7 Beam Background Studies

7.1 Beam Background Estimation based on 98 1/3 Data Set

7.1.1 Tuning of Beam Background Cuts

Beam background cuts include both "function" and "pathology" cuts; see Appendix for the description. Using 10% of 98 data, the existent cut functions, which were applied in the previous 95-97 analyses, were checked and the timing windows re-tuned in order to accommodate 98 data. B4DEDX and TGCCD cut positions are adjusted in the light of acceptance studies. Two more cut categories were added to TGGEO cut.

The setup cuts in Technical Note No. 331 were applied to select data samples for the tuning of beam background cuts.

- *Tuning of timing windows*

  According to the distributions of the time-related variables used in the beam background cuts, we reset the timing windows for: B4TRS, BHTRS, BWTRS, CPITAIL, CPITRS, CKTAIL, CKTRS, DELC, OPSVETO, TIMCON, TGCCD.

- *Adjustment of cut positions*

  Because of the similarity of data acquisition trigger conditions, we compared 98 $K_{\mu 2}$-based acceptance study results with 97b's and found that B4DEDX and TGCCD were, about 1.0% and 7.0%, respectively lower in acceptance, whereas PBNRS was 3.3% higher. The cut positions of the former two were then adjusted correspondingly, while the current PBNRS leaves no room to be tightened without a high acceptance loss ($pbnrs$ was required to be ≤ 1). $K_{\mu 2}$ and π-scattering data were checked for distributions of $b4abm2$, which is used in the B4DEDX cut; and both indicated a minor shift in $b4abm2$ to lower values but with no run dependency (Fig. 12). This could probably be explained by the change of the beam momentum (97b: 670 MeV/c, 98: 710 MeV/c, see **TN 367**). A new TGCCD cut position is tuned using $K_{\mu 2}$ data according to the $(ccdtk-b4trs)$ versus $(ccdtk-trs)$ 2-dimensional plot shown in Fig. 13. From Fig. 14, where $pbnrs$ distributions are present for 96, 97b and 98 data, it is visible that the Lead Glass Counter in 98 suffered from a same problem as in 96.

- *Patch to TGGEO*

  The modification of TGGEO cut was done on the basis of remaining events in the beam background bifurcation studies. Two new categories were introduced.

  The first one extends the old TGGEO cut in the following case: the first kaon comes in and enters the middle of the target, but we don't detect its decay products because it decays downstream or decays very late. The second beam particle is a kaon which decays in flight, and its decay product misses the B4 and enters the target near the edge. It passes through the kaon blob and then goes into the RS with R, E, and P in the box. Fig. 15 displays one of this kind of events. This cut functions somehow similarly to the current OPSVETO cut, but includes opposite-side hits that are not "on the swath", and doesn't use target fiber's energy information.

Fig. 16 gives timing distributions of IC hits, where the μ track time is subtracted. ($K\mu_{21}$ monitoring data).

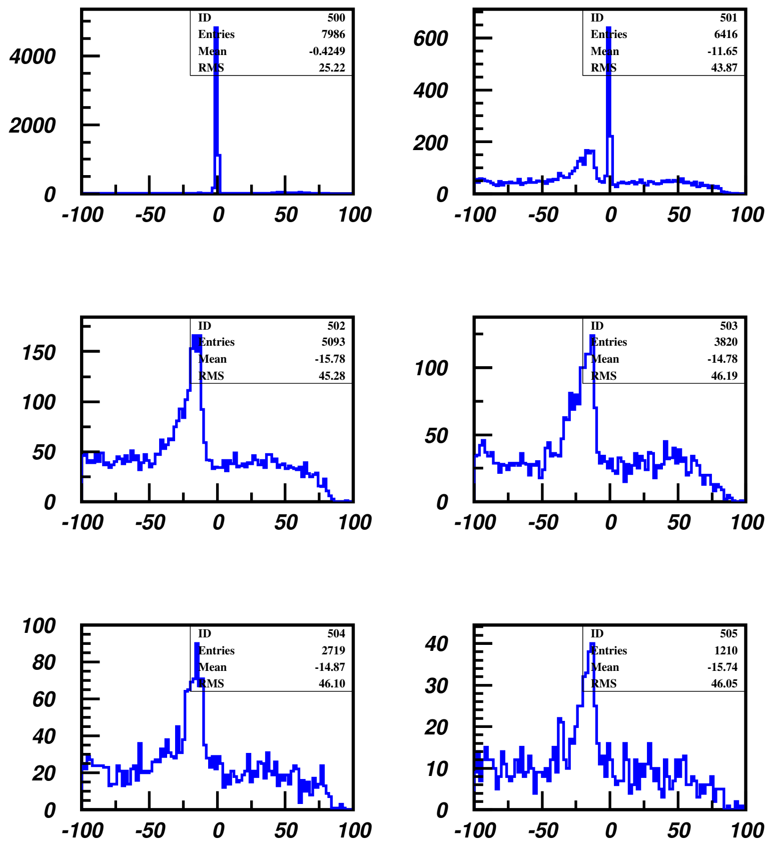

Figure 16: IC hits timing distributions. From the top left to the bottom right: $\Delta IC = 0$ (the same counter as that μ track passes through), 1, 2, 3, 4 and 5.

7.1.2 Single Beam Background

Single beam background includes kaon- and pion-entering. The single beam kaon-entering events are kaon decay-in-flight events, and single beam pion-entering events are events where a beam pion scatters into the detector. These are suppressed by DELC, CKTRS, CKTAIL, CPITRS and CPITAIL.

Figs. 17 and 18 summarize the estimation of single beam background level. The DELC rejection is estimated to be more than 2237. A loose setup (without TD and KIN cuts) gives us a higher rejection (8297). Conservatively, we take a rejection of 2237 in the background estimation.

The scheme of the normalization branch is shown in Fig. 18. Prompt events are divided into kaon-enterings and pion-enterings. The second bifurcations are to enhance the statistics. In the beginning of the kaon-branch and at the bottom of the pion-entering branch, it is easy to find out that (PBNRS $*$ B4DEDX) has a lower rejection compared to the 97b results. Further, combined with the double beam normalization analysis (Fig. 20), we will see that the problem is only due to PBNRS. 5.06 events ($N_K + N_\pi = 3.77 + 1.29$) are expected in the normalization branch. Therefore, the single beam background for 1/3 98 data is $5.06/(2237-1) = 2.26 \times 10^{-3}$ events.

7.1.3 Double Beam Background

Double beam events are the same as single beam events, except that an earlier kaon exists so that the DELC is fooled. These events are suppressed by looking for coincident activity in the beam-line detectors and RS.

For the double beam normalization branch, in order to obtain more statistics in the bottom line we made a minor modification based on the previous procedures- move the TGPV from the setup to TG $*$ TGkin.

Figs. 19 and 20 summarize the estimation of double beam background level. Both rejection and normalization branches are classified as $K-K$ events, where the second particle at track time is a kaon decay-in-flight, and $K-\pi$ events, where the second particle is a pion. The rejection of BWTRS $*$ CKTRS $*$ CKTAIL for $K-K$ events is estimated to be 176, and that of BWTRS $*$ CPITRS $*$ CPITAIL for $K-\pi$ events is 1290.4. Predictions of the $K-K$ and $K-\pi$ normalizations are given in the bottom line of Fig. 20: $N_{K-K} = 0.057$, $N_{K-\pi} = 0.016$. The double beam backgrounds for 1/3 98 data are estimated to be $0.057/(176.0-1) + 0.016/(1290.4-1) = 3.36 \times 10^{-4}$.

Therefore, the beam background for the 1/3 98 data is: $(2.60 \pm 0.98) \times 10^{-3}$. Like the previous analysis, the beam related backgrounds in this analysis are also dominated by single beam events.

7.1.4 Acceptance

$K_{\mu 2}$ monitor data are used to measure the acceptance of the all beam background cuts except those involving track energy in the target; $K_{\pi 2}$ monitor data are used to measure the acceptance of the beam background cuts which involve track energy in the target. The structure and results of the $K_{\mu 2}$- and $K_{\pi 2}$-based acceptance studies are shown in Tables 9 and 10. The 1998 result, $\mathrm{A}_{K_{\mu 2}} = 0.5590 \pm 0.0015$, is $\sim 0.3\%$ lower than 1997b result, and $\mathrm{A}_{K_{\pi 2}} = 0.8329 \pm 0.0177$, is almost at the same level as 1996.

7.1.5 CEX Background Measurement using 97 Beamfile

Version 6.0 UMC was used to generate CEX Monte Carlo events. The following modifications are made based on private Version 5.0 source codes.

- B4 information and kaon fiber timing information are read from the beam file and passed to UMC generated data.

To process the UMC data, PASS2 codes were also correspondingly changed.

- Energy smearing and energy-related time smearing are applied.

The 98 CEX beam file is currently not available, instead we use an old beam file, which was produced with 1997 real K^0_S CEX data. Two decay modes are simulated: $K^0_L \rightarrow \pi^+ e^- \bar{\nu}_e$, $\pi^+ \mu^- \bar{\nu}_\mu$. The equivalent $\mathrm{K_{Blive}}$ is

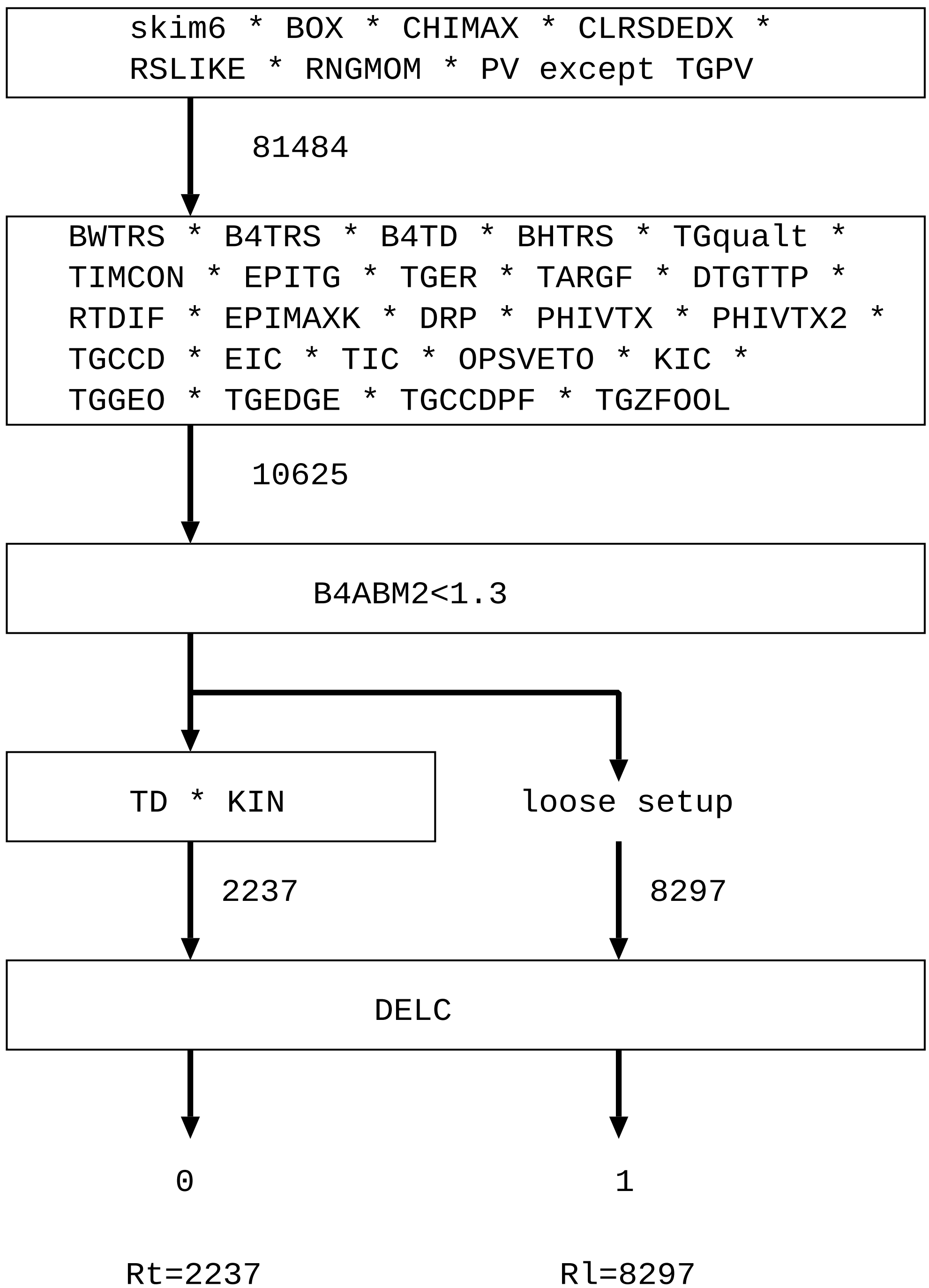

Figure 17: Single beam rejection branch.

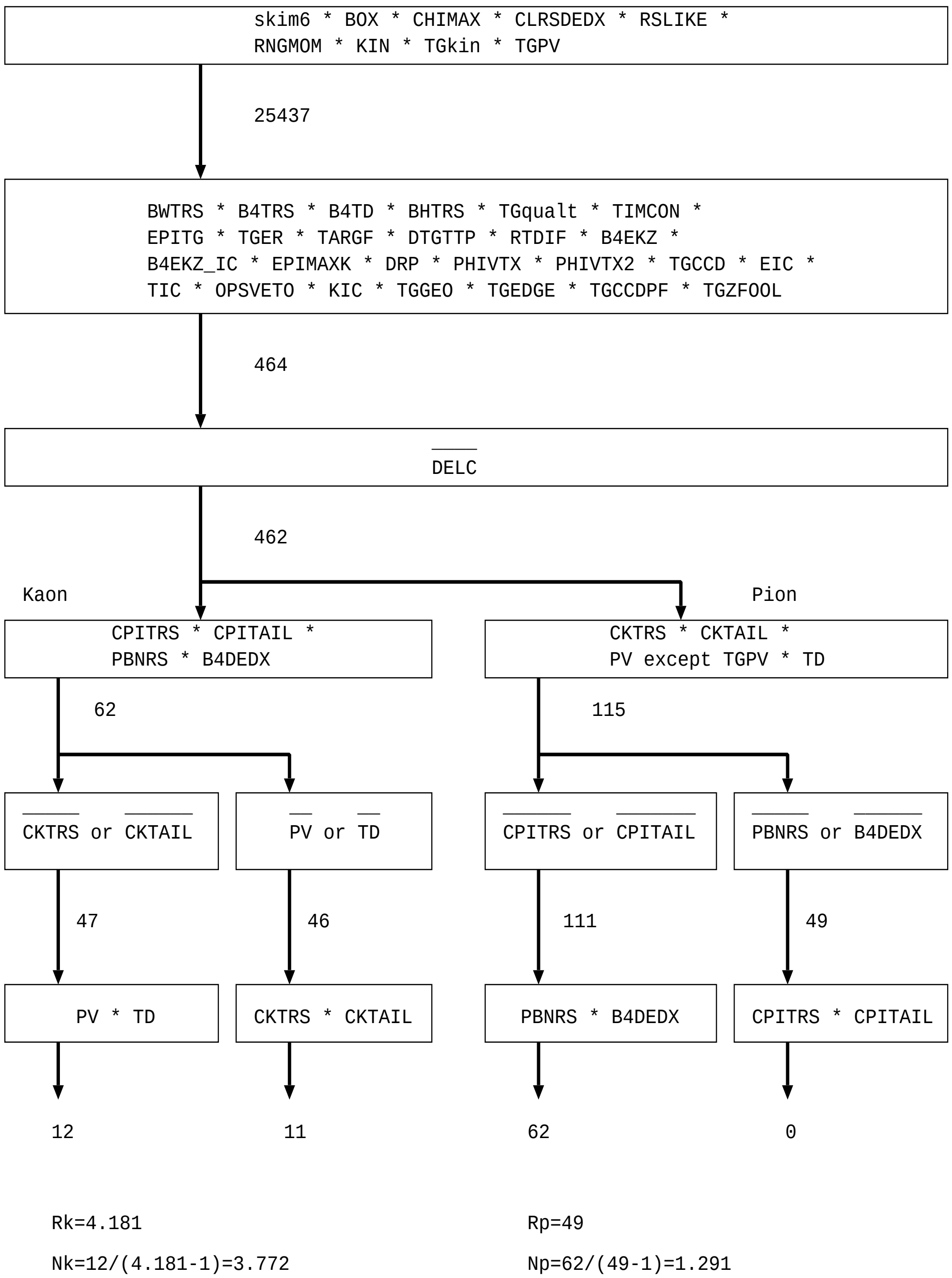

Figure 18: Single beam normalization branch. The left branch after $\overline{DELC}$ tag shows the estimation for kaon decay-in-flight events. The right branch shows the one for pion-entering events. TGkin in the setup includes TGDEDX, PIGAP, TGLIKE and TGB4 cuts

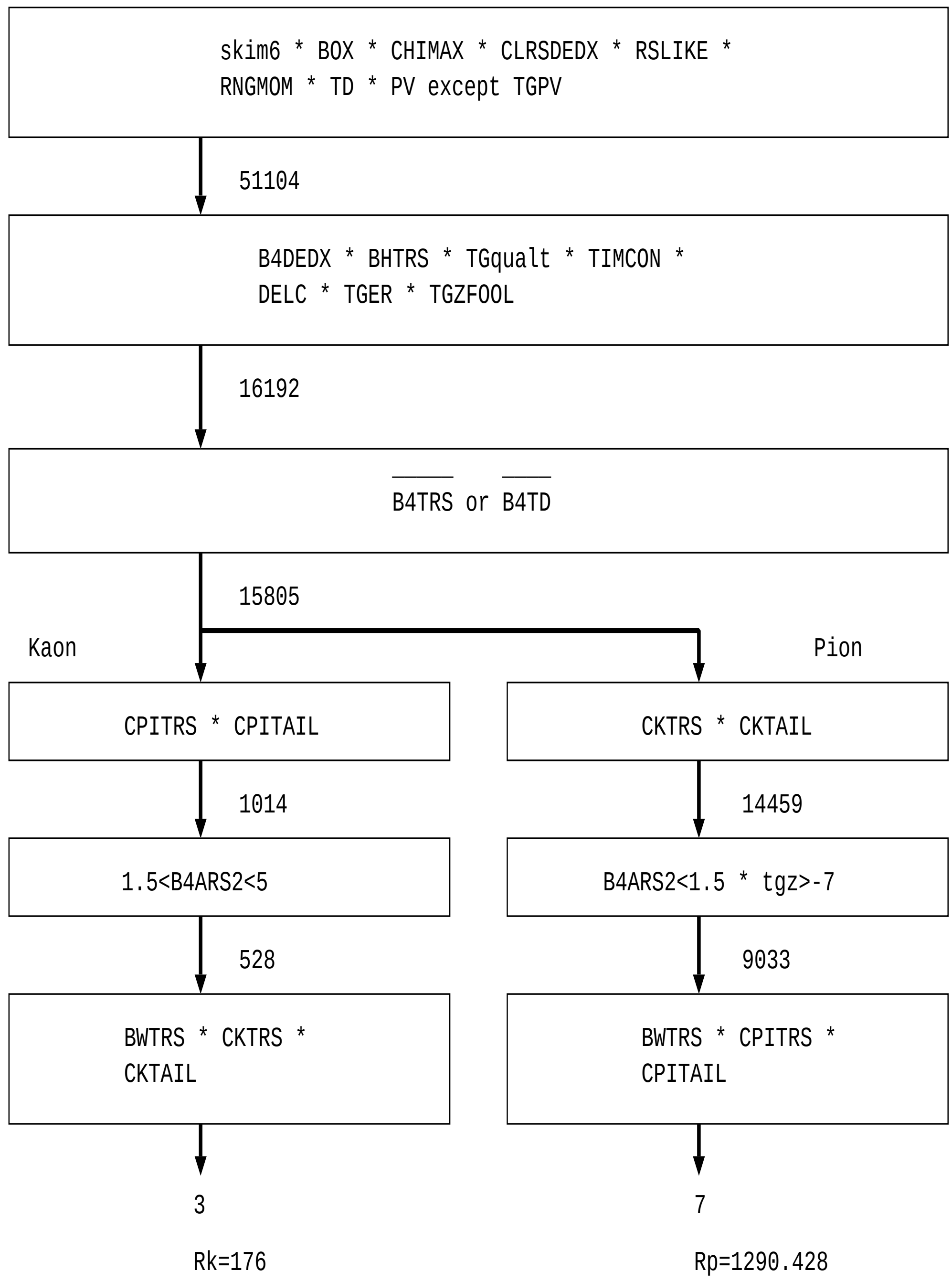

Figure 19: Double beam rejection branch. The left branch after B4 2-beam tag shows the estimation for $K-K$ events, where the second particle at track time is a a kaon decay-in-flight. The right branch shows $K-\pi$ events, where the second particle is a pion.

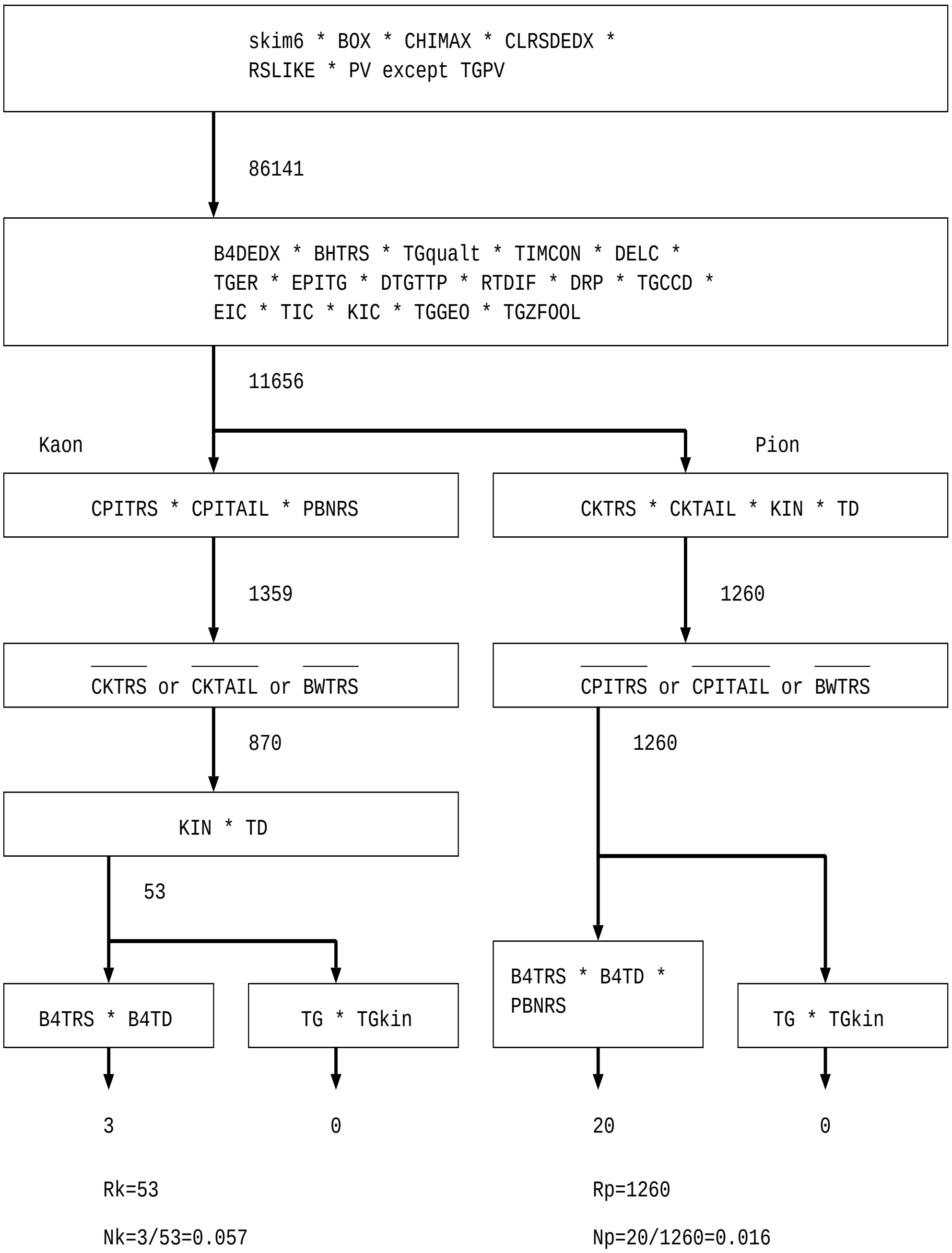

Figure 20: Double beam normalization branch. The left branch after the setup cuts shows the estimation for $K-K$ events. The right branch shows $K-\pi$ events. TG and TGkin cuts include TARGF, B4EKZ, B4EKZ_IC, EPIMAXK, PHIVTX, PHIVTX2, OPSVETO, TGEDGE, TGCCDPF, TGDEDX, PIGAP, TGLIKE, TGB4 and TGPV.

7.2 Beam Background Estimation based on 98 2/3 Data Set

The same procedures were used to predict the beam backgrounds for 1/3 and 2/3 date samples. In the previous section we have already described the bifurcation technique. Here we just briefly summarize the beam background result from the 2/3 data set.

7.2.1 Single Beam Background

Figs. 22 and 23 summarize the estimation of single beam background level. The DELC rejection is estimated to be more than 4769. A loose setup (without TD and KIN cuts) gives us a higher rejection (16412). Conservatively, we take a rejection of 4349 in the background estimation.

The scheme of the normalization branch is shown in Fig. 23. 7.29 events ($N_K + N_\pi =$ 5.67+1.62) are expected in the normalization branch. Therefore, the single beam background for 2/3 98 data is $7.29/(4349 - 1) = 1.67 \times 10^{-3}$ events.

7.2.2 Double Beam Background

Figs. 24 and 25 summarize the estimation of double beam background level. The rejection of BWTRS $*$ CKTRS $*$ CKTAIL for $K - K$ events is estimated to be 553.5, and that of BWTRS $*$ CPITRS $*$ CPITAIL for $K-\pi$ events is 4444.8. Predictions of the $K-K$ and $K-\pi$ normalizations are given in the bottom line of Fig. 20: $N_{K-K} = 0.0175$, $N_{K-\pi} = 0.0087$. The double beam backgrounds for 2/3 98 data are estimated to be $0.0175/(553.5 - 1) + 0.0087/(4444.8 - 1) = 3.4 \times 10^{-5}$.

Therefore, based on the 2/3 data sample, the beam background for the 2/3 98 data is: $(1.70 \pm 0.70) \times 10^{-3}$.

The background level obtained here is quite small in comparison with that measured from the 1/3 data analysis. The main reason for that is, in the case of the 2/3 data sample, the statistics is higher, and then, as a result, rejections for some cuts become 'higher'– for instance, rejection for DELC cut (single beam rejection branch) changes from 2237 to 4349; rejection for BWTRS $*$ CKTRS $*$ CKTAIL (double beam rejection K-entering branch) changes from 176 to 553.5; BWTRS $*$ CPITRS $*$ CPITAIL (double beam rejection π-entering branch) from 1290.4 to 4444.8.

In a compromising way, by simply summing up the 1/3 and 2/3 predicted backgrounds we get the beam background for whole 98 data set: $(4.30 \pm 1.20) \times 10^{-3}$.

7.2.3 Outside-the-Box Study

Two beam functions have been prepared; one for single beam and one for double beam. The single beam function is based on loosening DELC cut only and the double beam function based on loosening BWTRS $*$ B4TRS only.

For single-beam "outside-the-box" study, background is predicted as we did in the previous section, but the DELC cut is loosened in the rejection branch while the normalization branch is not changed in order to keep a sufficient statistics for the second bifurcation (see Figs. 17 and 18). Meanwhile, we loosen up the DELC cut for CEX background. In double-beam "outside-the-box" study, BWTRS is loosened in the rejection branch and B4TRS loosened in the normalization branch to get a background prediction (see Figs. 19 and 20).

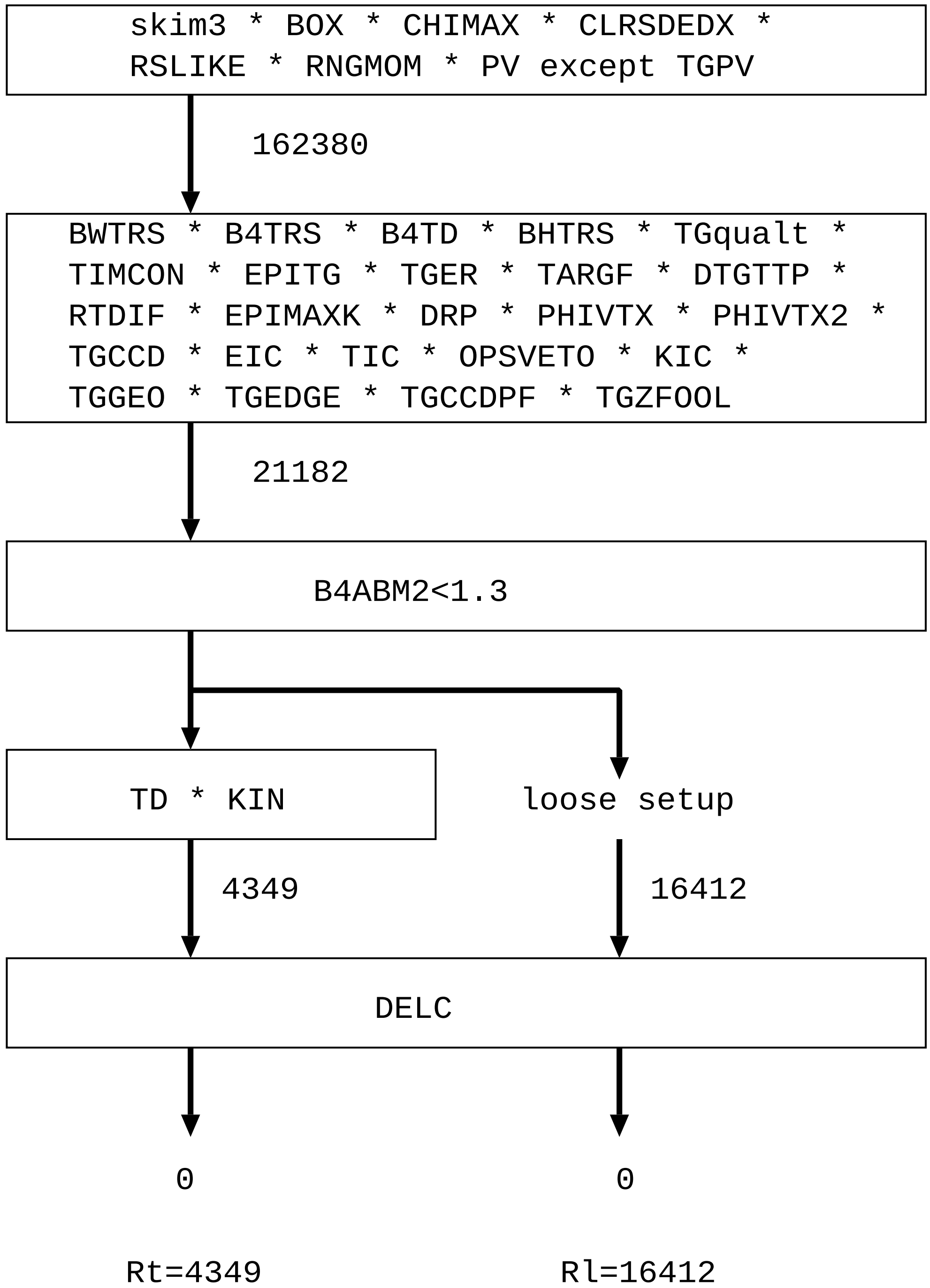

Figure 22: Single beam rejection branch.

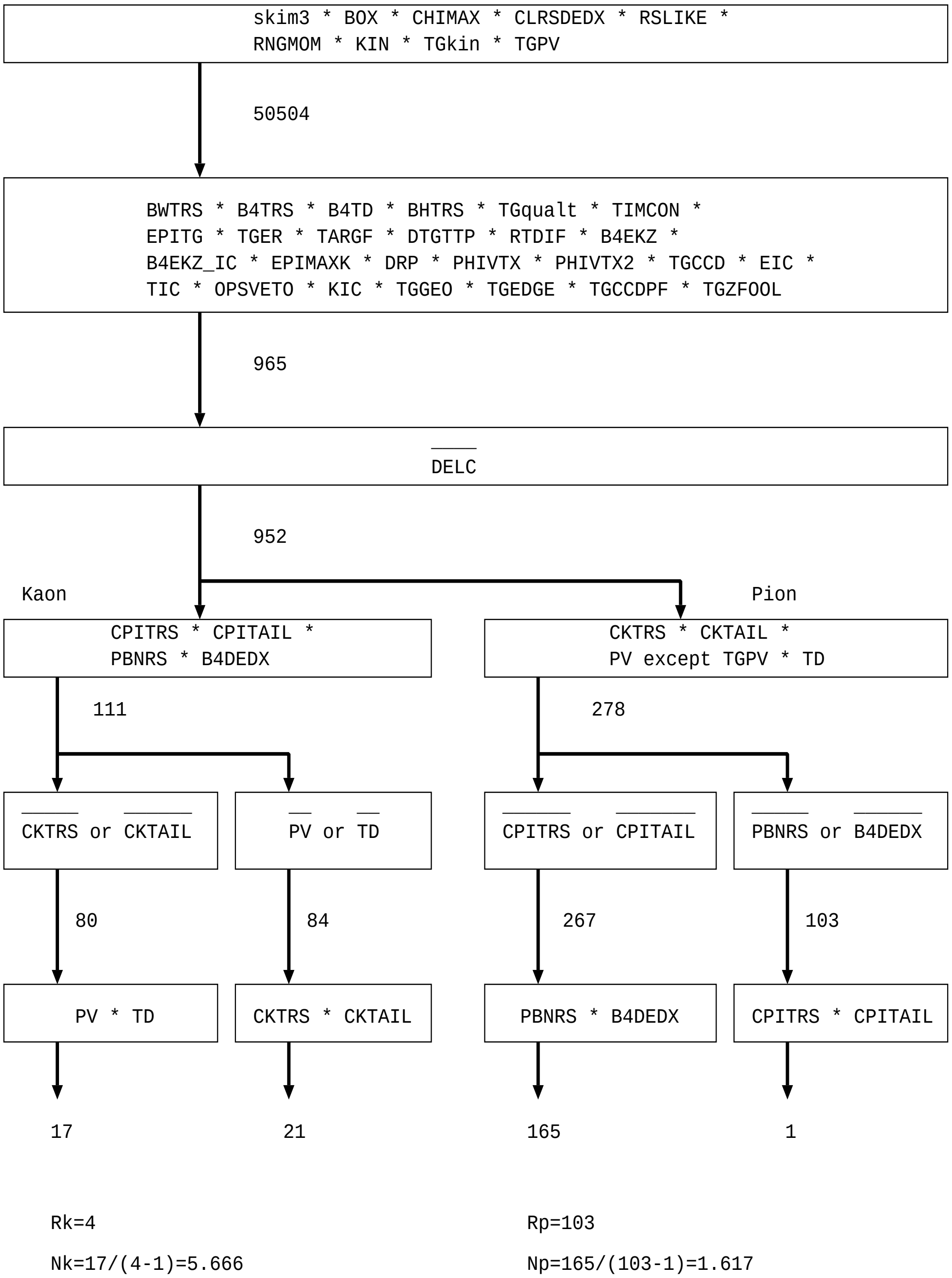

Figure 23: Single beam normalization branch. TGkin in the setup includes TGDEDX, PIGAP, TGLIKE and TGB4 cuts

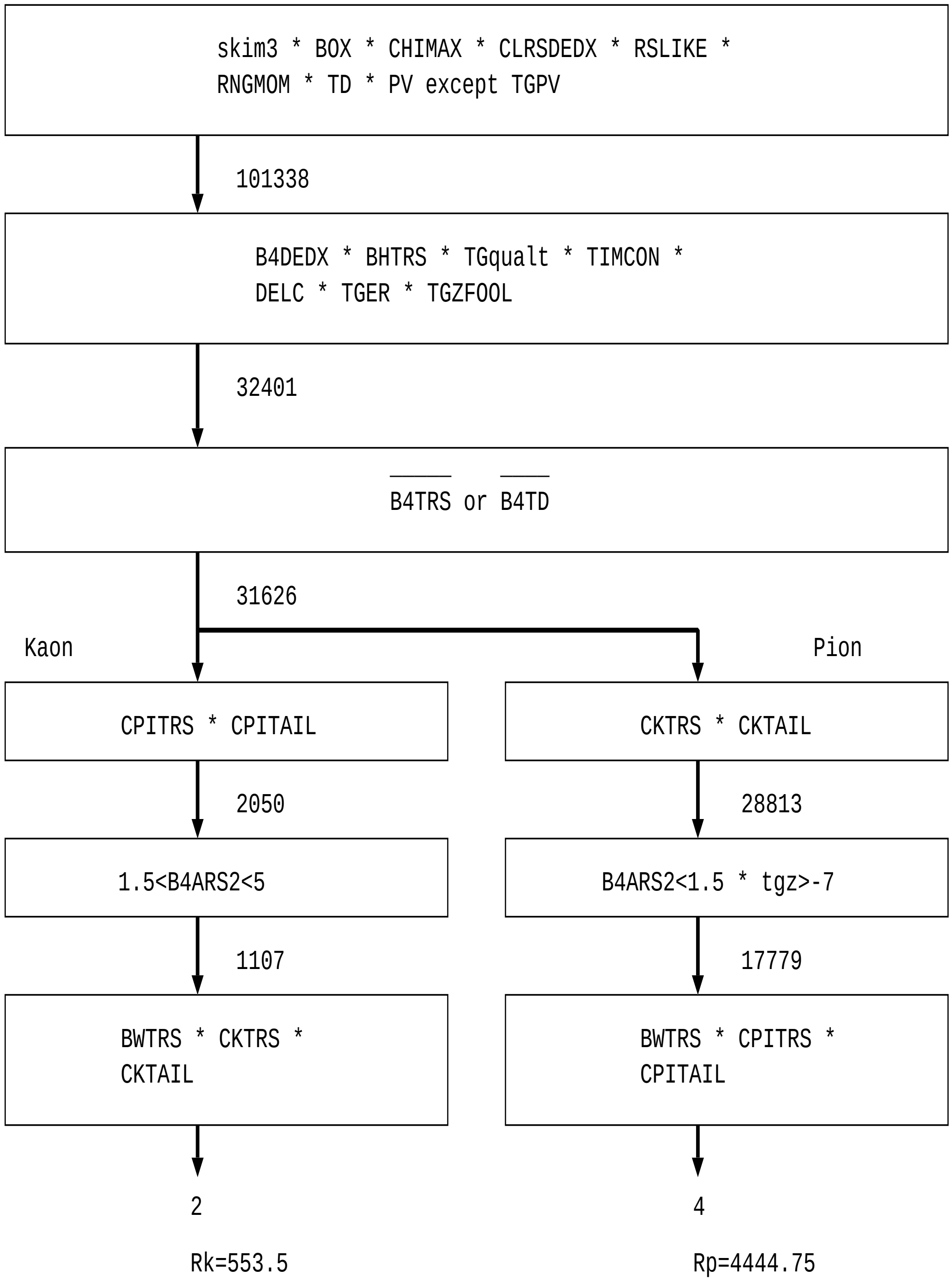

Figure 24: Double beam rejection branch.

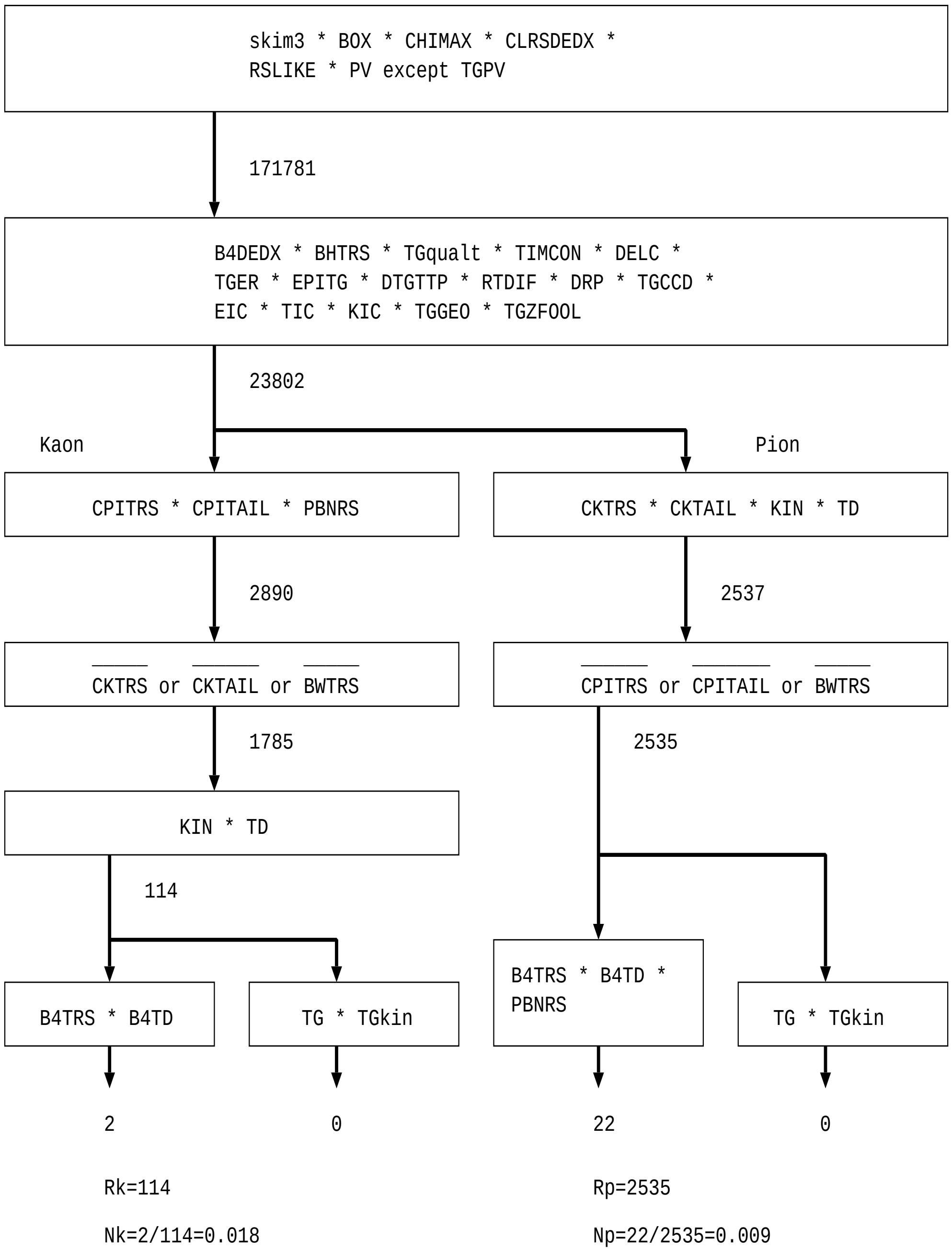

Figure 25: Double beam normalization branch. TG and TGkin cuts include TARGF, B4EKZ, B4EKZ_IC, EPIMAXK, PHIVTX, PHIVTX2, OPSVETO, TGEDGE, TGCCDPF, TGDEDX, PIGAP, TGLIKE, TGB4 and TGPV.