SBS Collaboration Meeting July 14, 2020

GMn Status

- Overview
- Scheduling
- Run Plan

Overview

E12-09-019 (GMn)

Precision Measurement of the Neutron Magnetic Form Factor up to $Q^2=13.5$ $(GeV/c)^2$ by the Ratio Method

B. Quinn, J. Annand, R. Gilman, B. Wojtsekhowski
Hall A collab

Approved by PAC 34

PAC 35 allocated 25 of requested 31 days.

What we learn from neutron form factors

Isovector form factor $G_{E/M}^{p} - G_{E/M}^{n}$ insensitive to disconnected quark loops. Ideal test case for lattice-QCD

Model-independent extraction of individual u/d flavor contributions. (assuming s-quark contributions are negligible)

.

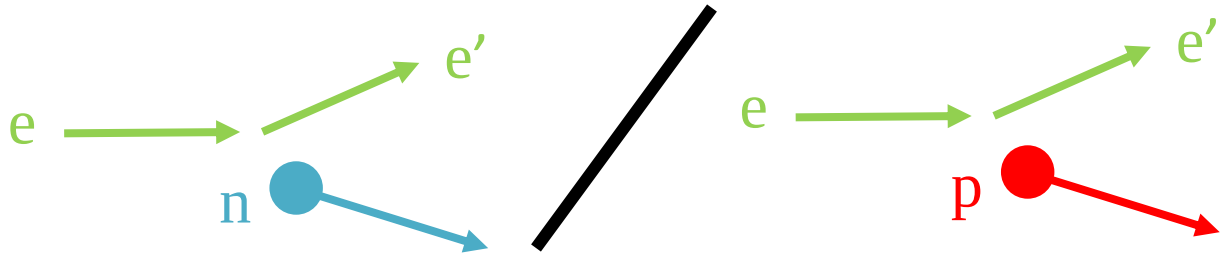
$$\left.\begin{aligned} F_{1,2}^{p} &= \frac{2}{3}F_{1,2}^{u} - \frac{1}{3}F_{1,2}^{d} \\ F_{1,2}^{n} &= \frac{2}{3}F_{1,2}^{d} - \frac{1}{3}F_{1,2}^{u} \end{aligned}\right\} \quad \begin{aligned} F_{1,2}^{u} &= 2F_{1,2}^{p} + F_{1,2}^{n} \\ F_{1,2}^{d} &= F_{1,2}^{p} - 2F_{1,2}^{n} \end{aligned}$$

Separated quark form factors (extracted using all four nucleon form factors) constrain GPDs

$$\int_{-1}^{1} dx\, H^{q}(x,\xi,Q^{2}) = F_{1}^{q}(Q^{2})$$

$$\int_{-1}^{1} dx\, E^{q}(x,\xi,Q^{2}) = F_{2}^{q}(Q^{2})$$

Technique



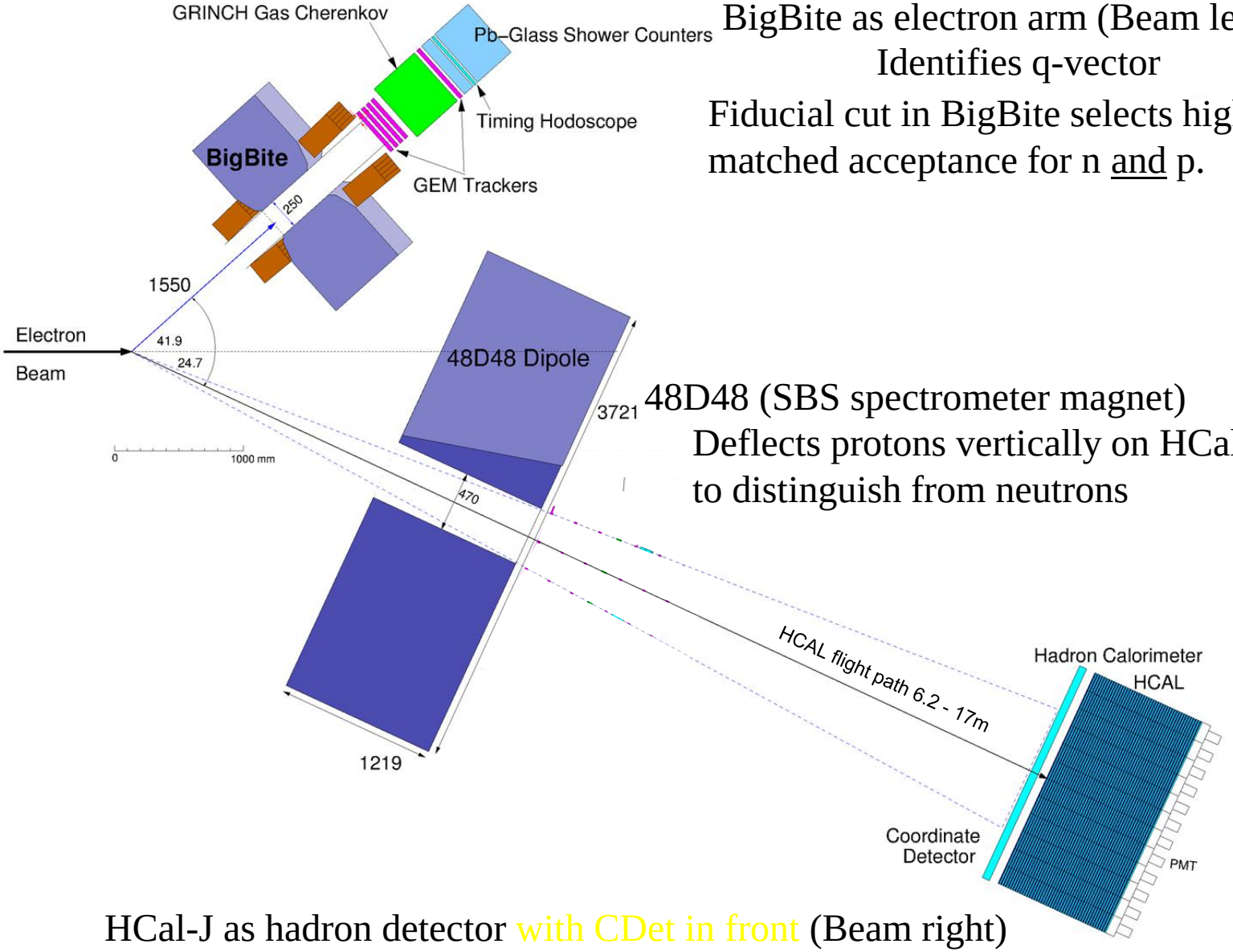
$$R'' = \frac{\left(\frac{d\sigma}{d\Omega}\right)_{d(e,e'n)}}{\left(\frac{d\sigma}{d\Omega}\right)_{d(e,e'p)}} \xrightarrow[\text{corr.}]{\text{nucl.}} \frac{\left(\frac{d\sigma}{d\Omega}\right)_{n(e,e')}}{\left(\frac{d\sigma}{d\Omega}\right)_{p(e,e')}} \xrightarrow{1\gamma} \frac{\eta\frac{\sigma_{\text{Mott}}}{1+\tau}\left(\left(G_E^n\right)^2+\frac{\tau}{\varepsilon}\left(G_M^n\right)^2\right)}{\left(\frac{d\sigma}{d\Omega}\right)_{p(e,e')}}$$

$$\xrightarrow[\text{Electric}]{\text{neutron}} \boxed{R = \frac{\eta\sigma_{\text{Mott}}\frac{\tau/\varepsilon}{1+\tau}\left(G_M^n\right)^2}{\left(\frac{d\sigma}{d\Omega}\right)_{p(e,e')}}}$$

Many systematic effects (experimental and theory) cancel in ratio.

Expect very small correction for Electric because small
form factor and large kinematic weighting of Magnetic

Schematic Experiment Layout



BigBite as electron arm (Beam left)
Identifies q-vector
Fiducial cut in BigBite selects high, matched acceptance for n and p.

48D48 (SBS spectrometer magnet)
Deflects protons vertically on HCal-J to distinguish from neutrons

HCal-J as hadron detector with CDet in front (Beam right)

Scheduling

ERR passed July 2017

Plans for Hall A running:

Aug to mid-Sept? 2020 Complete CREX

2020/21 SBS installation

(During CHL coldbox upgrade)

Fall?? 2021 GMn/GEnRP running

Run Plan

proposed

configuration	Q^2	E_{Beam}	θ_{BB}	θ_{SBS}	d_{BB}	d_{48D48}	48D48 field	Luminosity	dHCal
	$(GeV/c)^2$	(GeV)	(deg.)	(deg.)	(m)	(m)	integral (T-m)	$(10^{38}/A/cm^2/s)$	(m)
1	3.5	4.4	32.5	31.1	1.80	2.00	1.40	0.7	6.2
2	4.5	4.4	41.9	24.7	1.55	2.25	1.70	1.4	6.2
3	6.0	4.4	64.3	15.6	1.55	2.25	0.70	2.8	11
4	8.5	6.6	46.5	16.2	1.55	2.25	1.20	2.8	11
5	10.0	8.8	33.3	17.9	1.75	2.25	1.30	1.4	13
6	12.0	8.8	44.2	13.3	1.55	2.25	1.20	2.8	14
7	13.5	8.8	58.5	9.8	1.55	3.10	0.70	2.8	17
8 & 9	3.5/6.0	calibration of HCal using L-HMS at kinematics of config. 1 &3							

Modified (as of ERR)

configuration	Q^2	E_{Beam}	θ_{BB}	θ_{SBS}	d_{BB}	d_{48D48}	48D48 field	Luminostiy	dHCal
	$(GeV/c)^2$	(GeV)	(deg.)	(deg.)	(m)	(m)	integral (T-m)	$(10^{38}/A/cm^2/s)$	(m)
1	3.5	4.4	32.5	31.1	1.80	2.00	1.71	0.7	7.2
2	4.5	4.4	41.9	24.7	1.55	2.25	1.71	1.4	8.5
3	5.7	4.4	58.4	17.5	1.55	2.25	1.71	2.8	11
4	8.1	6.6	43.0	17.5	1.55	2.25	1.65	2.8	11
5	10.2	8.8	34.0	17.5	1.75	2.25	1.60	1.4	11
6	12.0	8.8	44.2	13.3	1.55	2.25	1.50	2.8	14
7	13.5	11.0	33.0	14.8	1.55	3.10	0.97	2.8	17
			$\theta_{L\text{-}HRS}$						
8	6.06	4.4	61.1,64.3	14.8		3.10	1.71	0.93	17
			67.5,70.7						
9	4.4	4.4	39.,42.	25.5		3.10	1.71	0.93	17

Run Plan

proposed

configuration	Q^2	E_{Beam}	θ_{BB}	θ_{SBS}	d_{BB}	d_{48D48}	48D48 field	Luminosity	dHCal
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3	6.0	4.4	64.3	15.6	1.55	2.25	0.70	2.8	11
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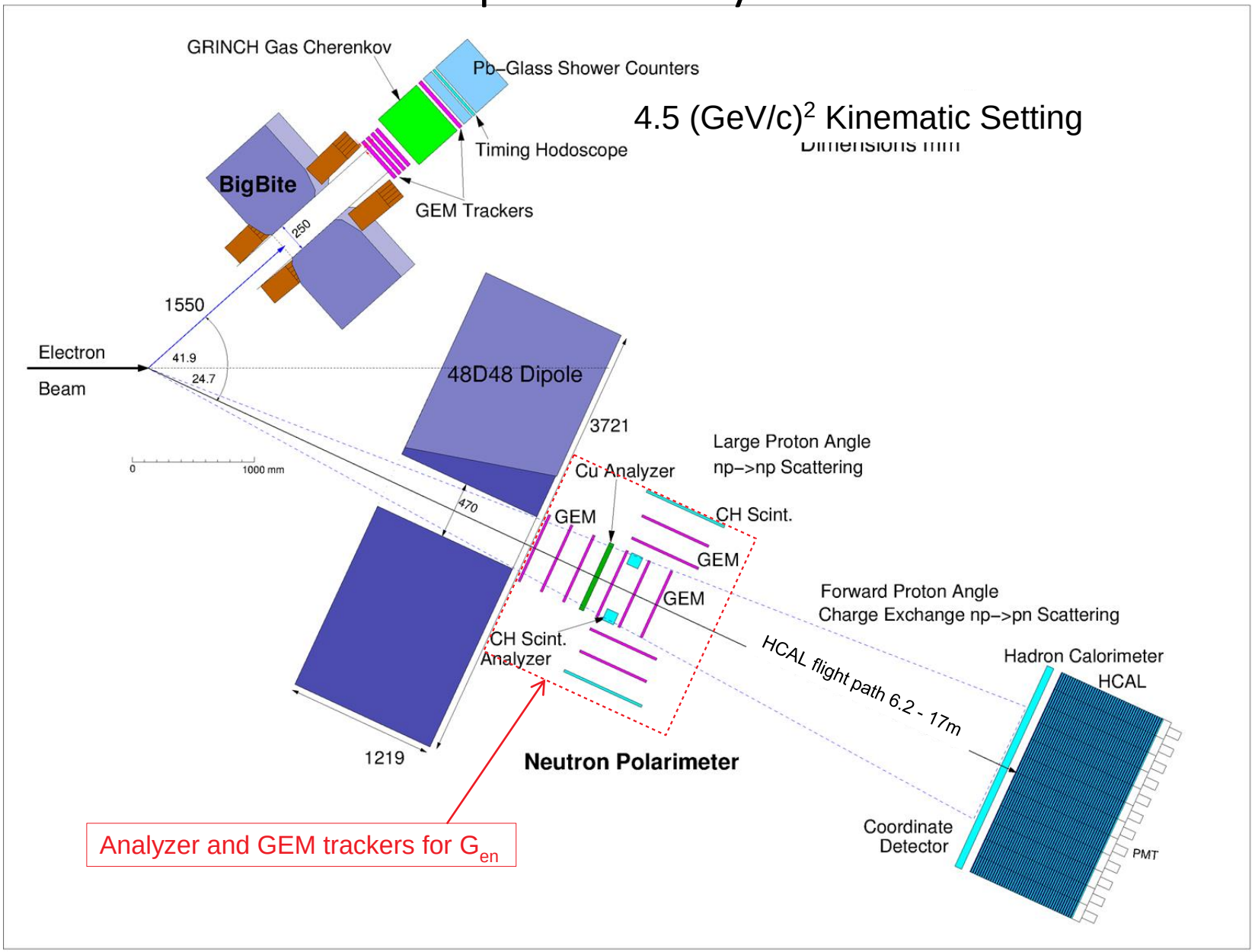
	$(GeV/c)^2$	(GeV)	(deg.)	(deg.)	(m)	(m)	integral (T-m)	$(10^{38}/A/cm^2/s)$	(m)
1	3.5	4.4	32.5	31.1	1.80	2.00	1.71	0.7	7.2
GEnRP → 2	4.5	4.4	41.9	24.7	1.55	2.25	1.71	1.4	8.5
3	5.7	4.4	58.4	17.5	1.55	2.25	1.71	2.8	11
4	8.1	6.6	43.0	17.5	1.55	2.25	1.65	2.8	11
5	10.2	8.8	34.0	17.5	1.75	2.25	1.60	1.4	11
6	12.0	8.8	44.2	13.3	1.55	2.25	1.50	2.8	14
7	13.5	11.0	33.0	14.8	1.55	3.10	0.97	2.8	17
			$\theta_{L\text{-}HRS}$						
8	6.06	4.4	61.1,64.3	14.8		3.10	1.71	0.93	17
			67.5,70.7						
9	4.4	4.4	39.,42.	25.5		3.10	1.71	0.93	17

Schematic Experiment Layout with GEnRP



Run Plan (Jan 2020)

Plan to optimize GEnRP/GMn changeover (removal of downstream SBS field clamp)

configuration	Q^2	E_{Beam}	θ_{BB}	θ_{SBS}	d_{BB}	d_{48D48}	48D48 field	Luminostiy	dHCal
	$(GeV/c)^2$	(GeV)	(deg.)	(deg.)	(m)	(m)	integral (T-m)	$(10^{38}/A/cm^2/s)$	(m)
GEnRP → 2	4.5	4.4	41.9	24.7	1.55	2.25	1.71	1.4	8.5
1	3.5	4.4	32.5	31.1	1.80	2.00	1.71	0.7	7.2
3	5.7	4.4	58.4	17.5	1.55	2.25	1.71	2.8	11
4	8.1	6.6	43.0	17.5	1.55	2.25	1.65	2.8	11
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7	13.5	11.0	33.0	14.8	1.55	3.10	0.97	2.8	17
			$\theta_{L\text{-}HRS}$						
8	6.06	4.4	61.1,64.3	14.8		3.10	1.71	0.93	17
			67.5,70.7						
9	4.4	4.4	39.,42.	25.5		3.10	1.71	0.93	17

Calibration: Elastic p(e,e'p) (SBS magnet on/off)
$p(\gamma,\pi^+n)$ near Bremsstrahlung endpoint

config	Changes required
	Remove downstream SBS field clamp, GEn analyzer, GEMs
2	
	reposition 48D48, HCal, BigBite
1	
	reposition 48D48, HCal, BigBite
3	
	Energy change, reposition BigBite
4	
	Energy change, reposition BigBite
5	
	reposition 48D48, HCal, BigBite
6	
	reposition 48D48, HCal, HRS , BigBite change beam pipe Energy change
7	
	Energy change/rig out BigBite
8	3 HRS moves (3 degrees each)
	reposition 48D48, HCal, HRS
9	one HRS move (3 degrees)

Total

1 Beam set-up
4 Energy changes
5 SBS 48D48/HCal moves
7 BigBite moves
1 Change of beamline
1 Rig out BigBite
6 lHRS moves

New estimates of background suggest troublesome BigBite single-arm trigger rates for kinematics 1, 2 and 3, mainly due to γ's from π^0 decay.
(This may not have been included in previous trigger rate estimates??)

Provakar Datta & Andrew Puckett:

(Rates for $\mathcal{L}$=2.8 X 10^{38} /A /cm^2/s)

Kin	Q^2	E_{beam}	trigger rate(kHz)	Q.E. rate (Hz)
1	3.5	4.4	9.7	800
2	4.5	4.4	10.2	200
3	5.7	4.4	14.5	20
3'	6.1	6.6	2.8	80
other Q^2's			< 2.2	

First two have high data rates so decreasing luminosity is an easy option.
Replacing kinematic 3 with 3' lowers trigger rate while increasing signal rate (within fiducial cut).
50 hrs of production running time at kin 3 could be reduced by 16 hrs to compensate for two additional energy changes and still increase statistics.

Run Plan (July 2020)

Plan to optimize GEnRP/GMn changeover (removal of downstream SBS field clamp)

configuration	Q^2	E_{Beam}	θ_{BB}	θ_{SBS}	d_{BB}	d_{48D48}	48D48 field	Luminostiy	dHCal
	$(GeV/c)^2$	(GeV)	(deg.)	(deg.)	(m)	(m)	integral (T-m)	$(10^{38}/A/cm^2/s)$	(m)
GEnRP → 2	4.5	4.4	41.9	24.7	1.55	2.25	1.71	1.4	8.5
3'	**6.1**	**6.6**	**30.5**	**24.7**	**1.85**	**2.25**	**1.71**	**2.8**	**8.5**
1	3.5	4.4	32.5	31.1	1.80	2.00	1.71	0.7	7.2
4	8.1	6.6	43.0	17.5	1.55	2.25	1.65	2.8	11
5	10.2	8.8	34.0	17.5	1.75	2.25	1.60	2.8	11
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7	13.5	11.0	33.0	14.8	1.55	3.10	0.97	2.8	17
			$\theta_{L\text{-}HRS}$						
8	6.06	4.4	61.1,64.3	14.8		3.10	1.71	0.93	17
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Calibration: Elastic p(e,e'p) (SBS magnet on/off)
p(γ,π^+n) near Bremsstrahlung endpoint

config	Changes required
	Remove downstream SBS field clamp/ remove GEn analyzer. Remove GEMs in acceptance????
2	
	reposition BigBite
3’	
	reposition SBS, HCal, BigBite
1	
	Energy change, reposition SBs, HCal, BigBite
4	
	Energy change, reposition BigBite
5	
	reposition SBS, HCal, BigBite
6	
	reposition SBS, HCal, HRS , BigBite change beam pipe Energy change
7	
	Energy change/rig out BigBite, move lHRS
8	3 lHRS moves (3 degrees each)
	reposition SBS, HCal, lHRS
9	one HRS move (3 degrees)

Total

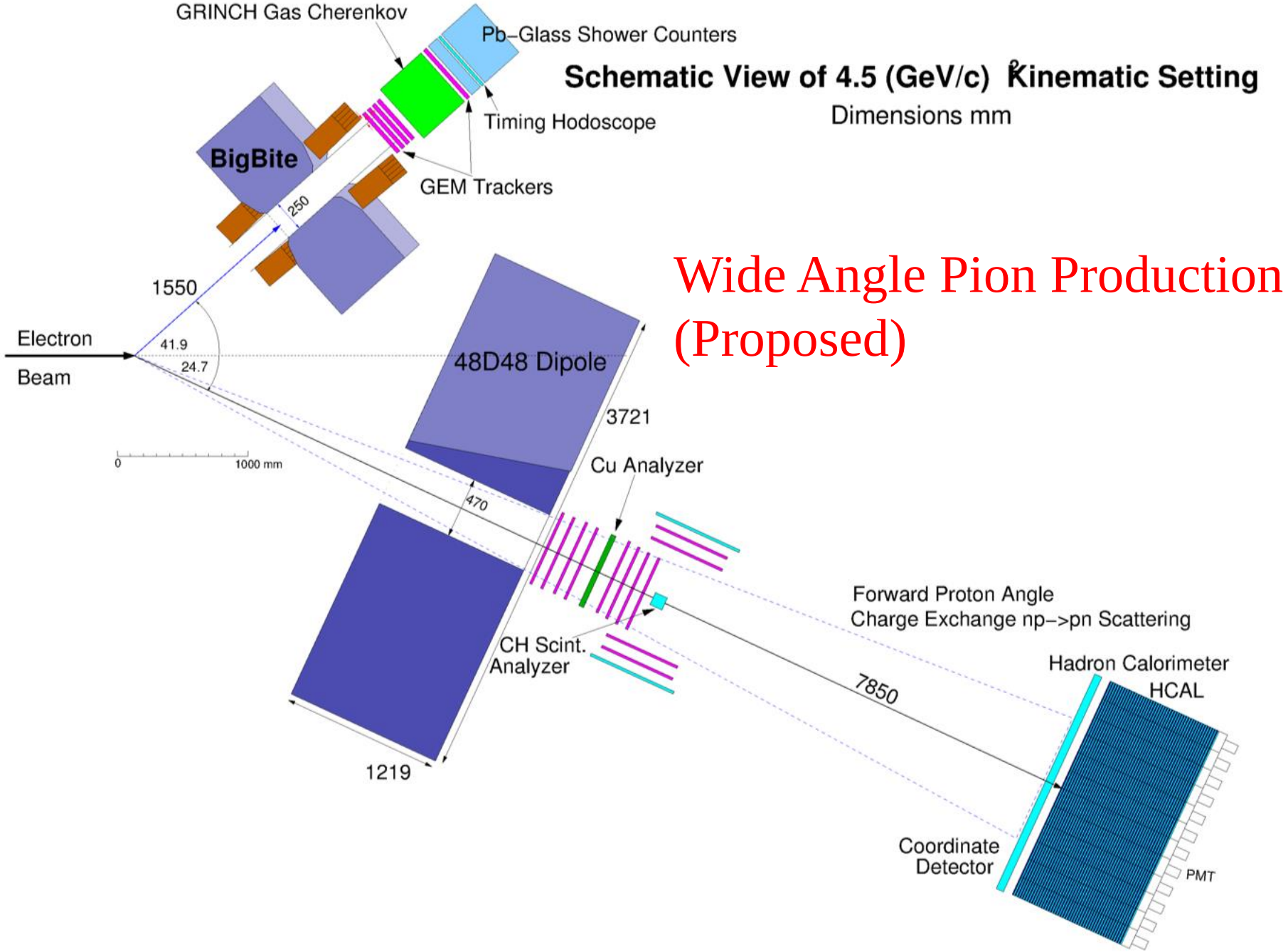
1 Beam set-up
6 Energy changes
5 SBS / HCal moves
7 BigBite moves
1 Change of beamline
1 Rig out BigBite
6 lHRS moves

TPE Proposal

Use $Q^2 = 4.5$ data taken for GMn at kinematics 2
(4.4 GeV $\theta_{BB} = 41^\circ$)

Also take $Q^2 = 4.5$ data at 6.6 GeV $\theta_{BB} = 23.2^\circ$)

Use e dependence of cross-section ratio to extract
σ^n_L / σ^n_T



Wide Angle Pion Production (Proposed)

Run Plan (July 2020 with TPE &WAPP)

configuration	Q^2	E_{Beam}	θ_{BB}	θ_{SBS}	d_{BB}	d_{48D48}	48D48 field	Luminostiy	dHCal
	$(GeV/c)^2$	(GeV)	(deg.)	(deg.)	(m)	(m)	integral (T-m)	$(10^{38}/A/cm^2/s)$	(m)
GEnRP → 2 (&TPE)	4.5	4.4	41.9	24.7	1.55	2.25	1.71	1.4	8.5
WAPP		6.6	41.9	24.7		2.25			8.5
3'	**6.1**	**6.6**	**30.5**	**24.7**	**1.85**	**2.25**	**1.71**	**2.8**	**8.5**
TPE	4.5	6.6	23.2	31.1	1.80	2.00			7.2
1	3.5	4.4	32.5	31.1	1.80	2.00	1.71	0.7	7.2
4	8.1	6.6	43.0	17.5	1.55	2.25	1.65	2.8	11
5	10.2	8.8	34.0	17.5	1.75	2.25	1.60	2.8	11
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7	13.5	11.0	33.0	14.8	1.55	3.10	0.97	2.8	17
			$\theta_{L\text{-}HRS}$						
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$p(\gamma,\pi^+n)$ near Bremsstrahlung endpoint

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	Remove downstream SBS field clamp/ remove GEn analyzer. Remove GEMs in acceptance????
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	reposition BigBite
3’	
	reposition SBS, HCal, BigBite
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	Energy change, reposition SBs, HCal, BigBite
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5	
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6	
	reposition SBS, HCal, HRS , BigBite change beam pipe Energy change
7	
	Energy change/rig out BigBite, move lHRS
8	3 lHRS moves (3 degrees each)
	reposition SBS, HCal, lHRS
9	one HRS move (3 degrees)

Total

1 Beam set-up
6 Energy changes
5 SBS / HCal moves
7 BigBite moves
1 Change of beamline
1 Rig out BigBite
6 lHRS moves

Summary

Run plans can accommodate GEn-RP, TPE, and WAPP without additional movement of SBS/HCal.

Single-arm trigger rates should be tolerable, for all Q^2 points, with reduced beam current at lowest Q^2 points.

Extra time for energy changes can be absorbed by reduced running time on kinematic 3' with higher QE rate.