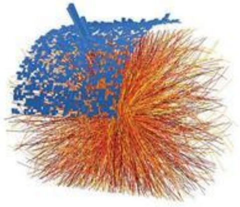
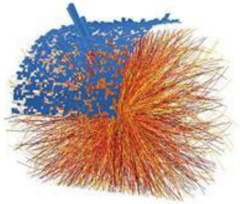


Geometry and event activity in very asymmetric collisions

…or: back to the “simple calibration problem”

G. David, BNL



Surprising, intriguing, controversial results from very asymmetric collisions

Systems meant to be the reference for strange phenomena in hot nuclear/partonic matter themselves exhibit strange properties:
- apparent flow, ridge in p/d+A
- enhancement/suppression in peripheral/central collisions

Is hot matter really formed in p/d+A? Is the initial state of a nucleus different from what we initially thought?

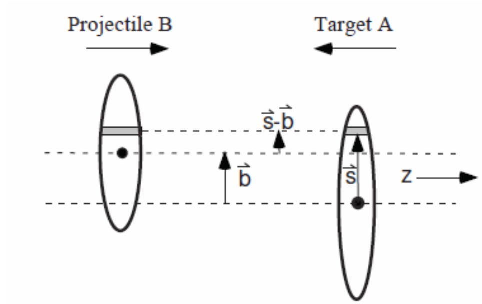
Or do we have a "calibration problem" when connecting measurable quantities ("event activity") to theoretical ones ("b", N_{coll}?)
→ do we really understand the *proton* under extreme conditions?

I'm not here to give you a definitive answer (btw my bet would be "a combination of all these"). All I want to do is re-emphasize a trivial, but plausible scenario that can play a major role

Plea: I won't claim to know what I don't…

Centrality: from ideal quantities to measurable signals

Impact parameter ("**b**")

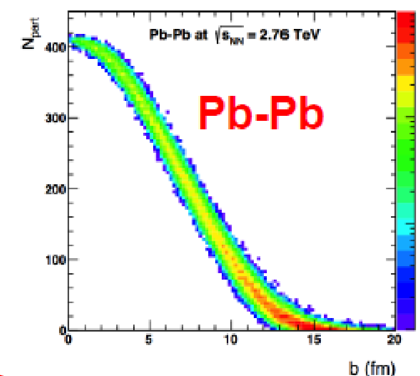


Nuclear overlap (**T_{AB}**)

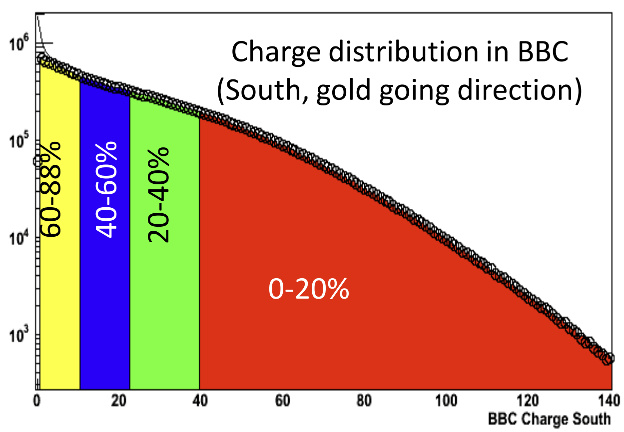
$$\hat{T}_{AB}(\mathrm{b}) = \int \hat{T}_A(\mathrm{s})\,\hat{T}_B(\mathrm{s}-\mathrm{b})\,d^2s.$$

A+A: clean correlations, if models can be trusted

NN cross-section (**σ_{pp}**)



Participants, collisions (**N_{part}, N_{coll}**)

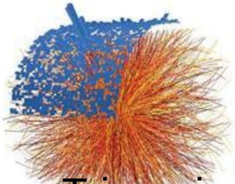


... and then an experiment happens...

Multiplicity, E_T, other global, fluctuating quantity, rapidity gap

In short, experimentally accessible "**event activity**"

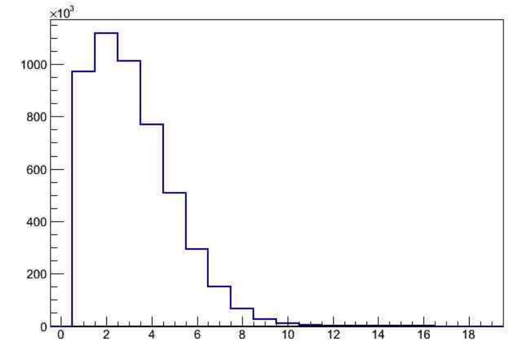
What's the connection?



The only verifiable case to connect hard and soft production per collision: p+p

Triggering and event characterization:
looking for activity (e.g. charged particle production N_{ch}, transverse energy E_T)
preferably **at a large rapidity gap with respect to the region of interest** (for simplicity let's take $|\eta|>>0$ and $\eta\sim0$)

Typical N_{ch} dist. close to the beam for average p+p



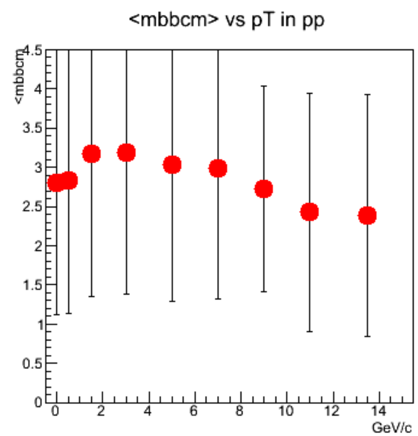
Now study those distributions as a function of the activity observed at $\eta\sim0$
"Activity" here is the **highest p_T for any particle seen around $\eta\sim0$**; could be jet energy, etc.
Can be done both in simulation and in data!

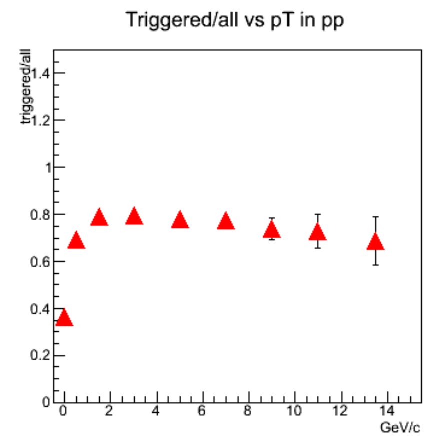
Mean and RMS of the N_{ch} dist. at large η vs max p_T in the center (η ~ 0)

Trigger efficiency vs max p_T in the center

However, at higher pT they start to drop slowly.
They have to, at least asymptotically, for simple kinematic reasons.

Note the characteristic rise initially (well-known: higher activity when hard scattering occurs)

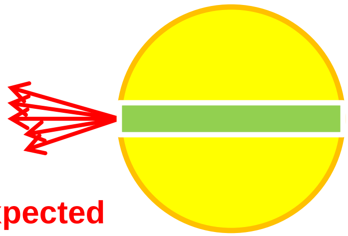




Of course ***other mechanisms can deplete*** forward activity ***way before kinematics*** does!

One plausible scenario: but is it true?

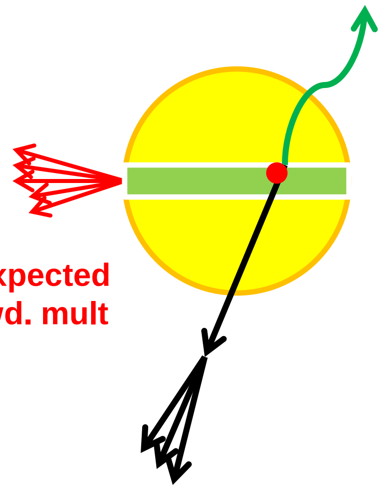
Here is your average,
higher centrality event



True b, N_{coll}

Expected
fwd. mult

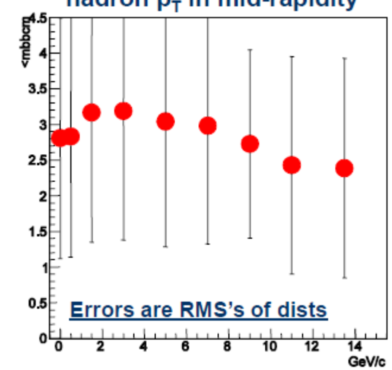
But now a very hard scattering happened (rare occurrence), with reduced fwd. response, therefore…



True b, N_{coll}

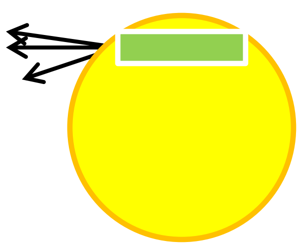
Expected
fwd. mult

Number of hits in BBC vs hadron p_T in mid-rapidity



…this is how you classify
the event…

Observed
fwd. mult

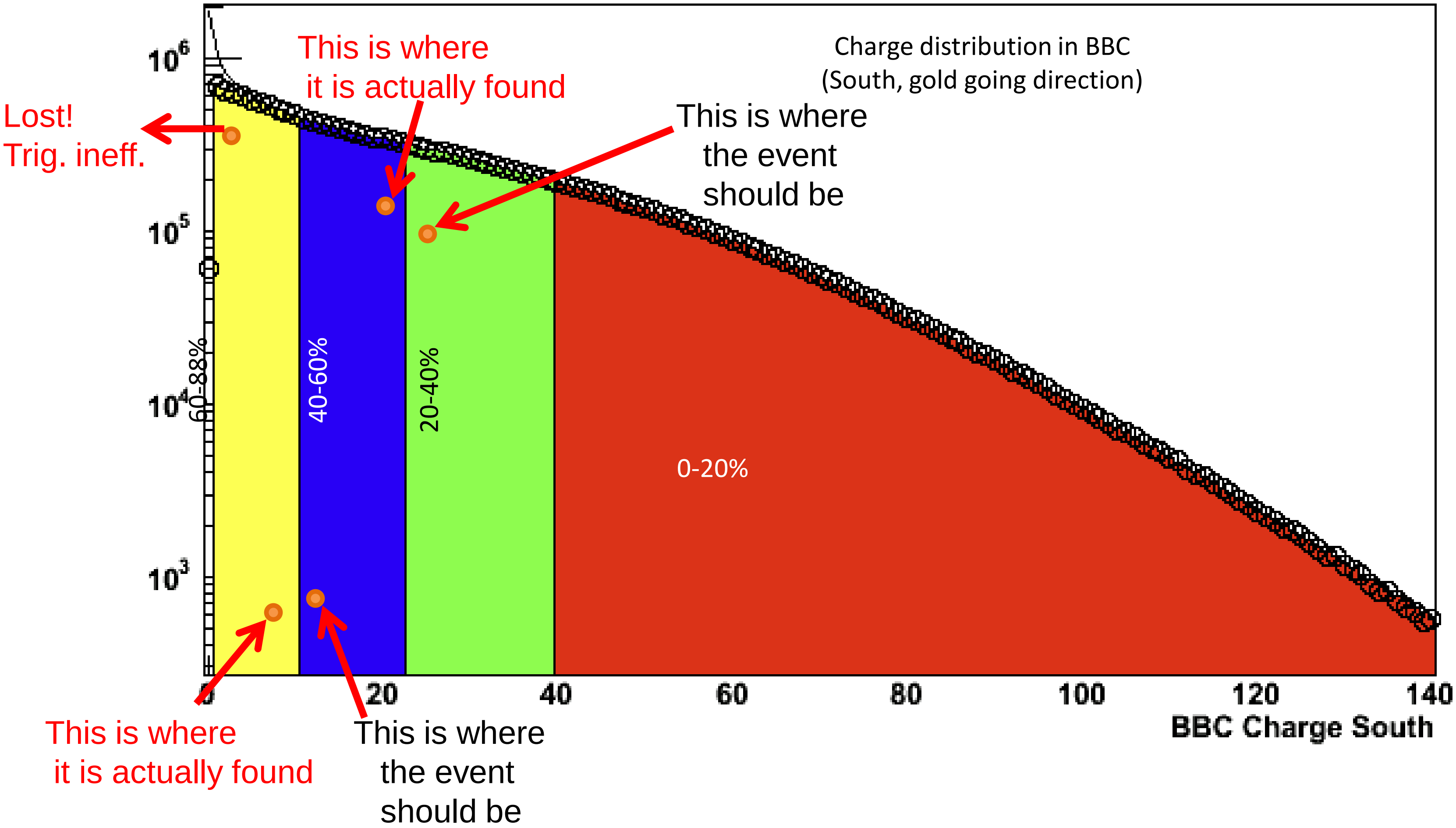


Percieved b, N_{coll}

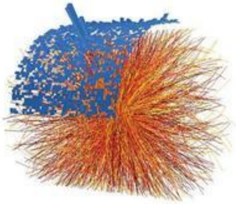
…and when you calculate R_{AA},
the denumerator ($N_{coll} * \sigma_{pp}$)
will be smaller than it should be
→ R_{AA} increases

(There can be other, even more serious effects)

Illustration: shift between multiplicity classes



If (experimental) centrality is determined with fixed (forward) multiplicity thresholds, irrespective of what happened at η~0, events may end up in the wrong centrality class – and attributed an incorrect <N_{coll}>



Some theoretical scenarios

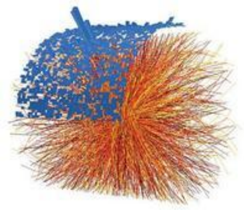
of what can happen with soft production
if a hard collision is present

Themes:

- color (cross-section) fluctuations

- bias toward high x → low-x part of the wavefunction depleted

- reduced soft response at/after hard collisions (semi-empirical)



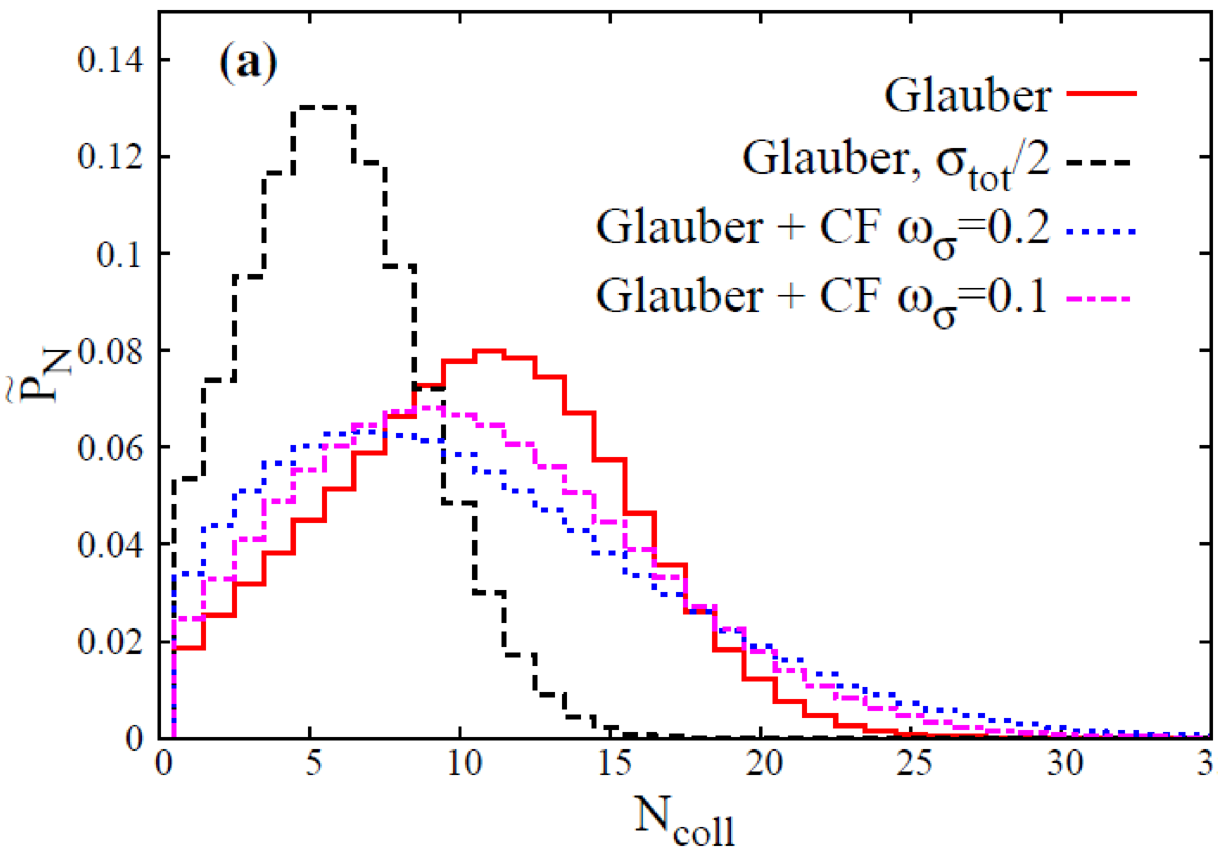
Cross-section fluctuations

Alvioli, Strikman, … 1301.0728, "flickering" 1402.2868

CF – color fluctuation model

ω_0 -- interaction strength param.

Probability of having N collisions, different cross-sections



What if σ is not constant?

What Glauber-Gribov says explicitely on changes in b-N_{coll} relations

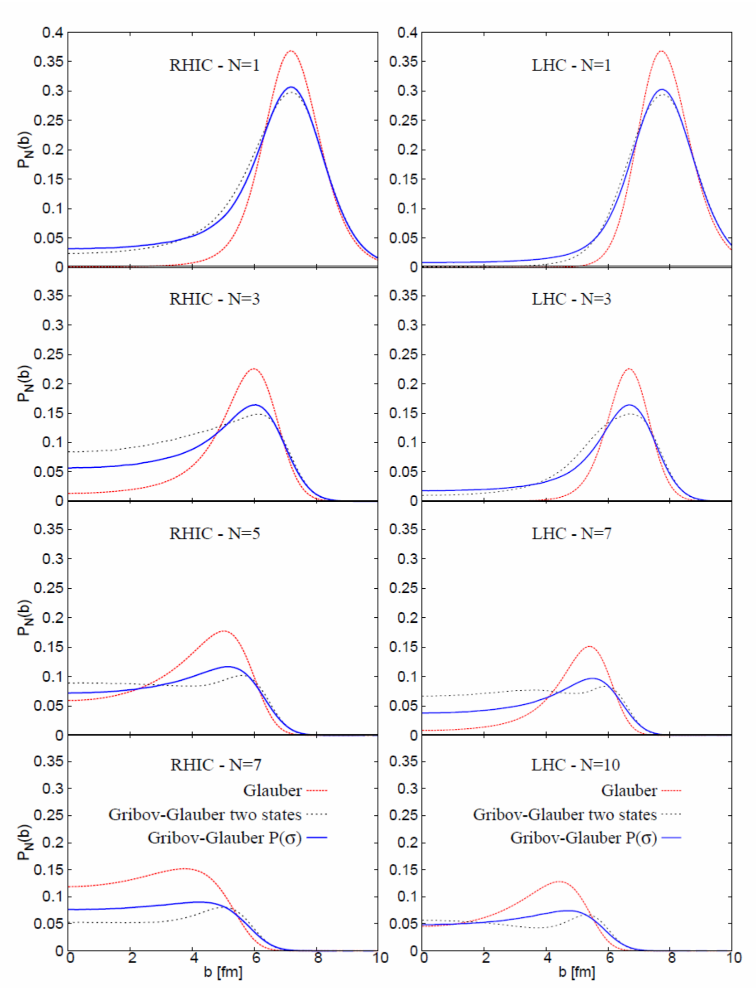


Figure 1: The probability $P_N(b)$ of having N inelastically interacting (wounded) nucleons in a pA collision, vs. impact parameter b, when using simple Glauber (red curves), a two states model (black curves) and a distribution $P_h(\sigma_{tot})$ (blue curves); *cf.* Eq. (16). The $P_N(b)$'s are obtained by extension of the MC code of Ref. [14] to include color fluctuations. Top row shows $P_{N=1}(b)$; the remaining panels correspond to $N = \langle N \rangle$ and $N = \langle N \rangle \pm 0.5\langle N \rangle$. $\langle N \rangle$ is taken as 5 and 7 for RHIC and LHC energies, respectively (*cf.* Table 1).

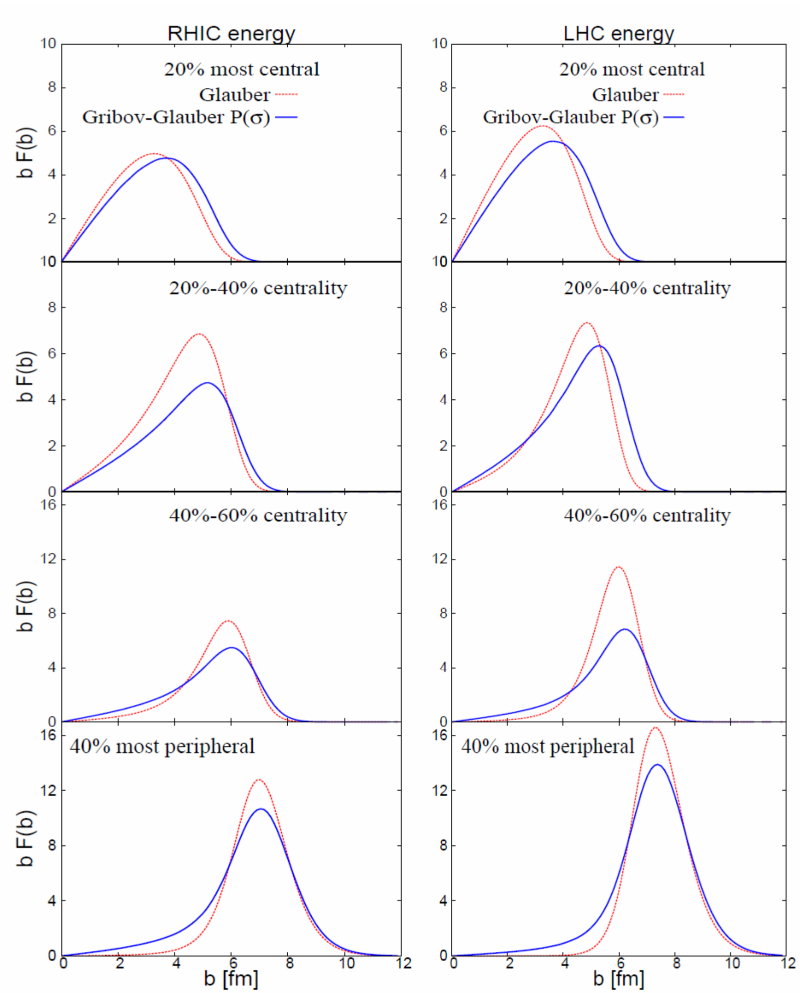


Figure 6: The distribution over impact parameter, calculated with our MC, of the different centrality classes 20% most central (first row), 20%-40% (second row), 40%-60% (third row), 40% most peripheral (last row), both for RHIC (left) and LHC (right) energies. Red: Glauber result; blue: Gribov - Glauber color fluctuations with $P(\sigma)$ distribution.

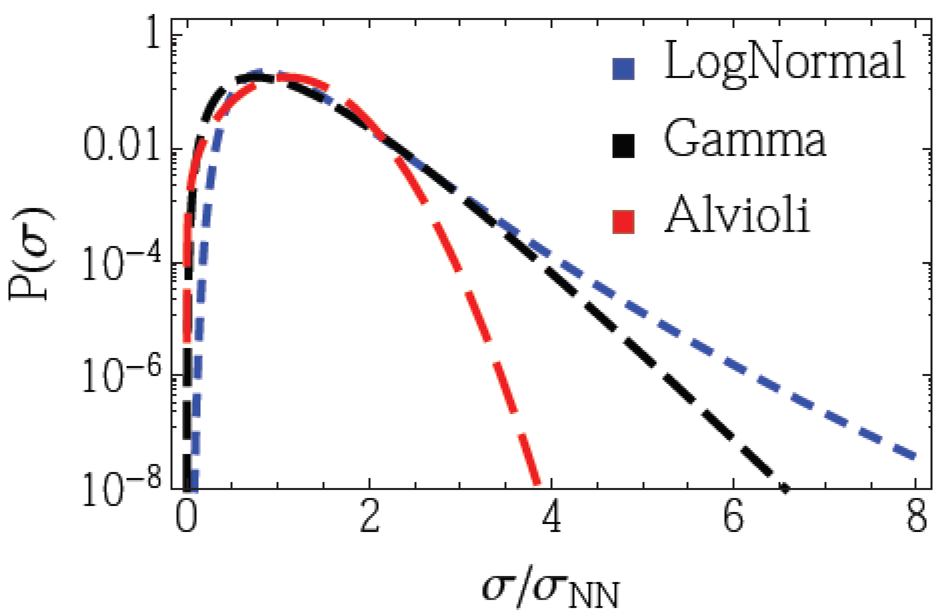
Phys. Lett. B 722 (2013) 347 (1301.0728)

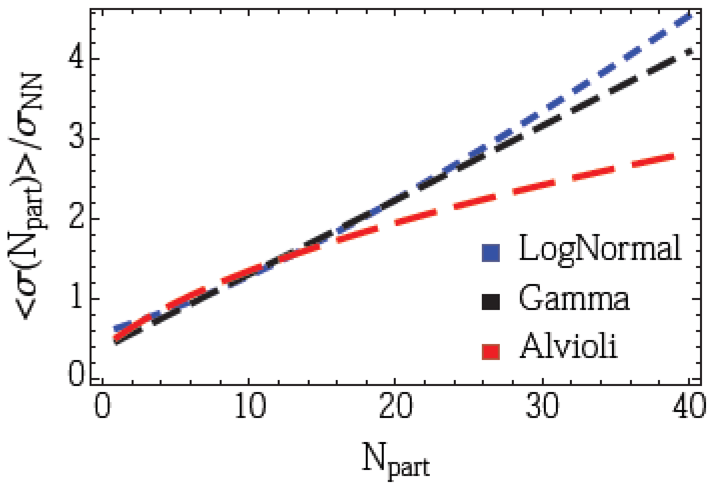
"Fat" protons

Coleman-Smith, Muller 1307.5911

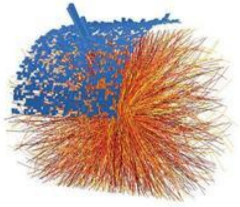
Triggered originally more by the ridge and apparent flow, and by justifying hydro in p+A, but relevant here, too

"*Fluctuations in the nucleon-nucleon cross section can induce large fluctuations in the number of participants in a central p+Pb event*."





Average cross-section fluctuations



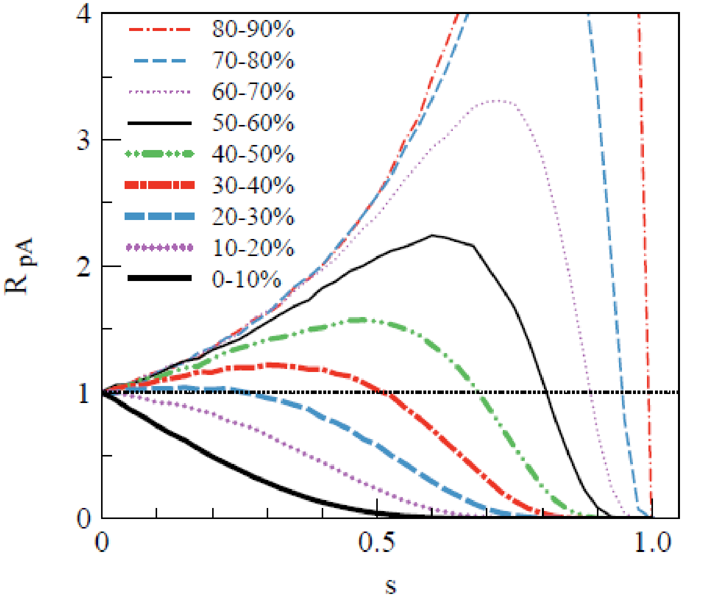
Bias toward high x – low x depleted

1408.3156, Bzdak, Skokov, Bathe *

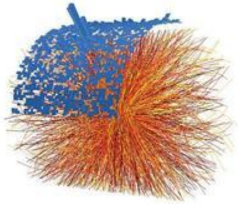
In the presence of a hard collision all collisions have reduced soft contribution
- the reduction factor "s" is energy dependent

Justification: a large-x parton is removed, reducing the number of low-x partons from splitting, which in turn are responsible for "soft" production

R_{pA} as a function of the soft response reduction factor "s"



* Similar (not identical) to what I've shown April 2013 at RBRC and September 2013 at Grenoble



A creative idea: count spectators!

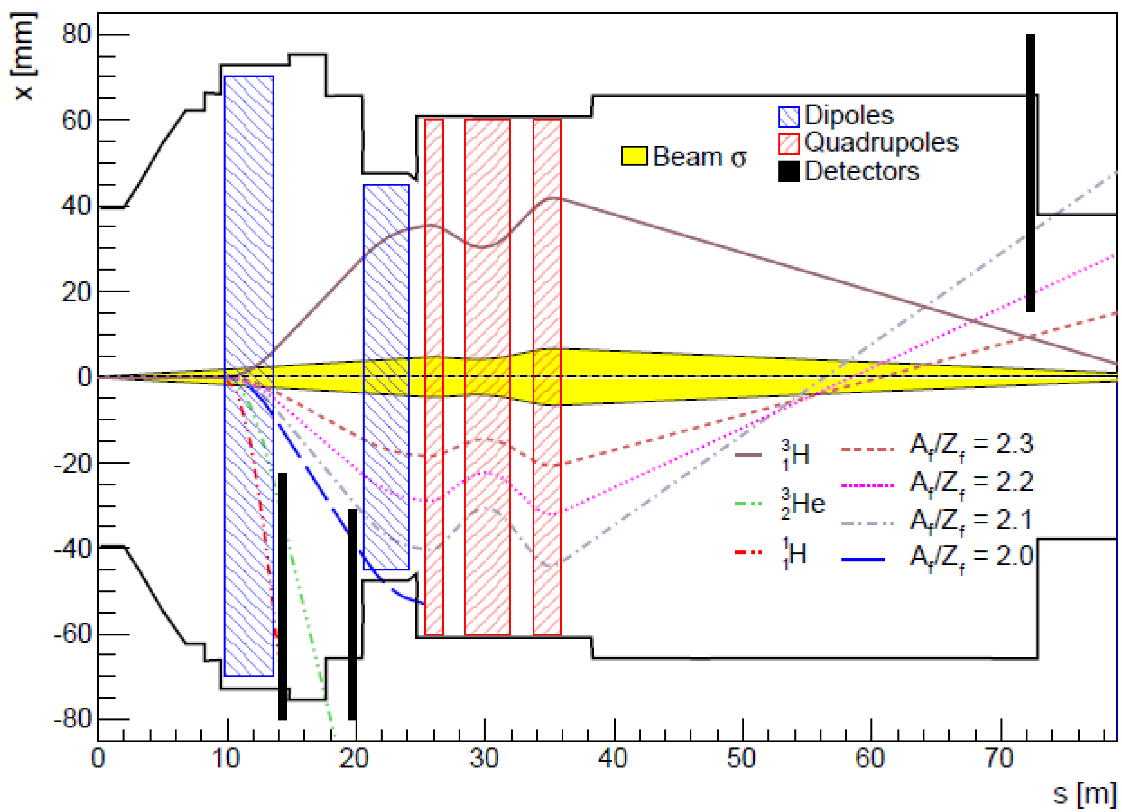
1405.4555 (Milov, Tarafdar, Zitron)

Advantages:
- model-independent to some extent
- presumably independent of the (hard) physics one measures in the collision

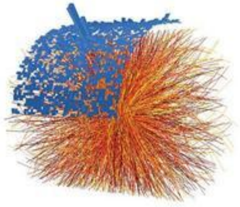
Relatively easy in fixed target, hard in collider

Strategically placed detectors catch different A/Z fragments

Backgrounds from
- the collision itself
- secondaries from fragments scattered off the beampipe, etc



No free lunch either, but a neat, fresh idea to a confoundingly complex problem!



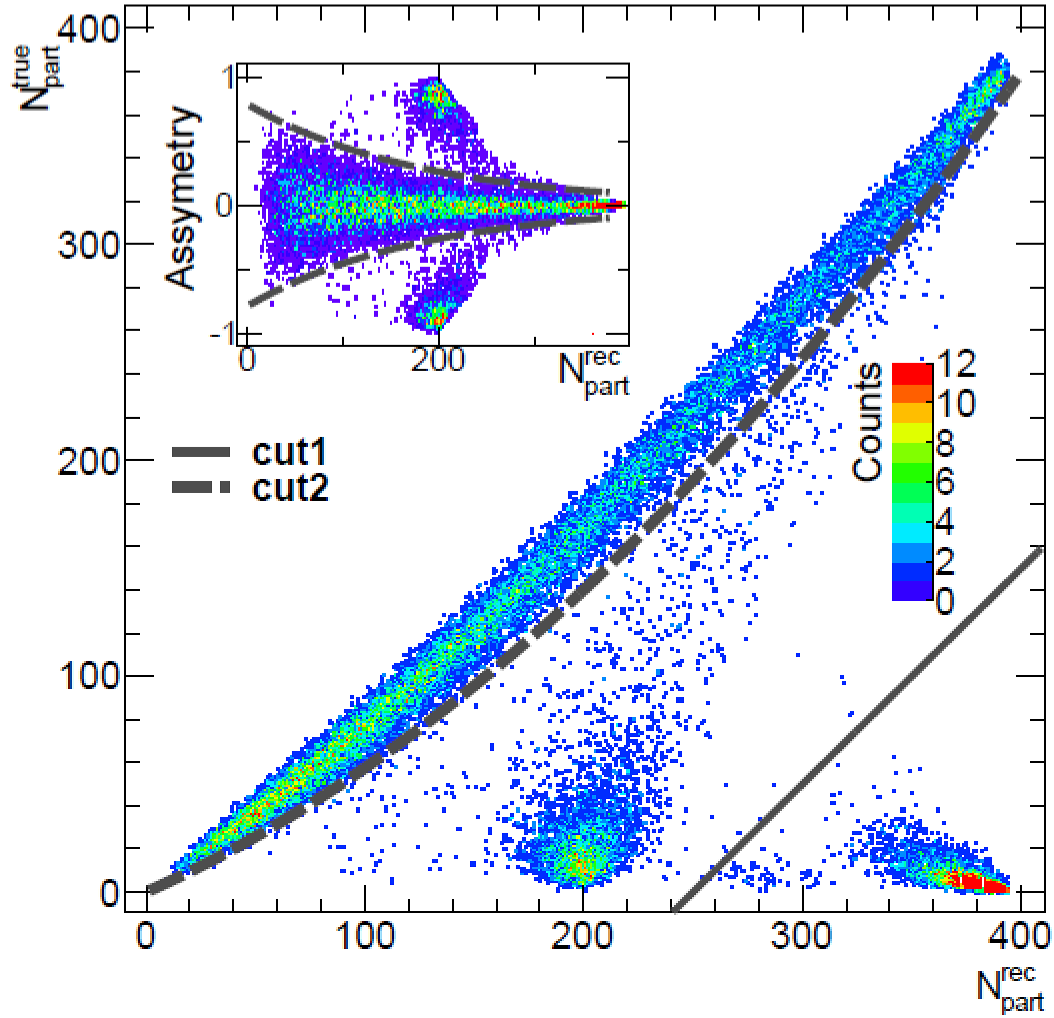
How well are participants restored?

Input: DPMJET, A+A

True vs reconstructed *participants*. Blobs near the x-axis come from inefficiencies of detecting *spectators*.

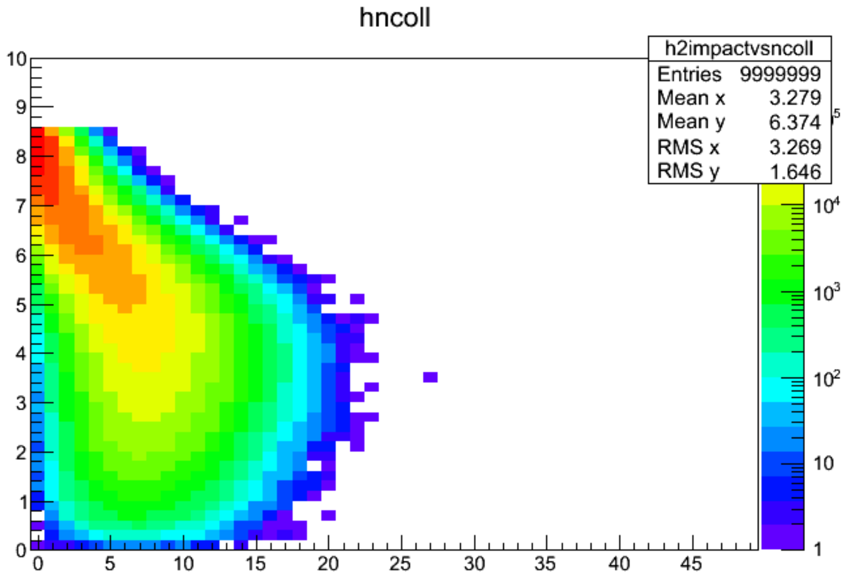
Even where the correlation is good, the number of true participants is slightly underestimated.

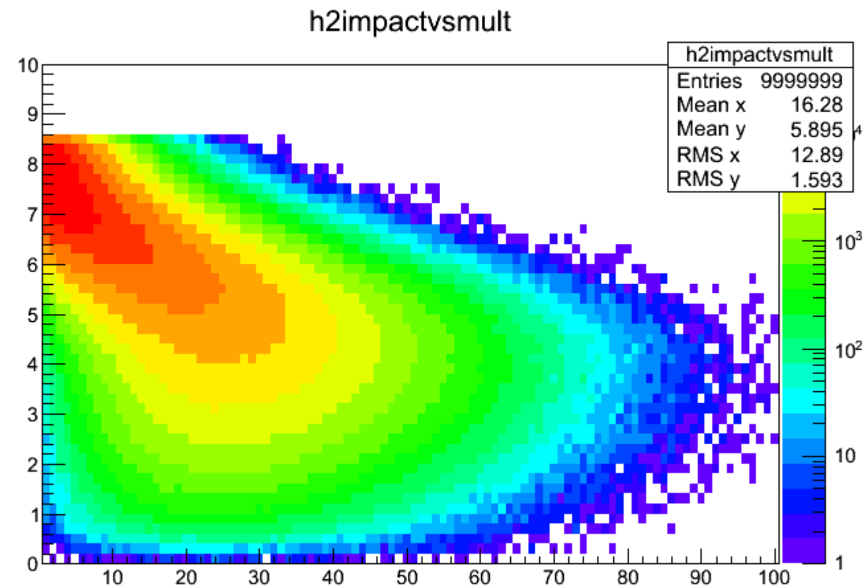
Asymmetry: ratio of reconstructed $N_{\mathbf{part}}$ in the two beam directions.



A trivial, confounding effect

Standard Glauber-model of pA collisions, real-life NBD distribution





Impact parameter vs N_{coll} Impact parameter vs multiplicity

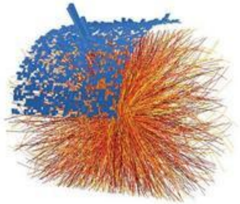
Selecting the highest N_{coll} events does NOT prefer b~0 (fluctuations and increased probability!)

Nor does the (experimentally accessible) multiplicity

Fluctuations win – putting truly b-dependent theoretical predictions in jeopardy

But the real trouble is, that all this depends on the NN cross section!

A large cross-section would restore a near-perfect anticorrelation, while a very small one would push it even more up (assuming the same NBD)



Why is this relevant?

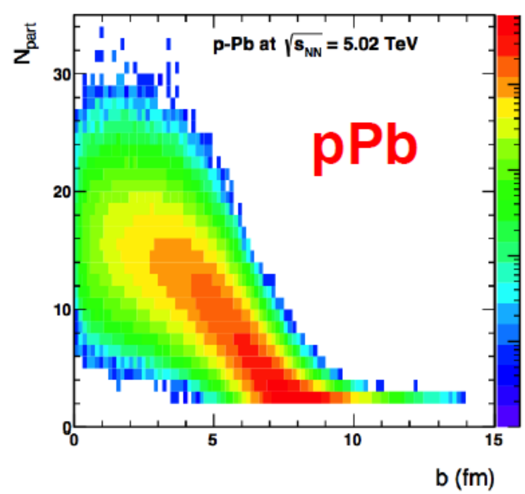
For more than a decade experiments keep finding special effects when looking at “top 5%” or even “top 1%” centrality. Those effects may – or may not! – be real (as opposed to a selection bias).

As we’ve seen, comparison to any theoretical quantity that is strictly “b”-based, is… problematic. On the other hand, even EPS09 relates “b” immediately to the nuclear thickness function, and implicitely to N_{coll}.

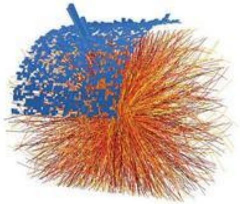
So if the overlap (→ N_{coll}) is the important physics quantity, and N_{coll} can be “measured” to some degree, there’s no problem, right?

To what degree?
($N_{part} = N_{coll} + 1$)

Not too well, but no show-stoppers so far.



(ATLAS simulation)

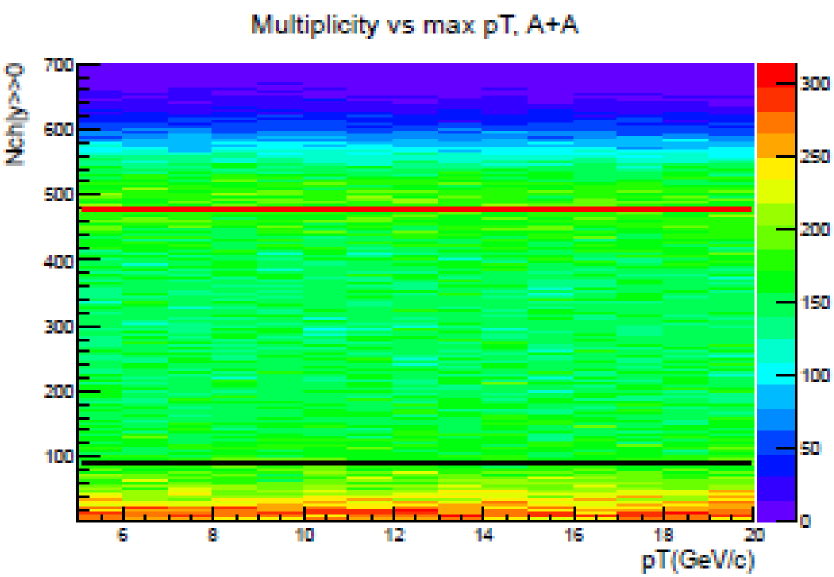


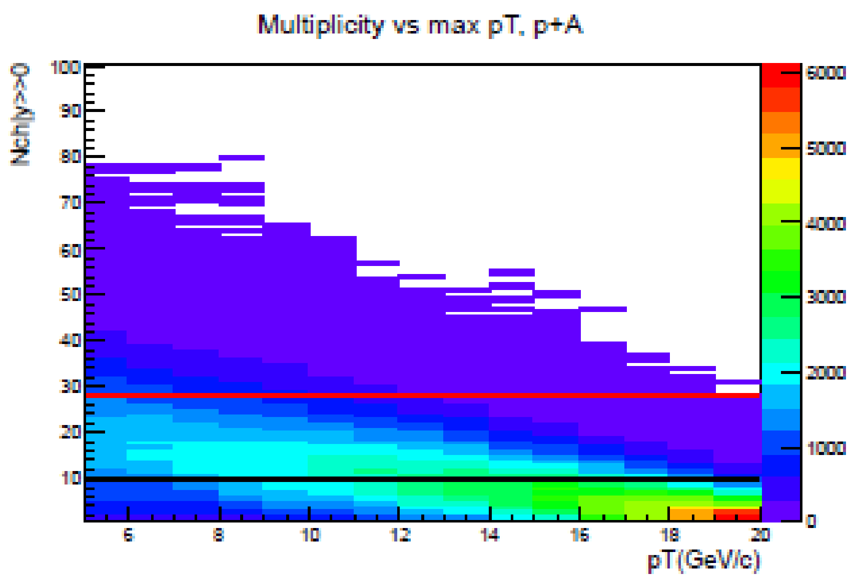
Centrality bias? A sanity check

Look at (forward) multiplicity vs highest p_T in the event
(not conclusive, but helpful)

A+A collisions:
- several/many nucleons on both sides,
  → "losing" one or two to hard scattering shouldn't noticeably change the overall soft production (rectangular shape)

p+A collisions:
- only one nucleon on one side
  → if it is involved in a hard scattering AND this reduces soft production, the highest multiplicities should be depleted (triangular shape)





(Uniform p_T dist. for emphasis)

Why suggestive, but not conclusive? / 1

p+A, same toy model: Glauber, NBD, but reduced response "after" a hard collision (whatever time ordering means)

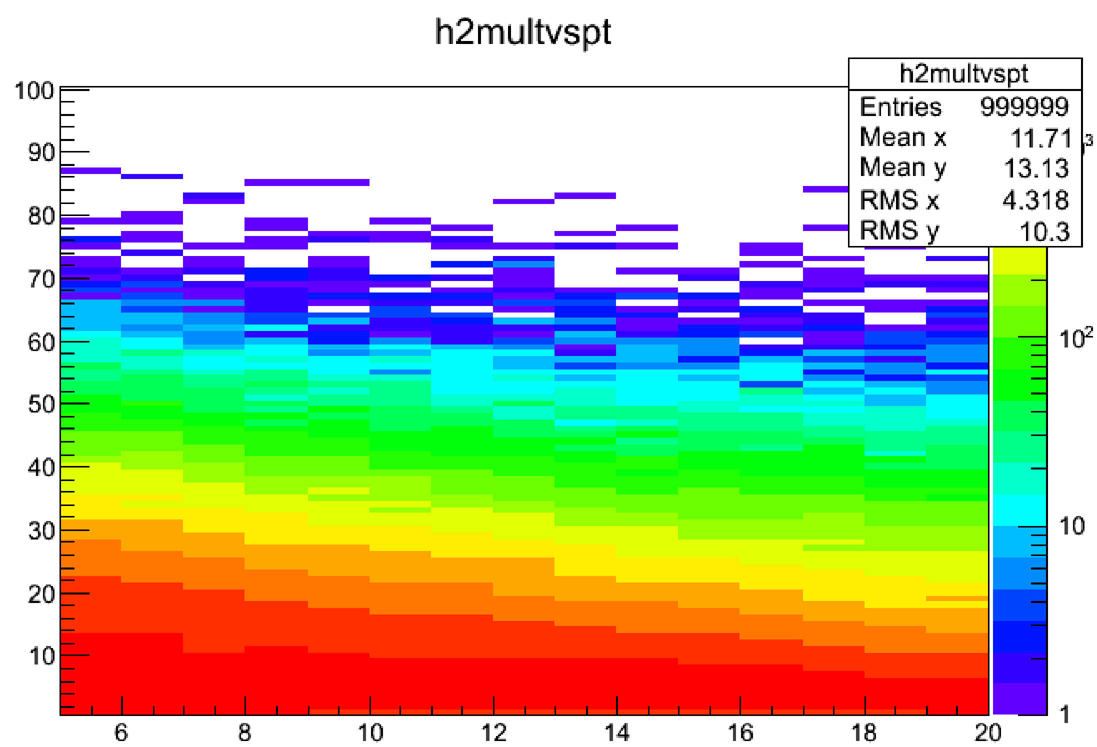
reduction in soft response depends on p_T

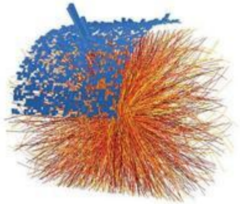
falling (but still not power-law) p_T spectrum

No suppression and unchanged soft response would still make a "rectangle".

If you had genuine suppression in central, and enhancement in peripheral, would you see a similar picture?

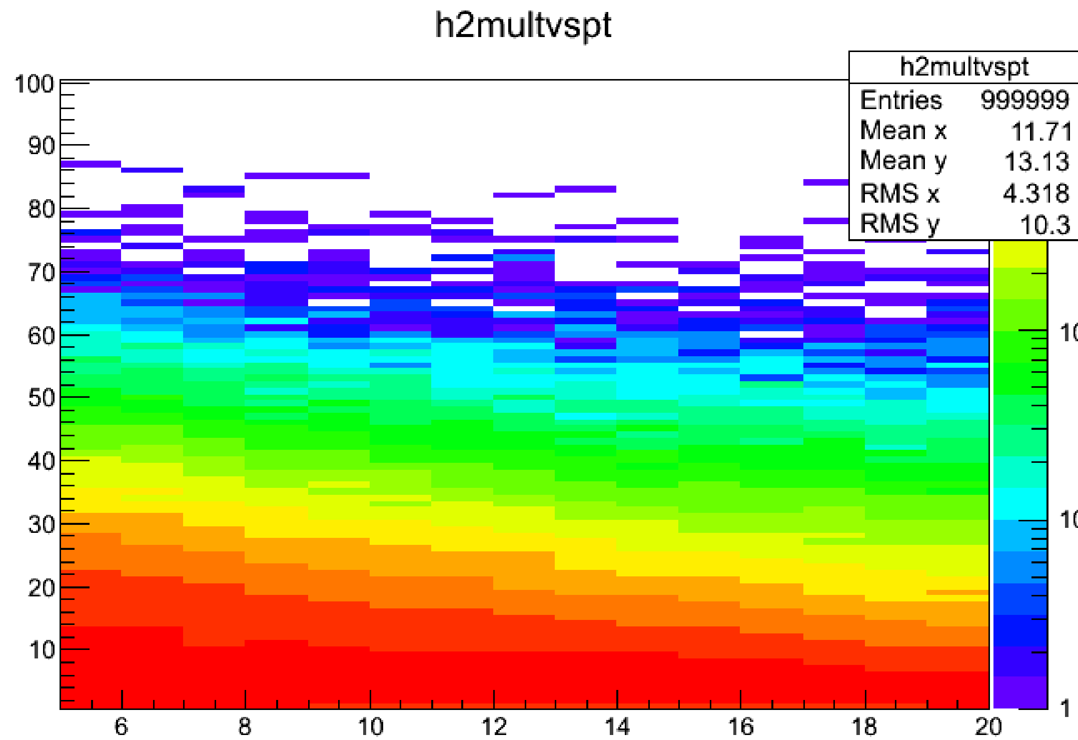
Important: you MUST define your centrality at low p_T, where statistics is large! No way to reasonably re-calibrate at arbitrary high p_T without serious model-dependence!





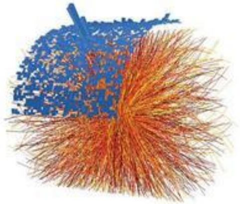
Why suggestive, but not conclusive? / 2

If you see a correlation like this (triangle), and set the centrality classes at low p_T (where you have statistics), you would interpret it as *monotonically increasing suppression* (decreasing R_{AA}) in central events.



Could be, in principle, but caused by what? In A+A, where you really have a medium, both for RHIC and LHC R_{AA} in this p_T regions already *bottoms out or even starts rising*.

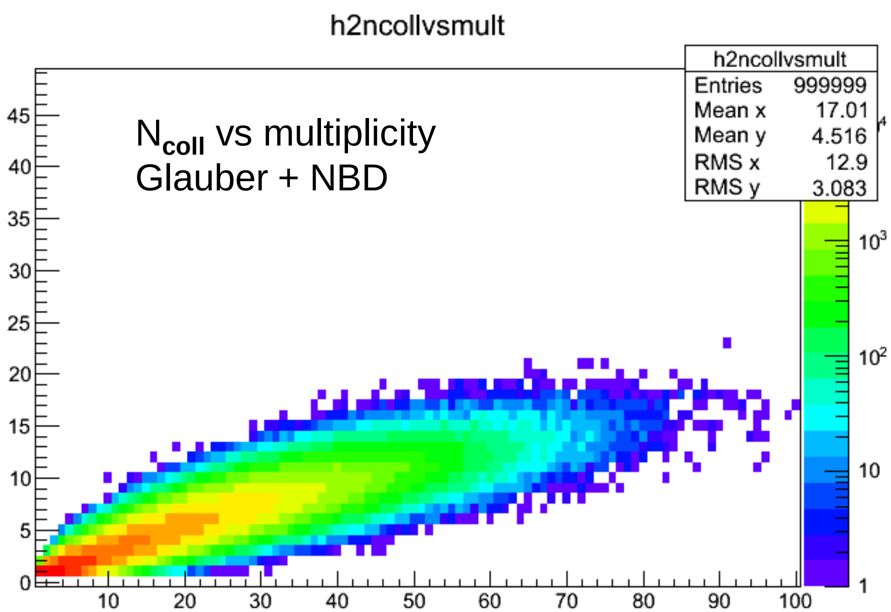
Occam: yes, there are *hints*, that tiny droplets of medium *might have been* formed. Should I rather believe that they cause energy loss that is *even more violent* than in huge A+A systems – or should I suspect that my event selection is *more and more biased*?

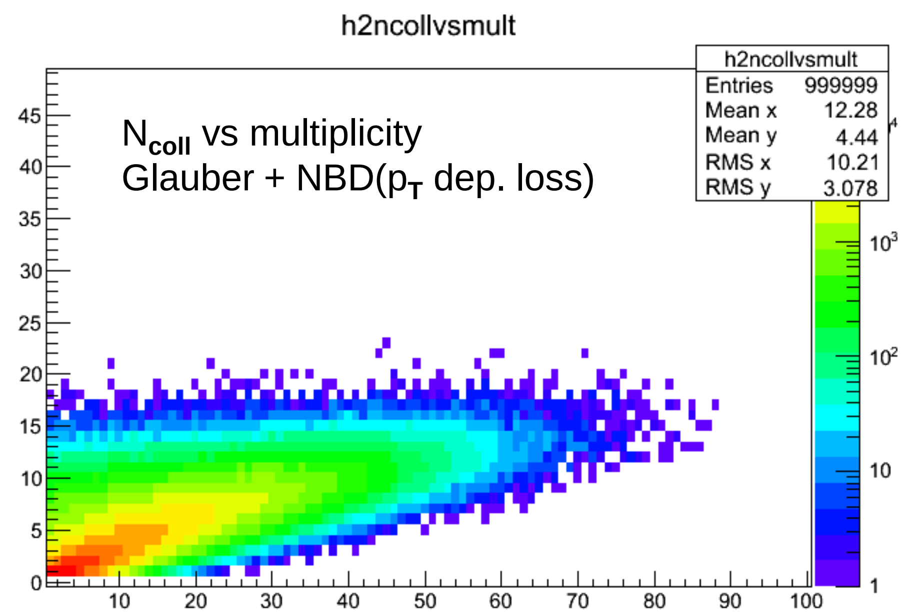


Estimating N_{coll}

p+A toy model, standard Glauber x NBD, and Glauber x p_T-dependent NBD. Soft production loss exaggerated to emphasize the important features

We had to give up on “b”, but N_{coll} is still correlated to multiplicity
Or is it?





In this model events with *very high N_{coll} can have extremely low multiplicities* (apparently peripheral)

Summary
(still more questions than answers)

Are we measuring cold nuclear effects in the nucleus,
or the properties of a nucleon – or yet something else?

Are very hard and soft processes really factorized in asymmetric collisions?

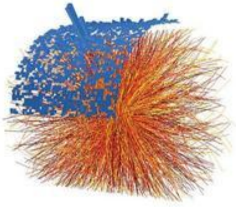
Which fluctuations dominate? Those of N_{coll}, or of the soft response (NBD)?

Look at *multiplicity vs max p_T correlations*… Also with various rapidity gaps.
They may be one key!

Be cautious about signals that show up prominently in an extreme centrality bin – but completely absent in minimum bias!

If the surprise observations are really dominantly come from the proton,
that's exciting, *unique possibilities out of reach in p+p*,
but as for cold nuclear matter, we may well *learn more at EIC…*

Centrality (a loaded word!) is not necessarily the same, as the observable event activity; just as "flow" – suggesting an underlying dynamics – is not the same as "azimuthal anisotropy". I think it is important to free ourselves from the implied, subtle biases.



Backup