Multiparticle production in nuclear collisions using effective energy approach

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A.N. Mishra, R. Sahoo, E.K.G. Sarkisyan, A.S. Sakharov

arXiv:1405.2819

Motivation

Bulk observables - *mean multiplicity and rapidity densities* - control parameters of the formation and evolution of the collision initial state

Extensively studied in heavy-ion collisions at RHIC

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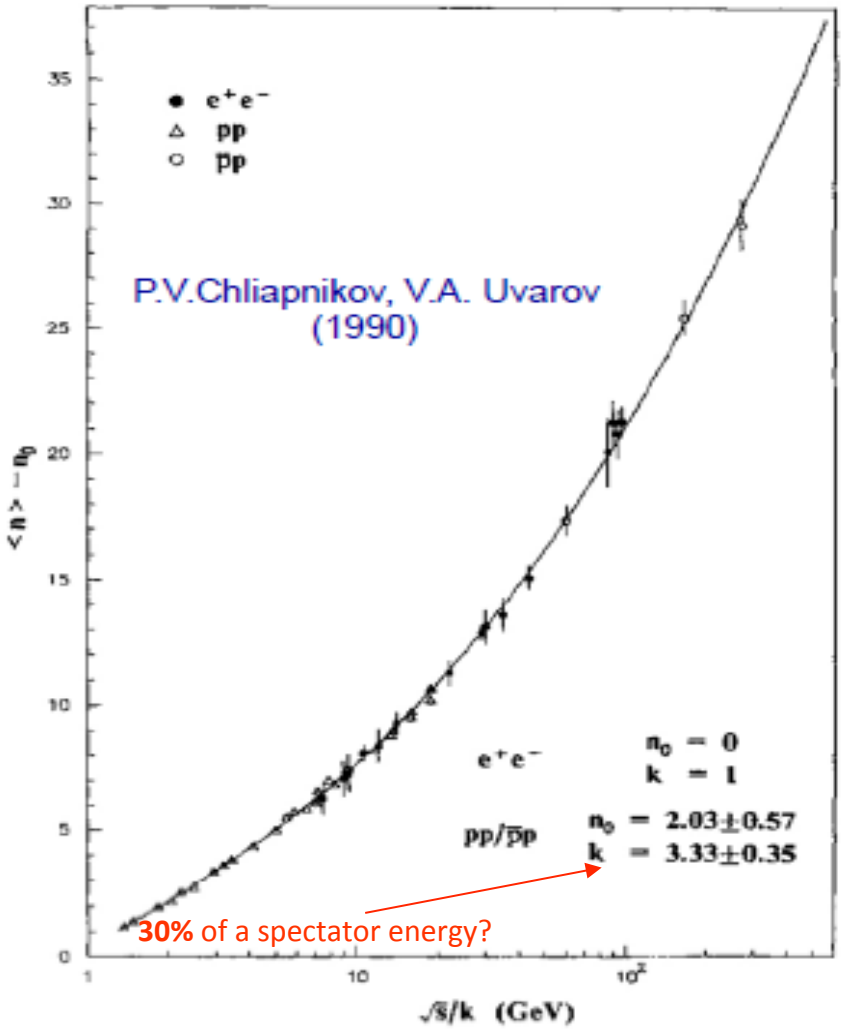

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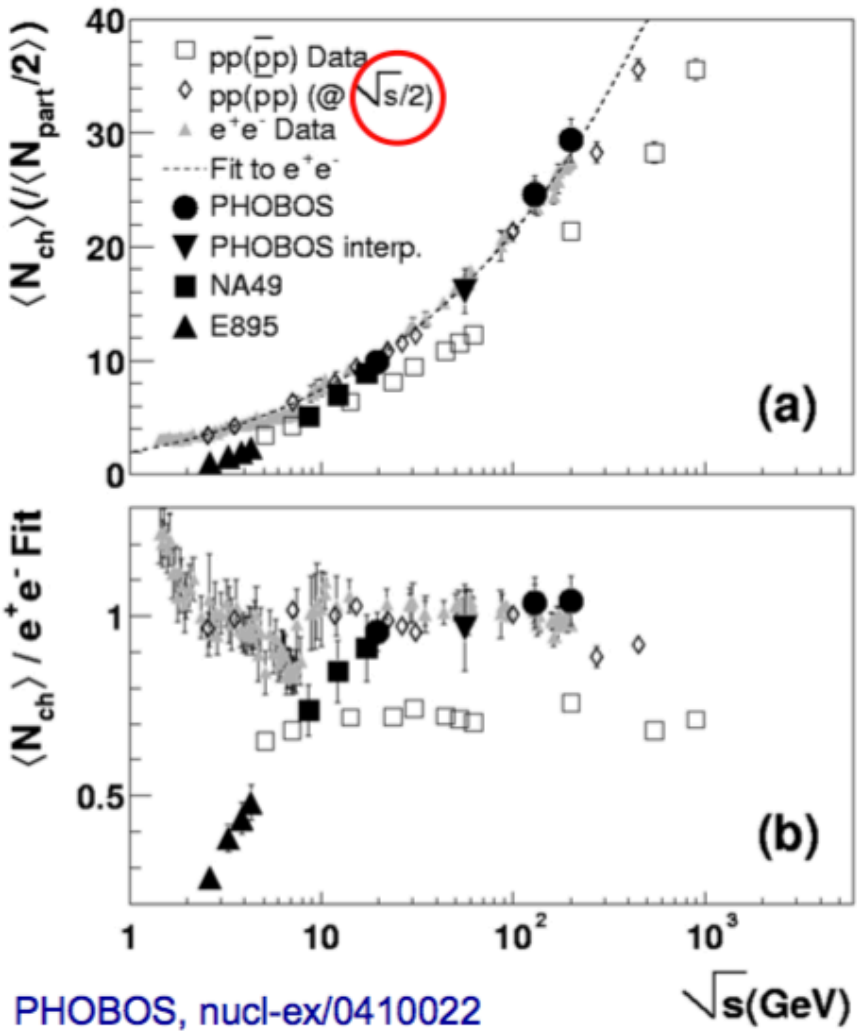

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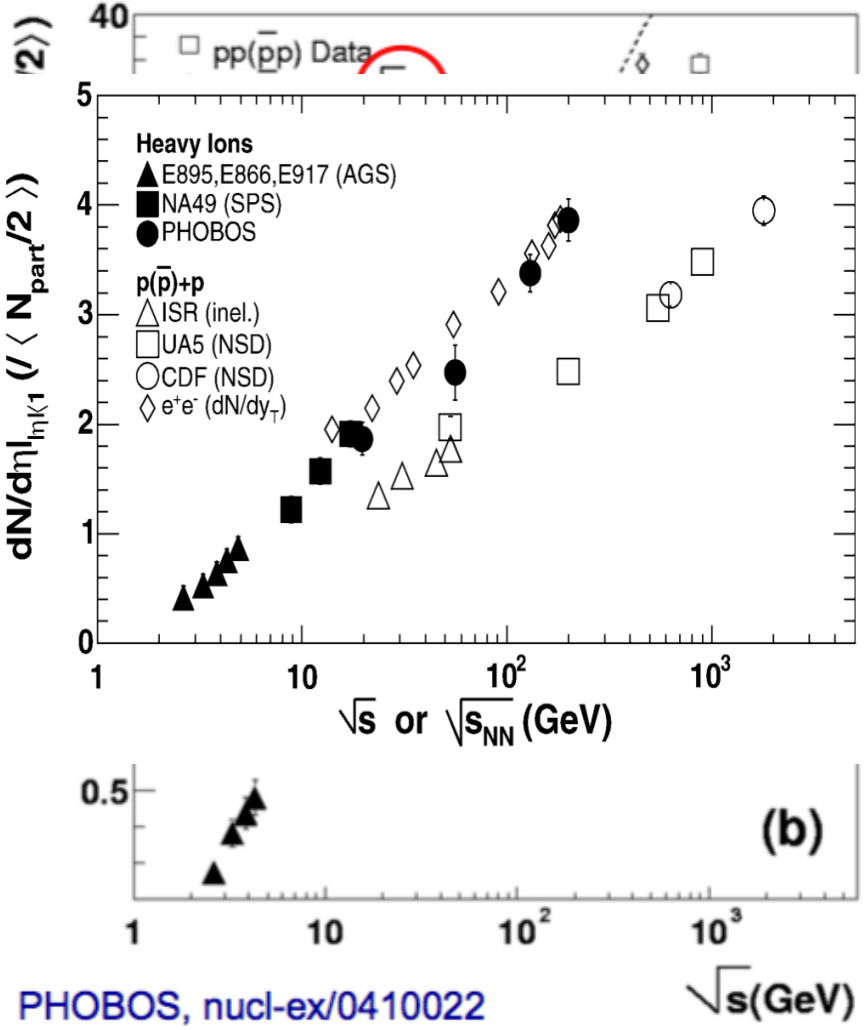

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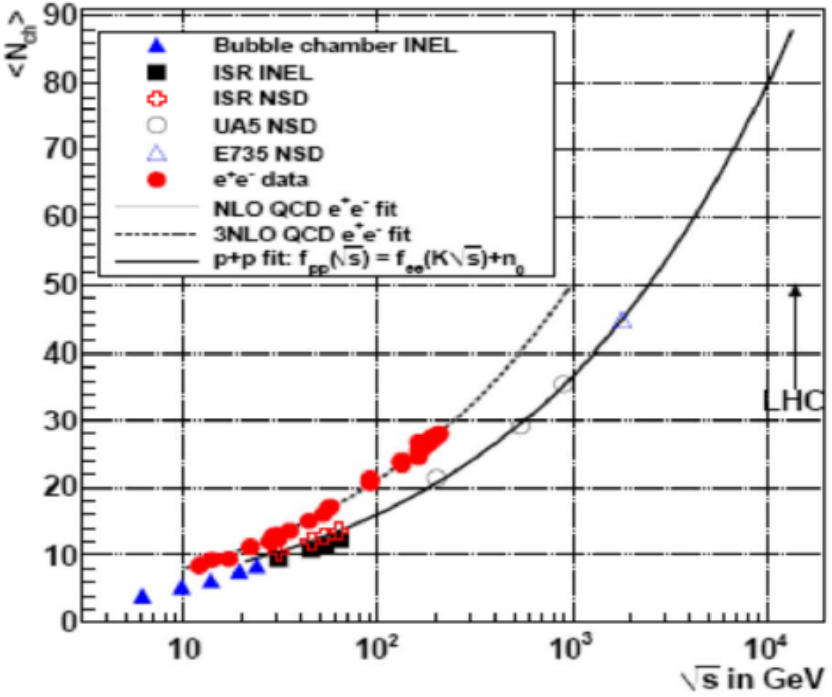
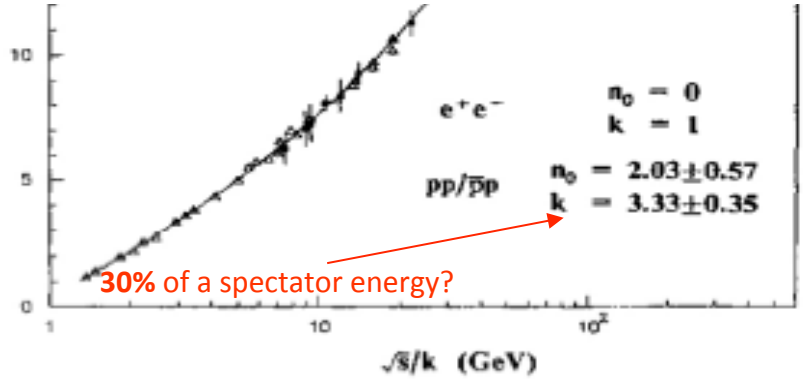
***Not* the same scaling for both variables and for different types of interactions**

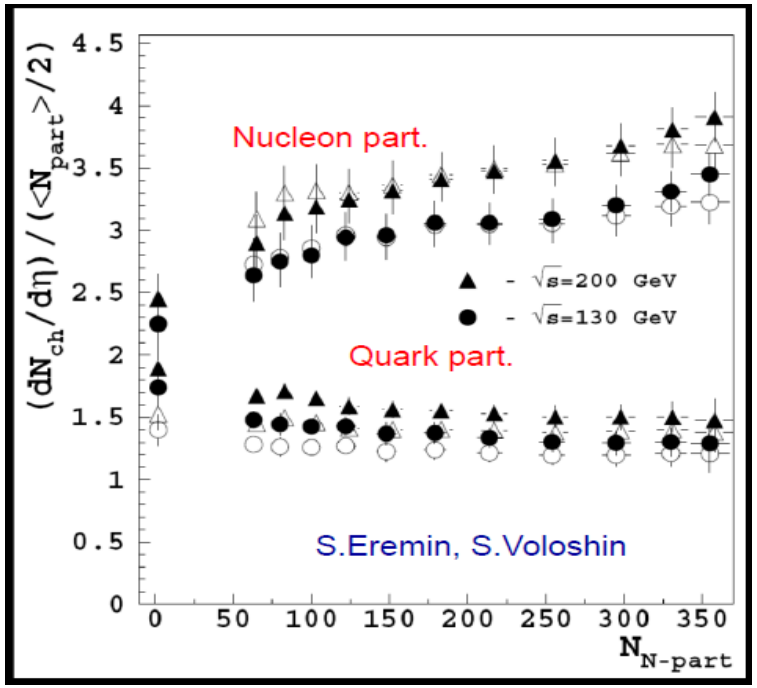


J.F. Grosse-Oetringhaus and K. Reygers (2010): K=1/3, n_0~2

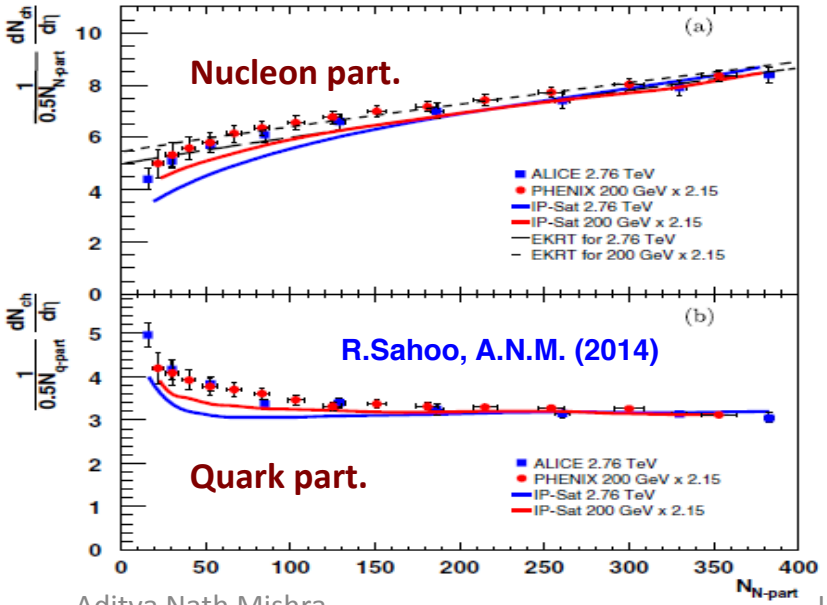


Constituent Quark Framework

No nucleon participant dependence as soon as calculated in the constituent quark framework



Nucleon Participant: Open vs solid symbols: hijing vs overlap model
Quark Participant: Open vs solid symbols: different σ_{pp}



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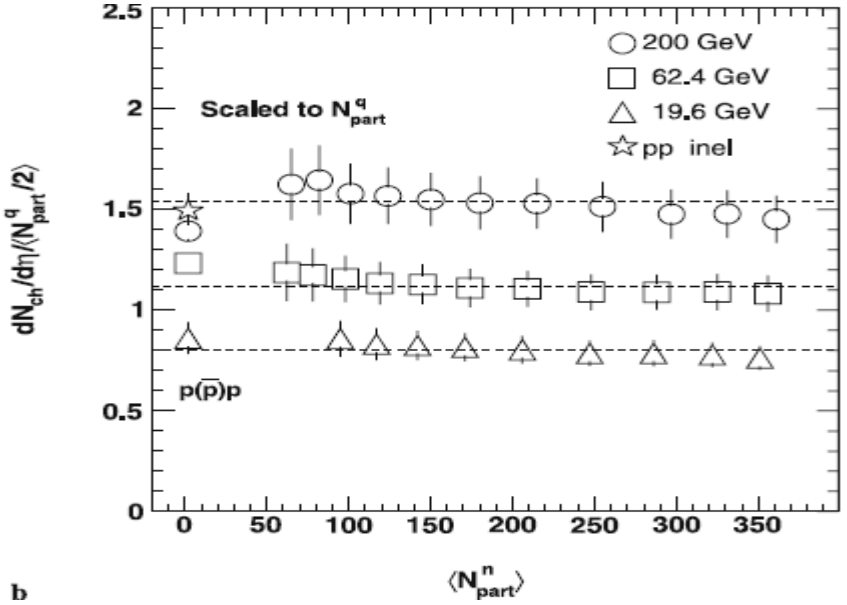

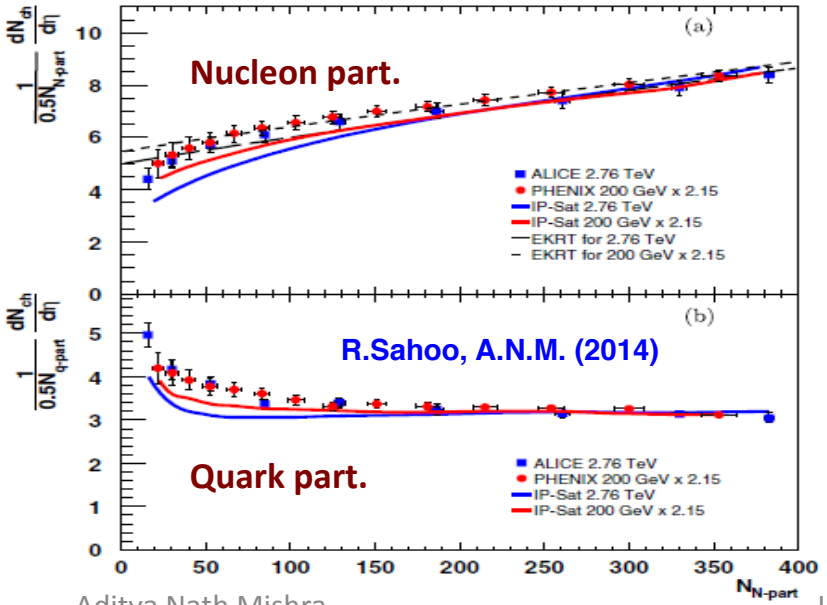

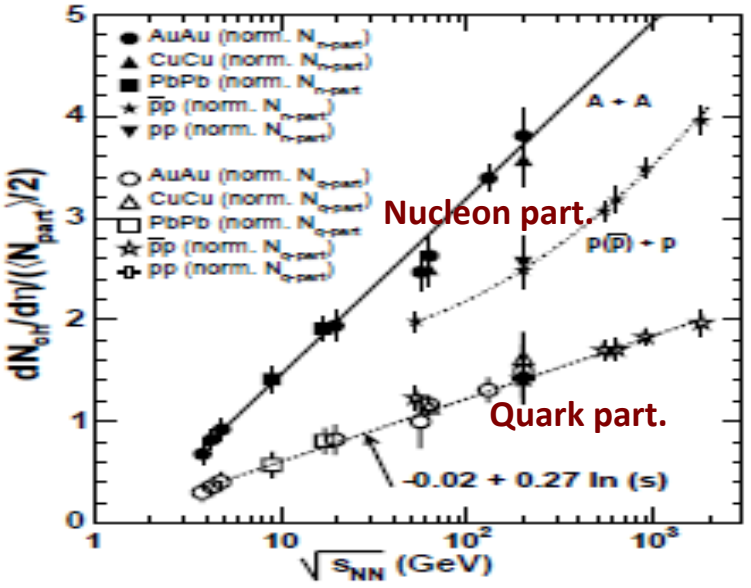

R. Nouicer (2007), PHOBOS data

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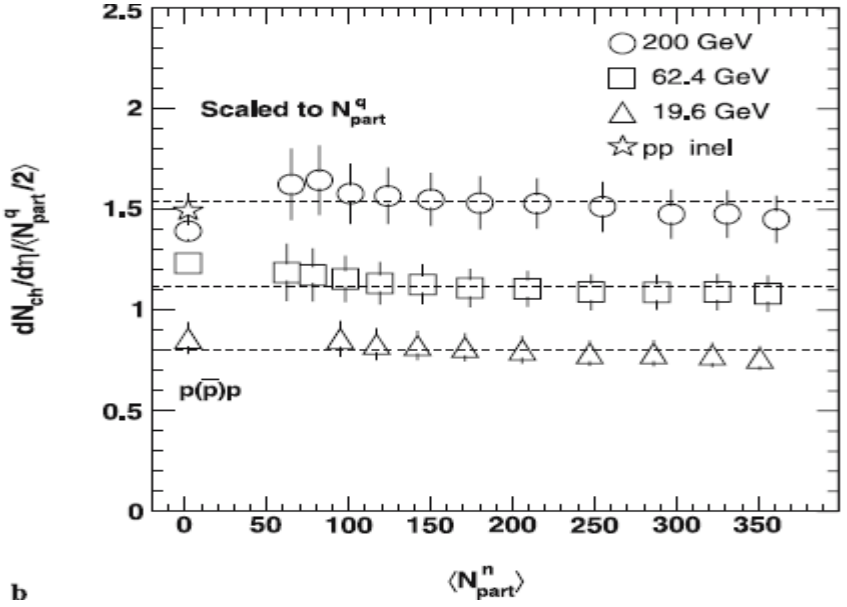
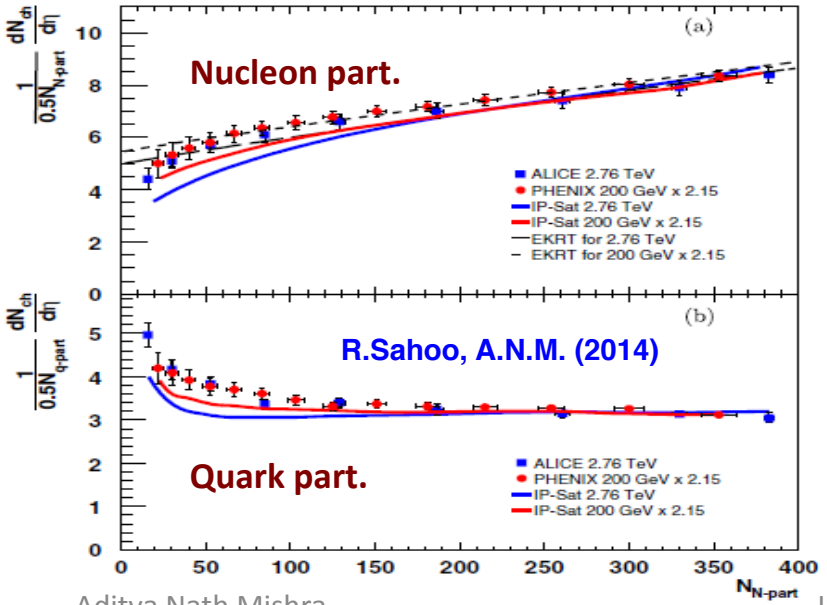
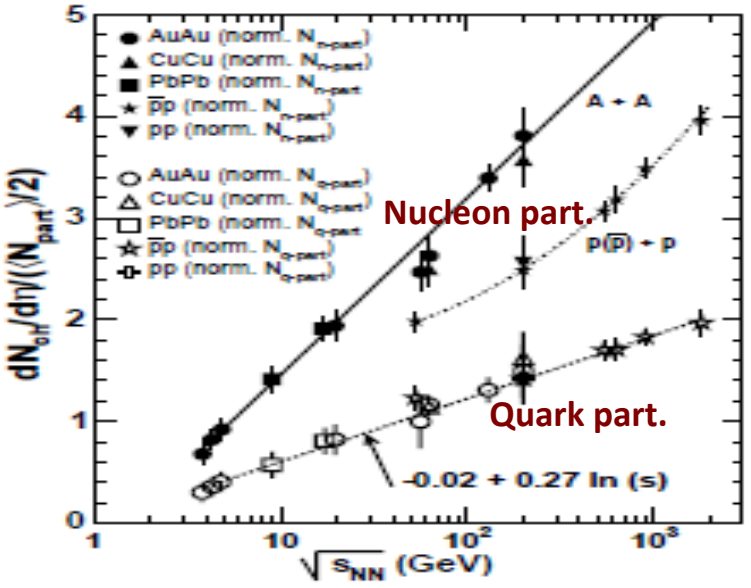
Quark degrees of freedom seem to play a role, not the nucleon ones







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Energy Scaling vs. Types of Collisions

- ✓ e^+e^- (structureless particles) annihilation - the ***total*** interaction energy is deposited in the initial state

- ✓ pp (superposition of three pairs of constituents) collision - only the energy of the interacting ***single quark pair*** is deposited in the initial state

- ✓ Both *multiplicity* and *midrapidity density* should be similar in pp at c.m. energy $\sqrt{s_{pp}}$ and e^+e^- at c.m. energy $\sqrt{s_{ee}} \approx \sqrt{s_{pp}}/3$

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- ✓ Head-on heavy ion collisions: ***all three quarks*** participate nearly simultaneously and deposit their energy coherently into initial state

- ✓ ***Both multiplicity* and *midrapidity density* should be similar in pp at c.m. energy $\sqrt{s_{pp}}$ and head-on AA at c.m. energy $\sqrt{s_{NN}} \approx \sqrt{s_{pp}}/3$**

E. Sarkisyan & A. Sakharov (2004) : dissipating energy participants

Hydrodynamics of Collisions

- Two head-on colliding Lorentz-contracted particles stop within the overlapped zone
  - Formation of fully thermalized initial state at the collision moment
  - The decay (expansion) of the initial state is governed by relativistic hydrodynamics - Landau model (1953)

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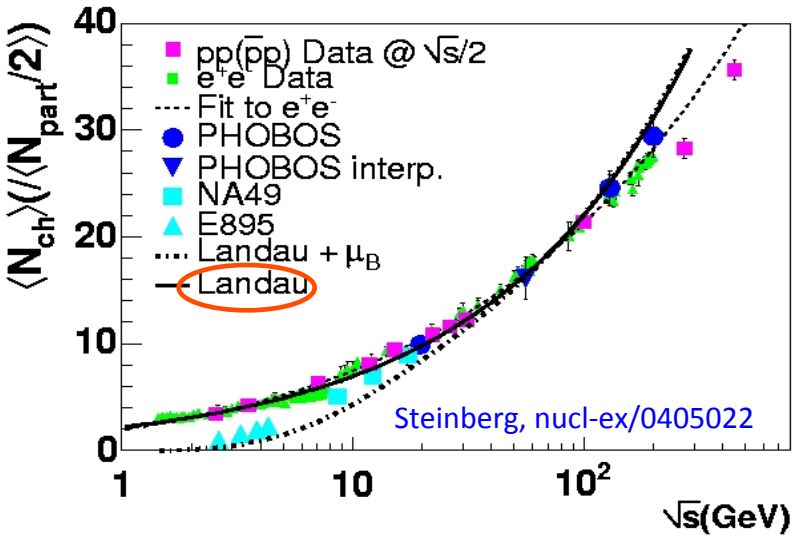

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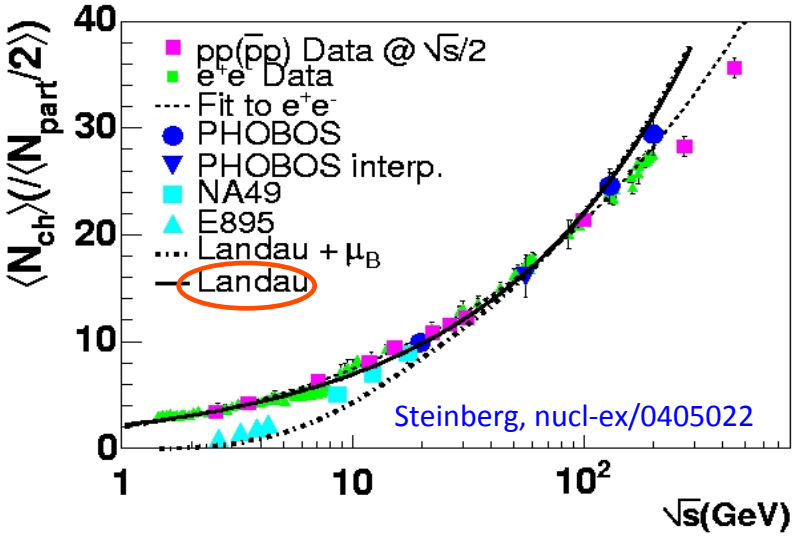

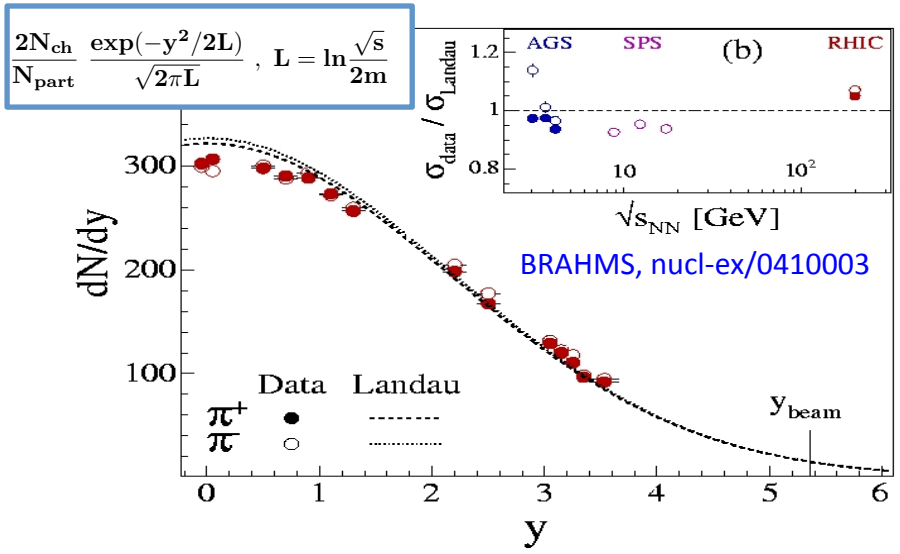

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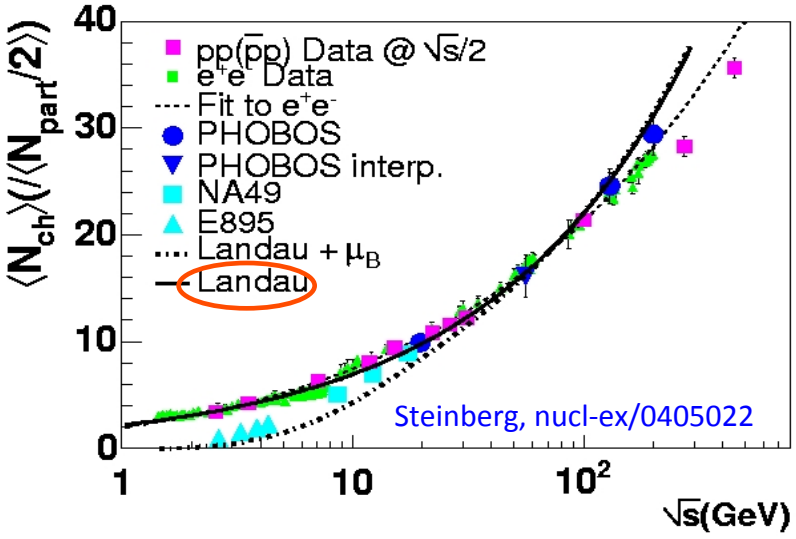

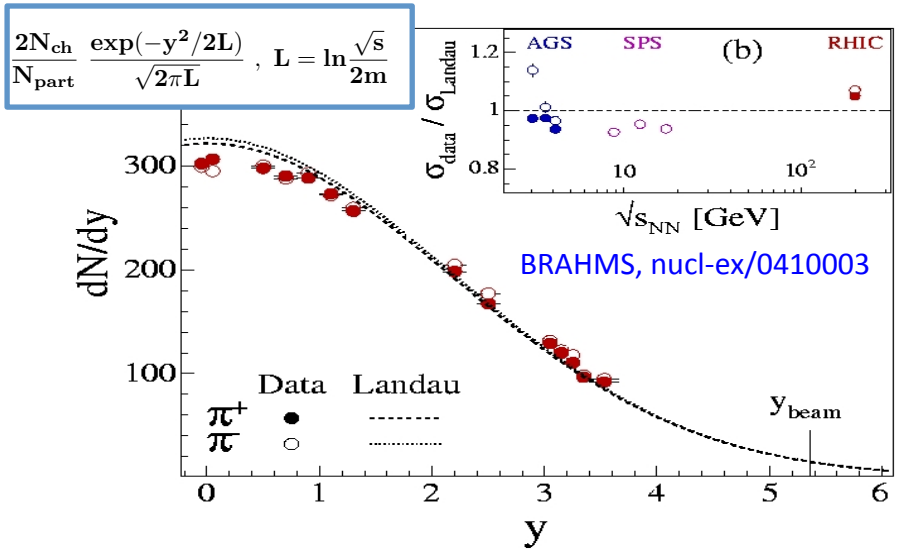

- The production of secondaries is defined by the energy deposited into the initial state

Hydrodynamics & Energy Scaling vs Data

from **Landau Hydrodynamics**

$$\rho(0) = \rho_{pp}(0)\frac{2N_{ch}}{N_{part}N_{ch}^{pp}}\sqrt{\frac{L_{pp}}{L_{NN}}} \quad L = \ln\frac{\sqrt{s}}{2m}$$

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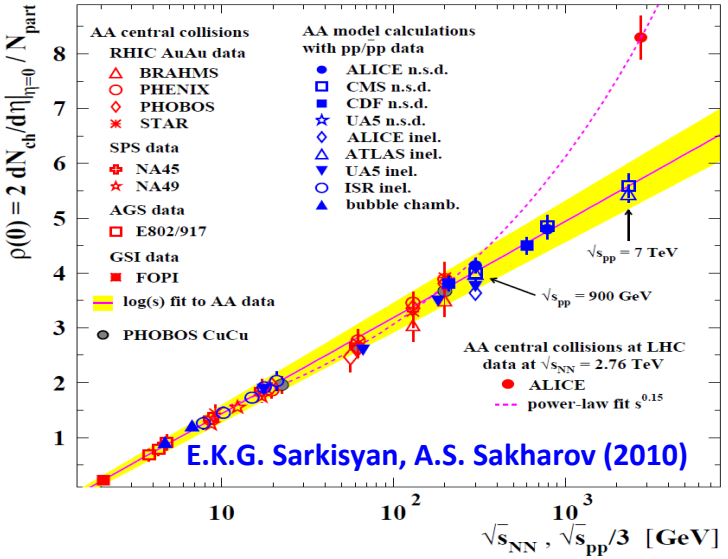

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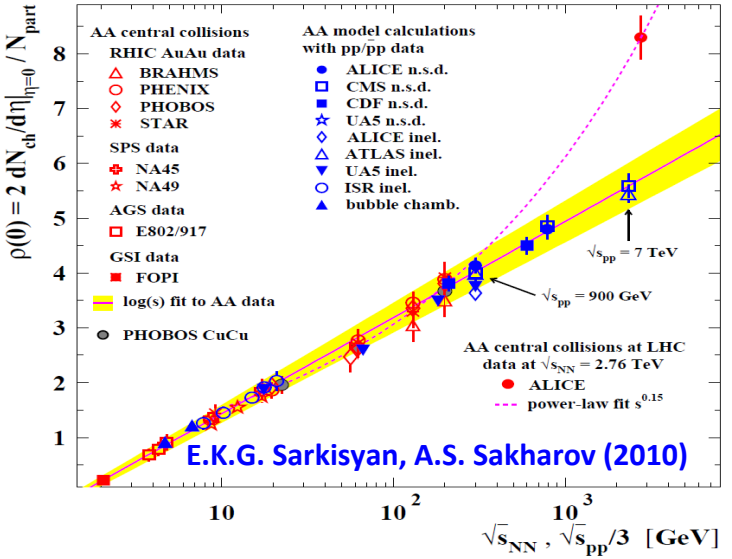

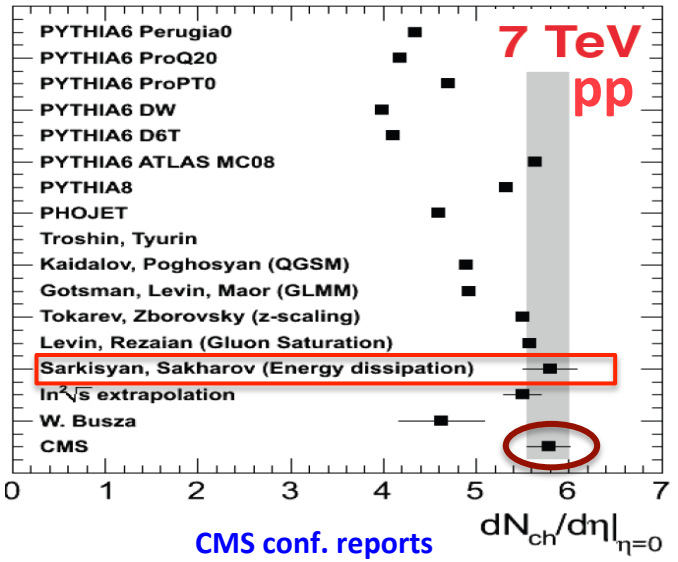

CMS conf. reports

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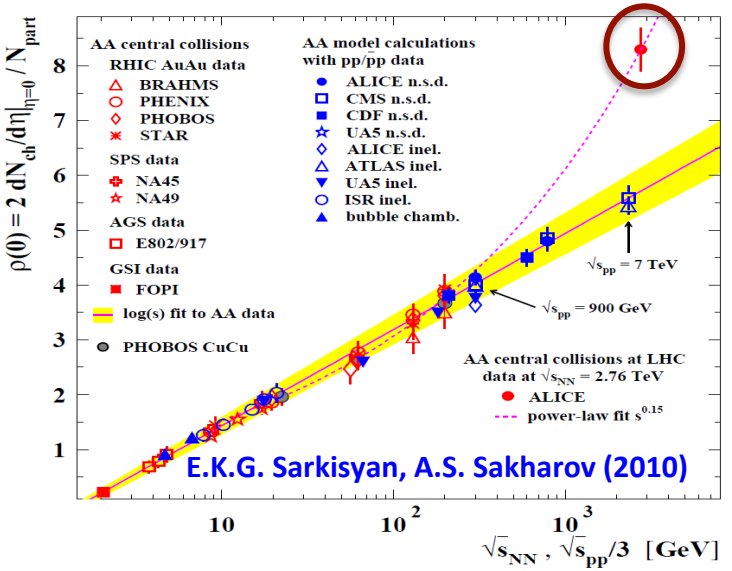

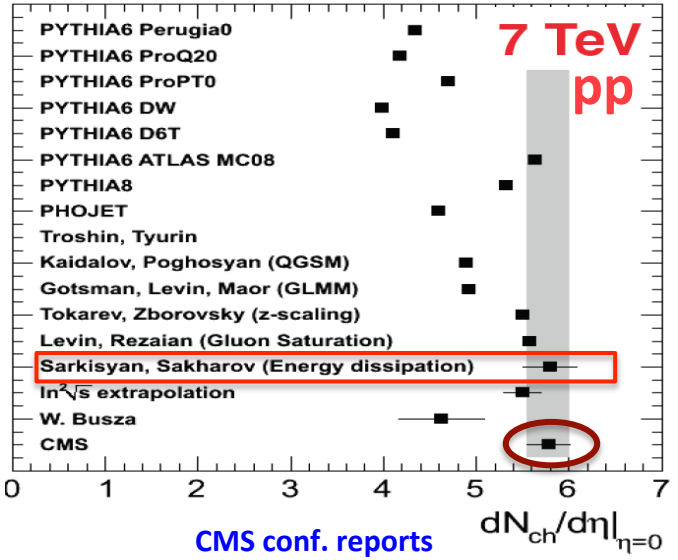

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Hydrodynamics and Effective Energy

Effective Energy:

Effective energy can be calculated as following:

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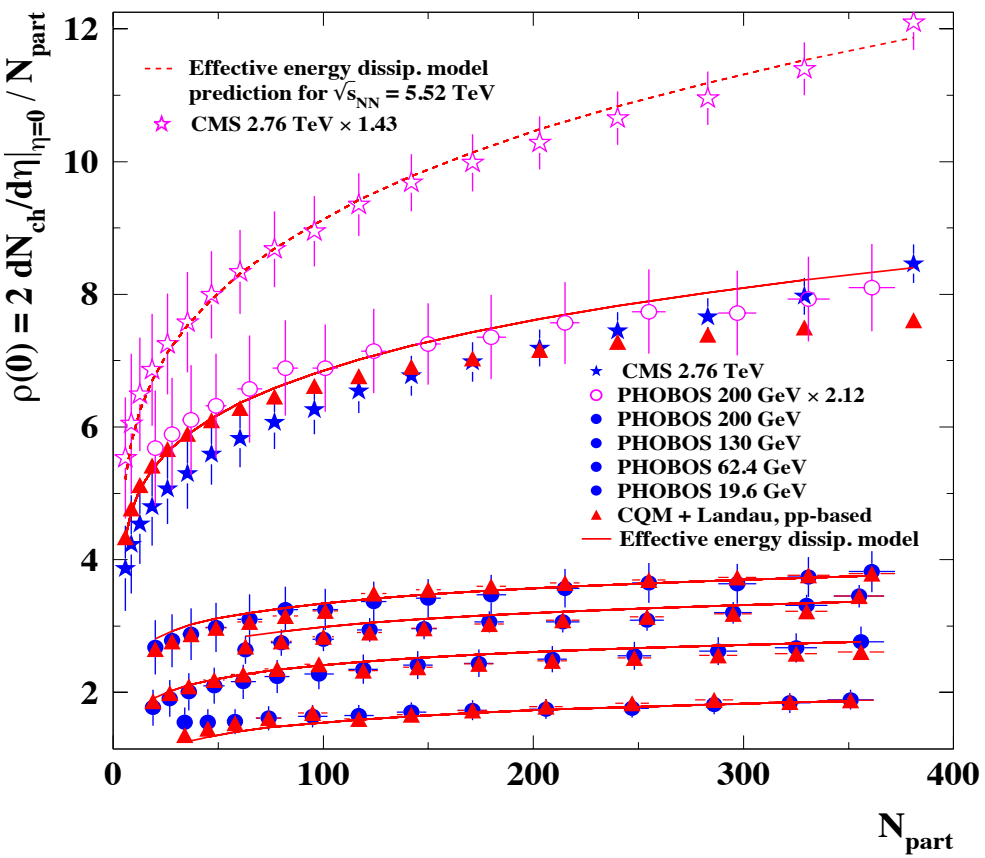
Charged Particle Mid-rapidity Density



Upto top RHIC energy the data show slight increase as centrality decreases

LHC data has monotonic increasing behavior

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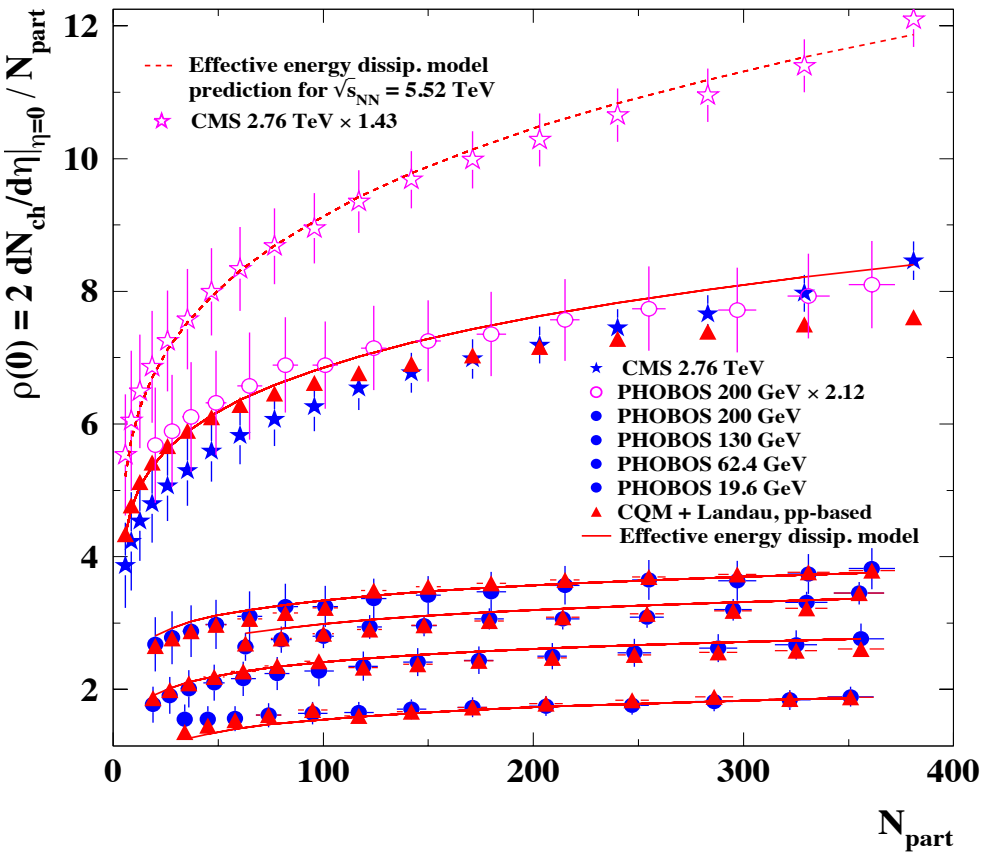

N_{ch} is calculated at $\sqrt{s_{NN}} = \varepsilon_{NN}$
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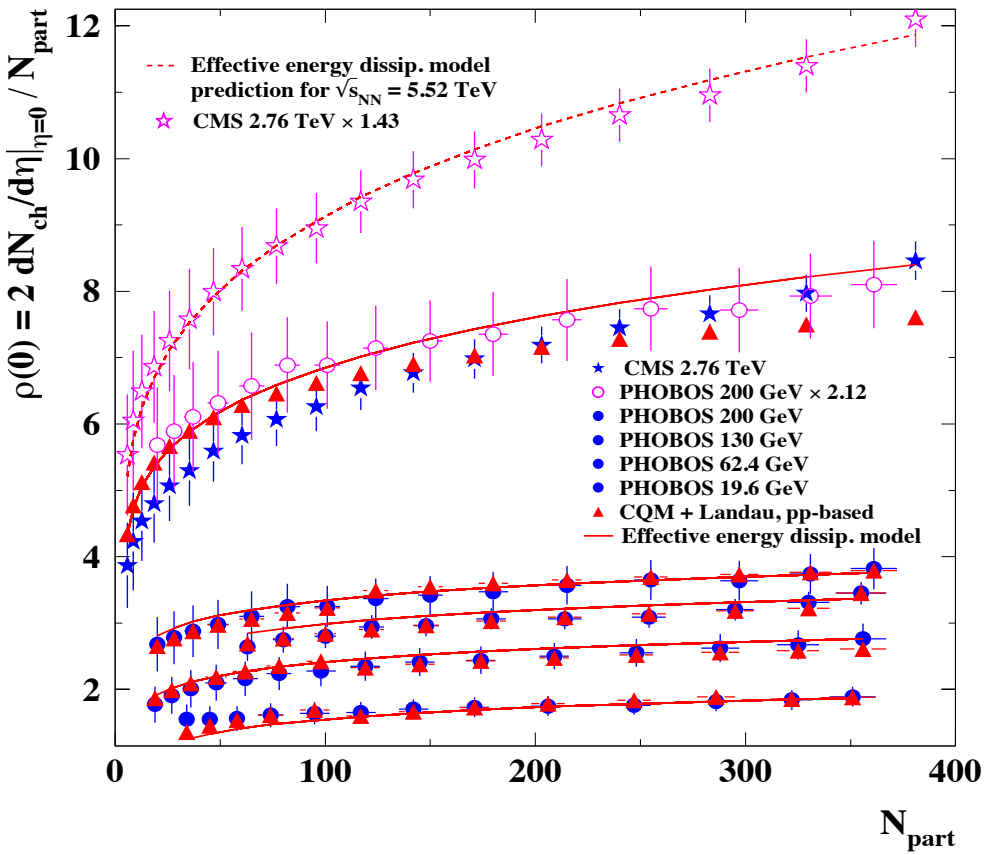

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Effective energy dissipation (red line of the fit to head-on collision data energy dependence [next slide]) also *explains* data and gives *predictions* at $\sqrt{s_{NN}}$= 5.52 TeV

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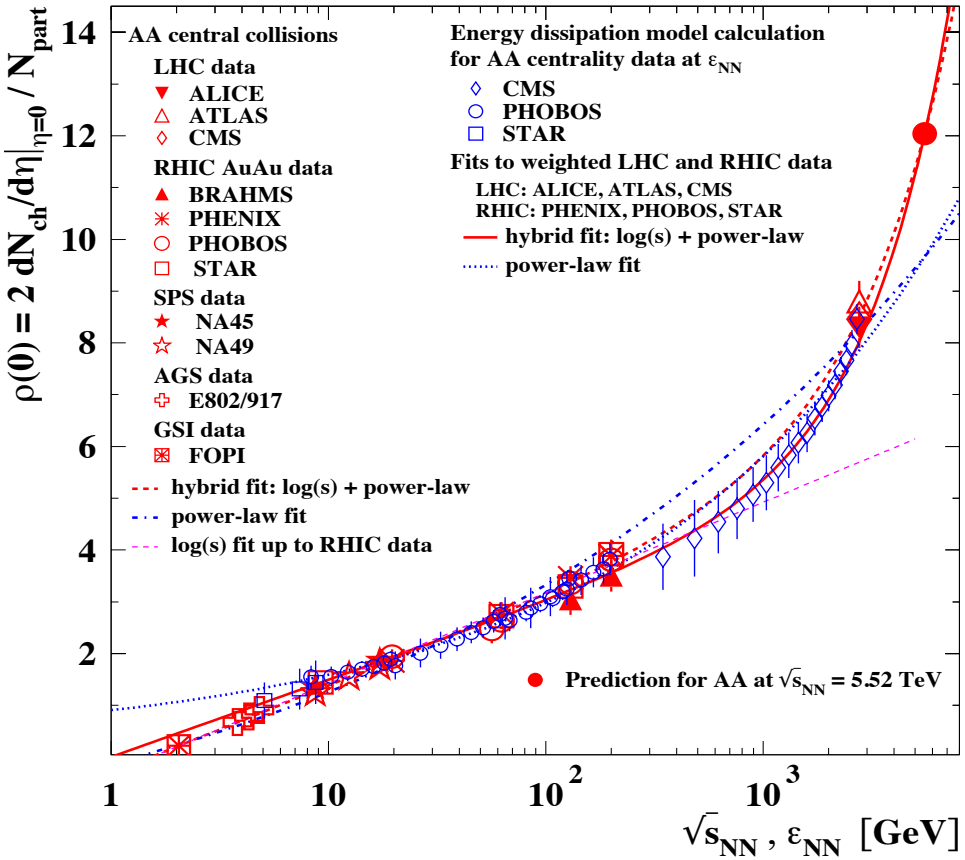

- ✓ Similarity in all the data from peripheral to the most central ones follow the same energy behavior

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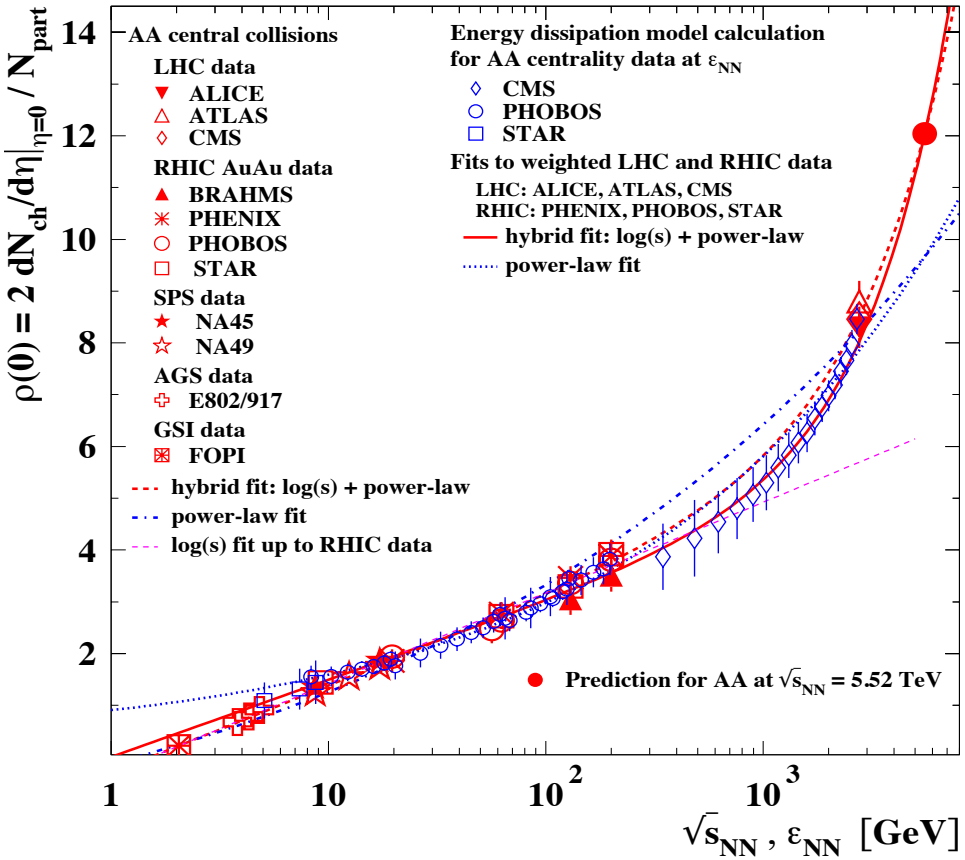

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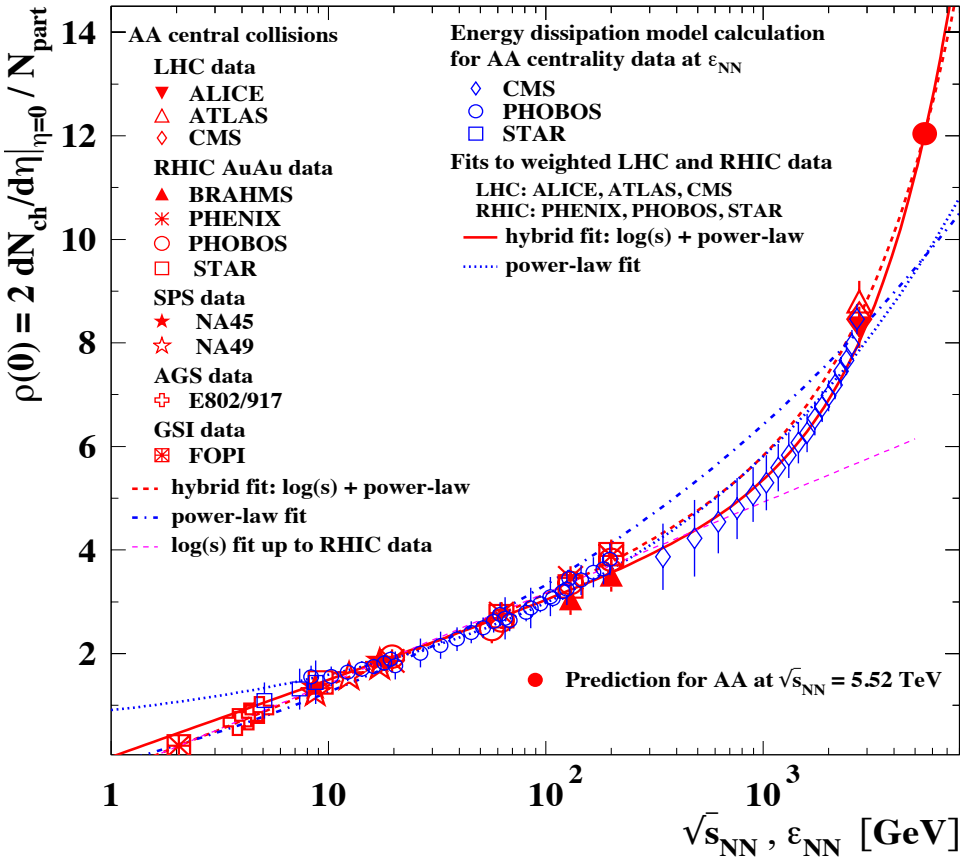

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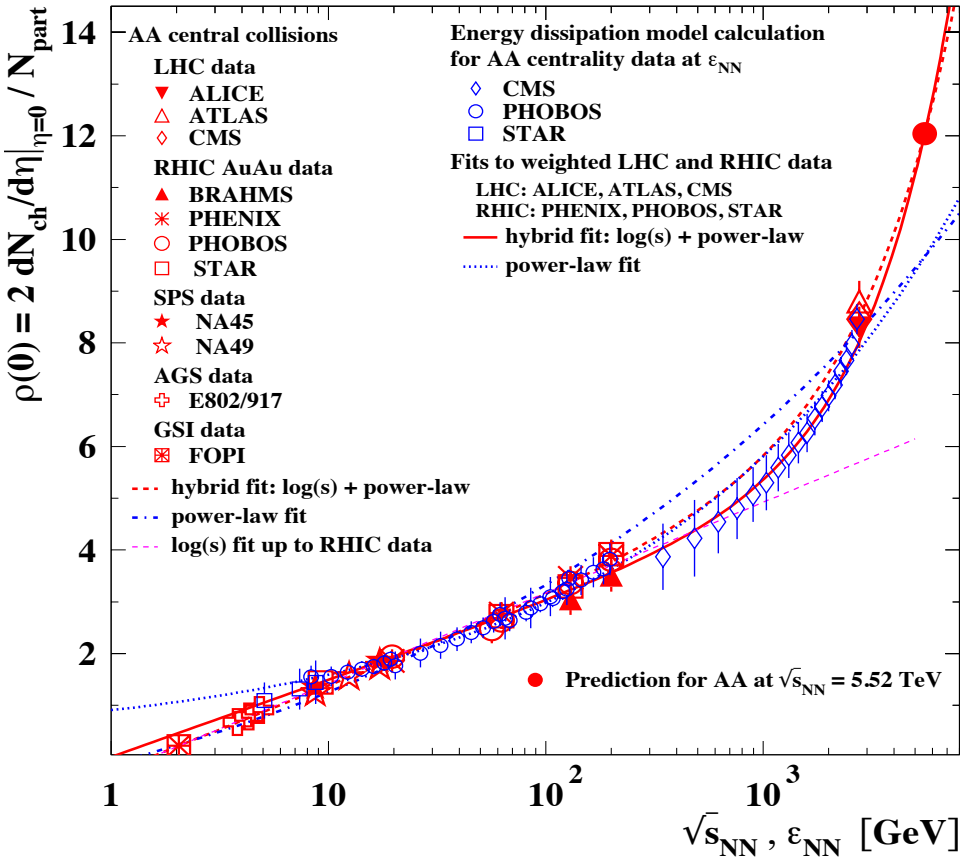

Prediction for charged particle mid-rapidity density for Pb+Pb collisions at $\sqrt{s_{NN}}$ = 5.52 TeV is about 12.0 (within 10% uncertainty)

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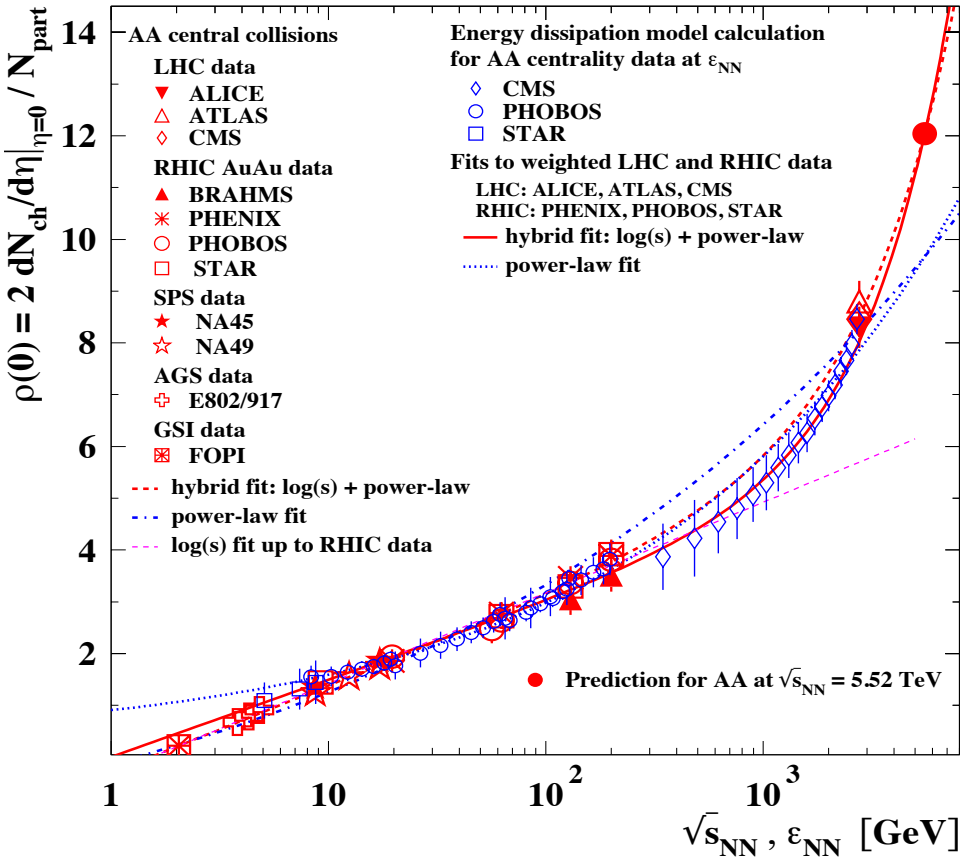

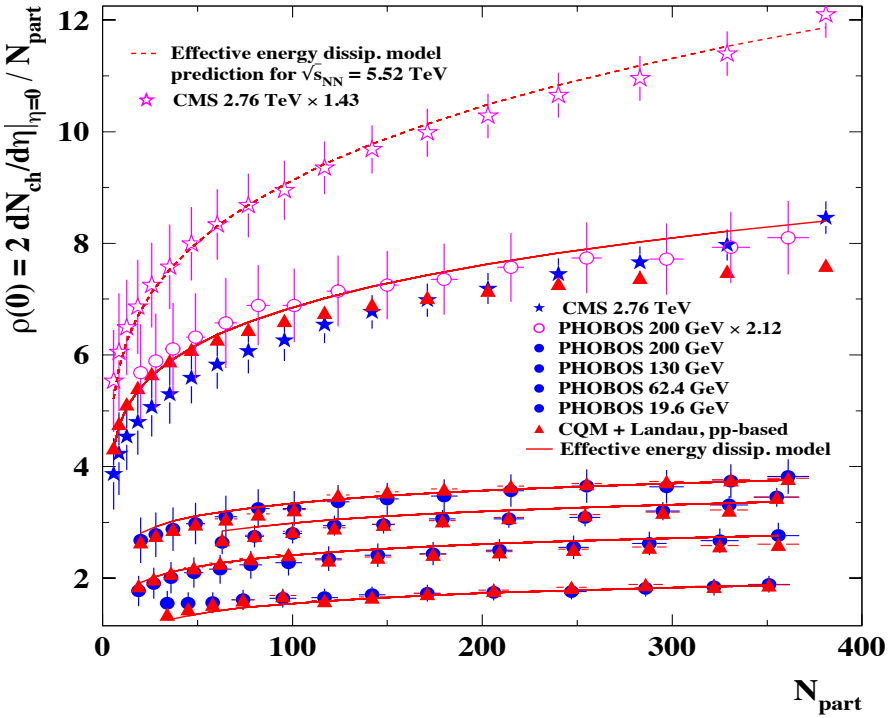

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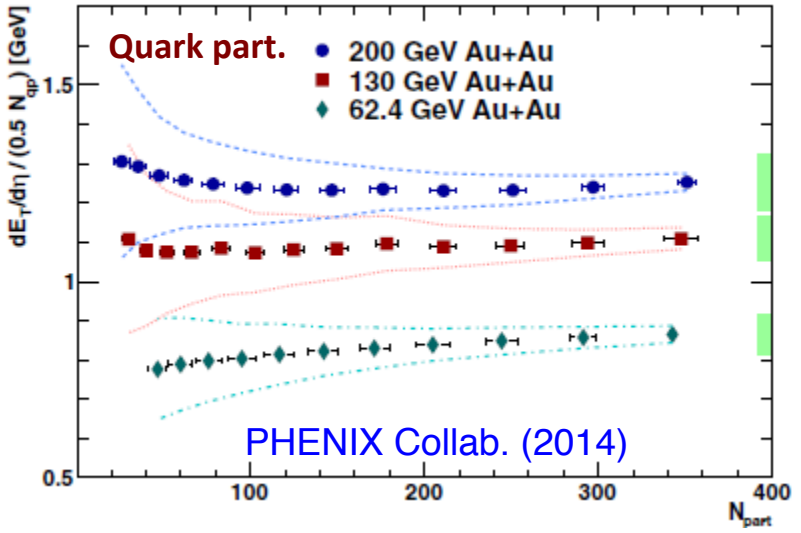
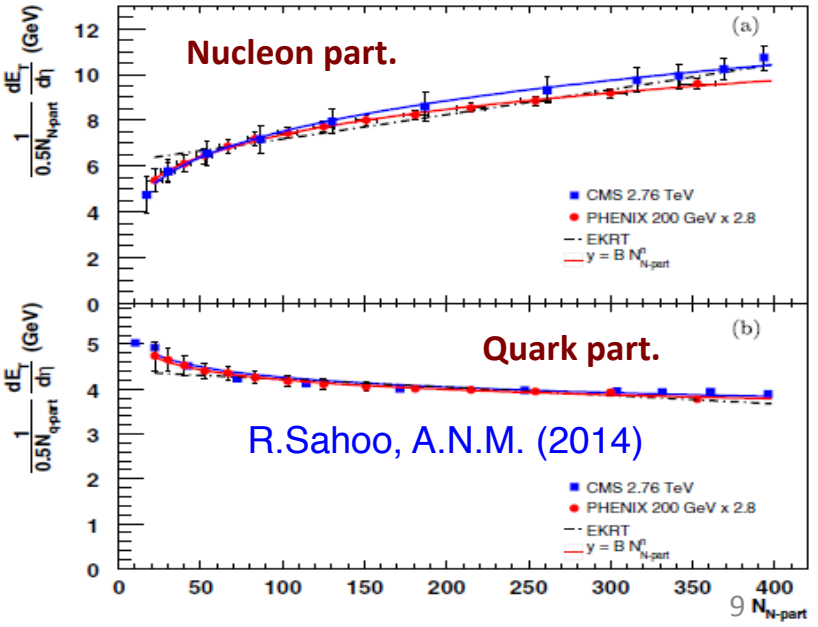
E_T in Constituent Quark Framework

- ✓ Similar to the midrapidity density E_T measurements show independence of centrality as soon as recalculated in the *constituent quark frame*





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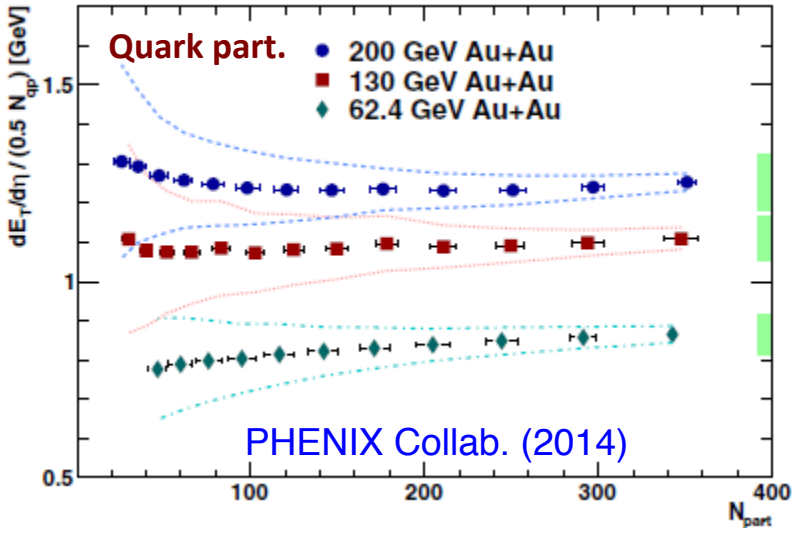
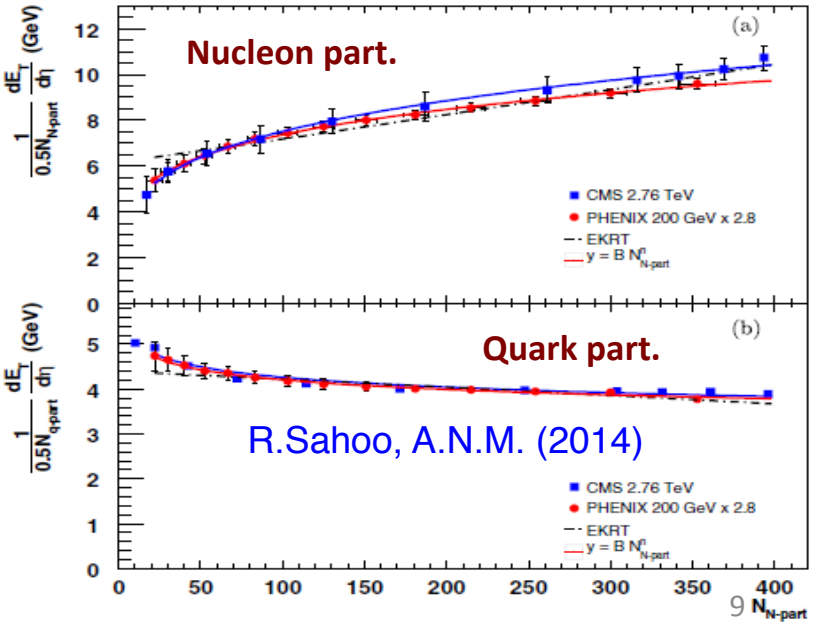
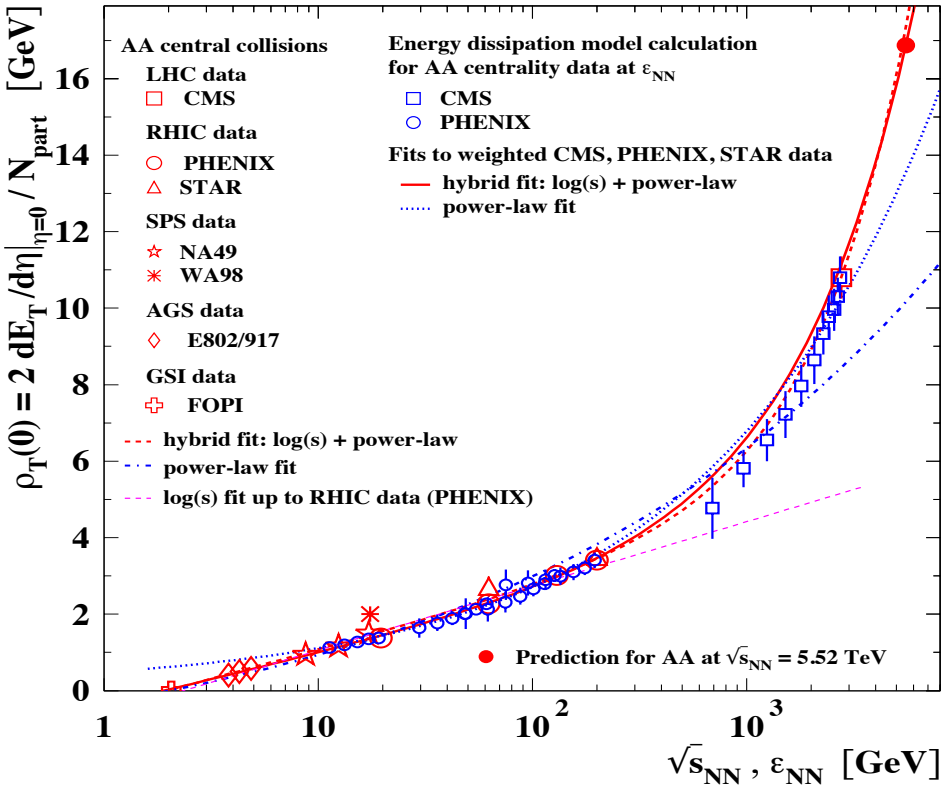


- ✓ Indicates an importance of constituent quark degrees of freedom, therefore the *effective energy of participants deriving particle production*

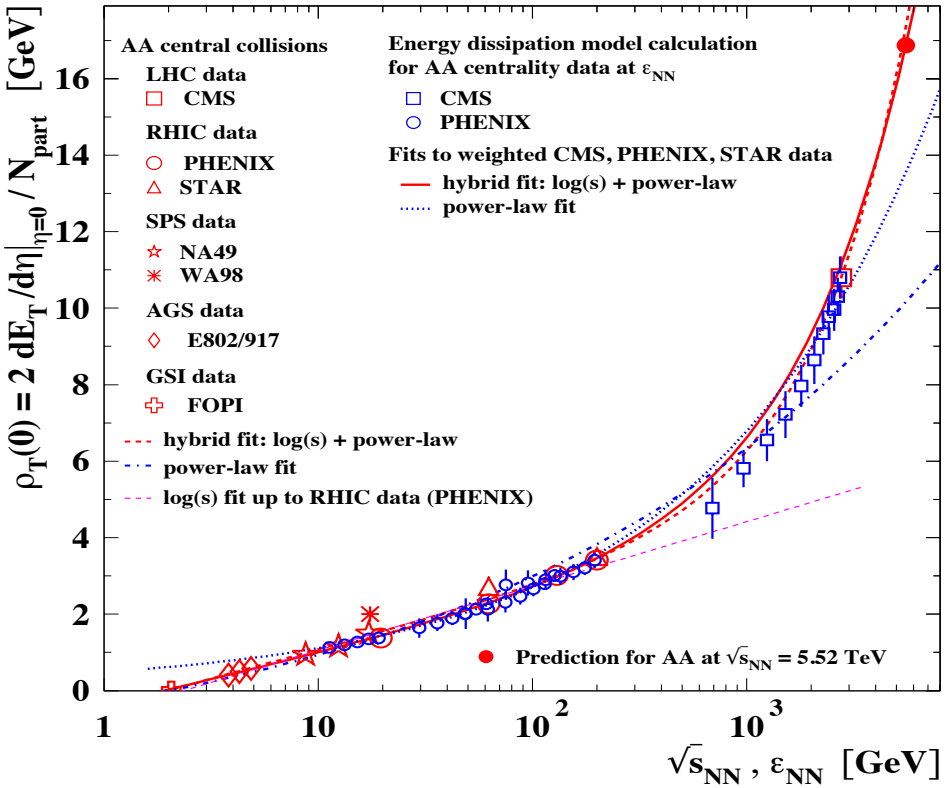


Transverse Energy Mid-rapidity Density



- ✓ Centrality data are shown as a function of the effective c.m. energy ε_{NN}

Transverse Energy Mid-rapidity Density



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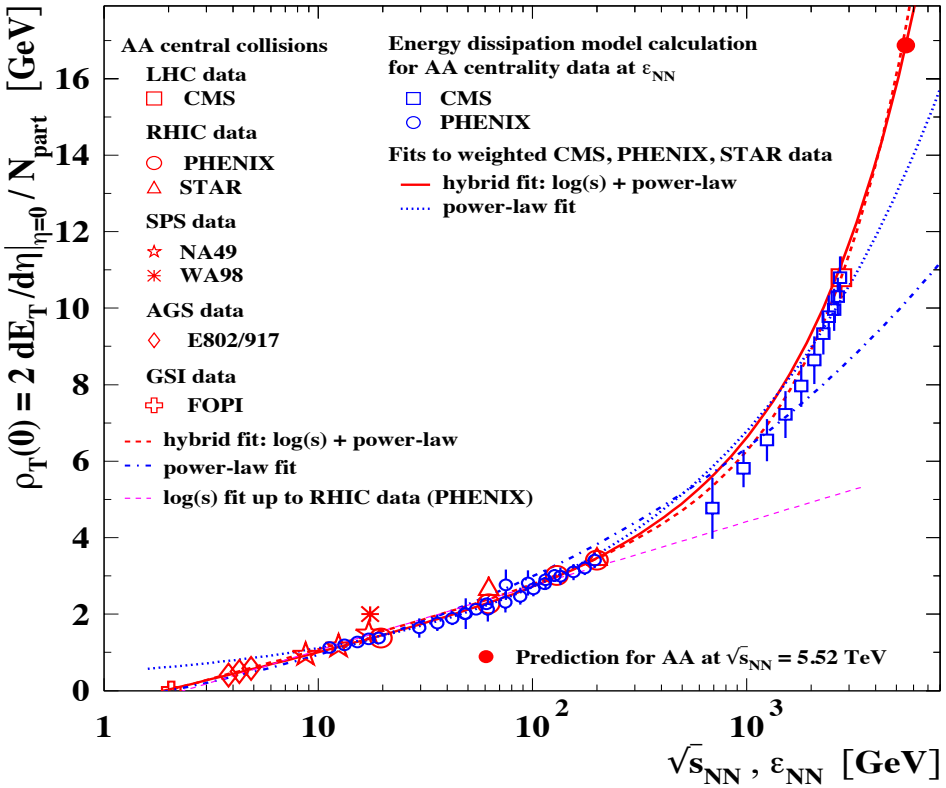

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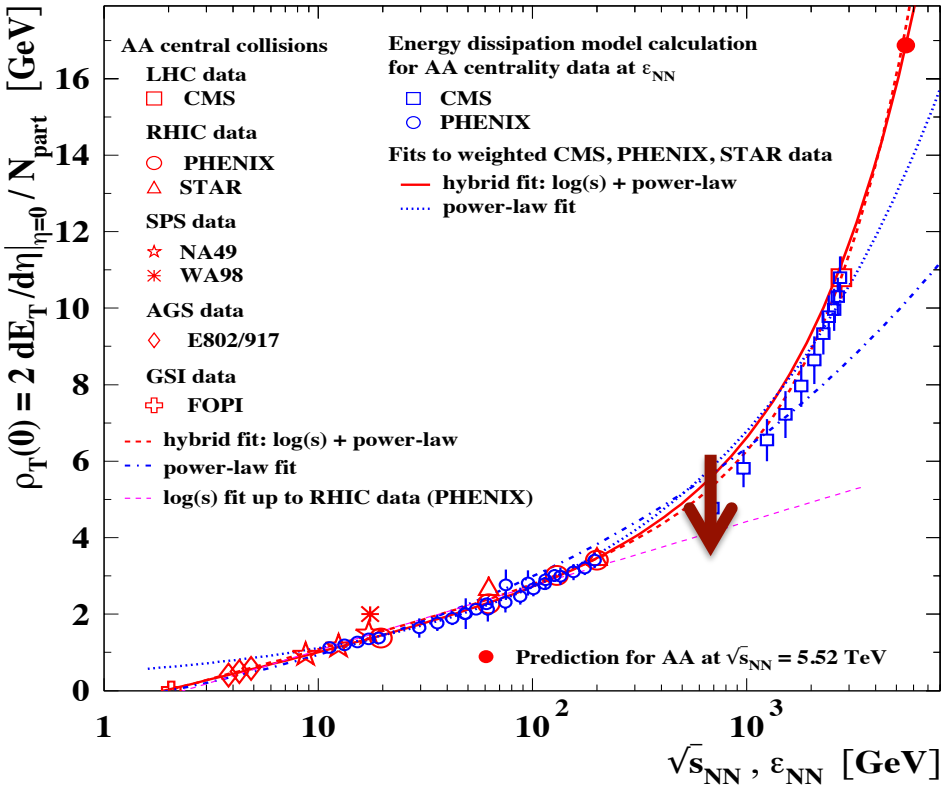

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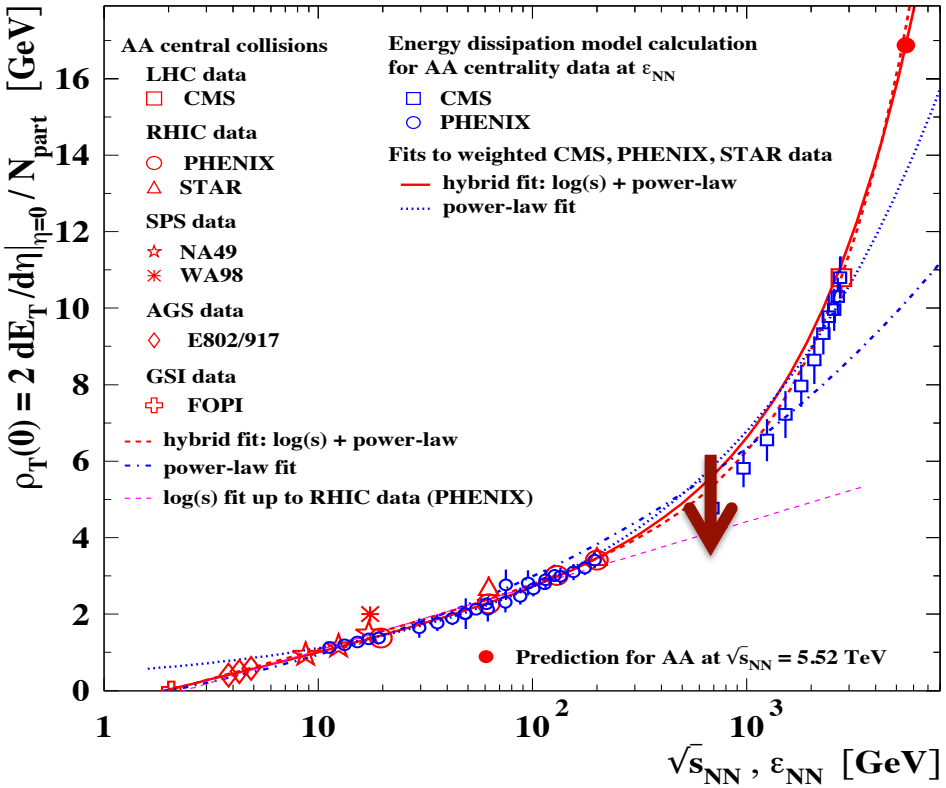

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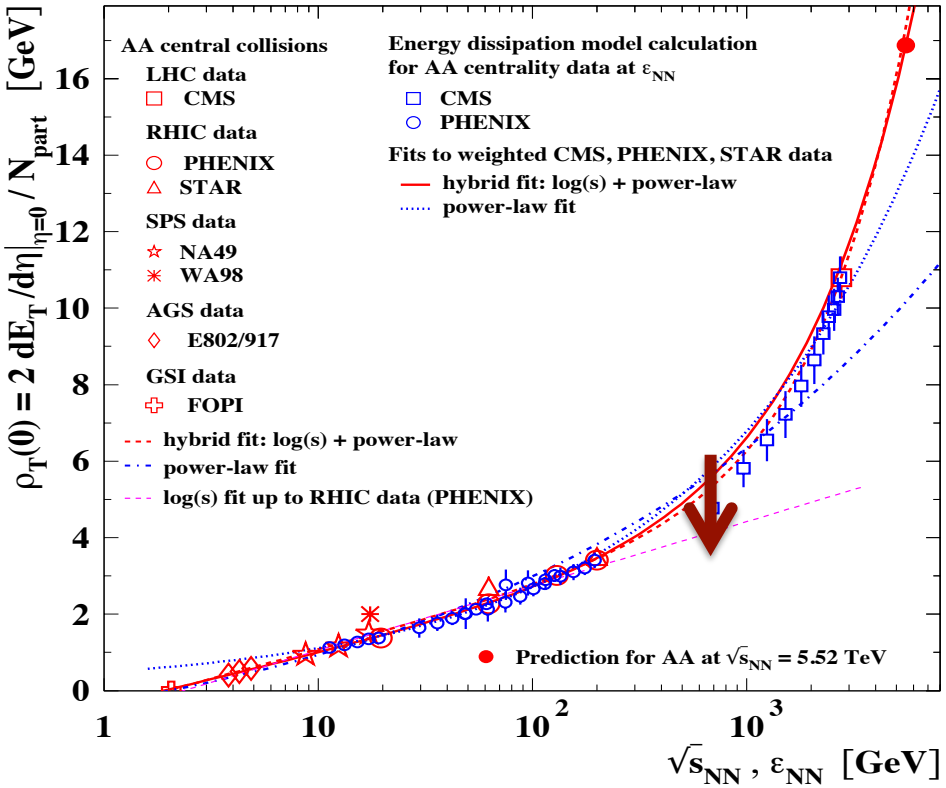

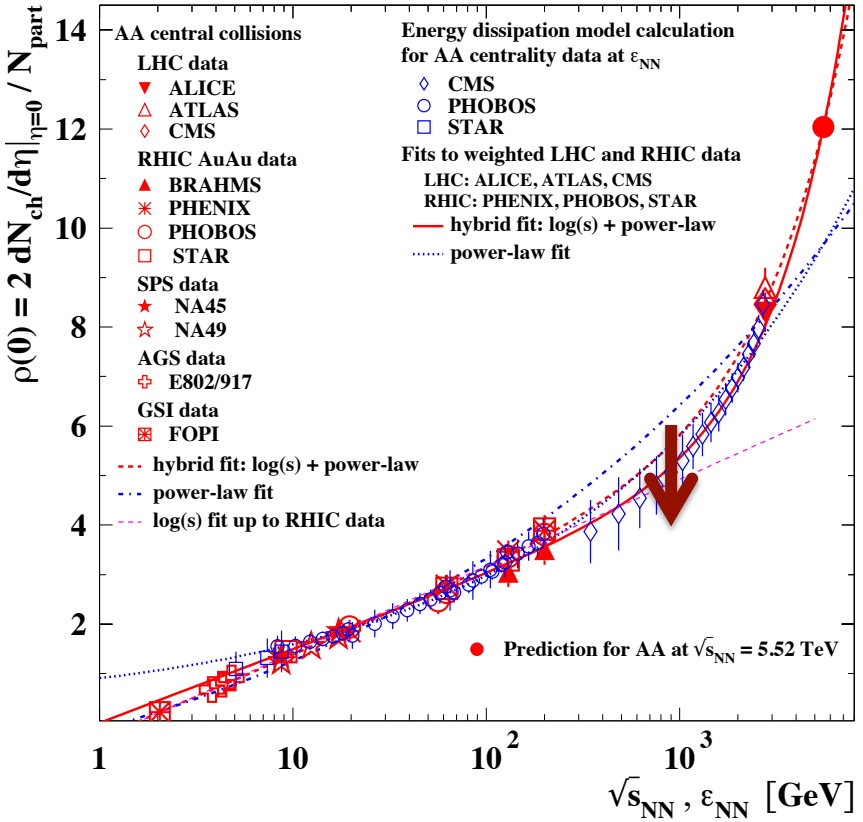

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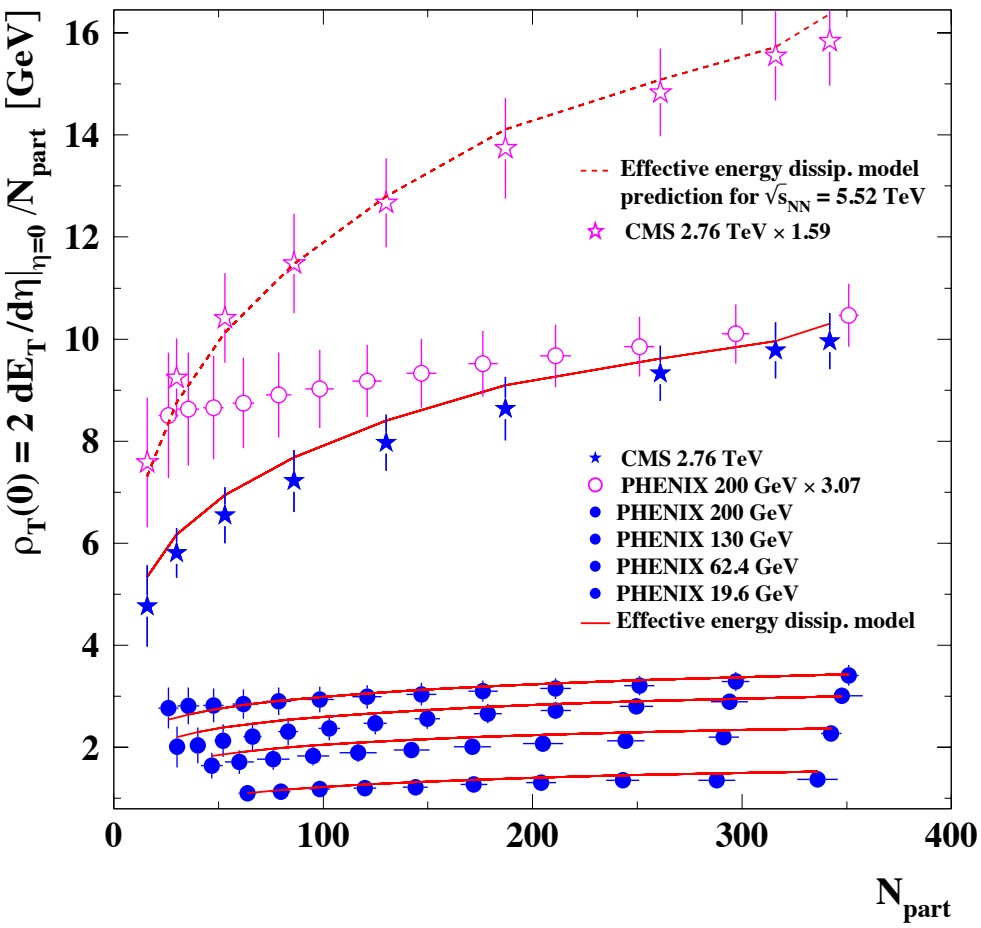

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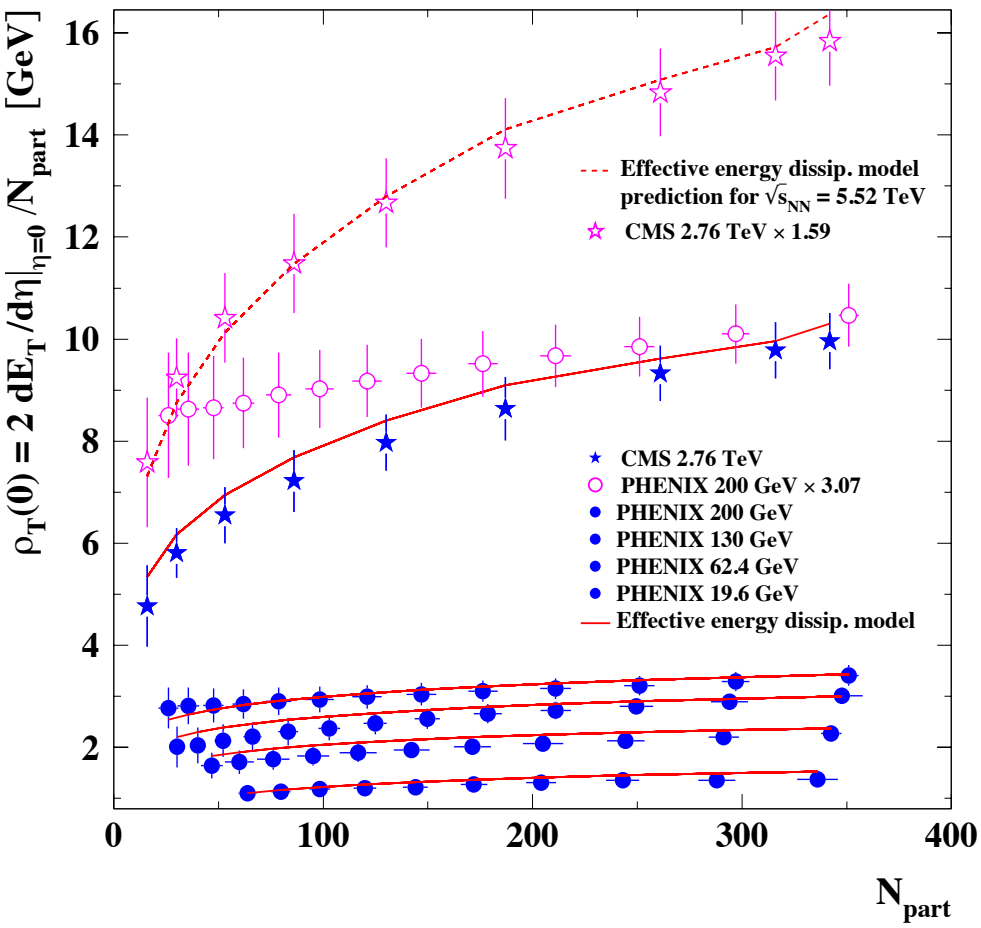

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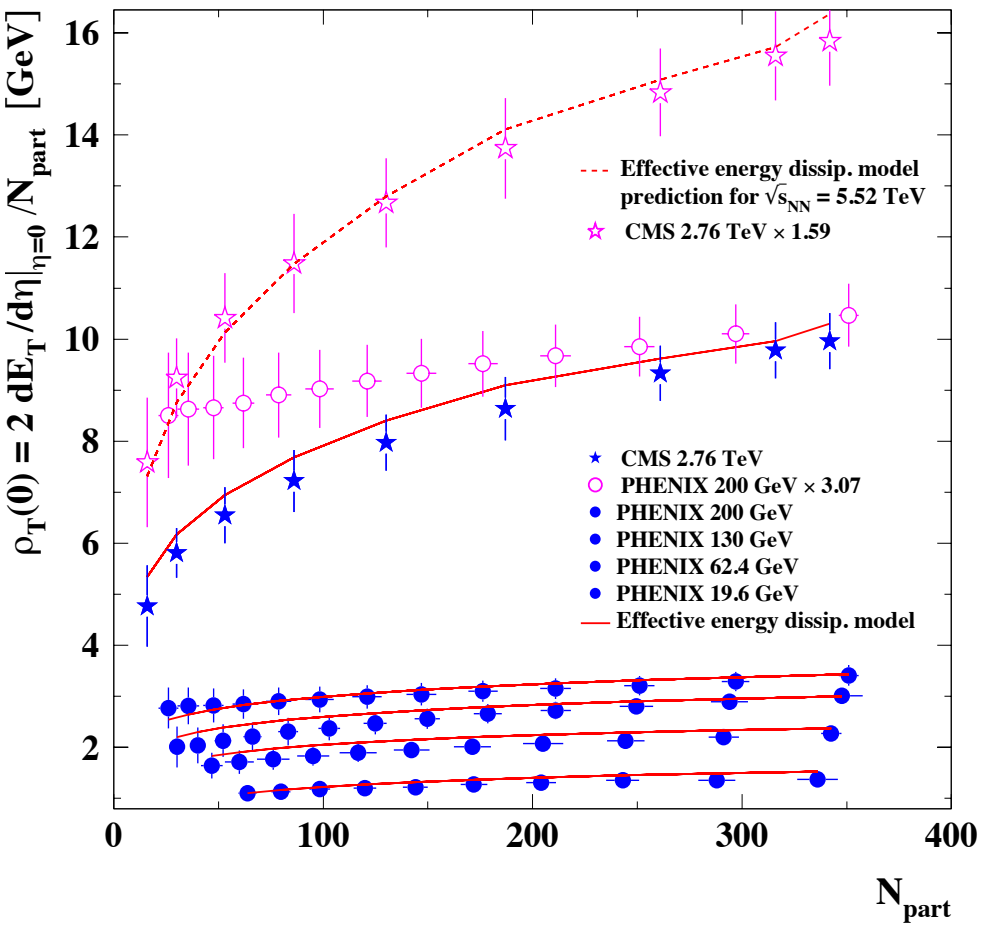

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Predictions for the future heavy-ion collisions at $\sqrt{s_{NN}}$ = 5.52 TeV given

Summary

- ✓ Centrality and c.m. energy dependence of bulk observables *(charged particle and transverse energy midrapidity density)* are analyzed for all available energies

- ✓ Universality in particle production process is obtained based on the model considering dissipating energy available at the early stage of collision from interacting participants depending upon their type

- ✓ Bulk observables in heavy-ion collisions are well reproduced from those in pp collisions, treated within constituent quark model and Landau hydrodynamics

- ✓ Available measurements upto LHC energies agree well with the model expectations. A possible transition to a new regime at $\sqrt{s_{NN}}$ = 0.5 – 1.0 TeV is indicated, the measurements are welcome

- ✓ Prediction for the foreseen LHC energy at 5.52 TeV Pb+Pb collisions is made

Thank you