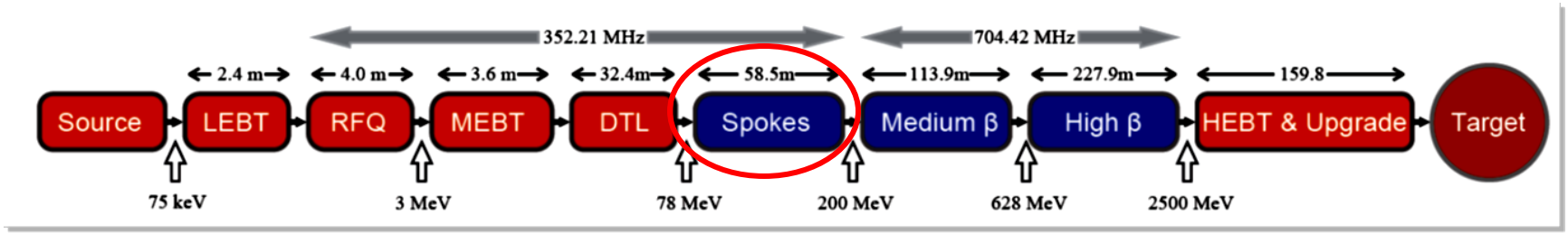
UPPSALA UNIVERSITET

RF Power Sources for ESS Spoke Linac and Proposed Test Program

Rutambhara Yogi & FREIA Group

Schematic of ESS Linac



Targets:

- Beam reliability 95 %
- RF system reliability 99 % (Under study for Spoke Linac)

Tasks of FREIA:

- To propose technology for ESS Spoke Linac amplifier
- High power test of prototype Spoke cavities, which are developed for the first time at IPN Orsay

Challenges:

RF Amplifier doesn't exist at ESS specifications: FREIA is developing amplifier at ESS specifications

ESS Specifications for Spoke Linac Amplifier

- Maximum RF power coupled to beam = **320 kW**
- Considering LLRF overhead = 15% (12.5% power overhead: Simulink model)
- RF loss in distribution system = 5%,
  Power of RF Power Station = 390 kW ≈ 400 kW
- Beam pulse width = 2.86 ms, repetition rate = 14 Hz,
  Natural fill time = $t_f = 2Q_L / \omega$ = 135 µs, ($Q_L = 1.5 \times 10^6$)
  RF pulse width = 2.86 ms + beam filling time = 3.1 ms ≈ **3.5 ms**
  Duty factor of the amplifier = 4.28 % ≈ 5%
- Spoke cavity band-width = 2.34 kHz
  system band-width ≈ 100 times larger than spoke resonator band-width for tuning and regulation delay.
  3 dB bandwidth > 250 kHz.

RF Power Station Specifications

Specifications:

Frequency = 352 MHz
Peak power = 400 kW
Average power = 20 kW
Pulse width = 3.5 ms
Pulse repetition frequency = 14 Hz

Test Aim 1: To confirm specifications of RF power station

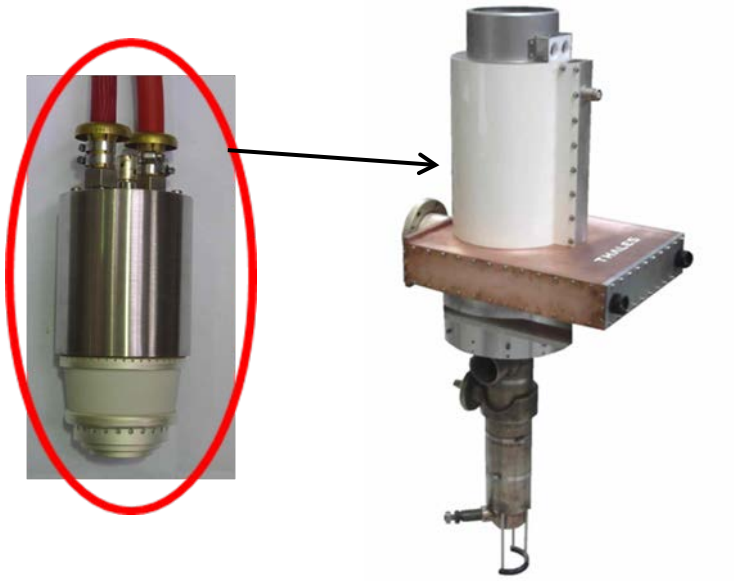
Target Reliability of ESS RF systems is 99%.

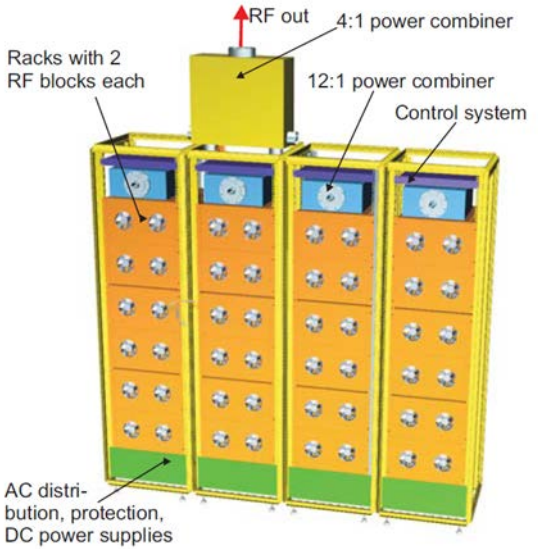
Test Aim 2:To test reliability / availability / stability of RF power station

Soak test of RF power station for few months ?? year ??

Compared all the possible RF Transmitters like Tetrode, Klystron, IOT, Solid state amplifier and selected Tetrode for the first RF power station (availability, price, footprint). [Reported in SLHiPP2012, Katania]

Expeted delivery: Jan / Feb 2014





High power RF Power Station using solid state technology under development by Siemens Research centre.

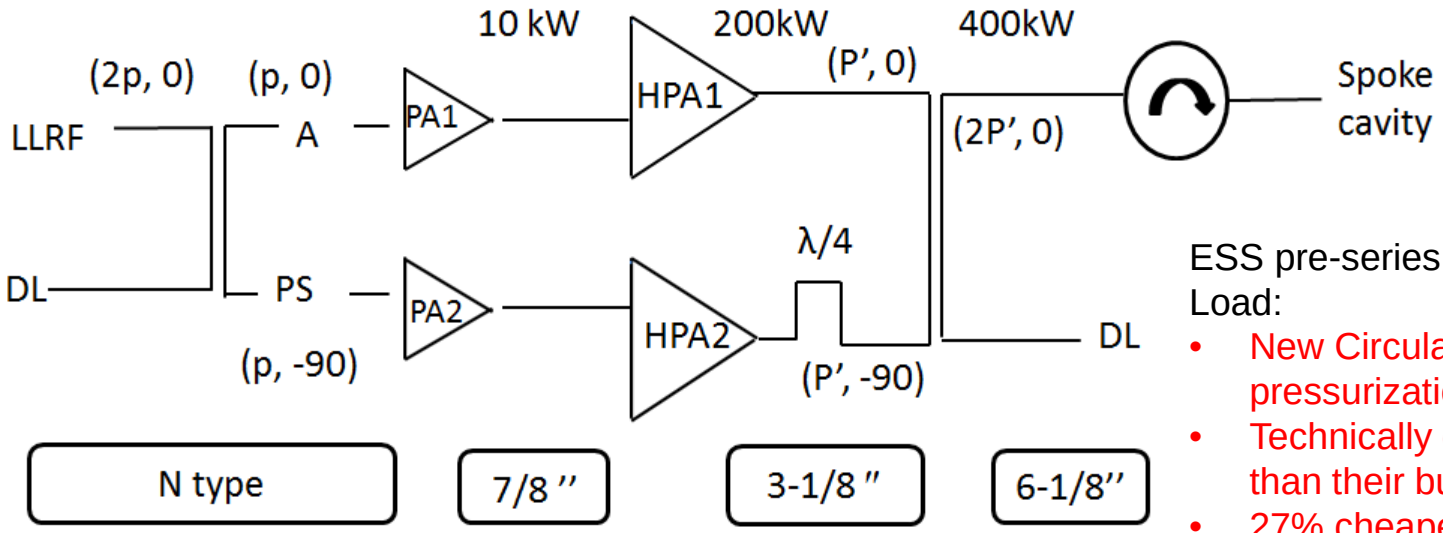
Expected delivery Jan / Feb 2014

ESS Amplifier technology will be proposed after testing tetrode and solid state RF power stations.

Tetrode RF Power Station (400 kW)

After comparing three tetrodes TH781, TH391 and TH595,
Tetrode TH595 is selected as HPA [Reported in SLHiPP2013, Belgium]

TH595 has been tested at Thales factory in Nov. 2012 for 200 kW power



Schematic of RF Power Station Layout

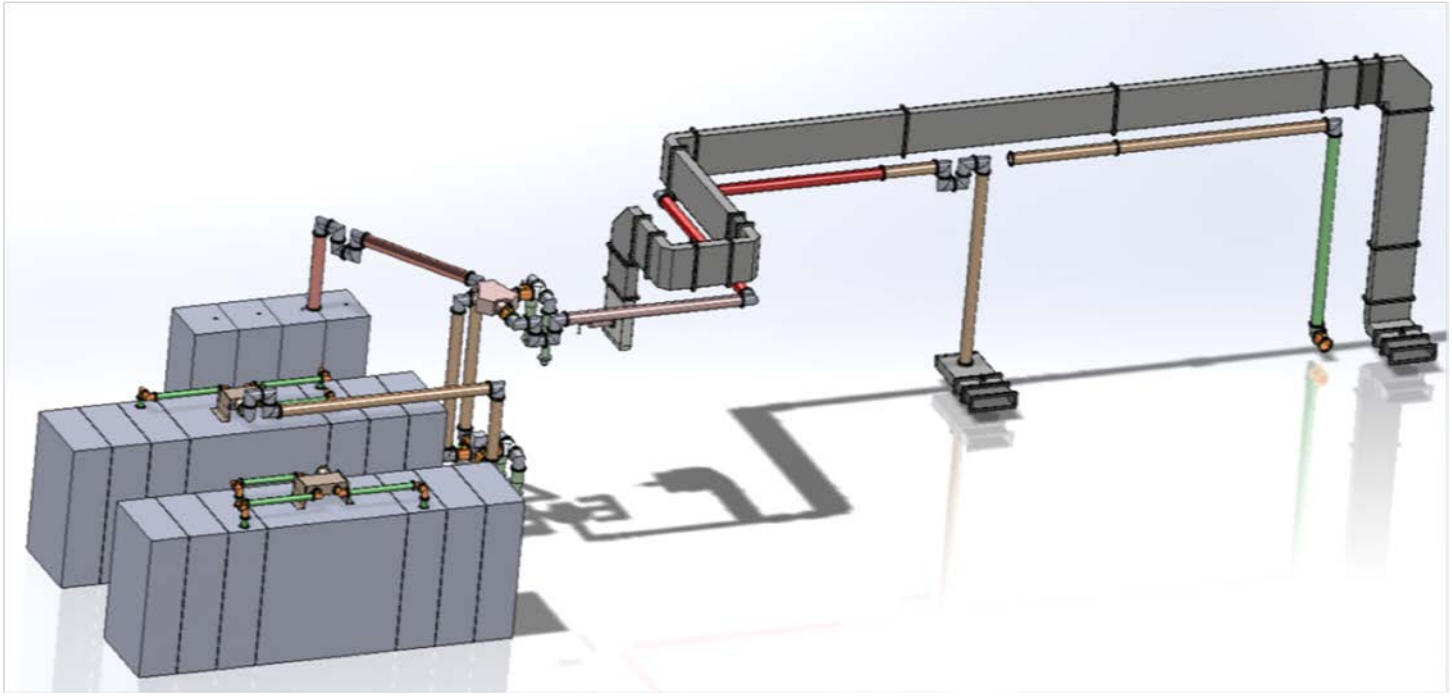
ESS pre-series tender for Circulator and Load:

- New Circulator design to avoid pressurization without NRE
- Technically good & 44% cheaper than their budgetary quotation
- 27% cheaper than their competitor

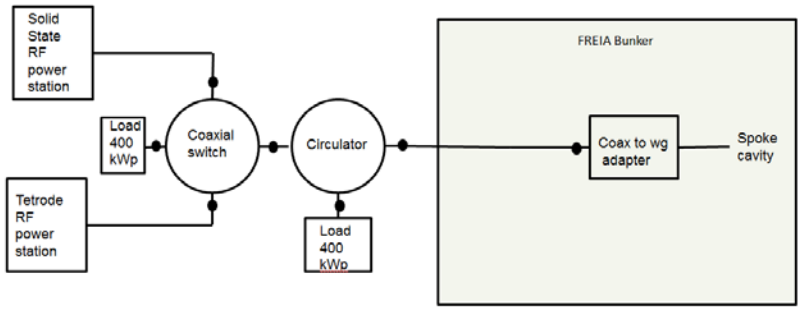
Due to λ/4 section, both Tetrodes see same phase of reflected signal

Test Aim T3: Circulator-less operation of tetrode
Under study: Collaboration with Eric Montesions (CERN)

RF Power Stations at FREIA (400 kW)



Foot print:
5.4 m x 1.2 m

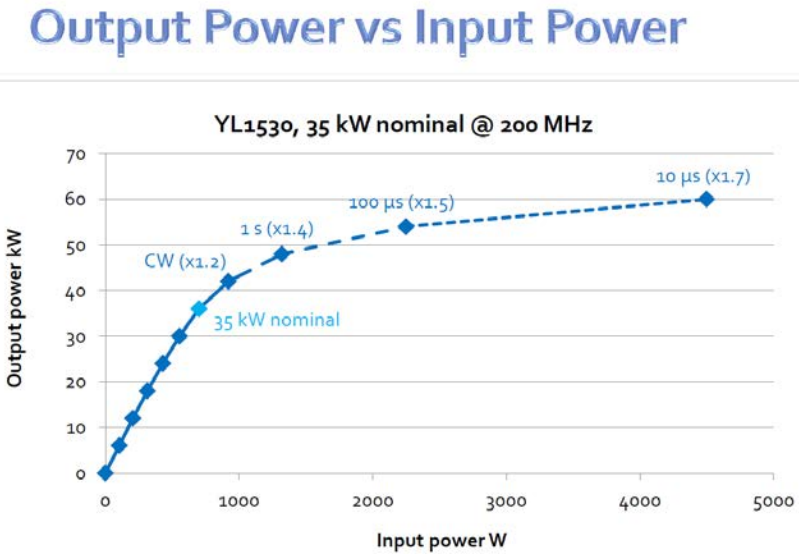


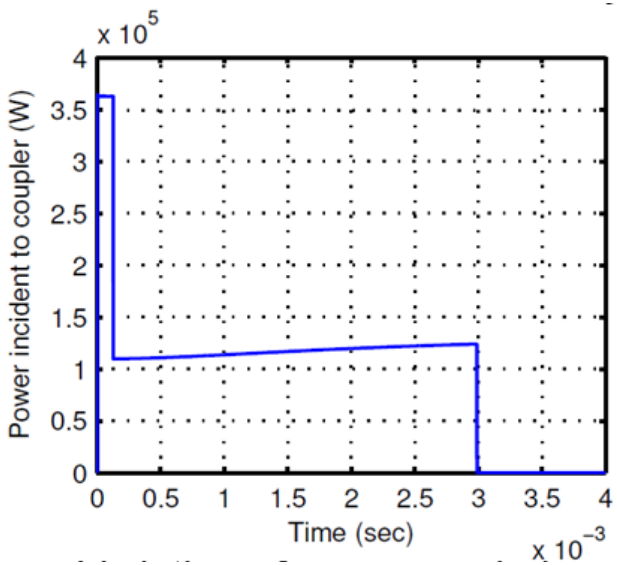
Schematic of RF distribution layout

Tetrode RF Power Station (400 kW)

For calculating Spoke amplifier power,
LLRF overhead = 15%

Tetrodes can provide more than 1.5 times the nominal power for short time, with same power supply voltages, but more input power:
Excursions of gain curve
(Ref: Presentation by Eric Montesinos (CERN) during TIARA workshop)





Ref: Report by Vitaliy Goryashko

Lorentz detuning compensation of cavity

Instead of power sweep, pulses of power can be given ie. excursion of gain curve can be used, thus it can be used to decrease LLRF overhead for Amplifier power calculation.

Test Aim 4: Gain excursion curve for TH595

To test experimentally at FREIA and then propose to ESS

Tetrode RF Power Station (400 kW)

Use of ESS for Intense Neutrino Super Beam Experiment for Leptonic CP Violation Discovery

A very intense, cost effective and high performance neutrino beam will be delivered using ESS facility

Baseline program for ESS linac: It will be fully operational at 5 MW average power by 2022, producing 2 GeV 2.86 ms long proton pulses at a rate of 14 Hz.
Suggested proposal: To upgrade the linac to 10 MW average power and 28 Hz, producing 14 pulses/s for neutron production and 14 pulses/s for neutrino production.

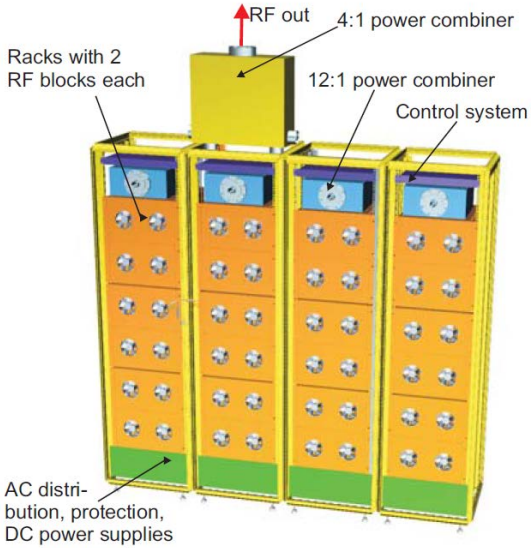
Specifications of the RF Power Station:

Frequency = 352 MHz
Peak power = 400 kW
Average power = **40 kW**
Pulse width = 3.5 ms
Pulse repetition frequency = **28 Hz**

Test Aim 5: To test RF Power Station for Neutrino Experiment ie. at double pulse repetition frequency.

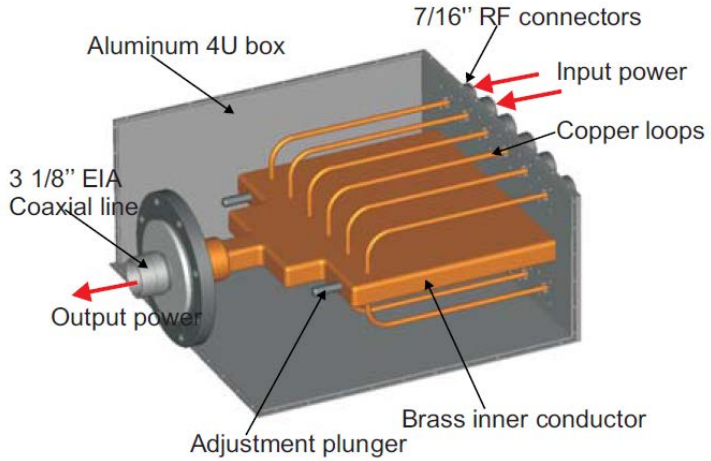
We have witnessed this test at Thales factory (Thonon) yesterday.

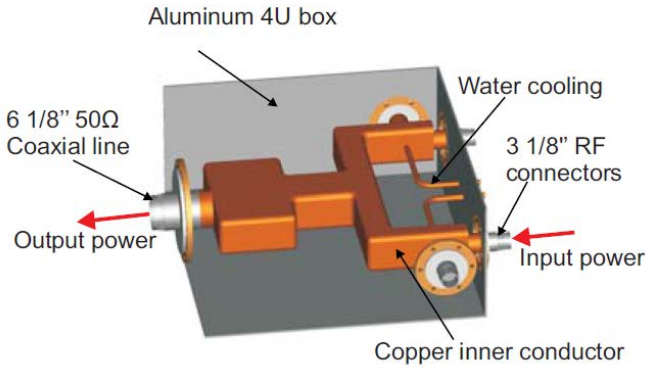
Test of Solid State RF Power Station (400 kW)



Schematic of RF Power Station 400 kW

First stage power combiner: 8 kW input, 12 inputs





Second stage power combiner: 100 kW input, 4 inputs

Claim of Siemens:
The RF power station doesn't need circulator for operation.

Aim of Test:
S1. To confirm specifications of RF power station
S2. To test reliability of RF power station
S3. Test with 100 % reflection ($\rho = 1$)
S4. Test Request by Siemens: Test with all other mismatched load values – To traverse whole Smith chart as far as posssible.
S5. Test with arc created by fast moving RF short-circuit. (Device from CERN)

Test Aims for both RF Power Stations (400 kW)

Aim of Tests for Tetrode RF Power station

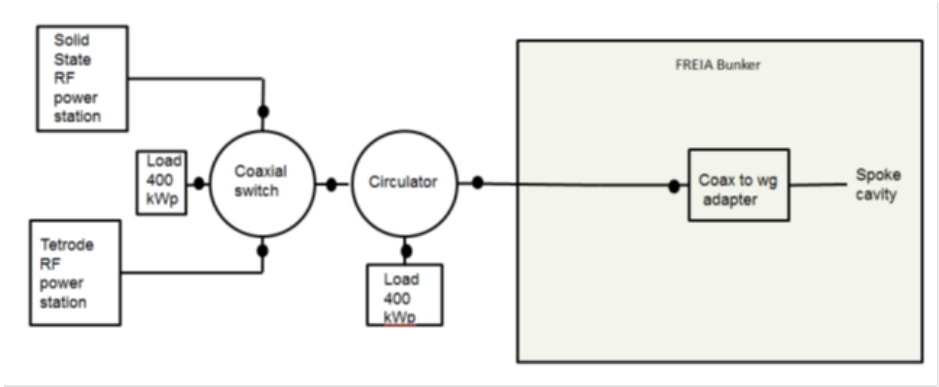
T1. To confirm specifications of RF power station
T2. To test reliability of RF power station
T3. Gain excursion curve for TH595
T4. To test RF Power Station for Neutrino Super Beam Experiment
T5. Circulator-less operation of tetrode (Under study)

Tetrode RF Power Station: All the tests for will be conducted on matched load (except for test T5)

Aim of Test for Solid State RF Power Station

S1. To confirm specifications of RF power station
S2. To test reliability of RF power station
S3. Test with 100 % reflection ($|\rho| = 1$)
S4. Test Request by Siemens: Test with all other mismatched load values – To traverse whole Smith chart as far as possible.
S5. Test with arc created by moving RF short circuit

Solid State RF Power station: Tests S1 and S2 for will be conducted on matched load Test S3 and S4 will be conducted on mismatched load.



Thank you !