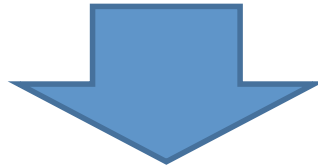


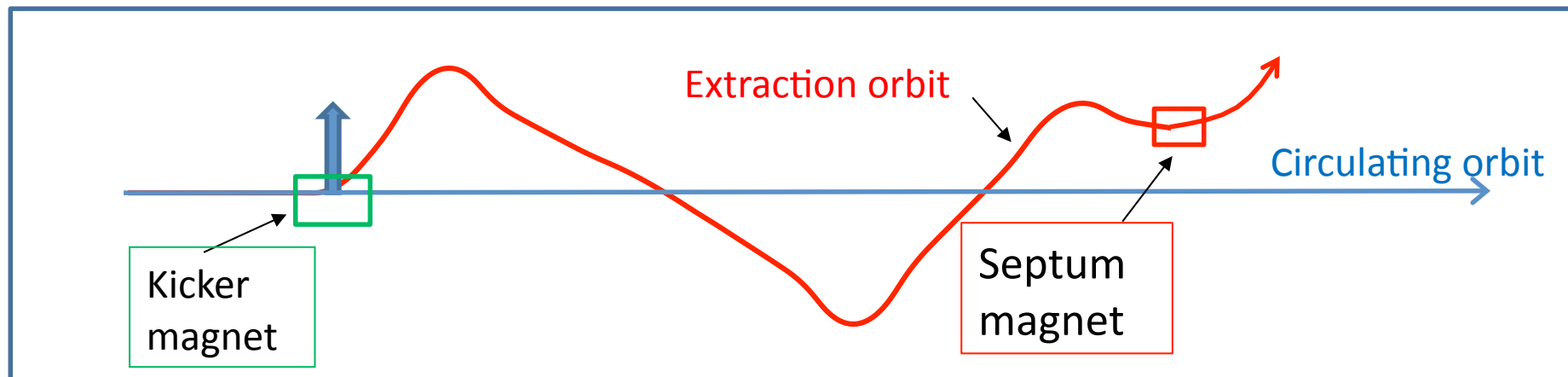
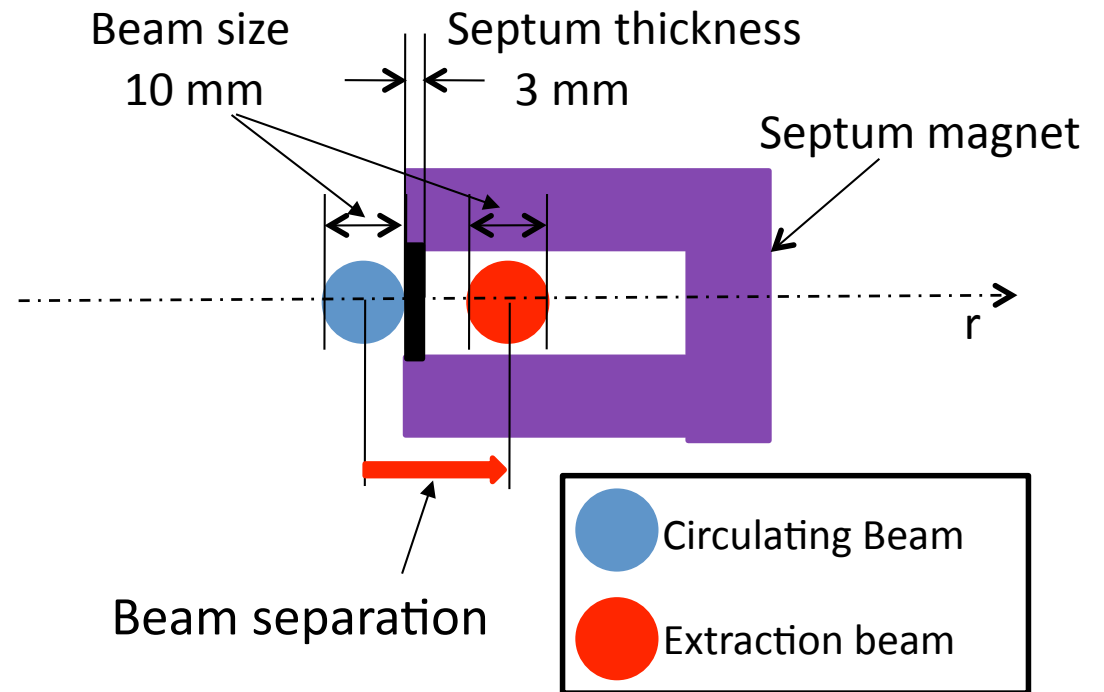
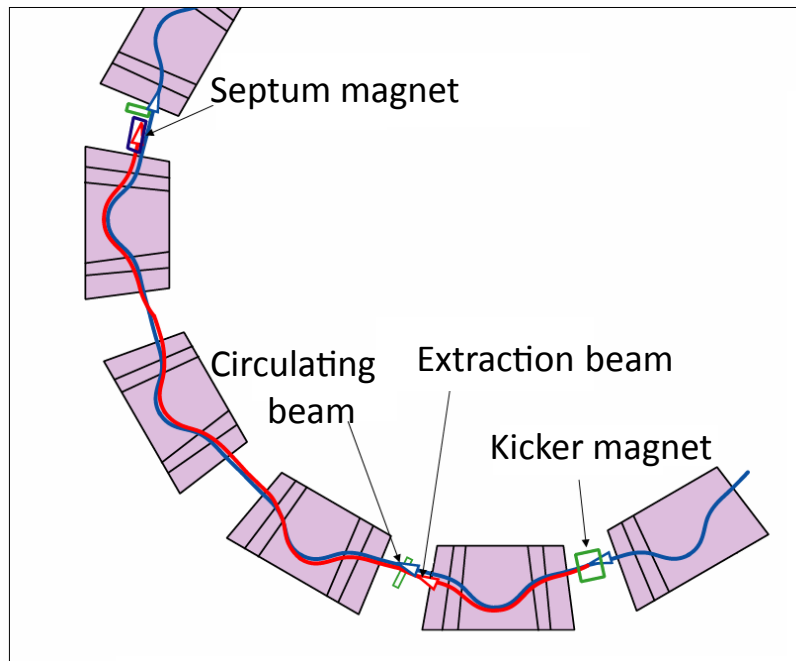
Introduction

In case of 150-MeV FFAG accelerator, **10%** of the extraction beam is lost at the septum magnet.

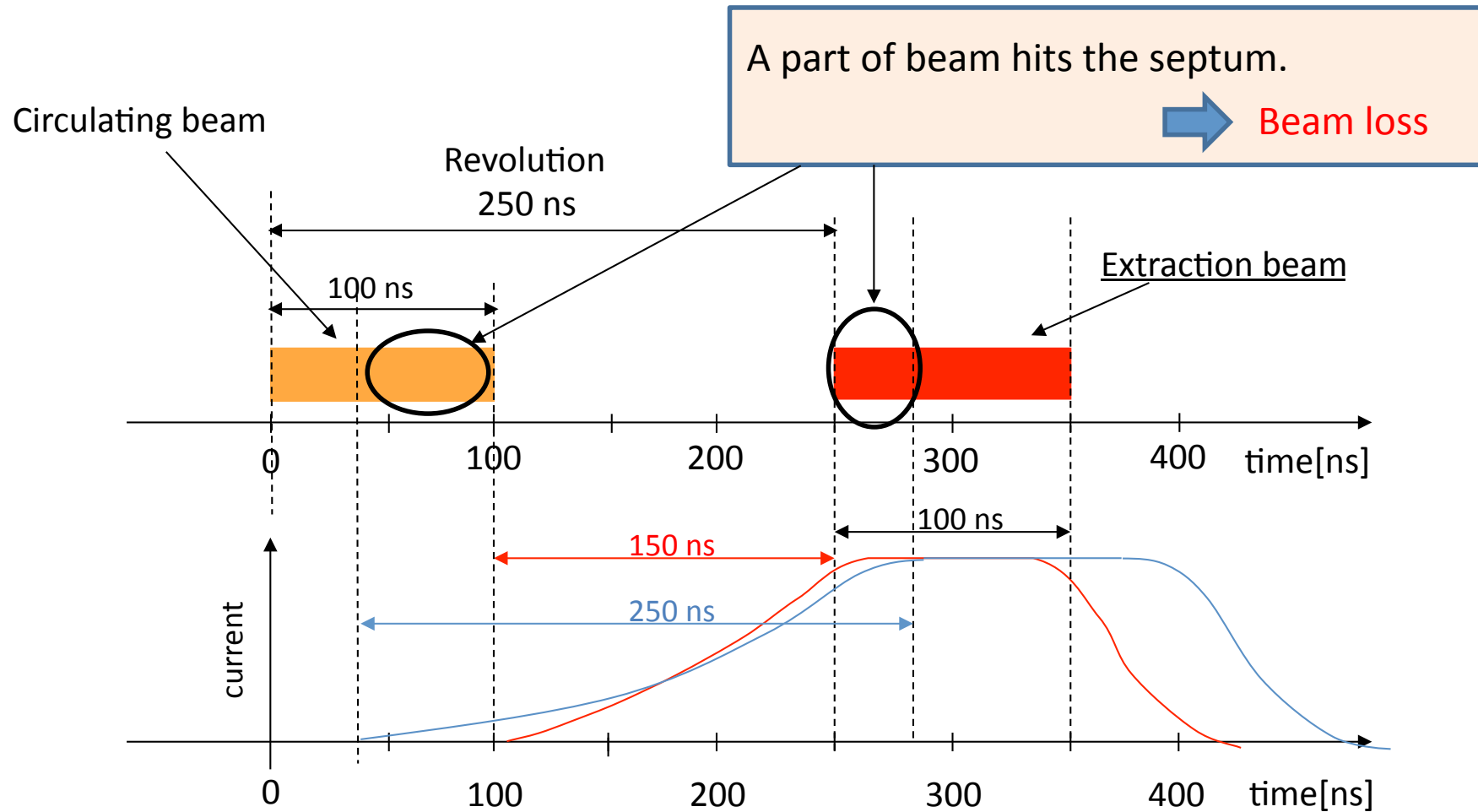


It is important to reduce the beam loss in order to utilize the FFAG accelerator for various applications.

Beam extraction system of 150 MeV FFAG



Requirements for the kicker magnet

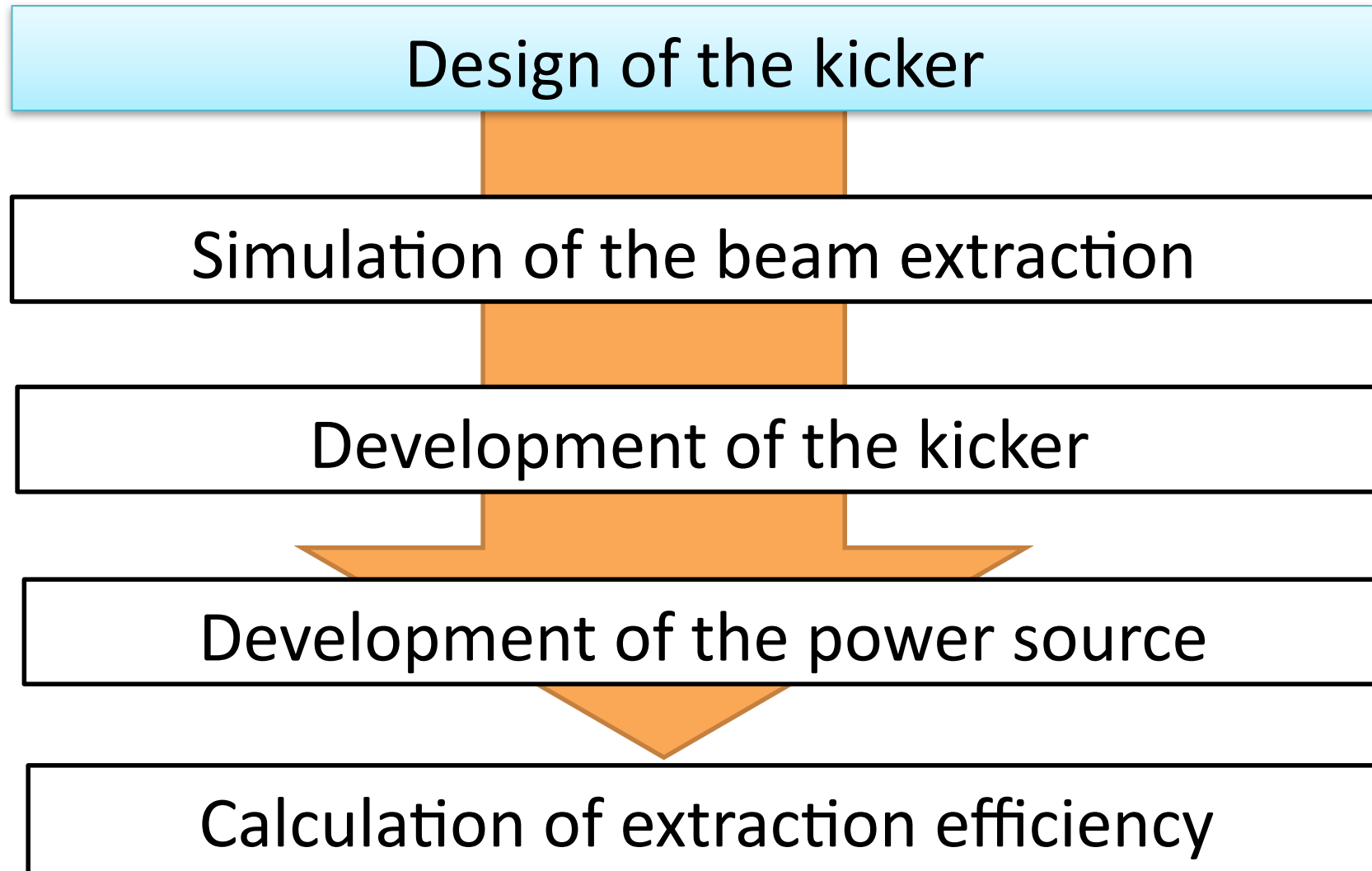


- Rise time is required to be less than **150 ns**.
- Flat top is required to be more than **100 ns**.

Purpose of study

Development of the kicker with fast rise time
in order to increase extraction efficiency

Flow chart



Principle of rise time and inductance

This is equation of self-induced electromotive force.

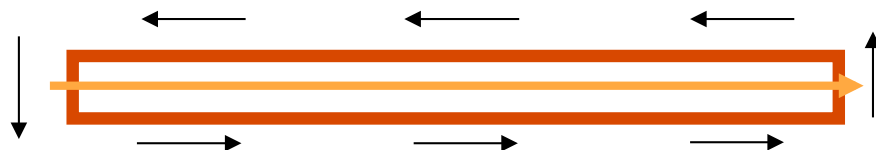
The diagram shows the equation $V = -L \frac{dI}{dt}$ with several annotations. An arrow points from the word "Voltage" to the V in a circle. Another arrow points from the word "Inductance" (in red) to the L in a red circle. A third arrow points from the word "Rise time" (in red) to the dt in a red circle. A fourth arrow points from the word "Peak current" (in black) to the dI in a circle.

$$V = -L \frac{dI}{dt}$$

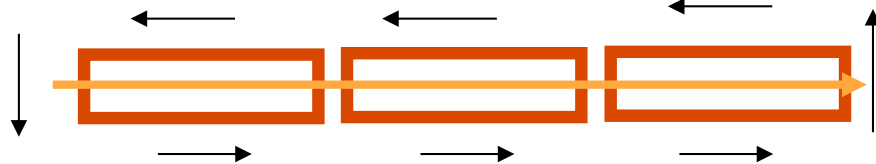
Smaller inductance realizes faster rise time.

New type of kicker magnet

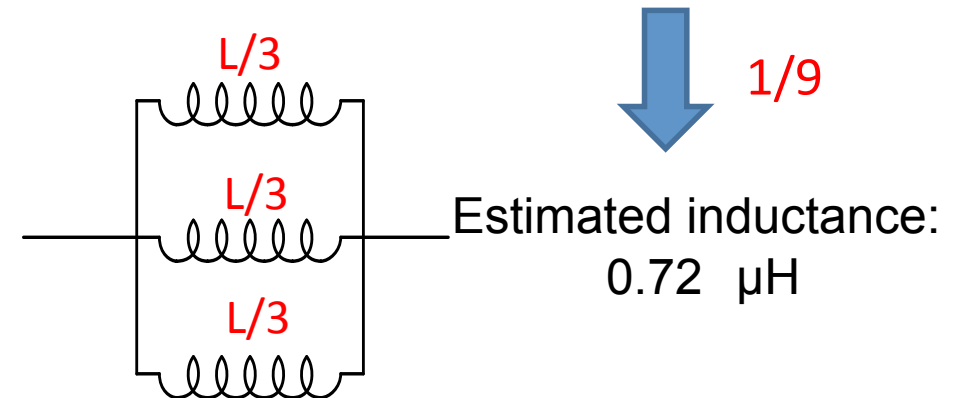
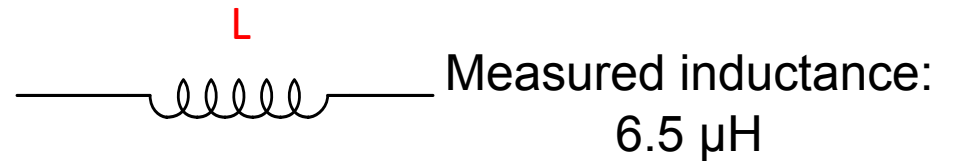
To reduce the inductance of the kicker, coil is divided into 3 parts.



present Kicker (1700 A)



New type of Kicker (1700A x 3 = 5100A)

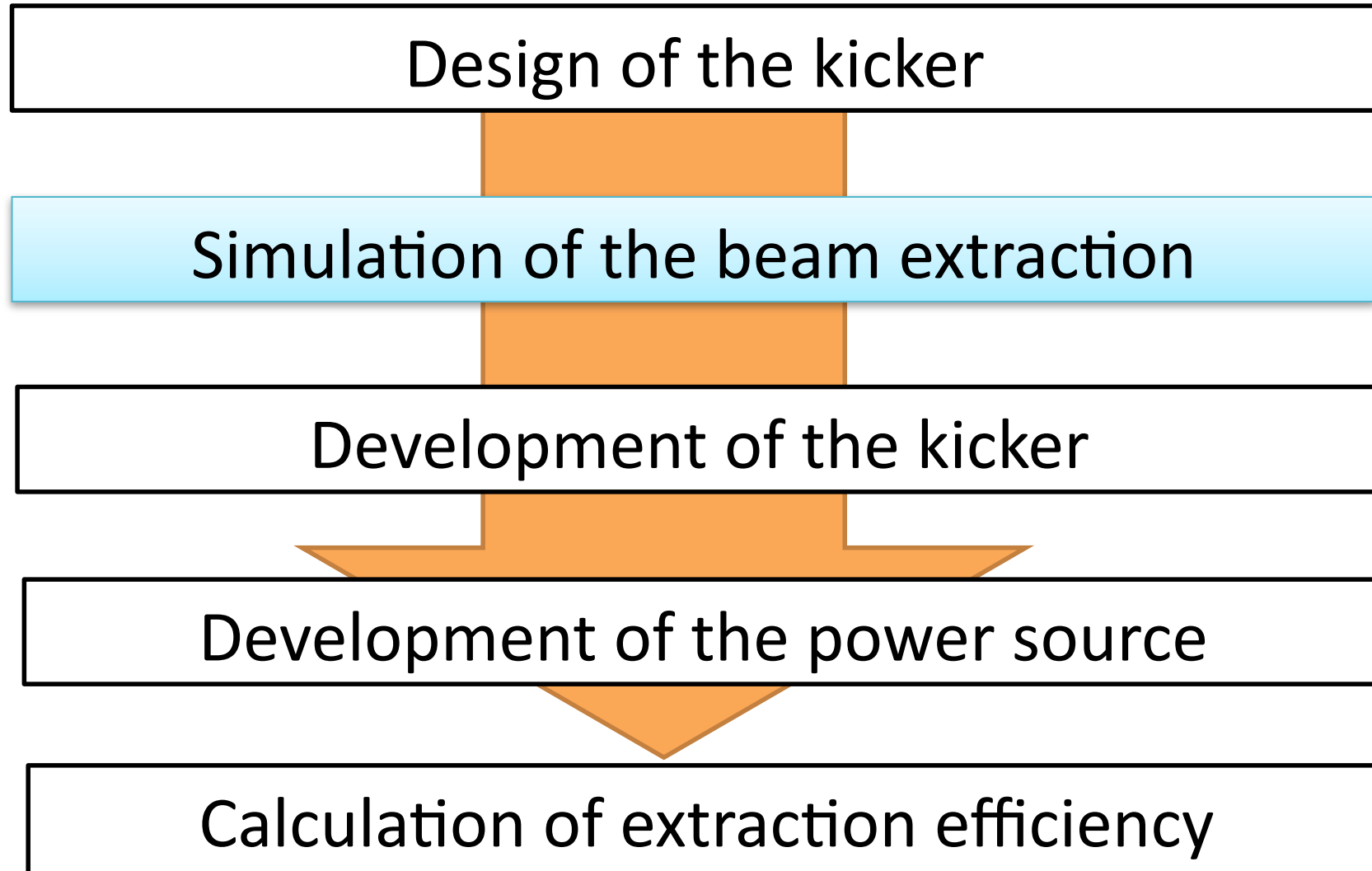


Peak current : 5100 A
Maximum voltage : 40 kV
Inductance: 0.72μH

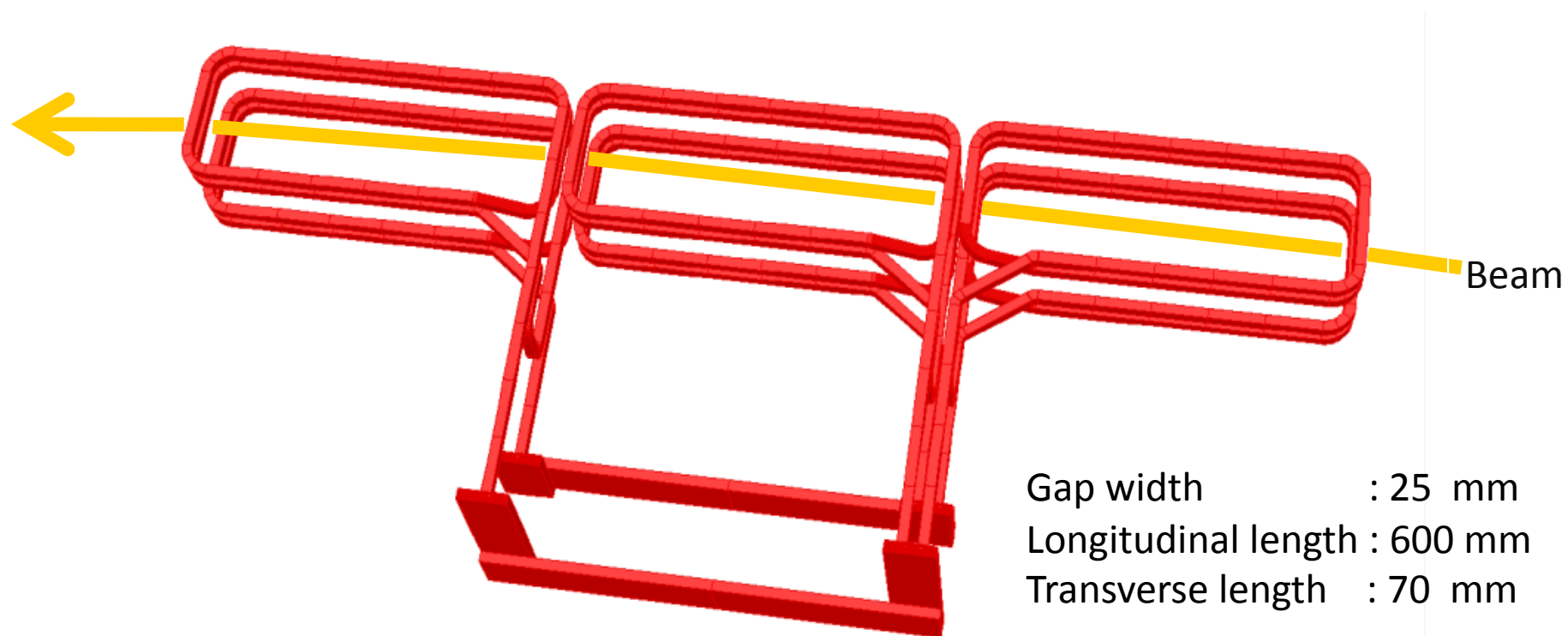


Rise time of the new kicker
is less than 150 ns

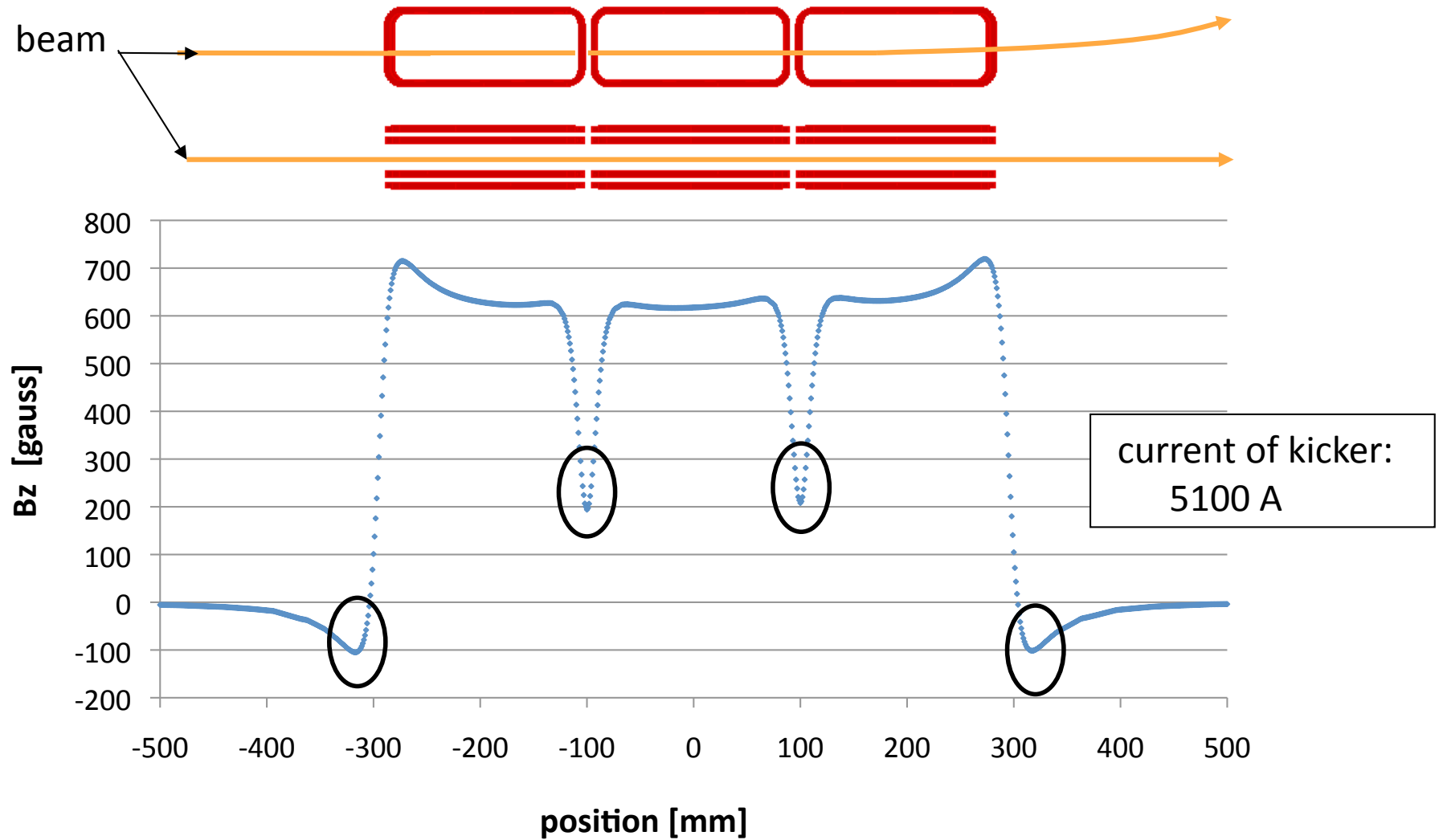
Flow chart



Tracking simulation with TOSCA

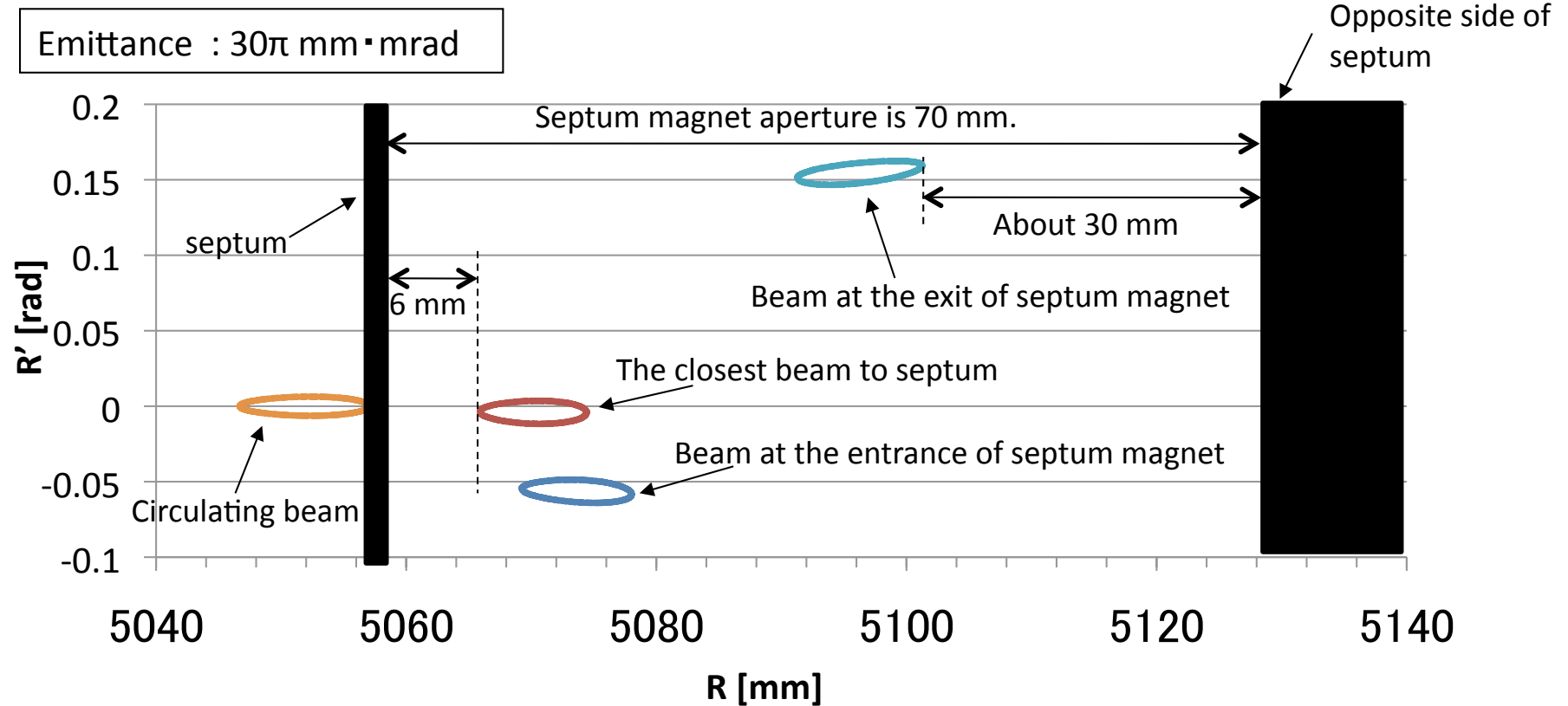


Calculation of magnetic field



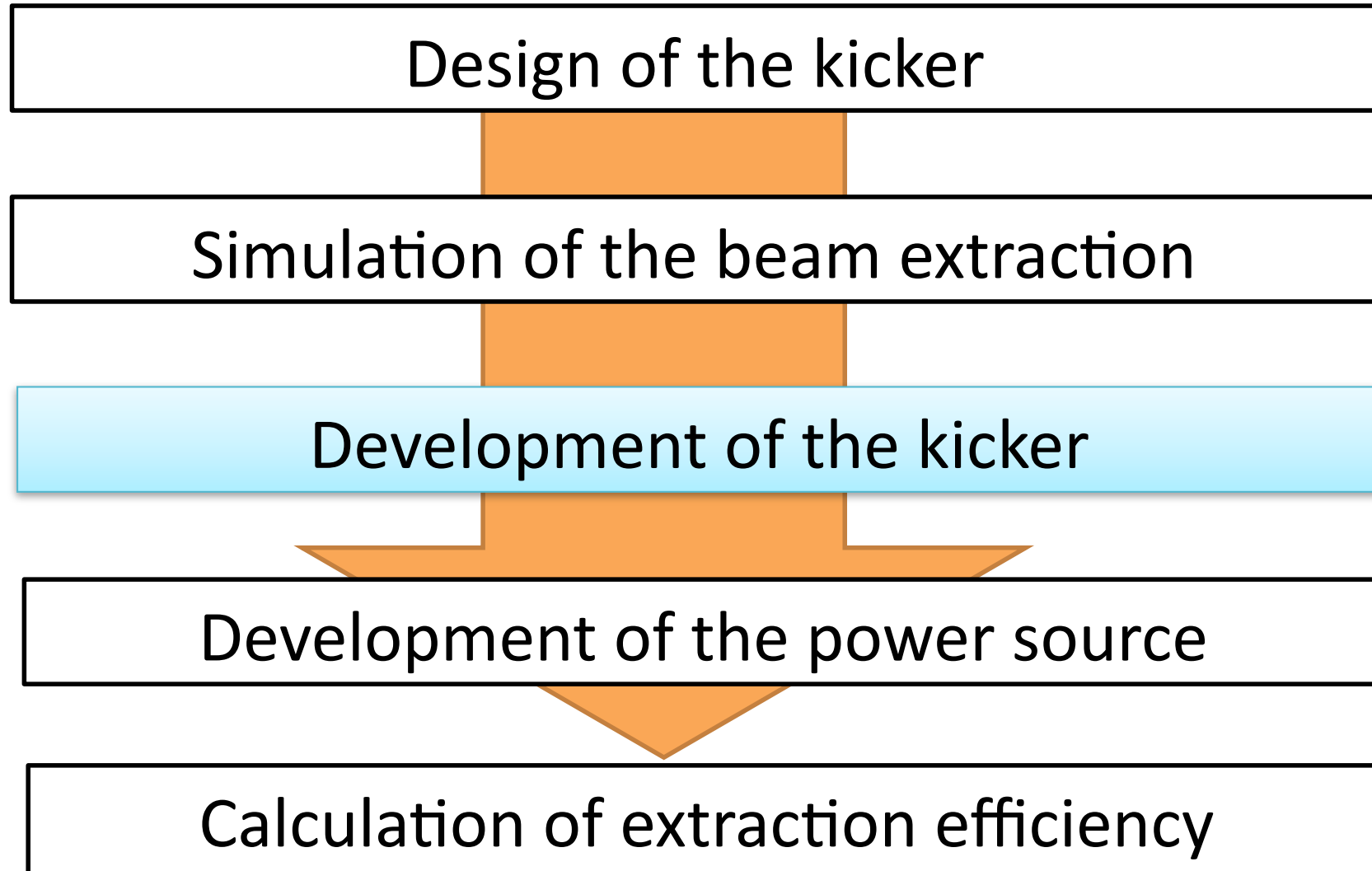
Simulation of the beam extraction

the extraction beam at septum magnet



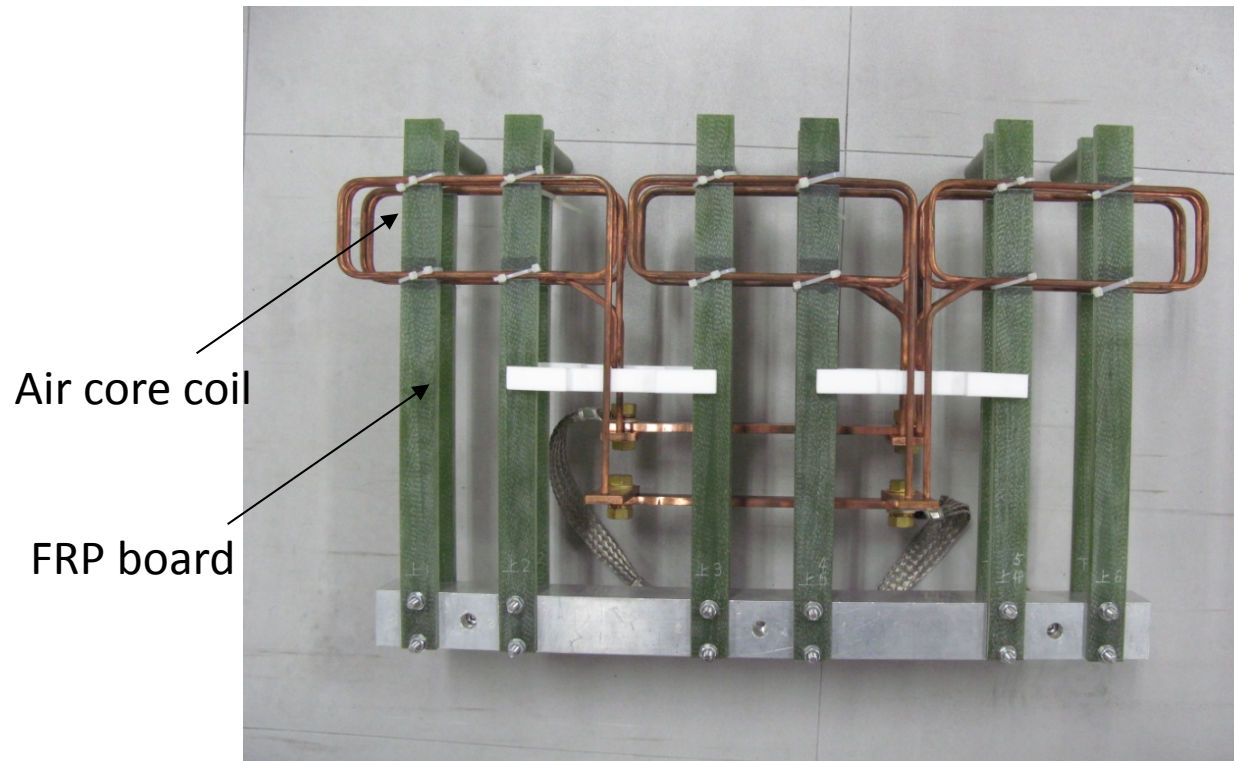
The extraction beam is not lost at the septum magnet.

Flow chart



Measurements of the kicker(1)

This is the kicker developed at Kyushu University.



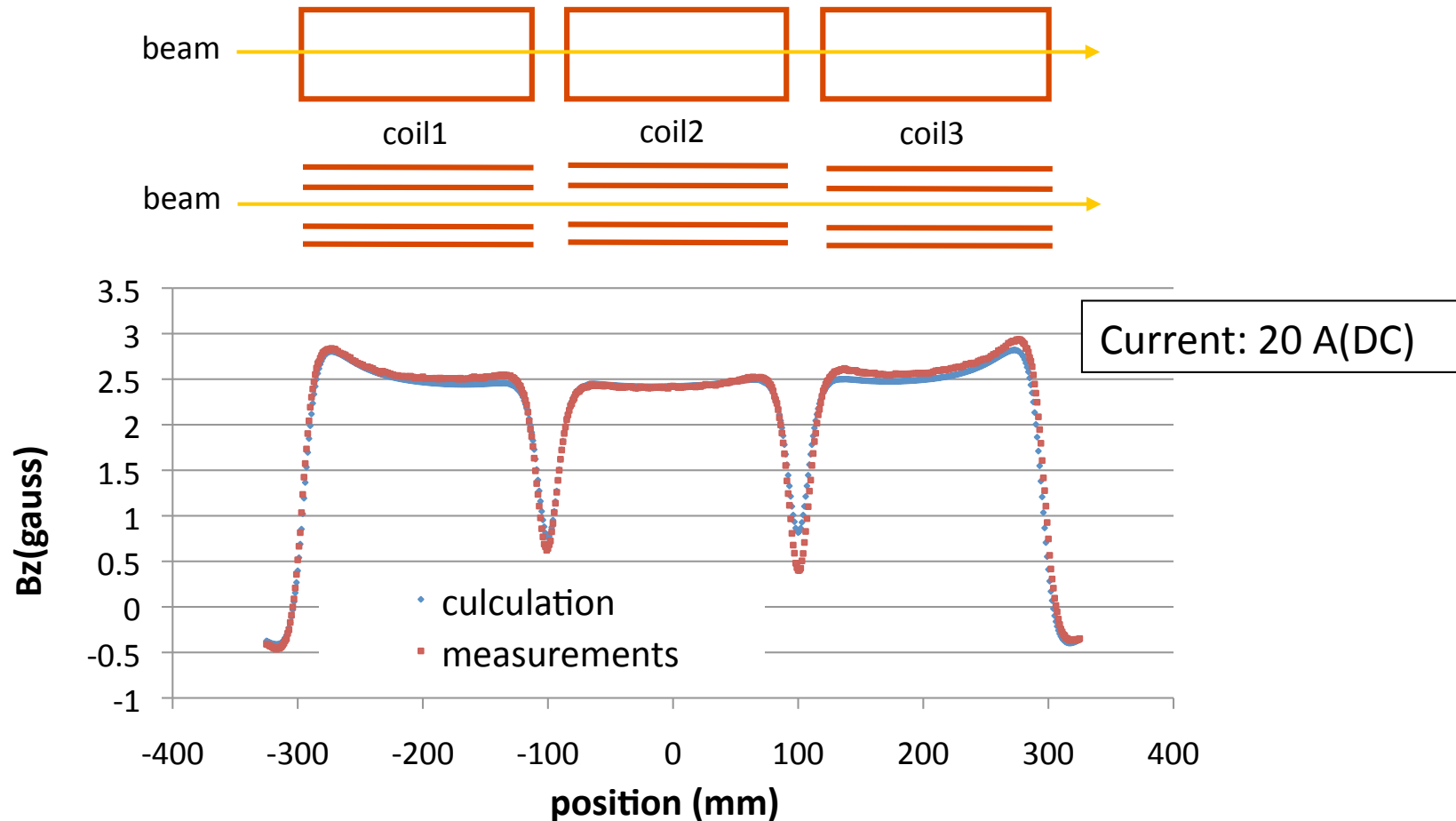
- The three divided air core coil is connected in parallel.
- Each coil is supported by FRP board.

Measured inductance by net work analyzer is $0.95 \mu\text{H}$.



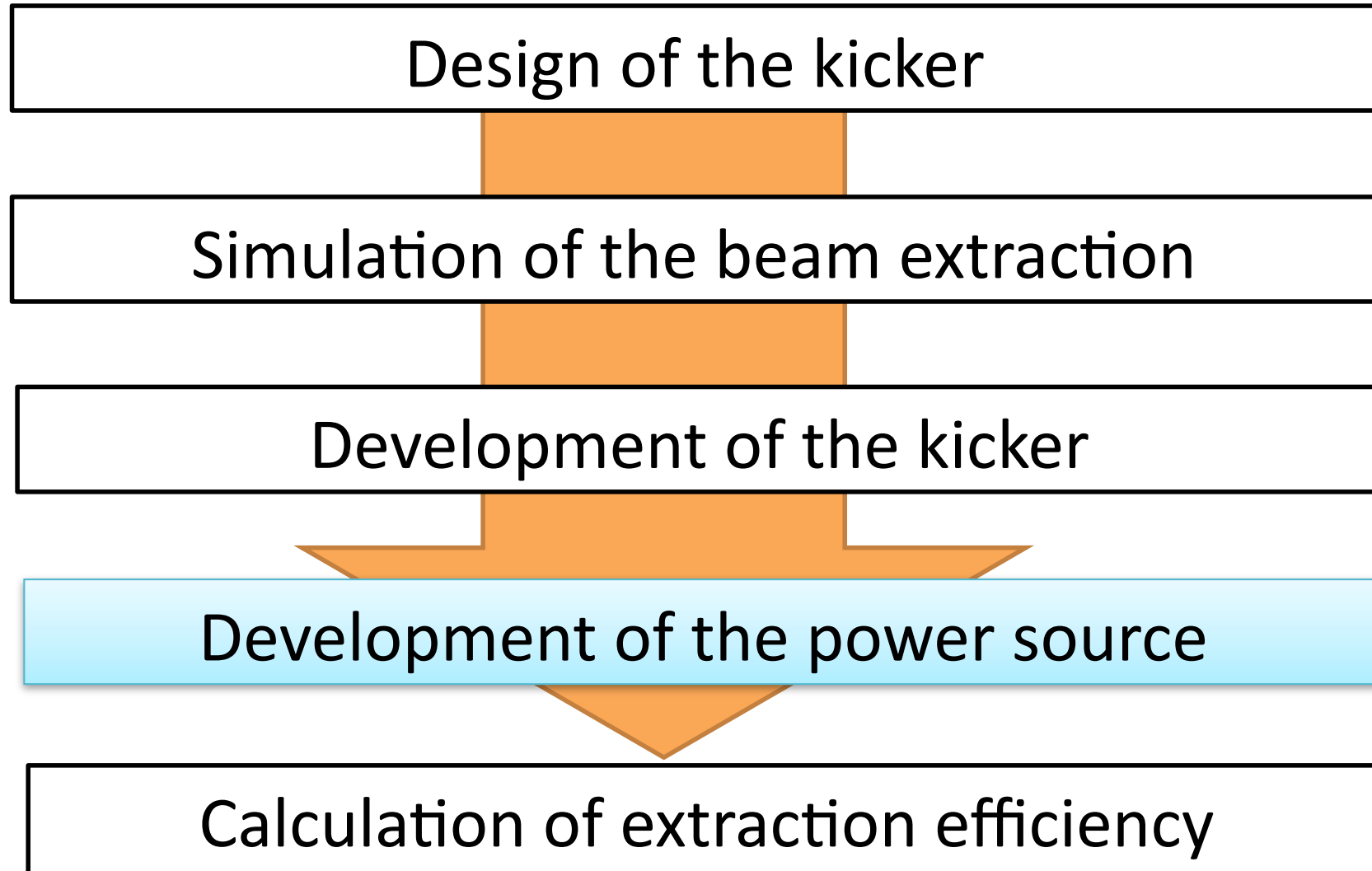
The inductance of the kicker meets requirements.

Magnetic field of the kicker(2)



Measured magnetic field of the kicker agrees with the calculation.

Flow chart

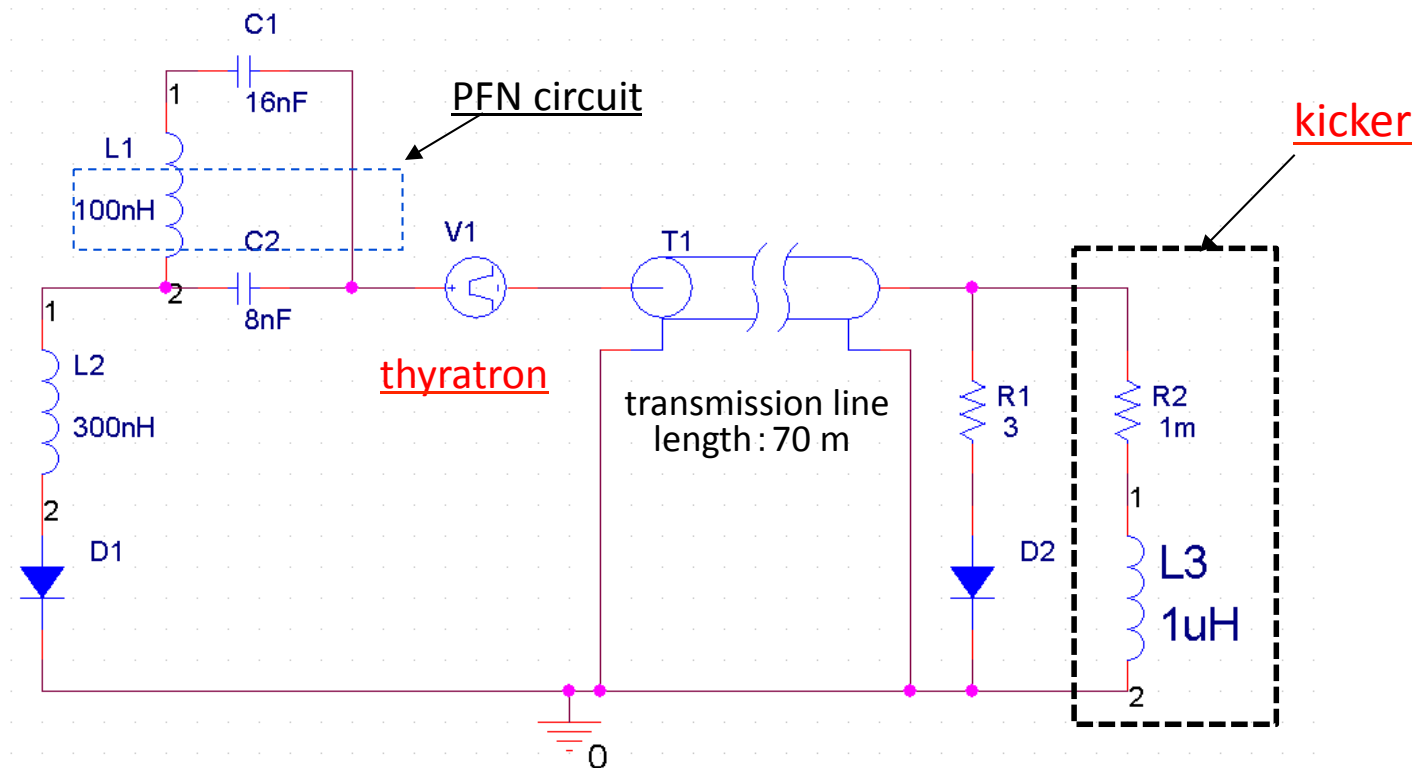


Power source

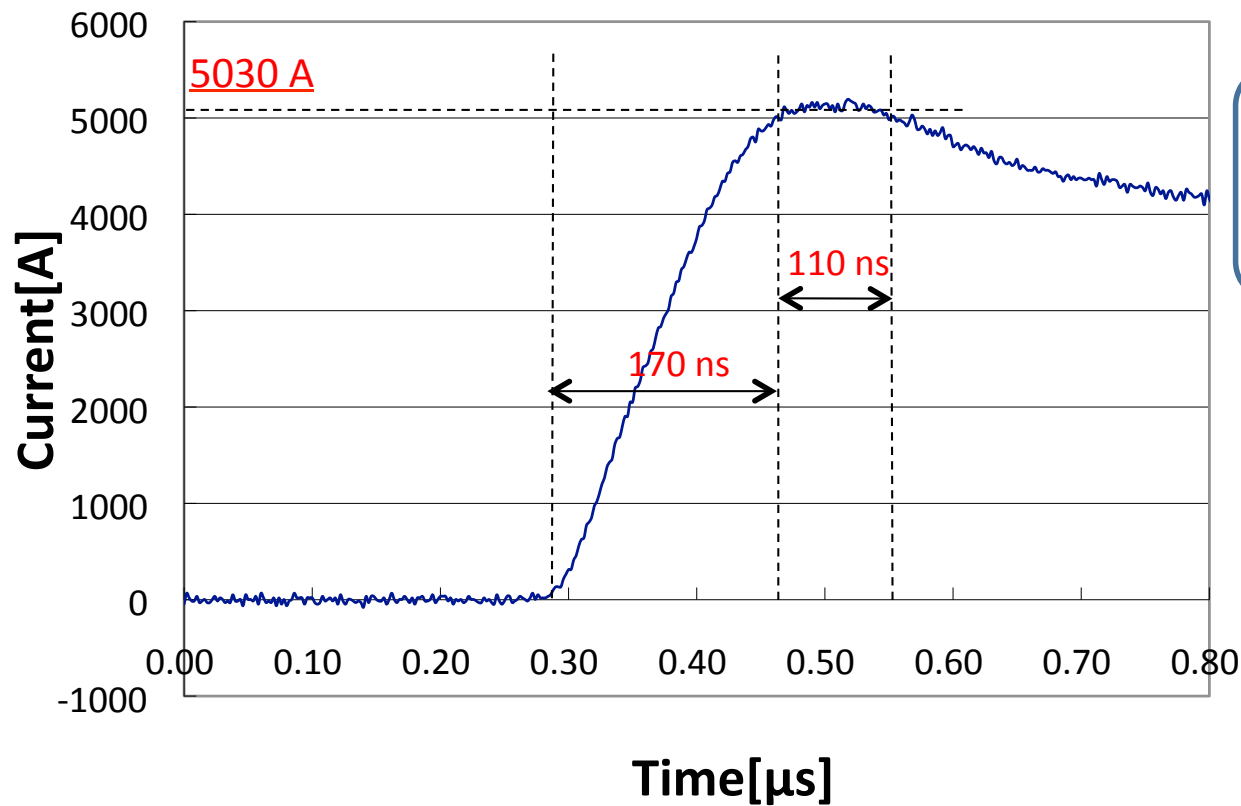
Requirements for power source

- Peak current : 5100 A
- Maximum voltage : 40 kV
- Rise time : 150 ns
- Flat top : 100 ns

- The power source consists of PFN circuit and thyatron.



Power test(1)



Experiment condition

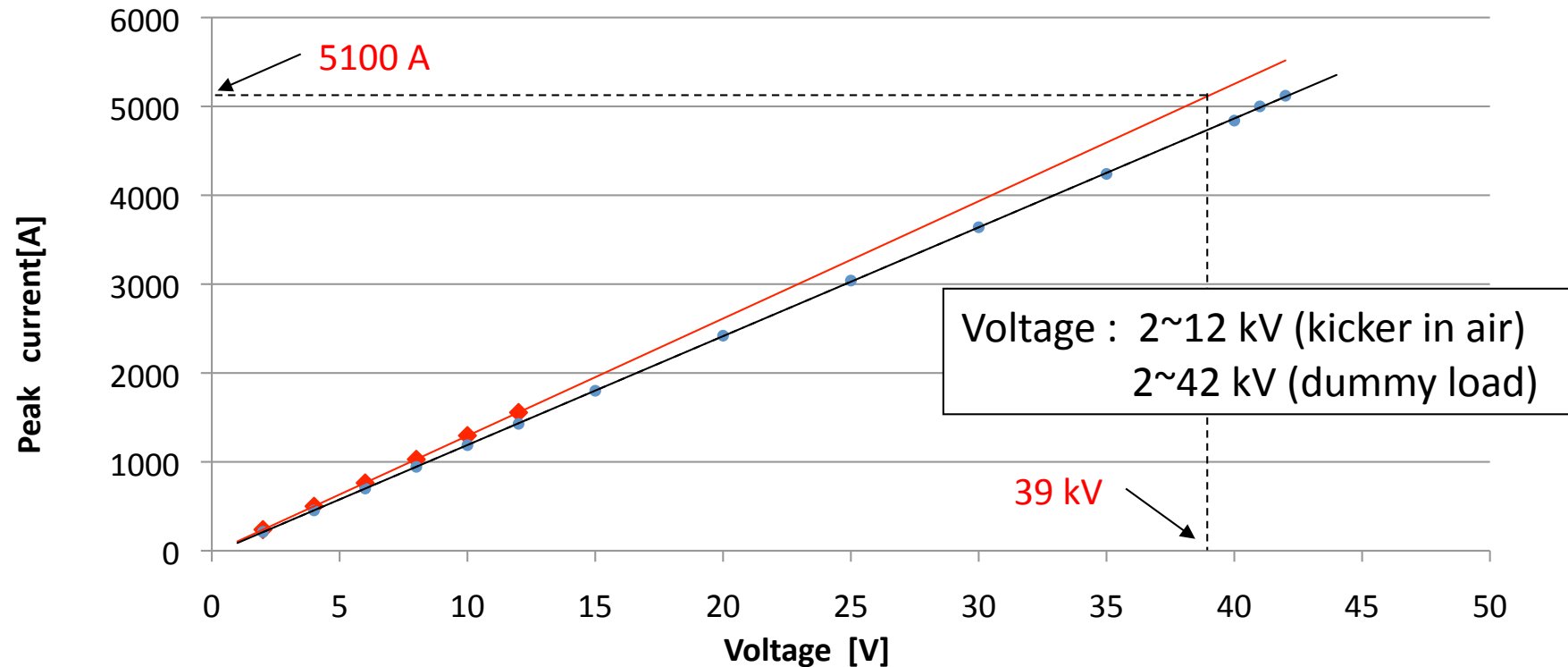
Dummy load: 1 μ H, 1 m Ω
Voltage : 42 kV(pulse)

Result

Rise time(0-96%): 170 ns
Flat top(more than 96%): 110 ns
Peak current: 5030 A

Power test(2)

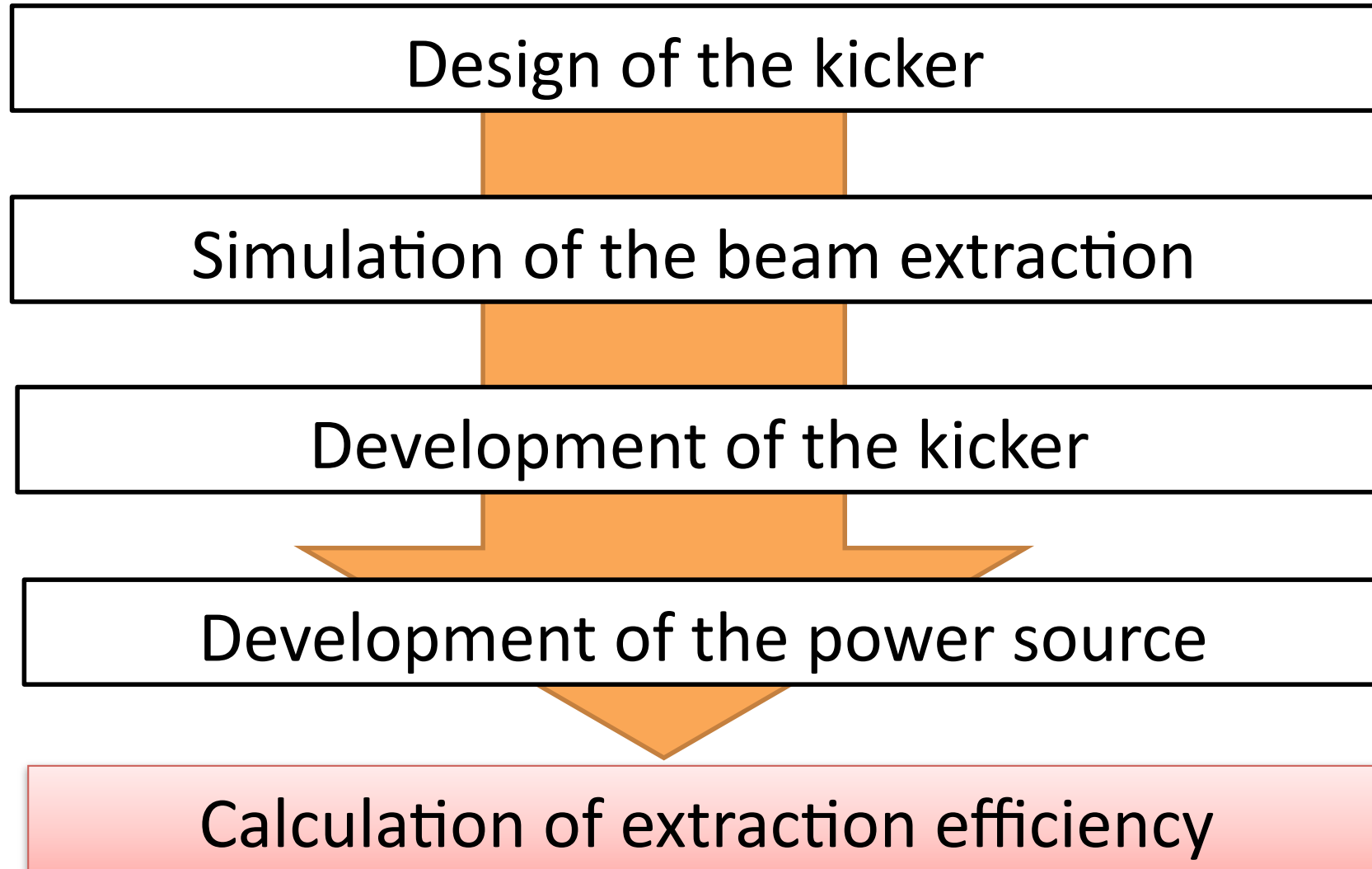
Measurement of peak current to voltage



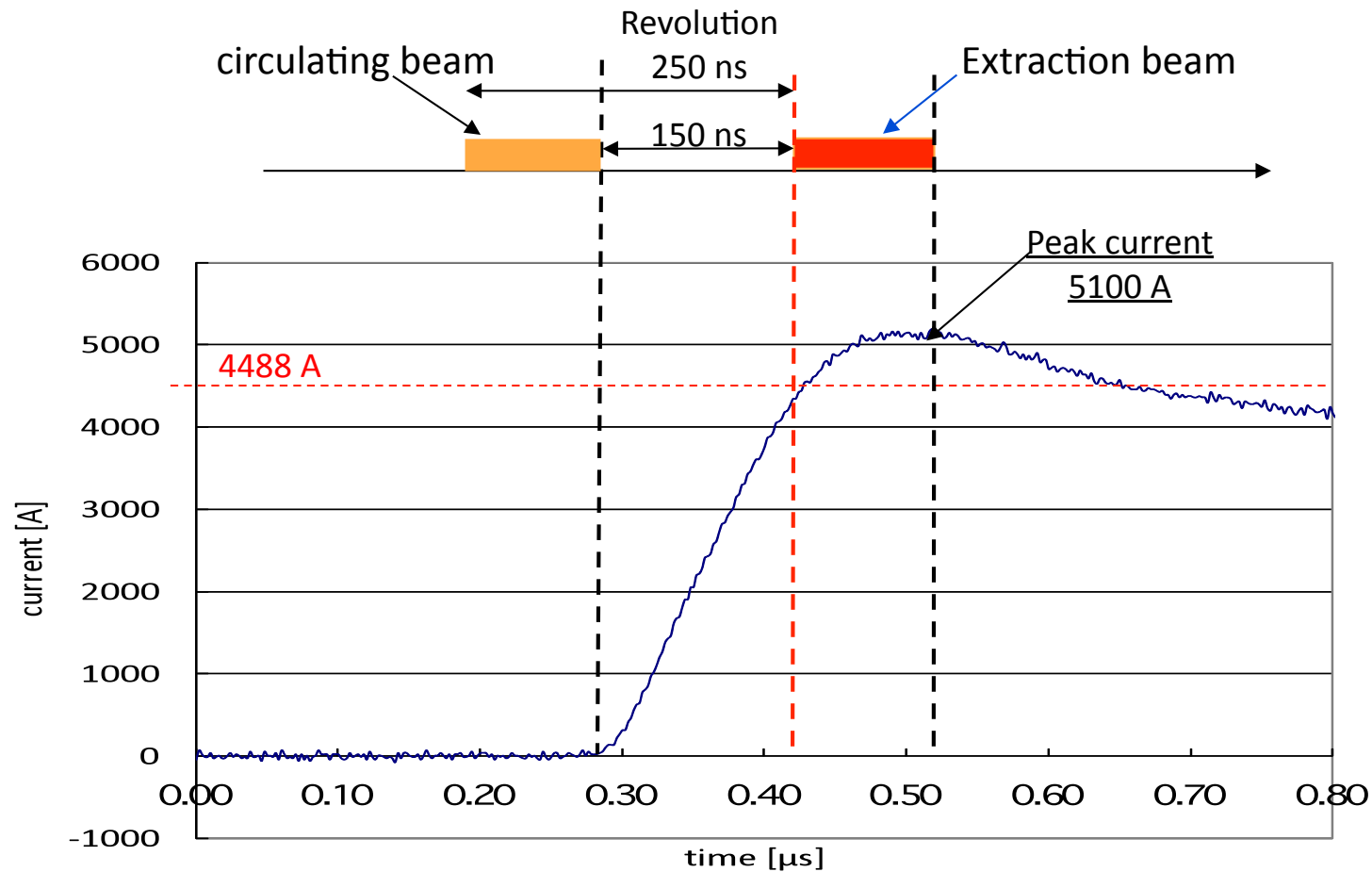
- Peak current is proportional to voltage of power source.

Required voltage is **39 kV** in order to realize required kicker current(5100 A).

Flow chart



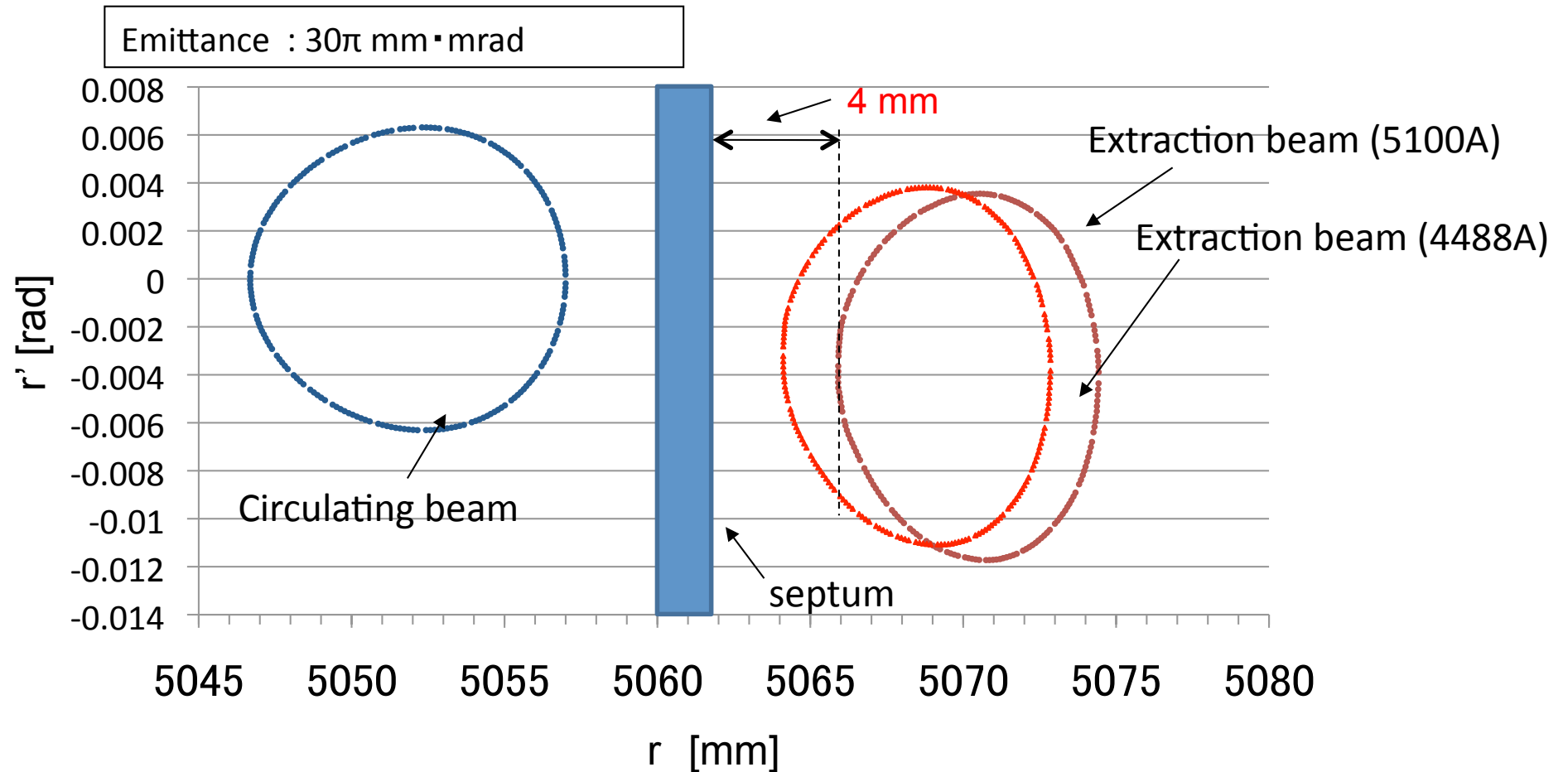
Simulation of the beam extraction(1)



Voltage 39 kV

- The extraction beam is kicked when the current of the kicker is from 4488 A to 5100 A.

Simulation of the beam extraction(2)



The calculated extraction efficiency is **100 %**.

Summary

Purpose of study

Development of the kicker with fast rise time in order to increase extraction efficiency

We designed a new type of the kicker

- The kicker coil was divided three part of coil

The new kicker was developed

- Inductance of the developed kicker is **0.95 μ H**

The power source for the kicker was developed

- Rise time of kicker current is **170 ns**,
and flat top is **110 ns**.

The simulation gives the extraction efficiency of **100%**

Thank you for listening to my presentation

