Physics Plans for CEBAF at 12 GeV

Bernhard A. Mecking
Jefferson Lab

QCD-N'02
Ferrara
April 3-6, 2002

CEBAF @ JLab Today

- Main physics programs
  - nucleon electromagnetic form factors (incl. strange)
  - $N \rightarrow N^*$ electromagnetic transition form factors
  - spin structure functions of the nucleon
  - form factors and structure of light nuclei

- Superconducting recirculating electron accelerator
  - max. energy 5.7 GeV
  - max current 200 μA
  - e polarization 80%

- Experimental equipment in 3 halls (simultaneous operation) L[$cm^{-2}s^{-1}$]
  - 2 High Resolution Spectrometers (p_{max}=4 GeV/c) 10^{39}
  - 2 spectrometers (p_{max}=7 and 1.8 GeV/c) + special equipment 10^{39}
  - Large Acceptance Spectrometer for e and γ induced reactions 10^{34}

Physics Drivers for CEBAF Upgrade

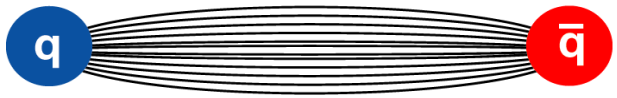
- New capabilities
  - search for origin of confinement (J^{PC} exotic mesons)
  - determine parton distributions (high Q^2 and W) via
    - polarized and unpolarized inclusive scattering
    - semi-inclusive (tagged) structure functions
    - exclusive processes (DVCS, meson production)

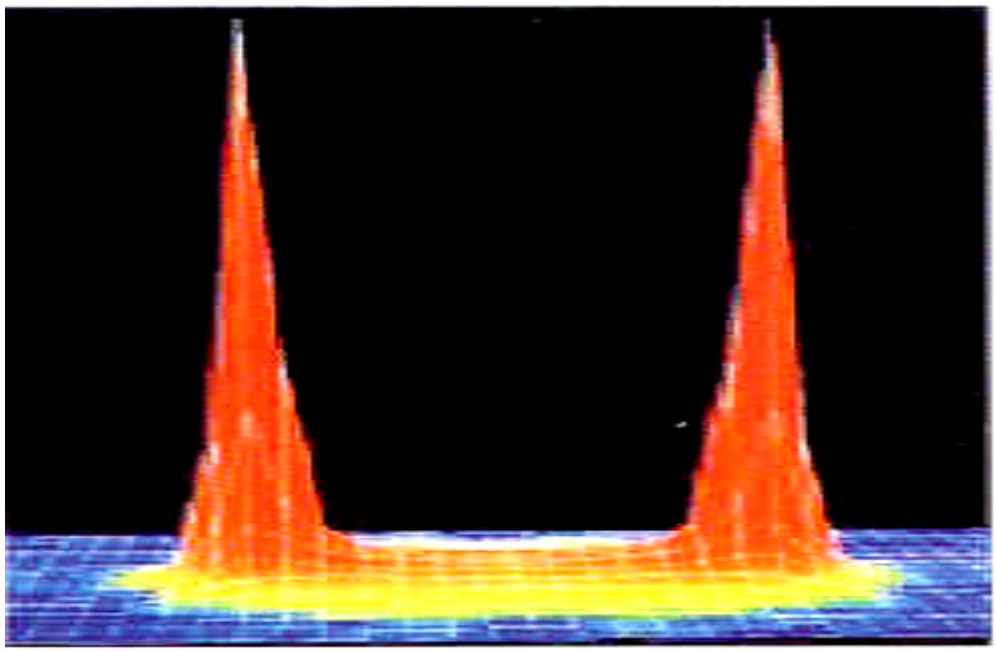
- Push present program to higher Q^2
  - form factors of mesons, nucleons, and light nuclei

Search for Exotic Mesons: Basic idea

Color field:

due to self interaction, confining flux tubes form between static color charges





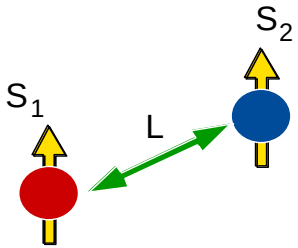
Original idea by Nambu,

now verified by Lattice QCD calculations

Excitation of the flux tube can lead to exotic quantum numbers

Excited Flux Tube Quantum Numbers

Normal mesons: $J^{PC} = 0^{-+} \quad 1^{+-} \quad 2^{-+}$



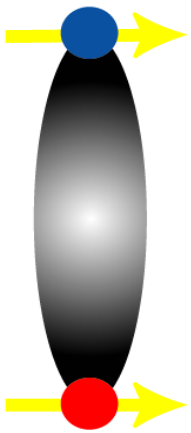
$S = S_1 + S_2$

$J = L + S$

$P = (-1)^{L+1}$

$C = (-1)^{L+S}$

First excited state of flux tube has J=1
combined with S=1 for quarks



$J^{PC} = 0^{-+} \quad 0^{+-} \quad 1^{+-} \quad 1^{-+} \quad 2^{-+} \quad 2^{+-}$

exotic
(mass ~ 1.7 – 2.3 GeV)

Photons couple to exotic mesons via $\gamma \rightarrow$VM transition (same spin configuration)

Strategy for Exotic Meson Search

- Use photons to produce meson final states
  - tagged photon beam with 8 – 9 GeV
  - linear polarization to constrain production mechanism

- Use large acceptance detector
  - hermetic coverage for charged and neutral particles
  - typical hadronic final states:

$$f_1\eta \longrightarrow K\bar{K}\eta \longrightarrow K\bar{K}\pi\pi\pi$$
$$b_1\pi \longrightarrow \omega\pi \longrightarrow \pi\pi\pi\pi$$
$$\rho\pi \longrightarrow \pi\pi\pi$$

  - high data acquisition rate

- Perform partial-wave analysis
  - identify quantum numbers as a function of mass
  - check consistency of results in different decay modes

Valence Quark Distribution

Physics issue:

compare behavior of u and d as $x_{Bj} \rightarrow 1$

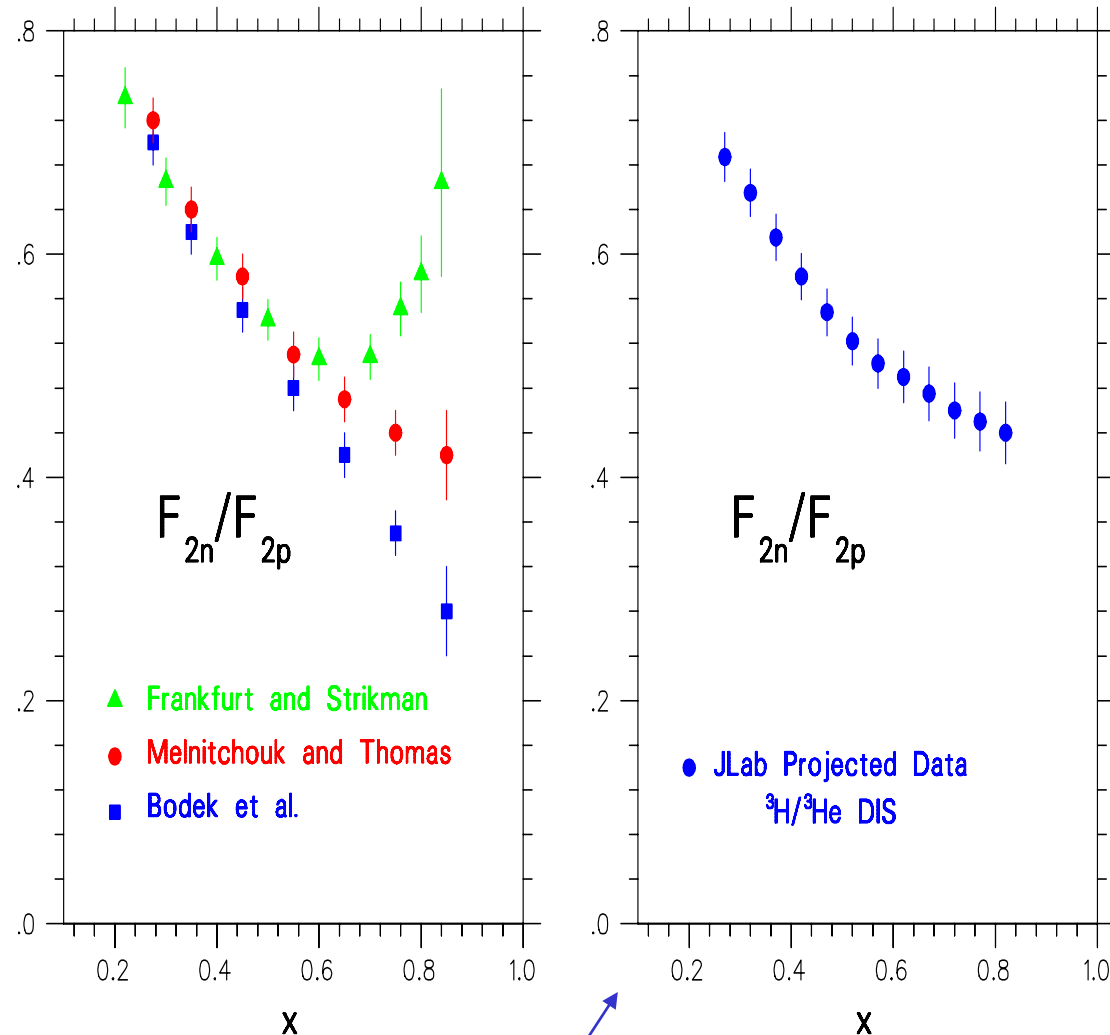
Experimental problem:

extract information from comparison of hydrogen and deuterium data

need to correct for nuclear effects in D

Solution for CEBAF upgrade:

compare DIS off ^{3}He and ^{3}H (nuclear effects ~ same)



Neutron Spin Structure Function A_1^n

Physics issue:

determine n spin structure

Experimental problem:

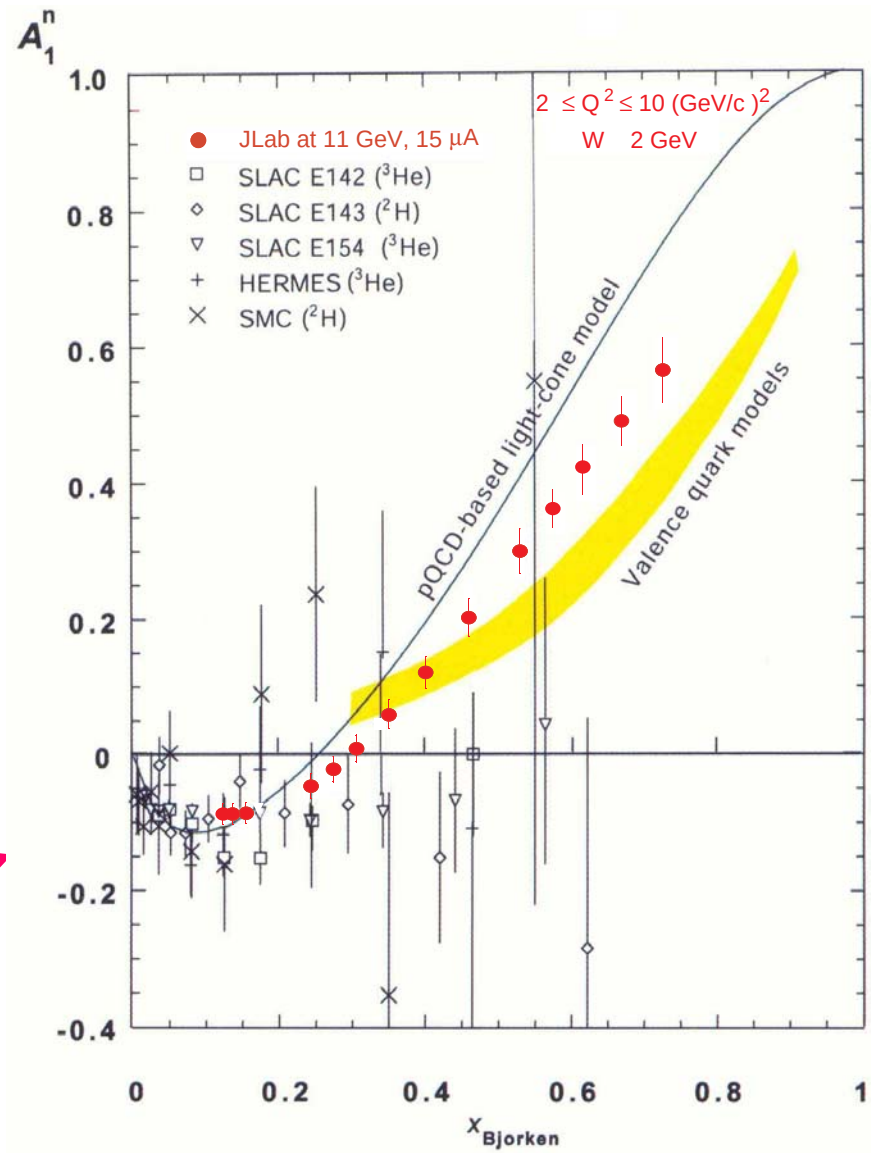
no free neutron target

choices: D – p or $^3\vec{He}$

Solution for CEBAF upgrade:

use $^3\vec{He}$ target and 15μA beam

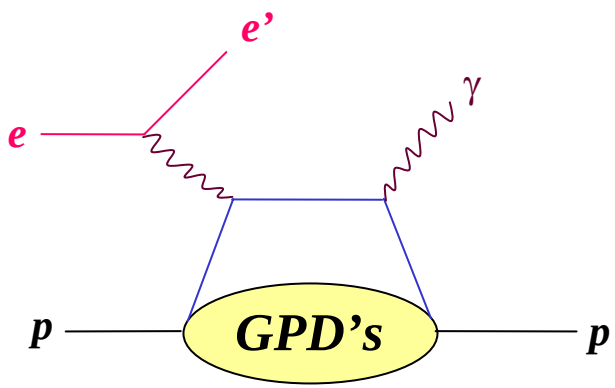
use broad acceptance spectrometer for e detection



DVCS

Physics issue:

constrain GPD's from DVCS measurement

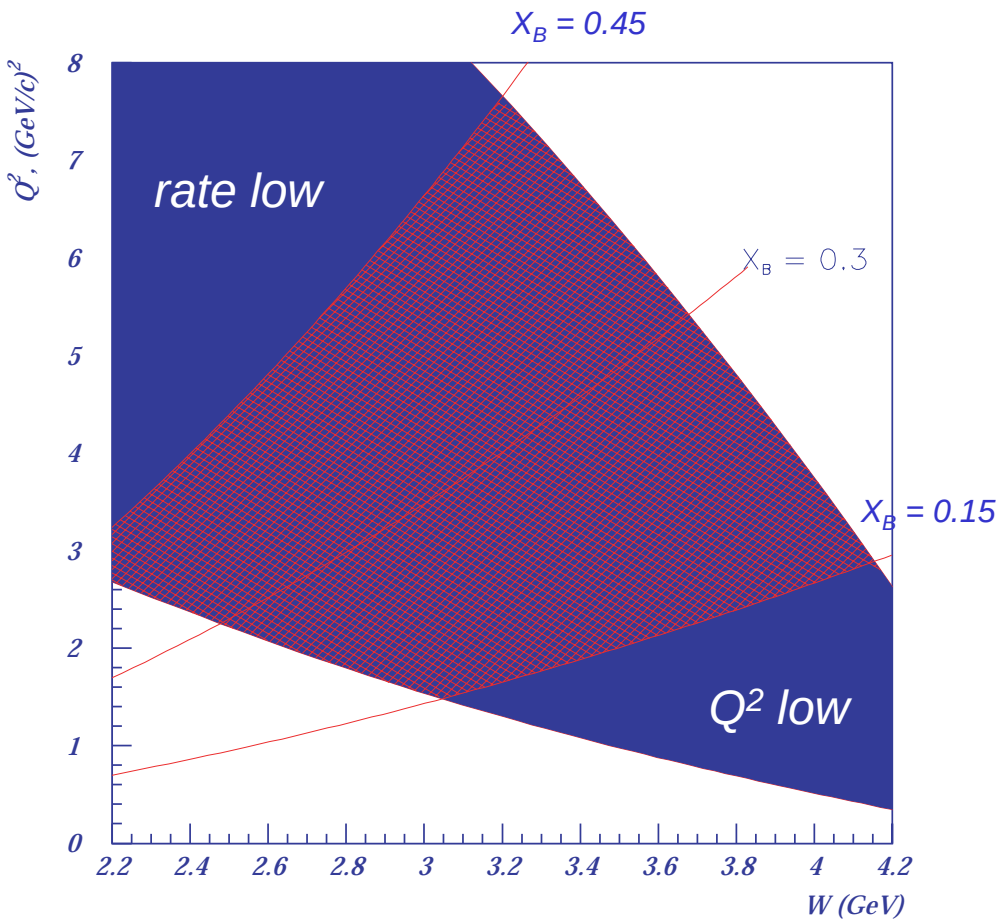


Experimental problem:

isolate small DVCS cross section

Solution for CEBAF Upgrade:

- use CLAS to detect all final state particles
- observe interference term DVCS-BH



CLAS acceptance for DVCS

DVCS Single-Spin Asymmetry

$Q^2 = (2.9 – 3.1)\ GeV^2$

$W = (2.65 – 2.95)\ GeV$

$-t = (0.2 – 0.4)\ GeV^2$

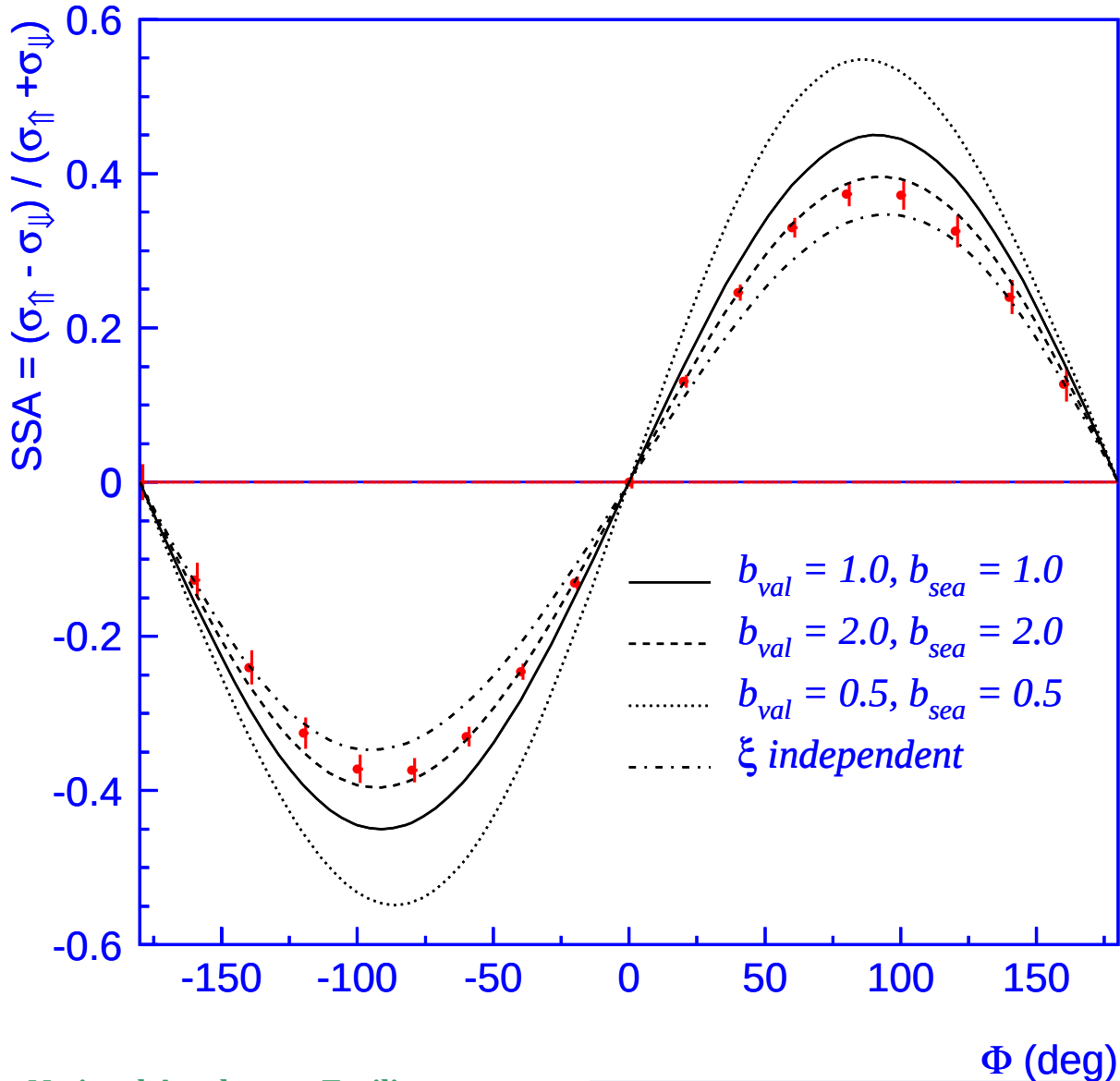
CLAS experiment

$E_0 = 11$ GeV

$P_e = 80\%$

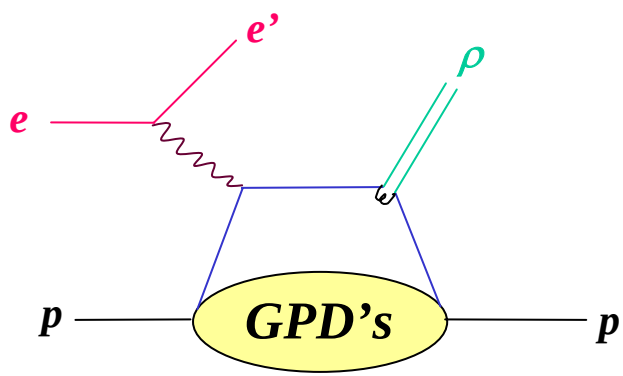
$L = 10^{35}\ cm^{-2}s^{-1}$

Run time: 500 hrs



Hard Meson Electroproduction (ρ^o)

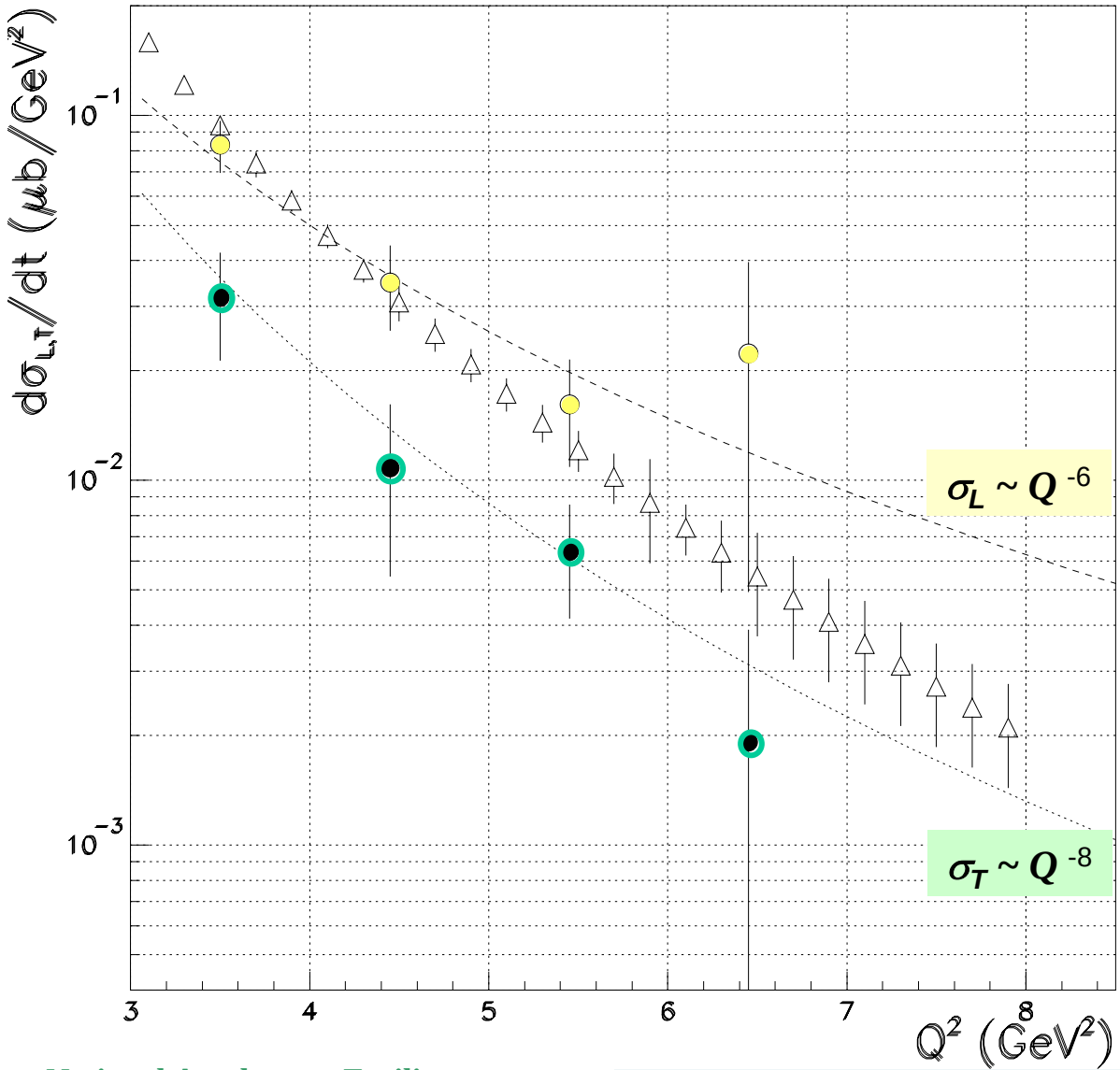
Physics issue: map out GPD's (need to isolate σ_L)



Technique: determine σ_L from $\rho \rightarrow \pi\pi$ decay angle distribution

CLAS at 11 GeV

400 hrs at L = 10^{35} $cm^{-2}s^{-1}$



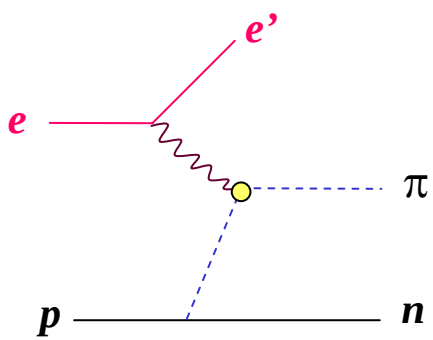
Pion Form Factor

Physics issue:

π electromagnetic structure, can be predicted in pQCD

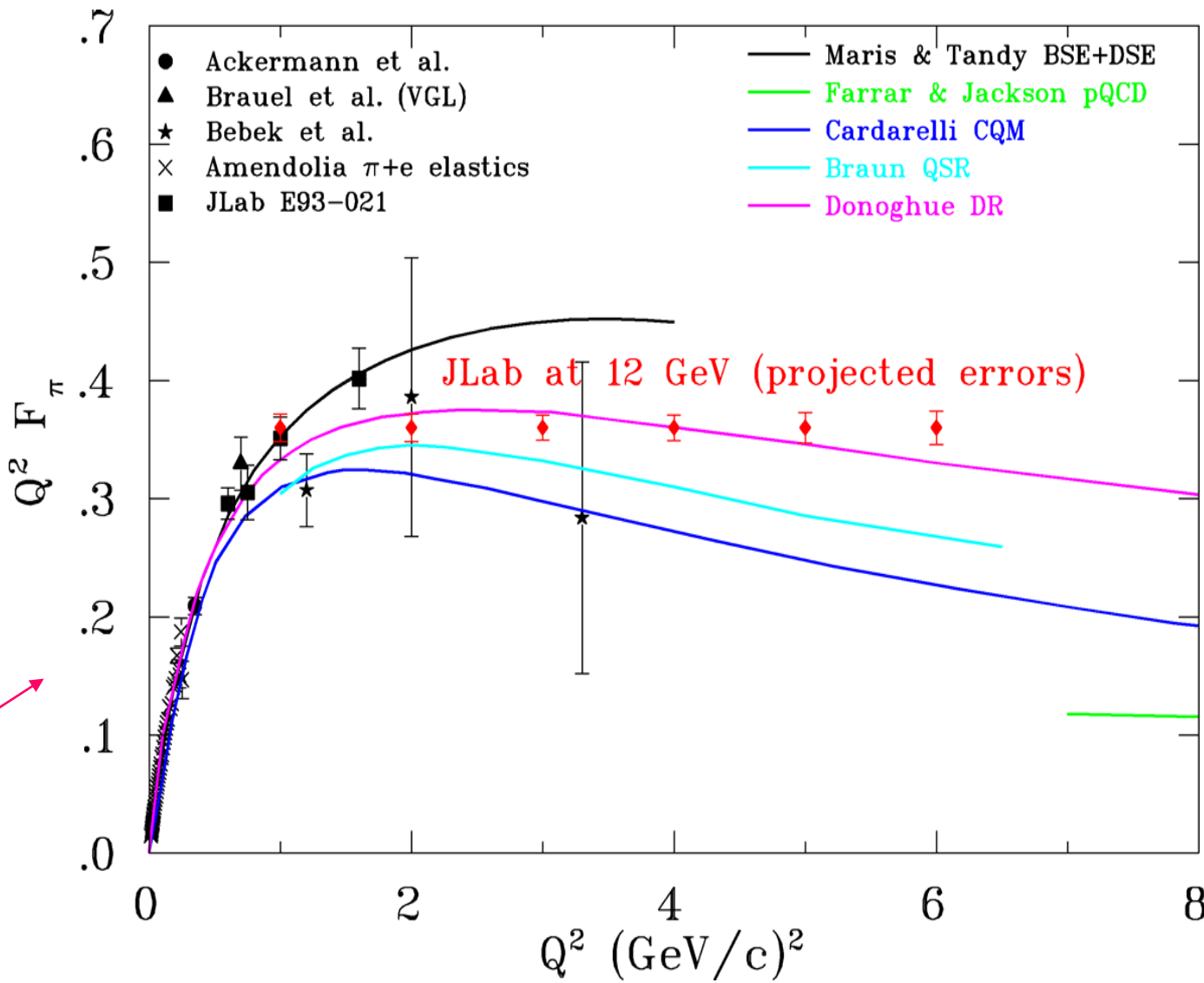
Experimental technique:

isolate $\gamma^* \pi \rightarrow \pi$ vertex



CEBAF Upgrade:

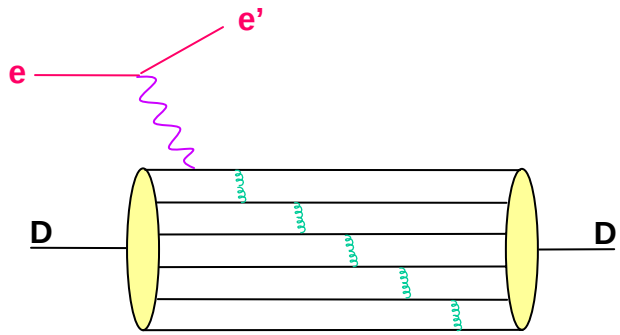
- use HMS to detect e'
- use SHMS to detect π



Deuteron Form Factor

Physics question:

at what Q^2 can the D be described as a 6q system

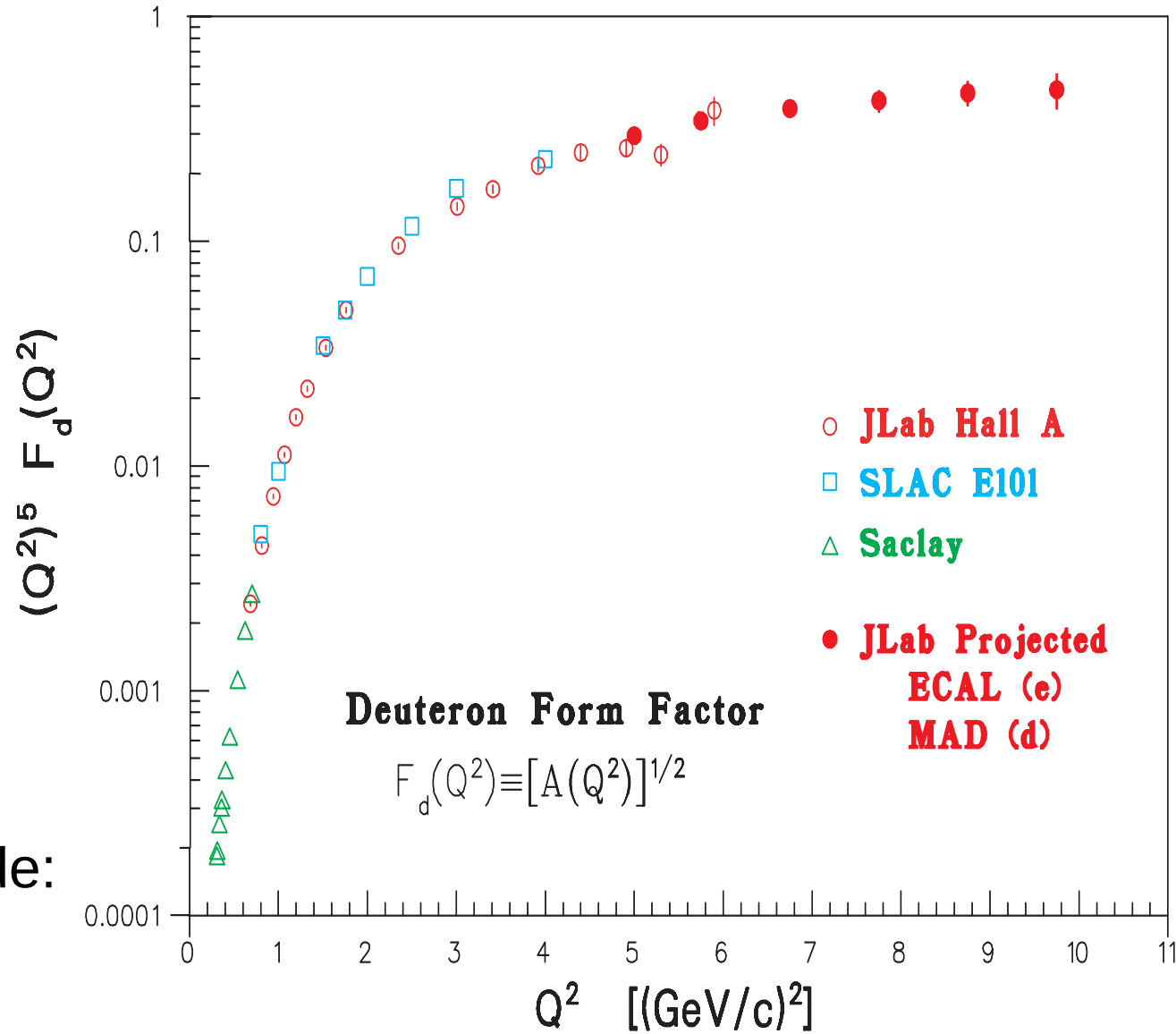


Experimental problem:

isolate small cross section eD→eD elastic process

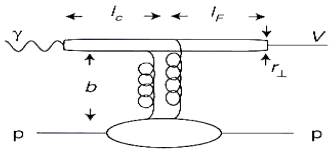
Solution for CEBAF Upgrade:

- use calorimeter for e' detection
- use MAD to detect recoil D

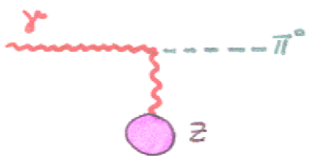


Other Physics Topics

- J/Ψ production at threshold



- duality in inclusive and semi-inclusive e scattering
- spin effects in semi-inclusive scattering
- coupling constant for $\eta \rightarrow \gamma\gamma$ via Primakoff



- color transparency in A(e,e'p)X and A(e,e'ρ^o)X
- short-range NN-correlations

CEBAF Upgrade Plan

- Upgrade accelerator to 12 GeV max. energy
  - maintain 100% duty cycle
  - keep beam power constant (1MW) $\longrightarrow$ max. current 80μA
- Build new experimental hall for meson spectroscopy (Hall D)
  - polarized tagged photon beam (coherent bremsstrahlung)
  - large acceptance detector for real photons only
- Upgrade existing 3 halls for higher beam energy

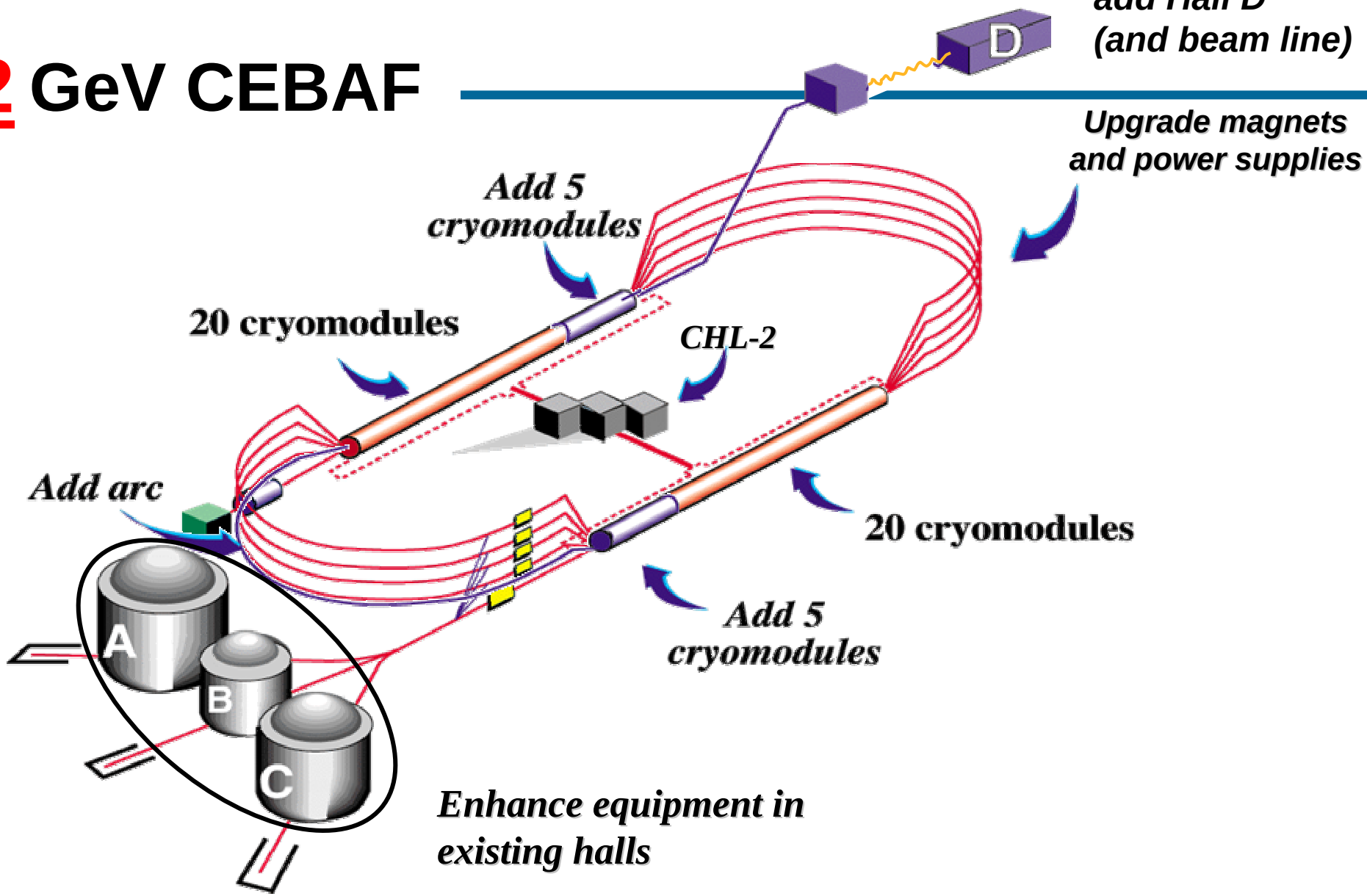
CEBAF Accelerator Upgrade

- keep present accelerating system

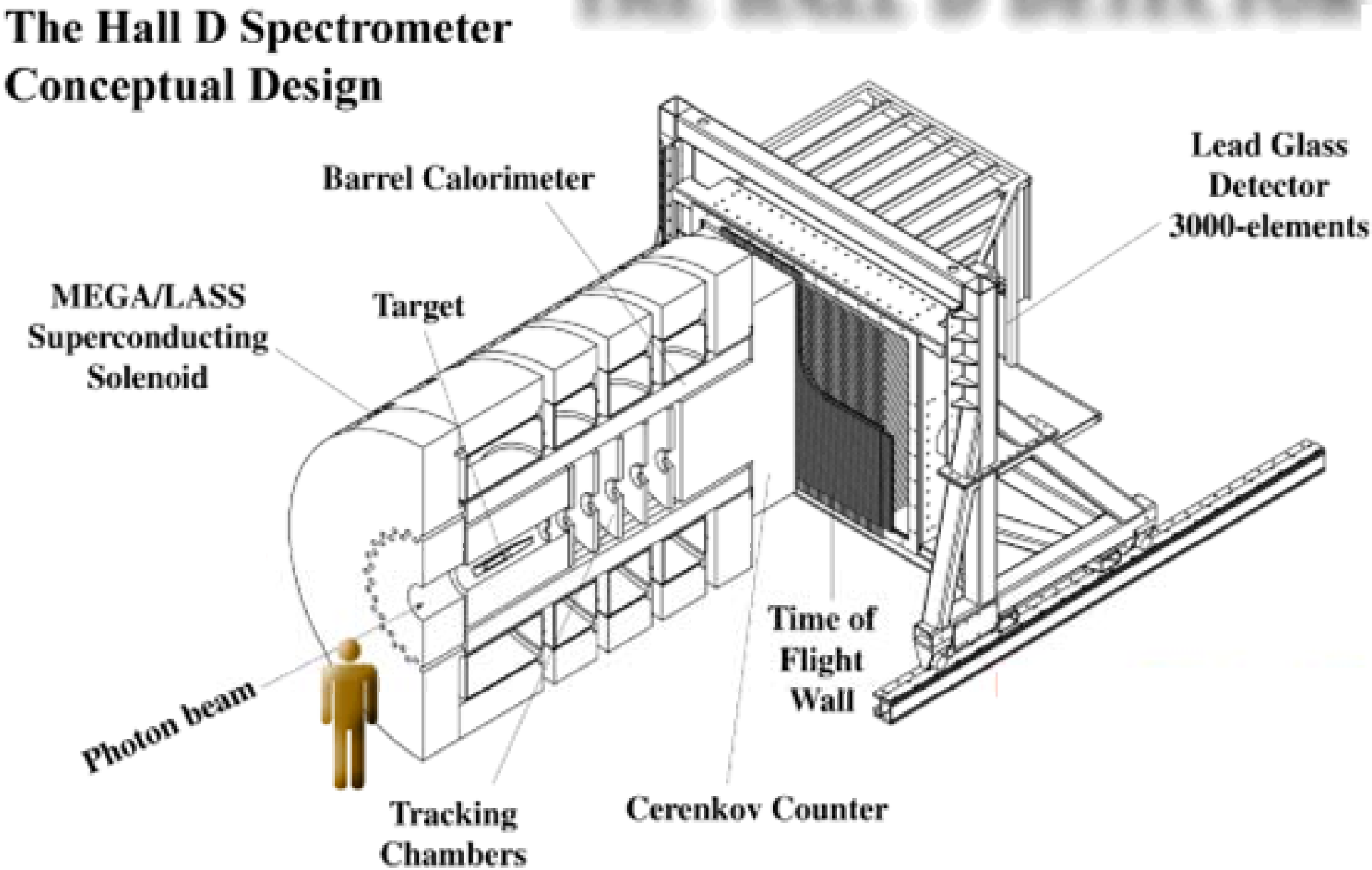
- add ten new cryomodules at 100MeV energy gain
  - present cryomodules provide ~30 MeV
  - increased performance can be achieved by
    - increased effective cavity length (5-cell $\Rightarrow$ 7-cell)
    - Increased average gradient (7.5 MV/m $\Rightarrow$ 17.5 MV/m)

- double cryogenic system capacity
- upgrade recirculating arcs
- add new beam line to Hall D

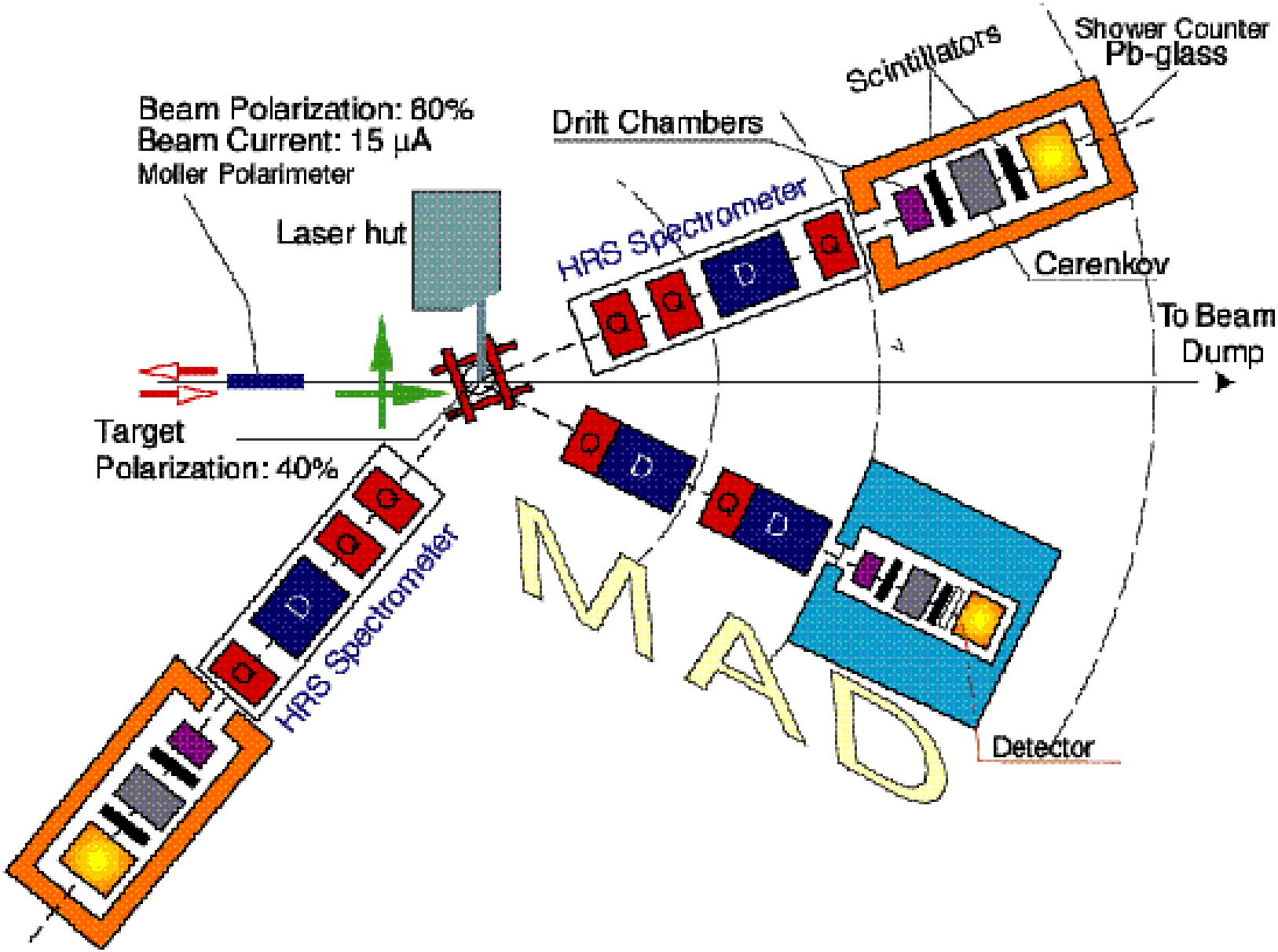
12 GeV CEBAF


add Hall D
(and beam line)
D
Upgrade magnets
and power supplies
Add 5
cryomodules
20 cryomodules
CHL-2
Add arc
20 cryomodules
Add 5
cryomodules
A
B
C
Enhance equipment in
existing halls

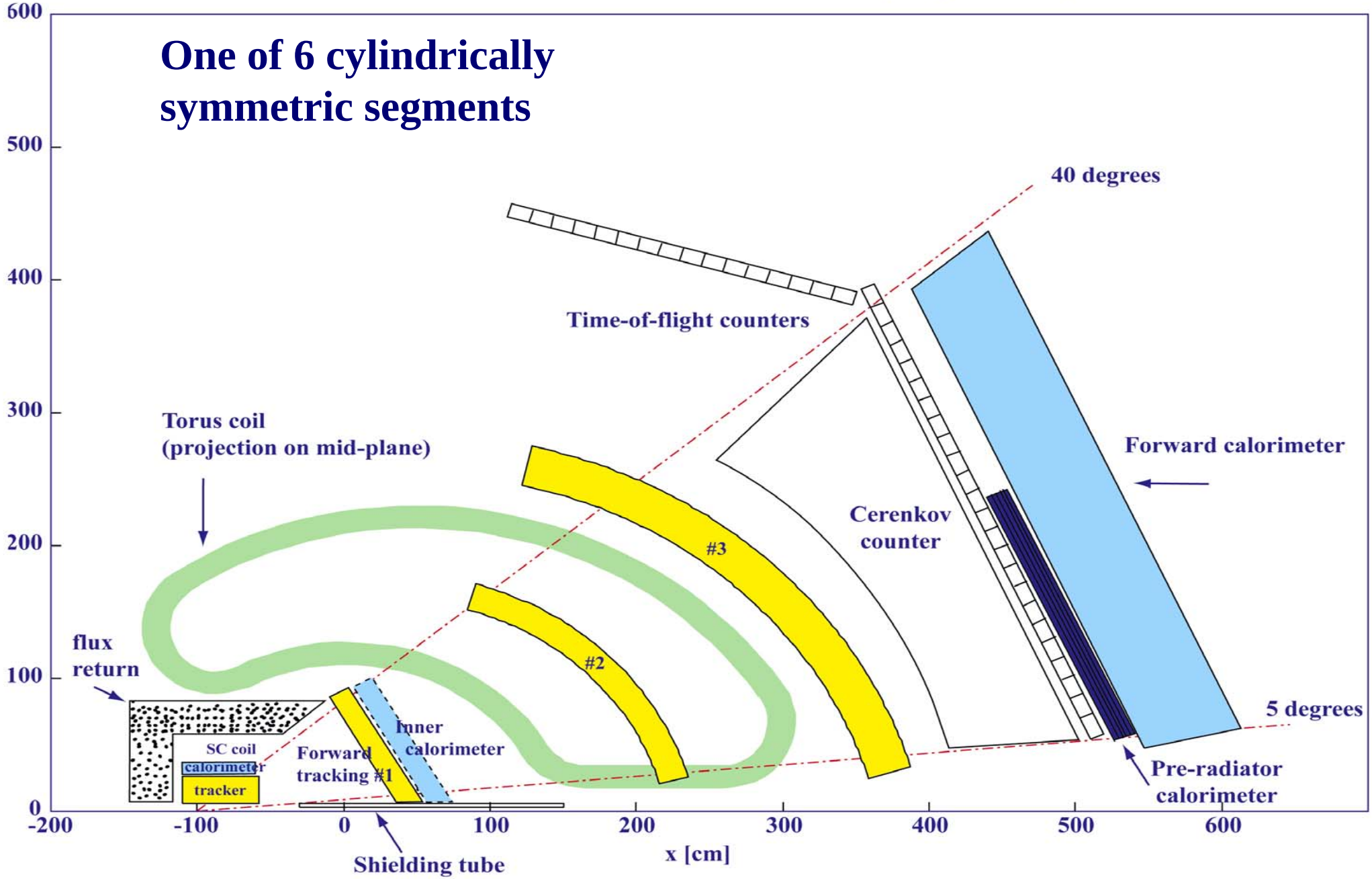
The Hall D Detector



Hall A Floor Plan with MAD Spectrometer

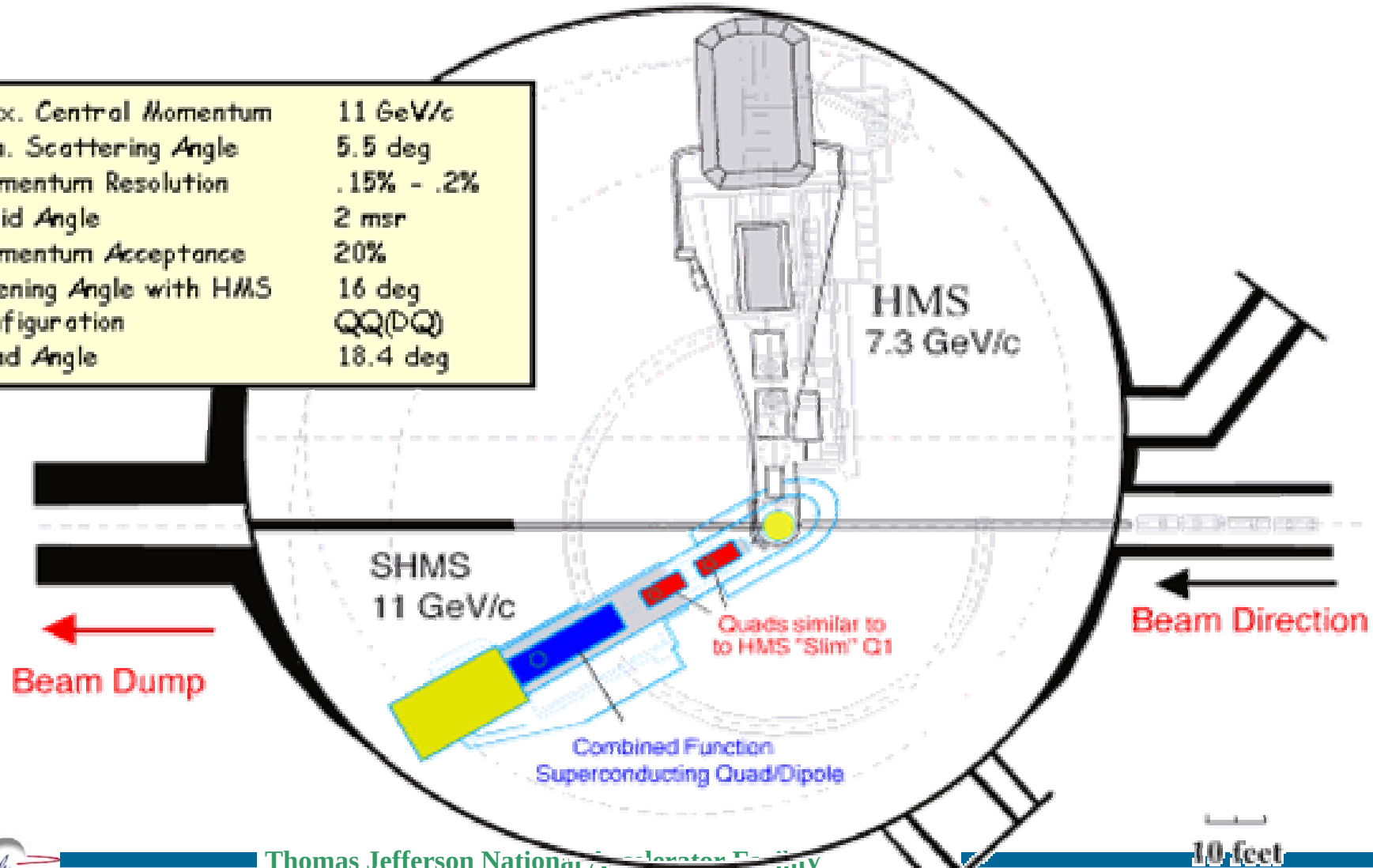


CLAS UPGRADE CONCEPT (Top View)



SHMS - HMS Spectrometers After Upgrade

Max. Central Momentum	11 GeV/c
Min. Scattering Angle	5.5 deg
Momentum Resolution	.15% - .2%
Solid Angle	2 msr
Momentum Acceptance	20%
Opening Angle with HMS	16 deg
Configuration	QQ(DQ)
Bend Angle	18.4 deg



12 GeV Upgrade Project Status

- Developed by CEBAF User Community in collaboration with JLab
- Nuclear Science Advisory Committee, NSAC
  - plan presented during last 5-year Long Range Plan
  - recommended by NSAC for new construction
- Plan presented to Department of Energy
  - presently waiting for CD-0 (determination of 'mission need')
- Construction
  - estimated costs: $158M (in FY02$)
  - construction start expected in FY2007 (October 2006)
  - 3 year construction project

Long-Term Future @ JLab

Study underway for an electron-light ion collider at JLab to investigate

- inclusive and semi-inclusive DIS
- deep exclusive reactions (GPD's)

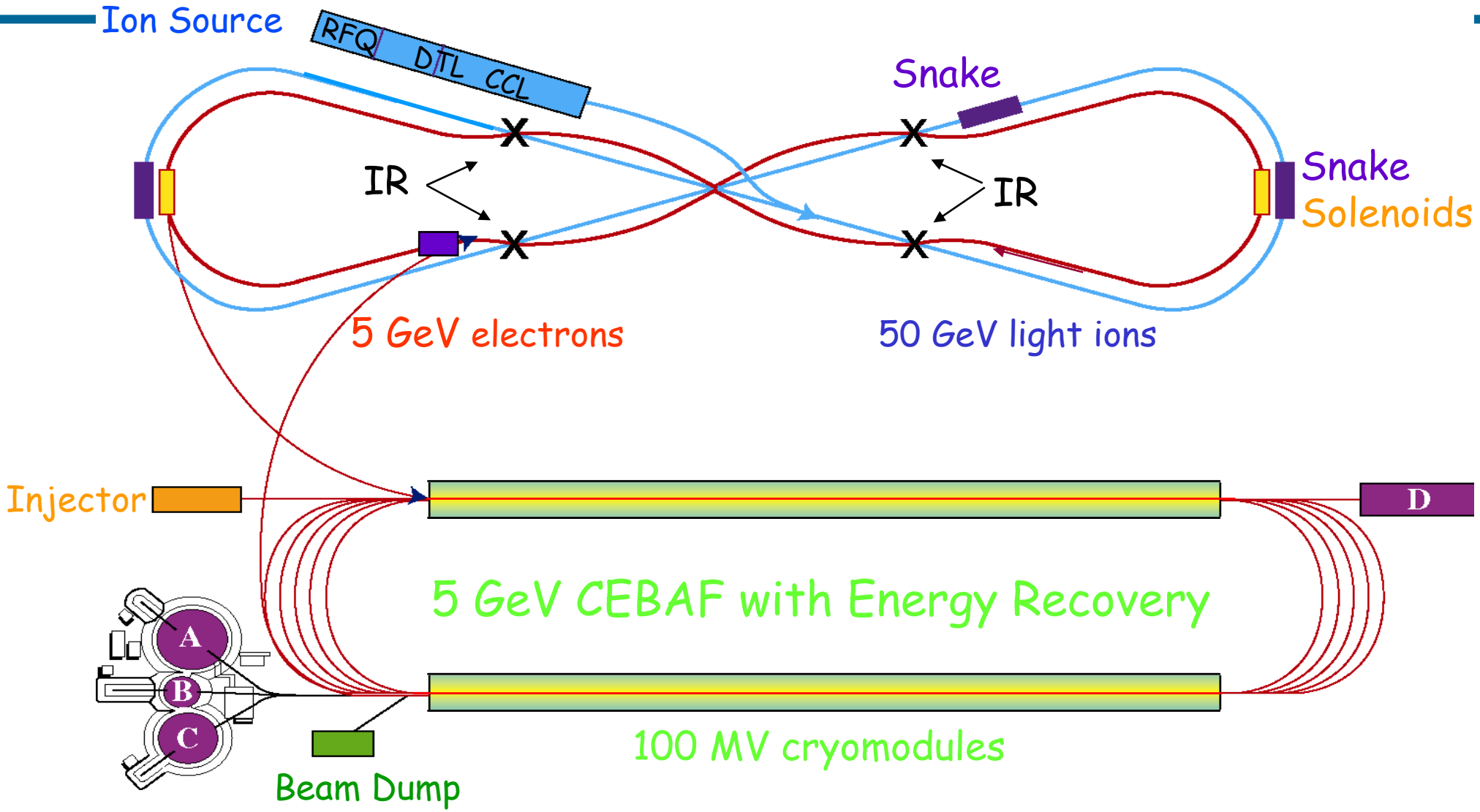
Parameters

electrons	3 - 5 GeV
ions (p, d, ^{3}He)	30-50 GeV
luminosity	$\leq 6\times10^{34}$ cm^{-2} s^{-1}

Design maintains fixed target capability with

- 25 GeV external beam
- luminosity ~10^{38} cm^{-2} s^{-1}

Electron-Light Ion Collider Layout



Lia Merminga at EIC Workshop, BNL 02/27/2002

ELIC Parameter Table

Parameter	Units	Point Design 0		Point Design 1		Point Design 2		Point Design 3	
		e^-	Ions	e^-	Ions	e^-	Ions	e^-	Ions
Energy	GeV	5	50	5	50	5	50	5	50
Cooling	-	-	No	-	Yes	-	Yes	-	Yes
Luminosity	$cm^{-2}s^{-1}$	1×10^{32}		1×10^{33}		1×10^{34}		6×10^{34}	
N_{bunch}	ppb	1×10^{10}	2.5×10^{10}	1×10^{10}	2.5×10^{10}	2×10^{10}	5×10^{9}	1×10^{10}	1×10^{10}
f_c	MHz	150		150		500		1500	
I_{ave}	A	0.24	0.6	0.24	0.6	1.6	0.4	2.5	2.5
σ^*	μm	45	45	14	14	6	6	4.5	4.5
ε_n	μm	10	2	10	0.2	10	0.2	10	0.1
β^*	cm	200	5	20	5	4	1	2	1
σ_z	cm	0.1	5	0.1	5	0.1	1	0.1	1
ξ_e / ξ_i	-	0.5	.0006	0.5	0.006	0.1	0.01	0.2	0.01
$\Delta\nu_L$	-	-	0.005	-	0.05	-	0.05	-	0.09

Summary

- CEBAF 12 GeV upgrade focused on elucidating the quark substructure of mesons and nucleons
- experimental program requires
  - new and upgraded equipment
  - luminosities between 10^{35} and 10^{39} $cm^{-2}s^{-1}$
- upgrade is a cost-effective extension
- strong community support and endorsement
- construction start expected in 2007
- long term: collider + high **L** fixed target facility