Collective flow in high-multiplicity proton-proton collisions

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Collective flow in high-multiplicity proton-proton collisions
(with Edward Shuryak).

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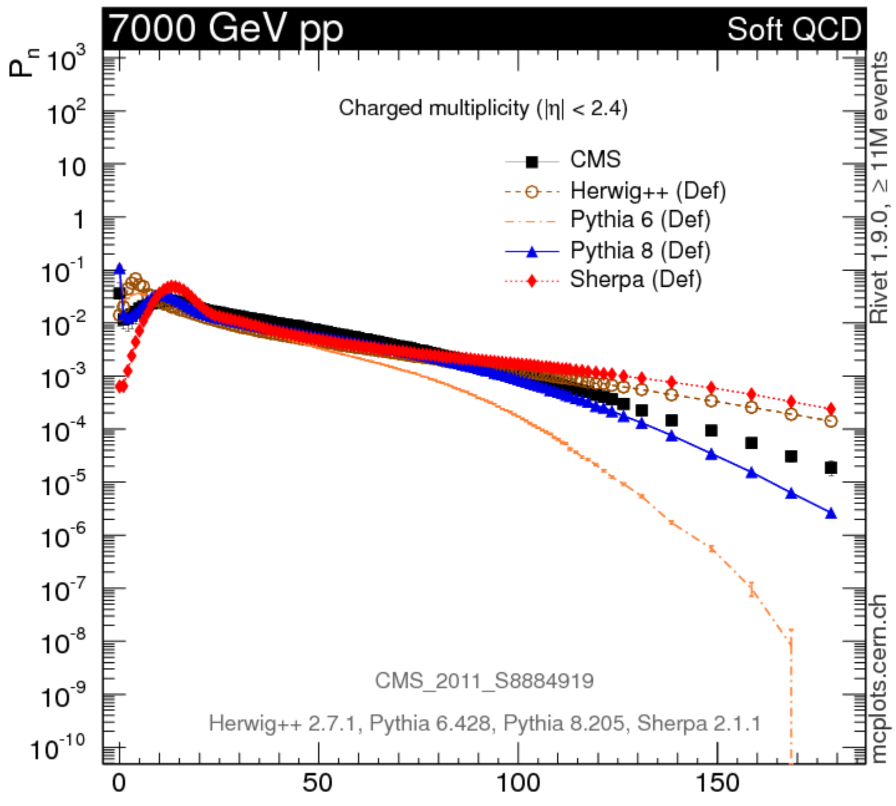
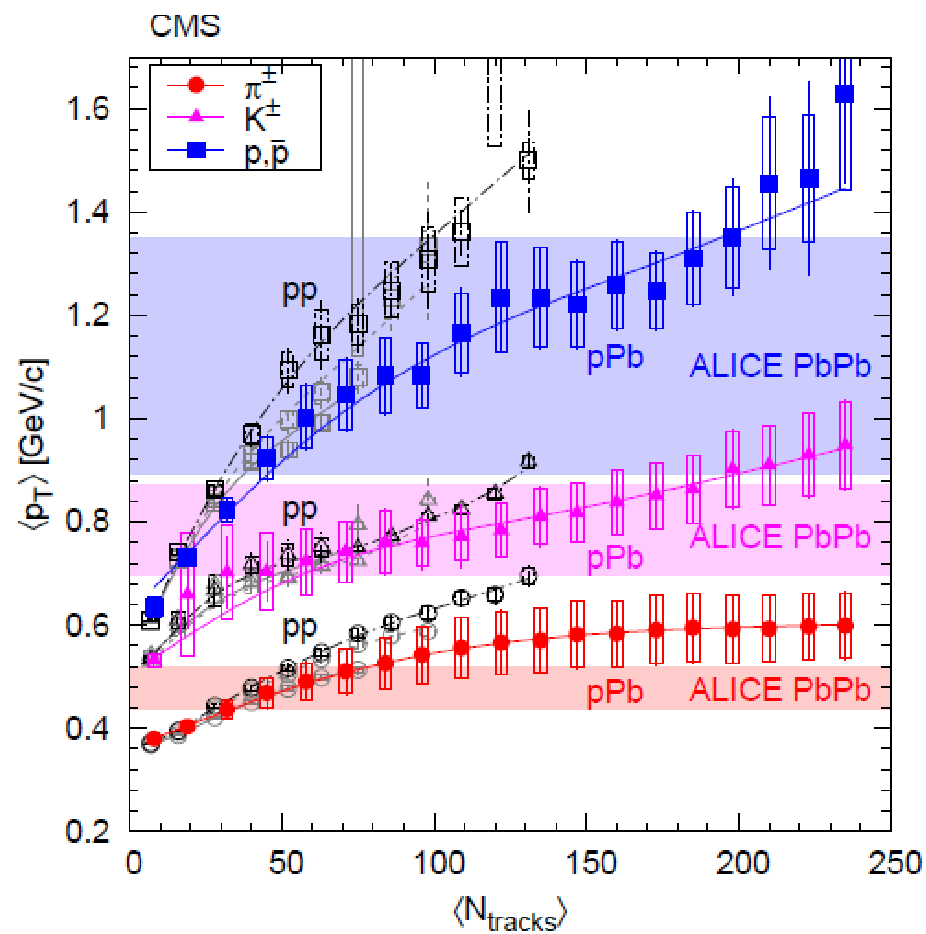
Motivation





- **Monte-Carlo generators do not reproduce the fraction of high-multiplicity events**
- **pp-collisions look even more „explosive“ than pA or AA.**

CMS: JHEP 1101 (2011) 079, EPJC 74 (2014) 2847

Gubser's flow and freezeout surfaces

$$\epsilon(\bar\tau,\bar r) = \frac{\epsilon_0 (2q)^{8/3}}{\bar\tau^{4/3}[1+2q^2(\bar\tau^2+\bar r^2)+q^4(\bar\tau^2-\bar r^2)^2]^{4/3}}$$

$$v_\perp(\bar\tau,\bar r) = \frac{2q^2\bar\tau\bar r}{1+q^2\bar\tau^2+q^2\bar r^2}$$

$$\tau = q\bar\tau$$

$$r = q\bar r$$

$$\epsilon_0 = f_*^{-1/3}\left(\frac{3}{16\pi}\frac{dS}{d\eta}\right)^{4/3}$$

$$\frac{\epsilon}{q^4} = \frac{\epsilon_0\, 2^{8/3}}{\tau^{4/3}\left[1+2(\tau^2+r^2)+(\tau^2-r^2)^2\right]^{4/3}}$$

$$v_\perp(\tau,r) = \frac{2\tau r}{1+\tau^2+r^2}$$

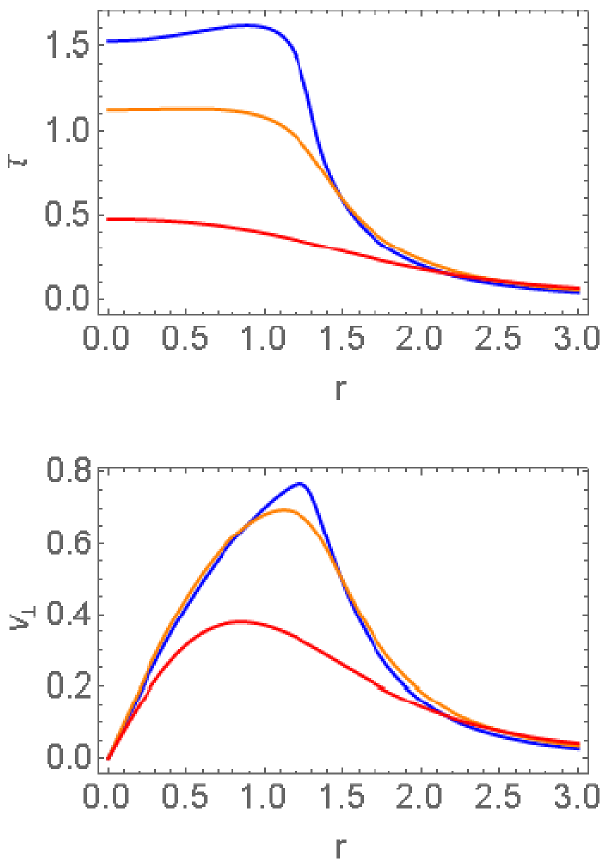
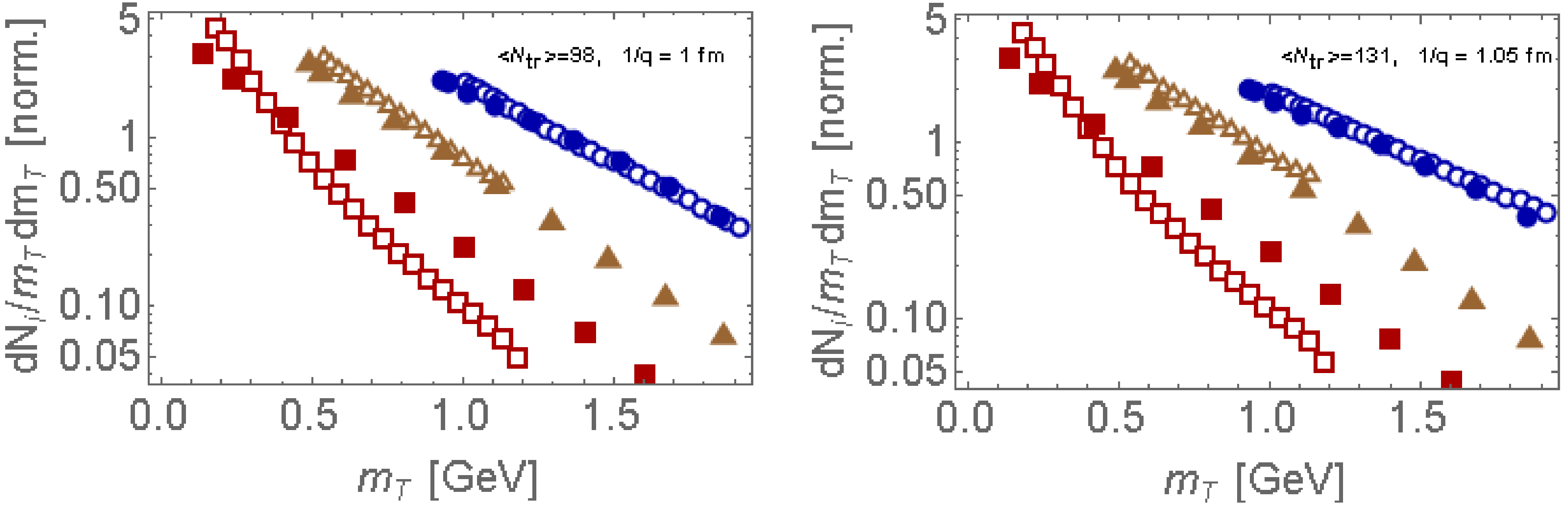


FIG. 1: (Color online) Profiles of the freezeout surfaces (upper plot) and the corresponding velocities (lower plot) for three different initial system sizes: at $\epsilon_0 = 10$ and $1/q = 0.7$ fm (upper blue), $1/q = 1$ fm (middle orange), $1/q = 2$ fm (lower red).

Particle spectra

From Cooper-Frye formula and freezeout curves



The data (open symbols) are from CMS, 7 TeV, fit done by the system size parameter q in the Gubser's flow solution and works for N > 75.
protons, kaons, pions

Initial fireball size q = 1 fm !