Experimental overview on EM observables

Yosuke Watanabe
Center for Nuclear Study, the University of Tokyo

2015 KOBE JAPAN

EM probes

Dilepton

- New results from PHENIX for $\sqrt{s_{NN}} = 200$ GeV (PHENIX)
- Collision energy/system size dependence (STAR)

Photon

- v_2 and v_3 of thermal photons (PHENIX)
- Thermal photon yield (ALICE)

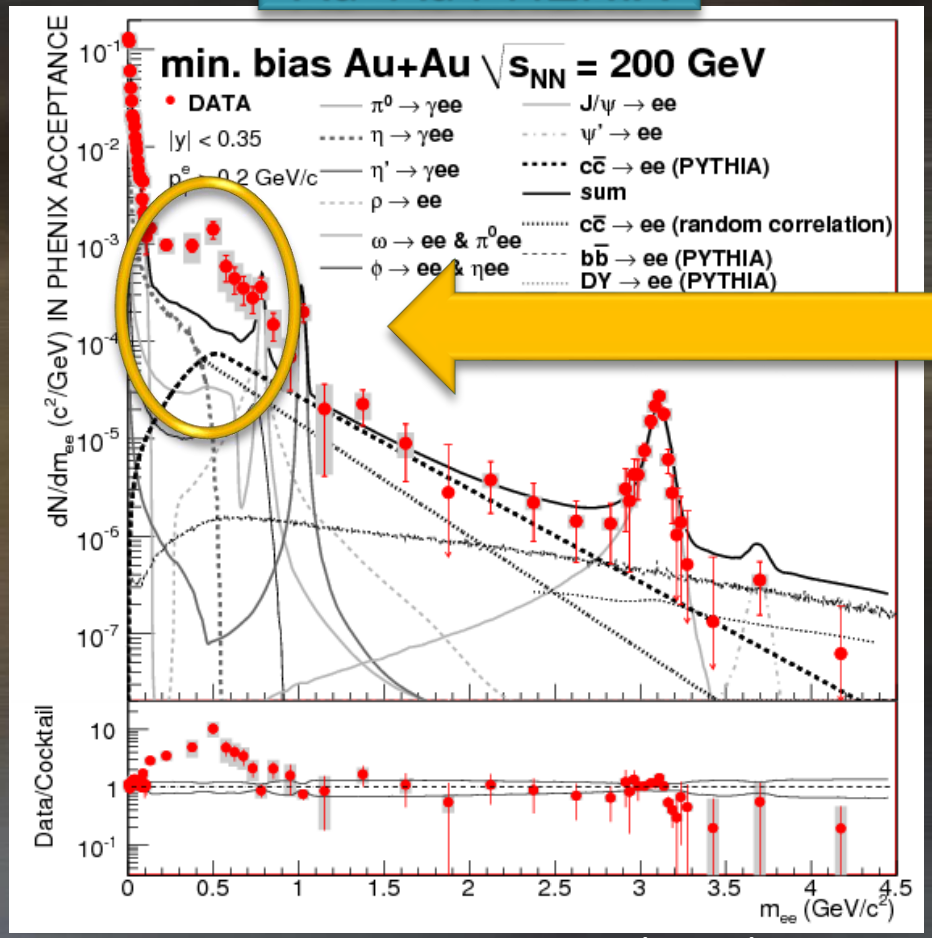
EW boson

- Centrality dependence in Pb+Pb (ATLAS/CMS)
- Centrality dependence in p+Pb (ATLAS)
- nPDF in p+Pb (ATLAS/CMS/ALICE)

Dilepton

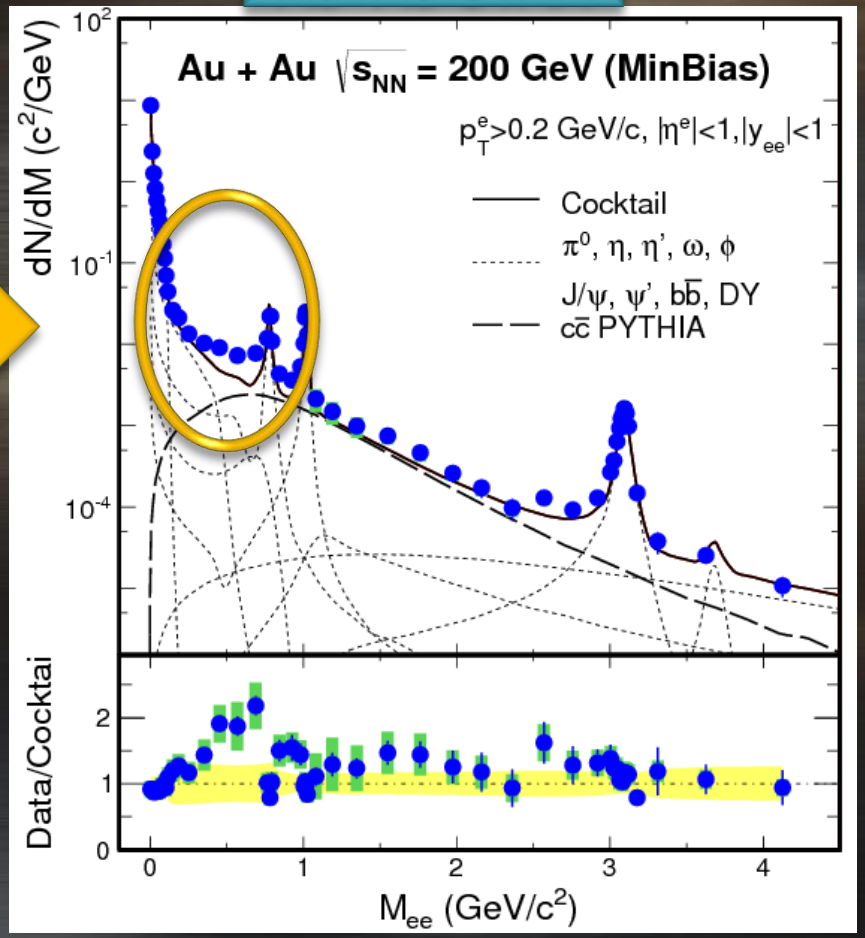
Au+Au $\sqrt{s_{NN}}$ = 200 GeV

Au+Au PHENIX



PRC 81 (2010) 034911

Au+Au STAR

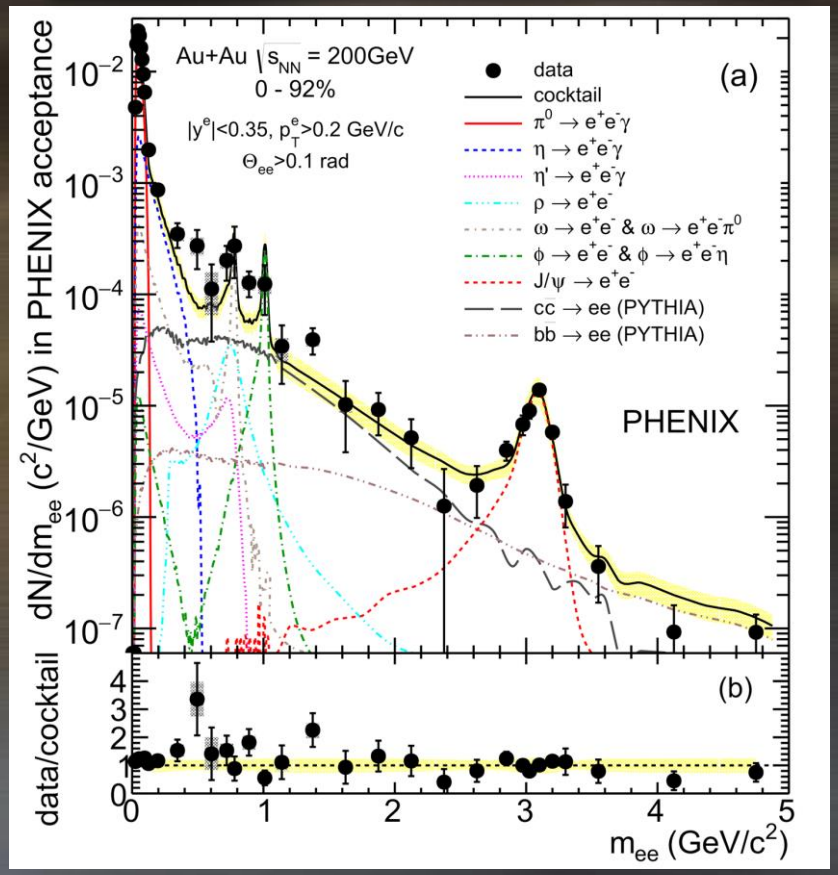


PRC 92 (2015) 024912

Talk by M. Makek

New PHENIX results

Au+Au PHENIX (2010 data)



arxiv: 1509.04667

- HBD upgrade
  - Better hadron rejection: 30% → 5%
  - Better signal sensitivity
- Analysis improvements
  - Neural Network
  - Flow modulation incorporated in the mixed events by an exact analytical method
  - Absolutely normalized correlated BG

Minimum bias data/cocktail

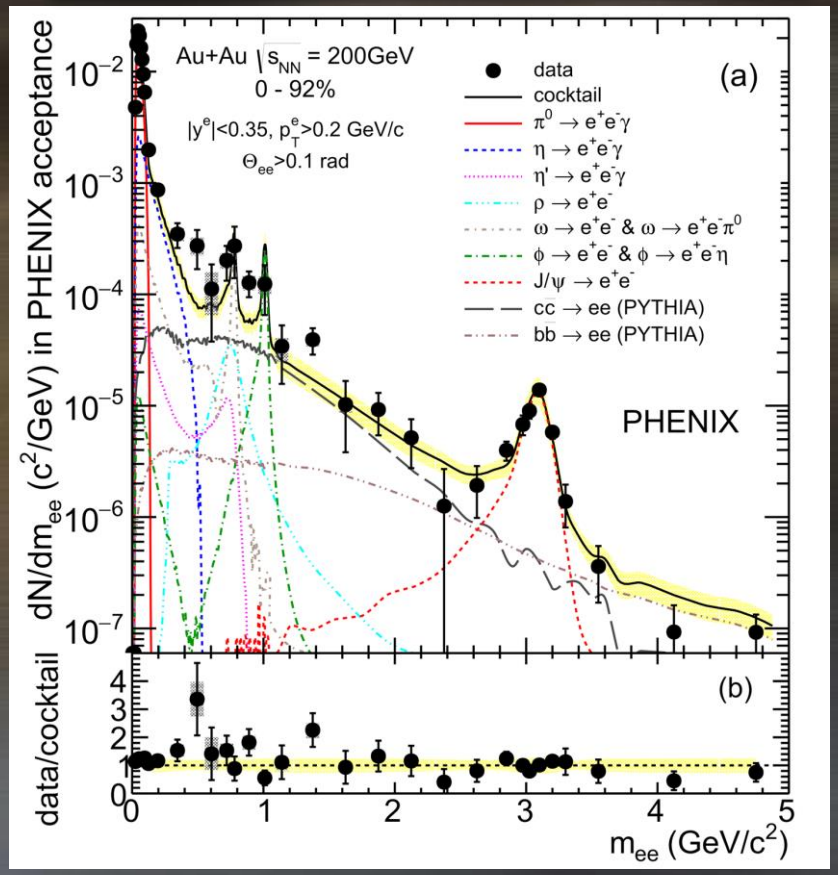
0.3-0.76 (GeV/c^2)	Data/cocktail $\pm$stat $\pm$syst $\pm$model
PHENIX 2010	$2.3 \pm 0.4 \pm 0.4 \pm 0.2$ (Pythia) $1.7 \pm 0.3 \pm 0.3 \pm 0.2$ (MC@NLO)
STAR	$1.76 \pm 0.06 \pm 0.26 \pm 0.29$

PHENIX and STAR results are now consistent

Talk by M. Makek

New PHENIX results

Au+Au PHENIX (2010 data)



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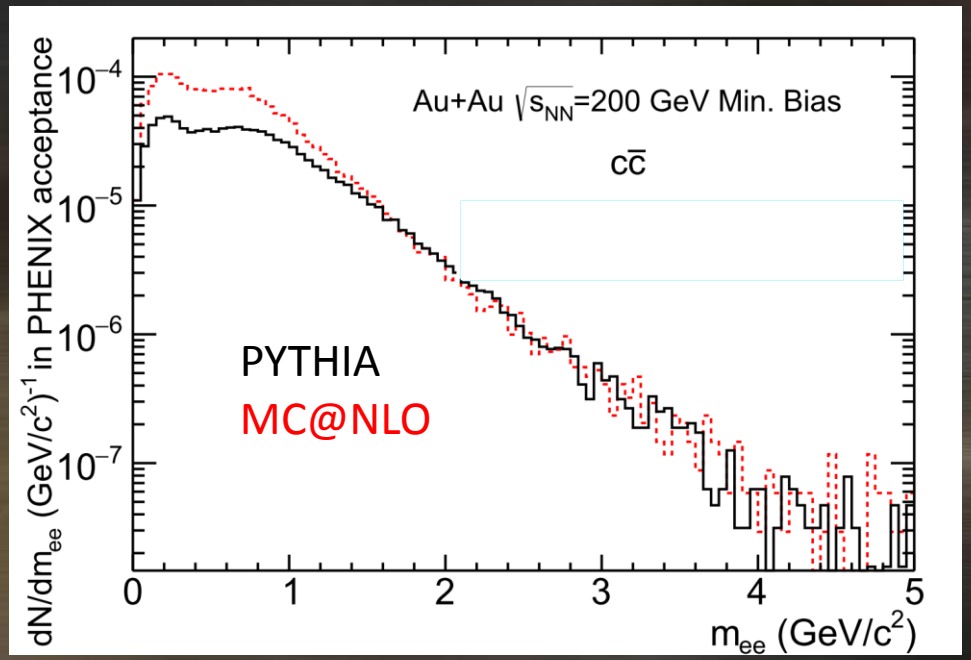
PHENIX 2010	2.3 ± 0.4 [illegible] thia)
	1.7 ± 0.5 ± 0.5 ± 0.2 (MC@NLO)
STAR	1.76 ± 0.06 ± 0.26 ± 0.29

40% difference

PHENIX and STAR results are now consistent

$c\bar{c}$ in cocktail: Pythia vs MC@NLO

Talk by M. Makek



arxiv: 1509.04667

	$d\sigma^{pp}_{c\bar{c}}/dy$ (μb)
PYTHIA	$106 \pm 9^{stat} \pm 33^{syst}$
MC@NLO	$287 \pm 29^{stat} \pm 100^{syst}$

PRC 91 (2015) 014907

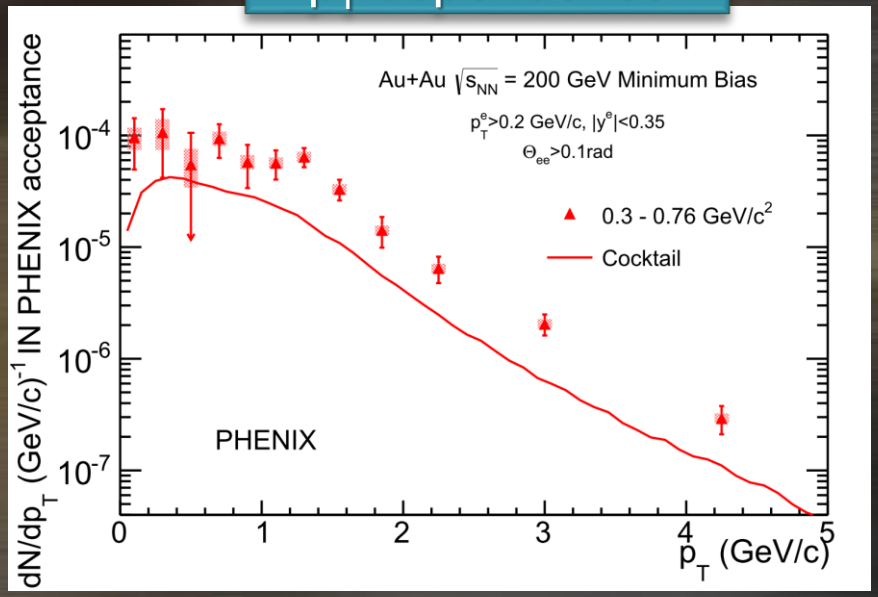
- Cross sections are derived using IMR in d+Au collisions
- Uncertainty in extrapolation to m~0
  - Lack of understanding in $c\bar{c}$ cross section/correlation
- Hadronic decays of D mesons (STAR, PRL 113 (2014) 022301)
  - dσ/dy = 171 ± 26 μb (PYTHIA)

Talk by M. Makek

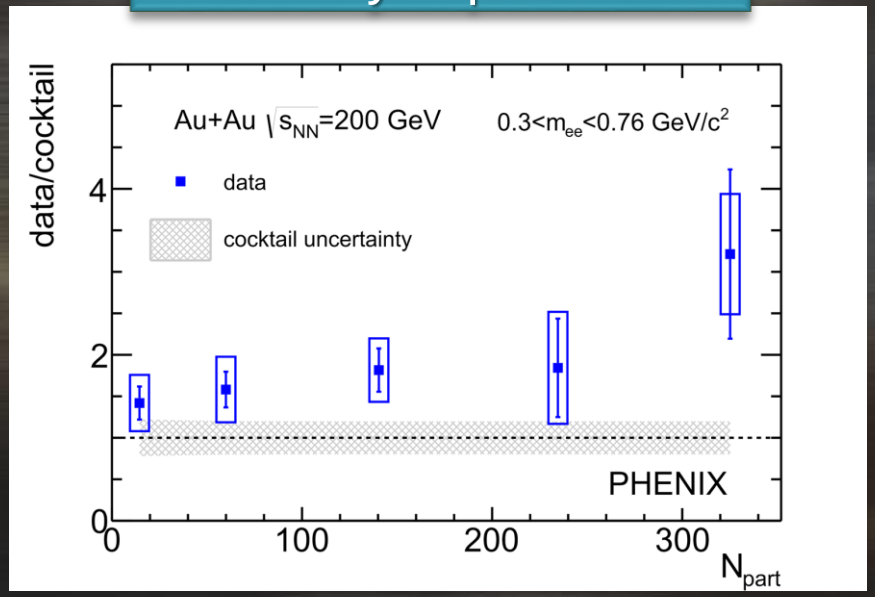
LMR (0.3 – 0.76 GeV/c^2)

Au+Au PHENIX

p_T dependence



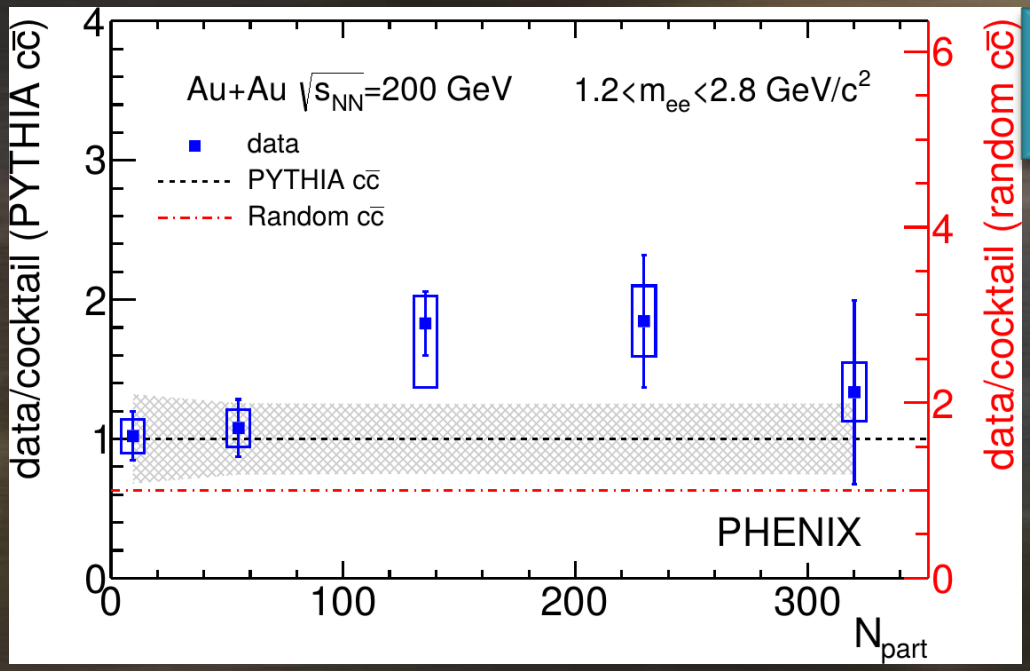
centrality dependence



arxiv: 1509.04667

- Enhancement over all p_T range
- Increase with centrality

IMR (1.2 – 2.8 GeV/c^2): QGP radiation



Au+Au
PHENIX

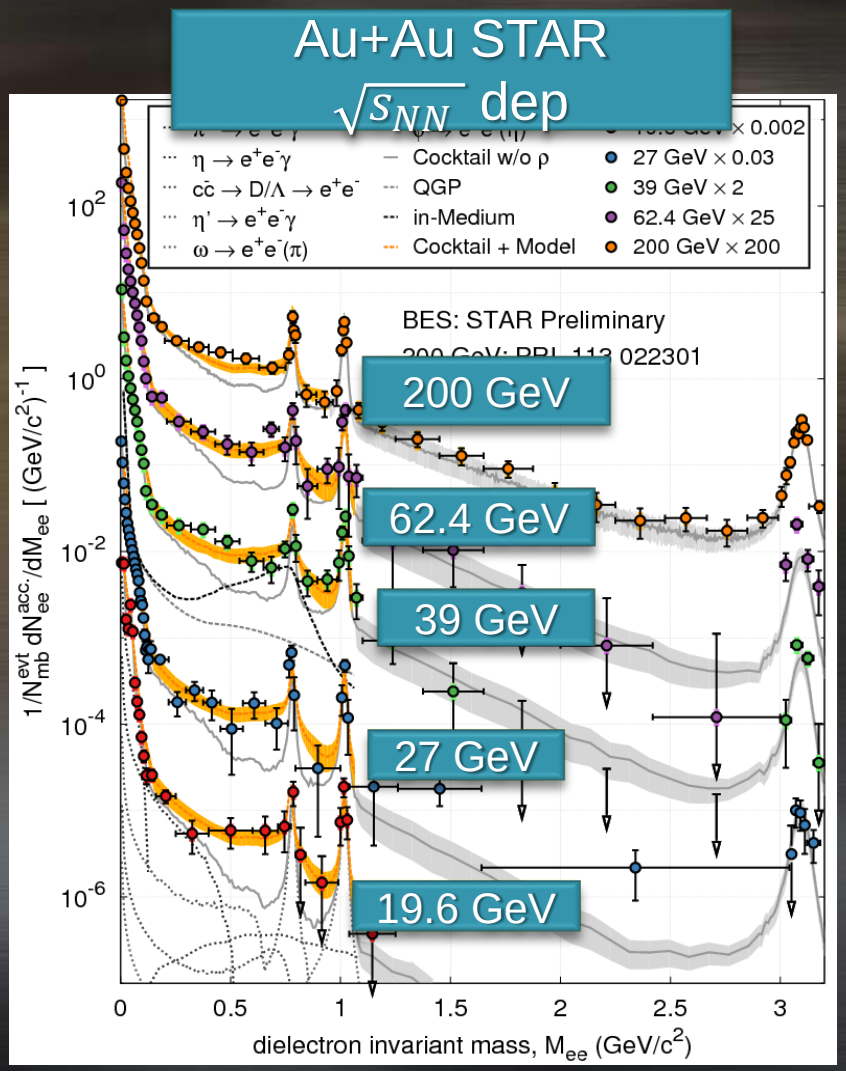
Talk by M. Makek

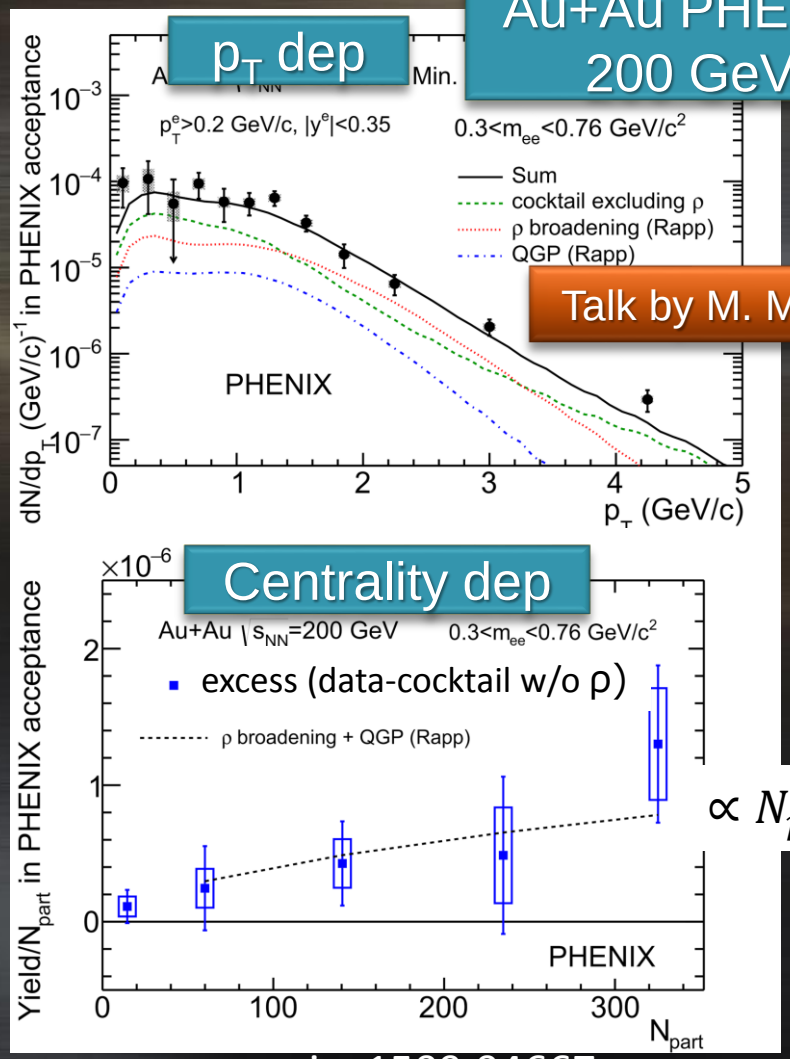
arxiv: 1509.04667

- Two extreme scenarios:
  - $c\bar{c}$ correlation remains the same in Au+Au as in p+p/p+A
  - $c\bar{c}$ totally decorrelated
    - There is room for QGP radiation
- Newly installed detectors in PHENIX/STAR
  - VTX(PHENIX)/HFT(STAR): Rejection of off-vertex electrons
  - MTD(STAR): e-μ (no contribution from QGP radiation)

ρ broadening

Broadening of ρ meson explains the LMR excess in the energy region $\sqrt{s_{NN}}$ =20-200 GeV including p_T and centrality dependence



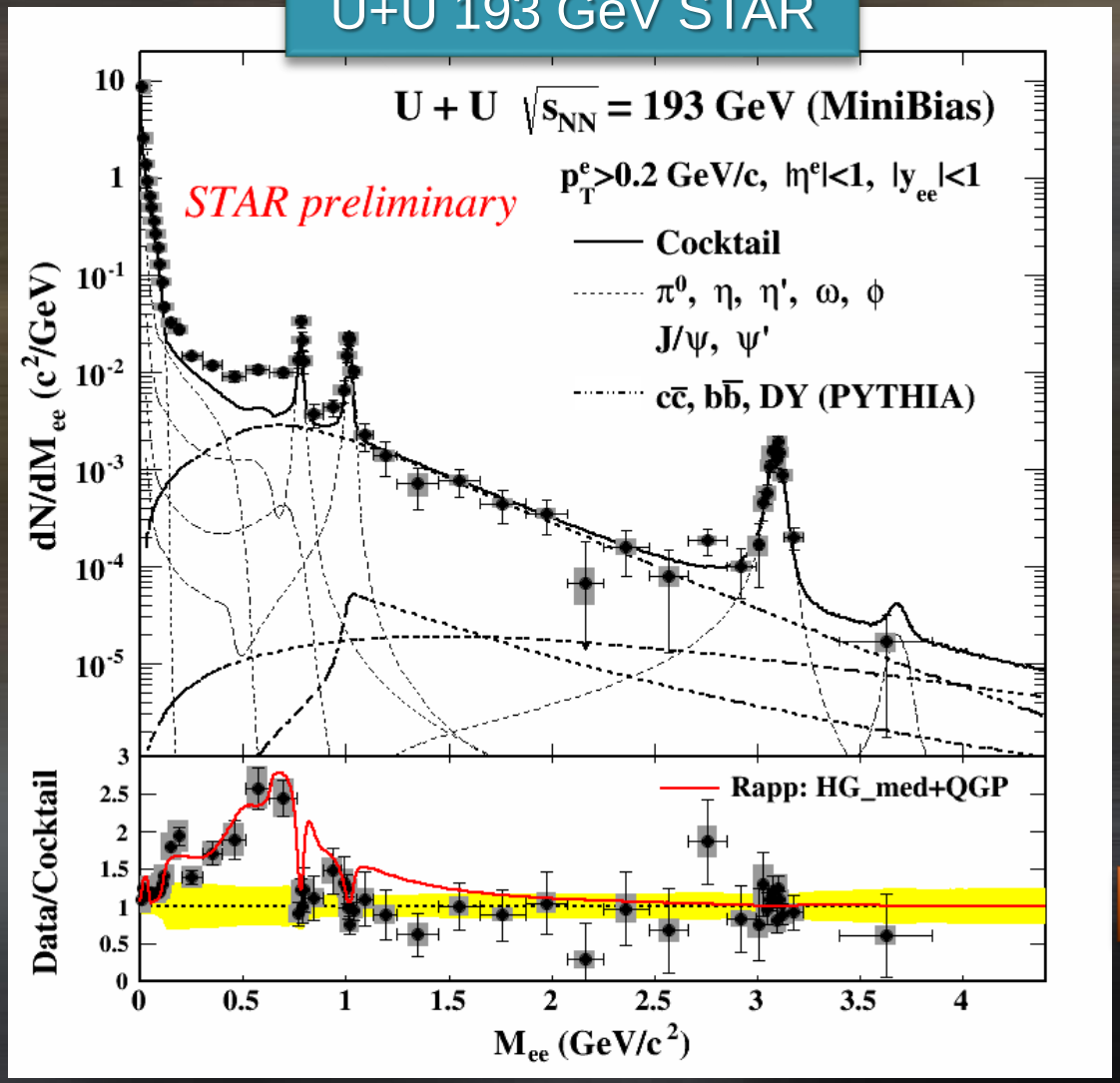


arxiv: 1509.04667

ρ broadening

Broadening of ρ meson describes LMR excess also in the heavier system

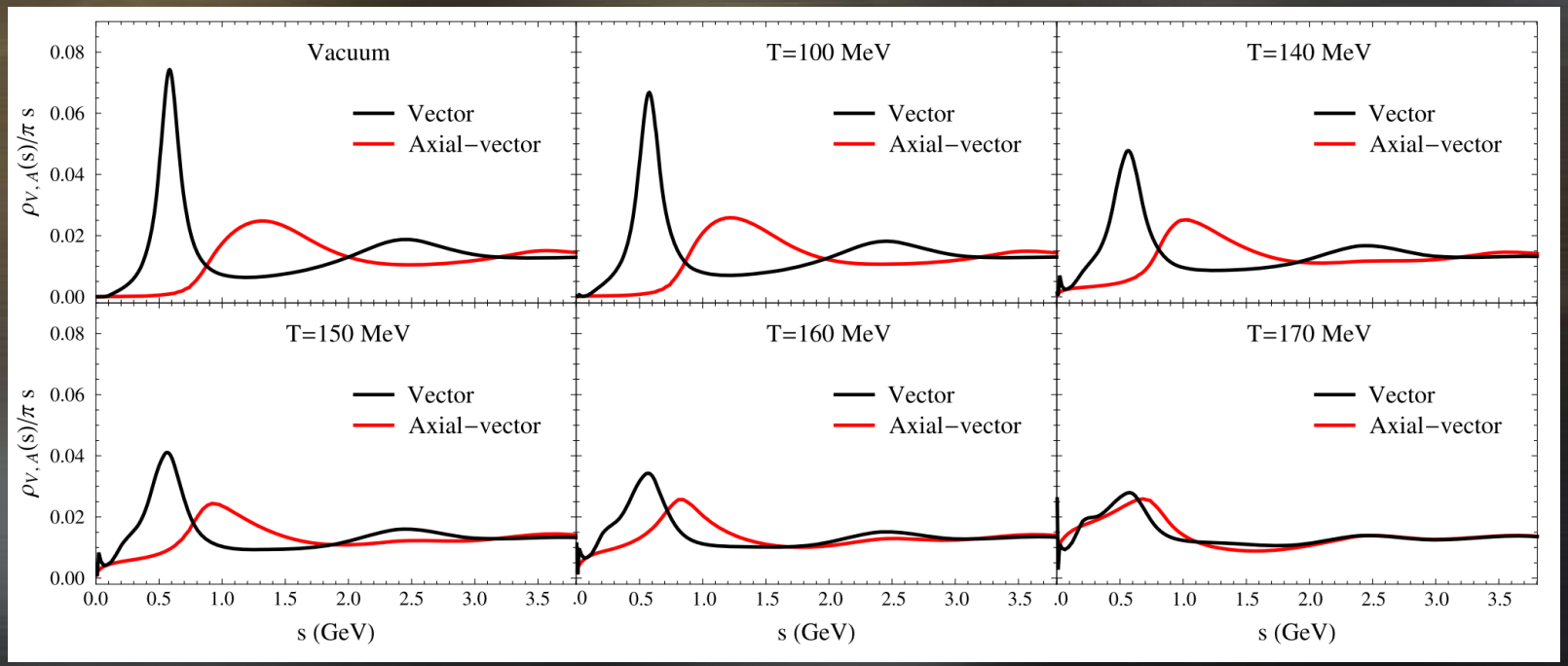
U+U 193 GeV STAR



Talk by S. Yang

Broadening of ρ meson

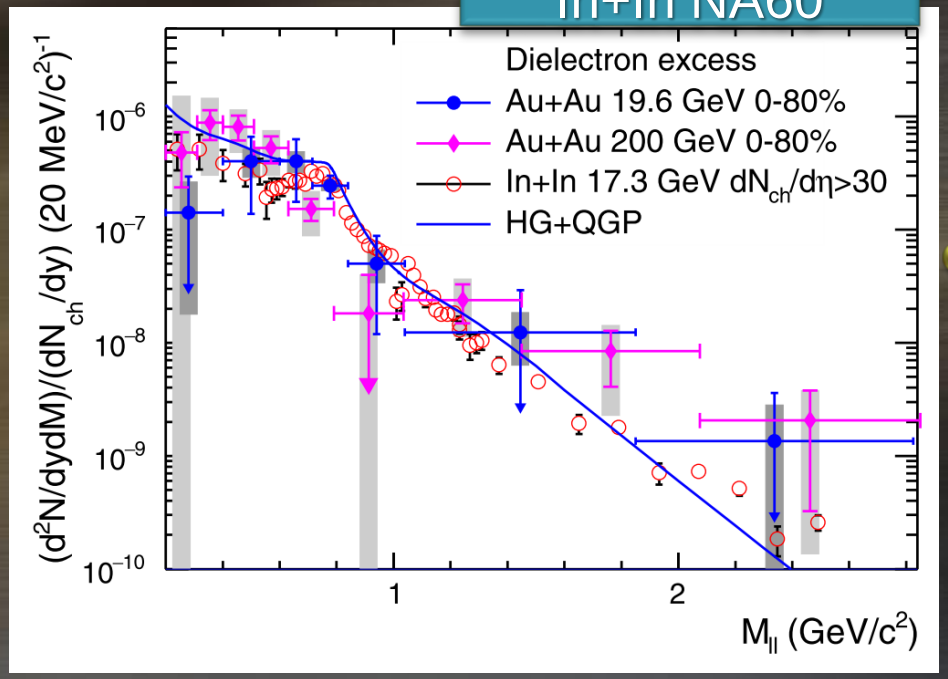
- Link to chiral restoration?
  - Measurement of the a_1 meson is experimentally difficult
  - According to PLB 731(2014)103, the medium-modified ρ and a_1 meson degenerate with each other at high T.



PLB 731 (2014) 103

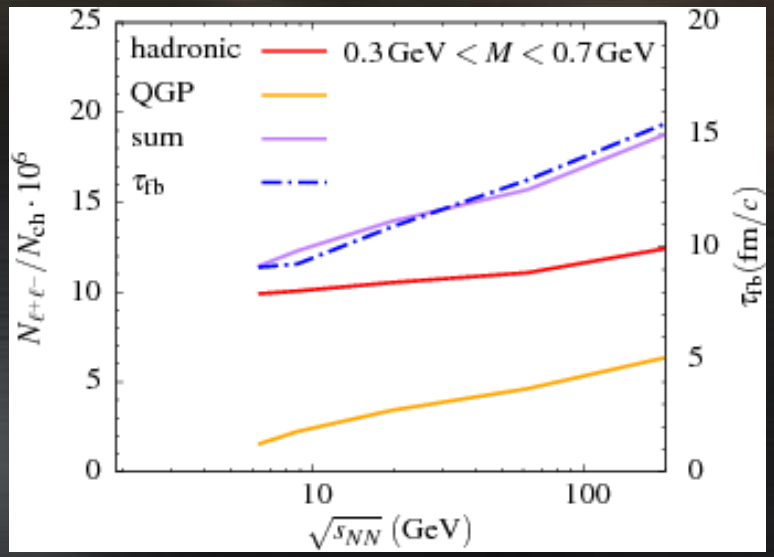
Acceptance corrected LMR excess

Au+Au STAR
In+In NA60



PLB 750 (2015) 64

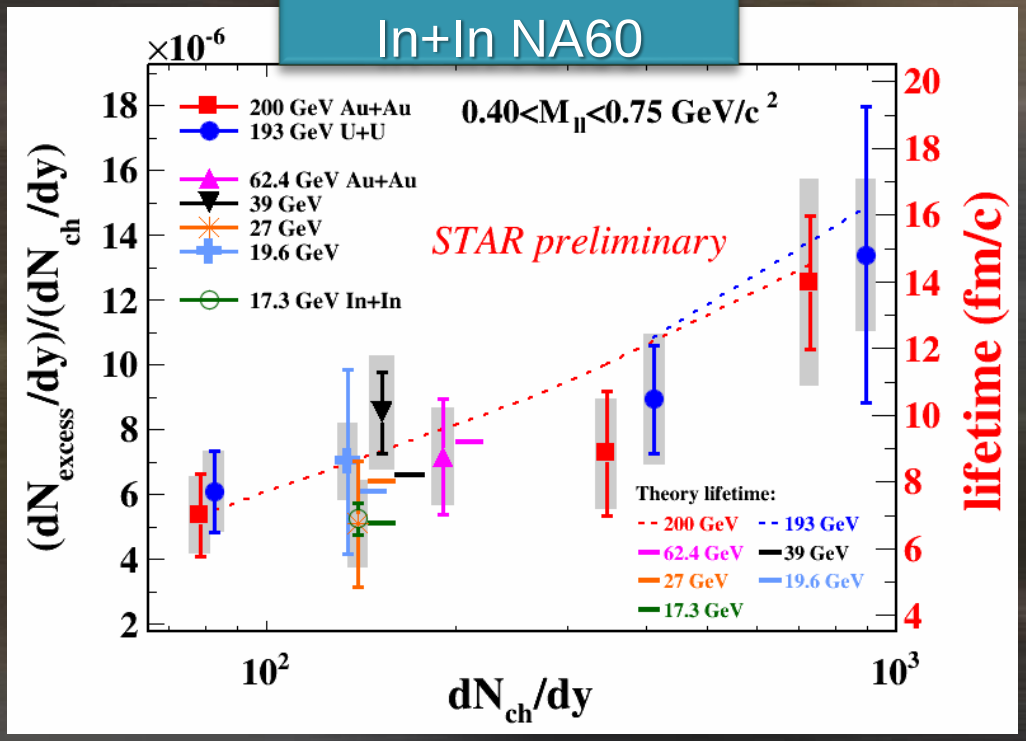
- Acceptance corrected excess in STAR is consistent with that in NA60 within large experimental uncertainties
  - BESII: x10 statistics
- Dielectron excess ∝ $T_{fireball}$
  - Size/Energy dependence



arxiv: 1411.4612

System size and energy dependence

Au+Au STAR
In+In NA60



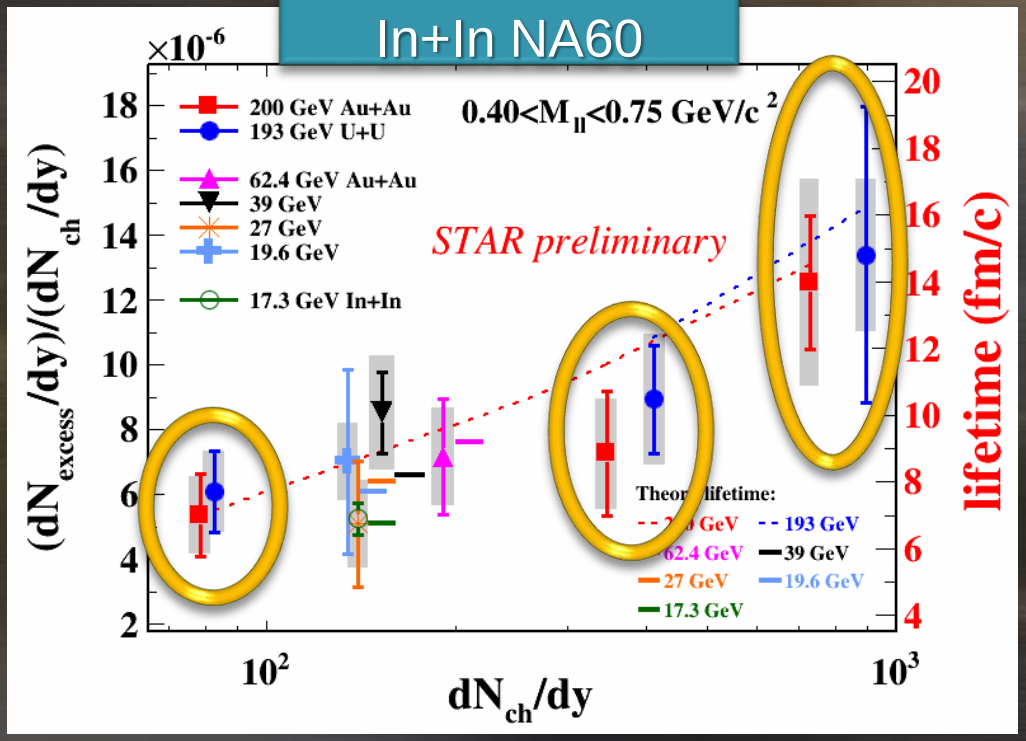
PLB 750 (2015) 64

EPJC 59 (2009) 607

Talk by S. Yang

System size and energy dependence

Au+Au STAR
In+In NA60



PLB 750 (2015) 64

EPJC 59 (2009) 607

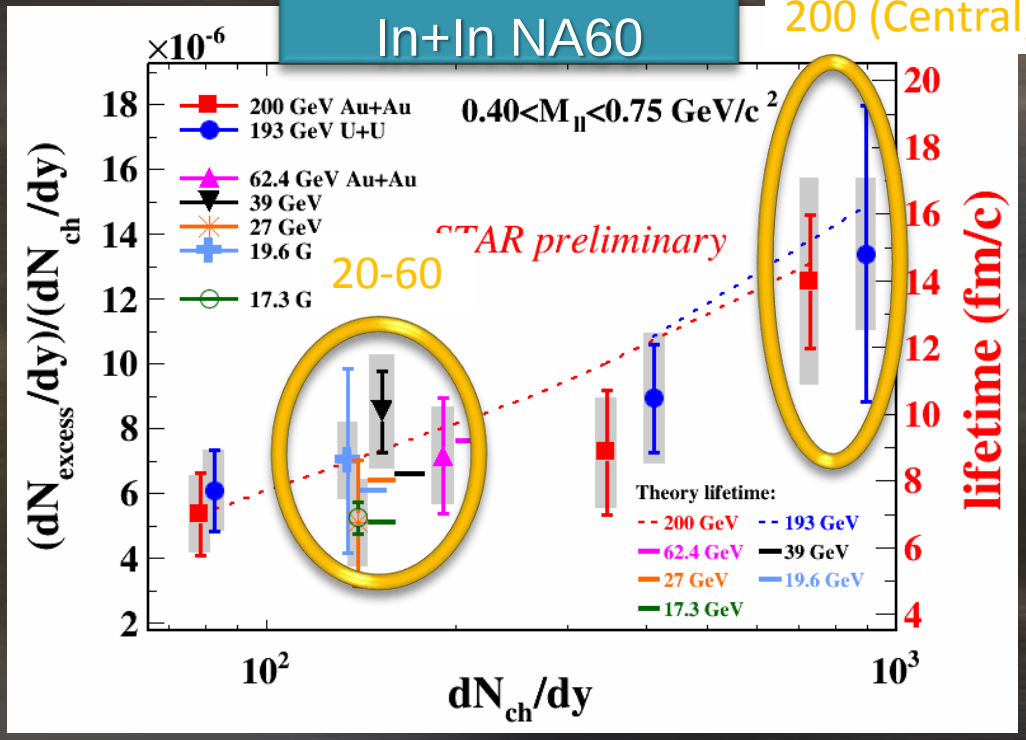
Talk by S. Yang

- Fireball lifetime is longer in central collisions than in peripheral collisions

System size and energy dependence

Au+Au STAR
In+In NA60

200 (Central)



PLB 750 (2015) 64

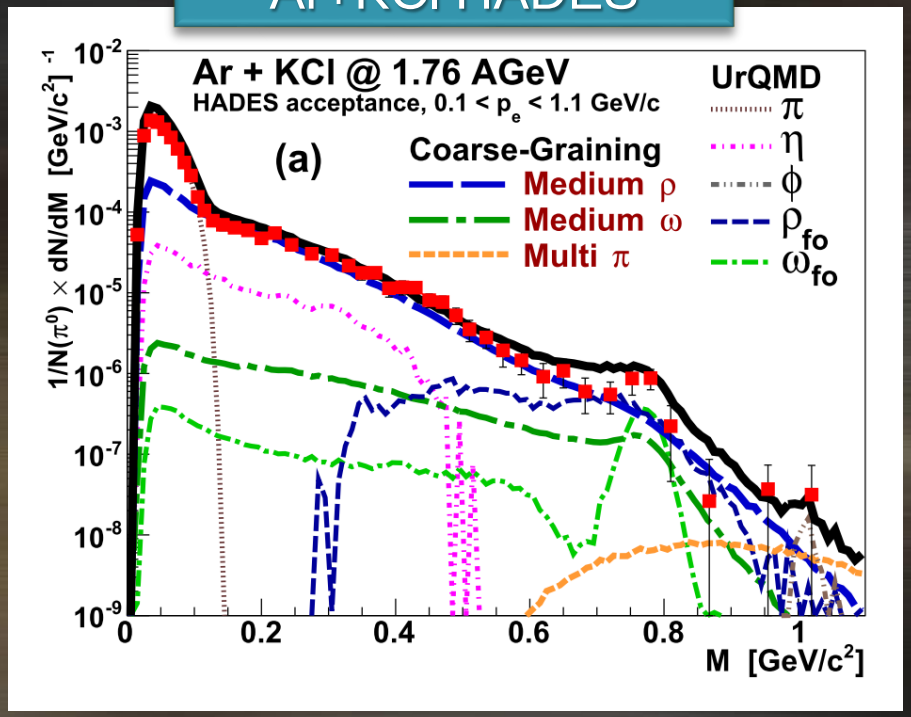
EPJC 59 (2009) 607

Talk by S. Yang

- Fireball lifetime is longer in central collisions than in peripheral collisions
- Fireball lifetime is longer in central 200 GeV than in low energies

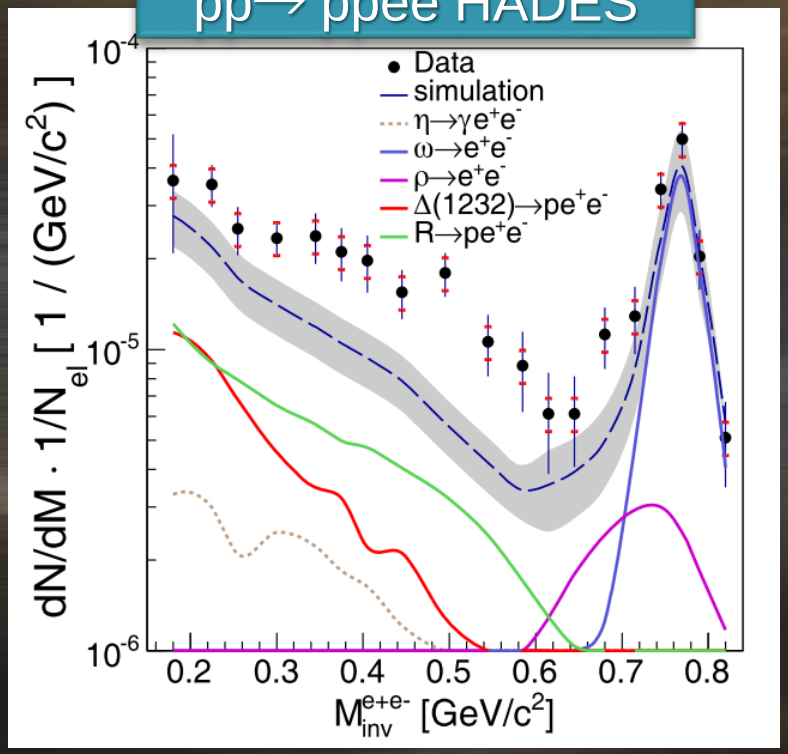
Low energy: HADES

Ar+KCl HADES



PRC 92 (2015) 014911

pp→ ppee HADES



EPJA 50(2014)82

- Ar+KCl: The spectrum is well described by a model
  - LVM broadening + system evolution with UrQMD
- pp: excess from cocktail
  - Insufficient description of Resonance → pee

Future Low energy experiments

J-PARC pA: E16 experiment (2017-)

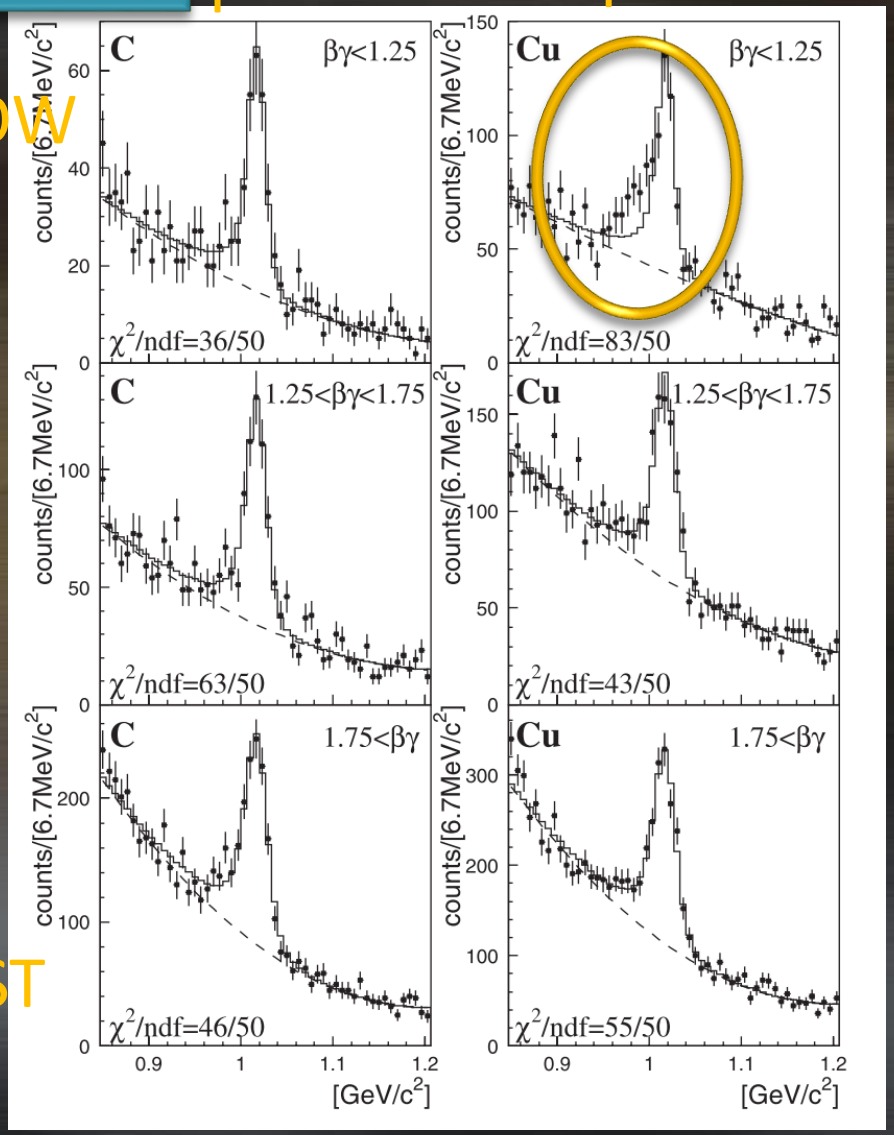
KEK E325

Poster by K. Ozawa

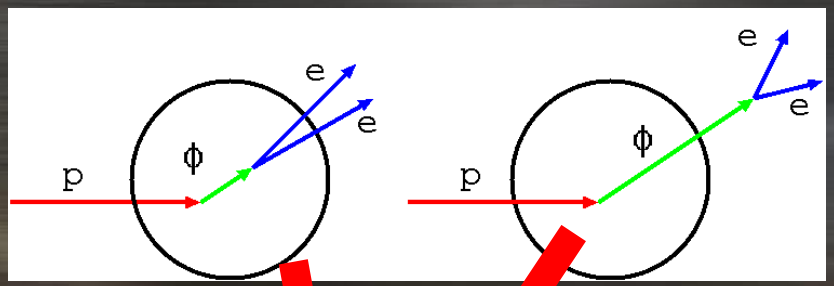
p+C p+Cu

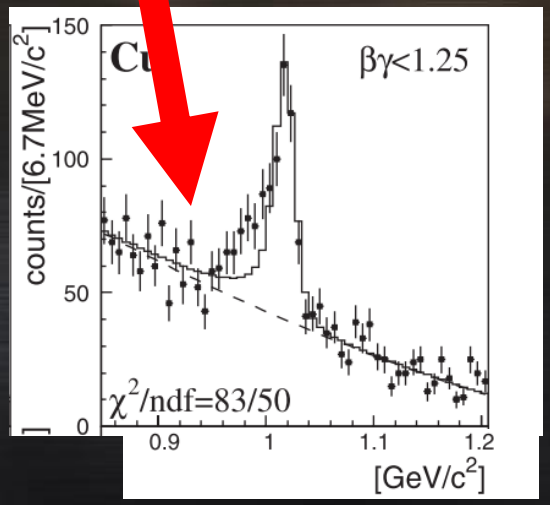
SLOW

FAST



In-medium modification of φ meson in cold nuclear matter

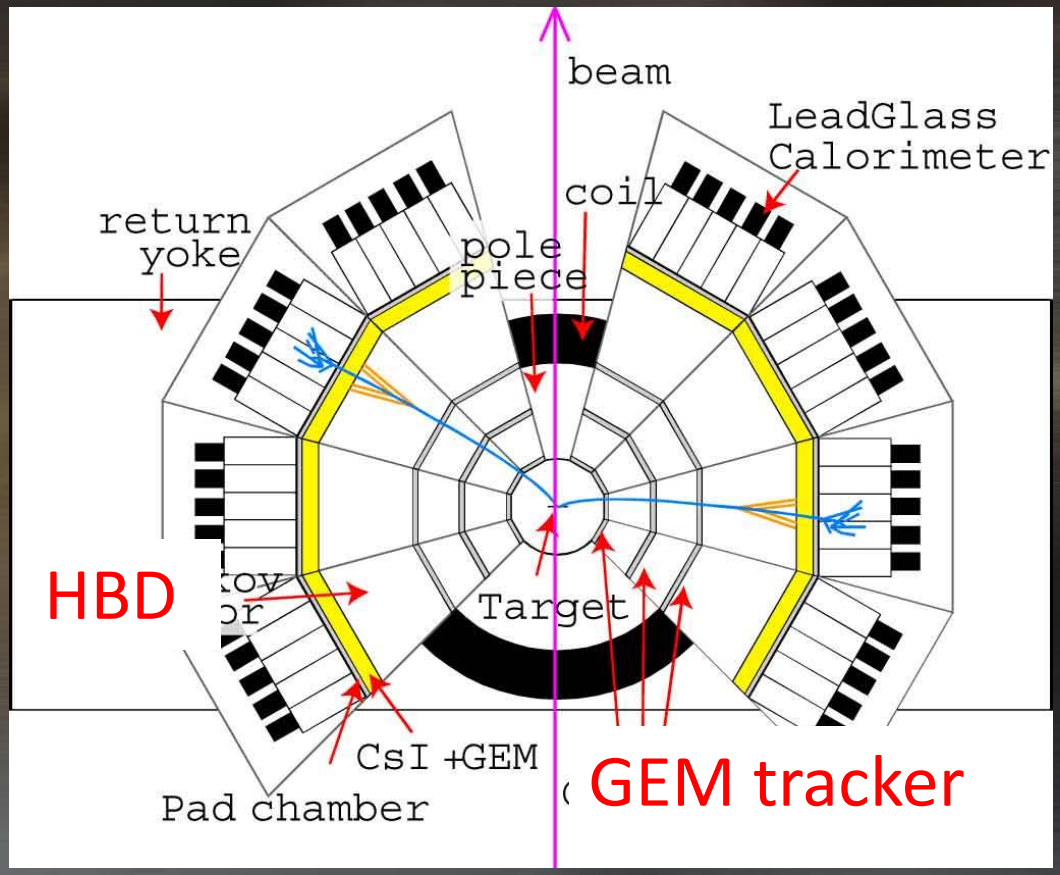


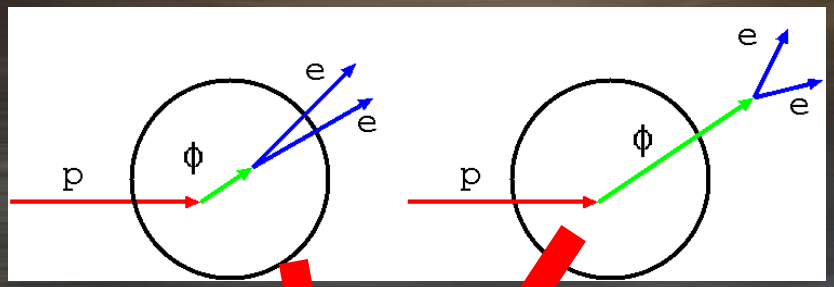


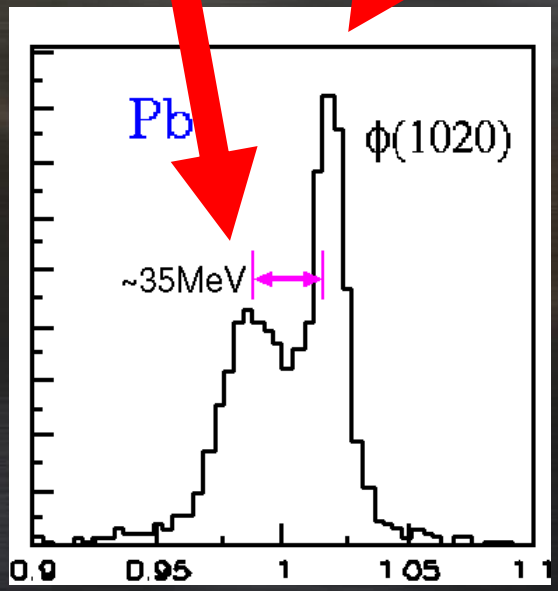
PRL98 (2007) 042501

J-PARC pA: E16 experiment (2017-)

Poster by K. Ozawa







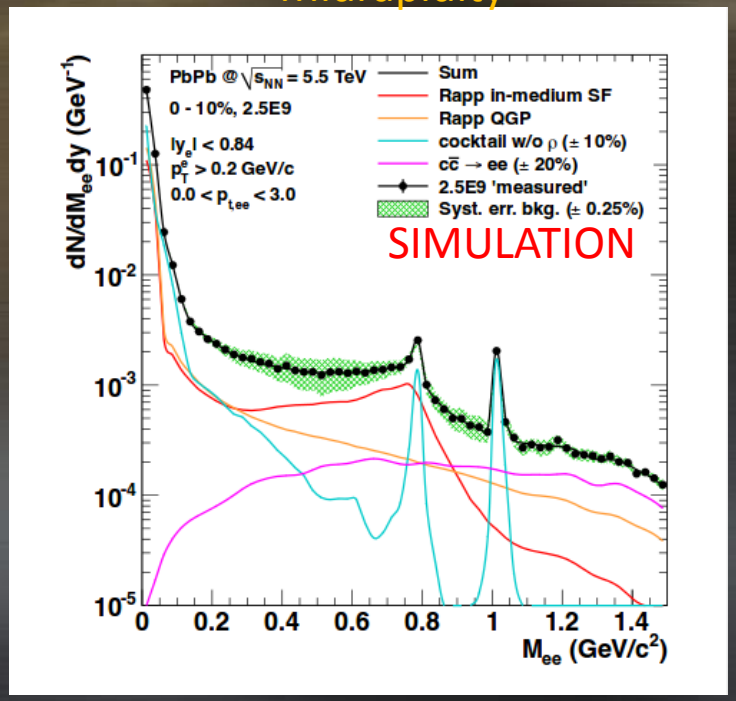
x100 stat, x2 mass resolution of E325

LHC-ALICE (2020-)

Talk by P. S. Reichelt

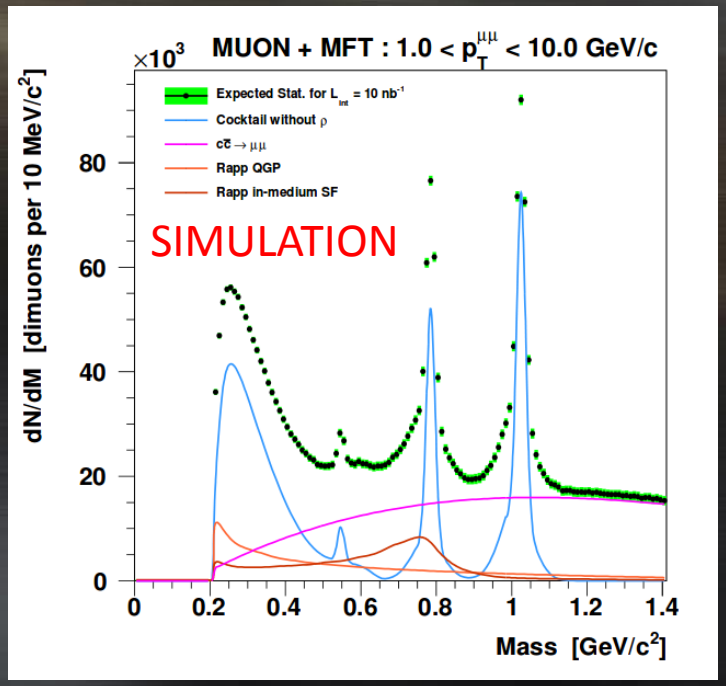
- Midrapidity
  - Inner Tracking System (ITS): Rejection of $c\bar{c}$ contribution, Less material butdget
  - Time Projection Chamber (TPC): Continuous readout using GEM
- Forward rapidity (-4 < η < -2.5)
  - Muon Forward Tracker (MFT): Improve mass resolution

Midrapidity



J. Phys. G 41 (2014) 087001

Forward



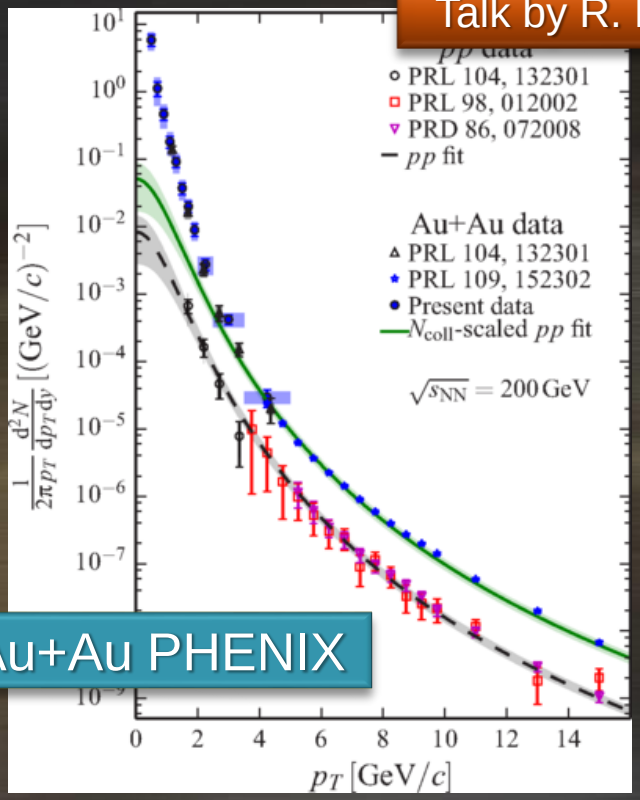
CERN-LHCC-2013-014

10.1109/NSSMIC.2012.6551391

Photon

Thermal photons

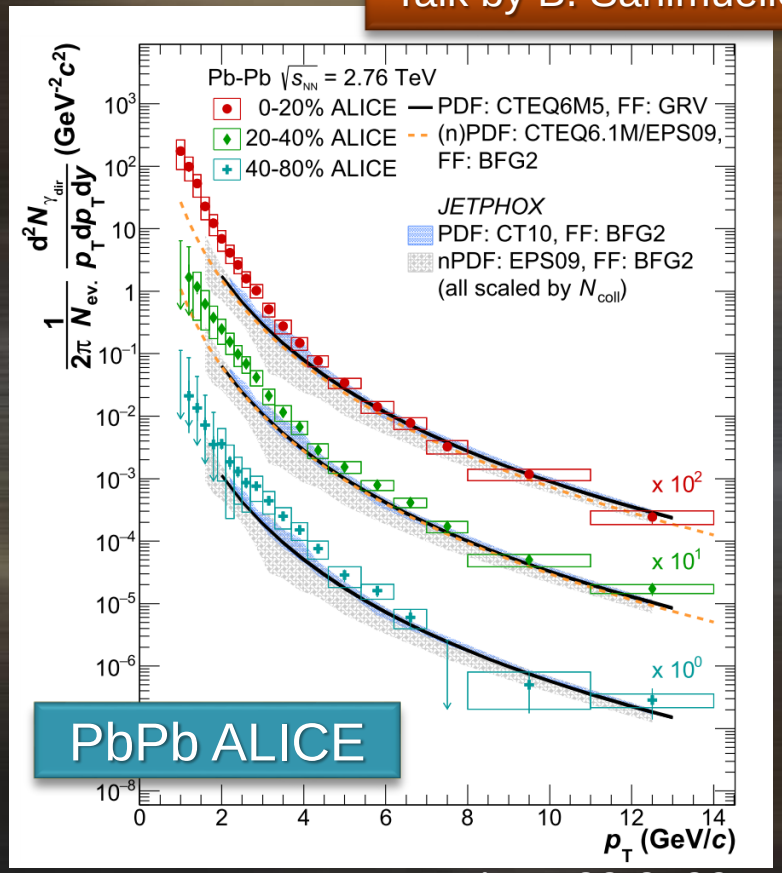
Talk by R. Petti



p+p/Au+Au PHENIX

PRC91(2015)064904

Talk by B. Sahlmueller



PbPb ALICE

arxiv:1509.07324

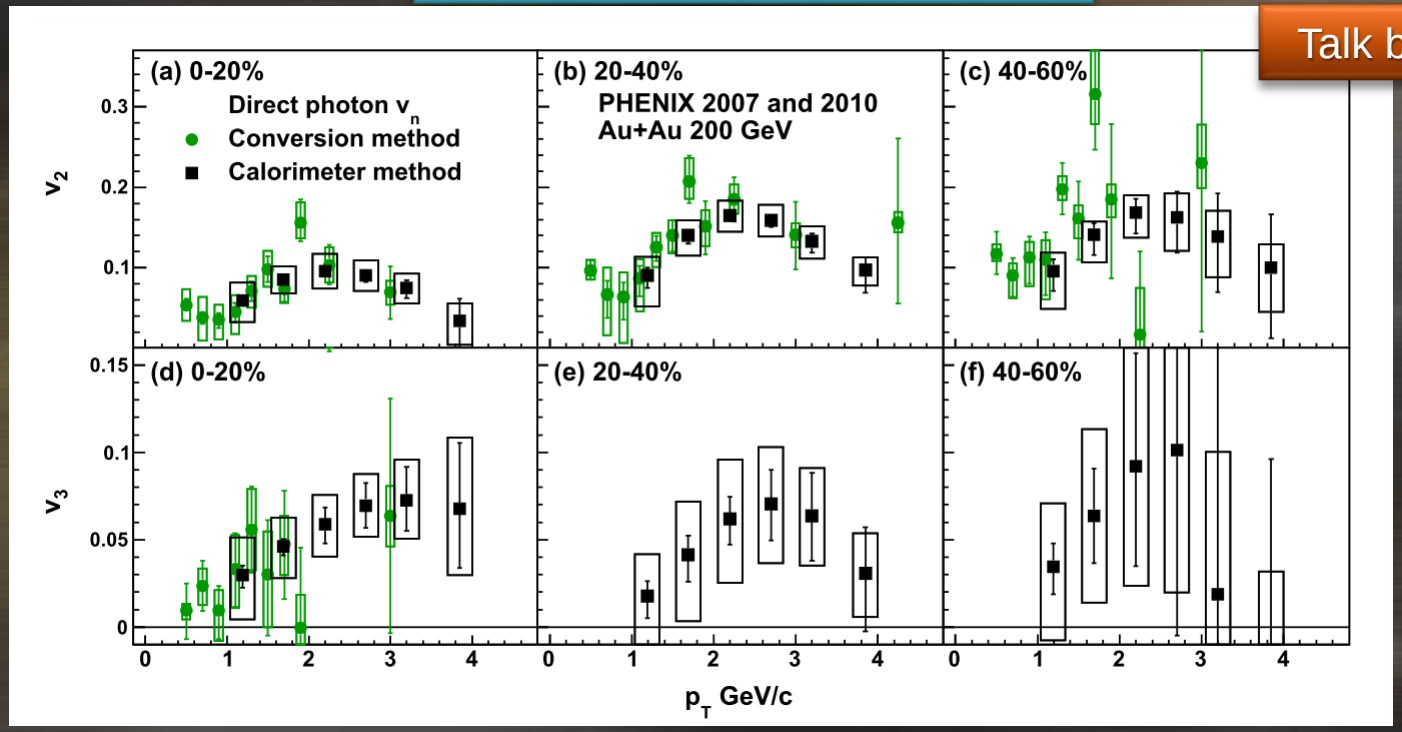
- Excess from pQCD component is visible
  - PHENIX: T_{slope} ~ 240 $\pm$ ~20 MeV independent of centrality
  - ALICE: T_{slope} ~ $304 \pm 11^{stat} \pm 40^{syst}$ MeV (0-20%)
- PHENIX: dN/dy $\propto N_{part}^{\alpha}$ ($\alpha = 1.38 \pm 0.03^{stat} \pm 0.07^{syst}$)
  - Similar to dielectron excess ($\alpha = 1.44 \pm 0.1$, STAR)

v_2 and v_3

Au+Au 200 GeV PHENIX

arxiv: 1509.07758

Talk by R. Petti

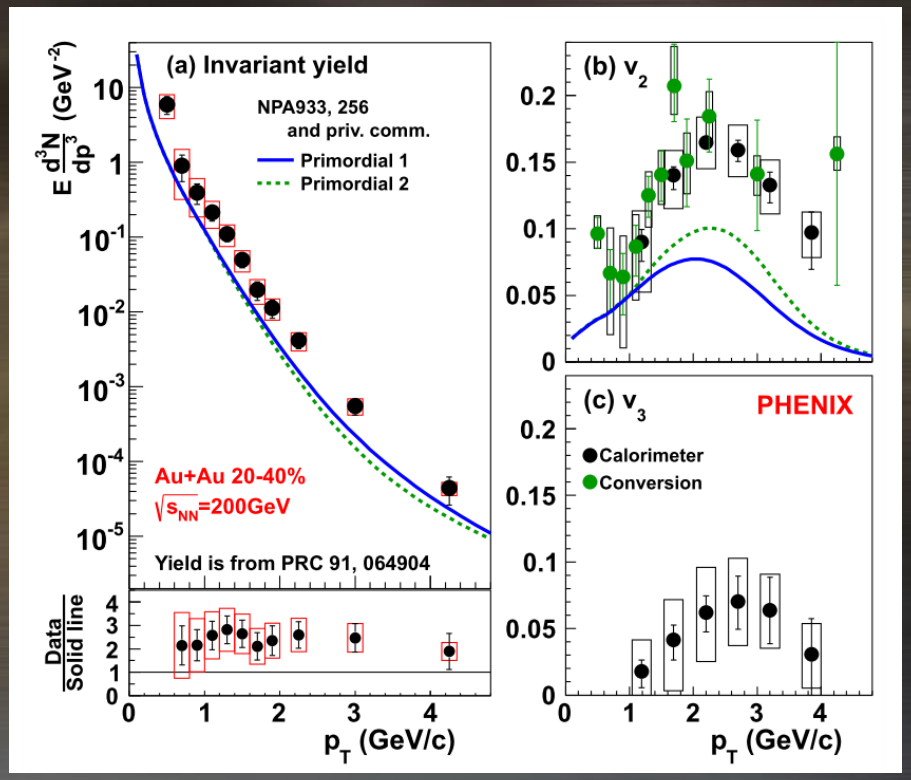


- Difficult to explain both "large yield" and "large v_2 and v_3"
- Many new theoretical ideas: more hadron-hadron interaction in HG, enhanced photon around T_c, semi-QGP, viscous correction, initial magnetic field etc

Comparison with models

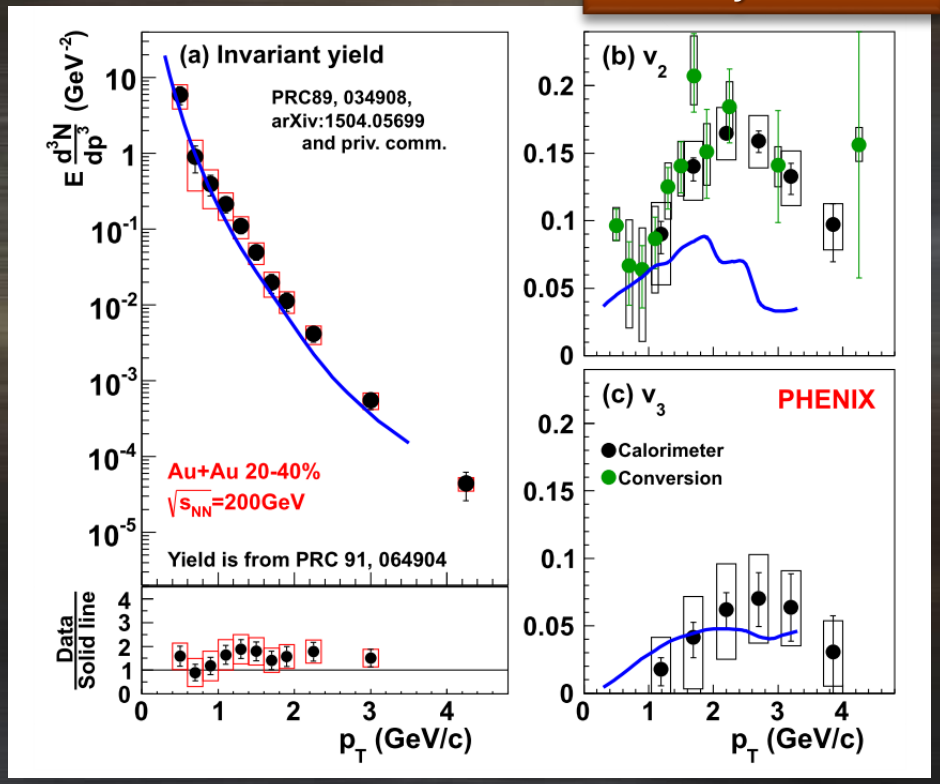
Au+Au 200 GeV PHENIX

Fireball



PHSD

Talk by R. Petti



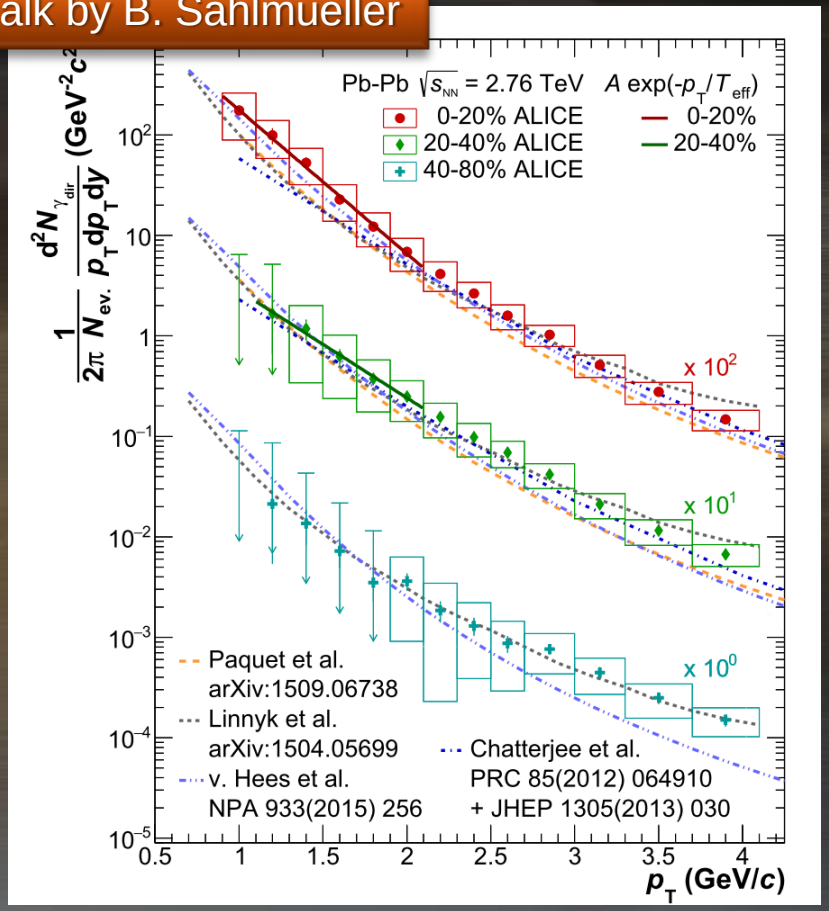
arxiv: 1509.07758

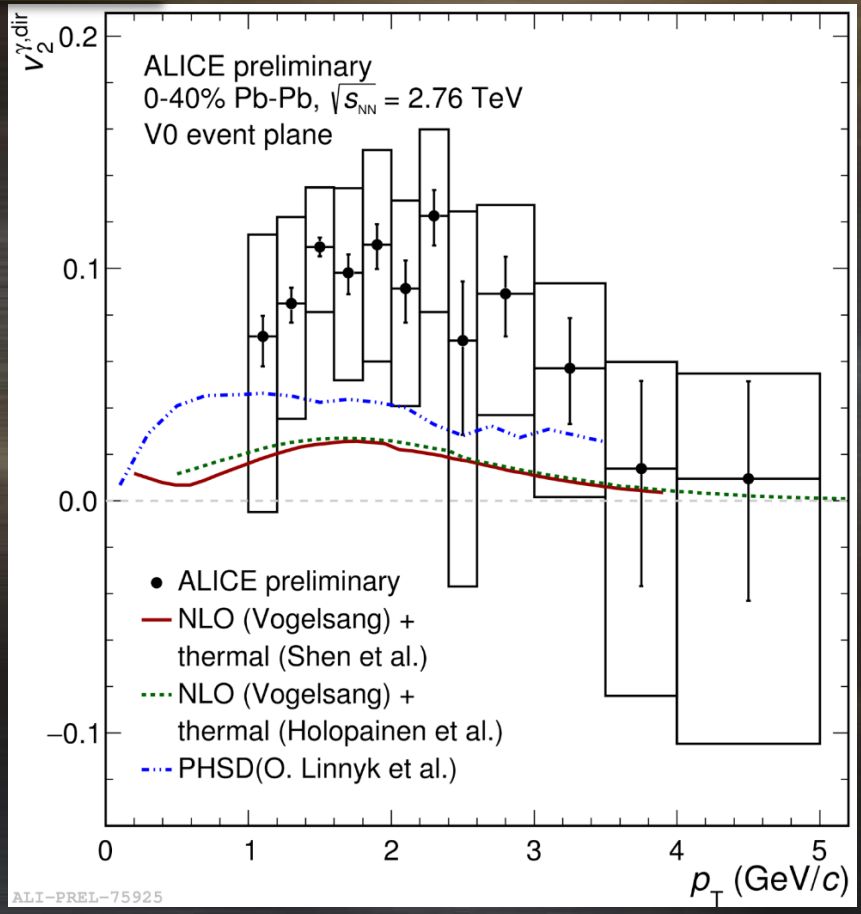
- Models tend to underestimate yield and v_2

Comparison with models

Pb+Pb ALICE

Talk by B. Sahlmueller





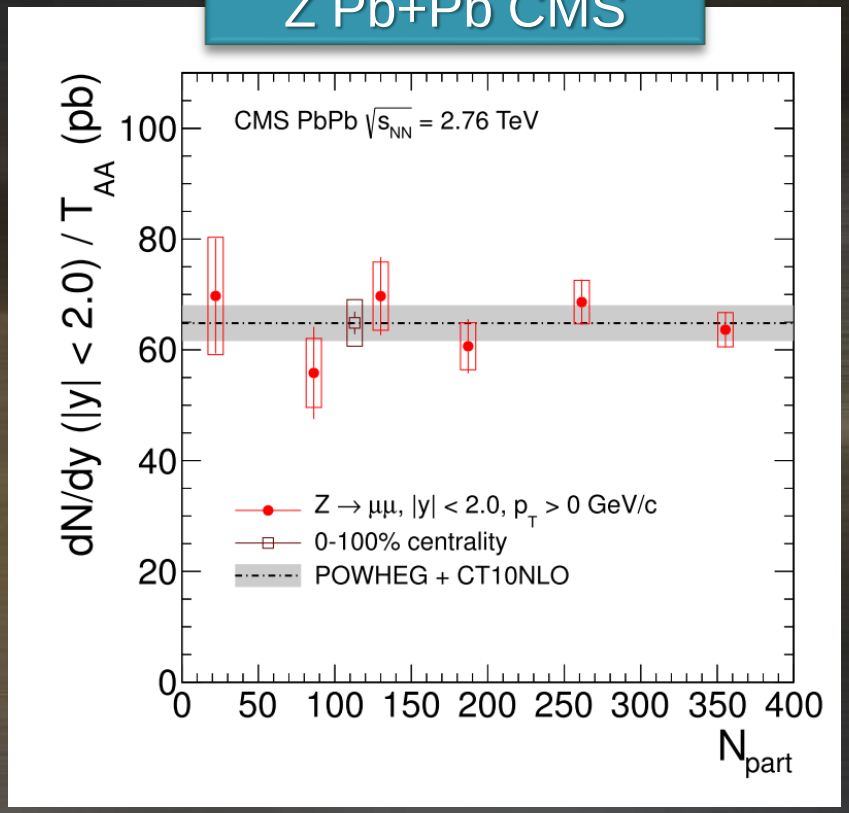
arxiv:1509.07324

- Similar trend as PHENIX? Theory lines are lower than data points both in yields and v_2

EW boson

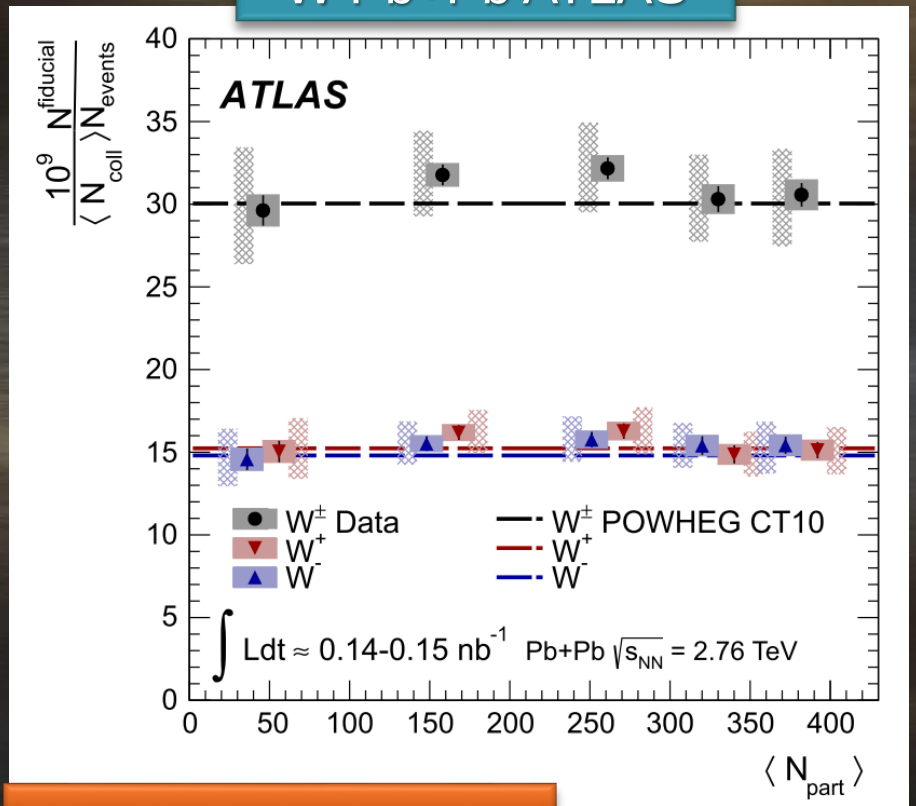
EW boson in Pb+Pb

Z Pb+Pb CMS



JHEP03(2015)237

W Pb+Pb ATLAS



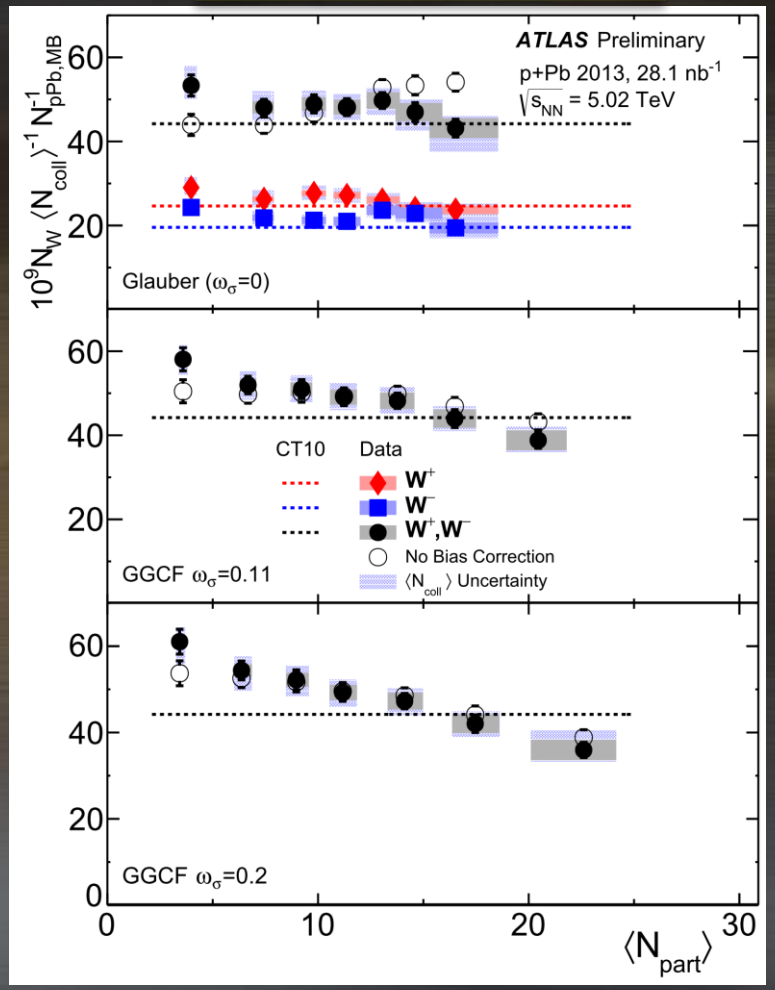
Talk by I. Grabowska-Bold

EPJC75(2015)23

- Understanding of collision geometry
- Baseline for the study of quenching via EW-jet
- No deviation from N_{coll} scaling is seen
  - Similar observation in Z (ATLAS) and W (CMS)

EW boson in p+Pb

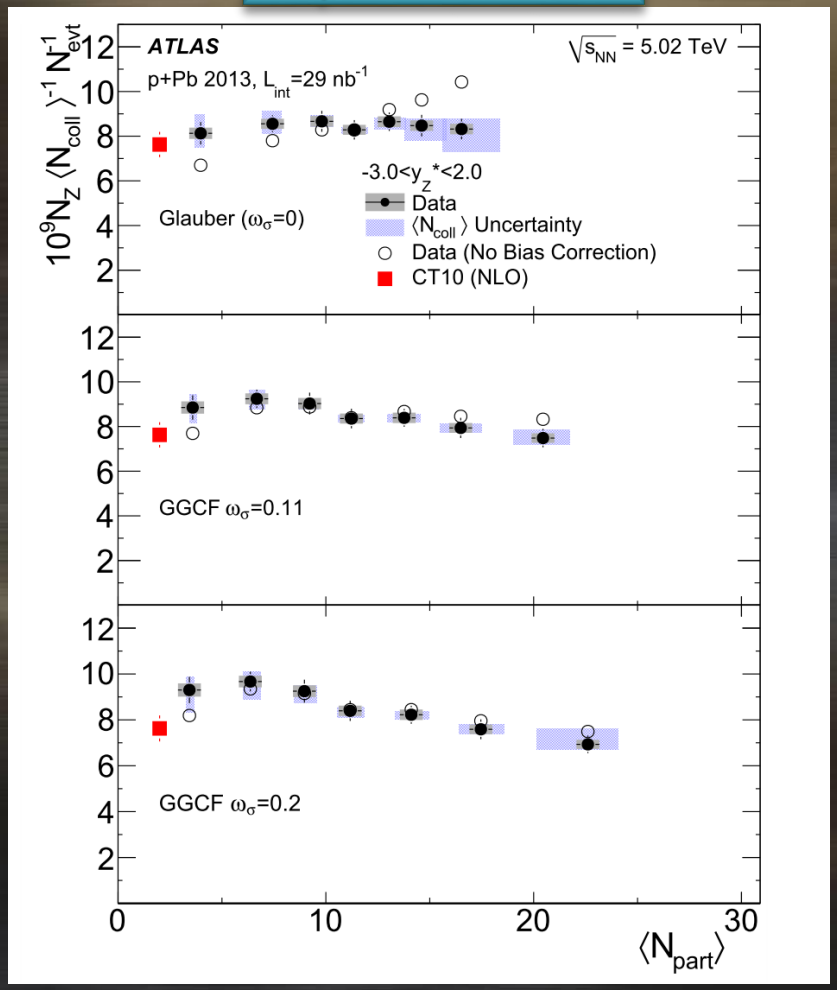
W p+Pb ATLAS



GGCF: Glauber-Gribov Color Fluctuation

Talk by I. Grabowska-Bold

Z p+Pb ATLAS

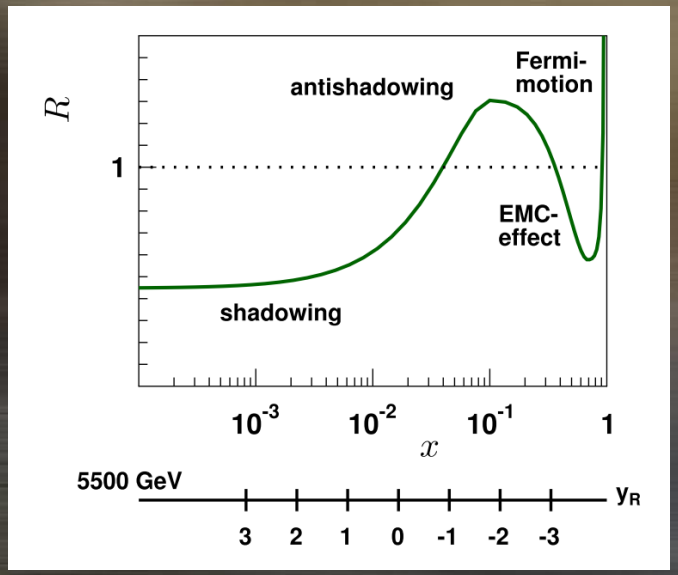


arxiv: 1507.06232

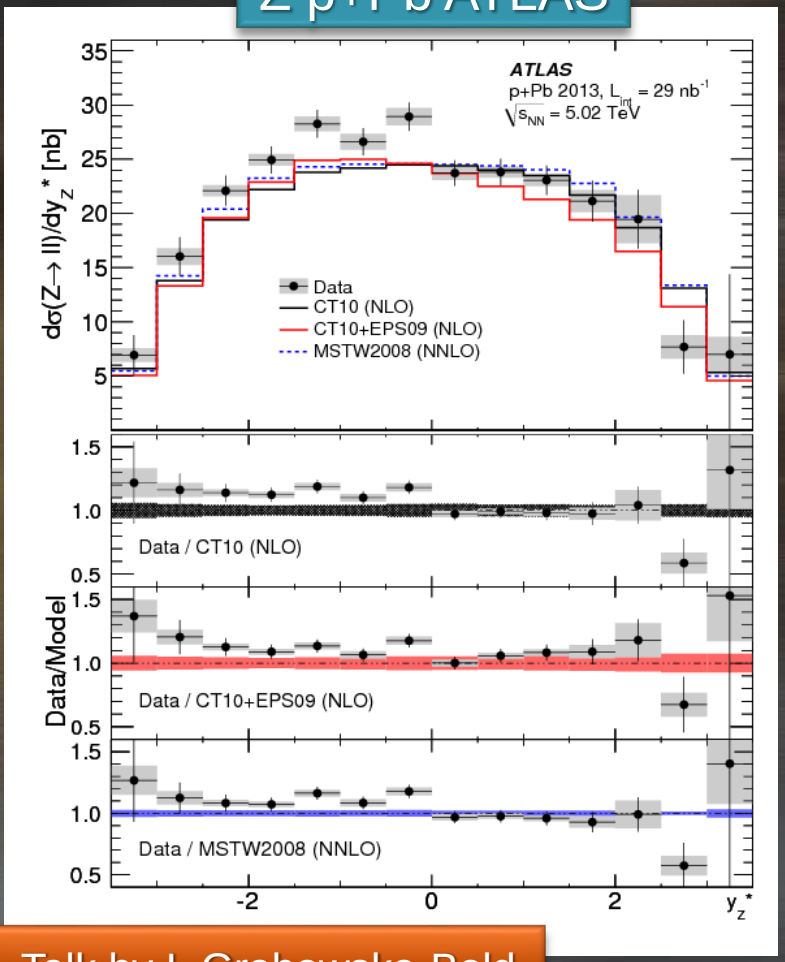
- Assuming EW boson production should scale with N_{coll}, data favors the standard Glauber as valid description of collision geometry in p+Pb collisions

JHEP03(2011)071

Nuclear PDF



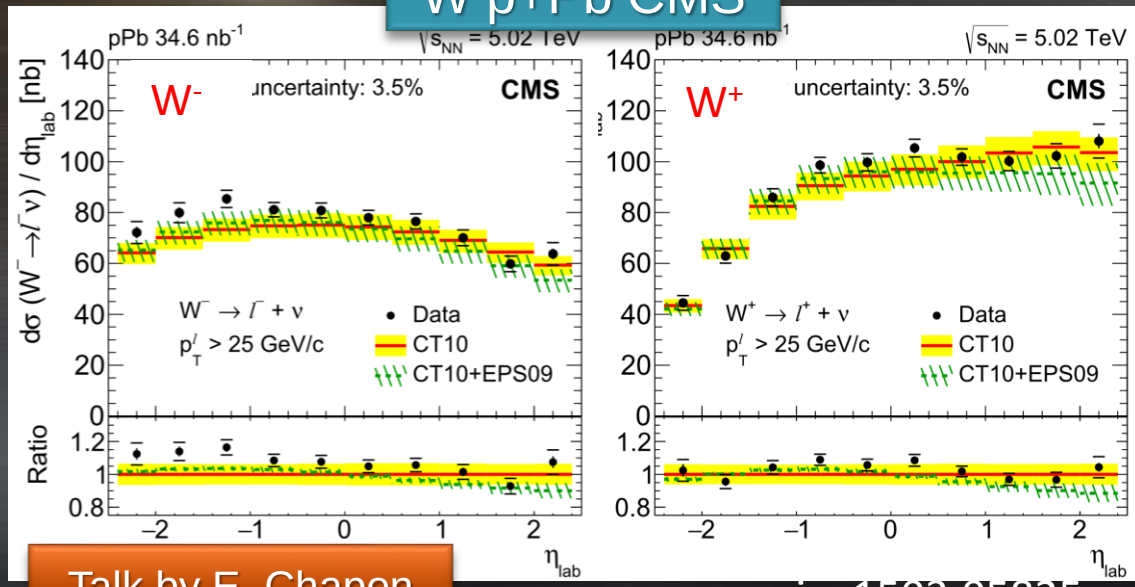
Z p+Pb ATLAS



Talk by I. Grabowska-Bold

arxiv: 1507.06232

W p+Pb CMS



Talk by E. Chapon

arxiv: 1503.05825

- The shapes of rapidity distributions are better described by CT10+EPS09

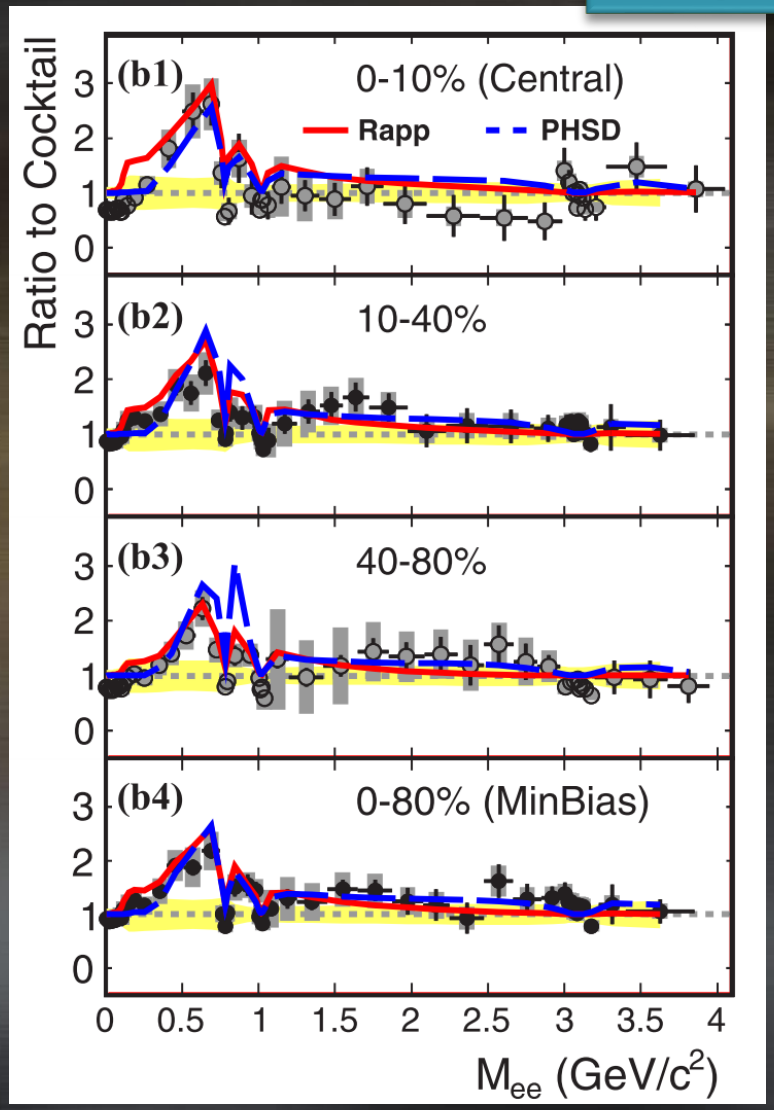
Summary

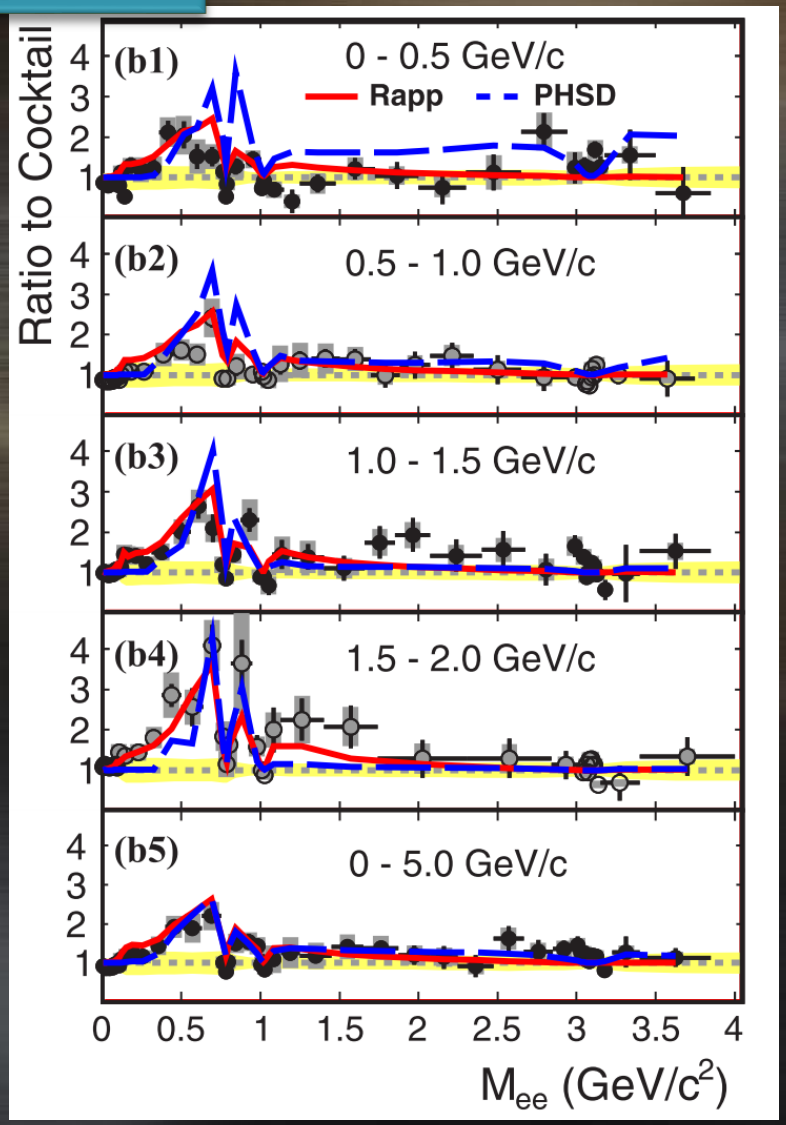
- Dilepton
  - PHENIX and STAR results at $\sqrt{s_{NN}} = 200\ GeV$ are now consistent
  - Uncertainty in the modeling of $c\bar{c}$ contribution affects both LMR and IMR
  - Acceptance corrected excess is studied as a function of system size/collision energy
- Photon
  - Large yield, v_2 and v_3 of thermal photons keeps being a source of new theoretical ideas
    - Later time emission seems significant
- EW bosons
  - Scale with N_{coll} in PbPb collisions
  - nPDF effects are visible in pPb collisions

Backup

Model comparisons: STAR

Au+Au STAR





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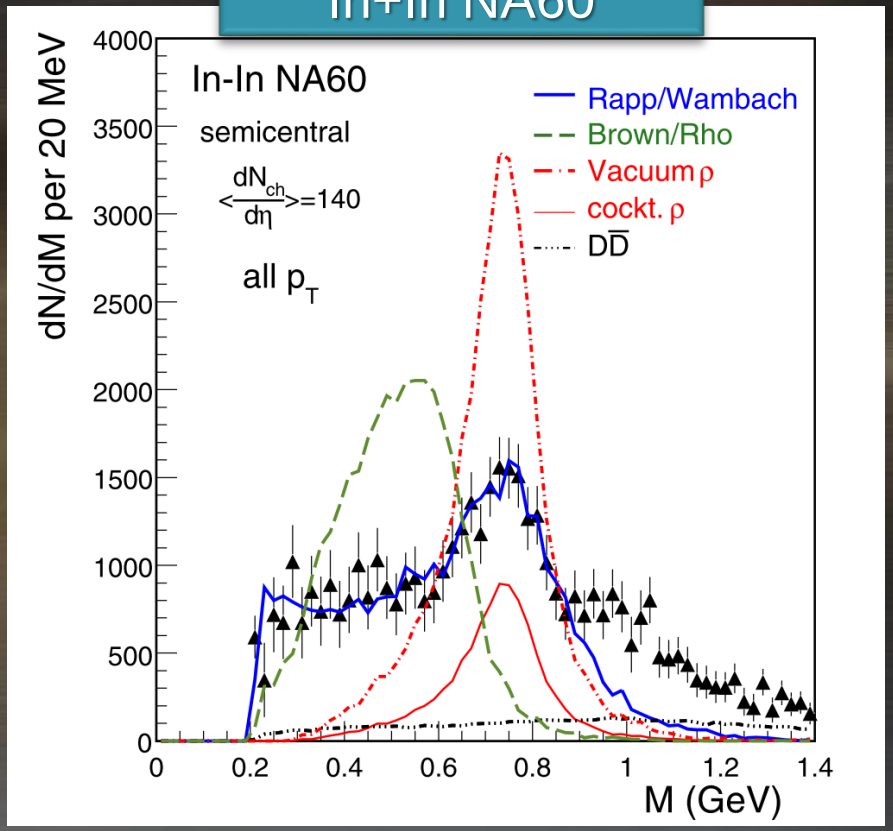
ρ broadening

In+In NA60



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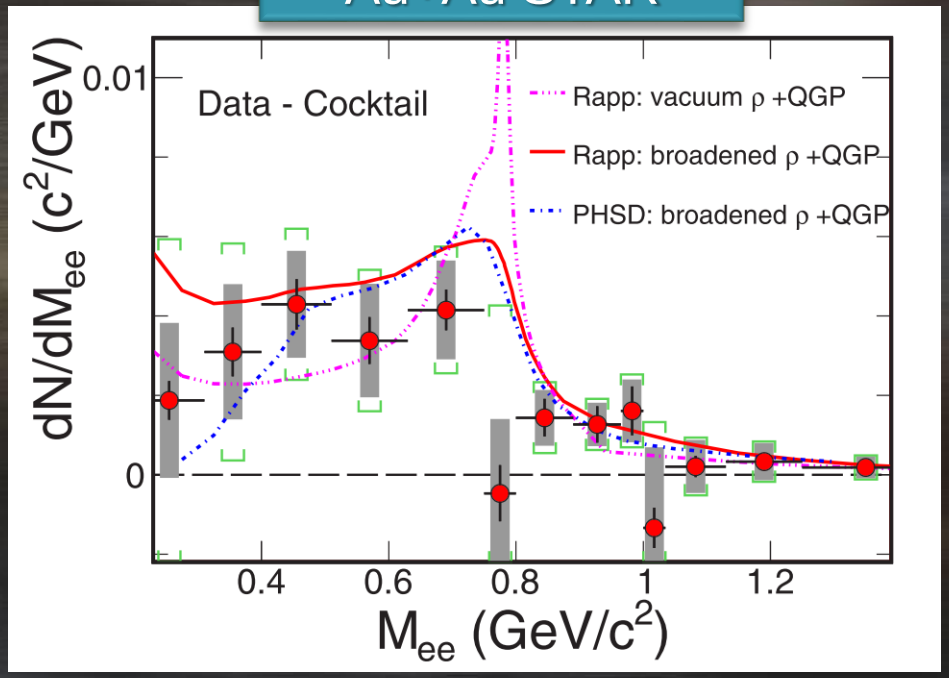
Au+Au STAR



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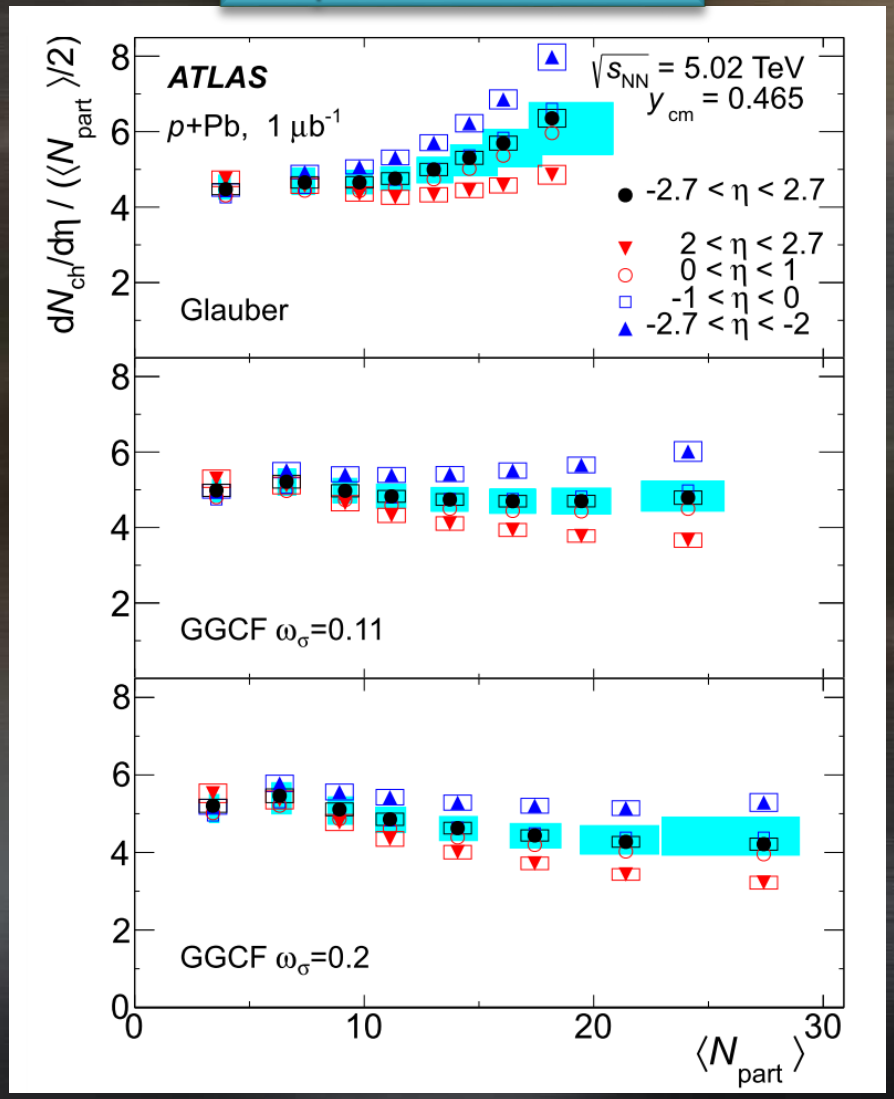
Glauber and GGCF

p+Pb ATLAS



arxiv:1508.00848