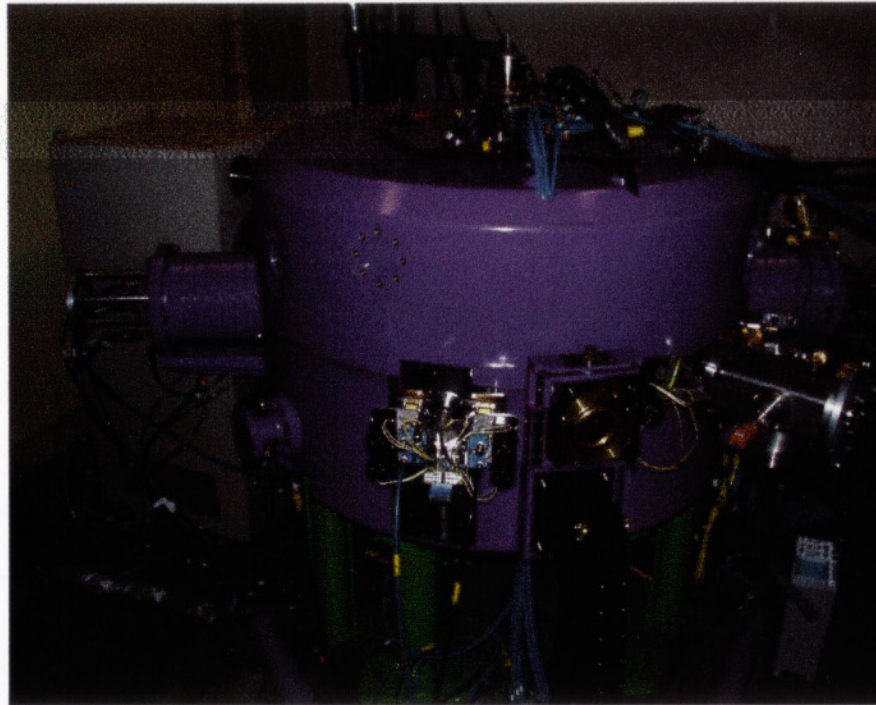


# H<sup>-</sup> Extraction From Baby Cyclotron



KEK FFAG Group  
Yujiro Yonemura

## ● Background

We consider following two schemes for the beam injection of 150 MeV FFAG synchrotron

(1)  $H^+$  injection

multi-turn injection with bumps orbit.

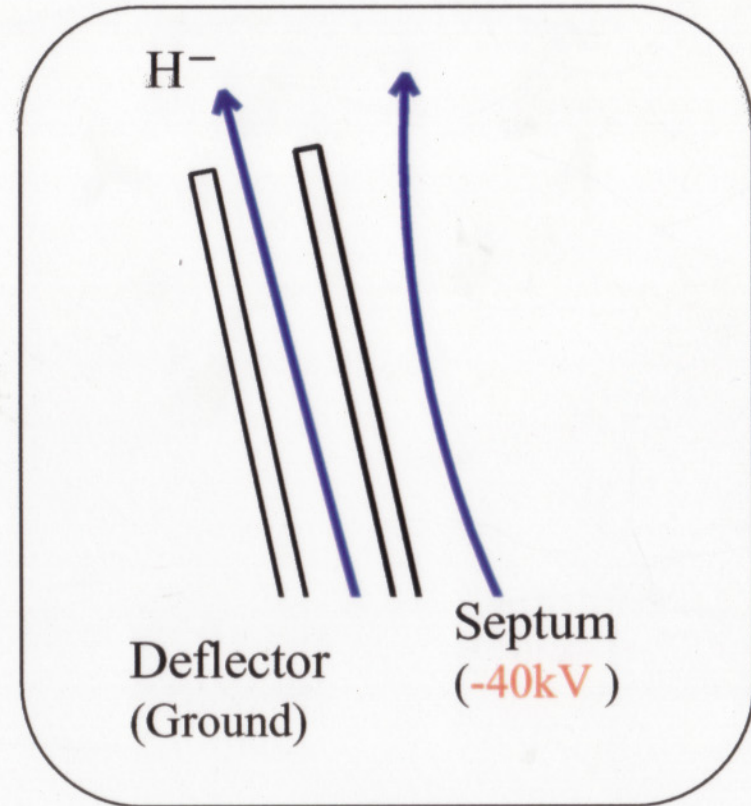
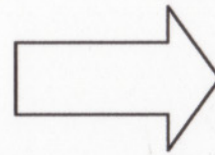
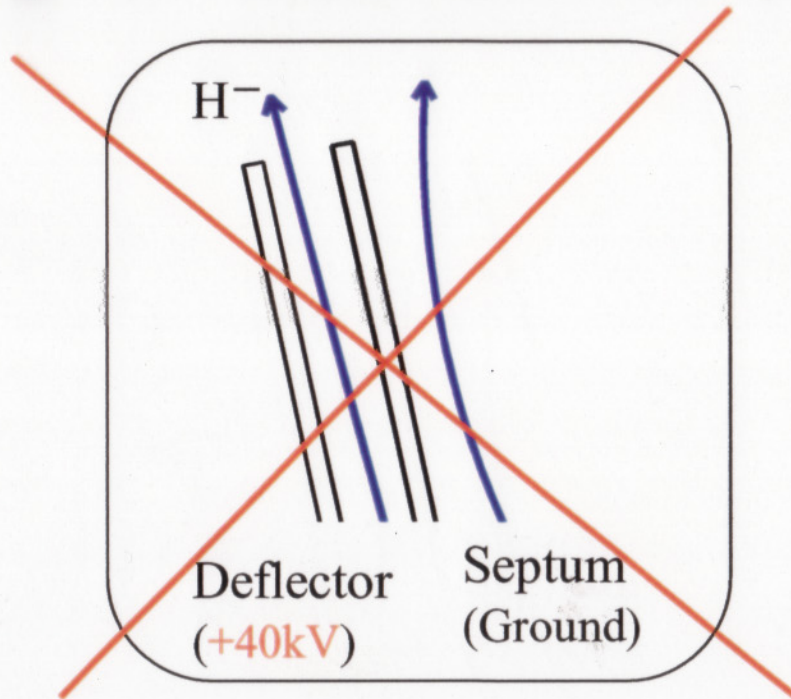
(2)  $H^-$  injection

charge exchange injection using a stripping foil

$H^-$  injection also have an advantage over  $H^+$  injection from the point of view of beam intensity.

$H^-$  extraction from Baby-Cyclotron is investigated

●  $H^-$  beam extraction system for 150MeV FFAG

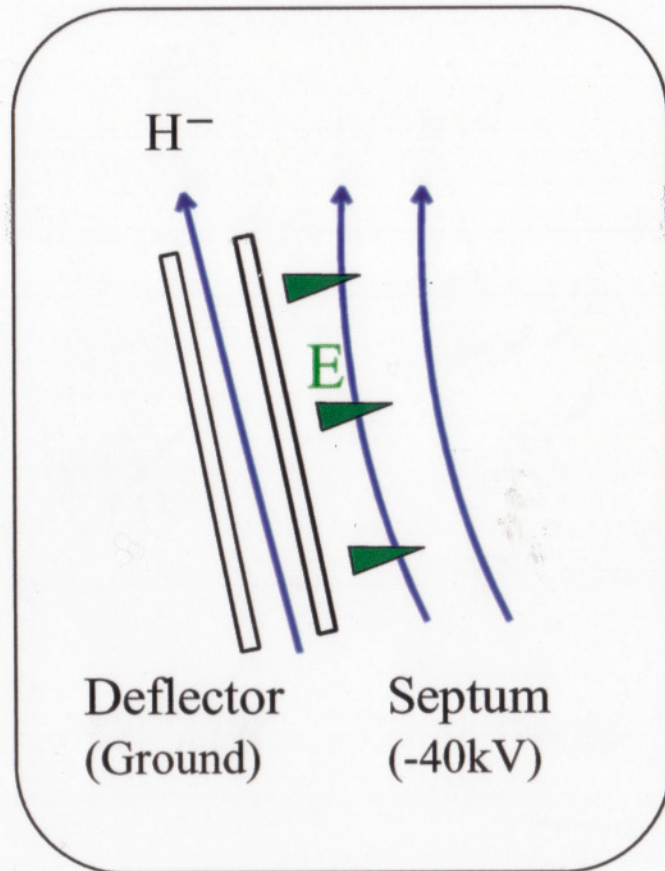


New scheme

- Glow discharge
- Discharge by electron

Positive voltage could not be applied on the deflector

## Problem of $H^-$ beam extraction



Electric field generated by the septum affect circulating beams



We should take account of the effect to the circulating beam

Tracking simulations of  $H^-$  beam is carried out

## ● H- beam tracking simulation

measured magnetic field of  
Baby-Cyclotron

Calculated Electric field  
with MAFIA

Solve dynamic  
equation of charged  
particles in Magnetic  
Field (Runge-Kutta )

$$m(\ddot{r} - r \dot{\theta}^2) = e(r \dot{\theta}^2 B_z - \dot{z} B_\theta)$$

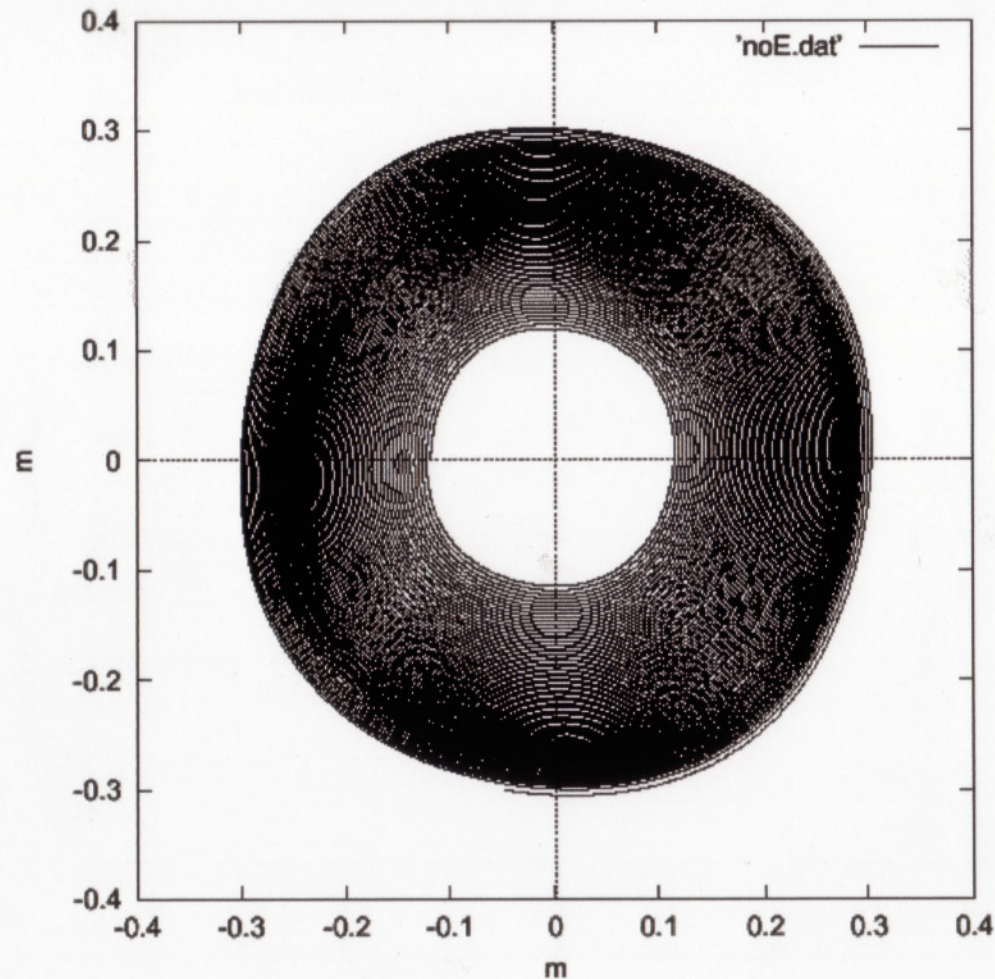
$$m \frac{1}{r} \frac{d(r^2 \dot{\theta}^2)}{dt} = e(\dot{z} B_r - \dot{r} B_z)$$

$$m\ddot{z} = e(r B_\theta - r \dot{\theta} B_r)$$

the possibility of H- beam extraction was  
investigated by tracking simulation

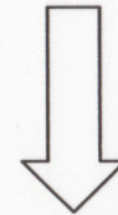


## determination of the initial condition



we don't know any binding conditions of this cyclotron.

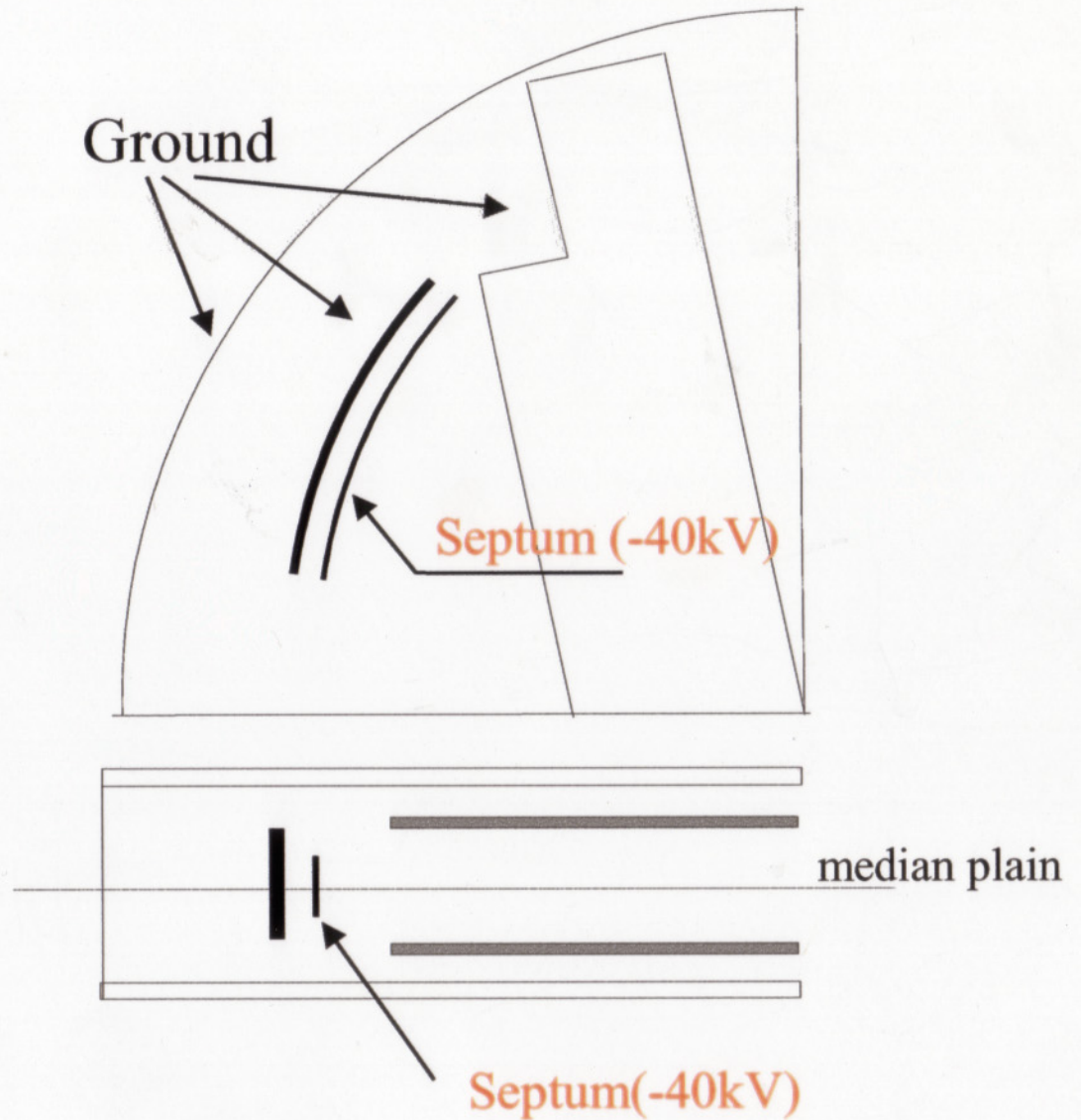
Zero emittance  
beam simulation



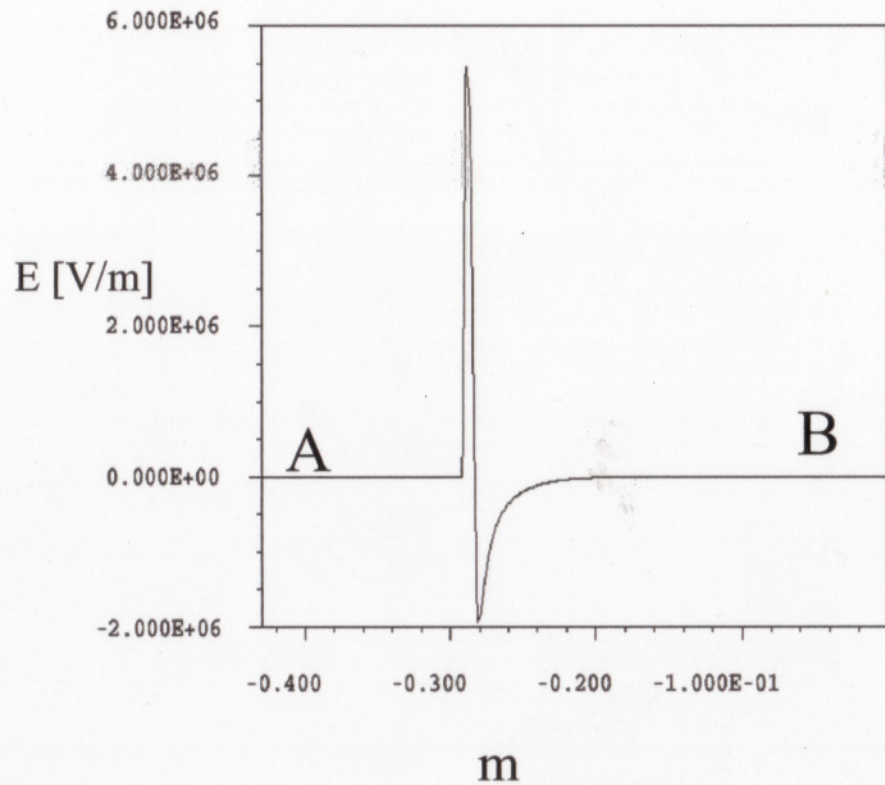
Initial condition:  
Energy: 5.021MeV  
R: 207.5mm

## ● Calculating of Electric Field

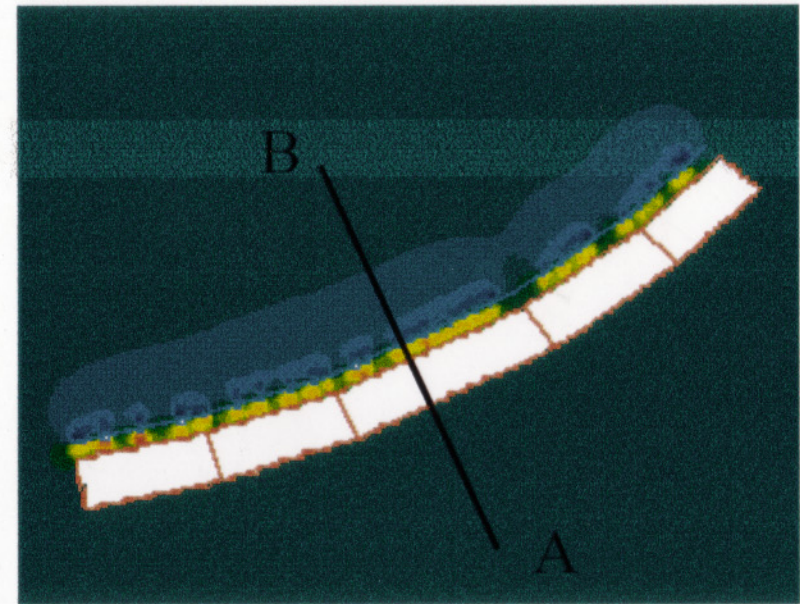
3D electric field was calculated with an calculation code to solve Maxwell's equation.



# Distribution of Electric Field Around Septum



Electric Field On the median plane  
(cut A-B plane)

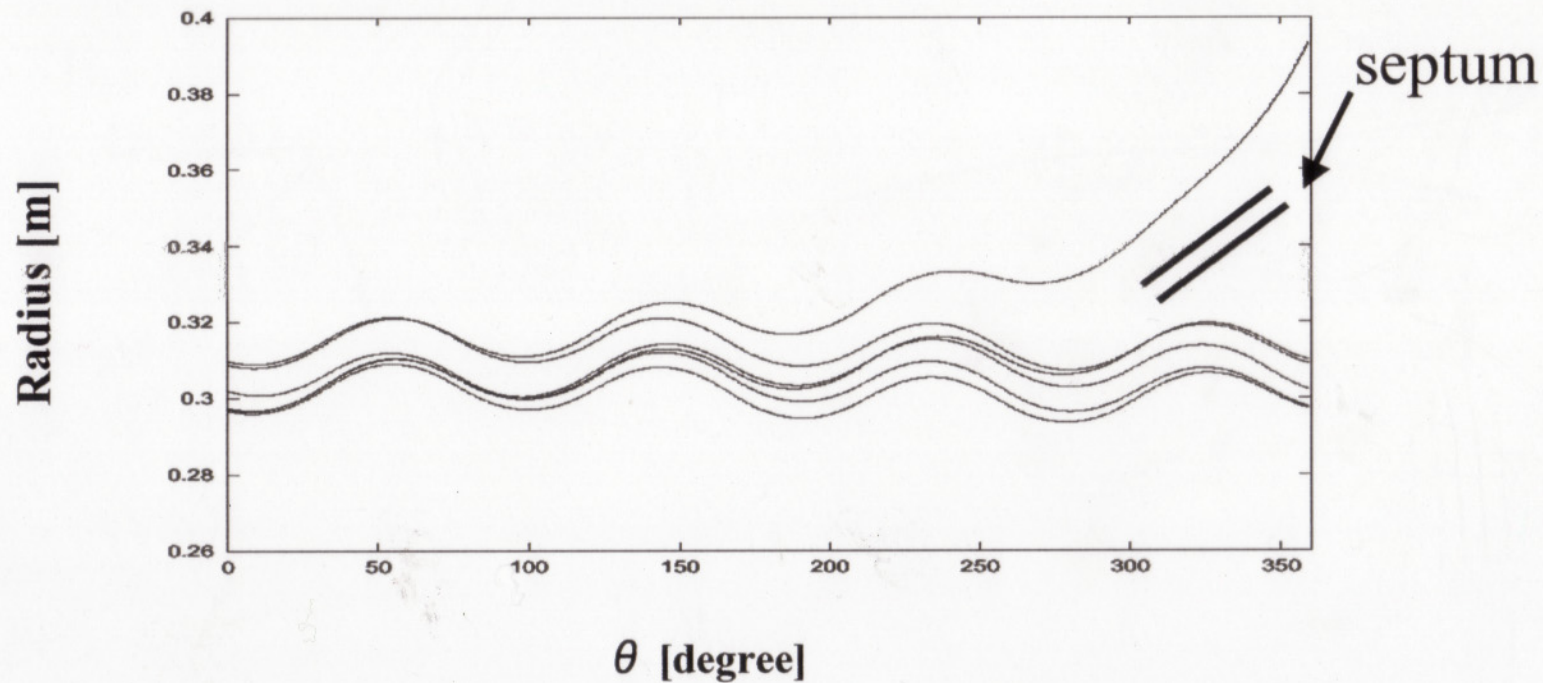


Distribution of Electric Field  
Around Septum

$E$  [V/m]



## The Results of Tracking



$H^-$  beam could not extracted under the electric field

Baby-Cyclotron has 4 sets of trim coils. With these coils, we tried to change the beam orbit and extract  $H^-$  beam.

## ● Conclusion

The result of simulation suggests that the electric field generated by septum affects the circulating beam strongly

We tried to extract  $H^-$  beam with magnetic trim coils

⇒ The shape of <sup>the</sup> electrode should be changed in order to reduce electric field