FROM RESEARCH TO INDUSTRY

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DISCUSSION OF RF POWER NEEDS AND POTENTIAL RF NETWORK CONFIGURATIONS

6 NOVEMBER 2020

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PIP-II CEA/FNAL MEETING:

RF Requirements for LB650 CM Testing at CEA

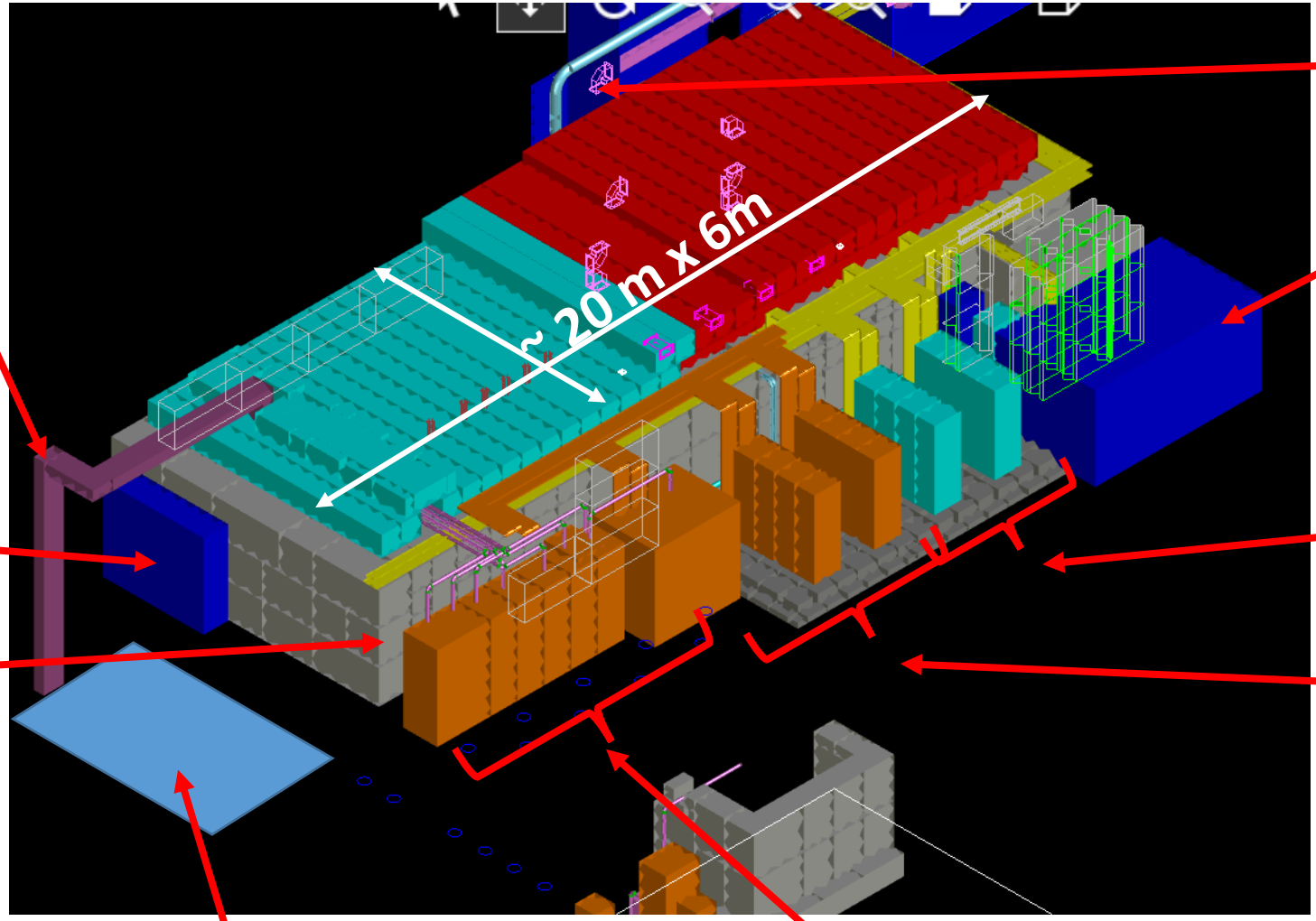
Introduction

- The following pages represent one of the main topics currently being discussed at CEA in the framework of the efforts aiming to prepare the LB650 Cryomodules test zone.
- Several RF sources configuration scenarios are under study in order to estimate the needed resources.
- The RF test discussions and meeting between CEA and FERMILAB, we are starting this week, will help to focus on the optimal solution.

Outline:

- Baseline test zone : current situation
- RF Power Needs (to be confirmed based on the test plan)
- RF sources configuration scenarios
- Comparison of the scenarios

Test Zone



Old 352 MHz Waveguide path

Current ESS 704 MHz WG path

ESS Control room

Electrical power Supply for JT60

Water supply, JT60 water loop

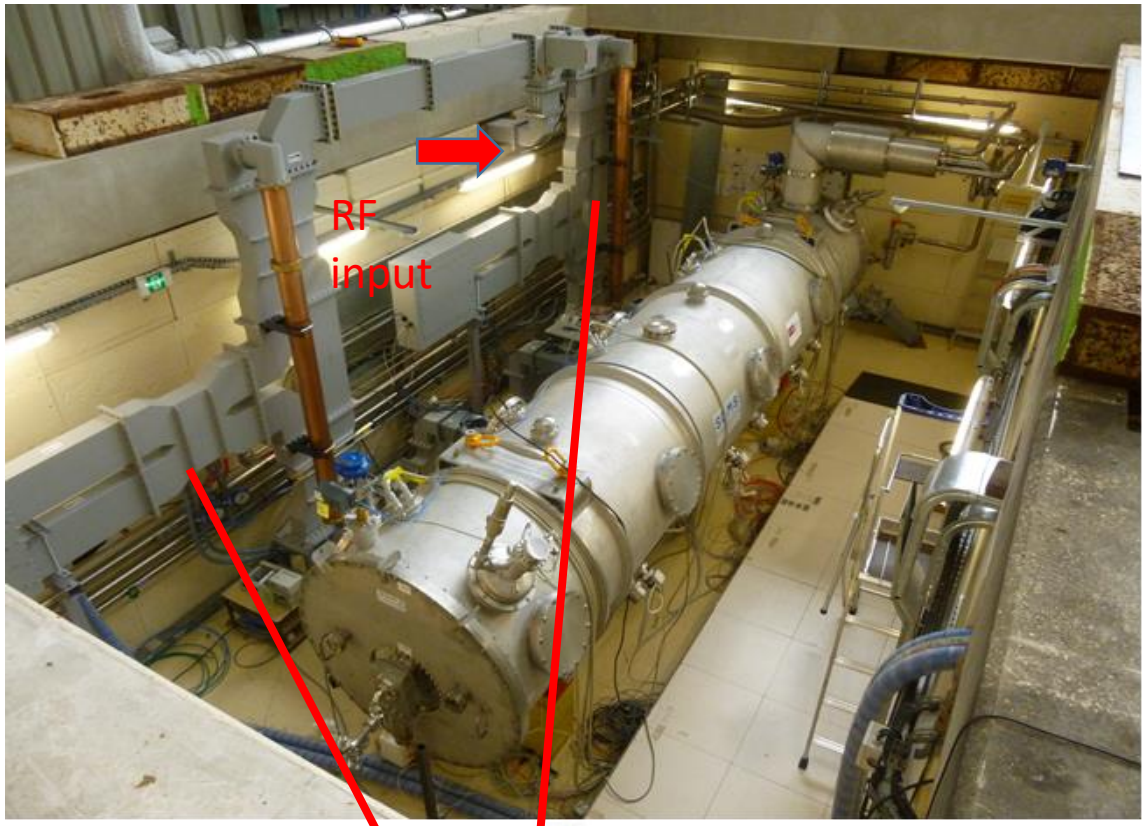
ESS Racks

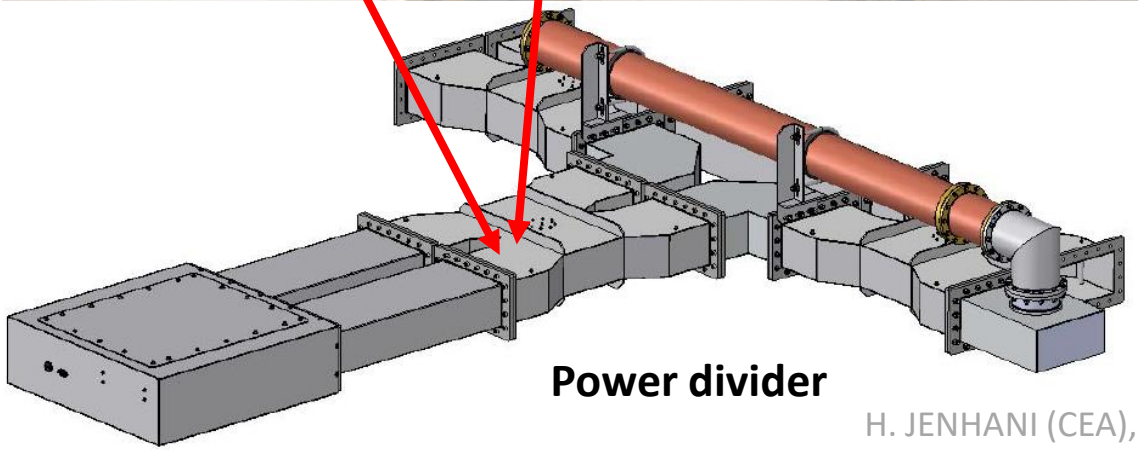
SARAF Racks

Future position of SARAF control room

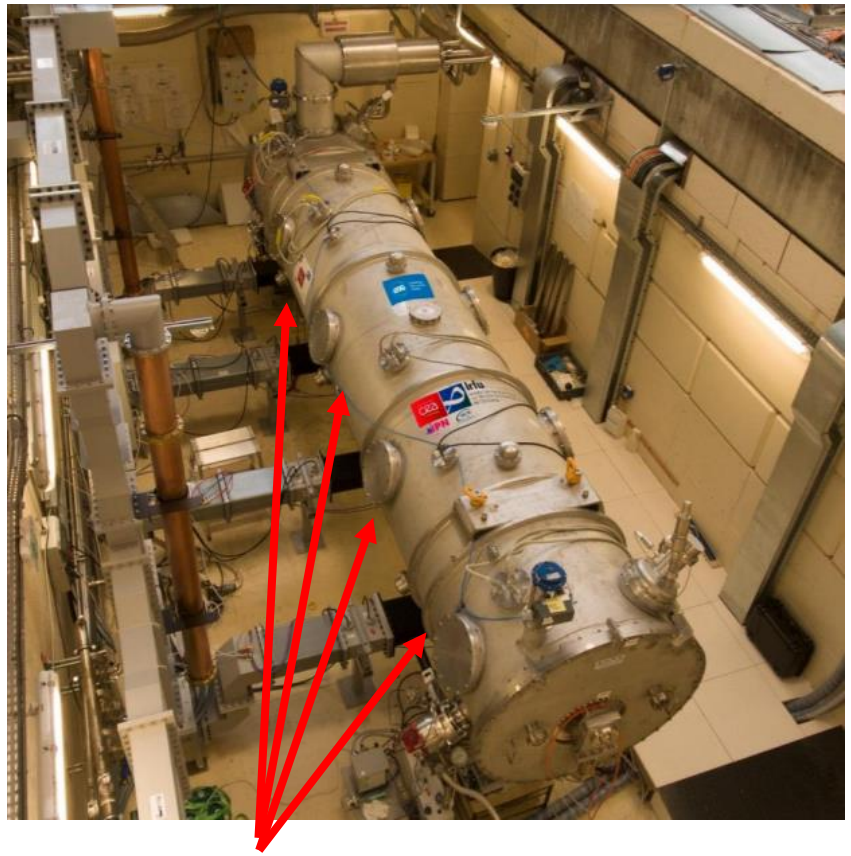
SARAF 176MHz SSAs and RF power equipment

Current RF Power Network Inside the bunker





Power divider



Waveguide transition of the power couplers underneath the cryomodule

ESS Cryomodule inside the bunker

RF Power Needs

	Values	Power increase ratio
Accelerating field Eacc [MV/m]	16.9	
Input power** for Eacc [kW]	10	
Input power** for Eacc+ 10% overhead [kW]	12.1	1.21
Input power** for Eacc+ 10% overhead+ (+/- 20% QL) [kW]	15.1	1.25
Input power** for Eacc+ 10% overhead+ (+/- 20% QL)+ 20Hz microphonics [kW]	19.1	1.26

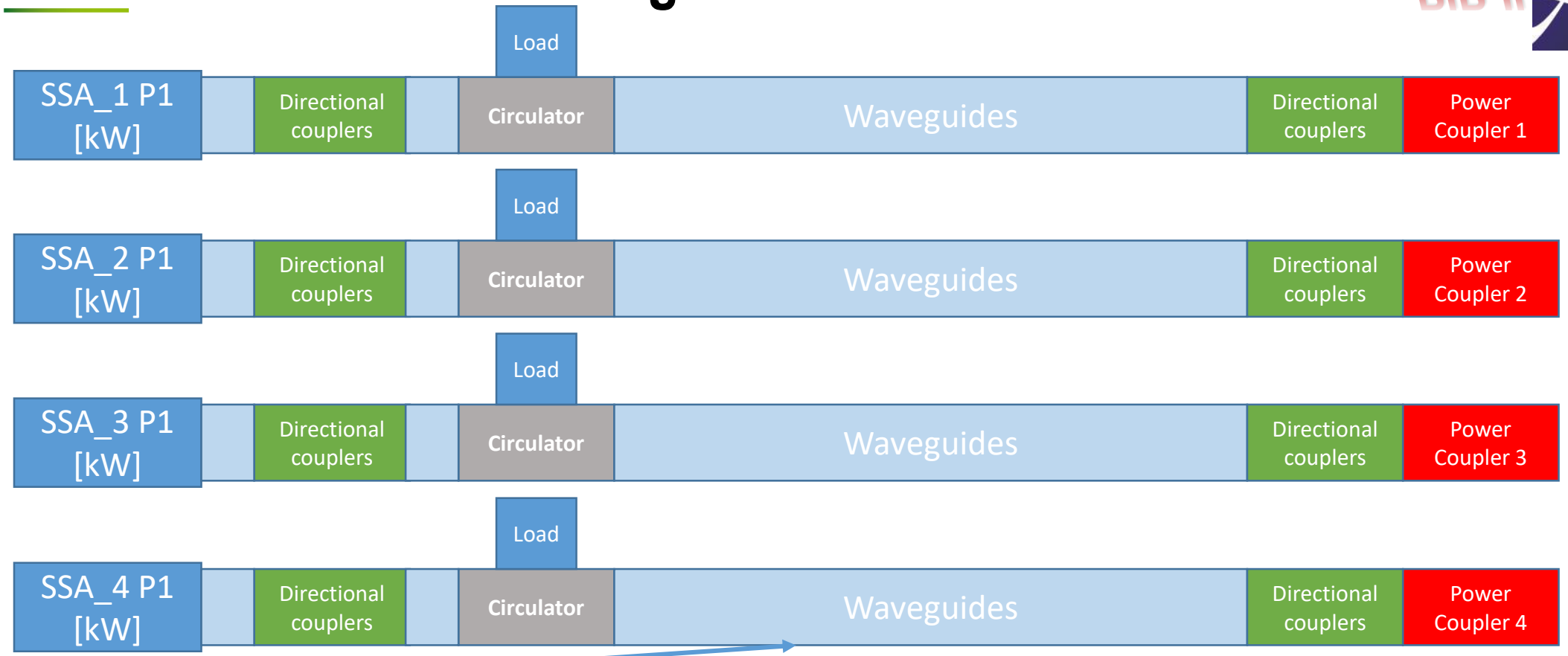
Parameters	LB650	HB650	Units
Nominal gradient	16.9	18.8	MV/m
Nominal QL	1.04e7	9.9e+6	
CM: Required nominal/maximum* Forward power for 2mA	30/35	43/53	kW
CM: Maximum* total power circulating in coupler for 2mA	44	68	kW
STC: Required nominal/maximum Forward power in STC test	10/15	16/25	kW
STC: Maximum Total power in coupler in STC test	30	50	kW
Forward/Total power required for coupler qualification in test stand	50/100	50/100	kW

**Power at the power coupler waveguide transition interface

Do we need to perform RF conditioning of coupler up to 30/35 KW?

**maximum power to cover ±20% variations in QL, 20Hz cavity detuning from microphonics and allows 10% higher gradient.*

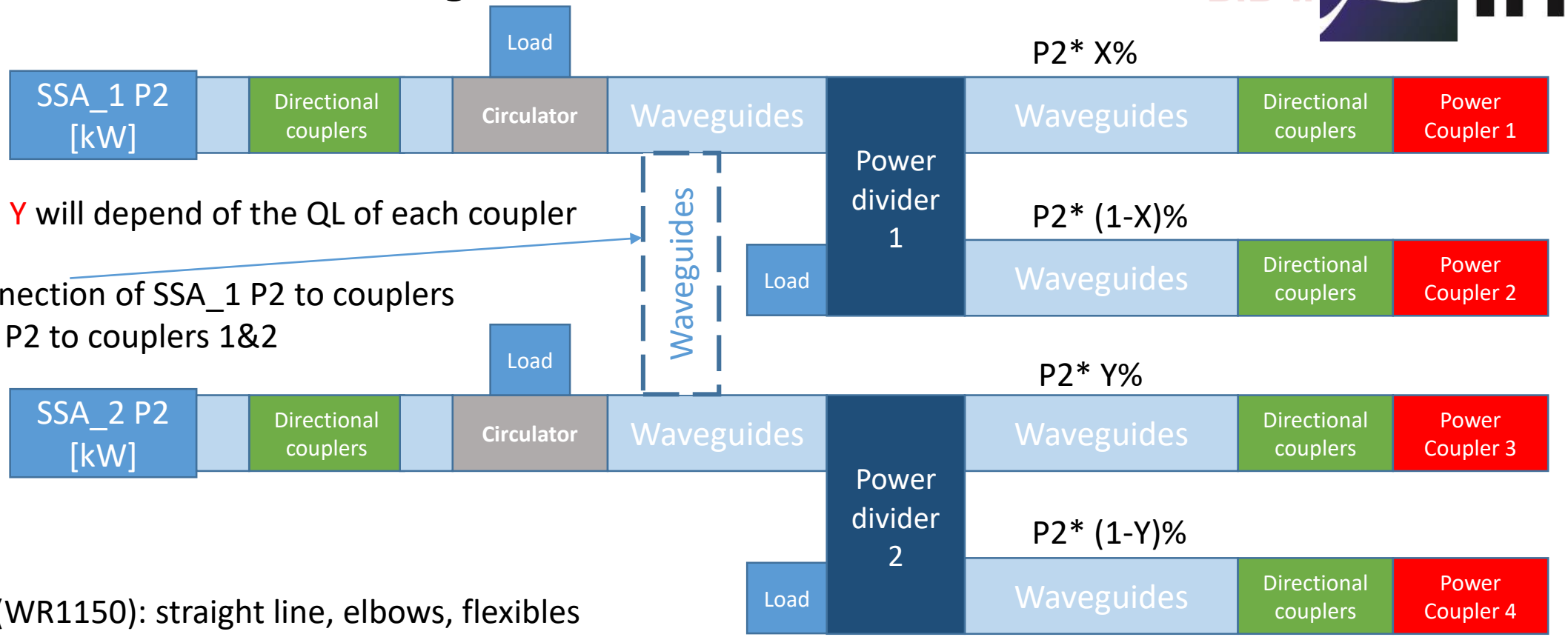
RF Power Test Configuration



- Waveguides (WR1150): straight line, elbows, flexibles
- We consider that we will need 2 flexibles for each RF path from the RF source to the power coupler
- We consider the waveguides length for each RF path to be about 40 m
- Maximum total losses in the RF network (based on manufacturer data) 0.5 dB

➔ P1= 21.5 kW

RF Power Test Configuration 2



Choice of X and Y will depend of the QL of each coupler

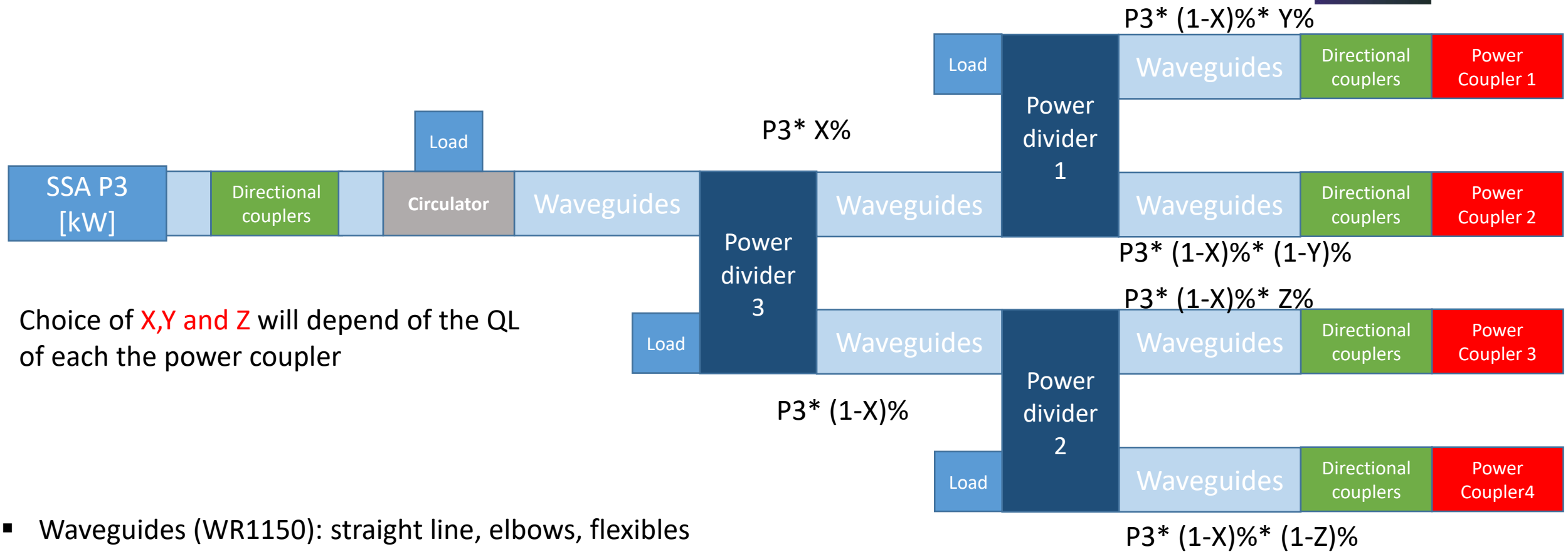
Removable connection of SSA_1 P2 to couplers 3&4 and SSA_2 P2 to couplers 1&2

- Waveguides (WR1150): straight line, elbows, flexibles
- We consider that we will need 2 flexible for each RF path from the RF source to the power coupler
- We consider the waveguides length for each RF path to be about 40 m
- Power divider adds 0.1 dB RF losses to each RF path
- Maximum total losses in the RF network (based on manufacturer data) 0.6 dB

➔ P2 ~ 44 kW max (this value will be reviewed after the discussion of the requirements for the cryomodule test)

➡ This configuration make RF conditioning of the couplers possible up to their maximum operating power

RF Power Test Configuration 3



Choice of X,Y and Z will depend of the QL of each the power coupler

- Waveguides (WR1150): straight line, elbows, flexibles
- We consider that we will need 2 flexible for each path from the RF source to the power coupler
- We consider the waveguides length for each RF path to be about 40 m
- 2* Power divider add 0.2 dB RF losses per power path
- Maximum total losses in the RF network (based on manufacturer data) 0.7 dB

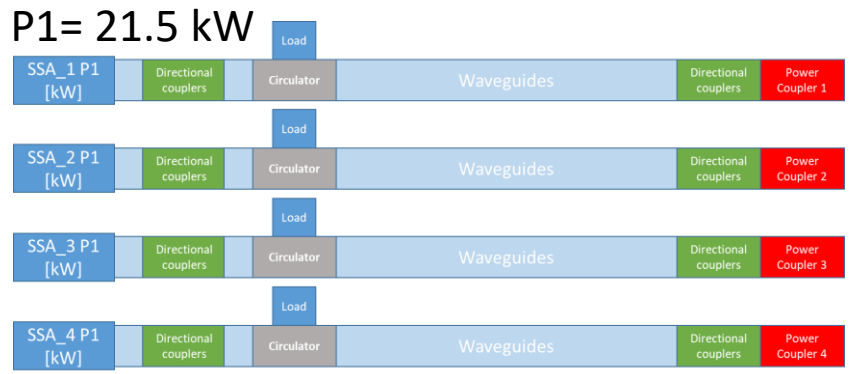
➔ P3 ~ 90 kW max (this value will be reviewed after the discussion of the requirements for the cryomodule test)

➔ This configuration makes the RF conditioning of the couplers possible up to their maximum operating power

Comparison Between the 3 Proposed Configurations

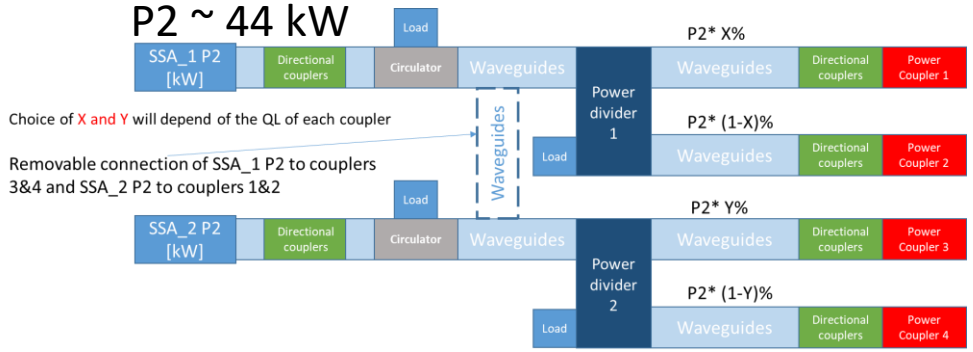
Config.1

(++) RF power increased independently on each coupler
(-) No possible test for the Power Coupler up to 30/35 KW
(-) More waveguide total length needed
(-) More equipment to install and command/control each source
(-) Four waveguide inputs to the casemate



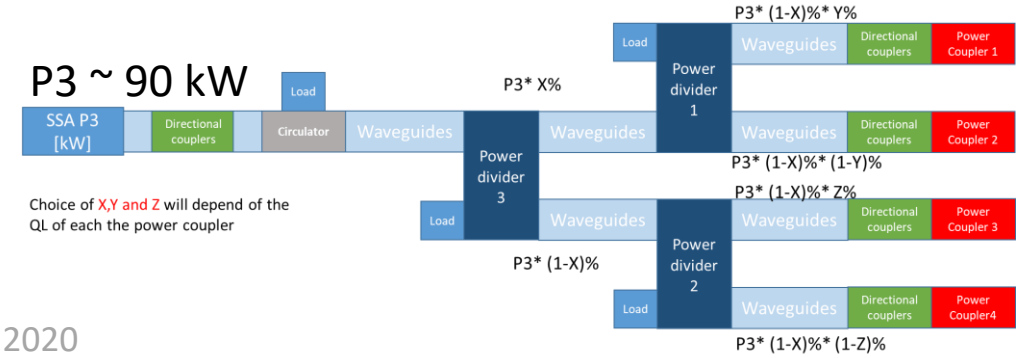
Config.2

(++) Possible test for the Power Coupler up to 30/35 KW
(+) Less waveguide total length than Config.1
(+) Less equipment to install and command/control each source
(-) RF power variation dependency between couplers (1&2) and (3&4)



Config.3

(++) Possible test for the Power Coupler up to 30/35 KW
(++) Less equipment to install and command/control each source
(+) Less waveguide total length than Config.2
(-) RF power variation dependency between couplers.
(-) In case of technical problem no RF test is possible



Miscellaneous (1)

Fermilab

Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Update of PIP2IT 650 MHz RF Distribution System

Ding Sun
For Final Design Review of PIP2IT 650 MHz RF Distribution System
August 25, 2020

Introduction

After the completion of PIP2IT beam operation, the PIP2IT cave will be converted to a test facility for high power test of PIP-II cryomodules (without beam). Both LB650 and HB650 cryomodules will be tested using the same RF system installed for PIP2IT test facility.

Functional requirement for each distribution line

RF functional requirement

- Capable of transporting power sufficient to test LB650/HB650 superconducting cavities to 115% of their specified gradient along beam line.
- Capable of operating with fully reflected RF power at any phase when each cavity is operated in either pulsed or CW mode.
- Provide an isolator to keep reflected power under maximum level required by SSA (Solid State Amplifier).

Technical specification for RF components

To meet Functional Requirement, the following are technical specifications for components to be used:

Overall specification (for all components): transport 40 kW output power, operate in either pulsed or CW mode with full reflection at any phase. Total attenuation: ≤ 0.4 db.

650MHz Coupler Specifications

Nikolay Solyak
650 MHz Coupler FDR/PRR
10 & 11 February 2020

In partnership with:
India/DAE
Italy/INFN
UK/STFC
France/CEA/Irfu, CNRS/IN2P3
Poland, WUST

Parameters	LB650	HB650	Units
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**maximum power to cover ±20% variations in QL, 20Hz cavity detuning from microphonics and allows 10% higher gradient.*

Miscellaneous (2)

PIP-II LB650 Cryomodule
Technical Requirements Specification

Document number: ED0009658, Rev. A

7. LB650 Fundamental Power Coupler Requirements

6.1 Introduction

PIP-II employs two types of 650 MHz superconducting cavities, low beta (LB650) and high beta (HB650) elliptical five cells cavities accelerating an H- beam. The maximum power delivered by LB650 cavities to the beam is about 23.8 kW in the case of 2 mA beam current. Accounting additional power for microphonics and mismatching compensation (cavity coupling is fixed) this requires a 26.6 kW coupler [6].