

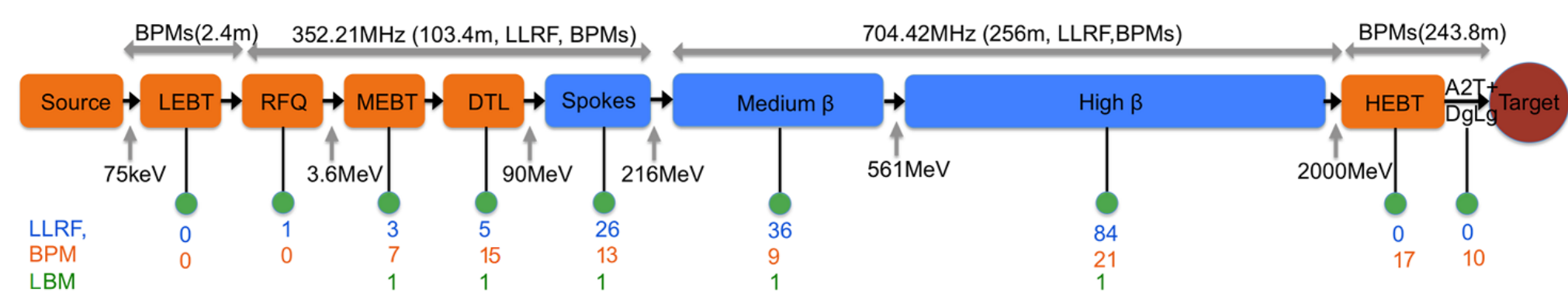
ABSTRACT

The **European Spallation Source (ESS)** requires precise phase synchronization of LLRF and Beam Diagnostics systems operating at frequencies of **352.21 MHz** and **704.42 MHz**. The required phase accuracy at both frequencies is **0.1° for short term (during 3.5 ms pulse)** and **2.0° for long term (hours to days) between any two points** in the 600 m long accelerator tunnel with LINAC.

The Phase Reference Distribution System (PRDS) is based on passive synchronization scheme where the pick-up cables from RF cavities and beam diagnostics instruments are paired and length-matched to corresponding reference cables from the PRDS. This minimizes phase drift errors between these two cables and enables precise synchronization in harsh radiation environment in accelerator tunnel where active drift compensation techniques cannot be used.

The main part of the PRDS is **Phase Reference Line (PRL)** which is a fully passive distribution system based on a single 1-5/8" coaxial rigid line placed in the tunnel along the LINAC. The PRL distributes both reference frequencies (352.21 MHz and 704.42 MHz) from Master Oscillator located in the Klystron Gallery to 58 tap points in the tunnel. Each tap point consists of 1-5/8" coaxial directional coupler together with passive splitting and filtering module. This provides locally multiple frequency-selective outputs.

OVERVIEW



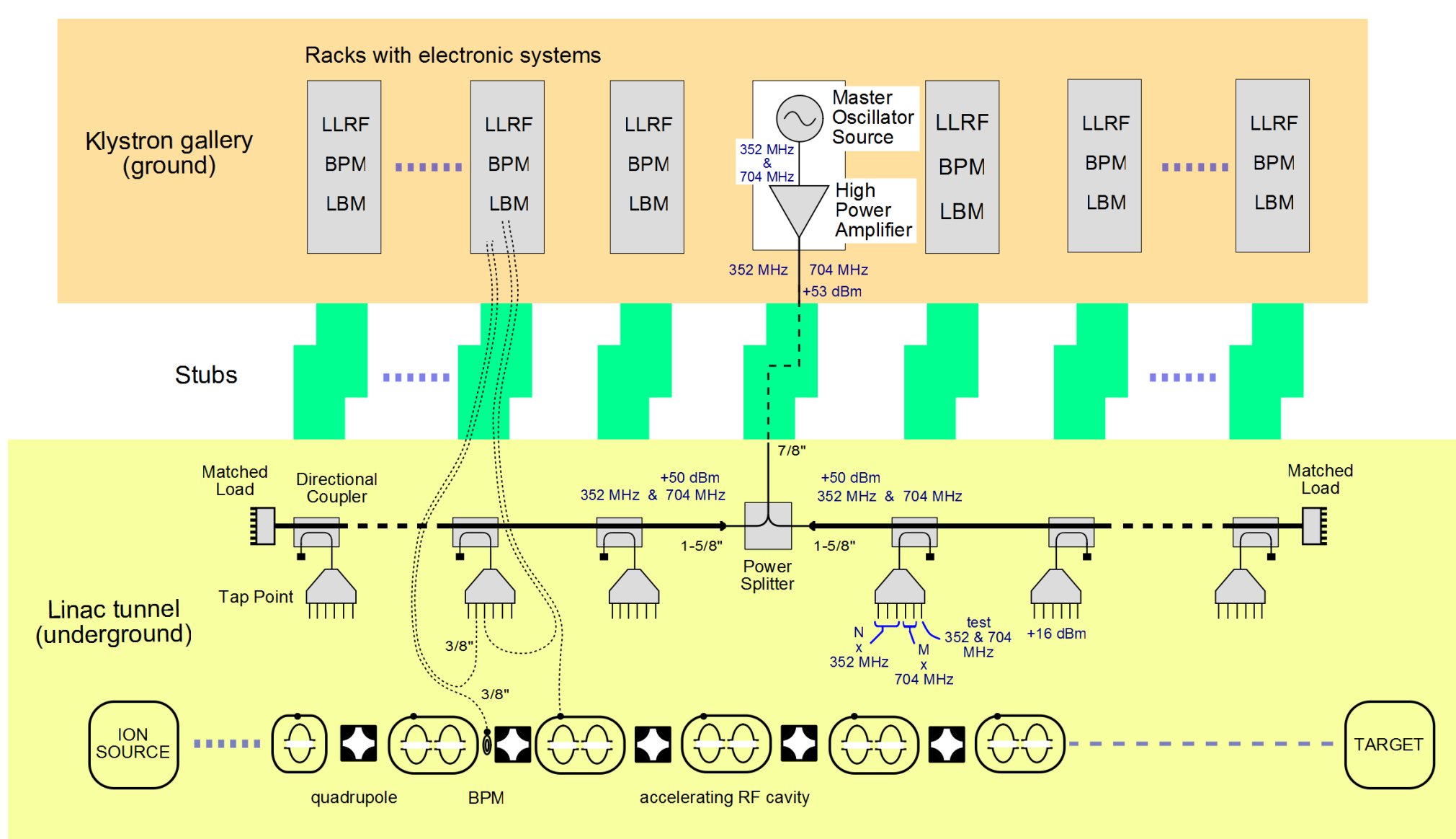
- Passive distribution of 352 MHz and 704 MHz harmonic signals in a single **1-5/8" coaxial rigid line (gas filled)**
- Total length of the PRL is **581 meters** (nearly 150 rigid line sections)
- Total number of signal outputs is ~300
- Output power from PRL is **+16 dBm (±2dB)**
- 58 x Tap Points** (3-way and 6-way)
- Signals delivered to:
 - 155 x LLRF systems
 - 101 x BPM systems
 - 4 x LBM systems
- Phase stability **0.1° short term / 2.0° long term**
- Jitter @ 704 MHz < **100 fs** (100 Hz ... 1 MHz)
- Jitter @ 352 MHz < **100 fs** (100 Hz ... 200 kHz)

Summary of PRL outputs

352 MHz outputs	52
704 MHz outputs	157
Test outputs	85
TOTAL	294

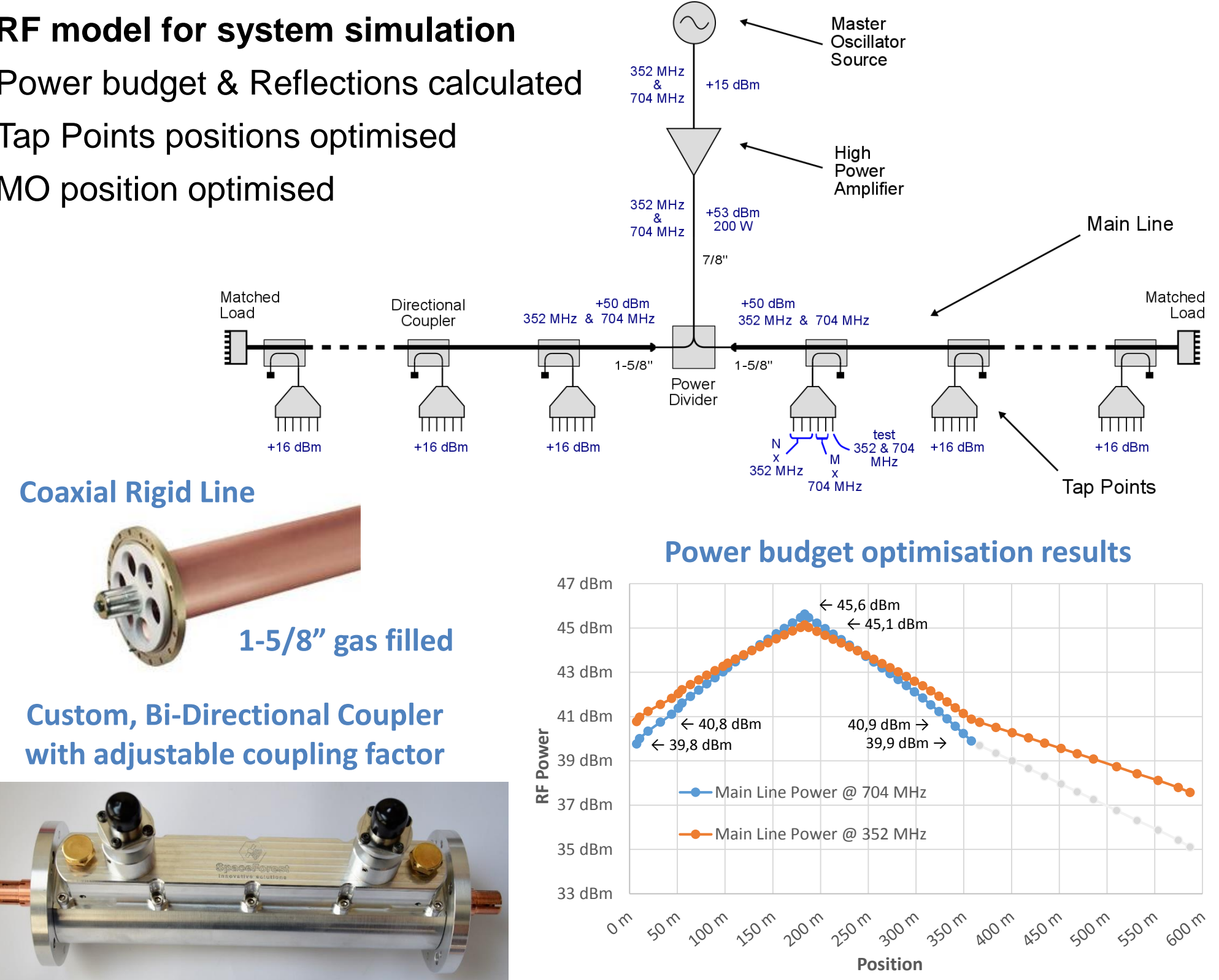
SYSTEM CONCEPT

- Single coaxial line to distribute both frequencies to minimize drifts
- Rigid line with multi-output Tap Points placed in the tunnel along the linac
- All electronics (e.g. MO with HP-amplifier, temperature controllers, etc.) placed in Klystron Gallery outside the tunnel to avoid radiation
- Pick-up cables from RF cavities and BPM/LBMs are paired and length-matched to corresponding reference cables from PRL tap points to minimize drifts errors
- All cables from the tunnel to the gallery go via 26 x stubs (passages)
- Master Oscillator and PRL input divider are in the ~middle of the Linac to optimize power & drift budget
- Auxiliary systems to improve phase stability in PRL: temperature, gas pressure & humidity control systems
- Online control and diagnostics in EPICS



RF CONCEPT

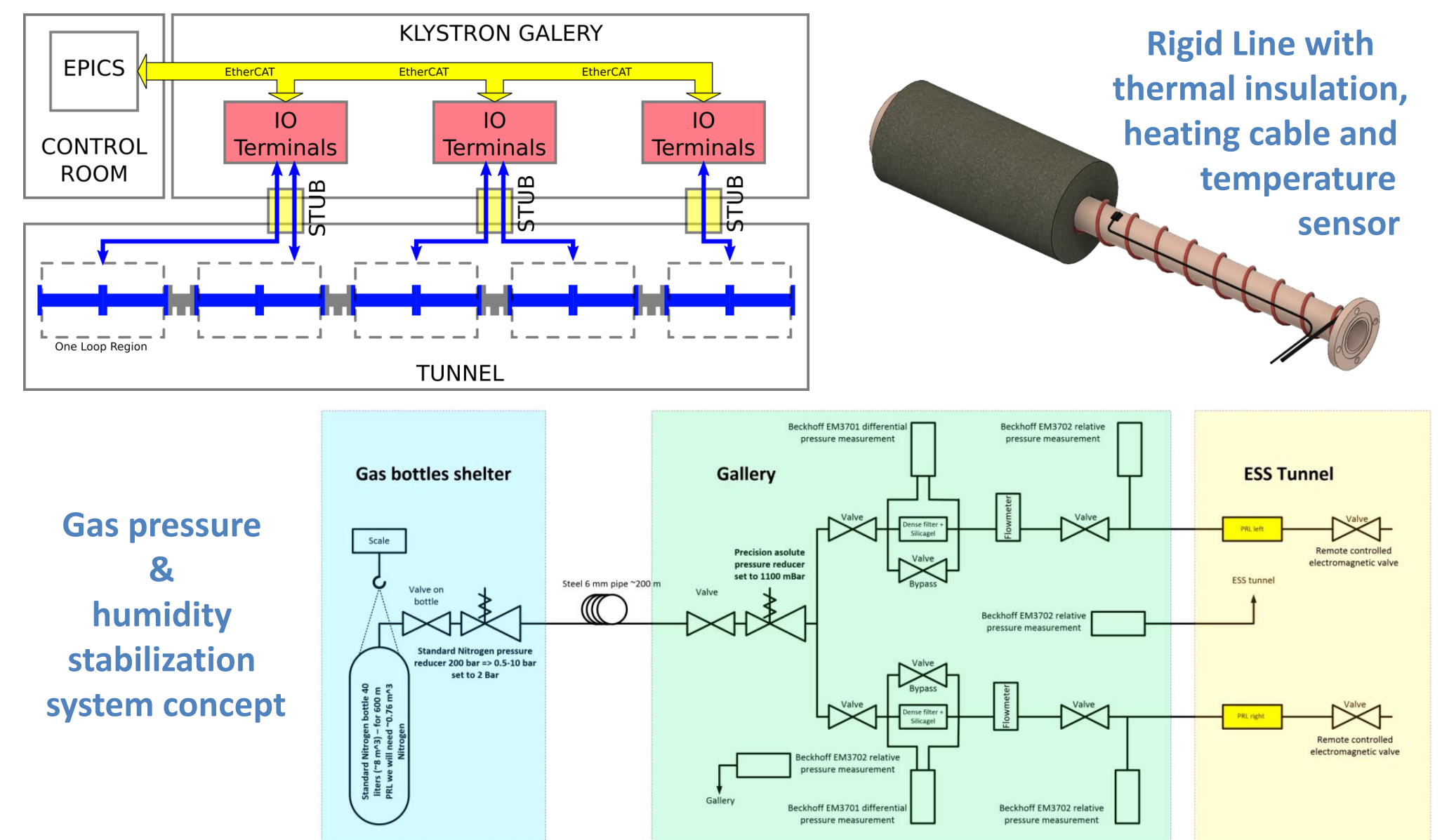
- RF model for system simulation**
- Power budget & Reflections calculated
- Tap Points positions optimised
- MO position optimised



TEMPERATURE AND PRESSURE STABILIZATION

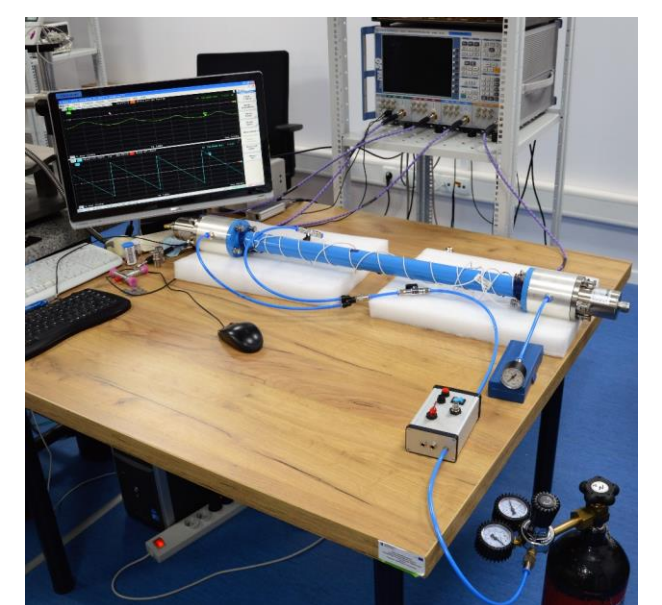
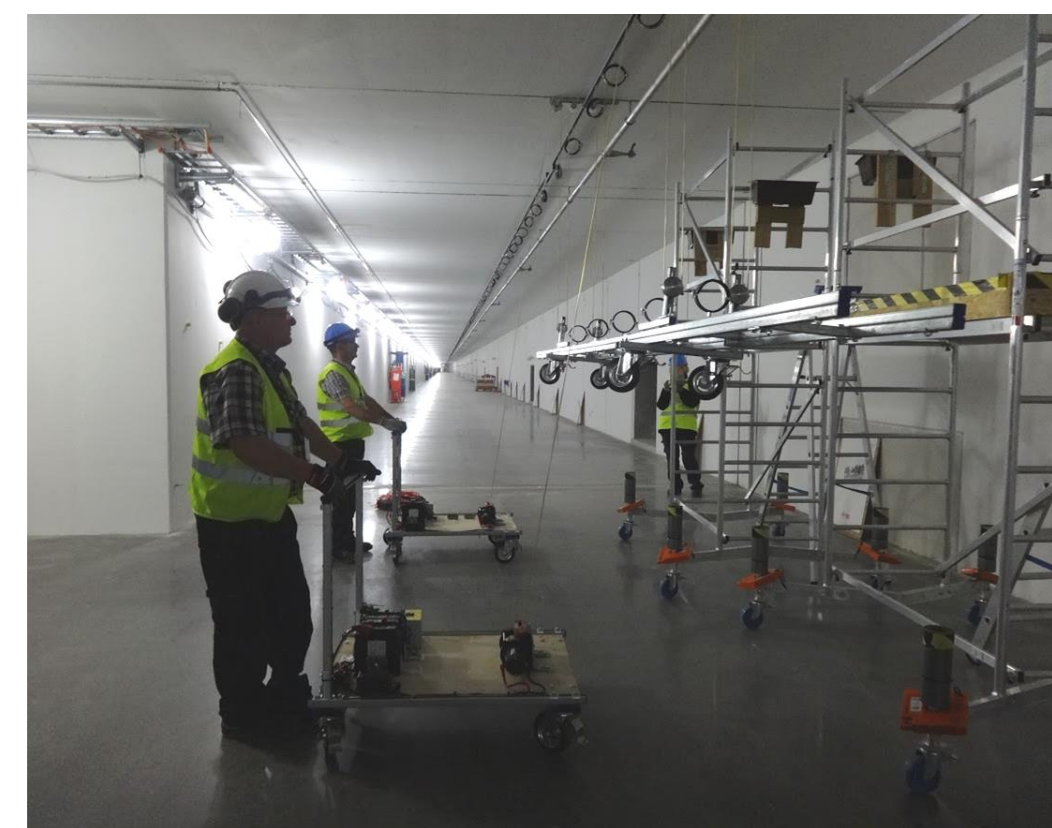
- To minimize reference signals phase drifts the system is equipped with:
- PRL **temperature stabilization** system: semi-active +40°C (± 0.1°C)
 - PRL **pressure and humidity stabilization** system: rigid line filled with dry Nitrogen @ 1100 mbar (±2 mbar)

Temperature stabilization system concept



PROTOTYPING & TUNNEL INSTALLATION

- 18 m long prototype installed in WUT
- RF characterization of components – model building
- Phase stability (drifts) tests
- Temperature & gas system tests
- PRL installation in ESS tunnel started (July 2017)**



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