Soft Physics with ATLAS and CMS

Sasha Milov

XXXIX International Symposium on Multi-particle Dynamics
Gold Sands
Gomel region
Belarus

Soft observables.

- Initial state, equilibration, energy density
  - $dE_T/d\eta$, $dN_{ch}/d\eta$
- Transport (η/s) , EoS
  - v_1, v_2,v_4
- Hadronization phase transition
  - Event-by-event Fluctuations
- Freeze out phase transition
  - Particle abundances
  - Particle spectra
  - HBT

Day-1 question:

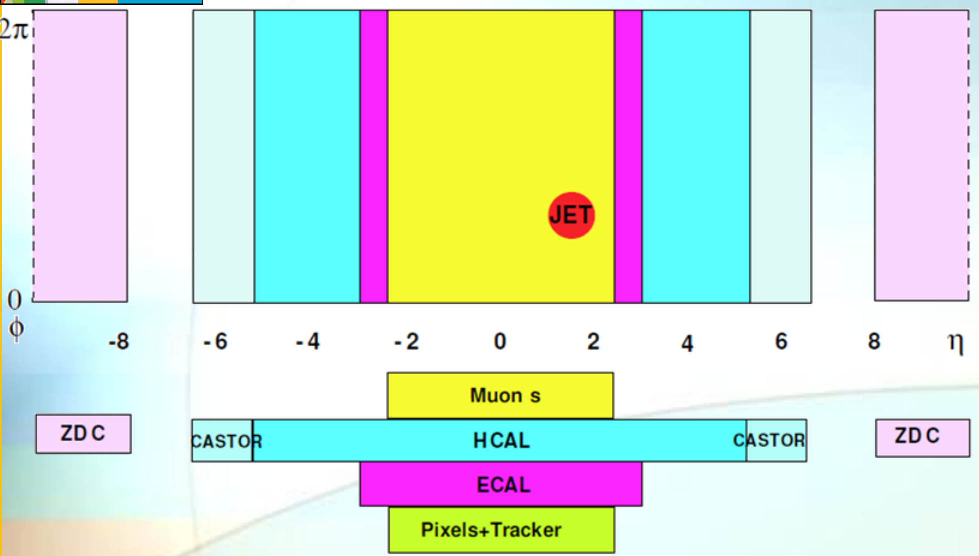
Central collisions	SPS	RHIC	LHC
$\sqrt{s_{NN}}$ (GeV)	17	200	5500
dN_{ch}/dy	430	700	$1\text{-}3\times10^3$
ε (GeV/fm^3)	3	5-10	15- 60
V_f(fm^3)	10^3	$7\text{x}10^3$	$2\text{x}10^4$
T / T_c	> 1	2	3-4

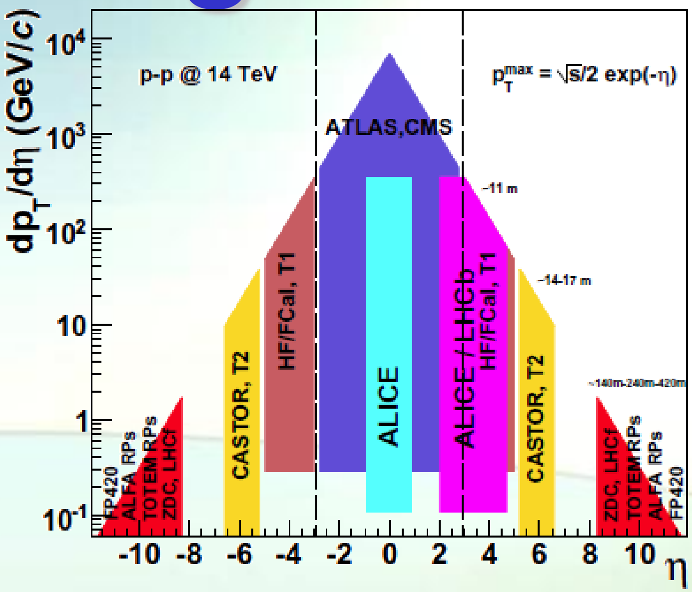
Larger, denser, hotter, longer lived …

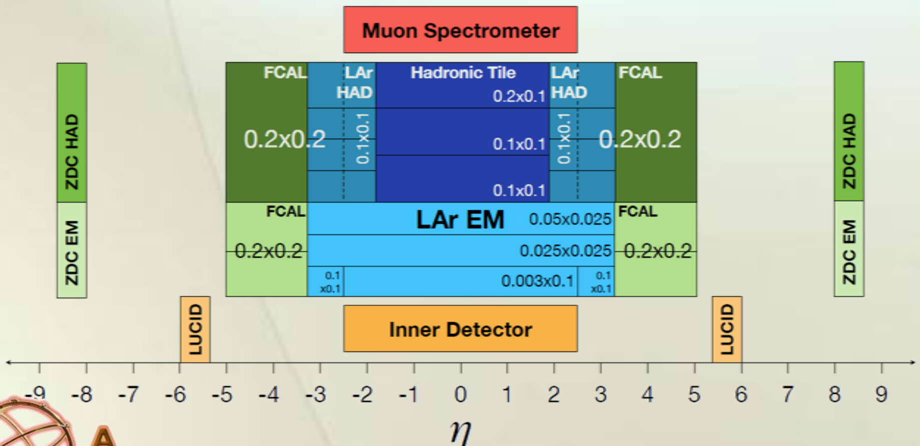
Is it different from matter created at RHIC or not?

Table from J.Velkovska slide @ CIPANP2009

The Coverage.







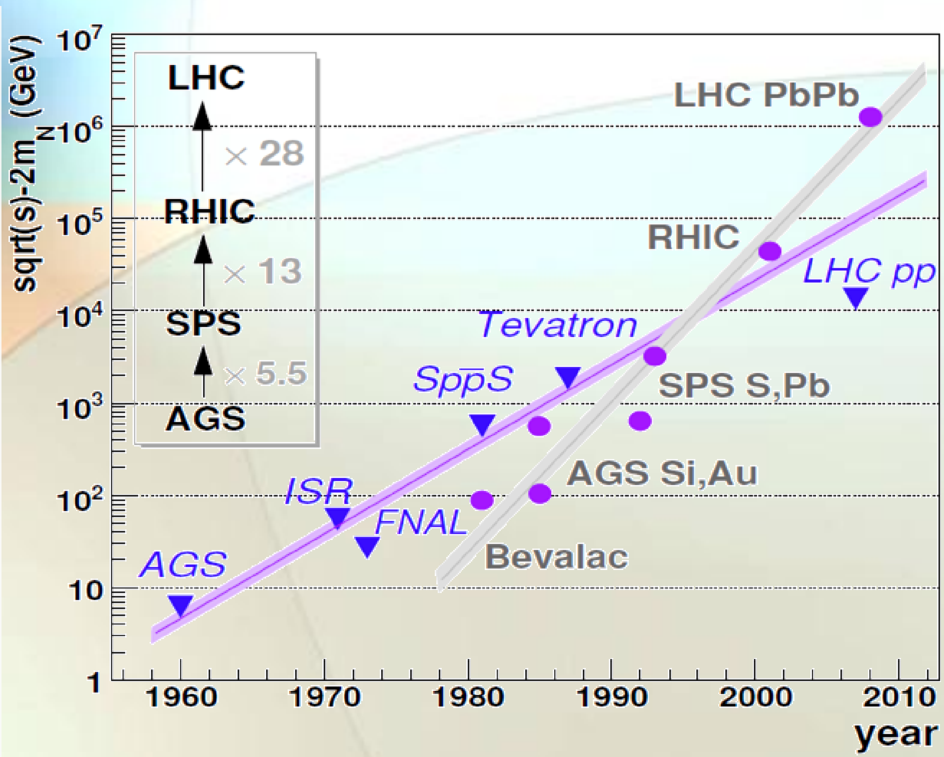
ATLAS and CMS are universal HE physics detectors with various subsystems and ~4π coverage.

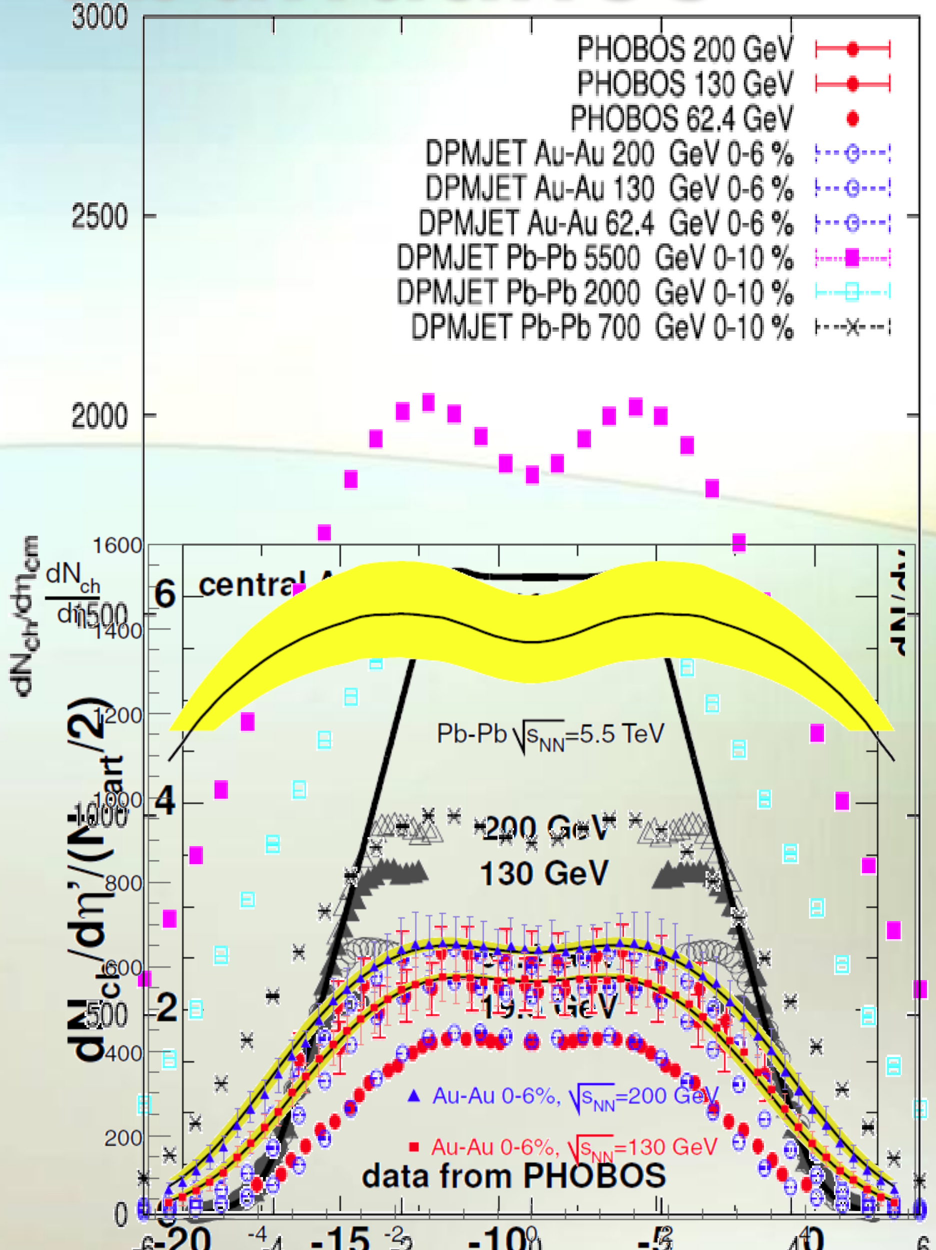
ATLAS: Calorimetry + tracking
CMS: Tracking + calorimetry

Almost perfect for HI physics.

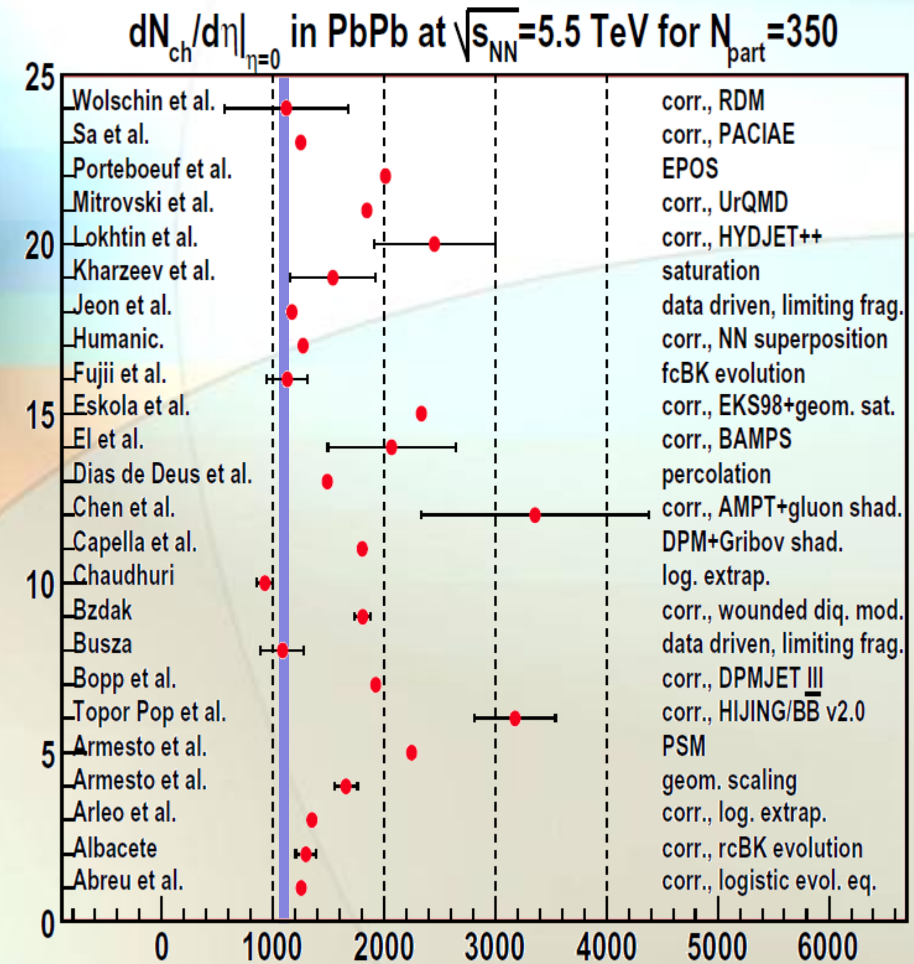
Particle abundance

The largest gain in the initial energy ever!
What to expect in the particle numbers?

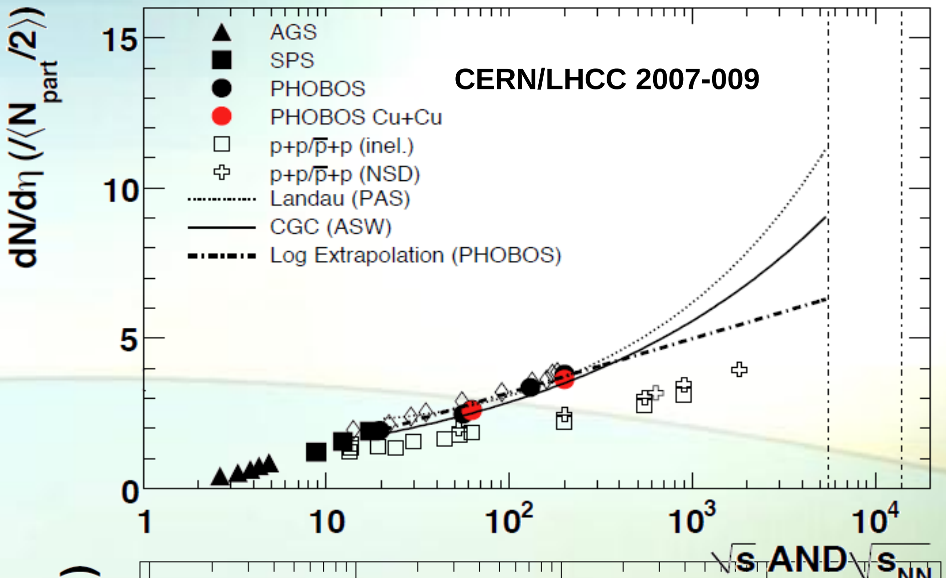


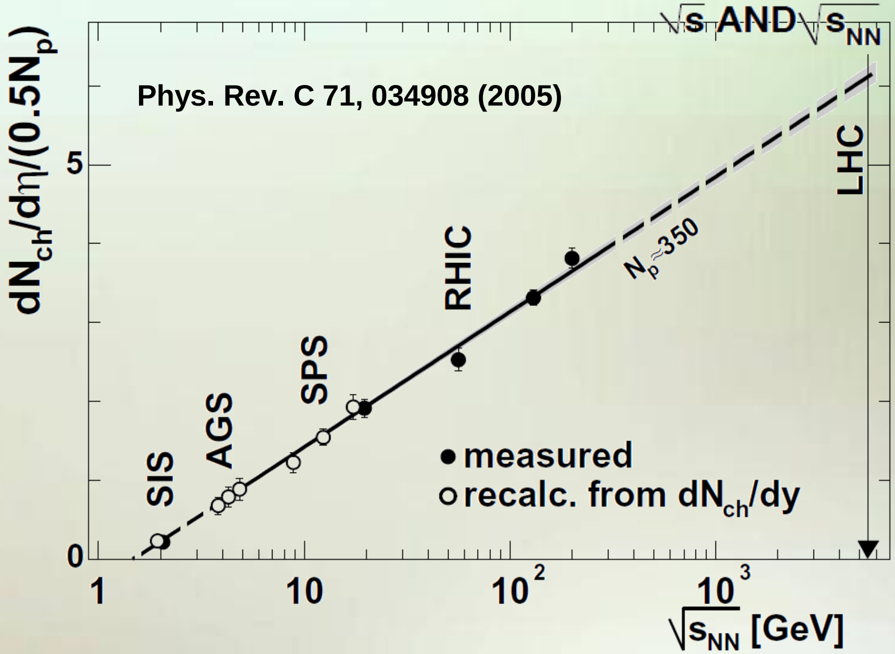


$dN_{ch}/d\eta$ at mid-rapidity.



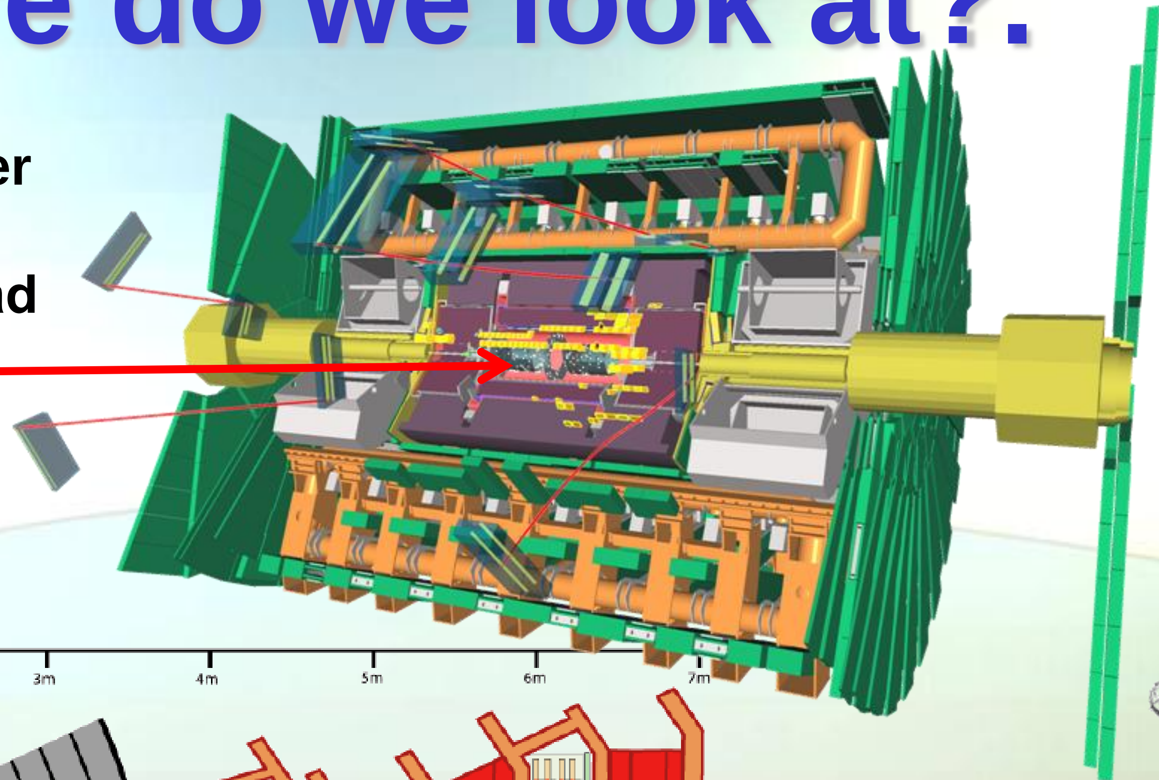
N. Armesto, arXiv:0903.1330v1

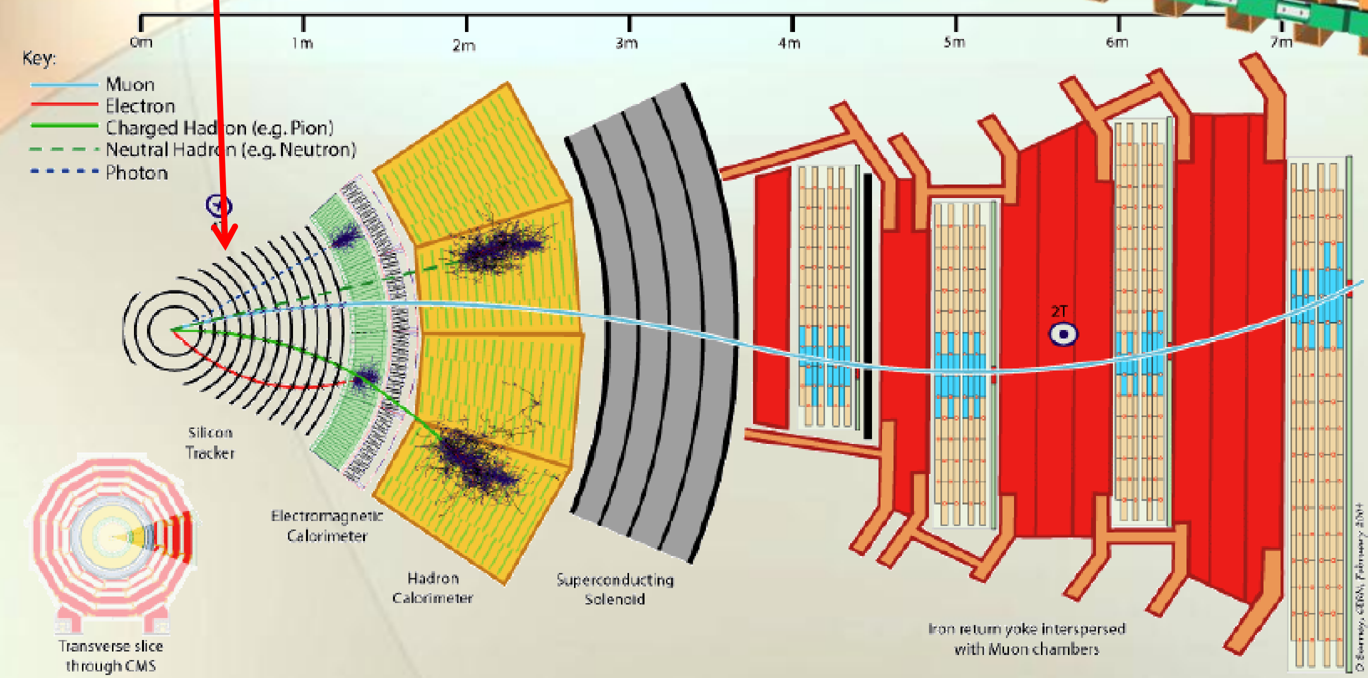




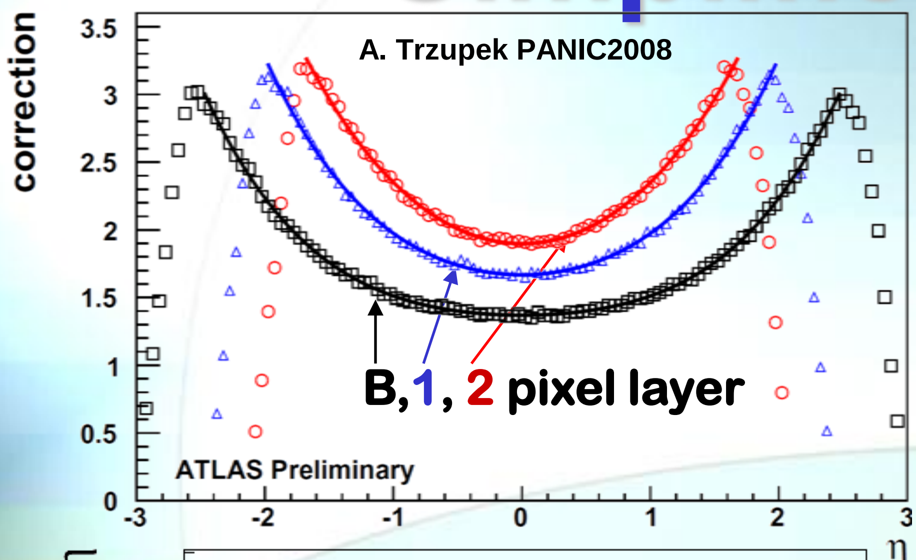
Where do we look at?.

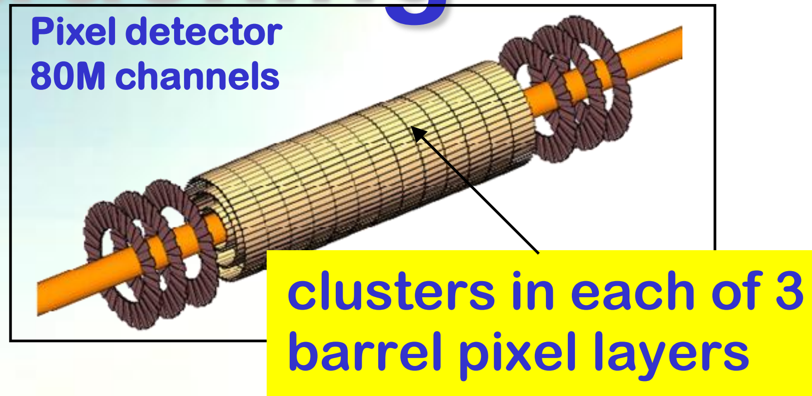
Look at the very inner part of the detector
Do “tracklets” instead of full track reconstruction



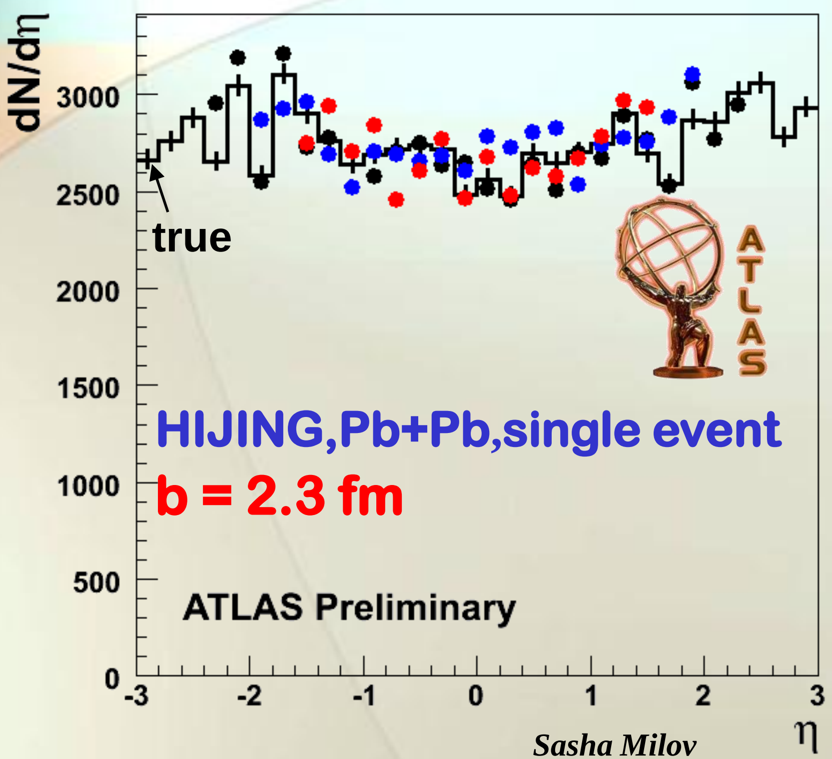


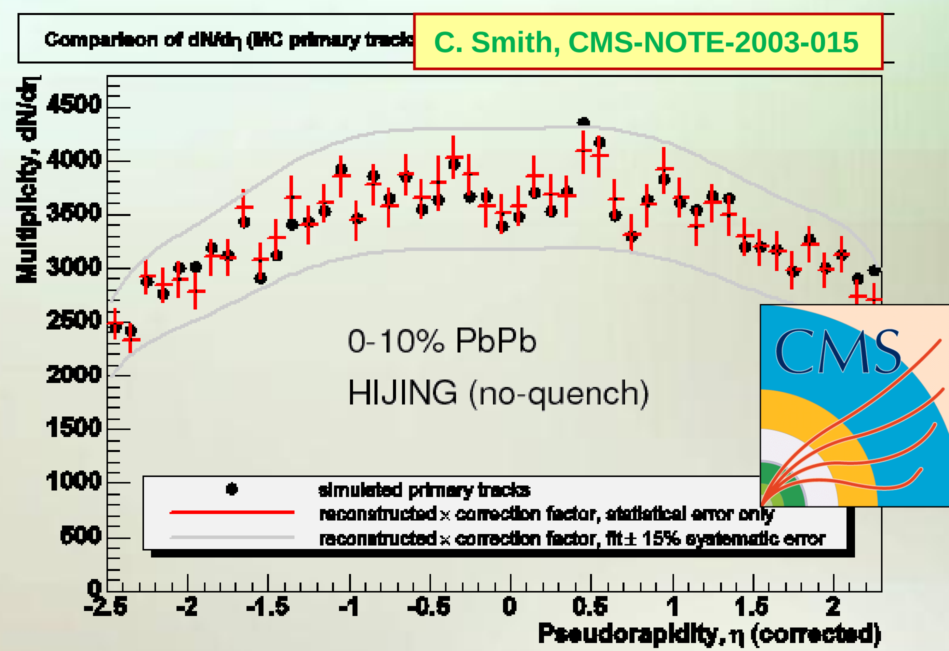
Simplified tracking



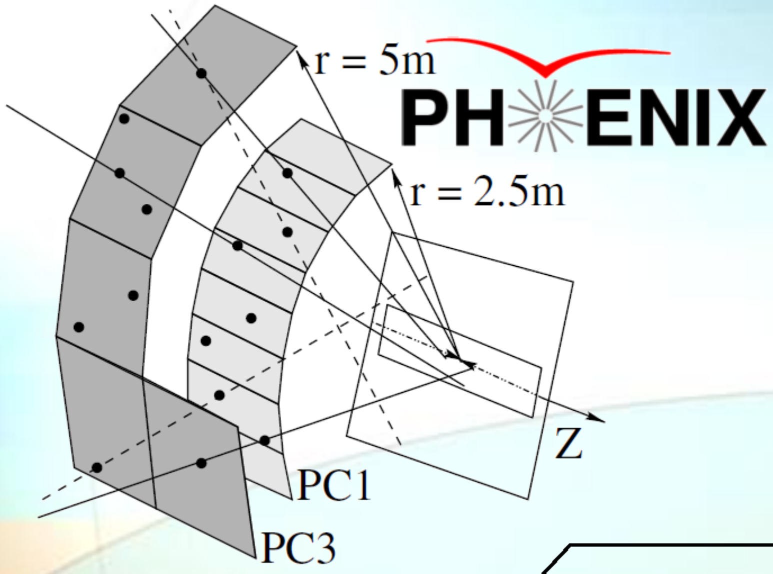


$$correction = \frac{< dN_{clus}/d\eta >}{< dN_{ch}/d\eta > MC - true}$$

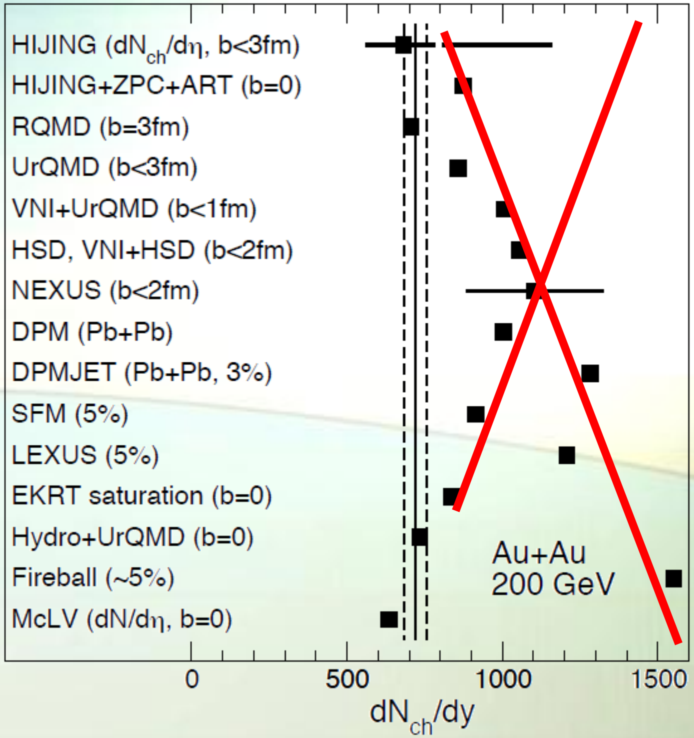


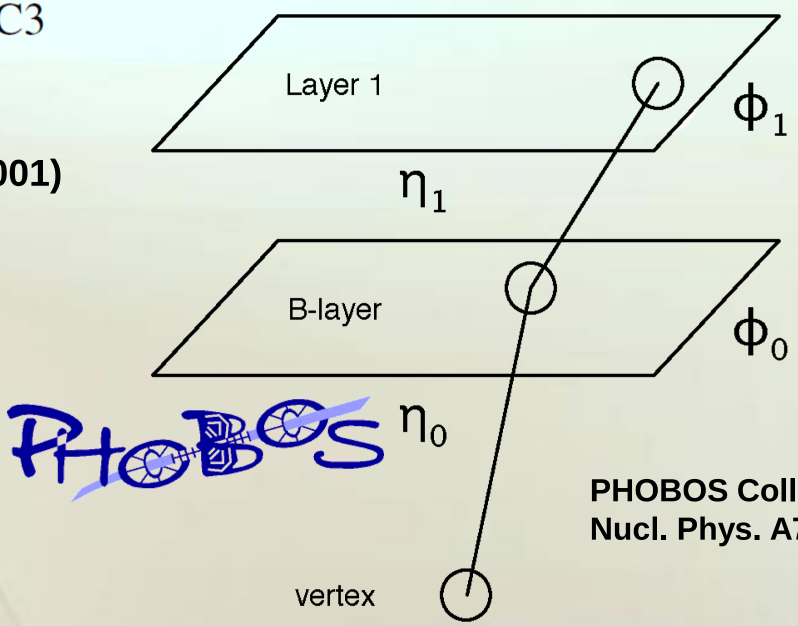


Simplified tracking Y2k.



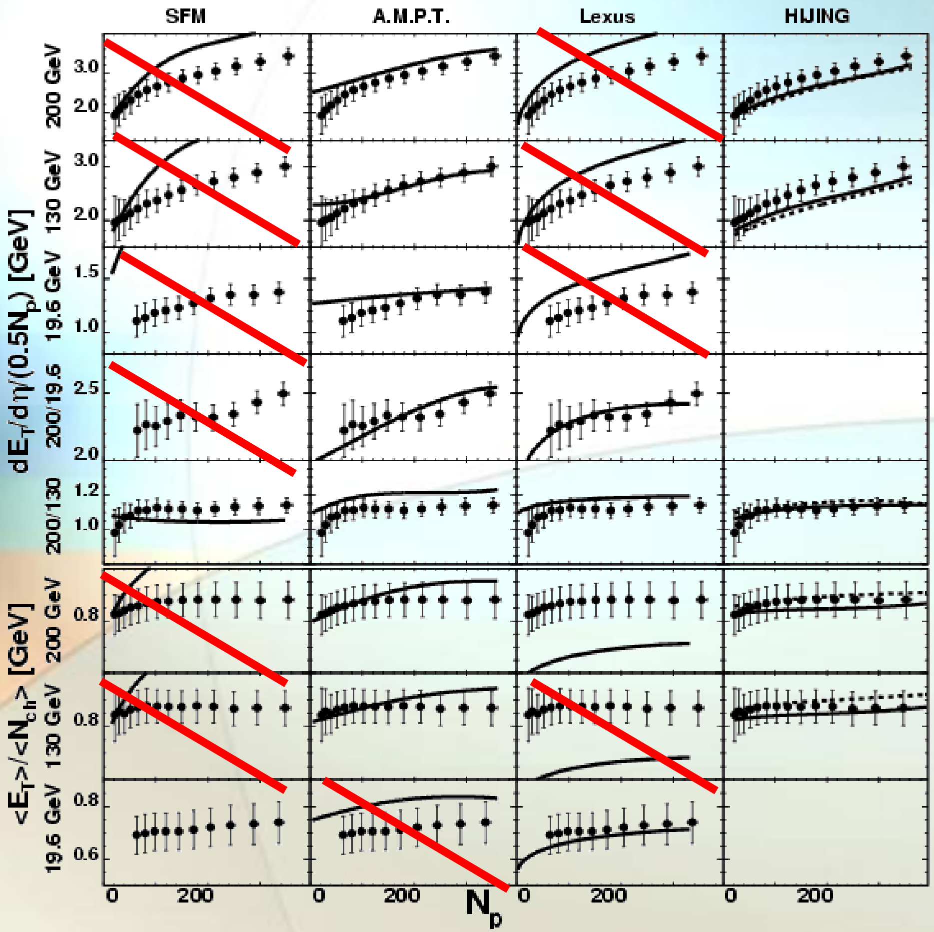
PHENIX Coll.
PRL86, 3500 (2001)

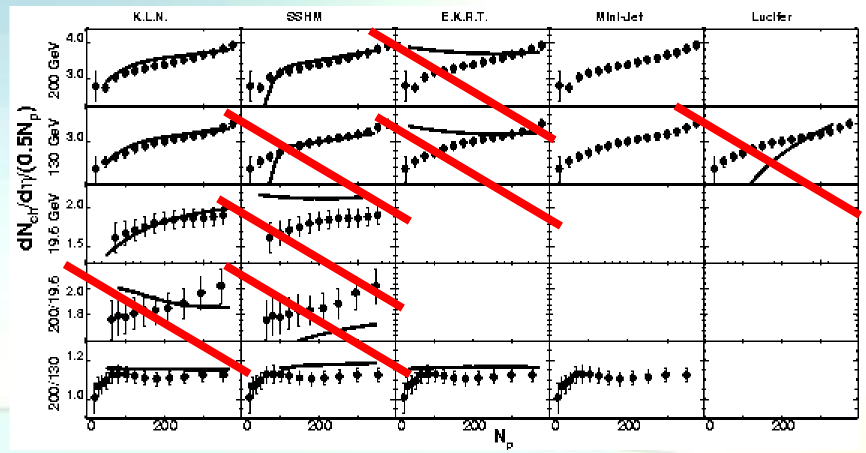


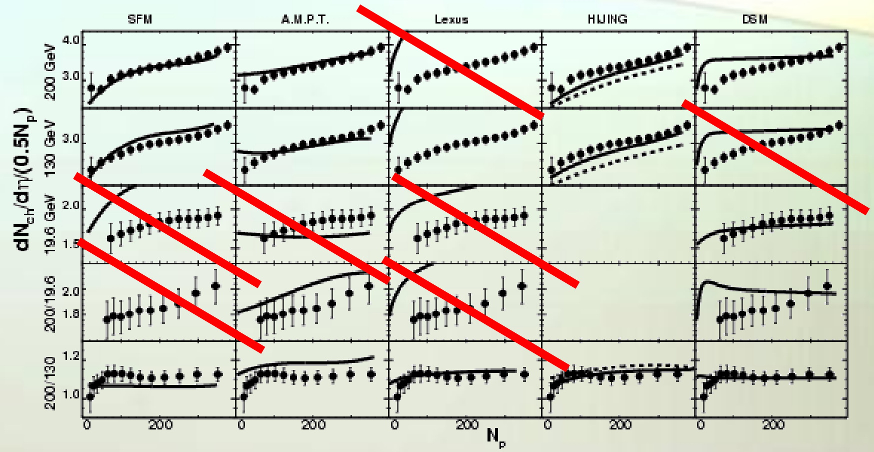


PHOBOS Coll.
Nucl. Phys. A757, 28

Y2k massacre.







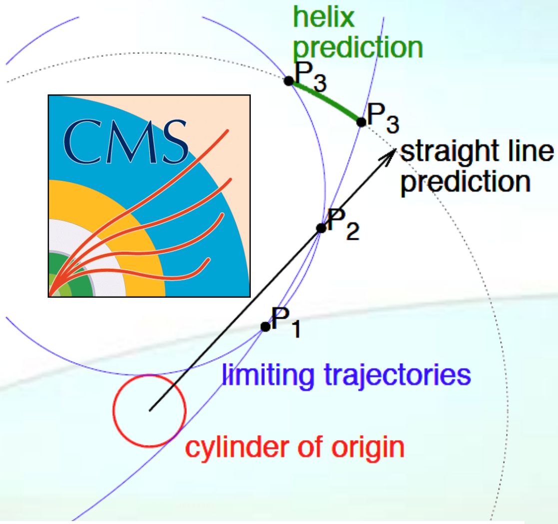
A.M. J. Phys. Conf. Ser. 5 17-36 (2005)

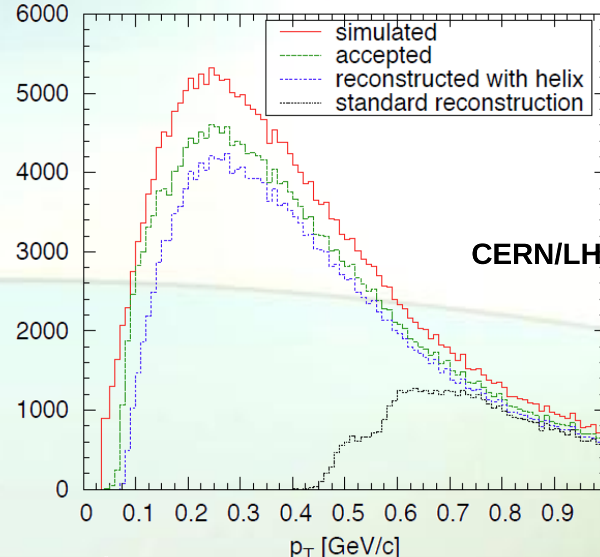
Y2.01k Theoretical Support: A LOT stronger than in 1999!

Last calls for predictions: RHIC: S.A.Bass et al., Nucl. Phys. A661, (1999) 205c (30 co-authors 146 references)
LHC: N. Armesto et al, J. Phys. G: Nucl. Part. Phys. 35 (2008) 054001 (176 co-authors 393 references)
Summaries: N. Armesto, arXiv:0903.1330v1

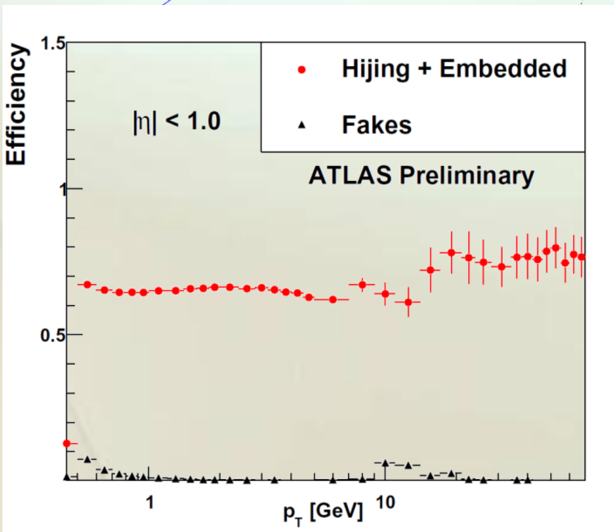
Low p_T tracking Y2.01k

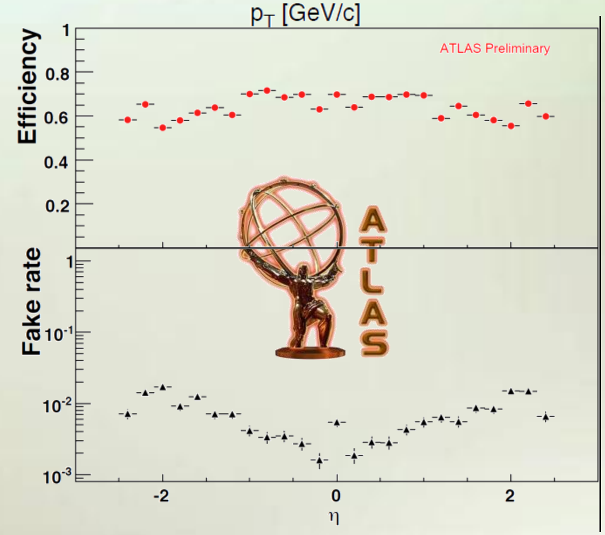
Standard tracking in ATLAS and CMS is good for p_T>0.5GeV/c which is too high for HI (soft) physics, an additional effort is undergoing to lower the threshold



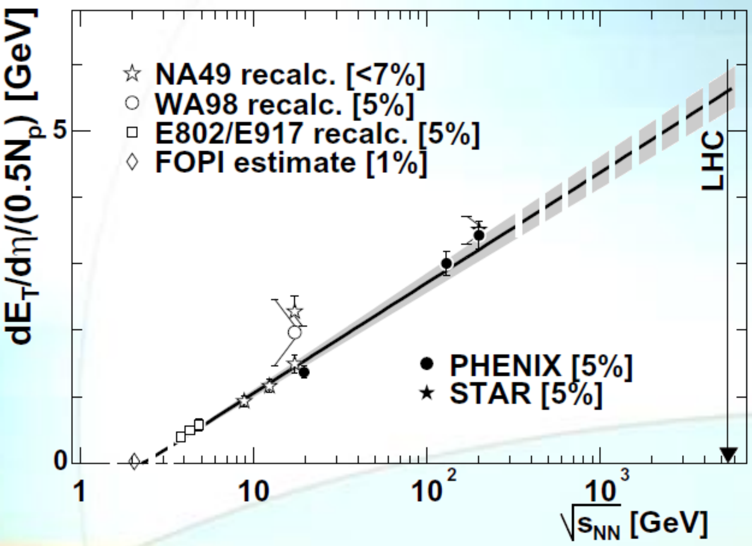


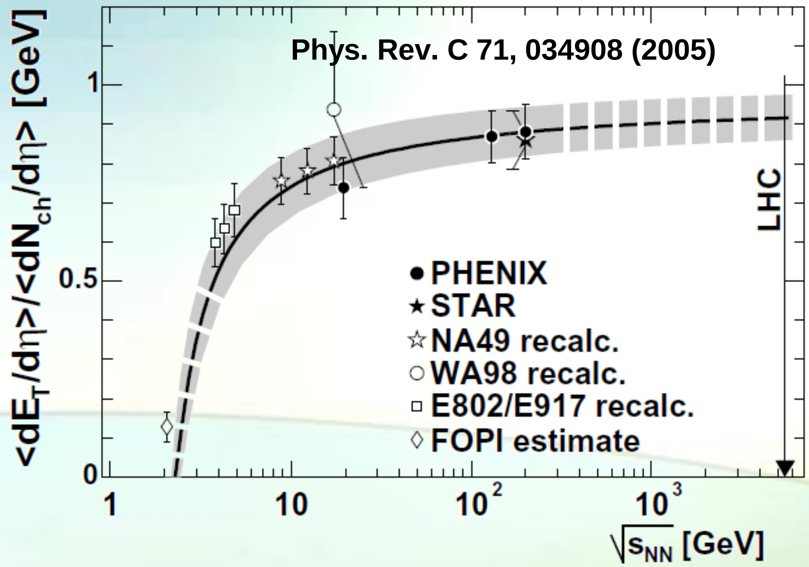
CERN/LHCC 2007-009



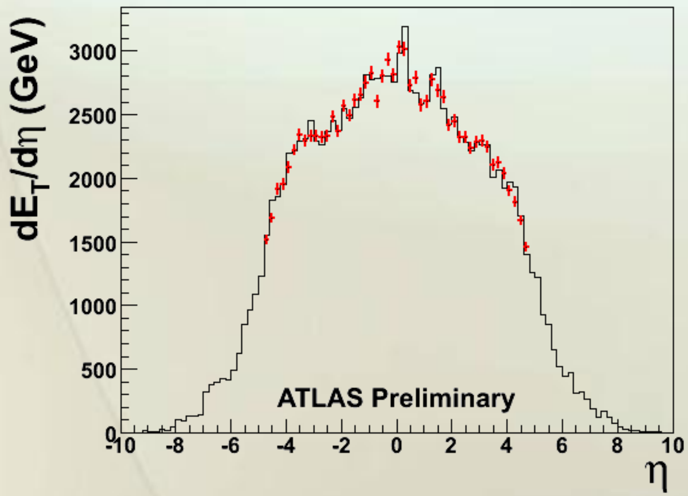


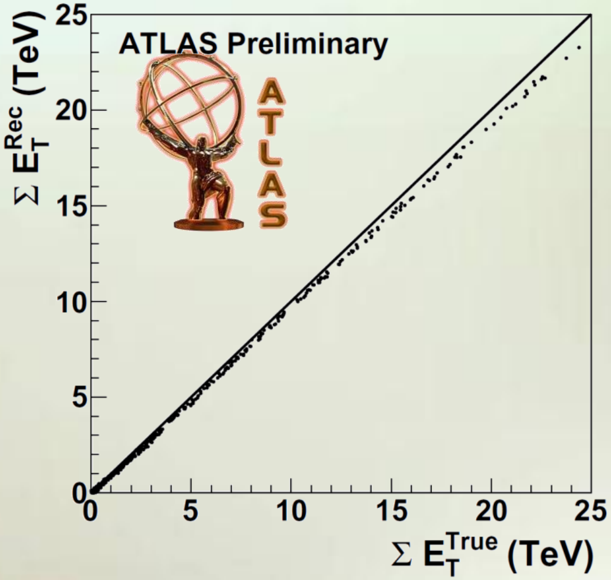
$dE_T/d\eta$ production.





Summing up the energy in EMC and HC

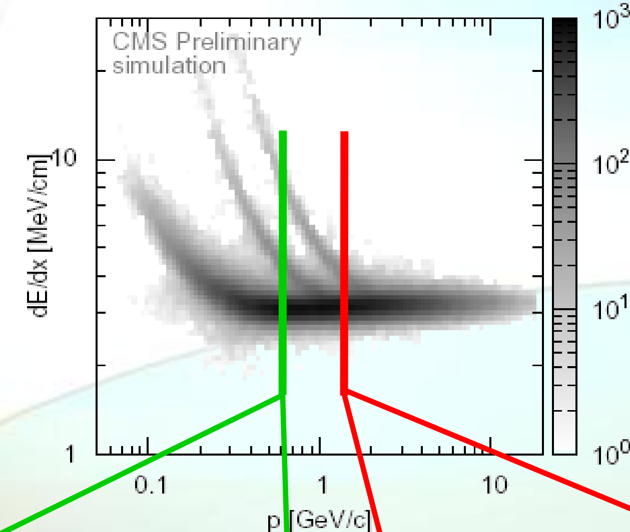


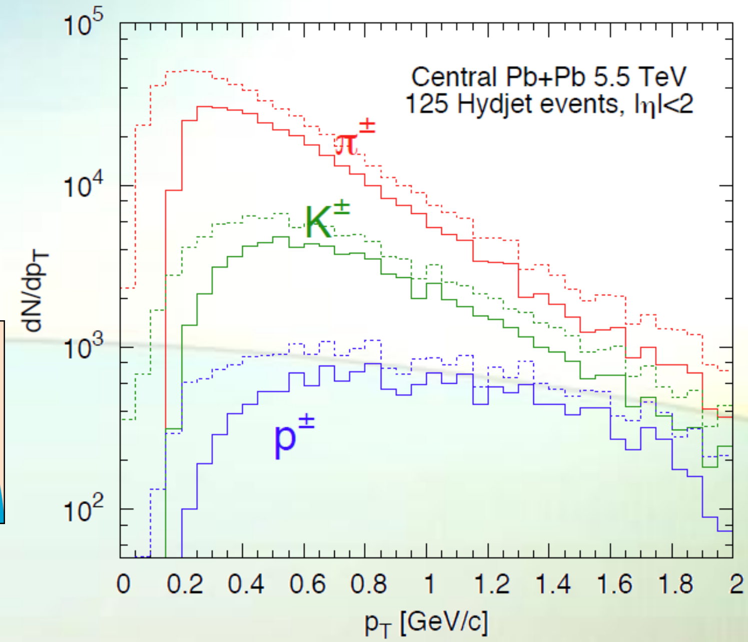


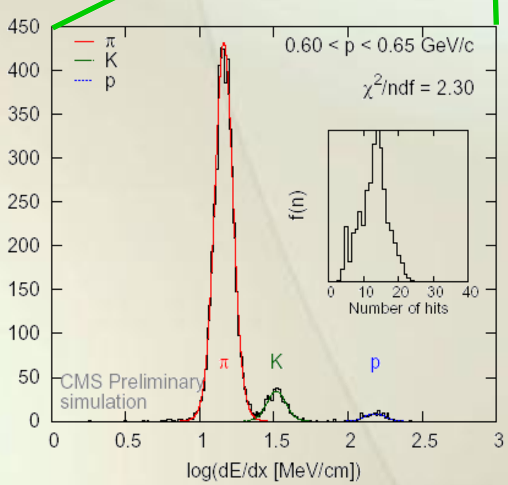
Particle identification

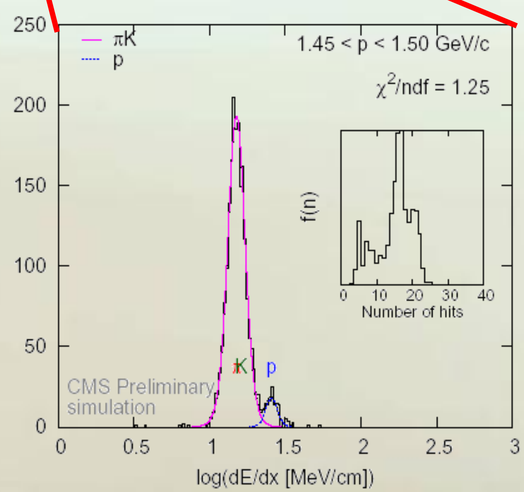
Particle identification using dE/dx in the pixels of inner tracking system

Pixels+Strips

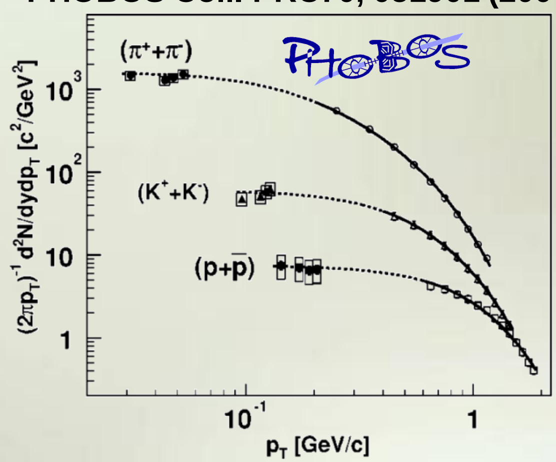






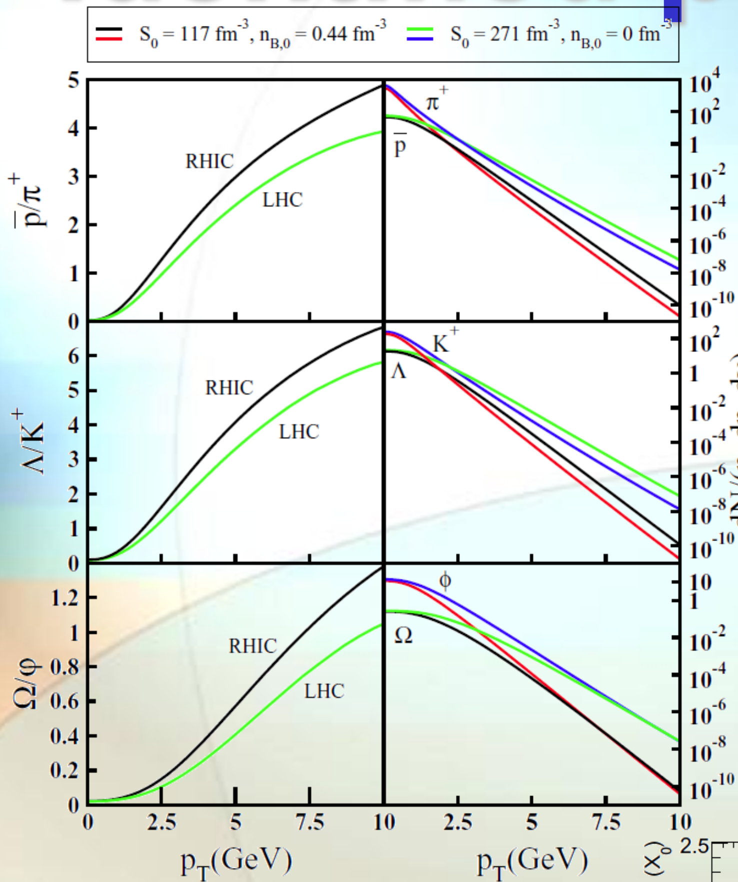


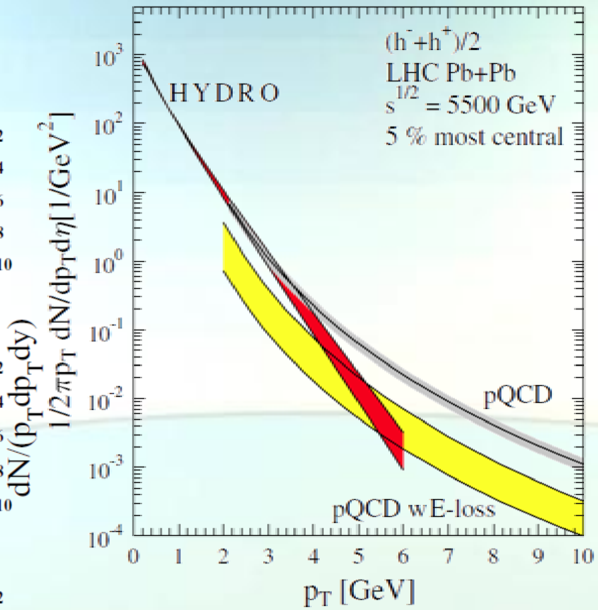
PHOBOS Coll. PRC70, 051901 (2004)

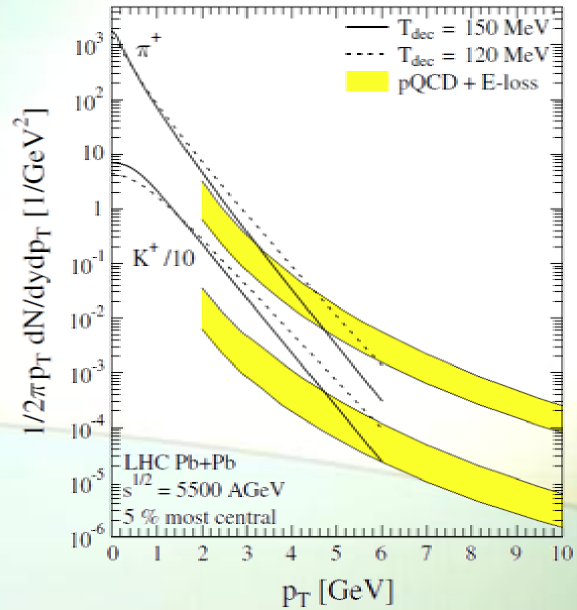


B. Hong SQM2008

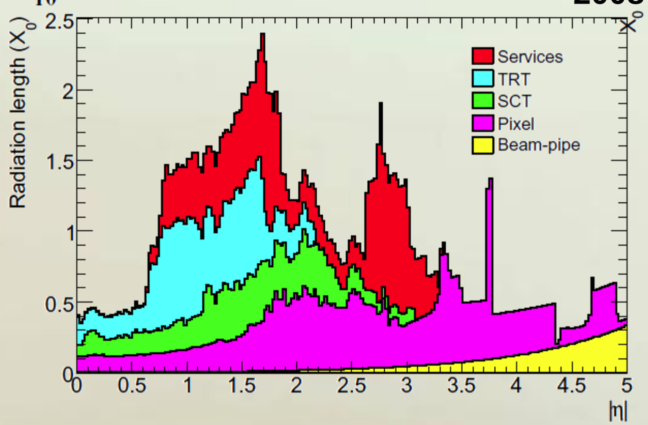
Identified particles challenge.

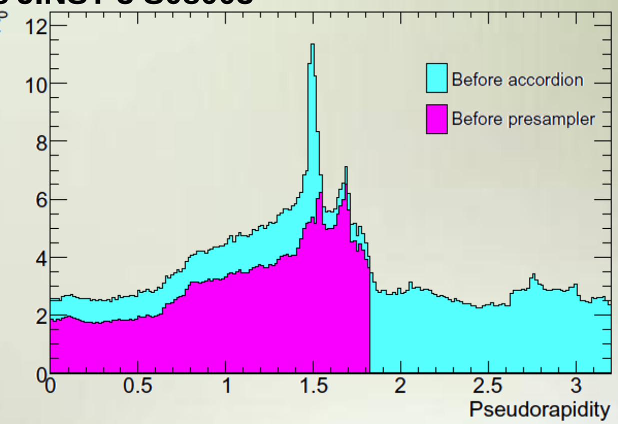






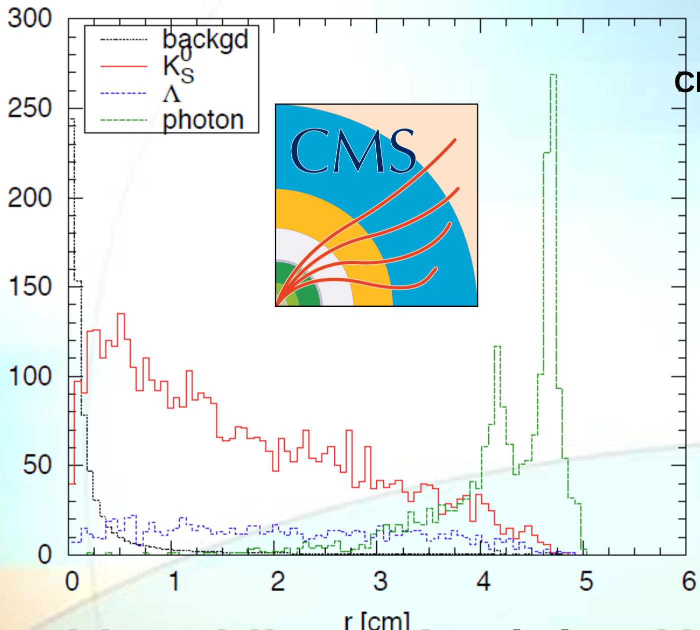
2008 JINST 3 S08003



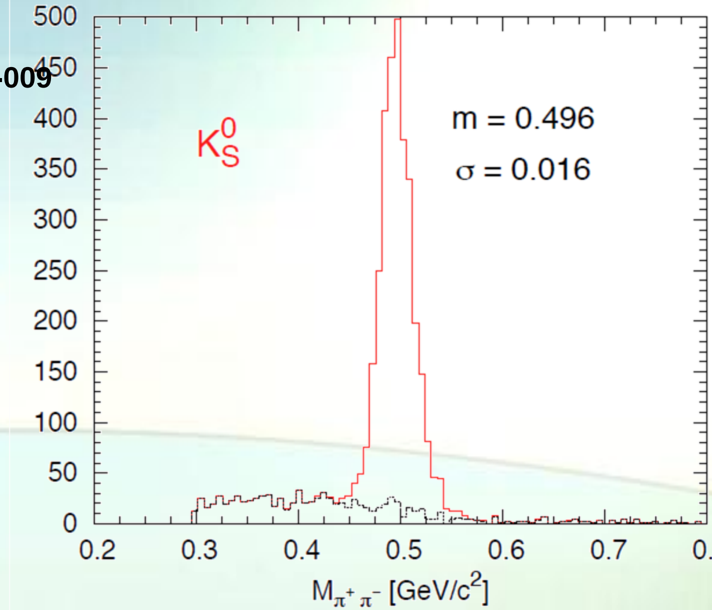


Decay reconstruction is difficult at low p_T with ATLAS and CMS due to detectore material.

Identified particles.

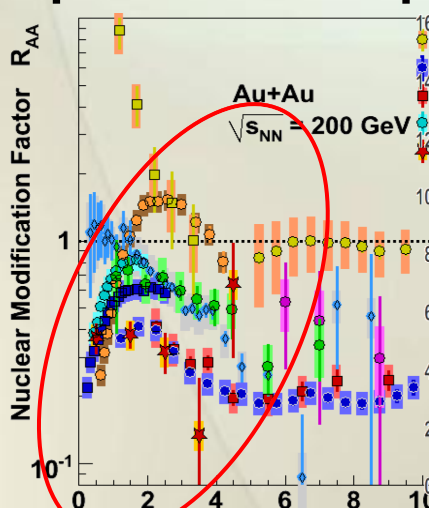


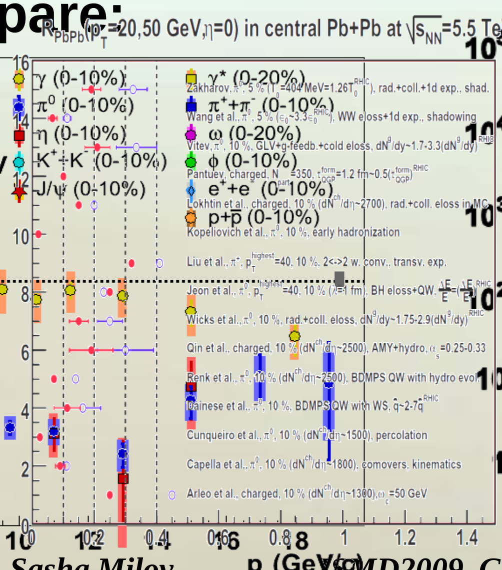
CERN/LHCC 2007-009

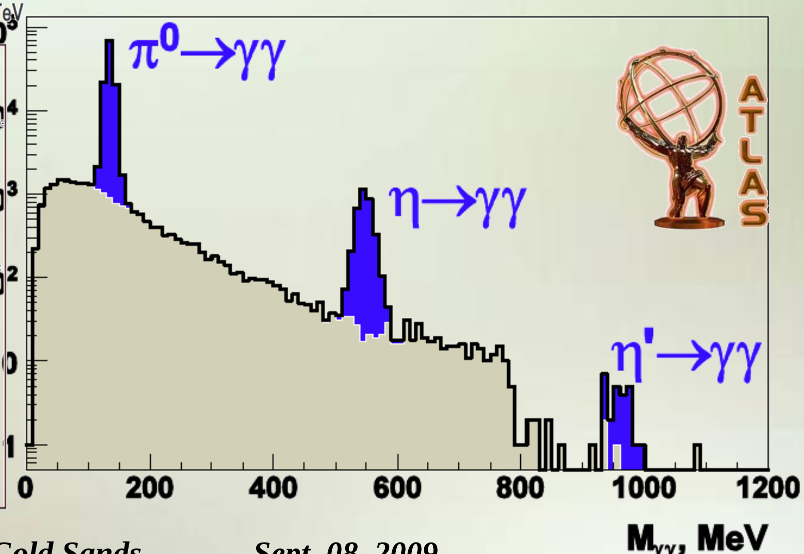


At mid-rapidity and at |η|>8 (!)

ID'ed spectra to compare:



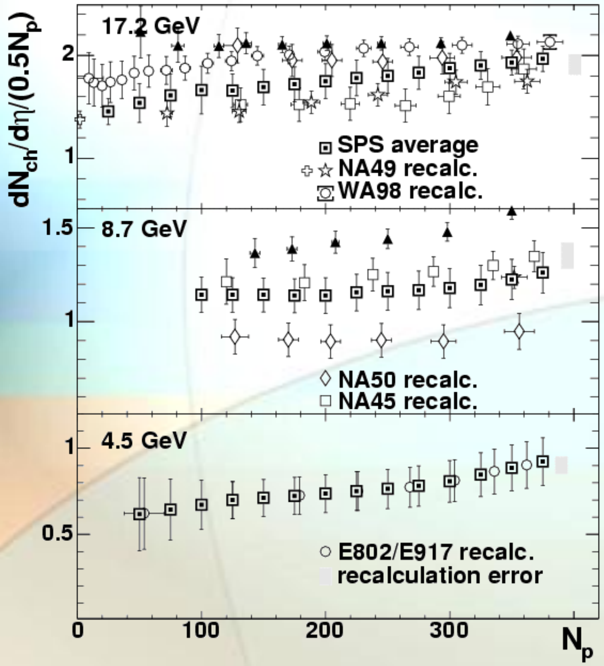


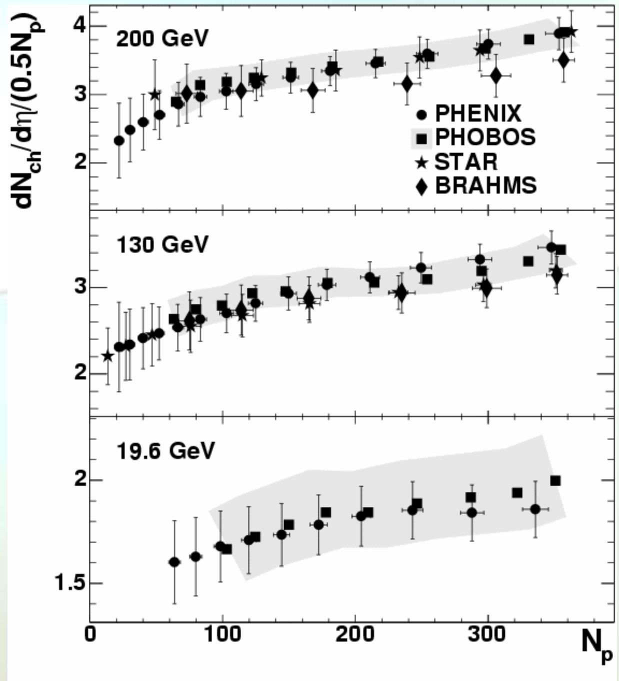


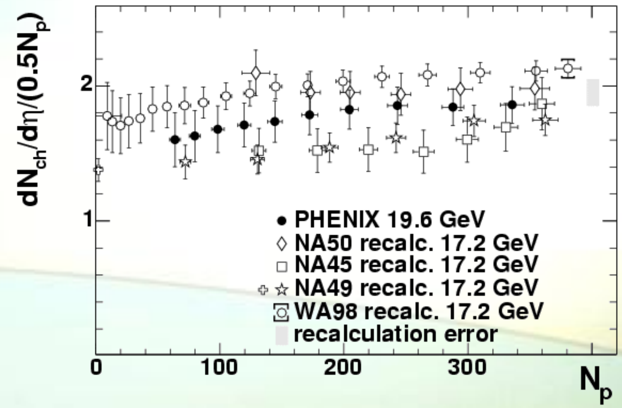
A.M. arXiv:0809.3880v1

Skeptic's question:

Why ATLAS and CMS plan to do what ALICE is suppose to do better? / easier?



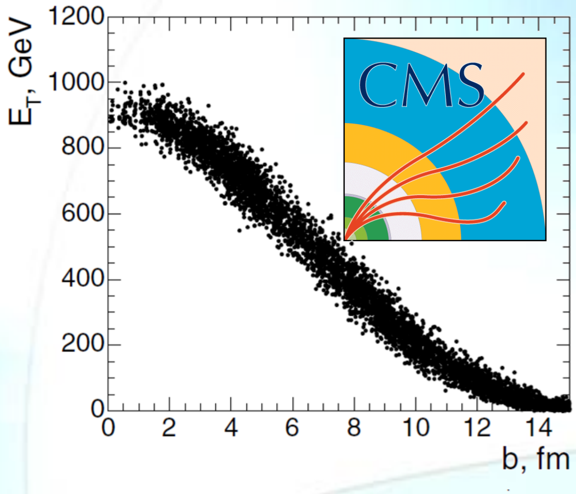


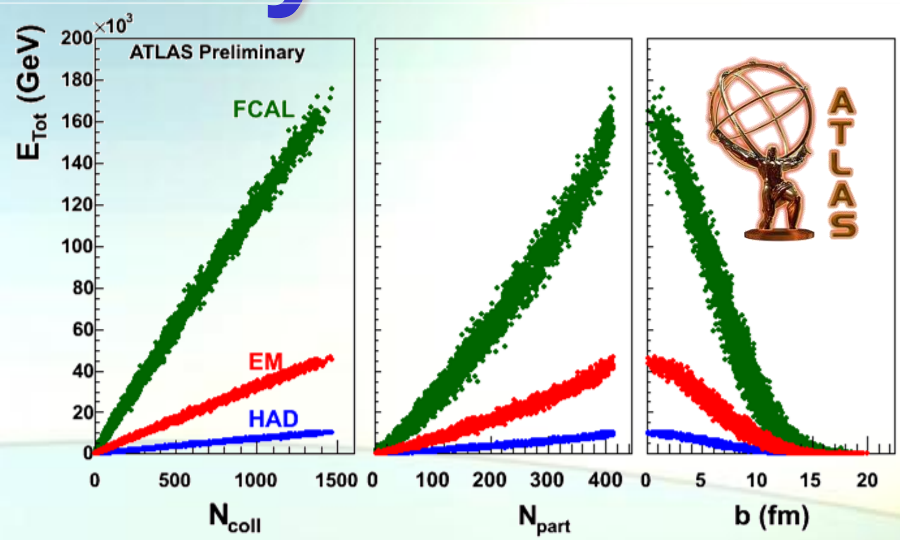


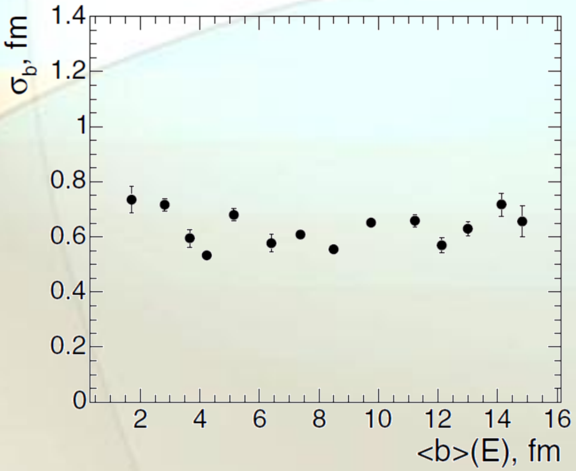
A.M. J. Phys. Conf. Ser. 5 17-36 (2005)

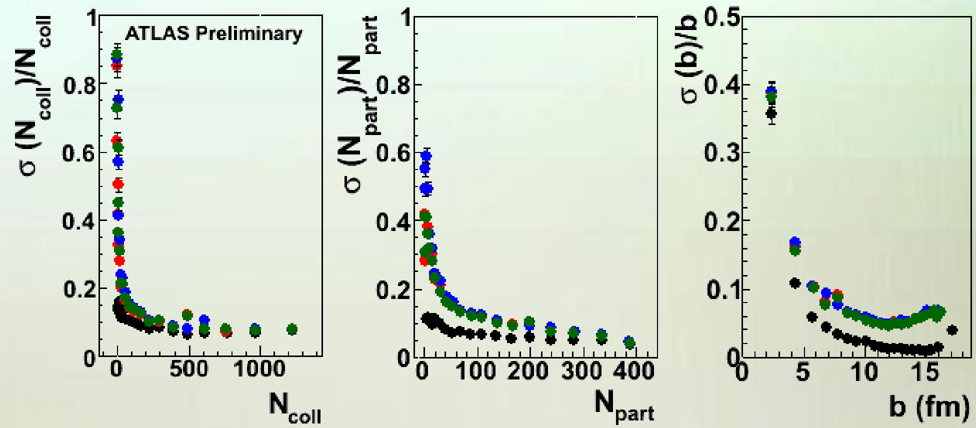
a) Let's be as precise as possible about our data.
b) We will have better answer when data come out…

Centrality.



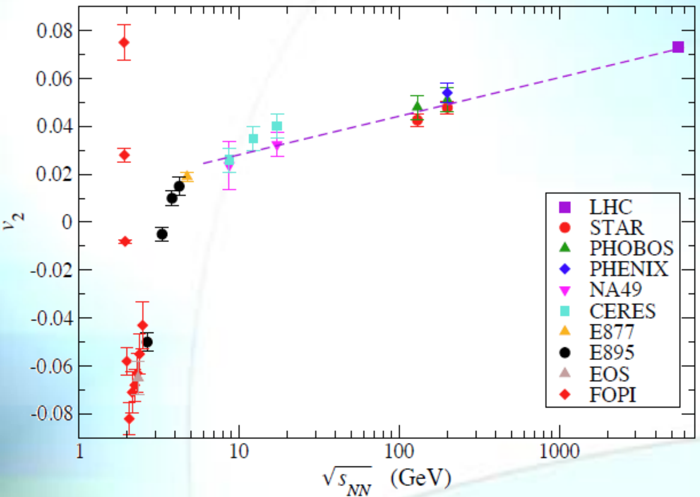


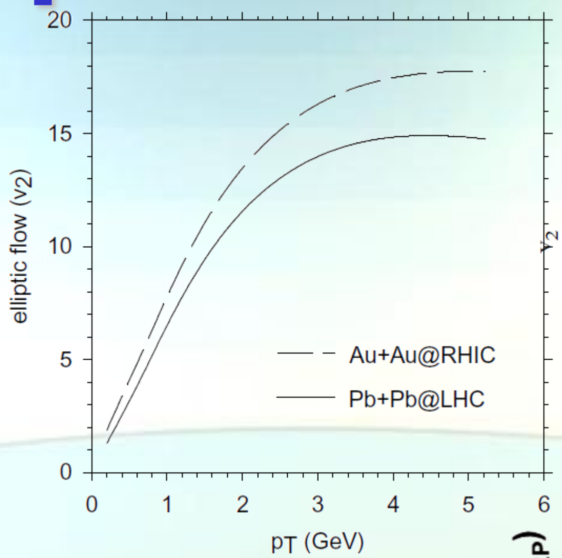


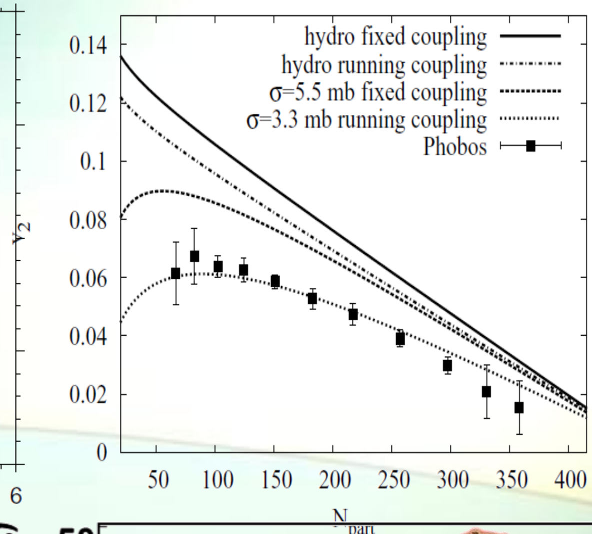


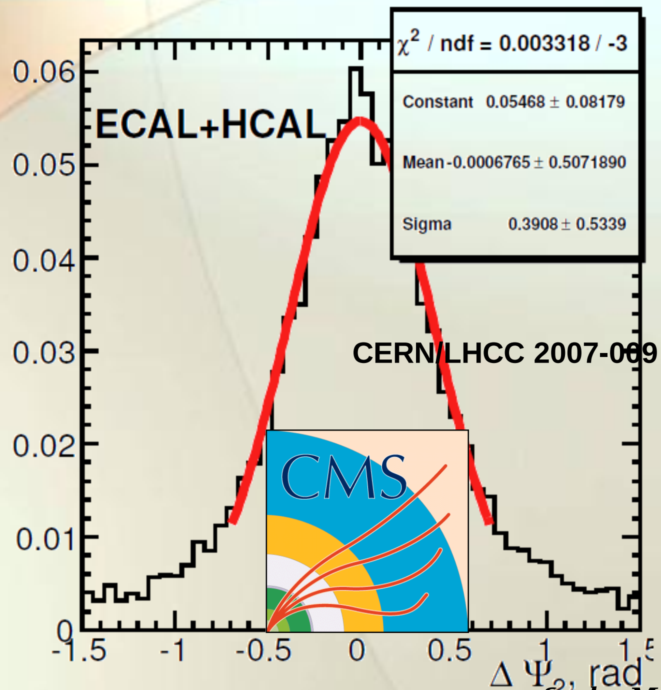
Centrality at LHC is going to be easier than at RHIC: higher yields, wider coverage and more ways to measure.
But must face a much more difficult challenge: isolate a sample as close as possible to N+N within Pb+Pb data because the p+p baseline is absent!

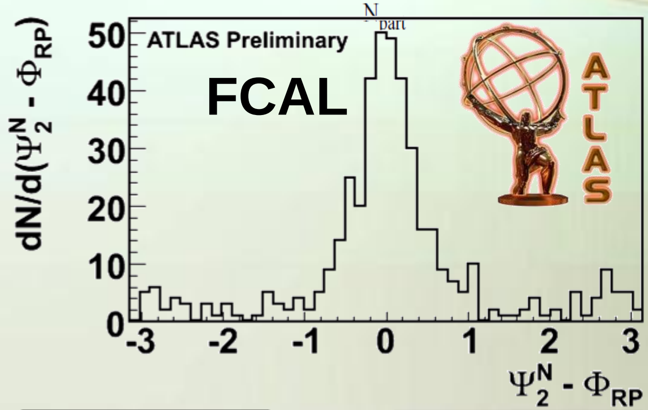
Elliptic Flow.

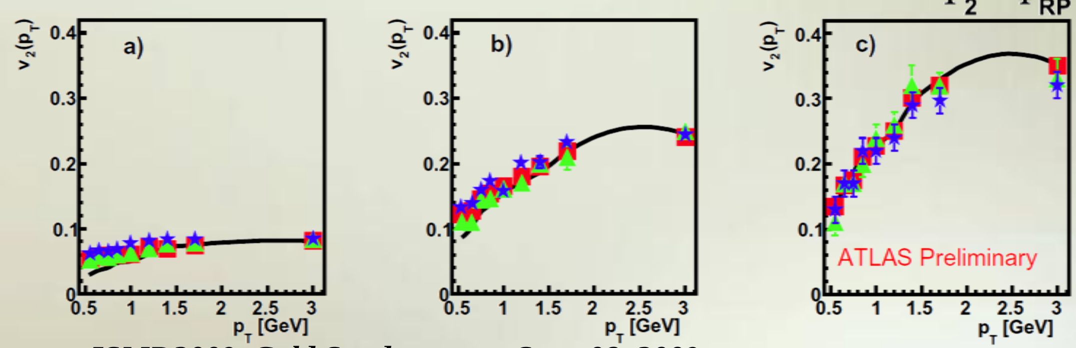












Summary

Physics of the Relativistic Heavy Ions is one the most dynamic fields of modern science in the last 20 years. Many discoveries came out of the AGS, SPS and RHIC data. There are even more open questions.

We are at the beginning of a very exciting time in HI physics. In about a year from now we will learn a lot more than what we know today.

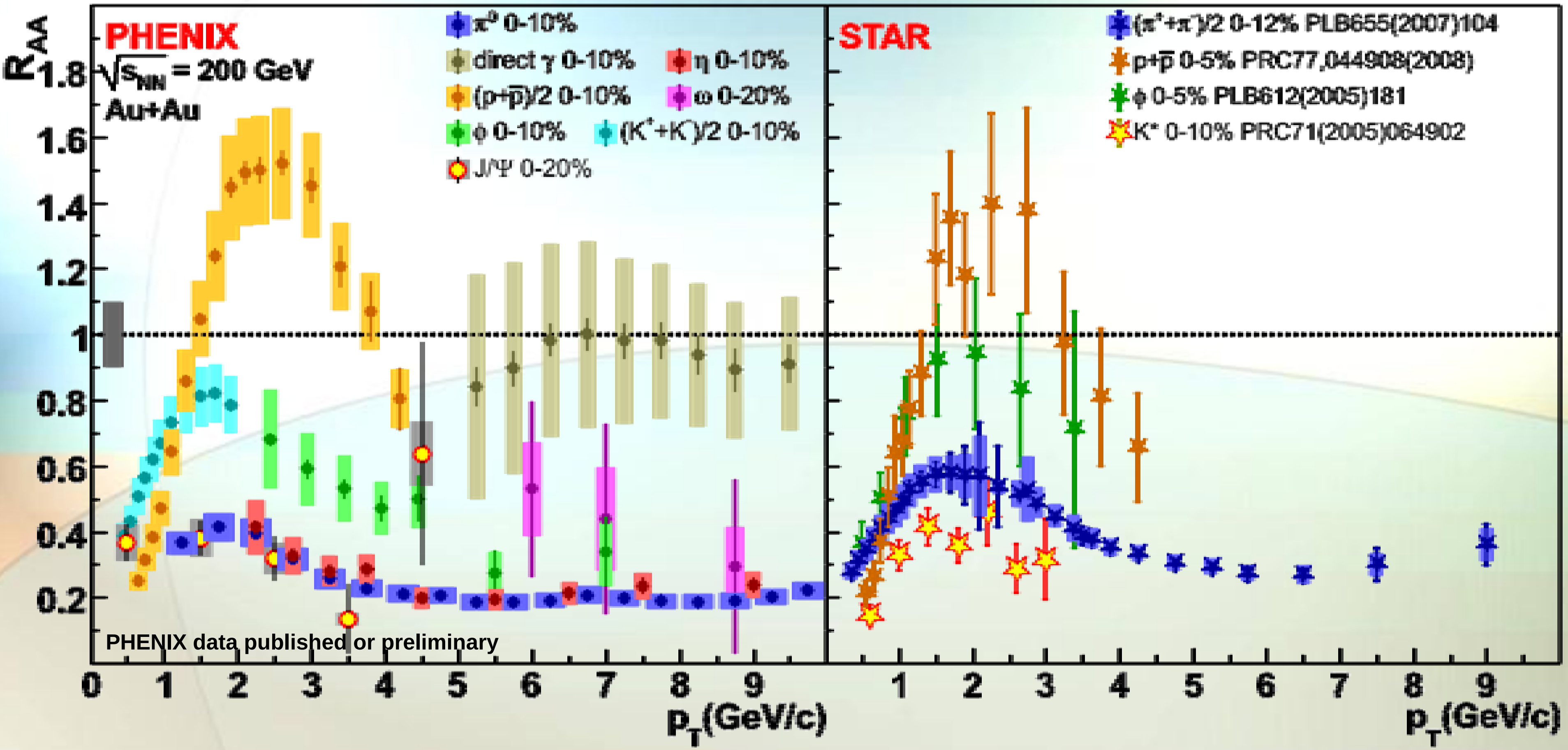
The LHC offers excellent opportunity to study HI with dedicated ALICE experiment and two universal detectors: ATLAS and CMS.

CMS and ATLAS are getting ready to analyze “foreign” Pb+Pb data and compete hard with ALICE and even on “soft” grounds.

There are challenges and difficulties, but the solutions are being worked out. Even a very first data may tell us a very new story.

BACKUPS

Yields and ratios.



π^0&$\pi^\pm$ are suppressed by ~4-5

γ's hold the N_{coll} scaling

η falls dead on π^0

Baryons are enhanced including strange (not shown).

ω is suppressed (inconclusive)

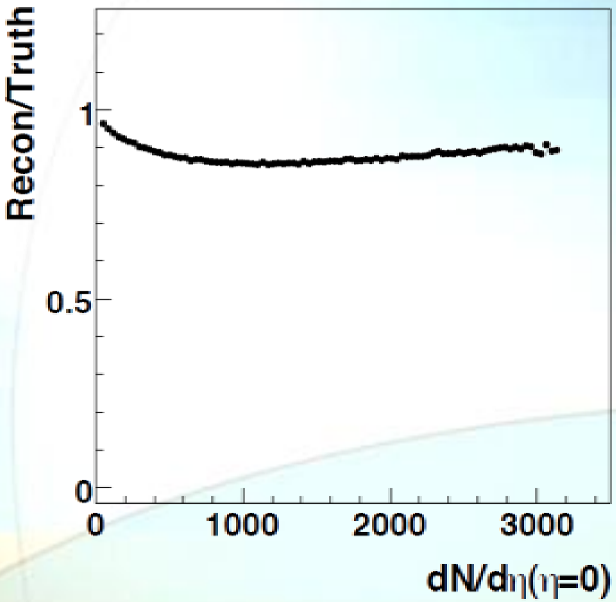
φ behaves differently. Why?

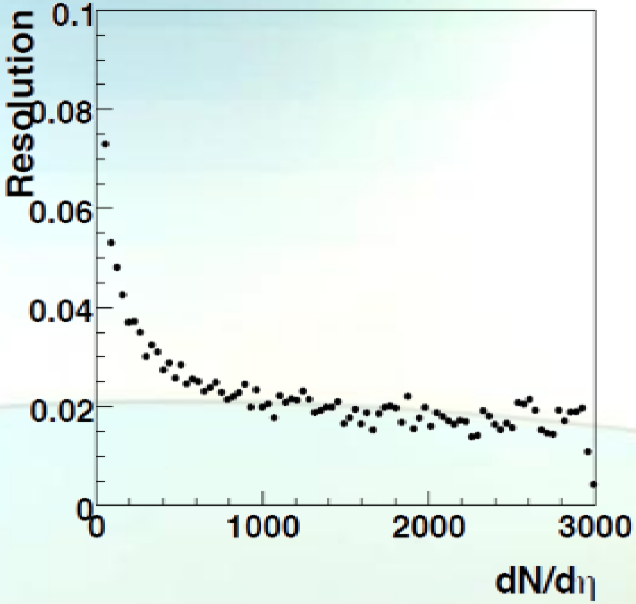
$K^\pm$ is at low p_T, no overlap.

K* behaves like π^0?

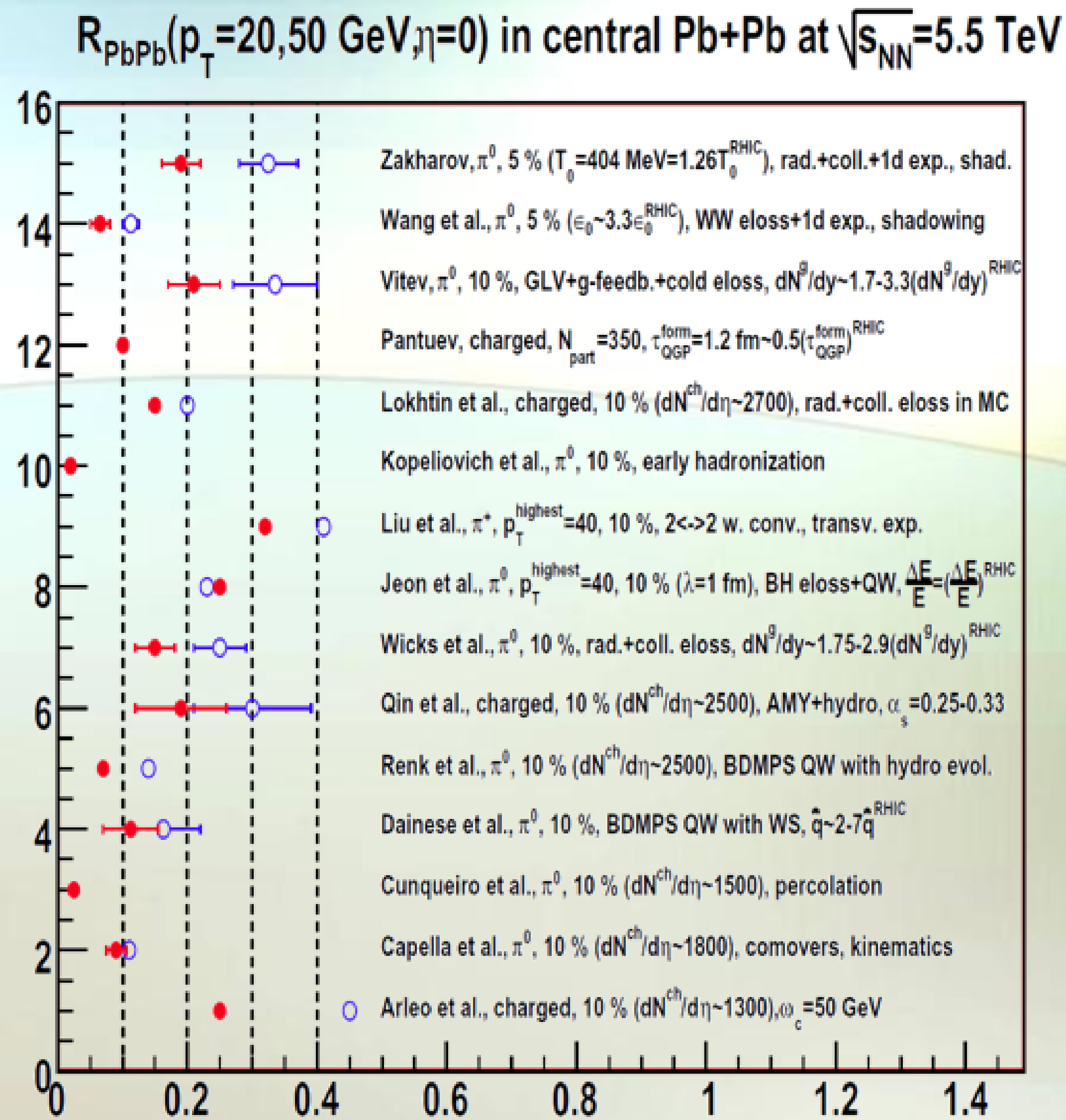
J/Ψ looks like K*… ?

dN/dη resolution.





R_{AA}



R_PbPb(p_T=20,50 GeV,η=0) in central Pb+Pb at √s_NN=5.5 TeV
16
14
12
10
8
6
4
2
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Zakharov, π0, 5 % (T0=404 MeV=1.26T0RHIC), rad.+coll.+1d exp., shad.
Wang et al., π0, 5 % (ε0~3.3ε0RHIC), WW eloss+1d exp., shadowing
Vitev, π0, 10 %, GLV+g-feedb.+cold eloss, dNg/dy~1.7-3.3(dNg/dy)RHIC
Pantuev, charged, Npart=350, τQGPform=1.2 fm~0.5(τQGPform)RHIC
Lokhtin et al., charged, 10 % (dNch/dη~2700), rad.+coll. eloss in MC
Kopeliovich et al., π0, 10 %, early hadronization
Liu et al., π+, pThighest=40, 10 %, 2<->2 w. conv., transv. exp.
Jeon et al., π0, pThighest=40, 10 % (λ=1 fm), BH eloss+QW, ΔE/E=(ΔE/E)RHIC
Wicks et al., π0, 10 %, rad.+coll. eloss, dNg/dy~1.75-2.9(dNg/dy)RHIC
Qin et al., charged, 10 % (dNch/dη~2500), AMY+hydro, αs=0.25-0.33
Renk et al., π0, 10 % (dNch/dη~2500), BDMPS QW with hydro evol.
Dainese et al., π0, 10 %, BDMPS QW with WS, q̂~2-7q̂RHIC
Cunqueiro et al., π0, 10 % (dNch/dη~1500), percolation
Capella et al., π0, 10 % (dNch/dη~1800), comovers, kinematics
Arleo et al., charged, 10 % (dNch/dη~1300), ωc=50 GeV

- The medium appears to be thermalized with chemical freeze-out T_{ch} ~T_c
  - Measured: hadron abundances – consistent with thermal model fit : μ_b= 24±4 MeV, T_{ch} =160±4 MeV
- The initial temperature $T_{init} > T_c$
  - measured thermal photon slope: T = 221 ± 23 ± 18 MeV in central Au+Au@ $\sqrt{s_{NN}}$ = 200GeV
    - Note: from hydro, the initial T is a factor of 1.5 – 3 higher due to expansion
- Initial energy density $\varepsilon \geq 5.5 - 10$ GeV/fm^3 →well above predicted transition to QGP
  - Measurements: $dN_{ch}/d\eta$, or $dE_T/d\eta$ or jet quenching
- Initial state gluon saturation governs particle production
- Near perfect fluid: very small viscosity/entropy density
  - Strong elliptic flow
- Medium opaque to jets and responds (by ridges and Mach cones)
- Hadronization by quark recombination plays significant role
  - Baryon/meson v_2 and R_{AA}

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