Day 3 – Mass Analyzers

To run these examples the large PA# files must be refined first, once they are refined and saved they no longer need to be refined when running the examples. The procedure to refine a file is:
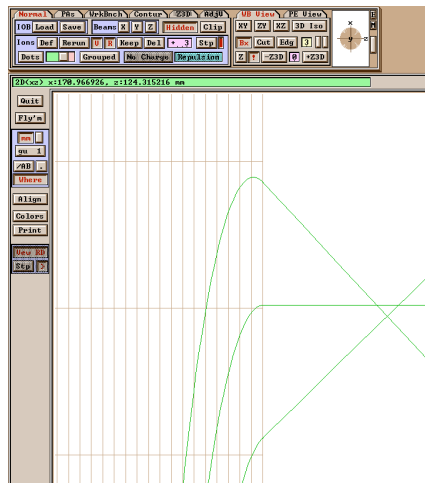
    a. Select Load, then select **the file.pa#** (left click when cursor is on the file), then OK.

    b. Select Refine, set Convergence Objective (lowest green panel) to 5 e-6 or lower.

    c. Push the Refine Fast Adjust Array button. Refining will take about from one to several minutes depending on the size.

    d. Push the Remove All PAs from Ram button.

Here are the files that need to be refined in this section:

        ∞ 90 degree magnet.pa#
        ∞ Esa.pa#
        ∞ Mag out.pa#
        ∞ Magnet profile.pa#
        ∞ Uniform B.pa#
        ∞ UV gun as built.pa#

1. Magnetic Sectors

    a. 90 degree magnet, ideal field (no fringing fields)

        i. From the main menu remove all PA's from ram

        ii. Push View, move to directory Day 3 SIMION, select **90 degree sector.iob**

        iii. Push the XZ view button then the Fly'm button and Fly

        iv. Use the view globe to rotate the view so x is vertical then on the WB View tab press the = button to get the asymmetric zoom, now select a long narrow window and zoom in on the focus region, it should look like:

What do you notice about the focus?

v. Go into the ion definition screen (push Def on the Normal tab), and change the First Az Angle to 1 and the Delta Az to -1, push OK, and fly the ions again.

vi. Zoom into the focus region and observe what has changed. Why do you think this happens?

b. 90 degree magnet, ideal field, magnification

   i. From the main menu remove all PA's from ram

   ii. Push View, select **magnification.iob**

   iii. **Fly'm** and set **_el_Angle_Off_Vel_Axis** to 1.0

   iv. Push the XZ view button and rotate view so x is vertical.

   v. Zoom in on the source region and measure the distance between the two emission points, then zoom into the focus region and measure the distance between the two focus points. Is the magnification = 1? Not exactly; record the ratio of the focus point separation to the emission point separation.

   vi. On the Normal tab push the Def button and on the ion definition screen change the First x value to 1.

   vii. Push OK, then Fly'm. Measure the ratio, is it the same as before? Does this agree with the theory? (Yes, magnification is only dependent on the distance from the source to the magnet, not the width of the source.)

c. 90 degree magnet with fringing fields.

   i. From the main menu remove all PA's from ram

   ii. Push View, select **fringing mag.iob**

   iii. **Fly'm** and push the XZ view button and rotate view so x is vertical.

   iv. What happened to the focal point position?

   v. Move the cursor around the area around the magnet and observe the field value (it is shown in the green panel just above the view window).

   vi. Explore the effects of the source size and angles as you did for the ideal field magnet. How has the magnification changed?

d. Full size 90 degree magnet with normal entrance and exit

   i. From the main menu remove all PA's from ram

   ii. Push View, select **270 mm 90 deg mag.iob**

   iii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** and **_az_Angle_Off_Vel_Axis** to 0.8 degrees, Fly, and push the **XZ** view button and rotate view so x is vertical.

   iv. Measure the distance from the source to the magnet entrance and from the magnet exit to the focal point. Are they equal?

   v. Select the **PAs** tab, set **Instance to 1**, push **Edit**, change the **Xwb+** value to 312, push OK. Then Fly'm and remeasure the source to magnet and magnet to focal point distances. How did they change? Note that they move along the line joining the source with the center of the radius of the magnet.

vi. Reset the position of the source to 282 mm and Fly'm. Swing the view so that y is in the vertical. What do you see is happening to the trajectories? What consequences would this have on the transmission to the detectors?

vii. Go into the ion definition screen, add a new ion with a mass of 101, change the color, and Fly'm. Rotate the view so that x is vertical.

viii. Measure the dispersion (distance between the two beams) at the focal point; record it.

ix. Now go to the ion definition screen and push Load, then select 238 239.fly, OK, select the PAs tab, change the Instance number to 2 (in the blue window) and push the Fadj button; change the value to 5850 and push **Fast Adjust PA**, now Fly'm.

x. Measure the dispersion between the two beams. How has it changed from the lower mass ions?

xi. Fast Adjust the magnet, returning the field to 3900 Gauss.

xii. Go into the ion definition screen and load **10 masses.fly**, Fly'm. Use the asymmetric zoom to view the focal points as a group, measure the distance from the magnet exit for the high and low mass ions and record them. How will this tilted focal plane affect our detector array?

e. Full size 90 degree magnet with non-normal entrance and exit – the VG 54 magnet.

i. From the main menu remove all PA's from ram

ii. Push View, select **VG 54 magnet.iob**

iii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** to 0.5 degrees, Fly, and push the **XZ** view button and rotate view so x is vertical.

iv. Measure the distance from the source to the magnet entrance and from the magnet exit to the focal point. How does this compare to the normal entrance magnet?

v. Move the source point closer to the magnet and observe what this does to the focal point. Return the source to its original position (0).

vi. Go into the ion definition screen, add a new ion group by pushing Copy Grp then Paste Grp, and change the color of group 2 to green and the mass to 101 Fly'm.

vii. Measure the dispersion (distance between the two beams) at the focal point; record it, how does it compare to the normal pole face magnet? Hence the term "double dispersion" geometry.

viii. Increase the ion emission angle (**_el_Angle_Off_Vel_Axis)**, how large of an angle can we practically expect to use?

ix. Push the Def button, and on the ion definition screen change the mass of group 2 to 100 and the First x position to 2.0, then Fly'm.

x. What is the magnification? How does it compare to the simple 90 degree magnets?

xi. Go to the ion definition screen and push Load, then select 238 239.fly, OK, select the PAs tab, change the Instance number to 2 (in the blue window) and push the Fadj button; change the value to 5850 and push **Fast Adjust PA**, now Fly'm.

xii. What is the dispersion between these two masses, and the width of the beams when the source is a point source and when it is 1 mm wide?

xiii. Go into the ion definition screen and load **10 masses.fly**, select the PAs tab, change the Instance number to 2 (in the blue window) and push the Fadj button; change the value to 3880 and push **Fast Adjust PA**, now Fly'm. Use the asymmetric zoom to view the focal points as a group, measure the distance from the magnet exit for the high and low mass ions and record them. How does this compare to the normal entry magnet? How will this affect our detector array?

f. Variable magnet exit pole.

   i. From the main menu push Remove All PA's from RAM.

   ii. Push View, select **Adjst exit pole.iob**

   iii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** to 0.5 degrees, Fly, and push the **XZ** view button and rotate view so x is vertical.

   iv. Push the Keep button to save the current set of trajectories. Zoom in on the focal point and note its location.

   v. Push the Def button, on the ion definition screen change the ion color, then OK.

   vi. Select the PAs tab, change the Instance number to 3, push Edit, then More and change the Az to -88.0; push OK. This rotates the exit pole of the magnet.

   vii. Fly the ions, zoom in on the focal region, what has happened to the focal point?

   viii. Change the magnet exit pole angle to -92 degrees and Fly'm, now where is the focal point? What is the approximate sensitivity of the focus point to exit angle (mm/degree)?

   ix. Return the exit pole angle to 90 degrees; on the Normal tab push the Del button to delete the trajectories; now push Fly'm but set the _az_Angle_Off_Vel _Axis to 0.5.

   x. Rotate the view so that the Y axis is vertical; use the asymmetric zoom (push the = key on the WB View tab) to view the focal point and note its location. What do you notice about the trajectories?

   xi. Rotate the view so that x is vertical and note the location of the focal point in this plane. Are they at the same location?

   xii. Push the XZ button on the WB View tab; use the mouse to draw a rectangle from the exit of the magnet to the bottom of the screen then push the +Z3D button on the WB View tab. Select the Z3D tab and set the Zmin value to 1 less than the Zmax value to select a small segment of the trajectory. Rotate the view so that y is vertical and zoom in on the trajectory, this is its cross section. You

can step in along the trajectory and observe how its cross section changes by change the Zmin and Zmax values (always keep them 1 unit apart). Look at the cross section at the x focal point, this is where the slit would be located.

g. Magnet Alignment

   i. Quit the current view and from the main menu push View, select **VG 54 magnet.iob**

   ii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** and **_az_Angle_Off_Vel_Axis** to 0.5 degrees, Fly, and push the **XZ** view button and rotate view so x is vertical. Zoom in on the focal region.

   iii. Select the Normal tab and push Keep to save the trajectories.

   iv. Select the PAs tab, select Instance 2, push Edit then More and change the El value to 0.17 degrees, push OK and then Fly'm. Push the XZ button then rotate the array so that y if vertical and zoom in on the focal point. How far has this moved the focal point? You could zoom in on the magnet and measure the distance one end of it moves, to save you the trouble I'll tell you that a 0.17 degree tilt corresponds to a 1 mm change in the magnet position height at one end of the magnet. The position of the beam and the quality of the focus are very sensitive to the position of the magnet.

   v. If you have time, change the position of the magnet a little (move it closer to the ion source, move it to the left or right, move it up or down) and observe the effect on the focal point position and quality.

h. Dispersion and Resolution

   i. From the main menu remove all PAs from Ram and push View then **VG 54 magnet.iob**.

   ii. Go to the ion definition screen and push Load, then select 238 239.fly, OK, select the PAs tab, change the Instance number to 2 (in the blue window) and push the Fadj button; change the value to -5880 and push **Fast Adjust PA**.

   iii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** and **_az_Angle_Off_Vel_Axis** to 0.2 degrees, Fly, and push the **XZ** view button and rotate view so x is vertical. Zoom in on the focal region. What is the distance between the two beams? Does this agree with theory?

   iv. **Fly'm** again and increase the angles to 0.8 degrees. Note that the distance between the centers of the two beams has not changed, but the width of the beams has changed. How will this affect the resolution?

   v. Fly'm again now with the angles at 0.5 degrees and the _y_Random_Offset_mm and _z_Random_Offset_mm set to 1.0. What has this done to the resolution? What can we say about the significance of the source size to instrument performance?

2. Energy filters

a. Electrostatic sectors (ESA, electrostatic analyzer).
   i. From the main menu remove all PAs from Ram and push View then **ESA.iob**.
   ii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** and **_az_Angle_Off_Vel_Axis** to 0.2 degrees, Fly, and push the **XZ** view button. Zoom in on the exit region of the ESA.
   iii. On the Normal tab push the Def button and look at what the energy is for each of the beams. Change the energy of the high and low energy beams and see what the energy resolution is.
   iv. Now on the Fly'm screen set the angles to 0.5 degree and the _z_Random_Offset_mm to 1 mm and fly. Now what energy resolution could we expect?
b. Retarding field energy filters
   i. From the main menu remove all PAs from Ram and push View then **RPQ.iob**.
   ii. **Fly'm,** set the **_el_Angle_Off_Vel_Axis** and **_az_Angle_Off_Vel_Axis** to 0.2 degrees, Fly. Zoom in on the lens.
   iii. Draw a rectangle around the lens and push the +Z3D button on the WB View tab, then switch to the the PE View tab. You can zoom in on part of the lens to see how it is operating.
   iv. On the Normal tab push the Def button and look at what the energy is, change it to 4990 eV. , push OK and Fly'm again. What happens?
   v. Select the WB View tab, and the Contur tab, set the value in the blue panel to 4990, push the Insert and Draw buttons. You can see that the ions make it up to the 4990 contour and then are turned around. You can see the contours on the PE View as well.
   vi. Change the ion energy until you find the point at which ions start to leak through. This is the effective filter resolution.
   vii. Change the ion energy to 5000 volts, Select the PAs tab, set the instance number to 2, push Edit, More, and change the El value to 2 degrees, then fly'm. Push the Align button (left hand side) and zoom in on the lens. Do all of the ions make it through now? A 2 degree rotation corresponds to about a 3 mm offset of the back of the lens.
   viii. Push the Align button again. Set the El value back to zero, push the Back key and change the Ywb- value to 2.0 and fly'm. Zoom in on the lens. How does this change affect the transmission through the lens? Alignment of this lens is crucial for good transmission.
3. Complete instruments
   a. Triple sector (BBQ) with modified VG 54 ion lens