BDS tunnel

presented at the Japanese local CFS meeting on 9/21
(some parts are written in Japanese)

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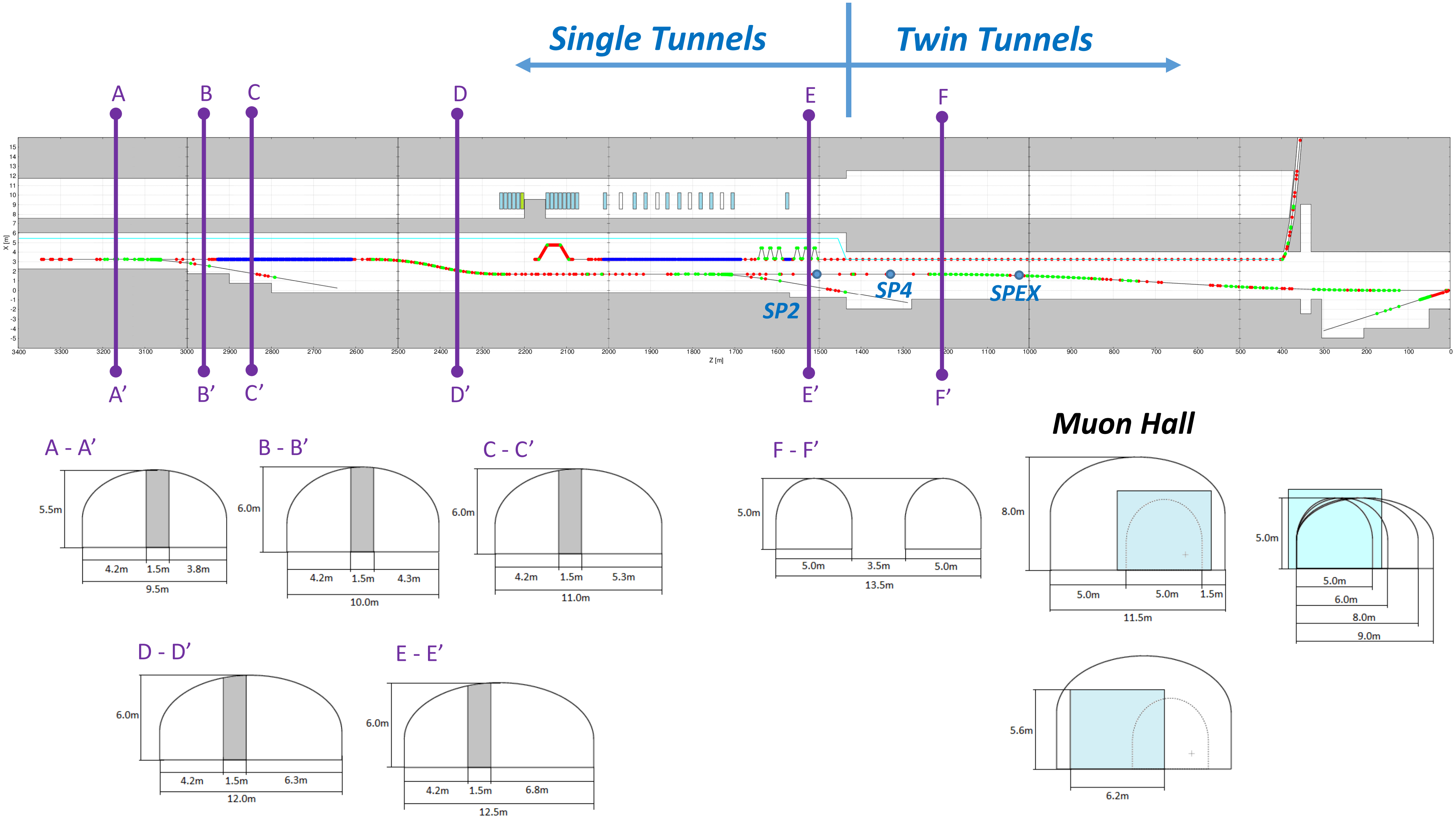
2016/ 09 /27
ILC CR meeting

Electron BDS tunnel

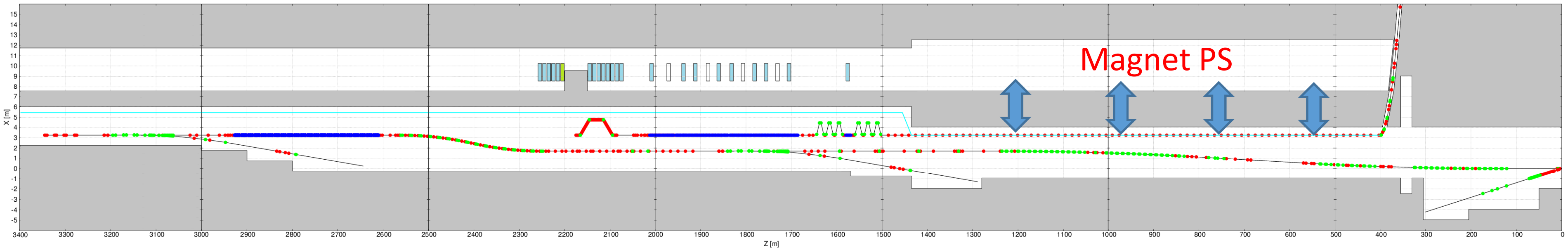
Electron BDS tunnel layout



The 1st half of BDS tunnel is single tunnel.

The 2nd half of BDS tunnel is twin tunnel.

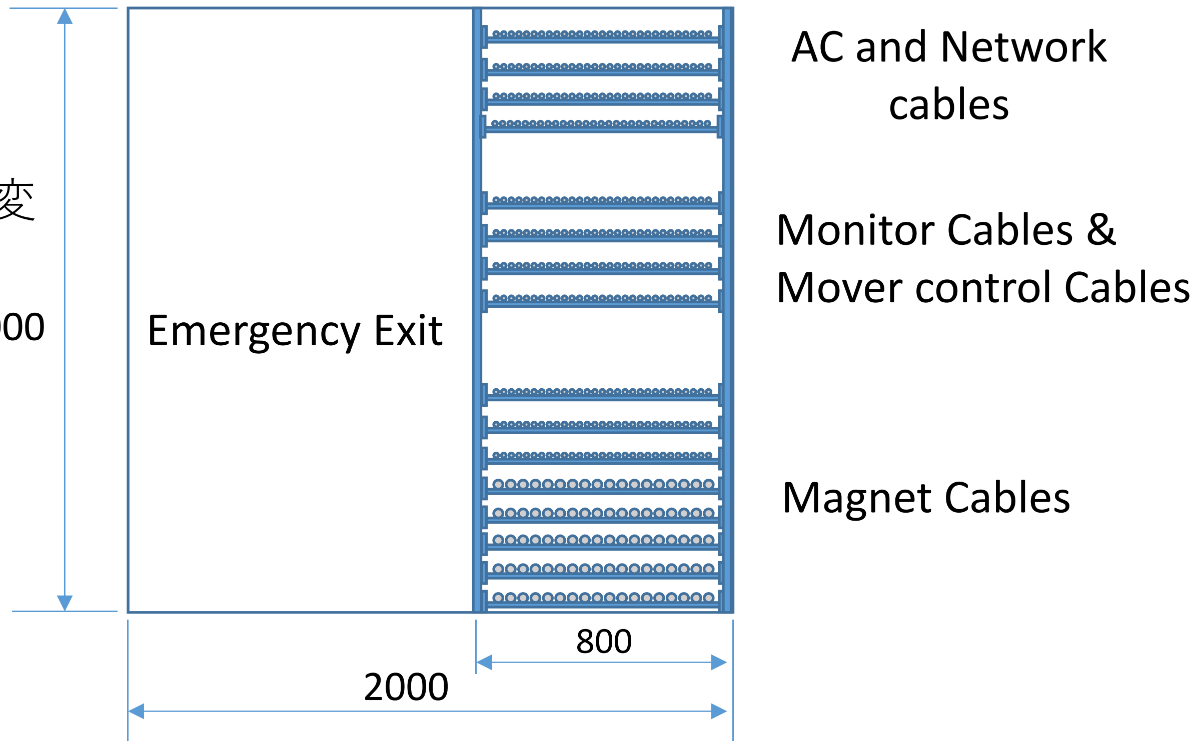
Cable penetration in twin tunnel



We need the penetration tunnel every 300m in twin tunnel for the emergency exit and cabling the devices.

２トンネルでは、
ケーブル・導波管等の
貫通口が高く、加工も大変

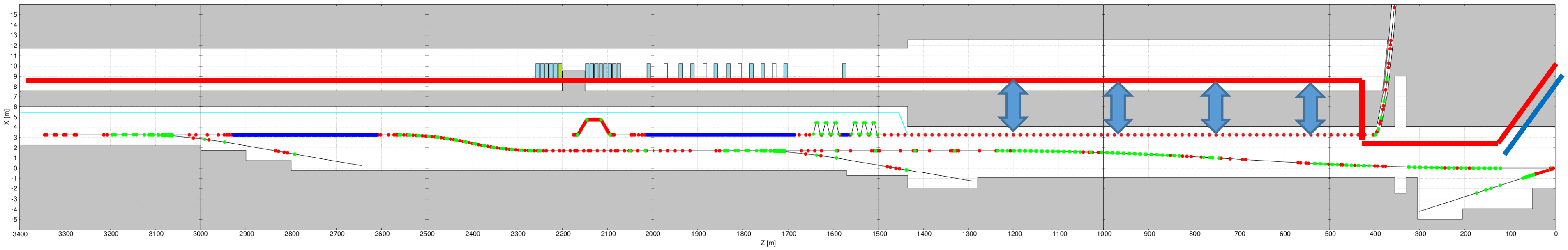
非常口と纏めて、
貫通口の数を減らす。



Penetration to Detector Hall

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.

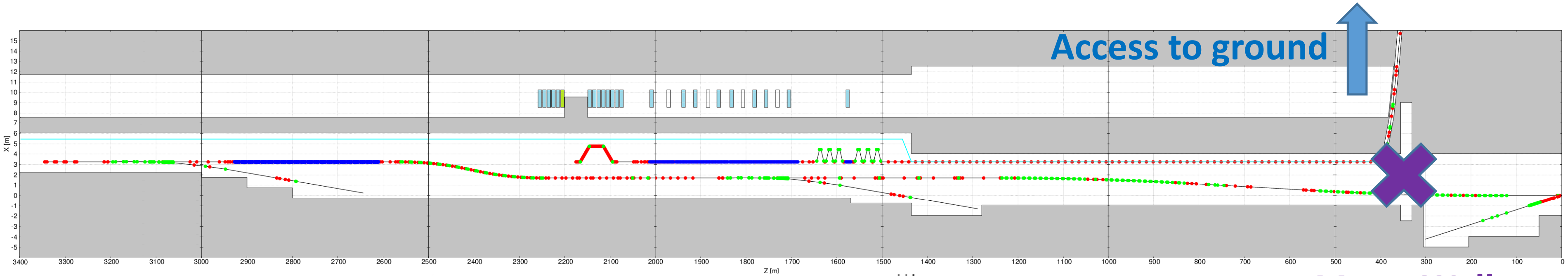
Since we don't have a service tunnel at the last part of BDS tunnel, AC power line must be arranged in accelerator tunnel.

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

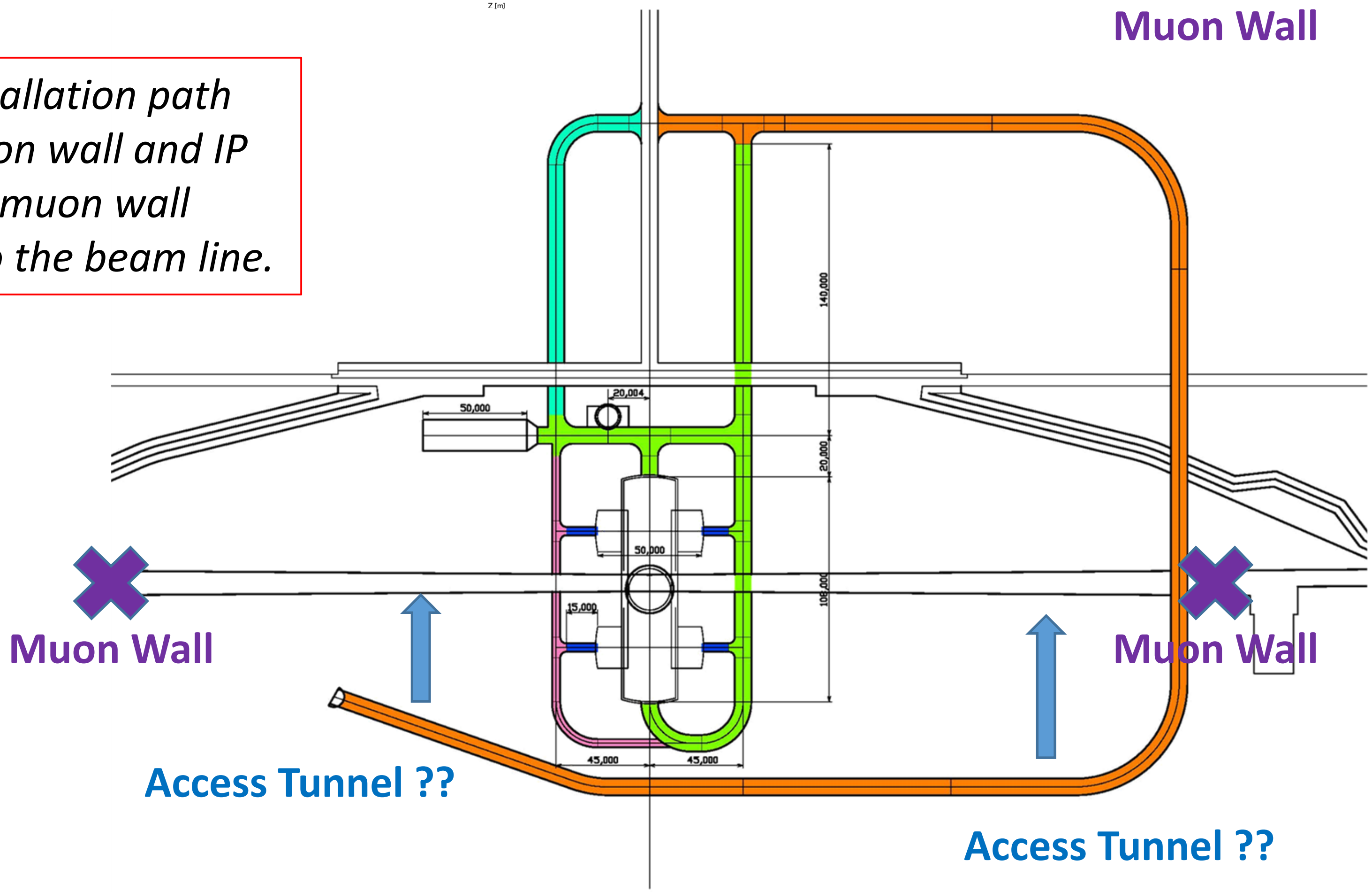
- We need the penetration to detector hall.

pac-man の外側に連絡口、兼、電力、ヘリウム用の通路が必要。

Access tunnel from access tunnel of central region

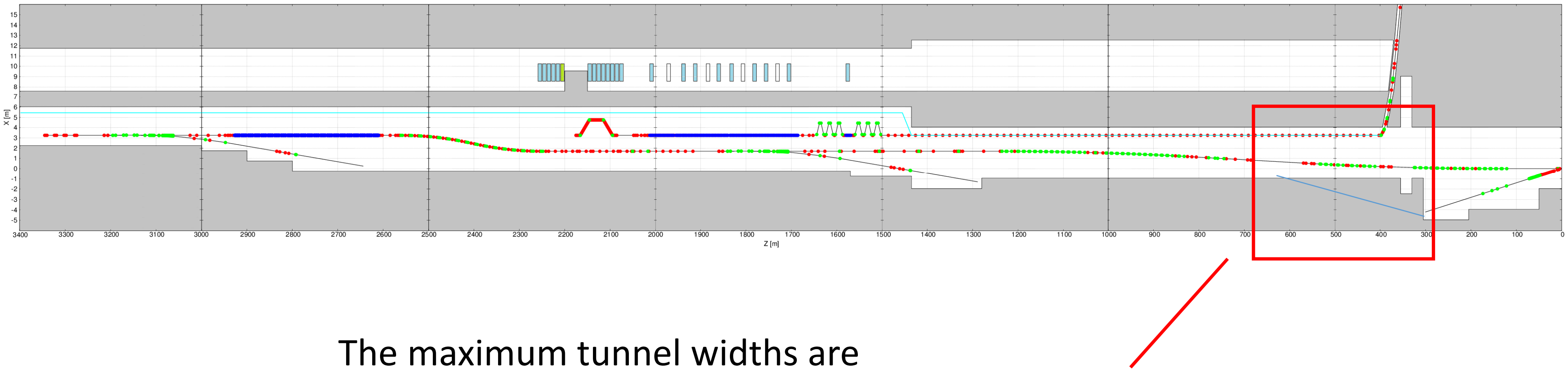


We have no installation path in between muon wall and IP after when the muon wall was installed to the beam line.



Tunnel extension for transportation to 10Hz dump

We need the tunnel extension,
if we will transport the beam to 10Hz dump.



The maximum tunnel widths are
- 9m (accelerator tunnel) and 5m (service tunnel) for twin tunnel.
- 14m for single tunnel.

10Hz dump を主ダンプへ導くためにはトンネル拡張が必要。
その際、後半を twin tunnel にした方がトンネル幅は抑えられる。

冷凍機

Helium for undulator will be provided
from vertical shaft with small cross section ?
(transfer line and elevator for access)

Compressor in ground level

日々の検査が必要なら
細い竪穴で結ぶ？

Helium for booster linac will be provide
from central region.

Daily access

Daily inspection
is important
for maintenance

4K cold box

2K cold box

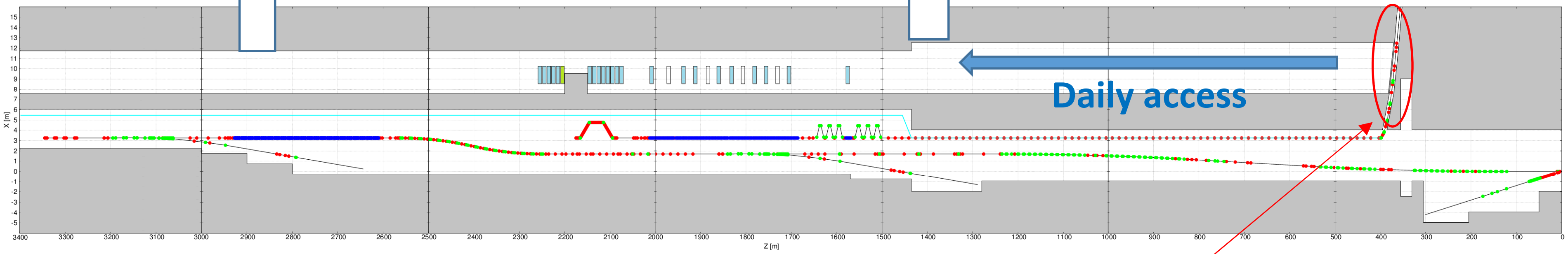
Compressor in central area

4K cold box

Make a cavern
to put 4K cold box

Make a cavern
to put the cold boxes

Daily access



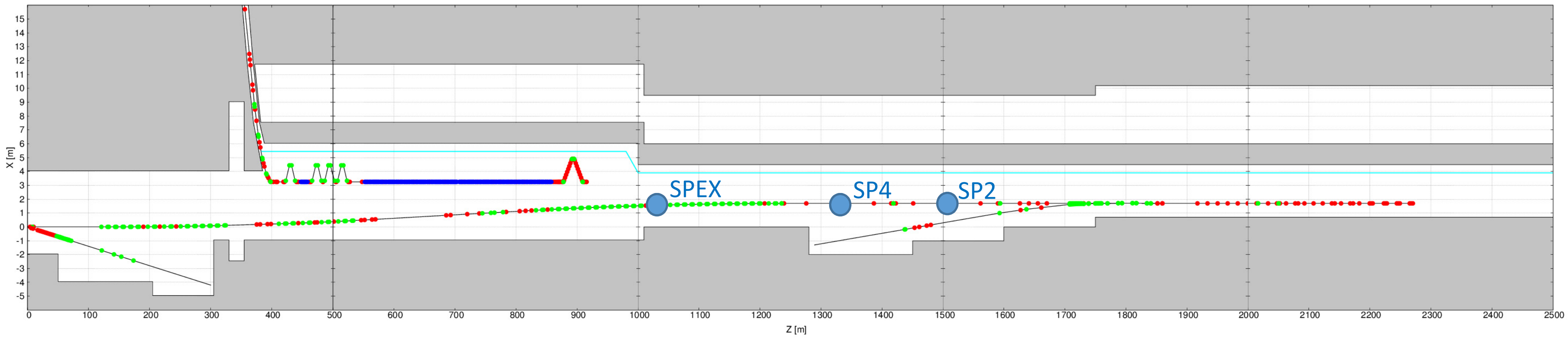
Spin Flipper Line を置くなら冷凍機が必要

Positron BDS tunnel

Positron BDS Tunnel Layout

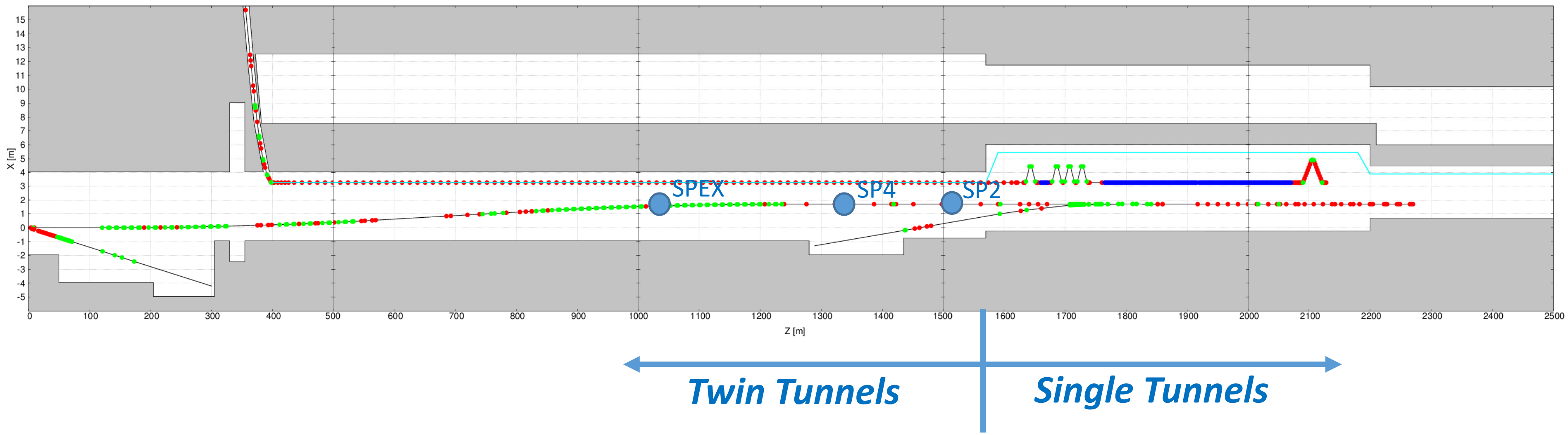
TDR

- Wide tunnel after collimators
- Large background to SC cavities (electron linac)



Proposal to move the electron source

Same background situation to electron BDS



Comment of Cooling Water Facility

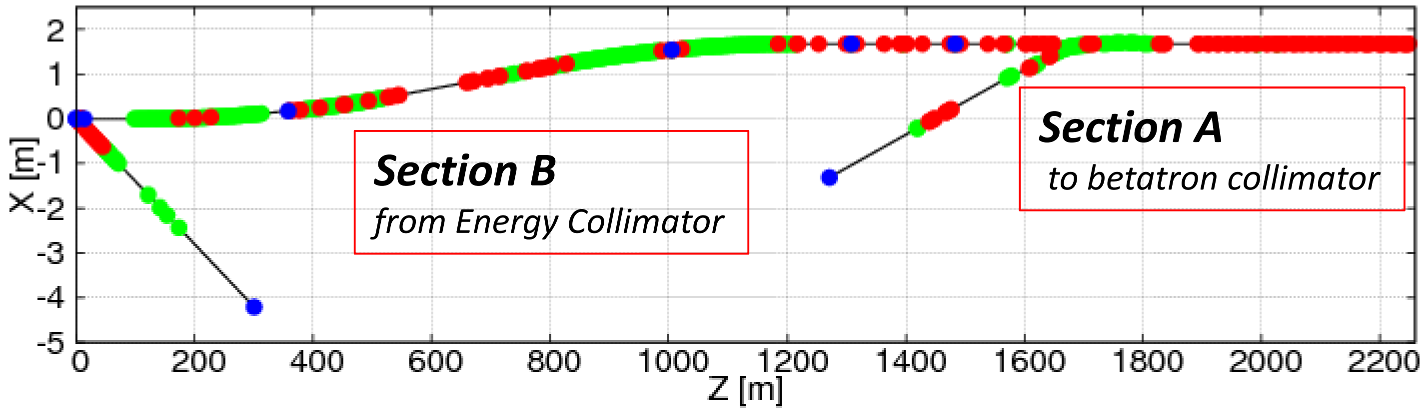
BDS optics for ECM=1TeV operation

ECM= 500GeV optics can be increased the beam energy up to 300GeV (ECM=600GeV)

The beam optics can be increased to ECM=1TeV by using same geometory.

- The most of magnets for ECM=500GeV can reuse to 1TeV optics.

- Some new magnets should be installed to extend to ECM=1TeV.



The number of components both for ECM=500GeV and ECM=1TeV

(not include the dumpline)

	Energy [GeV]	# of BEND	# of QUAD	# of SEXT	# of Steer	# of PS	# of Mover	# of BPM
Section A	500	16	64	0	19	73	70	78
	1000	43	108	0	19	115	108	116
Section B	500	63	33	7	55	46	40	101
	1000	176	41	7	55	56	48	112

簡単な４極電磁石の見積もり

４極電磁石（1TeV時、約150個　最初から1TeV対応にするのか？）

電磁石長　2.0m
ボア半径　13mm
ホロコン　10mm x 10 mm (6mmϕ)

	10度の温度上昇	30度の温度上昇
Turn / pole	10	16
Number of water channel	4系統/電磁石	2系統/電磁石
Maximum Current	437 A	273 A
Maximum Power	8.4kW (x 150=1.26MW)	5.6kW (x 150=0.84MW)
Pressure Drop	0.4 MPa	0.4 MPa
Water Flow	9.87 l/min (x 150=1480 l/min)	2.54 l/min (x 150=381 l/min)
Temperature Rise	12.2℃	31.8℃

温度上昇に対する考え方を変えると、
電源の大きさ、冷凍機の容量、冷却水の流量、冷却配管の太さなど
CFSへの影響がかなり変わる。

Solenoid Magnet for PS Capture Section

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

	Capture 1				Capture 2			
Length	15.5 m				34.4 m			
Magnetic Field	0.50 T							
Current	320 A							
Layer	20							
Inner diameter	0.40 m							
Outer Diameter	1.04 m							
ターン/冷却水	40	80	120	160	40	80	120	160
冷却水ヘッダー間隔	3.2cm	6.4cm	9.6cm	12.8cm	3.2cm	6.4cm	9.6cm	12.8cm
電力 [kW]	368.9	373.5	391.8	397.0	818.7	829.0	869.5	881.0
圧損 [MPa]	0.095	0.40	0.40	0.72	0.095	0.40	0.40	0.72
温度上昇 [℃]	10	13.3	26.3	30.0	10	13.3	26.3	30.0
流量 [l/m]	528.8	404.6	214.0	254.0	1173.7	898.0	474.8	563.7

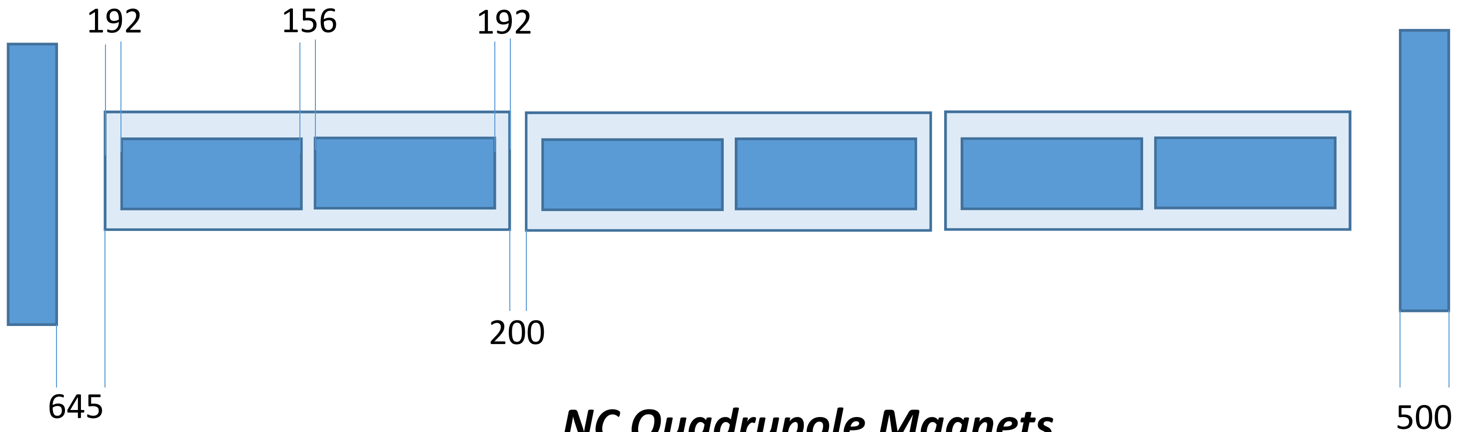
温度上昇に対する考え方を変えると、
冷却水の流量がかなり変わる。

Positron Source

Not only target area, but also many works to be considered

Undulator Cells in the optics deck

- *A cryomodule consists of two undulators.*
- *Quadrupoles are arranged every three cryomodules.*



NC Quadrupole Magnets

	ECM=240GeV(*)	ECM=300GeV	ECM=350GeV	ECM=500GeV
Magnetic Field	79 T/m (0.50T)	98 T/m (0.63T)	115 T/m (0.73T)	164 T/m (1.04T)
Length	0.5 m (12.7mmϕ)			
Number of Quadrupole	23			

(*) ECM=240GeV is based on A.Ushakov, LCWS2013

常伝導電磁石が強すぎる

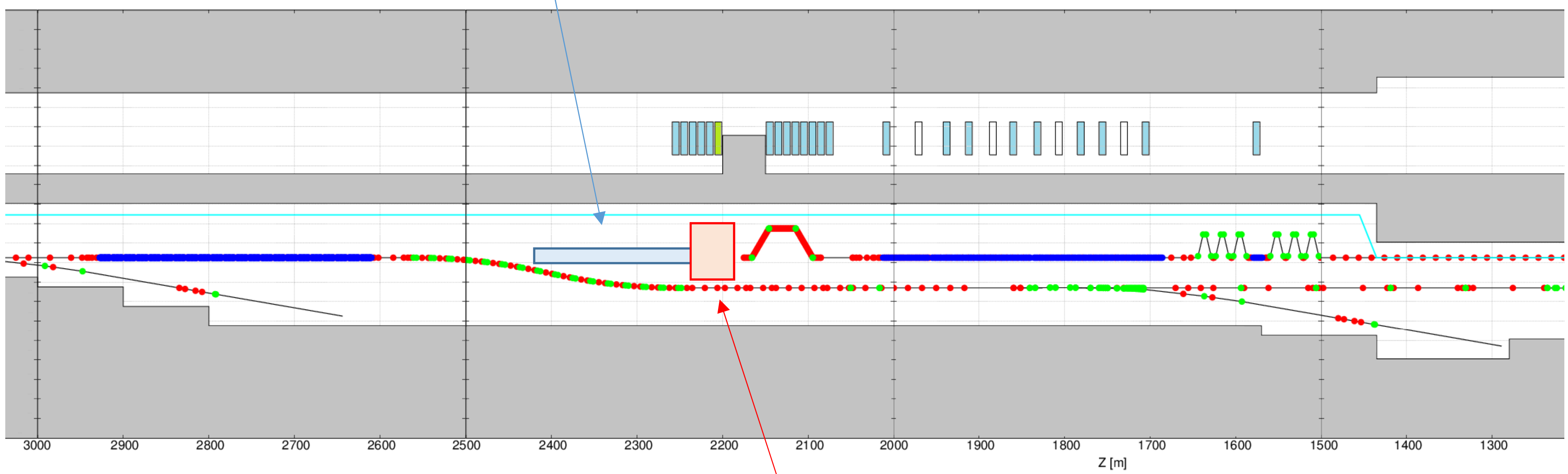
アンジュレーターの冷却？
四極電磁石の強さ？
アンジュレーター系のデザイン？

APS (Auxiliary Positron Source)

Service Tunnel ; Klystron and modulator

Accelerator Tunnel ; LINAC

We need tunnel extension for the devices.



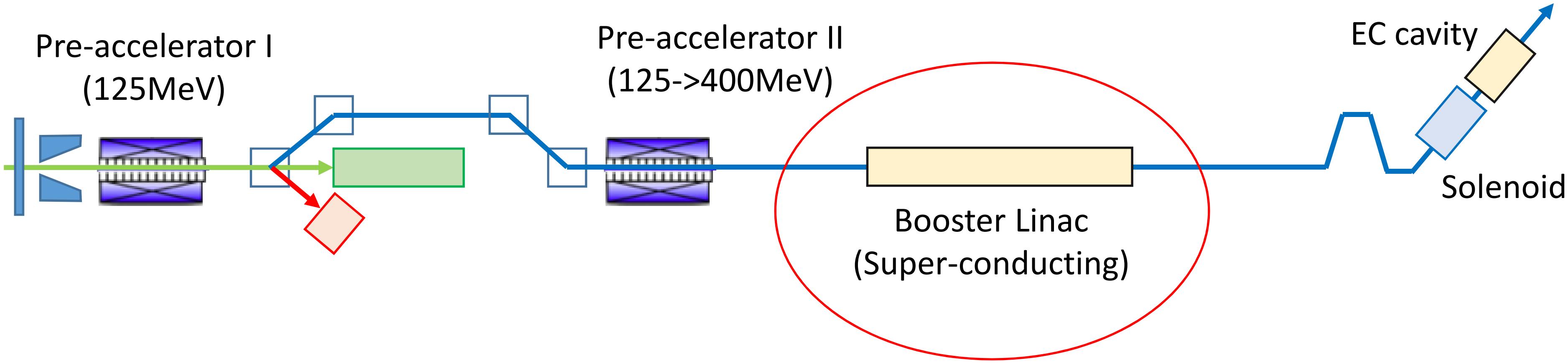
Photon Collimator

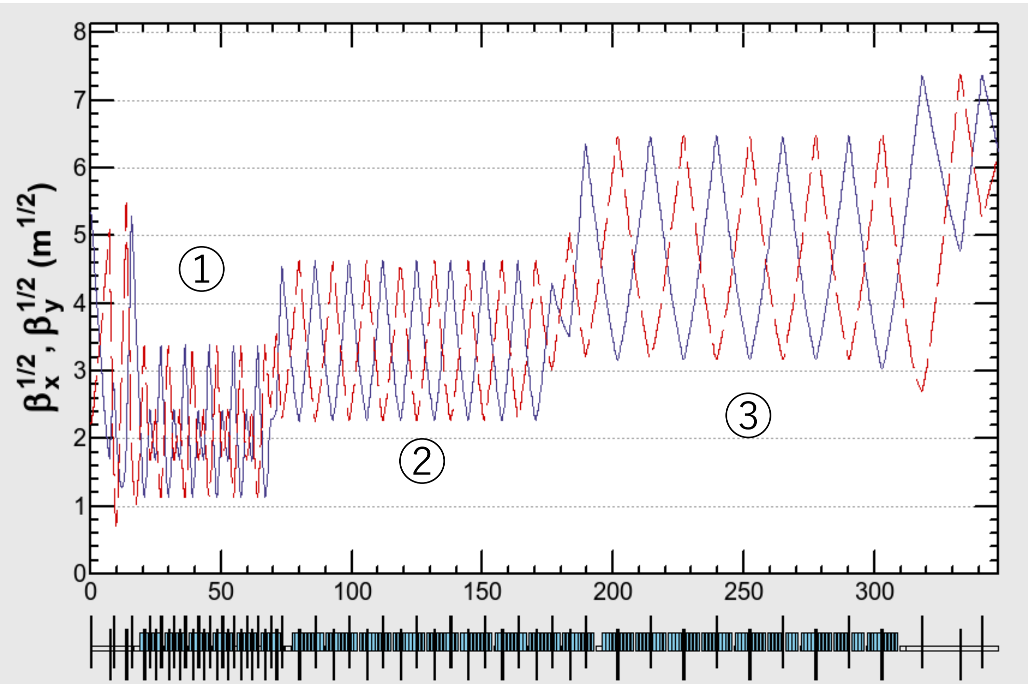
Collimated photon power O(a few 10 kW)

多分、スポイラーとアブソーバーを組み合わせたかなり大掛かりなもの。

ターゲット部だけでなく、
これらによるトンネルの拡張も
考える必要がある

Positron Booster Linac





We will use 3 type of cryomodules in booster linac

In optics deck,

Module 1 ; 27.45MV/m

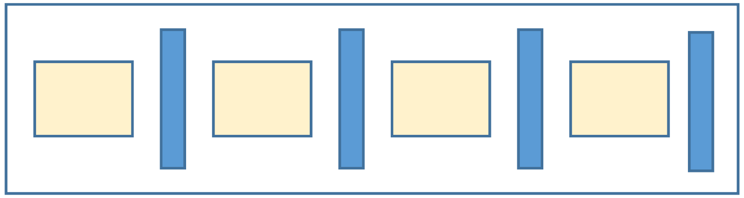
Module 2 ; 21.48MV/m

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 ;



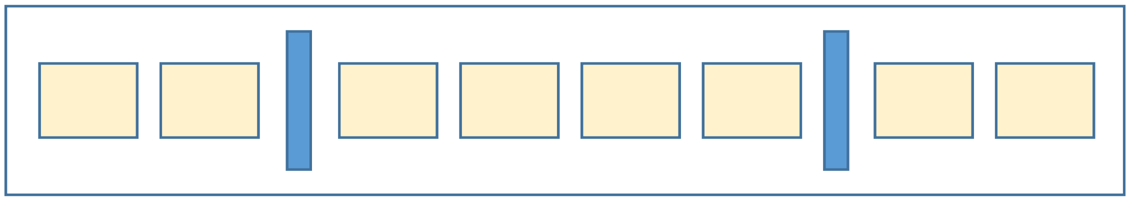
6 modules
- 4 cavities
- 4 quadrupoles

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

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

4T at 2a=80mm

Module 2 ;

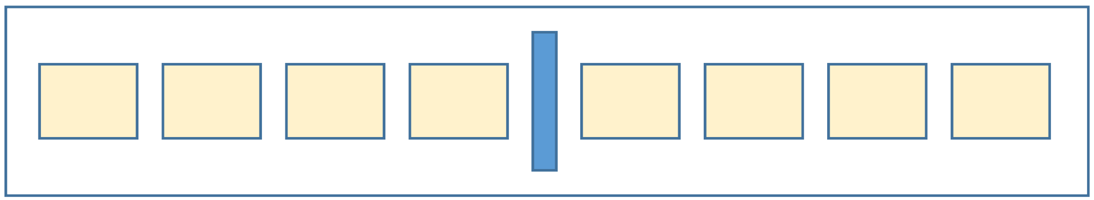


9 modules
- 8 cavities
- 2 quadrupoles

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

Module 1, 2 での電磁石が強すぎる。
四極電磁石の厚さを含めたクライオモジュールのデザイン。
加速管、電磁石の負荷を計算して、冷凍機のデザイン。

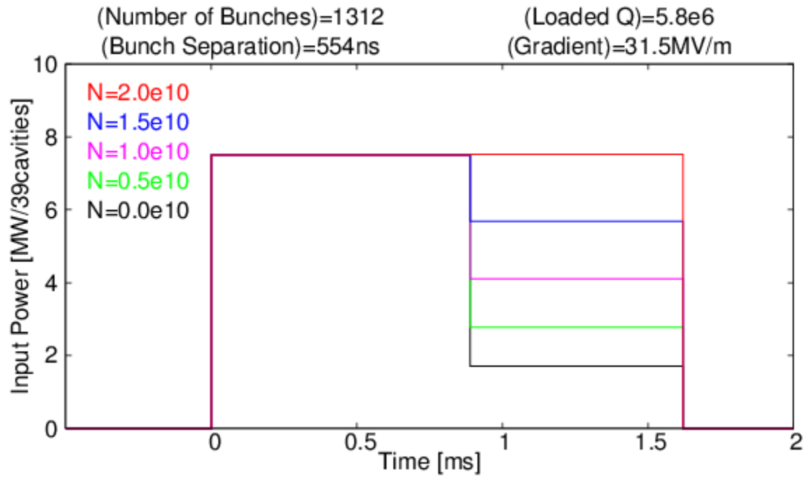
ILC TDR timing System (B.List)

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

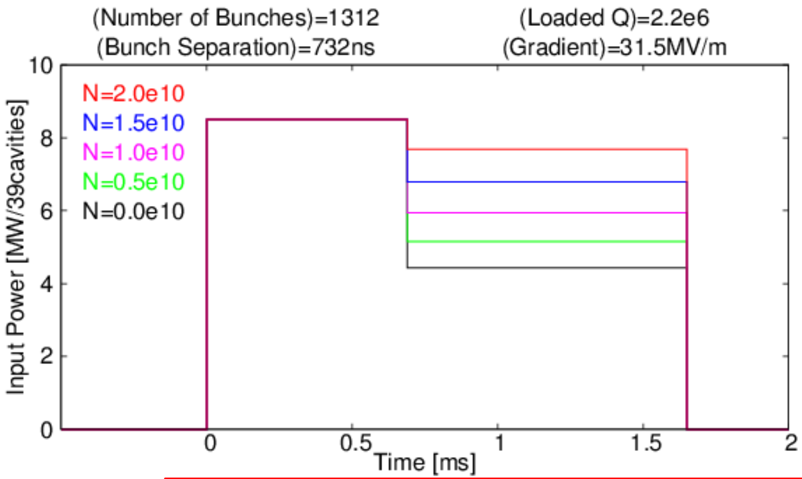
Main Linac RF for KCS (Baseline)

39 RF cavities for one 10MW klystron



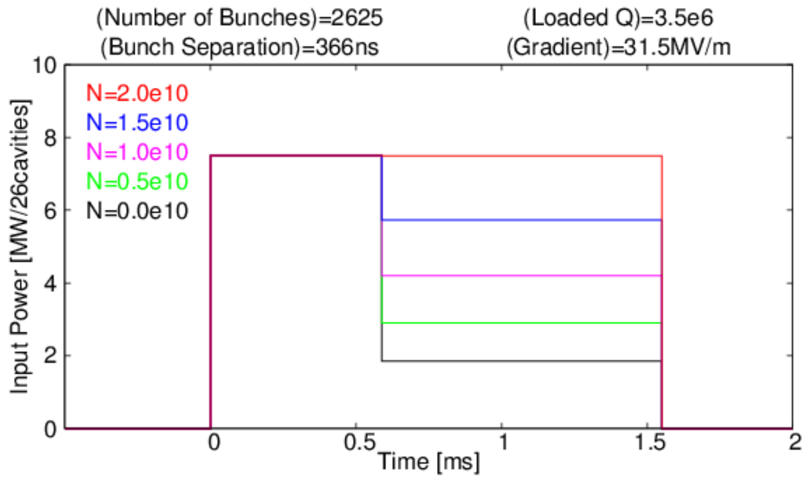
Main Linac RF for DRFS (Small DR Train Length)

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)

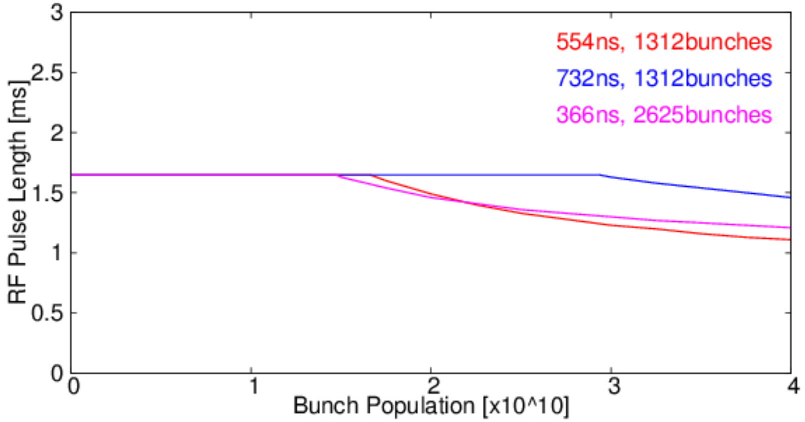


For lower intensity, the RF amplitude will be reduced after beam injection.

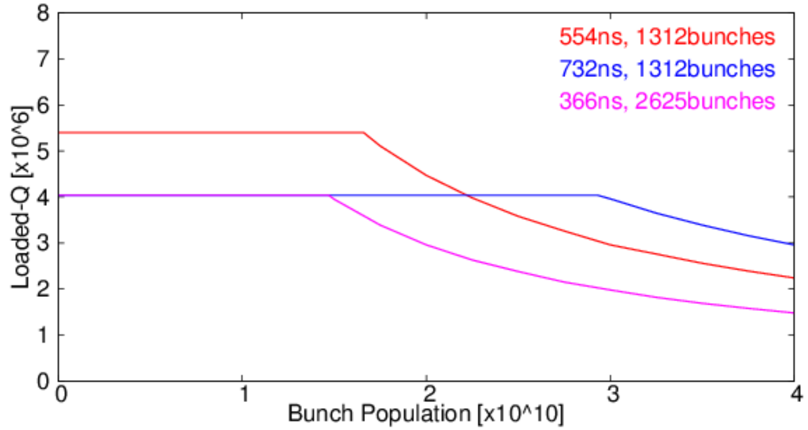
Superconducting RF system for Booster Linac

- *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*

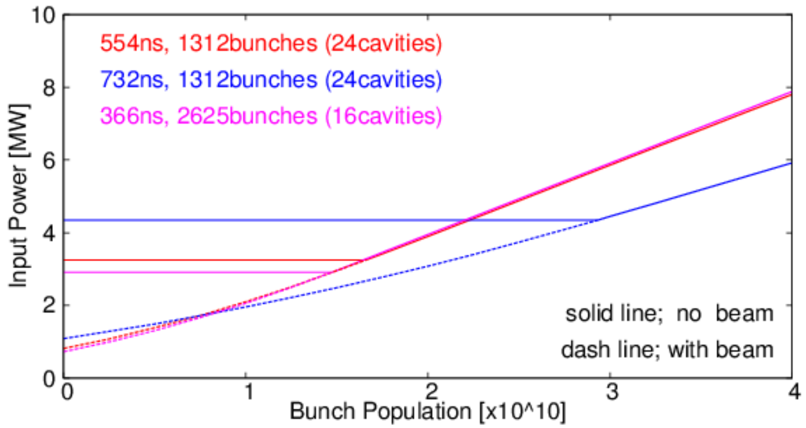
Requirement of RF pulse length (< 1.65ms)



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*

＋バックアップ

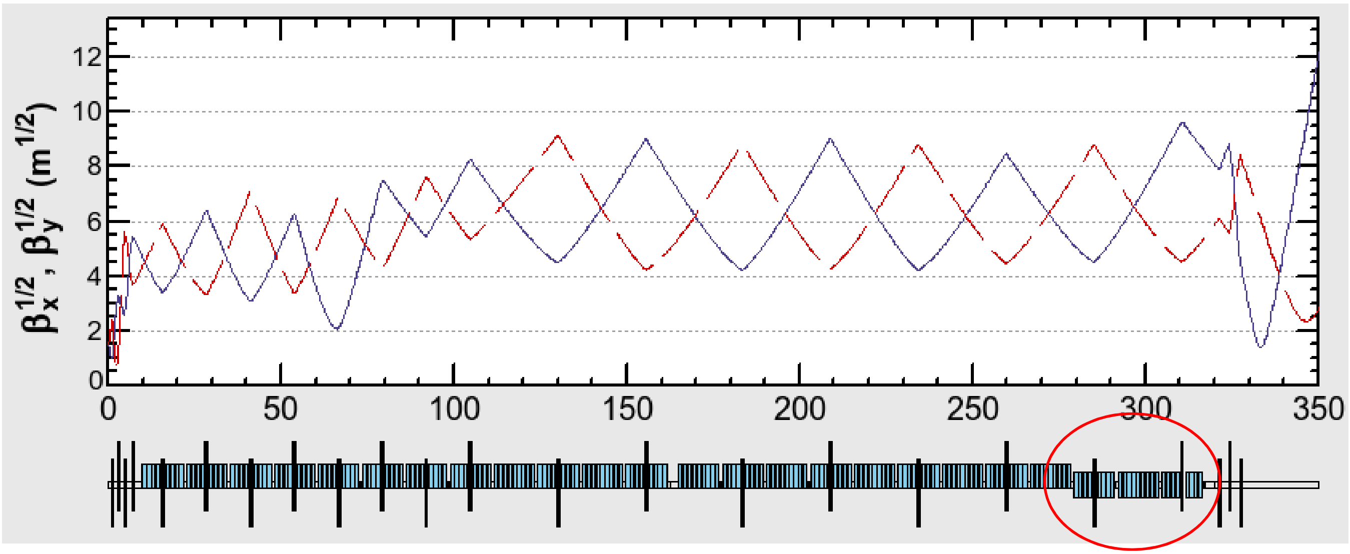
電子ブースターの例

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

全てMLと同じタイプ

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

Backup ; 3 cryomodules (25 9-cell cavities)



Backup Cryomodules

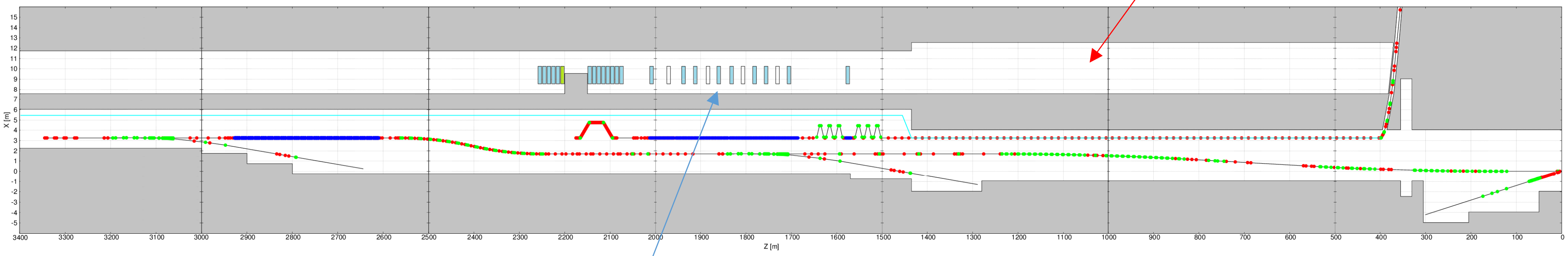
For positron booster linac, there are no backup cryomodules.

陽電子源のRFバックアップシステムはどう考える？

Summary

It is very important to evaluation of the capacities of cooling water and loads for He compressors to design the service tunnel.

電力ライン(66kV)
冷却水（水量要検討）
ヘリウム転送ライン (要検討)
電磁石電源　等が配置される。



Modulators and Klystrons

The square is the modulator and klystron space (10m long).
- But, it is difficult to put a modulator&klystron within 10m space.
- The modulator&klystron are crowded at the normal conducting area.

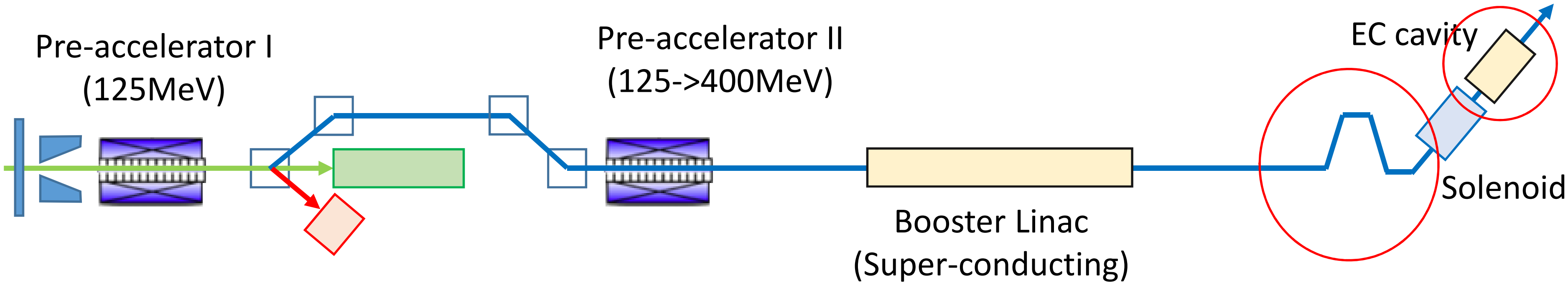
上図はクライストトン、モジュレーターのスペースを10mと仮定して書いてある。

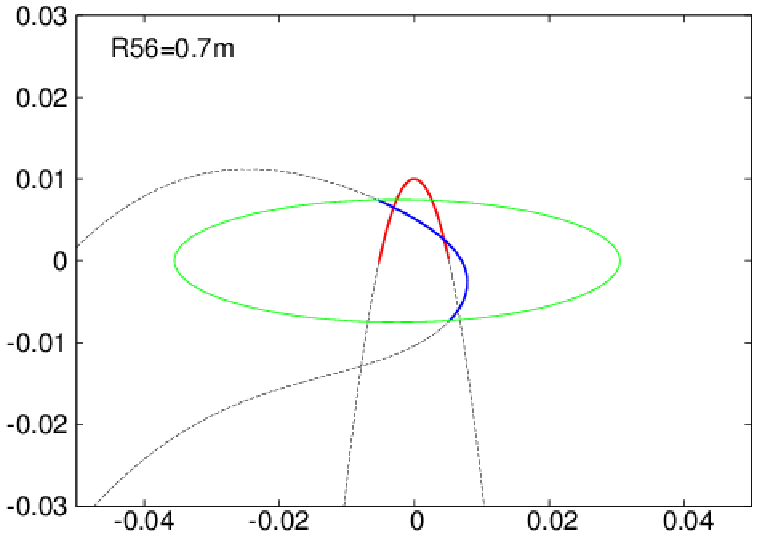
それぞれのクライストロンは10MW出力。
- 松本さんと簡単に話した感じでは10m間隔では難しい？

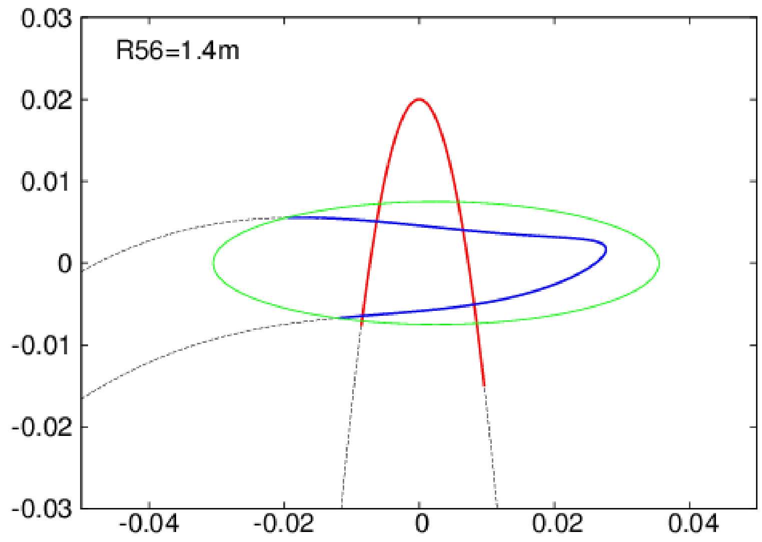
常伝導区間は密集しているので、慎重に配置を考える必要がある。

バックアップ

Energy Compressor





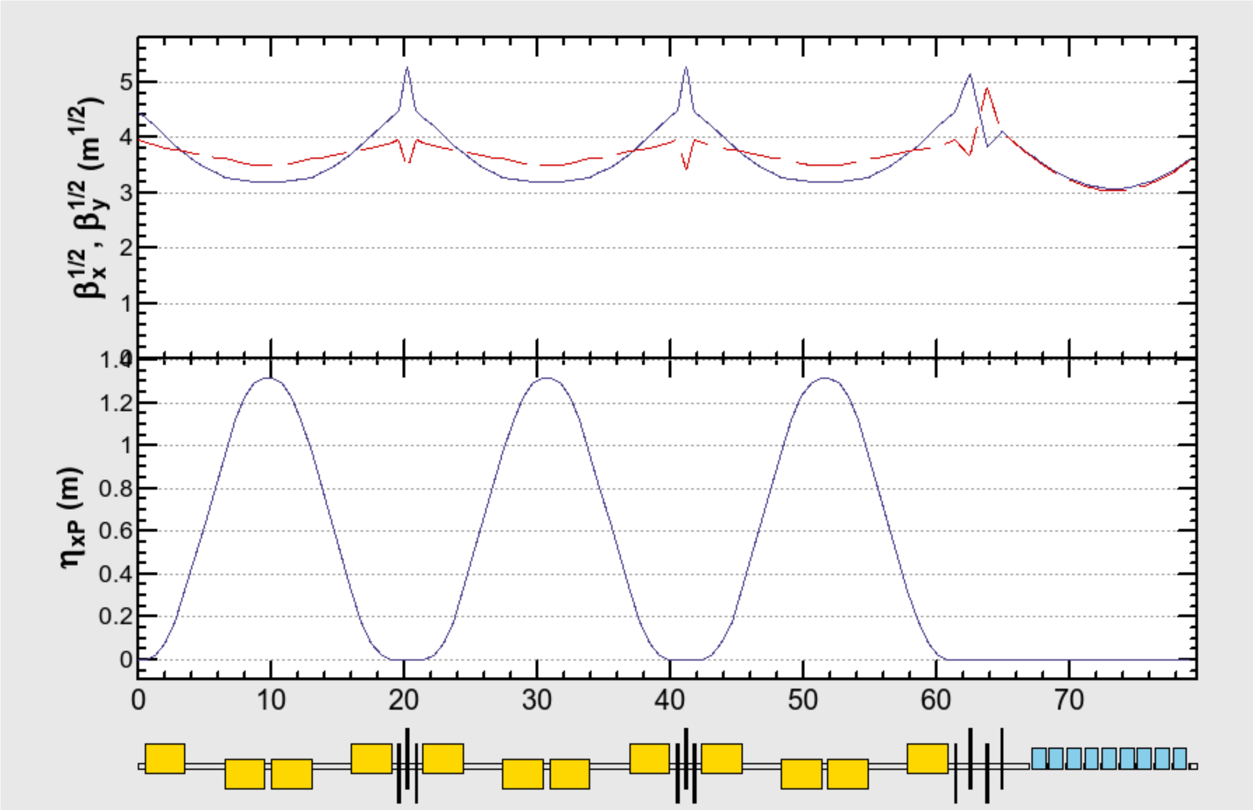


In present optics deck, the R56=0.7m, but the parameter is not effective to energy compress.

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

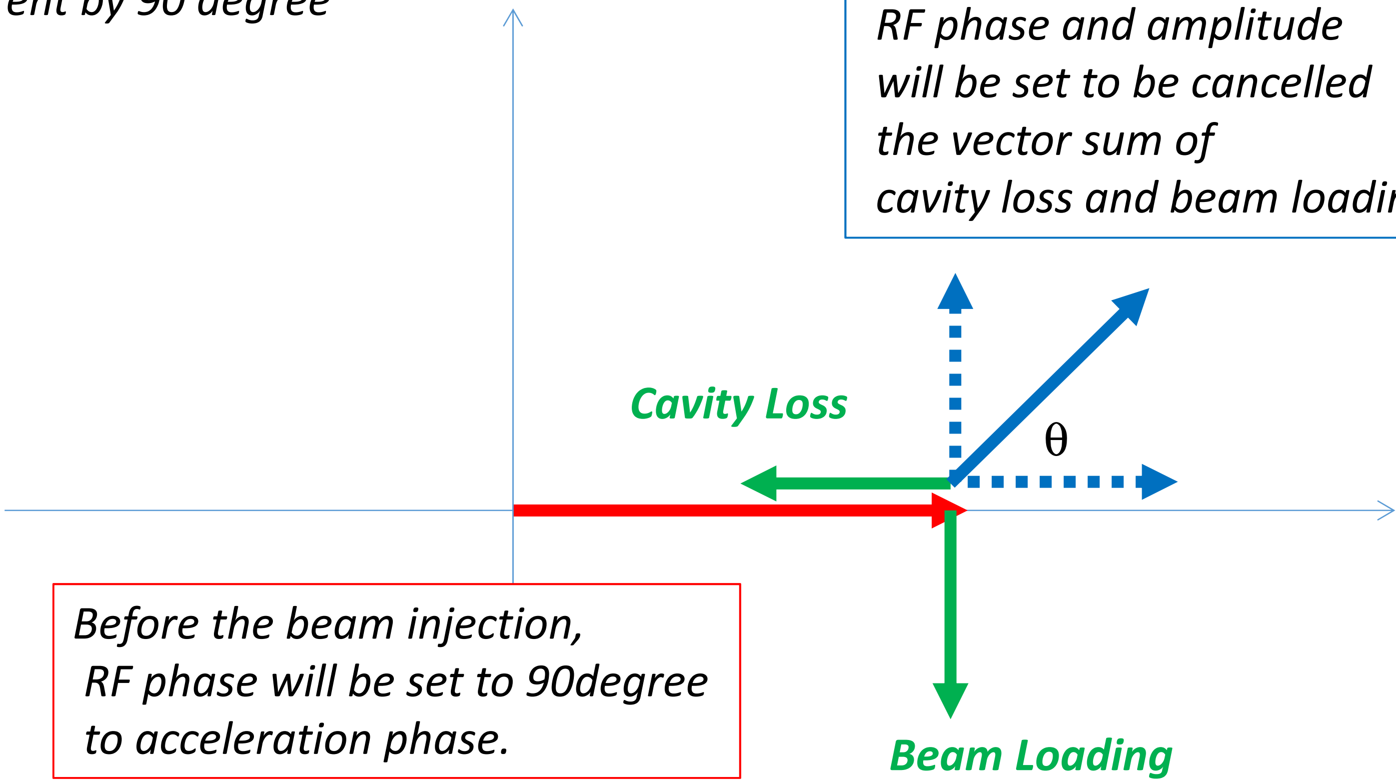
RF voltage
9 x 9cell cavity
（Type A module）

V = 131 MV

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

The RF field and beam loading are different by 90 degree

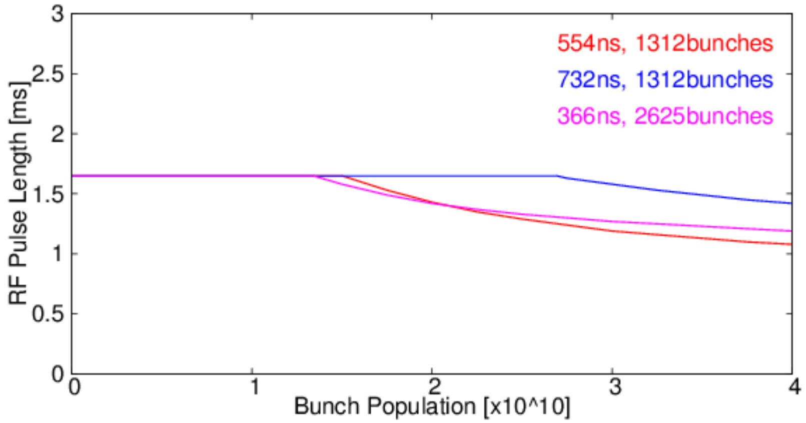
After the beam injection, RF phase and amplitude will be set to be cancelled the vector sum of cavity loss and beam loading.



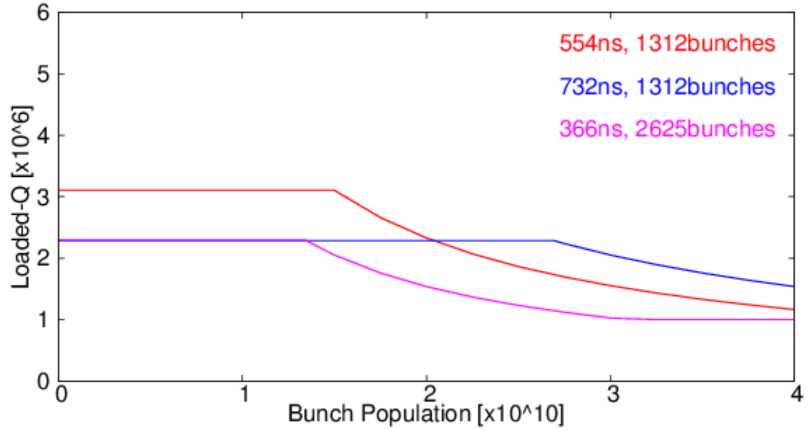
The most effective (small RF power) is 45degree after injection.

Amplitude & Phase Modulation

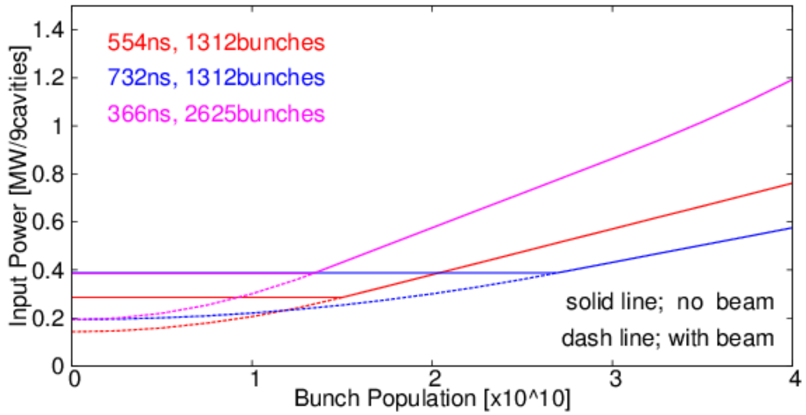
Requirement of RF pulse length (< 1.65ms)



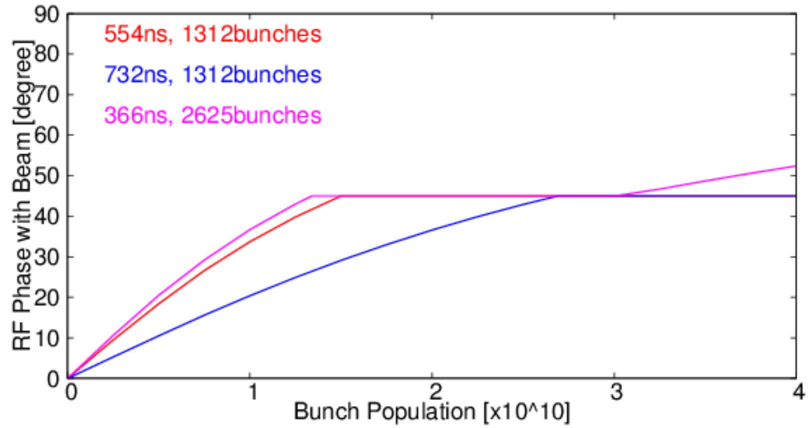
Requirement of loaded Q (1-10e6)



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.