A Status report of E-driven ILC Positron Source

LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

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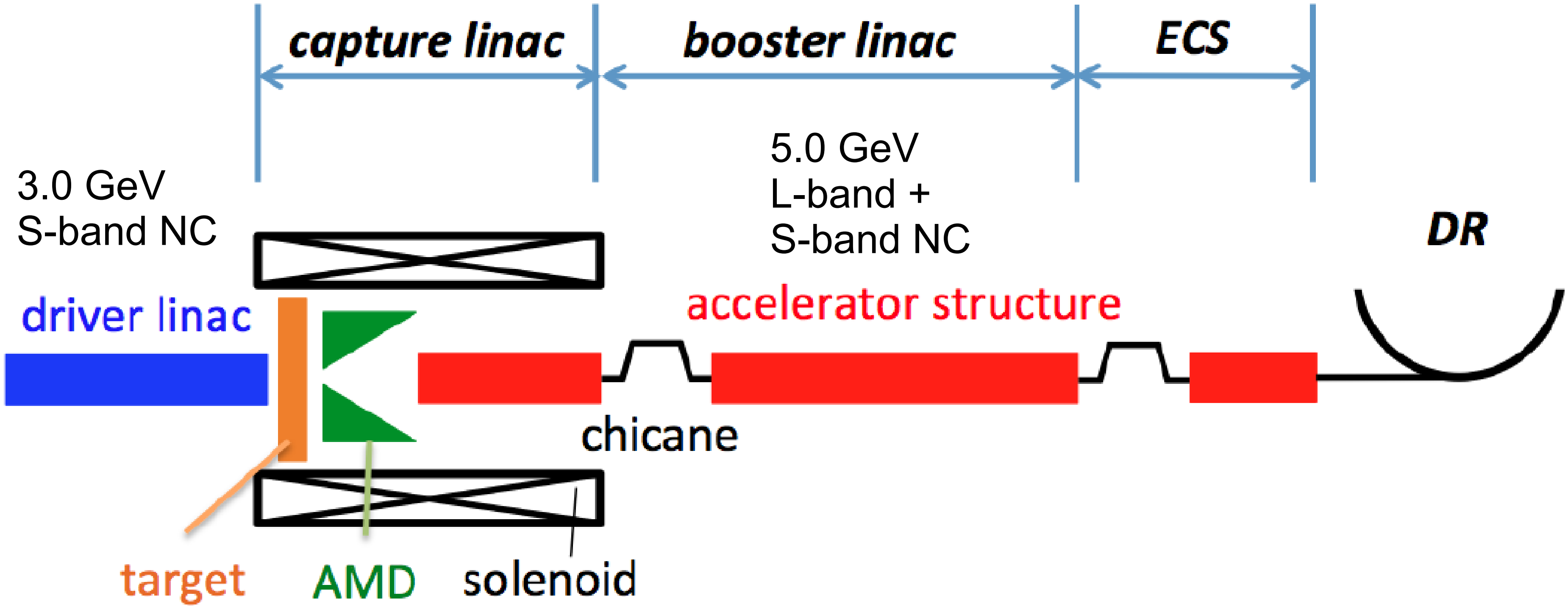
Introduction

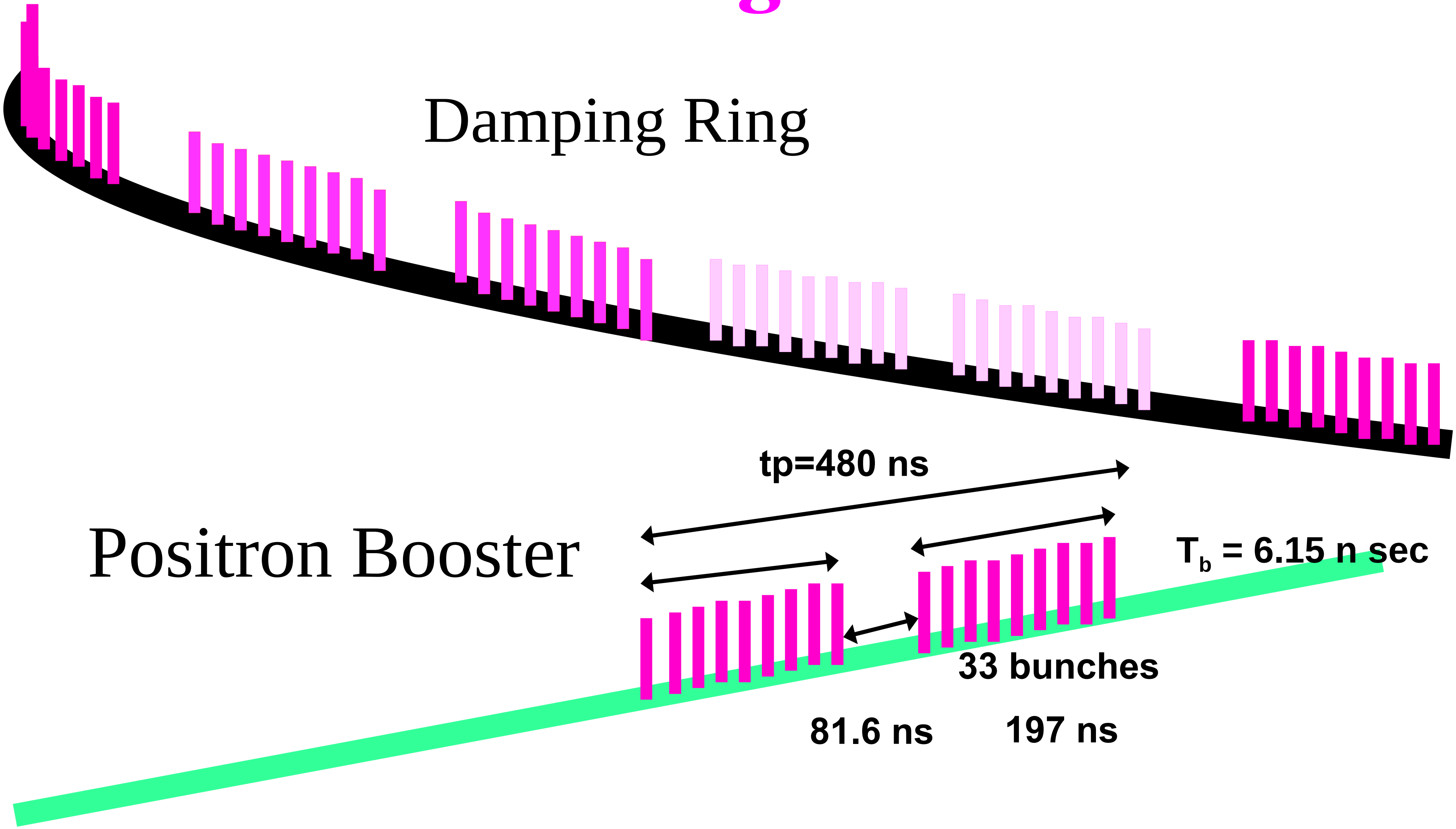
- The design of the ILC positron source based on off-the-shelf components has been established.
- Optimization for 250 GeV parameter as
  - Small beam size on target for better yield. (3.5 2.0 mm rms)
  - Lower drive beam energy for less cost. (4.8 3.0 GeV)
  - Consider only the nominal parameter.
- A margin for the booster energy is now reserved.
- A systematic optimization for higher yield.
- Target and 1st RF maintenance is considered.

E-driven ILC Positron Source



- 20 of 0.48us pulses are handled with NC linacs operated in 300Hz.
- 100 of 300 pulses are actually fired.

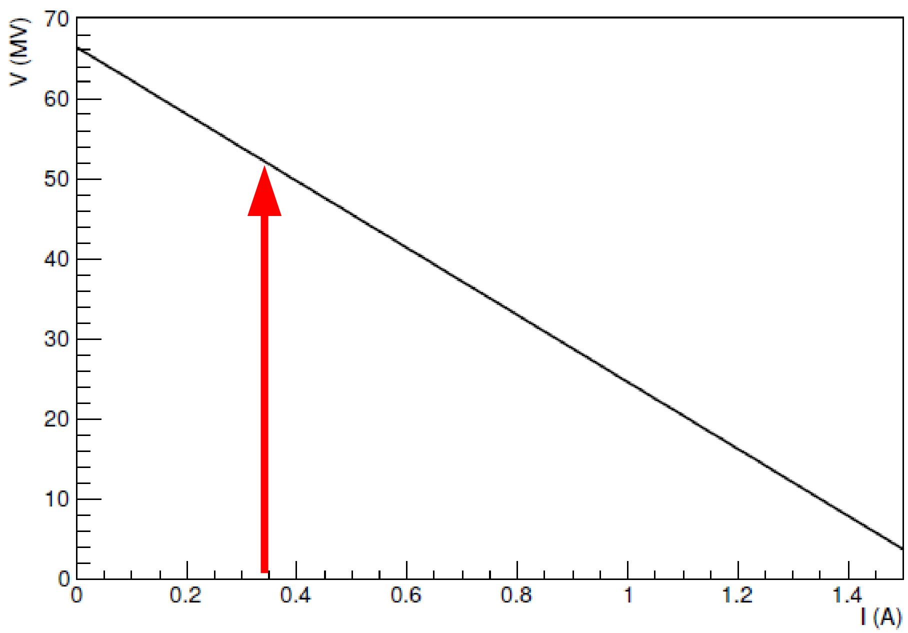
The beam handling and format



Electron Driver

- 3.0 GeV Electron beam with 2.0 mm RMS beam size at the target.
- 4.8/2.3 =2.1nC bunch charge is giving 0.34 A beam loading.
- S-band Photo-cathode RF gun for the beam generation.
- 80 MW klystron-modulator drives 2 structures.
- The effective input power for each tube is 36 MW. 50 MV/tube.

Parameter	Number	unit
Frequency	2856	MHz
Shunt Impedance	60.0	$M\Omega/m$
Aperture (2a)	25.3 - 18.4	mm
Group velocity	2.04 - 0.65	% of c
Filling time	0.83	μs
Attenuation	0.57	
Q value	13000	
Length	3.0	m



KEK CONCEPT DESIGN 80MW S-band RF & Solid State Modulator PARAMETERS

Fig: *K400-platform*

Main Parameters	Value	Unit
RF Frequency	2600	MHz
RF Peak Power	80	MW
RF Average Power	0.2 (12)[1]	kW
Mod. Peak Power	143	MW
Mod. Average Power	1.4 (86)[1]	kW
Klystron Voltage	382	kV
Klystron Current	375	A
RF Pulse width (top)	0.5	μs
Pulse Repetition Rate	5 (300)	Hz
Pulse-to-Pulse stability	<15	ppm

[1] *Corresponding to 300Hz operation*

OPTIONS: Integration of …

- Solenoid Power Supply
- Ion Pump Power Supply
- RF Drive amplifier
- Cooling of Klystron (Collector, Body), Solenoid
- All diagnostics and interlocks

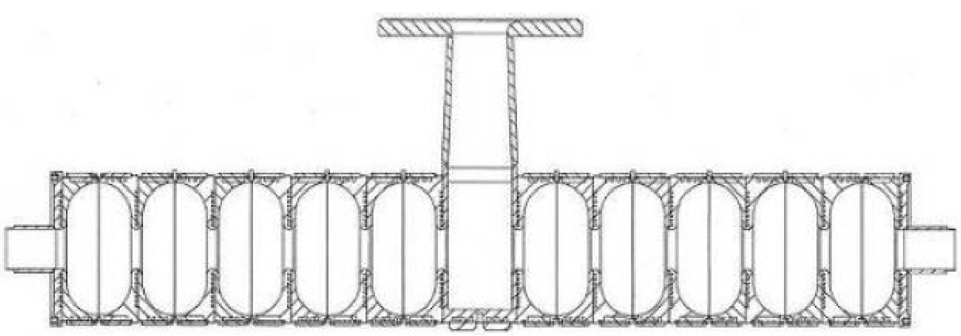
- 60 + 4 (spare) of 3m S-band TW structures for the acceleration. The energy is 3.2 GeV.
- The lattice design was based on ATF linac, 4Q + 2RF(S) up to 600 MeV, 4Q+4RF(S) for other.

Lattice	# of cell	Cell length(m)	Section length(m)
4Q+2S	6	8.0	48.0
4Q+4S	13	14.4	172.8

- The total length is 235.2 + 20 m (RF gun + matching section).

Positron Capture Linac

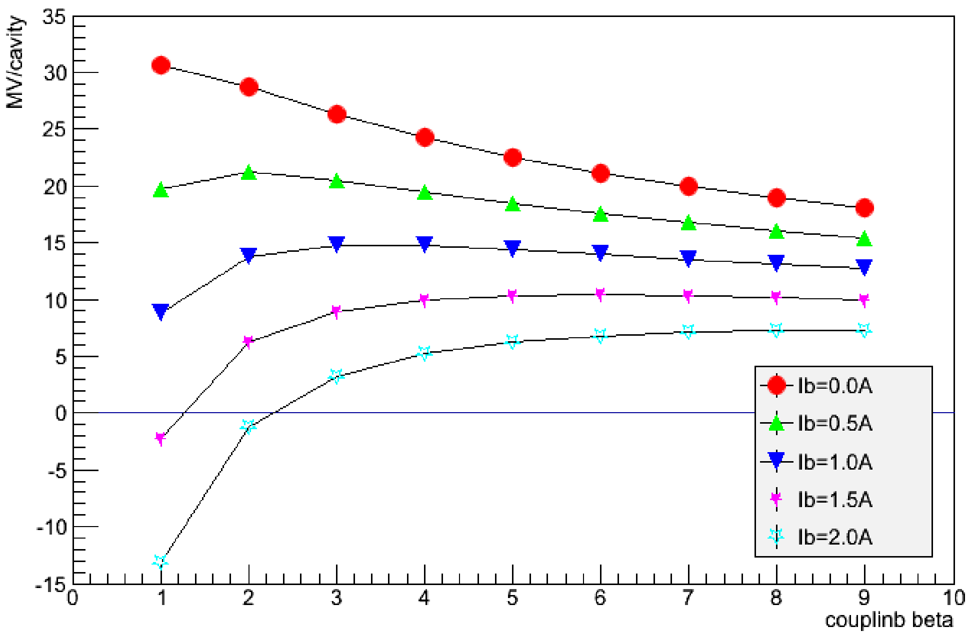
- 36 L-band SW structures designed by J. Wang (SLAC) for the undulator capture section is employed.
- Two structures are driven by one 50 MW klystron.
- Surrounded by 0.5 T solenoid field.

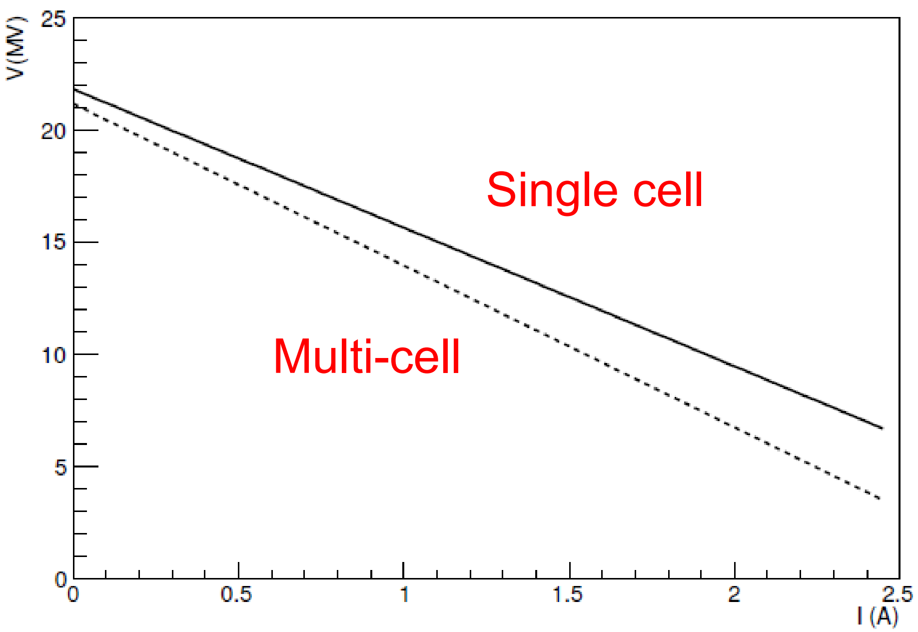


Structure Type	Simple π Mode
Cell Number	11
Aperture 2a	60 mm
Q	29700
Shunt impedance r	34.3 MΩ/m
E_0 (8.6 MW input)	15.2 MV/m

Acceleration Field

- L=1.27 m (11 cells, L-band SW)
- R=34e+6 Ohm/m
- P_0=22.5 MW (50MW at klystron, 5MW wave guide loss).
- 10.36 MV/tube with beta=6.0.





KEK CONCEPT DESIGN 50MW L-band RF & Solid State Modulator PARAMETERS

October 6, 2017

***Fig:** K300-platform*

Main Parameters	Value	Unit
RF Frequency	1300	MHz
RF Peak Power	50	MW
RF Average Power	0.125 (7.5)[1]	kW
Mod. Peak Power	76	MW
Mod. Average Power	0.7 (42)[1]	kW
Klystron Voltage	271.7	kV
Klystron Current	282	A
RF Pulse width (top)	0.5	µs
Pulse Repetition Rate	5 (300)	Hz
Pulse-to-Pulse stability	<20	ppm

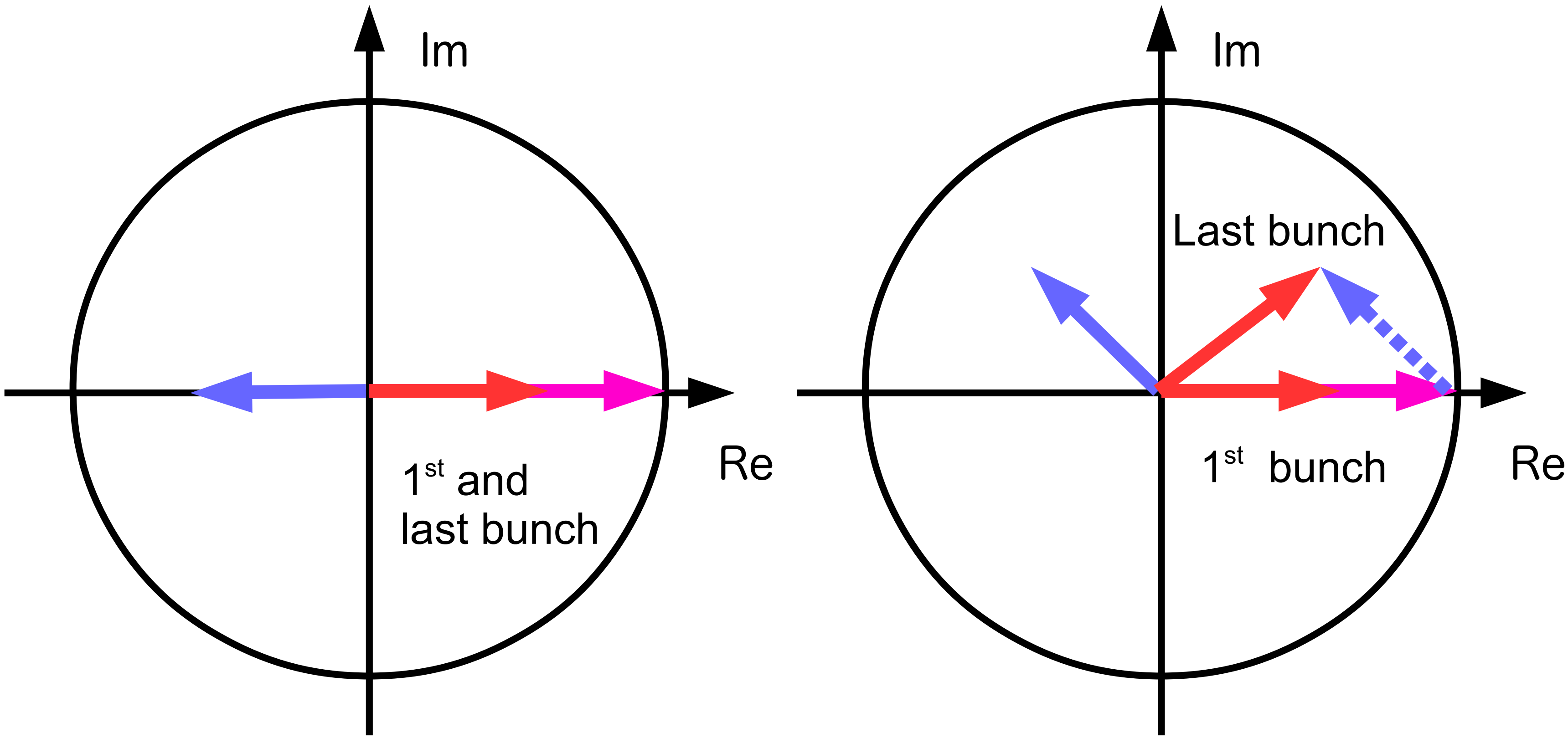
[1] *Corresponding to 300Hz operation*

OPTIONS: Integration of …

- Solenoid Power Supply
- Ion Pump Power Supply
- RF Drive amplifier
- Cooling of Klystron (Collector, Body), Solenoid
- All diagnostics and interlocks

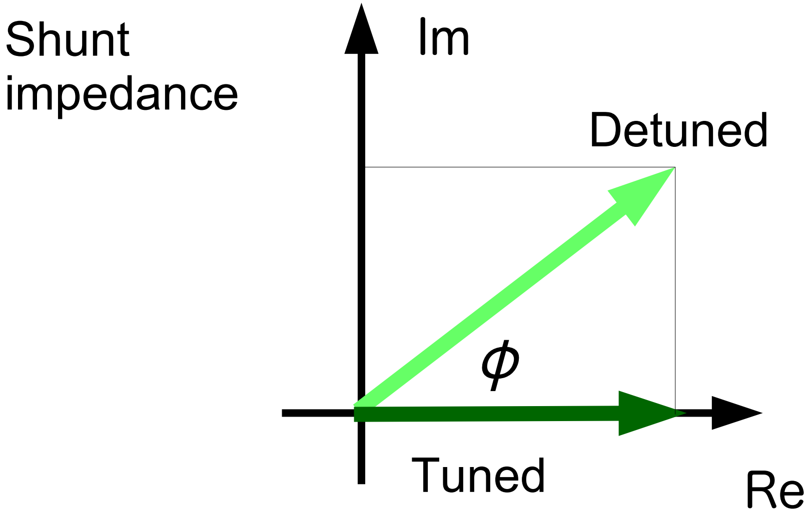
Beam Loading Compensation

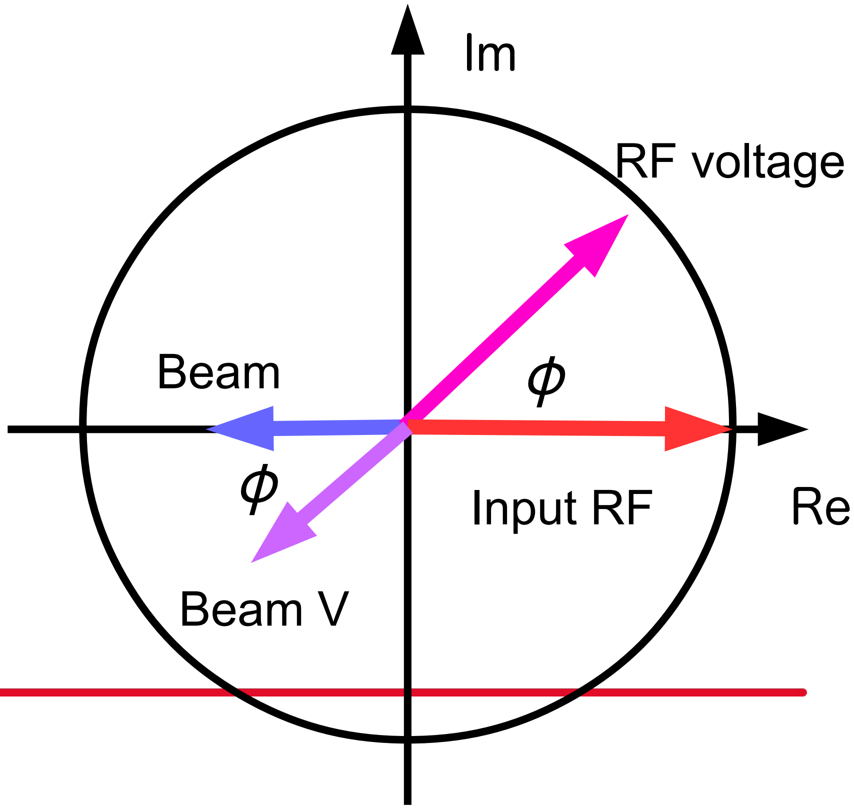
- Beam-loading compensation with Δt method is assumed.
- It works well, if RF and beam is in-phase (same phase).
- It cause phase and amplitude variations if they are off-phase.



Beam Loading Compensation

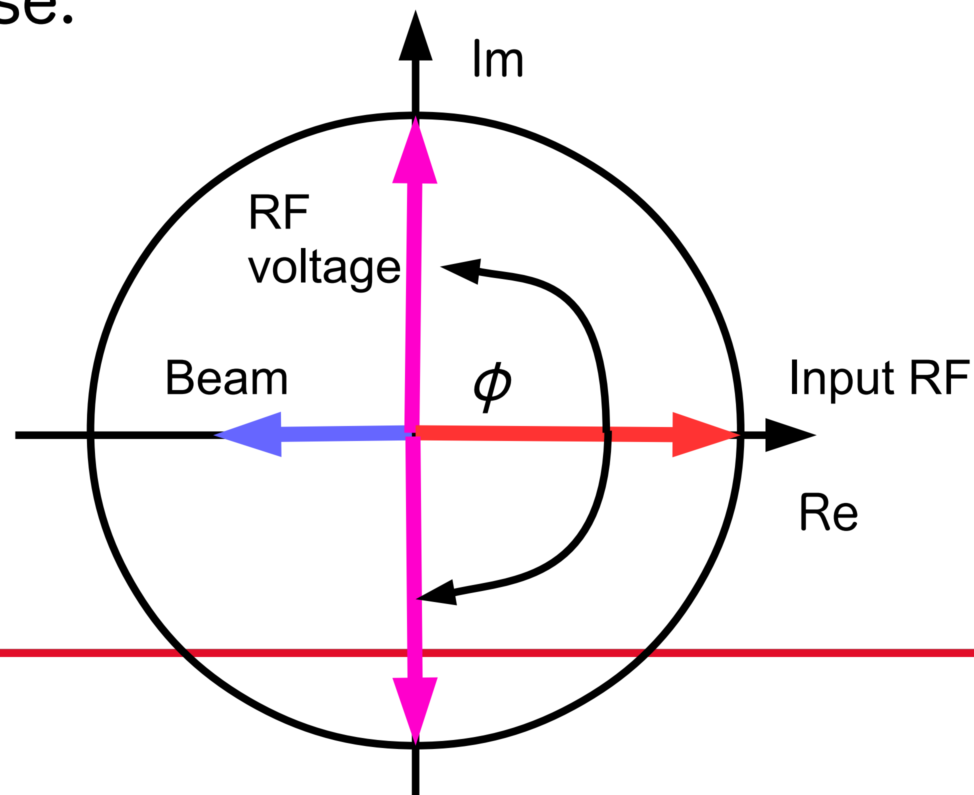
- The off-phase beam-loading can be compensate by introducing a detuning angle, ϕ.
- Source (RF input and Beam) and induced voltage (RF voltage and Beam loading voltage) are off phase, with the angle ϕ.
- Since the voltages are in-phase, the beam loading compensation works.



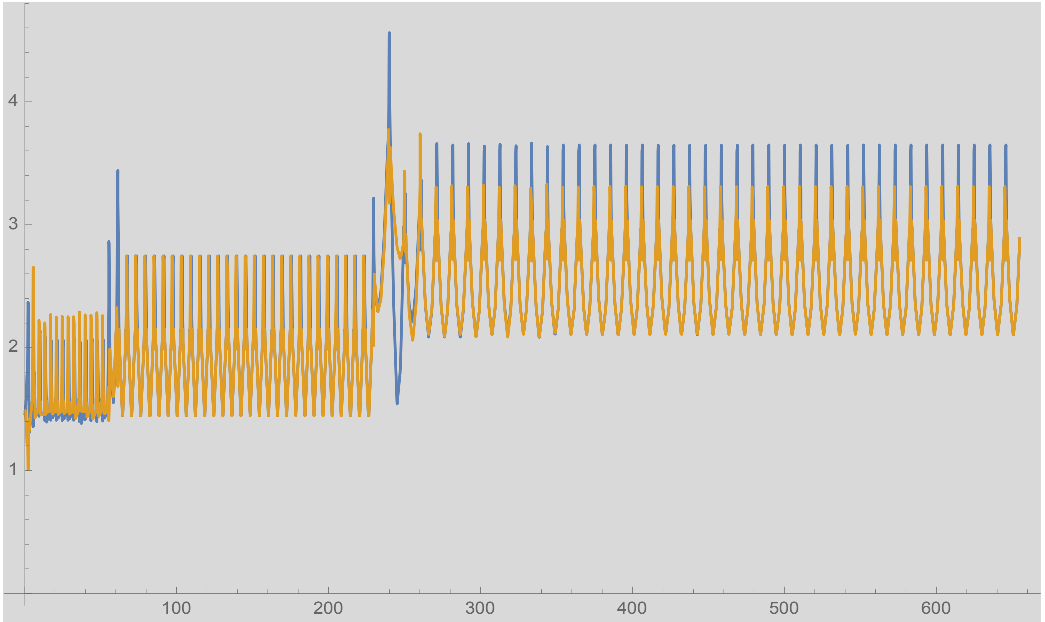


Beam Loading Compensation

- The detuning angle can be controlled by temperature.
- To detune $\pi/2$,
  $$\Delta T = \frac{f}{Q f \alpha} = \frac{1}{3.0\times 10^{4}\times 16.8\times 10^{-6}} = 2.0\,\mathrm{K}$$
  - Q=3.0e+4,
  - α=16.8e-6 thermal expansion coefficient of copper
- The deceleration phase can be obtained with the reverse input RF phase.



Booster



- A f irst half is implemented by L-band acc. and the last half is by S-band.
- 50MW L-band Klystron drives two L-band acc. (2a = 34 mm).
- 80MW S-band Klystron drives two S-band acc. (2a = 20 mm).

Lattice config.	N. of cells	Acc. energy	Energy at the exit	cell length	section length
4Q + 1L	14	243 MeV	493 MeV	3.8 m	53.2 m
4Q + 2L	29	1009 MeV	1502 MeV	6.0 m	174 m
4Q + 4L	18	1252 MeV	2754 MeV	10.4 m	187.2 m
4Q + 4S	26	2345 MeV	5099 MeV	10.4 m	270.4 m

Capture Simulation

- GEANT4 : 1000 3GeV electrons on target for positron generation.
- GPT : In the capture linac, the positron is decelerated and bunched at the acceleration phase by phase-slipping.
- SAD : Chicane improves the bunch length (bunching).
- SAD : Crest acceleration in booster.
- SAD : ECS improves the yield.

Yield Optimization

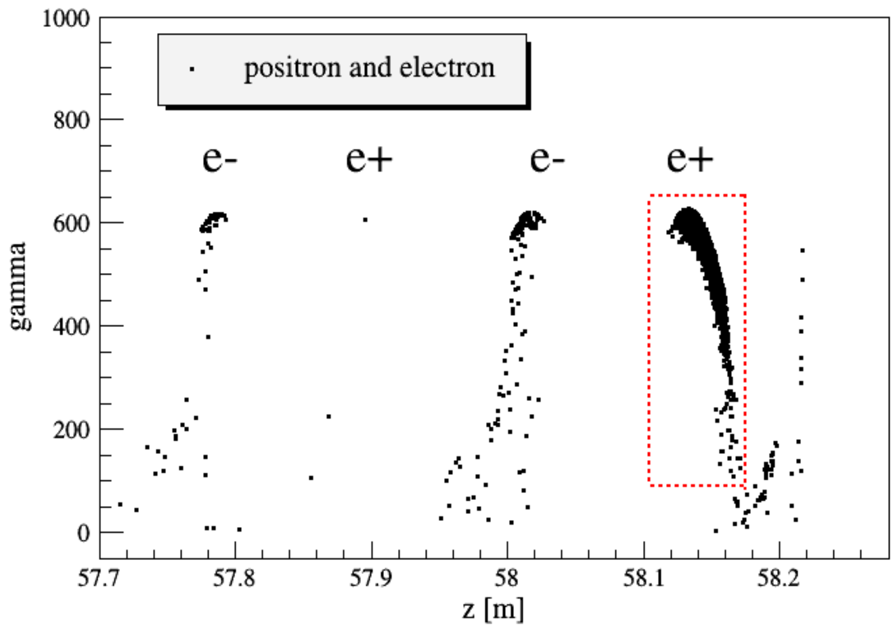
- Yield is determined as number of positron per electron in DR acceptance.

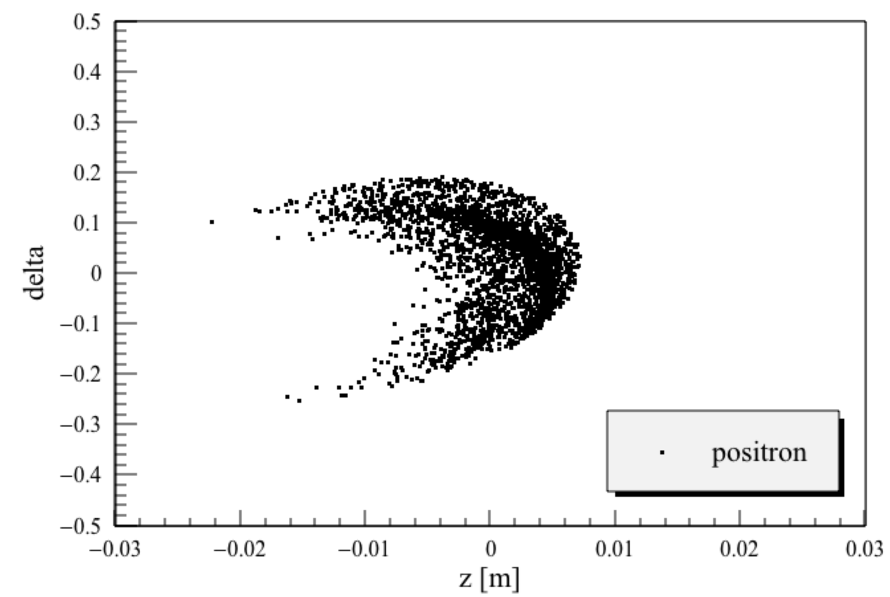
$$\gamma A_x + \gamma A_y < 0.07 \qquad \left(\frac{z}{0.035}\right)^2 + \left(\frac{\delta}{0.0075}\right)^2 < 1$$

- The positron yield is optimized systematically with: Capture linac RF phase, chicane angle, booster RF phase, ECS chicane angle and RF phase.
- The optimization was made with several iterations.

Capture RF phase

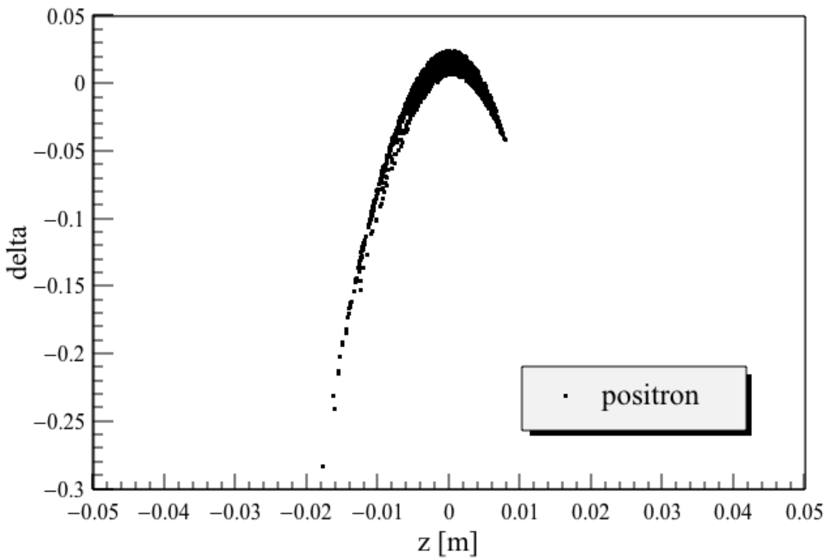
Chicane angle

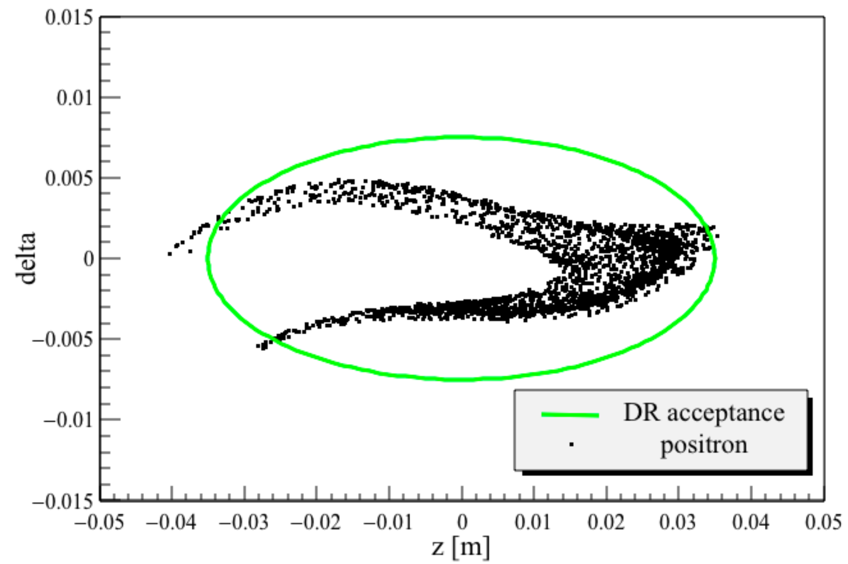




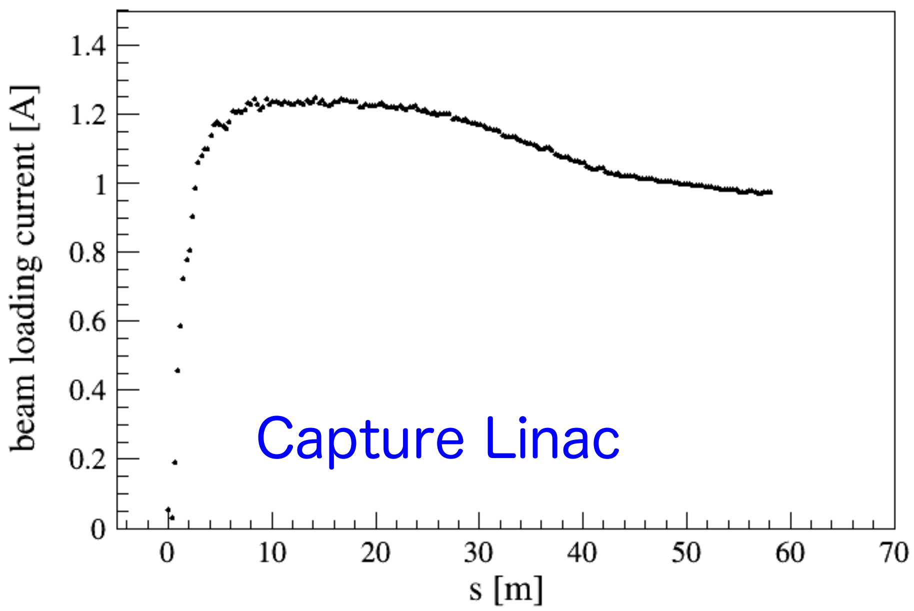
Booster Phase

ECS chicane angle





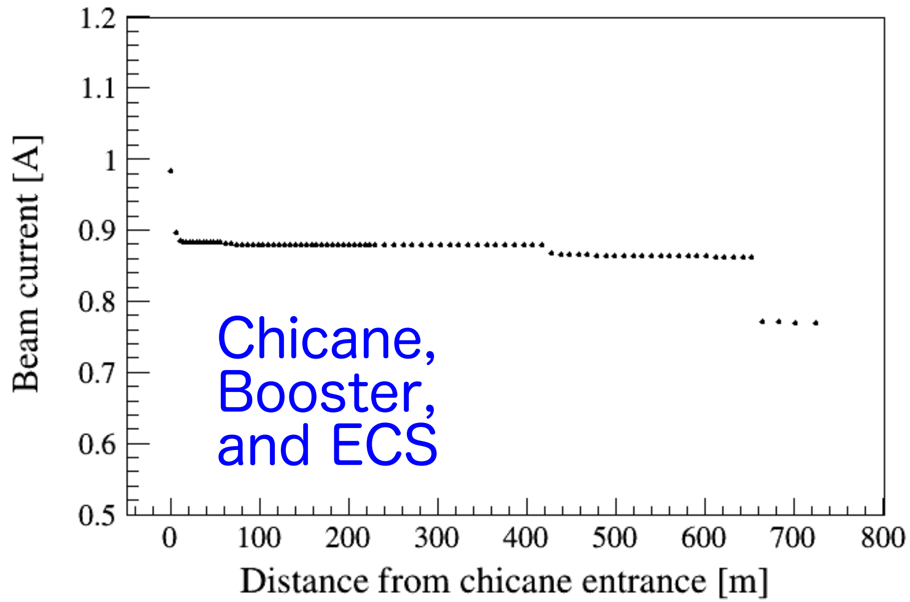
Beam Loading Current

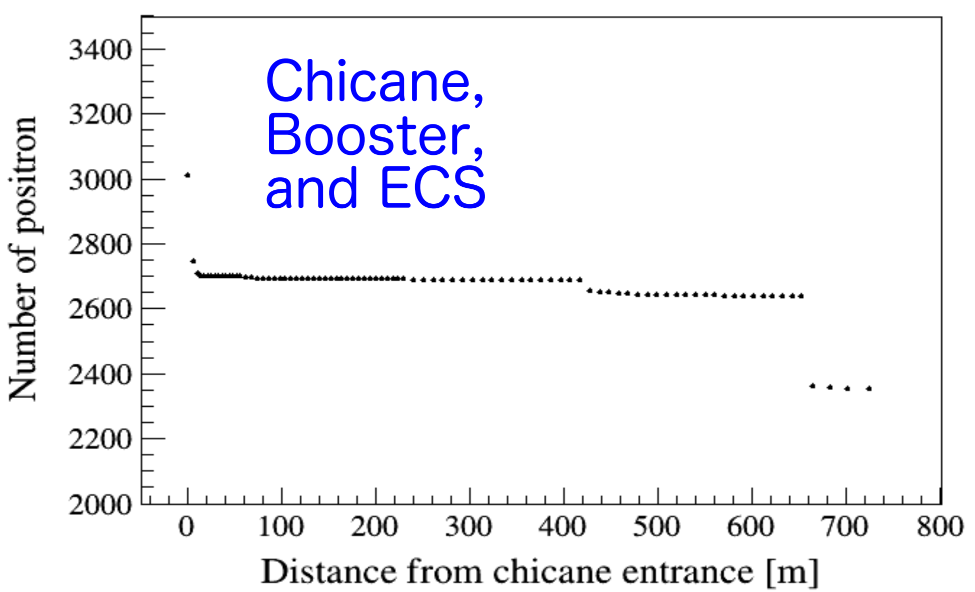


$$I_{BL} = \sum \frac{q}{t_b} \cos(\omega t - kz)$$

$$I_B = \sum \frac{q}{t_b}$$

$$q = \frac{4.8\,nC}{2310}$$





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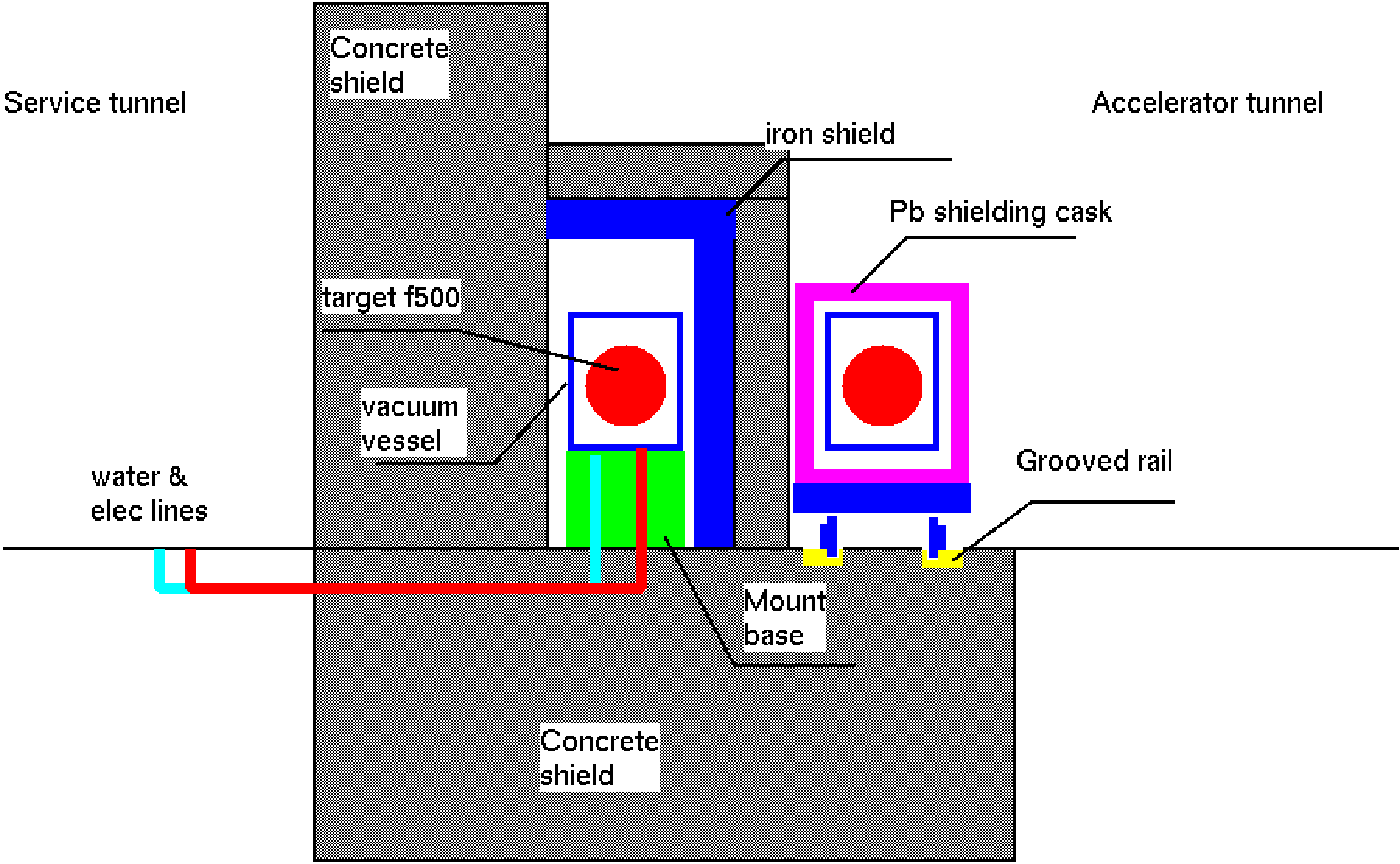
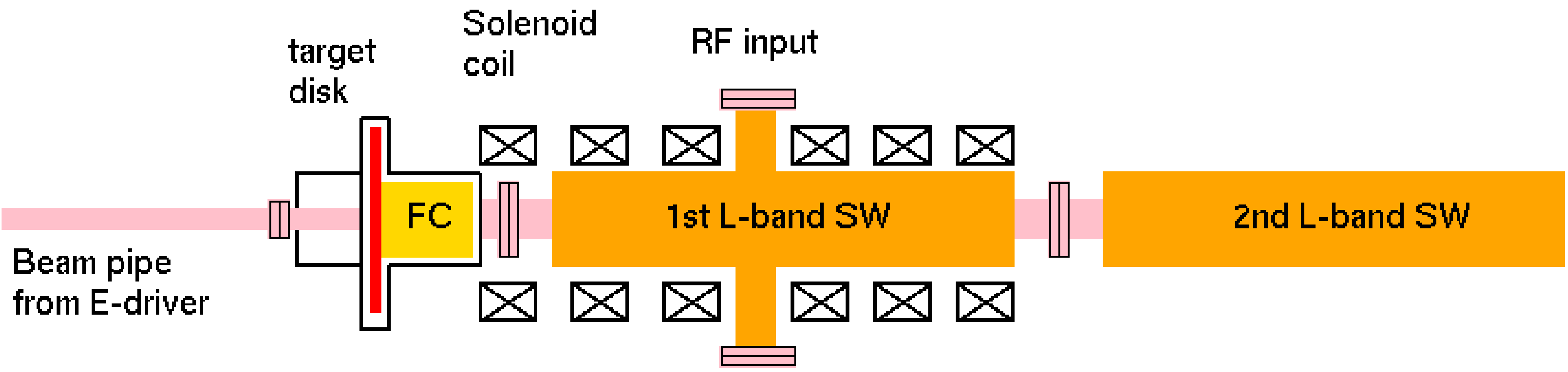
Positron CFS



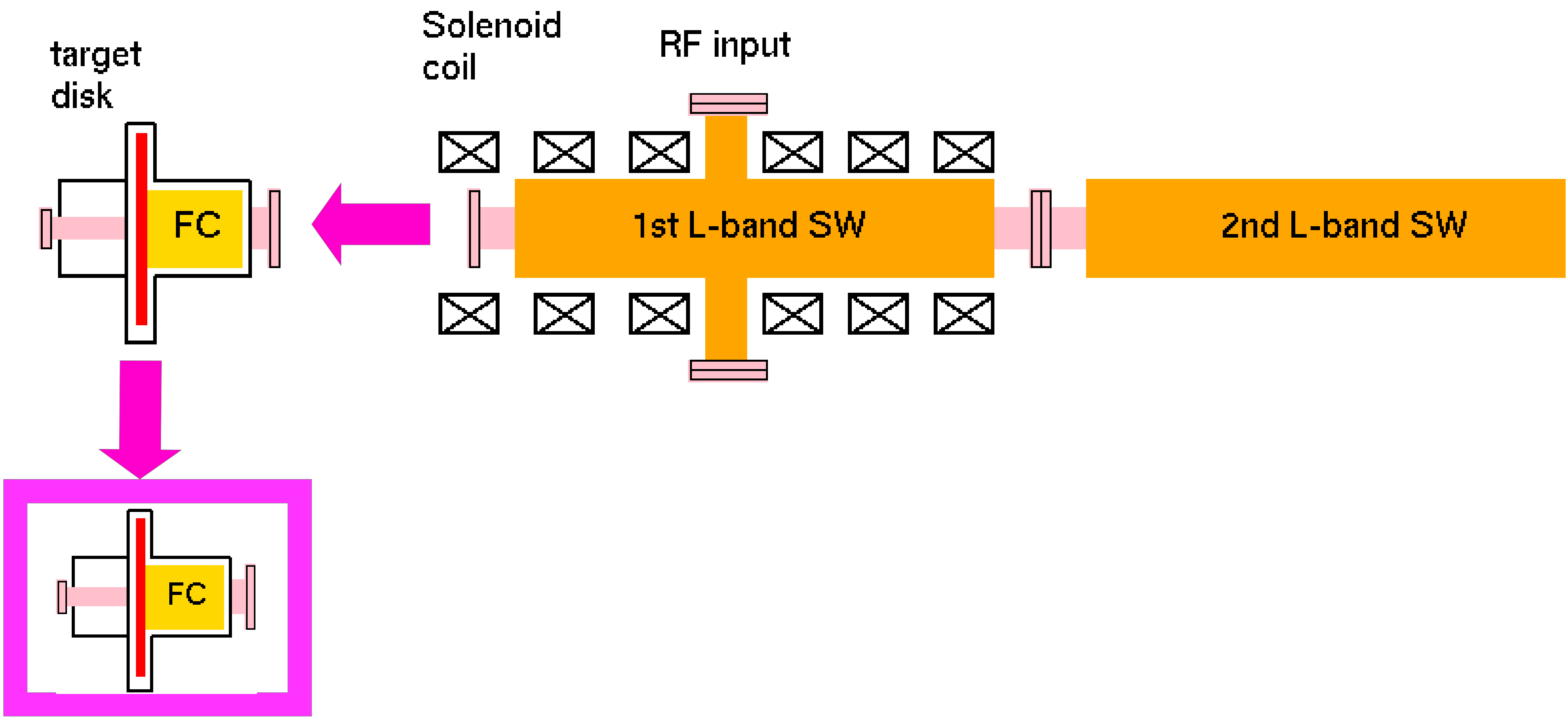
Concrete shield
Service tunnel
Accelerator tunnel
iron shield
Pb shielding cask
target f500
vacuum vessel
water & elec lines
Grooved rail
Mount base
Concrete shield

Top view of the target station

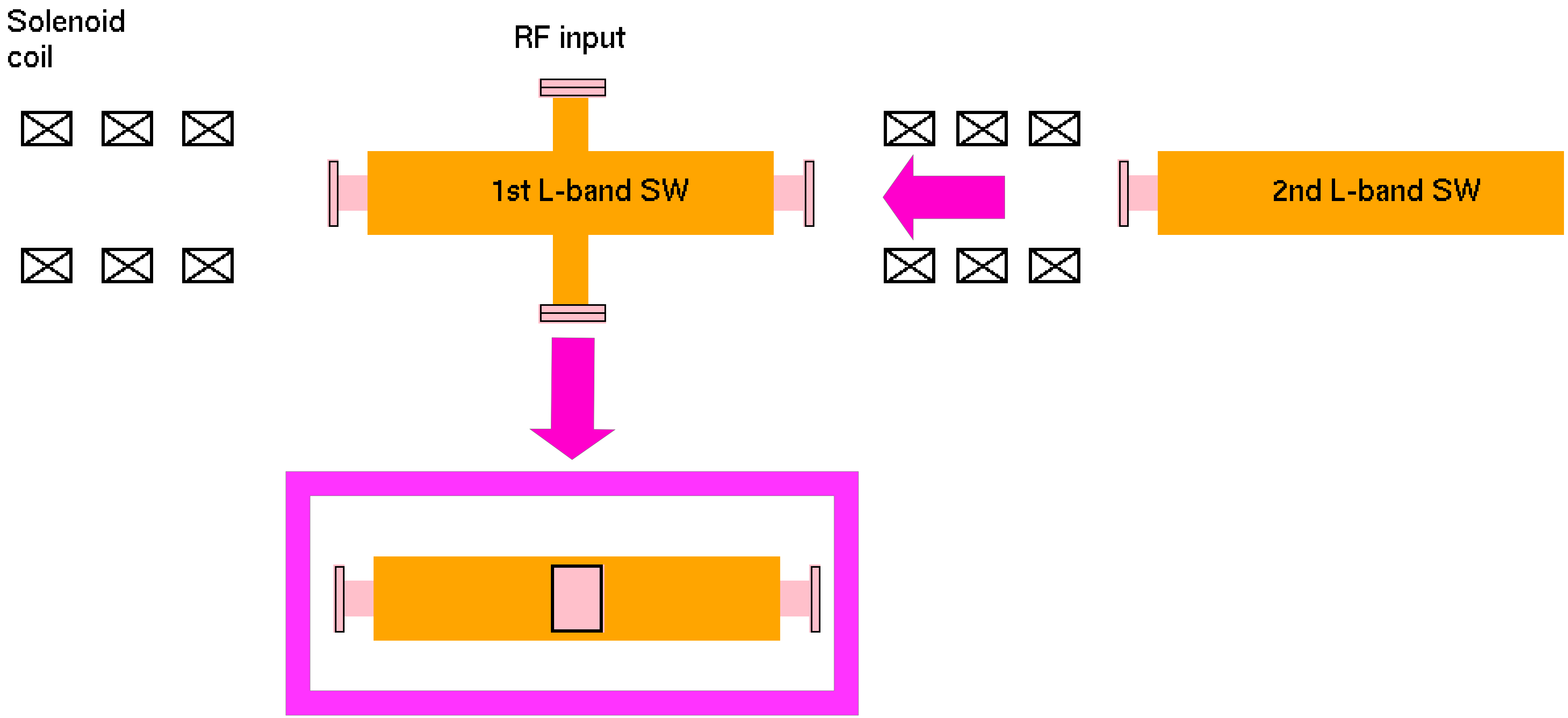


RF input is shown in horizontal direction for easy to see.
It is in vertical direction.

- The beam pipe from the E-driver should be removed.
- The target module is moved to upstream, and then uninstalled.
- The module is packed in the cask.



- Similar actions to uninstall the 1st RF.

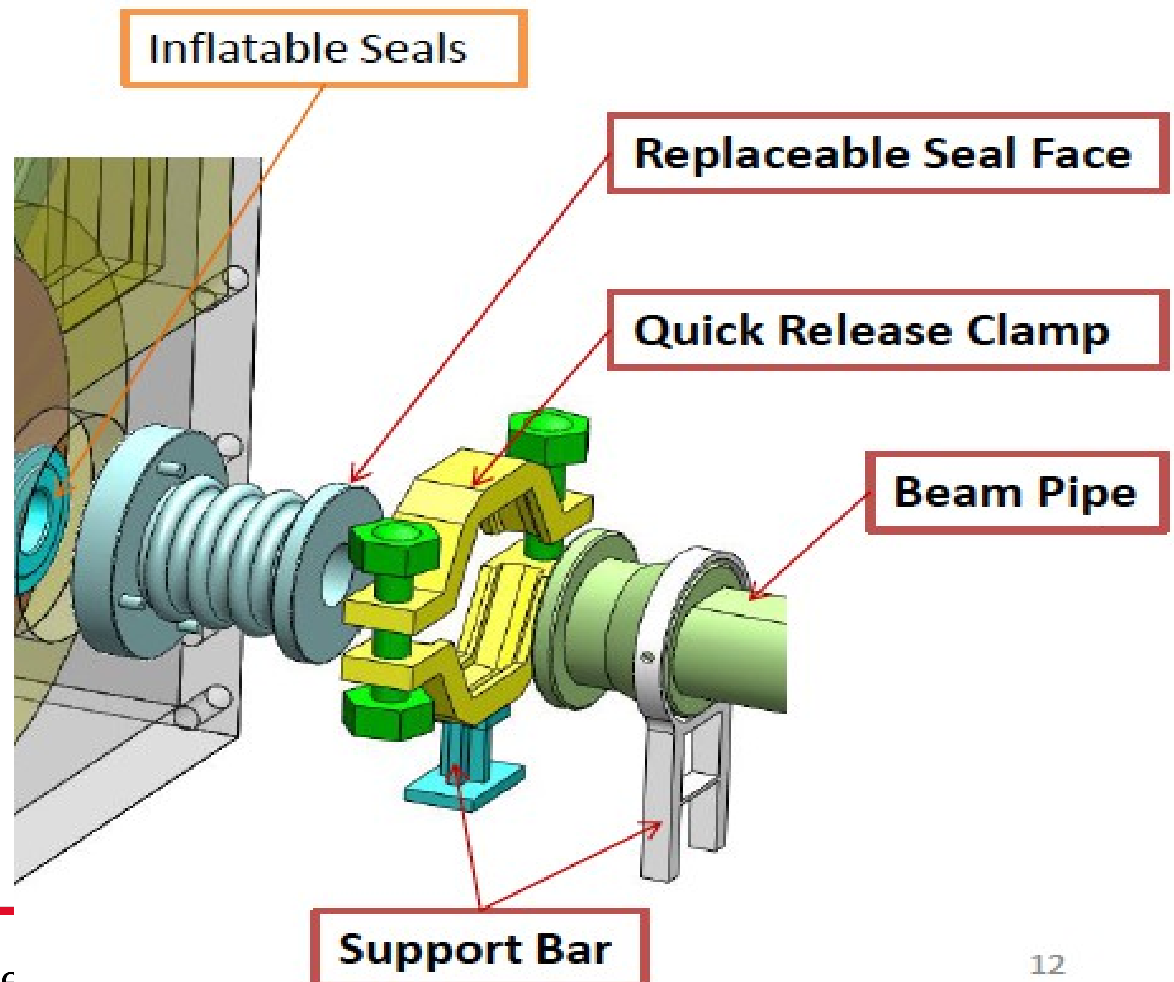


Electric and water Joints

- Electric and water joint should be remotely connect and disconnected to the target module and the 1st RF.
- One-touch joint with a positioning mechanism can be solution.

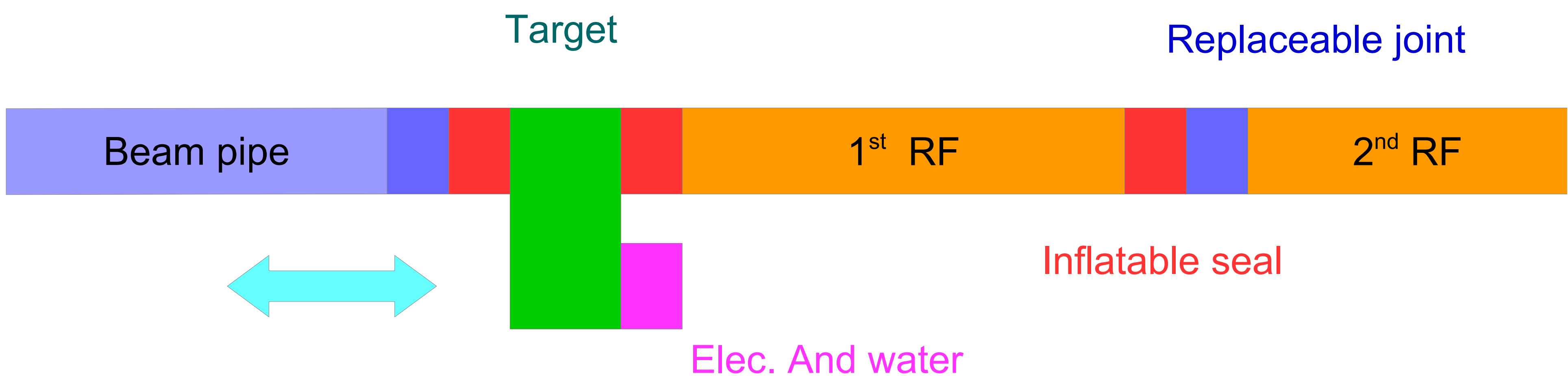
Vacuum connections

- Vacuum connection can be made with a inflatable seal.
- Positioning is required.
- Radiation damage?
- Leak check?



Single action connection

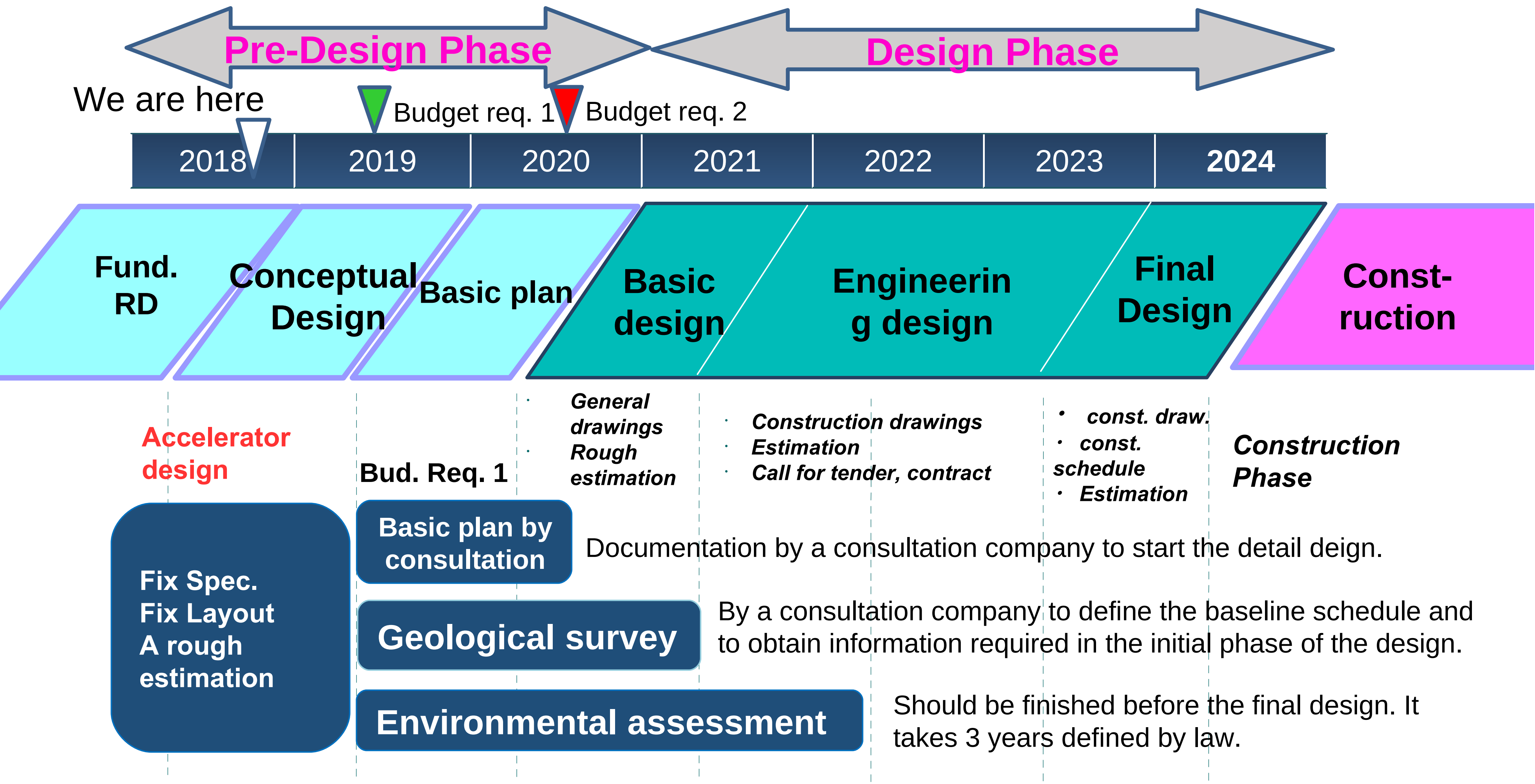
- To simplify the action and improve the reliability, a single action connection (vacuum, water, electric, RF connection) is desirable.
- Easy for electric and water joint.
- Inflatable seal with a replaceable joint for vacuum.
- RF could be difficult.



RF connections

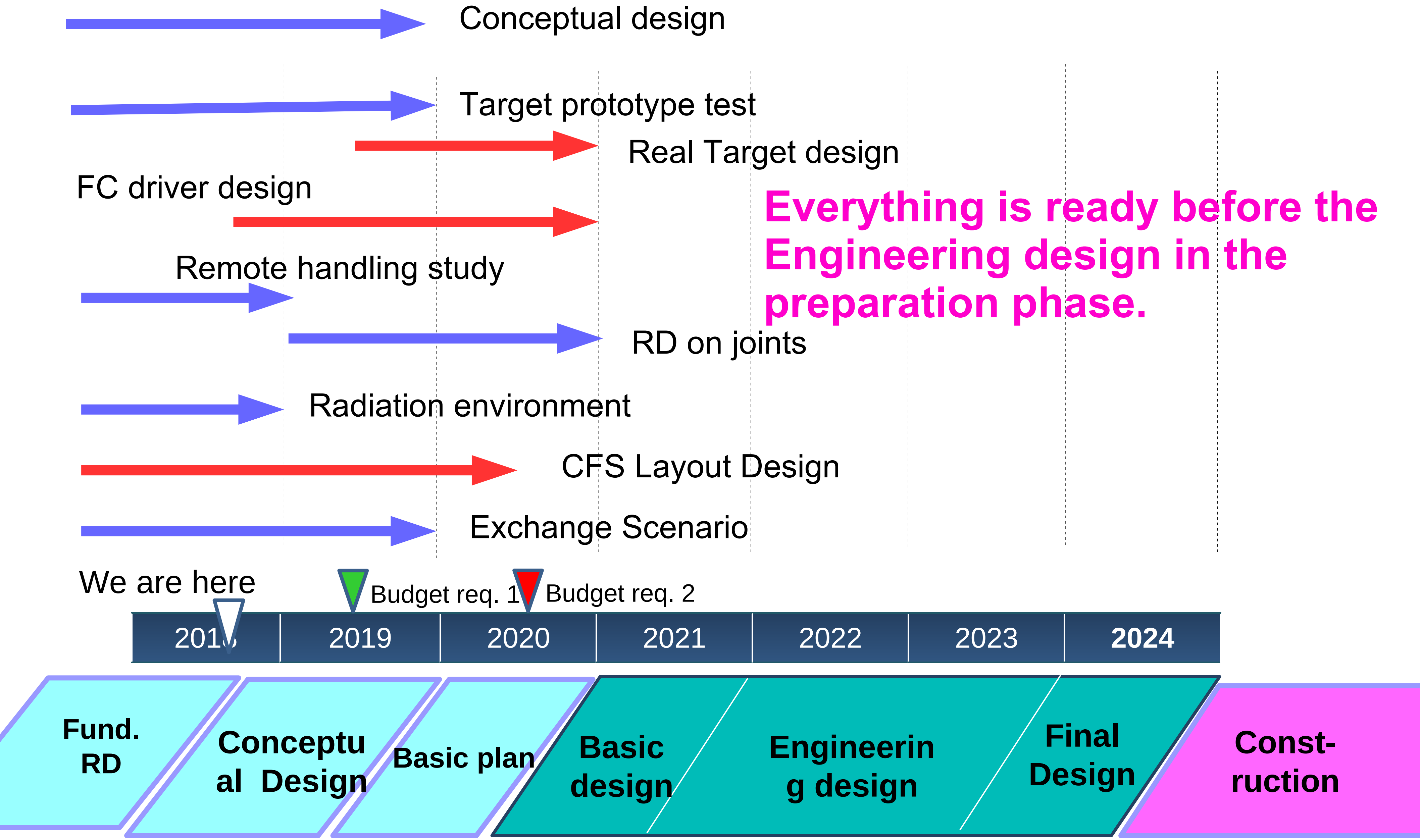
- Disconnection of the RF WG to the 1st RF should be remotely done, but might be not for connection, because the radiation dose could be limited.
- Connection can be manually done.
- Disconnection should be remotely done.
- Remote disconnection is much easier than the connection, because a precise positioning and tight pressure is not required.
- If the shield activation is too high, the scenario does not work. We might need a special shield, or full remote connection.

An Expected Schedule on Pre- and Design Phase



English translation by M. Kuriki
The slide is originally made by Y. Miyahara (CFS Group).

An Expected Schedule on Positron Source Design



Summary

- E-driven ILC positron source is optimized for 250 GeV ILC.
- Off-phase beam loading is compensated by introducing the detuning angle.
- By re-optimization, the yield is improved by 15 %.
- For remote handling, vacuum, water, and electric connections can be remotely done.
- RF connection can be manually connected, and remotely disconnected.
- We are finishing the fundamental R&D and finalizing the conceptual design.
- Move to technical and engineering designs.

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