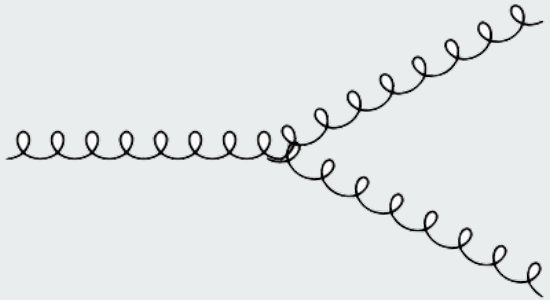
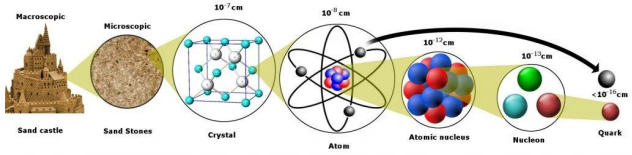
Shining light on the *glues* that bind us all



Kong Tu
Physics Department
09.09.2022

The strongest glue



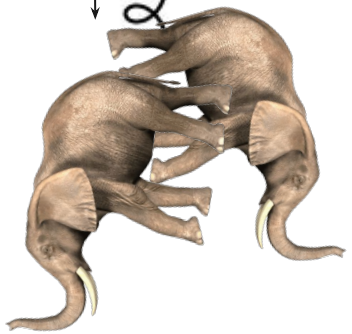
Fact sheet:

- Strong force, one of the four fundamental forces, is carried by the gluon. (stronger than gravitational force by 10^{38} times!)
- More than 99% the mass of visible matter is due to the presence of gluons - holding nucleons and nuclei together.
- Gluon: (almost) no mass itself, no electric charge, spin - 1, but the fundamental role of gluon in visible matter remains elusive.

quark

10^{-15} meter

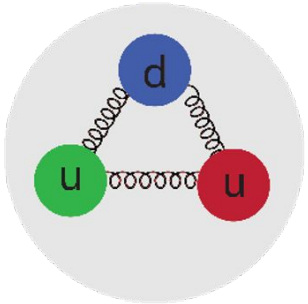
The gluon is super strong!



> 10 tons!

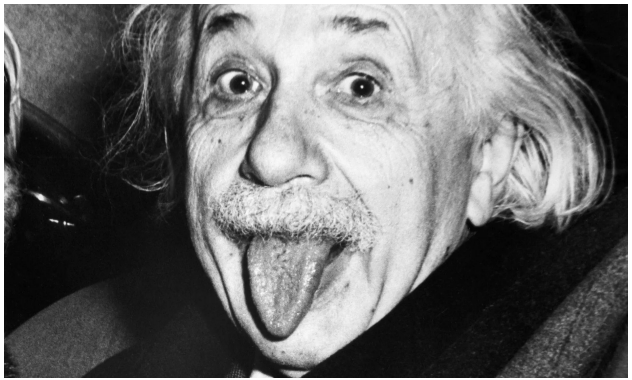
Gluons are everywhere, how do we find them?

Proton



Proton is sitting at rest in the lab

Einstein can see only 3 quarks and very few gluons.



An observer sitting at rest in the lab

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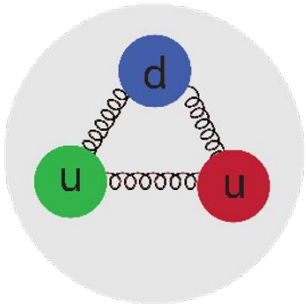
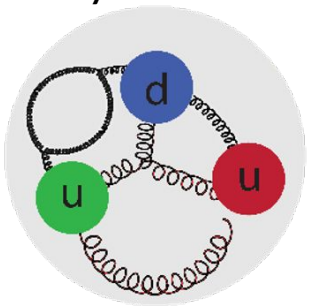
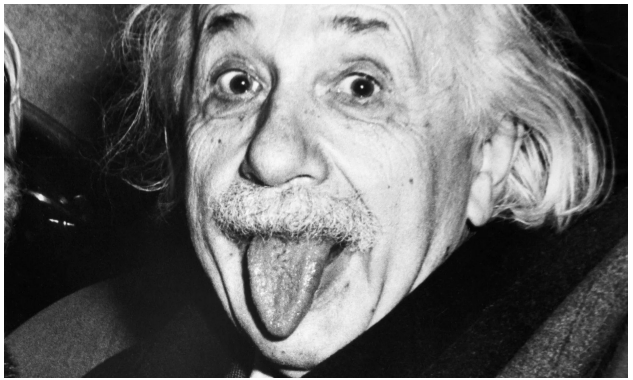


More gluons are showing up, as they are *slow*…



Speed of the proton (energy)

Special relativity - time dilation!



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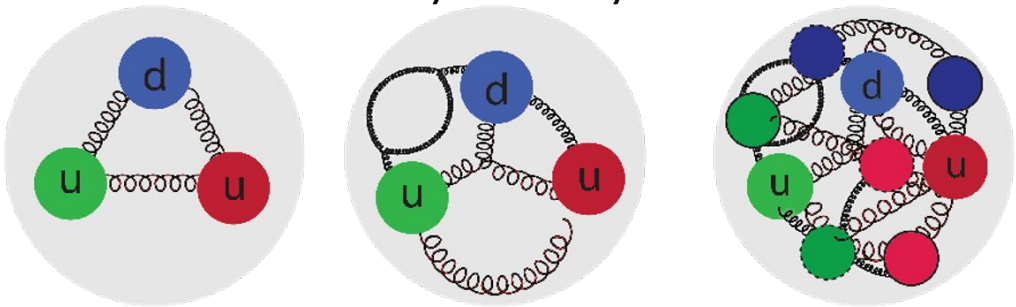

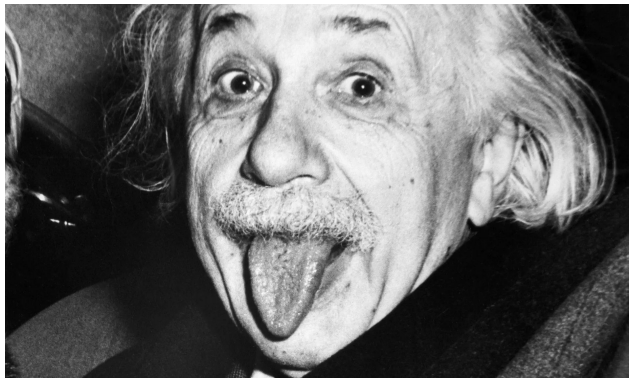

An observer sitting at rest in the lab

Speed of the proton (energy)

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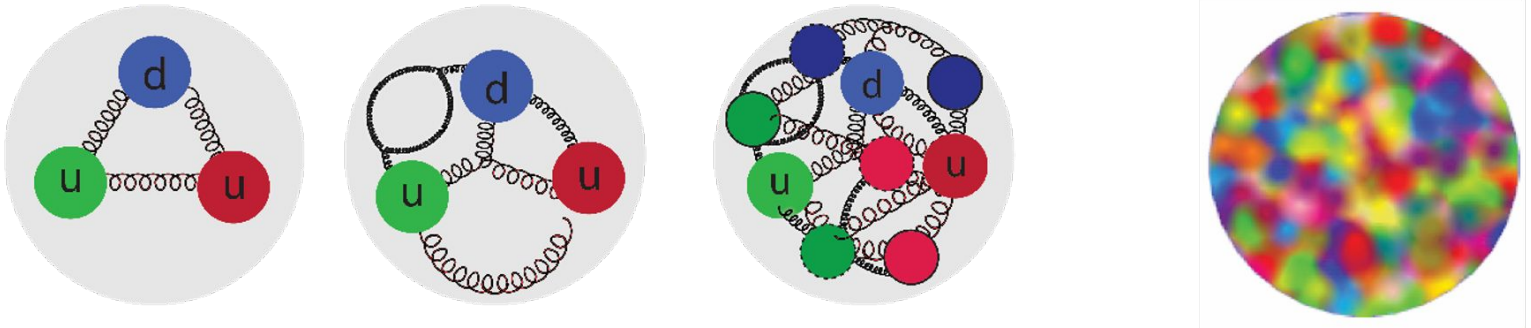


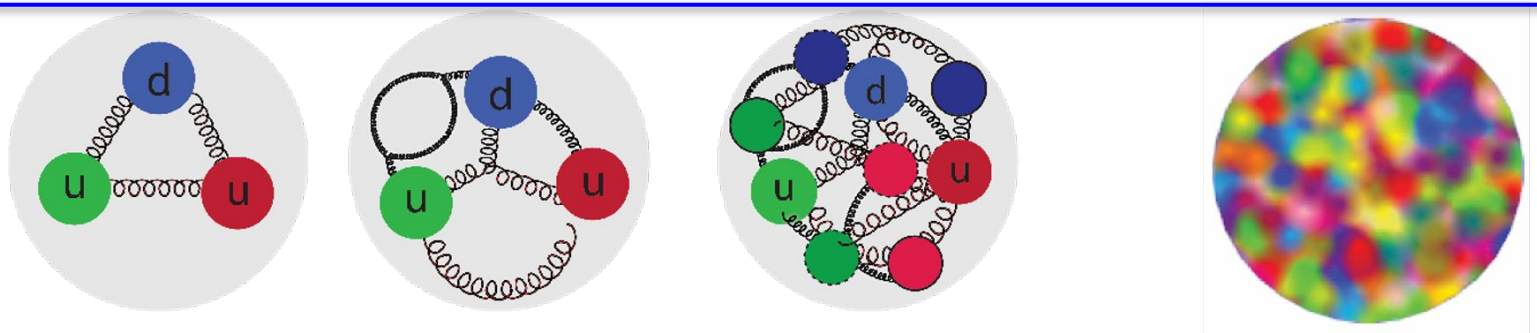
Speed of the proton (energy)

Now the proton has nothing else but gluons!

Gluons are everywhere, how do we find them?

Gluons are not only strong, but also abundant; we just need to accelerate them to high speed - Relativistic Heavy-Ion Collider at Brookhaven!

Proton



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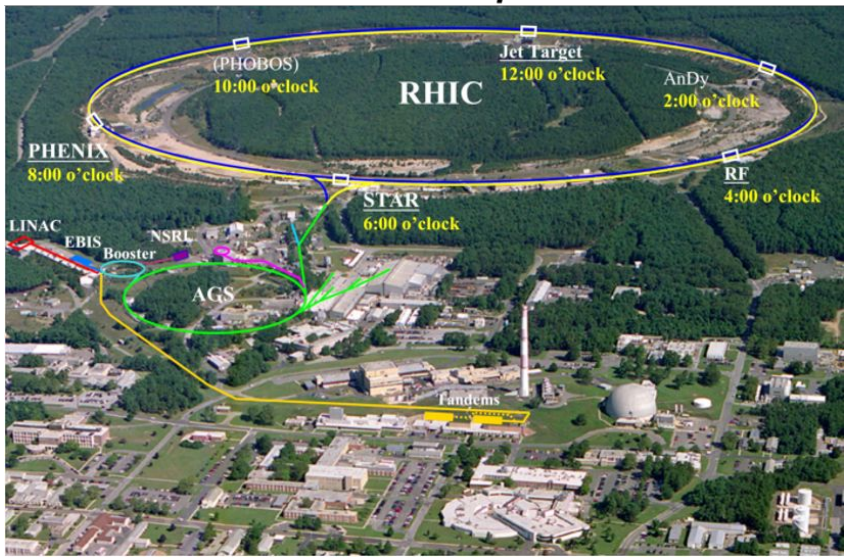
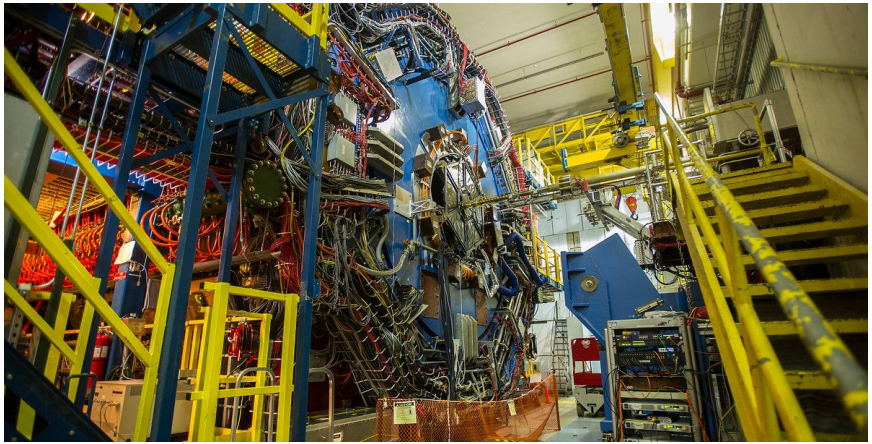
Particle collider experiments to study gluons

“Femtoscope”

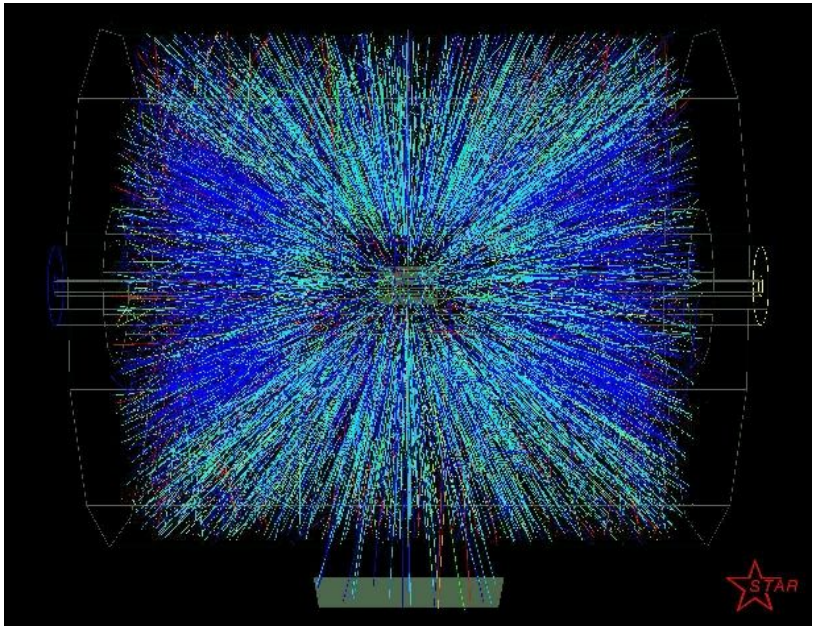


STAR detector



It’s like a super high-resolution camera to take billions of pictures every year to study particles like gluons

Particle collider experiments to study gluons



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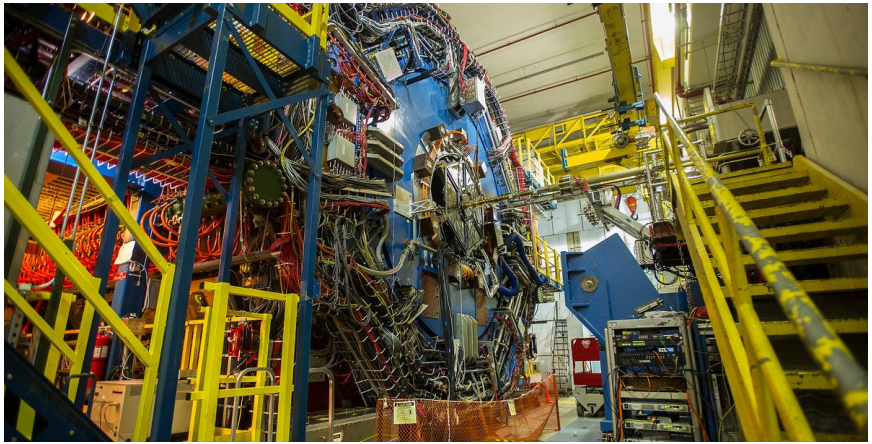

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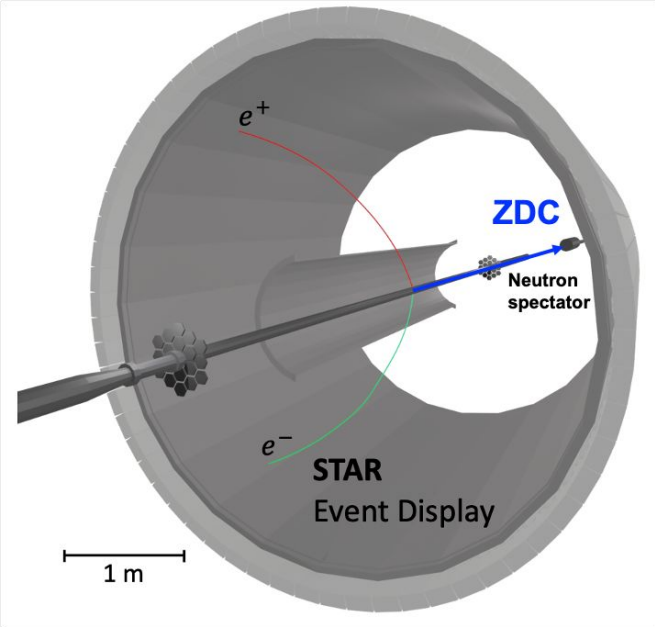
(events)

Among many pictures, a direct probe to study gluons:



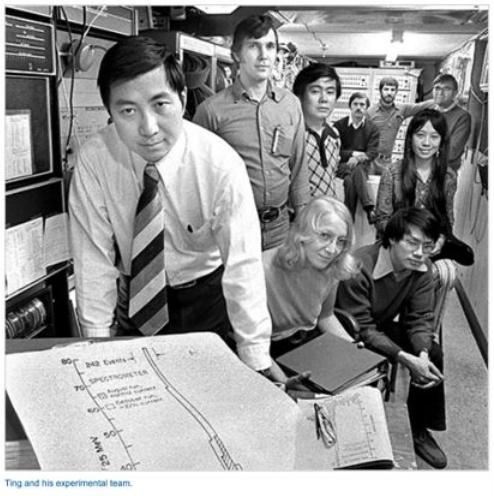
Discovery of a New Heavy Elementary Particle

The 1976 Nobel Prize in physics was shared by a Massachusetts Institute of Technology researcher who used Brookhaven's Alternating Gradient Synchrotron (AGS) to discover a new particle and confirm the existence of the charmed quark.

Samuel C.C. Ting (at left, with his research team) was credited for finding what he called the "J" particle, the same particle as the "psi" found at nearly the same time at the Stanford Linear Accelerator Center by a group led by Burton Richter. The particle is now known as the J/psi.

Ting's experiment took advantage of the AGS's high-intensity proton beams, which bombarded a stationary target to produce showers of particles that could be detected by complex detectors. A strong peak in electron and positron production at an energy of 3.1 billion electron volts (GeV) led Ting to suspect the presence of a new particle, the same one found by Richter.

Their discoveries not only won the Nobel Prize; they also helped confirm the existence of the charmed quark — the J/psi is composed of a charmed quark bound to its antiquark.



Ting and his experimental team.

J/ψ particle discovered at Brookhaven!

Scientific questions and our achievements

The big questions:

- What role does gluon play in nuclear structure such that it forms visible matter in our universe?
- What can gluons tell us about *confinement, e.g.,* why stable matter exist in the first place?

Our missions:

- Understand the gluonic structure of nucleon and light to heavy nuclei;
- Understand the detailed properties of gluons and their role in visible matter.
- …

Click here for our news
Click here for DOE highlight

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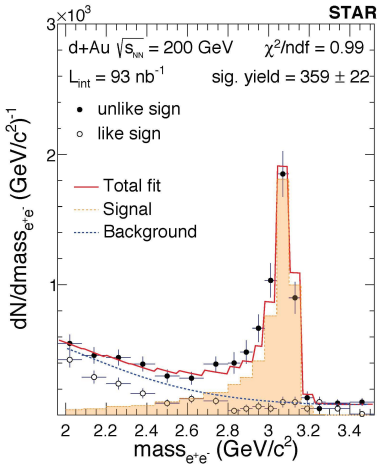
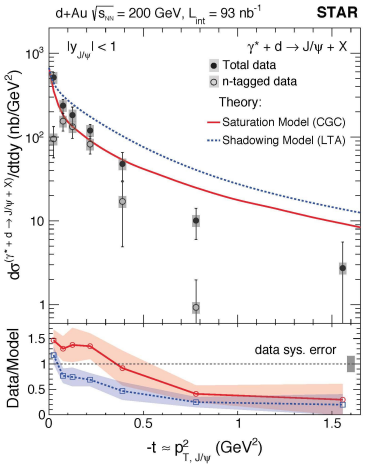
Recent achievements



J/ψ particle observed in photon-deuteron collisions



Gluon momentum/spatial distribution in deuteron

Phys.Rev.Lett. 128 (2022) 12, 122303

Click here for our news
Click here for DOE highlight

Scientific questions and our achievements

We have more in proton and gold nucleus!

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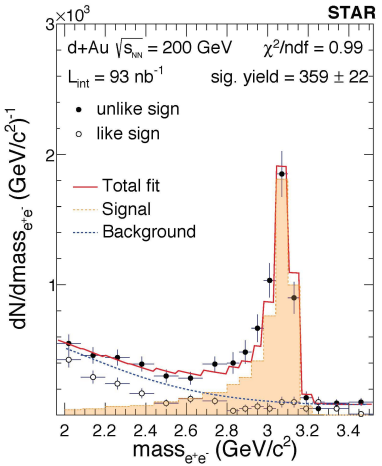
Recent achievements



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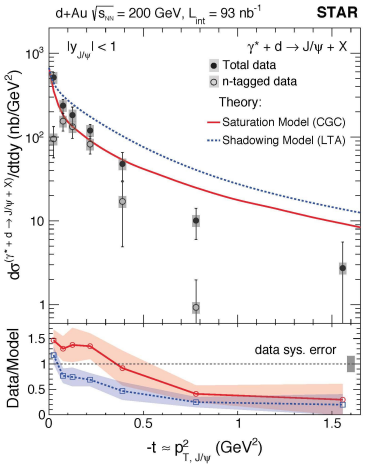

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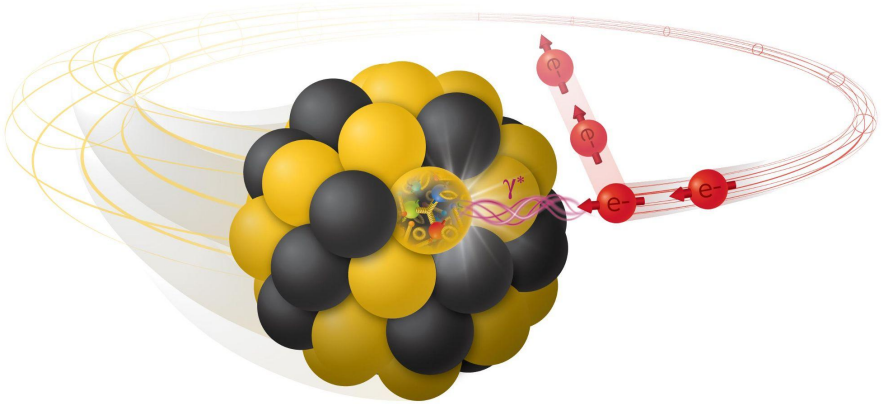
If you like to know more, check out EIC website for science@ https://www.bnl.gov/eic/science.php

Future is coming: Electron-Ion Collider (EIC)



Capabilities:

- **Systems:** proton, deuteron, He3,... Gold and Uranium;
- **Energy**: ~ 20-140 GeV
- **Probes:** ρ, J/ψ, and possibly ϕ, and more
- **Polarizations:** proton and light nuclei.
- **Detectors:** advanced detectors with state-of-the-art technology and AI/ML

EIC is the ultimate machine to understand *the glues that bind us all*. Come join us!