HARP Collaboration

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IMPROVING HARP TOF-WALL MEASUREMENTS

A. Fava, D. Gibin, A. Guglielmi, M. Laveder, M. Mezzetto
Dipartimento di Fisica "G.Galilei" and INFN, Padova, Italy

Abstract

The resolution in the time of flight measurement can be improved by using the overlap area between adjacent scintillator counters in the TOFW and by introducing a better definition of the target arrival time t_0. In such a way $\sim$ 135 ps of resolution was obtained in a test run with no target and with $5\,GeV/c$ particle momentum. This result, in turn, demontrates the possibility to separate kaons from pions at 3σ level up to $3\,GeV/c$ only by time of flight measurements.

1 Introduction

One interesting mesurement in HARP is the K/π separation especially in the case of MiniBooNE and K2K target replica (fig.1).

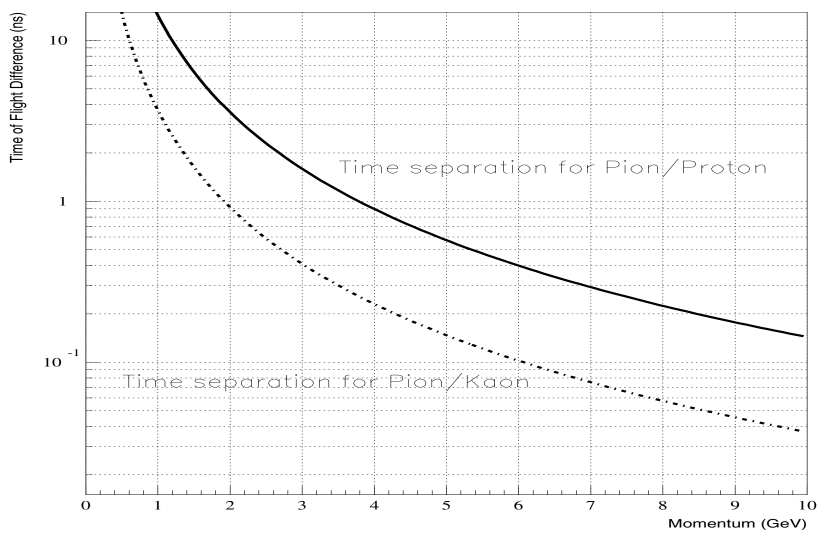

Figure 1: Time of flight separation for π K and p in HARP

At present, the excellent intrinsic TOFW resolution $\sigma_{TW} \sim 160$ ps allows to measure time of flights (t.o.f.) with respect to one of the beam tof counters (TOFA, TOFB, TDS, each with resolution $\sigma_0 \sim 120$ ps), with a total resolution $\sigma_{TOF} \sim 200$ ps (section 2). Therefore (see fig.1) one can separate pion from kaons at 3σ level up to $2.4\,GeV/c$ only by t.o.f. measurements. However the t.o.f system can do better, improving the resolution σ_{TOF} taking advantage of the overlap region between the TOFW scintillator counters (section 3) and by introducing a better definition of the target arrival time t_0 which replace the individual times from the TOF beam counters (section 4) . In order to better understand the t.o.f. potential, data were processed with the old v6r1 reconstruction software with the Beam TOF time calibration by the M. Chizov's algorithm.

2 TOFW and TOFA resolutions

Actual performance of the time of flight system in the forward direction can be easily tested selecting beam particles giving only 1 hit in the TOFW in "no target" run conditions. Run 14459 with $5\,GeV/c$ particle momentum has been used as test run. The π can be separated from p using the t.o.f between the beam counters TOFA , TOFB and TDS (see fig 2) by requiring:

$$(t_{TDS} - t_{TOFA}) < 377\,\text{ns} - 4.1 \cdot (t_{TOFB} - t_{TOFA}).$$

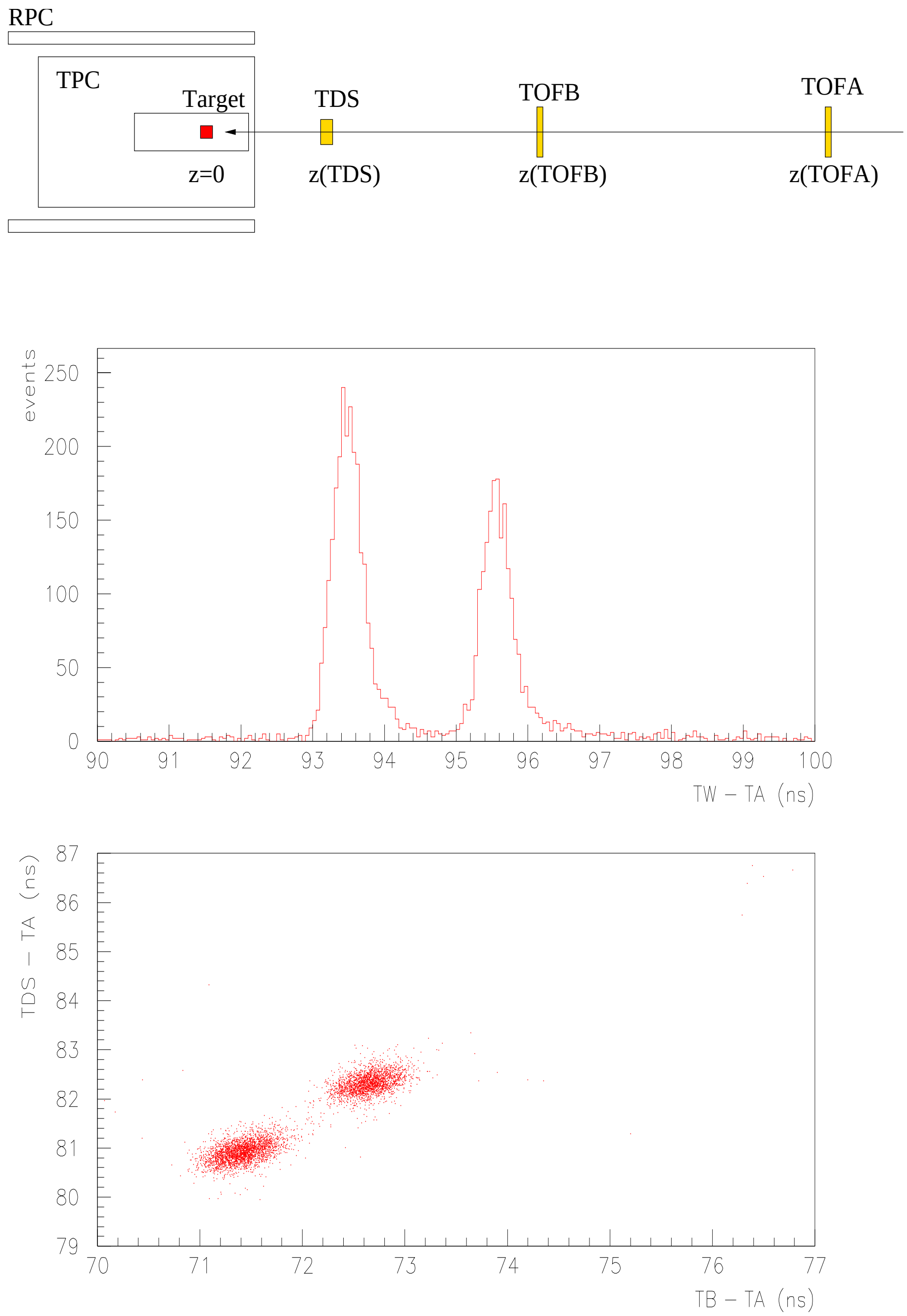

Figure 2: Layout of beam tof counters (top): the 3 beam counters TDS , TOFB and TOFA are located upstream the target ($z = 0$) respectively at $z(TDS) = -1.125$ m , $z(TOFB) = -4.050$ m , $z(TOFA) = -25.500$ m . Time-of-flight of TOFW-TOFA (center) and TDS-TOFA vs TOFB-TOFA (bottom).

The two resulting π and p peaks in TOFW-TOFA t.o.f. are then shown in fig. 3: the time resolution σ_{TOF} is 200 ps and 196 ps respectively. This means that the intrinsic time resolution of TOFA and TOFW are $\sigma_0 \sim 115$ ps if σ_{TW} is ~ 160 ps .

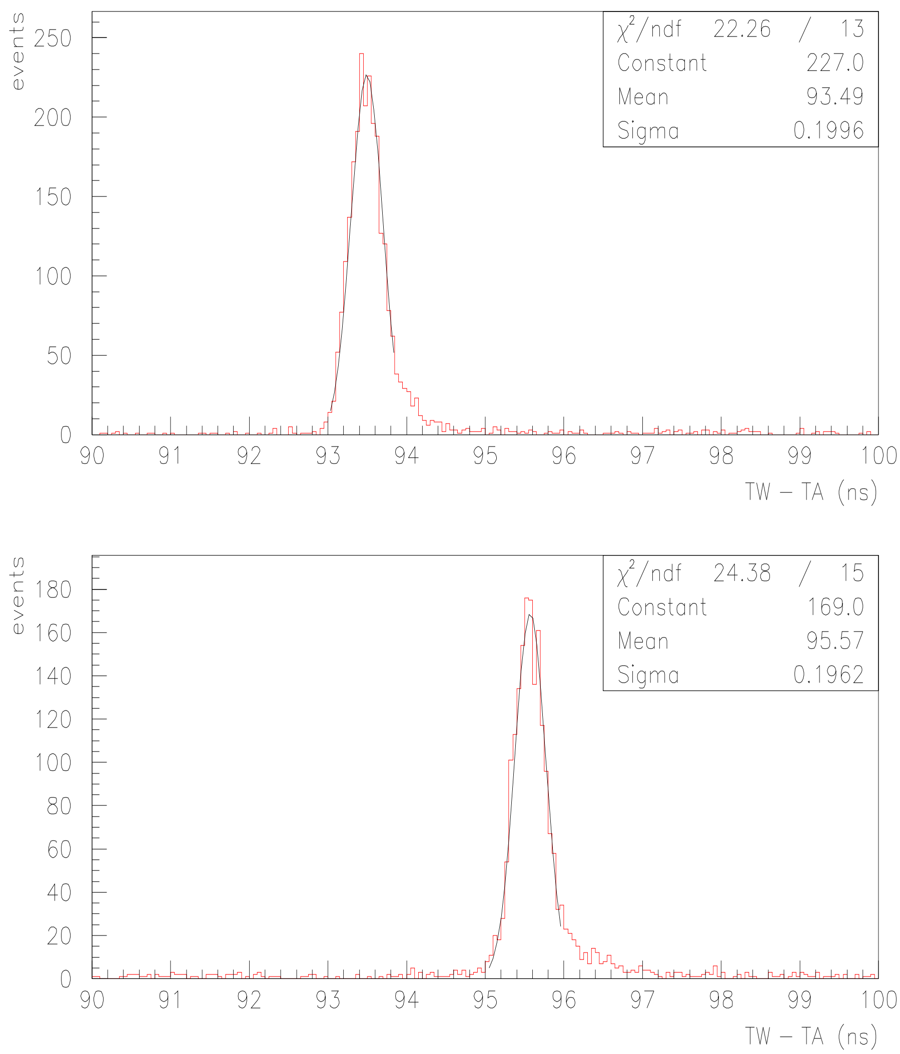

Figure 3: The two separated π (top) and p (bottom) peaks in TOFW-TOFA time of flight .

3 TOFW Overlap resolution

Events in the TOFW overlap regions are selected by requiring two adjacent counters fired in the TOFW. However the t.o.f. resolution with respect to TOFA with the signals from just one of the two counters fired is slightly degraded because the particles hitting the counters in the edges give a reduced photostatistics : 211 ps for π and 207 ps for p (see fig.4). It is useful to note here that although the overlap area is small (scintillator counters overlap by 2.5 cm over a width of 21 cm, $\sim 12\%$) events in the overlap are more than 40% of the total statistics for the beam particles thanks to the actual displacement of the TOFW Central palizade with respect to the beam position .

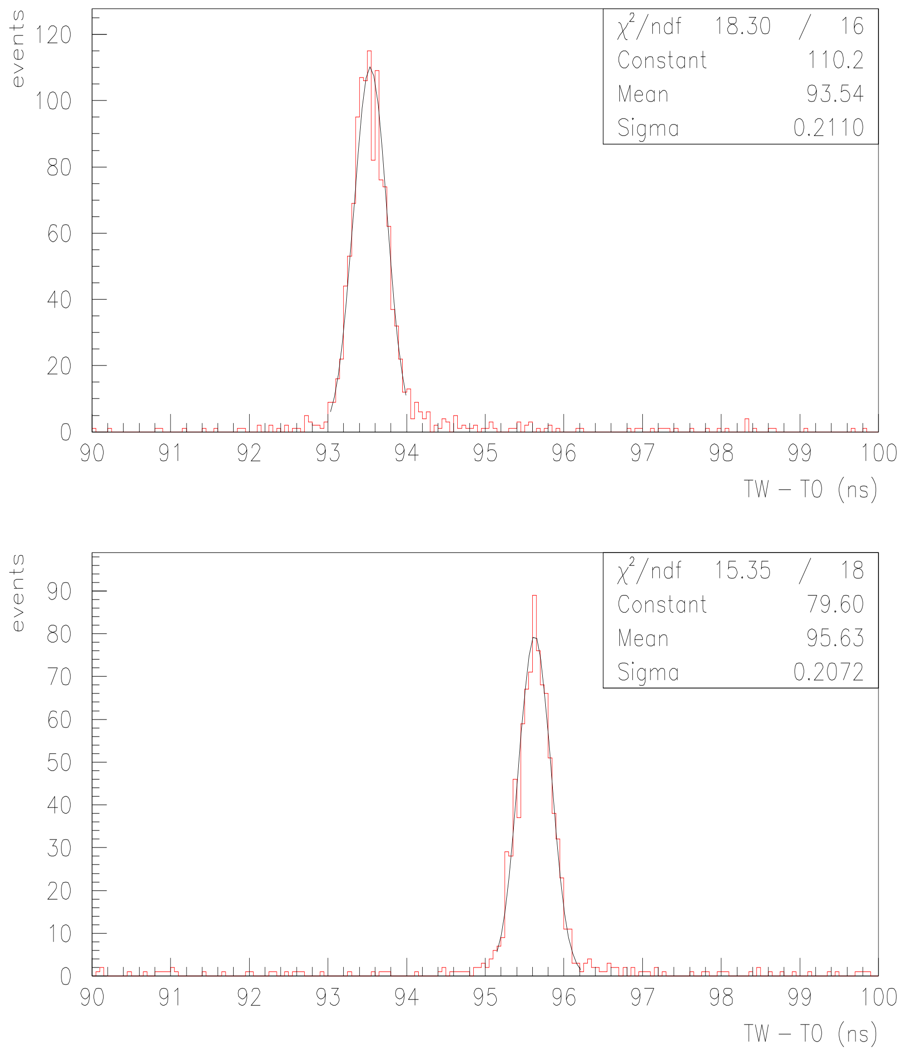

Figure 4: Particles crossing the TOFW overlap region with the signal from just one of the two counters fired: π (top) and p (bottom) peaks in TOFW-TOFA time of flight .

The averaged time in the TOFW overlap is then calculated:

$$t_{TW,OV} = \frac{t_{TOFW1} + t_{TOFW2}}{2}$$

where t_{TOFW1} and t_{TOFW2} are the averaged times in the two adjacent fired counters. The resulting t.o.f resolution $\sigma_{TOF,OV}$ is then 170 ps for π and 173 ps for p (see fig.5).

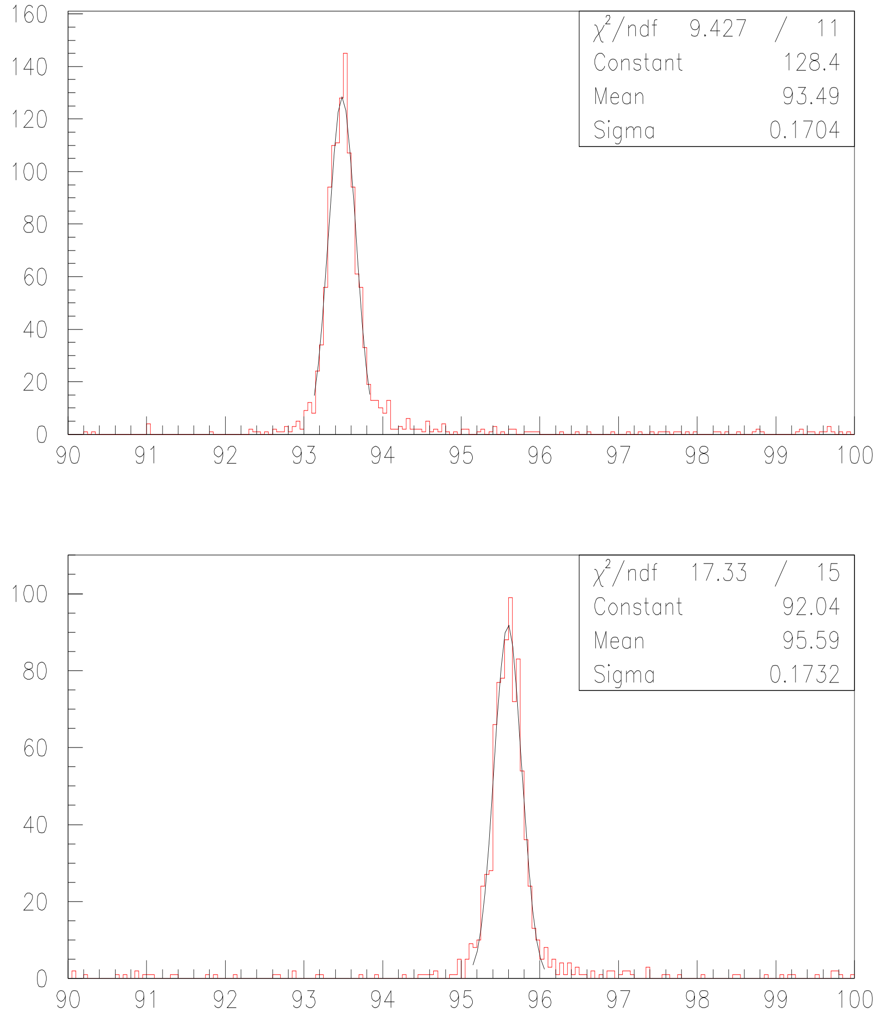

Figure 5: Particles crossing the TOFW overlap region with the signals from the two counters fired: π (top) and p (bottom) peaks in TOFW(overlap)-TOFA time of flight.

The tracks not crossing the full slab thickness, associated with a small charge deposition (see fig.6) and affected also by a severe time-walk correction, are rejected by requiring a signal in the range 0.6 mip $< Q_{PM} <$ 2 mip.

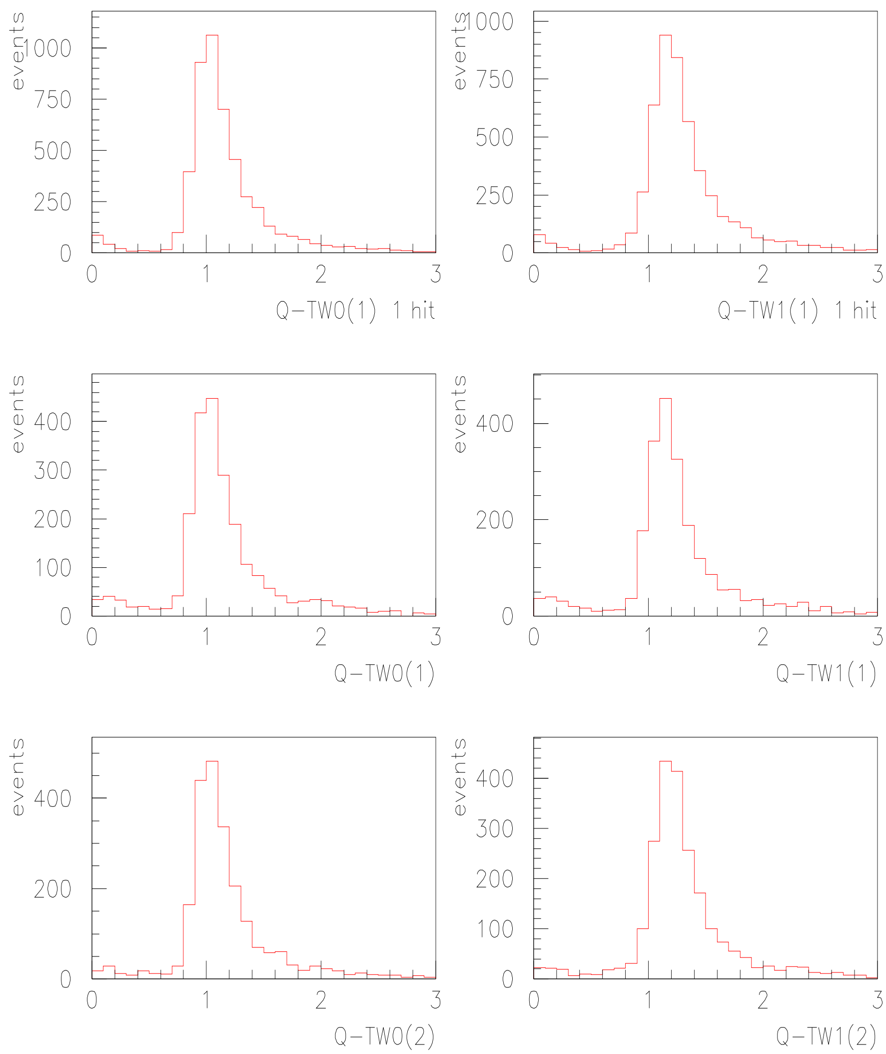

Figure 6: The PMT TOFW charge distributions for 1 hit TOFW (top) and particles crossing the overlap region of the counters (middle, bottom).

With the charge selection the time of flight resolution is improved to 157 ps for π and 159 ps for p (see fig.7). This in turn means that the intrinsic time resolution of TOFW in the overlap is $\sigma_{TW,OV} \sim 110$ ps, as expected for two independent measurements with a ~ 160 ps resolution.

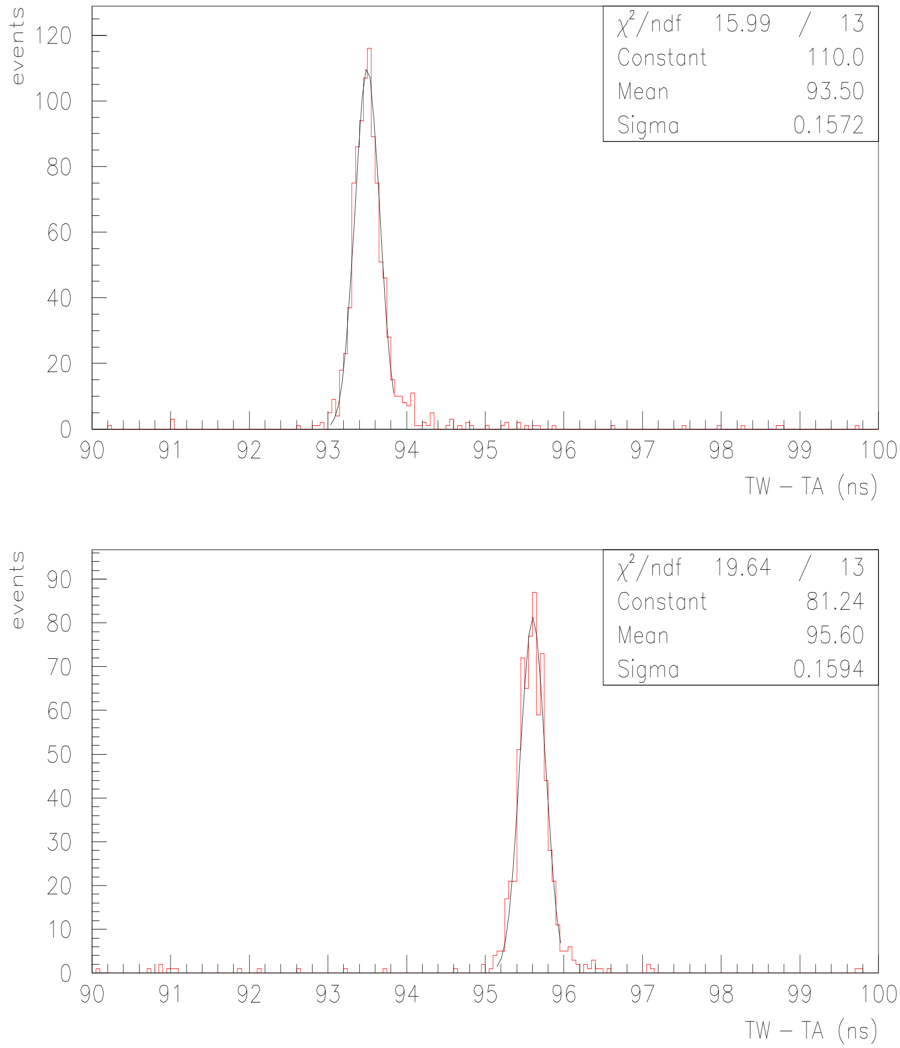

Figure 7: Particles crossing the TOFW overlap region with the signals from the two counters fired with the ADC selection: π (top) and p (bottom) peaks in TOFW(overlap)-TOFA time of flight .

These ADC cuts have no effect on the time resolution for the 1 hit TOFW events where particles are necessarily crossing the full counters (see fig.8).

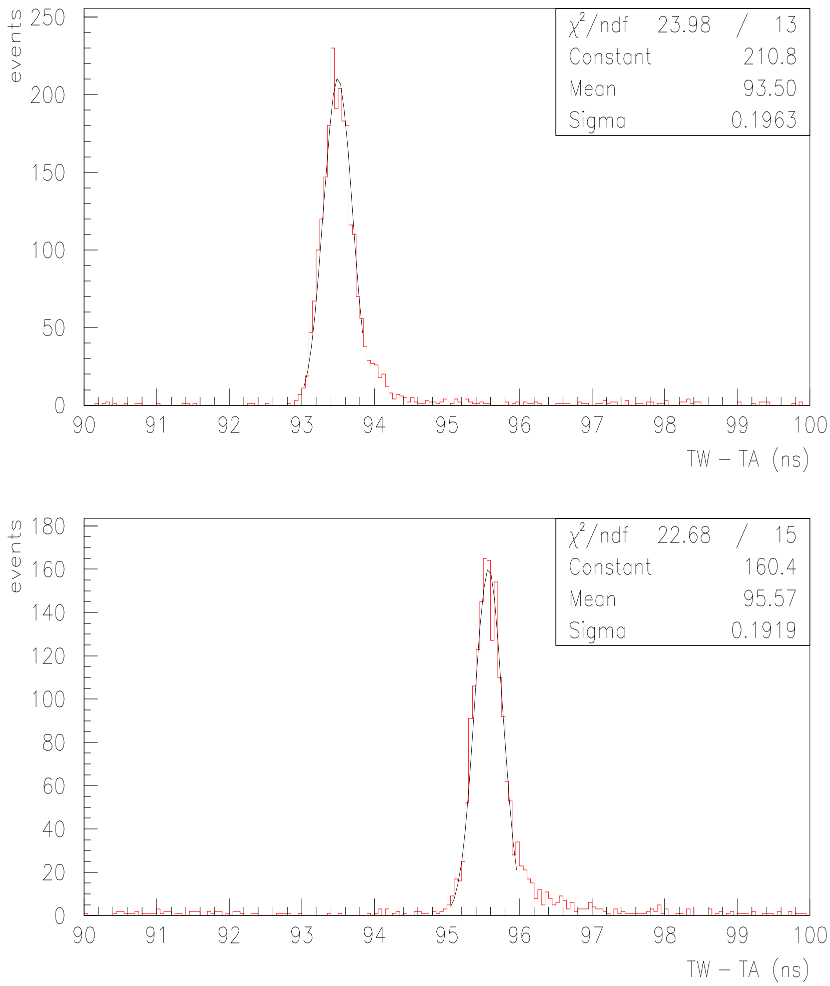

Figure 8: T.o.f. TOFW-TOFA for 1 hit TOFW events with the ADC selection : the t.o.f. resolution for the single TOFW counters is 196 ps for π (top) and 192 ps for p (bottom) .

Table 1 gives a summary of the obtained resolutions for different definitions/selections.

event type	$\sigma_{TOF,\pi}$ (ps)	$\sigma_{TOF,p}$ (ps)
1 hit TOFW - single counter	200	196
1 hit TOFW - single counter - ADC selection	196	192
2 hits TOFW - overlap - single counter time	211	207
2 hits TOFW - overlap - averaged time	170	173
2 hits TOFW - overlap - averaged time - ADC selection	157	159

Table 1: Time of flight resolutions σ_{TOF} for π and for p according to different event selection criteria. Time of flight here is always given by TOFW-TOFA.

4 Average target arrival time t_0 resolution

In order to improve the resolution on the t_0 signal, all TOFA, TOFB and TDS counters (see fig. 2) must be combined to obtain the time at the target center ($z = 0$):

$$t_0 = \frac{t_{0,A} + t_{0,B} + t_{0,TDS}}{3}$$

where the beam tof times have to be extrapolated to $z = 0$ accounting for the beam momentum P_{beam}. For example :

$$t_{0,A} = t_A + \frac{\sqrt{P_{beam}^2 + m_{\pi,p}^2}}{P_{beam}} \cdot \frac{Z_A}{c}$$

and similarly for $t_{0,B}$ and $t_{0,TDS}$. In such a way selecting events with only 1 hit in TOFW , the π and p t.o.f. resolutions $\sigma_{TOF,0}$ improve respectively to 167 ps and 172 ps (see fig. 9) . This means that the intrinsic time resolutions on t_0 becomes of the order of $\sigma_{t_0} \sim 60$ ps for $\sigma_{TW} \sim 160$ ps, in good agreement with the result obtained by D. Schmitz [1].

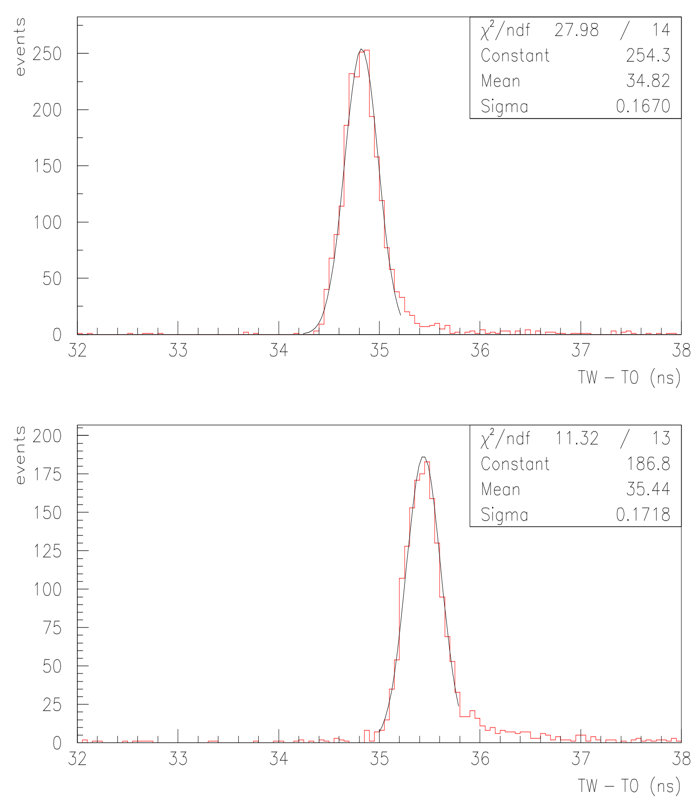

Figure 9: The two separated π (top) and p (bottom) peaks in the t.o.f. with respect to the t_0 averaged time at the target center. Only events with 1 hit in TOFW are selected here. Time of flight resolutions $\sigma_{TOF,0}$ are 167 ps for π and 172 ps for p.

The best time resolution is then obtained both requiring events in the overlap region in TOFW and using the average target arrival time t_0 defined above. The resulting $(t_{TW,OV} - t_0)$ t.o.f. distributions for particles crossing the overlap region of the counters, with the event charge selection, w.r.t. the t_0 reference are shown in fig. 10. The t.o.f. for particles in the forward direction hitting the TOFW counter overlap can be measured with a resolution of $\sigma_{TOF,OV,0} \sim 135$ ps !

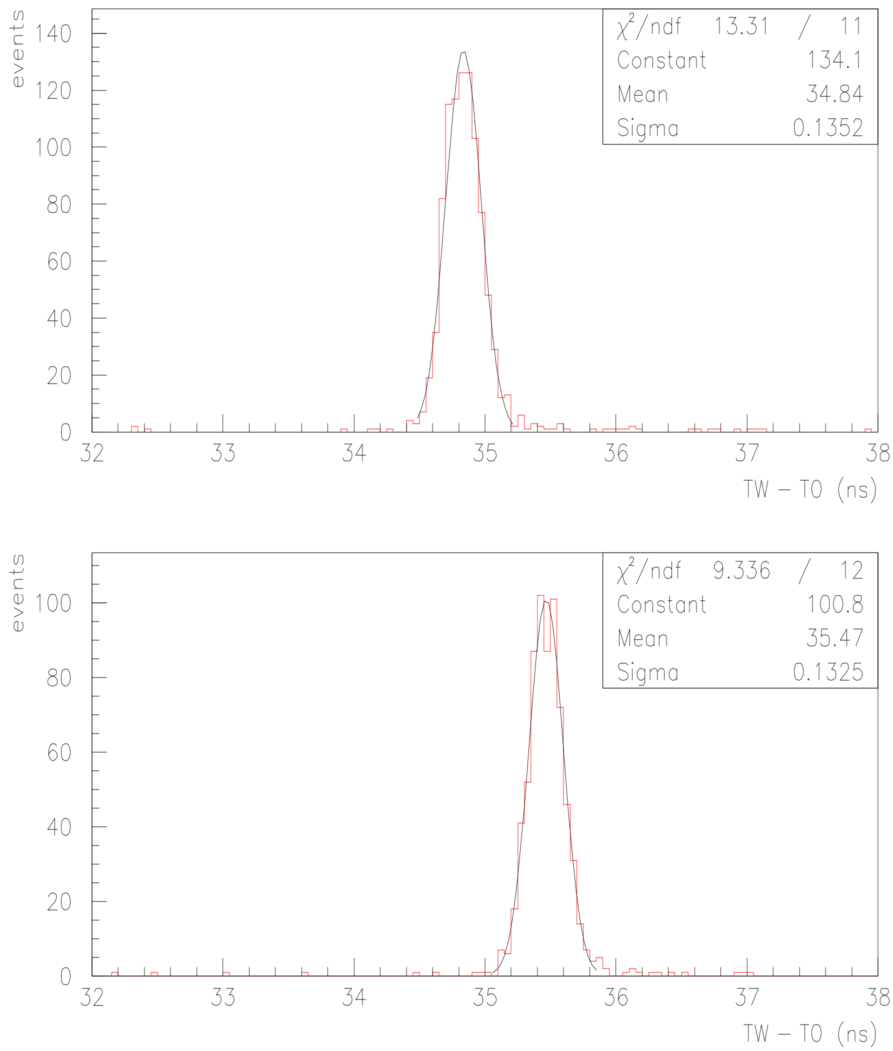

Figure 10: The two separated π (top) and p (bottom) peaks in TOFW(overlap)-T0 time of flight. Events in TOFW overlap region are selected by the charge deposition. Time of flight resolutions $\sigma_{TOF,OV,0}$ are 135 ps for π and 132 ps for p.

5 Conclusions

Thanks to the excellent intrinsic TOFW resolution in the overlap region, after a proper ADC selection, $\sigma_{TW,OV} \sim 110$ ps, and using the average target arrival time t_0 - from TOFA TOFB and TDS - with intrinsic resolution $\sigma_{t_0} = 60 \div 70$ ps , it is possible to measure particle time of flight with a total resolution $\sigma_{TOF,OV,0} \sim 130 \div 135$ ps. Therefore (fig. 1) one can separate kaons from pions at 3σ level up to $3\,GeV/c$ only by t.o.f. measurements. Moreover a 3σ $K - p$ separation up to $5\,GeV/c$ can be also achieved in such a way. These results were obtained in a test run with no target and with $5\,GeV/c$ particle momentum.

References

[1] D. Schmitz, HARP forward analysis meeting, June 4 , 2004