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Accelerators in a new light

An X-band system for phase space linearisation on CLARA

Louise Cowie

On behalf of the 4HC system design team at Daresbury Laboratory

Contents

- The CLARA accelerator
- Lineariser requirement and specification
- Proposed system:
  - Cavity
  - LLRF
  - HPRF
  - Power losses
- Further work

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CLARA

Compact **L**inear **A**ccelerator for **R**esearch and **A**pplications

An upgrade of the existing VELA Photoinjector Facility at Daresbury Laboratory to a 250MeV Free-Electron Laser Test Facility

Proof-of-principle demonstrations of novel FEL concepts and development of future accelerator technologies

Emphasis on **Stability, Synchronisation and new FEL capabilities**

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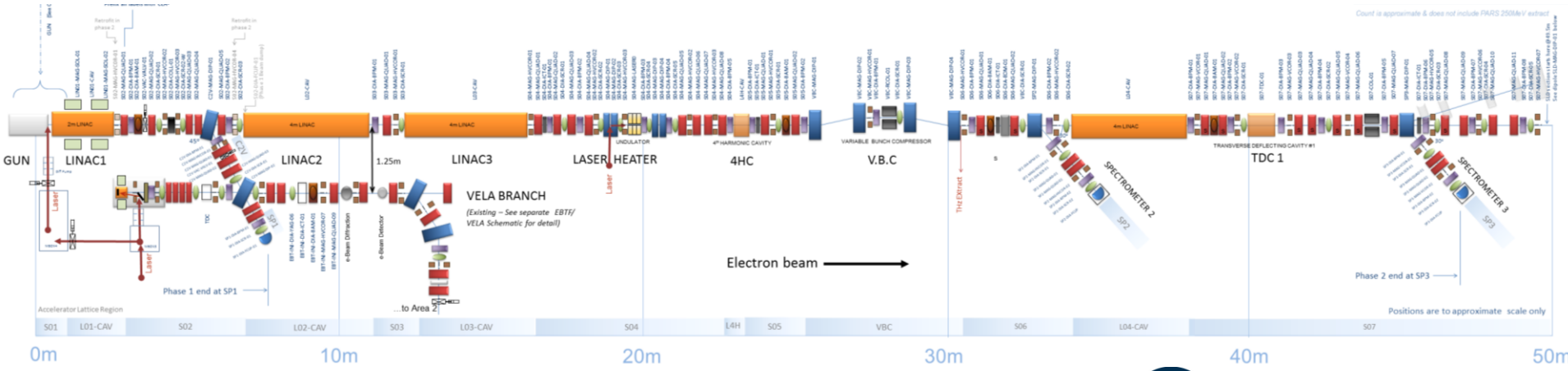
diamond
The Cockcroft Institute of Accelerator Science and Technology
John Adams Institute for Accelerator Science
Royal Holloway University of London
University of Oxford
Lancaster University
University of Liverpool
Manchester 1824 The University of Manchester
University of Strathclyde
University of Huddersfield
Swansea University Prifysgol Abertawe
UCL
The University of York
Imperial College London
Paul Scherrer Institut PSI
CERN
INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati
SLAC National Accelerator Laboratory

CLARA

- S-band linear acceleration up to 250 MeV
- Bunch charge 20-250 pC
- High repetition rate up to 400 Hz
- Electron bunch lengths 250-850 fs
- FEL wavelengths in the UV



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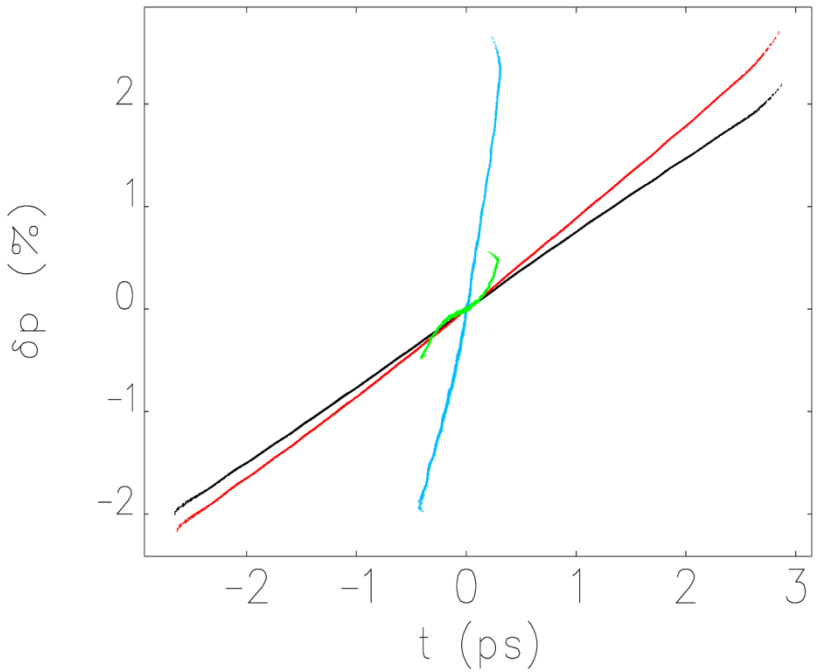
Lineariser requirement

- FEL requires short bunches
- 4-dipole compression
- Longitudinal phase space non-linearity from RF acceleration must be corrected
- 4th Harmonic x-band lineariser at decelerating phase



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Lineariser specification

Frequency	11994 MHz
Maximum Physical Length	980 mm
Maximum Gradient	30 MV/m
Repetition Rate	100 Hz
RMS Amplitude Jitter	< 0.1 %
RMS Phase Jitter	< 0.3 ˚
Integrated alignment monitors for beam based alignment	

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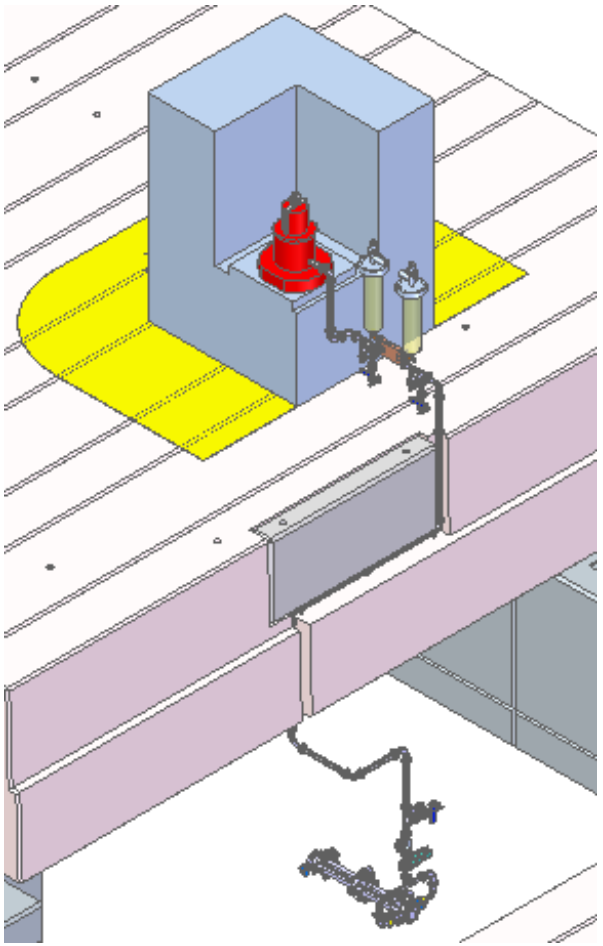
Proposed system

- CERN/PSI type X-band RF structure with integrated alignment monitors[1]
- 16.3 MW required at the cavity for 30 MV/m operation
- 6 MW Toshiba klystron with Scandinova K200 modulator
- SLED I type pulse compression
- LLRF from industry
- Vaccum WR90 waveguide



1. Dehler et al., Phys. Rev. ST Accel. Beams 12, 062001 (2009)

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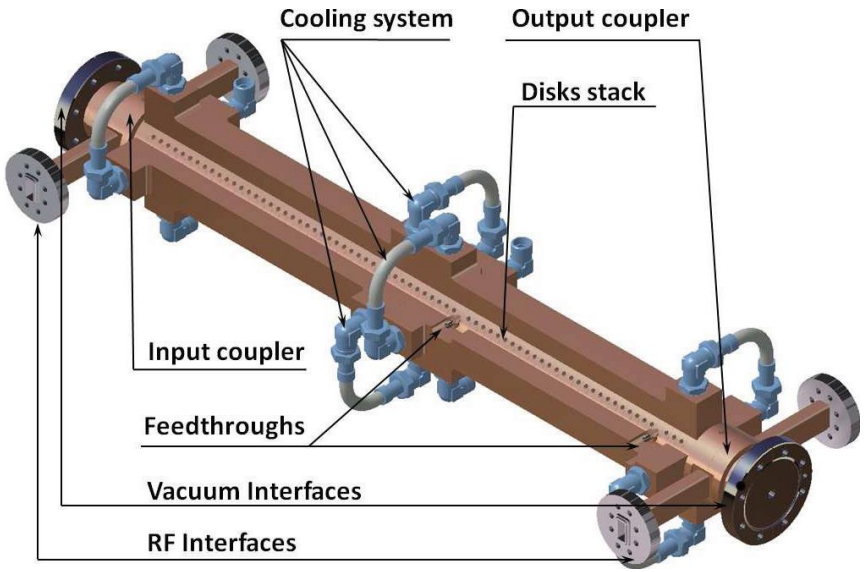
Cavity

- CERN/PSI travelling wave X-band structure with 5π/6 phase advance
- 40 MV/m at 29 MW input power reported
- For 30 MV/m 16.3 MW required
- Design frequency 11992 MHz with 10 MHz tuning range



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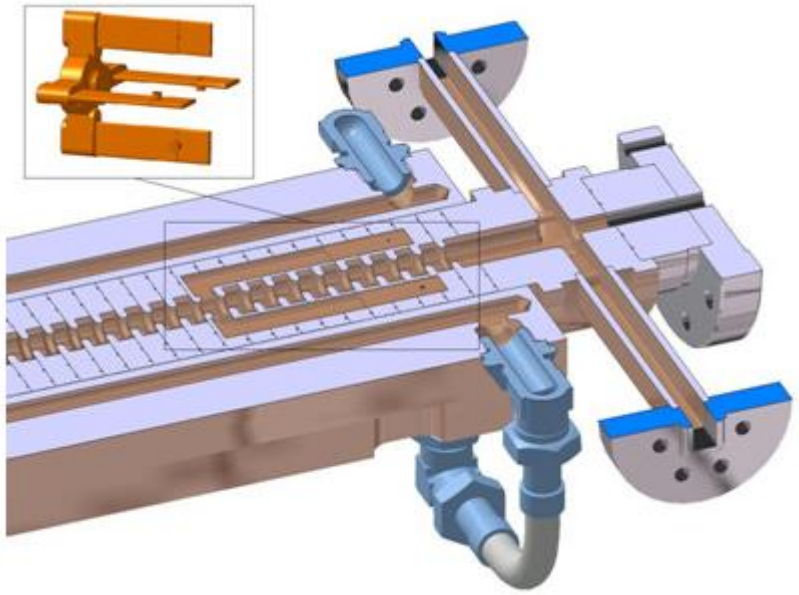
Cavity (2)

- Full length 965 mm
- The smallest aperture is 8.24 mm
- Integrated wakefield monitors allow for beam based alignment using actuators
- Two cooling circuits, blocks brazed to cavity
- Beam pipe tapers considered and rejected



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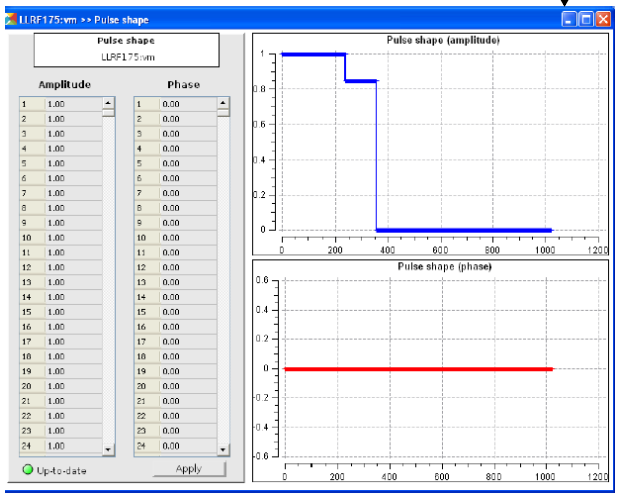
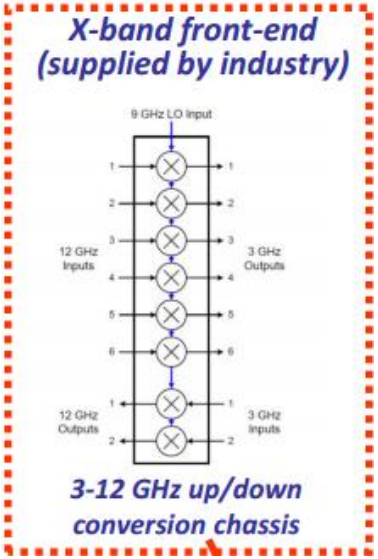
LLRF

CLARA LLRF from Instrumentation Technologies

- Currently operating at S band 2998.5 MHz
- For X band propose to use the same LLRF with a frequency convertor to operate at 11994 MHz
- Libera LLRF allows amplitude and phase adjustment to the output signal in 8 nS steps which can be used to flip the pulse compressor output





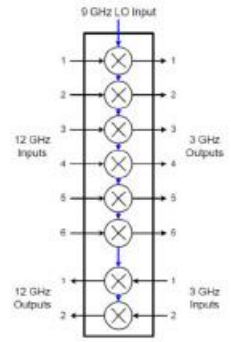
Pictures of commercial s/x band frequency convertor courtesy of Gerardo D'Auria Sincrotrone Trieste

Results of S/X band conversion for LLRF operating at Trieste

Elettra Sincrotrone Trieste

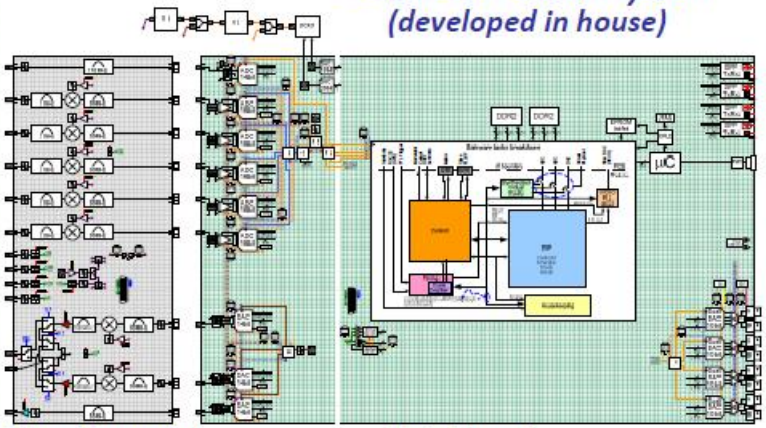
LLRF system

X-band front-end (supplied by industry)



3-12 GHz up/down conversion chassis

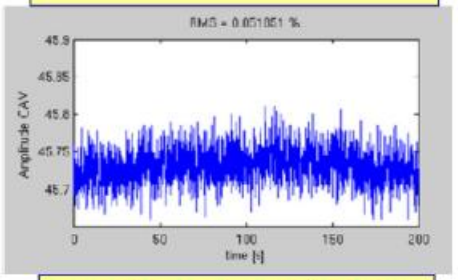
S-band LLRF S-band system (developed in house)



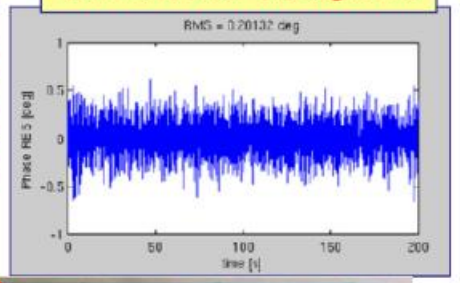
S-band front-end

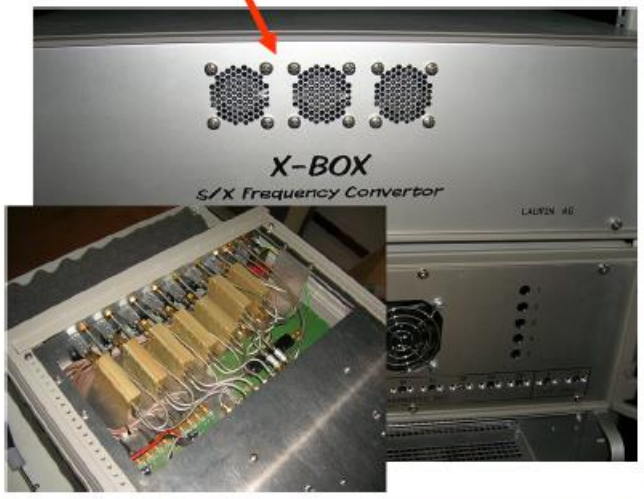
Digital board

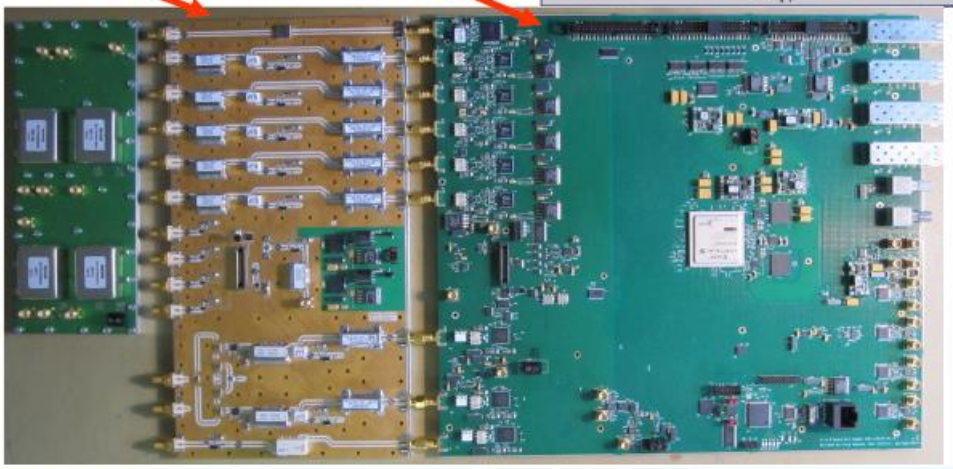
Cav. Ampl. stab. ~0.05% rms



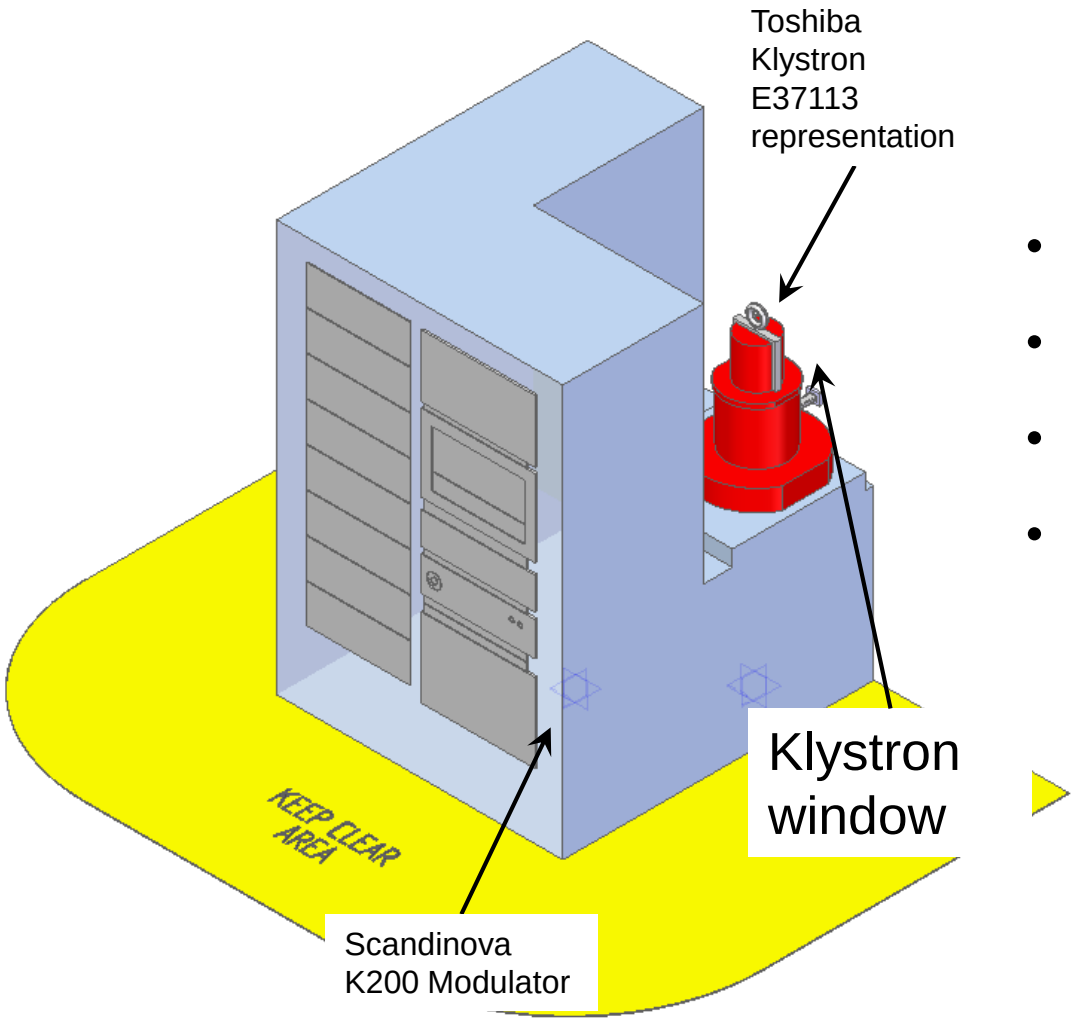
Cav. Phase stab. ~0.2 deg-X rms







Power amplification



- Microwave amplifiers SSA
- Scandinova K200 Modulator
- Toshiba Klystron E37113
- No services ports (Power & Water) included yet.

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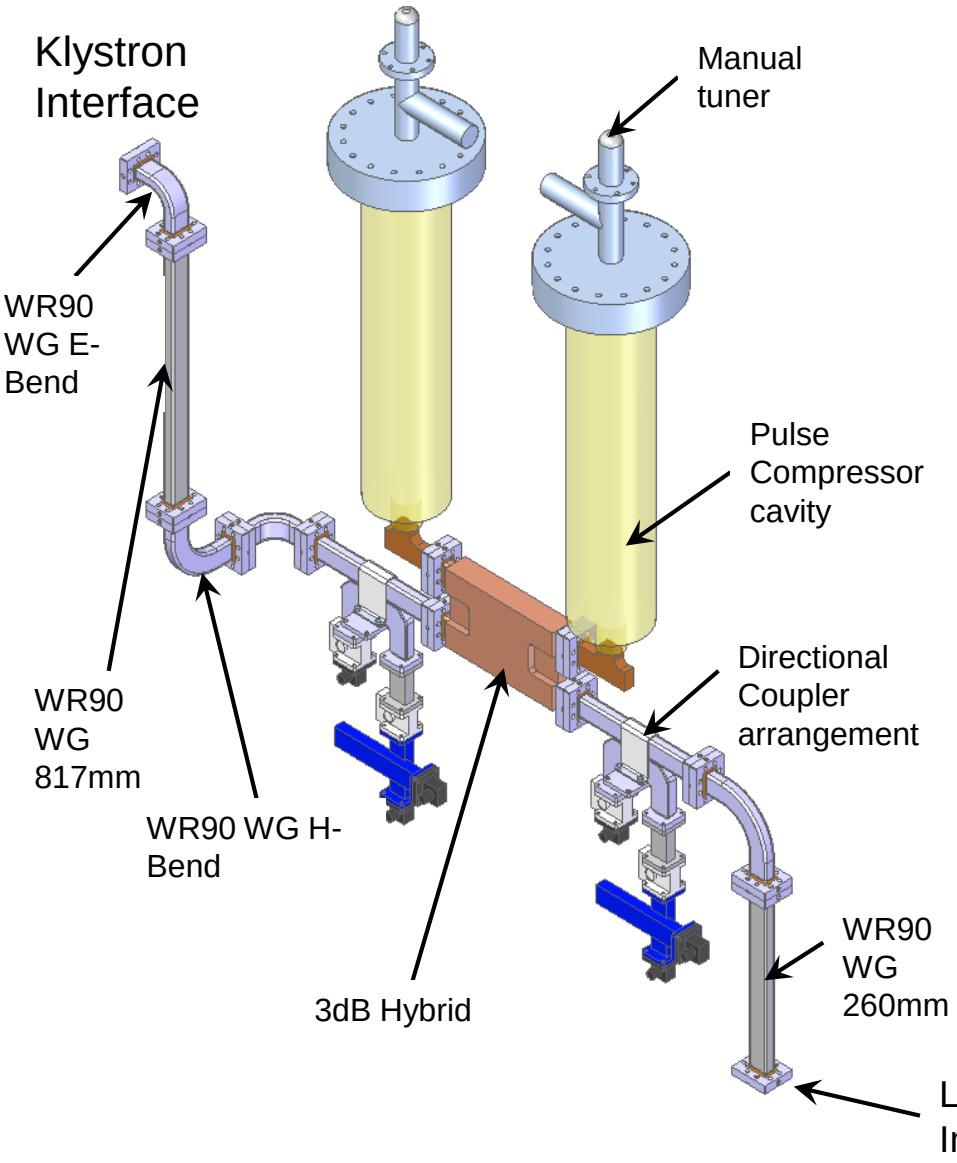
Pulse Compression



- Similar to CLIC X-Box 3 arrangement
- Directional couplers before and after pulse compressor
- Representation not showing vacuum pumping on cavities
- Cavities will be temperature stabilised by chillers

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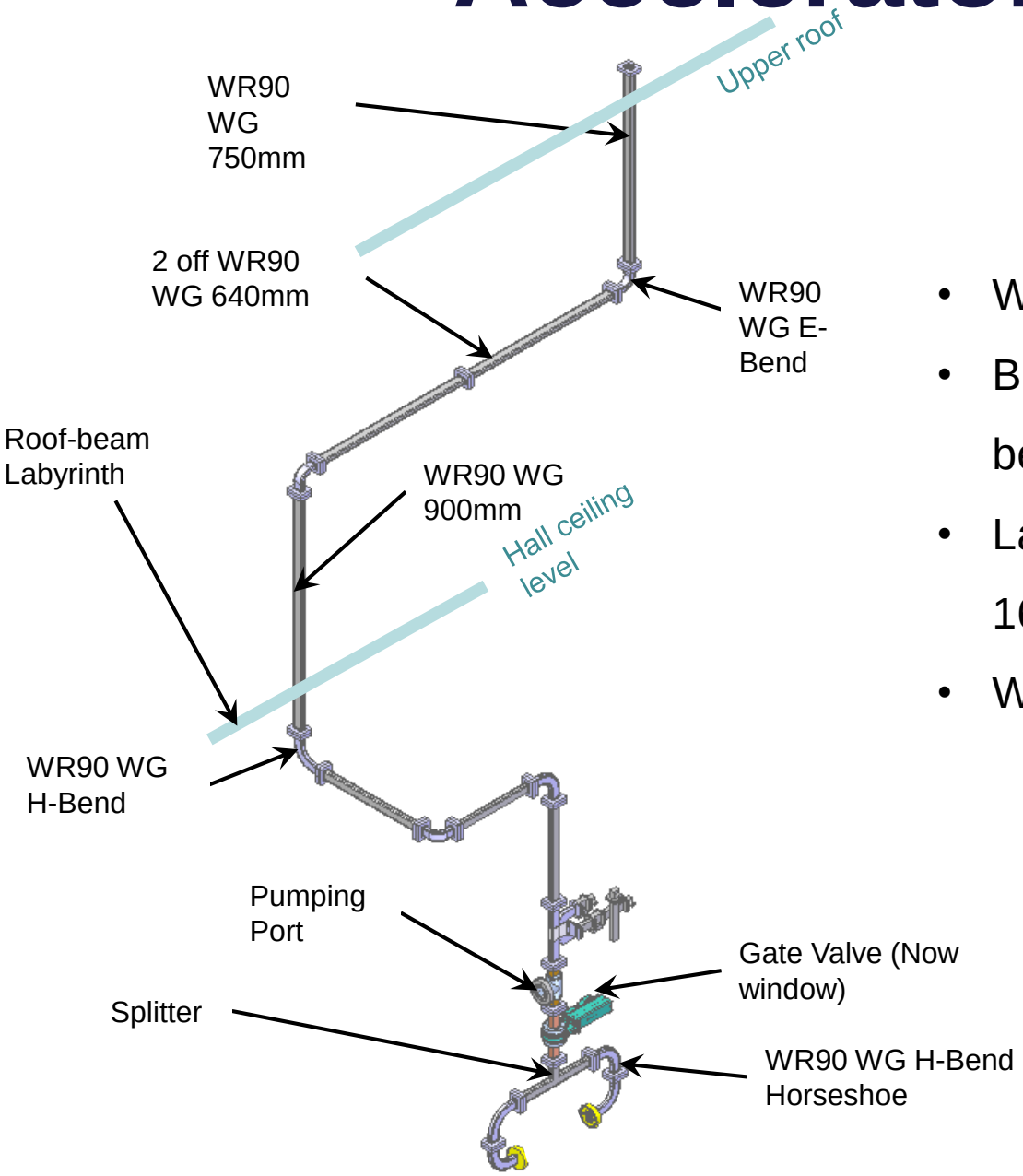
Accelerator hall



- WR90 vacuum waveguide
- Blue line indicates top of roof-beam and bottom of roof-beam.
- Labyrinth width 1500mm, height 1600mm.
- Waveguide length ~6m

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Power losses

Using assumptions:

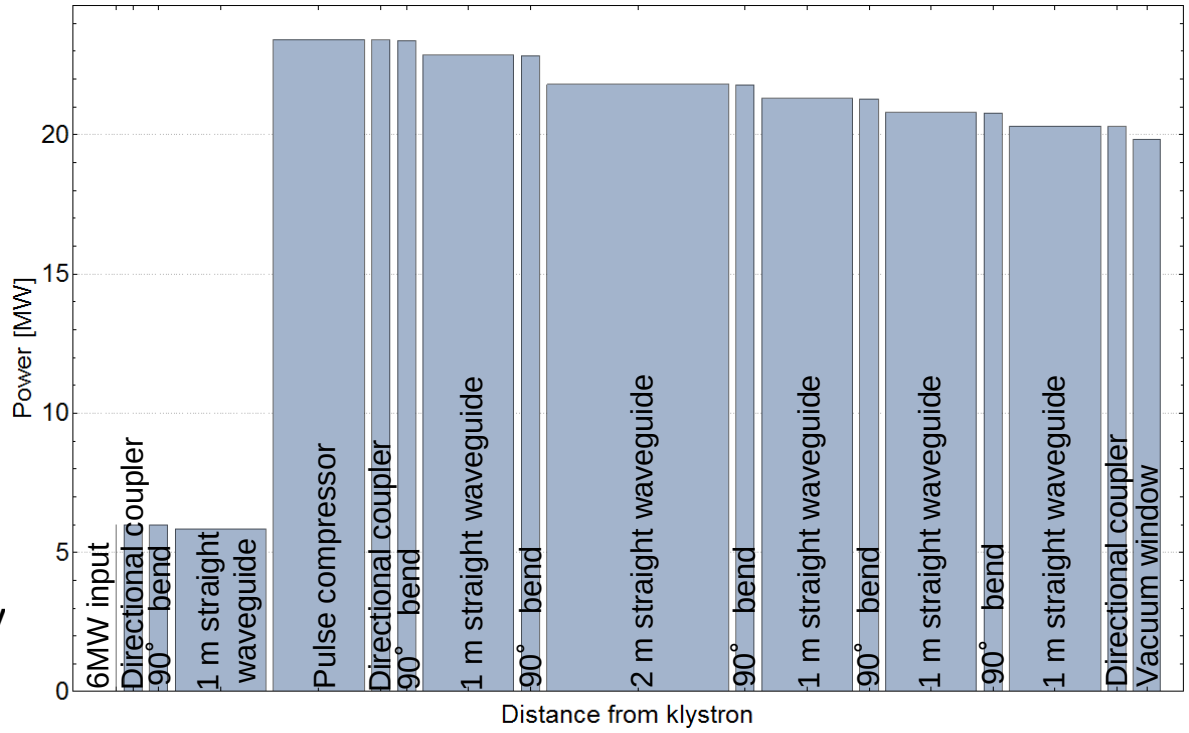
- Attenuation in straight waveguide of 0.1 dB/m
- Manufacturers max insertion loss for other components
- Pulse compression gain of 4, as seen at XBOX
- 6 MW from klystron

We expect 19.8 MW at the cavity

Contingency:

16.9 MW for pulse compressor gain 3

18.3 for pulse compressor gain 3 and 6.5 MW from klystron



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For Further Study

- Pumping port design choice and vacuum studies
- Arc detection and IR detectors for window heating
- Pulse compressor shielding requirements

Acknowledgement

The team would like to acknowledge the team at Xbox for their advice and enthusiastic support.

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