Hall A collaboration meeting

June 23rd, 2005

G_E^n at High momentum transfer

Hall A experiment - E02-013

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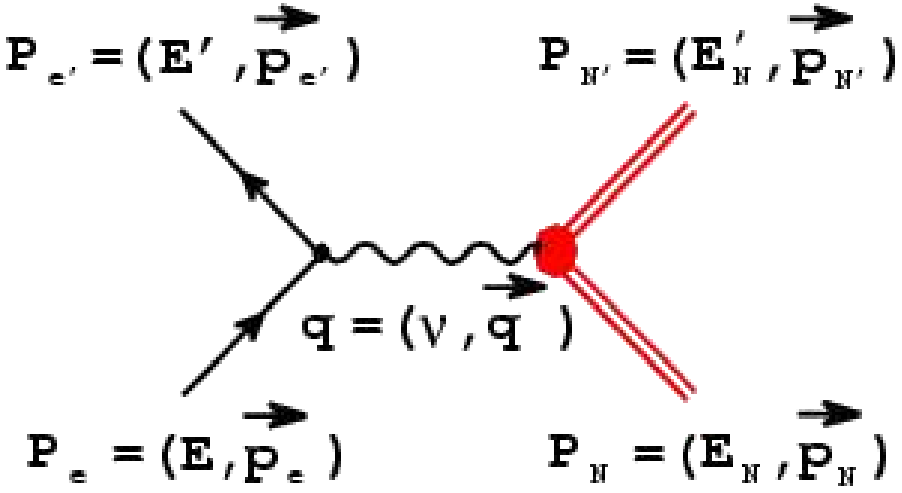
Outline

- **Motivation of the experiment or Why high momentum transfer measurement of G_E^n is so much needed?**
- **What was old and new in the proposal in 2002? and What is changed in the scheme in three years?**
- **E02-013 status: a collaboration, experimental equipment – target, e-arm, n-arm**
- **Milestones of the experiment in 2005**

Motivation - Form factors

- **Form factors (FFs) are functions in a hadron current operator**
  - **In one photon approximation scattering cross section is factorisable and FFs could be calculated (first Born approximation)**
  - **At low momentum transfer in first BA FFs are related to the classical charge and magnetic distributions of the nucleon**
  - **At intermediate momentum transfer the FFs deal with a convolution of the hadronic structure of the photon (Vector Mesons) and the nucleon structure (including the pion cloud)**
- **At large momentum transfer the valence quark components of the nucleon are providing a dominant contribution into FFs**
- **Asymptotic properties of the FFs are predicted in the pQCD limit**
- **Connections to Deep Inelastic electron Scattering, VDCS, and RCS were discovered recently in the GPD formalism**

One photon approximation



Nucleon vertex:

$$\Gamma^{\mu}_{EM}(p_N, p_{N'}) = \underbrace{F_1(Q^2)}_{Dirac}\gamma^{\mu} + \frac{i\kappa}{2m}\underbrace{F_2(Q^2)}_{Pauli}\sigma^{\mu\nu}q_{\nu}$$

Sachs form factors:

$$G_E(Q^2) = F_1(Q^2) - \kappa\frac{Q^2}{4m^2}F_2(Q^2)$$
$$G_M(Q^2) = F_1(Q^2) - \kappa F_2(Q^2)$$

Cross Section:

$$\frac{d\sigma}{d\Omega} = \sigma_{NS}\left[\frac{G_E^2(Q^2) + \tau G_M^2(Q^2)}{1+\tau} + 2\tau G_M^2(Q^2)\tan^2\frac{\theta}{2}\right]$$

Motivation - GPDs

unified description in GPD approach

new structure functions: $H,\ E,\ \tilde{H}, \tilde{E}\ \ (x,\ \xi,\ t)$

$$F_1(t) = \sum_a e_a \int_{-1}^{1} dx\, H^a(x,0,t),$$

$$G_A(t) = \sum_a \int_{-1}^{1} dx\, sign(x)\, \hat{H}^a(x,0,t),$$

$$F_2(t) = \sum_a e_a \int_{-1}^{1} dx\, E^a(x,0,t),$$

Motivation - Neutron Electric Form Factor and its importance for GPDs (Kroll et al)

Motivation of the ansatz for GPDs

to be fitted through sum rule to data on $F_{1,2}^{p,n}$, F_A

choose $\xi = 0$; only valence quarks are probed $\quad q_v(x) = q(x) - \bar{q}(x)$

$s(x) \simeq \bar{s}(x)$, $c(x) \simeq \bar{c}(x)$ assumed otherwise ....

ANSATZ: $\quad H_v^q(x,t) = q_v(x) \exp\left[f_q(x)t\right]$

$f_q = \left[\alpha' \log(1/x) + B_q\right](1-x)^{n+1} + A_q\, x(1-x)^n$

$\alpha' = 0.9\,\mathrm{GeV}^{-2}$ (fixed) $\quad n = 1, 2 \quad$ $q_v(x)$ from CTEQ (INPUT)

for large $-t$ and x: overlaps of Gaussian LC w.f. $\quad H_v^q(x,t) \to \exp\left[a^2 t \frac{1-x}{2x}\right] q_v(x)$

low $-t$, very small x: Regge beh. expected $\quad H_v^q(x,t) \to x^{-\alpha(0)} \exp\left[\alpha' t \log(1/x)\right]$

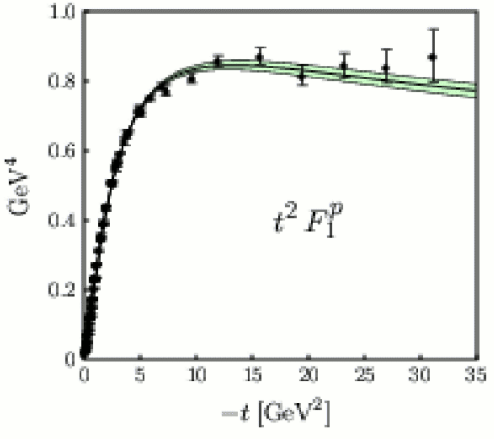
criteria for good parameterization (met by ansatz):

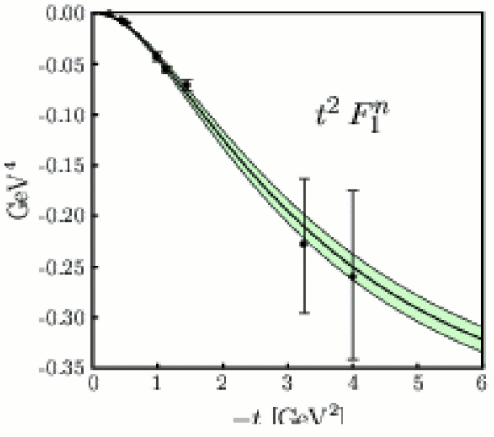
- simplicity
- consistency with theor. and phenom. constraints
- plausible interpretation of parameters (if possible)
- stability with respect to variation of PDFs
- stability under evolution (scale dependence of GPDs can be absorbed into parameters)

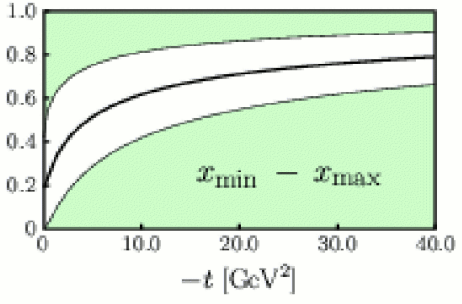
Motivation - Neutron Electric Form Factor

Dirac form factors

$$F_1^{p(n)} = \int_0^1 dx \, [e_{u(d)} H_v^u + e_{d(u)} H_v^d]$$





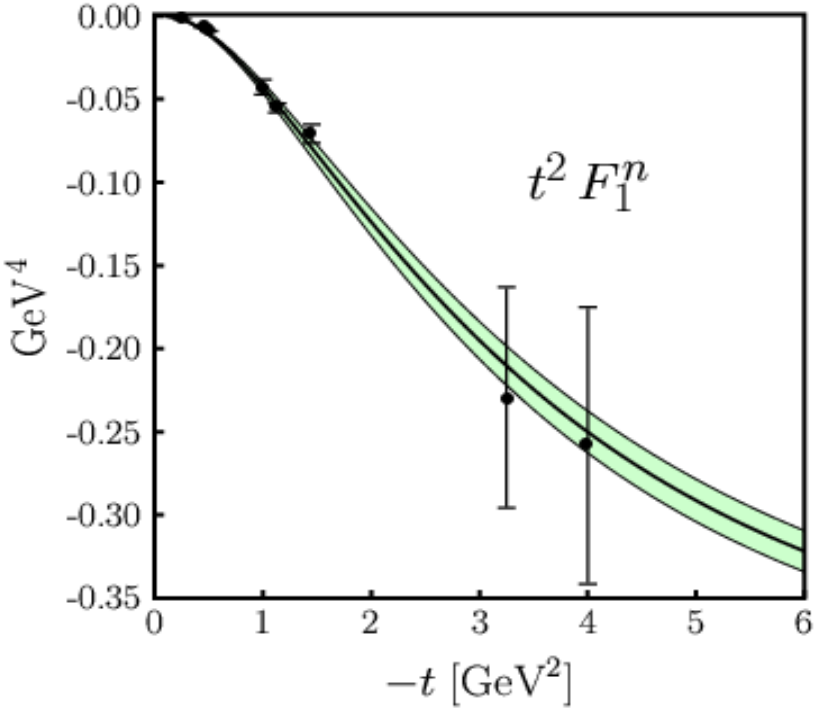


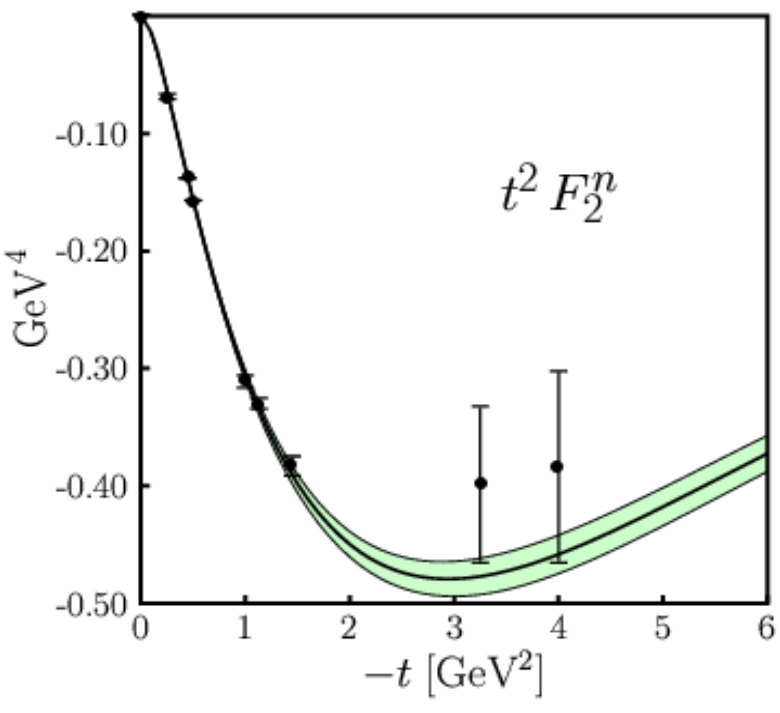
$$\int_{x_{max}(0)}^{1(x_{min})} dx \sum e_q H_v^q(x,t) = 5\% F_1^p(t)$$

parameters for $n = 2$ fit ($\mu = 2\,\mathrm{GeV}$):

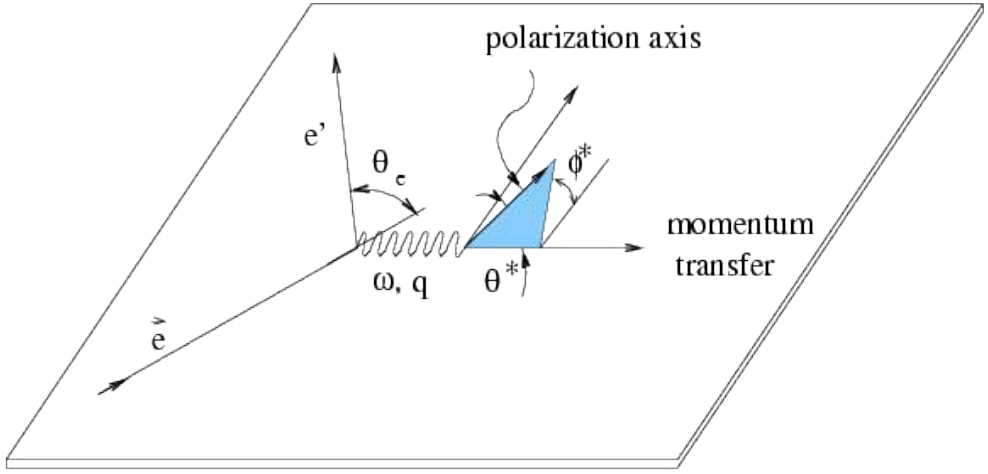
$B_u = B_d = (0.59 \pm 0.03)\,\mathrm{GeV}^{-2}$, $A_u = (1.22 \pm 0.02)\,\mathrm{GeV}^{-2}$, $A_d = (2.59 \pm 0.29)\,\mathrm{GeV}^{-2}$

Motivation - Neutron Electric Form Factor and its importance for GPDs





Beam / Target Asymmetry



Asymmetry:

$$A = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$

$$= A_\perp \sin\theta^\star \cos\phi^\star + A_\parallel \cos\theta^\star$$

(assuming $P_e = P_n = 1$)

Experiments either:

- **measure both components (by rotating target spin)**

or

- **rely on polarimetry**

$$A_\perp = -\frac{2\sqrt{\tau(\tau+1)}\tan(\theta/2)\,\frac{G_E^n}{G_M^n}}{(\frac{G_E^n}{G_M^n})^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

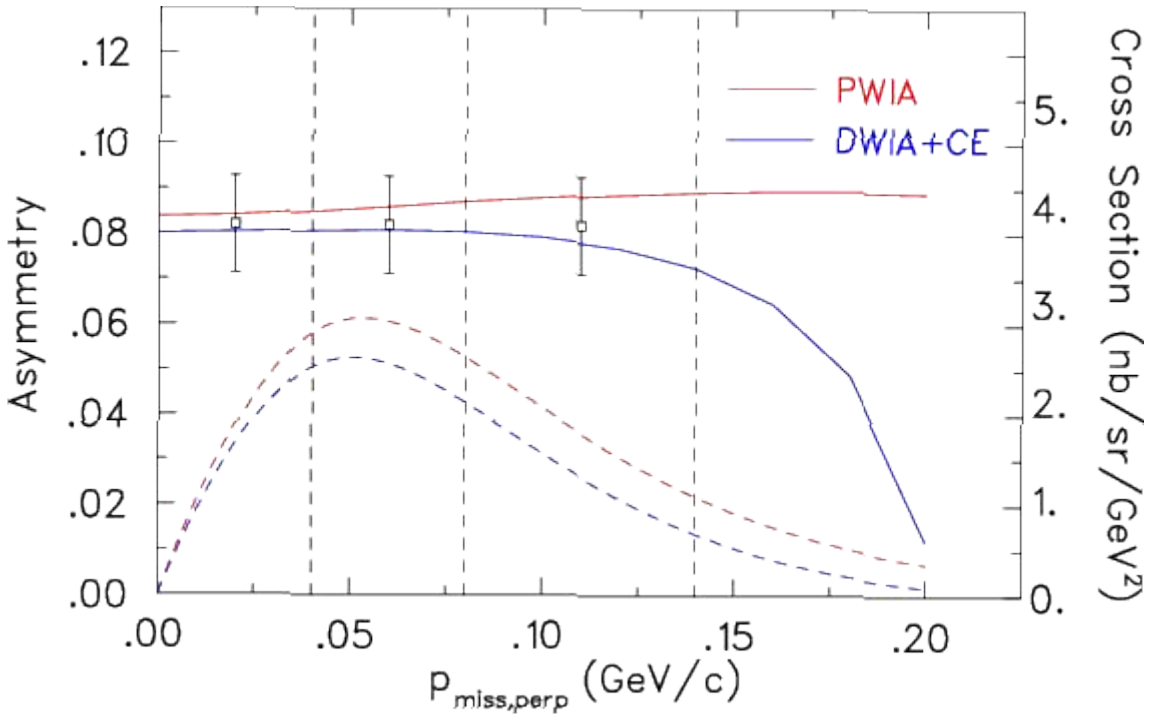
$$A_\parallel = -\frac{2\tau\sqrt{1+\tau+(1+\tau)^2\tan^2(\theta/2)}\tan(\theta/2)}{(\frac{G_E^n}{G_M^n})^2 + (\tau + 2\tau(1+\tau)\tan^2(\theta/2))}$$

(with $\tau = Q^2/4m_N^2$)

Main difficulties and our solutions

- Number of events ~ $L\ \Omega\ \varepsilon\ \sigma_M/(Q^2)^4$, so we need 100+ times higher $L\Omega\varepsilon$ than it was obtained in best prev. experiment $Q^2 \sim 1$ GeV^2
  - ^{3}He target allows for of 10 times higher luminosity than polarized ND_3 target
  - Nuclear effects in ^{3}He target unfavor at $Q^2 < 1$ GeV^2, at the Q^2 value of our interest ^{3}He target is a way to go!
  - Need also 10 times larger acceptance of the electron detector --> BigBite! Is 1% resolution enough? Is it possible to run at 10^5 higher luminosity than it used at NIKHEF ?
- Quasi elastic scattering vs inelastic channels (pion,two pions, delta..) for 2.5 GeV/c neutron $1-\beta = 0.07$. Resolution is just of 0.008.
  - Cut on $P_{transv,recoil}$ selects QES because of quite good angular resolution of the neutron detector!
  - Cut on $P_{long,recoil}$ is just +/-250 MeV/c

Asymmetry vs P_miss

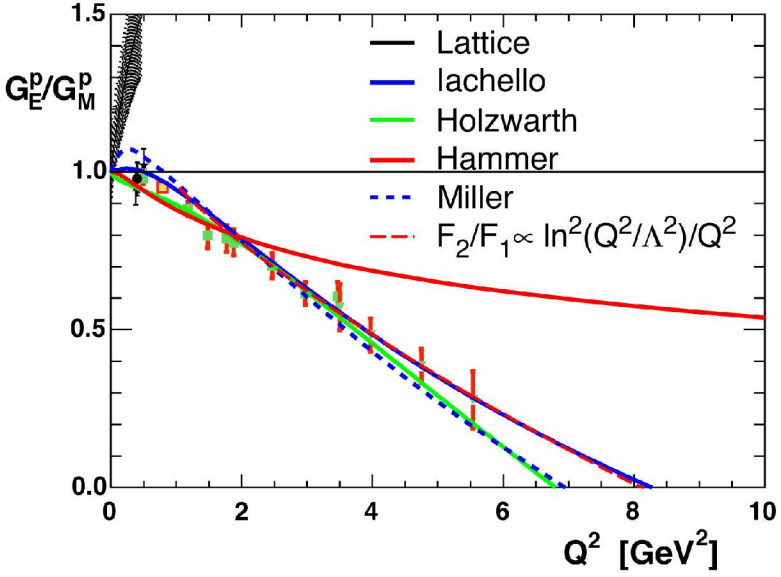


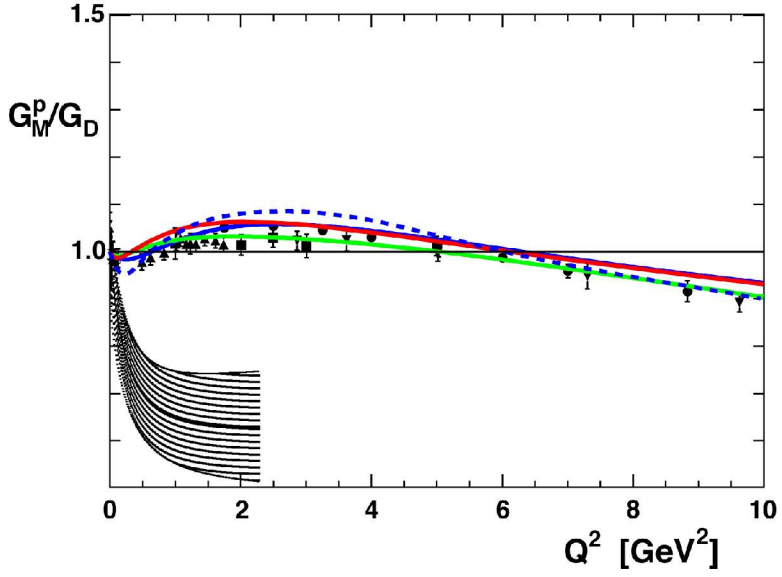
Jefferson Lab Experiment E02-013

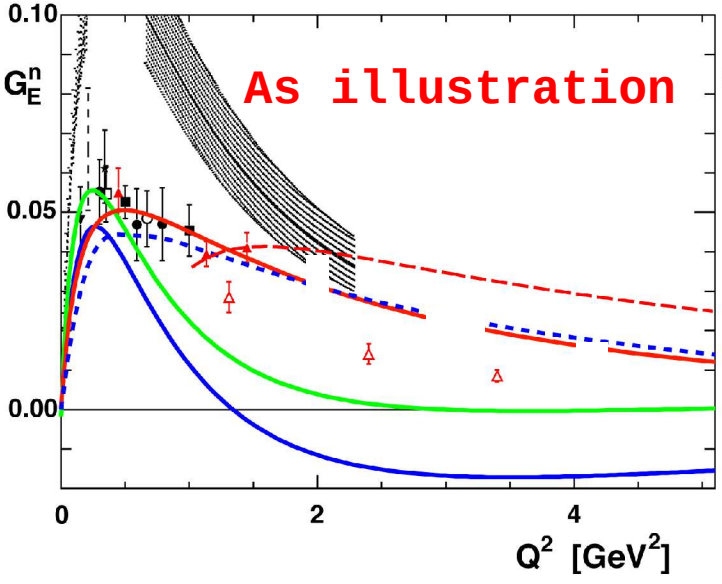
Will obtain G_E^n at three large values of Q^2

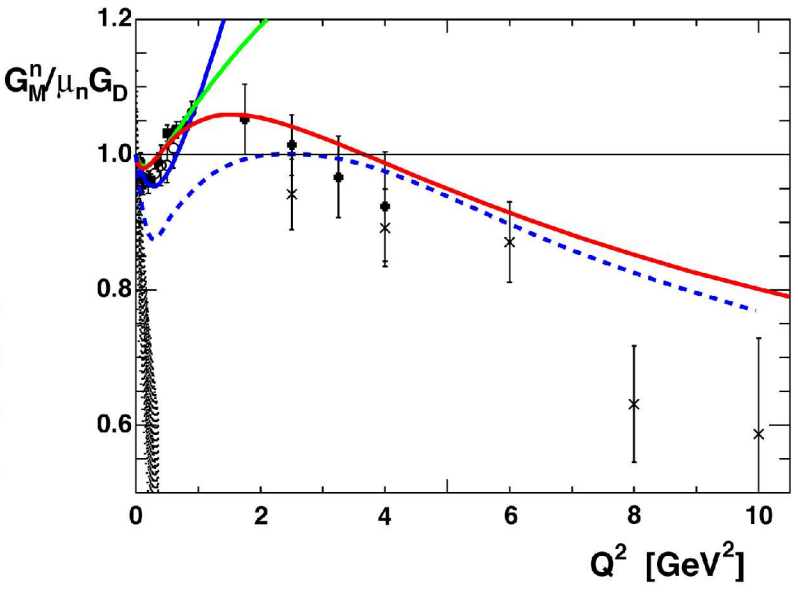
Q^2 (GeV/c)^2	E_i GeV	θ_e deg	p_e GeV/c	θ_n deg	p_n GeV/c	T_n GeV
1.31	1.644	54.6	0.95	35.2	1.34	0.70
2.40	2.444	54.6	1.17	28.3	2.01	1.28
3.40	3.244	50.6	1.43	25.4	2.58	1.81

Many models of form factors are developed

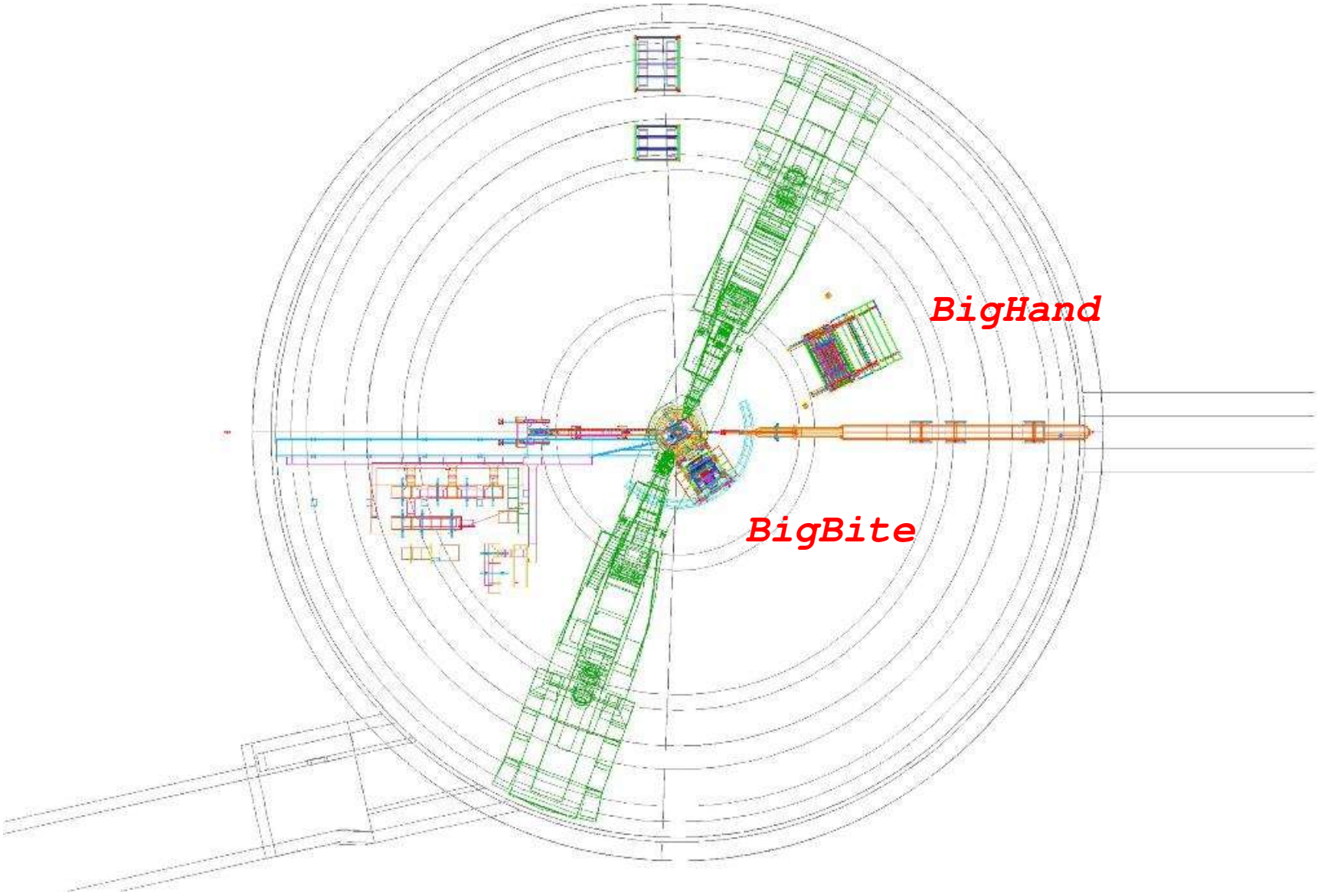




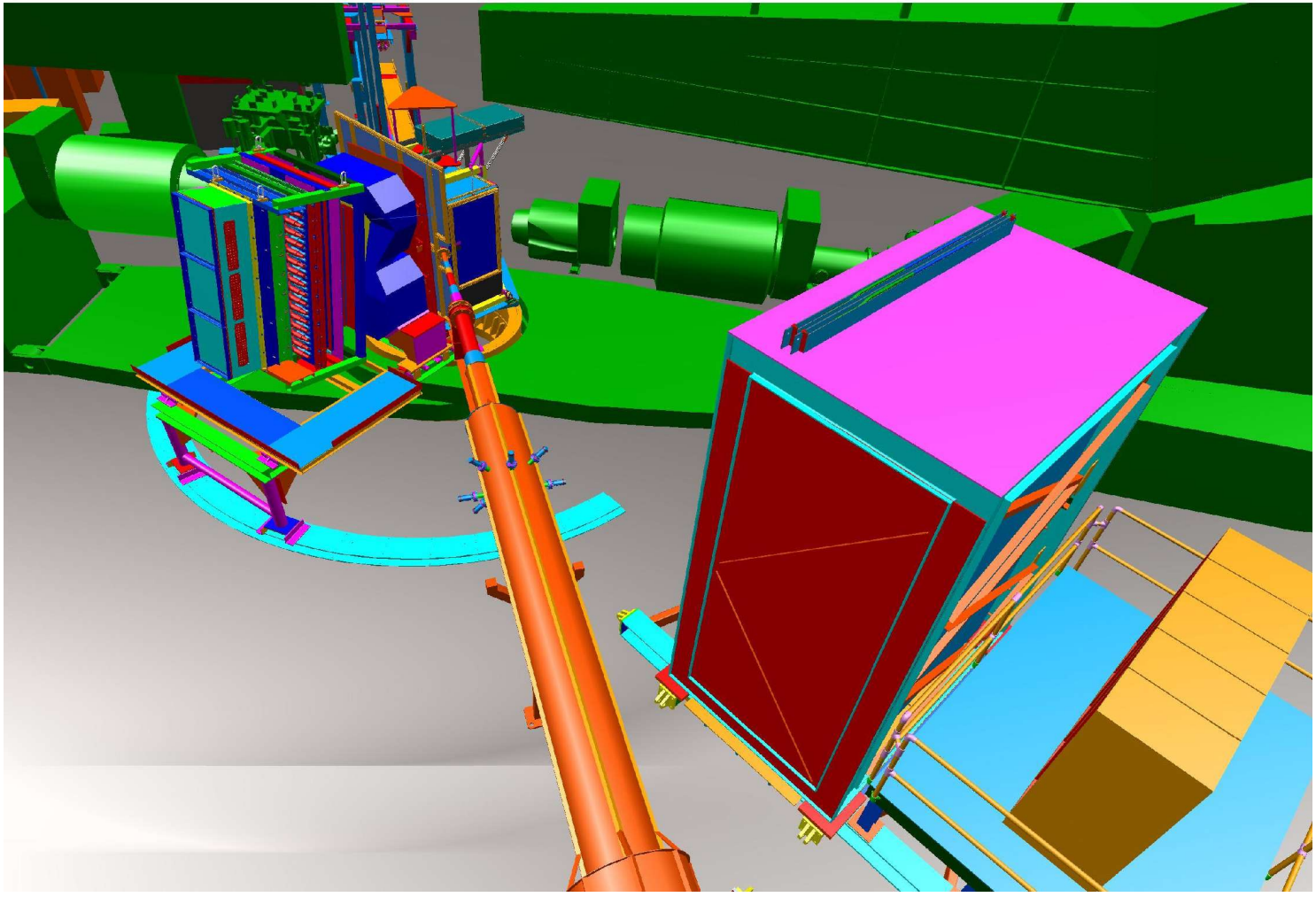




JLab Hall A During E02-013



Hall A E02-013: 3D View



Hall A Neutron Detector (HAND)

- Neutron bars
  - 241 neutron bars in 7 (5) layers
  - High neutron detection efficiency of 35% at trigger threshold of 50 MeVee
  - Large solid angle: active area of 160 cm x 470 cm
  - Position resolution: 5-7 cm
  - Timing resolution of 0.25 ns
  - $s(p_{m,perp})=30$, $s(p_{m,par})=250$ MeV/c
- Veto
  - 180 counters in two layers
  - Efficiency: 99% protons, 12% neutrons

GEN Collaboration

- Graduate students
  - Ameya Kolarkar, UK, (W. Korsch)
  - Aidan Kelleher, W&M, (T. Averett)
  - Singh Jaideep, UVA, (G. Cates)
  - Brandon Craver, UVA, (N. Lyianage)
  - Seamus Riordan, CMU, (G. Franklin)
  - Neil Thompson, UG, (G. Rosner)
- Institutions
  - Jlab, UVA, W&M, CMU, UK, UG, YerPhI, BINP, Temple, Madrid, NCCU, RU, Kent, SU,ITEP, FIU, ODU, Basel, UMd, UIUC, RPI, UNH, NSU, TU, INFN, Saclay

- project
  - Target
  - Target
  - Target*
  - MWDC
  - Software
  - Software

Milestones in 2005

- Target:
  - Two acceptable cells — July 1st
  - Polarized GEN hybrid target with final configuration — August 1st
  - Six acceptable cells — September
  - All major subsystems fuctional with polarimetry established — November 1st
  - Testing complete and target ready to be moved to the hall. — December
  - Beam line {pipe, bags, coll., field compensation} — December
  - Field direction —

Milestones in 2005

- Electron Arm
  - First wire chamber test — April, done
  - Calorimeter mounted — June, done
  - Wire chamber test in Hall A — July
  - Timing plane, preshower mounted — July
  - All wire chambers mounted — August
  - All detectors wired — September 1st
  - Cosmic tests completed, all problems solved — November 15th

Milestones in 2005

- Neutron arm
  - Cage structure
  - Neutron modules
  - Veto modules
  - Front end electronics
  - HV applied
  - Signal arrived to DAQ
  - Cosmic tests done
  - Lead shielding

-
  - May, done
  - July, GU in Sept.
  - May, done
  - July
  - August
  - September
  - September-November
  - October

Milestones in 2005

- DAQ/readout software
  - Wire chamber DAQ ready — May 1st, done
  - DAQ for Shower of BigBite — July 1st
  - DAQ of Neutron Arm — August 1st
  - Multi Crate DAQ, Trigger Logic setup, Pulser, Scalers Full HV system running — September 1st
  - Remote resets, HV GIU — October 1st
  - Cosmic tests completed — November 1st
  - Moving into the hall — December 1st
  - HRS-L (550/840 MeV at 20^{o})

Milestones in 2005

- Analysis software
  - Basic N-arm classes + calibration tools, basic preshower/shower + calibration tools, basic wire chamber classes + calibration
  - Tracking code for single tracks in BB-DC
  - Tools for all detectors to monitor detector performance and watch stability for all detectors (e.g. gains) event displays for all detectors
  - Scaler Readout Software
  - HRS-L (550/840 MeV at 20^{o})

-
  - June 1st
  - July 1st
  - September 1st
  - November 1st

Summary

- E02-013 is a very important experiment by itself and has impact on many other BigBite based initiatives
- Almost all detector equipment is constructed, a lot of testing MUST be done before November 15 – a day when we must to begin detector decabling
- Collaboration has just Five months to complete all preparations and testing
- I request each of you to bring as many as possible your students, friends students .... – **we have project for everybody**, don't worry about scheduling of the work, just come to contribute!
- Major efforts under way to finish design and construction of the polarized target
- Thanks collaborators and contributors for support of E02-013 and continuing efforts to make it successful
- Hope to see each of you during next Five months and later during the data taking period