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Transition Radiation From 100 to 250 GeV/c Pions*

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ABSTRACT

X-ray transition radiation from 100 to 250 GeV/c pions passing through either lithium or polypropylene foils was observed with proportional wire chambers. The x-ray intensity increases linearly with the Lorentz factor. Pions and protons at these momenta can be differentiated with a few radiator-detector units.

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In the past several years, fairly extensive experimental studies[1] on x-ray transition radiations were performed in order to develop transition radiation detectors (TRD) and assess their feasibility for particle identification at very high energies. Practically all of these experiments were done with high energy electrons taking advantage of their small mass and therefore large Lorentz factors (total energy/rest mass), which the total energy of the transition x-ray is linearly proportional to. For high energy electrons (> 1 GeV), the TRD's prove to be useful and practical, and experiments are either being installed or planned at high energy accelerators using such devices[2]. In the cosmic ray area on the other hand, such detectors are being tested for discrimination of pions (or muons) from protons at very high energies. Since multihundred GeV particle beams have become available, it is interesting and important to investigate if there is transition radiation also from high energy hadrons, and test if the TRD can be used to differentiate very high energy particles as indicated by the available electron data.

The experiment was performed in the M1 beam of the Fermi National Accelerator Laboratory. A schematic of the experimental setup and simplified electronic diagram is shown in Fig. 1. The momentum analyzed secondary beam was directed onto the TRD system, which consisted of a series of transition radiators and proportional wire chambers (PWC). The transition radiators were made either of 500 lithium foils 2 mil thick or 100 polypropylene foils of half mil thick, and the PWC's are 1/2" thick and have a sensitive area of 1" diameter. The incident particle was defined by the counter telescope $S_1S_2S_3$, with the Cerenkov counter C identifying pions and protons[3] and the shower counter identifying electrons[4]. The basic idea is that when an ultrarelativistic particle passes through the system, in addition to the ionization energy loss the PWC will detect x-rays emitted from the transition radiators. The resulting pulse height from the PWC will therefore be larger than the pulse height due to the ionization loss alone. Since the beam intensity is high ($\sim 10^6$ particle/pulse), it is important that only single particle passes the system. In addition to the hole veto counters $\bar{H}$ used to reject shower events, pulse height as well as timing information from S_1, S_2 and S_3 were used to veto

events in which more than one particle arrive within 200ns. The signals from PWC's were split into two, one for a pulse height analyzer display via a linear adder and the other for better particle discrimination via the majority coincidence system for fast logic application. The pulse height linearity and energy scale were established by calibration with various x-ray sources.

Fig. 2 shows the pulse height distribution of the added signals from only four PWC's with four Li radiators in place. Each radiator has 500 Li foils of 2 mil thickness. Two radiators have 20 mil spacing between the foils and the other two have 8 mil spacing. The "dummy" indicates the pulse height distribution when 1/16 inch Al absorbers are placed in front of the PWC's in order to remove the x-ray component while leaving the system virtually unchanged. Aside from the contribution of relativistic rise in the ionization loss which is insignificant in our measurement, the dummy spectrum is practically the same as that obtained with 250 GeV/c protons[6]. Thus, there are no detectable transition x-rays from 250 GeV/c protons. Fig. 2 therefore, also gives a picture showing the separation of pulse height distributions due to pions and protons at 250 GeV/c. Similar measurements were made with eight PWC's and eight polypropylene radiators each of which consisted of 100 foils half mil thick and spaced at 20 mils. In this case, the dummy spectra were taken with polypropylene plates 1/20 inch thick in place of the radiators.

The average x-ray energy detected by each PWC as the function of the pion momentum is plotted in Fig. 3. The solid circle were obtained with Li radiators and the squares with polypropylene foils. It is seen that the average x-ray energy increases linearly with the pion momentum. The previous data obtained with electrons at the Brookhaven Alternating Gradient Synchrotron are also plotted against the corresponding Lorentz factor. The solid triangle joins smoothly with the solid circles, thus supporting the theoretical prediction that the transition radiation depends on the Lorentz factor only and not on the mass of the particles. This is an important experimental verification which will enable researchers to work with electrons and confidently estimate what one would expect with high energy hadrons of corresponding Lorentz factor. The data we obtained so far at the M1 beam were taken with PWC's flushed with 90% Ar and 10%

methane mixture. Xe should have much higher detection efficiency for the x-rays as shown with the corresponding electron data (open triangles). We expect to take data with Xe after the beam resumes its operation. The theoretical lines were obtained by means of the single interface formula[7] and the effective number of foils $N_{eff} = (1-e^{-N\mu t})/(1-e^{-\mu t})$, where N is the number of foils, μ is the linear absorption coefficient of x-rays in the foil material and t is the thickness of each foil. This calculation, neglecting the multifoil interference effect, is a crude approximation, but provides in this case a simple and useful estimate of the average x-ray intensity.

In conclusion, the preliminary results of this experiment can be summarized as follows. (1) We have observed x-ray transition radiation from multihundred GeV pions. (2) The average x-ray intensity increases linearly with the Lorentz factor of the particle and is in reasonable agreement with the data obtained with electrons. (3) The TRD with relatively few radiator-detector units can differentiate multihundred GeV pions and protons and should be able to differentiate very high energy pions and kaons with further sophistication.

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References

1. More complete references are found in the following recent papers: M.L. Cherry, G. Hartmann, D. Muller, and T. Prince, Phys. Rev. D 10 (1974) 3594; J. Fischer, S. Iwata, V. Radeka, C.L. Wang, and W.J. Willis, Phys. Lett. 49B (1974) 393; C.L. Wang, Nucl. Instr. and 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 and L.C.L. Yuan and P.W. Alley, Phys. Lett. 43 B (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. and Meth. 107 (1973) 413.

2. CERN ISRC/73/33 Brookhaven, CERN, Syracuse, Yale collaboration; also W.J. Willis, private communication.

3. Pion and proton signals were provided through the courtesy of FNAL Exp. 7, ANL, Indiana, Michigan, FNAL, Purdue collaboration.

4. Electron signals were provided through the courtesy of Drs, J. Knauer and J. Younts of FNAL Exp. 87. The result obtained with 50 GeV electrons will be published elsewhere.

5. The fast logic signals for electrons using this transition radiation-detector were successfully used to calibrate the shower counter of ref. 4.

6. This is inferred from 100-200 GeV/c pion and proton runs, since we did not have a 250 GeV proton run.

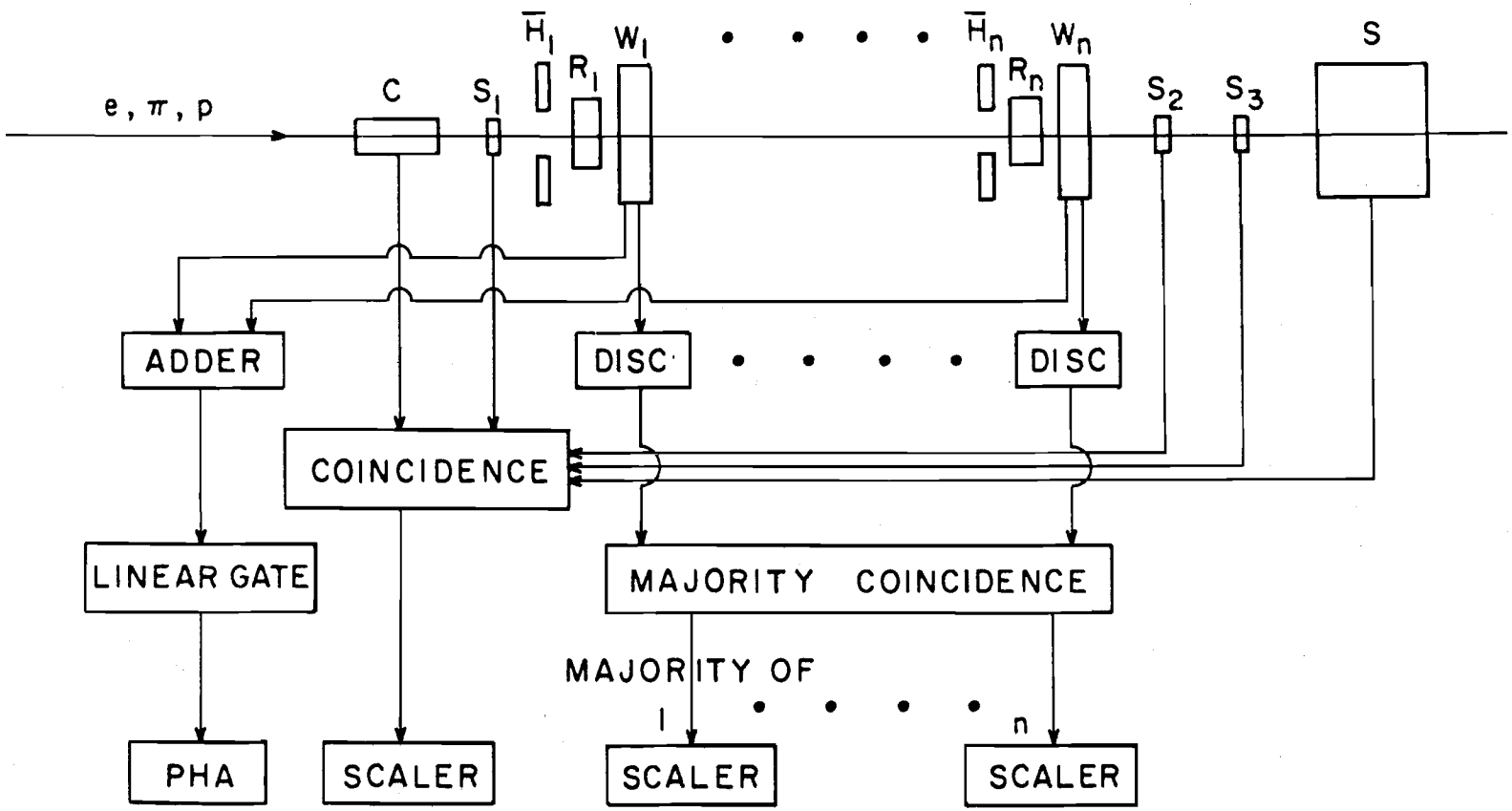
7. G.M. Garibian, Soviet Phys. JETP 12, (1961) 237.

Figure Captions

Fig. 1. A schematic of the experimental setup and simplified electronic diagram.

Fig. 2. The pulse height distributions of added signals from four proportional wire chambers when the Li radiators were in place and when absorbers were placed after the radiators.

Fig. 3. The average x-ray energy detected by each proportional wire chamber as the function of the Lorentz factor of pion and electrons. (See text for details).



W_i : PROPORTIONAL WIRE CHAMBER
R_i TRANSITION RADIATOR
C : CERENKOV COUNTER
S : SHOWER COUNTER
$S_i, \bar{H}_i$: PLASTIC SCINTILLATOR
PHA: PULSE HEIGHT ANALYZER

Fig. 1

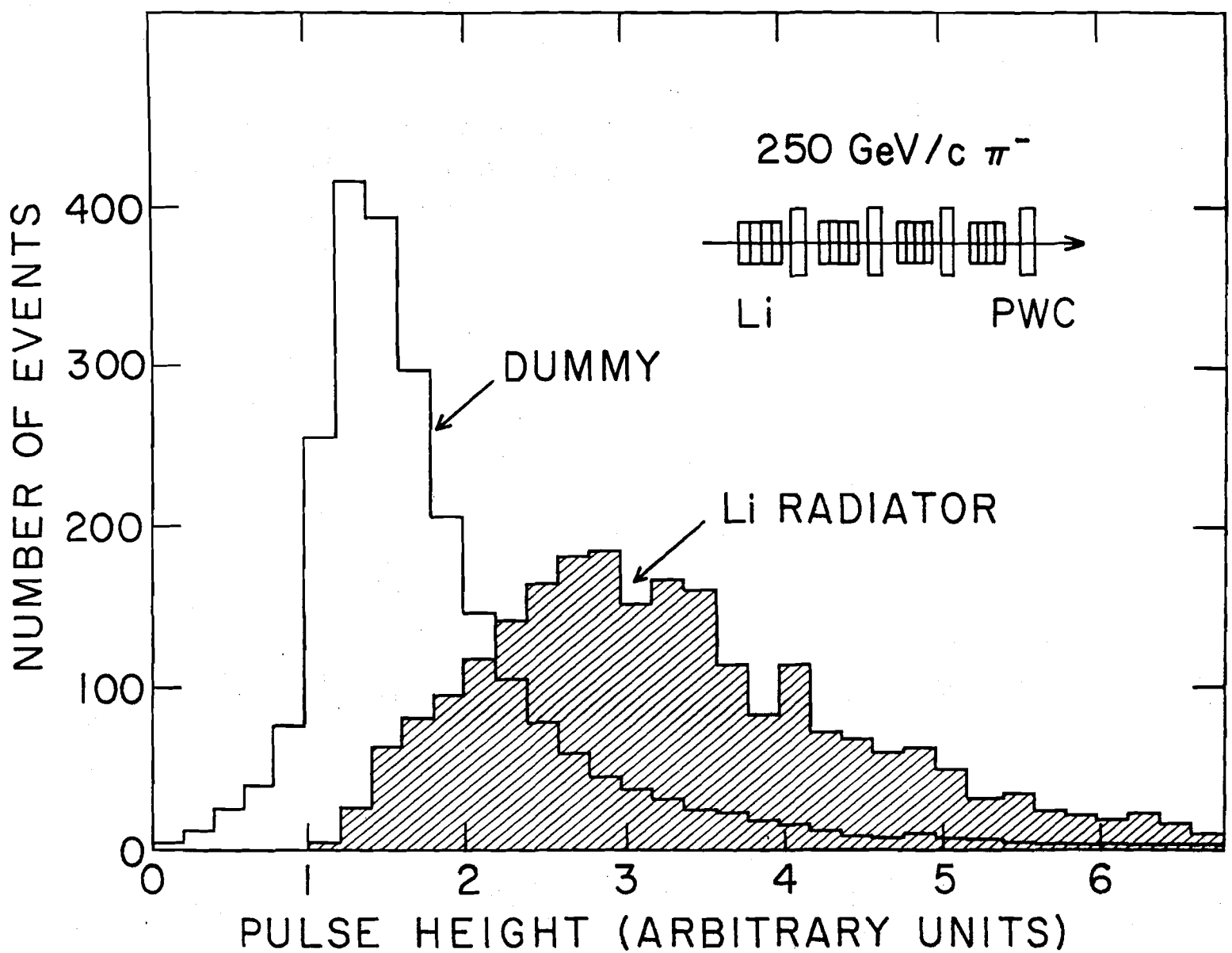

250 GeV/c π^-
Li
PWC
DUMMY
Li RADIATOR
NUMBER OF EVENTS
400
300
200
100
0
0
1
2
3
4
5
6
PULSE HEIGHT (ARBITRARY UNITS)

Fig. 2

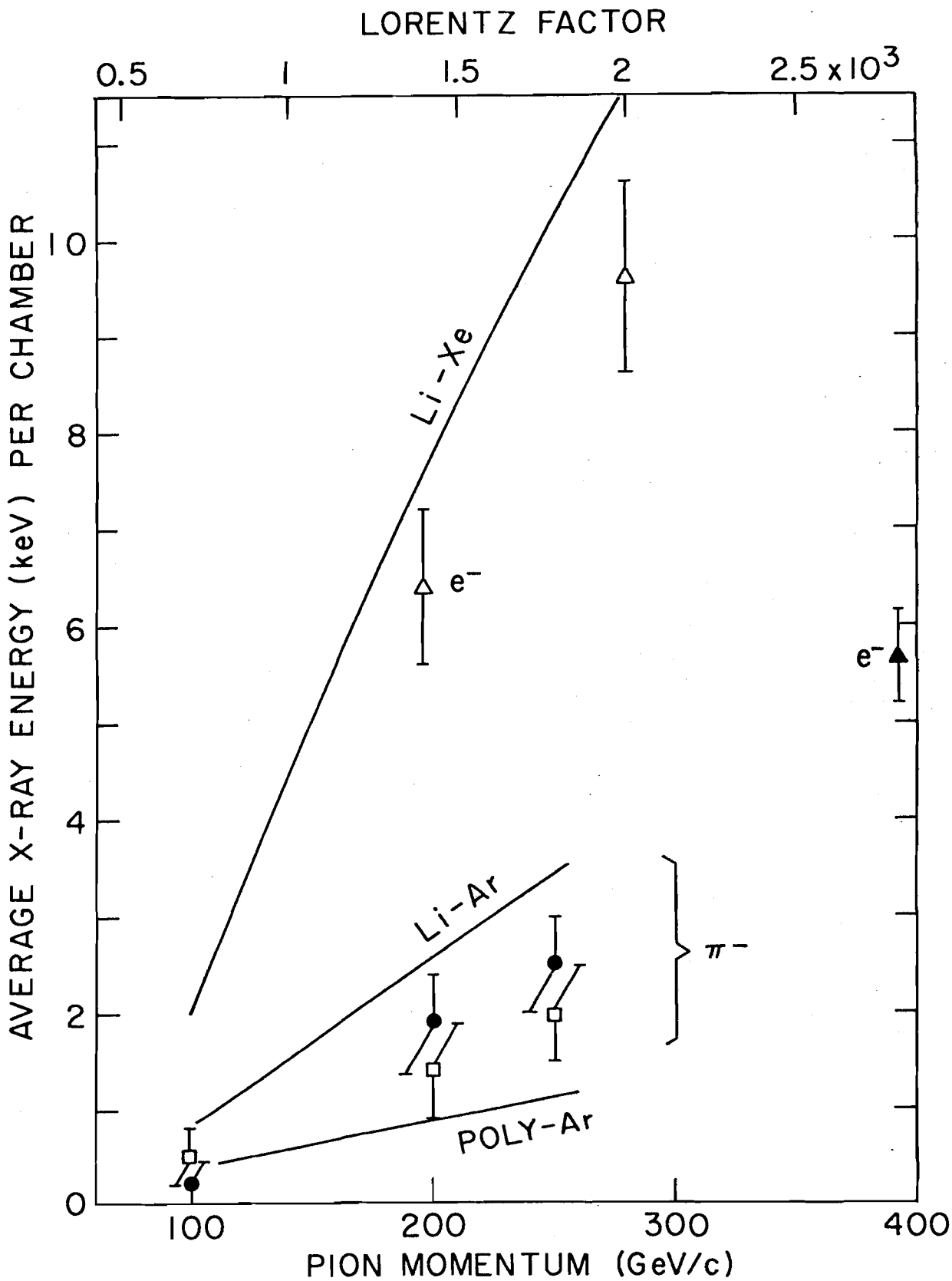

LORENTZ FACTOR
0.5
1
1.5
2
2.5 x 10^3
AVERAGE X-RAY ENERGY (keV) PER CHAMBER
0
2
4
6
8
10
Li-Xe
e⁻
e⁻
Li-Ar
π⁻
POLY-Ar
100
200
300
400
PION MOMENTUM (GeV/c)

Fig. 3