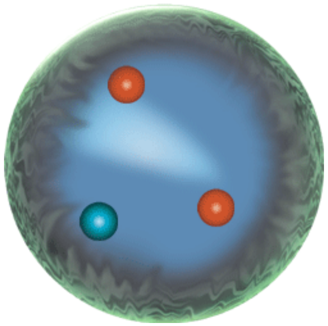
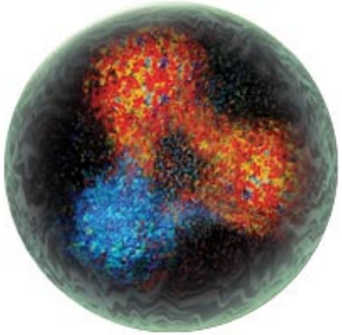
Spectrum and Structure of Excited Nucleons from Exclusive Electroproduction (INT 16-62W)

PIRE: Emergent Structures from Quarks and Gluons



Philip Cole
Idaho State University

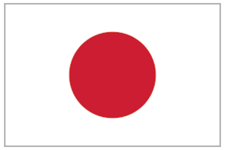
November 17, 2016



Pre-proposal was submitted to the NSF Program: Partnership on International Research and Education on September 8, 2016








What is the NSF Program Partnership for International Research and Education (PIRE)?

- Cross cutting across the NSF – supports all areas in the NSF.
- PIRE seeks to catalyze a higher level of international engagement in the U.S. science and engineering community.
- Enables coordination to partner with international funding agencies
- Designed to encourage high-risk/high-reward activities
- Designed to pursue potentially transformative ideas in
    - research
    - education

Our Research Vision for PIRE Grant

- We seek to **bring together representatives of all major experimental, phenomenology, and theory groups** across the globe, who are working on the nucleon resonance problem, into one consolidated collaboration.
- We seek to **strengthen existing links** and **forge entirely new ones within the** broad scope of the **international nuclear physics community**, dedicated towards pursuing
  - a new and rich direction on the study of understanding the underlying structure of nucleons,
  - the spectrum of excited baryon states,
  - and how quarks are confined and acquire mass through the mechanism of dynamical chiral symmetry breaking

Objectives

- Several independent theoretical nuclear physics groups, from across the globe, are working on this difficult problem.
- Our objective is to coordinate these disparate and independent efforts, experimental and theoretical, into a cohesive effort with broad ramifications for theoretical physics.
- By combining and focusing our efforts, we can solve the fundamental question of where the mass of the proton originates.
- Such an effort asks for the knowledge of experienced scientists and creative, motivated young scientists-in-training.

The Problem

- Senior members of experimental and theoretical research groups do communicate with one another through formal conferences and workshops at many international venues.

- On the whole, however, each group works autonomously, without the benefits of central coordination.

- As a result, students focus on specific problems within their group, but often lack a clear vision of the 'big picture' and the research endeavors of other, theoretical or experimental, research groups.

The Necessity for a PIRE Grant

- Baryon structure and spectroscopy is a problem of global scope and scale.
- It requires international cooperation among many universities, institutes, and laboratories.
- Only funding through the NSF PIRE program can such efforts be made possible in a globally-coordinated and timely way.

We are poised to crack the conundrum of the proton

The Collaboration: N* PIRE Group

PI/CoPIs:
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Department of Physics, ***Idaho State University***, Pocatello, ID 83209
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Ralf W. Gothe (*CoPI, Professor of Physics*)
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Kenneth Hicks (*CoPI, Professor of Physics*)
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Kyungseon Joo (*CoPI, Professor of Physics*)
Department of Physics, University of Connecticut, Storrs, CT 06269
Huey-Wen Lin (*CoPI, Asst. Professor of Physics*)
Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48823

Request: 5 Million Dollars
Period: 5 Years

The PIRE grant can be leveraged with potential grant monies from partnering funding agencies in Australia, France, Germany, Japan, and South Korea.

Senior Personnel:
Volker D. Burkert (*Hall B Leader*), **Latifa Elouadrhiri** (*Assistant Project Manager, 12 GeV Upgrade – Hall B*), **Victor I. Mokeev** (*Hall B Staff Scientist II)* TJNAF (JLab), Newport News, VA 23606
William Briscoe (*Professor and Chair of Physics*), **Helmut Haberzettl** (*Professor of Physics*) **Igor Strakovsky** (*Research Professor*), **Ronald Workman** (*Research Professor*)
Department of Physics, George Washington University, Washington, DC 20052
Craig Roberts (*Senior Physicist*), **Tsung-Shung Harry Lee** (*Senior Physicist*) Physics Division, *Argonne* National Laboratory, *Argonne,* IL 60439

Foreign Collaborators:
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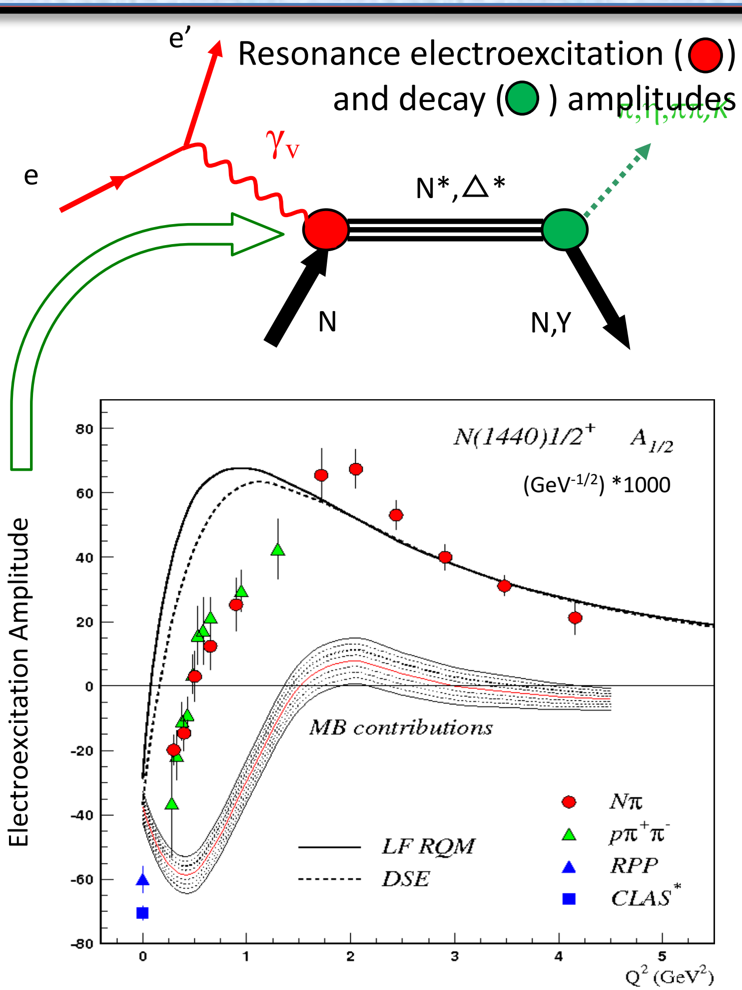
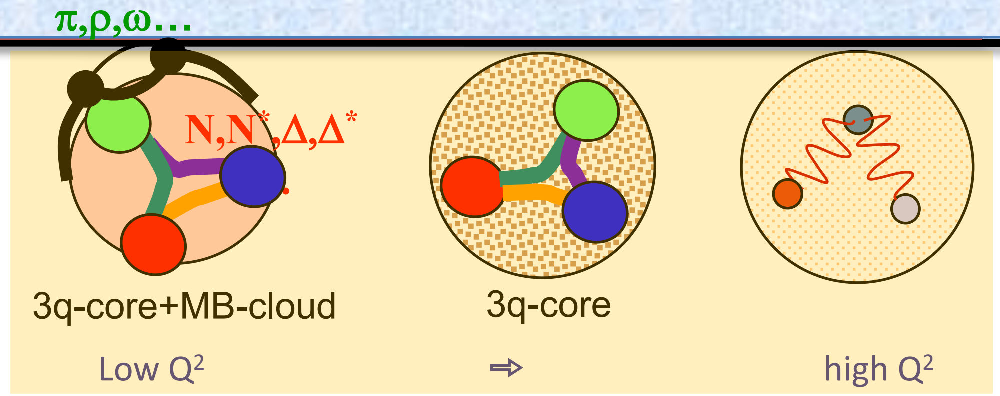
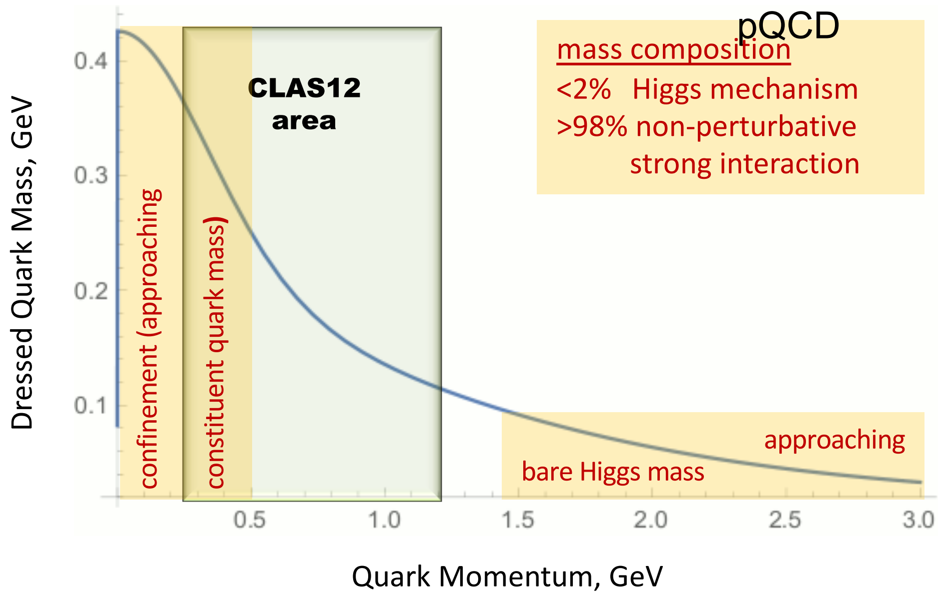
Béatrice Ramstein (*French Liaison, Research Physicist*), Institut Physique Nucléaire, Orsay, France
Hartmut Schmieden (*German Liaison, Prof. Dr.*), Universität Bonn, Physikalisches Institut **Reinhard Beck** (*Prof. Dr.*), **Bernhard Ketzer** (*Prof. Dr.*), **Ulrike Thoma** (*Prof. Dr.*) Universität Bonn, Helmholtz-Institut für Strahlen- und Kernphysik Bonn, Germany
Michael Ostrick (*Prof. Dr.*) Universität Mainz, Institut für Kernphysik, Mainz, Germany
Vladimir Braun (*Prof. Dr.*) Universität Regensburg, Fakultät Physik, Regensburg, Germany **Joachim Stroth** (*Prof. Dr.*) Goethe-Universität, Institut für Kernphysik, Frankfurt am Main, Germany
Hiroyuki Sako (*Japanese Liaison, Dr. Principle Researcher),* Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Japan.
Takashi Nakano (*Professor, RCNP Director*), **Toru Sato** (*Professor*) Dept. of Physics, Osaka University, Osaka, Japan
Hiroyuki Kamano (*Professor*), KEK Theory Group, Tsukuba, Japan
Jung Keun Ahn (*South Korean Liaison, Professor*), Korea University, Seoul, South Korea
Yongseok Oh (*Professor*) Kyungpook National University, Daegu, South Korea

Nucleon Electro-excitations and the Emergence of Hadron Mass



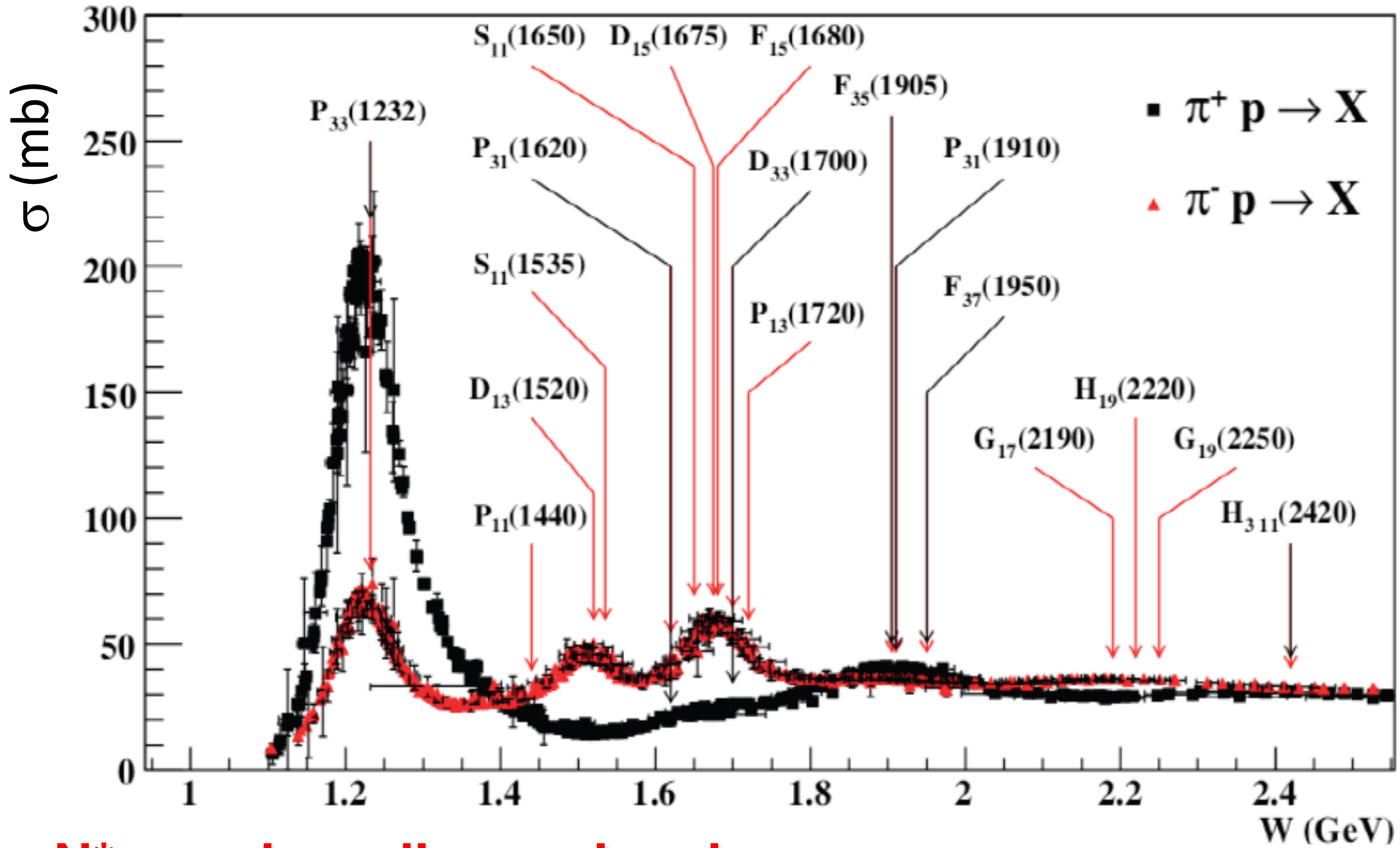
CLAS results versus non-perturbative
QCD expectations with running quark mass





N* electroexcitation studies with CLAS12 in Hall B at Jefferson Lab will address critical open questions:
What is the essence of confinement and how is >98% of the visible mass and the structure of hadrons generated?

Baryon resonances (N*s and Δ*s)

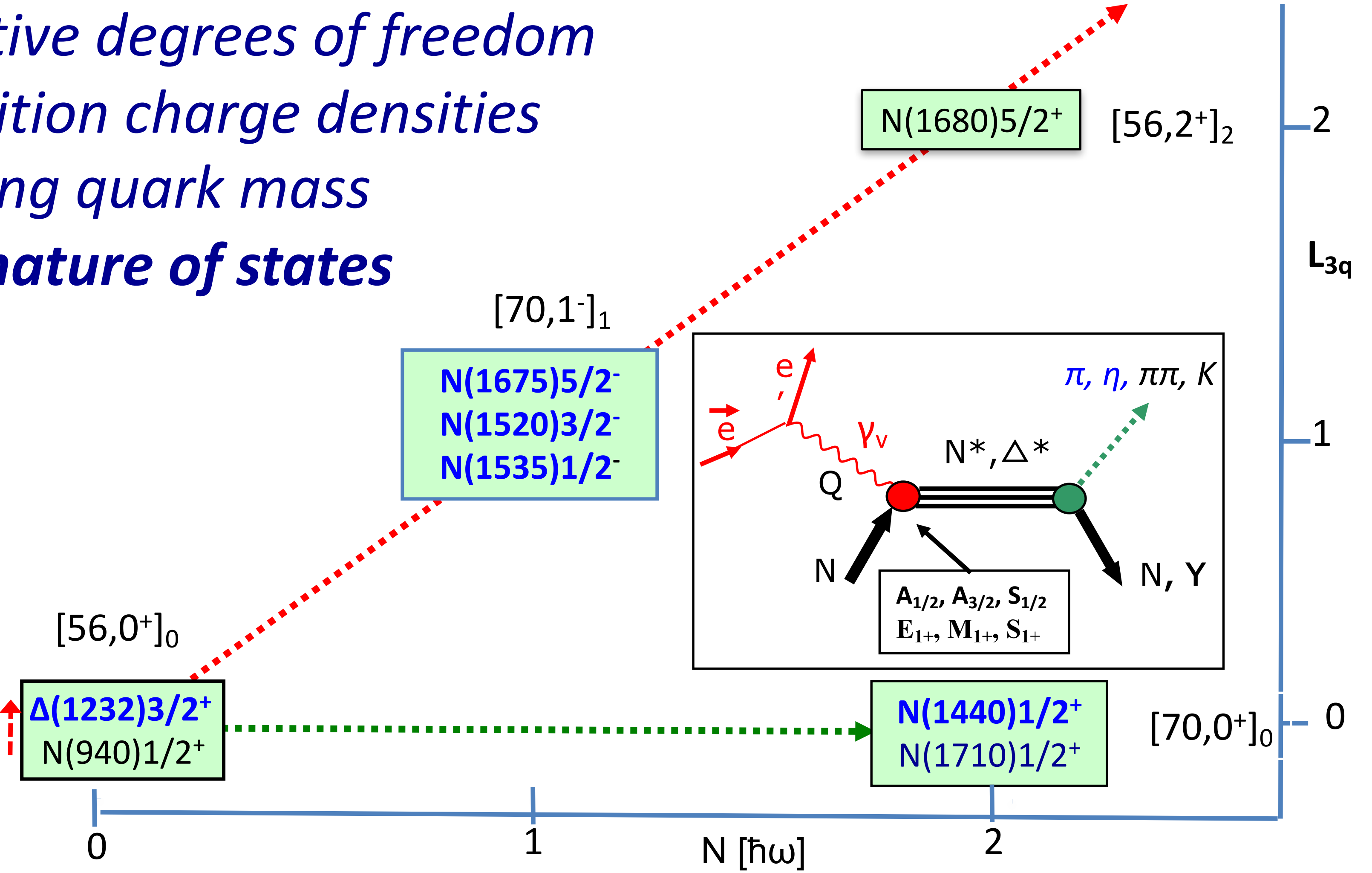


- **N*s are broadly overlapping**
- **Hard to disentangle without polarization observables**

Structure of excited baryons

- *effective degrees of freedom*
- *transition charge densities*
- *running quark mass*

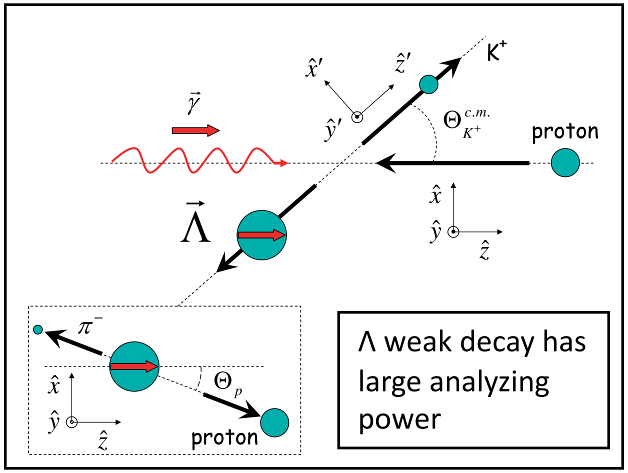
   => nature of states



I.G. Aznauryan et al., Analysis of p(e,e'Nπ); V.I. Mokeev et al., Analysis of p(e,e'pπ⁺π⁻)

Complete photoproduction experiments

$\gamma + p \longrightarrow K^+ + \Lambda\ (p\pi^-)$

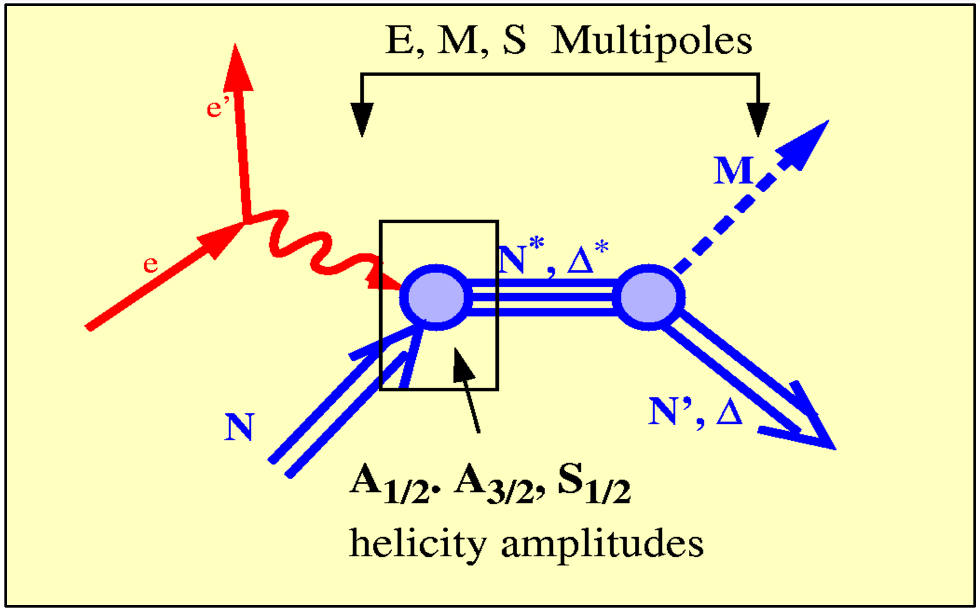


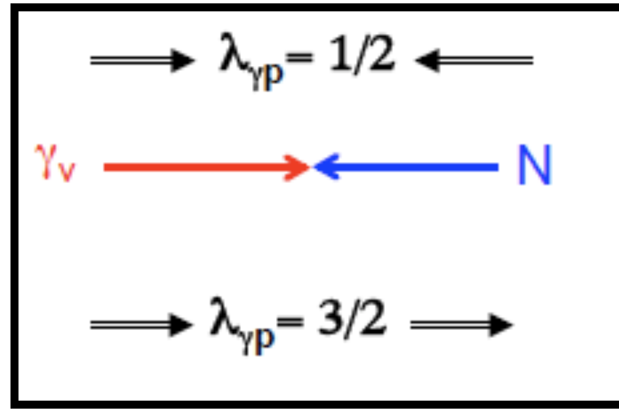
- Process described by 4 complex amplitudes
- 8 well-chosen measurements are needed to determine amplitude.
- Up to **16** observables measured directly
- **3** inferred from double polarization observables
- **13** inferred from triple polarization observables

Beam (P^γ)		Target (P^T)			Recoil (P^R)			Target (P^T) + Recoil (P^R)								
					x'	y'	z'	x'	x'	x'	y'	y'	y'	z'	z'	z'
		x	y	z				x	y	z	x	y	z	x	y	z
unpolarized	$d\sigma_0$		$\hat{T}$			$\hat{P}$		$\hat{T}_{x'}$		$\hat{L}_{x'}$		$\underline{\hat{\Sigma}}$		$\hat{T}_{z'}$		$\hat{L}_{z'}$
$P_L^\gamma \sin(2\phi_\gamma)$		$\hat{H}$		$\hat{G}$	$\hat{O}_{x'}$		$\hat{O}_{z'}$		$\hat{\mathbf{C}}_{\mathbf{z'}}$		$\hat{\mathbf{E}}$		$\hat{\mathbf{F}}$		$-\hat{\mathbf{C}}_{\mathbf{x'}}$	
$P_L^\gamma \cos(2\phi_\gamma)$	$-\hat{\Sigma}$		$\underline{-\hat{P}}$			$\underline{-\hat{T}}$		$-\hat{\mathbf{L}}_{\mathbf{z'}}$		$\hat{\mathbf{T}}_{\mathbf{z'}}$		$-\mathbf{d\sigma_0}$		$\hat{\mathbf{L}}_{\mathbf{x'}}$		$-\hat{\mathbf{T}}_{\mathbf{x'}}$
circular P_c^γ		$\hat{F}$		$-\hat{E}$	$\hat{C}_{x'}$		$\hat{C}_{z'}$		$-\hat{\mathbf{O}}_{\mathbf{z'}}$		$\hat{\mathbf{G}}$		$-\hat{\mathbf{H}}$		$\hat{\mathbf{O}}_{\mathbf{x'}}$	

A. Sandorfi, S. Hoblit, H. Kamano, T.-S.H. Lee, J.Phys. 38 (2011) 053001

Electroproduction





The helicity amplitudes are related to the matrix elements of the electromagnetic current via:

$A_{1/2}$: $\langle N^*, S_z^* = +1/2 \,|\, \varepsilon_\mu^{(+)} J^\mu_{em} \,|\, N, S_z = -1/2 \rangle$

$A_{3/2}$: $\langle N^*, S_z^* = +3/2 \,|\, \varepsilon_\mu^{(+)} J^\mu_{em} \,|\, N, S_z = +1/2 \rangle$

$S_{1/2}$: $\langle N^*, S_z^* = +1/2 \,|\, \varepsilon_\mu^{(0)} J^\mu_{em} \,|\, N, S_z = +1/2 \rangle$

Transverse
- $A_{1/2}$
- $A_{3/2}$

Longitudinal
- $S_{1/2}$

Towards a new extraction of N* couplings in the 2 π channel and pioneering studies of time-like electromagnetic transitions (HADES)

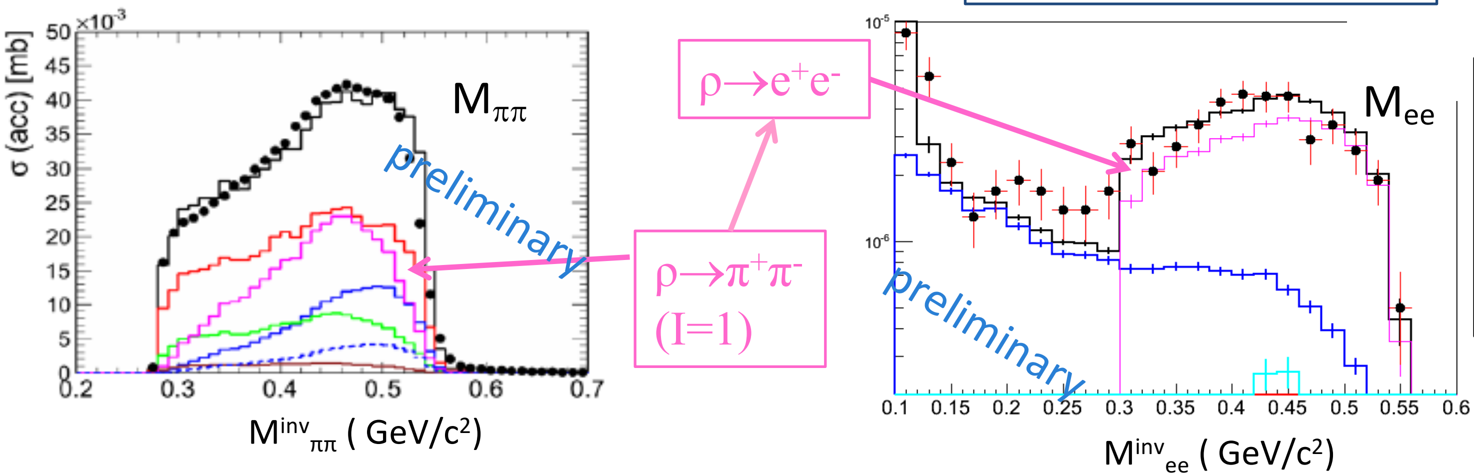
Goals: New data for baryon spectroscopy

- **Hadronic channels (ππ) :** Partial Wave Analysis with Bonn-Gatchina model (A. Sarantsev)
- 4 data samples from HADES ($\pi^- p \to n\pi^+\pi^-$ / $\pi^- p \to \pi^+\pi^0 p$) + photon and pion database
  → e.g. ***N(1520) branching ratio to Δπ, ρN ,σN***
- **Electromagnetic channels (e^+e^-)** ***Very first information for e.m. transitions in time-like region***

Partial Wave Analysis $\pi^- p \to n\pi^+\pi^-$

$\sqrt{s}$=1.49 GeV/c²

Quasi-free $\pi^- p \to ne^+e^-$



Total
$\pi^0 \to e^+e^-\gamma$
$\eta \to e^+e^-\gamma$
$N^0(1520) \to ne^+e^-$
$\Delta^0(1232) \to ne^+e^-$

Impact on:

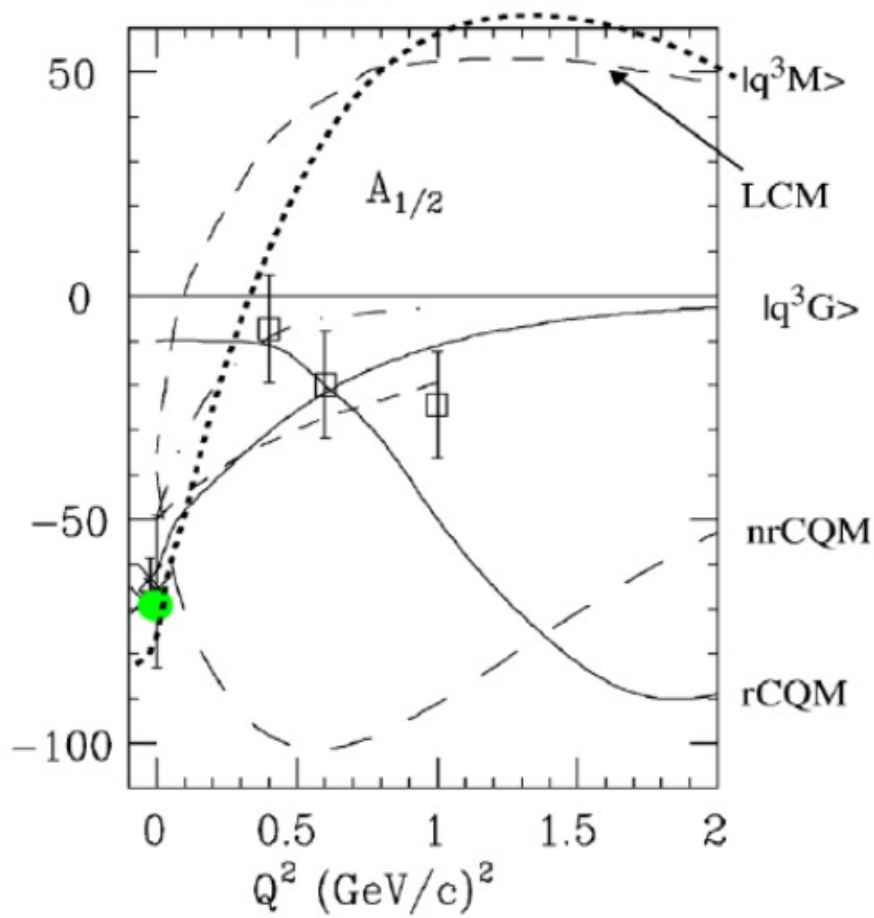
→ Space-like transition form factors extracted from ep → e'Nππ (CLAS data)

→ understand the role of ρ meson in time-like e.m. baryonic transitions (HADES data)

→ medium effects (ρ coupling to baryon resonances)

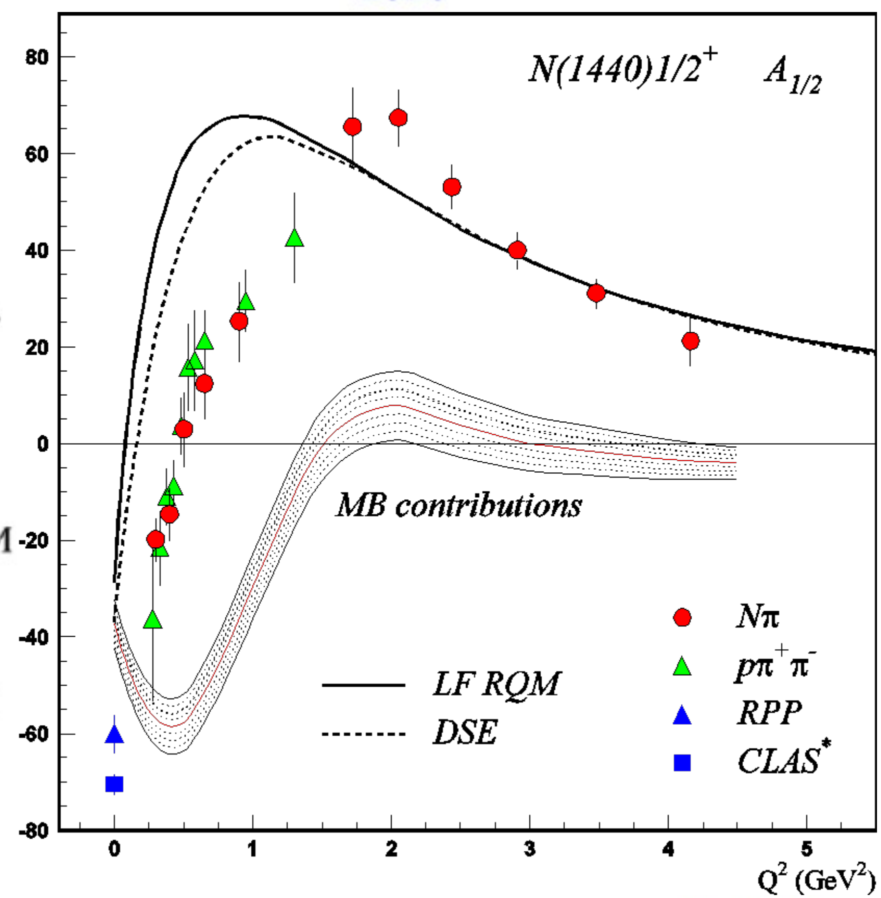
Roper resonance in 2002 & 2016

2002



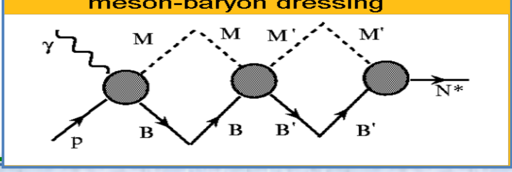
V. Burkert, Baryons 2002

2016



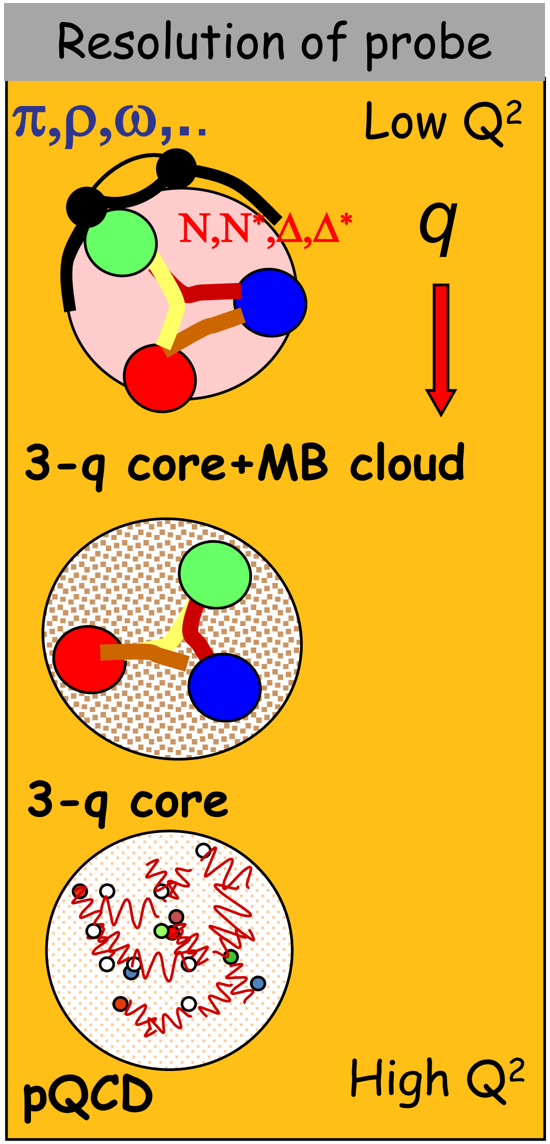
V. D. Burkert, Baryons 2016

The mechanisms of the meson-baryon dressing



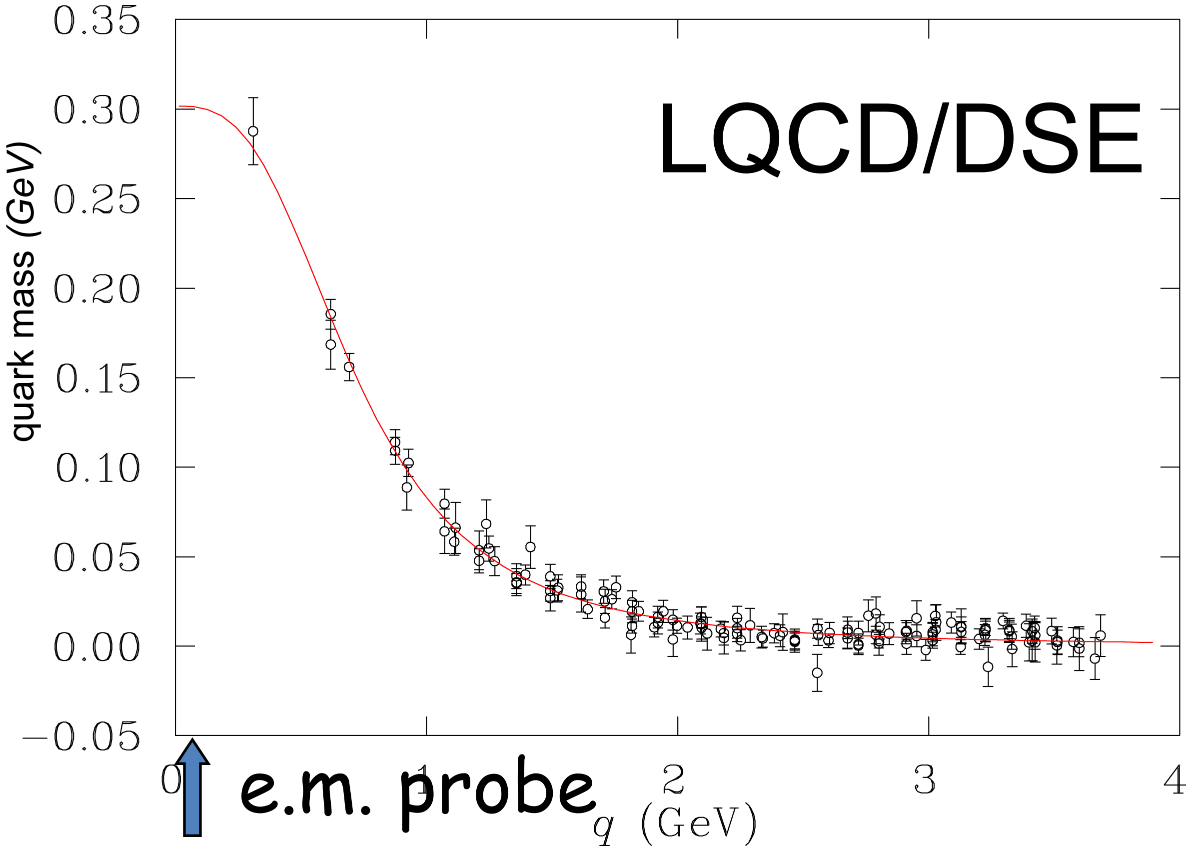
DSE describe successfully the nucleon elastic and the transition N→Δ(1232)3/2⁺, N→N(1535)1/2⁻ form factors <u>with the same dressed quark mass function (J.Segovia, et al., PRL 115, 171801 (2015)).</u>

One clear goal



Allows us to address central the question:

What are the relevant degrees of freedom at varying distance scale?



What is the Idea?

(pre-proposal is reviewed by panel — must be understandable to non-experts)

PROJECT SUMMARY

Overview:

We seek to understand how quarks and gluons self-assemble in forming protons, particles which are central to physics, chemistry, and the biochemical properties of life. Recent results from interrogating protons with polarized photon and electron beams at Jefferson Lab (U.S.) have provided precise information on the substructure of protons and their excitations leading us to a deeper understanding of the proton. Laboratories in Germany and Japan, however, are using pion beams to probe other aspects of the internal structure of protons. Such beams will not be available to the U.S. anytime in the foreseeable future. That is a serious lack, for to reveal the internal structure of the proton requires both electron/photon and pion beams. It follows, therefore, that there must be a coordinated effort among the laboratories in Japan (J-PARC & LEPS), Germany (ELSA, GSI, & MAMI), and the U.S. (JLab) employing photon, electron, and pion beams to make the necessary advances in both theory and phenomenology. We are poised to crack the conundrum of the proton.

What is the Big Idea for the PIRE Pre-Proposal?

- We seek to understand how quarks and gluons self-assemble in forming protons, particles which are central to physics, chemistry, and the biochemical properties of life.

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- Japan (J-PARC & LEPS),
- Germany (ELSA, GSI, & MAMI),
- and the U.S. (JLab)

employing photon, electron, and pion beams to make the necessary advances in both theory and phenomenology.

Three Fundamental Questions

1. **What is the essence of confinement?**

   That is, why is it that the three valence quarks are bound together so tightly and how does their binding evolve for nucleon resonances having different quantum numbers? And what role does the meson-baryon cloud play in quark-gluon confinement?

2. **How is confinement connected with dynamical chiral symmetry breaking?**

   This accounts for the origin of roughly 98% of the visible mass in the universe. The Higgs mechanism accounts for only 2% of the mass, the rest is due to the strong field in the nucleon.

3. **Can the Standard Model be further developed to successfully describe the complex structure of all excited baryon states?**

   If so, how does the spectrum of baryons emerge from the strong interaction among dressed quarks and gluons? How may we improve the connection between *ab-initio* calculations of QCD and the experimental observables?

Goal and Scope of the N* PIRE Group

The N* PIRE Group will deliver the following four major achievements through the 5-year proposed PIRE research activities:

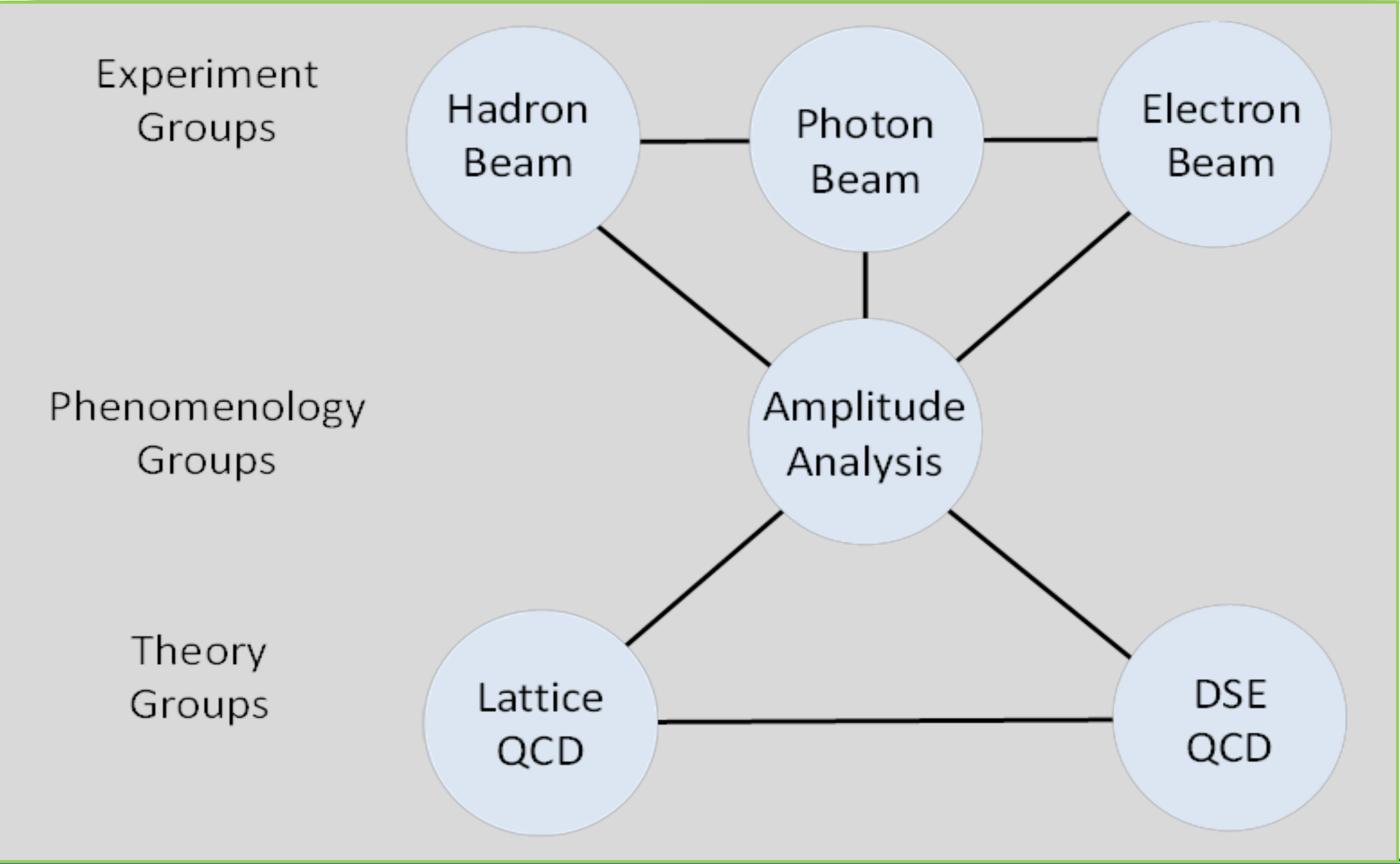
1. Establish the nucleon excitation spectrum and reaction models with emphasis on the high-mass region and gluonic excitations;

2. Measure space-like and time-like baryonic transition form factors, and thereby quantify the role of the active degrees of freedom in the nucleon excitation spectrum;

3. Pin down the dressed-quark mass as a function of quark momentum, which will critically deepen our understanding of mass generation dynamics and emergence of quark-gluon confinement.

4. Provide the analysis tools to enable comparisons of future lattice QCD simulations with experimental results.

How we will accomplish these goals



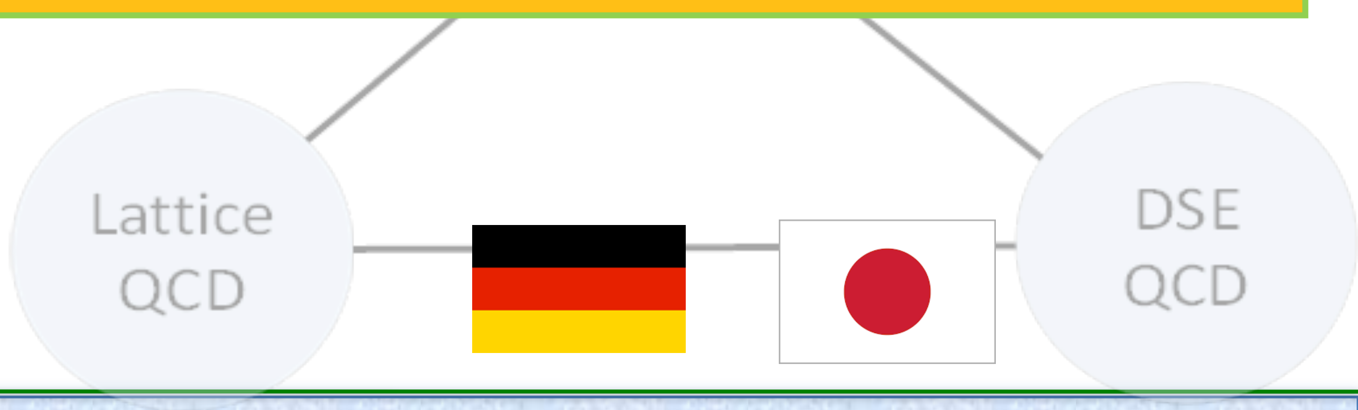
How we will accomplish these goals

Experiment

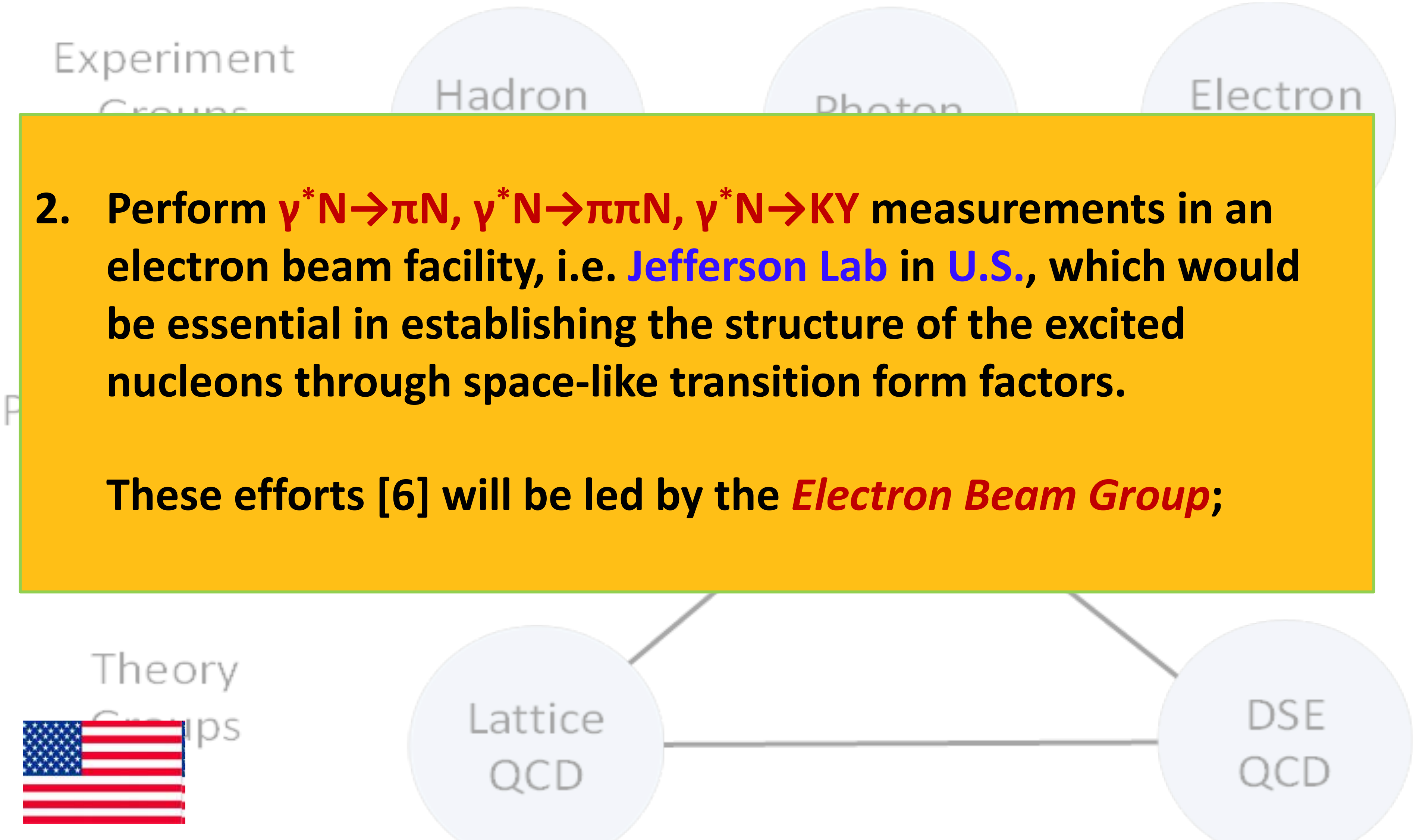
1. **Perform γN→πN, γN→ππN, γN→KY measurements at photon beam facilities such as Bonn [3] and Mainz [4] in Germany and SPRING-8/LEPS [5] in Japan, which would be essential in establishing the nucleon excitation spectrum.**

   These efforts will be led by the *Photon Beam Group*;

Theory Groups



How we will accomplish these goals



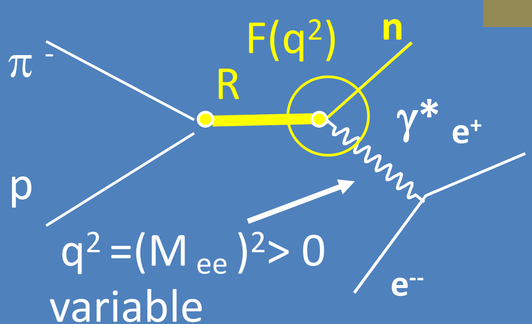
2. Perform $\gamma^* N \rightarrow \pi N$, $\gamma^* N \rightarrow \pi\pi N$, $\gamma^* N \rightarrow KY$ measurements in an electron beam facility, i.e. Jefferson Lab in U.S., which would be essential in establishing the structure of the excited nucleons through space-like transition form factors.

   These efforts [6] will be led by the ***Electron Beam Group***;

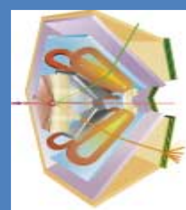
Electromagnetic baryonic transitions in time-like and space-like regions: towards a global picture?

Time-Like electromagnetic form factors

No data



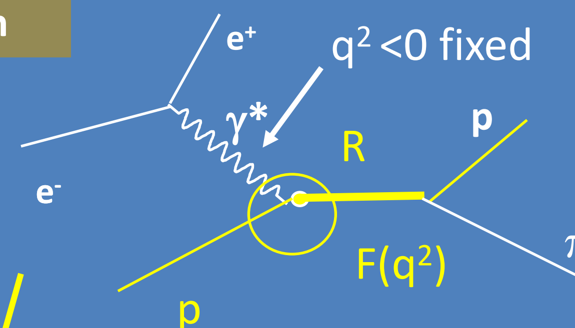
$q^2 = (M_{ee})^2 > 0$
variable

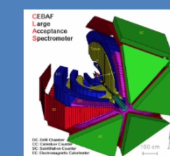


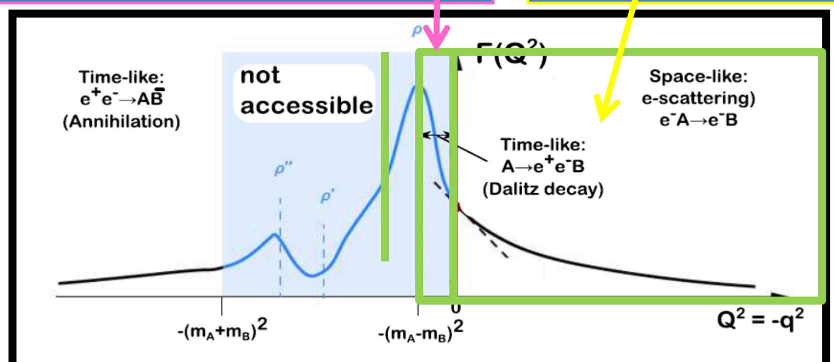
Inverse pion electroproduction

Space-Like electromagnetic form factors

Precise data from JLab/CLAS up to $-q^2 = 4$ GeV²







- ***Theoretical tools: Dispersion Relations, Dyson-Schwinger, Vector Dominance, Constituent Quarks ?***

How we will accomplish these goals

3. **Perform πN→πN, πN→ππN, πN→KY measurements in a hadron beam facility such as J-PARC in Japan [7], which would be essential in establishing the nucleon excitation spectrum, and are complementary to measurements in photon beam and electron beam facilities [8].**

   Also perform the leptonic pair (e^+e^-) in Dalitz decay measurements in a hadron beam facility such as HADES in Germany, which would be essential in determining time-like transition form factors [9].

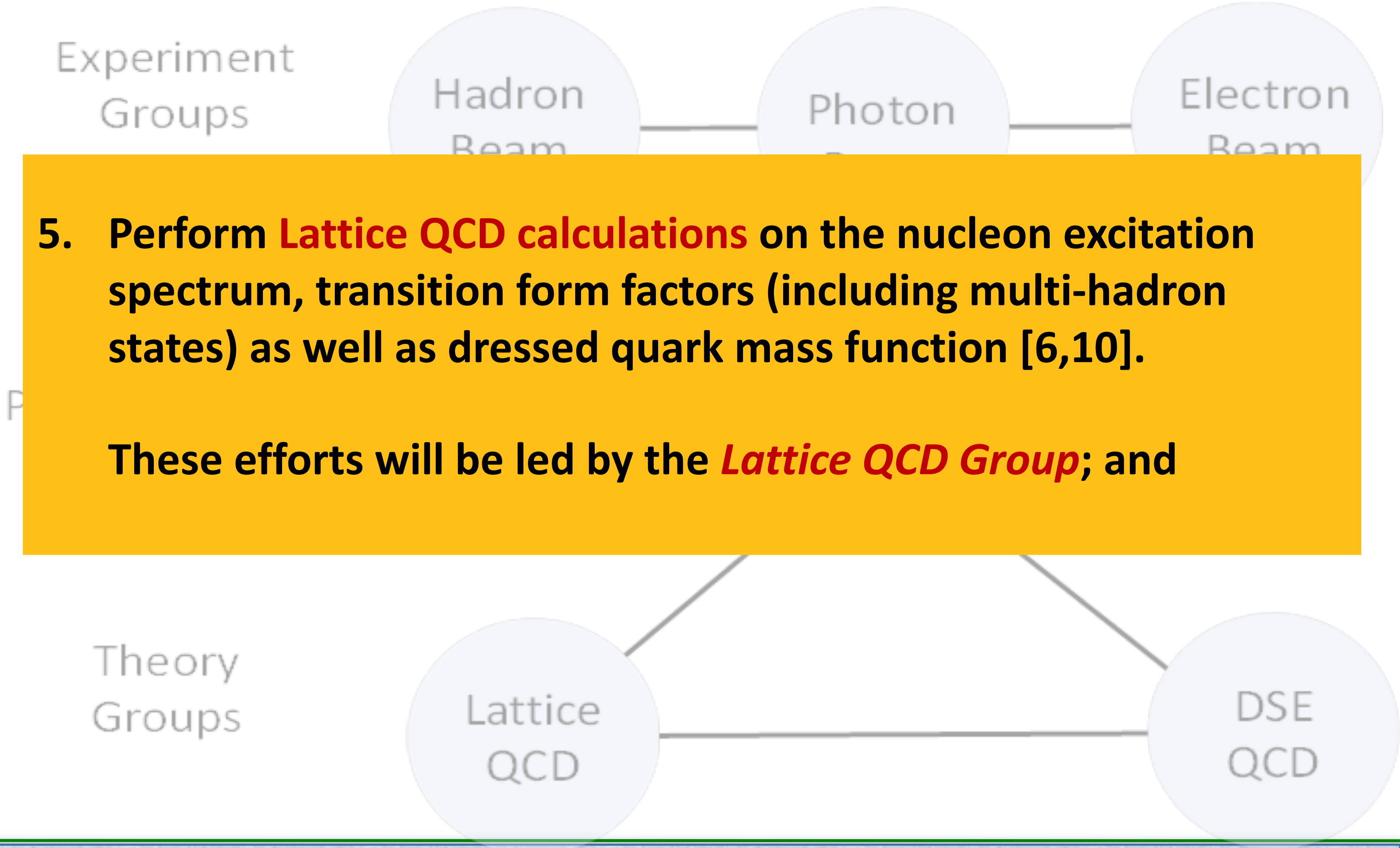
   These efforts will be led by the *Hadron Beam Group*;

How we will accomplish these goals

4. **Perform** **amplitude analyses** **to establish the nucleon excitation spectrum as well as reaction models simultaneously using all experimental data from photon beam, electron beam, and hadron beam facilities. Also determine space-like and time-like transition form factors.**

These efforts will be led by the ***Partial Wave Analysis (PWA)/Amplitude Analysis Group*****;**

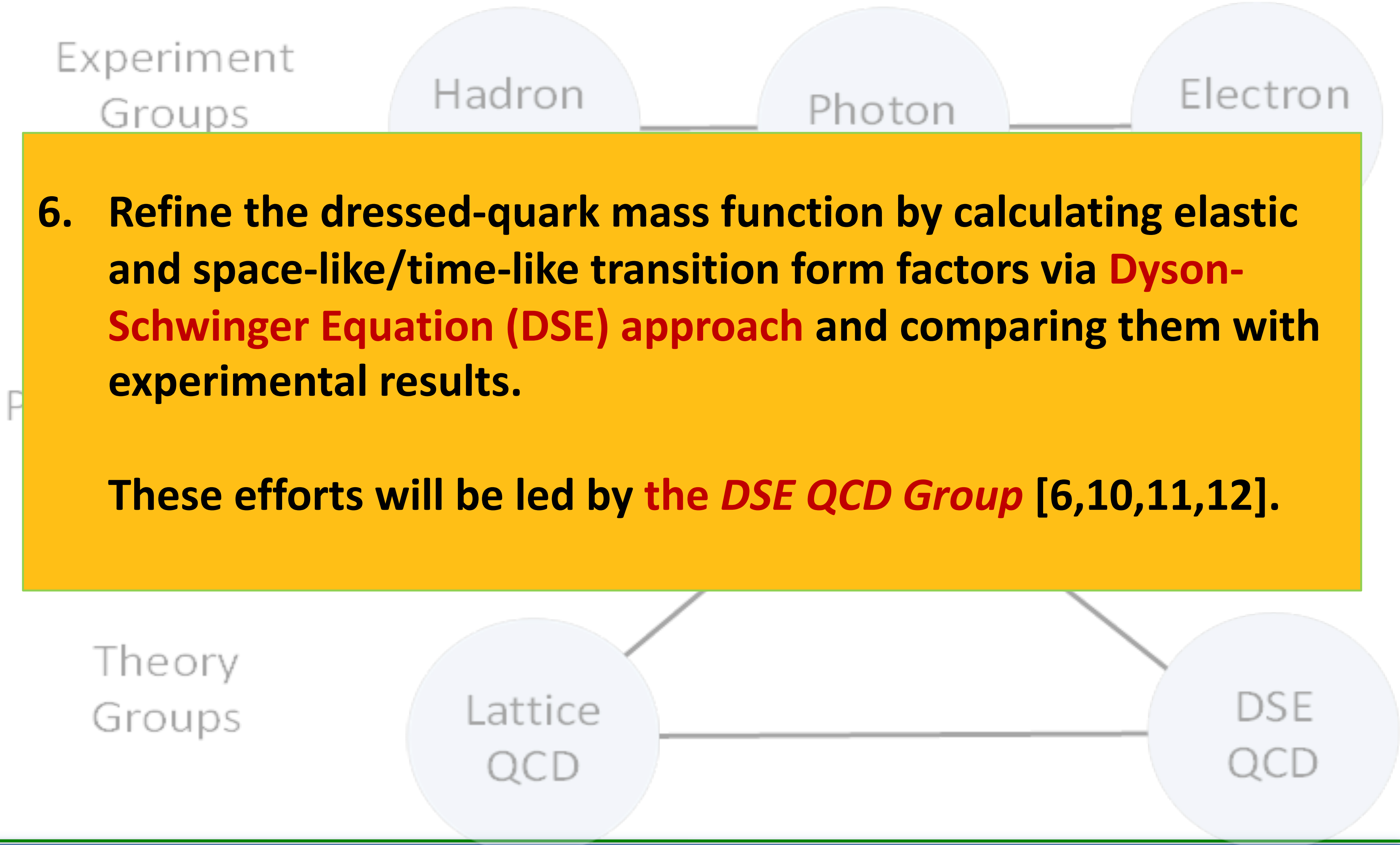
How we will accomplish these goals



5. **Perform** **Lattice QCD calculations** **on the nucleon excitation spectrum, transition form factors (including multi-hadron states) as well as dressed quark mass function [6,10].**

   These efforts will be led by the *Lattice QCD Group*; and

How we will accomplish these goals



6. **Refine the dressed-quark mass function by calculating elastic and space-like/time-like transition form factors via Dyson-Schwinger Equation (DSE) approach and comparing them with experimental results.**

   These efforts will be led by *the DSE QCD Group* [6,10,11,12].

Where do we stand (Nov. 17, 2016)?

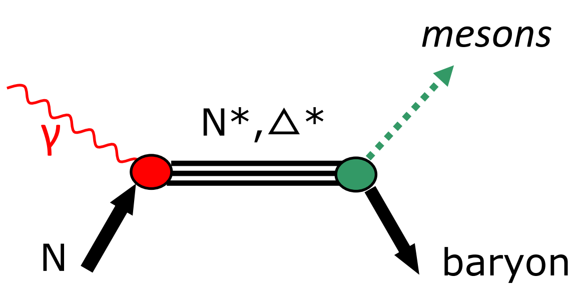
- We are awaiting word on the invitation to submit a full proposal
  - ~240 (pre-proposals) [*One pre-proposal per lead institution*].
  - → ~40 to 60 (*full proposals by invitation only*).
  - → 8 to 12 (*funded proposals*).
- Pre-proposal was submitted on Sept 8, 2016 (deadline: 9/14/16).
- The deadline for the 20-page full proposal is April 24, 2017

Modern tools for N* and Δ* studies

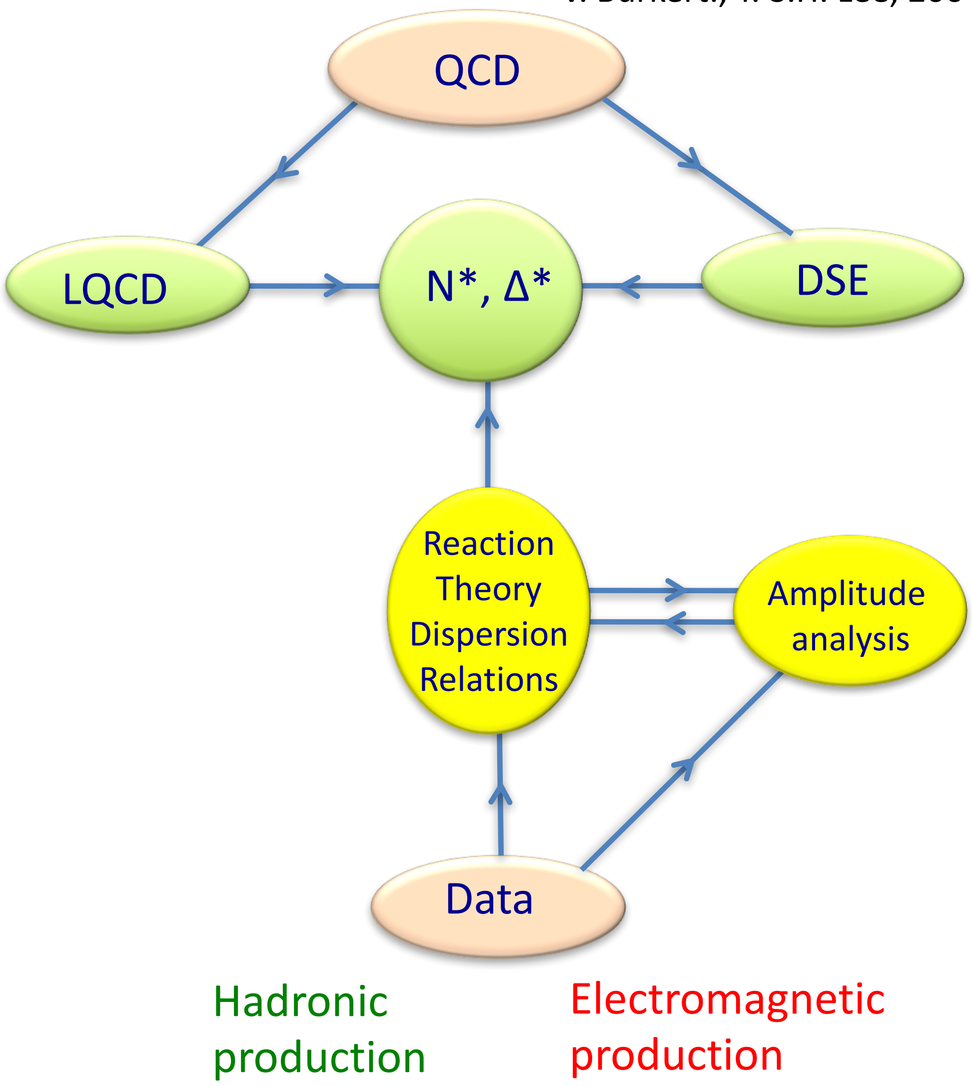
- Multi-GeV polarized cw beam, large acceptance detectors, polarized proton/neutron targets.
- Electromagnetically induced two-body processes, e.g. γp --> Nπ, Nη, KY in wide kinematics
- More complex reactions needed to access high mass states, Nππ, Nπη, Nω/ϕ, …

⇓

Extract s-channel resonances



V. Burkert., T.-S.H. Lee, 2004



A very positive development

Our application for the ECT* workshop was approved on Oct 27, 2016

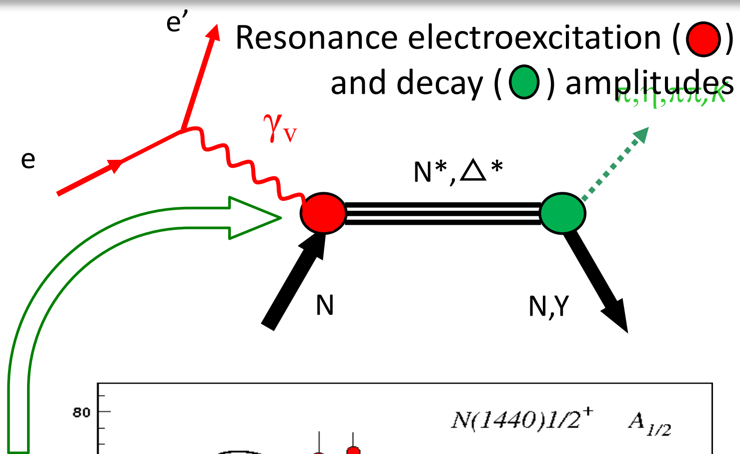
Title: ***Space-like and time-like electromagnetic baryonic transitions***

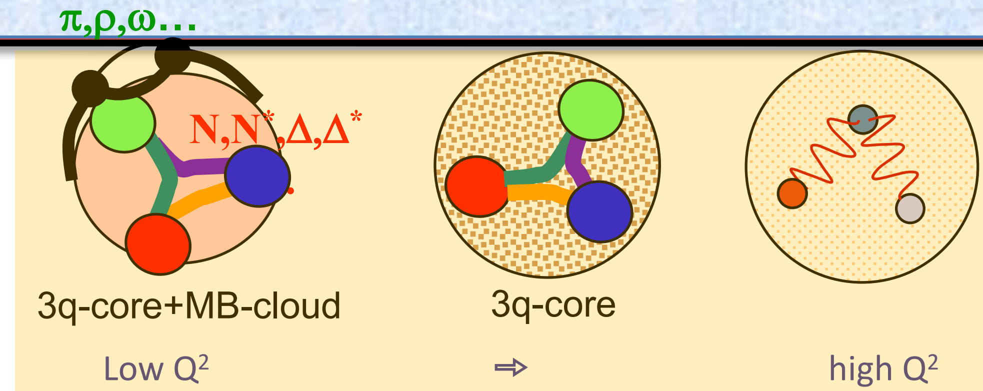
Organizers: **Philip Cole**
Béatrice Ramstein (coordinator)
Andrey Sarantsev

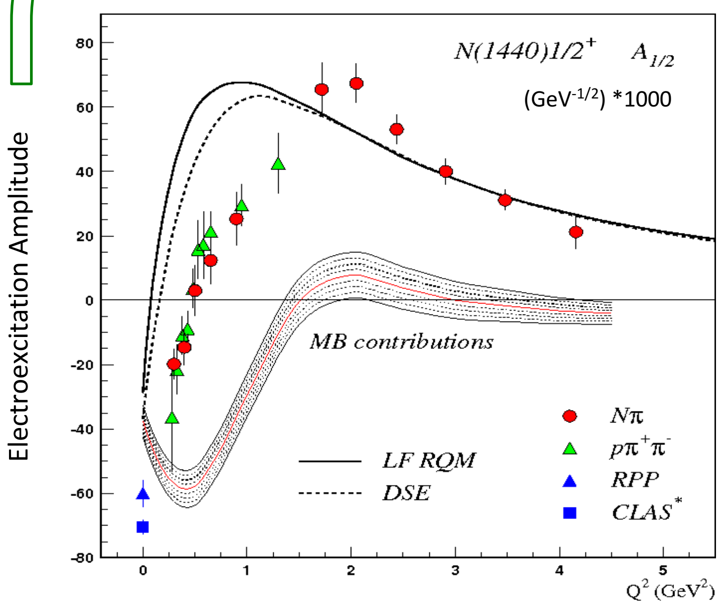
The European Centre for Theoretical Studies in Nuclear Physics (ECT*) workshop will convene May 8-12, 2017 in Trento, Italy.

Same idea as the PIRE pre-proposal

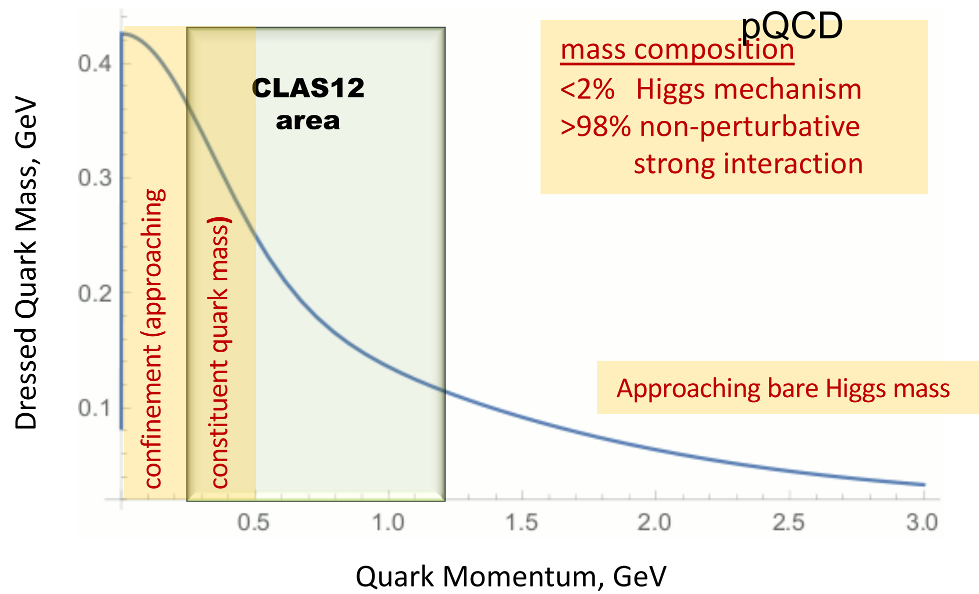
Nucleon Electro-excitations and the Emergence of Hadron Mass (R. Gothe)







CLAS results versus non-perturbative
QCD expectations with running quark mass



N* electroexcitation studies with CLAS12 in Hall B at Jefferson Lab will address critical open questions:
What is the essence of confinement and how is >98% of the visible mass and the structure of hadrons generated?

Summary/Outlook (V. Burkert)

- Excited baryons played a critical role in the evolution of the universe from the QGP phase to the hadron freeze out phase.
- High precision photoproduction data are the basis for the discovery of baryons and to improve evidence for poorly known states. Polarization observables are essential at high masses.
- Multi-channel partial wave analysis frameworks have been key in further establishing the nucleon excitation spectrum.
- Vector meson cross section and polarization data have great potential but have not been (fully) included in coupled channel frameworks.
- Electroexcitation of prominent states supported by advances in theory (DSE, FF RQM) reveals the N* quark core at $Q^2 > 3$ GeV^2 and allows quantifying the meson-baryon contributions.

Outlook (V. Burkert)

- Charge transition density of the Roper N(1440) appears to have a softer central quark core and a wider "cloud" than the N(1535) transitions. Need to go to higher Q^2 to probe the quark core more accurately.

- The N* program at higher energies will probe the running quark mass function at high Q^2, search for gluonic excitations at low Q^2, and search for doubly strange (Ξ^*) and triply strange (Ω^{-*}) states.

- For the search of new states in meson electroproduction we need to expand the multi-channel partial wave analysis to include virtual photons.

- Strangeness channels and multi-meson channels may be key in searching for high mass states.

Our Research Vision for PIRE Grant (again)

- We seek to **bring together representatives of all major experimental, phenomenology, and theory groups** across the globe, who are working on the nucleon resonance problem, into one consolidated collaboration.
- We seek to **strengthen existing links** and **forge entirely new ones within the** broad scope of the **international nuclear physics community,** dedicated towards pursuing
  - a new and rich direction on the study of understanding the underlying structure of nucleons,
  - the spectrum of excited baryon states,
  - and how quarks are confined and acquire mass through the mechanism of dynamical chiral symmetry breaking

Where do we go from here?

We seek to connect and coordinate with all interested parties and groups – domestically and abroad – to work on unraveling the time-like and space-like transition form factors for baryonic structure…

We are eagerly awaiting (*hopefully positive*) news from the NSF to submit a full PIRE proposal.

That said, where do we go from here?

This workshop affords an ideal platform for exchanging ideas on the spectrum and structure of the baryons.

How can we better understand baryon structure through probing the evolution of q^2?

And thereby allowing us to extract the transition form factors from space-like ($q^2 < 0$) to time-like ($q^2 > 0$), anchored at the $q^2 = 0$ point, *viz:*

- **What theoretical advances are required in LQCD, DSE, LC, SR, LF, RQCD, AdS/QCD for all q^2?**
- **What information does JüBo, BnGn, ANL-Osaka, MAID, SAID, Gießen + UIM, JM, Ghent-KY need for baryon spectrum and structure over all q^2?**

Through an NSF PIRE grant, we can transform our understanding of the spectrum and structure of baryons through international cooperation and coordination in research and education.

References cited in this presentation

[3] *The BGO-OD experiment at ELSA*, B. Bantes *et al.* (BGO-OD collaboration), Int. J. Mod. Phys. 26 1460093 (2014). Collaborative Research Centre 16 B1: [http://sfb-tr16.physik.uni-bonn.de/vfs/en/projects/b1/]

CBELSA/TAPS-Results, A1. Spectroscopy of baryon resonances, R. Beck, U. Thoma, Collaborative Research Centre 16 A1 [http://sfb-tr16.physik.uni-bonn.de/vfs/en/projects/a1/]

[4] *The MAMI facility*, Michael Ostrick, Scholarpedia, 5(8):10159 (20100.

[5] *Spin-Density Matrix Elements for $\gamma p \to K^0\Sigma^+$ at $E\gamma=1.85-3.0$ GeV with Evidence for the κ(800) Meson Exchange*, S.H. Hwang, K. Hicks, J.K. Ahn, T. Nakano *et al.*, Phys.Rev.Lett. 108 (2012) 092001;

Measurement of Spin-Density Matrix Elements for ϕ-Meson Photoproduction from Protons and Deuterons Near Threshold, W.C. Chang *et al.*, Phys. Rev. C82 (2010) 015205

Backward-angle η photoproduction from protons at E_γ = 1.6 - 2.4 GeV, M. Sumihama *et al.*, Phys. Rev. C80 (2009) 052201.

[6] *Studies of Nucleon Resonance Structure in Exclusive Meson Electroproduction*, I.G.Aznauryan *et al.*, Int. J. Mod. Phys. E22, 133015 (2015), arXiv:1212.4891[nucl-th].

[7] *3-Body Hadronic Reactions for New Aspects of Baryon Spectroscopy*, approved E45 experimental proposal for J-PARC 50 GeV Proton Synchrotron; Spokespersons: K.H. Hicks (Ohio University), H. Sako (JAEA) [j-parc.jp/researcher/Hadron/en/pac1207/pdf/P45_2012-3.pdf].

[8] *Physics opportunities with meson beams*, W. J. Briscoe, M. Döring, H. Haberzettl, D. M. Manley, M. Naruki, I. I. Strakovsky, and E. S. Swanson, Eur. Phys. J. A51, 129 (2015) [arXiv:1503.07763 [hep-ph]].

[9] *Resonance Production and Decay in Proton and Pion Induced Collisions with HADES,* Witold Przygoda *et al.*, (HADES collaboration), JPS Conf. Proc. 010013 (2016);

Studying time-like baryonic transitions with HADES, B. Ramstein *et al.*, (HADES collaboration), AIP Conf. Proc. 1735 080001 (2016);

The HADES Pion Beam Facility, NUPECC News 25 vol. 2 22 (2015), Piotr Salabura, Joachim Stroth, and Laura Fabbietti.

[10] *Running Masses in the Nucleon and its Resonances*, C.D. Roberts, JPS Conf. Proc. 10, 010012 (2016), arXiv1509.03311[nucl-th].