GMN/NTPE Analysis Update

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William & Mary



SBS weekly meeting, August 21st 2024



Reminder: GMN/NTPE

• GMN: E12-09-019 (A. Camsonne, B. Quinn, B. Wojteskhowski)

 \square simultaneous *en/ep* measurement on D_2

 \square Separation of p and n with SBS

 $\Box \sigma_{en} / \sigma_{en}$ with reduced systematics (cancellation of Fermi momentum,...)



Reminder: GMN/NTPE

• NTPE: E12-20-010 (E.F., S. Alsalmi, B. Wojteskhowski)

 \Box measurement of σ_{en}/σ_{en} at two beam energies, Q² = 4.5 GeV²

a neutron Rosenbluth slope;

D NTPE = Discrepancy between neutron Rosenbluth slope and polarization data



Status as of February 21st

Since *last update*:

- Method of evaluation of n/p ratio established;
- Method of extraction of physics from n/p provided;
- Pass 2 data ready;
- Pending items as of February 21st;

 = estimation of systematics from inelastic background;

estimation of n/p stability over selection cuts;

account for HCAL non-uniformity; estimation of systematics;

a extraction of observables with all systematic uncertainties;

Subtraction of inelastic background

- Three methods for inelastic background estimation/subtraction:
 - \Box 1) Combined fit quasi-elastic(gauss) + inelastic (pol2) of the Δx distribution;

2) Estimation of background with anti-selection of nucleon (out-of-time)

a 3) Inelastic MC generation with Christy-Bosted model;

SBS7, analysis credit <u>*A. Rathnayake*</u>: Induced systematic uncertainty ~0.9%



SBS14, analysis credit <u>P. Datta</u>: Induced systematic uncertainty ~1.2% SBS11: 3.5% (not shown here)

p Cross-section from: Ye et all, 2017 GEn from: Ye et all, 2017

R w/ MC bg. : 1.095 +/- 0.010 -> GMn/muGD: 0.8968
 R w/ data bg : 1.108 +/- 0.010 -> GMn/muGD: 0.9022
 R w/ poly. bg. : 1.112 +/- 0.010 -> GMn/muGD: 0.9039

n/p ratio stability over selection cuts



n/p ratio stability over selection cuts

- n/p ratio stability over several cuts:

 ^D W²;
 ^D E_{PS}, E_{SH}, E_{HCAL};
 - $\Box t_{HCAL} t_{Shower};$ $\Box \Delta x, \Delta y;$ $\Box fiducial cuts;$
- Analysis credit: <u>A. Rathnayake</u> SBS7









7

08/21/2024

Efficiency uniformity estimated with data (plots/analysis credit: <u>A. Puckett</u>)



• Impact on HCal global detection efficiency:



• Attempt to reproduce non-uniformity with MC [1]:

□ HCal gain in MC digitization: 10⁶;

 \Box Setting gains for red blocks on map: 10³;

 \square Efficiency on LH₂, SBS9 (independent analysis):



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	13 64-6349-12 14.2	14 64-1551-14 1.7.2	15 65-13P0-12 18.3	18 158-1585-14 1.7.3	17 15-13/95-12 1.8.2	18 88-10/95-14 1.9.2	19 61-14/H-13 1.8.3	20 b4-1654-55	21 55-14/5-13 1.10.2	22 65-1815-15 L11.2	23 88-1490-13 1.10.3	24 56-1640-15 111.3
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• Attempt to reproduce non-uniformity with MC [1]:

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□ HCal gain in MC digitization: 10<sup>6</sup>;
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 \square Setting gains for red blocks on map: 10³;

Energy deposit in blocks data Vs MC => needs tuning



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/	100 0145 CD	10 0315-02 L7.0	55 C645 04	66 87 85 C6	60 CB/15 08	65 1145-10	50-02/0 01	60 04/10 03	66 05/15 C6	10 65 CB/15 D7 L11.0	55 1040-09 L10.1	12 06-12/15-11 L11.1
	13 60-1344-12 14.2	14 64-1530-14 172	15 85-1395-12	18 85-1515-14 1.7.3	17 85-1335-12 L8.2	18 88-10/95-14 19.2	19 64-14/8-12 1.8.3	26 64-1654-15	21 58-14/15-13 L10.2	22 85-1895-15 L11.2	23 68-1495-13 1,10,3	24 56-16-15-15 L11.3
	25 E7-0147-00 L6.4	28 57-6337-02	27 67-06/97-04 LE.5	28 57-83/87-06 L7.5	23 67-0817-08	30 67-1167-10 L9.4	31 67-02/7-01 LBS	32 87-04/27-03 19.5	33 67-0047-05 L10.4	34 67-08/7-07 L11.4	35 67-1047-09 L10.6	38 57-1237-11 L11.5
	\$7 68-0148-00 L6.5	38 58-6319-02 17.6	39 65-06%8-04 L6.7	40 58-8745-06 17.7	61 b5-CB/10-05 L8.6	42 60-1143-10 L0.5	43 68-8279-01 LS 7	44 65 0448 03	45 68-05/15-05 L10.5	46 68-08/10-07 L11.6	47 68-1048-09 L10.7	48 58-1279-11 L11.7
	49 68-01-69-00 L6.5	50 16-8338-10 17.8	51 89-08/5-04 16.0	52 18-02-88-08 17.9	53 Ins-CRMs-CR L&A	54 88-1109-10 L0.5	55 N8-02/0-01 L\$ 9	56 19-00-19-03	57 168-05/18-05 L10.5	58 169-CR/18-327 L11.8	59 19-10/0-08 L10/0	60 68-12/8-11 L11.9
	61 67-1342-12 16-10	62 57-153(-14 L7.10	63 68-1348-12 66.11	64 68-1585-14 17.11	65 69-13/9-12 L0.10	66 69-10/9-14 19.10	67 67-1487-13 19.11	68 67-1847-65 19.11	69 68-14/05-13 L10.10	70 65-1898-15 L11.10	71 69-1469-13 L10.11	72 58-16/19-15 L11.11
	73 61-01-61-60 60.0	74 61-8511-50 L1.0	75 61-05/1-84 10.1	76 61-83-11-08 L1.1	77 h1-0871-88 L2.0	78 61-1101-10 63.0	79 61-83/11-01 L2:1	80 61-04/1-03 12.1	81 61-06/11-05 L4.0	82 61-08/1-07 L5.0	83 61-10(1-09 64.1	84 51-12/0-11 L5.1
	85 1:2-01-02-00 1:0.2	10-03372-00 L12	10-05/02-04 L0-3	88 10-83-83-08	8) 117-08/2-08 122	90 1:2-11:02-10 13.2	10-83/0-01 L23	92 112-04/2-03 12.3	93 62-06/12-05 L4.2	94 167-01(12-37 1.5.2	95 h2-10/0-08 L4.3	96 10-12/0-11 15.3
	97 E3-01-03-00 L0.4	98 18-40373-00 11.4	99 H3-06/0-04 L0.5	100 53-80/85-08 L1.5	101 h3-08/3-84 L24	102 83-1193-10 L3.4	103 K8-0395-01 L2.6	104 H3-04P3-03 L3.5	105 63-06/13-08 L4.4	106 10-011/0-07 1.5.4	107 153-1043-08 14.5	108 58-1285-11 L5.0
	119 61-13-11-12 10-8	110 51-1571-14	111 12-13/2-12 10.7	112 12-15/2-14	113 13-13/3-12 1.2/6	114 13-1503-14 13.8	115 61-14/11-13 1,27	116 61-18/1-15 137	117 62-14/12-13 14.6	118 12-18/2-15 1.5.0	119 63-14(13-13 14.7	120 56-16/3-15 1.57
Ľ	121 64-01-94-00 60.5	122 14-63/74-02	123 64-05/14-04 LIC.9	124 04-02/34-08	125 64-03/4-08 12.8	126 64-1164-10 13.5	127 14-0374-01 128	126 64-04/14-03 13.9	120 64-06/74-05 64.0	130 64-08/4-07 65.8	131 64-1064-09 64.9	132 04-12/14-11 1.5.8
L	133 15-0145-00 10.10	134 05-03/15-02 L1-10	535 65-05-04 60.11	136 16-0745-06 11-11	137 55-03/15-08 LZ.10	138 65-1145-10 L3.10	139 16-02/15-01 12:11	140 65:04/15:03 123.11	141 66-09/15-06 64.10	142 65-08/15-07 L5:18	143 65-1045-09 64.11	144 10-12/15-11 15-11
	145	146	147	148	149	150	151	152	163	154	153	156
	L0.0	L1.0	L0.1	L1.1	L3.0	L4.0	L3.1	L4.1	L6.0	LE.D	LSI	LE.1
0	42-01/11-00	a2 03/111-02	a2 05111-04	42-07/11-06	101 12-05/111-08	a2-11/11-10	42-C2T11-01	42 04/11 CB	42.05/111-05	42 CBT 1-07	10/11/09	a2-12/11-11
ō	169 x3-01/12-09 1.014	170 x3-13-112-02	171 x3-05112-04 10.5	172 #3-07/12-08	173 x3-00012-08 1.3-4	174 #3-11/112-10 14.4	175 +3-02/12-01 13.5	178 +01-040/12-031	177 #3405312-05 15.4	178 #3-08312-02 10.4	179 x3-10/12-09 1.5.5	180 x8-12/12-11 UE:5
-	181 a1-13#10-12 L0.6	182 a1-15/110-14 L1.6	185 82-13111-12 L0.7	184 32:16,#11-14 L1.7	185 s3-13/112-12 L3-6	188 a5-15(1)2-14 L4.6	187 at-16/10-13 L3.7	183 a1-16/10-15 L4.7	189 a2-144111-13 L6.6	190 32-16111-15 L6.5	191 53-14112-13 1,57	192 a3-16412-15 L6.7
	180 34 01.013 00 1.0.8	184 54 03/113 02 11.8	185 a4 65113 04 L0.9	196 34 07/13 05 L1.9	187 54 06413 06 138	188 a4 11.713 10 L4.8	198 a4 02/13-01 L3.9	200 p4 04/13 00 L4 9	201 a4 05/13 05 L5.5	202 a4 C0113 07 L6.8	203 54 10113 09 159	204 04 12/13 11 L8.5
	205 #5-01/114-00 L0.10	206 a5-03/114-02 L1.10	207 a5-05114-04 10.11	208 #5-07/14-08 L1.11	209 #5-09/114-08 13:10	210 #5-11/114-10 L4.10	211 45-02/14-01 1.3.11	212 46-04/14-03	213 #5-05/14-05 1.5.10	214 #5-08/14-07 1-6.10	215 15-10/14-09 15.11	216 #5-12/14-11 LH.11
	217 s8-01/15-00 L7.0	218 #8-03/115-02 L0.0	219 #8-05/115-04 L7.1	220 #8-07/15-08 L5.1	221 #8-000115-08 LB.C	222 #8-11/15-10 L10.0	223 #8-02/15-01 L9.1	224 #8-84-115-03 L10.1	225 #5-05/15-05 L11.0	226 x8-(8115-07 L12.0	227 #8-10/15-09 L11.1	228 #8-12/115-11 L12.1
	229 84-13#13-12 L7.2	239 54-15/113-14 L0.2	231 a5-13114-12 L7.3	232 85-15,914-14 L5.3	233 56-13/115-12 L0 2	234 30-15/10-14 L10/2	235 84-14(H3-13 L9.3	238 51-10/10-15 L10.3	237 35-14014-13 L/112	238 35-16314-15 L12.2	238 56-14115-13 L11.3	240 10-10-15-15 L12-3
	241 27-01/16-00 17-4	243 a7-03/116-02 L8.4	243 07-05116-04 L7.5	244 67-07/16-06 L8-5	245 67-05/116-06	245 a7-11.T16-10 L10.4	247 e7-02/16-01 L0.5	248 67-04/16-08 L10.5	249 67-05/116-05 L11_4	250 a7-08/16-07 L12-4	251 87-10/16-09 L11.5	252 e7-12/16-11 L125
	253 68-01/17-00 L7.8	254 a8-03/117-02 L8-6	255 05-05117-04 1.7.7	256 68-07/17-06 LS.7	257 08-00/117-06 L9-6	258 a5-11/17-10 L10/8	259 48-02/17-01 L0.7	260 48-04/117-08 L10.7	261 45-05/117-05 L11.8	262 45-CE117-07 L12-6	263 18-10/17-09 111.7	264 #8-12/17-11 L127
	265 #8+01/115400 L7.0	266 x6-10-118-02 L0.0	267 н9-05118-04 L7:9	268 #9-07/18-08	269 68-06/18-06 18-0	270 #9-11/118-10 L10/8	271 #9-02/18-01 L9-9	272 48-04-118-03 1,10,9	273 #0405318-0:0 L11.0	274 ##-CB3110-82/ L12.8	275 x8-10/15-08	276 #6-12/118-11 L12/8
	277 87-13918-12 17.10	278 x7-15(1)6-14 L8.10	279 a5-15117-12 L7.11	280 #8-18/17-14 L5.11	281 #8-13/16-12 10.10	2012 	283 a7-14/16-13 L3.11	264 st-16/15-15 L10.11	285 a5-14317-13 L11.10	288 a8-16317-15 L12.10	287 x8-14915-13 L11.11	285 16-16-15-15 L12-11

• Attempt to reproduce non-uniformity with MC:

Comparison between n/p ratios with new gain map vs uniform gain;

□ Analysis credit <u>Z. Wertz</u>: 3% increase in n/p ratio for SBS8, 50% SBS field;

□ In progress (other setting give results that remain to be understood);



- Alternate method to work around HCal efficiency non-uniformity: Reweight MC events with HCal non-uniformity map;
 - \Box Map efficiency along x_{expect} , y_{expect} ;
 - \Box weight MC with relative variation efficiency according to x_{expect} , y_{expect} map;
 - used by John for his analysis



- Alternate method to work around HCal efficiency non-uniformity: Reweight MC events with HCal non-uniformity map;
 - \Box Map efficiency along x_{expect} , y_{expect} ;
 - weight MC with relative efficiency variation
 - □ Improvement:
 - Apply same efficiency analysis for data, MC;
 - use ratio of η_{data}/η_{MC} ;
 - has yet to be deployed in analysis;



08/21/2024

GMN/NTPE results

• GMN (all students):

most advanced analysis include statistics and systematics except HCAL detection efficiency

GMN will still benefit from a refined correction of HCal non-uniformity

NTPE: (John, Sebastian, Zeke)
 Existing analyses very preliminary and need independent cross checks

u use very coarse corrections for HCal non-uniformity map

Result featured in John's thesis may change with a more refined correction of HCal non-uniformity;

Summary

• Progress:

□ Inelastic background subtraction nailed down (~1%-3% systematic induced);

Systematic studies of n/p stability;

• Getting to integrate the HCal non-uniformity in the analysis (in progress):

a using MC including non-uniformity effects;

a reweighting MC events with HCal non-uniformity map;

• Next steps:

Converge on HCal non-uniformity corrected analysis

□ Evaluate and propagate systematic;

Derepare publication;

Students status

- •John, Sebastian, Nathaniel, recently graduated (Congrats!);
- Anu, Provakar to graduate within 2-4 weeks;
- Maria, Zeke to graduate within the next 3-6 months;
- A few students may continue the analysis as post-docs;

Back up

Subtraction of inelastic background



Subtraction of inelastic background



Backg. method

20

n/p ratio stability over selection cuts

- R vs W^2 slice mid point n/p ratio stability over several cuts: 0.55 □ W²; 0.5 $\Box \mathsf{E}_{\mathsf{PS}}, \mathsf{E}_{\mathsf{SH}}, \mathsf{E}_{\mathsf{HCAL}};$ 0.45 0.4 $\Box t_{HCAL} - t_{Shower};$ с 0.35 $\Box \Delta x, \Delta y;$ 0.3 □ fiducial cuts; 0.25 0.4 < W^2 < 1.2 0.2
- Analysis credit: <u>A. Rathnayake</u> SBS7

0.378

0.376

0.374

0.37

0.368 0.366

0

0.1

0.2

₢ 0.372

Rvspse min

0.3

Pre-Shower Energy Min

0.4

0.5

0.6

0.7







08/21/2024

• Attempt to reproduce non-uniformity with MC:

08/21/2024

Comparison between n/p ratios with new gain map vs uniform gain;

□ For SBS9: 10% increase in n/p ratio (analysis credit <u>Z. Wertz</u>);

