The Super Bigbite Spectrometer (SBS) Physics Program At Jefferson Laboratory

Alexander Camsonne, Bogdan Wojtsekhowski
Jefferson Laboratory

Vincenzo Bellini - Physics and Astronomy Department – University of Catania

Brian Quinn, Carnegie Mellon University

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Outline

1. General information.
2. Introduction to the Form Factor Physics.
3. Experiments with SBS: layout and installation.
4. Recoil Neutron Polarimetry with SBS and Catania group involvement.

1.1 Super Bigbite Spectrometer

Coordinating Committee:

GEp	Evaristo Cisbani
GEn	Seamus Riordan (Chair)
GMn	Brian Quinn
A1n	Nilanga Liyanage
SIDIS	Andrew Puckett
TDIS	Dipangkar Dutta
Program	Bogdan Wojtsekhowski
Scientists	Gordon Cates
HallA Leader	Cynthia Keppel

1.2 Hall A Projected Experiment Schedule, updated 7/2016

Experiments in red represent PAC42 "high impact" experiments

	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
CY 2015	DVCS – I/ GMp	DVCS – I/ GMp X						
CY 2016			DVCS – I/ GMp	DVCS – I/ GMp				
CY 2017					$^3H/^3He$ group	$^3H/^3He$ group *Ar(e,e'p)**	*TBD:* *APEX* *PREX12* *CREX* A_1^n *DVCSII*	
CY 2018								***SBS → Start ??????***

*possible best effort

MOLLER, SoLID →→

2.1 Rosenbluth Separation Technique

The ground-state electromagnetic nucleon form factors (FFs) provide a powerful test of the non-perturbative structure of the nucleons, along with thorough tests of QCD and confinement. The two Sachs form factors G_E^p and G_M^p have been traditionally measured by the Rosenbluth separation technique [2]. By defining $\tau = \frac{Q^2}{4M^2}$, so that $\varepsilon = [1+2(1+\tau)\tan^2\frac{\theta_e}{2}]^{-1}$

is the virtual photon polarization, the modern version of the Rosenbluth separation technique, which uses the linear dependence in ε of the FFs in the reduced cross-section, can be written as:

$$\left(\frac{d\sigma}{d\Omega}\right)_{reduced} = \frac{\varepsilon(1+\tau)}{\tau} \frac{\left(\frac{d\sigma}{d\Omega}\right)_{exp}}{\left(\frac{d\sigma}{d\Omega}\right)_{Mott}} = G_M{}^2 + \frac{\varepsilon}{\tau} G_E{}^2, \tag{1}$$

where $\left(\frac{d\sigma}{d\Omega}\right)_{exp}$ is a measured cross-section, and $\left(\frac{d\sigma}{d\Omega}\right)_{Mott}$ the Mott one [3]. For a fixed Q^2, a fit to several measured reduced cross section values for a range of values of ε gives independently $\frac{1}{\tau}(G_E^p)^2$ as the slope and $(G_M^p)^2$ as the intercept. The accurate data from JLab [4], obtained via the recoil polarization method [5], have shown a striking deviation from the widely expected constant behavior of G_E^p/G_M^p ("empirical scaling law", i.e. $\mu_p G_E^p/G_M^p \sim 1$) with increasing exchanged four-momentum. The polarization data [4,6] are reported in Fig. 1, and compared with the data obtained with the Rosenbluth separation technique [7]. The polarization data show an approximate linear decrease for values of Q^2 above 1 $(\mathrm{GeV}/c)^2$. The 2014-scheduled 12 GeV upgrade of JLab's CEBAF accelerator will allow the measurement of G_E^p/G_M^p up to $Q^2 \approx 15$ $(\mathrm{GeV}/c)^2$, by taking advantage of the new large-acceptance forward spectrometer (Super BigBite, SBS) in Hall A. Measurements of neutron form factors in the kinematical region around 10 $(\mathrm{GeV}/c)^2$, where quark confinement plays an important role, are expected to show the behavior already observed in the proton case.

2.2 Nucleon Form Factor: State-of-art

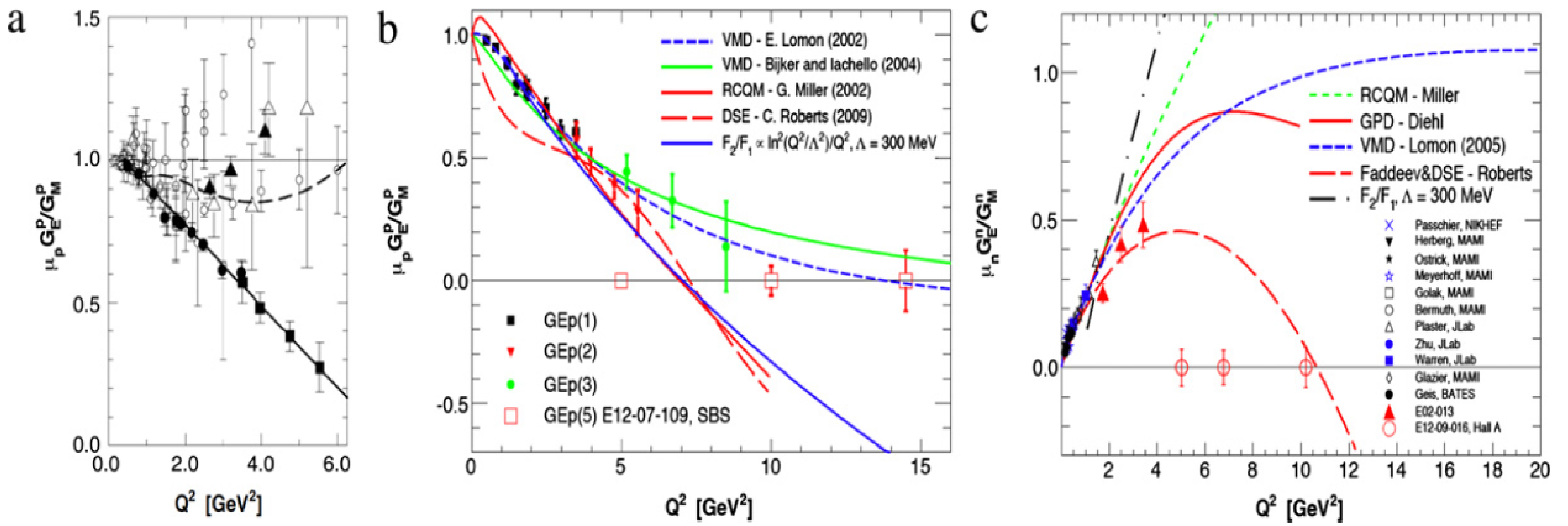


Fig. 1. (a) Comparison of $\mu_p G_E^p / G_M^p$ from the JLab polarization data [4,6,8], and Rosenbluth separation results [9,10]. Units are such that $c = 1$. JLab Rosenbluth results from [9,10] are shown as open and filled triangles, respectively. The dashed curve is a fit of Rosenbluth data [11]; the solid curve is a linear fit valid above $Q^2 \sim 0.4\,(\text{GeV/c})^2$, given by $\mu_p G_E^p / G_M^p = 1.0587 - 0.14265\, Q^2$; (b) Comparison of the new JLab data [4], including GEp(1) [6], GEp(2) [8], GEp(3) [12] and projected GEp(4) ones [13], with different predictions [14–16]. The projected errors for GEp(5) [17] are also included, and shown by the open squares. To emphasize the larger statistical power (a factor of ten) of GEp(5), the error bars that would be achieved using SBS at 13 $(\text{GeV/c})^2$ are also shown; (c) Comparison of existing neutron FF data [18], including those from [19], and preliminary results for GEn(1) (E02-013) [20] with several predictions. Projected errors for GEn(2) (E12-09-016) with SBS [18,21] are also shown.

Fig. 1. from Giusa et al, New trends in hadronic physics at Jlab, PPNP 67(2012) 575-579

3.1 Experiments with the SBS Spectrometer

The measurement of proton FF ratio will be performed by JLab's Hall A Collaboration via the elastic scattering of longitudinally polarized 11 GeV electrons from a liquid hydrogen target. The scattered electron will be detected in the existing lead-glass BigCal calorimeter used for GEp(3) [12]. The recoiling proton will be detected in a new large acceptance magnetic spectrometer, the SBS (Fig. 3). A "proton polarimeter" with a secondary scattering process in CH_2 is planned for this experiment (cfr. Fig. 3). The low efficiency of the aforementioned secondary scattering process requires a detecting system able to achieve high count rates. The key part of this system is a set of tracking chambers using Gas Electron Multipliers (GEM) [24] for the SBS trackers (front, second and third tracker), more than apt to tolerate the very high rates associated with SBS. An experiment, E12-09-016, has been approved for the measurement of G_E^n/G_M^n at $Q^2 \approx 10$ (GeV/c)^2, where the theoretical predictions are very different, and it will rely upon the same SBS equipment in a different configuration. This experiment will use a polarized $_3$He target, and the form factor ratio will be retrieved from the measured beam helicity asymmetry. A measurement of G_M^n/G_M^p up to $Q^2 = 18$ (GeV/c)^2 is also scheduled, *via* the approved experiment E12-09-019, again using the SBS. A compendium is illustrated for the neutron FF ratio G_E^n/G_M^n in Fig. 1; preliminary results from the GEn(1) experiment and projected errors for the approved GEn(2) are shown. Again, high Q^2 measurements are mandatory for discriminating between models.

3.2 SBS Configuration for Gep(5) Experiment

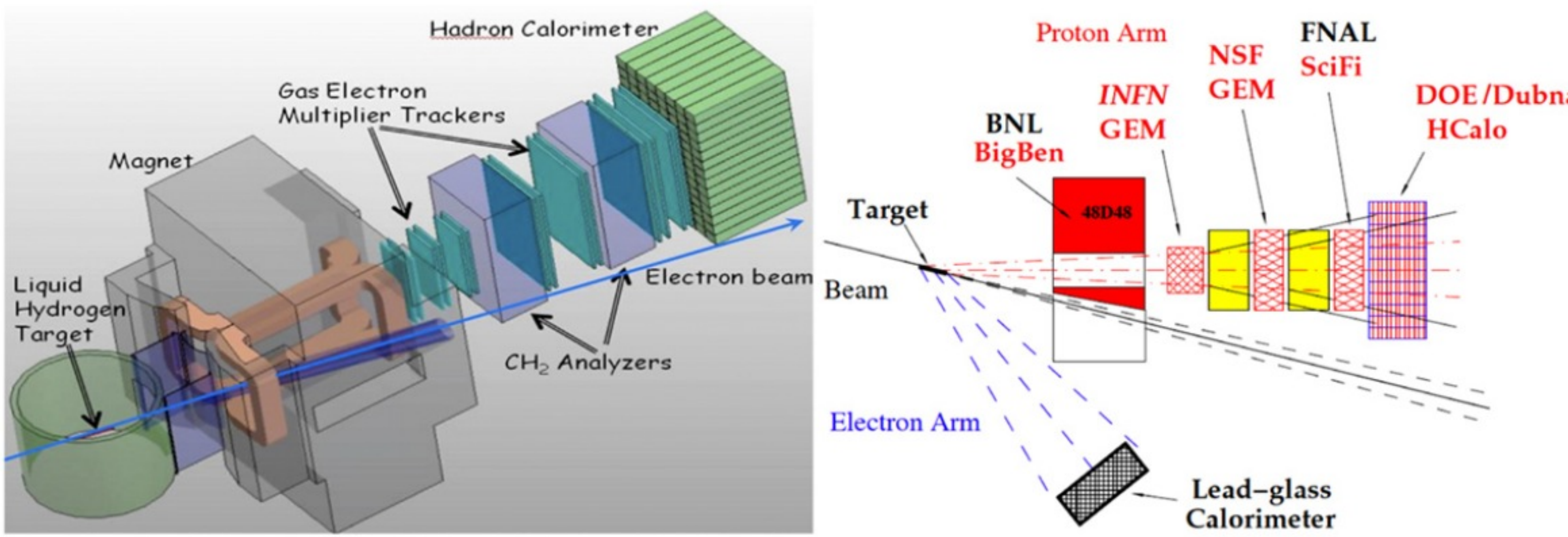
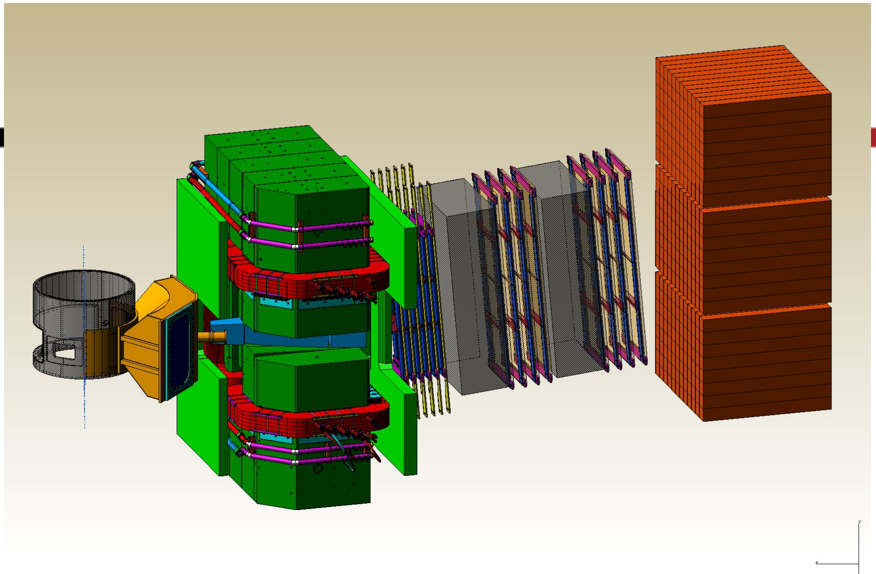


Fig. 3. Left: SBS configuration for GEp(5) [17], artist's view; Right: Schematic view of SBS configuration for GEp(5) (top view).

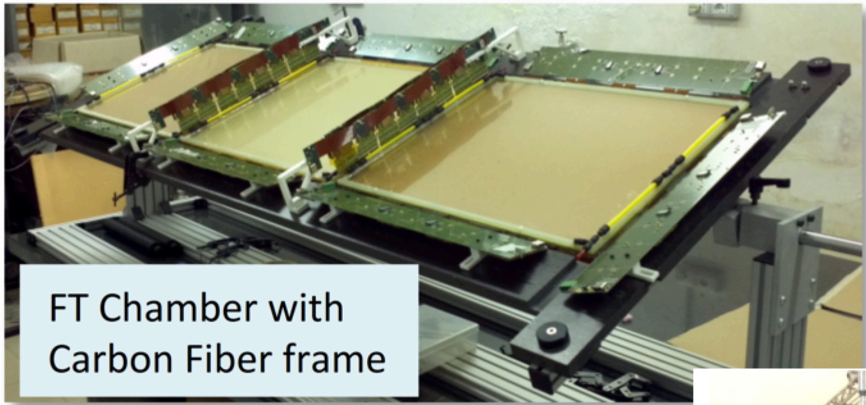
Fig. 3. from Giusa et al, New trends in hadronic physics at Jlab,
PPNP 67(2012) 575-579

3.3
SBS Construction

- Project started FY2013
  - Successfully passed third annual review November 2015
  - Final Review planned now for November 7,8 2016!
  - Last time some concerns about thermal annealing/design of ECAL and 3He target timeline
- Spectrometer, ECAL work at JLab



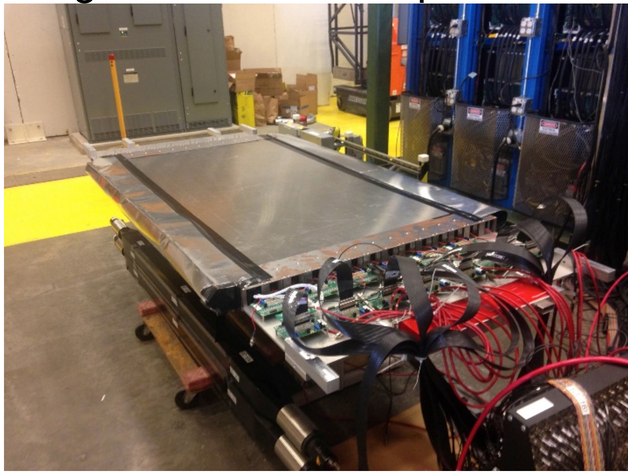
3.4 Super Bigbite Spectrometer (SBS) Detectors



FT Chamber with Carbon Fiber frame

INFN Front Tracker GEM chamber with carbon fiber frame at JLab

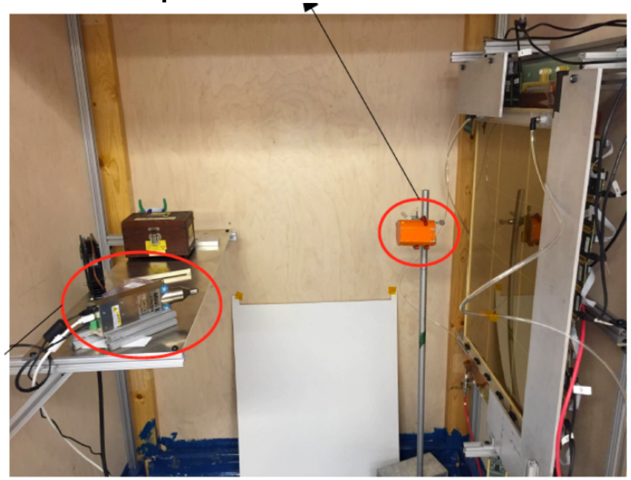
CDET module 1 ready for cosmic testing with full data acquisition



168 out of 288 Hadron Calorimeter modules at JLab

Rear GEM tracker modules at UVA, 32 constructed + 28 tested

UVa High rate X-ray testing setup for GEMs

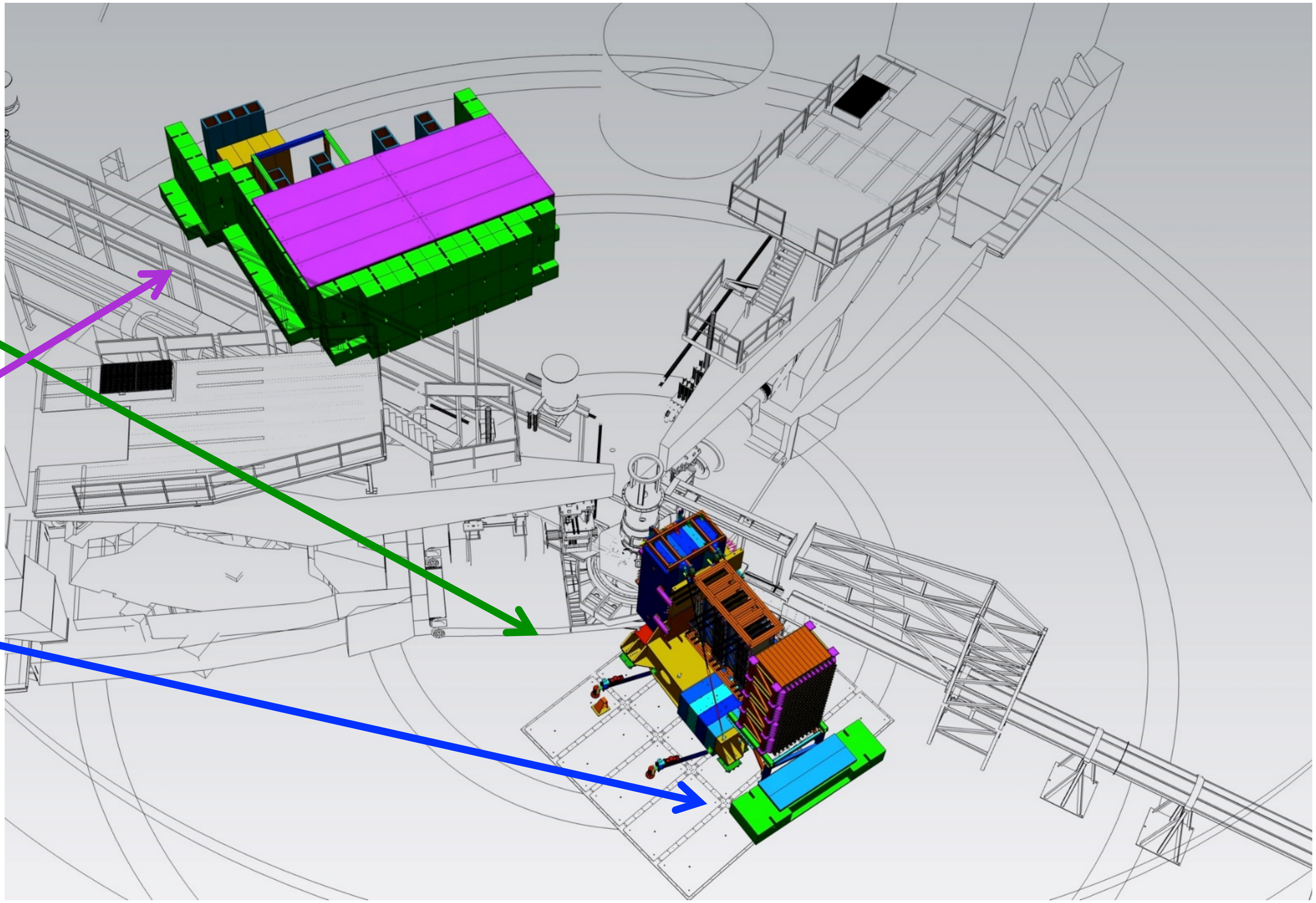


3.5 Installation – Hall Infrastructure Planning and Development

SBS

Electronics
"Hut"

GEM
electronics



Layout for maximal use of Hall, defines cable lengths, service requirement planning, installation concerns…..

4.1 The Need for a Better GEn/GMn Data

- In terms of Q^2 range and precision, neutron measurements still lag way behind proton measurements
- For measurements in space-like domain at medium-high Q^2 JLab is the only viable lab. Quasi-elastic electron scattering from neutron in ^2H, ^3He...
- Double polarised experiments are the way to go (since ~ 1990)
  Relatively low sensitivity to two-photon exchange effects compared to Rosenbluth separation
  Better access to relatively small G_E (compared to G_M)
- JLab: E12-09-016 G_{En}/G_{Mn} with polarized electron beam & ^3He target up to Q^2 of ~10 $(GeV/c)^2$.
- Neutron measurements extremely challenging...independent verification of results necessary
  Alternative method with polarised electron beam and polarimeter to measure polarisation transfer to recoiling neutron. Unpolarised ^2H target
- QE signal much cleaner with ^2H target compared to ^3He
- ^2H experiment should, as far as possible, match kinematic range and precision of ^3He experiment.
- Up to now no recoil polarimetry measurement at $Q^2 > 1.5$ $(GeV/c)^2$

Acknowledgments

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