Thermodynamical String Fragmentation

with Torbjörn Sjöstrand – arXiv:1610.09818

Nadine Fischer - November 24th, 2016

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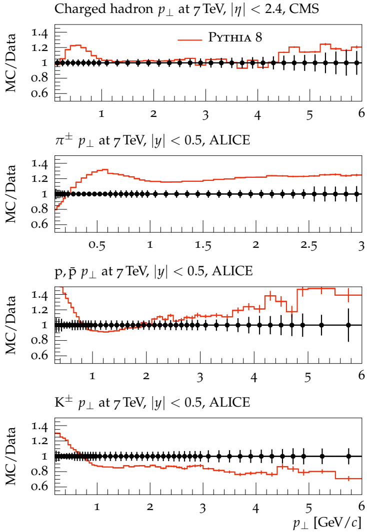
Motivation

$p_\perp$ distributions (ratio plots)



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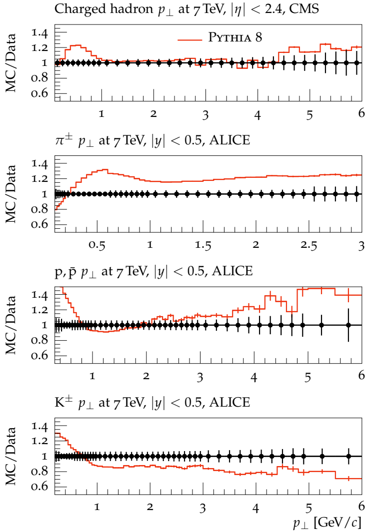
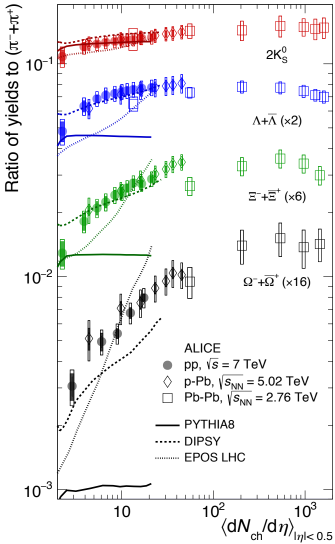
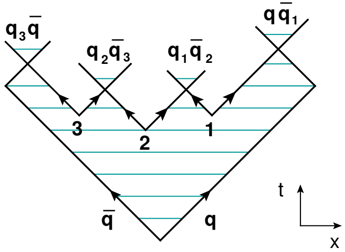


Enhanced strangeness with increasing n_{ch}



Lund String Fragmentation

Flavour and transverse momentum of hadrons:



- string streched between $q\bar{q}$
- $q\bar{q}$ moves apart $\rightarrow$ energy stored in string

  (potential $V(r) = \kappa\, r$)
- creation of $q_i\bar{q}_i$ pairs breaks string:

  $m_{\perp\, q_i} = 0$ on-shell production in single vertex

  $m_{\perp\, q_i} > 0$ tunneling probability

$$\exp\left(-\pi\, m^2_{\perp\, q_i}/\kappa\right) = \exp\left(-\pi\, m^2_{q_i}/\kappa\right) \exp\left(-\pi\, p^2_{\perp\, q_i}/\kappa\right)$$

$\downarrow$ flavour selection of $q_i\bar{q}_i$

$\downarrow$ $\langle p^2_{\perp\, q_i}\rangle = \kappa/\pi = \sigma^2$

- lots of flavour parameters:
  - suppression of strangeness and diquarks, η and η'
  - rates for different meson multiplets
- $\mathcal{O}(20)$ free parameters in total

Thermodynamical String Model

Idea: hadron-level suppression

$$\exp\left(-m_{\perp\,\mathsf{had}}/T\right) \quad \text{with} \quad m_{\perp\,\mathsf{had}} = \sqrt{m_{\mathsf{had}}^2 + p_{\perp\,\mathsf{had}}^2}$$

- generate $p_{\perp\,\mathsf{had}}$ according to

$$f_{\mathsf{had}}(p_{\perp\,\mathsf{had}})\,\mathrm{d}\,p_{\perp\,\mathsf{had}} = \exp\left(-p_{\perp\,\mathsf{had}}/T\right)\mathrm{d}\,p_{\perp\,\mathsf{had}}$$

- fourier transformation to obtain quark-level distribution

$$f_{\mathsf{q}}(p_{\perp\,\mathsf{q}}) \propto \int_0^\infty \frac{b\,J_0(b\,p_{\perp\,\mathsf{q}}/T)}{(1+b^2)^{3/4}}\mathrm{d}\,b \qquad \left[\ \text{fit:}\ \ \mathcal{N}\,\frac{\exp(-c\,p_{\perp\,\mathsf{q}}/T)}{(p_{\perp\,\mathsf{q}}/T)^d}\ \right]$$

- pick hadron flavour according to $P_{\mathsf{had}} = \exp\left(-m_{\perp\,\mathsf{had}}/T\right)$

  + multiplicative factors for spin-counting, $SU(6)$ symmetry factors, ..

- heavier hadrons obtain more $p_\perp$

- 3 free parameters in total

Close-Packing of Strings

Idea: more MPIs $\Rightarrow$ closer packing of strings

- transverse region shrinks $\Rightarrow$ larger string tension
- guess momentum of next hadron, based on average quantities
- n_{string} = number of strings that cross hadron rapidity
- effective number of strings $n_{\text{string}}^{\text{eff}} = 1 + \dfrac{n_{\text{string}} - 1}{1 + p_{\perp\,\text{had}}^2 \,/\, p_{\perp\,0}^2}$
- modify Gaussian width $\sigma \rightarrow \left(n_{\text{string}}^{\text{eff}}\right)^r \sigma$ (similar for temperature)

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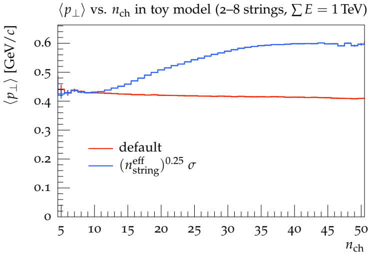
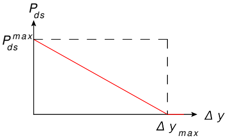


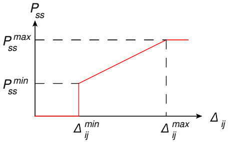
Hadron Rescattering

Idea: dense hadronic gas $\Rightarrow$ hadrons might rescatter on the way out

Find hadron pairs that can scatter:

- cut on the invariant mass of the hadron pair $m_{\text{inv}} < \sqrt{m_1^2 + |\vec{p}_{\text{max}}|^2} + \sqrt{m_2^2 + |\vec{p}_{\text{max}}|^2}$
- rescattering probability: overall probability $\cdot$ probability for same-string





- in CoM frame rotate around angles chosen flat in d Ω

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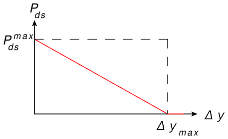

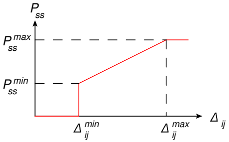

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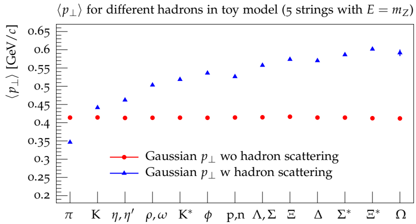
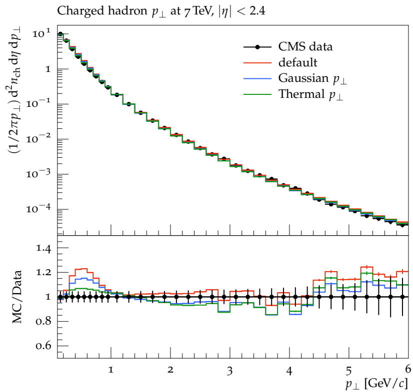
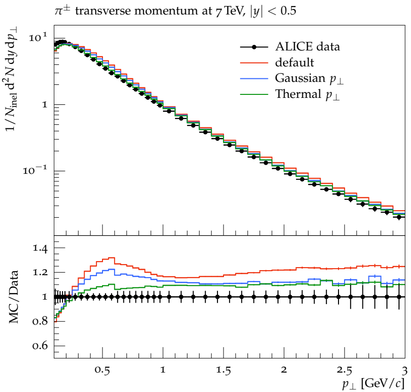


Results

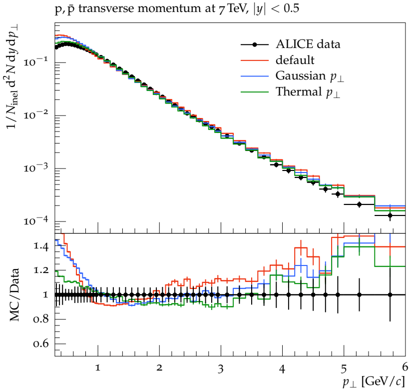
Transverse momentum distributions: inclusive and pions

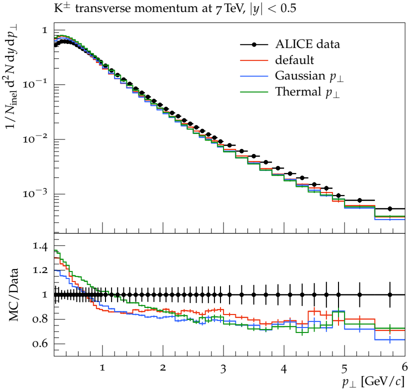




Results

Transverse momentum distributions: protons and kaons





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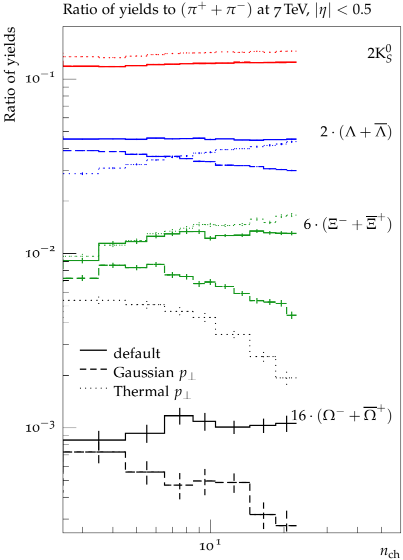

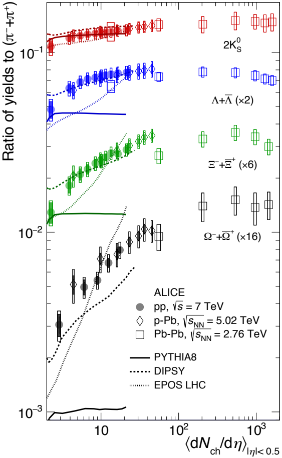

Summary and Outlook

What is new?

- option for generating $p_{\perp\,\text{had}}$ according to $\exp(-p_{\perp\,\text{had}}/T)$ with flavour selection according to $\exp(-m_{\perp\,\text{had}}/T)$
- effect of close-packing of strings
- simple model for hadron rescattering

What does it do?

- improves some observables, such as $p_\perp$ spectra, $\langle p_\perp \rangle (m_{\text{had}})$
- does not improve everything, e.g. kaon $p_\perp$ remains difficult
- hadron decays are a limiting factor

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Further work required!

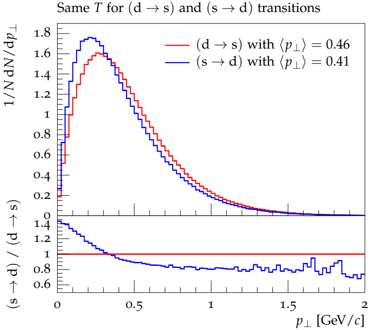
- microscopic tracing of the full space-time evolution (partons and hadrons, production and decay vertices)
- more detailed understanding and modelling

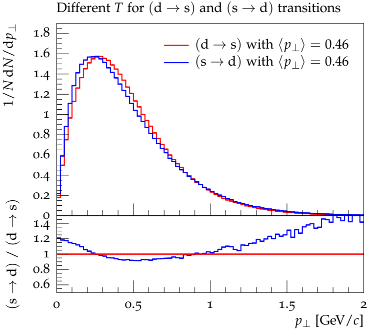
Backup

Flavour Asymmetry in Thermodynamical Model

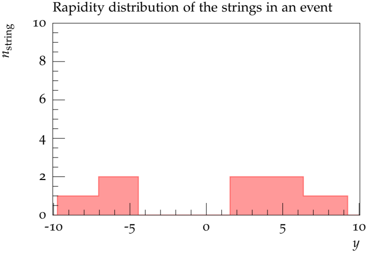
Toy model with d and s quarks only

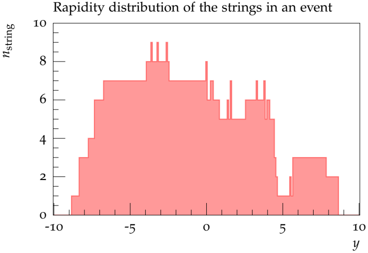
- (d $\to$ s) competes with (d $\to$ d) $\to$ d$\bar{\text{s}}$ obtains larger $p_\perp$
- (s $\to$ d) competes with (s $\to$ s) $\to$ s$\bar{\text{d}}$ obtains smaller $p_\perp$





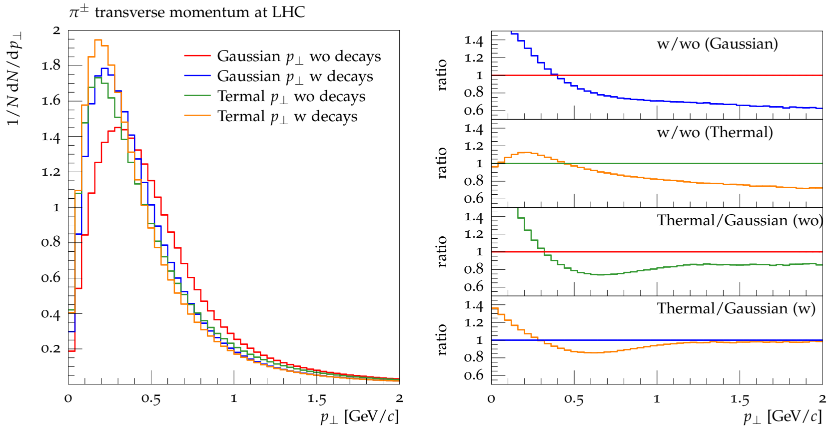
Rapidity Distributions





Limiting factor: Decays

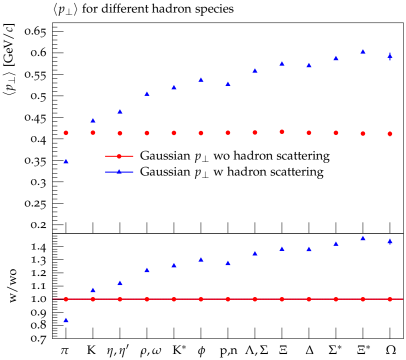
pion transverse momentum @ LHC, with and without decays, similar for protons

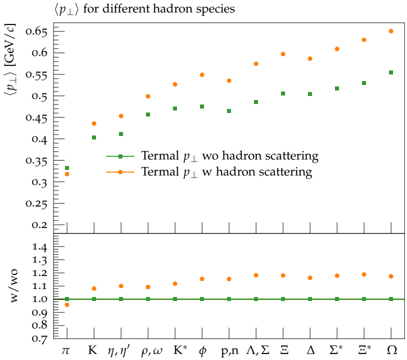


$\Rightarrow$ decays wash out effects present after fragmentation

Hadron Rescattering

$\langle p_\perp \rangle$ in toy model (5 strings with $E = m_Z$ on the z axis)





Average transverse momentum: as a function of n_{ch} and m_{had}