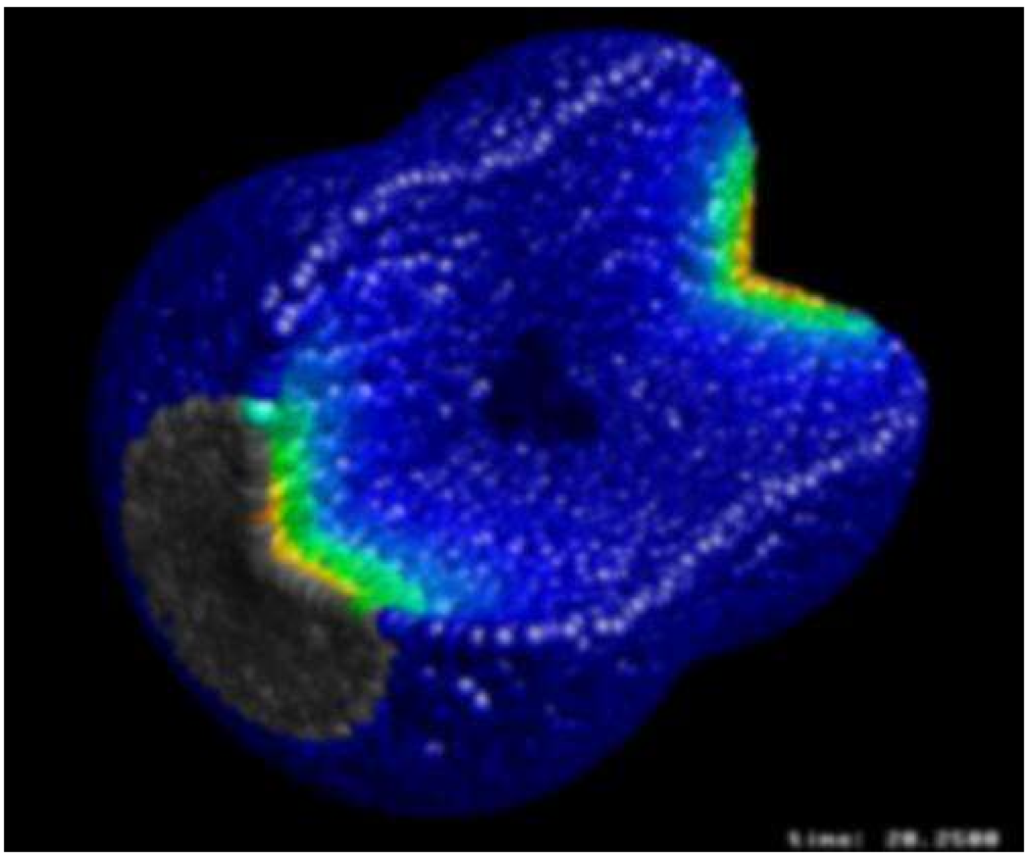
Transverse Spectra of Hadrons in Central AA Collisions at RHIC and LHC from pQCD+Saturation+Hydrodynamics and from pQCD+Energy Losses

arXiv:hep-ph/0506049



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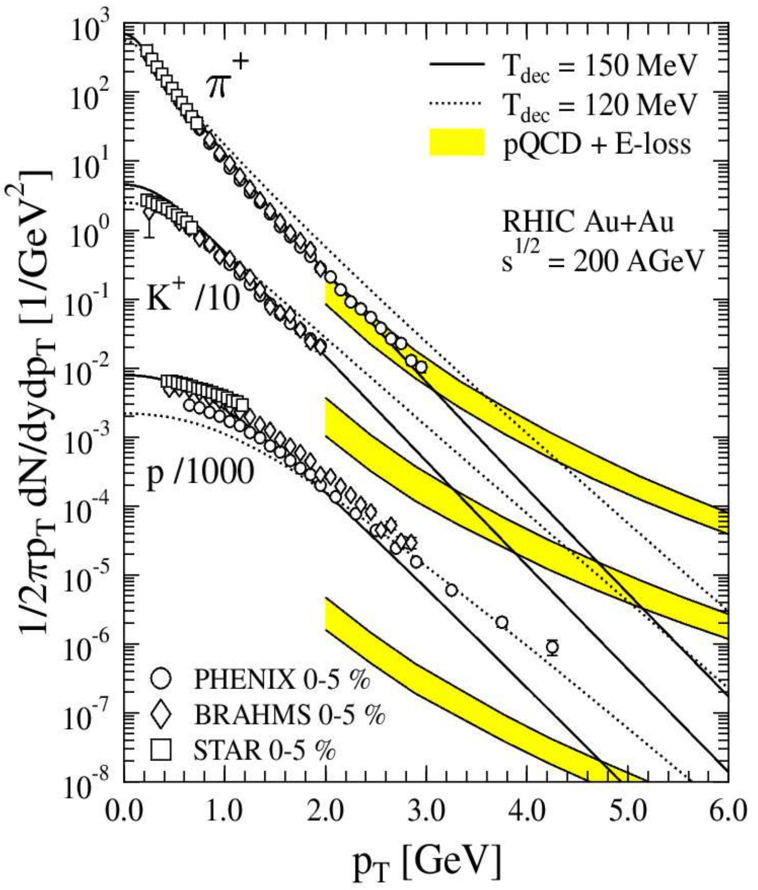
Model

We calculate both high-p_T and low-p_T hadron spectra in Au+Au collision at RHIC and Pb+Pb collision at LHC.

- EKRT final state saturation model for initial particle production
- Boost invariant hydrodynamics for the following evolution of the initial state

- pQCD + fragmentation + energy loss for the high-p_T particle production.



EKRT final state saturation

Eskola, Kajantie, Ruuskanen, Tuominen, Nucl. Phys. B **570** (2000) 379 [hep-ph/9909456]

- Idea: Low-p_T parton production is controlled by saturation among the produced gluons.

- Geometric estimate: Saturation sets in when produced gluons with $p_T > p_0$ fill the whole transverse overlap area of the colliding nuclei

$$N_{AA}(p_0, \Delta y = 1, \sqrt{s}) \cdot \pi / p_0^2 = \pi R_A^2$$

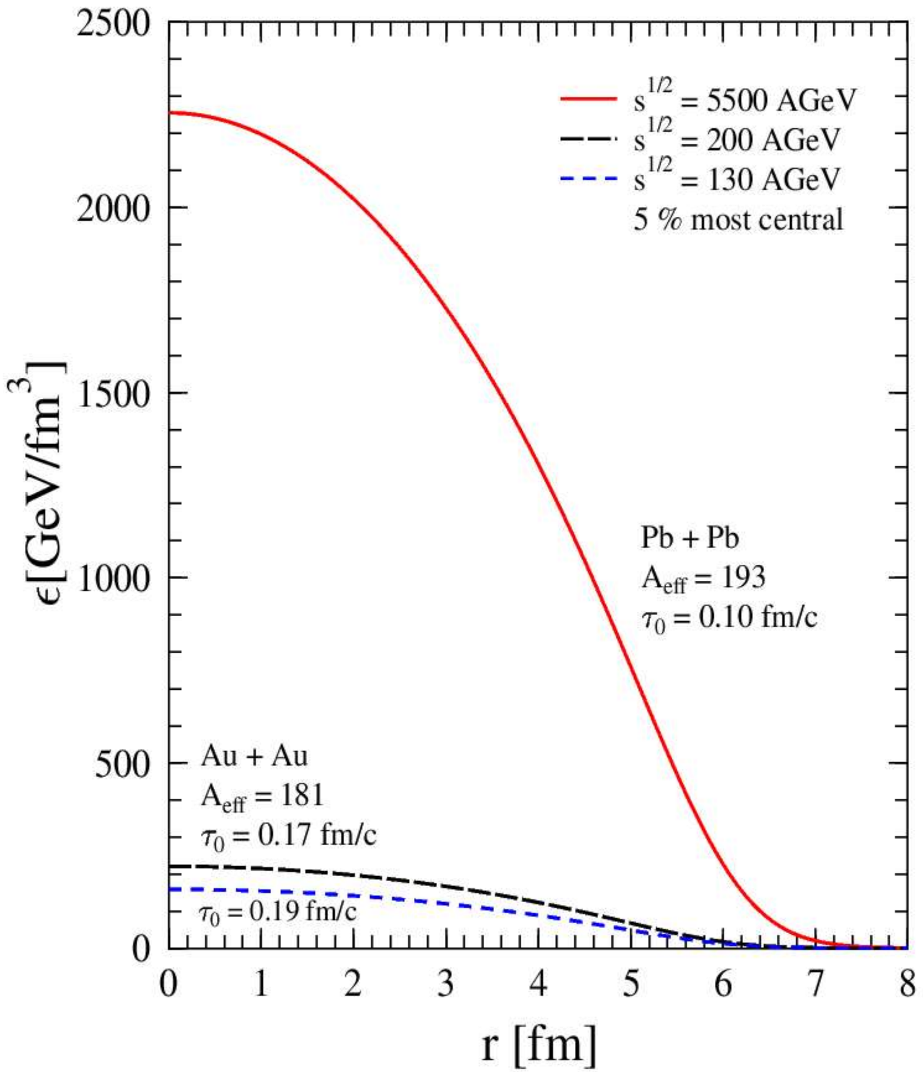
Nuclear radius (R_A)

Number of gluons with $p_T > p_0$ (N_{AA})

- Gives saturation scale p_{sat} for any AA collision
- If $p_{sat} \gg \Lambda_{QCD}$ pQCD particles with $p_T > p_{sat}$ can give a good estimate of the number of partons and energy produced to midrapidity
- $\tau_{prod} = 1/p_{sat}$

→ **transverse energy E_T & net baryon number N_B**

Initial state for hydrodynamics



RHIC $\sqrt{s_{NN}}$ = 200 GeV Au+Au

$\tau_0 \sim 0.17$ fm/c

$\varepsilon_{max} \sim 200$ GeV/fm^3

$dN_B/dy = 14.0$

LHC $\sqrt{s_{NN}}$ = 5500 GeV Pb+Pb

$\tau_0 \sim 0.10$ fm/c

$\varepsilon_{max} \sim 2200$ GeV/fm^3

$dN_B/dy = 3.11$

Hydrodynamics for low-p_T hadrons

If equilibration time τ_{therm} < production time $\tau_{prod} = 1/p_{sat}$ we can start hydrodynamics immediately after production of the initial state.

$$\partial_\mu T^{\mu\nu}(x) = 0 \qquad \text{and} \qquad \partial_\mu j^\mu_B(x) = 0,$$

$$T^{\mu\nu} = (\epsilon + P) u^\mu u^\nu - P g^{\mu\nu} \qquad \text{and} \qquad j^\mu_B = n_B u^\mu$$

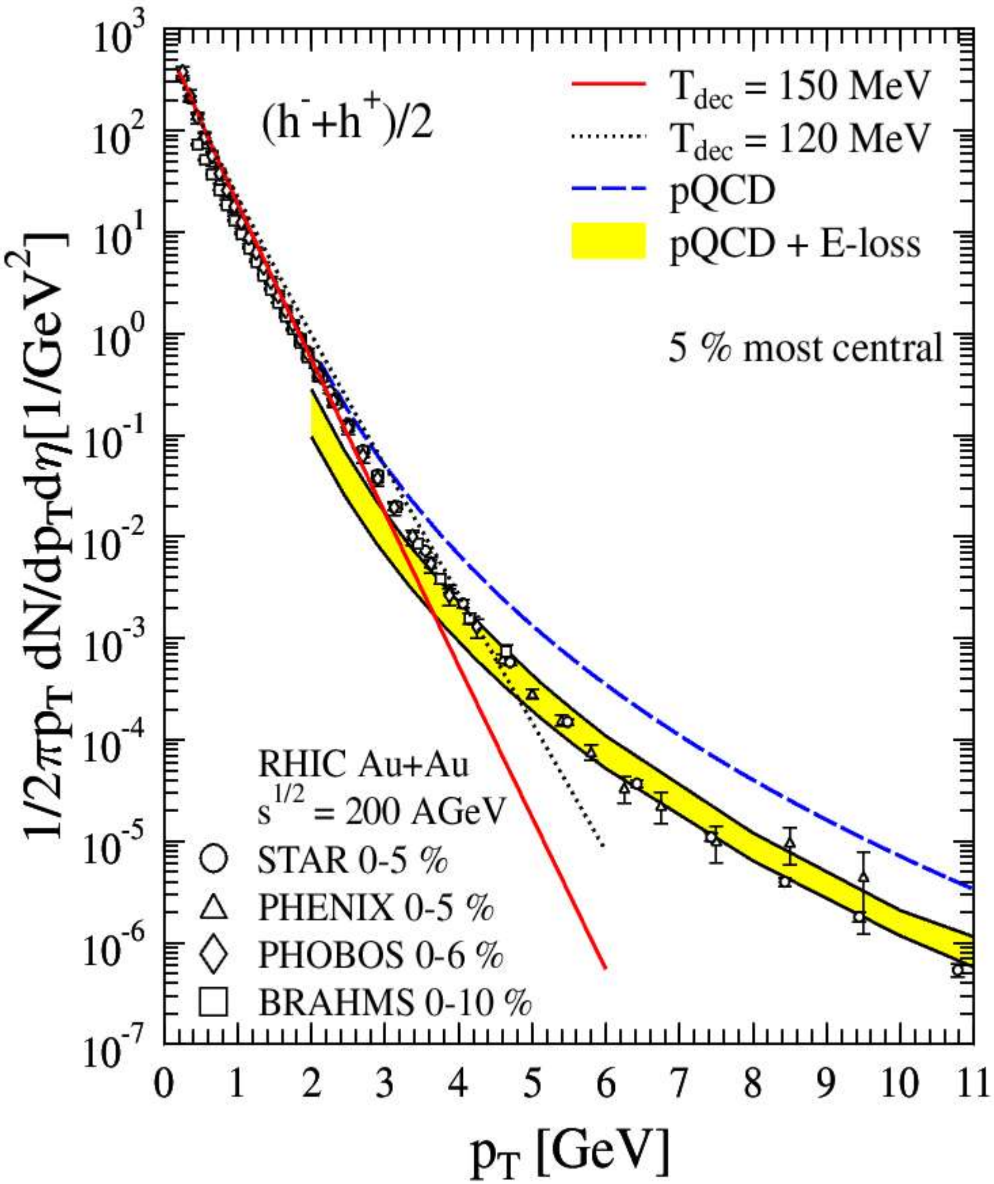
- Boost invariant ideal hydrodynamics with transverse expansion
- Full kinetic and chemical equilibrium
- Equation of State: Bag model EoS connecting Hadron gas with all hadronic states with m < 2 GeV and QGP with $N_f = 3$ ($T_c = 165$ MeV)
- Cooper-Frye decoupling
- All 2- and 3-body decays of unstable hadronic states

pQCD + energy loss

$$d\sigma^{AA\to h+X} = \sum_{ijk} f_{i/A} \otimes f_{j/A} \otimes \hat{\sigma}_{ij\to f+k} \otimes P_f(\Delta E, L, \hat{q}) \otimes D_{f\to h}$$

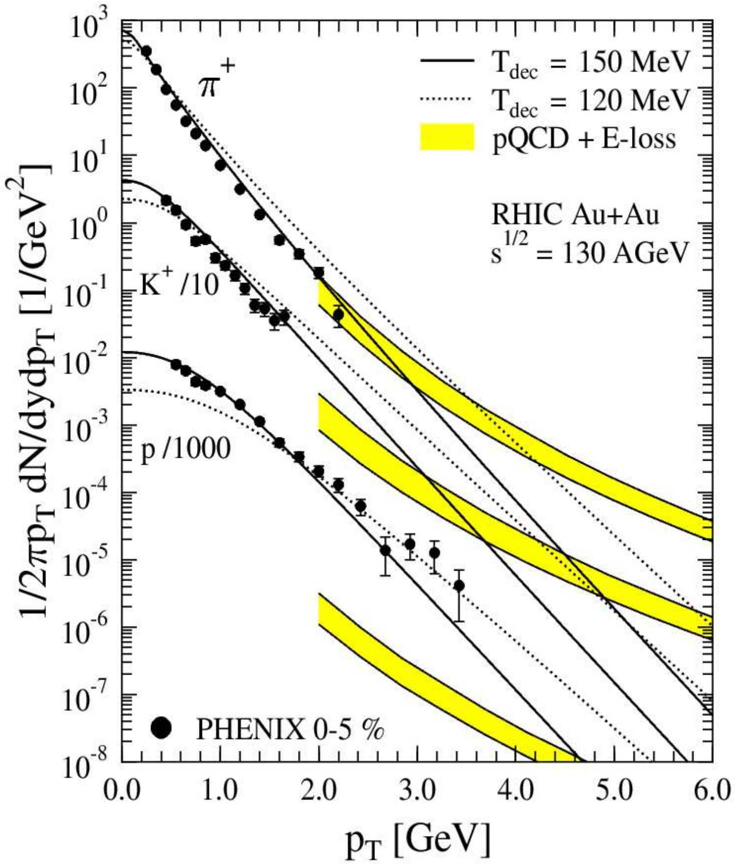
- LO factorized pQCD with fragmentation functions
- cms-energy dependent K-factors fixed from pp(anti-p)-data
  Eskola, Honkanen, Nucl.Phys.A713:167-187,2003 [hep-ph/0205048]
- EKS nuclear modifications applied to PDF
  Eskola, Kolhinen, Salgado, Eur.Phys.J.C9:61-68,1999 [hep-ph/980729]
- Energy losses included in terms of quenching weights Eskola, Honkanen, Salgado, Wiedemann, Nucl.Phys.A747:511-529,2005 [hep-ph/0406319]
- Eikonal (infinite energy) approximation in energy loss calculation
- Transport coefficient **q** fixed from √s = 200 A GeV Au+Au data

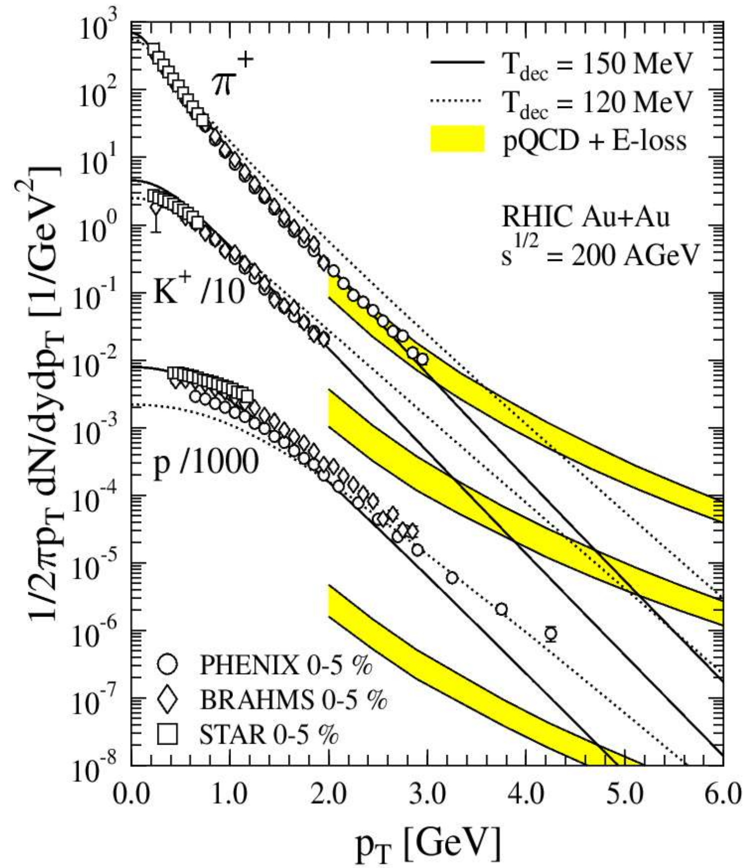
Charged hadrons at RHIC



- Hydrodynamics describes low-p_T data with $\mathbf{T_{dec} = 150}$ **MeV**
- Hydro results also shown with $\mathbf{T_{dec} = 120}$ **MeV** to estimate uncertainties in decoupling
- Transport coefficient **q** is fixed by $p_T > 5$ GeV, $\sqrt{s} = 200$ A GeV data
- Because $\mathbf{q} \propto n_g$ energy loss is predicted for $\sqrt{s} = 130$ A GeV and $\sqrt{s} = 5500$ A GeV
- Large uncertainty in energy loss is because eikonal approximation applied to finite energy jets

Identified positive hadrons at RHIC

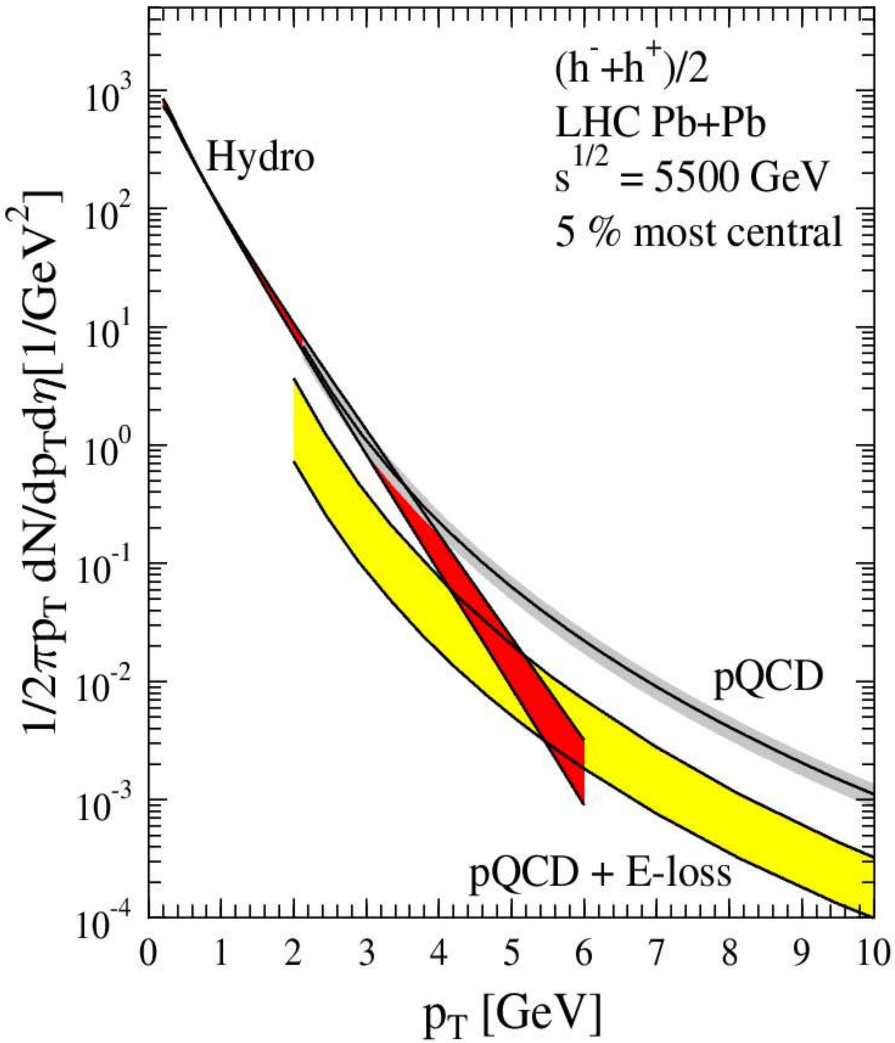




- Single high T_{dec} = 150 MeV describes both slopes and multiplicities reasonable well (similar to separate chemical and kinetic freeze out)
- For heavier particles overlap between fragmentation and hydro spectra is at much higher p_T and hydro should apply longer

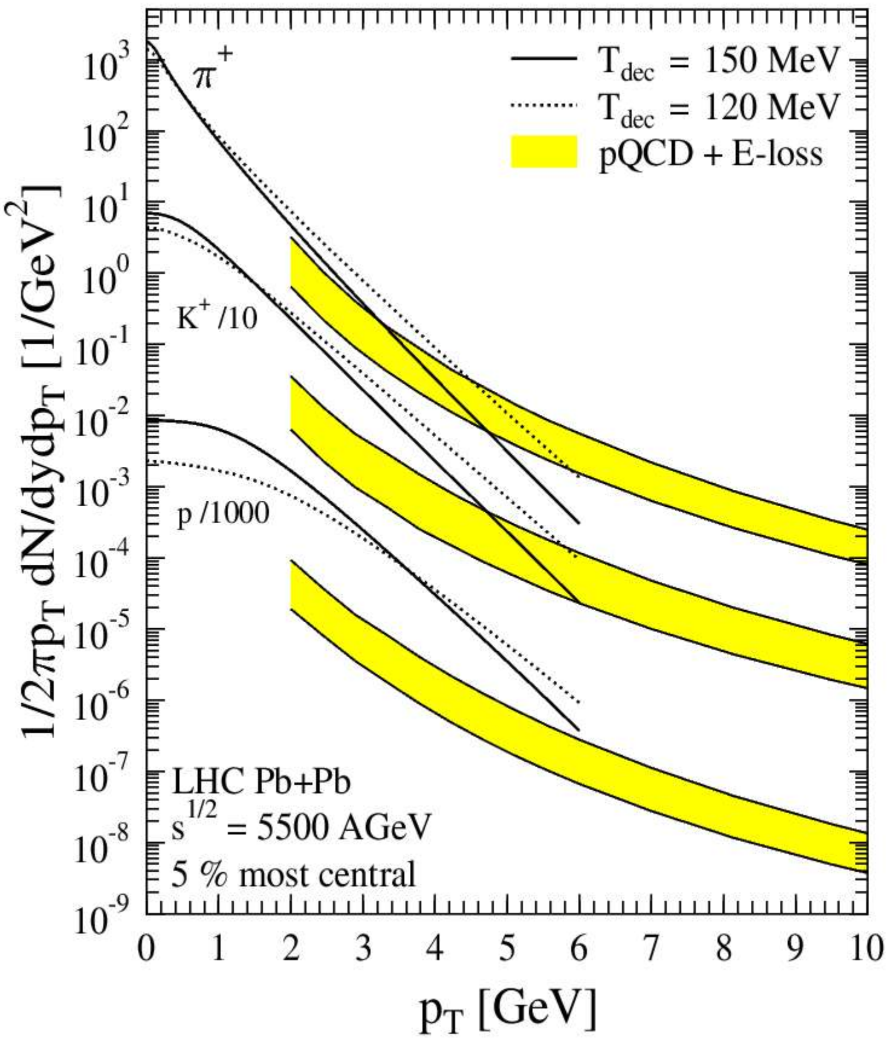
(**see also:** Hirano, Nara, Phys.Rev. C69:034908,2004 [nucl-th/0307015])

Unidentified charged hadrons at the LHC



- Initial state for hydrodynamic evolution is from EKRT saturation model
- Transport coeffients are fixed from RHIC $\sqrt{s}$ = 200 A GeV data
- Hydro results are shown as red band between T_{dec} = 120 and 150 MeV
- Grey band in pQCD results without energy loss shows uncertainty in extrapolating K-factor to LHC energy
- Yellow band shows uncertainty from eikonal approximation in energy loss
- Crossing between hydro and pQCD is at much higher p_T than at RHIC

Charged hadrons at the LHC



- Initial state for hydrodynamical evolution is from EKRT saturation model
- Yellow band shows uncertainty coming from eikonal approximation
- Same hierarchy as in RHIC results: For heavier particles hydrodynamics should apply for higher p_T.

$$dN_{CH}/dy \sim 2900$$

$$dN_B/dy = 3.11$$

Summary

- We have calculated low-p_T spectra for RHIC and the LHC AA collisions by calculating initial state for hydrodynamic evolution from EKRT final state saturation model
- hi-p_T spectra is calculated from pQCD + fragmentation + e-loss
- K-factors fixed from pp(anti-p) data
- Magnitude of the energy loss is fixed from RHIC $\sqrt{s}$ = 200 A GeV data(prediction for other cms-energies)
- Both hi- and low-p_T results for RHIC are in good agreement with data
- We have closed framework to make predictions for LHC energies