
STRATEGY

FOR THE TRANSVERSE

PHASE SPACE

presented by
P.J. Bryant

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PS, CERN

GENERAL

- The present aim is to design to a second-generation medical synchrotron that has customised lattice functions to perform specific tasks in different sections of the machine and to implement active energy variation and positional scanning. First-generation machines are characterised by regular lattices with passive scattering systems for changing beam momentum and shape.
- The natural starting point is the resonance extraction and the conditions it imposes upon the machine design.
- Transverse and longitudinal problems will, in many cases, be treated separately, for convenience.

The initial questions are:

- How do we manipulate the resonance and the waiting stack?
How do we layout the components for the resonant extraction?
How do we adapt the lattice to achieve the desired result?
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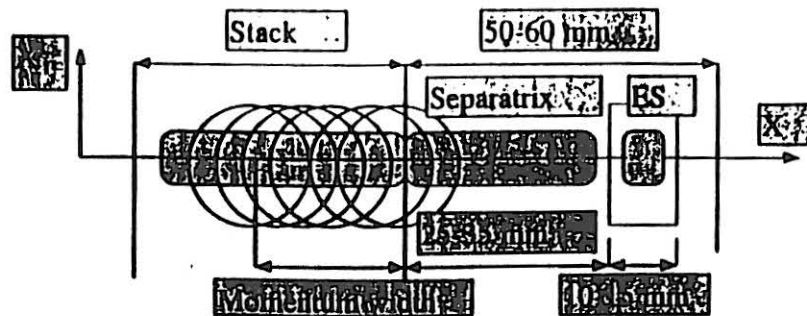
LAYOUT OF APERTURE

•The resonance needs to be in (or near) the centre of the chamber to give a balanced aperture for the growth of the separatrices.

•For negative chromaticity ($Q' < 0$) the waiting stack must be

In outer half of chamber, if below resonance	In inner half of chamber, if above resonance
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•Approximate dimensions should be:



•Extra aperture and a single passage through the “poor field” region might be needed between the electrostatic and magnetic septa.

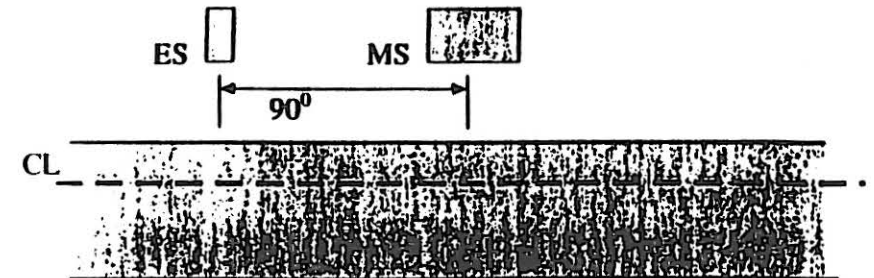
•It is likely that the separatrices (during their final 3 turns) define the maximum aperture requirement.

•The closer the ES is to the resonance, the shorter the separatrices, but the stronger the sextupole, which has a number of disadvantages.

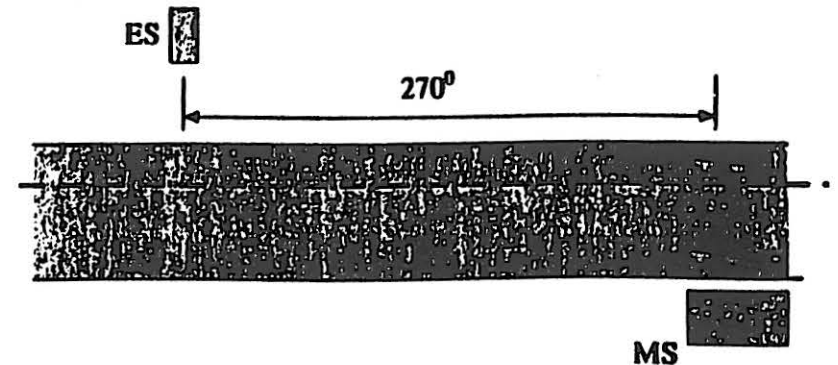
LAYOUT OF EXTRACTION ELEMENTS

Two principal possibilities exist:

• Septa on the same side of the chamber (inner or outer)



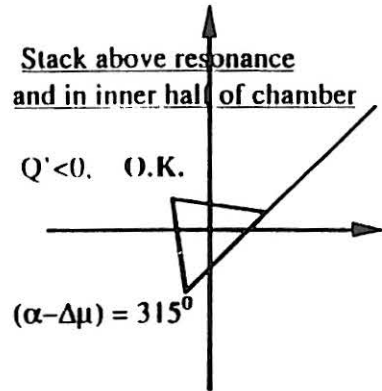
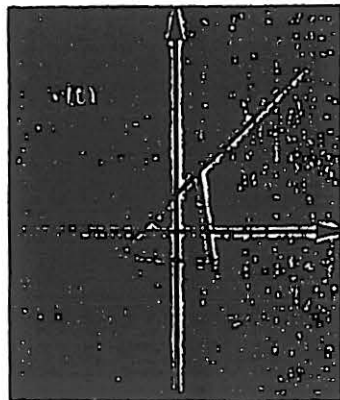
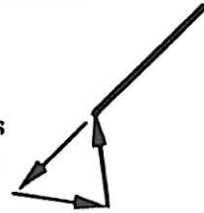
• Septa on opposite sides of chamber



• The electrostatic and magnetic septa will be at approximately equal distances from the centre line, since the electrostatic septum is best positioned at the 45° point on a “rising” separatrix and the magnetic septum at 45° on a “falling” separatrix.

1ST & 3RD QUADRANT OPERATION

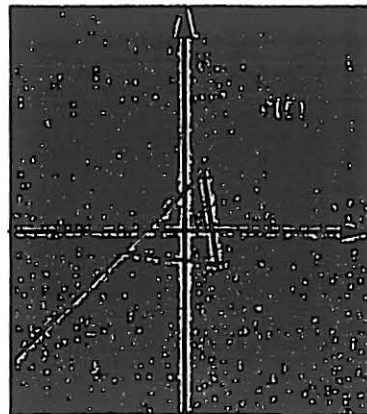
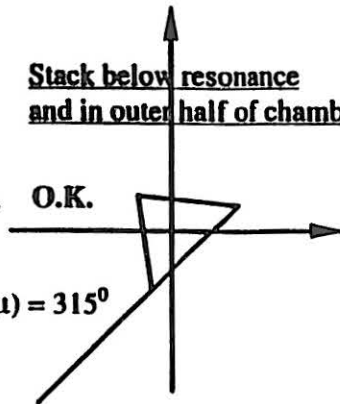
- Note: Anti-clockwise rotation = below resonance
- Negative chromaticity rules out the two possibilities for $(\alpha - \Delta\mu) = 135^\circ$ in 1st & 3rd quadrants (see earlier)



Stack below resonance
and in outer half of chamber

$Q' < 0$, O.K.

$(\alpha - \Delta\mu) = 315^\circ$



Second Conclusion

Of the above two possibilities, the stack positioned above resonance in the inner half of the chamber with 90° phase advance between the septa is preferred. This determines the term $(\alpha - \Delta\mu)$ for the Hardt Condition to be 315° .

The second choice is the stack below resonance in the outer half of the chamber, but with 270° phase advance to bring the magnetic septum to the outside for easy extraction. This again determines the term $(\alpha - \Delta\mu)$ for the Hardt Condition to be 315° .

• Operation of the ES in the 2nd and 4th quadrants was ruled out by losses on the septum wires (see Hardt Condition).

• The 270° phase advance is not ruled out, but has two unfavoured aspects: Firstly, it is more likely that it will be necessary to accept a sextupole between the electrostatic and magnetic septa, which puts a variable element into the extraction geometry if the resonance excitation and/or chromatic conditions are changed.

Secondly, it feels, intuitively, that aperture will be lost for the stack by "encasing" it between the two septa. However, that depends on the local lattice functions and may not be a valid objection.

BUILDING THE LATTICE

Two things are now required of the lattice for extraction:

- To satisfy the Hardt Condition with negative chromaticity.
- To provide a 90° , or 270° , achromatic transfer between the electrostatic and magnetic septa.

A number of candidate lattice types exist:

- "Square" lattice, using the "corner" dipoles to create dispersion bumps on two opposite sides and dispersion-free straight sections on the remaining two sides.
- The "extended-dispersion-bump" that increases the free space within the dispersion bump by adding a central dipole.
- Lattices that use two arcs separated by dispersion-free straight sections.
- It appears to be very difficult to satisfy all of the "ideal optics conditions" completely, but workable compromises can be found.
- Some discussion of the various lattice types can be found in the chapter Lattice Considerations.

THE FINAL STRATEGY

- Start from a lattice with two 360° -betatron-phase-advance, achromatic arcs, joined on each side by two dispersion-free straight sections.
- Place the electrostatic septum in the second half of the arc where the Hardt Condition can be adequately fulfilled.
- It is then necessary to relax the requirement of the achromatic transfer between the septa.
- Analytic solutions do exist for crossing dipoles achromatically, but in general these require more phase advance (at least 270°) than is conveniently available. Large phase advances also increase the possibility of having to include a sextupole between the septa.
- The first compromise is to search for a small m_{13} term and to leave the m_{23} term free.
- For the phase advance between septa, look for a compromise that fulfills the Hardt Condition and creates a reasonable gap for the MS while not creating a large m_{13} .