DIRAC note 2004-03

Dependence of breakup probability estimation on ScFi background

V.V.Yazkov
NPI, Moscow

June 11, 2004

Abstract

ScFi detector plays essential role in measurement of transversal components of relative momentum Q. For correct simulation of "Coulomb" correlation function it is needed to know errors of measurement which are induced by resolution of the detector and admixture of background hits in the experimental data. Influence of background hits on measured value of breakup probability is investigated.

Introduction

Background hits in ScFi detector could change a shape of "atomic" and "Coulomb" pair distributions. If there are two hits from particles of "atomic pair" in one ScFi plane then presence of 3-rd background hit leads to the event rejection by analysis procedure. But for the case of one correct hit per two particles (both particle hit the same column or one is not detected due to inefficiency) background hit could be taken as second one if it is sufficiently close in space (up to 2 cm) and in time (±4 ns). Therefore transverse component or relative momentum could be measured with big (few MeV/c) error.

The main source of additional hits is background particles. Their distribution and intensity was investigated and simulated recently [1].

The second source is a crosstalk between columns of fiber detector and optical crosstalk between PSPM channels.

In this report a probability of the second source is investigated. And influence of both background sources on the breakup probability is estimated.

1 Crosstalk

Numeration of ScFi channels in PSPM photocathodes is shown in Fig. 1.

Using channels from different PSPM it is possible to investigate crosstalk in ScFi detector itself with probability of two hits as function of column difference between them. For big distances this probability is constant. If crosstalk exists then for small distances probability is to increase.

32	31	30	29
25	26	27	28
24	23	22	21
17	18	19	20

16	15	14	13
9	10	11	12
8	7	6	5
1	2	3	4

Figure 1: Scheme of ScFi channel arrangement on the PSPM photocathodes.

After it is possible to repeat this procedure for channels connected to one PSPM. Subtracting effect of crosstalk in the detector it is possible to select pure optical crosstalk.

Analysis have been done using Ni2001 data. ARIANE based program selects events which fit a few criteria.

Firstly events have to have only one track per each arm.

On the second stage for each track the hits in X- (Y-) plane of fiber detector are found in ±1 cm regions around X- (Y-) coordinate which provides upstream track pointed to the beam position at the target. Time difference between ScFi and VH measurement is in the limits ±4 ns (time-of-flight is taken into account). Only event which have not crossed regions for different tracks and two hit at least in one space-time regions are selected.

Only two hit regions are used for final analysis.

To reject e^+e^- pairs the events with big amplitudes in Cherenkov counter are excluded. Admixture of e^+e^- pairs with low amplitudes have been estimated using PrSh detector. Influence of this events is compensated by subtracting of distribution filled by corresponding number of electron-positron pairs.

Table 1 presents probability of crosstalk from column number n to column number $n+i$ as function of i. Evidently probability of crosstalk to column number $n-i$ is the same. Statistical accuracy is at the level 0.02%.

Investigation of optical crosstalk in PSPM shows that crosstalk to the adjacent channel is at the level $0.25 \div 0.30\%$ (see Table 2) and it is practically zero in “diagonal” (for example from channel 1 to channel 7 in Fig. 1) direction. Summary crosstalk probability to at least one of

Table 1: Probability of crosstalk from n-th column to $n+i$-th in the ScFi detector.

i	Crosstalk in X-plane %	Crosstalk in Y-plane %
1	4.68	5.18
2	0.80	0.82
3	0.31	0.31
4	0.22	0.15
5	0.09	0.03
6	0.08	0.03
7	0.07	0.01

adjacent channel is at the level 1%. This is in agreement with ScFi detector description [2].

Table 2: Probability of optical crosstalk to adjacent channel of PSPM.

Plane	Downward directly %	Upward directly %	Downward diagonally %	Upward diagonally %
X	0.25	0.24	0.01	-0.01
Y	0.28	0.29	0.01	0.01

2 Simulated pair distributions for different background conditions

In order to investigate dependence of $A_{2\pi}$ breakup probability estimation on background conditions the "Coulomb" and "atomic" pair distributions have been simulated in 3 versions:

1. Monte-Carlo data generated by GEANT-DIRAC have been analyzed by ARIANE without generation of background hits.

2. ARIANE produces hits from background particle for intensity $3.5 \cdot 10^{11} \mathrm{s}^{-1}$. In one plane of ScFi this intensity provides average multiplicity which is 4.

3. ARIANE produces hits from background particle for intensity $3.32 \cdot 10^{11} \mathrm{s}^{-1}$ and from crosstalk is ScFi detector and PSPM for distances from 2 to 8 columns (Tables 1,2). The crosstalk to adjacent column is treated by PSC response simulation. The average ScFi Plane multiplicity is also 4.

In Fig. 2a,b normalized distributions of "atomic pairs" over Q are presented. Solid line in Fig. 2a is the distribution of "atomic pairs" without background, dashed line in Fig. 2a and solid line in Fig. 2b are the distribution with background from particles only and dashed line Fig. 2b is a distribution with background both from particles and crosstalk. In Figs. 2c,d normalized distributions of "atomic pairs" over Q_L are presented in the same order like Q-distributions in Figs. 2a,b.

Results of simulation of "Coulomb pairs" are presented in Fig. 3 as correlation functions of Q without background (solid line Fig. 3a), with background from particles only (dashed line in Fig. 3a and solid line in Fig. 3b) and with background both from particles and crosstalk. Correlation function of Q_L are presented in Figs. 3c,d similarly to correlation functions of Q in Figs. 3a,b.

From Figs. 2,3 it is seen that distributions over Q are essentially modified by background in ScFi detector. For Q_L such modification is significantly less.

3 Breakup probability for different background description

Experimental data obtained in 2001 with nickel targets have been analyzed using three sets of simulated data. Experimental correlation function is approximated by a mixture of "Coulomb" and "non-Coulomb" correlation function i the regions where "atomic pair" are absent. Fraction of "non-Coulomb pairs" and normalization coefficient are free parameters of fit. After fit number of "free pairs" with small Q (or its projection) is calculated. An excess of experimental data over this number is a signal from "atomic pairs" N_a. Ratio of "atomic pair" number to "Coulomb pair" number N_a/N_C together with coefficient k which have been calculated for each version of background allows us to calculate breakup probability $P_{\rm br}$. Also total number of "atomic pairs" $N_a^{\rm total}$ is calculated for each cut using simulated distribution of "atomic pairs" over Q and projections of Q.

For different cuts on Q_L table 3 presents a number of "atomic pairs" N_a , ratio of "atomic" and "Coulomb" pair numbers N_a/N_C, breakup probability $P_{\rm br}$ and total number of "atomic pairs" $N_a^{\rm total}$. Cut on Q_T is 4 MeV/c. In tables 4,5,6,7,8 these values are given for different variables and cuts.

The data in tables 3,4,5,6,7,8 shows that results obtained with Q_L are less sensitive to presence of background in ScFi detector. Also it is seen that difference of "atomic pair" numbers and breakup probabilities between Q_L analysis and Q (F) analysis (which is an estimation of systematic error) is less if background is taken into account during simulation.

Another way to obtain N_a is to fit whole interval over Q using shape of simulated distribution of "atomic pairs". Table 9 contains numbers N_a obtained in this approach for different background description for simulation procedure.

It is seen that this version of analysis demonstrates the same dependence on background description as for previous one.

Table 3: Atomic pair numbers and ionization probability analyzed with $Q_L(Q_T < 4)$.

Q_L	N_a	N_a/N_C	P_{br}	N_a^{total}
No background.				
0.5	3892. ± 283.	0.1842 ± 0.0157	0.4473 ± 0.0382	6311. ± 459.
1.0	5494. ± 444.	0.1330 ± 0.0124	0.4388 ± 0.0409	6242. ± 504.
1.5	6196. ± 571.	0.1041 ± 0.0109	0.4636 ± 0.0486	6569. ± 606.
2.0	6312. ± 678.	0.0827 ± 0.0099	0.4656 ± 0.0558	6585. ± 708.
Background.				
0.5	3883. ± 283.	0.1834 ± 0.0157	0.4441 ± 0.0381	6349. ± 463.
1.0	5509. ± 444.	0.1332 ± 0.0124	0.4392 ± 0.0409	6303. ± 507.
1.5	6243. ± 571.	0.1049 ± 0.0109	0.4662 ± 0.0485	6659. ± 609.
2.0	6378. ± 677.	0.0835 ± 0.0099	0.4693 ± 0.0557	6694. ± 711.
Background and crosstalk.				
0.5	3846. ± 284.	0.1815 ± 0.0156	0.4220 ± 0.0363	6251. ± 461.
1.0	5434. ± 444.	0.1312 ± 0.0123	0.4162 ± 0.0390	6203. ± 507.
1.5	6118. ± 572.	0.1026 ± 0.0109	0.4389 ± 0.0466	6513. ± 609.
2.0	6255. ± 679.	0.0818 ± 0.0099	0.4424 ± 0.0536	6553. ± 711.

Conclusions

These results allow to make three conclusions:

- Background hits in ScFi provide essential change of measured breakup probability and should to be taken into account during analysis.
- Despite of small fraction of background hits which occur due to crosstalk there influence is significant. Because they arise in vicinity to true hits in time and space. This fact allows then to fit selection criteria.
- Background hits distort mainly Q_T. Change of Q_L is essentially less. Therefore the best variable for analysis is Q_L because of Q_T value does not affect distribution of events between bins.

[1] O. Gortchakov. Report on DIRAC analysis meeting.
[2] B. Adeva *et all.*, Nucl. Instr. Meth. A515 (2003) 467.

Table 4: Atomic pair numbers and ionization probability analyzed with $Q_L(Q_T < 3)$.

Q_L	N_a	N_a/N_C	P_{br}	N_a^{total}
No background.				
0.5	3852. ± 248.	0.2779 ± 0.0225	0.4645 ± 0.0376	6533. ± 421.
1.0	5348. ± 390.	0.1979 ± 0.0176	0.4451 ± 0.0396	6356. ± 464.
1.5	5766. ± 501.	0.1493 ± 0.0153	0.4473 ± 0.0459	6398. ± 556.
2.0	5760. ± 590.	0.1174 ± 0.0139	0.4399 ± 0.0521	6290. ± 645.
Background.				
0.5	3897. ± 248.	0.2815 ± 0.0225	0.4733 ± 0.0379	6689. ± 425.
1.0	5406. ± 389.	0.2001 ± 0.0176	0.4524 ± 0.0398	6497. ± 468.
1.5	5888. ± 499.	0.1526 ± 0.0154	0.4597 ± 0.0464	6599. ± 559.
2.0	5912. ± 588.	0.1206 ± 0.0139	0.4548 ± 0.0524	6522. ± 649.
Background and crosstalk.				
0.5	3877. ± 248.	0.2797 ± 0.0225	0.4550 ± 0.0367	6604. ± 422.
1.0	5392. ± 390.	0.1995 ± 0.0176	0.4381 ± 0.0387	6452. ± 466.
1.5	5823. ± 500.	0.1507 ± 0.0153	0.4402 ± 0.0447	6500. ± 558.
2.0	5847. ± 589.	0.1191 ± 0.0139	0.4350 ± 0.0508	6425. ± 647.

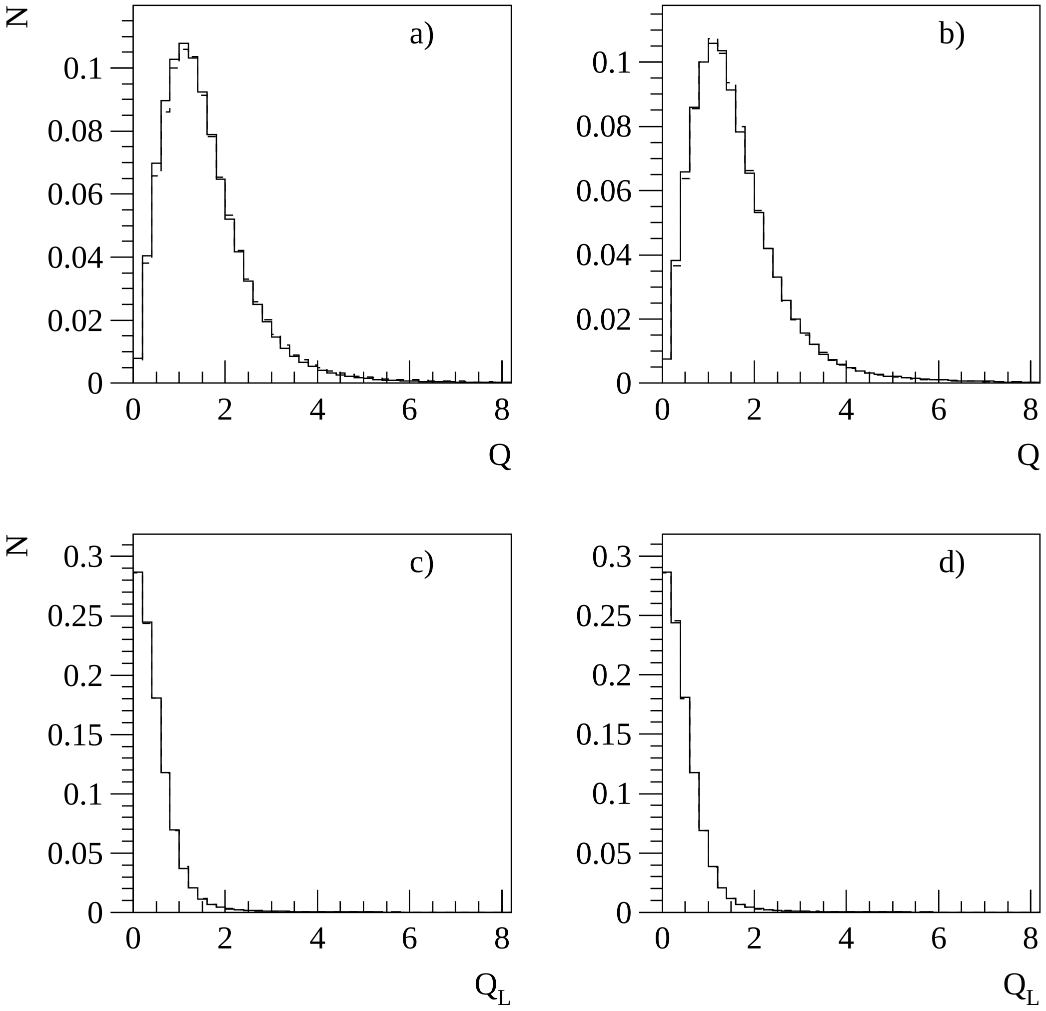

Figure 2: Normalized distributions of "atomic pairs" over Q: (a) solid line — without background and dashed line with background from particles only, (b) solid line — background from particles only and dashed line — background both from particles and crosstalk. Normalized distributions of "atomic pairs" over Q_L: (c) solid line — without background and dashed line with background from particles only, (d) solid line — background from particles only and dashed line — background both from particles and crosstalk.

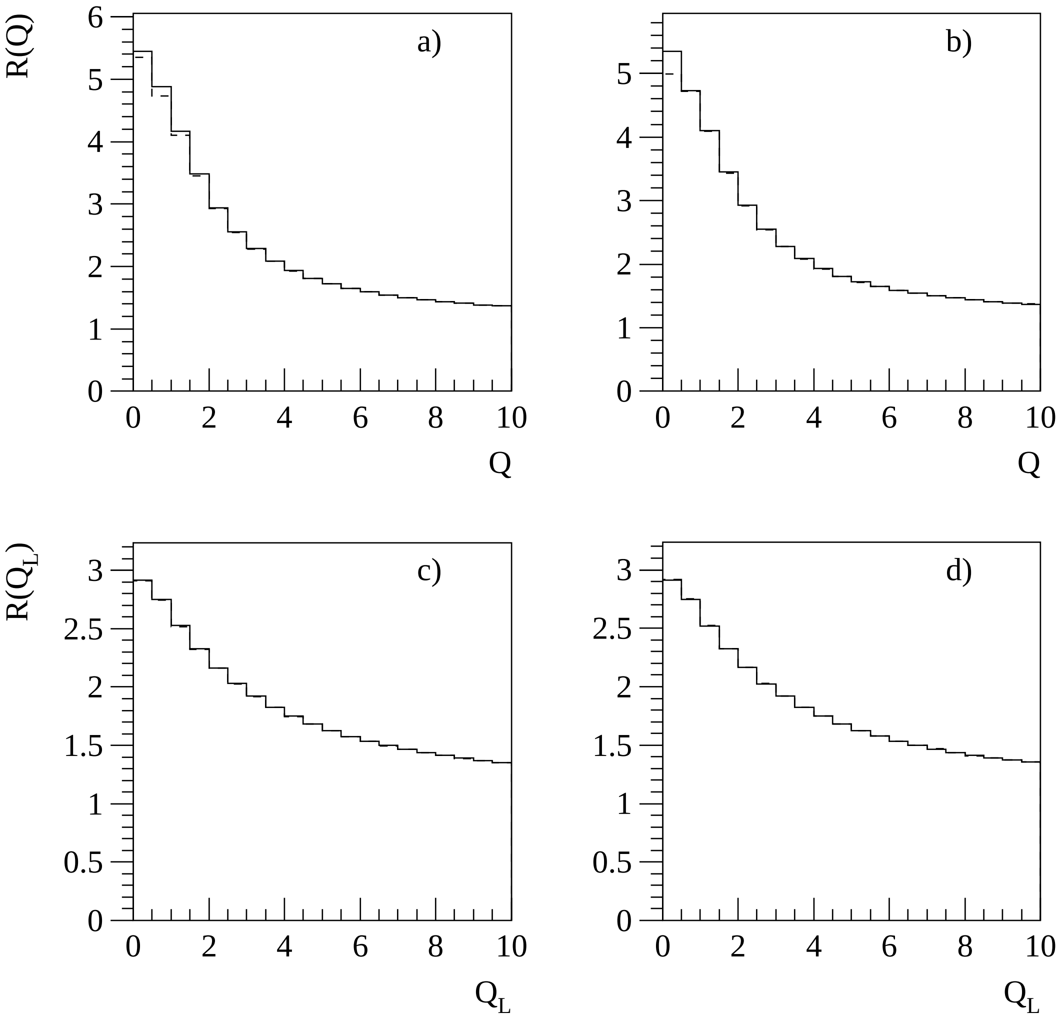

Figure 3: Simulated "Coulomb" correlation functions of Q: (a) solid line — without background and dashed line with background from particles only, (b) solid line — background from particles only and dashed line — background both from particles and crosstalk. Simulated "Coulomb" correlation functions of Q_L: (c) solid line — without background and dashed line with background from particles only, (d) solid line — background from particles only and dashed line — background both from particles and crosstalk.

Table 5: Atomic pair numbers and ionization probability analyzed with $Q_L(Q_T < 2)$.

Q_L	N_a	N_a/N_C	$P_{\rm br}$	$N_a^{\rm total}$
No background.				
0.5	3050. ± 202.	0.4087 ± 0.0373	0.4373 ± 0.0400	6261. ± 415.
1.0	4094. ± 318.	0.2838 ± 0.0289	0.4027 ± 0.0410	5901. ± 459.
1.5	4378. ± 405.	0.2158 ± 0.0250	0.4015 ± 0.0465	5896. ± 545.
2.0	4350. ± 473.	0.1709 ± 0.0226	0.3914 ± 0.0518	5766. ± 627.
Background.				
0.5	3084. ± 201.	0.4143 ± 0.0373	0.4474 ± 0.0403	6449. ± 421.
1.0	4182. ± 316.	0.2909 ± 0.0290	0.4184 ± 0.0417	6123. ± 463.
1.5	4505. ± 402.	0.2228 ± 0.0251	0.4192 ± 0.0472	6158. ± 550.
2.0	4498. ± 470.	0.1772 ± 0.0226	0.4113 ± 0.0525	6056. ± 632.
Background and crosstalk.				
0.5	3132. ± 200.	0.4231 ± 0.0376	0.4493 ± 0.0400	6449. ± 412.
1.0	4230. ± 315.	0.2950 ± 0.0290	0.4165 ± 0.0410	6124. ± 456.
1.5	4566. ± 401.	0.2264 ± 0.0252	0.4192 ± 0.0467	6177. ± 542.
2.0	4570. ± 468.	0.1804 ± 0.0227	0.4118 ± 0.0518	6086. ± 623.

Table 6: Atomic pair numbers and ionization probability analyzed with $Q(Q_T < 4)$.

Q	N_a	N_a/N_C	P_{br}	N_a^{total}
No background.				
0.5	274. ± 53.	0.5632 ± 0.1501	0.3084 ± 0.0823	4985. ± 969.
1.0	1361. ± 122.	0.4466 ± 0.0522	0.3367 ± 0.0394	5278. ± 475.
1.5	2511. ± 214.	0.2706 ± 0.0281	0.3057 ± 0.0318	4814. ± 410.
2.0	3417. ± 324.	0.1784 ± 0.0198	0.3081 ± 0.0342	4713. ± 447.
2.5	3837. ± 456.	0.1159 ± 0.0156	0.2991 ± 0.0403	4523. ± 538.
3.0	4376. ± 602.	0.0860 ± 0.0131	0.3219 ± 0.0490	4777. ± 658.
3.5	4573. ± 762.	0.0627 ± 0.0114	0.3290 ± 0.0598	4810. ± 801.
4.0	4546. ± 933.	0.0455 ± 0.0100	0.3232 ± 0.0710	4691. ± 963.
Background.				
0.5	282. ± 53.	0.5896 ± 0.1526	0.3194 ± 0.0829	5252. ± 982.
1.0	1445. ± 120.	0.4869 ± 0.0537	0.3761 ± 0.0416	5763. ± 480.
1.5	2670. ± 211.	0.2926 ± 0.0285	0.3348 ± 0.0327	5220. ± 413.
2.0	3643. ± 321.	0.1924 ± 0.0200	0.3359 ± 0.0349	5108. ± 450.
2.5	4100. ± 452.	0.1247 ± 0.0157	0.3245 ± 0.0409	4896. ± 540.
3.0	4660. ± 598.	0.0920 ± 0.0132	0.3466 ± 0.0497	5141. ± 660.
3.5	4891. ± 757.	0.0673 ± 0.0114	0.3545 ± 0.0601	5187. ± 802.
4.0	4860. ± 928.	0.0487 ± 0.0100	0.3464 ± 0.0711	5049. ± 964.
Background and crosstalk.				
0.5	313. ± 51.	0.6973 ± 0.1628	0.3945 ± 0.0924	5695. ± 923.
1.0	1474. ± 119.	0.5016 ± 0.0541	0.3834 ± 0.0415	5749. ± 466.
1.5	2704. ± 210.	0.2972 ± 0.0286	0.3384 ± 0.0326	5214. ± 406.
2.0	3724. ± 319.	0.1973 ± 0.0201	0.3406 ± 0.0347	5163. ± 443.
2.5	4212. ± 450.	0.1284 ± 0.0157	0.3287 ± 0.0402	4991. ± 533.
3.0	4791. ± 596.	0.0947 ± 0.0132	0.3478 ± 0.0485	5263. ± 655.
3.5	5014. ± 755.	0.0690 ± 0.0114	0.3524 ± 0.0582	5303. ± 798.
4.0	5005. ± 926.	0.0502 ± 0.0100	0.3446 ± 0.0687	5188. ± 960.

Table 7: Atomic pair numbers and ionization probability analyzed with $Q(Q_X < 4, Q_Y < 4)$.

Q	N_a	N_a/N_C	P_{br}	N_a^{total}
No background.				
0.5	275. ± 53.	0.5660 ± 0.1497	0.3100 ± 0.0821	5002. ± 965.
1.0	1367. ± 120.	0.4493 ± 0.0507	0.3388 ± 0.0383	5298. ± 465.
1.5	2527. ± 202.	0.2729 ± 0.0260	0.3083 ± 0.0294	4845. ± 386.
2.0	3450. ± 292.	0.1805 ± 0.0176	0.3117 ± 0.0304	4759. ± 404.
2.5	3892. ± 396.	0.1178 ± 0.0134	0.3041 ± 0.0346	4588. ± 467.
3.0	4458. ± 509.	0.0878 ± 0.0110	0.3287 ± 0.0412	4867. ± 556.
3.5	4688. ± 631.	0.0644 ± 0.0094	0.3379 ± 0.0493	4930. ± 664.
Background.				
0.5	283. ± 52.	0.5930 ± 0.1522	0.3213 ± 0.0826	5270. ± 978.
1.0	1451. ± 118.	0.4902 ± 0.0522	0.3786 ± 0.0404	5788. ± 470.
1.5	2689. ± 199.	0.2954 ± 0.0264	0.3380 ± 0.0303	5257. ± 389.
2.0	3681. ± 290.	0.1949 ± 0.0178	0.3402 ± 0.0311	5161. ± 406.
2.5	4163. ± 393.	0.1269 ± 0.0134	0.3302 ± 0.0349	4971. ± 470.
3.0	4753. ± 506.	0.0941 ± 0.0110	0.3545 ± 0.0415	5244. ± 558.
3.5	5020. ± 627.	0.0692 ± 0.0094	0.3645 ± 0.0495	5324. ± 665.
Background and crosstalk.				
0.5	314. ± 50.	0.7007 ± 0.1624	0.3965 ± 0.0922	5710. ± 919.
1.0	1480. ± 117.	0.5049 ± 0.0525	0.3859 ± 0.0402	5771. ± 456.
1.5	2722. ± 198.	0.2999 ± 0.0265	0.3415 ± 0.0302	5249. ± 383.
2.0	3760. ± 288.	0.1997 ± 0.0178	0.3447 ± 0.0308	5213. ± 400.
2.5	4273. ± 392.	0.1306 ± 0.0135	0.3343 ± 0.0346	5063. ± 464.
3.0	4881. ± 504.	0.0967 ± 0.0111	0.3552 ± 0.0408	5362. ± 554.
3.5	5139. ± 626.	0.0709 ± 0.0094	0.3621 ± 0.0480	5435. ± 662.

Table 8: Atomic pair numbers and ionization probability analyzed with $F(Q_X < 4, Q_Y < 4)$.

F	N_a	N_a/N_C	P_{br}	N_a^{total}
No background.				
0.5	165. ± 44.	0.5172 ± 0.1835	0.2725 ± 0.0968	4413. ± 1167.
1.0	1117. ± 99.	0.5502 ± 0.0656	0.3591 ± 0.0429	5570. ± 493.
1.5	2409. ± 166.	0.3842 ± 0.0333	0.3475 ± 0.0302	5354. ± 368.
2.0	3374. ± 241.	0.2522 ± 0.0215	0.3298 ± 0.0281	5031. ± 359.
2.5	4289. ± 323.	0.1853 ± 0.0162	0.3523 ± 0.0308	5263. ± 396.
3.0	4709. ± 414.	0.1308 ± 0.0130	0.3542 ± 0.0352	5256. ± 462.
3.5	4842. ± 512.	0.0934 ± 0.0109	0.3514 ± 0.0410	5161. ± 545.
4.0	4980. ± 614.	0.0705 ± 0.0095	0.3578 ± 0.0482	5189. ± 640.
Background.				
0.5	172. ± 43.	0.5536 ± 0.1878	0.2885 ± 0.0981	4658. ± 1162.
1.0	1176. ± 97.	0.5967 ± 0.0676	0.4008 ± 0.0456	6053. ± 500.
1.5	2514. ± 164.	0.4075 ± 0.0338	0.3736 ± 0.0311	5701. ± 372.
2.0	3529. ± 239.	0.2666 ± 0.0217	0.3523 ± 0.0287	5356. ± 362.
2.5	4490. ± 320.	0.1956 ± 0.0163	0.3748 ± 0.0313	5582. ± 398.
3.0	4964. ± 411.	0.1387 ± 0.0131	0.3776 ± 0.0357	5599. ± 464.
3.5	5081. ± 509.	0.0984 ± 0.0109	0.3713 ± 0.0411	5461. ± 547.
4.0	5216. ± 611.	0.0740 ± 0.0095	0.3756 ± 0.0482	5468. ± 641.
Background and crosstalk.				
0.5	192. ± 41.	0.6564 ± 0.2002	0.3616 ± 0.1106	5047. ± 1088.
1.0	1199. ± 96.	0.6153 ± 0.0682	0.4060 ± 0.0452	6032. ± 485.
1.5	2574. ± 163.	0.4216 ± 0.0341	0.3833 ± 0.0311	5738. ± 363.
2.0	3619. ± 237.	0.2755 ± 0.0218	0.3599 ± 0.0285	5424. ± 356.
2.5	4612. ± 319.	0.2020 ± 0.0164	0.3801 ± 0.0309	5688. ± 393.
3.0	5098. ± 410.	0.1431 ± 0.0131	0.3807 ± 0.0349	5725. ± 460.
3.5	5238. ± 507.	0.1018 ± 0.0110	0.3733 ± 0.0403	5615. ± 544.
4.0	5406. ± 609.	0.0769 ± 0.0095	0.3775 ± 0.0466	5657. ± 638.

Table 9: Atomic pair numbers are found using the signal shape for different background descriptions.

Variable	Cut MeV/c	Atomic pair number		
		No Background	Background	Background and crosstalk
F	$Q_{X,Y} < 4$	5023.0 ± 377.9	5339.1 ± 383.4	5481.2 ± 383.2
Q	$Q_T < 4$	4557.3 ± 405.7	4929.2 ± 412.2	5030.7 ± 412.5
Q_L	$Q_T < 4$	6079.0 ± 452.1	6059.9 ± 452.2	5988.9 ± 451.5