

What aspects of the initial stages will not be feasibly tested in the near future?

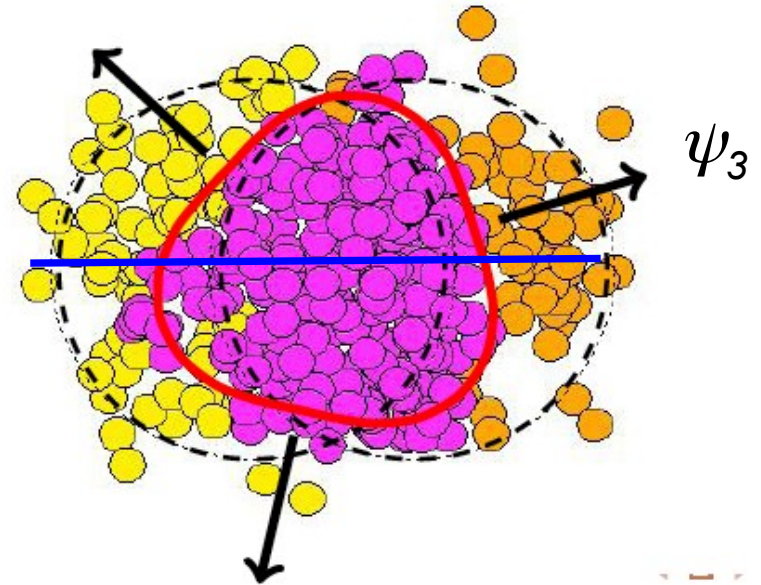
**What aspects of the initial stages
will not be feasibly tested in the
near future?**

Not a summary...

What aspects of the initial stages will not be feasibly tested in the near future?

Predicting the future...? A quiz.

What these pictures have to do with each other?

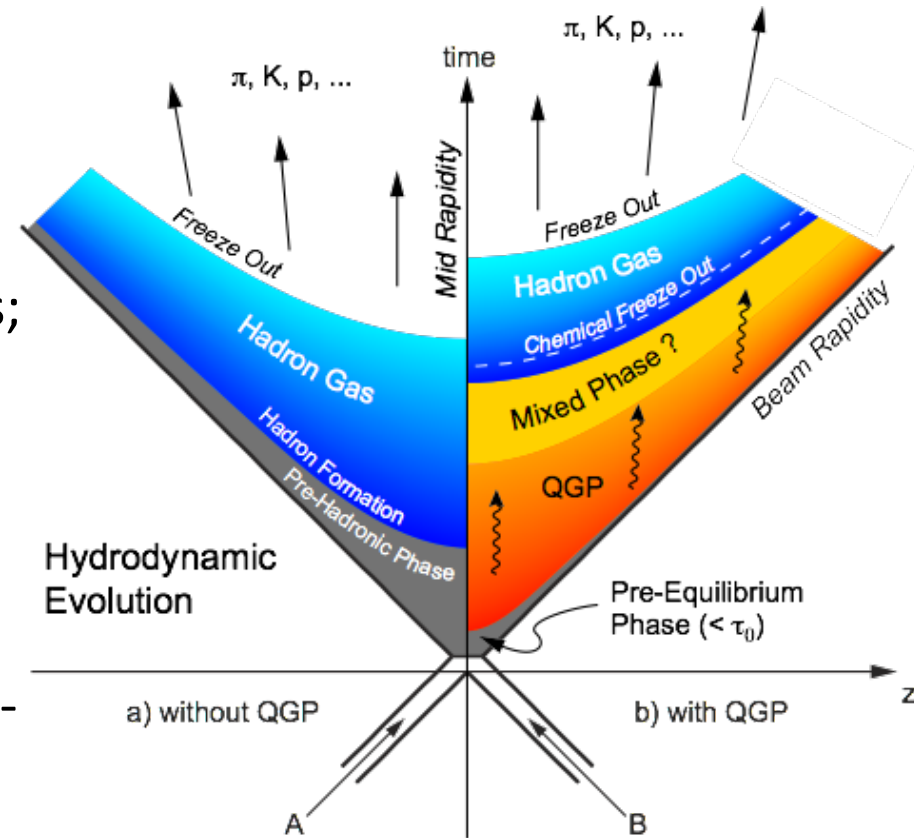


Time axis



Basic problem with measuring collisions

- Sensitivity to τ is limited – in particular, with an interacting system where large part of information “thermalizes”
 - “Recent complexity”: long range correlations in pp and pA collisions; strangeness from pp to pA...
- Task is to identify/measure observables related exclusively/pre-dominantly with a particular stage of the collision
 - Note of an “inverted logic”: heavy-ion collisions became **a reference** for pA (collectivity/flow; hydrodynamics; flavor production...)



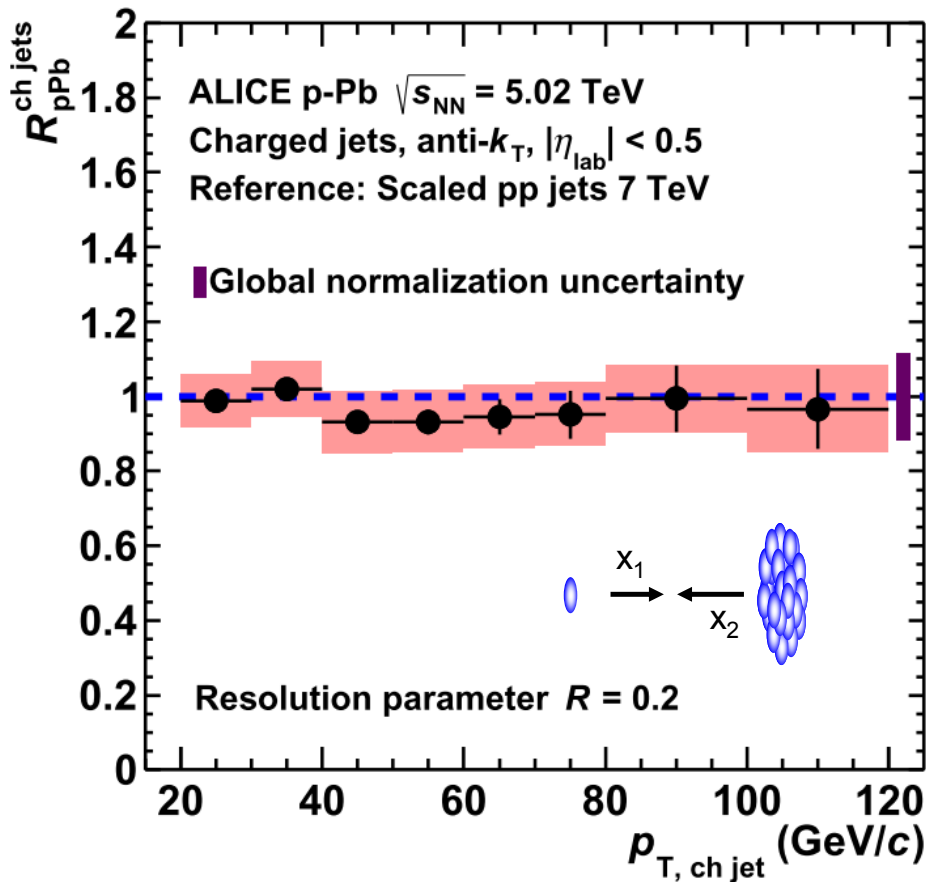
Reasons for “not be feasibly tested”

- Physics
 - Low production cross-sections / low magnitude effects
 - Thermalization, hydrodynamization...
 - Holding on to *rwong* observables (!?!)
 - Structure of the proton / fluctuations (in hadronic collisions)
- Instrumentation / data sources
 - SPS?, LEP?, HERA? **LHC, RHIC**, eIC, LHeC, FCC
 - New data vs. re-analysis of data on tape ?
 - Beam availability at working facilities
 - Variety of collision systems (needed?)
 - Experimental acceptance
 - Statistics/ and related systematic uncertainties
 - Knowledge of background sources
 - Detector performance / understanding (constantly improving!)

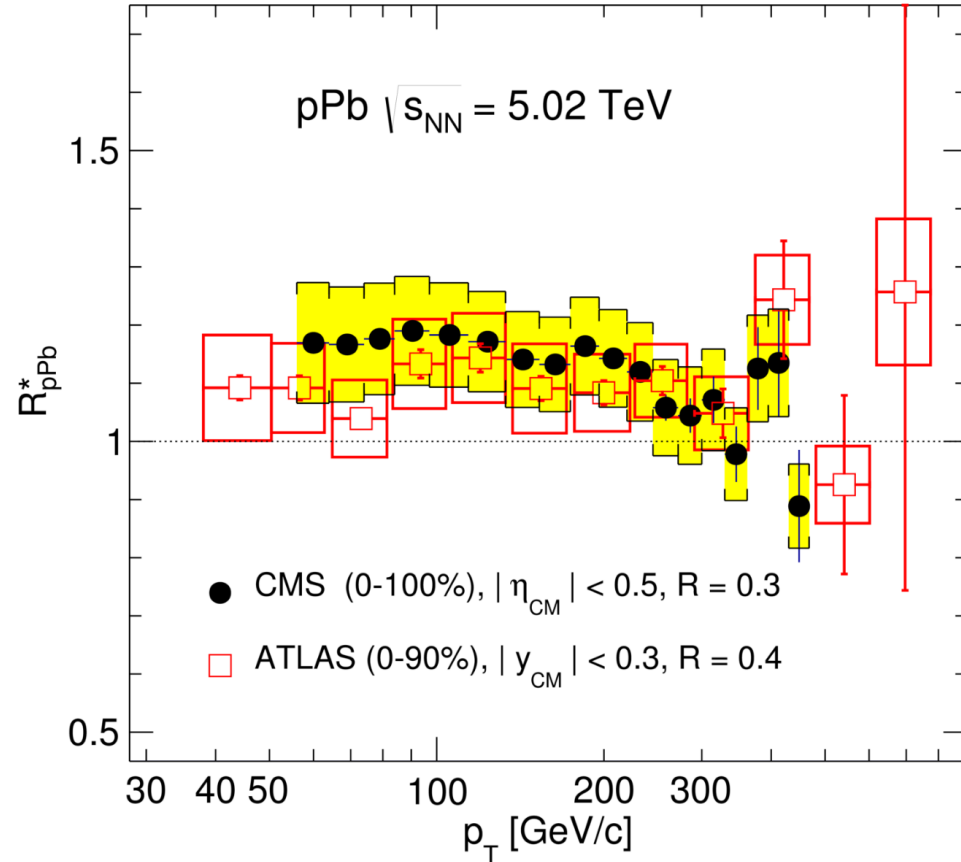
Sensitivity to $\tau=0$ / particle production

- Constrains to PDFs / hard processes
 - New LHC data soon: W, Z, [di]-jets, c, b ... t-quark
 - RHIC pA, dAu but also pp;
 - Limited outlook extended with sPHENIX (?)
 - Heavy-flavor production
 - “new” caveat: secondary c,b within parton shower
- New LHC data - multiple parton interactions
 - Psi/DY; associated charm production (Psi + D)
 - Double parton scattering: 4-jet, W+jj, DY, $\gamma\gamma$
 - Counting sources / 2-particle correlations / UE analysis a la UA1

Jets – example on limiting uncertainties

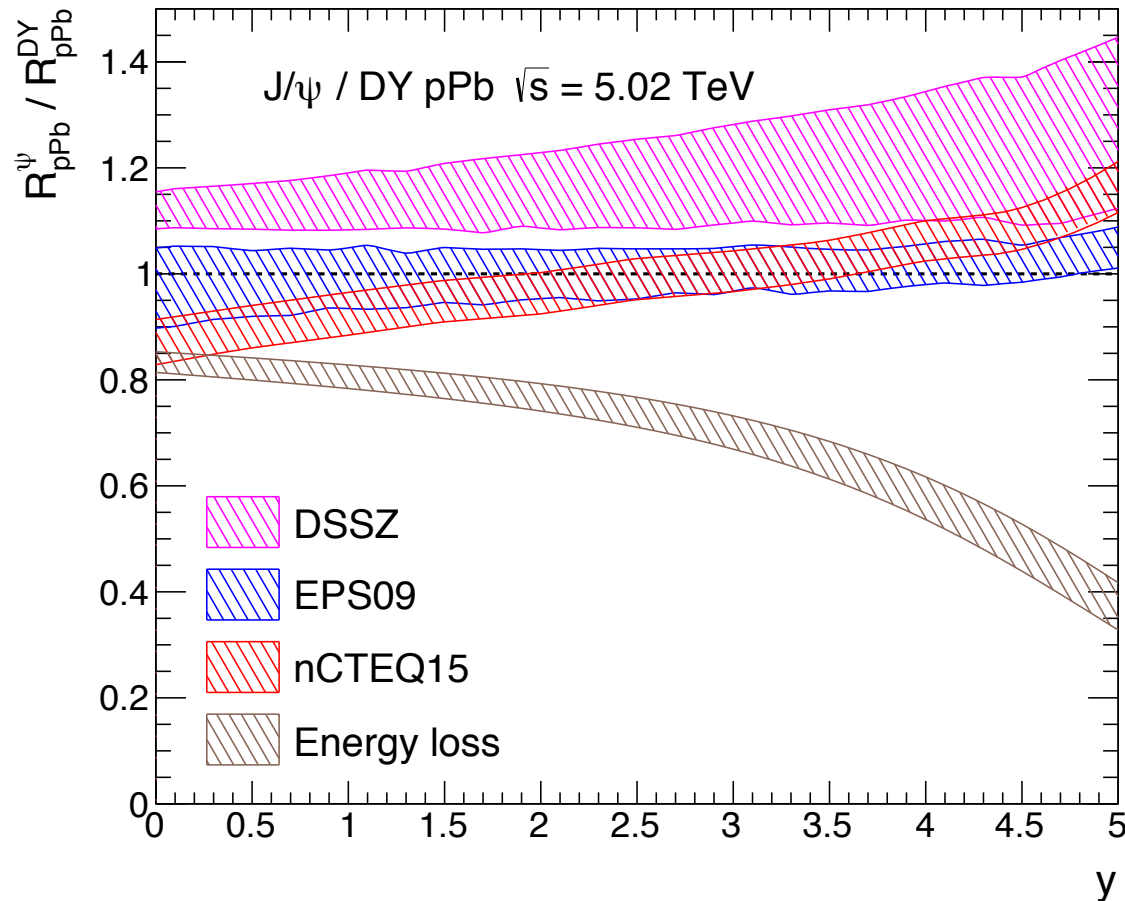


Yen-Jie Lee (Tuesday)



- Sensitivity of all inclusive / charged / b / c-jet R_{pPb} : limited by the systematical uncertainties and the interpolated reference
- Need to use **REAL PP REFERENCE**, reduce the relative jet energy uncertainty between pp and pPb data to **<<1%** level (also jet resolution uncertainty)

Q-Onia and DY: LHCb/theo. projection

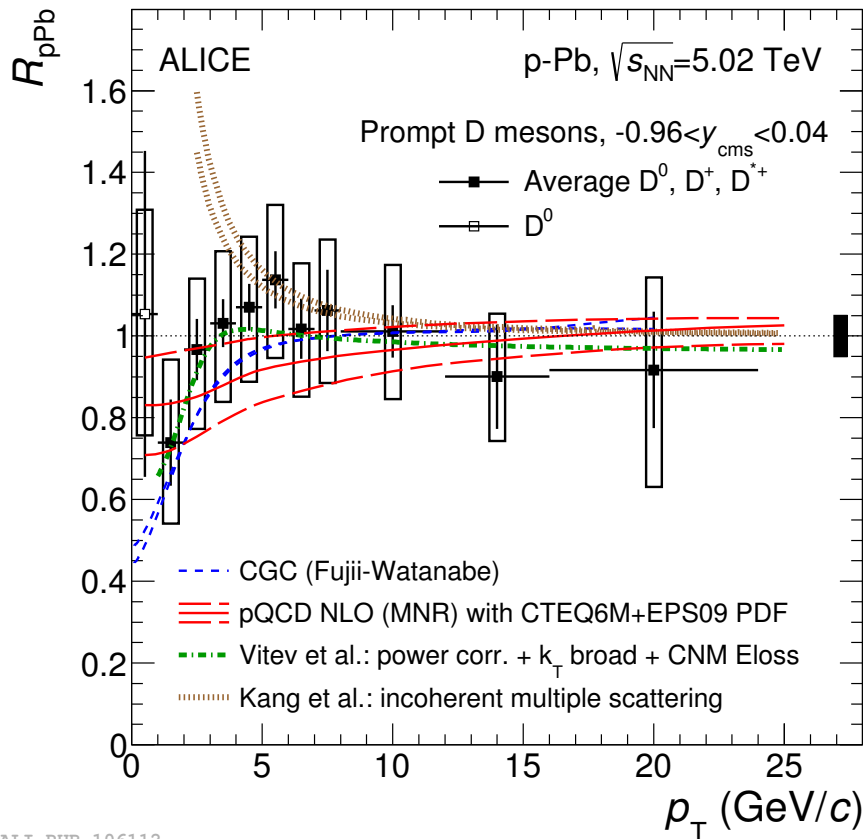


LHCb prospects: Shadowing (DSSZ, EPS09, nCTEQ15)
vs. energy loss model

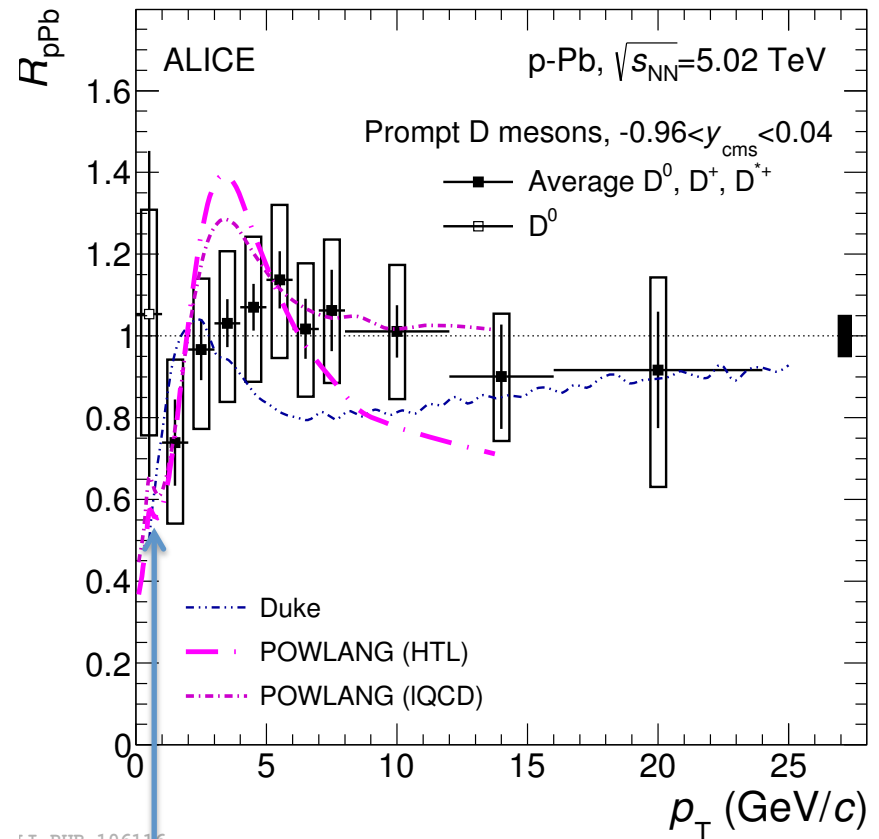
Charm in pA – “Cold” Nuclear Matter

arXiv:1605.07569

Theory with CNM only:



Theory with small QGP: PRL 113 (2014) 232301



Need to reduce uncertainties – down to lowest- p_T
 More differential measurements? / correlations?

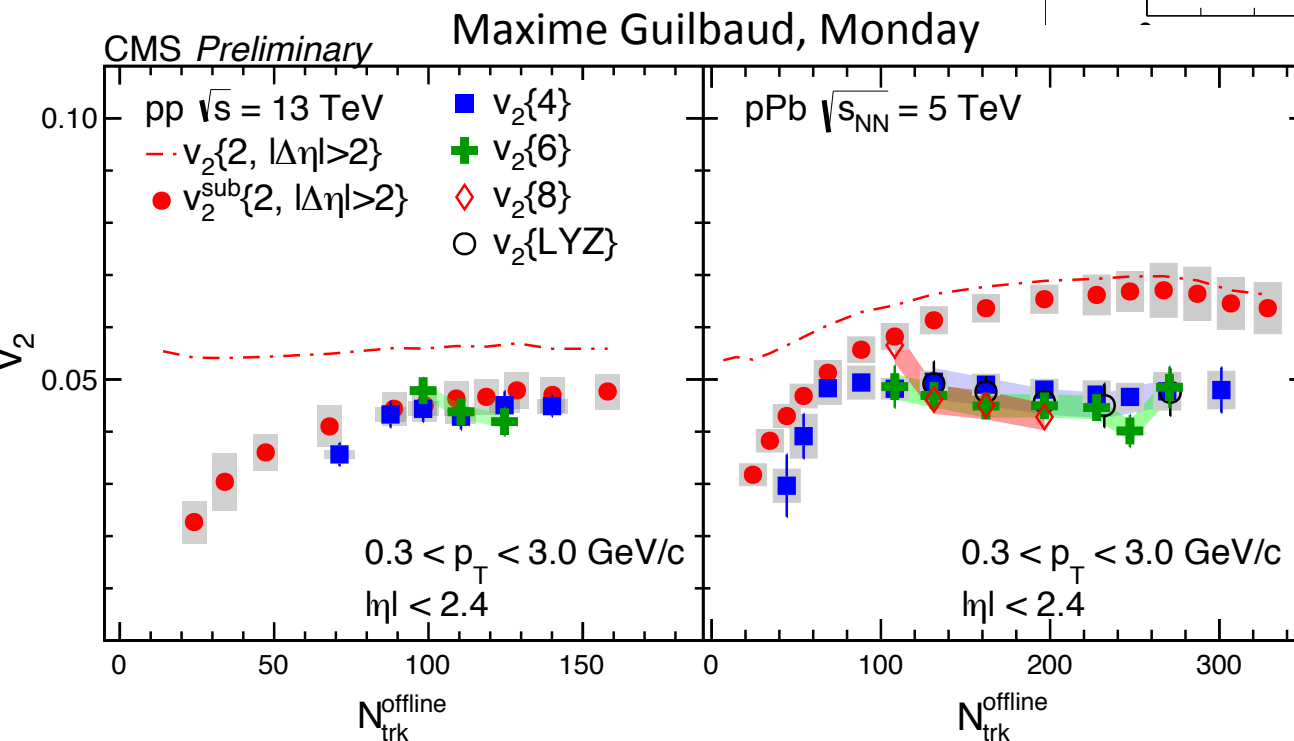
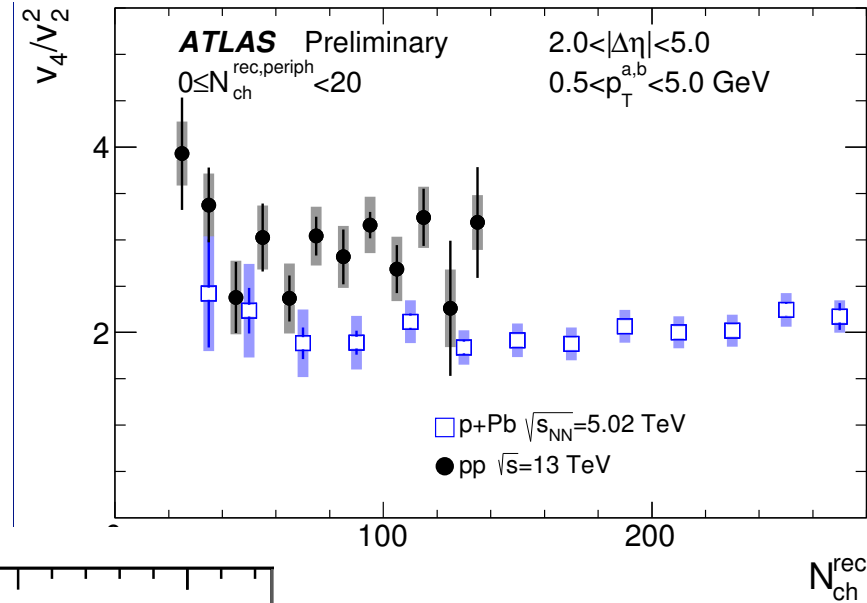
Elena Bruna

Small- τ Pre-equilibrium / off equilibrium?

- Development of the radial flow in pre-equilibrium (see U.Heinz yesterday's talk)
- **High statistics** $v_n[N]$ cumulant / fit measurements for **small multiplicities** in pp, pA; peripheral AA (trouble due to photo-production?)
- Evolution: look closer at mini-jets (SRC with jet reconstruction at unreasonable low- p_T ?) \Leftrightarrow study their “dissolving” structure as a function of multiplicity
- Correlate soft (multiplicity) with hard particle production \Leftrightarrow semi-inclusive measurements – a way to improved relation to impact parameter (?); off jet UE activity (?)

Particle correlations

- ATLAS – fit method – access to low-multiplicities (Brian Cole, Monday)
 - $v_4/v_2 \Rightarrow$ stronger non-linear coupling in pp?
 - $v_2(p_T)$ caling in pp, pPb, PbPb
- Complementary (new) methods on correlations (ALICE)



CMS cumulants

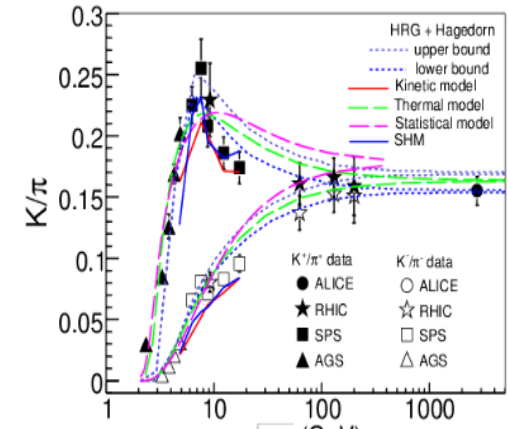
- $v_2\{2\}/v_2\{4\}$ less fluctuation sources
- How do higher $\{N\}$ drop with multiplicity?

Other directions...

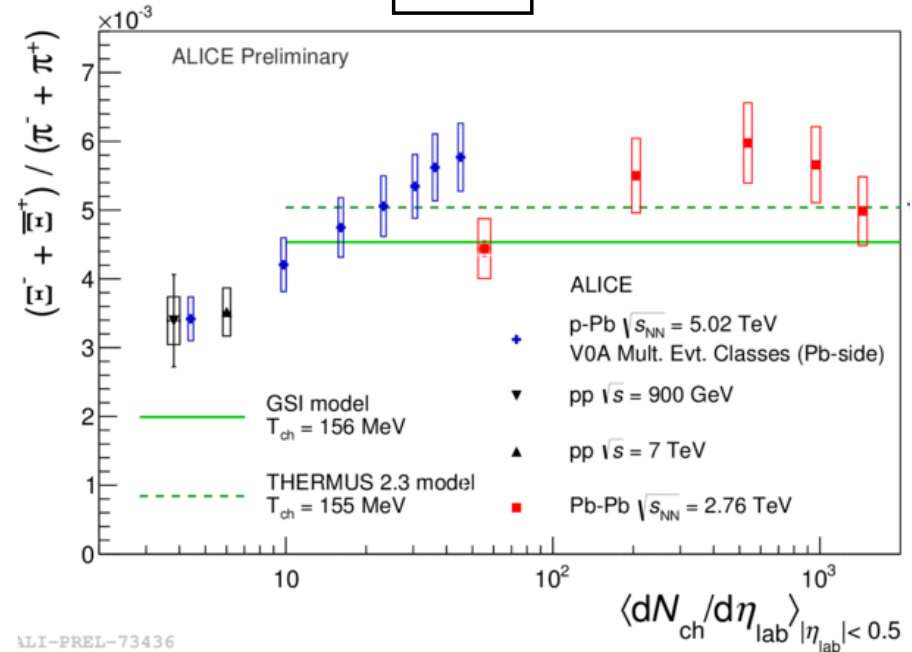
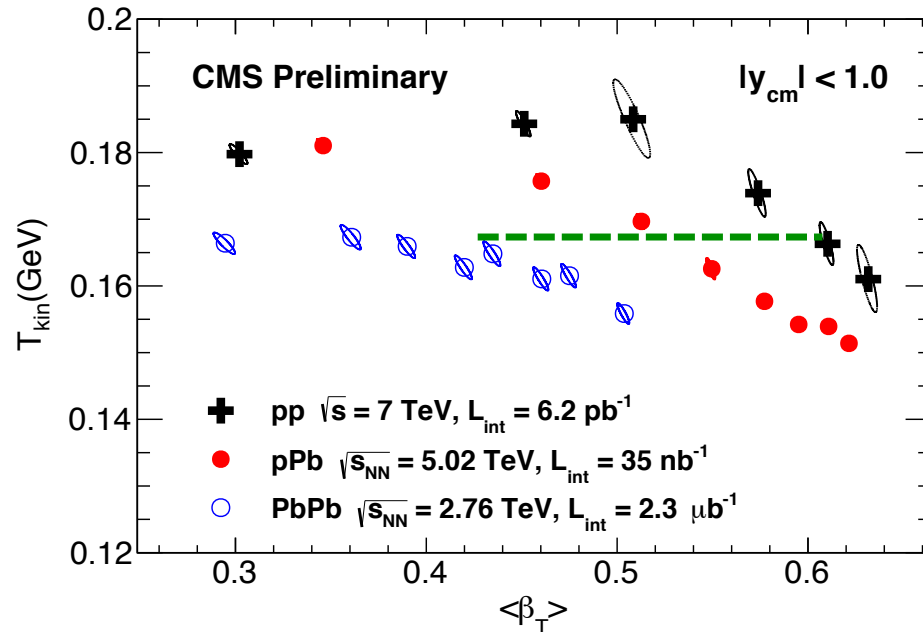
- “Resolving” HIC/QGP may help to unfold the sequence of stages
 - Quality data + systematic analysis of collision/initial/QGP/HGas parameters yields first results (S. Bass et al.)
 - Energy loss in small systems (?)
 - New data in pA on low- p_T charm production (R_{pPb} , v_2)
 - AA: Heavy-quark production & in-medium propagation (transport coefficients – details on longitudinal drag...)
 - Event shape engineering
- Crucial “final-state” component: understanding of **hadronization/particle-ization** process
 - How to: Fields/quanta/entropy => pions, ...
 - n-quanta to m != n particles – v_2 damping effects; multi-pion HBT / large coherence effects ?
 - Test of coalescence in the charm sector (D_s , Λ_c)
 - Looking forward to eIC data
- More on photo production (see Wednesday)
 - Challenging example: Nuclear wave function with di-jet production in UPC

Particle production

- Spectra and blast-wave fits as a function of multiplicity \Leftrightarrow radial flow systematics
- Role of strange flavor: shape in pA (and or pp) – high multiplicities (need data)

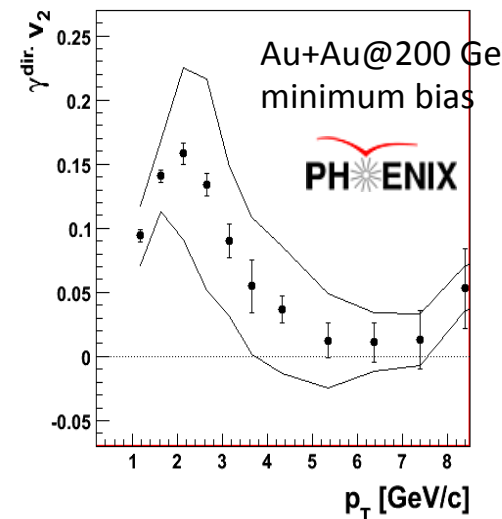
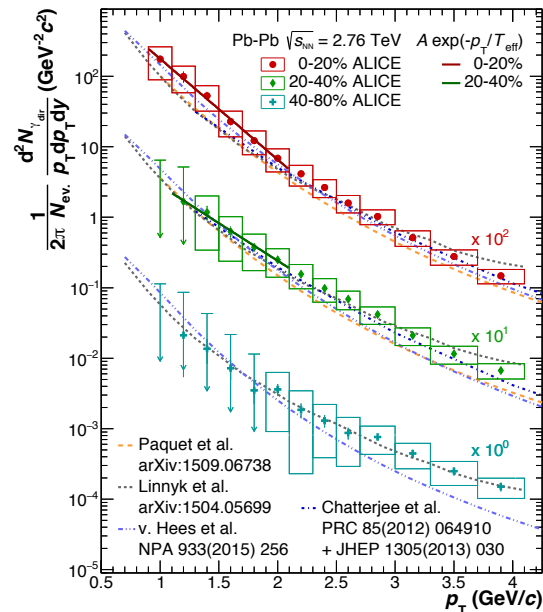
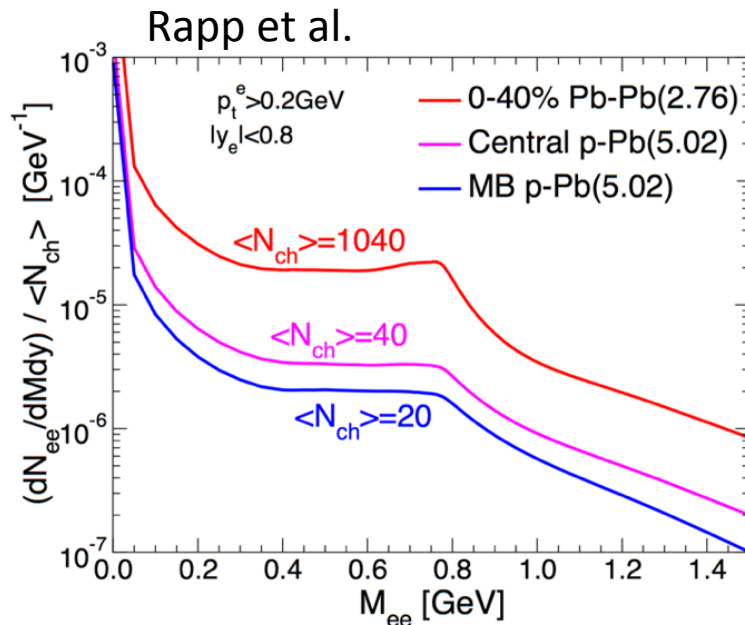


Ξ/π



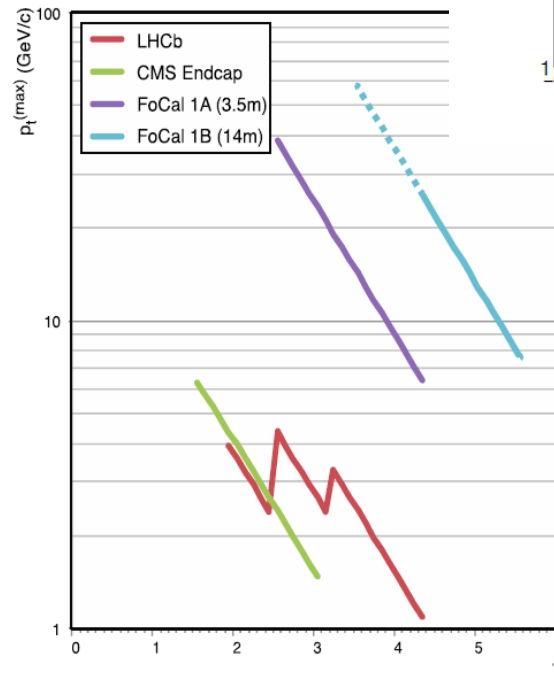
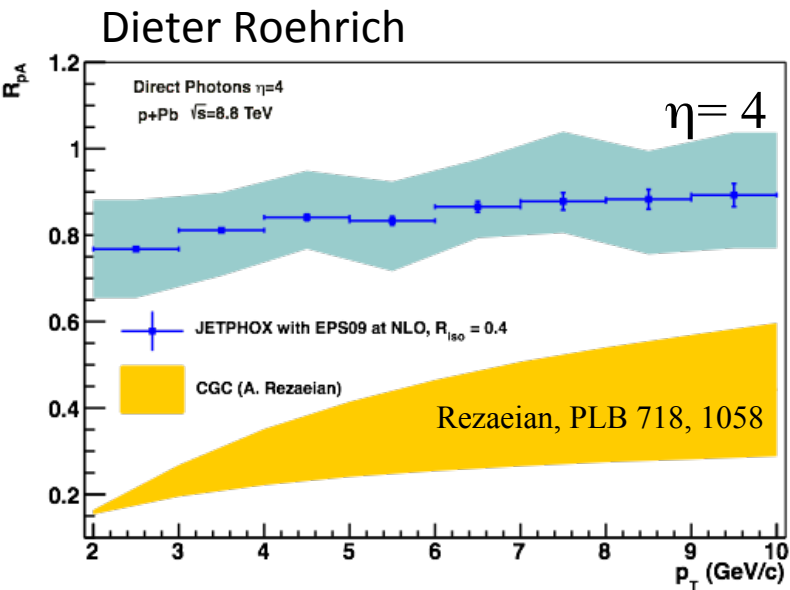
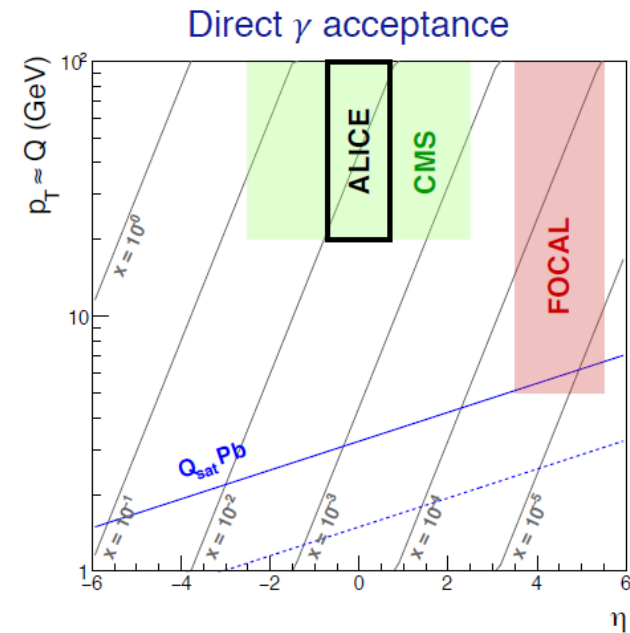
Di-leptons and γ not pristine anymore...

- However still interesting in the direction of resolving QGP...
- Experimentally difficult measurements
 - Di-leptons in LHC AA (\Rightarrow Run-3 statistics)
- Sources in multiple stages (flow from pre-equilibrium; di-leptons in pre-equilibrium? – control of charm; rho broadening – see B. Jacak talk)
- Thermal photons in pA (difficult measurement) $\Rightarrow v_2$?



Few remarks on instrumentation

- ATLAS tracking upgrade => $\eta=4$ (LHC Run-3) – see outlook for correlations in *Jiangyong Jia* and *Mingliang Zhou* (Thu)
- ALICE forward calorimeter (LHC Run-3)
 - Now: LHCb DY, di-muons (?)
- sPHENIX (=> Dave, Today)



Instead of an outlook:

- When you should start worrying about talks like this one?

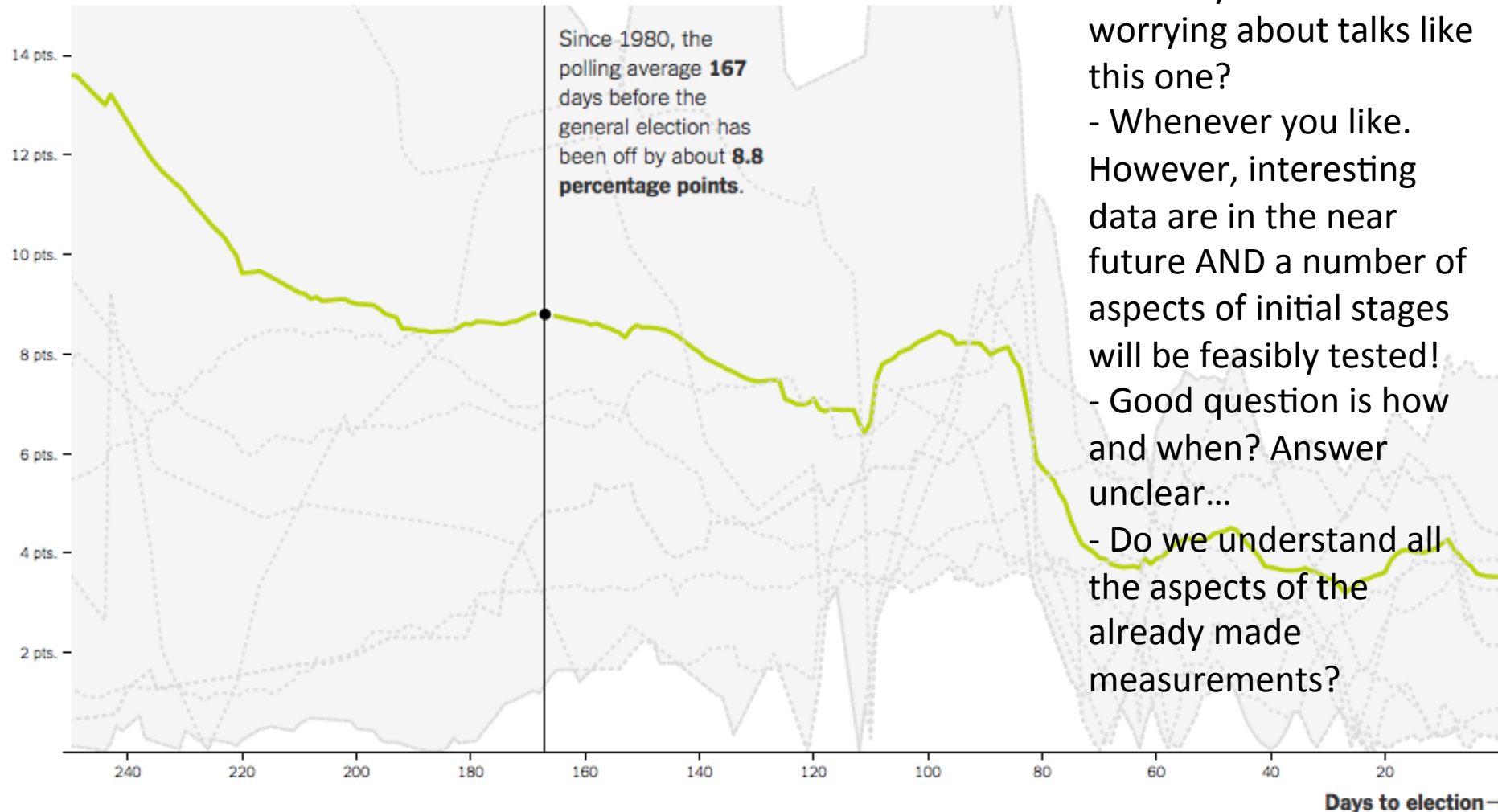
- Whenever you like. However, interesting data are in the near future AND a number of aspects of initial stages will be feasibly tested!

- Good question is how and when? Answer unclear...

- Do we understand all the aspects of the already made measurements?

How close the polling average has been to the final result

..... One election — Average since 1980



What aspects of the initial stages will not be feasibly tested in the near future?

Additional slides

What aspects of the initial stages will not be feasibly tested in the near future?

Instead of conclusions

