HIGH POWER RF TRANSMISSION LINES OF THE LIGHT PROTON THERAPY LINAC

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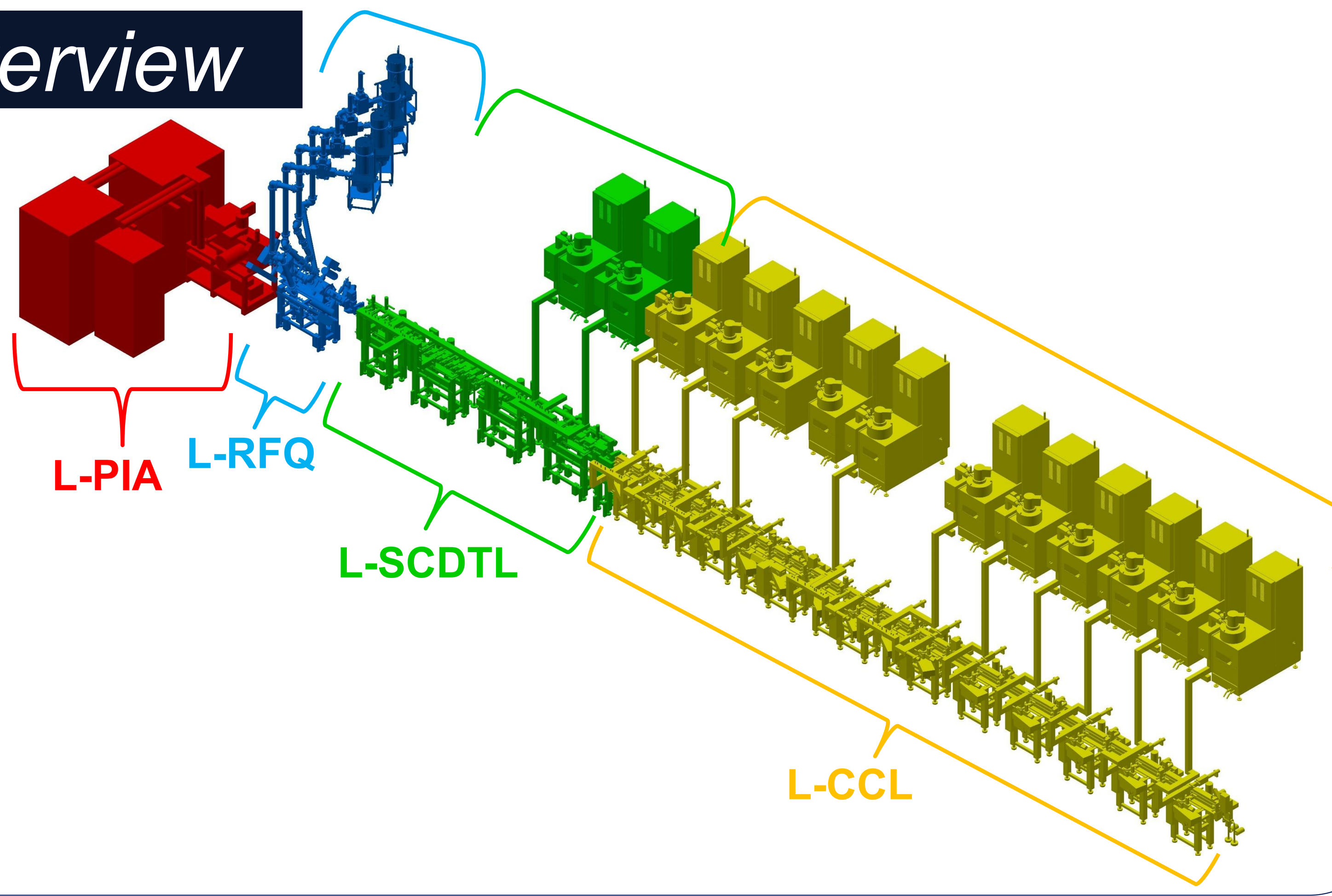
Abstract

The **Linac for Image-Guided Hadron Therapy (LIGHT)** machine is designed to **accelerate a proton beam up to 230 MeV** to treat deep seated tumours. The machine consists of three different kinds of accelerators: Radio-Frequency Quadrupole (RFQ), Side Coupled Drift Tube Linac (SCDTL) and Coupled Cavity Linac (CCL). These accelerating structures are fed with Radio Frequency (RF) power at 750 MHz (RFQ) and 3 GHz (SCDTLs and CCLs). This **power is delivered to the accelerating structures via the high power RF transmission network (RFN).** In addition, the RFN needs to offer other functionalities, like protection of the high RF power feeding stations, power splitting, phase and amplitude control and monitoring. The maximum power handling of the RFN corresponds to a peak **RF power of 8 MW and an average RF power of 9 kW**. It functions either in Ultra-High Vacuum (UHV) conditions at an ultimate operating pressure of 10^{-7} mbar, or under pressurized gas. The above listed requirements involve different challenges. In this contribution **we exhibit the main aspects to be considered based on Advanced Oncotherapy's (AVO) experience during the commissioning of the RFN units.**

LIGHT system overview

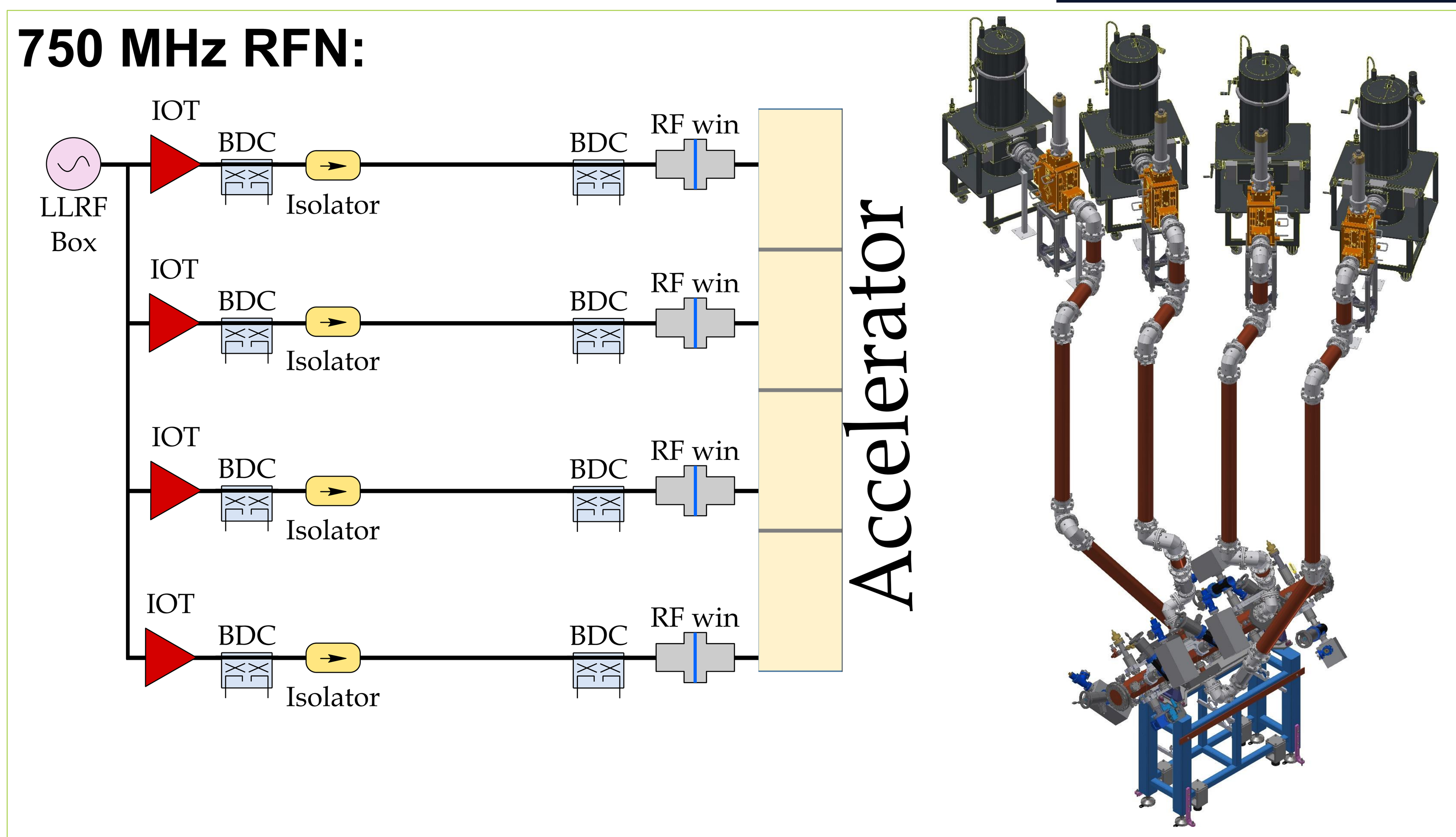
The **LIGHT accelerator** is composed by the following subsystems:

- LIGHT Proton Injector (**L-PIA**) that produces continuous **proton pulses of 5us at 200 Hz** and modulates their intensity.
- LIGHT Radiofrequency Quadrupole subsystem (**L-RFQ**) that comprises the necessary devices to produce, amplify, transport, monitor and control **RF at 750MHz** to feed an RF quadrupole cavity that is capable of capturing the **proton** pulses produced by the source, perform **bunching and accelerate** them **up to 5 MeV**;
- LIGHT Side Coupled Drift Tube Linac subsystem (**L-SCDTL**) composed of two units with the necessary equipment to produce, amplify, transport, monitor and control the **3GHz RF** power to feed accelerating cavities boosting **protons up to a fixed energy of 37.5 MeV;**
- LIGHT Coupled Cavity Linac subsystem (L-CCL) composed of 10 units able to produce, amplify, transport, monitor and control the **3 GHz RF** power to feed 15 CCL cavities able to dynamically modulate the energy of the **protons from 70 to 230 MeV**;
- After the main Linac other subsystems transport and deliver the beam to one or several treatment rooms, which are out of the scope of this contribution.



LIGHT RF NETWORK

750 MHz RFN:



Conceptual design (left) and integration at Daresbury lab (right) of the 750MHz RF Network

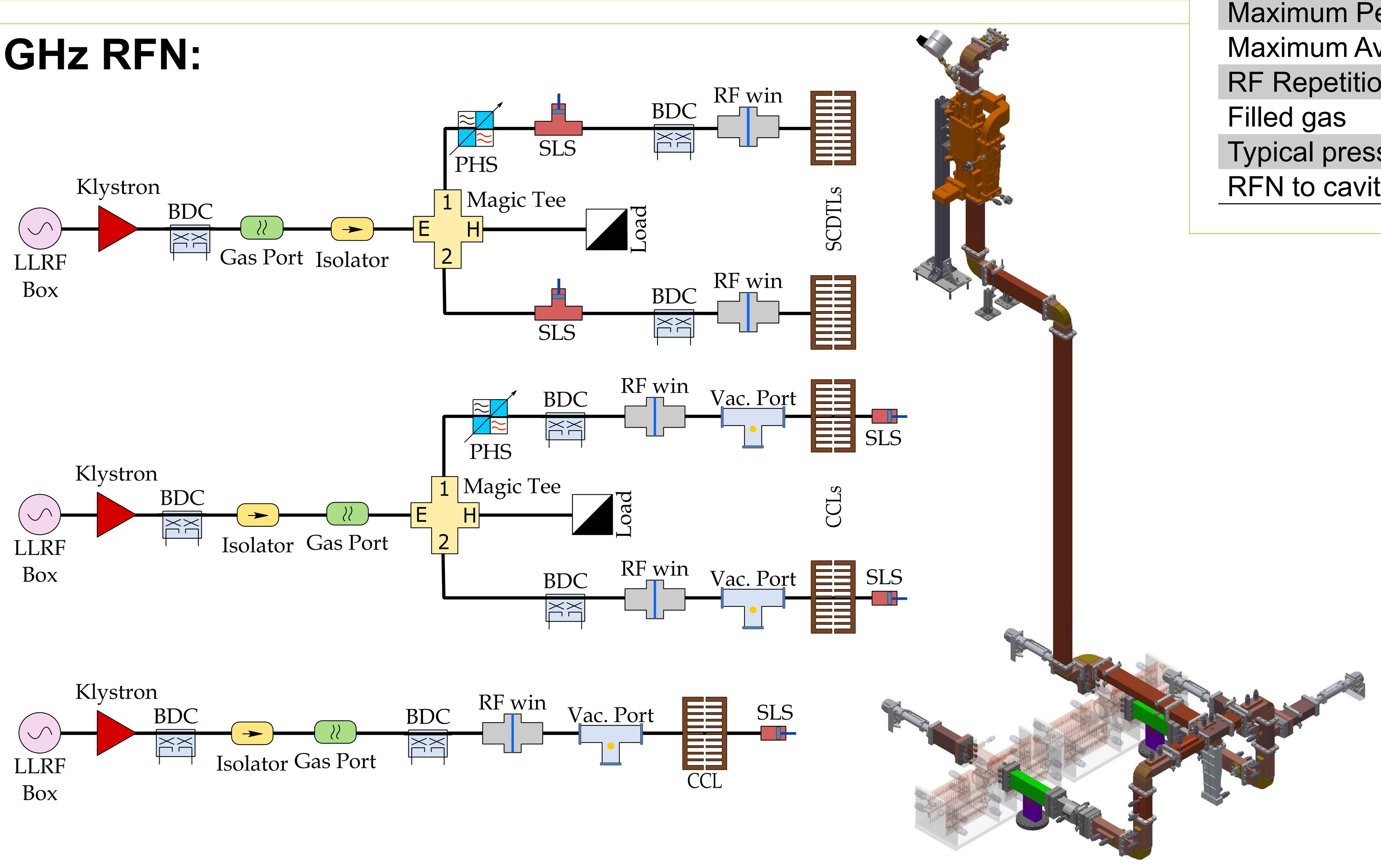
The 750 MHz RFN, composed of coaxial lines, connects 4 Inductive Output Tubes (IOTs) delivering up to 120 kW each to a Radio Frequency Quadrupole (RFQ) with 4 couplers to reach a power level of up to 480 kW.

Main functional components:

- **Circulators:** For IOT protection against reflected power.
- **Bi-directional couplers:** For RF power monitoring
- **PEEK windows** (integrated in RFQ): For vacuum to air separation

Table 1: RFN summary parameters	L-RFQ	L-SCDTL and L-CCL
Technology	Coaxial Lines 3 1/2 and 4 ½ inches	Heavy wall waveguides WR284
Working Frequency	**750 MHz**	**3 GHz**
Maximum Peak Power	120 kW	8 MW
Maximum Average Power	240 W	9 kW
RF Repetition Rate	200 Hz	200 Hz
Filled gas	Air	SF6 or vacuum
Typical pressure	1 bar	3.6 bars (SF6) or <10^{-8} mbar
RFN to cavity interface	PEEK windows	Coated ceramic Windows

3 GHz RFN:



Conceptual design for double (top and middle left) and single (bottom left) module feeding and integration at Daresbury lab (right) of a L-CCL 3GHz RF Network.

The 3 GHz RFN, composed of heavy wall WR284 waveguides connects 13 Modulator-klystron systems (MKS) to 19 accelerating cavities (4 SCDTLs and 15 CCLs). The power transported varies from 1 to 8 MW.

Main functional components:

- **Isolators:** For MKS protection against reflected power
- **Bi-directional couples:** For RF power monitoring
- **Magic Tees:** For power splitting
- **Phase shifters:** For phase and amplitude control
- **Line matchers:** For impedance matching
- **Gas and vacuum ports:** For SF6 filling or vacuum pump down
- **RF Windows:** For vacuum vs pressure sections separation

Conclusions

The LIGHT accelerator relies on the RFN to transport, manipulate and monitor the high-power RF used by the accelerating cavities. The RFN has been designed to meet all the AVO requirements and **is tailored to each installation site**. In this poster we present the main characteristics of the RFN. In the related proceedings, we have dissected the main points we have found **important to consider** after our experience with **the design, installation, and commissioning** of the first LIGHT system.