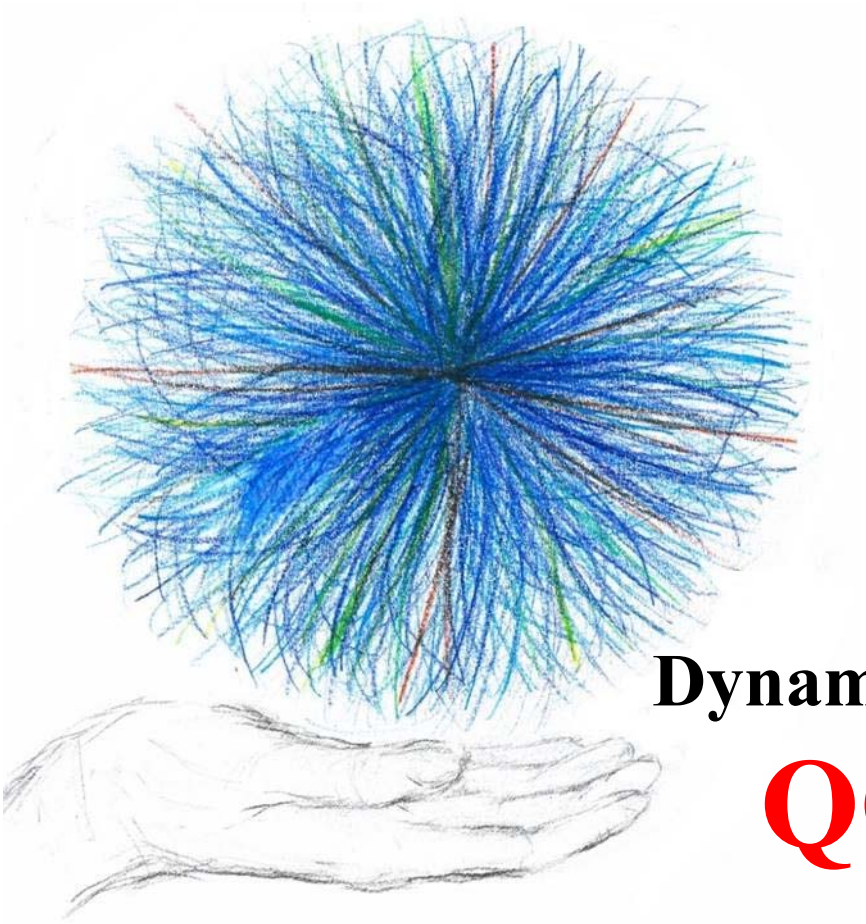


Dynamical energy loss as a tool for

QGP Tomography

Magdalena Djordjevic,

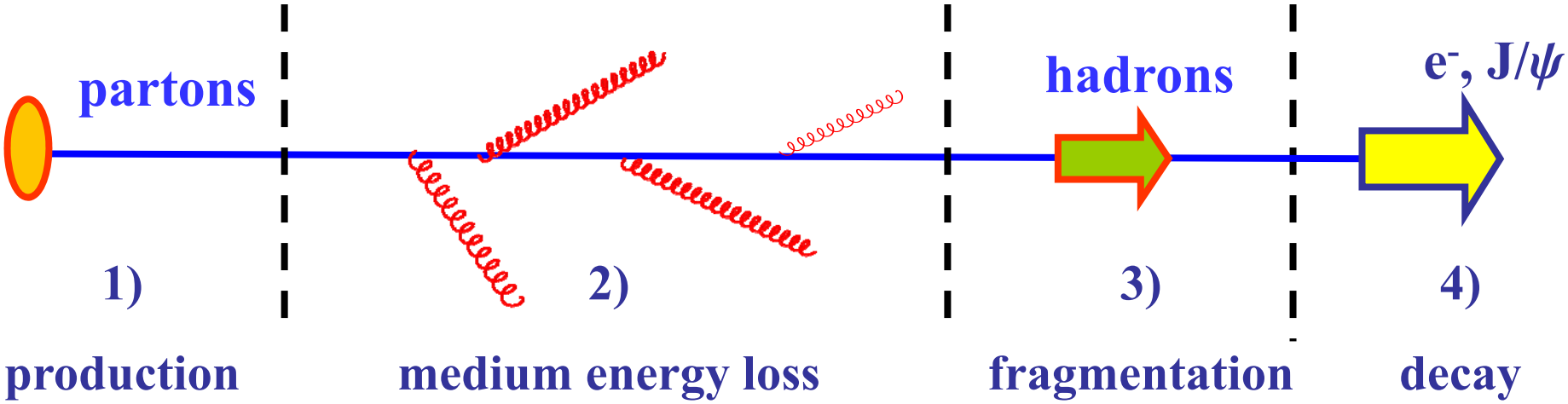
Suppression
– a traditional probe of QCD matter

Light and heavy flavour suppressions are considered as excellent probes of QCD matter.

Suppression for a number of observables at RHIC and LHC has been measured.

Comparison of theory with the experiments allows testing our understanding of QCD matter.

Suppression scheme



1) Initial momentum distributions for partons
2) Parton energy loss
3) Fragmentation functions of partons into hadrons
4) Decay of heavy mesons to single e^- and J/ψ.

Energy loss

Initially, most of the energy loss calculations assumed only *radiative* energy loss, and a QCD medium composed of static scattering centers. (e.g. GW, DGLV, ASW,BDMPS...)

However, these calculations lead to an obvious disagreement with the experimental data.

Is collisional energy loss also important?

Yes, collisional and radiative energy losses are comparable!

Non-zero collisional energy loss - a fundamental problem

Static QCD medium approximation (modeled by Yukawa potential).

With such approximation, collisional energy loss has to be exactly equal to zero!

However, collisional and radiative energy losses are shown to be comparable.

Introducing collisional energy loss is necessary, but inconsistent with static approximation!

Static medium approximation should not be used in radiative energy loss calculations!

Dynamical QCD medium effects have to be included!

The dynamical energy loss

- **Finite size medium of dynamical (moving) partons**
- **Based on finite T field theory and HTL approach**

M. D., PRC74 (2006), PRC 80 (2009), M. D. and U. Heinz, PRL 101 (2008).

Includes:

- **Same theoretical framework for both radiative and collisional energy loss**
- **Finite magnetic mass effects** (M. D. and M. Djordjevic, PLB 709:229 (2012))
- **Running coupling** (M. D. and M. Djordjevic, PLB 734, 286 (2014)).

Integrated in a numerical procedure including parton production, fragmentation functions, path-length and multi-gluon fluctuations

- **No free parameters**
- **Treats both light and heavy flavor partons**

Understanding the existing data

(200 GeV at RHIC and 2.76TeV at LHC)

- **Provide joint predictions across diverse probes**

  charged hadrons, pions, kaons, D mesons,

  non-photonic single electorns, non-prompt J/ψ

  M. D. and M. Djordjevic, PLB 734, 286 (2014)

- **Puzzles (apparently surprising data)**

  Measured charged hadron *vs.* D meson supression

  M.D., PRL 112, 042302 (2014)

- **Concentrate on all centrality regions**

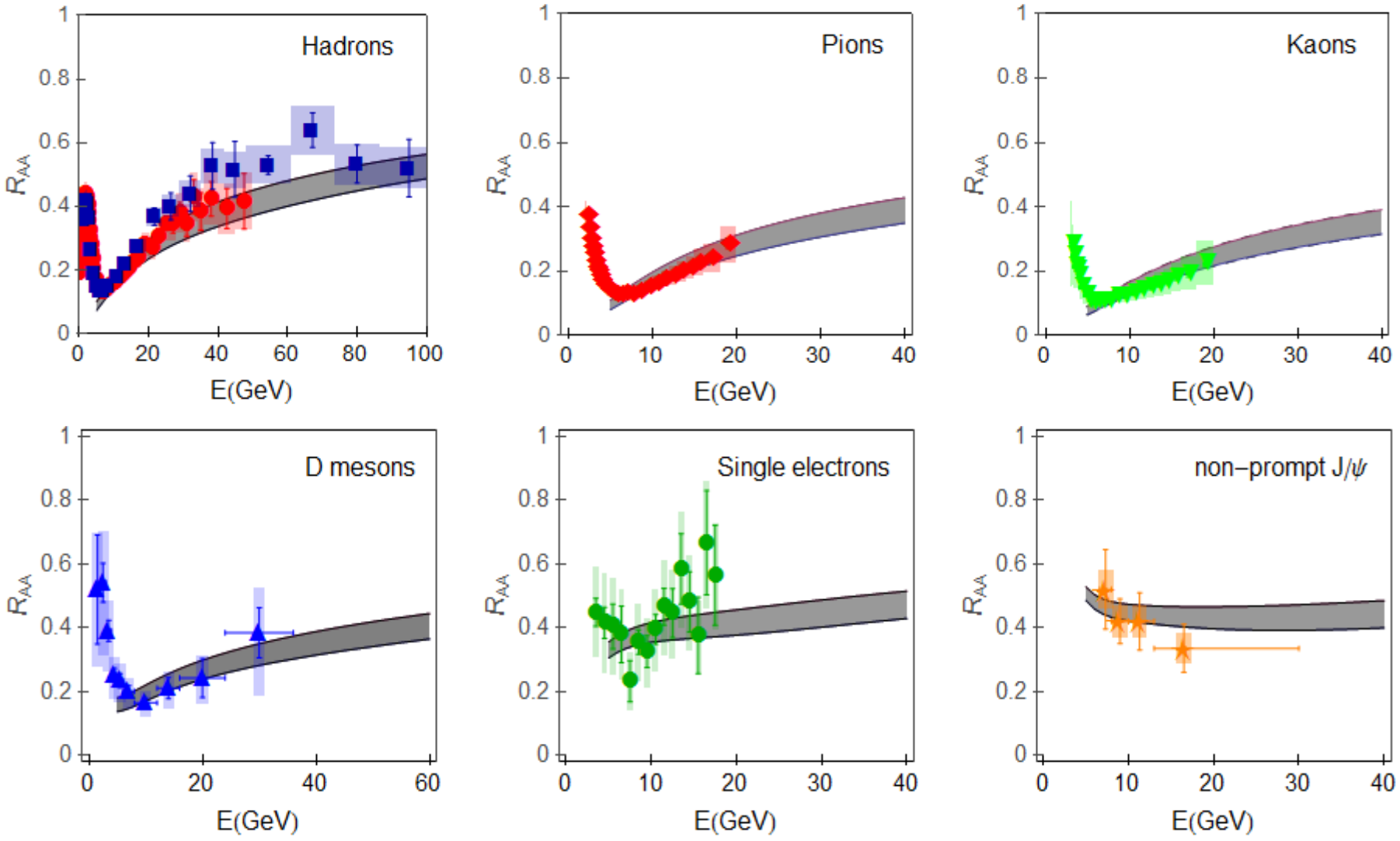
  M. D., M. Djordjevic and B. Blagojevic, PLB 737 298 (2014)

- **All predictions generated**

  - **By the same formalism**
  - **With the same numerical procedure**
  - **No free parameters in model testing**

Comparison with LHC data (central collision)

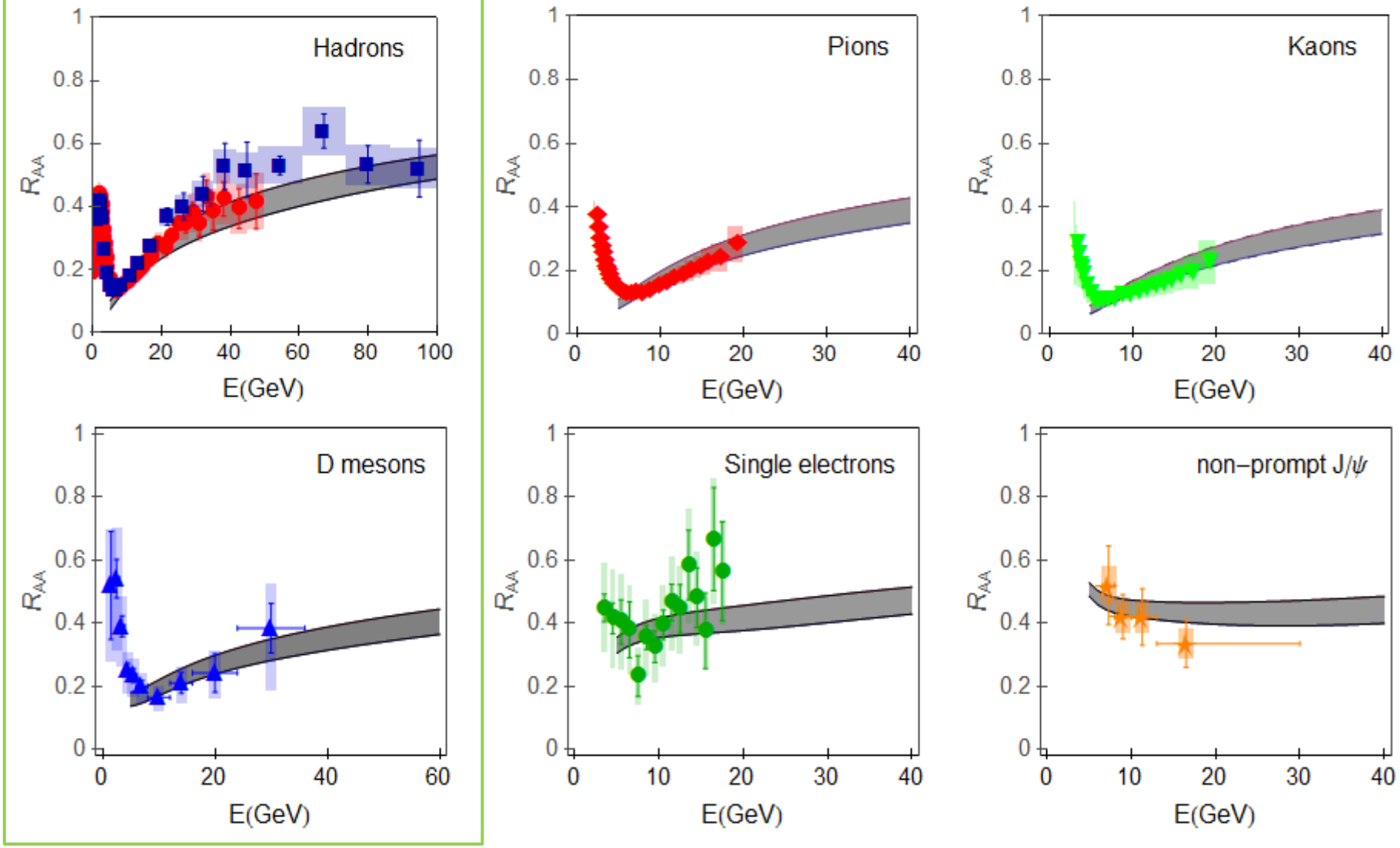
M. D. and M. Djordjevic, PLB 734, 286 (2014)



Very good agreement with diverse probes!

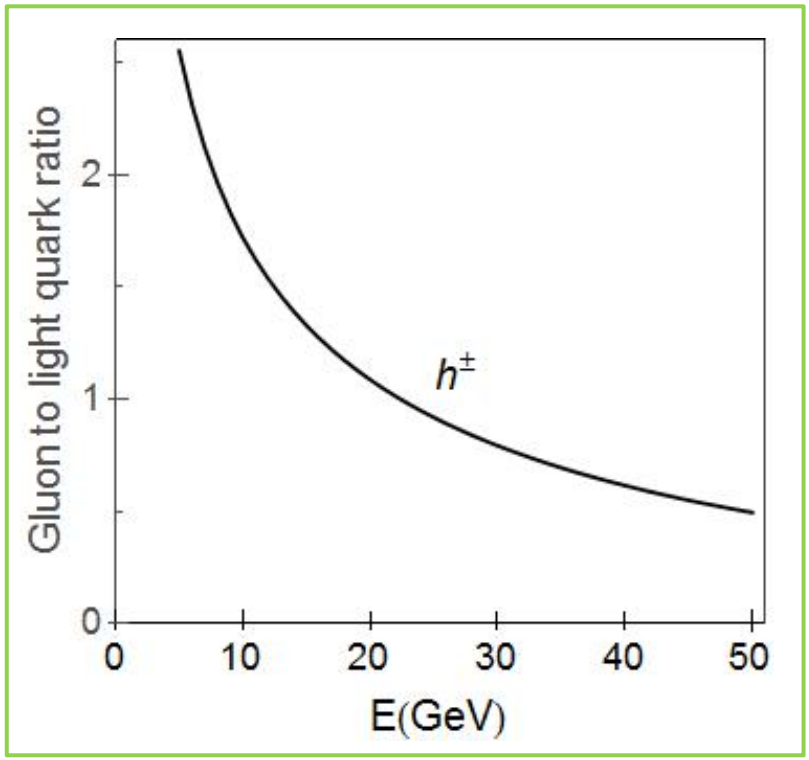
Comparison with LHC data (central collision)

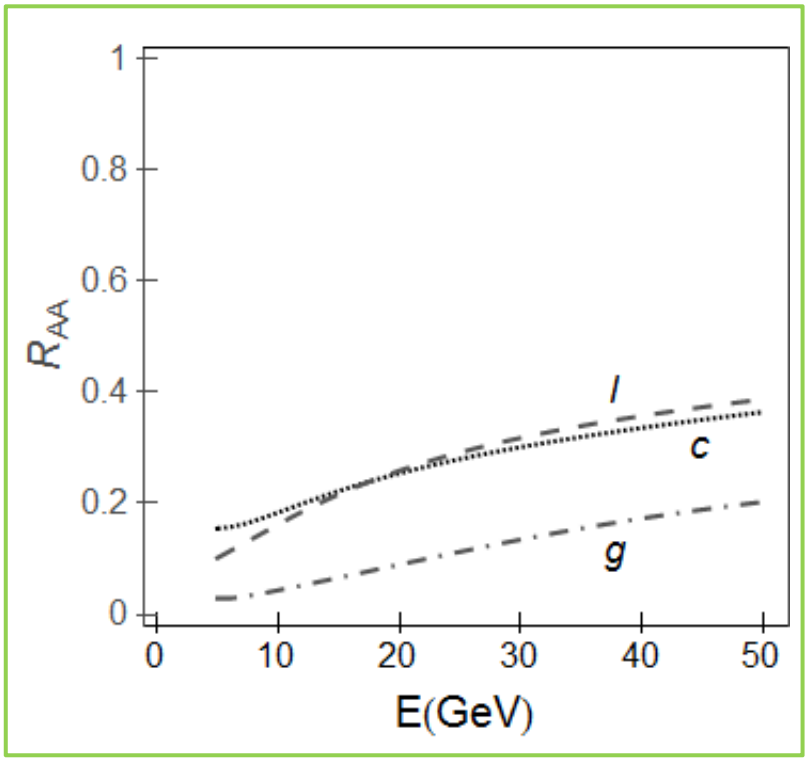
M. D. and M. Djordjevic, PLB 734, 286 (2014)



Very good agreement with diverse probes!

Heavy flavor puzzle at LHC



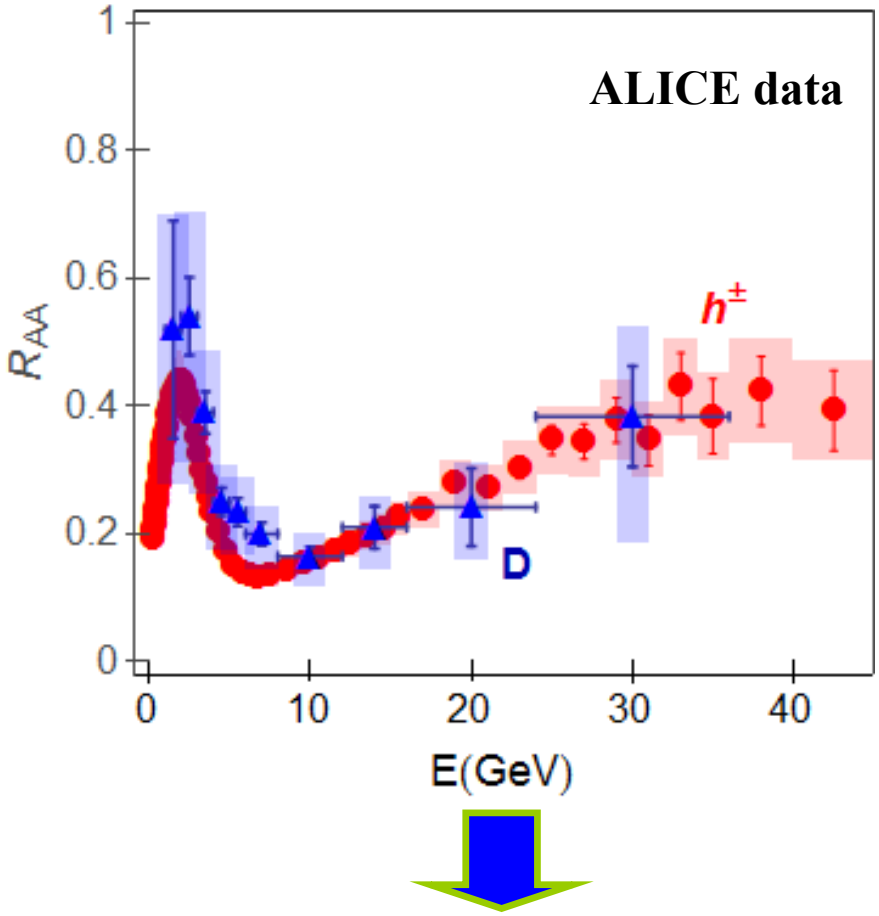


Significant gluon contribution in charged hadrons

Much larger gluon suppression

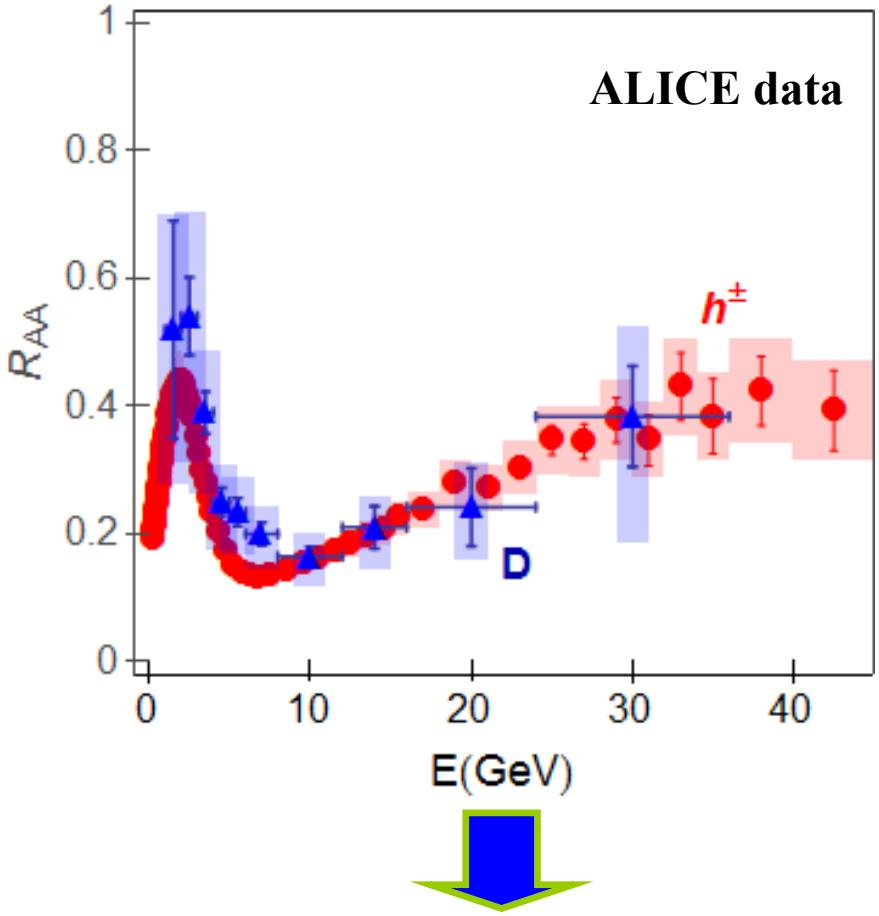
$$R_{AA}(h^{\pm}) < R_{AA}(D)$$

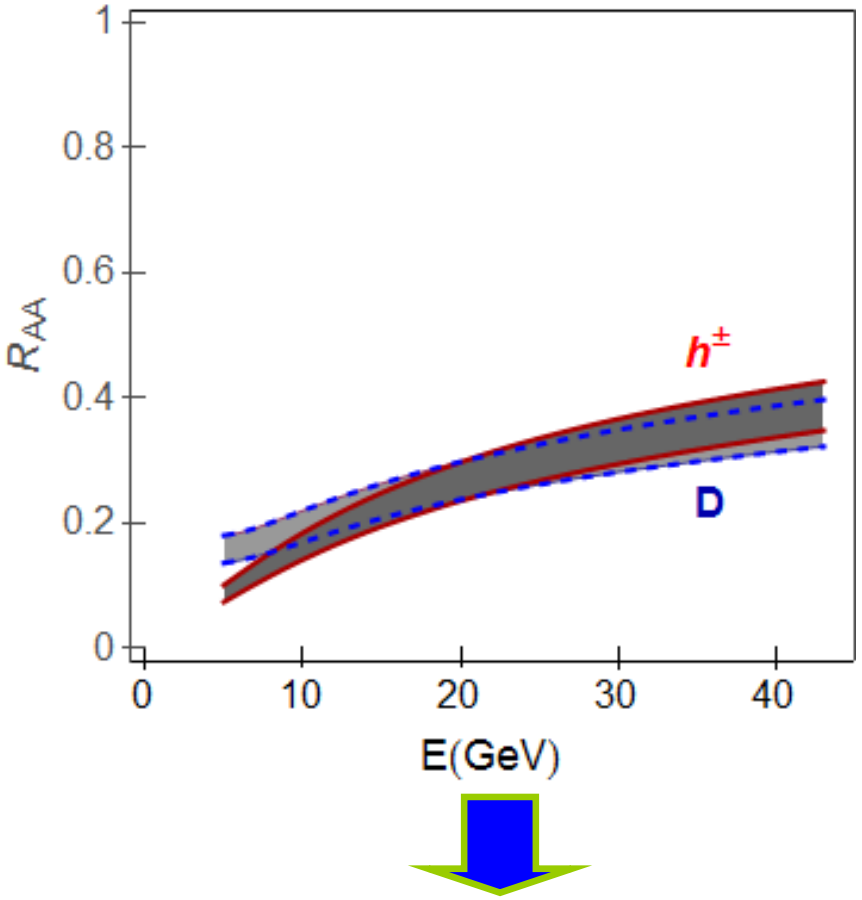
Charged hadrons vs D meson R_{AA}



$$R_{AA}(h^{\pm}) = R_{AA}(D)$$

Charged hadrons vs D meson R_{AA}





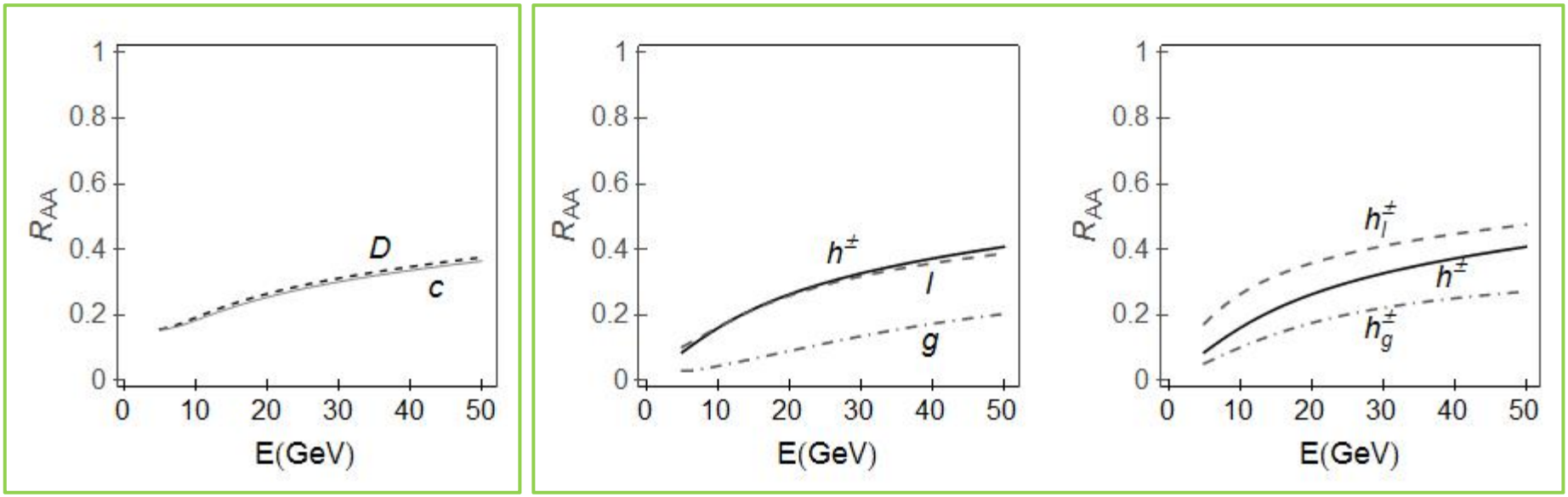
$R_{AA}(h^{\pm}) = R_{AA}(D)$

Excellent agreement with the data!

Disagreement with the qualitative expectations!

M.D., PRL 112, 042302 (2014)

Hadron R_{AA} *vs.* parton R_{AA}



D meson is a genuine probe of bare charm quark suppression

Distortion by fragmentation

Charged hadron R_{AA} = (bare) light quark R_{AA}

M. Djordjevic 12

M.D., PRL 112, 042302 (2014)

Puzzle summary

$R_{AA}(h^{\pm}) = R_{AA}$ (light quarks)

$R_{AA}(D) = R_{AA}$ (charm)

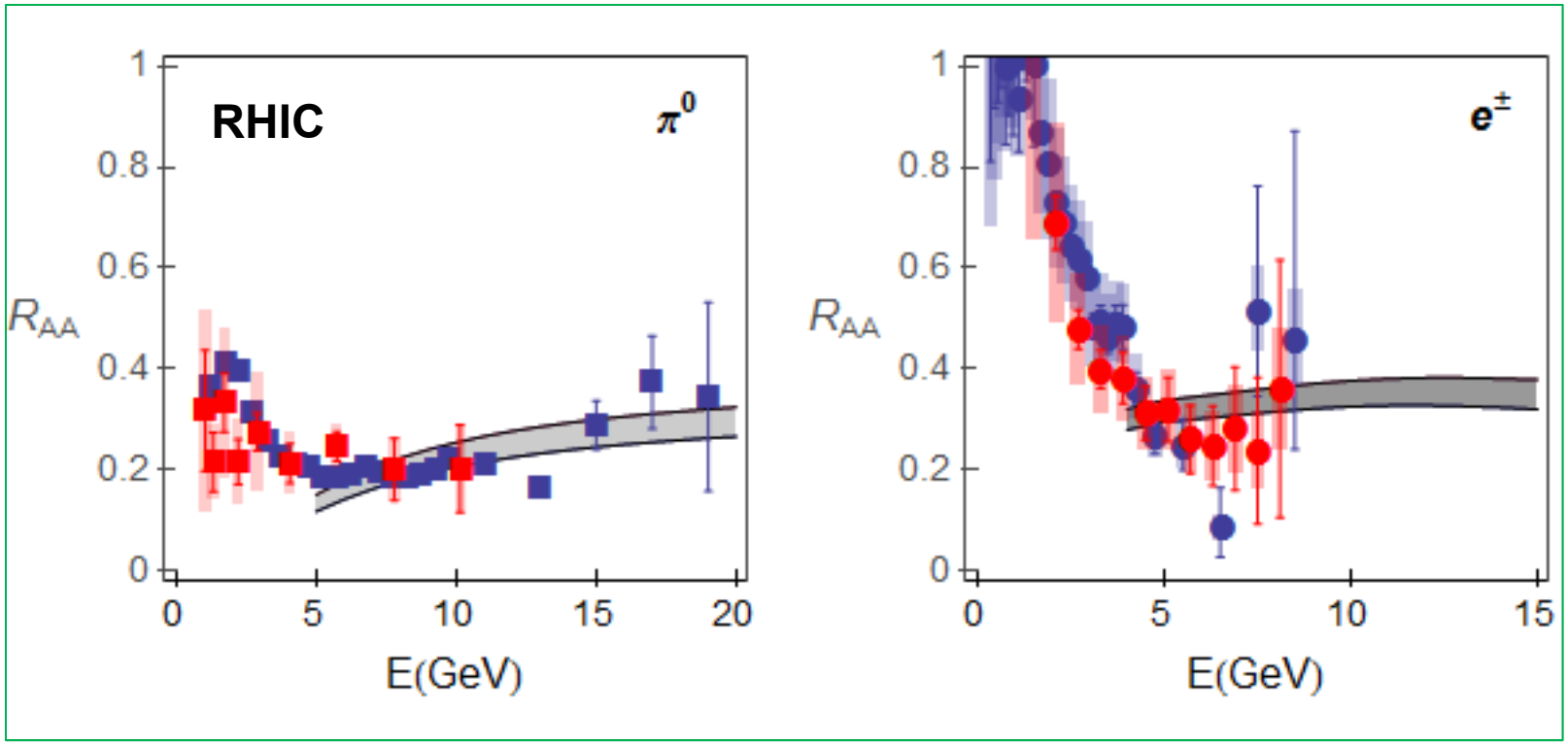
R_{AA} (light quarks) = R_{AA} (charm)

$R_{AA}(h^{\pm}) = R_{AA}(D)$

Puzzle explained!

M.D., PRL 112, 042302 (2014)

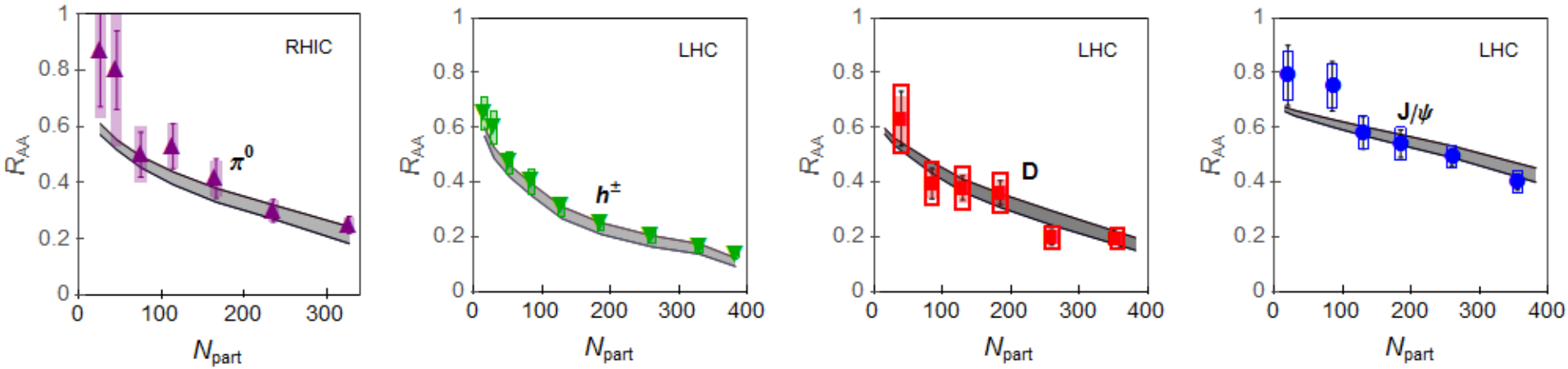
Comparison with RHIC data (central collisions)



Very good agreement!

M.D. and M. Djordjevic, PRC 90, 034910 (2014)

R_{AA} *vs.* N_{part} for RHIC and LHC



Excellent agreement for both RHIC and LHC and for the whole set of probes!

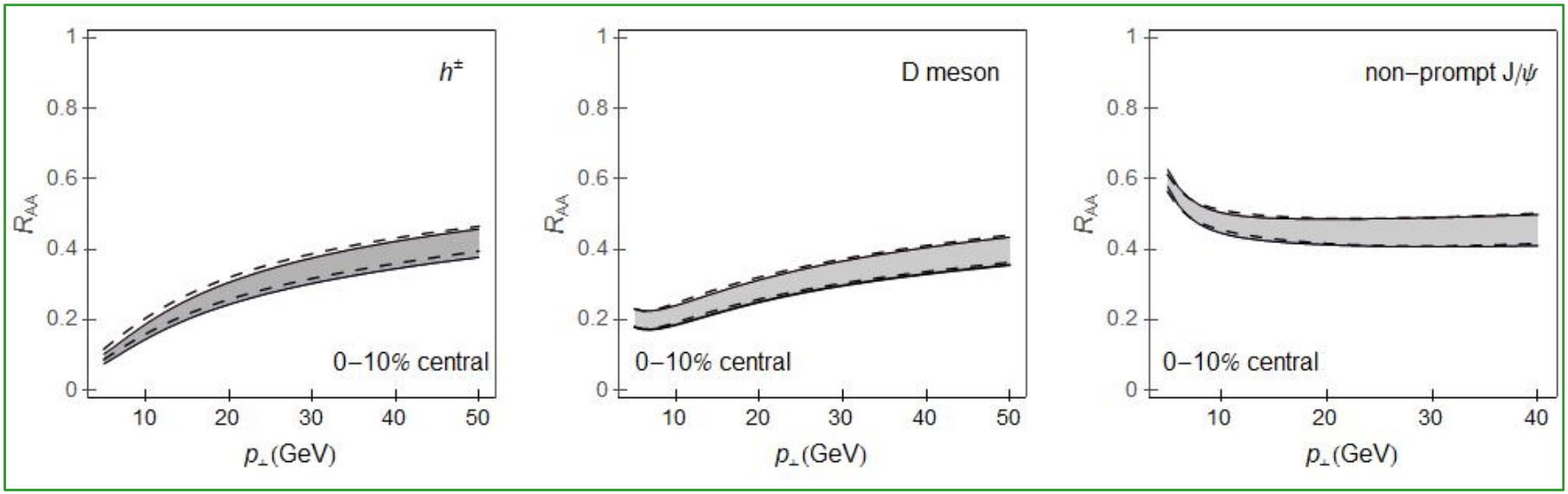
M. Djordjevic 15

M. D., M. Djordjevic and B. Blagojevic, PLB 737 298 (2014)

Predictions for the upcomming 5.1 TeV Pb+Pb at LHC

Comparison with the suppressions at lower beam energies

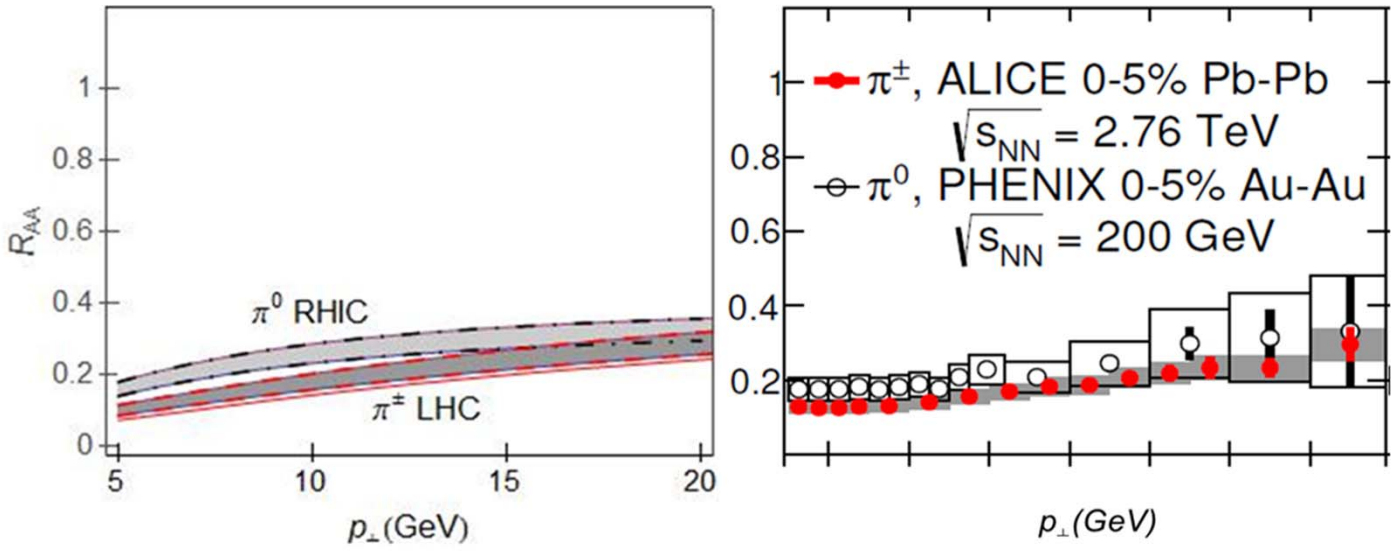
5.1 TeV Pb+Pb at LHC



The same suppression as at 2.76 TeV for all types of probes!

M. D. and M. Djordjevic, Phys. Rev. C 92 (2015) 2, 024918

5.1 TeV Pb+Pb at LHC



The same suppression as at 2.76 TeV for all types of probes!

In line with BES energy scan, which shows similar suppressions between RHIC and LHC.

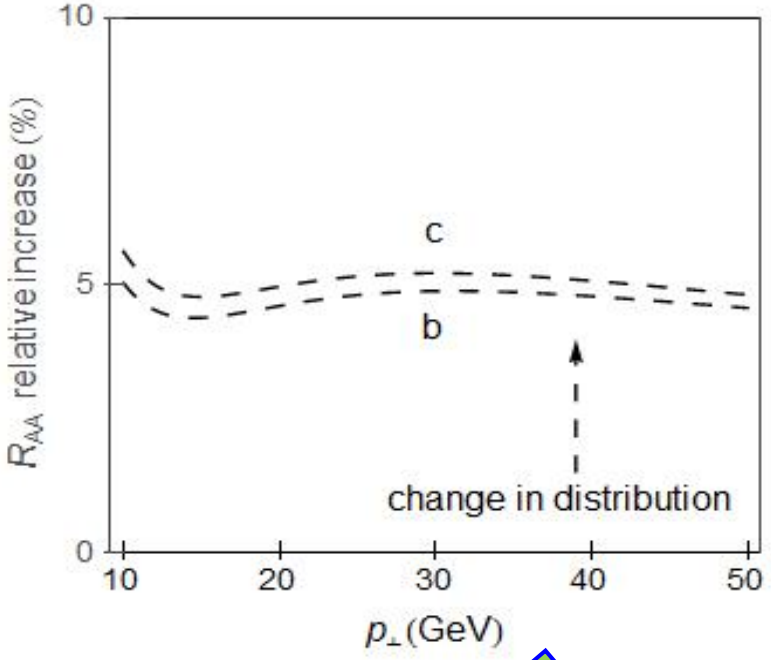
M. Djordjevic 17

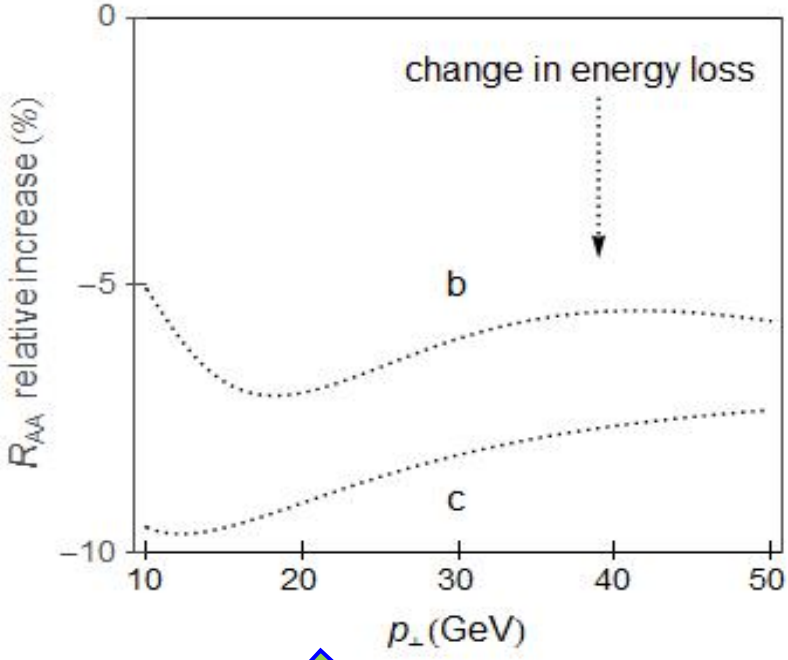
M. D. and M. Djordjevic, Phys. Rev. C 92 (2015) 2, 024918

Why the same suppression?

An interplay between initial distribution and energy loss effects.

(see poster 671, board 0570)





The two effects cancel!

M. D. and M. Djordjevic, Phys. Rev. C 92 (2015) 2, 024918

Energy loss summary

Dynamical energy loss formalism.

Tested on angular averaged R_{AA} data

Largely not sensitive to the medium evolution.

Good agreement for wide range of probes, centralities and beam energies.

Can explain puzzling data.

Clear predictions for future experiments.

The dynamical energy loss formalism can well explain the jet-medium interactions in QGP.

Outlook

Dynamical energy loss model + **Bulk medium evolution models** (Huovinen/Niemi, BAMPS)

Predictions of angular differential R_{AA} observables (e.g. elliptic flow) for high pt observables.

Presumably highly sensitive to the medium evolution.

A new sophisticated tool for precision QGP tomography.

Backup

Numerical procedure

- **Light flavor production** Z.B. Kang, I. Vitev, H. Xing, PLB 718:482 (2012)
- **Heavy flavor production** M. Cacciari et al., JHEP 1210, 137 (2012)
- **Path-length fluctuations** A. Dainese, EPJ C33:495,2004.
- **Multi-gluon fluctuations**

  M. Gyulassy, P. Levai, I. Vitev, PLB 538:282 (2002).
- **DSS and KKP fragmenation for light flavor**

  D. de Florian, R. Sassot, M. Stratmann, PRD 75:114010 (2007)

  B. A. Kniehl, G. Kramer, B. Potter, NPB 582:514 (2000)
- **BCFY and KLP fragmenation for heavy flavor**

  M. Cacciari, P. Nason, JHEP 0309: 006 (2003)
- **Decays of heavy mesons to single electron and J/ψ according to**

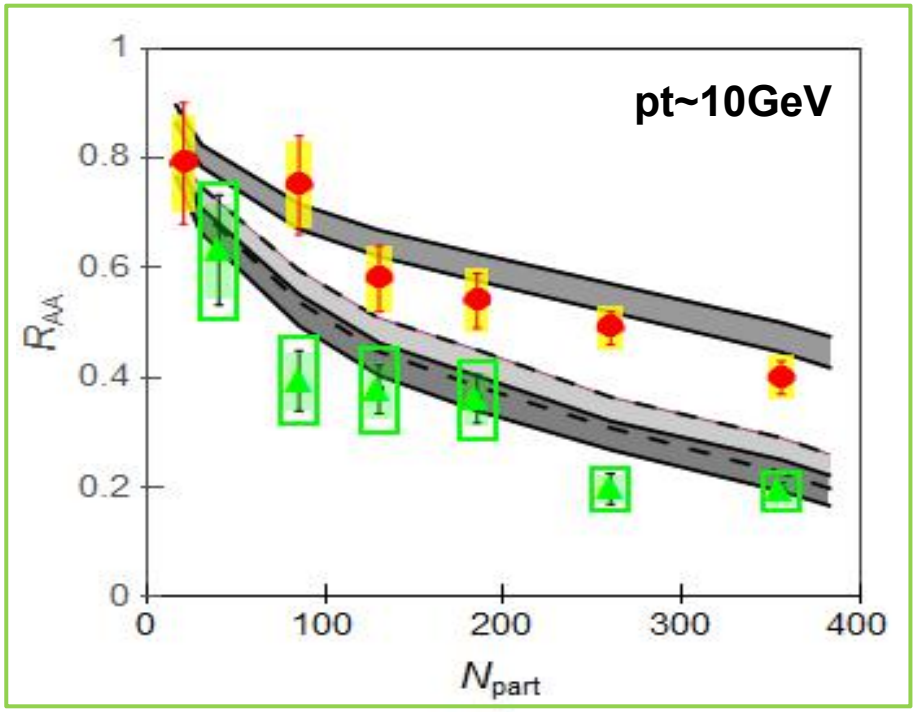
  M. Cacciari et al., JHEP 1210, 137 (2012)
- **Temperature T=304 MeV for LHC and T=221 MeV for RHIC.**

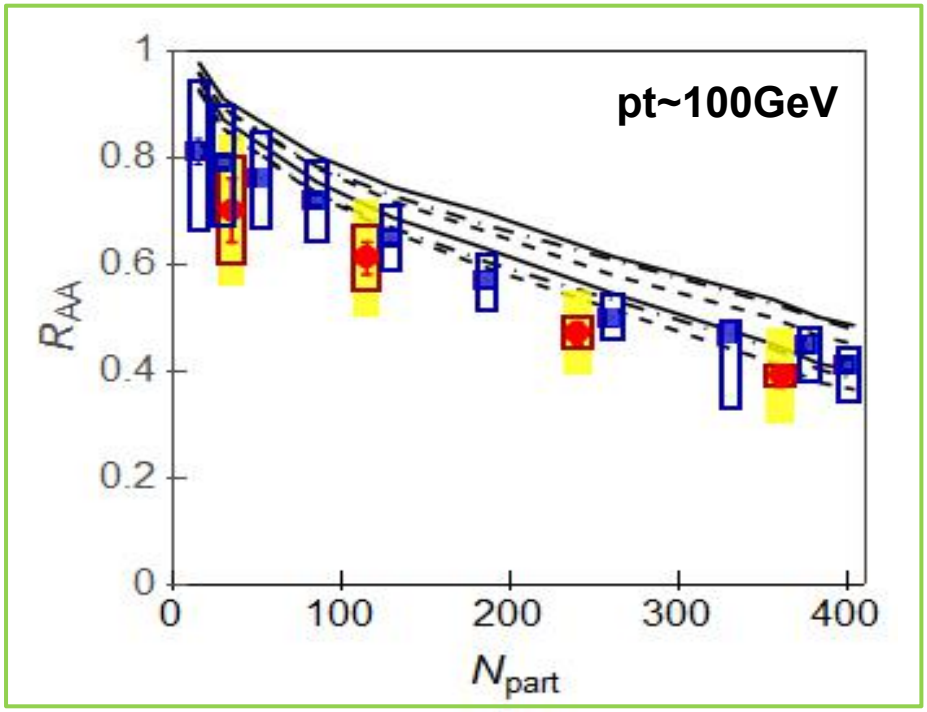
  M. Wilde, Nucl. Phys. A 904-905, 573c (2013) (ALICE Collab.)

  A. Adare *et al.*, Phys. Rev. Lett. 104, 132301 (2010) (PHENIX Collab.)

What about jets?

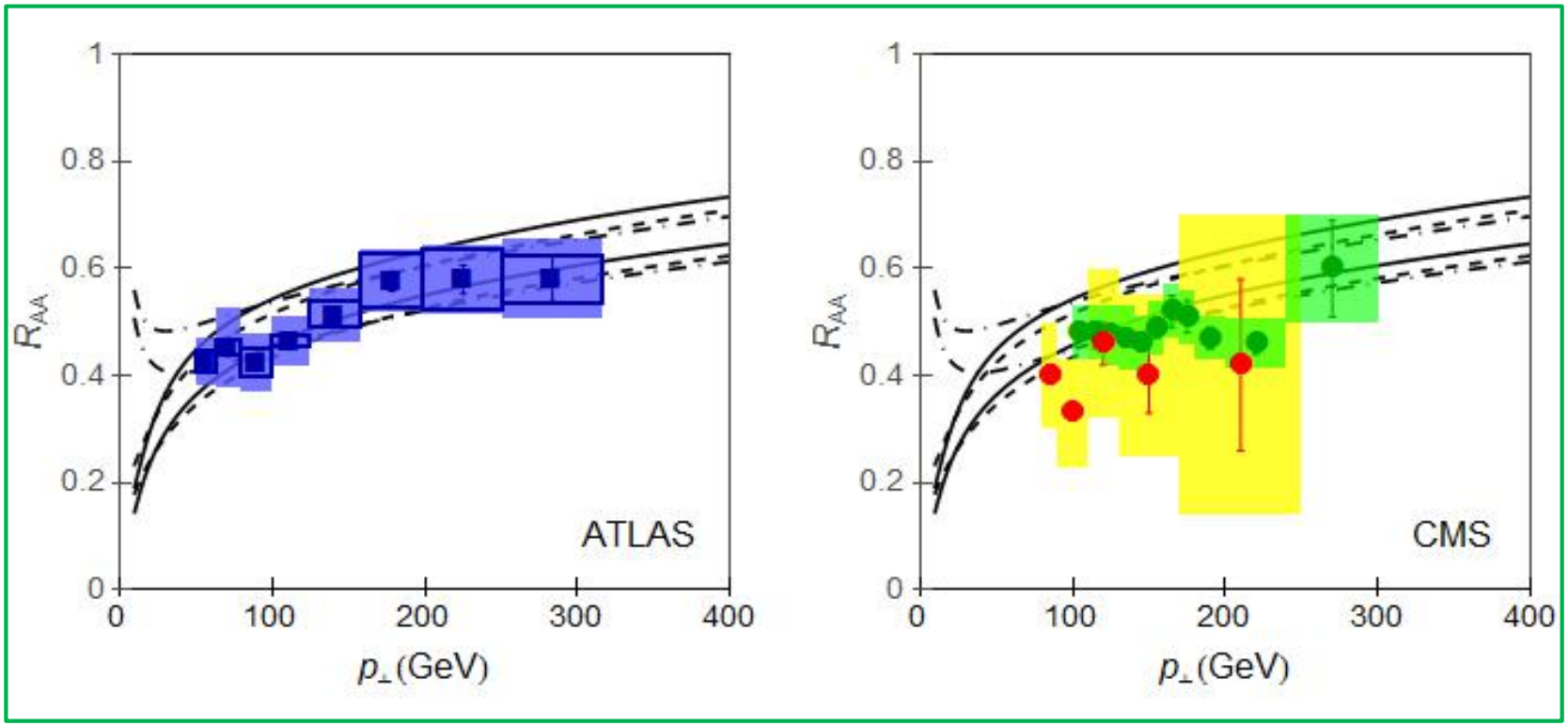
The dead cone effect





Good agreement at the low energy!

As well as for jets!



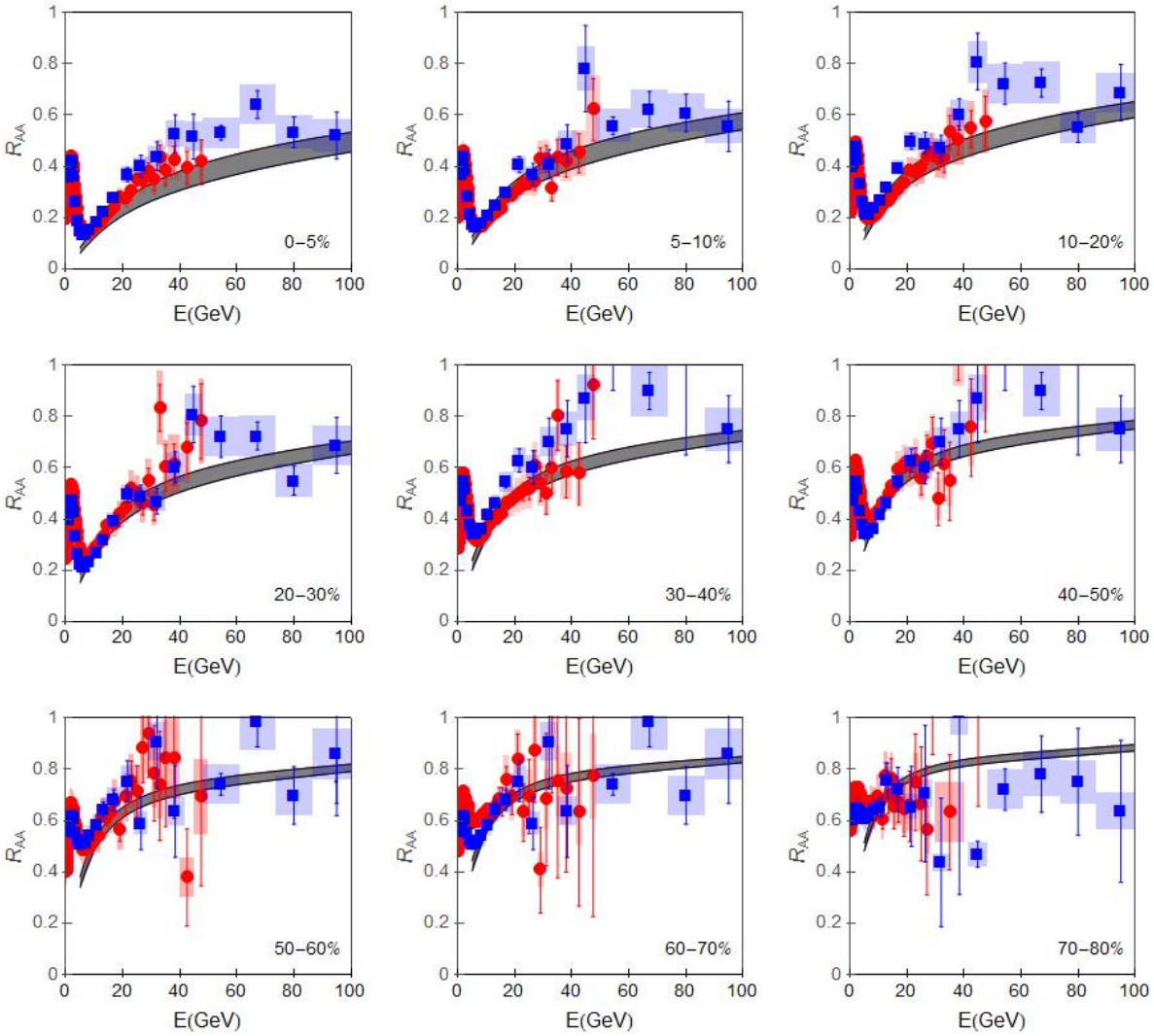
At high momentum, all types of particles have the same suppression

Good agreement between our model and the data

The model is in agreement with the jet data as well!

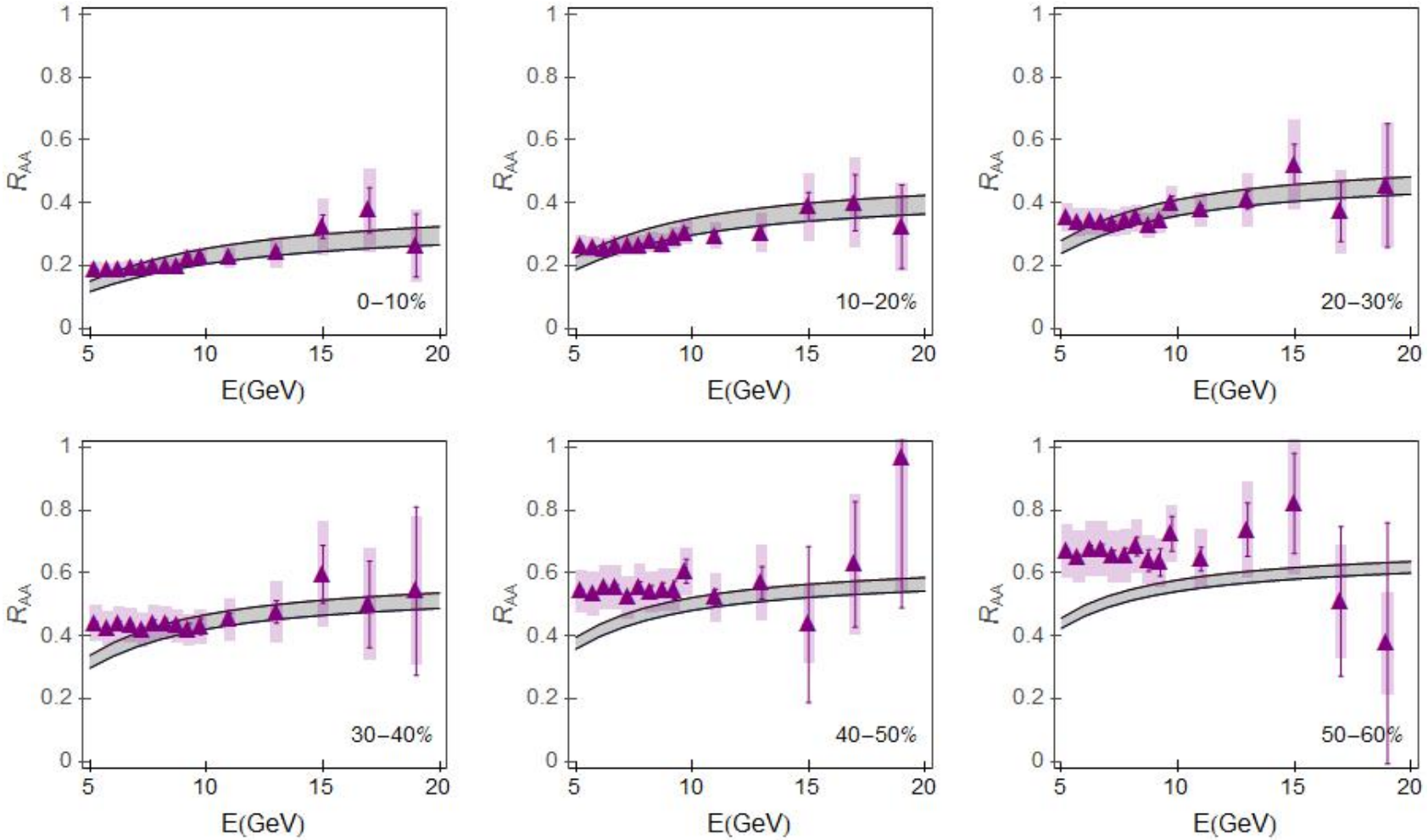
Non central collisions @ LHC
(fixed centrality and charged hadrons)

M. D., M. Djordjevic and B. Blagojevic, PLB 737 298 (2014)



An excellent agreement for different centrality regions!

Non central collisions @ RHIC (fixed centrality and neutral pions)



Also a very good agreement for RHIC!

M. Djordjevic 29

M. D., M. Djordjevic and B. Blagojevic, PLB 737 298 (2014)