Dear John:

I have been reading for a couple of days, and with a lot of profit — in particular the old paper by Siemens, Sobel, Bode and Bondorf, Nucl. Phys. A251, 502 (75), and the Cugnon-Mitsutani-Vandermeulen article on equilibration, Nucl. Phys. A352, 505 (81). I have "discovered" that there is an enormous difference between glancing over a paper, and really reading it. Finally I worked through the hadrochemistry papers. Result: I know exactly how and why these models, and the fireball model, all lead to different $\bar{\nu}$-yield predictions. Now this is a long story.

The essential point: cascade and hadrochemistry show that there never exists chemical equilibrium, at no time in the reaction (this eliminates both the fireball and hydrodynamics — and also Hagedorn). The $\bar{\nu}$-yield is a frozen-in feature of the non-equilibrium stage of the reaction. In $\text{La} + \text{La}$ or $\text{Pb} + \text{Pb}$, about 2-3 fm/c after the classical overlap time, there is the best chance of near-equilibrium conditions. But even then, the cascade model $\bar{\nu}$-yield exceeds a chemical model abundance by a two: it represents a frozen-in overshoot over the equilibrium concentration.

Now how does the cascade $\bar{\nu}$-yield come about?
Two principal stages:

1. Early interpenetration, $p/p_0 \rightarrow 2g^{cm}$, non-equilibrium. The initial part of this got to be a realistic description of what is going on in reality. Check: the cascade code describes the peripheral $\pi^-$ yield which is basically the same configuration, turned around by 90°.

2. Compressed zone develops. Shock compression > superposition density; $p/p_{\text{shock}} > 2g+1$. Δ's are produced:
   a. in the shock zone thermally
   b. in spectator – shock zone nuclear interact.

i.e. they go on in density $p/p_0 \times 2g+1$, but only a. is a "chemical" process, b. still is driven by relative motion spectator/thermal fireball at rest in CM.

This does not invalidate the simple "fireball subtraction result for the "compressional" energy", but a different argumentation is needed in this scenario. And in order to do this, it is very important to know whether the participant $p_{\perp}$ distribution inside the "test sphere" approaches $p_{\perp}$ at max $p/p_0$-time (or at the time of its maximum total energy or total $E_{\perp}$ content). If yes: argumentation about compressional $E_{\perp}$ remains straightforward. But if $T_{\parallel} > T_{\perp}$ by a large amount, there are possible errors in $E_{\perp}$ of the order of $\frac{2}{3}(T_{\parallel} - T_{\perp})$.

By the way I understand now why $R > 1$ at large times – basically our handwaving guess was right. In non-equilibrium, $p_{\perp}$ lacks at high $p_{\perp}$ at low $p_{\perp}$ late times in fixed sphere $\Rightarrow$ only slow particles left in there $\Rightarrow$ for these, $p_{\parallel}$ is undispersed; $R > 1$.

Will phone you about this. Regards! Reinhard
\[ R = \frac{\langle P_{\perp} + 1 \rangle}{\langle P_{\parallel} \rangle} \] as \text{ fct. of time} in cascade code

describes deviation from equilibrium but in a peculiar manner. \text{ In the test sphere:}

\[ P_{\perp} \ll P_{\text{beam}} \]
\[ P_{\perp} \ll \langle P^2 \rangle \approx 130 \text{ GeV/c} \]
\[ R \ll 1 \]

\[ 4 \text{ fm/c} \]

\[ \frac{\langle P_{\perp} \rangle}{\langle P_{\parallel} \rangle} \Rightarrow \text{ temperature + spectator} \]
\[ \text{ spectator + spectator beam} \]
\[ \text{ } /4 \text{ of } A \text{ unscattered} \]

\[ \Rightarrow \text{ look for } \text{ participant } R \]
\[ R \Rightarrow 1 \text{ ??} \]
\[ R < 1 \]

\[ \text{ somewhat later than classical overlap time: max. overall density} \]

\[ 11 \text{ fm/c} \]

\[ \text{ spectator influx stops, outflux } > \text{ influx } \Rightarrow \langle P_{\parallel} \rangle \Rightarrow \text{ hadron} \]

\[ R \Rightarrow 1 \]

\[ 15 \text{ fm/c} \]

\[ \text{ However: if there has never been perfect thermalization} \]
\[ P_+ = \text{ spectrum lacks at high momenta} \]
\[ \Rightarrow \text{ these result from slow-down!} \]

\[ \text{ at later times, when only slow nucleons are left behind in the test sphere:} \]
\[ R > 1 \text{ : artifact }! \text{ follows from similar reason as } R < 1 \]

\[ \Rightarrow \text{ Look at } R \text{ at time when } E_{\text{inspire}} \text{ is maximal!} \]

\[ \text{ Cugnon et al., Nucl.Phys. A552, 505(81)} \text{ Fig. 6} \]
Important for shock-front model:

at which time does $R_{\text{participants}} \rightarrow 1$

in $\text{Cu+Cu, La+La at } 1 \text{ GeV}$?

If $R \rightarrow 1$ (or whatever reasonable max. value)
already at about half max. interpenetration:

important for $\pi^-$ production!!:
incoming nucleons interact in high-
density fireball at rest in CM
not with nucleons going more or less
opposite $\Rightarrow$ less relative NN-energy $\Rightarrow$
$\Rightarrow$ less $\Delta$-production in subsequent collisions

i.e. we have a 2-phase $\pi^-$ production

1) Initial: interpenetration, buildup of shock front:
interactions go on at density $2\gamma$ among
mostly "virgin" pairs: $E_{\text{CM}}$ relative $= 2E_{\text{CM}}/A$

2) At $t \geq R$: in La+La, Pb+Pb there should
$2\beta \gamma \text{ cm now exist a shock zone}$
$p/p_0$ (shock zone) $\geq 2\gamma + 1!$ as we seem to observe
thermal equilibrium approached in shock zone
$\Rightarrow$ new $\Delta$'s are created by incoming nucleons interac-
ting inside the "fireball" (lower $E_{\text{CM}}$ relative than in
phase I). The shock zone has a $\Delta$-content that
results from Phase I and Phase II: not an chemical
equilibrium concentration at any time!