

The South Hall Ring and the BLAST Detector

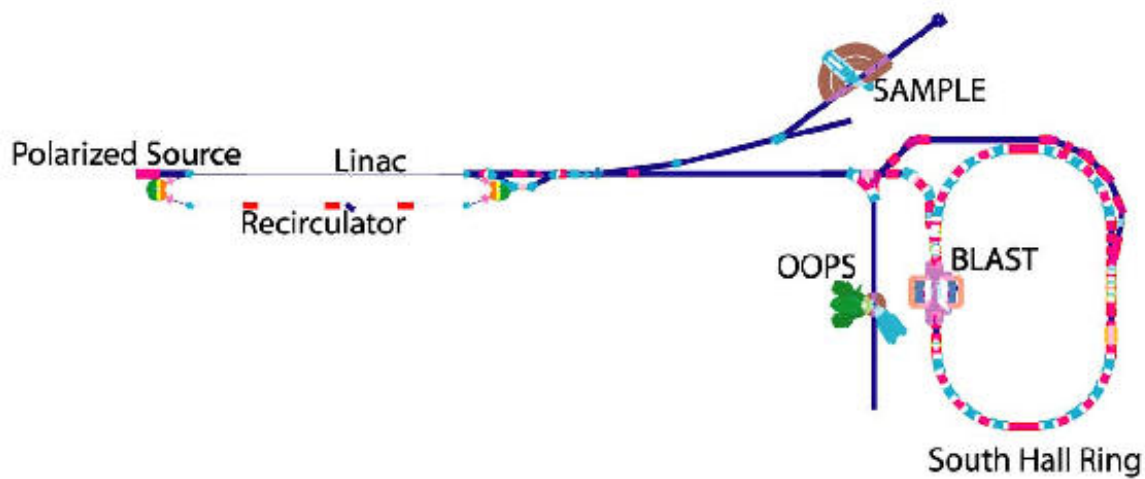


- ☆ **Introduction**
- ☆ **Status**
- ☆ **Scientific program**
- ☆ **Summary**

J. Calarco
LowQ Workshop, 8/01

The MIT-Bates Linear Accelerator Center

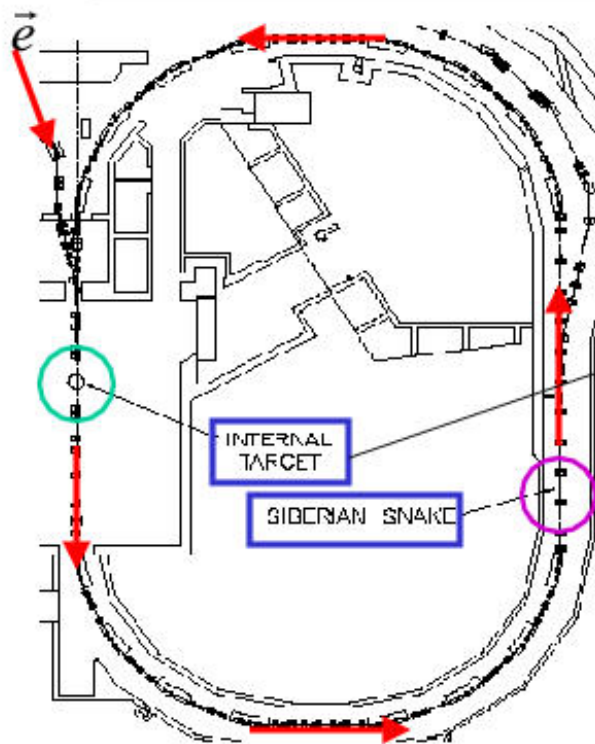
- ❖ 1 GeV electron microscope (~ 0.2 fm) with pulsed, stretched, and stored beams.



- ❖ Three innovative detectors (SAMPLE, OOPS, BLAST).

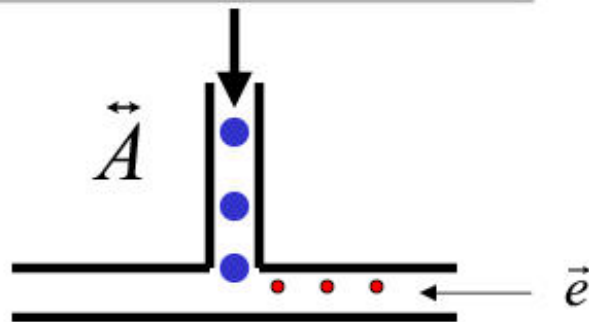
- Complementary capabilities to others in the US and worldwide.

Internal Target Physics at MIT-Bates



South Hall Ring

$$E_e \leq 1 \text{ GeV}, P_e = 40-80 \% \\ I_m = 200 \text{ mA}, \tau \geq 10 \text{ min}$$



- thin
- pure species
- high polarization
- thin cell
- low holding field

$$L = 10^{32}-10^{33} \text{ atoms cm}^{-2} \text{ s}^{-1}$$

Novosibirsk, AmPS, HERMES, IUCF, COSY

Bates Large Acceptance Spectrometer Toroid

- **Primary motivation:**
 - comprehensive program of measurements of the spin dependent electromagnetic response of few-body systems.
- **Focus:**
 - $A=1,2,3$ in terms of nucleon structure, the ground state few-body structure and the nature of the interaction for $Q^2 < 1$ (GeV/c)².
 - These aspects are *interrelated* in a complicated way and can only be *unambiguously* separated by a broad study of the few body systems.
 - ¹H, ²H, ³He polarized internal targets
 - CW polarized stored beam
- **Measurements:**
 - Complete reconstruction final state
 - Simultaneous measurements for inclusive and exclusive scattering
- **Upgrade:**
 - Clear possibilities exist so that the detector can evolve to match developing physics priorities.

Detector Requirements

- definition of the momentum transfer vector

$$(\Delta E/E)_e < 2 \% \text{ and } \Delta\theta_e \leq 5 \text{ mrad}$$

- optimize statistics $L \times \Delta\Omega_e \times \Delta\Omega_N$

- projected luminosities $L : 10^{32} - 10^{33} \text{ atoms} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$

Need Large Ω

- polarized targets: Atomic Beam & Laser Driven Sources

size: 1 m diameter
BLAST field = 0 at target
B-gradients $\leq 50 \text{ mG/cm}$

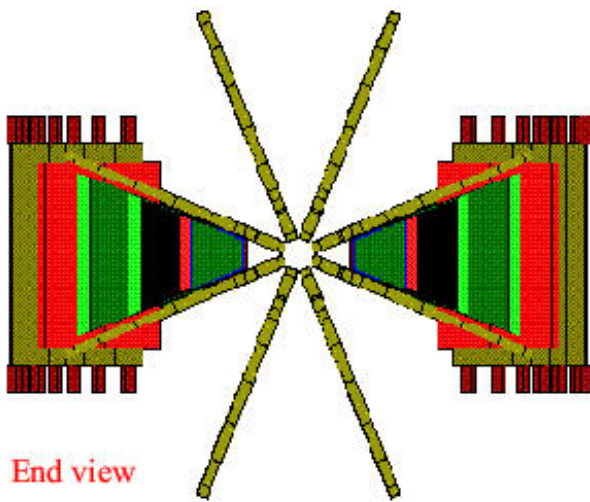
- simultaneous A-measurements

Symmetric Detector

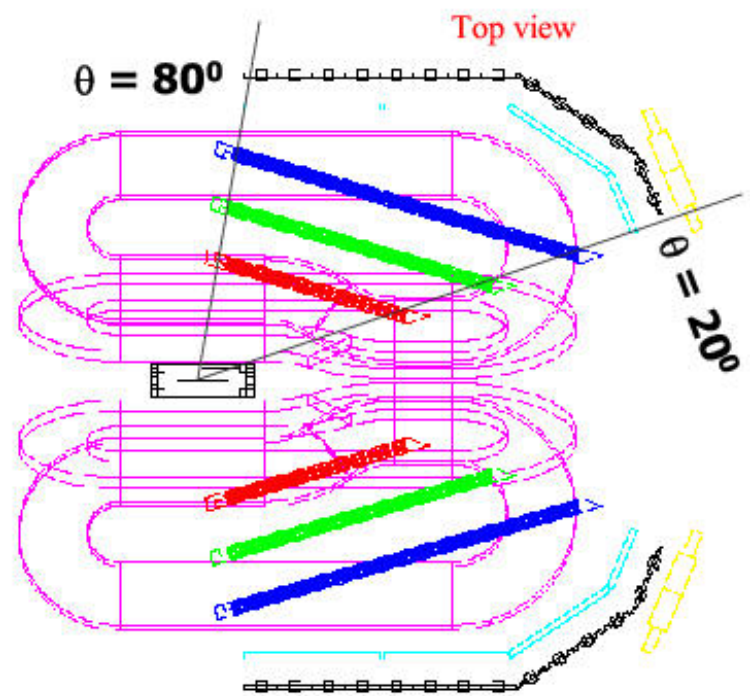
- e/p/n/ π^\pm separation

PID

Bates Large Acceptance Spectrometer Toroid



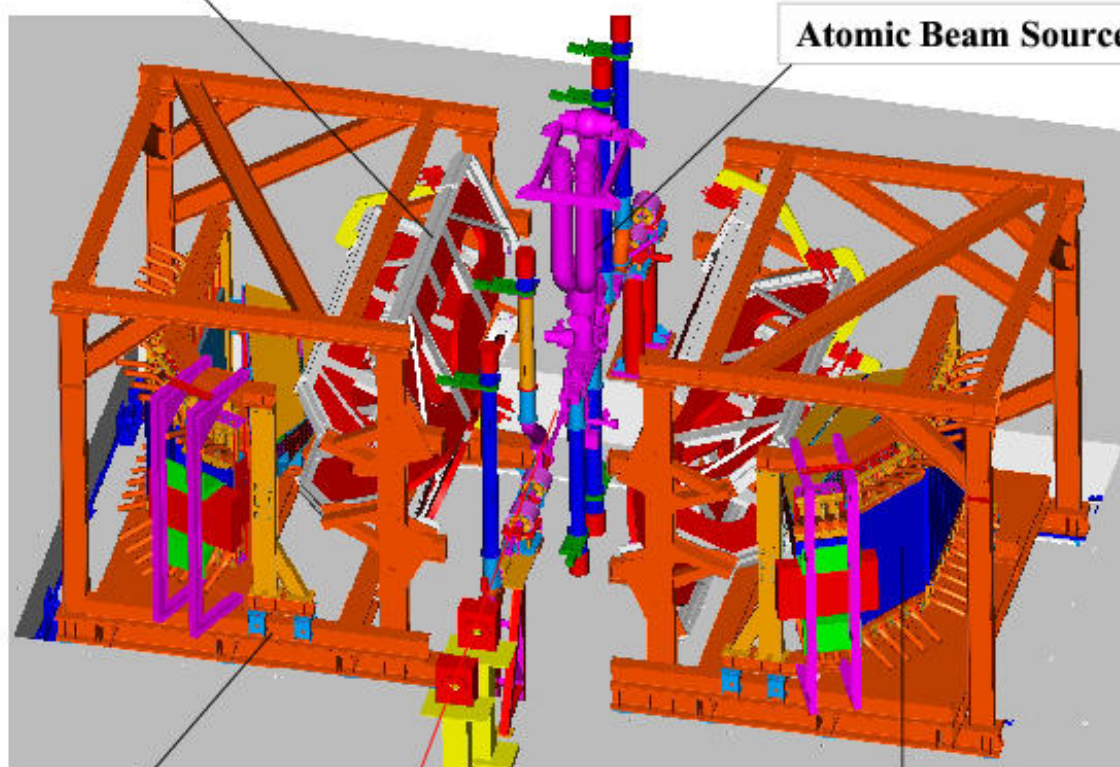
Magnetic Field:
toroidal, 8 coils



Instrumentation (per sector):
3 drift chambers, Cerenkov, TOF,
neutron detectors, recoil, calorimeter

Eight coils (toroid)

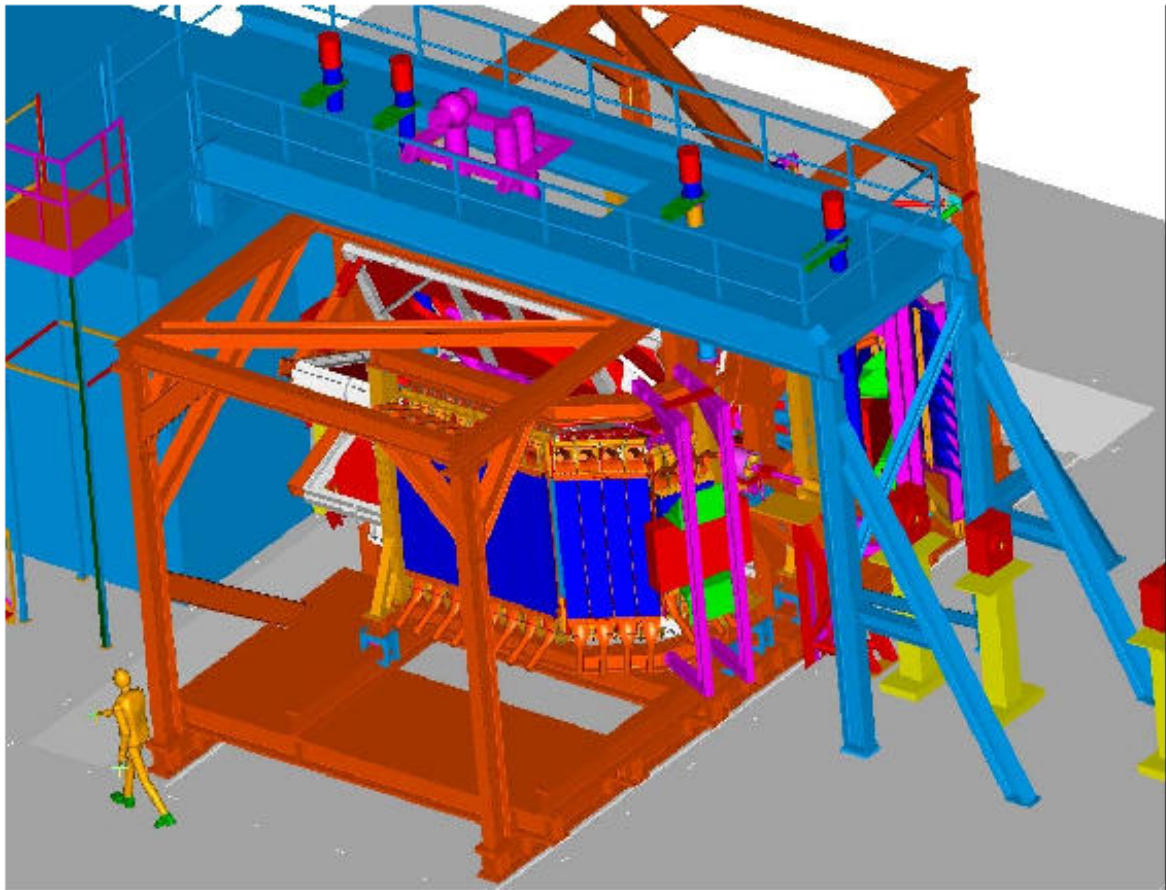
Atomic Beam Source



Movable structure

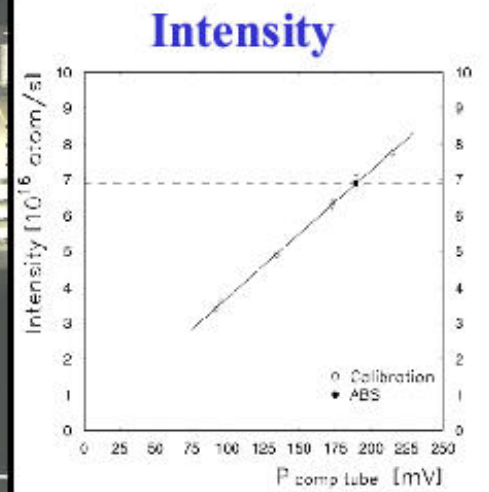
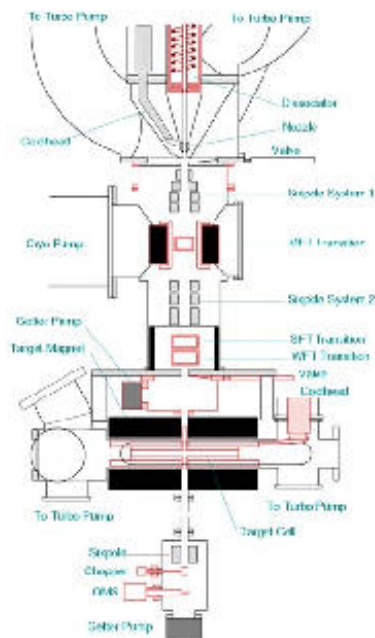
Two symmetric detector packages

The Bates Large Acceptance Spectrometer Toroid



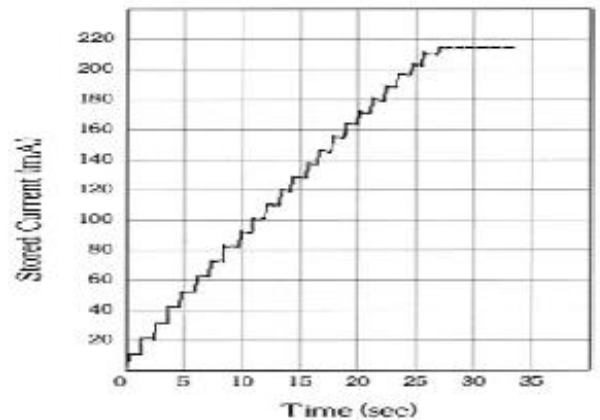
The BLAST Atomic Beam Source

In SHR

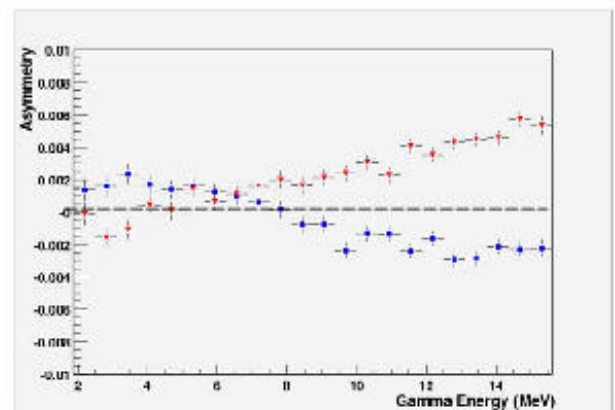


SHR Stored Beam

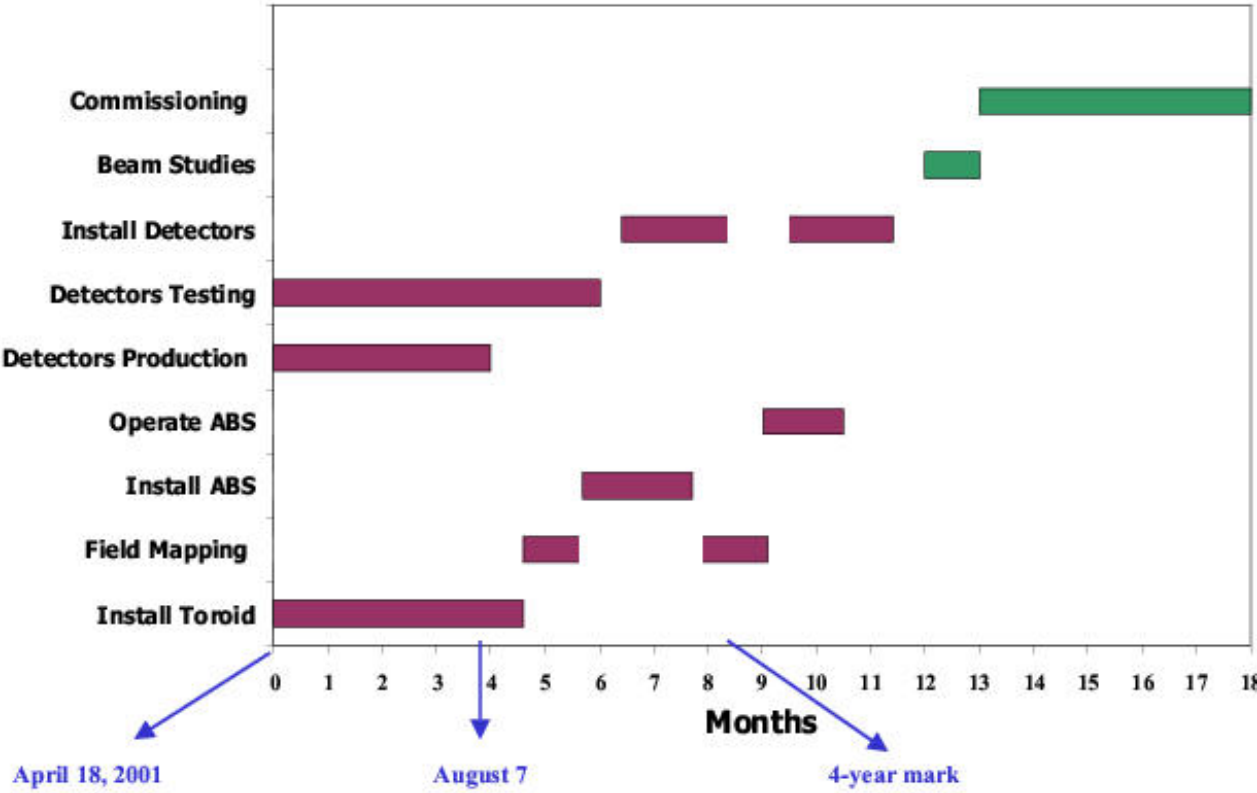
- **Current: 25 - 200 mA**
- **Lifetimes: 10 - 15 min @ 660 MeV**
- **Simple ring optics redesign will give even longer lifetimes up to 1.1 GeV**



- **Polarization > 60 %**
- **Compton Polarimeter**
- **Spin Flipper (Michigan)**



BLAST SCHEDULE



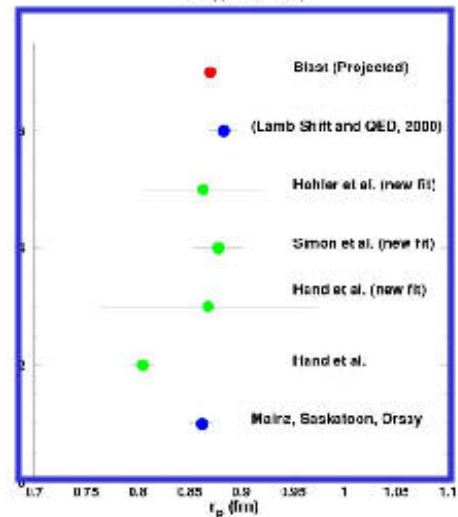
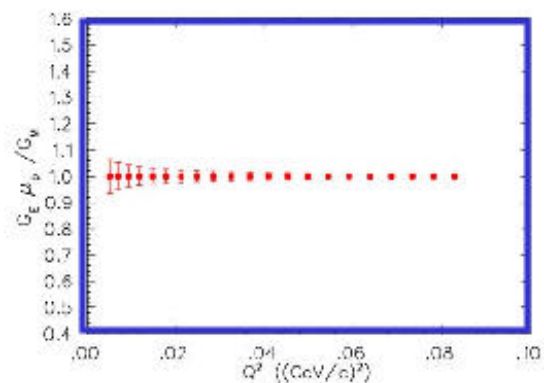
Precision Measurement of the Proton Charge Radius

- QCD: nucleon structure
- QED: hydrogen Lamb shift

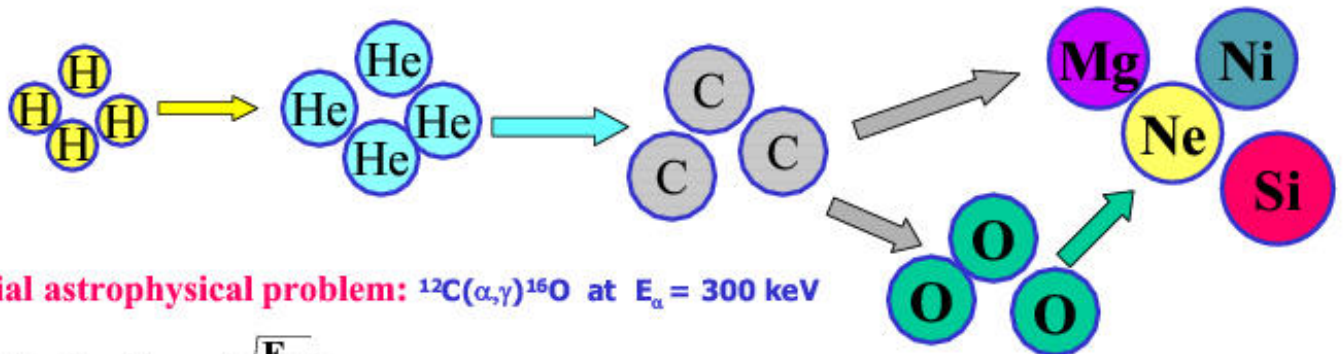
BLAST:

- 275 MeV (Q^2 : 0.13-0.22 fm⁻²)
- spin-dependent e-p elastic
- asymmetry ratios
- unpolarized σ (relative)

$$r_p = \langle r^2 \rangle^{\frac{1}{2}}; \quad \langle r^2 \rangle = -6 \left(\frac{dG_E}{dQ^2} \right)_{Q^2=0}$$



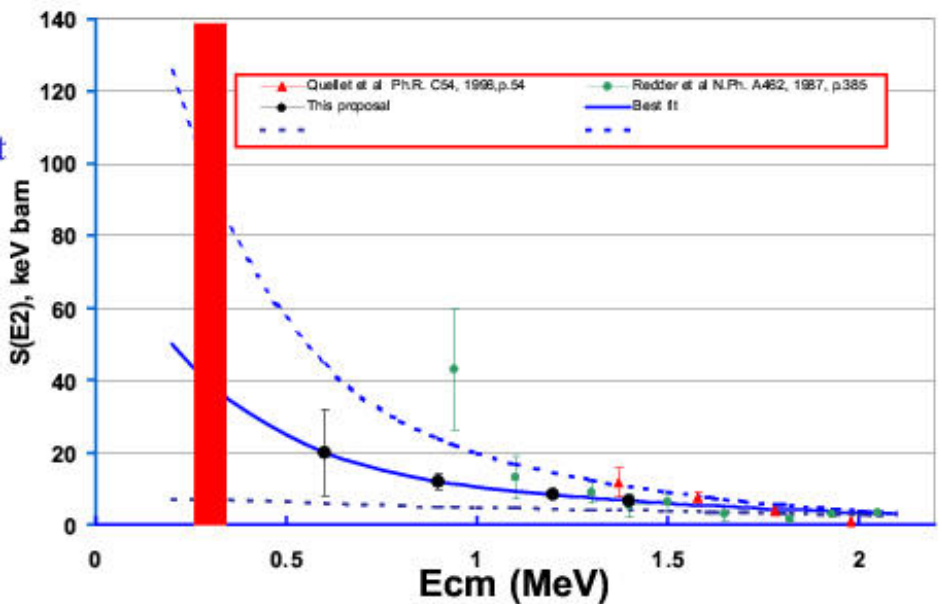
Measurement of the Astrophysical S-Factor of the $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ Reaction



Crucial astrophysical problem: $^{12}\text{C}(\alpha,\gamma)^{16}\text{O}$ at $E_\alpha = 300 \text{ keV}$

- $S(E) = E \cdot \sigma(E) \cdot \exp\left(\sqrt{\frac{E_G}{E}}\right)$
- $S(300 \text{ keV})$ needs accuracy $\leq 20\%$.

- **New approach : Internal Target**
- **BLAST + recoil**
- $^{16}\text{O}(e,e'\alpha)^{12}\text{C}$ reaction at $Q^2 \neq 0$
- **Triple coincidence**
- **Low background**
- **Concentrate on E2 to $Q^2 \rightarrow 0$**



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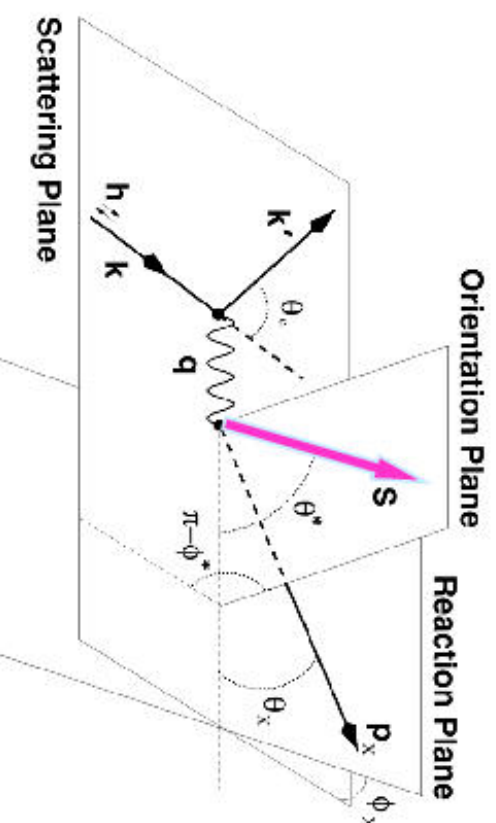
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Summary

- BLAST installation started on April 18, 2001.
- The project is on budget.
- Operation of BLAST with stored polarized beam and a polarized hydrogen/deuterium target starting in spring 02.
- BLAST is uniquely positioned to exploit the capabilities generated by the combination of the new SHR and internal polarized targets.
- Key measurements include:
 - **form factors ($Q^2 = 0.1 - 1.0 \text{ (GeV/c)}^2$) of the proton, neutron, and the deuteron**
 - **comprehensive program of electron scattering**
 - spin-dependent (momentum distributions, reaction mechanism)
 - multinucleon physics
 - **charge radius of the proton**
 - **astrophysical S-factor**

Spin-dependent Electron Scattering



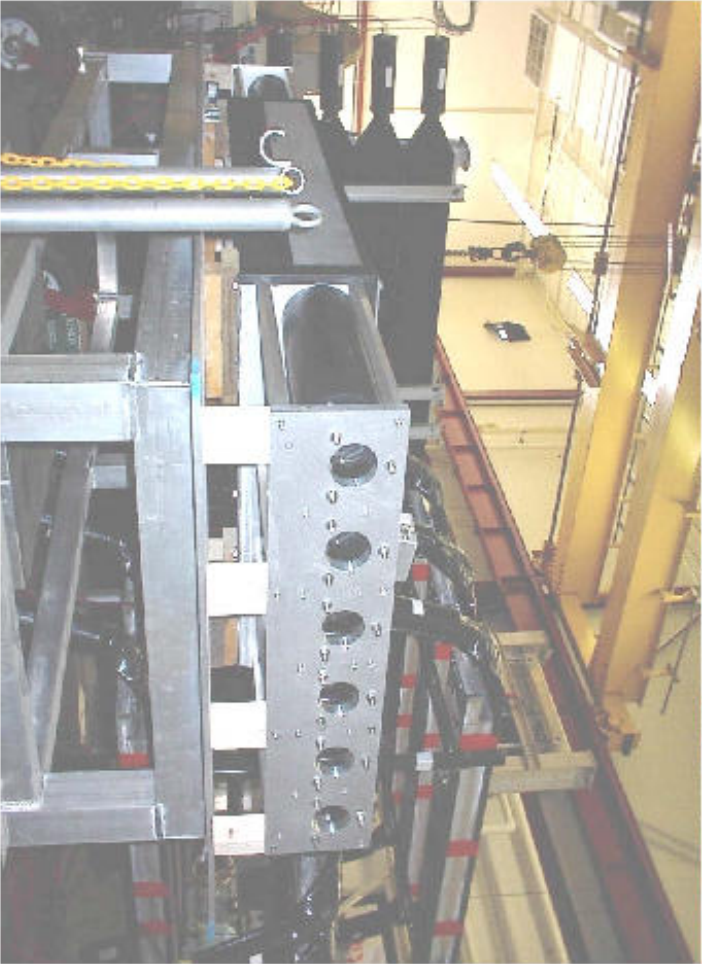
$$\frac{d\sigma^h}{de'd\Omega_e d\Omega_N} = \Sigma + \mathbf{h} \Delta$$

- e.g., elastic scattering from a polarized nucleon:
 - $\Sigma \approx V_L(G_E)^2 + V_T(G_M)^2$
 - $\Delta \approx V_{LT}, (G_E G_M) P_x + V_T, (G_M)^2 P_z$
- general case: more response functions
- spin acts as a knob to a “super-Rosenbluth” separation
- form asymmetries:

$$A_{x,y,z} = P_e \cdot P_T \frac{\Delta}{\Sigma}$$

The BLAST Drift Chambers

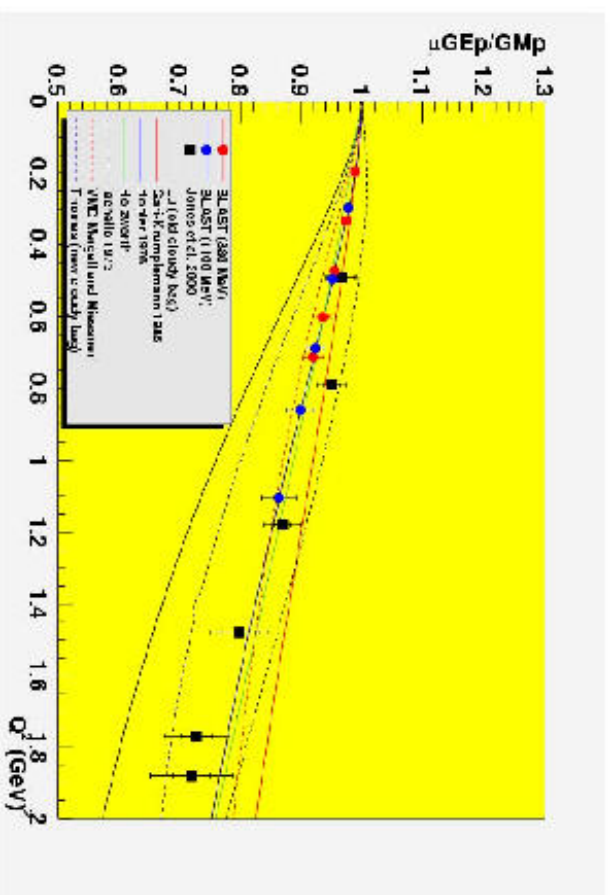




BLAST Scientific Program

- **Form Factor Measurements: $Q^2 \leq 1.0$ (GeV/c)²**
 - **Proton Charge and Magnetism**
 - Elastic Scattering with Polarized Beam and Target
 - **Neutron Charge and Magnetism**
 - Quasielastic Scattering with Polarized Beam and Target
 - **Deuteron Electromagnetic Structure**
 - Elastic Scattering off Tensor Polarized Deuterium
- **Simultaneously: Few-Body Physics**
 - Spin-dependent momentum distributions
 - NN interaction
 - S, S', D-wave components
 - Consistency of 2- and 3-body systems
 - Spin-dependent reaction mechanism
- **Nuclear Targets ($A \geq 3$)**
 - Multinucleon absorption of the virtual photon
 - Nuclear astrophysics

The Proton Charge and Magnetism

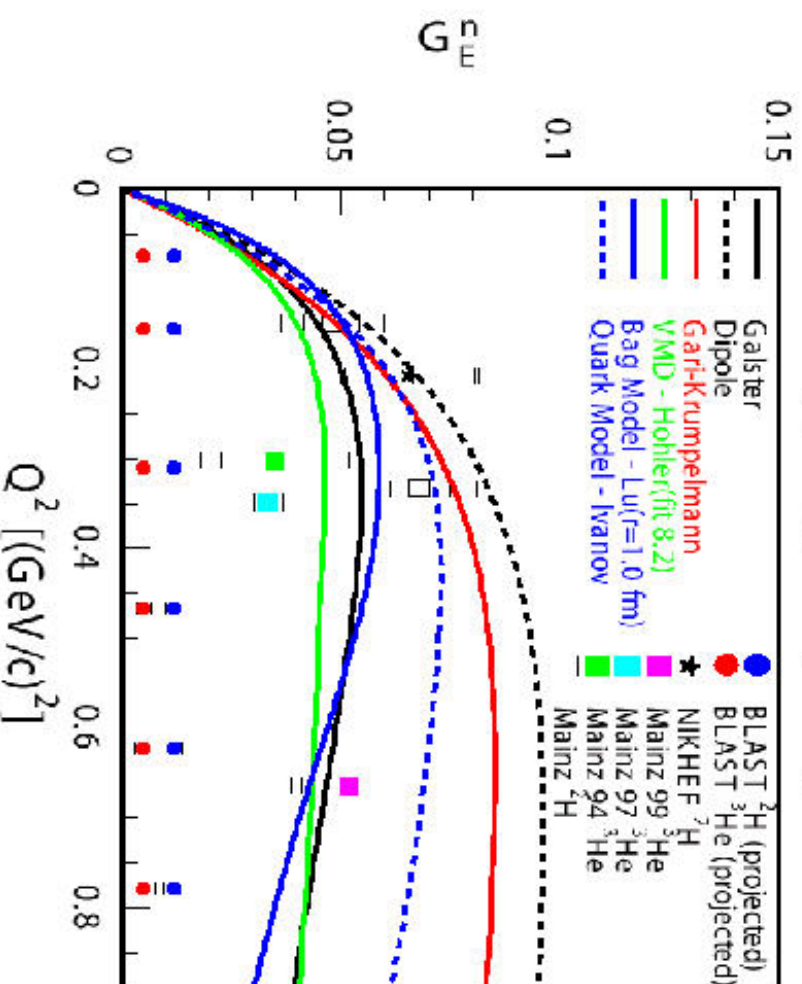


- Elastic Scattering from $Q^2: 0.1 - 1.0 (\text{GeV}/c)^2$
- Polarized beam and target
- Measure G_E/G_M
- Using world data for unpolarized cross section allows separation of G_E and G_M .
- Benchmark measurement for BLAST spin program

The Neutron Charge and Magnetism

$E_e = 880 \text{ MeV}$ quasielastic

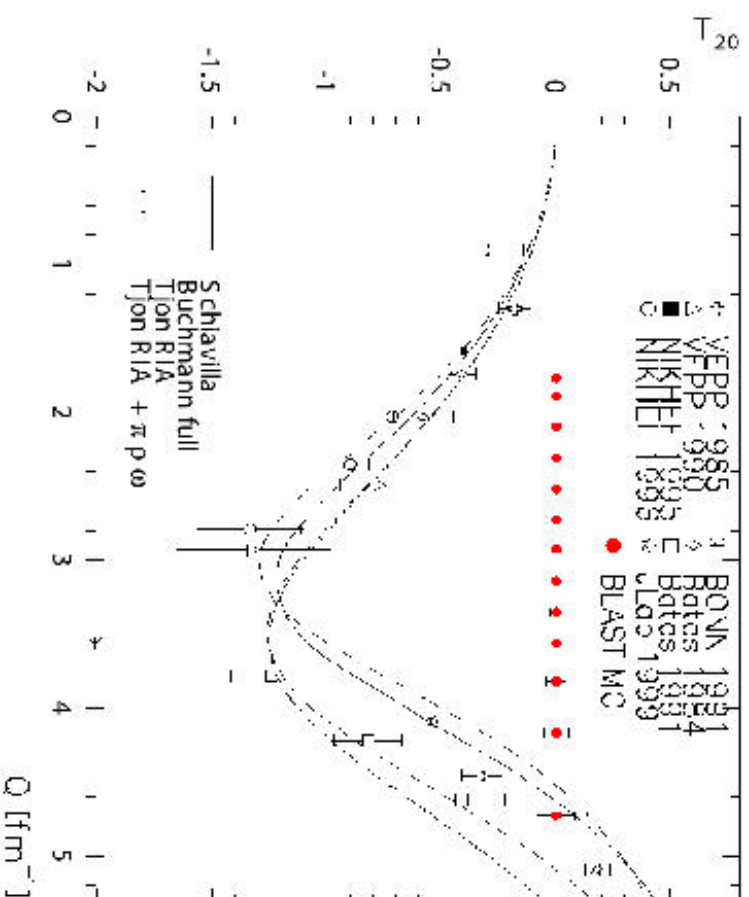
${}^2\vec{H}(\vec{e}, e'n); {}^3\vec{He}(\vec{e}, e'n)$



- Effective neutron targets in common apparatus
- Technique minimizes systematic uncertainties
- Many channels simultaneously over broad range of kinematics
- Fit data to best values of form factors

The Deuteron Structure

$$E_e = 900 \text{ MeV} \quad \text{elastic} \\ {}^2\vec{H}(e, e'd)$$

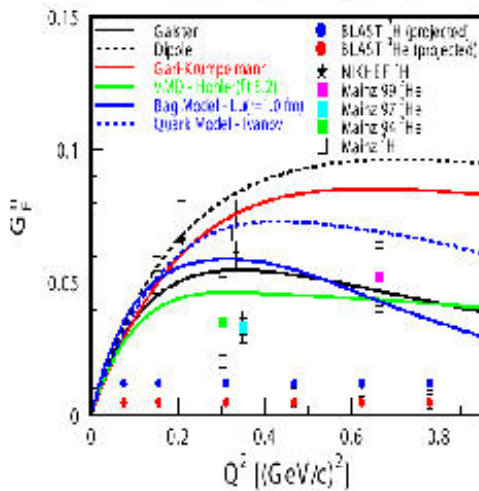


- Precision new data up to $Q^2 = 1.0 \text{ GeV}^2$
- Separation of the three form factors of the deuteron
- G_C zero-crossing
- Photodisintegration data
- Precision test of nuclear theory

Highlights of the BLAST Scientific Program

Structure of the Neutron

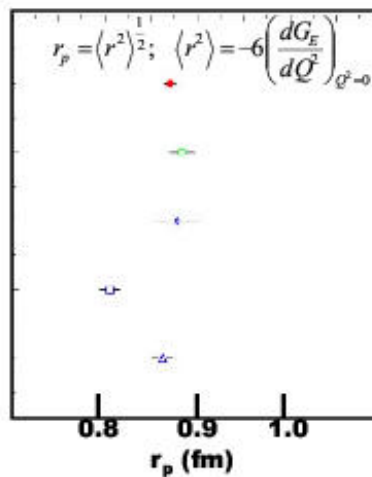
$E_e = 880 \text{ MeV}$ quasielastic
 ${}^2\bar{H}(\vec{e}, e'n); {}^3\bar{H}e(\vec{e}, e'n)$



- Effective neutron targets in common apparatus
- Technique minimizes systematic uncertainties
- Many channels simultaneously over broad range of kinematics
- Fit data to best values of form factors

Proton Charge Radius

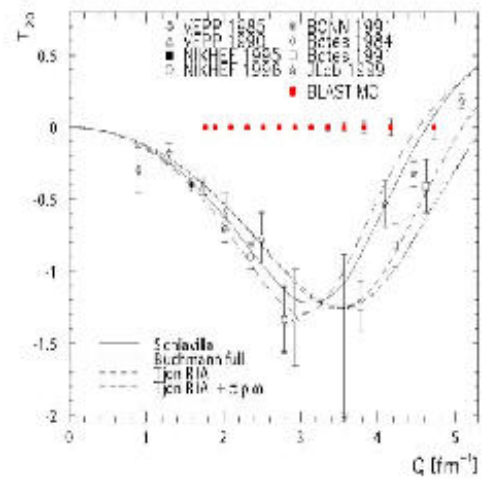
$E_e = 275 \text{ MeV}$ elastic
 ${}^1\bar{H}(\vec{e}, e'p) Q^2 = 0.13 - 2.2 \text{ fm}^{-2}$



- G_E/G_M from asymmetry ratios
- G_M from unpolarized cross section
- Factor 3 improvement
- Tests of QED and QCD

Deuteron Structure

$E_e = 900 \text{ MeV}$ elastic
 ${}^2\bar{H}(e, e'd)$



- Precision data up to $Q^2 = 1.0 \text{ GeV}^2$
- Separation of the three form factors of the deuteron
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