Muon background issues for ILC BDS tunnel

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BDS/MDI joint session

LCWS2015, Whistler (CANADA)

Future Change Requests related to BDS tunnel

1. ***Philosophical judgement of compatible tunnel both for undulator and e-driven positron source (CR from Source group)***

   - This CR is discussed in the accelerator plenary session from 11/03 16:00.

2. ***Twin tunnel -> Kamaboko tunnel (CR from CFS or BDS group?)***

   - This topics is proposed at ILC review(LAL) in 2015 April by M. Miyahara.

   - In order to make the optimum tunnel, I reviewed the positron and electron sources at first.

   Then, some beamline modifications of ***undulator positron source*** *was proposed at POSIPOL2015.*

   - The tunnel is designing and should be discussed with global group (CFS, BDS, MDI, detector and source etc.).

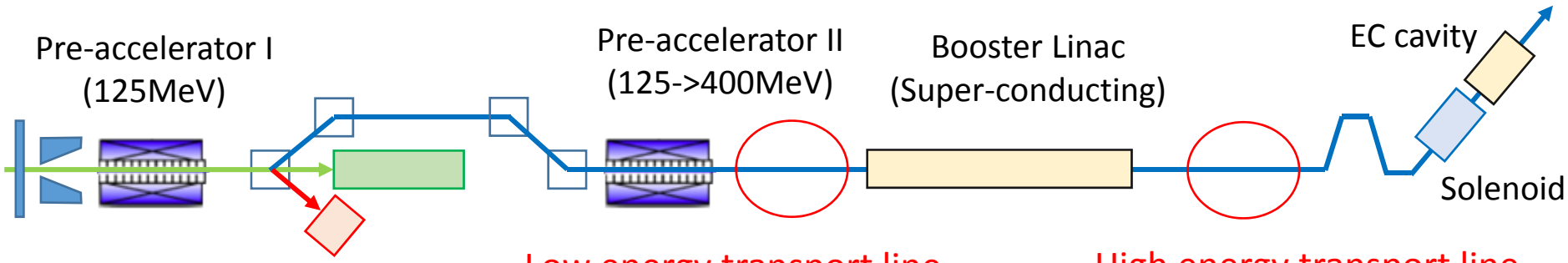
   - The tunnel layout will not include the e-driven positron source at the time.

   - The target of the CR submission is spring 2016 (?).

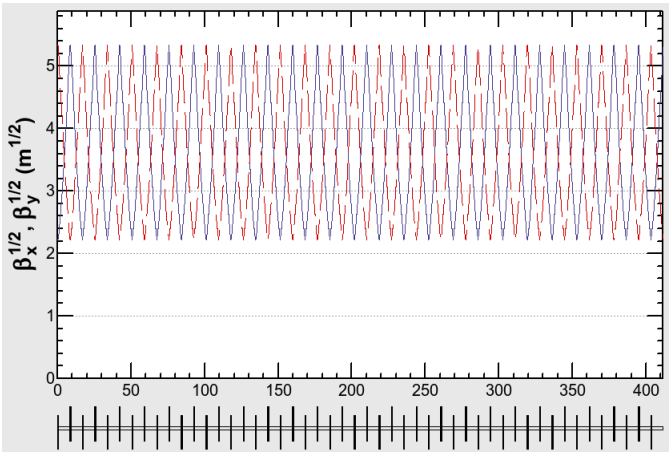
Electron BDS tunnel

- electron BDS
- undulator positron source
- (e-driven positron source)
- electron RTML

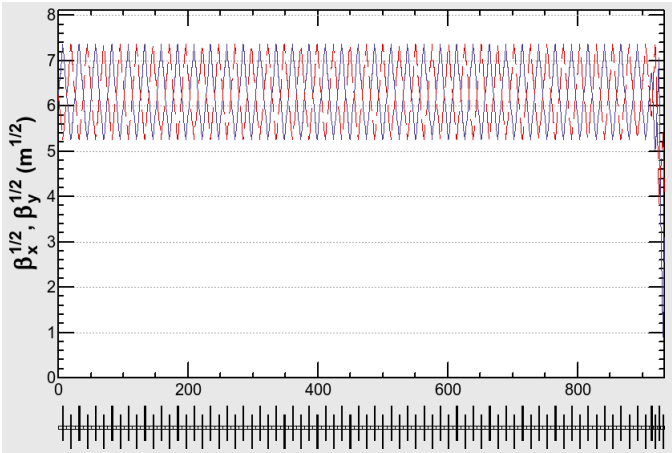
Positron Transport Line in BDS Tunnel



Low energy transport line
(E= 400 MeV)



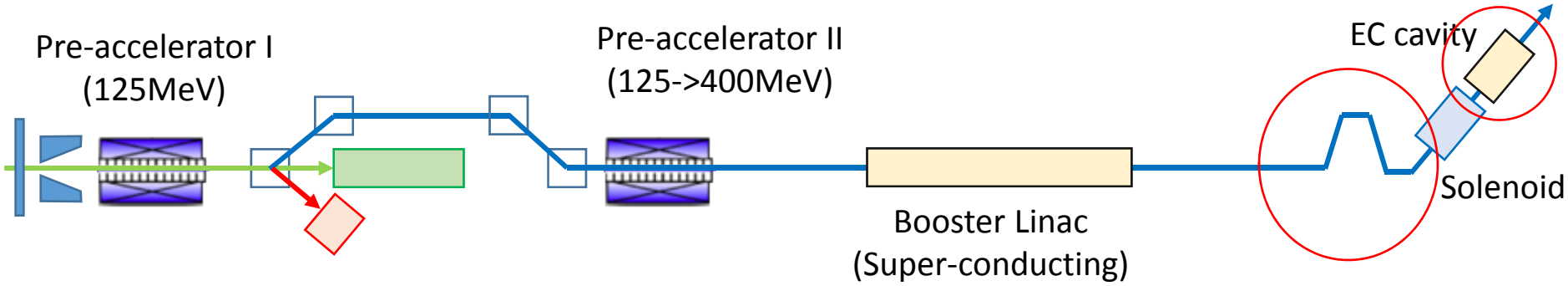
High energy transport line
(E= 5 GeV)

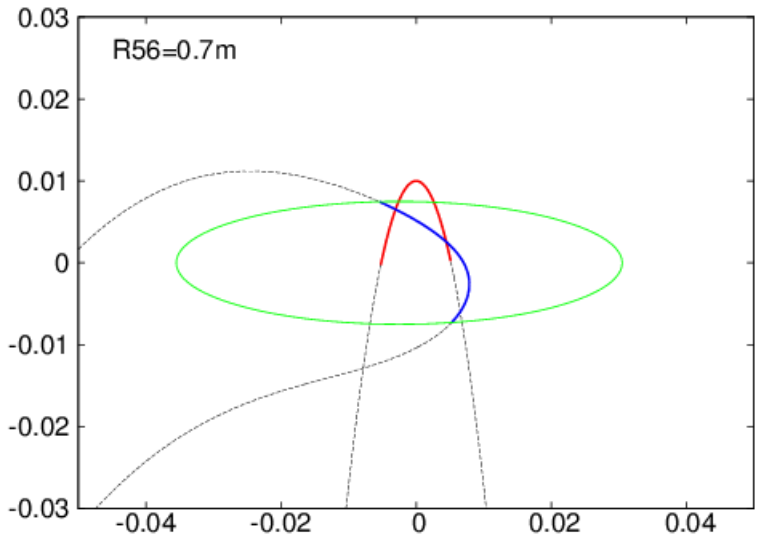


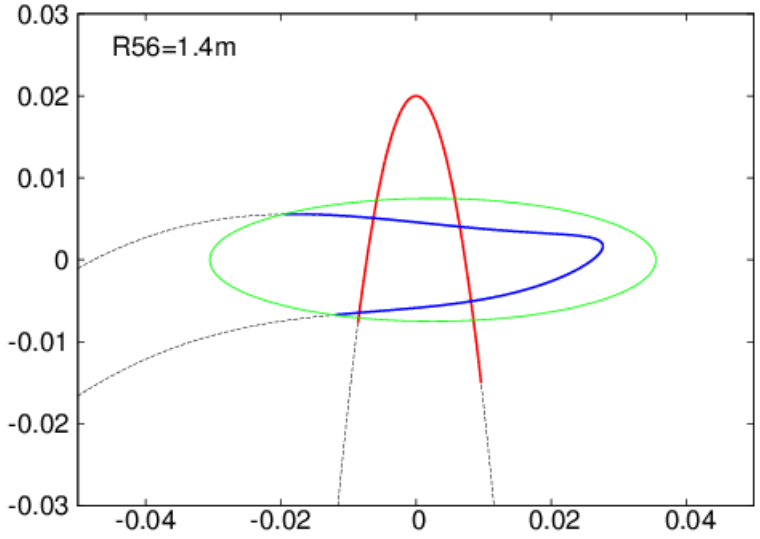
Long transport line
should be put
- after 5GeV acceleration
- after energy compressor

	Low Energy Transport	High Energy Transport (after EC)
Number of quadrupoles	119 quads/km	79 quads/km
Full aperture of DR acceptance	11 cm	5 cm
Chromaticity	- 250 / km	- 60 / km
Momentum Spread	> +/- 2 %	+/- 2 % (+/- 0.75 %)
(Chromaticity) x (Momentum Spread)	5 /km	1.2 /km (0.45 / km)

Energy Compressor





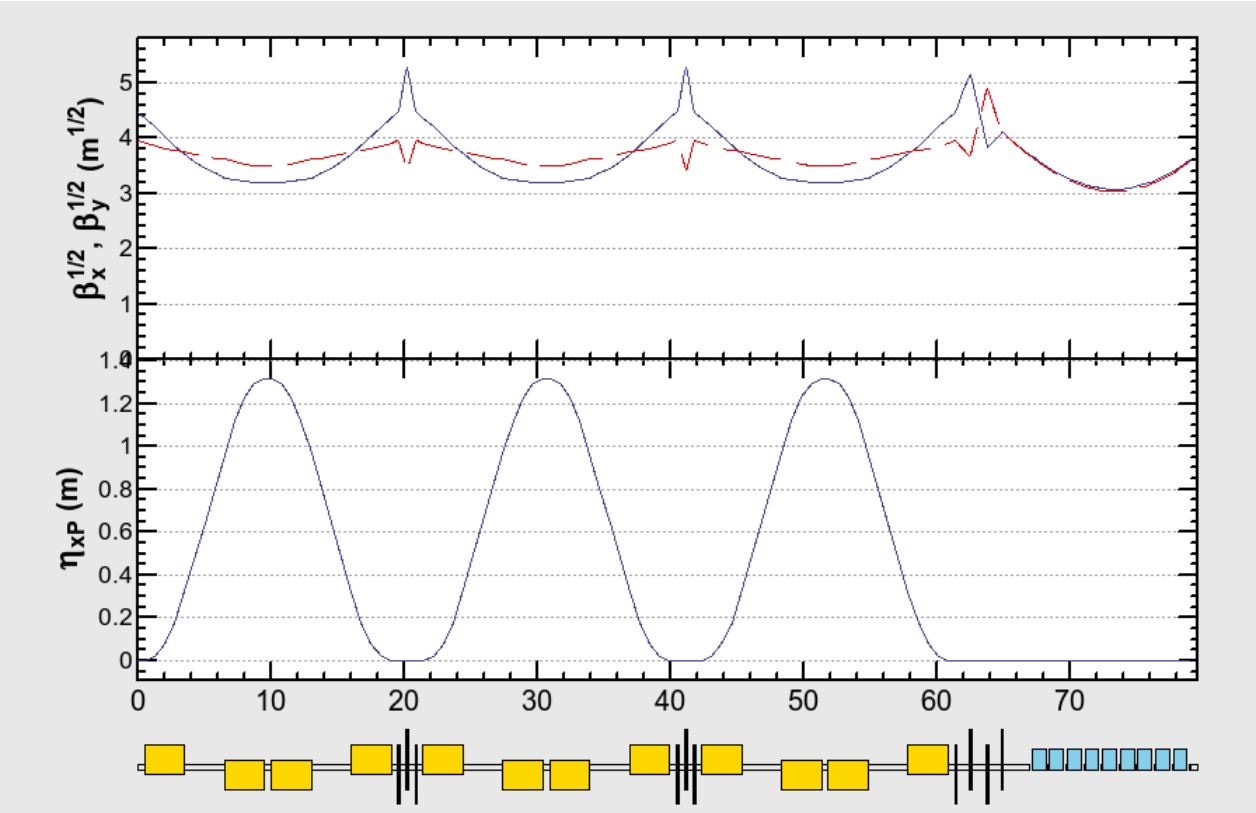


In present optics deck, the R56=0.7m, but the parameter is not effective to energy compress.

When R56 is increased twice as large as the present design (R56=1.4m),
the energy compress was more effective.

I recommend to increase R56 for energy compressor.

Beam Optics for Energy Compressor with R56=1.4m



Bending System

B = 1.2 T
3 chicanes
R56 = 1.4m

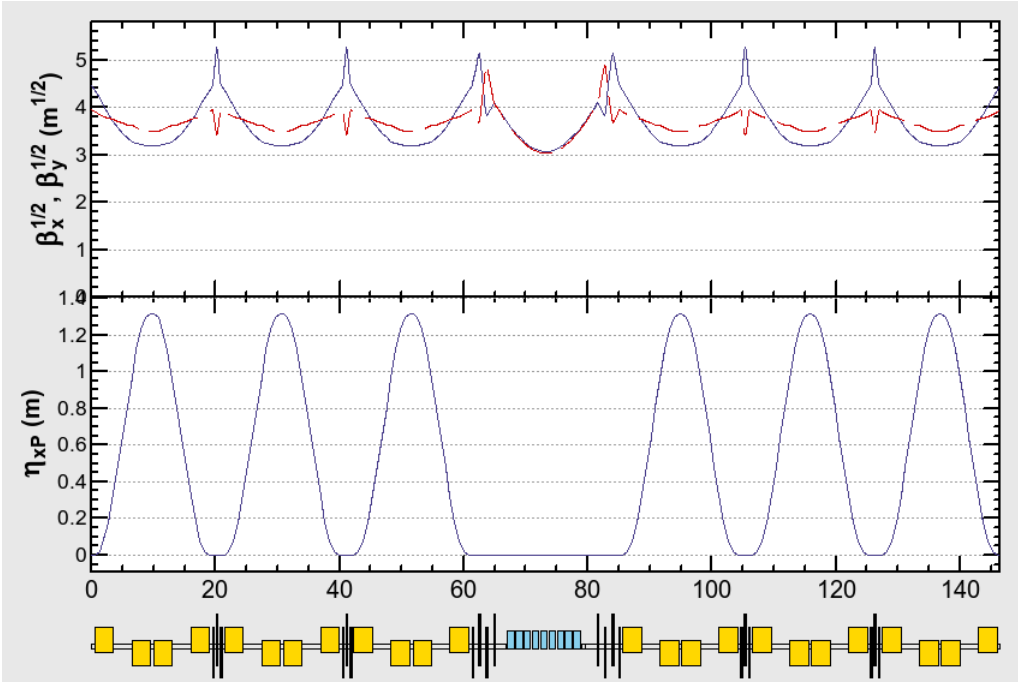
RF voltage
9 x 9cell cavity
（Type A module）

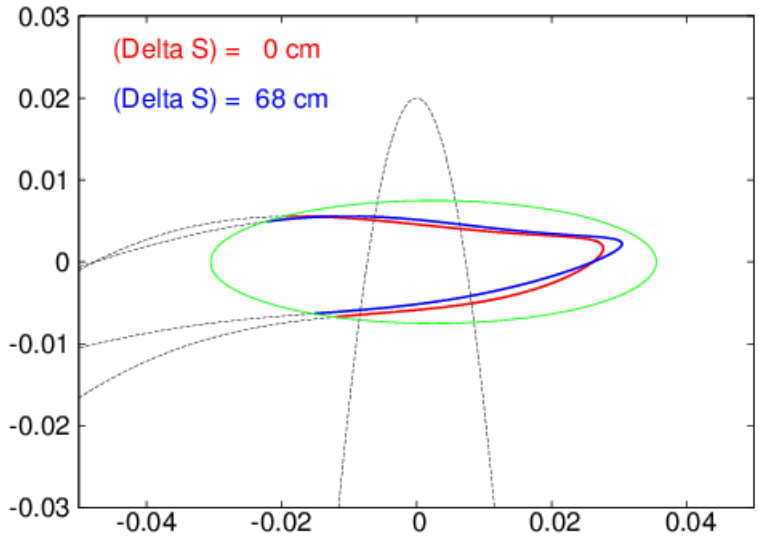
V = 131 MV

Path Length Adjuster

Path length adjuster is required in the positron source beamline in order to adjust the collision timing.

When we put the same chicane of energy compressor just after energy compressor, the path length will be able to change by 68cm by 3 chicanes.



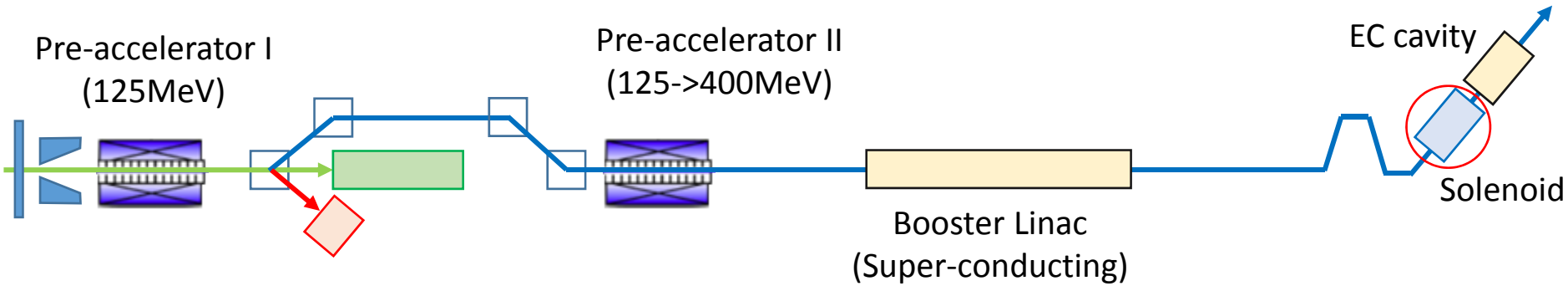


When the path length adjuster put after energy compressor, the longitudinal phase space is not change so much.

I recommend to put the path length adjuster after the energy compressor.

Solenoid Magnet for Spin Rotator

The solenoid for spin rotator is located far from other superconducting devices, I evaluated the possibility to use normal conducting solenoid.



	Spin Rotator	Capture 1	Capture 2
Length	40 m (8 x 5 m)	15.5 m	34.4 m
Magnetic Field	0.65 T	0.50 T	0.50 T
Current	376 A	425 A	425 A
Number of turn	22	15	15
Power	0.95 MW (total)	0.45MW	0.99 MW
Inner diameter	10.0 cm	40.0 cm	40.0 cm
Outer Diameter	80.4 cm	88.0 cm	88.0 cm

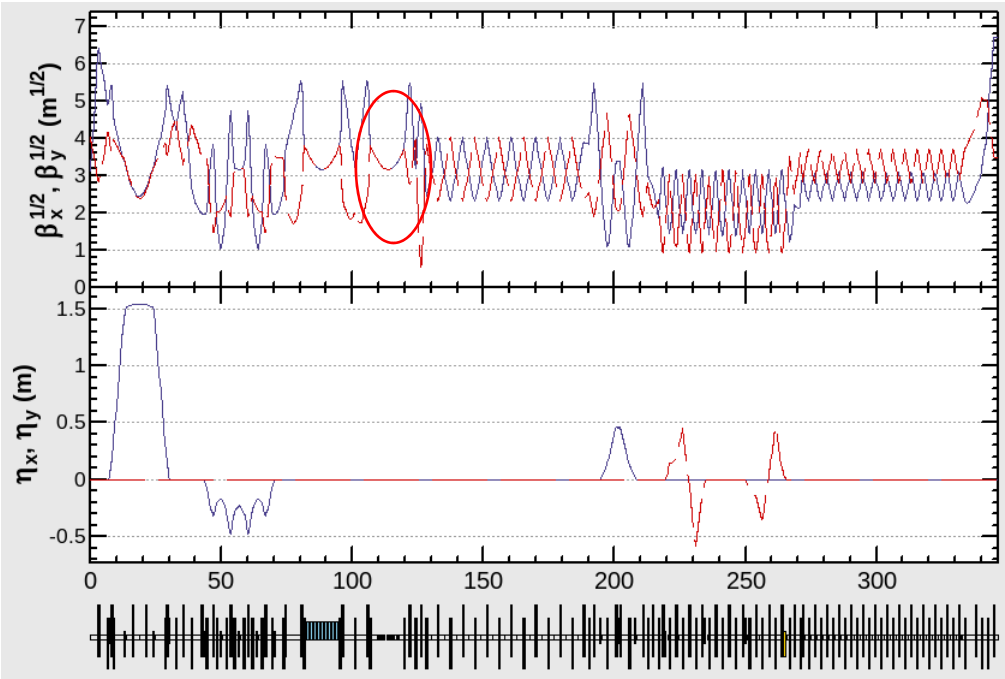
Assuming
Hitachi H-7018 hollow conductor
16mm x 16 mm (7mmϕ)

Other benefit for normal conducting solenoid;

easy to change the solenoid polarity (spin polarity). within a couple of minutes

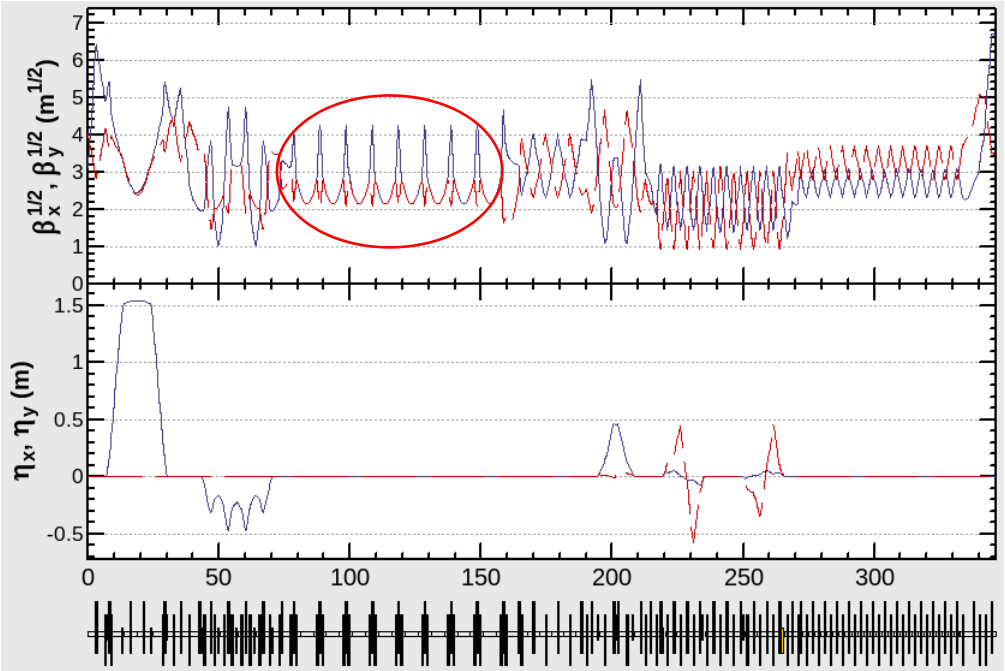
LTR optics with
superconducting solenoid
(3.125T, 8.32m)
Based on M.Woodley's deck.

TDR ; 5.25T 5m



LTR optics with
normal conducting solenoid
0.65T 8 x 5m

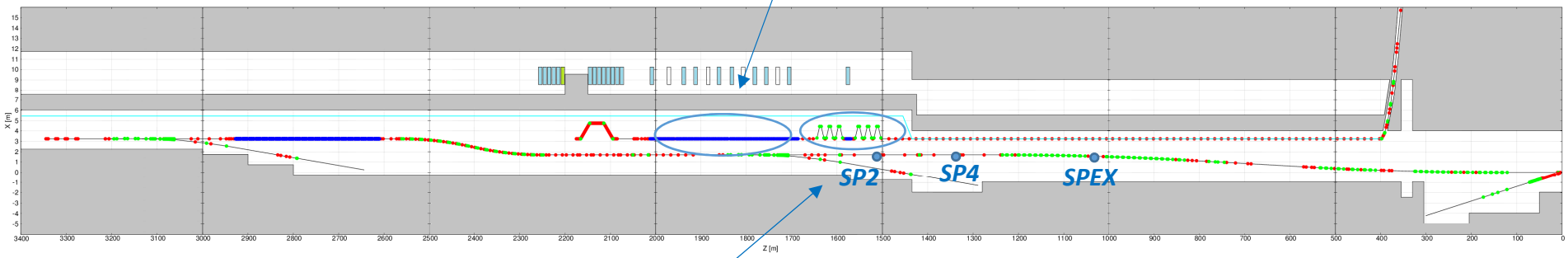
We have space to put the normal conducting solenoid magnets.



Beamline layout of undulator positron source

Booster linac was moved to upstream.

No SC magnet (4K He)
No SC cavity (2K He) in LTR



Energy compressor and path length adjuster was put before the long transport line.

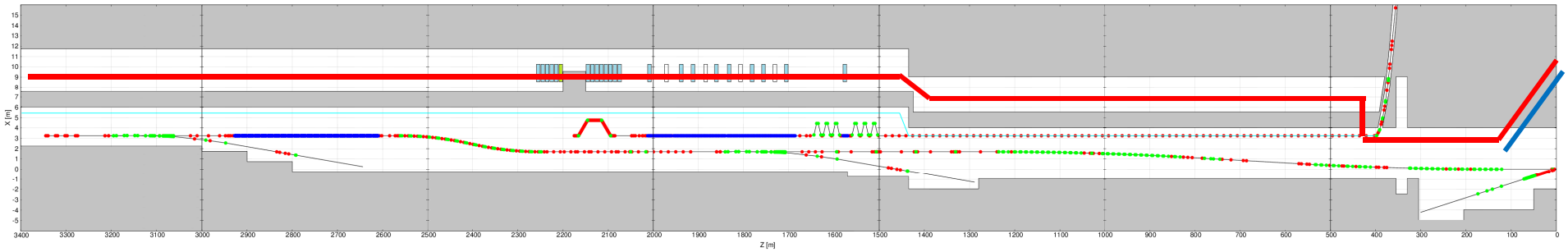
The super-conducting devices can be moved to the upstream of BDS beamline.

- *SC devices can be put with same to ML Kamaboko tunnel.*
- *SC cavities are located upstream of collimators.*
- *It is easy to arrange the Cryo-system, because the devices are close together. (No He compressor design in TDR)*

Other Issues

Penetration to detector hall

- Emergency exit
- AC power line
- He Transfer line for QF1 & Club cavity



AC power line (66kV) is arranged in service tunnel.

Since we don't have a service tunnel at the last part of BDS tunnel, AC power line must be arranged in accelerator tunnel.

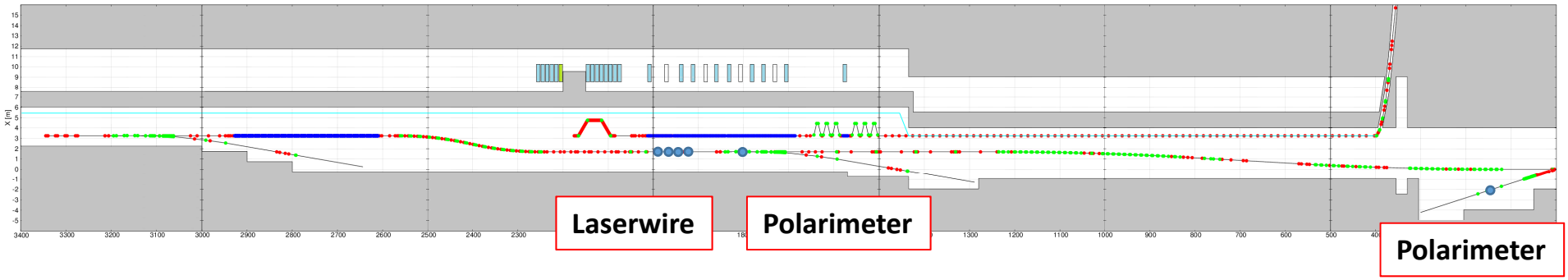
- Therefore, we must take care the location of AC power line to reduce the effect to signal cables.

- We need the penetration to detector hall.

Monitor stations in BDS tunnel

We will have a lot of monitors in BDS.

- BPMs, Energy Spectrometers
- Laser Wire
- Polarimeter



Laser station for monitors must also take into account.

There are 2 policies for laser arrangement by S. Boogert.

1) put the individual lasers to monitors (conventional)
- We must prepare the laser rooms for all lasers.
- We cannot access, when BEAM ON.

2) put the laser to central region,
and the lasers are transported via optical fibers.
- We only prepare the single laser room at central area.
- We can access, when BEAM ON.

Radiation dose for capture section of positron source

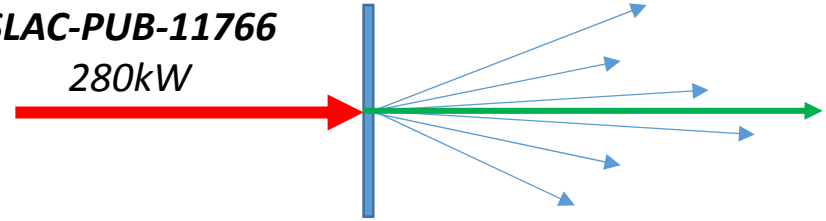
The power loss was evaluated at PAC'05 by V. Bharadwaj et al. (SLAC-PUB-11766).

One of the motivation for photon based source

Electron driven Scheme

SLAC-PUB-11766

280kW

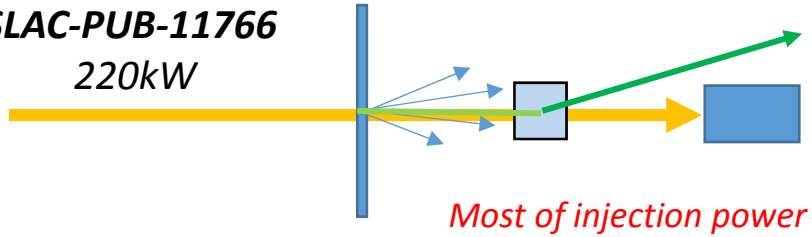


Most of injection power will be sprayed around target.

Undulator Scheme

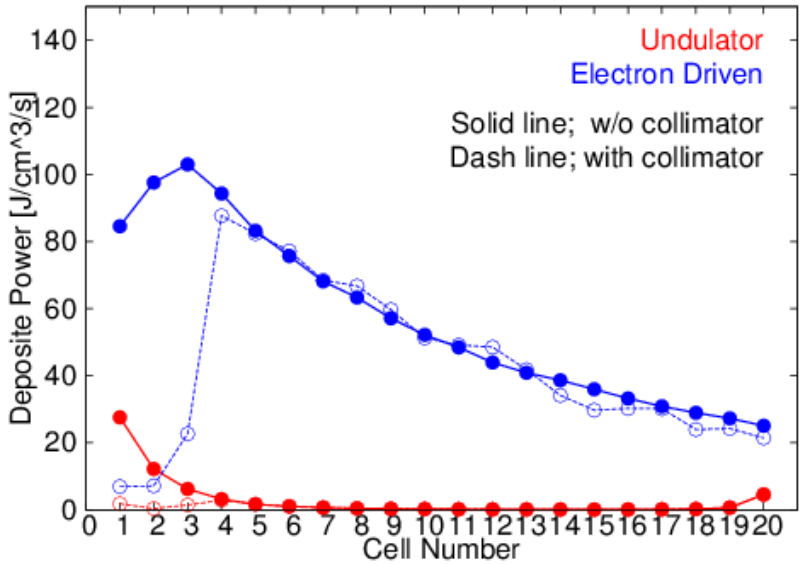
SLAC-PUB-11766

220kW



Most of injection power will be dumped to photon dump.

Power deposit of Innermost iris.



Injection beam power deposition

undulator scheme

6.1% in RF structure

1.5% in innermost iris for structures

Main radiation source is restricted around target.

Halo collimator between target and structure is effective.

electron driven scheme

53% in RF structure

22% in innermost iris for structures

Radiation source is distributed to wide area.

Beam loss will be located at the entrance of RF structure

Radiation effect to other components

Radiation loss scaled to present design.

	SLC maximum	Undulator PS [300GeV]	
		unpolarized	polarized
Beam power to target	40kW	63.1kW	94.7kW
1st acc. structure	**13kW**	3.8kW	5.8kW
Target	9kW	**7kW**	**10kW**

SLC Positron Target Arrangement in Beamline

The positron target was located to the separate area.
- to restrict the radioactive area.
- to protect the devices from the radiation dose .

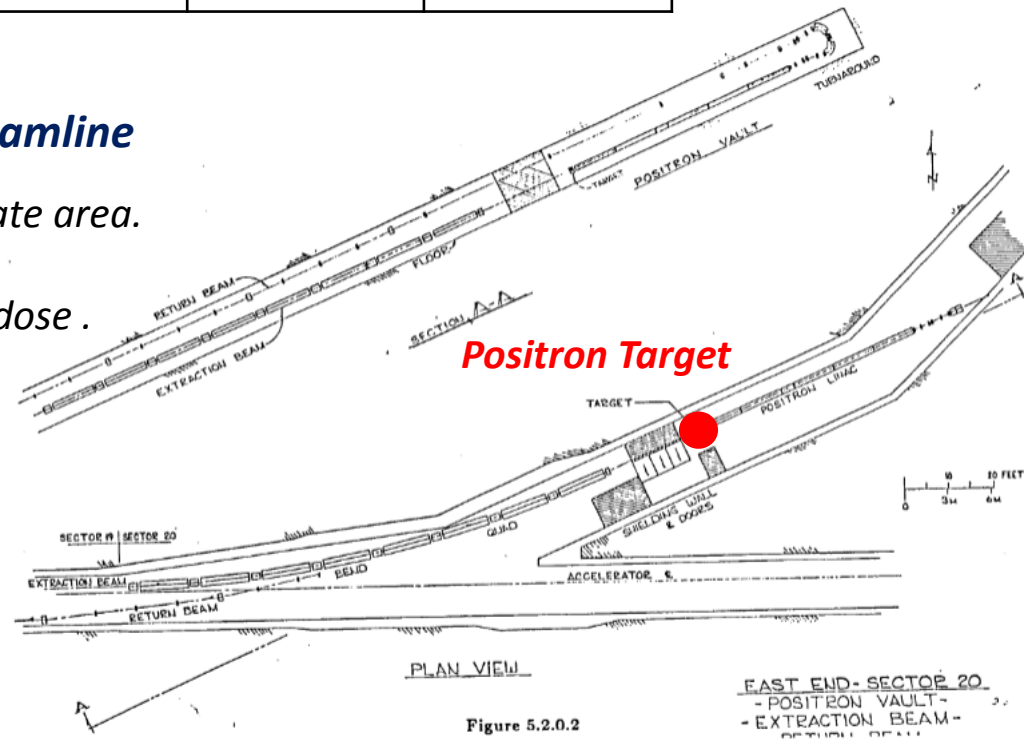


Figure 5.2.0.2

The radiation dose for undulator source also take care of effect to the other components, even though it will be smaller than SLC.

SLC Design Handbook

Target area for undulator positron source

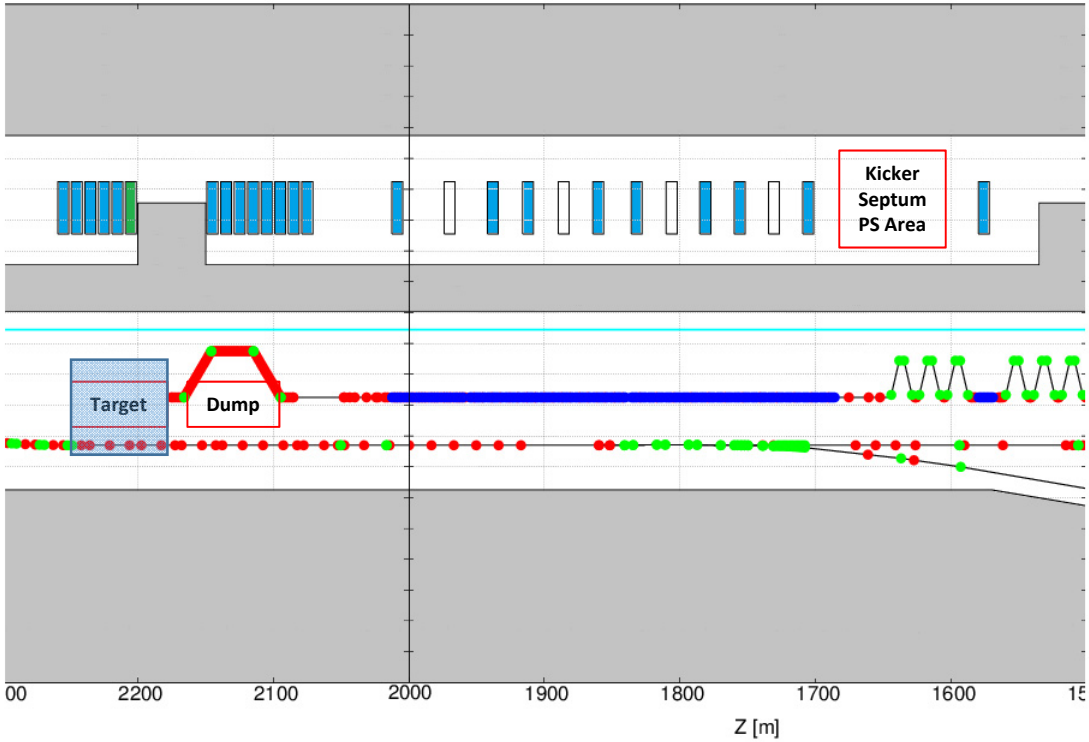
The radiation loss for undulator source is located only around target area.
The e-driven PS is along wide area.

I heard the positron target was covered with radiation shield.

We should make careful consideration about radiation shielding from positron target and dumps.

We have two selection.

- *to make separated area ?*
- *to cover only around target and increase the shield thickness around the target?*

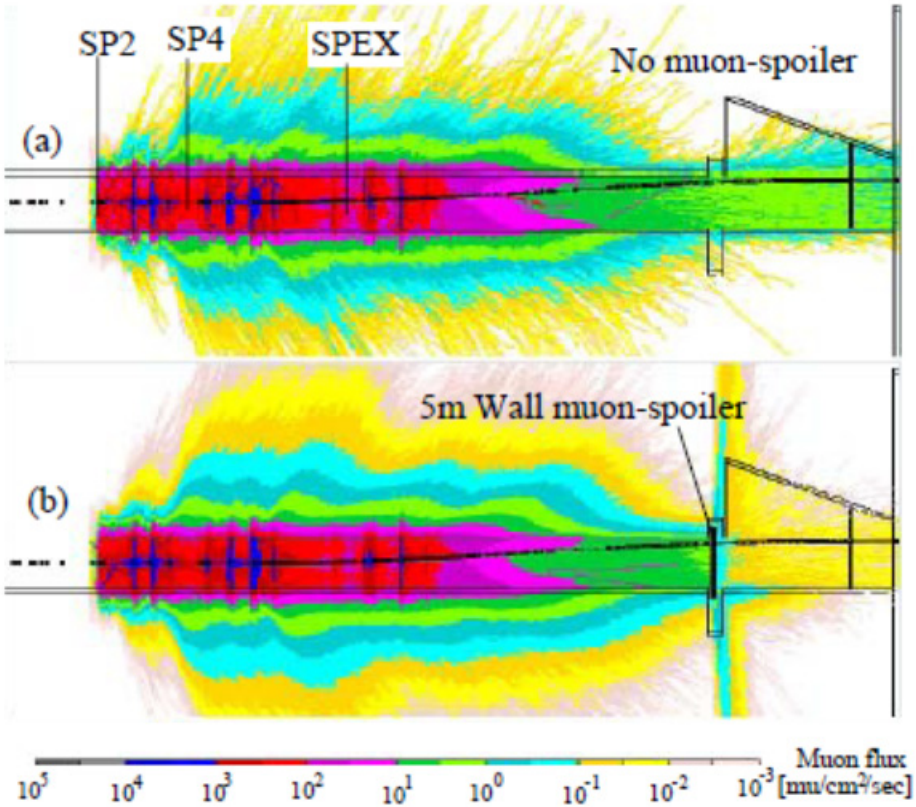


It is difficult to judge only by CFS group.

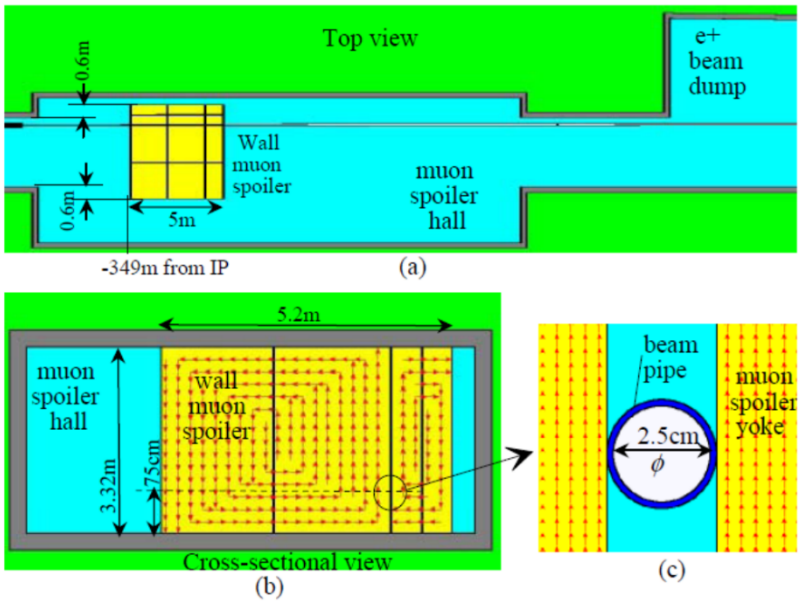
We hope to have consideration of source and radiation groups.

Muon Spoiler

It is better to make the tunnel cross section small
- in order to make the muon spoiler small
- in order to reduce the muon transmission in the tunnel .



The evaluation of muon background by SLAC will be restarted.



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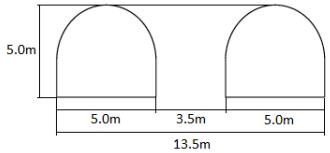
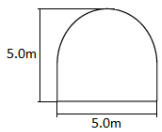
Case 1 ; Twin Tunnels

Accelerator Tunnel

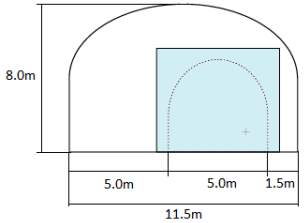


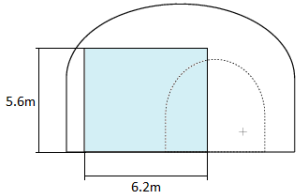
Neck



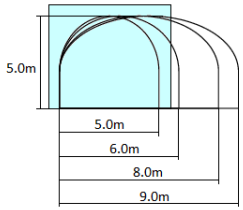
Since the smaller tunnel also is expensive, the tunnel widths was set to 5m for twin tunnel.

Muon Hall



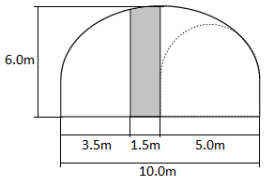


- *Same tunnel shape for entire BDS tunnel*
- *The size of muon spoiler is defined only by the cress section of BDS tunnel.*
- *We should take care of the cable penetrations in between service and accelerator tunnels.*

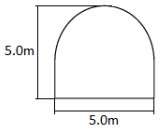


Case 2 ; Single Tunnels

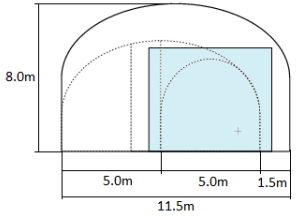
Accelerator Tunnel

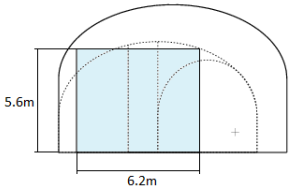


Neck

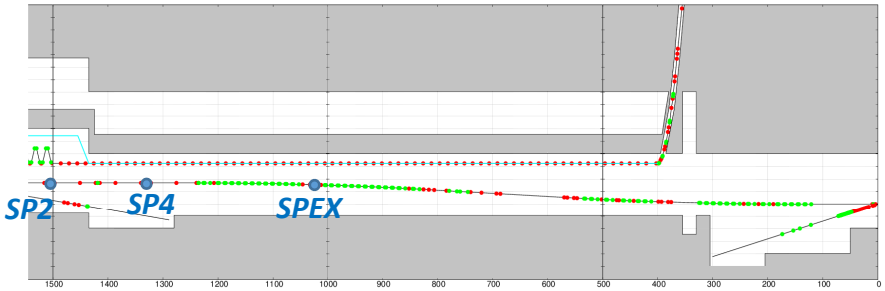


Muon Hall





- *Is large muon spoiler required to cover all of cress section for BDS tunnel?*
- *Cheaper than twin tunnel for thin shield.*



We should select the tunnel shape by taking account of

- *the penetration in between two tunnels for twin tunnel.*
- *the effect of the muon background to detector.*
- *the cost of the tunnel.*

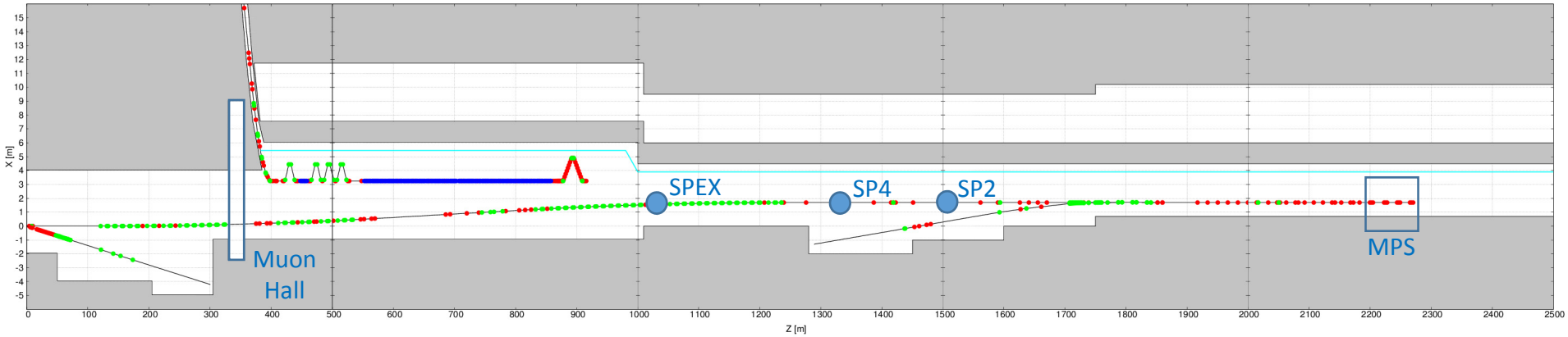
In order to decide the tunnel shape, we must evaluate

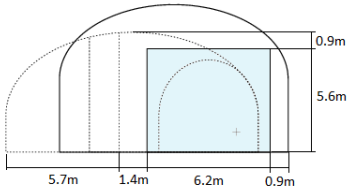
- *the number of penetration (evaluate the cable holes etc.).*
- *the effect of muon background for different BDS tunnel cross section.*

Positron BDS

- positron BDS
- electron source
- positron RTML

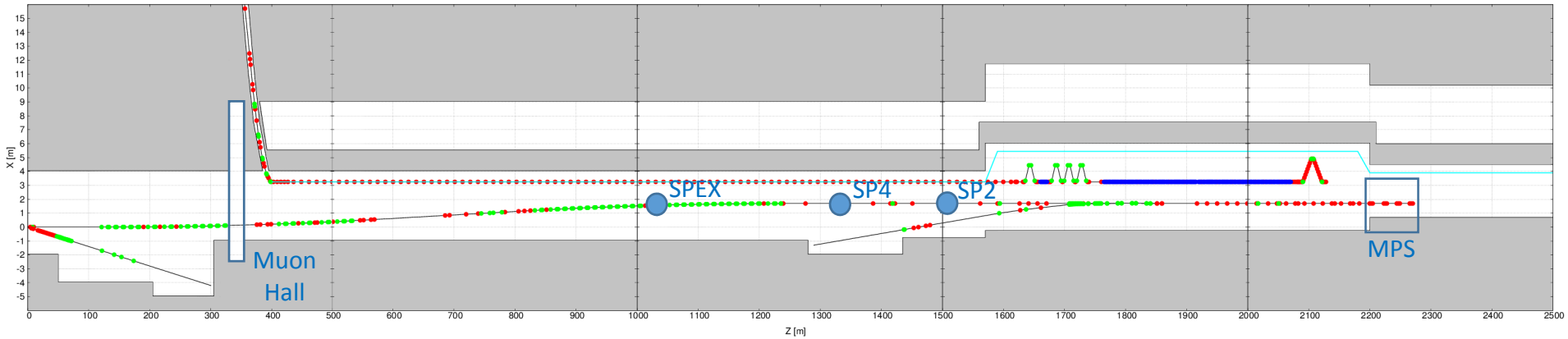
Case 1





- *Radiation Dose from collimators for SC cavities of electron source*
- *Muon background by large cross section of accelerator tunnel (much larger than the electron BDS)*

Case 2



- *Long transport line (about 1km)*

Tunnel Width Distribution (s=400m – 2400m)

Tunnel Width	Case 1	Case 2
9.5m	1070m	200m
10.0m		1020m
10.5m	150m	
11.0m		150m
11.5m	170m	
12.0m		630m
12.7m	610m	

The tunnel costs for two cases are ***comparable***
by rough evaluation from the tunnel cress sections.

But, we need additional beam transport line for case 2.

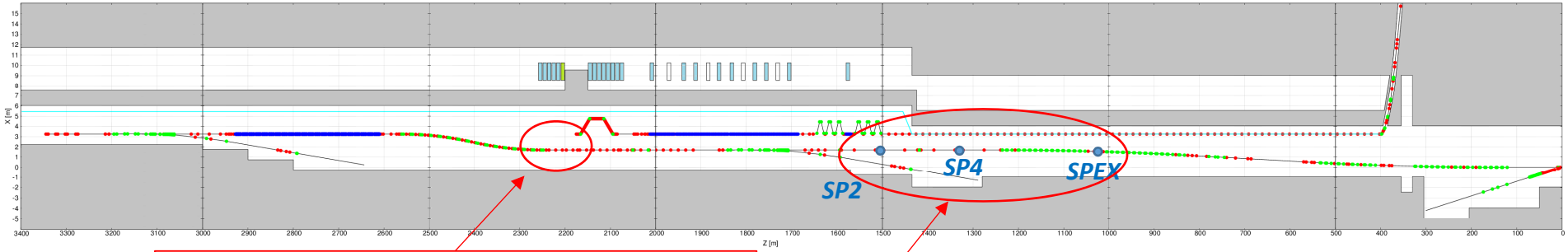
We need to evaluation of the muon background to detector
and the radiation to SC cavities from BDS collimators.

Thickness of Radiation Wall

The radiation shield thickness was assumed to be
- 3.5m for target & capture section
- 1.5m for other section temporally.

Even though we will not access to the service tunnel at beam on condition, is shield thickness enough to protect the PSs from radiation ?

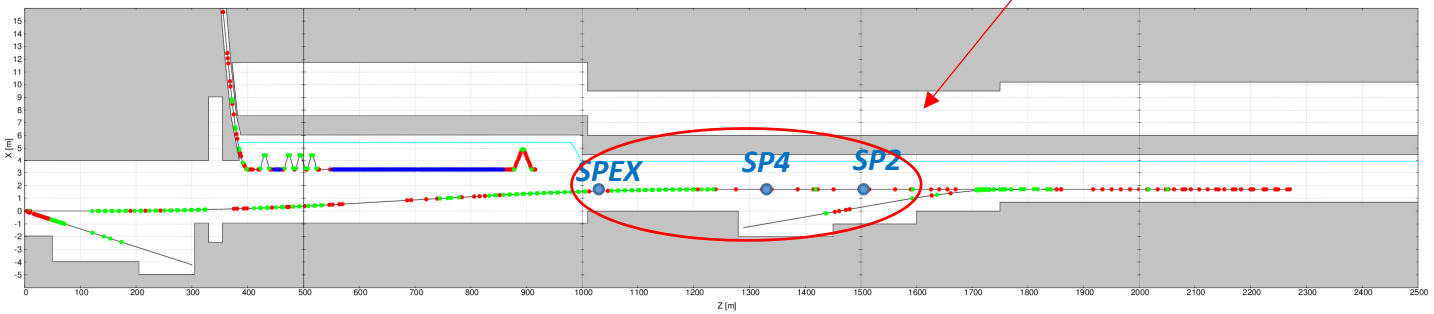
Electron BDS



Positron Target & Capture Section
10kW & 6kW for 300GeV pol.

Collimators
5MW x 1e-4 = 500W for 500GeV

Positron BDS



Summary

Electron BDS (undulator positron source)

The SC cavities for undulator positron source were moved to upstream in order to reduce the chromaticity of the long transport line.

The R56 for energy compressor was increased and the energy compressor was moved to upstream.

The path length adjuster was put just after energy compressor.

Positron BDS (electron source)

We have two candidate locations to put the electron source.

When we put the long transport line in between the electron source to LTR, the BDS tunnel cross section can be small.

Muon Background to detector

We need the muon background simulation to fix the BDS tunnel shape.

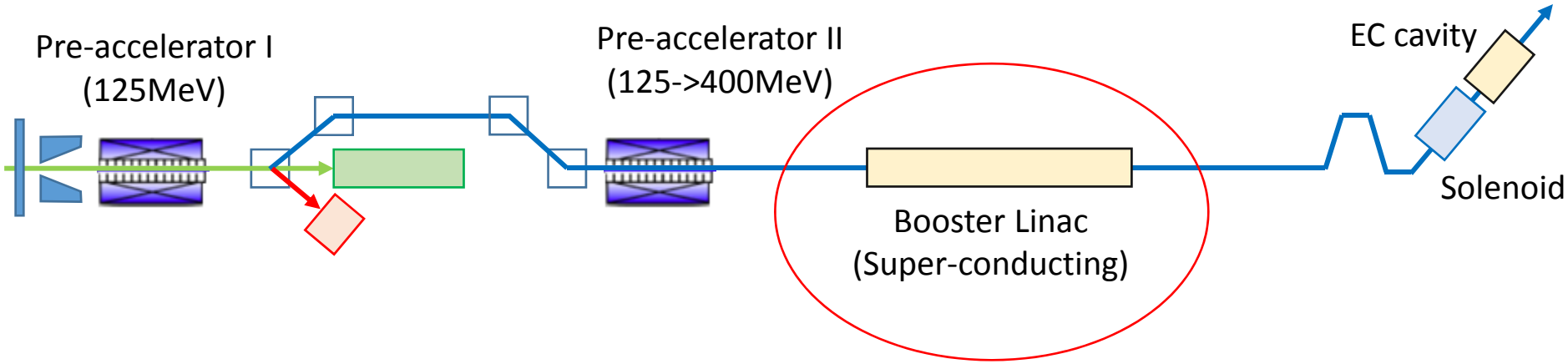
Radiation Wall Thickness

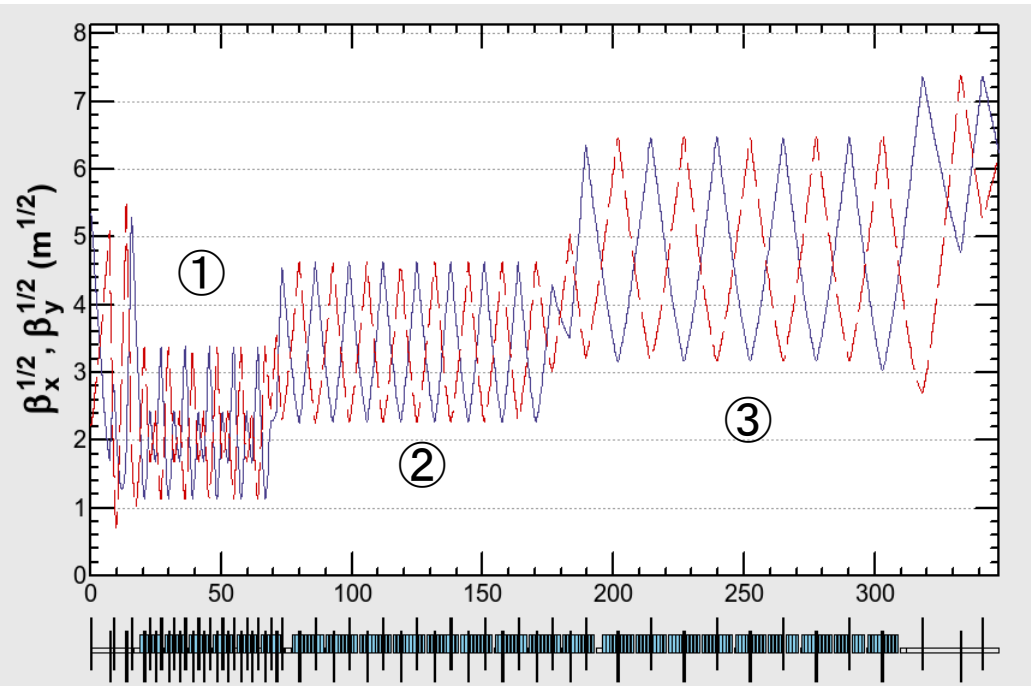
We need careful evaluation of the thickness of the radiation shield to protect PS.

Monitor Stations and Cable Penetrations

backup

Positron Booster Linac





We will use 3 type of cryomodules in booster linac

In optics deck,

Module 1 ; 27.45MV/m

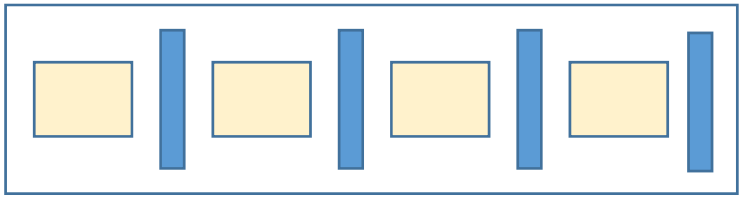
Module 2 ; 21.48MV/m

Module 3 ; 25.06MV/m

Cryomodules for Positron Booster Linac

When we set to V=27MV/m, we will use total 24 modules for booster linac.

Module 1 ;



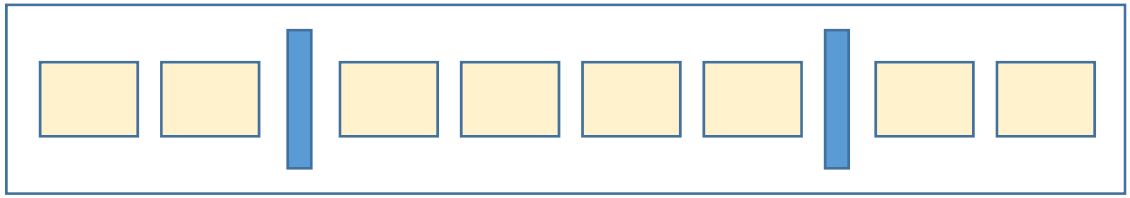
6 modules
- 4 cavities
- 4 quadrupoles

(TDR ; 4 modules
- 6 cavities
- 6 quadrupoles)

Quadrupole SPEC
- 20-cm long
- 36-97 T/m

4T at 2a=80mm

Module 2 ;

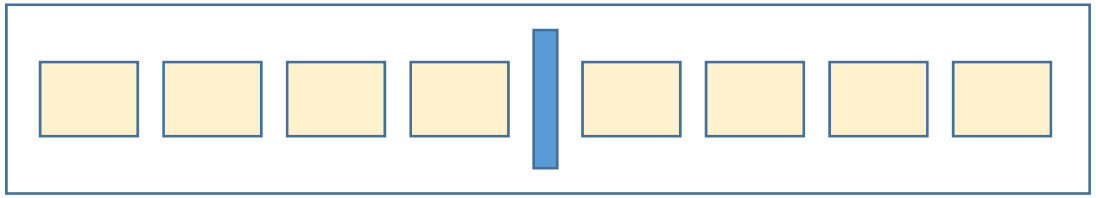


9 modules
- 8 cavities
- 2 quadrupoles

Quadrupole SPEC
- 20-cm long
- 35-99 T/m

4T at 2a=80mm

Module 3 ;



9 modules
- 8 cavities
- 1 quadrupole

(Type B module)

Quadrupole SPEC
- 66-cm long
- 2.3 – 3.8 T/m

The optimizations for the length of quadrupole magnets is important to design the cryo-system of booster linac.

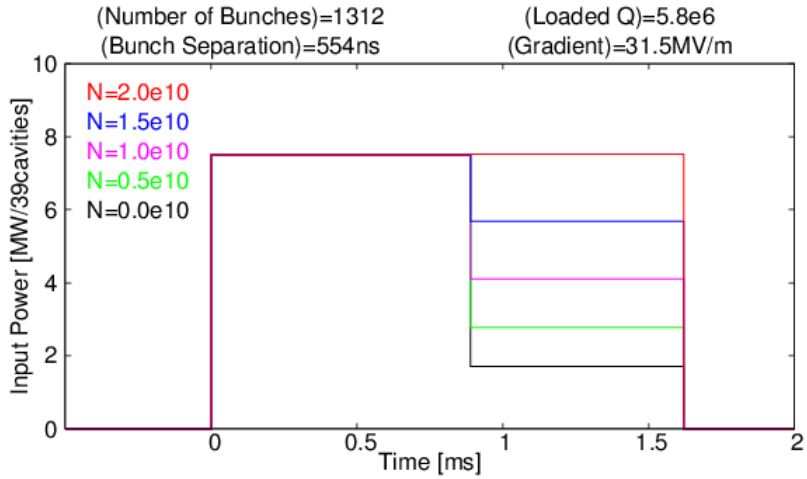
ILC TDR timing System (B.List)

It is better to design the positron source to be acceptable to every ILC beam parameters.

type	h	k_b	N_{bunch}	n_b	g	n_t	N_t	Q_b [10^{10}e]	t_b [ns]	I_{ML} [mA]	t_{pulse} [μs]
SB2009 nominal values								$c = 3248$ m			
DRFS	7042	463	1312	–	–	–	–	2.00	712	4.5	935
KCS	7042	347	1312	–	–	–	–	2.00	534	6.0	700
FP(e^-)	7042	231.5	2625	–	–	–	–	2.00	356	9.0	935
FP(e^+)	7042	231.5	1312	–	–	–	–	2.00	356	9.0	935
Solution 1								$c = 3238.68/3239.14$ m			
DRFS	7022	476	1312	4	33	23	59	2.00	732	4.4	961
KCS	7022	360	1312	4	45	34	39	2.00	554	5.8	727
FP(1Ring)	7022	238	2625	2	31	45	59	2.00	366	8.8	961
FP(2Ring)	7022	238	1312	4	75	23	59	2.00	366	8.8	961

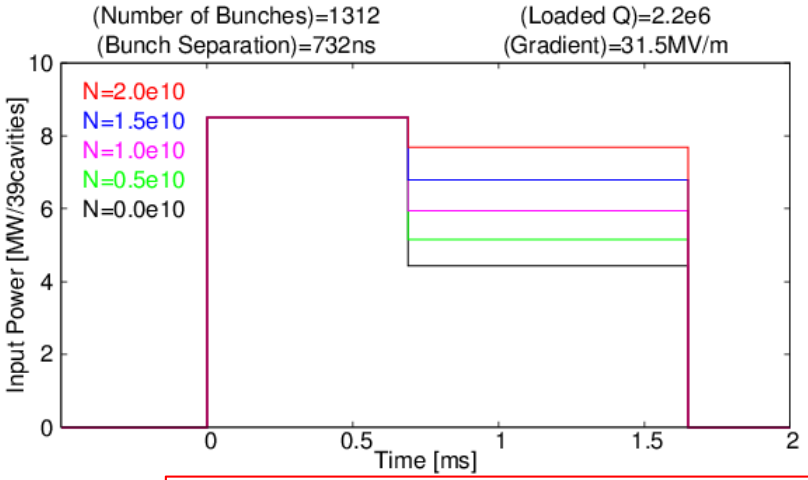
Main Linac RF for KCS (Baseline)

39 RF cavities for one 10MW klystron



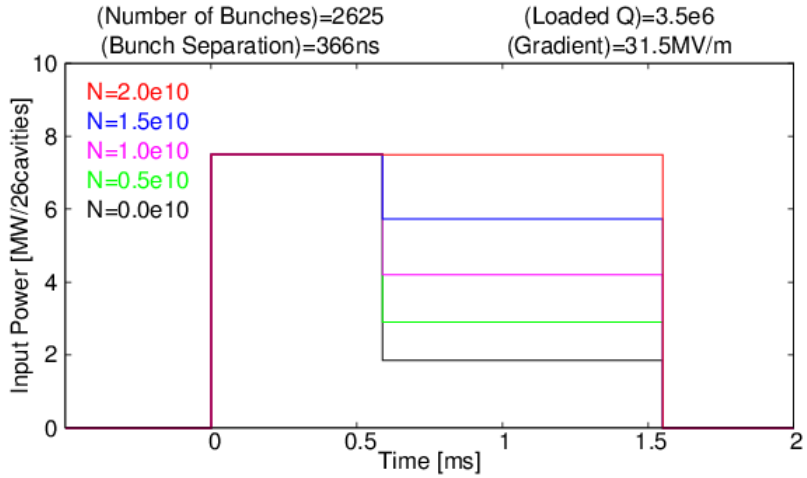
Main Linac RF for DRFS (Small DR Train Length)

39 RF cavities for one 10MW klystron
(same to baseline parameters)



Main Linac RF for FP (High Luminosity)

26 RF cavities for one 10MW klystron
(1.5 times larger than baseline parameters)

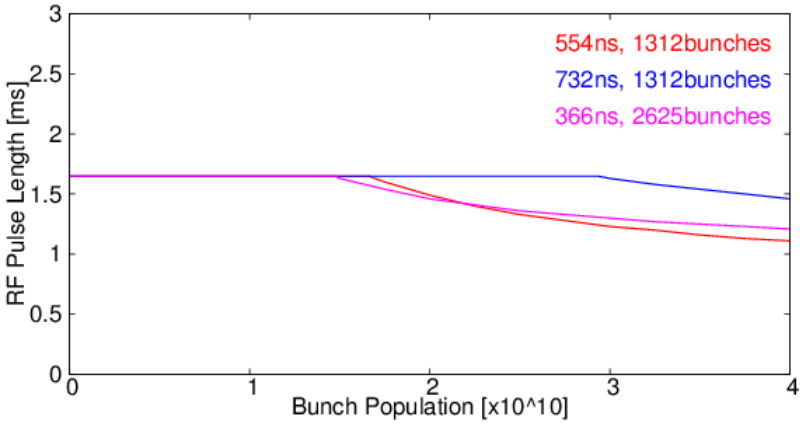


For lower intensity, the RF amplitude will be reduced after beam injection.

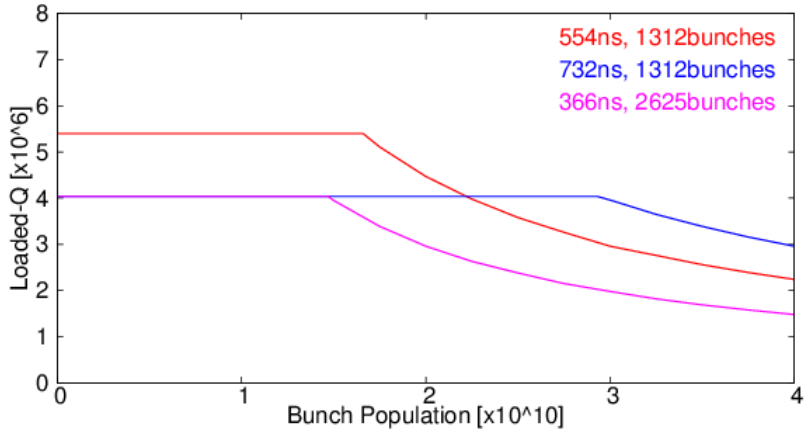
Superconducting RF system for Booster Linac

- Accelerating Gradient ; V=27MV/m (easy to arrange the klystrons to cavity)
- Bunch population ; N=0-3e10 or more
- Same RF system to Main Linac

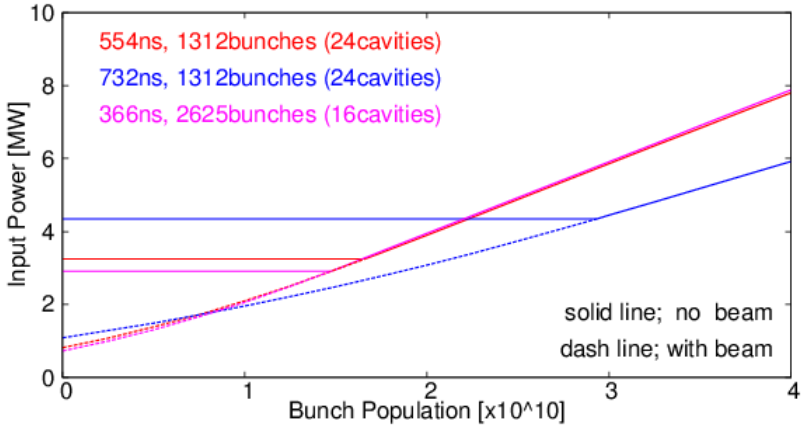
Requirement of RF pulse length (< 1.65ms)



Requirement of loaded Q (1-10e6)



Requirement of RF power (< 10MW)



Present Optics deck

Module 1 ; 27.45 MV/m
Module 2; 21.48 MV/m
Module 3; 25.06 MV/m

We can accelerate positron beams to V=27MV/m for 3 ML parameters
- total 168 9-cell cavities
- with seven 10MW klystrons for KCS, DRFS
- with eleven 10MW klystrons for FP

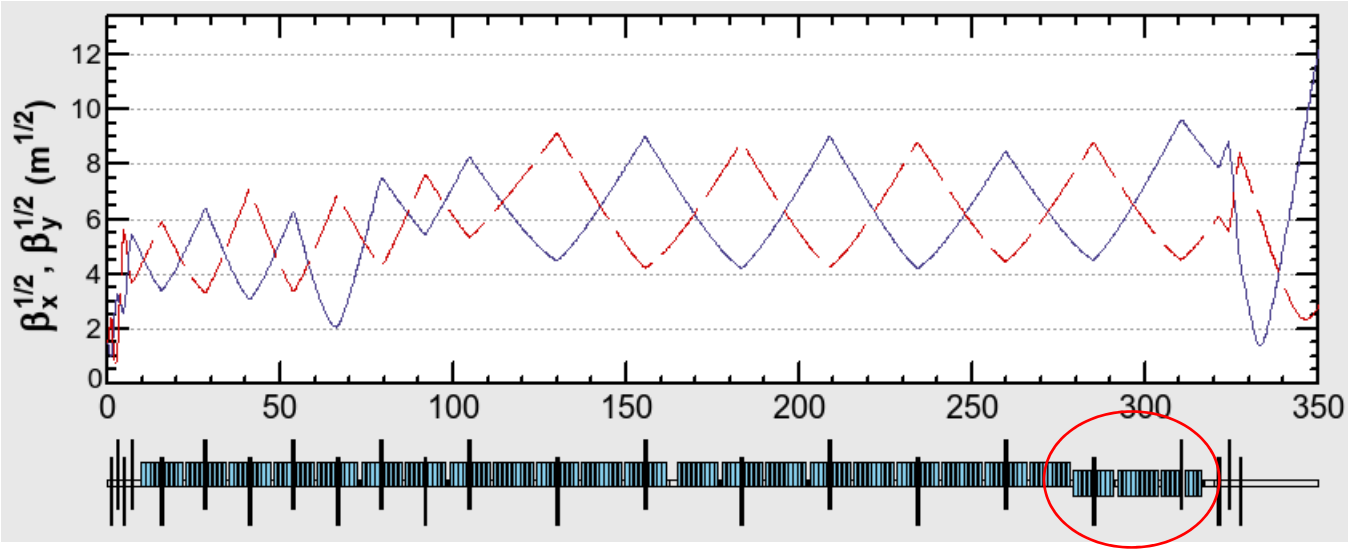
Can we fix the gradient to 27MV/m??

Electron Booster Linac

7 (+1) Type A cryomodules
14 (+2) Type B cryomodules

Nominal ; 21 cyroodule (175 9-cell cavities)
5GeV / 175 cavities , 27.5 MV/m

Backup ; 3 cryomodules (25 9-cell cavities)



Backup Cryomodules

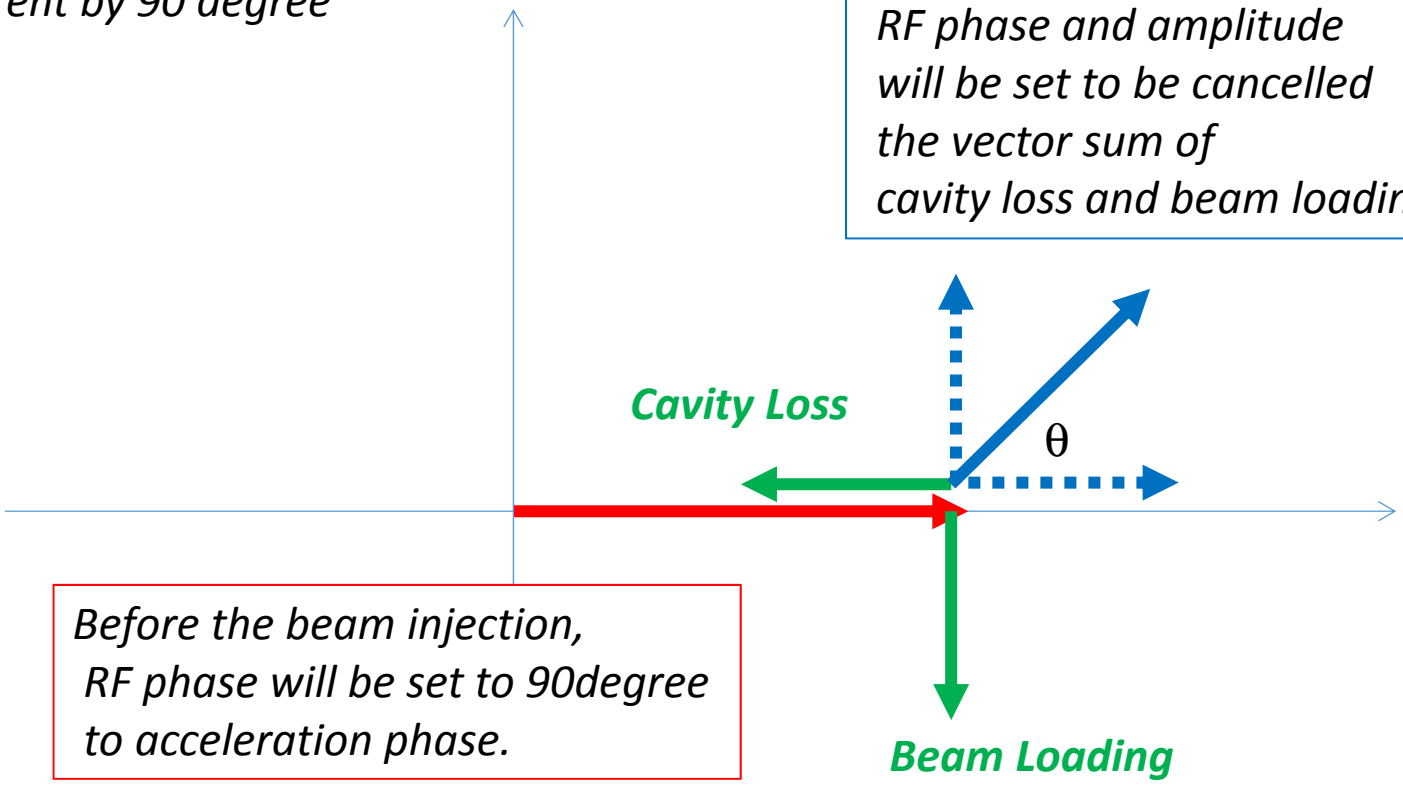
For positron booster linac, there are no backup cryomodules.

Will we arrange the backup modules for positron booster linac too ?

Beam Loading Compensation for Energy Compressor Cavity (Amplitude & Phase Modulation Method)

The RF field and beam loading are different by 90 degree

After the beam injection, RF phase and amplitude will be set to be cancelled the vector sum of cavity loss and beam loading.

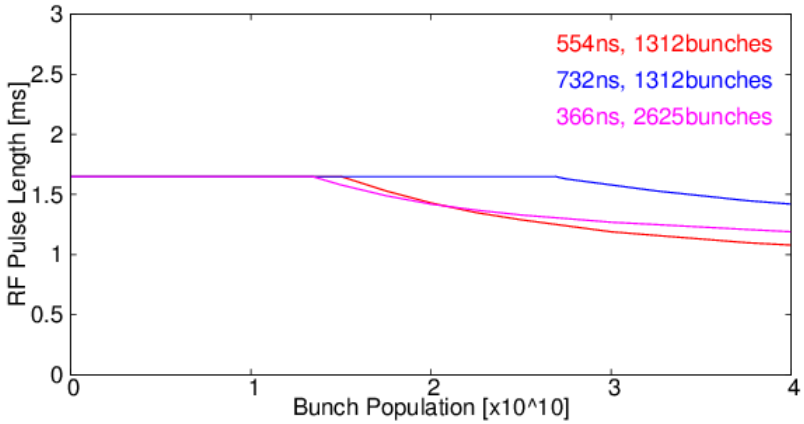


Before the beam injection, RF phase will be set to 90degree to acceleration phase.

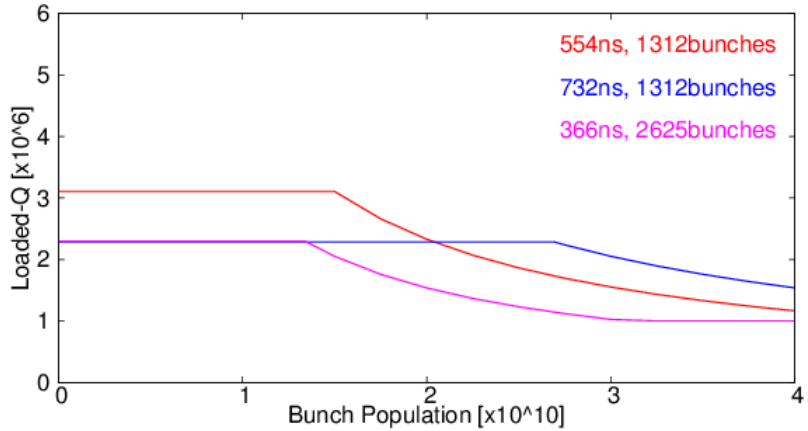
The most effective (small RF power) is 45degree after injection.

Amplitude & Phase Modulation

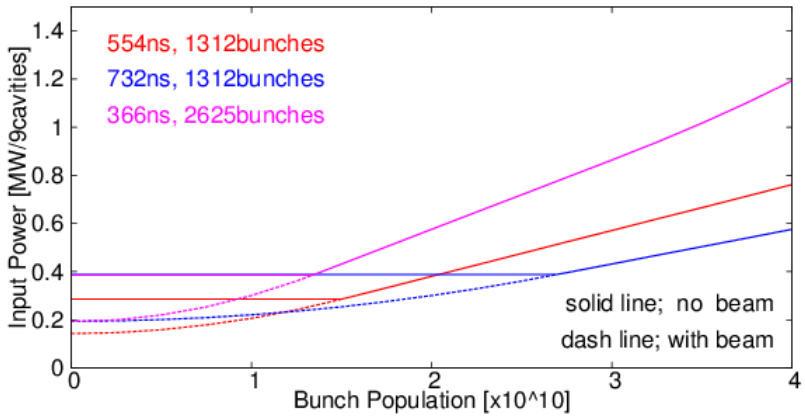
Requirement of RF pulse length (< 1.65ms)



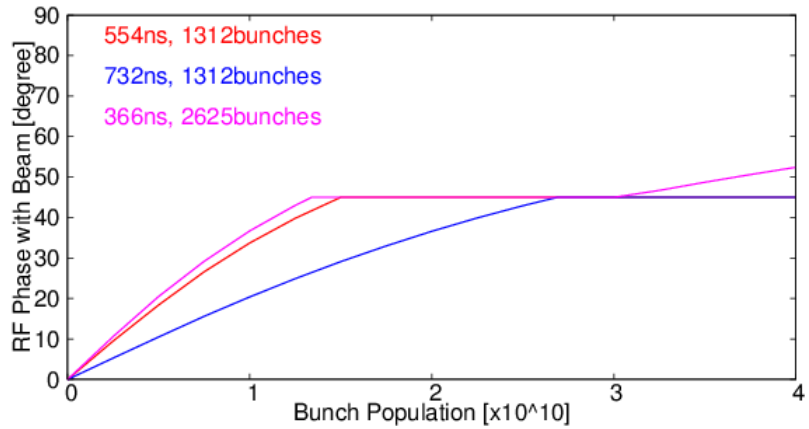
Requirement of loaded Q (1-10e6)



RF amplitude



RF phase jump when beam injection



The RF voltage and phase can be kept by using the amplitude and phase modulation.

1.5MW, 1.65ms klystron is necessary for the energy compressor.