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High Resolution Separator for DESIR

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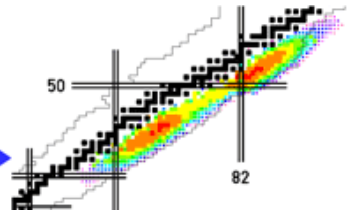
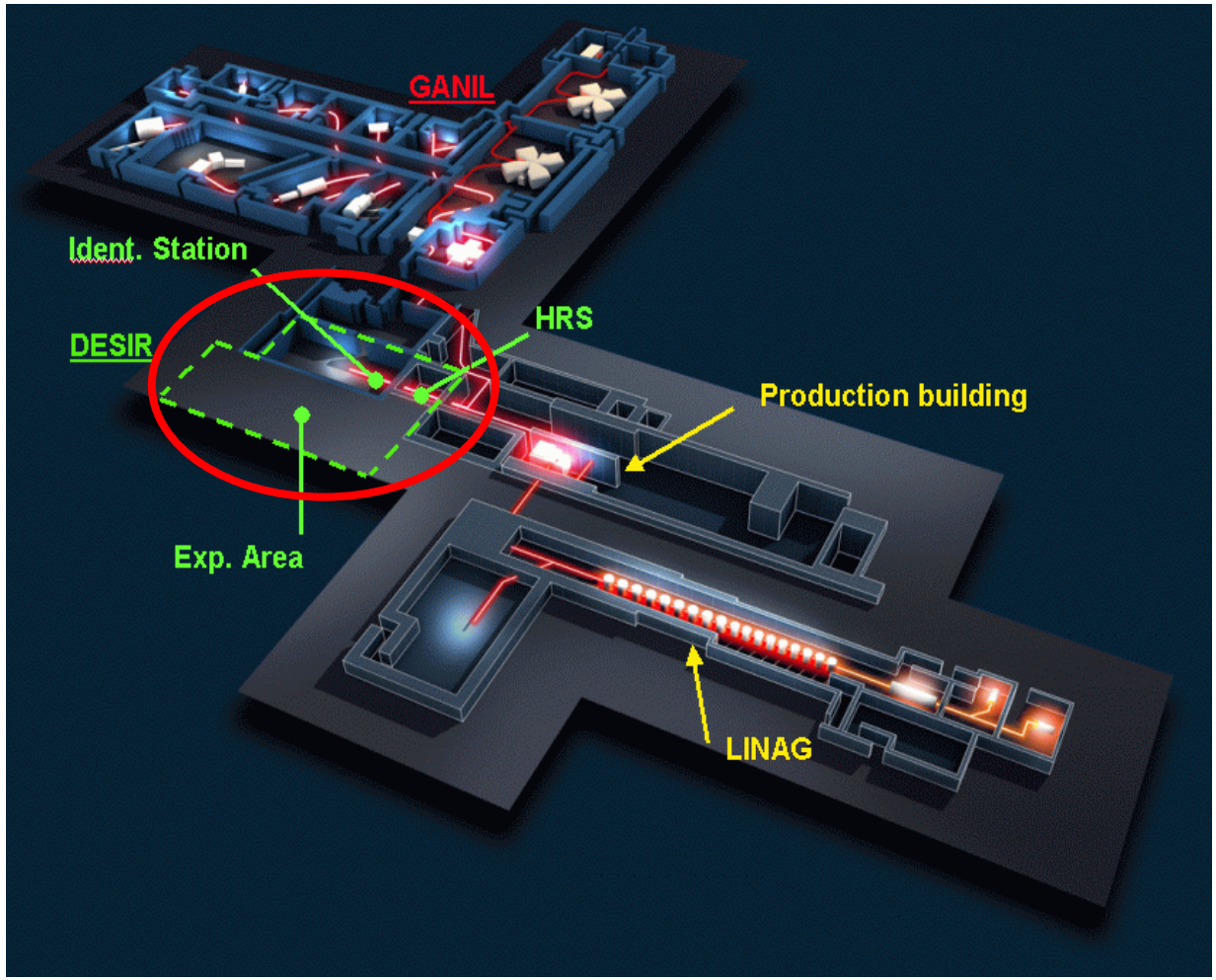
Spiral2



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



HRS Design Goals

- Beam emittance :

1 π mm mrad for a 1 μA beam at 60 keV

More conservative:

10 π mm mrad for a 100 nA beam at 60 keV

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

δx → beam width

δa → angular acceptance

Beam start with 1mm width, and ± 20 mrad

HRS Design Goals

- Resolving power:

Ideal case:

$$R = \frac{m}{dm}$$

$$R = \frac{(x|\delta)}{2x_{00}(x|x)} = \frac{D}{2x_{00}M_x}$$

Aberrations decrease the resolving power:

$$R = \frac{(x|\delta)}{2x_{00}(x|x) + \Delta}$$

Δ is the total amount of aberrations

To second order

$$x_f = (x|x)x + (x|a)a + (x|\delta)\delta + (x|xx)x^2 + (x|xa)xa + (x|x\delta)x\delta$$
$$+ (x|aa)a^2 + (x|a\delta)a\delta + (x|\delta\delta)\delta^2 + (x|yy)y^2 + (x|yb)yb + (x|bb)b^2$$

***x* and *y* are the horizontal and vertical positions, *a* and *b* (p_x/p_0) and (p_y/p_0) and δ the change in total energy ($E-E_0/E_0$) of the particle**

In order to obtain high resolution, a large value of (x|δ) and small values of (x|x) and Δ are desirable.

Resolving powers needed

- Some representative cases:

Nuclei	Mass	R neighbor	R for ^{132}Sn
$^{132}Cd_{48}$	131.9455500	10103	4756
$^{132}In_{49}$	131.9324903	8991	8990
$^{132}Sn_{50}$	131.9178157	39392	
$^{132}Sb_{51}$	131.9144669	22306	39392
$^{132}Te_{52}$	131.9085532	237340	14242
$^{132}I_{53}$	131.9079974	34316	13436
$^{132}Xe_{54}$	131.9041535	57832	9656
$^{132}Cs_{55}$	131.9064343	96074	11591
$^{132}Ba_{56}$	131.9050613		10343

To separate ^{132}Sn from ^{132}Sb

R~40000

Resolving powers needed

Nuclei	Mass	R neighbor	R for ^{78}Ni
$^{78}Ni_{28}$	77.9631800	6949	
$^{78}Cu_{29}$	77.9519600	5766	6949
$^{78}Zn_{30}$	77.9384402	11408	3151
$^{78}Ga_{31}$	77.9316082	8901	2469
$^{78}Ge_{32}$	77.9228527	75988	1933
$^{78}As_{33}$	77.9218273	17249	1885
$^{78}Se_{34}$	77.9173099		1700

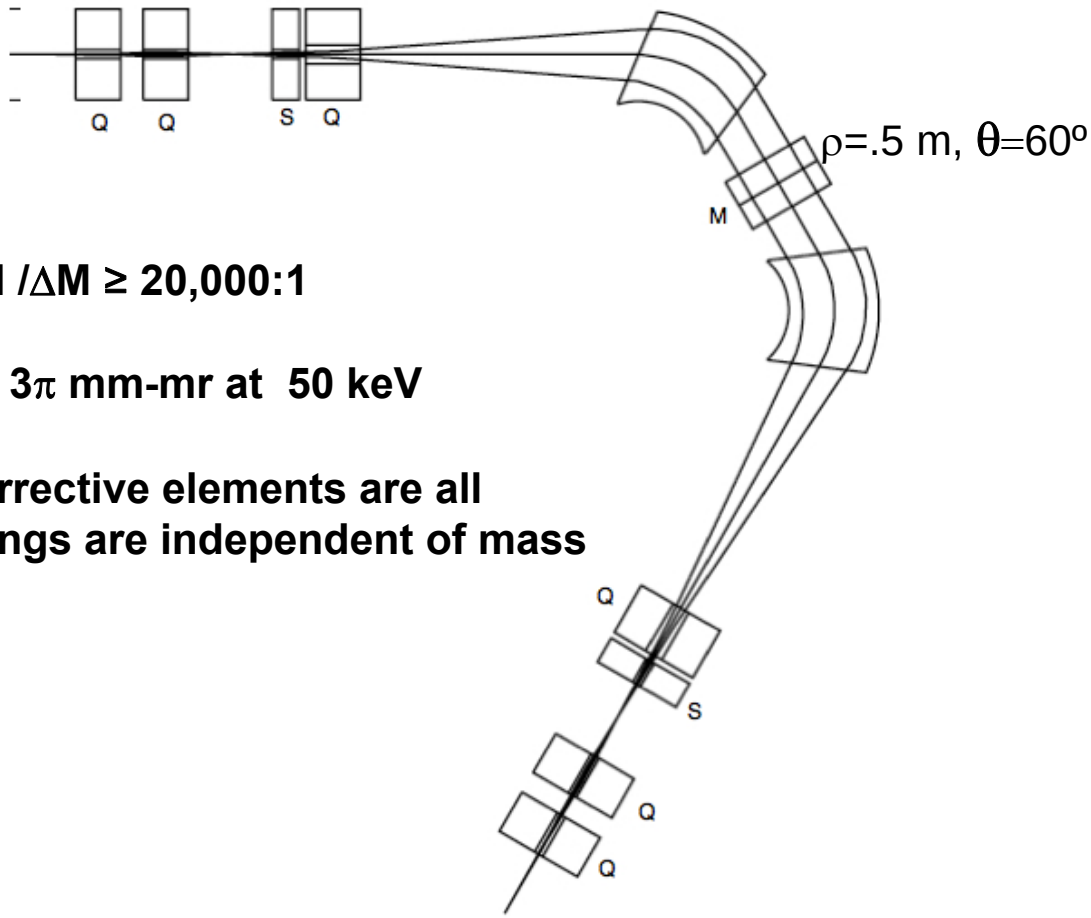
For ^{78}Ni R< 7000

R~ 20000

Nuclei	Mass	R neighbor	R for ^{31}Ar
$^{31}Ar_{18}$	31.0121230	1573	
$^{31}Cl_{17}$	30.9924131	2410	1573
$^{31}S_{16}$	30.9795547	5348	952
$^{31}P_{15}$	30.9737616	19339	808
$^{31}S_{14}$	30.9753632	3609	844
$^{31}Al_{13}$	30.9839466	2459	1101
$^{31}Mg_{12}$	30.9965460	1819	1991
$^{31}Na_{11}$	31.0135855	1588	21206
$^{31}Ne_{10}$	31.0331100	1136	1478
$^{31}F_{9}$	31.0604290		642

Proposed layout

- **CARIBU Isobar separator @ Argonne as an starting point**



Mass resolution M /ΔM ≥ 20,000:1

Beam emittance < 3π mm-mr at 50 keV

Focussing and corrective elements are all electrostatic, settings are independent of mass

Ion optics discussion

- 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 23º was chosen for the 60º 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

Ion optics discussion

- 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

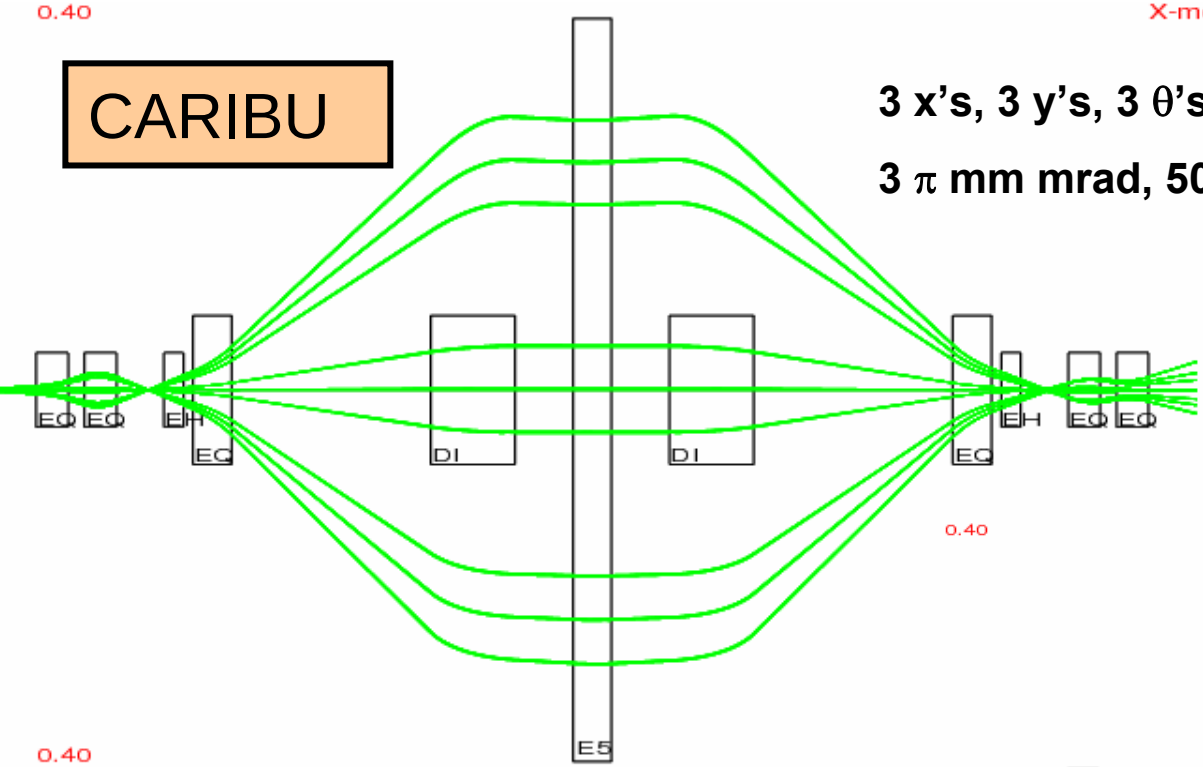
COSY INFINITY X- and Y-projections

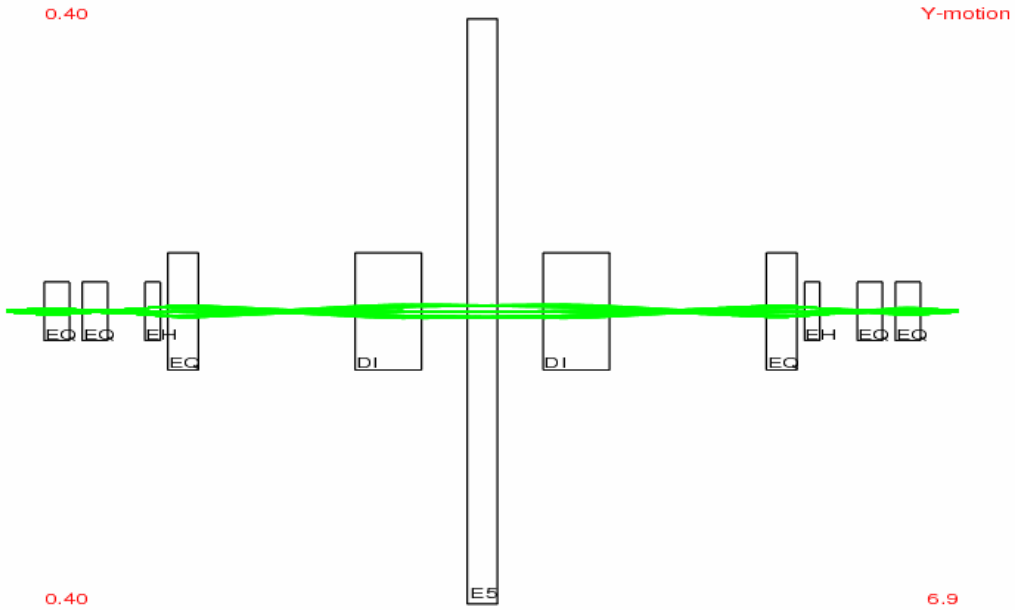
CARIBU

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

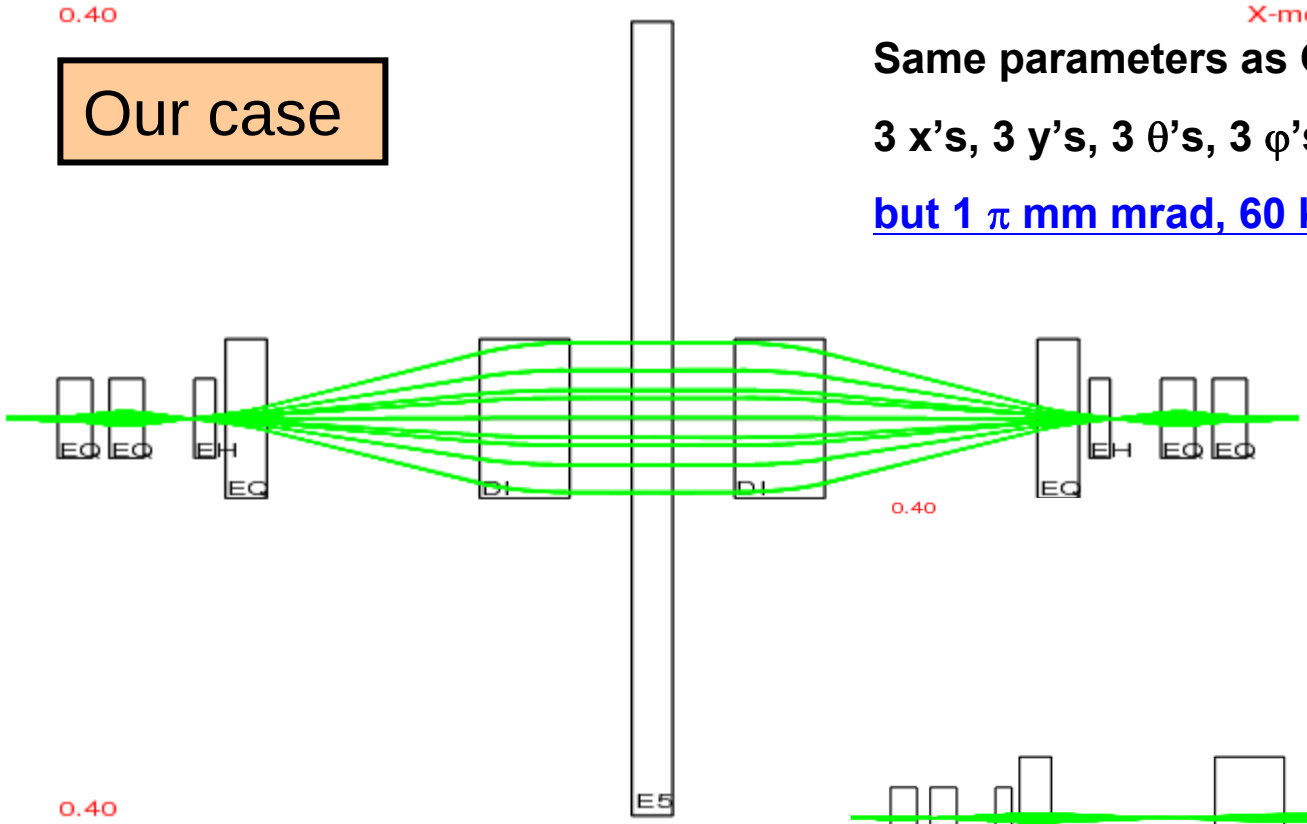
Our case

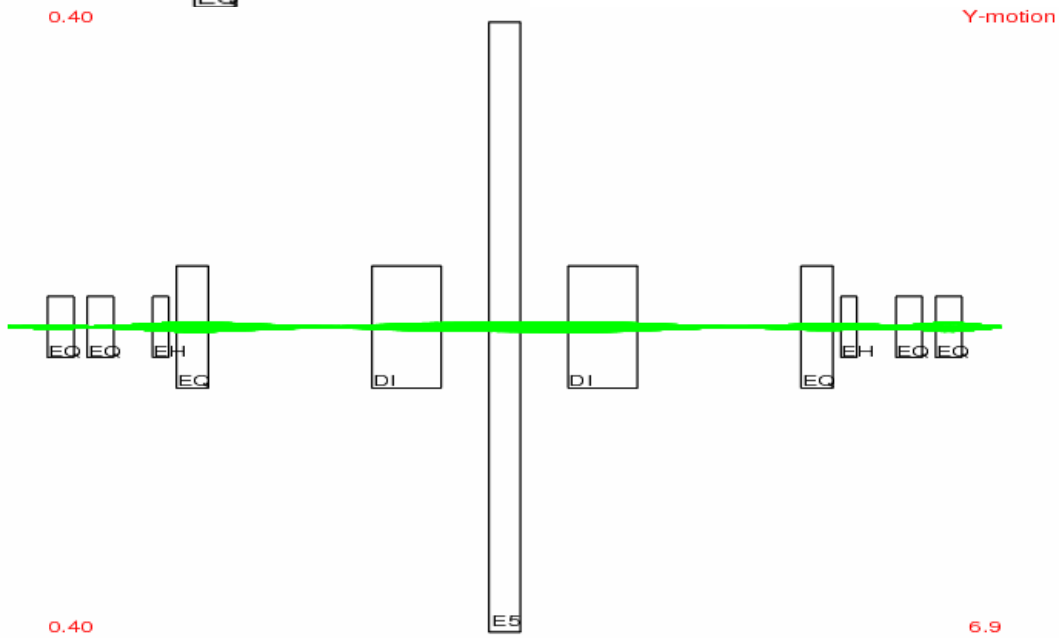
Same parameters as CARIBU,

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

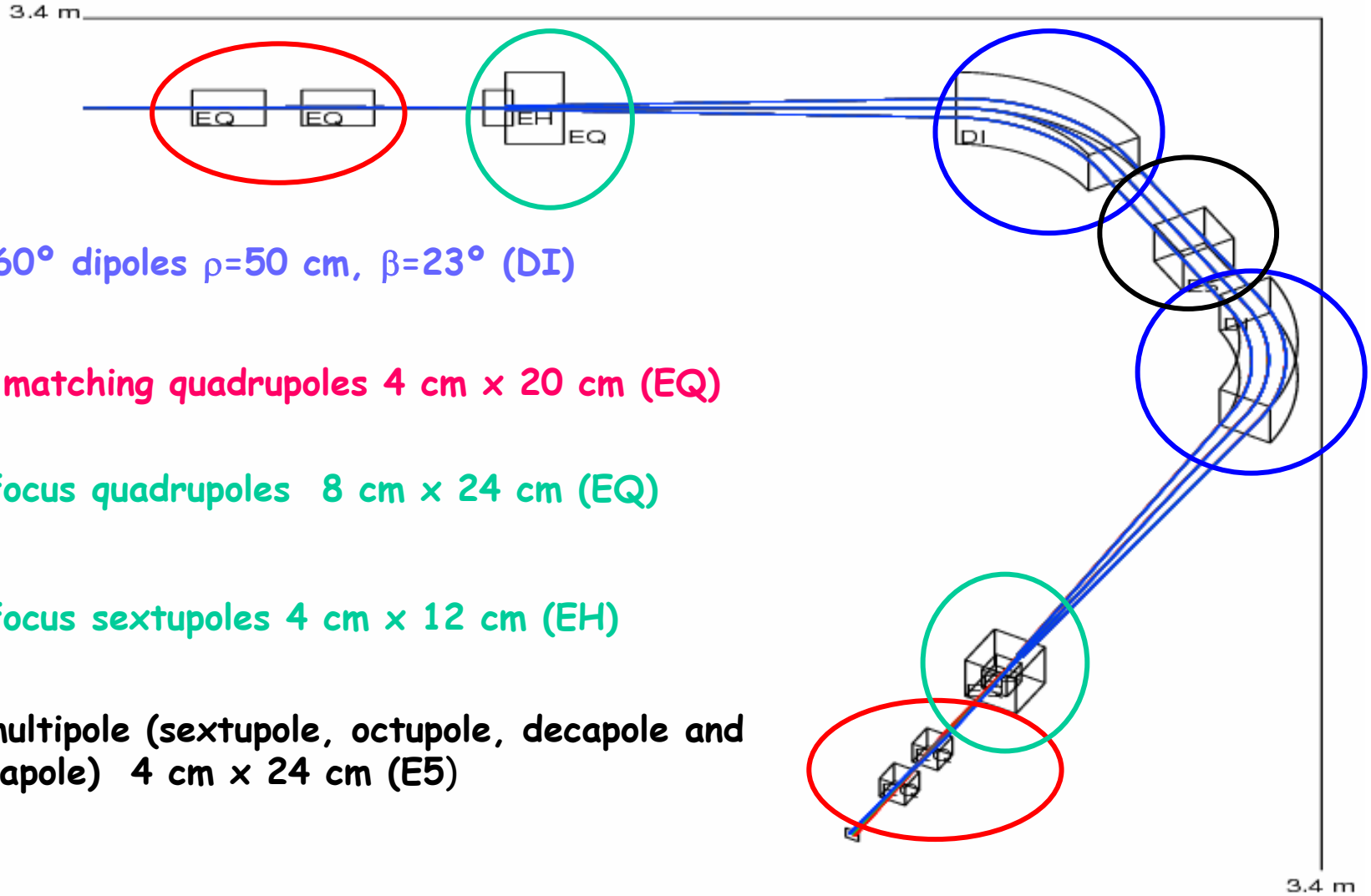
but 1 π mm mrad, 60 keV

R ~ 42000





Summary: proposed layout for DESIR HRS



→two 60° dipoles ρ=50 cm, β=23° (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)

Outlook

- 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