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Positron asymmetry and polarisation extracted from the E166 September 2005 run

This note summarises our analysis of the E166 data taken during the September 2005 run. In the present analysis we considered only the response of the central crystal #5. We intend in the future to integrate into the analysis the other eight surrounding crystals.

The approach that we have adopted here is a straight forward one, where we chained all the runs together. The underlying assumption in this method is that local variations are averaged out and that if no polarisation is seen in this scheme than its appearance, if at all, in more sophisticated and complex algorithm should be taken with great care.

Selection of runs and events

The selection of the runs were determined in two stages as follows:

1st stage

1) Runs were accepted if their spectrometer and lens values matched one of the pairs listed in Table 1.

Table 1: The accepted match between the spectrometer and lens values.

Positron energy [MeV]	3.65	4.38	5.11	5.84	6.57
Spectrometer [A]	100	120	140	160	180
Lens [A]	220	260	340	360	374

2) Only *superruns* were used.

3) Runs were rejected if at least one of the following conditions occurred:
   a) Empty runs;
   b) Beam was off;
   c) 15 Hz runs.

The list of runs used in our analysis is given in Appendix I.

2nd stage

In a second stage pairs of events were accepted only if:

1) Their 'trigger' word equals to 36864, i.e. signal (on top of the background) or equals to 36896, i.e. background.
2) The 'latch' word should have one of the following values:
   1320, 1800, 1832, 2824, 2856, 3336, 3368, 3848, 3880, 3898, 4904, 5416, 5928, 6440, 6952, 7432, 7464, 7944, 7976, 7962, 7994.

These numbers were selected after a careful study of the 'agup', 'x5_1[0]' and 'x5_1[1]'. Furthermore, events having ADC counts above 4000 were removed from the analysed sample.

Application of the toroid information

The toroid tor6130 current was first of all used to define the appropriate range of the data acceptance. In Fig. 1 are given two representative tor6130 reading distributions for the spectrometer currents of 100 and 140 A. The vertical dashed lines in the figure define the regions taken for the asymmetry analyses. In Fig. 2 the same information is shown for the

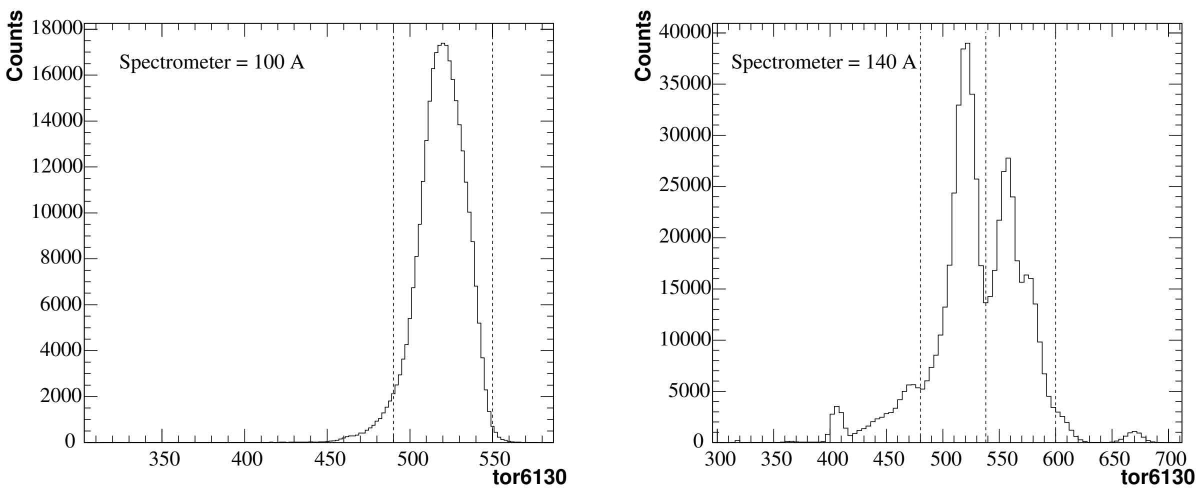

Figure 1: The tor6130 current of the selected positron pair events for the spectrometer value of, Left: 100 A and Right: 140 A. The vertical dashed lines specify the toroid regions used in the analysis.

electrons runs.

As for the toroid normalisation (i.e. division of the signals by the toroid values), we have studied the positron asymmetry with the a priori two possibilities namely, with and without normalising the data.

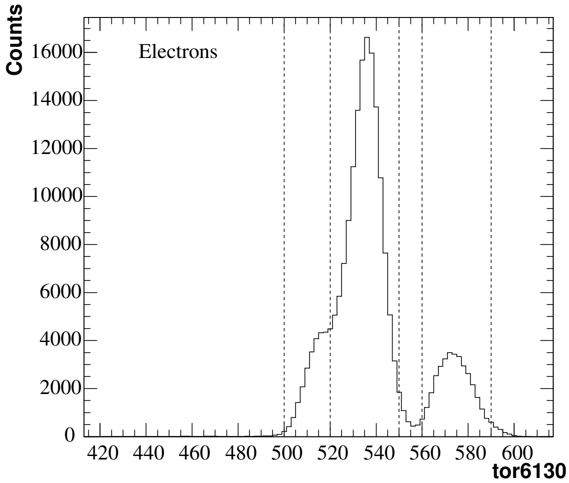

Figure 2: The tor6130 current of the selected electron pair events for the spectrometer value of 160 A. The vertical dashed lines specify the toroid regions used in the analysis.

The positron asymmetry

The event pairs considered in our analysis consisted of a signal lying on a background followed by its background. For the asymmetry calculation this background was subtracted from the signal which we donate by (Signal$-$Bg)$_{-60}$ or (Signal$-$Bg)$_{+60}$ pending on the polarity of the analysing magnet. For the analysis we further define in each case a valid range of the toroid current as illustrated e.g. in Figs. 1 and 2 by the vertical lines. In this way regions with strong instabilities of the SLC were avoided.

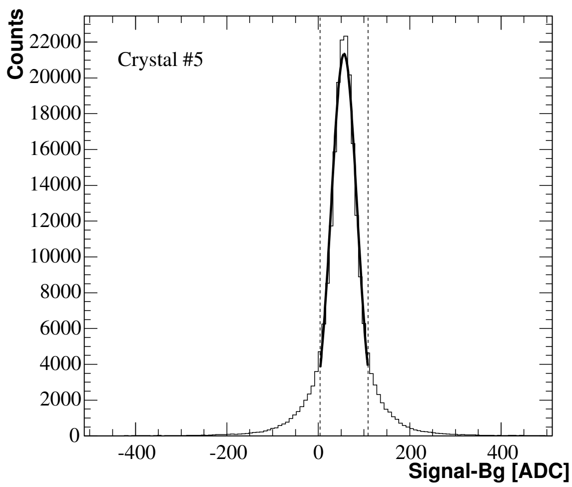

Figure 3: The ADC distribution of the (Signal$-$Bg)$_{-60}$ of crystal No. 5. The bold continuous line represents the fit of the Gaussian function in the range from -1.5 to +1.5 σ marked by the vertical lines.

A representative ADC distribution of the (Signal$-$Bg)$_{-60}$ is shown in Fig. 3 where it is fitted

to a Gaussian function shown by the bold continuous line from -1.5 to +1.5 σ which is marked by the vertical lines. The average value of <(Signal$-$Bg)$_{-60}$ > can then be determined either from the fitted Gaussian value or by the mean value of the histogram itself. In the final analysis of the two polarities -60 and $+60$ we have chosen the mean value of the histogram as we found it to be more reliable. The analysis was repeated for different gains (1 and 32) and high (15 bits) and low (12 bits) sensitivities.
Finally the positron (or the electron) asymmetry is given by

$$Asy \;=\; \frac{<(Signal - Bg)_{-60}> \;-\; <(Signal - Bg)_{+60}>}{<(Signal - Bg)_{-60}> \;+\; <(Signal - Bg)_{+60}>} \;=\; \frac{L \;-\; R}{L \;+\; R} \tag{1}$$

where for convenience we denote

$$L \;=<(Signal - Bg)_{-60}> \quad \text{and} \quad R \;=<(Signal - Bg)_{+60}> \;\; .$$

The error associated with Asy is given by:

$$\Delta Asy \;=\; \frac{2}{(L+R)^2}\sqrt{(L\Delta R)^2 + (R\Delta L)^2}\;. \tag{2}$$

If we further assume a Gaussian error, i.e. $\Delta L = L/\sqrt{N_L}$ and $\Delta R = R/\sqrt{N_R}$, then

$$\Delta Asy \;=\; \frac{2LR}{(L+R)^2}\sqrt{1/N_L + 1/N_R}\;. \tag{3}$$

The asymmetries of the positrons at different energies, gains, sensitivities using 1 and 1.5 σ regions are shown in Tables 2,4,6 and 8, where the normalisation procedure to the tor6130 was not applied. The results for the asymmetries values where the normalisation was used are given in Tables 3,5,7 and 9. In these tables are also listed the asymmetry values of the electrons at the energy of 5.84 MeV.

Table 2: The positron asymmetry as function of energy using a signal $-$ background with a gain 1, 12 bits applying a 1σ cut around the maximum counts. The data was not divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0044	0.0016
4.38	120	0.0085	0.0017
5.11	140	0.0082	0.0012
5.84	160	0.0121	0.0019
6.57	180	0.0101	0.0019
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0147	0.0020

General features of the asymmetries

A summary of the above given tables is illustrated in Fig. 4 for gain 1 low sensitivity and in Fig. 5 for gain 1 high sensitivity data. In these figures the positron asymmetries are plotted

Table 3: The positron asymmetry as function of energy using a signal − background with a gain 1, 12 bits applying a 1σ cut around the maximum counts. The data is divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0025	0.0016
4.38	120	0.0091	0.0017
5.11	140	0.0087	0.0012
5.84	160	0.0100	0.0019
6.57	180	0.0084	0.0019
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0136	0.0020

Table 4: The positron asymmetry as function of energy using a signal − background with a gain 1, 12 bits applying a 1.5σ cut around the maximum counts. The data is not divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0025	0.0015
4.38	120	0.0091	0.0016
5.11	140	0.0086	0.0011
5.84	160	0.0099	0.0017
6.57	180	0.0097	0.0017
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0137	0.0018

Table 5: The positron asymmetry as function of energy using a signal − background with a gain 1, 12 bits applying a 1.5σ cut around the maximum counts. The data is divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0034	0.0015
4.38	120	0.0093	0.0016
5.11	140	0.0086	0.0011
5.84	160	0.0100	0.0017
6.57	180	0.0087	0.0017
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0142	0.0018

against their energy. In both figures the full diamond data values and their errors correspond to the analysis results using the 1σ region. The other asymmetries values correspond to the other three conditions as indicated in the figures' inserts. To note is that the results of all four methods are consistent within errors. In general the results obtained for the high sensitivity are seen to be less dependent on the specific analysis method and show a more smooth energy

Table 6: The positron asymmetry as function of energy using a signal − background with a gain 1, 15 bits applying a 1σ cut around the maximum counts. The data is not divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0034	0.0016
4.38	120	0.0083	0.0017
5.11	140	0.0087	0.0012
5.84	160	0.0101	0.0019
6.57	180	0.0088	0.0019
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0138	0.0020

Table 7: The positron asymmetry as function of energy using a signal − background with a gain 1, 15 bits applying a 1σ cut around the maximum counts. The data is divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0043	0.0016
4.38	120	0.0092	0.0017
5.11	140	0.0090	0.0012
5.84	160	0.0103	0.0019
6.57	180	0.0087	0.0019
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0135	0.0020

Table 8: The positron asymmetry as function of energy using a signal − background with a gain 1, 15 bits applying a 1.5σ cut around the maximum counts. The data is not divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0050	0.0015
4.38	120	0.0088	0.0016
5.11	140	0.0091	0.0012
5.84	160	0.0100	0.0017
6.57	180	0.0089	0.0017
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0145	0.0018

dependence. Furthermore, from the figures it is found that the tor6130 normalisation procedure influences little, if at all, the final results.

Table 9: The positron asymmetry as function of energy using a signal − background with a gain 1, 15 bits applying a 1.5σ cut around the maximum counts. The data is divided by the tor6130 current.

e^+ Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
3.65	100	0.0049	0.0015
4.38	120	0.0093	0.0016
5.11	140	0.0090	0.0011
5.84	160	0.0100	0.0017
6.57	180	0.0090	0.0017
e^- Energy [MeV]	Spect. current [A]	Asymmetry	Δ Asymmetry
5.84	160	0.0141	0.0018

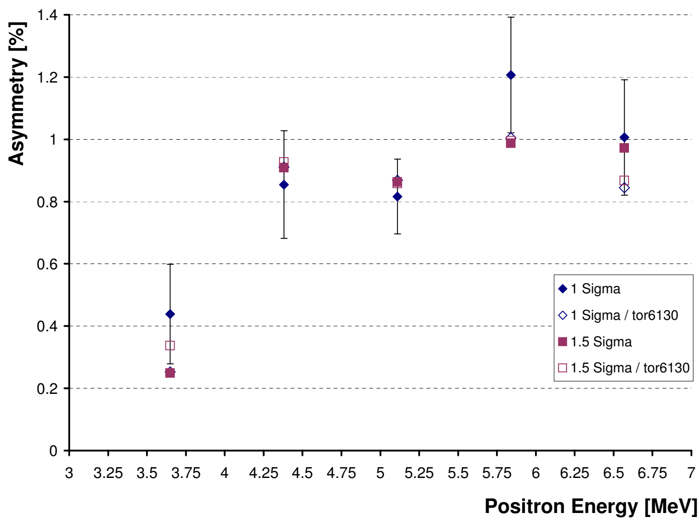

Figure 4: Positron asymmetry and its error versus its energy obtained from gain 1 low sensitivity data for a 1σ cut omitting the tor6130 normalisation procedure. In addition are also shown the asymmetry values for 1.5σ cuts and for toroid normalisation as indicated by the insert.

The positron polarisation

The relation between the asymmetry δ and the positron polarisation P_{e^+} is given by

$$P_{e^+} = \frac{\delta}{P_{e^-} A_{e^+}} \tag{4}$$

where P_{e^-} is the polarisation of the electrons in the analysing magnet and A_{e^+} is the analysing power of the experimental setup which should be evaluated via a Monte Carlo simulation.

Since at present the final simulation of the E166 experiment is still in progress we have chosen

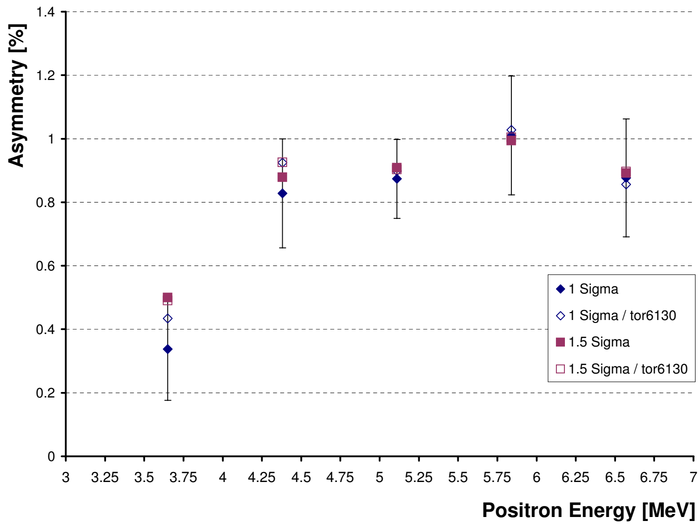

Figure 5: Positron asymmetry and its error versus its energy obtained from gain 1 high sensitivity data for a 1σ cut omitting the tor6130 normalisation procedure. In addition are also shown the asymmetry values for 1.5σ cuts and for toroid normalisation as indicated by the insert.

in the meantime to make use of the analysing power given in the E166 proposal (Fig. 17 and Table 13 in the 2003 proposal version).

The polarisation results obtained from the high sensitivity asymmetries and their corresponding statistical errors are shown in Fig. 6 where they are superimposed on the proposal expectation (figure 10 in the E166 2003 proposal version). As can be seen the measured polarisations are in good agreement both in their values and in their energy dependence with the proposal expectation.

Final remarks

In the present work we have opted to adopt a simple straightforward analysis method which already reveals the presence of polarised positrons by using only the central (No. 5) CsI crystal. For our final asymmetry values we have chosen the results obtained from the gain 1 high sensitivity data as they were found to be less dependent on the analysis details. Here we would like to stress that all the errors given in this report are only the statistical ones and no attempt has been made to estimate the systematic uncertainties. Clearly the method chosen by us is not the only one possible. At the same time the variation in the final results of all acceptable methods may serve as one of the ingredients for the estimation of the systematic errors.

As for the question whether one should normalise the data to the tor6130 values, it was found that the final asymmetry results are rather insensitive to the choice made.

Our analysis has also been repeated for the electron data at 5.84 MeV energy. The results are listed in Tables 2−9 where they are seen to be systematically higher than those derived for the positrons. Furthermore if one applies the positron analysing power given in the E166 proposal to the electron asymmetry then its corresponding polarisation values exceed 100%. The understanding of this situation has to be postponed until we have a final simulation of the experimental setup.

The comparison between the derived positron polarisations with its expectation from an experimental setup simulation is of a considerable importance in establishing the origin of the asymmetries. Thus the good agreement found between the measured polarisation and the expectation given in the E166 proposal, constitute an important supporting evidence for the nature of the asymmetry as being derived from polarisation. Further evidence for the asymmetry origin is expected to be supplied by the γ polarisation analysis.

In trying further to establish the nature of the asymmetry we have attempted to utilise the single run where the analysing magnets were turned down to zero for comparison with the magnets on data. However we found that the signals obtained between magnets on and magnets off seem to be inconsistent in their values so that no conclusion could be drawn.

Finally, we are planning to include in our future analysis all the nine CsI crystals with the hope to gain additional knowledge on the still open questions like the electron asymmetries values and the magnets off signals.

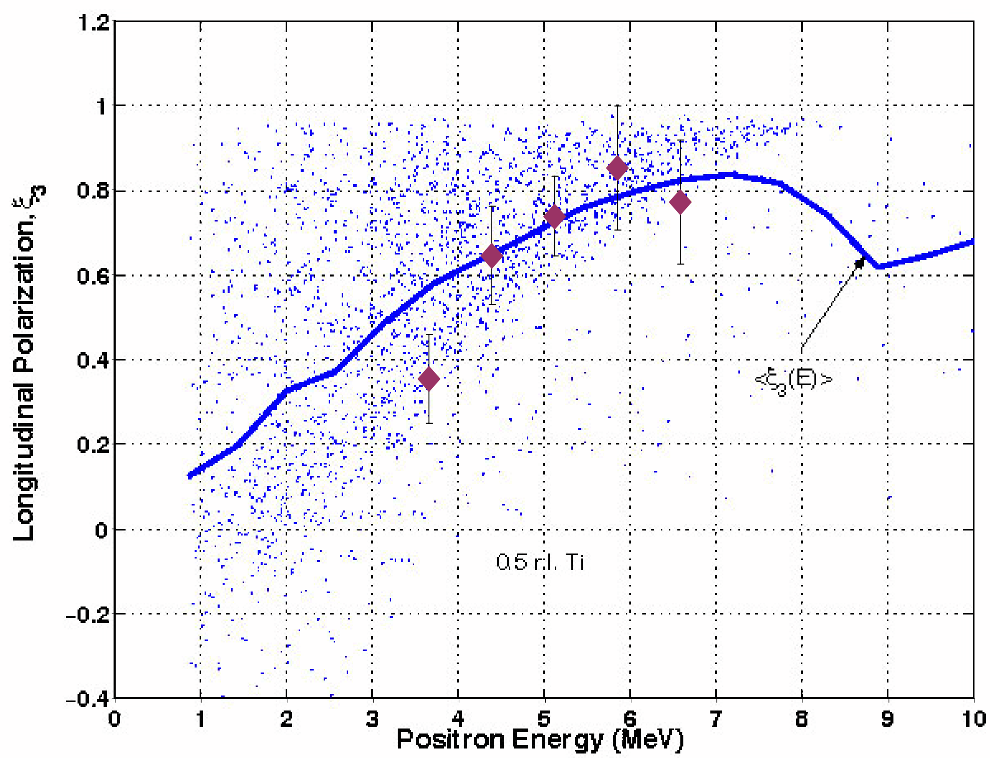

Figure 6: The measured positron polarisation values (using gain 1, high sensitivity data) with their statistical errors as a function of their energy superimposed on the expectation (solid line) given in the E166 experiment proposal.

Appendix I

'Target in' runs used in the analysis

Positrons, Spectrometer=100 [A]
2330, 2331, 2332, 2334, 2335, 2338, 2340, 2342, 2344, 2346, 2347, 2349, 2350, 2352, 2354, 2355, 2357, 2359, 2366, 2369, 2371, 2373, 2375, 2377, 2379, 2380, 2383, 2386, 2388, 2390, 2391, 2393, 2394, 2395, 2397, 2403, 2404, 2405, 2406, 2407, 2408, 2410, 2411, 2413, 2415, 2416, 2418, 2419, 2420, 2422, 2423, 2425, 2426, 2428, 2477.
Positrons, Spectrometer=120 [A]
2430, 2440, 2443, 2444, 2446, 2447, 2449, 2451, 2453, 2455, 2457, 2468, 2469, 2471, 2473, 2474, 2476, 2478, 2479, 2481, 2482, 2483, 2484, 2485, 2486, 2497, 2499, 2501, 2503, 2505, 2506, 2507, 2509, 2511, 2514, 2515, 2516, 2517, 2518, 2519, 2520, 2521, 2522, 2524, 2525, 2527, 2528, 2530, 2531.
Positrons, Spectrometer=140 [A]
2034, 2035, 2036, 2039, 2048, 2063, 2064, 2065, 2066, 2071, 2089, 2090, 2091, 2092, 2093, 2094, 2099, 2100, 2101, 2102, 2107, 2112, 2155, 2158, 2160, 2162, 2164, 2165, 2166, 2167, 2168, 2169, 2171, 2172, 2174, 2175, 2177, 2178, 2208, 2210, 2212, 2214, 2216, 2218, 2219, 2221, 2222, 2224, 2225, 2226, 2229, 2230, 2233, 2247, 2251, 2252, 2253, 2254, 2256, 2258, 2260, 2262, 2264, 2266, 2269, 2271, 2274, 2275, 2278, 2300, 2542, 2544, 2545, 2547, 2548, 2551, 2553, 2555, 2558, 2560, 2562, 2564, 2565, 2567, 2568, 2570, 2571, 2573, 2575, 2577, 2580, 2582, 2585, 2586, 2588, 2589, 2591, 2592, 2594, 2595, 2596, 2599, 2600, 2602, 2605, 2607, 2609, 2612, 2625, 2627, 2629, 2630, 2631.
Positrons, Spectrometer=160 [A]
2624, 2636, 2637, 2638, 2640, 2641, 2642, 2643, 2748, 2749, 2751, 2753, 2755, 2757, 2758, 2760, 2761, 2763, 2764, 2766, 2767, 2769, 2770, 2771, 2773, 2774, 2776, 2778, 2780, 2781, 2783, 2784, 2786, 2788, 2790, 2791, 2792, 2794, 2796, 2798, 2799, 2800.
Positrons, Spectrometer=180 [A]
2803, 2805, 2809, 2812, 2814, 2816, 2818, 2819, 2822, 2823, 2825, 2826, 2827, 2854, 2856, 2859, 2862, 2865, 2867, 2868, 2870, 2871, 2873, 2874, 2876, 2877, 2878, 2880, 2881, 2883, 2884, 2888, 2889, 2894.
Electrons, Spectrometer=160 [A]
2676, 2677, 2678, 2679, 2680, 2681, 2682, 2683, 2684, 2685, 2686, 2687, 2688, 2689, 2690, 2691, 2692, 2693, 2694, 2695, 2696, 2697, 2698, 2699, 2700, 2701, 2702, 2703, 2704, 2705, 2706, 2707, 2708, 2709, 2710, 2711, 2712, 2713, 2737, 2738, 2739, 2740, 2741, 2742, 2743, 2744, 2745, 2746.
Magnets 0ff, Spectrometer=120 [A]
2897