```
COMMON/MUPARS/MUDBUG,SIGT,SIGL,EFFCY,RANDOM,SIGTEW,PULSES
            REAL*8 RANDOM
            LOGICAL MUDBUG
                     MC parameter control common
                      MUDBUG   Debug flag
                      SIGT     Transverse Resolution (mm) of yoke
                                                and sidewall chambers
                      SIGL     Longitudinal Resolution (mm)
                      EFFCY    Chamber efficiency
                      RANDOM   Random noise in chambers
                      SIGTEW   End wall transverse resolution
                      PULSES   Multi-pulsing probability

                           Set by:  MUFIX
                           Used by: MUORDR,MUSTOR


COMMON/RESULT/XEND,YEND,ZEND,P,AMAS,SINL,COSL,SINP,COSP,NCH,EN,RS
      REAL NCH
                  Contains the current data for the current particle
                         XEND
                         YEND    position of this particle (cm)
                         ZEND
                         P       Momentum (Mev/c)
                         AMAS    mass     (Mev/c**2)
                         SINL    sin of dip angle
                         COSL    cos      "    "
                         SINP    sin of azimuthal angle
                         COSP    cos      "        "
                         NCH     Charge   (REAL*4 - don't ask me why!)
                         EN      Energy
                         RS      Available CMS energy

                                Used by:  everybody

COMMON/SUN/DELTN
                 DELTN   is the size of the current step (cm)

              Used by:  MUBREM,MUDKBG,MUINTA,MUPAIR,MURTNE,MUSCA,MUTRAK

COMMON/TODAY/HS,HMIN,HH,HD,HMO,HY
              Time of run - secs, mins, hour, day, month, year
                  all integer*2

                  Set up by BLOCK DATA (after MUCONM) or by the user

                    Read by MCDATE
```

COMMON BLOCKS

```
COMMON/ABUL/SIGB(100),ALPHA(100)
                        Cross section interpolation
                        For nucleon target X-section I mb
                        SIGB(I)   is the constant
                        ALPHA(I)  is the exponent

                             Used by MUSIGM


COMMON/CJTCDC/IBANK,IPART
                        Common created by main Monte Carlo
                        IPART = particle number

                             Used by:  MUORDR,MURTNE,MUSTOR

COMMON/CMURJB/LASTR
                         LASTR is the last region number visited

                              used by:  MURTNE,MUZAP

COMMON/CMUSIG/LMUX1,NH,IMUX1,IMUX2,IMUX9
                         Keeps track of hit lists
                         LMUX1    length of MUX1 banks (1 and 2)
                         NH       Number of hits.  -1, 0 are special
                         IMUX1    Index for MUX1:1
                         IMUX2    Index for MUX1:2
                         IMUX9    Index for MUX1:9

                              Used by:  MUORDR,MURTNE,MUSTOR

COMMON/DISPL/IDBUG,DECAY
          LOGICAL IDBUG,DECAY
                        IDBUG    debug printing flag
                        DECAY    flag set for decays

                         used by:  MUDKBG,MURTNE

COMMON/EVENT/NSIZE,NCUR,NEXT,NTOT,EVE(10000)
                       Stores all the particles yet to be tracked
                         NSIZE    Dimension of EVE
                         NCUR     Always 1
                         NEXT     Next empty word in EVE
                         NTOT     Total number of particles in EVE
                         EVE      Particle data. 10 words each.
                                           Correspond to RESULT values

                             Used by:  MUBREM,MUCAS,MUNUCL,MUPAIR,MURTNE
```

MUSGIL(BEAM,TARGET,ECM,PLAB,P4TOT)

```
Called by:          MUCAS
Calls:              None
Arguments/value:    BEAM and TARGET are beam and target masses
                     ECM  is the energy in the CMS (returned)
                     PLAB is the lab momentum
                     P4TOT(4) is the Lorentz frame for the event
Input Common(s):    SYMB2,INIT
Output Common(s):   SAGELL,SAGEWT
```

Does some initialisation for the SAGE package, before the call to MUSGNS which does the actual event generation. All energies etc in GeV. See SAGE manual for further details

MUSGNS(TECM,PP,NP,AMASS,PCM,RMAX,IENT)

```
Called by:          MUCAS
Calls:              MUSGRD
Arguments/value:     TECM is the cms energy
                     PP(4) is the Lorentz frame in which the event occurs
                     NP is the number of particles to be generated
                        according to longitudinal phase space
                     AMASS(NP)  are the particle masses
                     PCM(4,NP)  are the 4-momenta generated
                     RMAX is a control parameter for LPS.
                          Set to the recommended value of 0.4
                     IENT is the number of attempts at this event
Input Common(s):    SYMB2,COUNT,SAGEWT
Output Common(s):   COUNT,SAGEWT
```

Generates an NP particle event acording to LPS. For further details consult the SAGE manual (under routine GENIS).

This seems to give sensible results. I havn't done a detailed study - somebody probably should some time - but there's nothing really sticky here.

MUSIGM(P,AMASS,Q,A)

Called by: MUINTA
Calls: None
Arguments/value: P is momentum of incident particle
AMASS is its mass
Q is the charge
A is the atomic weight of the nucleus
Real value returned is the X-section in millibarns
Input Common(s): ABUL,MUSIGA
Output Common(s): None

Computes the absorption cross section.
Decides on the particle type by looking at AMASS and Q.
AMASS is restricted to certain non-obvious values: see the comments in the listing for complete details.
Then finds the cross section for Nucleon Targets for this momentum by interpolating in the MUSIGA common, obtained from the data compilations.
Then finds C and alpha for the formula C*A**alpha for nuclear targets. (Full details of this method will appear at some point).

Status: Good. I believe these numbers. Results agree with experimentals values of absorption cross sections within 3% - though it may be worse for e.g. low energy antiprotons

MUSTOR(I,X,Z)

Called by: MUZAP,MUORDR
Calls: none
Arguments/value: Chamber Number, transverse and longitudinal values
Input Common(s): CJTCDC,MUPARS,CMUSIG
Output Common(s): CMUSIG
Uses bank(s): MUX1:1, MUX1:2, MUX1:9

Stores a hit in the banks MUX1:1 (x) MUX1:2 (z) and particle info in MUX1:9. Multipulsing, smearing, and inefficiency are all applied here

MUPIO

Called by: MURTNE
Calls: MUROT
Arguments/value: None
Input Common(s): RESULT
Output Common(s): EVENT,RESULT

Goes right through the EVENT common looking for neutral pions. When it finds one, two gammas are produced, isotropically about the pi0 direction

MUROT(XP,YP,ZP)

Called by: MUPIO,MUDKBG
Calls: None
Arguments/value: Xp,etc
Input Common(s): RESULT
Output Common(s): RESULT

A rotation routine. A particle produced with components XP,YP,ZP and momentum P (in RESULT) in the frame of a particle with direction SINL,COSL,SINP,COSP (in RESULT) has its direction worked out. This new direction then overwrites the SINL etc values in RESULT.

MURTNE(PV,R,IDUM,*)

Called by: MCJADE
Calls: MUDKBG,MUFIND,MUMAT,MUPAIR,MUBREM,MUINTA,MUTRAK
MUSCAT,MUEXNU,MUNUCL,MUCAS,MUPIO
Arguments/value: PV is momentum vector
R is position
IDUM and * are not used
Input Common(s): DISPL,CJTCDC,CPROD,KUT,JEVENT
Output Common(s): EVENT,CMURJB,CMUSIG,RESULT,SUN,Bos Common
Output Bank(s): MUX1:1, MUX1:2, MUX1:9, MUCH

This is the general steering routine, called for each event.

First time through, it sets up some parameters (NSIZE,STEP,PCUT) and seeds the random number generator.

If this is the first track of an event, then the MUX1:1,2,9 banks are created.

The tracks parameters are then copied from PV and R to RESULT. Dimensions are converted from mm & GeV to cm & MeV.
K zeros are reassigned as K+-. This is OK for aborption but incorrect as far as energy loss goes.

MUMAGF(FIELD)

Called by: MUTRAK
Calls: none
Arguments/value: FIELD(3) is the direction of the field
value returned is the magnitude
Input Common(s): RESULT,MUTYPE
Output Common(s): none

Works out where it is in the return yoke or end walls and evaluates the magnetic field magnitude and direction. This is normalised to 1, the multiplication by 4.8 kG (or whatever) is done in MUTRAK

MUMAT(INDEED)

Called by: MURTNE
Calls: none
Arguments/value: INDEED is index to this material
Input Common(s): None
Output Common(s): MAT,MUABSL

This routine extracts the properties of the current material (density, radiation length, dE/dx parameters etc) from tables and puts them into MAT; MUABSL is also filled.

It looks very complicated, because it is a multi-purpose routine which can also be used to produce the tables for new materials. This part does not happen in normal use.

MUNUCL(TKIN)

Called by: MURTNE
Calls: None
Arguments/value: TKIN is energy to be used in creating fragments
Input Common(s): RESULT,KUT
Output Common(s): EVENT

Produces nuclear fragments. Distribution for KE is T exp-(100 T**2) Goes on producing fragments until all the available energy TKIN is used up.

Status: Uncertain. See MUEXNU.

MUEXNU(EN,AMAS)

Called by: MURTNE
Calls: none
Arguments/value: EN and AMAS are the energy and mass of the incident particle
Real value returned is the energy to go to nuclear excitation
Input Common(s): MAT

Decides on energy to evaporation nucleons. Gives 10 Mev/nucleon for collisions below 3 Gev, above 3 Gev multiplies this by E/3

Status: very suspicious. Grant's paper and program say different things here. Both are probably wrong. This is first on my list for improvements.
Output Common(s): None

MUFIND(IND)

Called by: MURTNE
Calls: ENDCLG,MUZAP
Arguments/value: Ind is material index: 0 = air (=vacuum)
-1 = left apparatus
1 - 92 are elements
100+ are composites
Input Common(s): RESULT,CGEO1,CMUREG
Output Common(s): MUTYPE

From the position it works out what material it is in (aluminium, lead-glass, iron, iron-loaded concrete, air...) It does this by looking at the geometry common values (for radius of coil, etc), by the lead glass routine ENDCLG which knows where the lead glass blocks are in the end cap, and by looking at the muon region list. If it discovers it is in a chamber, it calls MUZAP to score the hit.

MUCAS

Called by: MURTNE
Calls: MUPCN,MUTRYN,MUSGIL,MUSGNS,MUSGWT
Arguments/value: None
Input Common(s): RESULT
Output Common(s): EVENT

Generates a multiparticle event.

First decides on the probability of charge exchange (MUPCN) for the target. (p -> n or n -> p)

If the beam momentum is low (<400 Mev/c) then the multiparticle collision is not generated, instead the beam particle loses 10% of its energy, and that's it.

It decides randomly on proton or neutron as target particle.

For a nucleon-nucleon collision, if the target charge exchanges and if the energy is reasonably high, then there is a 50:50 chance of beam charge exchange too. This is a bit of a kludge.

It then decides on the number of charged and neutral pions produced. by calling MUTRYN. If there is not enough cms energy to create all these particles, it drops pi zeros until there is. If there still isn't enough after all the pi zeros have been dropped, then the low energy (<400 Mev/c) procedure is followed.

The SAGE routines are called to generate the event. SAGE produces weighted events, and these have to be selected by comparing the weight with the "maximum weight". This last is very time consuming to calculate. I have set the standard value to 2.0, from looking at actual values of the weight generated. If it takes more than 10 shots at the generation then it decides that 2.0 is far too high, and uses 3 times the average weight (from the >=10 tries it's just made) instead.
At the end, energy, momentum, and charge balance is checked.

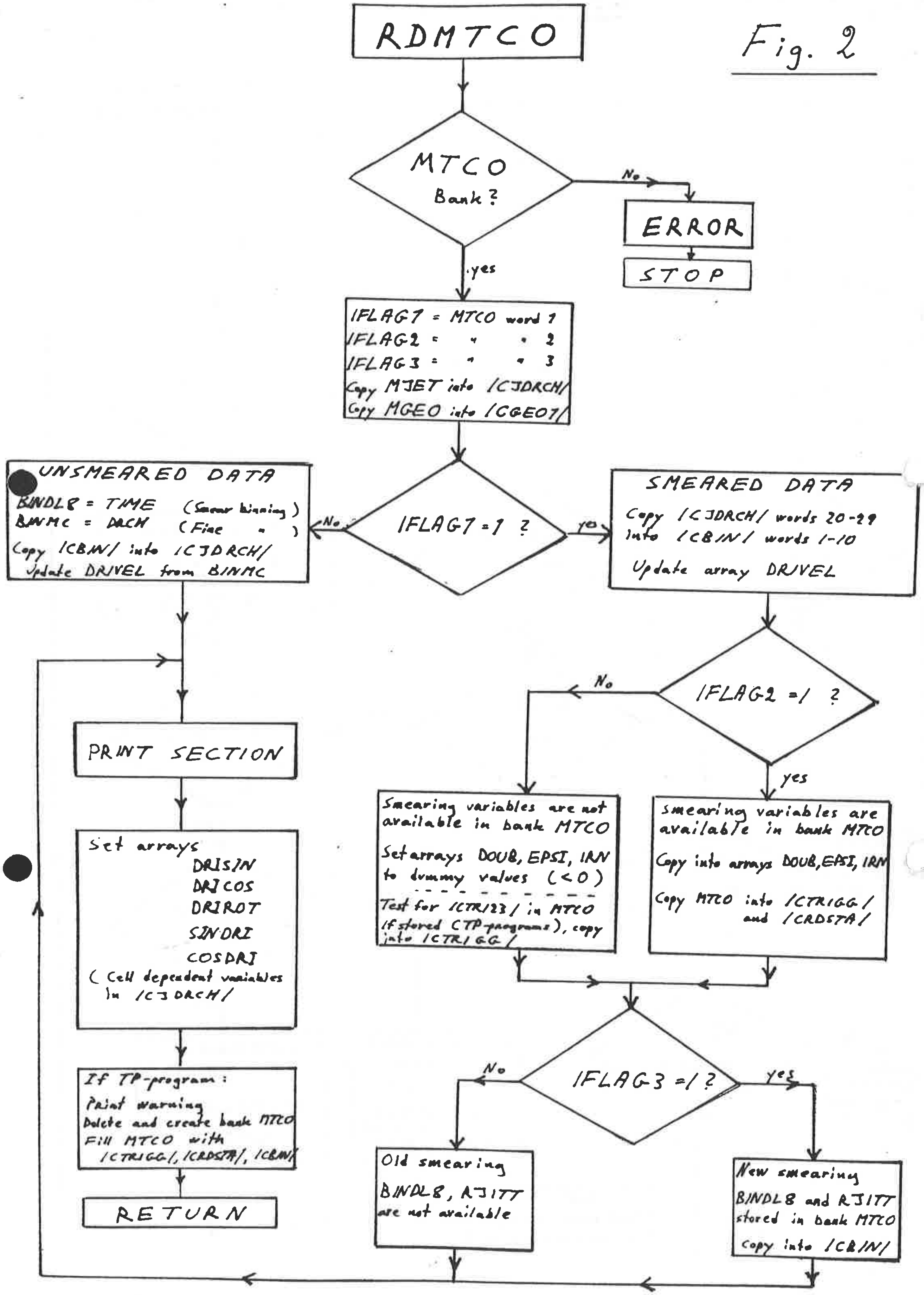
Status: Fairly satisfactory. Main defect is the lack of any Kaon production - everything is a pion or a nucleon (though the target mass is correct). If anyone had some numbers for kaon production fractions (which are probably easy - it's reactions like K p -> pi Lambda that will make life difficult) then it would be relatively easy to put them in - SAGE could handle them.

OVERVIEW

```
            MUCONM---------------MUFIX
           / get KALIBR consts      fix parameters
           |
           |
           |                  MUDKBG ---- MUROT
           |                 /  pi, K decay   rotate    ENDCLG
           |                 |                        /  from lead glass lib
           |                 | MUFIND ---------------+-MUZAP
           |                 |/  where am I ?         |   hit in muon chambers
           |                 |                        \
           |                 | MUMAT                   MUSTOR
           |                 |/  get material props.       save mu hit
           |                 |
           |                 | MUPAIR    ----- MUTRAK
           |                 |/  gamma -> e+e-
           |                 |
           |                 | MUBREM    ----- MUTRAK,MUSCAT
           |                 |/  e -> e gamma
           |                 |
           |                 | MUINTA ---------   MUSIGM
           |                 |/  did it interact?     get cross section
MCJADE---|-MURTNE ---------|
           | steers muon     |\
           |  part of MC     | MUTRAK ----------MUDEDX,     MUMAGF
           |                 |   move particle   energy loss     mag field
           |                 |\
           |                 | MUSCAT
           |                 |   coulomb scattering
           |                 |\
           |      these      | MUEXNU
           |      only       |   energy to nuclear excitation?
           |      called     |\
           |      if it      | MUNUCL
           |      interacts  |   Produce evaporation nucleons
           |                 |\
            \                | MUCAS -------------- MUPCN
             MUORDR-MUSTOR   |  generate         |     Charge exchange
              create MUEV    |   interaction     |\
                             |                   | MUTRYN - Multiplicity
                             |                   |\
                             \                   | MUSGIL - Sage initialise
                              MUPI0 --MUROT      |\
                                pizero decay     | MUSGNS - Sage generator
                                                 \
                                                  MUSGWT - Sage weight
```

Note: MUCONM is called only once, at the start of the job.
MURTNE is called for every track (that gets as far as the filter).
MUORDR is called once per event, at the end

Fig. 2



RDMTCO
MTCO Bank?
No
ERROR
STOP
yes
IFLAG1 = MTCO word 1
IFLAG2 = " " 2
IFLAG3 = " " 3
Copy MJET into /CJDRCH/
Copy MGEO into /CGEO1/
IFLAG1 = 1 ?
No
UNSMEARED DATA
BINDL8 = TIME (Smear binning)
BINMC = DRCH (Fine ")
Copy /CBIN/ into /CJDRCH/
Update DRIVEL from BINMC
yes
SMEARED DATA
Copy /CJDRCH/ words 20-29 into /CBIN/ words 1-10
Update array DRIVEL
IFLAG2 = 1 ?
No
yes
Smearing variables are not available in bank MTCO
Set arrays DOUB, EPSI, IRN to dummy values (<0)
Test for /CTR123/ in MTCO (if stored CTP-programs), copy into /CTRIGG/
smearing variables are available in bank MTCO
Copy into arrays DOUB, EPSI, IRN
Copy MTCO into /CTRIGG/ and /CRDSTA/
IFLAG3 = 1 ?
No
yes
Old smearing
BINDL8, RJITT are not available
New smearing
BINDL8 and RJITT stored in bank MTCO
Copy into /CBIN/
PRINT SECTION
Set arrays DRISIN DRICOS DRIROT SINDRI COSDRI (Cell dependent variables in /CJDRCH/
If TP-program: Print warning Delete and create bank MTCO Fill MTCO with /CTRIGG/, /CRDSTA/, /CBIN/
RETURN