Some questions from Lecture 5 (Berg):

1) Why are there 189 Characteristic Rays (see Procedure CHARAY)?
2) How realistic is Gaussian distribution for the incoming beam?
3) Difference between dispersive focus and achromatic focus.
4) On ST. GEORGE the reactions that push the energy acceptance (+/- 8%) also pushes the angular acceptance (+/- 40 mrad). This doesn't seem to be true in SECAR: 15O(p,g)19Ne pushes the energy acceptance (+/- 3.1%) but not in the angular acceptance (only +/- 15.6 mrad vs. SECAR's +/- 25 mrad acceptance). Is there a reason SECAR was designed with angular acceptance so much larger than the energy acceptance?
5) Purpose of SECAR Section 3?
6) On slide 6, what is the meaning of the arrows the Effective Field Length and Good Field Regions?
7) Extended target for SECAR?
8) Enge function (not from this Lecture)?
9) Is Q1 (Quad + Hex) used or only a design feature?
10) x_HO = (x'|x)*2_0 + HO, how are the higher order terms (HO) added
11) Clarify D in the definition of the Nominal Beam definition
12) Why is the alignment adjusted before and after the ion optical element?
13) Can the recirculatory- ring for projectile beam increase the nuclear reaction rate? I.E. can we return the projectile beam (passed through the target) to the beam again.
14) Alignment example not clear.
15) Does higher order effects give us details about the initial beam characteristic? Or do HO effects tell us that the beam line is different than what we think? (e.g. field imperfections in the magnets etc.)

Question 1)

Why are there 189 Characteristic Rays (see Procedure CHARAY)?

Answer: The Characteristic rays are used to characterize the image size in the focal plane of e.g. SECAR by calculating vmax-vmin of a grid pattern in the acceptance ellipsoid in x, a, y, b, and E. This allows to calculated the “Resolution” including higher order aberrations. The finer the grid and the more rays are used the more realistic this approach is. However, the time to calculate will quickly increase for more than a few hundred rays, in particular if higher orders are calculated and optimized

As a compromise, SECAR was optimized using 189 rays. To ensure that this is sufficiently high the optimization result was tested using several thousand rays in a Monte Carlo simulation. The number 189 is not magical, it came as the result with the particular choice of the grid (see COSY input file for SECAR). A finer grid with about 800 was used initially, but the computing time became too long for higher order calculations and corrections.

Question 2)

How realistic is Gaussian distribution for the incoming beam?

Answer: The short answer is “not likely”. Beams are produced by different ion sources and accelerated by a variety of accelerators with different properties. While it is a good assumption that the beam intensity distribution may be peaked in the center of the beam, a Gaussian is at best a rough representation near the center. At distances of several sigma from the center, the Gaussian assumption is surely not realistic. Also the beam profile may change with time during an experiment and beam profile measurements are difficult to conduct. This is one of the difficulties in bringing the calculated ion-optics in agreement with measured properties.

For the design of SECAR we define the “Nominal Beam Rejection” assuming a Gaussian beam distribution, lacking better knowledge of the real beam distribution of the ReA3 beam, to optimize the beam rejection and to compare the beam rejection of different recoil separators types. Here the assumption is that a real beam rejection will be better if it is better under the assumption it is Gaussian.

The justification that SECAR needs a mass separation of m/dm > 750 to achieve a beam rejection of !0E-13 is not based on the Nominal Beam rejection. It is based on experience with the DRAGON recoil separator, that achieved about m/dm = 350 for masses up to about A = 30 and SECAR’s goal to study masses up to A = 65.

Question 3)

Difference between dispersive focus and achromatic focus.

Answer: The expression " dispersive focus" is a misnomer. At a focus R12 = (x|a) = 0, in dependently of what the dispersion is If in addition the dispersion R16 is NOT zero, like in the focal plane of a spectrometer, this may be called "casually" a dispersive focus although it is recommended to say that there is a focus and the momentum dispersion is e.g. R16 = 17 cm/% like in the focal plane of the GRAND RAIDEN spectrometer.

An "achromatic focus" is an accepted expression, referred to: R12 = 0 and R16 = 0, and R26 = 0, i.e. there is a focus, the spatial dispersion is zero and the angular dispersion is zero. "Chromatic" refers to "momentum" or "energy" and "achromatic" means no dependence on "momentum" or "energy" i.e. R16 = R26 = 0

Question 4)

On ST. GEORGE the reactions that push the energy acceptance (+/- 8%) also pushes the angular acceptance (+/- 40 mrad). This doesn't seem to be true in SECAR: 15O(p,g)19Ne pushes the energy acceptance (+/- 3.1%) but not in the angular acceptance (only +/- 15.6 mrad vs. SECAR's +/- 25 mrad acceptance). Is there a reason SECAR was designed with angular acceptance so much larger than the energy acceptance?

Answer: The reaction for ST. GEORGE that requires the large angular (about +/- 40 mrad) and energy (about +/- 8%) acceptances is 18O(alpha,gamma)22Ne at 0.35 MeV center of mass energy. The reaction that determines the maximum acceptances for SECAR is a different reaction, namely 15O(alpha,gamma)19Ne [not (p,g) as the question quotes by mistake!] at 0.5 MeV center of mass energy. The differences in emittances and energy spread are purely kinematics and are caused by the different Q-values and the different center of mass energies.

Question 5)

Purpose of SECAR Section 3?

Answer:

SECAR Section 1 selects a single charge state.
Section 2 with Wien Filter 1 separates the “bulk” of the beam with a mass separation of m/dm about 500
Section 3 with Wien Filter 2 separates the remaining beam with a mass separation of m/dm about 750
Section 4 further cleans up the beam and prepares it for full transmission through the detector system.

Question 6)

On slide 6, what is the meaning of the arrows the Effective Field Length and Good Field Regions?
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Answer: In the upper, horizontal plane, the rectangle represent magnetic elements. The width (z direction) Is the Effective Field Length, the height (x direction) is the Good Field Region.

Question 7)

Extended target for SECAR?

Answer: The gas-jet target of SECAR has a diameter of 2 – 3 mm in the horizontal plane. The (p,gamma) reaction rate of a low-lying astrophysically relevant reaction can be measured if the energy of the beam is just right to be exited. If the resonance is not well known the beam energy may be incorrect and the resonance may be missed.

Here the “extended target” comes to the rescue. The extended target of SECAR is a 12 cm long tube (compared To 2 -3 mm of the jet), and is filled with the target gas. Since no window can be used to seal of the ends, a lot of pumping is provided outside the tube. The energy along the extended target covers a range of energies defined by the beam energy minus the energy loss. If the (not well known) energy of the resonance is within this energy range the resonance is still excited somewhere along the 12 cm long extended target.

This technique is successfully used at the DRAGON recoil separator and will be used at SECAR.

Question 8)

Enge function (not from this Lecture)?.

Answer: Owing to time limitations I only mentioned that Enge function is used to describe the fringe field drop-of at the entrance and exit of magnet without defining it. Please see Answer to Question 6 “Define fringe field” of the previous Lecture 2 (my Lecture 2, Lecture 3 in the overall numbering of Lectures).

Question 9)

Is Q1 (Quad + Hex) used or only a design feature?

Answer: Quadrupole one is designed and built as Multipole, i.e. a quadrupole and a hexapole, that can be excited with separate power supplies. The hexapole at the beginning of the SECAR system, was found to be very efficient to correct hexapole aberrations. Since there was not space for a separated hexapole magnet, the hexapole was built into the quadrupole.

Question 10)

x_HO = (x'|x)*2_0 + HO, how are the higher order terms (HO) added

Answer: The image size x_HO including HO effects are calculated by performing 4th order COSY calculations for the 189 Characteristic Rays at the focal planes and extracting x_max minus x_min from the RAY(1) array.

Question 11)

Clarify D in the definition of the Nominal Beam definition.

Answer: D is defined on slide 7 of Lecture 5 (my Lecture 4!). It is the distance of the beam and recoils owing to the mass separation (x|m)*dm divided by x_HO the image size including higher order effects. The previous Question 10) explains how x_HO is calculated.

Question 12)

Why is the alignment adjusted before and after the ion optical element?

Answer: As explained in the COSY Beam Manual, a misalignment command is applied to the complete downstream System, unless reversed by a corresponding command after e.g. an element. Since the misalignment parameters are given for each element, the misalignment is applied in front of each element and reversed after each element.

Question 13)

Can the recirculatory- ring for projectile beam increase the nuclear reaction rate? I.E. can we return the projectile beam (passed through the target) to the beam again.

Answer: The luminosity (reaction rate) in a Storage Ring is increased by the circulation frequency and decreased by the target thickness that is limited by the emittance increase in the target. Both factors are of similar magnitude so the luminosity is in praxis not much larger in Storage Rings. The energy loss in the target can be compensated relatively easily by an RF in the Ring, but the increase of the emittance in the target would require and Electron Cooler (see Cooler Storage Rings) because of the relatively low energy.

Question 14)

Alignment example not clear.

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DL 0.80+0.000106;                                              {DL1}

TA -0.0299 -0.0435; {Pitch Yaw}
RA 0.0035; {Roll}
SA 0.000290 -0.000002; {x, y}
M5 0.250 -0.400180+0.0008 -0.004421+0.0041 0 -0.00318 0 0.055;{Q1+Hex}
SA -0.000290 0.000002;
RA -0.0035;
TA 0.0299 0.0435;

DL 0.19+0.00105-0.0000106;                                      {DL2}
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Answer: The misalignment of an element is given by misalignment (x, y, and z) of the center of the element and misaligned orientation (Roll, Yaw, and Pitch). The example of the misalignment applied to Q1 of SECAR (Q1+Hex is defined by the M5 command) was given as shown in the insert. The misalignment commands In front of the M5 command are TA, RA for the orientation, the SA command for the x and y misalignment.
The z misalignment is given by the Command DL 0.80+0.000106.

As explained in Question 12) above, the misalignment has to be reversed after the element (M5 command) to limit its effect to this element. See example.

Question 15)

Does higher order effects give us details about the initial beam characteristic? Or do HO effects tell us that the beam line is different than what we think? (e.g. field imperfections in the magnets etc.)

Answer: The COSY input file and calculation of the recoils separators do not calculate anything about the properties of the incoming beam neither in first nor higher order. The incoming beam is given by input parameters that come from calculations or measurements of the beam.

COSY calculates the maps, matrix elements in arbitrary order in response to the fields and imperfections as long as they are realistically parametrized and entered with the appropriate commands that are available in COSY.