ISTITUTO NAZIONALE DI FISICA NUCLEARE

Sezione di Milano

INFN/AE-88/4
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BEAM PARTICLE MOMENTUM TAGGING FOR E687 EXPERIMENT AT FERMILAB.

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dei Laboratori Nazionali di Frascati

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Beam Particle Momentum Tagging for E687 experiment at Fermilab

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1. – *INTRODUCTION*

E687 at Fermilab is an Heavy Flavour photoproduction experiment which uses a Wide Band Photon Beam obtained by Bremsstrahlung of a previous formed electron beam.

The momentum acceptance of the electron beam magnetic system is very large $\frac{\Delta P}{P} \sim 20\%$; this configuration allows on one hand to reach the high intensity required for the beauty production and on the other hand to keep the hadronic contamination within tolerable limits (hadronic background / $\gamma \sim 10^{-5}$).

Event by event the Bremsstrahlung γ energy can be obtained by measuring the scattered electron energy and subtracting it from the primary electron one.

In E687, because of the wide momentum spread of the electrons before Bremsstrahlung, a further system is necessary to measure the momentum of the primary electrons; this apparatus is called the Primary Electron Tagging System.

The measure of the electron energy after Bremsstrahlung is carried out by 6 sweeping magnets to deviate, in the horizontal plane, the electrons with a total P_T of 3.69 GeV/c.

The measurement of the electron transversal position, and therefore of its momentum, is performed through 504 proportional tubes with thin wall ($\sim 50 \mu m$) and 3.18 mm diameter staggered on two rows for an equivalent spacing of ~ 1.8 mm.

In the read-out the tubes are grouped in such a way that the spatial resolution of the system decreases along the outside direction; the first tubes, only, are individually read-out.

In Fig.1 it is shown the photon energy resolution obtained with the proportional tubes for a monochromatic 450 GeV electron beam [1].

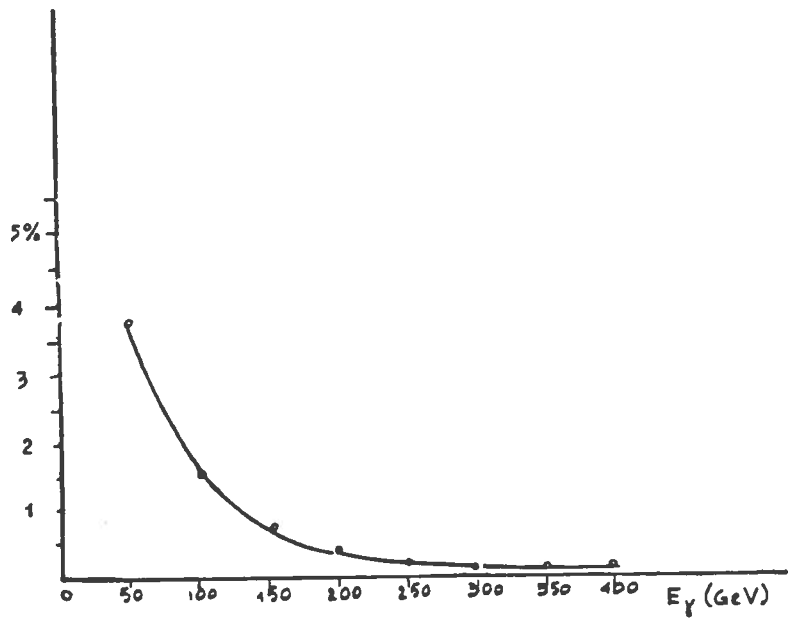

Fig. 1 γ energy resolution for 450 GeV incident electrons obtained through the proportional tubes

After this momentum measurement an energy determination is performed by an electromagnetic calorimeter segmented along the X coordinate,that is the bending one, in 14 counters each of them consisting of Pb/scintillator alternate layers.

The proportional tube system provides a good resolution but, because of spurious hits on the tubes themselves, the following electromagnetic calorimeter is crucial for a correct and unambiguos data interpretation.

The photon energy resolution of the electron calorimeter is shown in Fig.2 for a monochromatic 450 GeV electron beam [1].

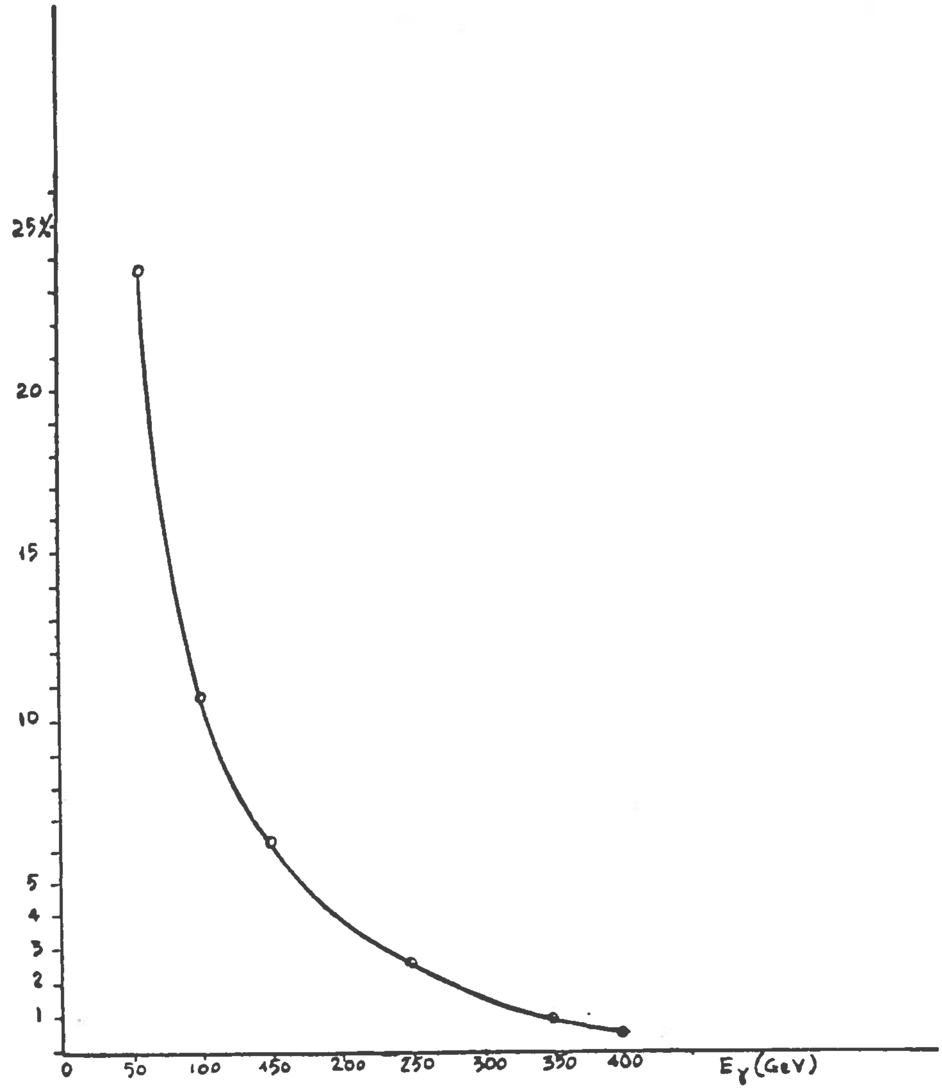

Fig. 2 γ energy resolution for 450 GeV incident electrons obtained through the electromagnetic calorimeter

2. – *BEAM ELECTRON MOMENTUM TAGGING*

To measure the primary electron momentum it has been realized a tracking system which uses the last bending magnets pair of the beam line [(2)]. This system must meet the requirements of high spatial resolution, capability of standing very high rates ($10^6 - 10^7$ particles/sec), time resolution sufficient to discriminate two RF following buckets ($\sim$ 50 Mhz) and radiation resistance.

It was decided to use Silicon microstrip detectors because suited to match the required conditions.

In principle the apparatus consists of 3 detectors placed upstream the bending magnets and 2 downstream, as shown in Fig.3, which allow, respectively,the reconstruction of the incoming and of the outcoming segments of a track.

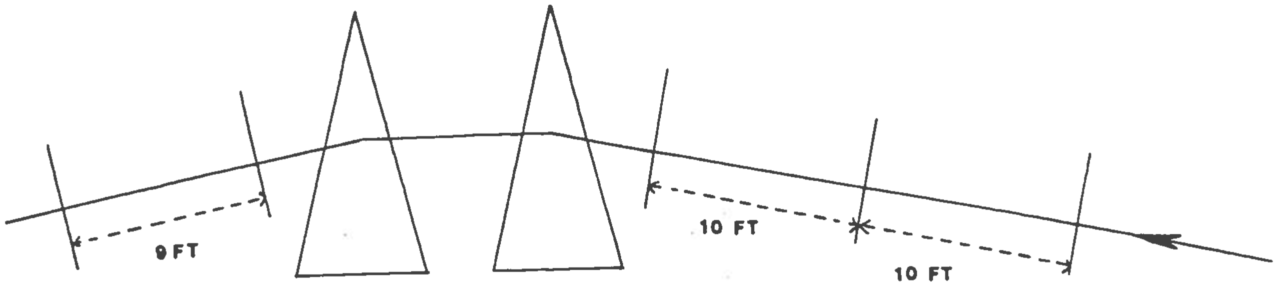

Fig. 3 Scheme of the Beam Electron tracking system.

For rays reaching the end of the magnetic system, the momentum is calculated using a sudden bend approximation at the center of the final bend string and the Least Square Method.

Although the contributions coming from both the systems are to be considered to calculate the total γ energy resolution, it is clear that the dominating error is that due to the primary electron tagging system; in addition the resolution of this system must be consistent with that of the spectrometer and so a value $\sigma_{\frac{\Delta P}{P}} \sim 1\%$ seems to be reasonable. This value can be obtained using 5 planes of 256 microstrips with 300 μm pitch.

3. – *ELECTRONIC READ – OUT*

The electronic analog processor employed in the Tagging System delivers, at the amplifier output, a 60 nsec base width signal with a rise time of only 10 nsec;it provides good timing performances keeping at the same time a good signal/noise ratio [3].

At the ~ 50 Mhz Tevatron RF, the problem is that, because of the amplifier output width, signals corrisponding to particles even 2 or 3 buckets apart have a not vanishing overlap.

To make the right association between the particle signal and RF buckets, the analog signals are transmitted to fast threshold discriminators;for signals above the threshold a 20 nsec width logical output is given with a 60 nsec dead time internally generated.

The probability that, during the dead time, the same strip is hitted by another particle is negligible; for an average electron rate of $\sim 10^7$ electrons/ sec one out of every five buckets is occupied and the mean rate on each strip is $\sim 6 \times 10^4$ electrons/ sec .

The RF itself is then used as clock signal to store all the inputs in a fast memory consisting of arrays of 256 cells for each channel; more accurately, as shown in the time diagrams of Fig.4, the discriminated signals are latched by the leading edge of the clock signal.

The memory, addressed by a 8 bit pointer with no carry, behaves as a circular buffer and the data acquisition proceeds with the same frequency as the accelerator one.

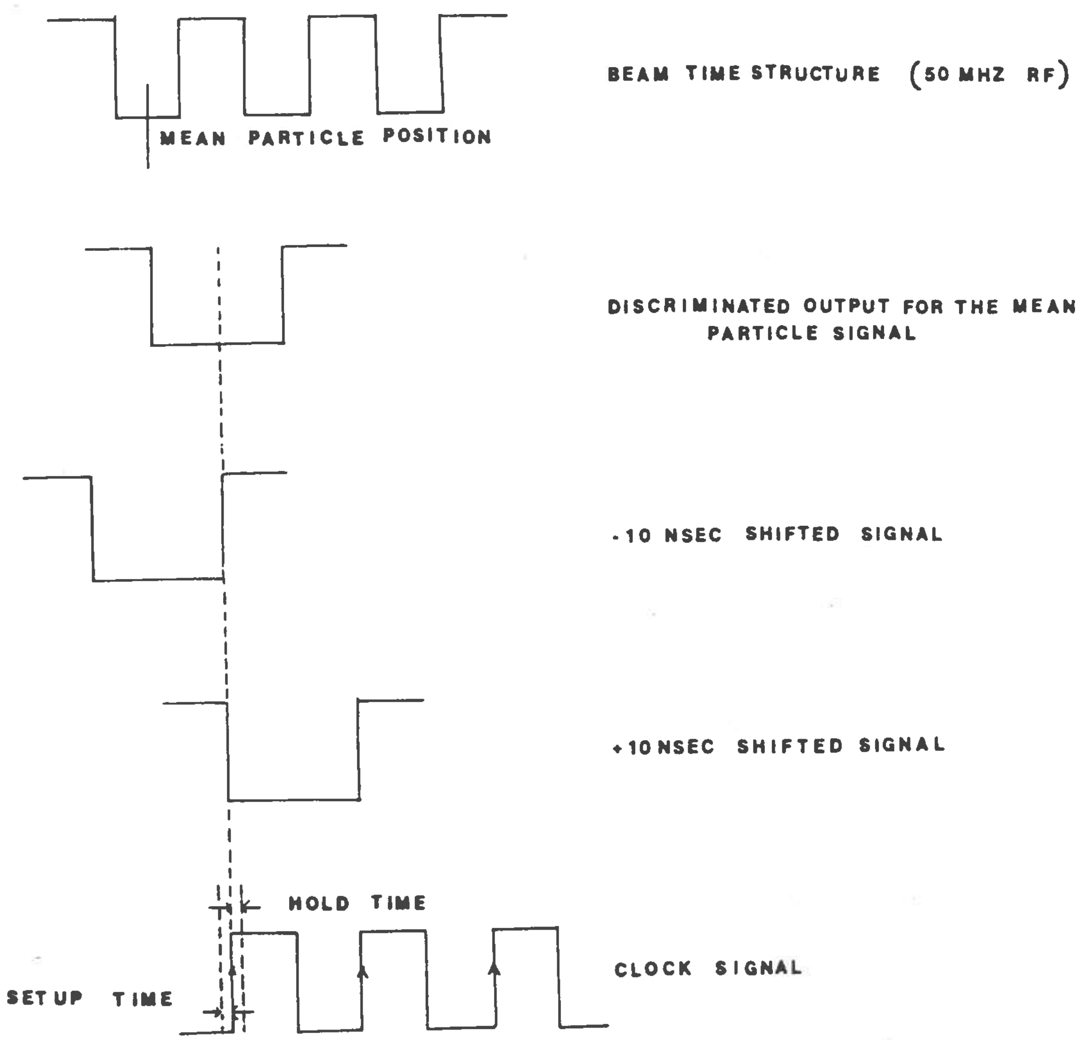

Fig. 4 Time diagrams.

After the acquisition of a single event, the pointer to the particular address in the memory array is shifted to the next one to make a correspondance between the address itself and the bucket number.

Considering a set-up time of $\sim$ 2 nsec and an hold time of $\sim$ 2 nsec [Fig.4] (typical values for ECL logic), necessary to latch the input signals, the maximum tolerable jitter turns out to be $\sim \pm$ 8 nsec for a 20 nsec discriminated signal. The main contributions to the jitter are due to noise, threshold walk and to particle dispersion within the RF buckets .

The 256 cell array fast memory, equivalent to 5120 nsec, is large enough to buffer all the events until the second level trigger signal, coming from the counting room, reaches the present apparatus.

In fact, taking into account that the whole read-out electronics is placed next to the microstrip detectors along the beam line, 150 m far from the counting room, the delay between the electron crossing the tagging detectors and the second level trigger arriving from the counting room is ~ 2640 nsec.

This resulting total delay is equivalent to 2640/20=132 cells; at the second level trigger command the recording memory is "frozen" and the information about the triggered event must be taken from the 132^{nd} address preceeding the position showed by the pointer.

4. – *PERFORMANCES*

The employed detectors, 300 μm thick, have an active area of $7.65 \times 5.65\,cm^2$ with the first dimension along the X coordinate,that is the bending one.

This rectangular shape provides a good beam acceptance compatibly with the commercially available Silicon detectors obtained from 4 inch diameter wafers.

The actual tracking system configuration has a 20 ft upstream lever arm and a 9 ft downstream lever arm which corresponds to the maximum extention fitting the real beam line structure.

The detectors behaviour has been simulated using a Monte Carlo program whose rays tracking is performed by Turtle [4] (Trace Unlimited Rays Through Lumped Elements), the standard version available at Fnal to simulate the beam transport system.

A discriminator threshold equivalent to 0.2 M.I.P., with a corresponding mean value of 4 spurious hits for each plane, was taken into account; these values follow from the measured noise performance of the analog electronics.

The momentum reconstruction is performed through a χ^2 fit of 5 hits with 3 free parameters:the angles of the track before and after the two bending magnets and the intercept on the principal planes. Beacause of the spurious hits more than a track can be reconstructed satisfying the χ^2 cut; in these cases only the best χ^2 track is considered to evaluate the momentum resolution.

The number of tracks for event satisfying the χ^2 cut is shown in Fig. 5. The efficiency of the recostruction method for rays inside the detectors acceptance can be calculated from histogram of Fig. 6: the bin 1 is the number of events with no matches between reconstructed and real track, the bin 6 content is the number of events with only one track satisfying the χ^2 cut and matching the real one, the bin 10 the number of events where more than one track is reconstructed satisfying the χ^2 cut and the minimum χ^2 track matches the real one; the resulting efficiency is $\sim 96\%$.

```
1 THE FOLLOWING IS A HISTOGRAM OF NMAT     FOR     1273 RAYS

            INTERVAL                                 SCALE FACTOR:  100 X'S EQUAL   513 RAYS
0LESS THAN        0.000         0

     0.000 TO     1.000         0
     1.000 TO     2.000       513   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     2.000 TO     3.000       424   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     3.000 TO     4.000       191   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     4.000 TO     5.000        90   XXXXXXXXXXXXXXXXX
     5.000 TO     6.000        29   XXXXX
     6.000 TO     7.000         9   X
     7.000 TO     8.000         4
     8.000 TO     9.000         6   X
     9.000 TO    10.000         4
    10.000 TO    11.000         0
    11.000 TO    12.000         2
    12.000 TO    13.000         0
    13.000 TO    14.000         1
    14.000 TO    15.000         0
    15.000 TO    16.000         0
    16.000 TO    17.000         0
    17.000 TO    18.000         0
    18.000 TO    19.000         0
    19.000 TO    20.000         0
    20.000 TO    21.000         0
    21.000 TO    22.000         0
    22.000 TO    23.000         0
    23.000 TO    24.000         0
    24.000 TO    25.000         0
    25.000 TO    26.000         0
    26.000 TO    27.000         0
    27.000 TO    28.000         0
    28.000 TO    29.000         0
    29.000 TO    30.000         0
0GREATER THAN    30.000         0
0          CENTER =         2.074   RMS HALF WIDTH =      1.332
```

Fig. 5 Number of tracks for event satisfying the χ^2 cut

```
1 THE FOLLOWING IS A HISTOGRAM OF IBIN     FOR     1273 RAYS

            INTERVAL                                 SCALE FACTOR:  100 X'S EQUAL   716 RAYS
0LESS THAN        0.000         0
     0.000 TO     1.000        44   XXXXXX
     1.000 TO     2.000         0
     2.000 TO     3.000         0
     3.000 TO     4.000         0
     4.000 TO     5.000         0
     5.000 TO     6.000       513   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
     6.000 TO     7.000         0
     7.000 TO     8.000         0
     8.000 TO     9.000         0
     9.000 TO    10.000       716   XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
0GREATER THAN    10.000         0
0          CENTER =         7.077   RMS HALF WIDTH =      2.356
```

Fig. 6 Reconstruction efficiency for 5 plane tracking system

The momentum resolution for rays inside the detectors acceptance is shown in Fig.7 and is $\sigma_{\frac{\Delta P}{P}} \sim 1.5\%$.

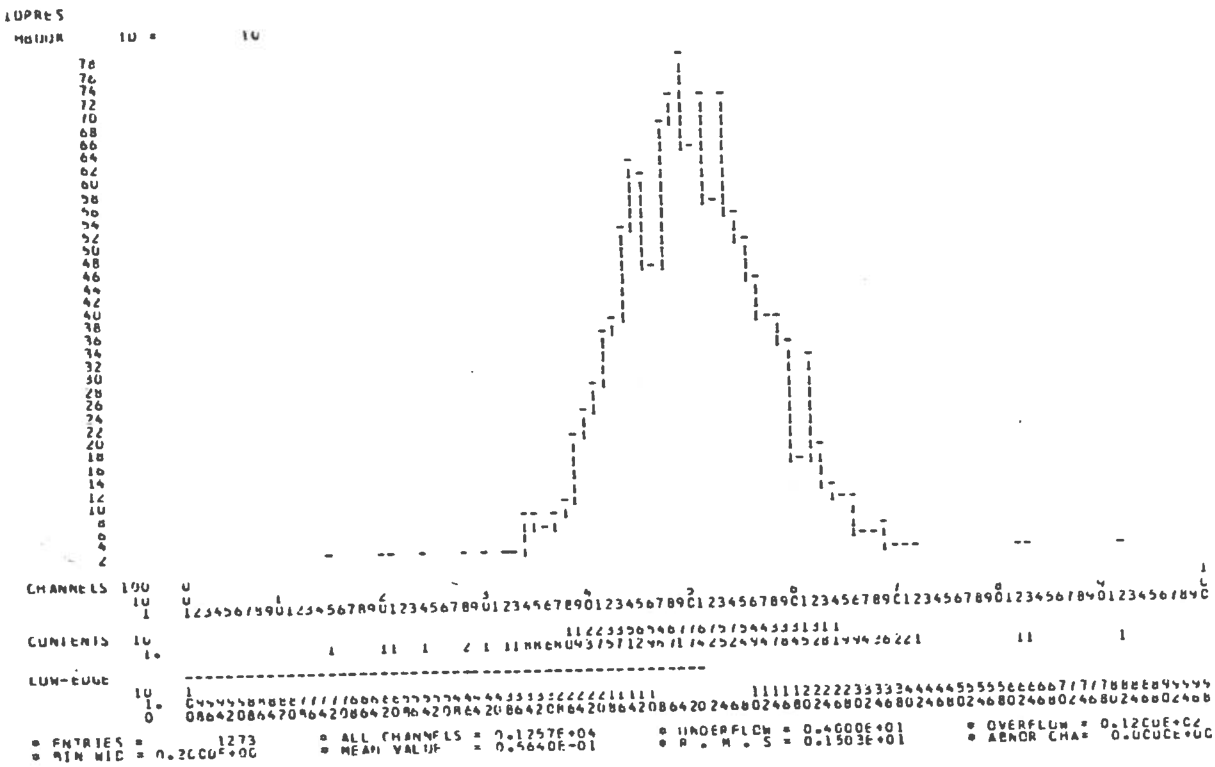

Fig. 7 $\sigma_{\frac{\Delta P}{P}}$ **for 5 plane tracking system**

5. – *CONCLUSION*

The primary electron tracking through the 5 microstrip planes detectors and the following residual energy measurement of the scattered electron through the proportional tubes and Pb/scintillator calorimeter gives the final γ energy resolution shown in Fig. 8; $\sigma_{\frac{E_\gamma}{E_\gamma}}$ of the total tagging apparatus is calculated assuming a primary electron beam energy of 450 GeV.

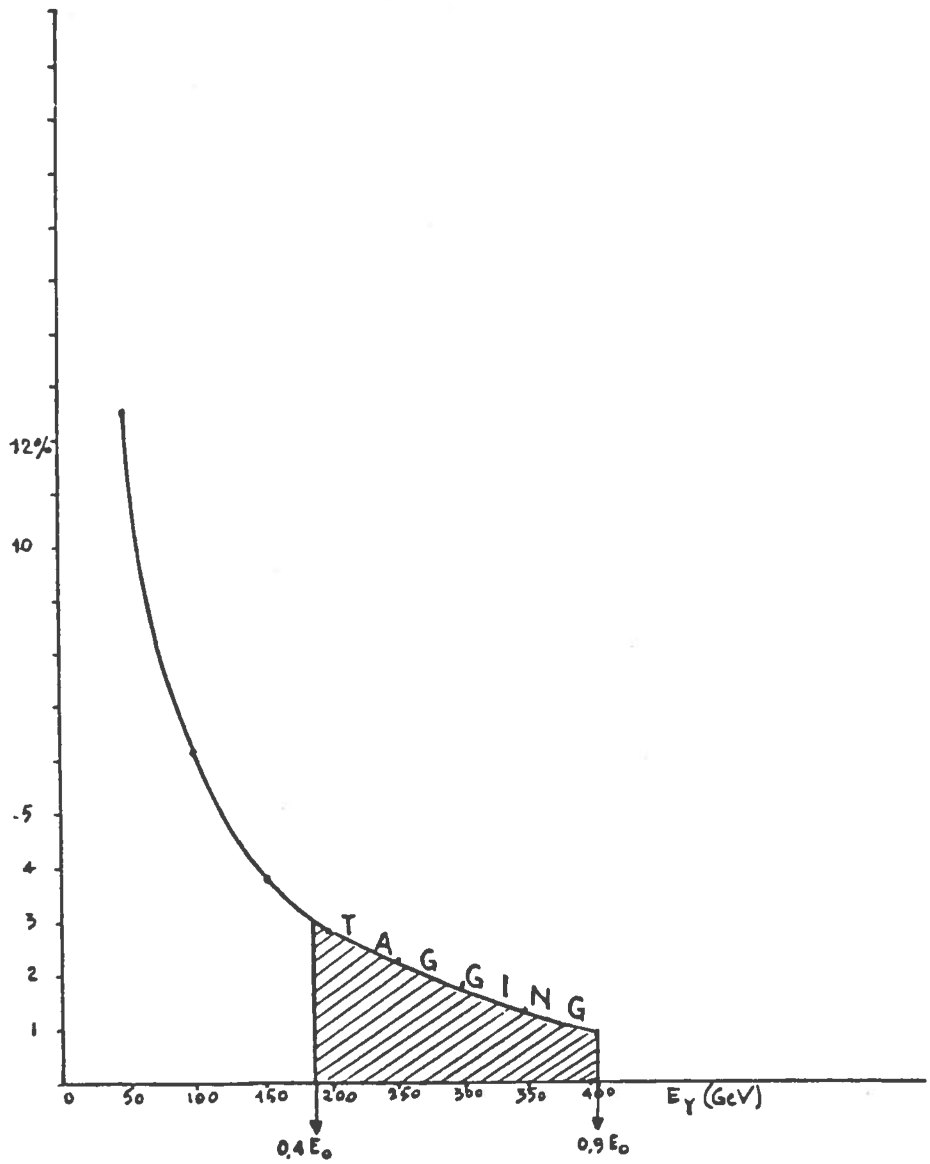

Fig. 8 $\sigma_{\frac{E_\gamma}{E_\gamma}}$ of the total tagging apparatus for 450 GeV primary electron beam

6. – *BIBLIOGRAFIA*

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