Submitted to: PHYSICS LETTERS B

PUB-75-176-E
E 0261

FERMILAB-PUB-75-176-E
BNL 19982

publ file
E 261

NATIONAL ACCELERATOR LAB.
MAY 19 1975
PROGRAM PLANNING OFFICE

X-RAY TRANSITION RADIATION FROM 50 GeV ELECTRONS*

R. Bosshard†, J. Fischer, S. Iwata‡,
V. Radeka, and C. L. Wang

Brookhaven National Laboratory
Upton, New York 11973

and

M. Atac

Fermi National Accelerator Laboratory
Batavia, Illinois 60510

April 1975

By acceptance of this article, the publisher and/or recipient acknowledges the U. S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

---

*Research carried out under the auspices of Energy Research and Development Administration.

†On leave from Laboratoire de l'Accélérateur Linéaire, University Paris-Sud, Bâtiment 200, F-91405 Orsay, France.

‡On leave from Nagoya University, Nagoya, Japan.

X-RAY TRANSITION RADIATION FROM 50 GeV ELECTRONS*

R. Bosshard†, J. Fischer, S. Iwata‡,
V. Radeka, and C. L. Wang

Brookhaven National Laboratory
Upton, New York 11973

and

M. Atac

Fermi National Accelerator Laboratory
Batavia, Illinois 60510

ABSTRACT

X-ray transition radiation from electrons up to 50 GeV traversing lithium foils was studied with xenon-filled proportional wire chambers. The x-ray yield up to the Lorentz factor 10^5 is consistent with theory. Excellent electron-hadron discrimination was achieved.

*Research carried out under the auspices of Energy Research and Development Administration.

†On leave from Laboratoire de l'Accélérateur Linéaire, University Paris-Sud, Bâtiment 200, F-91405 Orsay, France.

‡On leave from Nagoya University, Nagoya, Japan.

In a previous paper[1], we reported the first observation of transition radiation (TR) x-rays from very high energy hadrons, 100-250 GeV/c pions. By comparison with our electron data[2] in the GeV range, we found that in accordance with theory[3] the x-ray yield does not depend on the particle mass, but on its Lorentz factor (γ = total energy/rest mass) only. Although TR x-rays from electrons have been extensively studied[2,4,5], it is of interest to study their behavior at higher energies (in the very high γ region). Because the coherence length in a radiator material increases with γ and with photon energy[3], the destructive interference in the high energy part of the radiation from the various interfaces in the practical radiator of limited dimensions prevents the TR x-ray yield from increasing linearly with γ. The interference results in saturation above $\gamma \sim 10^4$ after a logarithmic increase[5]. Because of the above effect and partly because of the increasing importance of leptons in recent elementary particle physics, the TR x-rays from very high energy electrons ($\gamma \sim 10^5$) and the performance of an electron identifier utilizing this phenomena were investigated.

The experiment was performed in the M1 beam of the Fermi National Accelerator Laboratory. The experimental setup is described in detail in the previous paper[1]. The electrons, less than 10% of the 50 GeV/c secondary beam, were selected by a shower counter[6] after passing through the radiator-proportional wire chamber (PWC) arrays. The TR x-rays from each radiator were detected in the chamber gas together with the ionization energy loss of the incident particle. The radiator consisted either

of 2 mil-thick lithium foils[2] or ½ mil-thick polypropylene foils. The PWC of ½" thickness was filled with xenon + 20% CO_2 mixture at atmospheric pressure. The PWC signals were routed to a linear adder for pulse height analysis and also to a majority coincidence system[1] for fast logic application.

Figure 1 shows the pulse height distribution of the summed signals from only four PWC's with two lithium radiators (500 and 1000 foils) and two polypropylene radiators (450 foils). The discriminator threshold for the shower counter was set for a high electron efficiency and a low pion efficiency. Two distinctly separated peaks, electrons and pions, are apparent showing the big contribution of TR x-rays to the electron events. The electron detection efficiency of this system is 94% including only 1.7% pion contamination. The average number of detected photons per incident electron was estimated to be 8 ± 2. The total thickness of the materials in the beam amounted only to 4.7×10^{-2} radiation lengths and about 5% nuclear collision probability. Our fast logic signal based on the transition radiation from the majority coincidence, which provided pure electron signals, was also successfully used for the shower counter calibration. This clean separation of the two particles with a small number of TR detector sets is mainly due to the efficient x-ray detection by the xenon gas and the low x-ray self-absorption in the lithium radiators. This was confirmed by a measurement with a single PWC following the two lithium radiators (see Fig. 2), resulting in 95% electron efficiency with 8% pion contamination[7]. Even a single Li radiator-Xe PWC set was found to be a good electron identifier.

The TR x-ray yield was measured with a single lithium radiator of 500 foils followed by a PWC. The result is compared in Fig. 3 with that obtained in the GeV region at the AGS of Brookhaven National Laboratory. At 50 GeV the electron peak is well separated from pion peak, providing 95% electron efficiency with 10% pion contamination. The excellent performance of electron discrimination can also be seen in the ratios of the average x-ray yield to the ionization loss; 3.4 at 50 GeV and 2.9 at 2.5 GeV. The saturation of the x-ray yield at 50 GeV is evident when compared to the rapid increase in the few GeV range. The saturation energy under our condition is theoretically given by

$$E_s \approx \frac{\omega_o \cdot \ell}{2\pi \cdot c} \cdot mc^2 \quad ,$$

where ω_o is the plasma frequency of the foil material, ℓ is the foil spacing (0.5 mm), and mc^2 is the particle rest mass. In our case, this is about 3 GeV ($\gamma \approx 6\text{x}10^3$) and the present 50 GeV point agrees with this prediction as seen in Fig. 3. The x-ray yield saturates from a lower γ, but at a higher yield level than with the other detectors so far reported[4].

The optimum xenon thickness (x) was estimated by computing the x-ray yield as a function of x. The x-ray detection efficiency at less than 10 keV is already adequate with x = 1 cm, and the energy spectrum[2] is peaked at about 9 keV almost independently of γ, the higher energy part being suppressed due to the destructive interference effect. As a result, compared to the linear increase of the ionization loss, the

the x-ray yield (W) and the average number of photons (n) were found to increase only slowly with x;

$$W \propto \log (1 + x/0.37), \text{ and}$$

$$n \propto \log (1 + x/0.15), \text{ respectively.}$$

Therefore, although the ionization loss fluctuation (FWHM) improves from about 100% with 1 cm to 55% with 6 cm xenon[8], the optimum thickness in combination with our lithium radiator is between 1 and 2 cm for particle discrimination. This chamber thickness maintains a fast response to x-rays and is convenient for operation.

In conclusion, we can summarize our results as follows:

(1) The behavior of the TR x-ray production at the highest γ measured so far is as predicted by the theory;

(2) the Li-Xe combination permits an excellent electron identification against hadrons, even with a single radiator-PWC set;

(3) it offers a wideband electron identifier between 3 and 50 GeV/c or higher.

Acknowldegements

We thank Drs. M. Q. Barton, D. Berley, H. J. Foelsche, and R. R. Rau for their interest and support, Messrs. J. F. Gatz, III and F. C. Merritt for their expert construction of wire chambers and assistance. The help and cooperation of FNAL staff, in particular Drs. P. F. Koehler, J. R. Sanford, and A. A. Wehmann are gratefully acknowledged.

REFERENCES

1. R. Bosshard, J. Fischer, S. Iwata, V. Radeka, C. L. Wang, and M. Atac; preprint BNL 19946, submitted to Phys. Lett.
2. J. Fischer, S. Iwata, V. Radeka, C. L. Wang, and W. J. Willis; to be published, and also Phys. Lett. 49B (1974) 393.
3. G. M. Garibian; Soviet Phys. JETP 12 (1961) 237, 33 (1971) 23.
4. M. L. Cherry, G. Hartmann, D. Müller, and T. Prince, Phys. Rev. 10D (1974) 3594; C. L. Wang, Nucl. Instr. & Meth. 118 (1974) 453; A. I. Alikhanian, S. A. Kankanian, A. G. Oganessian, and A. G. Tamanian, Phys. Rev. Lett. 30 (1973) 109; A. Bamberger, G. F. Dell, Jr., H. Uto, L. C. L. Yuan, and P. W. Alley, Phys. Lett. 43B (1973) 153; F. Harris, T. Katsura, S. Parker, V. Z. Peterson, R. W. Ellsworth, G. B. Yodh, W. W. M. Allison, C. B. Brooks, J. H. Cobb, and J. H. Mulvey, Nucl. Instr. & Meth. 107 (1973) 413.
5. R. Ellsworth, J. MacFall, G. Yodh, F. Harris, T. Katsura, S. Parker, V. Peterson, L. Shiraishi, V. Stenger, J. Mulvey, B. Brooks, and J. Cobb, Technical Report 73-128, University of Maryland; M. L. Cherry, D. Müller, and T. A. Prince, Nucl. Instr. & Meth. 115 (1974) 141.
6. Shower counter signals were provided through the courtesy of Drs. J. Knauer and J. Younts of FNAL, Exp. 87. Pion plus electron signals were provided through the courtesy of FNAL, Exp. 7, ANL, Indiana, Michigan, FNAL, Purdue collaboration.
7. These values are conservative because the entrance window (two Aclar foils of 2 mil each) of the second radiator absorbed 90% of 6 keV x-rays from the first one.
8. A. P. Onuchin and V. I. Telnov, Nucl. Instr. & Meth. 120 (1974) 365.

FIGURE CAPTIONS

Fig. 1. Pulse height distribution of summed signals from four proportional wire chambers for 50 GeV/c beam of pions and electrons. The shaded area shows the electron events consisting of x-rays plus ionization loss.

Fig. 2. The same as Fig. 1, but of a single chamber signals with two lithium radiators in front. A peak at the highest position was caused by amplifier saturation.

Fig. 3. Average x-ray energy detected in a single chamber per incident electron with a lithium radiator of 500 foils. The dashed line indicates the saturation level of the x-ray yield predicted by theory.

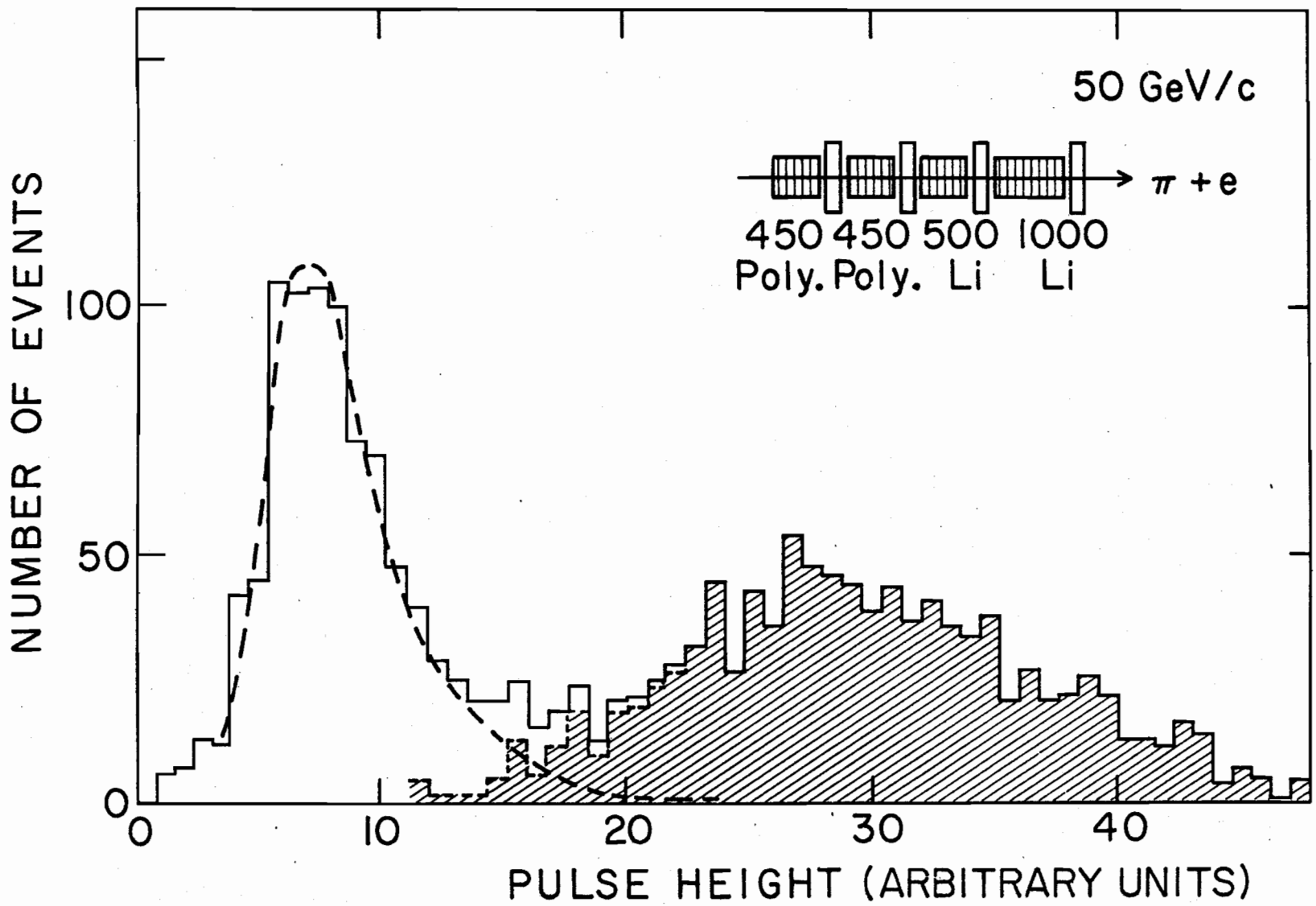
50 GeV/c
π + e
450 450 500 1000
Poly. Poly. Li Li
NUMBER OF EVENTS
0
50
100
0
10
20
30
40
PULSE HEIGHT (ARBITRARY UNITS)

Fig. 1

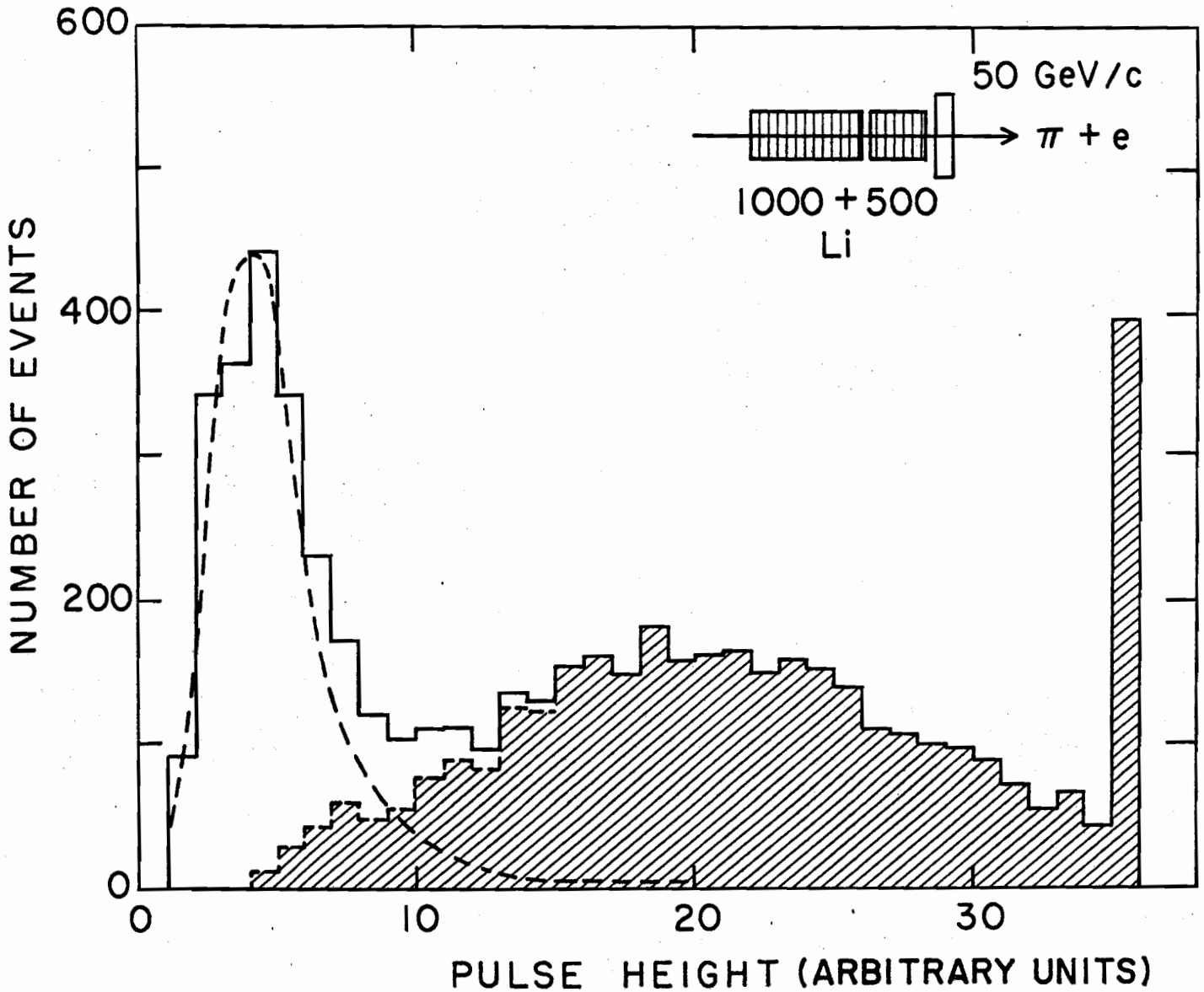
600
400
200
0
NUMBER OF EVENTS
0
10
20
30
PULSE HEIGHT (ARBITRARY UNITS)
50 GeV/c
π + e
1000 + 500
Li

Fig. 2

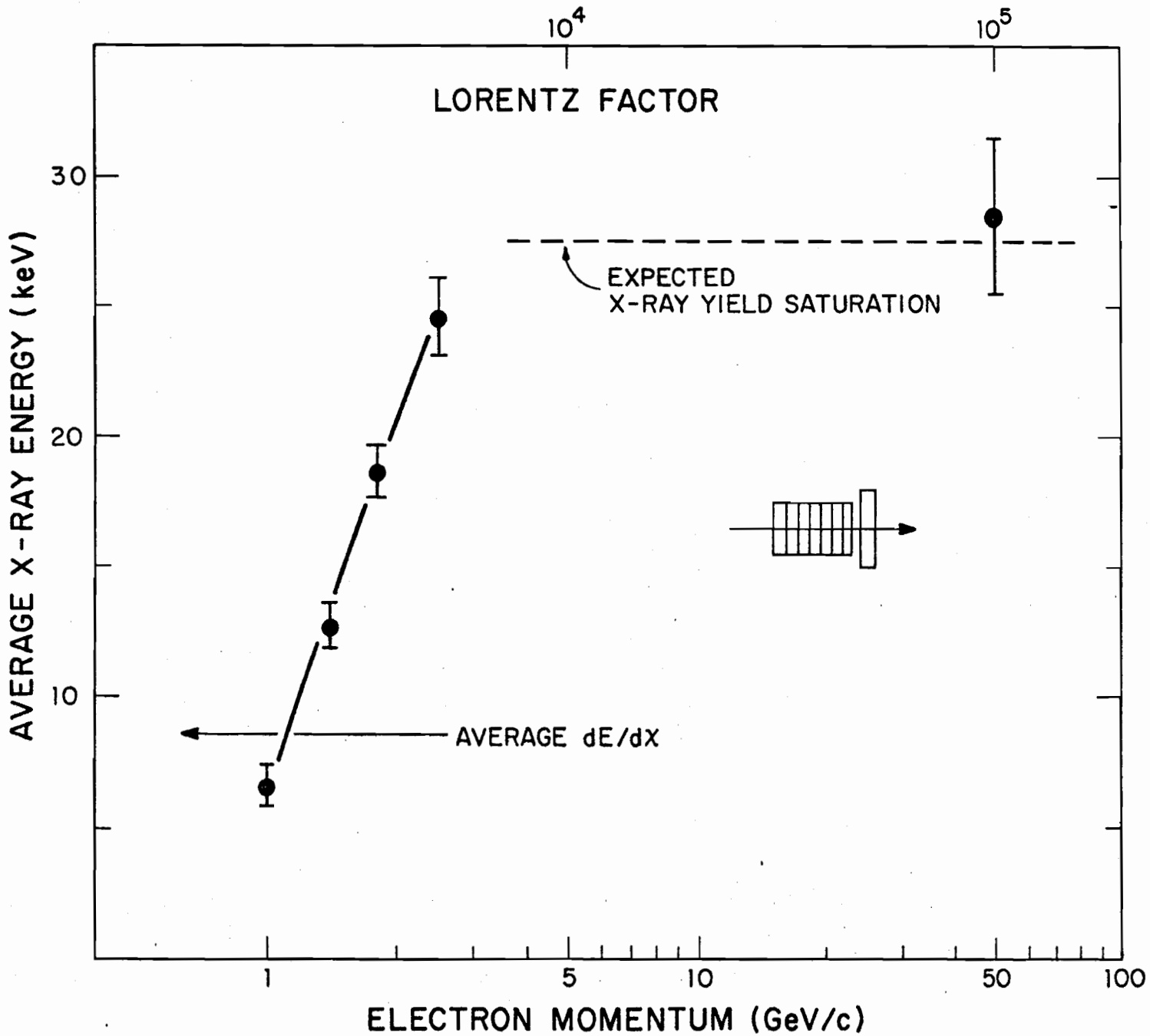
LORENTZ FACTOR
10^4
10^5
AVERAGE X-RAY ENERGY (keV)
30
20
10
EXPECTED
X-RAY YIELD SATURATION
AVERAGE dE/dX
1
5
10
50
100
ELECTRON MOMENTUM (GeV/c)

Fig. 3