PRELIMINARY LAYOUT OF THE ESS RF SYSTEM

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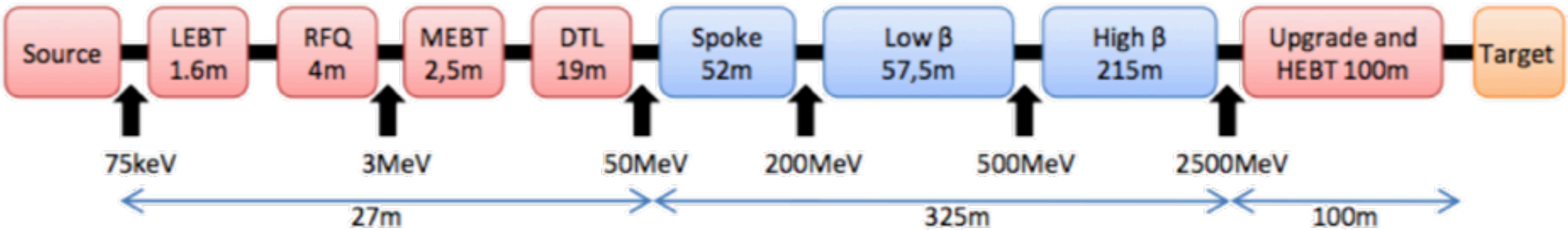
LINAC PARAMETERS

- ✓ **Average power: 5 MW**
- ✓ **Energy: 2.5 GeV**
- ✓ **Pulse length: 2 ms**

  2.3 ms including filling time of cavities
- ✓ **Repetition rate: 20 Hz**
- ✓ **Losses: ≤ 1 W/m**
- ✓ **Reliability: Better than 95%**
- ✓ **Operation: 4800 h / year**

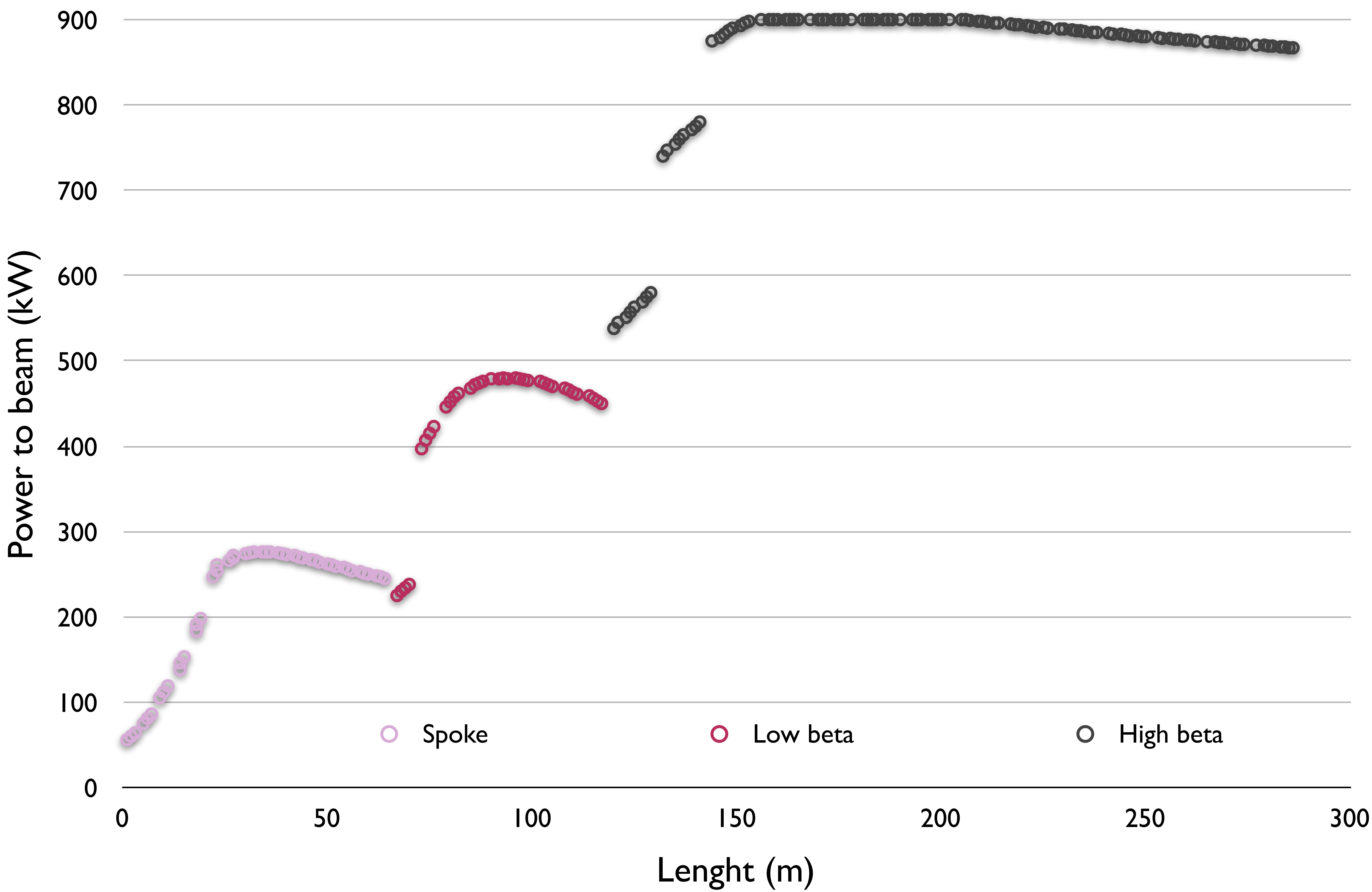
  5280 h including start up and R&D

LINAC LAYOUT

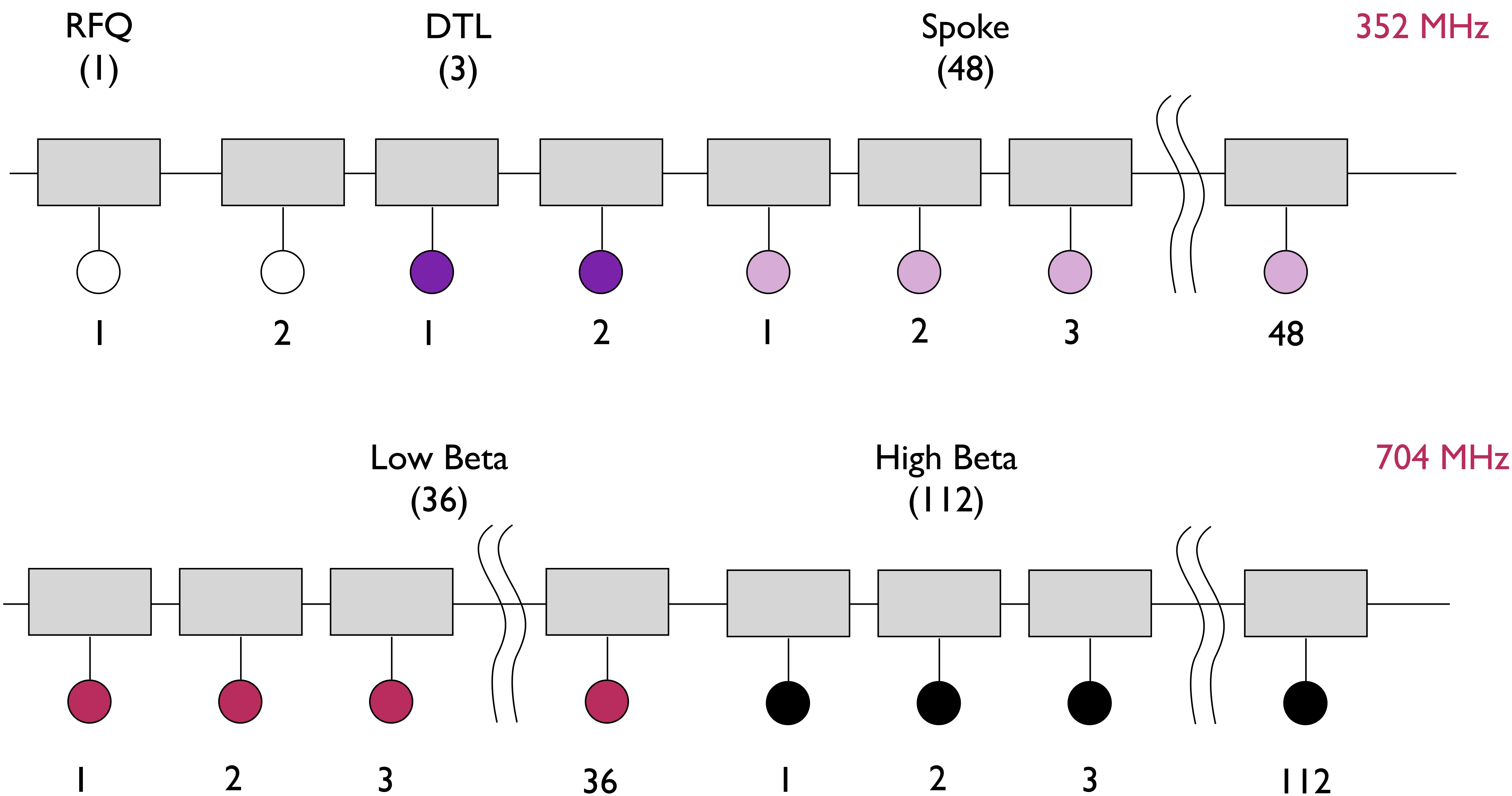


	Temp (K)	Freq. (Mhz)	Power to beam (MW)	Cavities
RFQ	300	352	~1	1
DTL	300	352	1–2	3
Spoke	2	352	≤0.3	16x3
Low Beta	2	704	≤0.5	9x4
High Beta	2	704	≤0.9	14x8

POWER TO BEAM

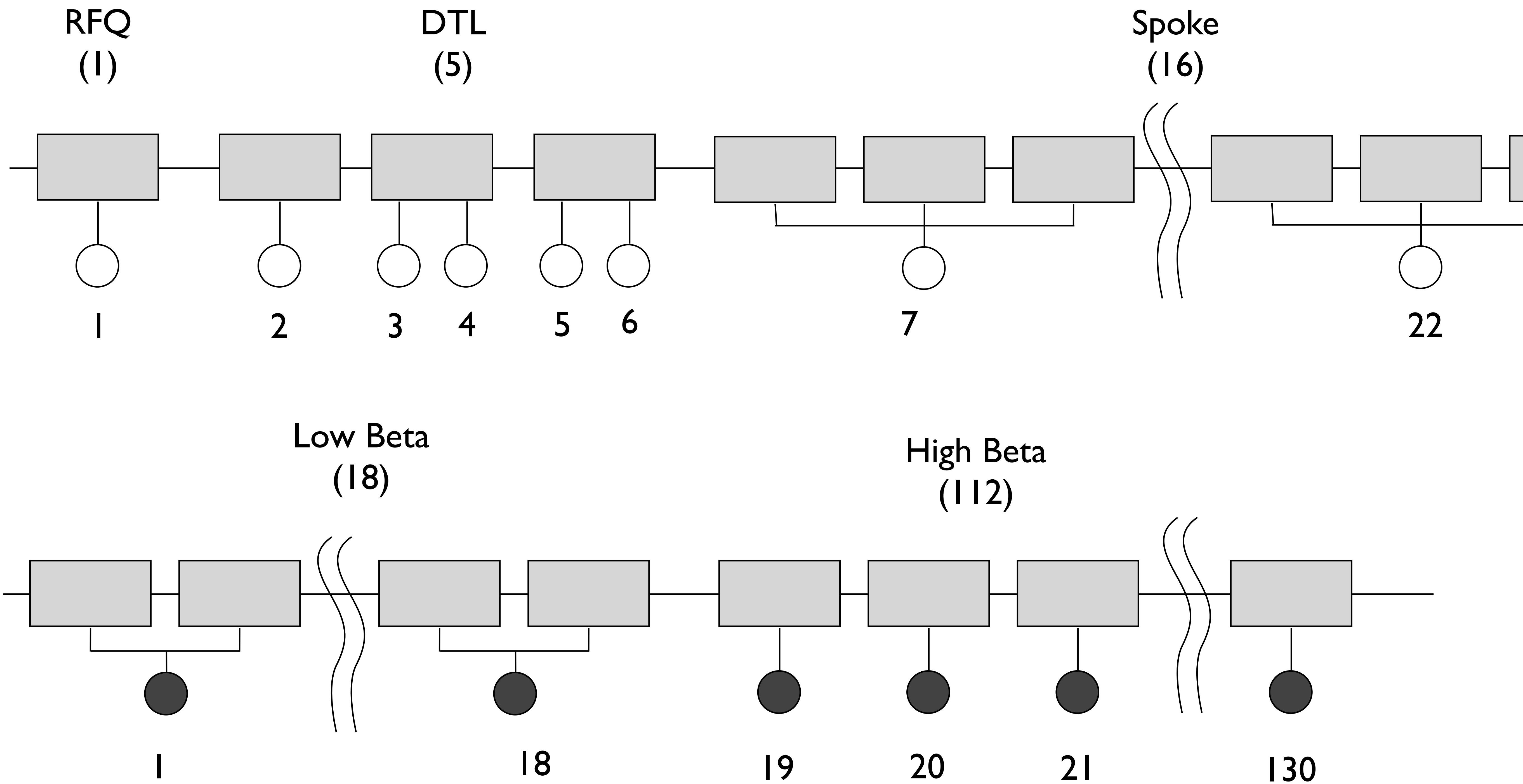


RF SOURCE SCHEME



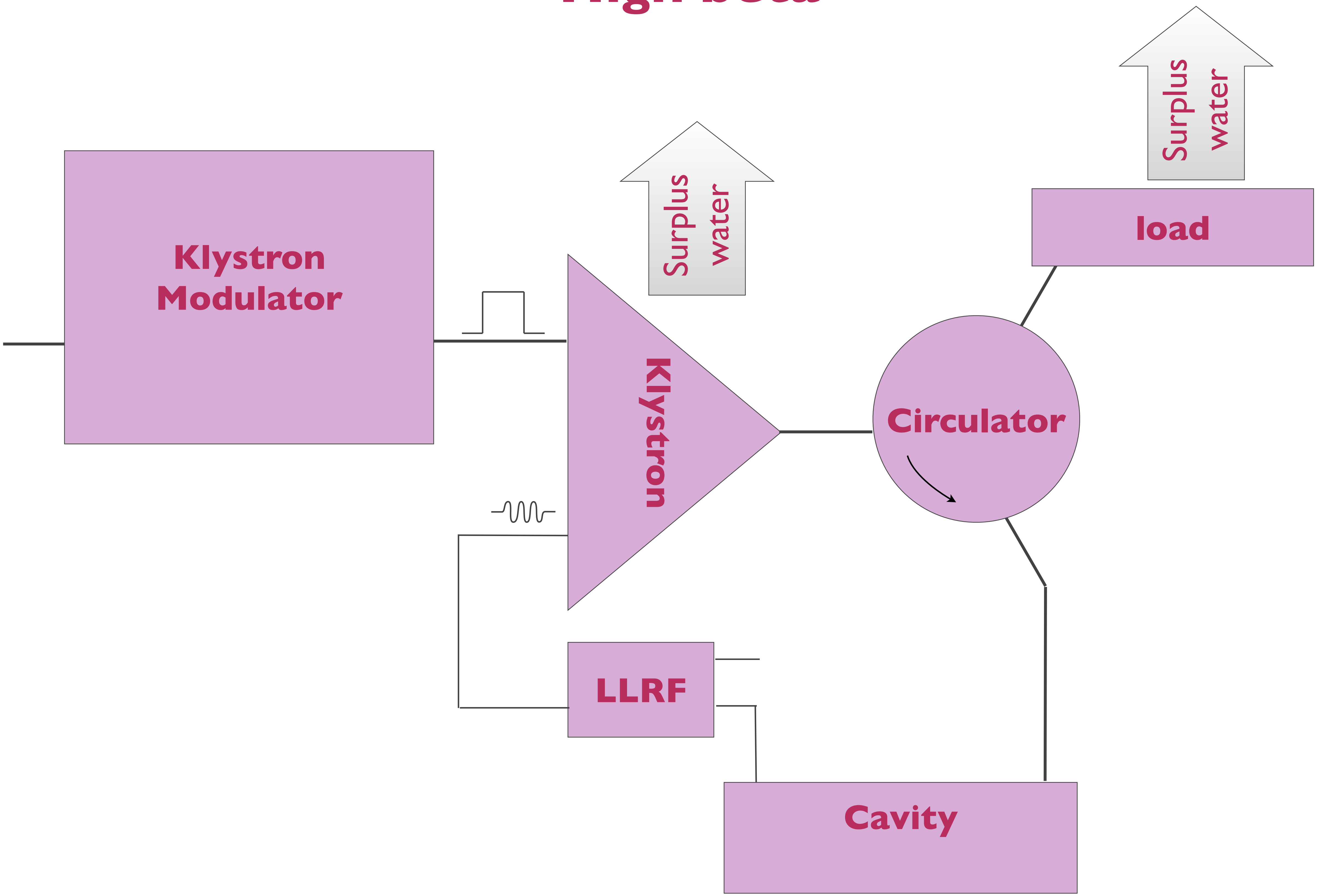
RF SOURCE SCHEME

RF power splitting



RF SYSTEM

High beta



KLYSTRONS

- ✓ **CPI**
  704 MHz, 1.5 MW with 65% efficiency and 100 000 h lifetime.
  (study)
  804 MHz: Installation at Oak ridge
  704 MHz: Installation at BNL and CEA
- ✓ **Thales**
  402 MHz: Installed at Oak Ridge
  804 MHz: Installed at Oak Ridge
- ✓ **Toshiba**
  325 MHz: Installed at ISIS test stand.
  JPARC

Statement of Work
1.5 Mw Pulsed, 704.4 MHz Klystron for ESS

This statement of work establishes the preliminary specifications and performance requirements for a 1.5 Mw, 704.4 MHz, cathode pulsed klystron.

This RF design utilizes an electron beam with micro-perveance equal to 0.548, similar to that used in the SNS klystrons at Oak Ridge, Tennessee. This is a high efficiency design with good gain and bandwidth. The length of the klystron is significantly longer that the SNS klystrons due to the lower operating frequency (704.4 MHz vs. SNS 805 MHz) and higher peak power (1.5 Mw vs. SNS 700 kw).

Parameter	Minimum	Nominal	Maximum	Units
RF Operating Frequency	703	704.4	706	MHz
Peak Output Power	1.5			MW
RF Duty Factor		4.6		%
RF Pulse Width			2.3	ms
Pulse Repetition Rate		20		Hz
DC to RF Efficiency	65			%
Beam Voltage		113	115	kV
Beam Current		20.8		A
Micro-Perveance	0.538	0.548	0.558	
RF Power Gain	46	48		dB
Instantaneous Saturated Bandwidth (-1dB)	4.0			MHz
VSWR Tolerance			1.2:1	

Physical and Electrical System Parameters

RF Circuit Configuration: The klystron RF circuit will utilize 6 RF cavities, including a cavity tuned near the 2[nd] harmonic for improved efficiency.

RF Circuit Cooling: The RF circuits will be water cooled.

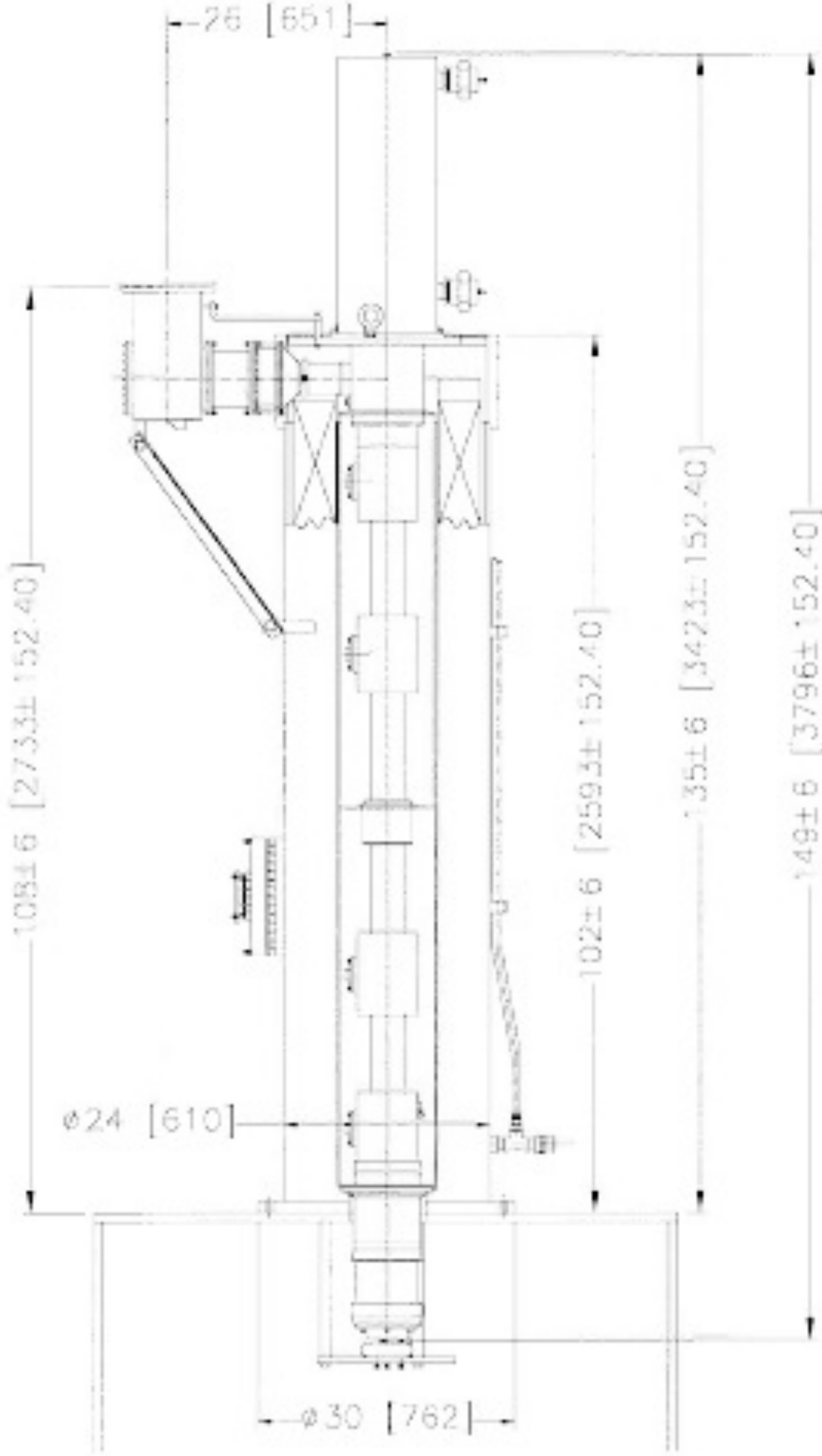
RF Input Connection: A type-N connector will be provided as the interface for the RF input drive power.

RF Output Connection: The RF output power will be coupled from the output cavity to through a coax line to a coaxial, alumina ceramic vacuum window, and then transition to a WR-1500 waveguide adapter for connection to the customer load. Forced air cooling may be required to cool the output window.

Electron Gun: A dispenser cathode will be utilized in a simple cathode pulsed diode configuration. The active cathode surface area will be sufficiently large to keep the cathode current load well below 1.0 a/cm^2, which should translate to an expected cathode life well in excess of 100,000 hours, based on CPI cathode life studies summarized in Figure 2 below.

E. L. Eisen

3/11/2010



PRELIMINARY VERTICAL LAYOUT
FOR 1.5MW PULSED, 704.4MHZ KLYSTRON
DIMENSIONS ARE INCHES [MILLIMETERS]

LONG PULSE MODULATORS

- ✓ **Scandinova (Uppsala)**
  State of the art for short pulses
  Modular
  Serviceability
  Irregular pulsing (repetition rate, pulse length)
  Upgradeability
- ✓ **DTI (Boston)**
  Reliable (used on warships)
  No transformer (lots of oil)
  $\leq$ 8 klystrons per modulator
  Installations at the ISIS test stand
- ✓ **PPT (Dortmund)**
  CERN and DESY installations
- ✓ **JEMA (Bilbao)**
- ✓ **Others?**

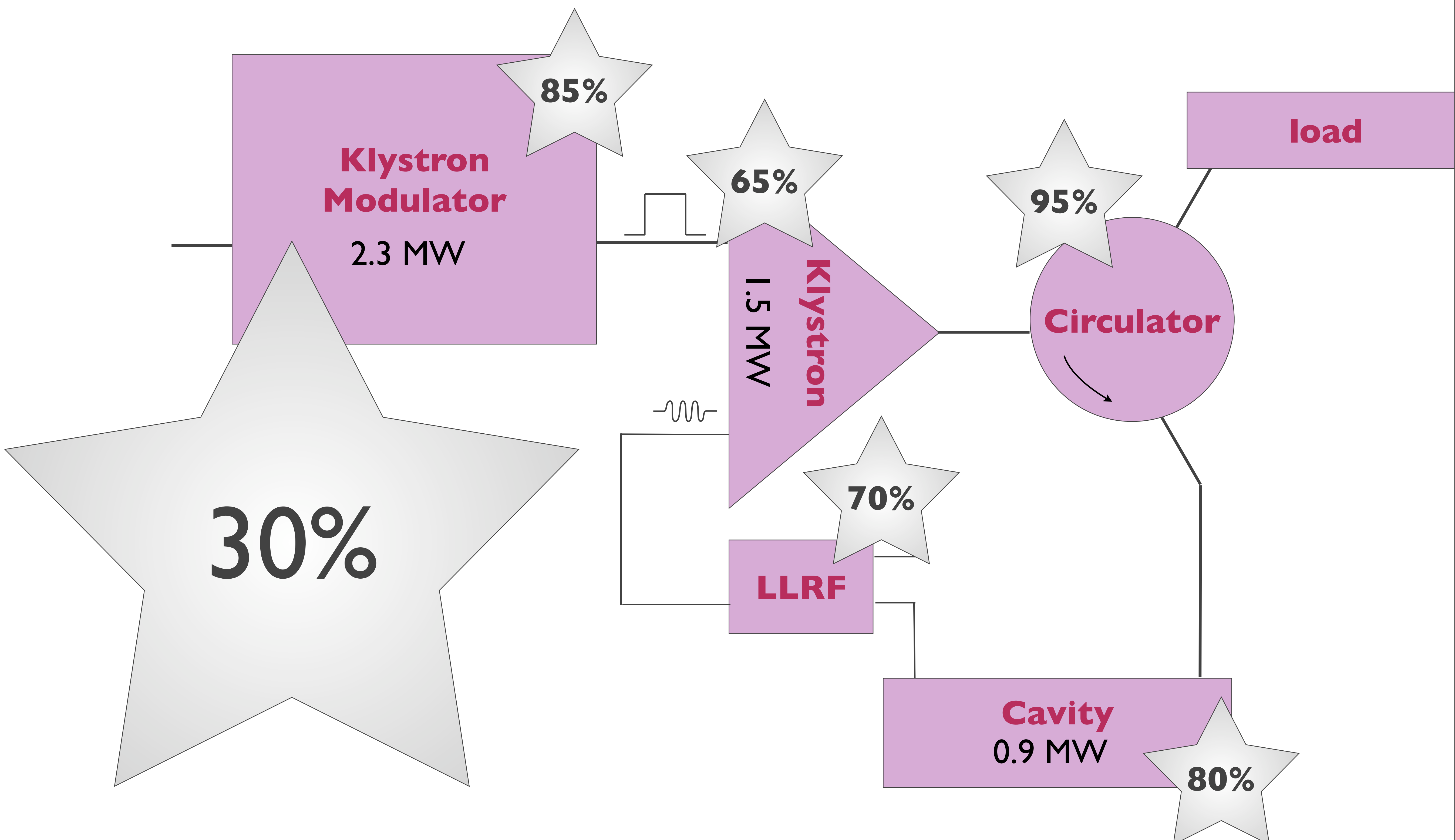
TENDERING FOR A TEST STAND MODERATOR

- ✓ **Specification for a test stand klystron modulator by the end of the summer**
- ✓ **Procurement by Jan 31, 2011**
- ✓ **Delivery Oct 2012**
- ✓ **Other demands than modulators for the ESS klystron gallery.**

  Power level and consumption, serviceability, repetition rates, flexibility, integration with the klystron, footprint, investment and operational cost, reliability, etc.

RF SYSTEM

High beta



RF POWER CALCULATIONS

- ✓ Power usage: 5MW / 0.30 = 17 MW peak power.
- ✓ 5 280 h operation per year gives 92 GWh
- ✓ A third of the ESS power budget will be spent in the klystron gallery.
- ✓ Strong motivation for R&D to minimize power consumption

IDEAS FOR R&D

- ✓ **Klystron efficiency:**
  Increase cathode voltage?
- ✓ **LLRF**
  Can the 30% margin be reduced?
- ✓ **Modulator pulse shape and droop compensation together with LLRF.**
  Compensate the modulator droop with LLRF
  Or create an arbitrary pulse shape. (Carlos Martins)
- ✓ **RF power distribution**
  Circulators
  Flanges
  Power splitting
  Vector modulators
- ✓ **Irregular pulsing**
  For energy efficient future upgrades
- ✓ **Piezo tuners**
- ✓ **Power couplers**
- ✓ **Cryogenics**
  Centrifugal compressors (Wolfgang Hees)
  Segmentation
- ✓ **Cooling**
  Surplus water recycling and creative plumbing to use cooling water efficient
  Vaporization cooling
  Dummy loads
- ✓ **Energy recover**
  Stirling motors
  Fritz Caspers idea

THANK YOU!