SYNCHROTRON INJECTION

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The 17th KEKB Accelerator Review Committee
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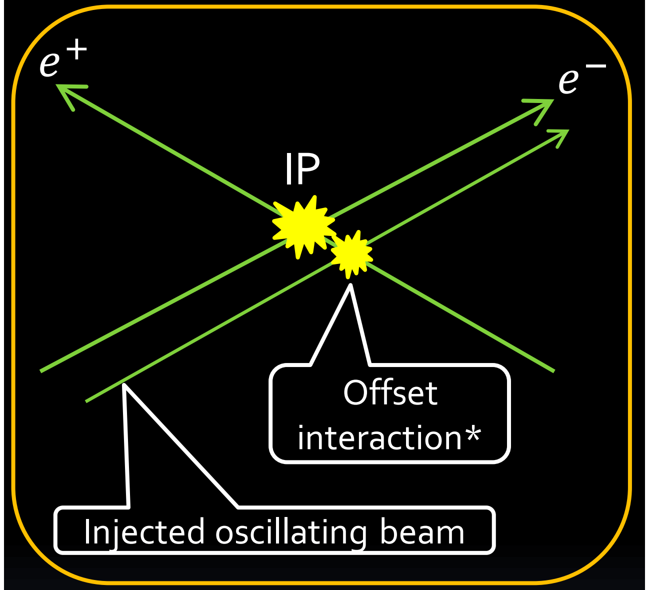
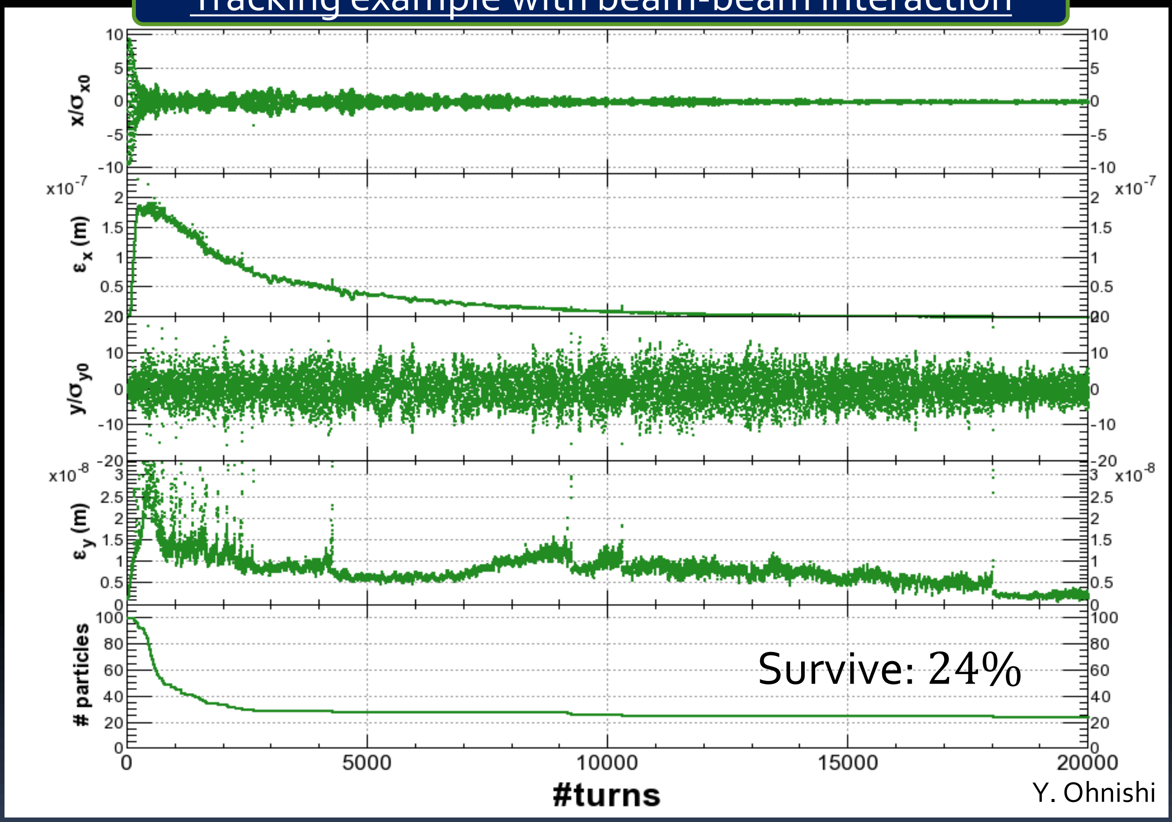
Why it necessary?

- Very low survival rate with betatron injection into HER is expected
  - If offset Δx from IP for betatron oscillation,
  - Kicked vertically by beam-beam force from the colliding beam



* Finite y-amplitude
$\Longrightarrow$ Large beam-beam kick
$\because$ Hour-glass effect

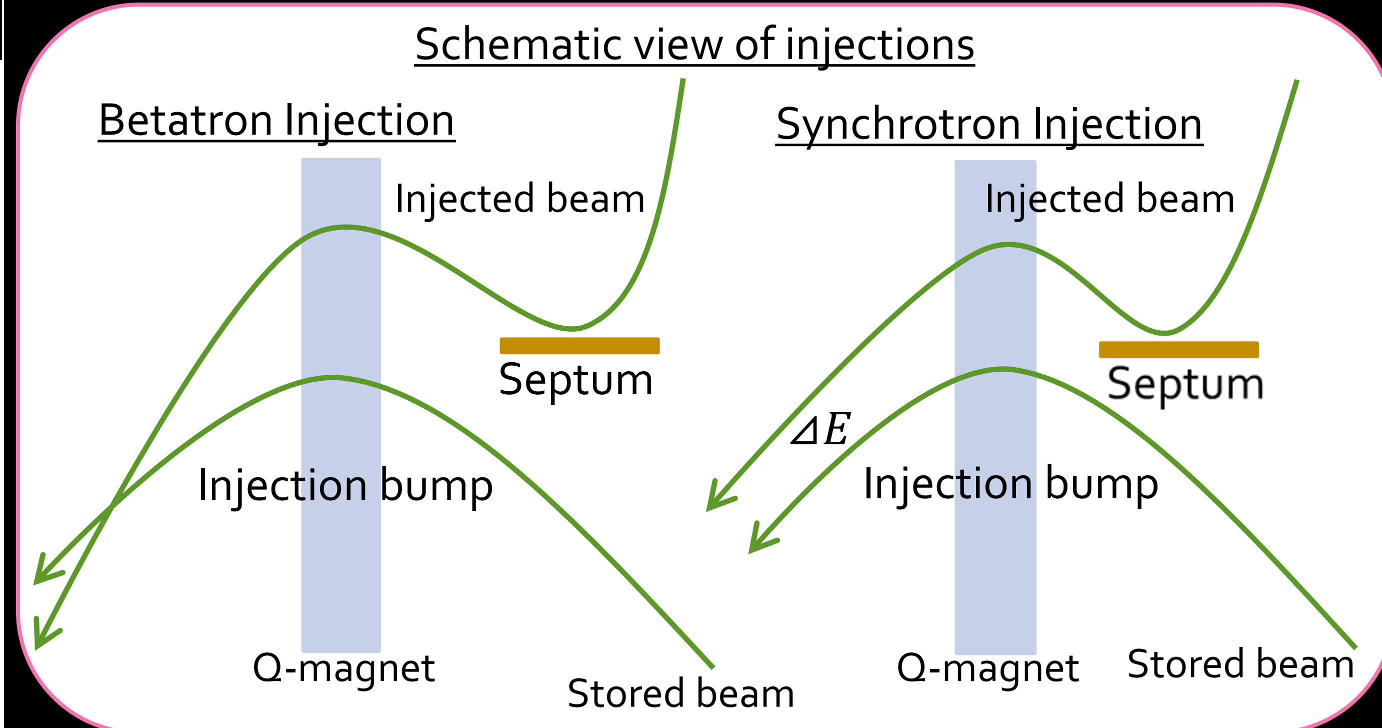
Tracking example with beam-beam interaction



- Synchrotron oscillation ⇒ no offset Δx ($\because \eta^* = 0$)

➡ **Synchrotron injection** (as a backup option of betatron inj.)

Synchrotron Injection



- Take advantage of synchrotron oscillation
  - Generate dispersion (η_{xR})
  - Injection with energy difference ($\delta_0 = \Delta p/p_0$)
  - $\Delta x = \eta\delta_0 = n_I\sigma_{xI} + w_S + n_R\sigma_{xR}$

$$\sigma_x = \sqrt{\beta_x\varepsilon_x + (\eta_x\sigma_\delta)^2}$$

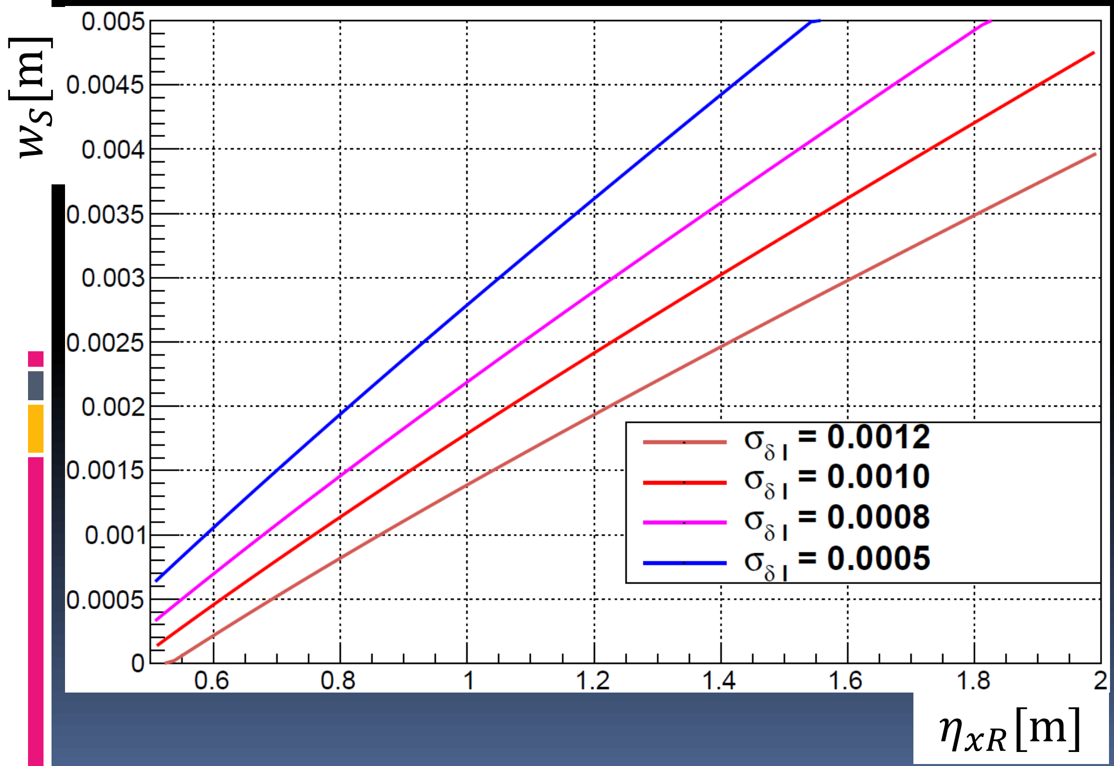
Parameter assumption

- $w_S = 5[\mathrm{mm}]$
- $\beta_{xR} = 60[\mathrm{m}]$
- $\varepsilon_{xR} = 4.6[\mathrm{nm}]$
- $\sigma_{\delta R} = 0.059[\%]$
- $n_R = 3.0$
- $\beta_{xI} = 20[\mathrm{m}]$
- $\varepsilon_{xI} = 1.46[\mathrm{nm}]$
- $\sigma_{\delta \mathrm{I}} = 0.1[\%]$
- $n_I = 2.5$

Synchrotron Injection

- What are requirements to realize?
  - $\Delta x = \eta_{xR}\delta_0 = n_I\sqrt{\beta_{xI}\varepsilon_{xI} + (\eta_{xI}\sigma_{\delta I})^2} + w_S + n_R\sqrt{\beta_{xR}\varepsilon_{xR} + (\eta_{xR}\sigma_{\delta R})^2}$

    Orbit shift | Injected beam spread | Septum width | Stored beam spread
  - Assumption from optics study: $\delta_0 + 2\sigma_{\delta I} = 0.65[\%]$



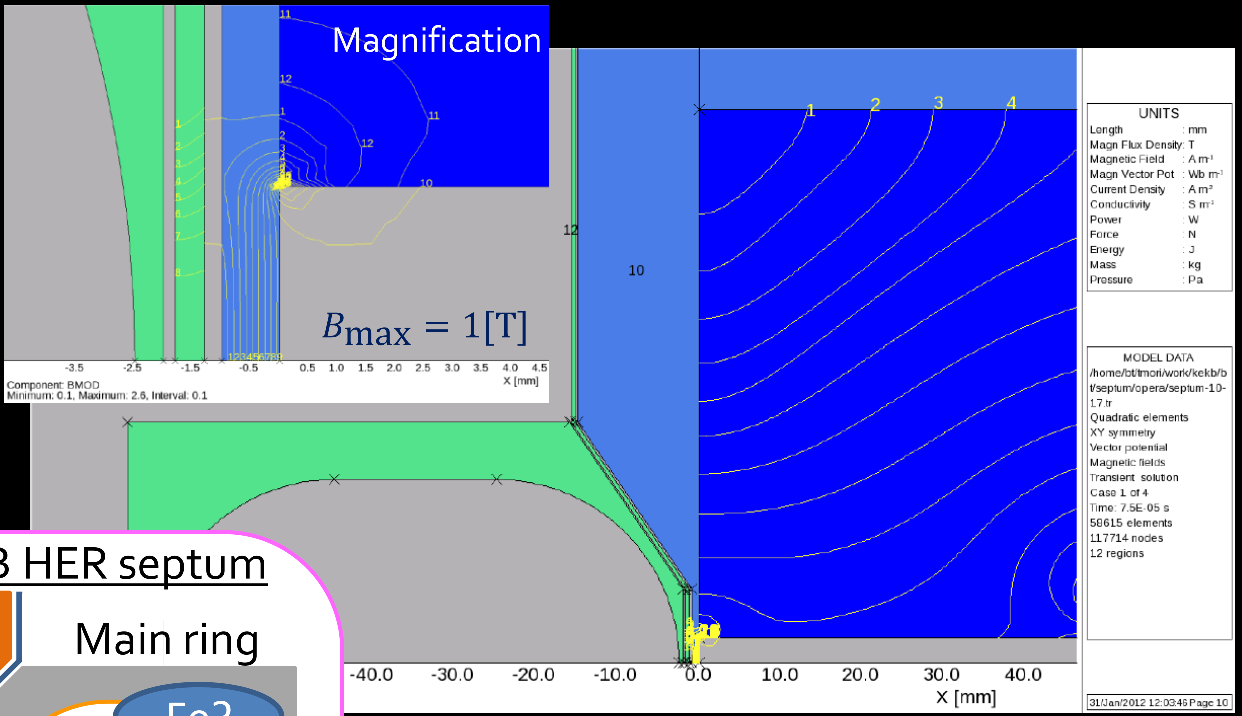
- $\sigma_{\delta I} = 0.1[\%] \& \eta_{xR} = 1.4[\mathrm{m}]$
  $\Rightarrow w_S < 3[\mathrm{mm}]$ required

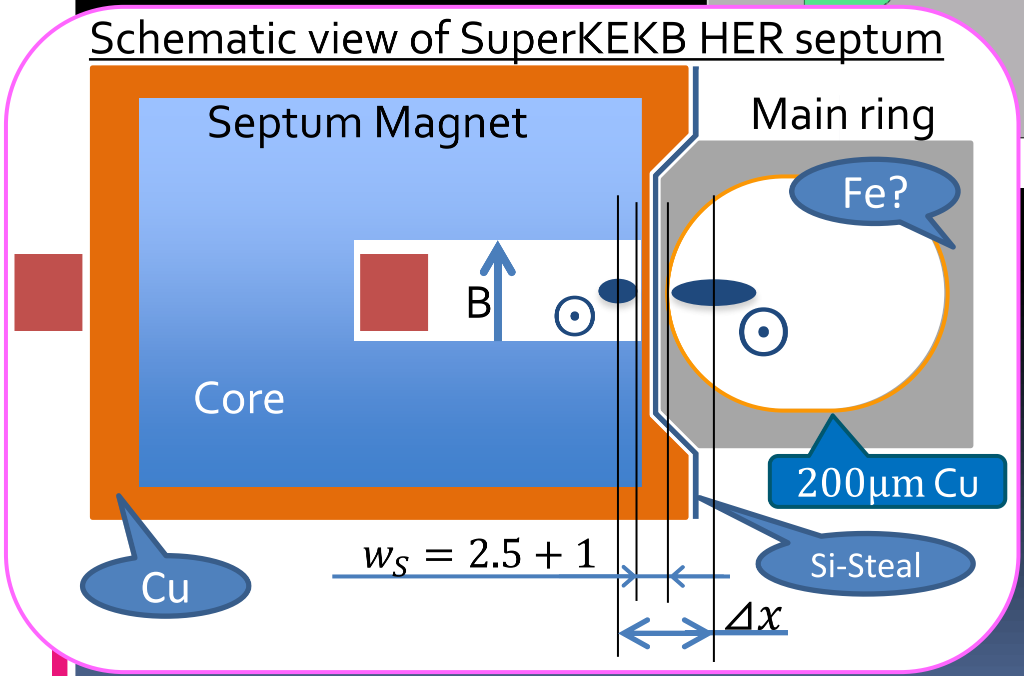
- Important parameters
  - w_S, η_{xR}, $\sigma_{\delta I}$
    - Have the 1st order effect

Injection Septum (w_S)

w_S η_{xR} $\sigma_{\delta I}$

- Get thinner w_S
- Suppress leak field
- Calculation (OPERA)
  - Transient analysis
    - Sine wave($\tau = 0.3[\text{ms}]$)
  - $B_{\max} = 1[\text{T}]$



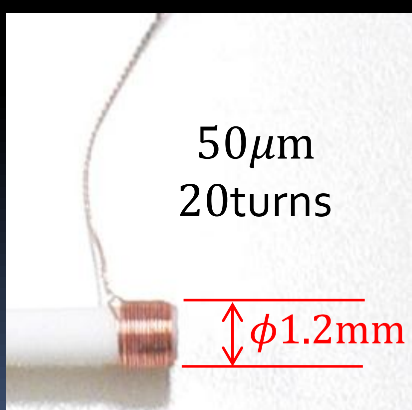


- Current : $w_S = 3.5[\text{mm}]$
  - Non-uniform field region included
  - KEKB: 5mm
- Issues
  - Magnetic material for vacuum chamber
  - Shim shape
    - To reduce non-uniform region

Injection Septum Upgrade

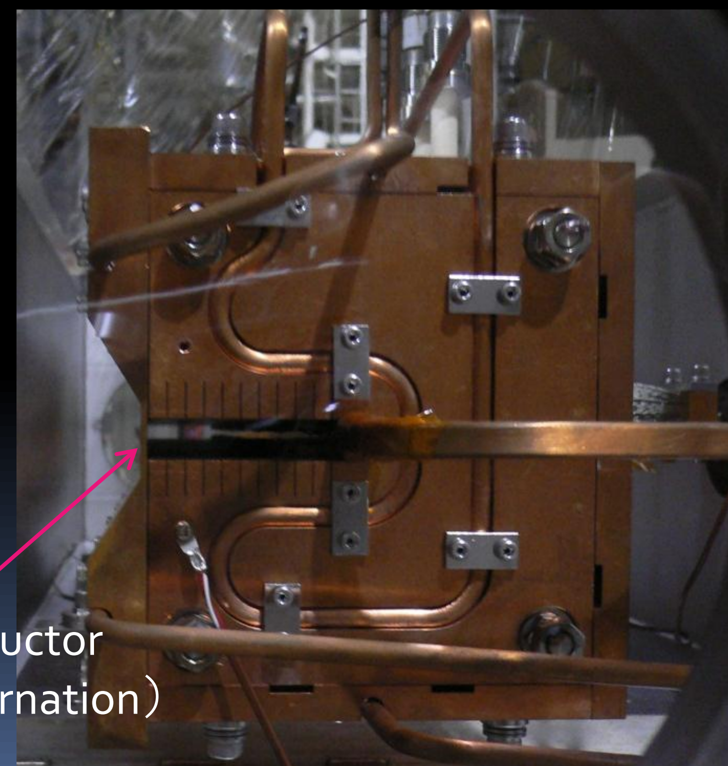
w_S η_{xR} $\sigma_{\delta I}$

- Alternation of septum conductor
  - Thickness: 1.5mm $\longrightarrow$ 1.0mm
  - Skin depth: 1.2mm $\Longrightarrow$ Leakage field should be considered
  - Perform field measurement
    - 3D transient field calculation is too heavy
- Producing
  - 1mm septum conductor
  - Mockup of beam chamber



Pickup coil

- $B = 10^{-4}$[T]
  - $V_0 = 30$[mV]

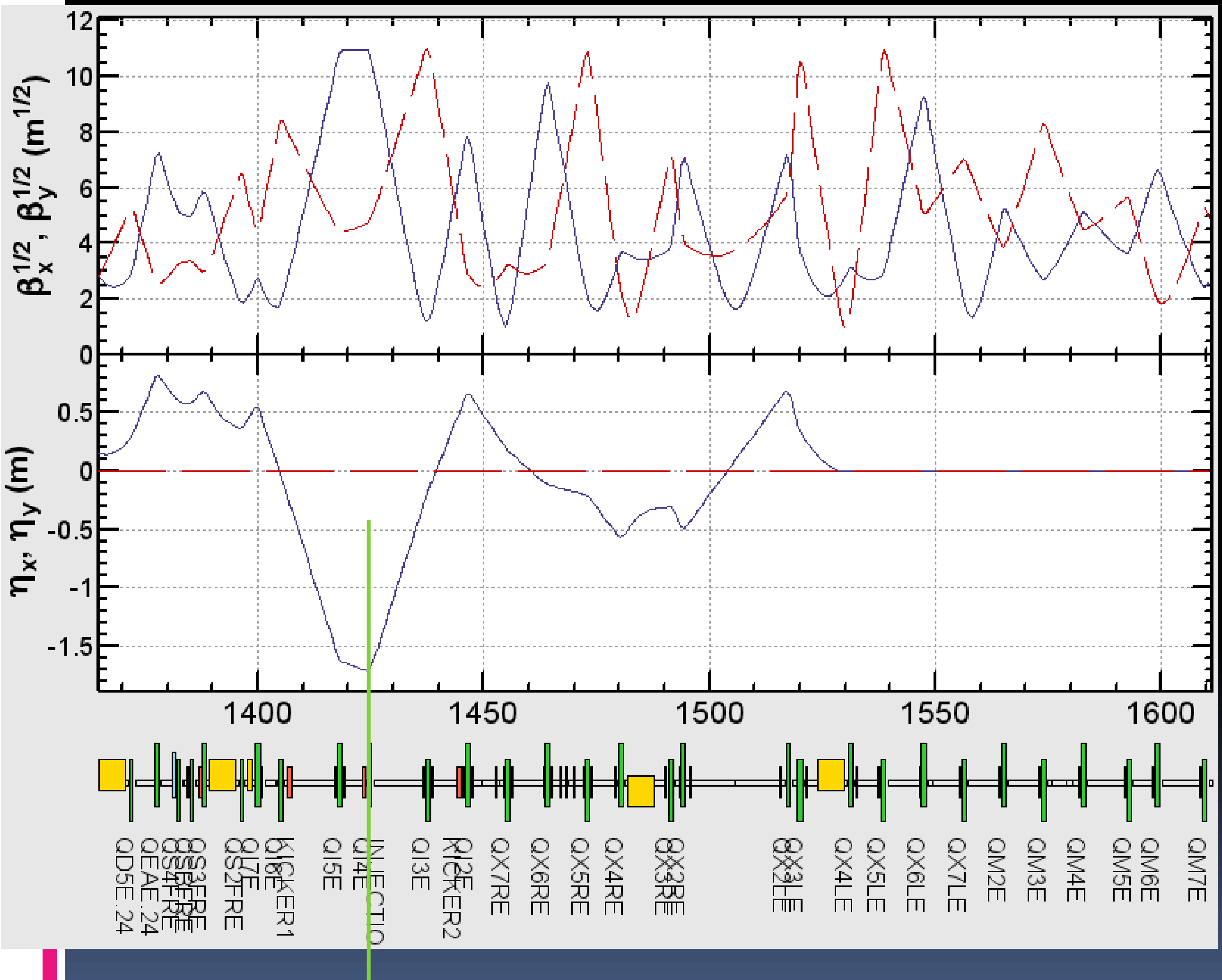


Septum conductor
（before alternation）

Dispersion (η_{xR})

w_S η_{xR} $\sigma_{\delta I}$

- Optics calculation



Injection point

Matching

- $\eta = -1.6[\mathrm{m}]$
- $\varepsilon_x = 4.6[\mathrm{nm}]$
- Kicker bump: 25mm

Energy Spread ($\sigma_{\delta I}$)

w_S η_{xR} $\sigma_{\delta I}$

- Simple calculation with Linac parameters
  - Acceleration field : 2856MHz
  - Bunch length : $\text{FWHM} = 3[\text{mm}]$
  - On crest acceleration
  - Space charge & wake field are not considered

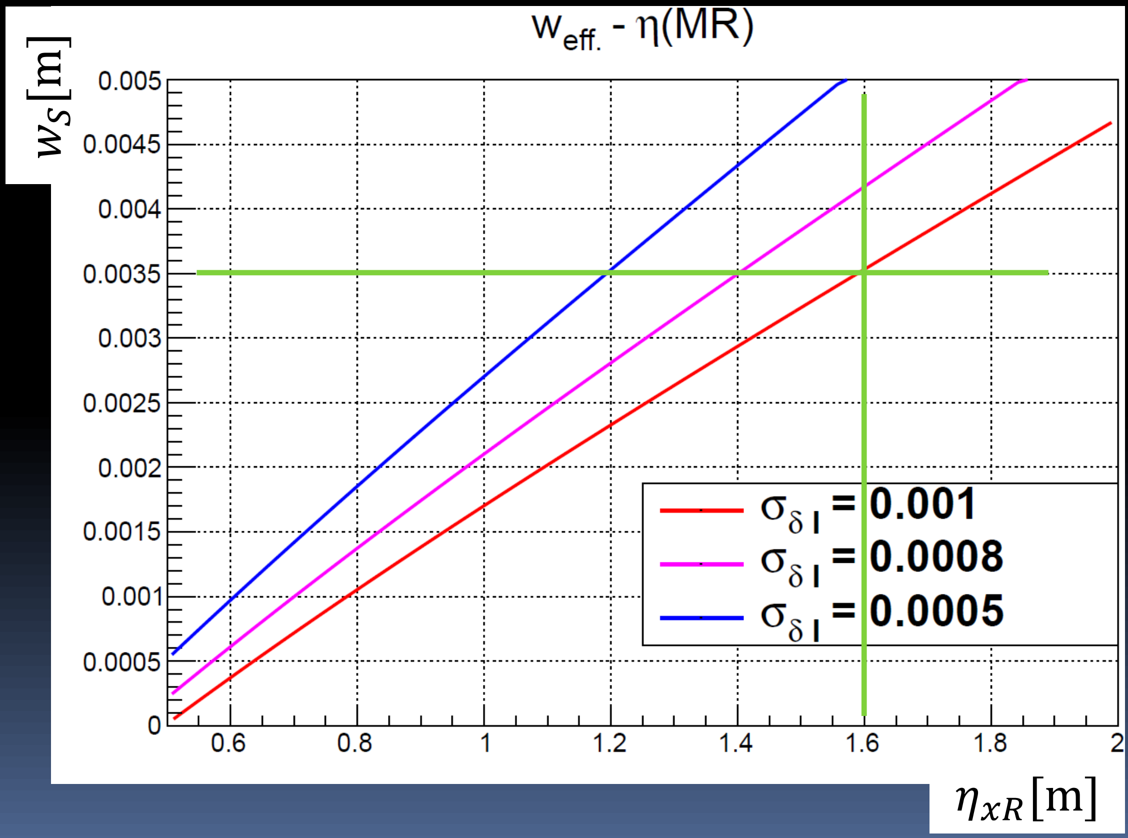
	Gaussian beam	Rectangular beam
$\sigma_{\delta I}[\%]$	0.41	0.12
Injection efficiency	0.7	0.9

- Assuming only $\delta_I \leq 0.1[\%]$ part of beam is successfully injected

- Study is on going in Linac group to reduce energy spread

Result & Summary

- Due to hour-glass effect, very low survival rate with betatron injection into HER is expected
  $\Longrightarrow$ synchrotron injection
- Considered requirements for synchrotron injection scheme
  - Effective septum width: $3.5\mathrm{mm}$
  - Dispersion: $-1.6\mathrm{m}$
  - Energy spread: $\sigma_{\delta I} = 0.1\%$



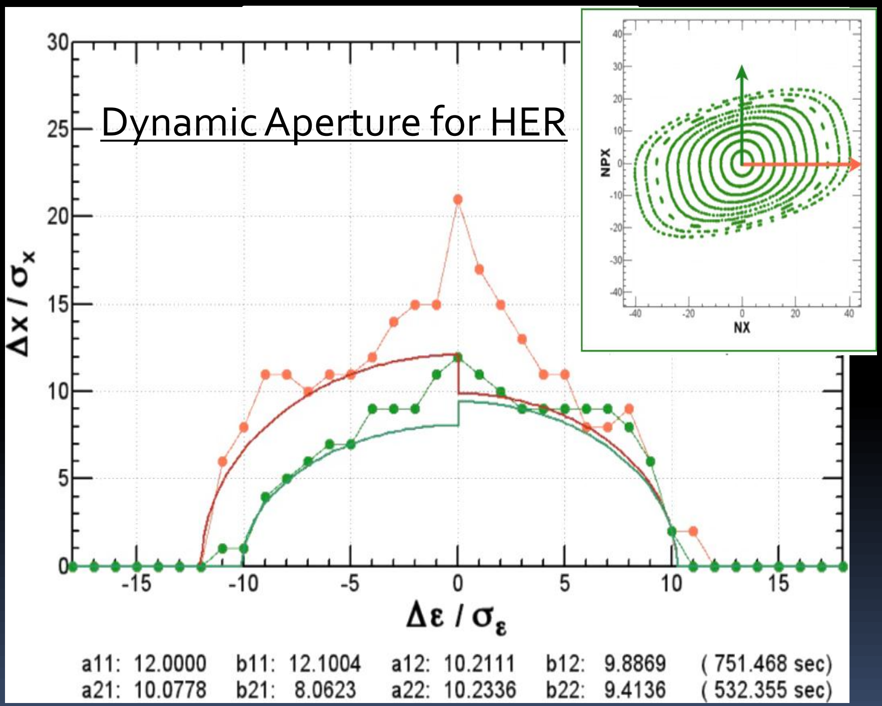
- In progress
  - Septum
    - Shim of pole
    - Storage beam chamber
    - 1mm septum conductor
  - Injection tracking
    - Check survival rate

Thank you!

Backup

Motivation

- Betatron injection is impossible
  - Because of low emittance
- More phase space expected in synchrotron oscillation



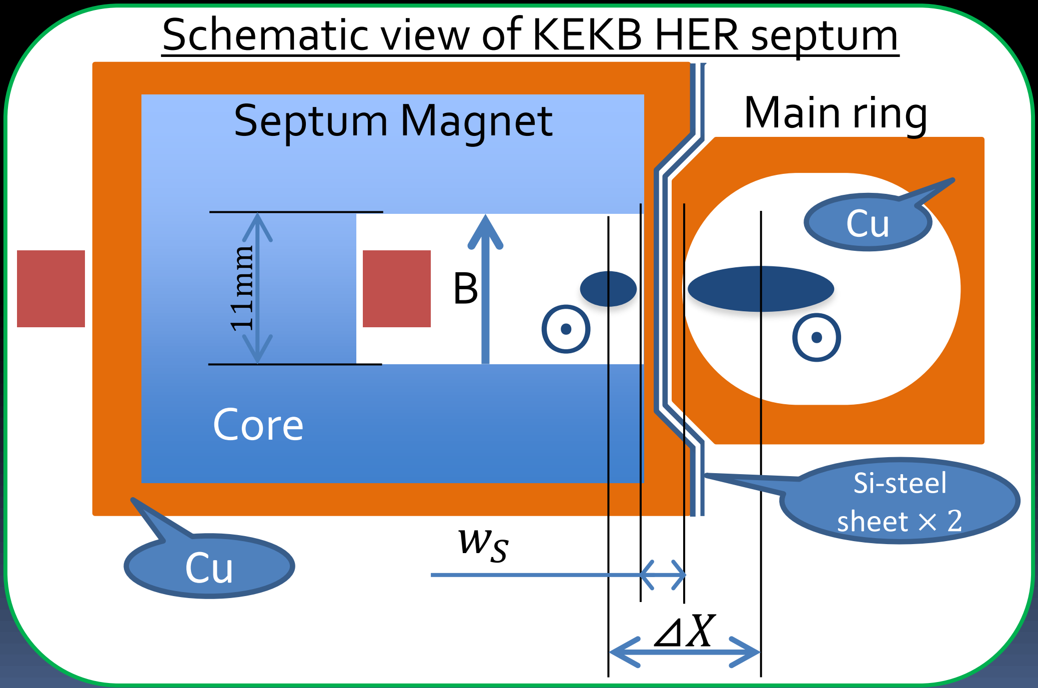
Y. Ohnishi

- $\Delta x \sim 7[\mathrm{mm}]$
  - $\varepsilon_x = 4.6[\mathrm{nm}]$
  - $\beta_x \sim 100[\mathrm{m}]$
  - $\sigma_x \sim 700[\mu\mathrm{m}]$

Synchrotron Injection

- Take advantage of synchrotron oscillation
  - Generate dispersion (η) at injection point
  - Injection with energy difference (δ_0)
  - $\Delta x = \eta\delta_0 = n_I\sigma_{xI} + w_S + n_R\sigma_{xR}$
  - $\delta_0 + 2\sigma_{\delta I} = 0.65[\%]$

$$\sigma_x = \sqrt{\beta_x\varepsilon_x + (\eta_x\sigma_\delta)^2}$$



KEKB parameters

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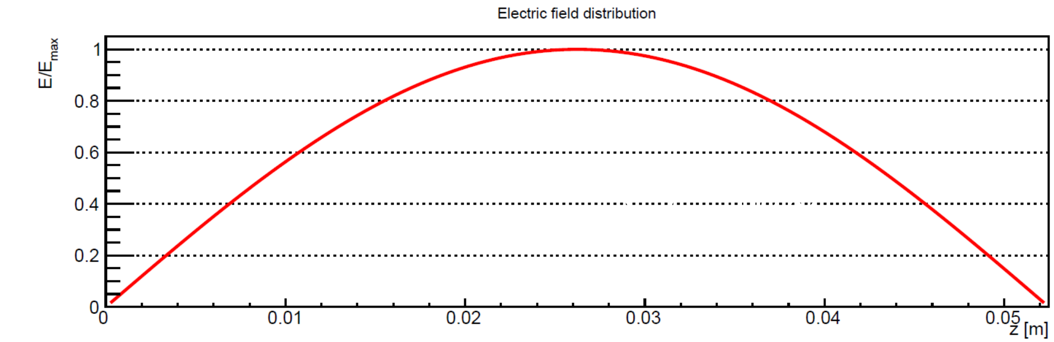
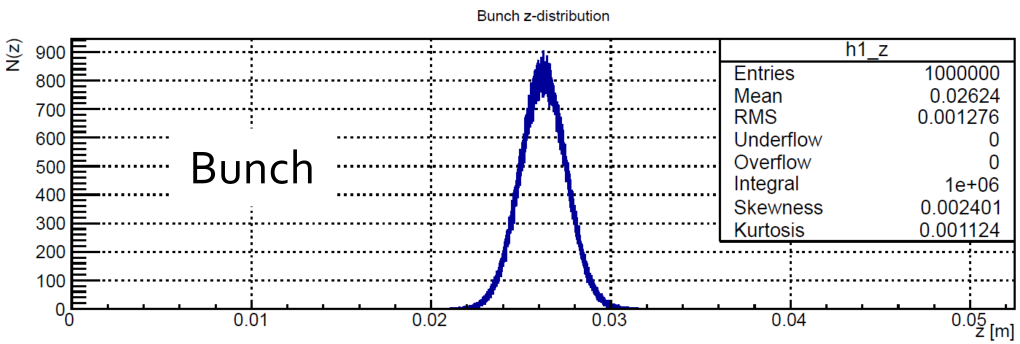
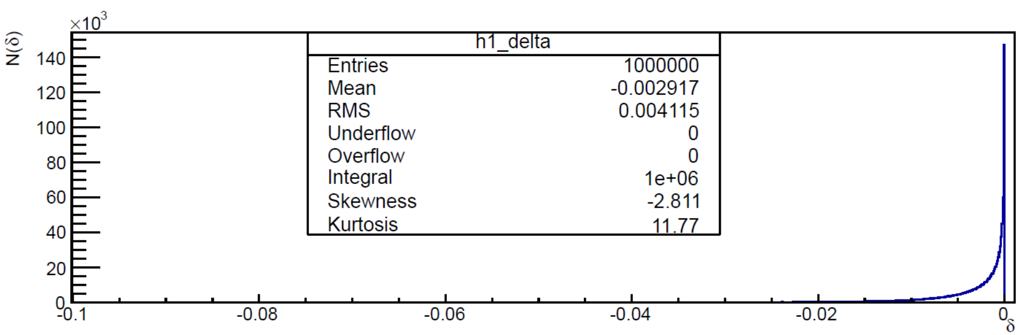
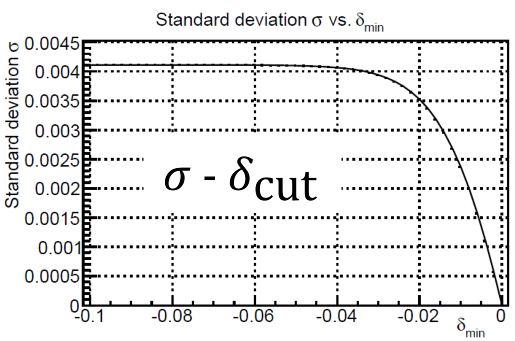
Gaussian Beam

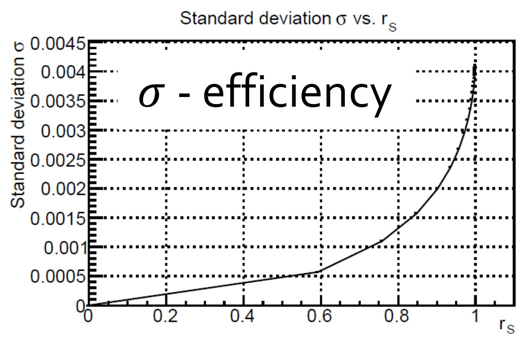
- $\sigma_\delta = 0.4[\%]$
- Obtain $\sigma_\delta = 0.1[\%]$
  - $\delta_{\text{cut}} = 0.4[\%]$
  - Efficiency : 0.7



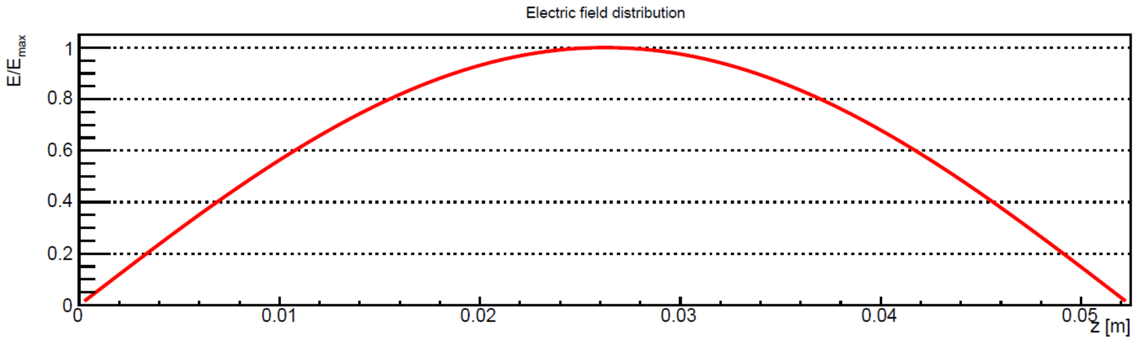


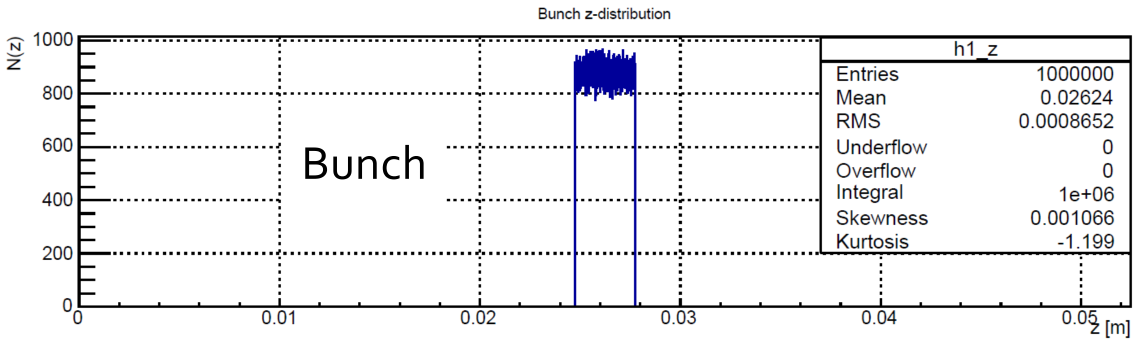


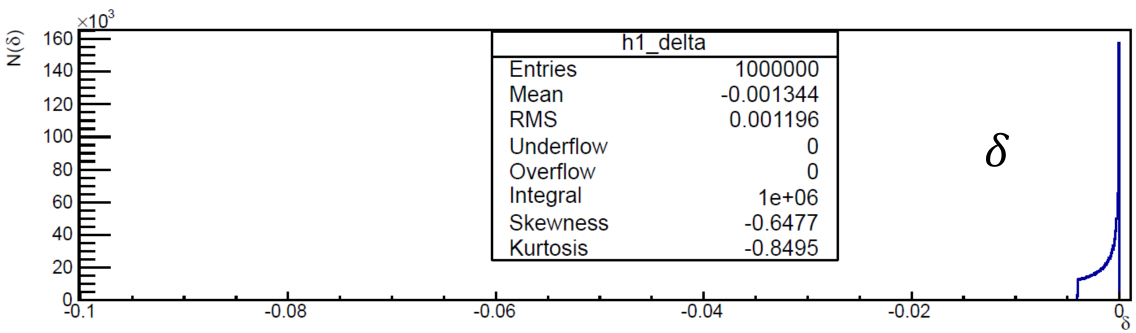


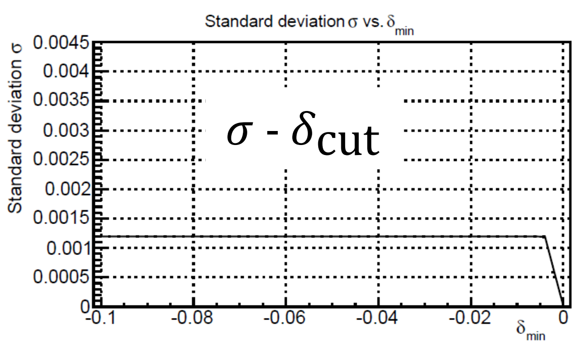


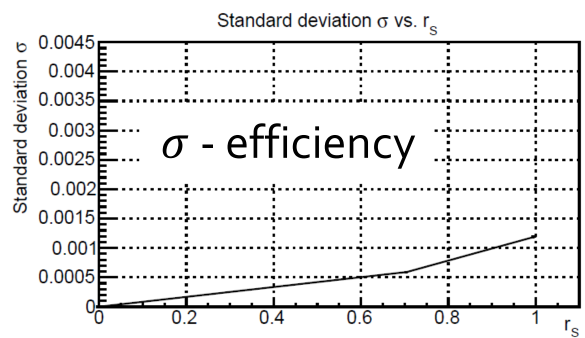
Rectangular Beam











- $\sigma_\delta = 0.12[\%]$
- Obtain $\sigma_\delta = 0.1[\%]$
  - $\delta_{\text{cut}} = 0.4[\%]$
  - Efficiency: 0.9

セプタム磁場の温度依存性