ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E1-2001-1

L.G.Afanasyev, M.Gallas*, V.V.Karpukhin, A.V.Kulikov

FIRST LEVEL TRIGGER OF THE DIRAC EXPERIMENT

Submitted to «Nuclear Instruments and Methods»

*University of Santiago de Compostela, Spain and CERN, Geneva, Switzerland

2001

The goal of the DIRAC experiment [1] is to measure the lifetime of an atom ($A_{2\pi}$) consisting of π^+ and π^--mesons. There is an exact relation between the atom lifetime and the pion scattering lengths a_0 and a_2 [2]. The pion scattering lengths are calculated in the frame of the chiral perturbation theory with a high precision, while the experimental data on the scattering lengths suffer from large errors or are model-dependent. The lifetime measurement of the pionic atom is a unique method to obtain these values in a model-independent way and thus to check the chiral theory predictions.

The experiment is under way at the CERN PS accelerator. The experimental setup is placed at the secondary beam produced by 24 GeV protons hitting the foil targets.

The pionic atoms $A_{2\pi}$ have a short lifetime $\sim 3 \cdot 10^{-15}$ s [3] and in vacuum quickly transfer to two neutral pions π^o thus escaping the detection. Nevertheless, with appropriate choice of the target material and thickness a part of atoms may dissociate into π^+ and π^- inside the same target where they had been produced. The detection of π^+ and π^- pairs from the $A_{2\pi}$ dissociation is the method of their observation [4].

The pions from $A_{2\pi}$ breakup possess a specific feature which helps to select them from a huge background of other pion pairs: they have a very low relative momentum, mostly $Q \leq 3\,\mathrm{MeV}/c$. The absolute majority of pion pairs coming to the setup solid angle are free pairs resulting from decays of short- or long-lived resonances and these pairs originally were not bound in the atom.

The experimental setup is schematically shown in Fig. 1. The π^+ and π^- are detected in the microstrip gas chambers $MSGC$, scintillating fiber detector $SciFi$, scintillation ionization hodoscope IH and then are bent in the magnet to two spectrometer arms. Each arm includes the vertical VH and horizontal HH scintillation hodoscopes, the drift chambers DC, gas Cherenkov counter Ch, preshower detector PSh consisting of a lead converter and scintillation counters and finally the muon detector Mu of two scintillation counter layers placed behind the iron absorber.

A multilevel trigger is applied to reduce the event rate to a level acceptable for the data acquisition system [5]. It includes the first level trigger and higher level hardware processors which impose the cuts for the relative momentum in a particle pair. The first level trigger employs the signals from the upstream IH detector and the downstream VH, HH, Ch and PSh detectors.

By requirements of the data analysis it is necessary to record not only the real coincidences in two spectrometer arms but also a large number of

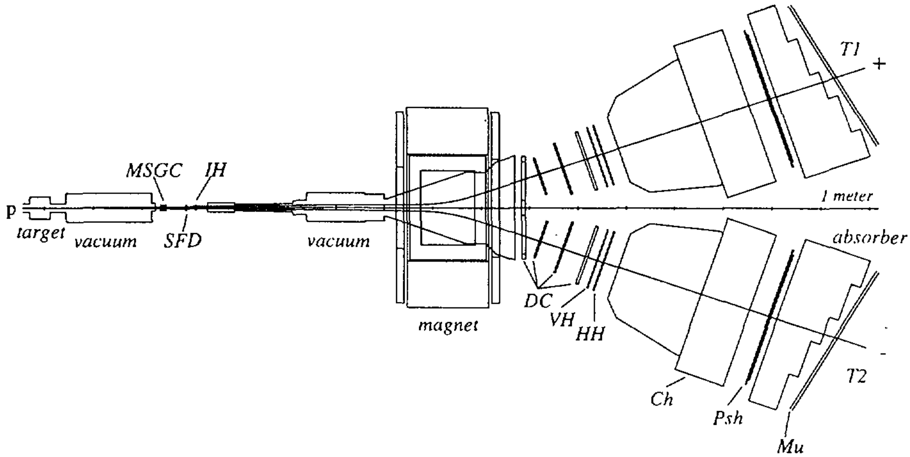

Figure 1: Schematic top view of the DIRAC spectrometer. Moving from the target station toward the magnet there are: four MicroStrip Gas Chambers ($MSGC$), two Scintillating Fibre Detectors (SFD) and two Ionisation Hodoscopes (IH). Downstream the dipole magnet, on each arm of the spectrometer, are located: four modules of Drift Chambers (DC), the Vertical and Horizontal Hodoscopes (VH, HH), the Cherenkov counter (Ch), the Preshower detector (PSh) and, behind the iron absorber, the Muon detector (Mu).

accidental coincidences: these events are used to reconstruct the distribution on the relative momentum for free (non-atomic) pion pairs without Coulomb correlation. With this aim equivalent conditions for the real and accidental coincidences, within a preselected coincidence width, should be provided by all trigger levels. A statistical error in the $A_{2\pi}$ lifetime depends on both the real events number and on the number of accidental events. The optimum ratio of real to accidentals at the existing experimental conditions is achieved with the $\pm 20\,ns$ coincidence width.

The first level trigger in DIRAC fulfills the following tasks:

a) selects the coincidences of detector signals in each arm downstream of the magnet;

b) identifies the particle type in each arm: a pion or an electron. The protons and kaons cannot be distinguished from pions at this stage and are treated like "pions". The muons can be identified but the muon detector signals are not used in trigger except for some dedicated measurements;

c) arranges the coincidences between the two arms. The coincidence width here defines the ratio between the real and accidental events in the collected data sample;

d) includes the IH signals to coincidences thus connecting the upstream and downstream parts of the setup in trigger;

e) for pion pairs applies the coplanarity cut: the difference of hit slab numbers in the horizontal hodoscopes $HH1$ and $HH2$ of two arms should be ≤ 2. This is the first of cuts on the relative momentum in a pair;

f) provides a parallel accumulation of events from several physical processes needed for the setup calibration: e^+e^- pairs, lambda-decays $\Lambda \to p + \pi^-$, $K^{\pm}$-decays to three charged pions, $\pi^+\pi^-$ pairs without the coplanarity selection. In particular, from e^+e^- data the corrections for a long-term instability of the time channels are obtained.

The scheme of the first level trigger is presented in Fig. 2. The front-end electronics (not shown in the figure) includes the constant fraction discriminators and meantimers for VH and HH and the linear fan-in/fan-out modules followed by the leading edge discriminators for IH, Ch and PSh. All trigger modules are ECL line programmable multichannel CAMAC units. Most of them are commercial LeCroy modules except a dedicated coplanarity processor developed in JINR. The coplanarity processor (15 ns decision time) reduces the trigger rate twice compared with the pion pair trigger without the coplanarity selection.

At the first step the particle signatures for a pion or an electron in the separate downstream arms are obtained through the detector coincidences in accordance with the formulae

$$
\begin{aligned}
VH1 \cdot HH1 \cdot \overline{Ch1} \cdot PSh1 &= \text{“}\pi 1\text{”} \\
VH1 \cdot HH1 \cdot Ch1 \cdot PSh1 &= \text{“e1”}
\end{aligned}
$$

in the 1-st arm and the similar signals "π2" and "e2" in the 2-nd arm. Here $VH1$, $HH1$ etc. denote the OR signals of all counters of the corresponding detector. Then these signatures are combined to produce the needed trigger.

The definitions of different subtriggers are the following.
The pion pair "atomic" trigger: $A_{2\pi} = IH \cdot$ "$\pi1$" $\cdot$ "$\pi2$" $\cdot\, Copl$,
where IH means the OR signal of the ionization hodoscope and $Copl$ is the positive decision of the coplanarity selection processor.
The electron pair trigger: $e^+e^- = IH \cdot$ "e1" $\cdot$ "e2".
The pion pair trigger (no coplanarity selection): $\pi^+\pi^- = IH \cdot$ "$\pi1$" $\cdot$ "$\pi2$".
The Λ-decay trigger $\Lambda \to p + \pi^-$:

$$\Lambda = IH \cdot (VH1[17] \cdot HH1 \cdot \overline{Ch1} \cdot PSh1)(VH2[1 \div 16] \cdot HH2 \cdot \overline{Ch2} \cdot PSh2)\,.$$

Actually it is the same formula like for the previous $\pi^+\pi^-$ trigger but here in the vertical hodoscopes only the slab 17-th in $VH1$ and the slabs $1 \div 16$ in $VH2$ from the total 18 slabs of each arm participate in trigger. This takes into account the kinematics of the Λ-decay.
The K-decay trigger ($K^+ \to \pi^+\pi^+\pi^-$, $K^- \to \pi^-\pi^-\pi^+$):

$$K = IH \cdot \text{"}\pi1\text{"} \cdot \text{"}\pi2\text{"} \cdot Maj[VH \geq 3] \cdot Maj[HH \geq 3] \cdot Maj[VH < 5]\,,$$

where Maj denotes the majority logic applied to the number of hits in the slabs of both VH or both HH. Thus from the pions detected in two arms only the events with at least 3 particles in the downstream detectors are selected and at the same time the events with a too high multiplicity ≥ 5 are rejected. A simultaneous majority selection in the vertical VH and horizontal HH hodoscopes helps to suppress a single particle edge-crossing of the adjacent hodoscope elements which could imitate the detection of two particles in one hodoscope.

In the last two triggers (Λ and K) the coincidence width is 2.5 times reduced as there is no need to take accidentals for these triggers. It is evident that the Λ- and K-triggers do not provide the detection of clean Λ- and K-events but they enhance their presence in the collected data sample.

The subtrigger signals pass through the mask register (Fig.2) and after prescaling are combined in the OR circuit. Any combination of these signals may be selected by a proper programming of the mask register. The timing of all subtriggers is the same. The independent prescaling in subtrigger channels allows to adjust their relative rates and keep the ratio of the main (atomic) and the calibration trigger rates at the optimum level. The specific mark of trigger type is recorded for every event, so the events can be sorted by their types at the off-line analysis and on-line monitoring.

The resulting first level trigger signal T1 starts an operation of the DAQ modules (gating of ADC, starting of TDC etc.) and triggers higher level

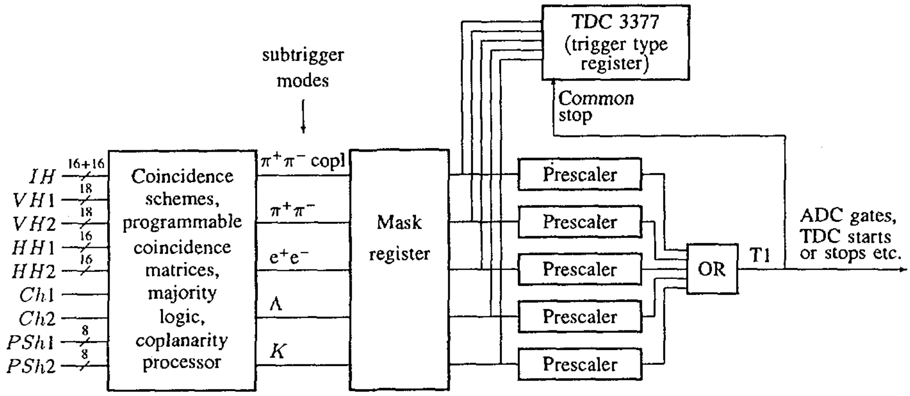

Figure 2: Logic of the 1-st level trigger. The definitions of different subtrigger modes are given in the text.

processors T3 [6] and T4. Depending on decisions of these processors the event data can be either converted and moved to the data collection memories or discarded. During this cycle a generation of a new T1 signal is disabled.

The rates of different subtrigger modes are recorded in a scaler which is read out in the end of every accelerator spill. These data are available on tape and are controlled in the on-line monitoring program. At the typical experimental conditions of DIRAC the rates for the "atomic" $A_{2\pi}$, $\pi^+\pi^-$, e^+e^-, Λ and K-triggers are (without prescaling) around $2.5 \cdot 10^3$, $5 \cdot 10^3$, 800, 300 and 200 spill^{-1}, respectively, at the ~ 450 ms accelerator spill width. After the prescaling of calibration triggers and suppression of $A_{2\pi}$ triggers by higher level processors the sum of all calibration triggers constitutes 15-20% of the final trigger which has a rate of about $1.5 \cdot 10^3$ per spill.

The whole system is fully computer controlled: no manual operations are needed to change the trigger conditions. At the start of the data taking run the parameters of all CAMAC trigger modules are loaded using a trigger file which defines the status of electronics in accordance with the selected trigger. The trigger file is structurized: it includes a set of subfiles describing the parameters of the electronic modules responsible for different detectors or different aspects of trigger operation (enabled subtriggers, prescaling factors etc.). Using this subfile structure the new modifications of the trigger file can be easily created. There exists also a tuning mode when the parameters of any module can be changed during the run without interruption of the data taking.

The authors are grateful to many members of the DIRAC Collaboration who participated in the data taking and the express data analysis which helped to improve the trigger quality.

References

[1] B.Adeva et al., Lifetime measurement of $\pi^+\pi^-$ atoms to test low energy QCD predictions, (Proposal to the SPSLC, CERN/SPSLC 95–1, SPSLC/P 284, Geneva 1995).

[2] J.Uretsky and J.Palfrey, Phys.Rev. 121 (1961) 1798.

[3] A.Gall, J.Gasser, V.Lyubovitskij and A.Rusetsky, Phys.Lett. B462 (1999) 335.

[4] L.Nemenov, Yad.Fiz. 41 (1985) 980.

[5] V.Olshevsky, S.Trusov, Preprint JINR E10-2000-150, Dubna, 2000. Submitted to NIM.

[6] M.Gallas, The Complete Software-Programmable Third Level Trigger for DIRAC, (Application Note AN–60, LeCroy Corparration, 1999)

Received by Publishing Department
on January 12, 2001.