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Z-Dependence of the Intensity of $|\Delta n| = 2$ Pionic X-rays*

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Abstract

The intensity per stopped π^- of $|\Delta n| = 2$ pionic X-rays are observed to have larger variations with atomic number Z than do the $|\Delta n| = 1$. The 6 - 4 intensity has a well defined maximum at Z = 34 with a FWHM of $\Delta Z \sim 10$.

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Previous experiments which measured the Z-dependence of the yield of mesonic X-rays include a comprehensive survey with kaons [1] and a survey of the $|\Delta n| = 1$ transitions with pions [2]. The observed variations in the yields cannot be completely explained by the Z-dependence of the Auger effect and/or the strong interaction. The depletion of certain X-rays is presumably due to nuclear capture of the mesons from low angular momentum states during early stages of the atomic cascade. Theoretical predictions [3,4] of the population of the initial angular momentum states of the meson at the time of atomic capture have treated the electrons statistically. i.e. it has not yet been possible to include the shell structure which is presumably necessary. However empirical correlations of the intensity variations with atomic diameter [5] and with the electron density in the outer part of the atom [6] have been noted.

The intensities of the $|\Delta n| = 1$ X-rays may tend to be relatively insensitive to the initial distribution of angular momentum states for the following reasons: in the early part of the cascade, there are many large Δn transitions which tend to populate preferentially the circular orbits, $\ell = n-1$ [7]. Once in a circular orbit, a meson descends by a series of $\Delta n = \Delta\ell = -1$ steps through more circular orbits. The population of a circular orbit n,ℓ is therefore approximately proportional to the sum of the initial distribution over most angular momentum states higher than this ℓ. Since the transitions between circular orbits dominate the $|\Delta n| = 1$ X-rays, the latter tend to be insensitive to the initial distribution.

$|\Delta n| = 2$ transition on the other hand, have only a small contribution from the circular orbits since these would have to be relatively weak quadrupole transitions.

As part of a comprehensive survey [8] of pionic X-ray intensity variations with Z, we have measured the less intense $|\Delta n| = 2$ pionic X-rays at TRIUMF for 57 elemental targets. Pion stops in each target were signalled by the usual $1 \cdot 2 \cdot 3 \cdot \bar{4}$ coincidence in a scintillator telescope and X-rays were measured with a hyperpure germanium detector of resolution 900 eV FWHM at 250 keV. Full details will appear in ref. [8]. Fig. 1 shows the intensity of the $n = 6$ to $n = 4$ pionic X-rays per stopped π^- as a function of Z. Corrections have been made for the change of detector efficiencies and target self-absorption with energy. Only the relative errors are shown in fig. 1, but there is an additional 25% normalization error. The curve is a prediction of a cascade code which incorporates electric dipole radiation between atomic levels, the Auger effect, pion decay, nuclear capture, and a statistical population of ℓ-states at $n = 17$. The decrease in intensity at low Z in the predictions is caused by the Auger effect.

The observed 6 - 4 intensities in fig. 1 are seen to have a well-defined maximum at a Z-value of approximately 34 with a FWHM of approximately 10. Part of this variation may be caused by the Auger effect but in addition there apprears to be some unknown effect of the electronic configuration on the distribution of the initial angular momentum of the pion. The intensities vary by a factor of approximately four, compared to factors of approximately two that we observe in our preliminary $|\Delta n| = 1$ data, and that have been reported [2] in other $|\Delta n| = 1$ cases.

References

[1] C.E. Wiegand and G.L. Godfrey, Phys. Rev. A9 (1974) 2282; G.L. Godfrey and C.E. Wiegand, Phys. Lett. 56B (1975) 255.

[2] A.R. Kunselman, Lawrence Berkeley Laboratory report, UCRL-18654 (1969).

[3] M. Leon and R. Seki, Phys. Rev. Lett. 32 (1974) 132.

[4] M. Leon and R. Seki, Nucl. Phys. A282 (1977) 445

[5] R. Kunselman, J.L. Law, M. Leon and J. Miller, Phys. Rev. Lett. 36 (1976) 446.

[6] G.T. Condo, Phys. Rev. Lett. 33 (1974) 126.

[7] Y. Eisenberg and D. Kessler, Phys. Rev. 123 (1961) 1472; Y. Eisenberg and D. Kessler, Phys. Rev. 130 (1963) 2352,

[8] R.M. Pearce *et al.*, to be submitted to Can. J. Phys.

Figure Caption

1. The observed percentage of $n = 6$ to $n = 4$ pionic X-rays per pion stop as a function of atomic number for elemental materials showing relative errors. The curve is the prediction from a cascade code.

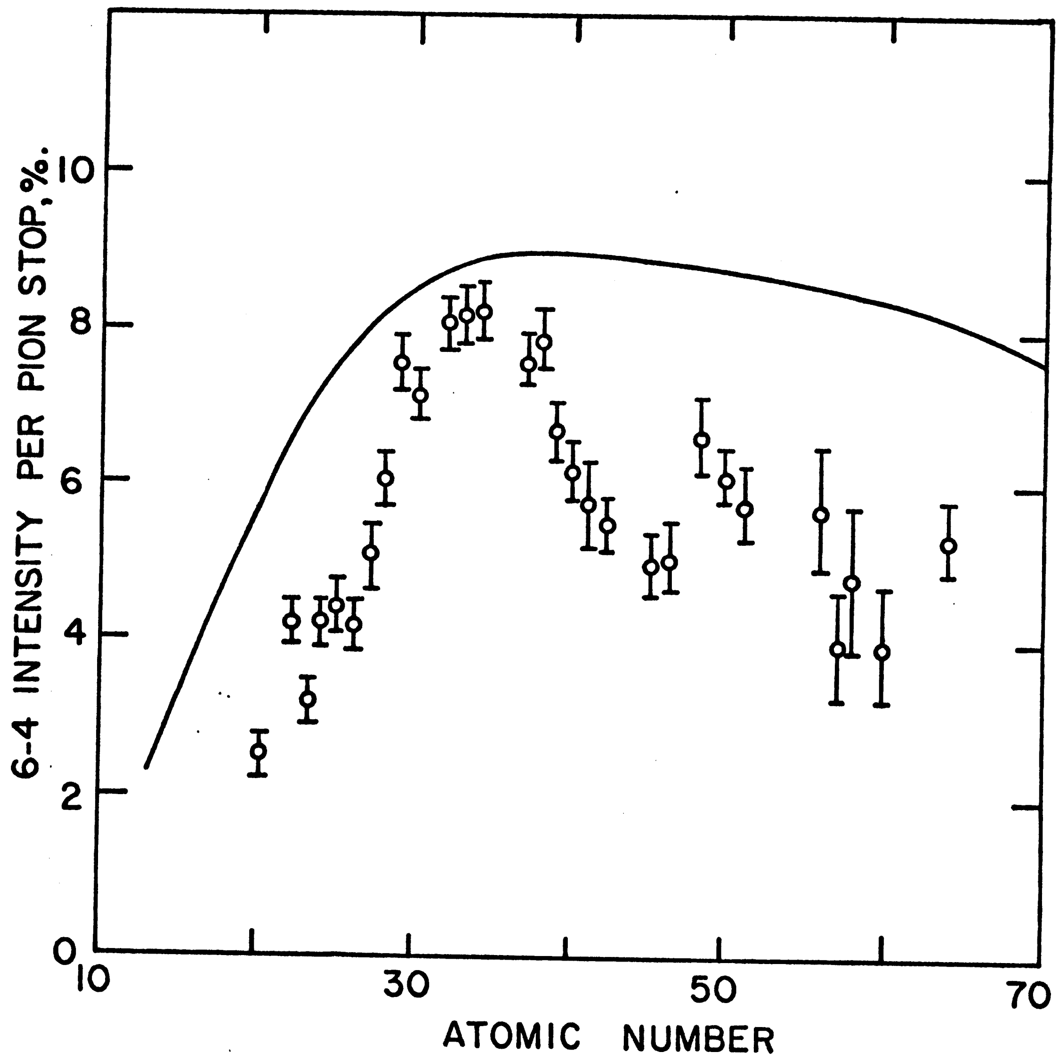

Fig. 1