Υ measurements in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV with the STAR experiment

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Outline

- Motivation
- STAR experiment
- Υ measurements in Au+Au collisions at STAR:
  - Υ(1S) suppression (R_{AA} vs. centrality, p_T)
  - Υ(2S+3S) suppression (R_{AA} vs. centrality, p_T)
- Comparison with LHC results and theoretical calculations
- Summary

Motivation

Quarkonium is a sensitive probe of the deconfinement in the QGP: color screening ⟶ dissociation

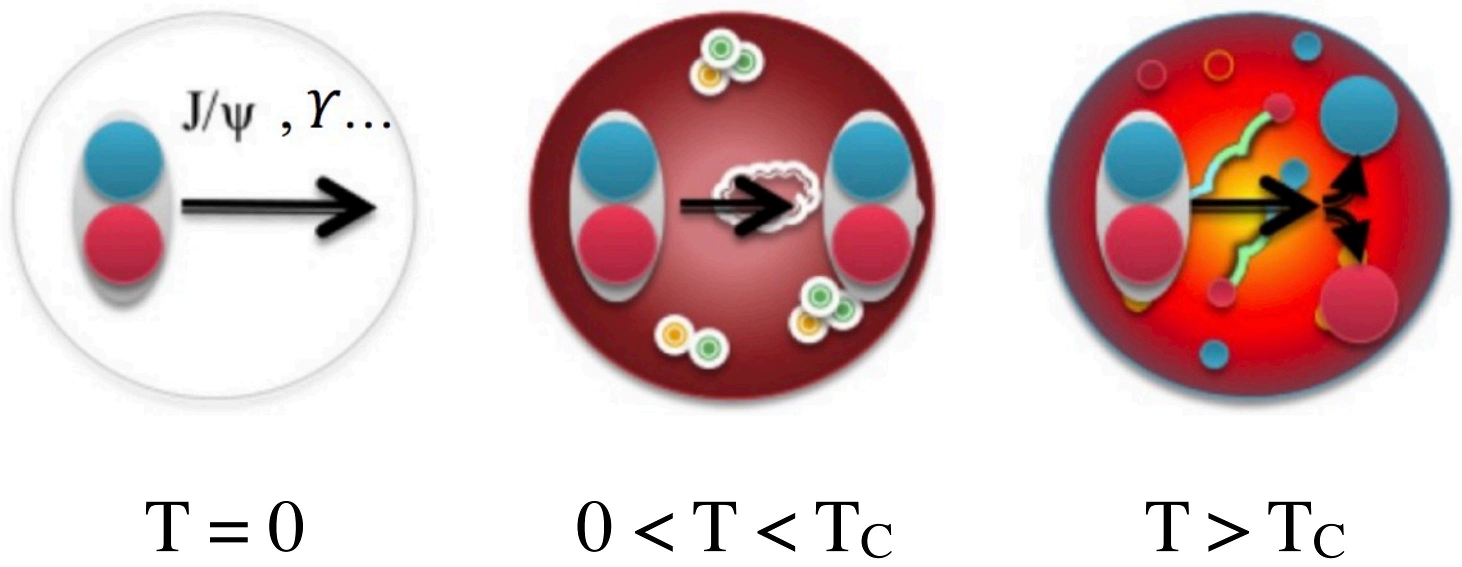
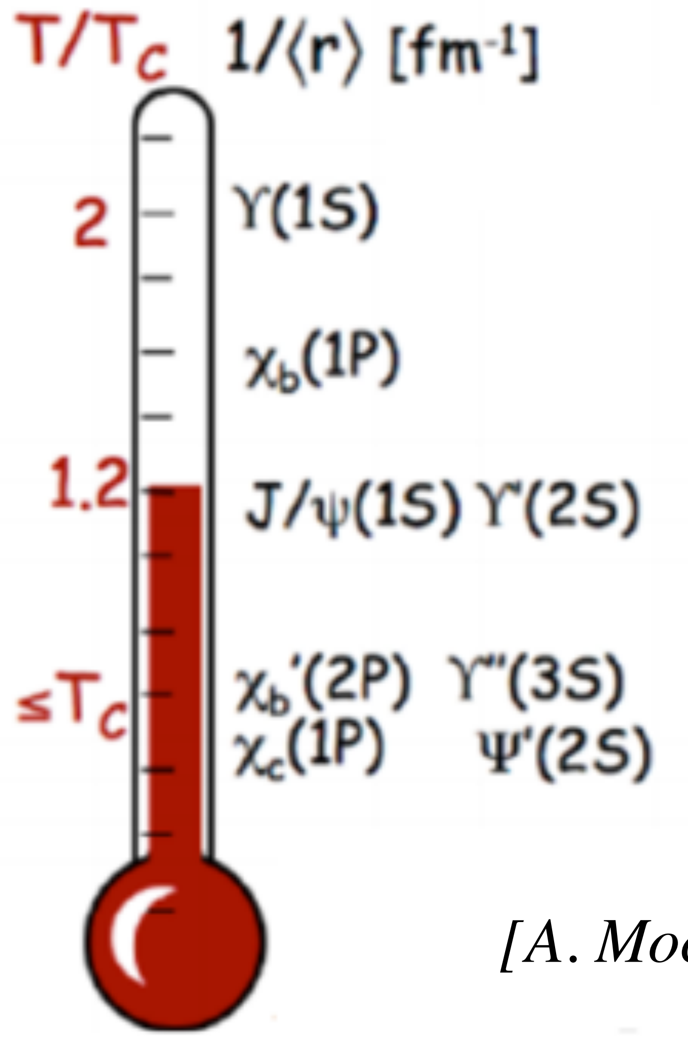


Illustration: A. Rothkopf

QGP "Thermometer"



[A. Mocsy, EPJ C61, 705 (2009)]

ϒ is a cleaner probe at RHIC:

- Regeneration is smaller compared to J/ψ

  [A. Emerick, X. Zhao and R. Rapp: EPJ A48, 72 (2012)]
  [X. Du, M. He, and R. Rapp: PRC 96, 054901 (2017)]

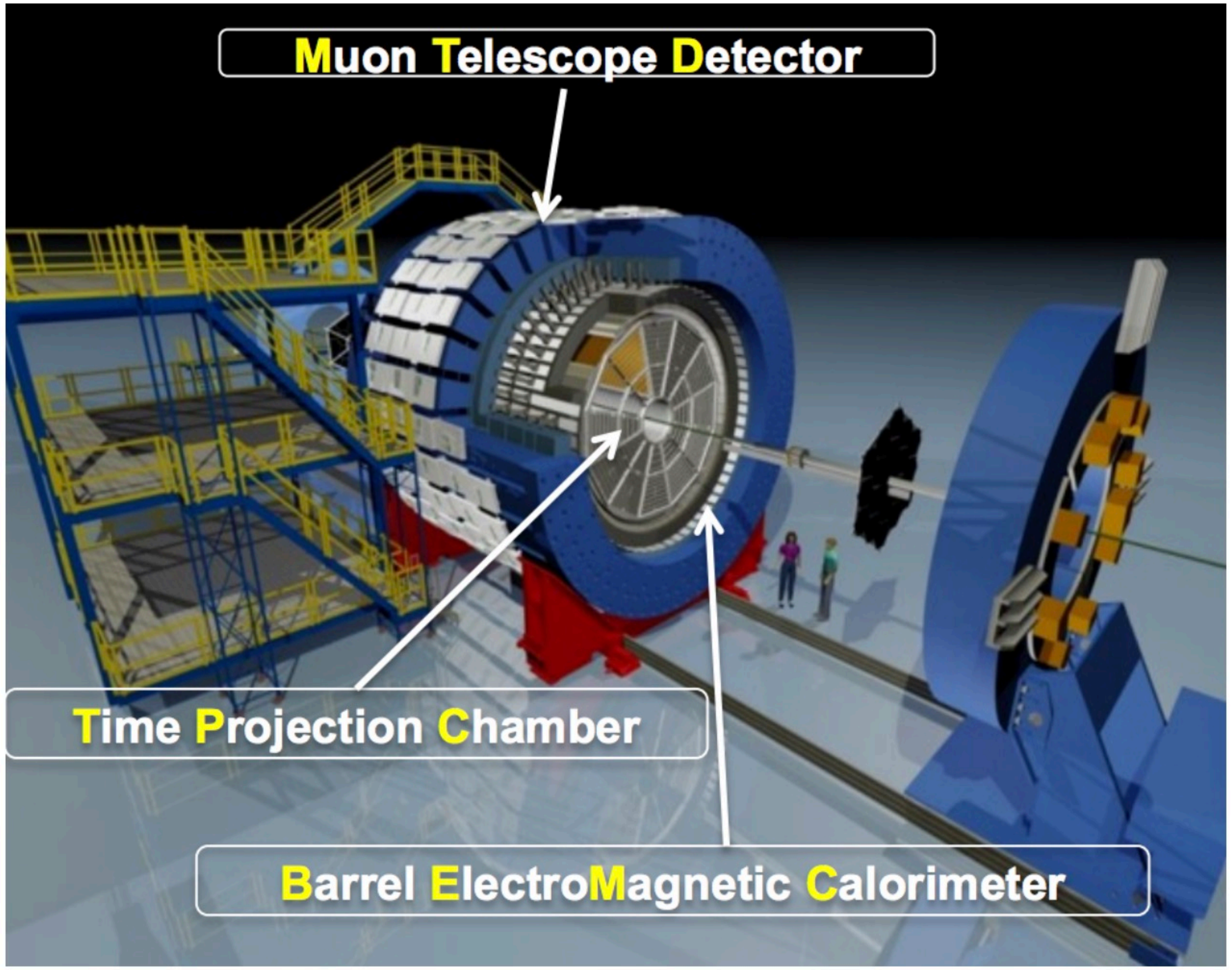
- Co-mover absorption is small

  [Z. Lin and C. Ko: PLB 503, 104 (2001)]

Challenge:

- Small production cross section

The Solenoidal Tracker at RHIC

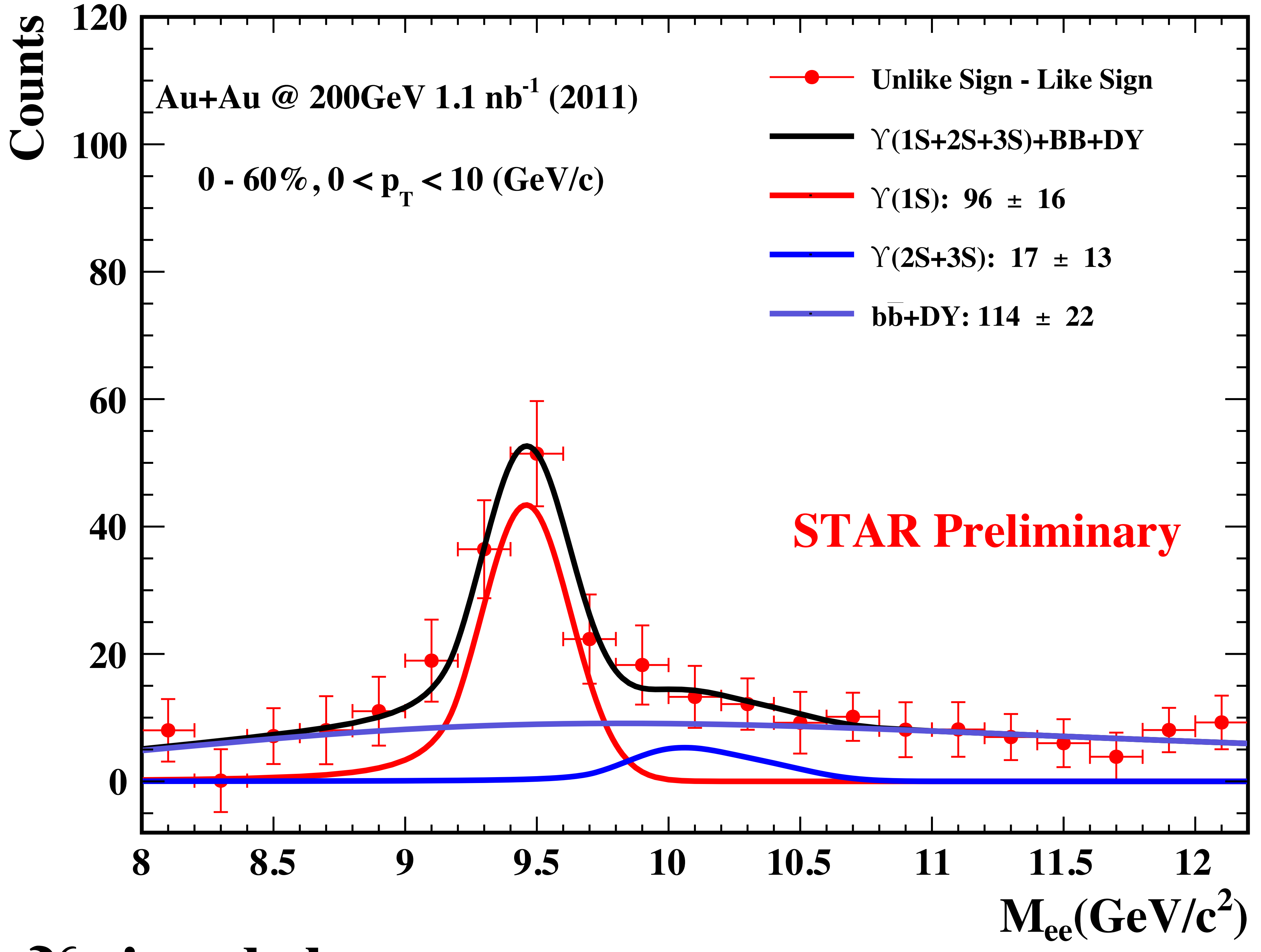


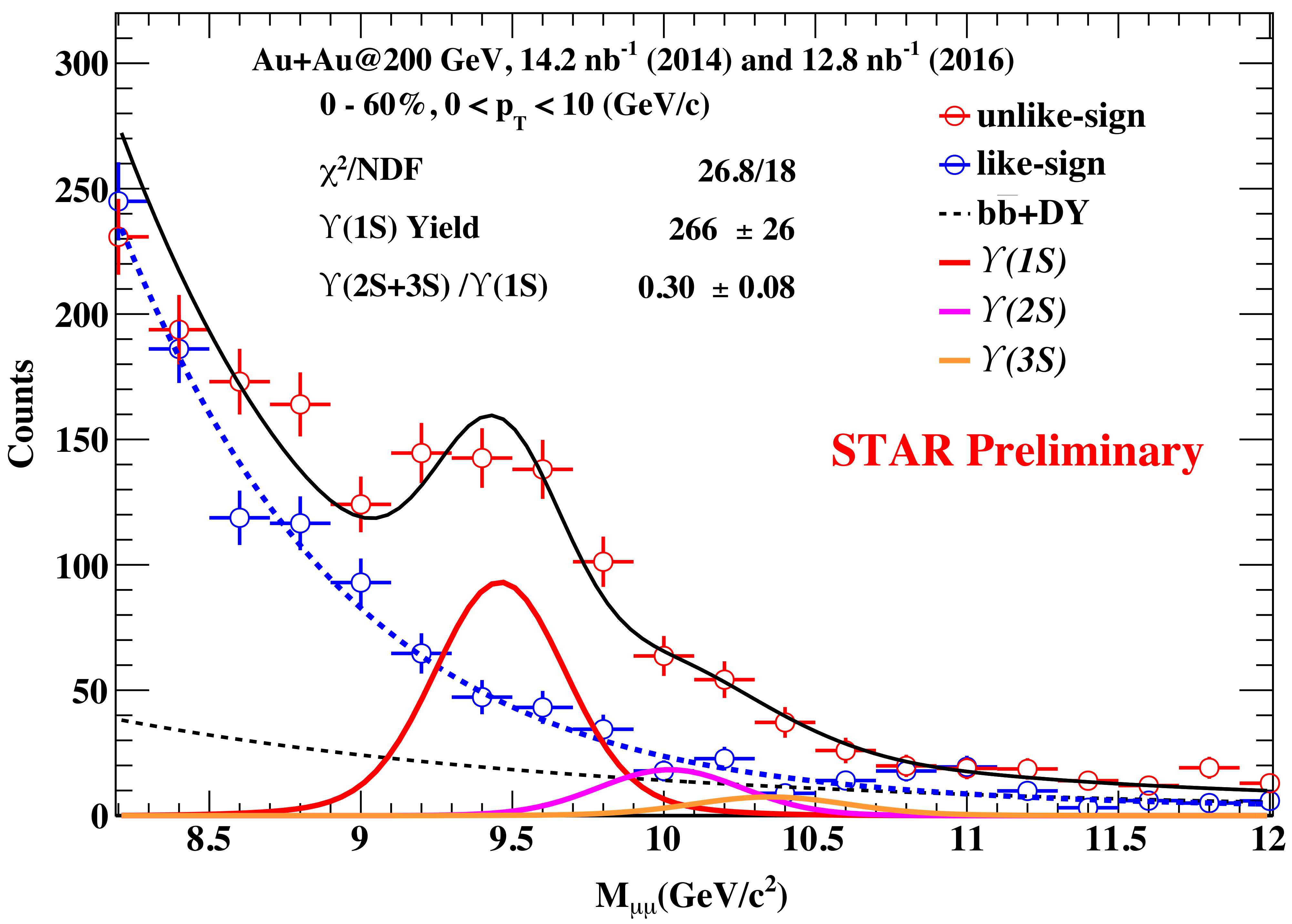
$\Upsilon \rightarrow \mu^+ + \mu^-$: TPC + MTD

$\Upsilon \rightarrow e^+ + e^-$: TPC + BEMC

- TPC ($|\eta| < 1$, $0 < \varphi < 2\pi$)
  - Tracking (momentum measurement, dE/dx)
- BEMC ($|\eta| < 1$, $0 < \varphi < 2\pi$)
  - Trigger and identification of high-p_T electrons
- MTD ($|\eta| < 0.5$, 45% in $0 < \varphi < 2\pi$)
  - Dimuon trigger and muon identification
  - Less bremsstrahlung: helps separate Υ(2S+3S) from Υ(1S)
  - Precise timing (~100 ps)
  - Good spatial resolution (~1-2 cm)

ϒ reconstruction in Au+Au @ 200GeV





ϒ signal shape:

- Geant simulation of STAR detector

Residual background ($\bar{b}b$+DY) shape:

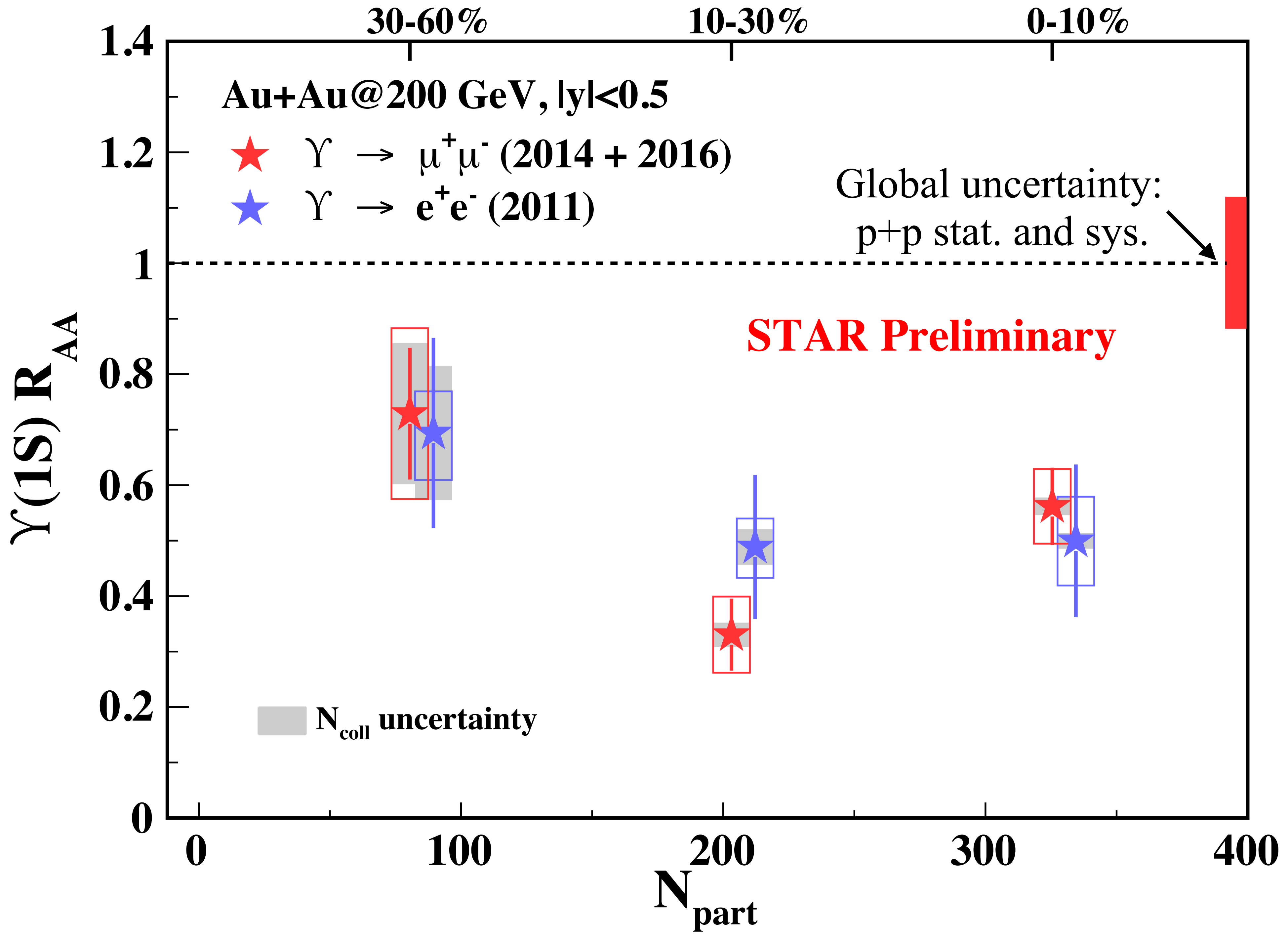
- PYTHIA

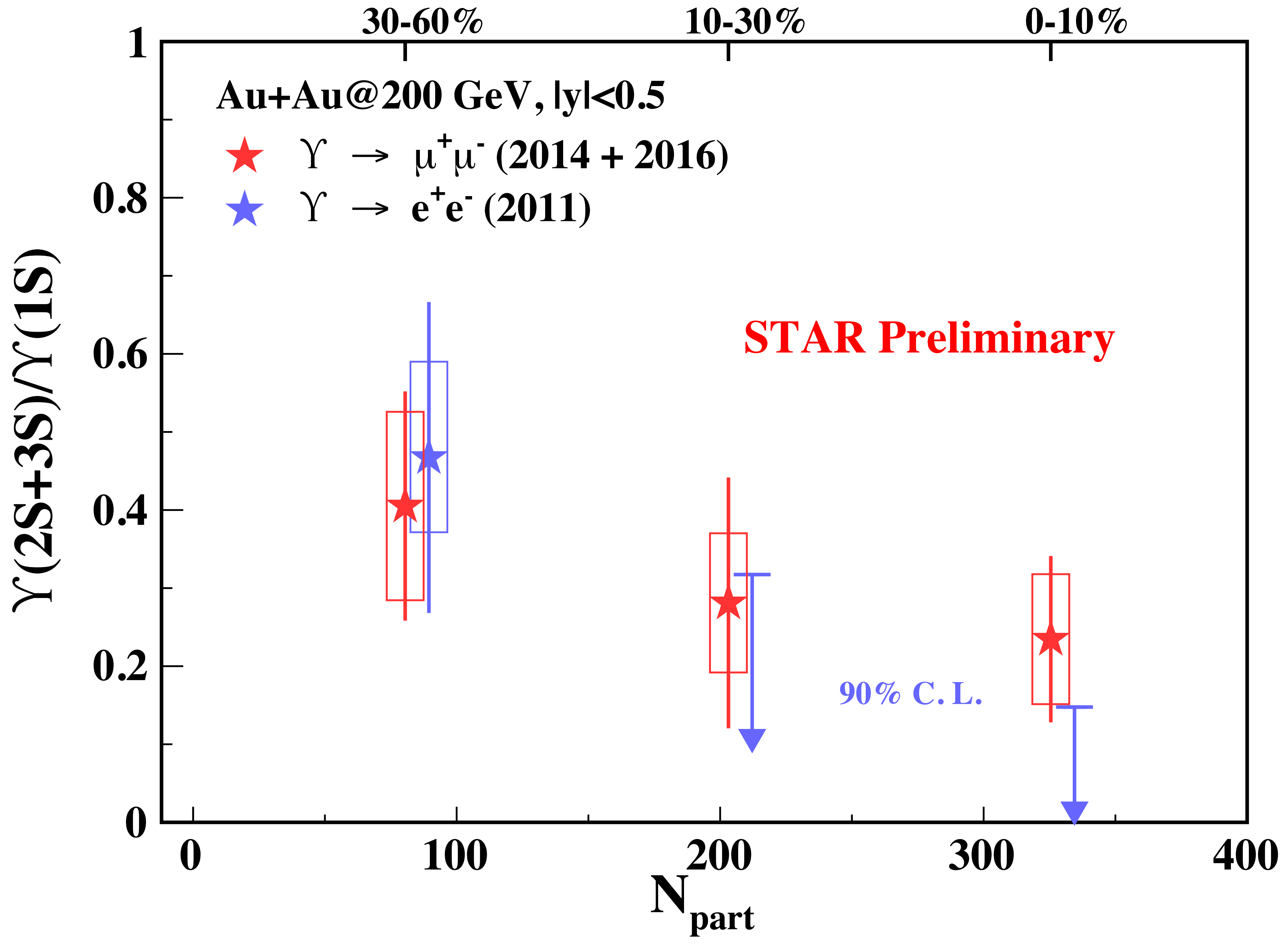
ϒ ➔ $\mu^+ + \mu^-$:

Datasets	2014	2014+2016
Integrated luminosity	14.2 nb^{-1}	27 nb^{-1}
ϒ(1S)	149±18	266±26

ϒ ➔ $e^+ + e^-$ analysis with 2014 dataset: Oliver Matonoha's poster, CT9 (#110)

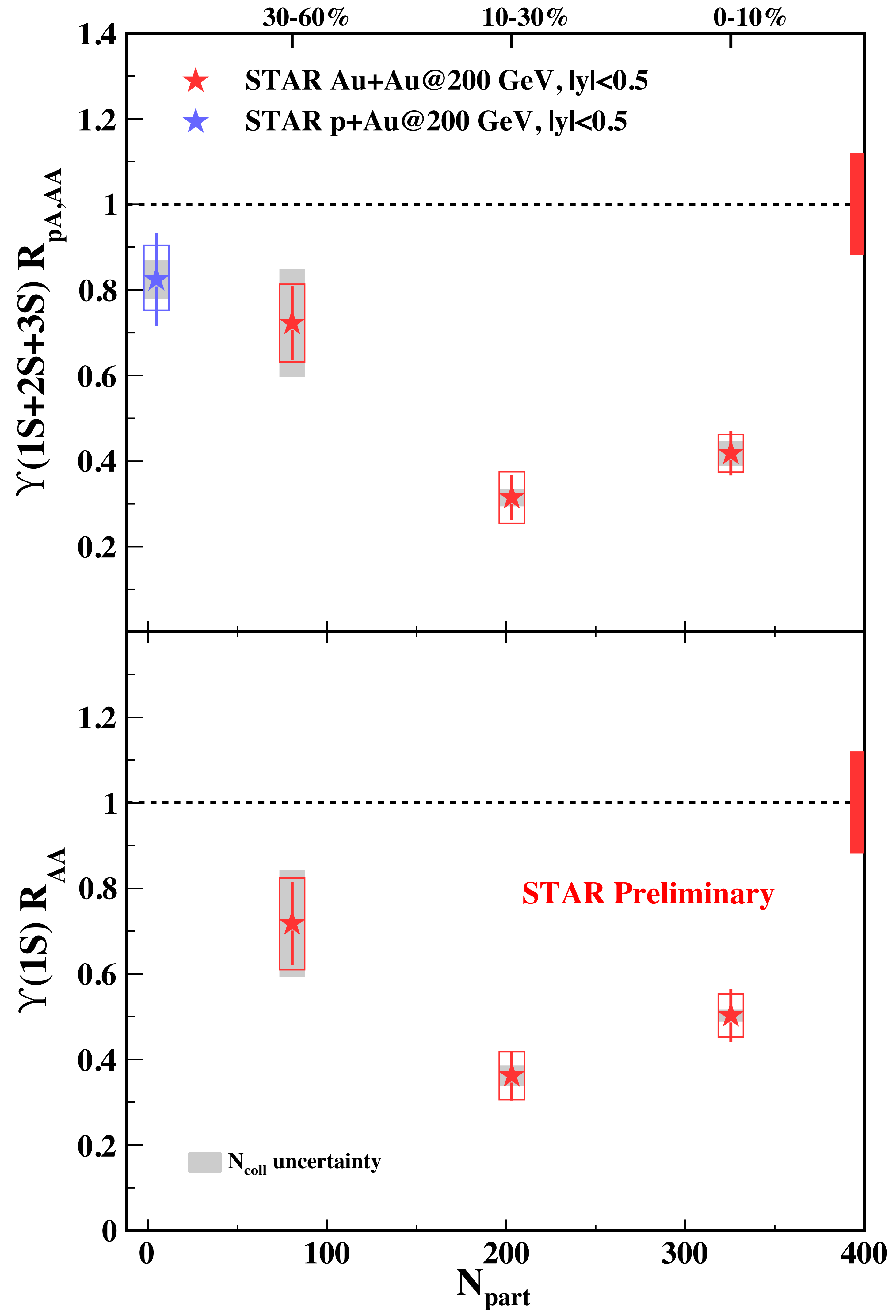
Dielectron vs. dimuon





- **Consistency between the dielectron and dimuon channels**
- **Results are combination of dielectron and dimuon channels unless otherwise specified**

Au+Au: Υ(1S) and Υ(1S+2S+3S) vs. N_{part}



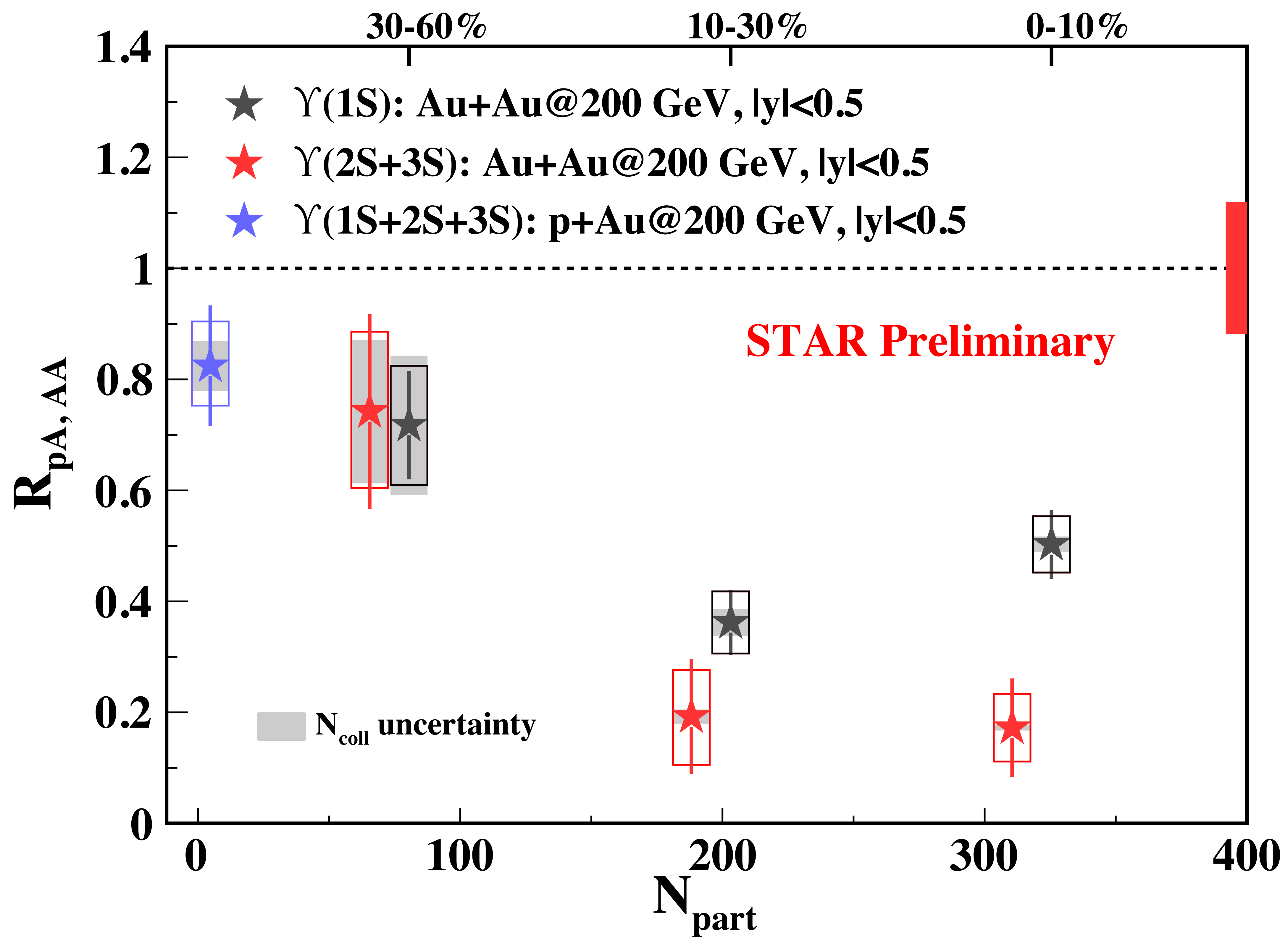
Υ(1S+2S+3S):

- Cold nuclear matter effects:
  R_{pAu}: 0.82 ± 0.10 (stat.) $^{-0.07}_{+0.08}$ (sys.) ± 0.10 (global)

Υ(1S):

- Indication of stronger suppression towards central collisions

Au+Au: ϒ(2S+3S) vs. N_{part}



ϒ(2S+3S):

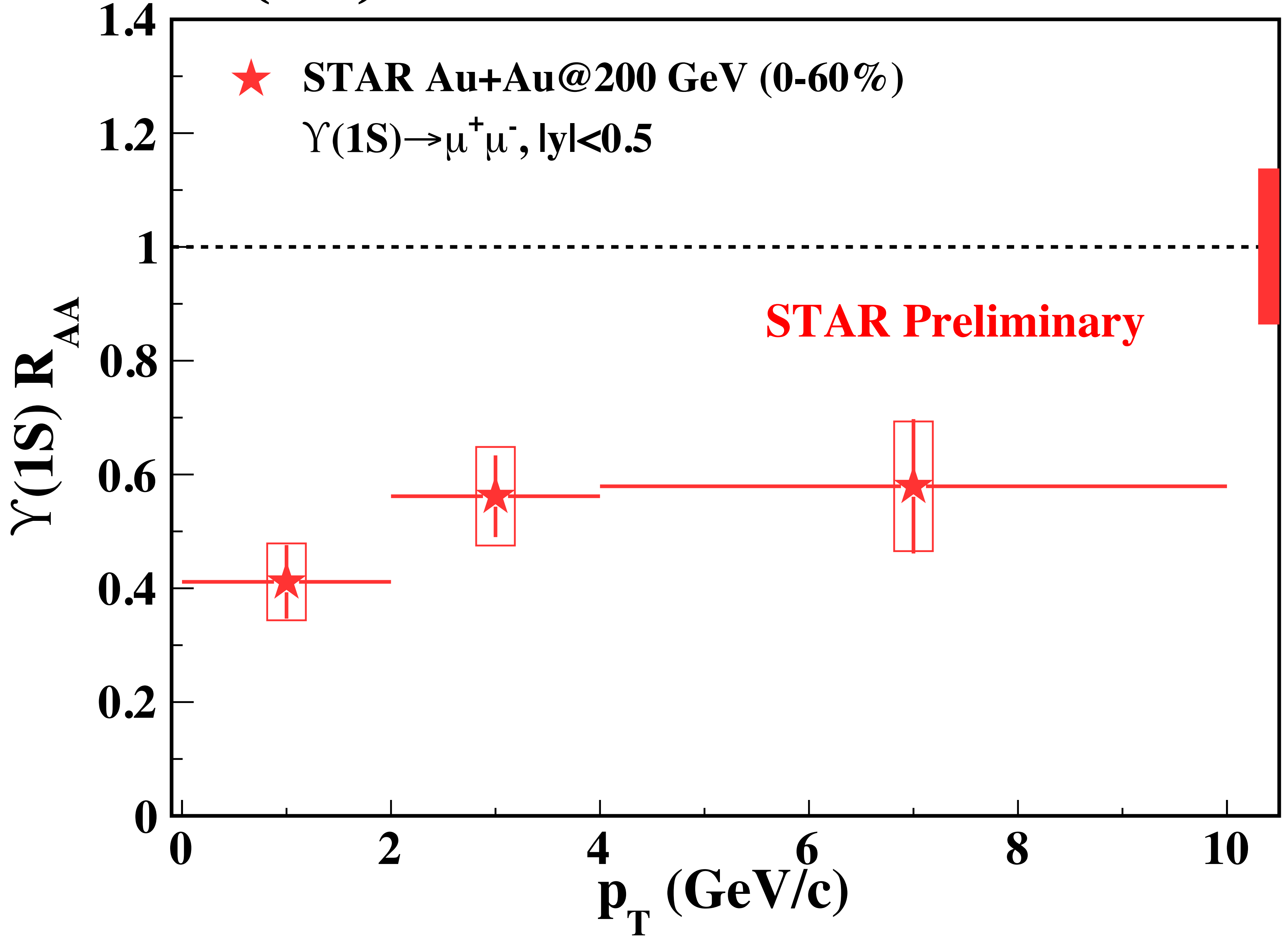
- **Stronger suppression in more central collisions**
- **More suppressed than ϒ(1S) in 0-10% — sequential melting**

ϒ(1S) R_{AA}: 0.50 ± 0.06 (stat.) ± 0.05 (sys.)

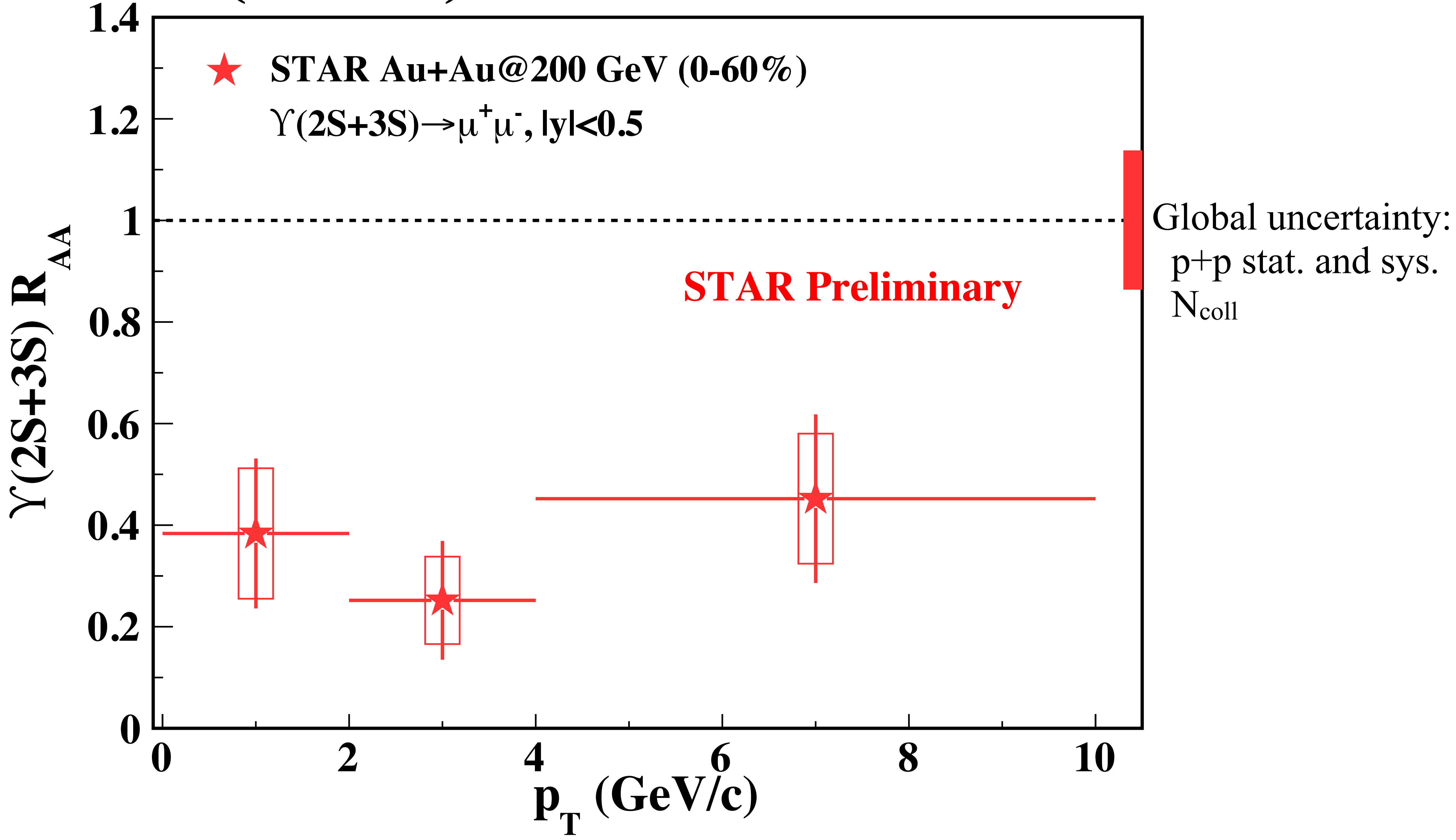
ϒ(2S+3S) R_{AA}: 0.17 ± 0.09 (stat.) ± 0.06 (sys.)

Au+Au: ϒ(1S) and ϒ(2S+3S) vs. p_T

ϒ(1S):



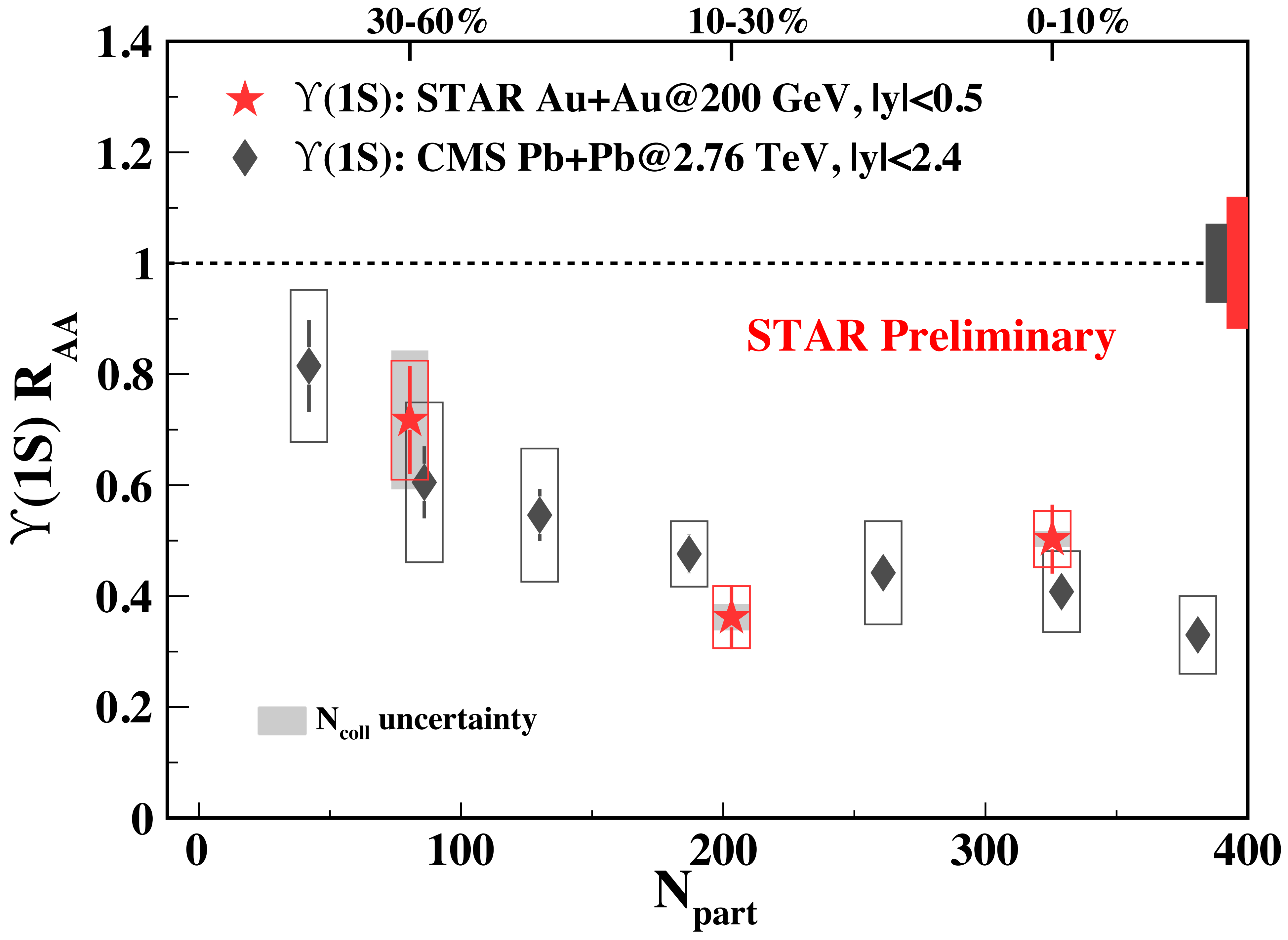
ϒ(2S+3S):

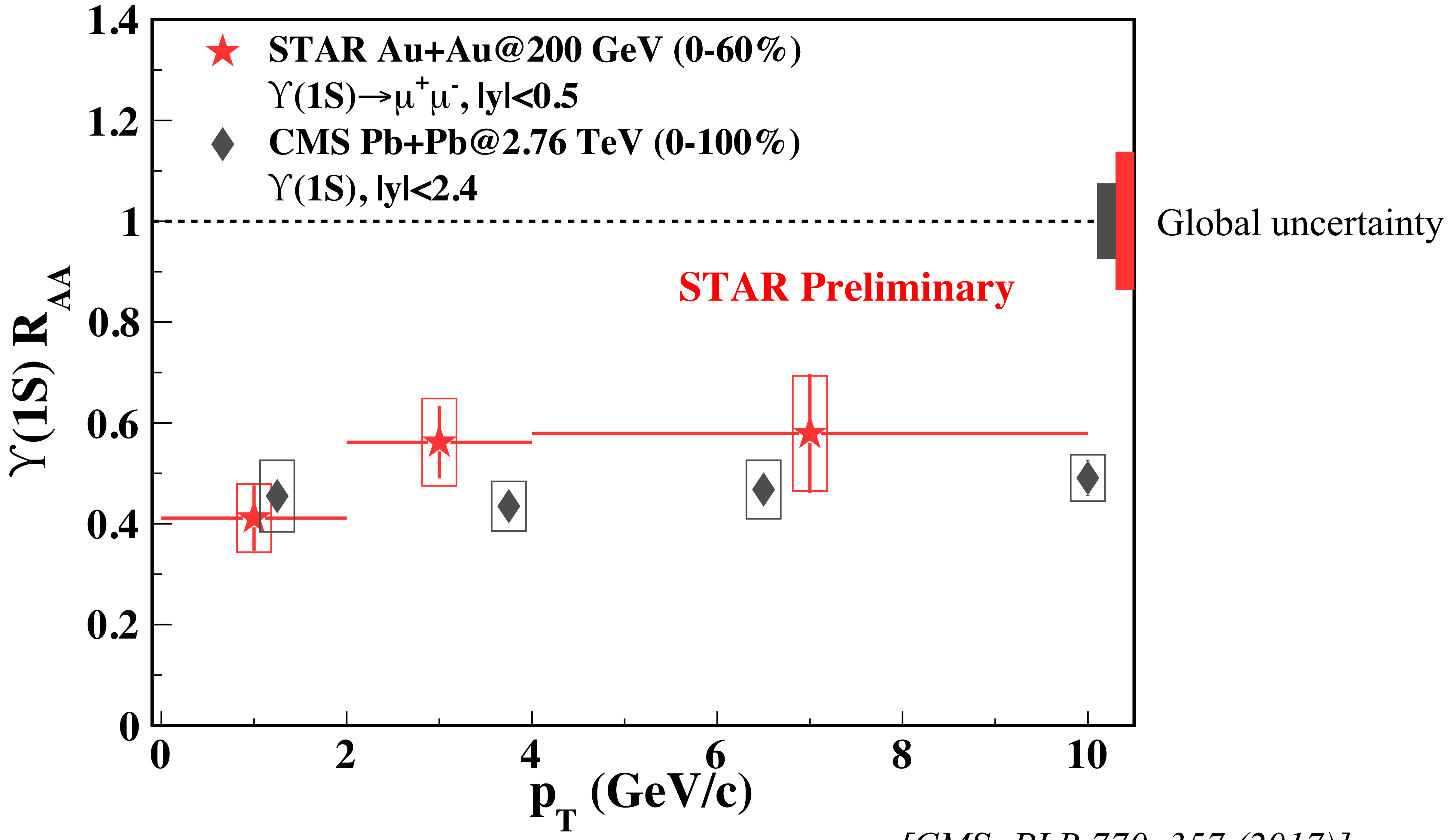


ϒ(1S), ϒ(2S+3S):

- No significant p_T dependence

Υ(1S) suppression: STAR vs. CMS



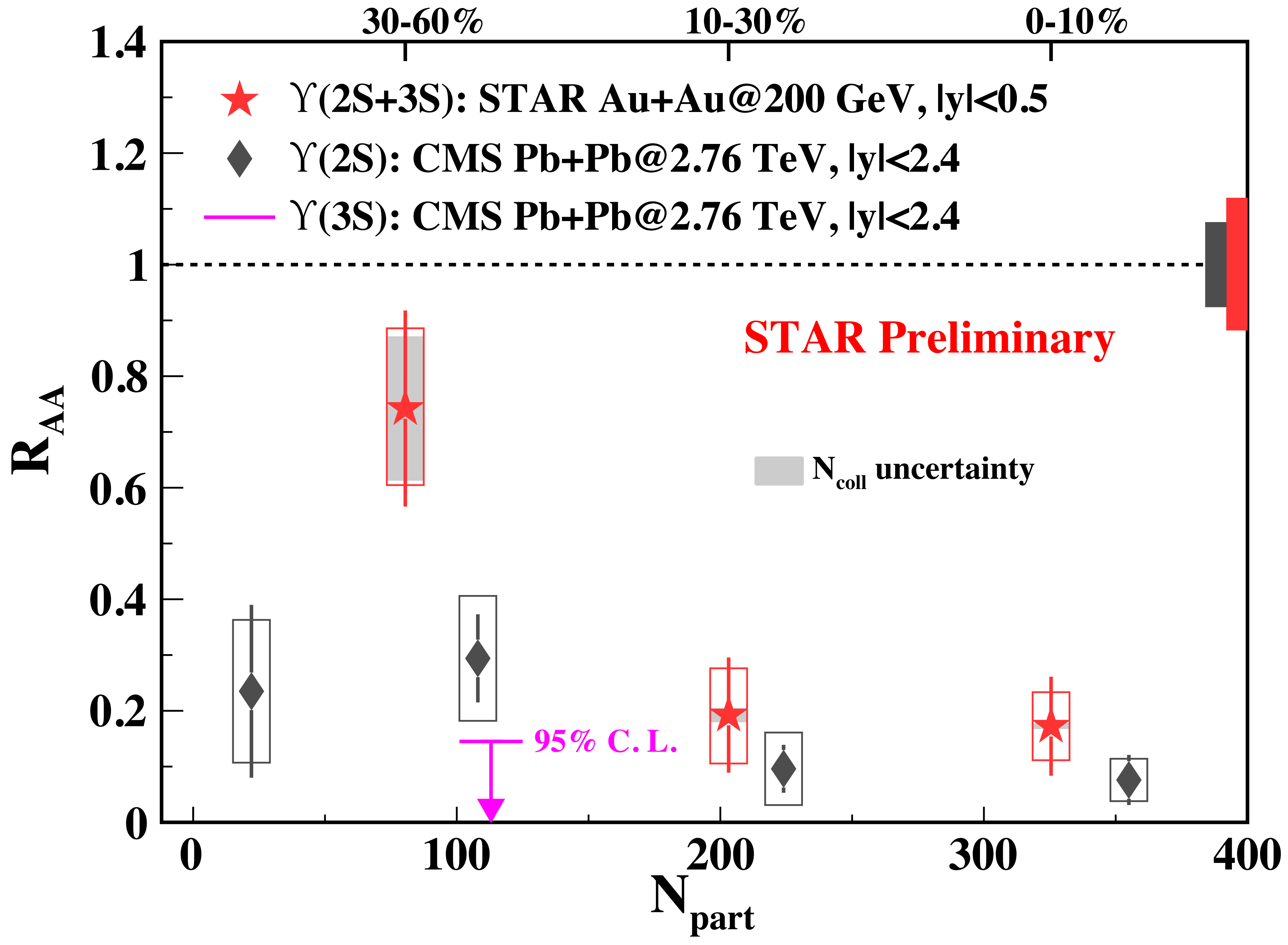


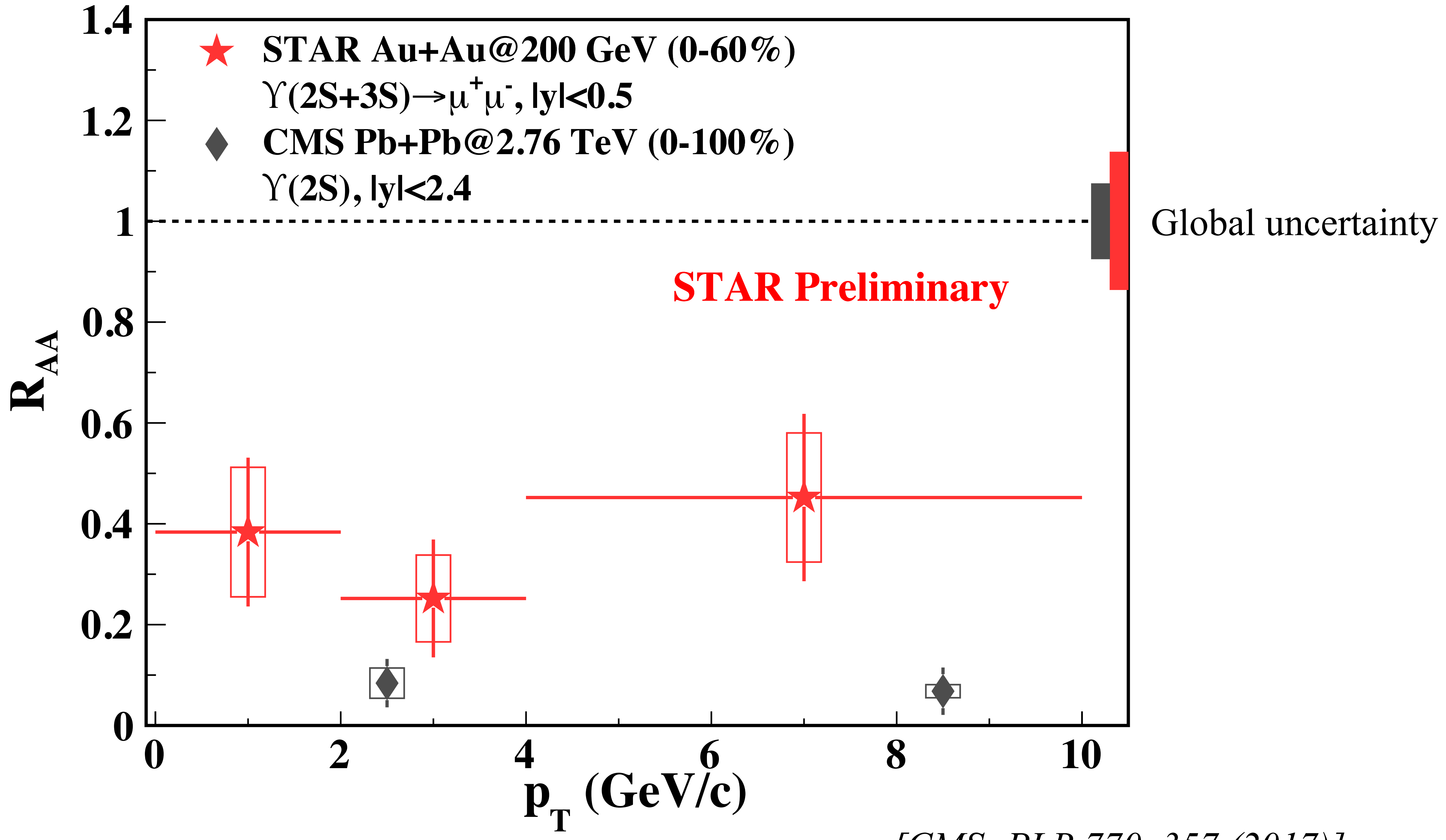
[CMS: PLB 770, 357 (2017)]

Υ(1S) suppression is similar at RHIC and LHC — could be due to:

- **Medium temperature is higher at LHC due to higher collision energy**
- **Regeneration contribution is larger at LHC**
- **CNM**

ϒ(2S+3S) suppression: STAR vs. CMS





[CMS: PLB 770, 357 (2017)]

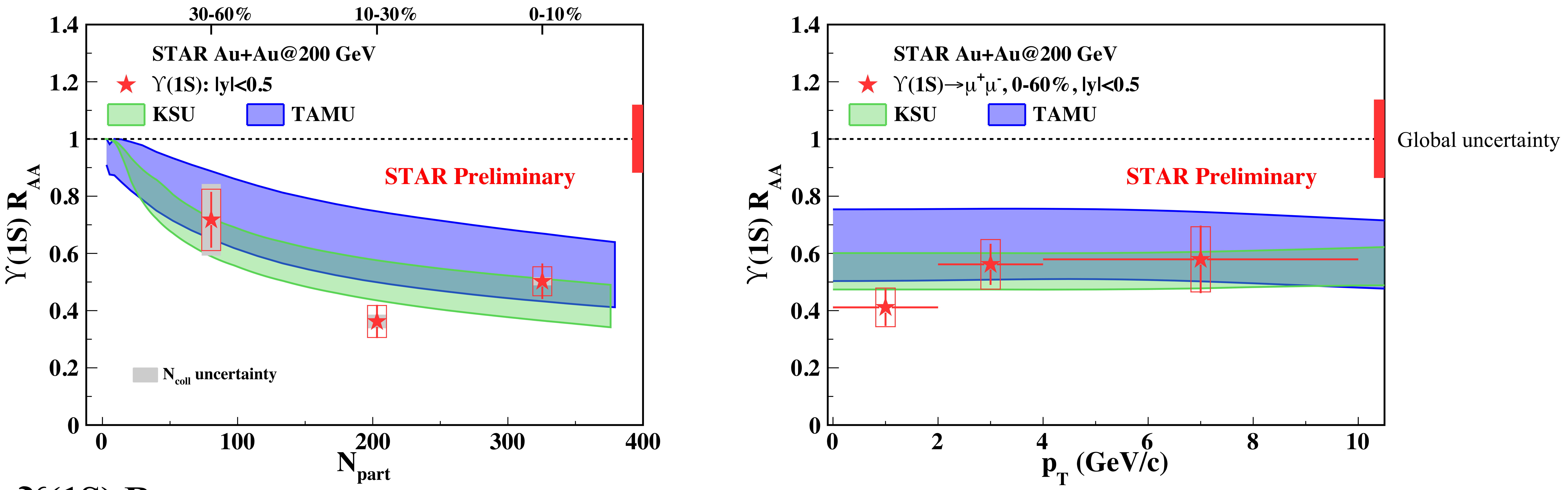
ϒ(2S+3S):

- **Indication of less suppression at RHIC than at LHC**

  STAR: ϒ(2S+3S) R_{AA}: 0.35 ± 0.08 (stat.) ± 0.10 (sys.) (0 < p_T < 10 GeV/c, 0-60%)

  CMS: ϒ(2S) R_{AA}: 0.08 ± 0.05 (stat.) ± 0.03 (sys.) (0 < p_T < 5 GeV/c, 0-100%)

Υ(1S) suppression: STAR vs. models



[B. Krouppa, A. Rothkopf, M. Strickland: PRD 97, 016017 (2018)]
[X. Du, M. He, and R. Rapp: PRC 96, 054901 (2017)]

Υ(1S) R_{AA}:

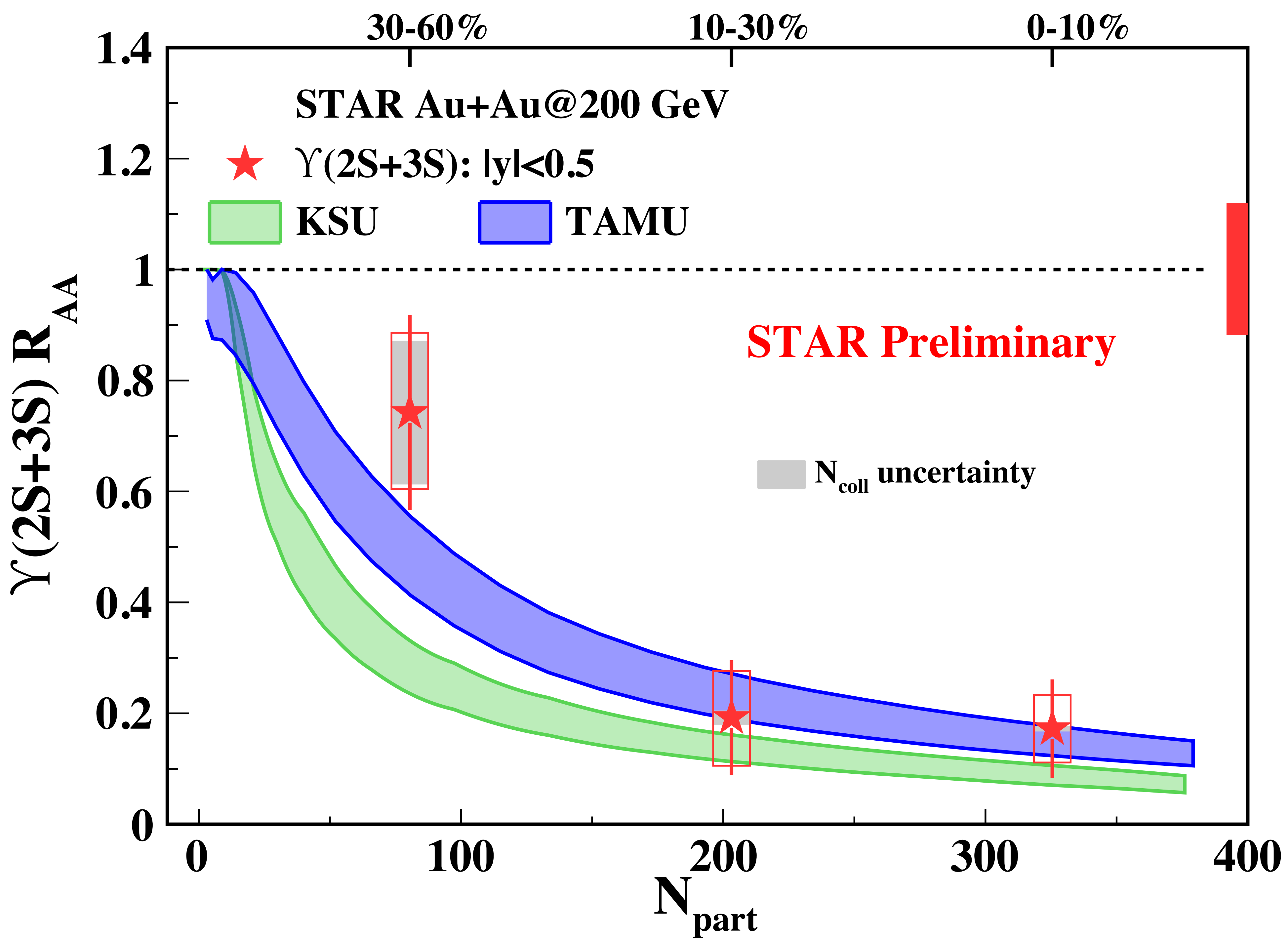
- **Both KSU and TAMU models describe data**

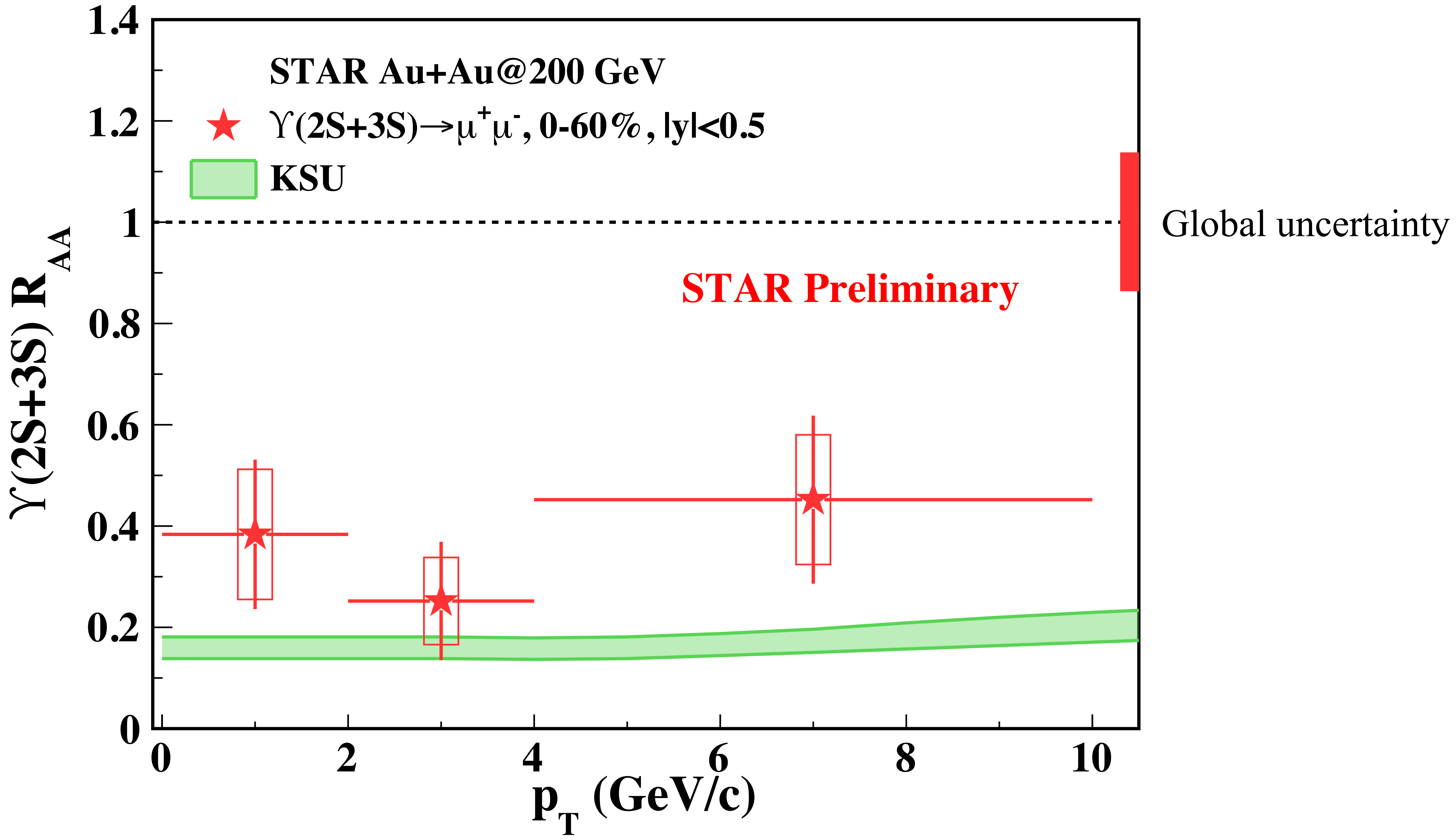
KSU model: use a lattice-vetted heavy-quark potential

TAMU model: use in-medium binding energies predicted by thermodynamic T-matrix calculations using internal-energy potentials, from lattice QCD

T_0^{QGP} (MeV)	RHIC (0.2 TeV)	LHC (2.76 TeV)
KSU	440	546
TAMU	310	555

Υ(2S+3S) suppression: STAR vs. models



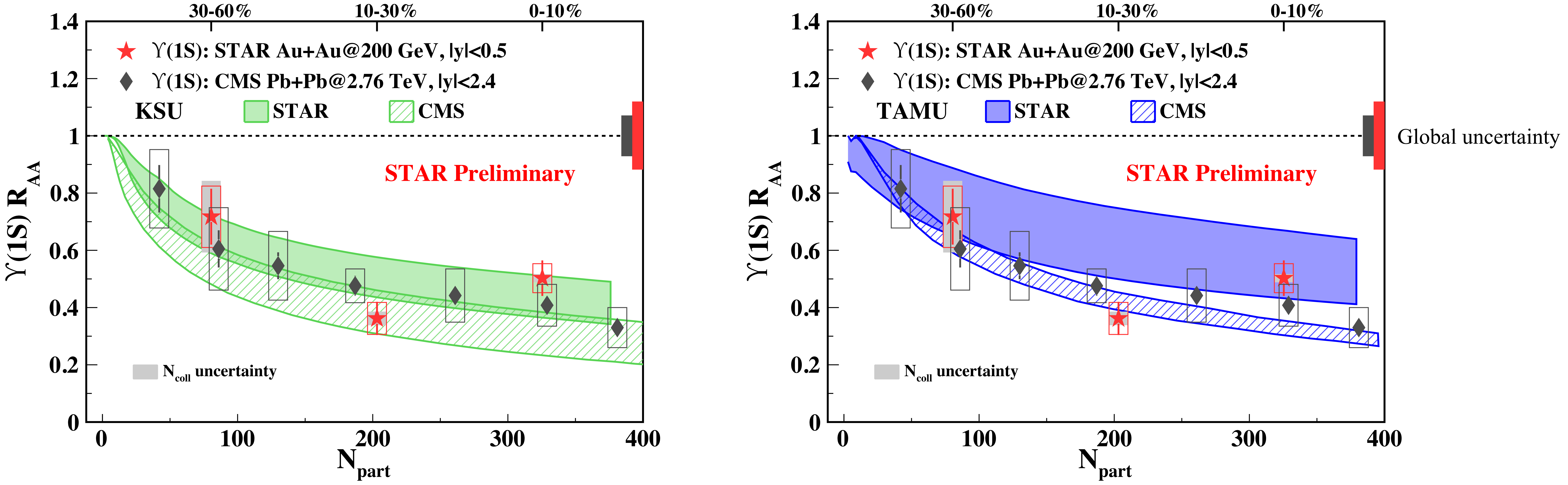


[B. Krouppa, A. Rothkopf, M. Strickland: PRD 97, 016017 (2018)]
[X. Du, M. He, and R. Rapp: PRC 96, 054901 (2017)]

Υ(2S+3S) R_{AA} :

- **TAMU model describes data**
- **KSU model calculation is slightly lower than data in 30-60%**

ϒ(1S) suppression: data vs. models



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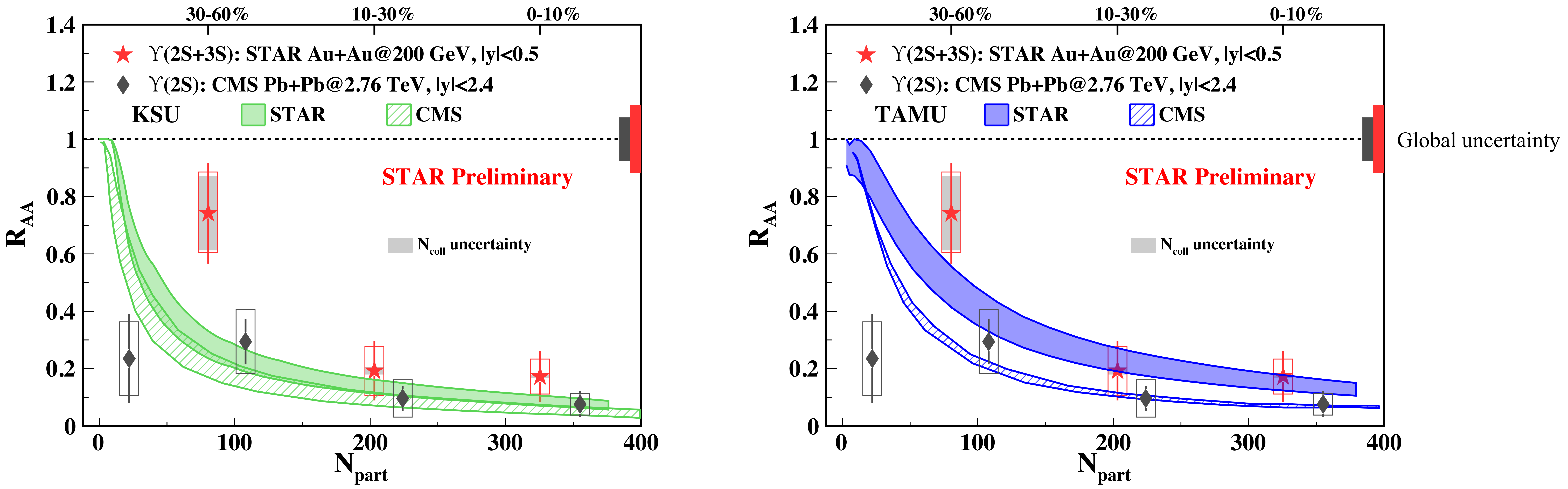
ϒ(1S) R_{AA}:

- **Both KSU and TAMU models are consistent with data at RHIC and LHC**

ϒ(2S+3S) suppression: data vs. models



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ϒ(2S+3S) R_{AA}:

- **Model calculations are consistent with both STAR and CMS results in central and semi-central collisions**

Summary

- With combined results from dielectron and dimuon channels using the datasets taken in 2011, 2014 and 2016, the precision of Υ measurements is improved compared to previous results.
- Υ suppression in Au+Au collisions:

  Υ(1S):

  ★ Indication of stronger suppression towards central collisions
  ★ Similar suppression as at LHC
  ★ Both KSU and TAMU models are consistent with data at RHIC and LHC

  Υ(2S+3S):

  ★ Stronger suppression in more central collisions
  ★ More suppressed than Υ(1S) in 0-10% — sequential melting
  ★ Indication of less suppression at RHIC than at LHC
  ★ Data at RHIC and LHC are consistent with model calculations in central and semi-central collisions

Thank you!