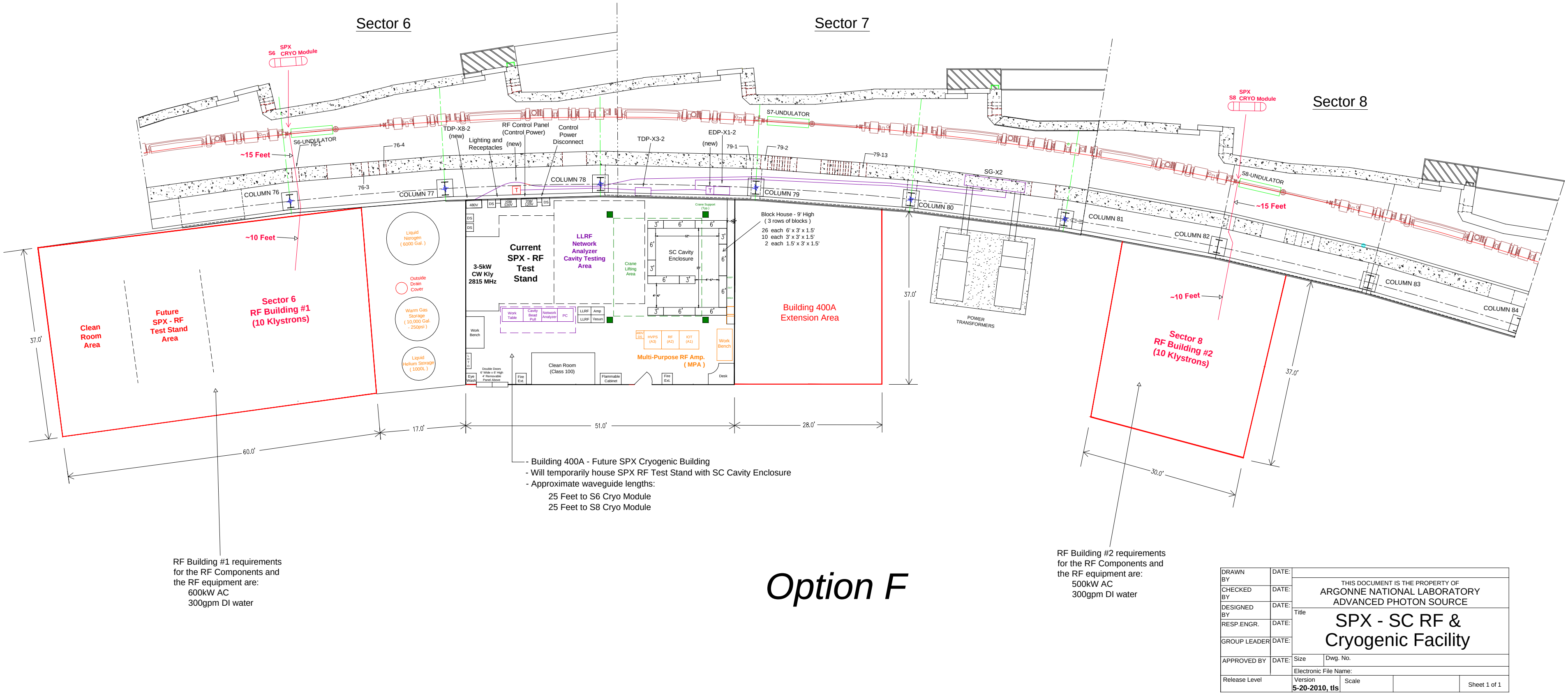
Cryomodule Concepts & Cryogenics

J.D. Fuerst

SPX Technical Study Group Meeting

27-29JUL10

SPX Layout



Sector 6
Sector 7
Sector 8
SPX S6 CRYO Module
SPX S8 CRYO Module
S6-UNDULATOR
S7-UNDULATOR
S8-UNDULATOR
~15 Feet
~10 Feet
COLUMN 76
COLUMN 77
COLUMN 78
COLUMN 79
COLUMN 80
COLUMN 81
COLUMN 82
COLUMN 83
COLUMN 84
TDP-X8-2 (new)
RF Control Panel (Control Power) (new)
Control Power Disconnect
Lighting and Receptacles
TDP-X3-2
EDP-X1-2 (new)
SG-X2
POWER TRANSFORMERS
Block House - 9' High (3 rows of blocks)
26 each 6' x 3' x 1.5'
10 each 3' x 3' x 1.5'
2 each 1.5' x 3' x 1.5'
Clean Room Area
Future SPX - RF Test Stand Area
Sector 6 RF Building #1 (10 Klystrons)
Current SPX - RF Test Stand
3-5kW CW Kly 2815 MHz
LLRF Network Analyzer Cavity Testing Area
SC Cavity Enclosure
Multi-Purpose RF Amp. (MPA)
Clean Room (Class 100)
Building 400A Extension Area
Sector 8 RF Building #2 (10 Klystrons)
37.0'
60.0'
17.0'
51.0'
28.0'
30.0'
- Building 400A - Future SPX Cryogenic Building
- Will temporarily house SPX RF Test Stand with SC Cavity Enclosure
- Approximate waveguide lengths:
25 Feet to S6 Cryo Module
25 Feet to S8 Cryo Module
RF Building #1 requirements for the RF Components and the RF equipment are:
600kW AC
300gpm DI water
RF Building #2 requirements for the RF Components and the RF equipment are:
500kW AC
300gpm DI water
Option F
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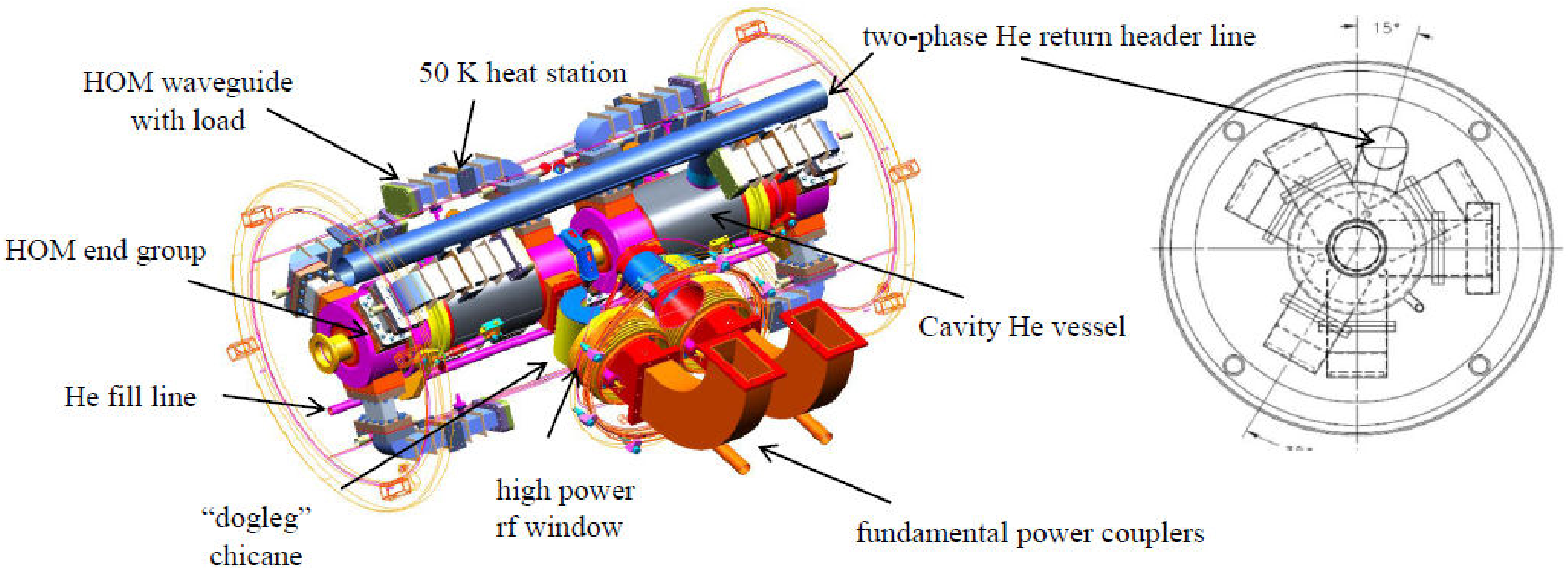
SPX - SC RF & Cryogenic Facility
5-20-2010, tls
Sheet 1 of 1

JLab 100mA Cryomodule Design

J. Preble, JLab

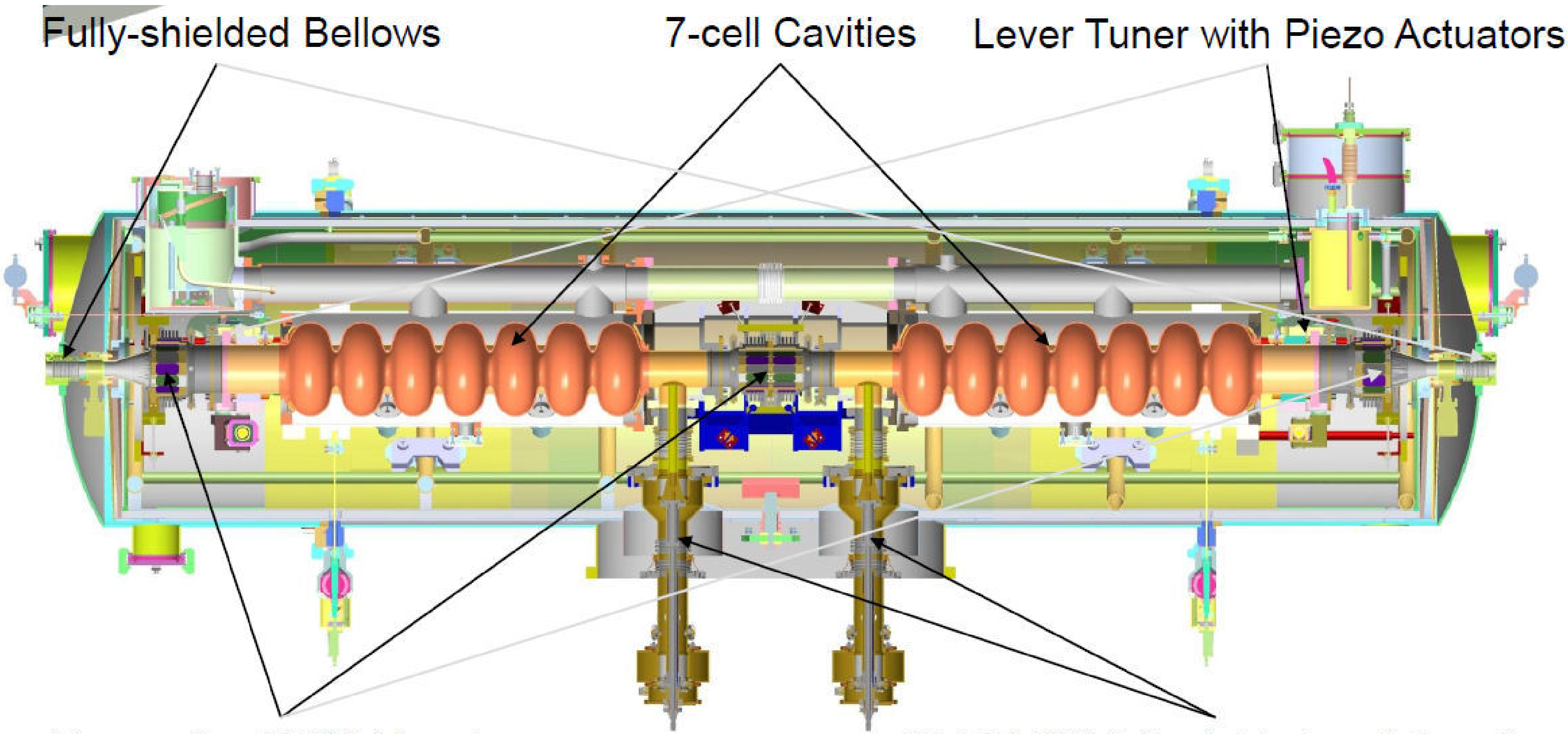
- RT HOM loads inside vacuum vessel



Conceptual design of a cavity-pair cryomodule

ELBE/ALICE ERL Cryomodule

P. McIntosh, STFC Daresbury Laboratory

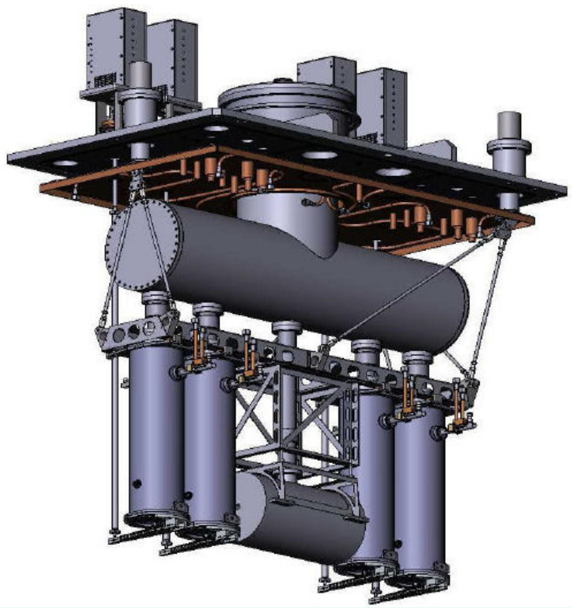


Original ELBE/ALICE Cryomodule 3D Drawings provided by FZD Rossendorf

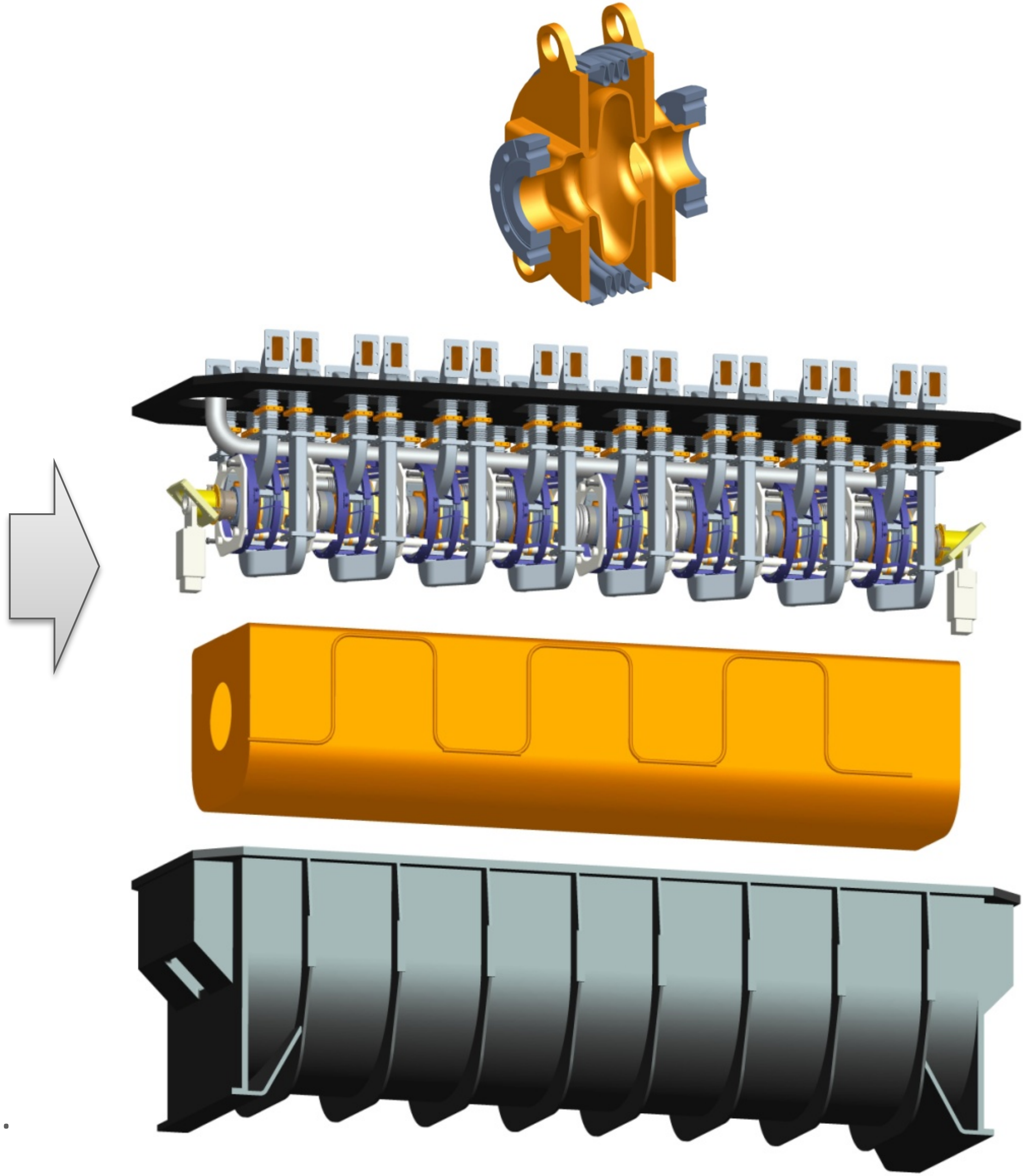
Heavy Ions: TRIUMF ISAC-II

R. Laxdal, TRIUMF

- Low-β drift tube-loaded quarter wave cavities
- Common beam & insulating vacuum spaces



Heavy Ions: ATLAS

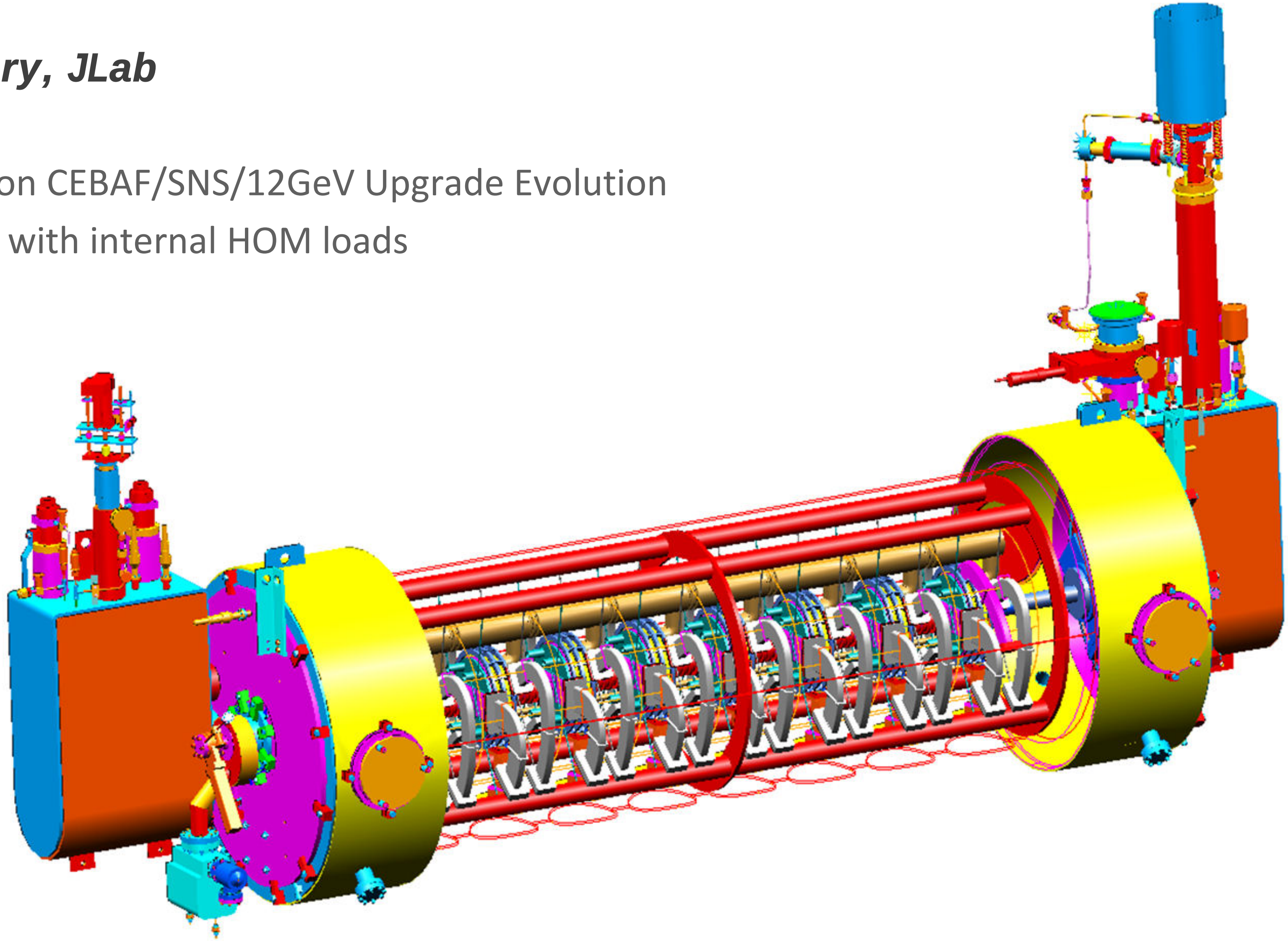


- β=0.15 DTL QWR
- Separated beam & insul. vac.

JLab SPX Cryomodule Concept (1)

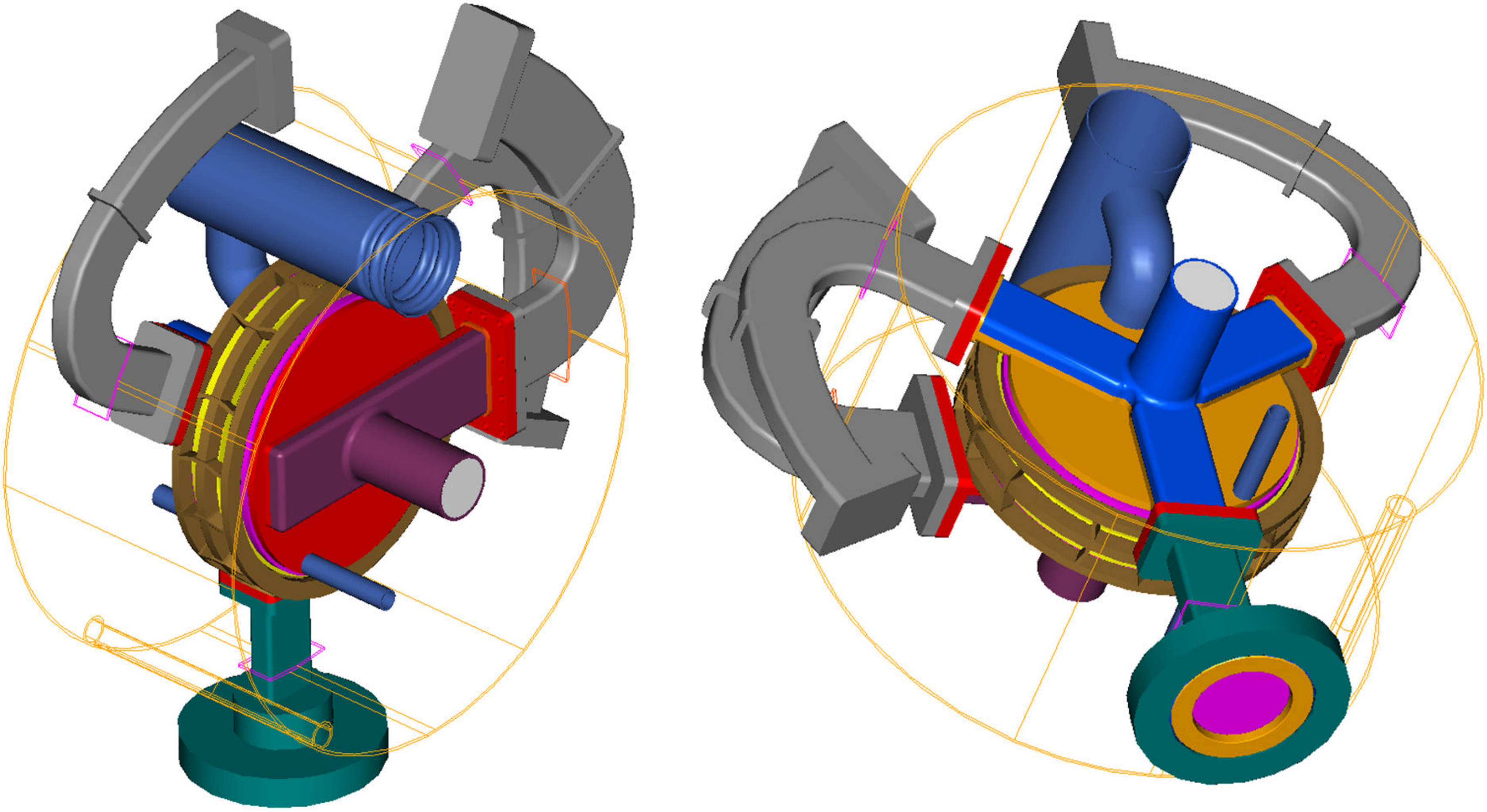
J. Henry, JLab

- Based on CEBAF/SNS/12GeV Upgrade Evolution
- Shown with internal HOM loads



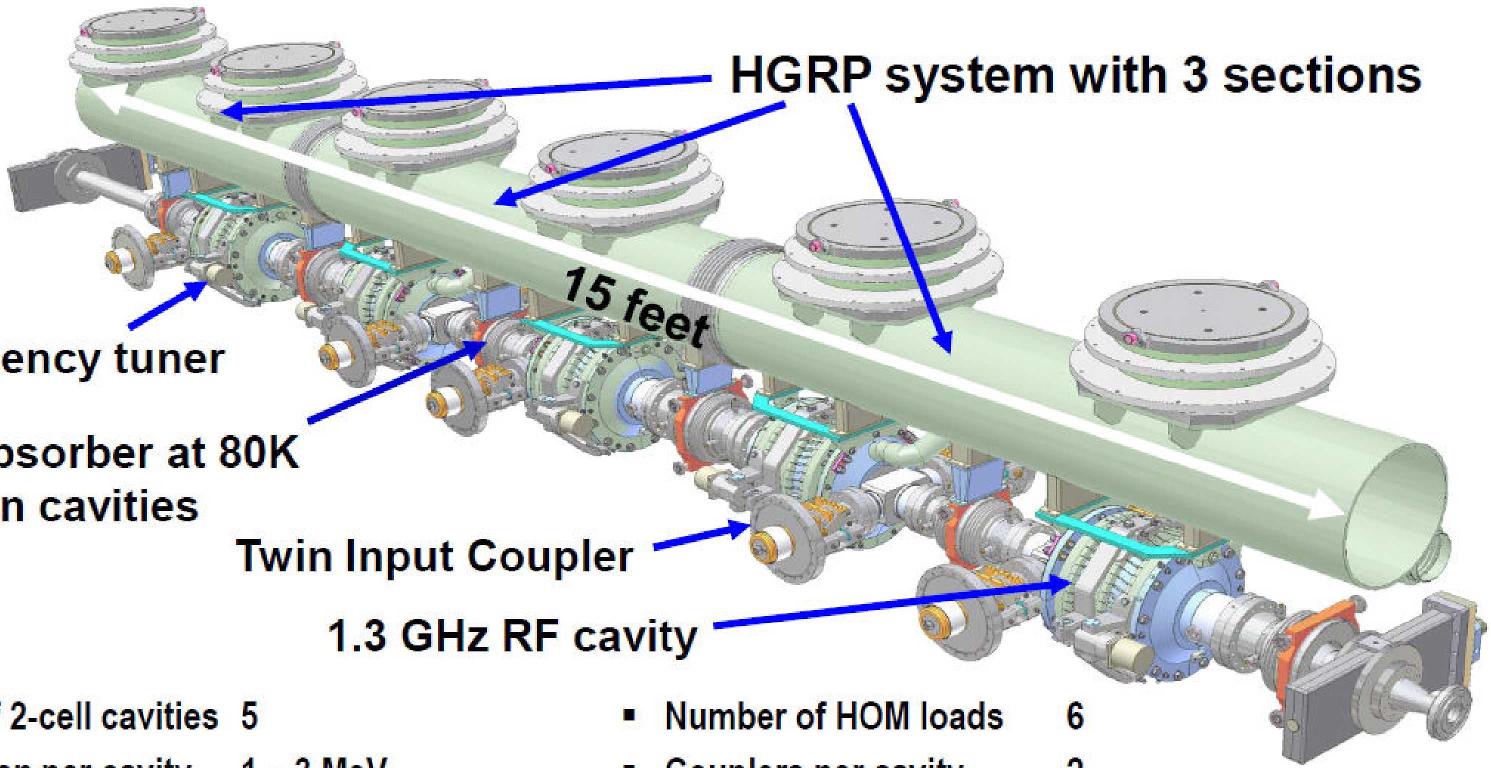
JLab SPX Cryomodule Concept (2)

J. Henry, JLab



Cornell ERL Injector Cryomodule (1): Cold Mass

M. Liepe, Cornell

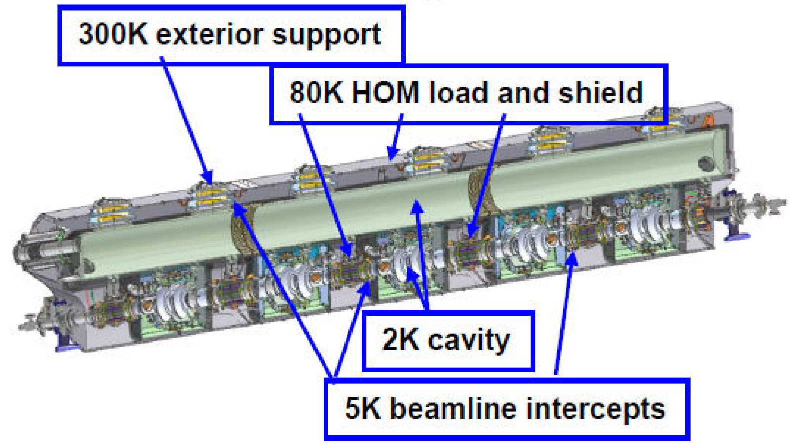


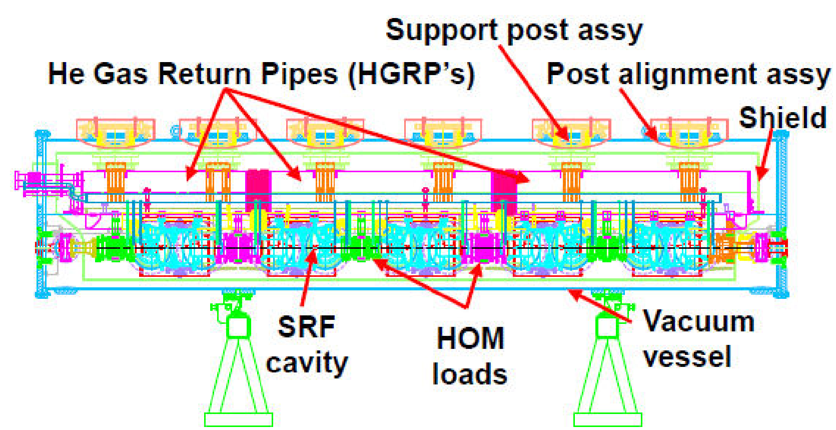
- Number of 2-cell cavities 5
- Acceleration per cavity 1 – 3 MeV
- Accelerating gradient 4.3 – 13.0 MV/m
- R/Q (linac definition) 222 Ohm
- Qext $4.6\times10^4 - 4.1\times10^5$
- Total 2K / 5K / 80K loads: 30W / 60W / 700W
- Number of HOM loads 6
- Couplers per cavity 2
- RF power per cavity 120 kW
- Amplitude/phase stability 10^{-3} / 0.1° (rms)
- ICM length 5 m

Cornell ERL Injector Cryomodule (2): TTF Evolution

M. Liepe, Cornell

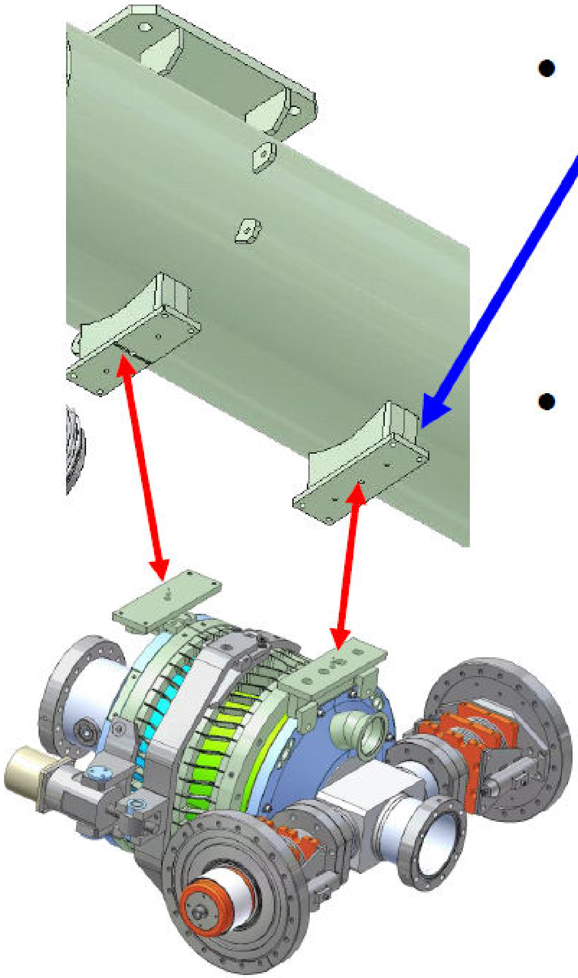
- Necessary changes compared to a TTF cryomodule:
  - Increased diameter of 2K He pipes for high dynamic CW cavity loads
  - Direct gas cooling of chosen 5K and 80K intercept points
  - No 5K shield, only a 5K cooling manifold
  - HOM absorbers between cavities
  - New end-cap and feed-cap concept with reduced length



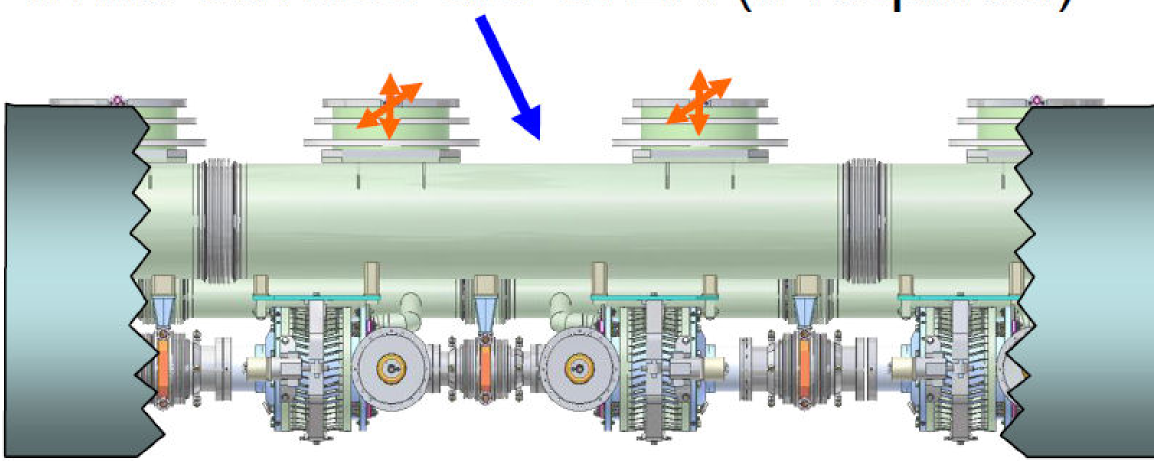


Cornell ERL Injector Cryomodule (3): CM Support

M. Liepe, Cornell



- Precision fixed cavity support surfaces between the beamline components and the HGRP
  ⇒ easy "self" alignment
- Cavity-subunits can be fine-aligned while cavities are at 2K (if required)

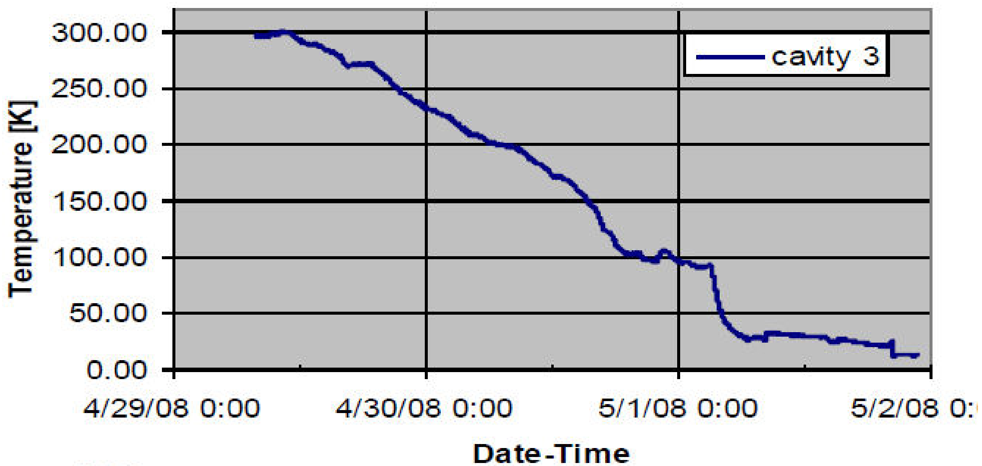


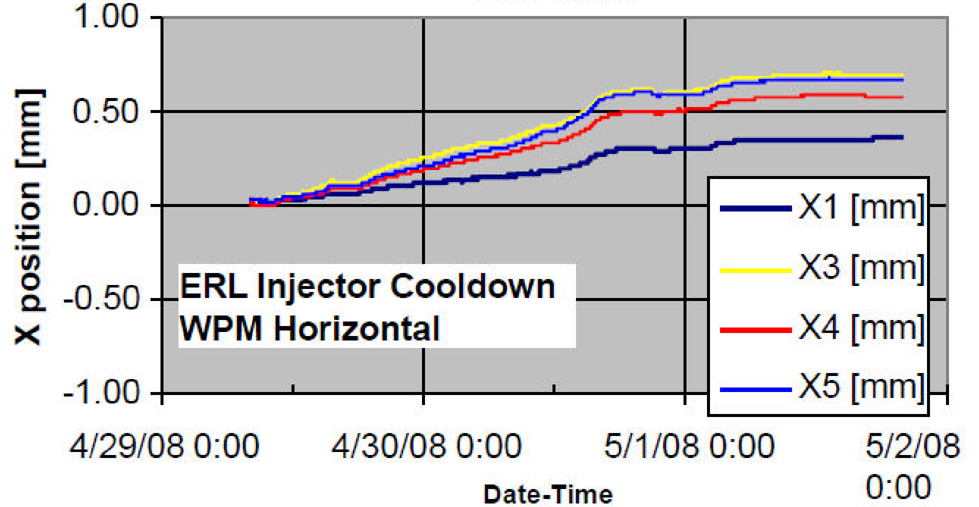
Cornell ERL Injector Cryomodule (4): Alignment

M. Liepe, Cornell

- Injector cryomodule cool-down to 4.2K in 2.5 days to minimize thermal stresses (<10 K/hour)
- Shift of cold mass (from Wire Position Monitor)
  - **Expected: dx= 0.38 mm dy= 0.94 mm**
  - **Observed: dx = 0.58 mm dy = 0.81 mm**

Cavity string is aligned to ±0.2 mm after cool-down!





Cornell ERL Injector Cryomodule (5): Maintenance

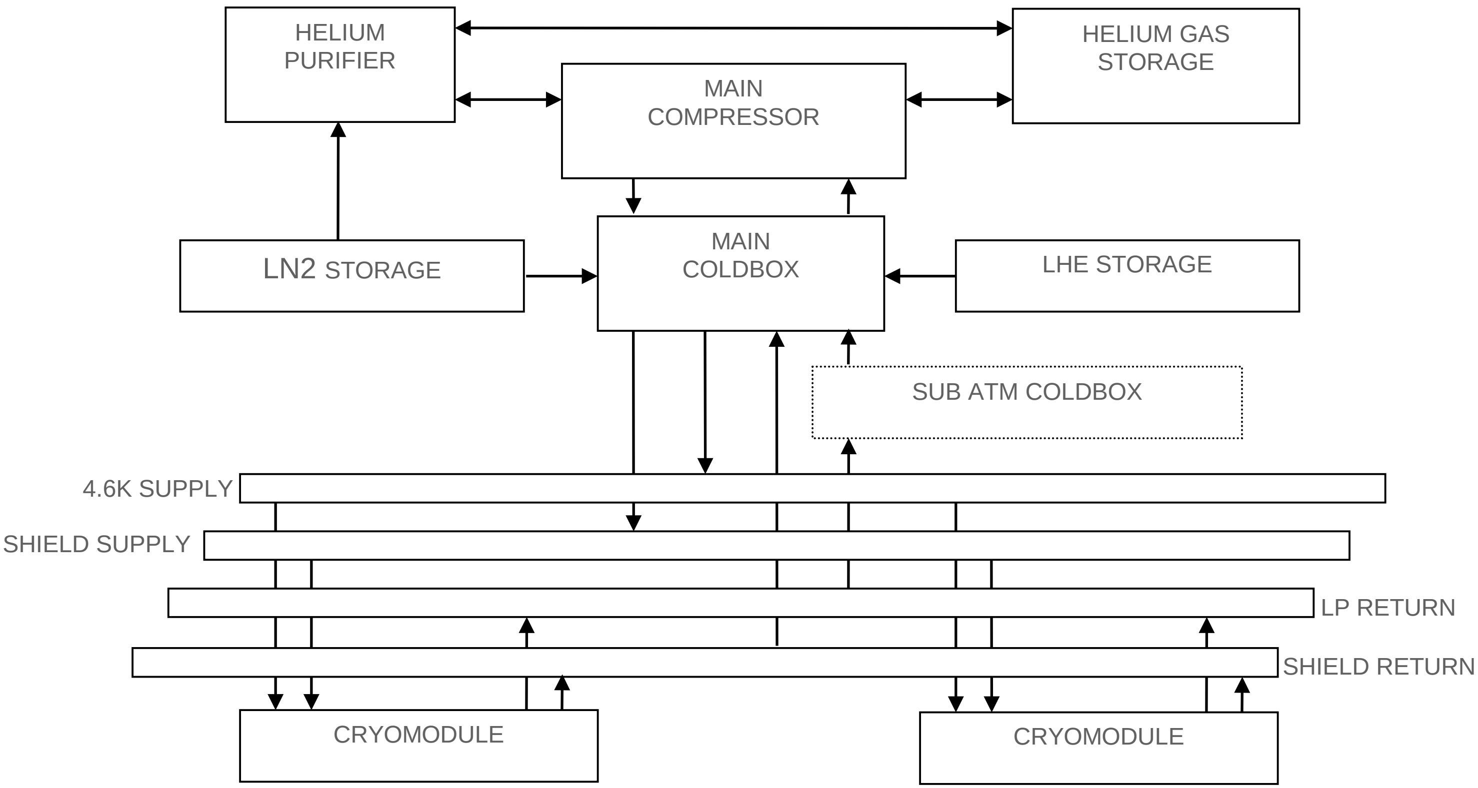
M. Liepe, Cornell

3 weeks later

"module in boxes"

- Injector module was dissembled during the last 3 weeks to
  - Re-process SRF cavities →improve Q_0
  - Fix absorber charging problem

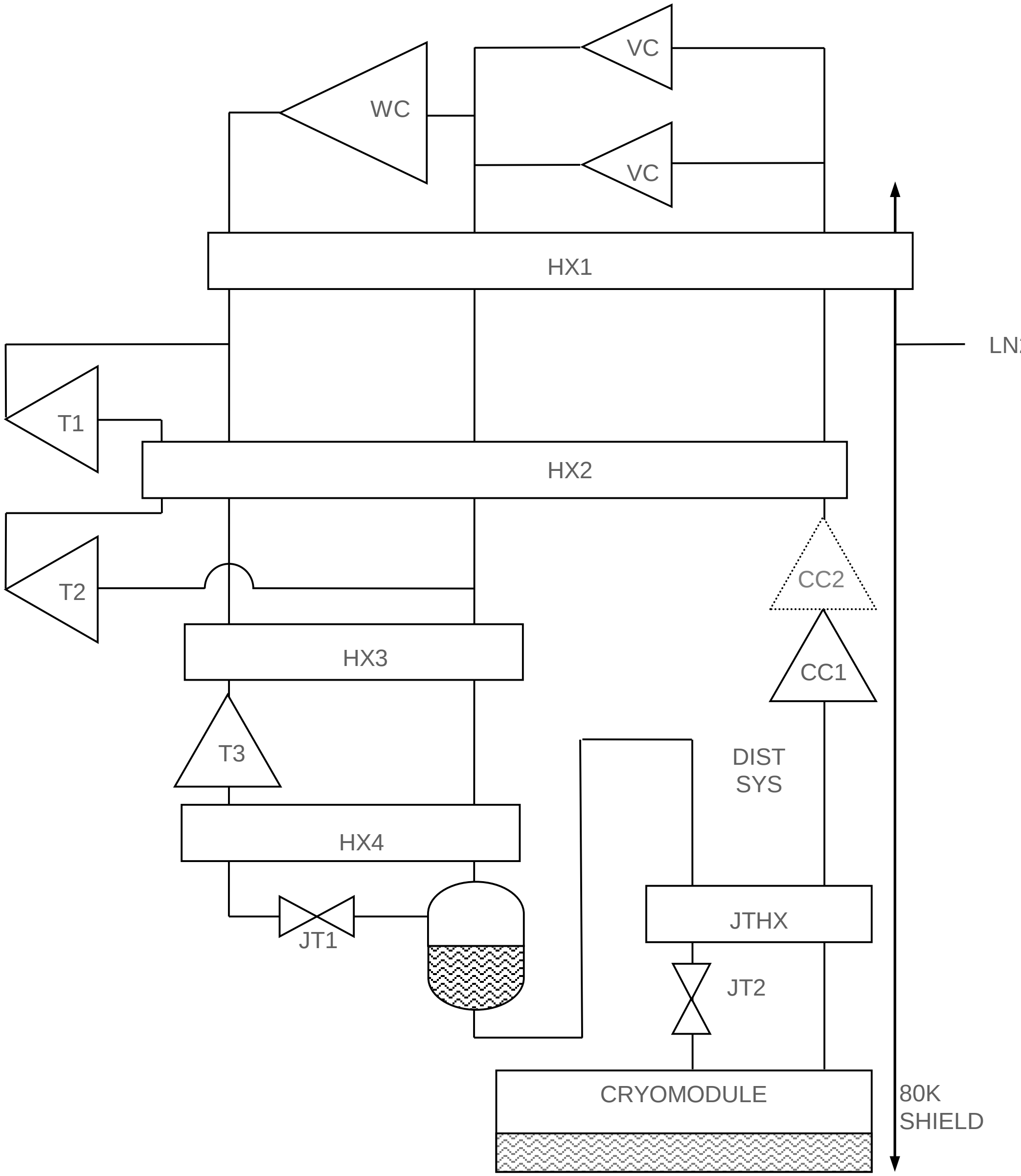
Refrigeration (1)



Refrigeration (2)

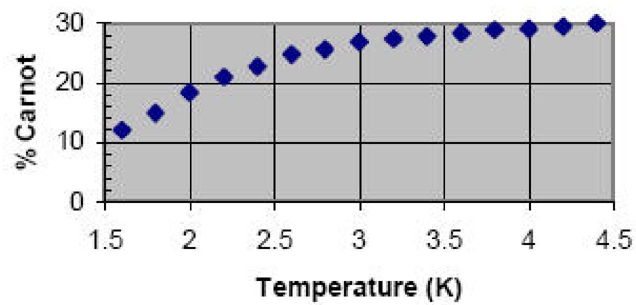
- Pressure stability
- Vibration
- Off-design operation
- System margin
- Upgradeability
- Safety
- Reliability
- Efficiency
- Cost/delivery

- Similar systems

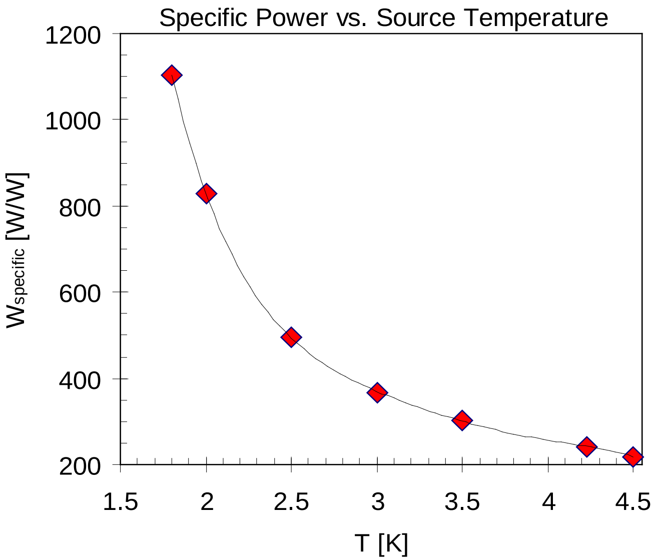


Refrigeration (3)

- Refrigeration @4.3K:
  - COP_{INV} = 70 W/W
  - Carnot efficiency = 30%
  - Input power required = 230 W per watt at 4.3K
- Refrigeration @2K:
  - COP_{INV} = 150 W/W
  - Carnot efficiency = 18%
  - Input power required = 830 W per watt at 2K

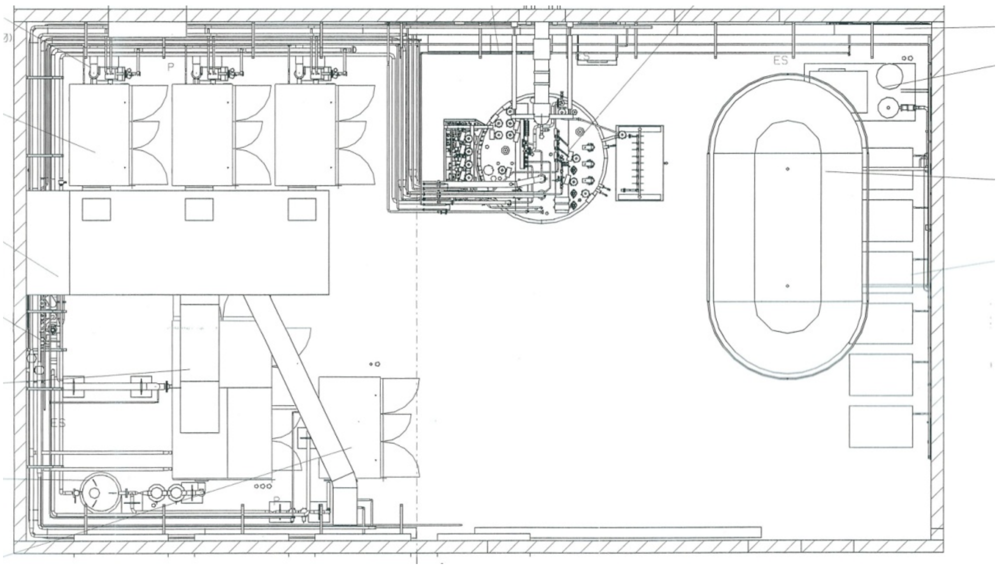


Schneider, Kneisel, Rode, "Gradient Optimization for SC CW Accelerators," PAC2003



ELBE Cryoplant
FZ-Rossendorf

- Cryoplant hall: 17m x 10m
- 220W @ 1.8K + 200W @ 80K, upgradeable to 380W with more comp & LN2 precooling
- 417kW at full load (220W)



Cryoplant Costs

- Requirements are calculated using data from T. Smith, 03MAY10:
  - 312W for Q=1E9
  - 200W for Q=3E9
  - 161W for Q=1E10
  - 152W for Q=2E10
  - Same Qs, but ½ voltage
- Equivalent load includes **300W** for 5-8K intercepts and distribution sys. losses and **200W** equivalent for 40-80K shield load. This extra load is a fixed value and assumed to be independent of the 2K load.
- For cryoplants of this type, 1.8K operation adds 33% to plant size compared to 2.0K operation.

Load [W] @ operating temp	Equivalent load @ 4.5K [W]	Cost scaled from FNAL* [M$]	Compressor power for 2.0K operation [kW]
270 (FNAL reference)	1230	8.0	295
312 (4MV @ Q=1E9)	1242	8.1	298
200 (4MV @ Q=3E9)	940	6.6	226
160.8 (4MV @ Q=1E10)	834	6.1	200
152.4 (4MV @ Q=2E10)	811	6.0	195
156 (2MV @ Q=1E9)	821	6.0	197
100 (2MV @ Q=3E9)	670	5.2	161
80.4 (2MV @ Q=1E10)	617	4.9	148
76.2 (2MV @ Q=2E10)	606	4.9	145

*Fermilab is buying a new cryoplant for ILC string tests. Design capacity is 270W@2K + 300W@5-8K + 4500W@40-80K (= 1230W equivalent at 4.5K). Costs scale with the 0.7 power of plant capacity (per Byrns & Green, *"An update on estimating the cost of cryogenic refrigeration,"* 1998).