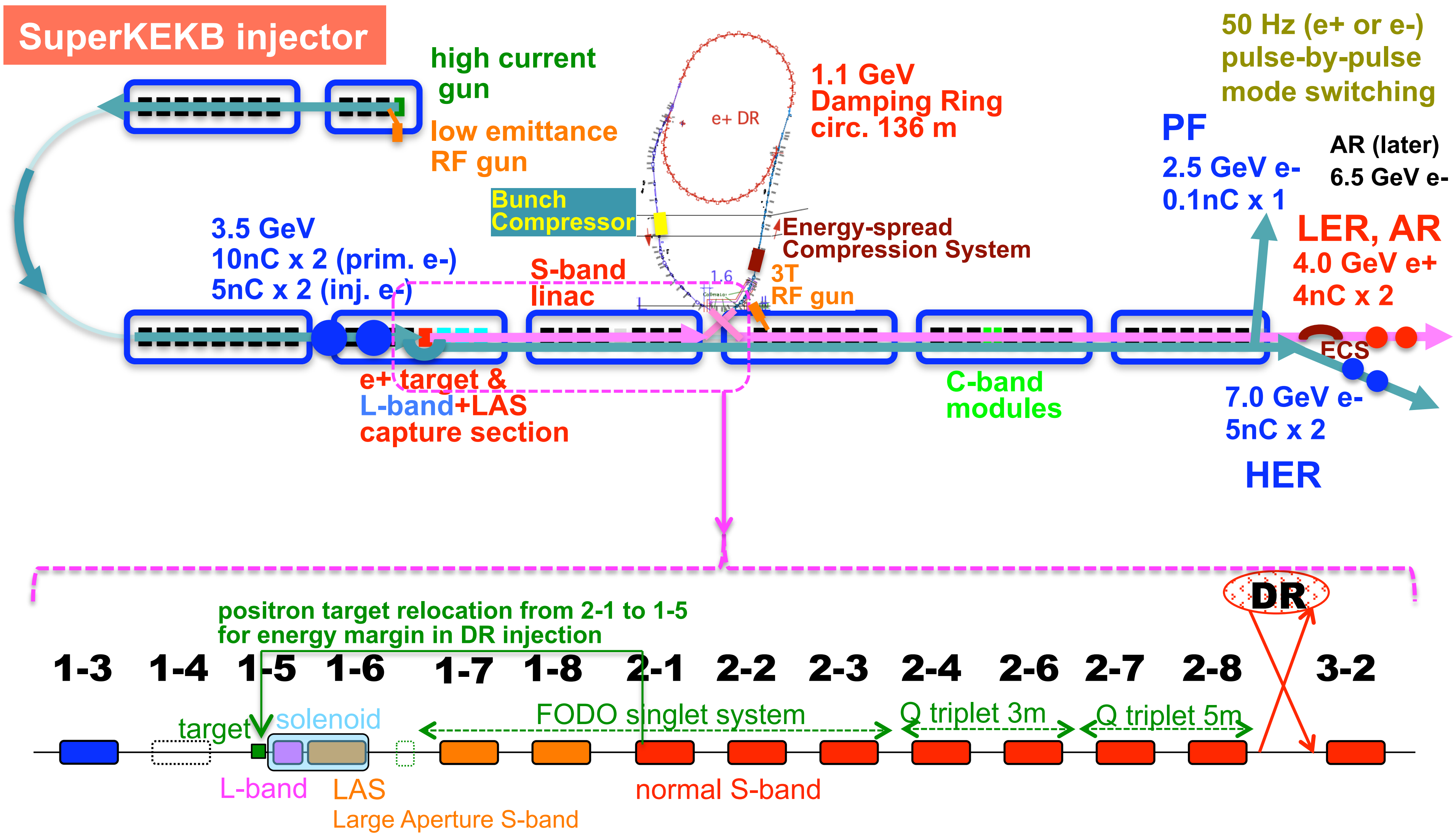
KEKB Review 2012

Positron Source Upgrade

KEKB injector linac
Takuya Kamitani

SKB Injector

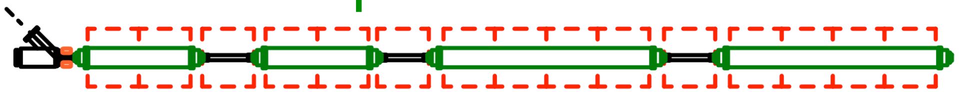


Positron Source Upgrade items

- positron production target
- positron matching device
- capture accelerating structure
- capture DC solenoid
- positron beam line & quad focusing system
- damping ring, LTR, RTL

SuperKEKB Capture section

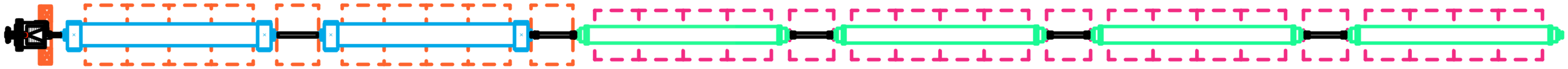
KEKB e+ capture section



- 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 (6.0 T x200mm + 0.4 T x15m)
  flux concentrator DC solenoids

Deceleration mode

- L-band -> 2 x 2m 10 MV/m, aper 2a = 39 -> 35 mm
  LA S-band -> 4 x 2m 10 MV/m, aper 2a = 32 -> 30 mm
- beam energy at capture section exit : 110 MeV

N(e+)/N(e-) = 65 % at 1.1 GeV DR
N(e+)/N(e-)/E(e-) = 19 %/GeV

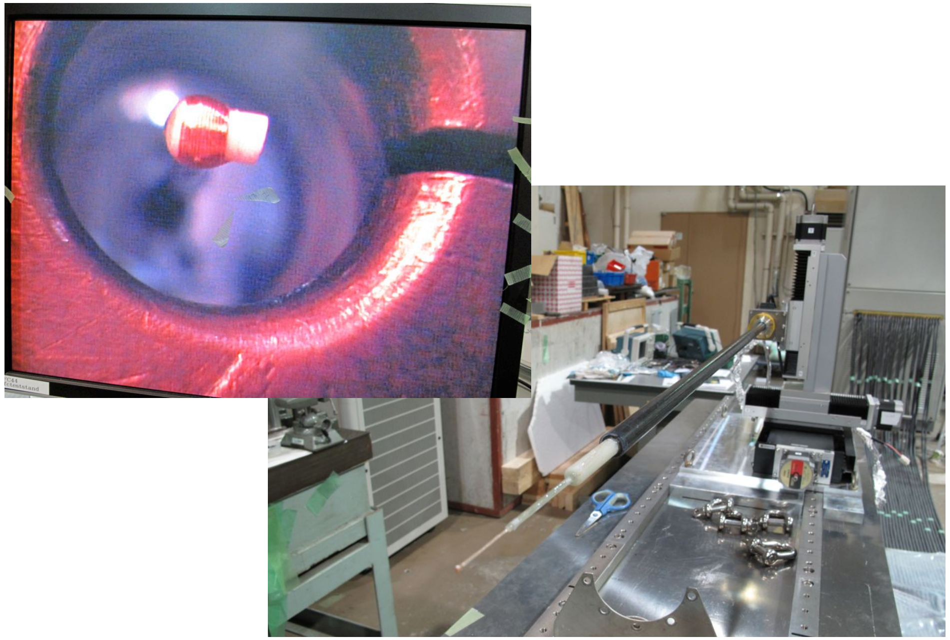
full L-band configuration

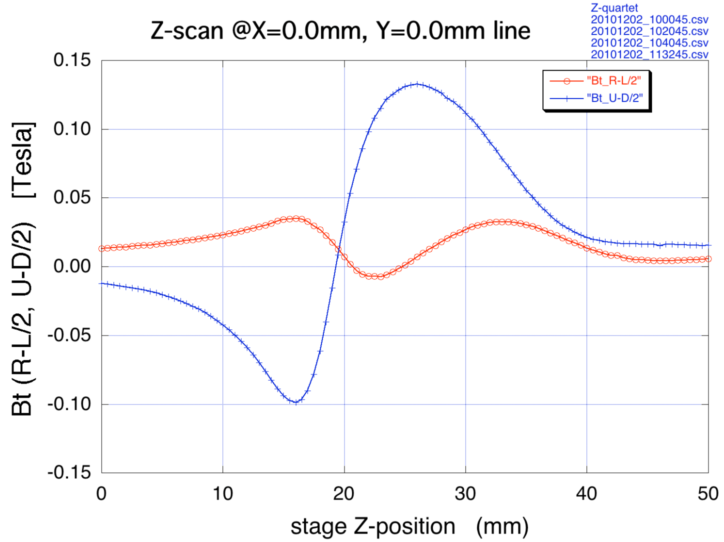
L-band + LAS configuration for comparable performance with reduced cost

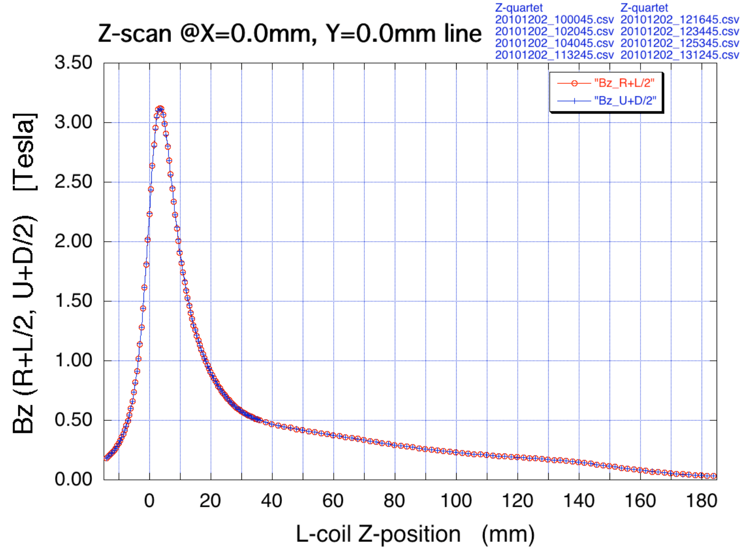
flux concentrator R&D
+ SC solenoid

Flux concentrator BINP-type

- in collaboration with BINP, prototype field measurement & high-power operation test performed at KEK from Nov. 2010 to March 2011.

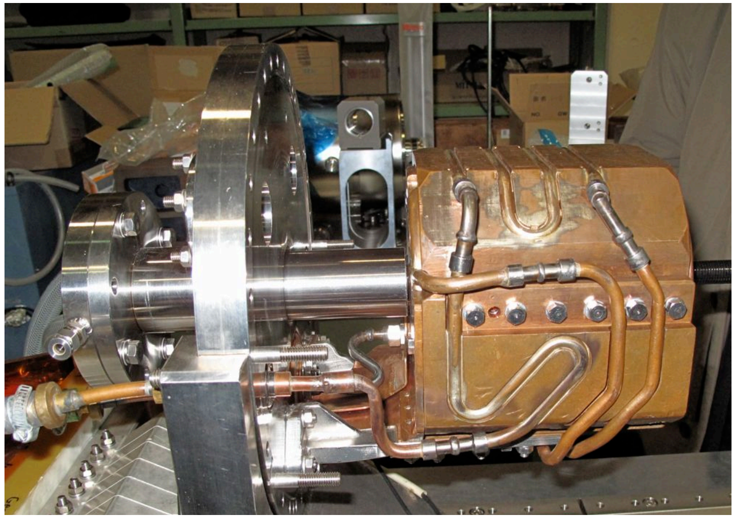


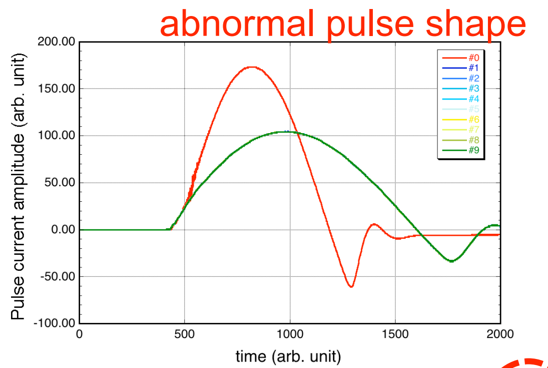


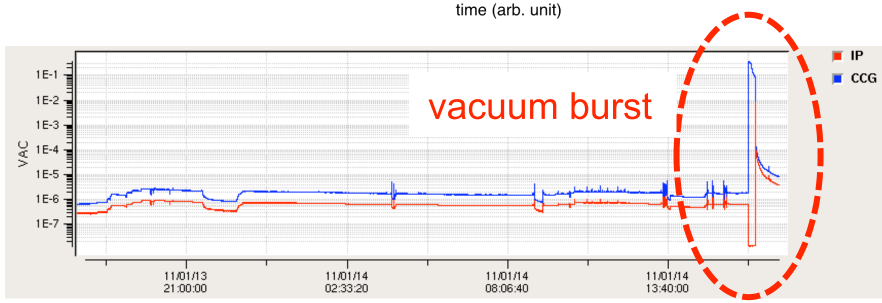


BINP FC breakdown issue

- Breakdown problem (vacuum burst by sparking) above 7 Tesla field level
- investigation with BINP experts continued at KEK until March 11 2011, collaboration work interrupted by the Earthquake.
- investigation of the FC will be performed at BINP by disassembling the magnet body.
- we continue collaboration study for future upgrade of FC.

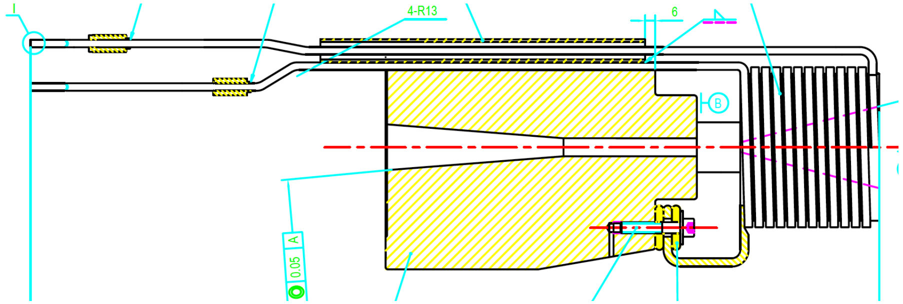


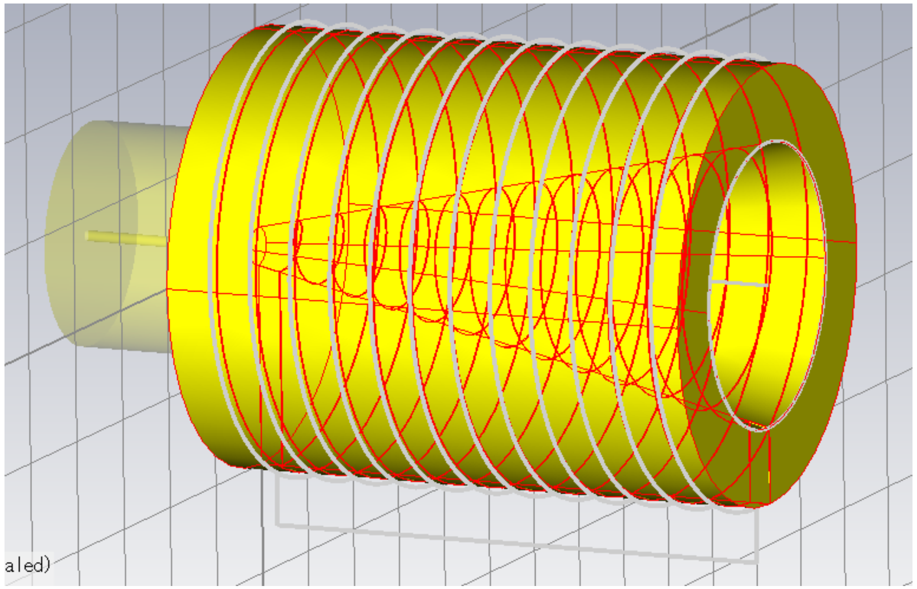


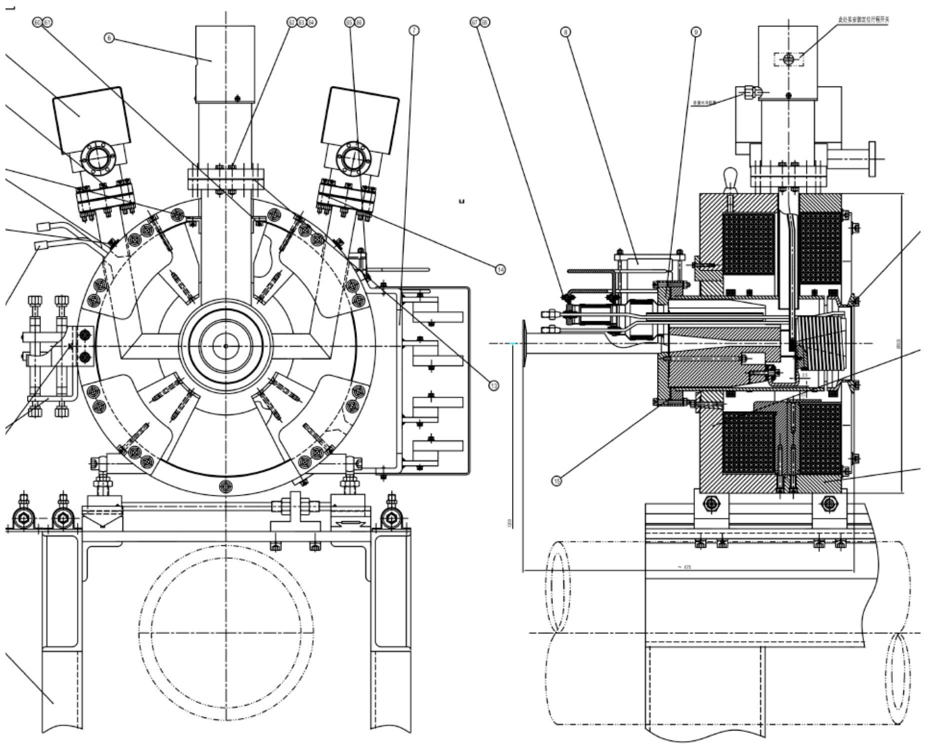


Flux concentrator SLAC-type

- with helps of SLAC and IHEP we are going to fabricate SLAC-type FC for linac commissioning from 2013 autumn and stable operation at T=0.





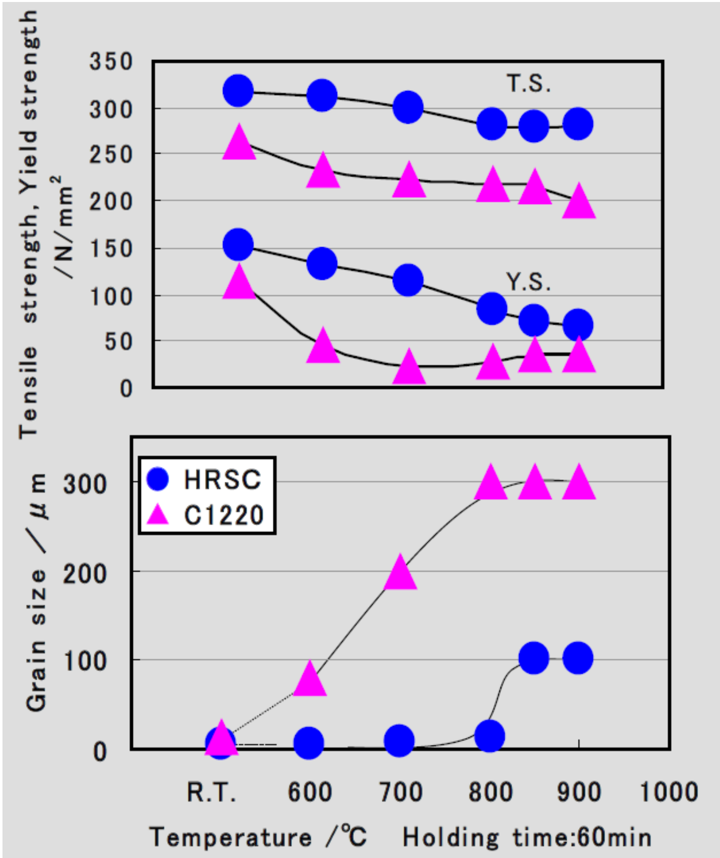


SLAC-type FC at IHEP

FC fabrication R&D

- careful discharge wire cut processing is needed to have smooth surface of FC slit.
- sapphire pulley and wire support structure are prepared, test processing soon starts.
- hardening of copper FC body is necessary to shift mechanical resonance frequency from 50 Hz.
  - manual pressing
  - hard copper material (HRSC)

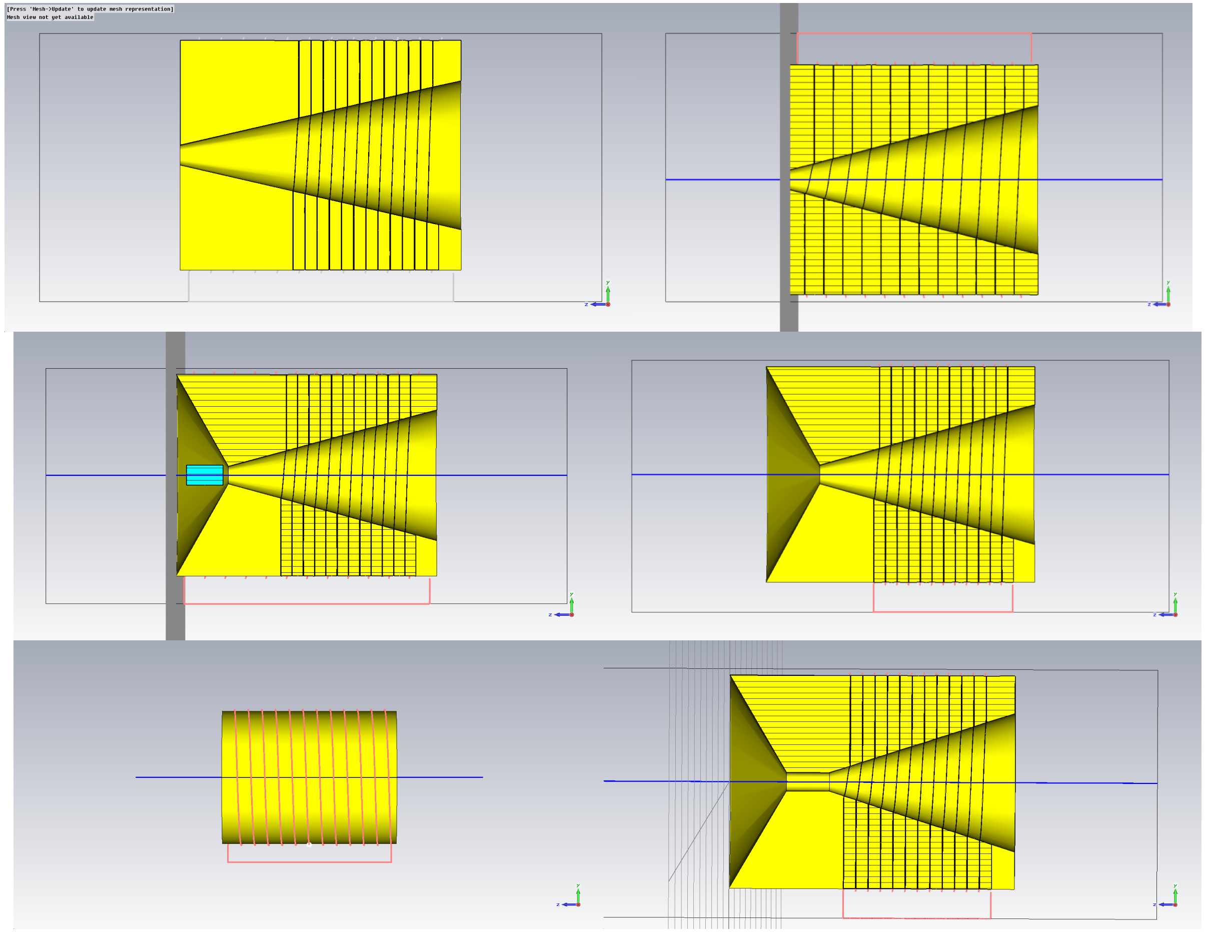
Heat Resistance, high Strength & Conductivity copper (Mitsubishi Material co.)



hard even after brazing !
conductivity ~ 80% of OFC

FC simulation study

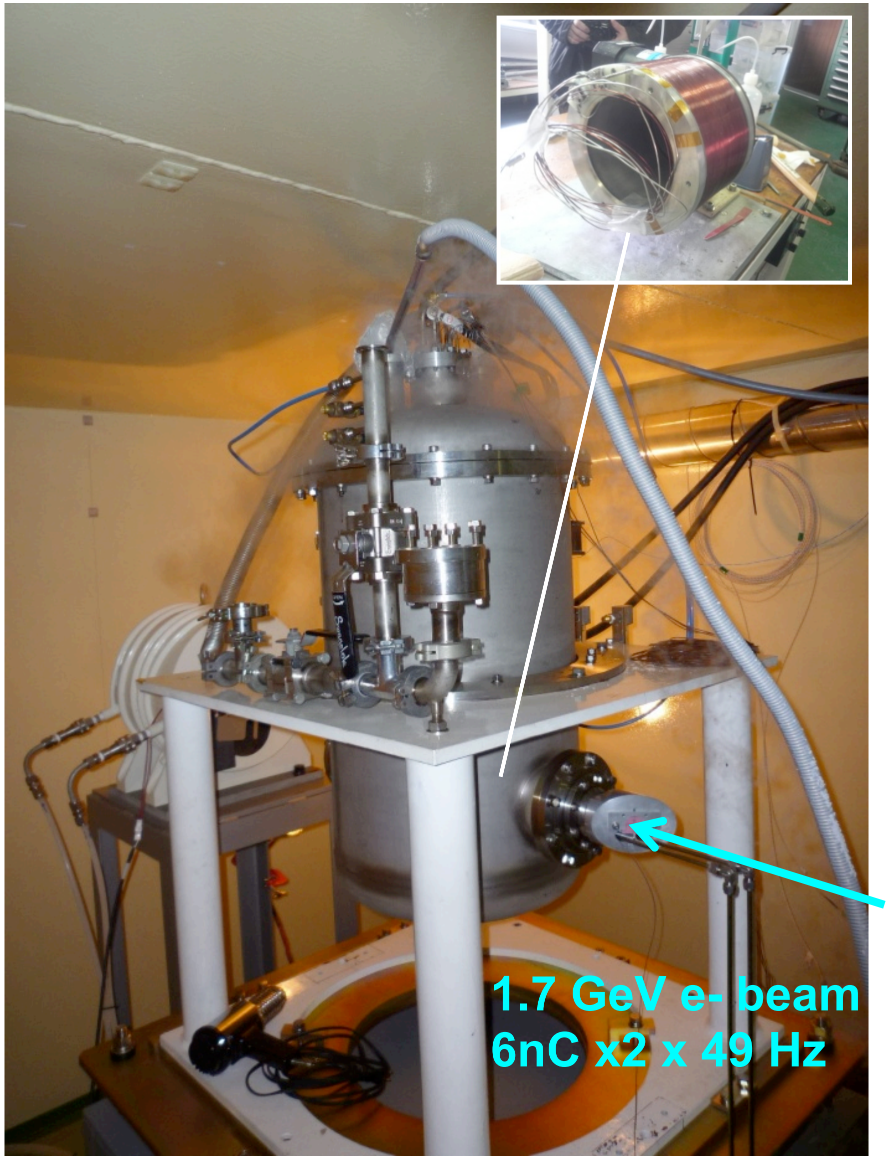
- design trial study in modified shape is ongoing for possible performance improvement (by Zang Lei)



for
higher peak field
lower transverse field
better adiabatic field

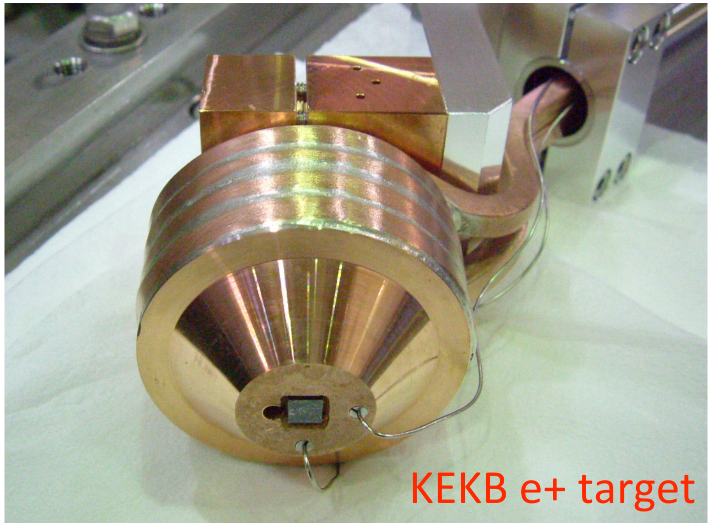
Superconducting solenoid

- Beam irradiation tests are performed to evaluate quenching limit.
- No quench in 10 minutes at 3.2 Tesla with irradiation of 1.7 GeV e- beam of 6nC x2 x 49 Hz. The Earthquake has discontinued the further study.
- Cost of refrigerator to make up for radiation heating will be a problem.
- need more time of R&D for future e+ source upgrade

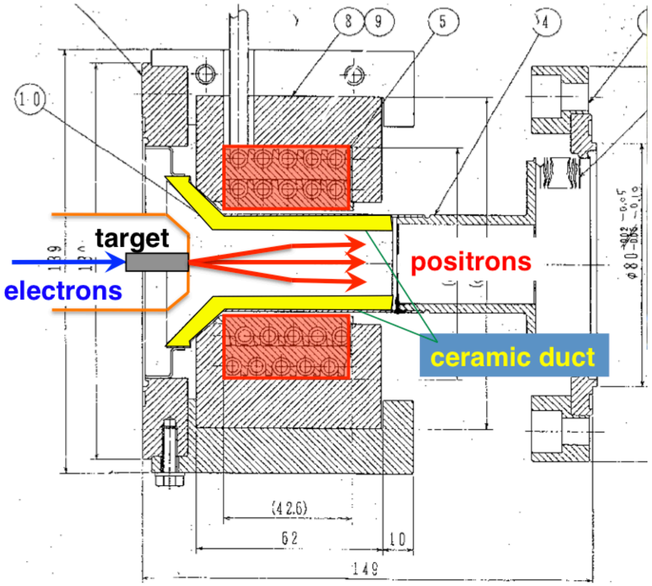


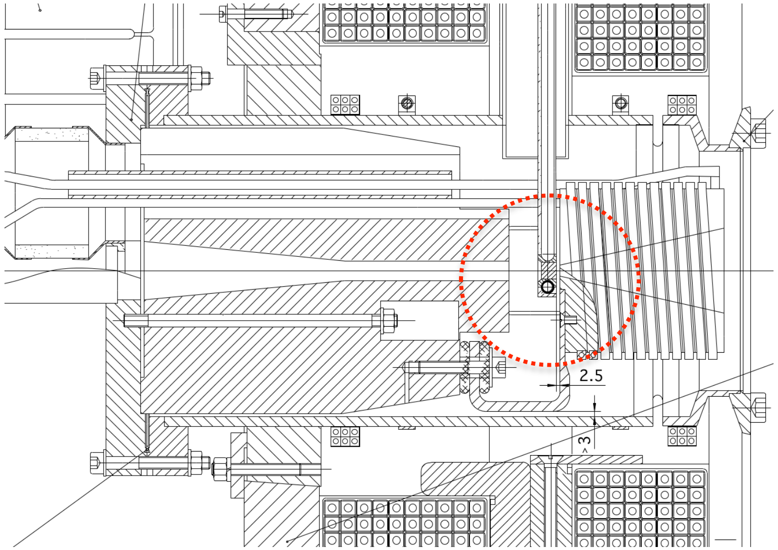
Positron Production Target

SKB positron target



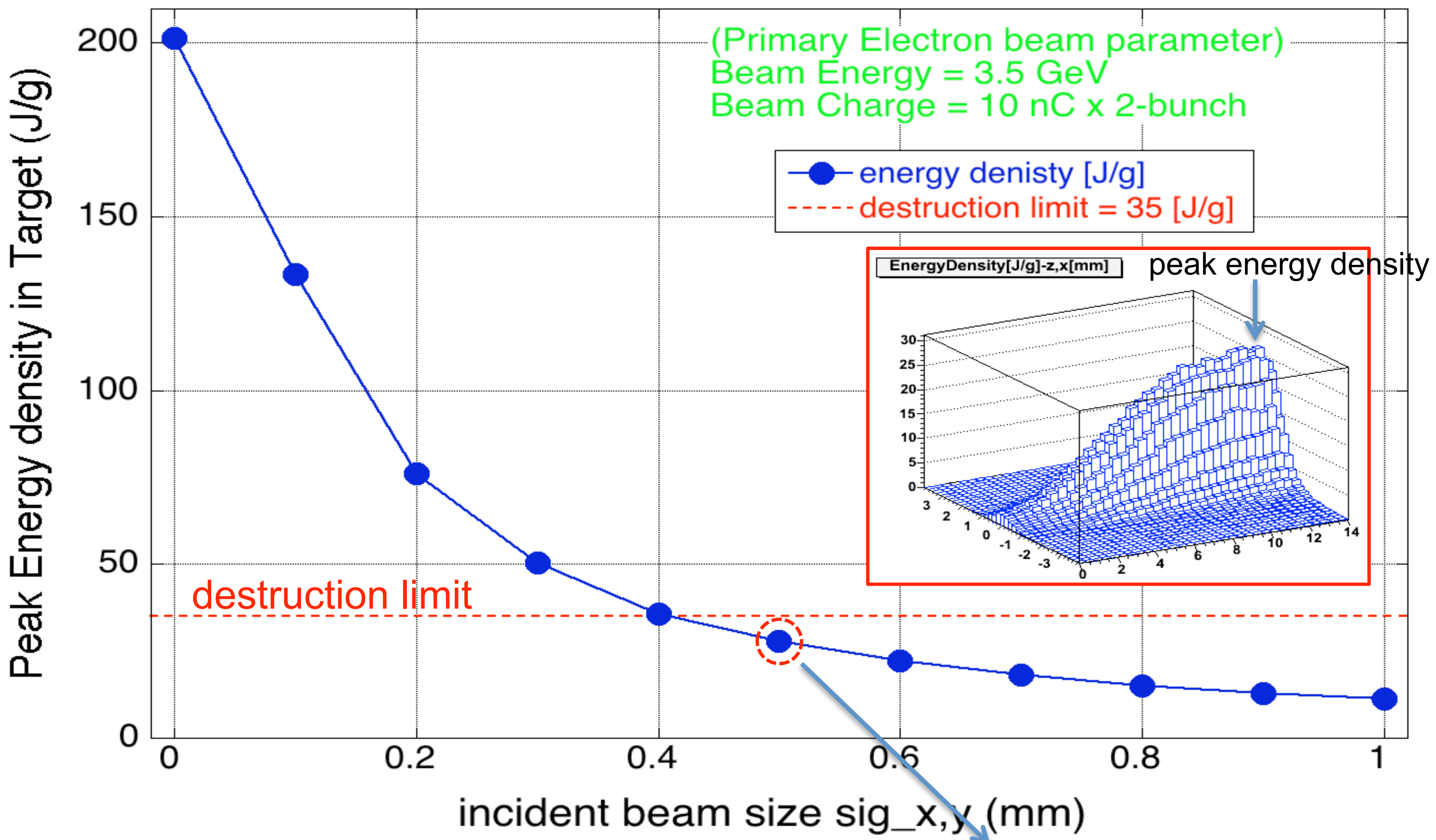
- KEKB target was optimized to pulsed air-core coil configuration.
- SKB target need to be optimized to FC configuration.
- amorphous Tungsten is used at T=0 and will be upgraded to crystal. (precise axis alignment needed)





target destruction issue

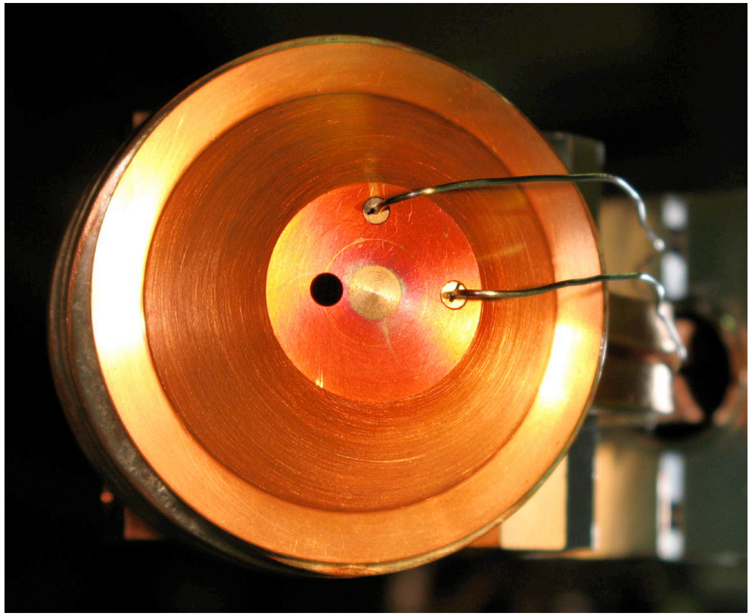
Energy density vs Beam spot size



peak energy density of SKB target is 27 J/g below the limit 35 J/g, but margin is small ! Needs some protection mechanism.

electron bypass hole in target

- pulse-to-pulse e+/e- beam switch by orbit bump with pulse steering magnets.
- injection e- beam pass through small hole in target assembly.
- to preserve e- low emittance e- orbit on the beam axis and e+ orbit 4 mm offset at SKB.
- FC axis at 3 mm offset considering FC field center offset and DC solenoid on the axis.
- to avoid transverse kick by solenoid fringe field and spiral excursion



L-band &
LAS (Large Aperture S-band)
components
development

why L-band + LAS ?

L-band

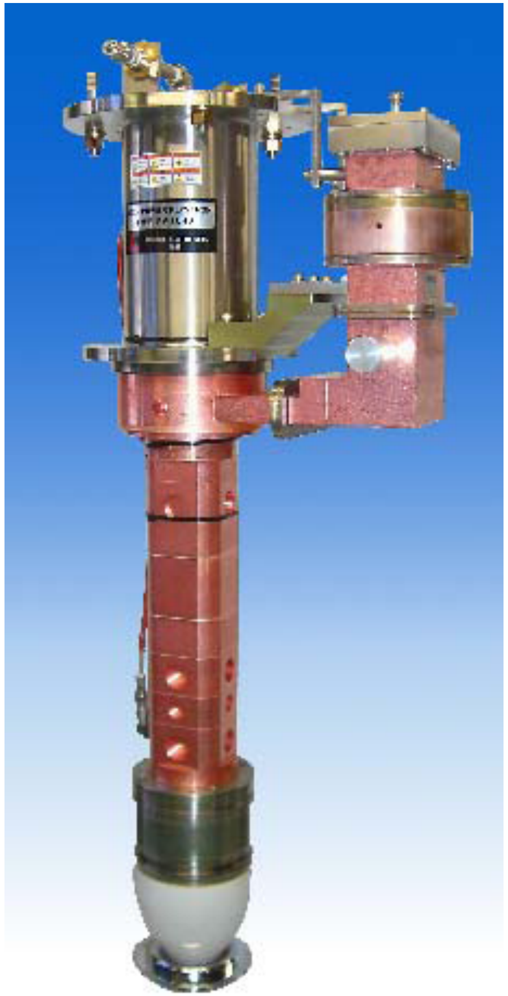
- large aperture (d=39~35mm) of accel. structure is desirable for transverse acceptance of Positron Capture Section
- coprime (5:11) frequency relation is effective to sweep out satellite bunches critical to DR radiation shield issue.
  Full S-band (LAS) capture section gives comparable e+ yield, but with plenty of satellite particles

LAS (Large Aperture S-band)

- medium large aperture (d=32~30mm) is desirable for transverse acceptance of PCS and quad focusing system
- existing S-band rf source, SLED, DC solenoids are available & compact Q at FODO (reduction in initial cost)

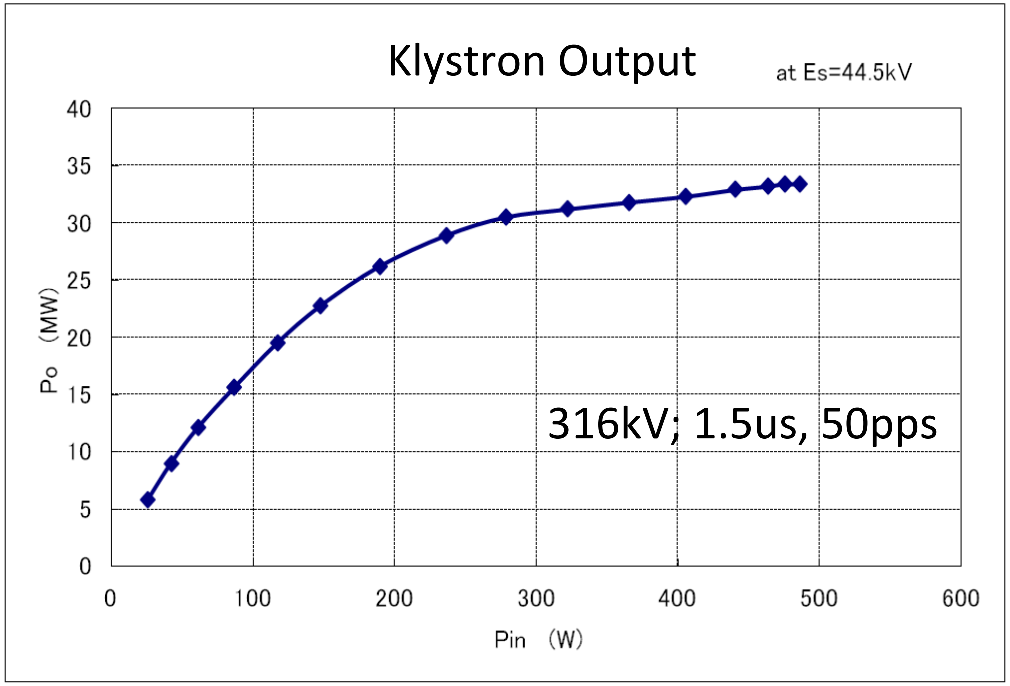
L-band klystron

- 40 MW L-band(1298 MHz) klystron PV-1040 designed by KEK and Mitsubishi Electric
- compatible with existing S-band modulator and KLY tank in KEKB linac
- first PV-1040 delivered in March 2010
- performance test since June 2011
- KLY operation spec. at SKB linac
  30 MW x 1.5 us x 50 pps achieved !
- another two PV-1040 will be delivered, we will have three L-band klystrons for
  (1) positron capture section
  (2) bunch compressor at DR
  (3) spare



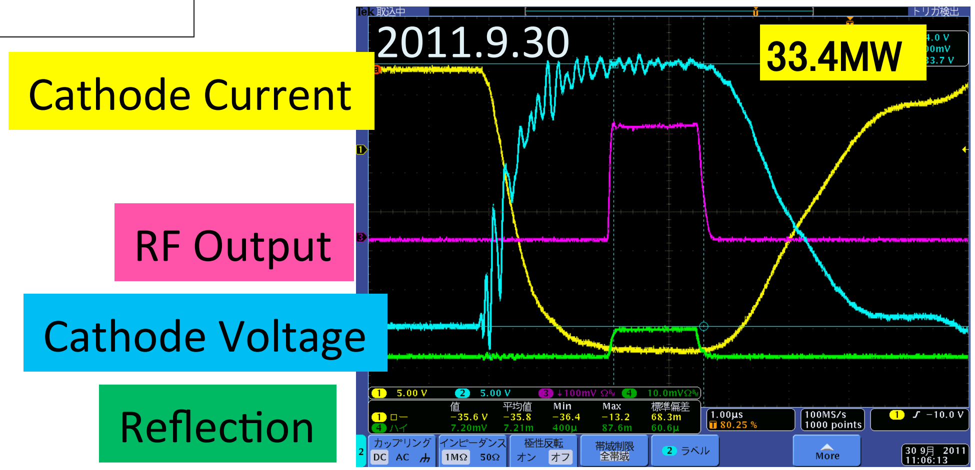
(KLY data by S. Matsumoto)

klystron PV-1040 performance



	Design	Operation
Frequency	1300MHz	1298MHz
Output power	>40MW	30MW
Voltage	<350kV	<350kV
Perveance	2±0.25μ	
RF pulse width	4μs	1.5μs
Rep rate	50pps	50pps
Gain	>50dB	
Efficiency	>40%	

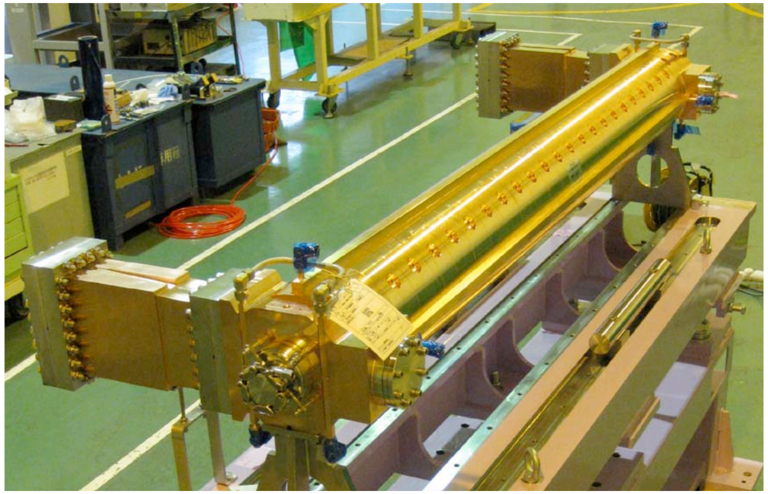
Established
operational spec. !



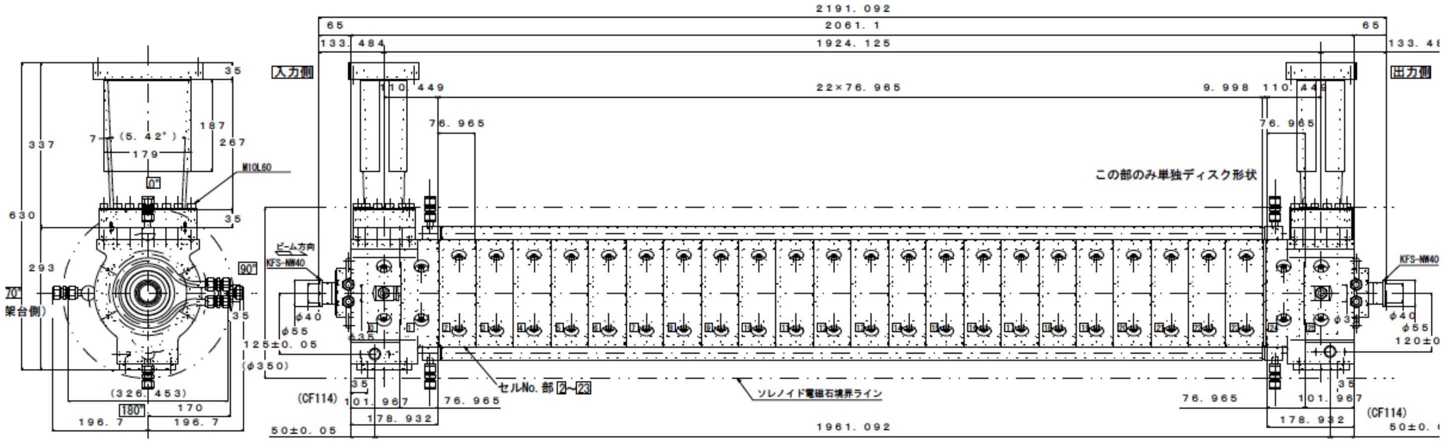
(performance data
by S. Matsumoto)

L-band accelerating structure

- first L-band structure completed in March 2010
- operation test at test stand from April 2012

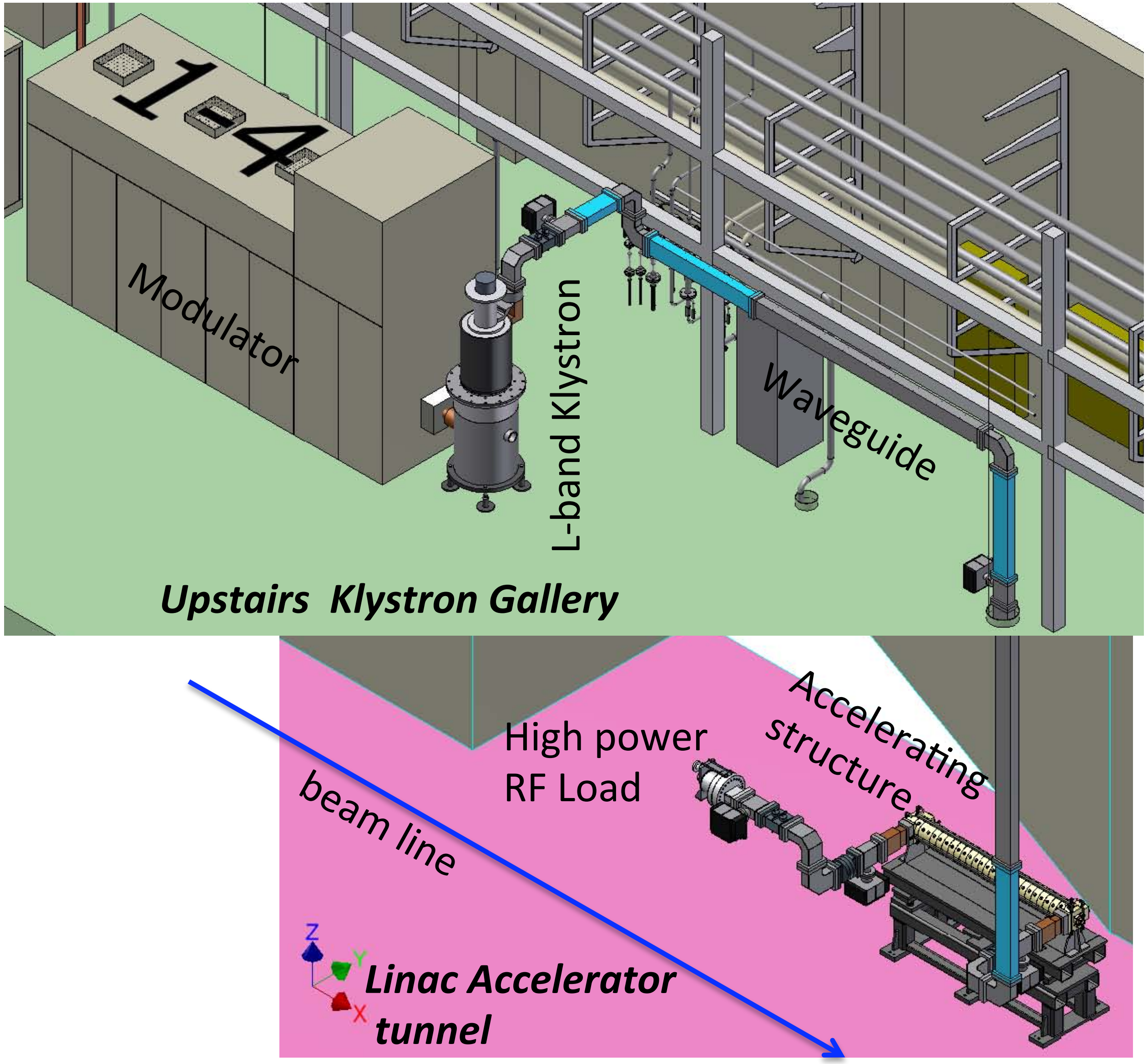


- RF frequency 1298 (=2856 x5/11) MHz
- traveling-wave structure (short rf pulse)
- constant gradient
- (2/3)pi phase advance per cell
- structure length 2.2 meter
- disk aperture 2a = 39.4 ~ 35.0 mm
- field strength 12 MV/m@15 MW input
- single feed coupler (with field symmetrized)
- attenuation constant tau = 0.26



(structure data by T. Higo)

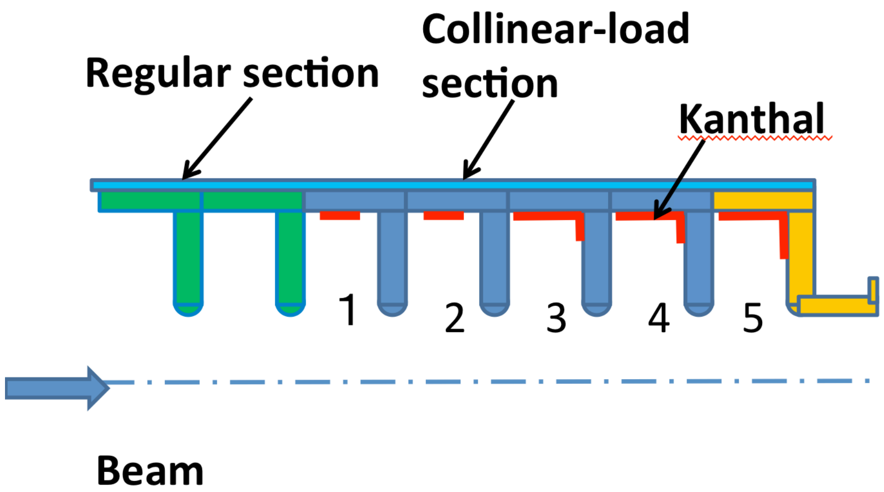
L-band structure test stand

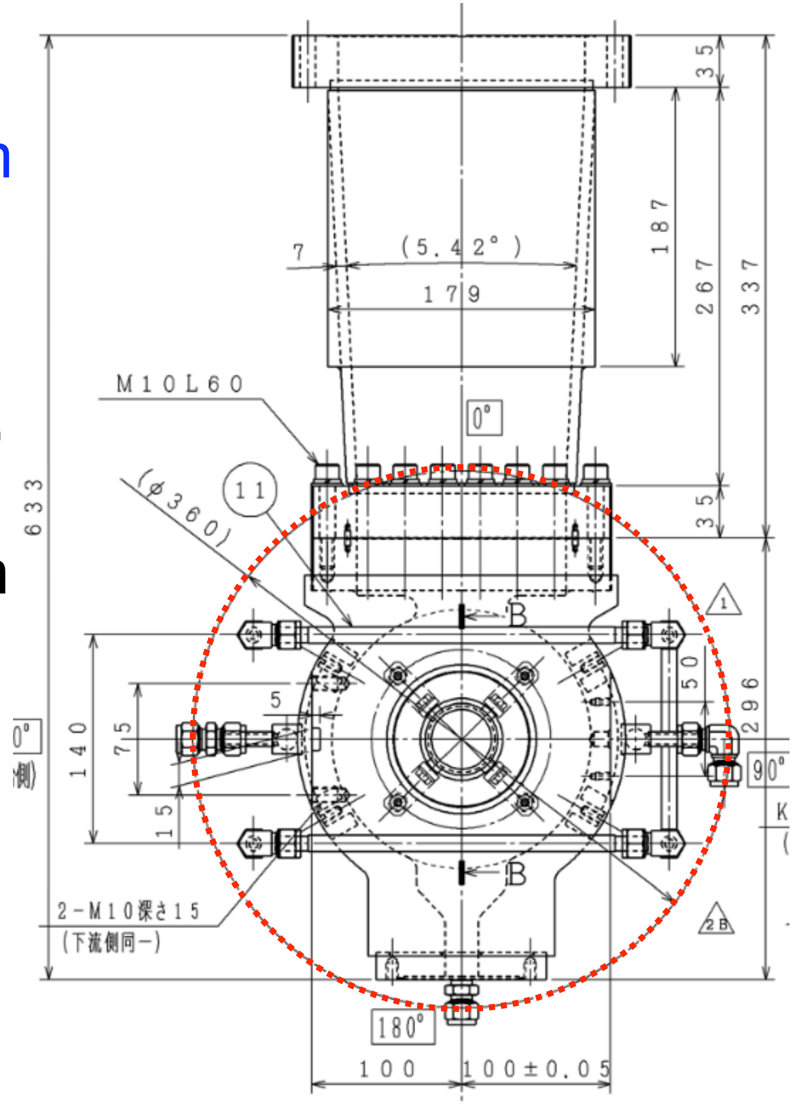


- high power operation test stand in linac tunnel (offline)

built-in collinear rf power load

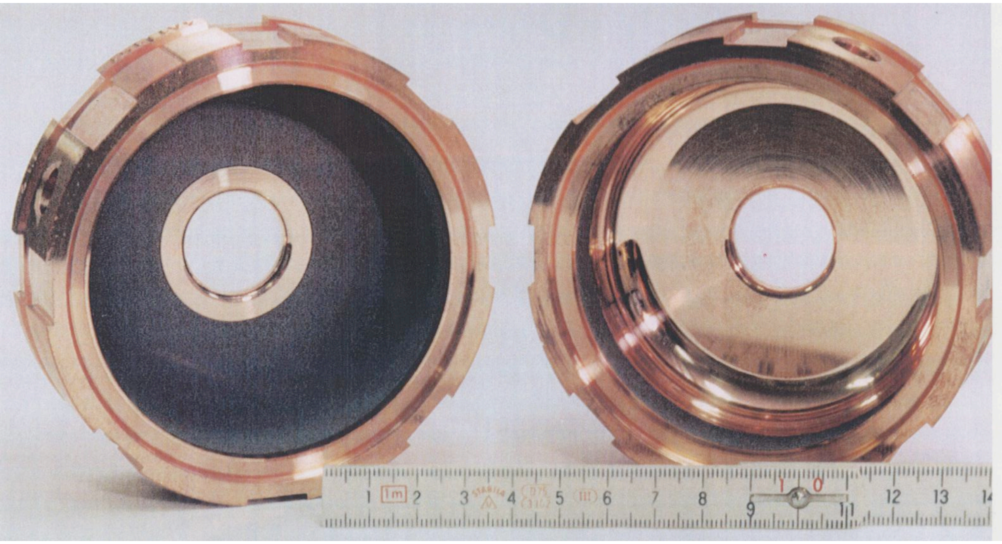
- L-band rf coupler limits DC solenoid inner radius >= 180 mm
- for regular cell region, the radius can be 130 mm
- with built-in collinear power load, the output coupler can be omitted and end-tail become thin





Kanthal as rf absorber

- Kanthal (A1) : Fe (72.2%) + Cr (22%) + Al (5.8%) alloys
- trademark owned by Sandvik in Sweden
- used for making protective layer
- electrical insulator, high thermal conductivity
- melting point (1,500 °C)
- used for high power load in S-band structure at DESY

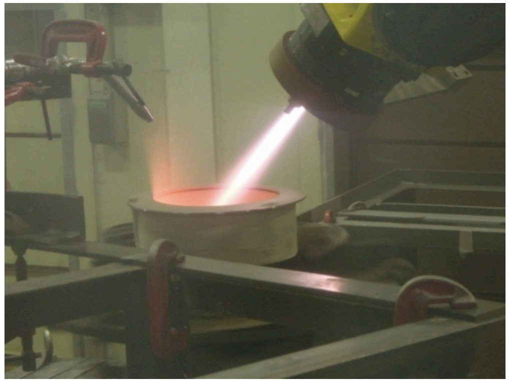


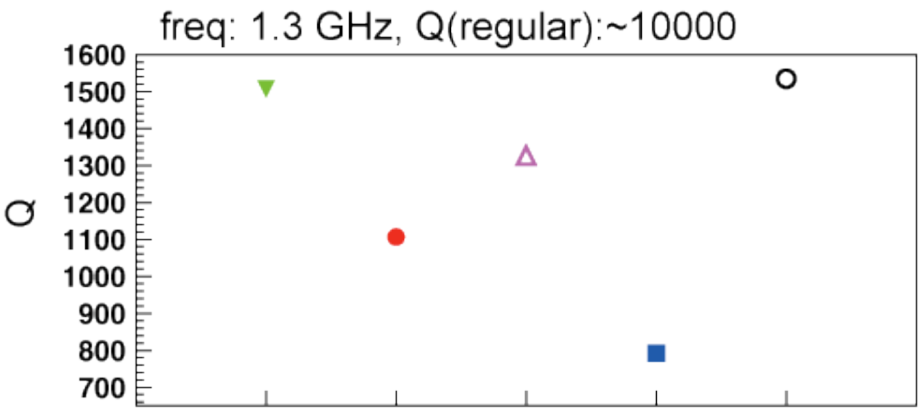
Kanthal cavity cell at DESY

L-band Kanthal cell

- various spraying technique studied for 50 times higher surface resistance and layer stability
- HVOF gives best performance but bad layer quality for slanted injection
- APS is the best candidate

	α
no Coating	1
Arc	60
APS	80
VPS	50
HVOF	120
DESY/LHT	50

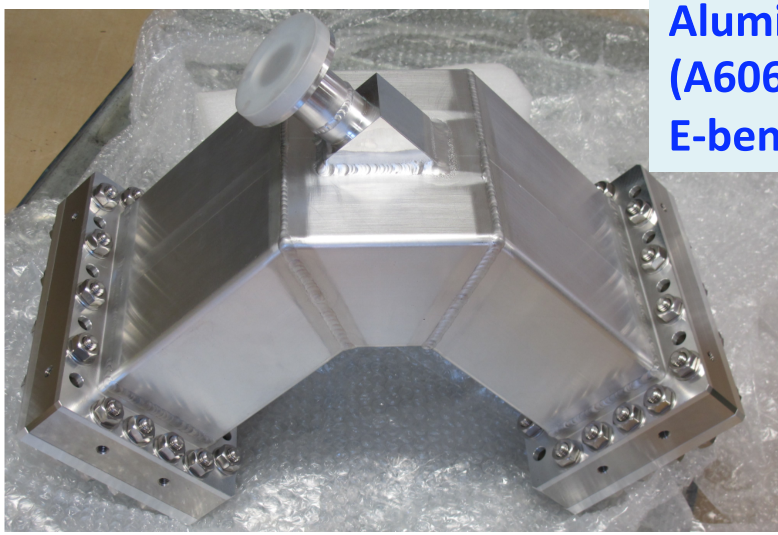




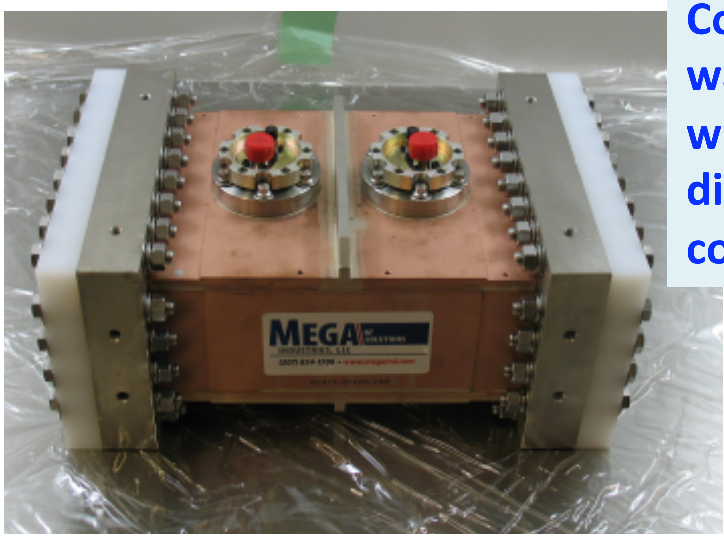
ARC: Electric arc spraying
APS: Atmospheric plasma spraying
VPS: Vacuum plasma spaying
HVOF: High velocity oxy-fuel coating spraying
DESY/LHT: Coating over a bonding layer (Ni-Al)

waveguide and power load

- WR650 (165.1mm x82.55mm)
- evacuated waveguide system (no gas inside)
- Al guides in most part + some Cu guides
- MO flange



Aluminium (A6063) E-bend

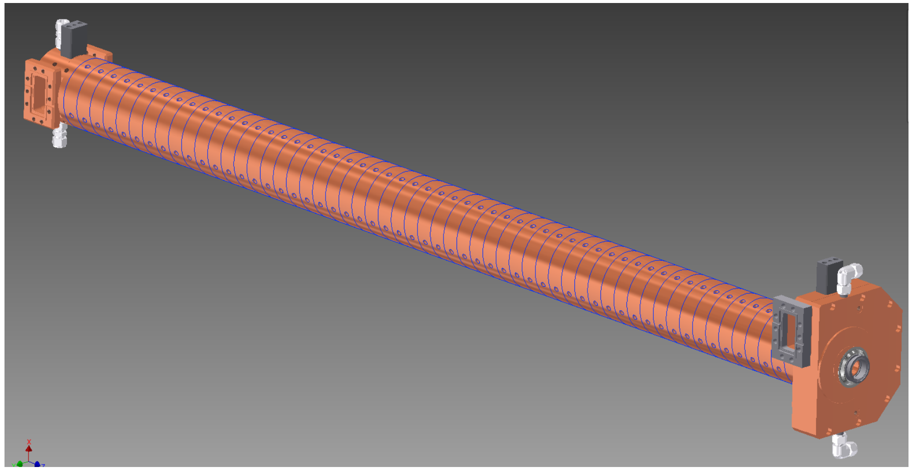


Copper waveguide with directional coupler

high power SiC load

Large Aperture S-band structure

- LAS structures are used,
  - in second unit of capture section
  - in two accelerator modules just behind capture section
- large aperture and compact outer diameter
  - existing rf source available
  - existing DC solenoid available
  - compact quad outside LAS structure compared with L-band
- cost-performance balance

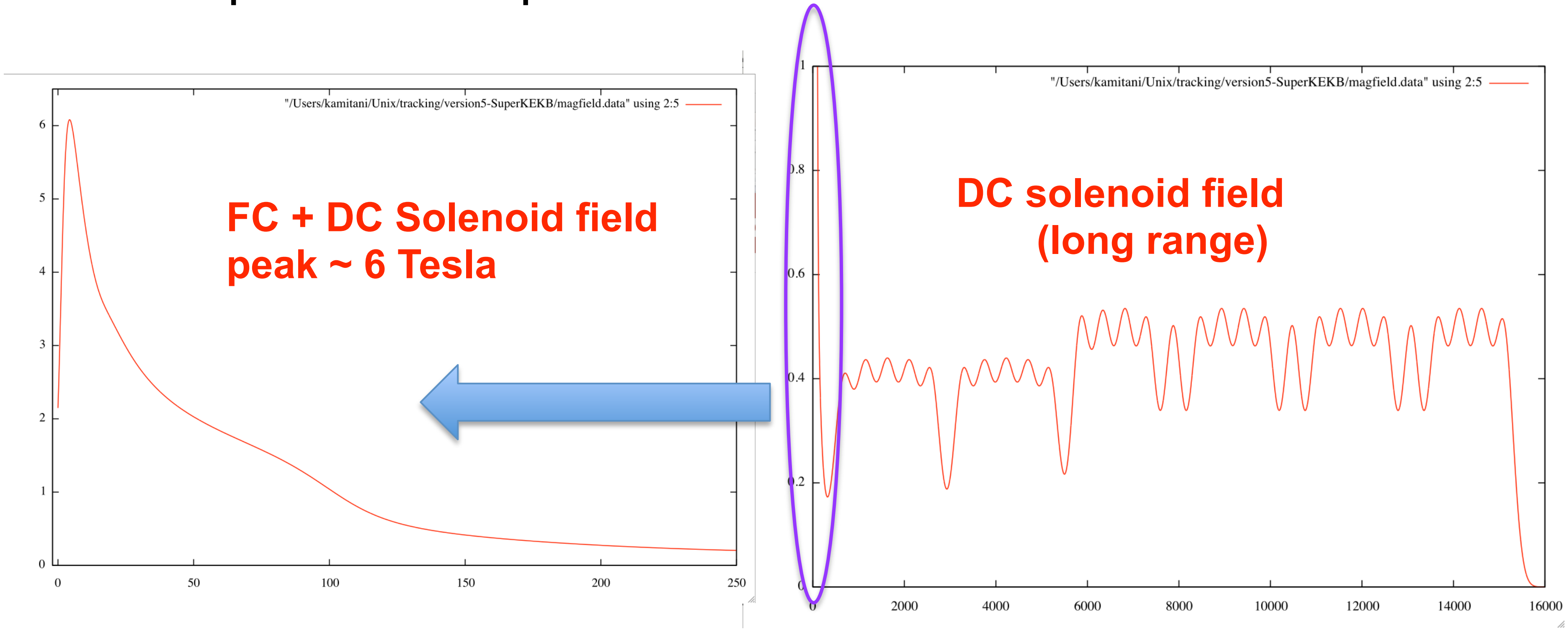


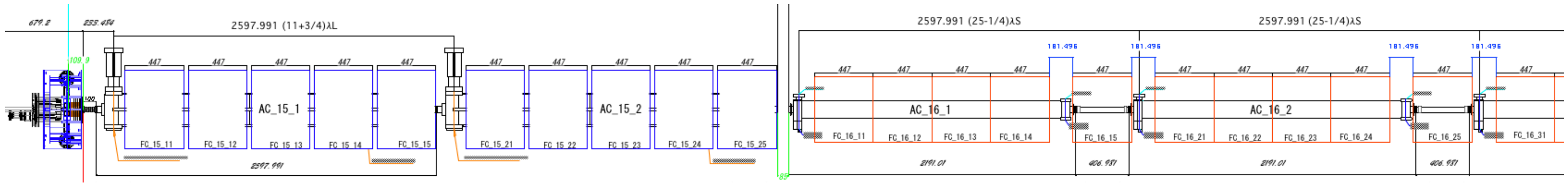
- traveling-wave structure
- constant gradient
- (2/3)pi phase advance per cell
- structure length 2.2 meter
- disk aperture 2a = 31.9 ~ 30.0 mm
- field strength 16.4 MV/m with SLED
  6.9 MV/m w/o SLED
- two port input coupler (J-shape side-couple)
  two port output coupler (ordinary shape)
- attenuation constant tau = 0.112

Beam optical design & tracking simulation

capture section solenoid field

- FC + DC solenoid field distribution determines transverse acceptance of capture section and e+ initial emittance.

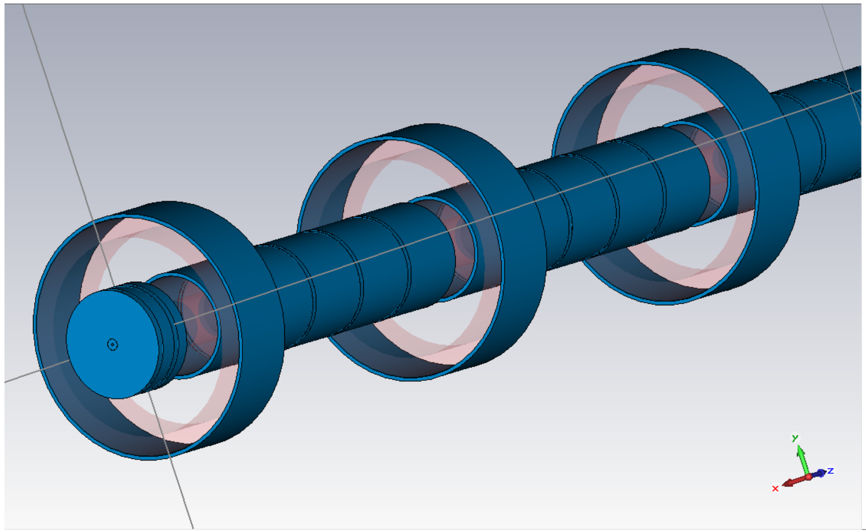


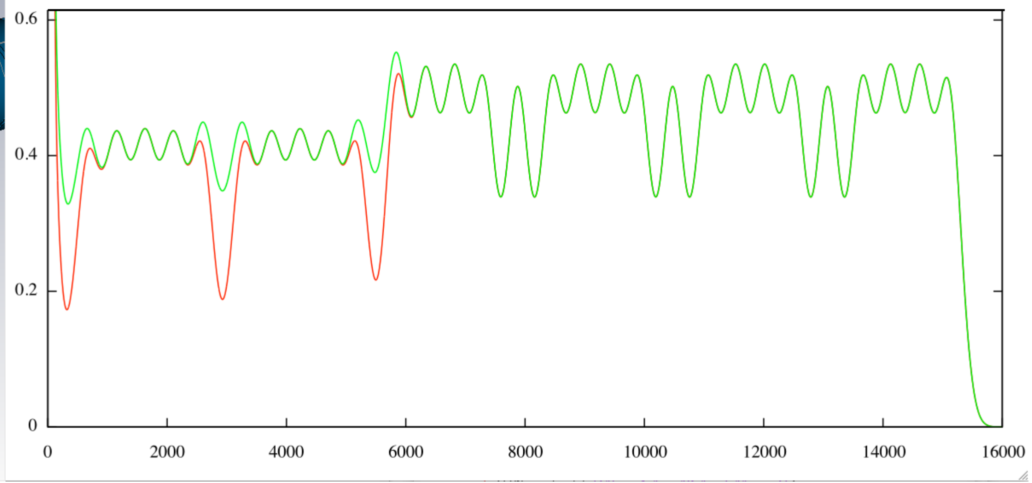


compensation with huge solenoid

- adding three huge solenoid compensates field dips in waveguide regions.
- e+ yield estimation is underway to judge whether to install these huge solenoids or not.

parameters for a solenoid module (L=447mm)	L-band solenoid	Huge solenoid
outer radius (mm)	295	680
1-turn wire length (m)	1.28	3.79
# of turns	245	189
current (A)	650	650
wire cross section (mm2)	171	132
power consumption (kW)	14.1	48.3
weight (kg)	606	1341





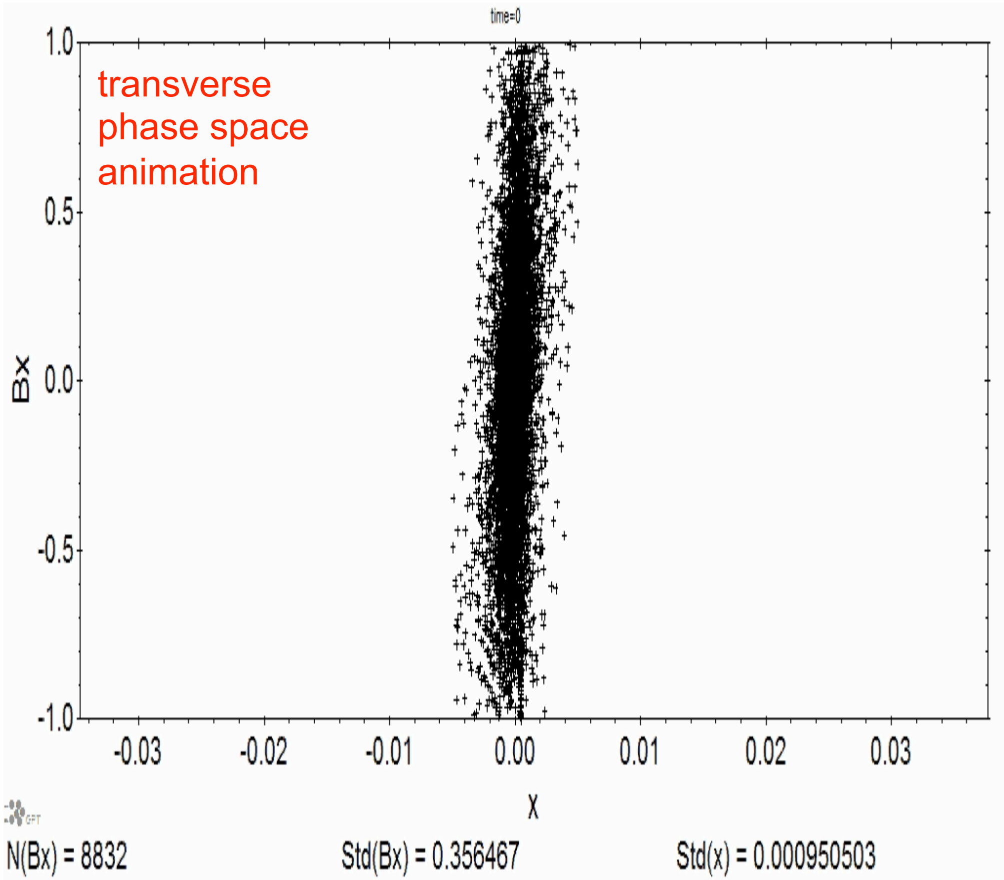
particle simulation

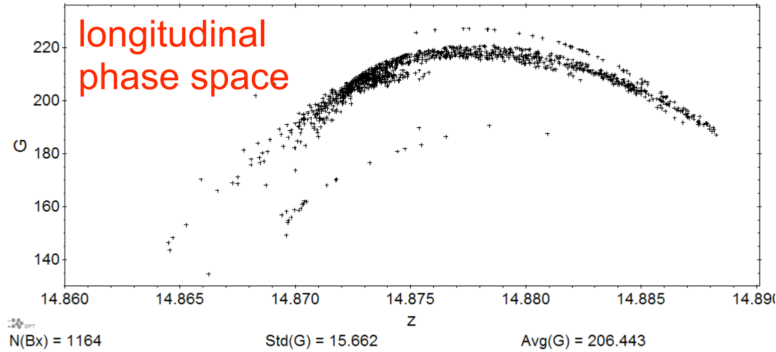
- e+ capture section (Zang Lei (GPT code), T. Kamitani)
- linac 1~2 sector + LTR (N. Iida (SAD code))
- DR beam dynamics (H. Ikeda)
- RTL + linac 3~5 sector + BT-line (N. Iida (SAD code))

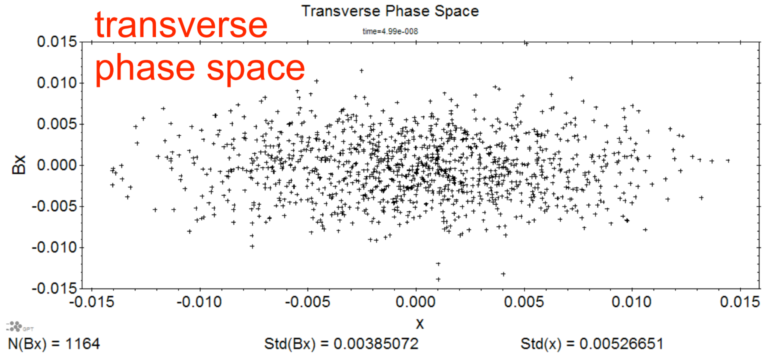
- e+ capture section tracking
  - e+ generation by GEANT4 or EGS4
  - FC field evaluated by CST EM Studio
  - DC solenoid field evaluated by CST EM Studio and data smoothed by approximating with analytic function
  - L-band structures Eacc = 10 MV/m, aperture 2a = 35 mm
  - LAS structures Eacc = 10 MV/m, aperture 2a = 30 mm
  - acceleration and deceleration phase modes

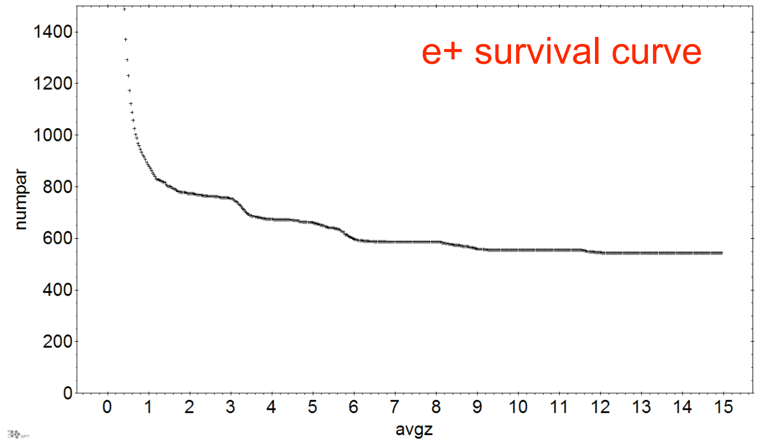
tracking in capture section

- tracking results with GPT (by Zang Lei)



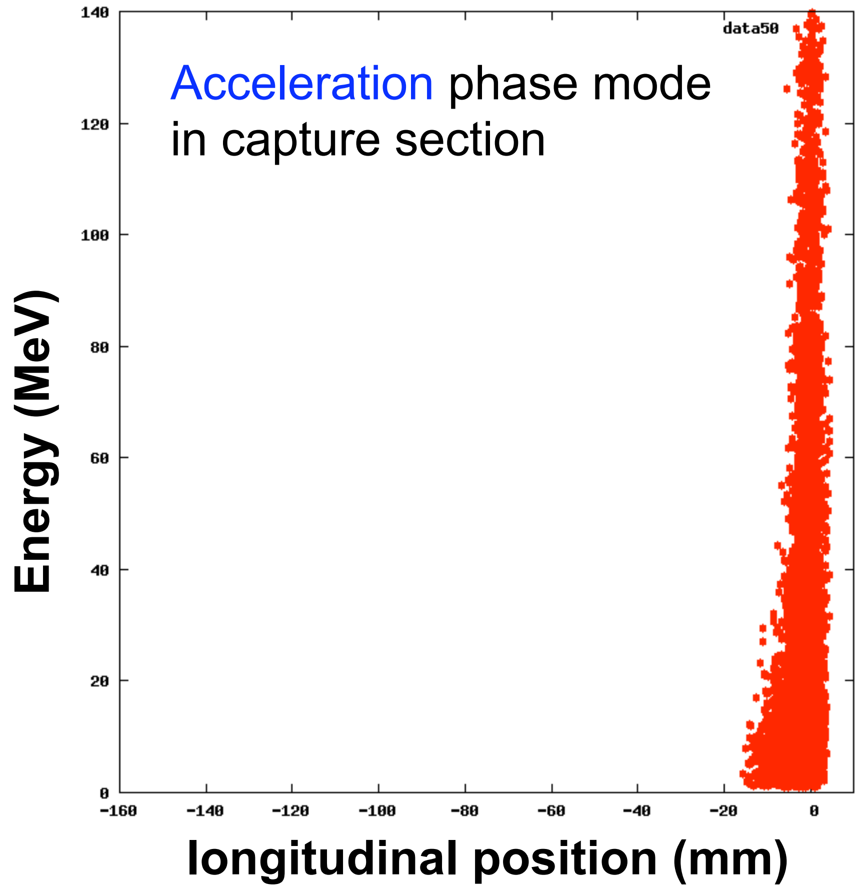


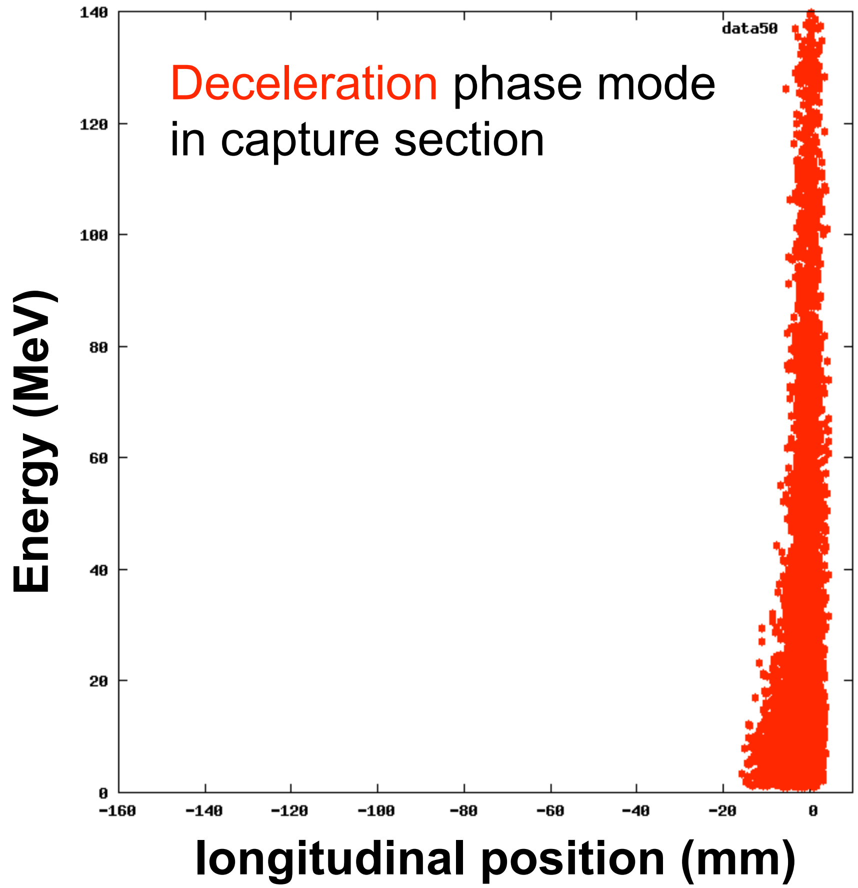




e+ capture animation

from target to capture section exit (120 MeV)

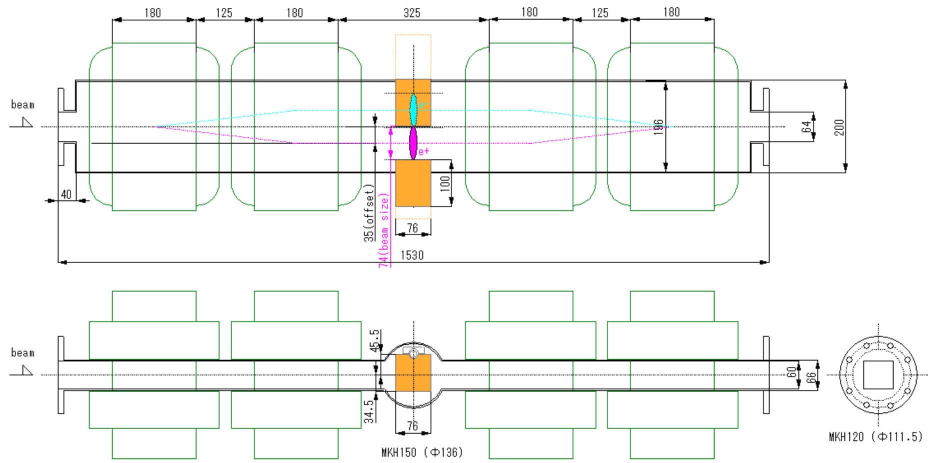


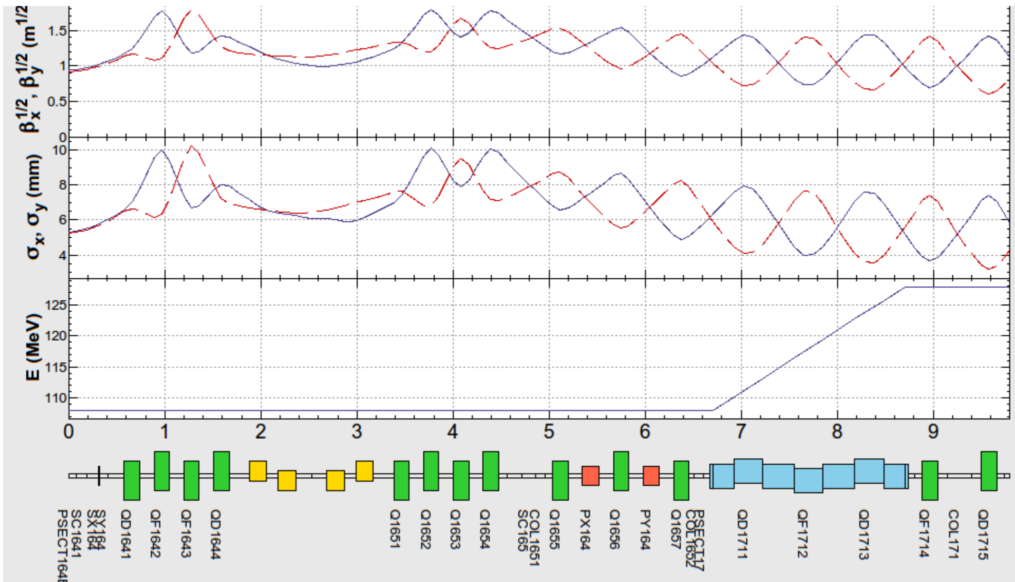


Capture efficiency is comparable in either mode.

optical matching & e- elimination

- optical matching from solenoid focusing region to FODO quad system
- e+/e- separator chicane and e- stopper for low energy e- from target, (injection e- go beside the stopper)
- collimators to remove off-momentum particles



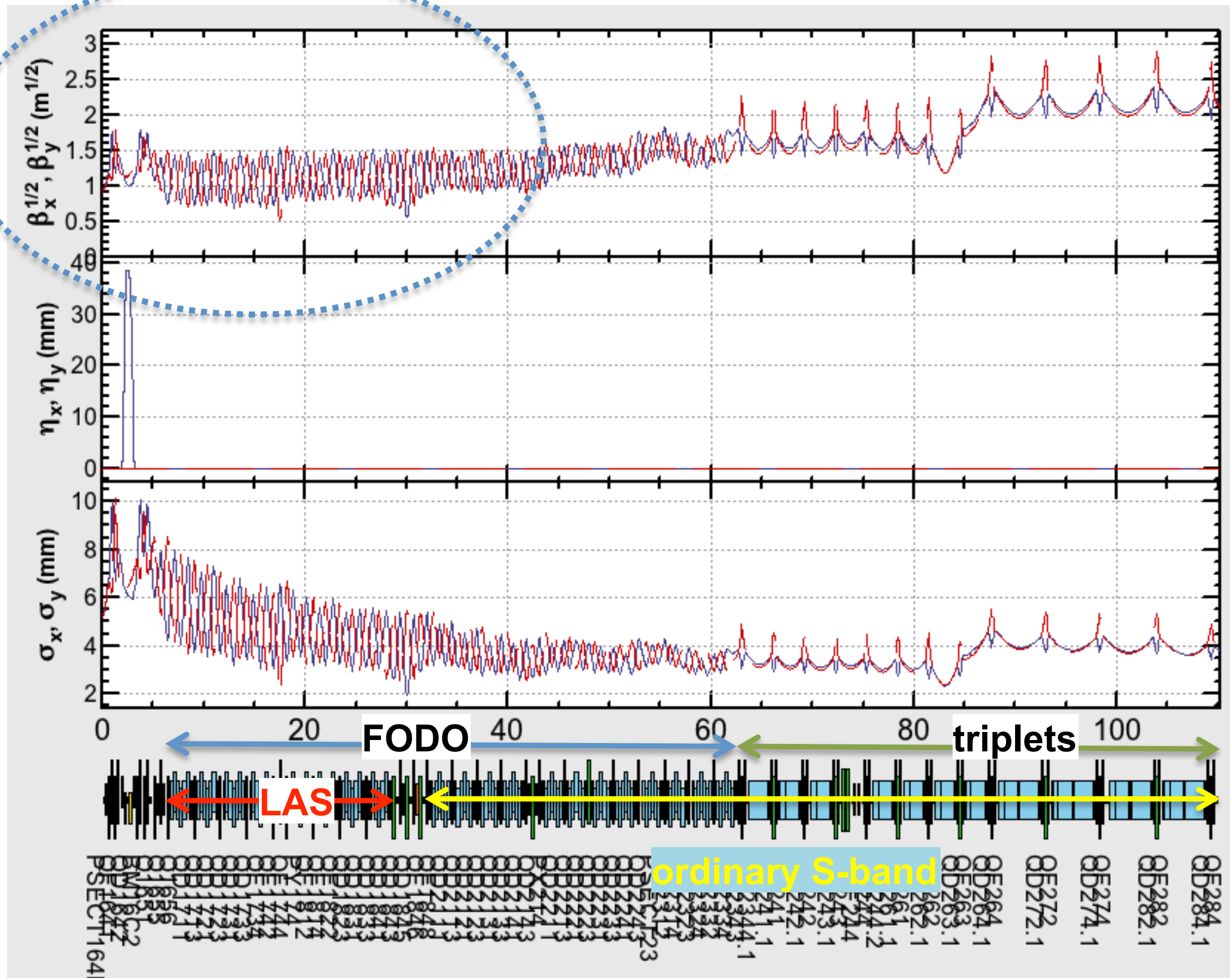


(optics calculation by T. Miura)

e+ beam optics (before DR)

- quad focusing system FODO in 60 m + triplets in 45 m before LTR to DR

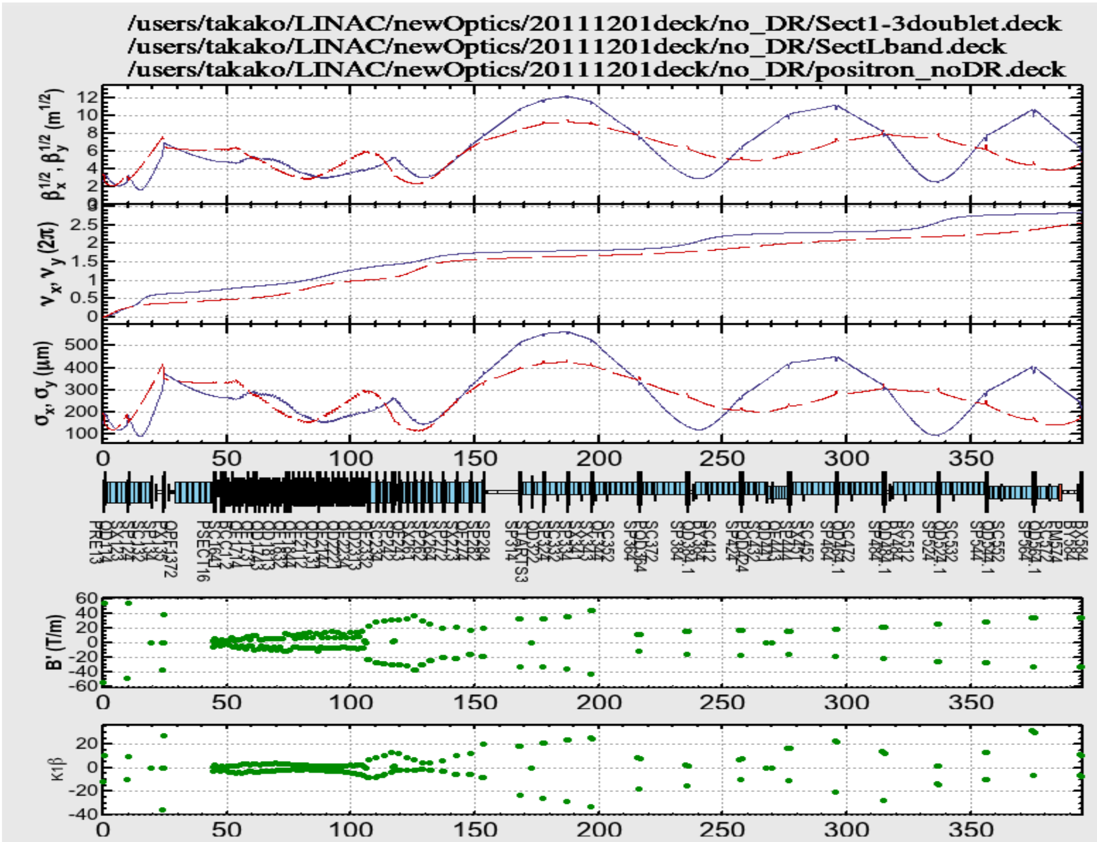
improved
beta-function



(optics calculation
by T. Miura)

e- beam optics

- e- beam transport in e+ oriented optics of focusing magnet strength. [e+/e- compatible optics] (because most of quads are existing DC magnets in Sector1 and 2 before DR)
- in Sector3 ~ 5 after DR, most quads will be replaced with pulse magnets for flexible optical setting for better matching in difference beam modes (e+, e-, PF e-)



(optics calculation by T. Miura)

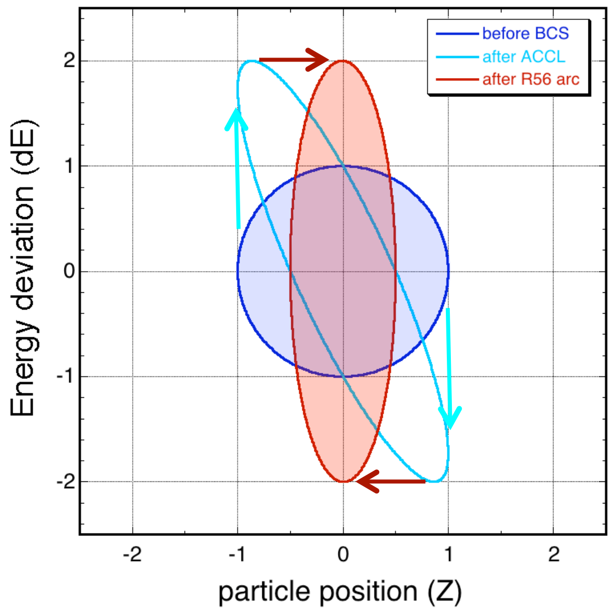
ECS in LTR & BCS in RTL

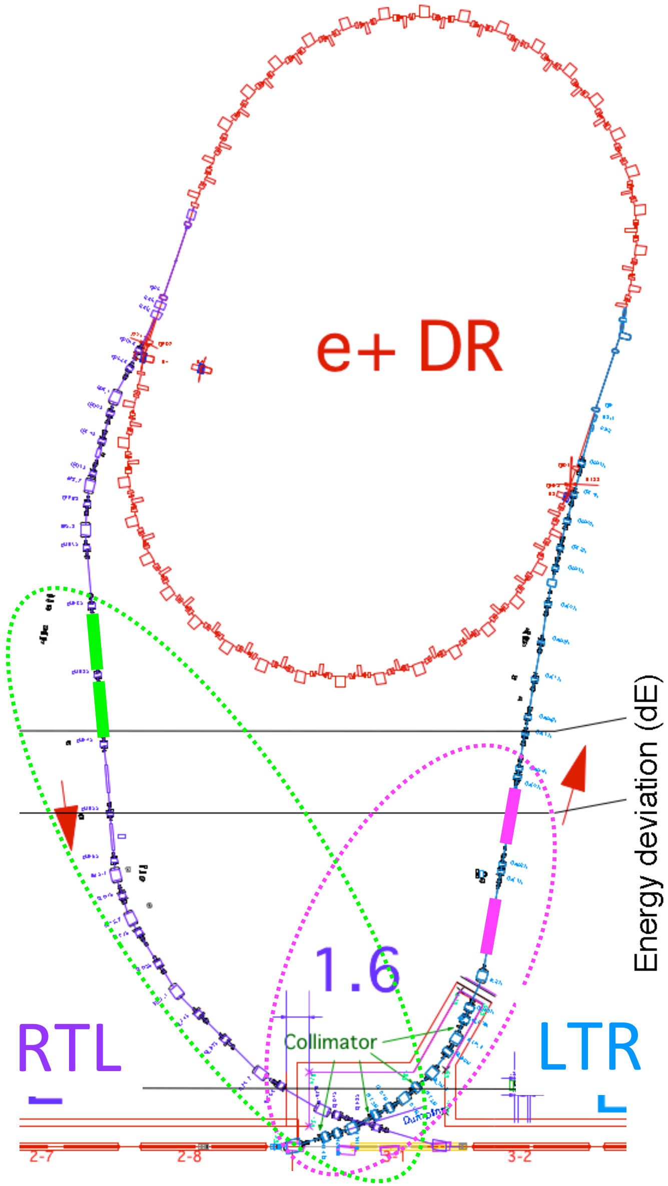
Bunch
Compression
System

BCS reduce bunch-length of e+ extracted from DR

energy gradient by RF field + non-isochronous arc

Vc = 37 MV (**L-band**)
R_{56} = -1.05 m
compression 1/9



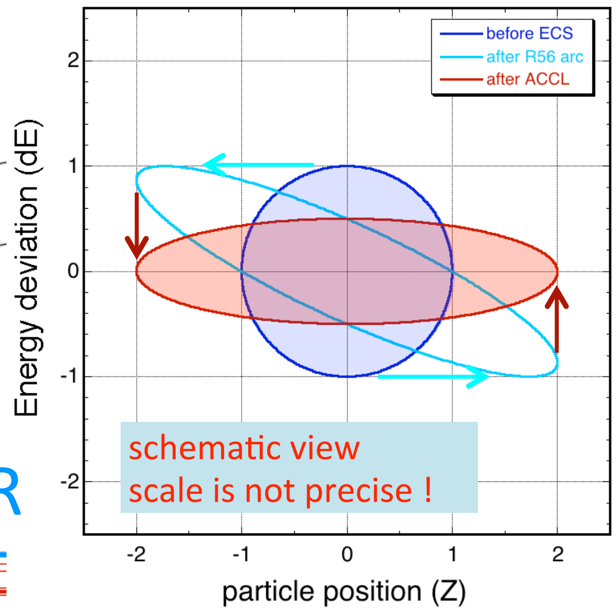


Energy-spread
Compression
System

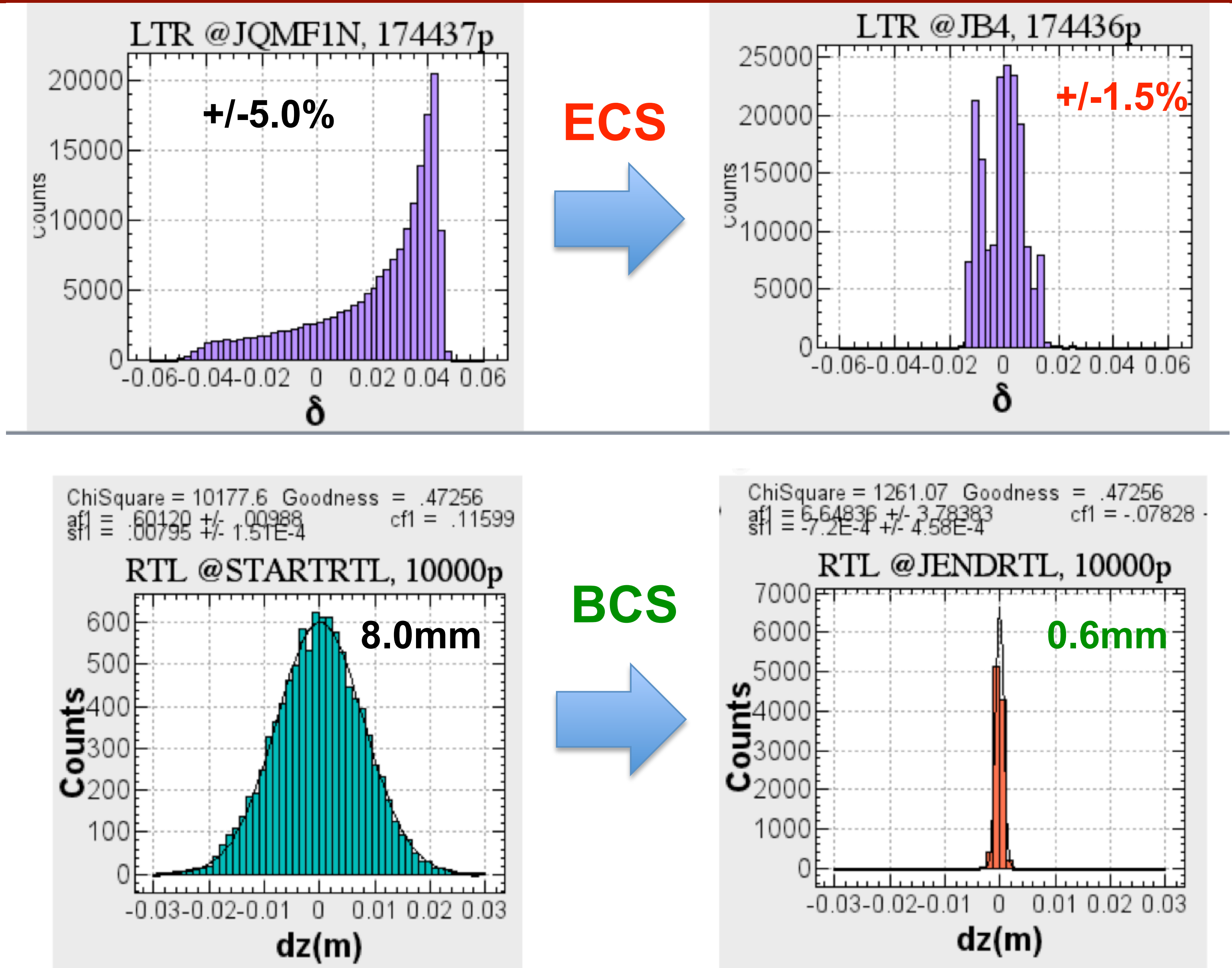
ECS reduce energy-spread of e+ entering DR

non-isochronous arc + energy correction by RF field

R_{56} = -0.61 m
Vc = 41 MV (S-band)
compression 1/3



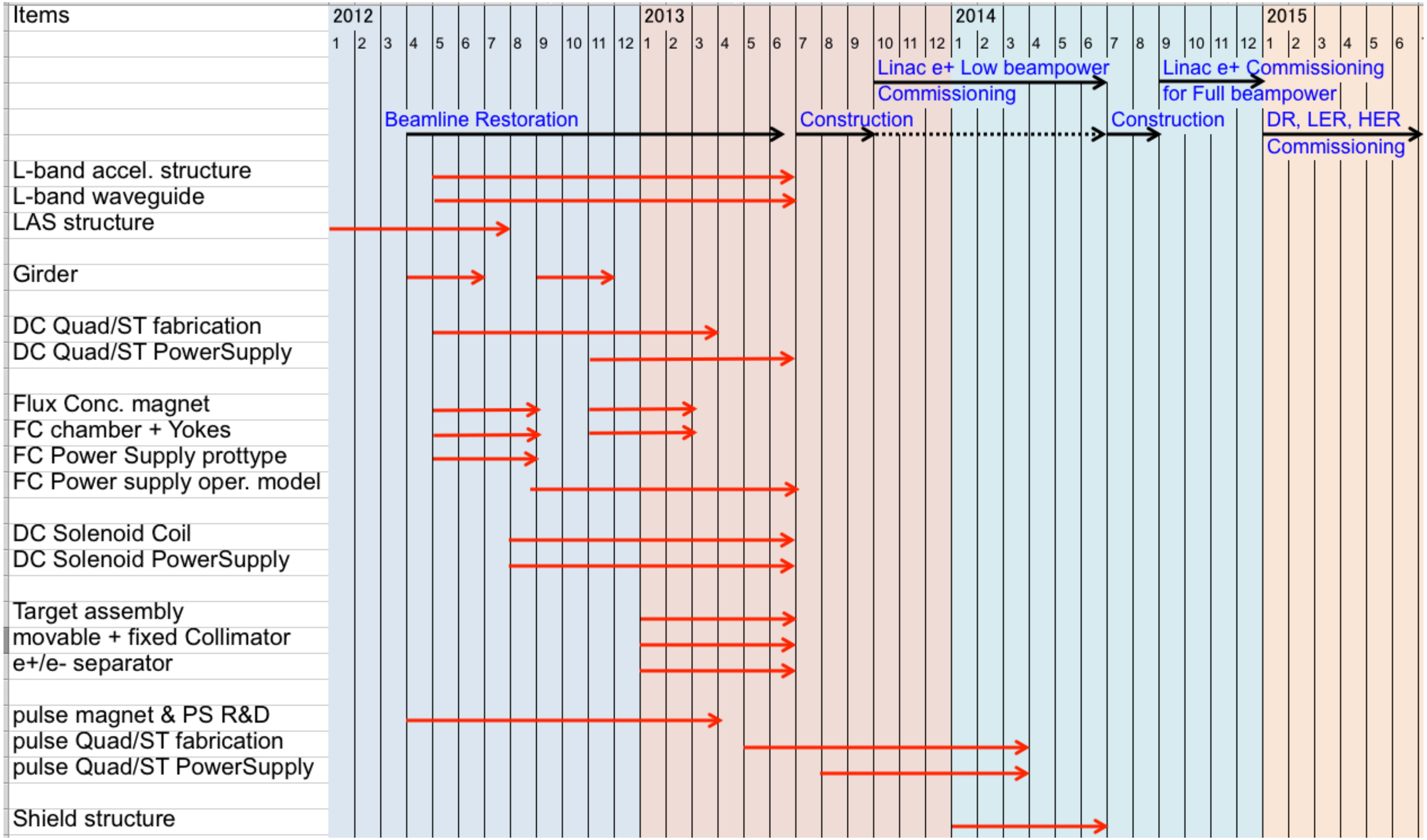
compression performance



(tracking
by N. Iida)

Schedule & Summary

Schedule


Items
2012
2013
2014
2015
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6
Linac e+ Low beampower Commissioning
Linac e+ Commissioning for Full beampower
Beamline Restoration
Construction
Construction
DR, LER, HER Commissioning
L-band accel. structure
L-band waveguide
LAS structure
Girder
DC Quad/ST fabrication
DC Quad/ST PowerSupply
Flux Conc. magnet
FC chamber + Yokes
FC Power Supply prottype
FC Power supply oper. model
DC Solenoid Coil
DC Solenoid PowerSupply
Target assembly
movable + fixed Collimator
e+/e- separator
pulse magnet & PS R&D
pulse Quad/ST fabrication
pulse Quad/ST PowerSupply
Shield structure

Summary

- concentrate on fabricating SLAC-type FC for T=0
- need consideration on target protection
- 1st L-band structure to be high-power tested
- L-band collinear load in R&D
- waveguides & loads in fabrication
- L-band klystron 1st tube ready
- LAS structures in fabrication
- DC solenoid field dips are moderated by huge solenoids
- beam optical design almost OK
- particle tracking simulation is ongoing for e+ yield and hardware parameter optimization
- DR, ECS, BCS are in construction