# Deuteron and Helium Form Factor Measurements at Large $Q^2$

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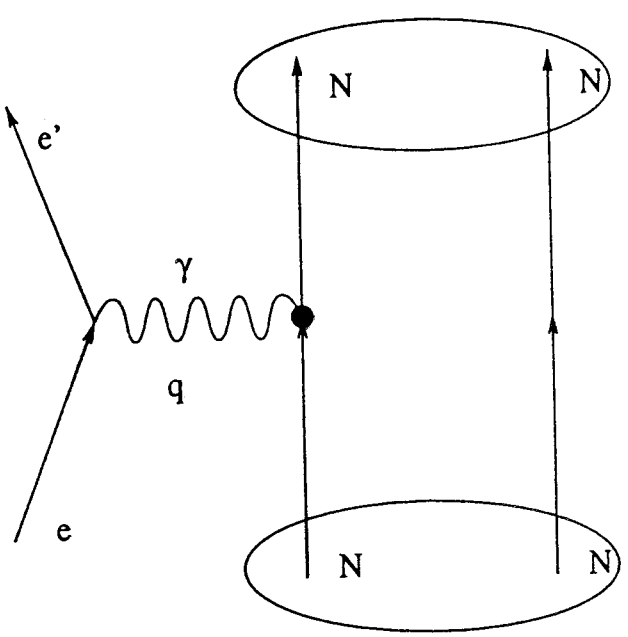
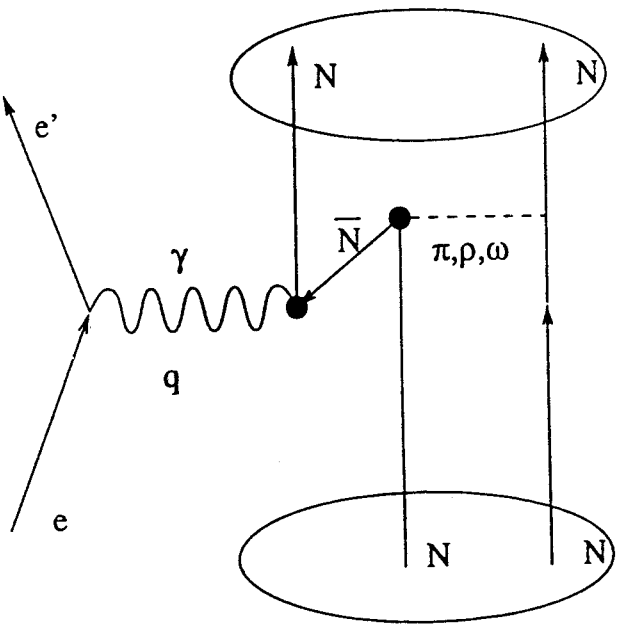
Kent State U.

JLab 12 GeV Workshop
January 2000

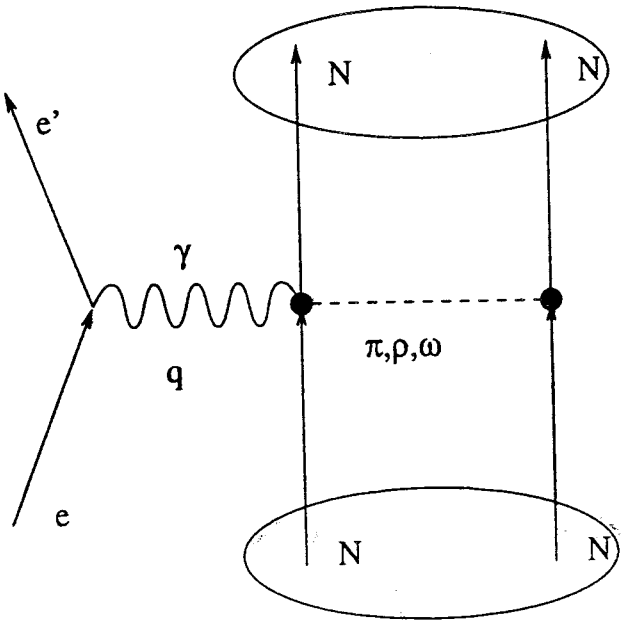
- Review of recent d measurements
- $F_d$ at larger $Q^2$
- $F^3_{He}$ at larger $Q^2$
- Experimental requirements

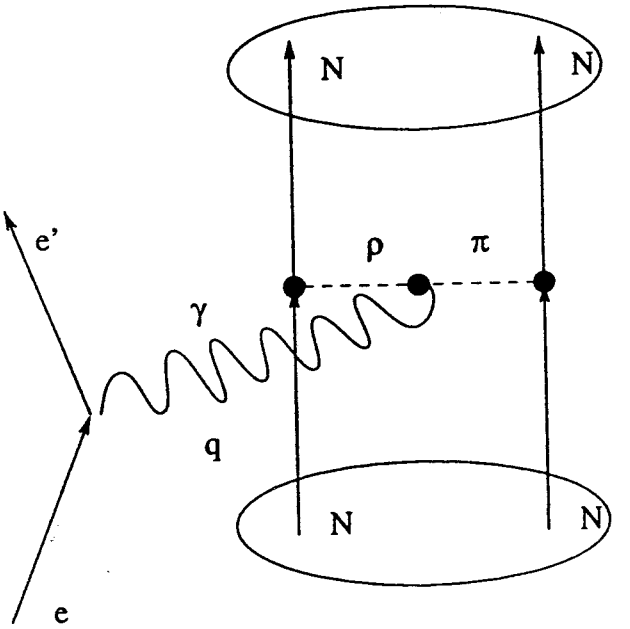
# Meson Exchange Currents (MEC)




## Impulse Approximation



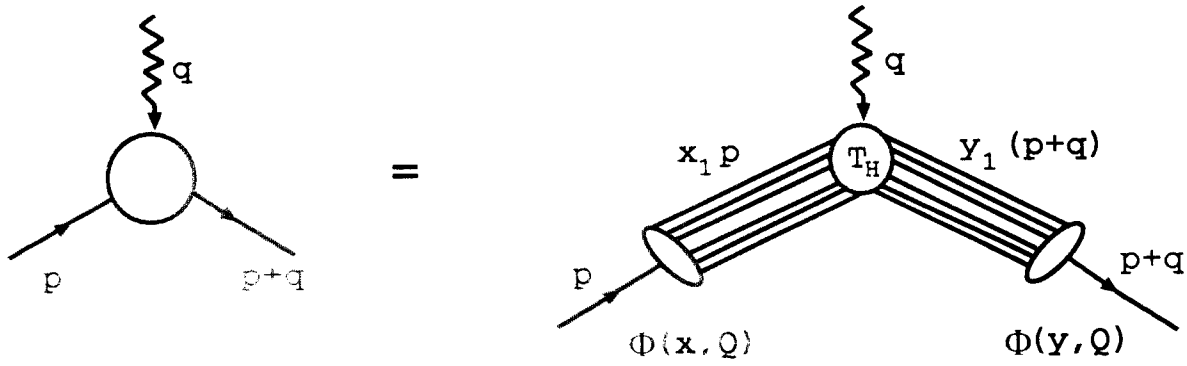



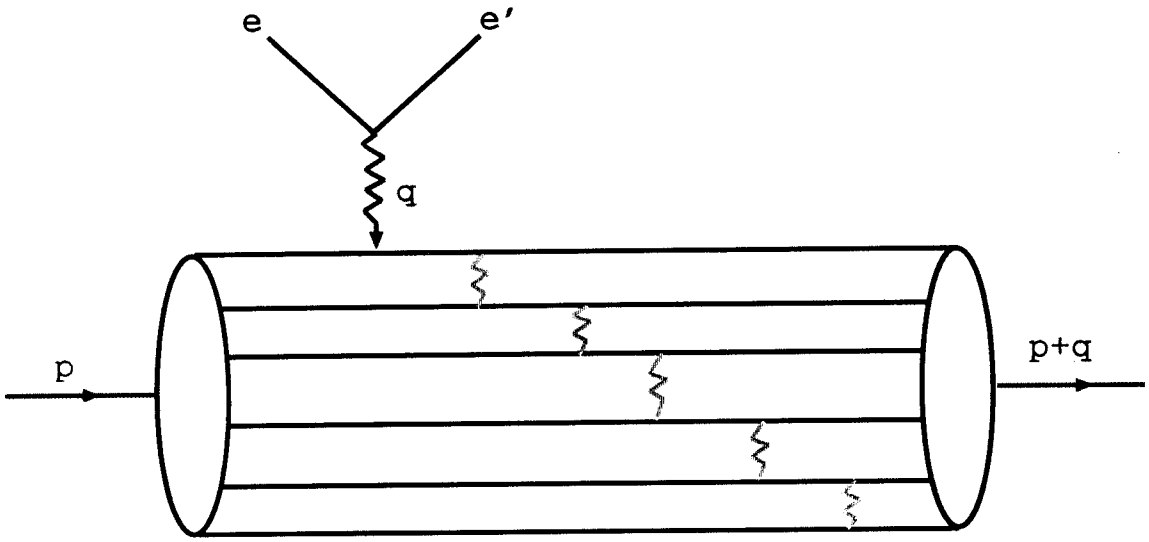
# DEUTERON FORM FACTORS

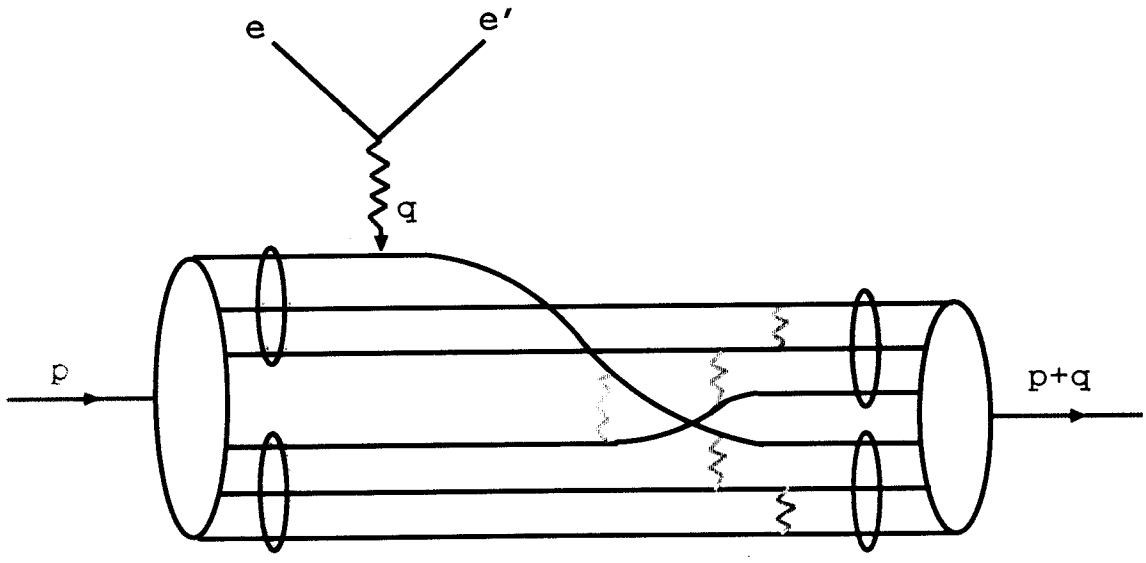
- Probe of deuteron structure
  - Conventional framework:
    - Impulse Approximation (IA)
      - Non-relativistic
      - Relativistic
    - Meson exchange currents (MEC)
    - Isobar configurations (IC)
    - Six-quark admixtures (6q)

$$F = F_{IA} + F_{MEC} + F_{IC} + F_{6q}$$

  - Quark-gluon approaches:
    - Dimensional scaling
    - Perturbative QCD


q
p
p+q
=
q
$x_1$ p
$T_H$
$y_1$ (p+q)
p
p+q
Φ(x,Q)
Φ(y,Q)


e
e′
q
p
p+q


e
e′
q
p
p+q

- Dimensional Scaling Quark Model

$$\sqrt{A} \sim (Q^2)^{-(n-1)}$$

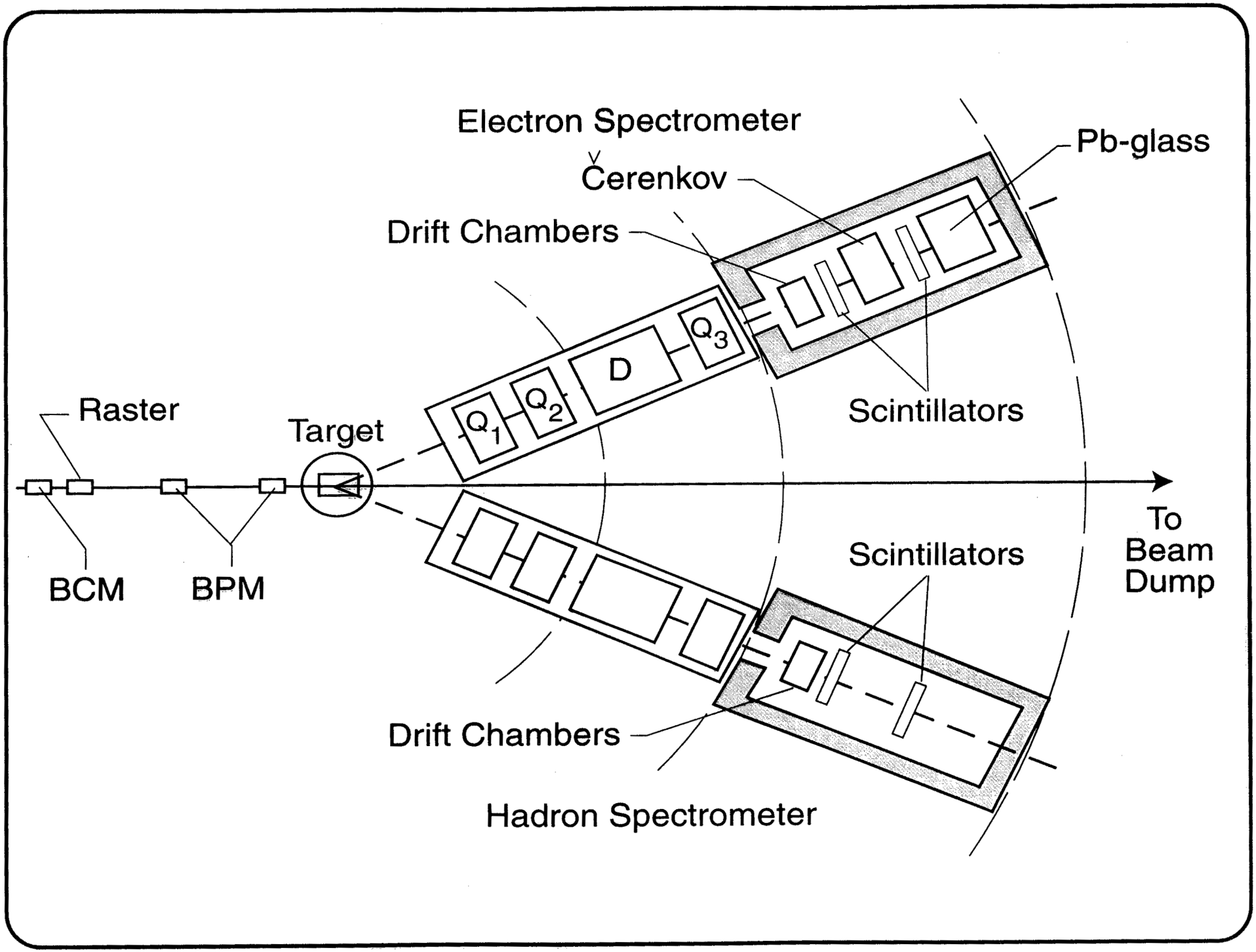
$n = 6$ quarks

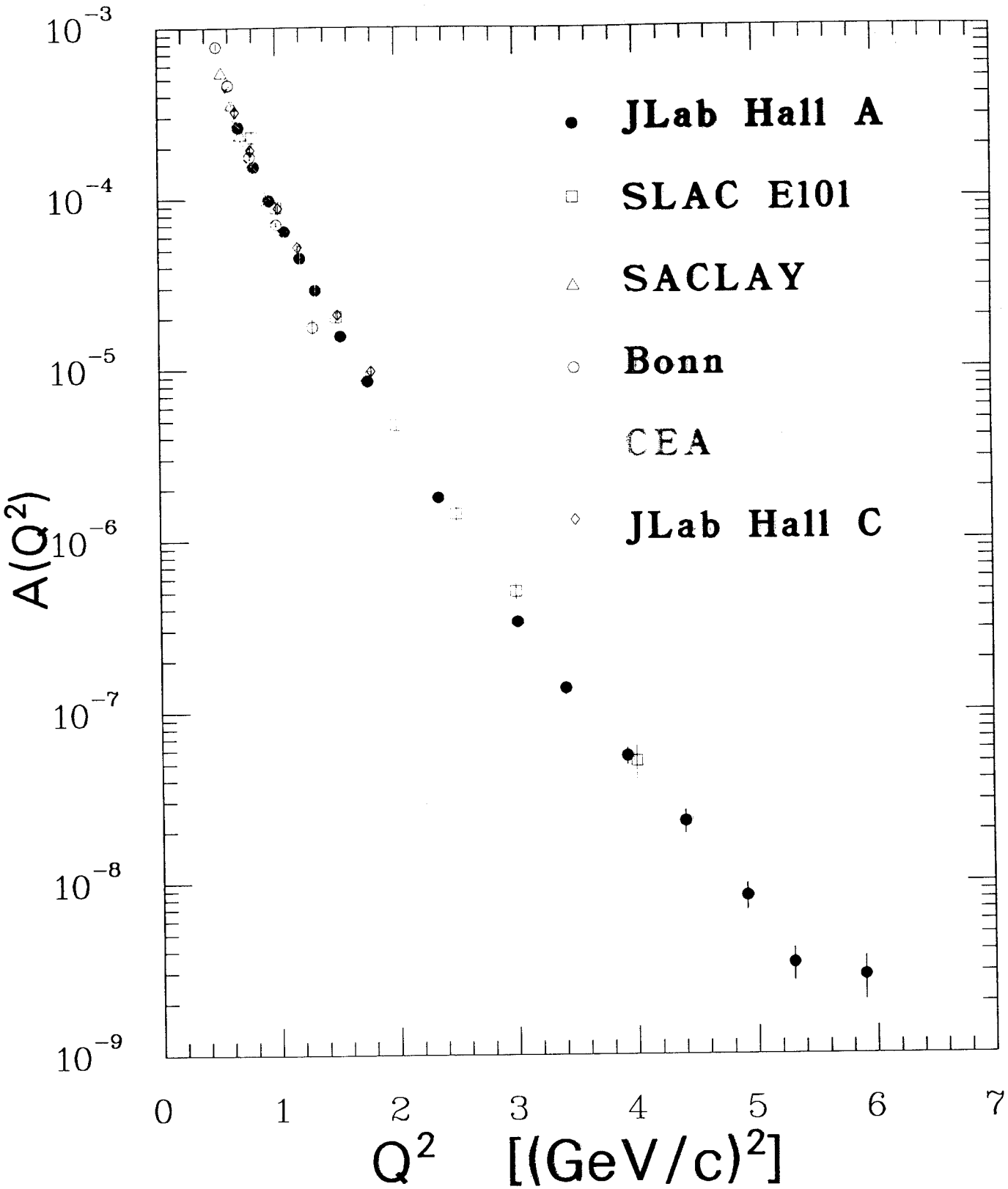
$$\sqrt{B} \sim (Q^2)^{-n}$$

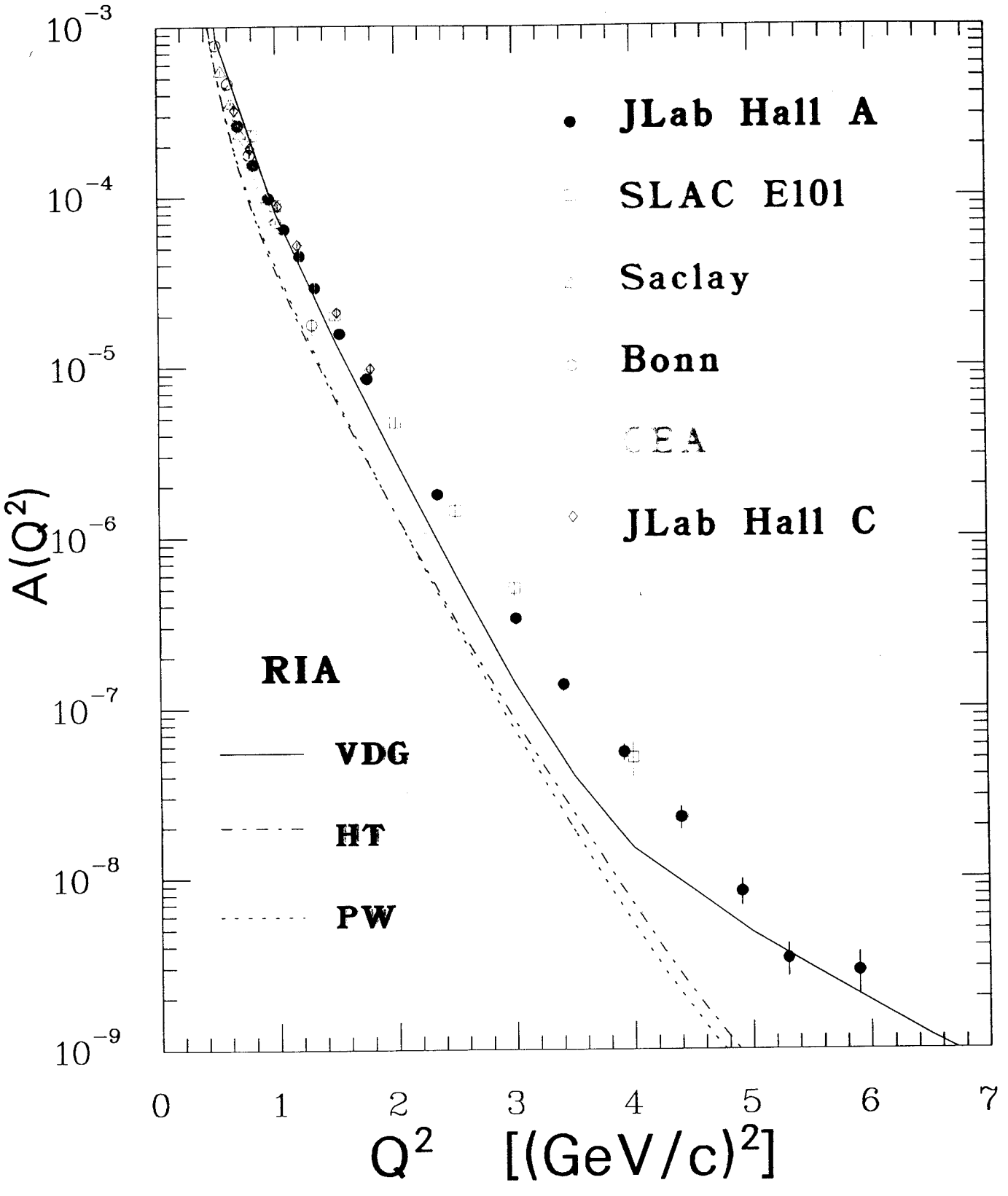
- Perturbative QCD

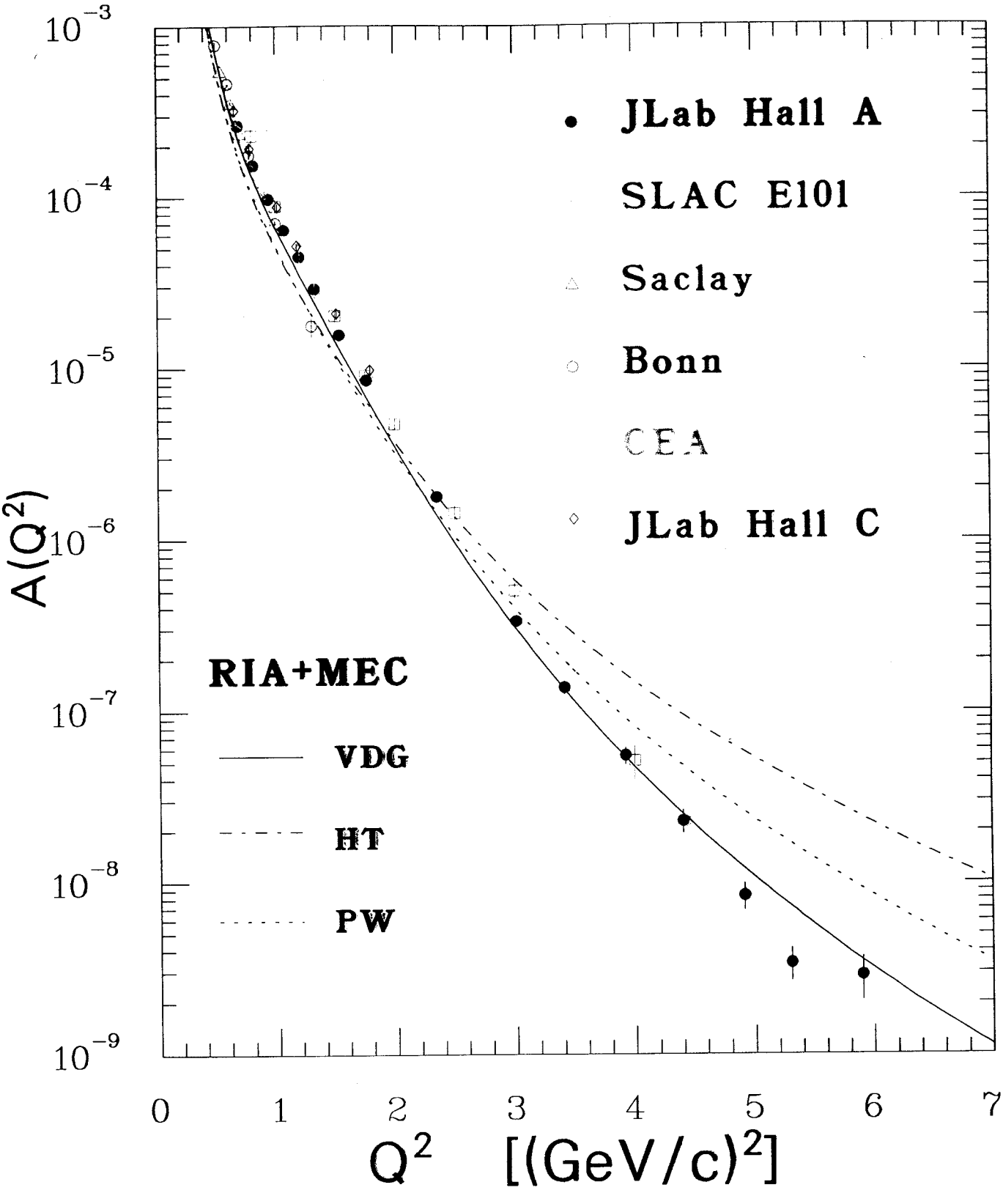
$$\sqrt{A} = \int_0^1 \int_0^1 dxdy\ \phi_d^+(y,Q)\ T(x,y,Q)\ \phi_d(x,Q)$$

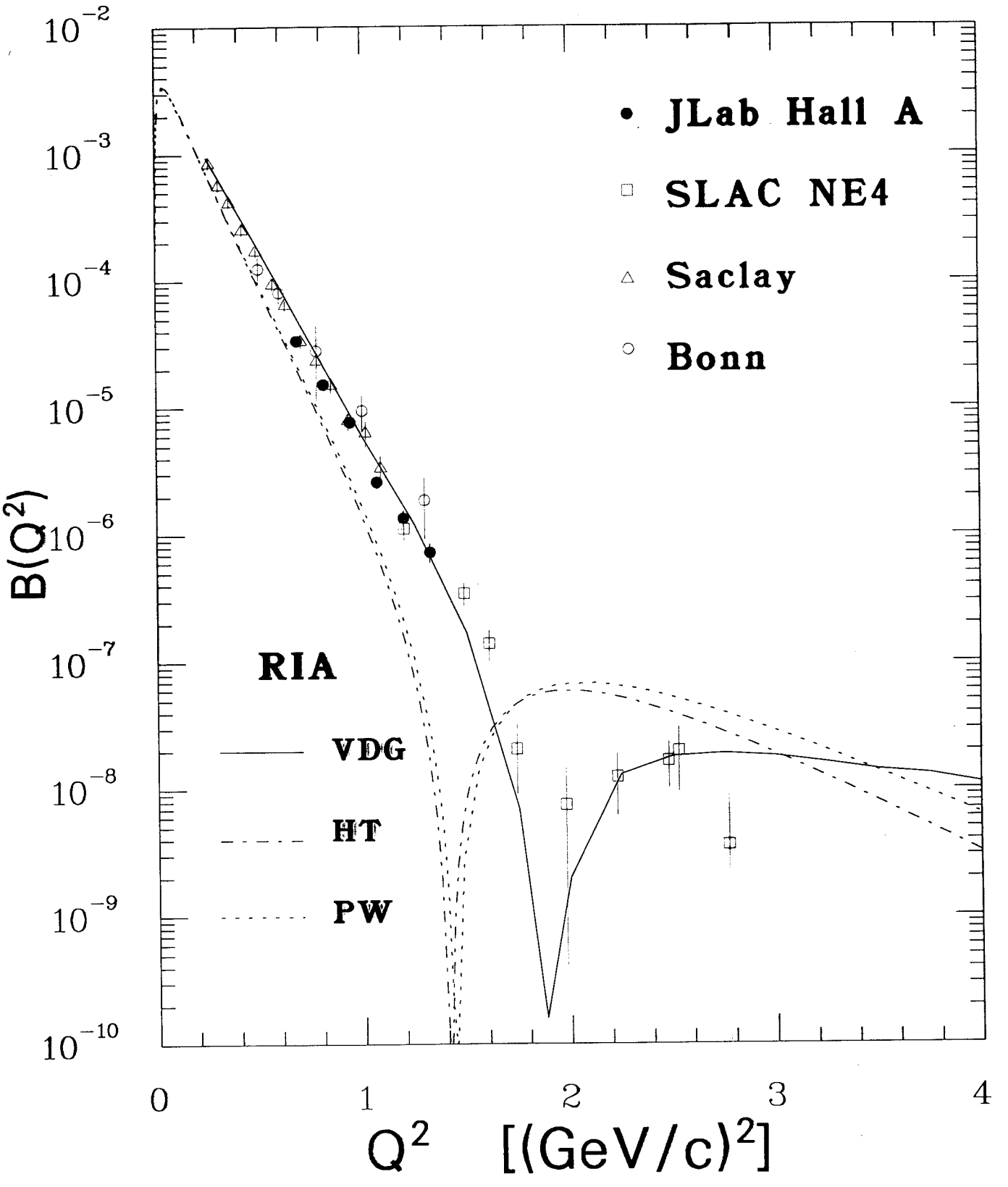
$$\sqrt{A} = \left[\frac{\alpha_s(Q^2)}{Q^2}\right]^5 \sum_{m,n} d_{mn} \left(\ln\frac{Q^2}{\Lambda^2}\right)^{-\gamma_n-\gamma_m}$$

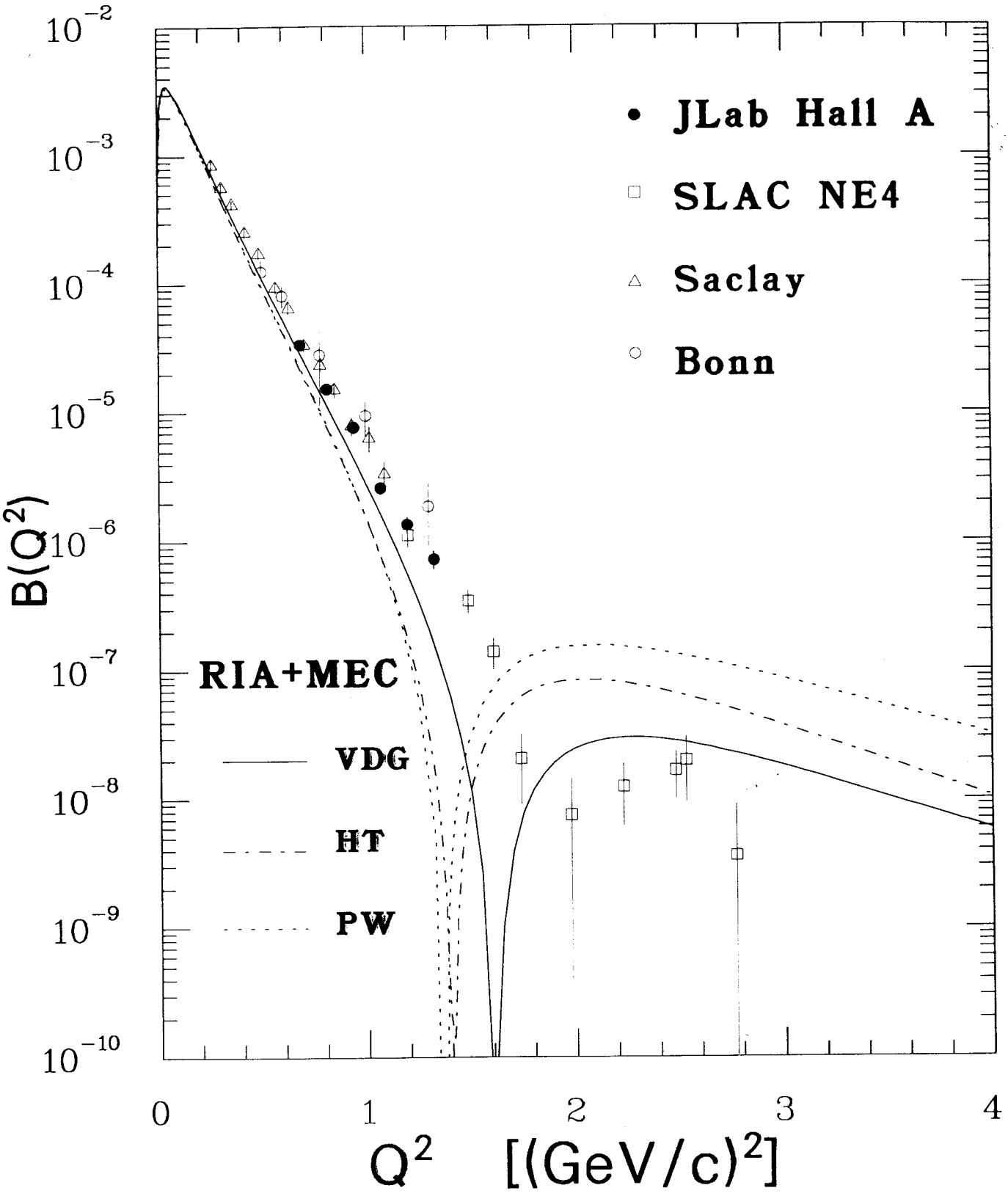

Electron Spectrometer
Cerenkov
Pb-glass
Drift Chambers
$Q_3$
D
$Q_2$
$Q_1$
Scintillators
Raster
Target
To
Beam
Dump
Scintillators
BCM
BPM
Drift Chambers
Hadron Spectrometer

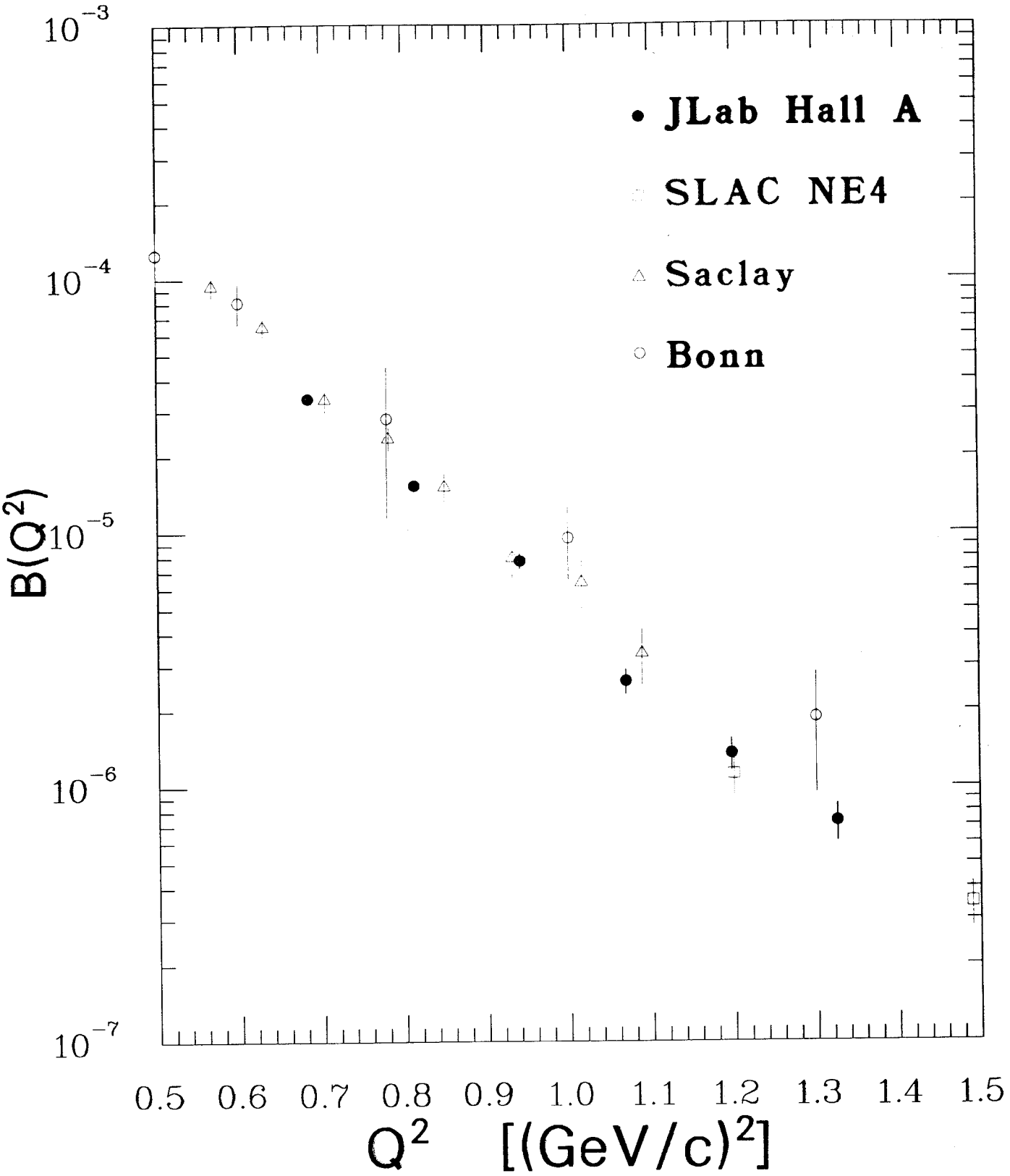

JLab Hall A
SLAC E101
SACLAY
Bonn
CEA
JLab Hall C
A(Q²)
Q² [(GeV/c)²]
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
0
1
2
3
4
5
6
7

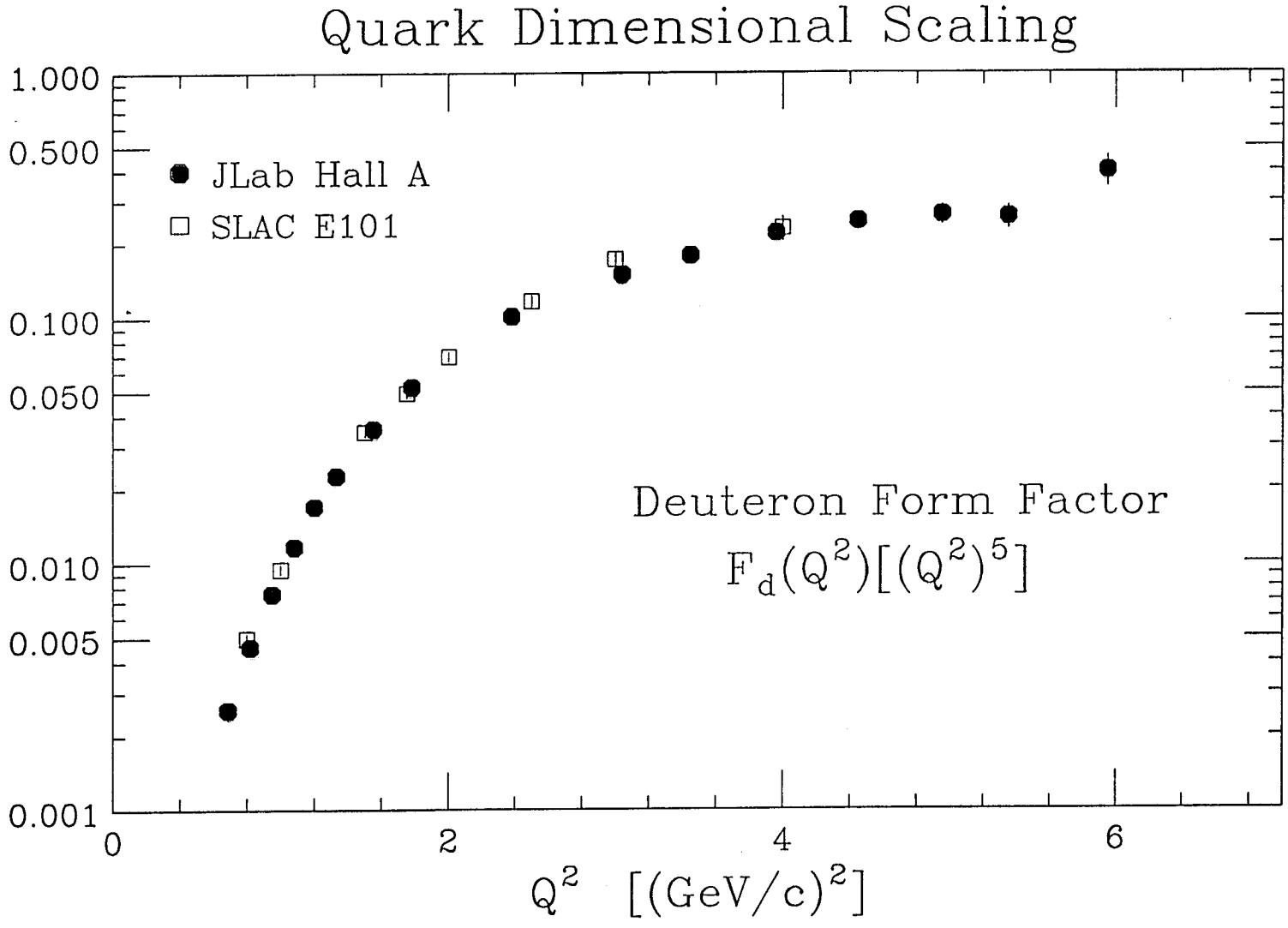

JLab Hall A
SLAC E101
Saclay
Bonn
CEA
JLab Hall C
RIA
VDG
HT
PW
A(Q²)
Q² [(GeV/c)²]
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
0
1
2
3
4
5
6
7


JLab Hall A
SLAC E101
Saclay
Bonn
CEA
JLab Hall C
RIA+MEC
VDG
HT
PW
A(Q²)
Q² [(GeV/c)²]
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
0
1
2
3
4
5
6
7

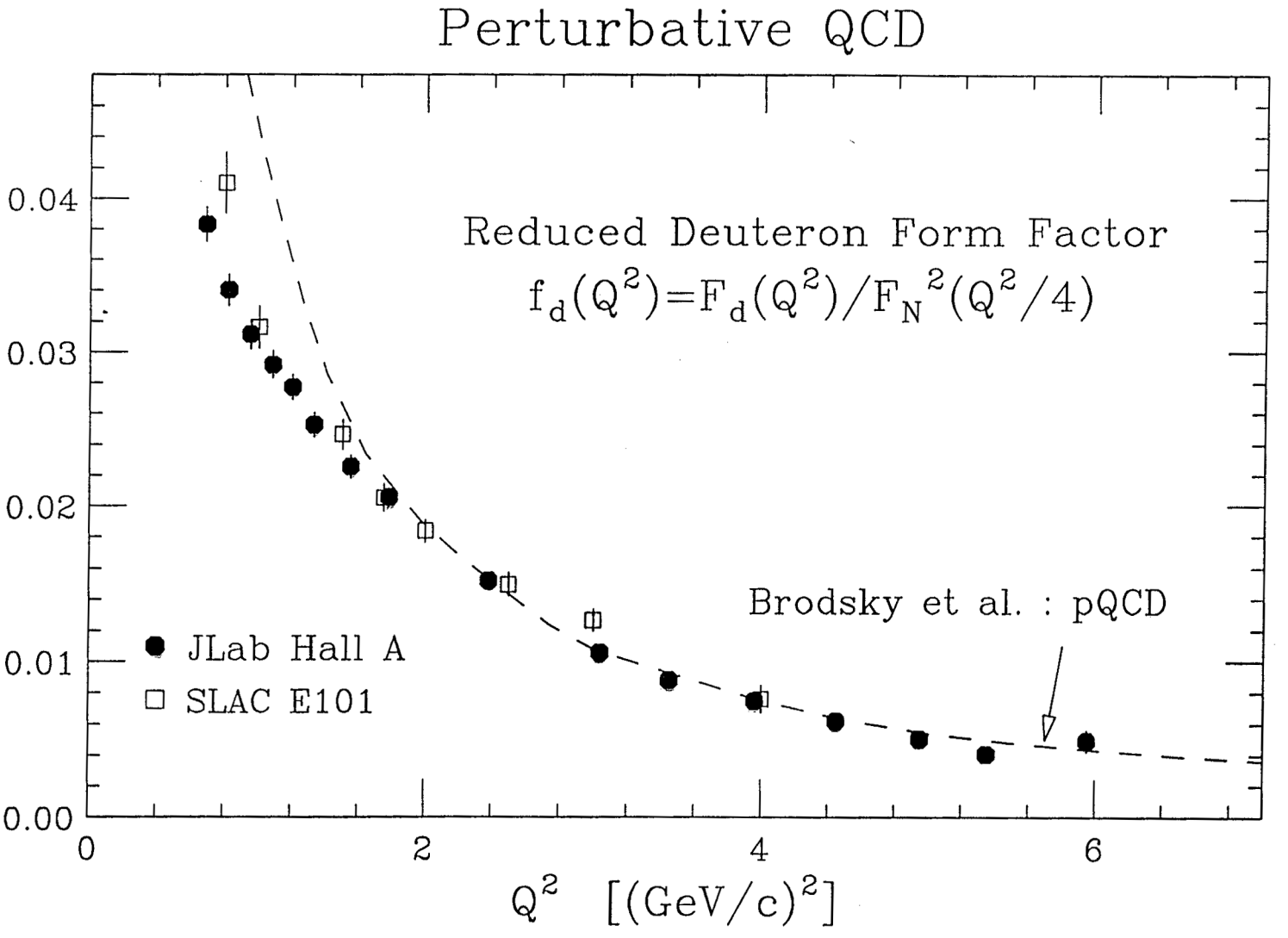

JLab Hall A
SLAC NE4
Saclay
Bonn
RIA
VDG
HT
PW
B(Q²)
Q² [(GeV/c)²]
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
0
1
2
3
4


JLab Hall A
SLAC NE4
Saclay
Bonn
RIA+MEC
VDG
HT
PW
B(Q²)
Q² [(GeV/c)²]
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
0
1
2
3
4

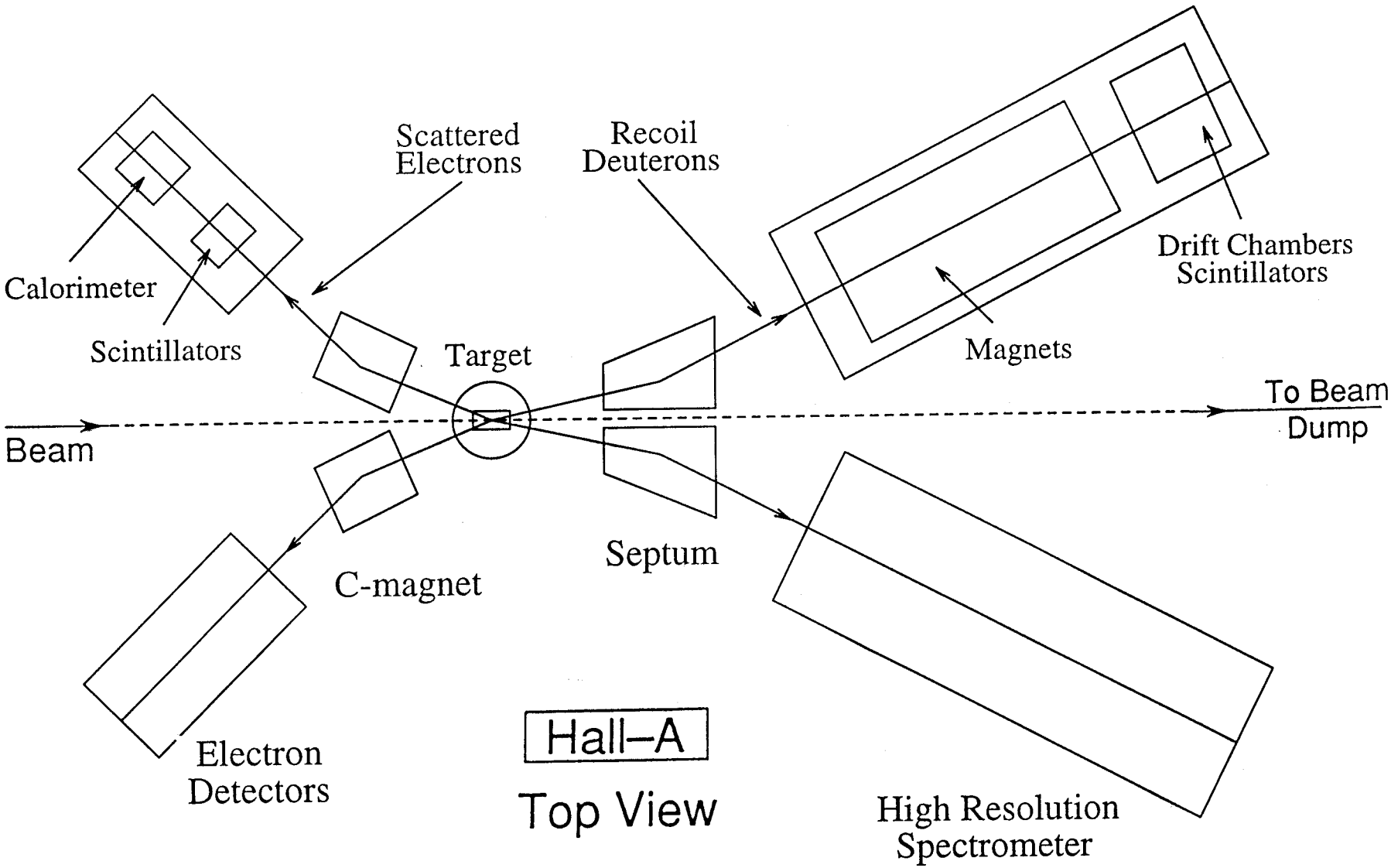

JLab Hall A
SLAC NE4
Saclay
Bonn
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$B(Q^2)$
0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5
$Q^2$ $[(GeV/c)^2]$

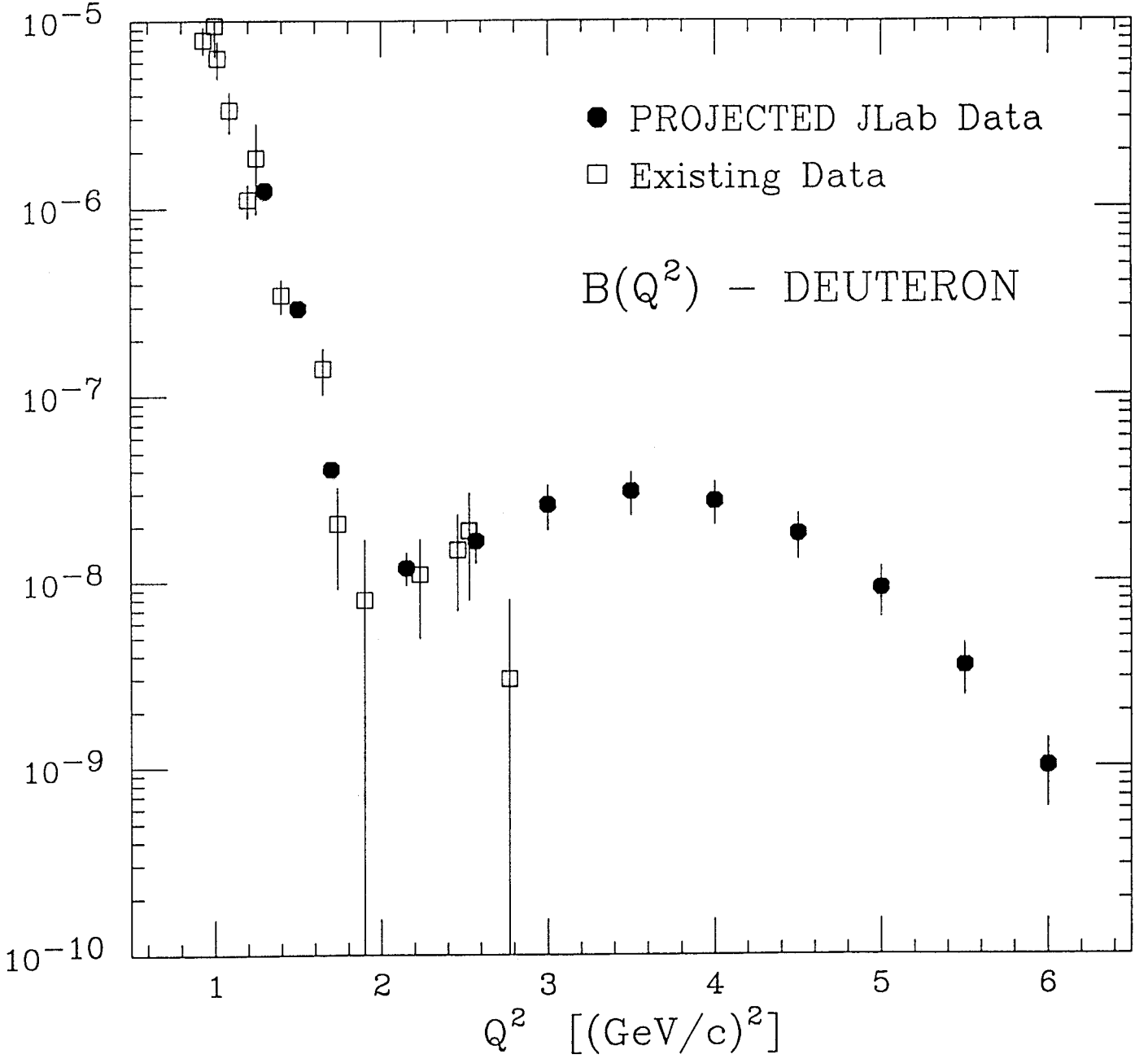


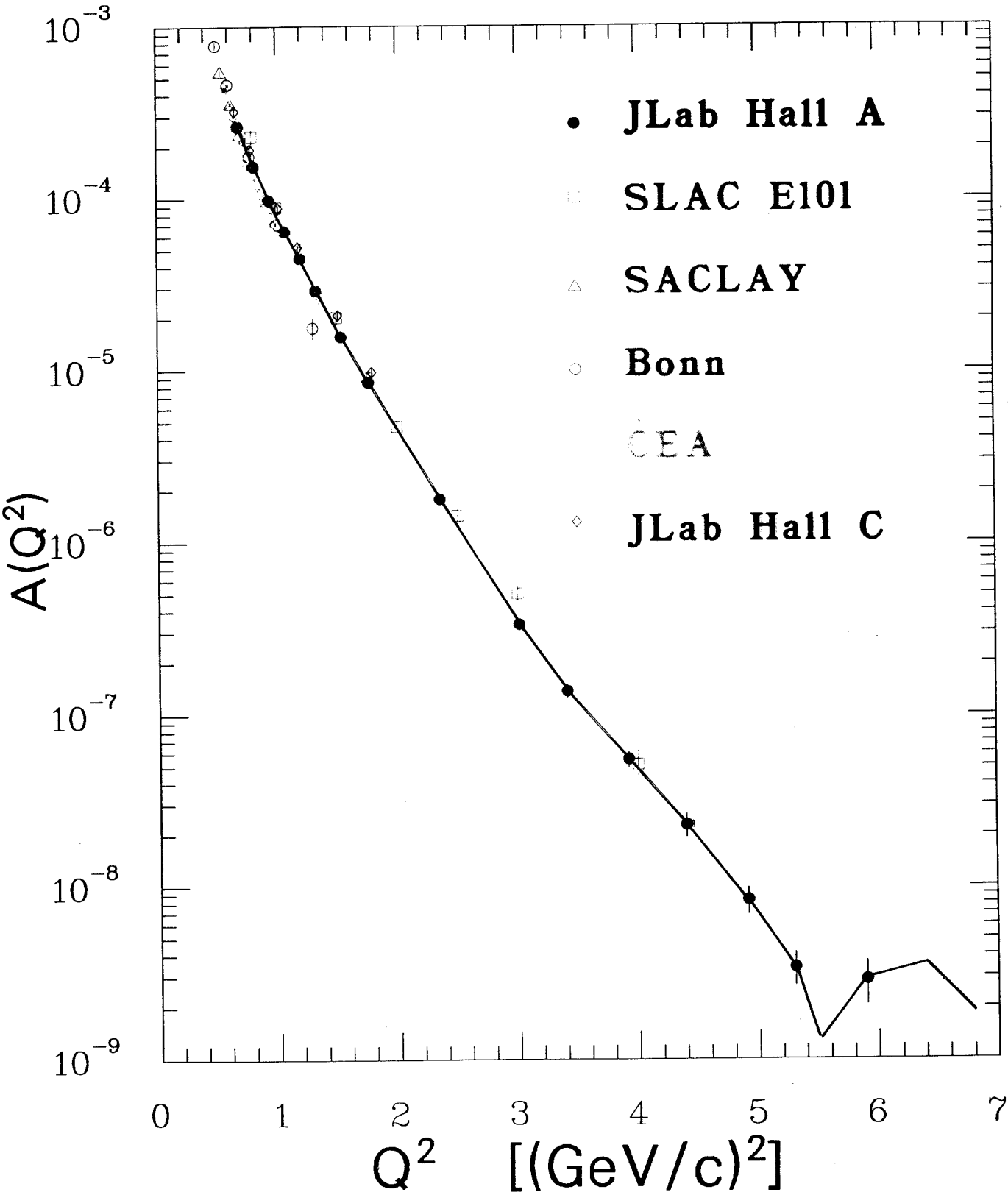

$F_d \equiv \sqrt{A}$

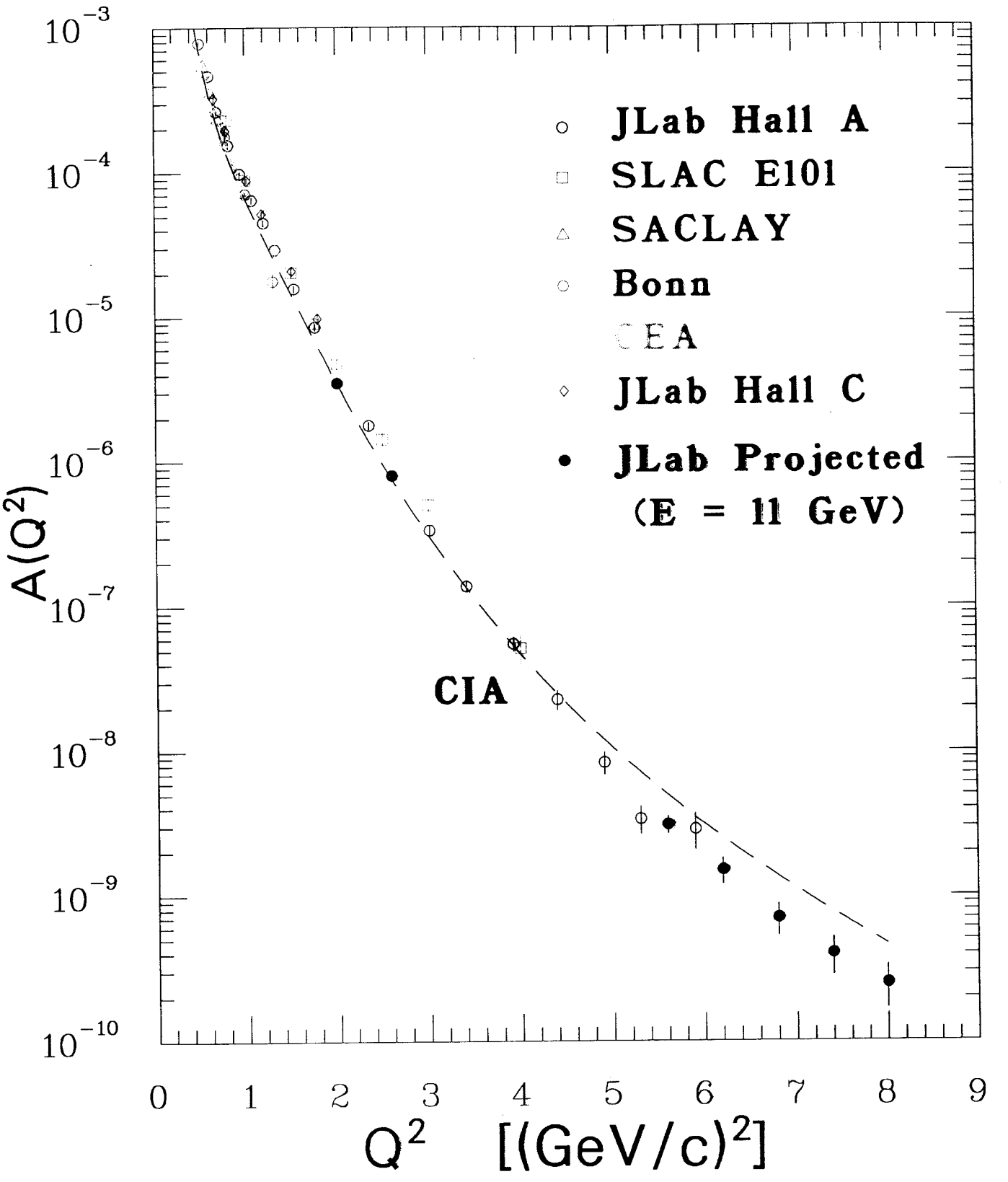

Perturbative QCD
Reduced Deuteron Form Factor
$f_d(Q^2)=F_d(Q^2)/F_N{}^2(Q^2/4)$
Brodsky et al. : pQCD
JLab Hall A
SLAC E101
0.04
0.03
0.02
0.01
0.00
0
2
4
6
$Q^2$ $[(GeV/c)^2]$

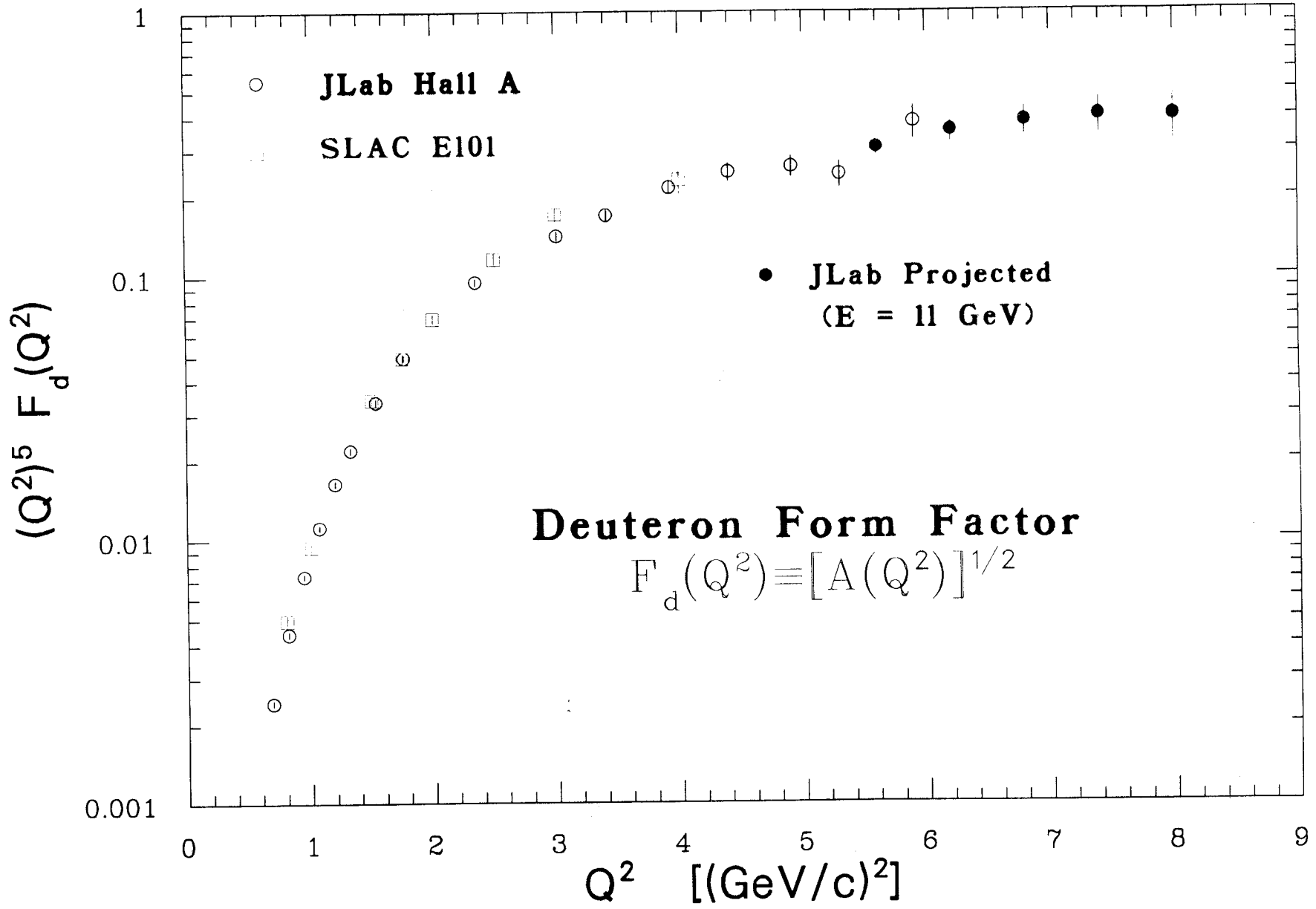
# Deuteron Magnetic Form Factor Setup

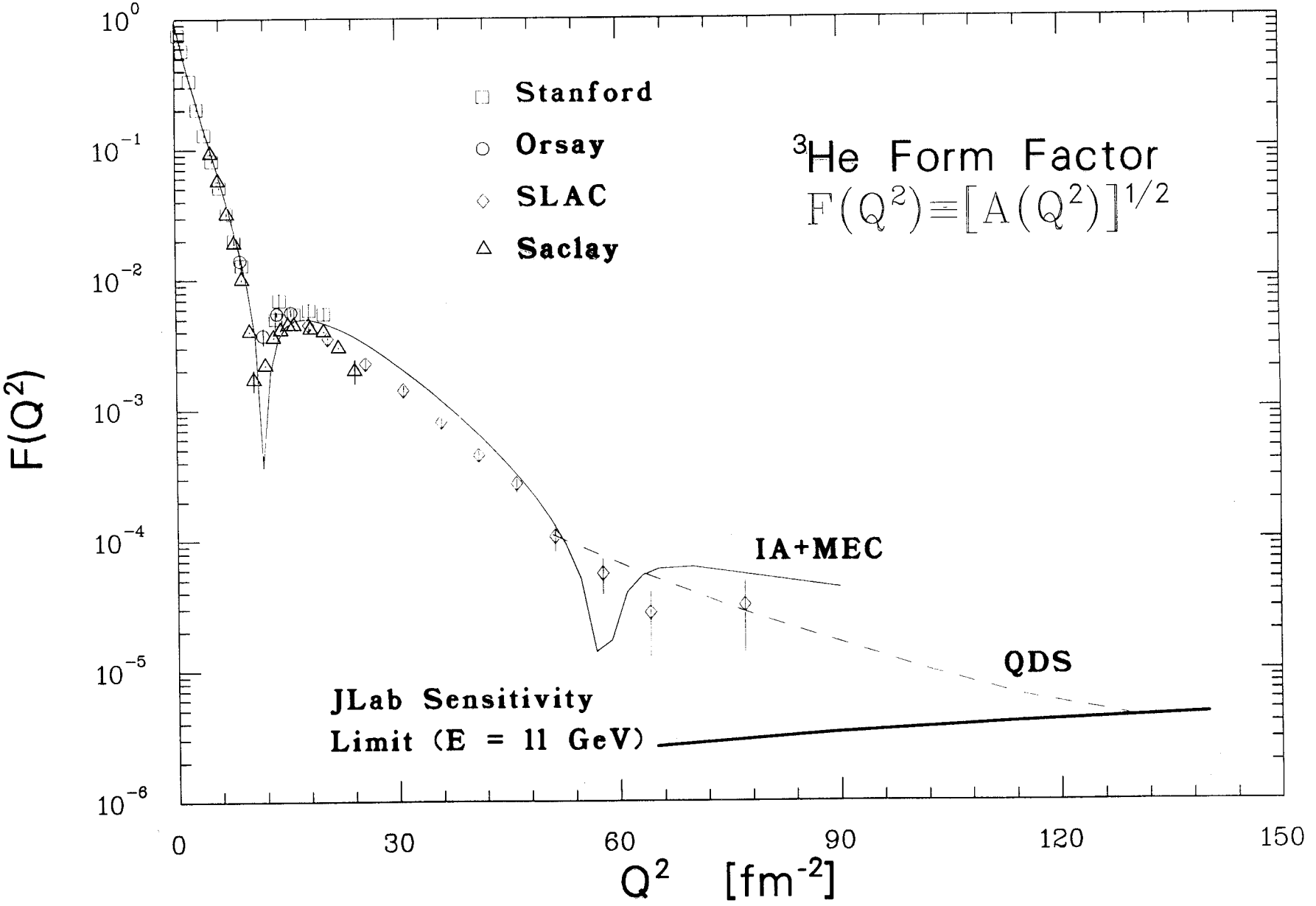


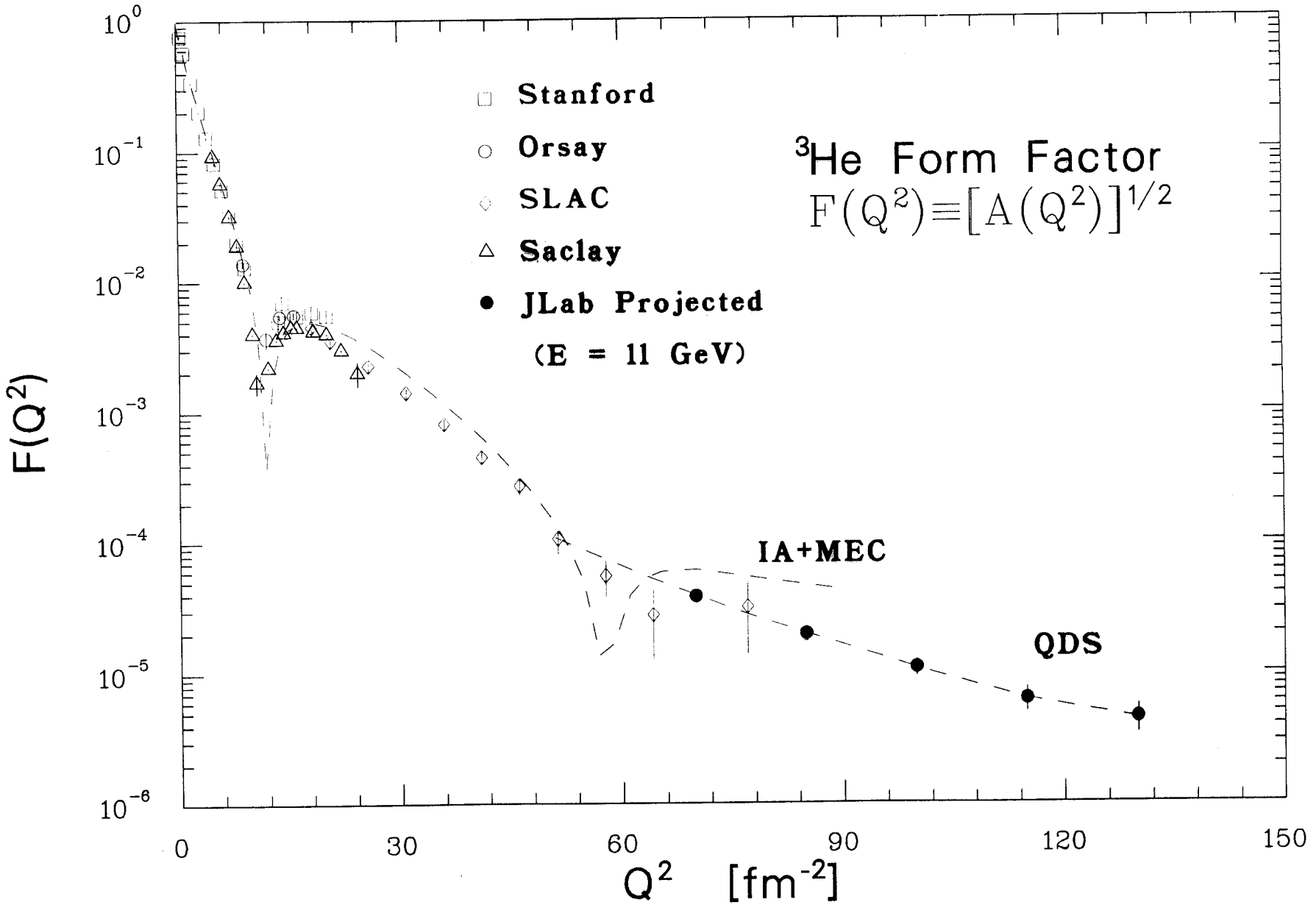

PROJECTED JLab Data
Existing Data
B(Q²) – DEUTERON
10⁻⁵
10⁻⁶
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
1
2
3
4
5
6
Q² [(GeV/c)²]

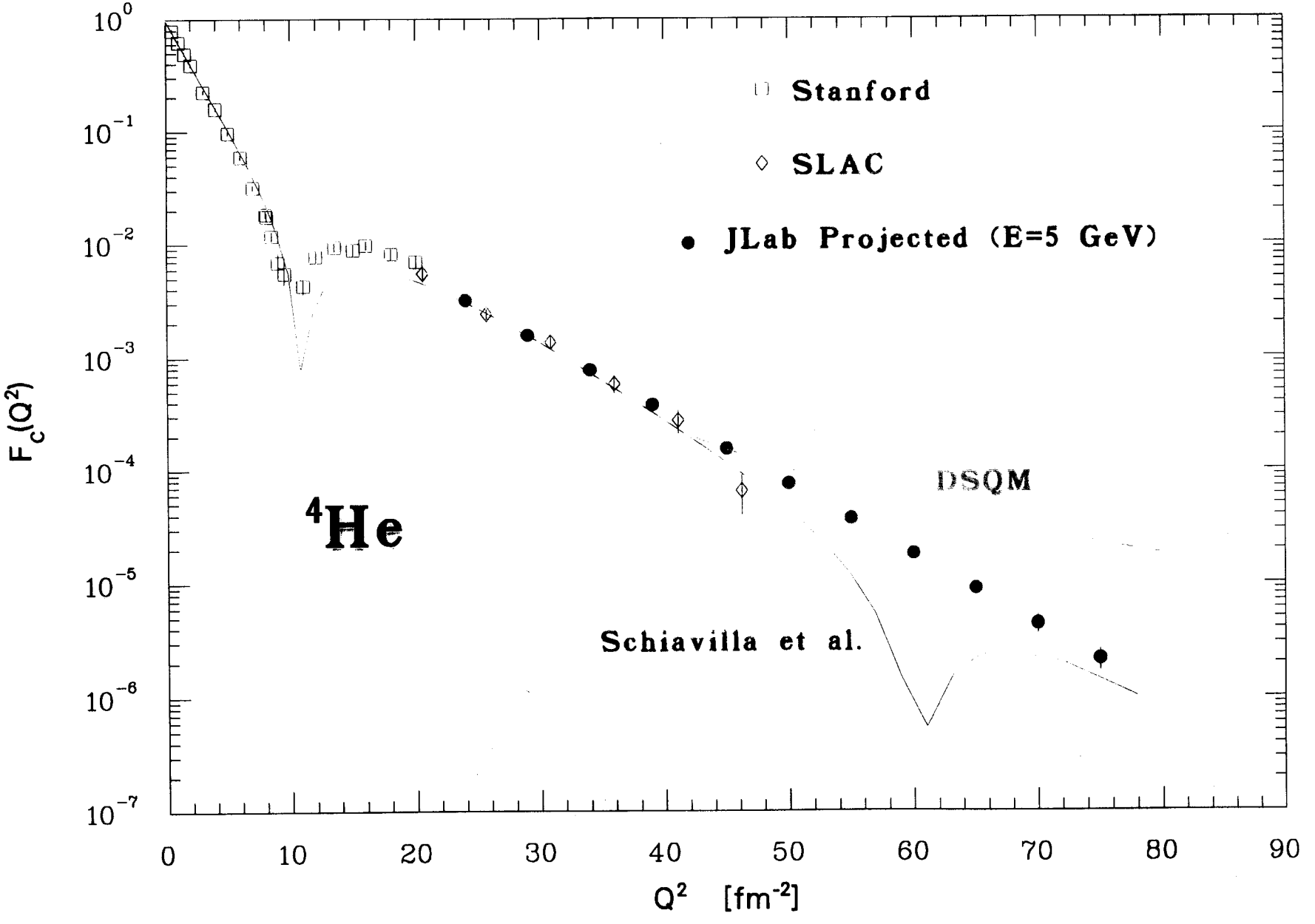

JLab Hall A
SLAC E101
SACLAY
Bonn
CEA
JLab Hall C
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$10^{-8}$
$10^{-9}$
$A(Q^2)$
0
1
2
3
4
5
6
7
$Q^2$ $[(GeV/c)^2]$


JLab Hall A
SLAC E101
SACLAY
Bonn
CEA
JLab Hall C
JLab Projected
(E = 11 GeV)
CIA
$A(Q^2)$
$Q^2$ [(GeV/c)$^2$]
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
$10^{-8}$
$10^{-9}$
$10^{-10}$
0
1
2
3
4
5
6
7
8
9


JLab Hall A
SLAC E101
JLab Projected
(E = 11 GeV)
Deuteron Form Factor
$F_d(Q^2) \equiv [A(Q^2)]^{1/2}$
$(Q^2)^5\ F_d(Q^2)$
$Q^2$ [(GeV/c)$^2$]
1
0.1
0.01
0.001
0
1
2
3
4
5
6
7
8
9


Stanford
Orsay
SLAC
Saclay
$^3$He Form Factor
$F(Q^2) \equiv [A(Q^2)]^{1/2}$
IA+MEC
QDS
JLab Sensitivity
Limit (E = 11 GeV)
$F(Q^2)$
$Q^2$ [fm$^{-2}$]
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
0
30
60
90
120
150


Stanford
Orsay
SLAC
Saclay
JLab Projected
(E = 11 GeV)
$^3$He Form Factor
$F(Q^2) \equiv [A(Q^2)]^{1/2}$
IA+MEC
QDS
$F(Q^2)$
$Q^2$ [fm$^{-2}$]
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
0
30
60
90
120
150


Stanford
SLAC
JLab Projected (E=5 GeV)
DSQM
Schiavilla et al.
4He
$F_c(Q^2)$
$Q^2$ [fm$^{-2}$]
$10^0$
$10^{-1}$
$10^{-2}$
$10^{-3}$
$10^{-4}$
$10^{-5}$
$10^{-6}$
$10^{-7}$
0
10
20
30
40
50
60
70
80
90

# $d$, $^3He$ $A(Q^2)$

- $ed$, $e^3He$ coincidence exps
- Beam current 50 $\mu A$
- $d$ target 25 cm
- $^3He$ target 20 cm
  5 K / 15 atm
  0.1 g/cm$^3$
- Electrons SHMS
- Recoils HMS
- Cross sections $\sim 10^{-41}$ cm$^2$/sr

# CONCLUSIONS

- $E = 11$ GeV <u>ideal/sufficient</u> for

  $F_d(Q^2)$ $\quad Q^2 \simeq 8$ GeV$^2$

  $F^3_{He}(Q^2)$ $\quad Q^2 \simeq 140$ fm$^{-2}$

- <u>Must have</u> 2 high $P$ spectrometers large $\Delta\Omega$

- <u>Invest</u> in longer targets to compensate for reduced current

- <u>Continue testing</u> Few-Body "Standard Model" and quark dimensional scaling predictions