Momentum imbalance of reconstructed dijets within a partonic transport model

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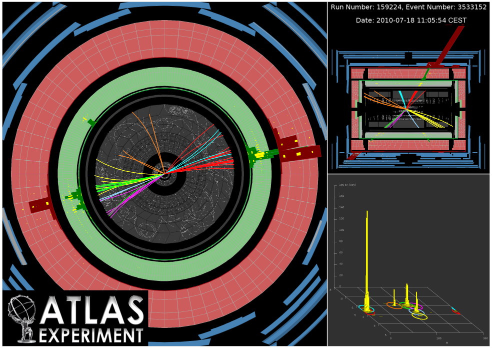
26.03.2012

What is a „true/full jet“?



- Jet structures are visible in every type of high-energy particle collision
- Direct consequence of branching probabilities of virtual initial partons in QCD
- Our „window“ on initial hard scattered partons

Jet reconstruction is a way to group hadrons/partons together to get information about the undetectable partons

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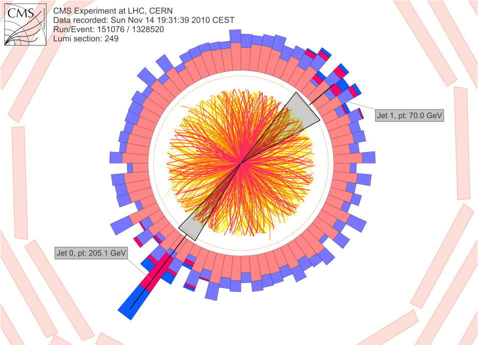

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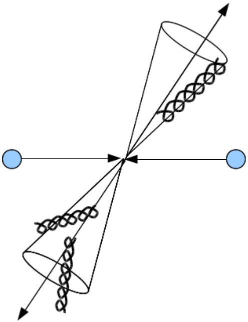
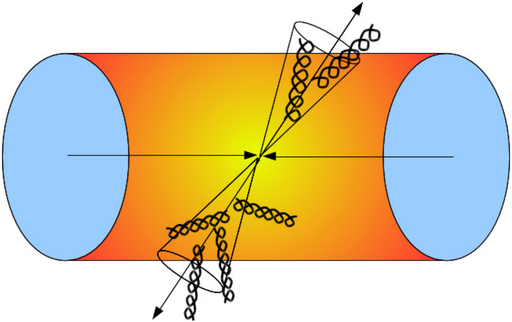
Momentum imbalance of reconstructed dijets in vacuum / in a medium

- Initial hard partons are produced with same value of transverse momentum but in opposite direction
- Stochastic nature of virtual splittings lead to momentum imbalance of reconstructed jets already in the vacuum
- Different in-medium pathlength and therefore energy loss out of the cone enhances momentum asymmetry in central HI-collisions

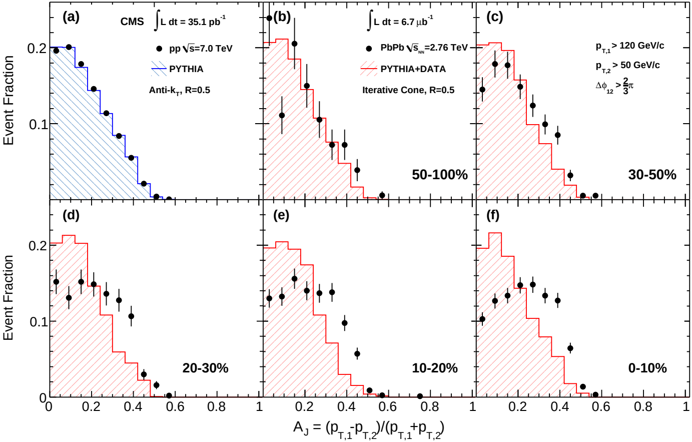




Experimental results by CMS collaboration, run 2010

Definition

$$A_J = \frac{p_{t;LeadingJet} - p_{t;SubleadingJet}}{p_{t;LeadingJet} + p_{t;SubleadingJet}}$$



CMS Collaboration, Phys. Rev. C 84, 024906 (2011)

Simulation of the medium scatterings with BAMPS

BAMPS $\widehat{=}$ Boltzmann Approach for Multi-Parton Scattering

- Numerical solver for the (3+1)D Boltzmann transport equation for partons on the mass-shell

$$\frac{\partial f}{\partial t} + \frac{\mathbf{p}}{E}\frac{\partial f}{\partial \mathbf{r}} = C_{22} + C_{23}$$

- Uses a stochastic method for the collision probabilities
- Based on LO pQCD-cross sections
- Involves $2 \to 2$ as well as $2 \leftrightarrow 3$ processes
- Includes processes of gluons as well as quarks (heavy quark scatterings are not considered in this talk, for this see talk by J. Uphoff)

Z.Xu and C. Greiner, Phys.Rev. C71, 064901 (2005)

Unfinished parton showers out of PYTHIA

- p+p-results show, that already showering of virtual partons of hard initial scatterings leads to momentum imbalance

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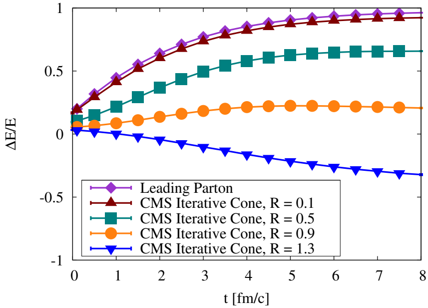
- Particles within BAMPS are considered on the mass-shell
  $\Rightarrow$ Simulation of $1 \rightarrow 2$ processes by shower routines of PYTHIA
- For medium simulation with BAMPS, a termination condition for the showering processes is needed in PYTHIA:
  - Hadronization/Fragmentation inside PYTHIA is switched off
  - Splittings of partons in PYTHIA are stopped when partons reach a minimum virtuality $Q_{0,i}$
  - Correspondence between $Q_{0,i} \leftrightarrow$ shower time τ, after which the partons has to be formed:

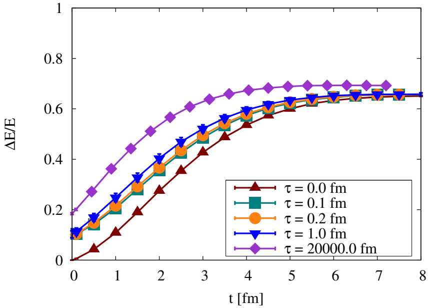
$$Q_{0,i} = \sqrt{\frac{E_{parton,i}}{\tau}}$$

  - Medium modification of shower particles is simulated with BAMPS

Energy loss of reconstructed jets in a static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV), for example:

$$\frac{\Delta E(t)}{E} = \frac{E_{parton} - E_{jet}(t)}{E_{parton}}$$





- Large cone radius ($R > 1.0$) leads to an energy gain in the reconstructed jets, small cone radii correspond to reconstruction of single partons
- Energy loss almost independent on modest values of the shower times τ

Setup for jet reconstruction within a full BAMPS-simulation

- Pb + Pb-collision with $\sqrt{s} = 2.76$ TeV and mean impact parameter $b = 3.4$ fm, which corresponds to centrality 0-10%

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- Reconstruction parameters and event trigger based on experiments:

„CMS, Run 2010“	„CMS, Run 2011“	ATLAS
CMS Iterative Cone, $R = 0.5$ $p_{t;Leading} > 120$ GeV $p_{t;Subleading} > 50$ GeV $\Delta\phi > 2\pi/3$	Anti-k_t, $R = 0.3$ $p_{t;Leading} > 120$ GeV $p_{t;Subleading} > 30$ GeV $\Delta\phi > 2\pi/3$	Anti-k_t, $R = 0.4$ $p_{t;Leading} > 100$ GeV $p_{t;Subleading} > 25$ GeV $\Delta\phi > \pi/2$

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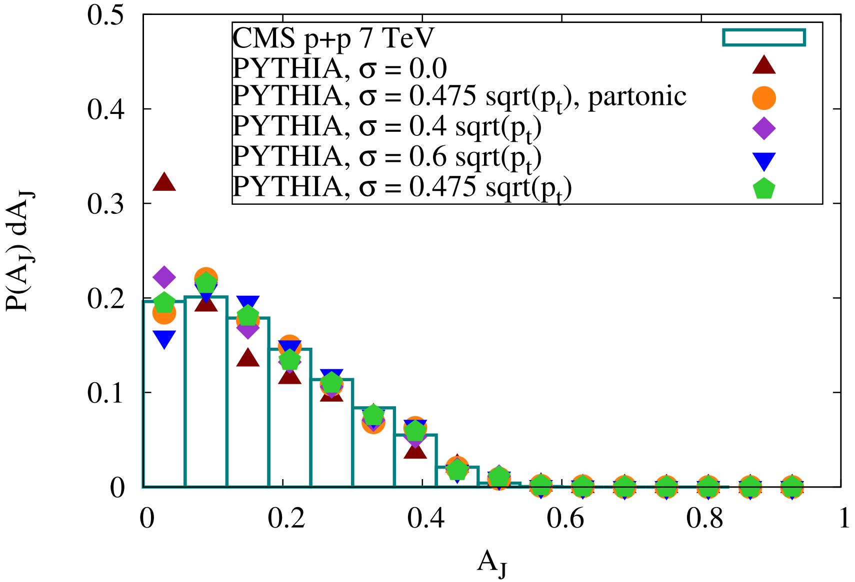
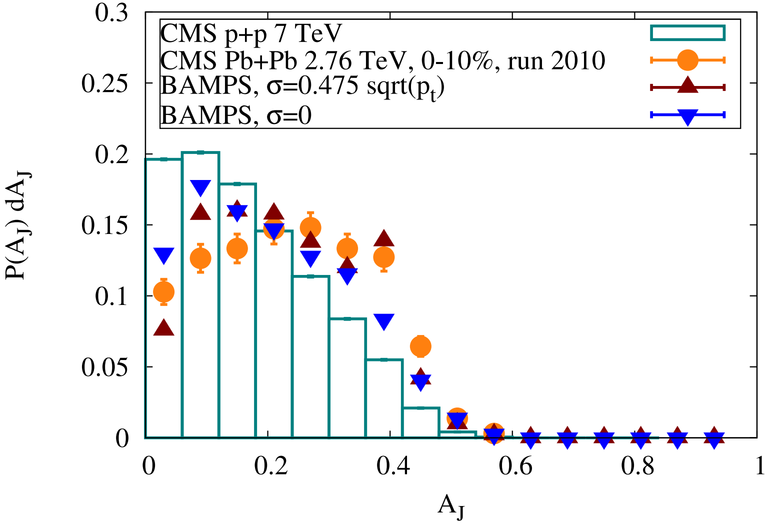
- Modeling of detector response:
  - Transverse momenta of the reconstructed jets are smeared out by a Gaussian ($\sigma \sim \sqrt{p_t}$) based on the comparison between p+p-A_J and „full PYTHIA shower“-A_J

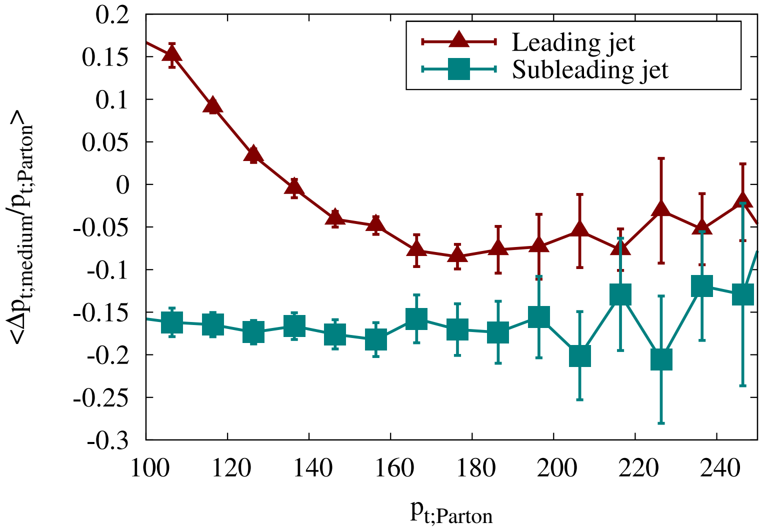
Gaussian smearing via p+p-events



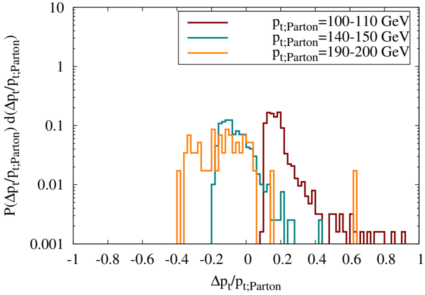
Momentum imbalance A_J within BAMPS for „CMS, run 2010“



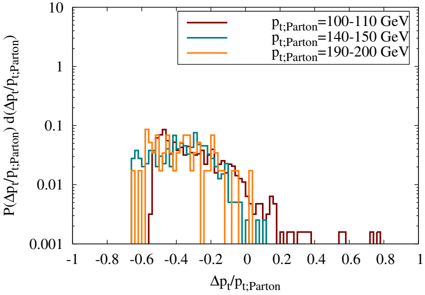
Momentum loss $\Delta p_t = p_{t;Jet} - p_{t;Parton}$ because of the medium, $p_{t;min} = 0$ GeV



Distribution of jet energy loss after traversing an expanding medium

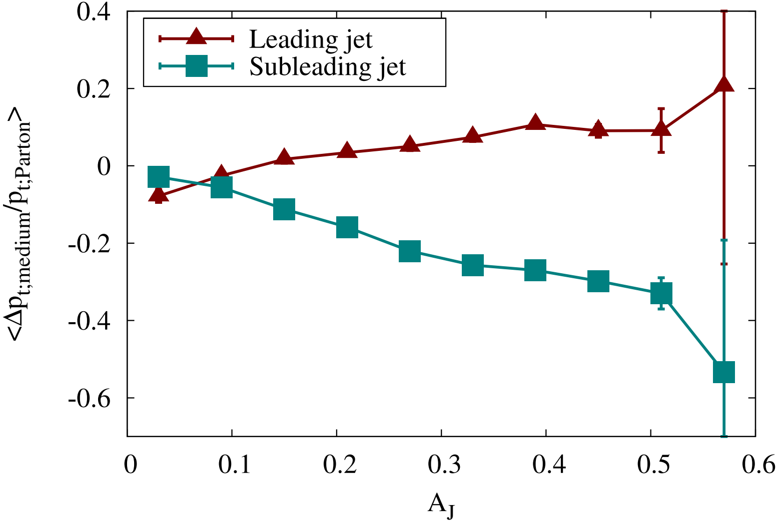


Leading jet



Subleading jet

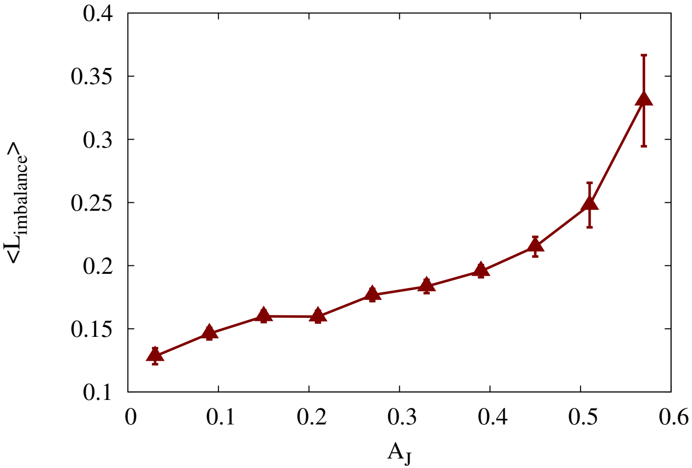
Dependence of momentum loss on momentum imbalance, $p_{t;min} = 0$ GeV



Imbalance of in-medium path length, $p_{t;min} = 0$ GeV

Definition

$$L_{imbalance} = \frac{L_{long} - L_{short}}{L_{long} + L_{short}}$$



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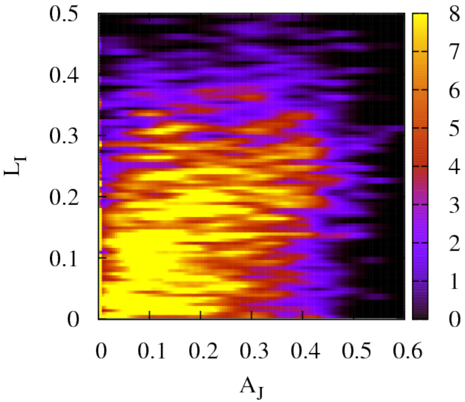
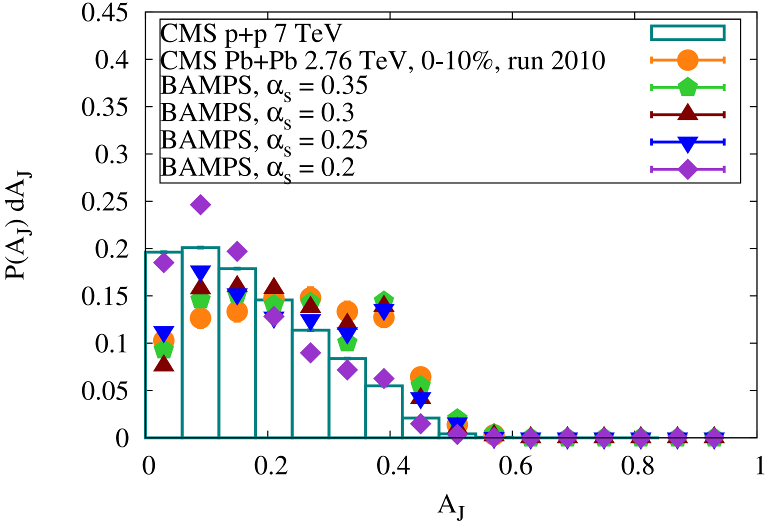
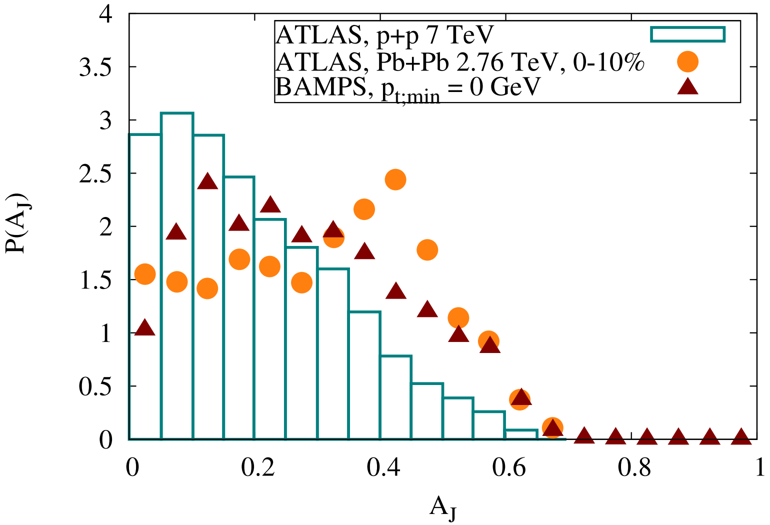


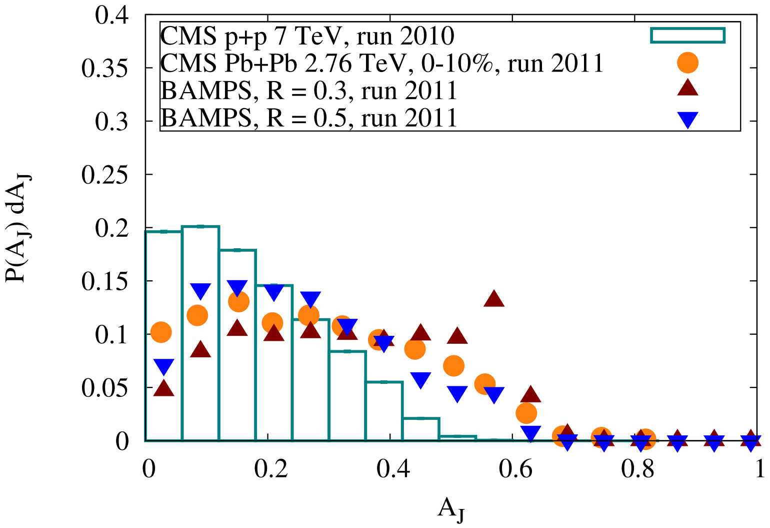
A_J for different α_s in comparison with Pb+Pb events (0-10%)



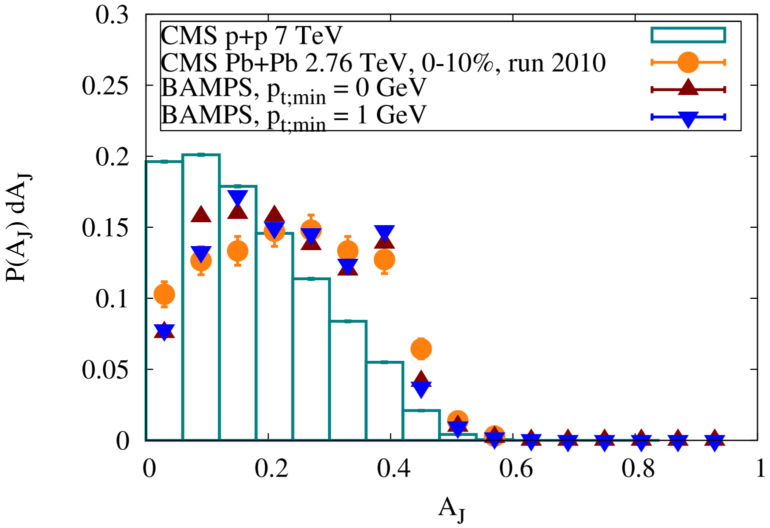
Momentum imbalance A_J within BAMPS for ATLAS



Momentum imbalance A_J within BAMPS for „CMS, run 2011"

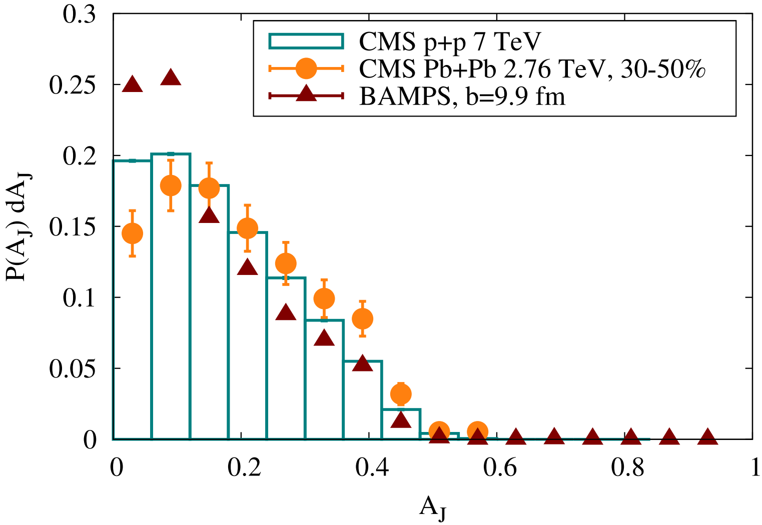


Termination of medium evolution with $p_{t;min}$



Note: $p_{t;min}$ is defined as cut parameter under which the single particle evolution is stopped

A_J for peripheral Pb+Pb events (30-50 %, $b = 9.9$ fm)



Summary

- Jets are the link between measurable hadrons and the partons of the initial hard scatterings
- Parton showers lose already energy in the vacuum because shower processes lead to a wide direction distribution
- Momentum imbalance of reconstructed jets in a medium simulated by BAMPS is in good agreement with experimental data (CMS run 2010)
- Asymmetric reconstructed dijet momenta are caused by a different in-medium path lenght of the jets

Outlook

- More systematic studies of jet reconstruction within BAMPS in a static medium as well as an expanding heavy-ion medium
- Consideration of effects by the underlying bulk medium on the energy of the jets
- Virtual showering processes and in-medium scatterings in one framework (implementing $1 \rightarrow 2$-processes into BAMPS)
- Long-term goal: Description of v_n, R_{AA} and A_J within one physical model

Thank you for your attention!

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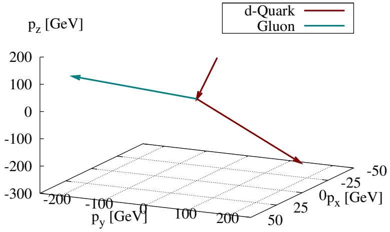
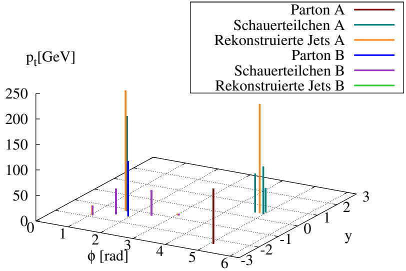
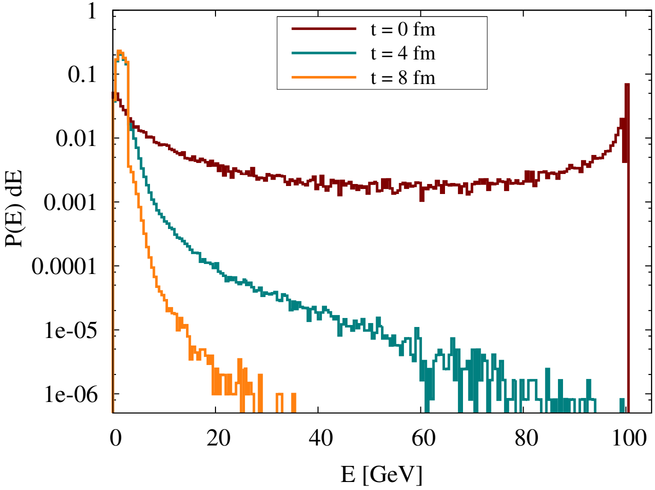
Event with larger transverse momentum of jet with respect to initial parton

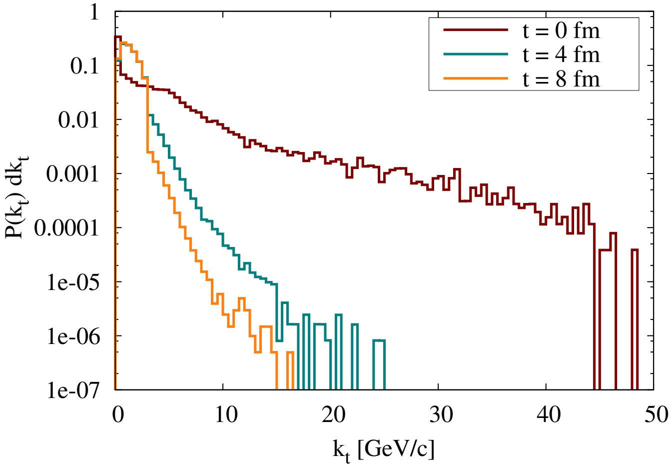




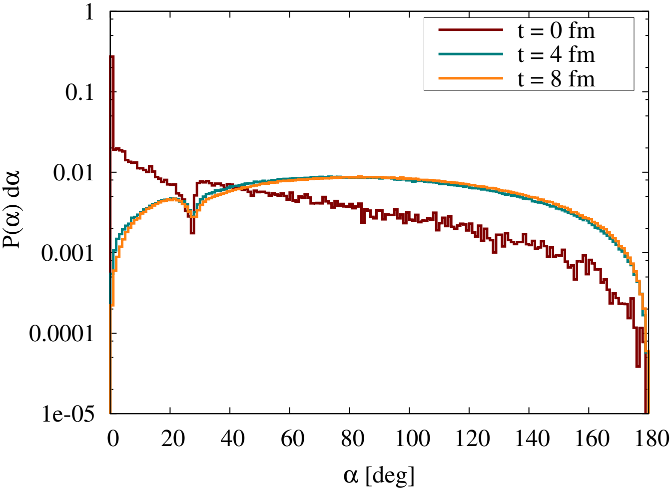
Particle energy distribution for quark-shower in static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV)



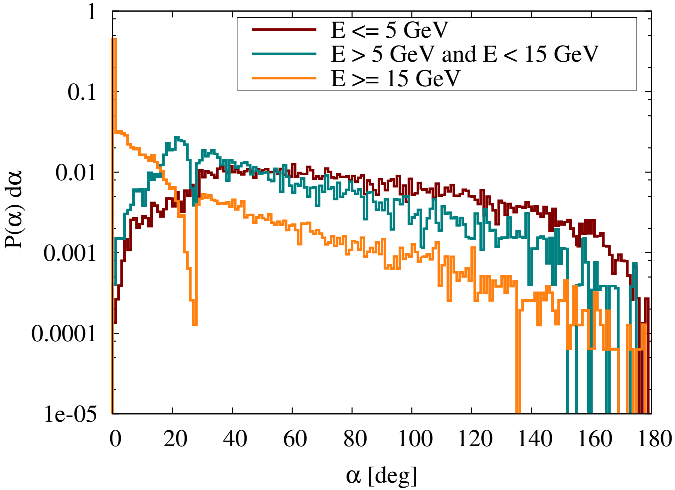
Transverse momentum k_t perpendicular to jet-axis for quark-shower in static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV)



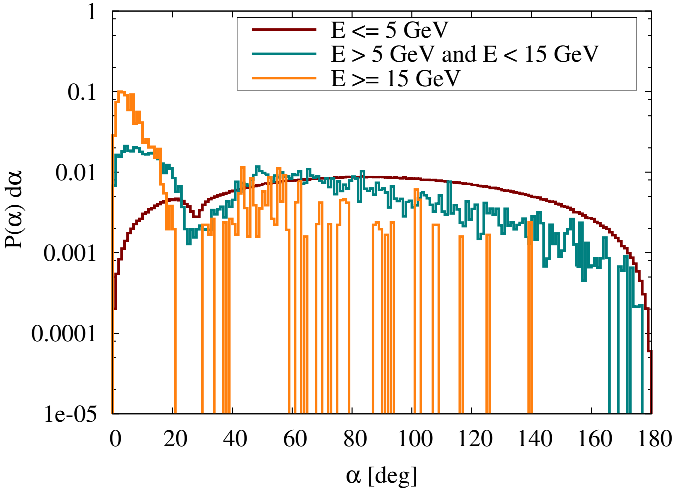
Angle α between particles and reconstructed jet-axis for quark-shower in static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV)



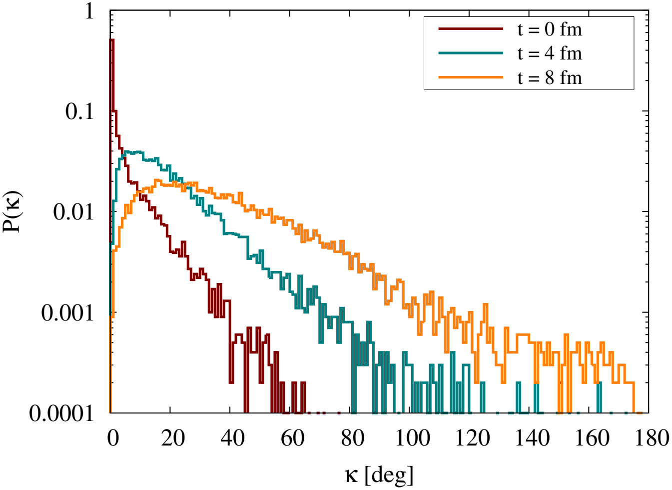
Angle α between particles and reconstructed jet-axis for quark-shower in static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV), initial



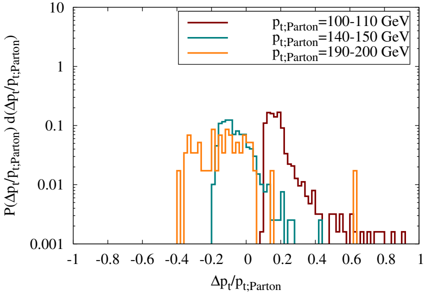
Angle α between particles and reconstructed jet-axis for quark-shower in static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV), final



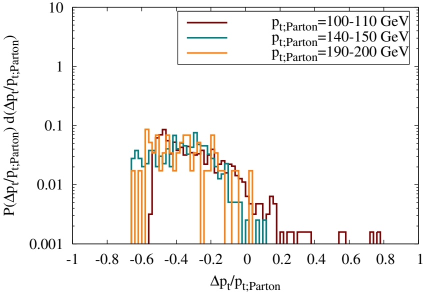
Angle between jet-axis and x-axis for quark-shower in static medium ($E_{parton} = 100$ GeV, $T = 400$ MeV)



Distribution of jet energy loss after traversing an expanding medium

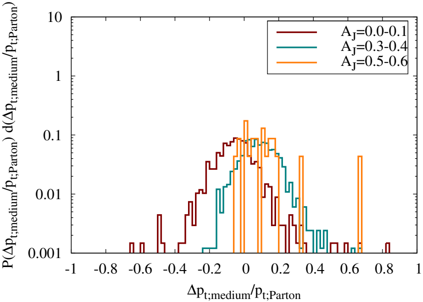


Leading jet

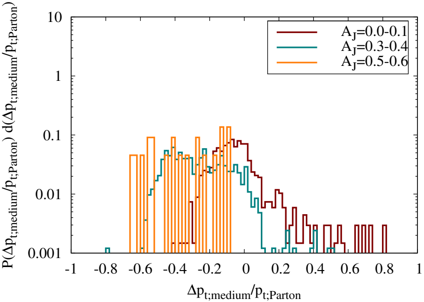


Subleading jet

Distribution of A_J depending on momentum loss

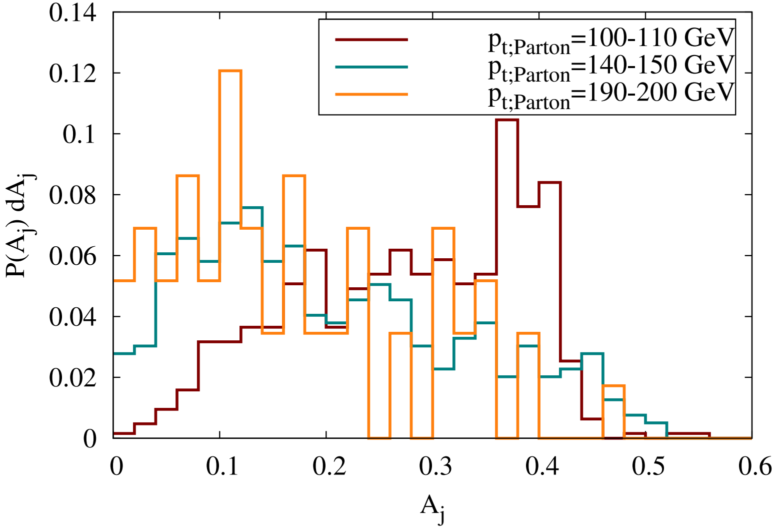


Leading Jet

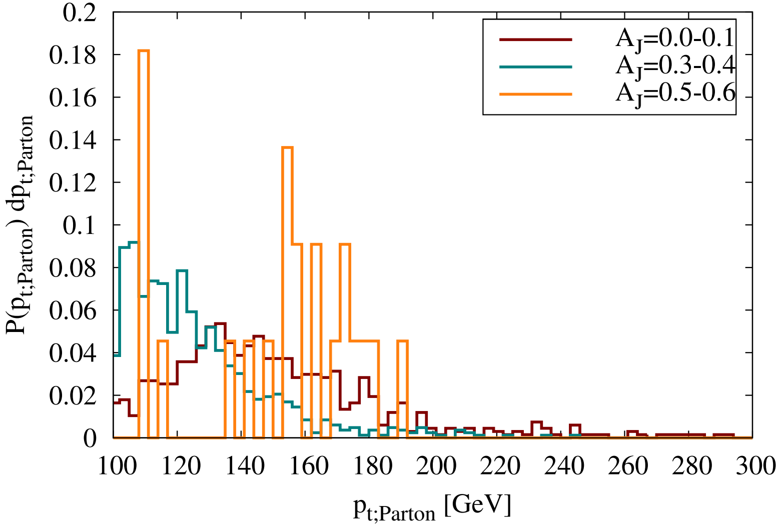


Subleading Jet

Distribution of A_J depending on initial parton momentum

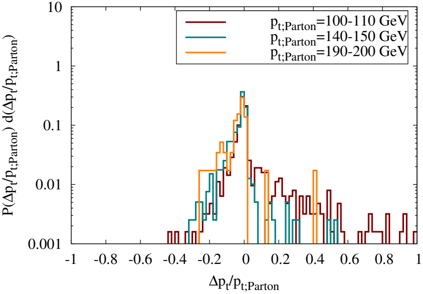


Distribution of initial parton momenta depending on resulting final A_J

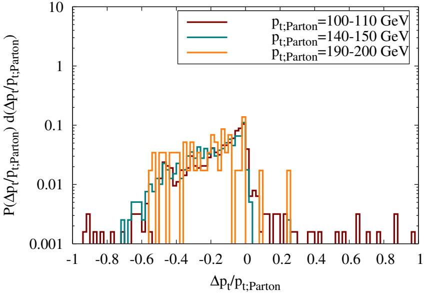


Dijet reconstruction before the medium, after showering

- $\Delta p_t = p_{t;Jet} - p_{t;Parton}$



Leading jet



Subleading jet

Jet-R_{AA} for „run 2010“