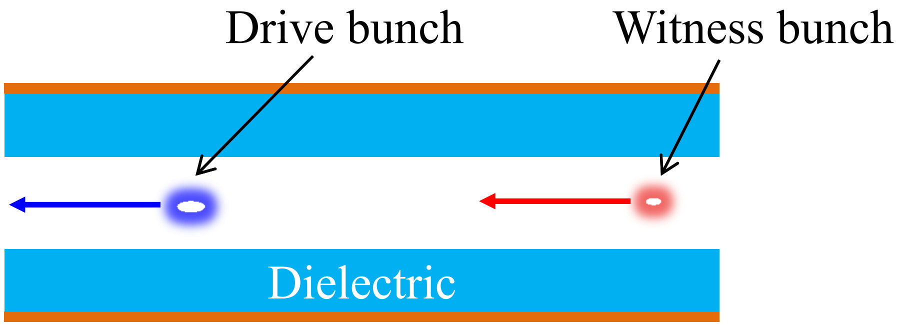
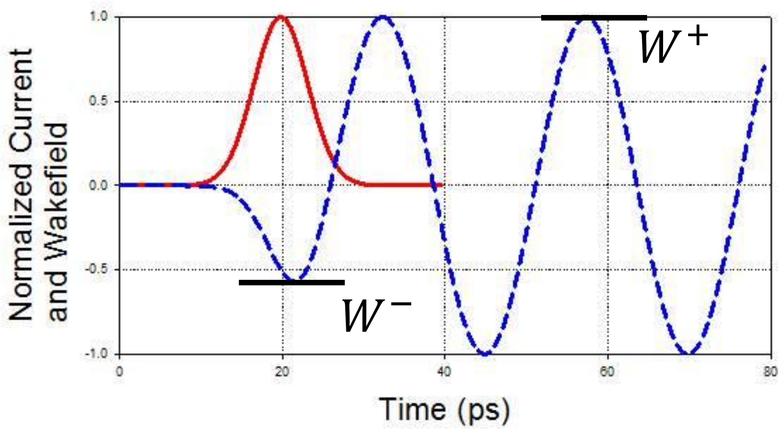
Demonstration of current profile shaping using EEX beam line at Argonne Wakefield Accelerator

Gwanghui Ha, POSTECH/ANL

7th International Particle Accelerator Conference
Busan, KOREA (May 8-13, 2016)

Motivation: wakefield acceleration and transformer ratio

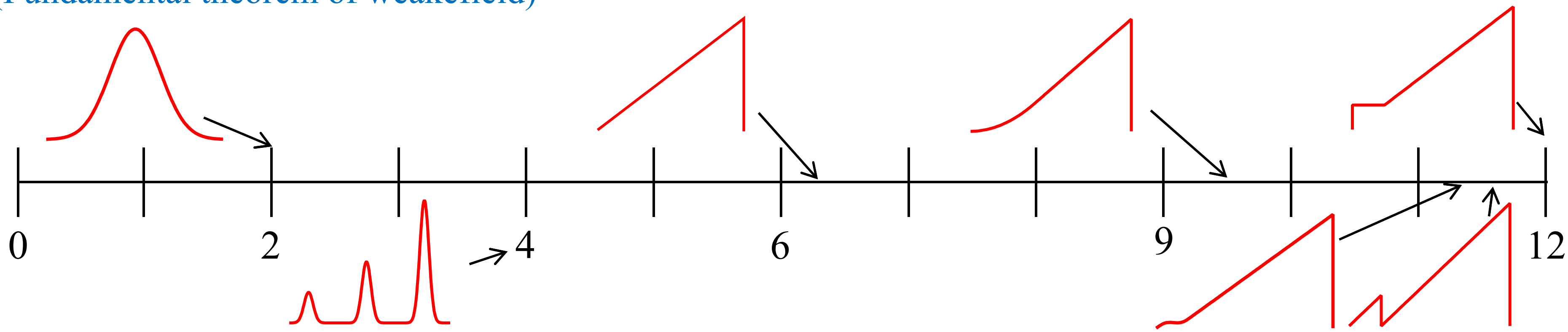




$$\mathbf{R} = \frac{W^+}{W^-} = \frac{\text{Maximum field behind drive bunch}}{\text{Maximum field inside drive bunch}}$$

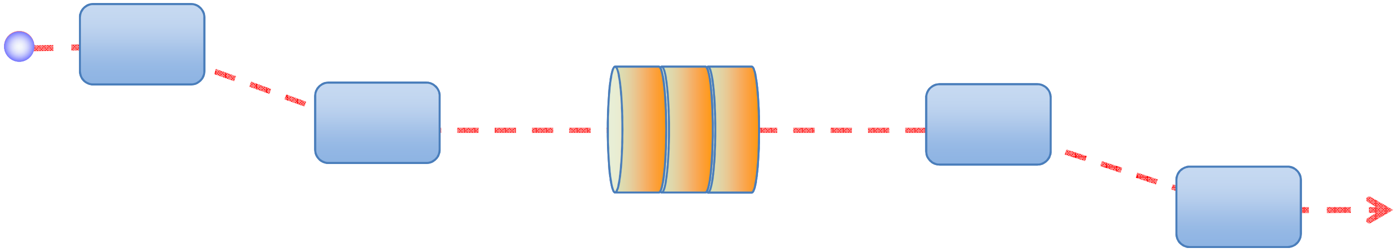
R<2 for symmetric bunches
(Fundamental theorem of weakefield)

Assume $N = Z/\lambda = 2$



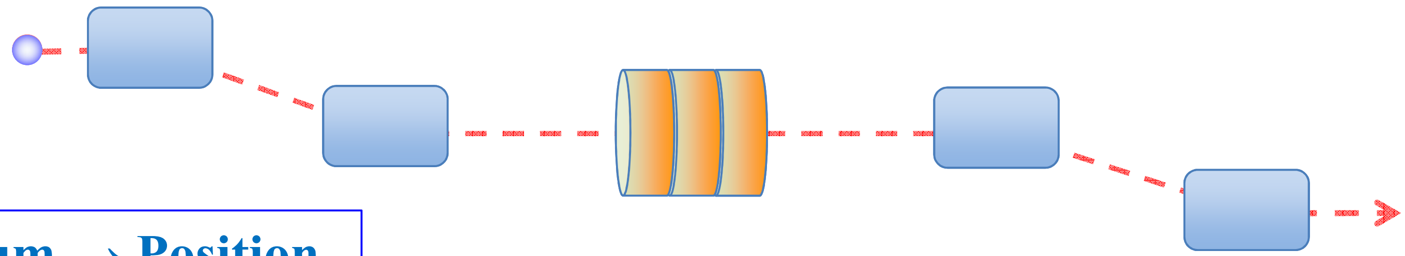
- K. L. F. Bane, SLAC-PUB-3662 (1985)
- F. Lemery and P. Piot, PRSTAB 18, 081301 (2015)

Property exchange in EEX beam line



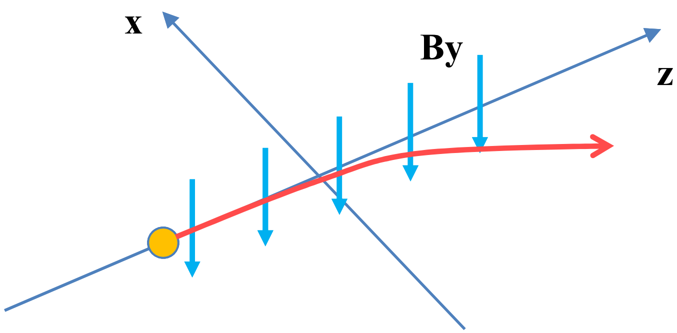
Double dog-leg emittance exchanger

Property exchange in EEX beam line



Double dog-leg emittance exchanger

Momentum → Position



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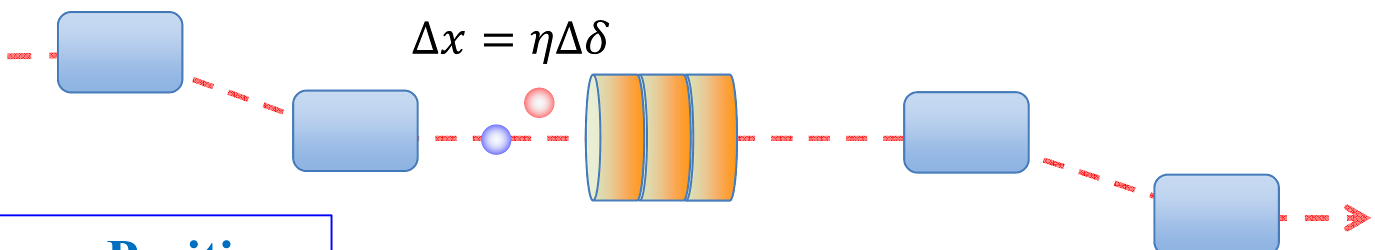

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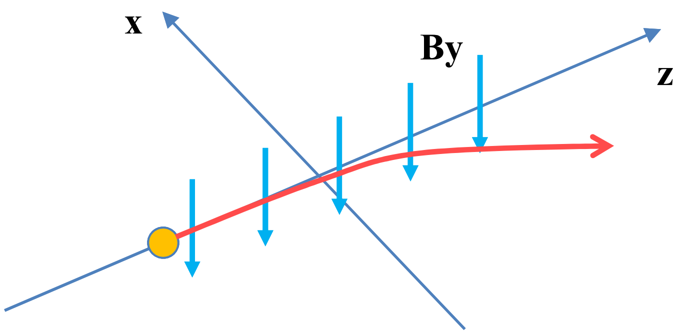

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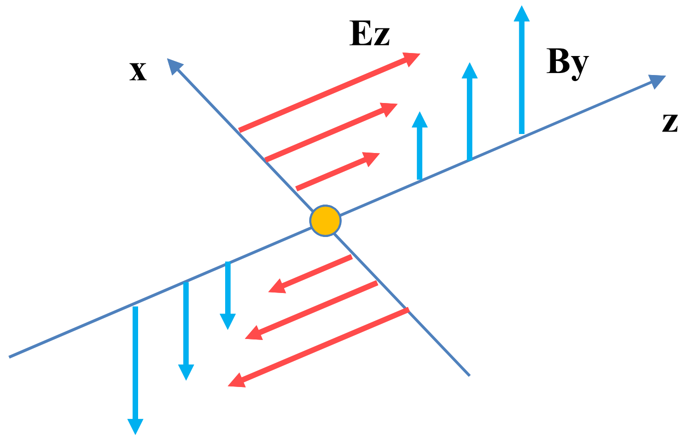

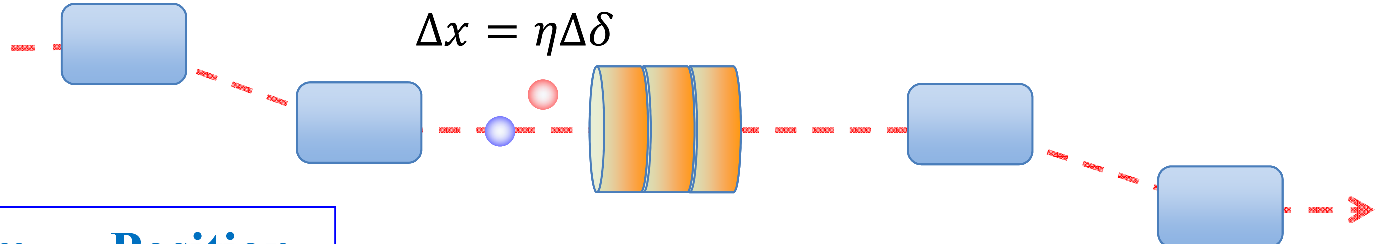

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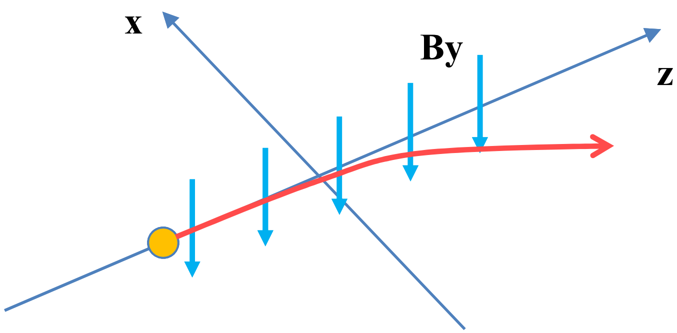

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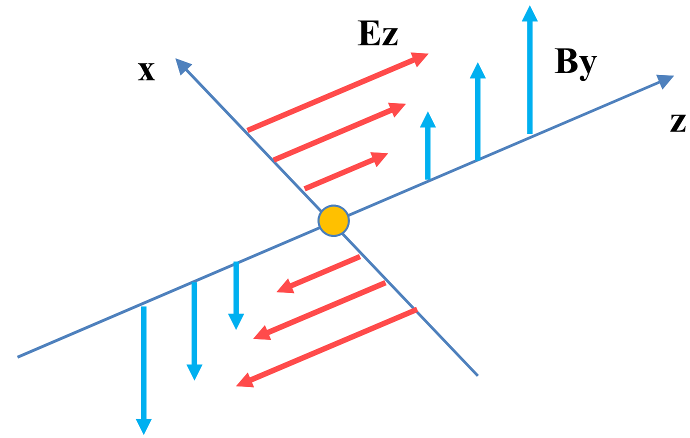
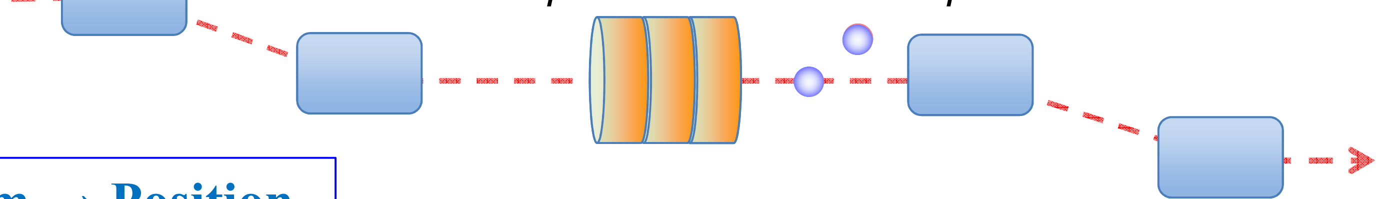


$$\Delta x = \eta \Delta \delta \qquad \Delta \delta = \Delta \delta + \kappa \eta \Delta \delta$$



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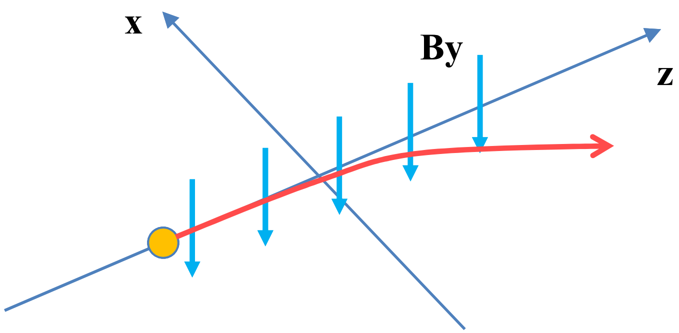


Double dog-leg emittance exchanger

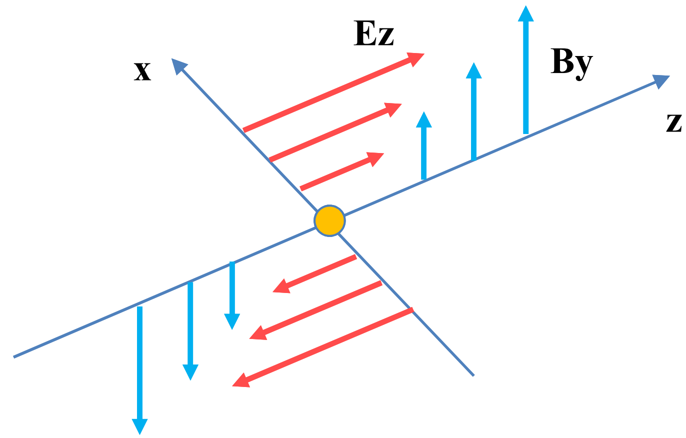
Property exchange in EEX beam line

Transport Matrix

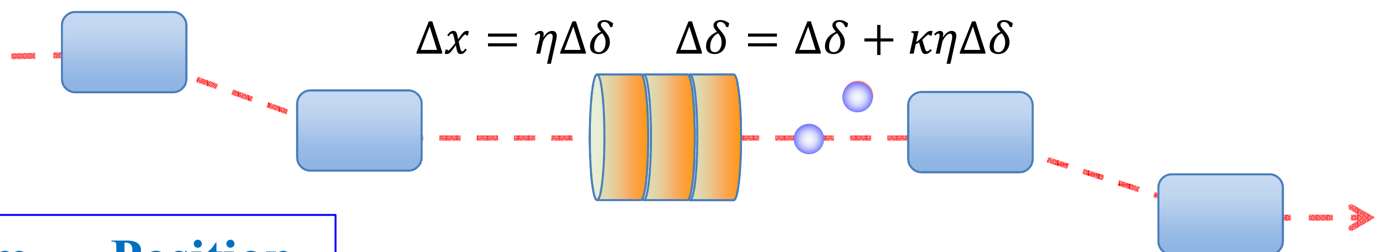
$$\begin{bmatrix} x_f \\ x'_f \\ z_f \\ \delta_f \end{bmatrix} = \begin{bmatrix} 0 & 0 & \kappa L & \eta + \kappa\xi L \\ 0 & 0 & \kappa & \kappa\xi \\ \kappa\xi & \eta + \kappa\xi L & 0 & 0 \\ \kappa & \kappa L & 0 & 0 \end{bmatrix} \begin{bmatrix} x_i \\ x'_i \\ z_i \\ \delta_i \end{bmatrix}$$

Final longitudinal properties are only determined by initial horizontal properties

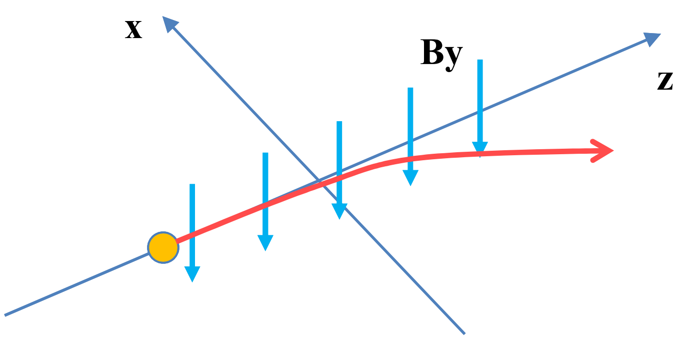
Position → Momentum



$\Delta x = \eta\Delta\delta \qquad \Delta\delta = \Delta\delta + \kappa\eta\Delta\delta$



Momentum → Position



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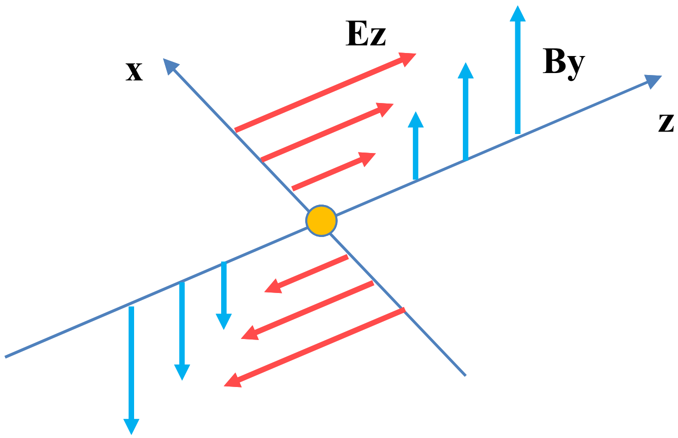

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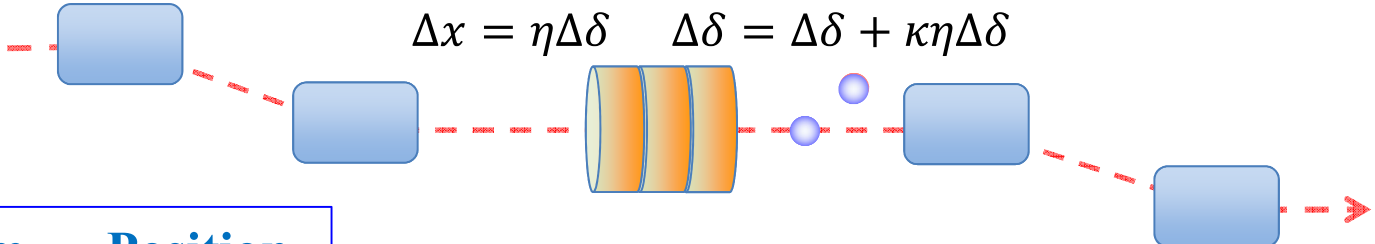
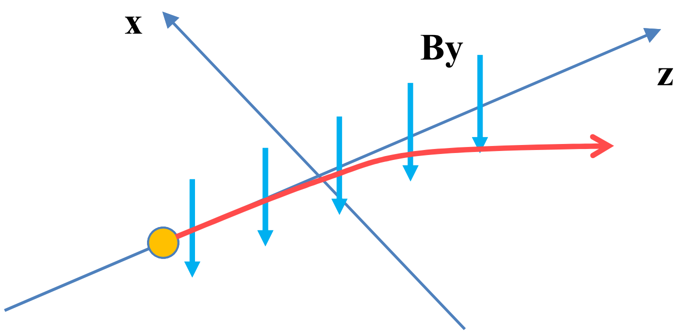
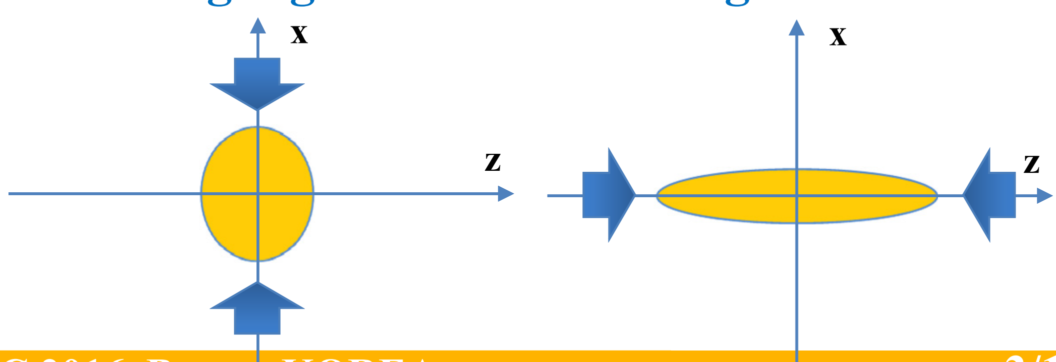


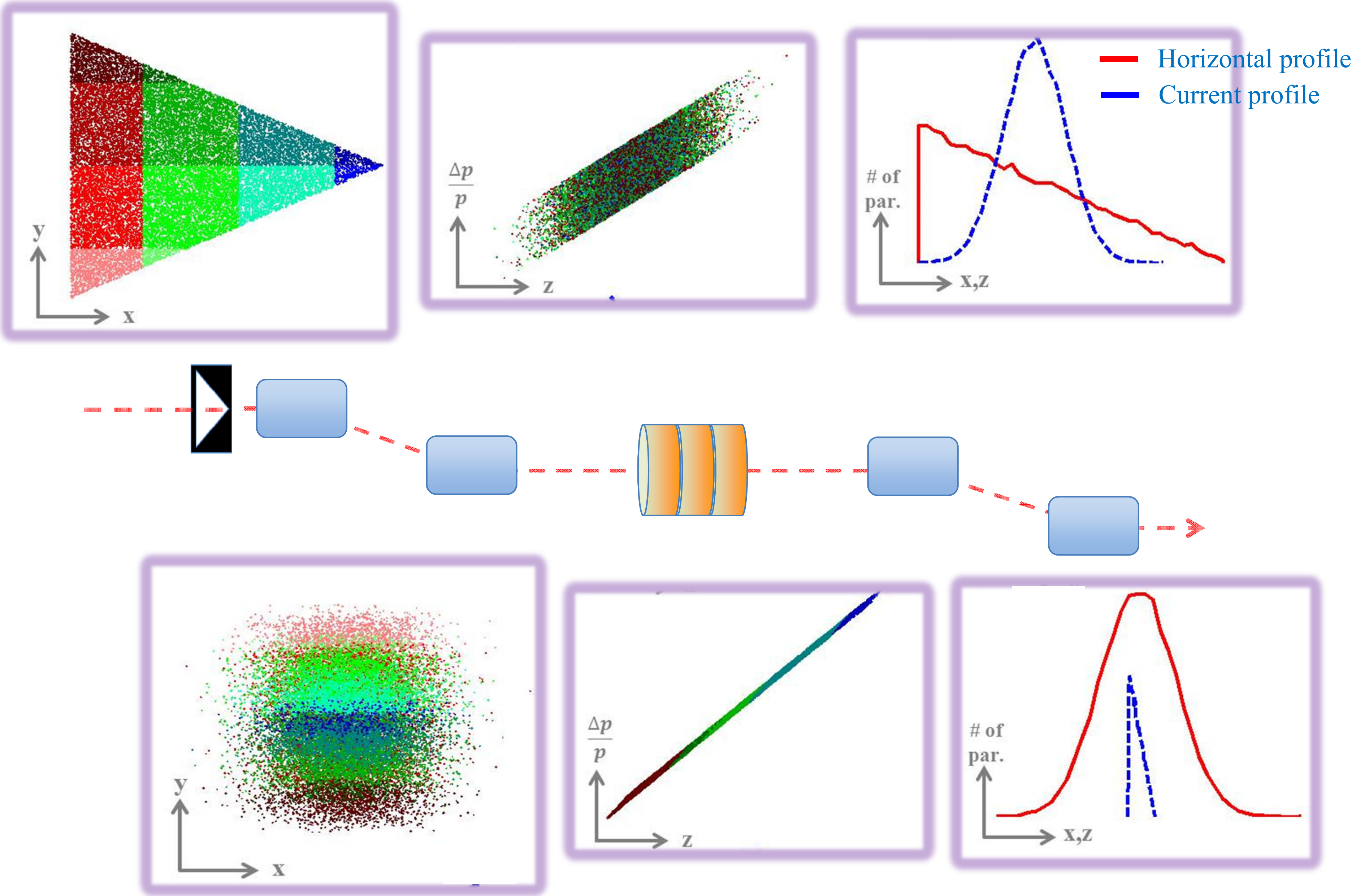
Momentum → Position



Double dog-leg emittance exchanger

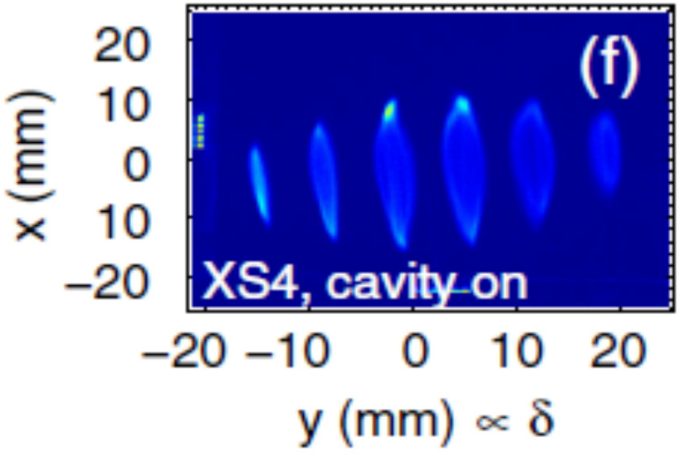


Property exchange and bunch shaping

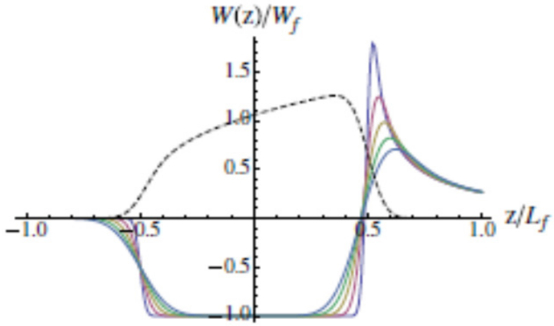


Other applications

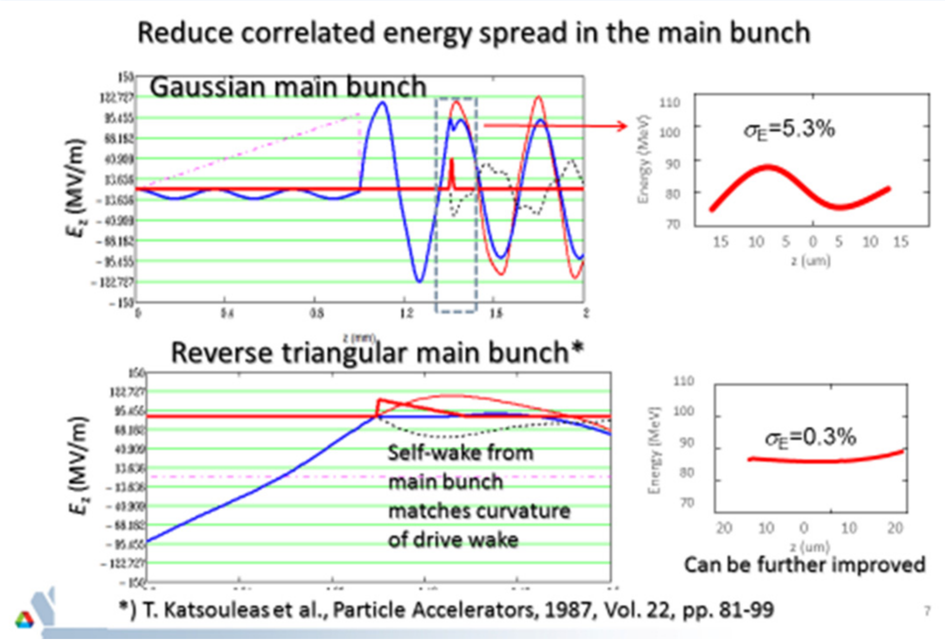
Y. –E Sun, PRL 105, 234801
Train generation



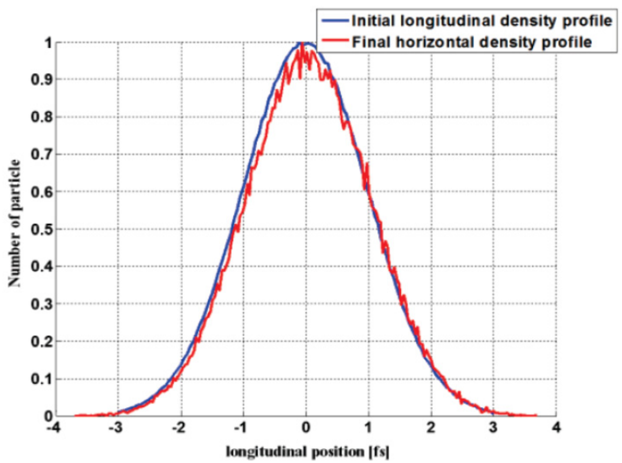
C. Mitchell, PRSTAB 16, 060703
CSR suppression



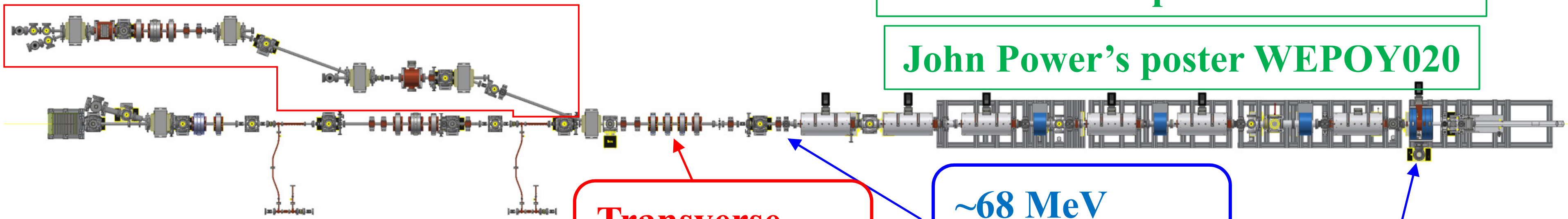
A. Zholents, FEL2014
Energy spread control

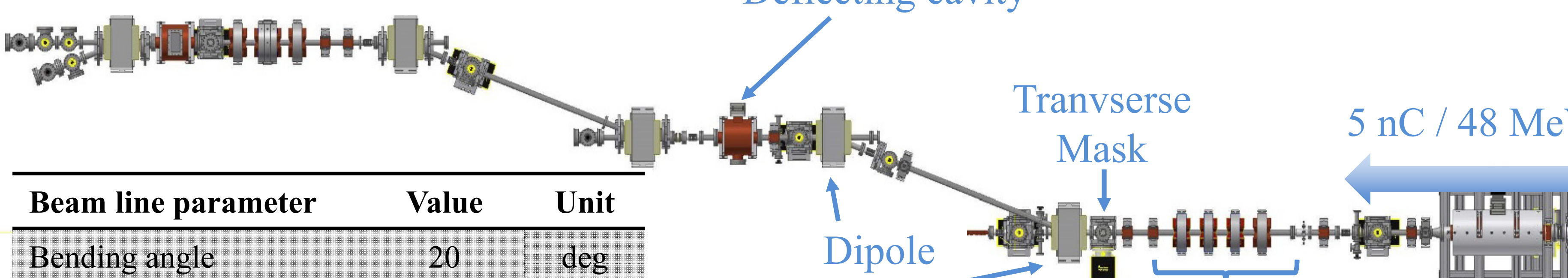


G. Ha, IPAC2015 MOPJE020
Longitudinal diagnostics



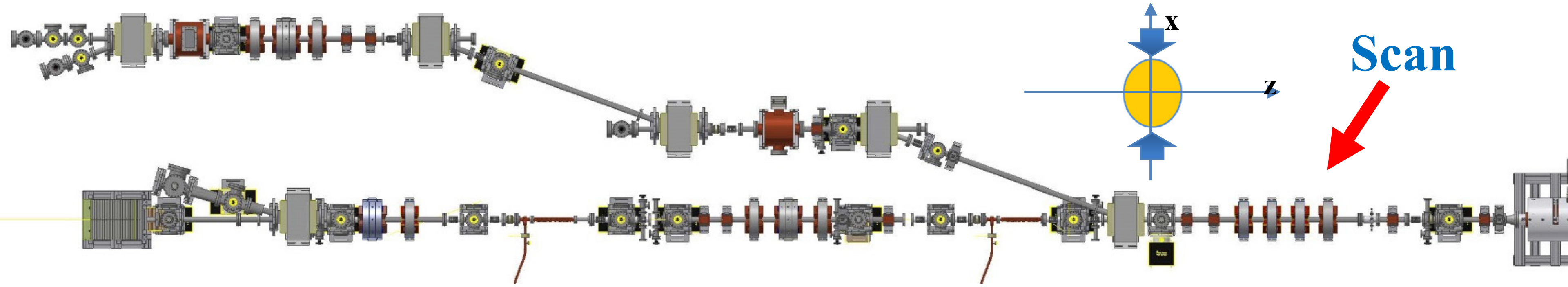
Double dogleg EEX beam line at AWA



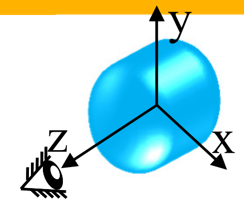


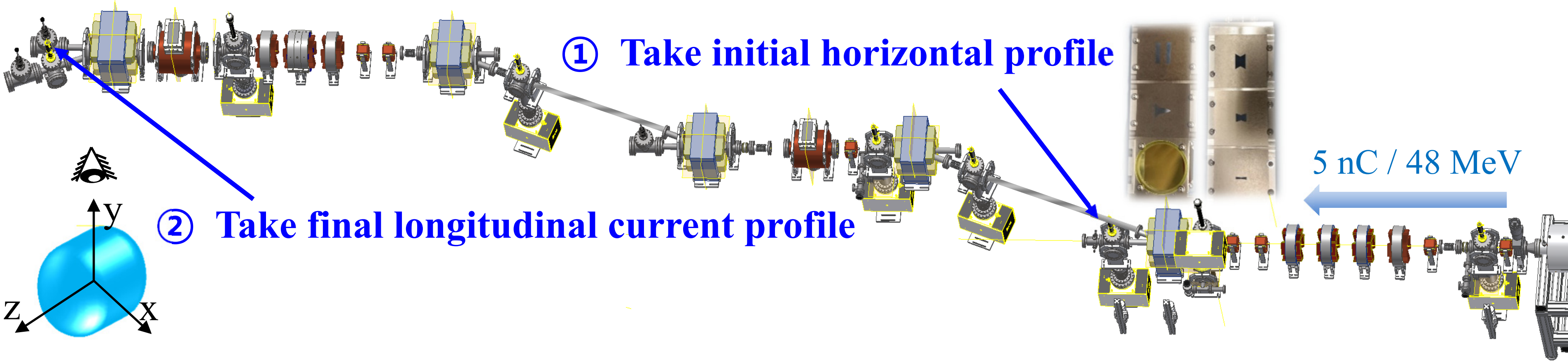
Beam line parameter	Value	Unit
Bending angle	20	deg
Dipole-to-Dipole	2.0	m
Dipole-to-TDC	0.5	m
Power to TDC	1.2	MW

Demonstration of zero-diagonal characteristic



Experiment result – shaping capability

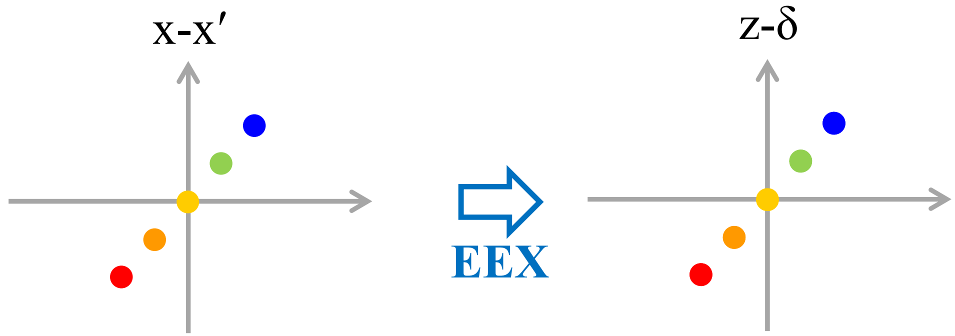




Perturbation on ideal exchange

Gwanghui Ha's poster TUPMY031

$$z_f = \underbrace{\kappa\xi x_o + \left(\eta + \kappa\xi\left(L + L_D + \frac{L_c}{4}\right)\right)x_0'}_{\text{Linear terms}} + \underbrace{T_{nm}X_nX_m}_{\text{Second order terms}} + \underbrace{\xi\Delta\delta}_{\text{Collective effects}}$$

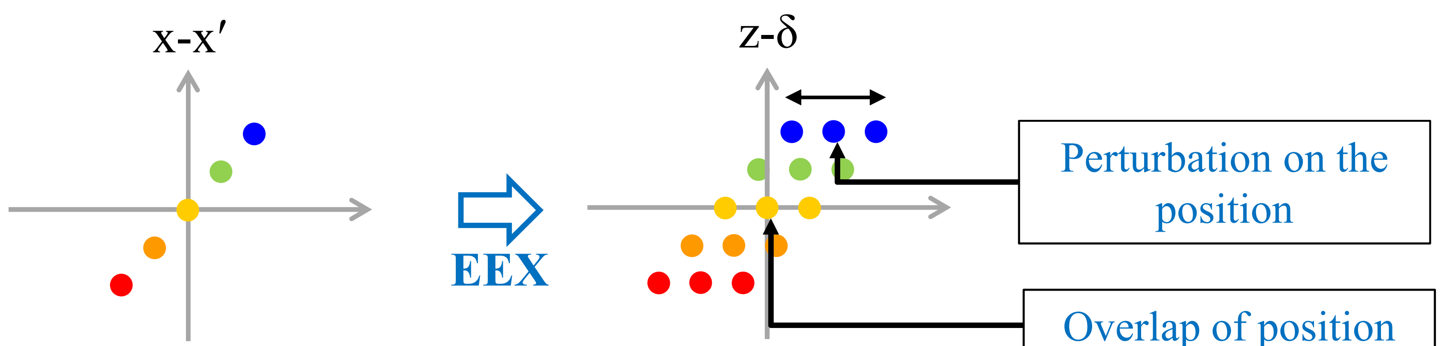


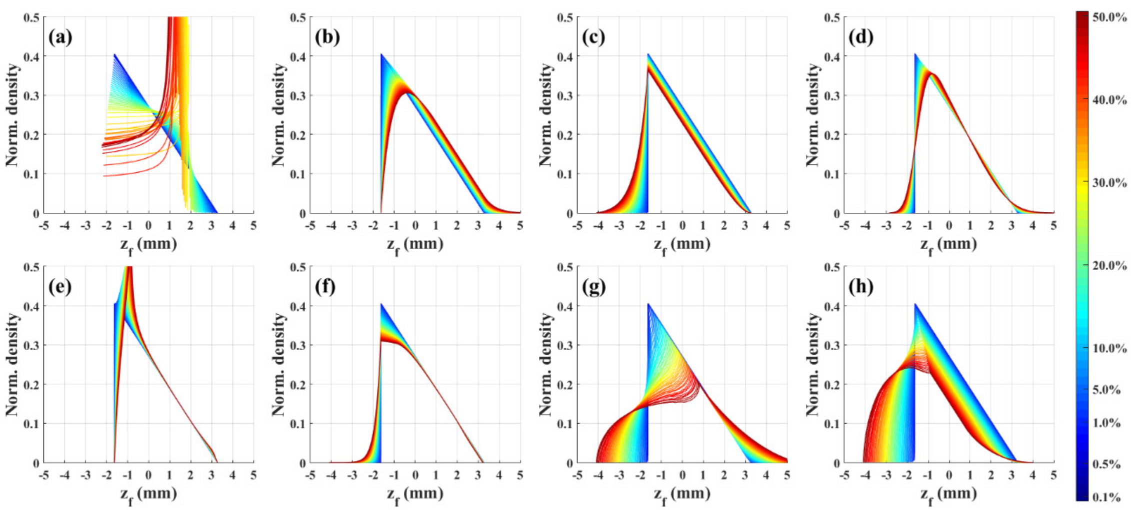
Perturbation on ideal exchange

Gwanghui Ha's poster TUPMY031

$$z_f = \underbrace{\kappa\xi x_o + \left(\eta + \kappa\xi\left(L + L_D + \frac{L_c}{4}\right)\right)x_0'}_{\text{Linear terms}} + \underbrace{T_{nm}X_nX_m}_{\text{Second order terms}} + \underbrace{\xi\Delta\delta}_{\text{Collective effects}}$$

Aberration patterns





Minimize with $\frac{x_0'}{x_0} = -\frac{2T_{11}}{T_{12}}$

$$T_{11}x_0^2 + T_{12}x_0x_0' + T_{22}{x_0'}^2$$

Aberration control by incoming slope manipulation

Linac phase control → thick-lens effect and collective effects

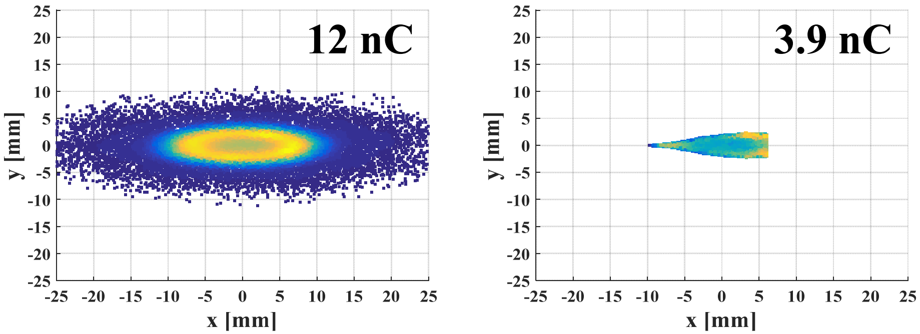
-10 deg **-15 deg** **-30 deg** **-40 deg**

Horizontal control → few critical second order terms

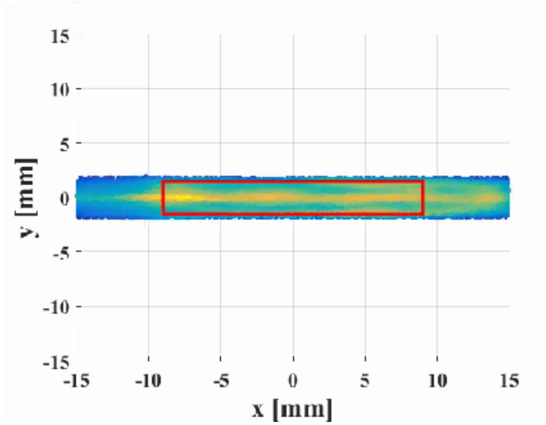
0.03 **0.17** **0.47** **0.60**

Continued shaping experiment – high transformer ratio

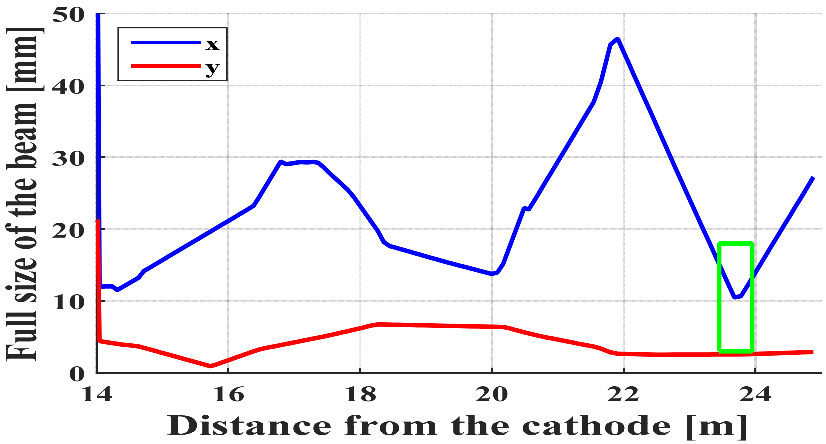
Mask



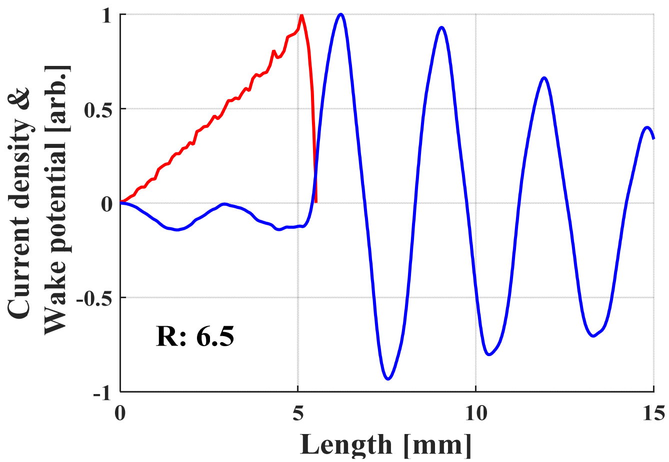
Beam transport through structure



Beam envelope



Current profile & Transformer ratio



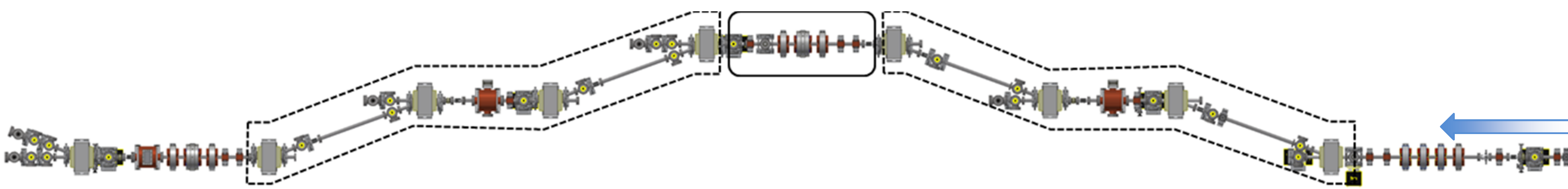
Double EEX experiment

New type of bunch compressor

- Tunable compression using quad
- No chirp requirement. No dechirper
- Control all longitudinal property at the same time

Shaping with preserved transverse emittance

2. Transverse manipulation



3. Bring the manipulated transverse properties back to longitudinal

1. Bring the longitudinal properties to the transverse space

Acknowledgement

M. H. Cho, W. Namkung

(Pohang University of Science and Technology)

J. G. Power, E. Wiesniewski, W. Liu, M. Conde, D. S. Doran, C. Whiteford, W. Gai

(Argonne National Laboratory, AWA)

K. –J. Kim, A. Zholents, Y. –E Sun

(Argonne National Laboratory, APS)

C. Jing, S. Antipov

(Euclid TechLabs)

P. Piot

(Northern Illinois University/Fermilab)

Q. Gao

(Tsinghua University)

Summary

- Current profile shaping can support collinear type wakefield acceleration, THz radiation, CSR or energy spread control etc.
- Zero diagonal characteristic of EEX beam line can be used for longitudinal current profile shaping.
- Double dogleg EEX beam line was installed at Argonne Wakefield Accelerator.
- Several different current profiles are successfully generated using transverse mask and EEX beam line.
- Aberration on the ideal current profile can be controlled by incoming slope of phase ellipse.
- AWA is working on continued experiment on EEX.

Thank you for your attention