Emission of Low Momentum Particles at Large Angles from Jet

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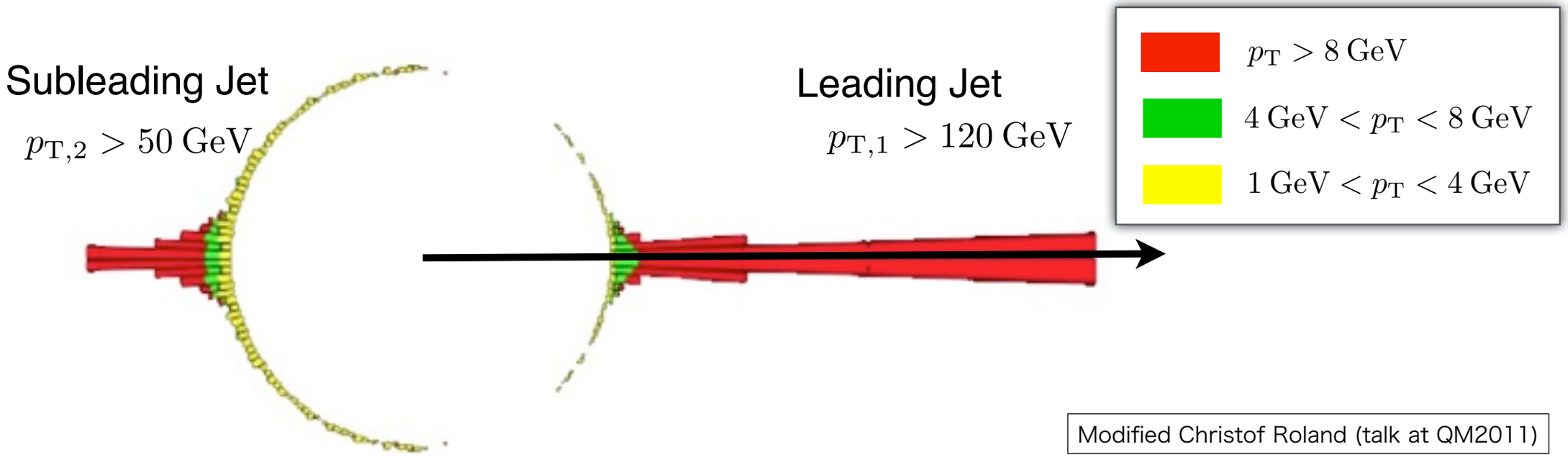
Introduction

■Jet quenching observed at LHC **CMS** (2011)



Modified Christof Roland (talk at QM2011)

Large angle emission of **low-p_{T} particles**

→ Originated from the collective flow ?

■ Purpose of the current study

QGP-fluid + jet model

Study the dynamics of the QGP fluid induced by jets

Introduction

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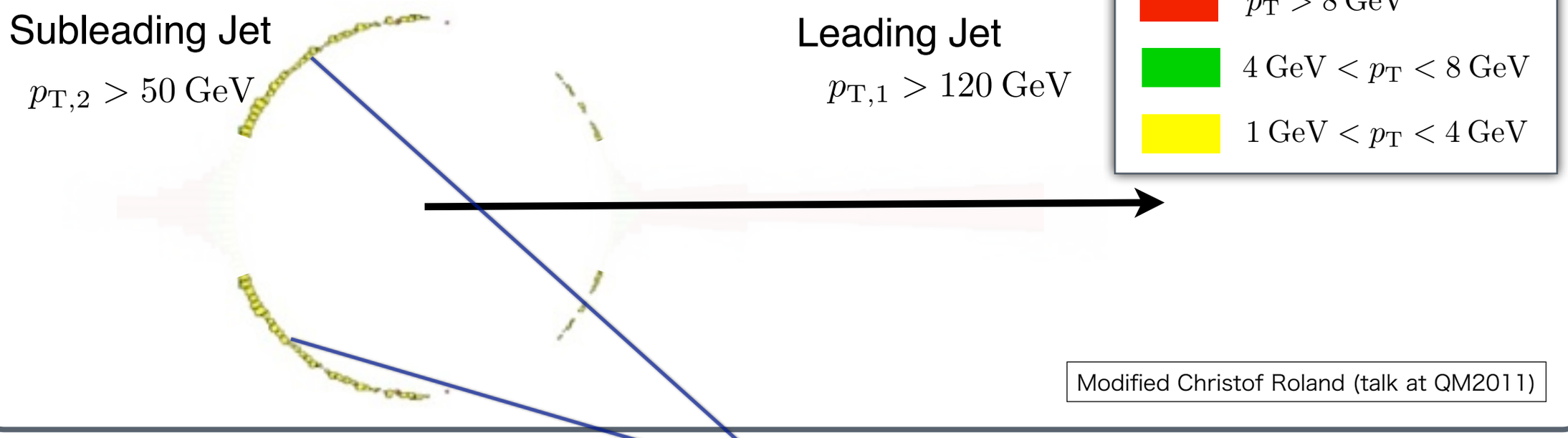

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<u>QGP-fluid + jet model</u>

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QGP-Fluid + Jet Model

■ **Relativistic hydrodynamic equation with an external source**

- (3+1)-D perfect QGP-fluid

$$\partial_\mu T^{\mu\nu} = J^\nu$$

Energy-momentum tensor of the QGP fluid

Energy and momentum deposited from the jets

- Massless jet particle traveling in a straight line
- Collisional energy loss

$$J^0(x) = \left[-\frac{dp^0_{\rm jet}}{dt} \right] \delta^{(3)} \left(\boldsymbol{x} - \boldsymbol{x}_{\rm jet}(t) \right)$$

$$\boldsymbol{J}(x) = \frac{\boldsymbol{p}_{\rm jet}}{p^0_{\rm jet}} J^0(x)$$

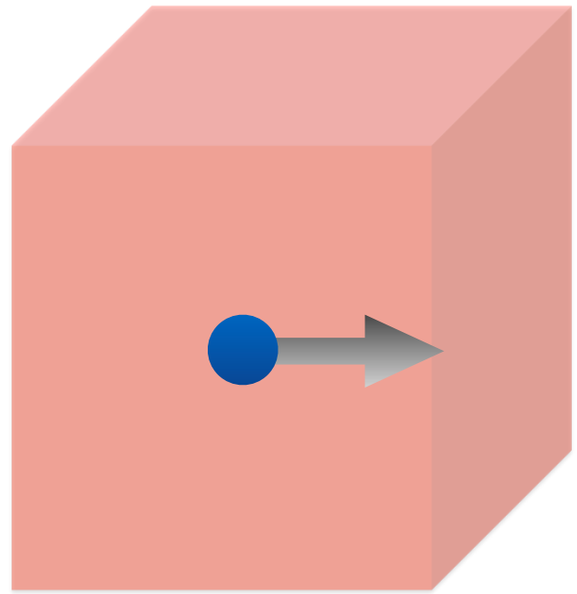
Solve this hydrodynamic equation numerically without linearization

Simulations

■ **Test case**

- 1-jet traveling through a uniform fluid

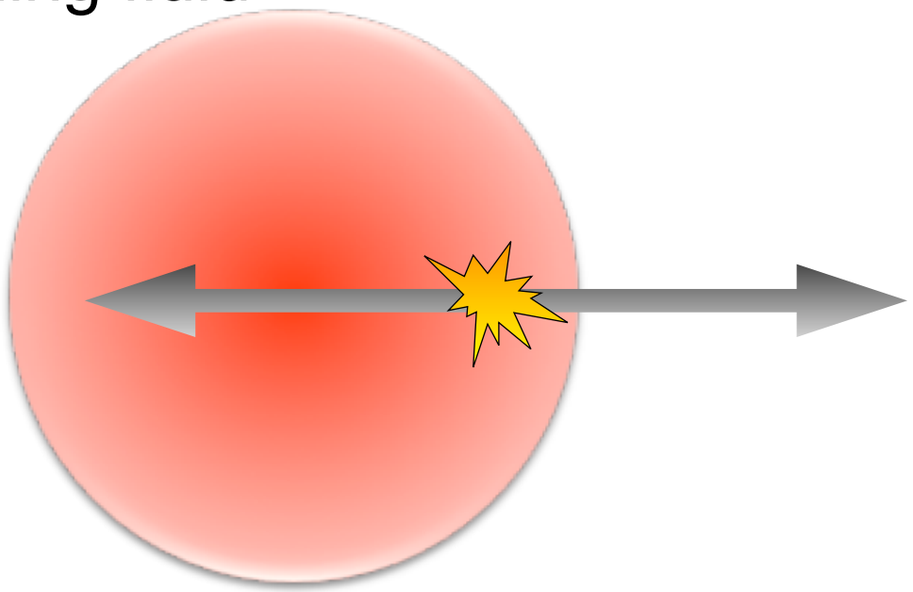
Flow induced by a jet particle



■ **More realistic case**

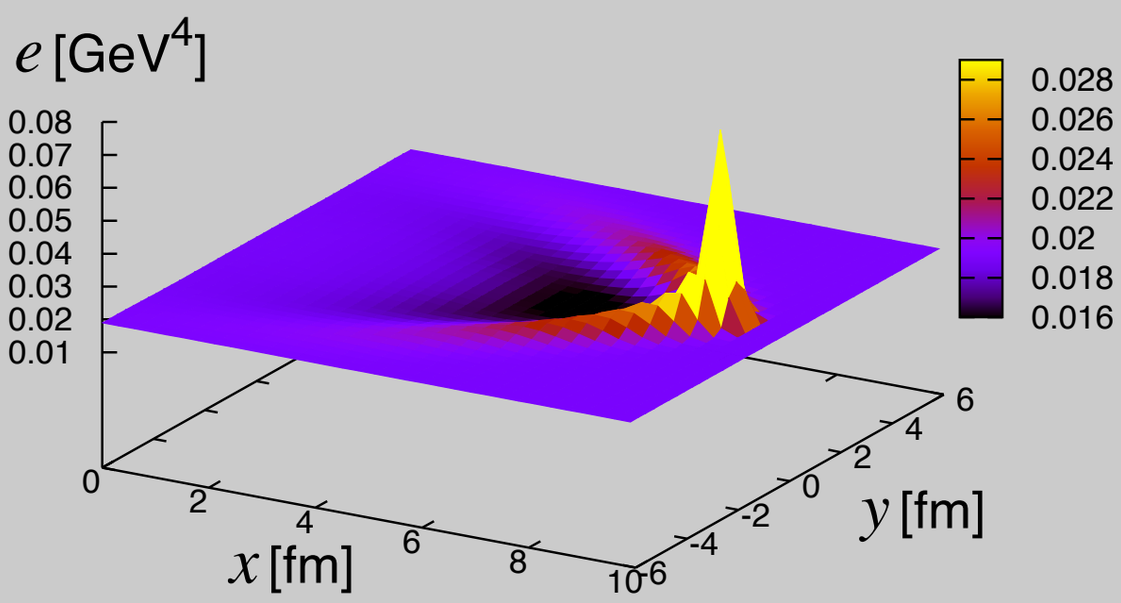
- A pair of jets traveling through an expanding fluid

Flow induced by jets
+
Radially expanding background

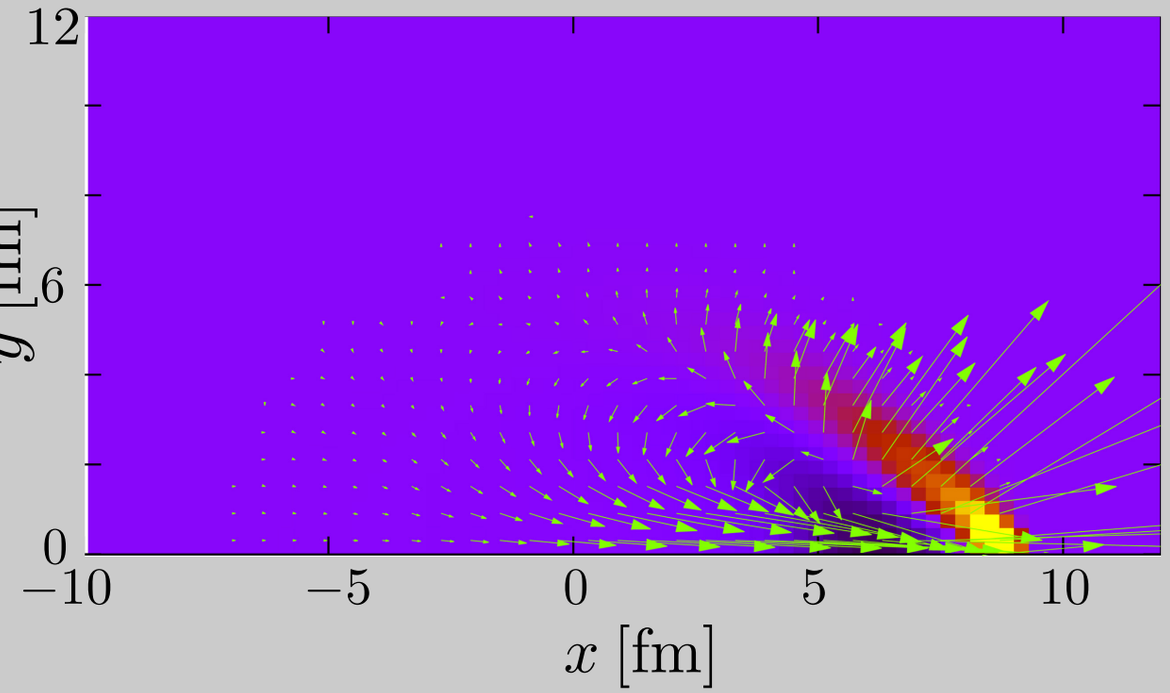


1-Jet Traveling through a Uniform Fluid

Energy density $(t = 9\ [\mathrm{fm}])$



Flow velocity $(t = 9\ [\mathrm{fm}])$



- **Mach cone** structure

- **Vortex ring** around the passage

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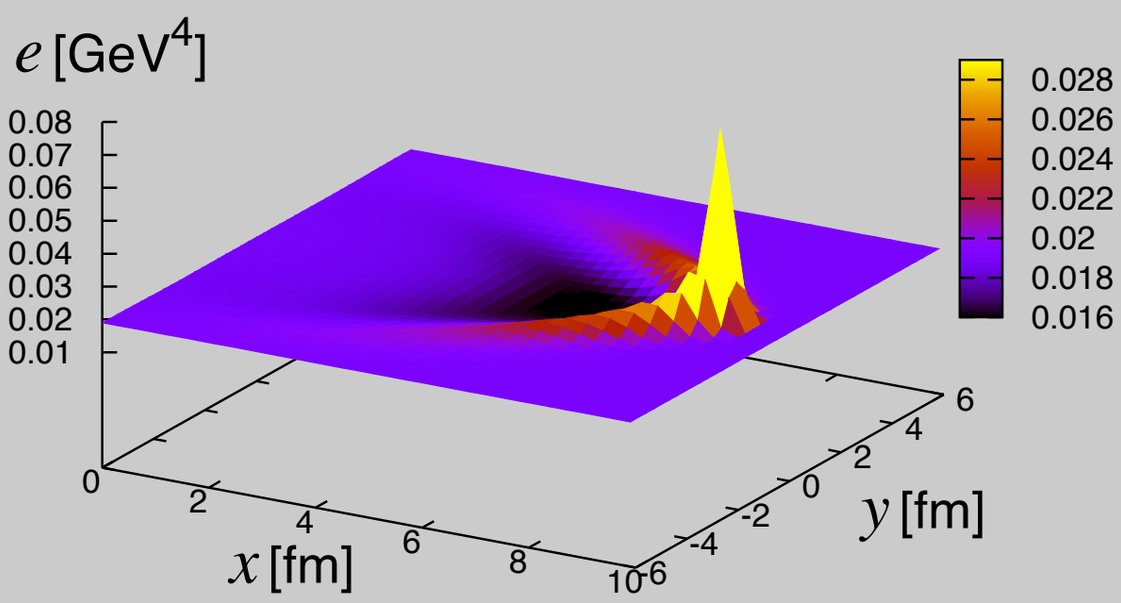

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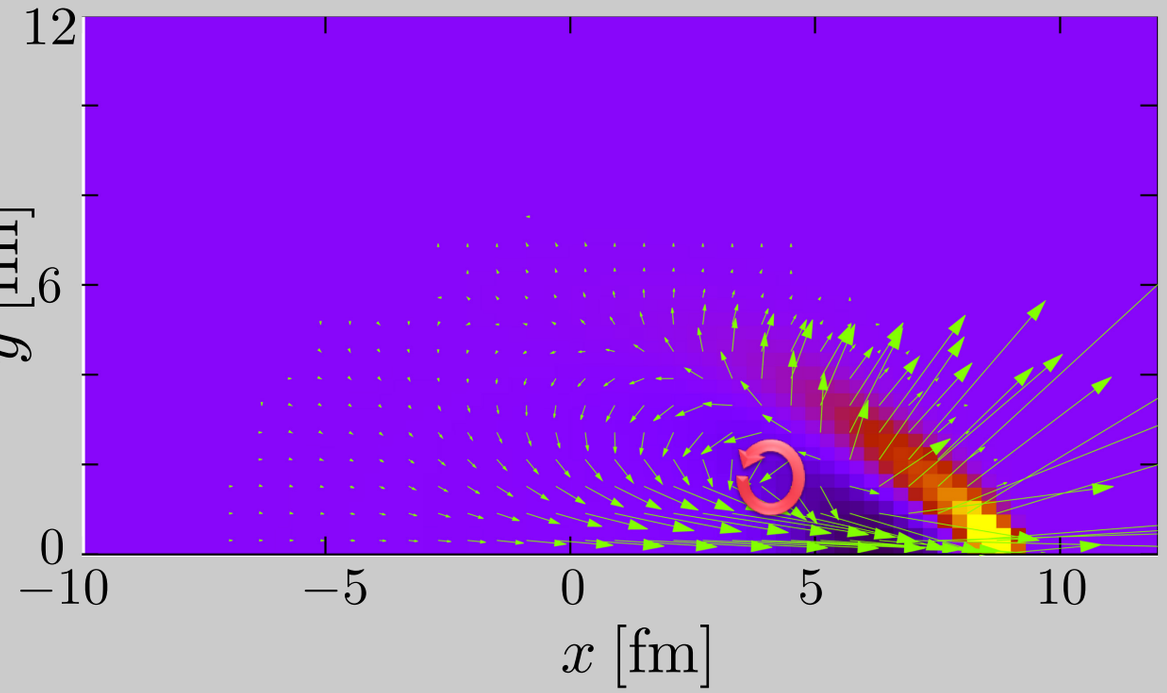

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Energy density $(t = 9\ [\mathrm{fm}])$ Flow velocity $(t = 9\ [\mathrm{fm}])$

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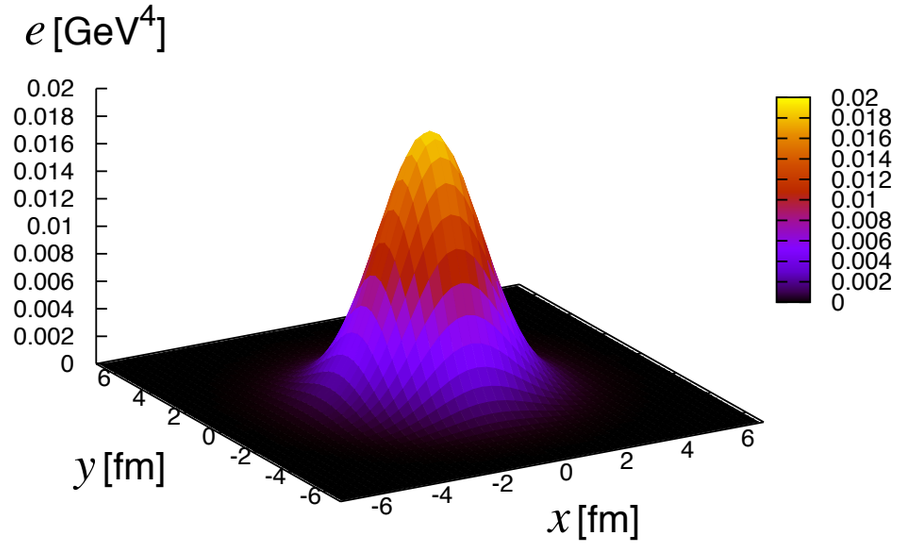
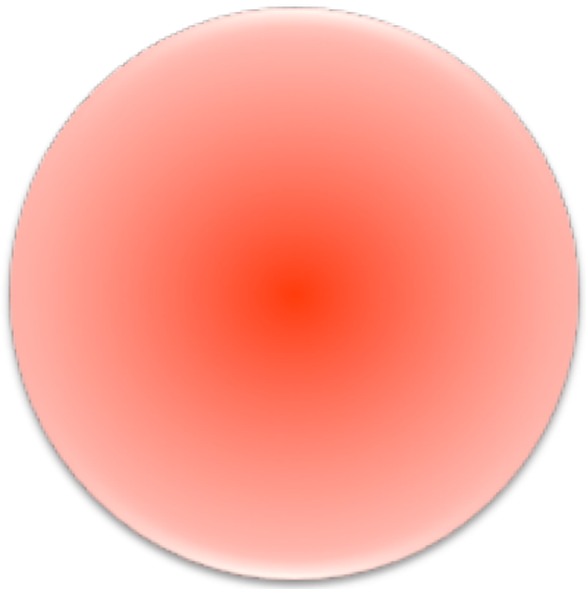
A Pair of Jets Traveling through an Expanding Fluid

- Initial condition of the energy density: 3D-Gauss + cut-off



- A pair of jets created at off central position



Back to back same energy jets

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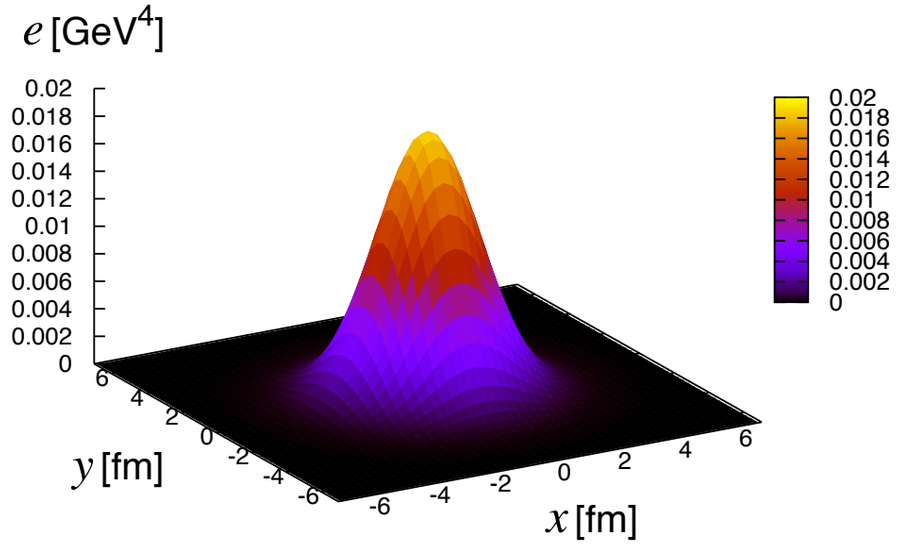

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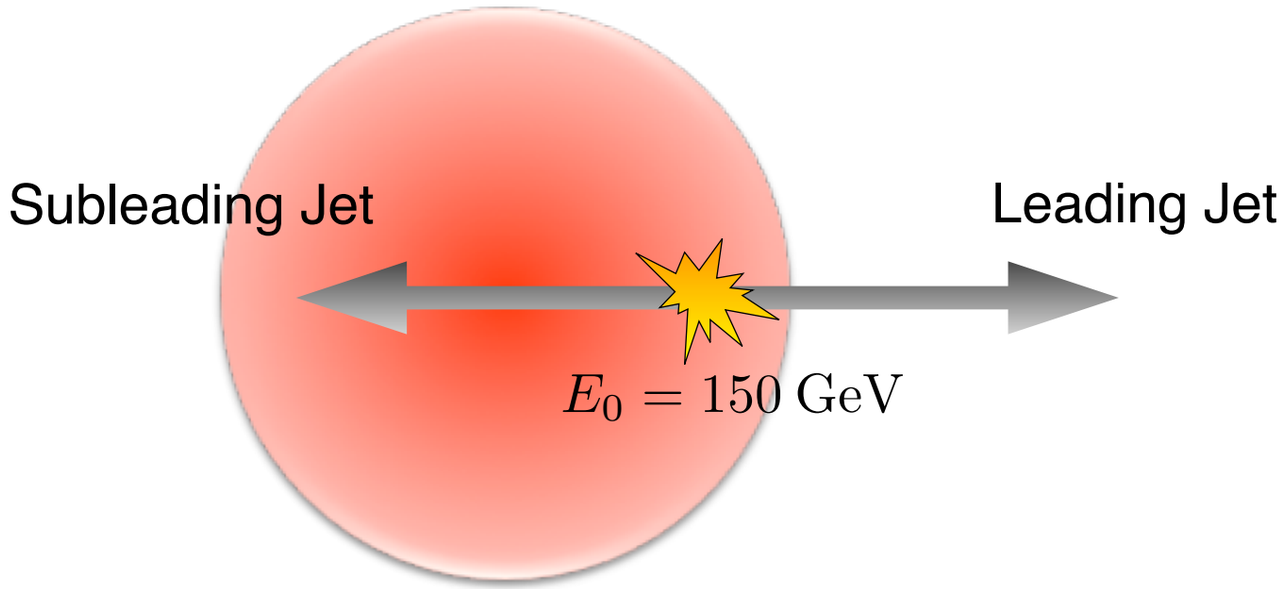


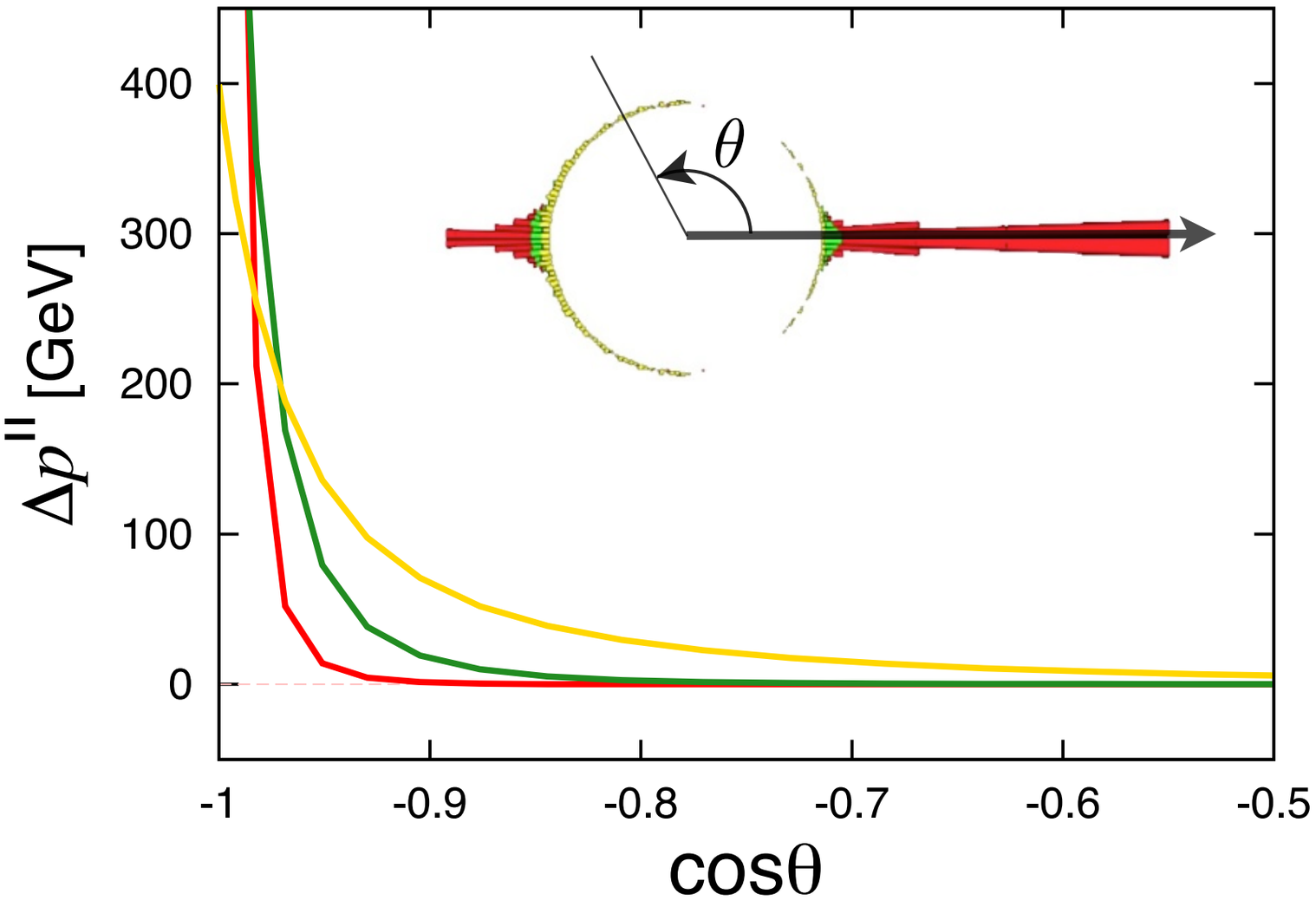
Back to back same energy jets

A Pair of Jets Traveling through an Expanding Fluid

Increase of momentum along the jets

$$\Delta p_i^{||} \equiv \sum_{p \in i} p^{||} - \sum_{p \in i} p^{||}{}_{\text{no jet}}$$

$p^{||}$: momentum component of the jet direction i = high, middle, low



high-p — $p > 8$ [GeV]

middle-p — $4 < p < 8$ [GeV]

low-p — $0 < p < 4$ [GeV]

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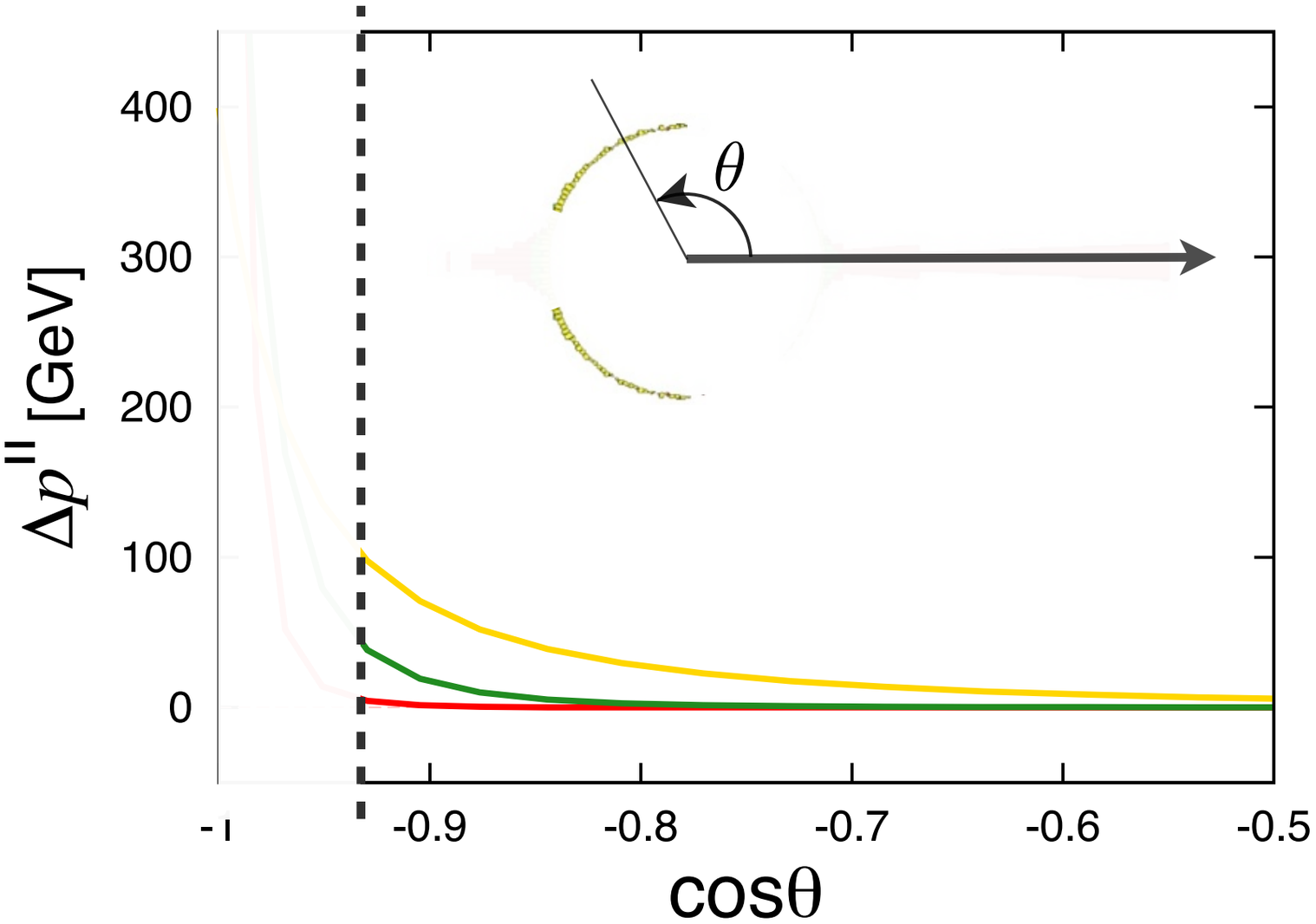

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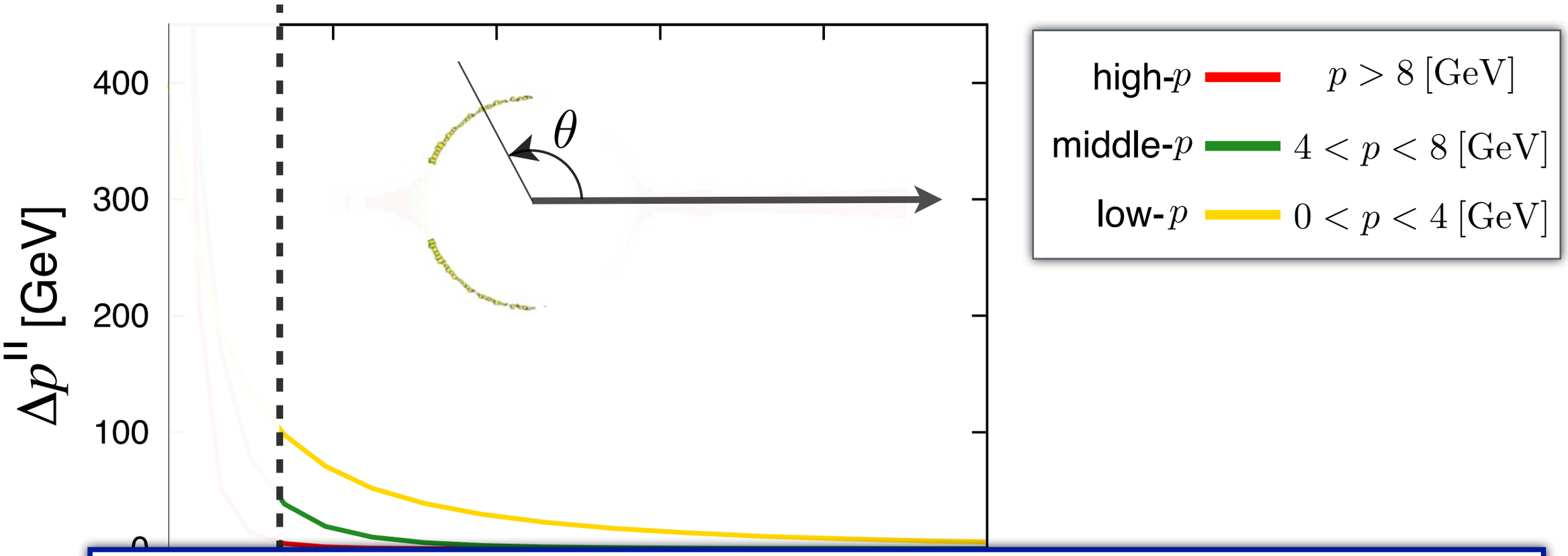

Low momentum particles are dominant at large angles from the jet

→ **Consistency with the CMS data**

Summary

■ **QGP-Fluid + Jet Model**

■ **1-jet traveling through a uniform fluid**

Mach cone structure

Vortex ring inside the cone

■ **A pair of jets traveling through an expanding fluid**

Collective flow induced by jets

→ **Large angle** emission of **low momentum** particles

Qualitative description of the CMS data