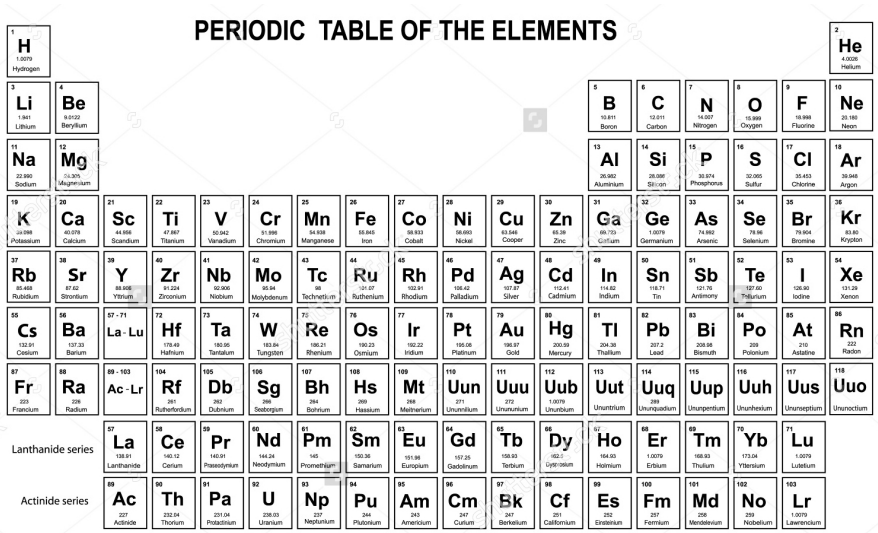
Hunting for Quarks and Gluons

Jerry Gilfoyle
University of Richmond

- What we know about the sub-atomic world and its forces - background.
- We're about to learn more at the upgraded Jefferson Lab (JLab) - physics motivation.
- How we measure things - technical details.
- Summary and Conclusions.

What Do We Know About the Structure of Matter?

- The structure of matter.
  → Table of Elements (TOE)



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- The current TOE!
  $\longrightarrow$ quarks and leptons.

FERMIONS matter constituents
spin = 1/2, 3/2, 5/2, ...

Leptons spin =1/2			Quarks spin =1/2		
Flavor	Mass GeV/c^2	Electric charge	Flavor	Approx. Mass GeV/c^2	Electric charge
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Unified Electroweak spin = 1

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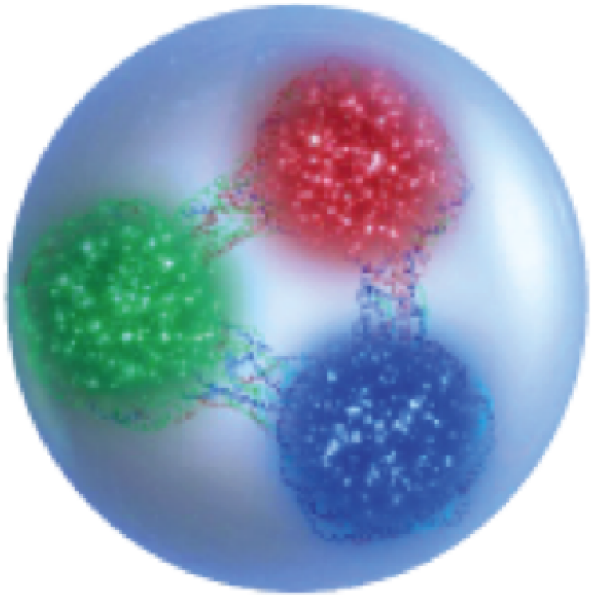
More than 99% of our mass is in quark triplets.

What is the force that holds us together?

- The color force binds quarks together via gluon exchange.
- The quarks are never alone.
  $\longrightarrow$ confinement
- At high energy the force is weak.
  $\longrightarrow$ asymptotic freedom



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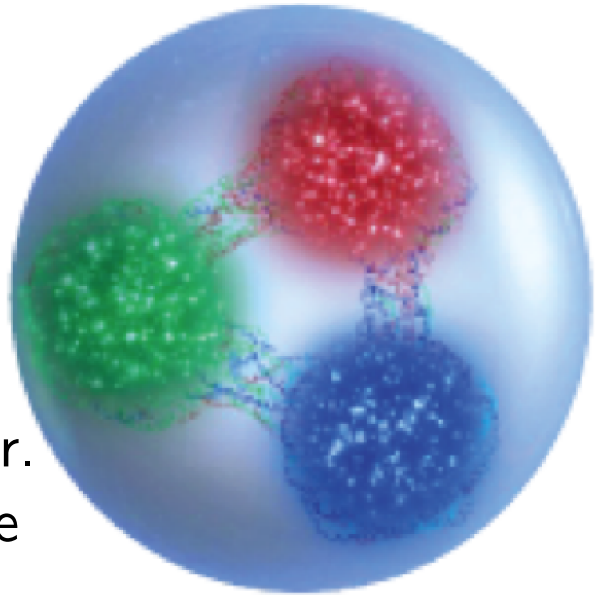

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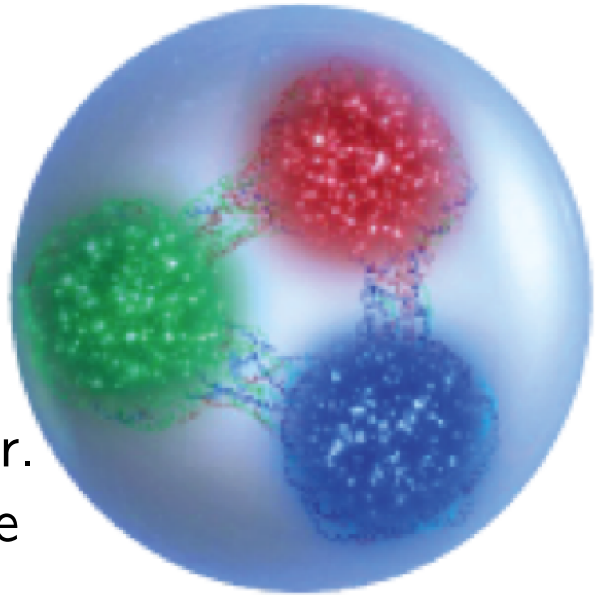

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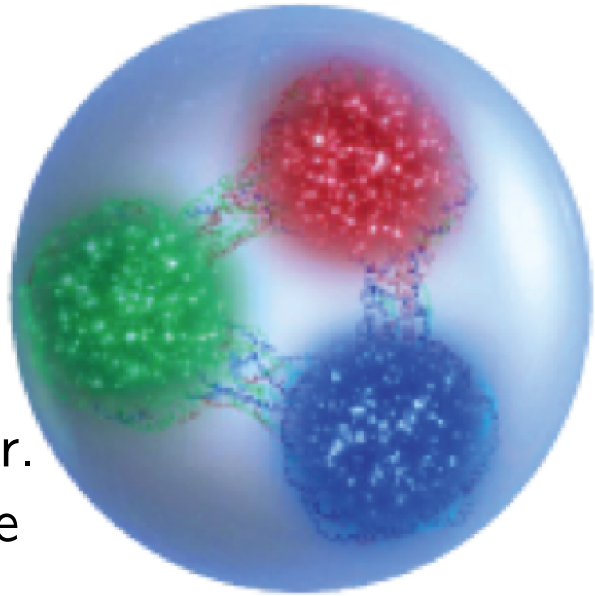

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Yet!

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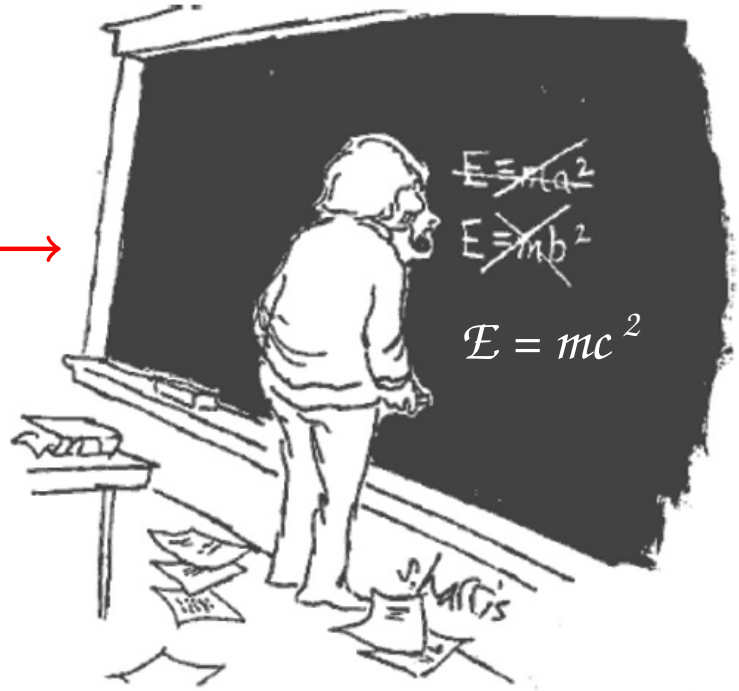

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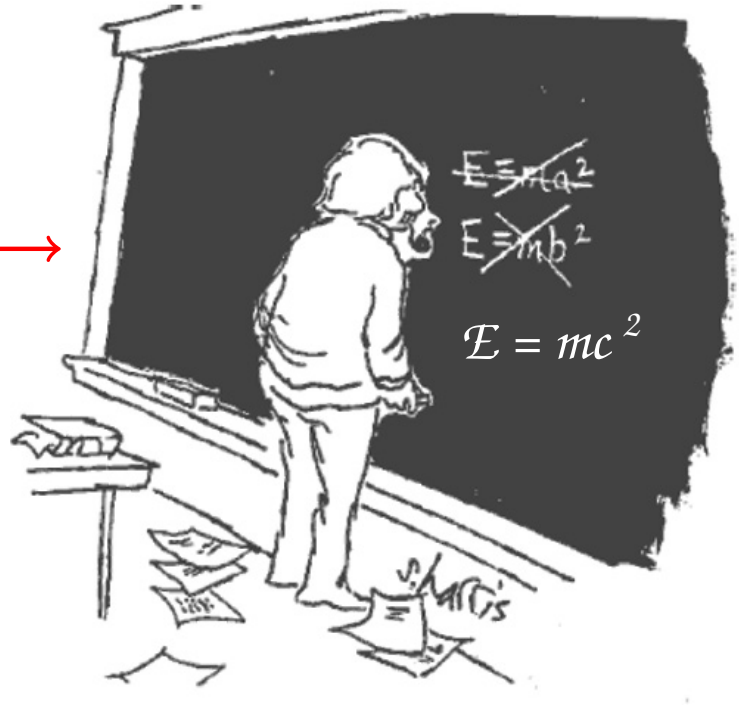

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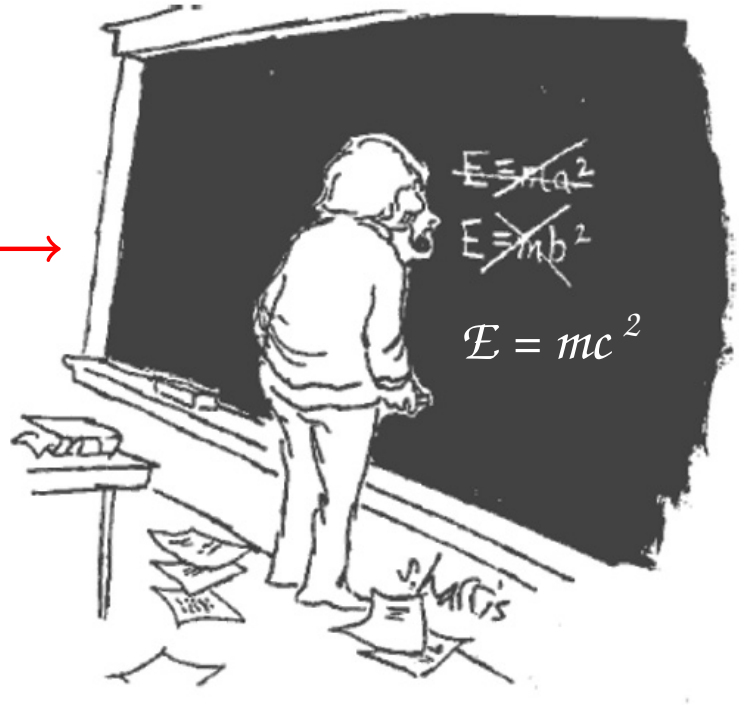

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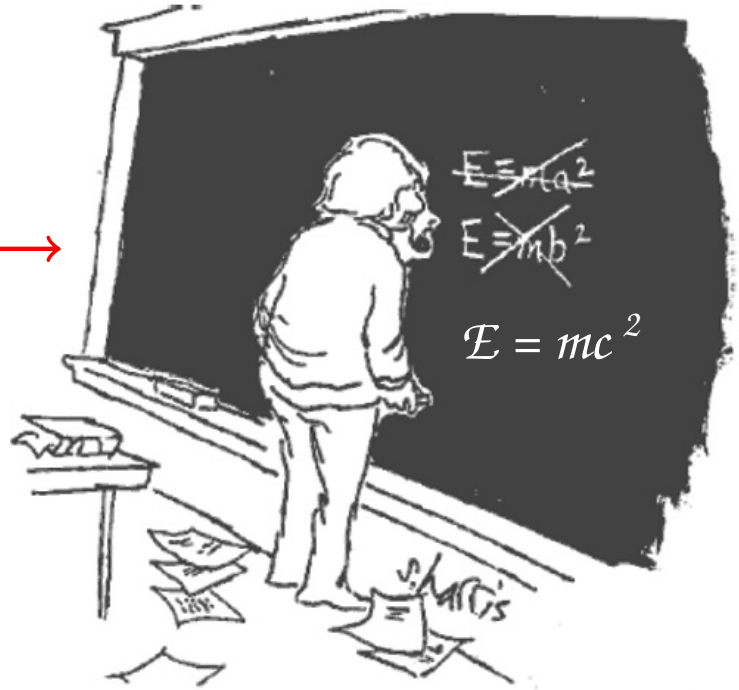

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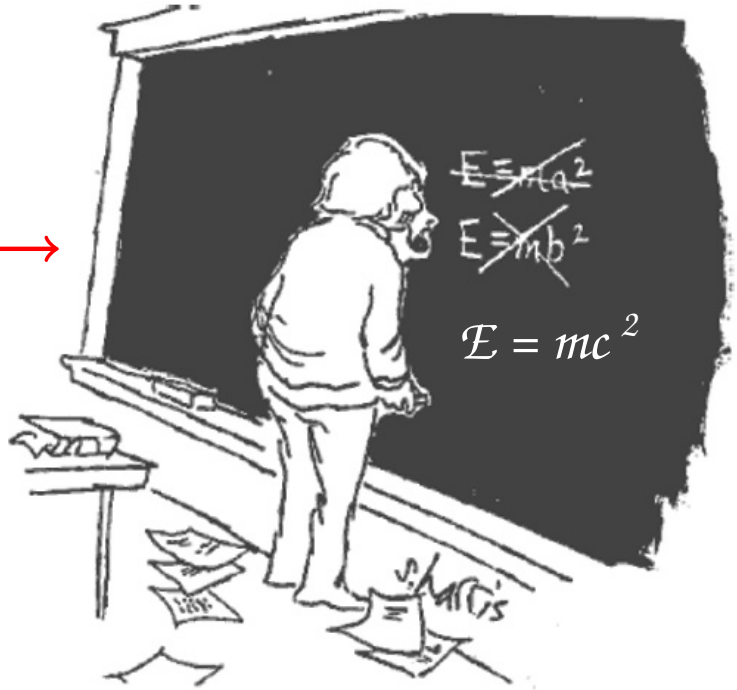

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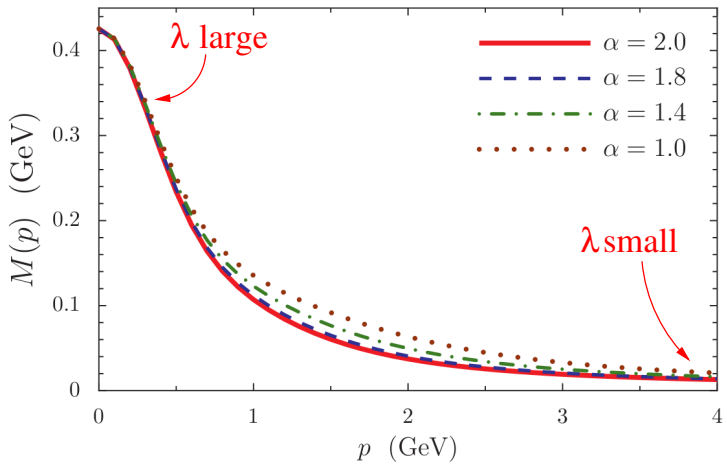
CR et al. PRL 111 (101803), 2013



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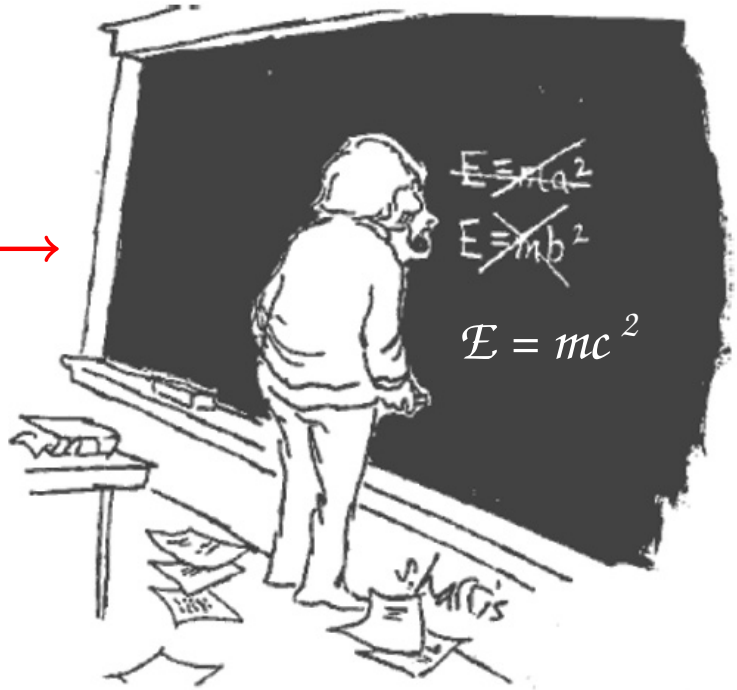

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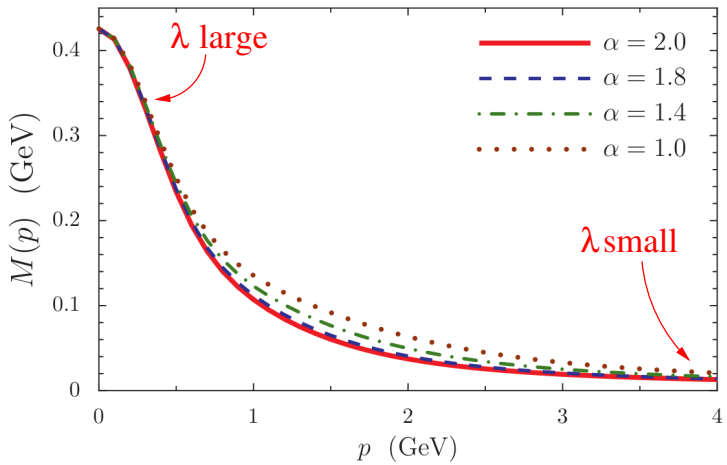

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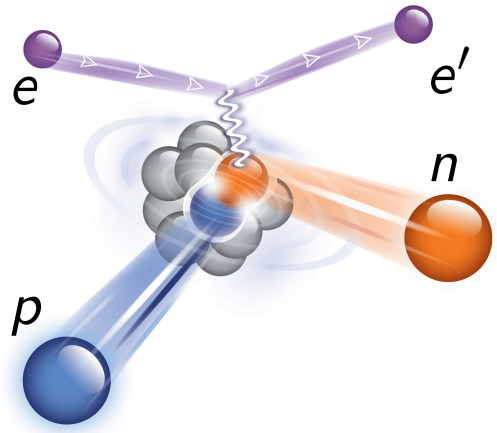

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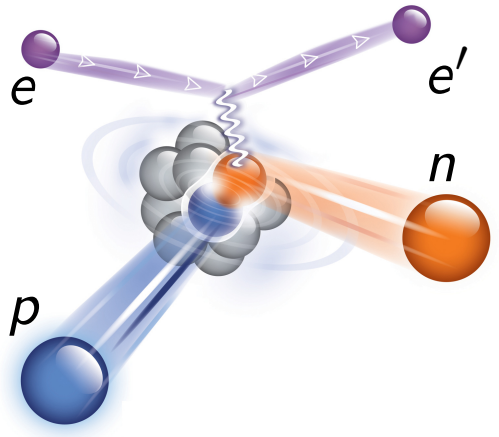

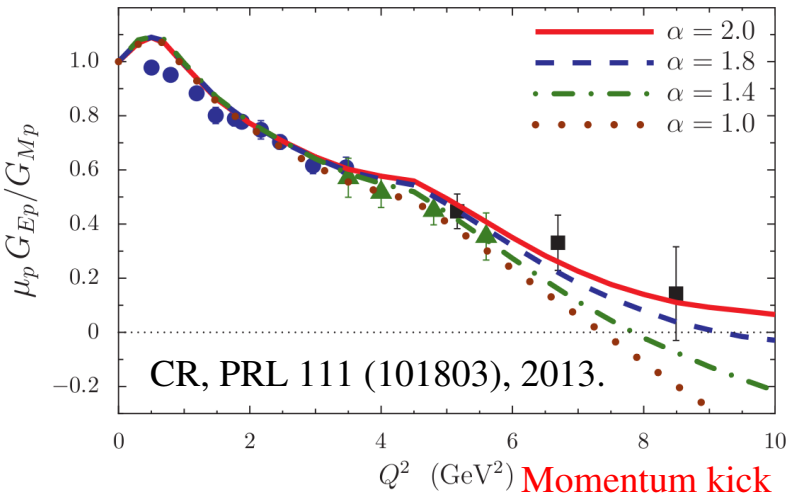

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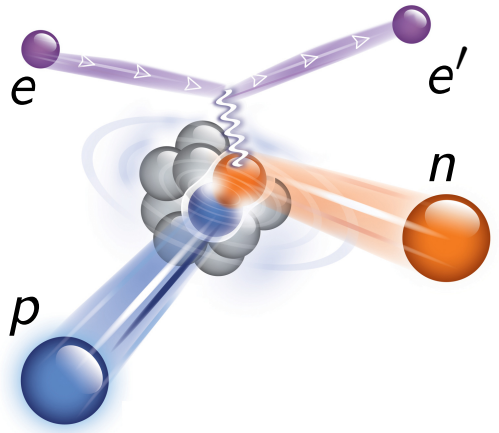
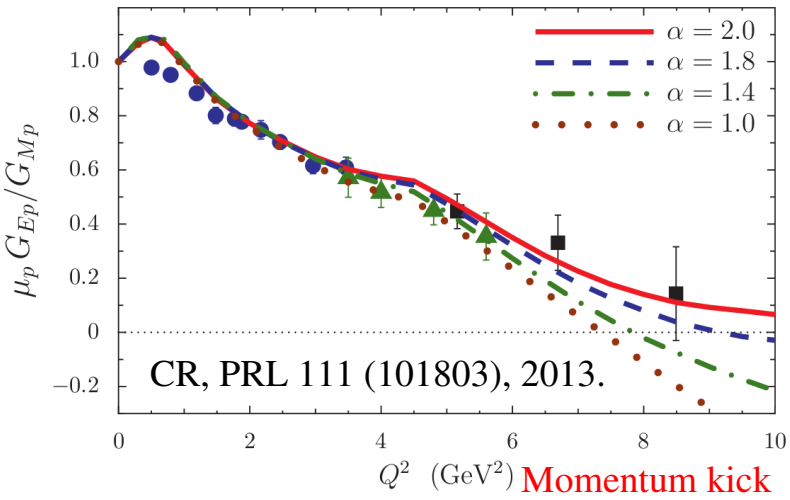
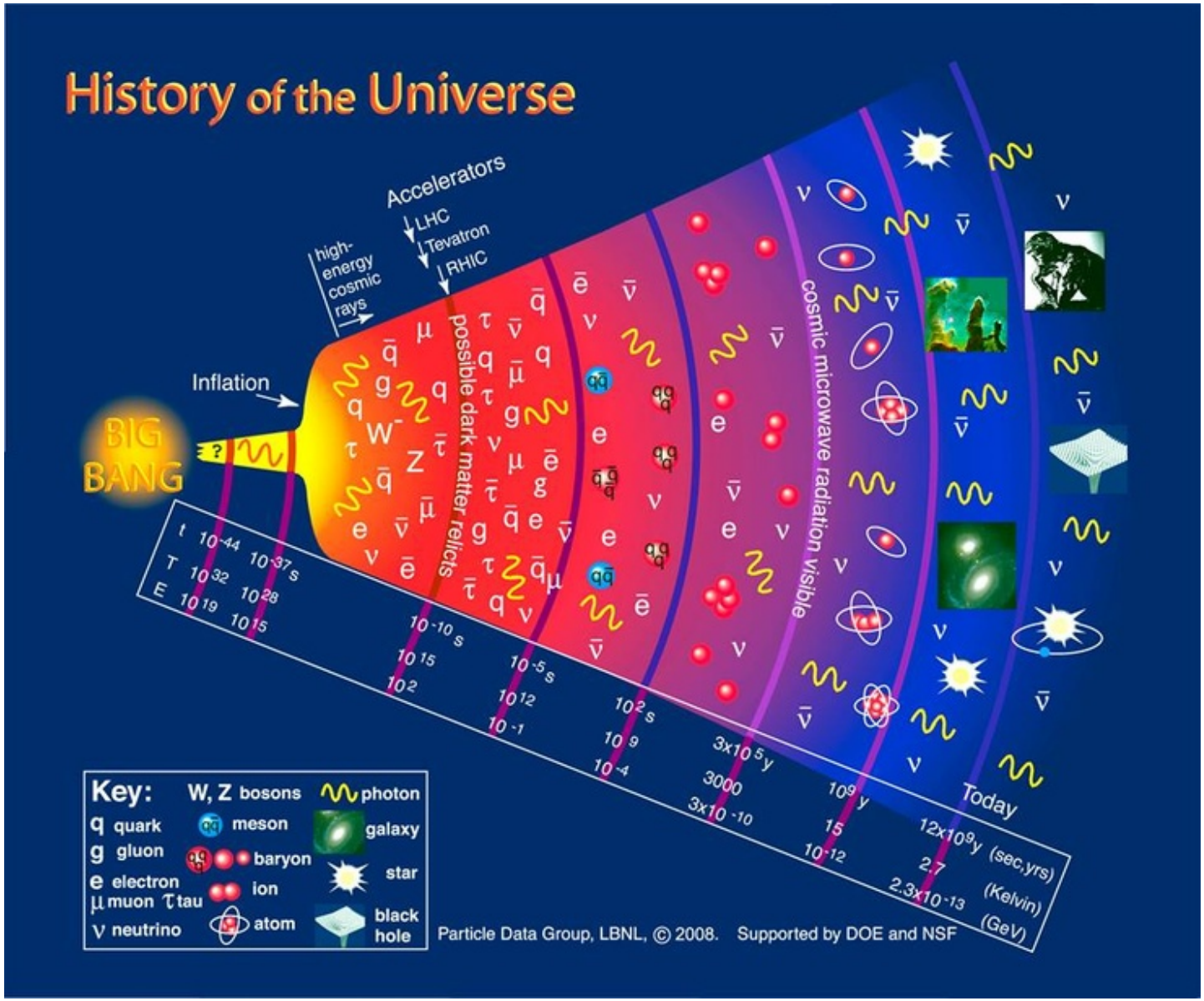




We are probing how mass emerges from QCD color fields.

A Connection With Ted



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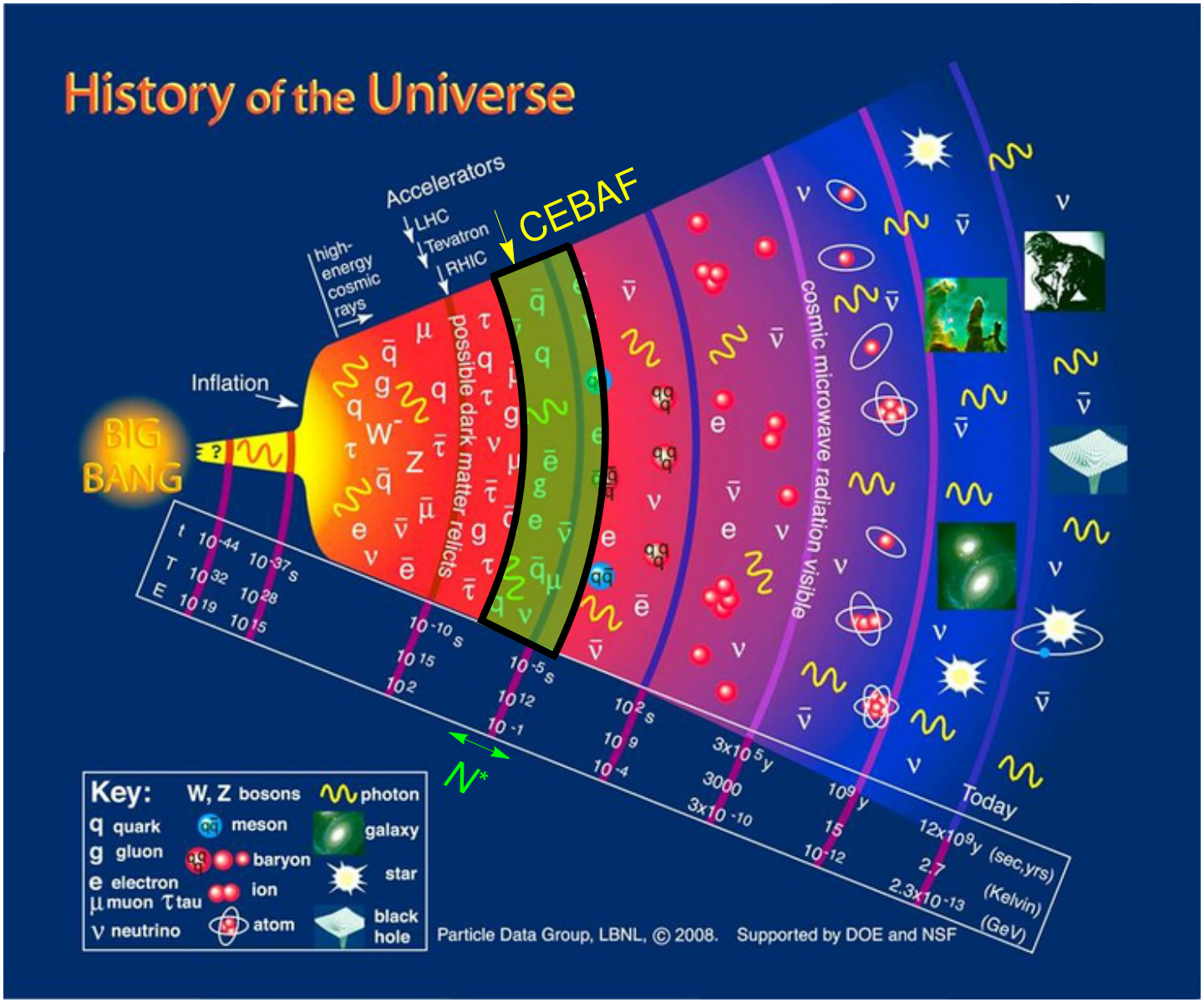

How Do We Measure the Form Factors? - 1

- Build the newest US national lab Jefferson Lab (JLab) in Newport News, VA
- The accelerator CEBAF is a mile-long, racetrack-shaped, superconducting linear accelerator.
- Rapidly varying electric fields push electrons to 12 GeV.
- Electron beam distributed to four halls.
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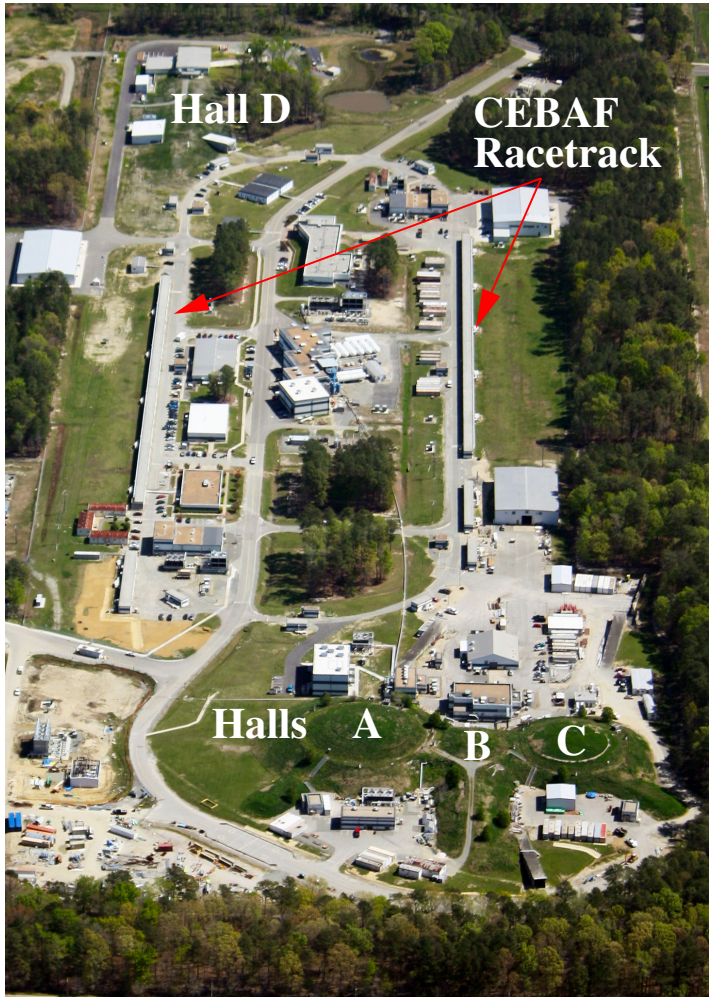

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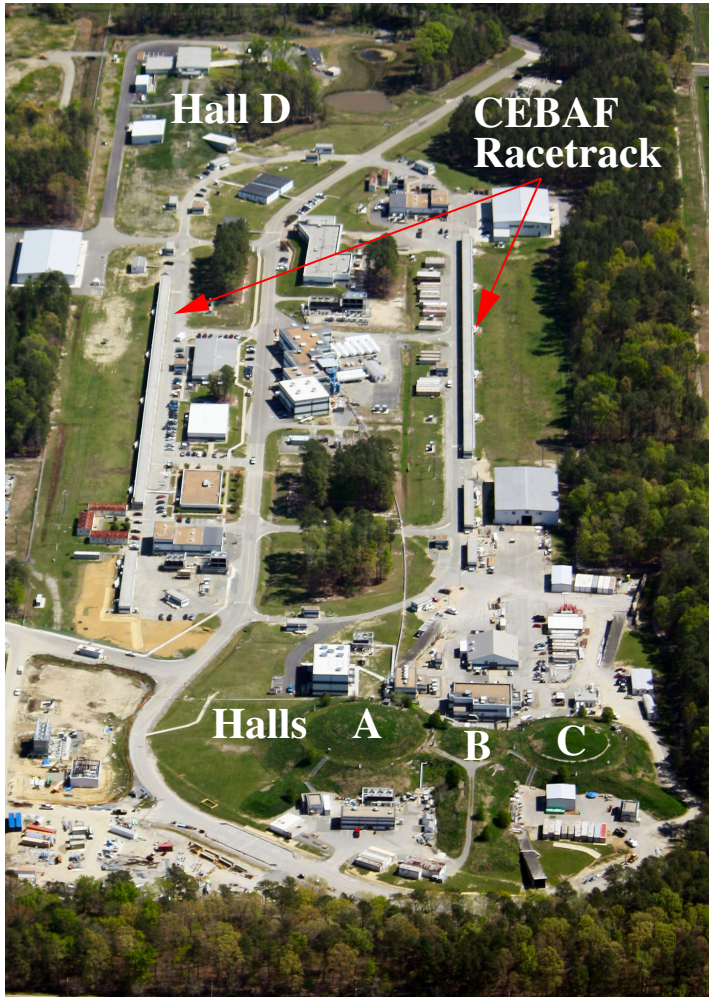
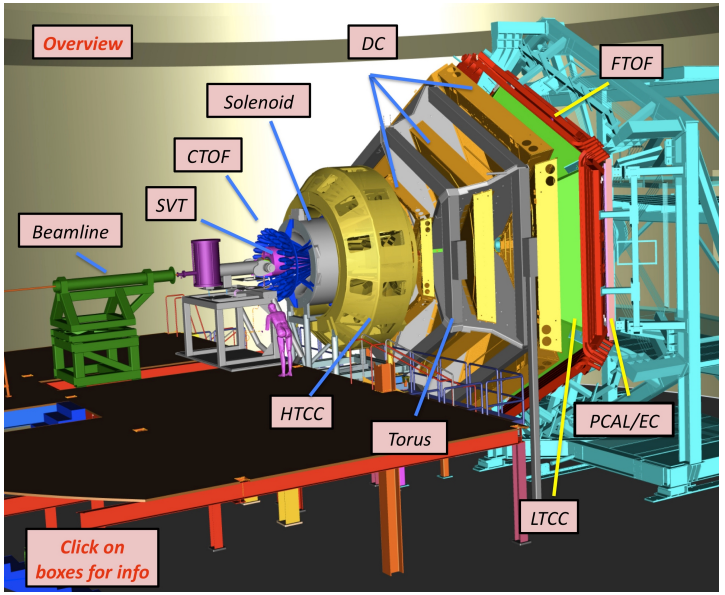
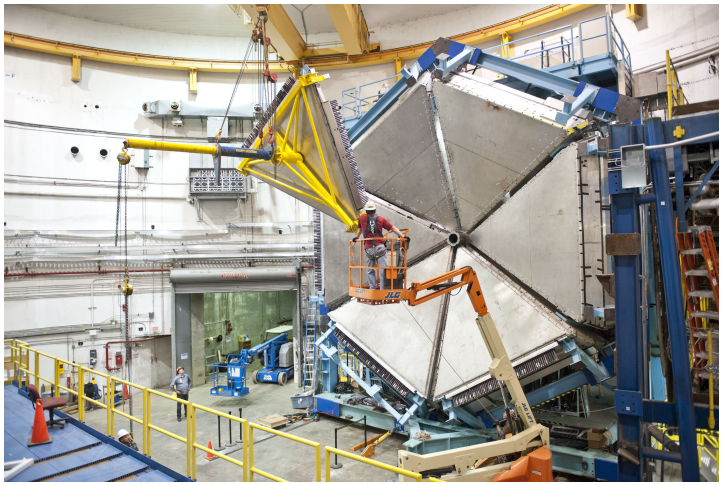


It's a QCD laboratory!

How Do We Measure the Form Factors? - 2

- Build a large (3-story, 45-ton) particle detector called CLAS12 in Hall B.
- Many layers measure the debris from electron-target collisions.
- 62,000 detecting elements in $\approx$ 40 layers.
- Large magnet bends charged particles to measure momentum.
- Get the 4-momenta of the debris out.
- Will write 5-10 TByte to disk each day.





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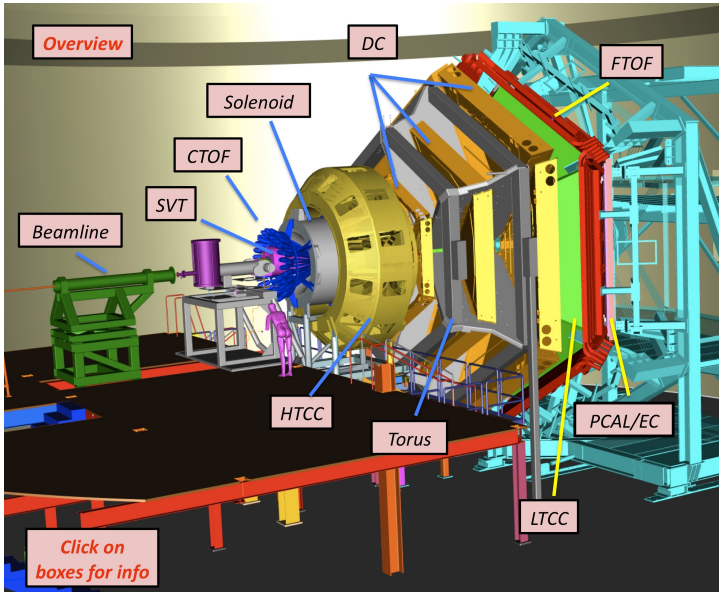
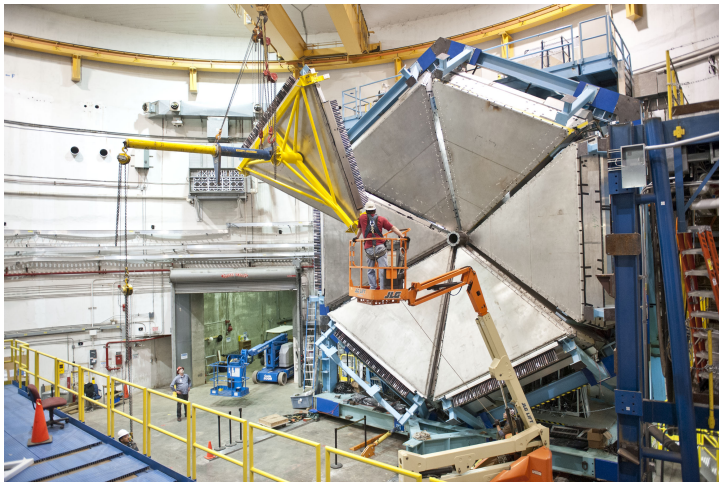
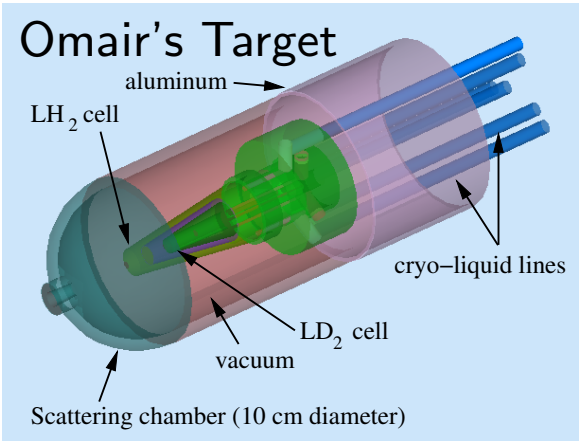
First beams are in April!



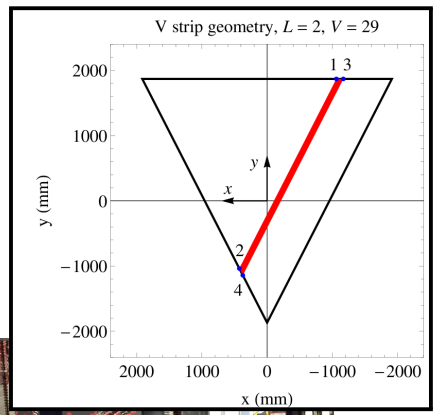


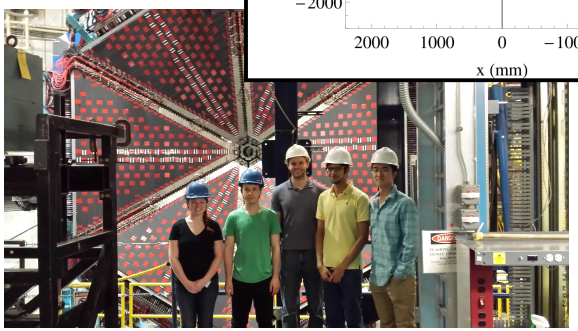
Some of the Nuclear Physics at the University of Richmond

- The usual suspects: Keegan Sherman, Omair Alam, Alexander Balsamo, David Brakman, Peter Davies, old gray-haired guy.
- Software is important! We are writing code for:
  - methods to align the 33,792 elements of the silicon vertex tracker to within $40 - 50\ \mu m$.
  - extracting the magnetic form factor G_M^n from the $eD \rightarrow e'p(n)$ and $eD \rightarrow e'n(p)$ reactions.
  - measuring the neutron detection efficiency needed for $eD \rightarrow e'n(p)$ with $ep \rightarrow e'\pi^+ n$.
  - monitoring and operating a cryogenic $\mathrm{LD}_2 - \mathrm{LH}_2$ target.
- Rely now on simulation of CLAS12 and cosmic ray data until 2017.
- Four student posters in Vancouver in October.



Keegan's geometry



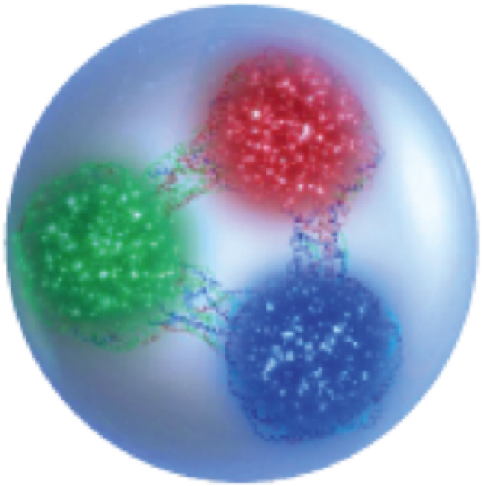


Summary and Conclusions

- JLab is at the frontier of our understanding of the basic properties of matter including most of the known mass.
- First measurement of the nucleon mass curve?
- CLAS12 is a large, complex particle detector about to see first beam.
- Our group is preparing feverishly to understand the deluge of data that is coming - first beams in April!

What is the force that holds us together?

- The color force binds quarks together via gluon exchange.
- The quarks are never alone.
  $\longrightarrow$ confinement
- At high energy the force is weak.
  $\longrightarrow$ asymptotic freedom



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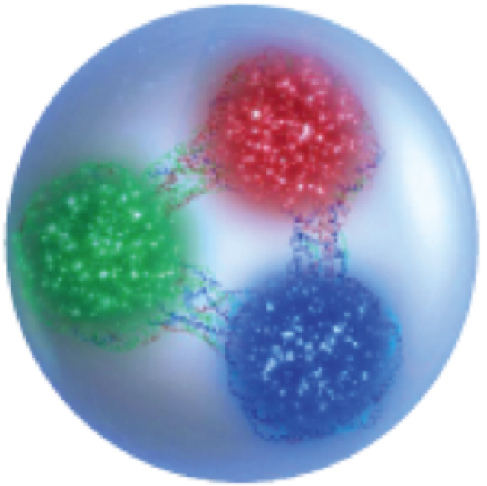

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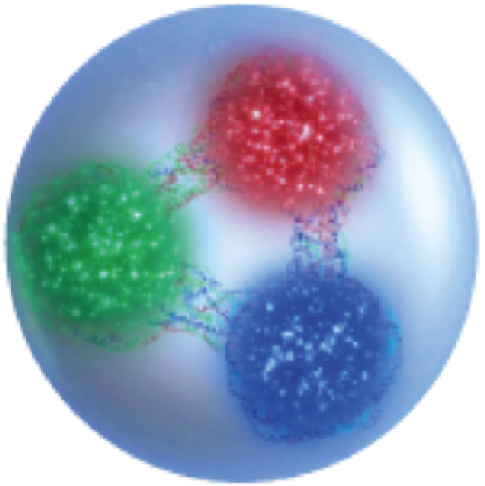

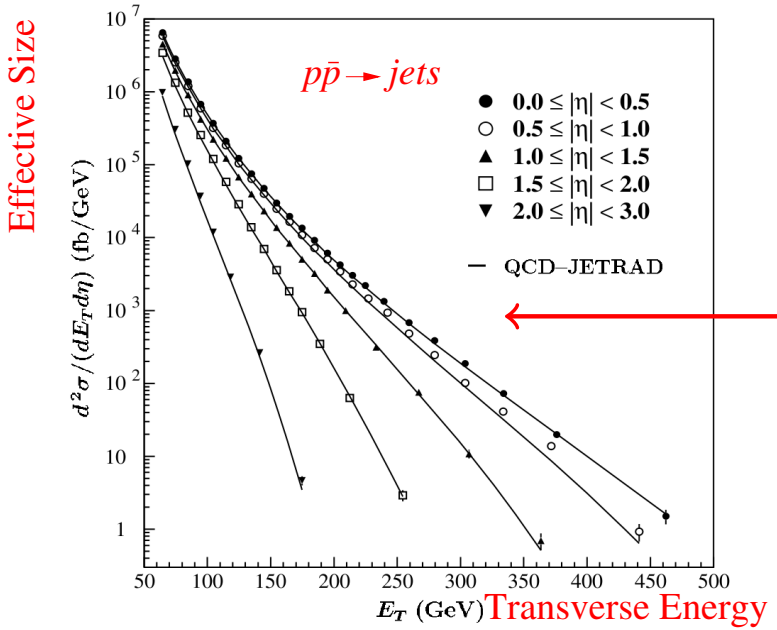

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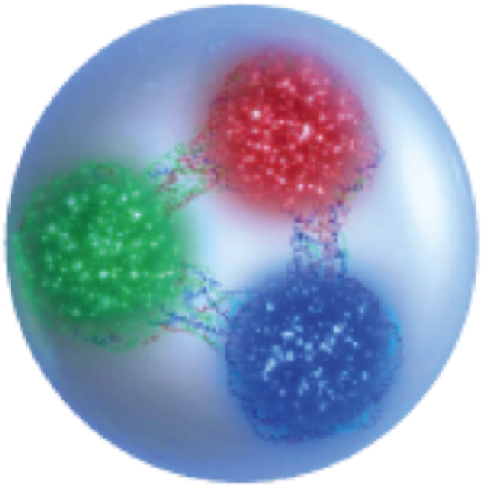
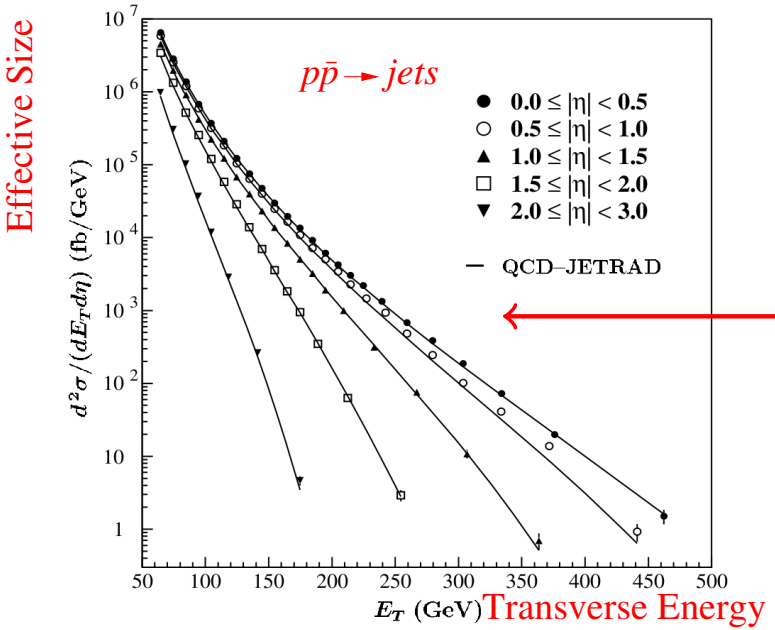


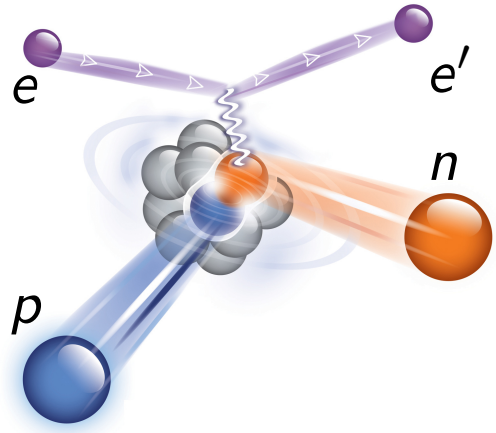


QCD is wildly successful!

But can't be solved at nucleon energies. Yet!

But is it real?

- The cross section reflects the effective size of the target in a scattering experiment.



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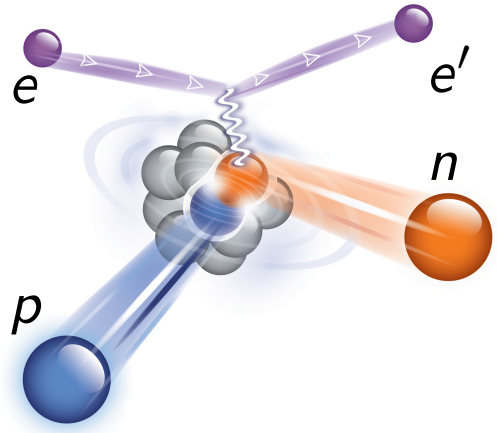

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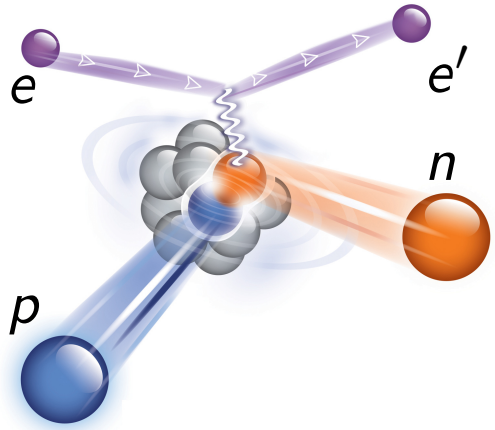

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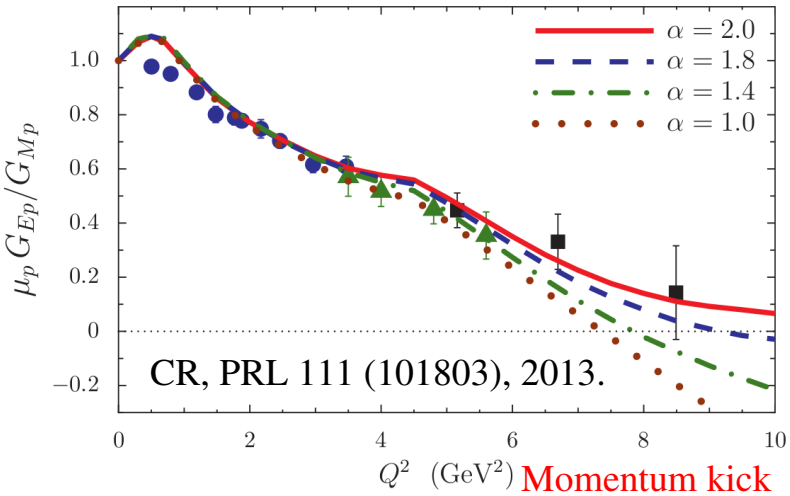
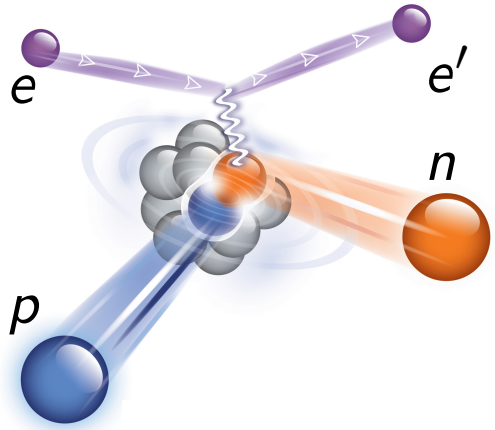


Momentum kick

But is it real?

- The cross section reflects the effective size of the target in a scattering experiment.
- This cross section can be expressed here in electric and magnetic form factors G_E and G_M.
- The ratio G_E/G_M for the proton has a zero crossing sensitive to the shape of the mass function.
- So does G_E/G_M for the neutron.



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