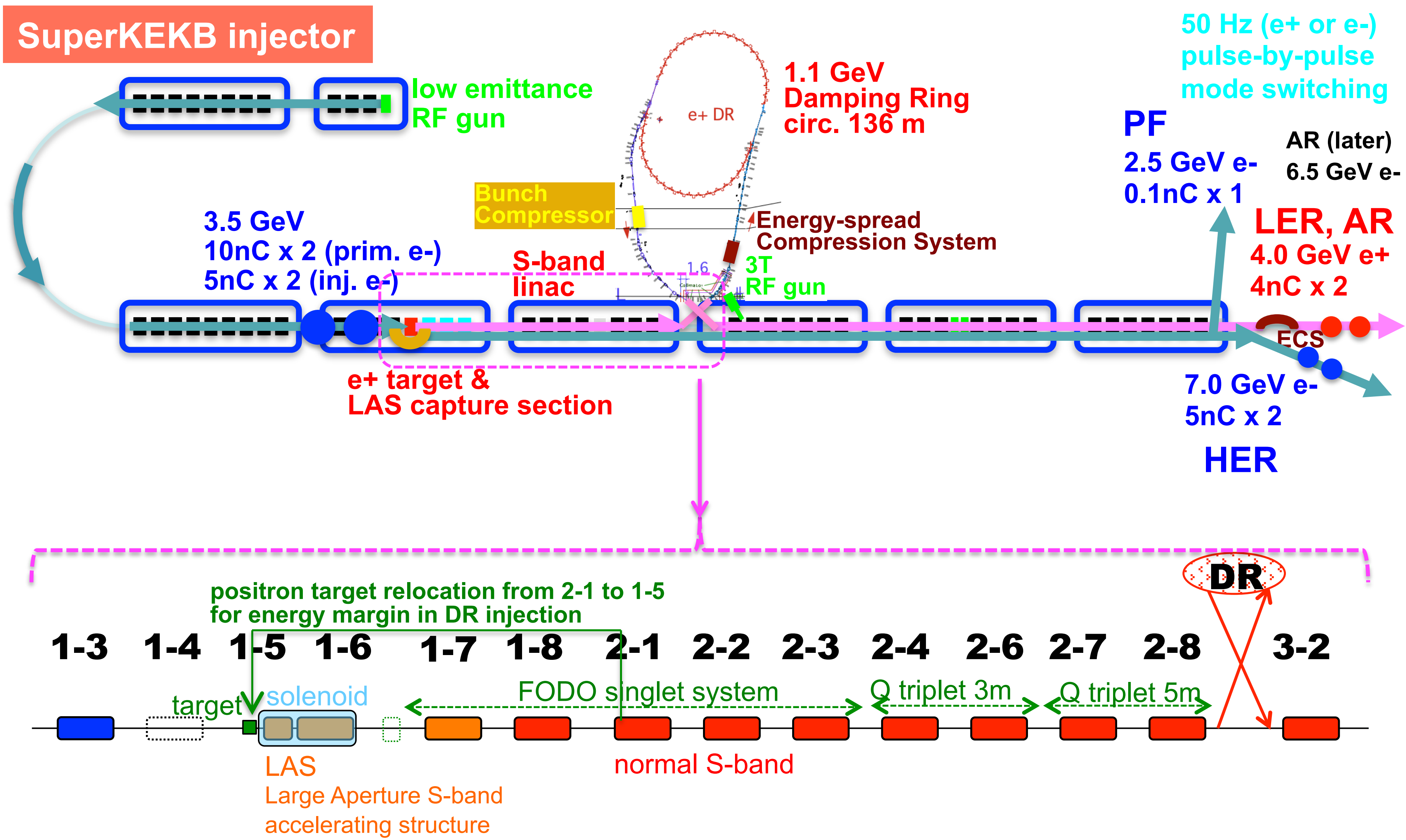
Positron Source Upgrade

(FC modulator development is covered by M. Akemoto's talk)

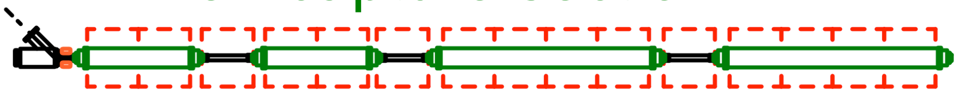
KEKB injector linac
Takuya Kamitani

SuperKEKB Injector



Positron Capture Section (PCS)

KEKB e+ capture section



- QWT system (2.0 T x45mm + 0.4 T x8m)
  air-core pulse coil DC solenoids
- KLY1 (S-band) -> 2 x 1m 12 MV/m, aper 2a = 27 -> 25 mm
- KLY2 (S-band) -> 2 x 2m 10 MV/m, aper 2a = 25 -> 21 mm
- beam energy at capture section exit : 80 MeV

N(e+)/N(e-) = 10 % at 3.5 GeV linac-end
N(e+)/N(e-)/E(e-) = 2.5 %/GeV

SuperKEKB e+ capture section

- AMD system (5.0 T x200mm + 0.4 T x15m)
  flux concentrator DC solenoids

Deceleration capture

- KLY1 LAS -> 2 x 2m 14 MV/m, aper 2a = 32 -> 30 mm
- KLY2 LAS -> 4 x 2m 10 MV/m, aper 2a = 32 -> 30 mm
- beam energy at capture section exit : 120 MeV

N(e+)/N(e-) = 49 % at 1.1 GeV DR
N(e+)/N(e-)/E(e-) = 14 %/GeV

We omit L-band components and redesign PCS with all LAS configuration which can give sufficient e+ yield and satellite elimination.

LAS : Large Aperture S-band structure

e+ source issues discussed here

1) **target & beam-spoiler design for protection against target destruction**

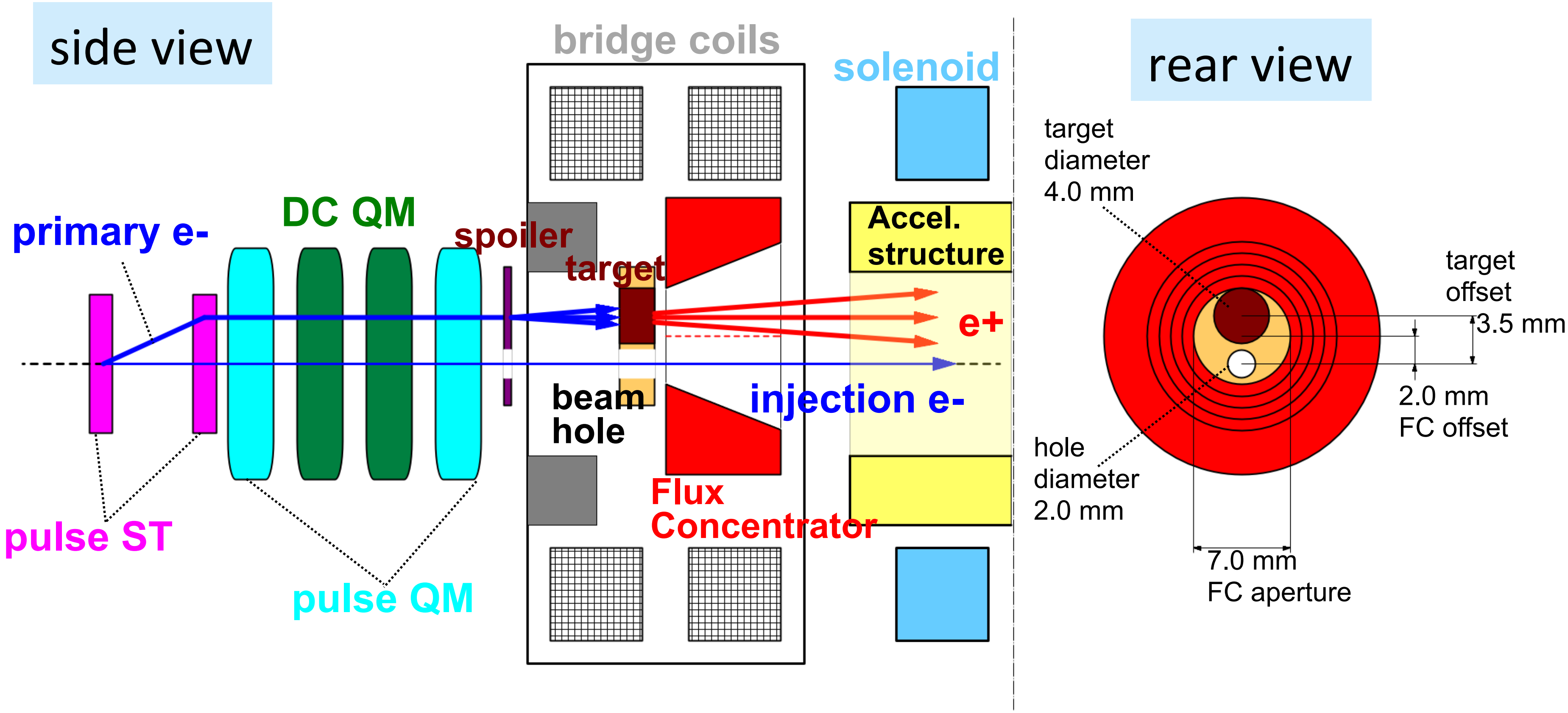
2) **Flux Concentrator system development (magnet, modulator, detachable girder)**

3) **Capture parameter optimization on e+ yield and satellite particle elimination**

4) **e+/e- compatible optics design and direct e+ injection without DR**

(1) Positron Production Target & Beam-Spoiler

target offset & beam hole

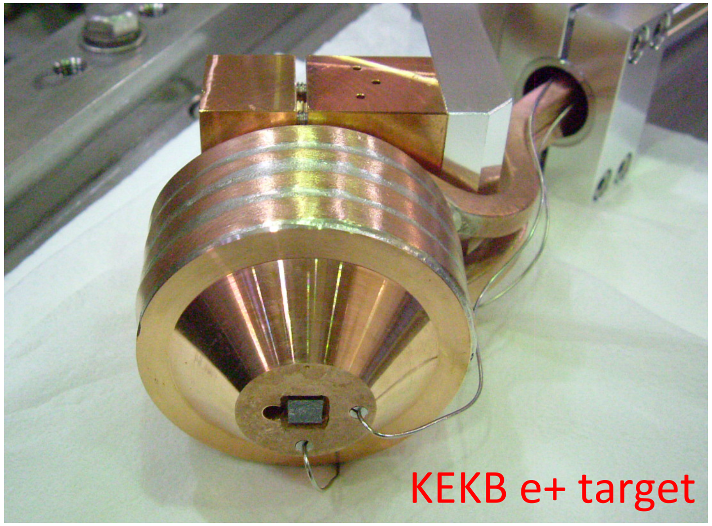


- **injection e- beam on axis to preserve low emittance**
- **primary e- beam 2~3 mm off axis**

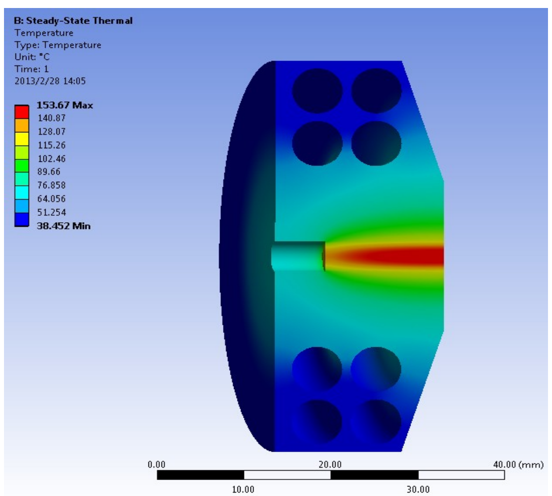
  (target offset 3.5 mm, FC offset 2.0mm)

  e+ yield degradation by this offset
  should be evaluated with full 3D tracking simulation

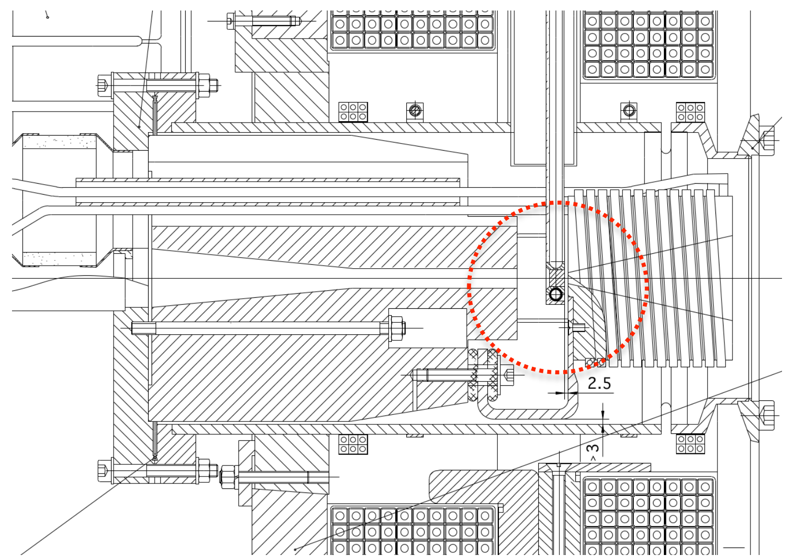
target shape & thermal analysis



- target design is ongoing considering
  cooling efficiency analysis and
  field reduction by eddy current
- target size should fit in the available space
  between a yoke and FC

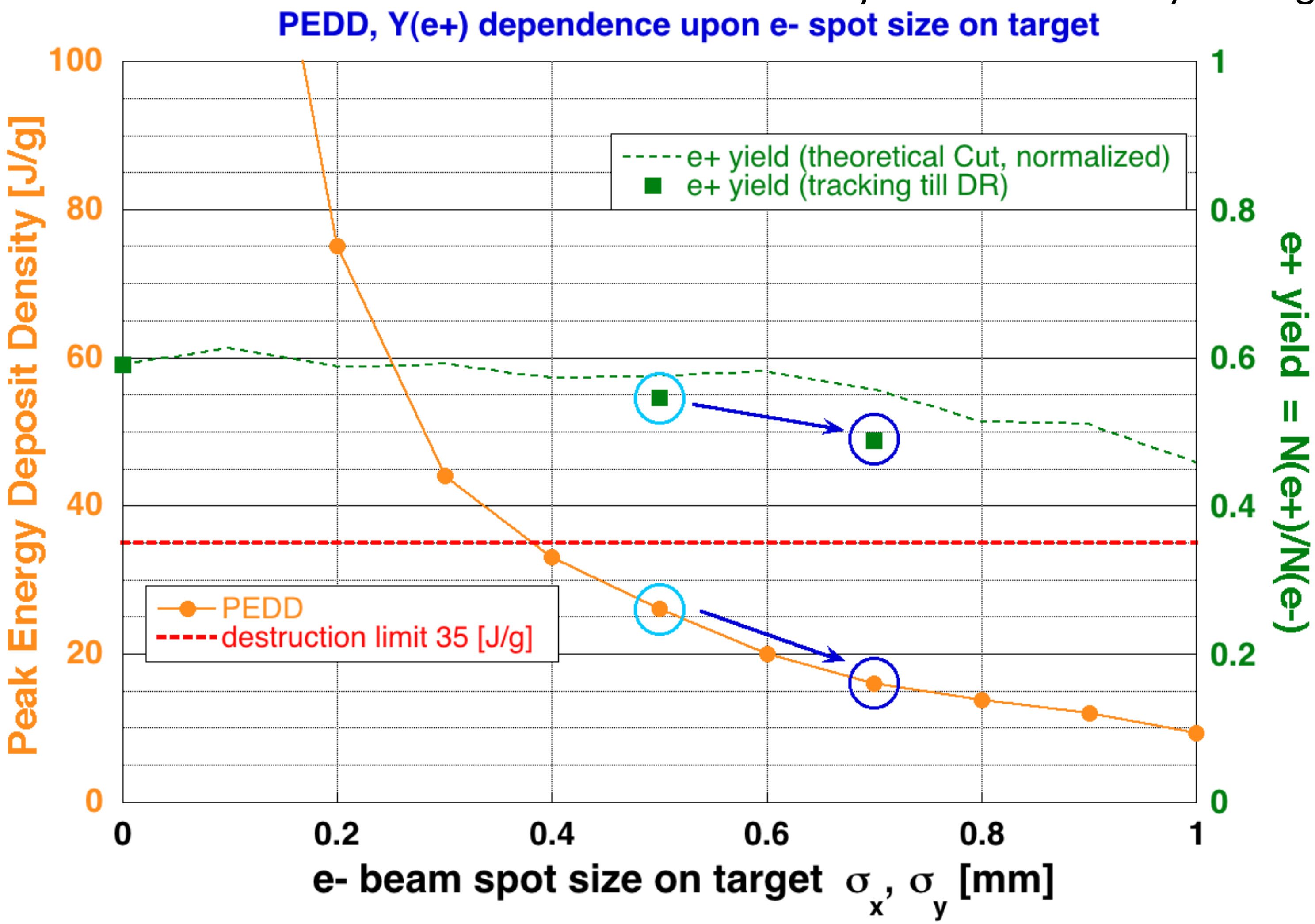


ANSYS calculation by L. Zang



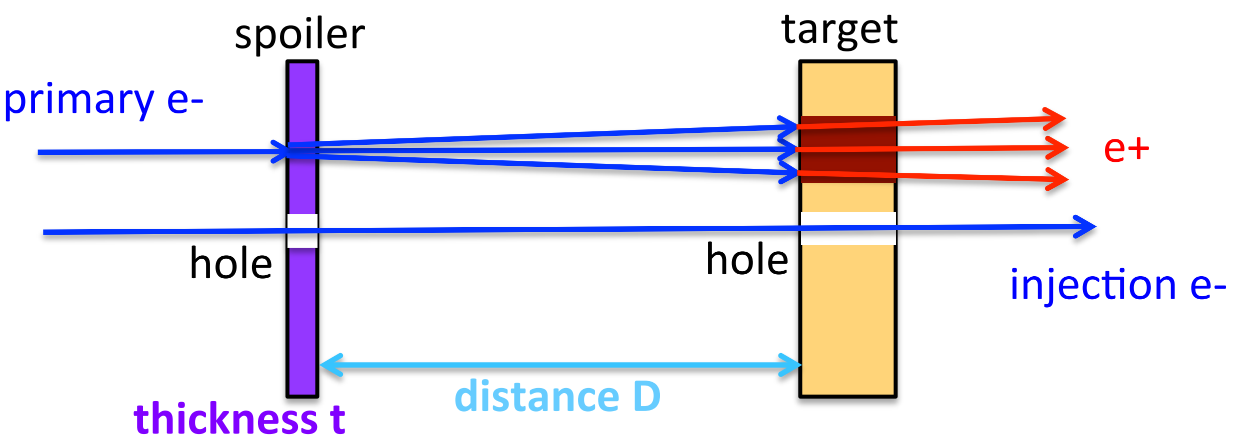
target destruction issue

FLUKA & yield calculation by L. Zang

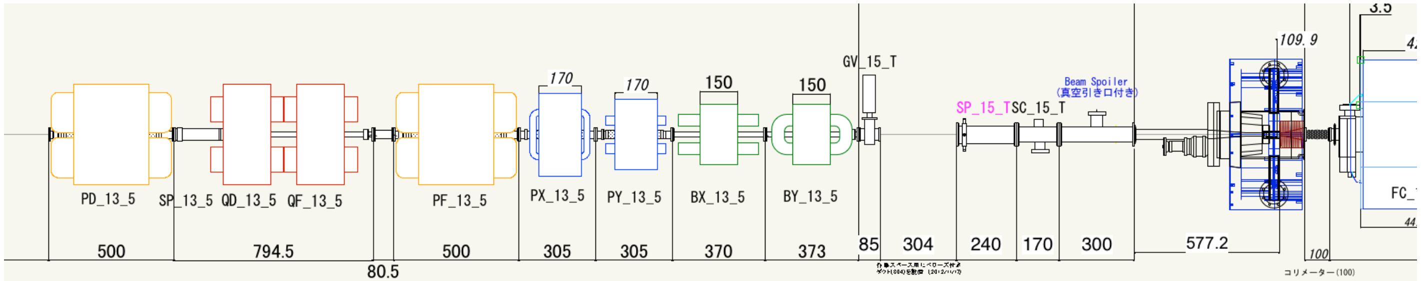


We should enlarge design spot size 0.5 mm -> 0.7 mm for safety margin at a cost of 10 % yield degradation

target protection



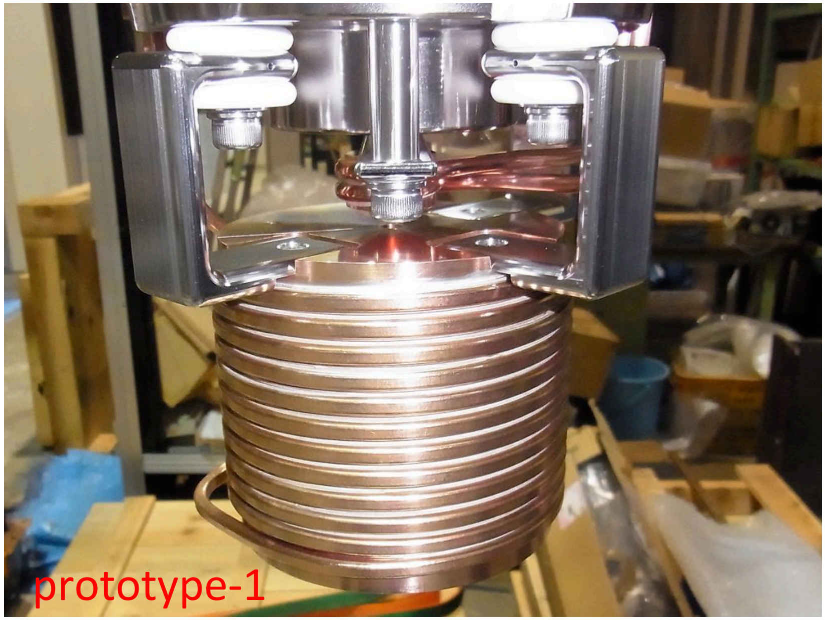
- beam spoiler to maintain spot size $\sigma_x, \sigma_y > 0.7$ mm on target
- avoid too small beam spot on spoiler & on target,
  need monitoring spot sizes and focusing magnet settings
- D & t should be optimized considering beam line layout
- at a distance D = 3.0 (m), thickness t = 0.5 (mm) for Al plate



(2) Flux Concentrator system development

SLAC-type Flux Concentrator

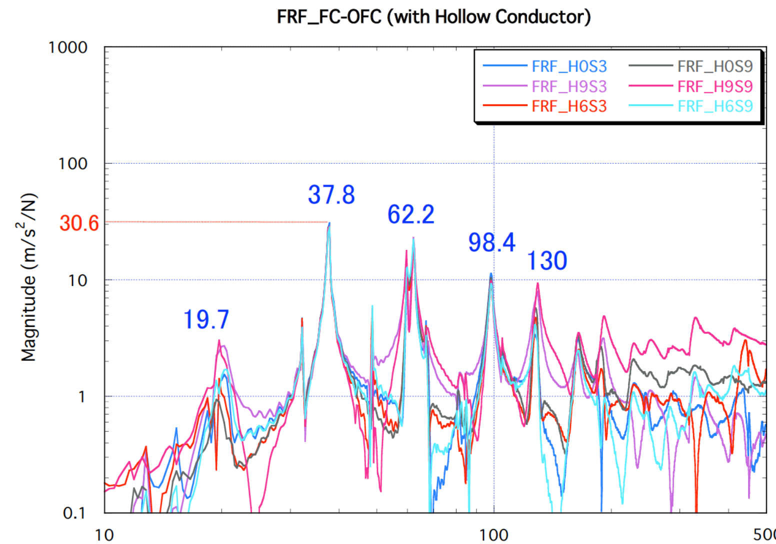
- First prototype is fabricated with helps of drawings from SLAC and IHEP
- it is for stand-alone test with a simplified vacuum chamber
- started a test operation and field measurement with a prototype modulator
- conductor is made of HRSC copper

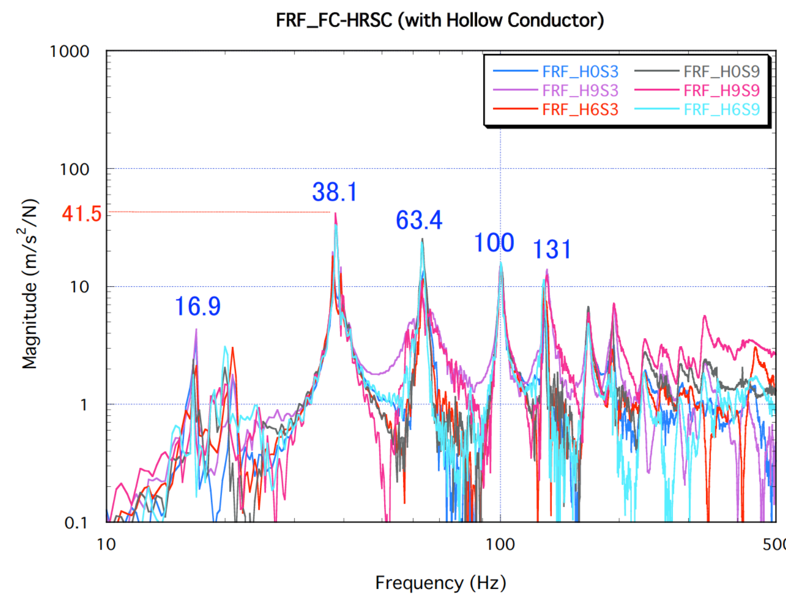


SLAC-type FC	parameters
length	100 mm
outer diameter	100 mm
inner diameter (min.)	7 mm
inner diameter (max.)	52 mm
peak current	12 kA
pulse width	5 μs (half-sine)
peak field	3.9 T
inductance	1.0 μH

FC material choice

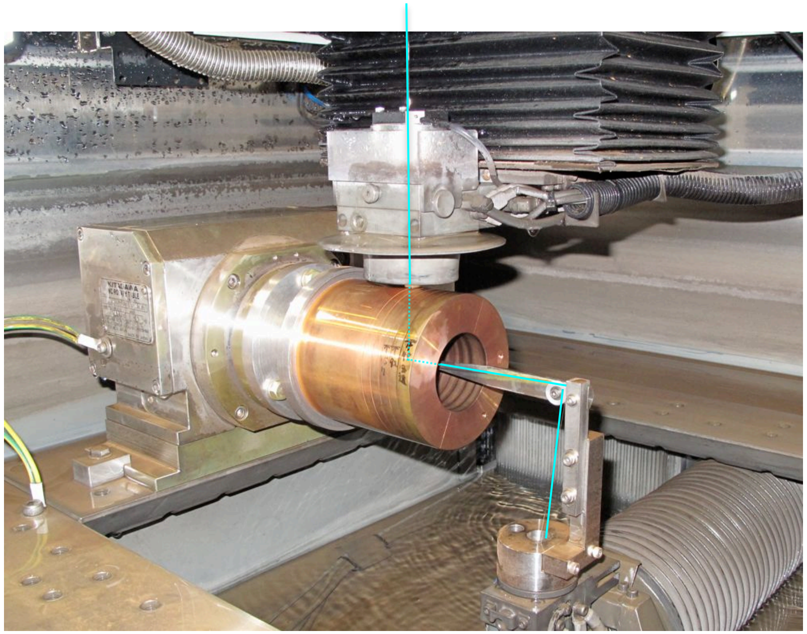
- candidate material OFC & HRSC
  Heat Resistance, high Strength & Conductivity copper
  (Mitsubishi Material co.)
- vibration measurement gives similar result
- avoid hardening of copper by manual pressing
- difference in impedances
  (80 % conductivity in HRSC)
- decision will be made with results of operation tests of
  prototype-1 (HRSC)
  prototype-2 (OFC) under fabrication

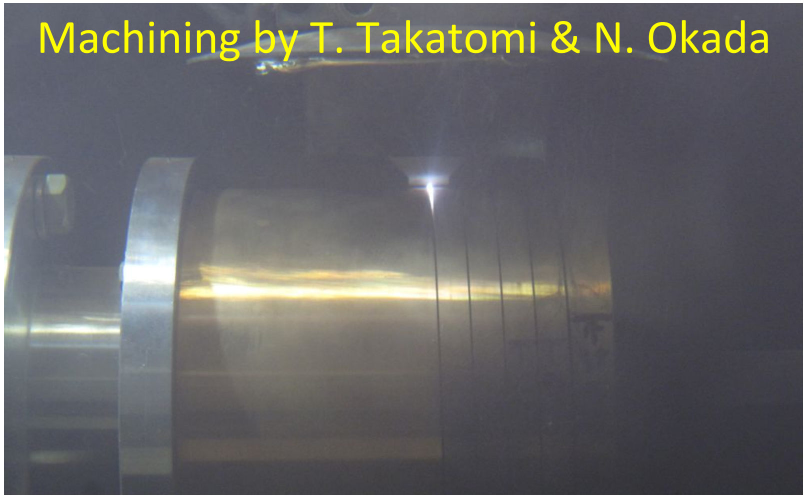




FC slit machining at KEK

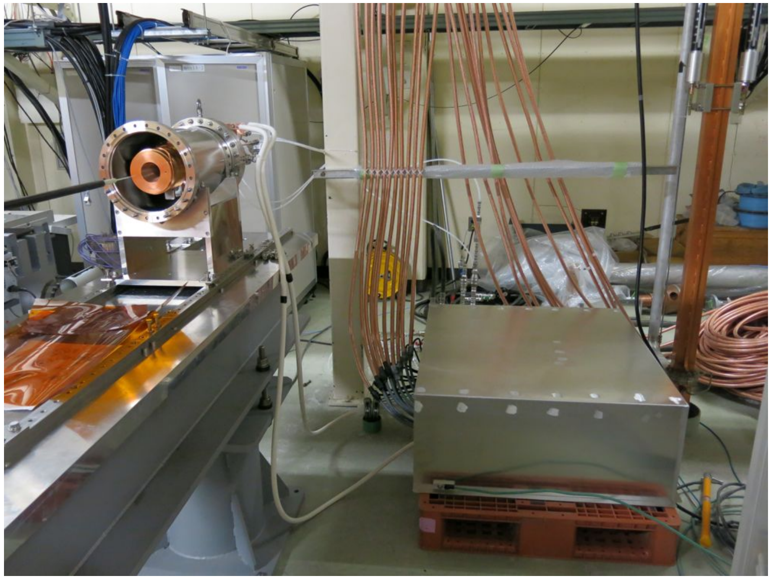
- Slit machining was performed at KEK machine workshop with an electrical discharge wire cutting machine.
- 0.15 mm thick wire
- 0.2 ~ 0.25 mm slit gap
- special wire path shape with a sapphire pulley devised for FC fabrication

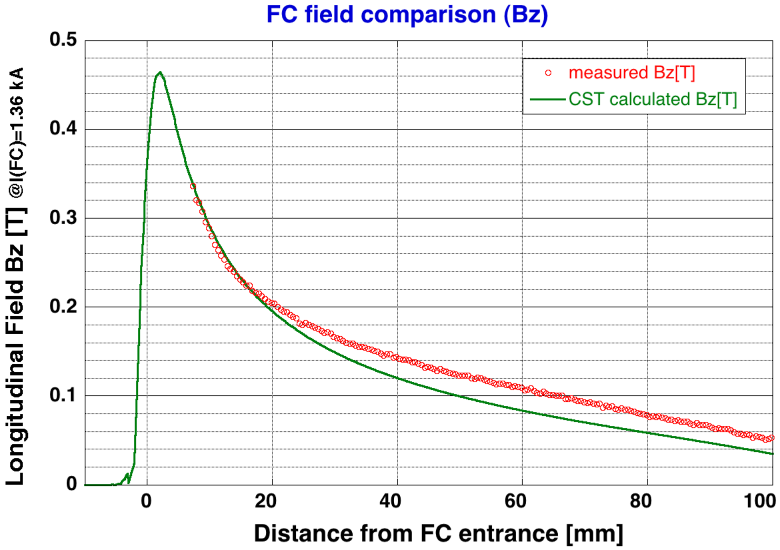


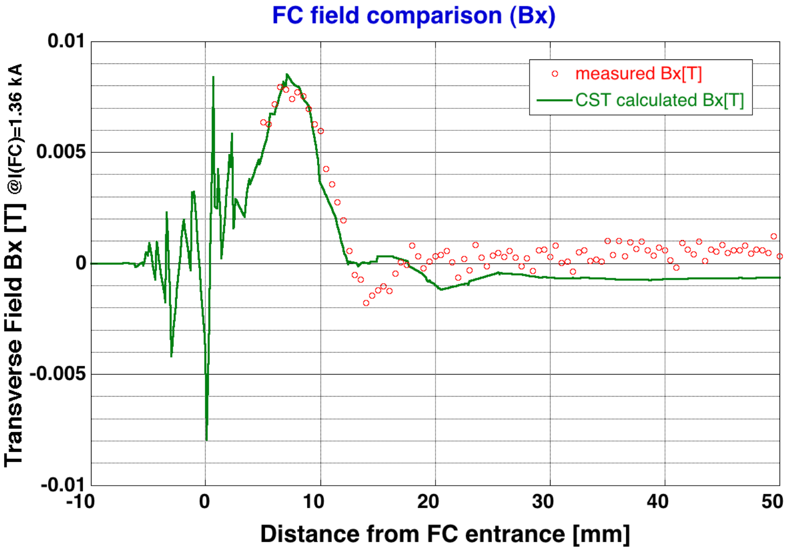


FC test stand

- started operation on 2013/2/26
- low current operation (1.36 kA) in the air for field measurement
- high current operation (~6 kA) in a vacuum will start soon



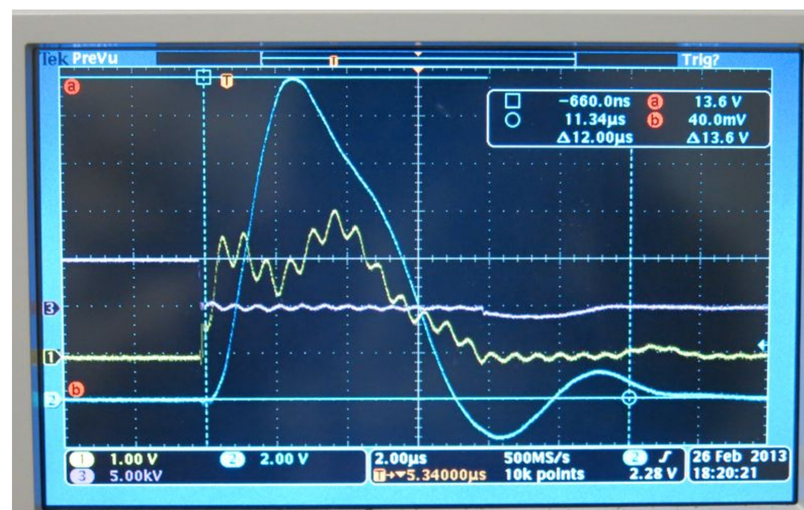




FC modulator (prototype)

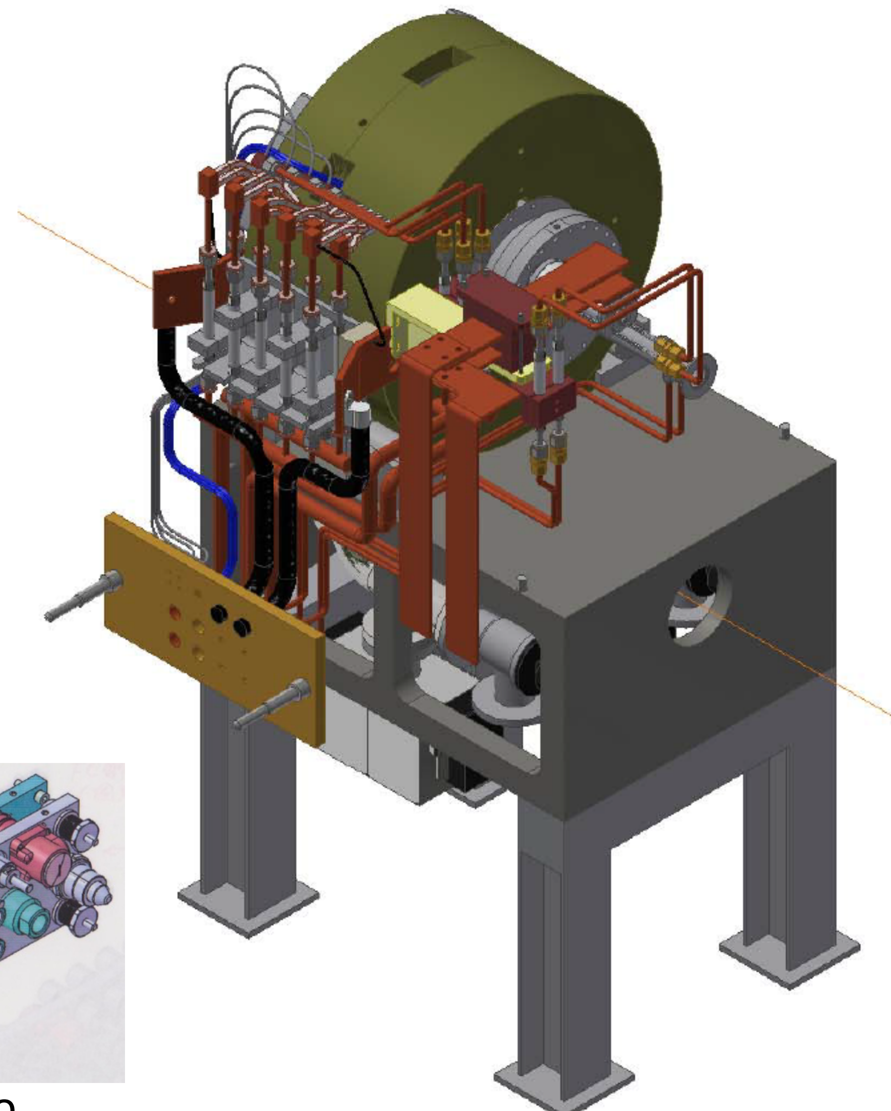
- modulator with thyratron
- [1] prototype modulator
  I_{peak} = 6 kA for FC tests and for initial commissioning (2013 Dec. -> 2014 Jun.)
- [2] operation model modulator
  I_{peak} = 12 kA for FC tests and for commissioning
  (2014 Oct. ->)
- half-sine 5 μsec pulse
- stability 0.3% p-p

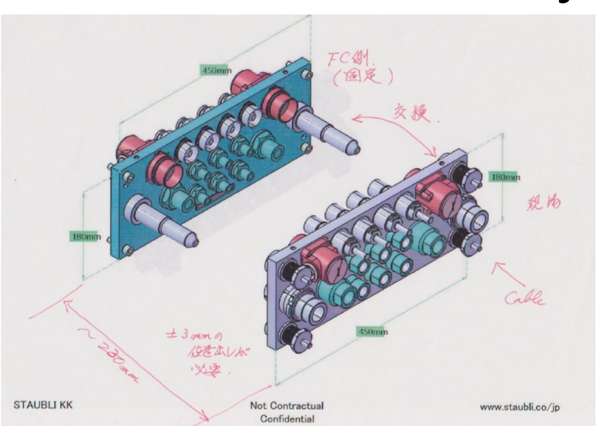
Details on the modulator is covered by M. Akemoto's talk

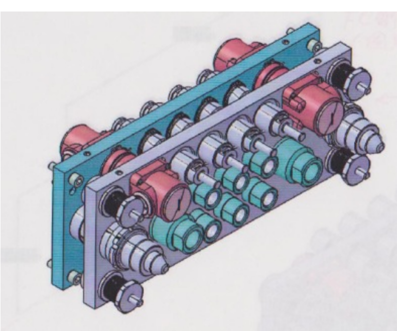


quick detachable girder

- FC girder is designed to be quick detachable to minimize worker's radiation dose in FC exchange work.
- wave guide disconnection in distant position from FC
- quick coupling vacuum flange
- quick coupling
  water, electricity connection



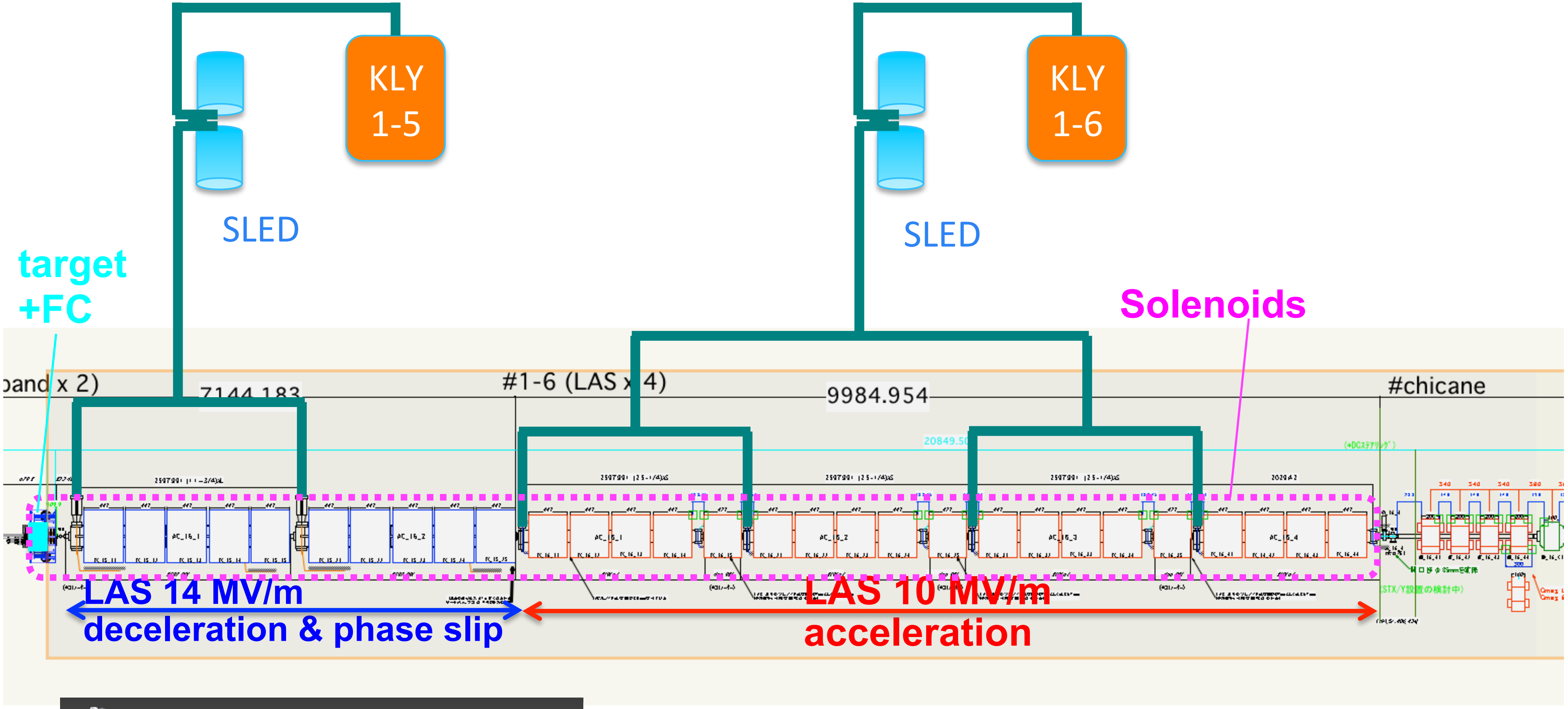


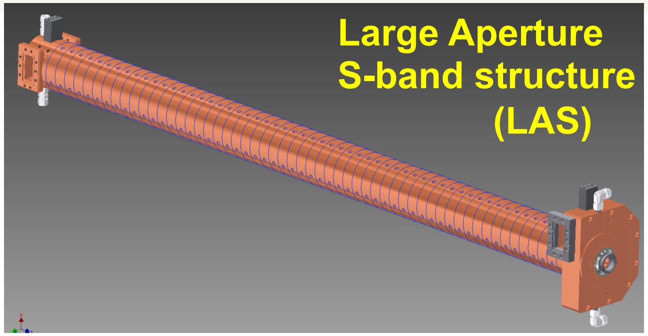


Solton Co.
Staubli Co.

(3) Capture parameter optimization on e+ yield and satellite elimination

Capture Section with LAS





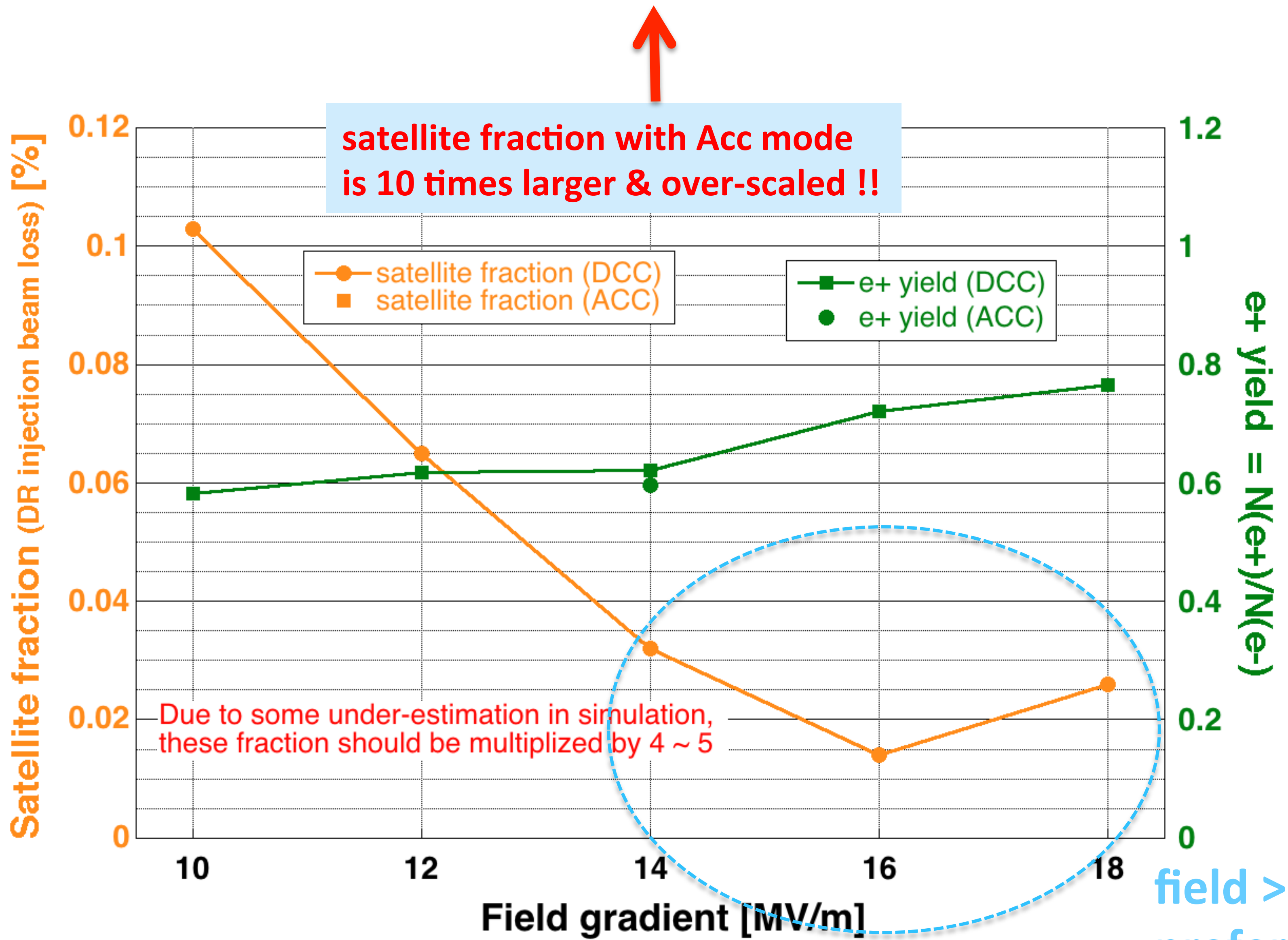
- LAS with SLEDs for sufficient field gradient
- breakdown issue of LAS in solenoid field
- non sharp-peaked RF pulse shape

why no L-band in PCS ?

- L-band first introduced for larger acceptance
- Later, L-band found useful for satellite particle elimination
- However, L-band components are costly

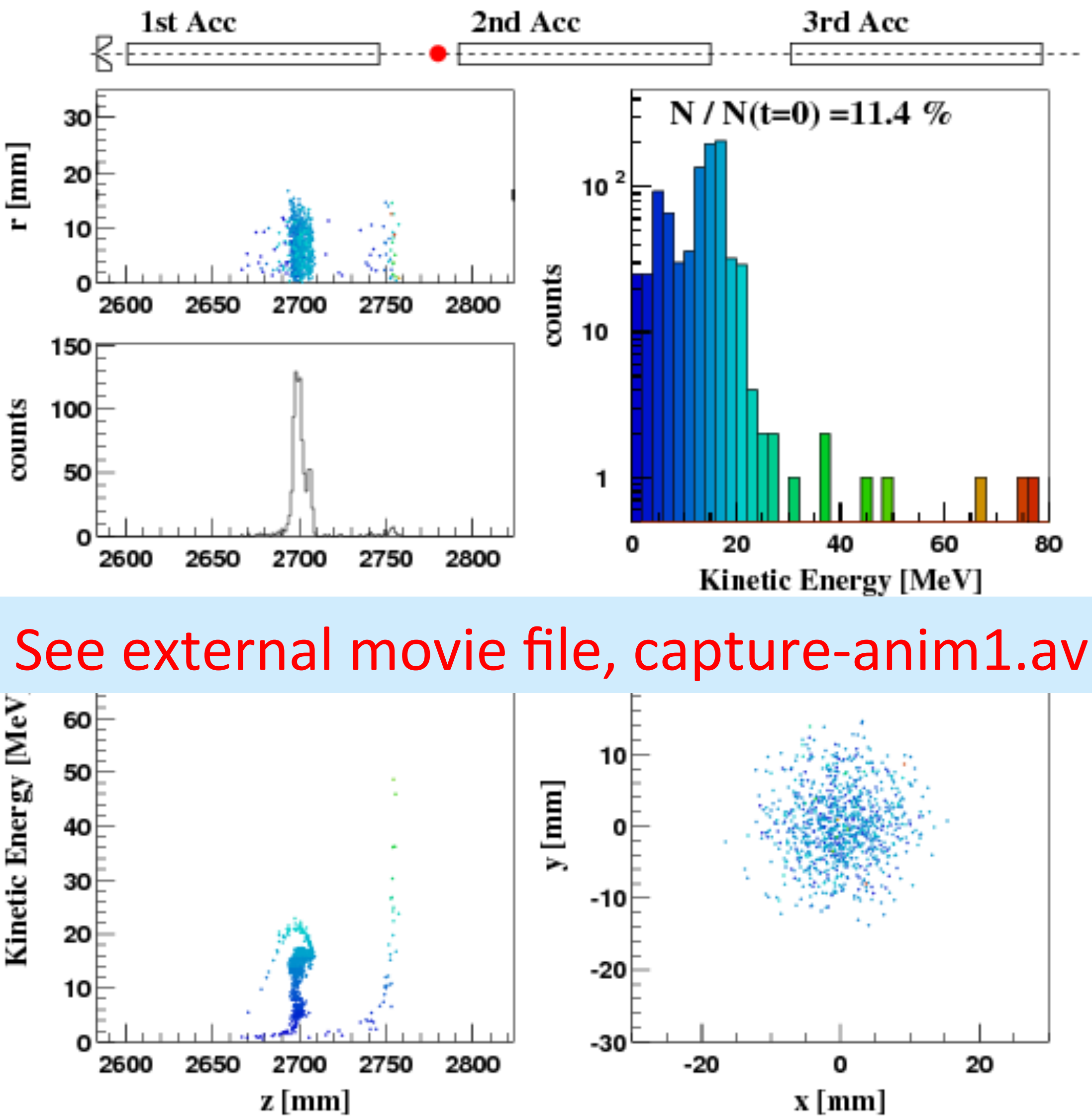
- Recent simulation study shows capture section of all LAS can give sufficient satellite particle elimination as L-band
- e+ capture with high-field deceleration is effective in this elimination

high-field decel. eliminate satellites



field >= 14 MV/m preferable

e+ capture simulation



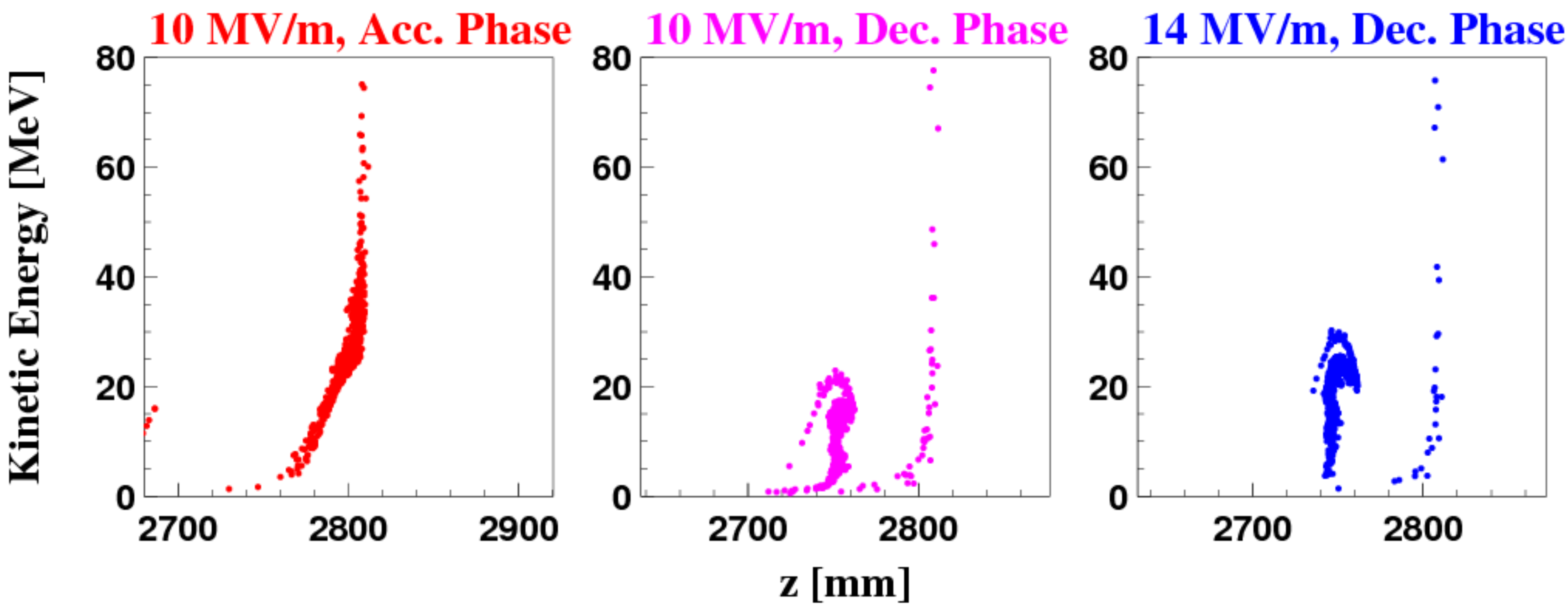
See external movie file, capture-anim1.avi !!

- capture tracking simulation with GPT by F. Miyahara & L. Zang
- beam line optics design with SAD by T. Miura
- beam line tracking simulation with SAD by N. Iida

- capture parameters optimized with the simulations
- deceleration capture with RF phase-slip gives less satellite particles

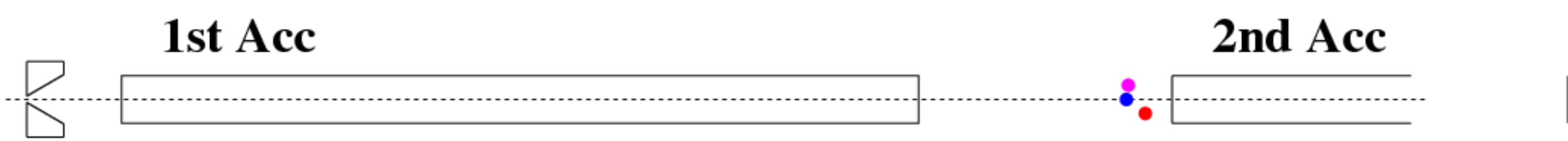
Animation by F. Miyahara

satellite formation



See external movie file, capture-anim2.avi !!

Animation by F. Miyahara

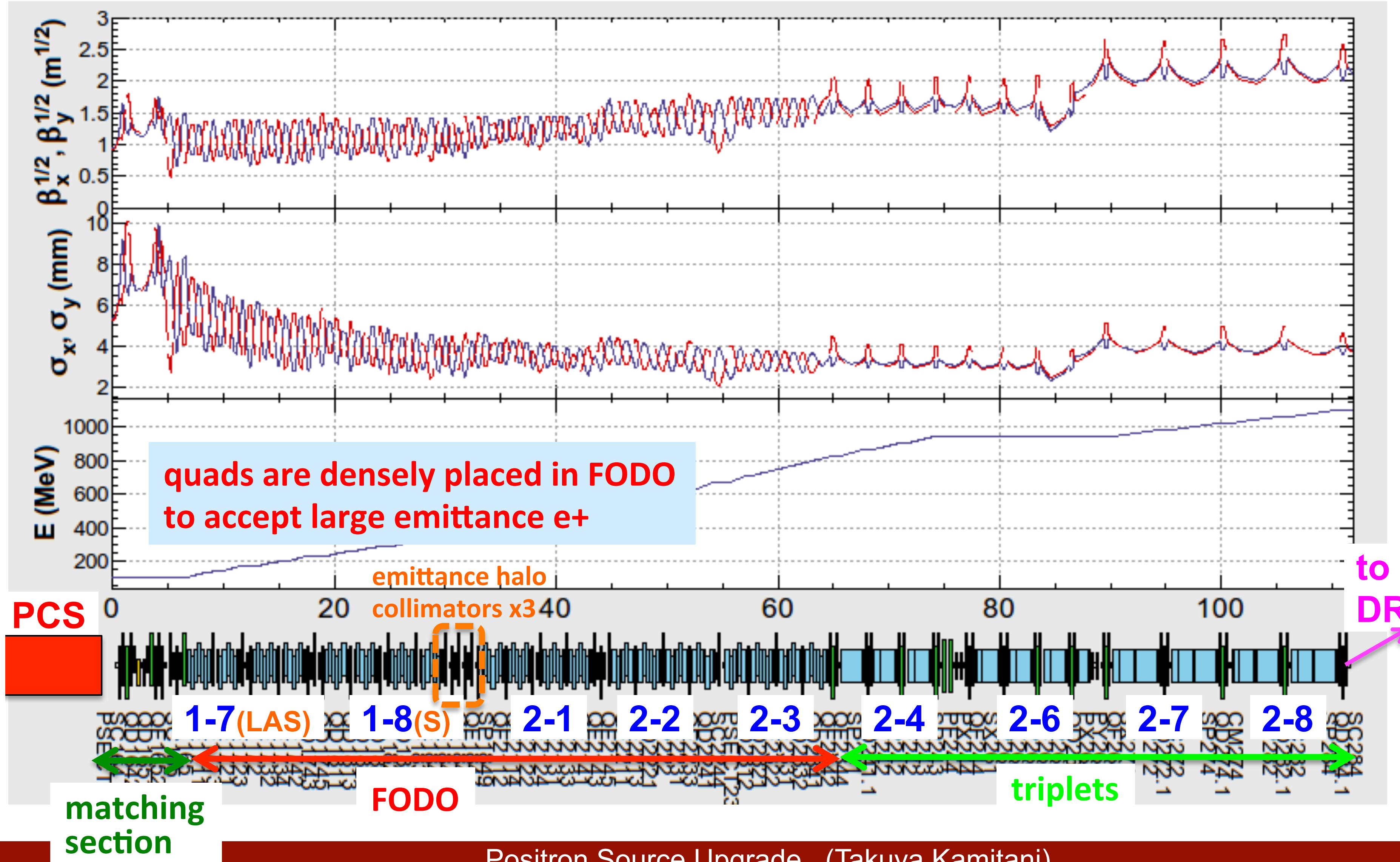


- in deceleration capture, satellites are mainly generated by low-energy particles at accel. structure gap
- high-field deceleration can avoid this trap

(4) e+/e- compatible beam optics design & direct e+ injection without DR

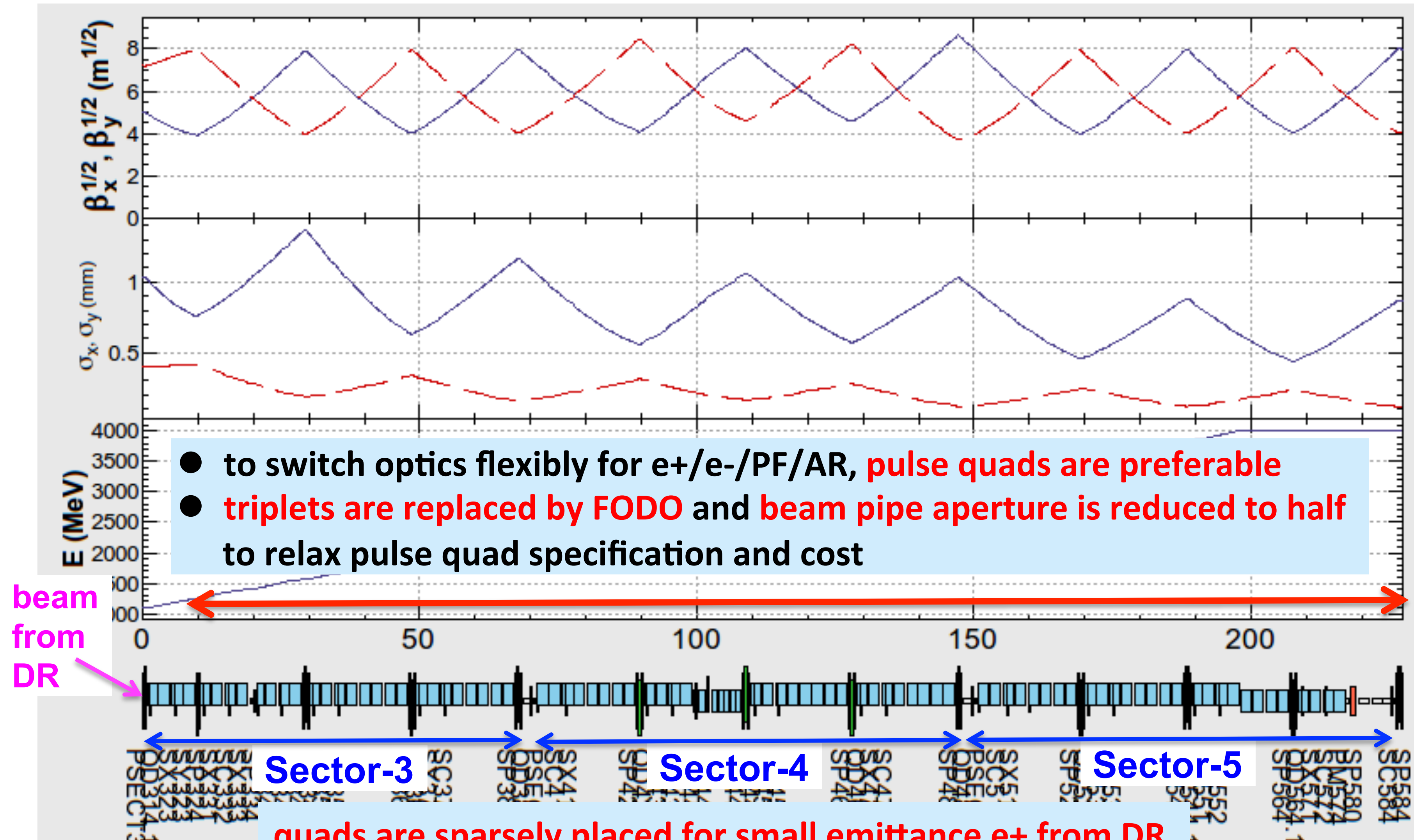
e+ beam line before DR (1-6→2-8) & optics

SAD calculation by T. Miura



e+ beam line after DR (3-1→5-8) & optics

SAD calculation by T. Miura

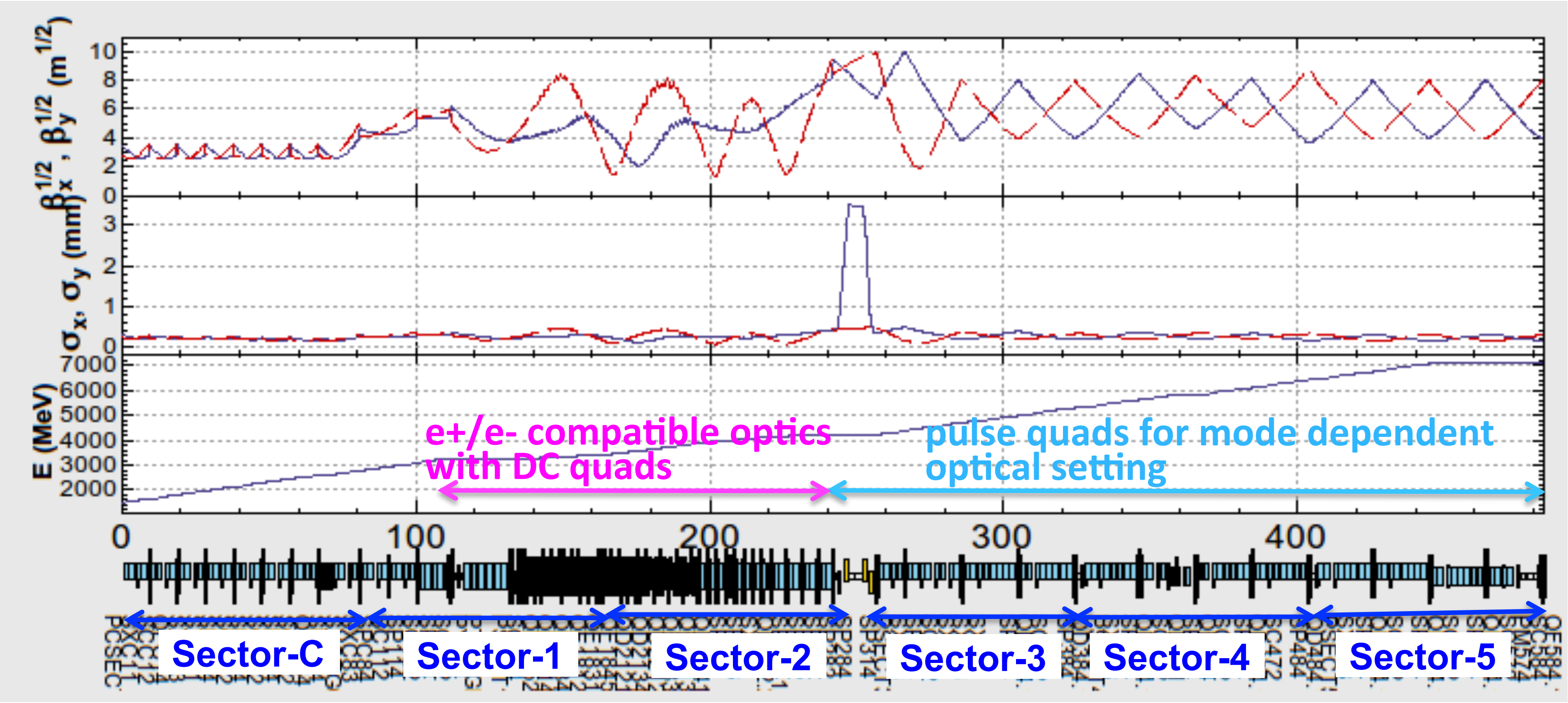


- to switch optics flexibly for e+/e-/PF/AR, pulse quads are preferable
- triplets are replaced by FODO and beam pipe aperture is reduced to half to relax pulse quad specification and cost

quads are sparsely placed for small emittance e+ from DR

e- beam optics

SAD calculation by T. Miura



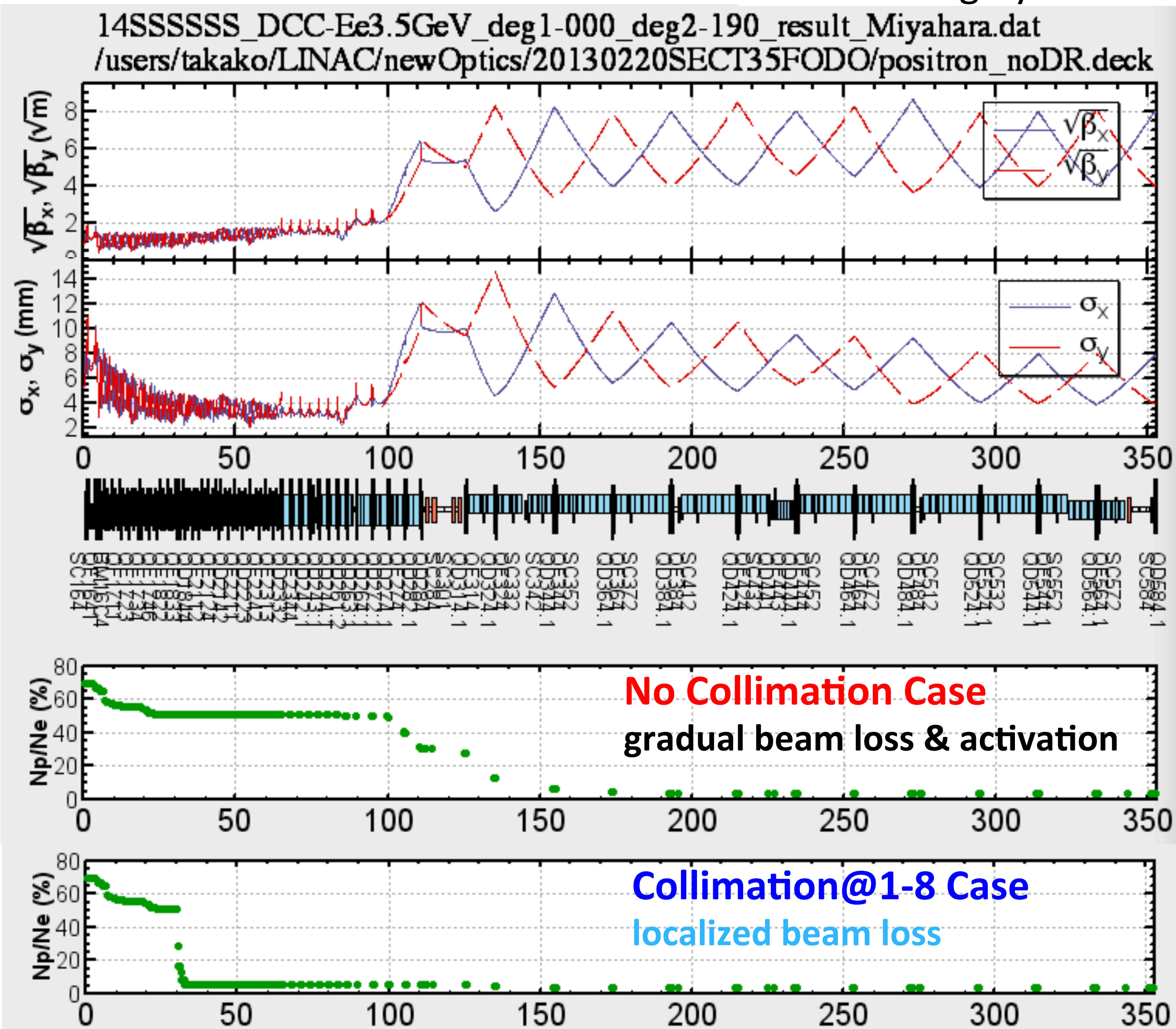
- e+/e- compatible (compromised) optics in Sector-1, 2 of DC quads area (e+ oriented optics with adjustment for e- matching)
- e- oriented optics setting in Sector-3,4,5 by pulse quads
- small acceptance in Sector-3,4,5 is sufficient for small emittance e-

direct e+ injection w/o DR

- in early design stage, LER injection w/o DR is not expected
- in sector-3, 4, 5, acceptance becomes smaller
  by introducing pulse quads,
  - [1] triplet->FODO
  - [2] smaller aperture
- this acceptance is sufficient for small emittance e+/e-,
  but not for large emittance e+
- very low e+ transmission in sector-3, 4, 5

beam loss of large emittance e+

SAD tracking by N. Iida



e+ intensity at linac-end

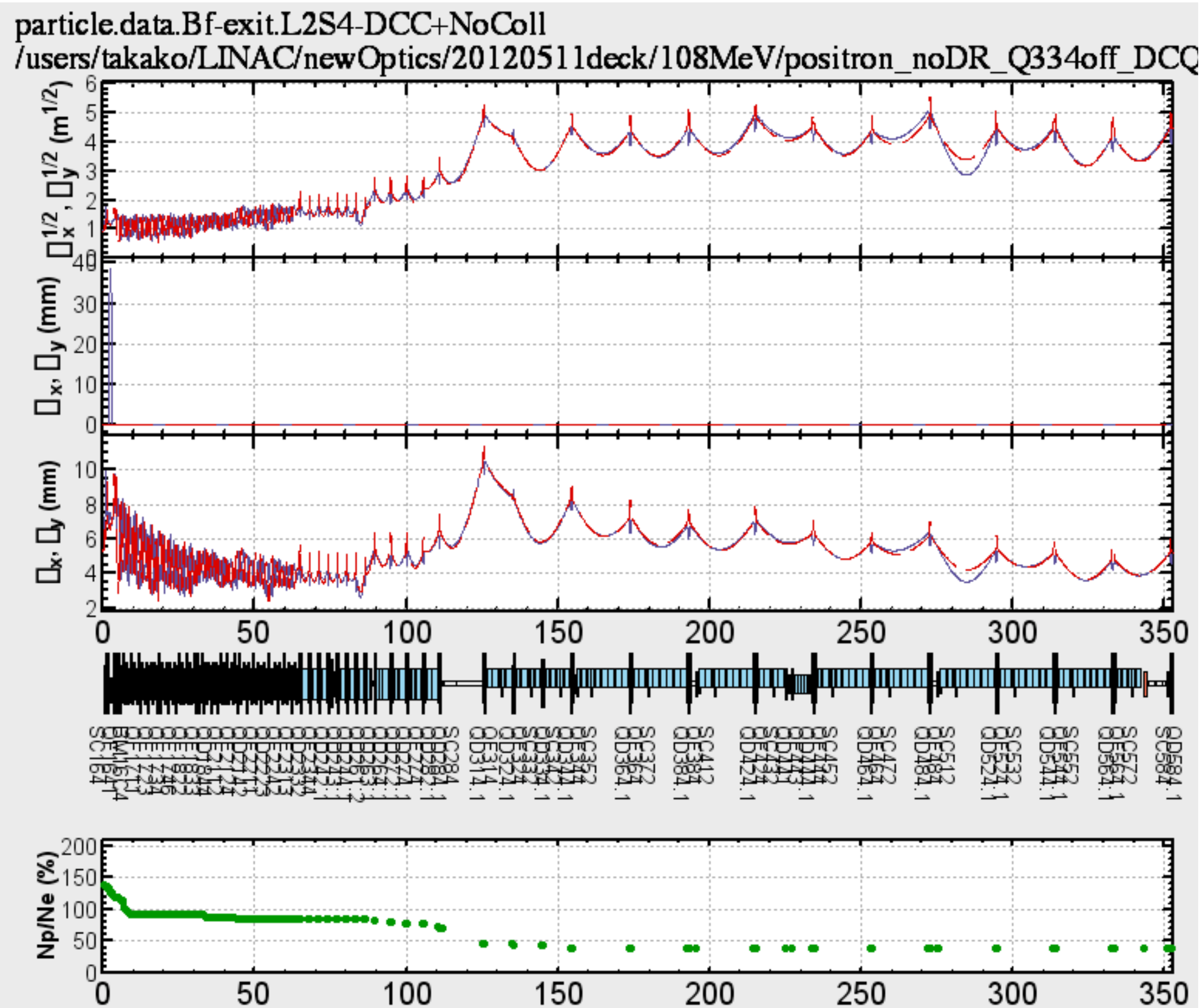
0.355nC

0.346nC

e+ intensity at BT-line will be ½ by energy acceptance

e+ injection with old quads ?

SAD tracking by N. Iida



Option to achieve higher e+ transmission

- Existing triplets in sector-3, 4, 5 with large aperture (a = 10 mm) gives larger beam transmission in linac
- cannot switch optics pulse-by-pulse with DC magnets
- budget constraint on pulse quad fabrication and installation

e+ intensity at linac-end

3.41 nC

transmission efficiency at BT-line should be evaluated !!

Schedule & Summary

e+ schedule for next 1 year

- components development & fabrication
- e+ capture section installation (2013 Jul, Aug, Sep)
  - DC solenoids & LAS installation
- e- commissioning from A1-gun to linac-end (2013 Oct)
- e+ target installation (2013 Nov)
  - e+ target, FC & FODO (Sector-1, 2) installation
- e+ commissioning (2013 Dec-2014 Jun)

  [Constraints]
  - e- intensity 5 nC (~ 10 nC)
  - beam repetition ~ 1 Hz radiation limit, w/o shield around target
  - FC current 6 kA (half of full spec.) prototype half spec. modulator
  - DC solenoid currents 325 A (half of full spec.)

    water & electricity facilities are not yet upgraded
  - pulse quads not yet installed

Summary

1) target & spoiler design is ongoing
2) FC prototype-1 started test operation with a prototype (half spec.) modulator
3) Capture section with no L-band designed for sufficient e+ yield and satellite elimination
4) e+/e- compatible optics in Sector-1, 2 and independent optics with pulse quads in Sector-3, 4, 5 designed
5) direct e+ injection w/o DR gives large beam loss in linac
6) development, fabrication and installation of components will be performed for 1-st stage e+ commissioning at 2013 December.