Neutron Magnetic Form Factor

Bogdan Wojtsekhowski, Jefferson Lab
for the GMn collaboration

JLab experiments

E12-09-019 D.Hamilton, A.Camsonne, B.Quinn, BW

E12-20-010 S.Alsalmi, E.Fuchey, BW

GMn experiments time line

1959 paper by L. Durand, Phys. Rev. 115 1020 (1959).
1960th-1970th DESY

Volume 39B, number 3 PHYSICS LETTERS 1 May 1972

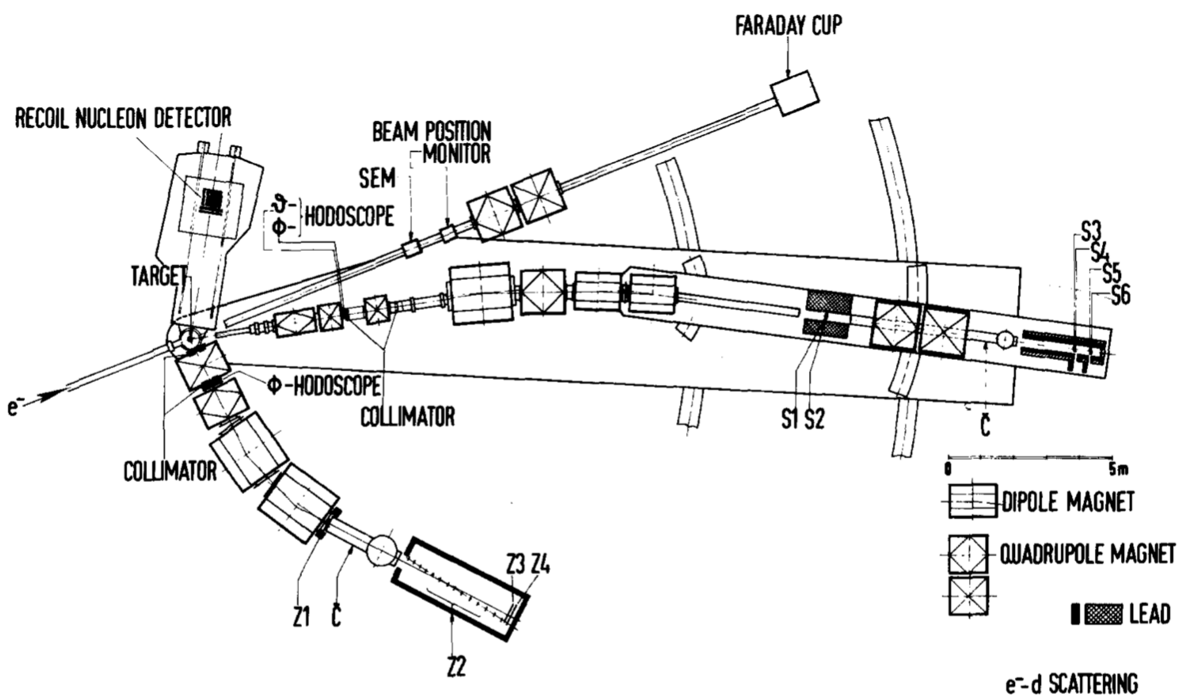
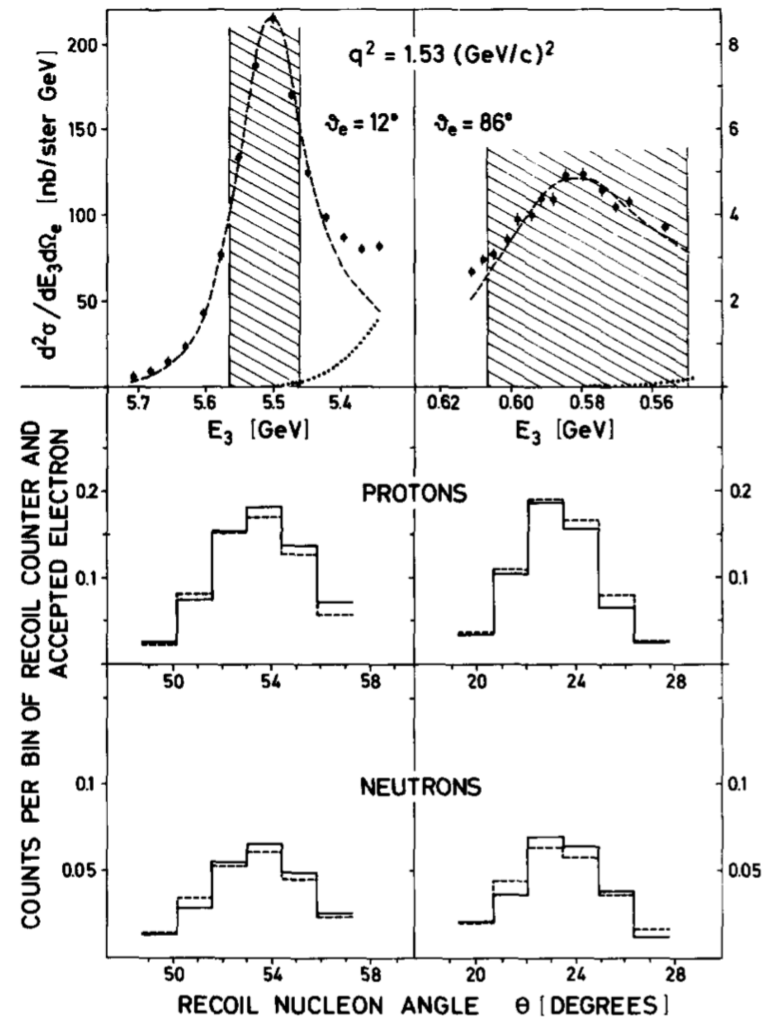
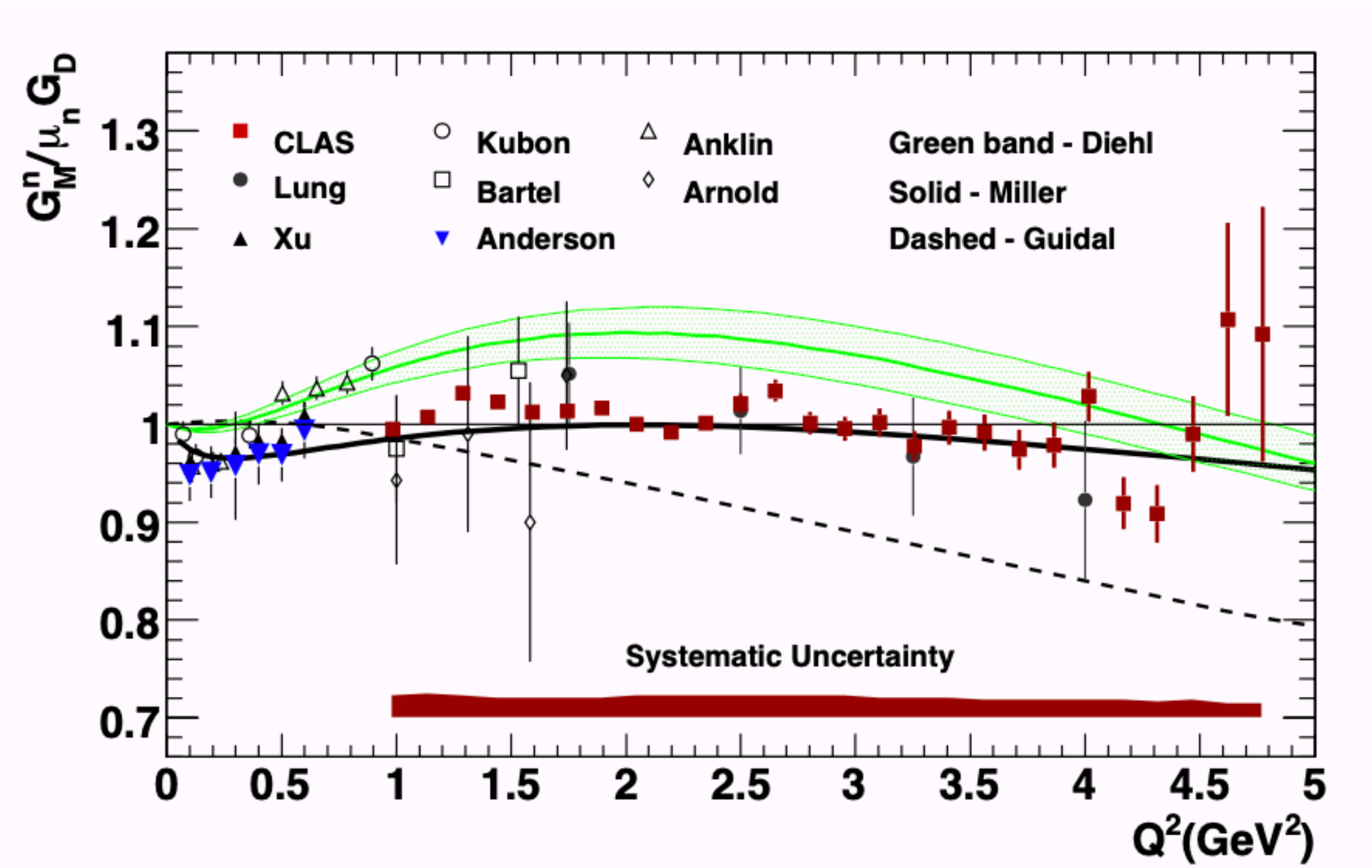


Fig. 1. Schematic view of the experimental set-up with the concrete shielding removed. S1 to S6 and Z1 to Z4 as well as the elements of the recoil nucleon detector are scintillation counters. S1 and Z2 are hodoscopes.



GMn physics time line

1959 paper by L. Durand, Phys. Rev. 115 1020 (1959).
1972 DESY, PL 39B. Q2 = 1.5 GeV2; δGMn/GMn ~ 5%
1994 CLAS6 W. Brooks; Q2 up to 4.8 GeV2; CMU analysis



GMn project development

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1994 CLAS6 W.Brooks; Q2 up to 4.8 GeV2; CMU analysis
2002 High luminosity D(e,e'N) for neutron Rosenbluth

The proposed scheme will use the magnetic spectrometer as an electron arm and a non-magnetic detector as a hadron arm. The last one will consist of a large array of plastic scintillators and veto detectors. At a few $(\mathrm{GeV/c})^2$ momentum transfer the kinetic energy of the recoiling nucleon is above 1 GeV and proton and neutron interactions with the detector are similar (nuclear interaction dominates). The neutron detection efficiency of different measurements will be similar to each other because of equal kinetic energy of the neutron in both measurements. Most of the remaining variations of the detector efficiency and solid angle will affect in the same way the complementary reaction $D(e, e'p)n$.

The ratio $F^2_{\epsilon_2}/F^2_{\epsilon_1}$, which defines as the value of g_n, can be expressed in the proposed experiment as

$$\left(\frac{F^n_{\epsilon_2}}{F^n_{\epsilon_1}}\right)^2 = \left(\frac{F^p_{\epsilon_2}}{F^p_{\epsilon_1}}\right)^2 \cdot \frac{N_2^{e,e'n}}{N_1^{e,e'n}} \cdot \frac{N_1^{e,e'p}}{N_2^{e,e'p}} \cdot \frac{\Omega^n_{\epsilon_2}}{\Omega^n_{\epsilon_1}} \cdot \frac{\Omega^p_{\epsilon_1}}{\Omega^p_{\epsilon_2}} \cdot \frac{\eta^n_{\epsilon_2}}{\eta^n_{\epsilon_1}} \cdot \frac{\eta^p_{\epsilon_1}}{\eta^p_{\epsilon_2}} \qquad (4)$$

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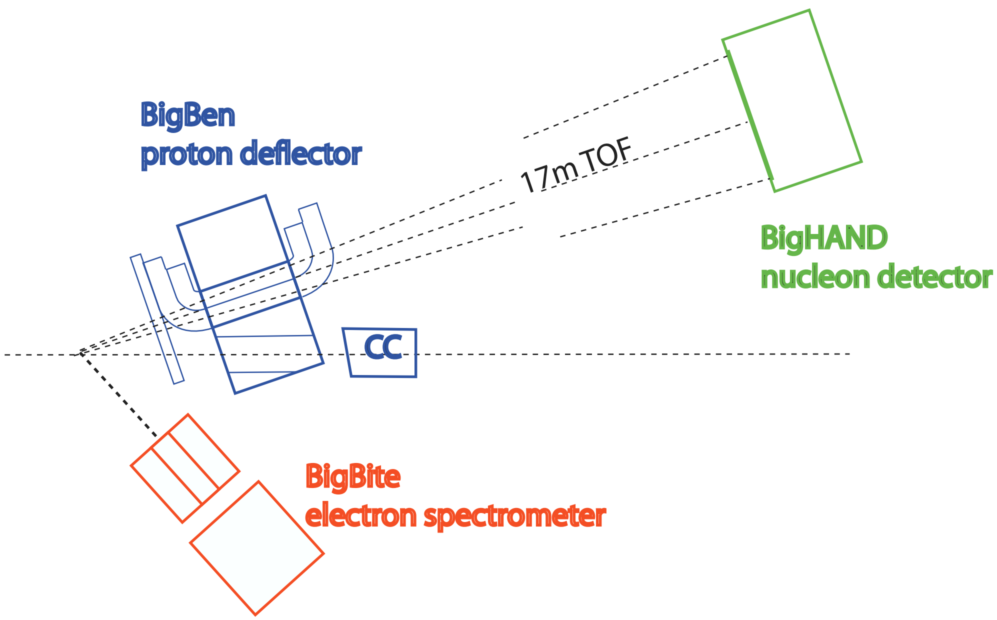
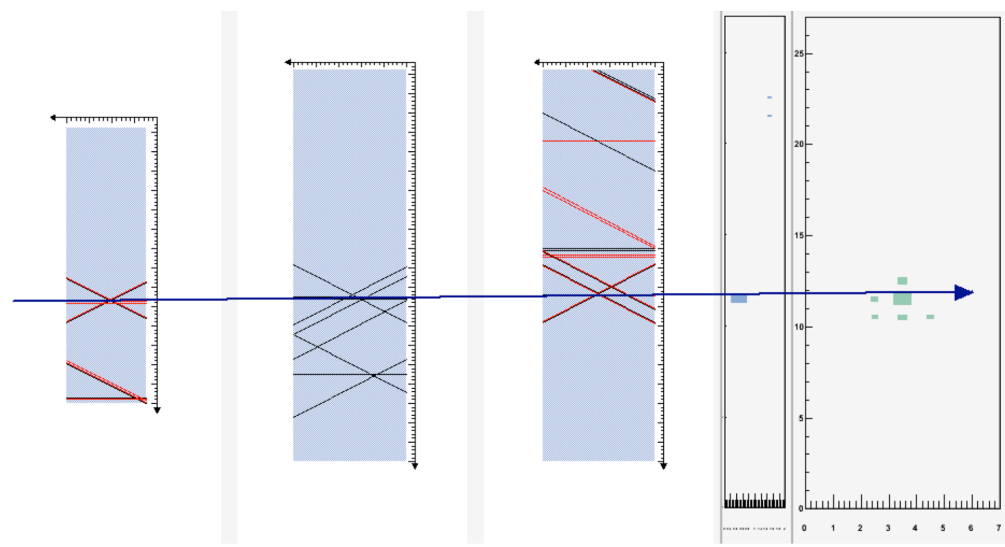
2002 High luminosity D(e,e'N) for neutron Rosenbluth
2006 GEn (He-3) experiment with BigBite and BigHAND
2007 GEP with SBS approved, magnet found at BNL
2007 SBS project: INFN funded GEM
2007 GMn proposal to PAC33; Q2 = 8 GeV2; reuse GEn-I detectors





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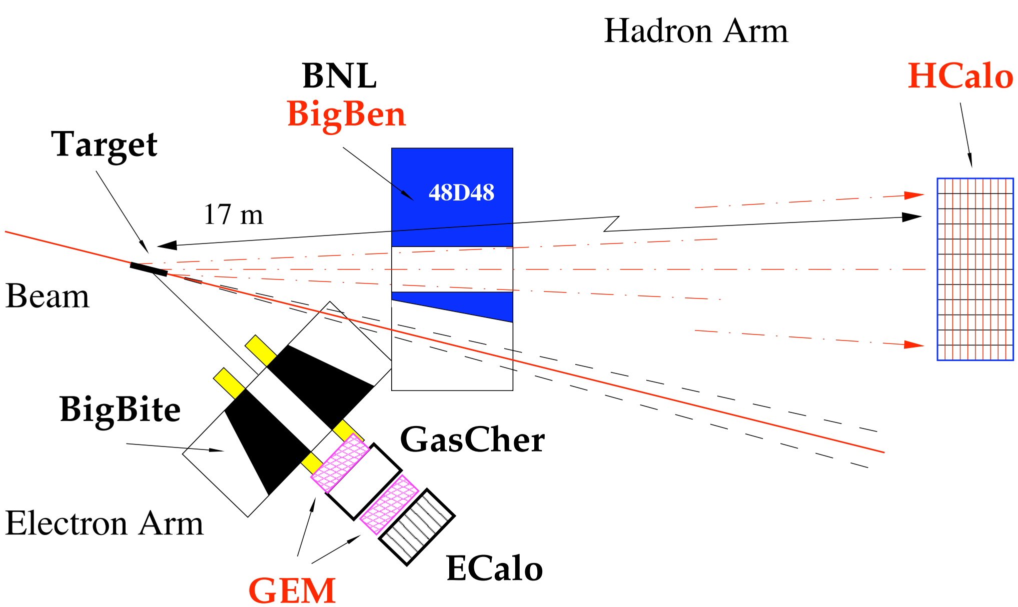

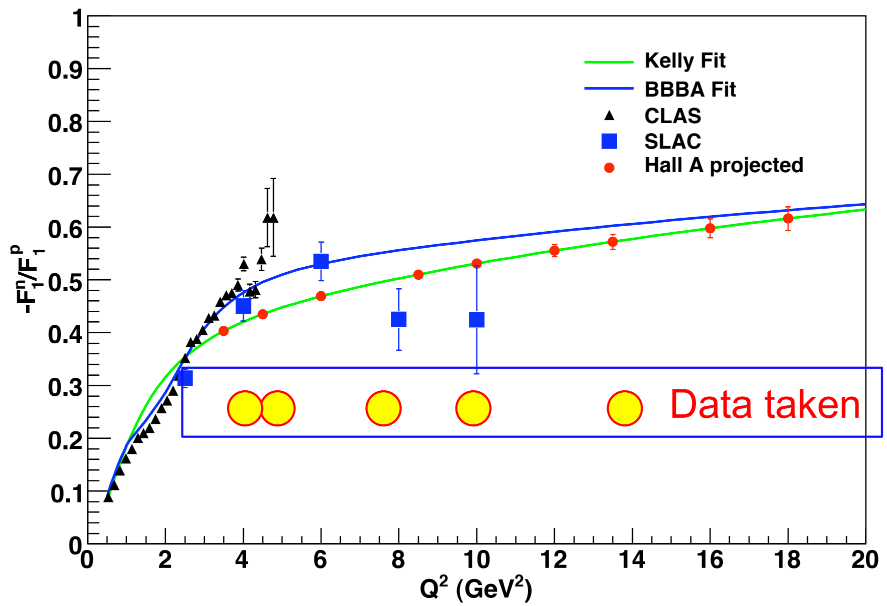

GMn project development

2009 GMn E12-09-19 approved to 13.5 GeV2
2007 INFN started GEM development
2008 UVa started GEM development
2009 SBS CDR project: SBS proposal to DOE; Letters

January 28, 2009

1 Introduction

A technical review of the Super Bigbite Spectrometer (SBS) for Jefferson Lab Hall A was held on Monday, November 17, 2008. The spectrometer is designed to provide the Hall A community with a large solid-angle capability at very high luminosity for the 12 GeV Upgrade.

The members of the review committee were:

Paul Brindza
Eugene Chudakov
Dave Doughty
Howard Fenker
Bernhard Mecking (chair)

The committee reviewed the written material prior to the meeting and heard discussions of the physics program and the technical features of the Super Bigbite Spectrometer. Based on the presentations and the discussions the committee asked for additional information which was received on December 15, 2008; this information is included in the latest CDR version of January 15, 2009.

8 Summary

The Super BigBite project in Hall A has been reviewed. The committee is impressed by the broad scope of the physics program and the anticipated performance of the spectrometer.

The SBS project is aiming at the Holy Grail in electron scattering instrumentation: the combination of large solid angle coverage at forward angles and the highest luminosity achievable with the upgraded 12 GeV CEBAF. The SBS consists of a transverse field dipole magnet equipped with high-rate GEM tracking detectors. Additional detectors, like calorimeters and Cerenkov counters will be used for triggering and particle identification

The committee finds that the experimental design has a very high probability of meeting the experimental requirements. The high rate and high resolution capability of the GEM detectors make them the ideal solution for this application. The present uncertainty in what ultimate luminosity can be achieved will be reduced by checking the sensitivity of the

GMn project development

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2009 SBS CDR project: SBS proposal to DOE; Letters

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One University. One World. Yours. | ASTRONOMY AND PHYSICS

Department Office
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F 902.496.8218

14 January, 2009

Dr. Bogdan Wojtsekhowski (SBS Project Coordinator) and Dr. Kees de Jager (Hall A Leader)
Jefferson Lab, MS-12H3
12000 Jefferson Avenue
Newport News, VA 23606

RE: Commitment for 2009 Canadian Funding Application for Scintillating Fiber Tracker of the Super Big-Bite Spectrometer in Jefferson Lab's Hall A

Dear Dr. Wojtsekhowski and Dr. de Jager:

This letter is to indicate my support and commitment for the Scintillating Fiber Tracker (SFT) of the Super-BigBite Spectrometer (SBS) Project in Jefferson Lab (JLab) Hall A. I understand that the SBS collaboration is submitting a Major Research Instrumentation (MRI) proposal to the US National Science Foundation focusing on the development of the Large GEM Tracker for the SBS, for use with the energy-upgraded 12 GeV machine at JLab. Also, I understand that the MRI proposal is a collaborative effort between JLab, Norfolk State University, the University of Virginia, and the College of William and Mary.

INFN Istituto Nazionale di Fisica Nucleare

ISTITUTO NAZIONALE FISICA NUCLEARE - SEZIONE DI ROMA
GRUPPO COLLEGATO SANITÀ

Viale Regina Elena 299
00161 Roma
Tel. 06-49901 (centr.)
Fax 06-4938 7075

Rome, 24 December 2008

TO WHOM IT MAY CONCERN ,

This letter is to confirm the participation of my research group in the instrumentation of Super-Bigbite spectrometer in experimental Hall A at Jefferson Lab. The proposed spectrometer will make possible many exciting experiments, including the study of ground state structure of the proton and the neutron with unprecedented precision by measuring their form factors up to high momentum transfer. An international collaboration has been formed to instrument the Super-BigBite spectrometer for these experiments. This collaboration includes physicists from 20 institutions in the U.S, Canada, UK, Italy, Ukraine, France and Russia.

GMn project development

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2008 UVa started GEM development
2009 SBS CDR project: SBS proposal to DOE; Letters

Carnegie Mellon

Department of Physics
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213-3890
(412) 268-2740

January 13, 2009

Dr. Kees DeJager, Hall A leader
Dr. B. Wojtsekhowski, SBS Project Coordinator
Jefferson Lab, MS-12H3
12000 Jefferson Avenue
Newport News, VA 23606

Re: Hadron Calorimeter for the Super Big-Bite Spectrometer

Dear Dr. DeJager and Dr.Wojsekhowski:

This letter will outline my group's intention to support the development of a new hadron calorimeter for the proposed Hall-A Super BigBite Spectrometer (SBS). It is my understanding that members of the SBS collaboration are submitting a Major Research Instrumentation (MRI) proposal to the NSF which will focus on the development of a GEM track for the SBS. It is my hope that the following information, along with statements of support from other collaborators, will be used to document the support for the entire SBS project.

University of Glasgow

John R.M. Annand
Department of Physics and Astronomy,
University of Glasgow,
G12 8QQ Glasgow, SCOTLAND, UK.
Tel. +44 141 330 6428, Fax. 5889
Email: j.annand@physics.gla.ac.uk

15th January 2008

Dr. C.W. de Jager
Hall-A Leader,
Dr. B. Wojtsekhowski,
SBS Project Leader,
Jefferson Laboratory, MS-12H3.
12000 Jefferson Avenue,
Newport News, VA 23606.

Dear Sirs,

Support for the Super BigBite Spectrometer from the Nuclear Physics Group of Glasgow University.

I wish to affirm my continuing support for the development of the Super BigBite Spectrometer (SBS) at Hall-A of Jefferson Laboratory (JLab). Currently members of the Glasgow Nuclear Physics group (NP) are engaged in calculating the properties of the spectrometer's dipole magnet and in development of of the GEM trackers. In the context of the Major Research Instrumentation proposal which SBS collaborators are submitting to the NSF, I have committed to provide GEM foils for prototyping studies.

GMn project development

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2009 SBS CDR project: SBS proposal to DOE; Letters
2010 HCAL G.Franklin/CMU; E.Bellini/CataniaU (GEn-RP)

COMPASS

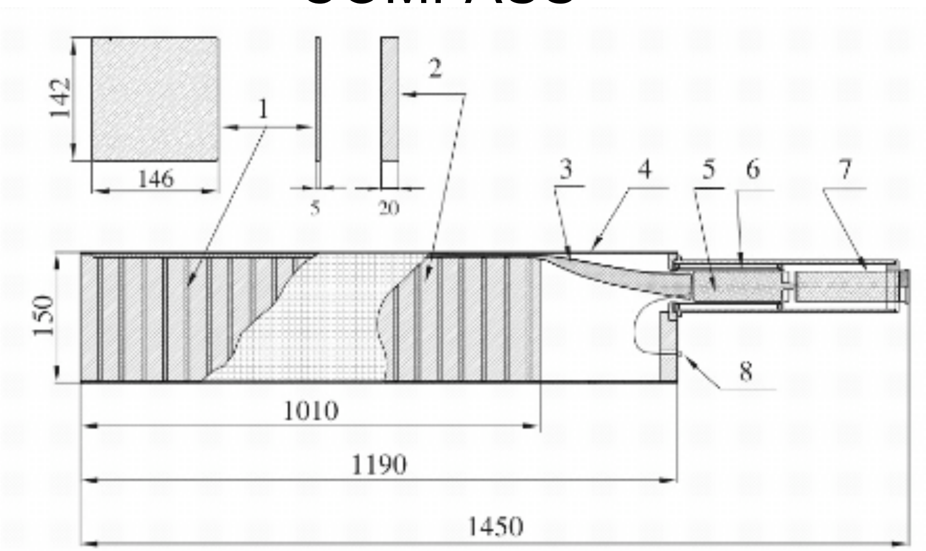
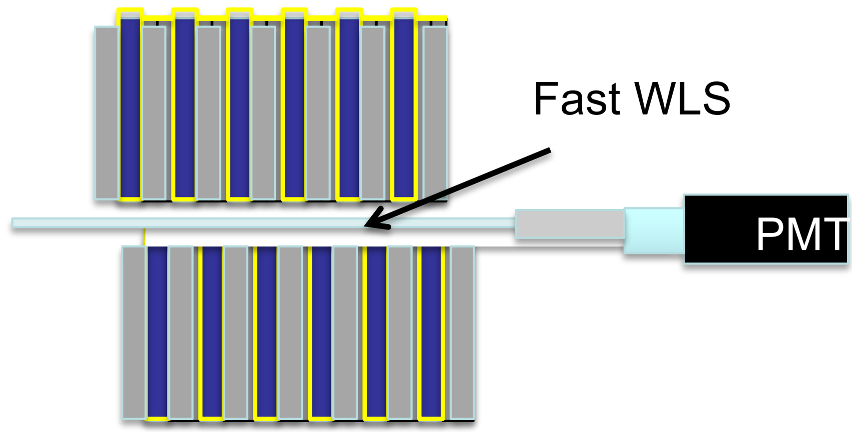


Fig. 48. Structure of the HCAL1 module: 1, scintillators; 2, iron plates; 3, light guide; 4, container; 5, PMT; 6, PMT magnetic shielding; 7, Cockcroft–Walton divider; 8, optical connector for LED control. Dimensions are in mm.



Novel adiabatic lightguide

GMn project development

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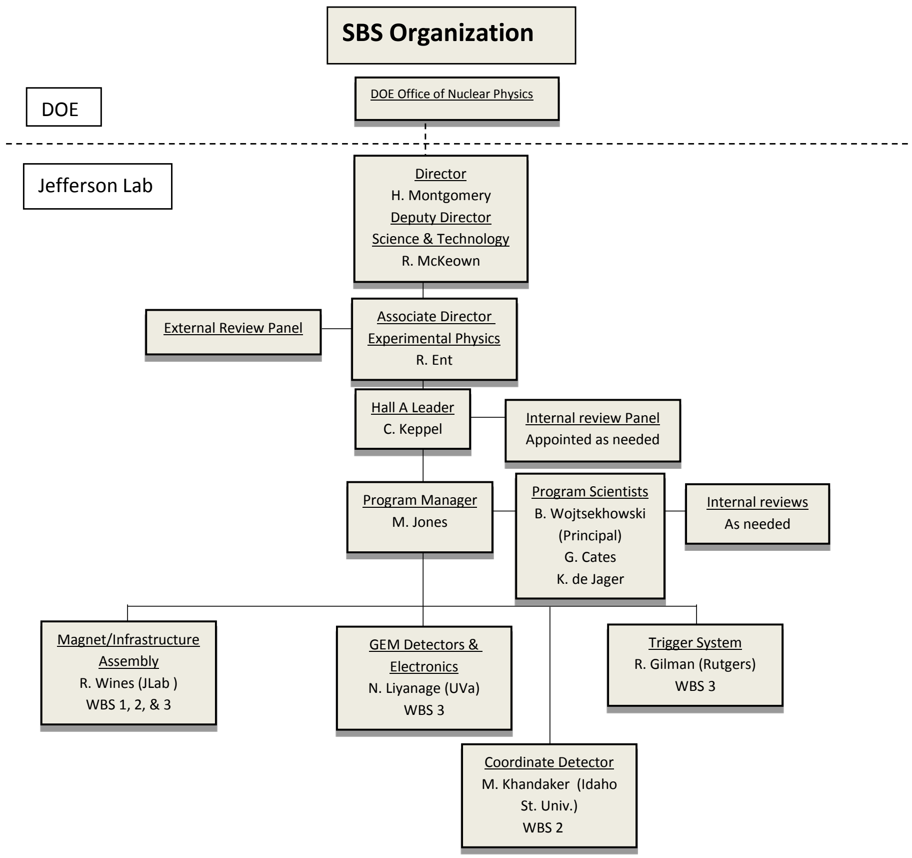
2010 HCAL G.Franklin/CMU; E.Bellini/CataniaU (GEn-RP)
2012 DOE approved funds for SBS+GEM+CDET

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1			year	year	year	year								
2			2	3	4	5								
3			2013	2014	2015	2016	Contingency							
4	escallated direct cost	direct cost	$ 516	$ 371	$117	$-	$ 367.82	$ 1,004		overall overhead		$1,003.64		overall overhead
5	scallated overhead co	overhead	$ 135	$ 137	$ 49	$-		$ 322	$1,325.36	32%		$ 441.60	$1,445.24	44%
6	escallated contingenc	contingency	$ 181	$ 146	$ 40	$-		$ 368	28%					
7	Total		$ 832	$ 655	$206	$-		$ 1,693						
8			$ 651	$ 508	$166	$-		$ 1,326	$1,693.18					
9		overhead %	26%	37%	42%									

SBS project

2. Program Organization

The SBS Program will be executed as a joint collaboration between Jefferson Lab, the University of Virginia, Rutgers University, and The College of William and Mary. Jefferson Lab will establish contractual agreements between itself and each University. A clear definition of the roles and responsibilities that individuals and their organizations play will be critical to the success of the overall SBS Program and its three sub- projects. Jefferson Lab will take the lead integrating the various equipment items together to assemble the SBS apparatus. The Universities are responsible for producing the deliverables identified later. We show below the SBS Organization Chart.



WBS structure

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Introduction:

The SBS Program consists of three separate, but interrelated Projects.

- The first Project, **SBS Basic (WBS 1)**, involves the acquisition of an existing magnet and the associated work of preparing it for use during the SBS research program. The effort includes modifications to the magnet, including machining a slot in the yoke for beam passage, field clamps, and a solenoid to reduce the transverse magnetic field on the beam line, the design and development of the infrastructure needed to run the magnet, and the construction of the platform on which it will stand.
- The second Project, **Neutron Form Factor (WBS 2)**, involves the construction of twenty-nine GEM detector modules with associated front-end and DAQ modules to meet the requirements of the approved neutron form factor measurements.
- The third and final Project, **Proton Form Factor (WBS 3)**, involves the construction of thirty-five GEM detector modules with associated front-end and DAQ modules and the addition of pole shims for increased magnetic field integral to meet the requirements of the approved proton form factor measurements.

Project Management Highlights:

This is the eighth Monthly Progress Report for the SBS Program. The collaboration is in place, and the Program Management Plan has been approved by Jefferson Lab management and by the DOE-NP Instrumentation Program Manager.

The first and second Projects within the SBS Program, SBS Basic (WBS 1) and Neutron Form Factor (WBS 2), started at the beginning of FY13.

The third Project, Proton Form Factor (WBS 3), isn't scheduled to start until FY14.

Jefferson Lab
Thomas Jefferson National Accelerator Facility

WBS 1: SBS Basic

WBS 1	**SBS Basic: (Hall A Infrastructure)**	**WBS 1.01**	Milestones
		WBS 1.02	Project Oversight
		WBS 1.1	Magnet, power and construction
		WBS 1.2	Magnet/detector platforms
		WBS 1.3	Beam line

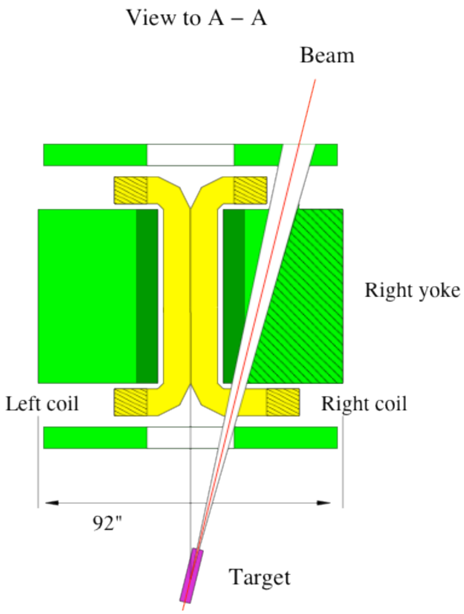
WBS 1.01 Milestones:

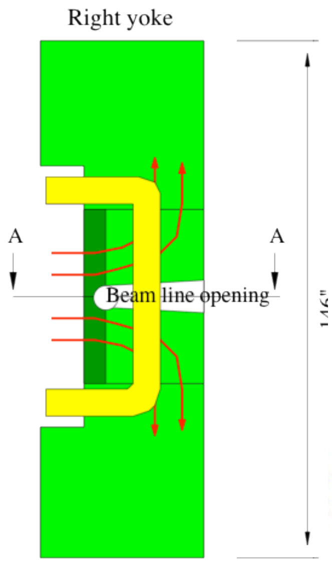
Id #	Level	Milestone	Scheduled Date	Expected Date 4/1/2013	Expected Date 5/1/2013	Actual Date
1.1-01M	1	Project start	10/1/2012	10/1/2012	**10/1/2012**	**10/1/2012**
1.2-01M	2	Magnet delivered to JLab	4/30/2013	4/30/2013	5/30/2013	
1.2-10M	2	Platform parts received	6/27/2014	6/27/2014	6/27/2014	
1.2-20M	2	Magnet assembled on platform	3/19/2015	3/19/2015	3/19/2015	
1.2-30M	2	Beam-line parts received	9/24/2015	9/24/2015	9/24/2015	
1.1-10M	1	Project completion	1/29/2016	1/29/2016	1/29/2016	

WBS 1.02 Project Oversight:

- SBS weekly meetings are being held via tele and video conference almost every Wednesday. During this Report period, meetings were held on Apr 3rd, Apr 10th, Apr 17th and Apr 24th. Participants included Jefferson Lab, University of Virginia, St. Mary's University, William and Mary, University of Massachusetts, Carnegie-Mellon University, University of Glasgow, Norfolk State University, Idaho State University, and INFN – Rome.
- Project is staffed appropriately for this beginning stage, and includes a Jefferson Lab manager, scientist, and magnet engineer.

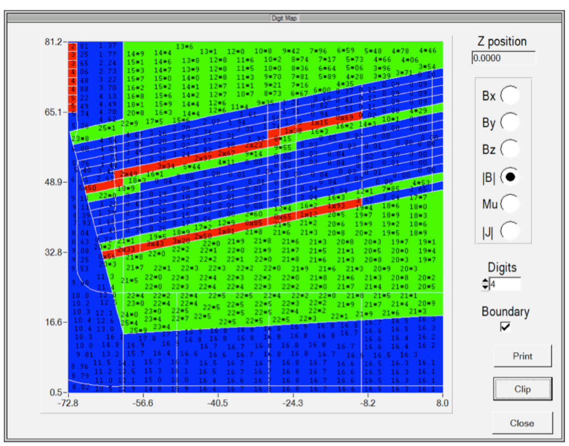
SBS magnet and beam line

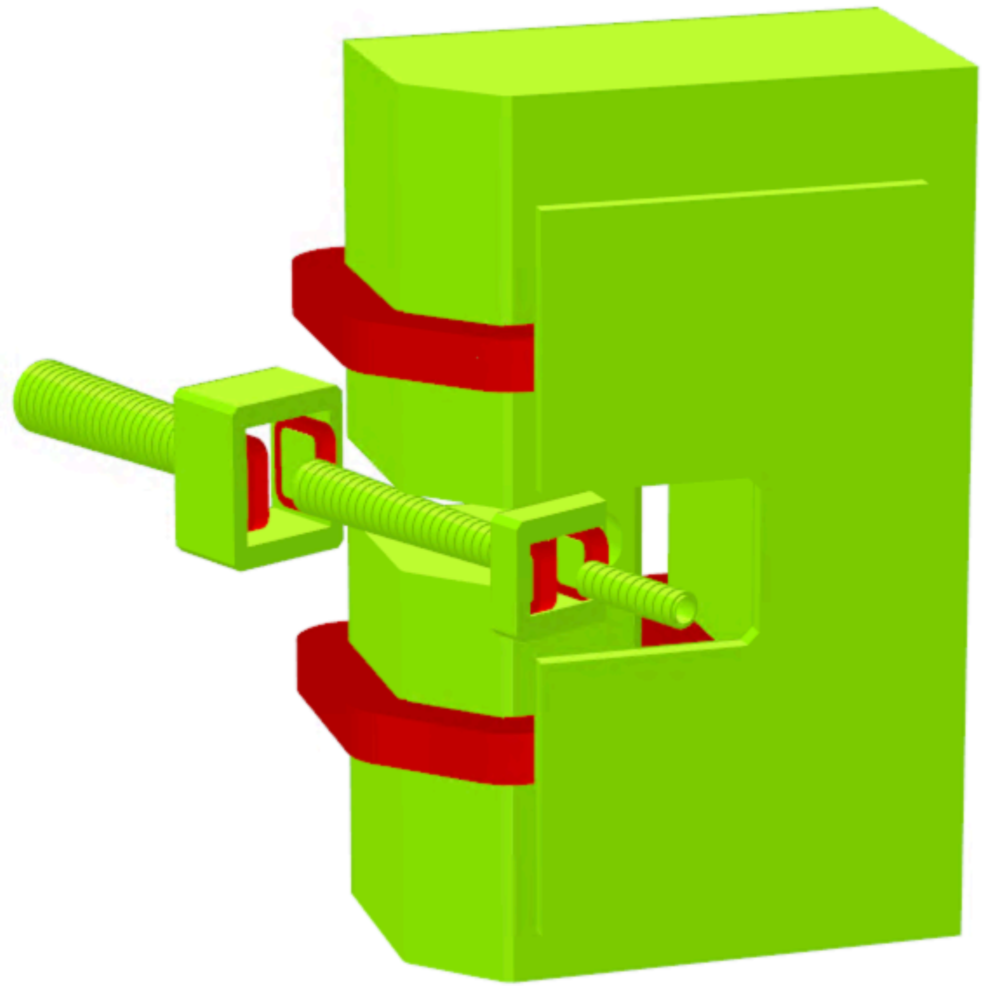




Lambertson

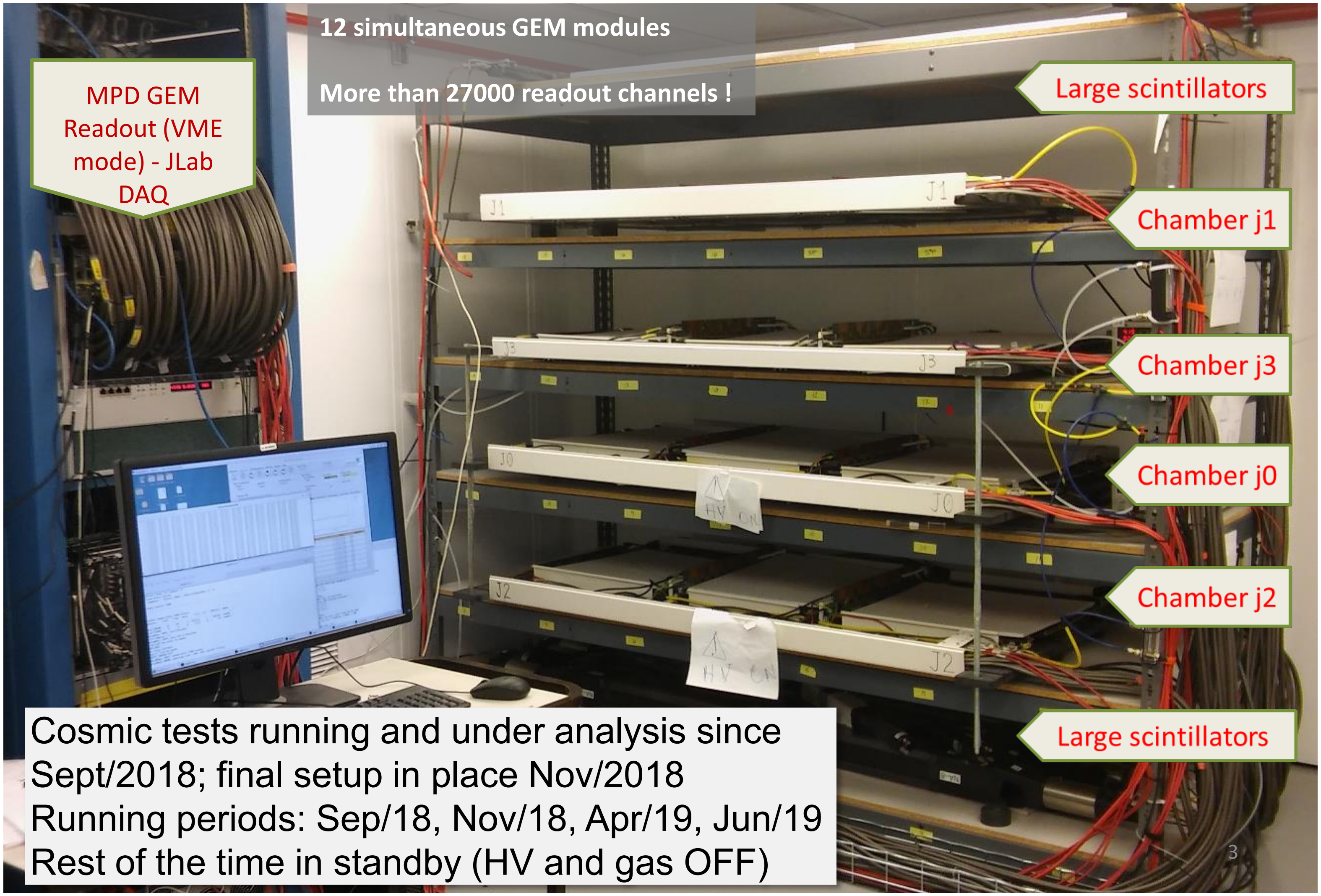
Shield saturation by long. field





SBS GEM at INFN

4(6) three-module chambers (40 cm x 150 cm)



SBS GEM at UVa

40 four-module chambers (60 cm x 200 cm)

- 48 modules built and tested
  - ⇨ 45 modules are fully operational, with 2 of them having one disabled sector but 97% operational
  - ⇨ 3 modules have issues and are under investigation
  - ⇨ **Parts for 2 more modules to be constructed soon**
- 29 modules already moved to JLab
  - ⇨ 24 in GEM clean storage room, 5 on test beam stand
  - ⇨ **12 more to be shipped next week (week Monday 26th)**
    - ⇨ Space in GEM "Clean" room is becoming critical
  - ⇨ All 41 modules tested again before shipping to JLab

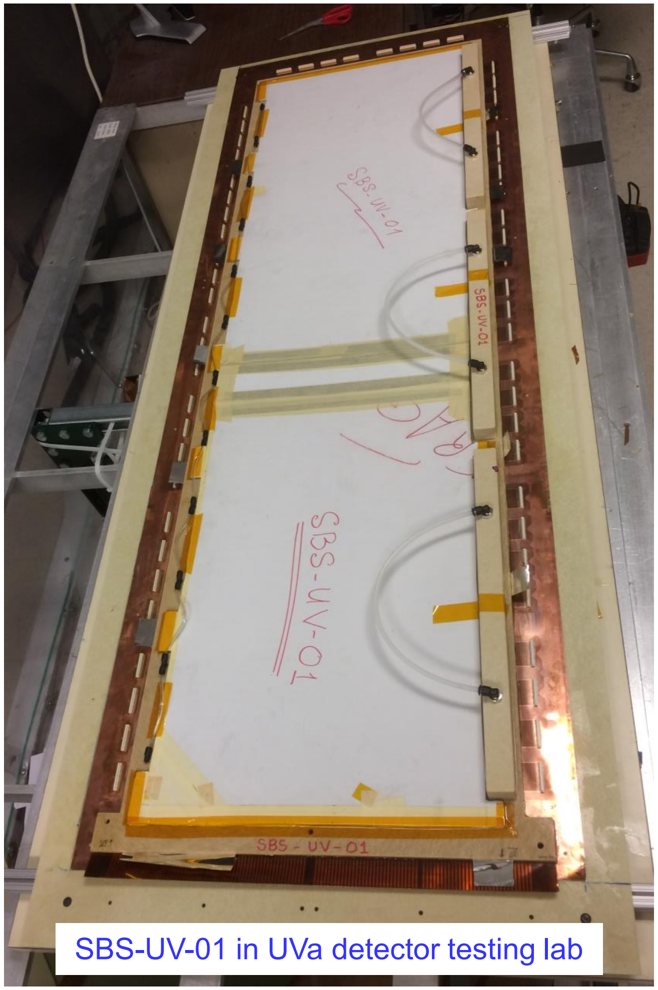
UVa GEM @ JLab

UVa GEM @ JLab

SBS U/V GEM at UVa

Funded by the collaboration

Status of U/V-strip GEM chambers: assembly SBS-UV-01 and SBS-UV-02



SBS-UV-01 in UVa detector testing lab

SBS-UV-01: Assembly in clean room part completed, chamber out of clean room ➪ Next steps:

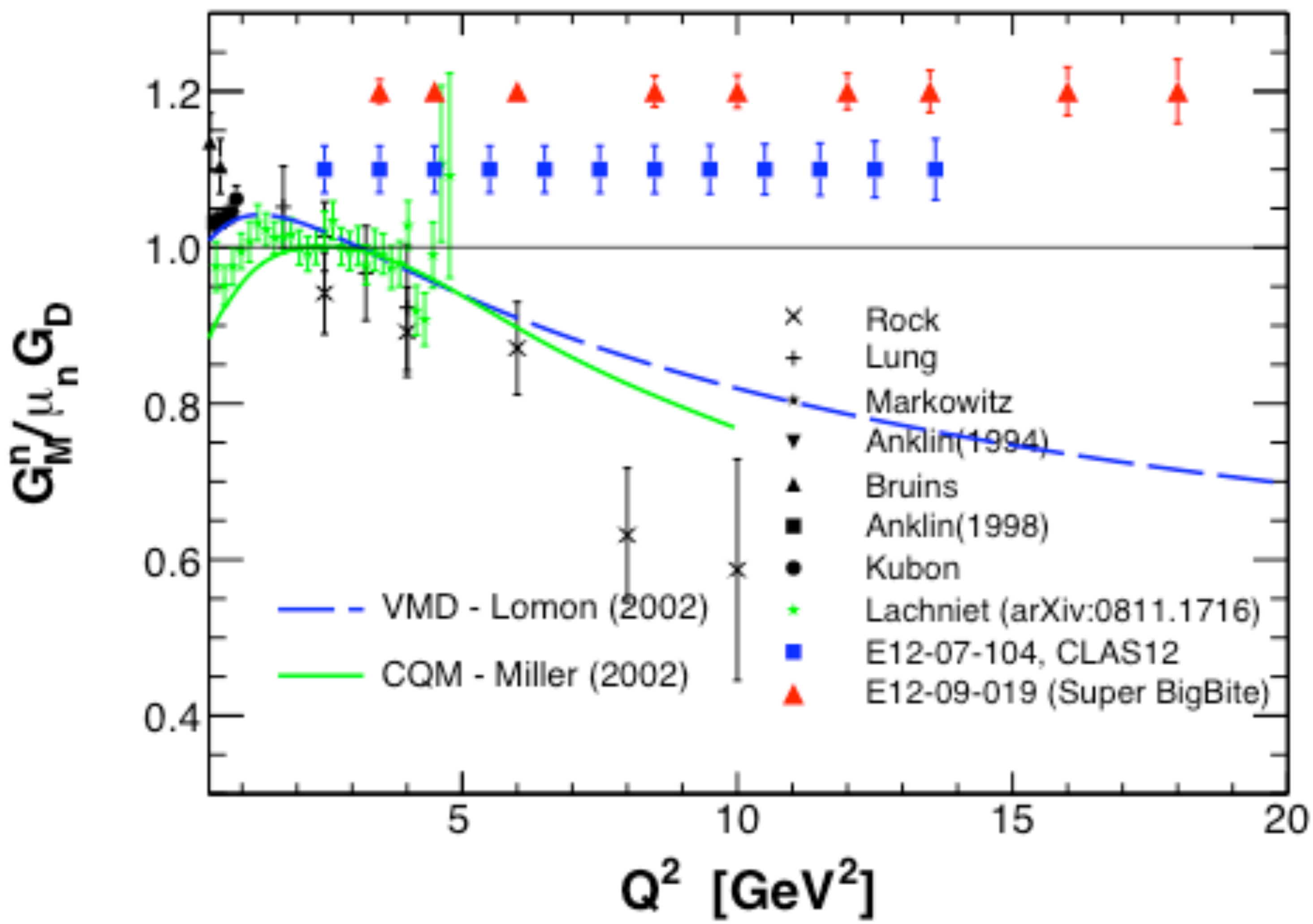
- HV test of all 180 individuals sectors in N2
- Mount the HV divider board and perform full HV test of the chamber
- Move the chamber to EEL124 Clean room at JLab for tests on cosmic stand

SBS-UV-02: Assembly in clean room almost completed, 3 GEMs glued to the R/O board ➪Next steps:

- cathode and entrance window foil remained to be glued to the chamber
- Complete the assembly with the gas distribution parts mounted
- Take the chamber out and apply the same steps as for SBS-UV-01 to complete assembly
- Two chambers likely to be brought together at JLab to EEL124 Clean room for cosmic test.
  - ✓ Target time for cosmic tests at JLab early February 2021
  - ✓ Would be ready for installation in BB frame early March 2021

SBS-UV-02 in clean room

GMn form factor at high Q^2



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2012 DOE fund SBS+GEM+CDET
2019 BigBite calorimeter; Timing Hodoscope (Cal State LA, Glasgow)
2020 College W&M joined INFN GEM preparation
2021 October start of GMn commissioning
2022 February 8 GMn data taking were completed

System experts

- **Design** – Robin’s team
- Hall A – Jessie’s team, HRS-L (Bob+Maria)
- Magnets – Jessie’s team + Jack’s team
- Beam line – Jessie’s team + D. Flay
- Target – Dave+
- DAQ - Alex+; Mark+; CPU - Ole/Bob
- GEM – INFN, UVa, HU, JLab, W&M
- HCAL – CMU, Scott, Sebastian
- BBcal – Arun, Provakar
- Timing Hodo – Glasgow + JLab
- GRINCH – W&M
- **DATA analysis** – Andrew+

Run coordination

- SBS webpage, Albert/St.MU/Temple/Brad
- Lead coordinator – Donald Jones
  - David Flay
  - Paul King
  - William Henry
  - Eric Fuchey
  - Mark-Macrae Dalton
  - Andrew Puckett
  - Brad Sawatzky
  - Xinzhan Bai
  - Eric King
  - Brian Quinn
  - Bogdan Wojtsekhowski
  - Caryn Palatchi
  - Kondo Gnanvo
  - Arun Tadepalli

Data taking shift crew

- The College of William and Mary; Kate Evans – 60 shifts; Maria Satnik - 43.5
- University of Virginia, Charlottesville, VA

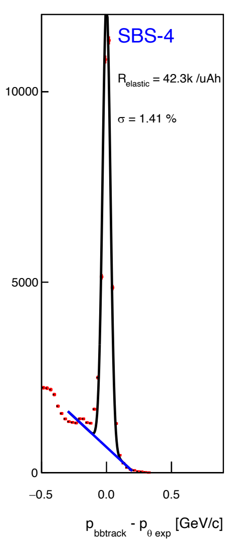
Name	Institution	Number of Shifts	Number of
Devi Adhikari	Idaho State University, Pocatello, ID	12	12
Salina Ali	University of Virginia, Charlottesville, VA	12	13.5
Konrad Aniol	California State University , Los Angeles, CA	5	7.5
John Arrington	Lawrence Berkeley Laboratory, Berkeley, CA	9	9
Todd Averett	The College of William and Mary, Williamsburg, VA	6	6
Carlos Ayerbe Gayoso	The College of William and Mary, Williamsburg, VA	7	10
Xinzhan Bai	University of Virginia, Charlottesville, VA	20	22.5
Scott Barcus	College of William and Mary	9	10
John Boyd	University of Virginia, Charlottesville, VA	12	12.5
Alexandre Camsonne	Jefferson Lab	4	5.5
Jian-Ping Chen	Thomas Jefferson National Accelerator Facility, Newport News	10	10
Cameron Cotton	University of Virginia, Charlottesville, VA	8	10.5
Silviu Covrig Dusa	Jefferson Lab	10	10
Mark-Macrae Dalton	Jefferson Lab	9	9
Provakar Datta	University of Connecticut, Storrs, CT	14	14.5
Pavel Degtiarenko	Jefferson Lab	2	2
Sarashowati Dhital	Hampton University , Hampton, VA	8	11.5
Vassu Doomra	Stony Brook, State University of New York	10	10
Kate Evans	The College of William and Mary	40	60
David Flay	Jefferson Lab	27	27
Eric Fuchey	University of Connecticut, Storrs, CT	30	39.5
Thir Narayan Gautam	Hampton University , Hampton, VA	11	14.5
Kondo Gnanvo	University of Virginia, Charlottesville, VA	8	8
Ole Hansen	Thomas Jefferson National Accelerator Facility, Newport News	10	10
Vimukthi Haththotuwa Gamage	University of Virginia, Charlottesville, VA	4	5
William Henry	Temple University, Philadelphia, PA	29	29
Tim Holmstrom	Randolph Macon College, Ashland, VA	4	4
Jack Jackson	The College of William and Mary	7	10.5
Sean Jeffas	University of Virginia, Charlottesville, VA	21	23
Donald Jones	Temple University, Philadelphia, PA	16	16
Mark Jones	Thomas Jefferson National Accelerator Facility, Newport News	4	4
Eric King	Syracuse University, Syracuse, NY	13	15.5
Paul King	Ohio University, Athens, OH	14	15.5
Paul King	Ohio University, Athens, OH	14	15.5
Tyler Kutz	Stony Brook, State University of New York	2	2
Nathaniel Lashley-Colthirst	Hampton University , Hampton, VA	23	26
Shujie Li	University of New Hampshire, Durham, NH	1	1
Wenliang Li	University of Regina, Regina, SK , Canada	8	10
Richard Lindgren	University of Virginia, Charlottesville, VA	10	10
Nilanga Liyanage	University of Virginia, Charlottesville, VA	14	14
Ralph Marinaro	Christopher Newport University, Newport News, VA	11	11
Robert Michaels	Thomas Jefferson National Accelerator Facility, Newport News	19	24
Gabriel Niculescu	James Madison University , Harrisonburg, VA	4	4
Michael Nycz	KENT STATE DEPT OF PHYSICS KENT, OHIO	9	10
Caryn Palatchi	University of Virginia, Charlottesville, VA	8	8
Bishnu Pandey	Hampton University , Hampton, VA	11	11
Lubomir Pentchev	Jefferson Lab	6	6
Sachinthani Premathilake	University of Virginia, Charlottesville, VA	10	10
Andrew Puckett	University of Connecticut, Storrs, CT	25	25
Bhasitha Thuthimal Dharmasena Purijjala Lindagawa Gedara	University of Virginia, Charlottesville, VA	4	5
Brian Quinn	Carnegie Mellon University , Pittsburgh, PA	21	23
Anuruddha Rathnayake	University of Virginia, Charlottesville, VA	27	31.5
Ryan Richards	Stony Brook, State University of New York	10	10
Maria Satnik	The College of William and Mary	33	43.5
Brad Sawatzky	Thomas Jefferson National Accelerator Facility, Newport News	8	8
Sebastian Seeds	University of Connecticut, Storrs, CT	14	15.5
Albert Shahinyan	Artem Alikhanian National Laboratory (AANL).	13	17
Manjukrishna Suresh	Hampton University , Hampton, VA	9	11.5
Holly Szumila-Vance	Jefferson Lab	7	7
Arun Tadepalli	Jefferson Lab	13	15.5
Liguang Tang	Jefferson Lab	4	4
Al Tobias	University of Virginia, Charlottesville, VA	7	10
Ezekiel Wertz	The College of William and Mary	15	15
Bogdan Wojtsekhowski	Thomas Jefferson National Accelerator Facility, Newport News	36	39.5
Weizhi Xiong	Syracuse University, Syracuse, NY	5	5
Bradley Yale	University of New Hampshire, Durham, NH	17	17
Weibin Zhang	Stony Brook, State University of New York	11	11

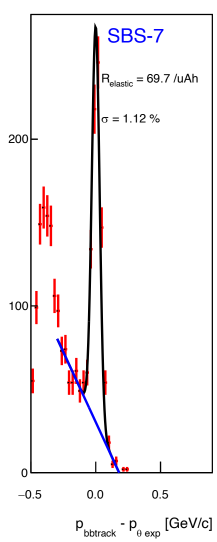
Ph.D. students

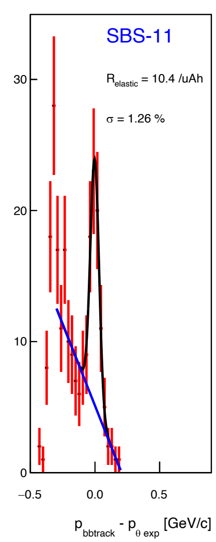
University	Student	Advisor	years in	Experiment	Instrument/subject	Graduation	Physics
W&M	Maria Satnik	Todd Averett		GMn	HRS-L, GRINCH		GMn/GMp, 3 and 10 GeV2
	Ezekiel Wertz	D. Armstrong		GMn	INFN GEMs		GMn/GMp, 10 and 13 GeV2
	Jack Jackson	Todd Averett		GEn-He-3	He-3 target		GEn/GMn, 4 and 7 GeV2
UConn.	S. Seeds	Andrew Puckett		GMn, nTPE	HCAL, DAQ	2023-2024	GMn/GMp, nTPE
	P. Datta	Andrew Puckett		GMn, high Q2	BBcal, DAQ	2023-2024	GMn/GMp, 10 and 13 GeV2
Glasgow	Ralph Marinaro	D. Hamilton		GMn	Timing Hodoscope, analysis		GMn/GMp, all Q2
	Gary Penman	R. Montgomery	2021-2024	GEn-He-3	DAQ, analysis	2024	GEn/GMn, 7 and 10 GeV2
	soon	R. Montgomery		PionALL	DAQ, analysis		ALL for GPD
Hampton U.	N. Lashley-Colthirst	Liguang Tang		GMn	Beam line, SBS-beam	2022	GMn/GMp, all Q2
	M. Suresh	Michael Kohl		GEn-RP	SBS polarimeter		GEn/GMn, all Q2
	Sarashowati Dhital	Michael Kohl		GEn-RP	RP polarimeter		GEn/GMn, all Q2
UVa	John Boyd	N. Liyanage		nTPE	SBS polarimeter	2023	Neutron Rosenbluth, 4.5 GeV2
	Sean Jaffas	N. Liyanage		GEn-He-3	UV GEMs, DAQ	2024	D(e,e'p)/H(e,e'p), all Q2
	Anu Rathnayake	N. Liyanage		GMn	XY GEMs, DAQ	2023	GMn/GMp, all Q2
	Vimukthi Gamage	N. Liyanage		GEp-5 or GEn-RP	XY GEMs, DAQ	2023	GMn/GMp, all Q2
	Bhasitha Dharmasen	N. Liyanage		GEp-5 or GEn-RP	XY GEMs, DAQ	2023	GMn/GMp, all Q2
UVa	Hunter Presley	Gordon Cates		GEn-He-3	He-3 target	2024	GEn/GMn, 2 and 10 GeV2
UVa	Chris Jantzi	Gordon Cates		A1n Hall C	He-3 target development	2022	A1n
Catania	Vanessa Brio	Vincenzo Bellini	2018-2021	HCAL	Design, MC, data analysis	2021	detector, HCAL
	Leonard Re	Evaristo Cisbani	2017-2020	INFN GEM	Construction, commisioning	2020	detector, GEMs

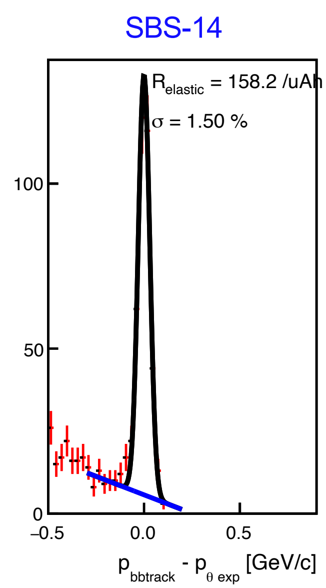
GMn production data

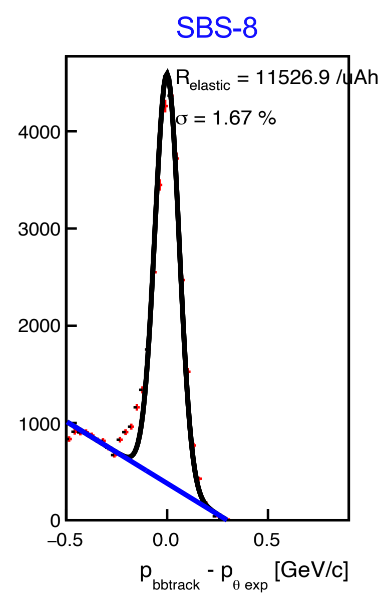
Name	Energy	Program Q2, GeV2	BB angle	BB distance	SBS angle	SBS distance	HCAL angle	HCAL distan.	SBS current % 2100 amp
SBS-1	1.92	Comm. 1	51.0	1.85	33.5	2.25	34.5	13.5	many
SBS-4	3.70	GMn 3.0	36.0	1.80	31.9	2.25	31.9	11	40%
SBS-7	8.00	GMn 10	40.0	1.85	16.1	2.25	16.1	14	80%
SBS-11	9.91	GMn 13.4	42.0	1.55	13.3	2.25	13.3	14.5	100%
SBS-14	6.00	GMn 7.5	46.5	1.85	17.3	2.25	17.3	14	75%
SBS-8	6.00	nTPE 4.5	26.5	2.00	29.9	2.25	29.9	10	
SBS-9	4.03	GMn 4.5	49.0	1.55	22.5	2.25	22.5	10	60%





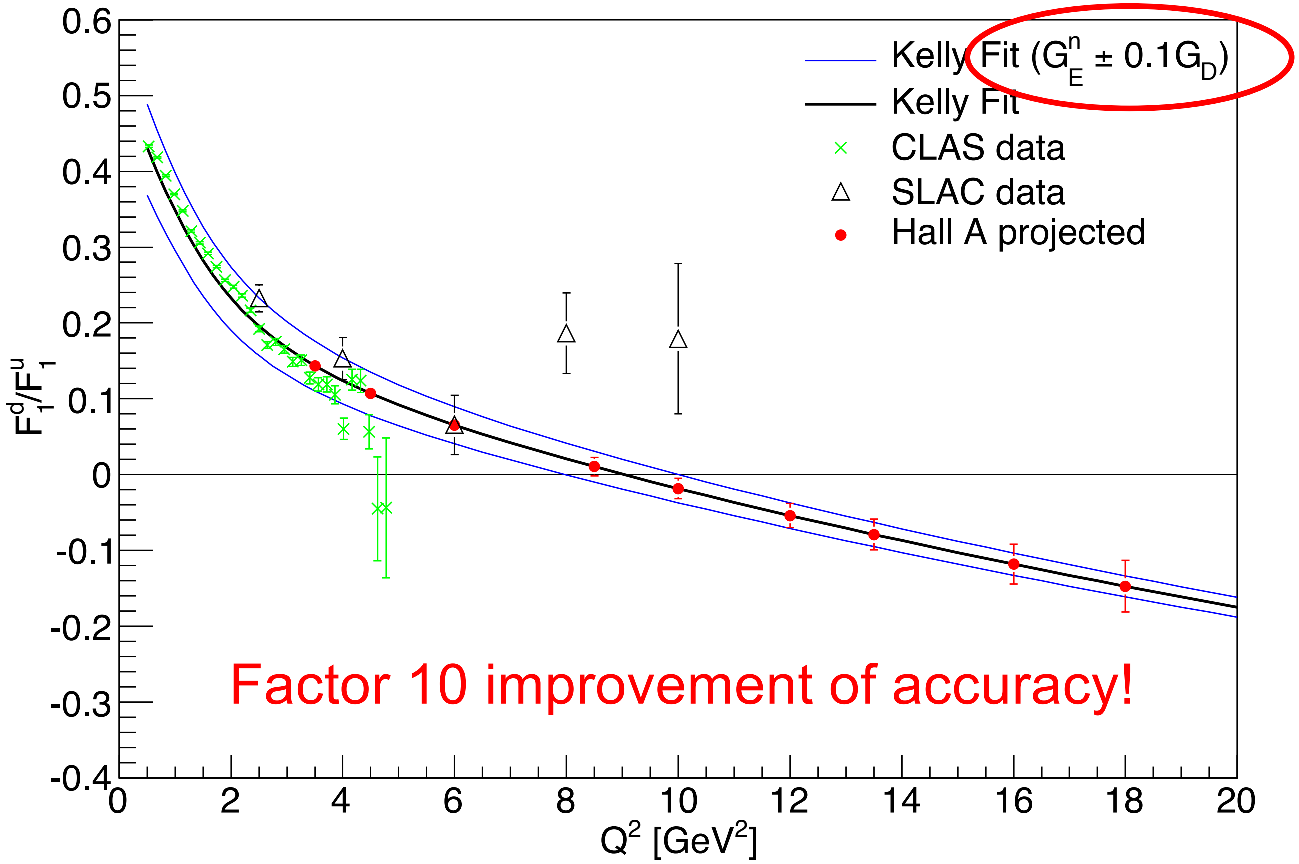






F_1^d/F_1^u form-factor ratio

$$F_1 = \frac{G_E + \tau G_M}{1+\tau} \qquad F_2 = -\frac{G_E - G_M}{1+\tau}$$



Experiments are diamonds

Form Factors are forever