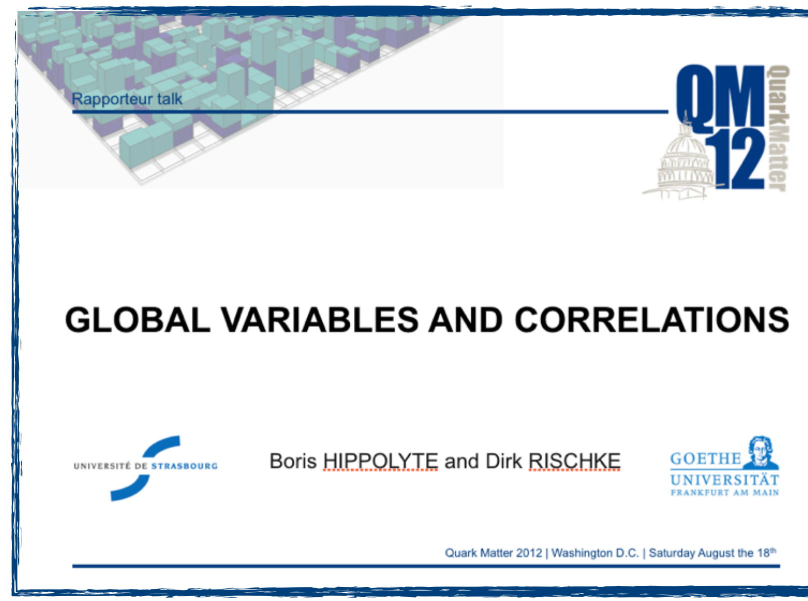
REVUE RÉSULTATS SAVEURS LÉGÈRES (QM 2012)



UNIVERSITÉ DE STRASBOURG
Boris HIPPOLYTE
IPHC Institut Pluridisciplinaire Hubert Curien Strasbourg

OUTLINE

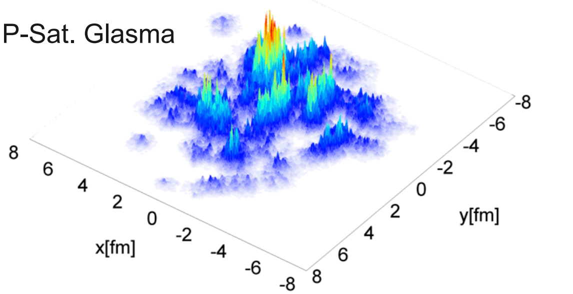
- Initial conditions and fluctuations;
- Measurements constraining the longitudinal expansion;
- Azimuthal anisotropy ($v_{n=1\text{-}7}$), BES to ultra-central LHC events;
- Number of constituent quark scaling: energy validity range;
- Event shape engineering;
- Current modeling of the system evolution;
- Developments to model the “interface” of the system evolution;
- Chemical freeze-out, hadrochemistry and L_{QCD};
- Hadronization (recombination, radial flow and kinetic freeze-out);
- Correlations
- Summary and outlook

INITIAL CONDITIONS AND FLUCTUATIONS...

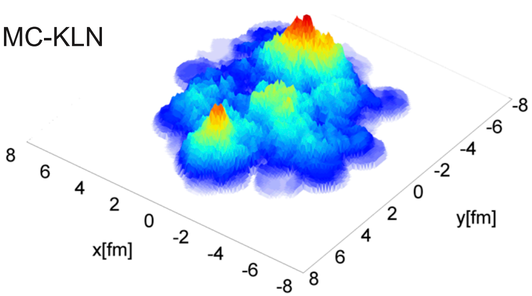
- cross roads: state-of-the-art modeling of initial conditions meets extremely precise experimental measurements of fluctuations !

Initial energy density (arb. units)

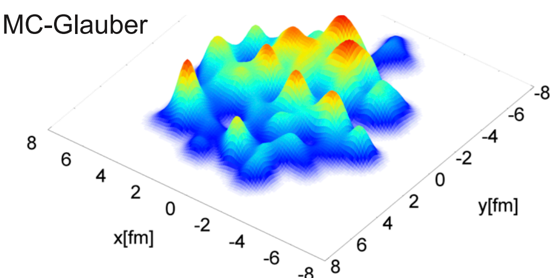
IP-Sat. Glasma



MC-KLN



MC-Glauber



B.Schenke, P.Tribedy and R.Venugopalan, Phys. Rev. Lett.108, 252301 (2012)

Spectacularly good level of agreement:

Talk of B.Schenke: 3A

“real QM time” matching of EbyE P($v_{n=2-4}$) vs. $v_{n=2-4}$ by ATLAS

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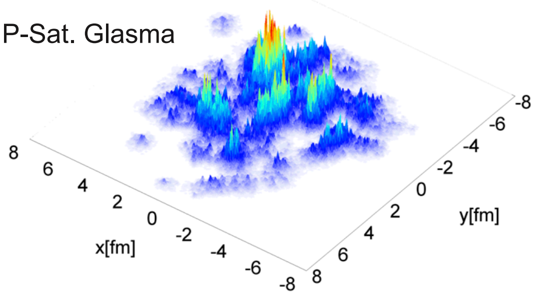

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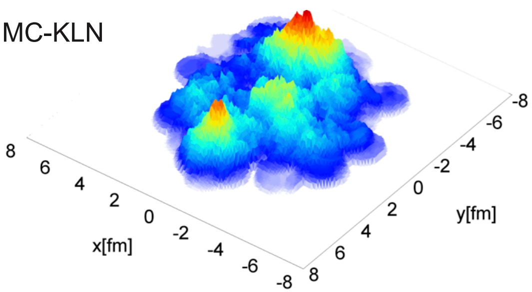

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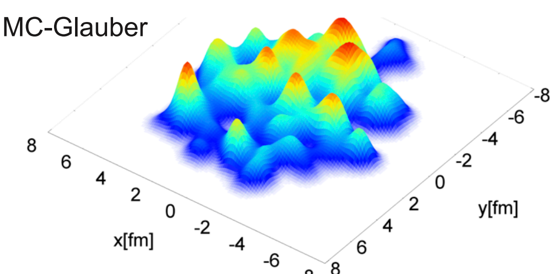

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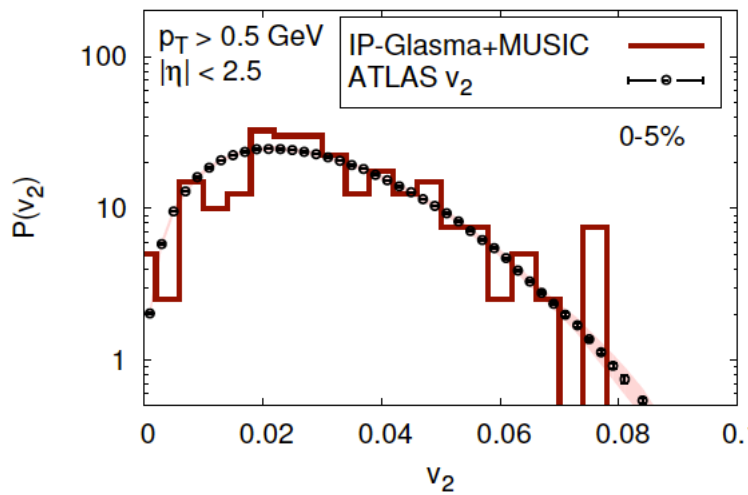

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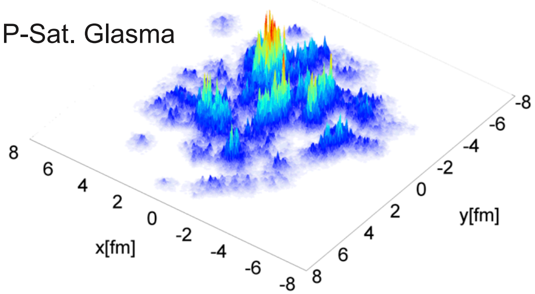

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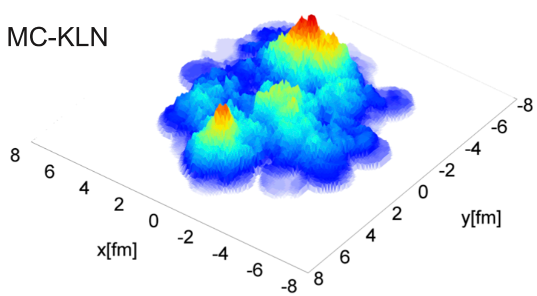

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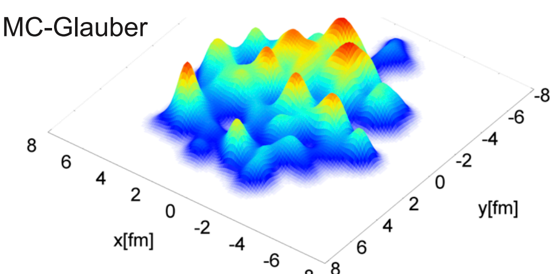

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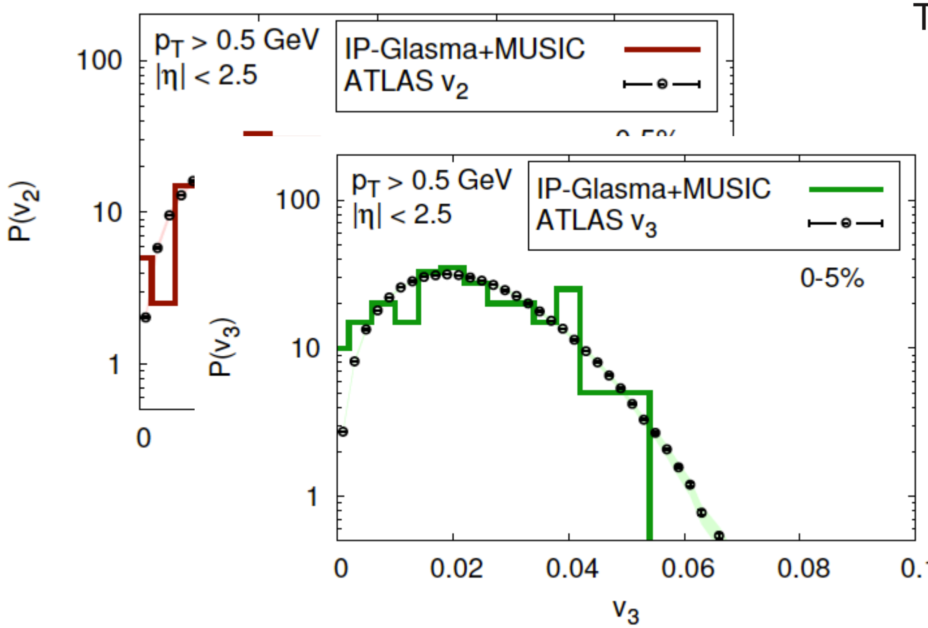

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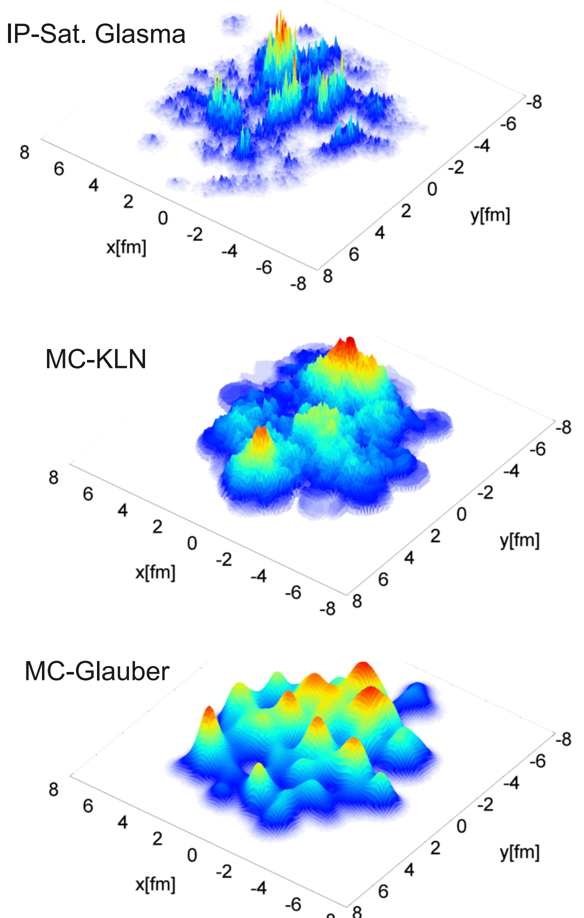

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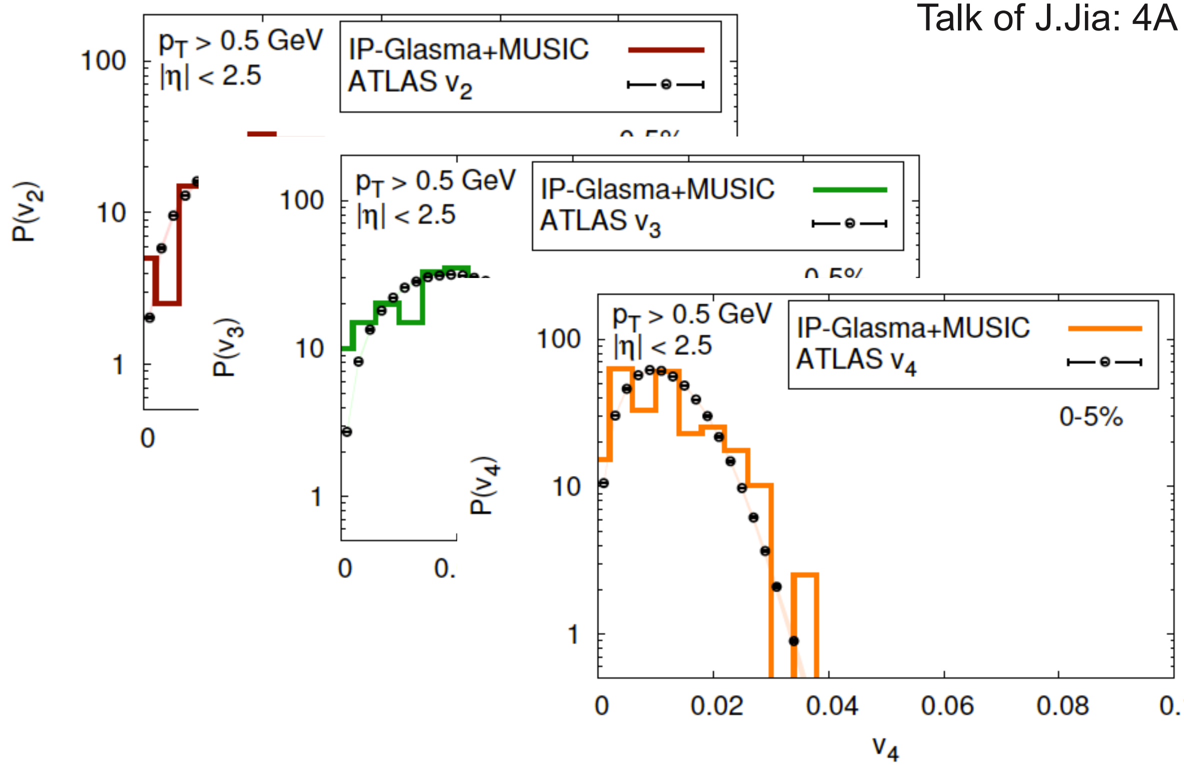

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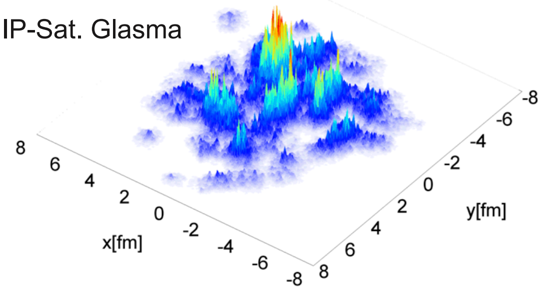

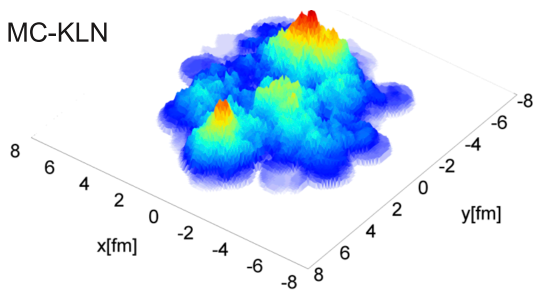

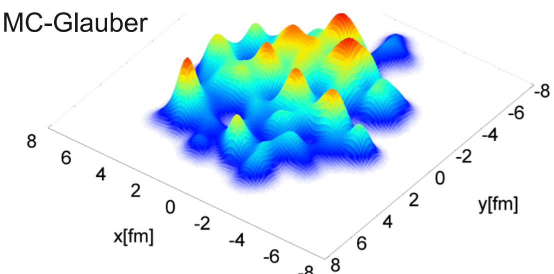

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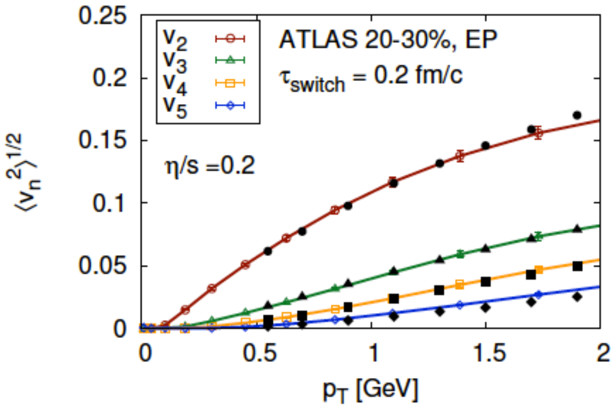
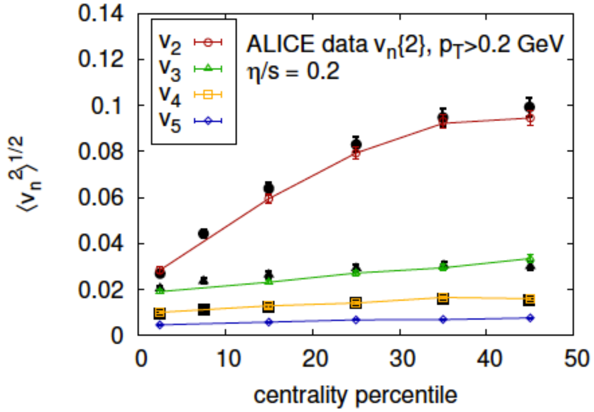
η/s=0.2 (using MUSIC hydro and matching ATLAS & ALICE v_n)





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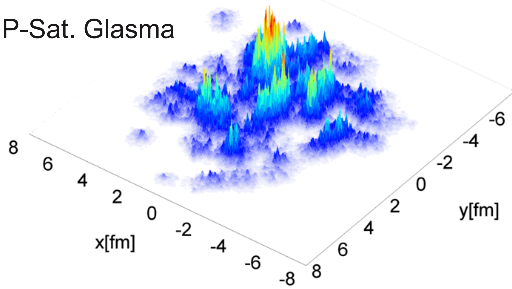

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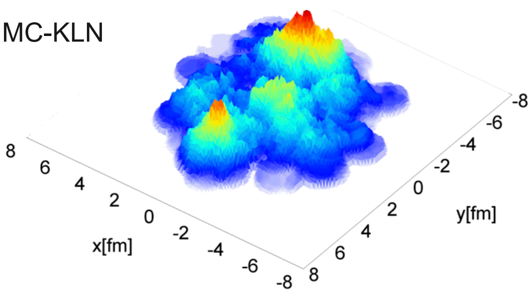

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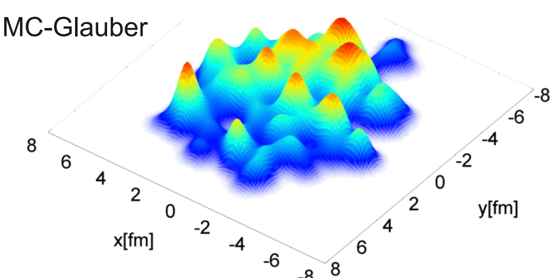

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Talk of J.Jia: 4A

$\eta/s=0.2$ (using MUSIC hydro and matching ATLAS & ALICE v_n)

Consistent results: shear viscosity / entropy density

quantification of syst. uncertainties when extracting η/s
“conservative” $0.07 \le \eta/s \le 0.43$

Talk of M.Luzum: 2A

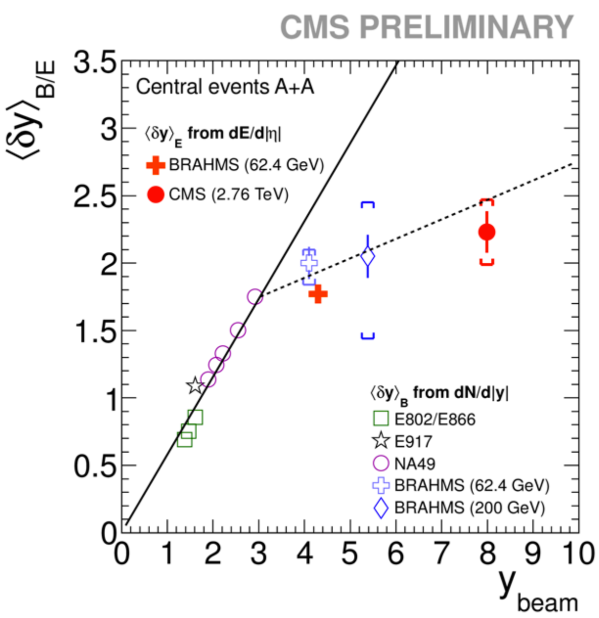
Additional and fresh constraints: from Ultra Central Collisions (2‰) by CMS: b<2 fm and $v_{n=2\text{-}6}\{2,\Delta\eta>2\}$

Talk of S.Tuo: 7D

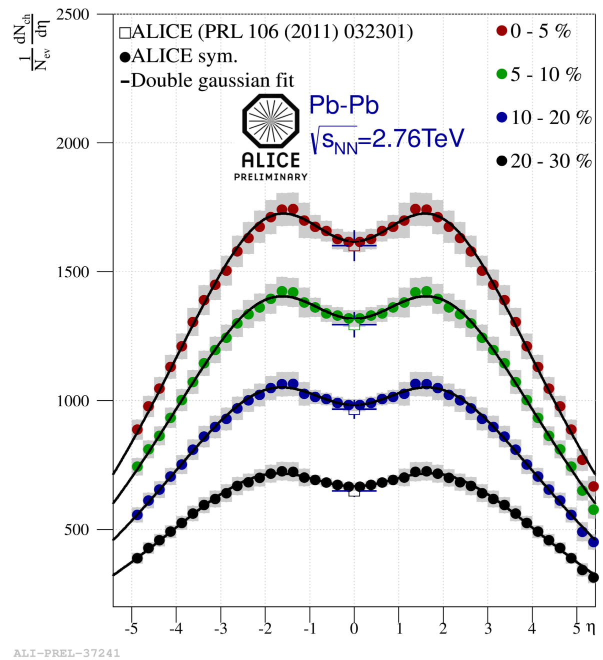
... MORE EXPERIMENTAL CONSTRAINTS...

- excitation function of nuclear stopping power;
- charge particle pseudorapidity density;
- transverse energy pseudorapidity density and excitation function;

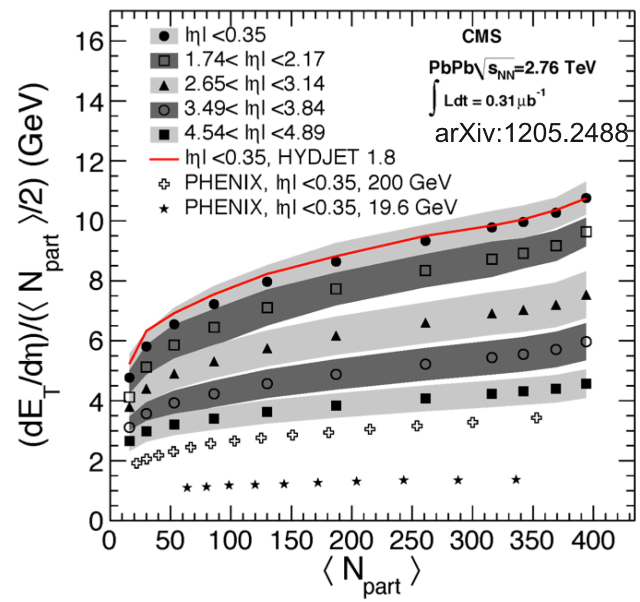
Talk of H.Wöhrmann: 3D



Talk of M.Guilbaud: 2A



Talk of M.Malek: 2A



Longitudinal constraints even if final state measurements...

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- excitation function of nuclear stopping power;
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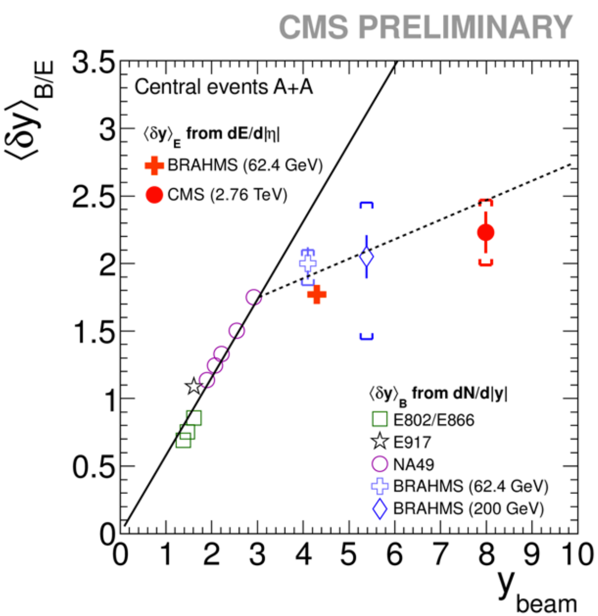

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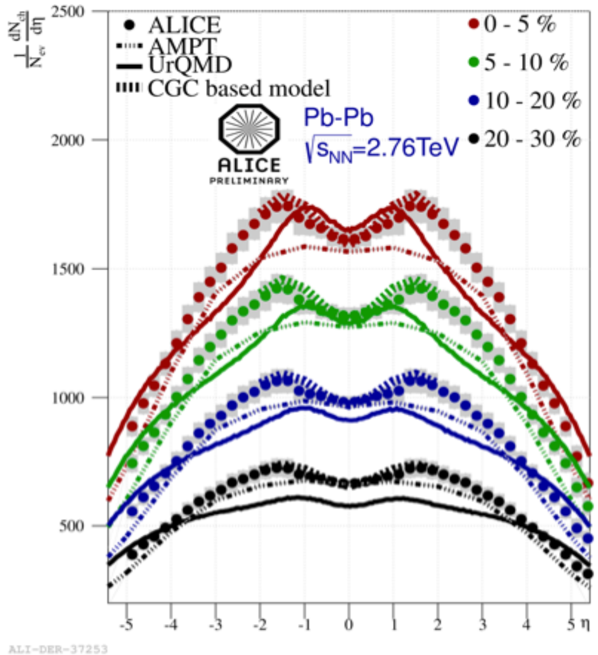

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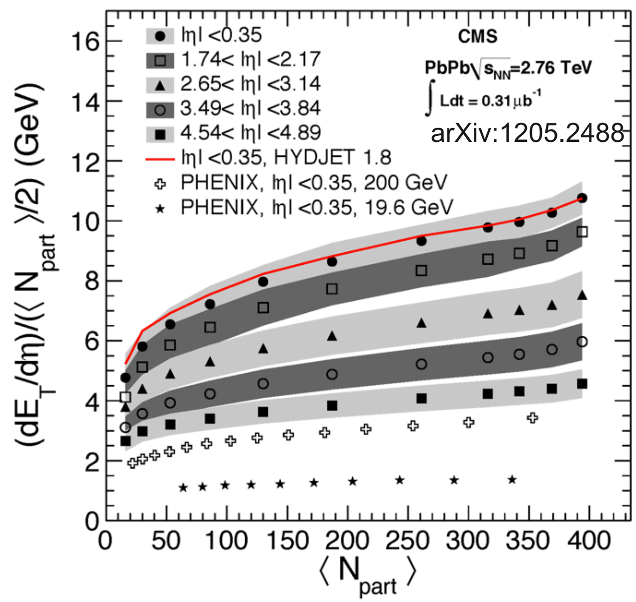

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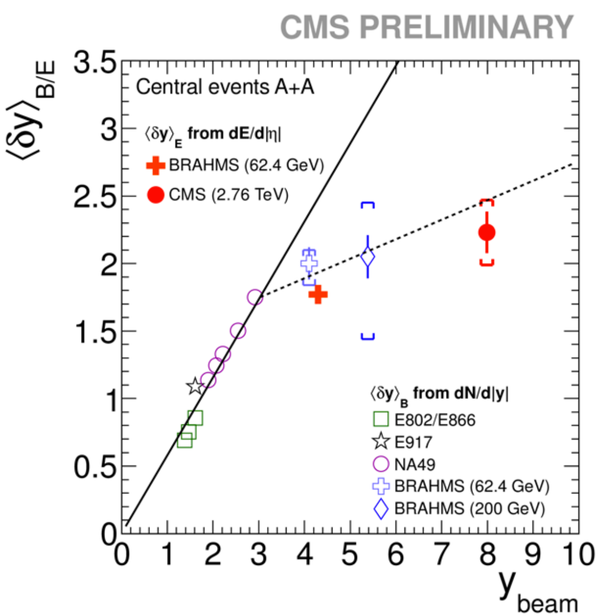

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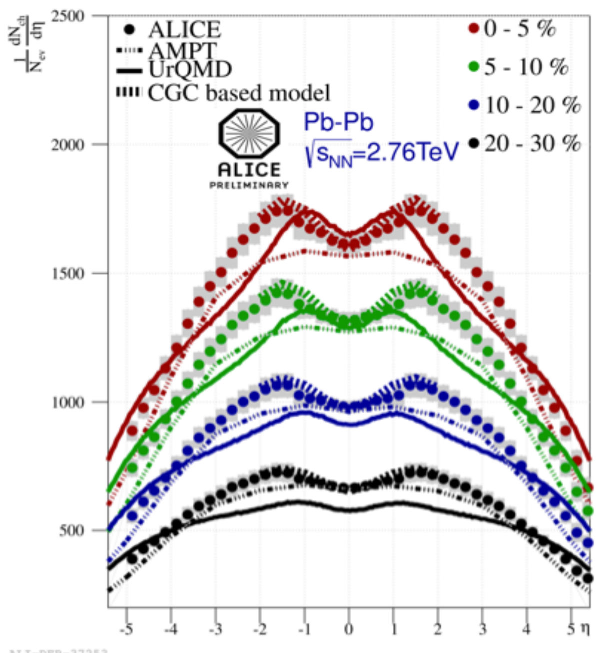
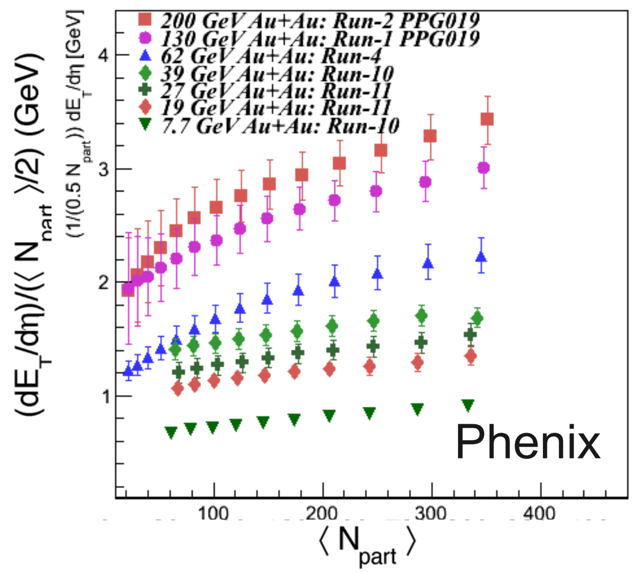


Talk of M.Malek: 2A

Talk of E.O’Brien: Plenary VA



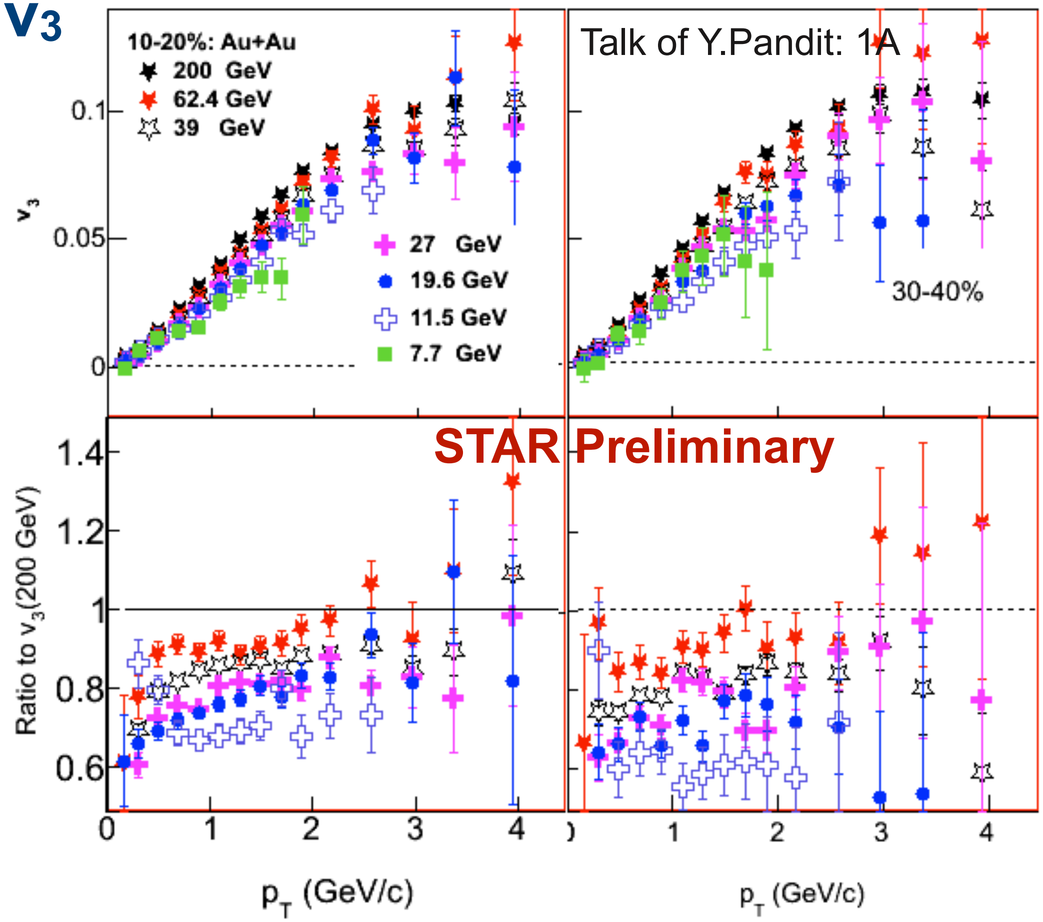
Longitudinal constraints even if final state measurements...

Rencontres QGP-France-12
Étretat 25-28 sept. 2012

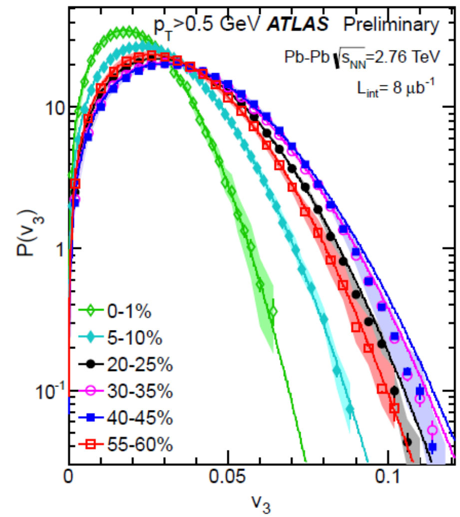
... ON FLUID-DYNAMICS: AZIMUTHAL ANISOTROPY

- starting from the **Beam Energy Scan at RHIC** then constraining further with **LHC measurements**...

v_3



E-by-E $v_{n=2-4}$ distributions



Talk of J.Jia: 4A

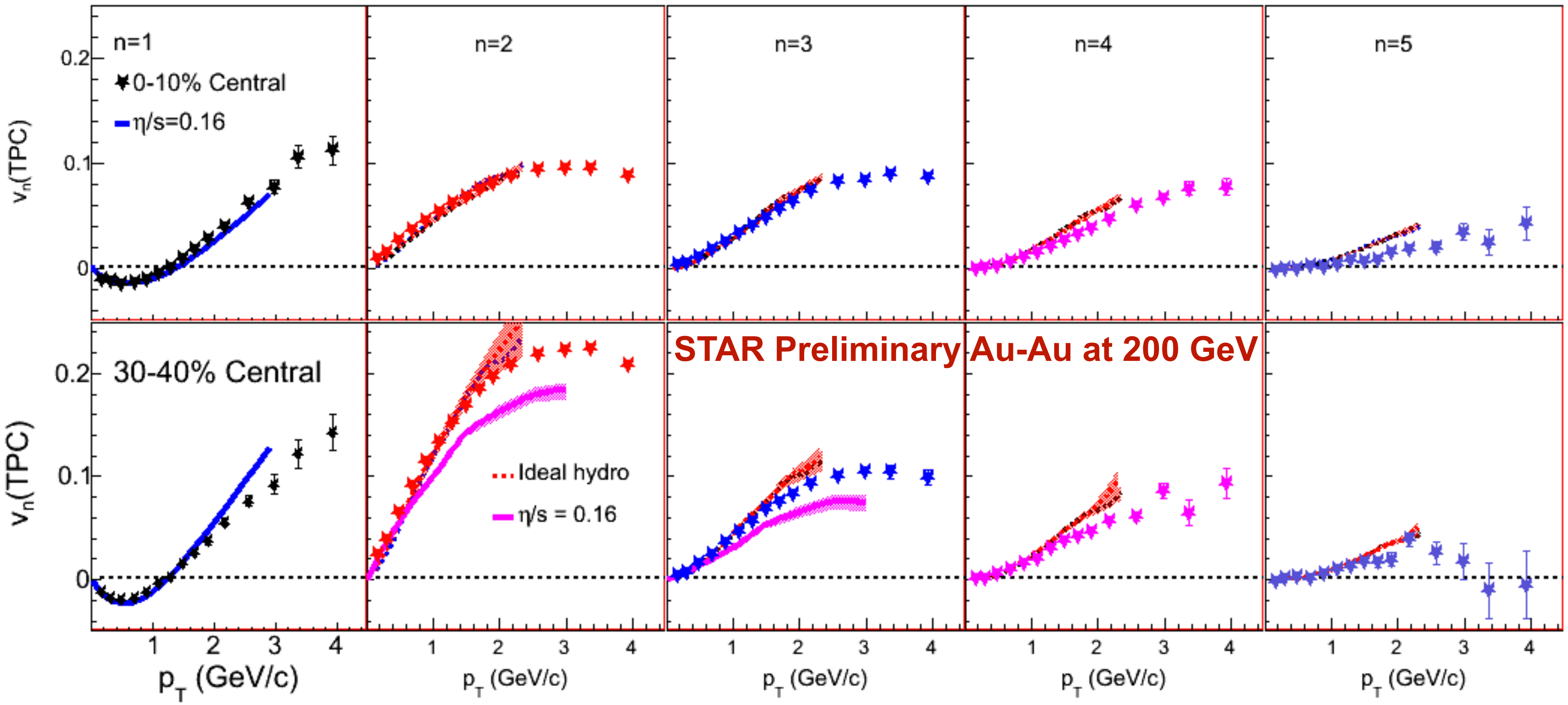
v_3 (p_T) from the BES systematically lower than 200 GeV values.

... ON FLUID-DYNAMICS: AZIMUTHAL ANISOTROPY

- to higher order harmonics at top RHIC energy ... $v_{n=1-5}$

Models by: (n=1) Retinskya *et al.*, PRL 108, 252302 (2012),
(n=2,3) Schenke *et al.*, PRL 106, 042301 (2011),
(n=2-5) Gardim *et al.*, arXiv: 1293.2882.

Talk of Y.Pandit: 1A



Low viscosity (η/s~0.16) is always favoured

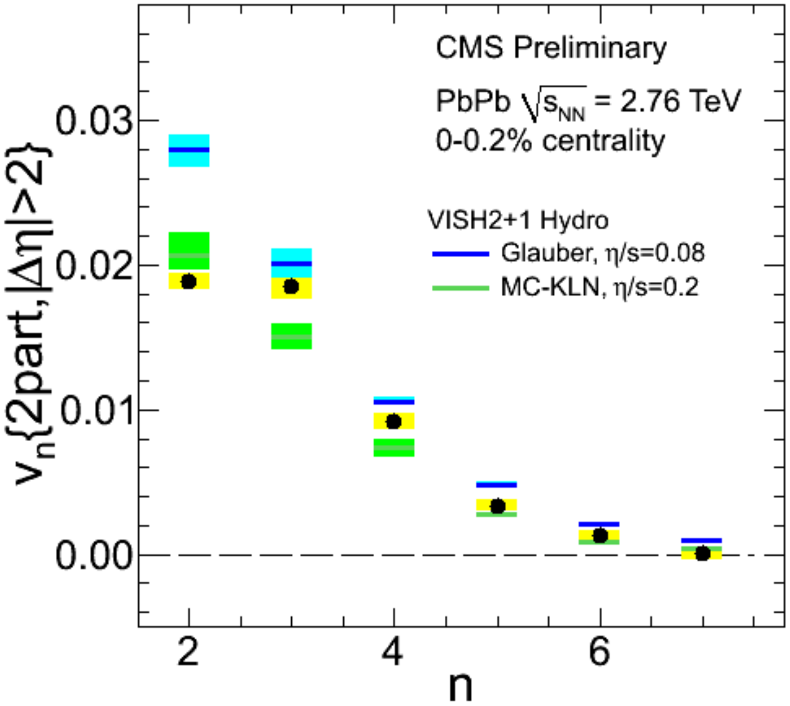
... ON FLUID-DYNAMICS: AZIMUTHAL ANISOTROPY

- up to Ultra Central Collisions (2‰) from CMS $v_{n=2-7}\{2\}$

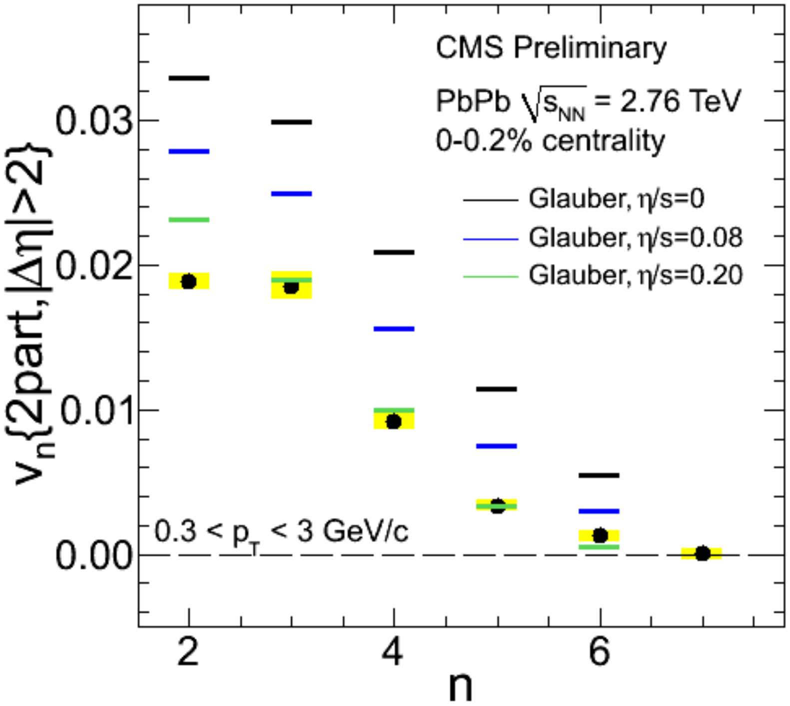
Talk of S.Tuo: 7D

Poster of W.Li: 242

Calculation by U.Heinz *et al.*



Calculation by M.Luzum *et al.*



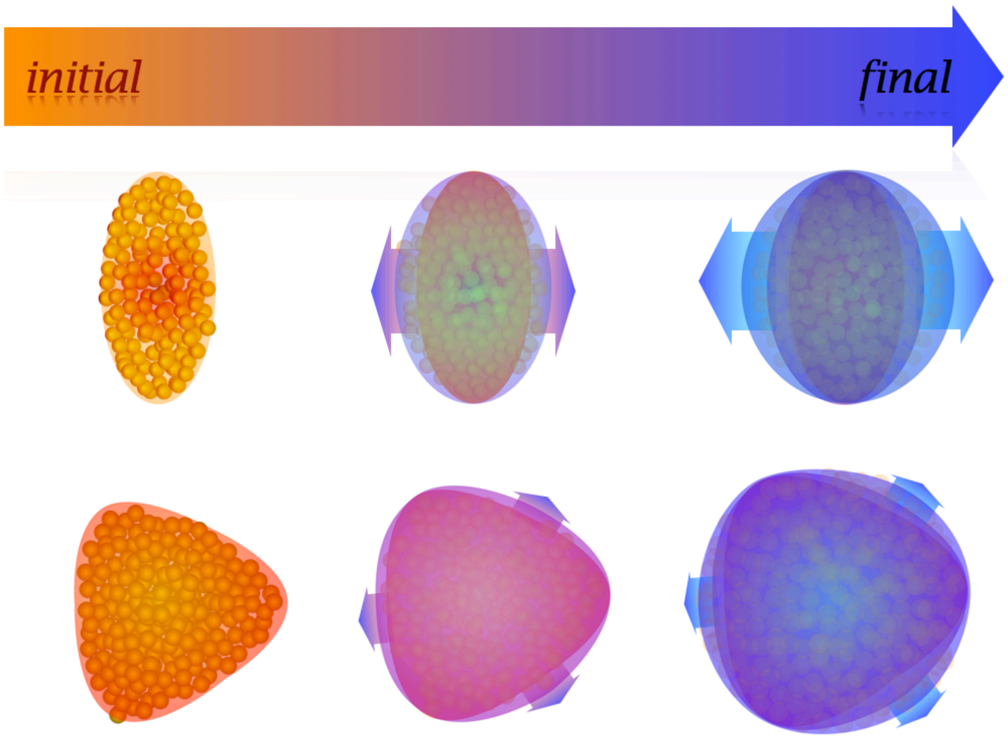
Would be interesting if IP-Glasma can also here reconcile v_2 and v_n with a single η/s...

Rencontres QGP-France-12
Étretat 25-28 sept. 2012

SUMMARIZING: AZIMUTHAL ANISOTROPY

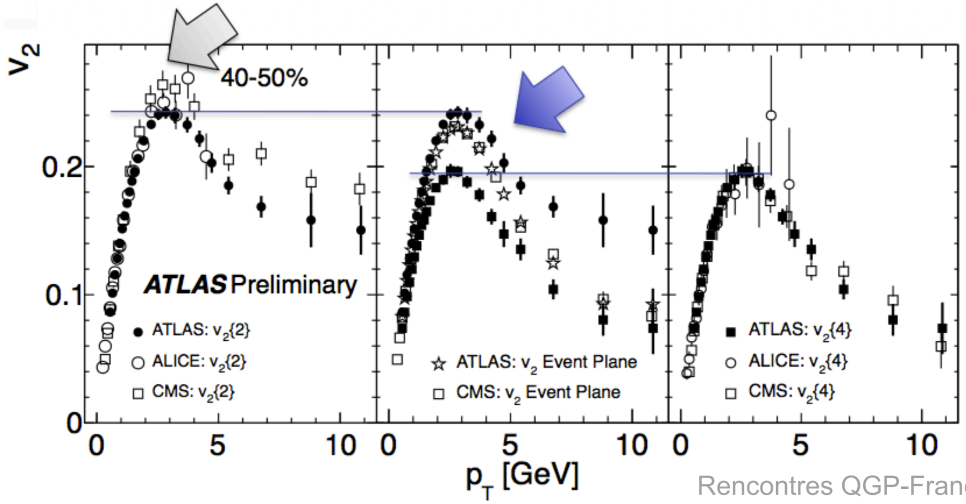
- Many measurements from BES at RHIC up to LHC energies: strong constraints on our understanding of the QGP: how these fluctuations survive the evolution ?

Talk of T.Niida: 1C



SUMMARIZING: AZIMUTHAL ANISOTROPY

- Many measurements from BES at RHIC up to LHC energies: strong constraints on our understanding of the QGP: how these fluctuations survive the evolution ? — Talk of T.Niida: 1C
- Possibility to measure v_n E-by-E distributions at the LHC; — Talk of J.Jia: 4A
- Low viscosity (η/s~0.16) is always favoured when comparing with models; — Talk of Y.Pandit: 1A
- CMS provides $v_{n=2\text{-}7}$ (2-part cumulant) for Ultra-Central Collisions (2‰); — Talk of S.Tuo: 7D
- Using higher cumulants for isolating non-flow and fluctuation contributions (and being careful -w.r.t. radial flow- when drawing a comparison up to LHC energies); — Talk of S.Shi: 6B
- ALICE provides higher harmonics with higher cumulants — Talk of A.Bilandzic: 7D
  - ➡ experimental fact: non-negligible 3rd moment when compared to 1st or 2nd;
  - ➡ strong centrality dependence of $v_2\{4\}$ but weak centrality dependence of $v_3\{4\}$;
- In general, excellent agreement between all results at the LHC. — Talk of T.Bold: 6D



Since then, consensus that we should abandon EP method asap !
(and not only for light flavours)

M.Luzum & J.-Y.Ollitrault:
“The event-plane method is obsolete”,
arXiv:1209.2323

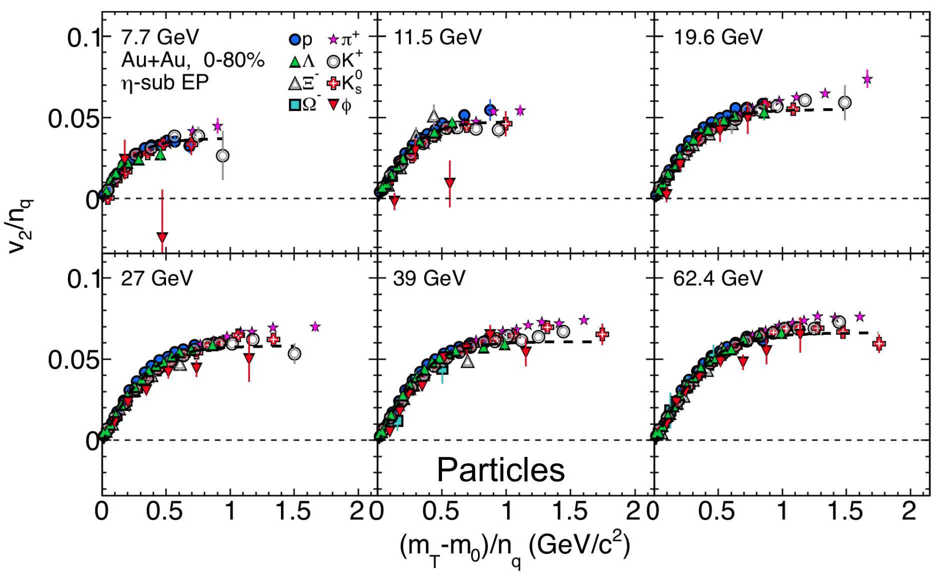
NUMBER OF CONSTITUENT QUARK SCALING… OR NOT

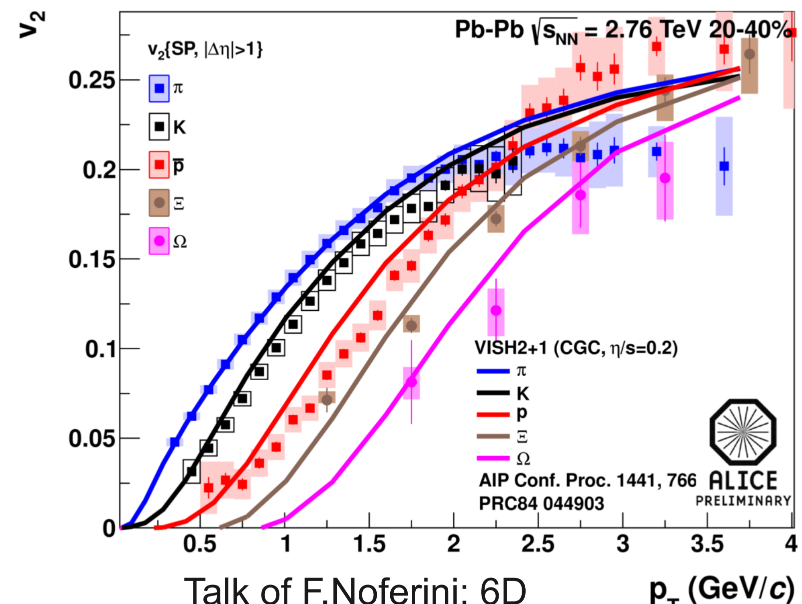
- v_2+PID ! probing hadron mass and constituent quark dependence

VISH2+1, talk by H.Song Plenary ID

STAR **at RHIC** Talk of S.Shi: 6B

ALICE **at the LHC**





Talk of F.Noferini: 6D

ALI-DER-32328

Precise measurements from π to Ω leaving very little (no) room for ncq scaling at the LHC…

ϕ (2σ) !

ncq scaling appears to work

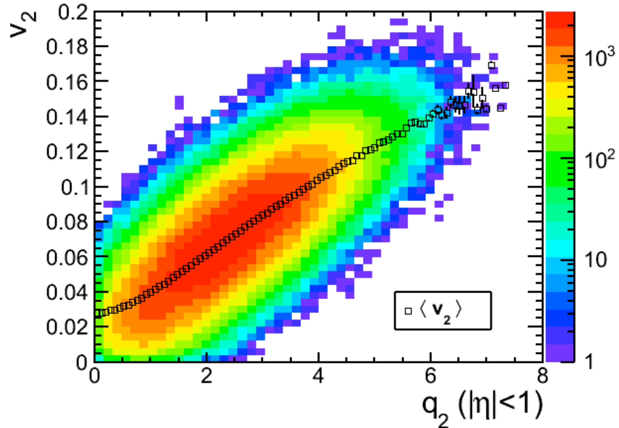
none !

7.7 11.5 19.6 27 39 62.4 200 2760 GeV

EVENT SHAPE ENGINEERING

Talk of S.Voloshin: Plenary IC

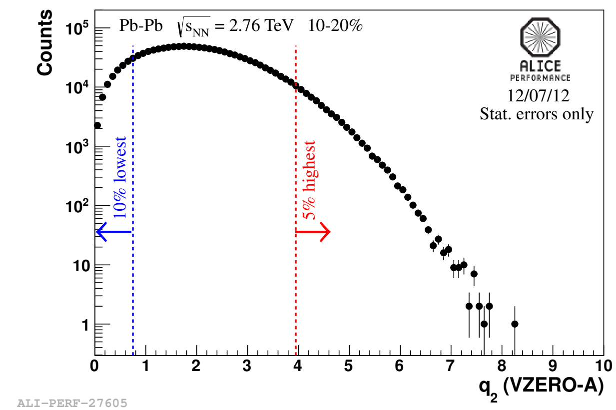
- Selection of azimuthally anisotropic events: length of flow vector, q_2



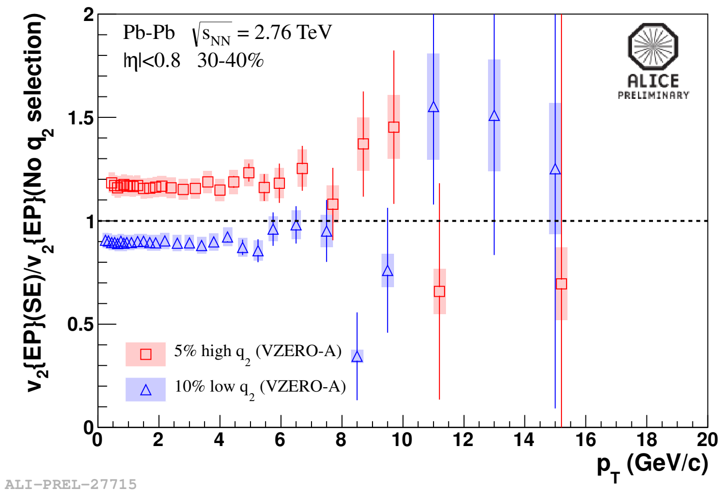
$$Q_{n,X} = \sum_{i=1}^{M} \cos(n\phi_i)$$

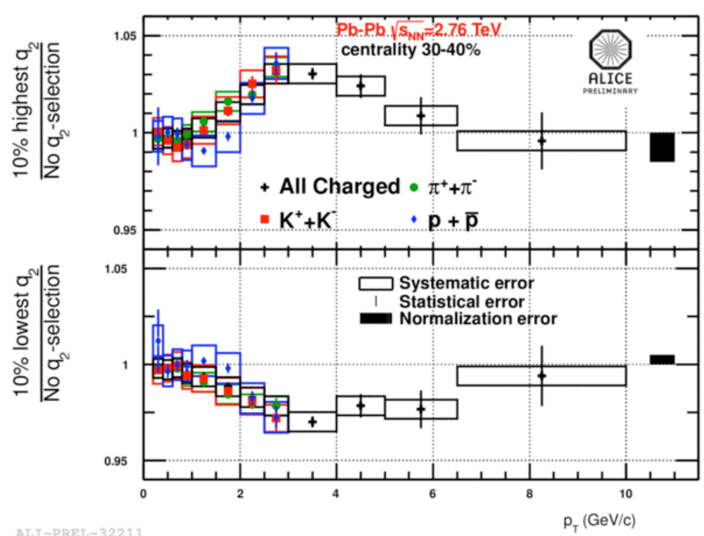
$$Q_{n,Y} = \sum_{i=1}^{M} \sin(n\phi_i)$$

$$q_n = Q_n/\sqrt{M}$$



Talk of A.Dobrin:1C





Talk of L.Milano: 5A

expected effect on v_2 and consequence on PID’ed transverse momentum spectra

STATE-OF-THE-ART SYSTEM EVOLUTION MODELING

- linking the wagons for a full description of the system evolution !

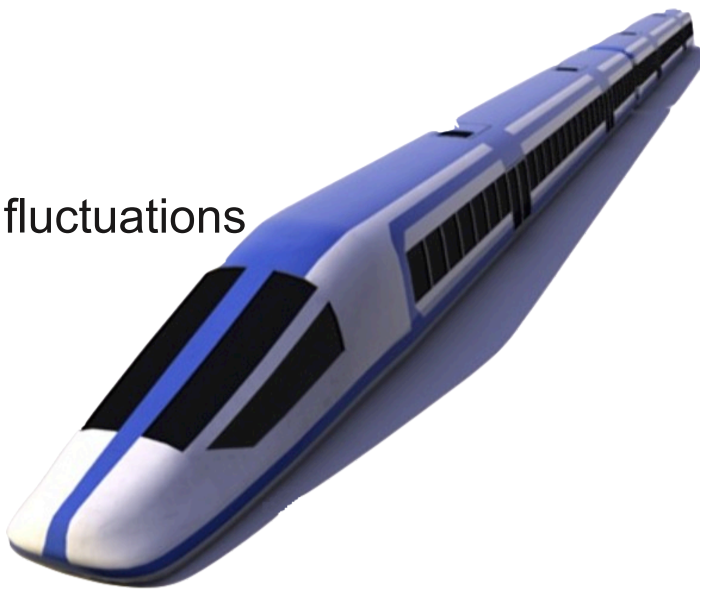
Talk of H.Petersen: Plenary VA

STATE-OF-THE-ART SYSTEM EVOLUTION MODELING

- linking the wagons for a full description of the system evolution !
  - state-of-the-art modeling of initial conditions;

Talk of H.Petersen: Plenary VA

initial fluctuations



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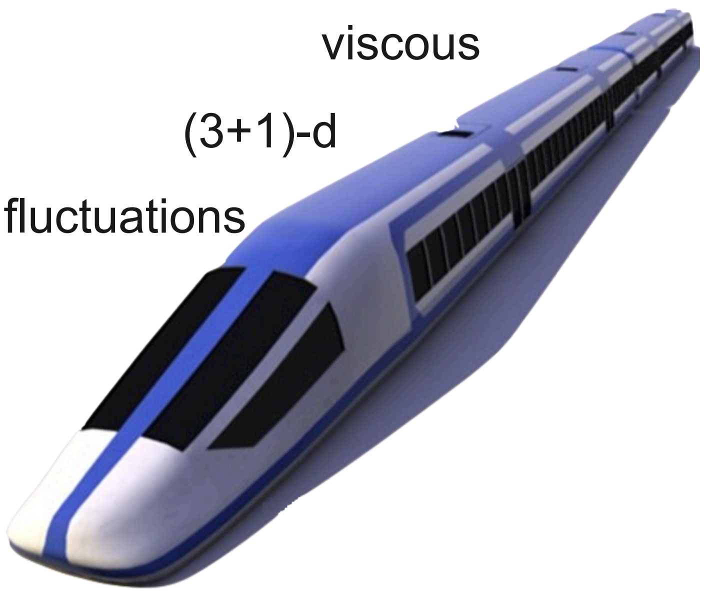

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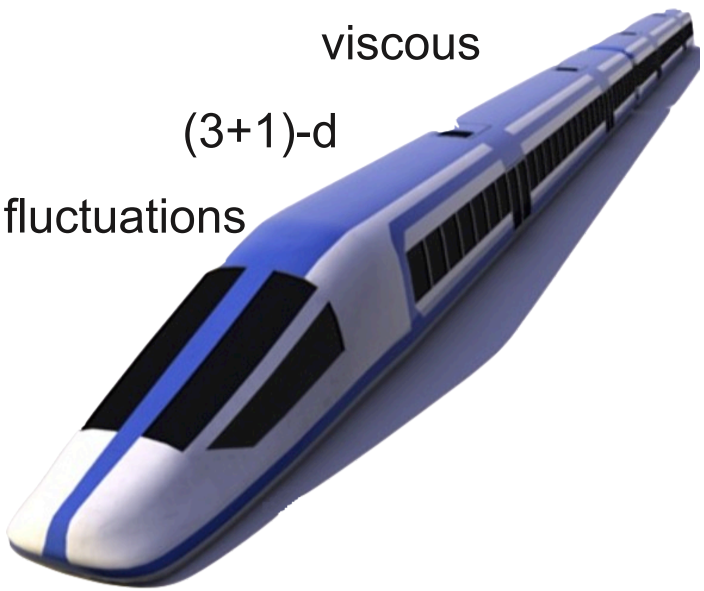
Talk of H.Petersen: Plenary VA

hadronic afterburner

viscous

(3+1)-d

initial fluctuations



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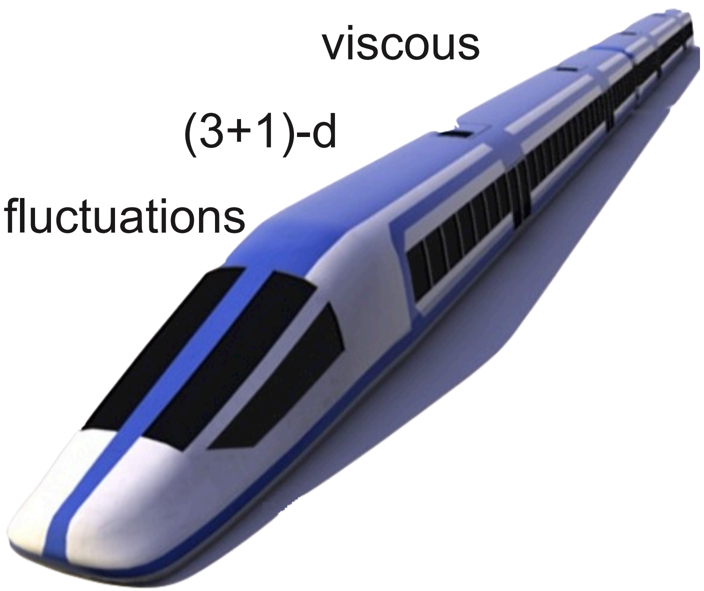
Talk of H.Petersen: Plenary VA

hadronic afterburner

viscous

(3+1)-d

initial fluctuations



Compilation by J.-Y. Ollitrault: Plenary IC

Author/Presenter	QM2012	arXiv	initial fluctuations	3+1d	viscous	afterburner
Huichao Song	ID	1207.2396			✓	✓
Teaney/Yan	IA	1206.1905			✓	
Chun Shen	1A	1202.6620			✓	
Sangyong Jeon	2A		✓	✓	✓	✓
Matt Luzum	2A				✓	
Piotr Bozek	2C	1204.3580	✓	✓	✓	
Björn Schenke	3A	1109.6289	✓	✓	✓	
Dusling/Schaefer	3A	1109.5181			✓	
Chiho Nonaka	3A	1204.4795	✓	✓	✓	
Ryblewski/Florkowski	3D	1204.2624		✓		
Longgang Pang	4D	1205.5019	✓	✓		
Hannah Petersen	VA	1201.1881	✓	✓		✓
Fernando Gardim	6D	1111.6538	✓	✓		
Zhi Qiu	29	1208.1200	✓		✓	
Gardim/Grassi	52	1203.2882	✓	✓		
Katya Retinskaya	57	1203.0931			✓	
Hirano/Murase	255	1204.5814	✓	✓		✓
Holopainen/Huovinen	284	1207.7331	✓			
Asis Chaudhuri		1112.1166	✓		✓	
Iurii Karpenko		1204.5351		✓		✓
Yu-Liang Yan		1110.6704		✓		✓
Josh Vredevoogd		1202.1509		✓	✓	
Ron Soltz		1208.0897			✓	✓
Rafael Derradi de Souza		1110.5698	✓	✓		

STATE-OF-THE-ART SYSTEM EVOLUTION MODELING

- linking the wagons for a full description of the system evolution !
  - state-of-the-art modeling of initial conditions;
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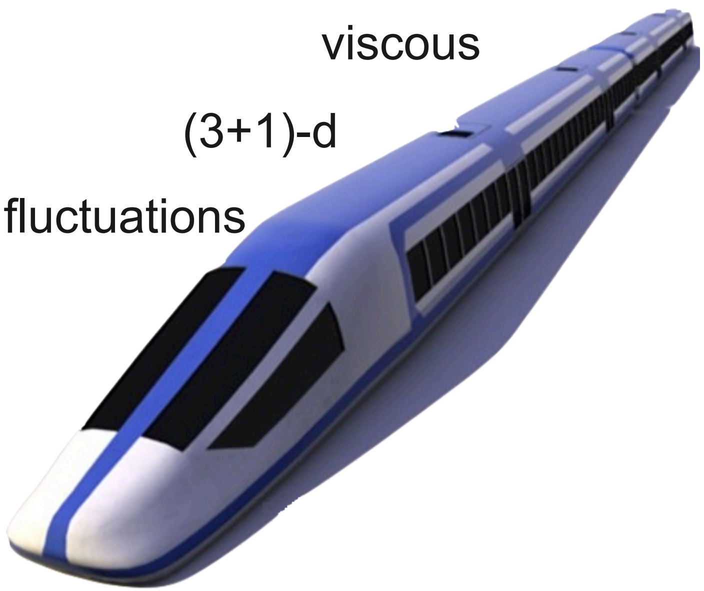
Talk of H.Petersen: Plenary VA



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Author/Presenter	QM2012	arXiv
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Laszlo Csernai	23	1112.4287
Amaresh Jaiswal	48	1204.3779
Ioannis Bouras	80	1208.1039
Flörchinger/Wiedemann	97	1108.5535
Harri Niemi	248	
Mate Csanad	295	1205.5965
Gavin/Moschelli	296/354	1205.1218
Jaki Noronha-Hostler	304	
Pilar Staig	365	
Akihiro Monnai	388	1204.4713
Philipe Mota	615	

more...

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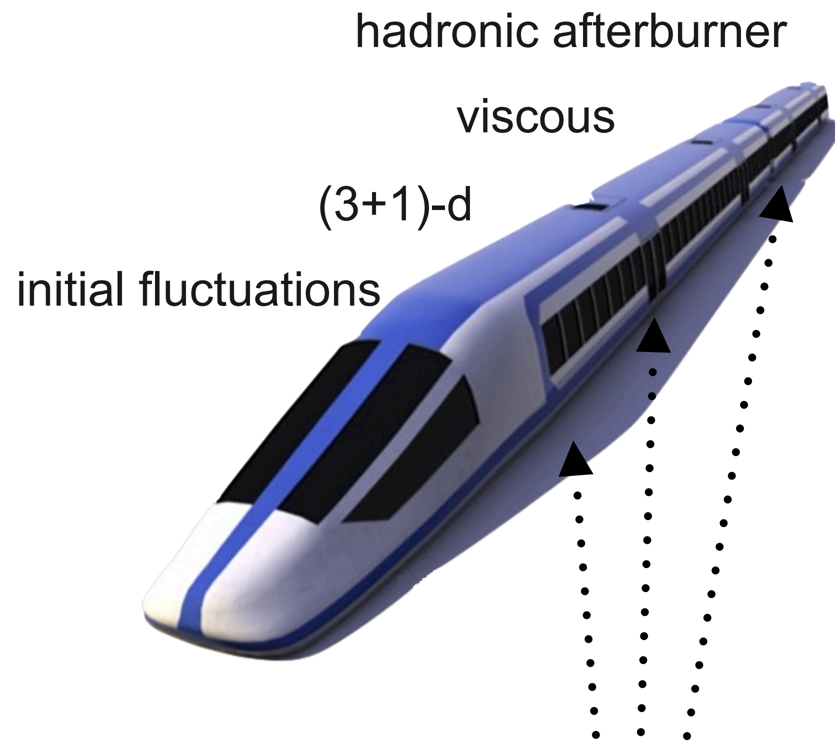
Talk of H.Petersen: Plenary VA



And control each interface !

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more...

CONTROL EACH INTERFACE

- Including quantum fluctuations

K.Dusling, T.Epelbaum, F.Gelis, R.Venugopalan arXiv:1206.3336

  - ➡ so far: matching of classical non-equilibrated Yang-Mills solutions to viscous (i.e. close to equilibrium) fluid dynamics;
  - ➡ needed: equilibration of YM solutions including *quantum fluctuations* for longitudinally expanding scalar field;

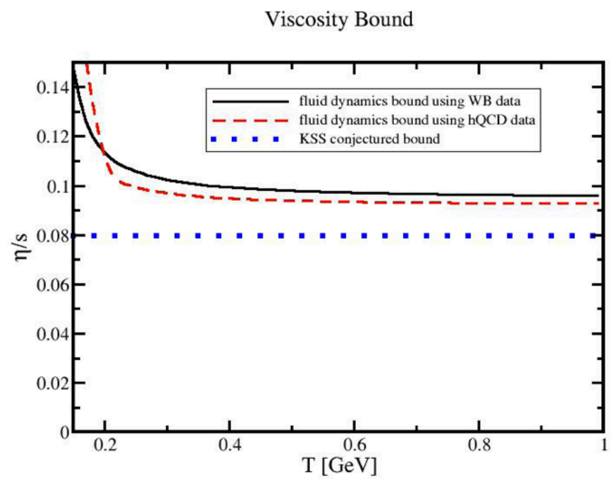
Talk of K.Dusling: Plenary IC
Talk of R.Venugopalan: 4D

- Converging on the EOS

Talk of Y.Hidaka: 6B

  - ➡ Budapest-Wuppertal and HotQCD agree: T_c = 155 MeV

- T_c dependence for η/s



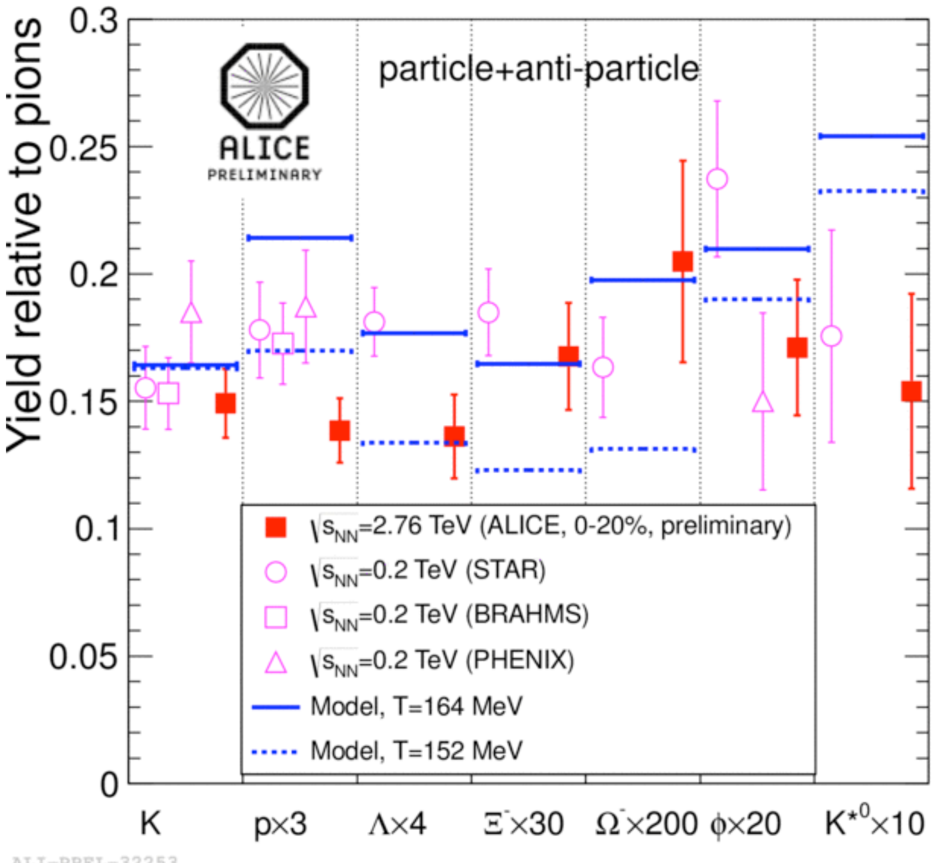
Talk of P.Romatschke: 5D

- Turning fluid into particles
  - ➡ δf corrections to the single-particle distribution function at freeze-out: $f = f_0 + \delta f$ $\delta f(p) \ \alpha \ p^2 f_0$?

K.Dusling, G.D.Moore and D.Teaney
Phys. Rev. C 81 (2010) 034907

CHEMICAL FREEZE-OUT FROM HADROCHEMISTRY

- between hydro and afterburners: T_{ch}



Talk of L.Milano: 5A

Some “tension” at the LHC for a statistical thermal description relying on T_{ch} only

Talk of P.Braun-Munzinger: 5A

Stressed the importance of corrections for feed-down and secondaries from interaction with material

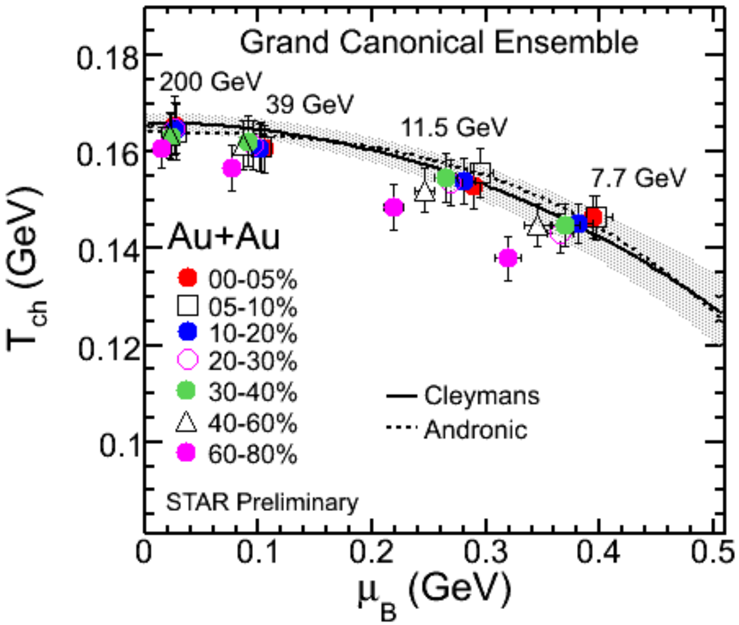
Poster of M.Petran: 319

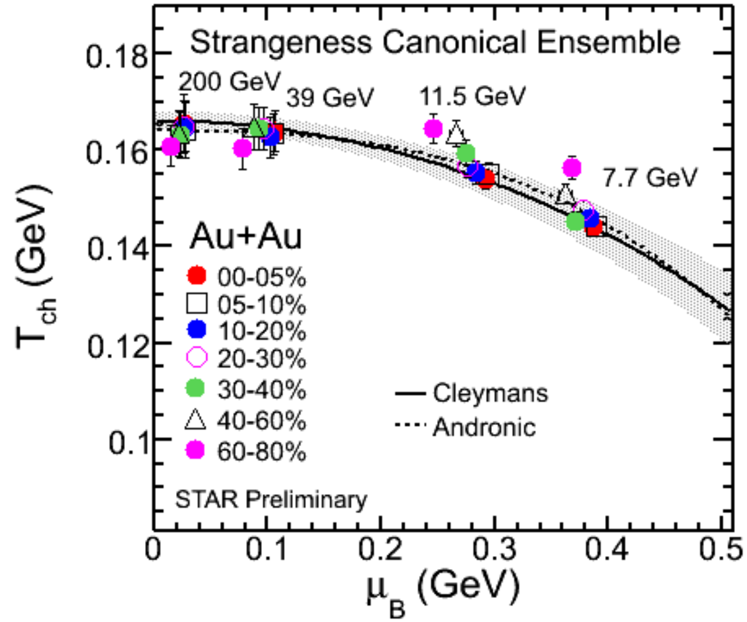
Underlined the importance of the charm contribution to strangeness production

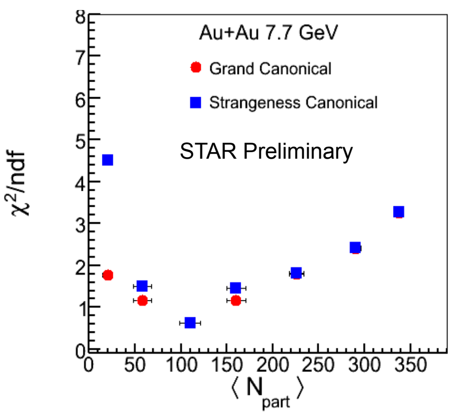
FURTHER CONSTRAINTS FROM HADROCHEMISTRY

- from BES at RHIC: T_{ch} vs. μ_B

talk of S.Das: 6B





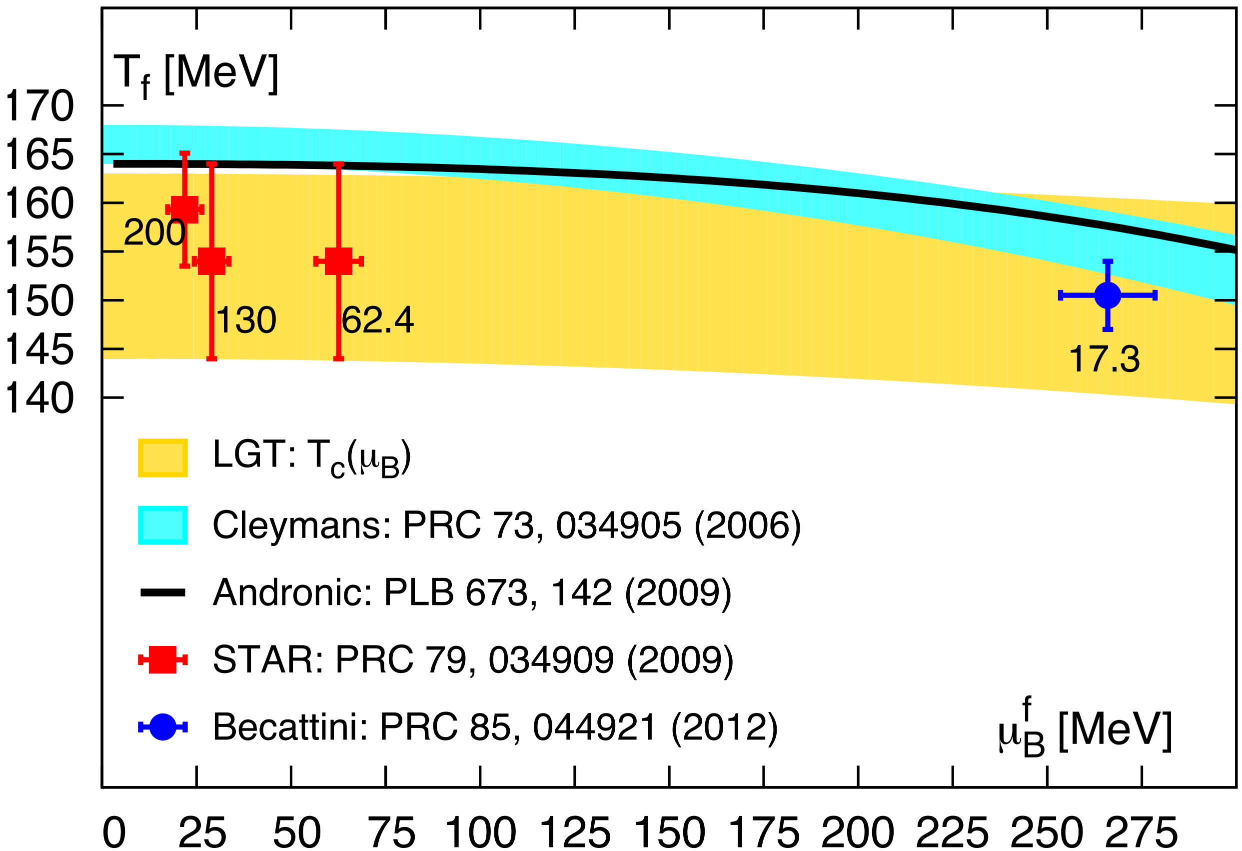


fits done with THERMUS, S.Wheaton et al., Comput. Phys. Commun.180:84-106, 2009

Observation of a centrality dependence of the freeze-out temperature vs. baryo chemical potential (beam energy)

COMPARISON WITH LQCD EXPECTATIONS

- Handles on chemical freeze-out, T_{ch}



Talk of V.Skokov: Plenary VA

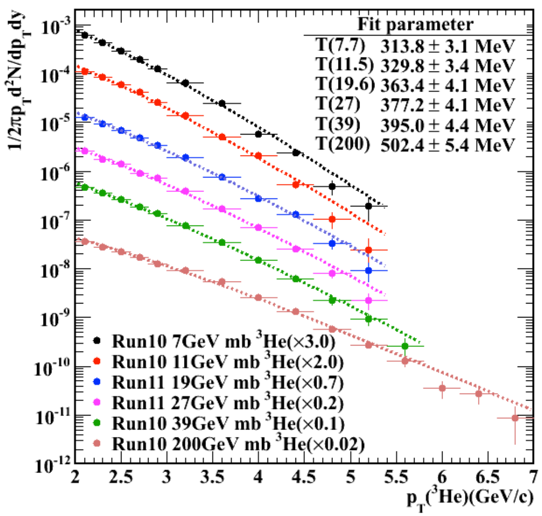
Talk of S.Das: 6B

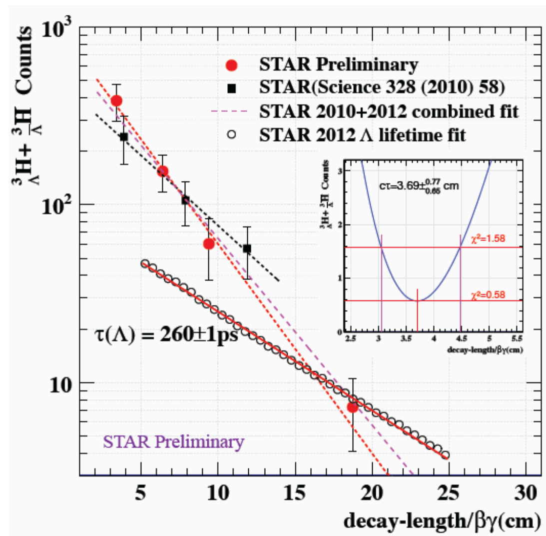
Talk of S.Mukherjee: 5B

Freeze-out is close to crossover line for energies from $\sqrt{s}$=200 GeV to $\sqrt{s}$=17.3 GeV

NUCLEI, HYPERNUCLEI AND EXOTICA

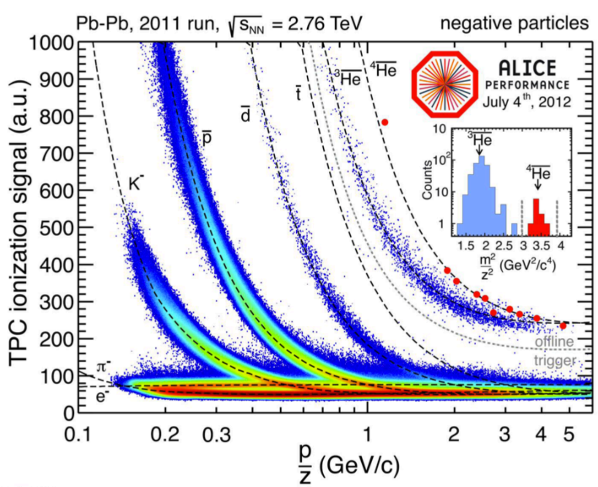
- both at RHIC and at the LHC

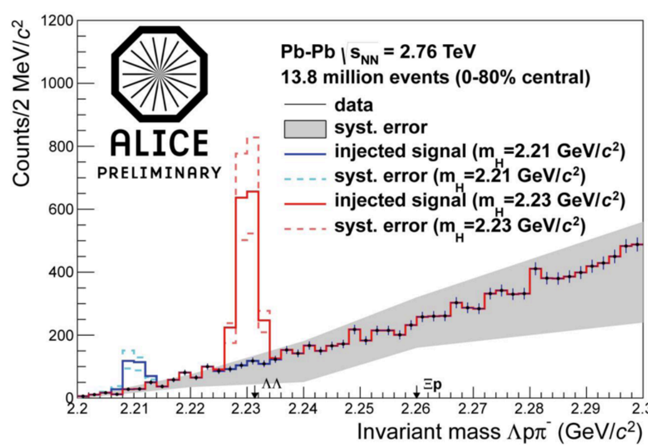




(anti-)Hypertriton spectra at RHIC, excitation function and lifetime !

Talk Y.Zhu: 5A



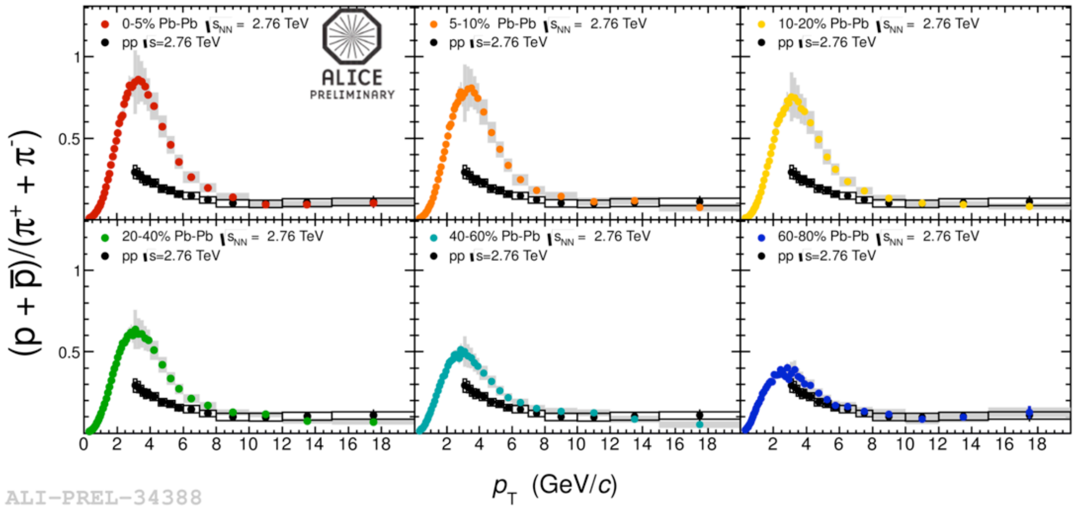


anti-Alpha and (anti-)Hypertriton measured at the LHC... no signal of H-dibaryon... yet !

Talk of B.Dönigus: 5A

INVESTIGATING THE RECOMBINATION SCENARIO

- Using baryon vs. meson production and p_T ratios at the LHC

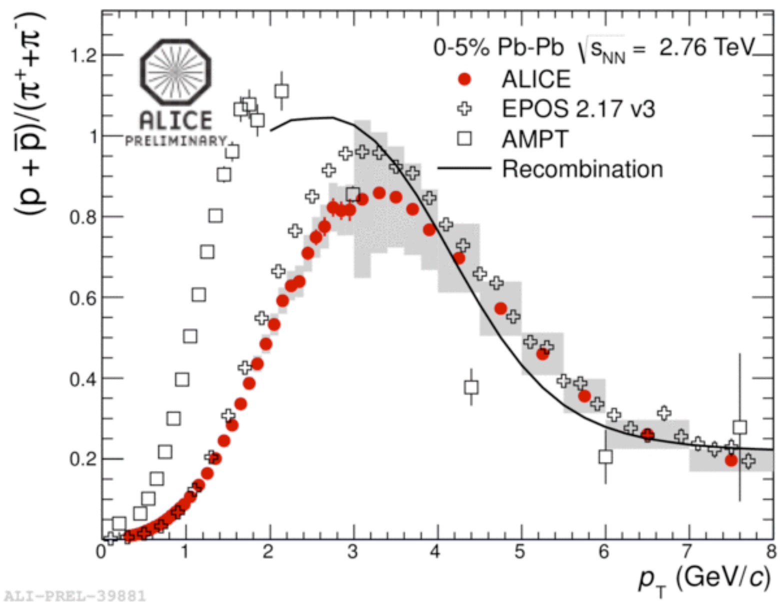


At intermediate p_T, the enhancement of the baryon/meson ratio seen at RHIC is still visible at the LHC

Talk of A.Ortiz: 5C

Effect getting smaller from central to peripheral events

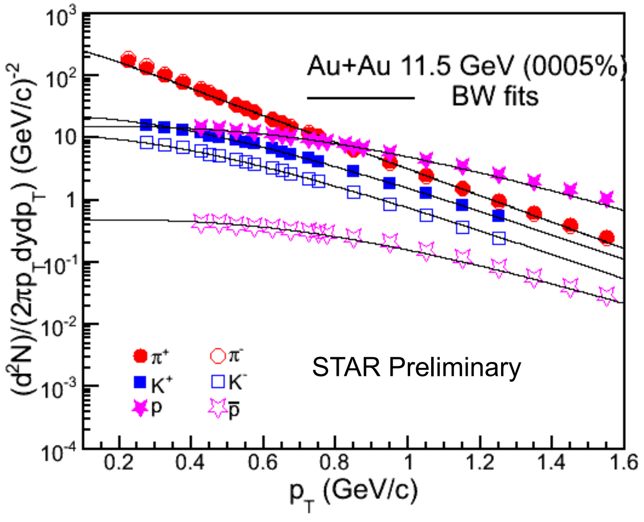
Several models using different hadronization mechanisms are compared...



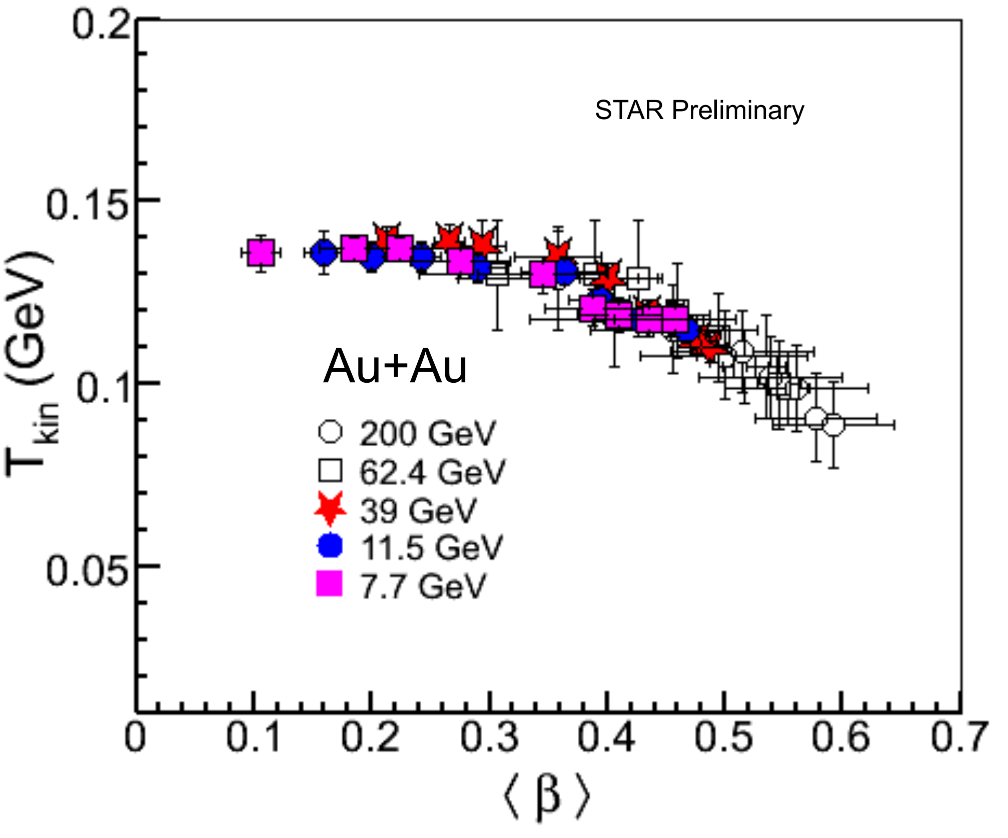
CONSTRAINTS FROM HADROCHEMISTRY

- Radial flow and kinetic freeze-out temperatureT_{kin}

Talk of S.Das: 6B



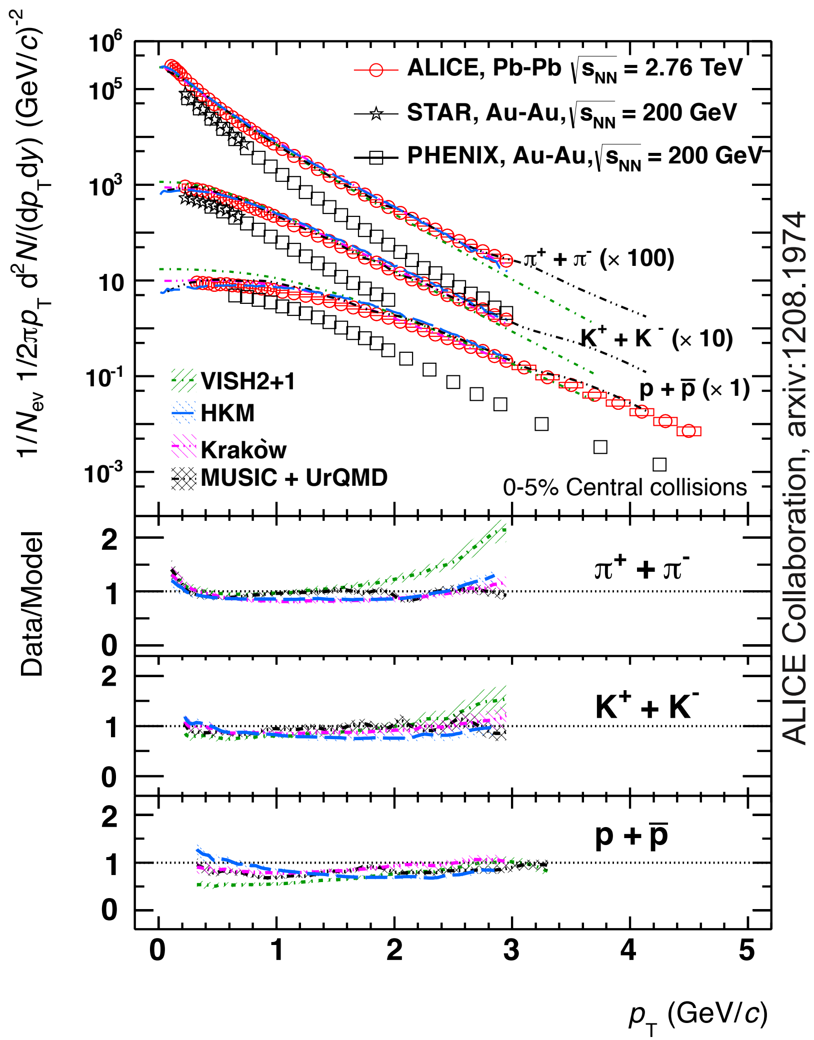
fits done with blast wave
on charged π,K and p



Radial flow increase from most peripheral collisions at $\sqrt{s_{NN}}$ = 7.7 GeV
to most central Au-Au events at $\sqrt{s_{NN}}$ = 200 GeV

CONSTRAINTS FROM HADROCHEMISTRY

- Radial flow and kinetic freeze-out temperatureT_{kin} Talk of L.Milano: 5A



Large radial flow: $\langle\beta_T\rangle = 0.65 \pm 0.02$
(~10% higher w.r.t. RHIC)

Very good description of hydro(s)...

model comparison:
- VISH2+1 (Viscous hydro)
- HKM (Hydro+ UrQMD)
- Krakòw (viscous corr., lower the effective T_{ch})
- **MUSIC** (EbE 3+1D Hydro + UrQMD): 100 events

Next: Evolution vs. centrality and for hyperons

Any room for a ~30% drop of protons due to hadronic rescattering and annihilation ?

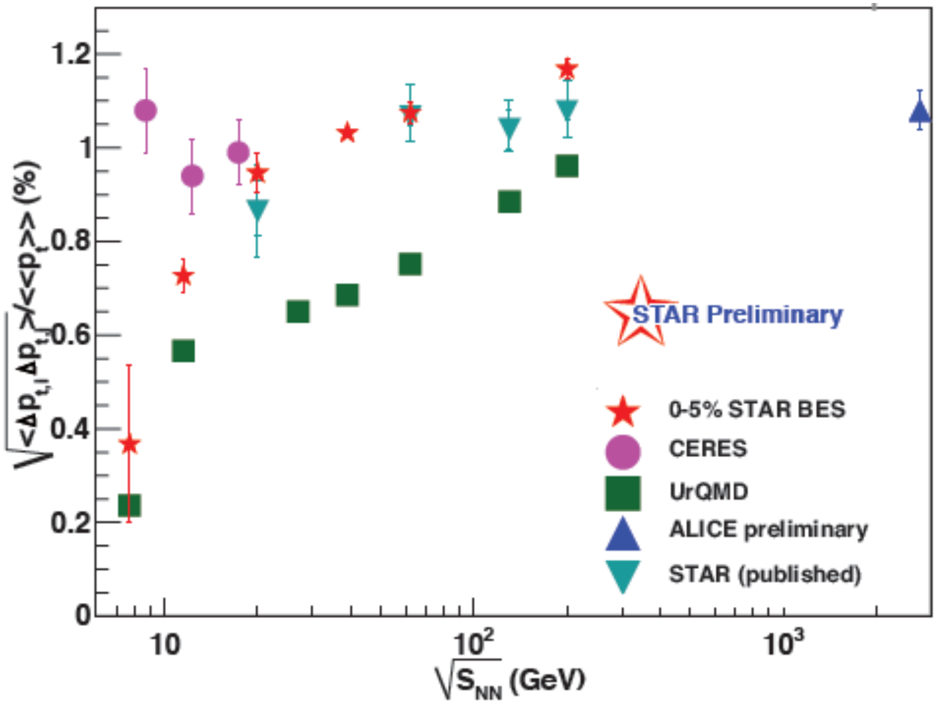
Test: Proton and Lambda femtoscopy

Talk of M. Szymański: 1C

SUMMARIZING: CORRELATIONS

- At RHIC,
  - ➡ correlations K/π and p/π (vs.√s) are below hadronic model predictions;
  - ➡ charged to neutral (ch_{tot},γ) shows anti-correlation (opposite to models);
  - ➡ <p_T> fluctuations increase with $\sqrt{s_{NN}}$ (~UrQMD) but differs strongly from CERES;

Talk of P. Tribedy: 2C



Effects of acceptance difference with CERES are under investigation.

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Talk of P. Tribedy: 2C

- Lattice QCD is trying to include electric charge fluctuations; Talks of C. Schmitt and S.Mukherjee: 5B
- Result from ALICE in charge fluctuations and balance functions
  - ➡ <Δϕ> and <Δη> decreases with $\sqrt{s_{NN}}$ (NA49 to STAR then ALICE);

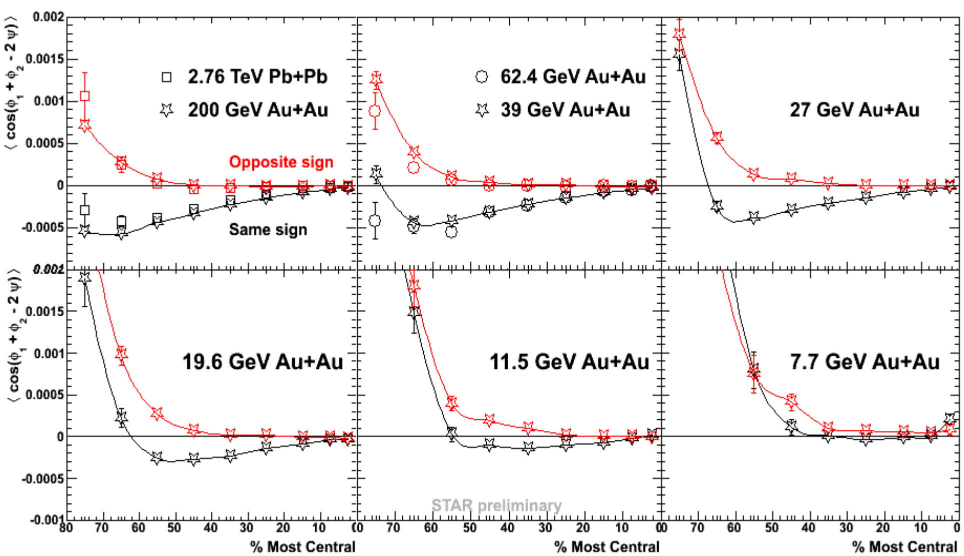
Talk of M.Weber: 2C

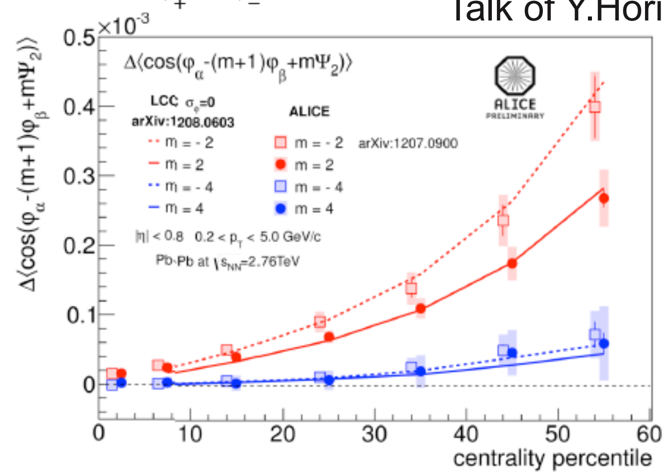
- Events with charge asymmetry seen at RHIC and at the LHC;

$$A_{\pm} = \frac{\overline{N}_{+} - \overline{N}_{-}}{\overline{N}_{+} + \overline{N}_{-}}$$

Talk of G.Wang: Plenary IVB

Talk of Y.Hori: 2C





CME or Effects of local charge conservation ?

SUMMARY AND OUTLOOK

- Very near future: scrutinize new measurements:
- Systematic studies for constraining initial conditions;
- Hydrodynamics with fluctuations;
- Hydrodynamics with dynamical chiral fields.