

核子形状因子と Jlab 12GeV Upgrade

理研
中川格

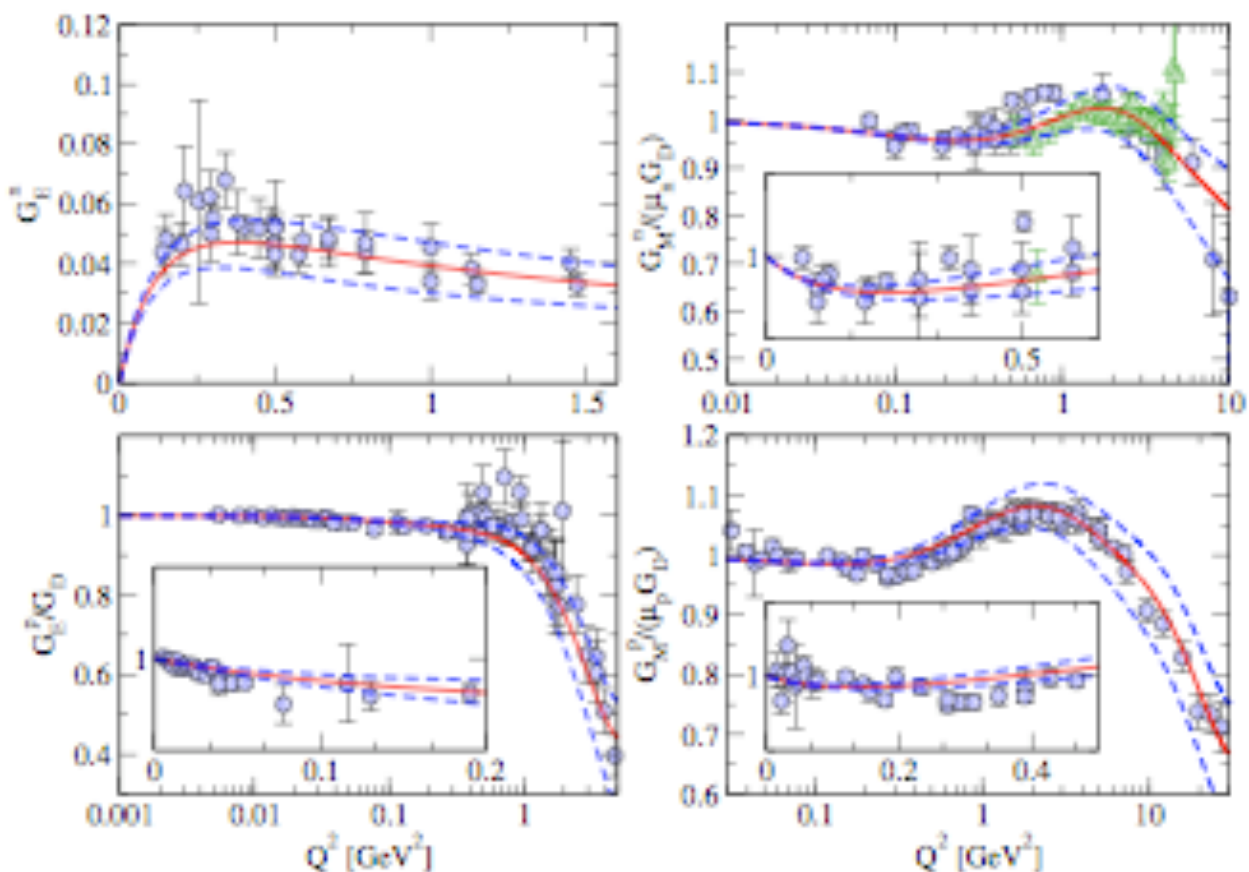
これまでの経緯

- 核子の弾性電磁形状因子の研究は電子加速器のエネルギーの拡張と供により高以降運動量領域での測定が行われ、核子-中間子の描像からクォークグルーオンの自由度による記述へと幅広いスケールで核子構造の理解が試みられて来ている。80～90年代頃には入射エネルギー50GeVのSLAC実験により陽子の弾性形状因子測定 Q^2 は 30GeV^2 に達し、pQCDによる記述に期待が高まった。一方加速器の強度や測定技術の向上により、Jlabが立ち上がった90年代から精密測定による再評価の側面も顕著になった。

現状

- 精密測定により、SLACの測定では見落としていた現象も見つかっている。陽子の電荷分布と磁化分布の比 G_E/G_M が Q^2 と共に1からずれていくという興味深い現象が高精度のJlab実験により明らかになった。この現象は高い Q^2 で電子が散乱される際に、1光子交換近似が成り立つのか疑問を呈した。
- また、中性子電磁形状因子の測定もより精度の向上とともにより高い Q^2 へ測定範囲も広がっている。そもそも広範囲の Q^2 を統一的に記述する手だてがない事と、さらに中性子と陽子の4つの電磁形状因子を同時に矛盾無く記述するのは現状では非常に難しい。Meson Cloud, VMD, quarkモデル等複数のフリーパラメーターを調節する形でフィットしているのが現状であり、決定的な知見を得られる程には理論の成熟度が不足している。

核子弾性形状因子の現状



•Low-Q:

- 荷電半径、diffuseness
- Dipole型からのずれ
- 中間子の雲
- ChPT

•High-Q:

- pQCD, Scaling
- Quark Model
- Vector Meson Dominance
- 2光子交換 etc..

5年後

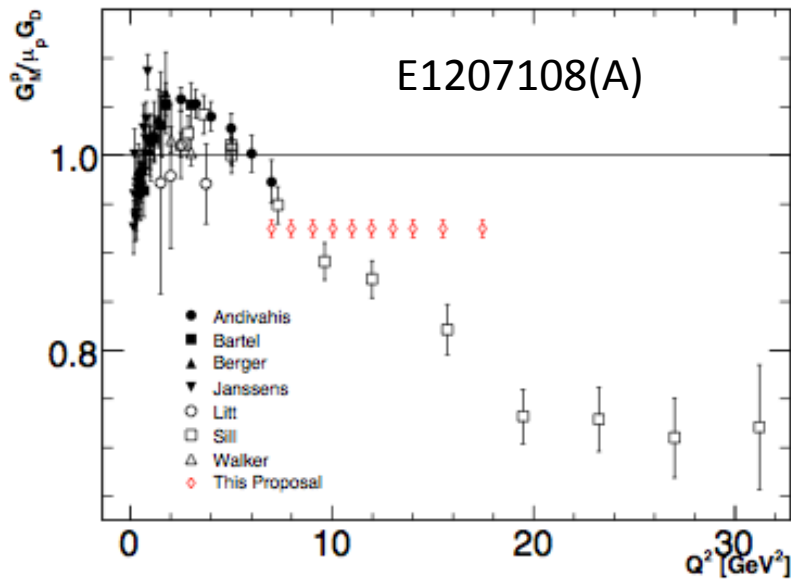
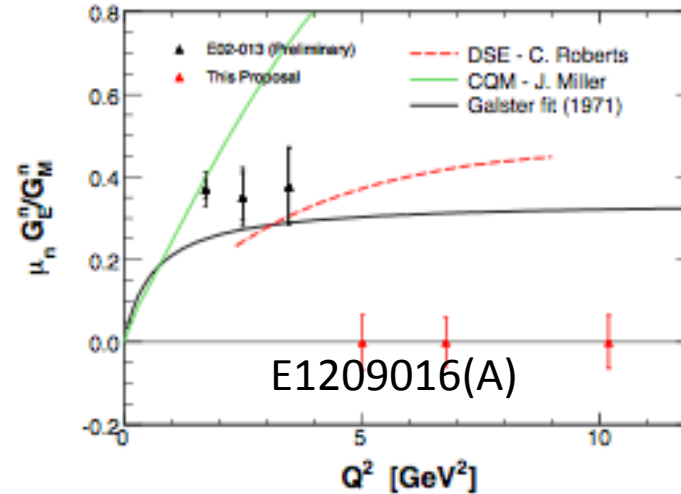
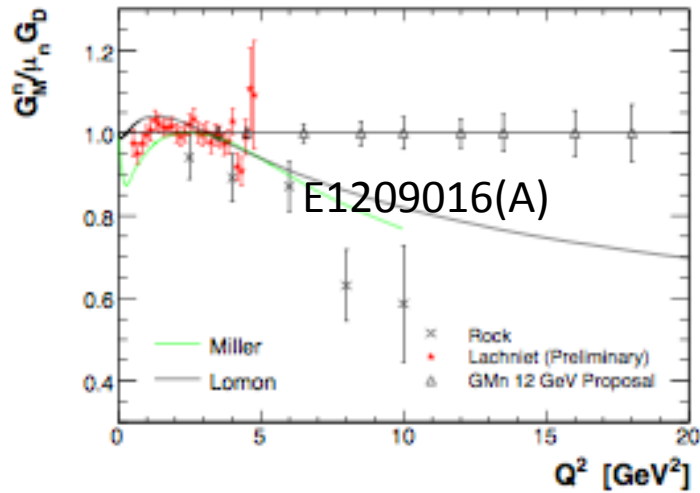
- Jlabでは12GeVへのアップグレードが計画されている。
- SLACの測定をより高精度で塗り替えて来た測定範囲をさらに高 Q^2 領域へと拡張していく。
- 従来のアプローチを再考し、2光子交換などプローブ自身の理解を深めながら、高精度データでpQCDの本格検証を行う。
- 一方でJlabのエネルギー領域では、核子-中間子自由度からパートン自由度への遷移現象を実測する事が期待されている。核子-中間子自由度とクォーク自由度を併せ持つハイブリッドモデルによる検証もなされている。

12 GeV Approved Experiments

Topic	Number of Proposals
Nucleon SPIN	7
GPD, F2 Structure Function	3
Elastic Nucleon EM Form Factors	7
MISC(Meson Production, Strangeness, Few Body, Color Transparency, PV, etc...)	20
Total	37

採択された課題の半数近くが核子及びスピン構造に関わる研究であり、12GeVでも引き続きこの研究テーマに高い関心が寄せられている。

12GeV プロポーザル



より高い Q^2 へ、より高精度の測定
(SLACの既存データを高精度で再測定。)

高 Q^2 ではpQCDの記述が可能になるはずだが、
現行データでは確認されていない。核子中間子
自由度からパートン自由度への遷移の観測を
目指す。

10年後

- eRHIC/ELICによる拡張？（ここはまだ調べきれ
ていません。）

Backup Slides

12GeV Approved Experiments

12GeV Experiments in Hall A

([E1206114](#)) ; Measurements of Electron-Helicity Dependent Cross Sections of Deeply Virtual Compton Scattering with CEBAF at 12 GeV
([E1206122](#)) ; Measurement of neutron asymmetry A_{1n} in the valence quark region using 8.8 GeV and 6.6 GeV beam energies and Bigbite spectrometer in Hall A
([E1207108](#)) ; Precision Measurement of the Proton Elastic Cross Section at High Q^2
([E1207109](#)) ; Large Acceptance Proton Form Factor Ratio Measurements at 13 and 15 (GeV/c)² Using Recoil Polarization Method
([E1209005](#)) ; An Ultra-precise Measurement of the Weak Mixing Angle using Moller Scattering
([E1209016](#)) ; Measurement of the Neutron Electromagnetic Form Factor Ratio G_E/G_M at High Q^2
([E1209019](#)) ; Precision Measurement of the Neutron Magnetic Form Factor up to $Q^2=18.0$ (GeV/c)² by the Ratio Method
([E1210001](#)) ; Study of light hypernuclei by pionic decay at JLAB
([E1210006](#)) ; An update to PR12-09-014: Target Single Spin Asymmetry in Semi-Inclusive Deep-Inelastic Electro Pion Production on a Transversely Polarized ³He Target at 8.8 and 11 GeV
([E1210007](#)) ; Precision Measurement of Parity-Violation in Deep Inelastic Scattering Over a Broad Kinematic Range

Number of 12GeV Experiments in Hall A = 10

12GeV Experiments in Hall B

([E1206106](#)) ; Study of Color Transparency in Exclusive Vector Meson Electroproduction off Nuclei
([E1206108](#)) ; Hard Exclusive Electroproduction of π^0 and η with CLAS12
([E1206109](#)) ; The Longitudinal Spin Structure of the Nucleon
([E1206112](#)) ; Probing the Proton's Quark Dynamics in Semi-Inclusive Pion Production at 12 GeV
([E1206117](#)) ; Quark Propagation and Hadron Formation
([E1206119](#)) ; Deeply Virtual Compton Scattering with CLAS at 11 GeV
([E1207104](#)) ; Measurement of the Neutron Magnetic Form Factor at High Q^2 Using the Ratio Method on Deuterium
([E1207107](#)) ; Studies of Spin-Orbit Correlations with Longitudinally Polarized Target
([E1209003](#)) ; Nucleon Resonance Studies with CLAS12
([E1209007](#)) ; Studies of partonic distributions using semi-inclusive production of kaons
([E1209008](#)) ; Studies of the Boer-Mulders Asymmetry in Kaon Electroproduction with Hydrogen and Deuterium Targets
([E1209009](#)) ; Studies of Spin-Orbit Correlations in Kaon Electroproduction in DIS with polarized hydrogen and deuterium targets
([E1210102](#)) ; The Structure of the Free Neutron at Large x-Bjorken

Number of 12GeV Experiments in Hall B = 13

12GeV Experiments in Hall C

([E1206101](#)) ; Measurement of the Charged Pion Form Factor to High Q^2
([E1206104](#)) ; Measurement of the Ratio $R=\sigma_L/\sigma_T$ in Semi-Inclusive Deep-Inelastic Scattering
([E1206105](#)) ; Inclusive Scattering from Nuclei at $x > 15$ in the quasielastic and deeply inelastic regimes
([E1206121](#)) ; A Path to 'Color Polarizabilities' in the Neutron: A Precision Measurement of the Neutron g_{2S} and g_{4S} at High SQ^2S in Hall C
([E1207105](#)) ; Scaling Study of the L-T Separated Pion Electroproduction Cross Section at 11 GeV
([E1209006](#)) ; The Neutron Electric Form Factor at Q^2 up to $7-(GeV/c)^2$ from the Reaction $e^+e^- \rightarrow e^+e^- \gamma^* \rightarrow e^+e^- \pi^0$ via Recoil Polarimetry
([E1209011](#)) ; Studies of the L-T Separated Kaon Electroproduction Cross Section from 5-11 GeV
([E1210002](#)) ; Precision measurements of the F_2 structure function at large x in the resonance region and beyond
([E1210003](#)) ; Deuteron Electro-Disintegration at Very High Missing Momentum
([E1210008](#)) ; Detailed studies of the nuclear dependence of F_2 in light nuclei.
([E1210101](#)) ; Measurement of Neutron Spin Asymmetry A_{1n} in the Valence Quark Region Using an 11 GeV Beam and a Polarized ³He Target in Hall C
([E1210104](#)) ; The Search for Color Transparency at 12 GeV

Number of 12GeV Experiments in Hall C = 12

12GeV Experiments in Hall D

([E1206102](#)) ; Mapping the Spectrum of Light Quark Mesons and Gluonic Excitations with Linearly Polarized Photons
([E1210011](#)) ; A Precision Measurement of the eta Radiative Decay Width via the Primakoff Effect

Number of 12GeV Experiments in Hall D = 2

Number of Approved 12GeV Experiments in all Halls- 37

12 GeV Approved Experiments (Conditionally)

Conditionally Approved 12GeV Experiments

12GeV Experiments in Hall A

- [\(E1206118\)](#) ; Measurement of the F_2^n/F_2^p , d/u Ratios and $A=3$ EMC Effect in Deep Inelastic Scattering off the Tritium and Helium Mirror Nuclei
- [\(E1209012\)](#) ; Precision Measurement of Parity-Violation in Deep Inelastic Scattering Over a Broad Kinematic Range
- [\(E1209018\)](#) ; Measurement of the Semi-Inclusive π and κ electro-production in DIS regime from transversely polarized ^3He target with the SBS&BB spectrometers in Hall A
- [\(E1210009\)](#) ; Search for new Vector Boson A_1 Decaying to $e+e-$
- [\(E1210103\)](#) ; Measurement of the F_2^n/F_2^p , d/u Ratios and $A=3$ EMC Effect in Deep Inelastic Scattering off the Tritium and Helium Mirror Nuclei

Number of 12GeV Experiments in Hall A = 5

12GeV Experiments in Hall B

- [\(E1206113\)](#) ; The Structure of the Free Neutron at Large x -Bjorken

Number of 12GeV Experiments in Hall B = 1

12GeV Experiments in Hall C

- [\(E1206107\)](#) ; The Search for Color Transparency at 12 GeV
- [\(E1206110\)](#) ; Measurement of Neutron Spin Asymmetry A_1^n in the Valence Quark Region Using an 11 GeV Beam and a Polarized ^3He Target in Hall C
- [\(E1207101\)](#) ; Hadronization in Nuclei by Deep Inelastic
- [\(E1207102\)](#) ; Precision Measurement of the Parity-Violating Asymmetry in Deep Inelastic Scattering off Deuterium using Baseline 12 GeV Equipment in Hall C.
- [\(E1207106\)](#) ; The A -dependence of J/ψ Photoproduction near Threshold
- [\(E1209001\)](#) ; GEp/GMp with an 11 GeV electron beam
- [\(E1209002\)](#) ; Precise Measurement of π^+/π^- Ratios in Semi-inclusive Deep Inelastic Scattering PartI: Charge Symmetry violating Quark Distributions
- [\(E1209017\)](#) ; Transverse Momentum Dependence of Semi-Inclusive Pion Production

Number of 12GeV Experiments in Hall C = 8

Number of Conditionally Approved 12GeV Experiments in all Halls = 14

Grand Total Number of 12GeV Experiments in all Halls = 51