G0: Measurement of the Strange Quark Currents in the Proton

Backangle Configuration (Update)

G0 Collaboration:

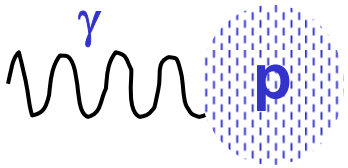
Caltech, CMU, Hampton, IPN-Orsay, ISN-Grenoble, JLab, LaTech, NMSU, TRIUMF, U.Connecticut, UIUC, U.Kentucky, U.Manitoba, U.Maryland, U.Massachusetts, UNBC, Virginia Tech, William & Mary, Yerevan

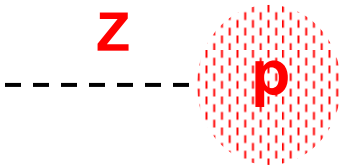
Goal: Measure $G^{Z,p}$: Weak *vector-current* form factor

- Weak interaction analogue of the usual EM form factors

$G^{\gamma}_{E,M}$: EM charge & magnetic FF

$G^{Z}_{E,M}$: weak charge & magnetic FF



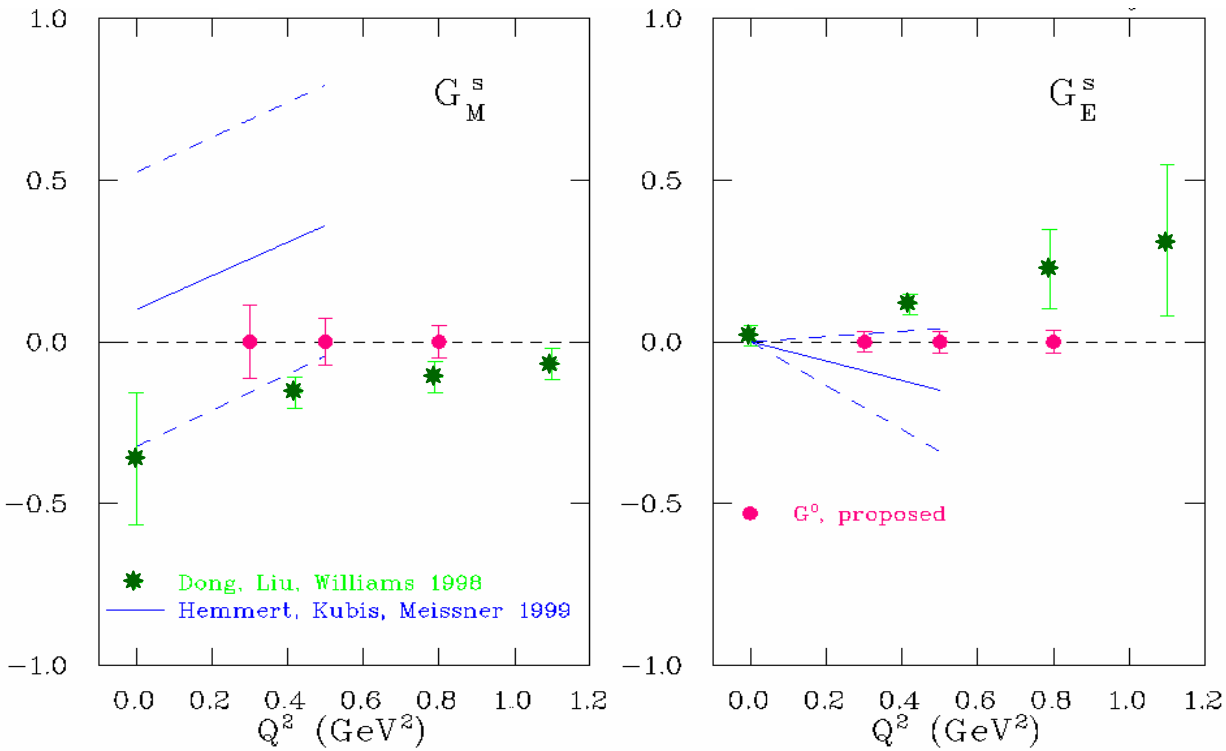


G^{Zp} , $G^{\gamma p}$ ⇨ $G^{s,p}$ Strangeness form factor of proton $\langle p | \bar{s} \gamma^{\mu} s | p \rangle$

Role of sea quarks at low *E*

Theoretical Estimates & Expected Errors for G0

$$G^{s,p}_{E,M} = (1 - 4\sin^2\theta_W)\, G^{\gamma\, p}_{E,M} - G^{\gamma\, n}_{E,M} - G^{Z\, p}_{E,M}$$



Related Measurements

HAPPEX $(G^S_E + 0.39G^S_M)$ at Q^2=0.48 (GeV/c)^2 — Results consistent with zero

SAMPLE G^S_M at Q^2 = 0.1 (GeV/c)^2 — $G^S_M = 0.37 \pm 0.20 \pm 0.26 \pm 0.07$

PVA4 at Mainz $(G^S_E + 0.21G^S_M)$: — Q^2 = 0.23 (GeV/c)^2

SAMPLE 2001 (D_2 Tgt): — Q^2 = 0.03 (GeV/c)^2

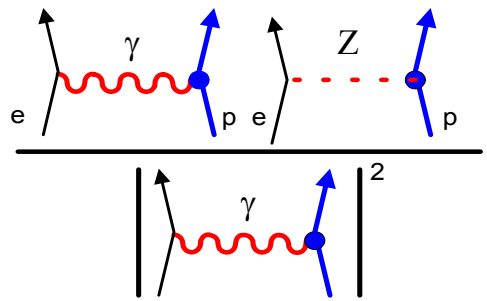
HAPPEX: — Q^2 = 0.1 (GeV/c)^2

Form Factors from Parity-Violating Asymmetry

Asymmetry **Proton Weak Form Factors**

$$A(Q^2) = -\frac{(G_F Q^2)}{\pi\alpha\sqrt{2}} \frac{\{\ \varepsilon G^{\gamma}_E G^Z_E + \tau G^{\gamma}_M G^Z_M + \eta G^{\gamma}_M G^Z_A\ \}}{\varepsilon (G^{\gamma}_E)^2 + \tau (G^{\gamma}_M)^2} \ [\ 1/P_Z\ ]$$

(where ε , τ , η are kinematical parameters)



Determine G^Z_E and G^Z_M

Do **2** measurements of $A(Q^2)$ *[Rosenbluth separation]*

For a given Q^2, ε ranges from **1** (small angles) → **0** (large angles)

i) At small **(forward)** angles, measure a combination of G^Z_E and G^Z_M

ii) At large **(backward)** angles, measure G^Z_M

→ Combine both measurements to ***extract*** G^Z_E

G0 MEASUREMENTS : 3 Phases

A) Forward Angle Mode

B) Backward Angle Mode

C) Deuterium Target Mode *(Rad. Corr. to G^Z_A)*

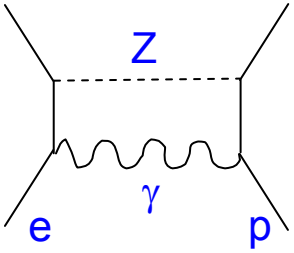
Axial Form Factor of the Proton

PV Asymmetry : $A(Q^2) \propto \varepsilon G^{\gamma}_{E} G^{Z}_{E} + \tau G^{\gamma}_{M} G^{Z}_{M} + \eta G^{\gamma}_{M} G^{Z}_{A}$ (Extract G^{Z}_{E}, G^{Z}_{M})

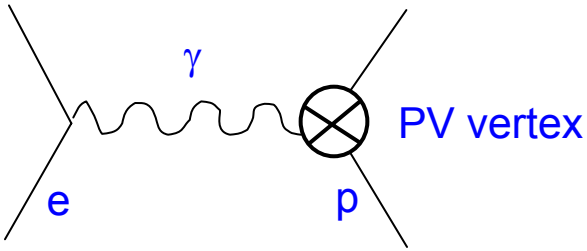
G^{Z}_{A} : axial form factor
tree level Z-exchange contribution, *"known"* …

In e-p scattering, there are radiative corrections: $G^{Z}_{A} \rightarrow G^{e}_{A} = G^{Z}_{A} + R^{e} + \eta F_{A}$

(a) R^{e} : box diagrams, 1-quark EW r.c., etc…



(b) Additional diagrams with $Z^0/W^{\pm}$ exchange between quarks



An "effective" axial (PV) coupling of the photon to the nucleon, F_A, the ***Anapole Moment*** of the nucleon (Zel'dovich, '57)

Effective Axial Form Factor

Radiative corrections in e-p scattering: $G^Z_A \rightarrow G^e_A = G^Z_A + R^e + \eta F_{Anapole}$

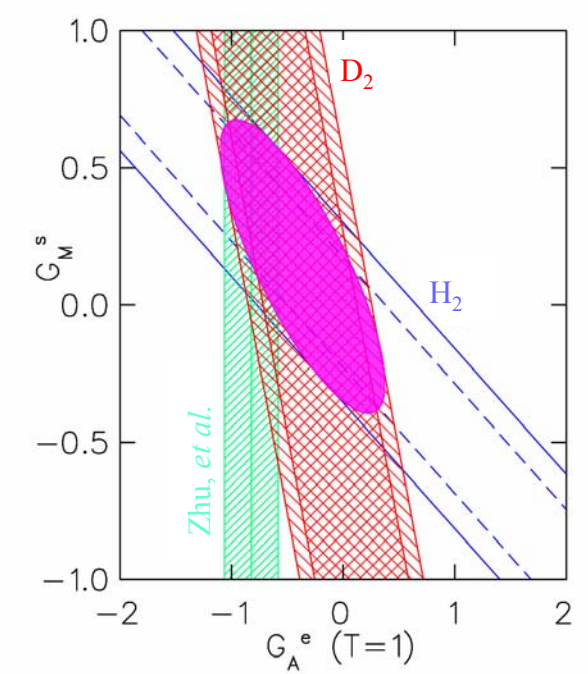
Option: Deuterium quasielastic scattering at back-angles

More sensitive to G^e_A than to G^S_M → eg., at $Q^2 \sim 0.1$ GeV^2

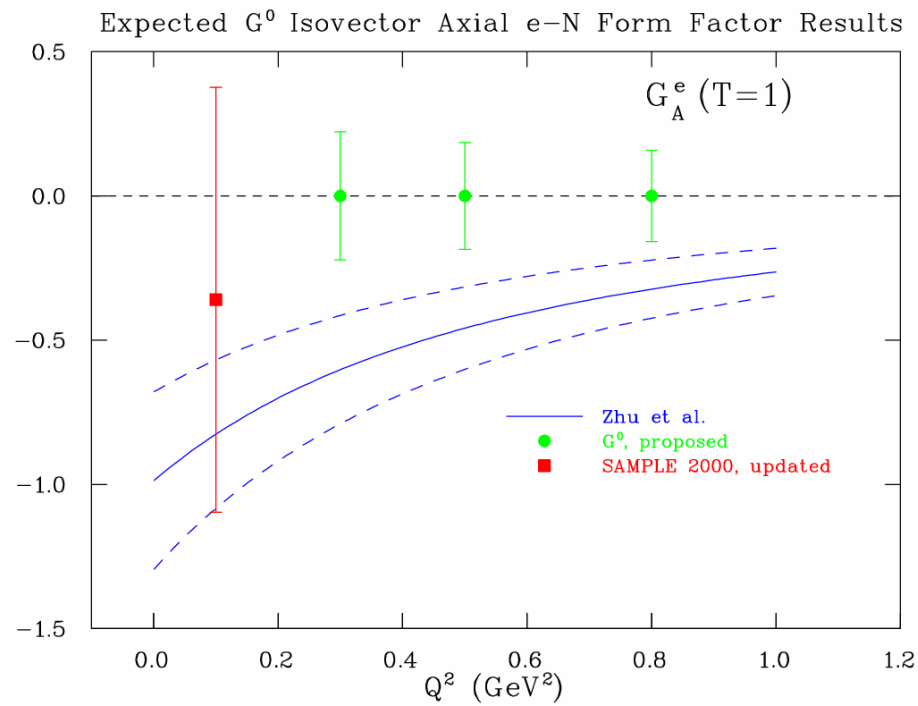
$A^{ed} \sim Q^2 (1 + 0.22\, G^e_A - 0.10\, G^S_M)$

vs $A^{ep} \sim Q^2 (1 + 0.24\, G^e_A - 0.61\, G^S_M)$

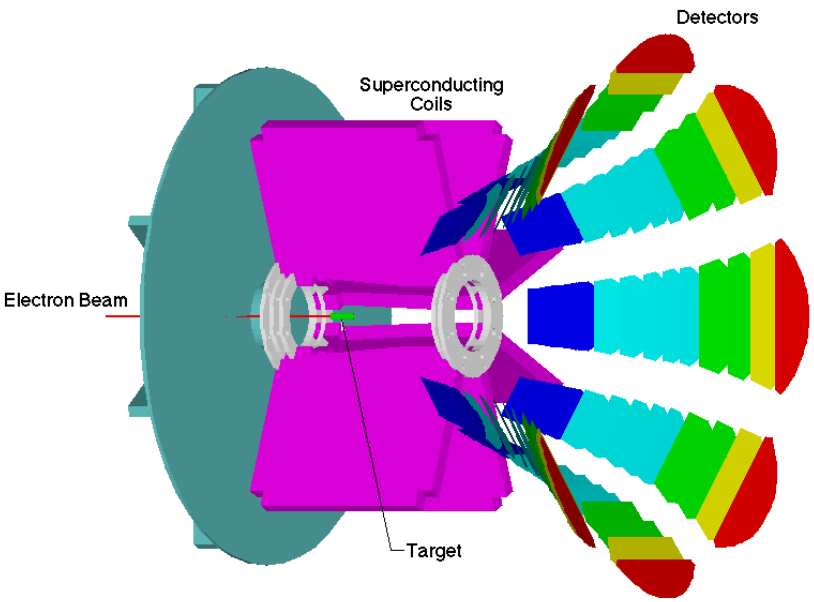
SAMPLE 2003

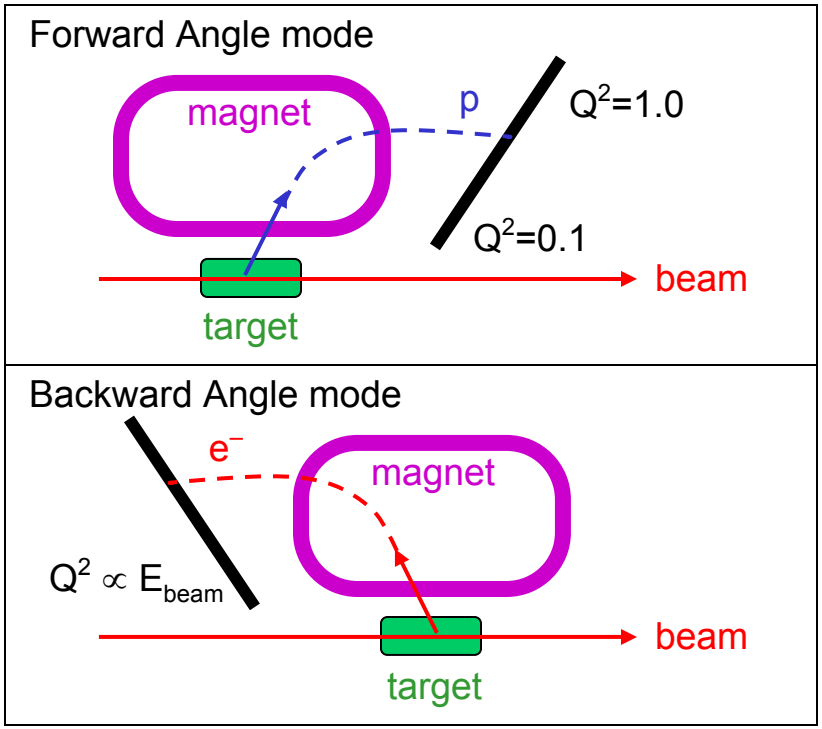


Extraction of G^e_A with Deuterium Target



G0 Schematic Layout and Experiment Parameters





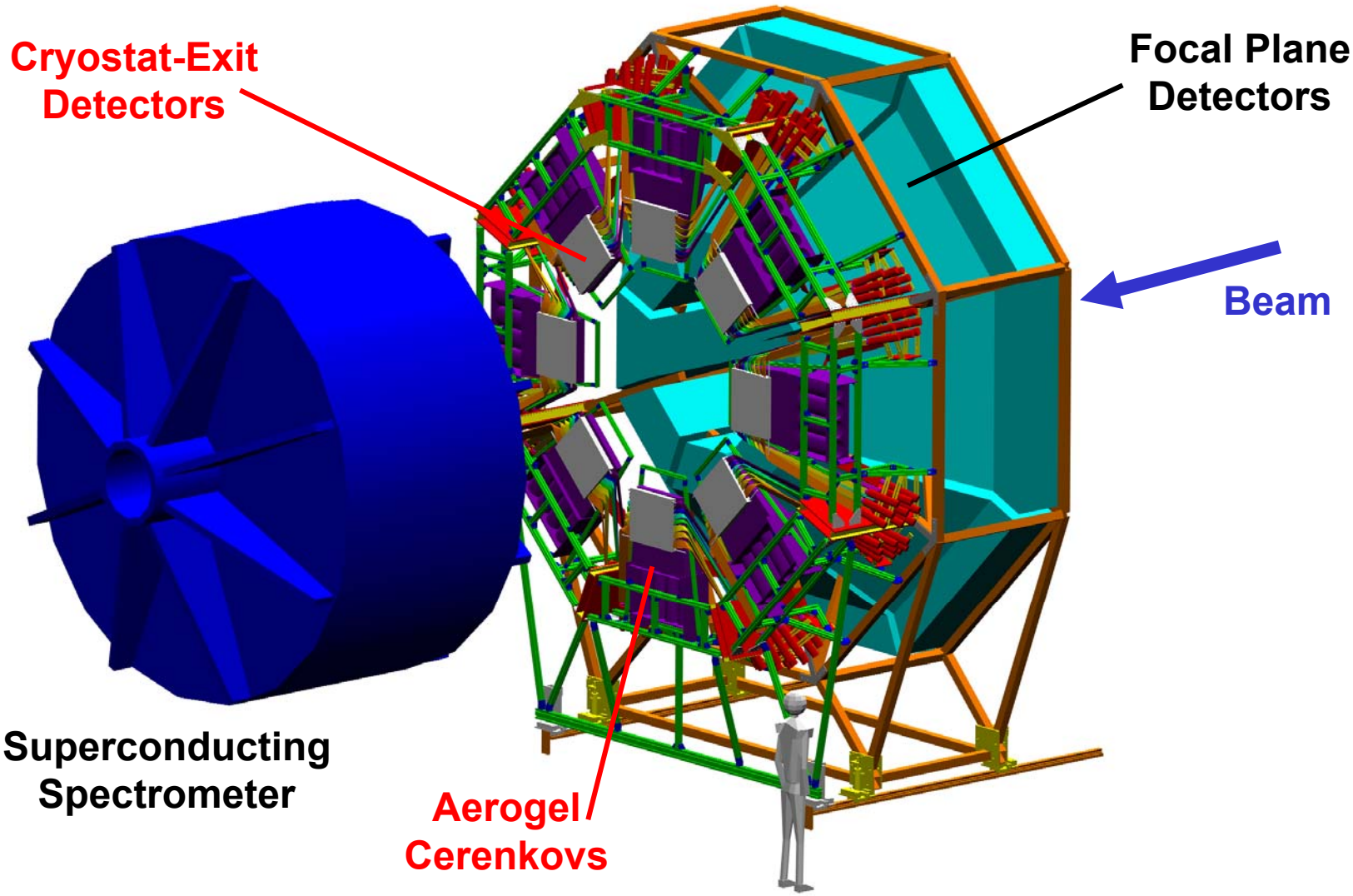
Backward angle rates (elastic, quasielastic)

Target	E(GeV)	Q^2(GeV^2)	Rate (MHz)
LH2	0.424	0.3	1.017
LD2	0.424	0.3	1.391
LH2	0.585	0.5	0.359
LD2	0.585	0.5	0.505
LH2	0.799	0.8	0.095
LD2	0.799	0.8	0.137

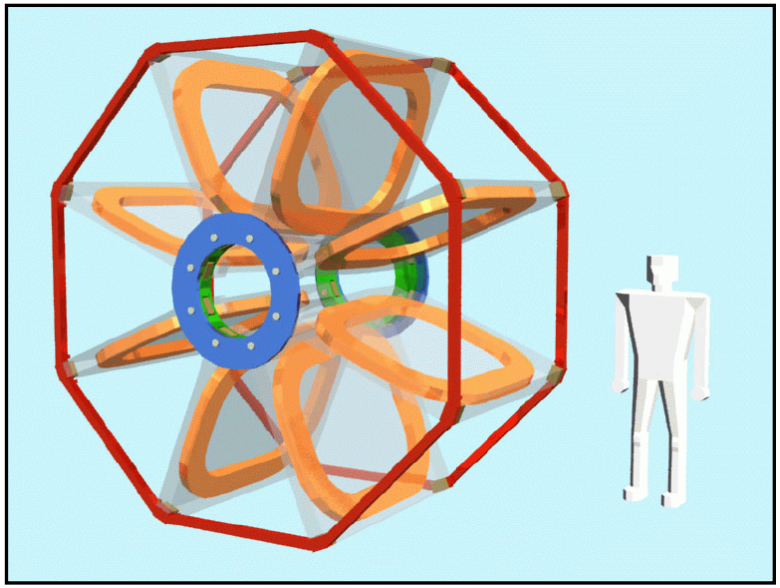
G0 BackAngle Configuration

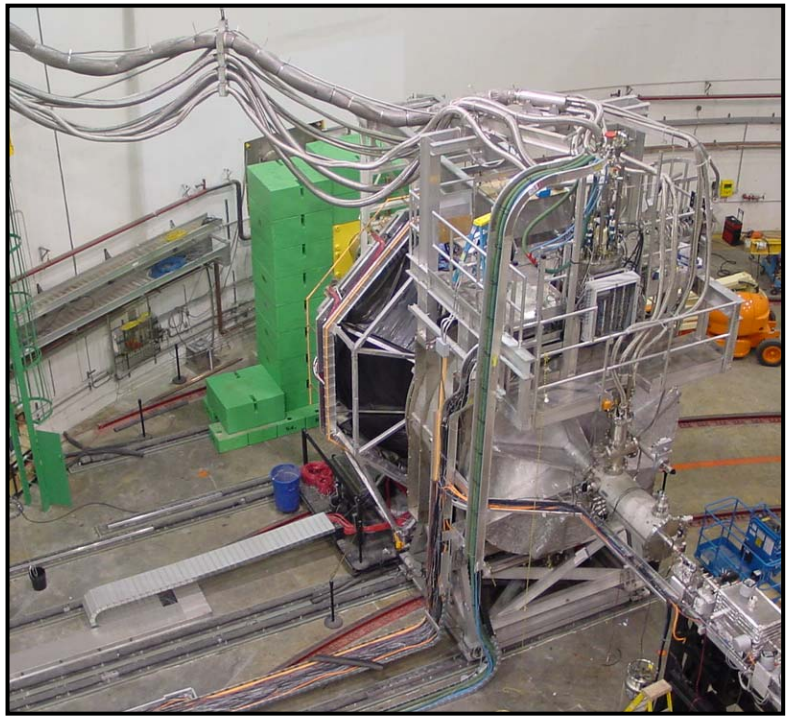
Magnet & Detector Package *turned around ;* Detect back-scattered electrons

Additional Detectors ; 2nd *(Mini)* Ferris-Wheel Support Structure



G0 Superconducting Toroidal Magnet (SMS)





8-Sector, *Iron-free*
R ~ 2m, L ~ 2m
T_o ~ 4.5 K
θ_{accept} ~ 62º–78º
35º < θ_{bend} < 87º
$\Delta\Omega$ ~ 0.5–0.9 sr

(forward mode)
I_o ~ 5000A
B_ϕ ~ 1.7 T
Currently running in Forward mode

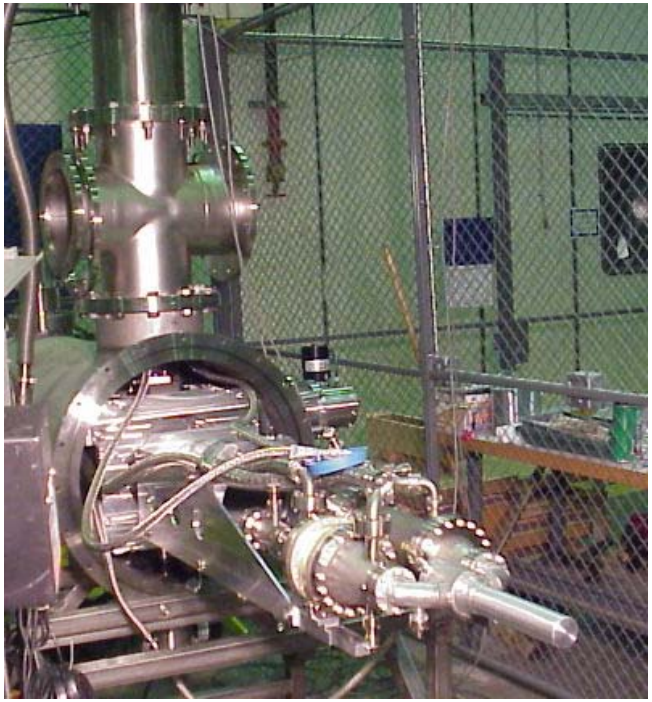
"Turn-Around" → BackAngle mode

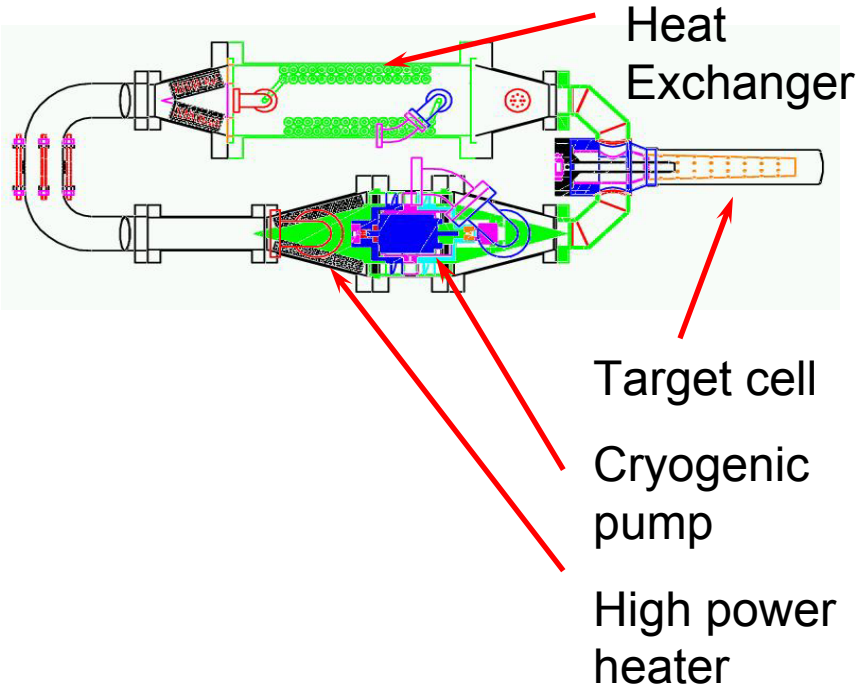
Logistics: Scheduling
Equipment
Fixtures

Magnet/Target: further downstream

Lower currents

G0 Liquid Hydrogen/Deuterium Target



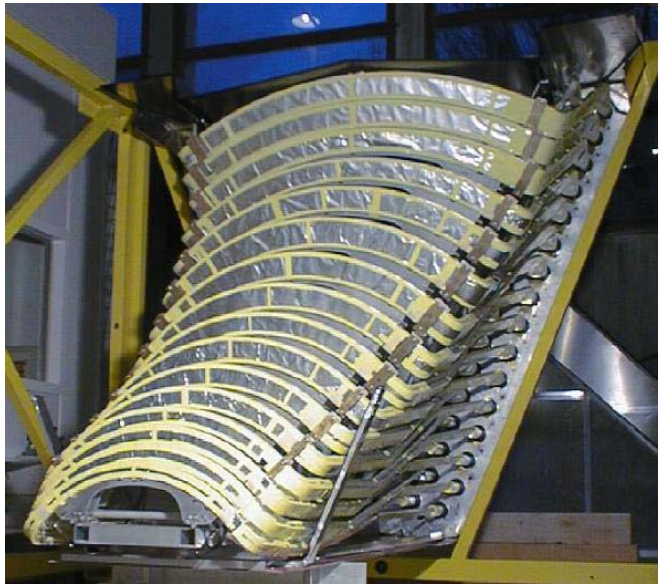


- **20 cm LH_2 cell**
- **250 W heat load from 40 μA beam**
- **High circulation rate to minimize target density fluctuations**

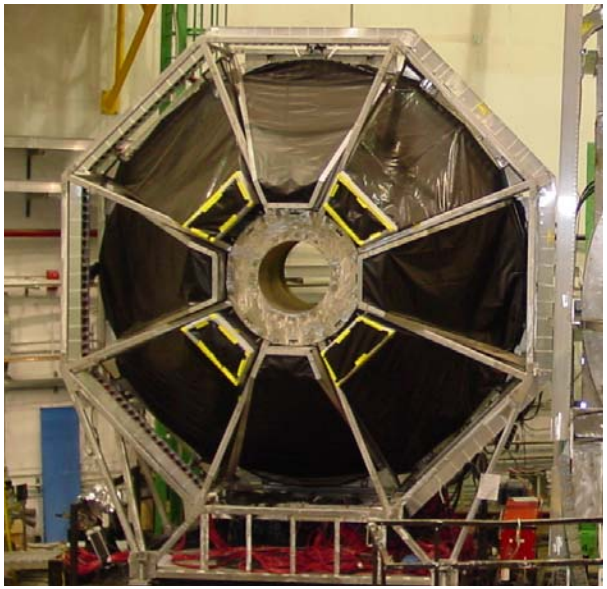
- **Target/Services remain on upstream side of magnet**
- **Extension Piece fabricated for Backangle Configuration**
- **Run with LH_2 and LD_2 targets (~30 days for each target, at each Q^2)**

Focal Plane Detectors (FPD)

North American FPD octant



French FPD octant



FPDs on Ferris-Wheel support

FPDs: 16 Detectors per sector

→ Scintillator shape: Q^2 Contours (defined for Forward angle mode)
→ *Front/Back* detector pairs in coincidence (Forward angle mode)
→ Long lightguides w/ helical bend → brings light to PMT in low-field region

Detectors installed within 8 light-tight boxes, mounted on "The Ferris Wheel"

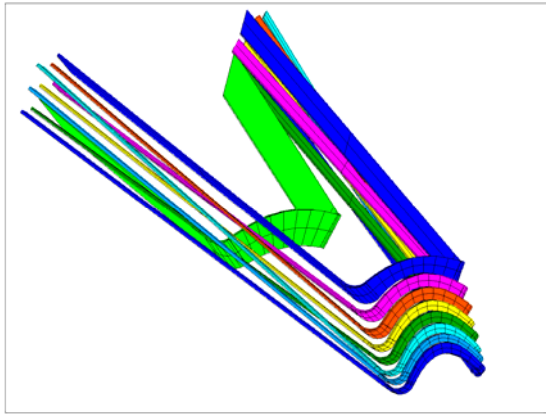
Ferris Wheel/FPD Assembly *"Turn-Around"* → Backangle Configuration

Only *"front"* scintillators will be used *(in coincidence w/ Cryostat-Exit Detectors)*

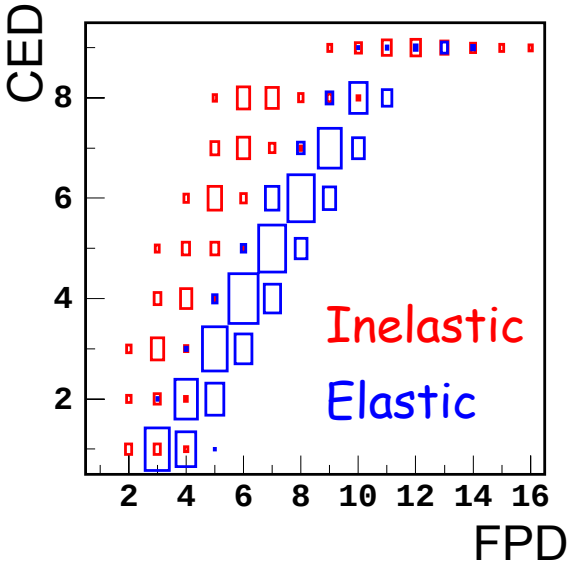
Cryostat-Exit Detectors *(new)*

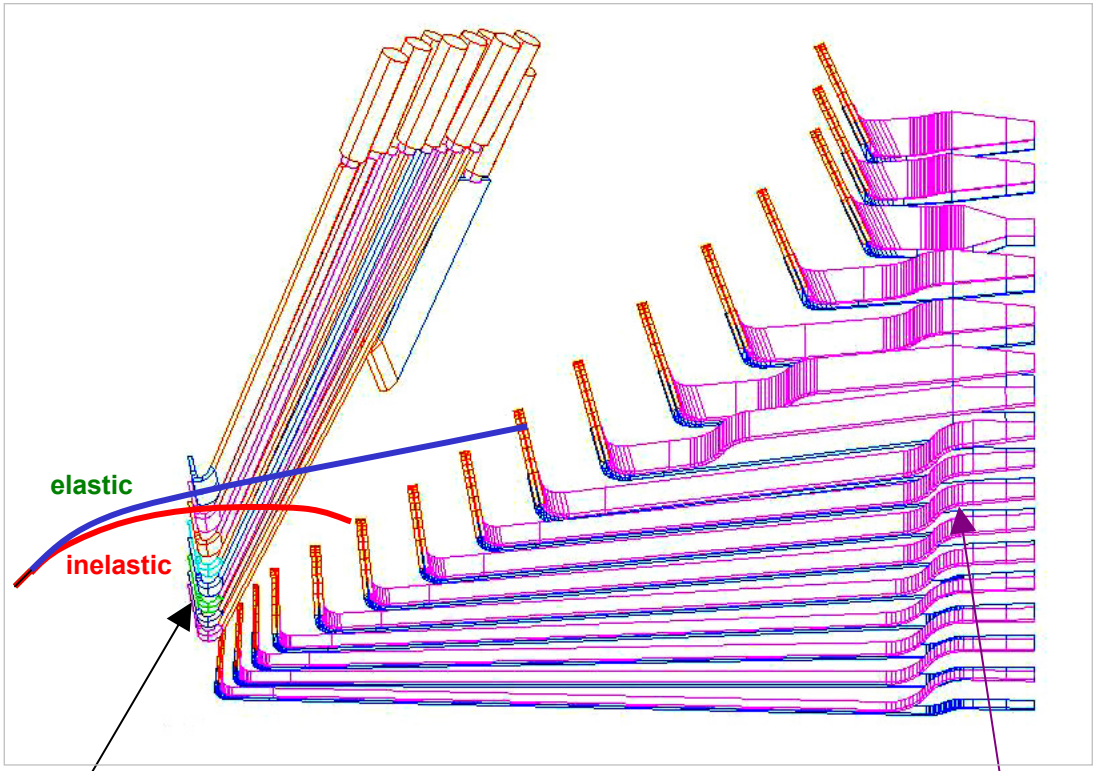
Measure back-scattered electrons

- Require additional det.^{s}: Cryostat-Exit Detectors (CED) (9 detectors per octant)
- CED-FPD coincidence to separate elastics/inelastics e^{-}
- Inelastics also interesting (N-Δ axial transition FF)



CED-FPD correlation at $Q^2 \sim 0.3\ (GeV/c)^2$





CEDs (Cryostat Exit Detectors)

FPDs

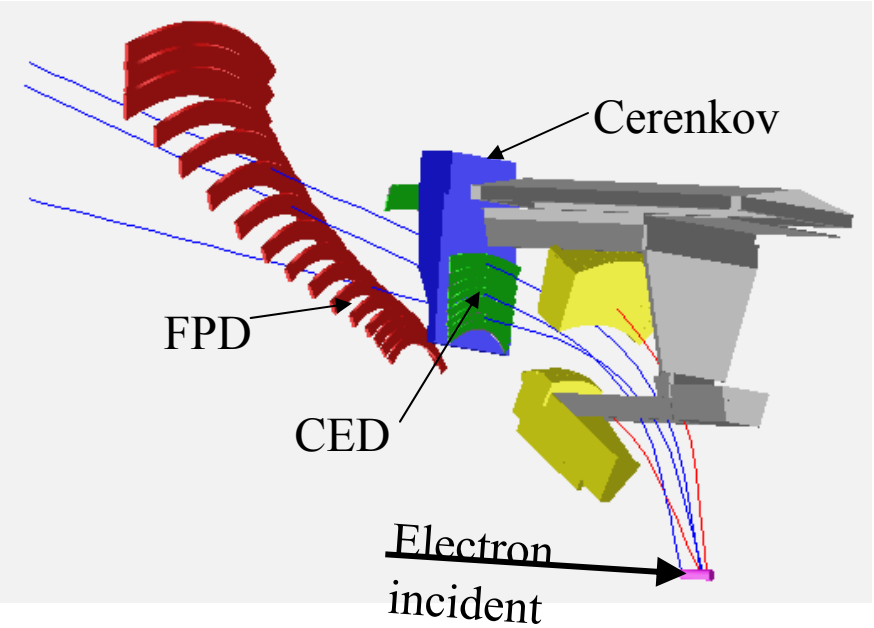
Cerenkov Detectors *(new)*

Back-scattered electron:

- CED-FPD coinc. separates elastic & inelastic e^- 's

Deuterium measurement:

- pion production off D_2
- $(\pi+\mu)/e$ ratio ~ 8:1 (at 0.8 GeV^2)
  [somewhat better at other Q^2]
- Pion rejection important
- Cerenkov for π^-/e^- discrimination
  [rejection factor ~125 ; δ-ray]



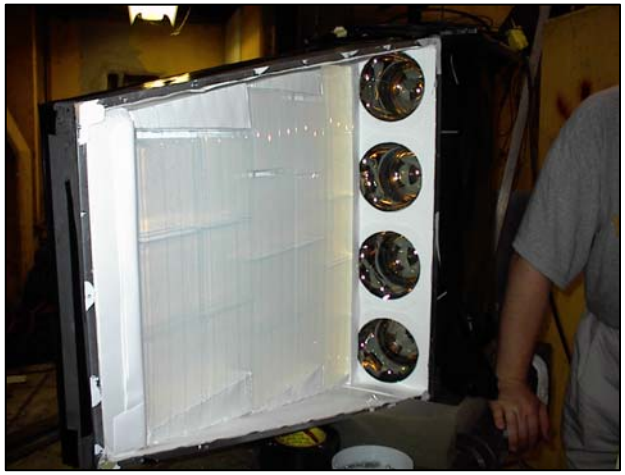
Cerenkov Detector:

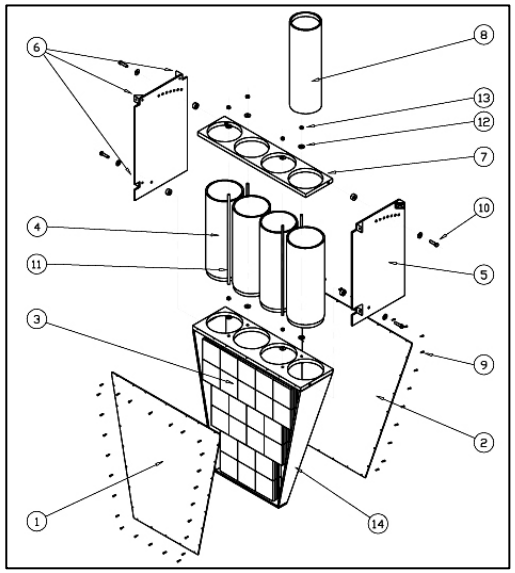
- single detector in each octant → 4 North American, 4 French detectors
- 5 cm of aerogel, n ~ 1.03, p_{thres} ~ 570 MeV
- diffuse reflection, viewed by 4 x 5 inch PMTs
- simulations: expect ~7 photoelectrons
- included in electron trigger

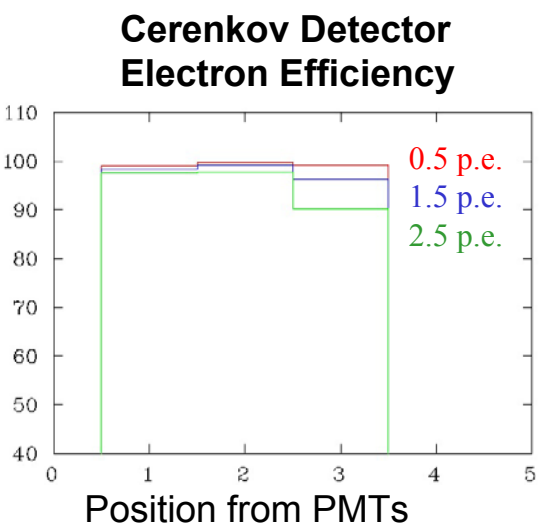
Aerogel Cerenkovs

Aerogel Cerenkov Detector: 11 x 11 x 1 cm^3 tiles (5 deep), Millipore-lined Light Diffusion Box

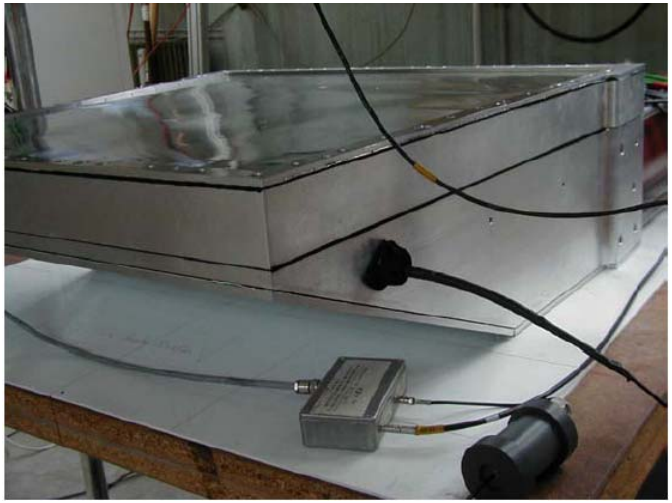
North American Cerenkov

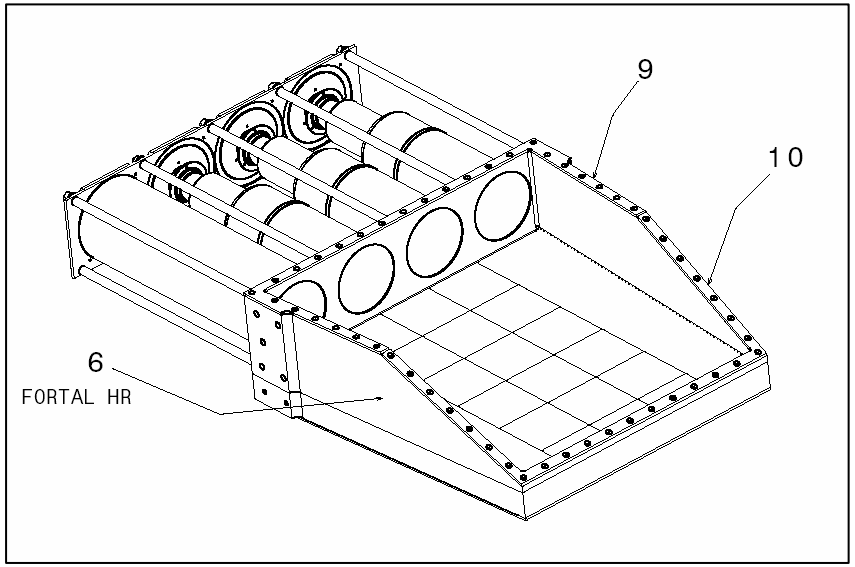






French Cerenkov





Backangle Electronics

- Forward angle mode: custom electronics provide high-rate histogramming

  NA: mean-timer → LTDs (latching time digitizer) → scalers

  French: DMCH16X [mean-timer → flash TDCs]

French DMCH16X Module

NA CED•FPD modules

- Backward angle mode: reuse much of the same electronics (MTs, DMCH16X)

  - Time-encoding not as useful for backangle mode

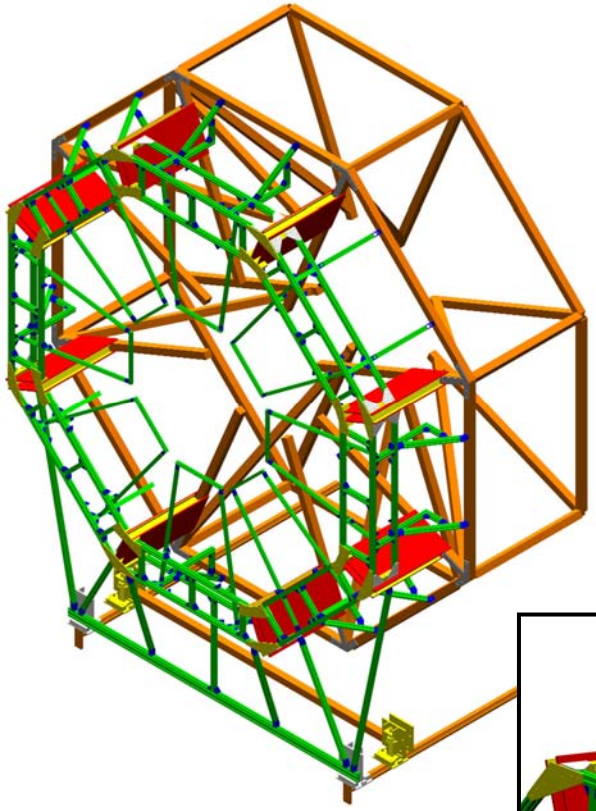
- **New** CED•FPD coincidence board required (PLDs – Altera chip)

  - Cerenkov signal included (strobes CED•FPD coincidence)

  NA: mean-timer → CED•FPD coinc. boards → scalers

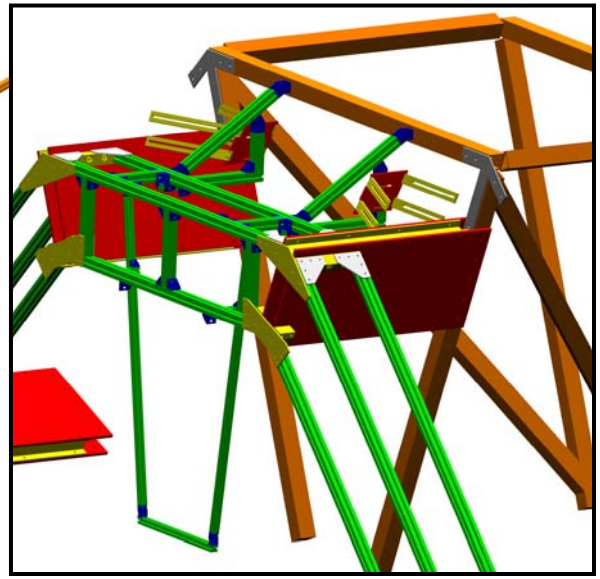
  French: DMCH16X → CED•FPD coinc. board (incl. ASIC scalers)

Cerenkov-CED Support Frame

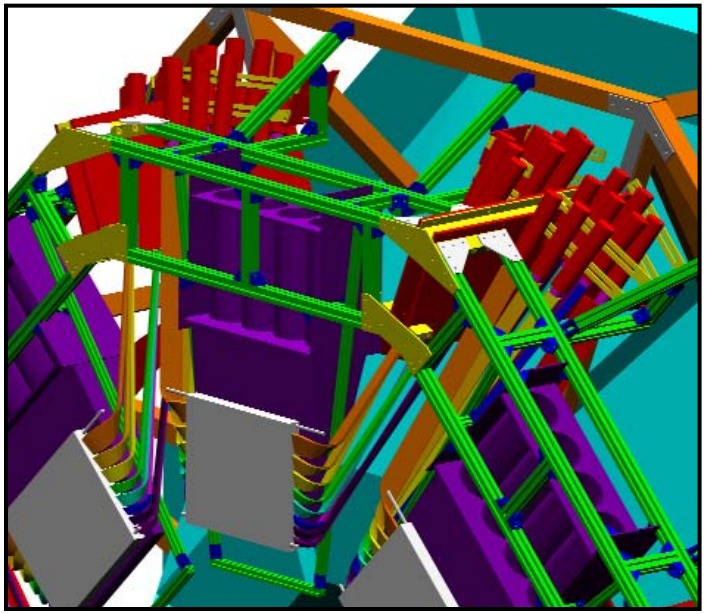


"Mini"-Ferris Wheel

→ Supports CEDs & Cerenkov Detectors
→ Supports lead (Pb) shielding
→ Coupled to existing FPD Ferris Wheel
→ Foot/Carriage on existing rail system
→ Prefab aluminum extrusions (Bosch)

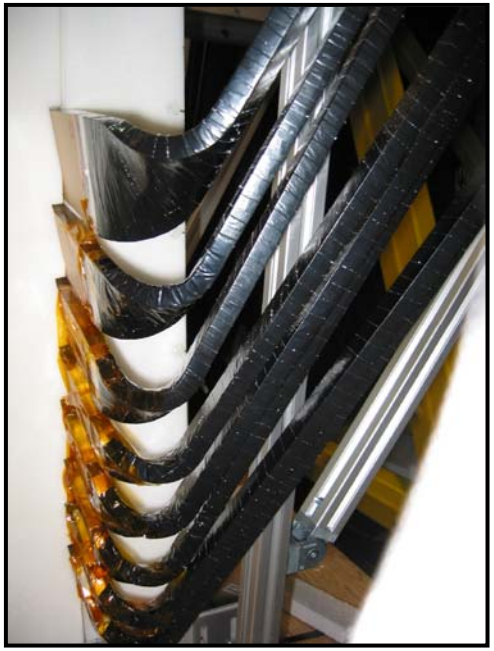


Back-Angle Support Structure & Test Assembly



Test-fitting & Installation

→ CED scintillator supported in a rohacell "frame"
→ Concern w/ interferences near helical bends
→ Interferences of CED lightguides identified near PMT end → resolved by modifying PMT support fixtures ("flexibility" built-in)
→ Wooden "mock-up" Cerenkovs (French & North American versions) test-fitted → OK
→ "Go-Ahead" given to complete the helical bends on CED lightguides



Status of BackAngle Detectors & Electronics

Cryostat-Exit Detectors:

Scintillators	- fabrication completed, delivered to JLab
Lightguides	- first octant completed, delivered to JLab Test-fit w/ scintillators & support structure - remaining octants → fabrication almost complete final helical bends - delivery to JLab ~ spring/summer 04

Aerogel Cerenkov Detectors:

French & NA	- results from prototype tests - fabrication of *"production"* detectors underway - delivery to JLab ~ spring/summer 04

Electronics:

NA CED•FPD boards	- 1 full octant of prototype boards tested - essentially *"ready"* to go into production - delivery to JLab ~ fall 04
French CED•FPD boards	- prototype boards tested - fabrication of *"production"* modules ~ early 04 - delivery to JLab ~ summer 04

Cerenkov-CED Support Frame & Detectors: Timeframe

Summer/Fall 03:	Test Assemble one octant of: Support, CEDs, Lightguides, PMTs, Cerenkov Mock-up
Winter 03/Spring 04:	Order prefab parts for 7 more octants and the leg assembly for “Mini”-Ferris Wheel
	Bend remaining CED Lightguides
	Fabricate Cerenkov Boxes
	Tests/Studies (cosmics) w/ 1st octant
Spring/Sum/Fall 04:	Assemble/Test/Install remaining Octants of Supports, CEDs, & Cerenkovs

Summary: G0 Backangle Configuration

- Measurement of elastic asymmetries at backangles
  - at Q^2 = 0.3, 0.5, 0.8 GeV^2

- Physics goal is to separate G^s_E, G^s_M, G^e_A
  - Measurements at forward and back angles on hydrogen target
  - Measurements at back angles on deuterium target

- Additional detectors and support structure required
  - Cryostat-Exit Detectors
  - Aerogel Cerenkov
  - Mini-Ferris wheel

- Beamtime (~ 70 days per Q^2 point)
  - 10 days commissioning time
  - 30 days on hydrogen target
  - 30 days on deuterium target