Hadronic composition as a characteristics of jet quenching at the LHC

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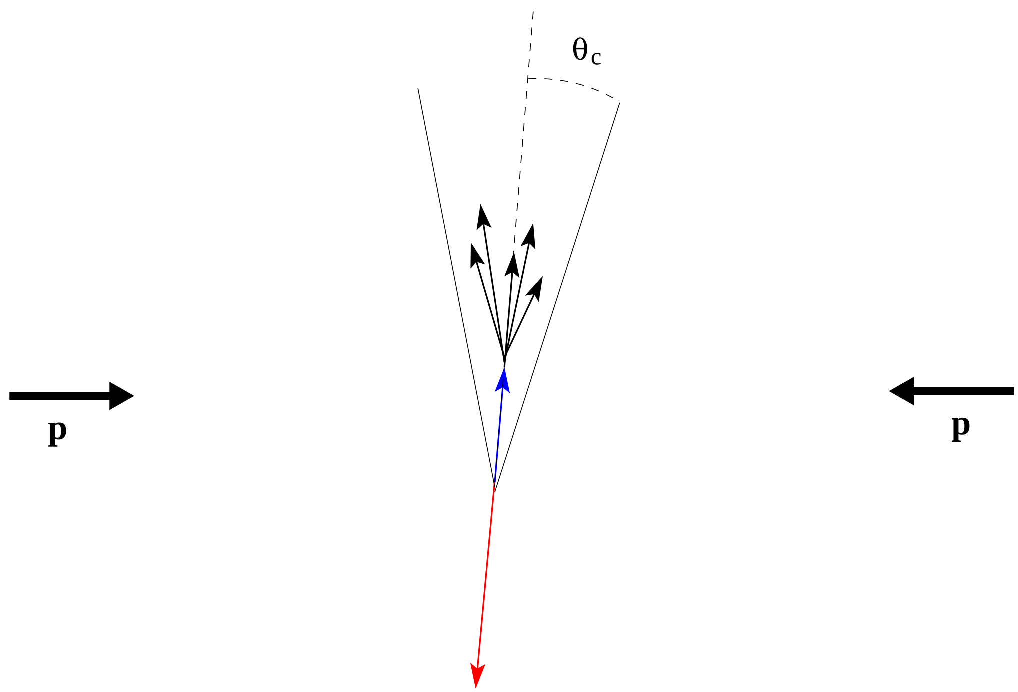
in collaboration with **Urs Achim Wiedemann**

based on arXiv:0707.3494[hep-ph]

Workshop on parton fragmentation processes in the vacuum and in the medium,
ECT* - Trento, February 25-29, 2008

JETS AT SMALL x

VACUUM



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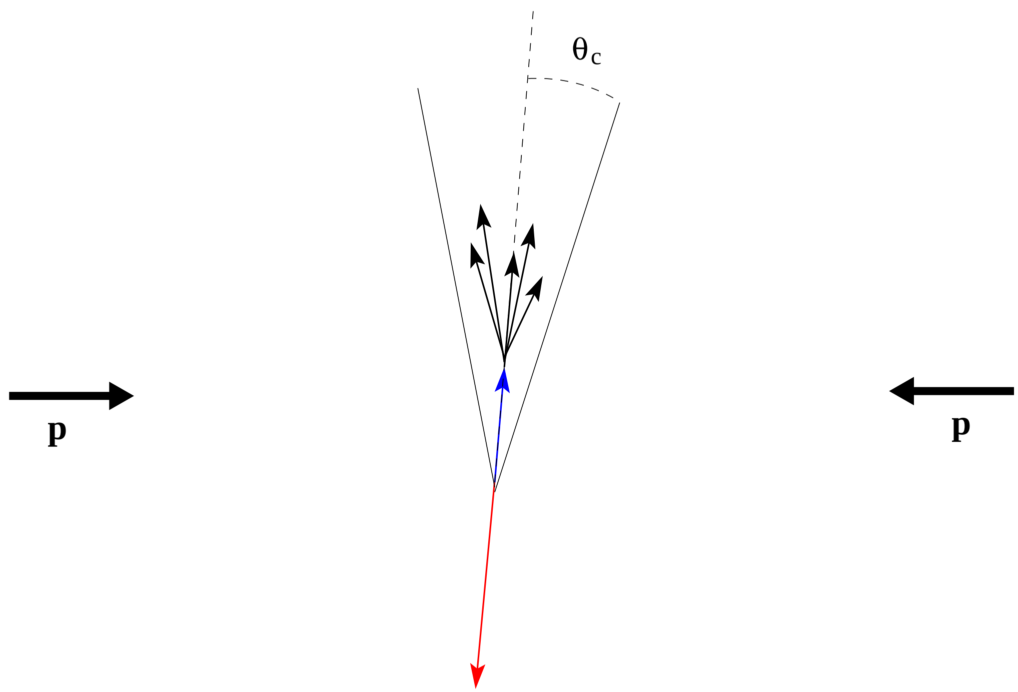

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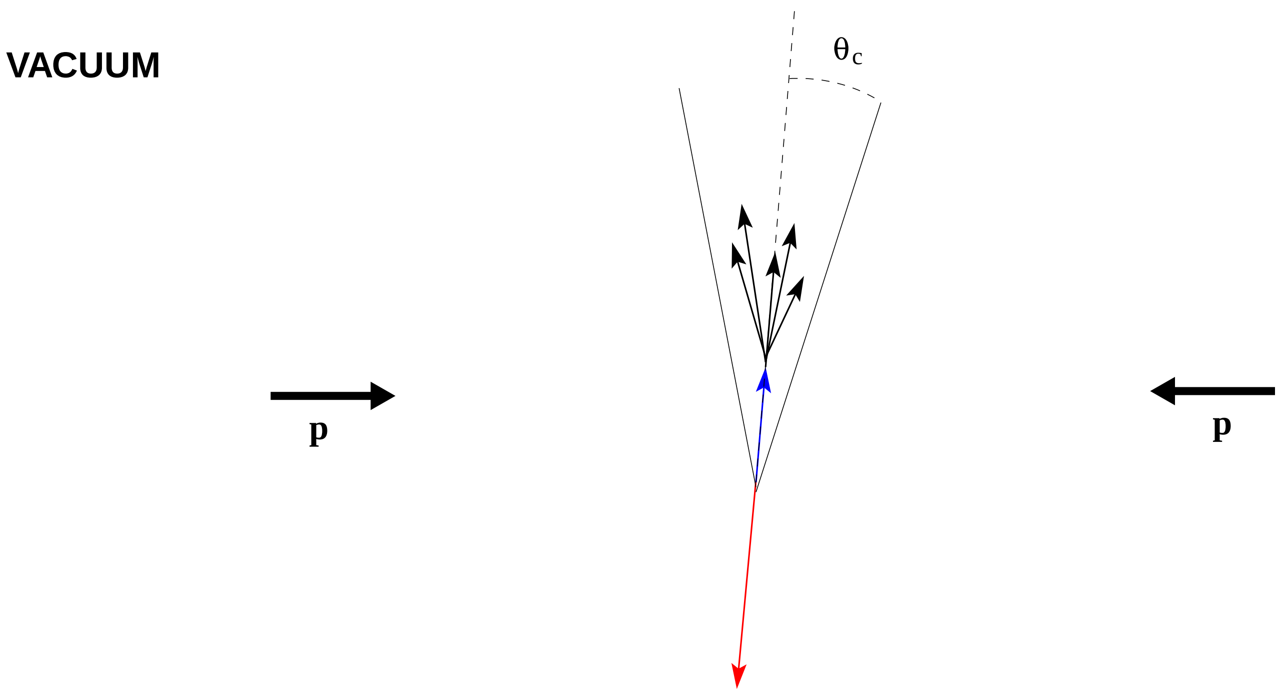
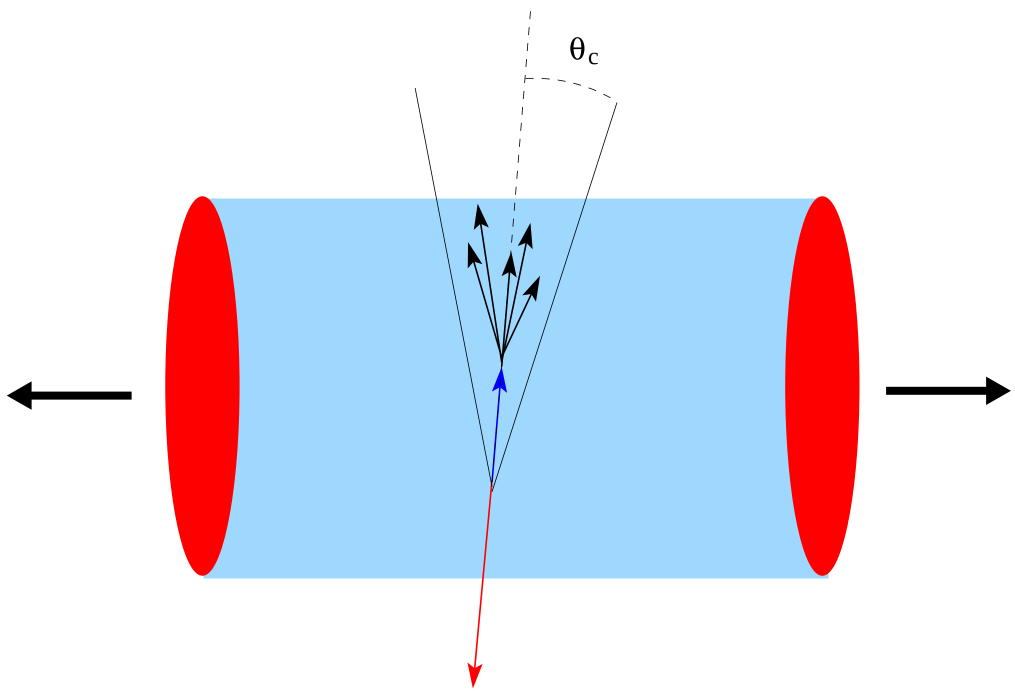


- $x = \dfrac{p}{E_{\rm jet}}$ – fraction of jet energy carried by the hadron
- perturbative approach of
  Modified Leading Logarithmic Approximation (MLLA)
- hypothesis of Local Hadron-Parton Duality (LPHD)

THE PROCESS

MEDIUM



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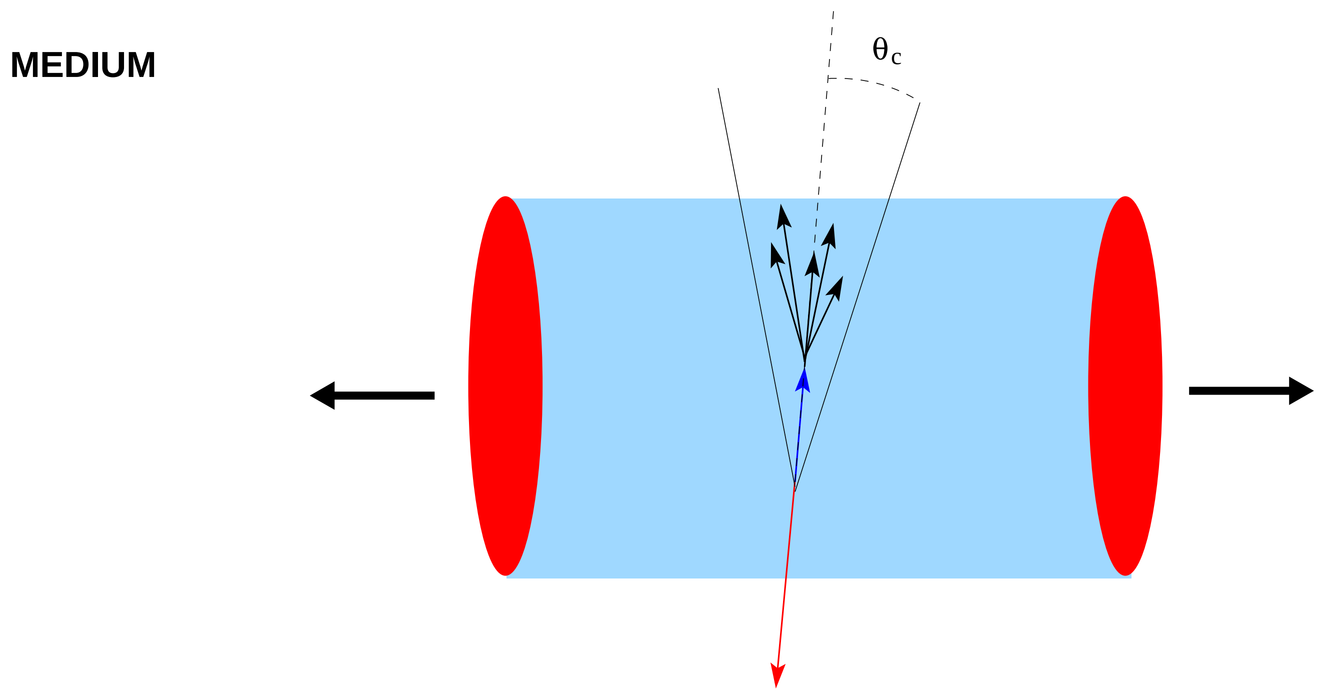

Highly energetic jet superimposed on the top of the heavy ion background

Possible mechanisms medium affects hadrochemistry:

- color transfer effects
- flavor and baryon number exchange between medium and projectile
- recombination of partons from jet and medium
- recoil effects a.k.a. collisional energy loss
- medium components kicked into the jet cone
- momentum exchange between medium and projectile

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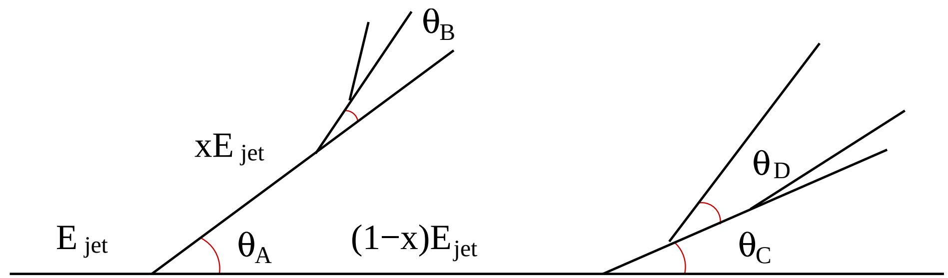
This is likely to underestimate the medium-modifications of jet hadrochemistry. However, it may serve as a baseline on top of which other signatures of hadrochemical modifications can be established.

MODIFIED LEADING LOGARITHMIC APPROXIMATION (MLLA)

[Yu.L.Dokshitzer, V.A.Khoze, S.I.Troyan; 1980s]

parton cascade



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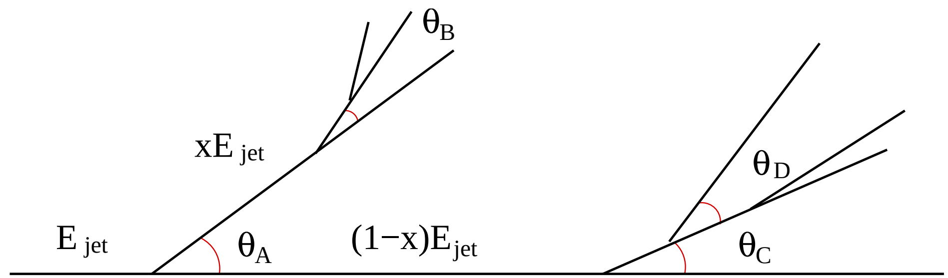

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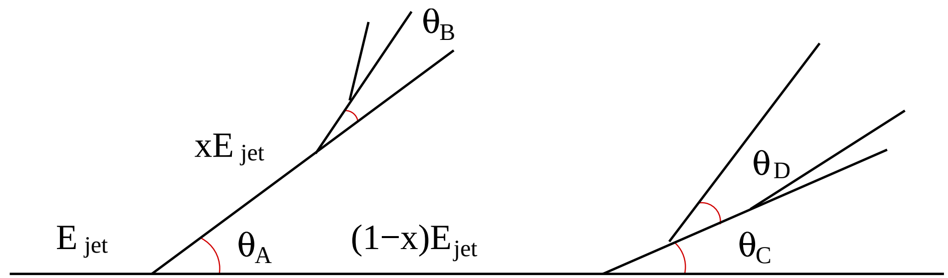

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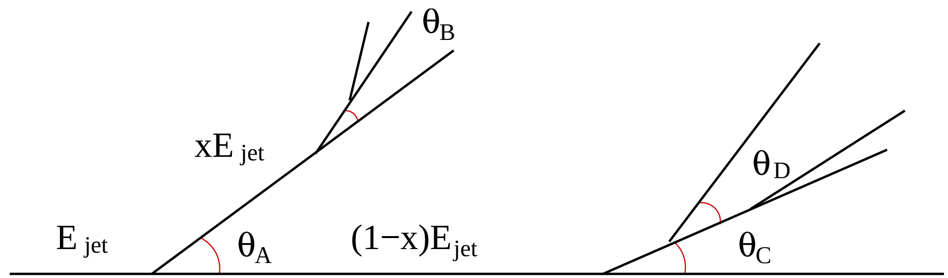

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- the above boils down to the probabilistic picture of parton splittings with the prescription of exact angular ordering being the consequence of the quantum interference
- pair of evolution equations for parton distributions inside a quark and gluon jets

$$\frac{\partial}{\partial \ln \theta} \left[\begin{array}{c} D_Q(\nu, \ln \theta) \\ D_G(\nu, \ln \theta) \end{array} \right] = \hat{\Phi} \left(\nu + \frac{\partial}{\partial \ln \theta} \right) \left[\begin{array}{c} D_Q(\nu, \ln \theta) \\ D_G(\nu, \ln \theta) \end{array} \right]$$

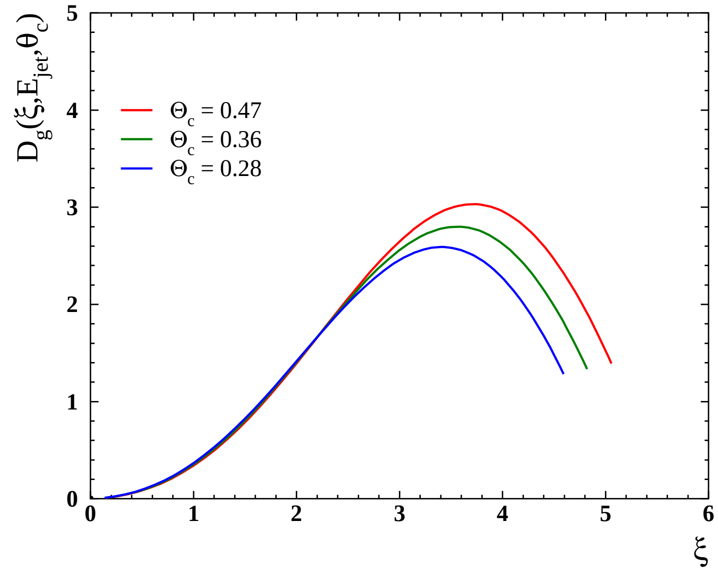
ν - Mellin conjugate to x

MLLA + LOCAL PARTON-HADRON DUALITY (LPHD)

- the solution: hump-backed plateau

$$D_g(\xi = \ln\frac{1}{x}, E_{\rm jet}, \theta_c, Q_0, \Lambda)$$

Q_0 – cutoff on $k_\perp$, Λ – QCD scale



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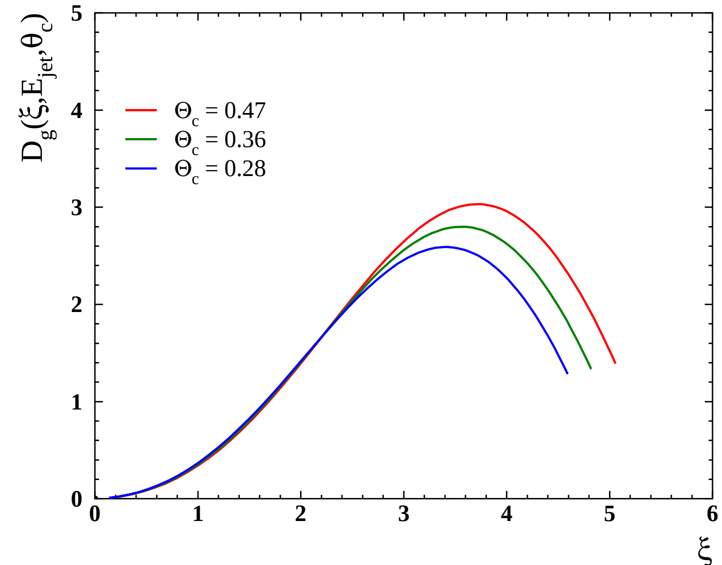

- *limiting spectrum* $Q_0 = \Lambda$ – a specific way to model confinement

$$D_g^{\rm lim}(\xi, E_{\rm jet}, \theta_c, \Lambda)$$

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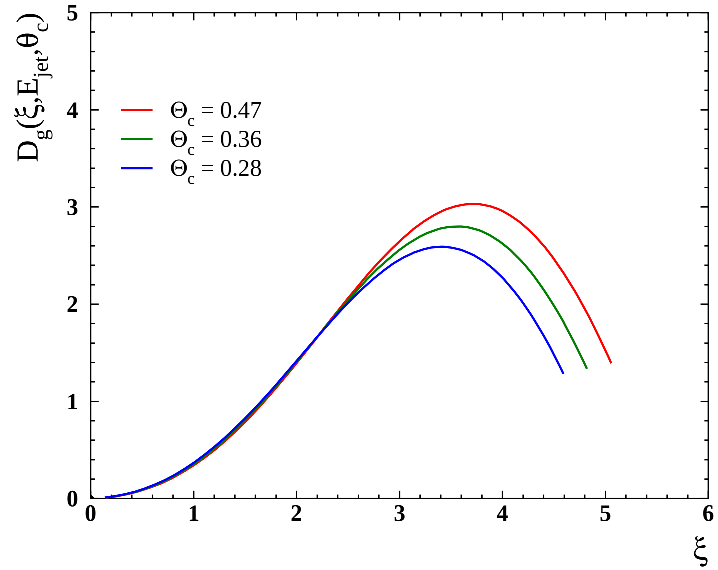

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- Local Parton-Hadron Duality (LPHD); $K_{\rm LPHD}$ of the order of unity

$$\frac{dN^h}{d\xi} = K_{\rm LPHD}\, D(\xi, E_{\rm jet}, \theta_c, Q_0, \Lambda)$$

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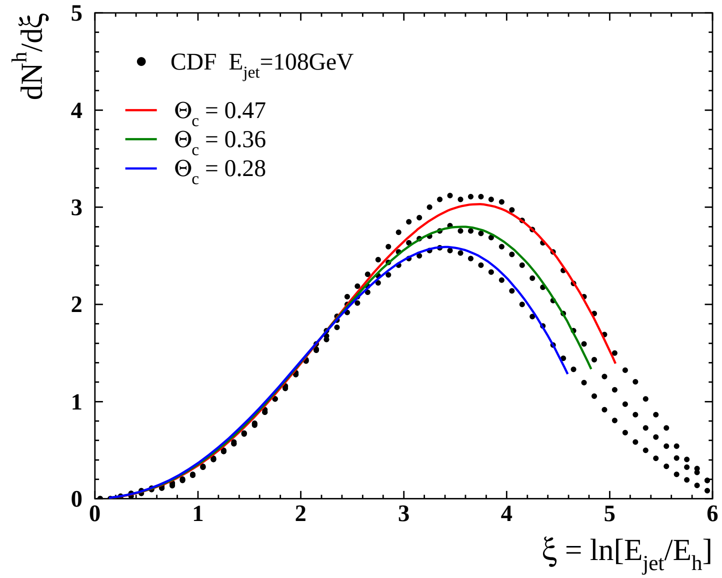

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MLLA + LPHD – IDENTIFIED HADRONS

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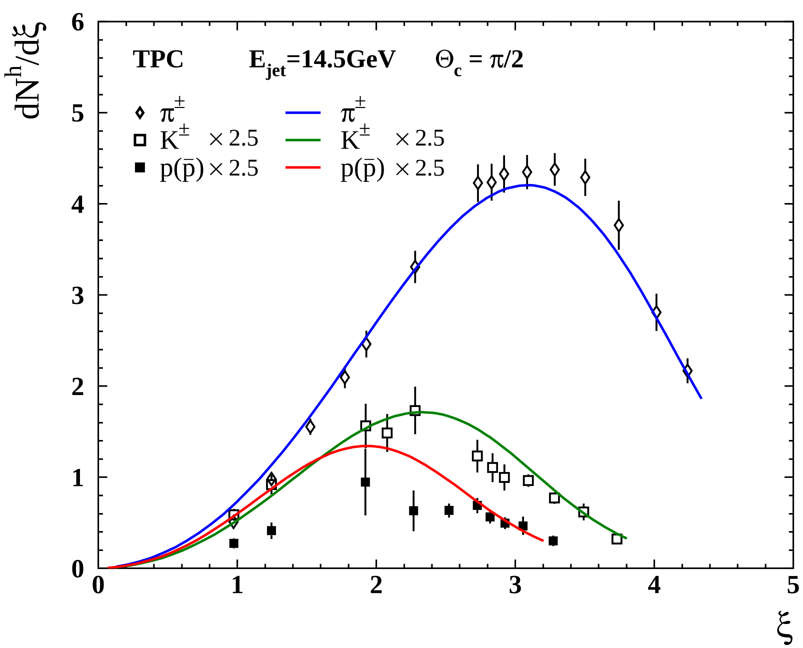

We have fair theoretical control on jets in vacuum

THE MODEL OF MEDIUM MODIFICATION

[N.Borghini, U.A.Wiedemann; 2005]

- medium enhances the singular part of splitting functions, e.g.

$$P_{qq}(z) = C_F \left\{ \frac{2\,(1+f_{\rm med})}{(1-z)_+} - (1+z) \right\}$$

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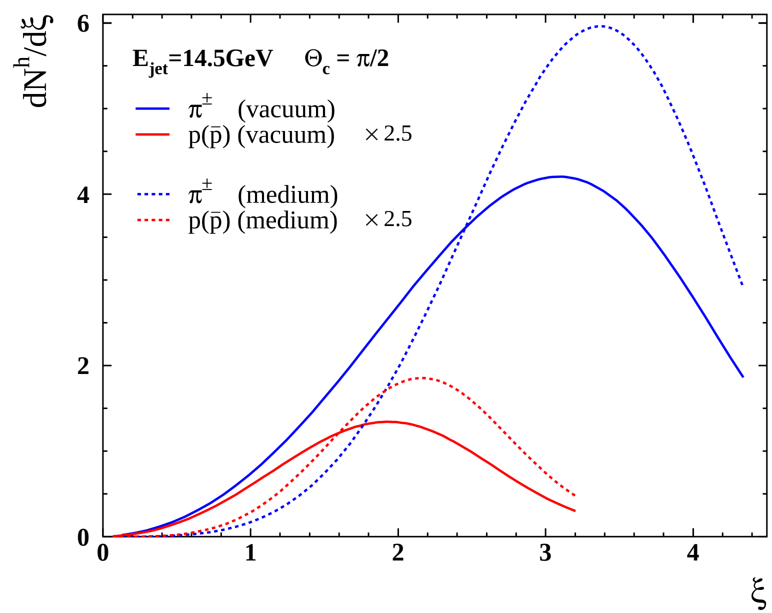

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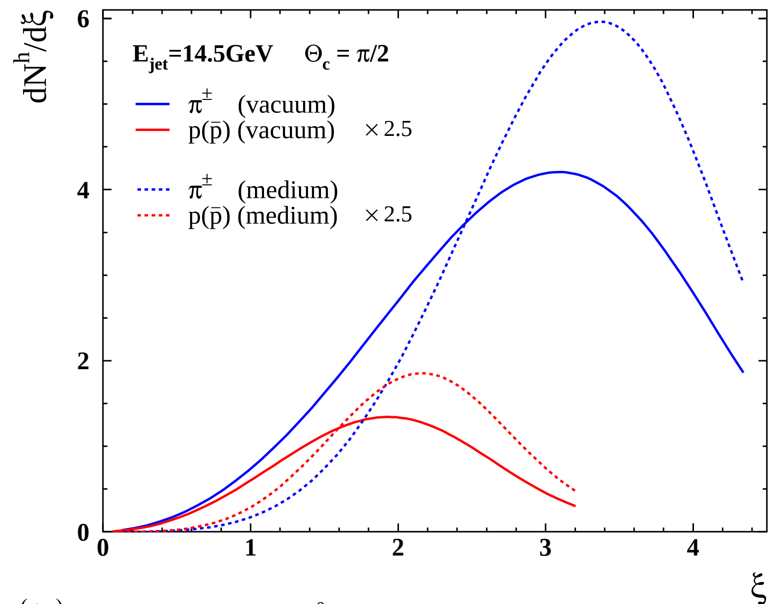
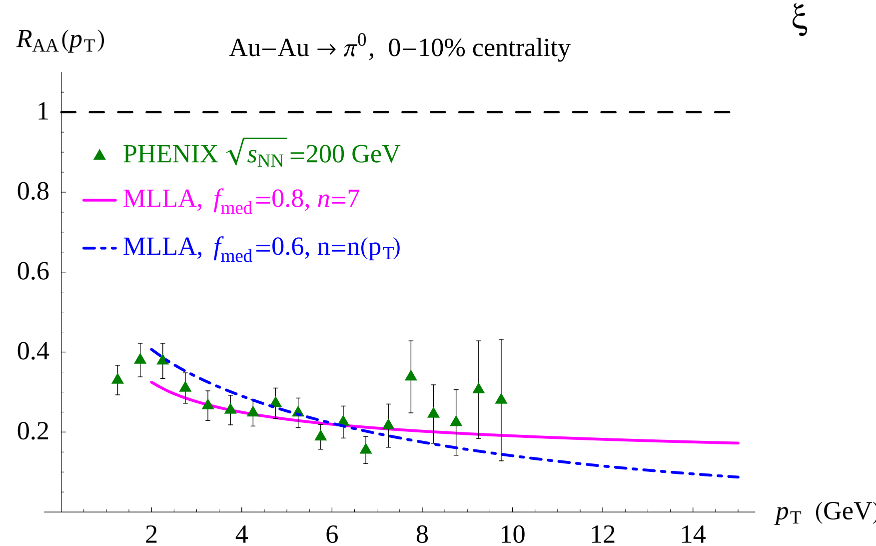
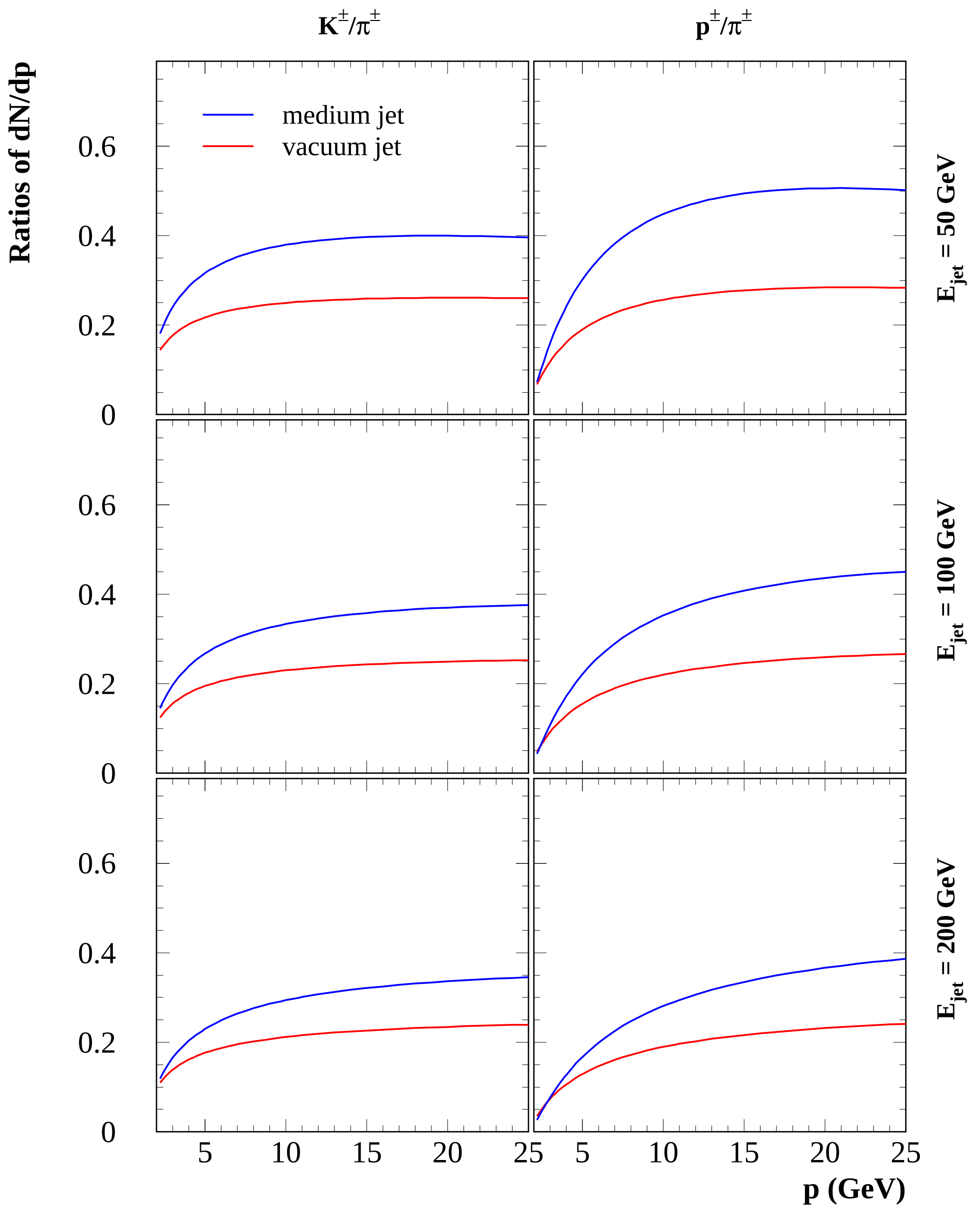
- enough to account for the observed suppression of single inclusive spectra





JETS AT THE LHC

HADRON RATIOS



jet cone size: $\theta_c = 0.28$

factor 0.7 for kaons from jet

K_{LPHD} assumed to be unchanged

Pure jets

- significant difference of hadron ratios for medium modified and unmodified jets at high momenta

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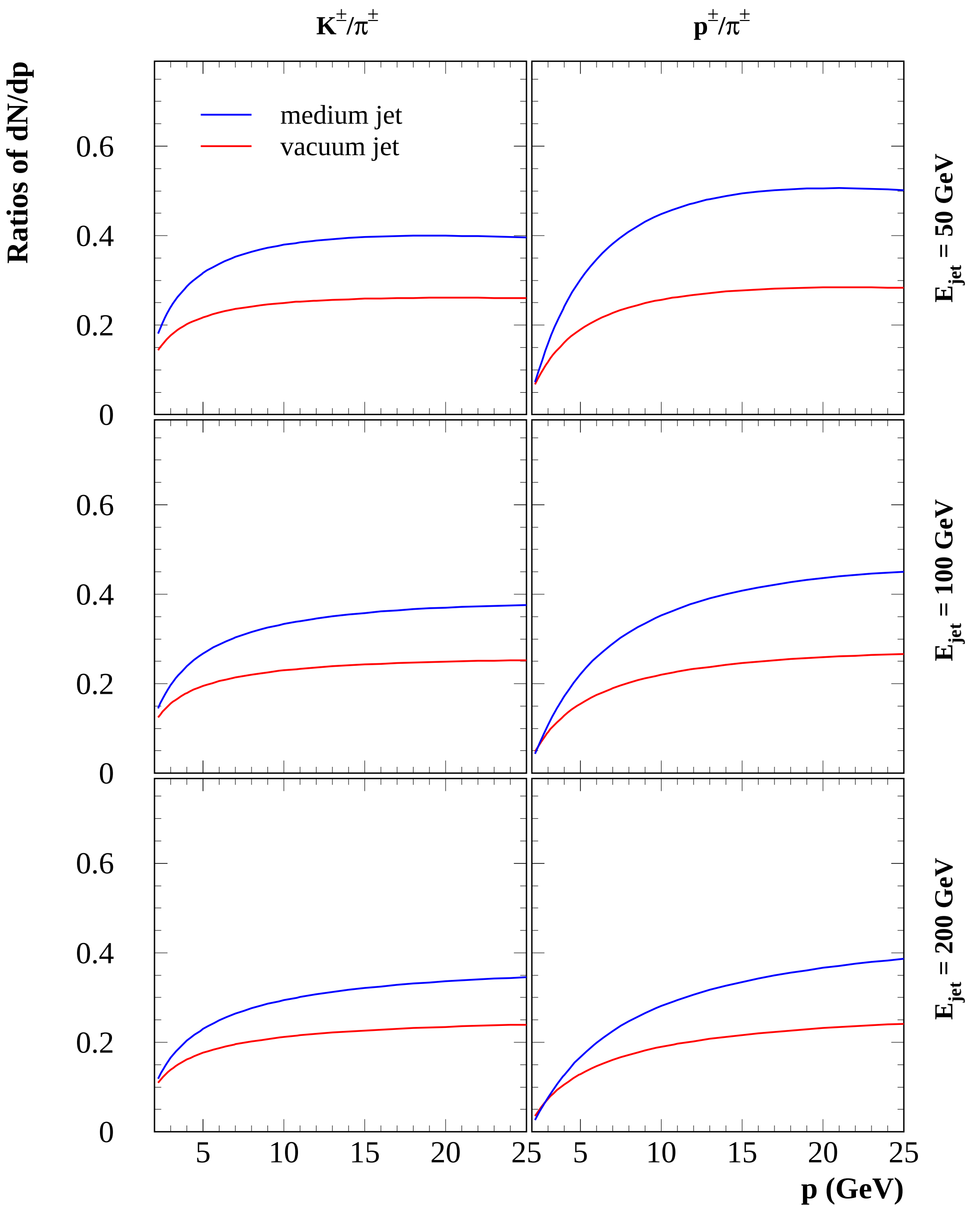

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Pure jets

- significant difference of hadron ratios for medium modified and unmodified jets at high momenta
- ratios level off at high hadron momenta

$$D^{p,K}\left(\ln\frac{p}{M_{p,K}}\right)\Big/ D^{\pi}\left(\ln\frac{p}{M_{\pi}}\right)$$

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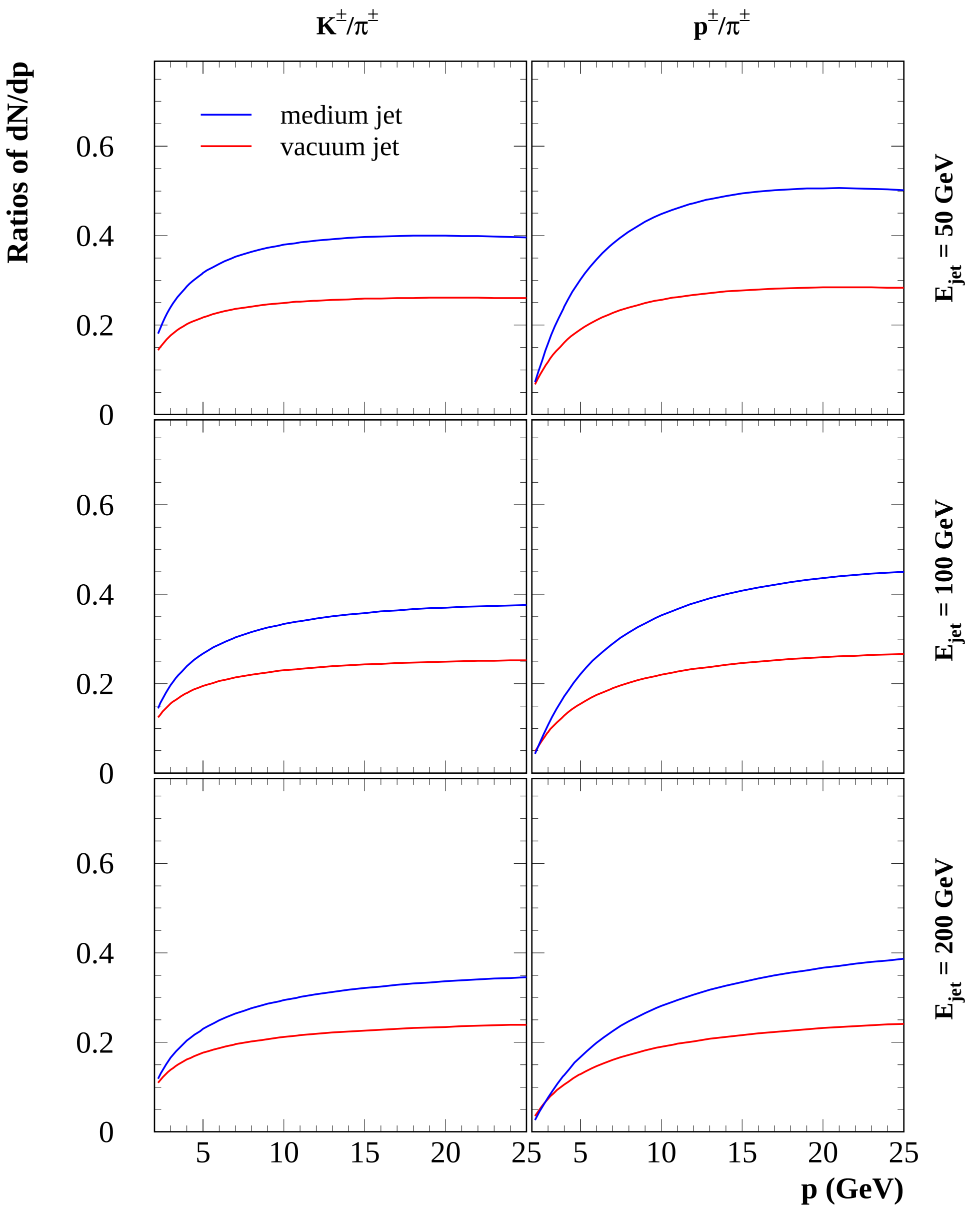

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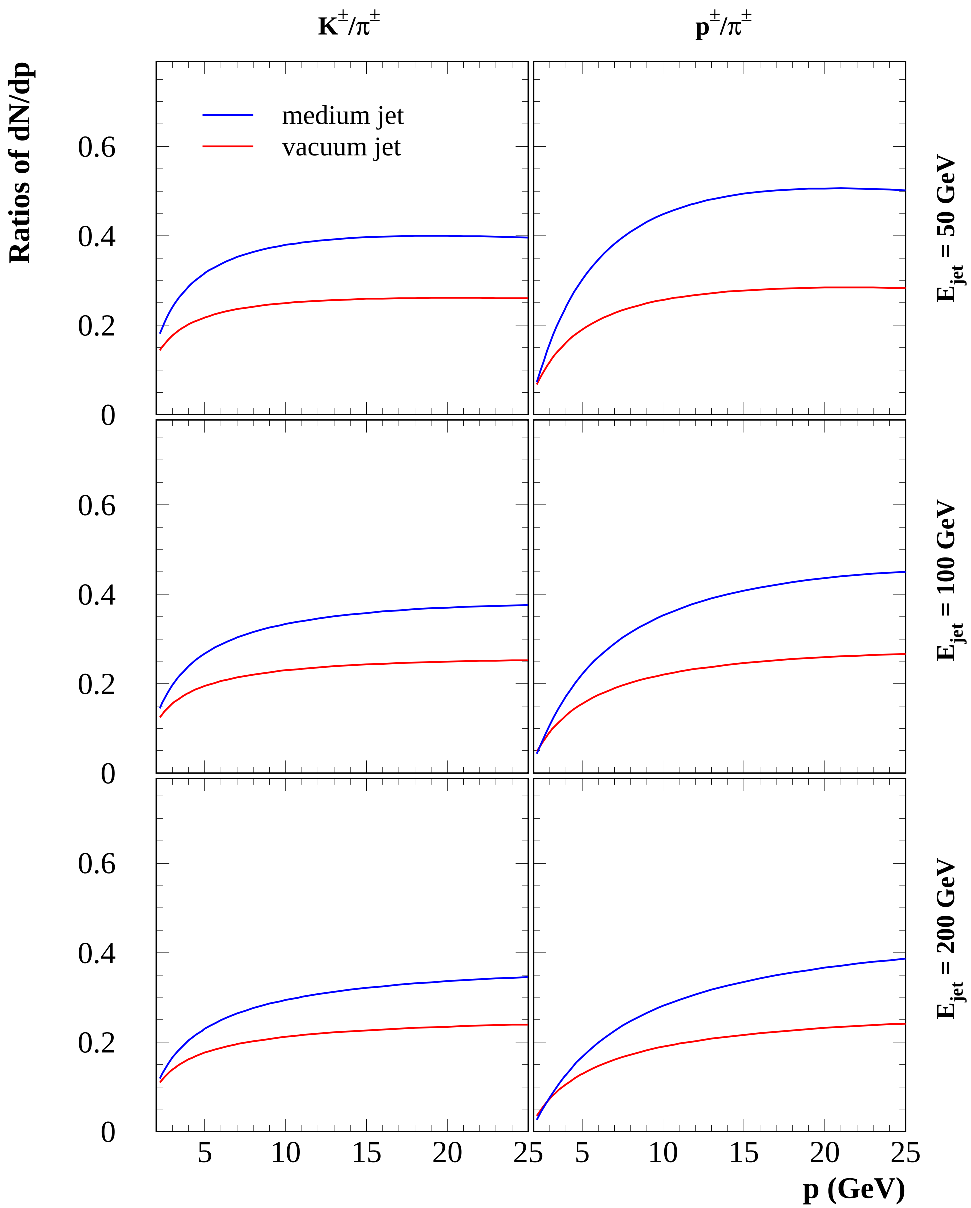
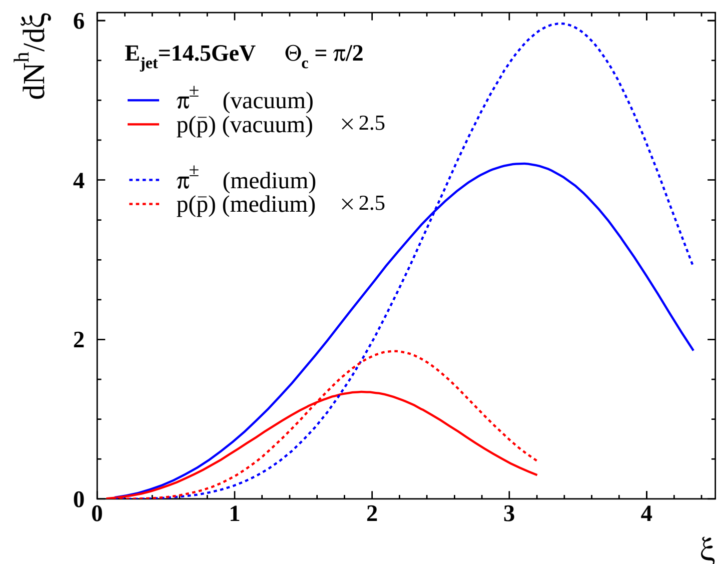


- ratios in medium-modified jets larger
- there is always a region of the ratio enhancement



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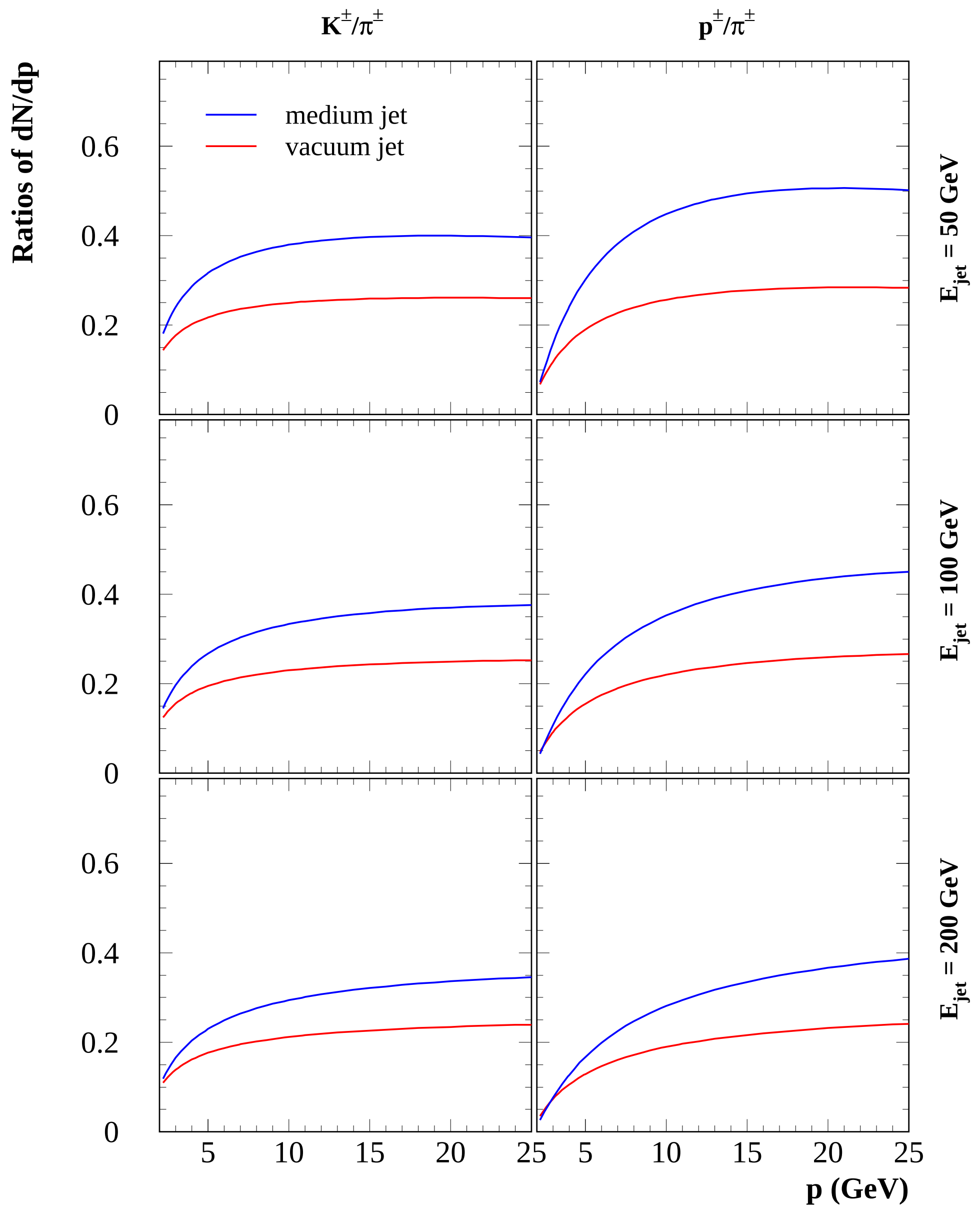

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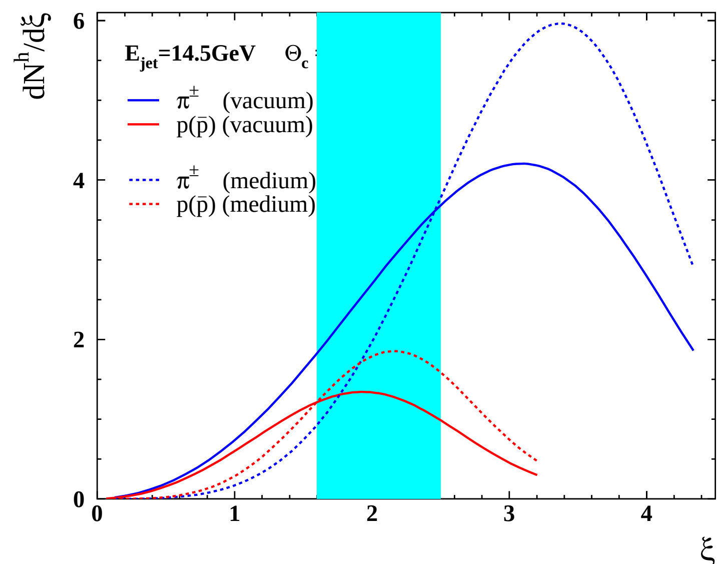

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Two competing mechanisms

- recombination of constituent quarks
  $v_{\perp} = 0.55$ (RHIC), $v_{\perp} \approx 0.7$ (LHC),
  T = 175 MeV
- fragmentation of perturbative partons
  KKP parametrization, suppression of particles with high p taken into account

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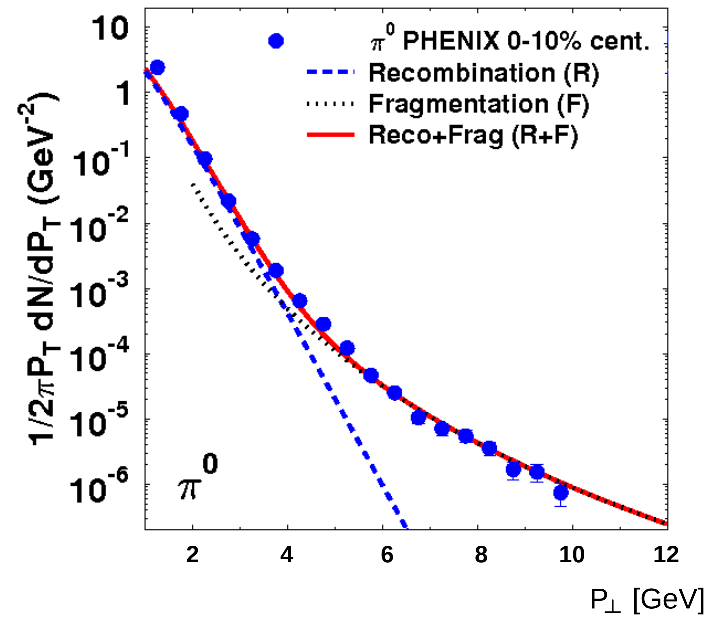

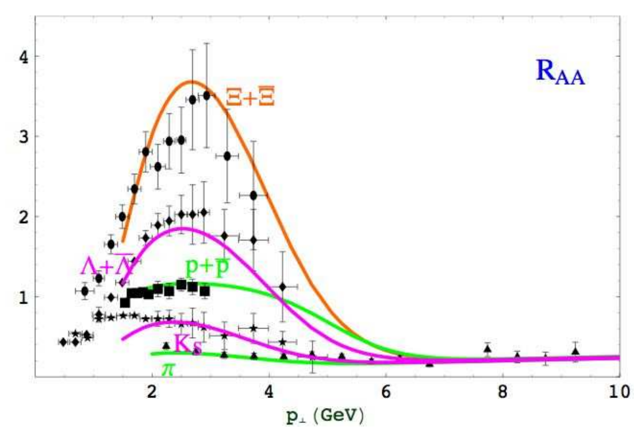

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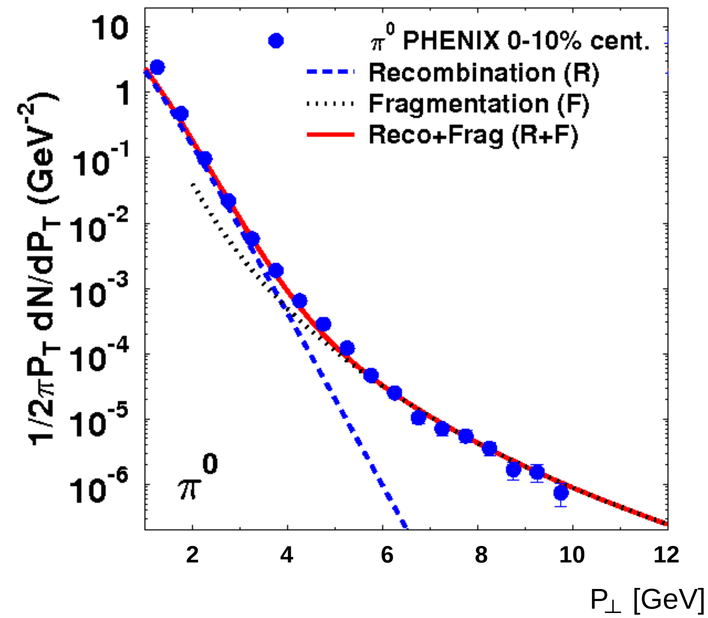

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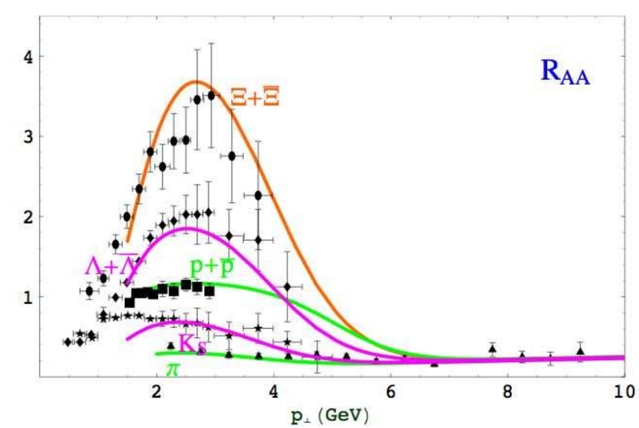
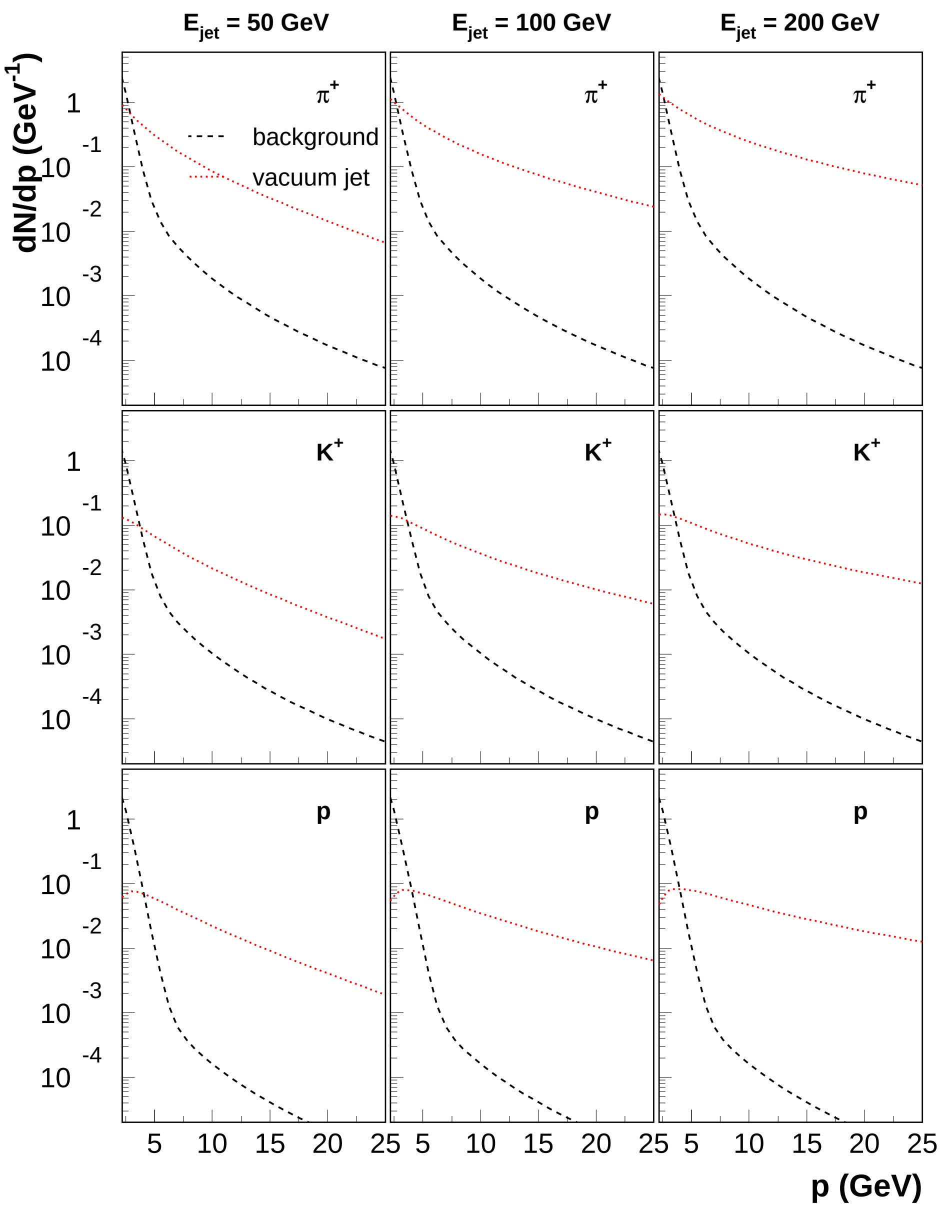


LHC spectra expected to be dominated by re-combination component up to the momenta higher by 2 GeV w.r.t. RHIC spectra

HADRON SPECTRA

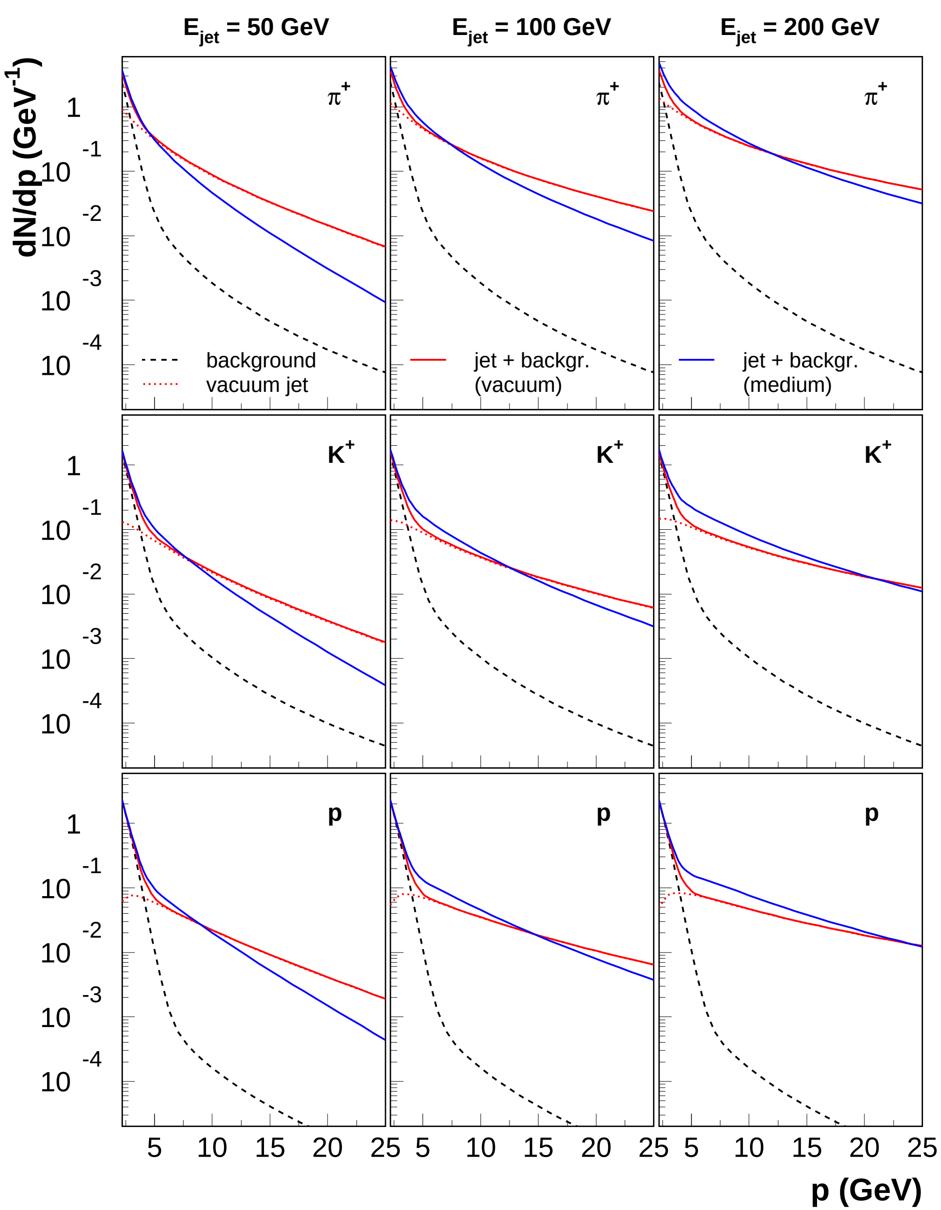


jet cone size: $\theta_c = 0.28$

factor 0.7 for kaons from jet

- characteristically different spectra for the soft background and jets
- despite the high multiplicity environment the harder distribution of jets dominates rapidity over the background at momenta around 5-7 GeV
- the larger jet energy the stronger the effect
- proton spectra particularly well separated

HADRON SPECTRA



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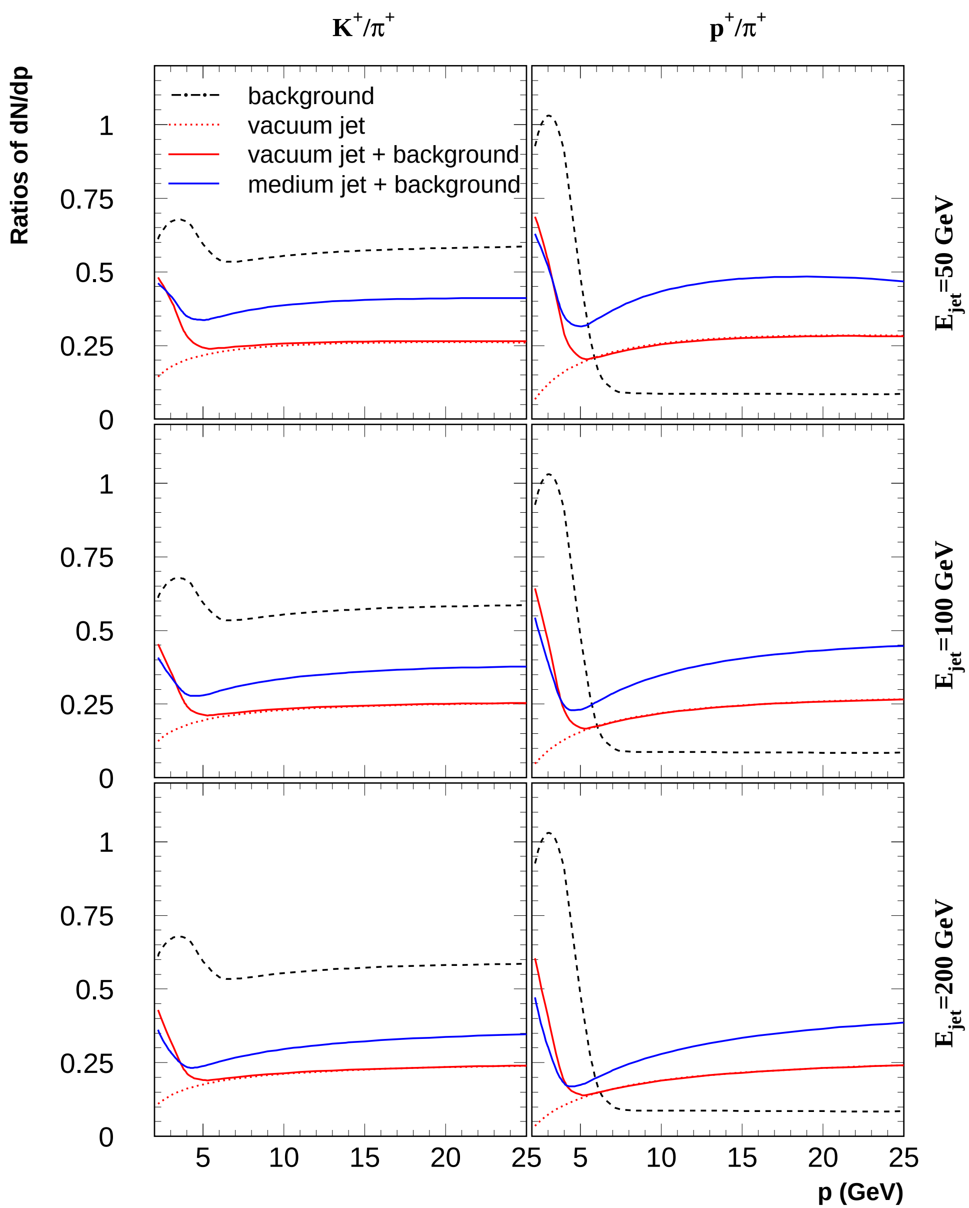
- the slope steepens in the presence of medium
- medium affects hadrochemistry within the jet cone
- medium modification varies with hadron species and jet energy
- modified spectra well separated from the background

HADRON RATIOS



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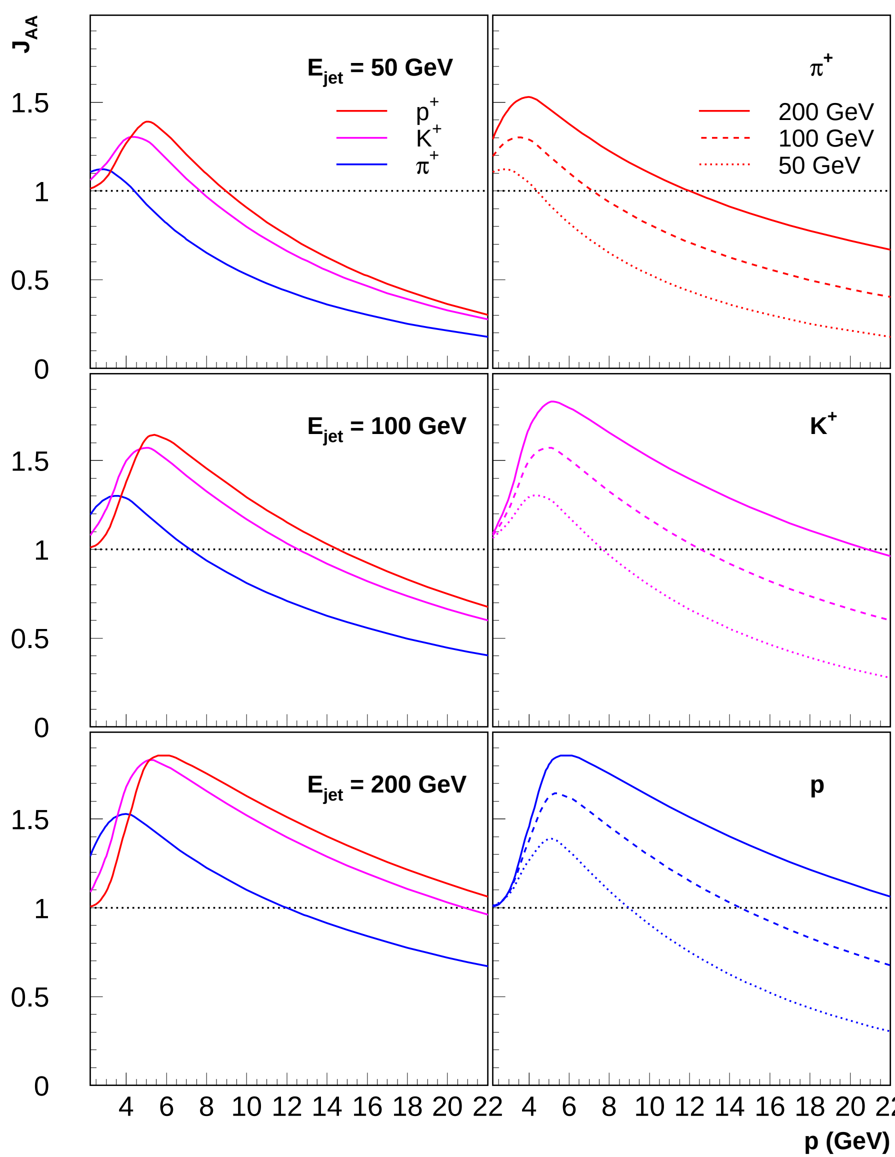
Jets + background

- difference of hadron ratios persists
- mild dependence on energy for $E_{\rm jet}$ and θ_c for certain p-range

MODIFICATION FACTORS



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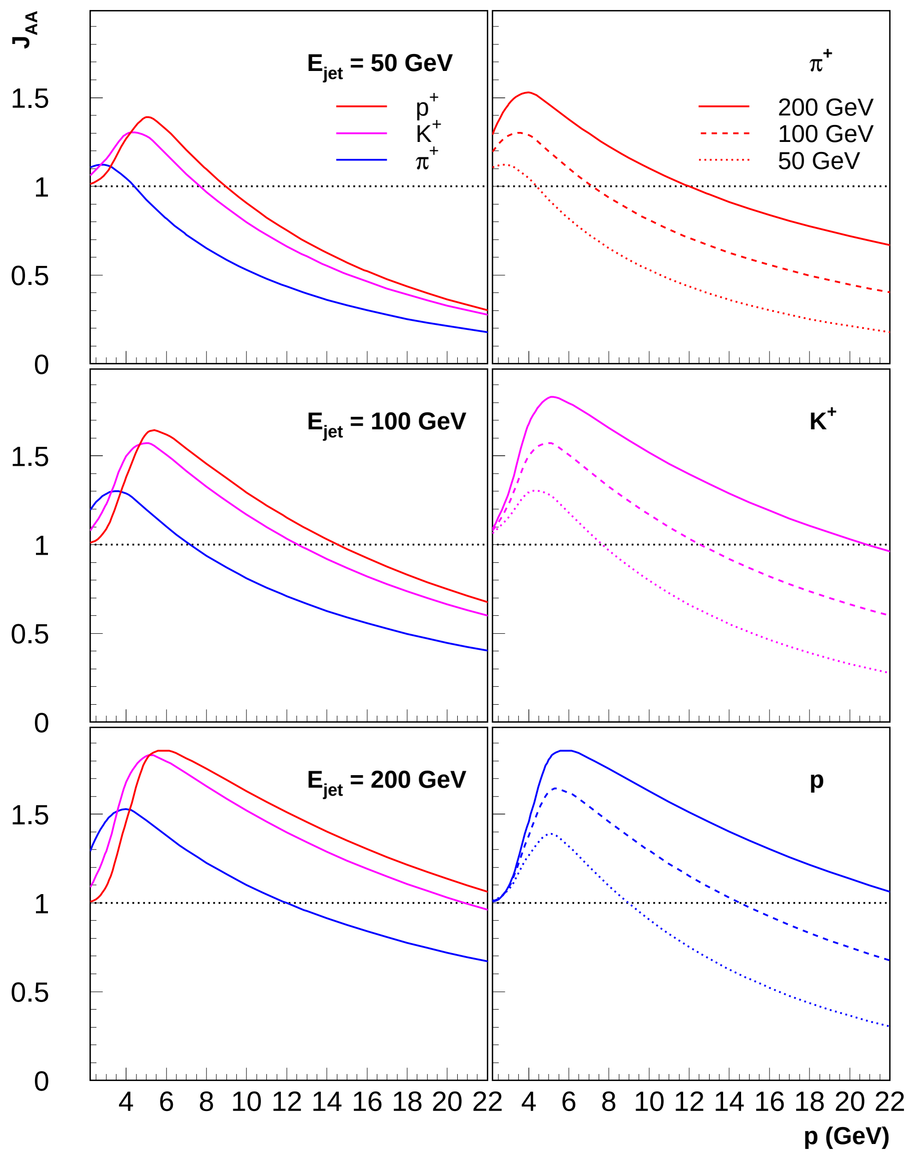
Jets + background

$$J_{\rm AA} \equiv \frac{\frac{dN}{dp}\Big|_{\rm med}}{\frac{dN}{dp}\Big|_{\rm vac}}$$

- critical momentum varies significantly both with hadron species and with energy
- protons the least sensitive to the background

MODIFICATION FACTORS



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Jets + background

- $D^p_{\rm med}/D^\pi_{\rm med} > D^p_{\rm vac}/D^\pi_{\rm vac}$

$$\Downarrow$$

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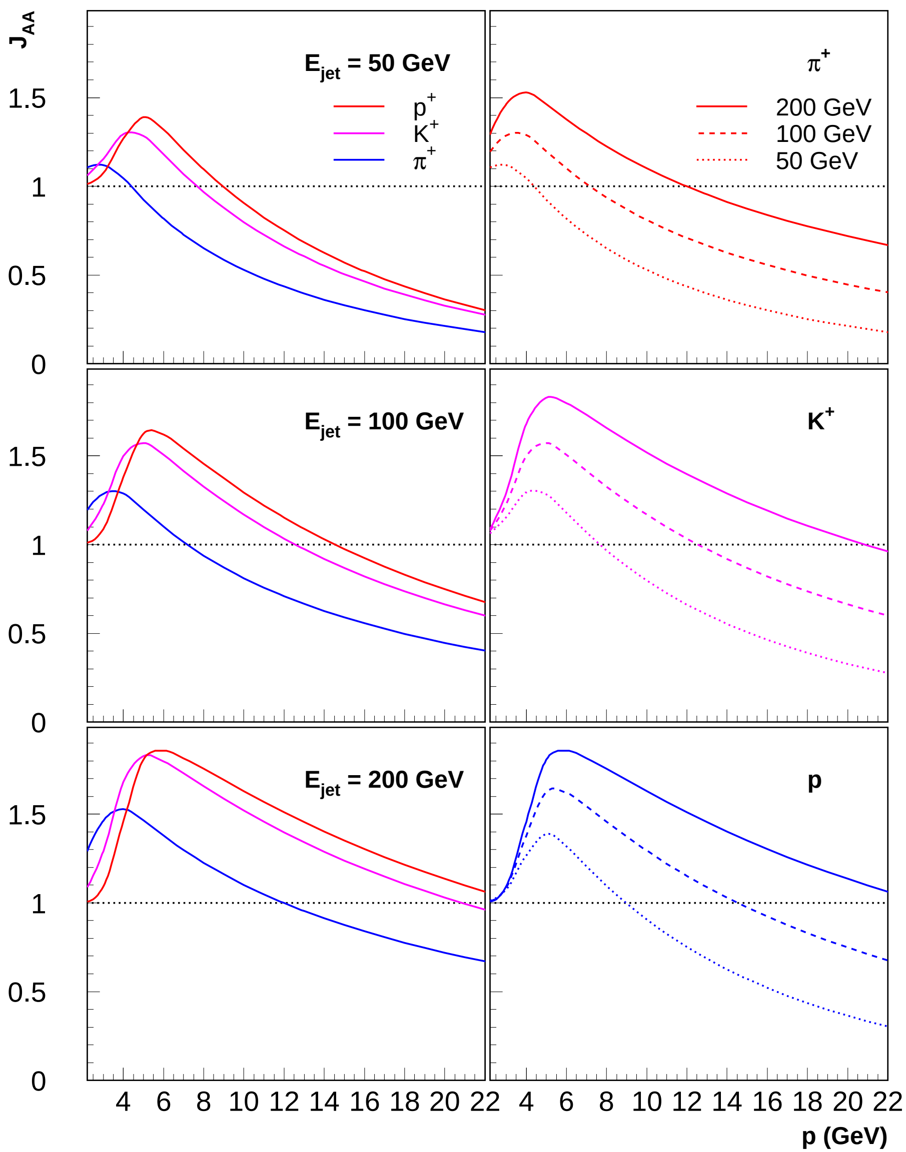

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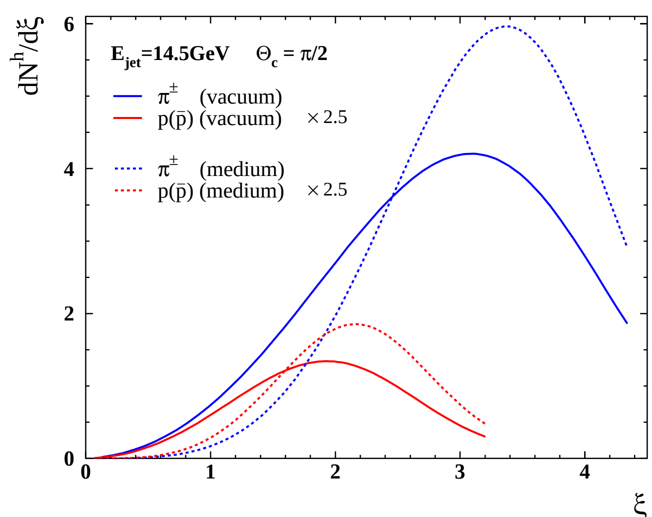
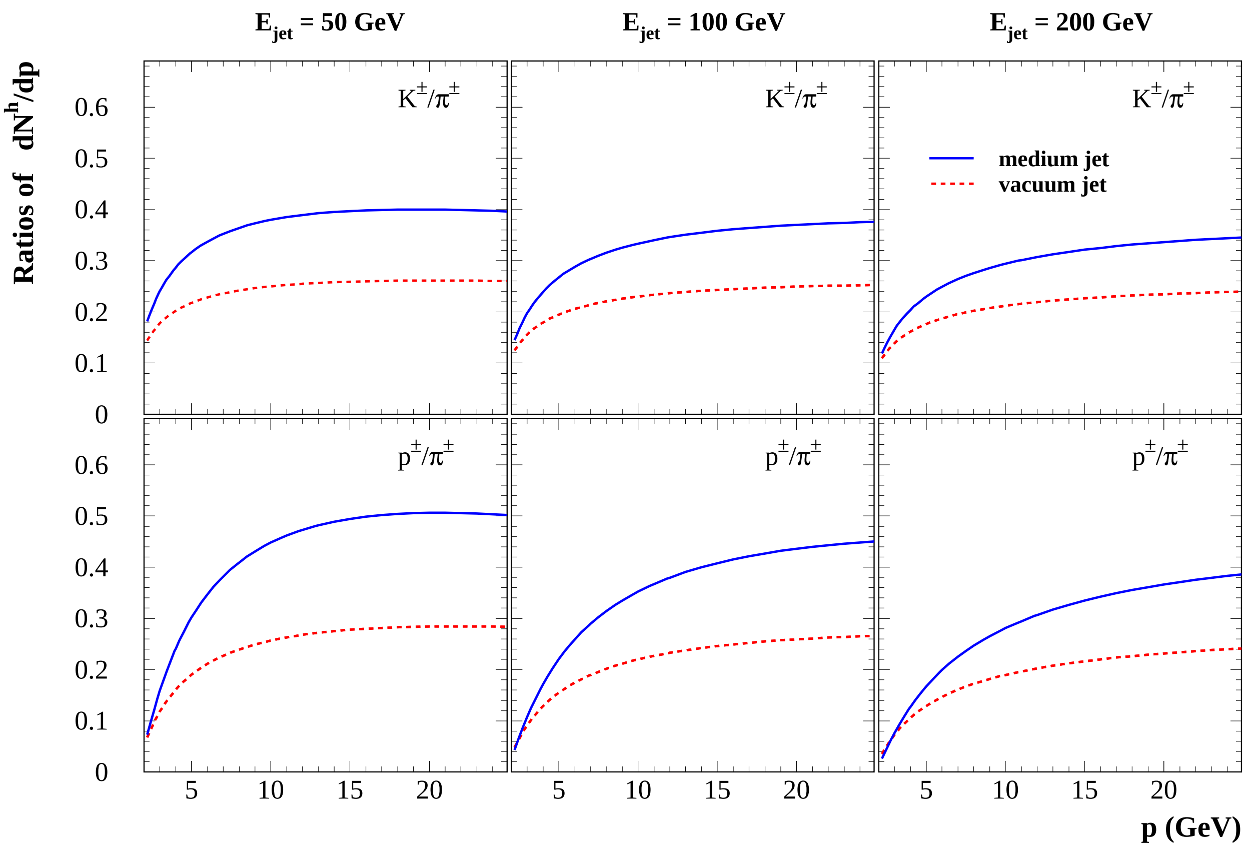


SUMMARY

The prediction



Central result: enhanced parton splitting alone without modification of hadronization can lead to significant changes in the hadronic composition of jets at the LHC

SUMMARY

- Though formulated within a specific approach our result is to large extend generic for radiative energy loss mechanisms
- Modifications of spectra and ratios vary with hadron species and jet energies
- Because of characteristically different hadrochemistry of jets and the soft background this signature persists even if one does not separate the two