PIBETA NOTE: **Backgrounds from Hadronic Interactions in the Active Degrader and Active Target**

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This note summarizes some salient results of the work done by K. Assamagan and D. Počanić with the help of E. Frlež up to June 1995 on the simulation of the backgrounds coming from the hadronic interactions in the active degrader and target.

1. Hadronic Events in AD and AT – General Features

Events involving a hadronic interaction of the beam π^+ in the degrader or target have been studied using the realistic GEANT Monte Carlo simulation (versions 3 and 4) which calls the GHEISHA package. These events mostly include strong elastic and inelastic scattering, as well as nucleon knockout and similar reactions. These generally result in a prompt event in the calorimeter (BR $\simeq 0.96\%$), and less frequently in a delayed event involving a scattered π^+ which decays at rest (BR $\simeq 0.22\%$). Virtually all of these events are associated with a charged particle track in the plastic veto and/or MWPC's. The neutral showers following a hadronic interaction in the degrader/target are almost exclusively due to single charge exchange and π^0 detection (full or partial). As the latter events are of particular interest for the PIBETA measurement, questions related to the single charge exchange reactions are discussed separately in Sect. 2.

Fig. 1. shows the timing spectrum of CsI showers (in logarithmic scale) for the first 100 ns following the appearance of a beam pion 25 cm upstream of the active degrader. The PROMPT and DELAYED components of this background are clearly visible; their relative strength was borne out by our 1994 measurement of the $\pi \to e\nu$ decay.

Fig. 2. shows the CsI calorimeter energy response for the PROMPT hadronic events (top panel) and DELAYED hadronic events (bottom panel). Several features are important:

(a) The PROMPT events are harder than the DELAYED, mostly comprising protons and non-minimum-ionizing particles. Practically all of the events are dominated by charged particles registering in the tracking counters.

(b) The few high-energy events above 100 MeV are all π^0's from charge exchange reactions in the degrader. Neutral events below 100 MeV are similar in number.

(c) The DELAYED events are dominated by the scattered pions decaying at rest, as evideced in their CsI energy spectrum.

All of these features have been observed in the 1994 test run. The prompt background was sufficiently suppressed by an online 10 ns delay requirement in the trigger gate.

2. Pion Charge Exchange in AD and AT

At the pion beam momentum of $\sim$ 115 MeV/c used in the our experment, single charge exchange (SCX) takes place predominantly in the degrader, being suppressed in the target by the negative Q value for SCX on ^{12}C. The branching ratio of SCX observable

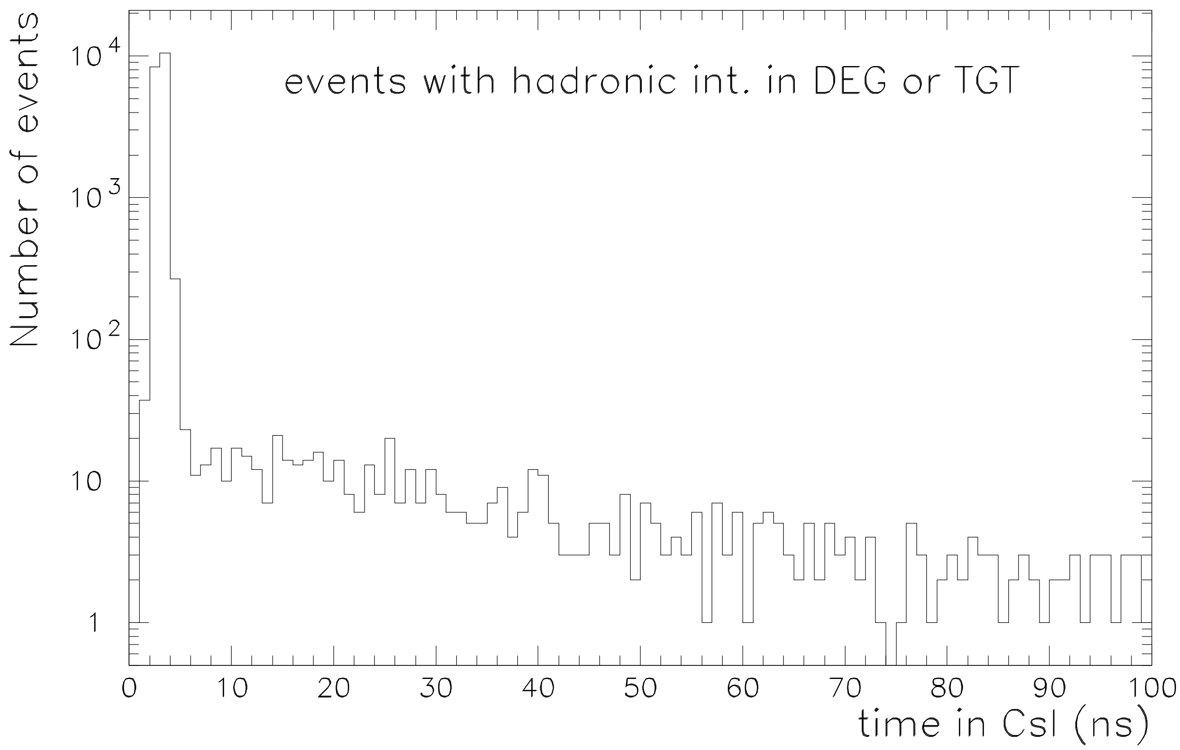

Fig. 1. Timing response of the CsI calorimeter to all events involving a hadronic interaction in the target.

by the CsI calorimeter is $BR \simeq 6.0 \times 10^{-6}$. Fig. 3. summarizes the important features of this background: the CsI energy response (top panel) and time response (bottom panel).

The CsI energy spectrum of the SCX π^0's contains two peaks, one corresponding to the detection of both photons in the π^0 decay, and the other, lower, to the events in which one photon escapes detection. The respective branching ratios are $\sim 4 \times 10^{-6}$ and $\sim 2 \times 10^{-6}$. The former class of events (double photon detection) provides an important background for $\pi\beta$ detection. In order to eliminate these events at the 0.1% level of the $\pi\beta$ yield, we need to suppress SCX reactions occurring in the AD or AT during our trigger gate initiated by undetected second beam pions. The additional suppression factor required is $\sim 2.5 \times 10^{-6}$. It is provided in the following way: (a) at our highest beam rate of 1×10^6 s^{-1}, pileup beam pions are suppressed by the factor of 2×10^{-2} per beam bunch, (b) the additional factor of 10^{-4} is provided by our beam counters plus the degrader. A more detailed analysis of their efficiency in pileup SCX suppression will be discussed in a separate note.

We also stress that this background can be efficiently suppressed off-line in several ways. Firstly, SCX due to beam pileup in the degrader/target persists equally at all times, i.e., also during our late, Michel triggers. We will accumulate a large sample of such events, obtain their energy and time response and precise branching ratio. Secondly, pileup SCX events would stick out prominently in the exponential decay time spectrum of the $\pi\beta$ events, which would identify them clearly for exclusion. Finally, the energy of the SCX π^0's is higher by about 10 MeV than for the $\pi\beta$ events, giving us yet another handle in data analysis.

The CsI time response of the SCX π^0's is clearly prompt (Fig. 3. bottom). In all our

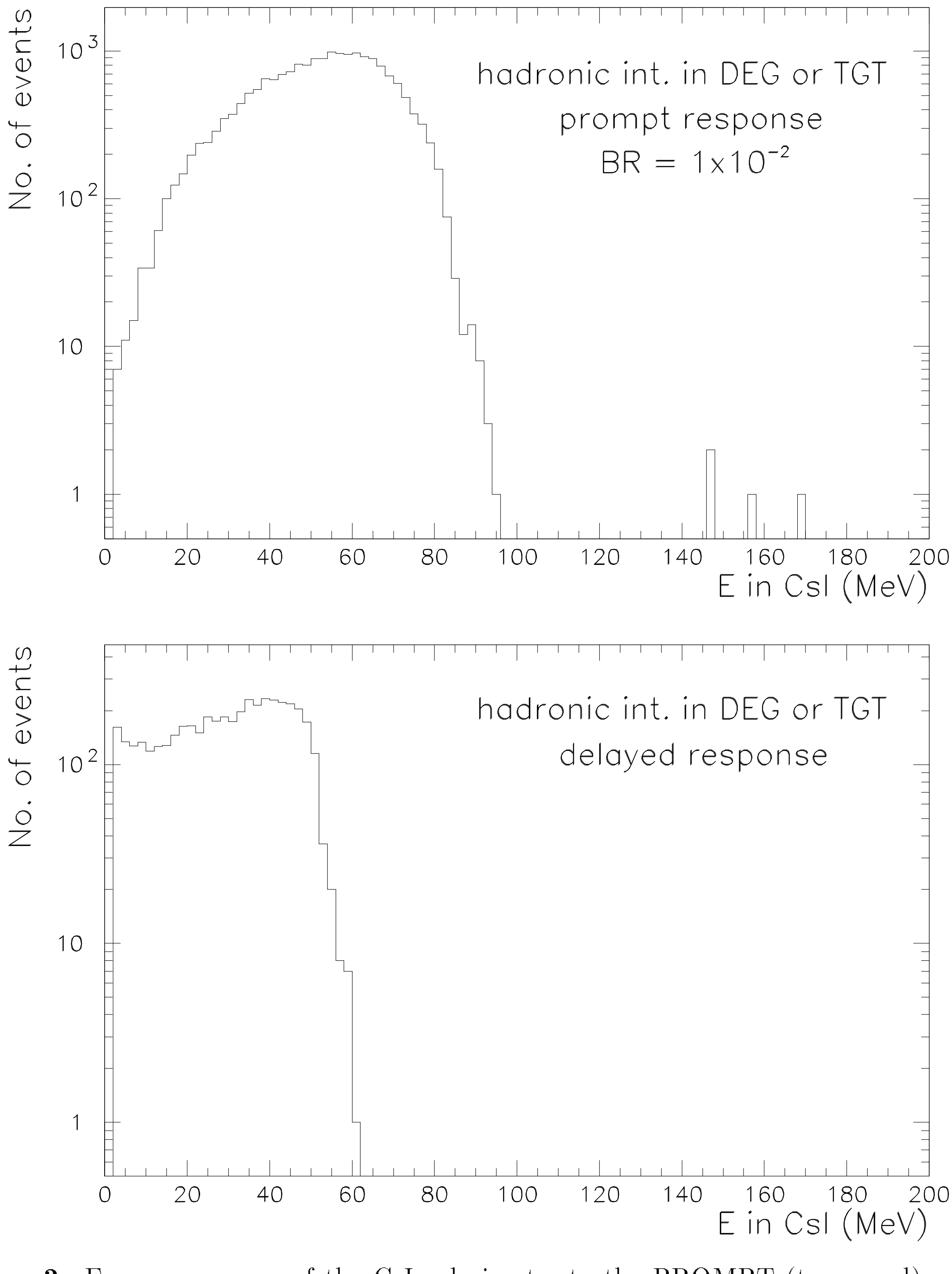

Fig. 2. Energy response of the CsI calorimeter to the PROMPT (top panel) and DELAYED events (bottom panel) involving a hadronic interaction in the degrader or target.

attempts at modeling we have not been able to produce a significant timing tail extending beyond 10 ns. The likely processes that could possibly induce that would involve π^+ back-scattering off distant massive objects into the target/degrader region. Such effects cannot at present be simulated reliably in our GEANT code because we have not yet put in an accurate layout of the entire support structure. Simple estimates yield very high suppression factors.

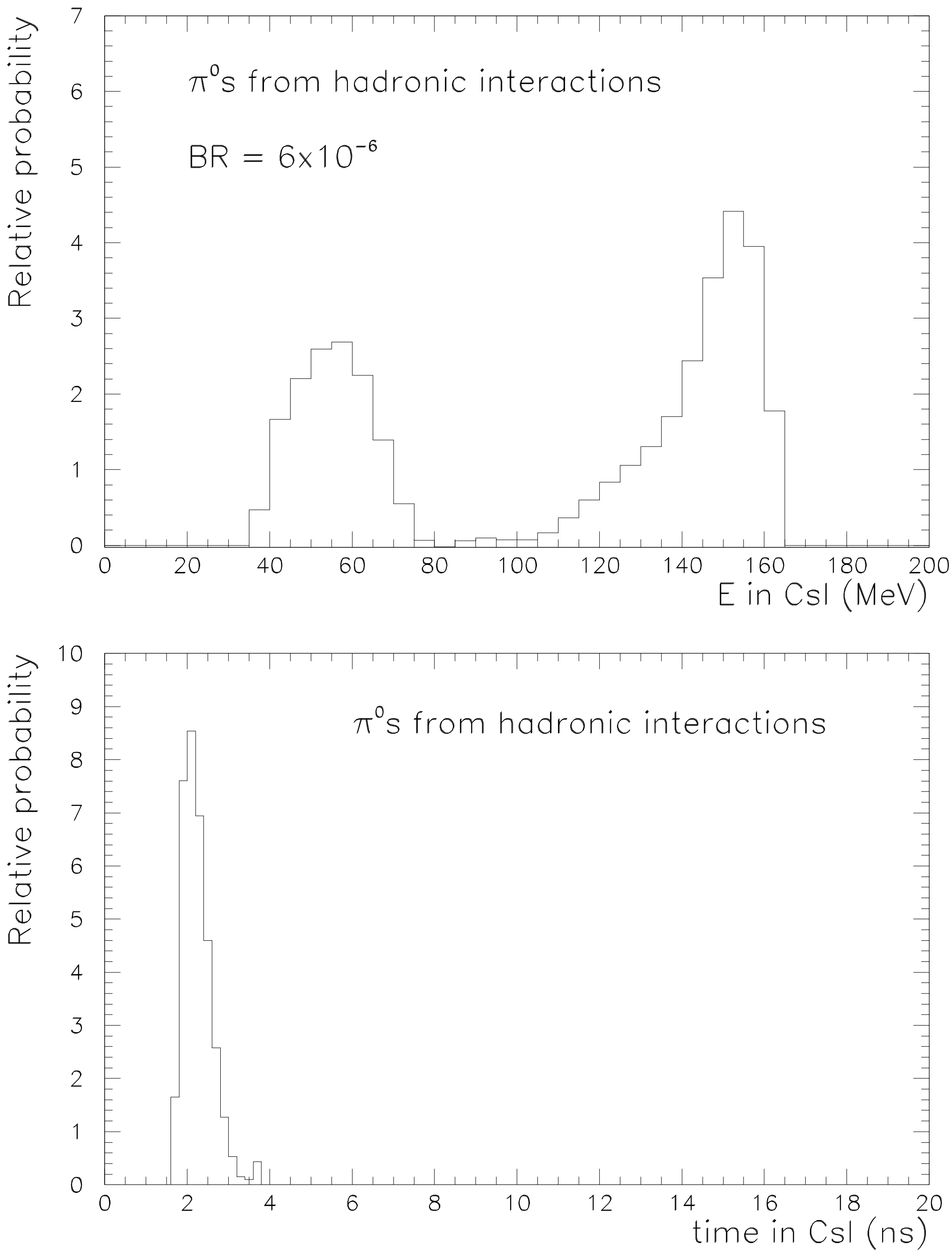

Fig. 3. Energy response (top panel) and time response (bottom panel) of the CsI calorimeter to events involving a single charge exchange reaction in the degrader or target.