Efficient Description of medium response to jet energy loss

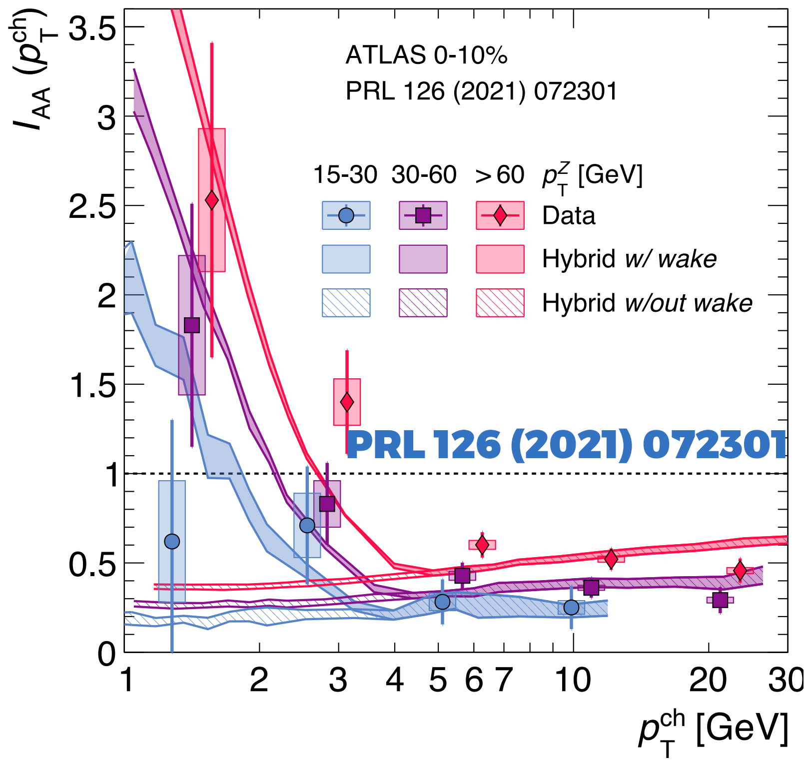
Jorge Casalderrey-Solana

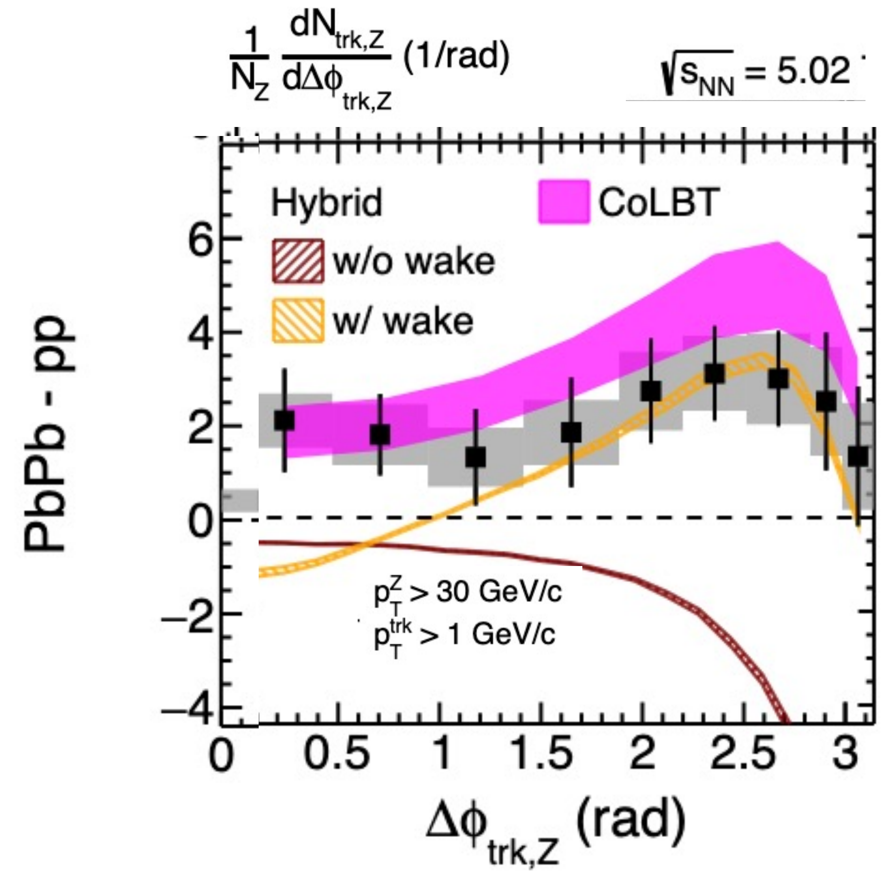
In collaboration with

G. Milhano, D. Pablos, K. Rajagopal and Xiaojun Yao

UNIVERSITAT DE BARCELONA

Jet Wakes





Phys. Rev. Lett. 128 (2022) 122301

- Soft structure of jets is modified in heavy ion collisions

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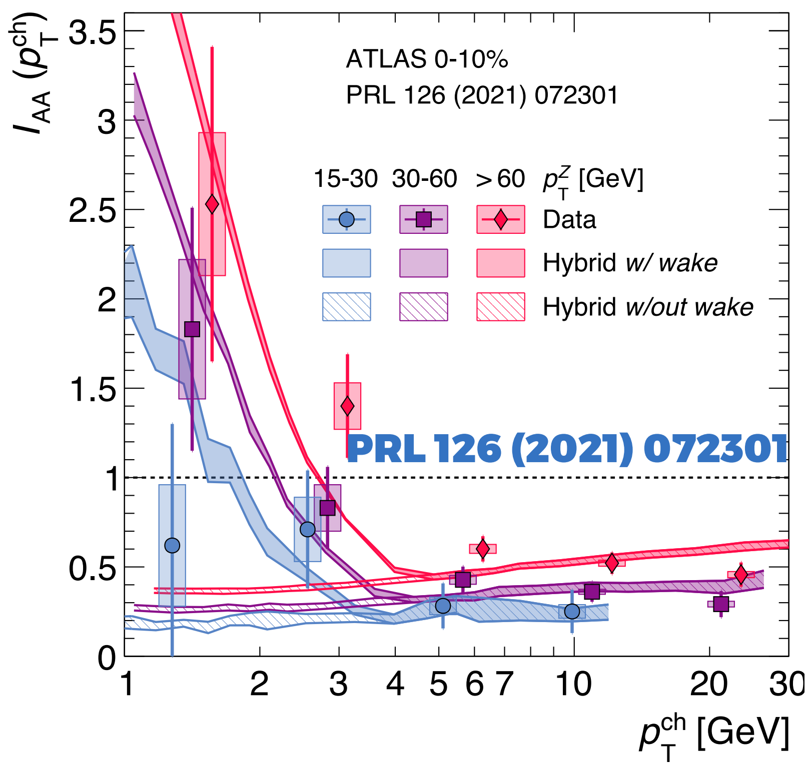

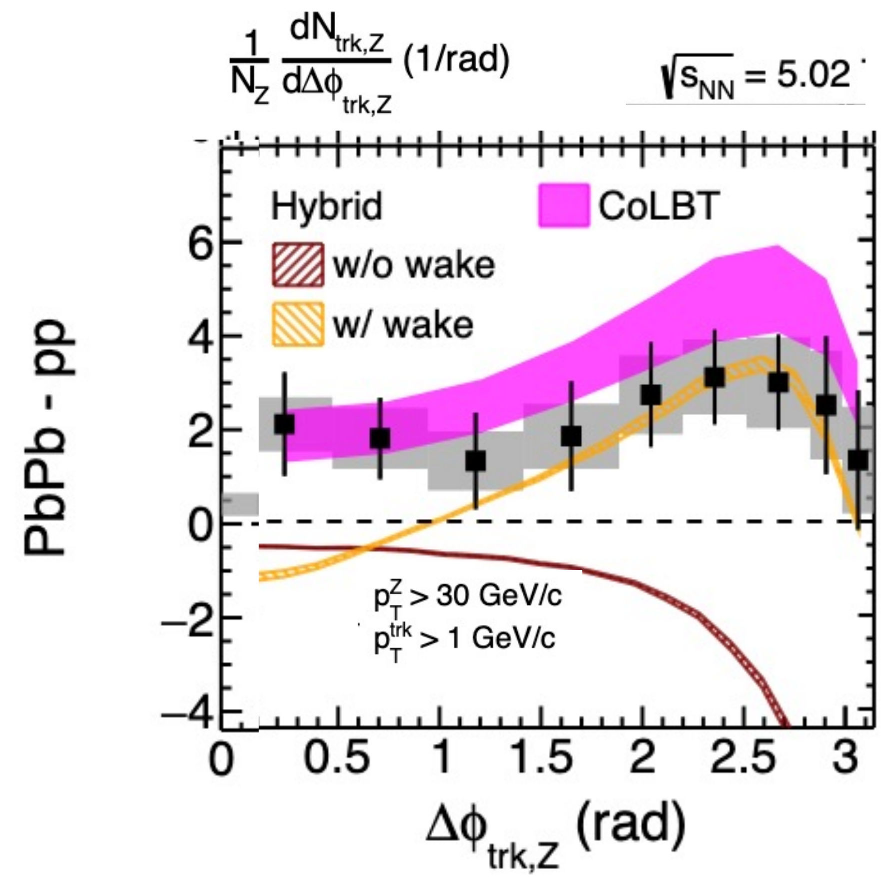

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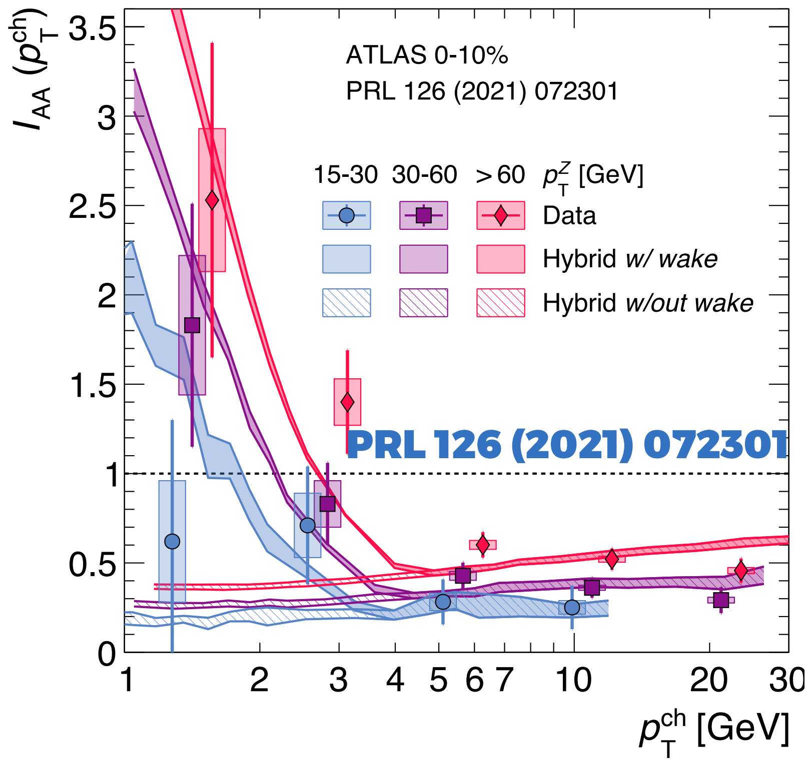

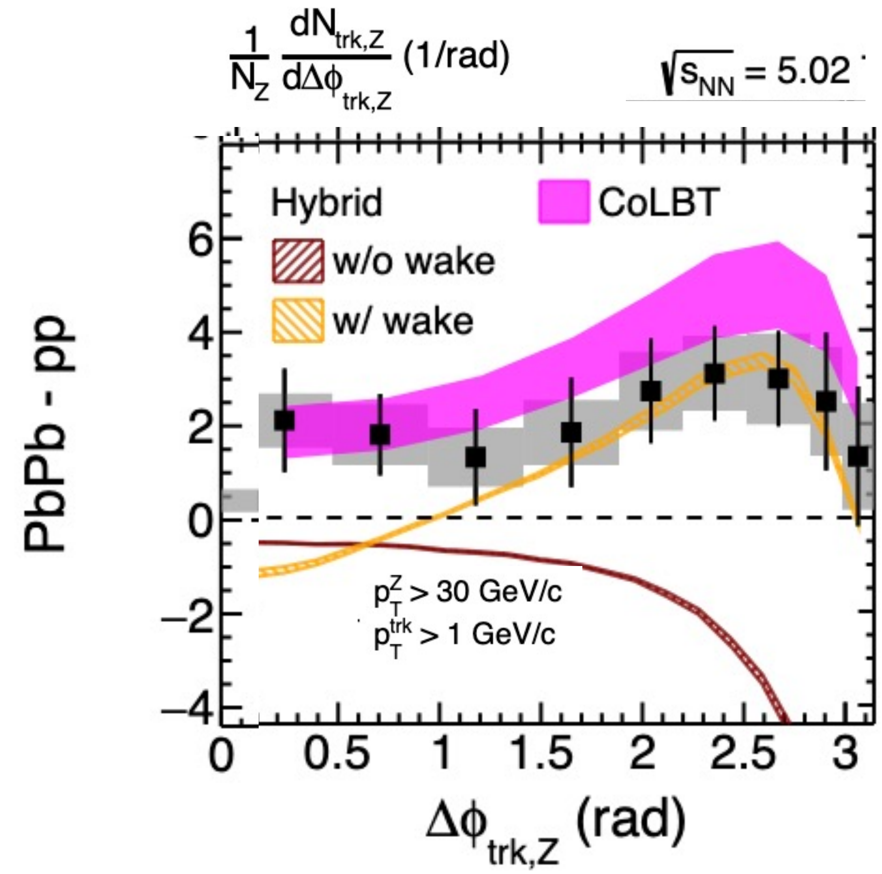

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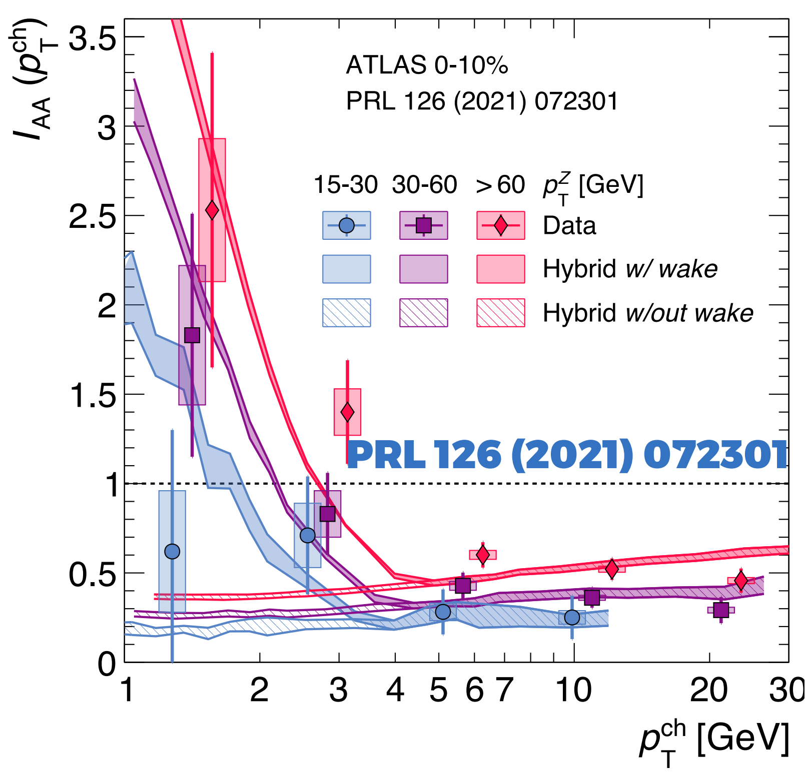

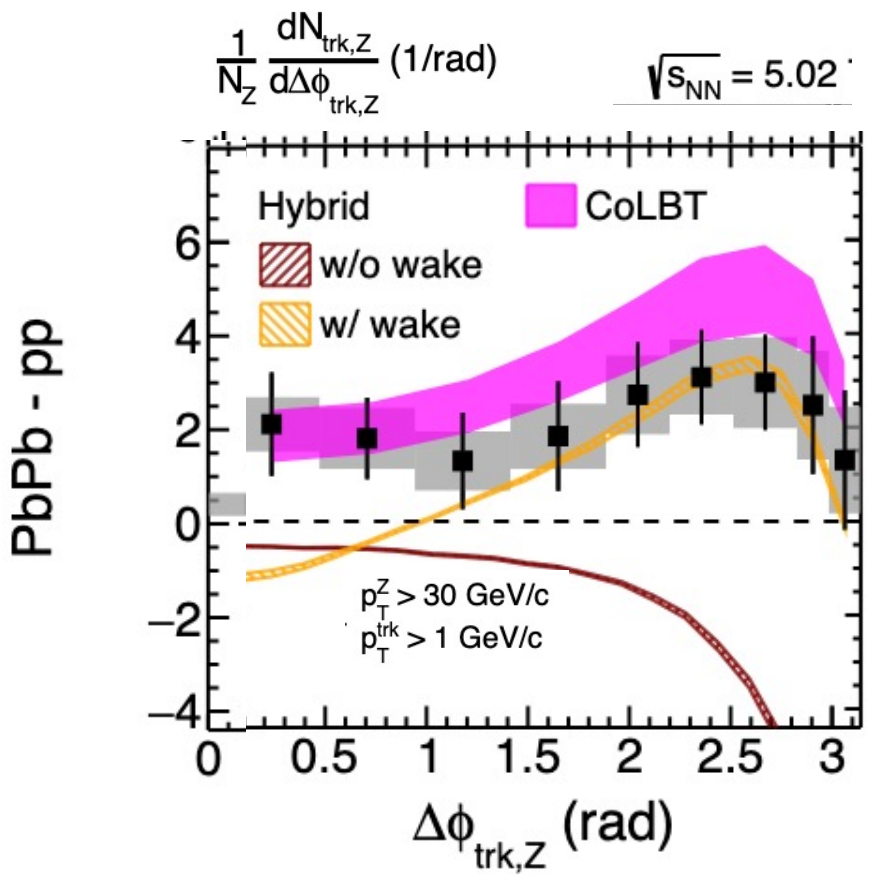

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- Soft structure of jets is modified in heavy ion collisions
  - Soft particle production is enhanced
  - Soft emission persists to very large angles
  - Well understood in terms of hydrodynamic response

Hydro response studied by many groups: Hybrid, CoLBT, Tachibana et al, MUSIC, …

Hydrodynamic Procedure

- Hydrodynamics with a source

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

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- Injection of energy by the jet
  - Integrates to the total deposited energy
  - Depends on the thermalization process

Chesler and Yaffe 07; Hong, Teaney and Chesler 12, …
Mehtar-Tani, Schlichting, Soudi 22;
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  - Concrete form still unknown
    (here modelled by a Gaussian)

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- Collective response
  - Transports energy away from jet
  - Produces sound and diffusion
  - Interplay with radial flow

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- Monte Carlo analysis: millions of events
- Full hydro analysis of back-reaction:

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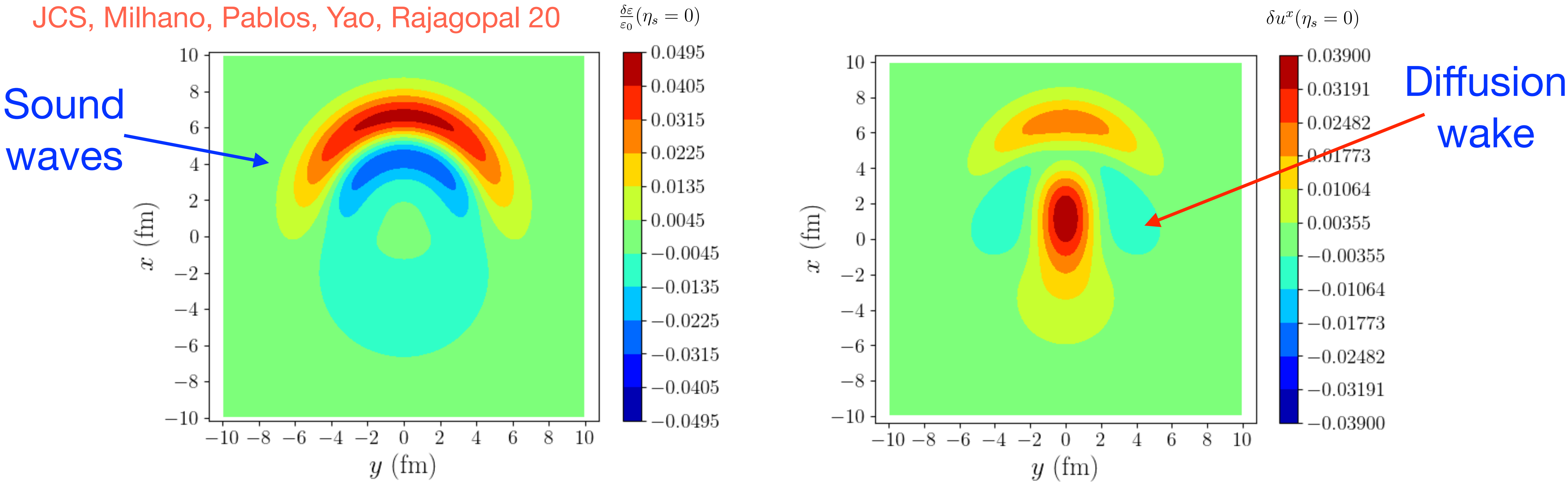
  - But not everything is linear:
    - Deposition rate
    - Particle production $E \gg T$

} Non-linear dependence on jet energy

Response without Transverse Flow

- Building block: perturbation on-top of Bjorken flow

JCS, Milhano, Pablos, Yao, Rajagopal 20



- Sound waves ⇒ take energy away from jet
- Diffusion wake

  ⇒lost momentum becomes moving fluid along the jet path
- On average:

JCS, Teaney and Shuryak 05

diffusion wake dominates over sound waves in particle production

See for Yang, He, Chen, Ke, Pang and Wangattempts to disentangle Mach and wake in COLBT

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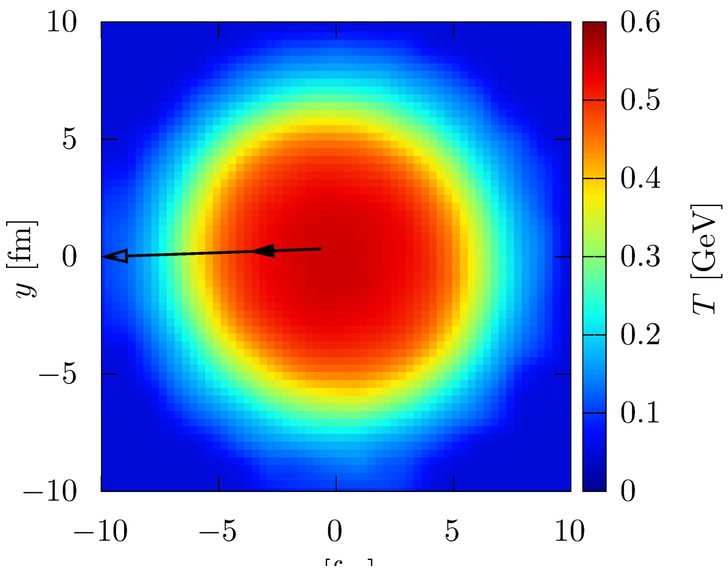
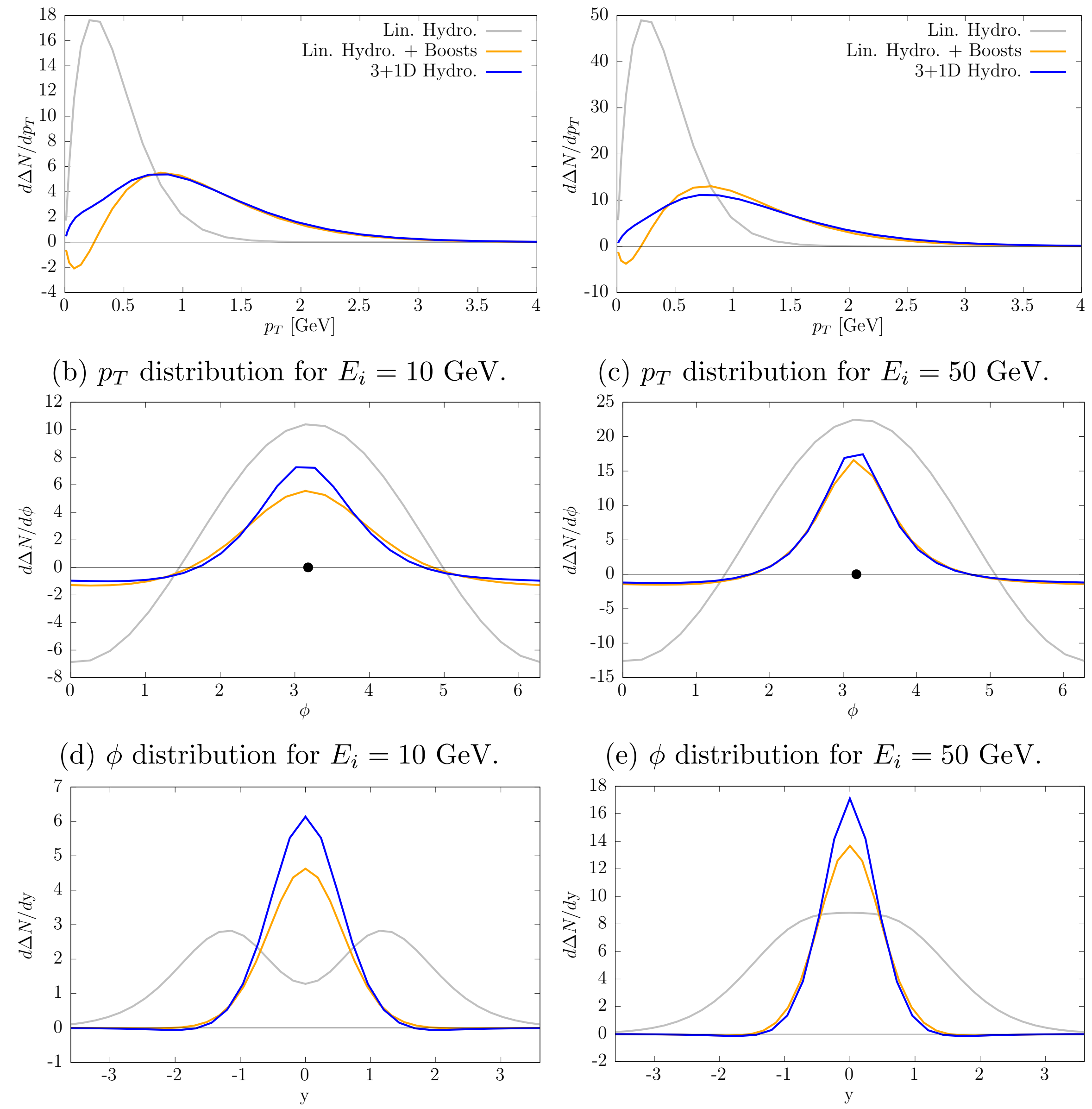
  - Compute time between deposition time and freezeout depending on transverse flow
  - Applicable to any transverse flow
  - Fast generation of flow fields induced by jets
    - Library of cases for each deposition point + linear superposition

Calibration Against Full Hydro



- Excellent agreement with non-linear hydro
- Effects of transverse flow
  - Harder
  - Narrower
  - Less “negative”



(b) p_T distribution for $E_i = 10$ GeV.
(c) p_T distribution for $E_i = 50$ GeV.
(d) ϕ distribution for $E_i = 10$ GeV.
(e) ϕ distribution for $E_i = 50$ GeV.
(f) y distribution for $E_i = 10$ GeV.
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Non-linear hydro response from Music

Other non-linear response: Tachibana et al.; CoLBT

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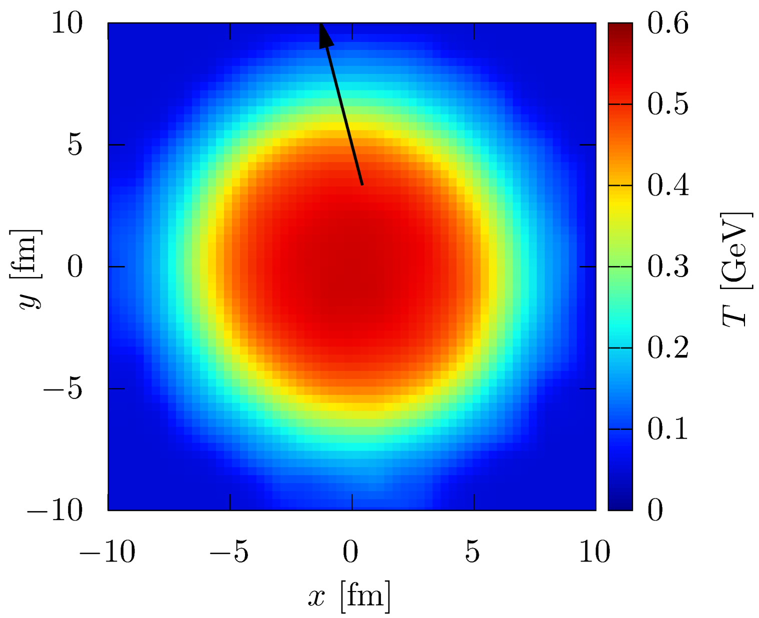
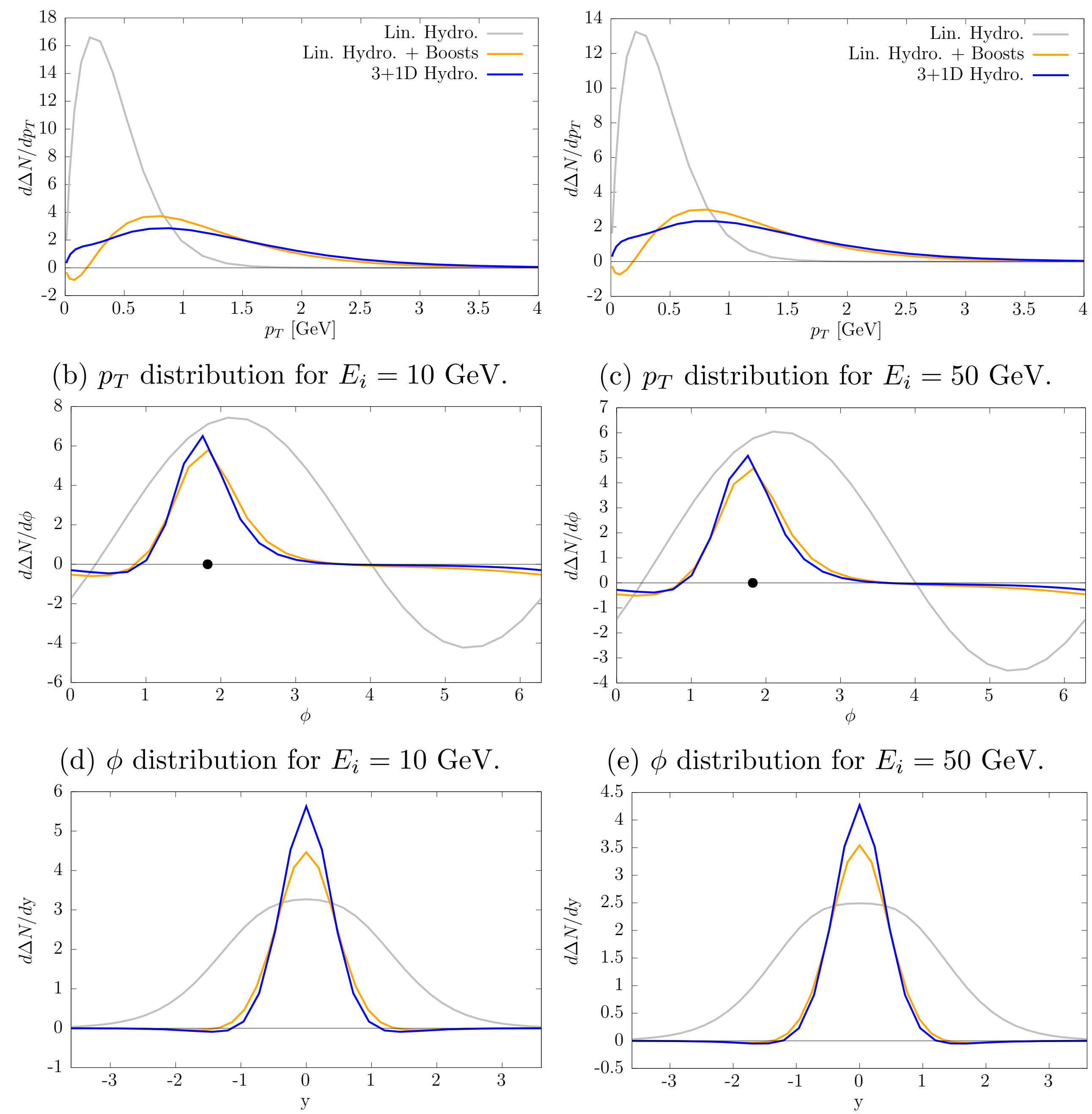


- Very good agreement with non-linear hydro
- Soft particle spectrum

  changes event by event



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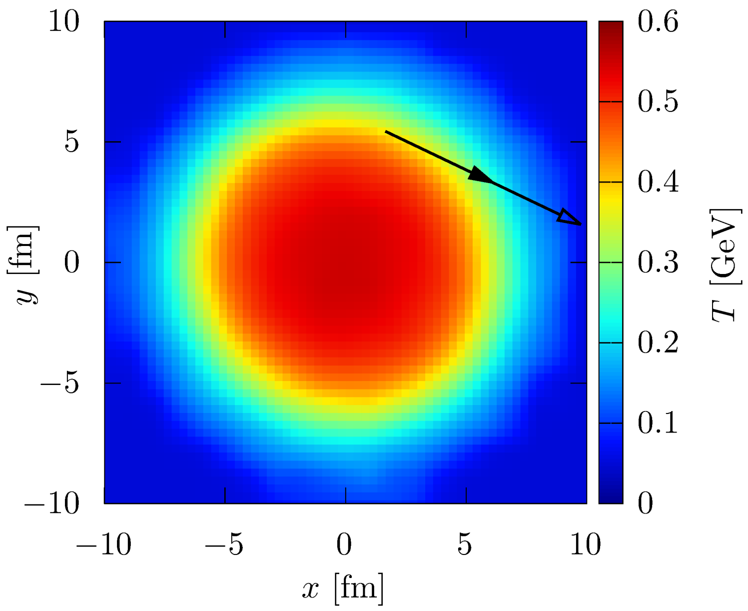
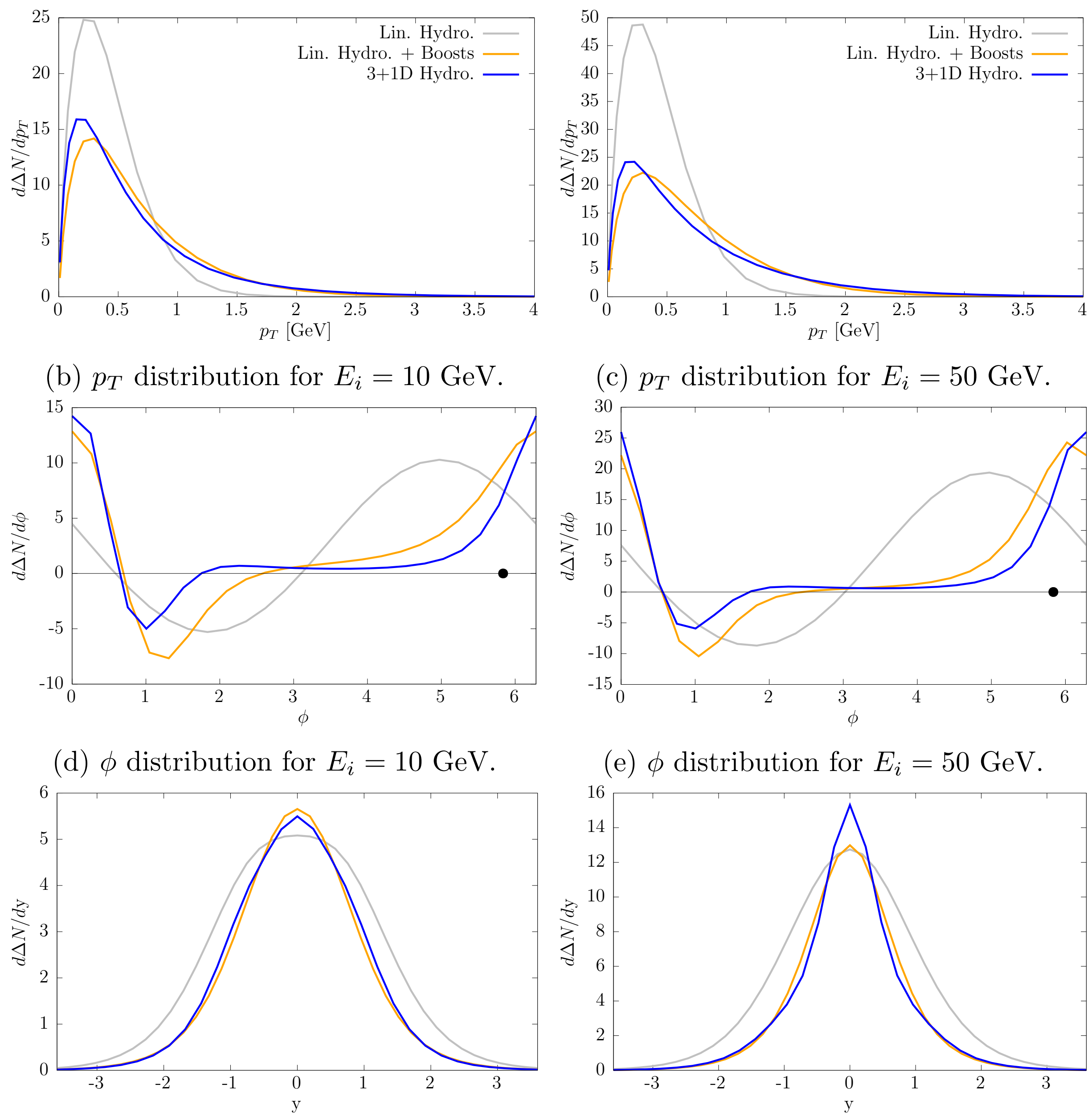


- Good agreement with non-linear hydro
- Soft particle spectrum
  changes event by event
- Intricate angular patterns
  depending on point of origin
  jet direction
  radial flow encountered



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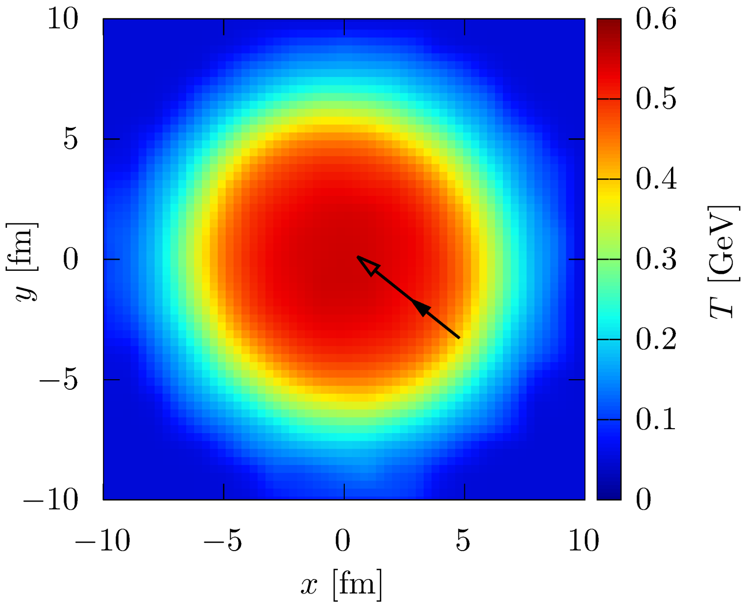
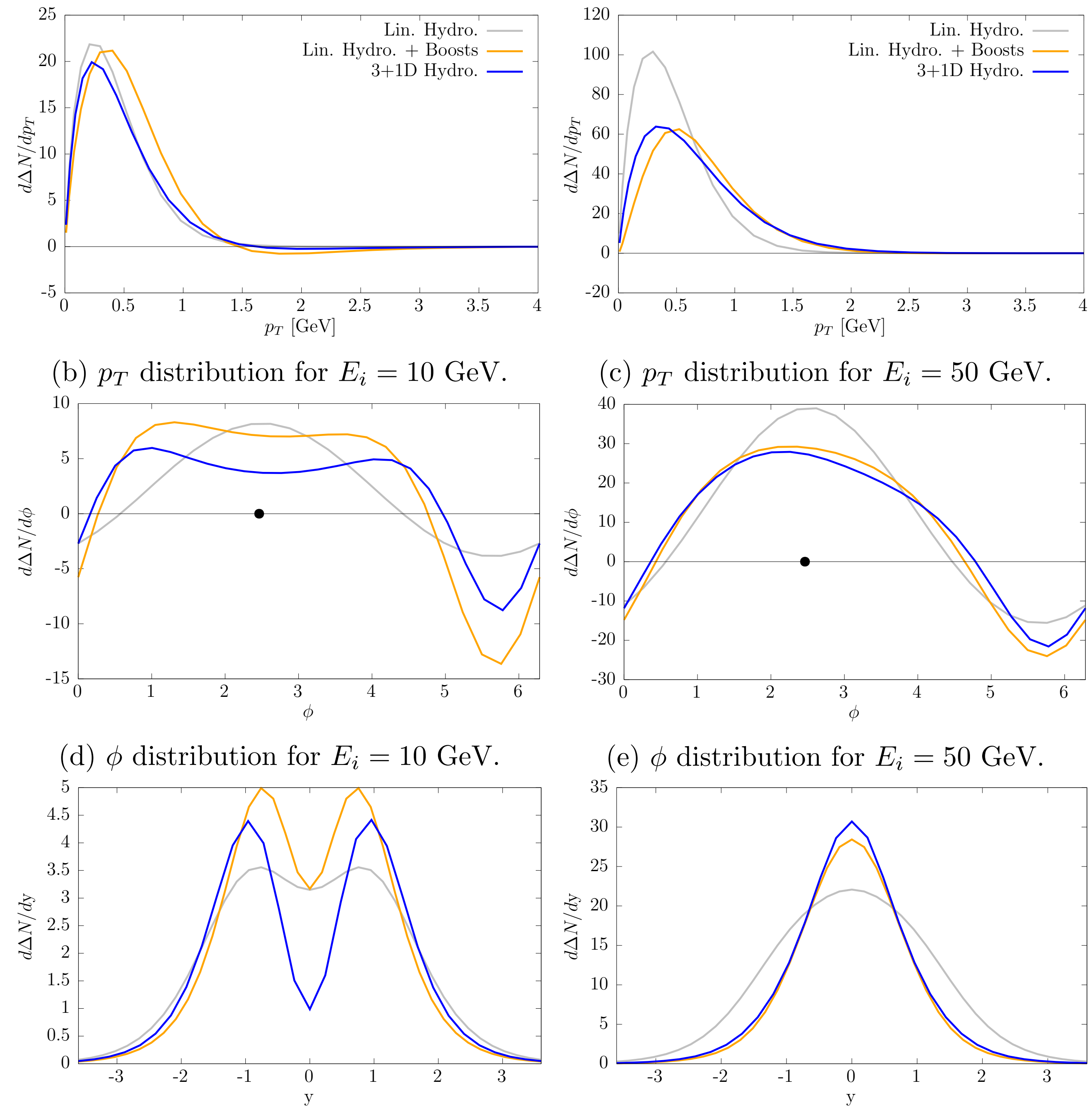


- Semi-quantitative agreement with non-linear hydro
- Soft particle spectrum changes event by event
- Intricate angular patterns



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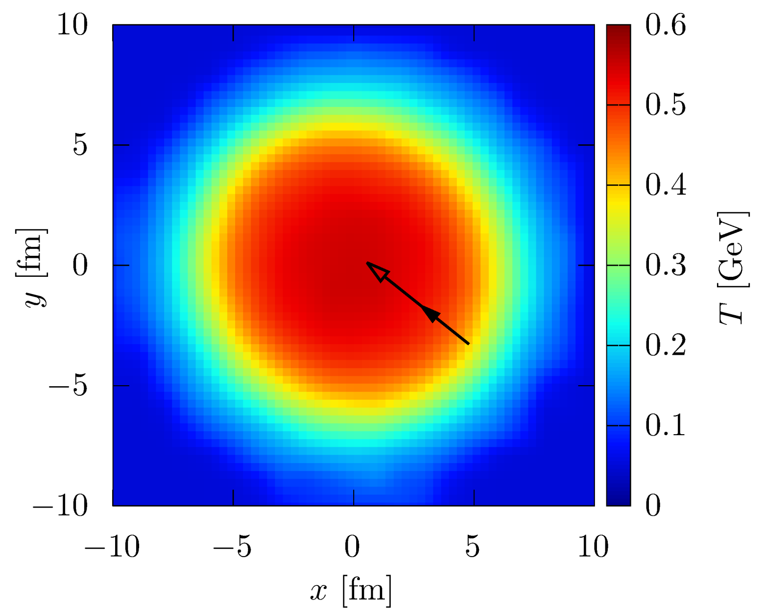

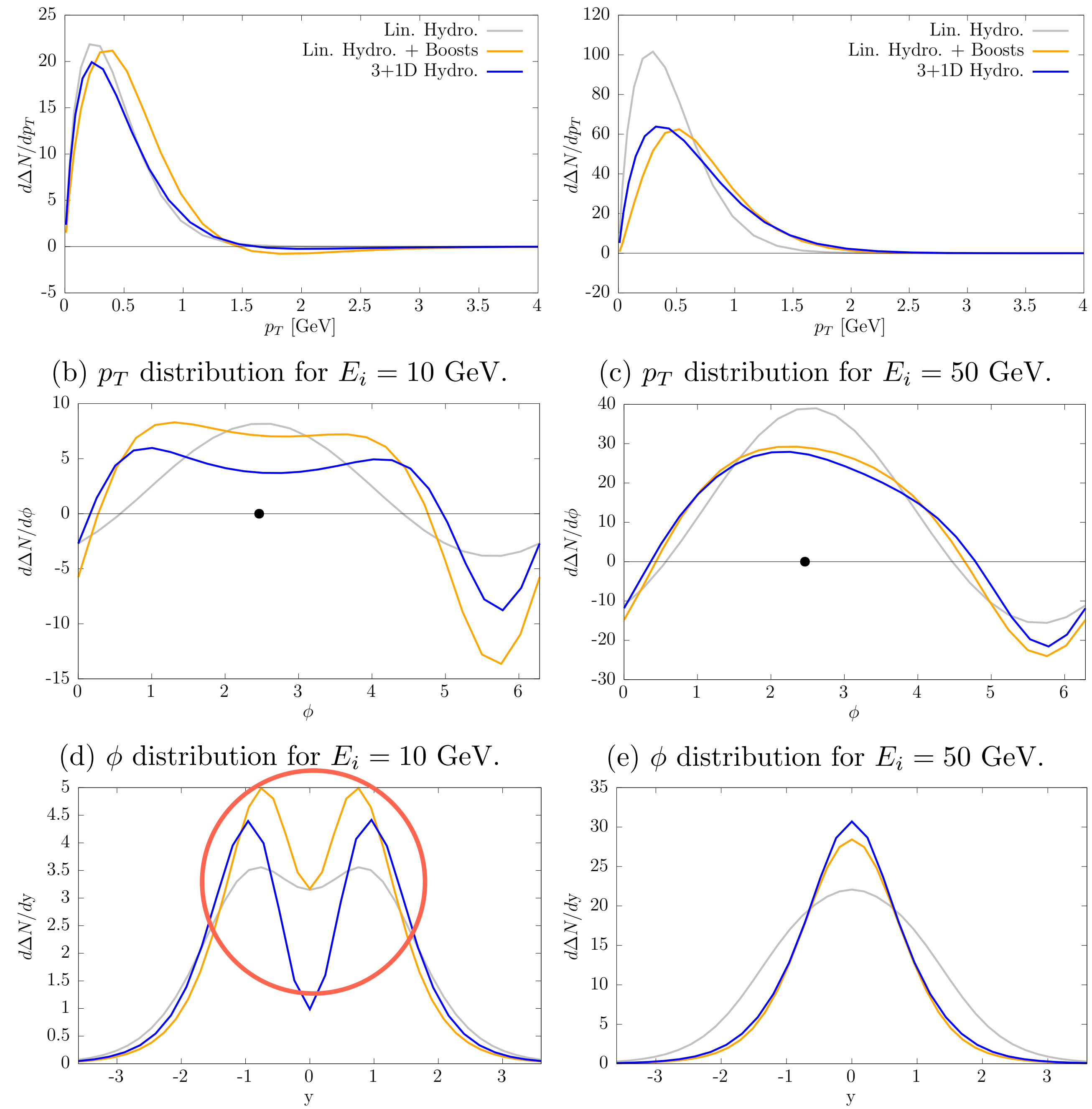

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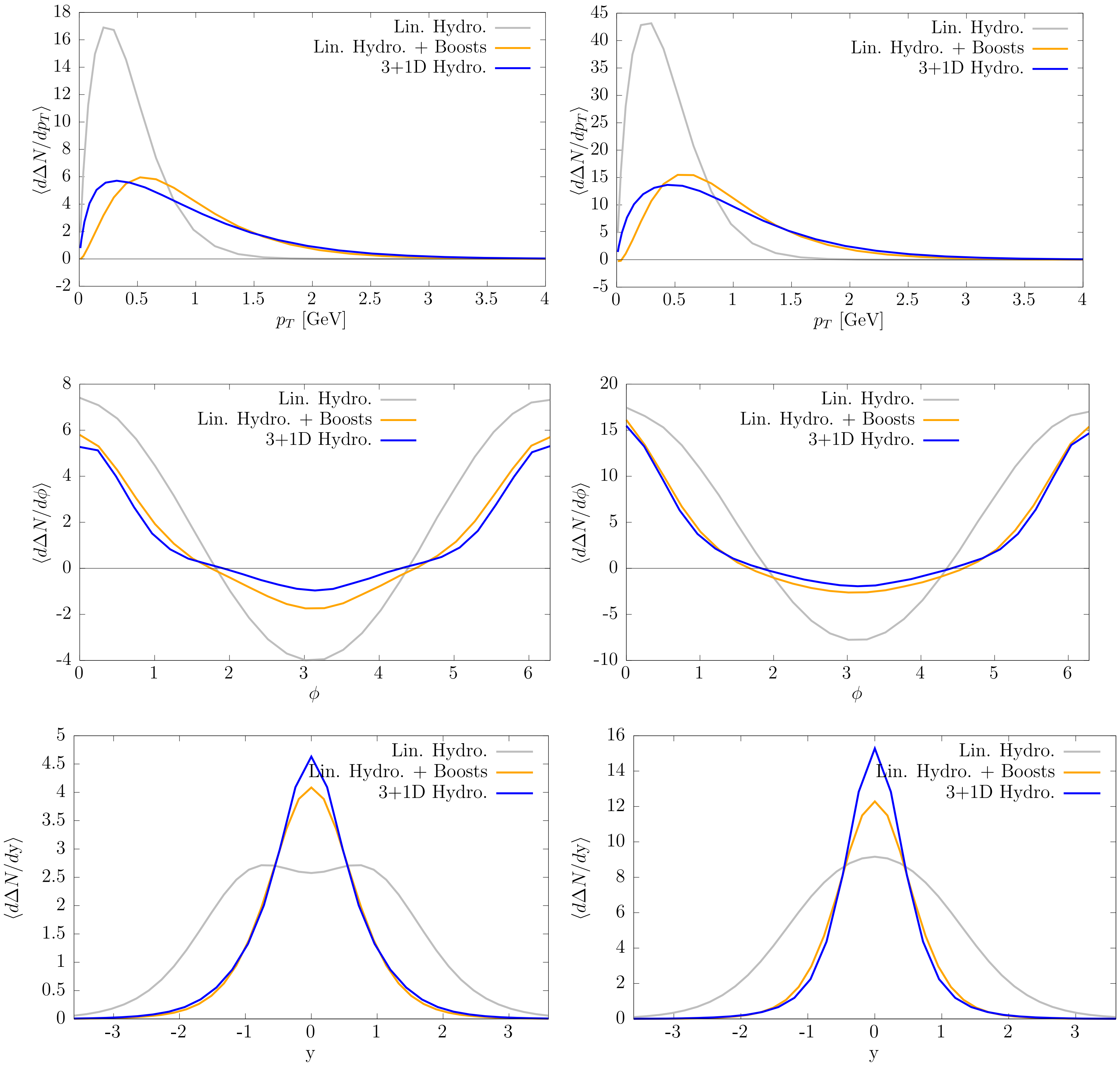
Non-linear hydro response from MUSIC

Manifestation of sound waves in rapidity (for certain configuration)

Average over events



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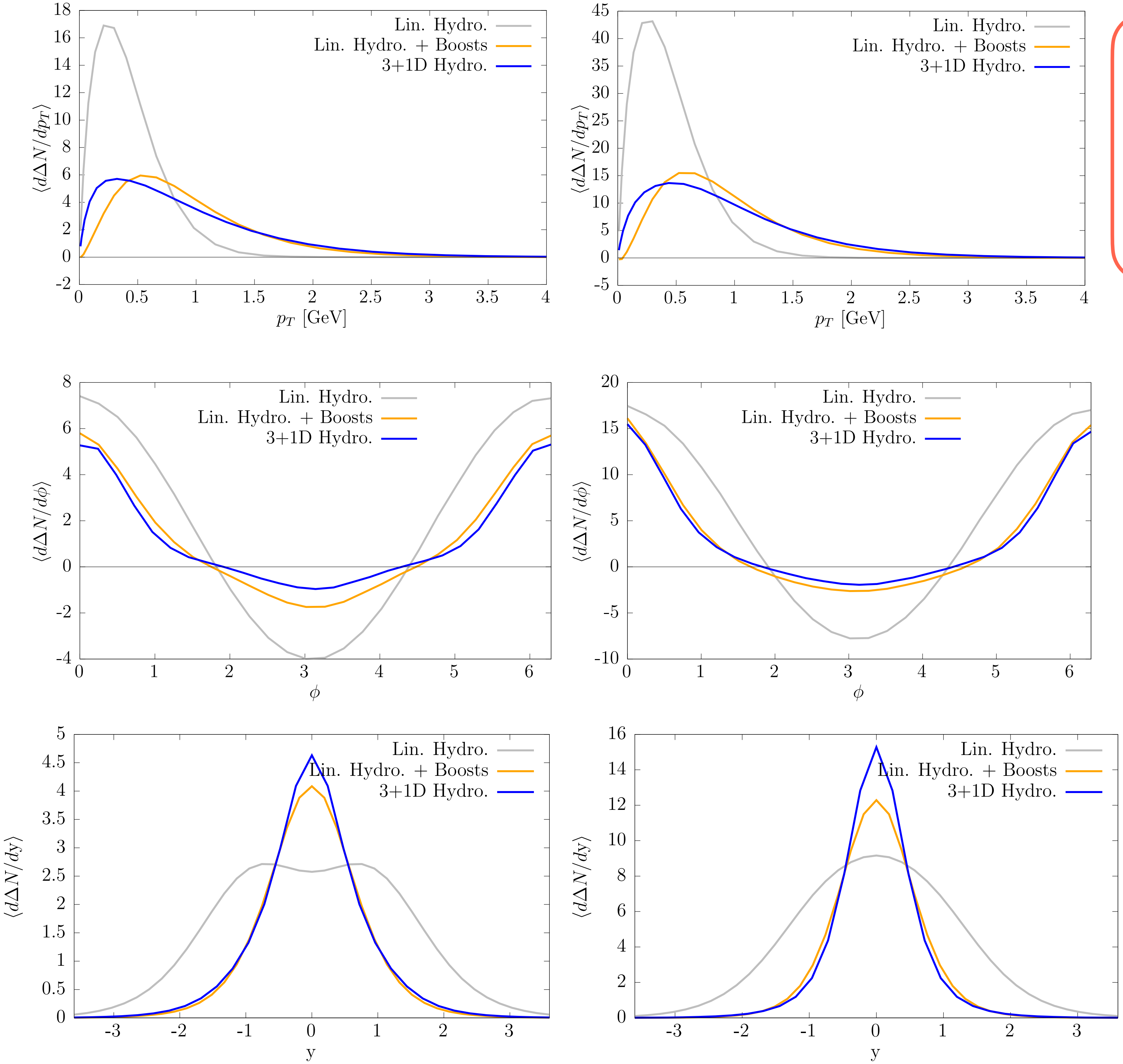

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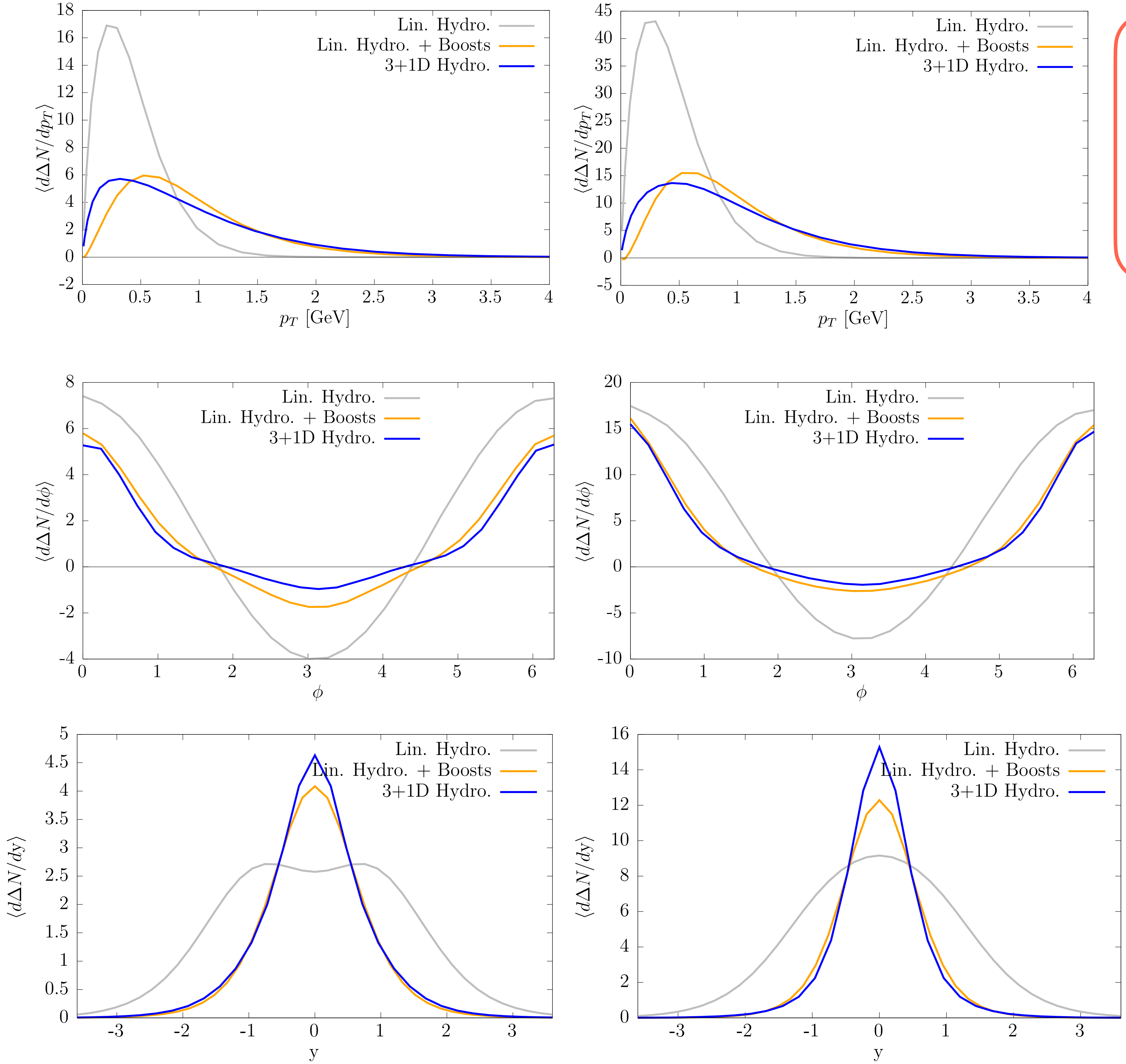

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Spectrum becomes
Harder
Narrower
With fewer negatives than in previous approx.

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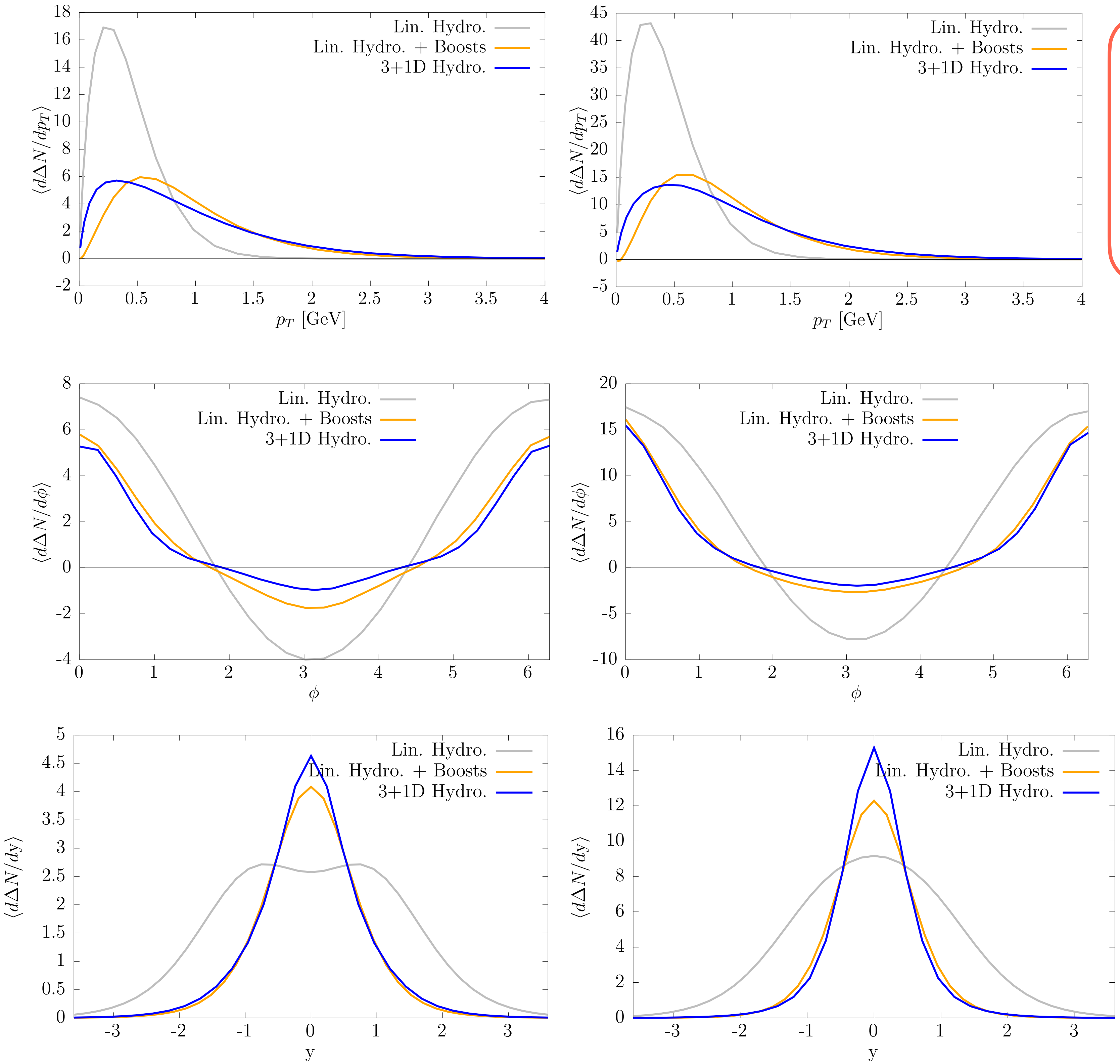

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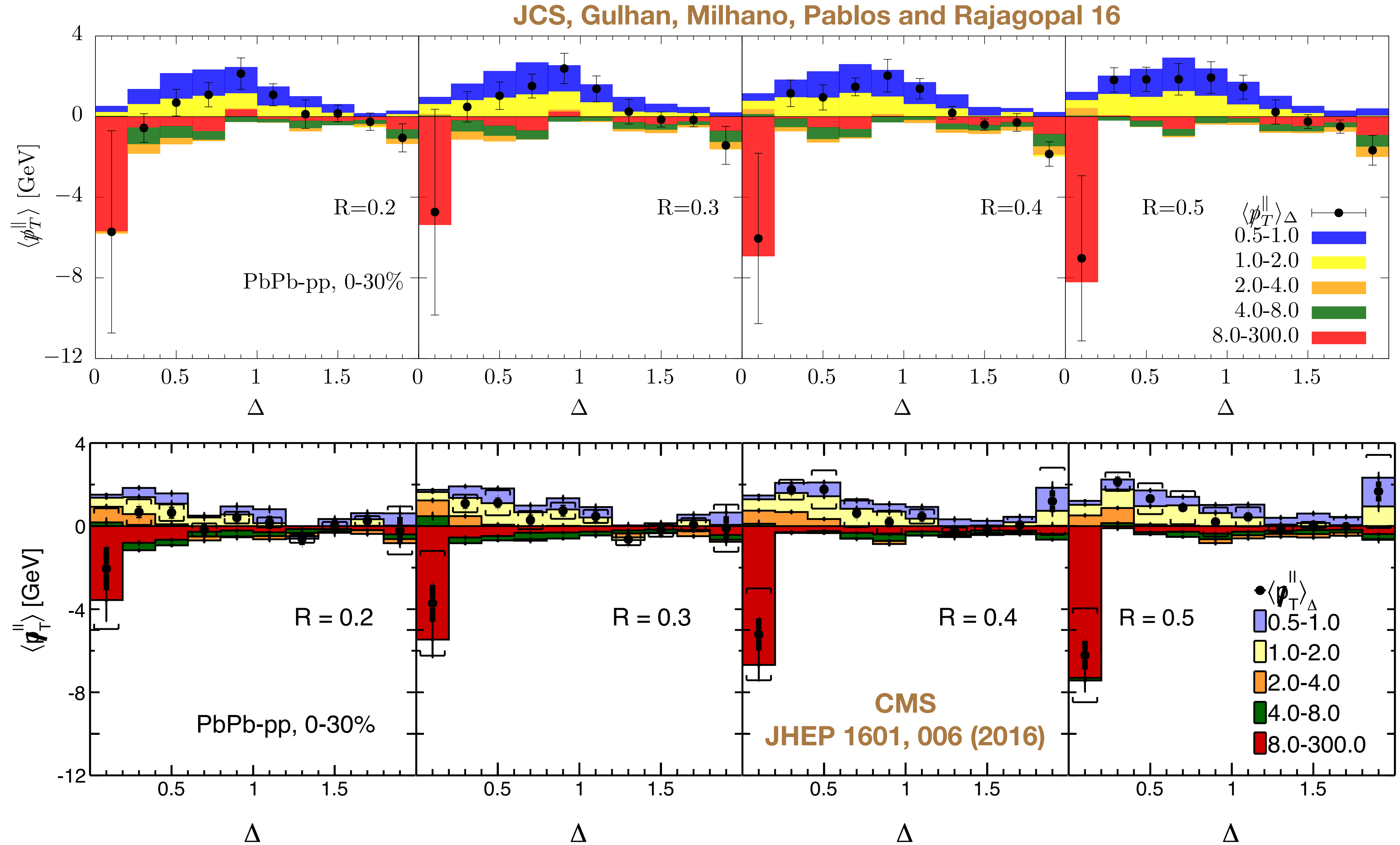
At least 1000 X faster than non-linear solution

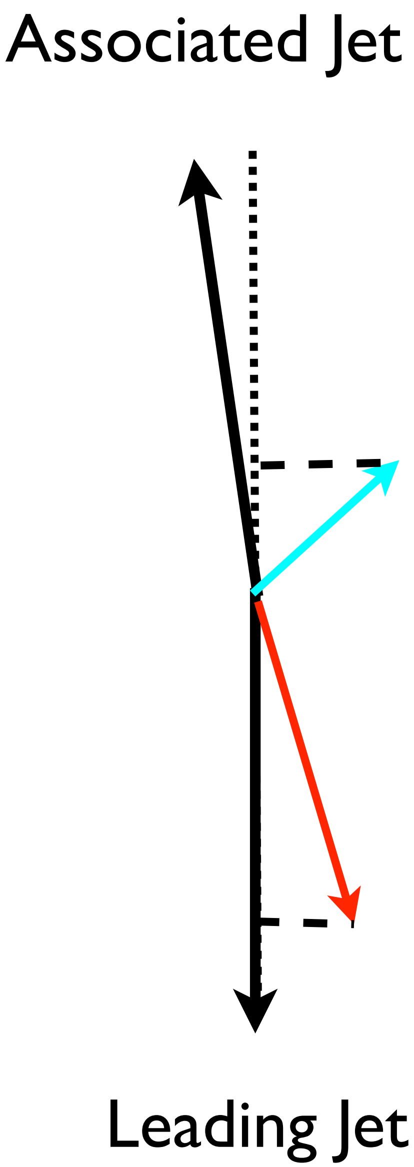
Conclusions

- Medium response affects the soft jet structure
  - They exhibit interesting flow patterns
    - Depends on collision geometry
    - Provides complementary tomographic information
    - May also help to constrain hydrodynamization
- However, full hydro response is computational expensive
  - Our procedure captures the main physics of medium response
  - At least 1000 X faster than non-linear solution
  - We are now ready for a Monte Carlo implementation

    And for a more stringent comparison with RHIC and LHC data

Too simple⇒Too Soft & Too Wide





- The simple back-reaction implemented in hybrid model:
  - Captures the general features of the energy-degradation
  - Produces too many soft particles at large angles
- In this talk: first steps towards a better description of back-reaction