Jets:

In-medium parton evolution in small systems

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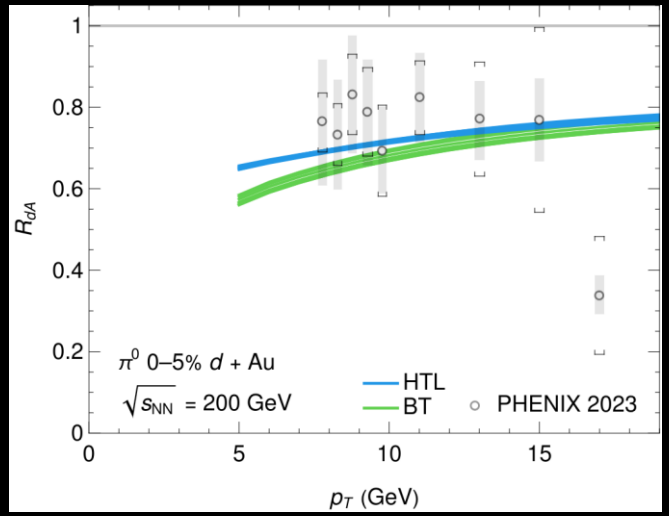
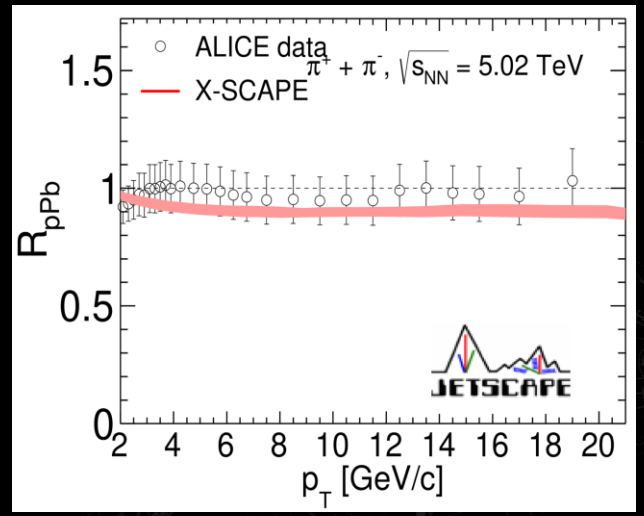
Thank you to Souvik Adhya, Carlota Andres, Jasmine Brewer, André Cordeiro, Dani Pablos, Wilke van der Schee, Ismael Soudi, Konrad Tywoniuk, Urs Wiedemann for advice and illuminating discussions.

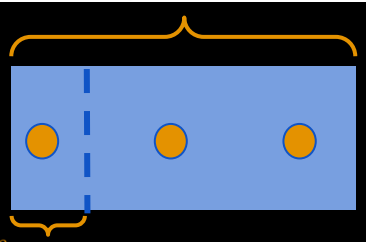
Recent calculations





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

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



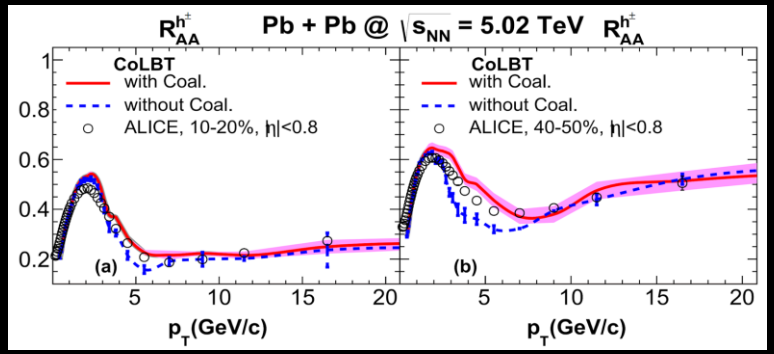
It's not the things you don't know that will hurt you..

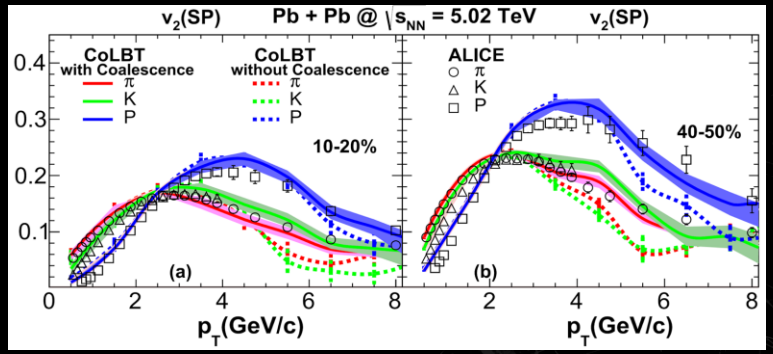
It's the things you're sure you know,

that just ain't so. – Mark Twain

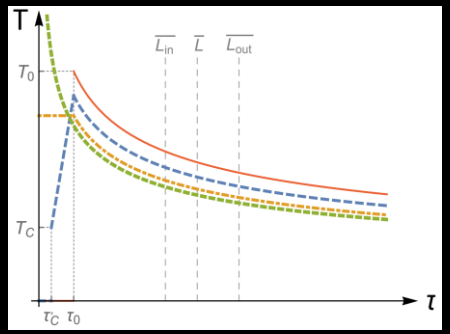
Andres *et.al.*: 2211.10161 | Zigic *et.al.*: 1908.11866 | Zhao *et.al.*: 2103.14657 | Mehtar-Tani et.al:2402.07869

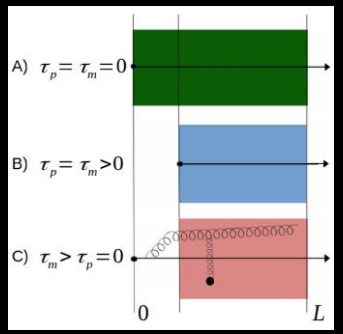
$R_{AA} \otimes v_2$ non-trivial even in AA



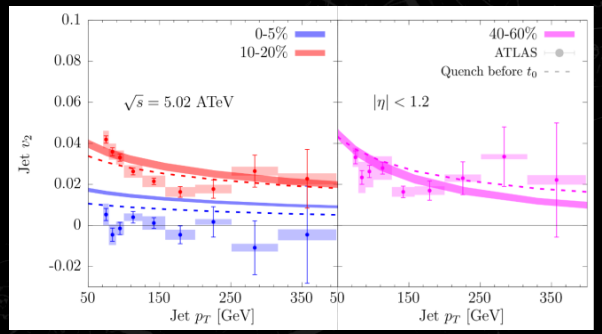


Sensitive to hadronization

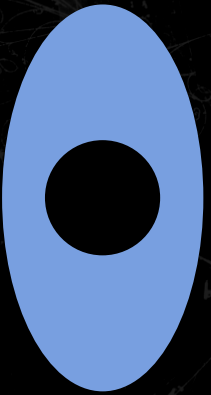




Sensitive to late-time temperature profile?

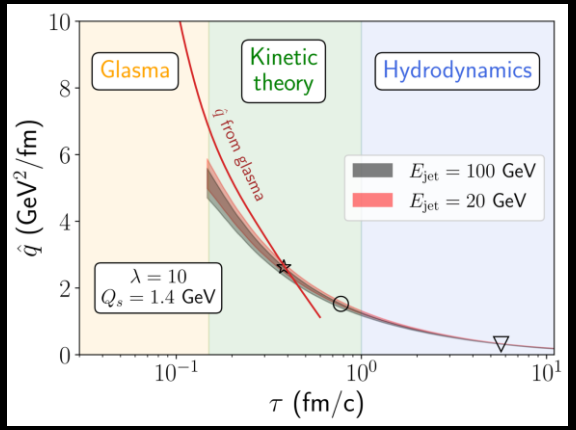


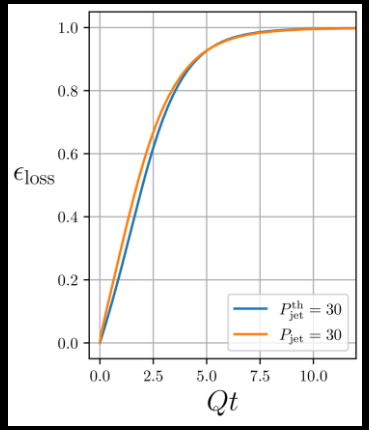
Sensitive to the nature of radiation in the early stages

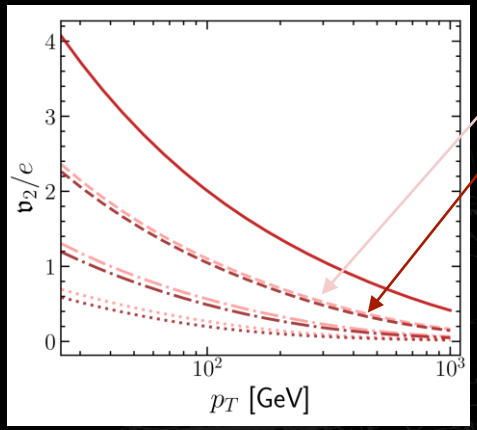


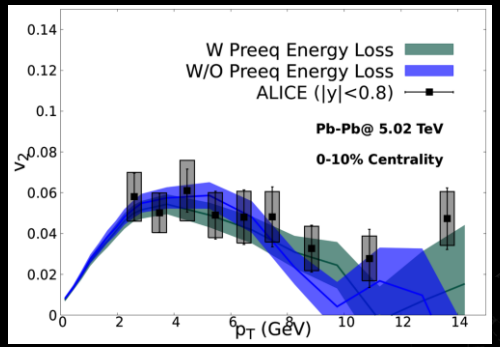
Dominated by the early stages

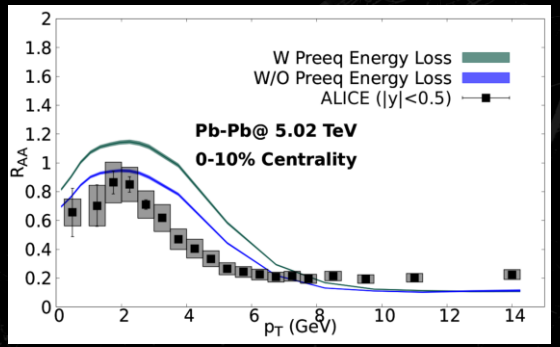
Large $\hat{q}$





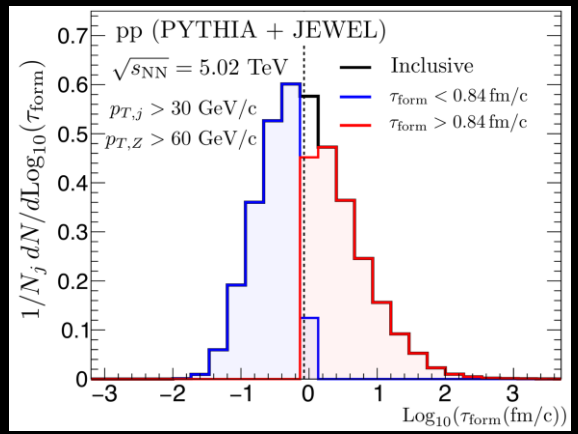


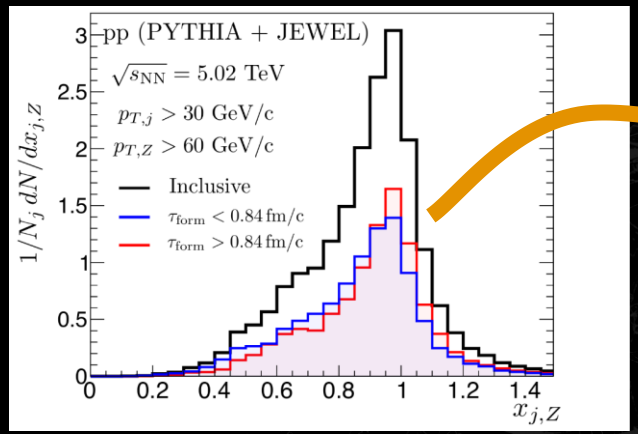


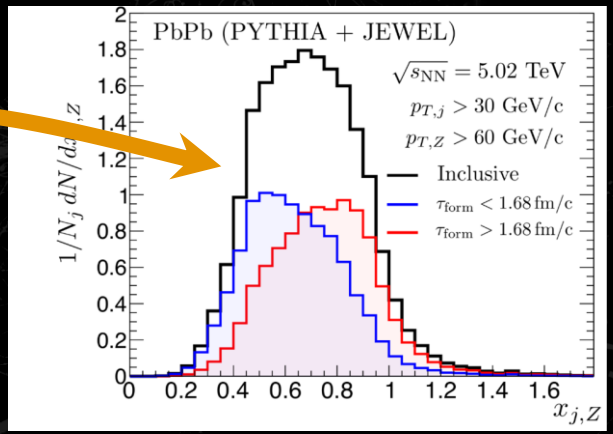


Need a space-time picture

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

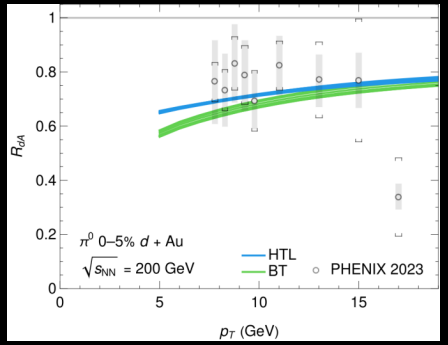


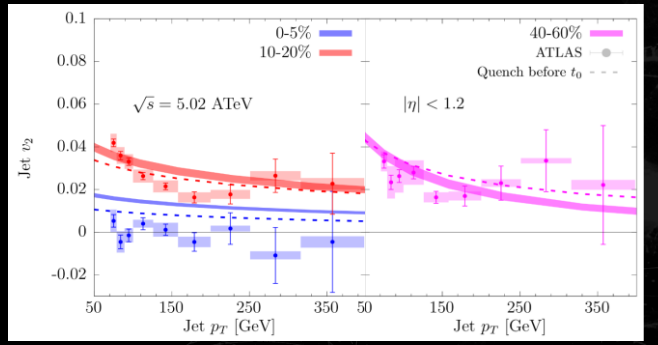


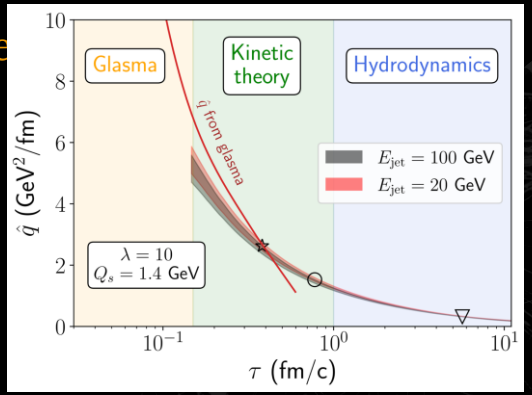


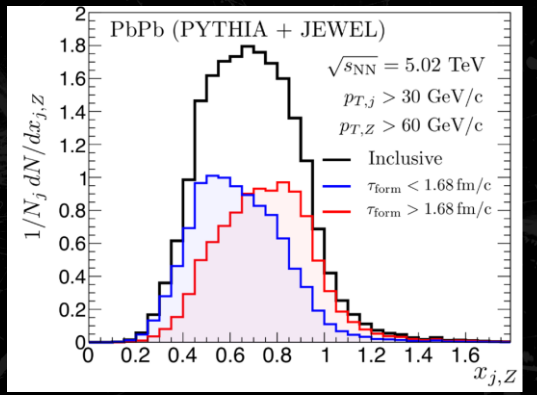
Conclusions

- Calculations exist
- Path-length dependence is not we known.
- Dominated by early stages
- Need a space-time picture









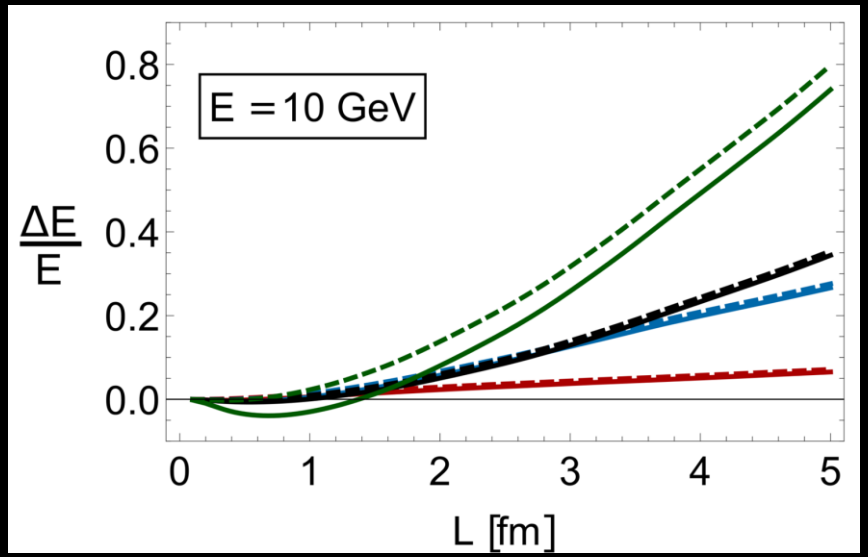
Thank You!

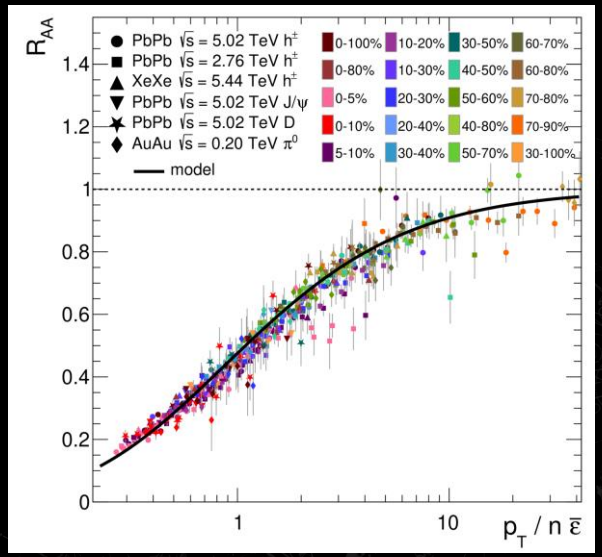
Backups

Kolbe: 1511.09313

Arleo *et.al.* 2212.01324

What is the pathlength dependence?





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

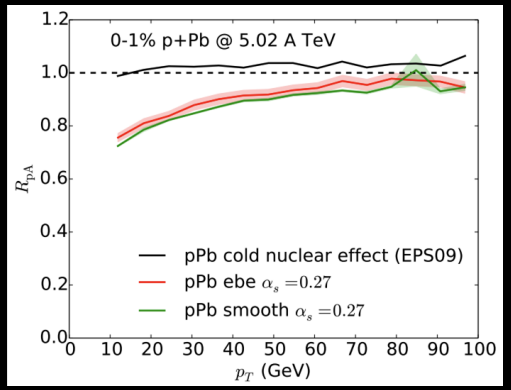
$$\beta = 1.02^{+0.09}_{-0.06}$$

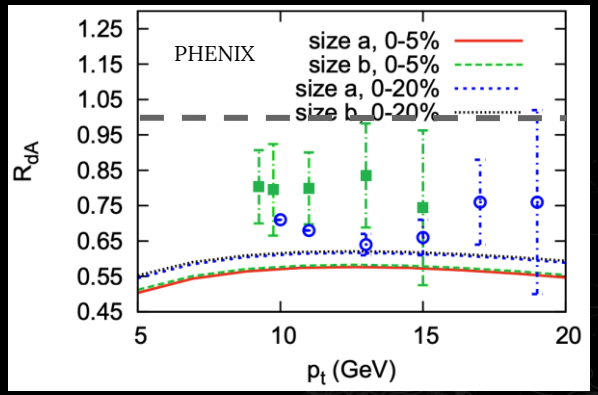
Xie *et.al.* 2003.02441 | Shen *et.al.* 1601.03070 | Zhang *et.al.* 1311.5463 | Tywoniuk 2014

Start by varying the pathlength

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

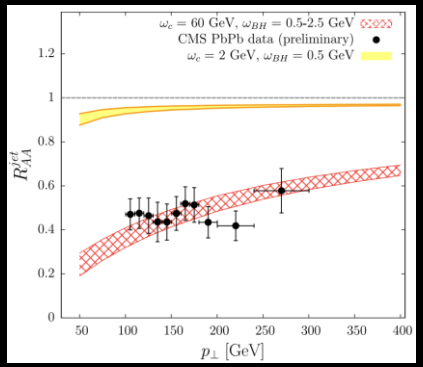
Energetic partons + MARTINI

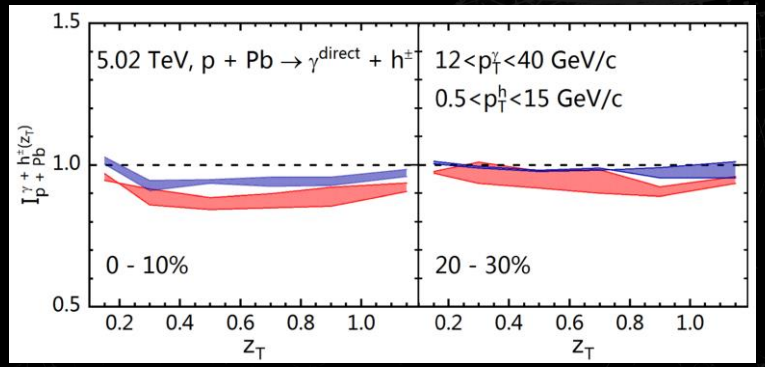




Enhanced energy loss near T_c

Estimate energy and length scales, multiple soft scattering



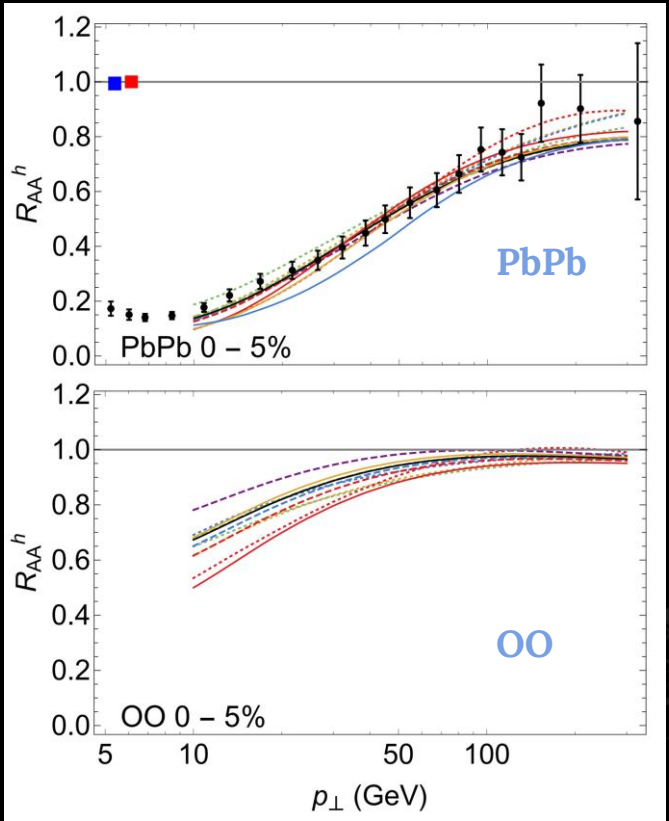


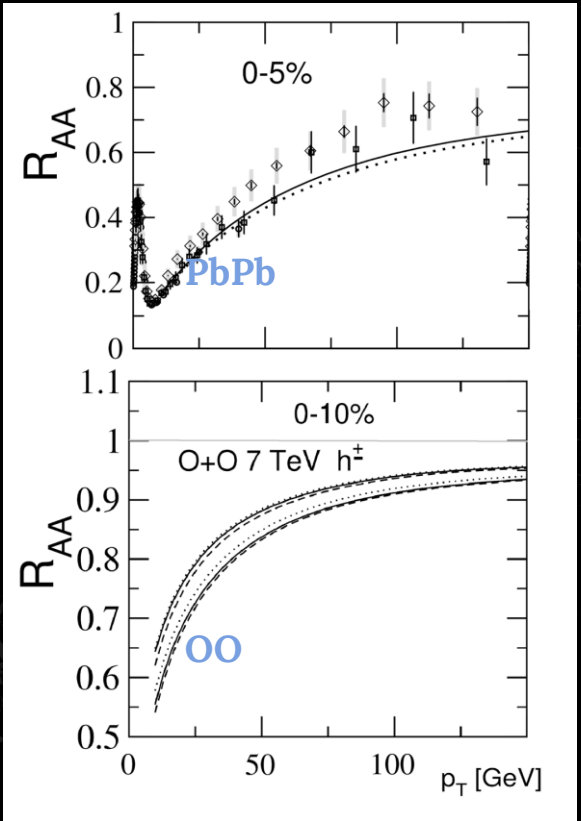
Higher-twist energy loss

Huss *et.al.* 2007.13758

Zakharov: 2105.09350

Lighter ions



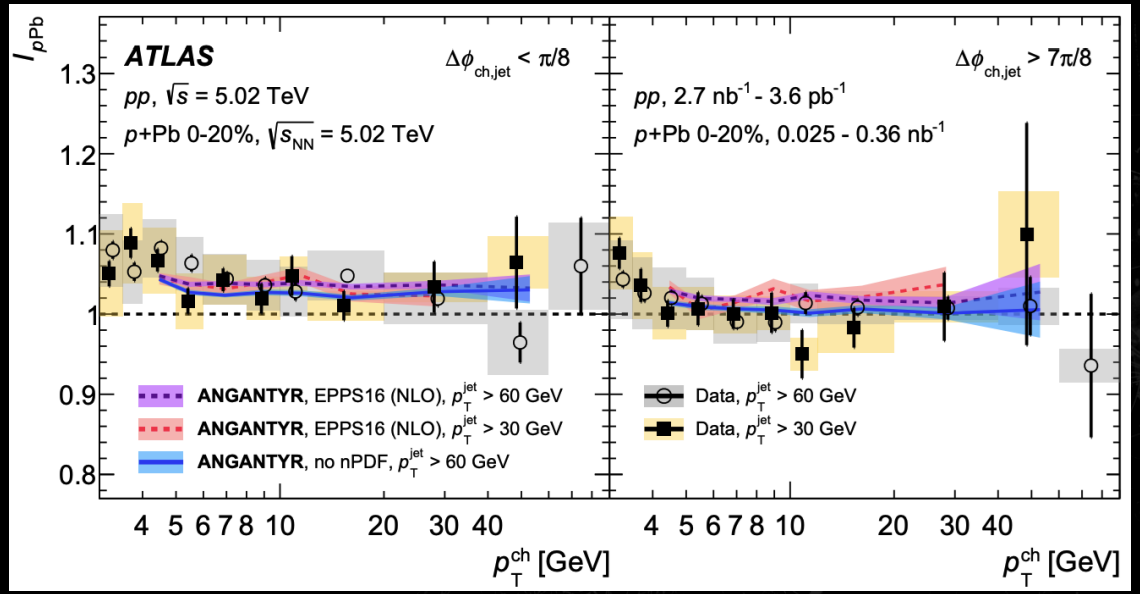


ATLAS: 2206.01138 | Bierlich *et.al.* 1806.10820

No quenching?

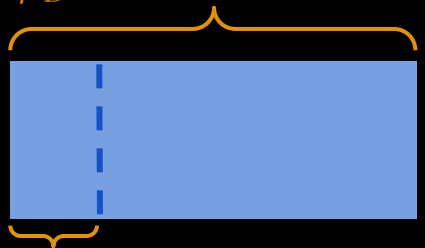
ANGANTYR with string-shoving OFF

Caveat: 0-20% bin in pPb is quantitatively different to 0-5%



Relaxing large-L approximation

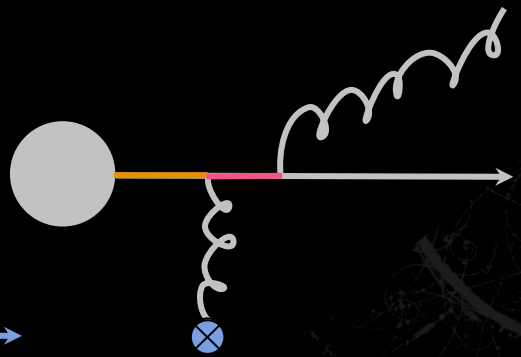
$$\frac{1}{\mu_D} \ll \Delta z \sim \lambda_{mfp} \ll L$$

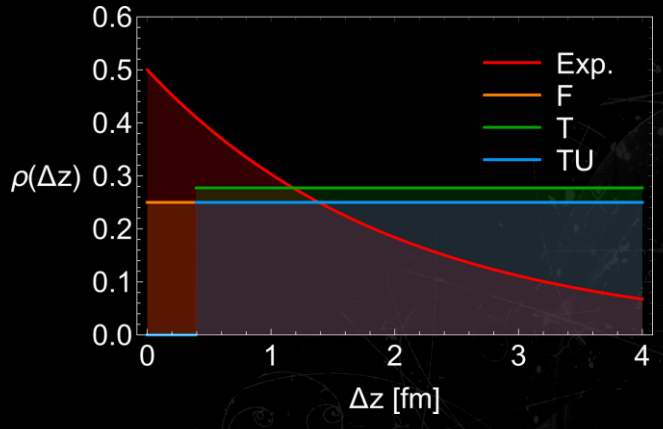


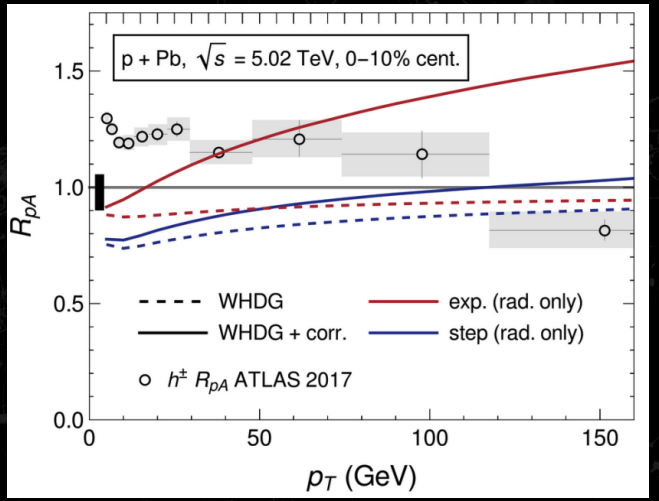
$$\frac{1}{\mu_D} \ll \lambda_{mfp}$$

DGLV poles

corr. pole





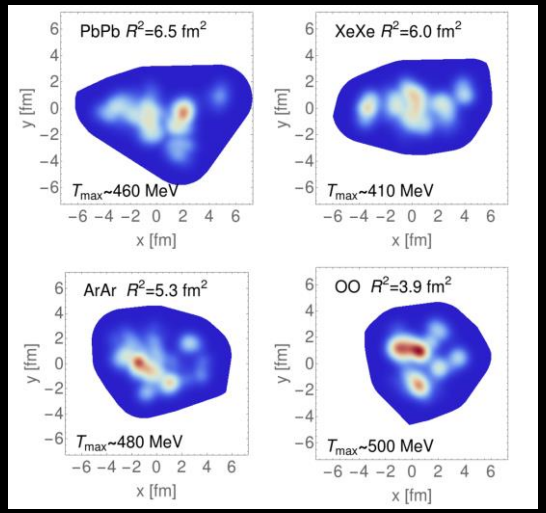


Sievert *et.al.* 1901.01319

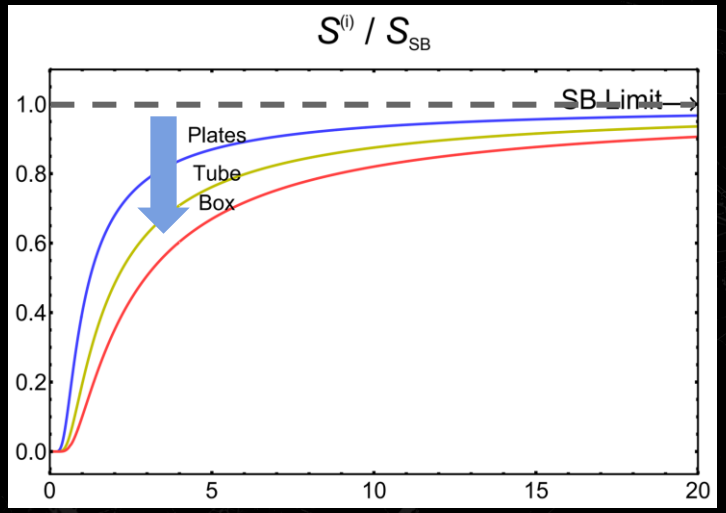
Mogliacci *et.al.* 1807.07871

Small is not the only problem

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

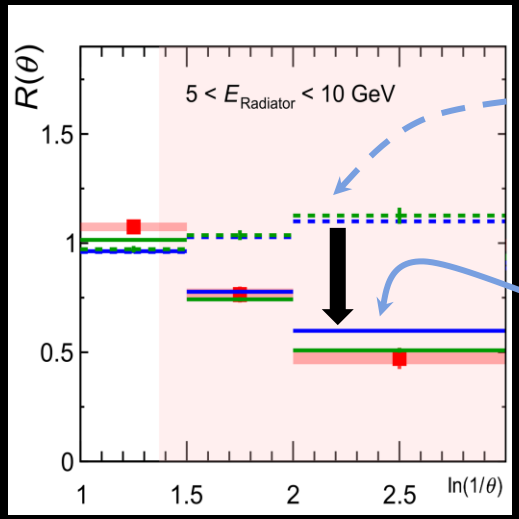


Smaller systems are hotter at the same multiplicity



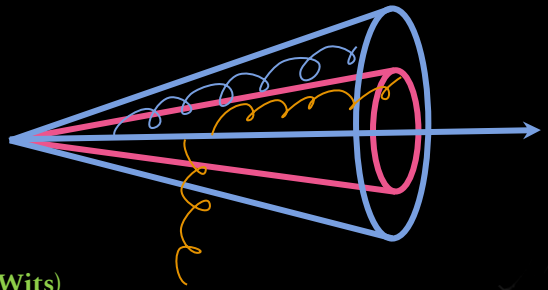
Single, massless, non-interacting, scalar field in a finite box

The dead cone

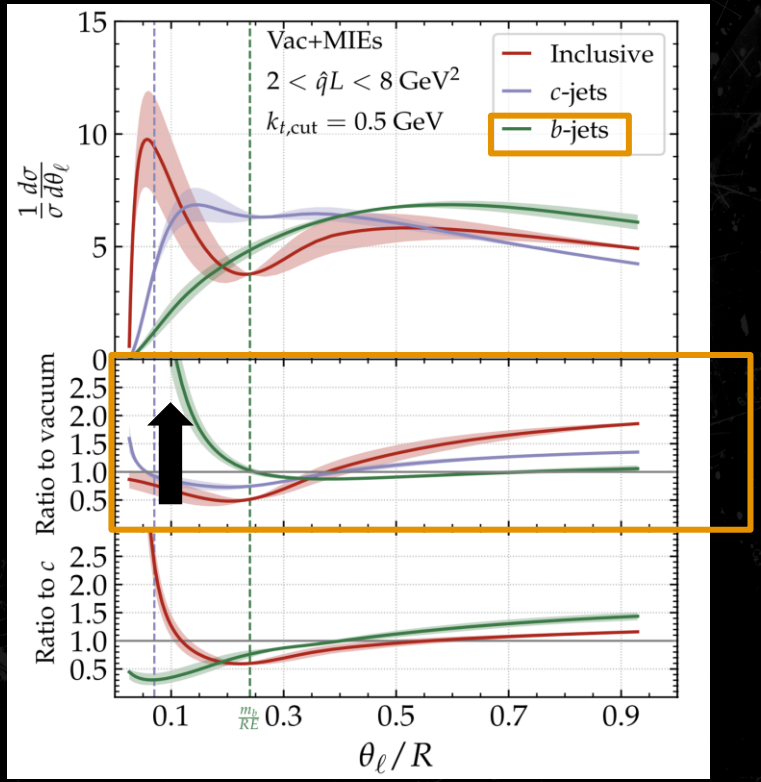


light -flavour

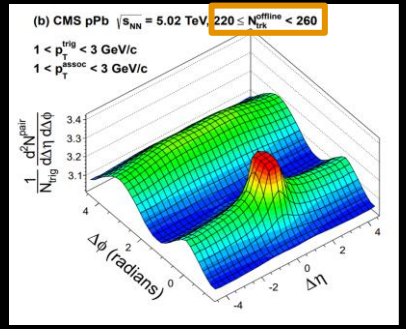
heavy -flavour

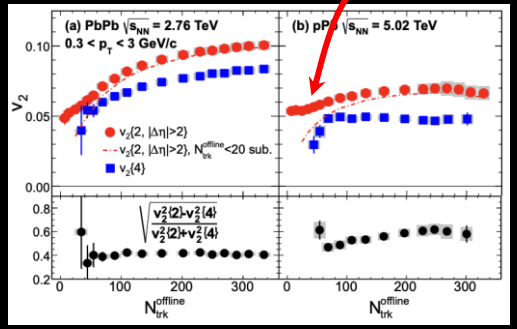


In-medium radiation fills the dead cone



R_{AA}, v_2 , and Centrality



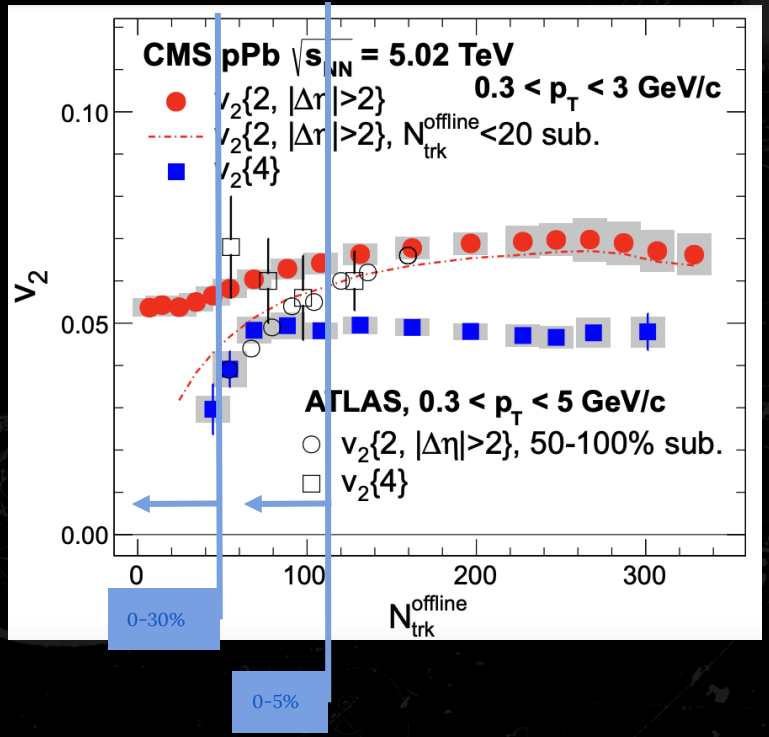


Subtract low mult-data (match ATLAS)

$N_{trk}^{offline}$ bin	PbPb data ⟨Centrality⟩ ± RMS (%)	⟨$N_{trk}^{offline}$⟩	⟨$N_{trk}^{corrected}$⟩	pPb data Fraction	⟨$N_{trk}^{offline}$⟩	⟨$N_{trk}^{corrected}$⟩
[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	0-50%	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	0-10%	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

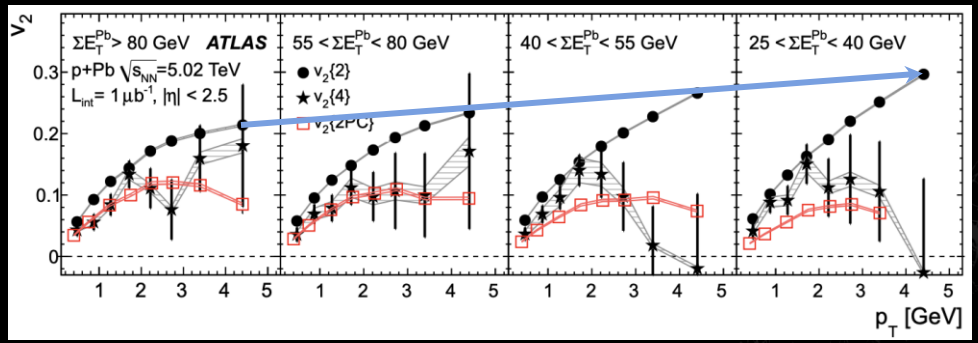
0-30%

0-0.00631% bin



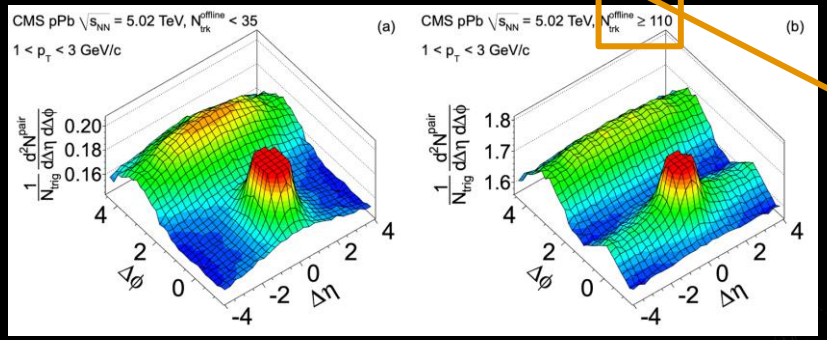
R_{AA}, v_2 , and Centrality (Alternative - ATLAS)

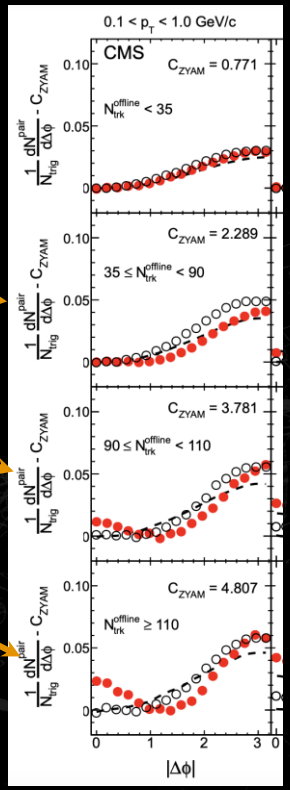
$\Sigma E_{\mathrm{T}}^{\mathrm{Pb}}$ range [GeV]	$\langle \Sigma E_{\mathrm{T}}^{\mathrm{Pb}} \rangle$ [GeV]	range in fraction of events [%]	$\langle N_{\mathrm{ch}}^{\mathrm{rec}} \rangle$ (RMS)
> 80	93.7	0–1.9	134 (31)
55–80	64.8	1.9–9.1	102 (26)
40–55	46.7	9.1–20.0	80 (23)
25–40	31.9	20.0–39.3	60 (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

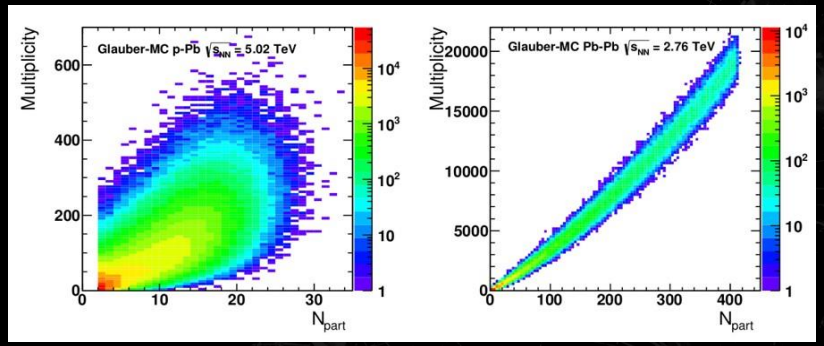


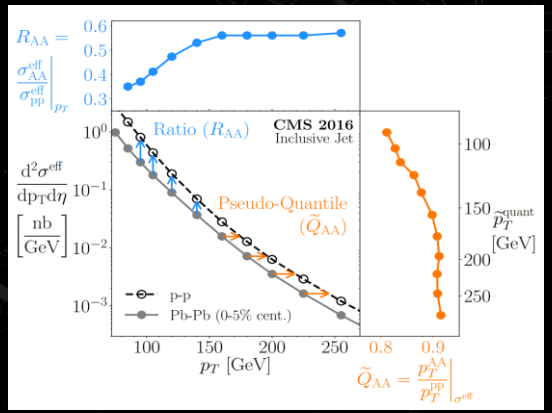


Correlated yield

Why R_{AA} is not ideal for small systems

- Reliance on a reference system
- Steeply falling production spectrum
  - Sensitive only to large ΔE
  - Sensitive to PDFs and nPDFs
  - Species-dependent
- 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





Dai *et.al.*: 2205.14668

Dead cone prediction in AA