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SOLENOIDAL DETECTOR NOTES

SLC LEPTON IDENTIFICATION SOFTWARE

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MARK II/SLC NOTE #249 AND T/G NOTE #401

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TITLE: **SLC Lepton Identification Software**

This note describes the software used to identify leptons at the SLC. Isolated charged tracks identified as electrons or muons are used for the measurement of the Z-boson branching fraction into hadrons containing bottom quarks [Kral 90a, Kral 90c].

The identification methods are adapted from the procedures developed for electron identification with the LA calorimeter at PEP [Nelson 83a, Nelson 83b] and muon identification with the muon system at PEP [Nelson 83b, Ong 88]. An excellent note by Pat Burchat and Mark Nelson, Mark II/SLC Note #114 [Burchat 85] summarizes these PEP lepton-identification algorithms and suggests modifications for the SLC. Andrew Weir [Weir 88] and Dolly Wu [Wu 90] respectively changed the muon and the electron identification software in anticipation for SLC running.

This note is a guide to the changes in the software for the SLC, as embodied in my two subroutines `[ECPUB 192] SLCELEC FORTRAN` and `[ECPUB 192] SLCMUON FORTRAN`, where `[ECPUB 192]` is the Mark II `G` disk on SLACVM.

The next note, Mark II/SLC Note #250, *Inclusive Lepton Analysis at the Z* [Kral 90d], details how to efficiently identify isolated electrons and muons in hadronic events while rejecting hadrons by using the software describe here. Note that this software is not intended for identifying leptons in lepton-pair events [Abrams 89].

Together, these two notes (#249 and #250) supercede but do not entirely replace the unofficial memos, *Muon Identification Using the Muon System at the SLC* [Kral 89f] and *Electron Identification Using the LA Calorimeter at the SLC* [Kral 89g], circulated during October 1989.

This note contains the following sections and appendices,

1. Changes for the SLC
2. How to use `SLCELEC` and `SLCMUON`
3. Details about Electron Identification
4. Details about Muon Identification
5. Suggested Improvements
6. Acknowledgements

A. Mark II Software
B. Sample Software
C. Sample Analysis.

I recommend looking at Section 2 to quickly take advantage of the new SLC software and Section 5 to get ideas for further improvements.

1. Changes for the SLC

In this section I outline conditions at the SLC which are different from PEP and changes in the lepton-identification software which are designed to address these differences. The analysis used to calibrate the SLC lepton-identification code is described in detail in the next note [Kral 90d]. For ideas about how to further improve lepton identification at the SLC, please refer to Section 5 of this note.

1.1 Conditions at the SLC

The main differences in the physics at the SLC compared to at PEP are that momenta of particles are about three times larger and that angular separations of particles in jets are smaller. Differences in the detector include the higher resolution of the SLC main drift chamber (DC) compared to the one at PEP and a thicker coil inside the liquid argon barrel calorimeter (LA) at SLC. In addition, the SLC itself gives rise to more severe backgrounds than did PEP, especially in the outer layers of the muon chambers. In summary, the differences in the conditions at the SLC, compared to those at PEP, include

- increased particle momenta and more track-overlap in jets,
- upgraded detector components, and
- more severe machine backgrounds.

The changes in the lepton-identification algorithms resulting from these new conditions are described below.

1.2 Changes in the Software

To address the different conditions at the SLC, we have changed the software in these three areas: the inclusive lepton analysis method, the calibration of the lepton-identification algorithms and the Monte Carlo simulation (MC).

Analysis Method

The analysis method for using leptons to measure the Z-boson branching fraction to hadrons containing bottom quarks is covered in the following note (# 250) [Kral 90d]. Appendix C of this note translates my analysis procedure into Mark II software variables [Kral 89e] and Appendix B contains a list of my $Z \rightarrow b\bar{b}$ analysis software [Kral 89j].

One of the changes from PEP, motivated by the larger momenta at the SLC, is the use of p_t defined with respect to the nearest hadronic jet instead of with respect to the thrust axis. The subroutine in `[KRAL 192] RHOISO FORTRAN` is an example of how to find $p_t =$ `PTJET`. To reduce effects from the increased track-overlap in the $Z \rightarrow b\bar{b}$ analysis, I use events containing leptons which are *isolated* from the nearest jet, leptons with $p_t > 1.25$ GeV/c [Kral 90d].

Algorithm Calibration

The electron and the muon algorithms have been updated from PEP to the SLC. To reduce electron misidentification from overlap in the denser jets at the SLC, we have narrowed by a factor 0.6 the LA road widths used to form the ratios E_{LA}/p_{DC} [Wu 90]. To reduce muon misidentification from noise hits in the outer layers of the muon system, we demand that the three outer hits be correlated (`MUCORR`) [Weir 88]. These changes are incorporated in my new subroutines `SLCELEC` and `SLCMUON FORTRAN G`. Sections 2–4 of this note describe this new software and Appendix A contains a list of the code I recently installed on the `G` disk [Kral 90b].

The calibration of the electron-identification algorithm was done with known electrons from radiative and non-radiative Bhabha scattering events recorded at PEP with the upgraded Mark II detector. This recalibration leads to more efficient electron identification, since the old algorithm was calibrated on low-momentum electrons from SPEAR. Furthermore, the recalibration uses data from the upgraded detector.

The calibration of the muon-identification algorithm was done with known muons from cosmic-ray events recorded at the SLC. To incorporate the improved muon identification resulting from the improved resolution of the DC at the SLC over the one at PEP, I used cosmics to find new DC track-extrapolation-error constants (`COMMON/MUMODE/USLRES`).

Refer to the next note (#250) for details about the lepton-identification algorithms [Kral 90d, Kral 90c].

Monte Carlo Simulation

There are numerous improvements in the Monte Carlo simulation addressing the different physics, upgraded detector and increased machine noise at the SLC.

To generate hadronic Z events, we use the successful parton-shower models BIGWIG 4.1 with Webber cluster fragmentation, `[PUBEE 194] WEBB41Z5 HOWLCARD F`, and JETSET 6.3 shower with Lund string fragmentation, `[PUBEE 194] LU61SHZ5 HOWLCARD F`. I fragment heavy quarks in the Lund model with the Peterson function tuned to PEP and PETRA data [Kral 89a, Kral 90c].

The materials in the simulation of the upgraded detector are ordered correctly, making electron analysis, multiplicity measurement and vertex studies possible [Kral 89c]. The DC simulation has been greatly improved to give realistic tracking efficiencies for the direction-sensitive lepton-identification measurements [Weinstein 89, Dauncey 89]. The simulation of the LA calorimeter response is done with EGS4 [Nelson 85] and HINT2 [Gan 87], as described in my thesis [Kral 90c]. The muon misidentification probabilities were checked against a study using FLUKA87 [Weir 87].

To mimic the effect of beam-induced backgrounds in the DC, LA and muon systems, we mix the signals from each MC event with the signals from one of many background events recorded at random beam crossings during the same time period as Z candidates [Wicklund 89, Kral 89d].

The Monte Carlo tapes used for my $Z \rightarrow b\bar{b}$ analysis are

```
MIXed  Nevt B  Model      Vr Pa T MMDDYY Userid      Comments
=============================================================
RU0170 3000 3  Lun Shower 63 Pe K 111489 HEARTY/KRAL
RU0171 3000 4  Lun Shower 63 Pe K 111489 HEARTY/KRAL
RU0140 2954 6  Lun Shower 63 Pe K 111489 HEARTY/KRAL Copy problem
RU0173 1929 7  Lun Shower 63 Pe K 111489 HEARTY/KRAL
RU0174 3000 3  Lun Shower 63 Pe K 111489 HEARTY/KRAL
RU0175 3000 4  Lun Shower 63 Pe K 111489 HEARTY/KRAL
RU0380 2916 6  Lun Shower 63 Pe K 111489 HEARTY/KRAL Copy problem
RU0177 1928 7  Lun Shower 63 Pe K 111489 HEARTY/KRAL
RU0230 3000 3  Webber     41 -  K 111489 HEARTY/KRAL
RU0231 3000 4  Webber     41 -  K 111489 HEARTY/KRAL
RU0232 3000 6  Webber     41 -  K 111489 HEARTY/KRAL
RU0233 1929 7  Webber     41 -  K 111489 HEARTY/KRAL
RU0234 3000 3  Webber     41 -  K 111489 HEARTY/KRAL
RU0235 2650 4  Webber     41 -  K 111489 HEARTY/KRAL Pass1 crash
RU0236 3000 6  Webber     41 -  K 111489 HEARTY/KRAL
RU0237 1929 7  Webber     41 -  K 111489 HEARTY/KRAL
```

and they are documented, together with many more tapes, in `MKMIX LOG G` [Kral 89b].

More information about the MC simulation can be found in Chapter 3 of my thesis [Kral 90c].

2. How to use SLCELEC and SLCMUON

This section shows simple ways to identify electrons and muons. Software details are described in the following sections.

For electrons, I require each value $r_i = E_i/p$, where E_i is the energy deposit in a particular strip orientation of the front half of the LA calorimeter and $i = 1$–3, to be at least 55% of the median value for Mark II upgrade Bhabha electrons and $\sum r_i$ to be at least 65% of the median value for the sum. The code needed to identify electrons is,

```
...
Call Slcelec(itrack, R4dumA, I4dumA, L4dumA, R4dumB, Eoplofr)
If (Eoplofr .gt. 0.55) then              ! Identified Electron
...
```

which selects electron-like tracks which are either inside or clip the edges of the LA calorimeter. To remove the tracks which clip the edges, add a common block and make an additional cut,

```
...
Common/Elssle/R4dumC, Iclass, R4dumD(5)
...
If (Iclass .eq. 0) then                    ! Inside LA
...
```

thus ensuring that tracks be within 1.5 units of strip width from the edges of the front layers of the LA.

For muons, I require hits to be found in all four layers of the muon system within 3σ of the extrapolated DC track and the associated hit in the fourth layer to be within a 3-standard-deviation width of the path defined by the associated hits in the second and third layers. The code needed to identify muons is,

```
...
Call Slcmuon(itrack, 3.0, Mustat3, Mucorr3, R4dumE, R4dumF)
If (Mustat3 .eq. 15 .and. Mucorr3) then  ! Identified Muon
...
```

which selects muon-like tracks which are no more than 3σ outside the muon system fiducial region. To remove tracks which are outside the muon fiducial region, add a common block and make an additional cut,

```
...
=MULST
...
If (Muleve .eq. 4) then                    ! Inside muon system
...
```

thus ensuring that tracks be contained within the edges of the fourth layer and that the track momentum be sufficient to penetrate to the fourth layer.

3. Details about Electron Identification

This section describes the variables returned by the main electron-identification subroutine SLCELEC, and lists the routines called by SLCELEC. This section and the following section about muon identification contain little that is not documented in the software itself.

I designed SLCELEC and SLCMUON to have the same structure. Both routines return logical variables encoding the pattern of layers passing a given cut as well as continuous variables with the value of the layer that has the least lepton-like signature.

The routine SLCELEC contains the following variables

```
Subroutine Slcelec(Itrack, Eopcut, Elstat, Elecfr, Eoplo, Eoplofr)
```

```
Integer*4  Itrack                    ! Input track number
Real*4     Eopcut                    ! Input E/p cut
Integer*4  Elstat                    ! Output Elstat for Eopcut
Logical*4  Elecfr                    ! Output Elecfr for Eopcut
Real*4     Eoplo                     ! Output lowest E/p (F, T, U)
Real*4     Eoplofr                   ! Output Eoplo with Front: Test1
Common/Elssle/Eopfr, Iclass, Eops
Real*4     Eopfr                     ! Front E/p normalized to median
Integer*4  Iclass                    ! LA fiducial region
Real*4     Eops(5)                   ! E/p (F, T, U, Front, Scaled)
```

the most important of which are EOPLOFR and ICLASS, as described in the previous section (2). A track which passes a cut (e.g. EOPCUT = 0.55) in all three layers (EOPLO > 0.55) and passes the scaled cut for the sum of the three front layers (EOPFR > 0.65), i.e. has EOPLOFR > EOPCUT, gets the bit code ELSTAT = 15. Tracks in the LA fiducial region have ICLASS = 0, tracks which clip the edges have ICLASS = 1, tracks which miss the LA have ICLASS = 2, and tracks satisfying $p < 1$ GeV/c have ICLASS = 3.

The routine SLCELEC uses the following software

```
SLCELEC                              ! Electron id driver
  PTOTGET                            ! Momentum magnitude
  LAELECS                            ! E/p ratios
    ELECLAS                          ! LA associated energies
      FDSLCT
      UNPACK
      LAECH
      LAECOR
      LALAZM
      ENRMFD
      CHNNL
```

where I recommend using PTOTGET modified according to the prescription in Appendix C (in brief, I always use momentum measurements from the fit without vertex constraint, SUBTYP 2, except for $|p|$ from tracks with $p > 10$ GeV/c, for which I use the vertex constrained value, SUBTYP 6).

4. Details about Muon Identification

This section describes the variables returned by the main muon-identification subroutine SLCMUON, and lists the routines called by SLCMUON. This section contains little that is not documented in the software itself.

I designed SLCMUON and SLCELEC to have the same structure. Both routines return logical variables encoding the pattern of layers passing a given cut as well as continuous variables with the value of the layer that has the least lepton-like signature.

The routine SLCMUON contains the following variables

```
Subroutine Slcmuon(Itrack, Delcut, Nustat, Mucorr, Delhi, Delhicr)

Integer*4  Itrack                  ! Input track number
Real*4     Delcut                  ! Input number of sigma cut
Integer*4  Nustat                  ! Output Mustat for Delcut
Logical*4  Mucorr                  ! Output Mucorr for Delcut
Real*4     Delhi                   ! Output highest Delta 4 layers
Real*4     Delhicr                 ! Output highest Delhi or Delt4

Common/Mussle/Delt4, Nustat5
Real*4     Delt4                   ! # sigma correlated in layer 4
Integer*4  Nustat5                 ! Five-sigma Nustat
```

the most important of which are MUSTAT, MUCORR, and MULEVE, as described in Section 2. A track which passes a cut (e.g. DELCUT = 3.0) in all four layers (ABS(DELHI) < 3.0) gets the bit code NUSTAT = 15. If a track passes the correlation cut between the middle layers and the fourth layer (ABS(DELT4) < 3.0) then the logical variable MUCORR = .TRUE. A track satisfying both of these requirements, i.e. having ABS(DELHICR) < DELCUT, gets the bit code MUSTATCR = 15. The variable MUSTATCR is used in my thesis [Kral 90c] but is not defined in my software. The common block MULST COMMON G contains additional muon-system information for the selected track; for example, /MULST/MULEVE = 4 indicates that a track satisfies the muon system fiducial criteria.

The routine SLCMUON uses the following software

```
SLCMUON                            ! Muon id driver
  UNPACK(8)                        ! Unpack raw muon data
  MUNCHS                           ! Muons tracked with SLC DC
  LMULST                           ! Decode /TRKLST/ SUBTYP 5
```

and is thus indirectly responsible for first refilling /TRKLST/ with muon data using the SLC-tracking constants (through MUNCHS) and then unpacking this muon data into /MULST/ (through LMULST). Notice that when DELCUT = 3.0, NUSTAT = /MULST/MUSTAT.

5. Suggested Improvements

In this section, I point out possible improvements to my analysis. Needless to say, having four times as much data (2000 events) would greatly strengthen the inclusive lepton analysis by significantly reducing the statistical and systematic errors (e.g. from using data instead

of MC to find misidentification probabilities). Also, tuning our hadronic MC with LEP data may help reducing systematic errors.

As mentioned in Section 1, the differences in the conditions at the SLC, compared to those at PEP, include

- increased particle momenta,
- more track-overlap in jets, and
- upgraded detector components.

Improvements addressing the different conditions at the SLC are possible in the areas of the inclusive lepton analysis method (to be incorporated in future lepton-identification algorithms) and the Monte Carlo simulation for both electron and muon identification.

5.1 Electrons

The suggested improvements for electron identification are listed here and those for muon identification are listed in the following subsection.

Increased Momenta

The increased momenta at the SLC suggest that it may be advantageous to use information from the back of the calorimeter. Studies so far indicate that it is not terribly important to do so, probably because the shower maximum is only $\ln 3 = 1.1$ times deeper into the calorimeter at the SLC than at PEP. I believe that the LA electron-identification algorithm is pretty good as is, except perhaps for the possibility of making tighter cuts in the u layers.

The MC simulation for LA electrons (EGS4) is good. The library of LA pions (HINT2) lacks statistics and could be replaced by the Geisha hadron simulation, though it would take quite a bit of tuning [Porter 89].

Track Overlap

Track overlap at the SLC is a severe problem for the strip geometry of the LA calorimeter. To identify electrons in the core of jets, i.e. by using tracks with $p_t < 1.25$ GeV/c, it would be helpful to use the central drift chamber dE/dx system (FDC) signals. The routine in [KRAL 192] SLCDXEL FORTRAN (old name DXELEC) shows how to get started (e.g. for tracks with $p < 8$ GeV/c, relax LA cuts and use a cut of DXEL > -2.0 sigma together with fiducial criteria that are well-simulated in the MC). Before further work on dE/dx, it is advisable to determine if the physics analysis benefits from adding dE/dx, as I found was not the case for $Z \to b\bar{b}$ with 400 hadronic Z decays [Kral 89h]. One simple improvement for the dE/dx analysis would be to toss out shared hits, since they are difficult to simulate correctly.

The MC simulation for dE/dx was not adequate during the early fall of 1989 (see [KRAL 192] ELIDDXE- TOPDRAW to find out how bad it was), principally because the separation

between the few electrons and the many pions is small and because it is difficult to simulate the crowded environment in the DC. Since then, improvements have been made in the simulations of the DC [Weinstein 89, Dauncey 89] and of the dE/dx (see the 11/22/89 entry in `MKMIX LOG G` for tapes with FDC changes).

Upgraded Detector

The upgraded DC could be efficiently used to identify photons which convert into electron–positron pairs in the material preceding it. Mark Nelson's routine written for this purpose `PRFIND` has been extensively documented [Burchat 87]. I suggest looking at my routine in `[KRAL 192] PAIRFD FORTRAN` to get started on pair finding.

The simulation of closely spaced tracks in the DC was not good enough for me to make use of the pair finder. Since the early fall of 1989, the DC simulation has been improved [Weinstein 89, Dauncey 89].

The upgraded endcap calorimeters (EC) could be used to increase the fiducial volume solid angle by about 10%. The routine in `[KRAL 192] SLCECEL FORTRAN` indicates how to do so, although my version of `ECELEC`, `ECELECS` was accidentally erased in December, 1989.

The simulation of EC electrons leaves a lot to be desired. I decided not to use the EC in my analysis after many questions remained unanswered [Hearty 89]. One serious problem with the EC simulation is that the geometrical translation of pions from the test-beam data into hadrons in MC jets is not precise enough for the electron-identification algorithm.

The dE/dx measurements of the upgraded detector are potentially useful. See above (Track Overlap) for improvements with DC dE/dx measurements using the FDC system. Inclusion of the drift chamber vertex detector (DCVD) dE/dx measurements is probably not worth the trouble. I find the DCVD dE/dx resolution to be inferior to that of the DC; the dE/dx resolution in the DC obtained from using a truncated mean of 75% of, at most, 72 charge measurements is better than 7.2% (perhaps as low as 6.5%), while the dE/dx resolution for the DCVD is about 9% when using truncated means of more than half of, at most, 38 charge measurements per track in the DCVD.

5.2 Muons

The suggested improvements for muon identification are listed here.

Track Overlap

Track overlap is not a big problem for muon identification. I believe that the muon-identification algorithm is pretty good as is, except perhaps for the possibility of making additional cuts rejecting multiple secondaries in the absorber.

The MC simulation of hadrons in the muon system is no good. For my low-statistics study, I found ways around this weakness for isolated tracks. The agreement between the MC and the data for tracks inside jets is terrible, as can be seen in Figure 11 of the following

note (# 250) [Kral 90d]. The reason for the disagreement is most likely that the simulation does not produce multiple secondaries which set `MUCORR = .FALSE.` There exists an improved version of this simulation [Snyder 90]. The best way of simulating hadrons would be to install a library of hadrons generated by FLUKA87, but that may be a lot of work. In addition, and much easier to implement, the per-layer inefficiency for MC tracks at SLC has to be changed from 1% to 4% [Kral 90d].

Upgraded Detector

The upgraded DC could be used to identify muons from hadron decay in flight since decays produce kinks at the decay vertex.

The quality of the MC simulation of kinked tracks is unknown to me; a number of Mark II analyses use decays in the DC.

The upgraded muon system (MUP) could potentially be used. It is very sensitive to SLC backgrounds.

6. Acknowledgements

Thanks to all the Mark II physicists involved in lepton identification throughout the years. The algorithms designed by Alain Blondel and Mark Nelson have been extremely useful, as have been the modifications implemented by Dolly Wu and Andrew Weir. The whole Caltech group deserves thanks for making lepton identification with the LA and muon systems possible at the SLC. Finally, I thank Gerry Abrams, Gary Feldman, Gerson Goldhaber, Chris Hearty, René Ong, George Trilling and Rick Van Kooten for help and advice on my lepton identification work.

Appendix A

Mark II Software

This is a list of the Mark II lepton identification software used to identify isolated charged tracks as electrons or muons [Kral 90d, Kral 90c]. The software is installed on the Mark II G disk ([ECPUB 192]). This list is available on SLACVM [Kral 90b].

```
[KRAL 192] SLCLEPT NOTEBOOK                          8/19/90 - Lepton id code
                                                     8/30/90 - Code installed

        SLC LEPTON IDENTIFICATION ROUTINES
        - - - - - - - - - - - - - - - - - -

Effort to put the [KRAL 192] routines on G disk:

                                                                        Pub
                                                                        ---
SLCMUON FORTRAN                                                         add
  MUNCHS FORTRAN                                                        add
    MUMODE COMMON (from [KRAL 192] MUMODES COMMON)                      rep
      --> recompile BLKDAT FORTRAN                                      rec
      --> recompile MUNCH FORTRAN                                       rec
  LMULST FORTRAN                                                        add
    MULST COMMON                                                        add

SLCELEC FORTRAN                                                         add
  LAELECS FORTRAN                                                       add
  ELECLAS FORTRAN                                                       add
  PTOTGET FORTRAN G (already used for ECELEC --> ECDCDEL)
```

Appendix B

Sample Software

This is a partial list of the software I use to measure the Z-boson branching fraction into hadrons containing bottom quarks using isolated charged tracks identified as electrons or muons [Kral 90a, Kral 90c, Kral 90d]. This list is available on SLACVM [Kral 89j].

```
[KRAL 192] RBPRSOFT NOTEBOOK                                  11/24/89 created
                                                              10/04/90 updated

            SOFTWARE FOR THE B FRACTION MEASUREMENT
            - - - - - - - - - - - - - - - - - - - - -

PURPOSE:
To quickly make the new lepton analysis routines widely available.

WARNING:
UNLESS OTHERWISE NOTED, THE FILES ARE ON [KRAL 192].
MOST FILES REQUIRE EXTRA UTILITY ROUTINES WHICH ARE LISTED IN
THE FILE "TAGBBU FORTRAN".
THE ROUTINES IN "SLCLEPT NOTEBOOK" HAVE BEEN PUT ON G DISK
AND THE FOLLOWING SOFTWARE HAS NOT BEEN TESTED SINCE THEN.

DISCLAIMER:
This software is run with [KRAL 191] and [KRAL 192] linked and
otherwise uses standard G disk routines.  It may not work with
someone else's disks linked.  The only routine I know of that
is both in "TAGBBU FORTRAN" and on the G disk is "PTOTGET FORTRAN."


B fraction analysis software

Main driver routine:                                          TAGBB FORTRAN
Main lepton events analysis routine called from Tagbb:        TAGTK FORTRAN
Main inclusive lepton track analysis driver routine:          TAGEU FORTRAN
Fit program (use with [KRAL 191] RUN EXEC) for b fraction:    FITB  FORTRAN
Fit program (use with RUN EXEC) for b and c fractions:        FITBC FORTRAN
```

Useful routines:

```
HADRONK   FORTRAN -- Fills tracklist and does hadronic event selection.
HADRONH   FORTRAN -- New track selection for use with EC electrons.
RHOISO    FORTRAN -- Finds Pt for a track to the nearest cluster.
SLCMUON   FORTRAN -- Re-tracks muons and provides muon id variables.
SLCELEC   FORTRAN -- Finds LA E/P ratios within a narrow road.
SLCECEL   FORTRAN -- Endcap electron id (ECELECS lost).
SLCDXEL   FORTRAN -- Electron id with dE/dx.
```

Appendix C

Sample Analysis

This is a description of the procedure I use to measure the Z-boson branching fraction into hadrons containing bottom quarks using isolated charged tracks identified as electrons or muons [Kral 90a, Kral 90c, Kral 90d]. This description is available on SLACVM [Kral 89e].

```
DESCRIPTION OF B FRACTION ANALYSIS.
- - - - - - - - - - - - - - - - - - -

                                        J. F. KRAL 9/28/89
                                        corrected 10/30/89
                                        updated    6/15/90
                                        updated   10/04/90

     ANALYSIS FOR COUNTING THE NUMBER OF HADRONIC EVENTS AND
    THE NUMBER OF B-BAR B EVENTS TAGGED WITH ISOLATED LEPTONS

DOCUMENTATION:

  J. F. Kral, Mark II/SLC Note # 24x, "Muon Identification using the
Muon System at the SLC," October 24, 1989 (unofficial).
  J. F. Kral, Mark II/SLC Note # 24y, "Electron Identification using the
LA Calorimeter at the SLC," October 27, 1989 (unofficial).
  J. F. Kral, SLAC Memorandum, "First measurement of the b b-bar fraction
in hadronic Z^0 decays," October 27, 1989 (unofficial).
  J. F. Kral, "List of lepton candidate tracks used in b fraction
analysis," [KRAL 192] LEPTLIST NOTEBOOK, November 22, 1989 (on disk).
  J. F. Kral, "Software for the b fraction measurement,"
[KRAL 192] RBPRSOFT NOTEBOOK, November 24, 1989 (on disk).
  J. F. Kral et al., Phys. Rev. Lett. 64, 1211 (1990).
  J. F. Kral, "SLC Lepton Identification Routines,"
[KRAL 192] SLCLEPT NOTEBOOK, August 19, 1990 (on disk).
  J. F. Kral, "Measurement of the Z-Boson Branching Fraction into
Hadrons Containing Bottom Quarks", Ph.D. Thesis, LBL-29485,
September 5, 1990 (unpublished).
  J. F. Kral, Mark II/SLC Note # 249, "SLC Lepton Identification
Software," October 1990 (unpublished).
  J. F. Kral, Mark II/SLC Note # 250, "Inclusive Lepton Analysis at
the Z," October 1990 (unpublished).

These and more documents on all aspects of the analysis are available
through KRAL@SLACVM.BITNET and by looking on the SLACVM disk [KRAL 192].
```

I. HADRONIC EVENT SELECTION

This selection uses standard cuts developed for the event-shape paper, the lepton-pair paper and the particle-search paper.

A. TRIGGER required in data and simulated in Monte Carlo (MC). The trigger simulation used is CHGEMUL and SSTEMUL written by Chris Hearty and used for the mass/width paper. None of 16948 MC hadronic events which pass the below cuts fail the trigger simulation.

B. NCH >= 7 is the number of charged tracks required.

C. EVIS > 0.15*ECM is the visible energy, the sum of the energies of the selected charged and neutral particles for each event.

D. CHARGED TRACK SELECTION

1. RM <= 0.010 meters is radial d.c.a. to I.R.

2. ABS(ZM) <= 0.030 meters is the Z d.c.a. to I.R.

3. MOMENTUM and ENERGY calculation.
Subtype 2 momenta are used always, except that for certain tracks, the Subtype 6 (vertex constrained fit) momentum magnitude |P| = P6 is used instead of P2. For clarity, Subtype 2 is labelled with a "2" and Subtype 6 is labelled with a "6."

a. PXY2 >= 0.150 GeV/c is X-Y plane momentum.

b. ABS(PZ2/P2) = ABS(COSTHETA) < 0.85 is DC fiducial cut.

***UPDATE NOTICE: the cut used to be 0.82 before third draft of b fraction paper, November 1989.

c. PBEST < Eb = 0.5*ECM, where PBEST is |P| obtained by the following prescription formulated by Chang-Kee Jung:

PBEST for hadronic events			
P6 \ P2	0 < P2 =< 10	10 < P2 =< Eb	Eb < P2
0 < P6 =< 10	P2	P6	P6
10 < P6 =< Eb	P2	P6	P6
Eb < P6	P2	P2	00

d. E = SQRT(PBEST**2 + 0.140**2) is the energy filled for charged tracks.

D. SHOWER SELECTION

1. LASHQ < 100.

2. MIN(ABS(XSH), ABS(YSH), ABS(XSH)) <= 3.0 meters.

3. COS(THETSH) <= 0.68 selects LA showers.

4. 0.70 < COS(THETSH) <= 0.95 selects EC showers.

***UPDATE NOTICE: the outer edge used to be 0.74 before third draft of b fraction paper, November 1989.

5. ESH >= 1.0 GeV is the minimum energy cut.

6. If shower is associated with a charged track, i.e. PBEST exists, then require ESH > 2.0*PBEST.

II. LEPTON TAGGED EVENT SELECTION FOR COUNTING B-BAR B EVENTS

A. NLEPT >= 1 requires at least one identified lepton/hadronic event.

B. PTJET > 1.25 GeV/c for identified lepton.
If NLEPT > 1, take PTJET of lepton with highest PTJET, MXPTJET, and require MXPTJET > 1.25 GeV/c.

C. PTJET CALCULATION FOR A GIVEN TRACK
The method used here is the same as the one used by Tim Barklow to construct the variable rho for particle search analyses.

1. Remove the charged track from the list of charged tracks.

2. Run LCLUS$ on the remaining charged tracks and showers.
Use the default value for /LUDATA/PARA(4) = D_JOIN = 2.5.

3. Loop over the number of clusters (j = 1, NJET) to find the cluster which gives the smallest value of [1 - COS(THETA_1_j)], where THETA_1_j is the angle between the track and the cluster.
Call the angle to the nearest cluster THETAMIN.
If COS(THETAMIN) < 0.0 set COS(THETAMIN) = 0.0.

4. For the nearest cluster, form the quantity
PTJET = PBEST*SIN(THETAMIN), the transverse momentum of the track to the nearest cluster formed by the other particles in the event.

D. LEPTON IDENTIFICATION

The MARKII/SLC NOTE #114 by Pat Burchat and Mark Nelson, "Lepton Identification using the LA Calorimeter and Muon System" describes most of the information left out here.

1. Require PBEST > 2.0 GeV/c.

2. Require the track to be identified as muon or electron.

a. Muon identification

Except for the new DC extrapolation errors, the muon identification is the same as the one used by Mark Nelson for his Ph.D. thesis (LBL) with the addition of MUCORR by Andrew Weir, as described in MARKII/SLC NOTE # 213.

i. Refill the muon tracklist using a version of MUNCH which reads in the Upgrade Drift Chamber extrapolation errors from the array /MUMODE/USLRES(4,4). The errors were obtained using cosmic ray tracks and reflect uncertainty in the location of the muon chamber wires.

DC extrapolation errors for cosmic ray muons			
Layer	Chambers	Coordinate	Error (m)
1	East/West	z	0.011
2	East/West	y	0.014
3	East/West	y	0.014
4	East/West	y	0.017
1	Top/Bottom	z	0.009
2	Top/Bottom	x	0.008
3	Top/Bottom	x	0.008
4	Top/Bottom	x	0.009

ii. MULEVE = 4 is the fiducial and momentum cut.

iii. DISTANCE < 0.75 (1.00) meters for layer(s) 1 (2-4). DISTANCE is the distance between the DC track extrapolation in each layer to the hit closest to the DC extrapolation.

iv. MUSTAT = 15, equivalent to ABS(DELHI) < 3.0 sigma. DELHI = DELTA(layer) for the layer with the largest ABS(DELTA(layer)). DELTA(layer) = signed number of sigma from DC track extrapolation to the nearest hit in a muon chamber layer.

v. MUCORR(3.0) = .TRUE., equivalent to ABS(DELT4) < 3.0 sigma. DELT4 is the signed number of sigma between the closest hit in layer 4 and the projection along the line formed by the projected momenta in layers 2 and 3.

b. Electron identification

Electron identification with the LA calorimeter is described in Mark Nelson's Ph.D. thesis. Some of the constants have been changed for the SLC running. In particular, Dolly Wu has introduced a narrower search road around the DC extrapolated track. Also, E/P distributions for PEP Upgrade Bhabha's and radiative Bhabha's selected by her, are used to define new identification cuts.

i. ICLASS = 0, calculated in LAELEC, selects LA fiducial volume for electron identification.

ii. Construct the quantities EOPLO and EOPFR.
EOPLO is designed to make sure that the track leaves a large "electron-like" energy deposition in each of the 3 orientations of the front section of the LA. EOPLO is calculated as follows:

(a) Add energy deposited within a small search road around the DC track extrapolation, w_search = w_shower + w_gang*tan(delta) in each of the ganged layers F1+F2, U and T1. The angle delta is the angle between the extrapolated track and the normal to the layer. The old values for w_shower = 0.75, 0.70 and 0.75 are used for these 3 layers and a new set of smaller w_gang = 0.5, 0.9 and 0.9 were introduced.

(b) Divide by the momentum PBEST.

(c) For each layer, divide by a median E/P for the the layer. The median E/P values were obtained from a sample of PEP Bhabha's and depend (slightly) on the momentum:

Median E/P for PEP Upgrade Bhabha's				
P (GeV/c)	LA layers			
	F1+F2	T1	U	FRONT
3 - 8	0.235	0.235	0.235	0.725
8 - 13	0.235	0.210	0.220	0.665
13 - 16	0.230	0.205	0.215	0.645

We now have 3 normalized E/P ratios, EOP(layer) = (E/P)/(E/P)_median, one for each of F1+F2, U and T1. Take the least electron-like (lowest) EOP(layer), EOPLO = MIN(EOP(F1+F2), EOP(U), EOP(T1)).
If P < 3 GeV/c, use the 3 - 8 GeV/c bin and if PBEST >= 16 GeV/c, use the 13-16 GeV/c bin.

(d) EOPFR is calculated in a similar fashion.
First add the E/P ratios for the 3 layers. Then divide by the median for this FRONT layer sum shown in the above table.

iii. Require EOPLO > 0.55 and EOPFR > 0.65.

***UPDATE NOTICE: The above cuts were simplified during November 1989. So don't get confused by reading the unofficial memo MARK II/SLC Note #24y which uses the following old cuts on EOPLO and, for low momentum electrons, EOPFR:

(a) EOPLO > 0.40 and EOPFR > 0.60 for PBEST < 8 GeV/c.

(b) EOPLO > 0.65 for PBEST >= 8 GeV/c.

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