TPE Measurement with SBS

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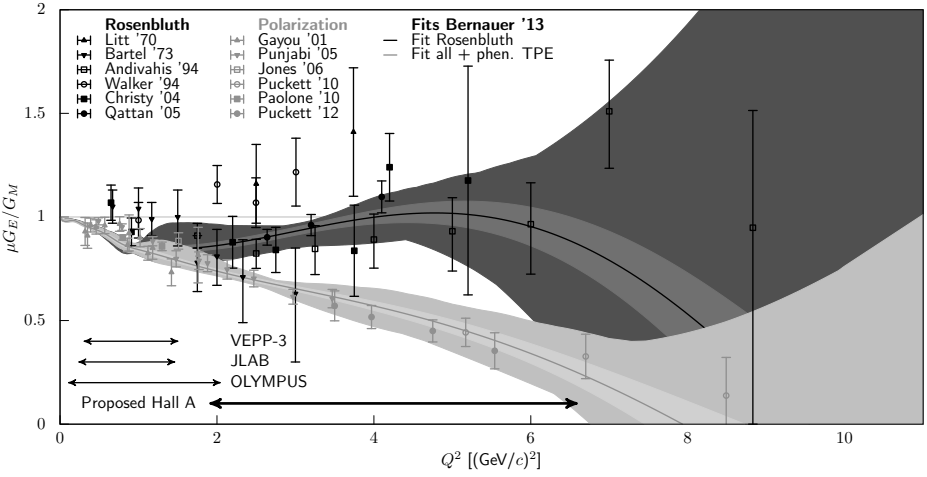
Positron Source at JLab and Whitepaper

- Proposed positron source at JLab
- Several whitepapers written https://arxiv.org/pdf/2007.15081.pdf
- What physics can be done with $e^{\pm}$ at JLab?
- Many ideas, will focus on those involving SBS/BB
- Upcoming topical issue in EPJA

An Experimental Program with Positron Beams at Jefferson Lab

A. Accardi[1-39], A. Afanasev[3], I. Albayrak[41], S.F. Ali[56], M. Amaryan[17], J.R.M. Annand[37], J. Arrington[11], A. Asaturyan[59], H. Avakian[1], T. Averett[57], C. Ayerbe Gayoso[15], L. Barion[32], M. Battaglieri[1,9], V. Bellini[28], F. Benmokhtar[18], V. Berdnikov[56], J.C. Bernauer[20,22], A. Biancon[27,45], A. Bisell[31], M. Boer[29], M. Bondi[9], K.-T. Brinkmann[34], W.J. Briscoe[3], V. Burkert[1], T. Cao[39], A. Camsonne[1], R. Capobianco[21], L. Cardman[1], M. Carmignotto[1], M. Caudron[2], L. Causse[2], A. Celentano[9], P. Chatagnon[2], T. Chetry[15], G. Ciullo[32,33], E. Cline[20], P.L. Cole[24], M. Contalbrigo[32], G. Costantini[27,45], A. D'Angelo[52,53], D. Day[5], M. Defurne[35], M. De Napoli[28], A. Deur[1], R. De Vita[9], N. D'Hose[35], S. Diehl[21,34], M. Diefenthaler[1], B. Dongwi[39], R. Dupré[2], D. Dutta[15], M. Ehrhart[2], L. El-Fassi[15], L. Elouadrhiri[1], R. Ent[1], J. Erler[13,14], I.P. Fernando[39], A. Filippi[55], D. Flay[1], T. Forest[49], E. Fuchey[21], S. Fucini[18], Y. Furletova[1], H. Gao[7], D. Gaskell[1], A. Gasparian[38], T. Gautam[39], F.-X. Girod[21], J. Grames[1], P. Gueye[30], M. Guidal[2], S. Habet[2], D.J. Hamilton[37], O. Hansen[1], D. Hasell[4], M. Hattawy[17], D.W. Higinbotham[1], A. Hobart[2], T. Horn[56], C.E. Hyde[17], H. Ibrahim[36], A. Italiano[28], K. Joo[21], S.J. Joosten[11], N. Kalantarians[20], G. Kalicy[56], D. Keller[5], C. Keppel[1], M. Kerver[17], A. Kim[21], J. Kim[11], P.M. King[23], E. Kinney[26], V. Klimenko[21], H.-S. Ko[2], M. Kohl[19], V. Kozhuharov[8,54], V. Kubarovsky[1], T. Kutz[3,4], L. Lanza[52,53], M. Leali[27,45], P. Lenisa[32,33], N. Liyanage[5], Q. Liu[12], S. Liuti[5], J. Mammei[58], S. Mantry[6], D. Marchand[2], P. Markowitz[44], L. Marsicano[9,10], V. Mascagna[27,45], M. Mazouz[16], M. McCaughan[1], B. McKinnon[37], D. McNulty[49], W. Melnitchouk[1], Z.-E. Meziani[11], M. Mihovilović[43], R. Milner[4], A. Mkrtchyan[59], H. Mkrtchyan[59], A. Movsisyan[32], M. Muhoza[56], C. Muñoz Camacho[2], J. Murphy[23], P. Nadel-Turoński[20], J. Nazeer[39], S. Niccolai[2], G. Niculescu[40], R. Novotny[34], M. Paolone[42], L. Pappalardo[32,33], R. Paremuzyan[29], E. Pasyuk[1], T. Patel[39], I. Pegg[56], C. Peng[11], D. Perera[5], M. Poelker[1], K. Price[2], A.J.R. Puckett[21], M. Raggi[8,19], N. Randazzo[28], M.N.H. Rashad[17], M. Rathnayake[39], B. Raue[44], P.E. Reimer[11], M. Rinaldi[18], A. Rizzo[52,53], J. Roche[23], O. Rondon-Aramayo[5], G. Salmè[51], E. Santopinto[9], R. Santos Estrada[21], B. Sawatzky[1], A. Schmidt[3], P. Schweitzer[21], S. Scopetta[18], V. Sergeyeva[2], M. Shabestari[46], A. Shahinyan[59], Y. Sharabian[1], S. Širca[43], E. Smith[1], D. Sokhan[37], A. Somov[1], N. Sparveris[47], M. Spata[1], S. Stepanyan[1], P. Stoler[21], I. Strakovsky[3], R. Suleiman[1], M. Suresh[39], H. Szumila-Vance[1], V. Tadevosyan[59], A.S. Tadepalli[1], M. Tiefenback[1], R. Trotta[56], M. Ungaro[1], P. Valente[19], L. Venturelli[27,45], H. Voskanyan[59], E. Voutier[2], B. Wojtsekhowski[1], S. Wood[1], J. Xie[11], Z. Ye[25], M. Yurov[5], H.-G. Zaunick[34], S. Zhamkochyan[59], J. Zhang[5], S. Zhang[1], S. Zhao[2], Z.W. Zhao[7], X. Zheng[5], C. Zorn[1]

TPE Measurements



- Proton form factor ratio discrepancy
- Positron source at JLab allows for definitive measurements of TPE
- Measurement of e^+p/e^-p cross sections
- SBS can provide key measurements

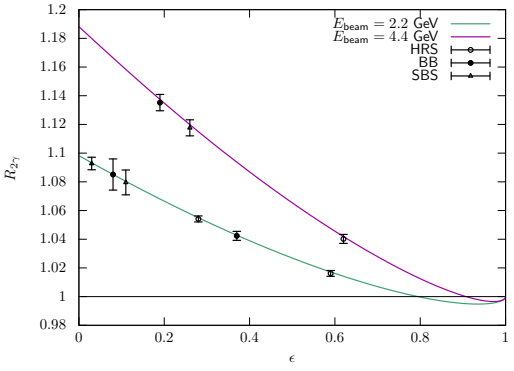
Full Measurement Plan

SBS is used to detect protons, the corresponding lepton angle is given in parentheses

E_{beam}	2.2 GeV			2.2 GeV			4.4 GeV		
Spec. Angles (°)	50	70	**12 (110)**	80	120	**6.2 (140)**	40	80	**15 (70)**
$Q^2[(GeV/c)^2]$	1.9	2.5	**3.1**	2.7	3.2	**3.3**	4.3	6.6	**6.2**
ϵ	0.59	0.37	**0.11**	0.28	0.08	**0.03**	0.62	0.19	**0.26**
Time [day/spec.]	1			2			3		

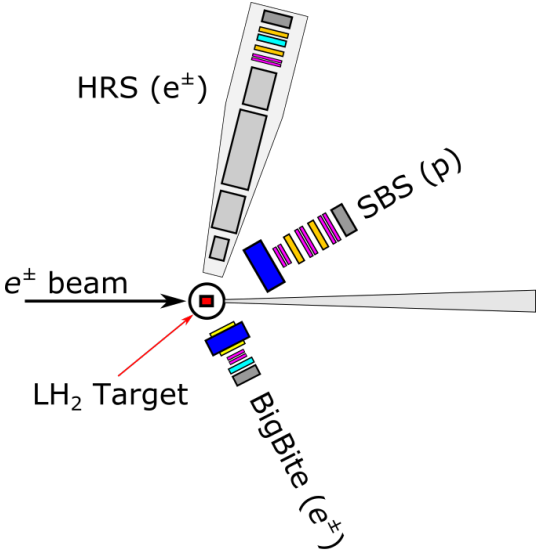
The following table and figures from E. Cline *et al.* "Direct Two-Photon Exchange Measurement via e^+p/e^-p scattering at low ε in Hall A", https://arxiv.org/pdf/2007.15081.pdf

Projected Statistical Uncertainties



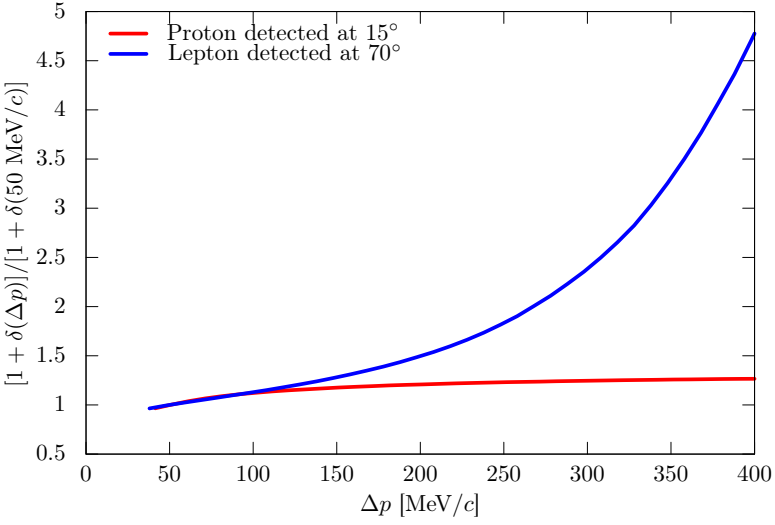
- Measure a small number of data points quickly
- Unpolarized beam, 10 cm long target, 1 μA current
- Cover a wide range of epsilon
- Existing TPE data $\varepsilon > 0.5$
- Not the only possible TPE measurement...

Using SBS as a Proton Detector



- Don't need to change magnetic fields between measurements
- Final state proton radiative corrections are smaller than for $e^{\pm}$
- e^{+} background

Proton Radiative Corrections



Courtesy of Axel Schmidt, using the OLYMPUS generator.

Polarization Transfer Measurements

The following figure and tables from A. J. R. Puckett *et al.*, "Polarization Transfer in $\overrightarrow{e}^{+}p \rightarrow e^{+}\overrightarrow{p}$ Scattering Using the Super BigBite Spectrometer", https://arxiv.org/pdf/2007.15081.pdf

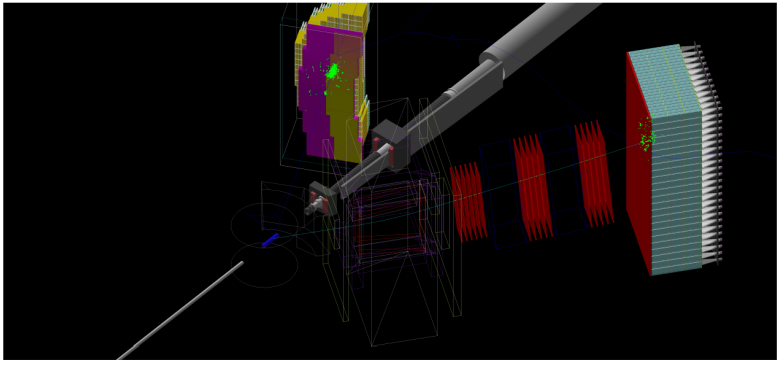


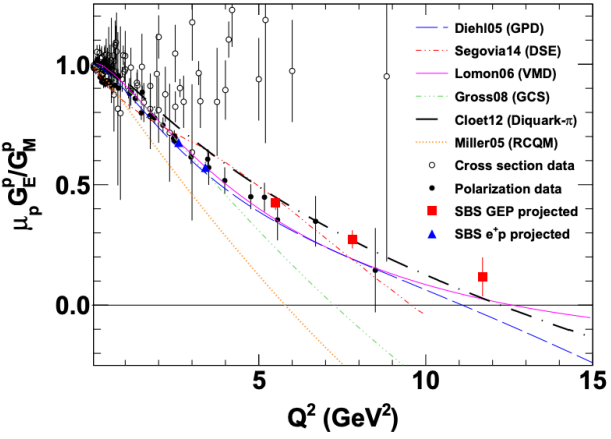
Fig. 41. Screenshot from the GEANT4-based Monte Carlo simulation of the SBS-GEP apparatus, illustrating one elastic $e^{+}p$ event generated within the 40-cm liquid hydrogen target, with the electron detected in the lead-glass calorimeter (located on beam left) and the outgoing polarized proton detected in the SBS on beam right.

Polarization Transfer Measurements

SBS and lead glass calorimeter measurement.

Lepton	E_e GeV	$\langle Q^2 \rangle$ GeV^2	θ_e deg.	$\langle \epsilon \rangle$	θ_p deg.	p_p GeV	Event rate Hz	Days	ΔR (absolute)
e^+	4.4	2.6	27.0	0.84	36.2	2.15	16	30	0.021
e^+	4.4	3.4	32.5	0.76	31.1	2.56	7	60	0.023
e^-	4.4	3.4	32.5	0.76	31.1	2.56	1,050	1	0.01

Polarization Transfer Measurements



- Polarized beam, 200 nA beam, 40 cm target
- Measure a few data points to reconfirm existing data at higher precision
- In conjunction with GEp
- Orthogonal to cross section ratio measurements

Summary

- Proton Form Factor Ratio still unresolved
- e^+ source at JLab a font of interesting physics
- SBS can be utilized to make definitive TPE measurements