SOKENDAI

Development of the RF power distribution System for the ILC Prototype Cryomodule

LCWS2024
2024/07/09

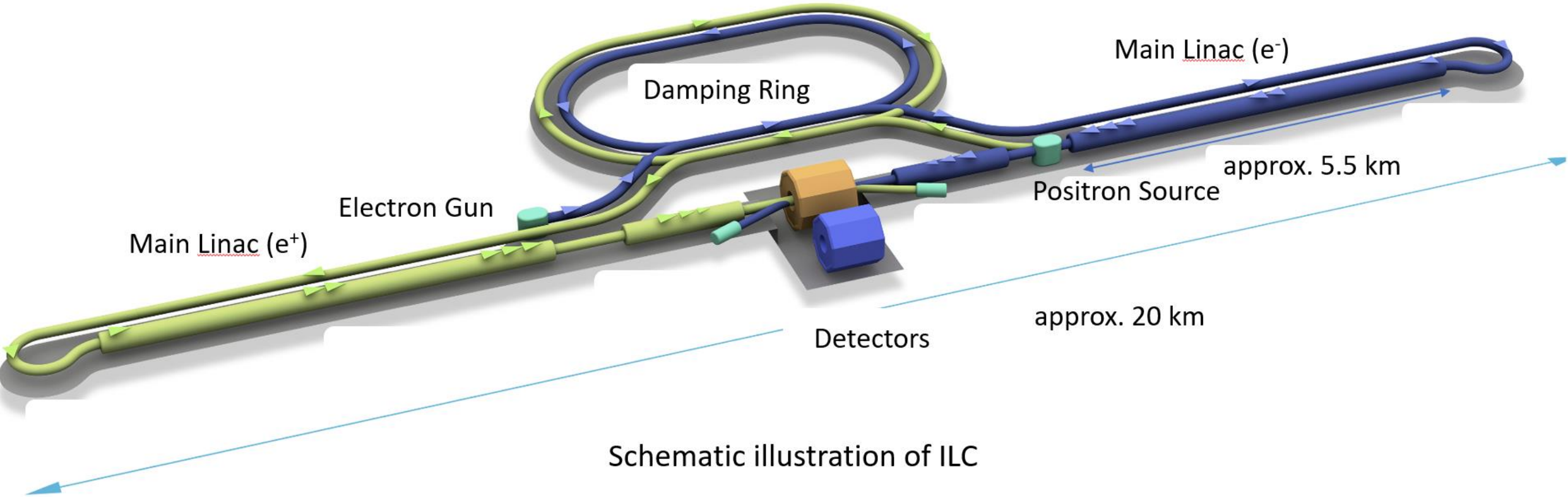
Prakash JOSHI

Contents

- International Linear Collider (ILC) and its main linac
- Local power distribution system (LPDS) for ILC Technology Network (ITN) cryomodule
- Proposed updates in the ILC power distribution system (PDS)
- Concept of circulator-less LPDS
- Summary

- International Linear Collider (ILC) and its main linac
- Local power distribution system (LPDS) for ILC Technology Network (ITN) cryomodule
- Proposed updates in the ILC power distribution system (PDS)
- Concept of circulator-less LPDS
- Summary

ILC and Main Linac

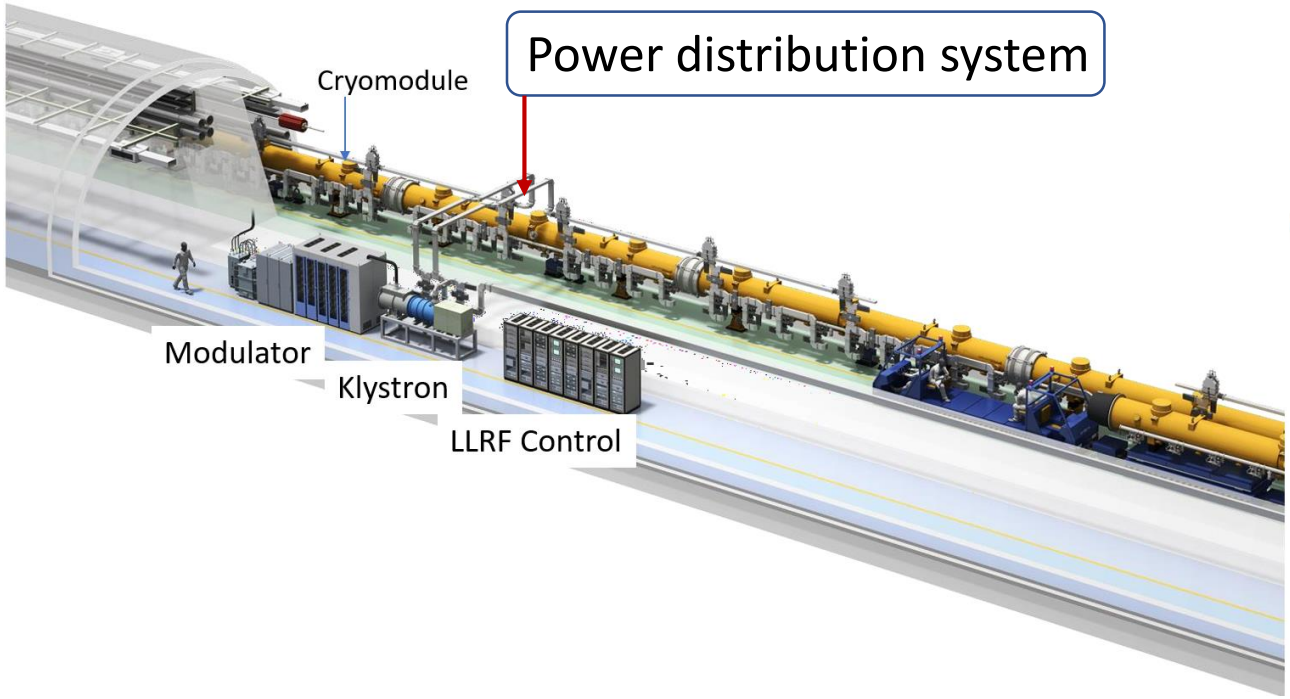


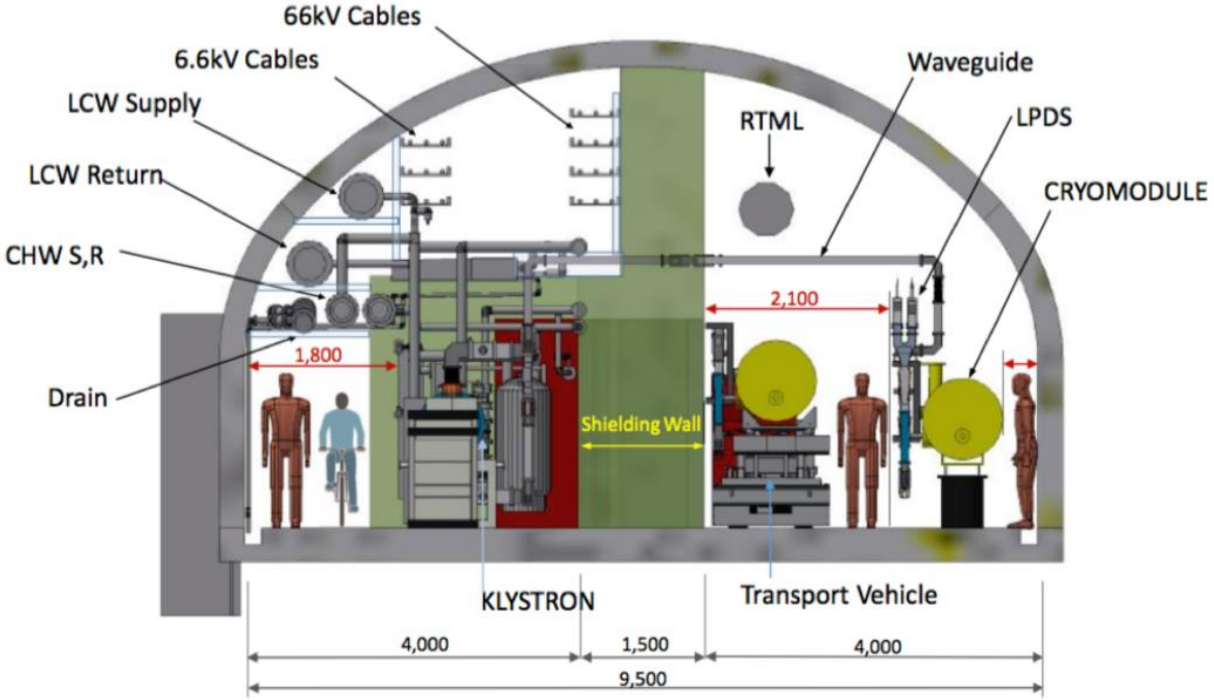
Schematic illustration of ILC

- Future linear electron-positron collider
- Center of mass energy 250 GeV
- Total length of about 20 km, with a length of both main linacs of about 11 km
- In main linacs, about 8000 SRF cavities driven nearly in about 200 RF stations

Ref.: https://linearcollider.org

ILC Main Linac



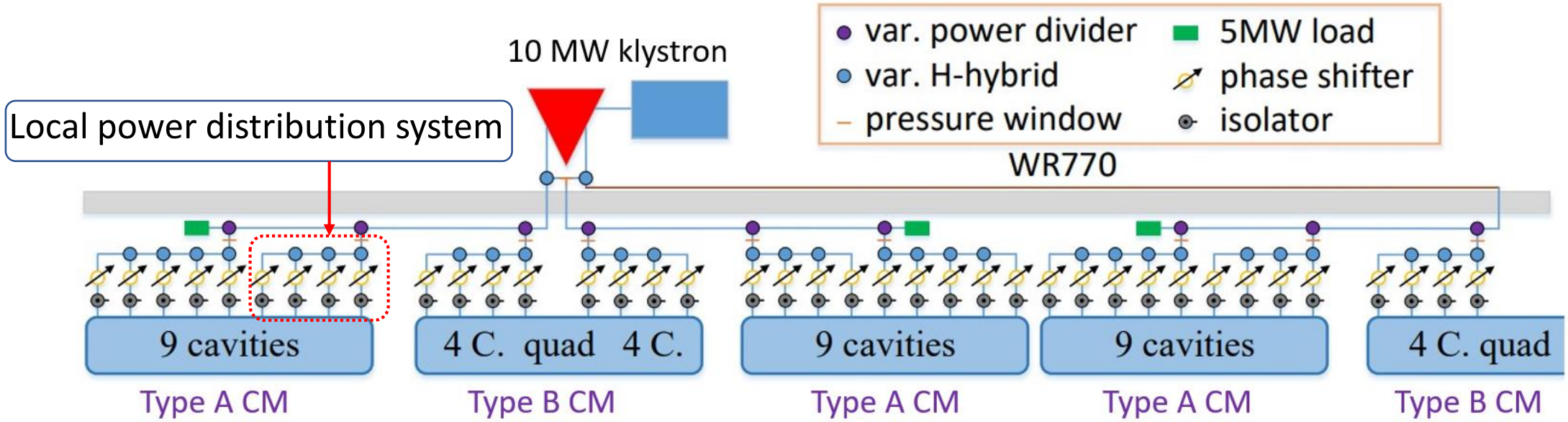


- Accelerator tunnel and klystron gallery separated by shielding wall
- Allows access to modulators, klystrons, and LLRF control racks during operation
- Local power distribution system integrated with cryomodule (based on European XFEL experience)

Ref.: https://linearcollider.org

ILC-TDR Power Distribution System

- A 10 MW Multibeam klystron drives 39 SRF cavities
- A type A cryomodule contains 9 Cavities and a type B cryomodule contains 8 cavities
- A type B cryomodule is placed between two type A cryomodules

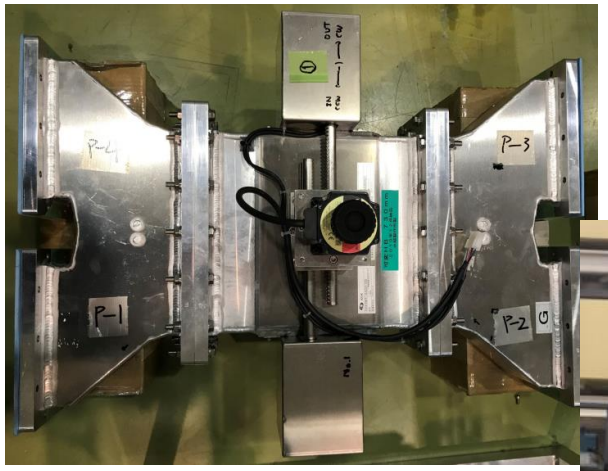


Power Distribution System (PDS) according to ILC-TDR

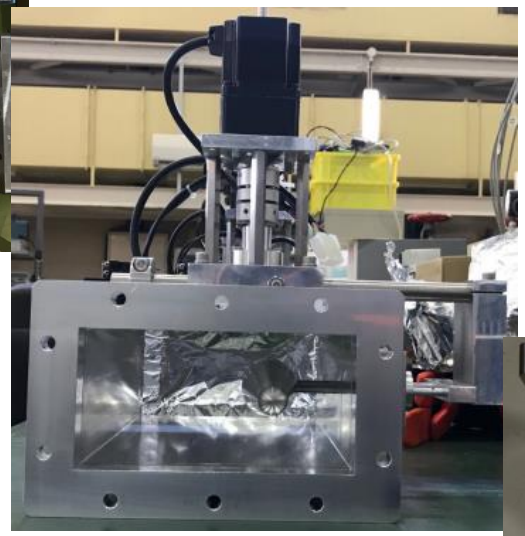
Ref.: ILC-TDR volume-3 II

Local power distribution system for the ILC

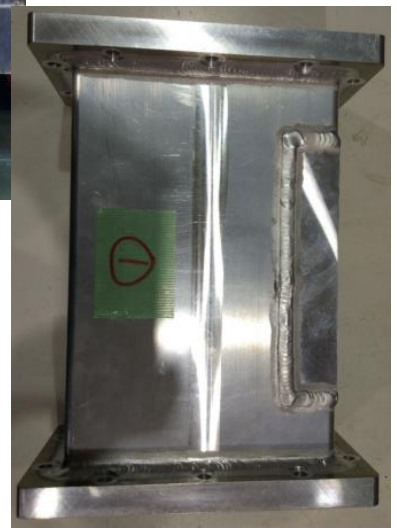
LPDS with adjustable RF power and phase, which is necessary to operate each cavity with its max. possible gradient to achieve max. possible beam energy



Variable hybrid



Variable phase shifter



Fixed phase shifter

Compact LPDS developed at KEK

- Variable hybrid (VH) to adjust the coupling ratio
- Variable phase shifter (VPS) mitigates the phase introduced by VH
- Fixed phase shifter (FPS) for the RF input phase difference of 90^{o} between the adjacent cavities

- International Linear Collider (ILC) and its main linac
- Local power distribution system (LPDS) for ILC Technology Network (ITN) cryomodule
- Proposed updates in the ILC power distribution system (PDS)
- Concept of circulator-less LPDS
- Summary

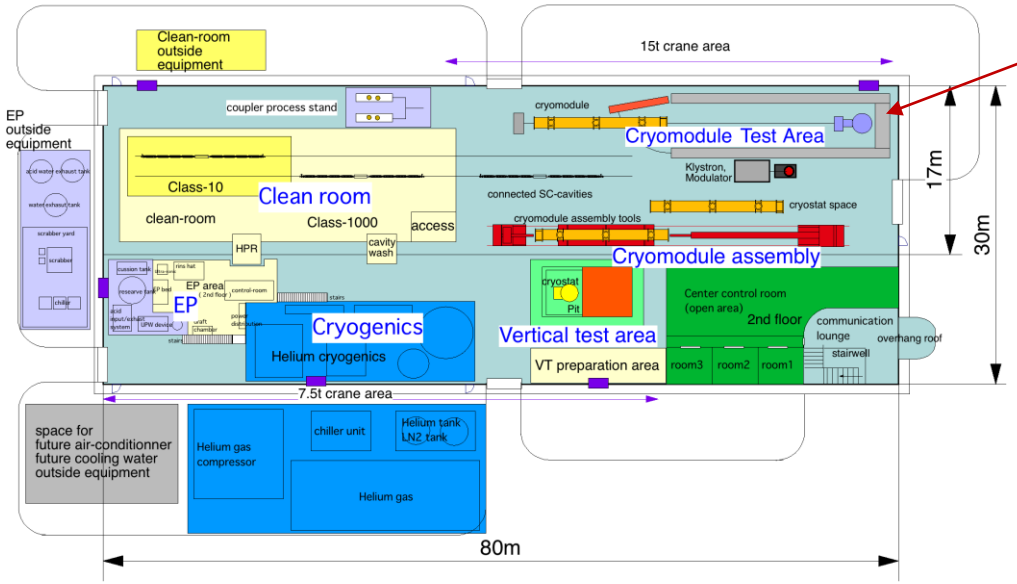
ITN CM construction and RF system

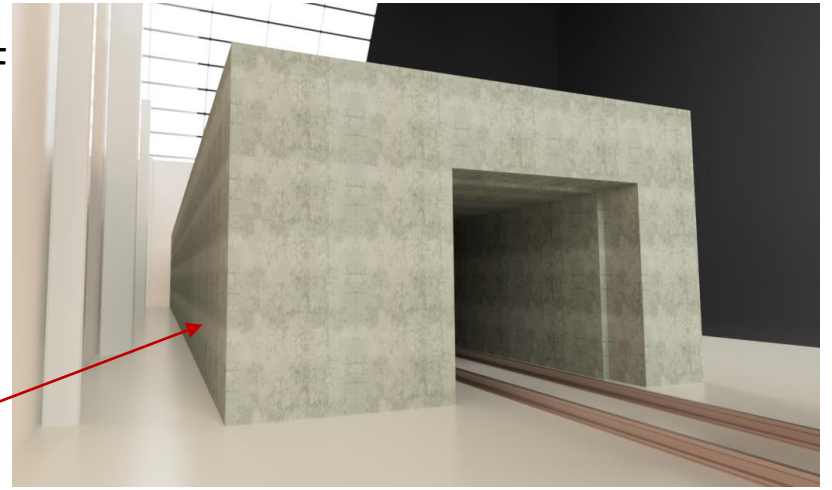
The ILC Technology Network (ITN) is jointly initiated by KEK and the International Development Team (IDT) of the ILC to execute High-priority work packages such as SRF

Details: Talk from T. Saeki
"Status of fabrication of 9 cell cavities"

Center of Innovation (COI) Building

Superconducting Accelerator Development Hall





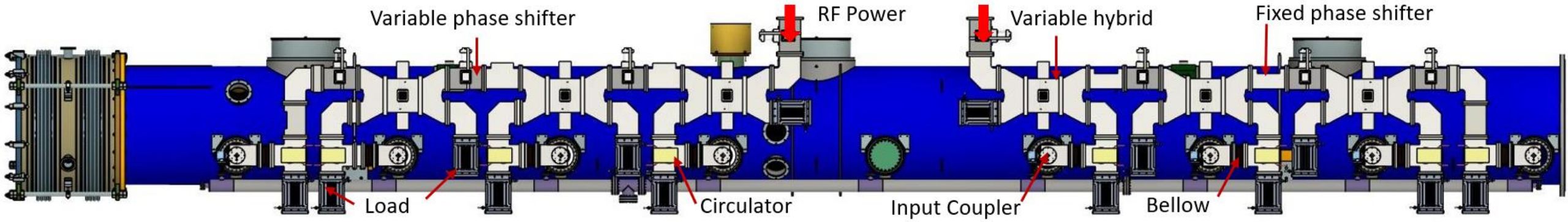
Test bunker for ITN

E-XFEL Accelerator Module Test Facility

The cryomodule test is planned in the Japan FY 2027

Refer: Y. Yamamoto SRF 5-year plan in Japan for ILC, LCWS2023

LPDS for the ITN CM

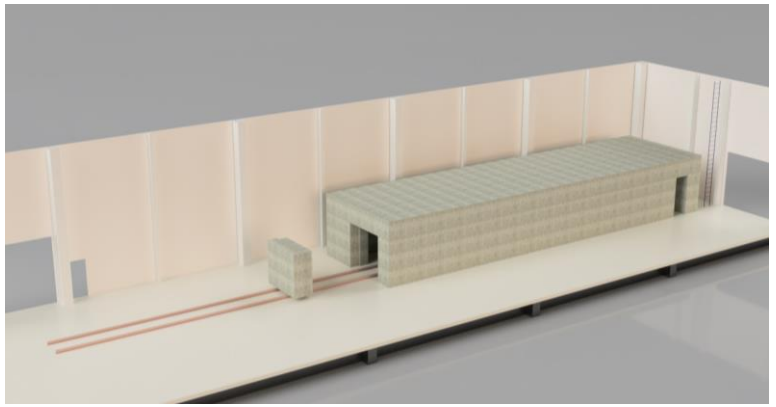


Main features of the LPDS

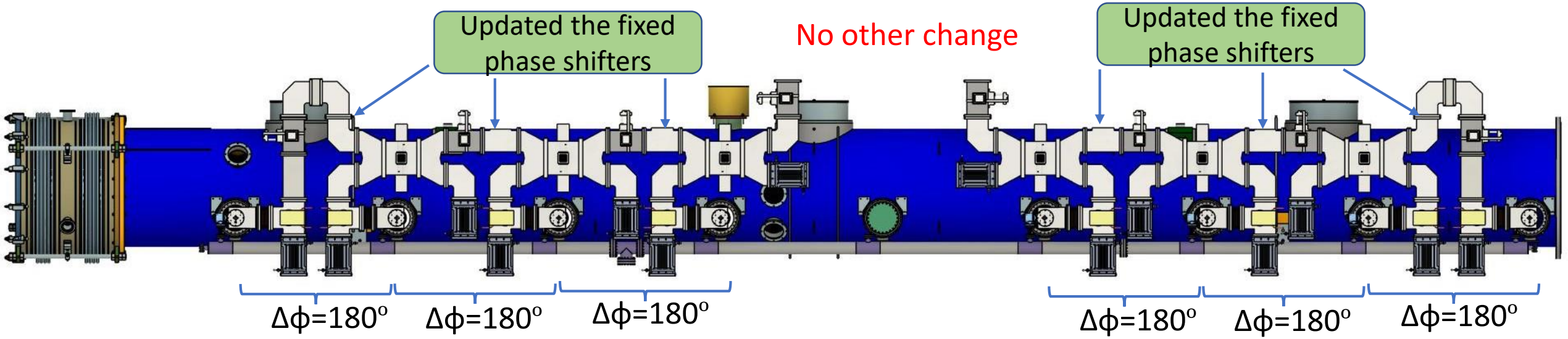
- Ensure LPDS stays within the length of the CM which is necessary for multi-CM assembly
- Low center of gravity for mechanical stability
- The circulators connected to the input couplers using bellows to minimize mechanical stress on the input couplers
- Minimum number of the waveguide components as possible to reduce the mass and cost of the system

Low field emission model for the ITN CM

- This is necessary due to the insufficient thickness of the concrete shielding wall due to limited space at the planned test stand
- The RF input phase difference between the adjacent cavities is 180 degrees to avoid the acceleration of dark current



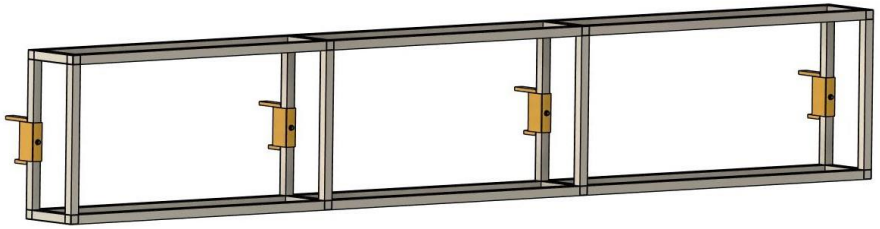
Planned test stand



LPDS Support System

Motivation

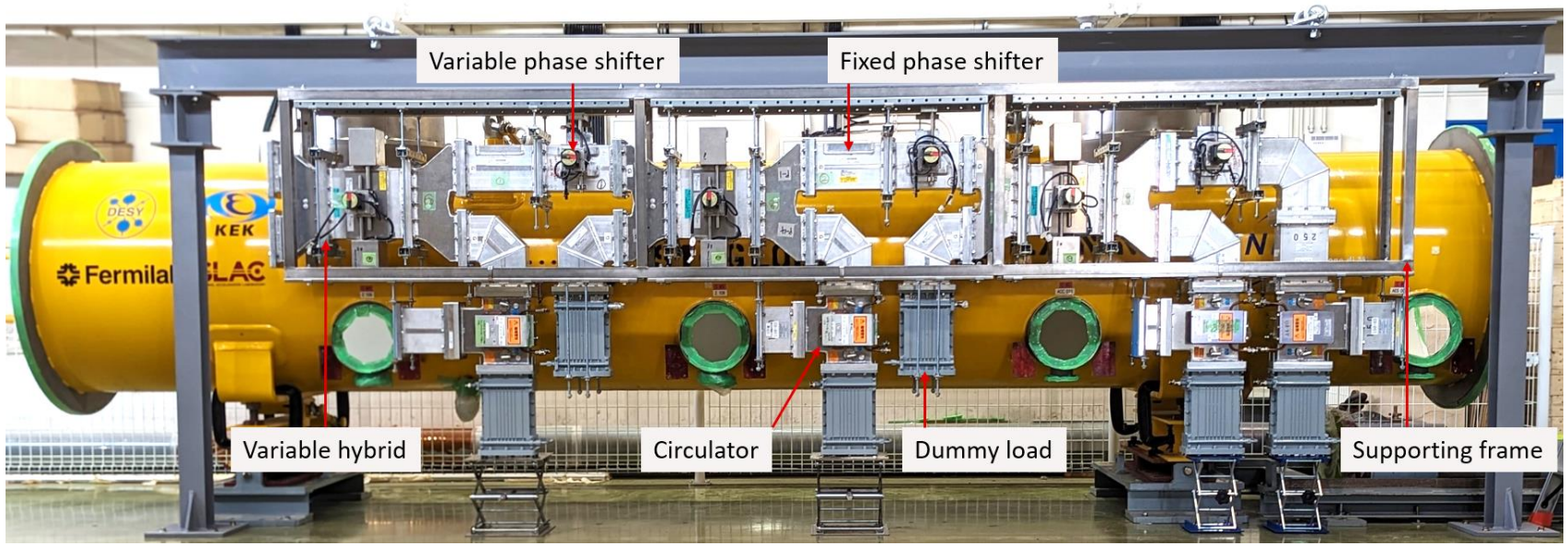
- Mounting LPDS onto CMs inside the tunnel is not efficient
- CM pre-assembled with LPDS will be installed inside the tunnel
- A prototype LPDS support system was designed and fabricated
- A first integration of LPDS into the support system was tested
- Transferred in front of the CM



CAD model of the support frame

Plan: The support frame will be updated so that it can be fastened to CM

Lateral view



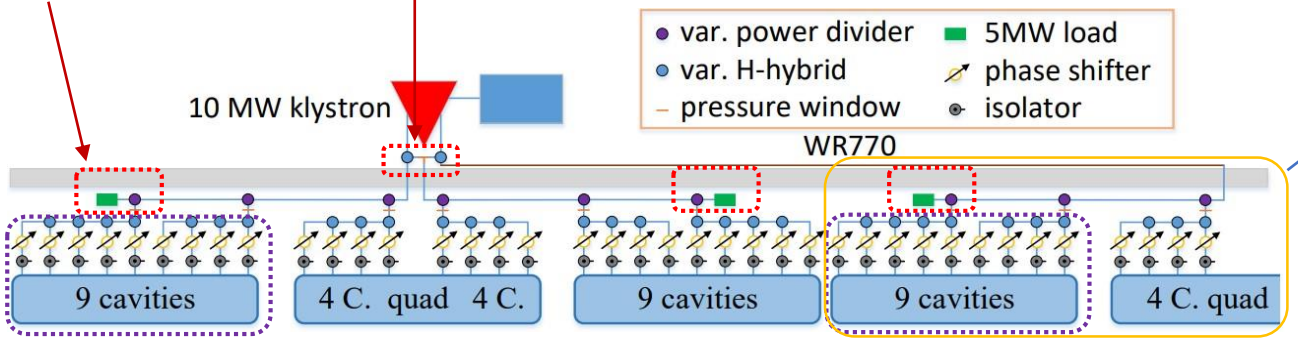
Front view of the LPDS integrated in support frame

- International Linear Collider (ILC) and its main linac
- Local power distribution system (LPDS) for ILC Technology Network (ITN) cryomodule
- Proposed updates in the ILC power distribution system (PDS)
- Concept of circulator-less LPDS
- Summary

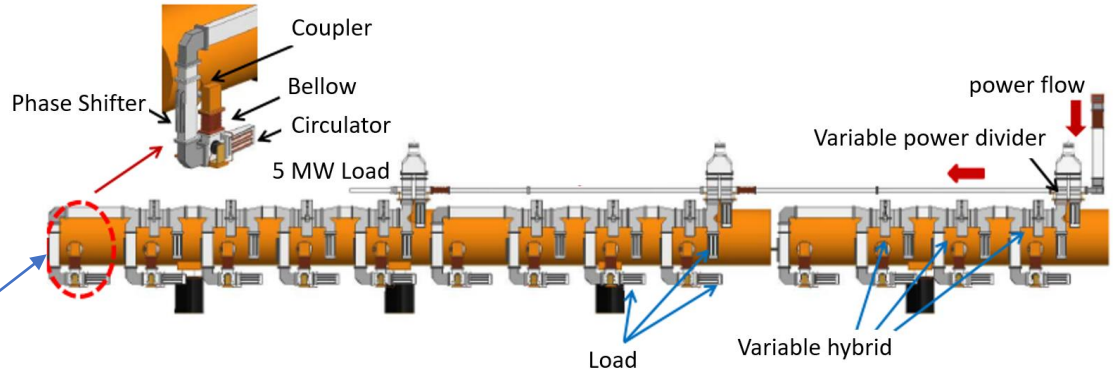
Proposed updates in the ILC PDS

Remove
VPD & 5 MW load

Update
5 MW variable power divider (VPD)
(Under development)

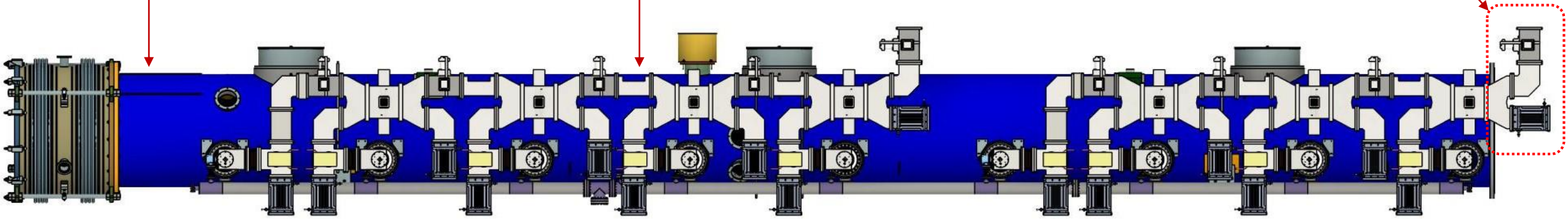


PDS according to ILC-TDR



LPDS according to ILC-TDR

LPDS conflicts with CM during multi-CM assembly



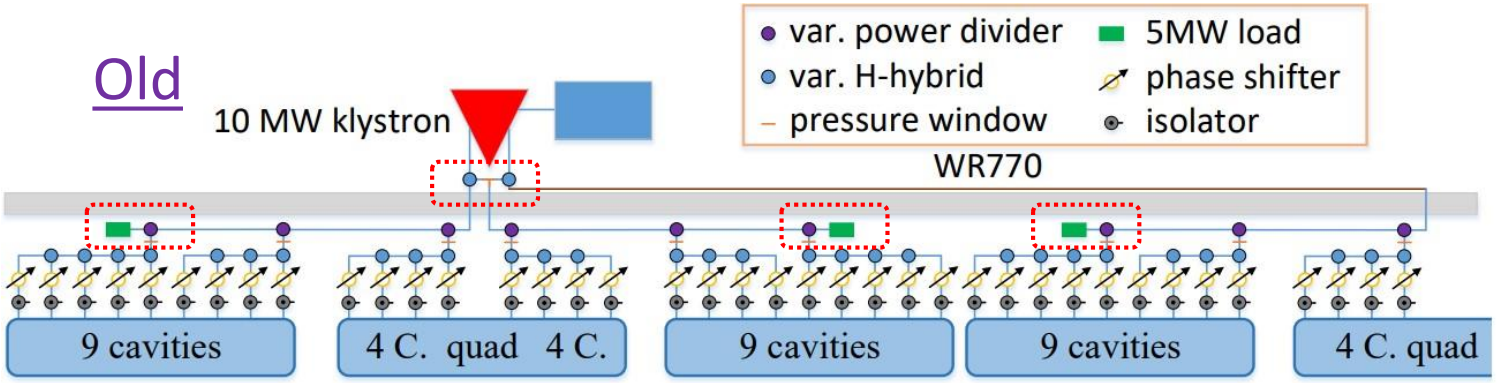
LPDS configuration based on ITN

Proposed updates in the ILC PDS

Updates

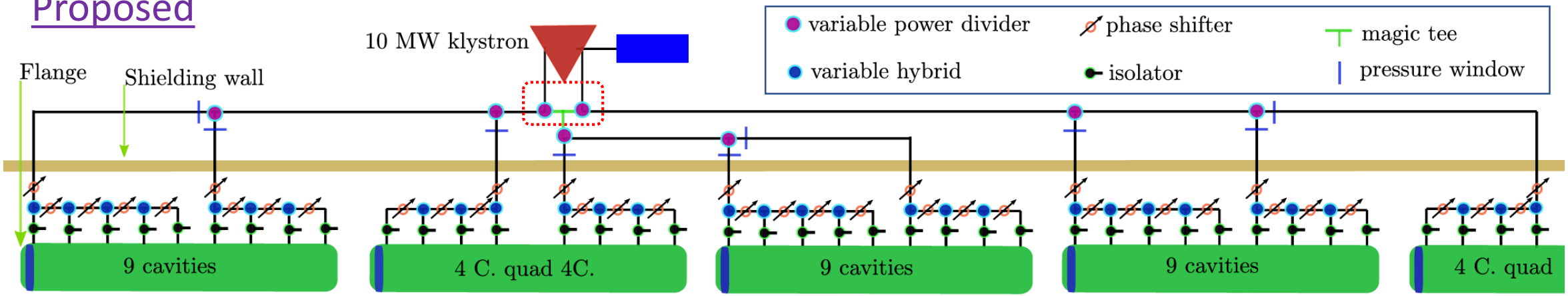
- Installation of 5 MW VPD at the output port of klystron
- Remove the 5 MW load and VPD at the end of the LPDS
- Revise the configuration of the LPDS
- VPD and pressure window in klystron gallery

Old



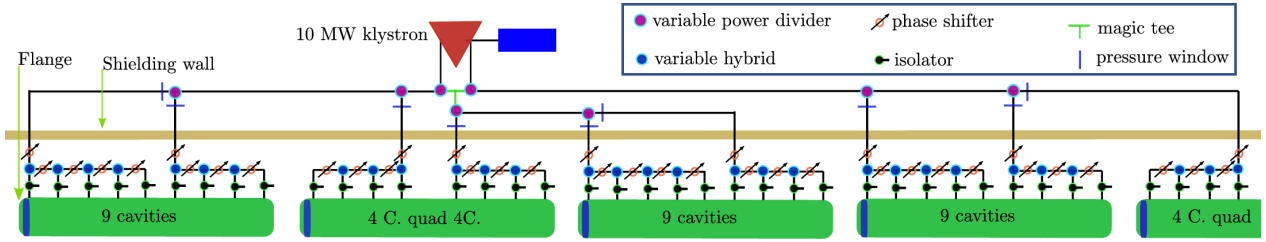
PDS according to ILC TDR

Proposed



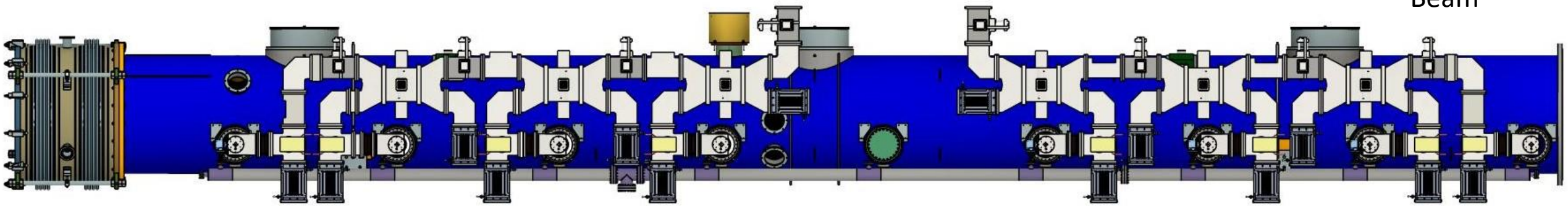
Proposed PDS for the ILC

PDS for the ILC

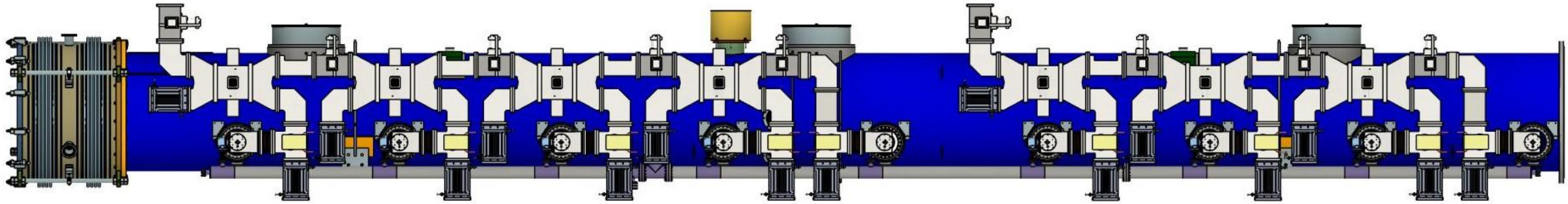


Use of these LPDS
can drive the ILC main Linac

Beam



LPDS for type B (ITN) CM



LPDS for type A CM

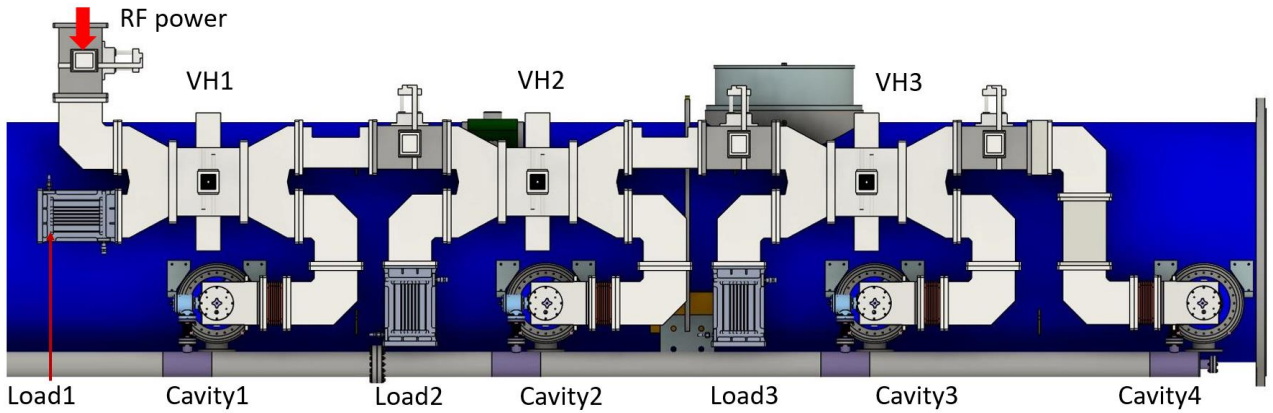
- International Linear Collider (ILC) and its main linac
- Local power distribution system (LPDS) for ILC Technology Network (ITN) cryomodule
- Proposed updates in the ILC power distribution system (PDS)
- Concept of circulator-less LPDS
- Summary

Concept of LPDS without Circulator

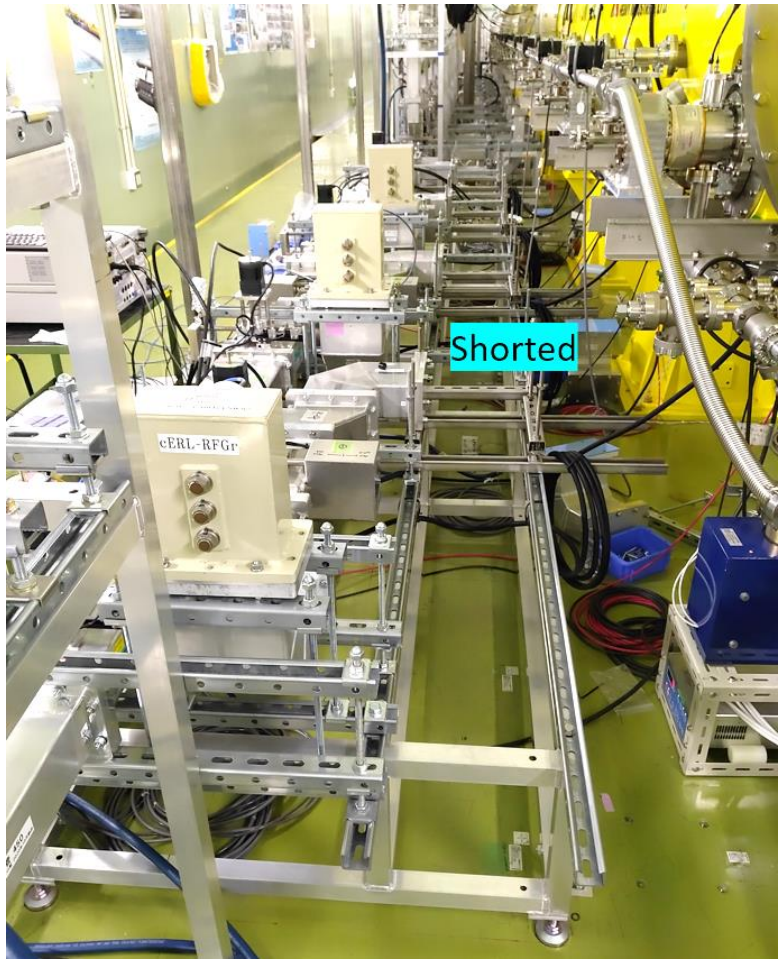
Motivation

- Reduction of the cost and mass of the waveguide system without compromising the safety of the klystron

Four Cavity LPDS



LPDS without Circulator



Low-power measurement of LPDS without circulator

Conclusion:

- Average power distribution: No power is reflected upstream
- Worse case*: About 6% of the input power was reflected upstream

*Worse case: Reflection from odd-numbered cavities 25% below and even-numbered cavities 25% above the average or vice-versa.

- International Linear Collider (ILC) and its main linac
- Local power distribution system (LPDS) for ILC Technology Network (ITN) cryomodule
- Proposed updates in the ILC power distribution system (PDS)
- Concept of circulator-less LPDS
- Summary

Summary

- LPDS of the ITN cryomodule was updated
  - LPDS within the length of CM
  - Low center of gravity
  - Minimum number of waveguide components
  - Alternate configuration of low-field emission
- A prototype support system was fabricated and the first integration tested
- Proposed updates for the ILC power distribution system
  - Installation of 5 MW VPD at the output port of the klystron
  - Removable of VPD and load at the end of LPDS
  - Revised configuration of LPDS
- The concept of LPDS without a circulator was introduced
  - Analytical calculations, simulations, and low-power tests look promising

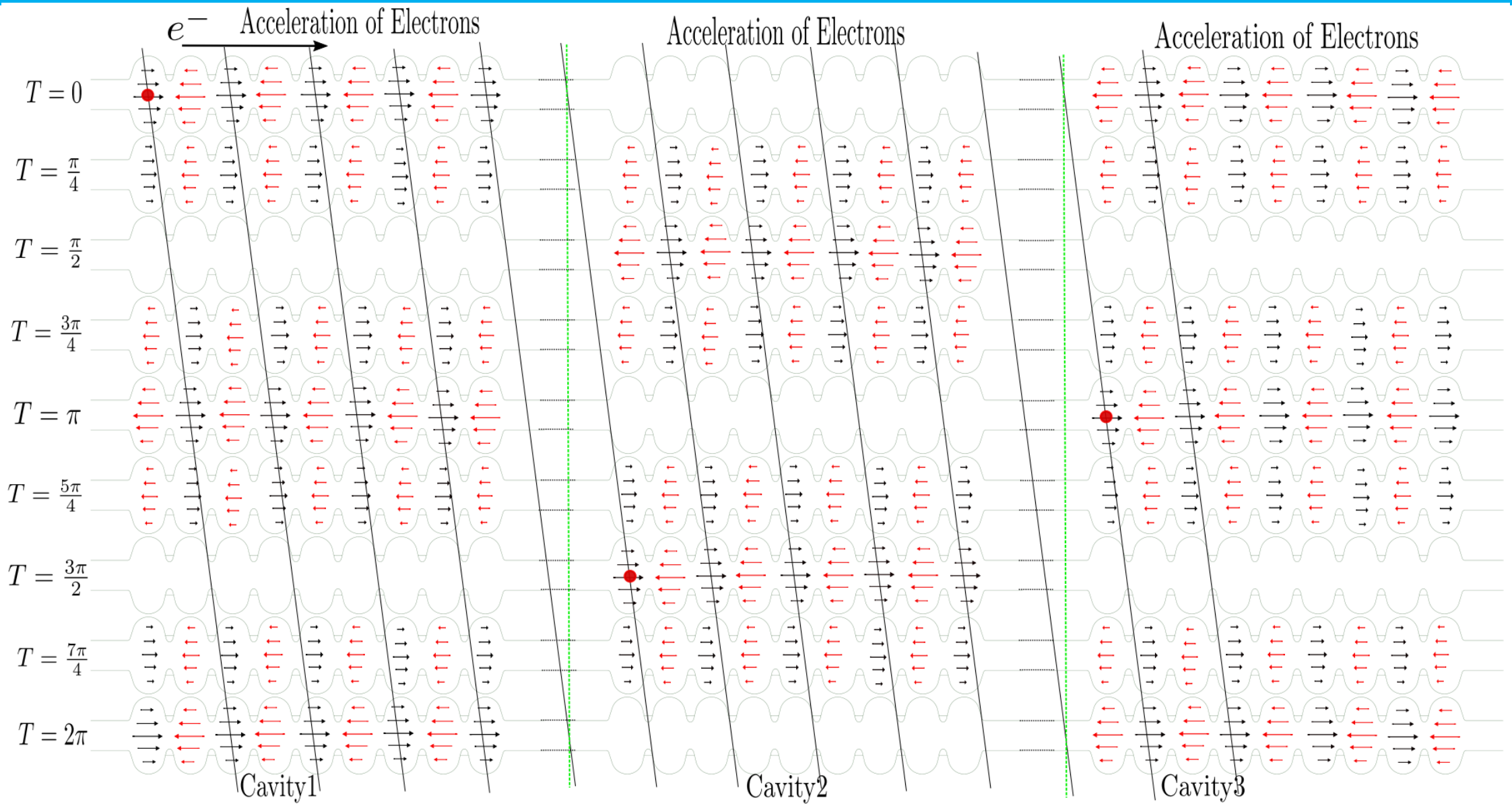


Thank you for your attention

Supported by: MEXT Development of key element technologies to improve the performance of future accelerators program (JPMXP1423812204).

Email: prakashj@post.kek.jp

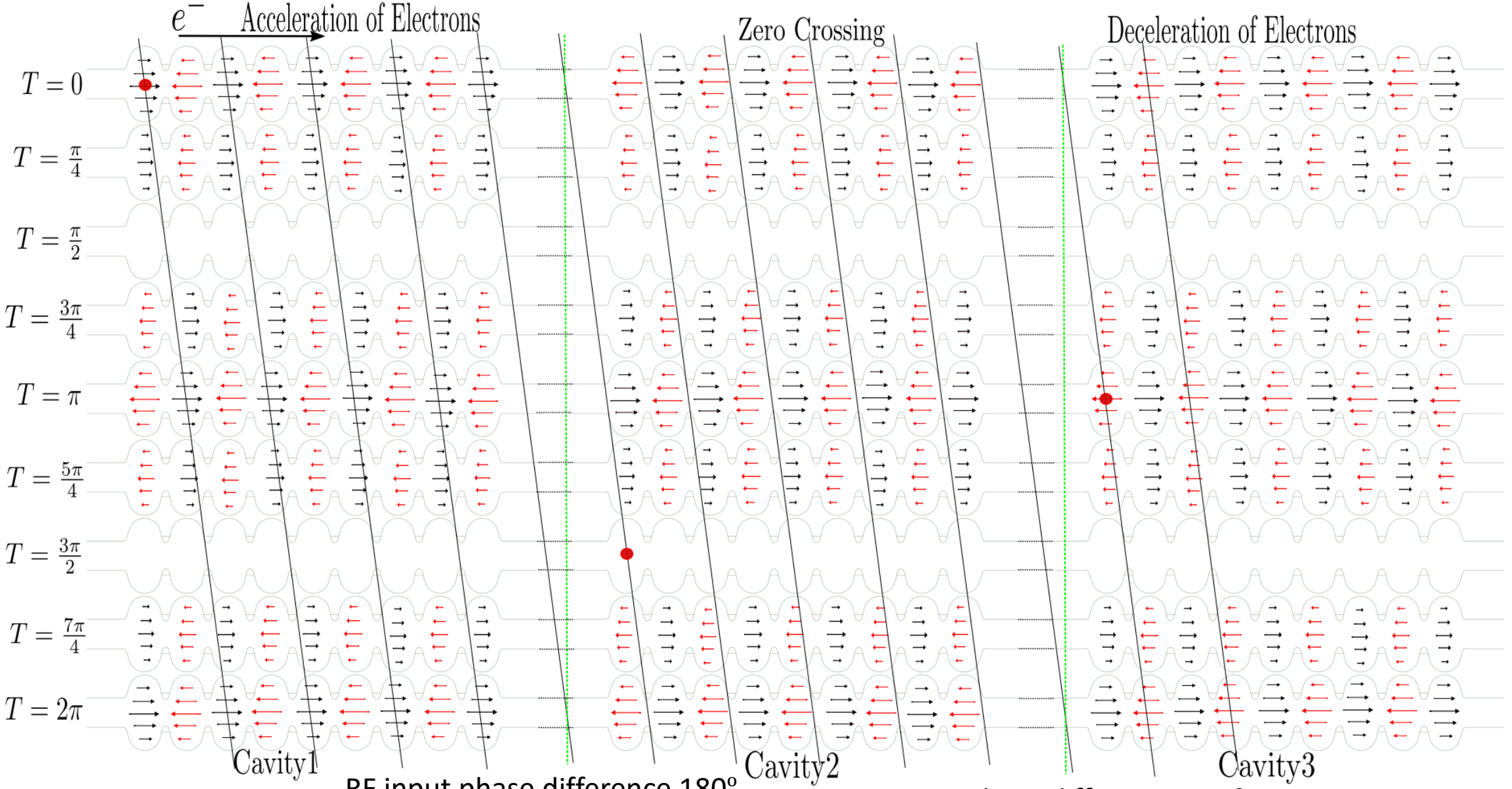
Backup Files



RF input phase difference 90°

RF input phase difference 90°

Low Field Emission



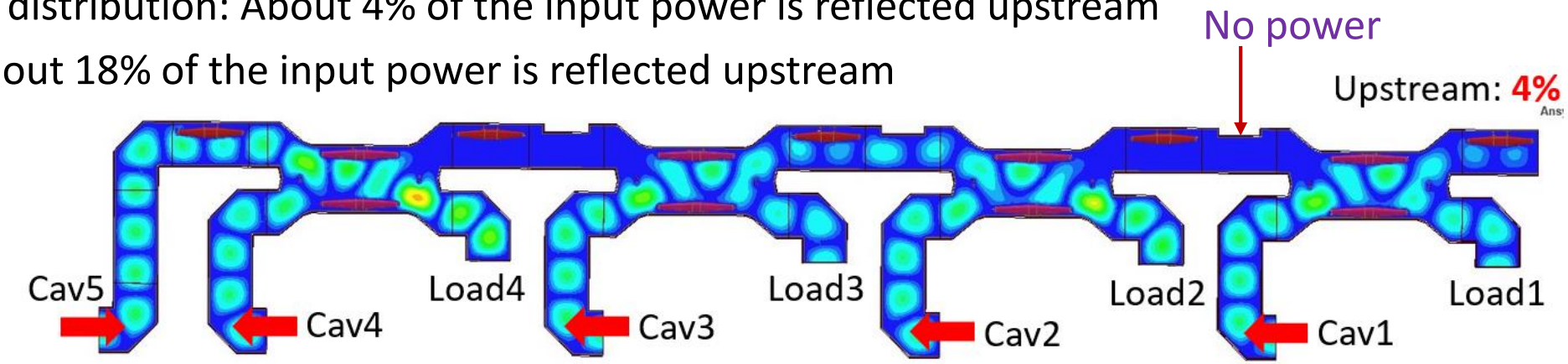
RF input phase difference 180°

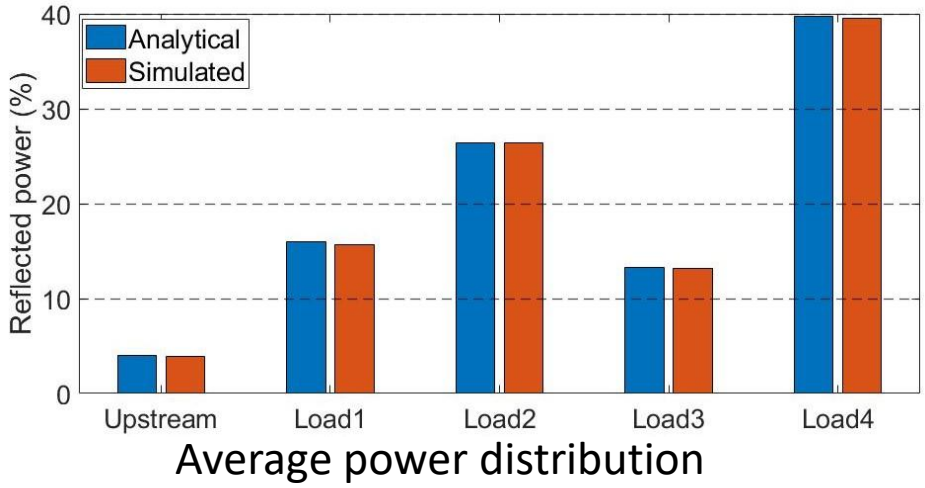
RF input phase difference 180°

Concept of CM without Circulator

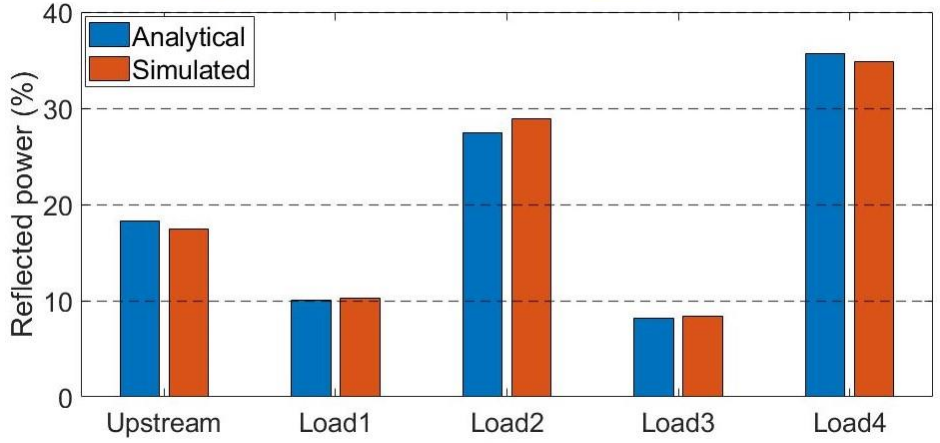
Five Cavity LPDS

- This is similar to adding one variable hybrid at the input of the 4 cavity LPDS
- Average power distribution: About 4% of the input power is reflected upstream
- Worse case: About 18% of the input power is reflected upstream





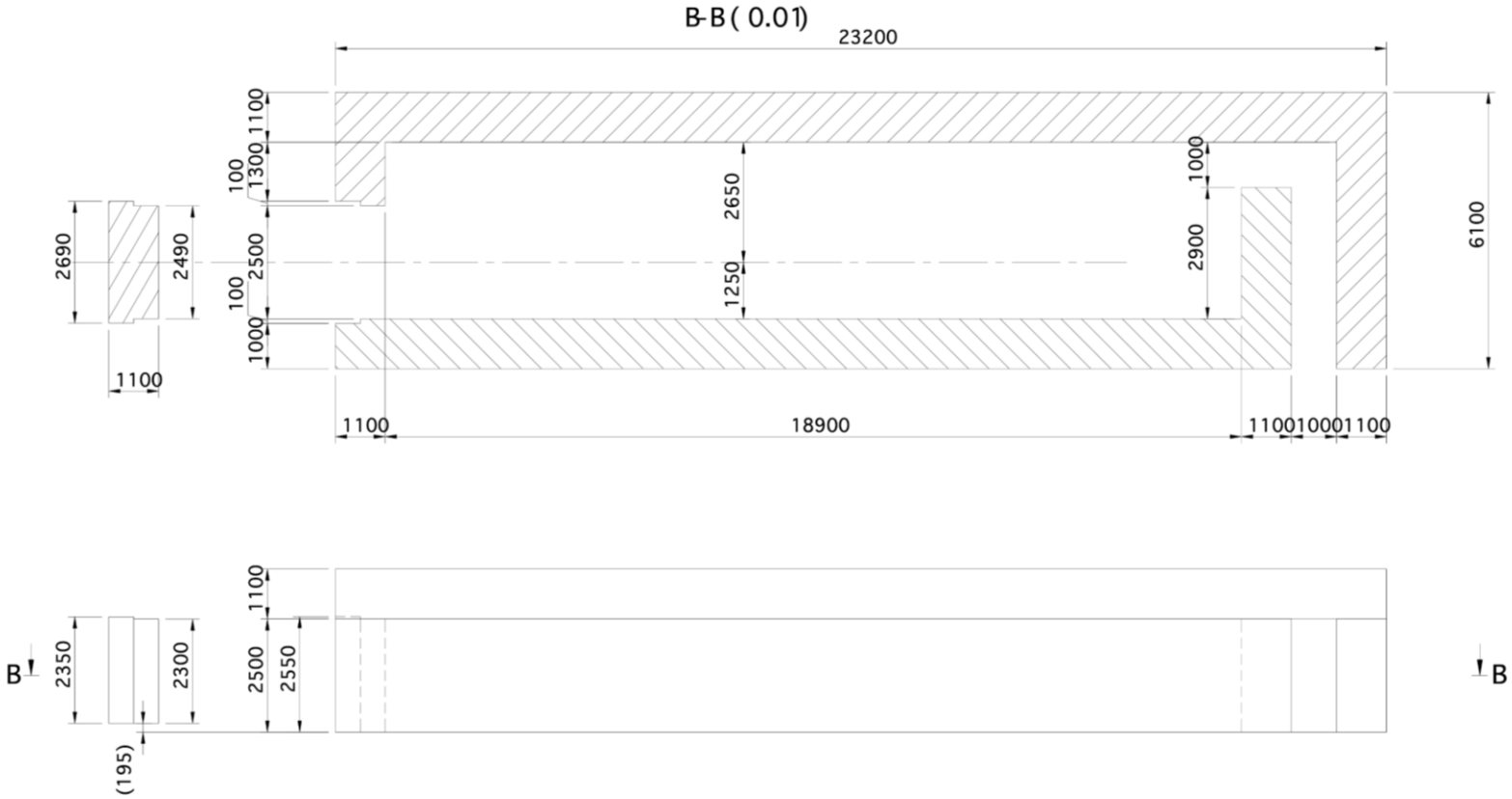
Average power distribution

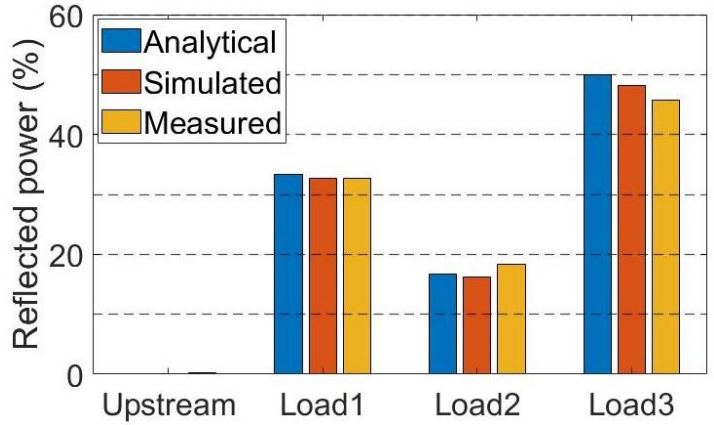


Cavity1, 3 and 5, 25% above the average and Cavity2 and 4, 25% below the average.

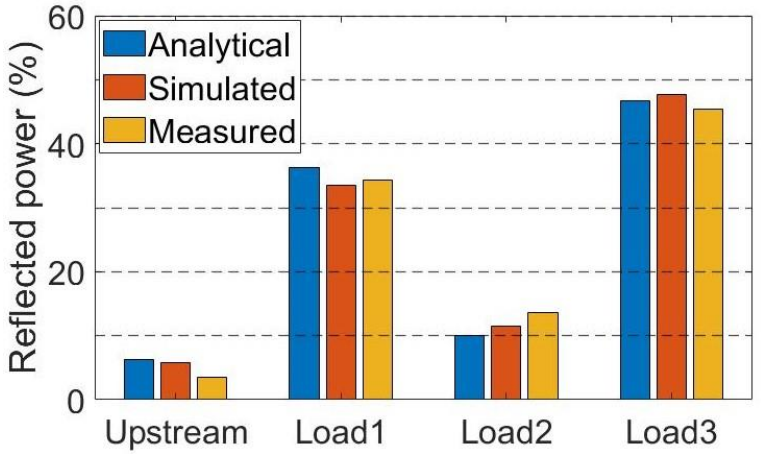
Comparison among analytical calculation, simulation and low-power measurements for four cavity LPDS

Drawing of the ITN test stand





Average power distribution



Odd-numbered cavities 25% below and even-numbered cavities 25% above the average or vice-versa.