

Beam injection and extraction in EMMA NS-FFAG

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FFAG 07(Grenoble)

Introduction

- Considering the nature as a test machine, the difficulty of EMMA beam injection (extraction) is to cope with broad varieties of injection conditions(i.e. Energy 10~20MeV, phase advance: 0.1~0.4/cell, various operation mode)
 - * Considering the beam size, scheme which can inject the beam into the center of the phase space can inject beam with any required amplitude
 - The requirements of injection and extraction is quite similar
 - ⇒ Similar scheme can be employed for both injection and extraction
 - Kicker field strength and beam distribution at the septum are important issues to be considered.
- ⇒ Present status of injection study is summarized
(Scheme, beam distribution, kicker field)

Specifications for injection system

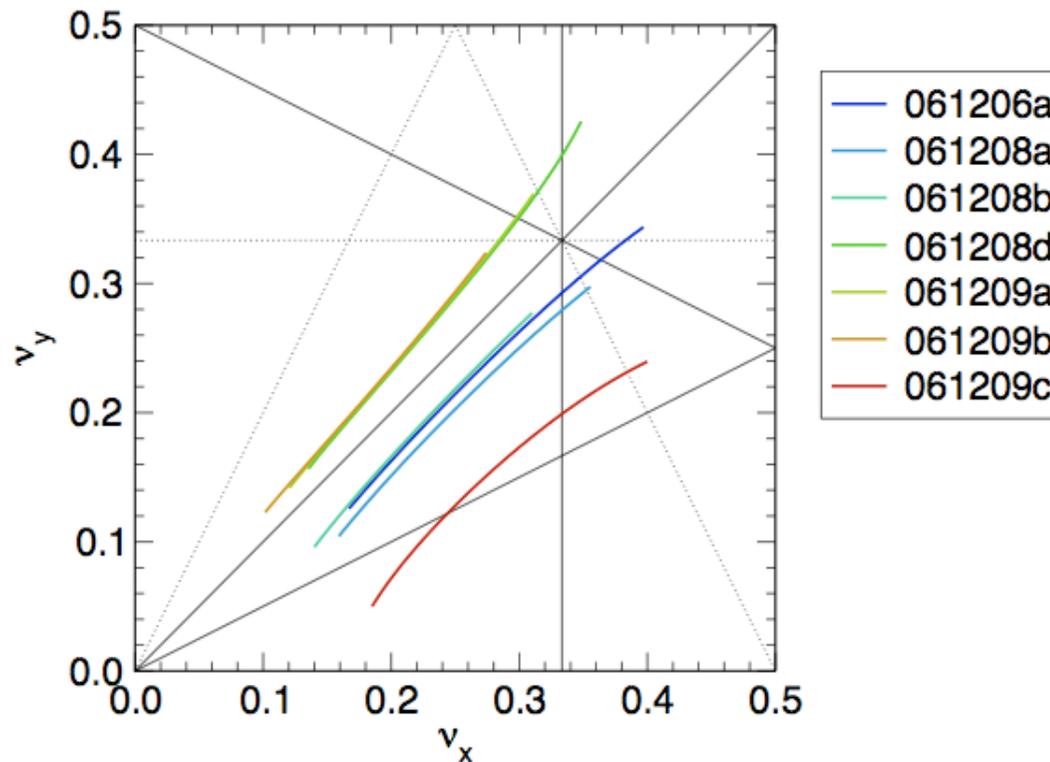
- RF cavity aperture[-16.808mm,17.917mm]
⇒Kicker aperture is tentatively assumed : 45(H) × 45mm(V):window frame type * Kicker aperture size can be reduced
- Kicker length:100mm (long straight section: 210mm)
⇒Bare inductance ~130nH
- Maximum available kicker field :820gauss (with current aperture)
- Space for (septum + margin) : 5mm
* pulse septum is assumed to be employed
⇒Beam envelope should be outside of ±23mm
- Beam emittance: 3π mm·rad(normalized)

**Tracking using ZGOUBI w/o fringing field(sharp edge)

In the following study, only the orbit separation was checked to compare the feasibility of various schemes and separate the problem from the fringing field modeling.

Operational Point

- As typical operating points, 3 operation points were checked(061206a,8a,9c)
- Horizontal phase advance : 0.1 ~ 0.4/cell



1-kicker option or 2-kickers option ?

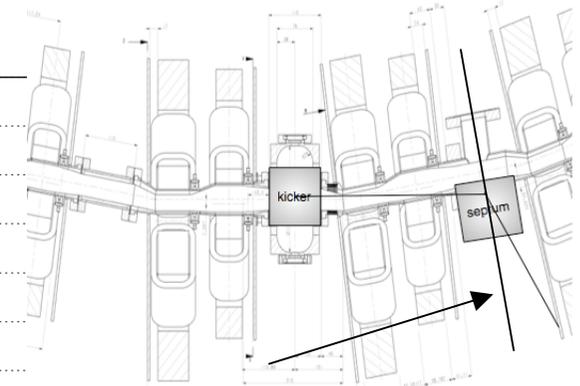
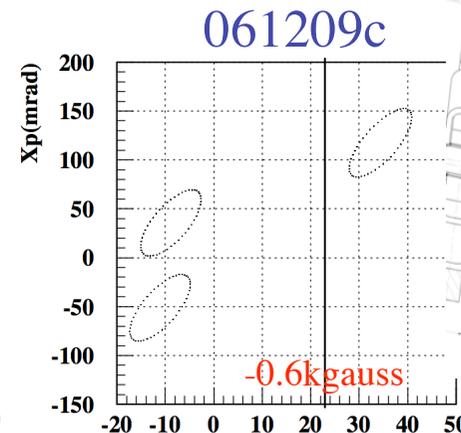
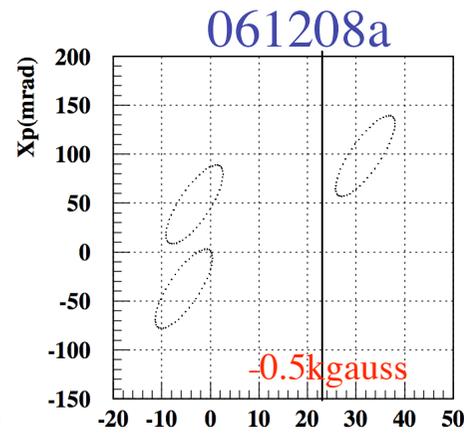
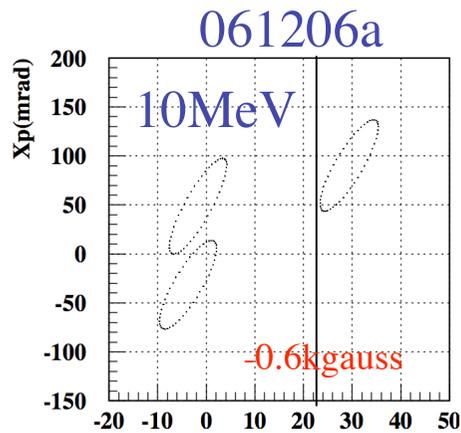
1 kicker

- Simple system
- Smaller phase variation(0.1~0.4/cell)
- × (Possibly) larger kick angle is required

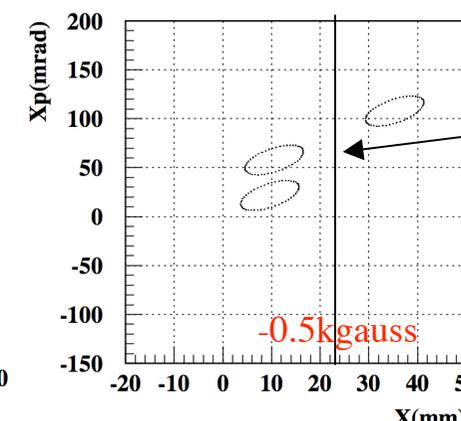
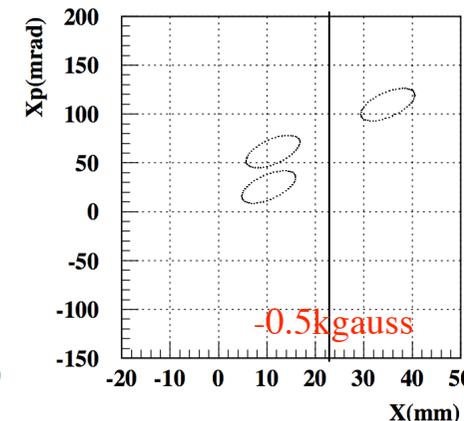
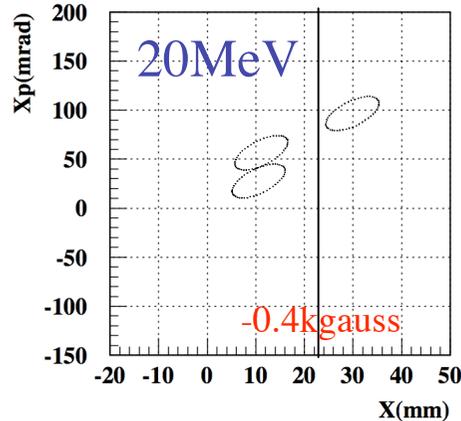
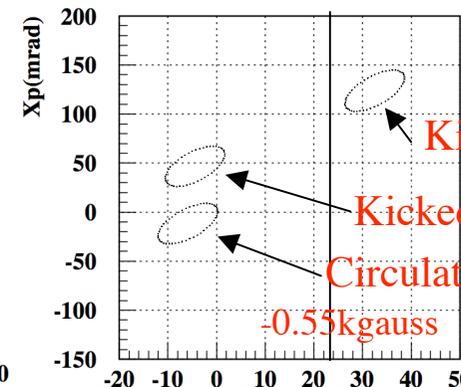
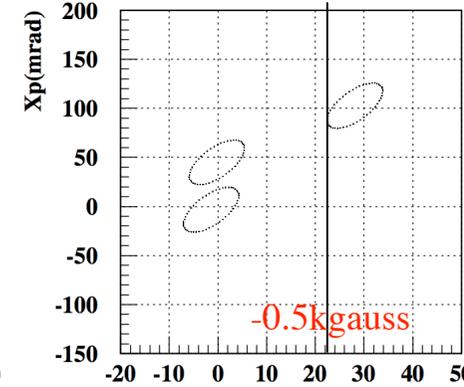
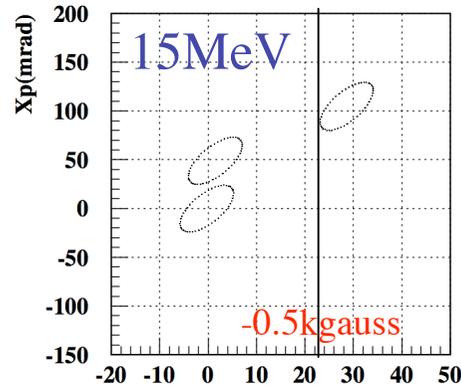
2 kicker

- (Possibly)relatively smaller kick angle
- More flexible for the injection error correction
- × Complex system configuration
- × Larger phase variation(0.2~0.8/2cell)

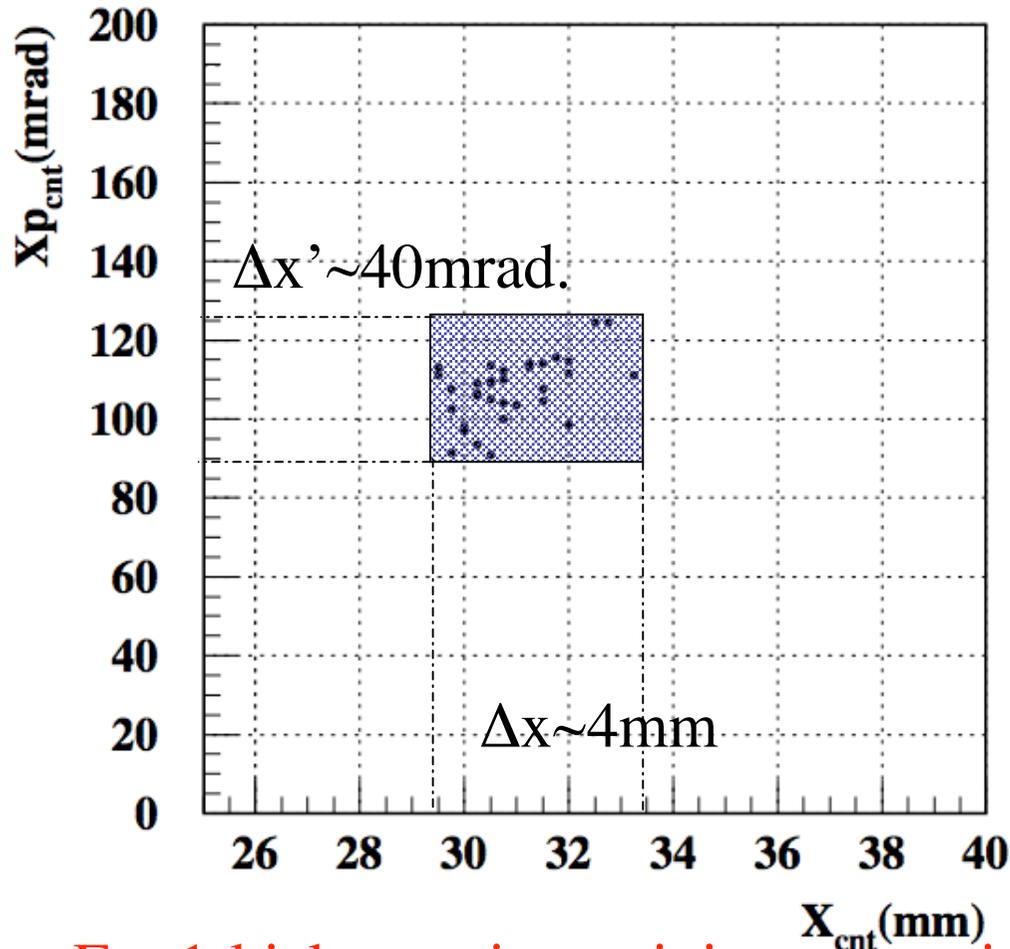
Example of 1kicker injection



Observed here



Injection Point Distribution in 1-kicker (outward) option



Adjust kicker fields to minimize the injection point distribution

10MeV~20MeV(1MeV step)
3 operation points
Max field: 0.6kgauss
(0.05kgauss step)

For 1-kicker option, minimum required field is 0.6kgauss for kicker length of 10cm(Still, acceptable field strength)
**no 1-kicker inward solution

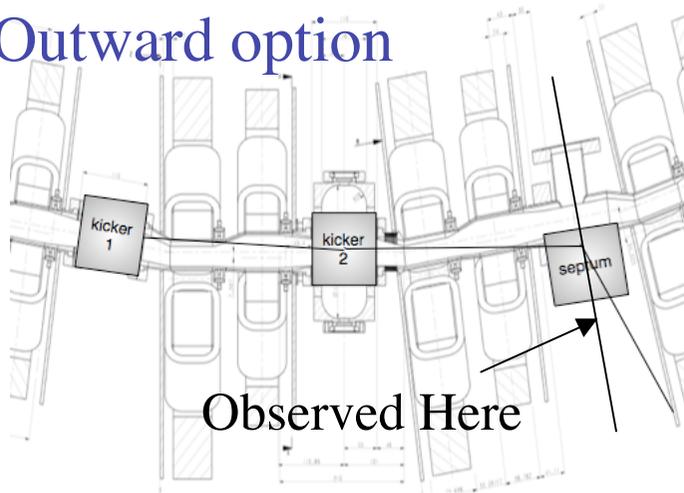
2-kicker options

- The minimum required field of 1-kicker option is 0.6k gauss
- ⇒ Acceptable maximum field for the 2-kicker option is 0.6k gauss
- Bi-polar kicker can be employed
- Three cases are examined(see next slide)
- Field strengths of individual kickers are independently varied within $\pm 0.6k$ gauss(0.05kgauss step)

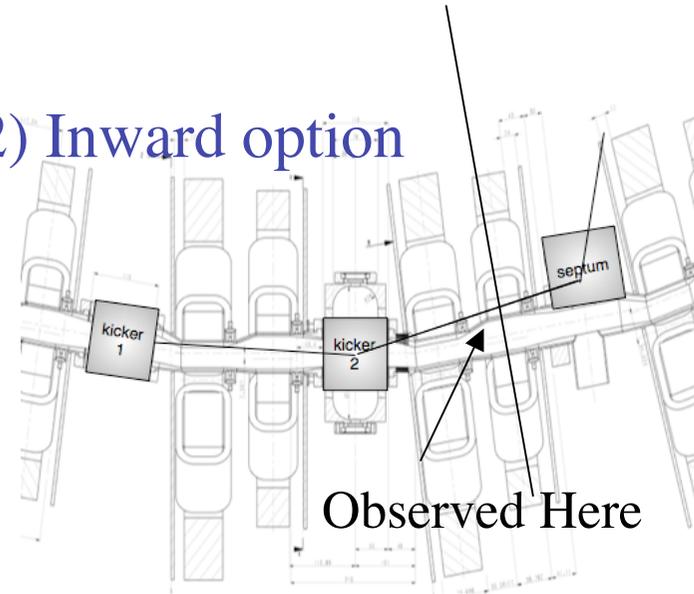
Variations of 2-kicker option

At present, 3 options are proposed....

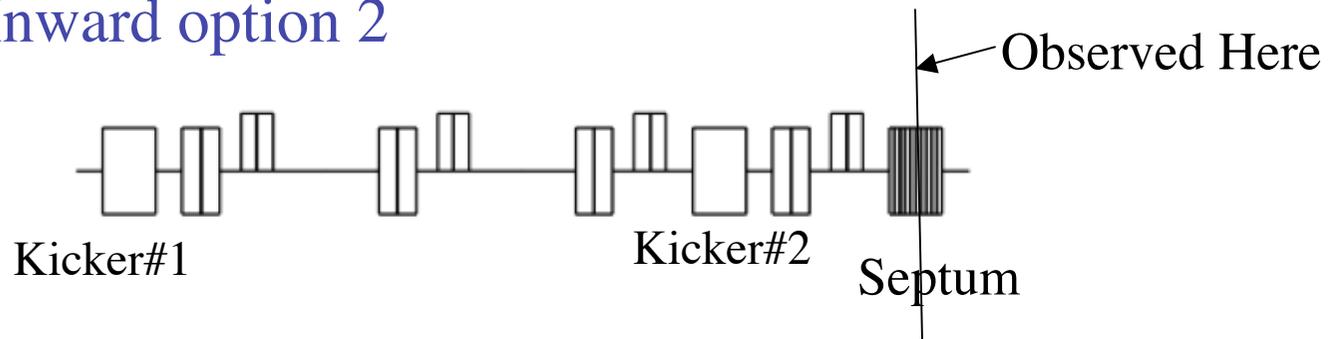
(1) Outward option



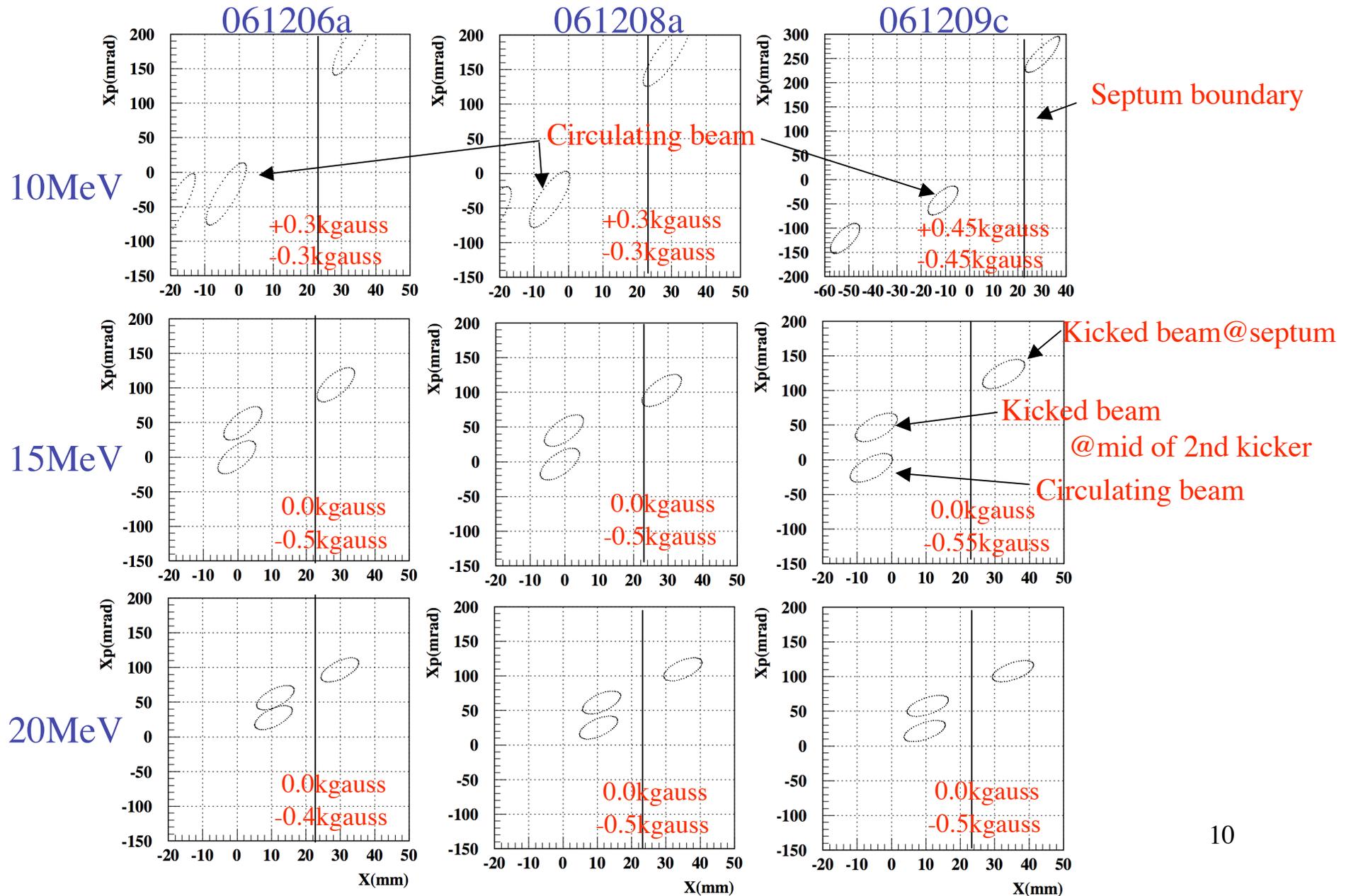
(2) Inward option



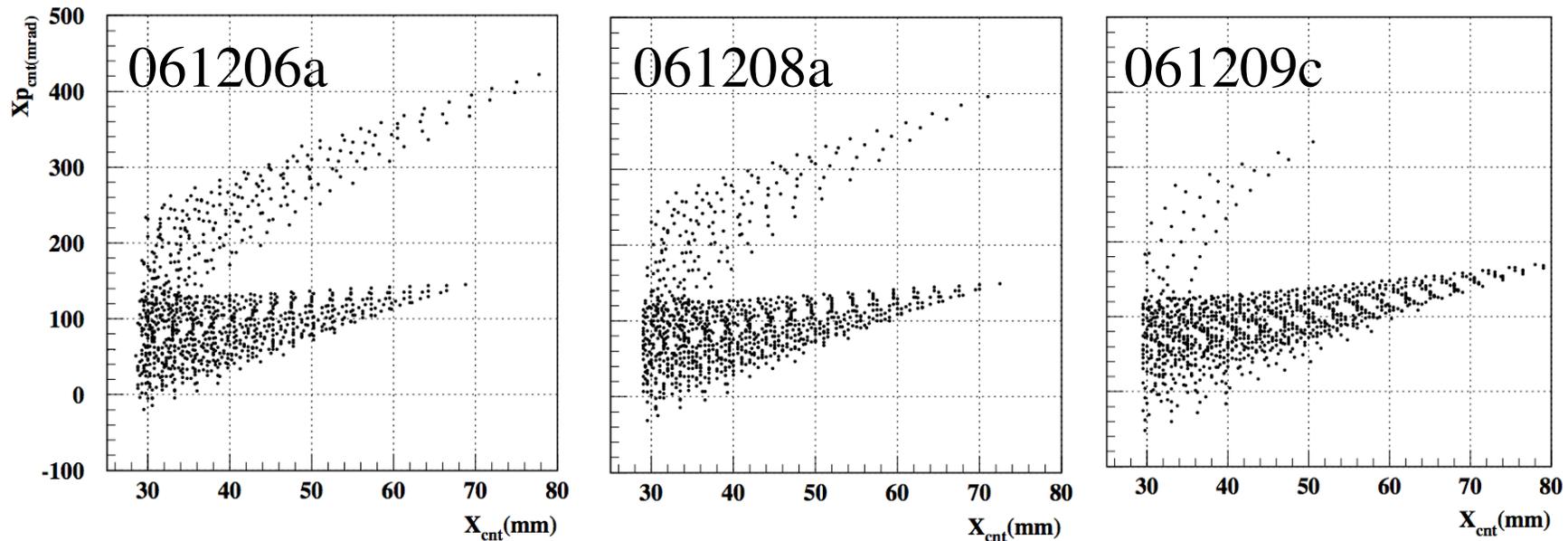
(3) Inward option 2



Example of 2-kicker injection(outward)



Injection Point Distribution (ex 2-kicker outward)

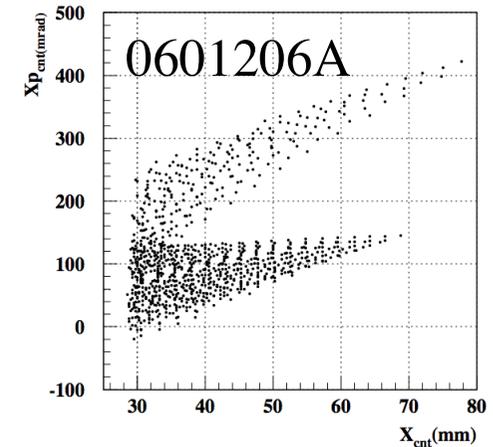
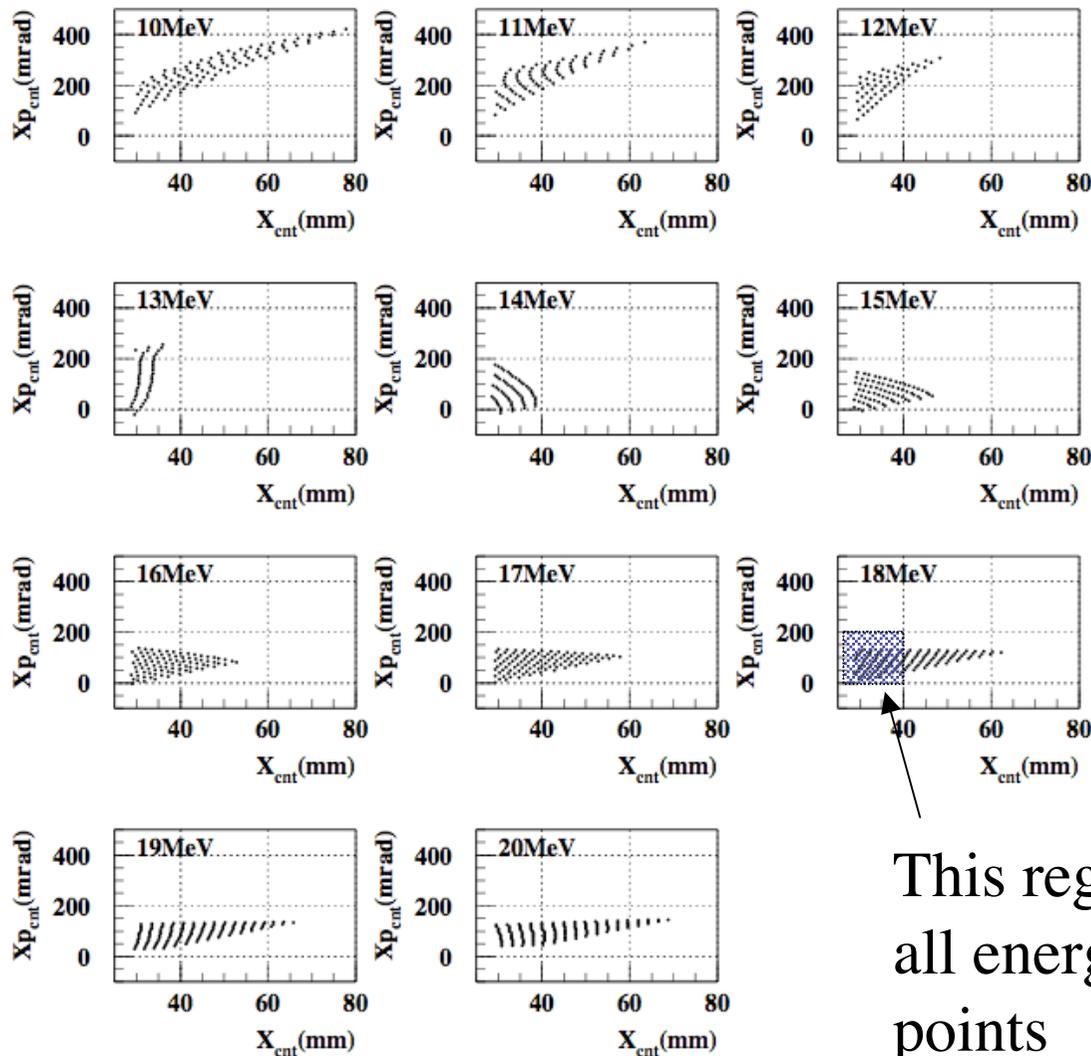


*Energy: 10~20MeV(1MeV step),

*Field : -0.6k~0.6k gauss(0.05kgauss step)

Combining 2 kickers, the injection points are widely distributed

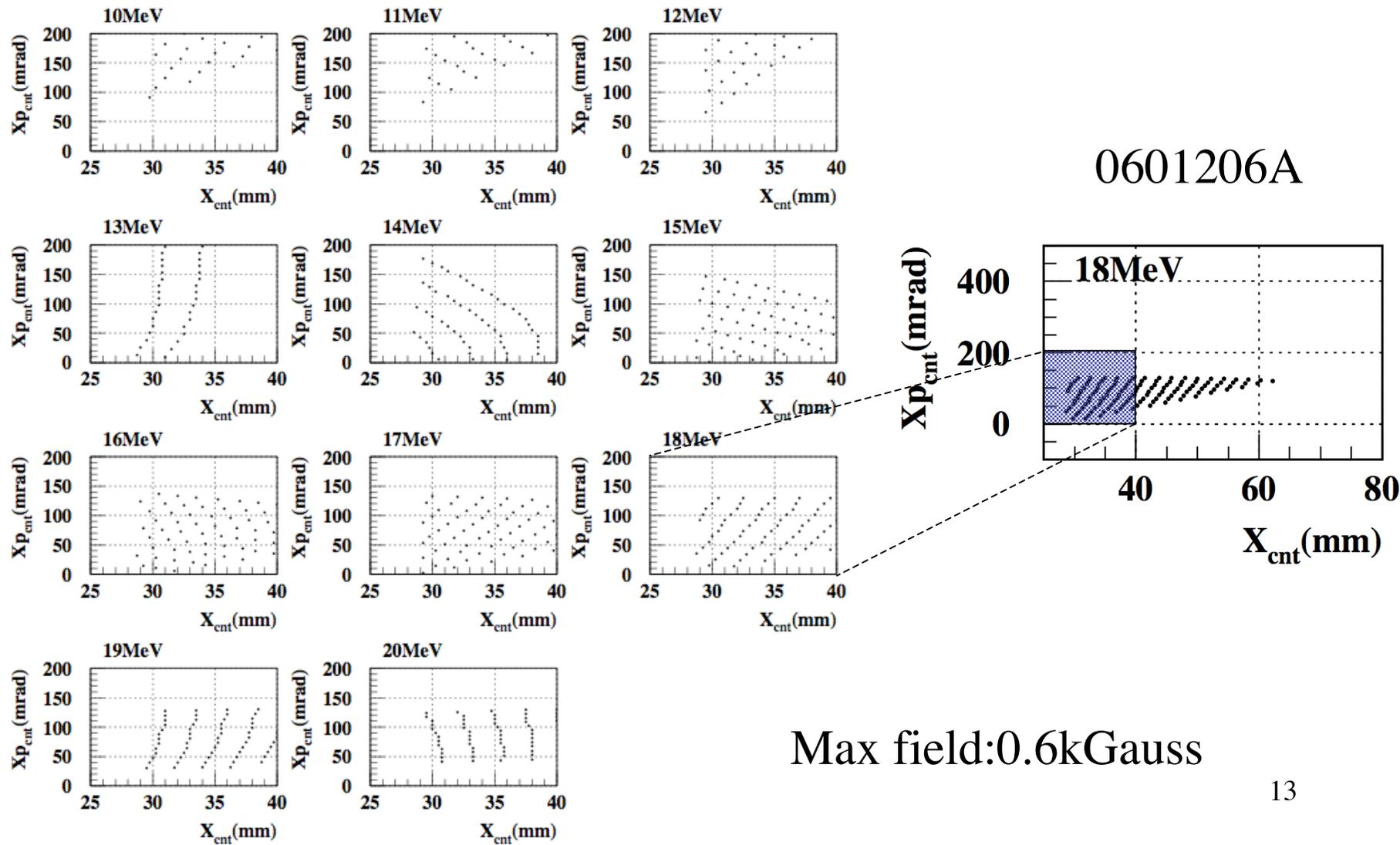
Example of Injection Point Scan (ex 2-kicker outward)



10~20MeV

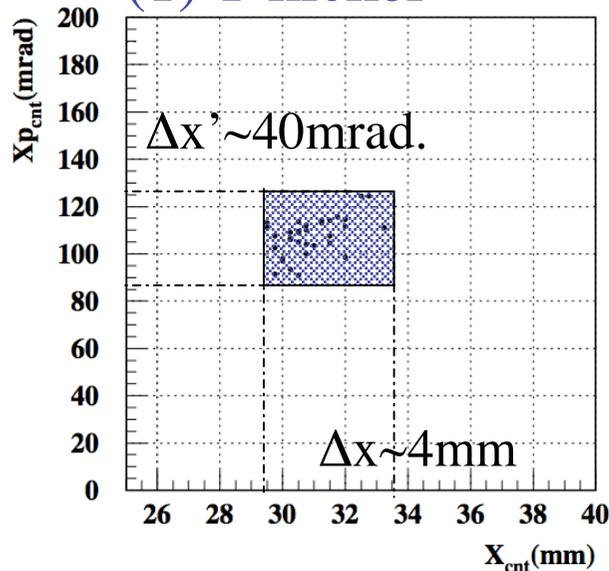
This region is common in all energies and operational points

Example of Injection Point Scan (ex 2-kicker outward)

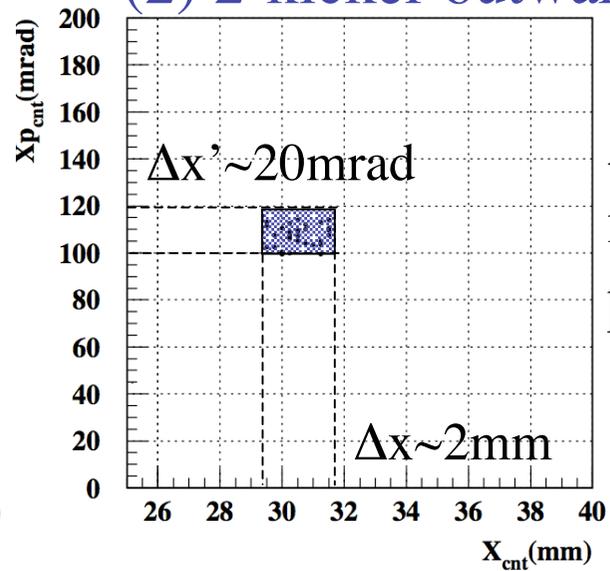


Injection Point Distribution

(1) 1-kicker

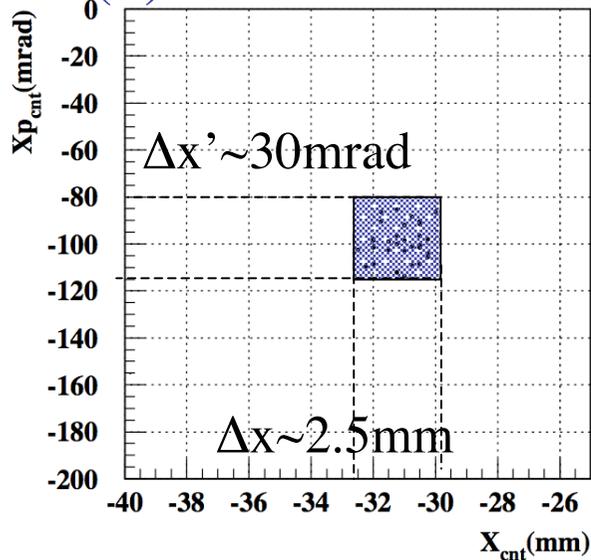


(2) 2-kicker outward

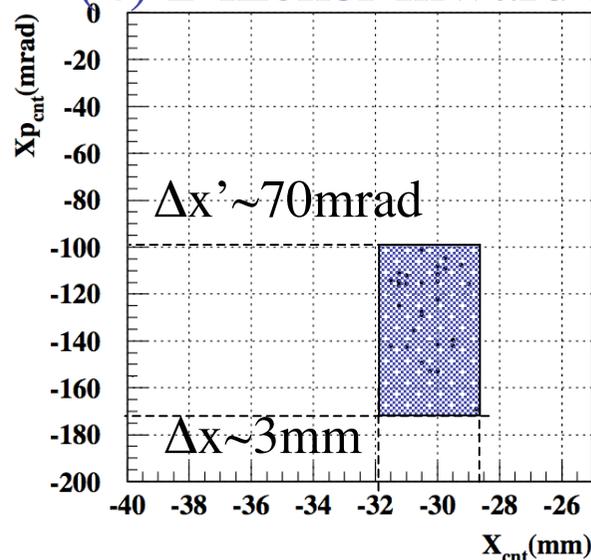


Adjust kicker fields to minimize the injection point distribution

(3) 2-kicker inward



(4) 2-kicker inward 2



Kicker field

-0.6kgauss~0.6kgauss
(0.05kgauss step)

Energy

10~20MeV(1MeV step)

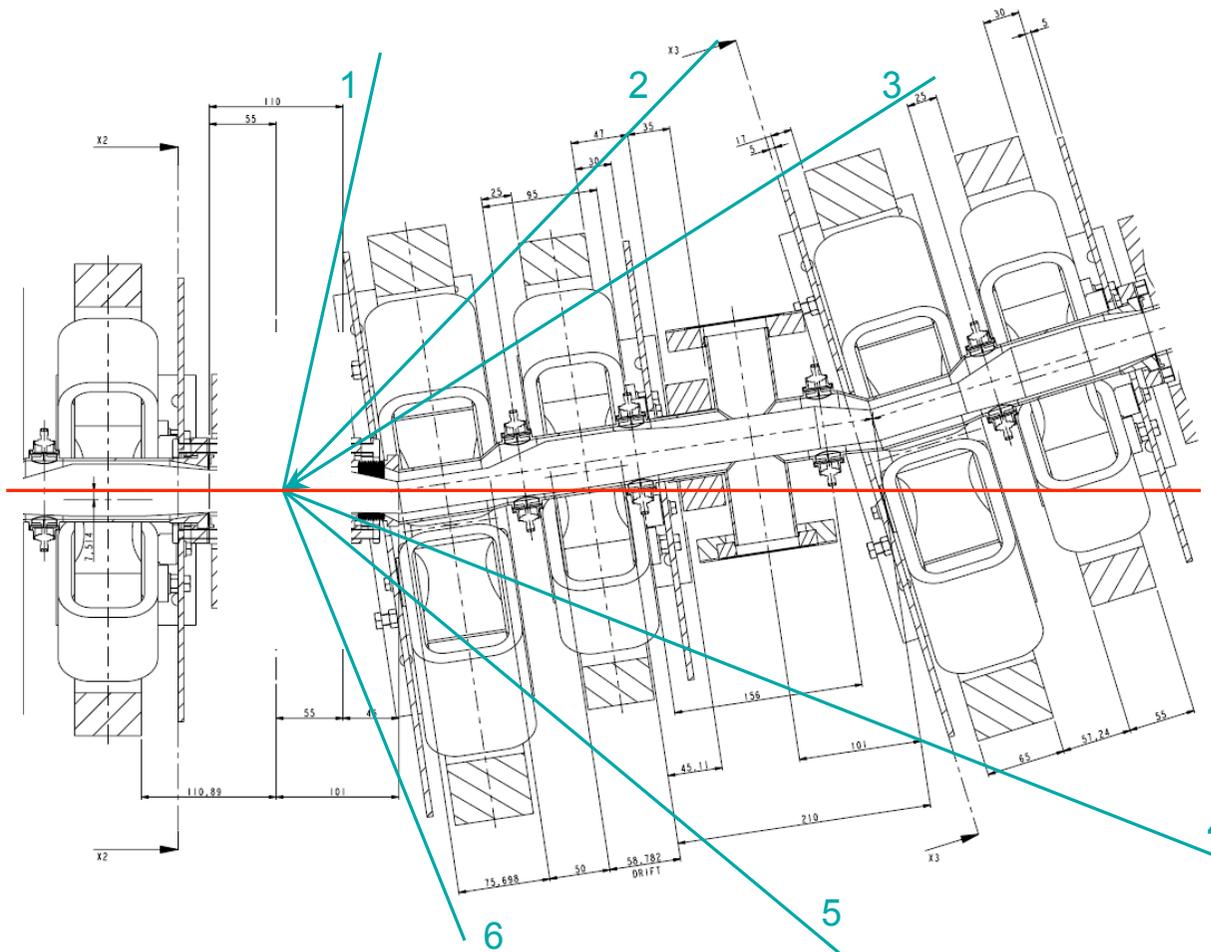
3 operation points

From result of injection point scanning

- Required kicker field is 0.6kgauss(0.05kgauss precision)
- 2-kicker outward option gives the smallest injection point distribution(2mm×20mrad with 0.05kgauss field precision)
 - * Finer tuning will give further improvement
- Accepting larger injection point distribution, the minimum required field gets reduced to 0.45kgauss(inward option)
- Among three 2-kicker options, outward option is less sensitive to the change of operation condition
- Septum will also give further improvement for injection point distribution

At the moment, 2-kicker outward option seems to be most preferable

Injection angle(septum)



Angles to straight axis (red)

- | | |
|---|------|
| 1 | 78° |
| 2 | 46° |
| 3 | 32° |
| 4 | -21° |
| 5 | -39° |
| 6 | -68° |

cf. 90° bending septum(length:10cm) :5.6kgauss@20MeV

To do list

- Including septum into tracking
- Confirmation for extraction
- Including 3D field map into tracking
(hard edge \Rightarrow realistic field)

\Rightarrow Finalize the injection(extraction) orbit and specification of the apparatus

Summary

- With kicker field of 0.6kgauss, beam injection which covers the entire energy range and operation point is possible (1-kicker, 2-kicker inward and outward)
- The minimum required field is 0.45kgauss (2-kicker inward scheme) at the cost of broader beam distribution.
- Considering the stability and injection point distribution, 2-kicker outward option is most preferable
- Beam distribution should be investigated including septum contribution(septum can plausibly contribute to reduce the spread of injection point distribution)
- Fringing field effect should be included \Rightarrow The similar studies should be carried out using realistic 3D field