IFUSP/P 667
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30 NOV 1987

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PUBLICAÇÕES

IFUSP/P-667

E2, E4 AND E6 STATISTICAL DECAY SPECTRA IN ^{208}Pb

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Outubro/1987

ABSTRACT

Statistical decay spectra for the decay of giant resonances in ^{208}Pb are calculated using the Hauser-Feshbach formalism and the experimental levels of the residual nucleus. The predicted decay spectra are compared with available experimental results.

1. Introduction

We have shown[1] that the decay of the giant monopole resonance in ^{208}Pb is dominantly statistical. This was achieved by comparing a measured decay spectrum with the results of a Hauser-Feshbach calculation in which the experimental energy levels of the residual nucleus are used instead of a level density function. Since the decay spectrum of the isoscalar E2 resonance has been measured for ^{208}Pb in an (α,α',n) coincidence experiment[2], it is interesting to compare the measured decay spectrum with that predicted for a statistical decay, to find out if also the decay of the isoscalar E2 resonance is dominantly statistical.

In ref. 2) a statistical calculation was performed for the relative branching ratios of the decay into the low lying states of ^{207}Pb, for E2, E4 and E6 multipolarities. The authors conclude that the obtained branching ratios are in qualitative agreement with their experimental data for the population of the lowest three states in ^{207}Pb, under the assumption of pure E2 strength. Because a strong population of the $(13/2)^+$ state in ^{207}Pb is observed, they conclude that in the region of the isoscalar E2 resonance there are, also higher multipolarities. Assuming that there are only E6 and E2 multipolarities in this energy region (8.5 - 12.5 MeV excitation energy in ^{208}Pb) they set a lower limit of 20% for E6 admixture.

In this work we calculate the predicted statistical neutron decay spectra for E2, E4 and E6 multipolarities and compare them with the experimental spectrum[2].

2. The statistical calculations

In order to calculate the predicted neutron spectra we use the Hauser-Feshbach formalism[3,4] following the same procedure described in ref. 1). For this case there is no need to use a nuclear model to assign spins and parities to experimental energy levels of ^{207}Pb, as in ref. 1), because all levels that can be populated and their corresponding spins and parities are known from experiment[5]. The transmission coefficients are computed using the global optical potential from Rapaport et al.[6]. The influence of different parametrizations of the optical potential in the transmission coefficients and their effect in the predicted statistical decay spectra is discussed in ref. 1).

3. Results

Figs. 1 to 3 show the predicted statistical neutron decay spectra, for an excitation energy of 10.6 MeV in ^{208}Pb, under the assumption of pure E2, E4 and E6 multipolarities, respectively. In these figures it was assumed that the experimental energy resolution for neutron detection is Γ = 300 MeV, representing each neutron line by a Gaussian with FWHM equal to the energy resolution. These figures show that at this excitation energy, where few levels of the residual nucleus can be populated, the decay spectrum is very sensitive to the multipolarity of the excited state. Consequently, under the assumption of a statistical process, multipolarity admixtures can be inferred from measured decay spectra.

Fig. 4 shows the experimental neutron decay spectra

(histogram) from ref. 2), which also has an energy resolution of 300 keV. The curve is the predicted decay spectrum assuming that the excited states around 10.6 MeV in ^{208}Pb are pure 2^+ states. In the experimental spectrum peaks A and B do not belong to the decay of ^{208}Pb, since they do not correspond to decay into any low lying state of ^{207}Pb. Since peaks A and B are spurious, it is difficult to assess if the peak at the energy corresponding to decay into the $(13/2)^+$ state in ^{207}Pb is real. If this peak is also spurious, one would conclude that there is a reasonable agreement between the measured spectrum and that predicted for a pure E2 statistical decay. The agreement is good for the first three low lying states, but is poor in the region of the group of states: $\frac{5}{2}^+$, $\frac{7}{2}^+$, $\frac{1}{2}^+$, $\frac{9}{2}^+$. However, assuming that the peak in the region of the $(13/2)^+$ state is real, than from Figs. 1 to 3, it is evident that this peak implies E4 and/or E6 admixtures.

Fig. 5 shows the same experimental data as Fig. 4, but the curve is the predicted decay spectrum assuming 80% E2 and 20% E6. Now the decay into the $(13/2)^+$ state is well accounted for, but the agreement between measured and calculated spectrum becomes worst for the other peaks, relatively to the spectrum for pure E2 (Fig.3). This, along with the existence of spurious peaks A and B casts doubts about the E6 admixture. We have tried to explain the experimental spectrum with a higher admixture of E6, with admixtures of E2, E4 and E6 and also with E4 and E2 admixture. All these trials yielded spectra incompatible with the experimental results.

4. Conclusions

We have shown that the shapes of statistical decay spectra are sensitive to the multipolarity of the excited state. This opens the possibility of studying multipolarity admixtures from measured decay spectra.

In the case studied here, which refers to the decay of the isoscalar E2 resonance, located at 10.6 MeV in ^{208}Pb, it was not possible to determine the multipolarity admixture because of the existence of spurious peaks in the experimental spectrum in the vicinity of the $(13/2)^+$ peak. The assumption of E6 admixture accounts for the existence of the $(13/2)^+$ peak but does not improve the agreement between the other observed peaks and the predicted spectrum. If the peak located at the energy position corresponding to decay into the $(13/2)^+$ level of ^{207}Pb is assumed to be a spurious peak, as certainly are the other two imediatly before and after it, then there is a reasonable agreement between measured and calculated spectrum, assuming a statistical process for the decay of the isoscalar E2 resonance.

Acknowledgements

The authors acknowledge financial support from Financiadora de Estudos e Projetos, Fundação de Amparo à Pesquisa do Estado de São Paulo e Conselho Nacional de Desenvolvimento Científico e Tecnológico.

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FIGURE CAPTIONS

Fig. 1 - Predicted statistical decay spectrum for an E2 excitation at 10.6 MeV in ^{208}Pb.

Fig. 2 - Predicted statistical decay spectrum for an E4 excitation at 10.6 MeV in ^{208}Pb.

Fig. 3 - Predicted statistical decay spectrum for an E6 excitation at 10.6 MeV in ^{208}Pb.

Fig. 4 - The histogram is the experimental neutron decay spectrum from ref. 2). The curve shows the calculated statistical decay spectrum for an E2 excitation at 10.6 MeV in ^{208}Pb. Peaks A and B in the experimental spectrum do not belong to the decay of ^{208}Pb.

Fig. 5 - The histogram shows the same experimental data of Fig. 4. The calculated spectrum assumes that the excited state around 10.6 MeV in ^{208}Pb has an admixture of 80% E2 plus 20% E6.

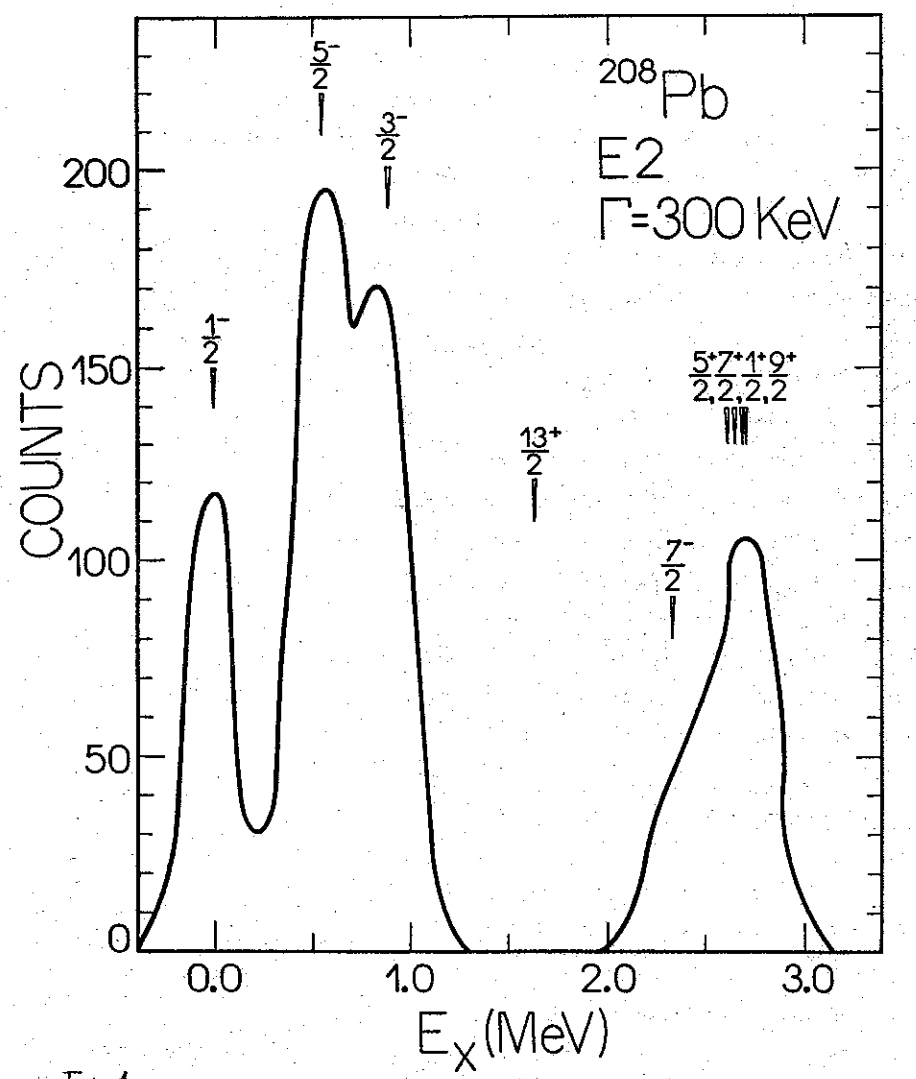

Fig 1

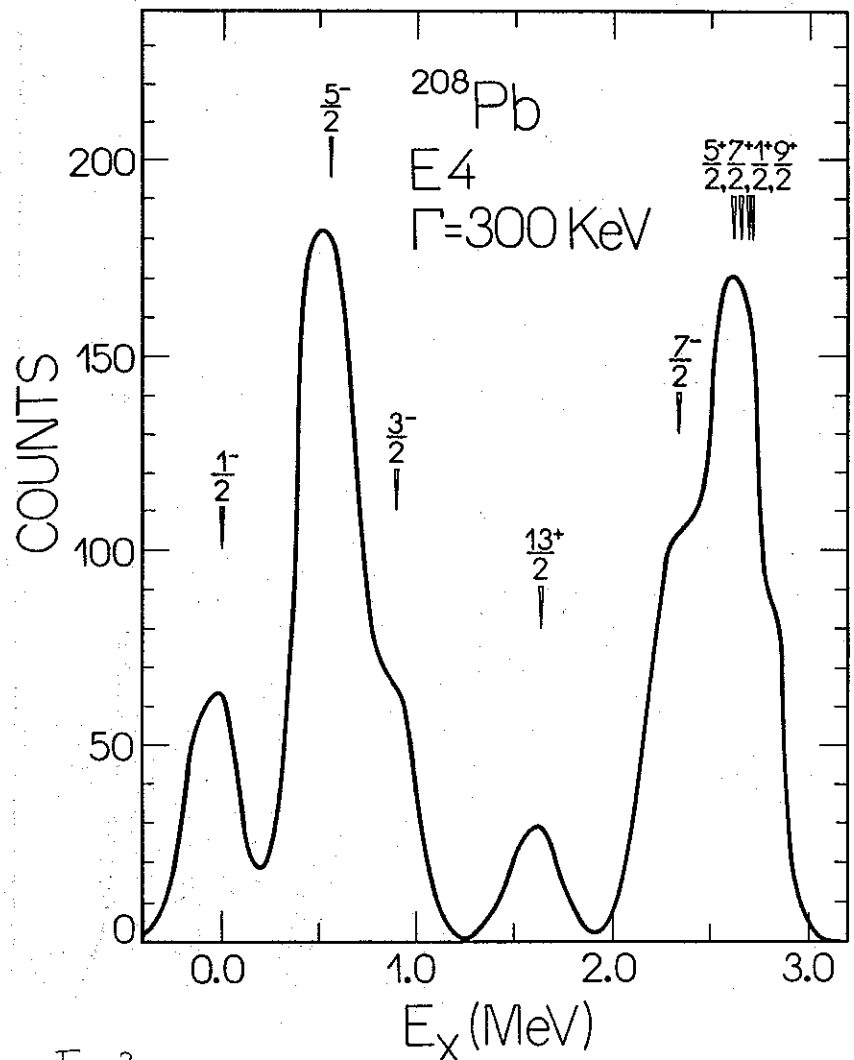
208Pb
E4
Γ=300 KeV
COUNTS
200
150
100
50
0
0.0
1.0
2.0
3.0
Ex (MeV)
1/2 1-
5/2 5-
3/2 3-
13/2 13+
7/2 7-
5/2,7/2,1/2,9/2 5+,7+,1+,9+

Fig 2.

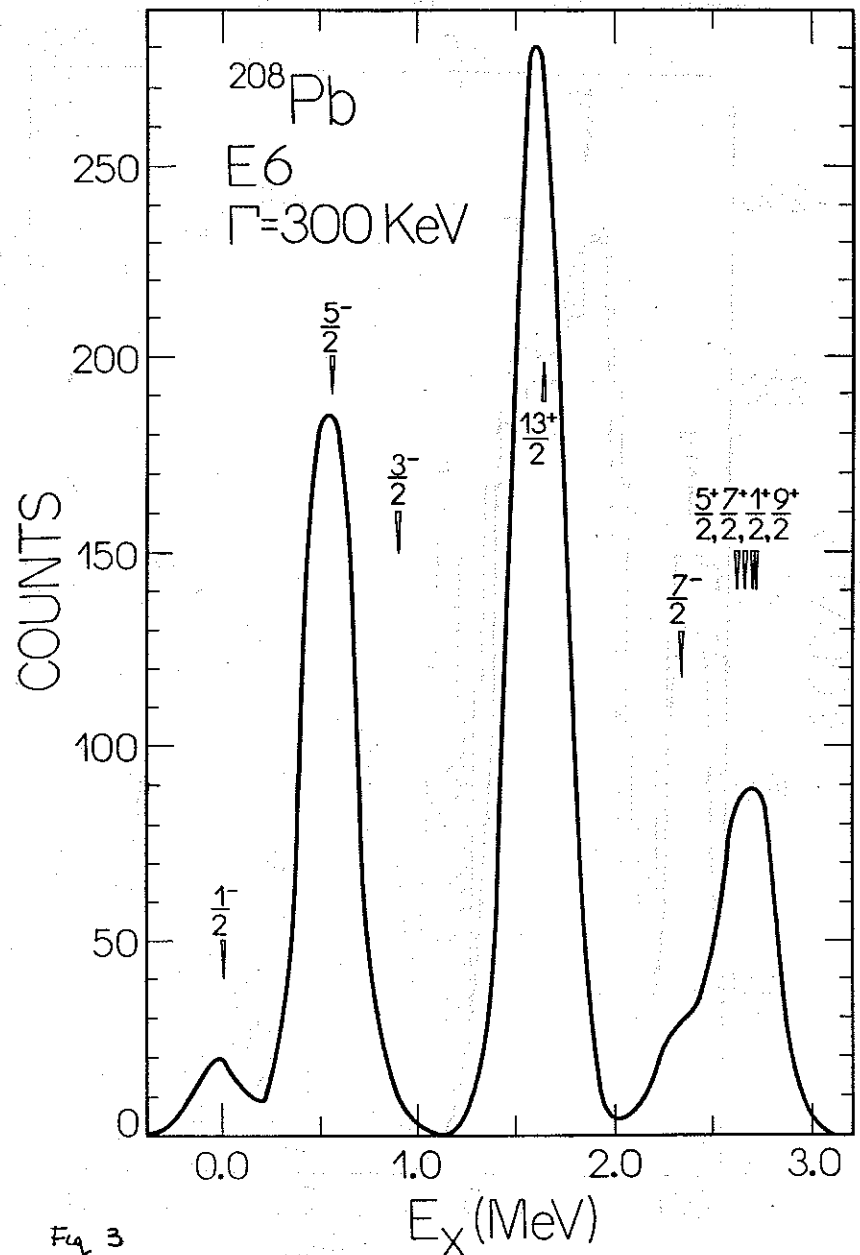
208Pb
E6
Γ=300 KeV
COUNTS
250
200
150
100
50
0
0.0
1.0
2.0
3.0
Ex (MeV)
1/2 1-
5/2 5-
3/2 3-
13/2 13+
7/2 7-
5/2,7/2,1/2,9/2 5+,7+,1+,9+

Fig 3

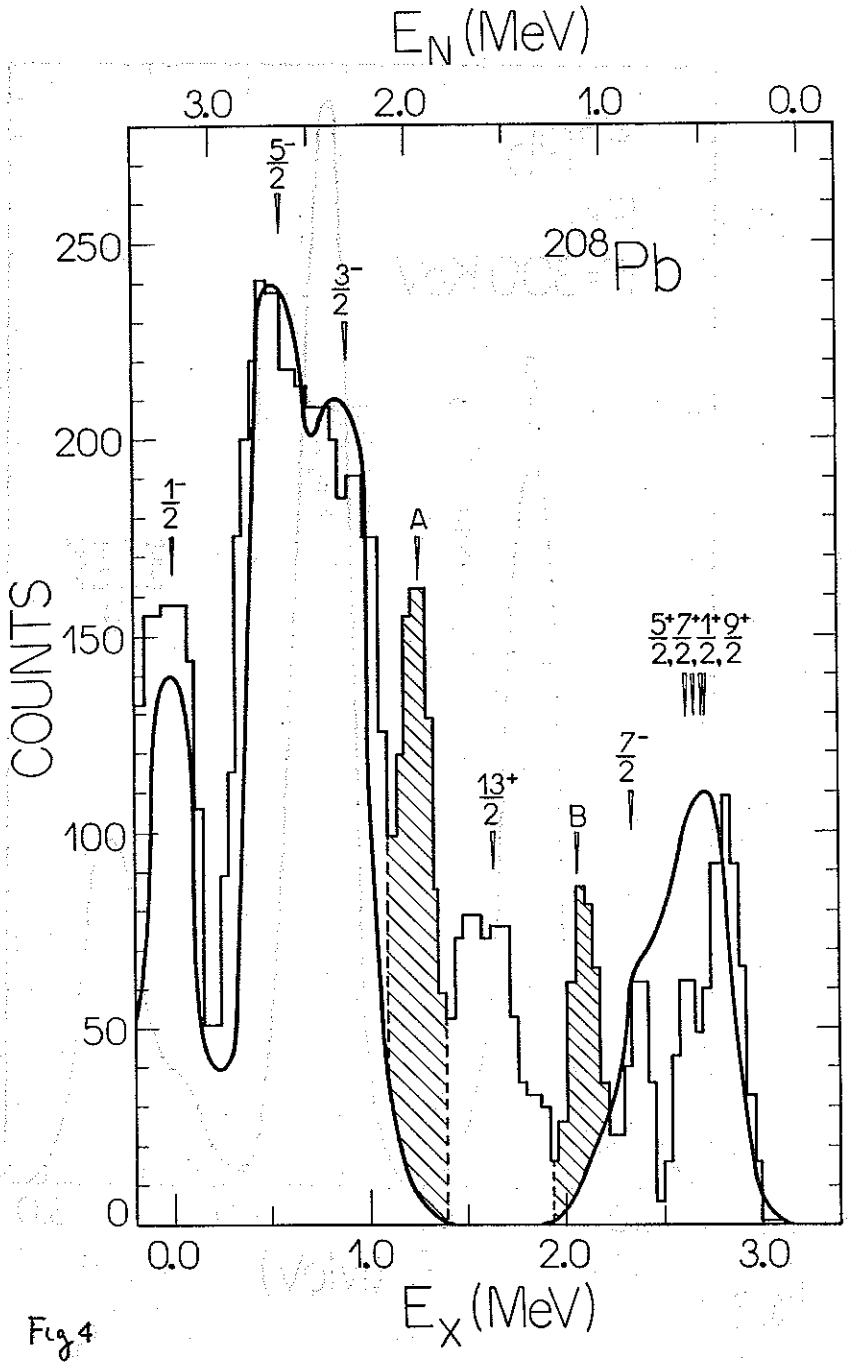
E_N (MeV)
3.0
2.0
1.0
0.0
208Pb
5⁻/2
3⁻/2
1⁻/2
A
13⁺/2
B
7⁻/2
5⁺7⁺1⁺9⁺/2,2,2,2
COUNTS
250
200
150
100
50
0
0.0
1.0
2.0
3.0
E_X (MeV)

Fig 4

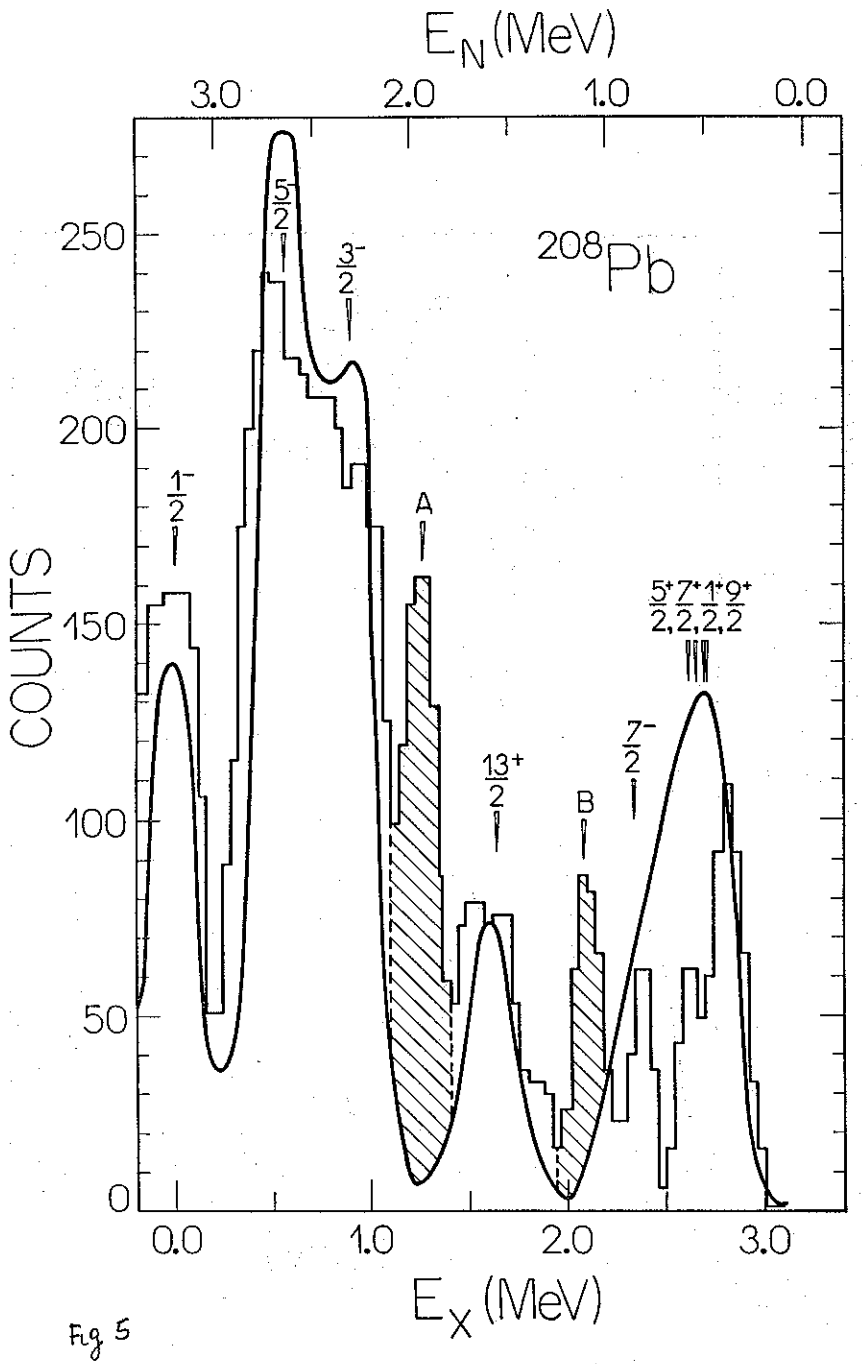
E_N (MeV)
3.0
2.0
1.0
0.0
208Pb
5⁻/2
3⁻/2
1⁻/2
A
13⁺/2
B
7⁻/2
5⁺7⁺1⁺9⁺/2,2,2,2
COUNTS
250
200
150
100
50
0
0.0
1.0
2.0
3.0
E_X (MeV)

Fig 5