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Proton to pion ratio in accidental coincidences

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Abstract

An admixture of protons to pions in accidental trigger events were determined by a measurement of time of flight between upstream detectors and vertical hodoscope.

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1 Introduction

The main goal of this job was an estimation of proton contribution to a positive pion spectrum used to reconstruct pion spectra from events caused by accidental coincidence trigger. Accidental events are used to calculate the background to be subtracted in order to get a number of pion pairs coming from $\pi^+\pi^-$ atom ionization. So, any particle misidentification may introduce a systematic error in the final result.

The idea to use time of flight between up- and downstream detectors to estimate the proton contribution was discussed rather long time by many persons and its author is unknown now. I was asked to investigate the problem by L.Nemenov.

2 Event selection criteria and data handling

Seven run data files: 4520, 4522, 4523, 4524, 4526, 4527, 4529 were handled to determine a proton to pion ratio in accidental events. The data were collected with standard trigger and read-out configurations. A calibration file

$$/afs/cern.ch/exp/dirac/events12/yazkov/calmods20\_2002\_DB.dat\_br$$

and a geometry file

$$/afs/cern.ch/exp/dirac/events12/yazkov/det55\_2002\_DB.dat$$

were used at processing of all data files.

The ARIANE version 304_20c was used with some extensions. Dedicated routines were called at JobEventProcessing job level, i.e after a standard tracking was done. Data stored in FitTrkDC, TmTrxDC, IndEdX, InScFi, and HodDC common blocks were used. In this ARIANE version the data of ScFi U-plane are not present in HitFltUp array, so they were extracted during dedicated data handling of ScFi hits.

The event selection criteria are:

- Only one DC track was found in each arm
- Accidental coincidence event were selected, i.e.
  - · time t1 of VH1 is in [20, 30] ns or in [43, 56] ns ranges
  - · time t2 of VH2 is in [36, 42] ns range
  - · t1–t2 $<$ –10 ns or t1–t2 $>$ 7.5 ns

- For each DC track there are hits in three planes of ScFi which gives "space point", and there is one and only one "space point" for each DC track, and they are different for different tracks. "Space point" means that X- , Y- and U-planes contain hits with a small time difference and fiber coordinates may belong to a track coming from the target.
- For each DC track there are hits in each of 4 planes of dEdX and there is no common dEdX hits for DC tracks. It means that minimum distance between tracks is about 3 mm in X- and Y-projections.

The data handling was done in three passes:

(1) Delays between second and third planes in respect to first plane of ScFi were determined, as well as a time resolution in each plane were obtained;
(2) Using previous results the times measured by second and first planes were corrected as if they were detected in the first ScFi plane and the weighted mean value of all three measurements was calculated for each event and differences between this value and times detected in each dEdX planes were stored in histograms. Then delays of each plane of dEdX were obtained from these histograms relatively SciFi.
(3) All time values measured by dEdX planes were corrected to averaged time of SciFi using delay values got in the previous pass and weighted mean value of dEdX time was calculated. Then weighted mean mean value of SciFi and dEdX measurements was calculated. A difference between this value and time measured by vertical hodoscope is a particle time of flight and we put these differences in a two dimensional plot (See Fig. 1).

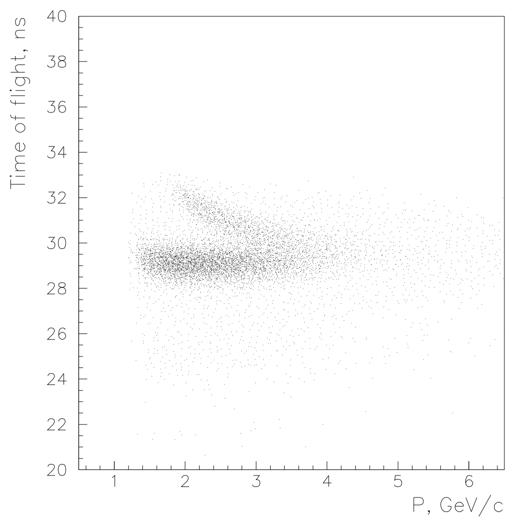

Fig. 1. *Particle time of flight versus momentum.* Two branches are clear seen, the upper one corresponds to protons and another one — to pions. The protons are suppressed at low momenta due to standard ARIANE criteria of 4 ns on the time difference between up- and downstream detector signals.

In fact the described procedure was done only for 4520 run data file. For all other runs we used delays obtained for 4520 run. As it was recognized later, the delays between signals are different in different runs and the maximum deviation is about 0.2 ns for processed data files. To be more accurate, the delays should be determined for each run before further analysis. It could allow us to improve a time of flight resolution and hence improve a separation of pions and protons at large particle momenta. It should be remarked that only about 3–5% of initial events pass through applied criteria and the most of events were rejected by requirements related with space resolution in upstream detectors and impossibility to find out a unique correspondence between track in drift chambers and hits in upstream detectors.

Two dimensional plot (Fig. 1) was sliced over momentum with 0.1 GeV/c binning and then we used slice histograms (see Appendix), to get final results. Different approaches could be used to analyze the data. For example, one could fit slice histograms by a sum of two normal distributions with all parameters free. It is evident, that while proton and pion peaks are well separated this approach works well, but it leads to unreliable results when peaks become close to each other. Parameters obtained in these fits are shown in Fig. 3.

The knowledge of particle trajectory length could allow us in principle to determine a TOF mean values at given momentum for protons and pions and then fix a corresponding parameters in normal distributions. The ARIANE provides to user a particle trajectory length (See Fig. 2).

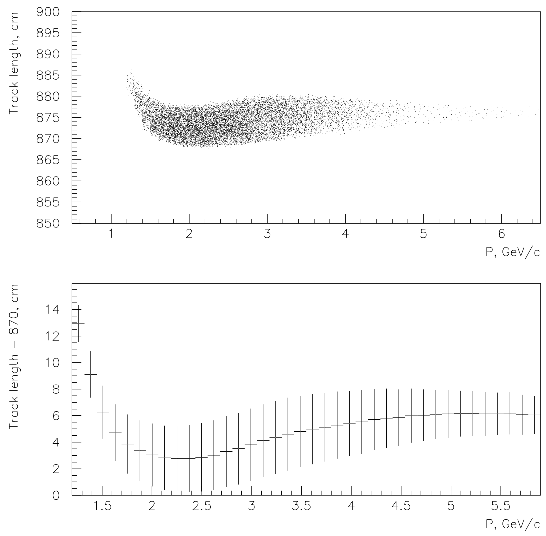

Fig. 2. *Particle trajectory length versus momentum.* The two dimensional plot is shown on the upper picture, the down picture shows the mean value of trajectory length as momentum function. To make the dependence more clear, the 870 cm was subtracted from the length values.

The binning over momentum in Fig. 2 is the same as in Fig. 1. It allow us determine a mean value of trajectory length for TOF slice histograms and use well known formula for time of flight to calculate expected TOF value for a particle. We can expect that measured values of TOF contain a systematics, so we tried to determine TOF mean values and TOF resolution using histograms shown in Fig. 3. TOF histograms was fitted by the function

$$t(p) = L(p) \cdot par_1 \cdot \sqrt{1 + m^2/p^2}, \tag{1}$$

where $L(p)$ — mean value of trajectory length at momentum p, par_1 — free parameter, m — mass of particle. $L(p)$ values were obtained from a fit of trajectory length (from Fig. 2) by a 9-th order polynom. The expected value of free parameter par_1 is $1/c$ (c — speed of light), but obtained values are slightly different (the difference is about 0.3% for pions).

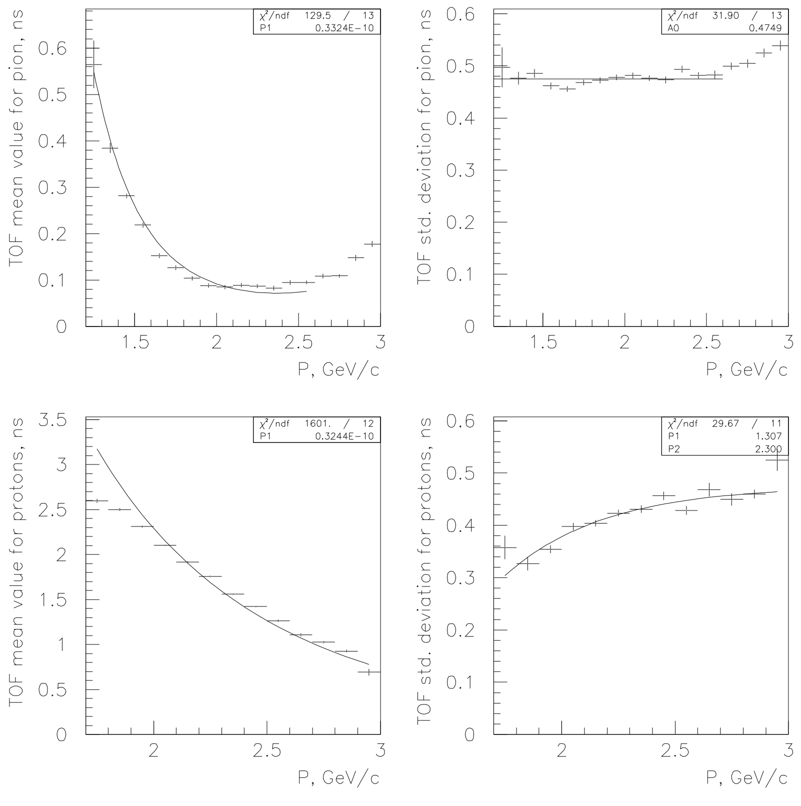

Fig. 3. *Parameters of normal distributions fitting TOF for pions and protons at different momenta.* Smooth curves show the results of a fit described in the text.

This difference as well as not so good quality of the fit may be explained by few reasons:

- Trajectory length calculated by ARIANE may (or may not) contains a systematic shift, as well as a calculated momentum of a particle.
- We used $L(p)$ calculated from polynomial fit and it also can introduce a systematics.
- All values are taken at the center of histogram bins, and it may introduce a systematics as the most of distributions are not linear.
- For protons with momenta less 2 GeV/c signal amplitudes are larger due to increasing of ionization losses at low momenta. As L.Tauscher remarked the leading edge discriminators will give output signals earlier in this case, i.e. TOF values will be less. The distributions may be distorted also by ARIANE selection criteria (on up- and downstream time difference).
- As it was mentioned above the time differences between dEdX planes and SciFi planes were different in handled data files. Maybe it decreases a quality of the fit also.

As it is seen from Fig. 3 the standard deviation for pions may be described by a constant value of 0.475 ns up to 2.6 GeV/c. For larger momenta pion and proton peaks are close to each other and a quality of fit goes down. For protons the TOF standard deviation (or TOF resolution) depends on the momentum. It may be explained by the fact that ionization losses of protons (and hence the amplitude of signals in dEdX and SciFi) are larger at small momenta and hence the leading edge discriminators give a smaller variations in time measurements. We fitted this dependence by a function

$$\sigma(p) = 0.475 \cdot (1 - exp((p - par_1)) \cdot par_2)), \tag{2}$$

supposing that at large momenta the time resolution for protons and pions is the same and equals to 0.475 ns. In this function p — proton momentum, par_1 and par_2 — free parameters.

Now we can use obtained dependencies of TOF mean values and standard deviations in order to fix four from six parameters in sum of two normal distributions and use resulting function to fit time slice histograms. The left two free parameters are normalization coefficients for proton and pion distributions. The results of fit are shown in APPENDIX. As it is seen from Fig. 7 – Fig. 13, the description of TOF distributions is not so bad even when proton and pion peaks cannot be separated. To obtain proton to pion ratio we can use the parameter values produced by fit procedure. The integral of the normal distribution with normalization coefficient $N(p)$ and standard deviation $\sigma(p)$ is proportional to $N(p) \cdot \sigma(p)$ and represents the number of detected particles in arbitrary units. Proton and pion spectra are shown in Fig. 4. At low momenta the pion spectrum was calculated also from the fit by the normal distribution with all three parameters free. As one can see the both procedures give very close results for pions in 1.7 – 2.6 GeV/c range. Starting from about 3.5 GeV/c the number of detected particles is rather small and pion and proton peaks are very close. So, the uncertainty in results becomes larger.

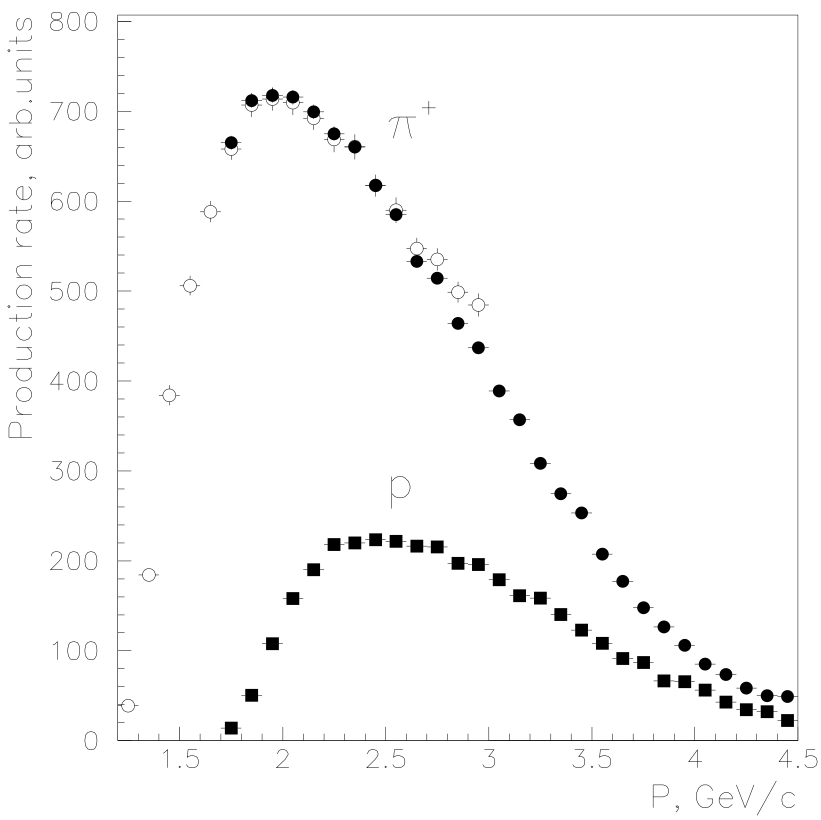

Fig. 4. *Proton and pion spectra.* Open circles stands for fit result of pion spectrum only, closed circles (π) and squares (p) stands for fit by sum of two normal distributions with two free parameters only corresponding to normalization coefficients

The proton to pion ratio as function of momentum can be calculated as

$$R(p) = \frac{N_p(p) \cdot \sigma_p(p)}{N_\pi(p) \cdot \sigma_\pi(p)}, \tag{3}$$

where subscripts p and π stands for protons and pions correspondingly. This ratio is shown in Fig. 5.

There is important question is there any systematics related with the procedure of event selection? The most questions (at least from my view point) come from the fact that the most number of events was rejected due to inability to put in unique correspondence tracks found in drift chambers and hits in upstream detectors. It is rather difficult to check availability or absence of this

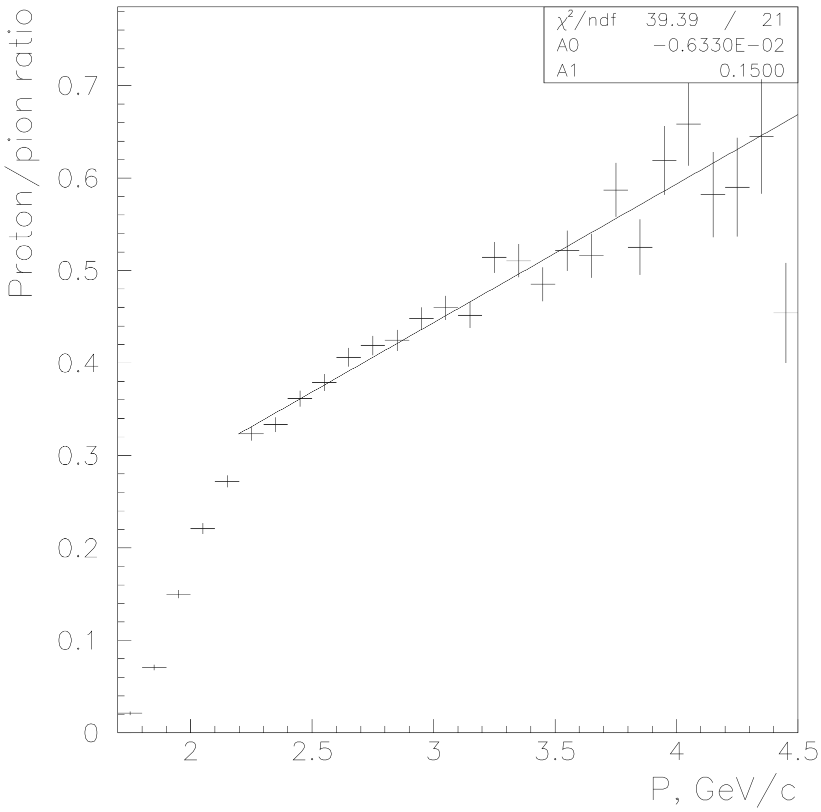

Fig. 5. *Proton to pion ratio.* Solid line is a result of fit in 2.2–4.5 GeV/c range and serves "to guide eyes".

systematics. We splitted all events in two sets: with distance between tracks less 1.5 cm and more than this value and put these groups in different two dimensional plots. Than proton to pion ratios were determined for both plots. The results are shown in Fig. 6. As it may be seen without complicated analysis there is no any difference between two event groups. It should be remarked that during fit procedure we did not recalculate dependencies $L(p)$, $\sigma(p)$ and mean value $TOF(p)$ and used the functions with parameters determined for all events, as well as the same delays between dEdX and SciFi planes. Of course, the more accurate approach could be used. The another problem is that both event sets are already events with unique correspondence between DC tracks and upstream detector hits. So, it is not possible to estimate that there is no systematics for events with a distance between hits in upstream detectors less than 3 mm.

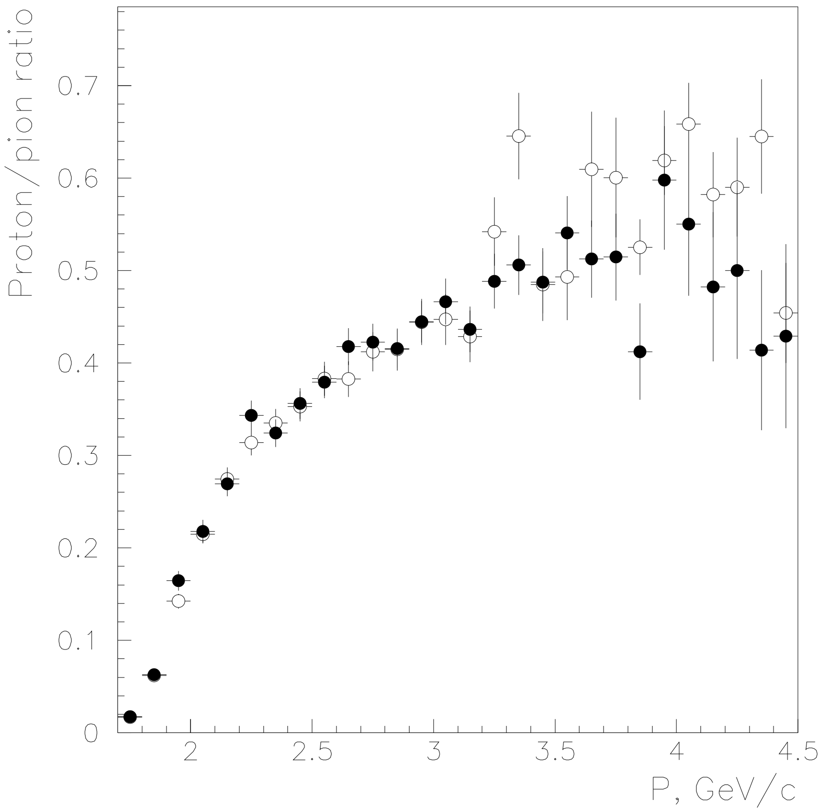

Fig. 6. *Proton to pion ratio.* Open circles stands for events with distance more 1.5 cm, closed circles for another events.

3 Conclusion

The performed analysis shows that the proton to pion ratio in accidental coincidence events may be determined by the measurement of particle time of flight between upstream and downstream detectors in the case when tracks found in drift chambers corresponds to upstream detector hits in the unique way. There are few evident improvements which may be done to increase the TOF resolution:

- More precise time calibration. As it was mentioned above the delays between planes of dEdX and SciFi varies from run to run. It seems that a precision of standard calibration procedure is not enough for this kind of tasks. Or more exactly, calibrations should be done more often, even few times for a data file.
- The time to amplitude correction for dEdX could be used. The attempt to use them for this job failed due to invalid content of the calibration file in this part.

- In principle a hit coordinate to time correction for dEdX and SciFi hits may be useful also.
- It is necessary to understand what is the reasons for discrepancy in TOF and a particle trajectory length and find out the way to exclude it.
- In principle the use of time measured by horizontal hodoscope should improve TOF resolution slightly.

And there are things which should be investigated more accurately:

- As it was mentioned above only few percents of events passed through selection criteria and the most part of events was rejected because we cannot handle them properly. It may be a source of systematic errors, especially if results will be used for events selected in another way.
- The event selection may be done more accurately. For example, in this job we selected events with detected hits in all dEdX and SciFi planes. The fraction of events where one or few planes are not efficient is not so small, as well as a number of hits with the timing close to each other but corresponding to different particles. So, we could make a mistake during selection of the hits. And it concerns also a lot of things used during event selection, like a possible mismatches in finding hits in dEdX and SciFi, few particles hitting the same dEdX slab and so on.
- The code used to get results required a lot of manual interventions, mainly due to the absence of adequate calibrations needed for this kind of tasks. The fit procedures should be automated also, and it is time consuming job also as the results may depend on initial values of parameters in a dramatic way.

Nevertheless it seems that obtained results is not so bad first approach to experimental estimation of proton to pion ratio in accidental events. It is interesting to know how sensitive final results (i.e. number of $\pi^+\pi^-$–atoms) is to this ratio. If it will be sensitive, I am afraid a more detailed calibration procedures will be necessary to obtain this ratio in a reasonable way.

Acknowledgements

I would like to thank V.Iazkov, V.Brekhovskikh, M.Jabitski for help in the understanding how to use the ARIANE, L.Nemenov. L.Tauscher and all collaborators for fruitful discussions and remarks.

4 APPENDIX

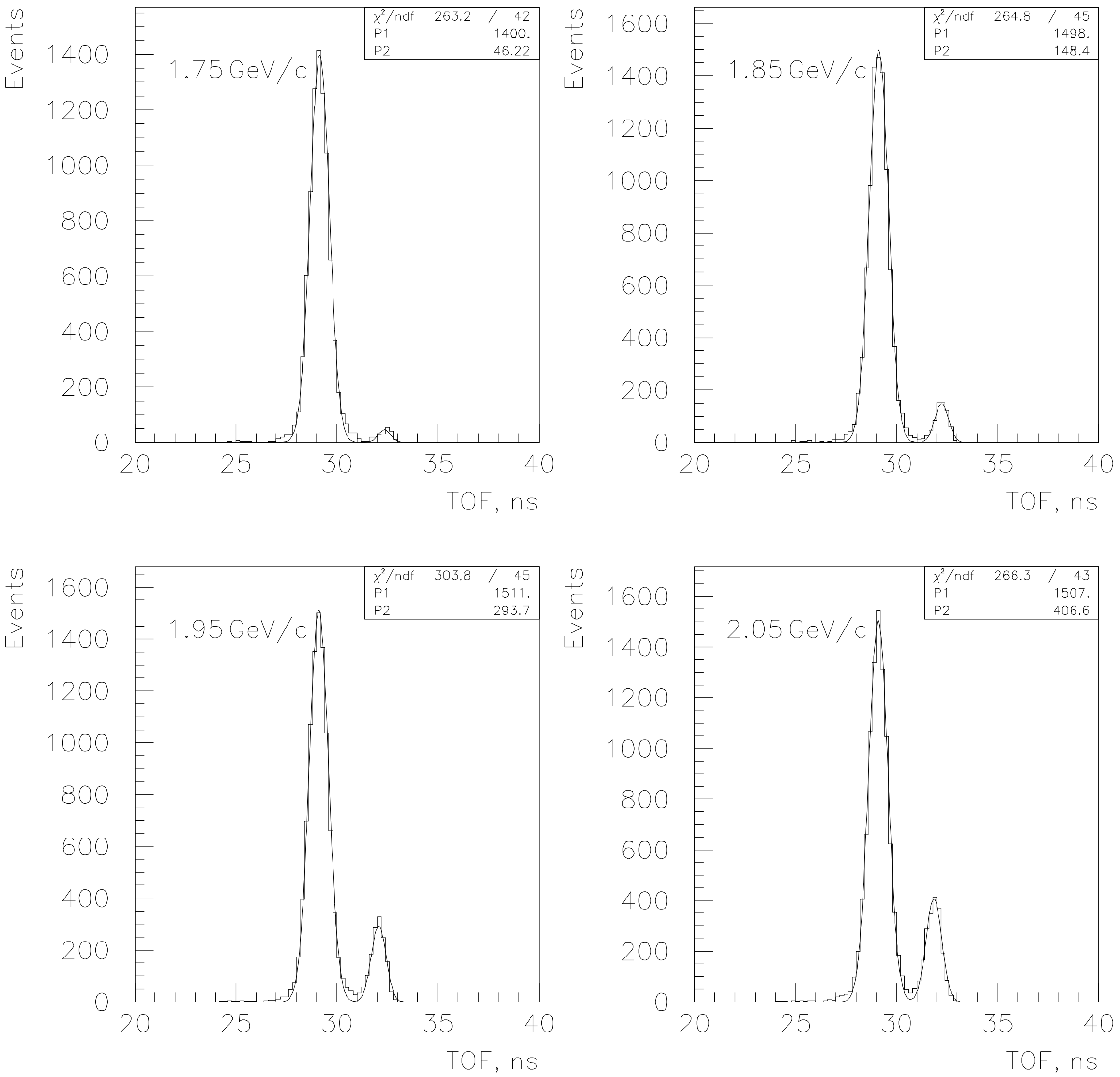

Fig. 7. *TOF at different particle momenta.*

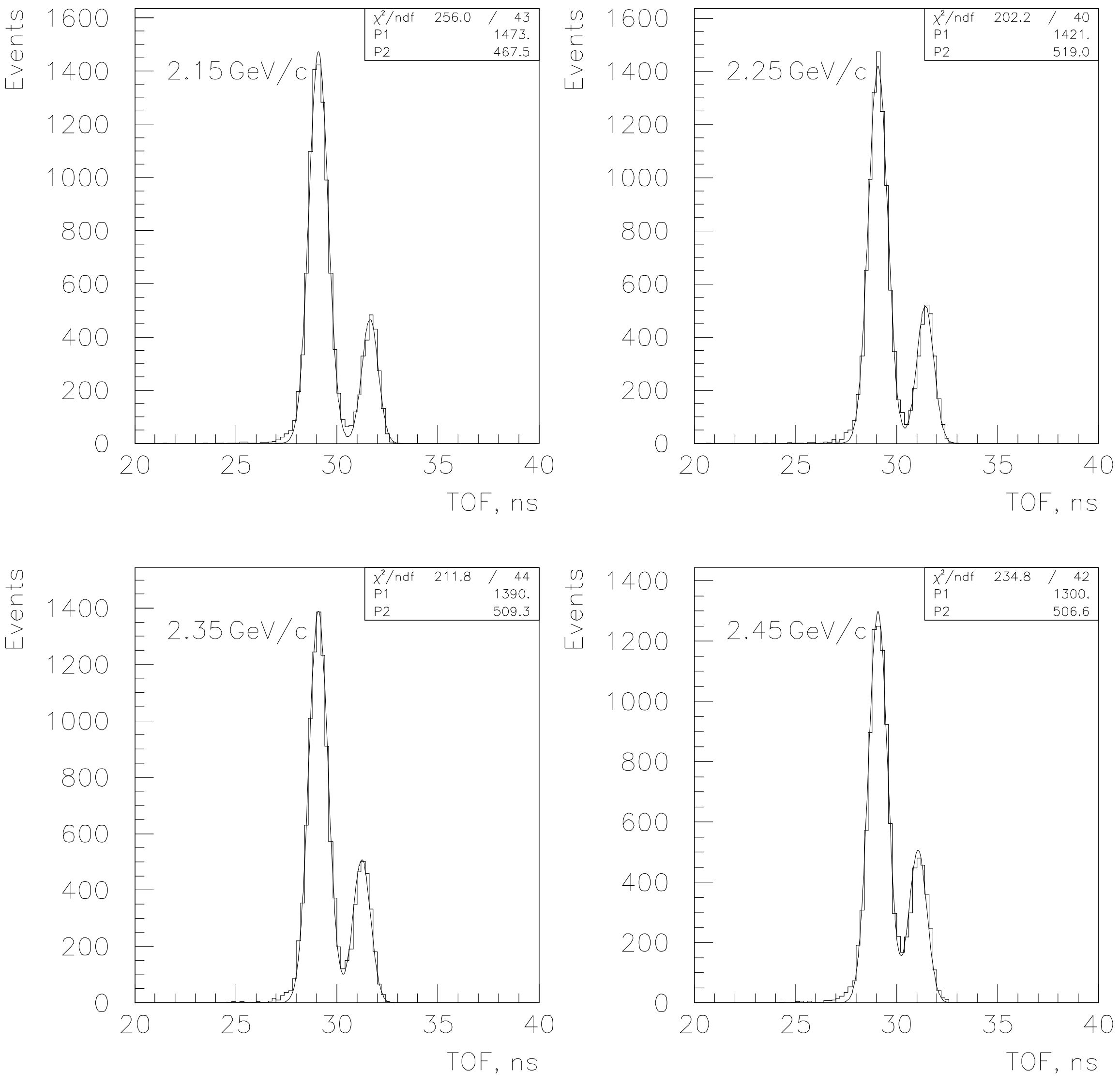

Fig. 8. *TOF at different particle momenta.*

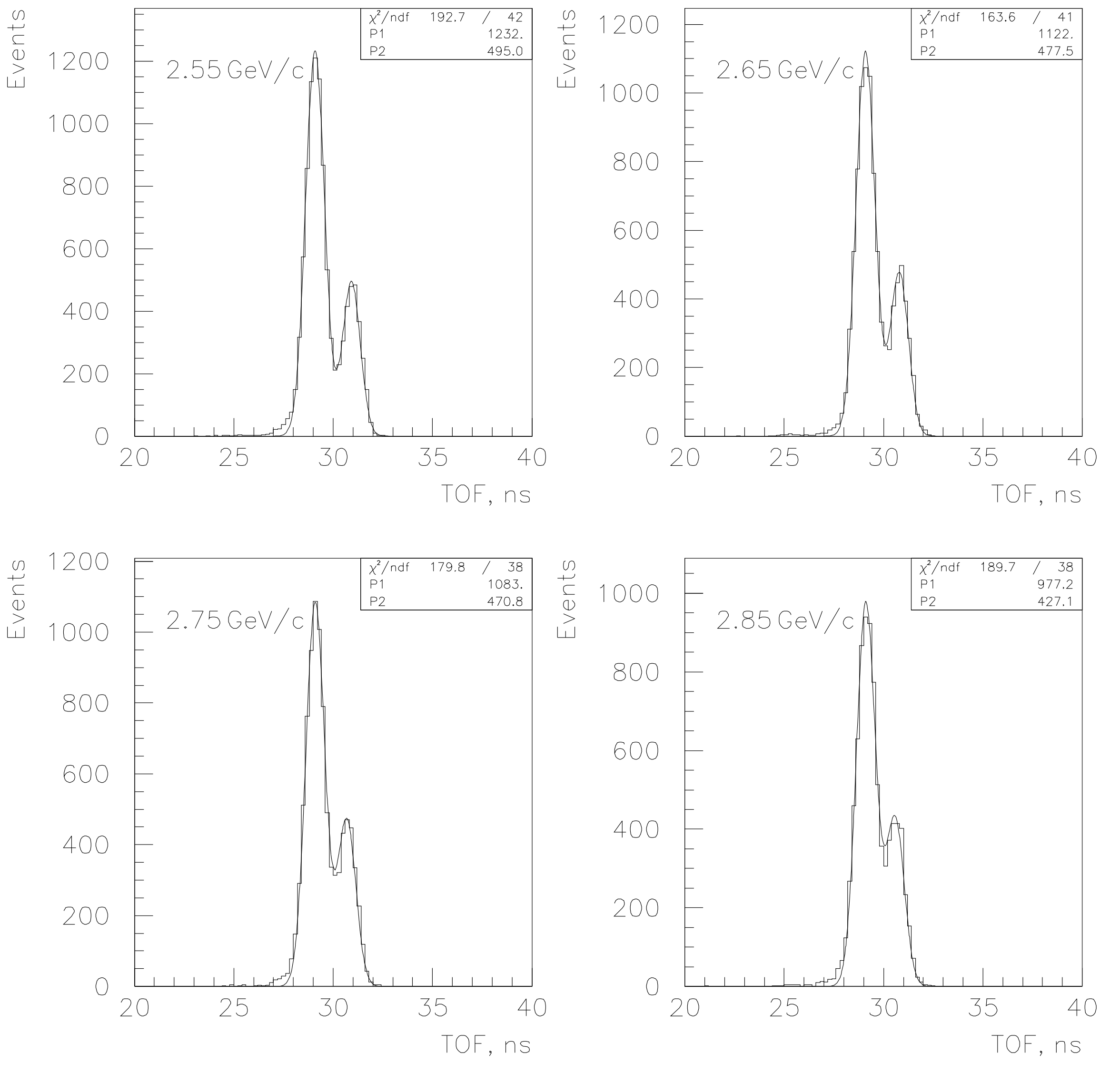

Fig. 9. *TOF at different particle momenta.*

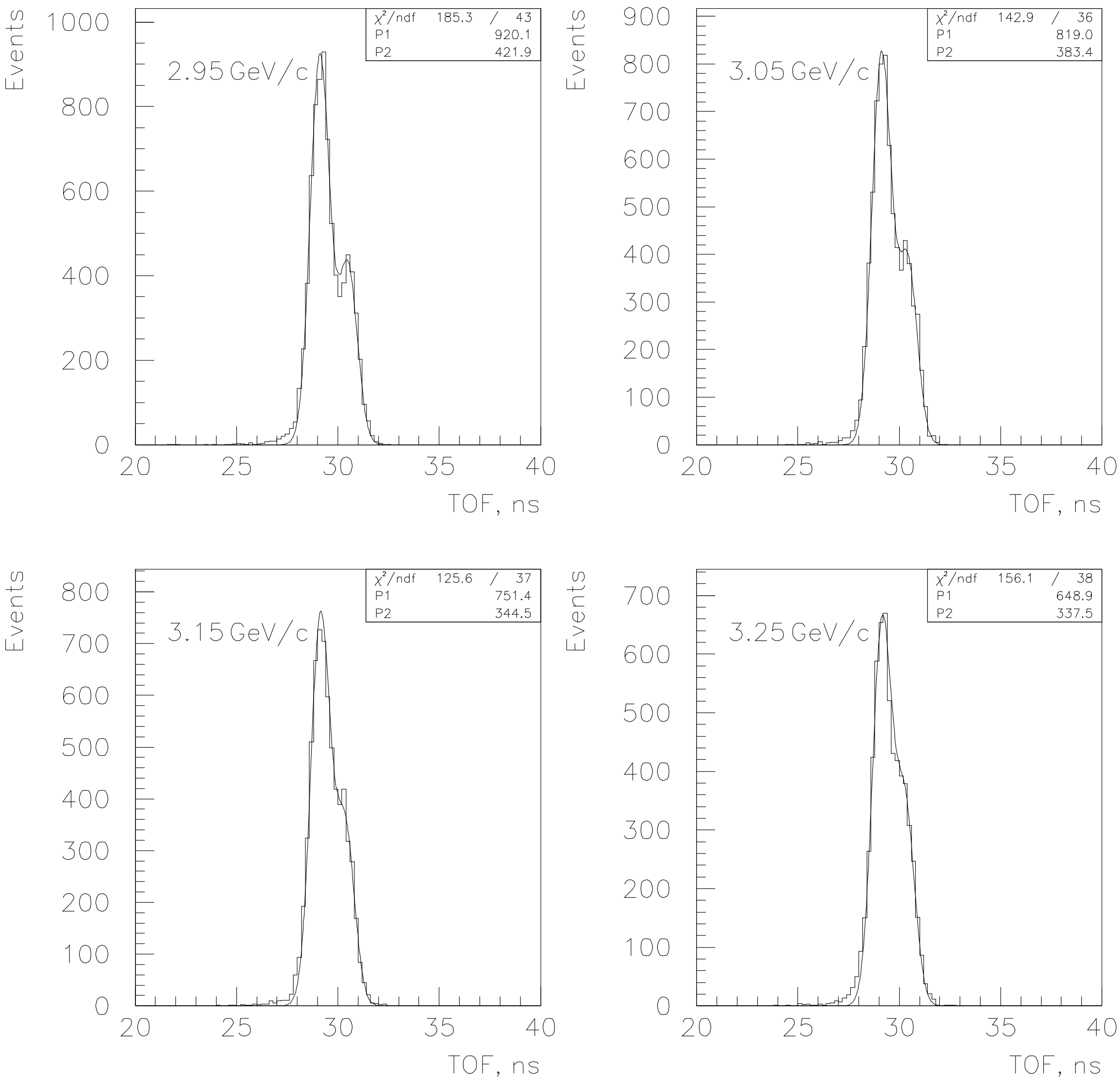

Fig. 10. *TOF at different particle momenta.*

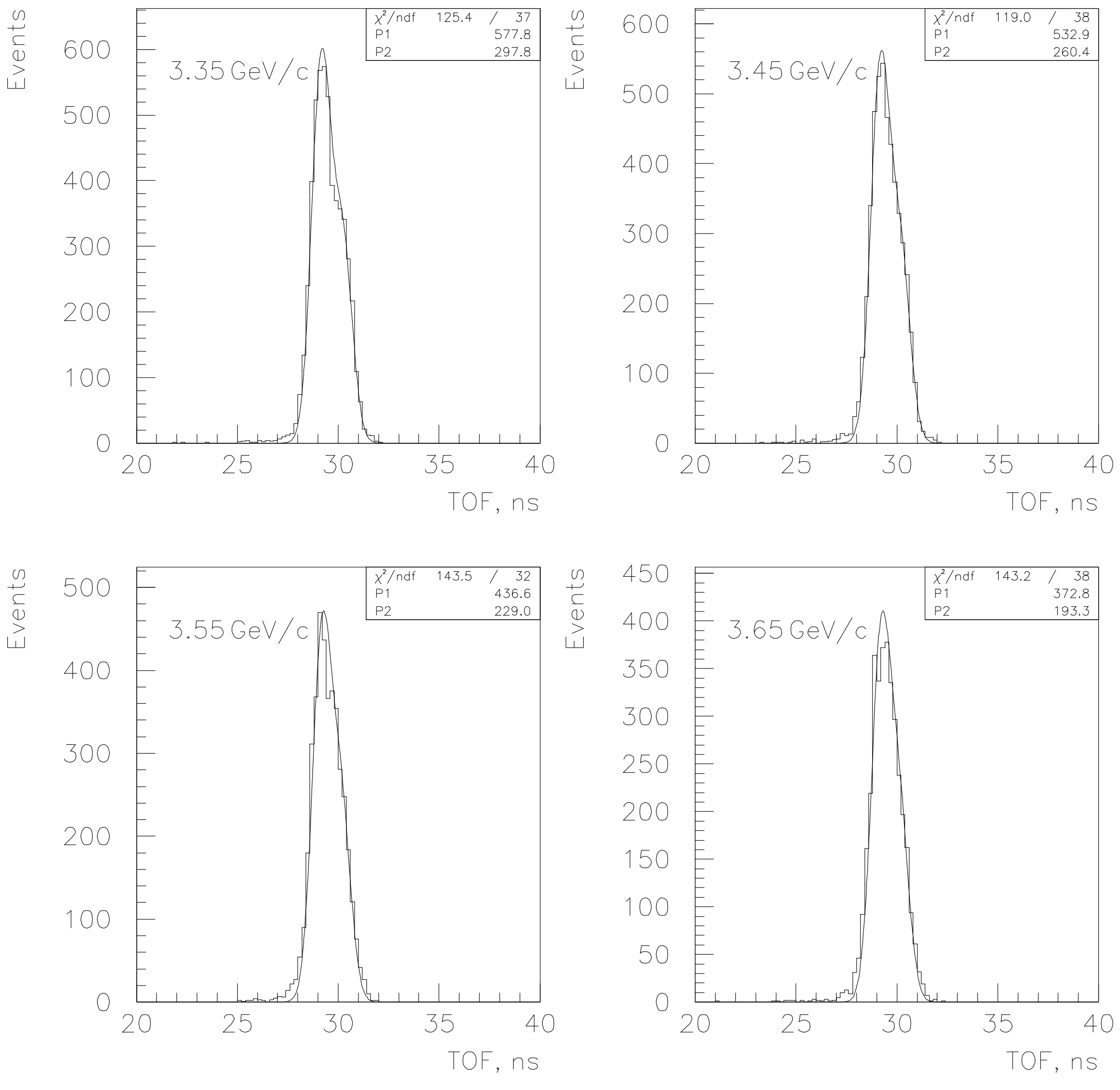

Fig. 11. *TOF at different particle momenta.*

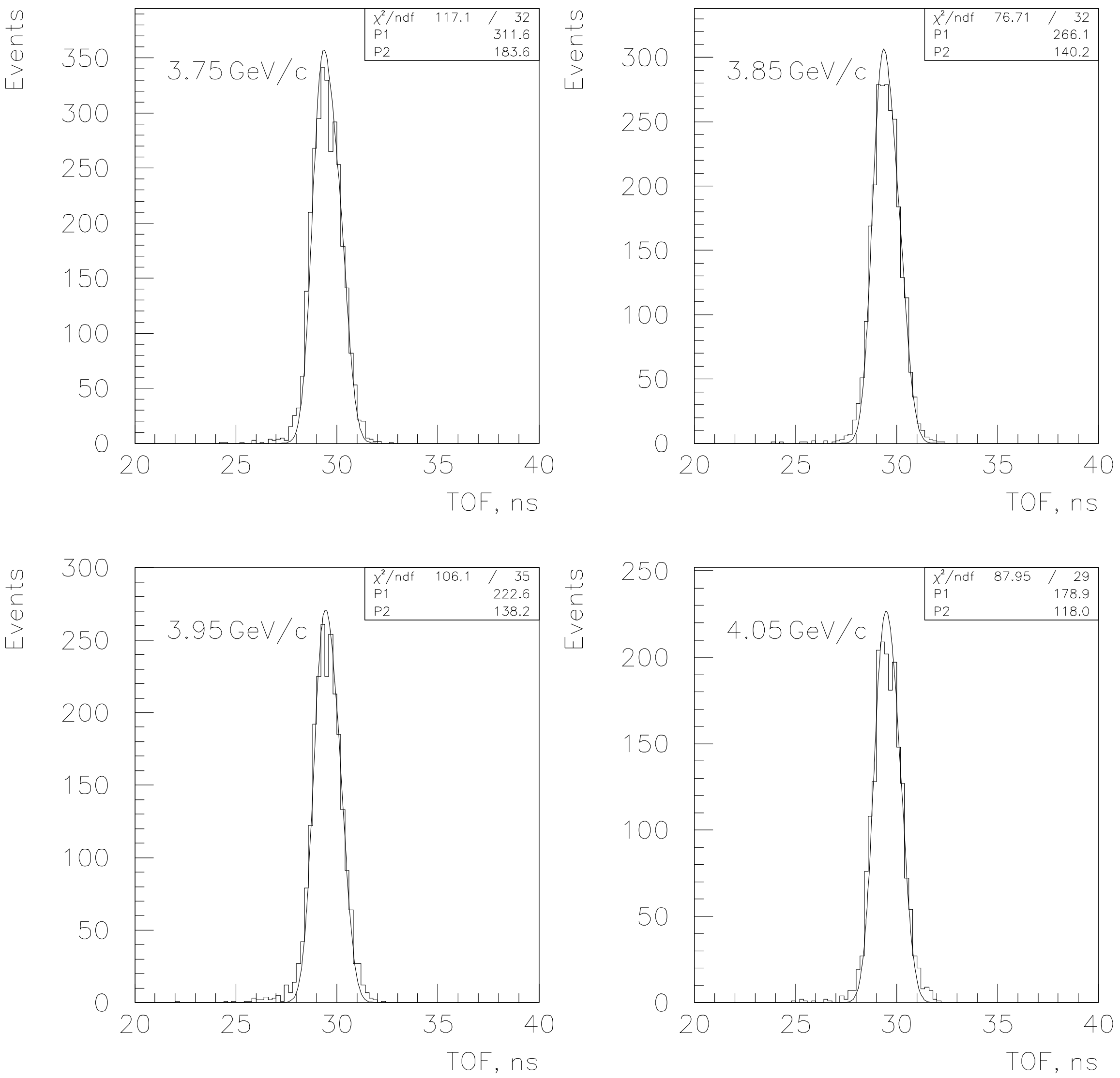

Fig. 12. *TOF at different particle momenta.*

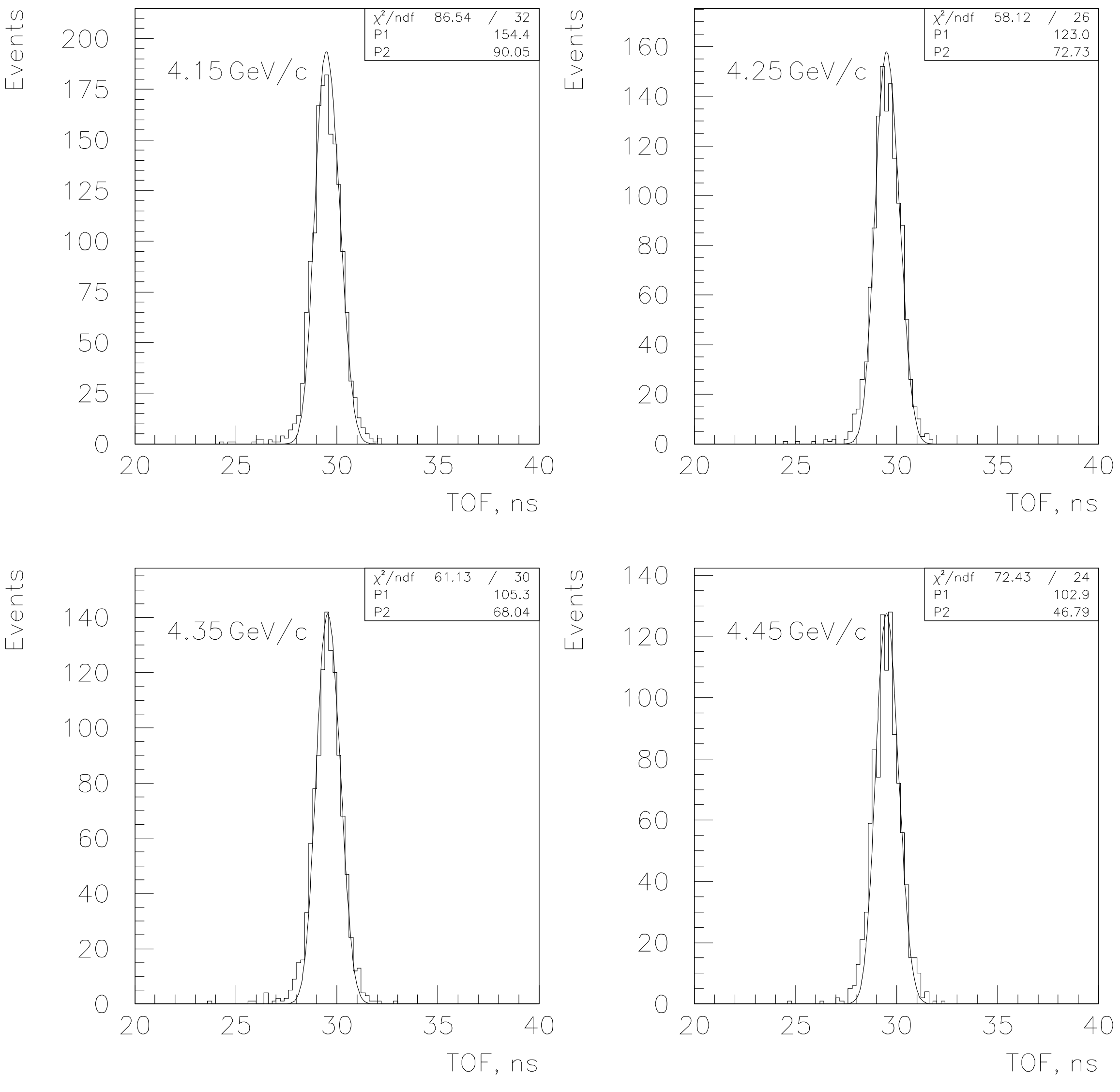

Fig. 13. *TOF at different particle momenta.*