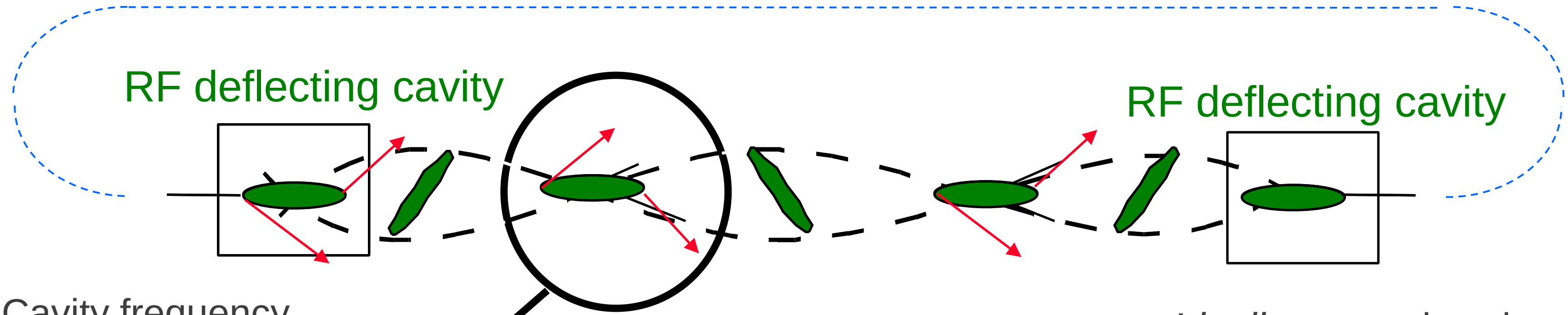
SPX Cryogenics

J.D. Fuerst, ANL

Project X Collaboration Meeting

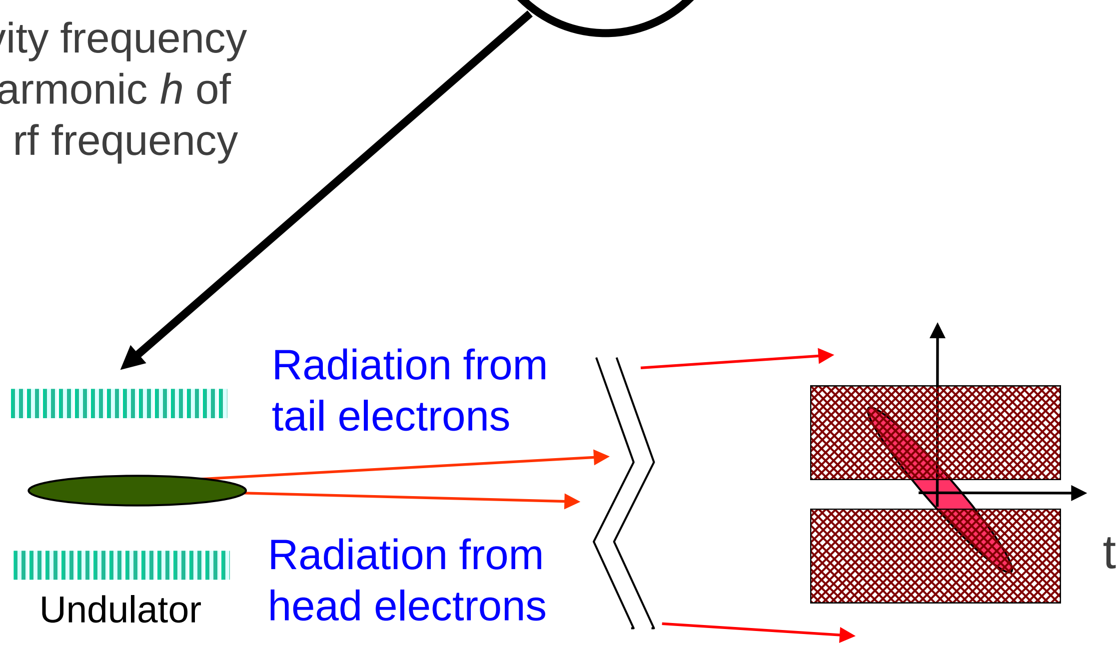
08-09SEP10

Zholents' Transverse Rf Chirp Concept[1]



Cavity frequency is harmonic *h* of ring rf frequency

Ideally, second cavity exactly cancels effect of first if phase advance is n*180 degrees

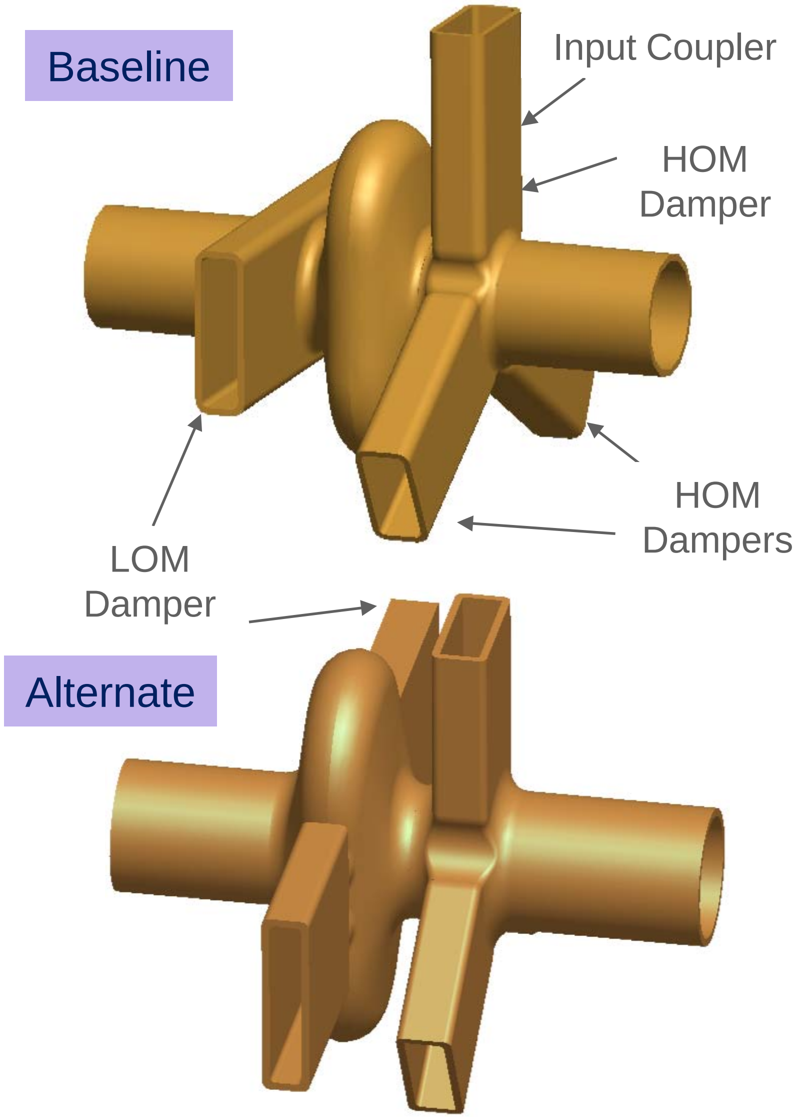


Pulse can be sliced or compressed with asymmetric cut crystal

(Adapted from A. Zholents' August 30, 2004 presentation at APS Strategic Planning Meeting.)

[1]A. Zholents *et al.*, NIM A 425, 385 (1999).

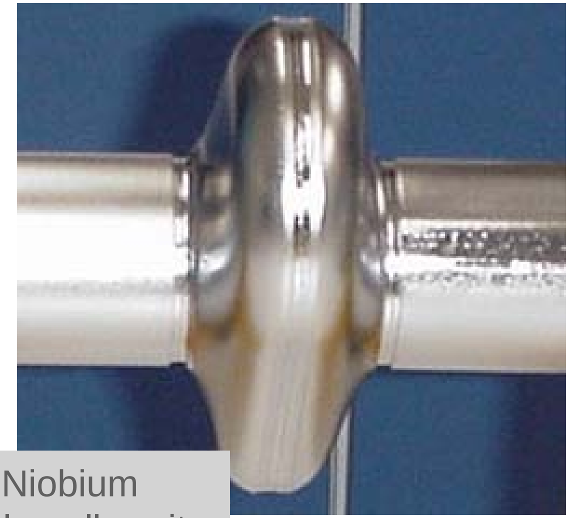
Single-Cell SC Cavity



Frequency	2815	MHz
Q_U	$\sim 10^9$	
V_t	0.5	MV
Energy	0.39	J
$k_{\|\|}$	0.615	V/pC
(R/Q)'	17.8	Ohm
E_{peak} / V_t	83	1/m
B_{peak} / V_t	182	mT / MV
P_{loss}	7	W
I_{beam}	200	mA
Cavity Iris Rad	25	mm
Cavity Beam Pipe Rad	26	mm
Cavity Active Gap	53.24	mm
Q_{ext}	$\sim 10^6$	
Cells / Cavity	1	
No. Cavity	4 * 2	

Parameters for the Baseline Cavity

Nb Prototypes at JLAB



Niobium
single-cell cavity

Niobium
2-cell cavity

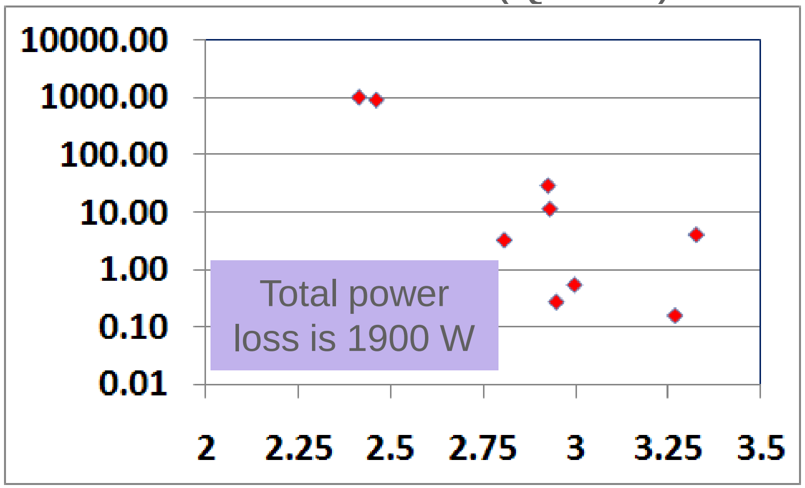
- Prototyped cavities at JLAB
  - Created cavity dies
  - Performed trimming and EB welding.
  - Performed chemistry processing and HPR
- Cavities at 2K for Q, maximum field, and Lorentz force detuning

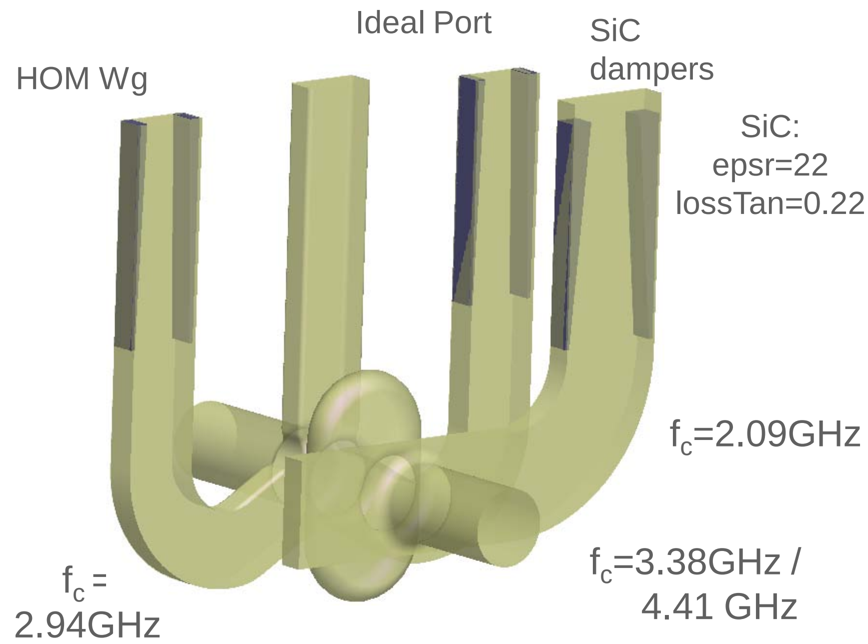
Niobium single-cell cavity with on-cell damper

Courtesy H. Wang / R. Rimmer

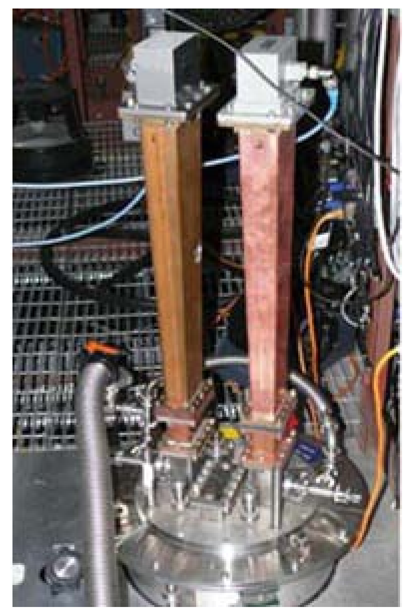
RF Loading of Dampers

Total Power Loss (Q=100)





- If losses are sufficiently low in HOM dampers, they may be cooled at 80K.
- Broadband loss calculated with the loss factor is 3.75kW for 24 bunch mode at 200mA.
- Above estimates are too low. Broadband loss should match losses for Q=100 case above.
- Losses in dampers are dependent on which modes in eigenmode simulation are considered to be ‘real’.



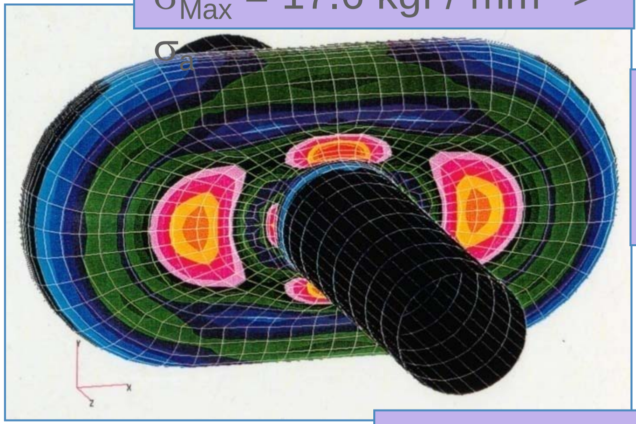
Each SPX cavity must extract kW’s of HOM/LOM beam power

JLAB: Low-power damper testing

SPX Tuner Requirements

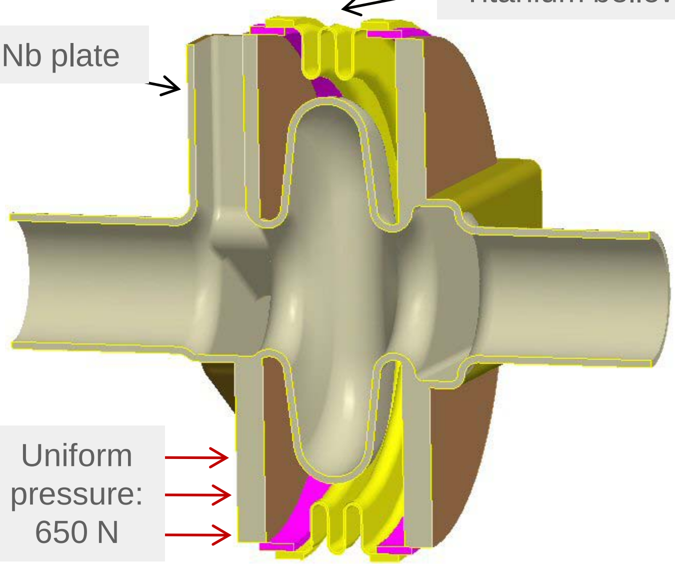
- Evenly applied axial pressure of ±650 N along Y-end group plate produces approximately 500 kHz tuning range.
- Cavity should always be under compression in order to avoid “dead spot” in tuning.
- Peak stress is located along narrow racetrack dimension => 17 MPa

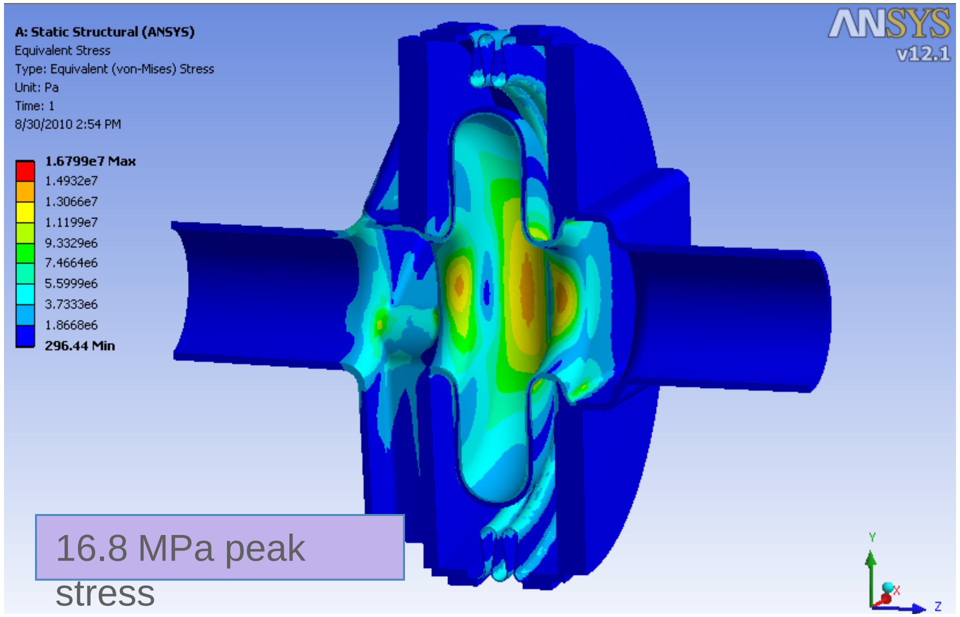
σ_{Max} = 17.6 kgf / mm^2 >



KEK 500MHz Crab Cavity

σ_a = 8.1 kgf / mm^2 or 79 MPa according to KEK





16.8 MPa peak stress

Cryomodule Parameters

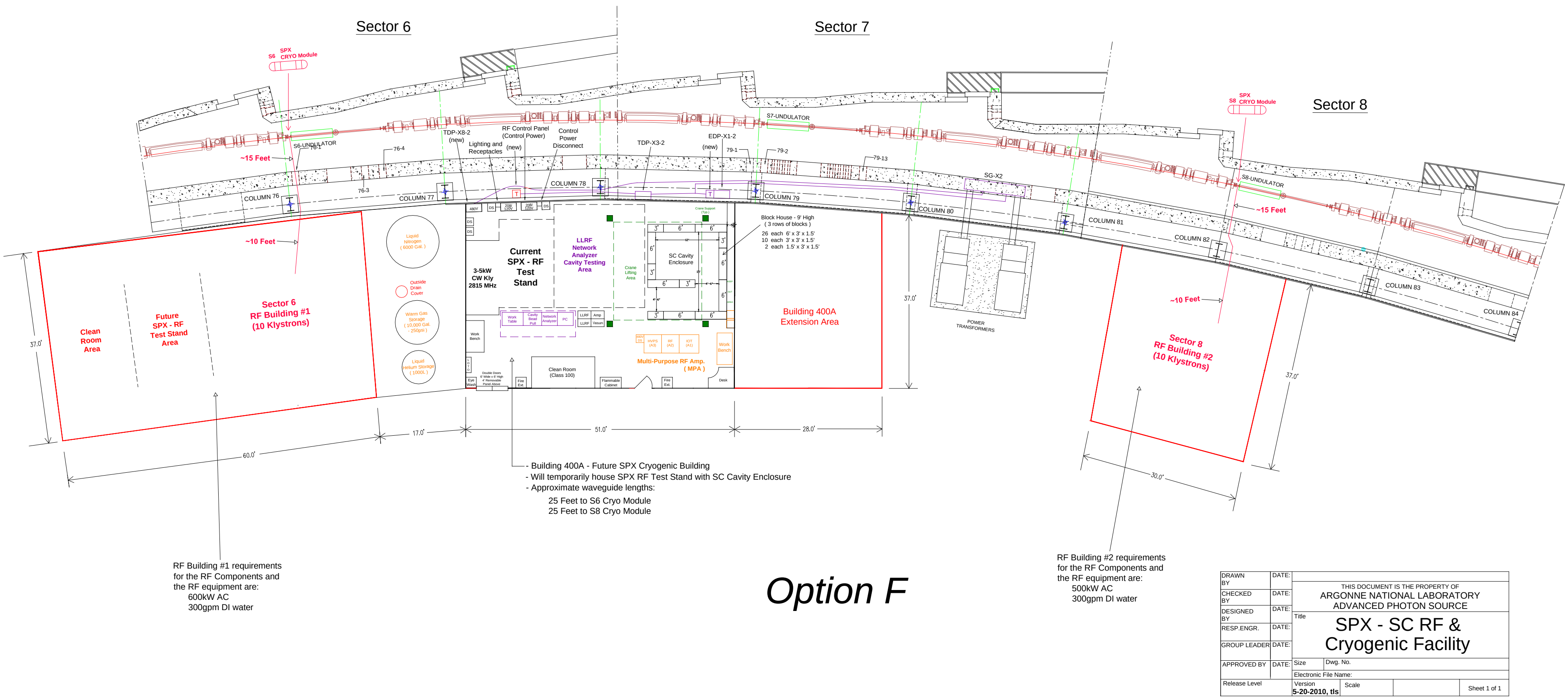
Preliminary Estimate of 2.0K Losses

2.0K Cryogenic Losses	
Static / Dynamic Losses due to Waveguides / Tuners per Cavity	2.4 W
Wall Losses per Cavity @ $Q_u=10^9$	7.0 W
Static Heat Load due to Cryo Losses e.g., Beampipe Transistions / Supports	2.0 W
Total Heat Load (8 cavities) @ $Q_u=10^9$	79 W

Estimated System Parameters

System Parameters	
Slow Tuner Range	+/-200kHz
Number of Cavities per Cryomodule	4 (8)
Total Number of Cryomodules	2
Cavity Offset Alignment Tolerance	0.3 mm
Beam Offset Tolerance	0.05 mm
Klystron Power per Cavity	5 kW

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)
Lighting and Receptacles
RF Control Panel (Control Power) (new)
Control Power Disconnect
TDP-X3-2
EDP-X1-2 (new)
SG-X2
POWER TRANSFORMERS
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
Crane Lifting Area
SC Cavity Enclosure
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'
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
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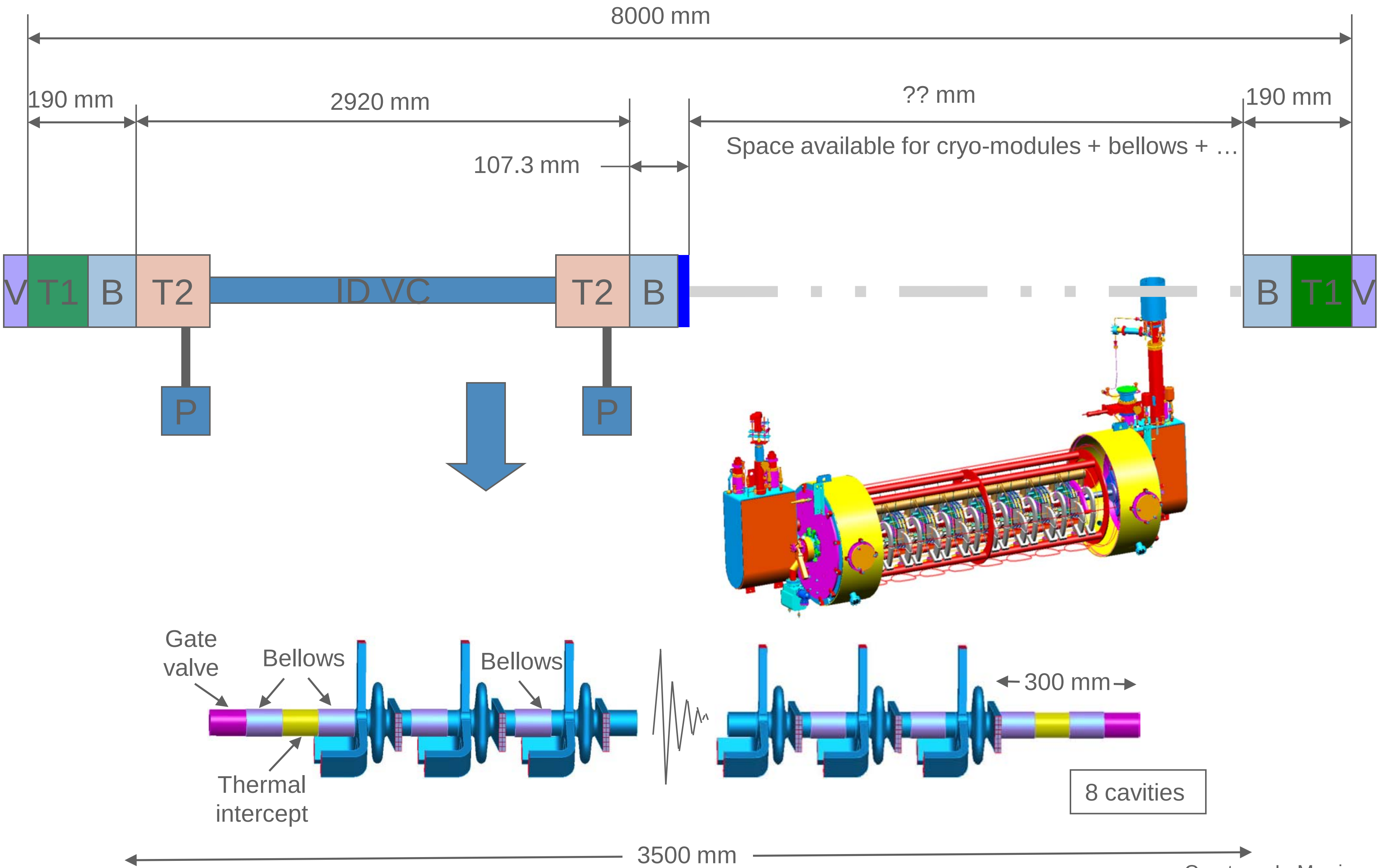
Sheet 1 of 1

Deflecting Cavity Cryomodule Insertion

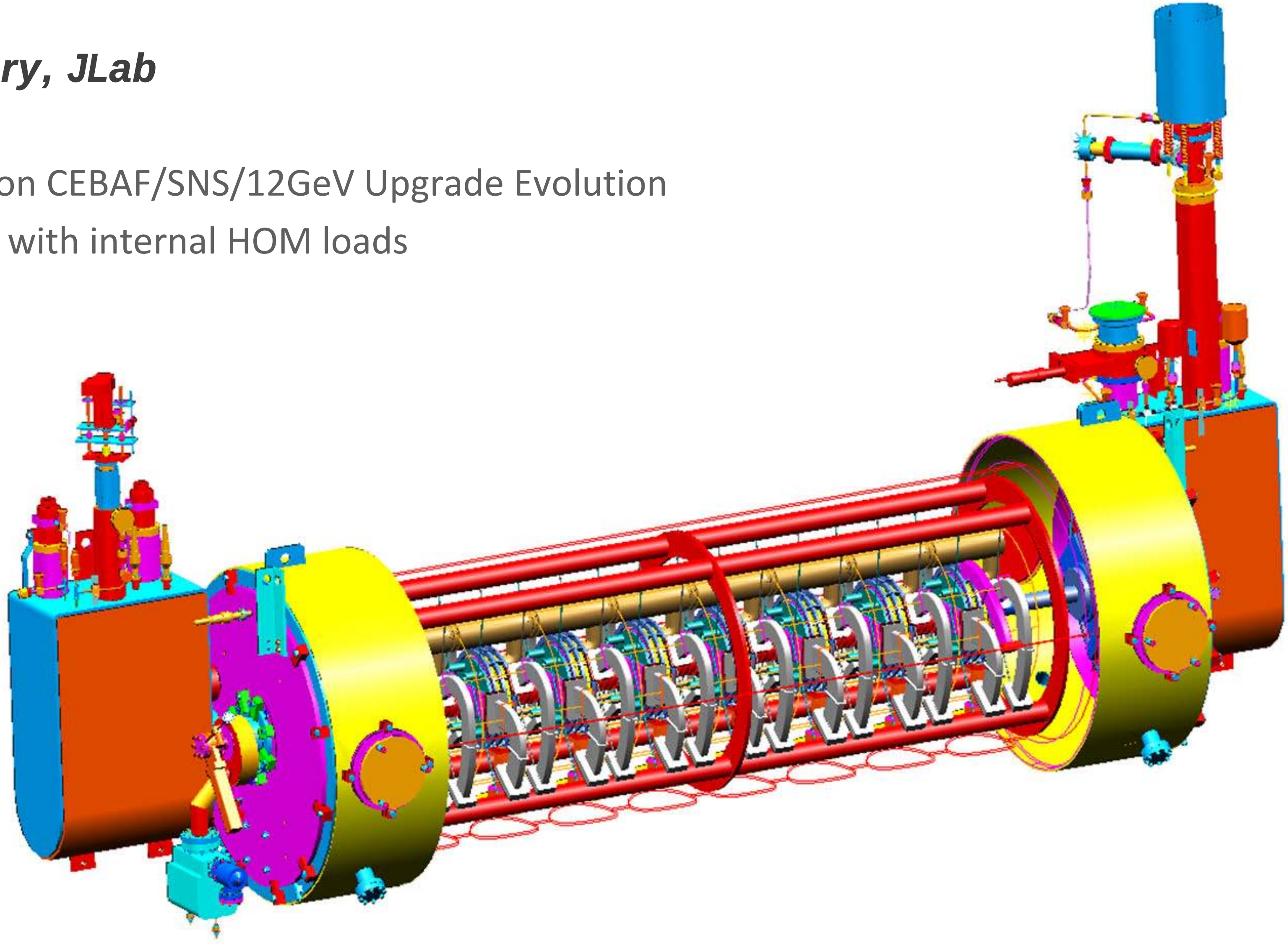


Courtesy: L. Morrison

JLab SPX Cryomodule Concept (1)

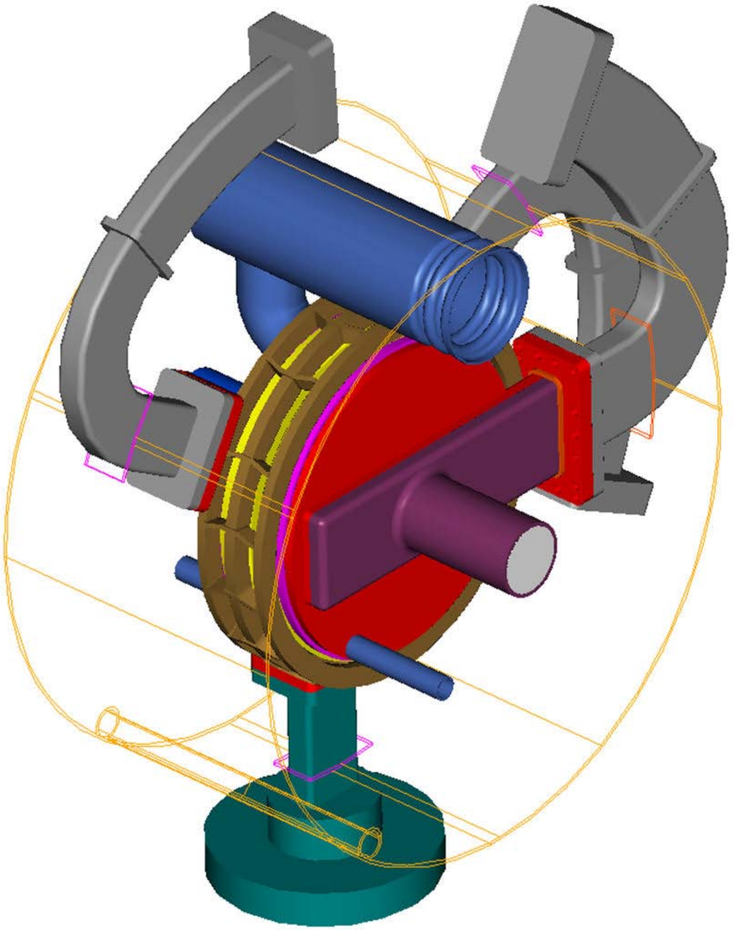
J. Henry, JLab

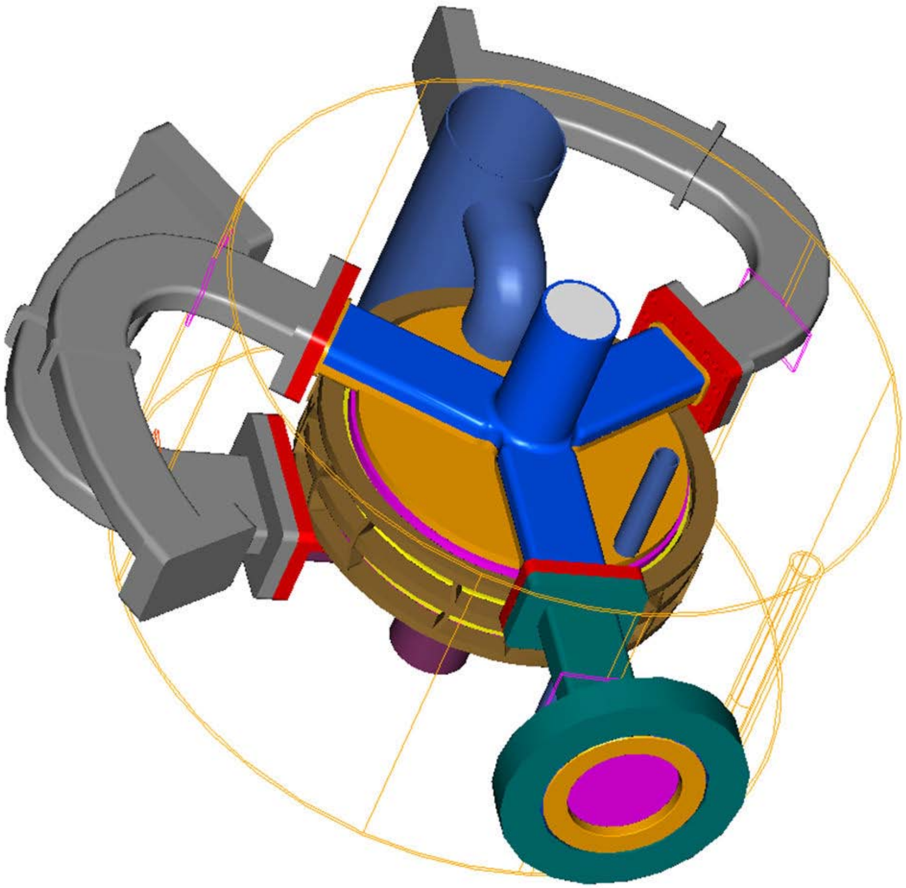
- Based on CEBAF/SNS/12GeV Upgrade Evolution
- Shown with internal HOM loads



JLab SPX Cryomodule Concept (2)

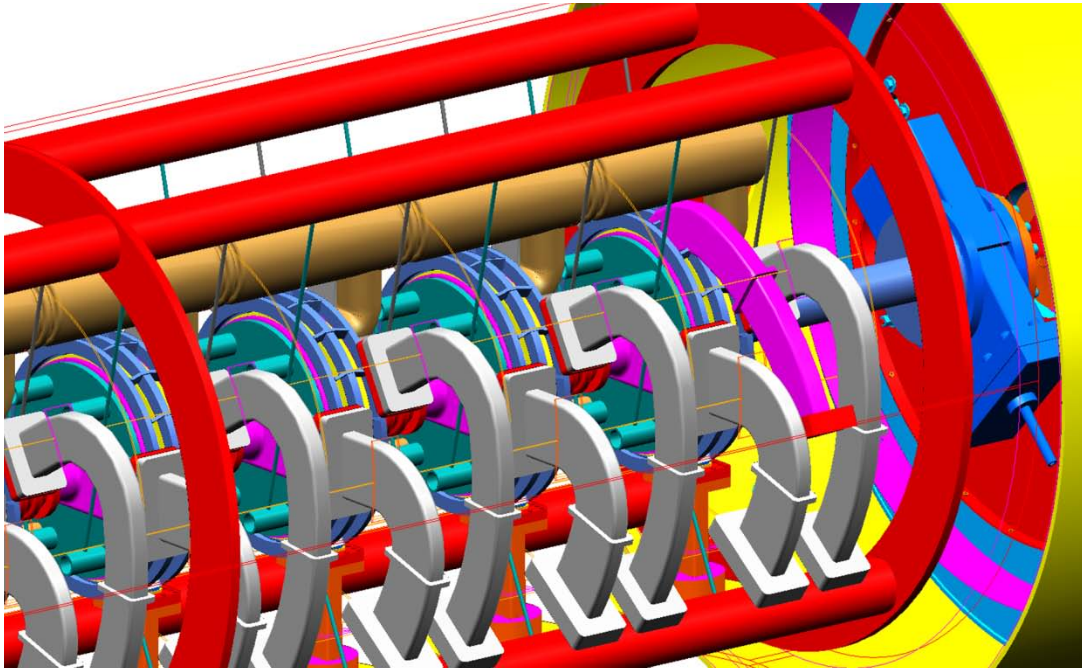
J. Henry, JLab

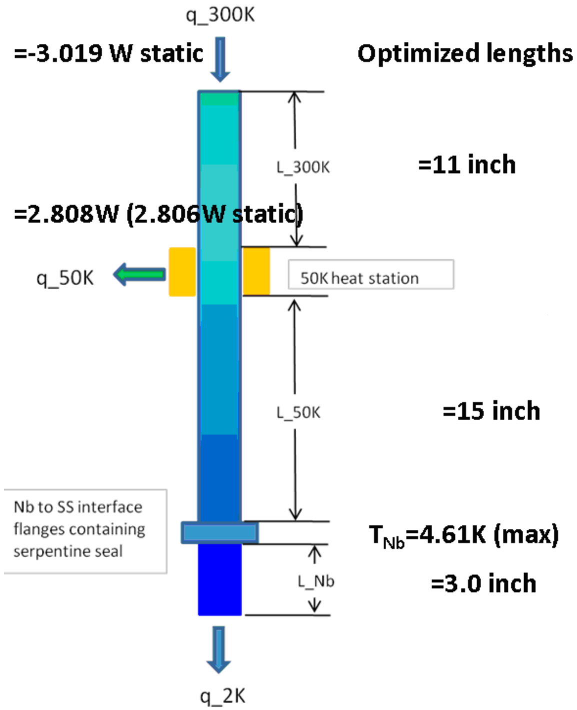




JLAB Cryomodule Concept

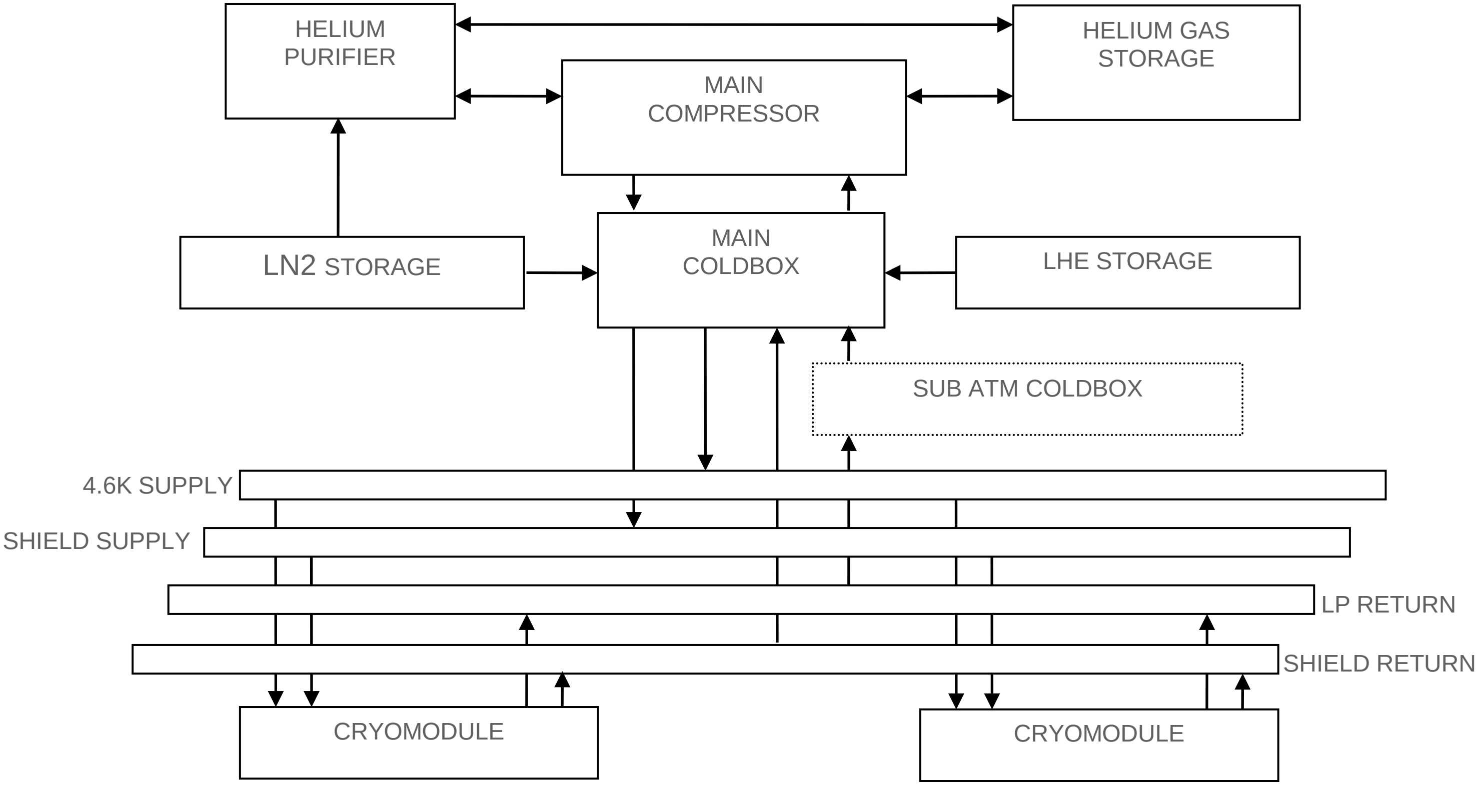
- Based on JLAB cylindrical cryomodule design.
- Dampers are located in vacuum shield of cryomodule - similar to JLAB's ampere-class cryomodule concept.
- Blade tuner located around helium vessel chosen for concept





- 1-D analysis of losses along beam pipe from cavity to room temperature estimated 0.26W at 2K with optimized lengths.

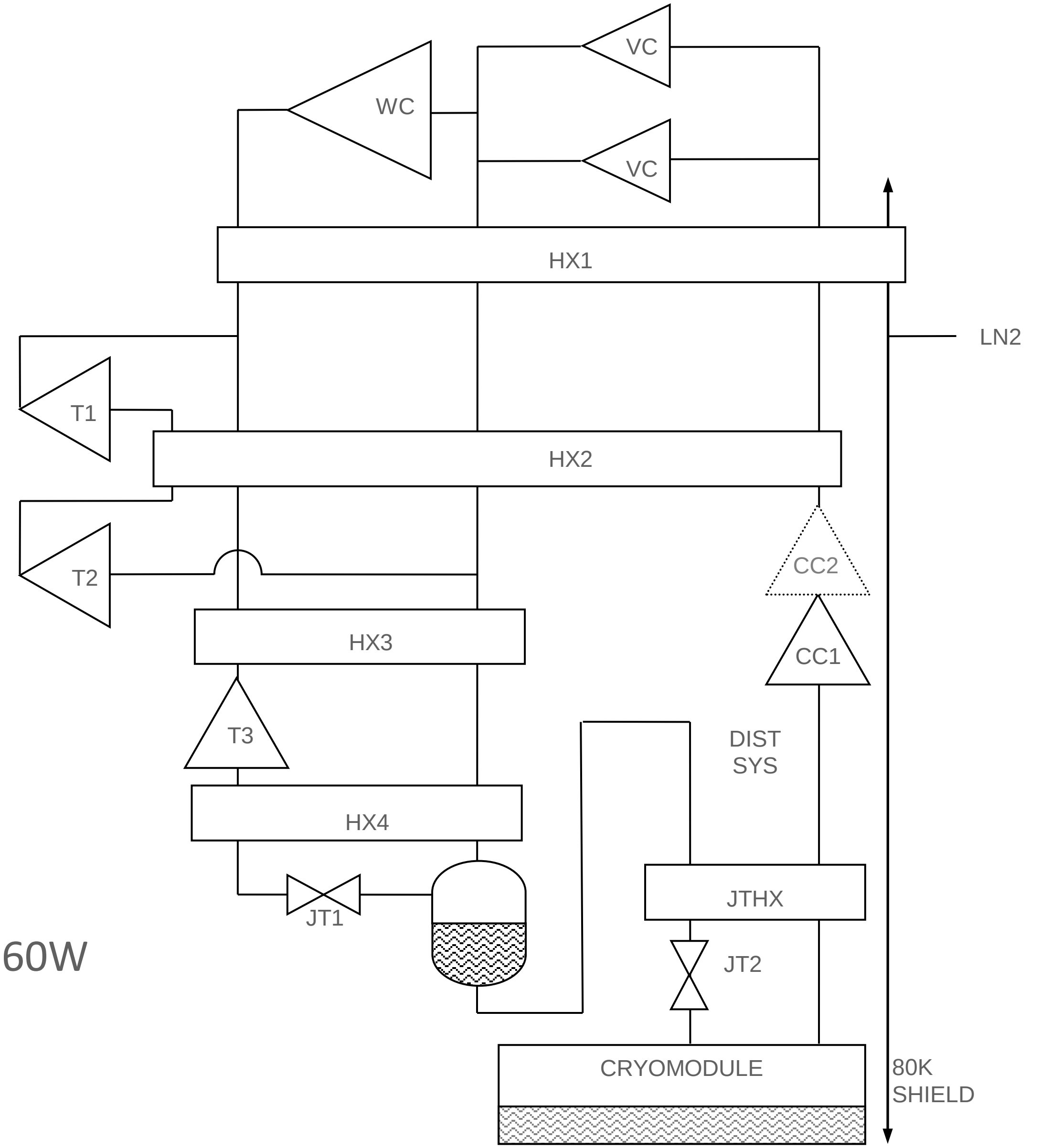
Refrigeration (1)



Refrigeration (2)

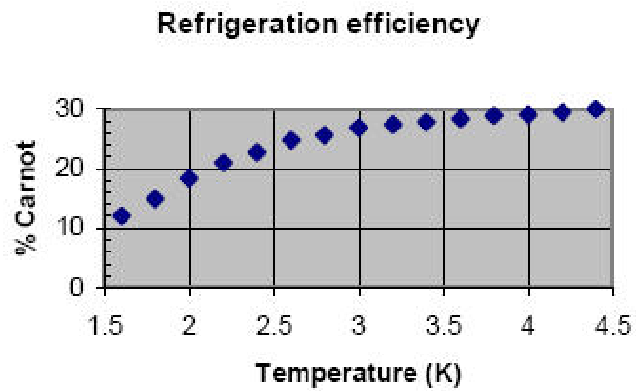
- Pressure stability
- Vibration
- Off-design operation
- System margin
- Upgradeability
- Safety
- Reliability
- Efficiency
- Cost/delivery
- Similar systems

- Required 2.0K capacity:
  80W/module*2 modules = 160W
  + 100% margin = **320W**

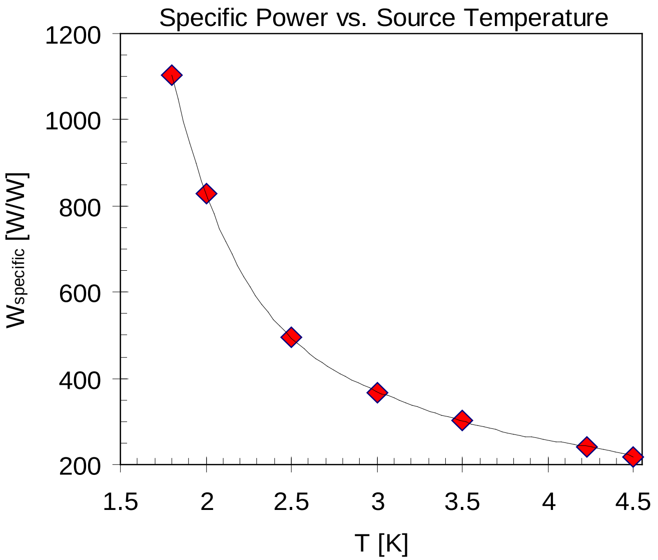


Refrigeration (3)

- Refrigeration at 4.3K:
  - COP_{INV} = 70 W/W
  - Carnot efficiency = 30%
  - P_{in} required = 230 W per watt at 4.3K
- Refrigeration at 2.0K:
  - COP_{INV} = 150 W/W
  - Carnot efficiency = 18%
  - P_{in} required = 830 W per watt at 2K
- Refrigeration at 1.8K:
  - COP_{INV} = 167 W/W
  - Carnot efficiency = 15%
  - P_{in} required = 1100 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):
  1900 W/W