Geant4 and Jefferson Lab

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Structure

I. Jefferson Lab

a) Overview

b) Experimental Halls & Geant4

c) Medical Physics & Geant4

I. Fundamental Physics

a) Geant4 issues

b) Future programs at JLab & NIST

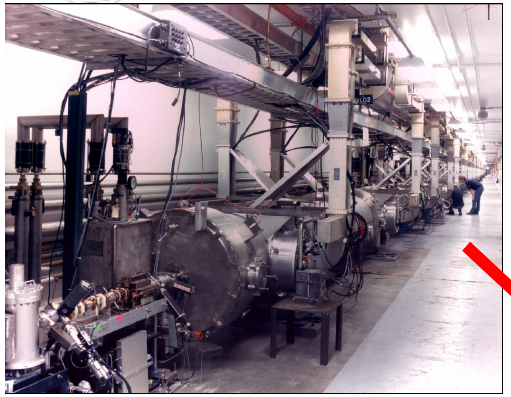
Jefferson Lab
(GeV-scale Physics)

Continuous Electron Beam Accelerator Facility

Maximum Energy: 1.2 – 6 GeV

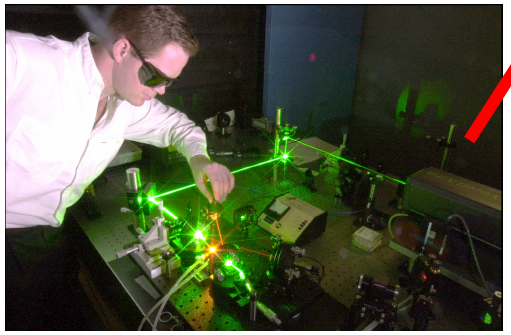
Beam: electrons, photons

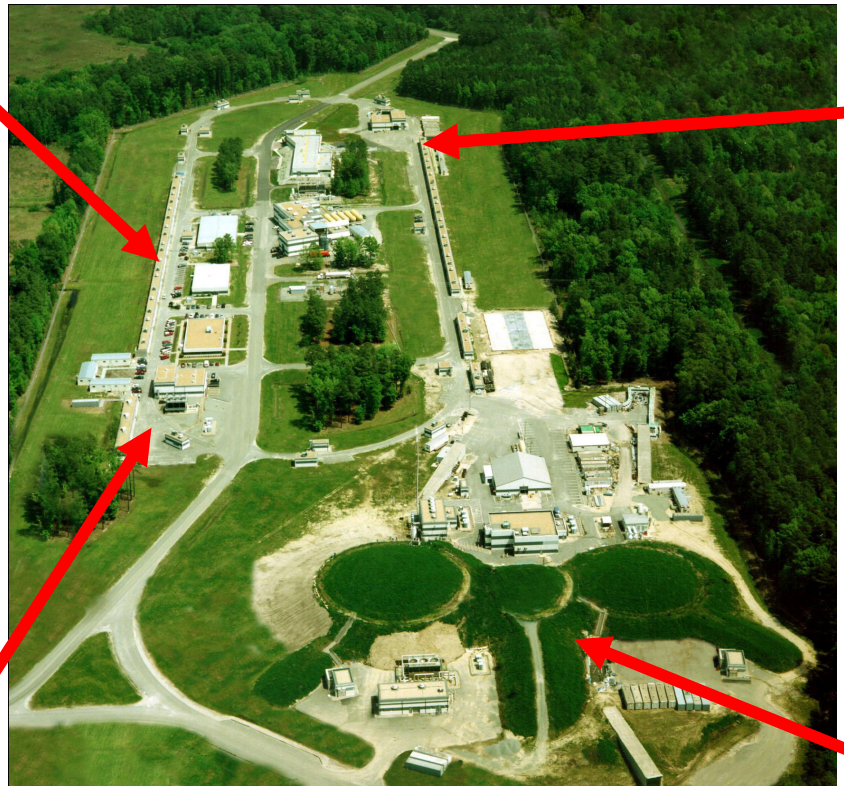
Properties: 1.5 GHz, 200 μA



Superconducting Cavities [2 Linacs]

Photoionic Electron Gun





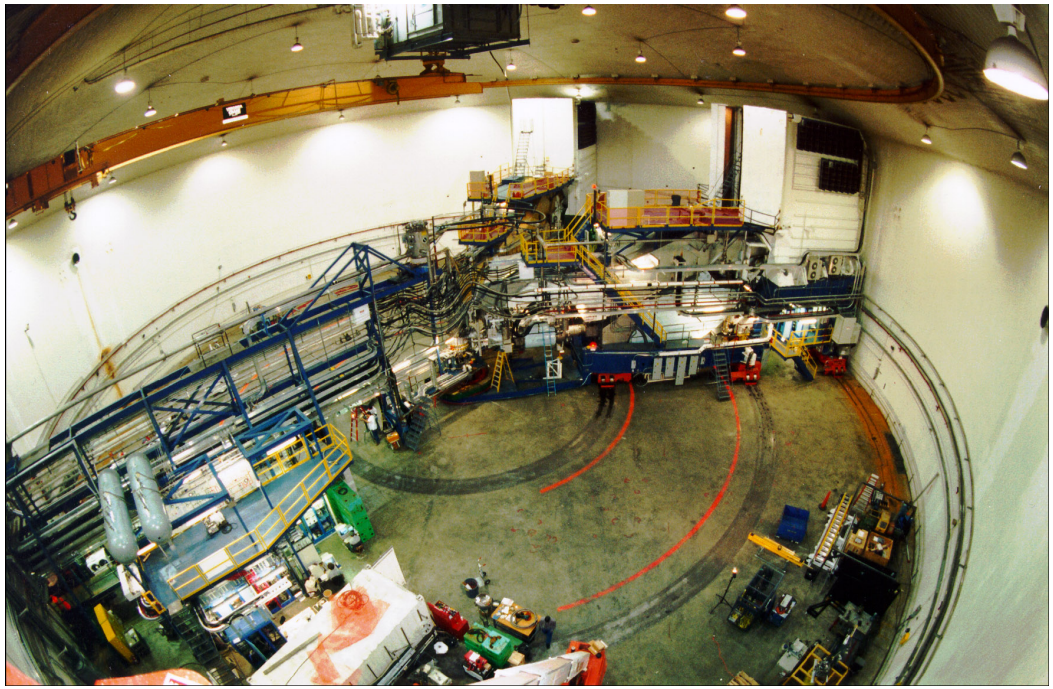
Newport News, Virginia - USA

http://www.jlab.org

Two 180º Arcs

3 Experimental Halls: A, B & C

4th @ end of North Linac (D)

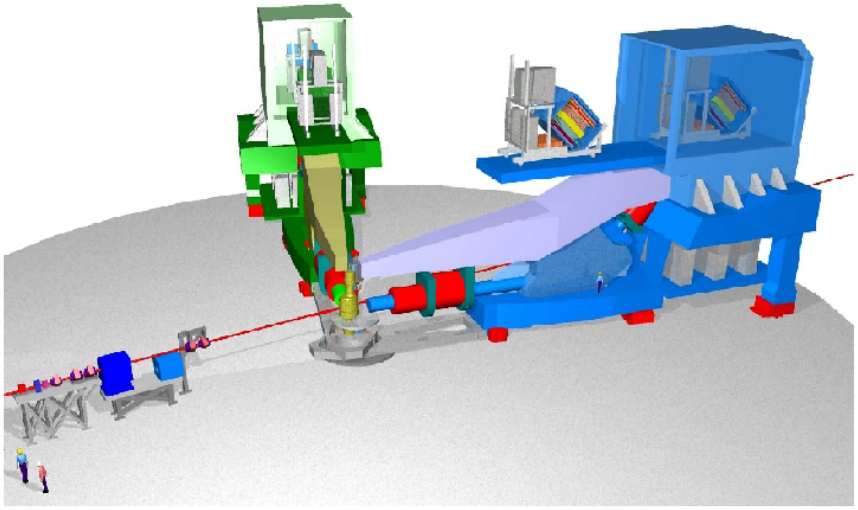


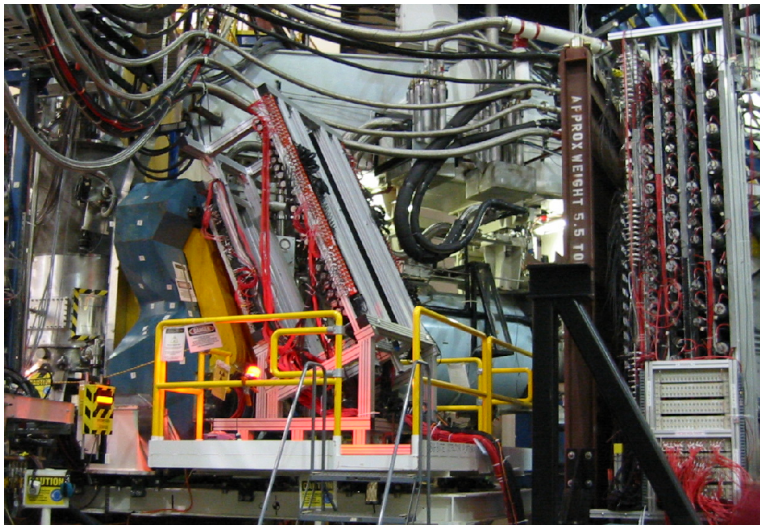
Hall A

2 HRS Spectrometers

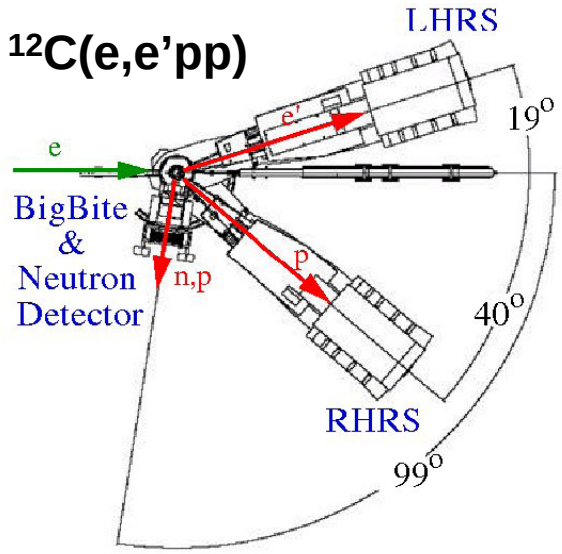
1 BigBite Spectrometer

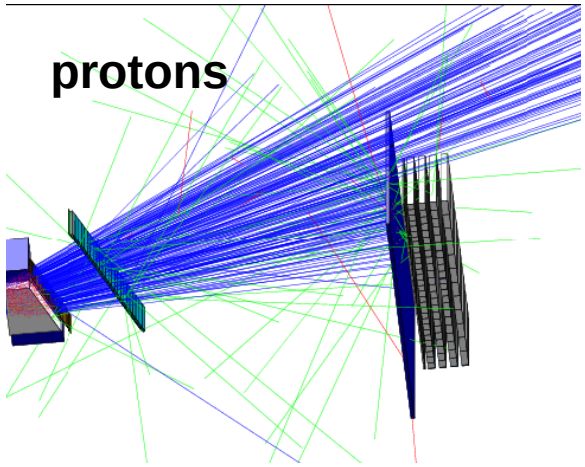
(from NIKKHEF)

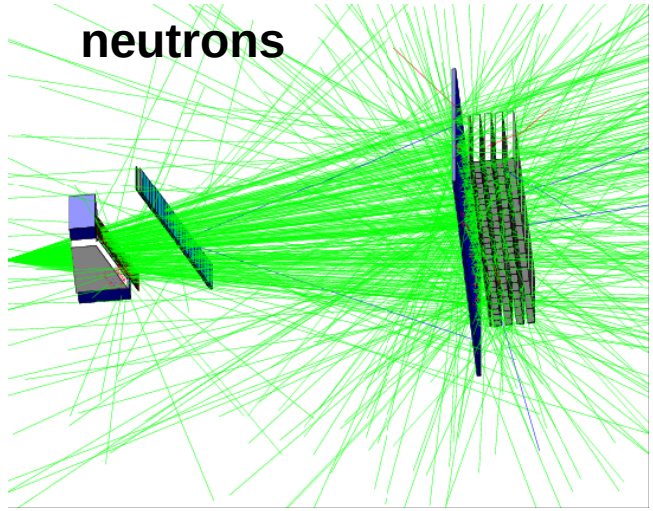




Geant4 in Hall A



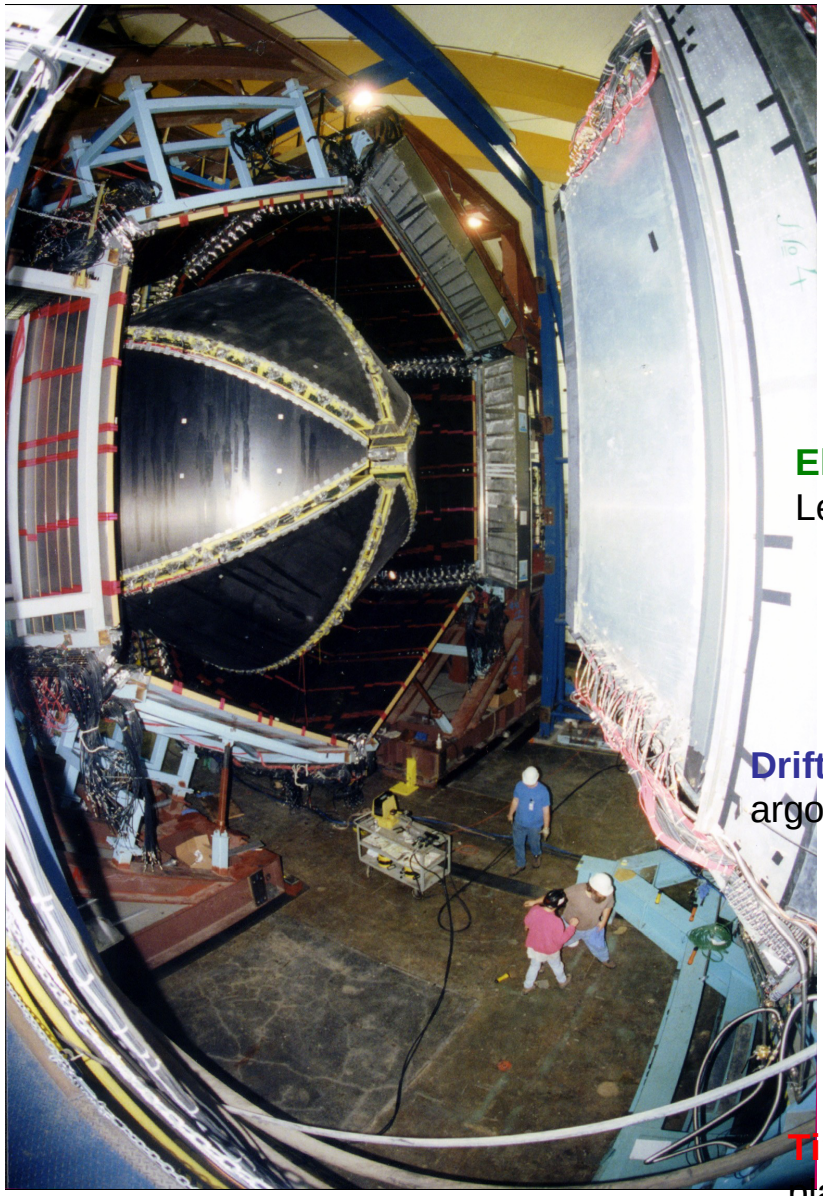




Ø **Detector design**

Ø **12 GeV upgrade of (standard) HRS spectrometers**

Hall B

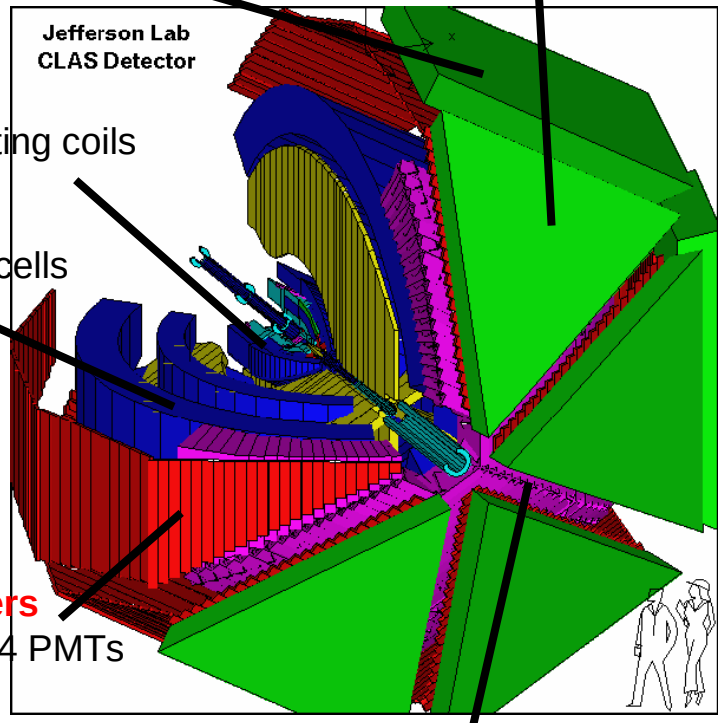


CLAS Spectrometer

(CEBAF Large Acceptance Spectrometer)

Gas Cherenkov counters
C4F10 Gas, 216 PMTs

Electromagnetic calorimeters
Lead/scintillator, 1296 PMTs



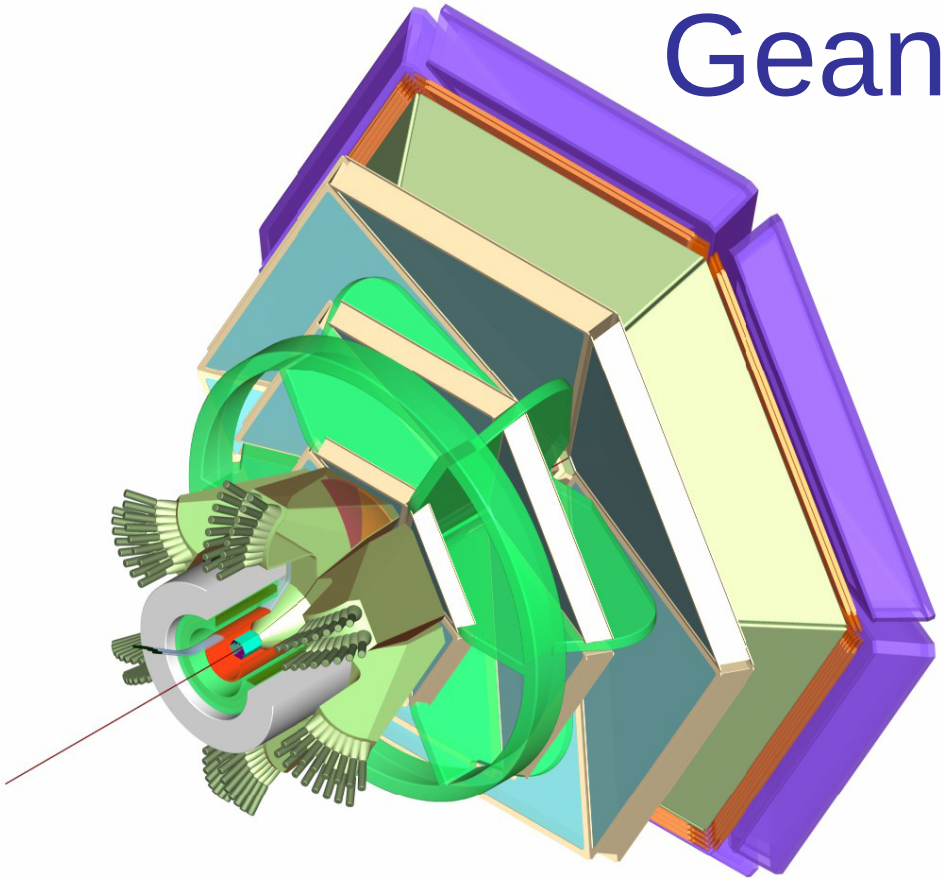
Torus magnet
6 superconducting coils

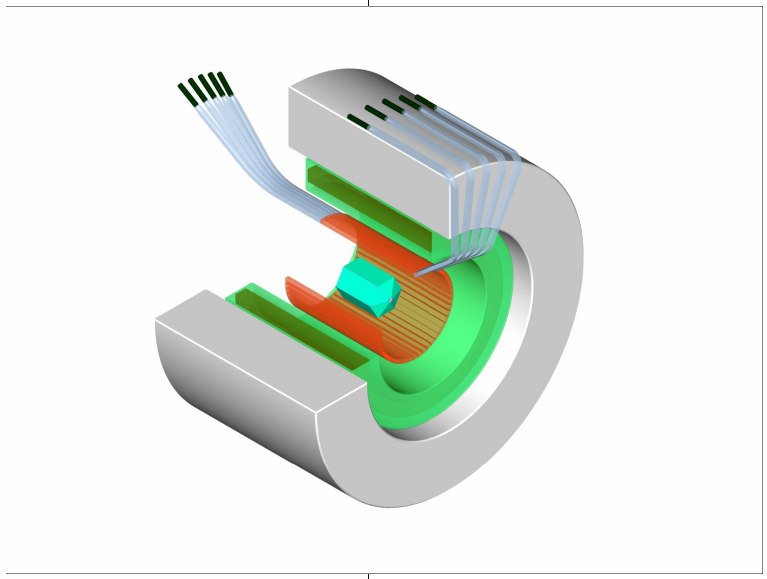
Drift chambers
argon/CO2 gas, 35,000 cells

Time-of-flight counters
plastic scintillators, 684 PMTs

Large angle calorimeters
Lead/scintillator, 512 PMTs

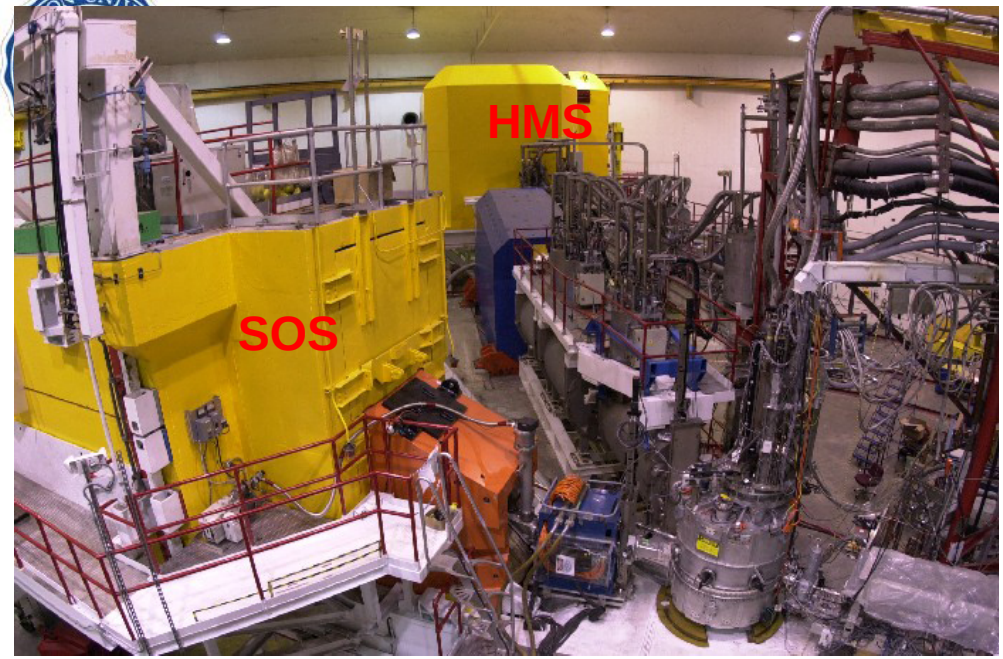
Geant4 in Hall B





12 GeV upgrade (CLAS12) solely done with Geant4

(in parallel with Hall D – see later)

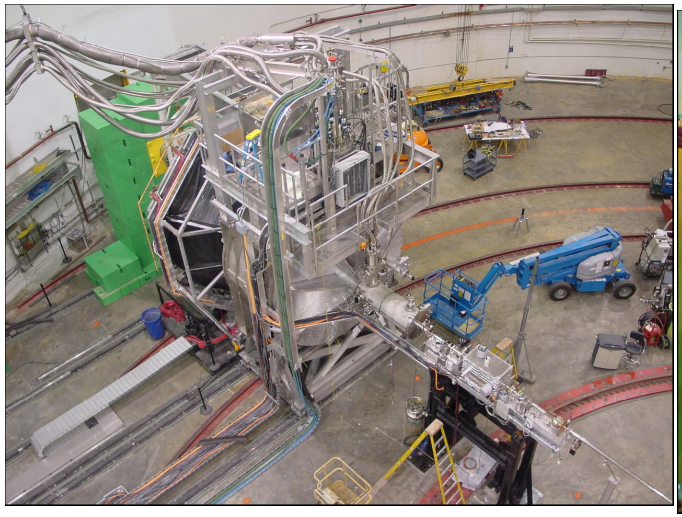


Hall C

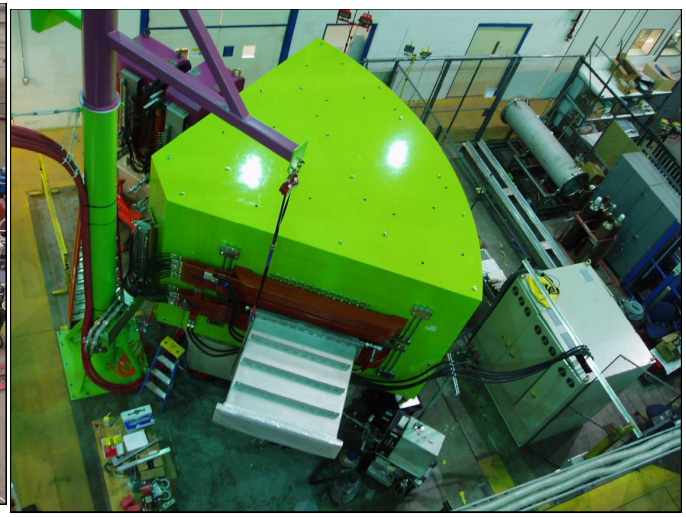
Short Orbit Spectrometer

High Momentum Spectrometer

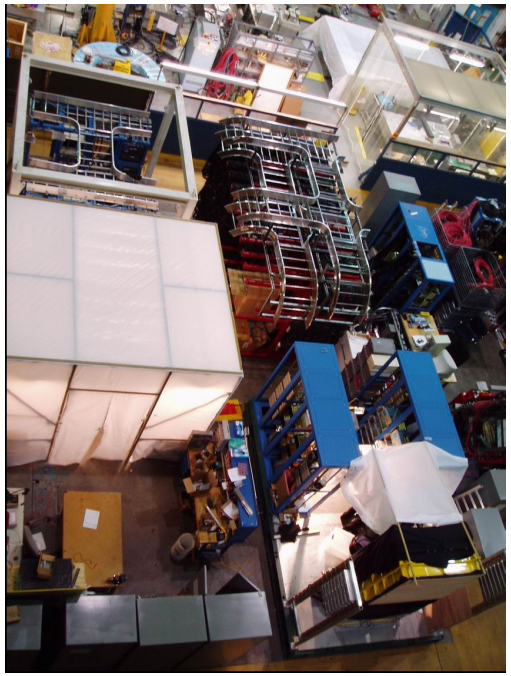
Custom (large) experiments



G0: strange content of nucleons

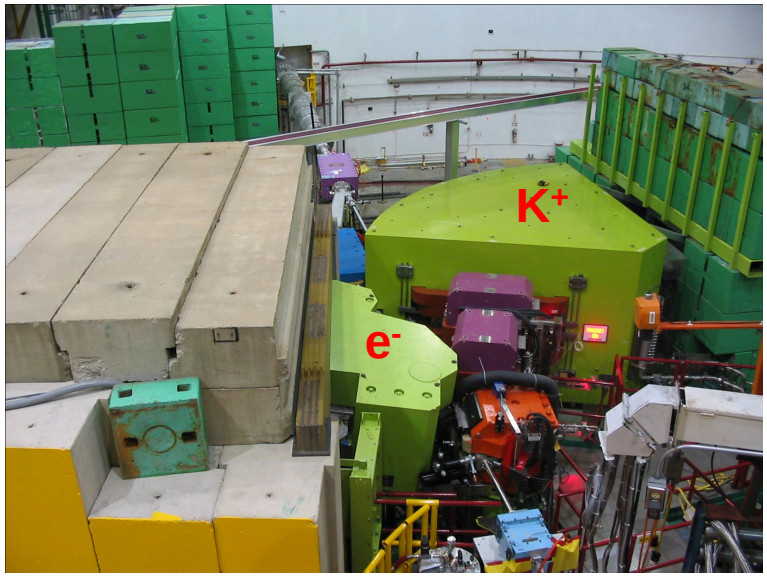


HKS: hypernuclear spectroscopy

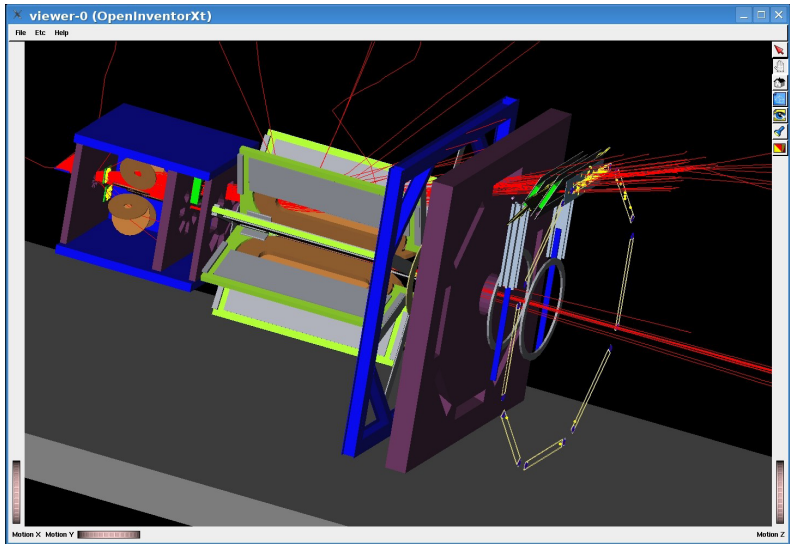


t_{20}: tensor-polarization (n,p)

Geant4 in Hall C

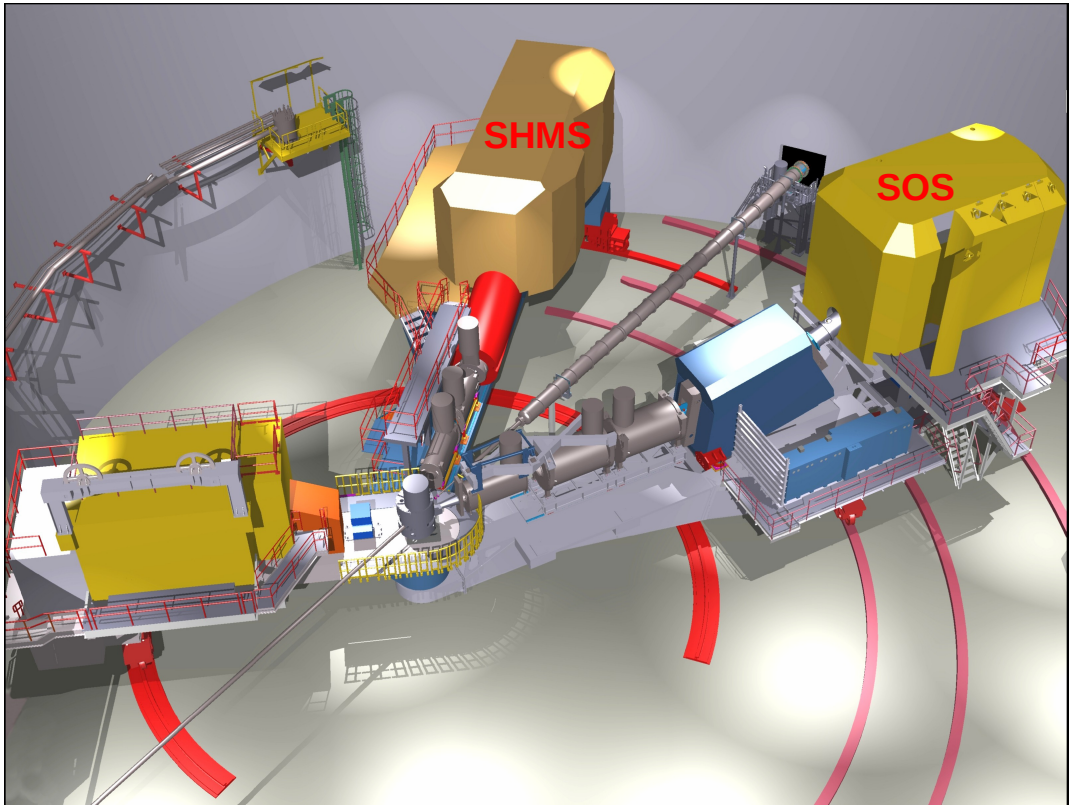


New Electron Spectrometer (HKS)



Qweak [parity] Experiment

(weak charge of the proton)

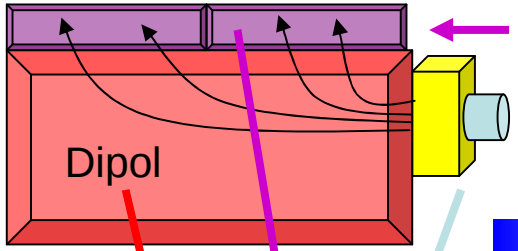


12 GeV upgrade

Medical Physics Research (MeV-scale Physics)

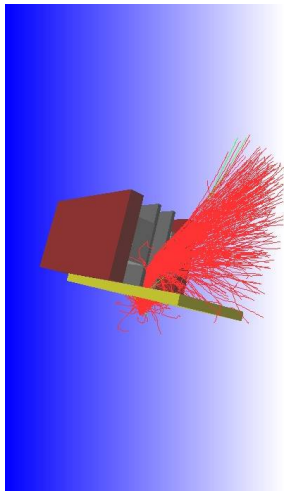
Mono-energetic Brachytherapy Sources

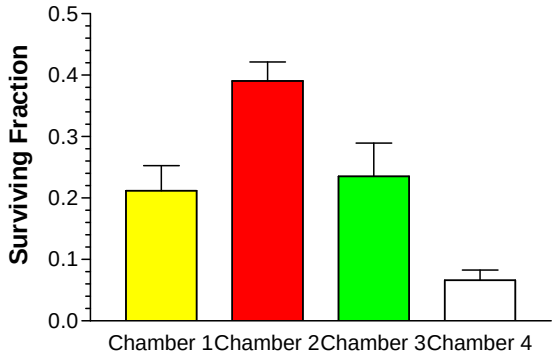
(Coll: Jefferson Lab, EVMS, HU)



Breast cancer cells

Collimator and Sr/Y-90 source

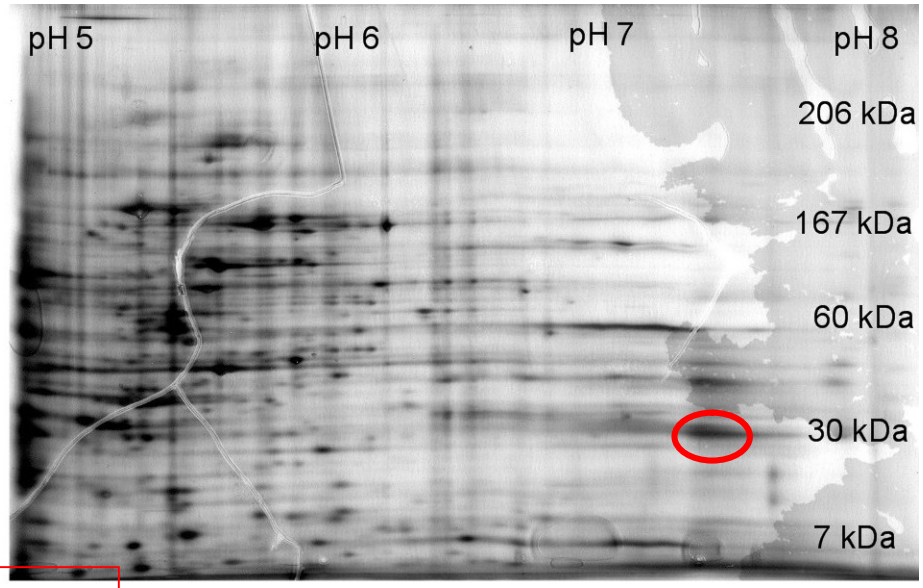




Chamber 1
Chamber 2
Chamber 3
Chamber 4

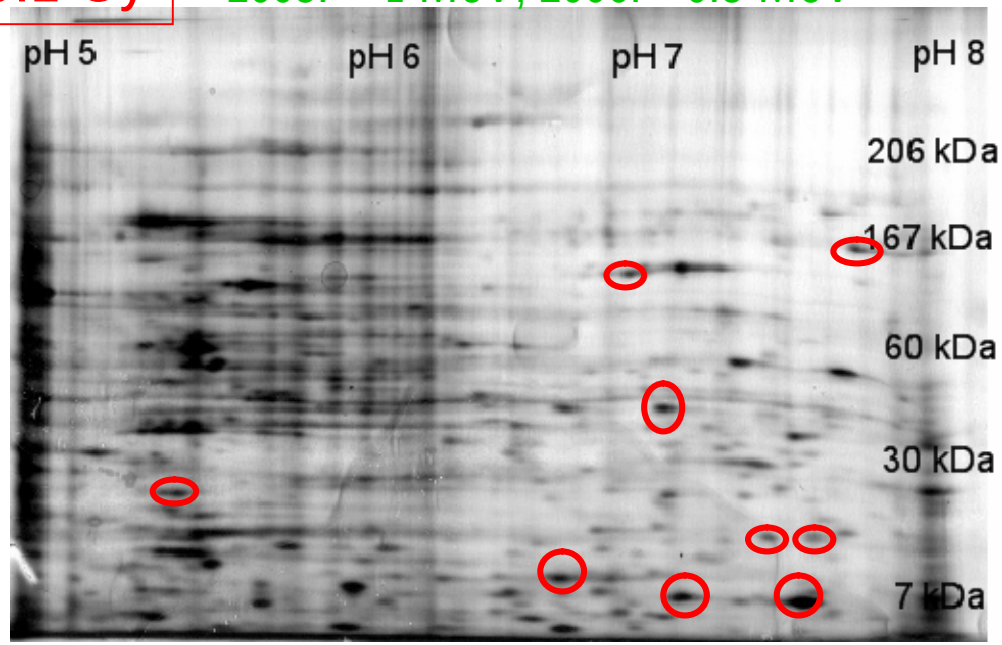
MDA321

2005: 1-2 MeV – 2006: 0.5-1 MeV



0.2 Gy

2005: < 1 MeV; 2006: <0.5 MeV



G4NAMU

- G4NAMU
  - Coherent working groups in the US & Canada
  - Four topics: Brachytherapy, proton therapy & PET/SPECT (GATE)
  - Chair of the Brachytherapy group
  - Site: http://geant4.slac.stanford.edu/g4namu/
- Physics
  - Electromagnetic cascade
  - Coulomb potential
  - **Experimental cross sections (JLab, NIST)**
  - Theory (HU, JLab)
- Treatment plans verification
  - Bench marks
  - Examples
- Micro dosimetry
  - Simulation at the molecular level
  - mono energetic dose distribution

Fundamental Physics
Geant4: Monte Carlo Simulation

Electromagnetic & Hadronic Physics

Electromagnetic

Need elementary cross section data

- Ø Beams
  - Electrons and photons
  - E < 50 MeV
  - Polarized and non-polarized
- Ø A-dependence
- Ø Thickness dependence
- Ø Processes
  - Elastic, inelastic, excitation, Bremsstrahlung, ionization
  - …

Hadronic

Need elementary cross section data

- Ø Beams
  - Hadrons production
  - 0.5 < E (GeV) < 10+
  - Polarized and non-polarized
- Ø A-dependence
- Ø Thickness dependence
- Ø Processes
  - Elastic and inelastic

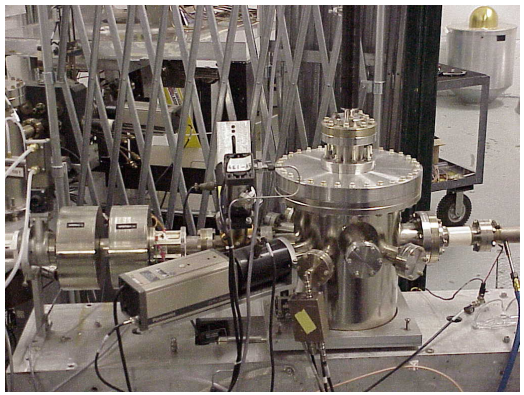
Data Accuracy

EEDL - Bremsstrahlung	***10 eV to 1 keV*** ***10 to 25%*** ***1 keV to 2 MeV*** ***5 to 10%*** ***2 to 50 MeV*** ***< 10%***
Validation Studies	***S. Cruotelli et al. (2005)*** ***OK with NIST*** ***E. Poon and F. Verhaegen (2005)*** ***Problem: electron transport***
Accuracy/Errors in experimental data not considered!!	

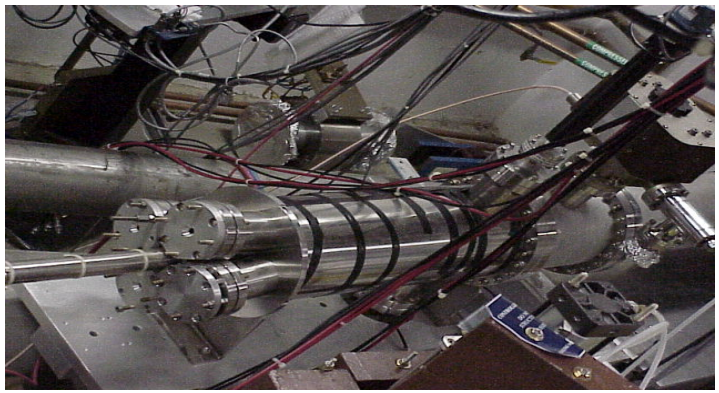
Fundamental Measurements With Electromagnetic Beams

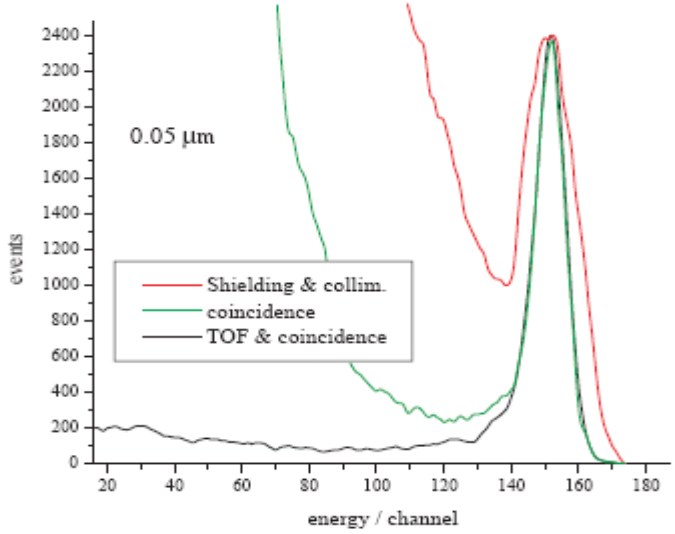
Jefferson Lab **Newport News, Virginia (USA)**	***Gun*** ***50 keV to 120 keV [50 MeV]*** ***Injector*** ***3 MeV to 8 MeV*** ***Accelerator*** ***1 GeV to 6 GeV (12 GeV)*** ***1.5/0.5 GHz – 200 μA (max)*** ***Polarized (85%) and non-polarized***
NIST **Gaithersburg, Maryland (USA)**	***20 eV to 450 eV*** ***DC – mA*** ***Non-polarized***
Possibilities for (open) collaboration: **Experimental et Theoretical**	

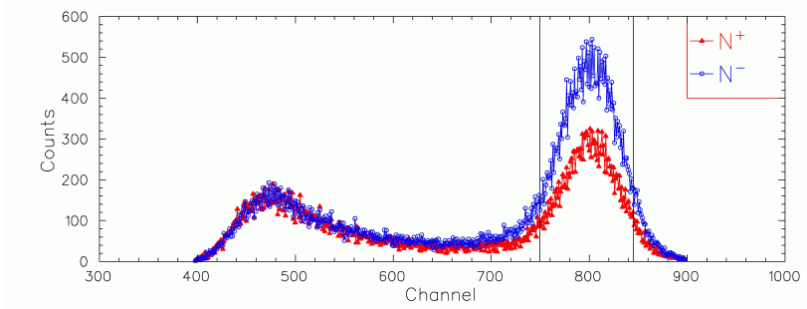
Polarization at Jefferson Lab

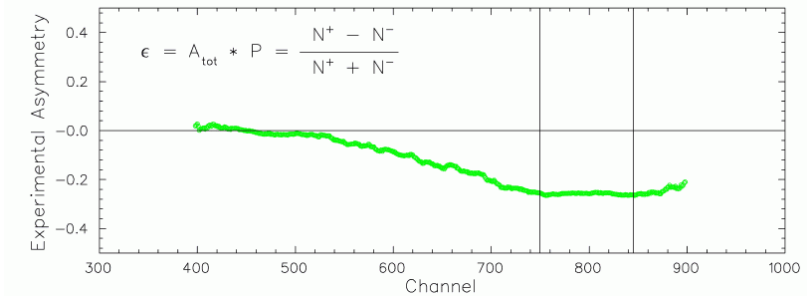


100 keV Mott polarimeter
[Energy: 50-120 keV]



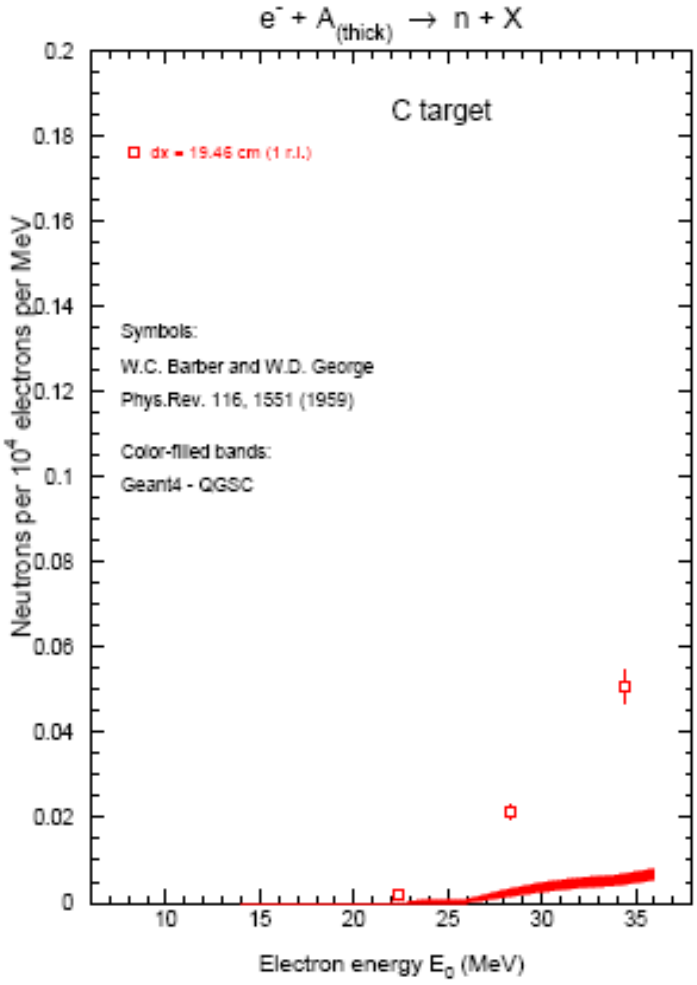


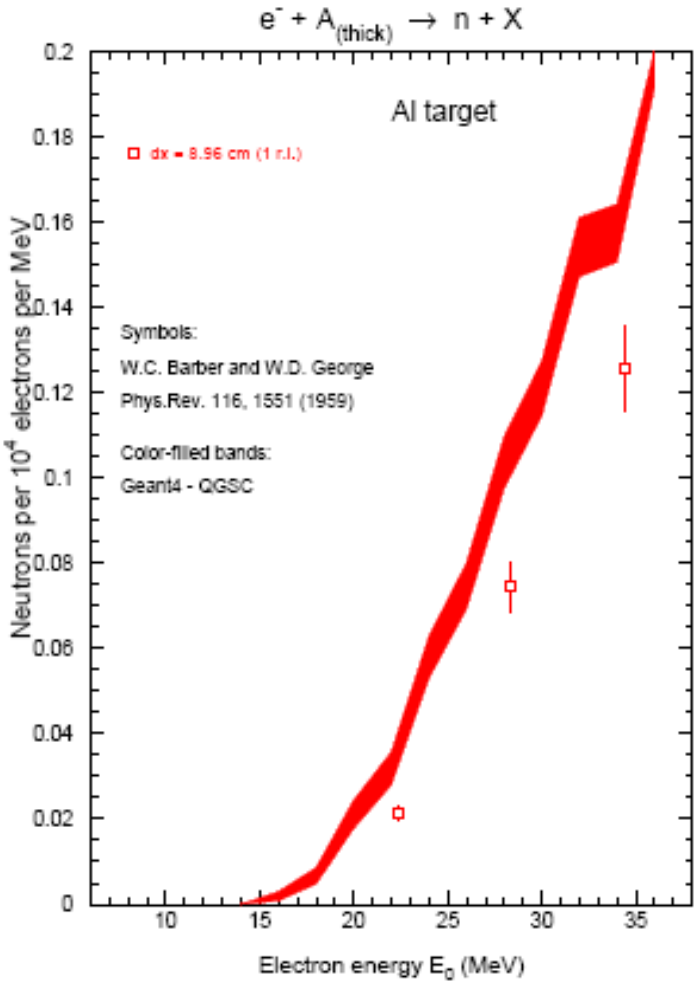




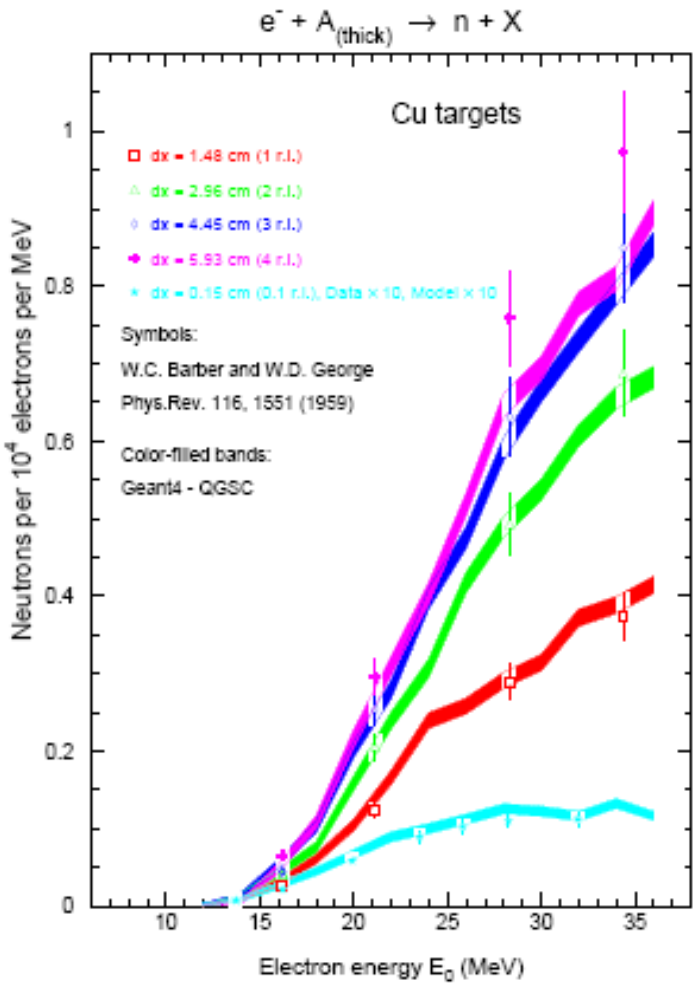
5 MeV Mott polarimeter [Energy: 3-8 MeV]
Electron scattering on 1 µm gold foil

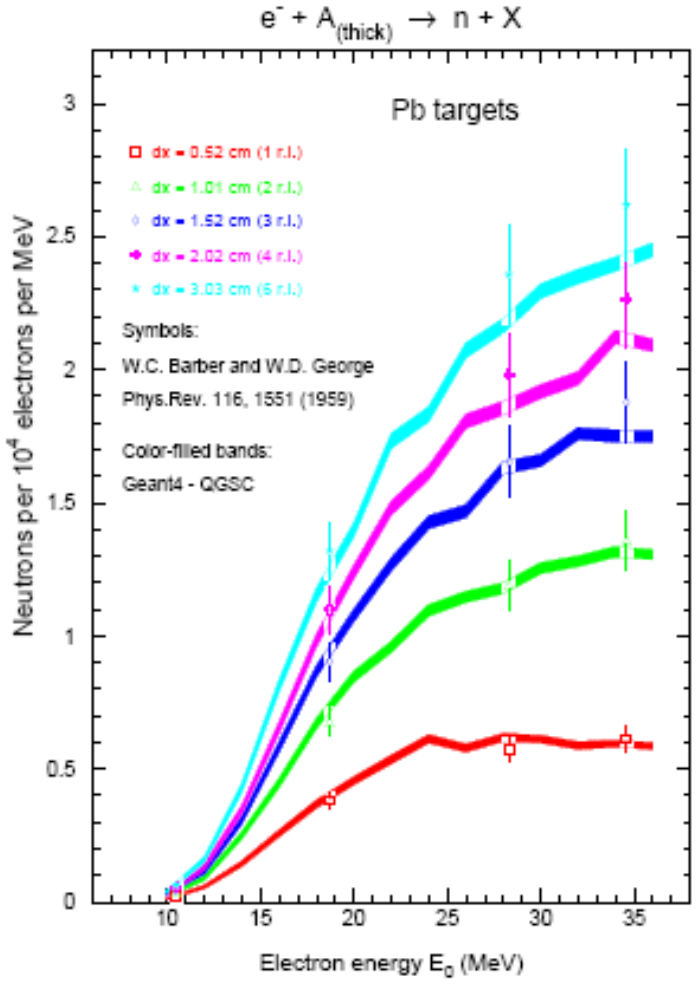
Benchmarking I



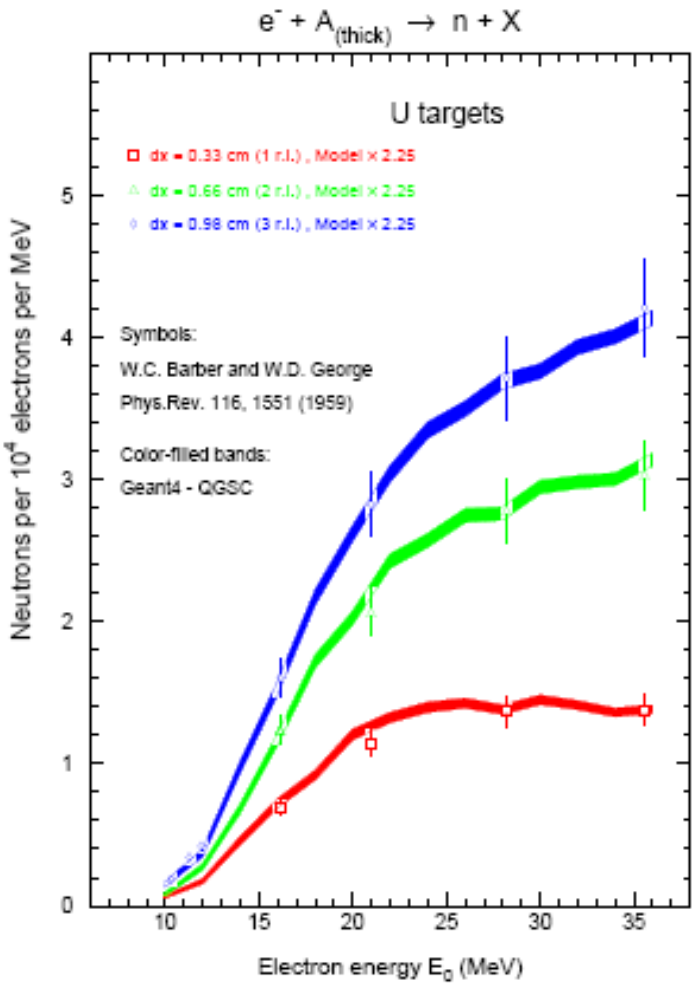


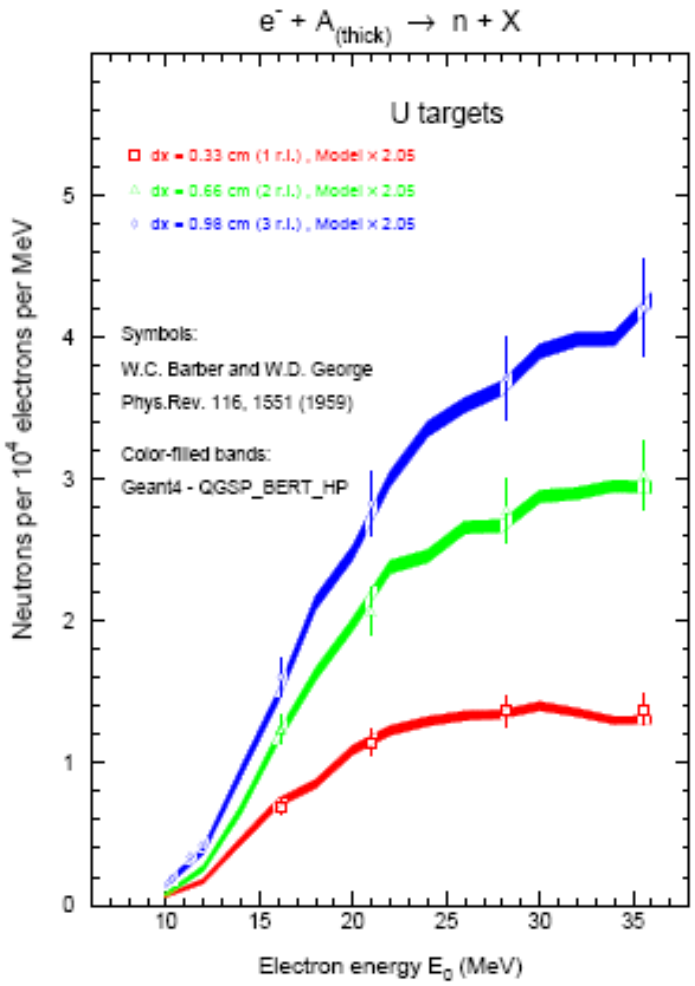
Benchmarking II





Benchmarking III





Summary Benchmarking

- ***Neutron yield***
  - Al, Cu, and Pb**: Remarkably good** near threshold
  - U and C: **Apparent problems**

- ***Problems***
  - Uranium

    Believe due to **absence of a photo-fission** model in Geant4
  - Carbon

    Model with apparent **problem in the fragmentation stage**

    Good cross section

    Fragmentation products are **mostly alphas**

Conclusion & Future

- Benchmark Geant4 with electro-production data
- Global fit on elastic scattering
  - (e,p) John Arrington, Phys. Rev. **C69**, 022201(R) (2004)
  - (e,n) Jim Kelly, Phys. Rev. **C66**, 065203 (2002)
- Hadron production
  - Mesons: π, K, ρ …
  - Baryons: N*, Δ, Λ, Σ …
- Accelerator physics
  - Sandwich Geant4/Parmela
  - Space charge effect
- Radiation biology
  - Low energy e, γ, n …
  - Proton therapy