On similarities in multihadron production in nuclear and particle collisions

Edward SARKISYAN-GRINBAUM

(CERN and University of Manchester)

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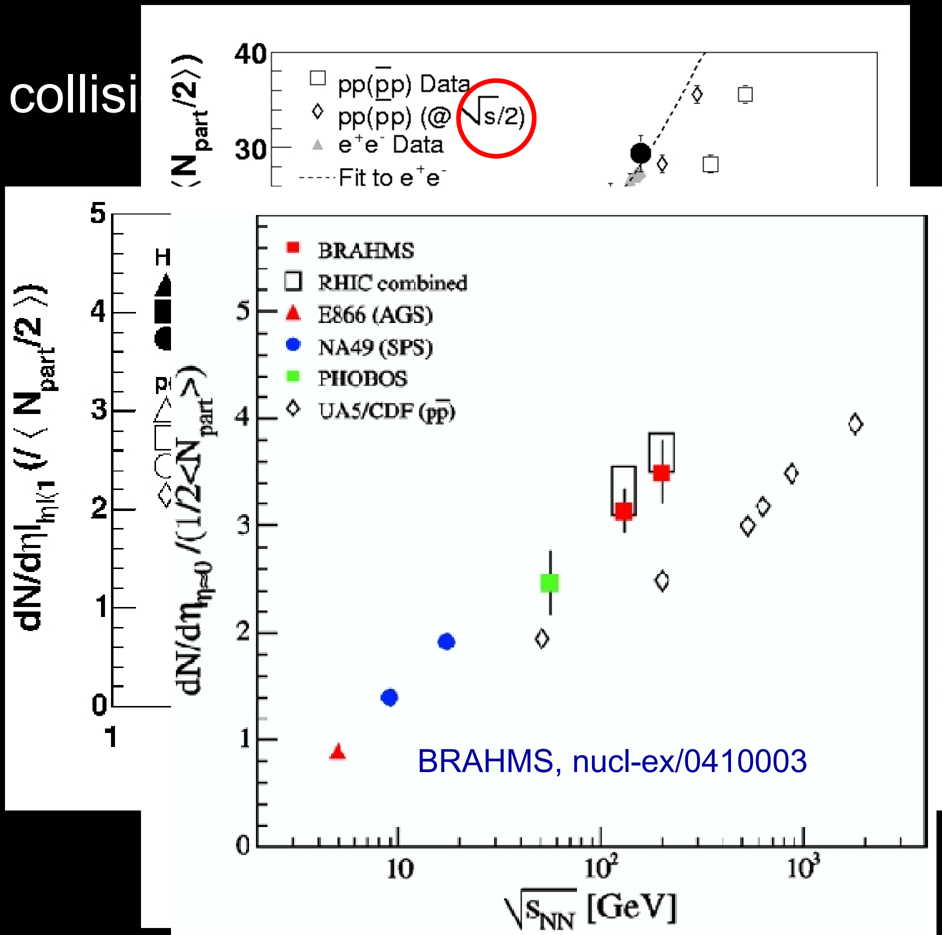
E.K.G. Sarkisyan, A.S. Sakharov, hep-ph/0410324

Motivation

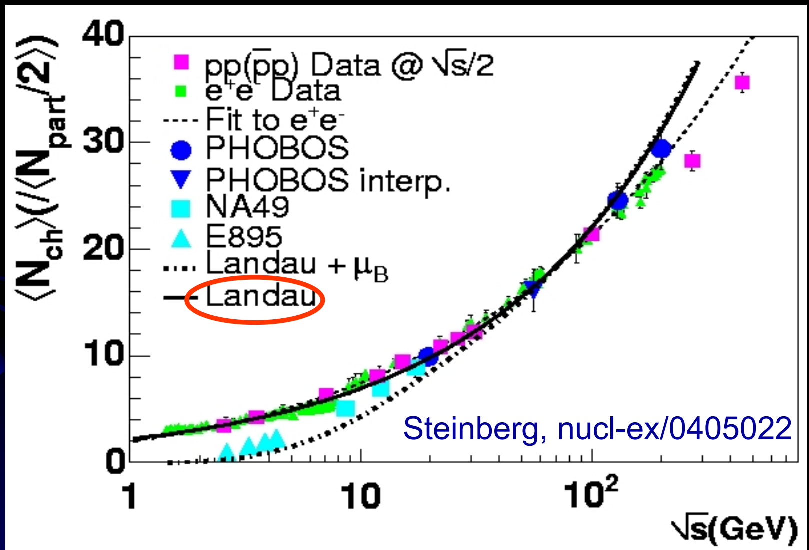
- Bulk observables - mean multiplicity and rapidity densities - control parameters of the formation and evolution of the collision initial state
- extensively studied in heavy-ion collisi
- similarities with e^+e^- and pp data:
- *pp multiplicity data to be scaled*
- *not the same* scaling for *both* variables
- *no scaling* needed for dAu vs pp

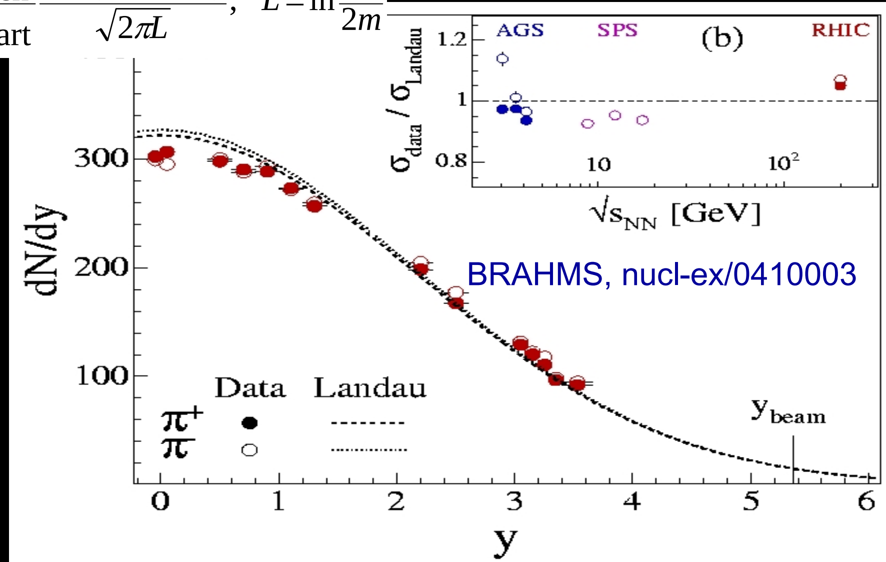


Hydrodynamics of collisions

- two head-on colliding Lorentz-contracted particles stop within overlapped zone
  - formation of fully thermalised initial state at the collision moment
  - the decay (expansion) of the initial state is governed by relativistic hydrodynamics - Landau model

$$\frac{2N_{ch}}{N_{part}}\frac{\exp\left(-y^2/2L\right)}{\sqrt{2\pi L}}, \quad L=\ln\frac{\sqrt{s}}{2m}$$





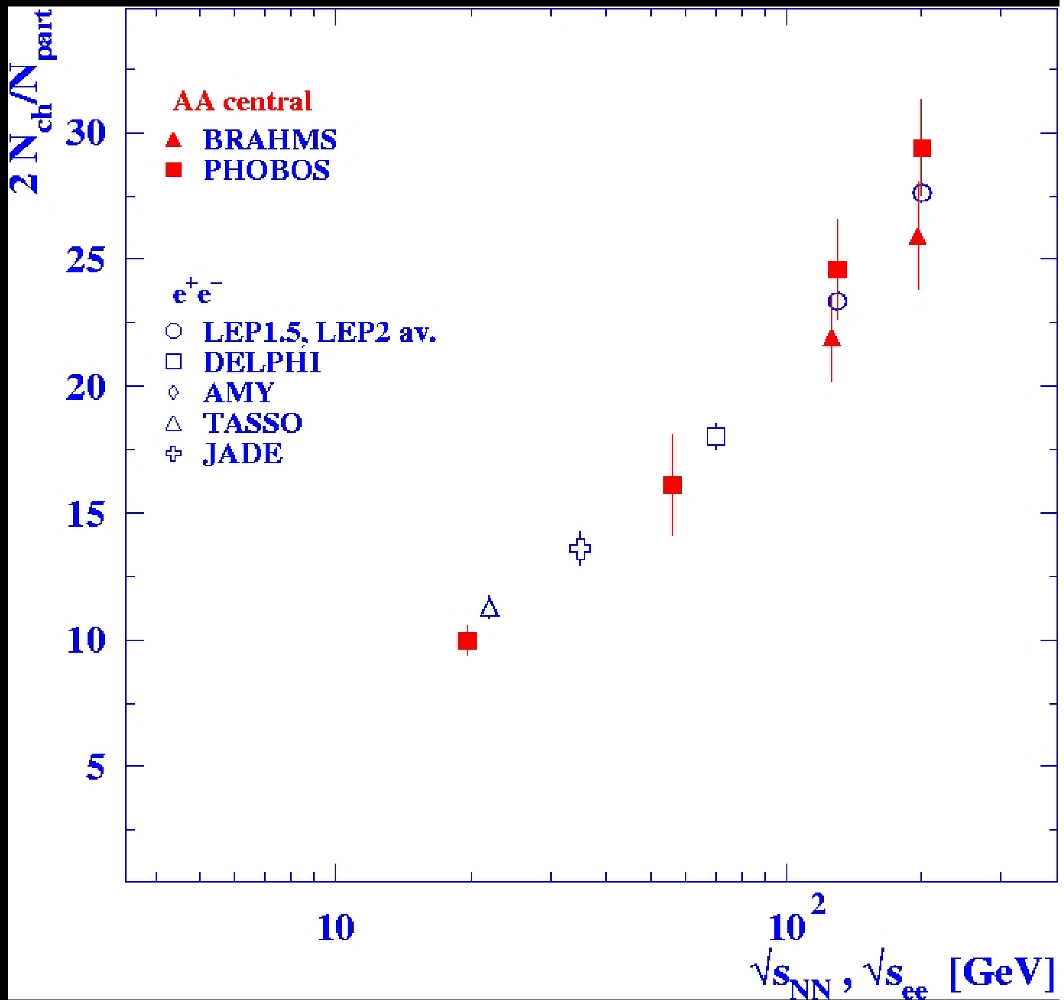
- the production of secondaries is defined by the energy deposited in the initial state

Hydrodynamics and energy scaling

- 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
- multiplicity and mid-rapidity density should be similar in pp at c.m. energy $\sqrt{s_{pp}}$ and e^+e^- at c.m. energy $\sqrt{s_{ee}} \approx \sqrt{s_{pp}}/3$
- central heavy ion collisions: more than one quark per nucleon participates
- head-on heavy ion collisions: all three quarks participate nearly simultaneously and deposit their energy coherently into initial state
- multiplicity and mid-rapidity density should be similar in pp at c.m. energy $\sqrt{s_{pp}}$ and head-on AA at c.m. energy $\sqrt{s_{NN}} \approx \sqrt{s_{pp}}/3$

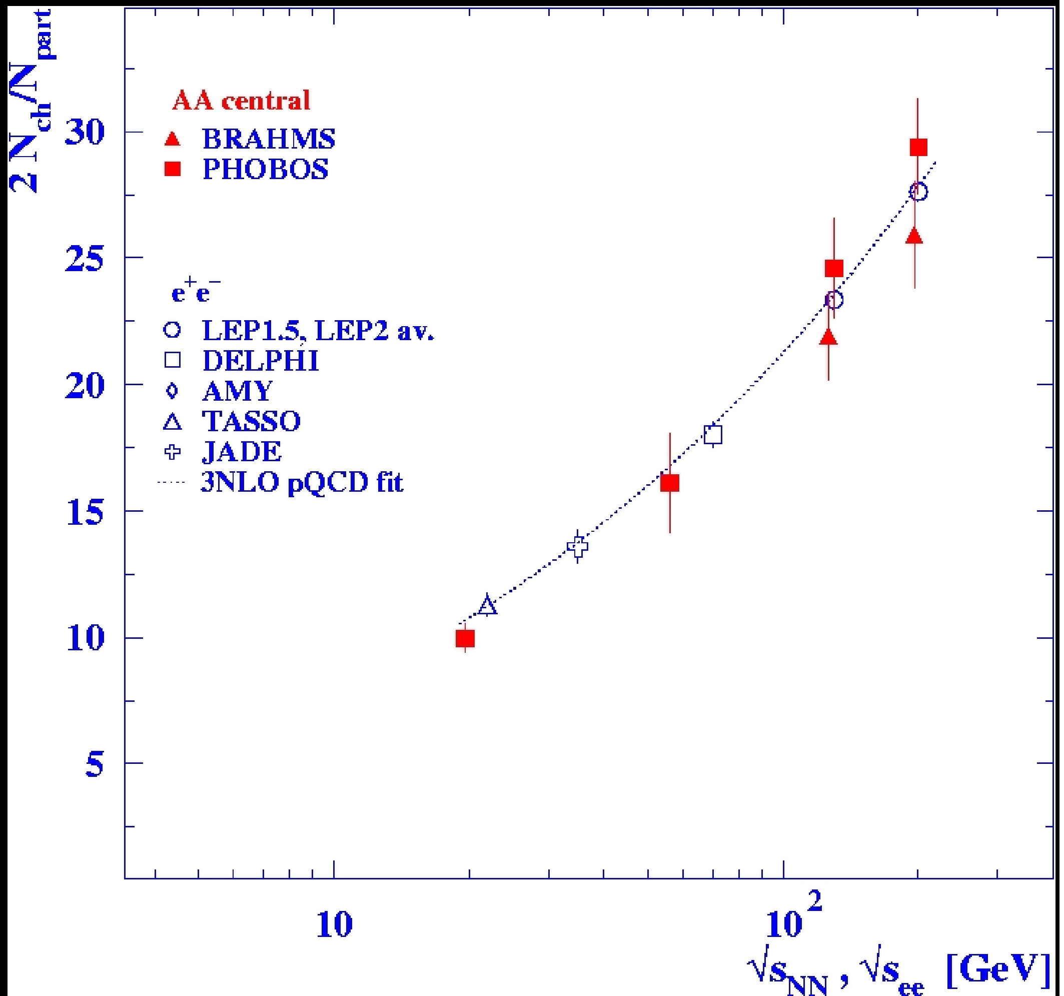
Multiplicity in e^+e^-, pp and AA

- e^+e^- data similar to AA data at RHIC energies



Multiplicity in e^+e^-, pp and AA

- e^+e^- similar to AA data
- well reproduced by 3NLO pQCD



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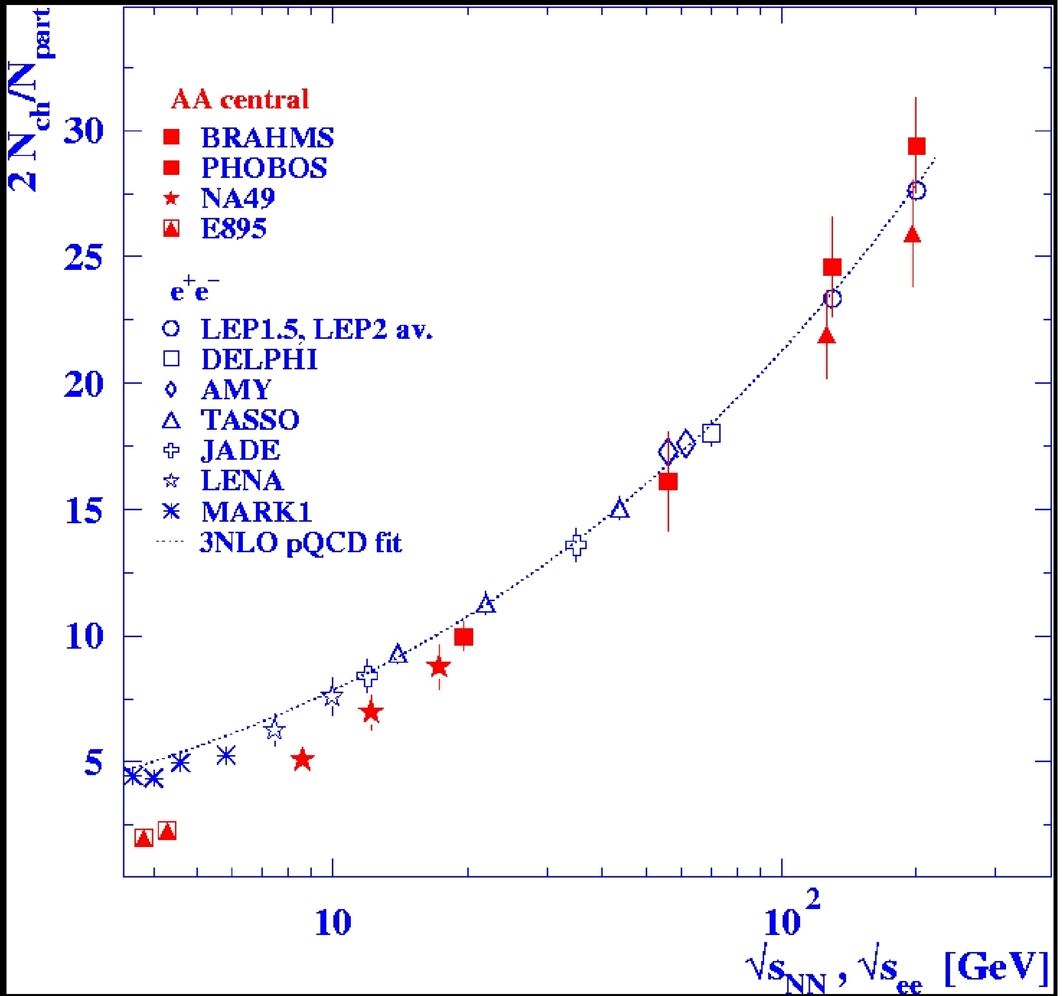

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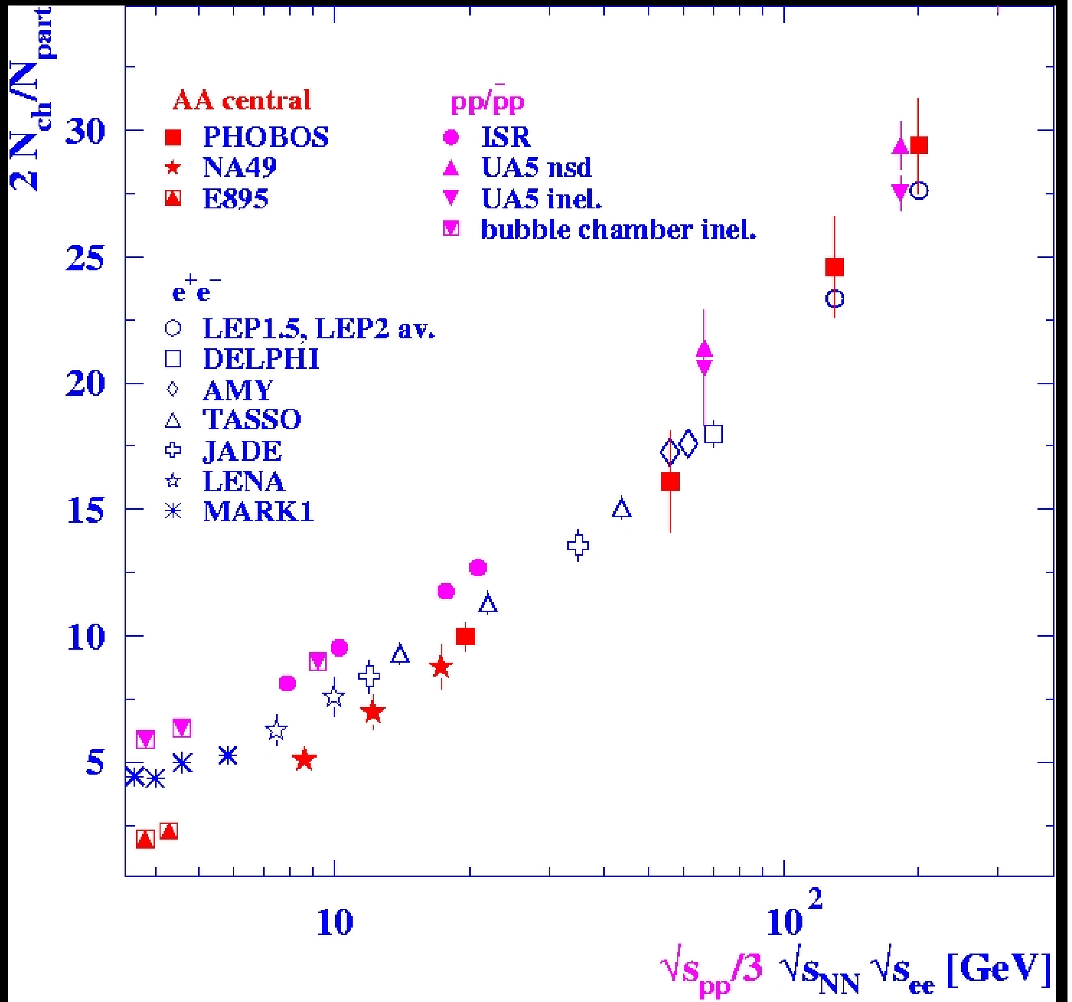
- pp data similar to e^+e^- and AA as $\sqrt{s_{pp}} = 3\sqrt{s_{NN}}$
- difference at $\sqrt{s_{NN}} < 20$ GeV due to *spectator contribution*



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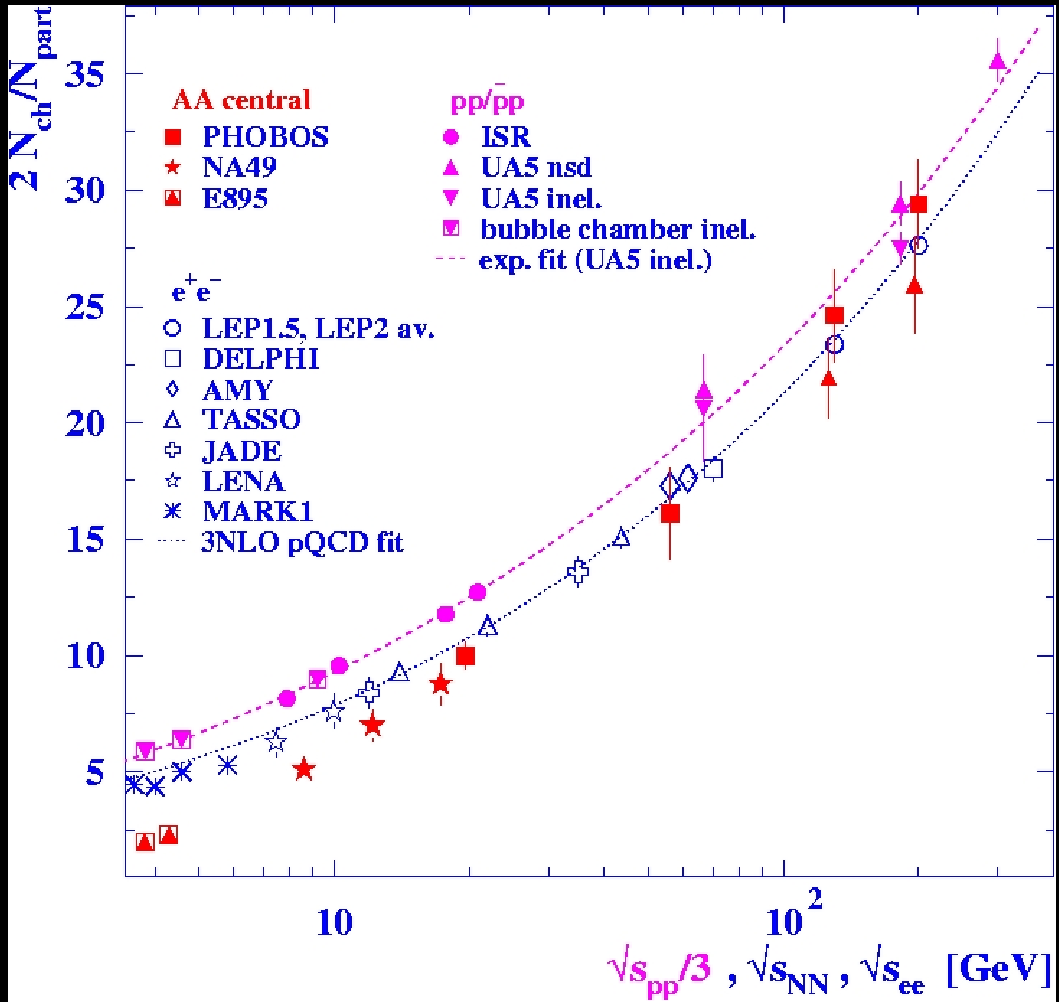
  - fit to pp data behaves as 3NLO pQCD fit



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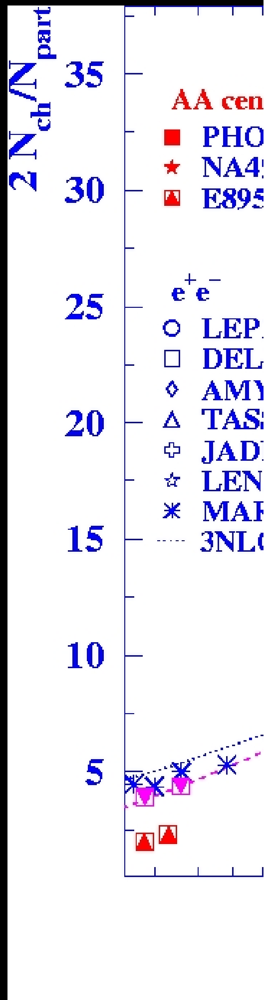
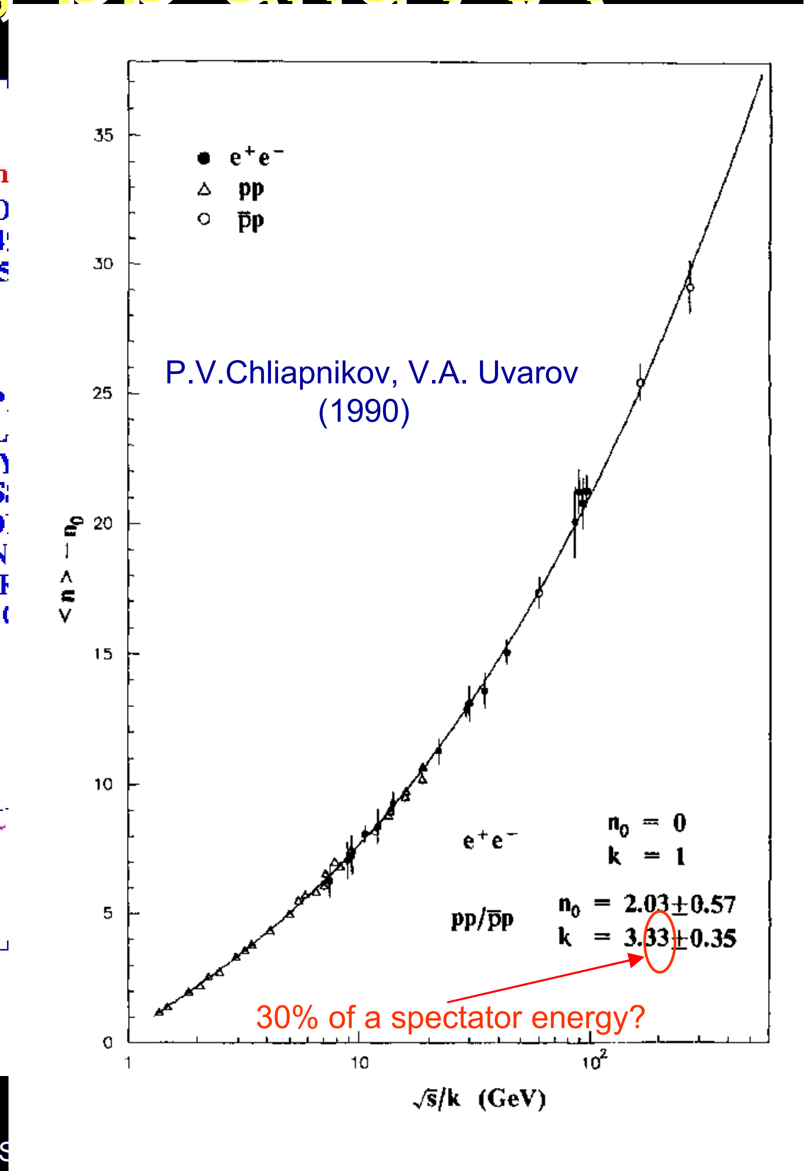
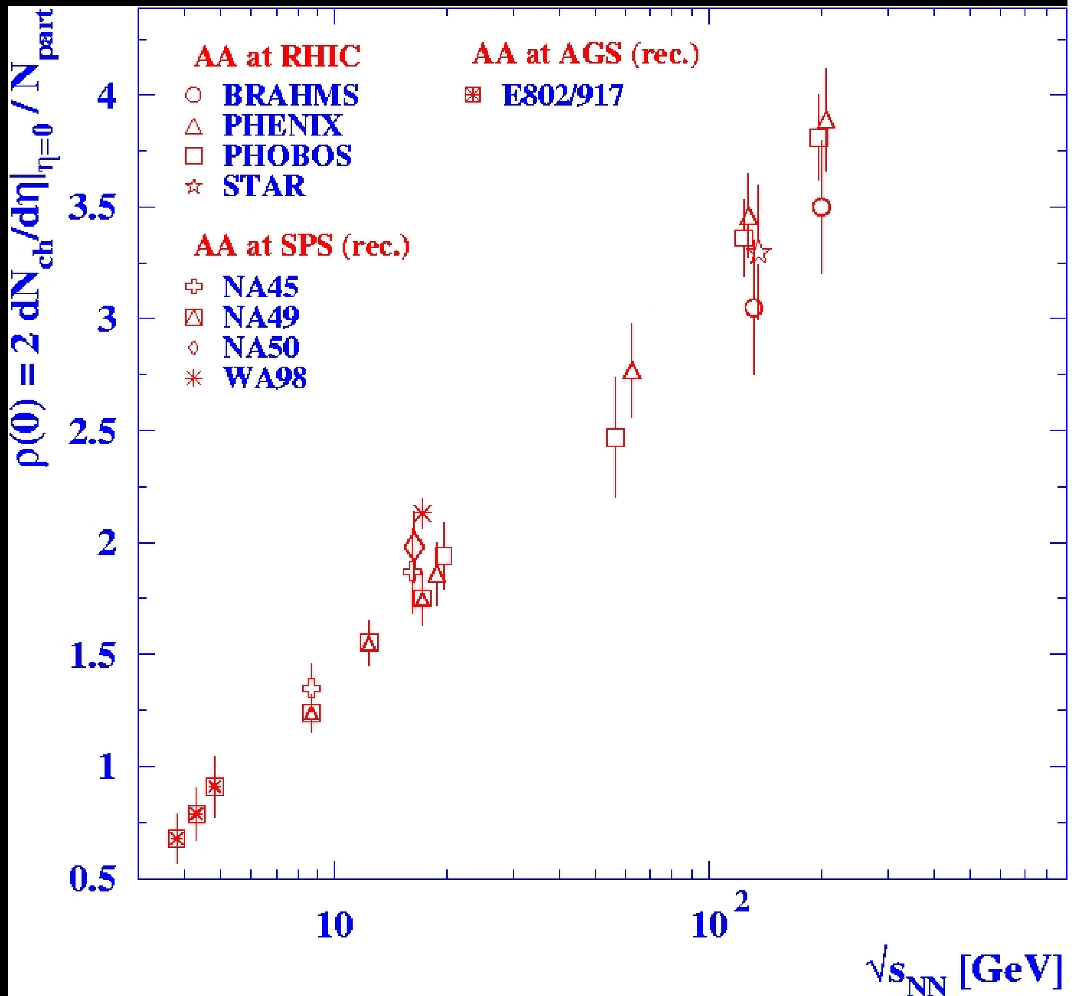
  - difference at $\sqrt{s_{NN}}$ < 20 GeV due to *spectator contribution*
  - *leading particle effect:* N_{ch}*-2:* less to be substracted at $\sqrt{s_{NN}}$ < 20 GeV
  - indicated al LEP starting years





Mid-rapidity density in pp and AA

- *no* visible *difference* in the c.m. energy dependence



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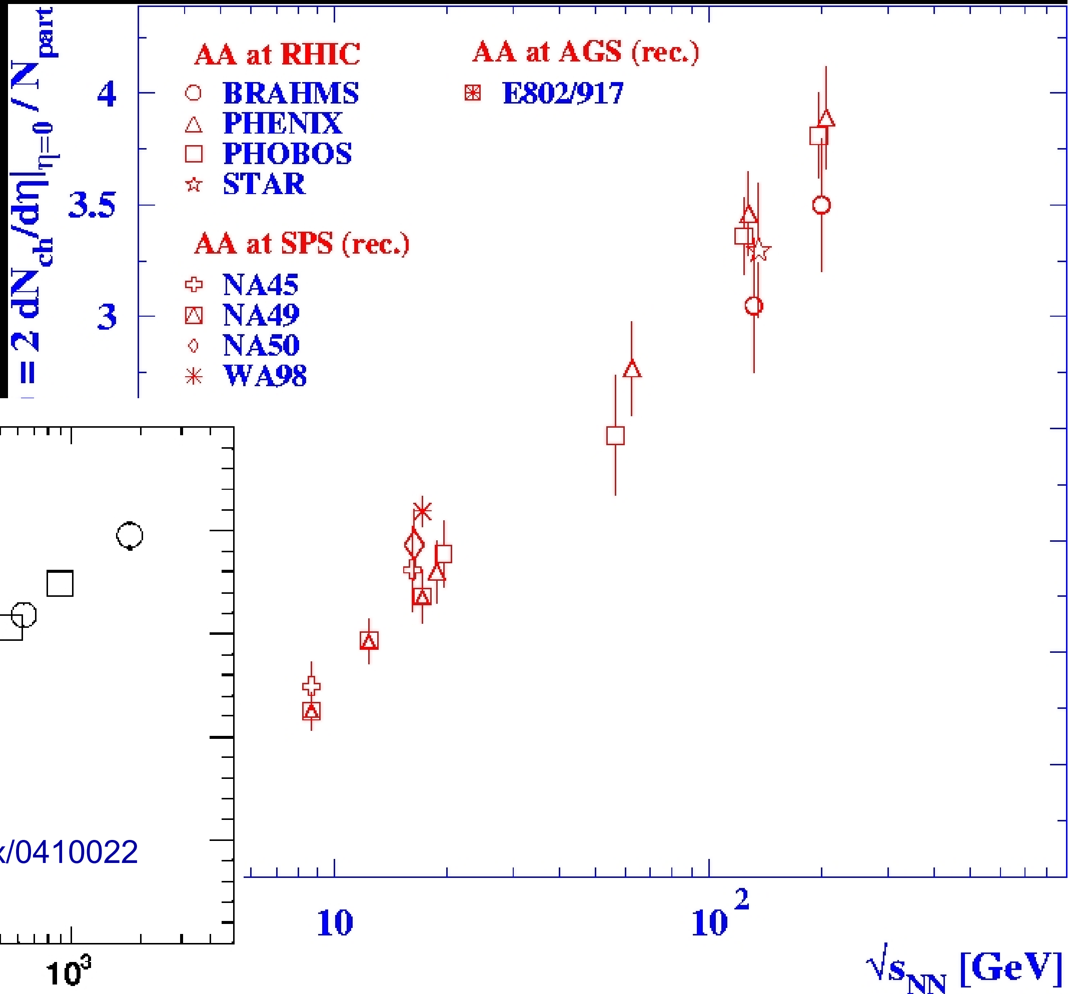
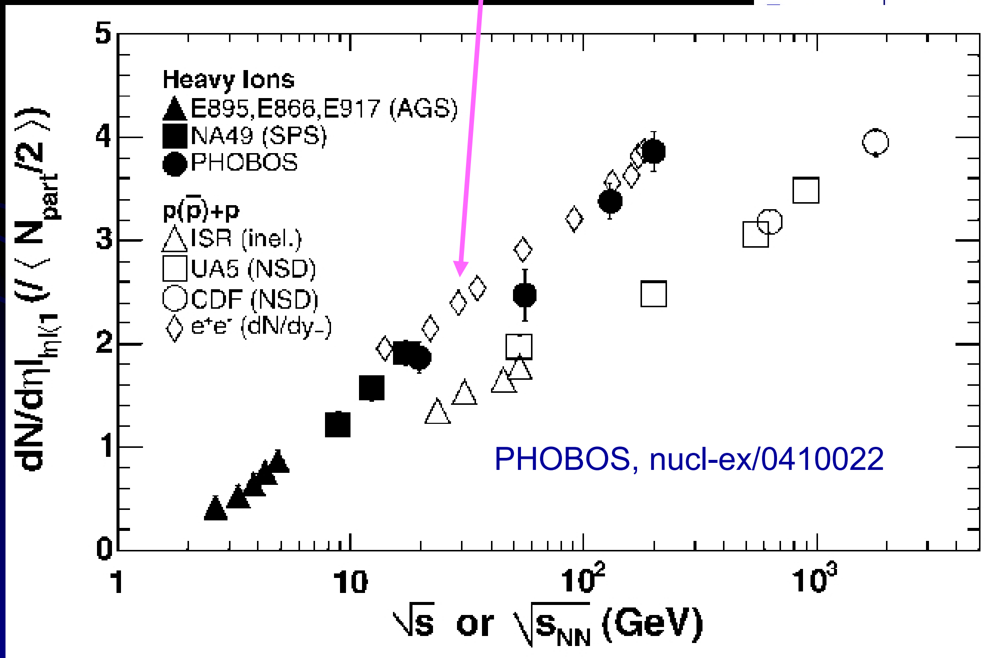
- AA data *similar* to e^+e^- data





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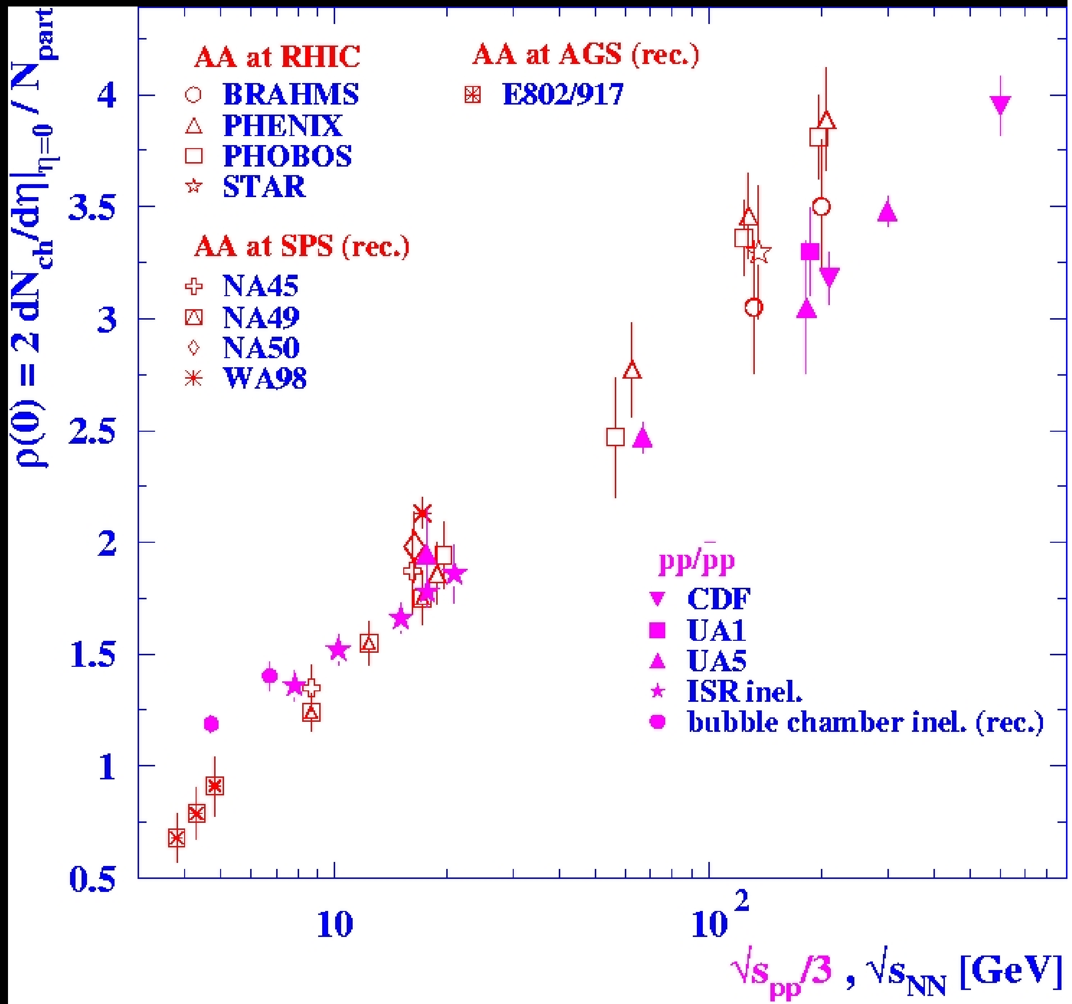
- AA data *similar* to e^+e^- data
- pp data *similar* to e^+e^- and AA as $\sqrt{s_{pp}} = 3\,\sqrt{s_{NN}}$
  - *different behaviour* at $\sqrt{s_{NN}} < 20$ GeV vs. $\sqrt{s_{NN}} > 20$ GeV: *nucleus break-up* at lower energies
  - other possible mechanisms
    Roizen, Feinberg, Chernavskaya, hep-ph/0412394
    Letessier, Rafelski, nucl-th/0504028



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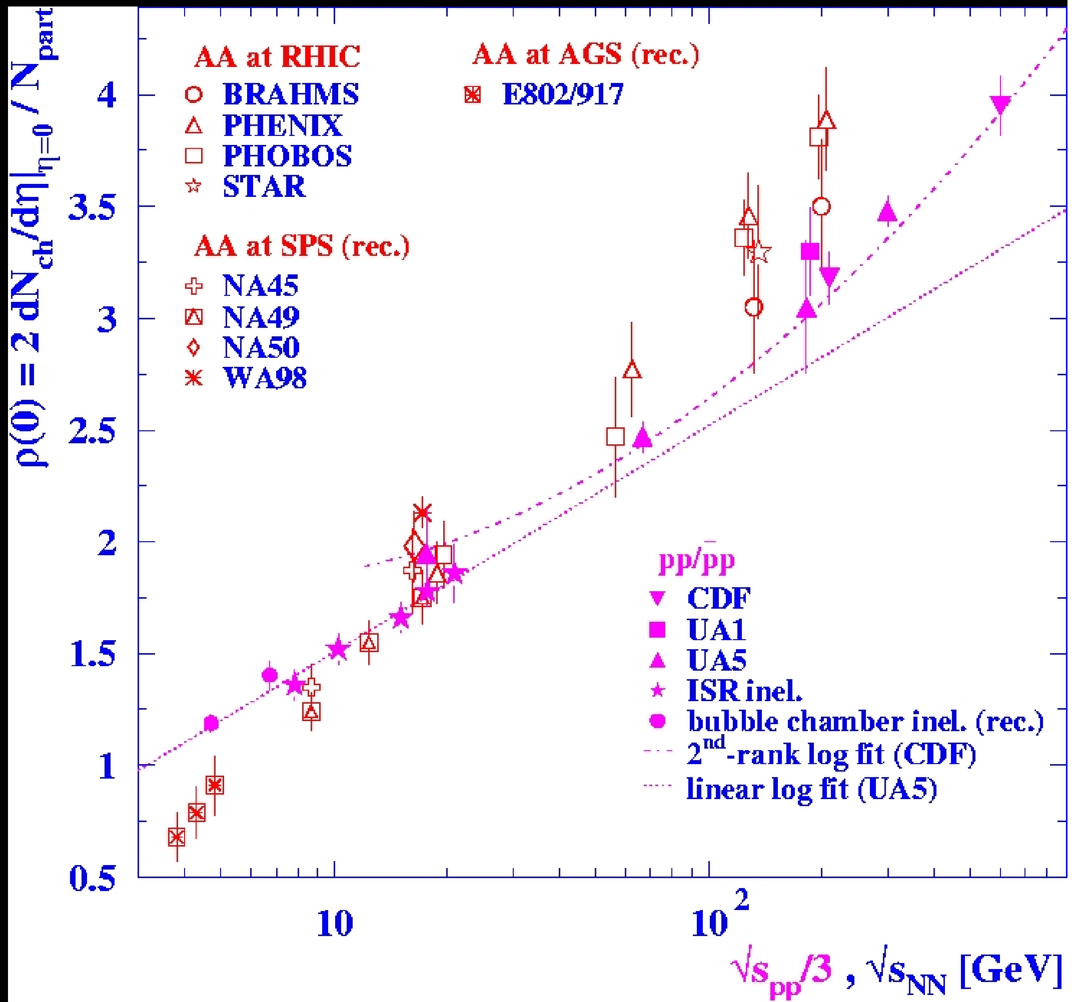
  - *different behaviour* at $\sqrt{s_{NN}} < 20$ GeV vs. $\sqrt{s_{NN}} > 20$ GeV: *different fits* to pp data



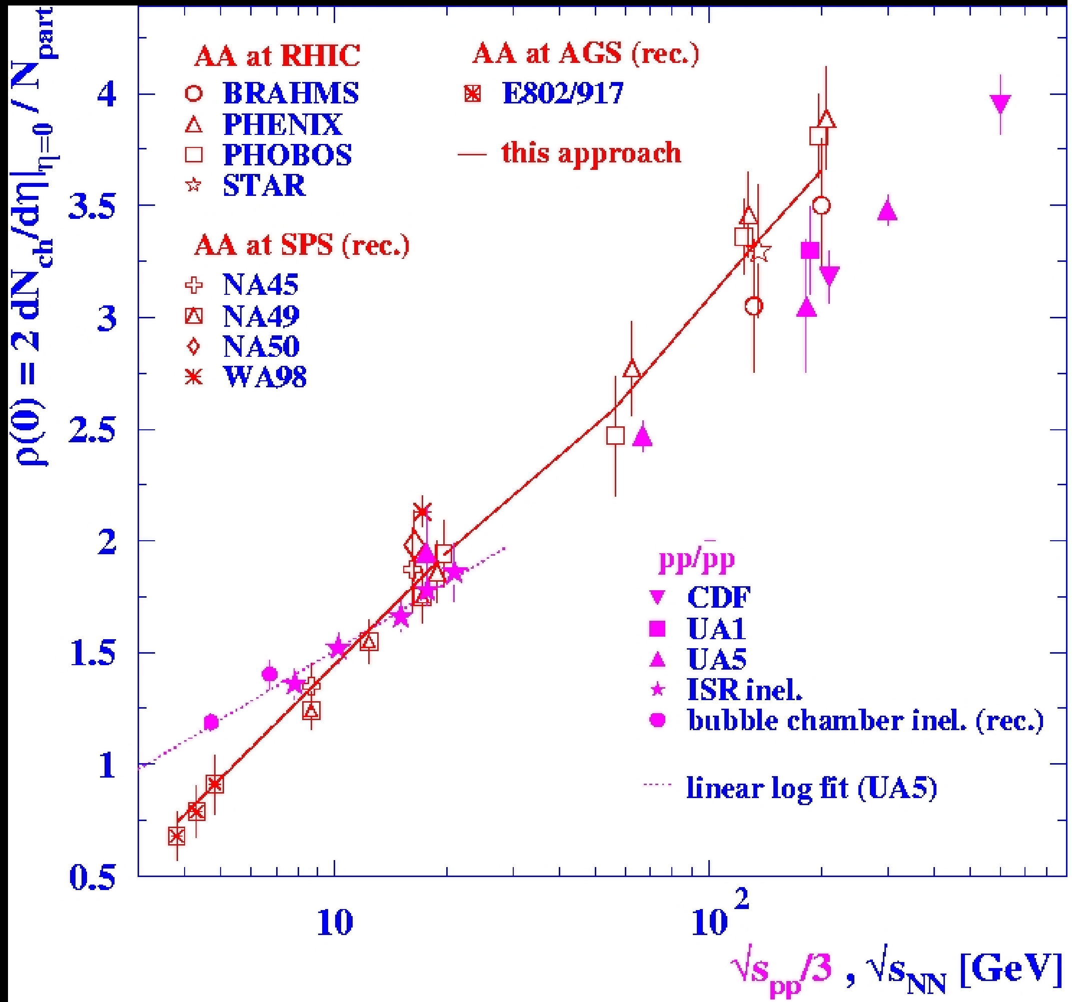
Mid-rapidity density: from pp to AA

- from Landau hydrodynamics:

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

- for AA m = m_p, for pp m = $m_p/3$
  $\sqrt{s_{NN}} = \sqrt{s_{pp}}/3$

- AA data and *different behaviour* at $\sqrt{s_{NN}} < 20$ vs. $\sqrt{s_{NN}} > 20$ GeV:
  → *well reproduced*



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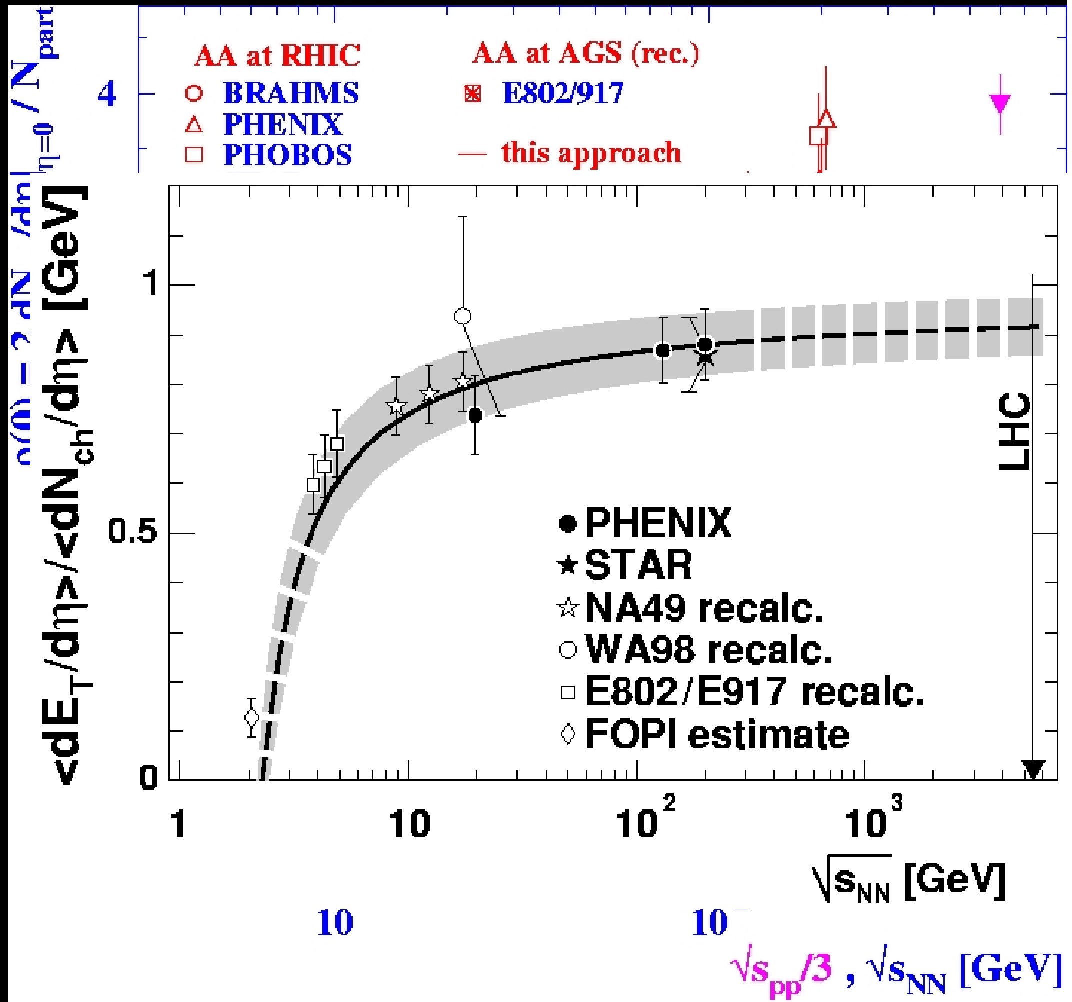
- for AA $m = m_p$, for pp $m = m_p/3$
  $\sqrt{s_{NN}} = \sqrt{s_{pp}}/3$
- AA data and *different behaviour* at $\sqrt{s_{NN}} < 20$ vs. $\sqrt{s_{NN}} > 20$ GeV:
  → *well reproduced*
- changes in energy dependence agrees with experiment
- the same effect in E_T: *similar description*



From mid-rapidity density to multiplicity

- from Landau hydrodynamics:

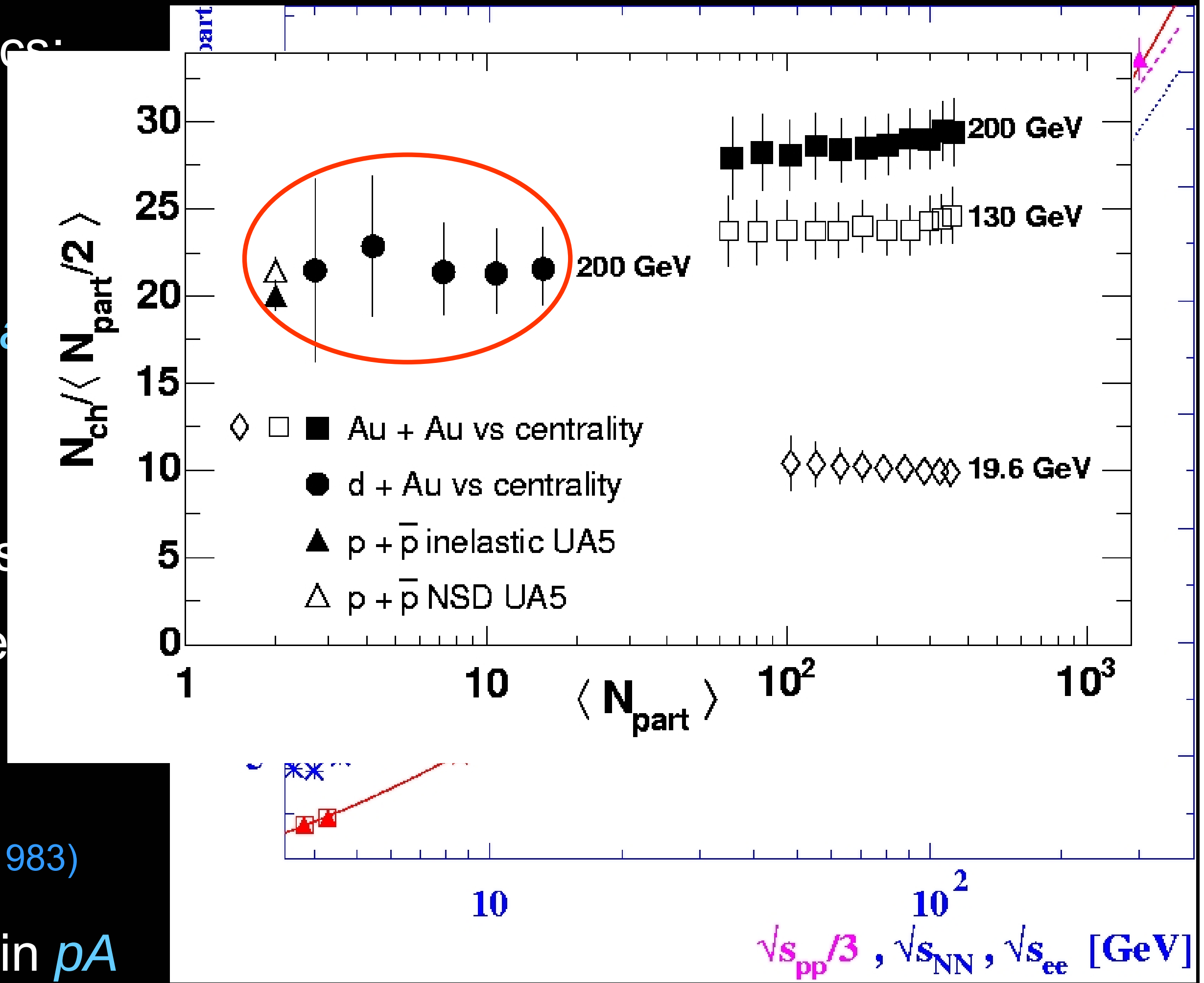
$$\frac{\rho_{NN}(0)}{\rho_{pp}(0)},\quad N_{ch}^{pp} \Rightarrow \frac{2N_{ch}}{N_{part}}$$

- AA data and *different beha*
  at $\sqrt{s_{NN}} < 20$ vs. $\sqrt{s_{NN}} > 20$
  well reproduced

- AA *beyond RHIC* energies
  - faster increase than in e
  - overshoot pp data

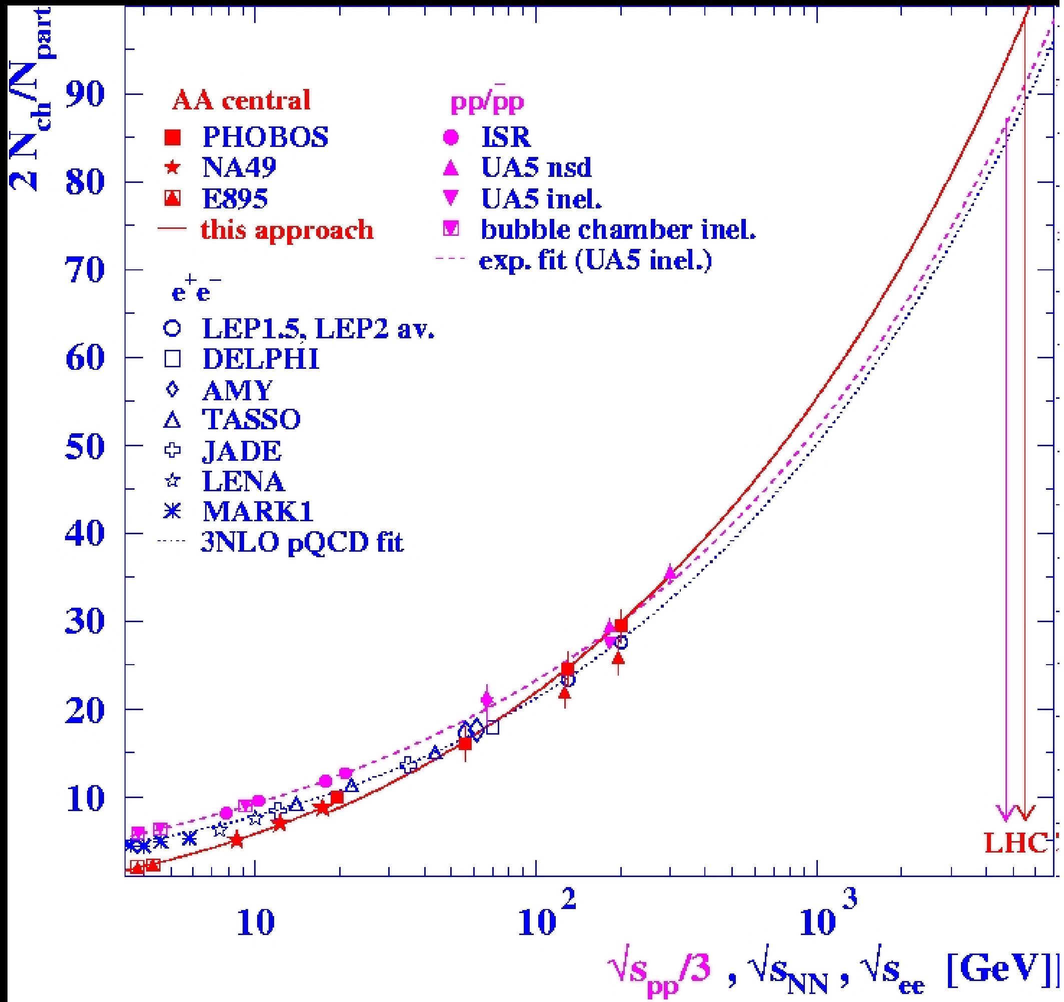
- pA *similar to* pp data
  as $\sqrt{s_{NN}} = \sqrt{s_{pp}}$ (Feinberg, 1983)

- No centrality dependence in *pA*



Higher-energy predictions

- mid-rapidity density at $\sqrt{s_{NN}} > 200$ GeV :
- agrees with *experimental extrapolation* (PHENIX, PHOBOS)
- agrees with *LHC expectations* (ATLAS)
- multiplicity at $\sqrt{s_{NN}} > 200$ GeV :
- AA *beyond RHIC* energies:
  - faster increase than in e^+e^-
  - overshoot pp data
  - but small (<10%) difference



Conclusions

- Similarities of bulk observables (average multiplicity and mid-rapidity density) in heavy-ion collisions e^+e^- and pp interactions analysed at c.m. energies from a few GeV to hundreds GeV per nucleon
- The universality of the hadroproduction process is obtained based on the dissipating energy of participants and their types
- In head-on nuclear collisions protons behave as effectively structureless patterns in sense of the energy deposited into hadrons, similar to e^+e^- interactions
- The bulk observables in heavy-ion collisions are reproduced from those in pp interactions, treated within the additive quark model
- Two separated regions are reproduced with a boundary about highest SPS energy (to be understood from pp interactions?)
- The consequences of the description for pA collisions agree with resent RHIC data
- Predictions for energies up to the LHC energies are made and agree with expectations from experiments