JEWEL for ~~small systems~~ any system

Isobel Kolbé

Joint LIP/IGFAE workshop

MC jets with JEWEL

1311.0048

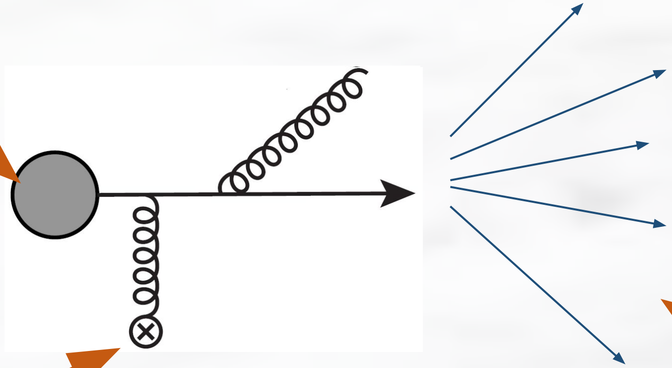
1

1. Production:
Sample energy density distribution of collision

Use PYTHIA to generate particles

2

2. Vacuum Radiation:
DGLAP evolution



3

3. In-medium radiation:
Sample medium model to get T.

Use 2 – 2 scattering matrix
+ parton shower

4

4. Give evolved jet and all radiated partons back to PYTHIA for full event generation

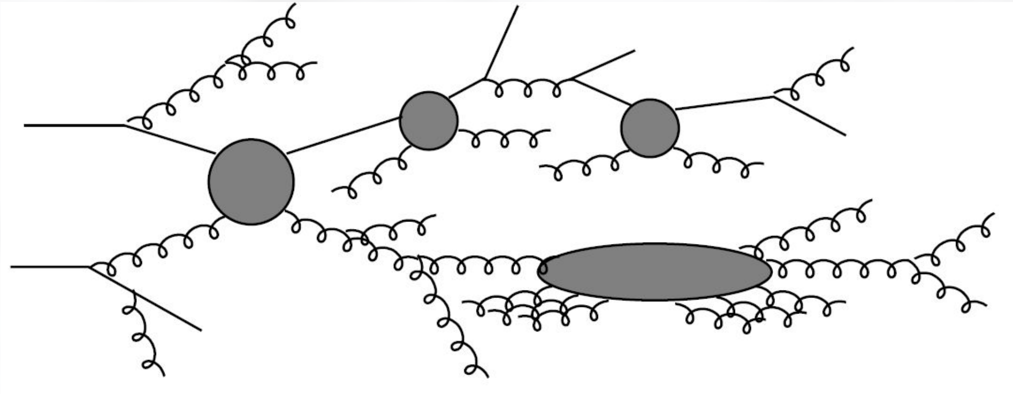
The medium in JEWEL (new public version! jewel-2.4.0)

1. Vacuum: virtuality ordered parton shower (DGLAP evolution)
2. In-medium: vacuum JEWEL + medium interaction

Simple (Bjorken + T^4)

Glauber Woods-Saxon

LHAPDF 6



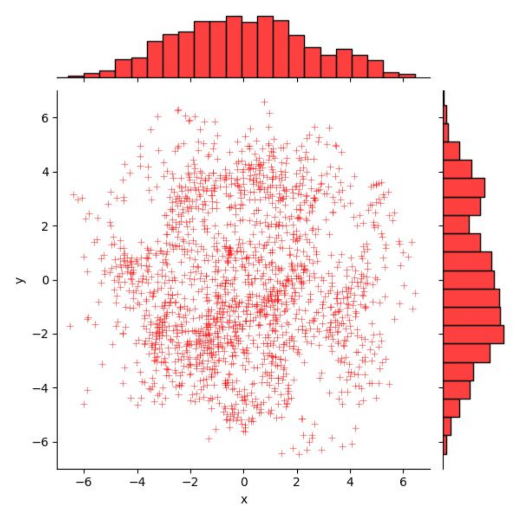
Subtleties:

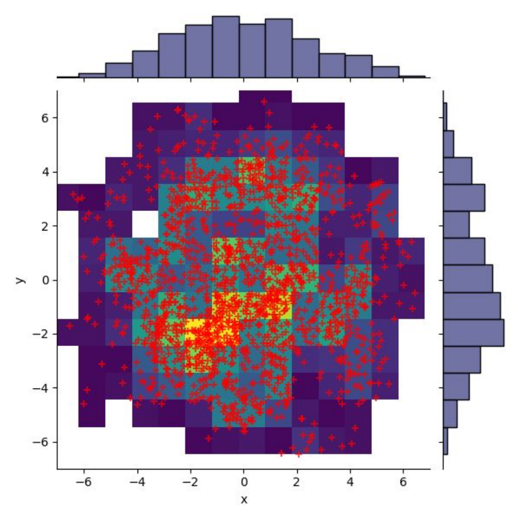
- Tracking medium recoils
- Subsequent subtraction
- Soft event constituents

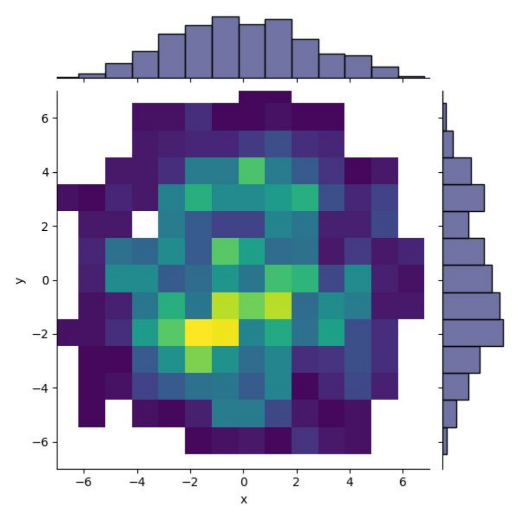
Hydro interface for JEWEL

New jewel-2.4.0-hydro-2D:

- Built on jewel-2.4.0-simple
    - Similar use of temperature and velocity for scattering centers
    - Similarly separable from main jewel code.
- Can include *any* (2+1)D background with T and (u_x, u_y) information
- Jet production location from N_{coll} information
- Subtleties with density determination
- Runs on IGFAE cluster







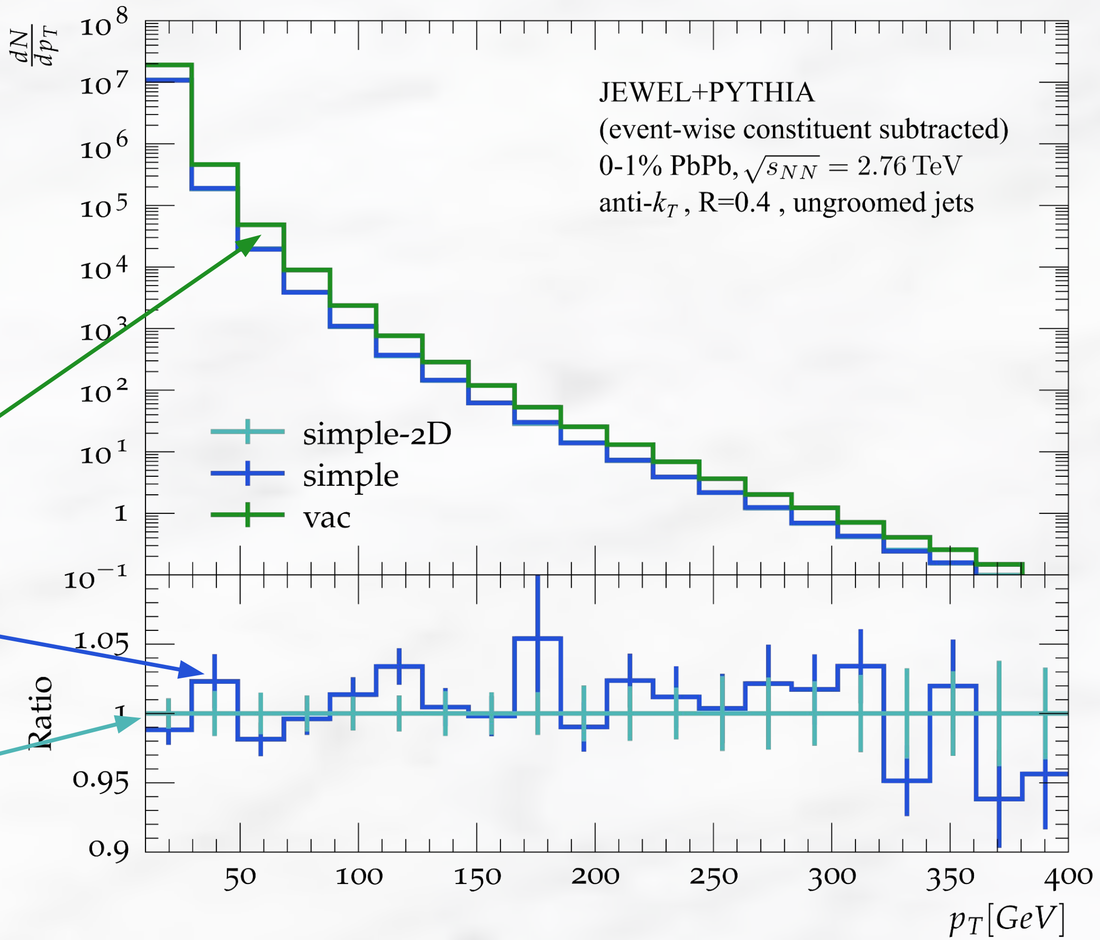
Validation of the hydro interface

- Ships with jewel-2.4.0:
  - Vacuum
  - Simple
- NEW! (2+1)D hydro interface

No medium

JEWEL's built-in "simple" medium

2D medium using JEWEL's model



Physics

The small system “problem”

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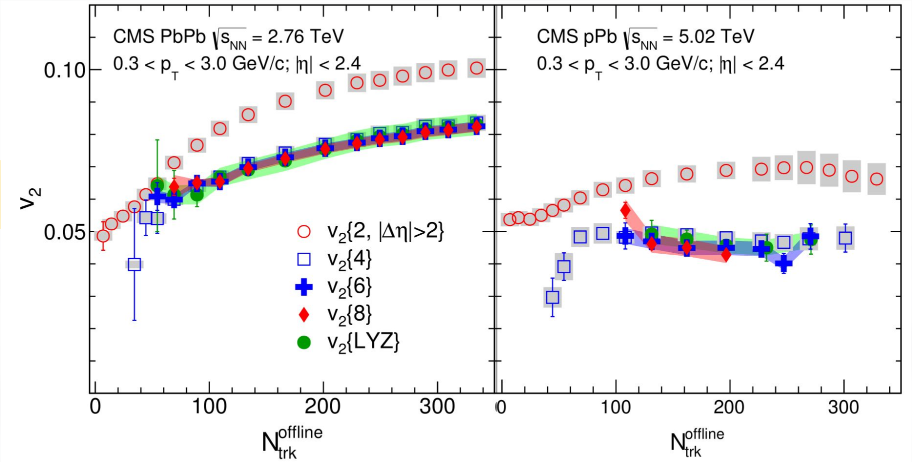
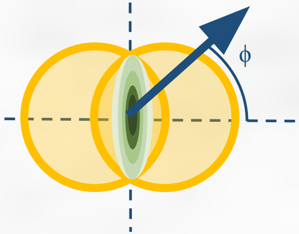
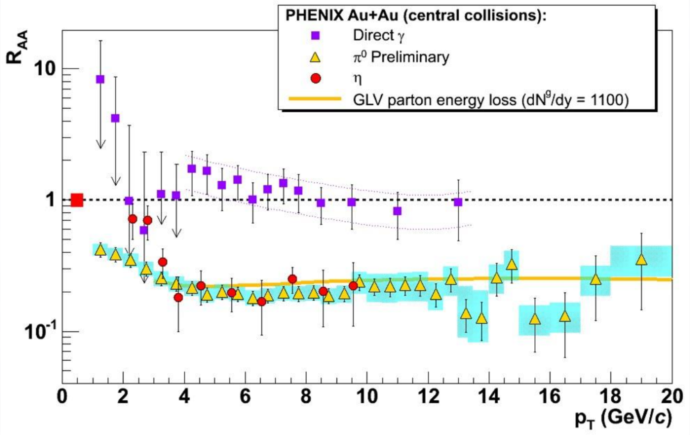
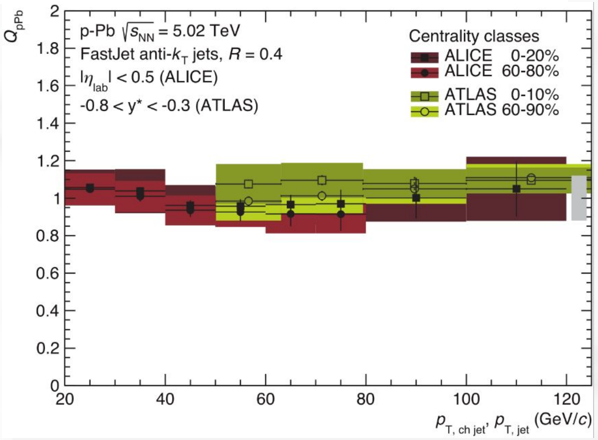




$$\frac{d^3N}{d\phi dp_T dy} \propto \left[1 + 2v_1\cos(\phi) + 2v_2\cos(2\phi) + \ldots\right]$$

$$R_{AA}(p_T) = \frac{1}{\langle T_{AA}\rangle}\frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$





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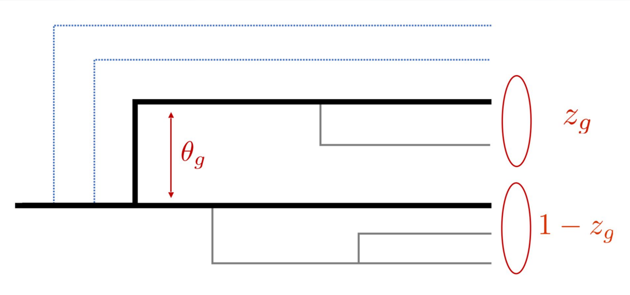
Not clear if this is because

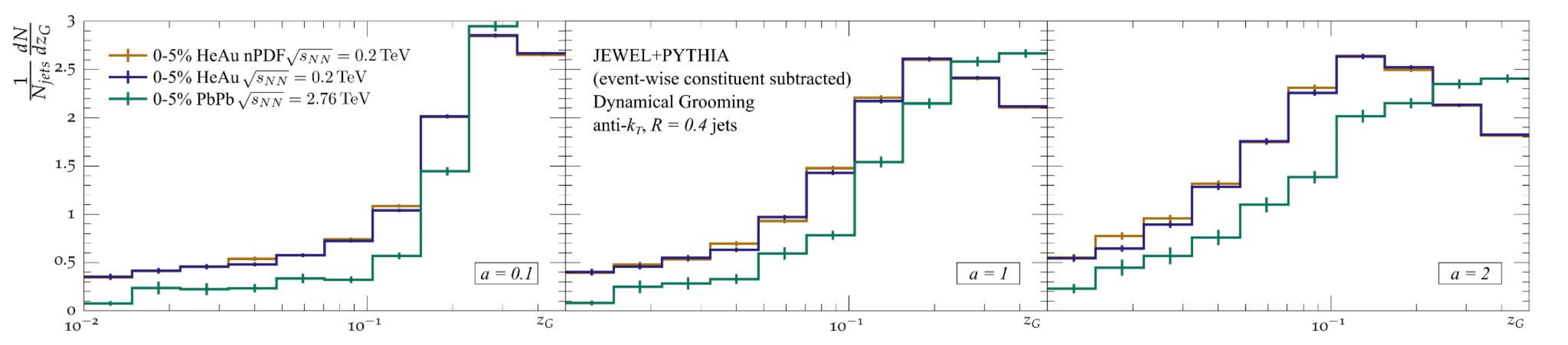
1. the modification is too small to be measured (the jets are not modified at such short scales)
2. There is no deconfined state
3. Observables like RAA are inappropriate.

Jet substructure example



$$\kappa^{(a)} = \frac{1}{p_T} \max_{i \in \text{C/A seq.}} \left[z_i (1 - z_i)\, p_{T,i} \left(\frac{\theta_i}{R} \right)^a \right]$$

Dynamical Grooming (1911.00375)



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DEI

Blinded applications
Track DEI stats

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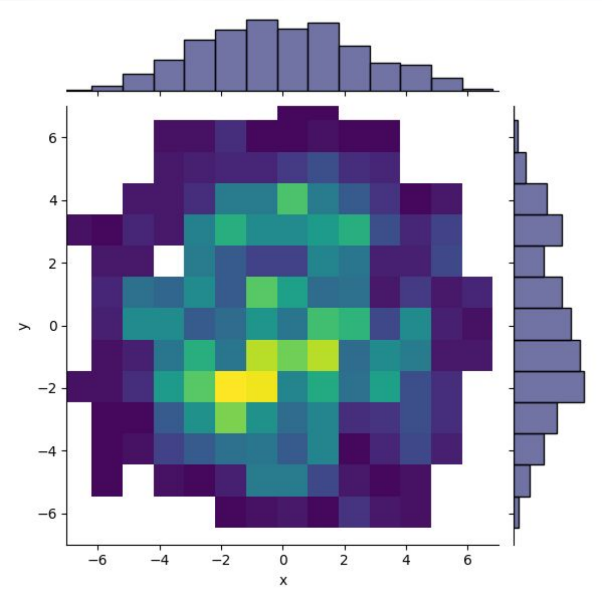
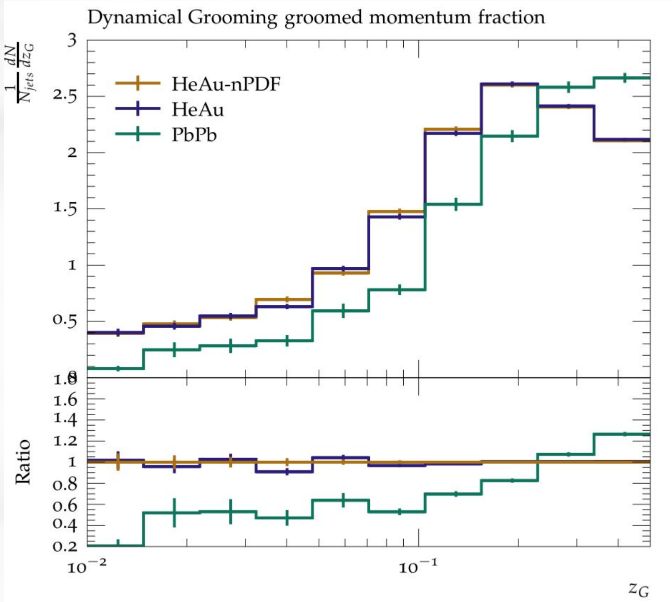
Summary

- Presented hydro hack for JEWEL
- Argued its usefulness for studying small systems
- Argued its usefulness for other YoctoLHC projects
- Presented groomed jet mass and momentum sharing fraction





Backups

What (other) physics can we do with this?

- **Initial goal:** Explore new observables in a variety of collision geometries.
- Explore *any* medium effect on jets:
  - Time-delays
  - Flowing medium
- Realistic R_{AA} vs v_2 in AA (more work)

What does the modification of high-p_T partons look like in small systems?

What role do initial state fluctuations play on jet properties?

How do other environments affect jets?

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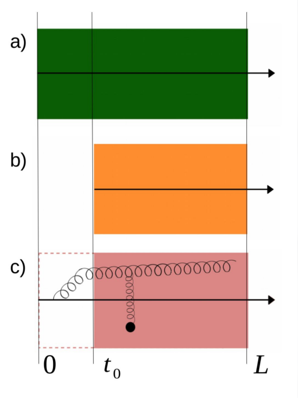

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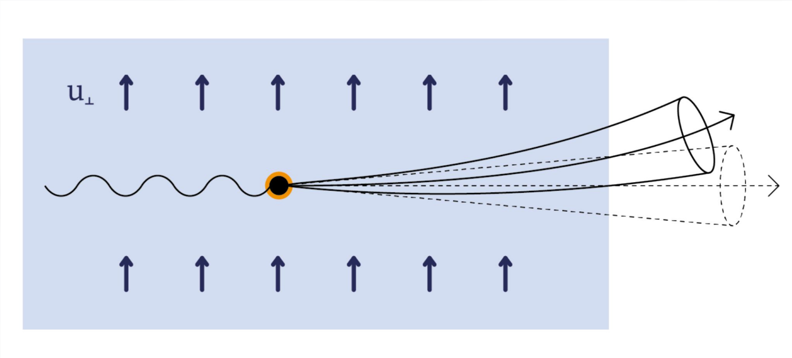

Why R_{AA} is the worst (in small systems)

- Reliance on a reference system
- Steeply falling production spectrum
  - Sensitive only to large ΔE
  - Sensitive to PDFs and nPDFs
- Sensitive to initial condition
  - Geometry
  - Momentum anisotropy
- Sensitive to jet fragmentation
- Supposed to quantify ΔE, but
  - $\Delta E \leftarrow L \leftarrow N_{coll}$: uncontrolled
  - $\Delta E = \Delta E(T)$: T is uncontrolled

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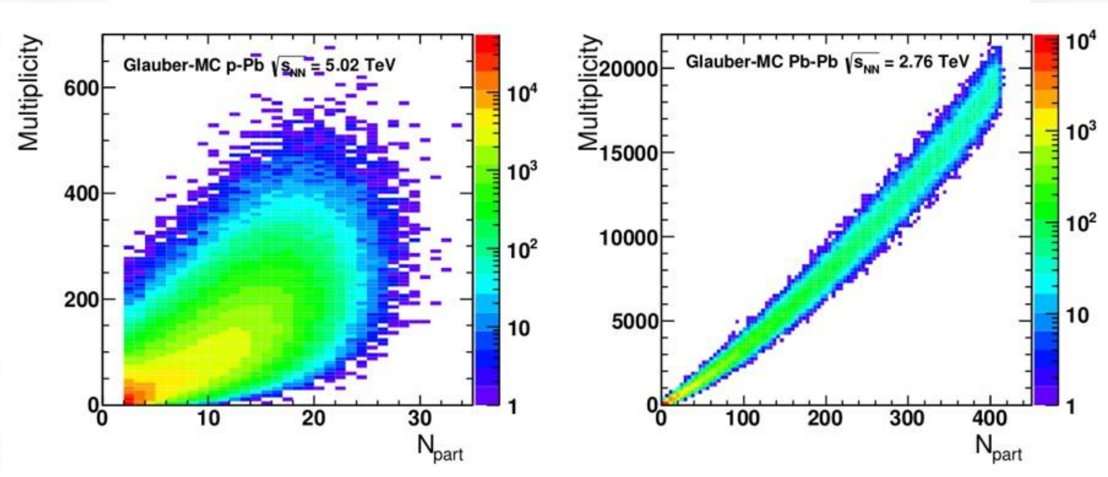
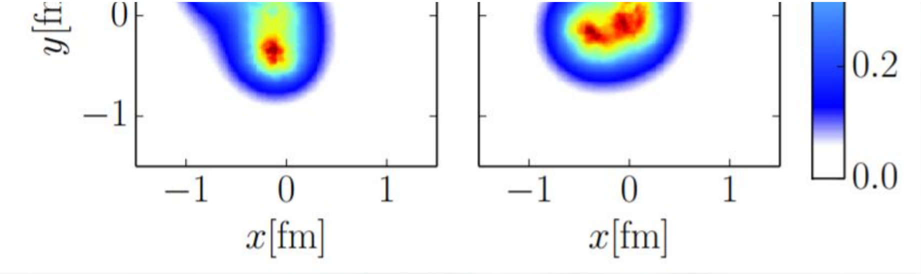
1607.01711

1412.6828





$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$

Why it's not just "The path length is too short"

- Path-length dependence is model dependent even for large systems.
- *All* the models rely on large L assumptions.
- Can try to relax those assumptions, it does not go well
- The very nature of the medium might well be different

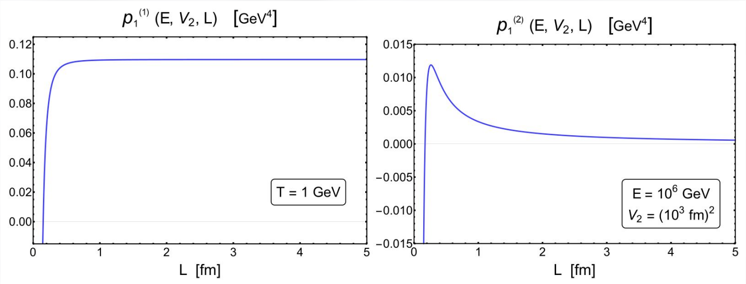
$$\Delta E^{(1)}_{ind} = \frac{C_R\alpha_s L E}{\pi\lambda_g}\int dx \int \frac{d^2\mathbf{q}_1}{\pi}\frac{\mu^2}{(\mu^2+\mathbf{q}_1^2)^2}\frac{d^2\mathbf{k}}{\pi} \times \int d\Delta z\,\bar{\rho}(\Delta z)\Bigg[-\frac{2(1-\cos\{(\omega_1+\tilde{\omega}_m)\Delta z\})}{(\mathbf{k}-\mathbf{q}_1)^2+M^2x^2+m_g^2} \times \left(\frac{(\mathbf{k}-\mathbf{q}_1)\cdot\mathbf{k}}{\mathbf{k}^2+m_g^2+x^2M^2}-\frac{(\mathbf{k}-\mathbf{q}_1)^2}{(\mathbf{k}-\mathbf{q}_1)^2+M^2x^2+m_g^2}\right) + \frac{1}{2}e^{-\mu_1\Delta z}\Bigg\{\left(\frac{\mathbf{k}}{\mathbf{k}^2+m_g^2+x^2M^2}\right)^2 \times \left(1-\frac{2C_R}{C_A}\right)\left(1-\cos\{(\omega_0-\tilde{\omega}_m)\Delta z\}\right) + \frac{\mathbf{k}\cdot(\mathbf{k}-\mathbf{q}_1)}{(\mathbf{k}^2+m_g^2+x^2M^2)((\mathbf{k}-\mathbf{q}_1)^2+M^2x^2+m_g^2)} \times \left(\cos\{(\omega_0-\tilde{\omega}_m)\Delta z\}-\cos\{(\omega_0-\omega_1)\Delta z\}\right)\Bigg\}\Bigg]$$

DGLV

$$\approx \quad \Delta E^{(1)}_{LO} = \frac{C_R\alpha_s}{4}\frac{L^2\mu^2}{\lambda_g}\log\frac{E}{\mu}$$

correction

$$\approx \quad \Delta E^{(1)}_{NLO} = \frac{E C_R\alpha}{\pi\lambda_g}\left(-\frac{2C_R}{C_A}\right)\frac{L}{2+L\mu}\times \left(\log\left\{\frac{2EL}{(2+L\mu)}\right\}-1\right)$$



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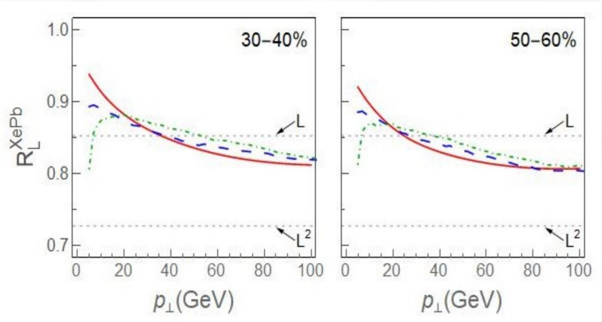

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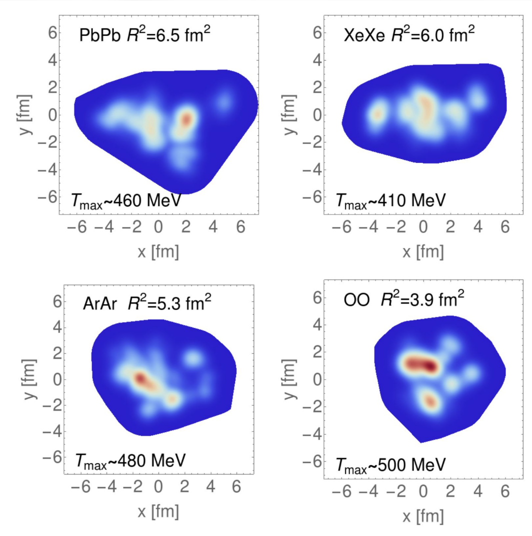
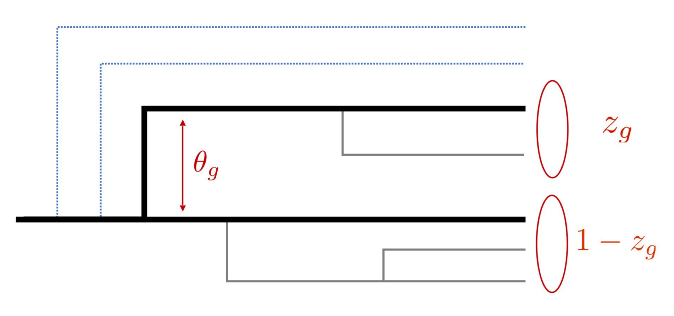


Grooming



Soft Drop (1402.2657)

$$\frac{\min(p_{T1}, p_{T2})}{p_{T1} + p_{T2}} > z_{\text{cut}} \left(\frac{\Delta R_{12}}{R_0} \right)^{\beta}$$

Dynamical Grooming (1911.00375)

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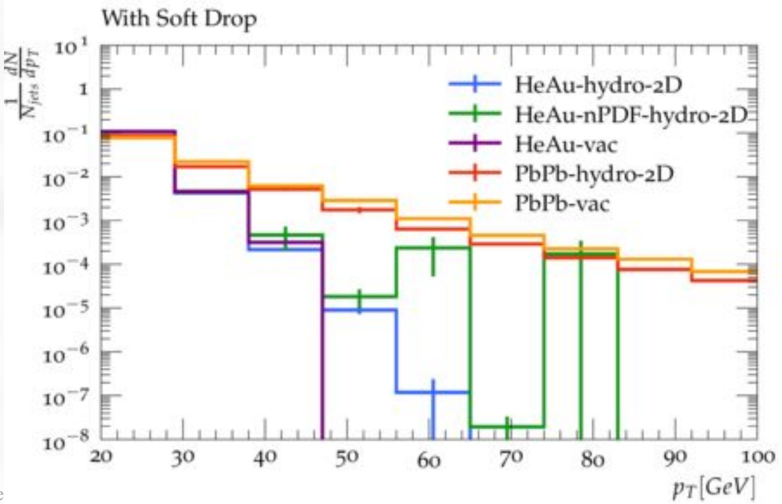

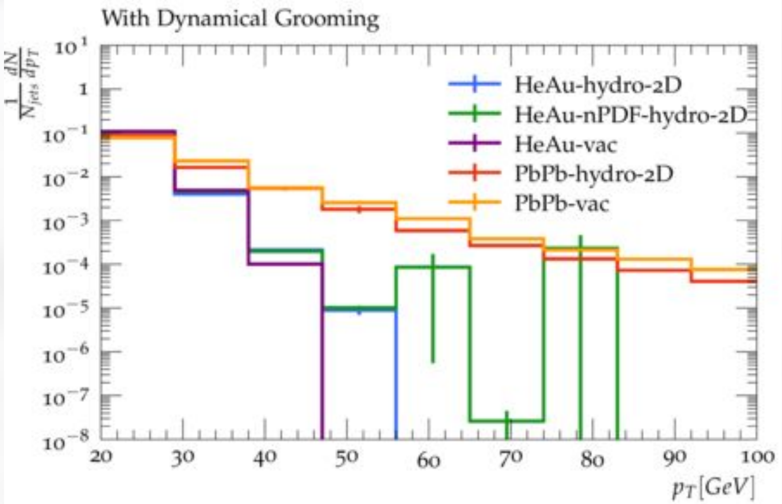

About event-selection

1305.0609

$N_{trk}^{offline}$ bin	PbPb data: $\langle$Centrality$\rangle$ $\pm$ RMS (%)	PbPb data: $\langle N_{trk}^{offline} \rangle$	PbPb data: $\langle N_{trk}^{corrected} \rangle$	pPb data: Fraction	pPb data: $\langle N_{trk}^{offline} \rangle$	pPb data: $\langle N_{trk}^{corrected} \rangle$
$[0,\infty)$				1.00	40	50±2
$[0,20)$	92±4	10	13±1	0.31	10	12±1
$[20,30)$	86±4	24	30±1	0.14	25	30±1
$[30,40)$	83±4	34	43±2	0.12	35	42±2
$[40,50)$	80±4	44	55±2	0.10	45	54±2
$[50,60)$	78±3	54	68±3	0.09	54	66±3
$[60,80)$	75±3	69	87±4	0.12	69	84±4
$[80,100)$	72±3	89	112±5	0.07	89	108±5
$[100,120)$	70±3	109	137±6	0.03	109	132±6
$[120,150)$	67±3	134	168±7	0.02	132	159±7
$[150,185)$	64±3	167	210±9	4×10^{-3}	162	195±9
$[185,220)$	62±2	202	253±11	5×10^{-4}	196	236±10
$[220,260)$	59±2	239	299±13	6×10^{-5}	232	280±12
$[260,300)$	57±2	279	350±15	3×10^{-6}	271	328±14
$[300,350)$	55±2	324	405±18	1×10^{-7}	311	374±16

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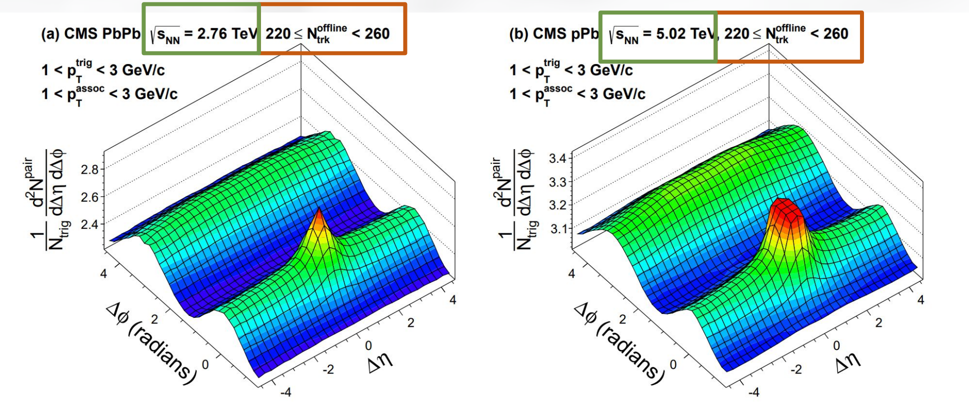

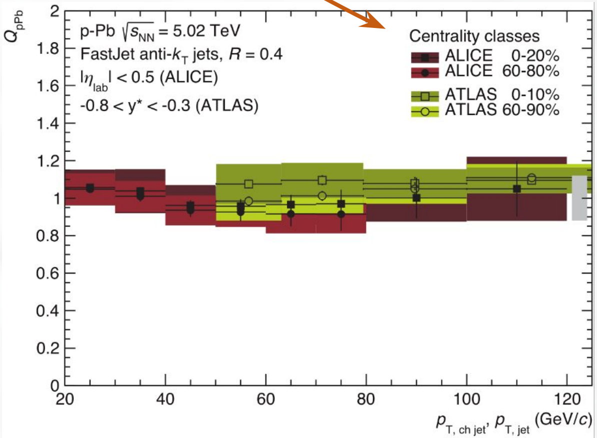

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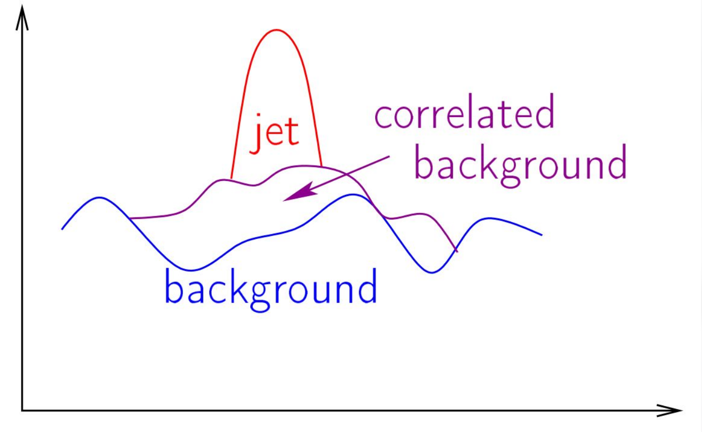
Recoils and Subtraction in JEWEL

- Track correlated background
- Subtraction RIVET plugin exists
- jewel-2.4.0 has several recoil and recoil tracking modes



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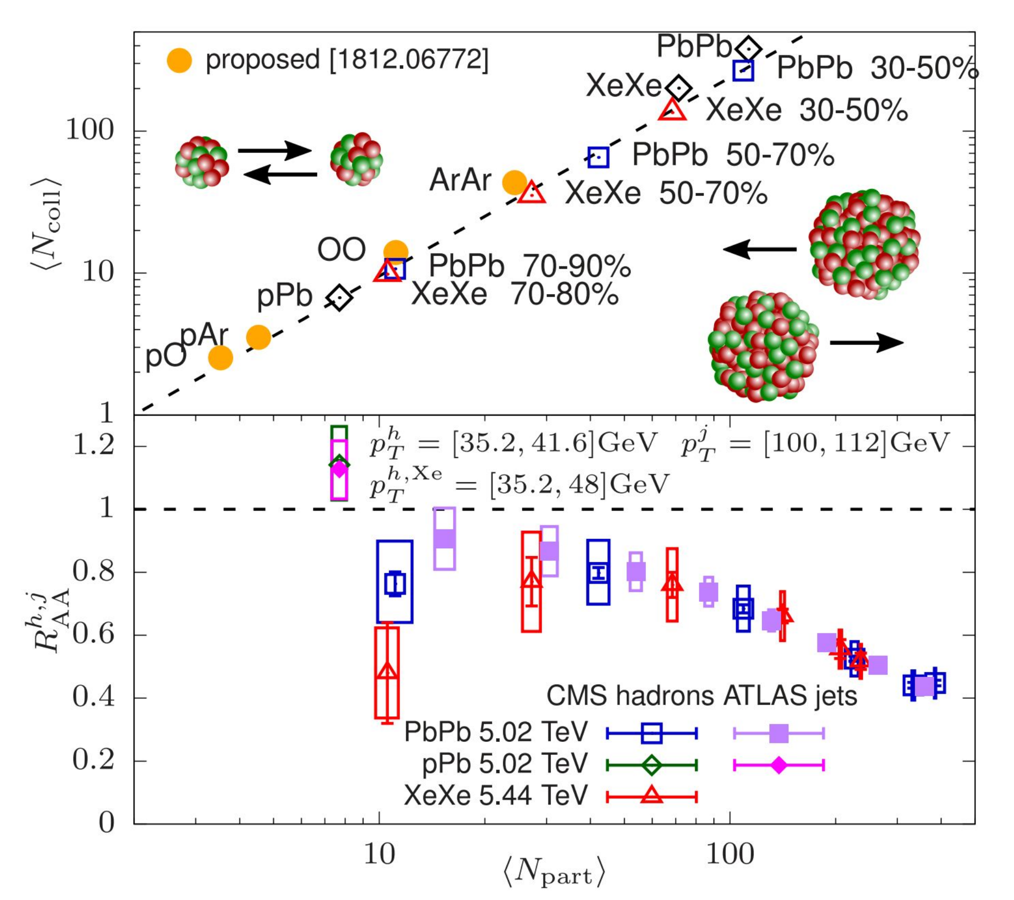

On multi-particle correlations

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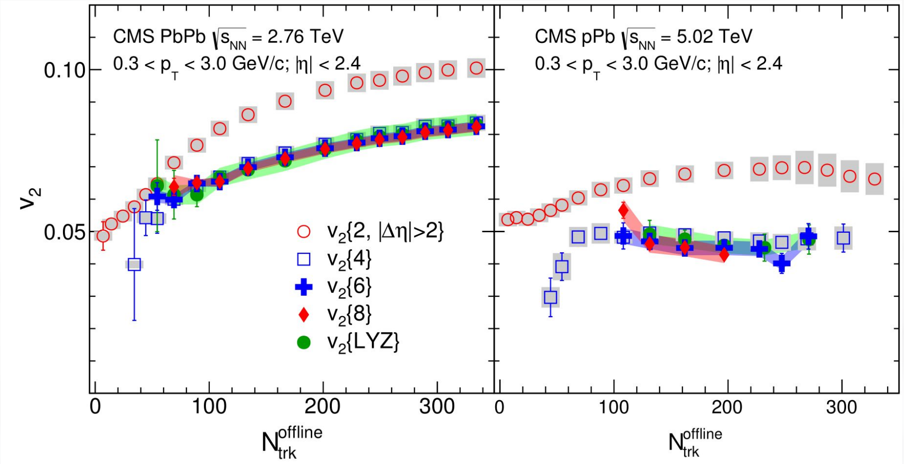

Two- and four-particle correlations may still be influenced by non-collective effects (eg. fragmentation of back-to-back jets), so need higher correlations.

The fact that 4, 6, 8, and LYZ lie on top of each other suggests that these other effects are not the cause.