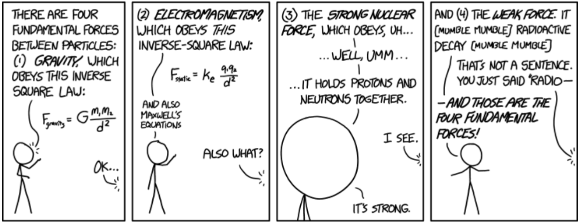
Hunting for Quarks and Gluons

Jerry Gilfoyle
University of Richmond

- What we know and don't know about the sub-atomic world and its forces.
- What we'll learn with Jefferson Lab (JLab).
- How we measure things - CLAS12.
- What we do.



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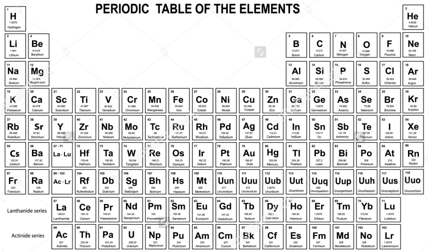
- The structure of matter.
  $\rightarrow$ Table of Elements (TOE)



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BOSONS force carriers spin = 0, 1, 2, ...

Unified Electroweak spin = 1

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

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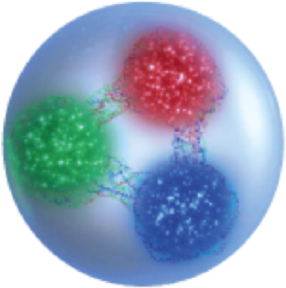
What is the force that holds us together?

- Quarks are bound by the 'color' force.
- There are three kinds of 'color' charge.
- The quarks are never alone.
  $\rightarrow$ confinement
- At high energy the force is weak.
  $\rightarrow$ asymptotic freedom



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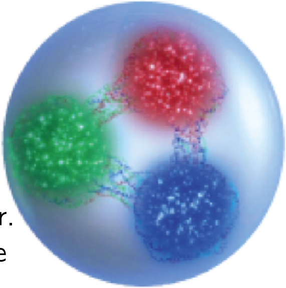

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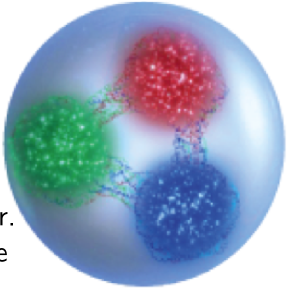

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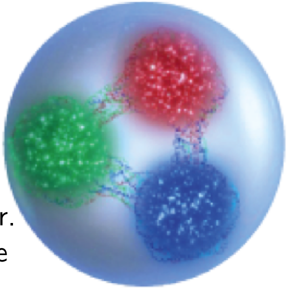

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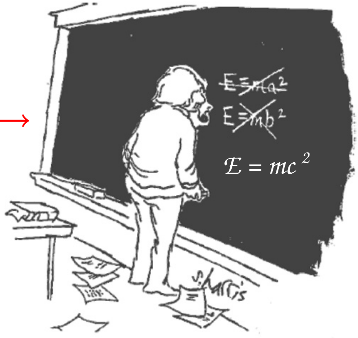

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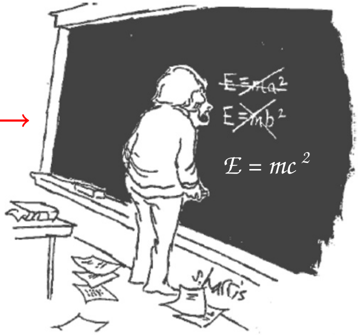

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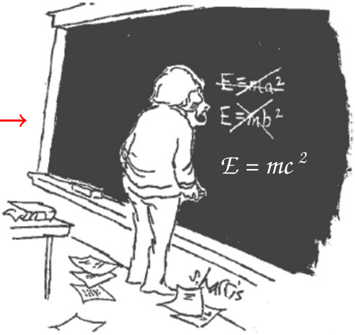

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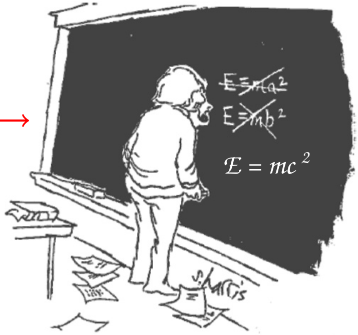

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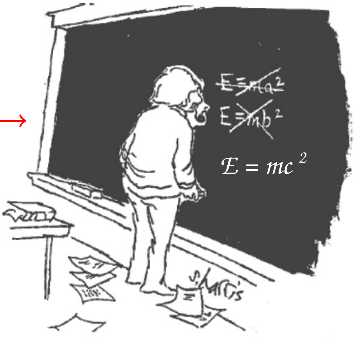
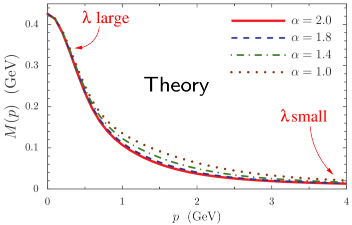


CR et al. PRL 111 (101803), 2013



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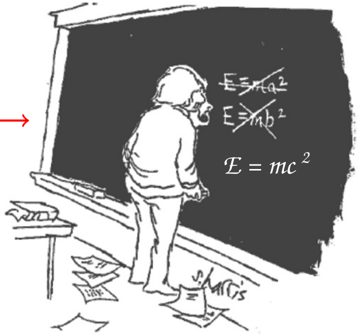
- At low momentum you probe the whole cloud.



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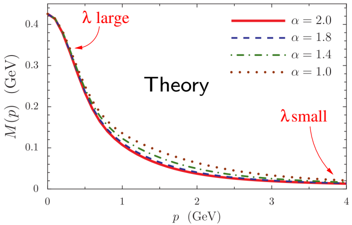

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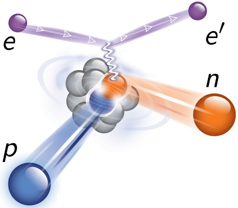

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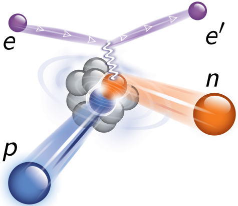

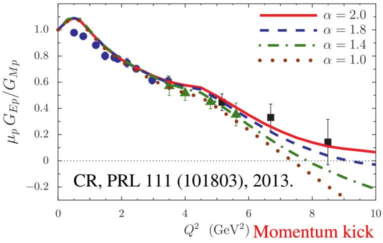

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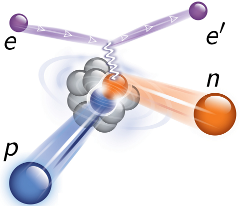
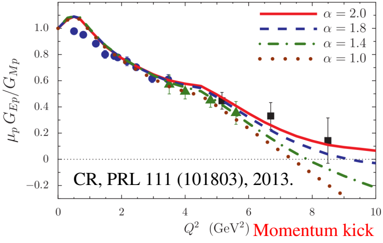
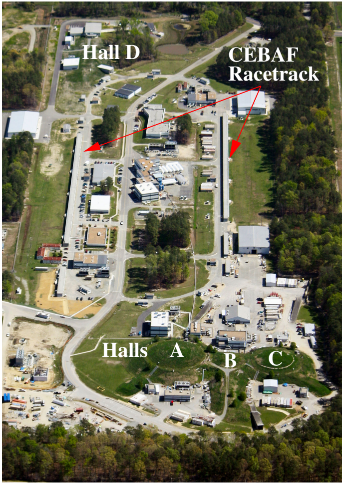




We are probing how mass emerges from QCD color fields.

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 close to 12 GeV.
- Electron beam distributed to four halls.



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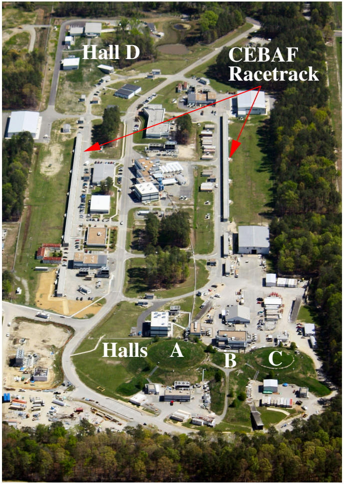

It's a QCD laboratory!

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- Build a large (3-story, 45-ton) particle detector called CLAS12 in Hall B.
- Many layers measure debris from electron-target collisions.
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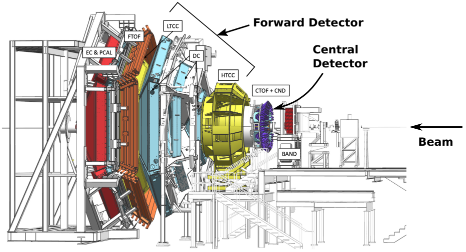
- Large magnets bend charged particles to measure 4-momenta.
- Will collect 10-30 TByte each day.



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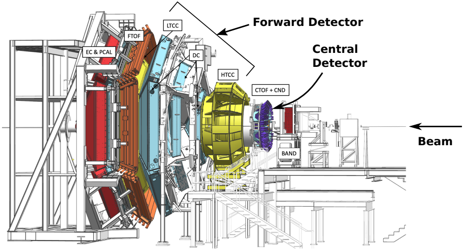

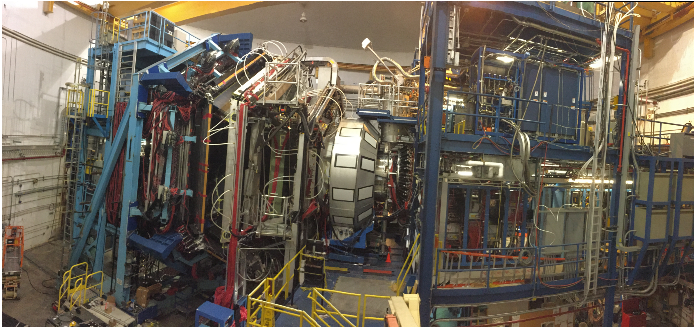

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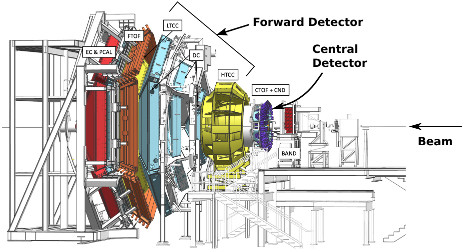
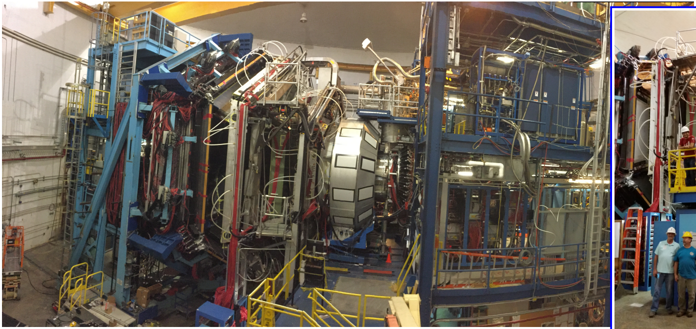
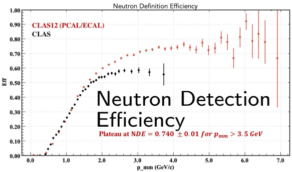
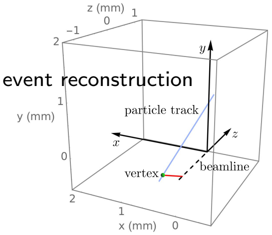


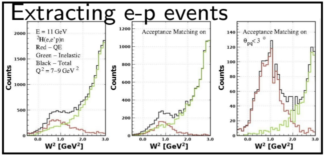


Some of the Nuclear Physics at the University of Richmond

- The usual suspects: Sarah Hu, Jessie Hess, Matthew Hayrich, Ryan Sanford, Alexander Balsamo, Chris Childs, Ben Weinstein, Michael Armstrong, Adrian Saina, Lamya Baashen, old gray-haired guy.
- Software is important! We are writing code for:
    - analyzing CLAS12 data and simulations.
    - extracting the neutron magnetic form factor G_M^n from the $eD \to e'p(n)$ and $eD \to e'n(p)$ reactions.
    - measuring the neutron detection efficiency (NDE) needed for $eD \to e'n(p)$ with $ep \to e'\pi^+ n$.
    - determine the CLAS12 NDE *in situ*.
    - establish benchmarks for the CLAS12 event reconstruction resolution.
    - install reconstruction unit tests.
    - build CLAS12 subsystem geometry.
- Ten students over last three years.
- Seven presentations at national meetings.





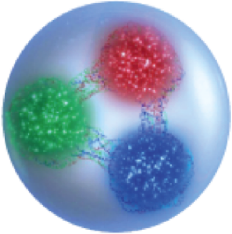


Summary and Conclusions

- JLab is at the frontier of our understanding of the basic properties of matter including most of the known mass.
- Putting QCD on a precise quantitative basis in the nuclear energy regime.
- CLAS12 is a large, complex particle detector. Software is the key element to bring it all together.
- Our group is feverishly working to understand the deluge of data that has arrived!
- Students are using and developing essential tools for handling complex systems with large data sets.

What is the force that holds us together?

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



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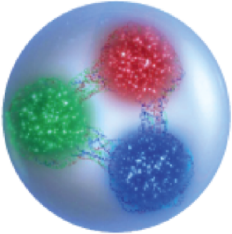

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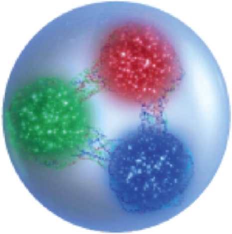

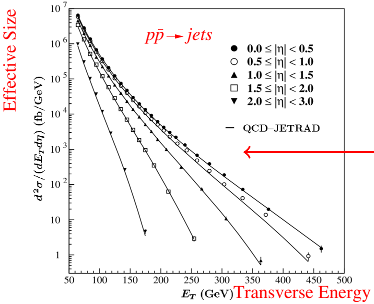

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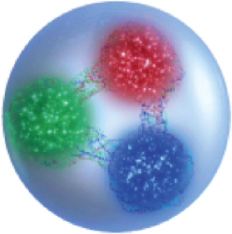

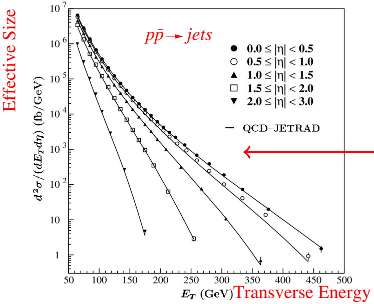

QCD is wildly successful!

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