List of Figures

1 QCD predicts a confining flux tube is formed between distant static charges. 4

2 Evidence for flux tubes and linear potentials from lattice QCD. 4

3 Model-independent spectrum of the glue (flux tube) of Fig. 1. 5

4 The conceptual design of the proposed detector to study the photoproduction of mesons in the mass region around 2 GeV. 7

5 A projected measurement of the neutron polarization asymmetry A_1^n, determined by the spin structure of the valence quarks, made possible by the proposed 12 GeV Upgrade. 10

6 A projected measurement of the ratio of momentum distributions of valence d quarks to u quarks made possible by the proposed 12 GeV Upgrade. 11

7 The asymptotically dominant contribution to deep inelastic scattering (DIS). 12

8 The special deep exclusive scattering (DES) processes that have been identified as providing a new window on the quark-gluon wavefunctions of the nuclear building blocks. 12

9 The asymptotically dominant diagram for DES with meson production. 14

10 Two possible Generalized Parton Distributions that are consistent with available deep inelastic scattering data but contain very different quark-quark correlations . . 15

11 Projected measurements of the pion elastic form factor through the kinematic regime of the expected transition region from confinement- to perturbative-dominated dynamics made possible by the proposed 12 GeV Upgrade. 17

12 An example of the type of DIS measurement that can be made to study short-range correlations. 20

13 The relative splittings of the $Q\bar{d}$ states are shown to scale from the heaviest to the lightest with the center-of-gravity of the ground state multiplets aligned: $b\bar{d}$, $c\bar{d}$, $s\bar{d}$, and $u\bar{d}$. 21

14 The $Q\bar{Q}$ states from the heaviest to the lightest: $b\bar{b}$, $c\bar{c}$, $s\bar{s}$, $s\bar{d}$, and $u\bar{d}$. 22

15 The configuration of the proposed 12 GeV CEBAF Upgrade. 25

16 Comparing force field lines for QED and QCD 31

17 Evidence for flux tubes and linear potentials from lattice QCD. 31

18 A level diagram showing conventional nonets and expected masses of glueballs, hybrids, and molecular thresholds. 33

19 E852 results: acceptance-corrected effective mass distributions for the $\pi^+\pi^-\pi^-$ combination and $\pi^+\pi^-$ combination. 38

20 E852 results: the combined intensities for all waves fit. 39

21 Various figures of merit to choose the optimal photon beam energy. 42

22 Photon beam flux and degree of linear polarization for various values of electron energy. 43

23 Figure of merit: relative meson yield as a function of photon beam energy for various meson masses and a fixed incident electron beam energy of 12 GeV. 43

24 Ratio R^{np} of neutron to proton structure functions as a function of x_{Bj}, as extracted from the SLAC data, and projected results for a proposed JLab experiment. 51

25 Large-x_{Bj} data for A_1^n and A_1^p. 54

26 Simulated data for a measurement of A_1^n in the large Bjorken-x region, where it is determined by the spin structure of the valence quarks, made possible by the proposed 12 GeV Upgrade. 58

27 The preliminary results for the g_2^n spin structure function from SLAC experiment E155x, and the expected uncertainties from an 11 GeV JLab measurement. 60

28 The parton distribution function and the pion distribution amplitude. 62

29 Hard electroproduction processes: the general structure and perturbative QCD factorization. 63

30 "Handbag" diagrams for DVCS and meson production. 63

31 Comparison of experimental data on the $\gamma^*\gamma\pi^0$ form factor with different theoretical predictions. 67

32 The accessible range of Q^2 and W at 11 GeV beam energy with the upgraded CLAS detector. 69

33 Single-spin asymmetry of the $ep \to ep\gamma$ reaction measured with a longitudinally polarized 11 GeV electron beam. 70

34 World data for $R = \sigma_L/\sigma_T$ in the $ep \to e'\rho p$ channel as a function of Q^2. 72

35 Simulation of the L/T separated cross section $d\sigma/dt$ for ρ electroproduction with an 11 GeV electron beam. 74

36 Separated and unseparated differential cross section $d\sigma/dt$ for $ep \to \pi^+ n$ as a function of Q^2. 75

37 Projected statistical and systematic uncertainties versus Q^2 for the proposed measurements of $G_M^n(Q^2)$, contrasted with previous data. 78

38 The RCS vector form factor $R_V(t)$, multiplied with t^2, versus t. 78

39 $Re(E_{1+}^* M_{1+})/|M_{1+}|^2$ for excitation of the $\Delta(1232)$ as a function of Q^2. 79

40 Measurements of the pion elastic form factor through the expected transition region from confinement- to perturbative-dominated dynamics made possible by the proposed 12 GeV Upgrade. 81

41 Monte Carlo simulation of experimentally measured angular distribution of $\eta\gamma\gamma$ events on ^{12}C, and projected uncertainties for a measurement of the η transition form factor. 84

42 Sample hydrogen νW_2 structure function spectra obtained at $Q^2 = 0.45, 0.85, 1.70,$ and 3.30 $(\mathrm{GeV}/c)^2$ and plotted as a function of the Nachtmann scaling variable ξ. . 89

43 The projected mean fragmentation function as a function of x_{Bj} for two bins in z. . 94

44 Examples of low-energy fragmentation. 96

45 Three of the simplest interactions between two nucleons: pure gluon exchange, quark exchange, and meson exchange. 98

46 The characteristic time scales in J/ψ production on the proton. 99

47 The variation of the cross sections of J/ψ elastic photoproduction near threshold for two- and three-gluon exchange mechanisms. 100

48 The simplest diagram to reveal hidden color state in deuterium. 100

49 The Q^2-dependence of the nuclear transparency. 105

50 The Q^2-dependence of the ratio $R = \sigma(p = 400\ \mathrm{MeV}/c)/\sigma(p = 200\ \mathrm{MeV}/c)$ for the $(e, e'p)$ reaction on deuterium. 106

51 Expected errors on the ratio of cross sections for ρ production at $-t = 0.4$ and $0.8\ \mathrm{GeV}/c^2$ for 30 days of running on CLAS with an 11 GeV beam. 109

52 Phase diagram for nuclear matter. 112

53 Projected data for the deuteron form factor $F_d(Q^2)$ with an 11 GeV beam. 113

54 Projected data for the ^{3}He elastic form factor $F(Q^2)$ with an 11 GeV beam. 115

55 Prediction of the onset of scaling for the $^{56}\mathrm{Fe}(e, e')X$ reaction for a two-nucleon and multi-nucleon short-range correlation model. 120

56 The scaling window for $\alpha = 1.4$. 122

57 The configuration of the proposed 12 GeV CEBAF upgrade. 127

58 Prototype seven-cell cavity. 135

59 A seven-cell cavity in its helium vessel. 136

60 A CAD drawing of the helium vessel in its space-frame. 137

61 A CAD cut-away drawing of the assembled cryomodule. 138

62 Prototype fundamental power coupler. 139

63 A drawing of the new HOM coupler design. 140

64 Prototype cavity tuning mechanism. 141

65 The detuning curve for the seven-cell cavities. 143

66 The original and upgraded versions of the northeast spreader. 148

67 The extraction scheme for the present CEBAF accelerator. 149

68 The cross section of a typical arc dipole (left); and a photo of the dipole modified from the C to H configuration by the addition of three iron plates (right). 151

69 Block diagram of modular power supply. 154

70 The layout of the 12 GeV cryogenics distribution system. 159

71 Monte Carlo calculations of position, angular, and momentum resolutions for the MAD spectrometer. 170

72 The 3D grid used for TOSCA calculations of the properties of the MAD spectrometer's combined-function superconducting magnet. 173

73 TOSCA-generated modulus of the magnetic field in the aperture, showing a quadrupole field configuration offset to the left of the magnet center. 174

74 Side view of the support structure for MAD. 177

75 Schematic layout of the basic detector system planned for the proposed MAD spectrometer. 178

76 Photon resolution for DVCS experiments on a plot Q^2 vs. s. 182

77 CLAS as viewed along the beam direction and as viewed from above. 185

78 The angular acceptance of CLAS for π^+ and π^- plotted versus lab angles. 188

79 Mass distribution for charged particles produced in the $ep \to eX$ reaction at $E_o =$ 2.4 GeV. 189

80 Missing-mass distribution for $ep \to e\pi^+X$ or $ep \to epX$ at $E_o = 4$ GeV. 190

81 Conceptual view of the CLAS upgrade. 194

82 Conceptual view of the CLAS central detector. 195

83 Møller flux rate as a function of the z coordinate along the beam versus the radial position. A 5° line is shown for comparison. 200

84 Simulated missing mass for the reaction $ep \to e'\pi^+ N$. 202

85 Beam envelopes through the SHMS. 210

86 Estimated resolutions of the reconstructed target quantities for the SHMS. 211

87 Cutaway view of the combined-function SHMS dipole. 214

88 The detector stack of the SHMS. Dimensions along the bottom axis are in meters. . 216

89 Beam envelope in the detector stack at 2.5 GeV/c. 217

90 A schematic view of the Hall D photon beam line. 222

91 The effect of collimation on the coherent bremsstrahlung spectrum. 224

92 The collimated coherent bremsstrahlung spectrum for two crystal radiator thicknesses. 225

93 A 3D cut-away view of the Hall D detector (left) and schematic diagram of its major subsystems (right). 226

94 The Hall D start counter and central tracker. 229

95 The Hall D calorimeters. 231

96 Particle identification in Hall D. 232

97 Simulated PWA Results in Hall D. 238

98 Simulated PWA Results in Hall D. 239

99 PWA fits to the data in two α bins. 240