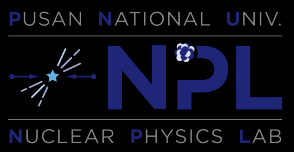
Development of Monte Carlo simulation for quarkonia production in heavy-ion collisions

arXiv:2209.12303

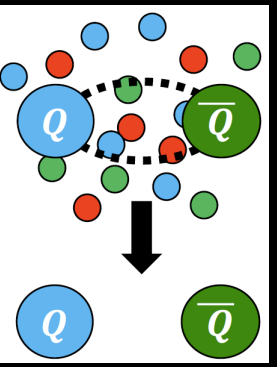
The beauty of the imperfection

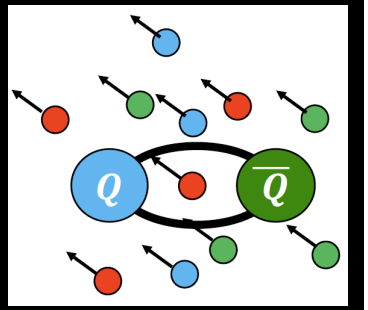
Sanghoon Lim
Pusan National University

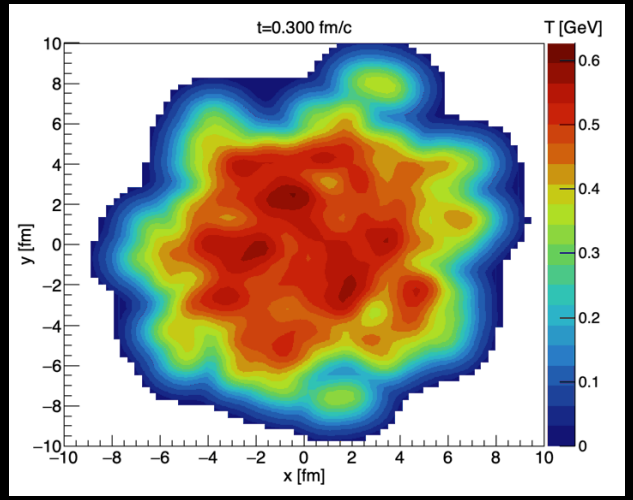


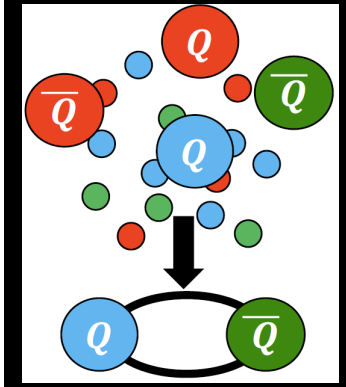
Collaboration with:
Junlee Kim, Jinjoo Seo, Jaebeom Park, Su Houng Lee, Juhee Hong
Eun-Joo Kim, MinJung Kweon, Byungsik Hong

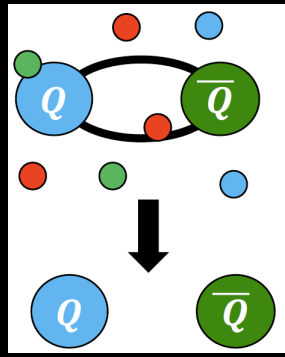
- Heavy quarks are mostly produced in the early stage of HI collisions
  - Inside full evolution of the QGP











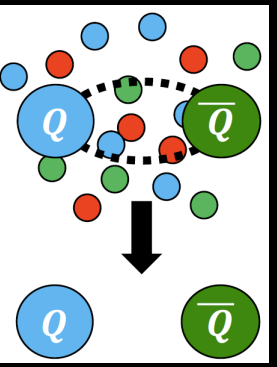
Dissociation via color screening

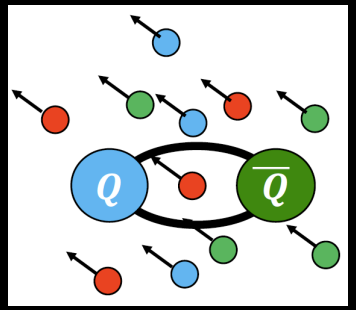
Hydrodynamic flow

Production via recombination

Suppression via interaction with comoving particles

- Heavy quarks are mostly produced in the early stage of HI collisions
  - Inside full evolution of the QGP





Dissociation via color screening

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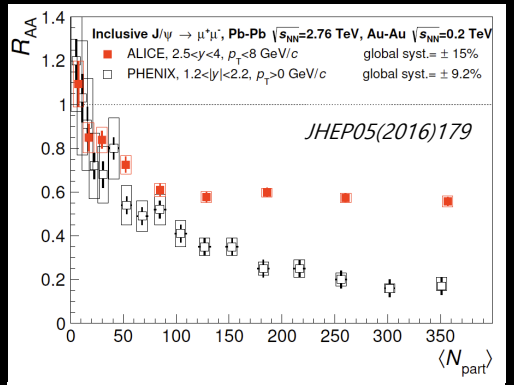
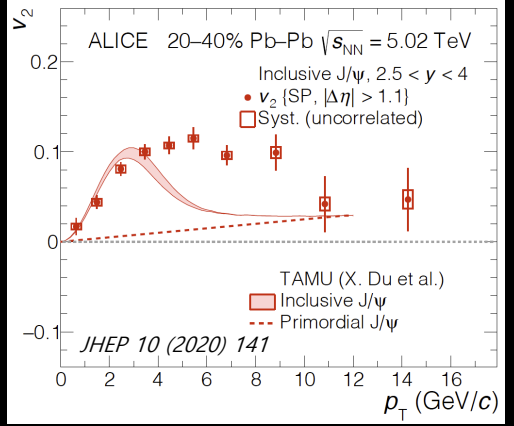
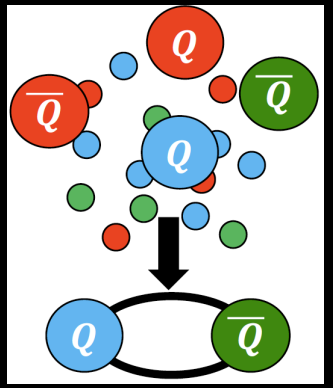
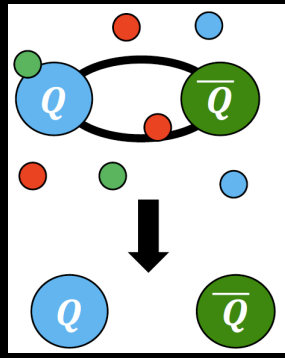






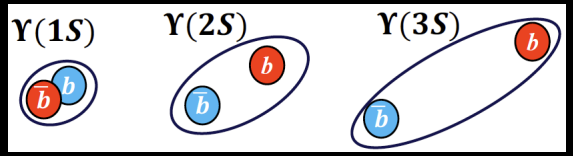


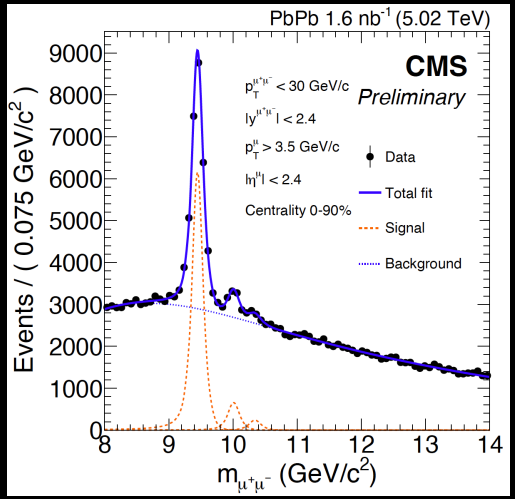
Production via recombination

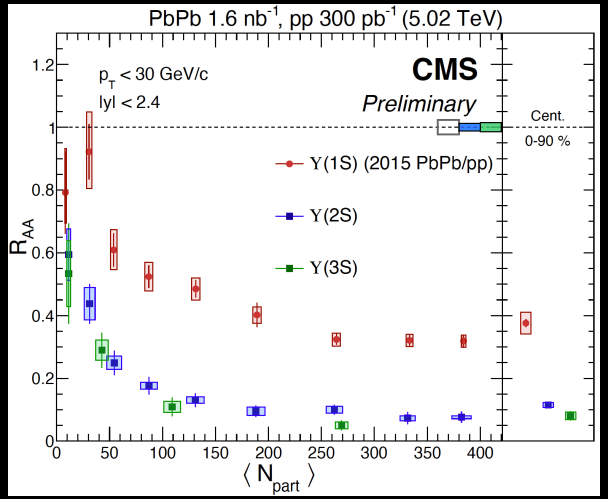
Suppression via interaction with comoving particles

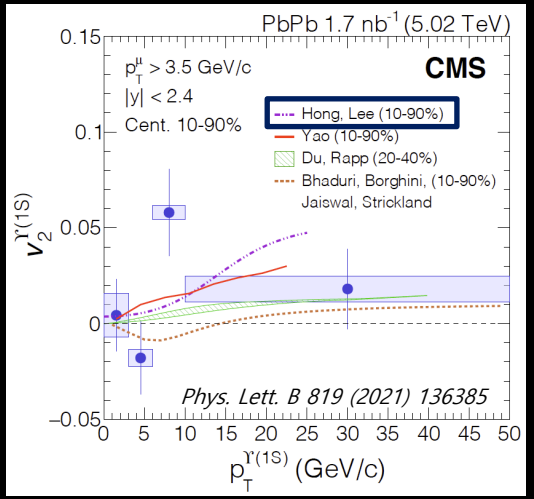
Heavy quarkonia in heavy-ion collisions

- Heavy quarks are mostly produced in the early stage of HI collisions
  - Inside full evolution of the QGP
- Quarkonia of different binding energies will be modified differently



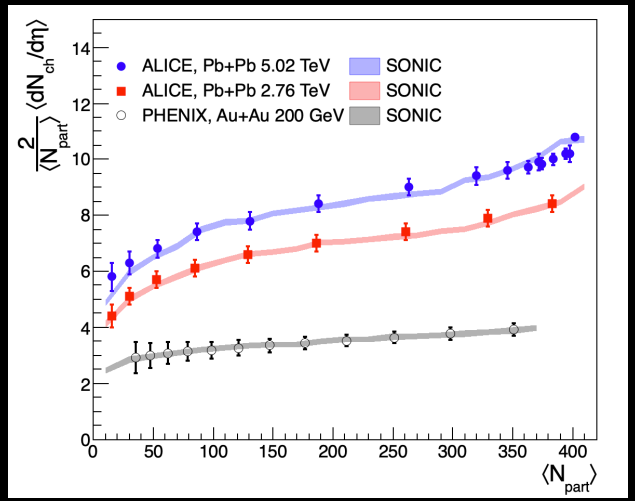


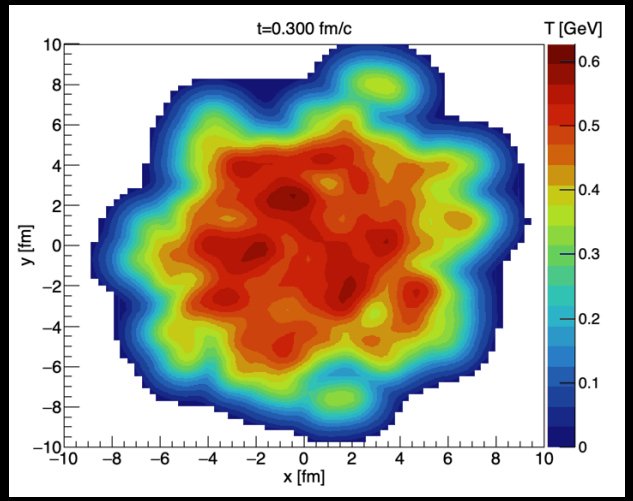


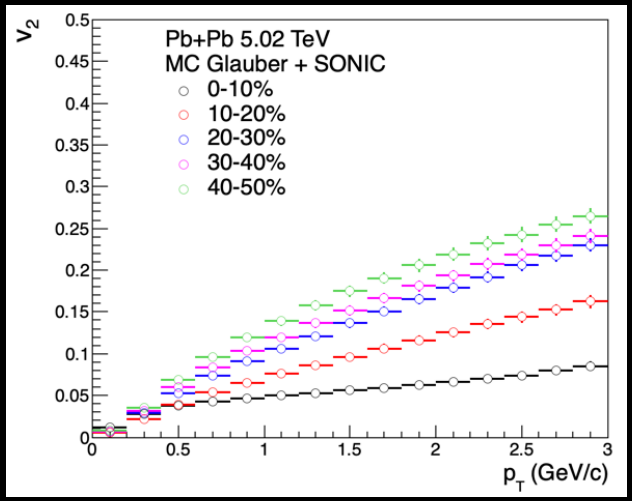


- Monte Carlo simulation is useful to have a detailed study on medium response

Quark-gluon plasma
from hydrodynamic simulation



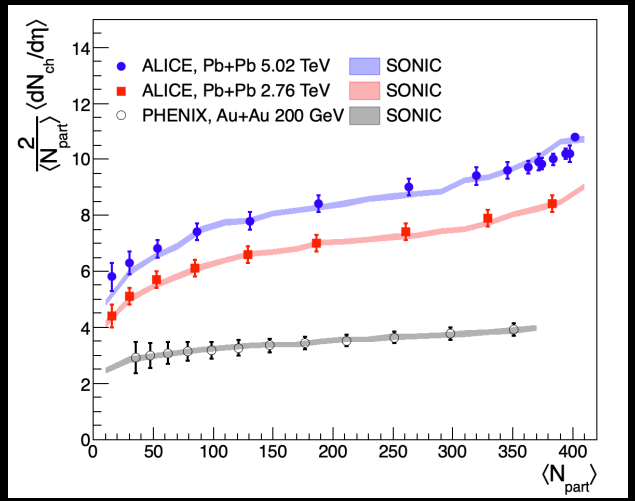


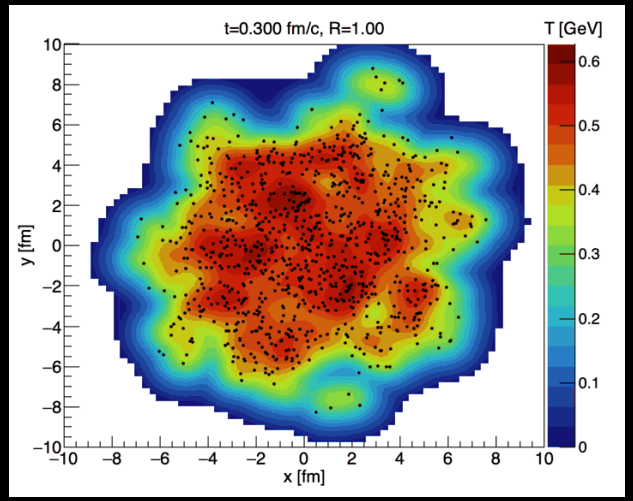


MC Glauber
SONIC

- Monte Carlo simulation is useful to have a detailed study on medium response

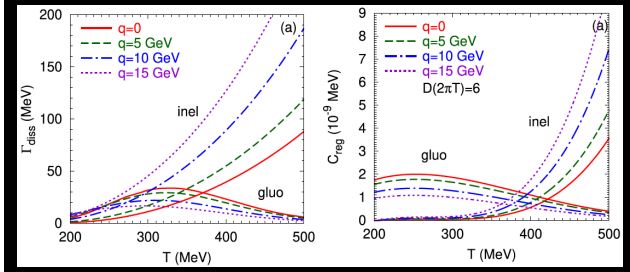
Quark-gluon plasma from hydrodynamic simulation

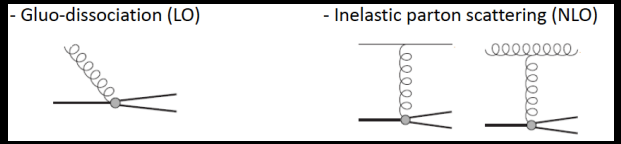




Medium response of Upsilson

$$\left(\frac{\partial}{\partial t}+\boldsymbol{v}\cdot\frac{\partial}{\partial \boldsymbol{x}}\right) f_\Upsilon(t,\boldsymbol{x},\boldsymbol{q}) = -\Gamma^{\text{gluo+inel}}_{\text{diss}}(t,\boldsymbol{x},\boldsymbol{q})\, f_\Upsilon(t,\boldsymbol{x},\boldsymbol{q}) + C^{\text{gluo+inel}}_{\text{reg}}[f_b, f_{\bar{b}}](t,\boldsymbol{x},\boldsymbol{q}), \quad (1)$$





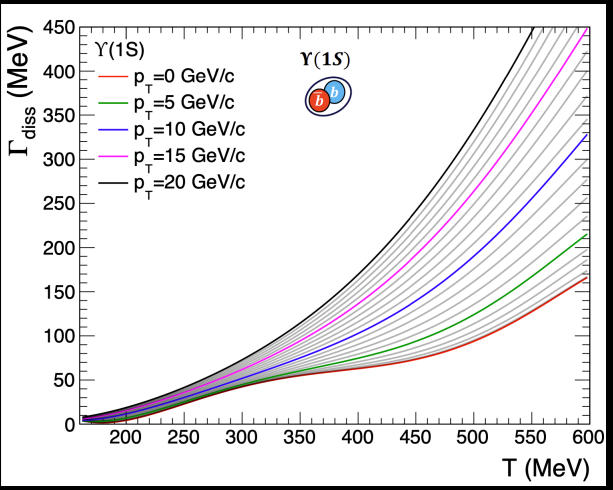
MC Glauber SONIC

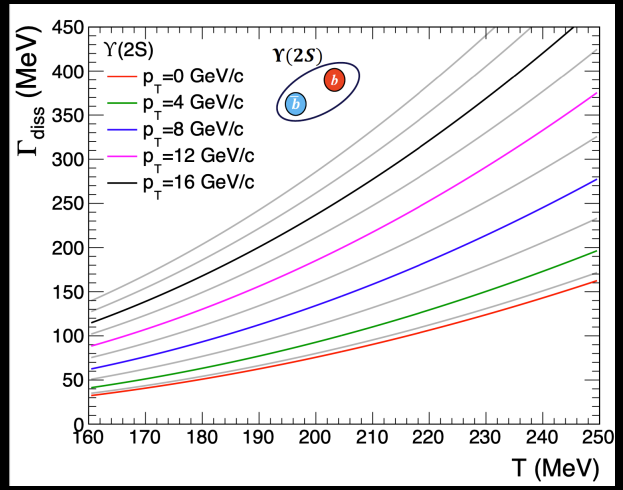
Theory

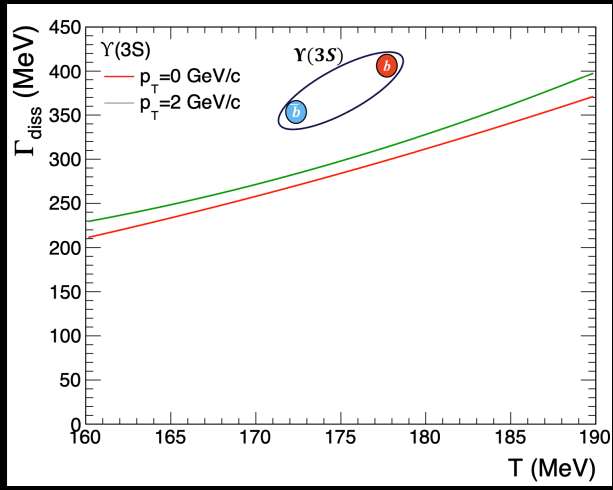
Phys. Rev. C 99, 034905 (2019)
Phys. Lett. B 801 (2020) 135147

Only dissasociation effect is considered!

- Monte Carlo simulation is useful to have a detailed study on medium response
- Three states of different thermal widths and formation times (0.5, 1.0, 1.5 fm/c)





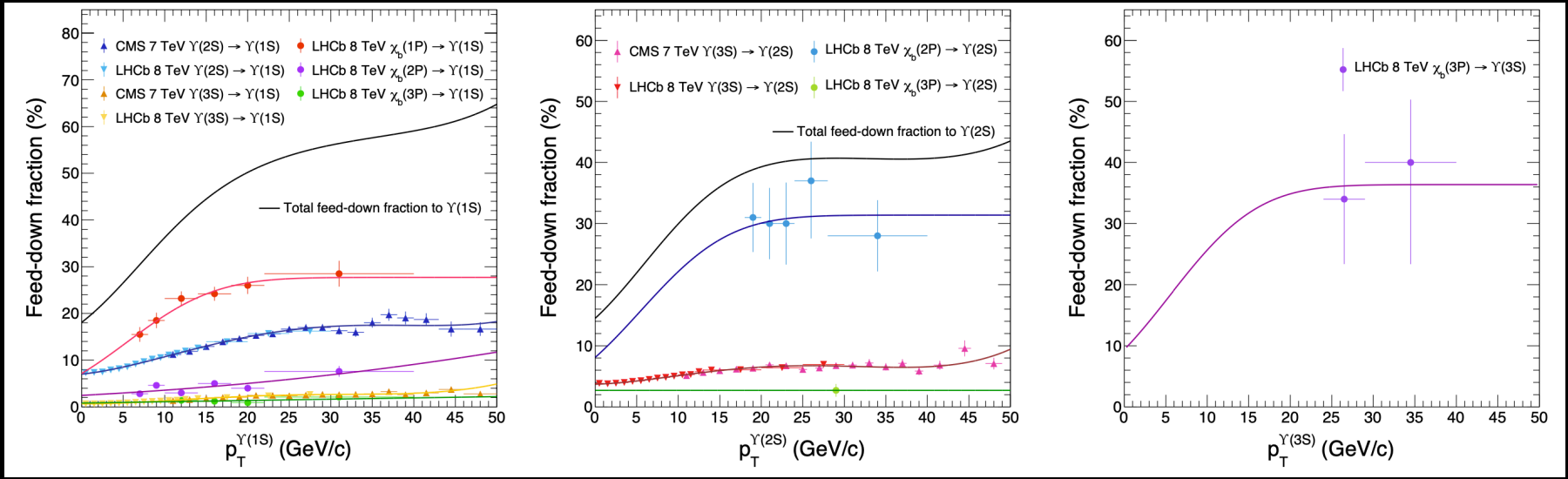


$$\frac{N(t+\Delta t, p_T)}{N(t, p_T)} = e^{-\int_t^{t+\Delta t} dt' \, \Gamma_{diss}(t', p_T)}$$

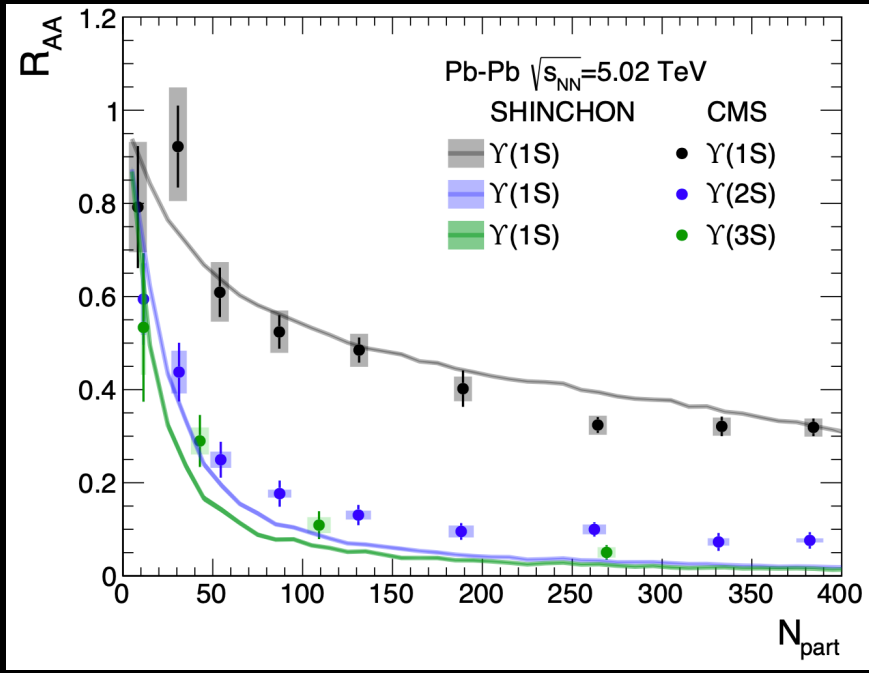
Only dissasociation effect is considered!

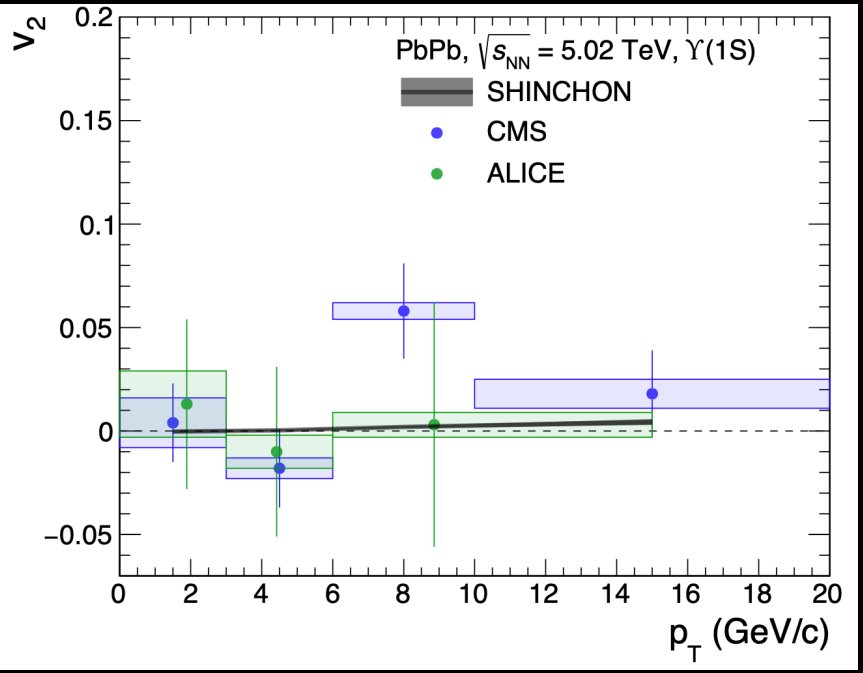
- Monte Carlo simulation is useful to have a detailed study on medium response
- Three states of different thermal widths and formation times (0.5, 1.0, 1.5 fm/c)
- Feed-down contribution is considered

$$R_n(p_T) = \Sigma R_i(p_T) F_{Q_n}^{Q_i}(p_T)$$



Modification and flow in heavy-ion collisions

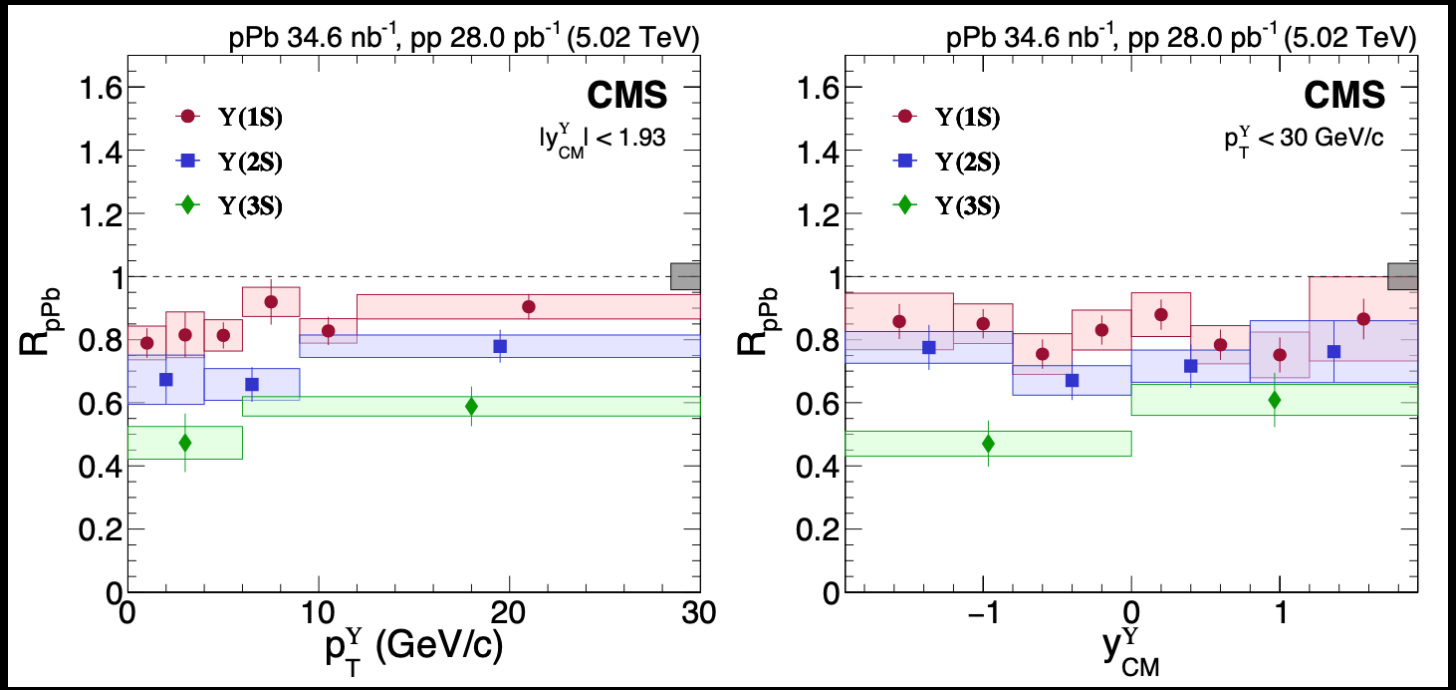




Only dissasociation effect is considered!

How about small collision systems?

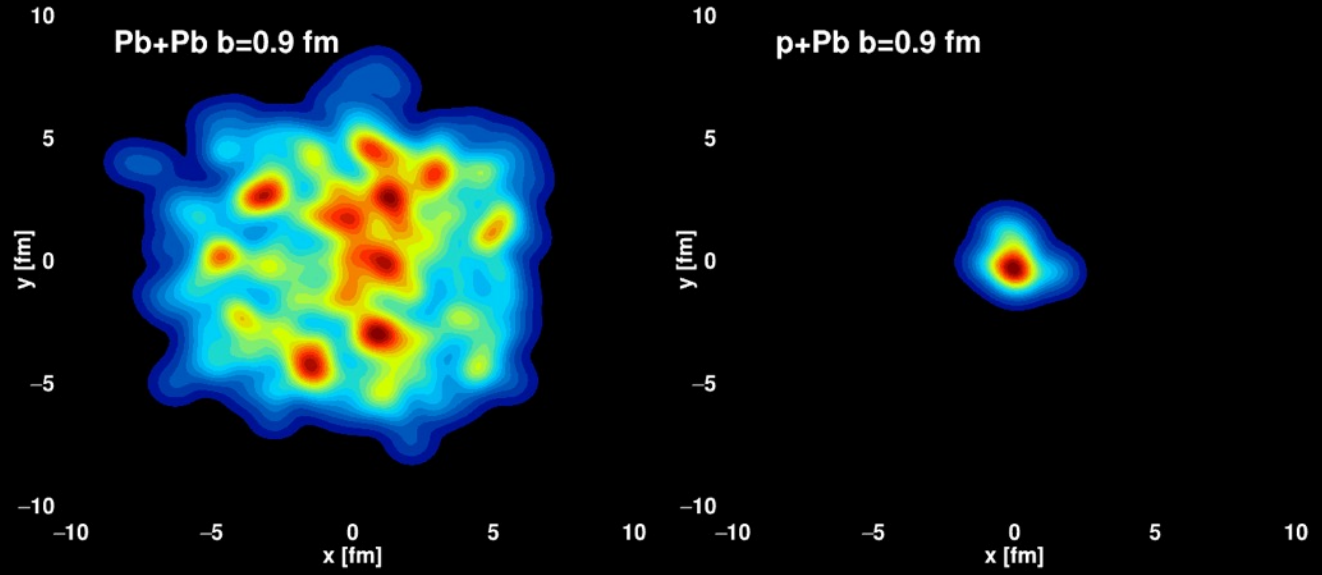
- There are many experimental results showing QGP-like behavior in small collision systems
- Sequential suppression in p+Pb collisions!



How about small collision systems?

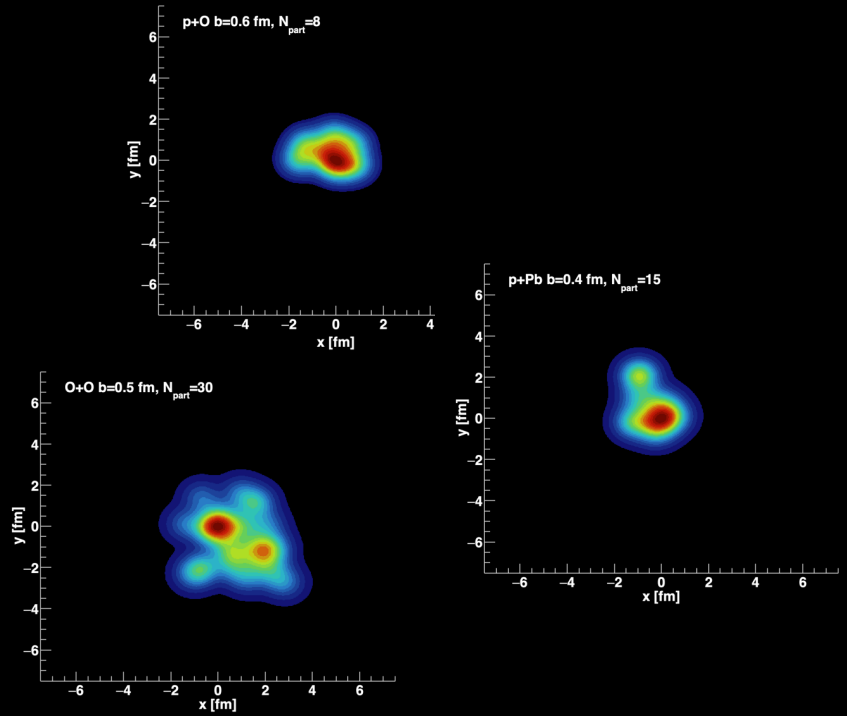
- There are many experimental results showing QGP-like behavior in small collision systems
- Can we simply extend this framework to small collision systems?
  - The size of p+Pb is **small** but may be still **hot!**

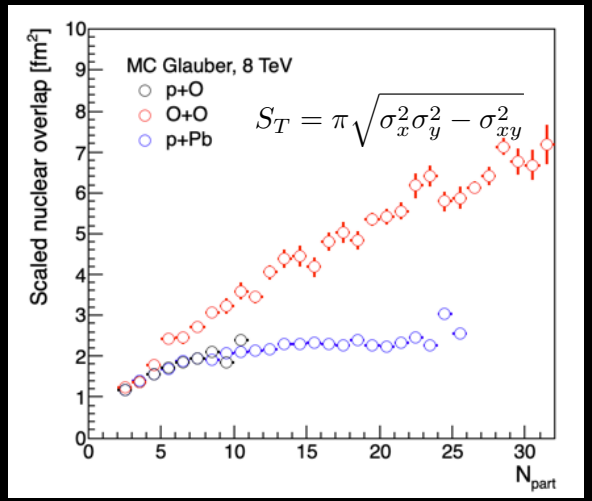
Initial geometry (MC Glauber)



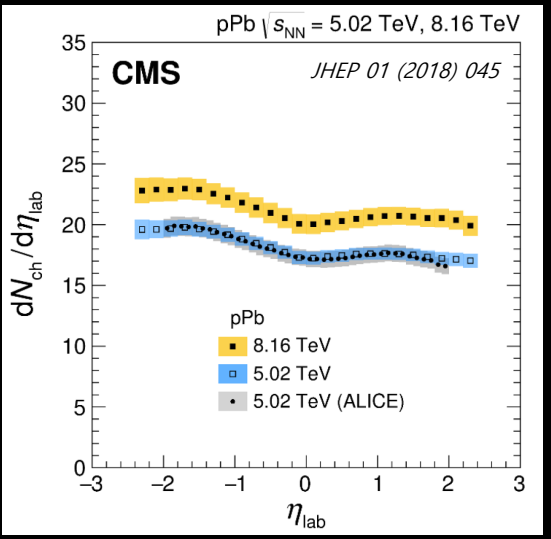
How about small collision systems?

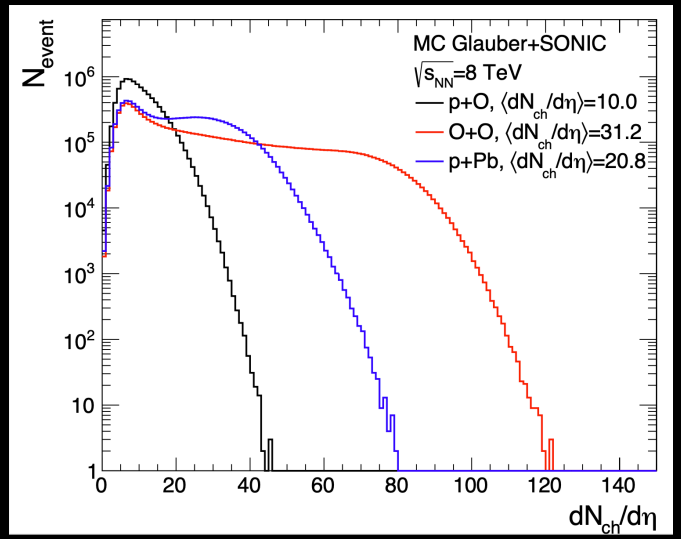
- There are many experimental results showing QGP-like behavior in small collision systems
- Can we simply extend this framework to small collision systems?
  - **Various size of small systems in the LHC Run-3**

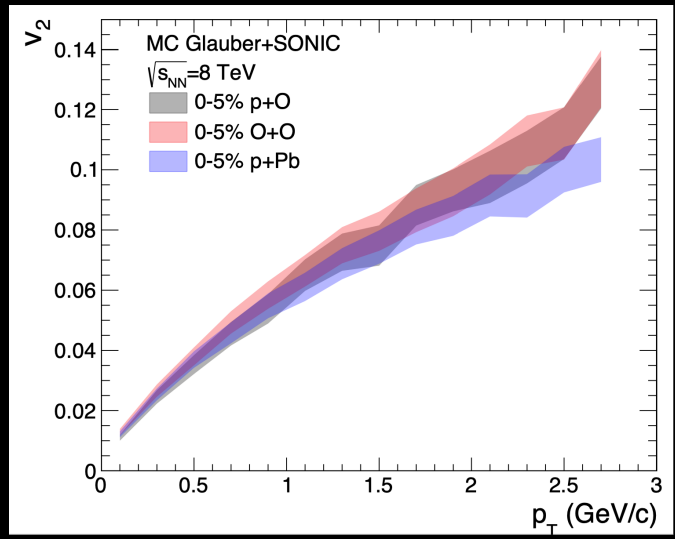




- p+Pb, p+O, and O+O in 8 TeV
- Scaling factor to convert MC Glauber initial condition to initial energy density for SONIC based on measured multiplicity in p+Pb 8 TeV

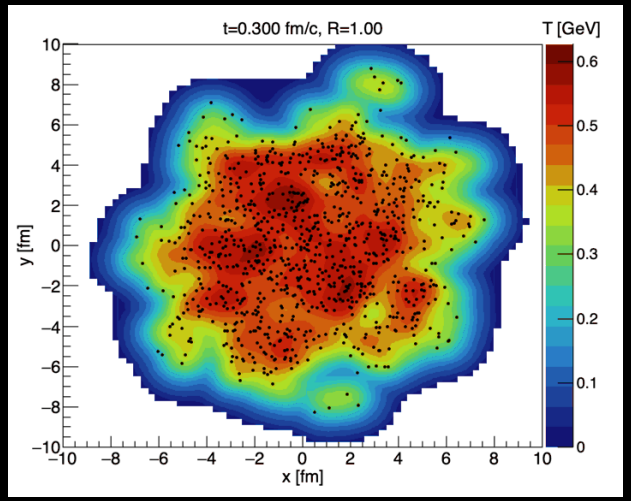




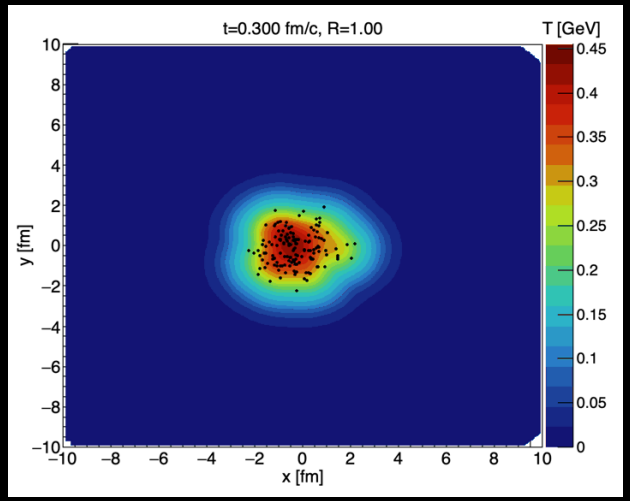


- Modification due to disassociation only
  - Utilize the same framework in all collision systems

Pb+Pb collision



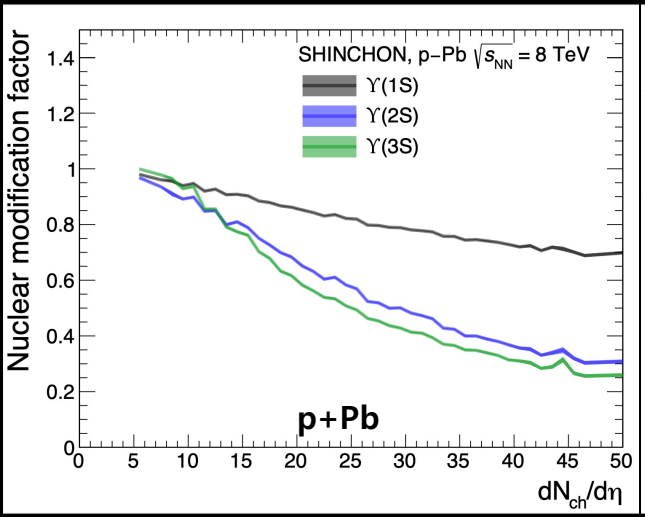
p+Pb collision

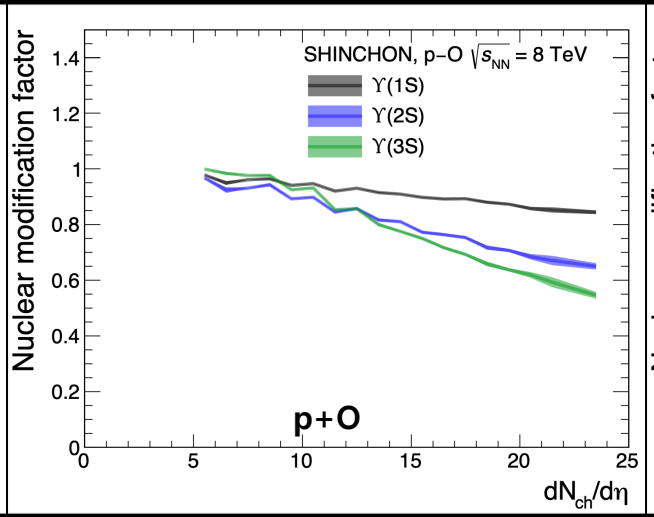


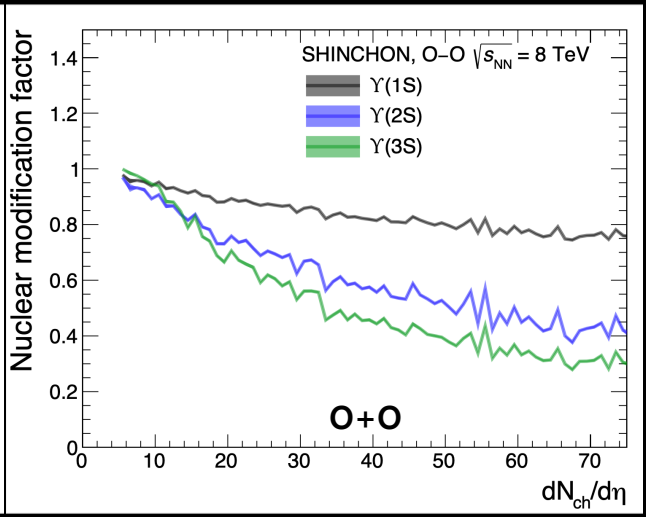
Only dissasociation effect is considered!

Modification of Y(nS) in small collision systems

- Modification due to disassociation only
  - Utilize the same framework in all collision systems







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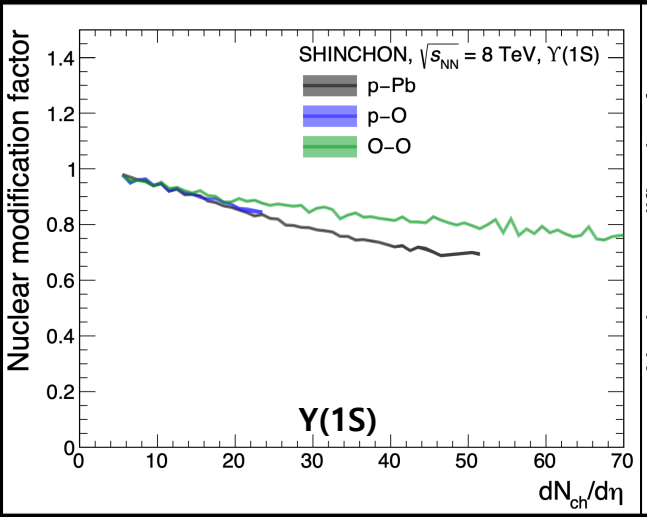

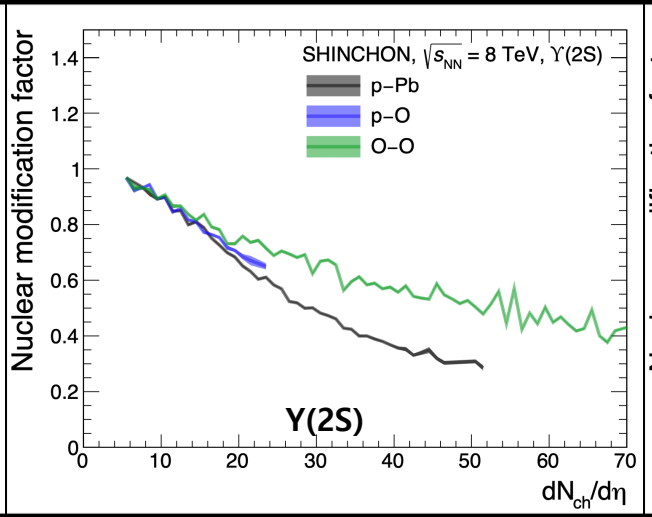

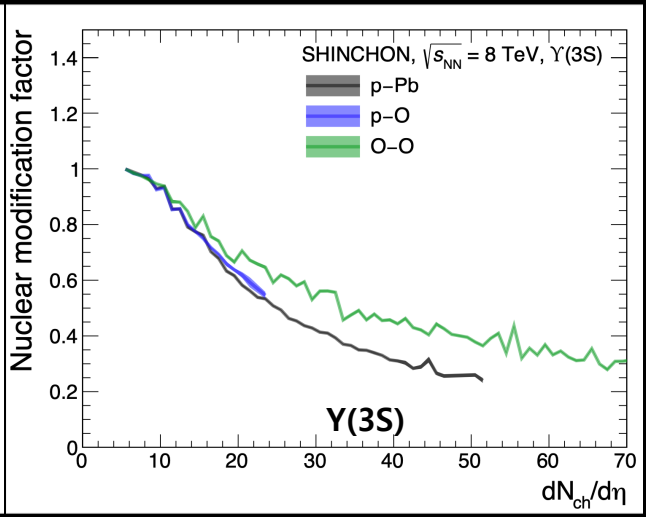

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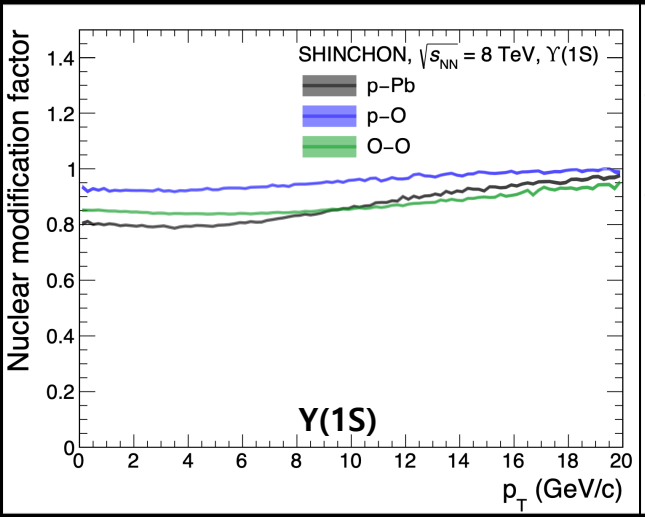
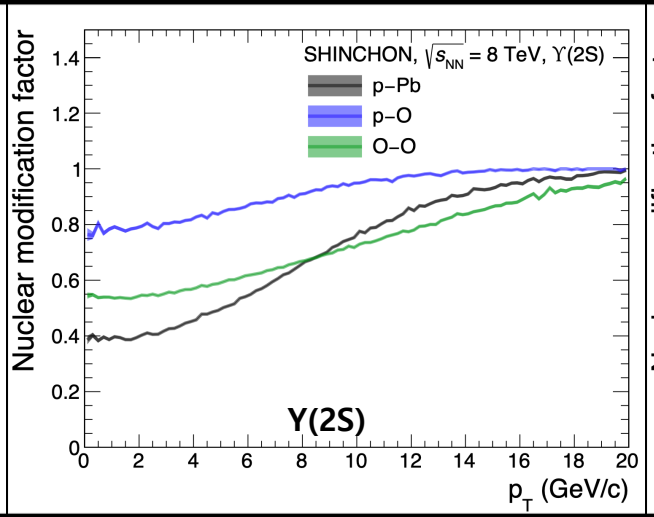
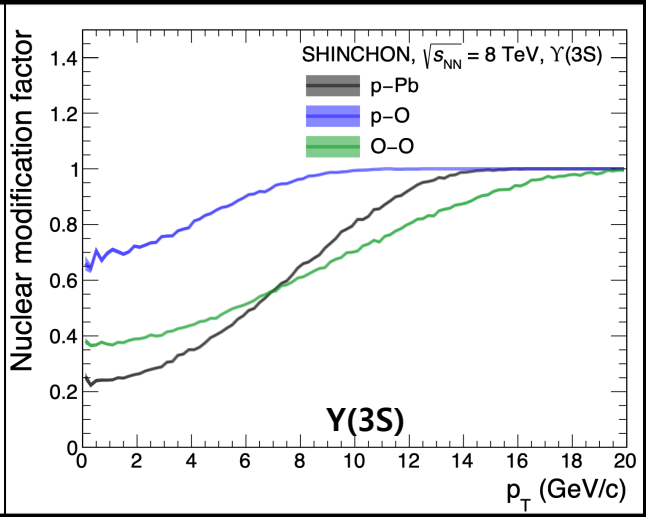
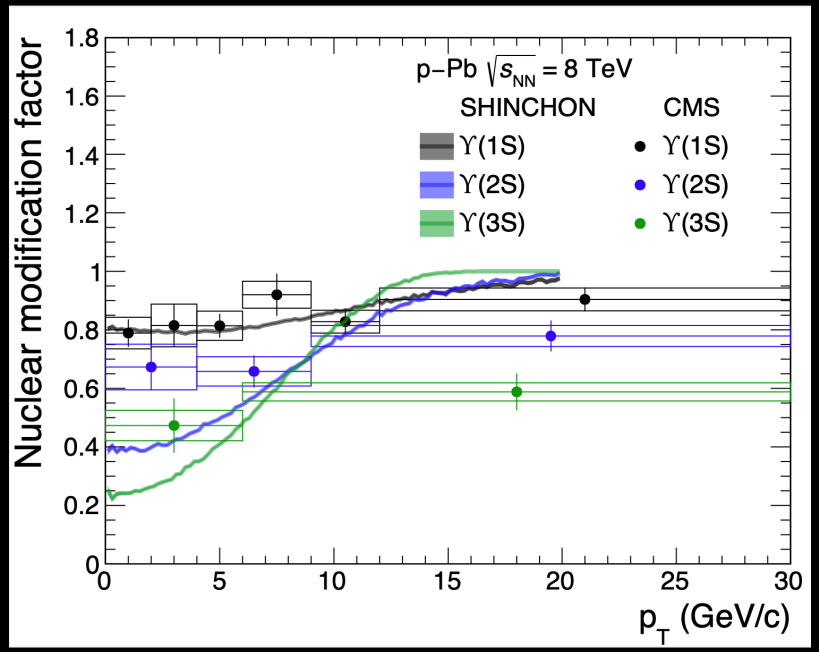






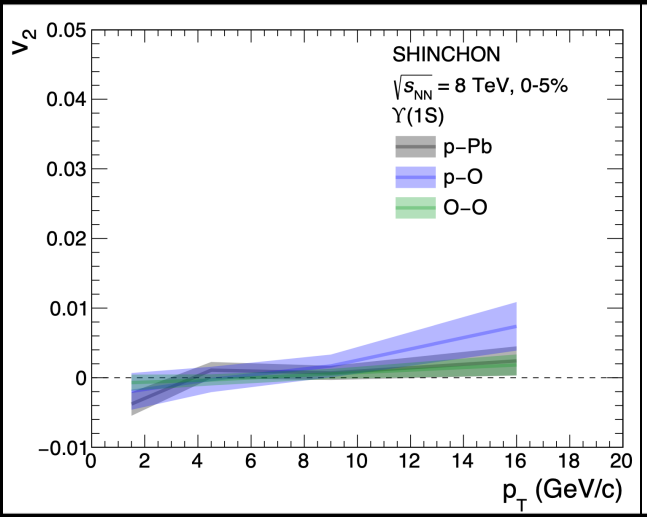
Modification of Y(nS) in small collision systems

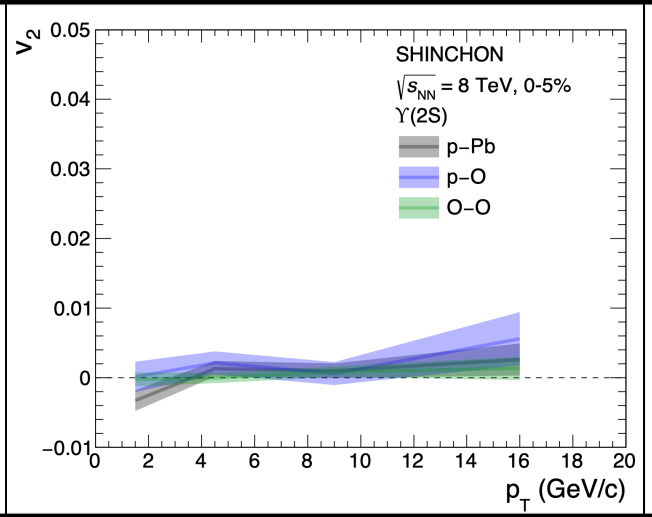
- Modification due to disassociation only
  - Utilize the same framework in all collision systems
- Comparison with CMS results

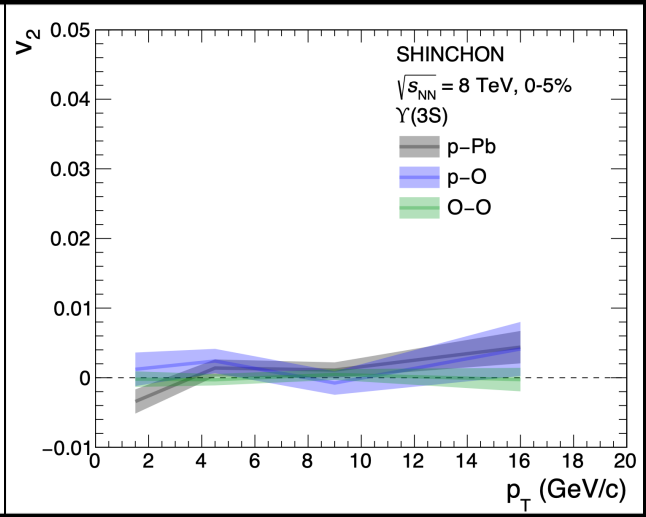


Elliptic flow of Y(nS) in small collision systems

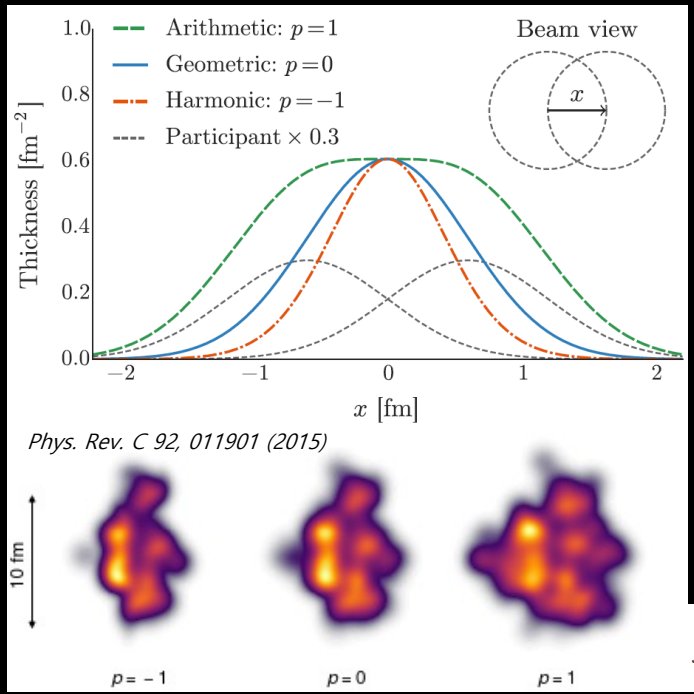
- Modification due to disassociation only
  - Utilize the same framework in all collision systems
- Event plane is calculated with wounded nucleons in MC-Glauber

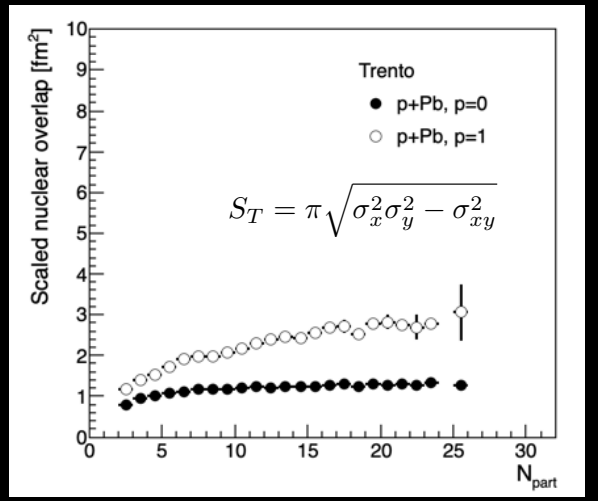






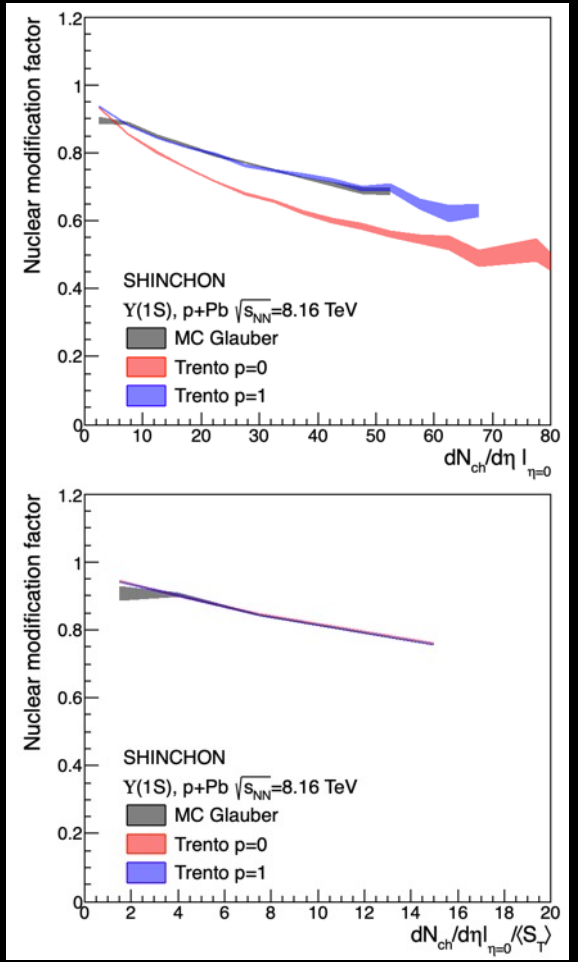
- Depending initial condition models, charged particle density varies
  - Different nuclear modification in collisions of the same total multiplicity





Very different overlap region!

$$f = T_R(p; T_A, T_B) \equiv \left(\frac{T_A^p + T_B^p}{2}\right)^{1/p}$$



Summary

- Simulation study for Upsilon production in heavy-ion collisions
  - Medium evolution with hydro (SONIC)
  - Dissociation based on thermal widths of different states
- Useful to investigate what can be explained and what is missing
- 3D hydro can be utilized for a more detailed study

arXiv:2209.12303

Model study on $\Upsilon(nS)$ modification in small collision systems

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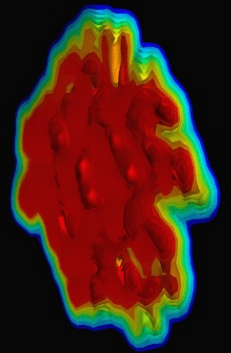
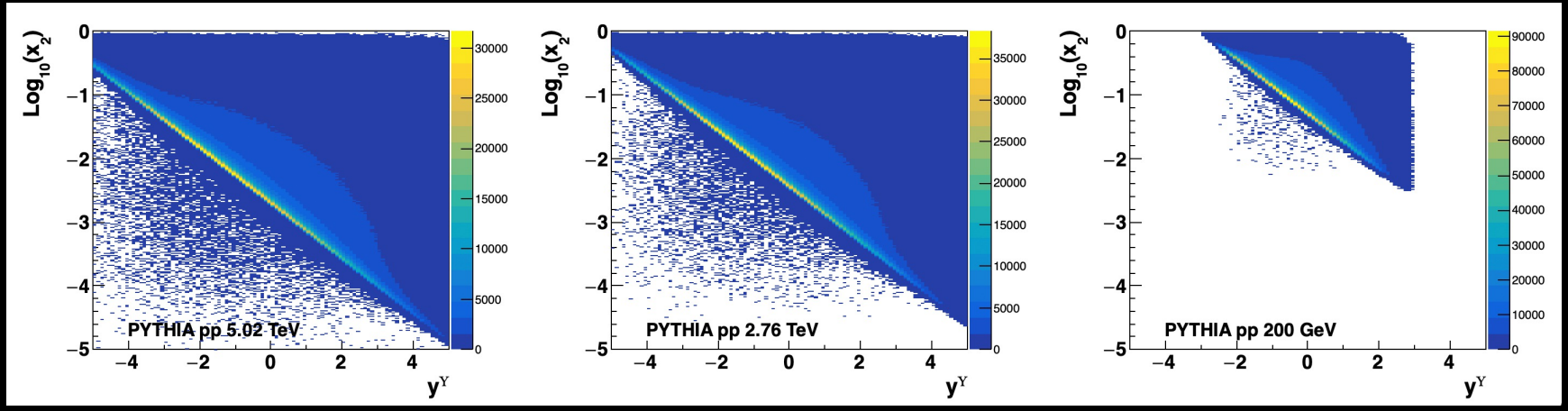
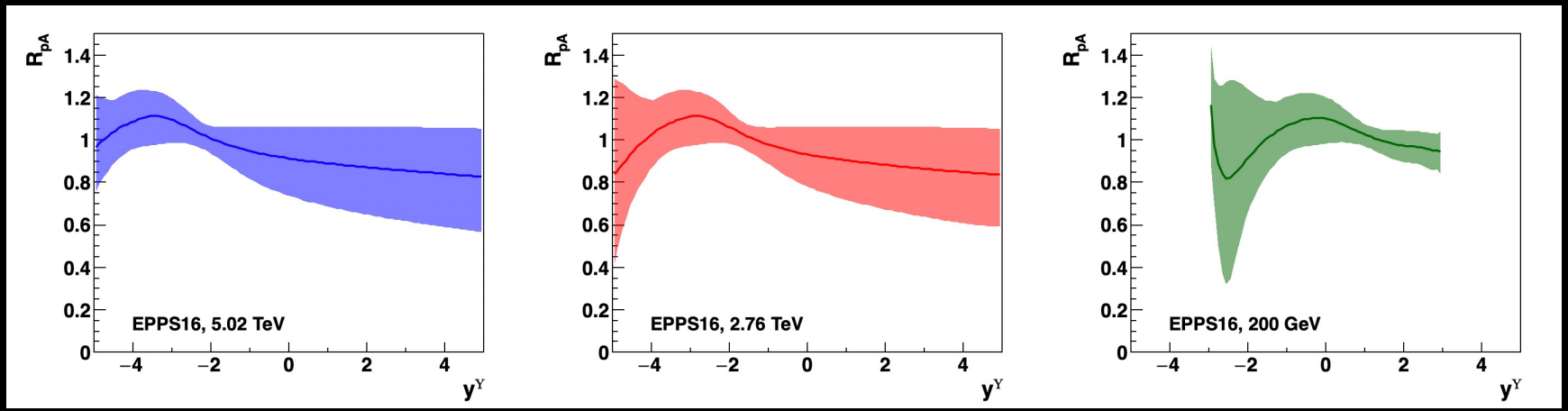
(Dated: September 27, 2022)



B. Schenke

BACKUP





Small nPDF modification at mid-rapidity