CFS and Target Maintenance for ILC Positron Source

ALCW2018

LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

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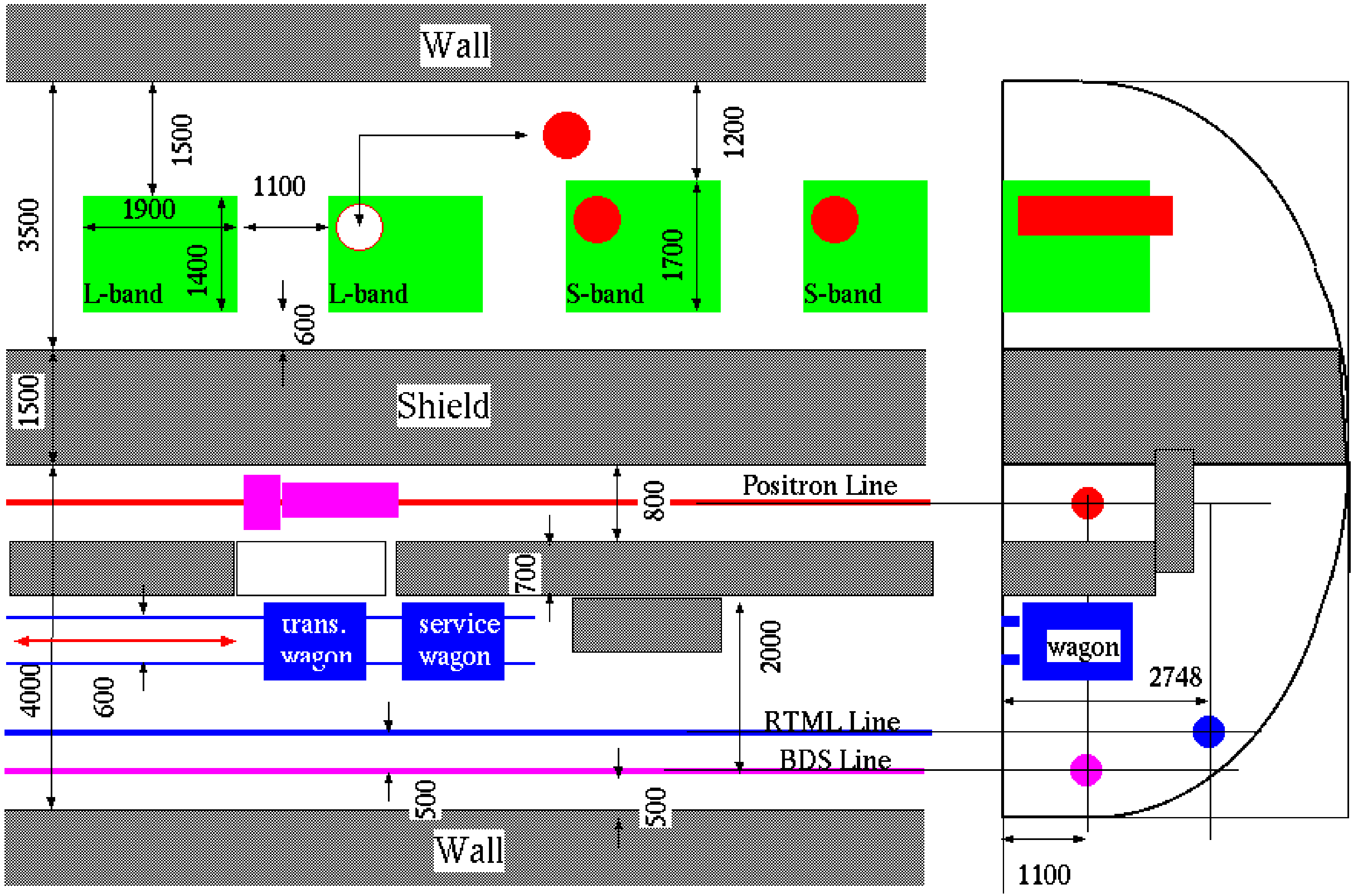
Introduction

- Positron generation target is highly activated after the operation.
- The maintenance of the target should be remotely done, otherwise, we have to stop the operation for a long time.
- CFS design depends on the maintenance scenario of the target and it should be fixed with a reasonable accuracy before the design;
  - How to install the new target.
  - How to uninstall the used target.
  - How to replace the target.
- Most of the studies can be shared between the two positron source concept, i.e. E-Driven and Undulator.

Target Layout



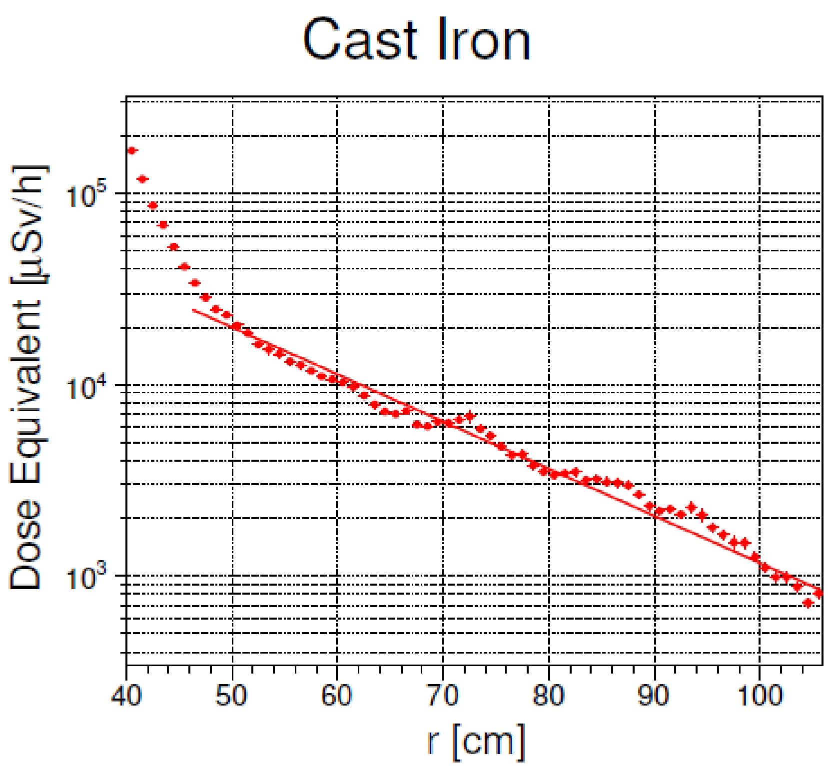
Radiation shield

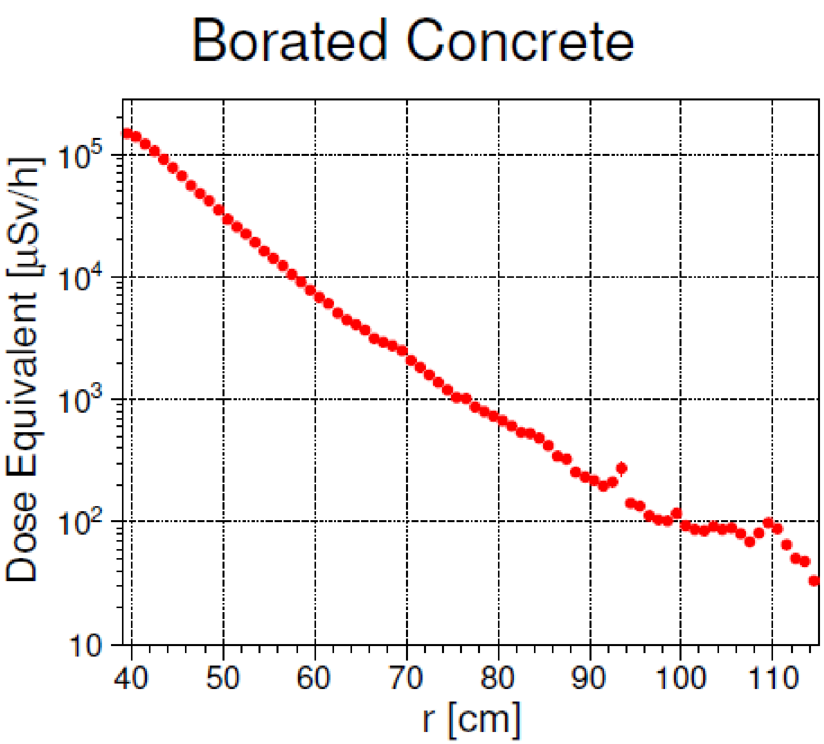
- **The design criteria for the radiation shield will be determined according to the safety policy.**
- **The safety policy should include**
  - ALARA principle,
  - Radiation safety law,
  - Protection for equipment,
- **<5 mSv/h during operation in the bedrock to avoid a significant activation for environment.**
- **<20 uSv/h in the work area (tunnel) during maintenance period. (according to Terunuma's report)**

Radiation shield

- 1500mm concrete shield to the service tunnel is assumed. It is same as it in ML.
- 700mm iron + concrete shield to the accelerator tunnel (RTML and BDS) is assumed.
- The radiation dose without beam is dominated by activation of the shield. The configuration should be studied. Iron + concrete is a working assumption.
- The radiation shield on the floor (2m?) to prevent potential activation of bedrock.
- Air control?

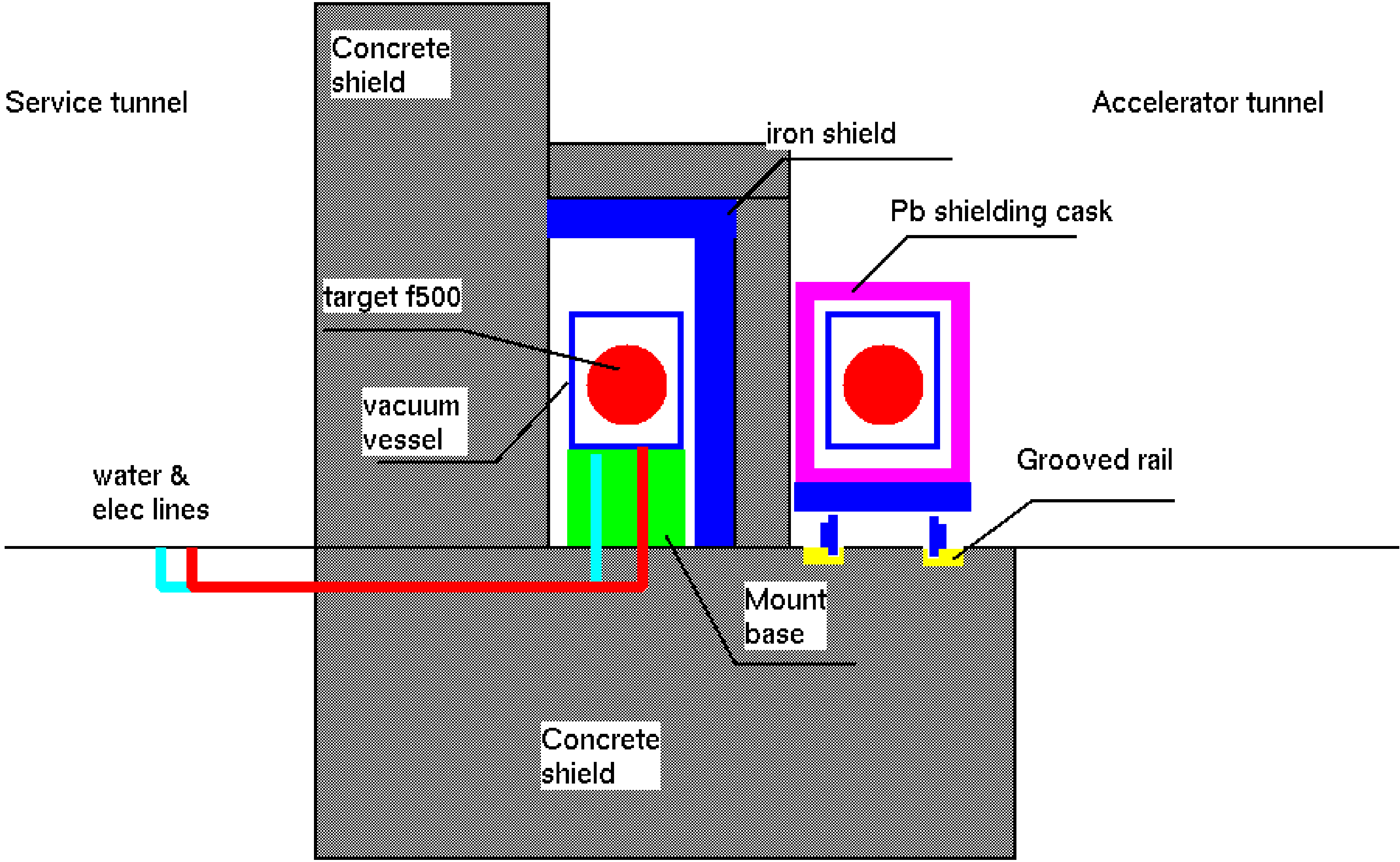
Borated Concrete vs Cast Iron





Borated concrete with **75 cm** thickness reduces rate of dose equivalent (averaged over 1 m in z-direction) to **30 μSv/h** after 5000 hours of source operation and 1 hour cooling

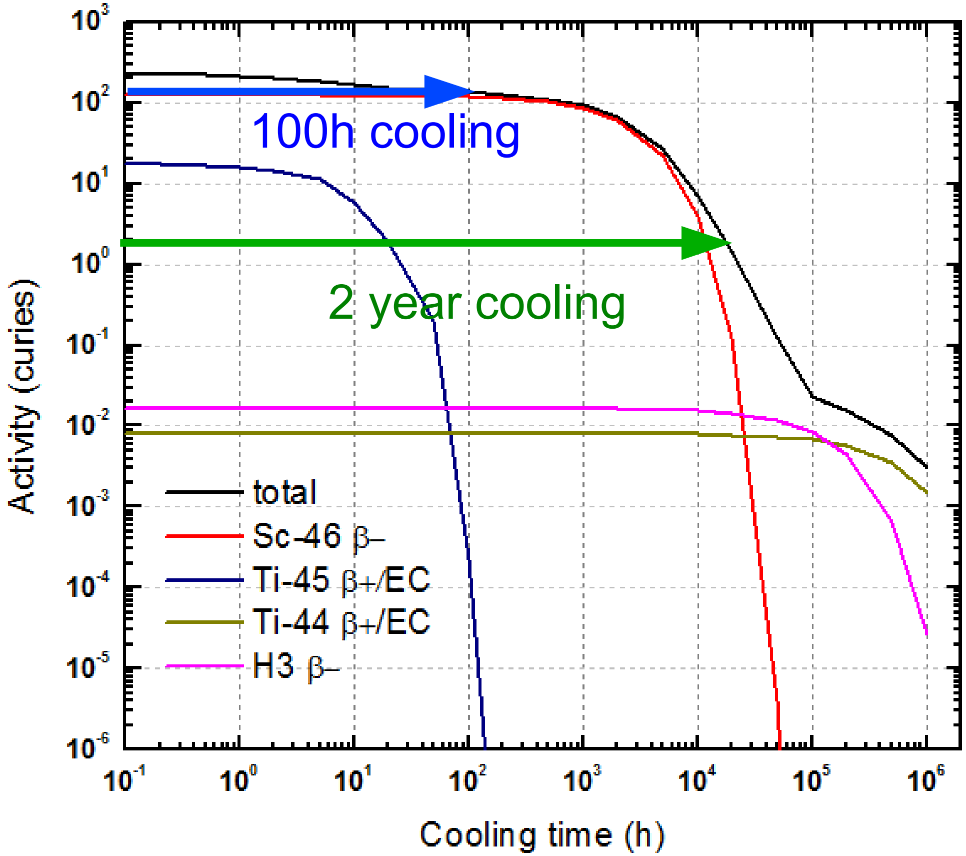
My suggestion is to use 1 m borated concrete to have some safety margin.


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

Activation and cooling

- After 5000h operation with 150kW photon beam and 100h cooling time, total activity is 100 Ci (7.4e+12 Bq).
- After 2 years, 2 Ci (7.4e+10 Bq).
- Activation with electron beam should be evaluated, but it could be similar (Takahashi, ECFA LC 2016).

5000h, 150kW



Target Shielding :

- 70mm Pb (600 mm concrete) for shielding cask.
- With the cask, 10μSv/h 100 h after the operation; it is acceptable for a short work in acc. tunnel.
- It goes down to 0.1 μSv/h after 2 years. it is acceptable in service tunnel.
- But, it is hard to handle without the cask.

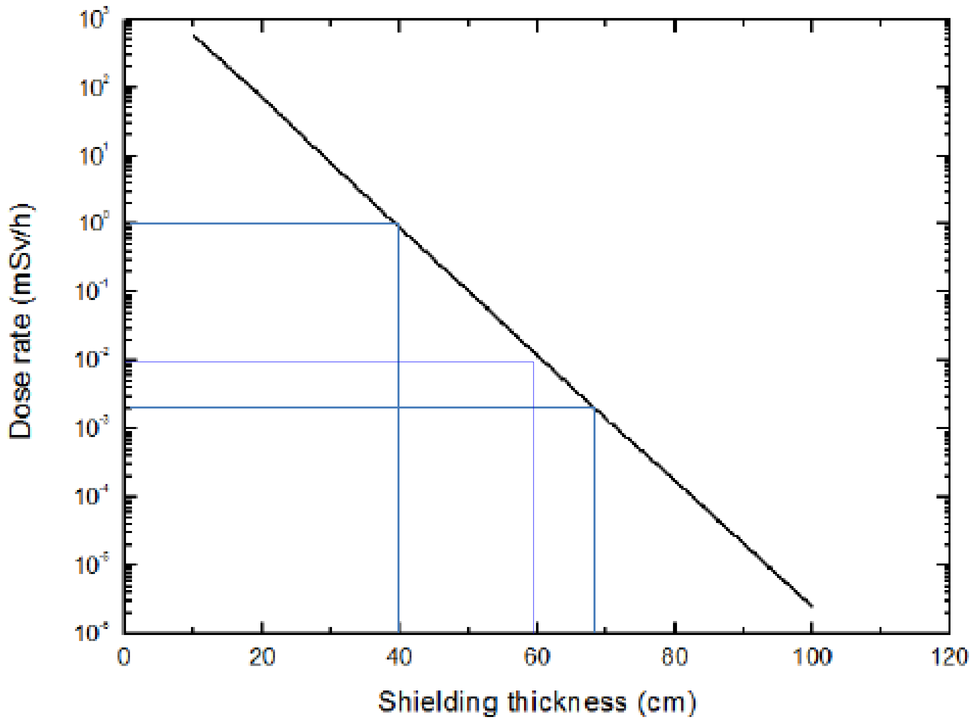
Codes and libraries

MCNPX2.5.0, CINDER90,

libraries:mcplib04, e103, endf60

Target: Ti-6%wtAl-4%wtV, density 4.5g/cc

Magnetite concrete: density 3.53 g/cc



Target Maintenance Scenario

- The target module contains: target, rotor, FC, vacuum vessel, but no RF; It is replaced with the remote handling.
- The first accelerator should be replaceable with the remote handling system, but separately.
- The target and 1st RF should be stored and packed in the cask remotely.
- No man access to the area with the target and 1st RF.
- Other maintenance can be made without remote handling when the target and 1st RF are removed. It is done by removing the concrete shield.

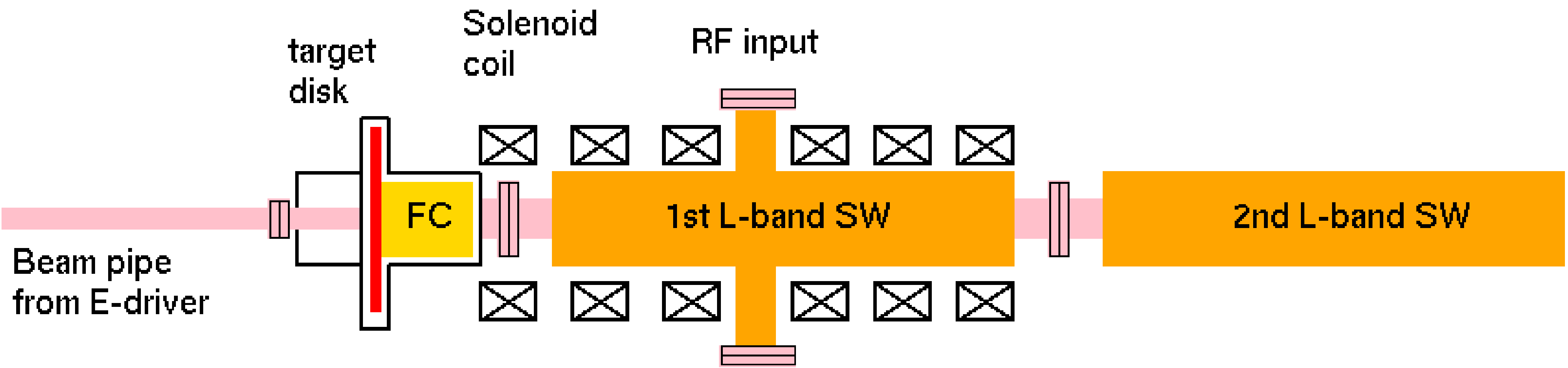
Overhead Crane at the Target Station

- 1.0x0.5x0.75 m steel top plate : 3.0 ton.
- 1.0x1.6x0.75m steel side shield : 10 ton.
- target and 1st RF < 1.0 ton.
- 10 ton crane is OK for the target station.
- It could be less with smaller blocks.

Connections

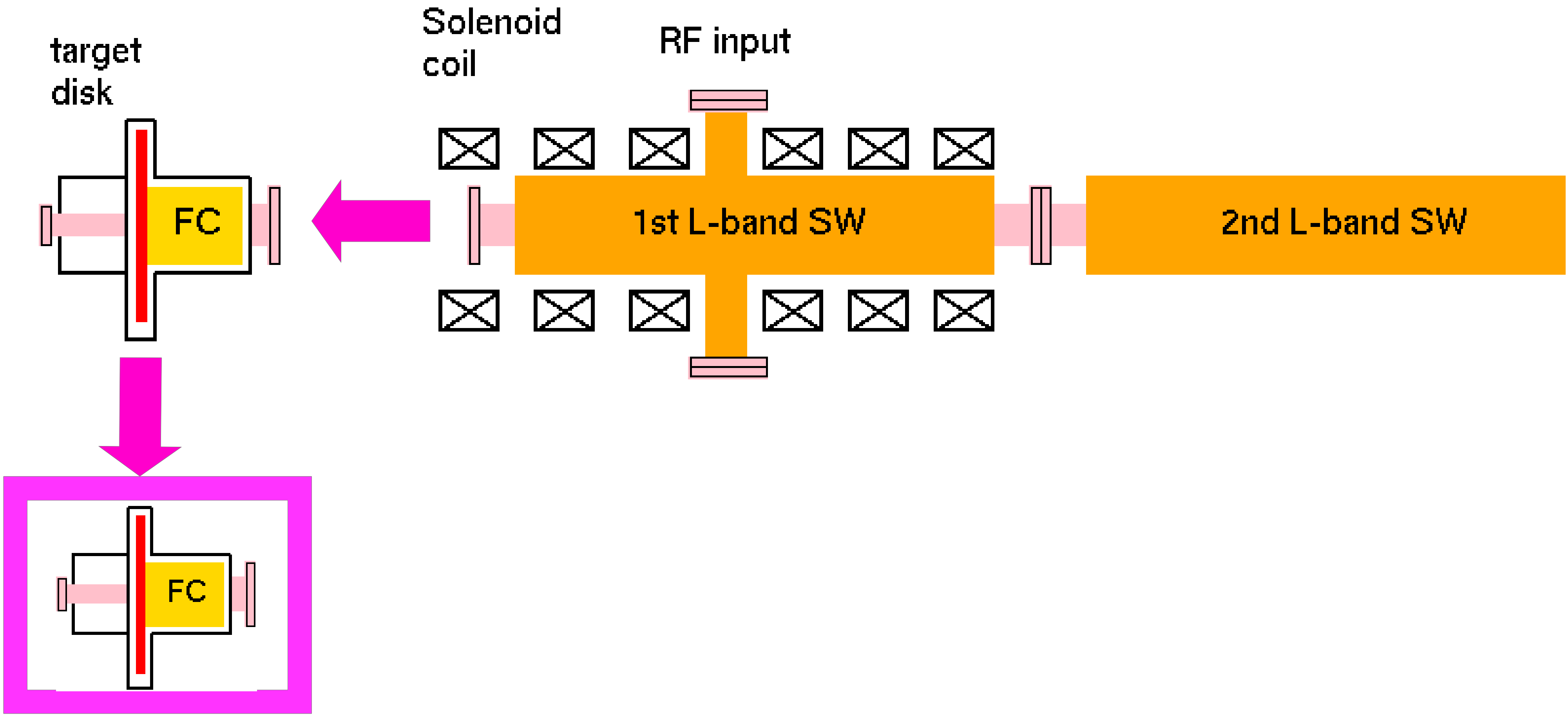
- **These lines should be connected and disconnected remotely.**
  - Vacuum line, water pipe, electric line for the target.
  - Vacuum line, water pipe, and RF WG for the 1st RF.
- **To install / uninstall them, a part of beam line and the solenoid magnets have to be escaped.**

Top view of the target station

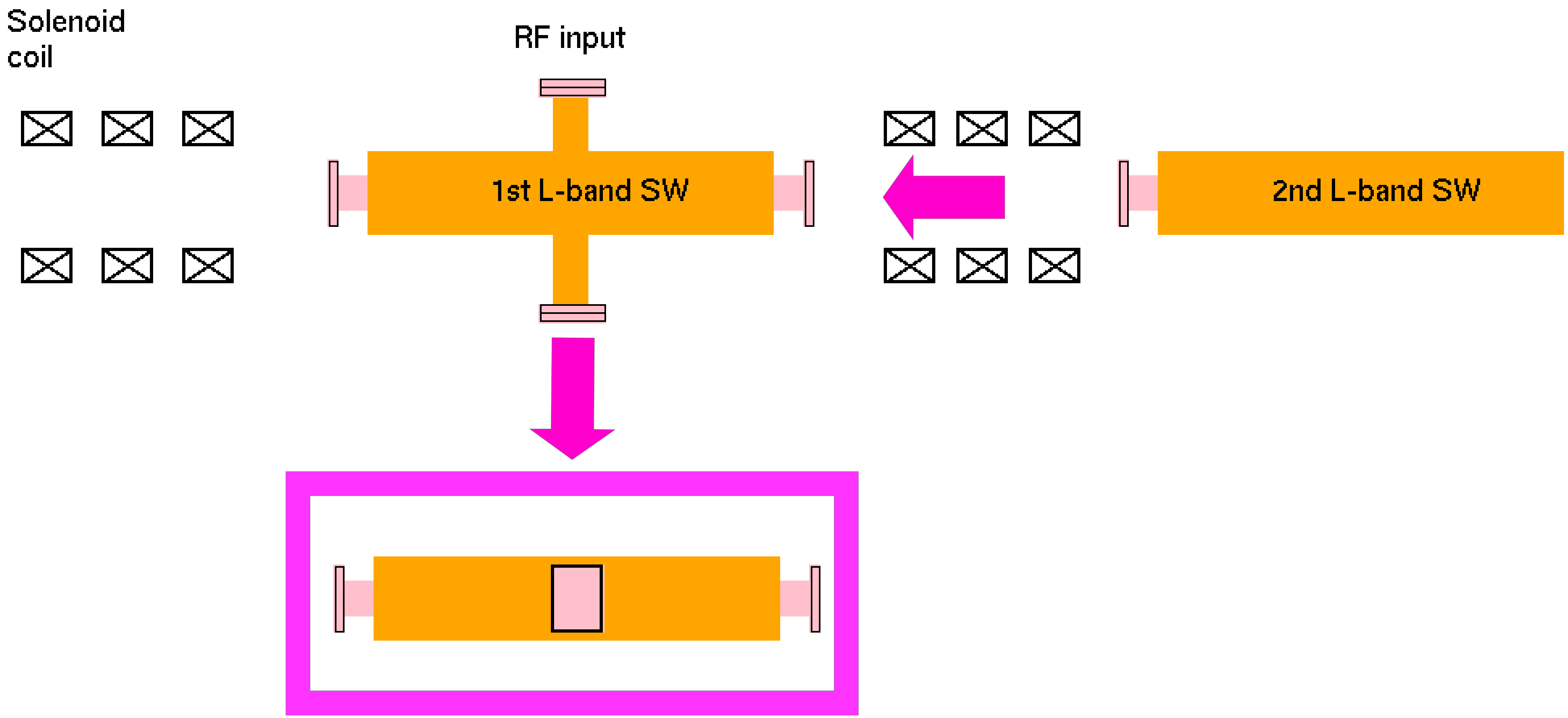


RF input is shown in horizontal direction for easy to see.
It is in vertical direction.

- 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.



Water Joints

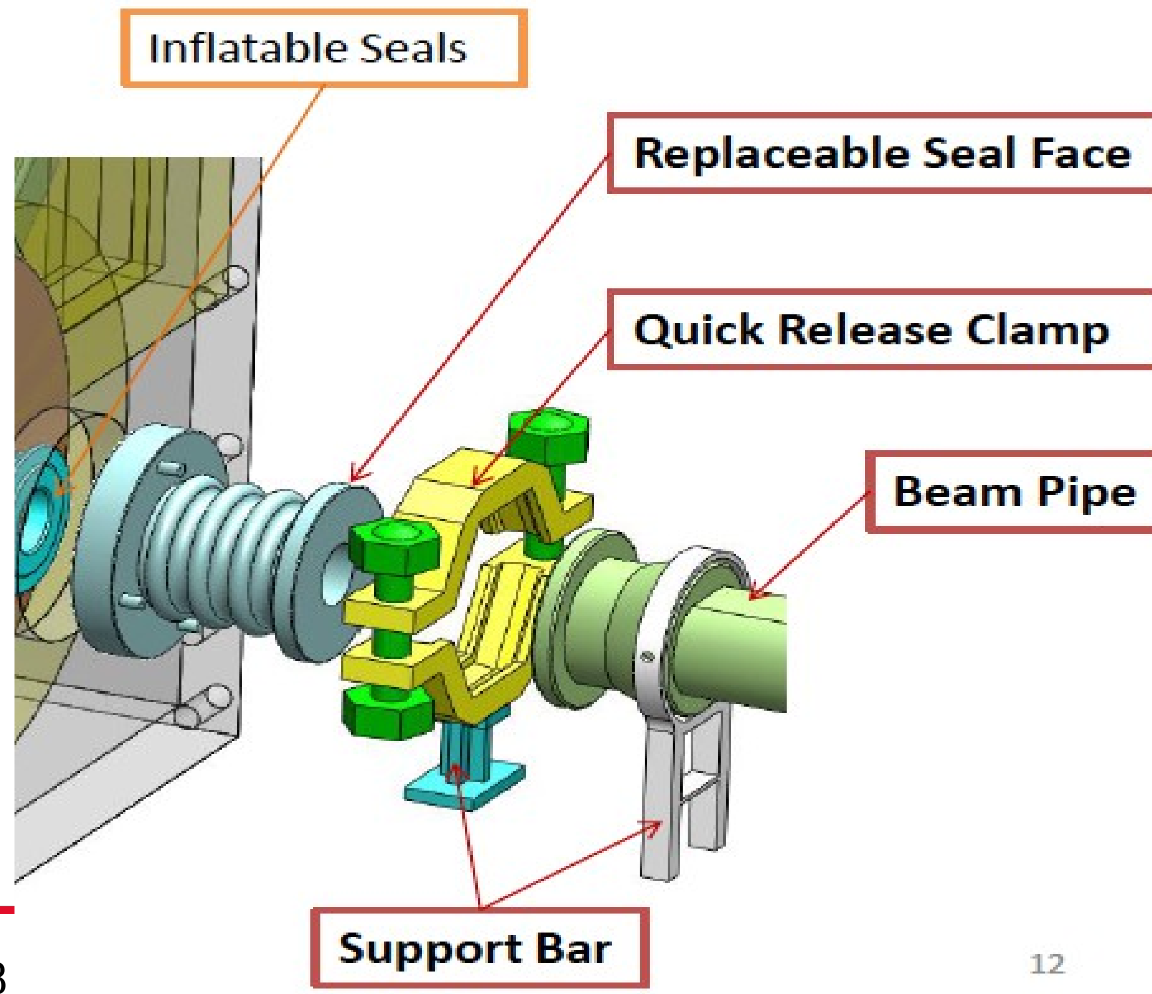
- Water joint should be remotely connect and disconnected to the target module and the 1st RF.
- One-touch joint with a positioning mechanism can be solution.

Electrical contact

- Electric contact (joints) is easy to implement.
- That should contains power lines, control lines, and monitor lines.
- Radiation protection for electric module (motor, controller, etc) should be considered.

Vacuum connections

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



RF connections

- Connection/disconnection of the RF WG to the 1st RF should be remotely done.
- We need a precise positioning to prevent RF discharge by a displacement.
- The contact (clearance) between two joints is also precisely controlled to prevent discharge.
- We need our own R&D?

Target and 1st RF transport

- The target and the 1st RF should be transported with the cask to prevent radiation exposure.
- 70 mm Pb shield (800x1500x1200 mm inner size): 9 tons.
- The target and 1st RF < 1 ton.
- The total weight is 10 tons.

Narrow Gauge Train

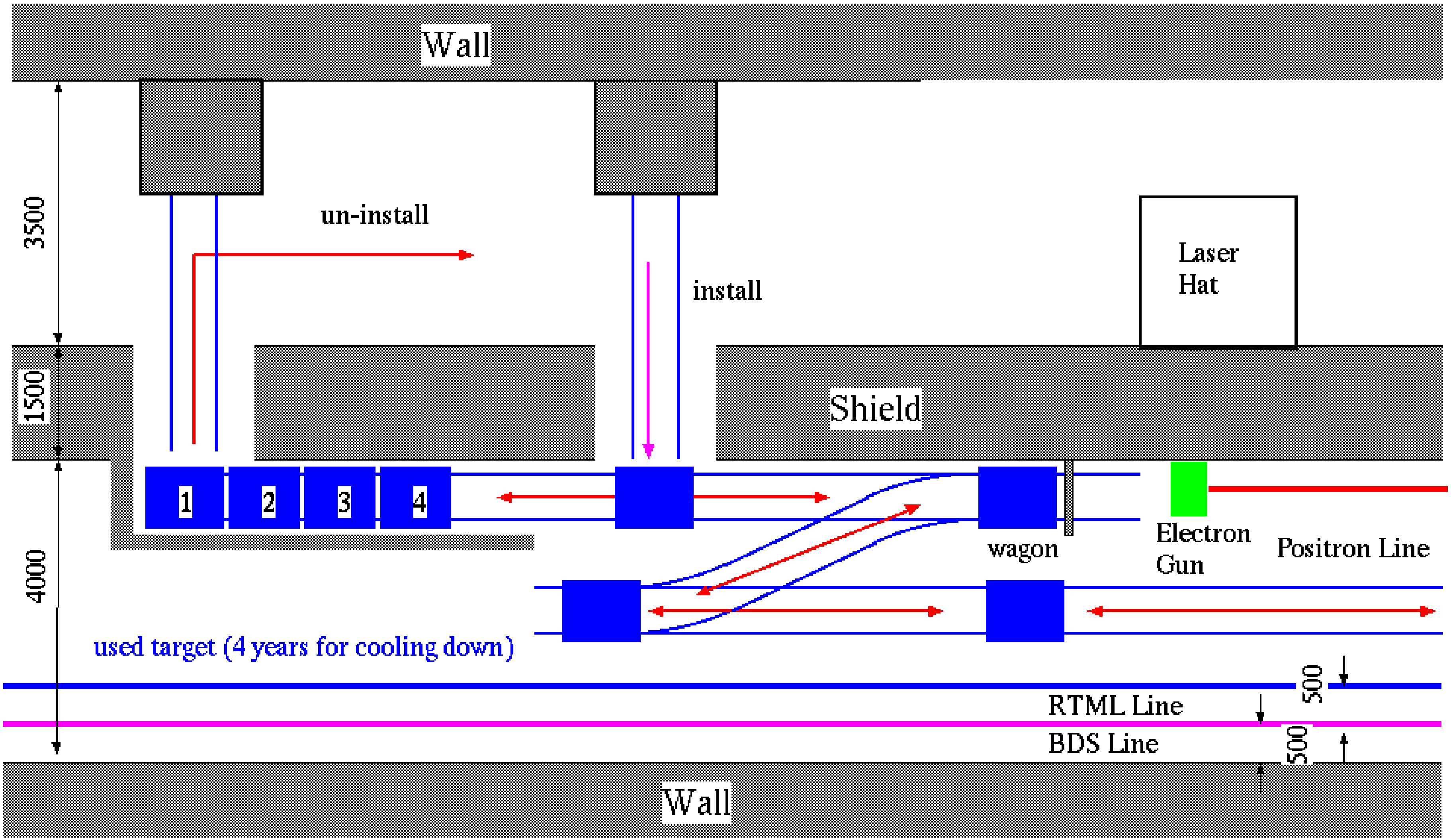
- Narrow Gauge Train is good for the transport.
- 600 mm gauge (like a mine train): 9 ton/axis.
- 2 axis wagon is capable to transport the 18 ton wagon.
- Automatic control wagon is popular, e.g. airport shuttle.

Osarizawa cupper mine
Akita, Japan

Target Handling

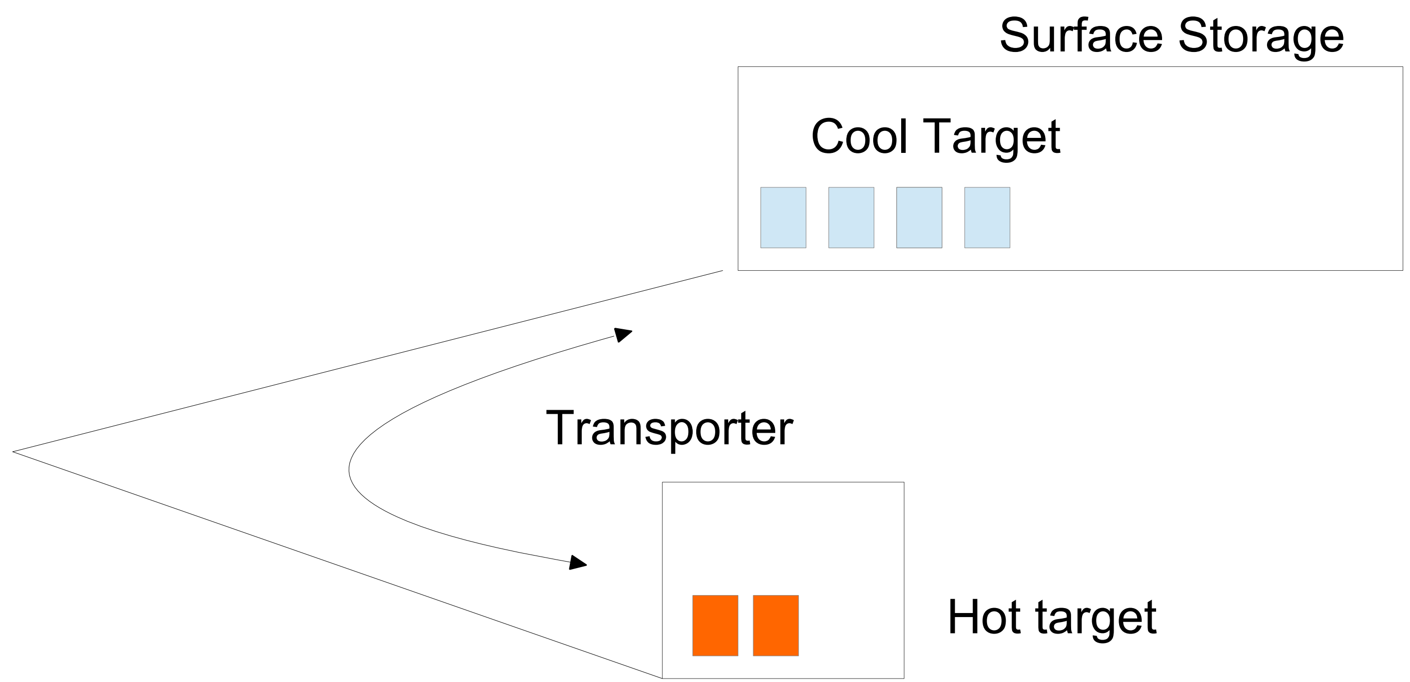
- Target yard is placed at the upstream of the E-driver linac.
- Target is installed / uninstalled from/to the yard.
- The target transportation between the yard and the target station (~250m) is done by the wagon on the rail to avoid any accident to beam lines.
- For the used target and 1st RF, they are handed with 70mm Pb cask.
- The used target is stored in this shape for two years in the yard storage area.
- After the cooling time, the dose is below 1uSv/h at the surface.
- It can be transported through the access tunnel.

Target Yard


Wall
un-install
install
Laser
Hat
3500
1500
Shield
1
2
3
4
wagon
Electron
Gun
Positron Line
4000
used target (4 years for cooling down)
500
RTML Line
BDS Line
500
Wall

From/To the surface

- The access tunnel is very close to the target yard.
- From the target yard, the transporter for the cryomodule can handle the cask (10 tons), because the surface dose is quite low (<1uSv/h) after 2 years cooling.
- The used target after cooling time can be stored on surface.

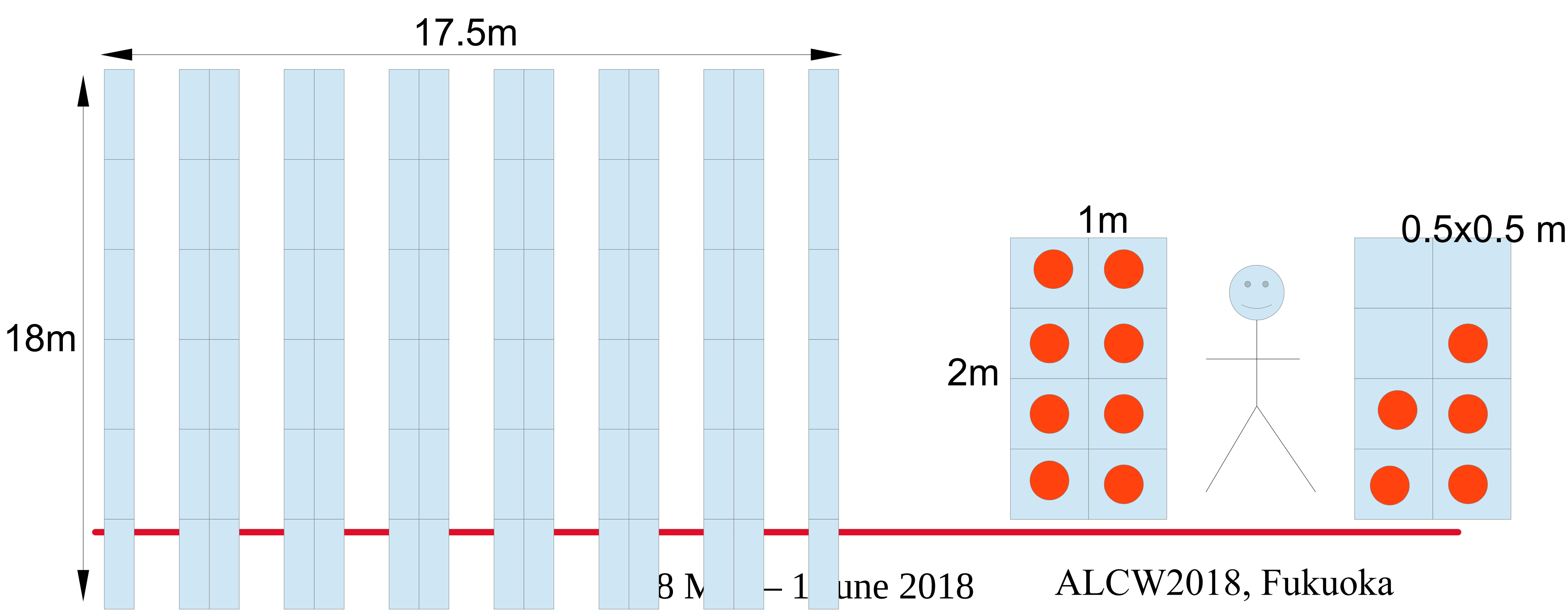


Decommission of E-Driven Source

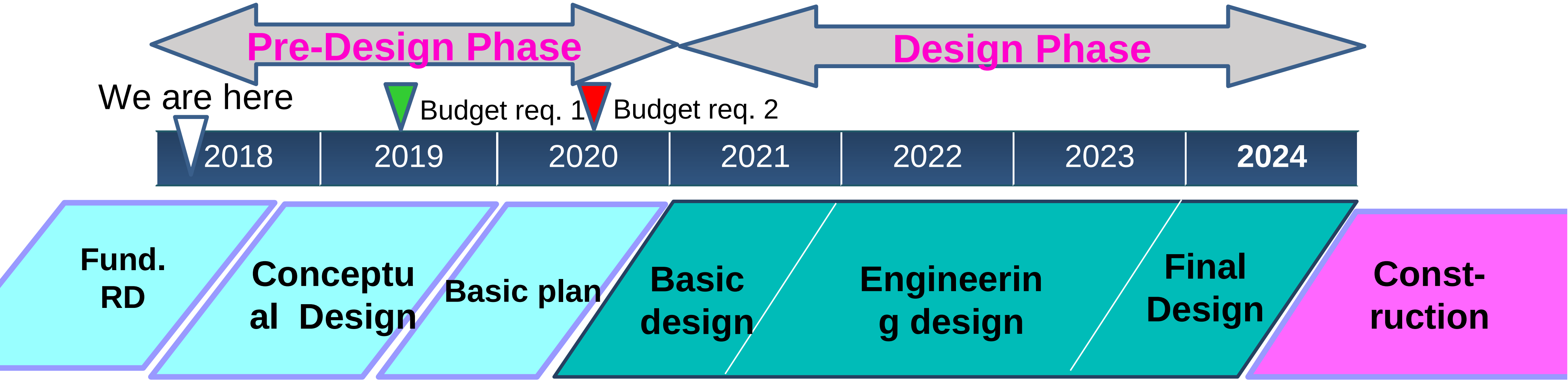
- If we choose E-Driven as the starter, eventually, we might need an upgrade from E-Driven to Undulator, when the technology for Undulator was even matured.
- The decommissioning of E-Driven is considered.
- According to radiation safety regulation, any components which are potentially activated are considered to be activated object. The components should be stored in a controlled area anyhow.
- A heavily activated object (>20uSv/h) requires a special attention.
- A weakly activated object (<20 uSv/h) is handled in usual way in the controlled area.

Storage Area for E-Driven components.

- If the most of the components from E-Driven are weakly activated, the components can be stored in a controlled area.
- To store 340 accelerator tubes, 18 x 18 m^2 is enough.
- The scenario does not work if a significant amount of components are heavily activated. We need an evaluation anyway.



An Expected Schedule on Pre- and Design Phase



Accelerator design

Fix Spec.
Fix Layout
A rough estimation

Bud. Req. 1

Basic plan by consultation

- *General drawings*
- *Rough estimation*

- *Construction drawings*
- *Estimation*
- *Call for tender, contract*

- *const. draw.*
- *const. schedule*
- *Estimation*

Construction Phase

Documentation by a consultation company to start the detail deign.

Geological survey

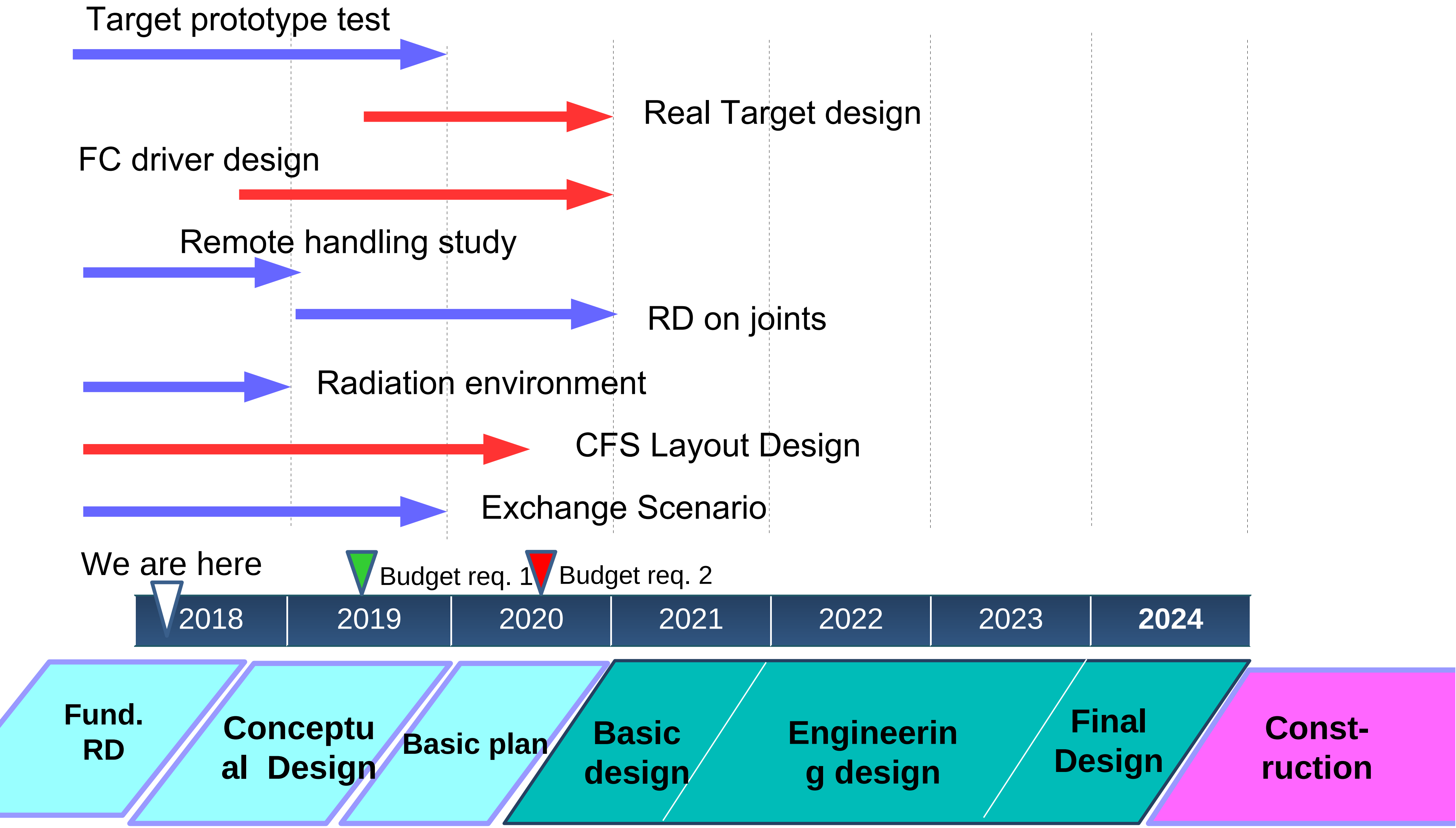
By a consultation company to def ine the baseline schedule and to obtain information required in the initial phase of the design.

Environmental assessment

Should be f inished before the f inal design. It takes 3 years def ined by law.

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

An Expected Schedule on Positron Source Design



Summary

- Target area design is considered.
- Install and uninstall the target through the accelerator tunnel on rail.
- Target storage area for cooling at the upstream of electron driver.
- To make a detail design, the remote handling is the most critical. Especially, how to implement RF joints is a most critical technique.
- The design can be ready before the engineering design in the preparation phase?
- The expected radiation should be evaluated with the exact condition. (need iterations)
- Most of the studies can be shared between E-Driven and Undulator.

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Modulator and Klystron

- 1420x1894x1927 : L-band 50 MW
- 1725x2447x1982:S-band 80 MW
- 600mm space near the modulator is enough for maintenance. The system is composed from modules and no need to move the whole modulator.

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

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

Fig: *K400-platform*

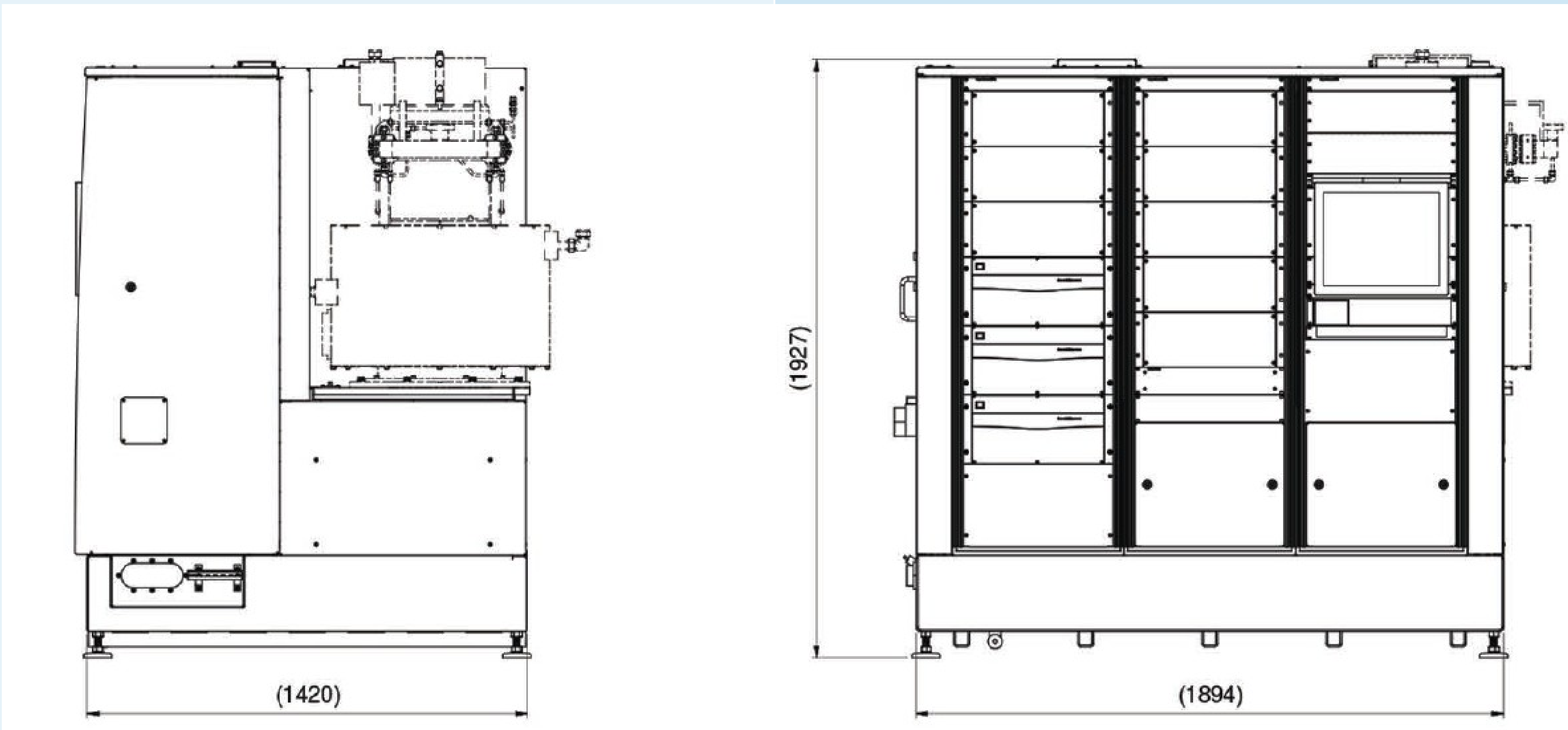
Main Parameters	Value	Unit
RF Frequency	2600	MHz
RF Peak Power	80	MW
RF Average Power	0.2 (12)[1]	kW
Mod. Peak Power	143	MW
Mod. Average Power	1.4 (86)[1]	kW
Klystron Voltage	382	kV
Klystron Current	375	A
RF Pulse width (top)	0.5	µs
Pulse Repetition Rate	5 (300)	Hz
Pulse-to-Pulse stability	<15	ppm

[1] *Corresponding to 300Hz operation*

OPTIONS: Integration of …

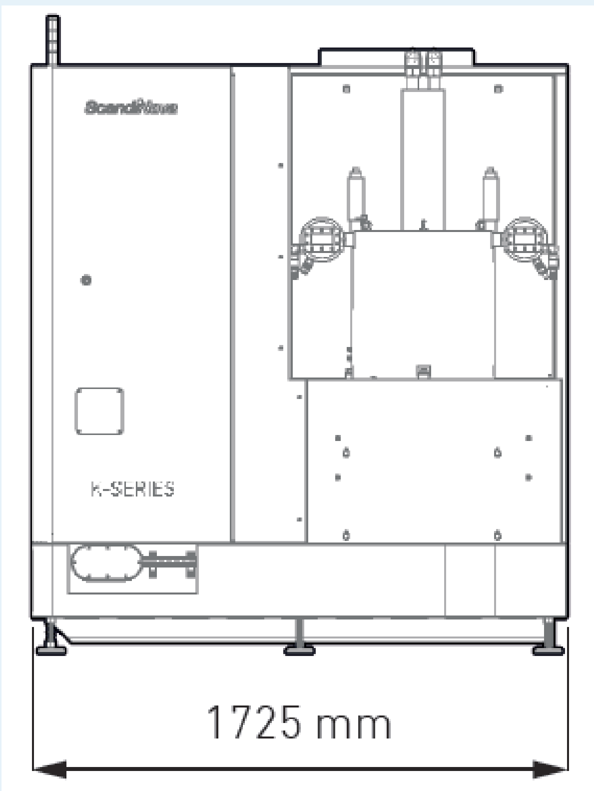
- Solenoid Power Supply
- Ion Pump Power Supply
- RF Drive amplifier
- Cooling of Klystron (Collector, Body), Solenoid
- All diagnostics and interlocks

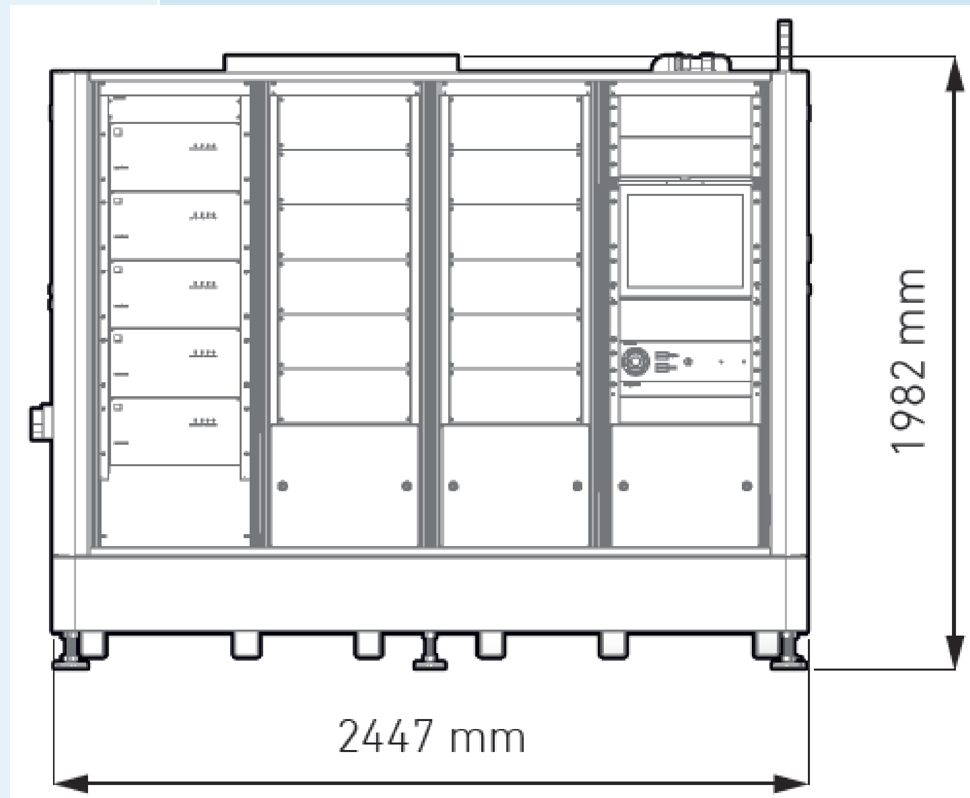
KEK CONCEPT DESIGN 50MW L-BAND – Solid State Modulator DIMENSIONS & WEIGHT



Weight approx 3300kg (including Klystron, Solenoid, oil)

KEK CONCEPT DESIGN 80MW S-BAND
– Solid State Modulator DIMENSIONS & WEIGHT





Weight approx 4500kg (including Klystron, Solenoid, oil)