# Effect of shower partons on soft and semihard hadrons produced in Pb-Pb collisions at LHC

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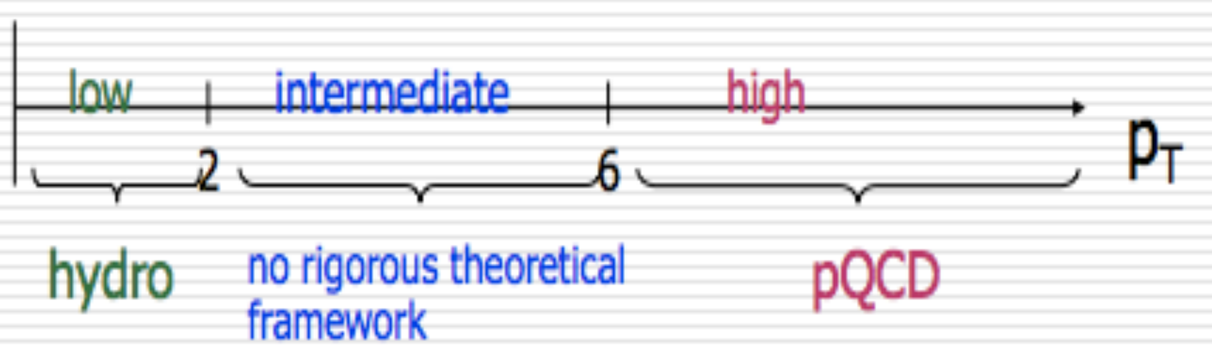
## Motivations

- At intermediate $p_T$ recombination model has been successful. That is where abundant experimental data exist.




- There are thousands of soft hadrons and multiple hard jets produced in Pb-Pb collisions at 2.76 TeV.
- It's our aim to investigate what minijets' effects are and to offer an explain of the observed hadronic spectra and all $p_T$ measured up to 20 GeV/c.
- It will become clear that the hadronization problem at LHC is drastically different from that at RHIC.

## Quark Recombination Model

- The basic framework that describes the recombiantion and shower parton

$$p^0\frac{dN^M}{dp_T} = \int \frac{dp_1}{p_1}\frac{dp_2}{p_2}F_{q_1\bar{q}_2}(p_1,p_2)R^M_{q_1\bar{q}_2}(p_1,p_2,p_T)$$

$$p^0\frac{dN^B}{dp_T} = \int \left[\prod_{i=1}^{3}\frac{dp_i}{p_i}\right]F_{q_1q_2q_3}(p_1,p_2,p_3)R^B_{q_1q_2q_3}(p_1,p_2,p_3,p_T)$$

- ➢ $R^M$ and $R^B$ : the recombination functions (RFs) for meson and baryon, respectively.
- ➢ The central issue is determination of the parton distribution $F_{q_1\bar{q}_2}$ and $F_{q_1q_2q_3}$.

- There are two types of partons: thermal (T) and shower (S)

$$\mathcal{T}(p_1) = p_1\frac{dN_q^T}{dp_1} = Cp_1e^{-p_1/T}$$

$$\mathcal{S}^j(p_2) = \int\frac{dq}{q}\sum_i \hat{F}_i(q)S_i^j(p_2,q)$$

- ✓ $\hat{F}_i(q)$ : the distribution of hard or semihard parton of type i at the medium surface.
- ✓ $S_i^j(z)$ : the unintegrated shower parton distribution (SPD).

- Parton distributions before recombination

$$F_{q_1\bar{q}_2} = \mathcal{TT}+\mathcal{TS}+\mathcal{SS}$$

$$F_{q_1q_2q_3} = \mathcal{TTT}+\mathcal{TTS}+\mathcal{TSS}+\mathcal{SSS}$$

The 2(3) shower partons could be from one or two jets.

## Momentum Degradation

Calculation in pQCD is not reliable at intermediate q and difficult to account for the nuclear complications at various c and $\phi$

dynamical path length

$$F_i(q,\xi) = \int dk k f_i(k)G(k,q,\xi)$$

Fries, et al PRC(03) $f_i(k)$ — parton distribution at creation point; $p_2$; $F_i(q)$

The degradation of momentum from k to q can be written as a simple exponential *Hwa-Yang(10)*

$$G(k,q,\xi) = q\delta(q-ke^{-\xi})$$

Nuclear complicatioin is in the determination of $\xi$

That is contained in the probability function $P(\xi,\phi,c)$ in relating $F_i(q,\xi)$ to $\bar{F}_i(q,\phi,c)$

$$\bar{F}_i(q,\phi,c) = \int d\xi P(\xi,\phi,c)F_i(q,\xi)$$

The probability of having $\xi$ at $\phi$ and c in the medium

For calculating the $p_T$ spectra of any hadron produced later, we make $\bar{F}_i(q,c)$ averaged over $\phi$

$$\hat{F}_i(q,c) = \frac{1}{2\pi}\int_0^{2\pi} d\phi \bar{F}_i(q,\phi,c)$$

minijet distribution, averaged over $\phi$ , initial creation points.

## Mean Dynamical Path Length

Whereas $\xi$ depends on $\phi$, c implicitly, the mean $\bar{\xi}_i(\phi,c)$ depends on them explicitly.

$\gamma = 0.11$

determined by fitting nuclear modification factor $R_{AA}$ *Hwa-Yang(10)*

The dynamical effect of energy loss per unit length i=g, q.

probability of production of a (semi)hard parton at creation point $x_0$ and $y_0$

$$\bar{\xi}_i(\phi,c) = \int d\xi \xi P(\xi,\phi,c) = \gamma_i \int dx_0\, dy_0\, l(x_0,y_0,\phi,c)Q(x_0,y_0,c)$$

$$l(x_0,y_0,\phi,c) = \int_0^{t_1(x_1,y_1)} dt D(x(t),y(t))$$

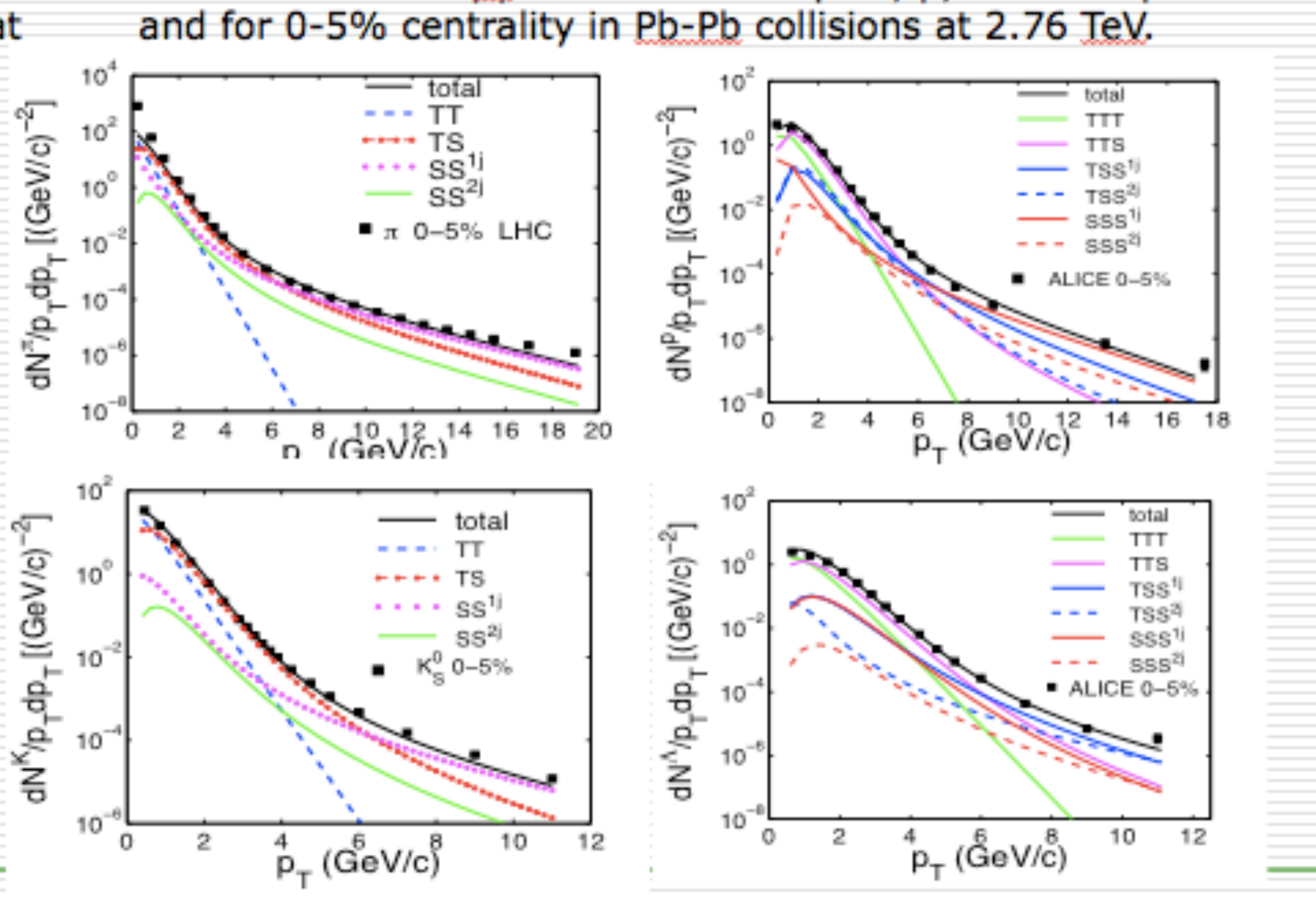
not time

The geometrical path length is weighted by the local density along the trajectory marked by t.

As the system expands, the density D decreases but $t_1$ increases, so $l$ is not very sensitive to the expansion dynamics.

## Results

We now can calculate the $p_T$ distributions of pion, p, K and produced at and for 0-5% centrality in Pb-Pb collisions at 2.76 TeV.




- $C = 23.2\,\text{GeV}^{-1}$, $T = 0.31\,\text{GeV}$
- The data in [7] suggest that jet quenching becomes less severe at higher momentum, so the momentum degradation factor $\gamma_i$ decreases as the hard parton momentum increases. Hence, we parameterize $\gamma_g$ as,

$$\gamma_g(q) = \frac{\gamma_0}{1+q/q_0}$$

- With the choice $\gamma_0 = 0.8$ and $q_0 = 10\,\text{GeV/c}$, we can fit the data for wide $p_T$ spectra and obtain the different components.
- $T_s = 0.34\,\text{GeV/c}$ for kaon, which is slightly higher than T.
- The value of $T_s^\Lambda$ =0.42 GeV/c is higher because the mass is higher.
- one- and two-jet contributions are included.

## Conclusions and Outlook

- new features of momentum degradation of minijets produced at intermediate q before hadronization.
- The $p_T$ spectra of pion, p, k and Lambda are well reproduced-by the minijet approach in the framework of the recombination model.
- Extension of the study to hyperons production, such as: Omega, Xi and phi.

## References

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