High Resolution Separator for DESIR

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Outline

- Design goals for the High Resolution Separator (HRS)
- Proposed layout:
  - Argonne CARIBU as an starting point
- Ion optics discussion
- Outlook
Layout showing DESIR location
 Beam emittance:

1 \( \pi \) mm mrad for a 1 \( \mu \)A beam at 60 keV

More conservative:

10 \( \pi \) mm mrad for a 100 nA beam at 60 keV

\[
\varepsilon = \frac{\pi}{4} \delta x \cdot \delta a
\]

\( \delta x \) \(\rightarrow\) beam width
\( \delta a \) \(\rightarrow\) angular acceptance

Beam start with 1mm width, and \( \pm 20 \) mrad
HRS Design Goals

- Resolving power:

  **Ideal case:**
  \[ R = \frac{m}{dm} \]
  \[ R = \frac{(x \mid \delta)}{2x_{00}(x \mid x)} = \frac{D}{2x_{00}M_x} \]

  Aberrations decrease the resolving power:
  \[ R = \frac{(x \mid \delta)}{2x_{00}(x \mid x) + \Delta} \]

  \( \Delta \) is the total amount of aberrations

  To second order
  \[ x_f = (x \mid x)x + (x \mid a)a + (x \mid \delta)\delta + (x \mid xx)x^2 + (x \mid xa)x + (x \mid xx\delta)x\delta \]
  \[ + (x \mid aa)a^2 + (x \mid a\delta)a\delta + (x \mid \delta\delta)\delta^2 + (x \mid yy)y^2 + (x \mid yb)y + (x \mid bb)b^2 \]

  \( x \) and \( y \) are the horizontal and vertical positions, \( a \) and \( b \) (\( \rho_x/\rho_\phi \)) and (\( \rho_y/\rho_\phi \)) and \( \delta \) the change in total energy (\( E-E_\phi/E_\phi \)) of the particle

In order to obtain high resolution, a large value of \((x \mid \delta)\) and small values of \((x \mid x)\) and \(\Delta\) are desirable.
Resolving powers needed

Some representative cases:

<table>
<thead>
<tr>
<th>Nuclei</th>
<th>Mass</th>
<th>R neighbor</th>
<th>R for $^{132}\text{Sn}$</th>
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<td>$^{132}\text{Cd}_{48}$</td>
<td>131.9455500</td>
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To separate $^{132}\text{Sn}$ from $^{132}\text{Sb}$
R~40000
Resolving powers needed

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For $^{78}\text{Ni}$ R< 7000

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R~ 20000
 Proposed layout

- CARIBU Isobar separator @ Argonne as an starting point

Mass resolution $M / \Delta M \geq 20,000:1$

Beam emittance $< 3\pi$ mm-mr at 50 keV

Focussing and corrective elements are all electrostatic, settings are independent of mass
Symmetric design helps to minimize aberrations.

Large mass dispersion (x|δ) and small aberration coefficients are obtained by increasing the incident and exit angles at the boundary of a magnetic sector.

For CARIBU 23° was chosen for the 60° bending dipoles

Quadrupoles are used as the focusing mode in the y-direction and the defocusing mode in the x-direction.

By choosing suitable distances and fitting the quadrupole strengths, a beam profile in the dipole gap can be made very wide in the x-direction and narrow in the y-direction, attaining two advantages simultaneously:

- High transmission
- Small image magnification (x|x) to attain high resolution
The quadrupole doublet matching section produces a ribbon-shaped beam, so y-angles are small, minimizing $b$ aberrations.

The first quadrupole diverges in $x$ and converges in $y$, giving a small $y$ size which minimizes $y$ aberrations.

The large $x$ area in the magnets gives mass dispersion.

Focus conditions in centre: $(a|a)=(y|b)=(b|y)=0$

The reverse matching section transforms the ribbon-shaped beam back to a circular cross-section, allowing a 1 mm $x$-selection slit at the focal plane.

The 2 sextupoles and 1 multipole to correct aberrations to 5th order.

COSY INFINITY 9.0 for the ion optics calculations.
CARIBU

3 x’s, 3 y’s, 3 θ’ s, 3 ϕ’ s, 1 mass, 1 energy

3 π mm mrad, 50 keV

R = 22091
COSY INFINITY X- and Y-projections

Same parameters as CARIBU,
3 x’s, 3 y’s, 3 θ’s, 3 φ’s, 1 mass, 1 energy
but 1 π mm mrad, 60 keV

R ~ 42000
Summary: proposed layout for DESIR HRS

→two 60° dipoles $\rho=50$ cm, $\beta=23^\circ$ (DI)

→four matching quadrupoles 4 cm x 20 cm (EQ)

→two focus quadrupoles 8 cm x 24 cm (EQ)

→two focus sextupoles 4 cm x 12 cm (EH)

→one multipole (sextupole, octupole, decapole and duodecapole) 4 cm x 24 cm (E5)
Mass resolving power of at least ~20000 is desirable for DESIR High Resolution Separator.

This high resolution can be achieved using the CARIBU isobar separator scheme as an starting point.

COSY INFINITY is being used for the ion optics calculations and to track particles through the separator.

Ion optics simulations are in process for the optimal design of the HRS.