V. Appendices

A. Simulation of The OPIG Using SIMION

SIMION was used to simulate the ion exiting the **OPIG** and aided in determination of the voltage settings on the quadrupole lenses used to focus the ions onto the position sensitive detector. In this appendix a simulation of the trajectory of Ar^{8+} ions through the quadrupoles and vertical and horizontal steerers is discussed. Ar^{8+} ions with an initial energy of 320 eV are set at the center of the of the axis of the beam line and the azimuthal and elevation angles were varied from -10 to +10 degrees, in steps of 2 degrees. The ions are placed just to the right of a potential of 1910 V, which accelerates the ions as they pass through the quadrupole region. The voltages on the first three elements of the downstream lenses of the **OPIG** are the same for both simulations. (The elevation angles and azimuthal angles are scanned in two separate runs.) The potentials on the first three lens elements (from left to right) are 1300V, 166V, and 366V. The potential on the first (left) quadrupole lens was -670V for the vertical poles, and -179V on the horizontal poles. The potential on the second (right) quadrupole lens was 400V on the vertical poles, and 113V in the horizontal poles.

A side view of the quadrupoles and vertical and horizontal steerers is shown in **Figure A.1**. In this simulation, the azimuthal angle was varied. The beam is vertically focused to a point infinitely far away.

Figure A.1 A SIMION simulation, showing a side view of the quadrupoles and vertical and horizontal steerers. Ar^{8+} ions, with an initial energy of 320 eV, and azimuthal angles ranging from -10 to 10 degrees, are focused so that they don't diverge in the vertical plane.

The ion beam is intentionally focused to a node in the horizontal plane before the analyzing magnet because the magnet acts as a lens as well. Proper positioning of the focal point in the horizontal direction will allow the magnet to refocus the ion beam onto the detector.

Figure A.2 A SIMION simulation, showing a side view of the quadrupoles and vertical and horizontal steerers. Ar^{8+} ions, with an initial energy of 320 eV, and elevation angles ranging from -10 to 10 degrees, are focused before the analyzing magnet in the horizontal plane.

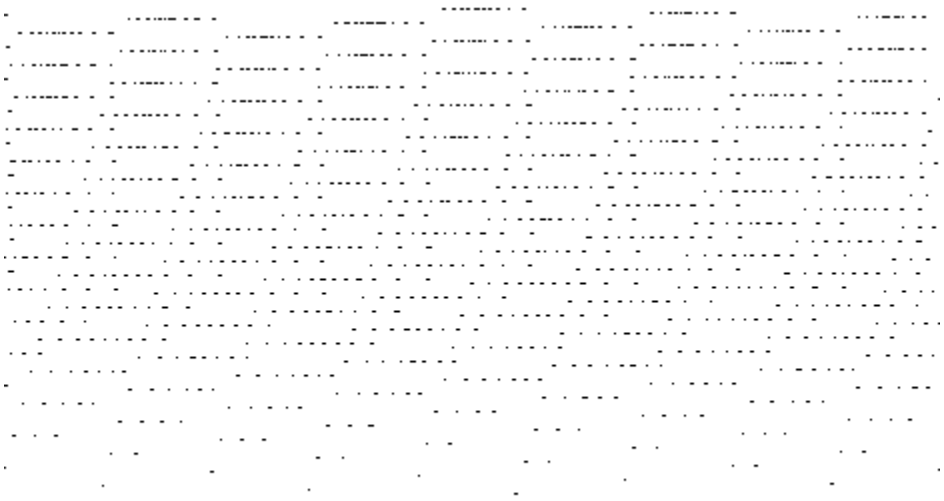

Figure A.3 A SIMION simulation, showing a three dimensional view of the quadrupoles and vertical and horizontal steerers. Ar^{8+} ions, with an initial energy of 320 eV, and azimuthal angles between -10 to 10 degrees, are focused in the horizontal plane.

B. Data Analysis Code (.EVL) and (.COM) files

The data acquisition system, XSYS has been used to process and record signals from the CAMAC electronics. This system reads and stores data in a list mode. Since all the data for each event are stored separately, the experiment can be re-run “offline”, with different parameters and sorting conditions, which makes data analysis more convenient. There are two types of files used for sorting. One file is referred to as a (.com) file, and another which is called an (.evl) file. The (.com) file is used to generate histograms, and plots where analyzed data can be stored. The (.evl) file is a code which sorts the data, and which specifies the operations to be performed on the data. XSYS uses the EVAL language, and does operations only on the one quantity in the accumulator. The (.evl) files sorting code increments each memory area allocated with the (.com) file on an event-by-event basis. Three files (not included in this appendix) that are also needed to collect data, are the USERCONFIG.H, USEREVENTS.H, and USERBEGIN.H files, which are specific to the electronics and CAMAC crate that is used for a particular experiment.

The following program is the OPIG02.COM file, which was used to allocate space, and generate the windows are displayed during data acquisition.

```
$! OPIG02.COM
$ DMEM ALL GLOBAL FILE
$ AMEM NEW 10000 PAGES*
$ AMEM  20   PXspec        2048
$ AMEM  21   PYspec        2048
$ AMEM  22   PRspec        2048
$ AMEM  23   PSspec        8192
$ AMEM  24   PXpospec      512
$ AMEM  25   PXYspec       512 512
$ AMEM  26   PBspec        2048
$ AMEM  27   SCspec        2048
$ AMEM  28   DCspec        2048
$ AMEM  29   Rampspec      2048
$ AMEM  30   SUMspec       2048
$ AMEM  31   proj1   2048
$ AMEM  32   proj2   2048
$ AMEM  33   proj3   2048
$ AMEM  34   proj4   2048
$ GATE NEW
$ GATE 24 3
$ CLEAR FLAGS
$ CLEAR ALL
```

The following program is the OPIG02.EVL file, which was used to sort the data for this experiment.

```
! opig02.EVL (For OPIG experiment)
!
!from opig.evl, modified 03-26-2002!
!*****************************************************************
!This program has been modified from the original OPIG.evl file.
!A ramp voltage is applied to a channel of the ADC ( that represents
!the decel voltage on the OPIG).  A spectra displaying the events vs.
!ramp voltage has been included. 3 spectra displaying the PB, SC, DC
!counts vs. this ramp voltage are also included in this modification.
!A spectra displaying the sum, SUM=PB+SC+DC, has been added as well.
!
!*****************************************************************
!
OPTION TAPE
!
! GENERAL PURPOSE PARAMETERS
!****************************
INTEGER I255=255
INTEGER I511=511
INTEGER I1023=1023
INTEGER I2047=2047
INTEGER Seed=8723645      ! random number seed
INTEGER INEG=-1
REAL RAMPfact=16.0        !factor for displaying spectra
!                         !RAMPfact=4. displays 512 channels
!                         !RAMPfact=2. displays 1024 channels
!                         !RAMPfact=1. displays 2048 channels, etc.
!CAUTION: if RAMPfact is changed, change the size of spectra also
REAL dChannel
REAL R256=256.0
REAL temp                 ! temporary variable
!

! Projectile position parameters
!********************************
REAL PXsig                ! Projectile X signal
REAL PYsig                ! Projectile Y signal
REAL PRsig                ! Projectile R signal
REAL PSsig                ! Projectile SUM X + Y + R
REAL PXthre=40            ! Projectile X threshold
```

```
REAL PYthre=40              ! Projectile Y threshold
REAL PRthre=40              ! Projectile R threshold
REAL PSthre=140             ! Projectile SUM threshold
REAL PXoffse=0              ! Projectile X offset
REAL PYoffse=0              ! Projectile Y offset
REAL PRoffse=0              ! Projectile R offset
REAL PXgain=1.0             ! Projectile X gain
REAL PYgain=1.0             ! Projectile X gain
REAL PRgain=1.0             ! Projectile X gain
REAL PRamp=1.38             ! Projectile R amplification factor
REAL PDetScal=3.5  ! Scaling factor for Projectile Detector size
REAL PSHIFT=62              ! Shift of x & y of Projectile detector image
REAL PXipos         ! Projectile x intermediate position
REAL PYipos         ! Projectile y intermediate position
INTEGER PXpos               ! Projectile x position
INTEGER PYpos               ! Projectile y position
REAL PcosAng=1.0   ! Projectile PSD rotation angle cosinus
REAL PsinAng=0.0   ! Projectile PSD rotation angle sinus
!
!
GATE PBgate PXPOSPEC 1
GATE SCgate PXPOSPEC 2
GATE DCgate PXPOSPEC 3
 !
! RAMP parameter
!*******************************
INTEGER RAMPsig             !RAMP voltage signal
!
!
!*************************************************************
!*                          SORTING                          *
!*************************************************************
OPTION ALLSPEC              ! this defines the spectra and 2-d gates
!
!REAL DATA IS 11 BITS. HERE 12TH BIT IS INCLUDED FOR OVERFLOW
DETECTION
!
FORMAT RAMP      1 12 1  ! Ramp voltage
FORMAT SPX       2 12 1  ! Wedge
FORMAT SPY       3 12 1  ! Strip
FORMAT SPR       4 12 1  ! Reminder
!
!
EVENT BEGIN
TAPE
!
```

```
EVENT 2
TAPE
!
!*************************************************************
!*                    Projectile Position                    *
!*************************************************************
!
RAN (Seed)          ! Randomize to prevent beats
STA dChannel
GET SPX                     ! Get X Projectile PSD signal
FLOAT
ADD dChannel
SUB PXoffse
MUL PXgain
IF GE I2047 EXIT    ! Exit if it is an overflow
IF LE PXthre EXIT   ! Exit if less than lower threshold
STA PXsig           ! Store as real variable
FIX
!                   ********************************
TINC PXspec         ! Increment PX spectrum              *
!                   ********************************
!
RAN (Seed)          ! Randomize to prevent beats
STA dChannel
GET SPY                     ! Get Y Projectile PSD signal
FLOAT
ADD dChannel
SUB PYoffse
MUL PYgain
IF GE I2047 EXIT    ! Exit if it is an overflow
IF LE PYthre EXIT   ! Exit if less than lower threshold
STA PYsig           ! Store as real variable
FIX
!                   ********************************
TINC PYspec         ! Increment PY spectrum              *
!                   ********************************
!
RAN (Seed)          ! Randomize to prevent beats
STA dChannel
GET SPR                     ! Get R Projectile PSD signal
FLOAT
ADD dChannel
SUB PRoffse
MUL PRgain
IF GE I2047 EXIT    ! Exit if it is an overflow
IF LE PRthre EXIT   ! Exit if less than lower threshold
```

```
STA PRsig           ! Store as real variable
FIX
!                   ********************************
TINC PRspec         ! Increment PR spectrum              *
!                   ********************************
!
LDA PRsig
MUL PRamp
ADD PXsig
ADD PYsig
IF LE PSthre EXIT   ! Exit if less than lower threshold
STA PSsig           ! Resistive anode Recoil PSD charge signal
FIX
!                   ********************************
TINC PSspec         ! Increment PS spectrum              *
!                   ********************************
!
!************************Position calculation*******************
!
IF PSsig EQ 0. EXIT ! prevent devide by zero
!
LDA PXsig
DIV PSsig
MUL I511
SUB PSHIFT          ! Shift detector image
MUL PDetScal                ! Detector scaling factor
SUB I255
STA PXipos          ! Store for 11 bit position later
!
LDA PYsig
DIV PSsig
MUL I511
SUB PSHIFT          ! Shift detector image
MUL PDetScal                ! Detector scaling factor
SUB I255
STA PYipos          ! Store for 11 bit position later
!
!**************************Rotation*****************************
MUL Psinang
STA temp
LDA PXipos
MUL Pcosang
SUB temp
ADD I255
STA PXpos           ! Projectile X coordinate
!
```

```
LDA PXipos
MUL Psinang
STA temp
LDA PYipos
MUL Pcosang
ADD temp
ADD I255
STA PYpos           ! Projectile Y coordinate
!
!                   ****************************************
TINC PXpos PYpos PXYspec! Increment Proj. 2D position spectrum       *
!                   ****************************************
!
STA PXPY            ! Store 2D index from PXYspec
!
LDA Pxpos
!                   ****************************************
TINC PXpospec               ! Increment X  position spectrum      *
!                   ****************************************
STA Pxpos
!
!
!
!*****************************************************************
!*                displaying spectra Ramp, PB, SC, DC...       *
!*****************************************************************
!
!
RAN (Seed)          ! Randomize to prevent beats
STA dChannel
GET RAMP            ! Get RAMP voltage signal
FLOAT
ADD dChannel
IF GE I2047 EXIT    ! Exit if it is an overflow
IF LE 0 EXIT        ! Exit if lowerflow
DIV RAMPfact                ! to display RAMPspec with 2048/RAMPfact
channels
FIX
STA RAMPsig                 ! Store as real variable
!                   ********************************
TINC RAMPspec               ! Increment RAMP spectrum           *
!
IF Pxpos PBgate
TINC RAMPsig PBspec
TINC RAMPsig SUMspec
ENDIF
```

```
IF Pxpos SCgate
TINC RAMPsig SCspec
TINC RAMPsig SUMspec
ENDIF
IF Pxpos DCgate
TINC RAMPsig DCspec
TINC RAMPsig SUMspec
ENDIF


END
```