Sensitivity of flow harmonics to sub-nucleonic scale fluctuations arXiv:1508.02455

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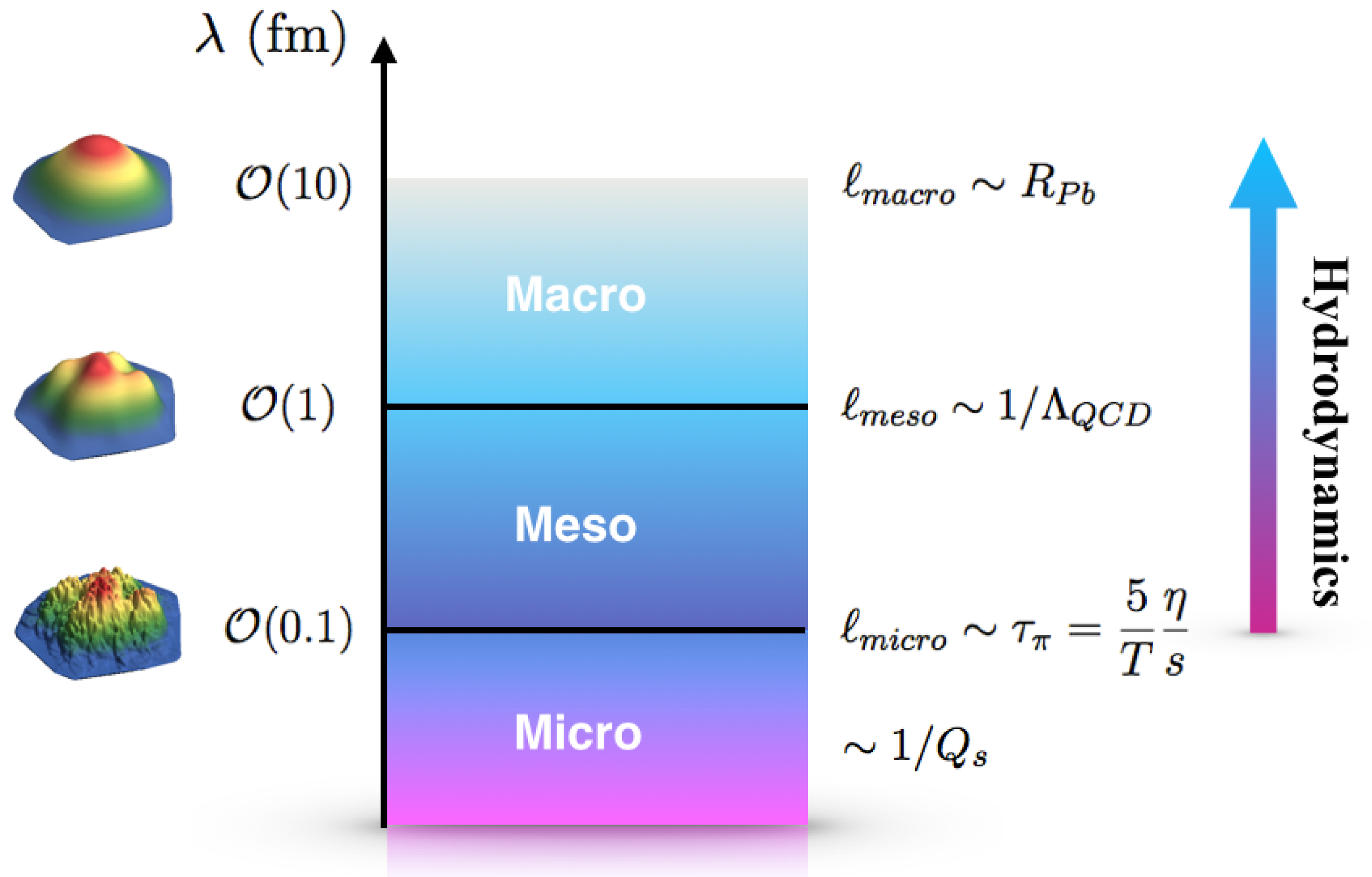
A tale of scales

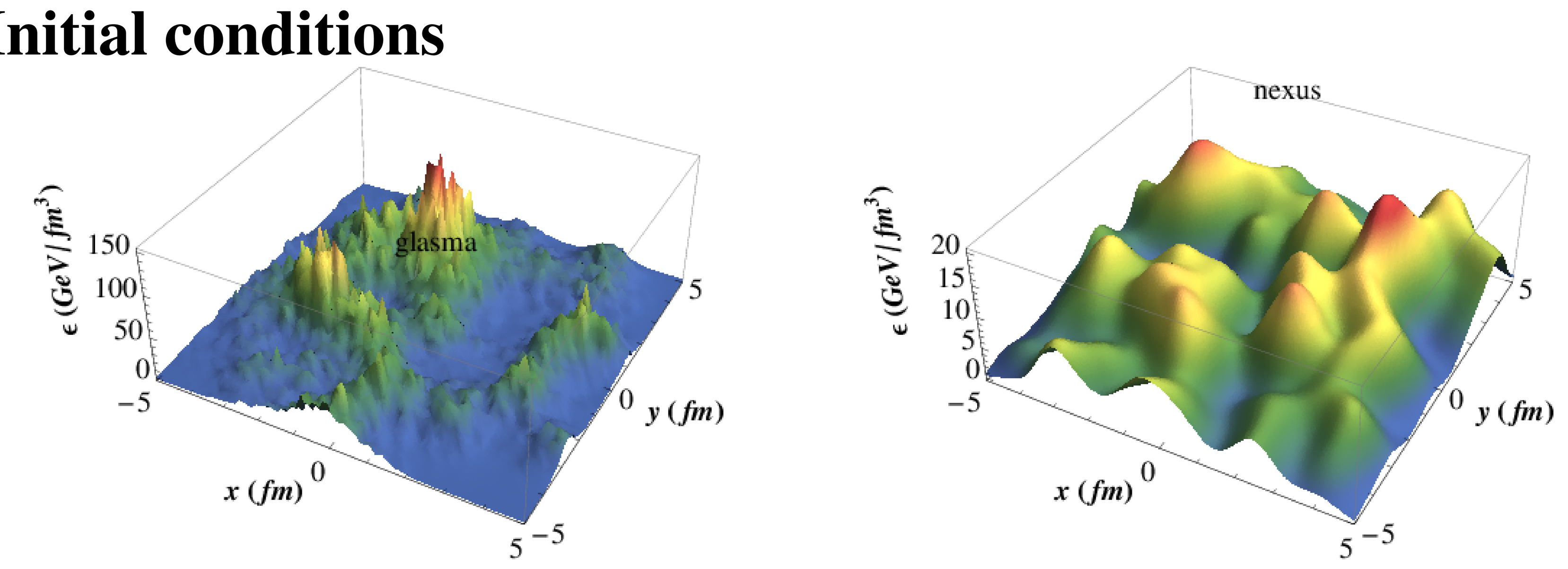
Relativistic heavy-ions probes three different scales:

- **macroscopic scale** of the order of the radius of a large nucleus 10 fm
- **mesoscale scale** of the order of the size of a proton 1 fm
- **microscopic scale** set by the inverse saturation scale $1/Q_s \approx 0.1$ fm

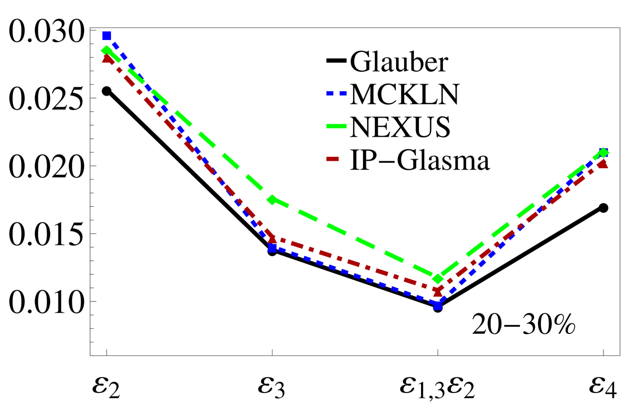


What scales do the known observables measure?

Initial conditions



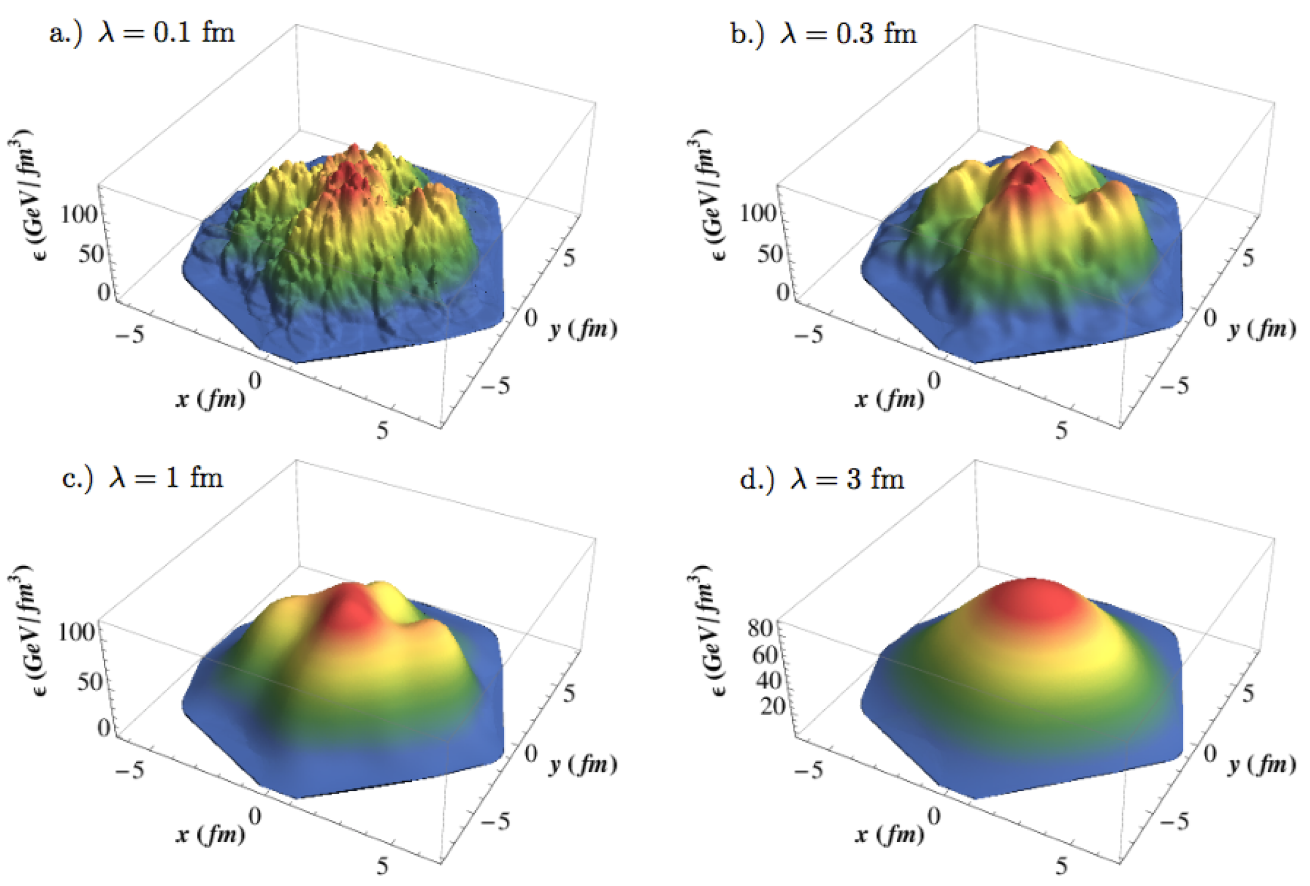
Schenke et al,PRL108(2012)252301 Drescher et al,Phys.Rept.(2001)350 93

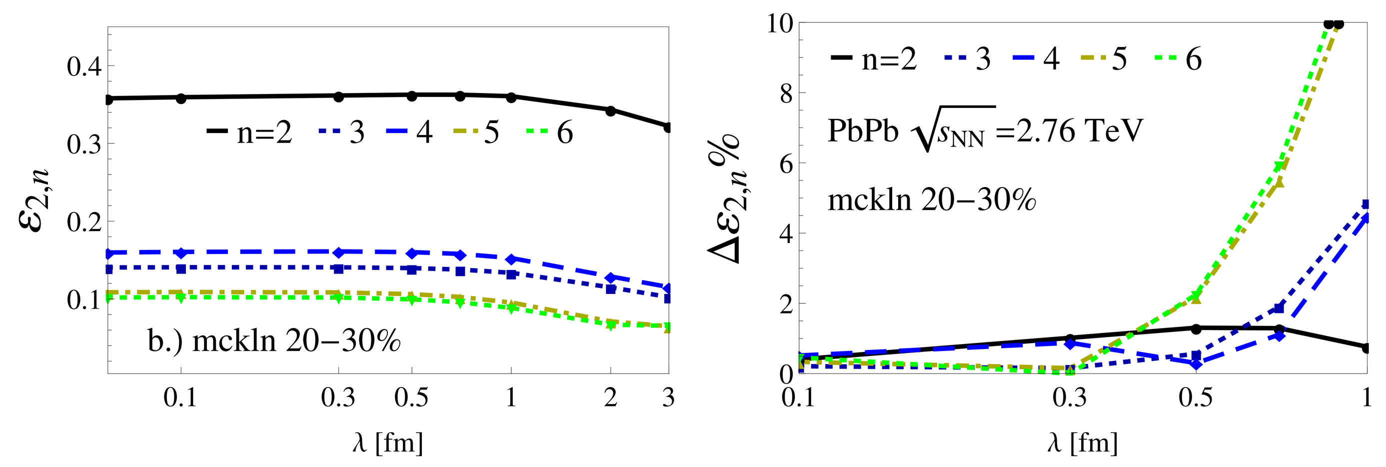


Initial condtions with subnucleonic fluctuations [1] (e.g. IP-Glasma/mckln) vs. nucleonic fluctuations [2] (NEXUS, Glauber, UrQMD etc) are hard to compare directly because they have both different scales and different eccentricities. Moreover, the eccentricities are the strongly correlated with the final flow harmonics [3].

Smoothing Fluctuations

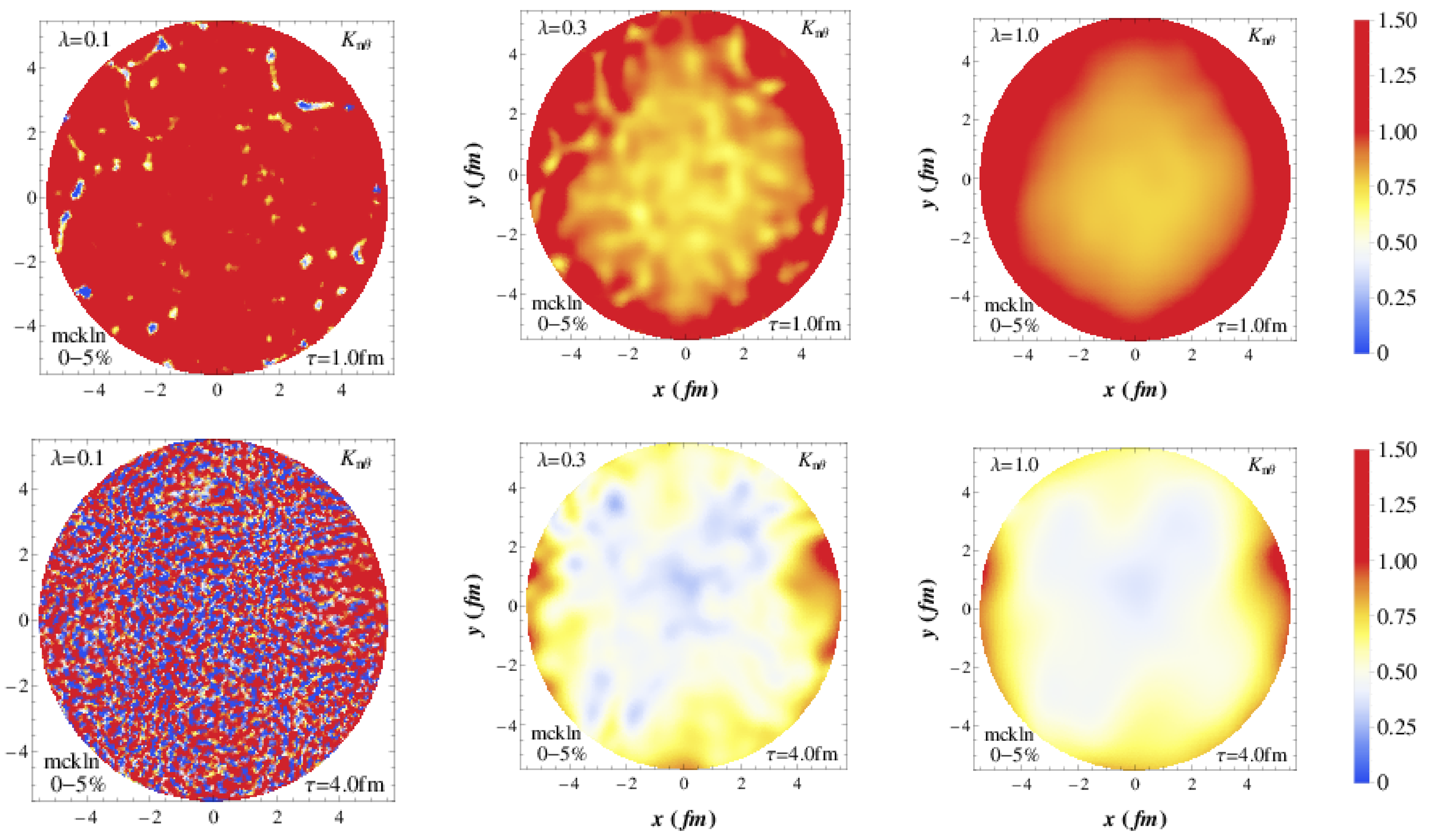
A cubic spline we can smooth out energy fluctuations without changing the eccentricities
All hydrodynamical calculations are done in v-USPhydro [4]





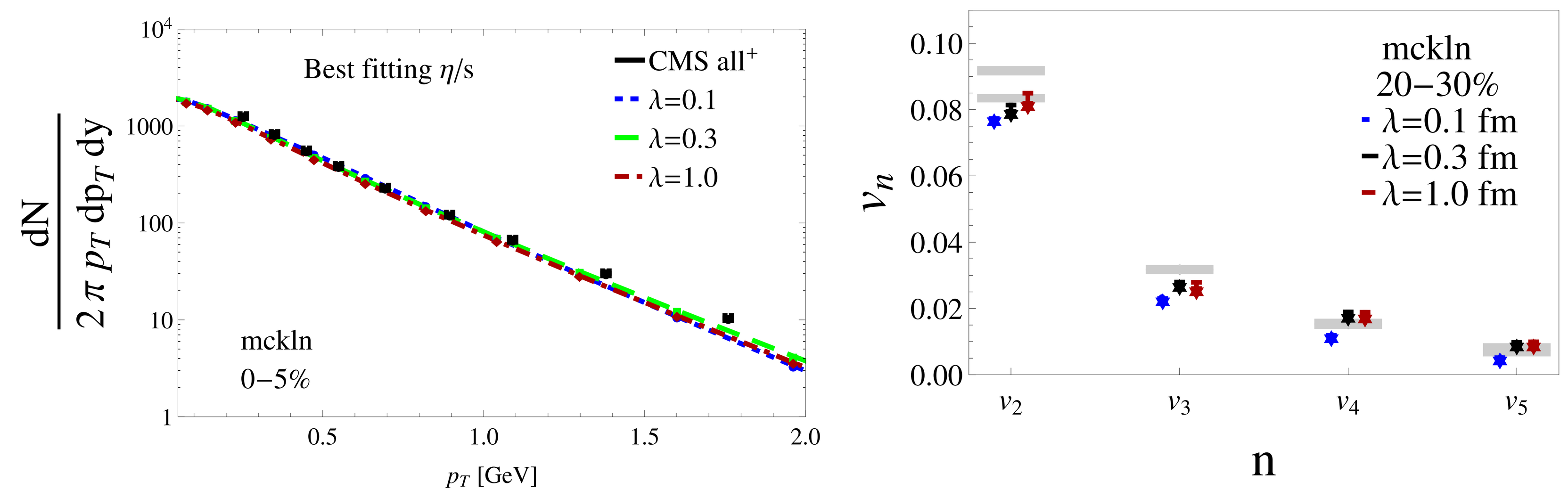
Applicability of hydrodynamics

Separation of scales needed for hydro Knudsen number $K_{n\theta} = l_{micro}/L_{macro} \to \tau_\pi\,\theta$
Microscale is set by $\tau_\pi = 5\eta/(Ts) \approx 0.25$ fm



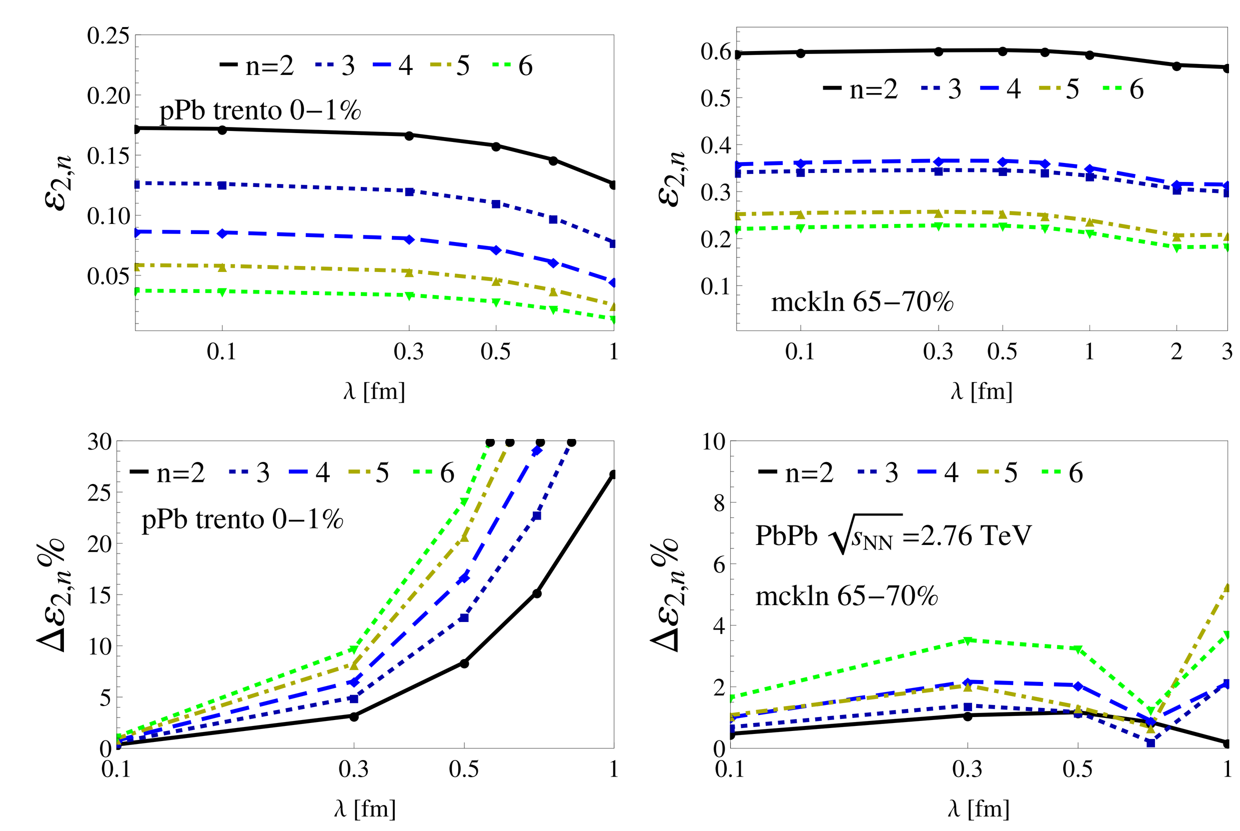
"bad $K_{n\theta}$" for $\lambda < \tau_\pi$

Robustness of Spectra and v_n's



- Only elliptical flow is slightly affected by the scale
- Even "bad" Knudsen number ($\lambda = 0.1$) fits reasonably well for spectra, below for v_n's
- $\lambda = 0.1 \to \eta/s = 0$, $\lambda = 0.3 \to \eta/s = 0.11$, $\lambda = 1.0 \to \eta/s = 0.1125$

Small Systems



- Trento [5] used $p = 0.3, k = 1.3$ ($p = 0, k = 1.4 \Downarrow \varepsilon_{m,n}$'s and $\Uparrow$ dependence on λ).
- $\varepsilon_{m,n}(pPb)$ much $< \varepsilon_{m,n}(PbPb)$ for the same multiplicities at LHC

Conclusions and Outlook

- $PbPb$ and to a lesser extent pPb surprisingly robust to smoothing fluctuations λ
- New observables needed to probe energy density scale
- pPb on the very edge of applicability of Israel-Stewart eqs. What about pp collisions???
- Effects from other transport coefficients such as bulk viscosity

References

[1] Schenke et al,PRL108(2012)252301;Drescher and Nara,PRC75(2007)034905
[2] Miller et al, Ann. Rev. Nucl. Part. Sci. 57, 205 (2007);Alver et al, arXiv:0805.4411; Loizides et al,arXiv:1408.2549;Petersen PRC78(2008)044901;Drescher et al,Phys.Rept.(2001)350 93
[3] Gardim et al, PRC91(2015)3,034902;PRC85(2012)024908
[4] JNH et al, PRC90(2014)3,034907;PRC88(2013)044916
[5] Moreland et al, PRC92(2015)1,011901