A REMARK ON STOPPING NUCLEONS

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IN STANDARD MODELS OF PARTICLE PRODUCTION AT HIGH ENERGY, THE PROJECTILE SLOWS DOWN AFTER COLLISION BY EMITTING PARTICLES AND THUS LOOSING ENERGY.

EXAMPLE:
IN THE LUND MODEL THE PROJECTILE EXCHANGES COLOUR WITH THE TARGET AND CREATES A STRING WHICH SLOWS IT DOWN AT THE RATE GIVEN BY STRING TENSION $\sigma \approx 1$GeV/fm. STRING BREAKS AND PRODUCES PARTICLES.

SIMPLE OBSERVATION

THIS PICTURE IMPLIES THAT THE PROJECTILE SLOWED DOWN TO C.M. RAPIDITY CLOSE TO ZERO, IS NOT SITTING $z \approx 0$ BUT RATHER AT $z \approx E/\sigma$.

THUS IN A pp COLLISION 10+10 GeV NUCLEONS IN THE CENTRAL RAPIDITY REGION ARE LOCATED ABOUT 10 fm APART FROM THE CENTRE!

SIMILAR ARGUMENTS ARE VALID ALSO IN THE WOUNDED NUCLEON MODEL AND IN THE WOUNDED QUARK (OR DIQUARK) MODELS.

CONSEQUENCES

THERE ARE TWO IMPORTANT QUALITATIVE CONSEQUENCES IF THIS OBSERVATION:

(i) LARGE NET BARYON DENSITY DIFFICULT TO ACHIEVE.
Since the nucleons stopped at $y \approx 0$ are located far from the point $z = 0$, they do not overlap in configuration space and thus do not produce the expected high net baryon density.

(ii) STOPPING NUCLEONS DO NOT EQUILIBRATE
As the quark-gluon plasma is expected to be produced at the centre (both in rapidity and in the position along the z-axis) the stopped nucleons do not interact effectively with the plasma (because they are sitting et the place where there is no plasma).

SPACE-TIME PICTURE

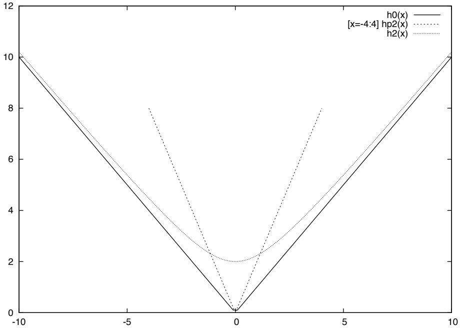

Figure: Space-time picture of particle production

LOWERING THE ENERGY

THE PRESENTED QUALITATIVE ARGUMENT REFERS TO HIGH-ENERGIES. QUESTION: IS IT RELEVANT FOR THE BEAM ENERGY SCAN PROGRAM AT RHIC?

CONSIDER THE NUCLEONS CLOSE TO $y = 0$. LET THEIR DISTRIBUTION IN RAPIDITY BE $f(y)dy$. USING

$$E_p = E - \sigma(z - z_c) \quad [z_c \textit{ is the collision point}], \tag{1}$$

THE DISTRIBUTION IN z BECOMES

$$\bar{F}(z - z_c)dz = \frac{\sigma}{M_\perp} \frac{f[arcosh(1 + x)]}{\sqrt{(1 + x)^2 - 1}} dz \equiv \Phi(x)dz; \tag{2}$$

with $x = \sigma(\zeta - z_c)/M_\perp$,

$$\zeta = z_{max} - z; \quad z_{max} = (E - M_\perp)/\sigma.$$

THE FUNCTION $\Phi(x)$

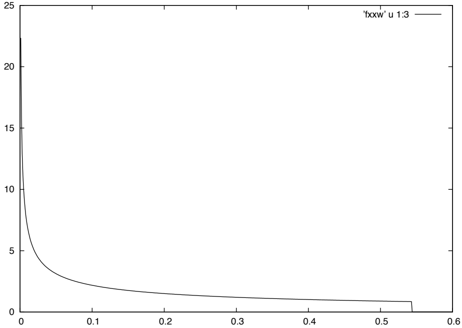

Figure: The function $\Phi(x)$, $x \geq 0$ for $0 \leq y \leq 1$

AVERAGING OVER COLLISION POINTS

THE FUNCTION $\bar{F}(z - z_c)$ SHOWN IN THE PREVIOUS SLIDE DOES NOT DESCRIBE THE ACTUAL DISTRIBUTION OF THE NUCLEON POSITION IN z. IT SHOULD BE AVERAGED OVER THE POSITIONS OF THE COLLISION POINTS z_c (IN THE COLLISION OF TWO LARGE NUCLEI, THE WIDTH OF THE DISTRIBUTION OF z_c IS OF THE ORDER OF NUCLEAR DIAMETER). THUS WE HAVE

$$F(z)dz = \int dz_c G(z_c)\bar{F}(z - z_c) = \int dz_c G(z_c)\Phi(x)dz \qquad (3)$$

FOR SIMPLICITY WE USE A GAUSSIAN:

$$G(z_c) \sim e^{-(z_c\gamma/R_A)^2} \qquad (4)$$

THE DISTRIBUTION OF NUCLEONS IN z

$\sigma = 1$ **GeV/fm (WOUNDED NUCLEON MODEL)**
$R_A = 6.5$ **fm**

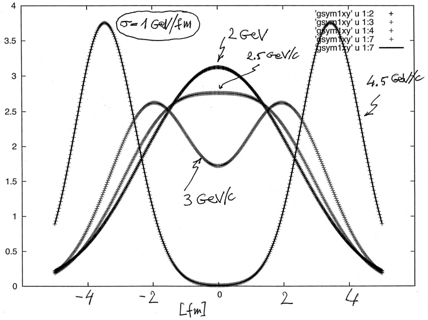

Figure: The distribution of the position along the z axis of the nucleons with $|y| \leq 1.$ averaged over the collision points. $\sigma = 1$ GeV/fm.

THE DISTRIBUTION OF NUCLEONS IN z

$\sigma = 3$ **GeV/fm (WOUNDED QUARK MODEL)**
$R_A = 6.5$ **fm**

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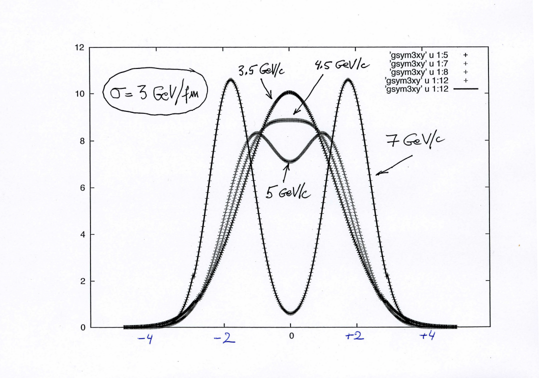

Figure: The distribution of the position along the z axis of the nucleons with $|y| \leq 1$. $\sigma = 3$ GeV/fm.

SUMMARY

1. AT HIGH ENERGIES, NUCLEONS LOCATED IN THE CENTRAL RAPIDITY REGION ARE WIDELY SEPARATED IN CONFIGURATION SPACE AND THUS ARE UNLIKELY TO PRODUCE HIGH NET-BARYON DENSITY.
2. WHEN EXTRAPOLATED TO LOW ENERGIES (AS THOSE IN THE BES PROGRAM), THIS OBSERVATION IMPLIES THAT THE PROBLEM MAY BE PRESENT ALREADY AT C.M. ENERGIES ABOVE ~ 4 GeV.
3. AT ENERGIES ABOVE $\sim$ 8 GeV, THE THERMODYNAMIC EQUILIBRIUM OF THE NUCLEONS WITH THE PRODUCED QUARK-GLUON PLASMA SEEMS DIFFICULT TO ACHIEVE. .
4. THE PROBLEM DESERVES CLOSER ATTENTION