GAP-CROSSING RESONANCE IN CYCIAE-100 CYCLOTRON

Hongjuan Yao [1, 3], R. Baartman[2], Y.-N. Rao[2], Tianjue Zhang [1], Yuzheng Lin [3]

[1] China Institute of Atomic Energy, Beijing, 102413, P.R. China
[2] TRIUMF, Vancouver, V6T 2A3, Canada
[3] Department of Engineering Physics, Tsinghua University, Beijing, 100084, P.R. China

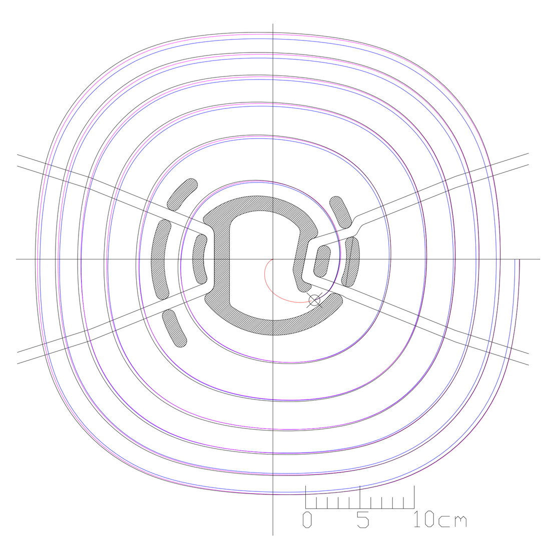
ABSTRACT

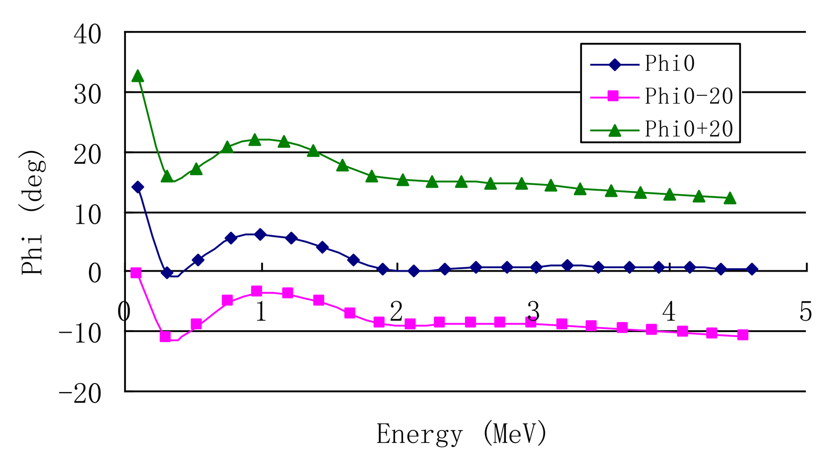
In simulations for the central region of CYCIAE-100, we found that the gap-crossing resonance causes mismatch of particles with different RF phases in the radial phase space: negative phases suffer less radial stretching and distortion, so they are more stable than the positive phases. But on the other hand, negative phases are electrically defocused. We carried out analytical calculations and compared with the simulation results. We were able to find best centering conditions and optimum Dee angles to minimize the mismatch and consequently maximize the acceptances in the radial, vertical and RF phase spaces.

CENTRAL REGION

Basic parameters

2 Dees, Harmonic No. is 4, RF freq. is 44.4 MHz, 60 kV;
Dee angle: 45°in Central Region, ~37°between 1st & 2nd gap, RF cavity 36°; 40keV , H^- ions.

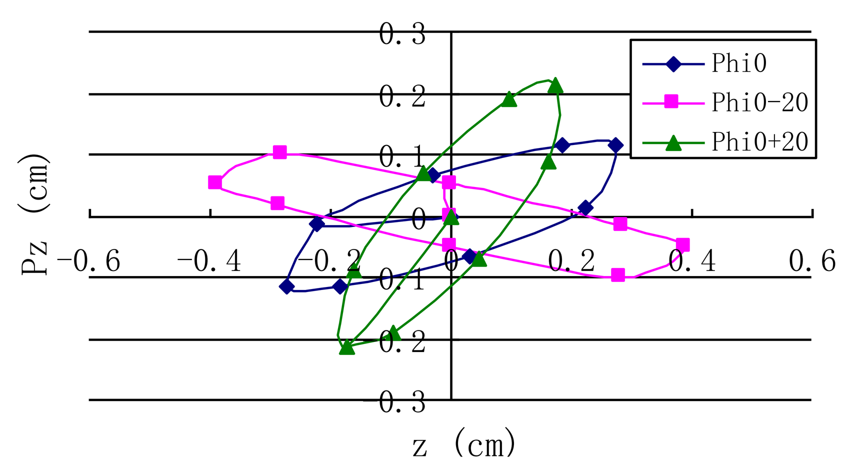




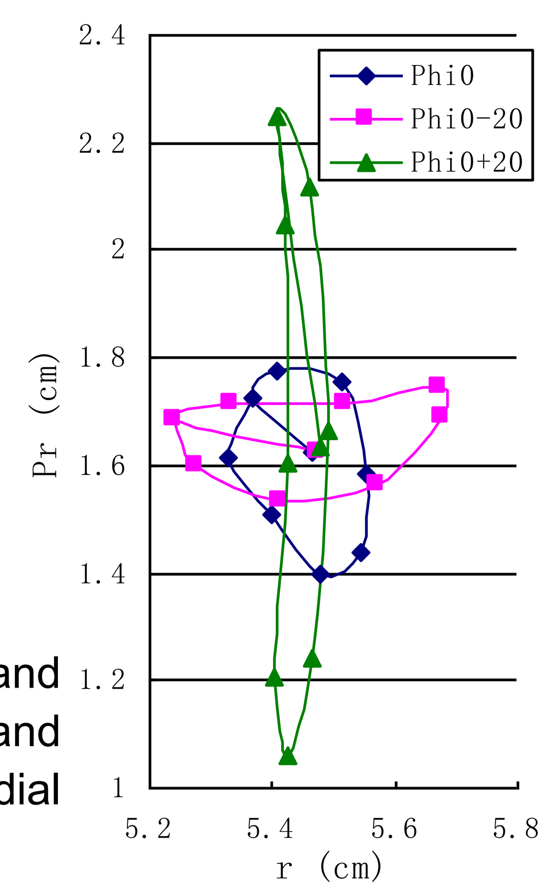
Note the phase slipping and also that an initial 40° phase band is bunched by the central region into 23°.

MATCHING CALCULATIONS

The negative phases become the dominant of the vertical acceptance.

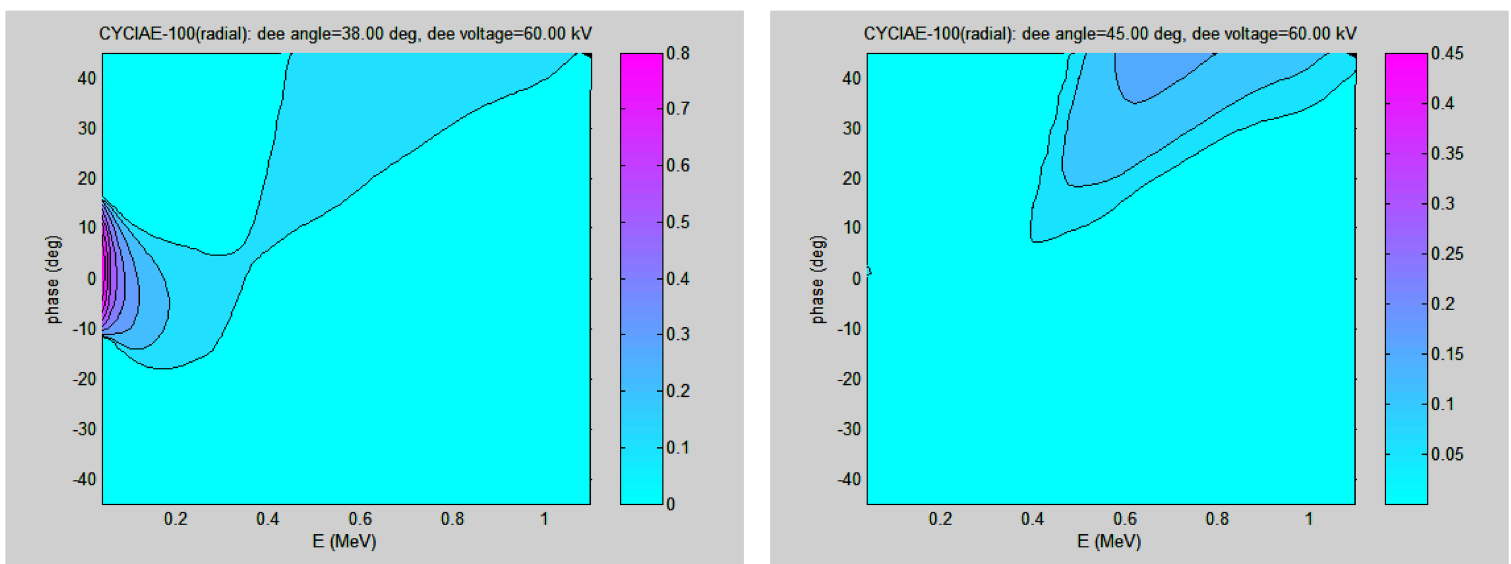


The radial phase space was distorted and negative phase suffer less radial stretching and distortion. The positive phase limits the radial acceptance.



RADIAL INSTABILITY

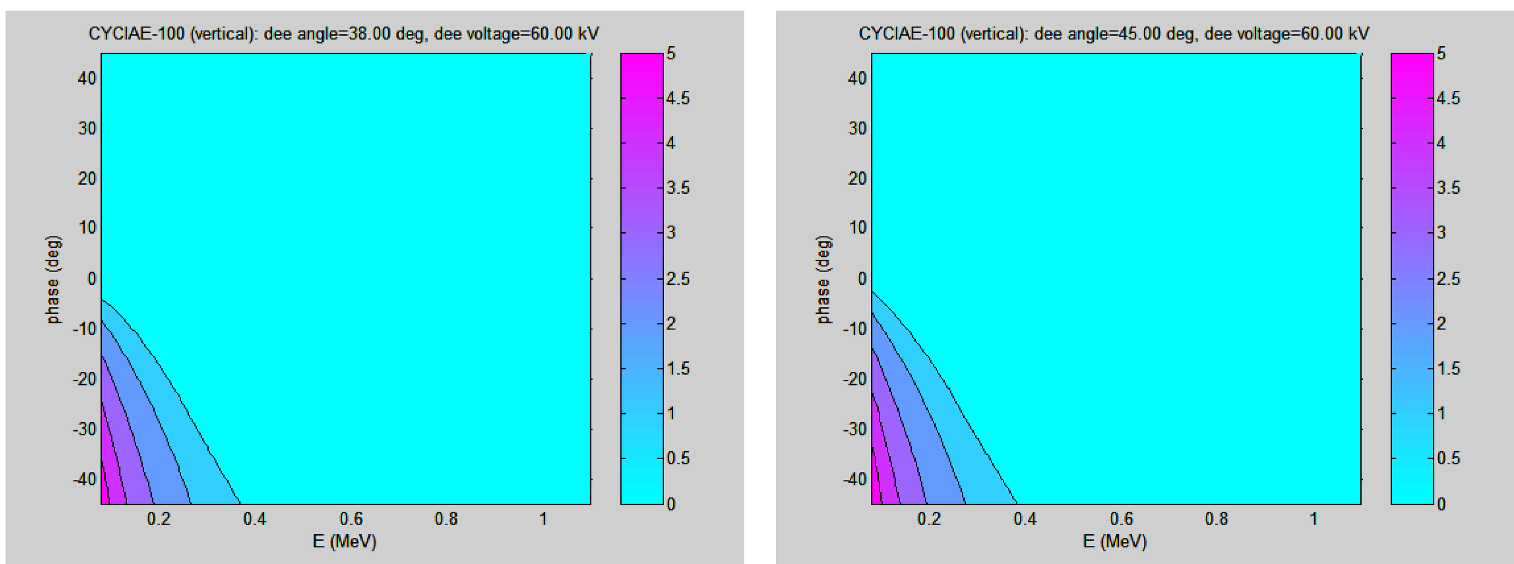
$$(\upsilon_r^* - 1)^2 = (\upsilon_r - 1)^2 - \frac{hqV_0 \sin\frac{hD}{2}}{\pi T_c}\sin\phi\cdot(\upsilon_r - 1) + \frac{1}{4}\left(\frac{hqV_0 \sin\frac{hD}{2}}{\pi T_c}\right)^2\left(\sin^2\phi - \cot^2\frac{hD}{2}\cos^2\phi\right)\sin(\pi - D)\cdot\sin D$$



◆ In radial phase plane, negative phases (early ones entering the Dee gap) are more stable than positive phases (late ones entering the Dee gap).
◆ Dee angle of 45° (sin (hD/2) =1) is preferred for central region, but not very strongly; a large range of phases will still have frequency near zero.

VERTICAL INSTABILITY

$$\upsilon_z^{*2} = \upsilon_z^2 + \frac{hqV_0 \sin\frac{hD}{2}}{\pi T_c}\sin\phi - \left(\frac{hqV_0 \sin\frac{hD}{2}}{\pi T_c}\right)^2\left(\sin^2\phi - \cot^2\frac{hD}{2}\cos^2\phi\right)\frac{\pi - D}{2}\cdot\frac{D}{2}$$



◆ The scale of the contours is bigger than the radial case, so the vertical instability is much stronger for the wrong phases.
◆ For different Dee angles the contour plot is almost the same.

SUMMARY

The central region has been carefully optimized to overcome the effects of vertical defocusing. It should be noted that the analytic calculations apply to particles with a constant energy, but in fact the energy changmore stable in radial phase plane and much stronger instability in vertical. The dee angle (denoted by D) in the central region satisfying sin (hD/2) =1 is preferred, which can minimize es non-adiabatically on the first turn and this reduces the effects of the vertical defocusing. For two-dee system one can say that negative phases are the mismatch at low energy.