JEWEL
On
Fluctuating Backgrounds

Isobel Kolbé
Govert Nijs, Wilke van der Schee

University of the Witwatersrand (Wits)
National Institute for Theoretical and Computational Sciences (NITheCS)
Mandelstam Institute for Theoretical Physics (MITP)
SA-CERN Collaboration

Jet quenching

In small systems

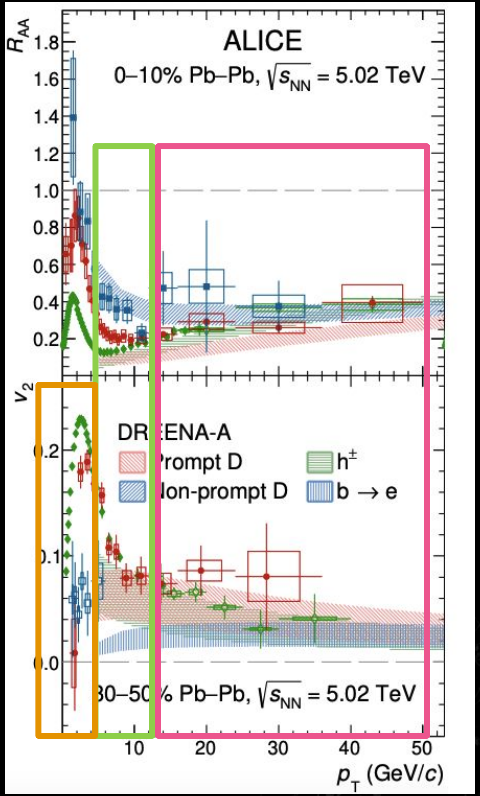
A phrasing of the problem:

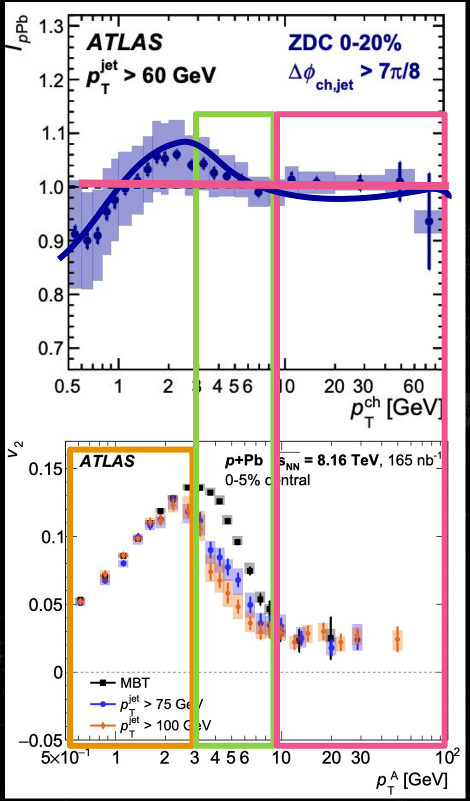
Self-consistent paradigm in AA:

Strong-coupling:
Multiple interactions

Kinetic transition:
Few interactions

Path length-dependent energy loss





Unclear interpretation in small systems

An E.loss description of v_2 and R_{AA} is non-trivial in AA

Sensitive to:
-starting time
-temperature profile
-hadronization

See backups

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

- Reliance on a reference system
- Steeply falling production spectrum
  - Survival bias
  - 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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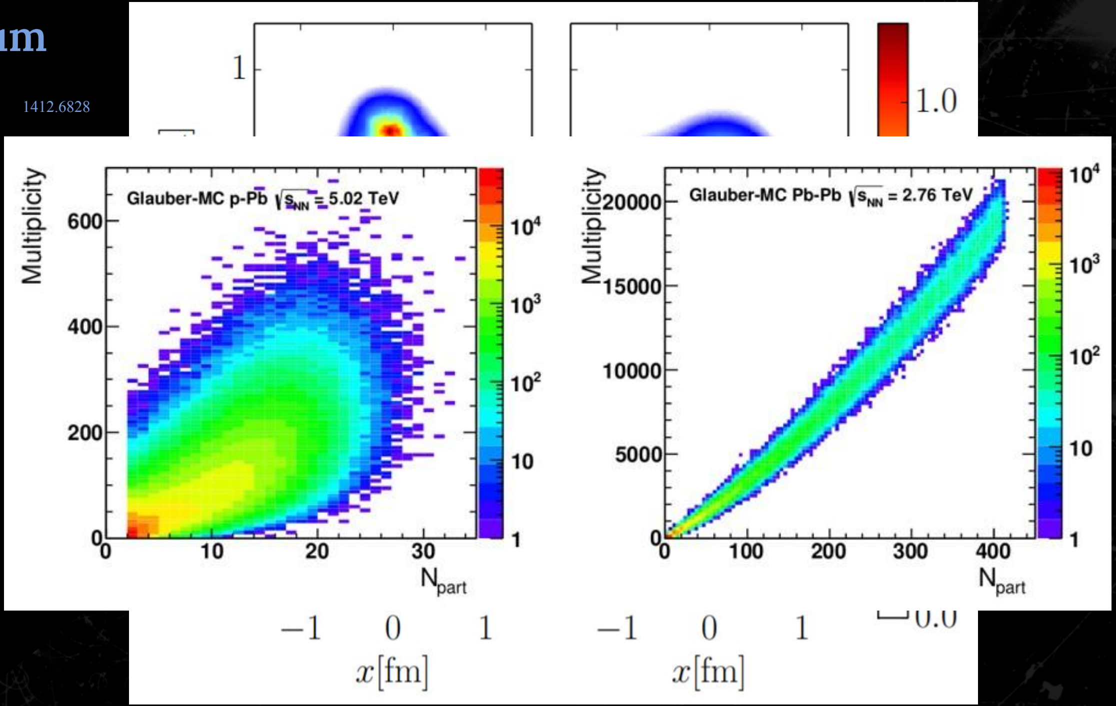
1412.6828



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

Light ions solve much of this problem

- Min. bias - still sensitive to fluctuations
- Explore path-length dependence
- Points to a need for more precision in heavy-ions

A tool to help

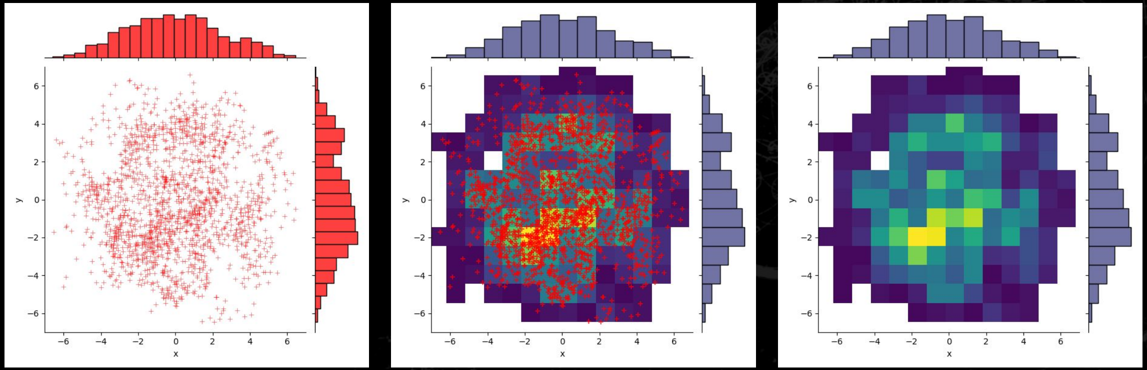
Hydro interface for JEWEL

```
gh repo clone isobelkolbe/jewel-2.4.0-2D
```

New jewel-2.4.0-hydro-2D:

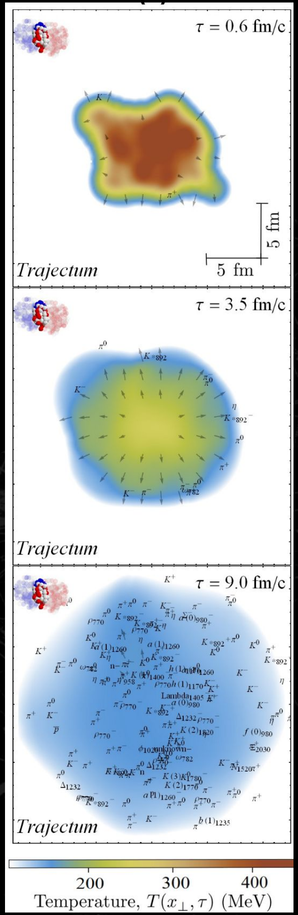
- Built on jewel-2.4.0-simple
  - Similar use of temperature and velocity for scattering centers
  - Similarly separable from main jewel code.
- Can include *any* (2+1)D background with T and (u_x, u_y) information
- Jet production location from N_{coll} information
- Subtleties with density determination,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

$$n_{eff} = \frac{n_0}{\cosh\eta - \sinh\eta\cos\theta}$$

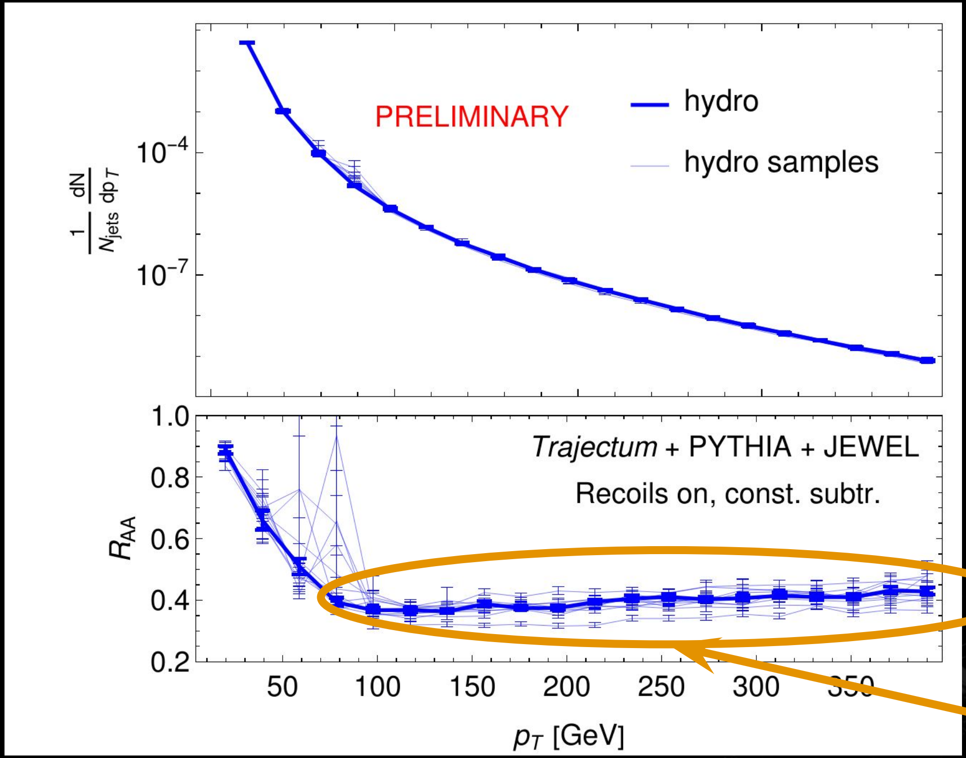


Trajectum

- Utrecht / MIT / CERN
- Contains:
  - Initial stage (Trento)
  - pre-eq.
  - Hydro
  - Freeze-out
  - Hadron phase
- Fast
- Bayesianized parameter lists (for PbPb)



Ultra-preliminary results - R_{AA}



Simple: Standard JEWEL medium.

Hydro: 1k JEWEL events each on 500 *Trajectum* profiles.

Hydro samples: 200k JEWEL events on each of 10 randomly chosen *Trajectum* profiles.

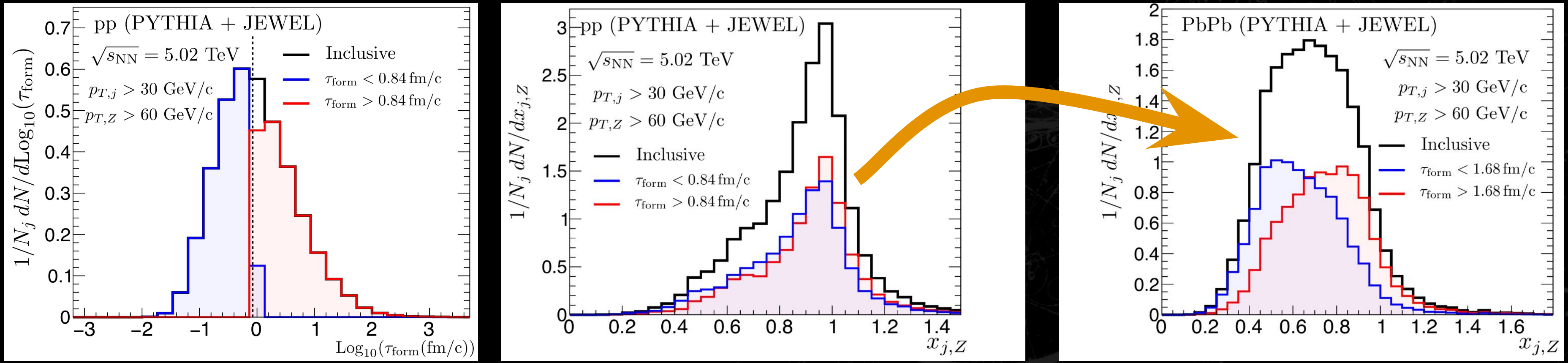
All normalized to JEWEL vacuum.

Really need ensemble

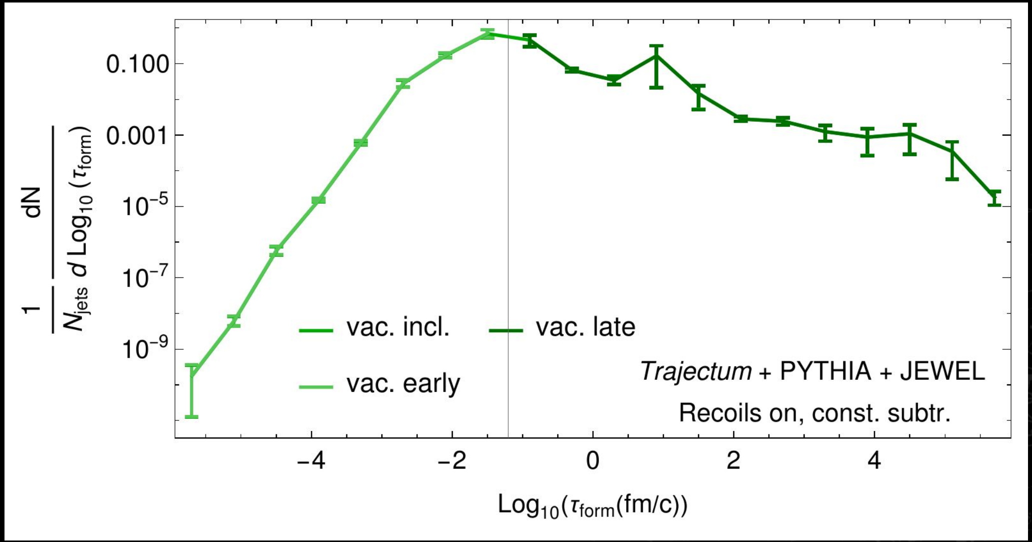
Can we do something else?

Need a space-time picture

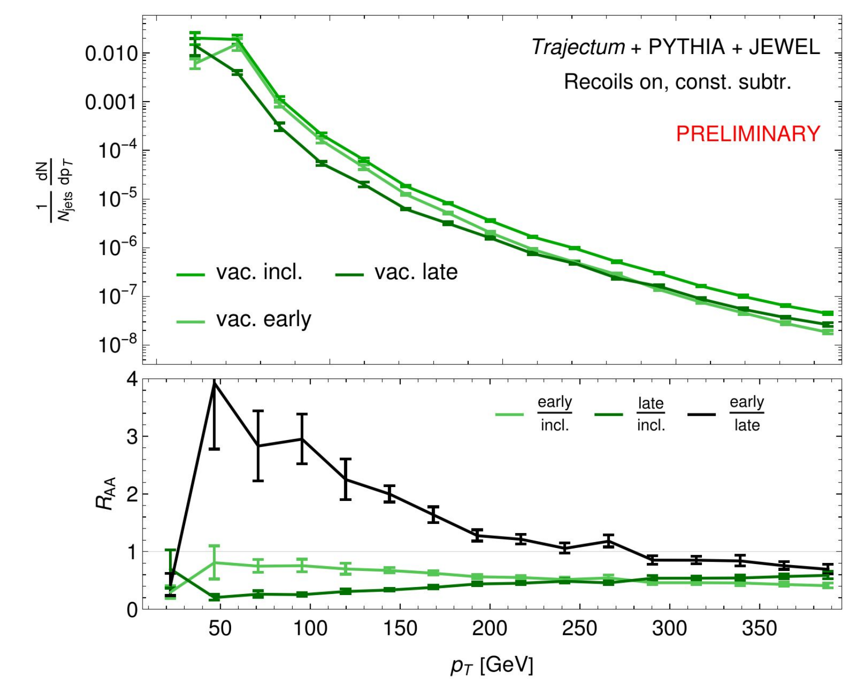
Time reclustering: $d_{ij} = \min\left(p_{T,i}^{2p}, p_{T,j}^{2p}\right)\frac{\Delta R_{ij}^2}{R^2} \xrightarrow{p=0.5} p_{T,i}\theta^2 \sim \frac{1}{\tau_{form}}$

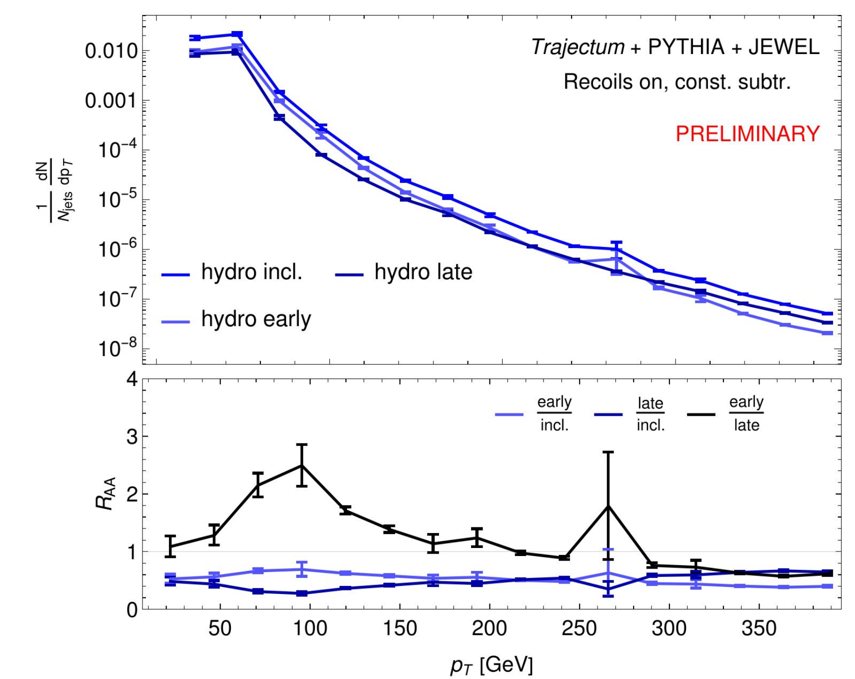


Ultra-preliminary results - time reclustering



Ultra-preliminary results - time reclustering - PbPb





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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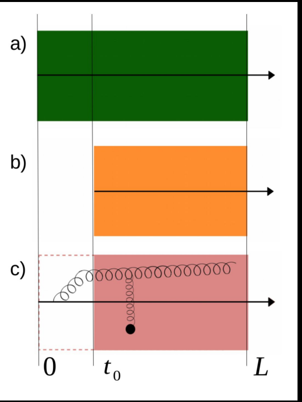

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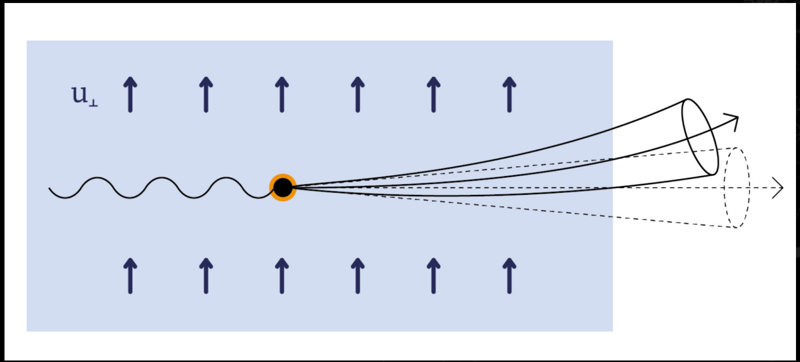
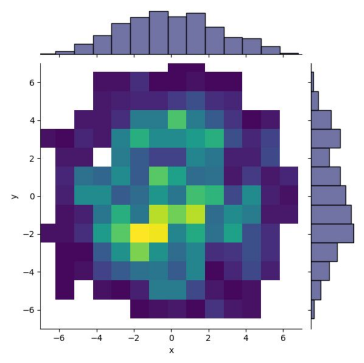
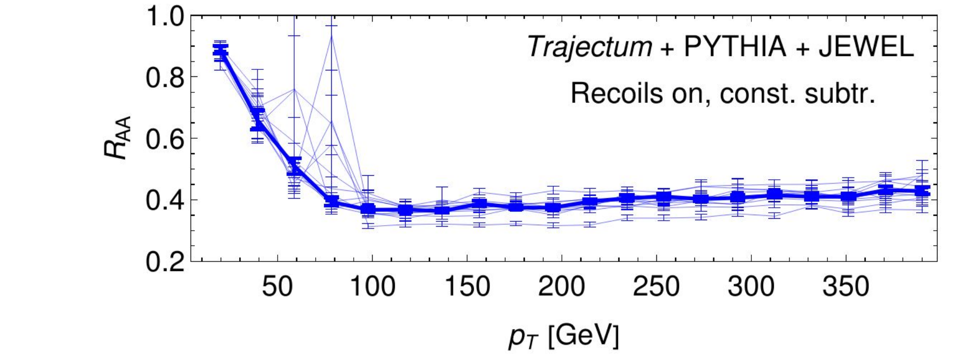
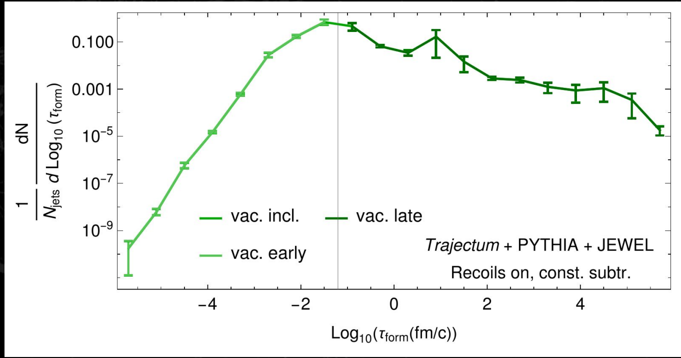


Summary & Conclusions



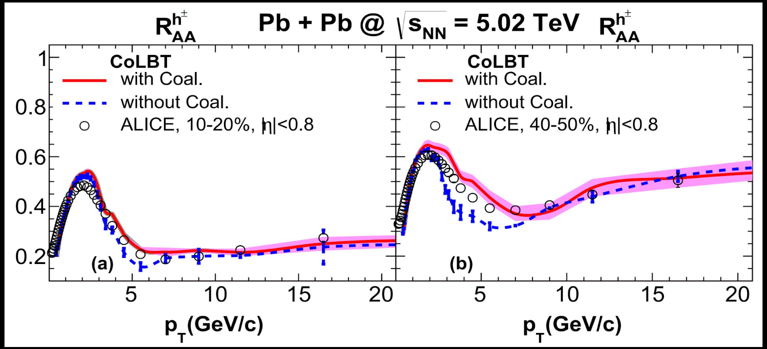
- Jet quenching in small systems is hard
- Light-ion runs are critical
- Hydro plugin for JEWEL - also NB for AA
- Also need better observables

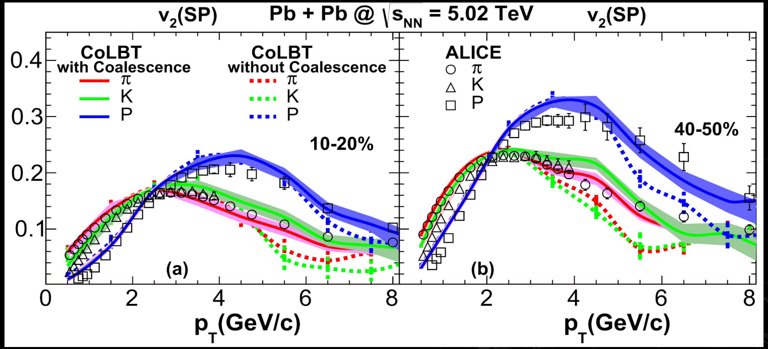




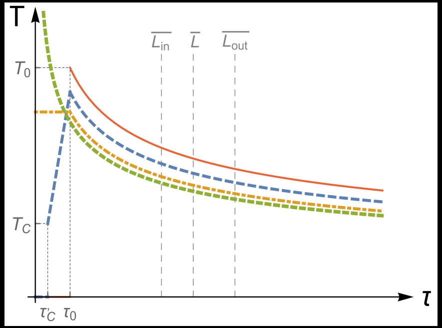
Backups

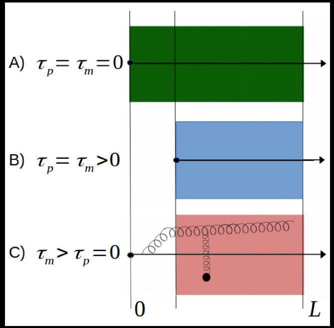
$R_{AA} \otimes v_2$ non-trivial even in AA



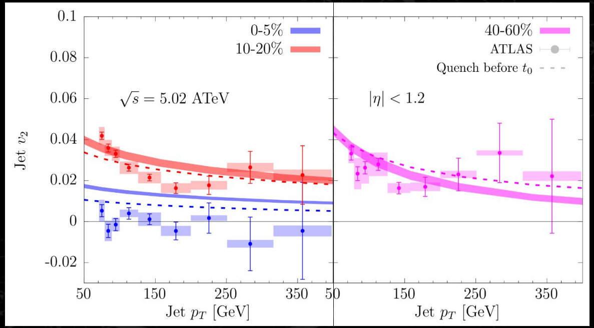


Sensitive to hadronization

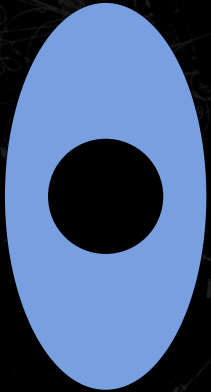




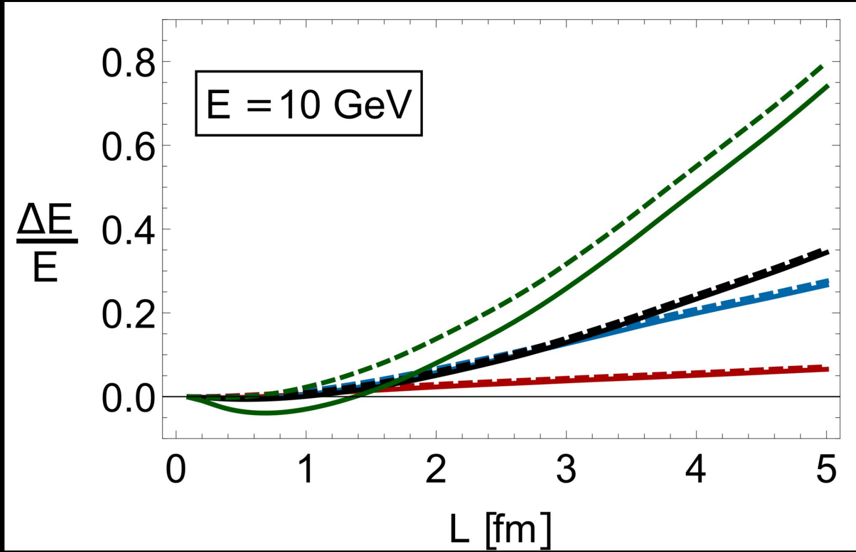
Sensitive to late-time temperature profile?

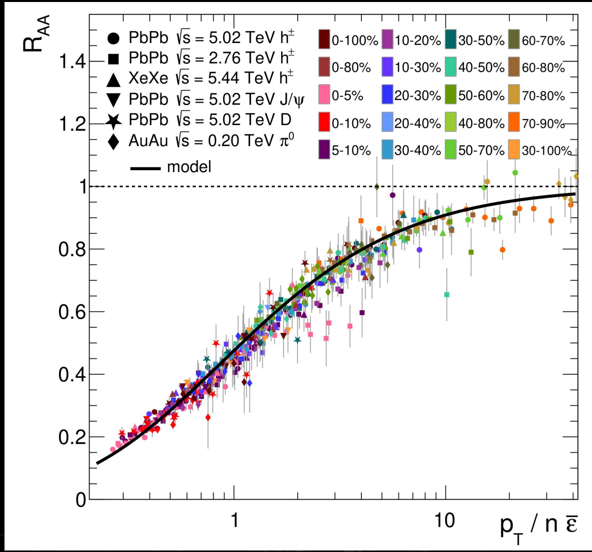


Sensitive to the nature of radiation in the early stages



What is the pathlength dependence?





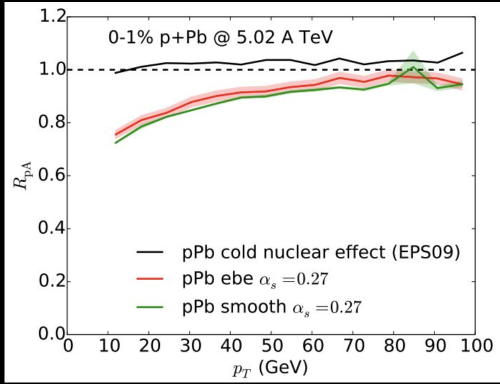
$$\langle \epsilon \rangle = L^{\beta}$$

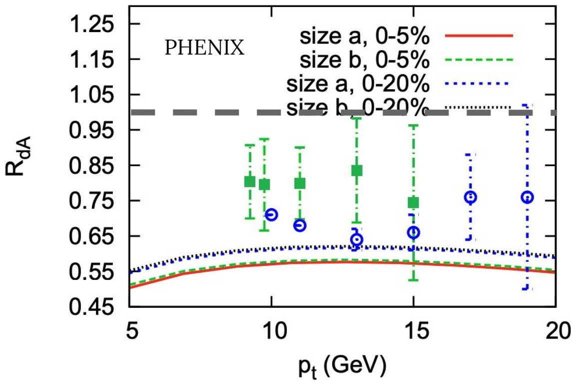
$$\beta = 1.02^{+0.09}_{-0.06}$$

Start by varying the pathlength

Caveat: Centrality determination is non-trivial (see backups)

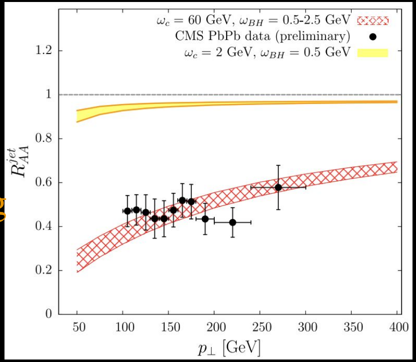
Energetic partons + MARTINI

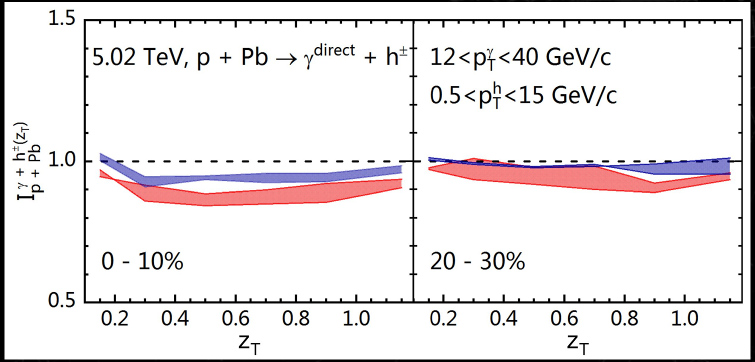




Enhanced energy loss near T_c

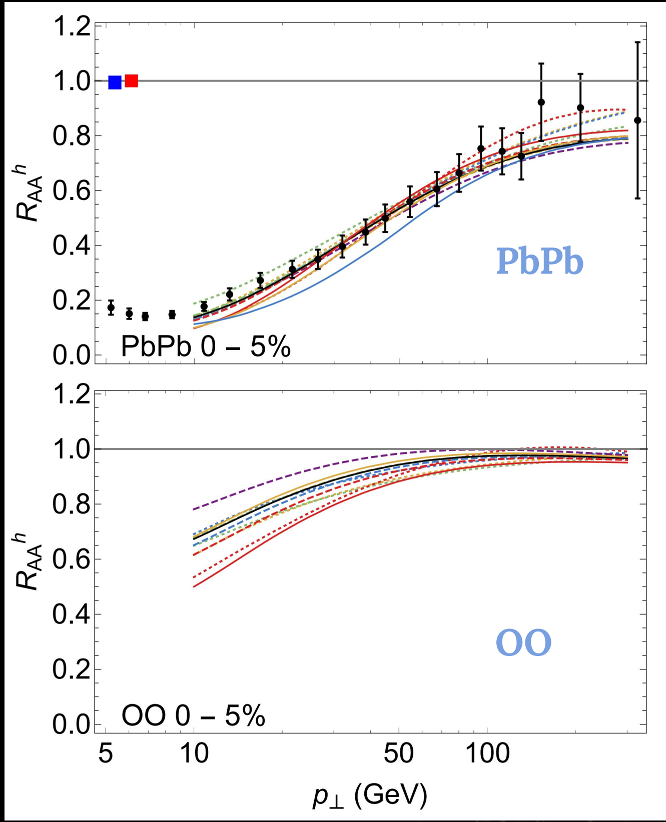
Estimate energy and length scales, multiple soft scattering

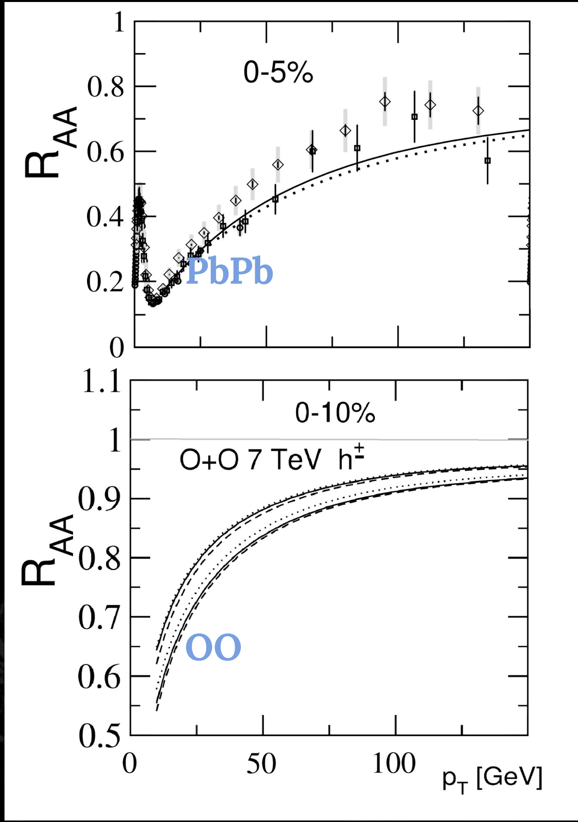




Higher-twist energy loss

Lighter ions

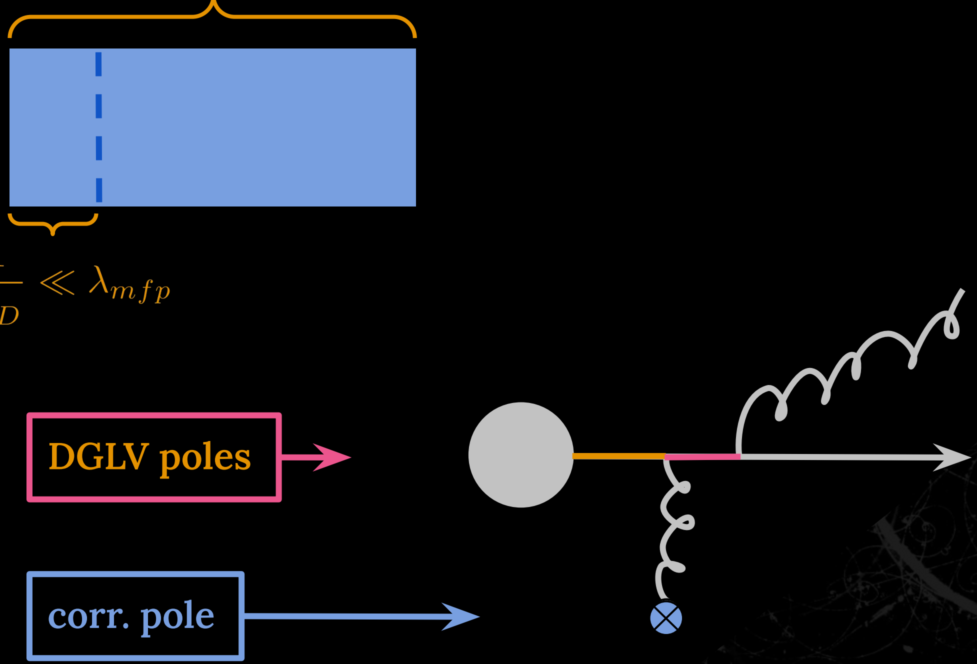


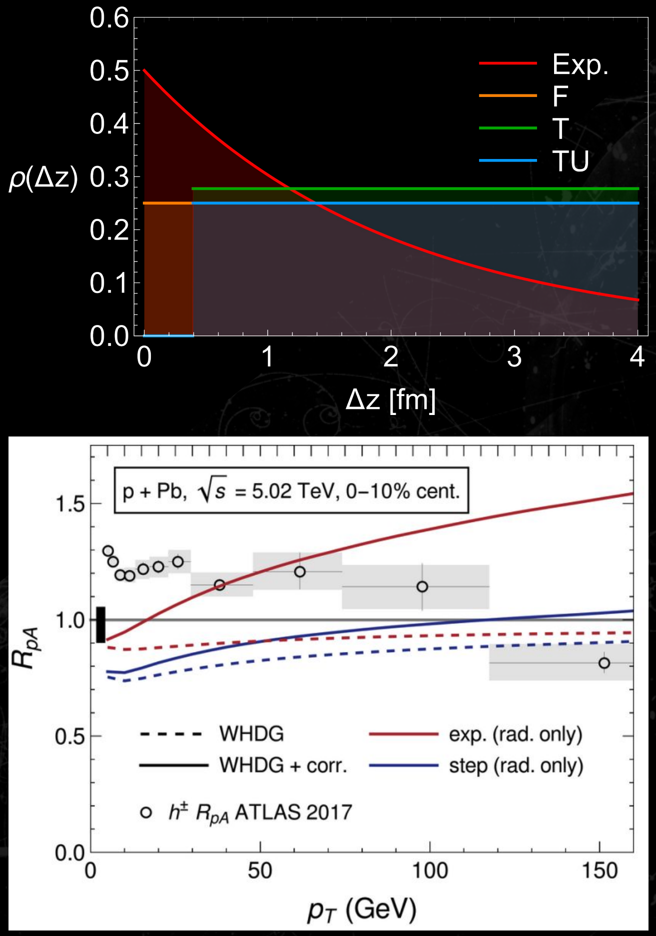


Relaxing large-L approximation

$$\frac{1}{\mu_D} \ll \Delta z \sim \lambda_{mfp} \ll L$$

$$\frac{1}{\mu_D} \ll \lambda_{mfp}$$

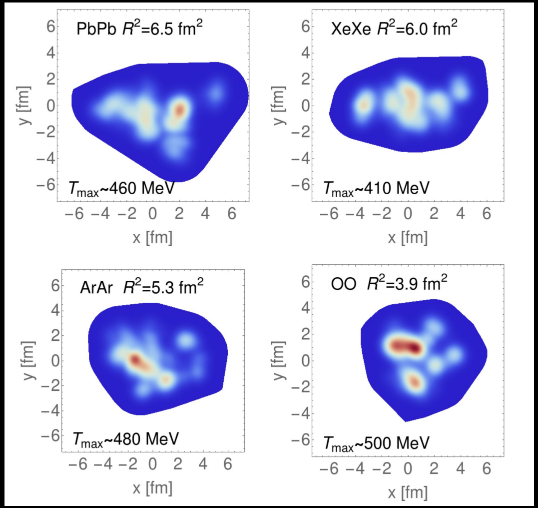




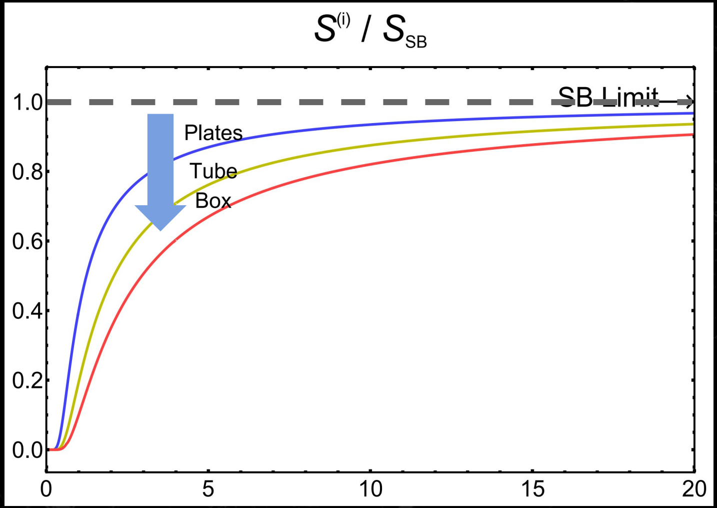
Small is not the only problem

$$\lambda_{mfp} \sim \frac{1}{\rho\sigma} \sim \frac{1}{g^2 T}$$

$$\mu_D \sim gT$$



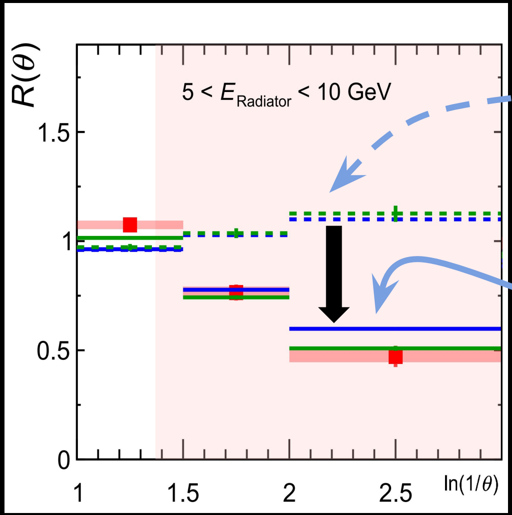
Smaller systems are hotter at the same multiplicity



Single, massless, non-interacting, scalar field in a finite box

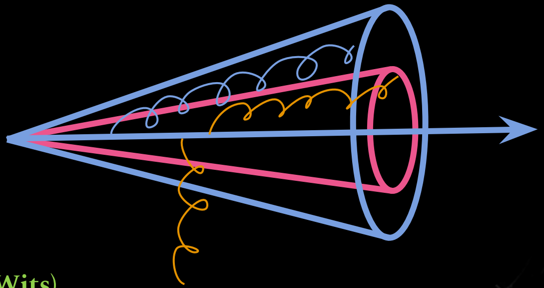
The dead cone

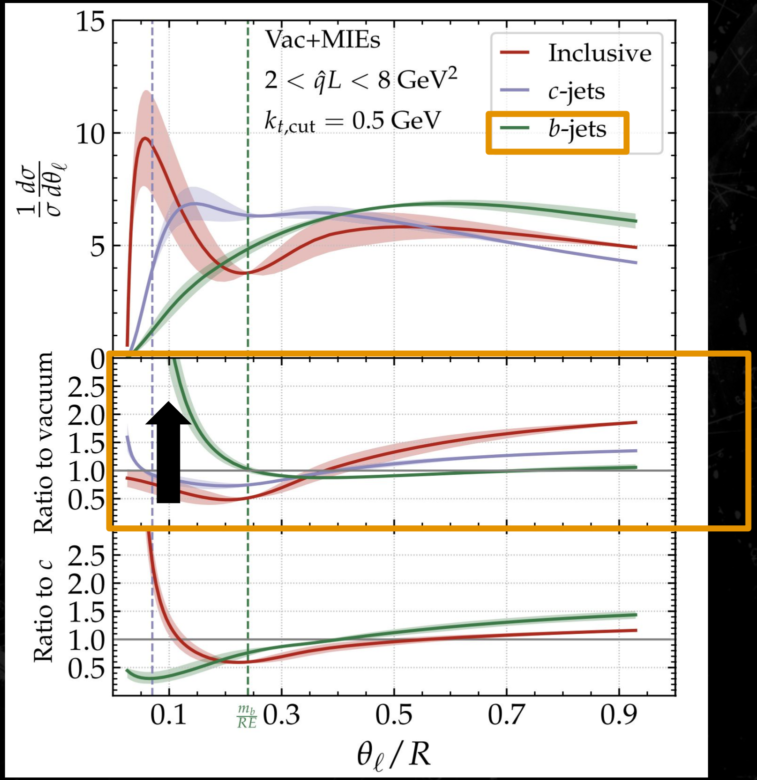
In-medium radiation fills the dead cone



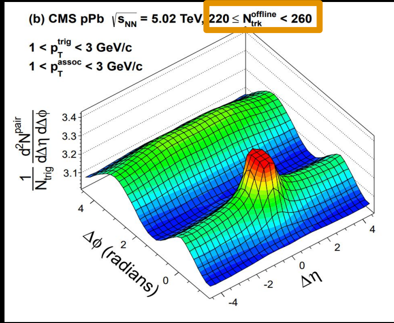
light -flavour

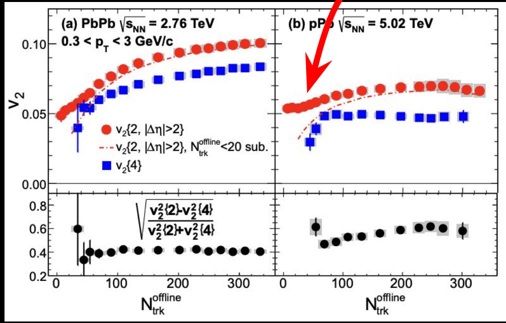
heavy -flavour



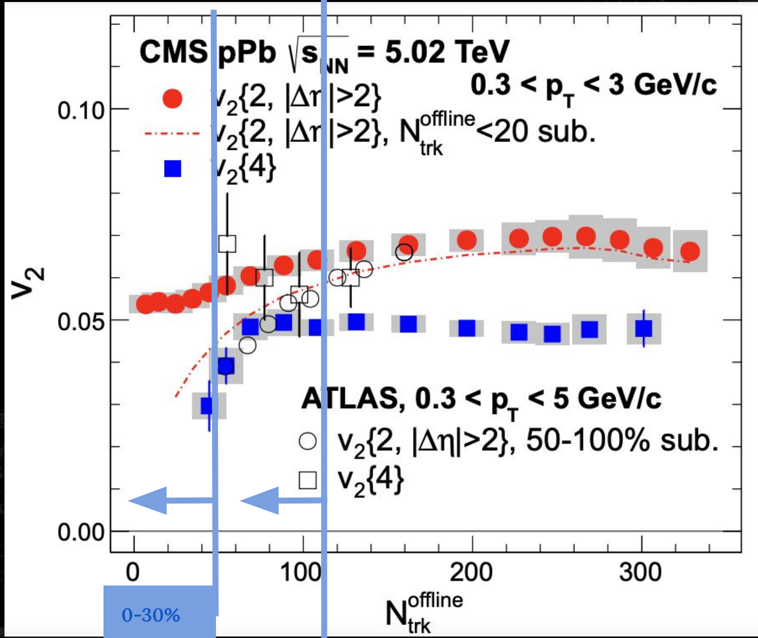


R_{AA}, v_2, and Centrality





Subtract low mult-data (match ATLAS)



$N_{trk}^{offline}$ bin	PbPb data: ⟨Centrality⟩ ± RMS (%)	PbPb data: ⟨$N_{trk}^{offline}$⟩	PbPb data: ⟨$N_{trk}^{corrected}$⟩	pPb data: Fraction	pPb data: ⟨$N_{trk}^{offline}$⟩	pPb data: ⟨$N_{trk}^{corrected}$⟩
[0, ∞)				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		0.12	35	42±2
[40, 50)	80±4	44		0.10	45	54±2
[50, 60)	78±3	54		0.09	54	66±3
[60, 80)	75±3	69	87±4	0.12	69	84±4
[80, 100)	72±3	89		0.07	89	108±5
[100, 120)	70±3	109		0.03	109	132±6
[120, 150)	67±3	134		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

0-50%

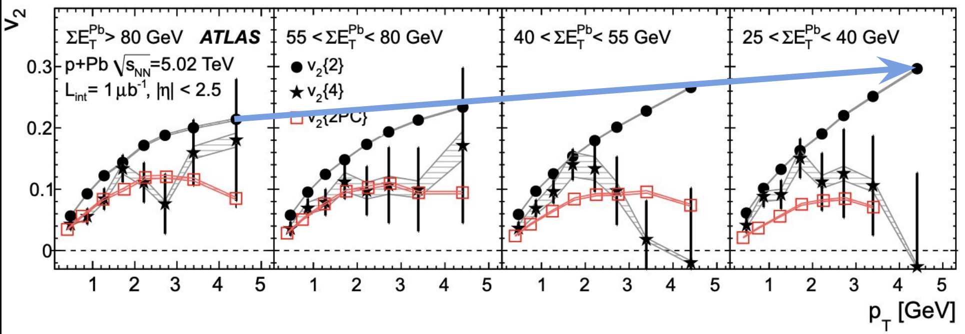
0-10%

0-30%

0-0.00631% bin

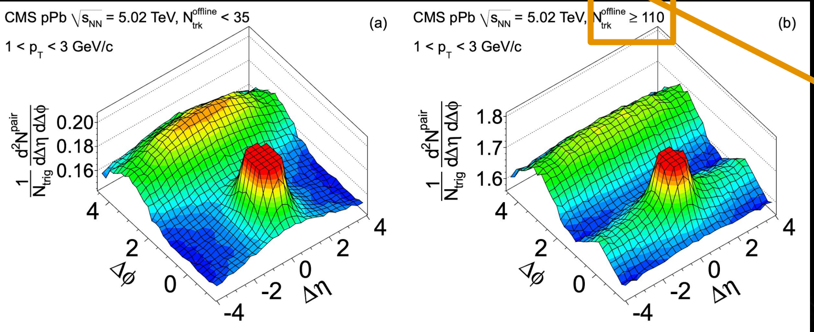
R_{AA}, v_2, and Centrality (Alternative - ATLAS)

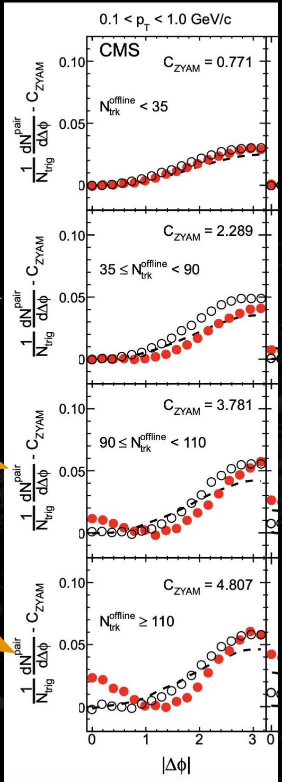
ΣE_T^{Pb} range [GeV]	$\langle \Sigma E_T^{Pb} \rangle$ [GeV]	range in fraction of events [%]	$\langle N_{ch}^{rec} \rangle$ (RMS)
> 80	93.7	0–1.9	134 (31)
55–80	64.8	1.9–9.1	102 (26)
40–55	46.7	9.1–20.0	80 (23)
25–40	31.9	20.0–39.3	60 (20)
10–25	16.9	39.3–70.4	37 (17)
< 10	4.9	70.4–100	16 (11)



R_{AA}, v_2 , and Centrality (Alternative - peripheral)

Multiplicity class ($N_{trk}^{offline}$)	Fraction (%)	$\langle N_{trk}^{offline} \rangle$	$\langle N_{trk}^{corrected} \rangle$
Minimum Bias	100.0	40.6	53.4±2.9
$N_{trk}^{offline} < 35$	50.4	17.1	23.5±1.3
$35 \leq N_{trk}^{offline} < 90$	41.9	56.3	75.6±4.1
$90 \leq N_{trk}^{offline} < 110$	4.6	98.2	114.3±6.2
$N_{trk}^{offline} \geq 110$	3.1	128.2	149.1±8.1





Correlated yield

Dead cone prediction in AA