dN_H(\delta)\sigma_{\delta A}; \quad \sigma_{HA} dw_A(\delta; H) = A dN_H(\delta)\sigma_{\delta H} \quad (10)$$

giving

$$\sigma_{HA}\rho_{HA}(p_\perp; y) = \int d\delta^2 G(\delta; y)\frac{\sigma_{\delta A}}{\sigma_{\delta H}} e^{-p_\perp^2 \delta^2} + A\sigma_{HH}\rho_H(p_\perp, -y) \quad (11)$$

The second term gives the contribution from the nucleus: it is simply proportional to the number of collisions, like in the wounded nucleon model. The first term -giving the contribution from the nucleon- contains, however, the enhancement factor $\sigma_{\delta A}/\sigma_{\delta H}$. For very small $\sigma_{\delta H}$ this factor may reach the value of A: A really large enhancement.
In the limit $\sigma_{\delta H} \to 0$, one has $\rho_{HA}(p_\perp; y) = \nu_A \rho_{HH}(p_\perp; y)$

CONSTITUENT CROSS-SECTION

RESULTS DEPEND ON ONE PARAMETER, $\sigma_{\delta H}$, THE CROSS-SECTION OF A SINGLE CONSTITUENT ON THE NUCLEON ($\sigma_{\delta A}$ can be evaluated from the Glauber model).. POSSIBILITY: THE DIPOLE MODEL [Golec-Biernat & Wuesthof, PR D60 (1999) 114023]

$$\sigma_{\delta H} = \sigma_G \left[1 - e^{-\delta^2 / R_G^2} \right] \tag{12}$$

$$x \approx 0.18 \, [R_G^2]^{3.47} \tag{13}$$

COLOR-NEUTRAL CONSTITUENTS?

ENHANCEMENT FACTOR: INPUT DEPENDENCE

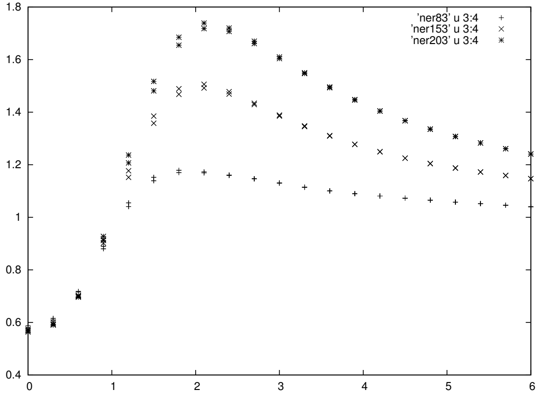

Figure: Enhancement factor at $b = 0$ versus $p_\perp$ (plotted in GeV) for partons. $\sigma_G = 23mb$, $R_G^2 = .3fm^2$. Tsallis parameter Lower three lines: Tsallis input, $k = 8, 15, 20$.

ENHANCEMENT FACTOR: $p_\perp$ DEPENDENCE

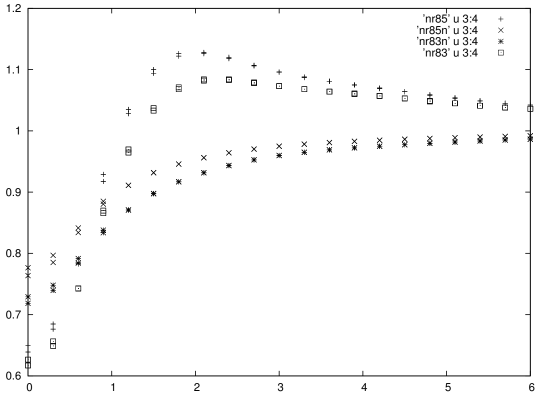

Figure: Enhancement factor per collision at $b = 0$ versus $p_\perp$ (plotted in GeV) for partons. Tsallis input, $k = 8$. $\sigma_G = 23$ mb, $\sigma_H = 30$ mb, $R_G^2 = 0.3$ and 0.5 fm ^{2}. Lower two lines: no multiple scattering.

ENHANCEMENT FACTOR: WOUNDED NUCLEONS

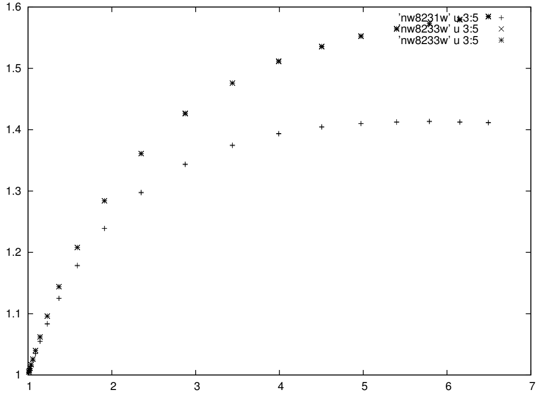

Figure: Enhancement factor per wounded nucleon integrated over $p_\perp$ plotted as function of number of collisions. $\sigma_G = 23$ mb, $R_G^2 = 0.3$ and 0.5 fm^2. Tsallis input, $k = 8$.

COMMENTS

1. Application of the Golec-Biernat & Wuesthof formula for the constituent cross-section requires that the constituents which are to become "wounded" are colourless dipoles.

2. Multiple scattering in the nucleus does not change the particle emission from the "wounded" source but it changes the direction of the source. Therefore also the distribution of transverse momenta with respect to incident direction is changed. Numerical estimates show that the effect may be important at transverse momenta up to $\sim$ 5 GeV.

3. Nuclear enhancement (suppression) at $p_\perp \geq 4 - 5$ GeV gives the measure of the gluon density (saturation?) in the nucleus.

NUCLEUS-NUCLEUS COLLISIONS

ANALOGOUS FORMULAE CAN BE WRITTEN DOWN FOR NUCLEUS NUCLEUS COLLISIONS. NATURALLY, THE ENHANCEMENT FACTORS APPEAR IN BOTH LEFT- AND RIGHT- MOVING TERMS.

HERE, HOWEVER, ONE HAS TO FACE THE PROBLEM OF THE COLLECTIVE EFFECT INDUCED DURING EXPANSION OF THE QUARK-GLUON PLASMA: THE TRANSVERSE FLOW CHANGES THE TRANSVERSE MOMENTUM SPECTRUM.
ALSO ENTROPY (AND THUS MULTIPLICITY) MAY INCREASE.

THEREFORE THE MODEL MAY DESCRIBE THE *INITIAL CONDITIONS* **RATHER THAN THE FINAL STATE OF THE SYSTEM.**