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Two slit interferometer at fermi scale:
Coherent photoproduction from **UPC** to **HHIC**

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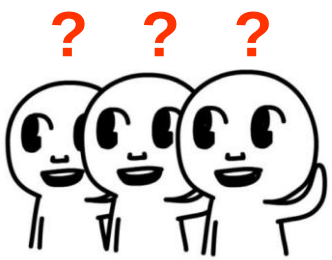
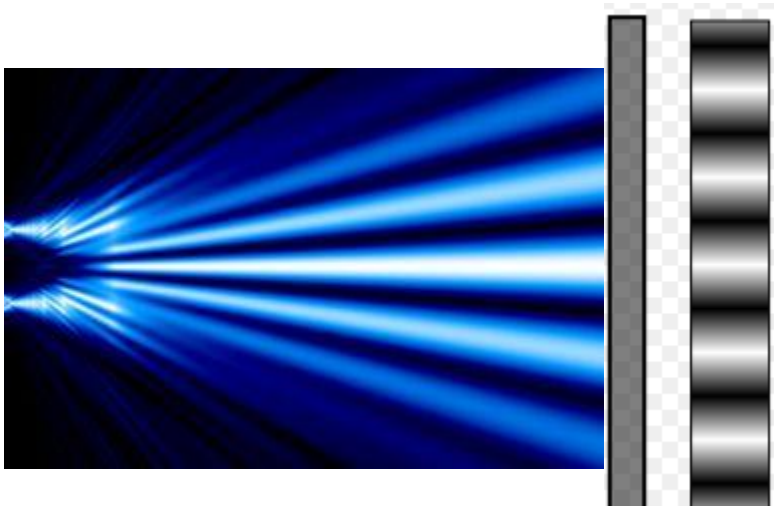
The heart of quantum mechanism
Wave-particle duality

Young's Double-Slit Interference Experiment

Which slits?





Path length differences result in a phase shift, creating an interference pattern!

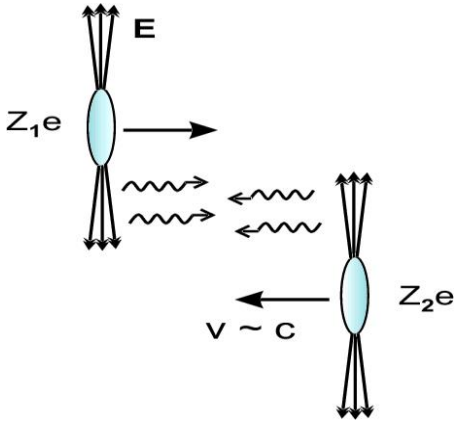
Interference of individual particle?

Interference of particle species: photon, electron, proton, neutron, atom, molecule, fullerene…

Demonstrate the principle of wave-particle duality!

All of quantum mechanics can be gleaned from carefully thinking through the implications of this single experiment! --- Feynman

Entities for the interferometer
Coherent photon products



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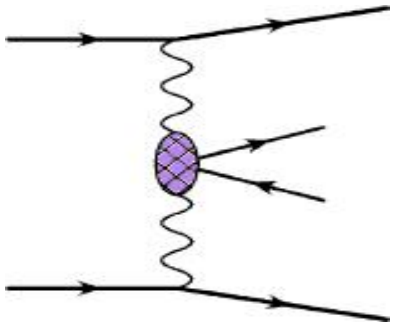
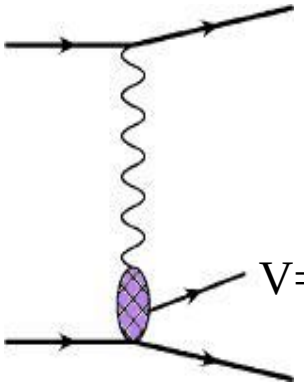


Photon-photon interactions

+

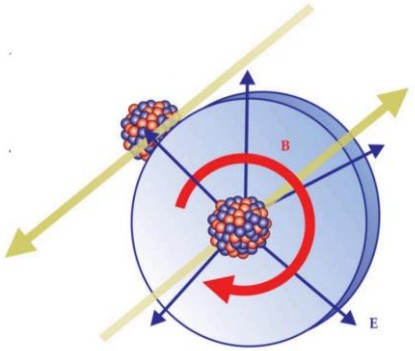


Photon-nucleus interactions

Ann. Rev. Nucl. Part. Sci.**55**:271 (2005)

$V=\rho, \omega, \phi, J/\psi$

- View photons as "partons" being present with fast moving ions!
  - ✓ Photon-nucleus interactions: Vector meson
  - ✓ Photon-photon interactions: dileptons …
- The extent of photons swarming about the ions:
  - ✓ Take the photoproduction of ρ (Au+Au 200 GeV)in ultra-peripheral collisions (UPCs) as example: $\langle R_{producton} \rangle \sim 40$ fm $R_{photons} >> R_{Nuc}$



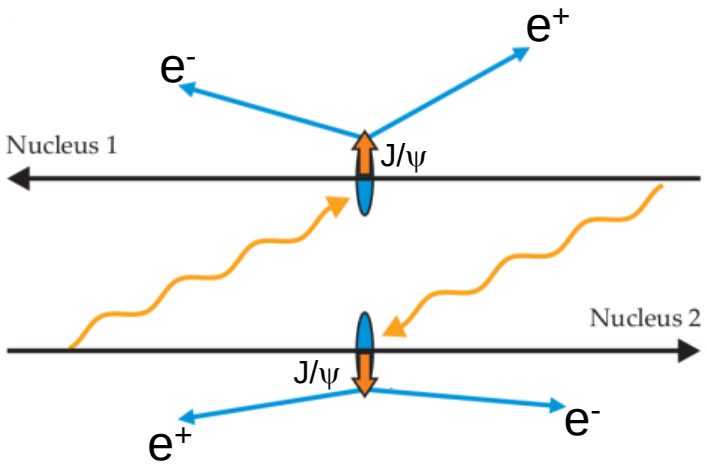
Physics Today **70**, 10, 40 (2017)

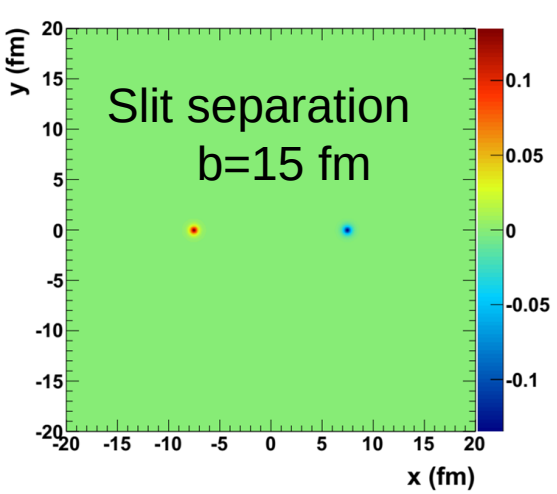
The setup of the interferometer

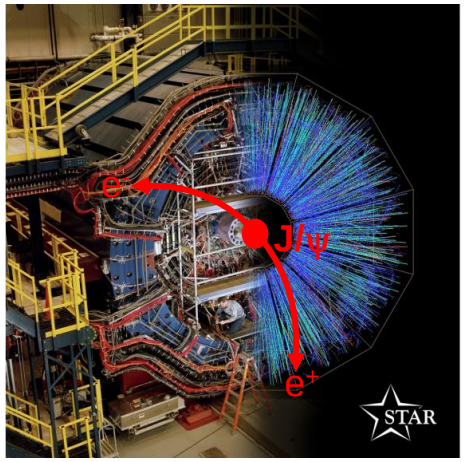
- The choice without information:
  - ✓ Which is photon emitter?
  - ✓ Which is the Pomeron provider?

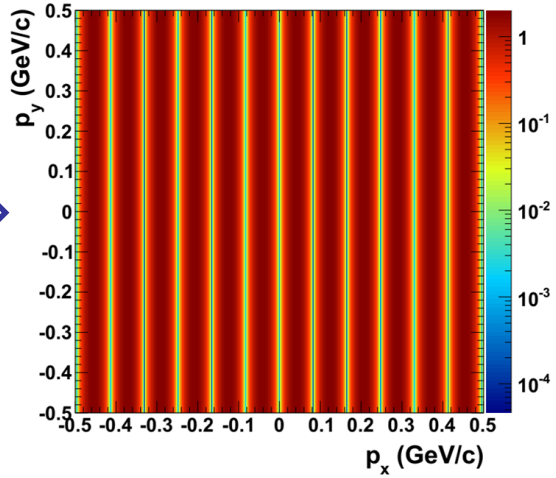
The slits: two colliding nuclei

Interferometer of individual J/ψ



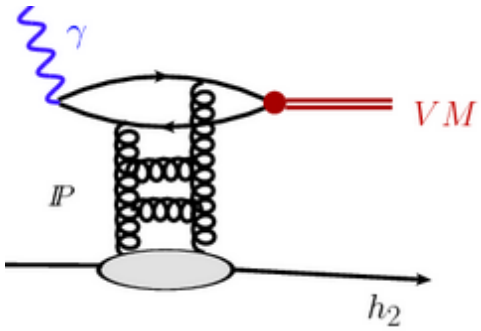






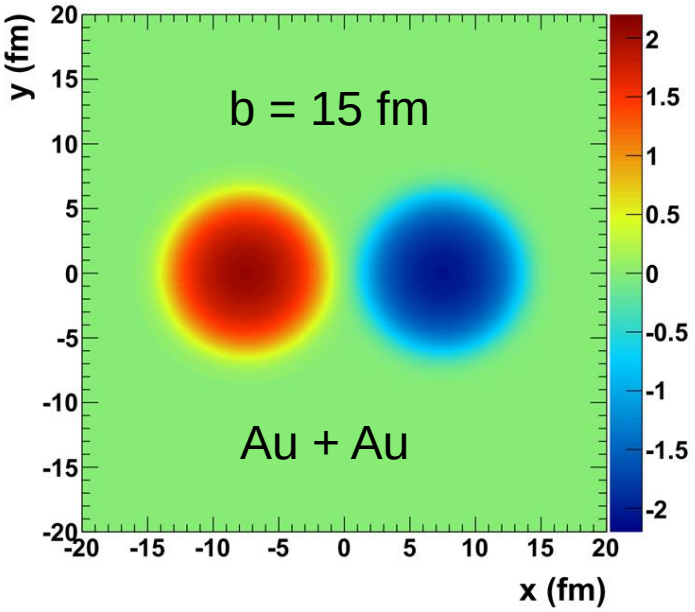
✓ The parity of J/ψ is -1, the phase shift between the two slits is π

The size of slits



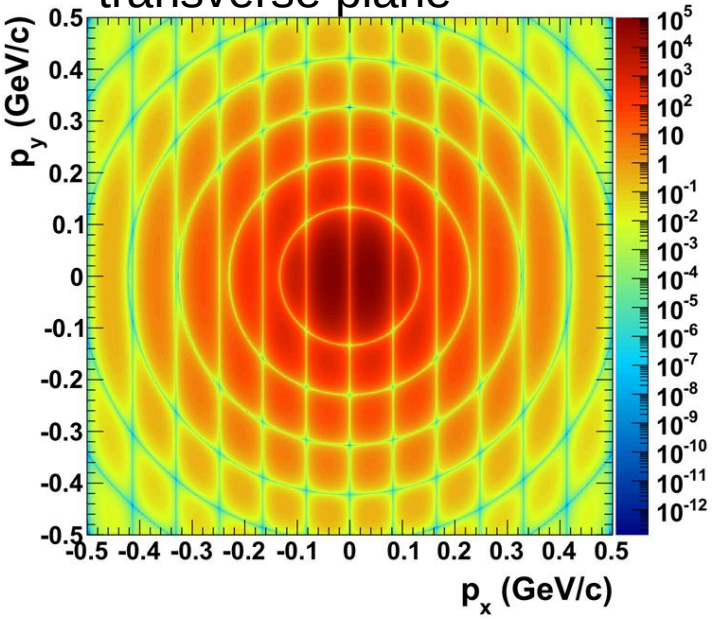
Production rate ∝ Pomeron density ∝ gluon density^2 ∝ nuclear density^2
Amplitude ∝ nuclear density

Amplitude density



Wood-Saxon distribution

Momentum distribution in transverse plane

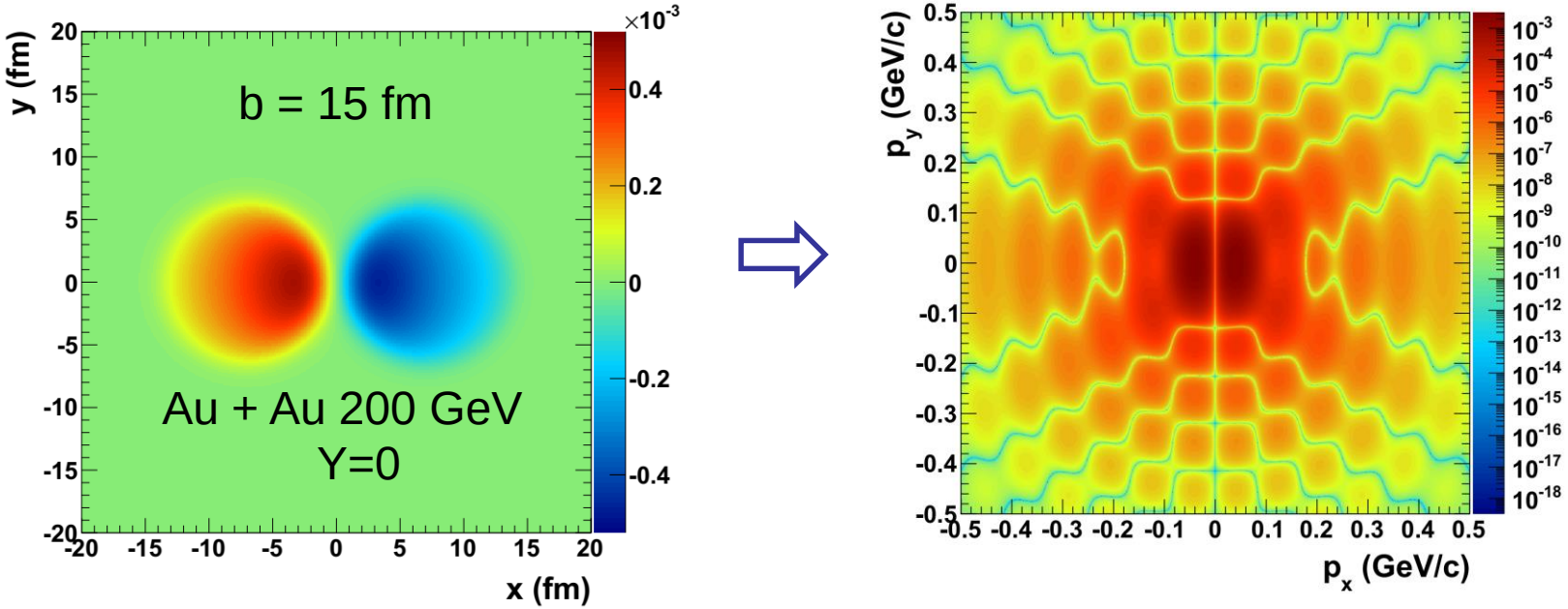


J/ψ y=0

Interference fringes + diffraction rings

The final interference pattern

EPA flux + VMD approach



- The slits become more asymmetric!
  - ✓ The interference + diffraction pattern changes.
- This interference pattern can not be observed in ultra-peripheral collisions.
  - ✓ No special azimuthal direction can be determined as reference.
- Only possible in hadronic heavy-ion collision --- the two nuclei collide
  - ✓ Reaction plane can be precisely obtained

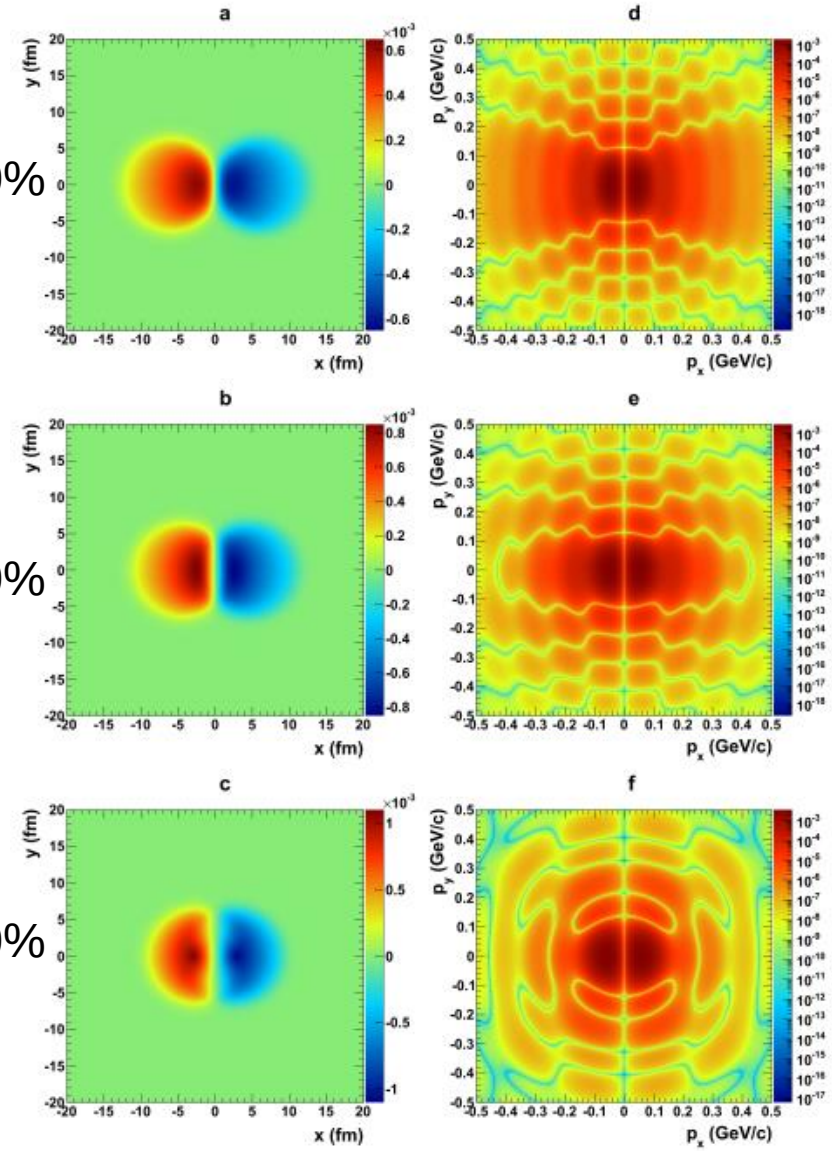
Can we change the distance between the slits?

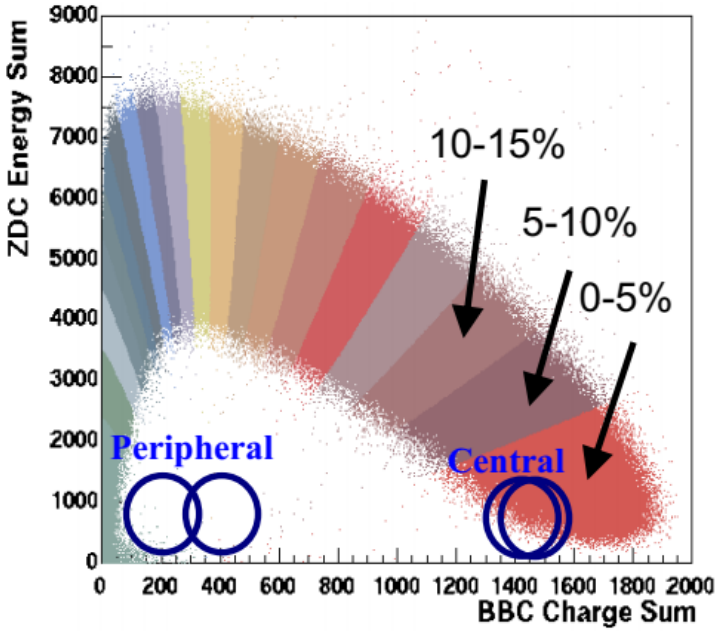
Centrality dependence

70 - 80%

40 - 50%

20 - 30%





- The slit separation --- impact parameter can be precisely determined by the detector!

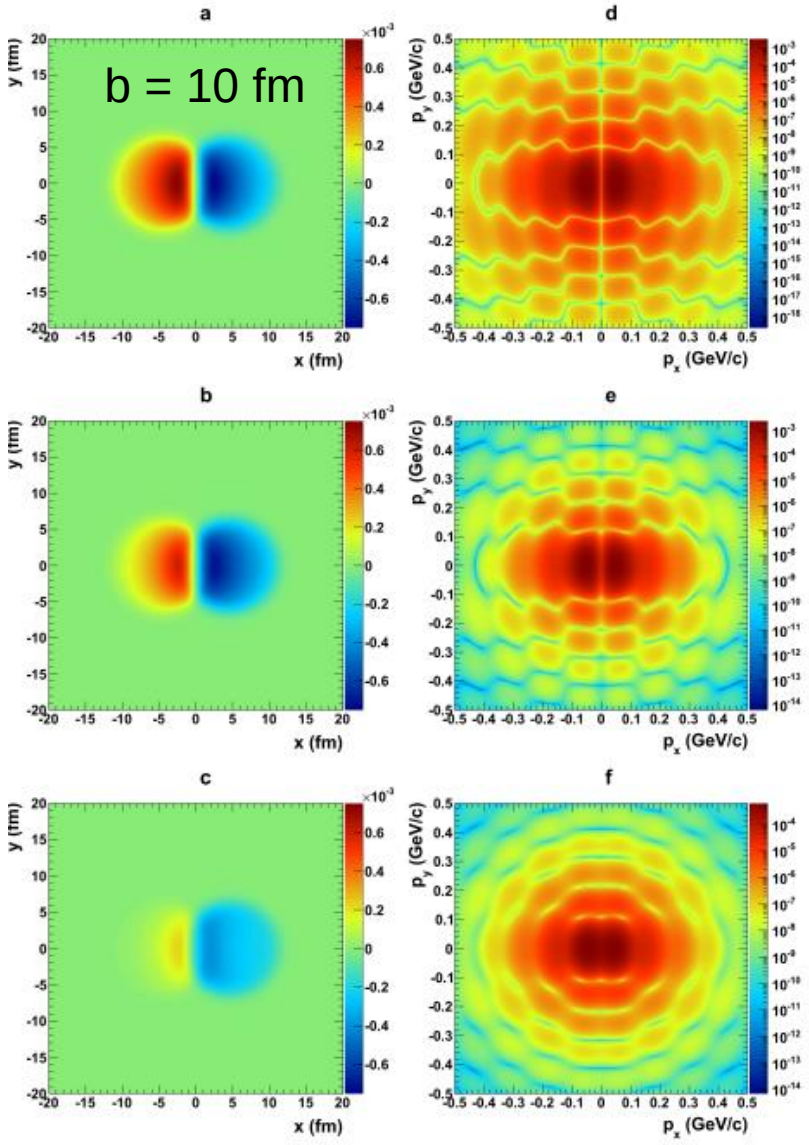
Can we dim one of the slits?

Rapidity dependence

Y=0

Y=0.6

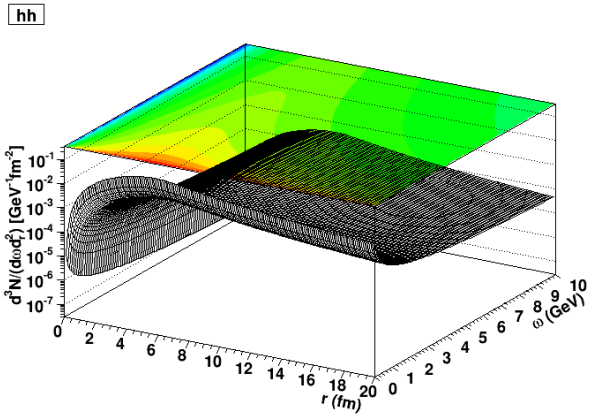
Y=1.4



The photon energy from the two direction :

$$w_1 = \frac{1}{2} M_{J/\psi} e^{+y}$$

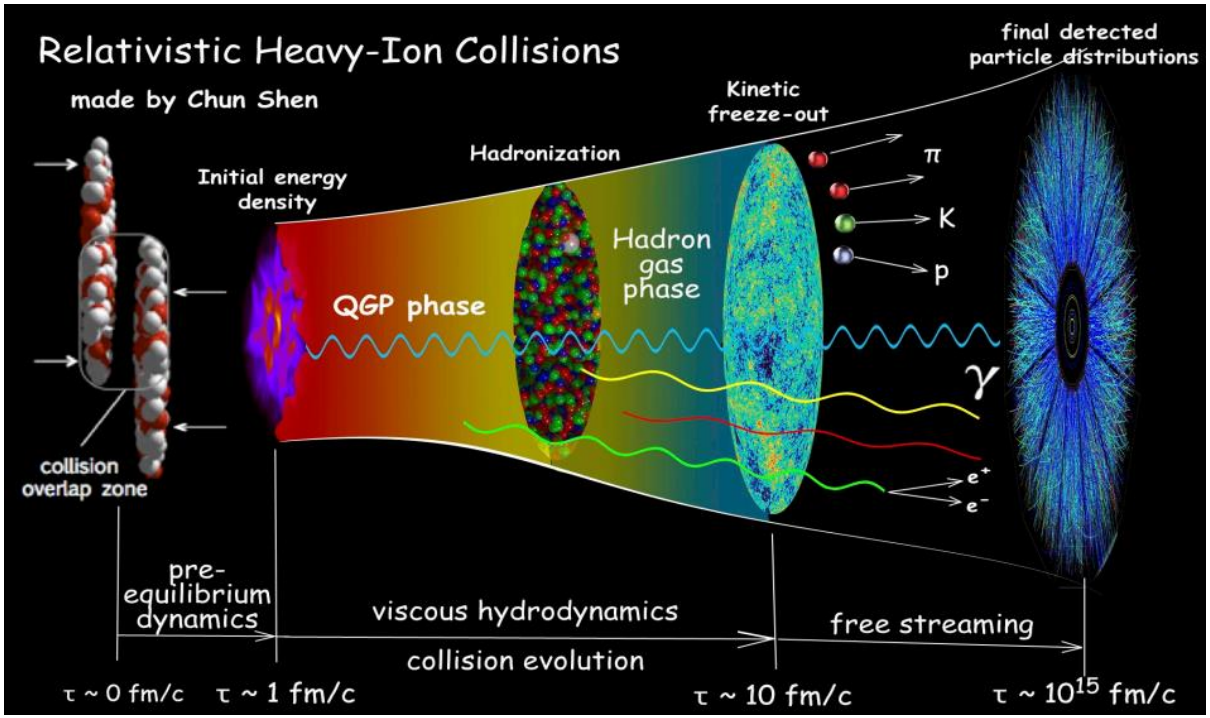
$$w_2 = \frac{1}{2} M_{J/\psi} e^{-y}$$



- The amplitude from the two direction will change with rapidity!

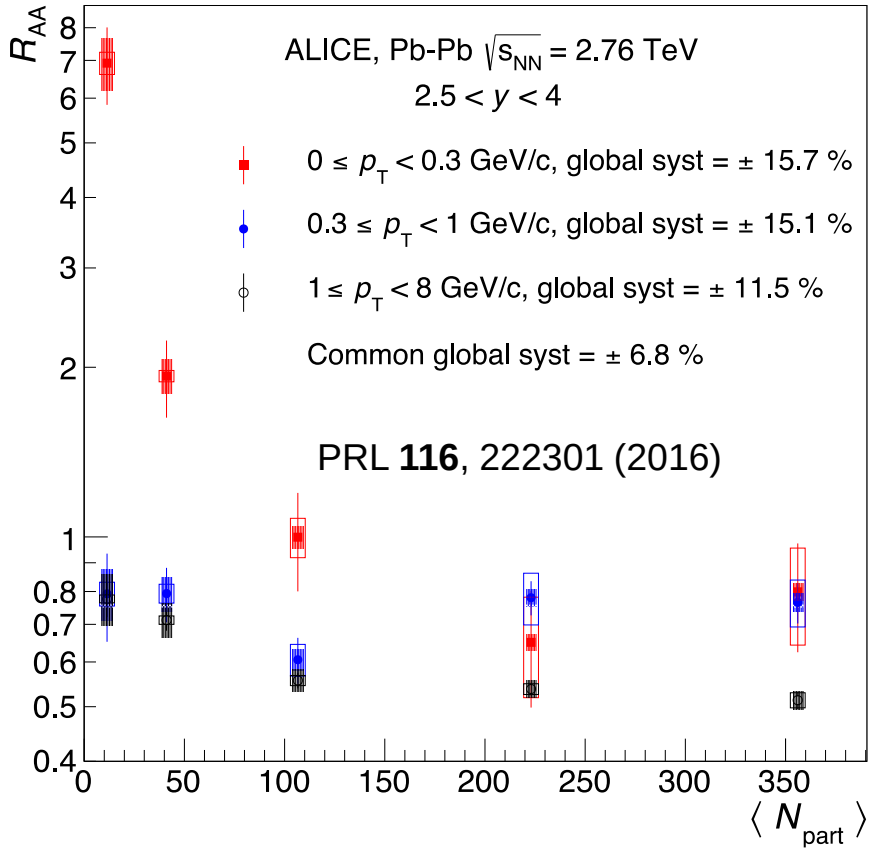
Observation Affects Reality!

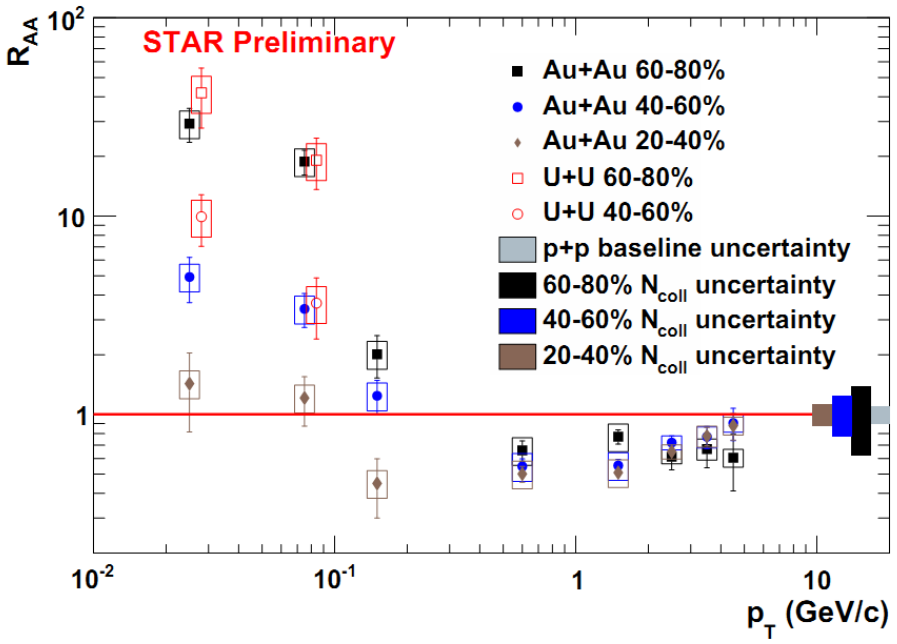
- Take the Young's Double-Slit Interference Experiment as example:
  - ✓ If we place detectors at the slits, knows which slit the photon goes ("which-way" or "path" solved), the interference pattern disappear!
    --- Observation collapse the wave function!



- The hot medium (QGP) detect the J/ψ, and prohibit the coherent photoproduction?

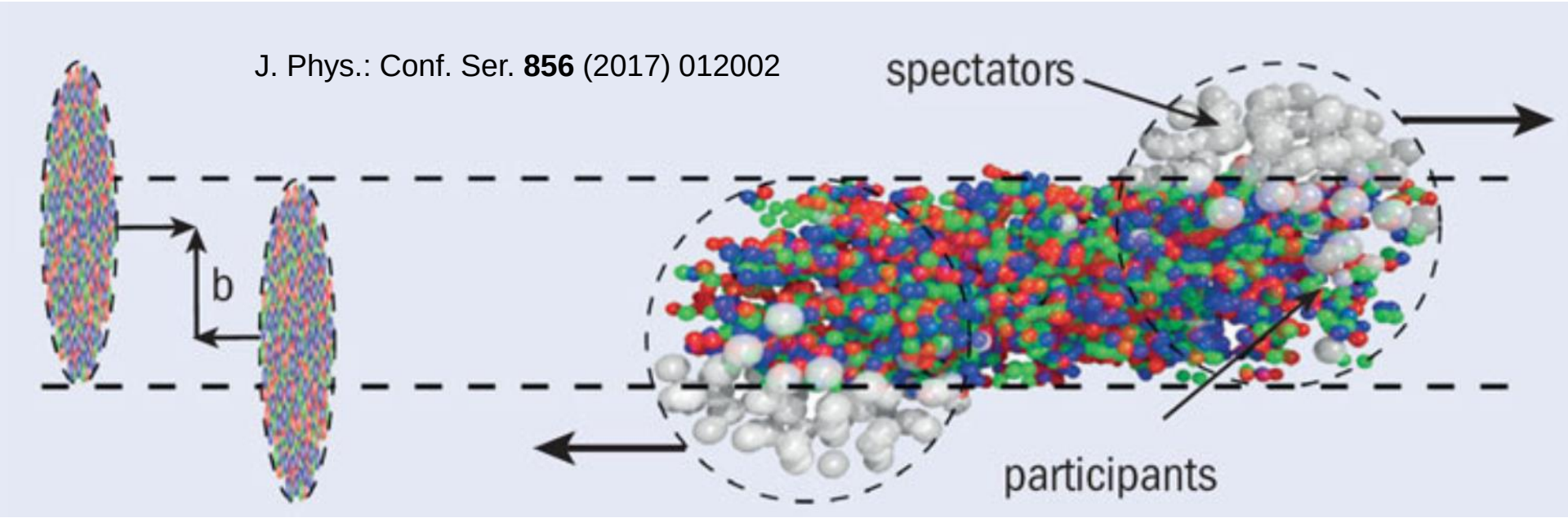
The coherent photoproduction in HHIC!





- Coherent produced J/ψ are observed in HHIC!

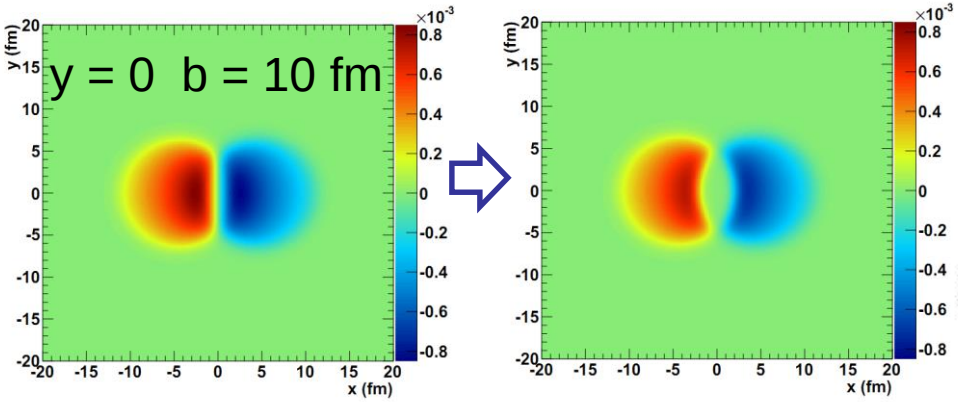
Why?



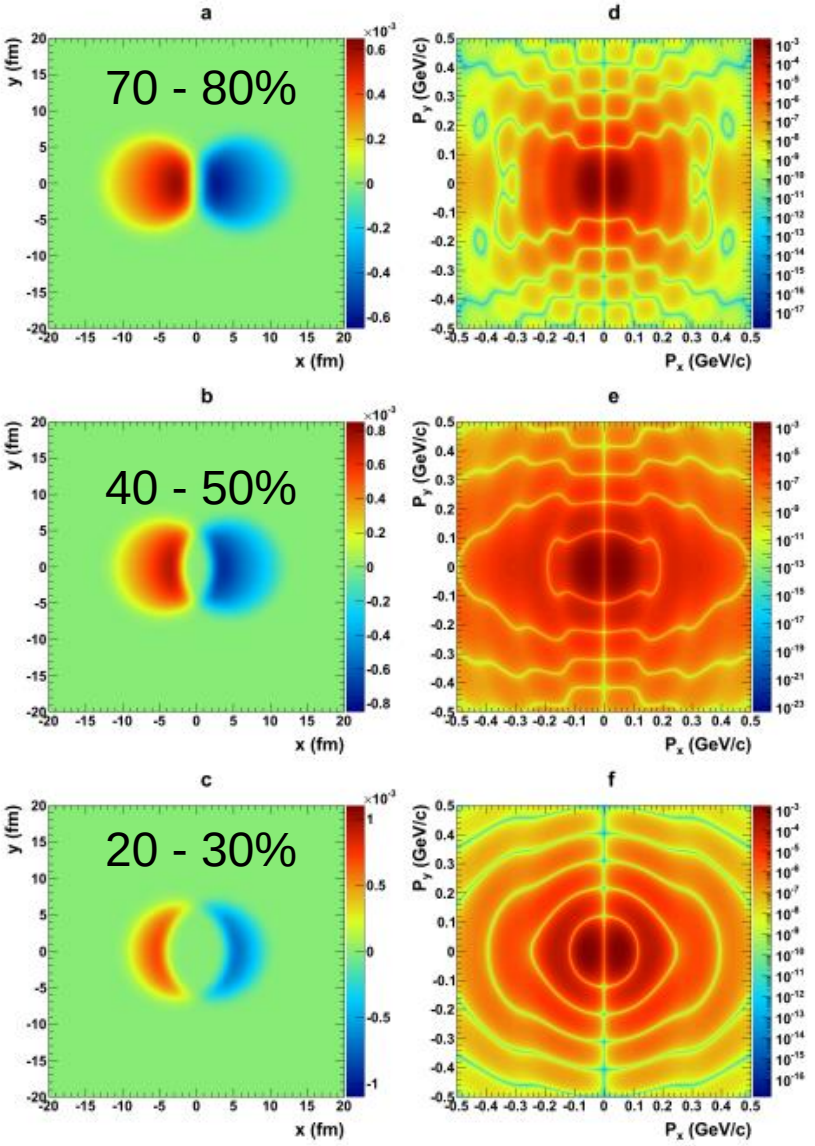
- The strong interactions in the overlap region observe the created J/ψs in this region, solve the “which-way” or “path” problem for the J/ψs in the overlap region!
  - ✓ The interference in this area disappear!
- The slits are only sectional blocked!

The interference with observation effect

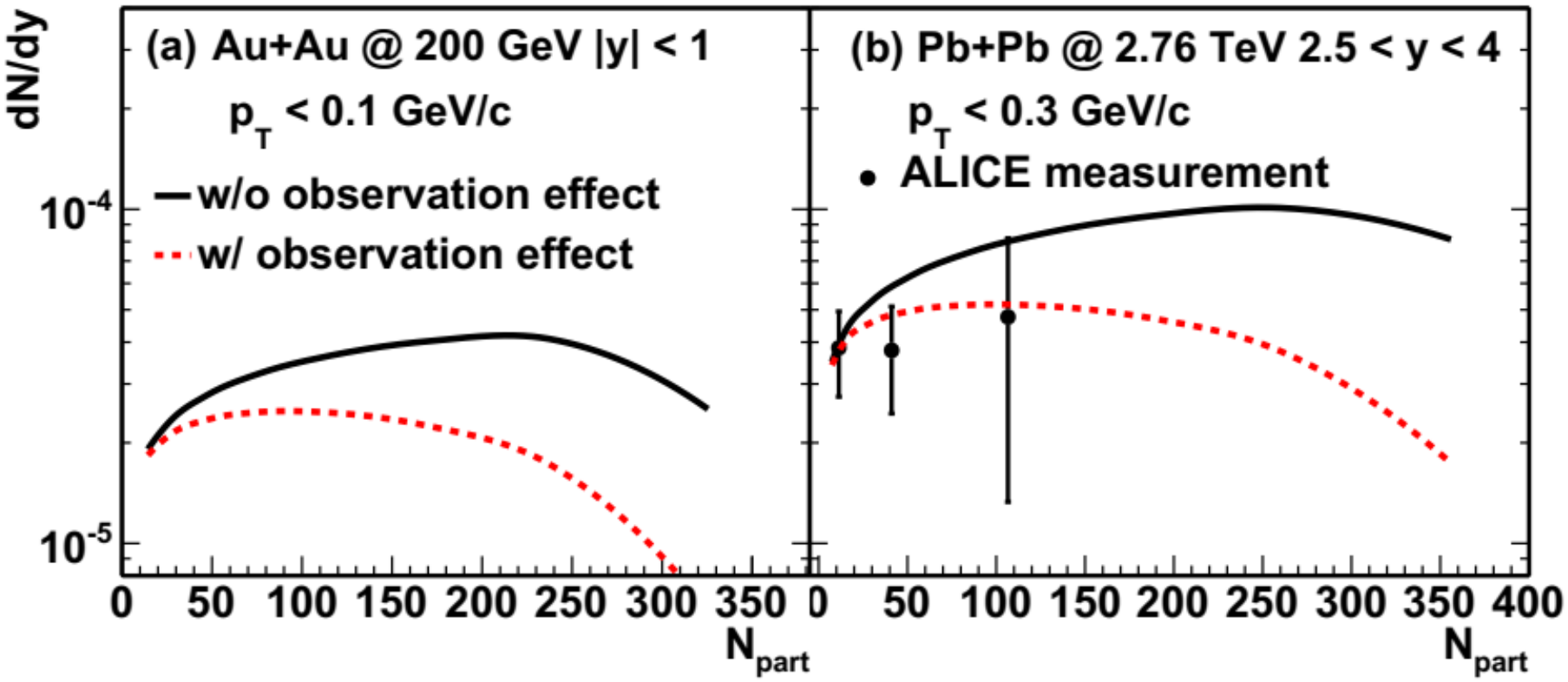
Exclude the amplitude in the overlap region!



- The interference and diffraction pattern change significantly with the observation effect!



The observation effect on cross section



- The observation effect significantly reduce the cross section!
- The calculations with observation effect describe the data better!

Summary

- The two-slit interferometer at fermi scale
  --- coherent photoproduction in heavy-ion collisions
  - ✓ Interference entities --- J/ψ
  - ✓ The radius of the slit --- at the level of fm (Au: 6.3 fm)
  - ✓ The distance between the slits --- at the level of fm (0 – 13 fm for Au+Au 200 GeV)
- Vary the distance between the slits --- centrality
- Adjust the relative brightness between the slits --- rapidity
- Check the observation effect --- complementary principle
- Looking forward to the experimental measurements