Status Update of PSI Experiment R-89.01.1

A PRECISE MEASUREMENT OF THE $\pi^+ \to \pi^0 e^+ \nu$ DECAY RATE

THE PIBETA COLLABORATION

2 December 1998

The PIBETA project at PSI is a program of measurements with the aim of making a precise determination of the pion beta decay rate, initially to $\sim 0.5\%$. This document presents a condensed update of the current status of the experiment and a beam time request for 1999.

1. Activities completed in 1998

During 1998 our collaboration has successfully completed a critical stage in the PIBETA project. The important milestones are listed below.

(1) After many manufacturing delays and problems, in April 1998 we took delivery of the final batch of the pure CsI crystal detectors from Amcrys, Ukraine. As with all other crystals, physical dimensions of these detectors were measured immediately, and their light output and uniformity calibrated promptly. Since the final assembly of the CsI calorimeter was initiated already in January of 1998, the whole sphere was enclosed and mounted on its platform by mid-May.

(2) In the space of about one month we were able to finish cabling the detector fully (over 2500 cables), as well as to cable the trigger electronics. This was possible due to thorough preparation beforehand and to a concerted effort of a large number of collaborators. Thus, in spite of last-minute delays in the deliveries of the final CsI modules, the detector was essentially ready to take beam by 25 June.

(3) We ran with beam for six weeks from 25 June to 5 August. During this beam time our tasks were: shakedown of the complete detector system, adjustment of all hardware timing, gain and environment parameters (calorimeter temperature and humidity), detailed checkout and fine-tuning of the trigger logic, live checkout of the data acquisition system, measurement of the trigger and background rates, and, finally, acquisition of a sample of data with reasonable statistics at several pion stop rates, to serve as the basis for refining of our off-line analysis and to guide us in further detector improvements before "production" runs start. We are happy to report that we have accomplished all of these goals. Some of the preliminary results are discussed below.

(4) Since the completion of the June–August beam time we have been working on the analysis of the acquired data, on identifying the sources of background processes, suppressing them both by software cuts and by hardware modifications, on improving the data analysis package, as well as on planned improvements to the trigger and readout electronics. As the available time has been short and the tasks many, as of this writing we can only report some basic and preliminary results of the run. More critical and comprehensive results will be available in early 1999.

2. Preliminary results of the 1998 run

The most fundamental fact that we established is that our detectors all work, and that they are all performing at or close to their design specifications. A definitive measurement of the energy resolution of the CsI calorimeter has not yet been evaluated as we are still refining our off-line analysis procedures. However, from observing the on-line $\pi \rightarrow e\nu$ energy spectra we can state that, averaging over the 240-detector calorimeter, we should not have trouble meeting and most likely exceeding the energy resolution achieved with the 44-detector array in our 1997 test run. This would confirm our expectations based on the calibration results of the individual CsI crystals performed as we took delivery. While we did reject all substandard performers upon delivery, in principle we could not rule out detector impairment during assembly and installation. It appears that this has not occurred.

Perhaps the single most important result of all is that our trigger electronics has functioned well, and our trigger rates were as expected, even at or near the highest pion stop rates anticipated. The PIBETA trigger logic uses a number of specialized modules, including some designed and manufactured specifically for this experiment at the University of Virginia. All have been thoroughly tested in the past, but not with the full detector complement instrumented. Most importantly, our trigger logic is minimally restrictive, in order to minimize bias and the resulting systematic uncertainties. Even so, the raw trigger rates at the design pion stop rate were low and easily manageable by the MIDAS data acquisition system. This indicated already on-line that the various background problems that we knew we would have to address are in principle manageable. The computer dead time was always below 15 %.

Below we provide a brief illustration of the current performance of the PIBETA detector on the example of the charged particle tracking system. Look for further results on the PIBETA Web site.

Fig. 1 shows the combined preliminary inefficiency of our charged particle tracking (not including wire chamber cathode information at this time). Even this preliminary number is quite good, of the order of 10^{-5}. Fig. 2 shows that this will be further improved by focusing on the interdetector gaps in the plastic veto (PV) array and fixing a broken light-guide glue joint in one of the PV detectors. A similar analysis has been carried out for the MWPC wires. Fig. 3 shows how well the PV detectors distinguish between minimum ionizing particles and protons, which is valuable in suppressing hadronic backgrounds to $\pi \rightarrow e\nu$ decay events.

3. Tasks to be completed in 1999

There are still several questions we need to answer in order to have a more precise and quantitative understanding of the detector's performance. Answers to these questions are forthcoming as we are presently finalizing some of the key lower level analysis tasks and

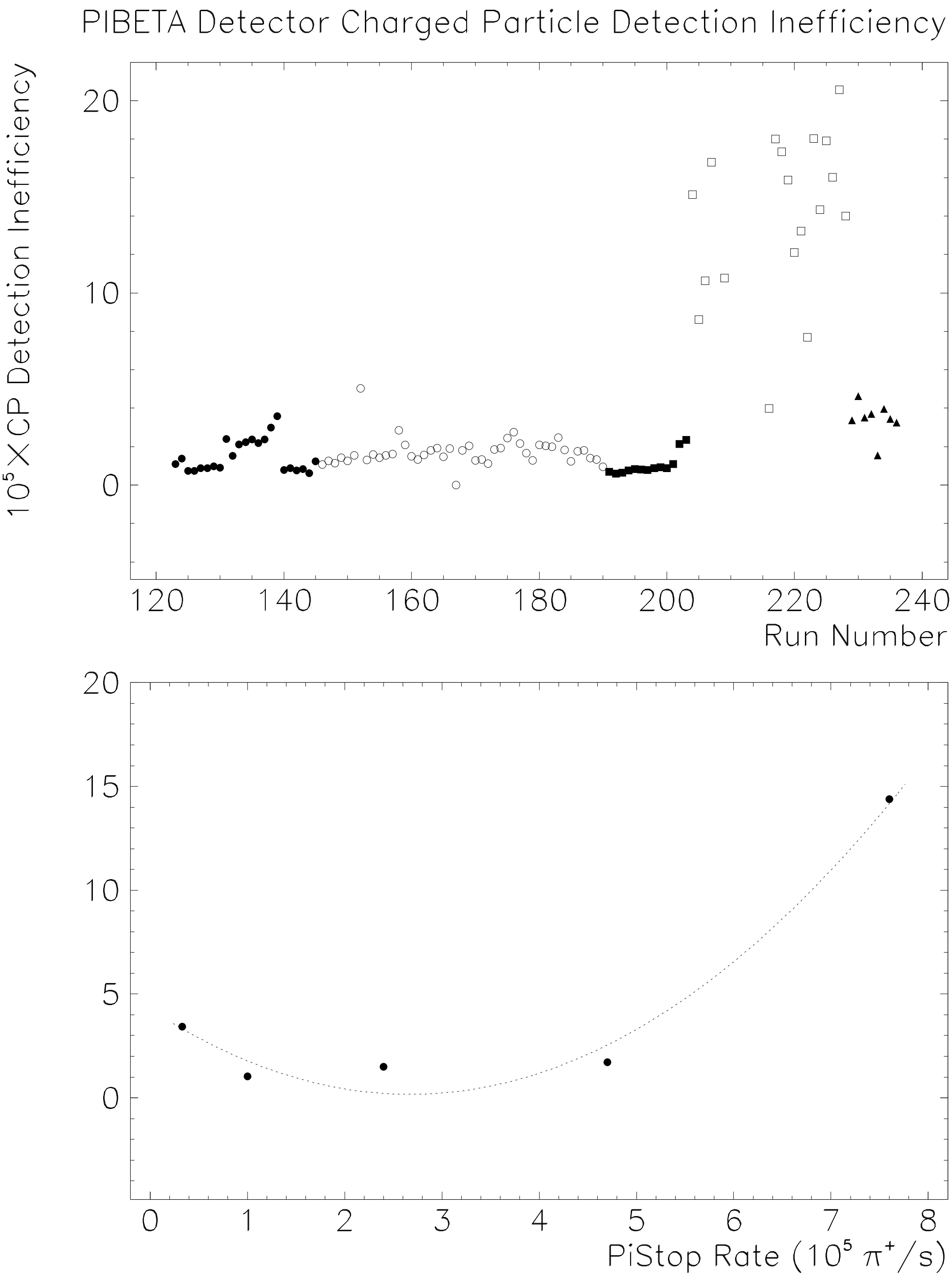

Fig. 1. Combined inefficiency of charged particle tracking, not including wire chamber cathode information, in units of 10^{-5}, as a function of pion stop rate (very preliminary).

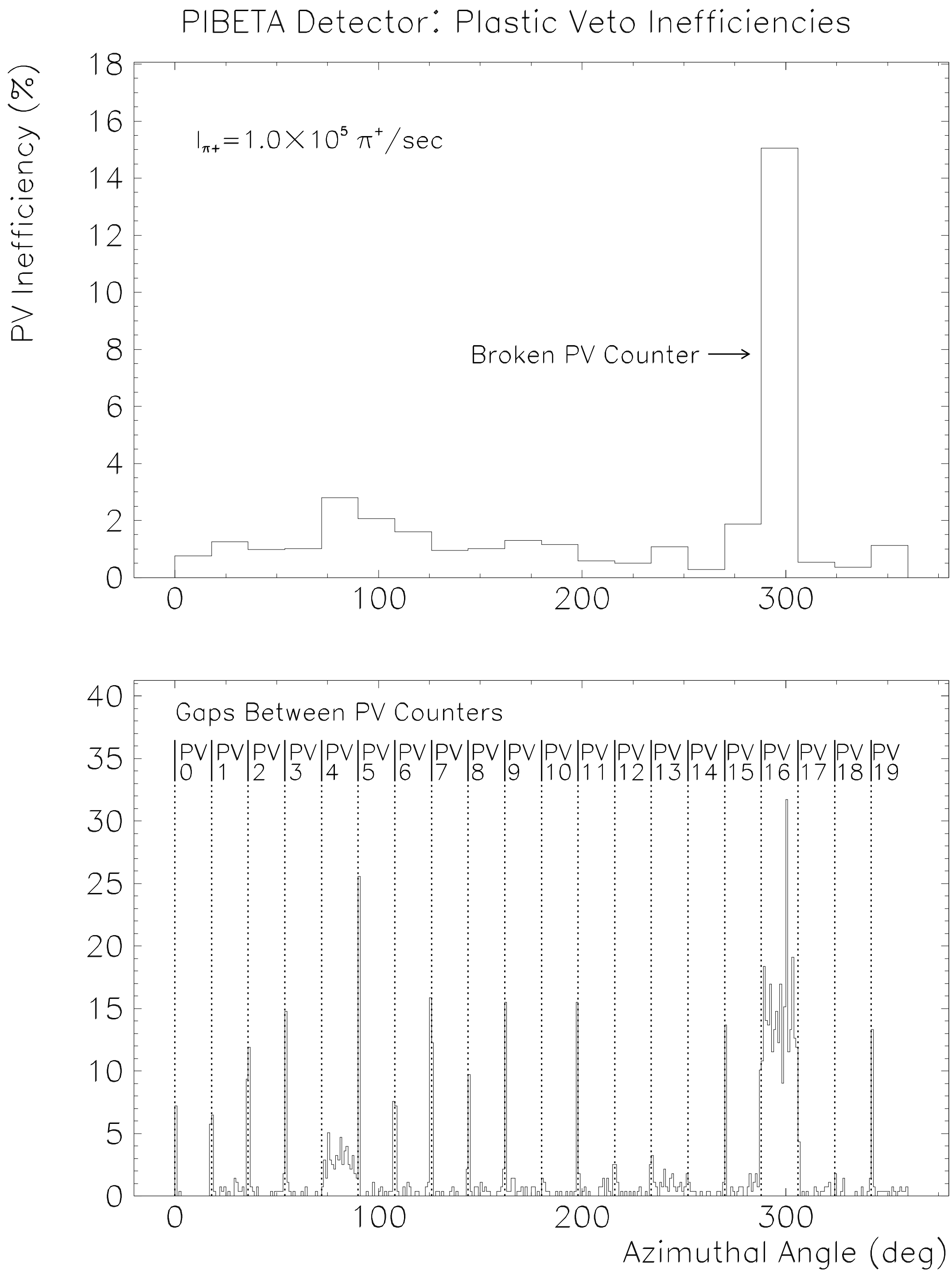

Fig. 2. Details of the ϕ dependence of the PV detector inefficiency, showing that most of it comes from one counter whose light-guide glue joint was broken in installation. Also, interdetector gaps will be tightened up, as there is clear evidence that a number of them can be improved.

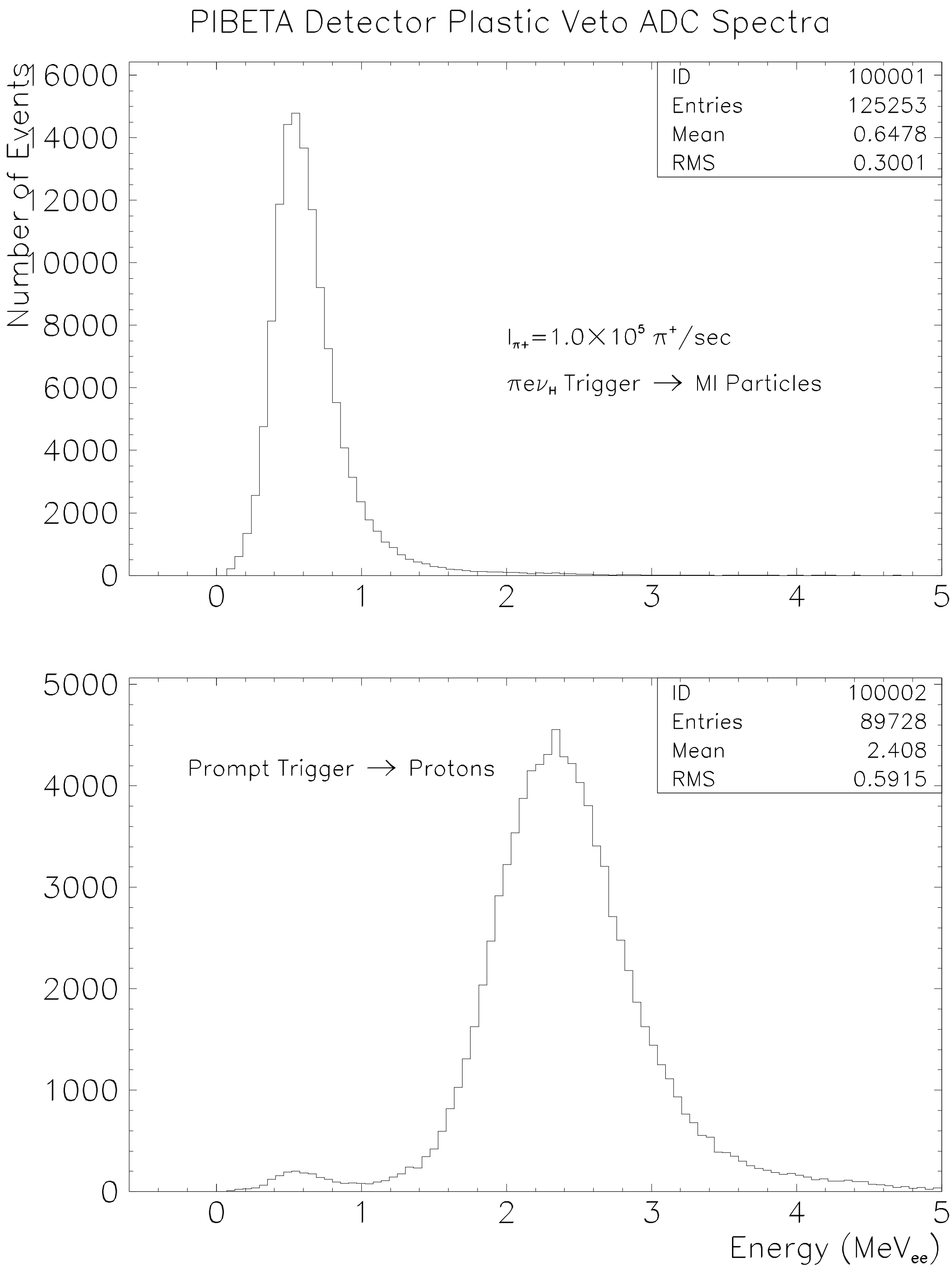

Fig. 3. PV counter ADC spectra for minimum ionizing particles (Michel trigger, top) and protons (prompt trigger, bottom). Note that there are some residual MIP's in the prompt trigger spectrum. Resolving the two types of events is important in suppressing hadronic reaction backgrounds to the $\pi \rightarrow e\nu$ decay events.

routines. We will present current histograms of the relevant physics variables at the time of the forthcoming BV meeting.

During the 1998 run we have identified several items in the trigger electronics that need improvement. These include the modification of an ECL shaper unit, a new more flexible trigger logic unit, implementation of sampling/digitization of the beam counter signals first, and, finally, of all of the calorimeter signals. All these projects are currently being worked on at PSI, and nearly all will be completed in early 1999.

While analyzing our 1998 data we have identified an anticipated source of background stemming from stray beam pions stopping somewhere around the beam pipe, not registering in the degrader or target, and giving rise to low energy π^0's. These events can be suppressed by a combination of the following improvements: (1) installing active beam "collimator" detectors, (2) tightening up the trigger and RF timing which will be made easier with the above trigger electronics improvements, and (3) possibly improving on the pion beam optics. Item (1) will require some physical modifications of the conical vacuum beam pipe in the detector. Use of the sampling chip on the active target detectors should finally eliminate this background by requiring a beta decay positron signature in the target signal, in coincidence with the pion beta decay trigger (calorimeter).

The MIDAS analyzer code is being constantly improved. Besides steady refinements of such critical basic routines as the shower clustering algorithms, a comprehensive single-event display is being added. It will be fully functional before our next beam time.

We are planning to implement the domino sampling chip in our data acquisition electronics before we start running routine "production" runs. This has to be tested in beam first, as do all of the other presently envisioned trigger electronics changes.

In the 1998 summer run we did not use the segmented "production" active target, using instead a simpler one-piece version. The segmented target is now available and needs to be tested in beam before true "production" runs commence. The active voltage dividers required in its running are presently under construction at UVa.

4. Experiment timetable and beam request for 1999

In light of all of the above, we propose the following beam time schedule.

(i) We request first a 4 week run to test the trigger electronics improvements discussed above, and to evaluate any changes made to the "nose piece" vacuum pipe, as necessary. The time required to implement these modifications, as well as the teaching schedules of several collaboration members, dictate that this beam time cannot be scheduled before late April. It should also not be scheduled much later than that if we are to follow up with another run during the summer.

(ii) We request a second, longer beam run, to be scheduled allowing for a reasonable time to absorb the results of the April/May beam time and to implement necessary changes. Given that we will likely still be ironing out some "kinks", and also allowing for reasonable staffing, we would like to run for 6-8 weeks starting around 1 July. We plan to return to the BV with a precise request in May/June 1999 once we better establish our running conditions based on the run starting in late April.

(iii) We expect to request a third beam period late in the year to take more data in a stable configuration. We expect that we will reach a stable running configuration during the summer run at the latest.

We realize that this is an ambitious schedule. We feel, however, that the tasks ahead of us require it, if we are to achieve progress in a timely fashion.

Finally, if necessary, we could accept a lower primary beam current in our first run (April/May) without adverse consequences.