RF Development for ESS

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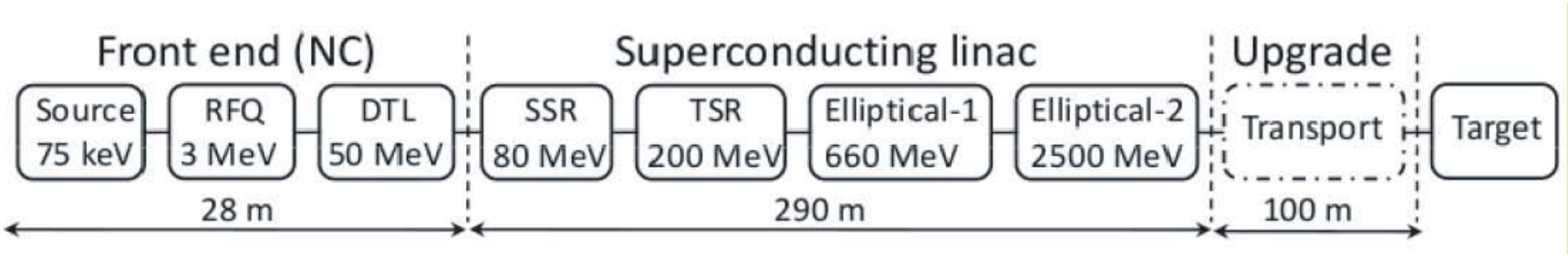
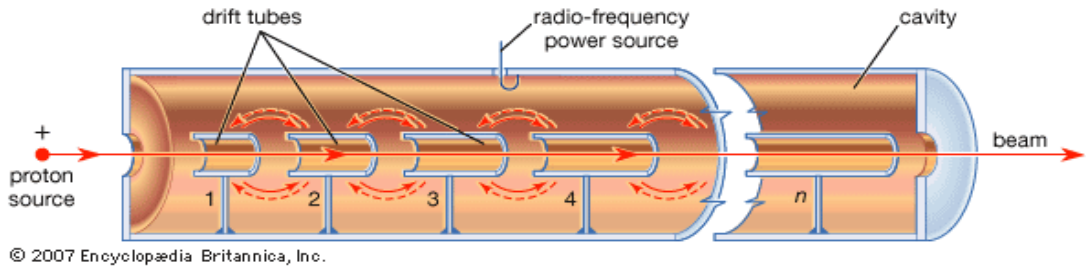
The ESS Proton Linac

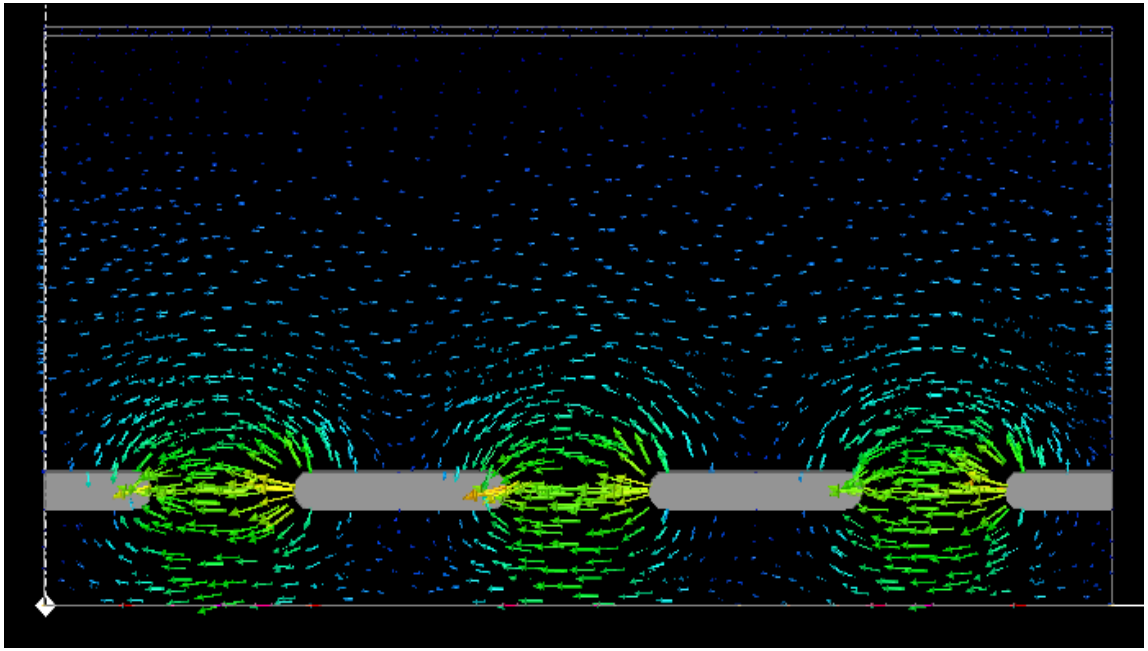


- High reliability: >95%
  - 2.5 GeV, 2.0 ms pulses at 20 Hz
  - 50 mA, average 5.0 MW (beam loss <1 W/m)
  - Future upgrade to 75 mA, 7.5 MW
- Services:
  - electricity, vacuum
  - cooling water and liquid helium
  - RF power at 352.2 and 704.4 MHz

RF Accelerating Structures

synchronize particle
with an
electromagnetic wave!





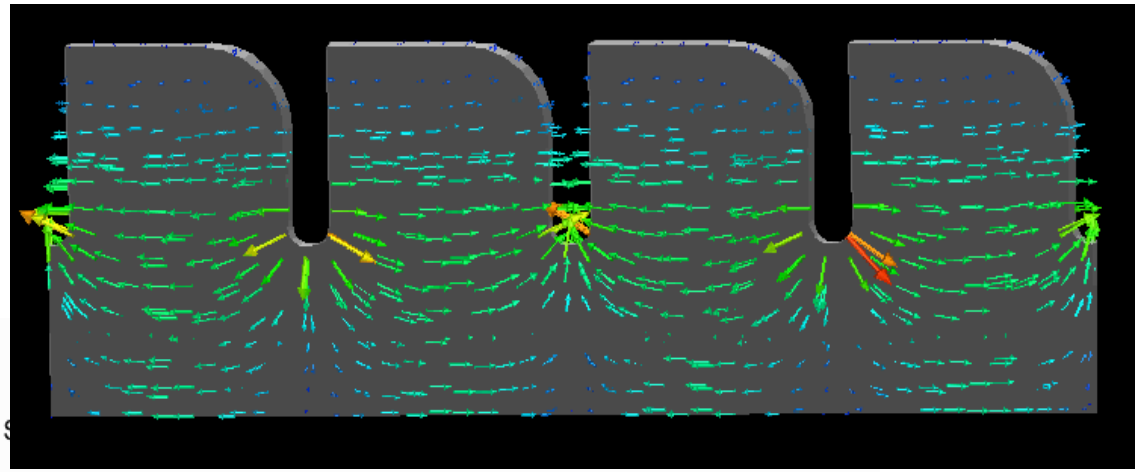
Courtesy E. Jensen

Superconducting Elliptical Cavity

Use waveguide with ”discs” to slow down EM wave;

$v_{phase} = v_{particle} < c$

Travelling or standing wave



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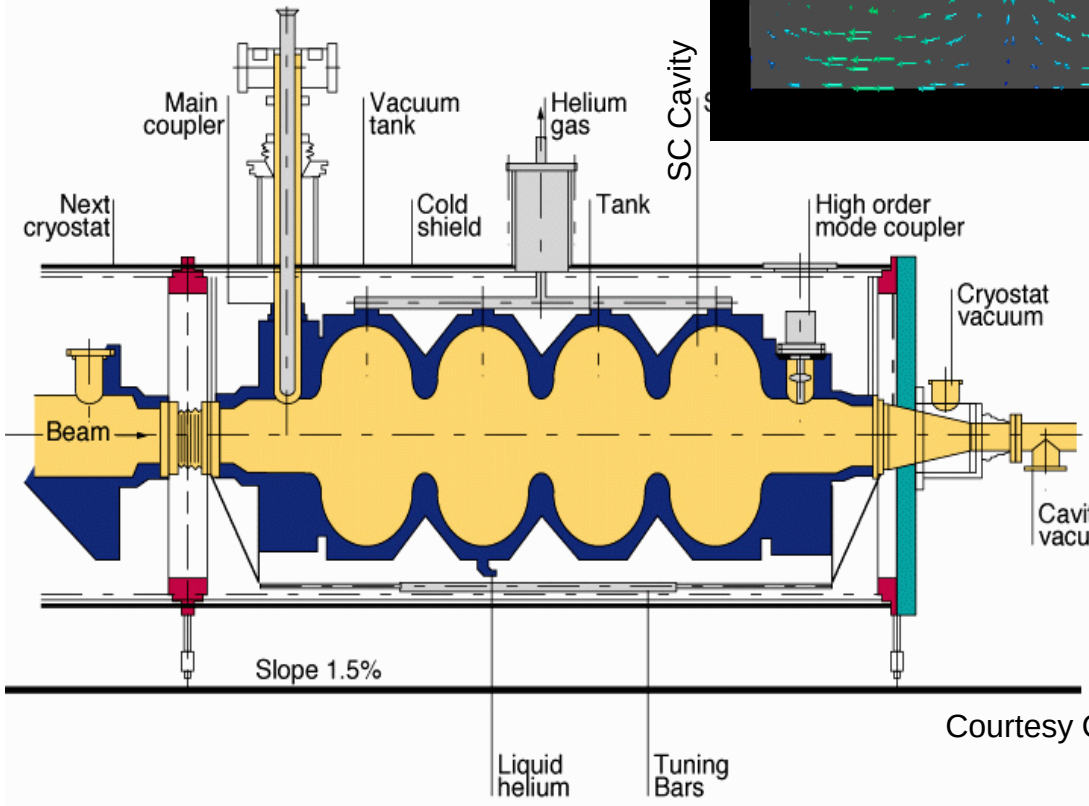
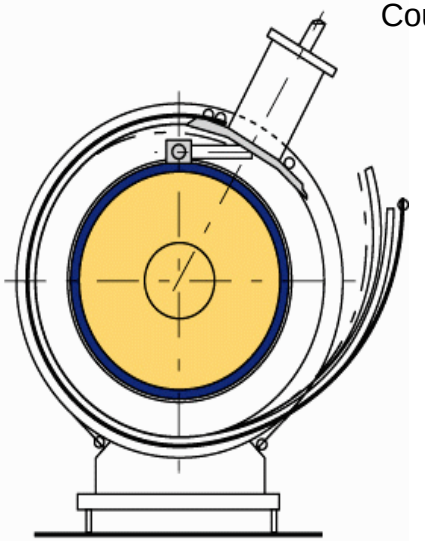
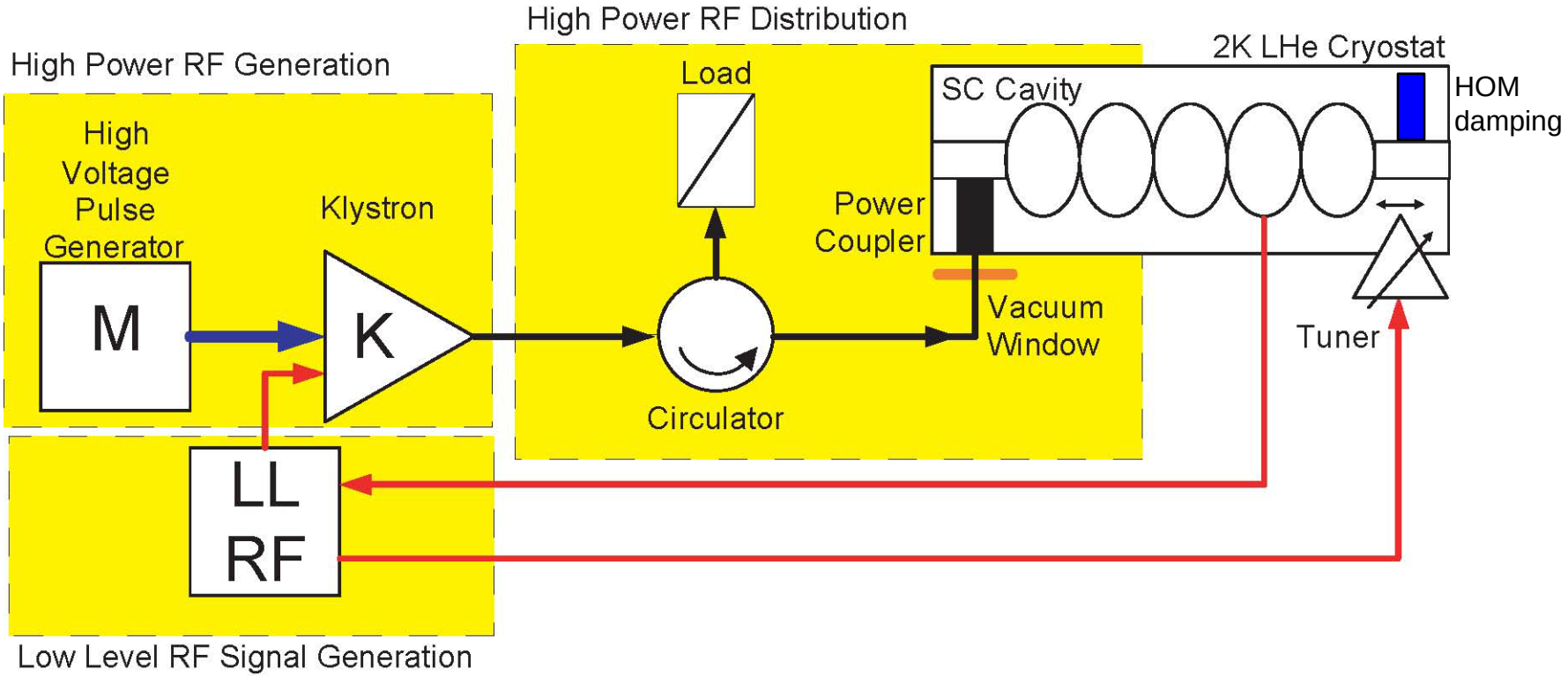




Courtesy CERN LHC-PHO-1994-006

Basic Layout RF System



- LLRF:
  - RF source, regulate (A, Ph)
  - monitor cavity RF (A,Ph)
  - cavity tuning
- High power RF:
  - klystron amplifier
  - power distribution (A, Ph)
  - power coupler, HOM coupler

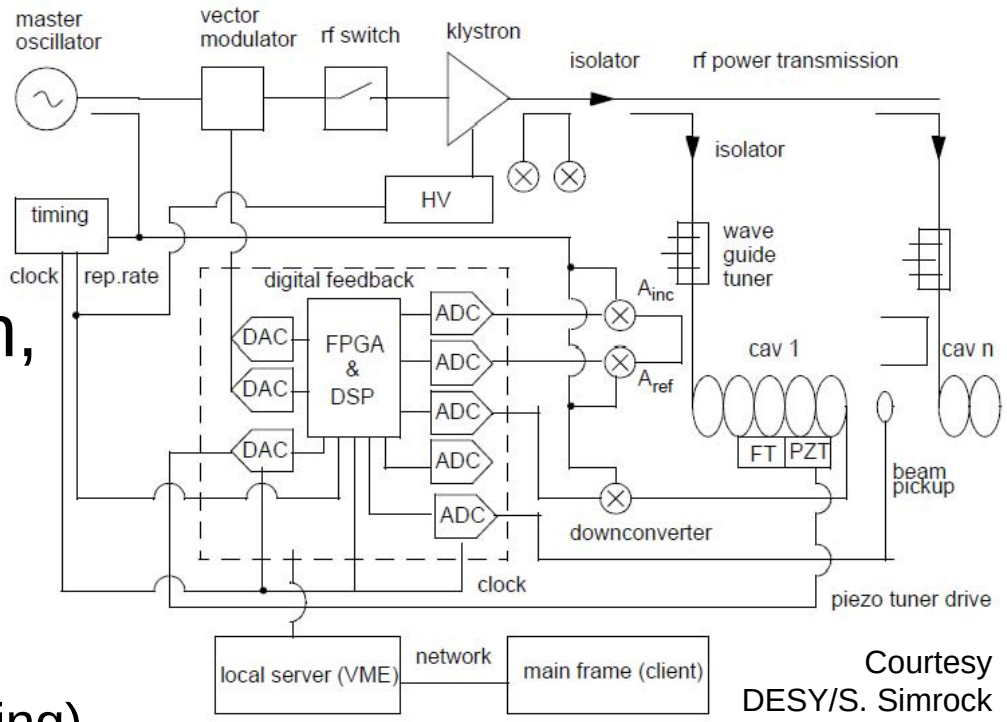
R&D Proposal from Uppsala

- **Development 704 MHz RF system**
  - Development and test of LLRF controls
    - signal generation, power modulation, cavity tuning (FB+FF)
  - Development and test of high power components:
    - 1 MW vector modulator, 8 MW pulse modulator, 4 MW klystron
    - power couplers, circulators, phase shifters, loads
  - Tests facility with
    - 2 Elliptical cavities in horizontal cryostat
    - Modulator, Klystron, Cryogenics
  - Test different RF distribution system combinations
    - 1 or 2 cavities per klystrons
    - with and without vector modulator

Low Level RF Development

- FB + FF
- signal generation
- high power modulation,
- cavity tuning:
  Detuning under
  - Pulsed power
    (microphonics, Lorenz detuning)
  - Beam loading

  → cavity moves away from resonance
  - Counteract with mechanical tuner and RF phase (FB+FF)



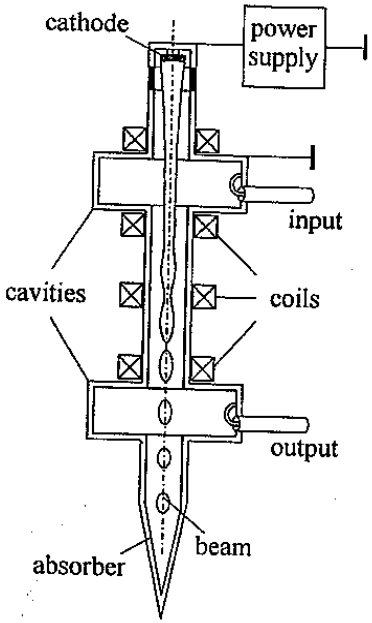
Courtesy
DESY/S. Simrock

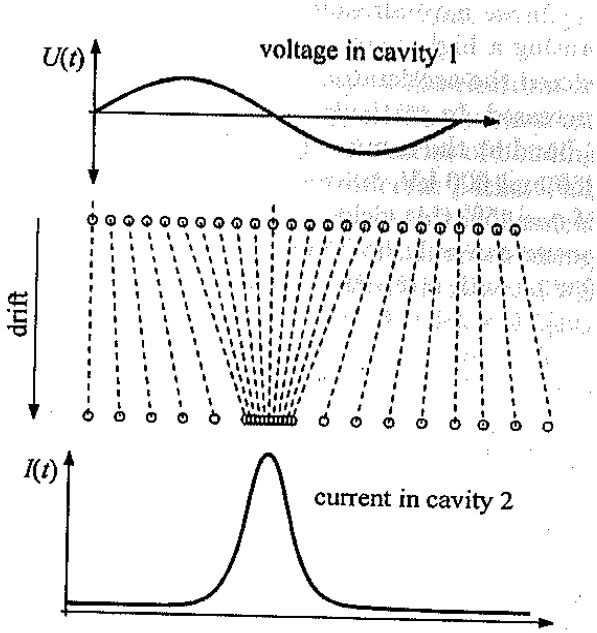
RF Power Amplification Development

- 8 MW high voltage pulse modulator [Scandinova]
- 4 MW power amplifier (klystron)

CPI VKP-7952 klystron:

- 704.4 MHz, 1 MW, 2 ms pulse
- 95 kV, 21 A beam
- 40 dB gain; 65 % efficiency
- 5x1x1.5 m; 2.5 ton

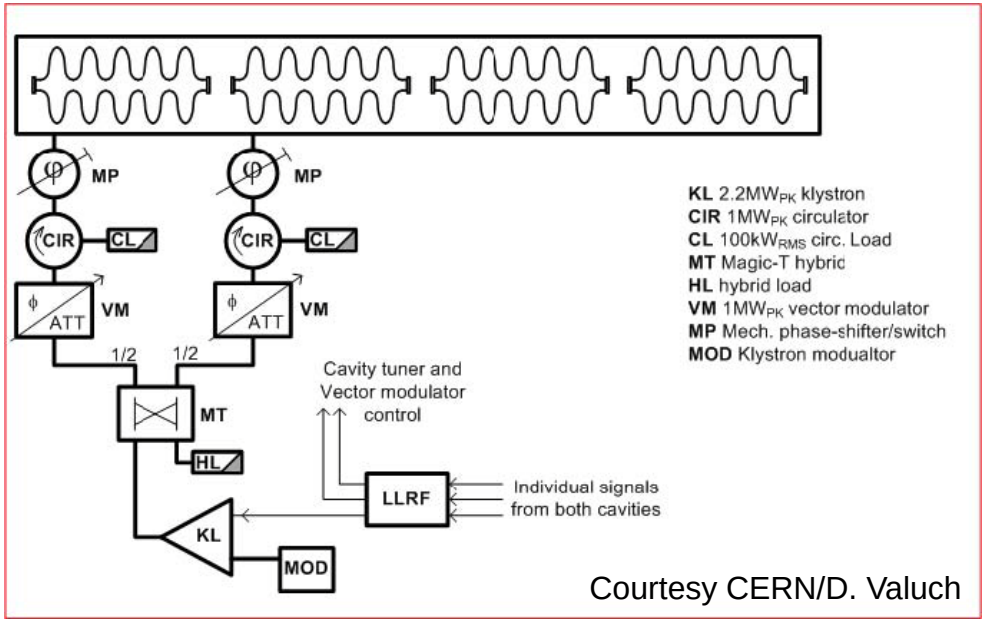




$$dB := \frac{P_{\text{output}}}{P_{\text{input}}} = 10^{4.8}$$

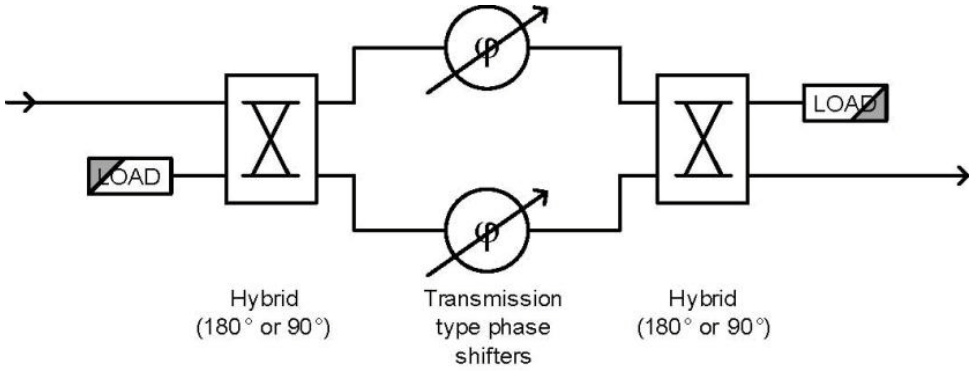
RF Power Distribution Development

- **RF distribution:**
  - 2 cavities per klystron major cost saving!
  - with or without 1 MW vector modulator
- **Power components:**
  - power couplers,
  - HOM couplers,
  - circulators,
  - phase shifters,
  - loads



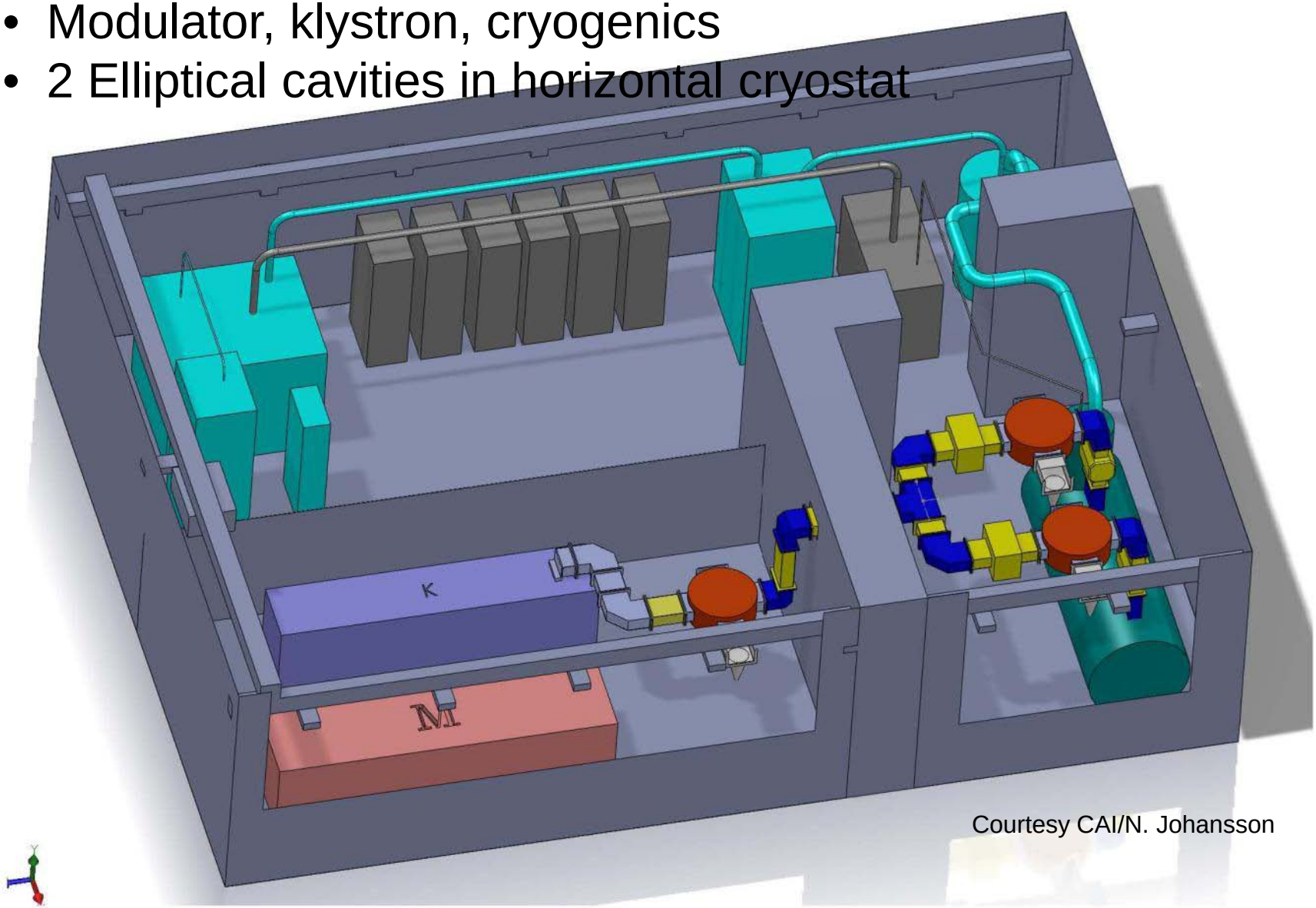
Courtesy CERN/D. Valuch

Vector Modulator



R&D Facility Proposal

- Modulator, klystron, cryogenics
- 2 Elliptical cavities in horizontal cryostat



Courtesy CAI/N. Johansson