CLAS Dihadron Measurements

Extracting the Unpolarized Fragmentation Function

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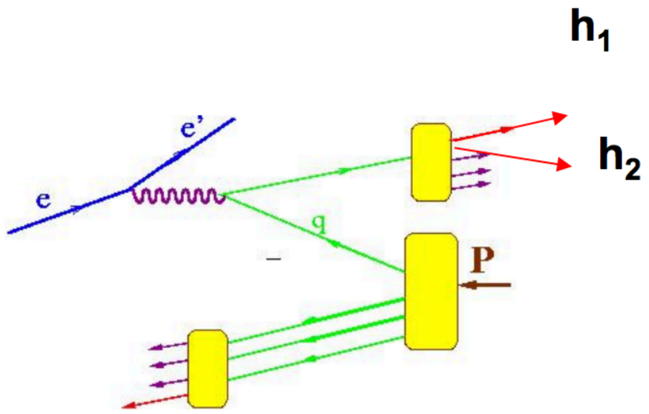
WILLIAM & MARY
CHARTERED 1693

Dihadron Fragmentation Functions

- Similar to single hadron formalism
- Additional degree of freedom (relative momentum) allows for numerous advantages
  - Separate contributions to asymmetries
  - Existence of fragmentation functions with no single hadron correlation



Unpolarized-Unpolarized Cross Section

- D_1, the unpolarized fragmentation function, is multiplied by the well known PDF f_1
- Can be isolated from the ϕ-dependent terms
- Limited data available (Belle e^+e^-), extractions from fitting the single pair distribution functions from MC)

$$
\begin{aligned}
d^9\sigma_{OO} = \sum_a \frac{\alpha^2 e_a^2}{2\pi Q^2 y} \Bigg\{ & \boxed{A(y)\,\mathcal{I}\left[f_1\, D_1\right]} - B(y)\,\frac{|\vec{R}_T|}{M_h}\cos(\phi_h+\phi_R)\,\mathcal{I}\left[\frac{\vec{p}_T\cdot\hat{P}_{h\perp}}{M}\, h_1^{\perp}\, \bar{H}_1^{\triangleleft}\right] \\
& + B(y)\,\frac{|\vec{R}_T|}{M_h}\sin(\phi_h+\phi_R)\,\mathcal{I}\left[\frac{\hat{P}_{h\perp}\wedge\vec{p}_T}{M}\, h_1^{\perp}\, \bar{H}_1^{\triangleleft}\right] \\
& - B(y)\,\cos(2\phi_h)\,\mathcal{I}\left[\frac{2(\vec{p}_T\cdot\hat{P}_{h\perp})(\vec{k}_T\cdot\hat{P}_{h\perp})-\vec{p}_T\cdot\vec{k}_T}{M M_h}\, h_1^{\perp}\, H_1^{\perp}\right] \\
& + B(y)\,\sin(2\phi_h)\,\mathcal{I}\left[\frac{(\vec{p}_T\cdot\hat{P}_{h\perp})(\hat{P}_{h\perp}\wedge\vec{k}_T)+(\vec{k}_T\cdot\hat{P}_{h\perp})(\hat{P}_{h\perp}\wedge\vec{p}_T)}{M M_h}\, h_1^{\perp}\, H_1^{\perp}\right]\Bigg\}
\end{aligned}
$$

Bachetta, Radici. hep-ph/0212300

Motivation for Multiplicity Measurement

- Range in Q^2 allows for many bins to better understand z and $m_{\pi\pi}$ dependence
- Fixing the normalization of D_1 allows it to be used in the extraction of other fragmentation functions
- Study contribution from higher-waves
- No model dependent or phenomenological concerns
- See E12-09-008B, S. Pisano and A. Courtoy

Multiplicities

- Measure the dihadron multiplicities defined by

$$M^h(Q^2, x_B, z, m_{\pi\pi}) = \frac{\sum_q e_q^2 f_1^q(Q^2, x_B) D_1^q(Q^2, z, m_{\pi\pi})}{\sum_q e_q^2 f_1^q(Q^2, x_B)}$$

$$= \frac{d\sigma_{UU}^{\gamma^* N \to (\pi^+\pi^-)X}}{dQ^2 dx_B dz dm_{\pi\pi}} \frac{dQ^2 dx_B}{d\sigma_{UU}^{\gamma^* N \to X}}$$

$$= \frac{N^{DH} / \Delta Q^2 \Delta x_B \Delta z \Delta m_{\pi\pi}}{N^{DIS} / \Delta Q^2 \Delta x_B}$$

Event Generator

- Stephen Gliske (HERMES) developed object-oriented generator "TMDGen"
- Includes SIDIS dihadron models for angular dependence
- No beam polarizations or longitudinally polarized target cross sections programmed for dihadrons

Distribution Functions	Model Identifier
f_1	CTEQ [74]
f_1	LHAPDF [75]
f_1	BCR08 [76]
f_1	GRV98 [77]
g_1	GRSV2000 [78]
f_{1T}, $h_{1T}^{\perp}$, h_1	Torino Group [79, 80, 81, 82, 83]
f_1, g_1, g_{1L}, g_{1T}, f_{1T}, h_1, $h_1^{\perp}$, $h_{1T}^{\perp}$	Pavia Spectator Model [31]

Table 3.1: Models of distribution function available in `TMDGen`.

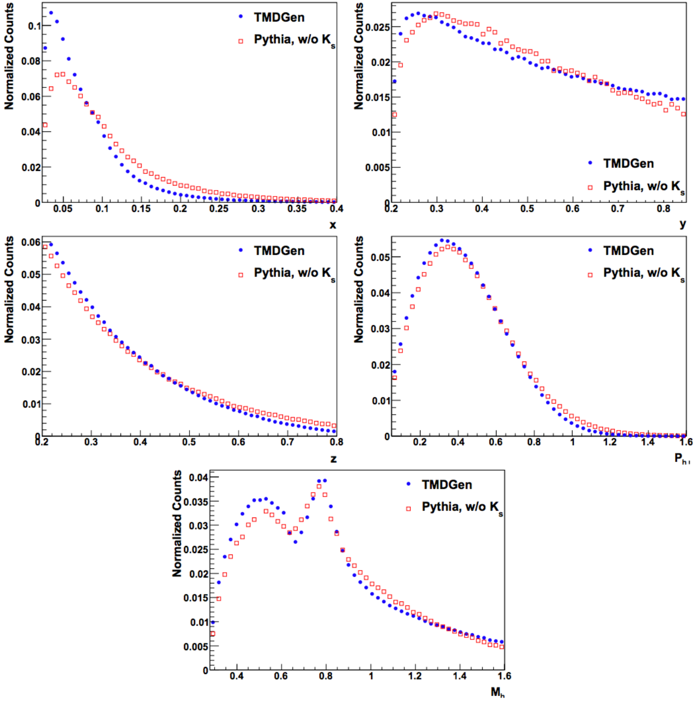
Frag. Functions	Final State	Model Identifier
D_1	pseudo-scalar	fDSS [84, 85]
D_1	pseudo-scalar	Kretzer [86]
D_1, $H_1^{\perp}$	dihadron	Spectator Model (Section 2.4)
D_1, $H_1^{\perp}$	dihadron	Set given partial wave proportional to any other partial wave

Table 3.2: Models of fragmentation function available in `TMDGen`.

Gliske thesis (HERMES)

Event Generator

- Gliske comparisons between Pythia and TMDGen for e' $\pi^+\pi^-$X



[Gliske thesis (HERMES)]

Configurations and Channel Selection

CLAS software

gemc 4a.2.3

coatjava-5c.3.4

Configurations

Torus +1.0

Solenoid -1.0

Runs analyzed: 3222, 3973 and 3975, ~ 2300 files

Channel Selection

DIS

$Q^2 > 1.0\ GeV^2$

$W > 2.0\ GeV$

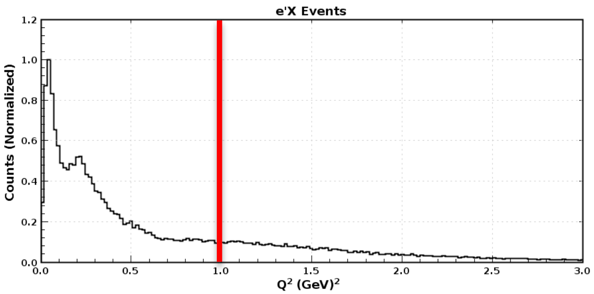
SIDIS

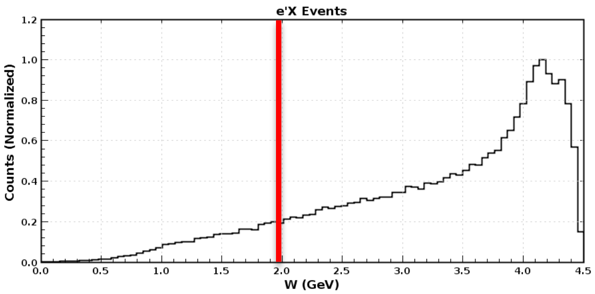
$m_X > 1.05\ GeV$

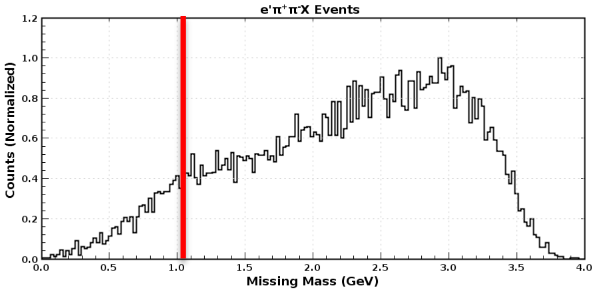
Particles

EventBuilder

Highest energy e', π^+, π^-

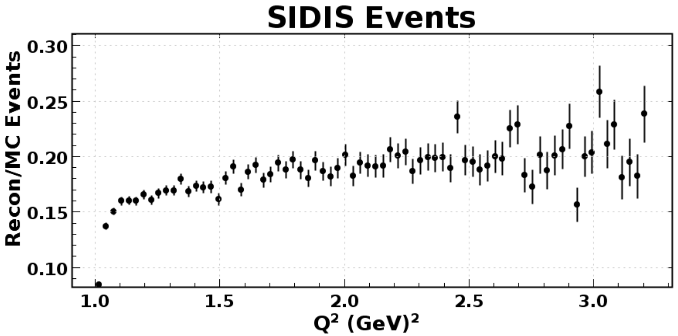


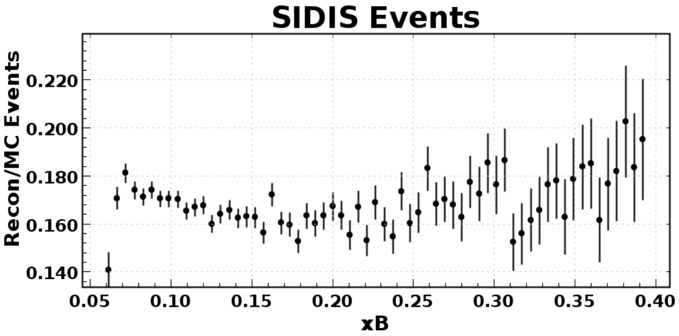


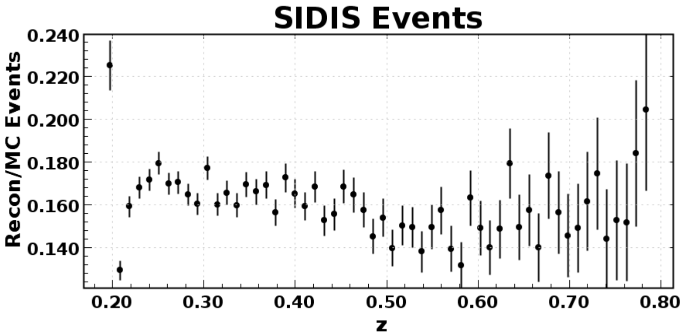


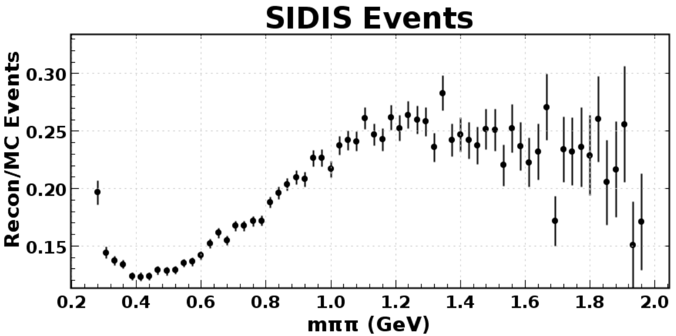
CLAS Acceptance Analysis

- Reconstructed rate for Q^2, x_B, z and $m_{\pi\pi}$ with +1.0/-1.0 configuration





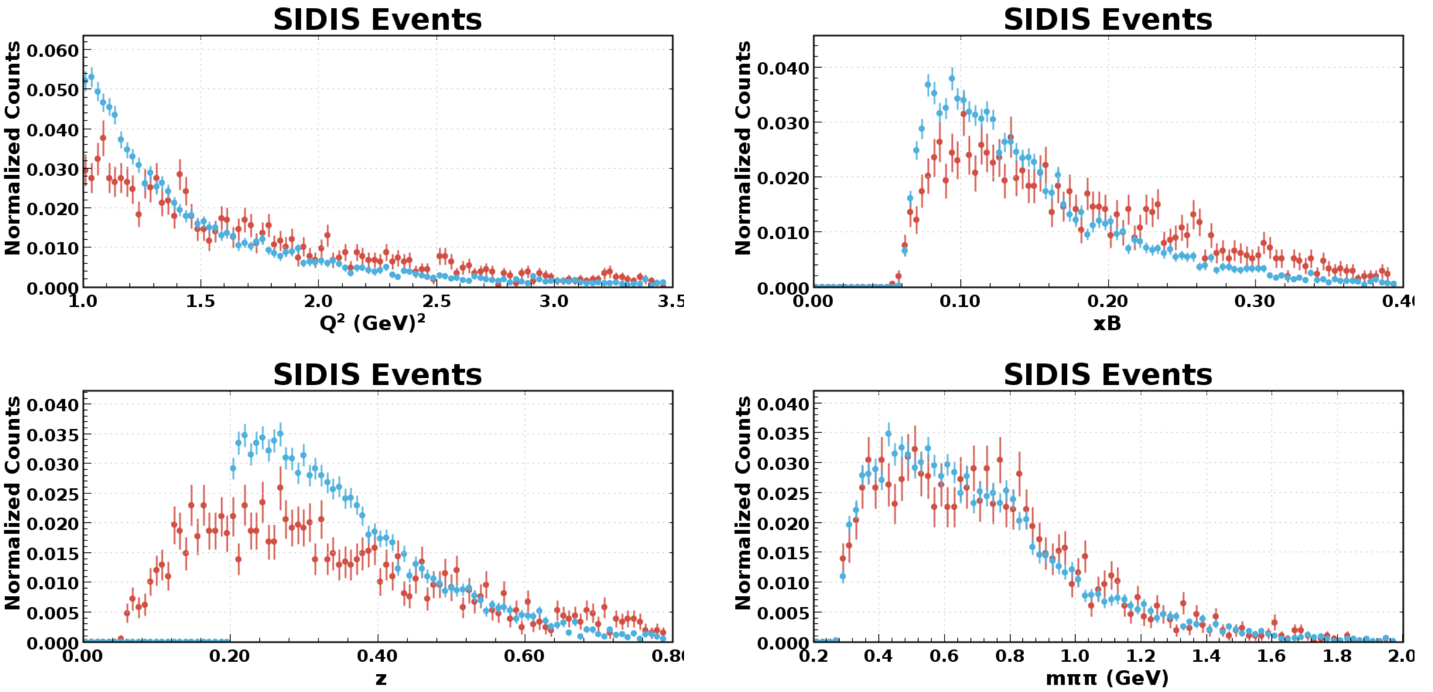




Monte Carlo Comparison with SIDIS Data

- 3 files chosen at random from run 3222

Event Generator
Experimental



Bin Limits

- Q^2 limits chosen by evaluating the effects from the evolution of f_1
- x_B and z bins chosen for statistics
- $m_{\pi\pi}$ chosen from two-pion spectra, avoiding bins centered in meson resonances
- Again, see E12-09-008B, S. Pisano and A. Courtoy

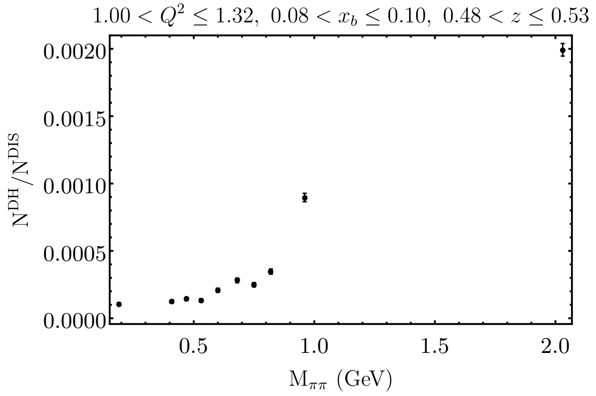
Q^2 bin	min (GeV^2)	max(GeV^2)
1	1.0	1.32
2	1.32	1.65
3	1.65	2.09
4	2.09	2.86
5	2.86	11.0

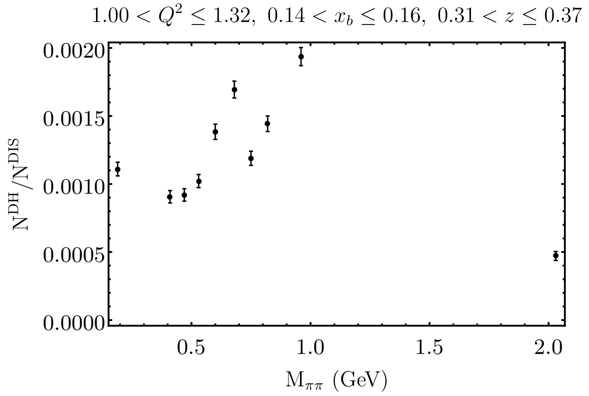
x_B bin	min	max
1	0.0	0.08
2	0.08	0.1
3	0.1	0.12
4	0.12	0.14
5	0.14	0.16
6	0.16	0.19
7	0.19	0.22
8	0.22	0.26
9	0.26	0.31
10	0.31	0.8

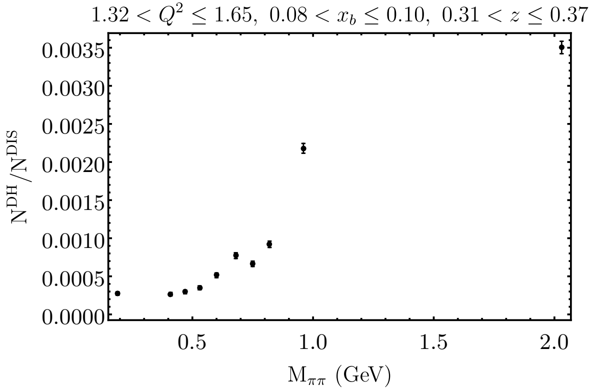
z bin	min	max
1	0.0	0.31
2	0.31	0.37
3	0.37	0.43
4	0.43	0.48
5	0.48	0.53
6	0.53	0.58
7	0.58	0.63
8	0.63	0.69
9	0.69	0.76
10	0.76	1.0

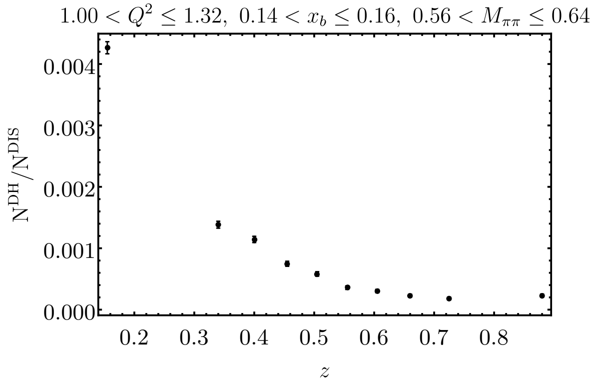
$m_{\pi^+\pi^-}$ bin	min (GeV)	max (GeV)
1	0.0	0.38
2	0.38	0.44
3	0.44	0.5
4	0.5	0.56
5	0.56	0.64
6	0.64	0.72
7	0.72	0.78
8	0.78	0.86
9	0.86	1.06
10	1.06	3.0

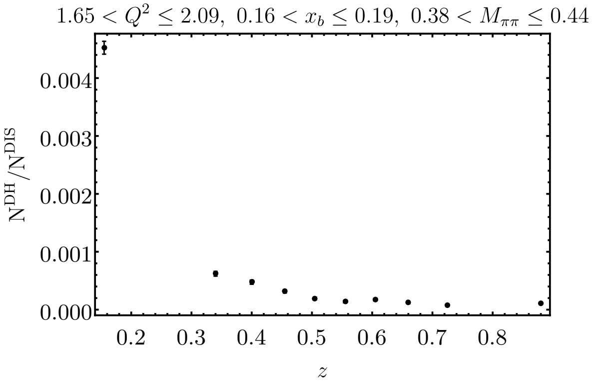
Selected Results (chosen at random)

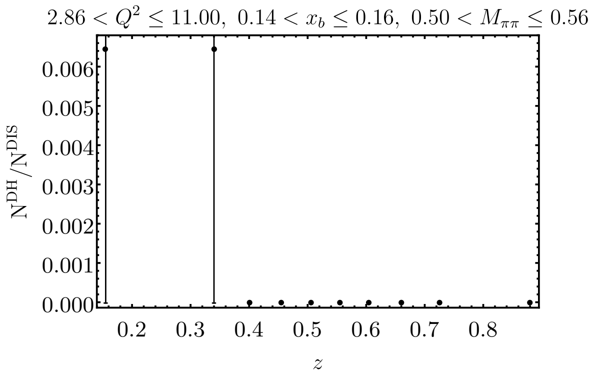












To Do

- Fiducial cuts in DC and PCAL (etc?)
- Improve hadron PID with beta/p check (cut out protons)
- Error bars should really be larger (currently just statistics)
  - Enhanced PID cuts will reduce statistics
  - Include systematic resolution effects in error bars
  - Adjust for acceptance (need acceptance for DIS events)
- Other?

Further Results

DIS Counts

x_b bins

Q^2 bins

1 033 259	929 317	713 771	563 473	441 494	485 456	332 144	287 072	87 261	6911
43 677	530 328	482 244	405 891	344 131	422 420	332 814	341 451	300 969	89 522
0	32 913	330 754	338 479	281 226	372 458	310 957	333 225	322 203	310 020
0	0	2566	131 887	240 886	346 452	278 527	318 201	325 244	548 314
0	0	0	0	155	69 512	155 016	234 790	289 020	986 932

Further Results

SIDIS Counts, $1.00 < Q^2 < 1.32$

$0.00 < x_B < 0.08$

$m_{\pi\pi}$ bins (columns); z bins (rows)

6991	4912	5367	6054	8259	8341	6270	7247	11472	7110
304	279	300	333	561	723	716	979	2409	3556
159	175	188	201	325	433	404	593	1394	3058
75	84	107	113	167	229	222	290	763	2113
31	56	54	66	111	162	152	195	535	1760
31	38	41	46	73	101	78	135	341	1424
11	24	30	32	49	59	65	87	248	1118
9	20	23	26	37	38	41	72	183	1108
8	9	18	15	28	44	33	56	141	886
6	11	14	24	29	53	48	73	137	1249

$0.10 < x_B < 0.12$

$m_{\pi\pi}$ bins (columns); z bins (rows)

5019	3313	3594	3827	4695	4415	2969	2964	3651	968
479	408	478	562	935	1091	877	1224	2218	1383
300	319	334	364	605	696	623	834	1830	1662
166	162	196	205	323	425	371	525	1211	1472
104	124	136	136	218	297	280	401	897	1355
79	94	89	113	155	233	237	298	710	1271
48	67	75	64	109	163	155	227	508	1135
40	61	63	78	100	131	139	204	495	1214
34	45	50	51	77	97	121	163	341	1144
23	45	61	69	107	193	220	267	450	1712

$0.14 < x_B < 0.16$

$m_{\pi\pi}$ bins (columns); z bins (rows)

2755	1674	1643	1787	1883	1485	837	744	501	38
490	400	406	451	611	748	525	637	855	208
318	258	307	343	505	564	474	592	961	381
170	174	218	222	330	383	313	447	778	467
111	119	125	148	257	320	286	308	623	522
89	72	110	111	158	230	197	284	592	570
50	71	72	75	134	168	157	201	452	529
63	62	60	75	101	121	128	212	418	641
38	51	42	52	81	126	130	148	349	625
36	72	75	75	102	190	211	263	433	973

$0.22 < x_B < 0.26$

$m_{\pi\pi}$ bins (columns); z bins (rows)

1397	793	753	729	570	337	120	54	20	0
456	312	320	312	445	415	235	175	96	8
324	247	268	292	384	366	250	277	236	45
198	159	180	179	290	304	191	234	324	51
150	136	143	150	235	263	190	236	348	104
109	111	106	112	191	190	159	213	344	125
78	79	90	100	143	153	133	181	331	156
56	53	76	87	115	164	125	163	346	210
47	50	68	66	101	135	115	167	300	235
55	98	77	80	138	200	177	194	299	391

Further Results

SIDIS Counts, $1.65 < Q^2 < 2.09$

$0.00 < x_B < 0.08$

$m_{\pi\pi}$ bins

z bins

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$0.10 < x_B < 0.12$

$m_{\pi\pi}$ bins

z bins

2183	1602	1769	1957	2702	2646	2088	2360	3603	2337
95	77	94	130	196	222	200	302	746	1157
51	53	63	54	113	132	146	168	440	894
25	36	31	38	44	64	78	105	233	639
19	21	24	35	33	46	46	58	170	492
5	14	19	28	27	40	46	49	117	428
6	15	10	7	12	22	33	26	96	349
2	7	11	7	10	23	15	31	51	328
2	7	5	4	11	15	16	25	34	328
1	6	12	7	13	12	15	21	49	346

$0.14 < x_B < 0.16$

$m_{\pi\pi}$ bins

z bins

1923	1281	1493	1615	2235	2034	1422	1508	2102	780
150	148	191	193	330	401	308	449	890	759
110	112	134	132	206	272	222	333	687	803
69	61	82	91	110	158	104	161	460	665
54	44	59	56	68	121	103	134	305	569
23	35	43	46	78	59	68	97	250	524
20	28	32	32	39	60	51	73	164	450
16	29	31	30	39	62	51	72	163	469
12	13	18	24	28	34	50	44	122	449
12	23	17	20	38	58	61	88	165	691

$0.22 < x_B < 0.26$

$m_{\pi\pi}$ bins

z bins

2017	1237	1318	1456	1645	1421	823	781	795	142
291	247	271	328	467	566	405	474	742	289
236	156	194	249	368	388	325	415	770	463
137	106	128	160	231	290	219	297	575	453
109	65	103	96	167	229	161	223	502	441
78	60	79	82	117	165	141	157	382	499
57	48	57	66	94	117	108	144	312	459
44	45	56	32	93	118	97	141	294	488
28	34	42	42	54	83	85	107	246	467
32	41	64	41	69	134	137	179	314	761

Further Results

SIDIS Counts, $2.86 < Q^2 < 11.0$

$0.00 < x_B < 0.08$

$m_{\pi\pi}$ bins

z bins

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$0.10 < x_B < 0.12$

$m_{\pi\pi}$ bins

z bins

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$0.14 < x_B < 0.16$

$m_{\pi\pi}$ bins

z bins

5	0	1	1	2	1	1	0	4	1
0	0	0	1	0	0	0	0	1	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	1
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

$0.22 < x_B < 0.26$

$m_{\pi\pi}$ bins

z bins

992	673	802	937	1206	1254	872	986	1440	769
75	62	66	74	142	133	125	153	350	470
47	31	44	31	79	95	87	111	242	432
19	32	23	27	38	48	44	53	145	317
18	19	30	18	35	43	35	46	106	266
13	16	14	14	20	24	28	46	82	235
8	9	9	11	20	22	27	22	49	197
1	7	9	8	11	24	14	12	46	202
2	4	3	9	10	12	19	16	34	195
5	2	4	6	10	15	25	25	44	225