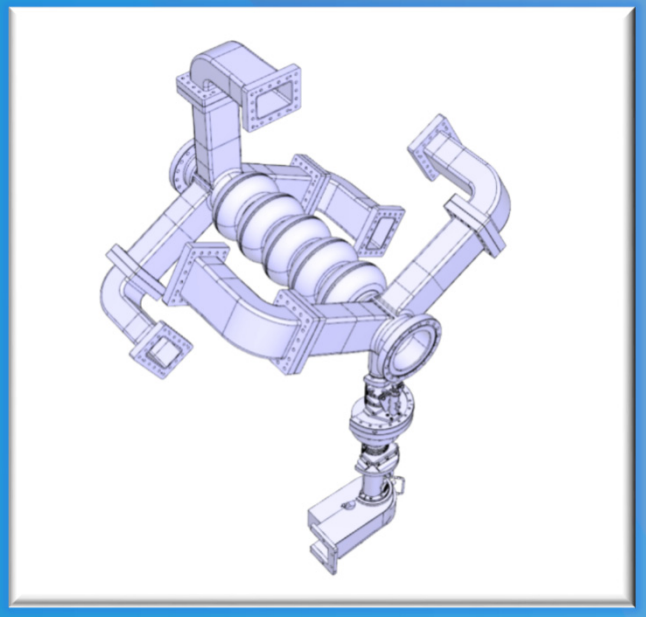
BESSY VSR

HZB Helmholtz Zentrum Berlin

BESSY VSR: SRF challenges and developments for a variable pulse-length next generation light source

Institut SRF - Wissenschaft und Technologie (FG-ISRF)



Adolfo Vélez et al.

SRF17 Lanzhou, 17-21/7/2017

The concept of BESSY VSR

BESSY II @ present

Normal conducting cavity system

- ❖ All other users are in the dark
- ❖ Low-α shifts only 12 days a year

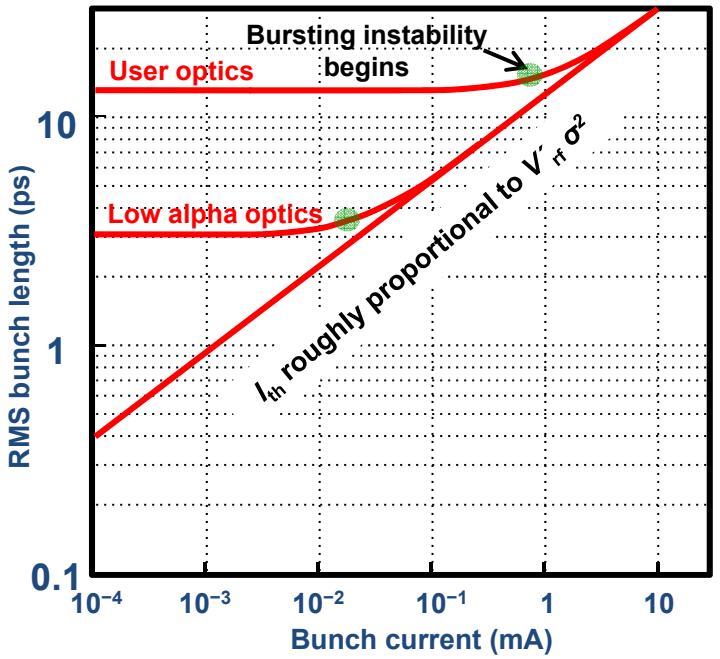
- **Limited pulse length in storage ring**

$$\sigma \propto \sqrt{\frac{\alpha}{\dot{V}_{rf}}}$$

← Machine optics

← Hardware (RF cavities)

- **At high current beam becomes unstable**
- **For ps pulses, flux is reduced by nearly 100**



The concept of BESSY VSR

BESSY II @ present

- **Limited pulse length in storage ring**

$$\sigma \propto \sqrt{\frac{\alpha}{\dot{V}_{rf}}}$$

← Machine optics

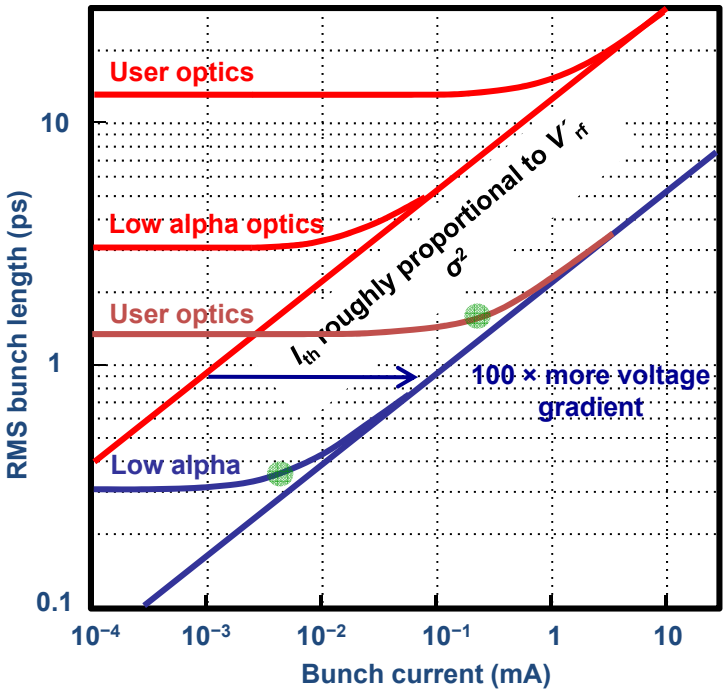
← Hardware (RF cavities)

- **At high current beam becomes unstable**
- **For ps pulses, flux is reduced by nearly 100**

Supply short pulses down to 1.5 ps
100× more bunch current

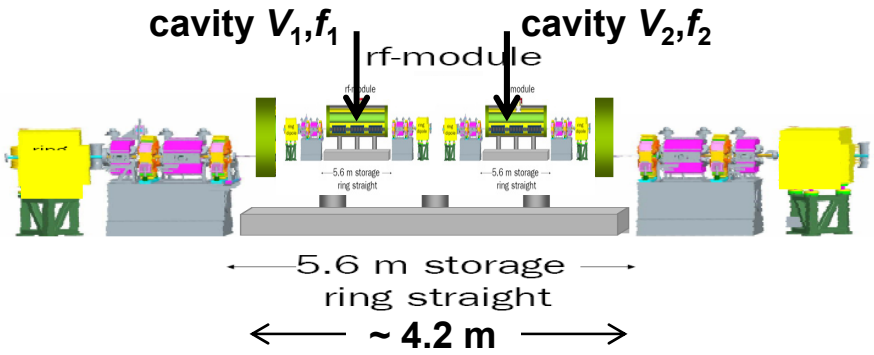
Low α permits few 100 fs

Configure BESSY^{VSR} so 1.5 ps and 15 ps bunches can be supplied simultaneously for maximum flexibility and flux!



The concept of BESSY VSR

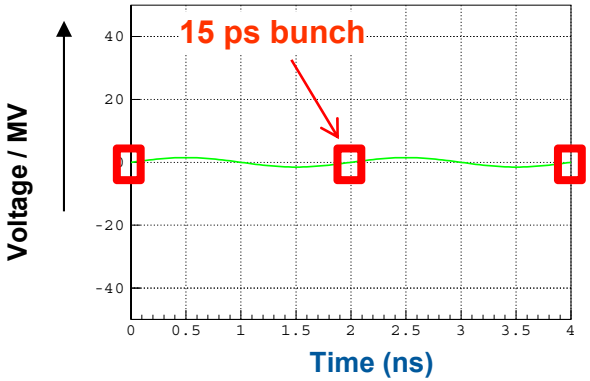
BESSY II , SC Upgrade



G.Wüstefeld et al.
„Simultaneous long and short electron bunches in the BESSY II storage ring“
IPAC2011

- 1.5GHz and 1.75GHz ---- RF beating
- Odd (voltage cancelation, 15 ps bunches)
- Even (voltage addition, long.focussing, 1.7 ps)

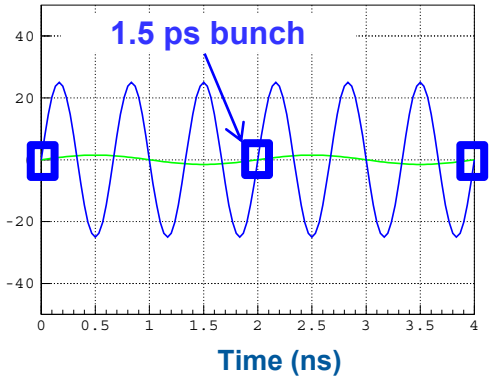
Present



Voltage: 1.5 MV @ 0.5 GHz

$$\dot{V} \propto V \times f_{\mathrm{rf}} = 0.75\ \mathrm{MV} \times \mathrm{GHz}$$

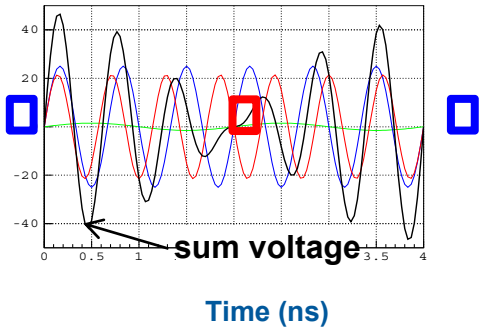
Phase I



Voltage: 20 MV @ 1.5 GHz

$$\dot{V} \propto V \times f_{\mathrm{rf}} = 30\ \mathrm{MV} \times \mathrm{GHz}$$

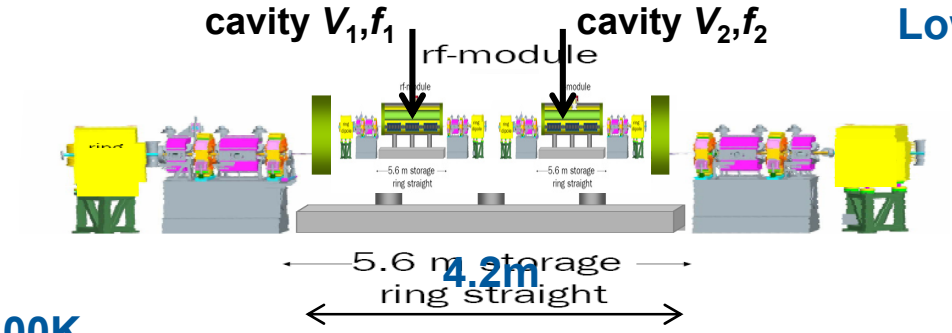
Phase II



Voltage: 20 MV @ 1.5 GHz
+ 17.1 MV @ 1.75 GHz

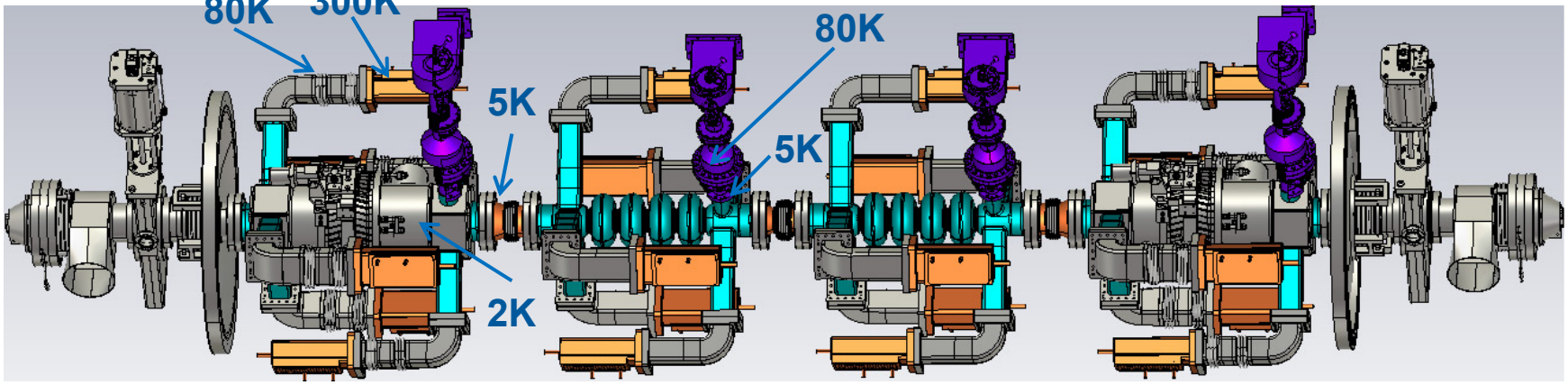
$$\dot{V} \propto V \times f_{\mathrm{rf}} = 60\ \mathrm{MV} \times \mathrm{GHz}$$

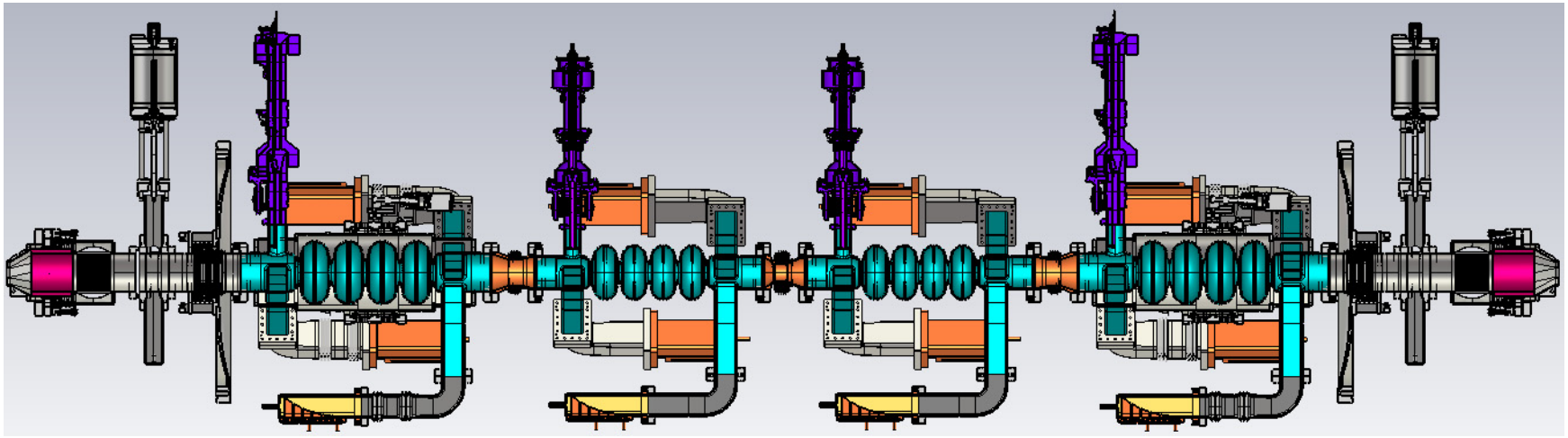
BESSY VSR Cold-String



Low Beta straight

Courtesy of A. Tsakanian





BESSY VSR Cold-String: SRF Cavities

Main VSR Challenge :

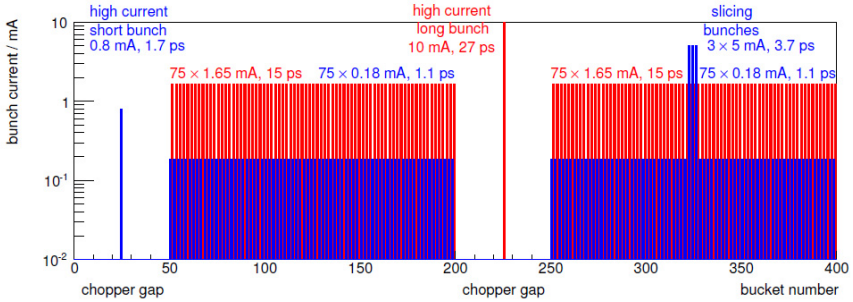
CW + High current (300mA) + Exotic filling pattern

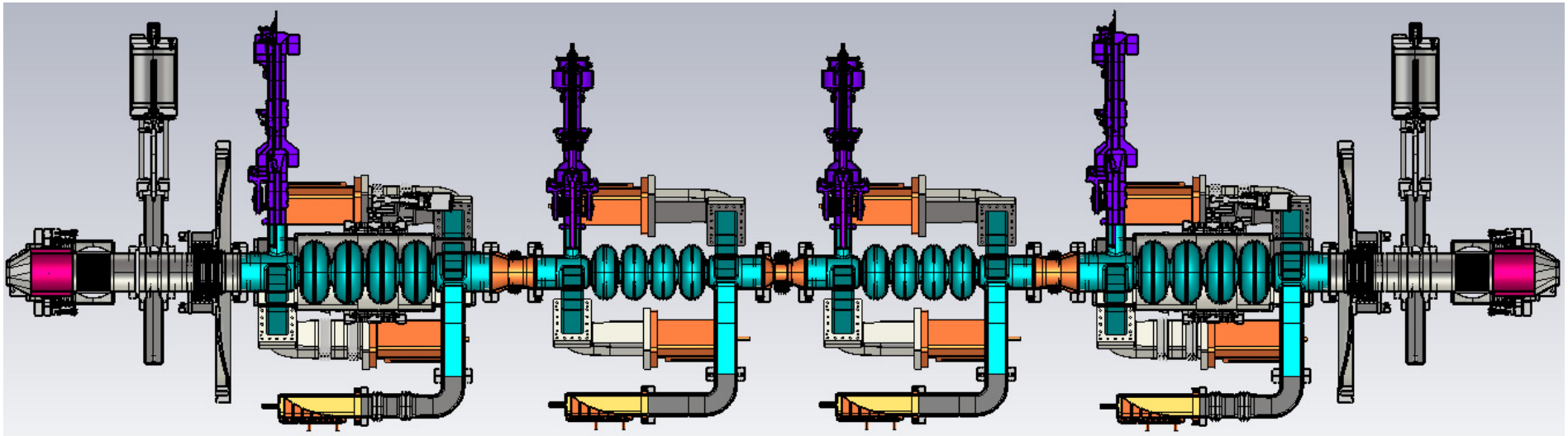
⇩

High HOM damping level required *to avoid CBI's*

Very Low *Impedance tresholds with feedback:*

- ***5e4 Ω,*** *longitudinal modes*
- ***1e7 Ω/m,*** *transverse modes*





BESSY VSR Cold-String: SRF Cavities

Main VSR Challenge :

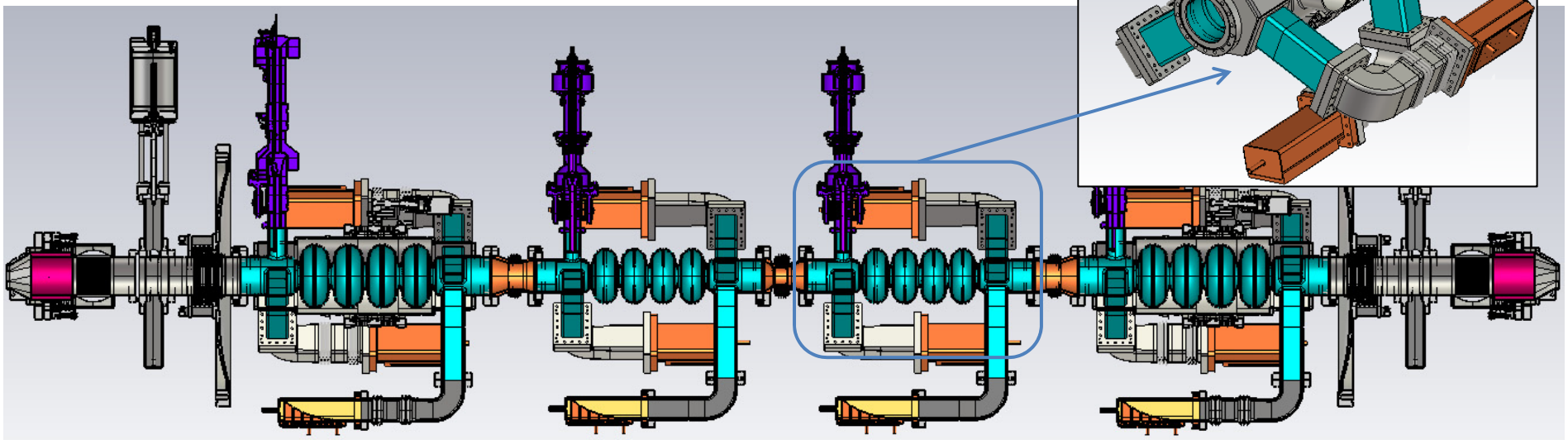
CW + High current (300mA) + Exotic filling pattern

⇩

High HOM damping level required *to avoid CBI's*

Very Low *Impedance tresholds with feedback:*

- ***5e4 Ω,*** *longitudinal modes*
- ***1e7 Ω/m,*** *transverse modes*



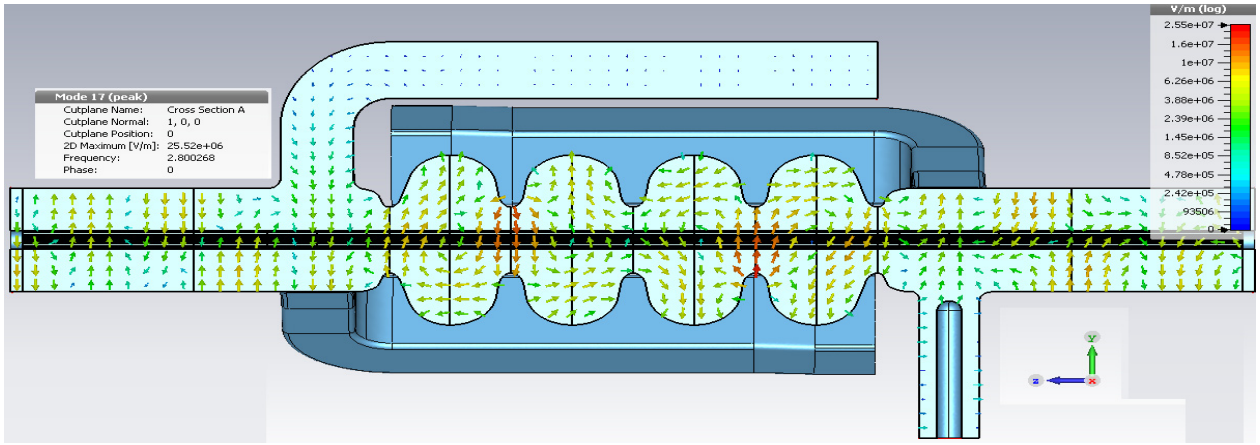
2x1.75 GHz SRF + 2x1.5 GHz Cavities

5 cell cavities down-scaled to 4 cell ⇨

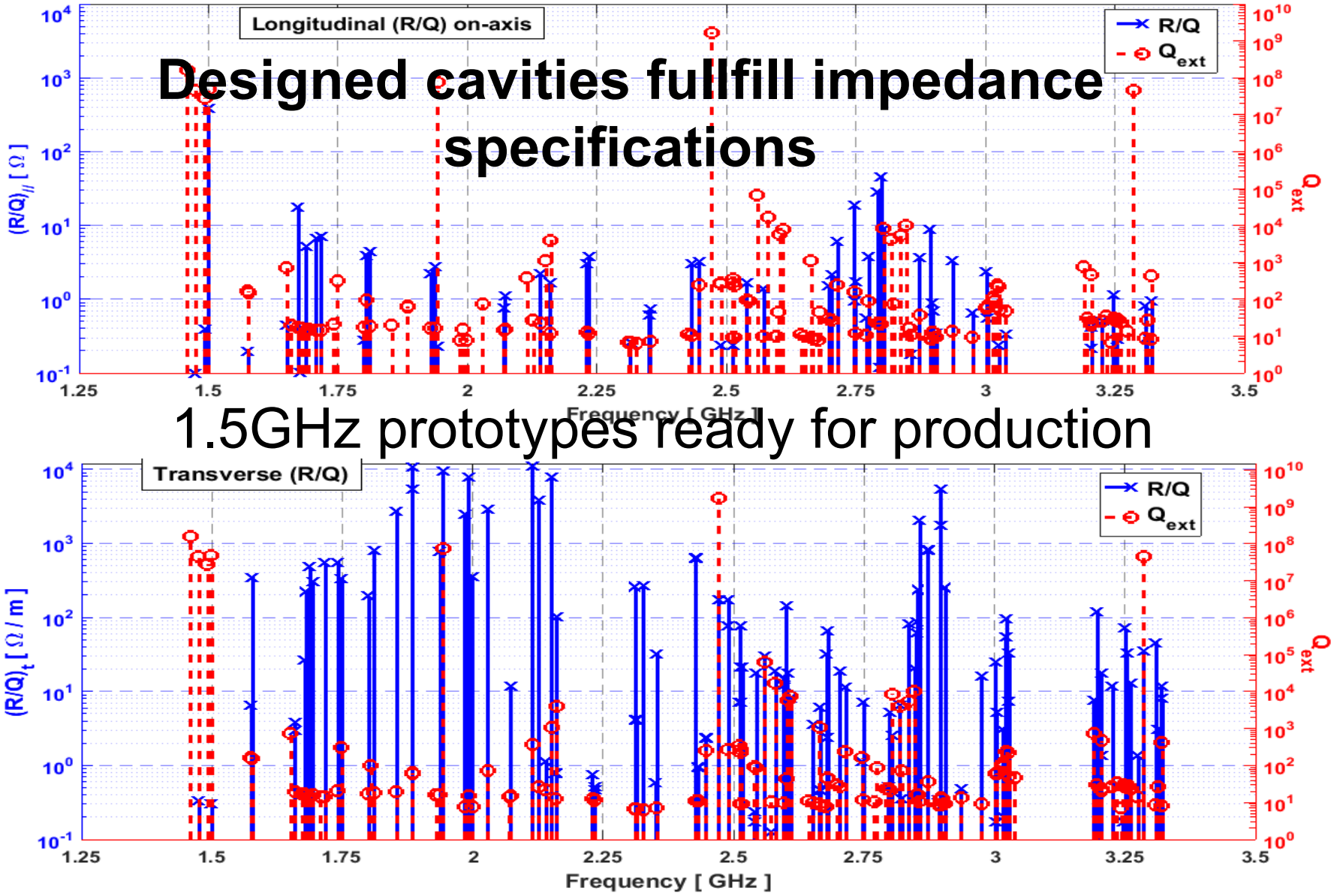
Module voltage drops from 37.2 MV to 29.71 MV (20%)

Expected short bunches increase from 1.7 ps to 1.87 (10%)

Eigenmodes of VSR 1.5GHz 4-cell Cavity



Eigenmodes of VSR 1.5GHz 4-cell Cavity



Designed cavities fullfill impedance specifications

1.5GHz prototypes ready for production

Resonant Mode Extraction from Wakes : Pole-Fitting Technique

Prony-Pisarenko Fit — **Circuit definition**

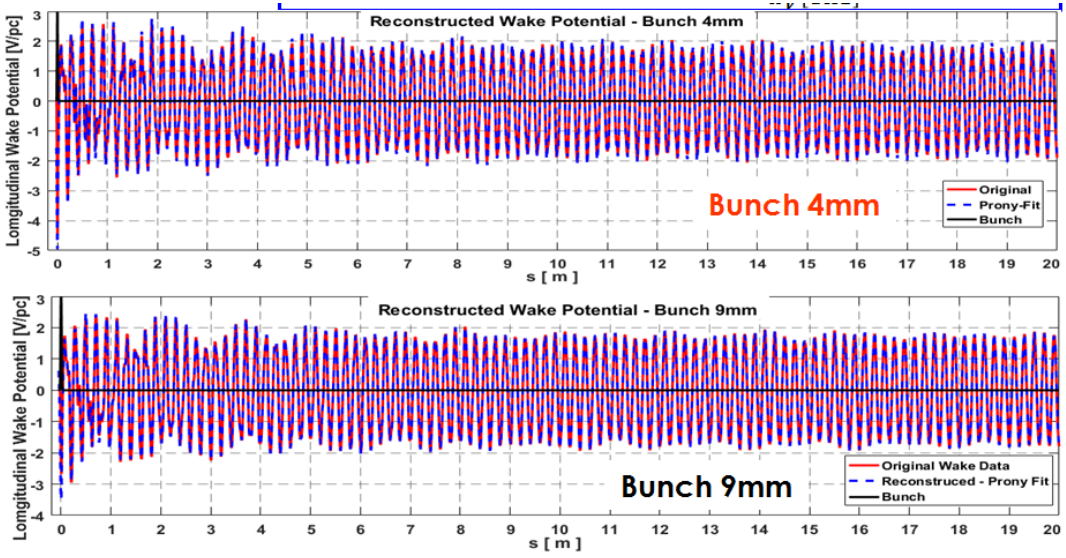
N	Freq. [GHz]	R / Q [Ω]	Q_{loaded}	0.5 · R/Q · Q_{loaded} [Ω]
1	1.499 1.499	386.46 420.44	8.97e+4 1.25e+4	1.73e+7 2.64e+6
2	1.649 1.657	17.877 26.45	4.46e+2 1.69e+2	3.99e+3 2.24e+3
3	2.713 2.709	7.05 7.047	3.4e+2 4.61e+2	1.2e+3 1.62e+3
4	2.794 2.793	130.0 143.02	1.0e+2 9.85e+1	6.5e+3 7.04e+3
5	4.326 4.330	7.535 10.65	1.34e+3 5.5e+2	5.05e+3 2.92e+3
6	4.385 4.384	21.19 25.39	2.87e+2 2.65e+2	3.04e+3 3.36e+3
7	5.941 5.944	3.939 5.233	2.76e+2 2.42e+2	5.43e+2 6.32e+2
8	6.280 6.278	9.88 10.12	2.3e+3 2.32e+3	1.13e+4 1.17e+4
9	6.324 6.339	3.713 8.960	3.79e+2 7.43e+1	7.04e+2 3.33e+2
10	6.836 6.863	3.815 4.128	4.04e+2 3.79e+2	7.72e+2 7.82e+29

Impedance budget for cavities recalculated

Wake Potential Long Range

$$W(s) = \sum_{\nu} 2\,K_\nu \cos\left(\frac{\omega_\nu}{c}s\right) e^{-\alpha_\nu s}$$

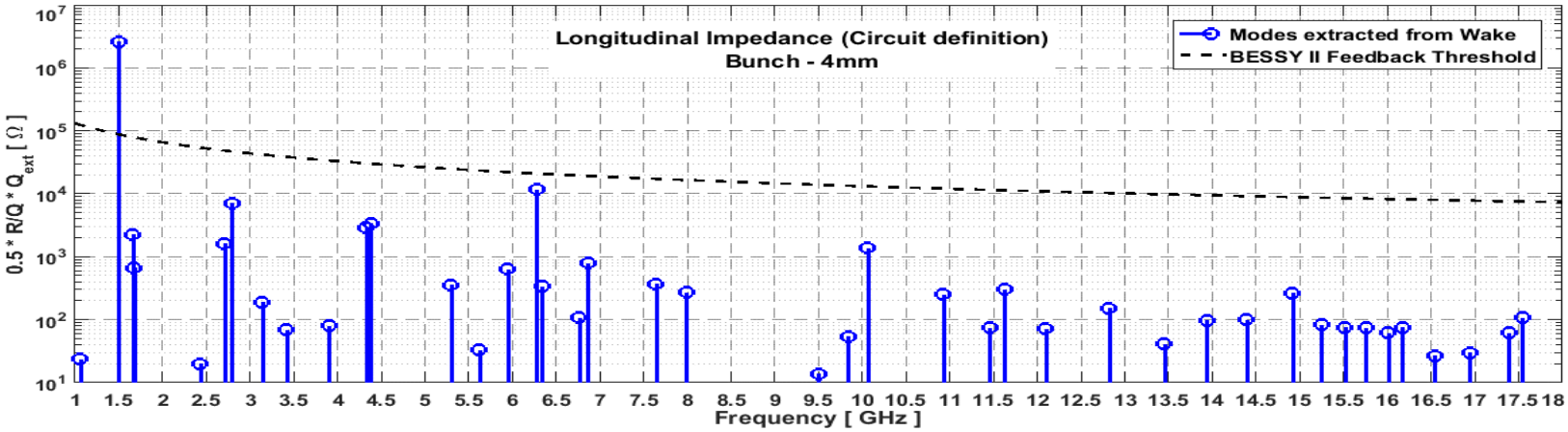
$$\alpha_\nu = \omega_\nu / (c\ 2\ Q_{loaded}) \ , \ R/Q[\Omega] = \frac{4\,K_\nu\,[V/pC]}{\omega_\nu\,[GHz]}\,10^3 \quad (Linac)$$

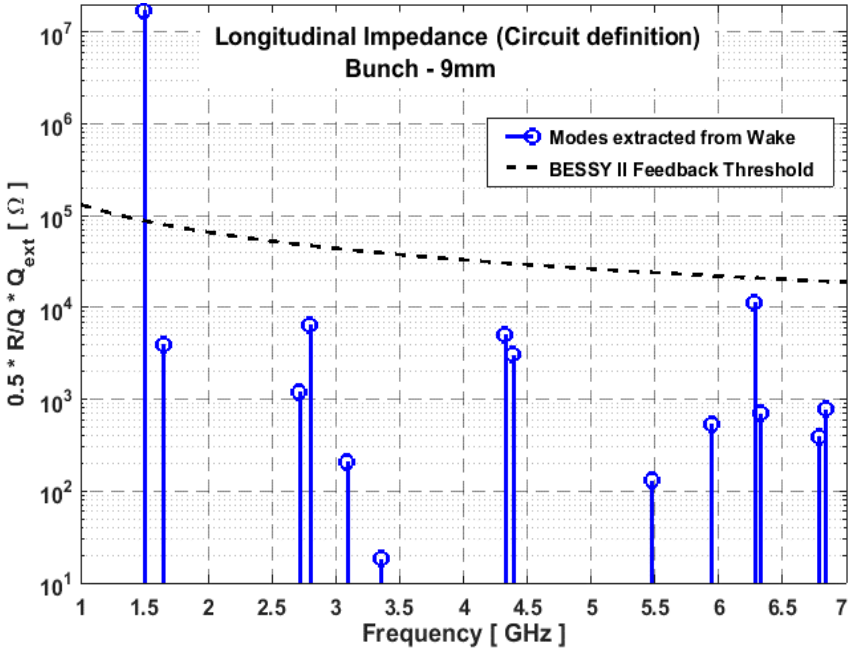


Courtesy of A. Tsakanian

- **Pole-fitting gives quantitative estimate on the resonances of the system (Mode type undefined).**
- **For the fundamental mode Qext=5e7 should be used, because the wake length 20m is too short to extract such high Qext.**
- **The search for best fit is done manually, it depends on frequency range & filter settings in the algorithm.**

Resonant Mode Extraction from Wakes : Pole-Fitting Technique



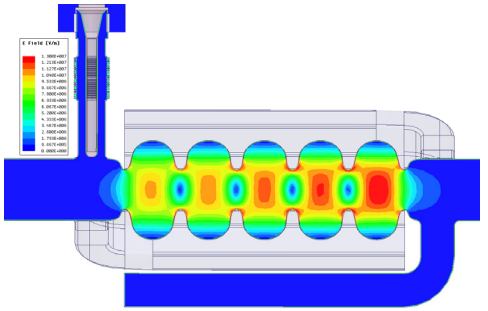


- Pole fitting is a fast estimate of the resonances in the system (low resolution).
- Shorter bunch calculations (4mm) extend to higher frequency ranges. Computing demands are higher. Less resolution accuracy
- Longer bunch calculations (9mm) offer higher accuracy in the low frequency range.

BESSY VSR Cold-String: Fund. Power Coupler

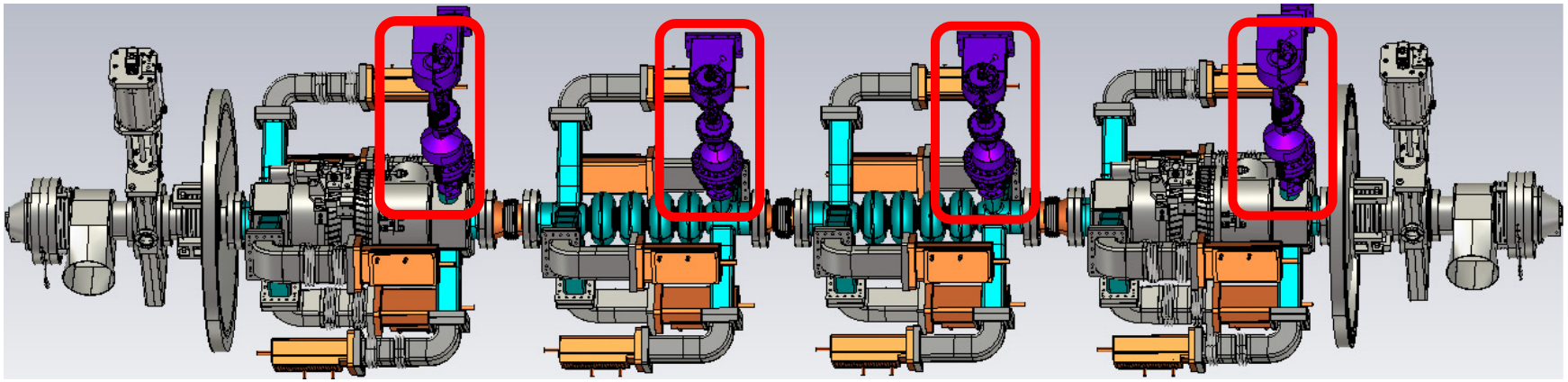
13 KW (Peak) / 1.5 KW (av.) FPCs @ 1.5 GHz

RF Studies, Thermal Studies, Mech. Studies …

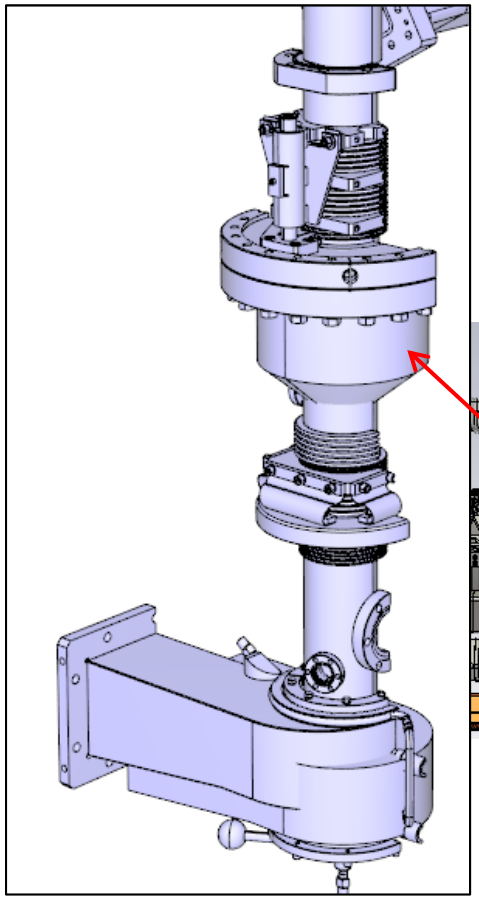


High Qext>1e7 with low power < 10kW (no beam loading)
Adjustable coupling due for parking and impedance control

Design based on Cornell Injector coupler

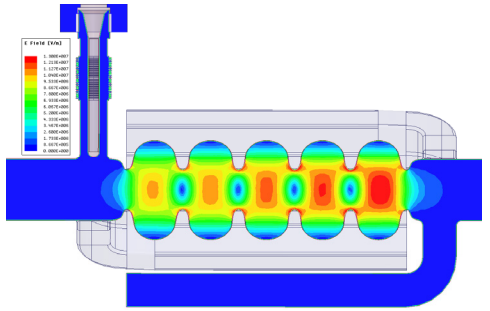


BESSY VSR Cold-String: Fund. Power Coupler



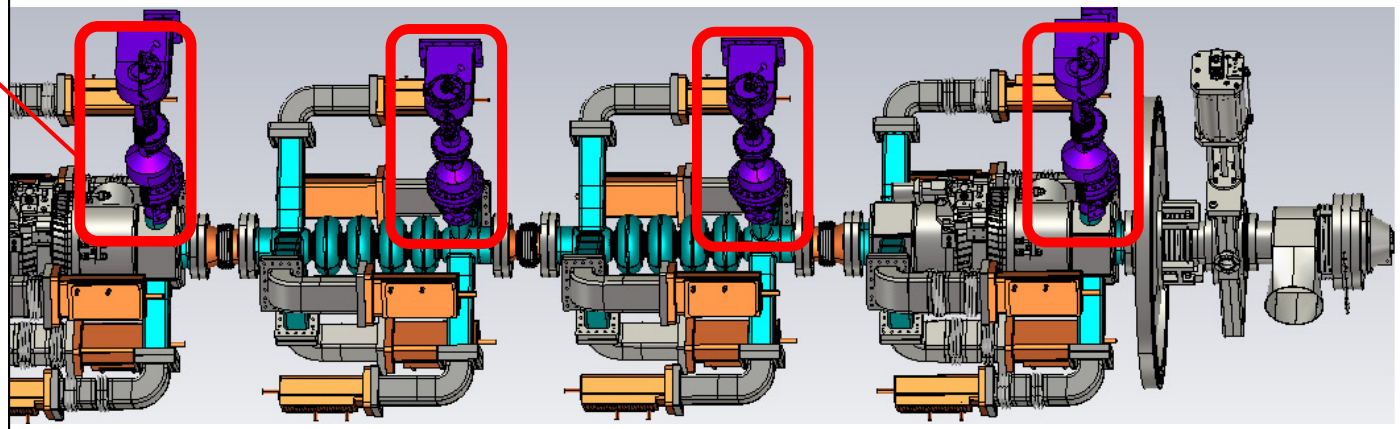
13 KW (Peak) / 1.5 KW (av.) FPCs @ 1.5 GHz

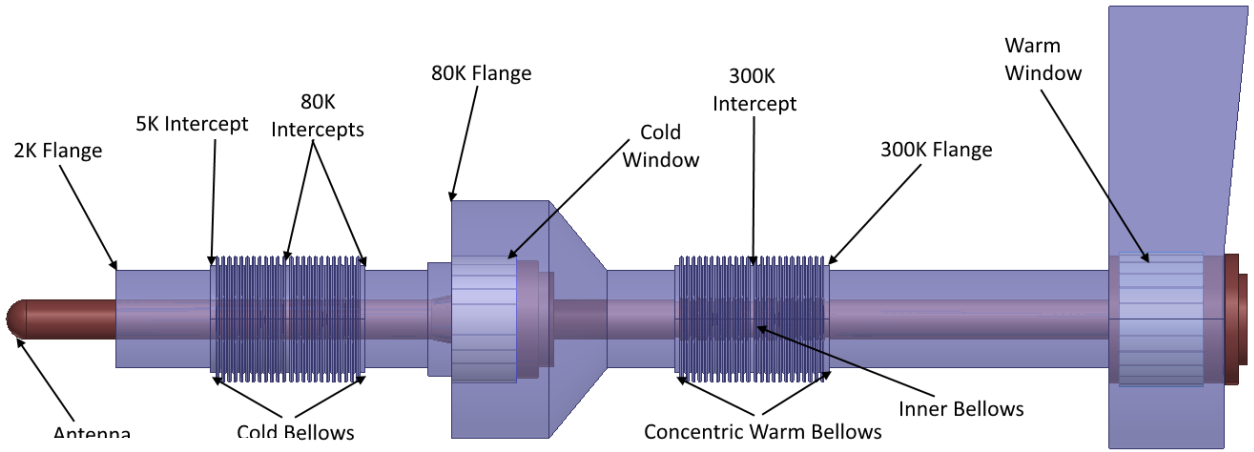
RF Studies, Thermal Studies, Mech. Studies …



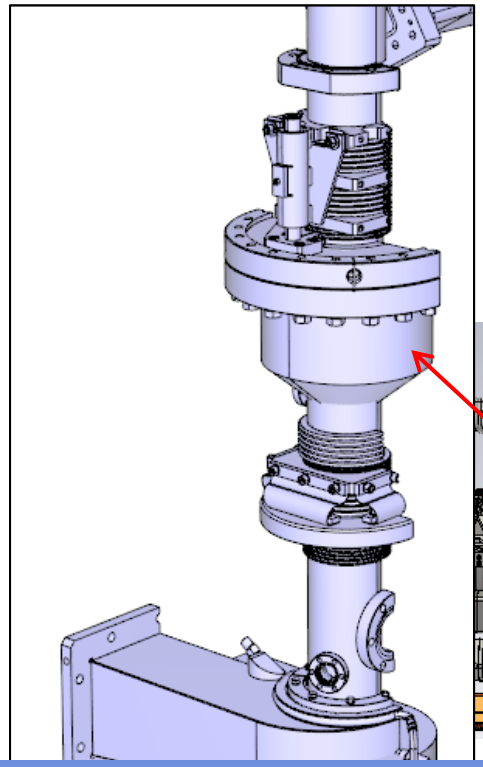
High Qext>1e7 with low power < 10kW (no beam loading)
Adjustable coupling due for parking and impedance control

Design based on Cornell Injector coupler



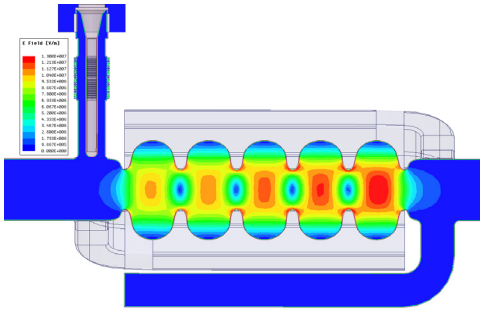


BESSY VSR Cold-String: Fund. Power Coupler



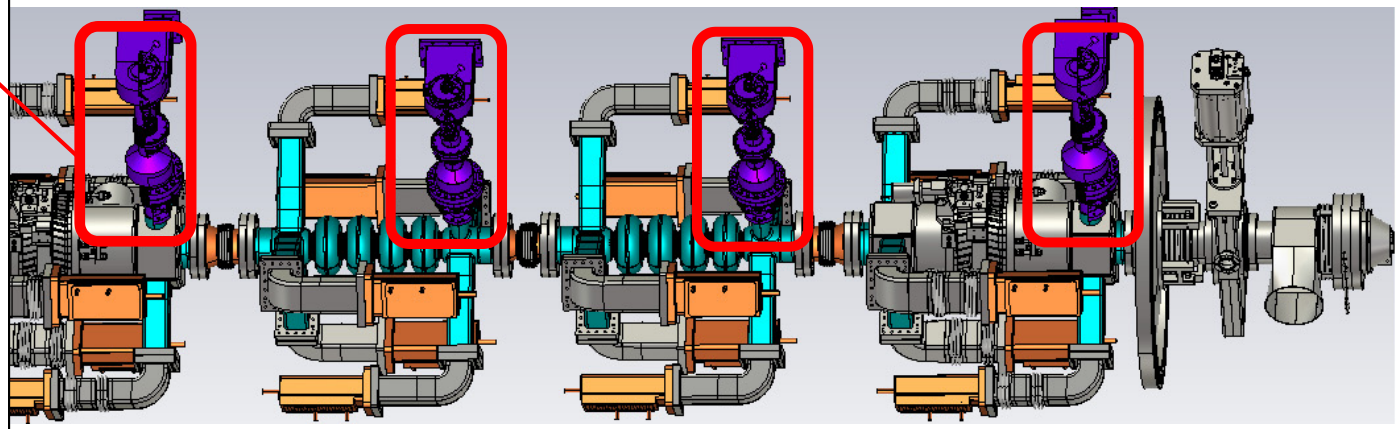
13 KW (Peak) / 1.5 KW (av.) FPCs @ 1.5 GHz

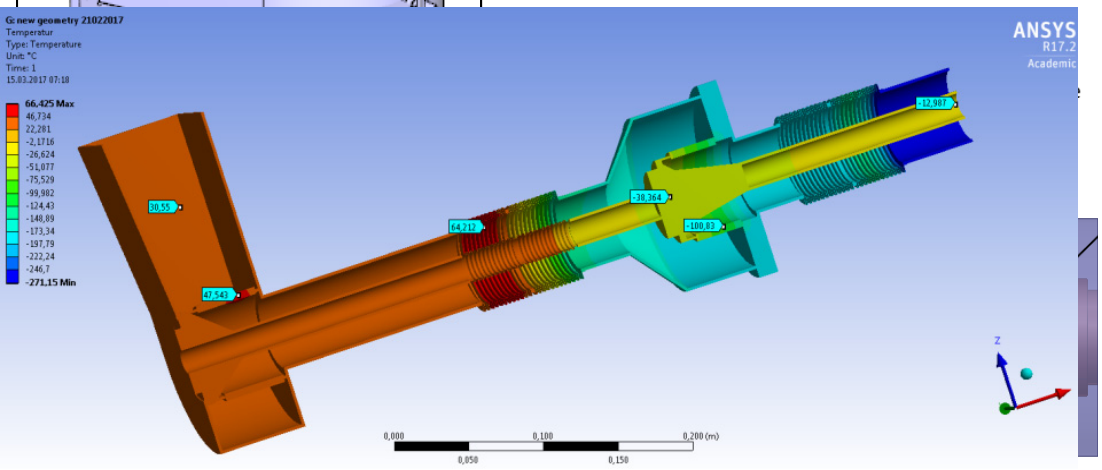
RF Studies, Thermal Studies, Mech. Studies …



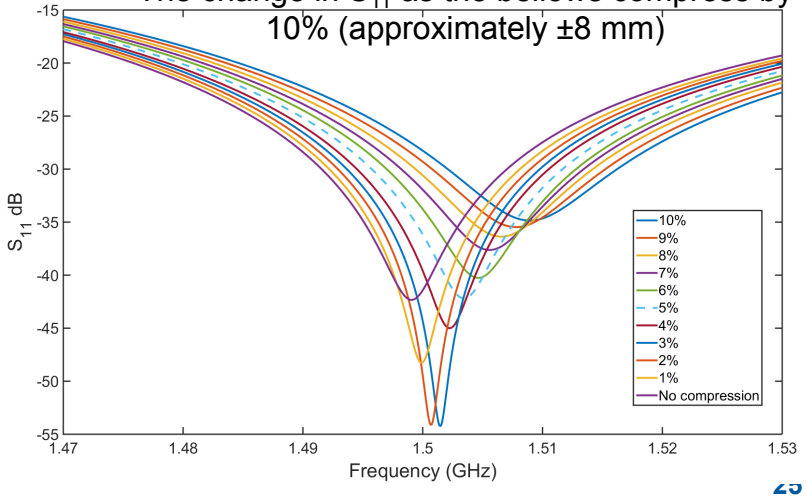
High Qext>1e7 with low power < 10kW (no beam loading)
Adjustable coupling due for parking and impedance control

Design based on Cornell Injector coupler



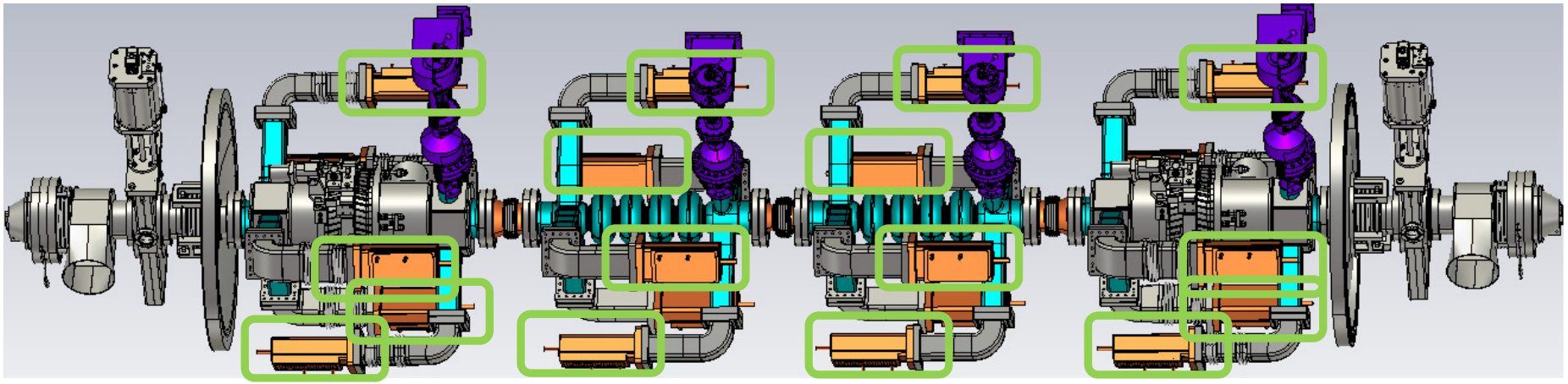


The change in S_{11} as the bellows compress by 10% (approximately ±8 mm)



BESSY VSR Cold-String: HOM Loads

Water-cooled HOM loads (room temperature 300K)
Specifications: 460W per load
Design, fabrication and tests @ JLab

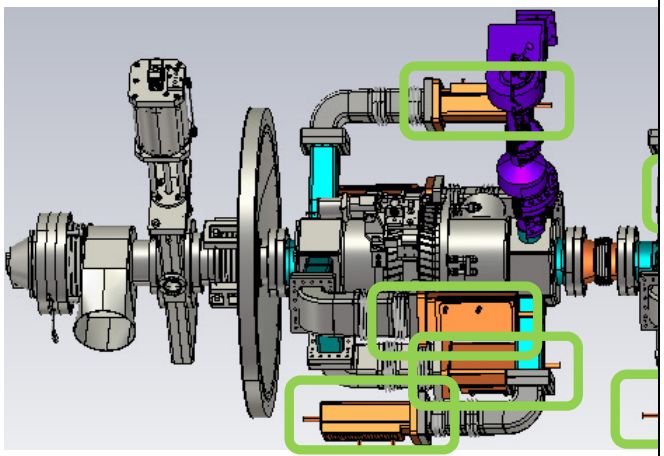


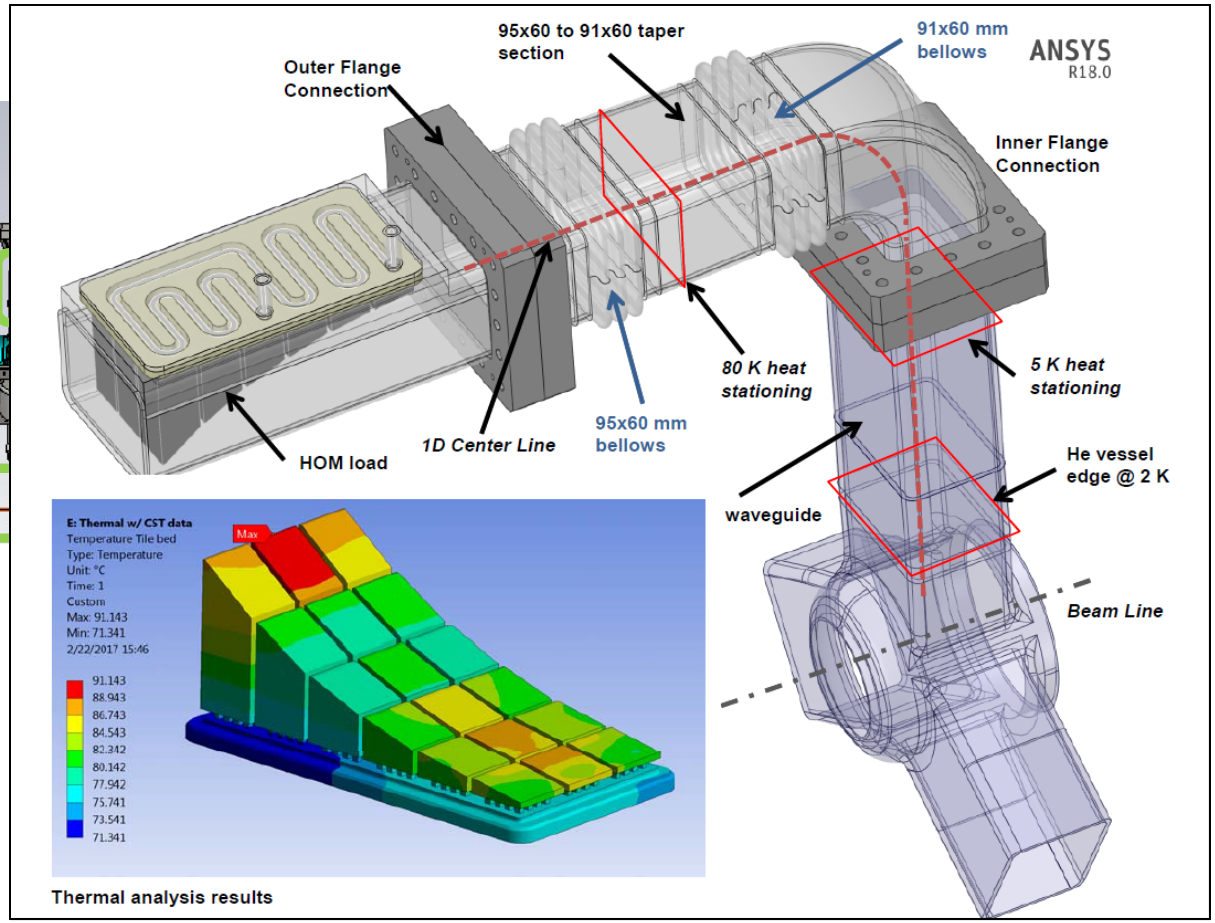
Courtesy of Jefferson Lab

BESSY VSR Cold-String: HOM Loads

Water-cooled HOM loads (room temperature 300K)
Specifications: 460W per load
Design, fabrication and tests @ JLab

Jefferson Lab



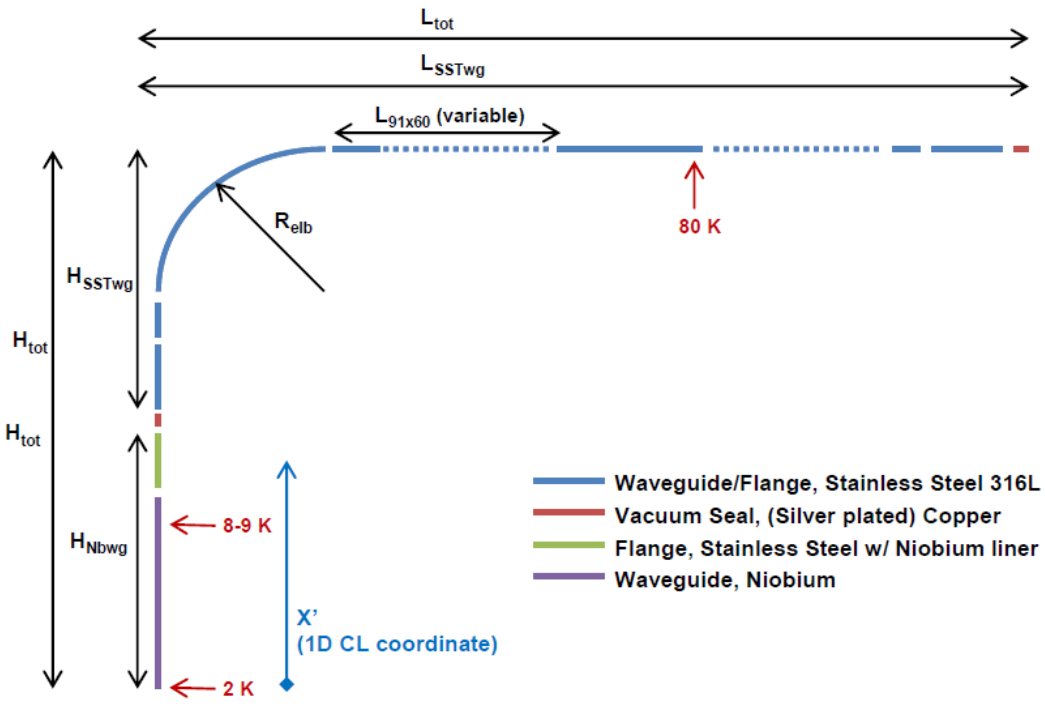


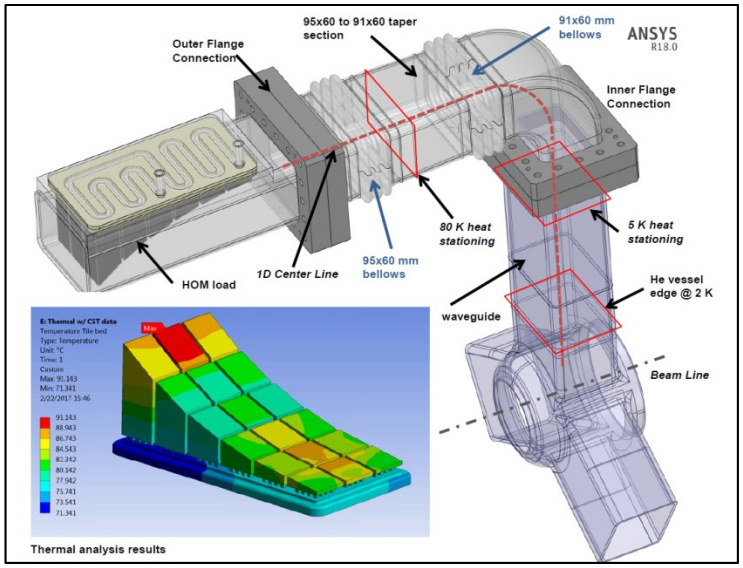
Courtesy of Jefferson Lab

VATseal gasket: Off the shelf, allow re-openning (vertical testing)

BESSY VSR Cold-String: HOM Loads

Water-cooled HOM loads (room temperature 300K)
Specifications: 460W per load
Design, fabrication and tests @ JLab





Courtesy of Jefferson Lab

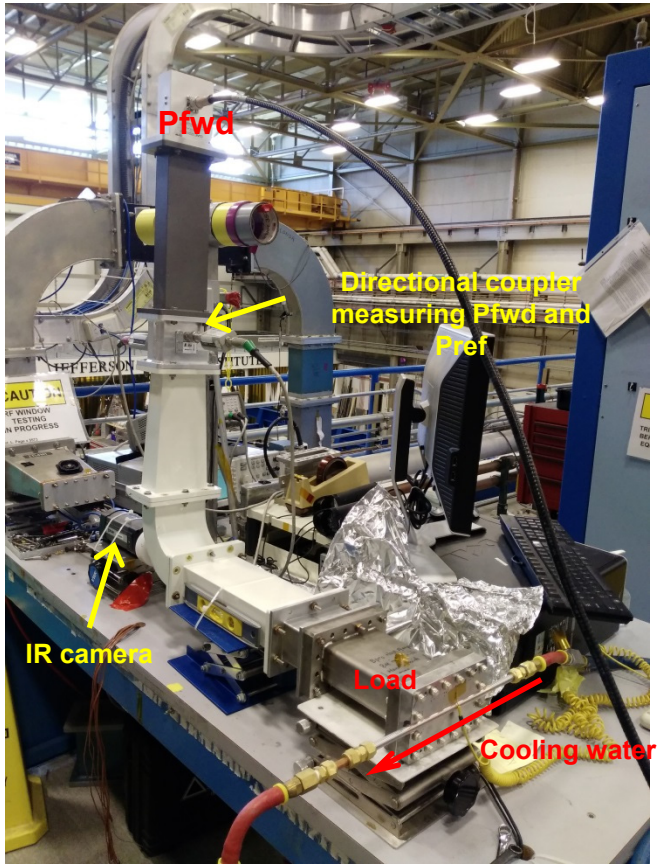
- 1D+3D thermal analysis of the 450 W HOM waveguide developed by JLAB
- Optimum position of thermal intercepts founded
- Heat loads calculated (2K,5K,80K)
- WG section must be copper coated SS
- Fabrication of the prototypes starting (releasing drawings)

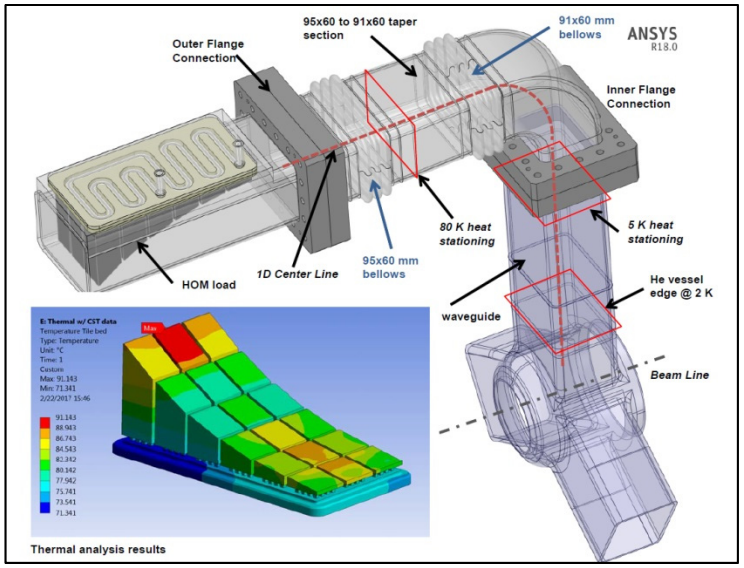
BESSY VSR Cold-String: HOM Loads

Water-cooled HOM loads (room temperature 300K)
Specifications: 460W per load
Design, fabrication and tests @ JLab

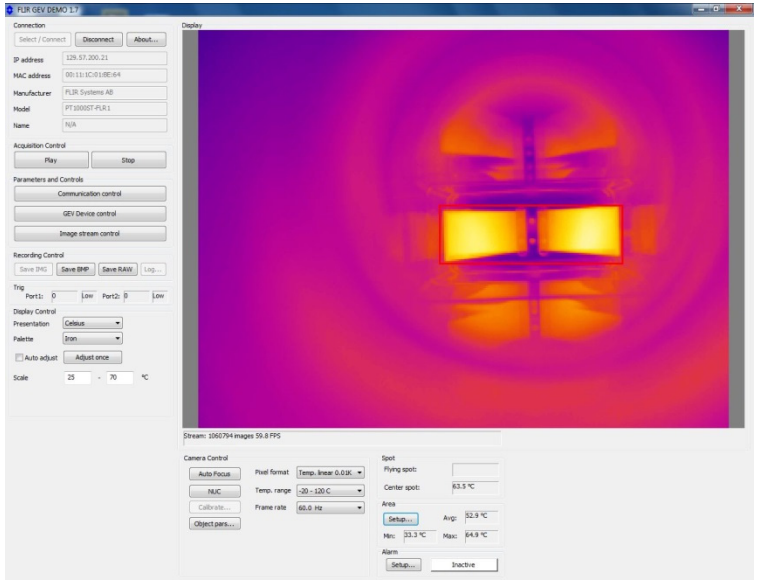
Sinergy with bERLinpro

HOM load tests at Jlab





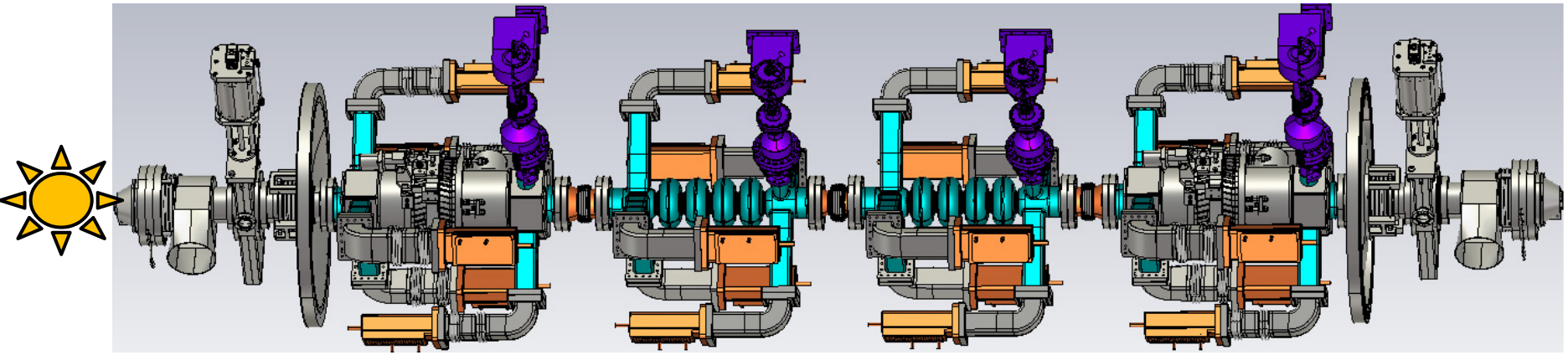
Courtesy of Jefferson Lab



BESSY VSR Cold-String: Just the beginning

Synchrotron Light

89 W !!!

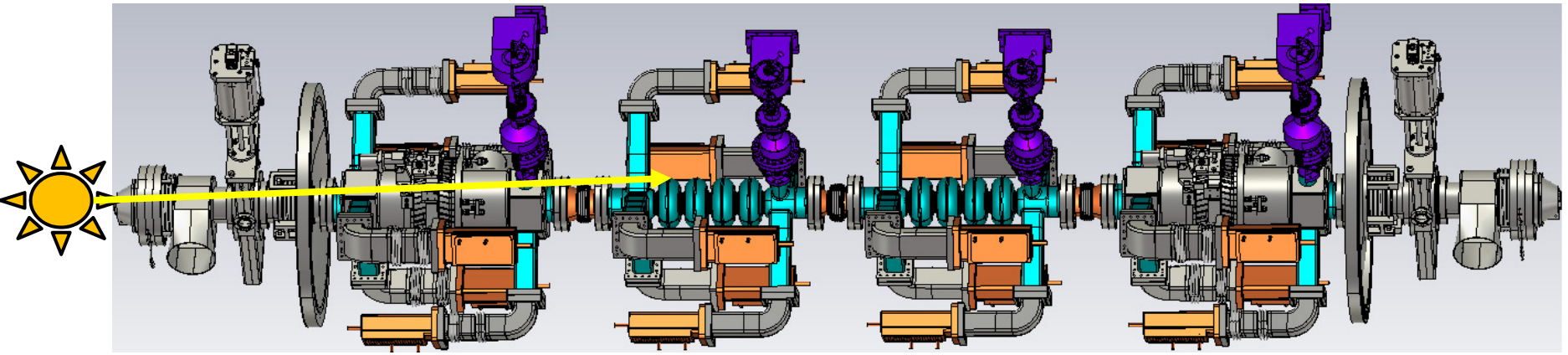


Courtesy of H.W.Glock

BESSY VSR Cold-String: Just the beginning

Synchrotron Light

89 W !!!



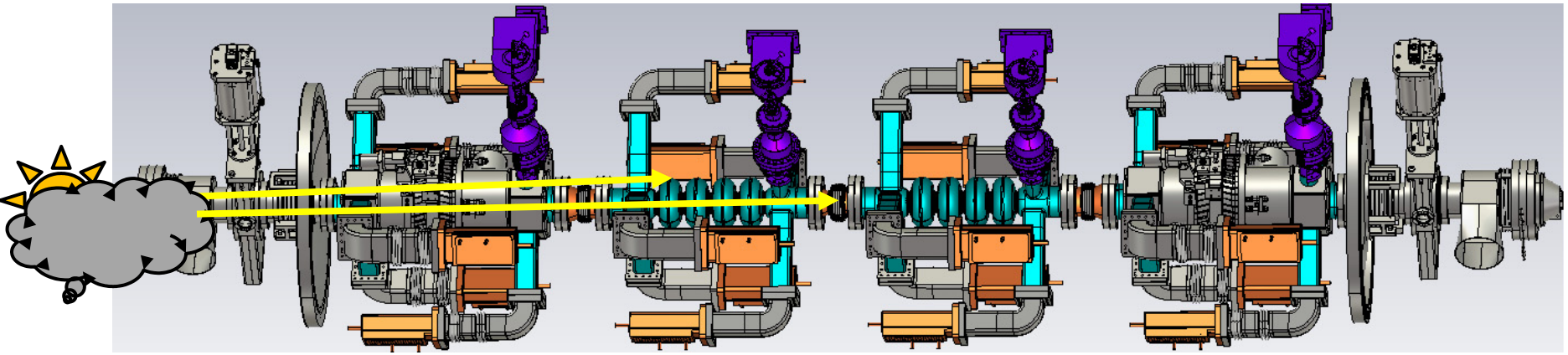
Courtesy of H.W.Glock

- Impact points over cavity surface (iris 2nd cavity)

BESSY VSR Cold-String: Just the beginning

Synchrotron Light

89 W !!!

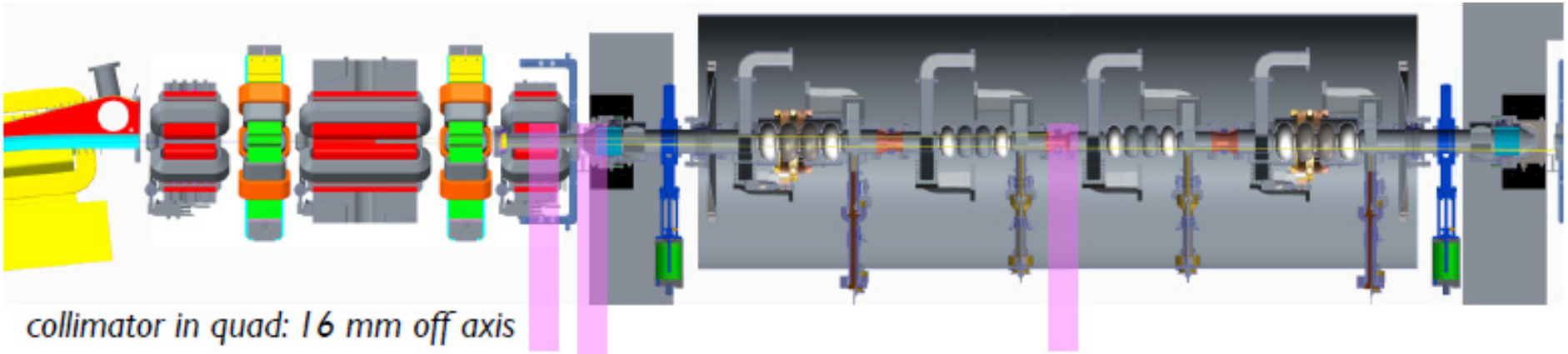


Courtesy of H.W.Glock

- Impact points over cavity surface (iris 2nd cavity)

- Collimator takes part of the inciden power
- Remaining beam is hitting the central bellow section (11W) or leaving the module

BESSY VSR Cold-String: Just the beginning



collimator in quad: 16 mm off axis

moveable collimator in taper:

≤ 16 mm off axis

collimating shielded bellow:

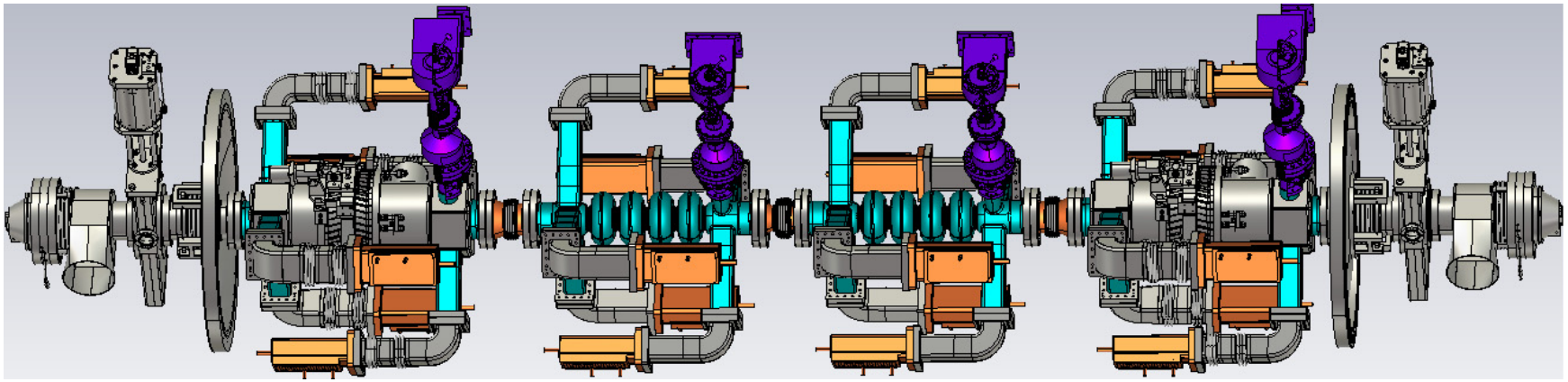
26 mm radius

P_{rad} @ ...	... collimator in quadrupole	... on moveable collimator	... collimating bellow	... leaving cold module
moveable not activated	63 W	0 W	11 W	15.3 W

BESSY VSR Cold-String: Just the beginning

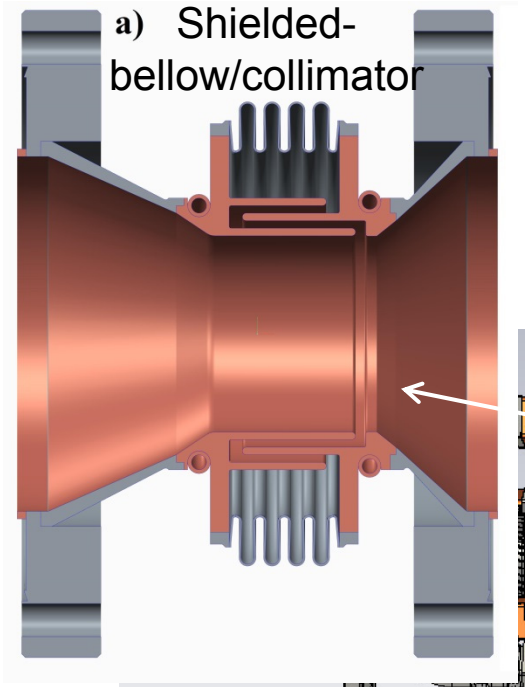
Synchrotron Light

89 W !!!



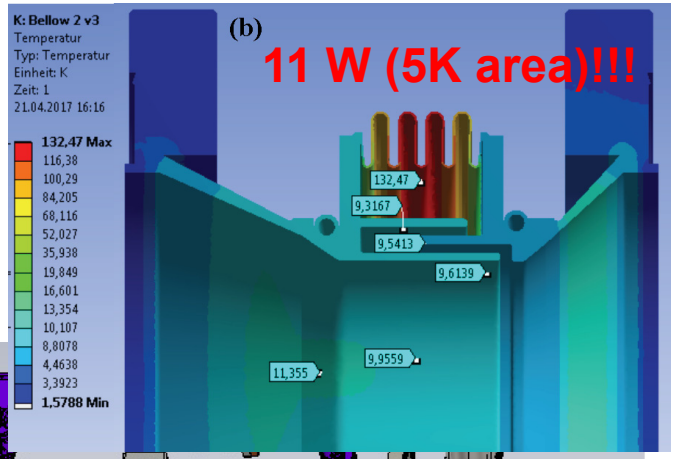
Courtesy of H.W.Glock

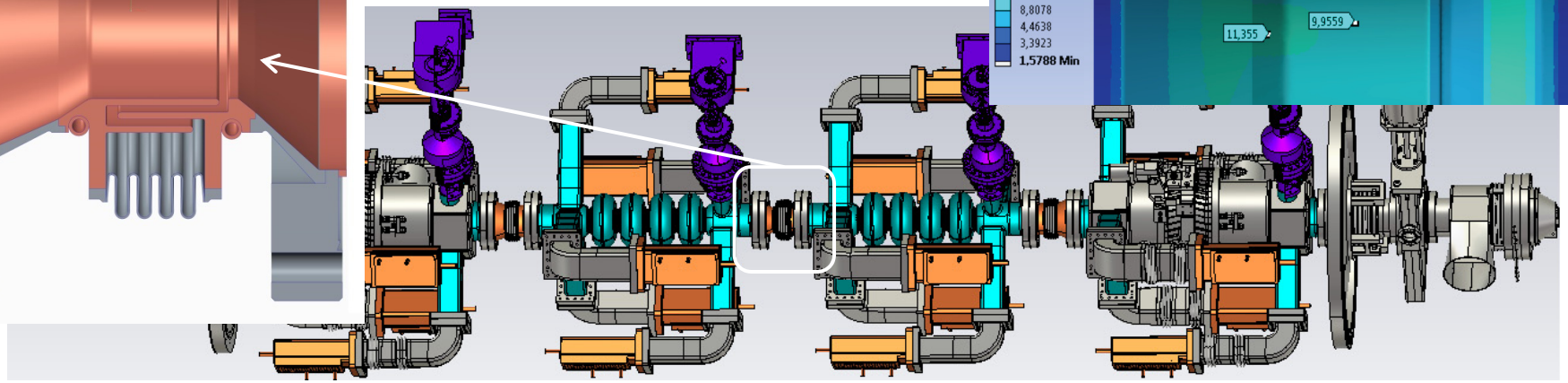
BESSY VSR Cold-String: Just the beginning



Synchrotron Light

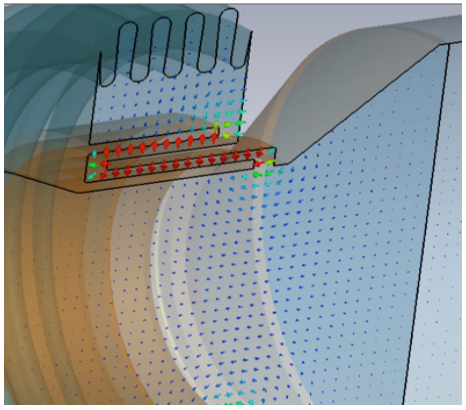
89 W !!!



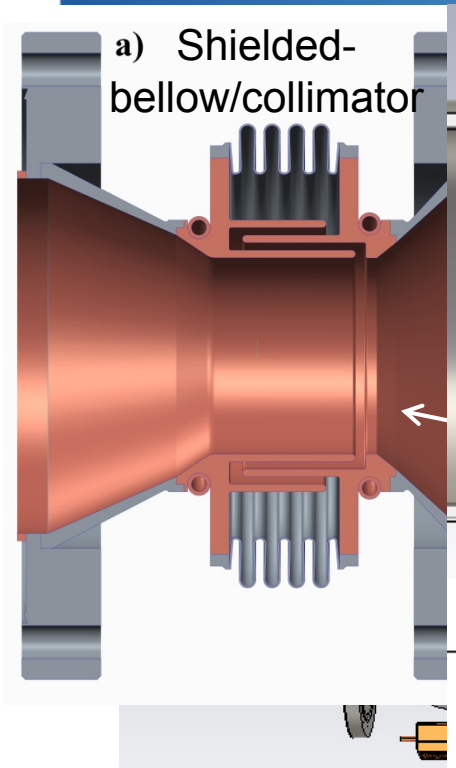


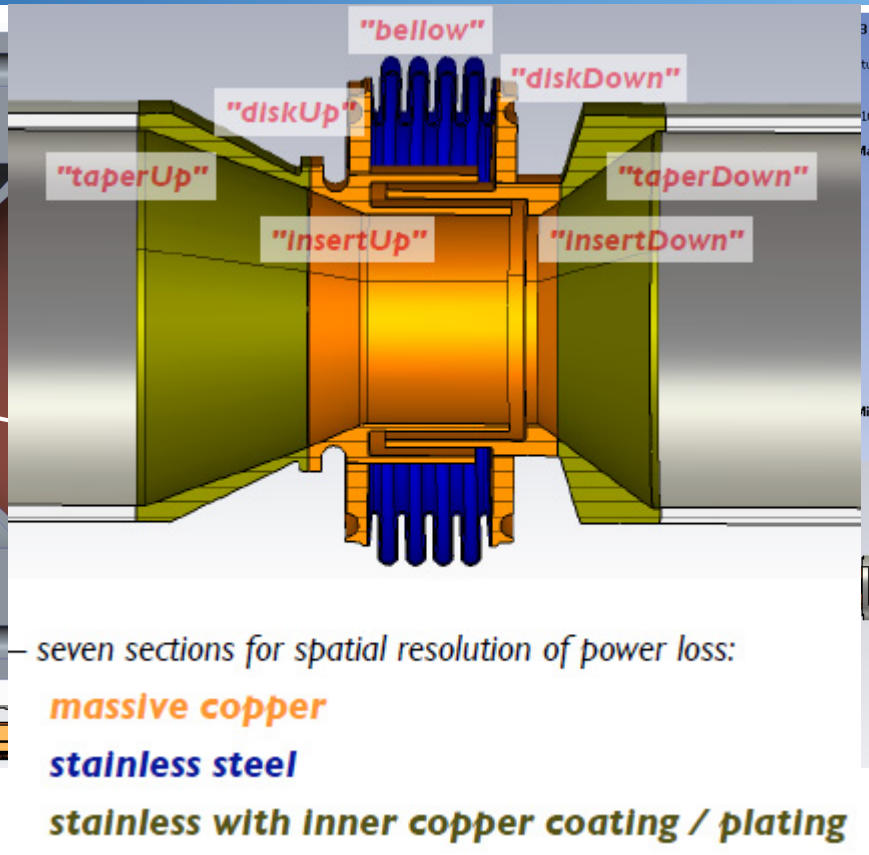
Courtesy of H.W.Glock

- Leaked power fundamental mode cavities (shielding)
- Incident light from synchrotron radiation (upstream magnet section)
- Cover for long. Lateral displacements (.5mm, mech.restriction)
- Avoid heat load transfer to 2K enviroment
- Avoid self resonant modes
- Avoid impedance growth (Wakefields & impedance calculated)



BESSY VSR Cold-String: Just the beginning



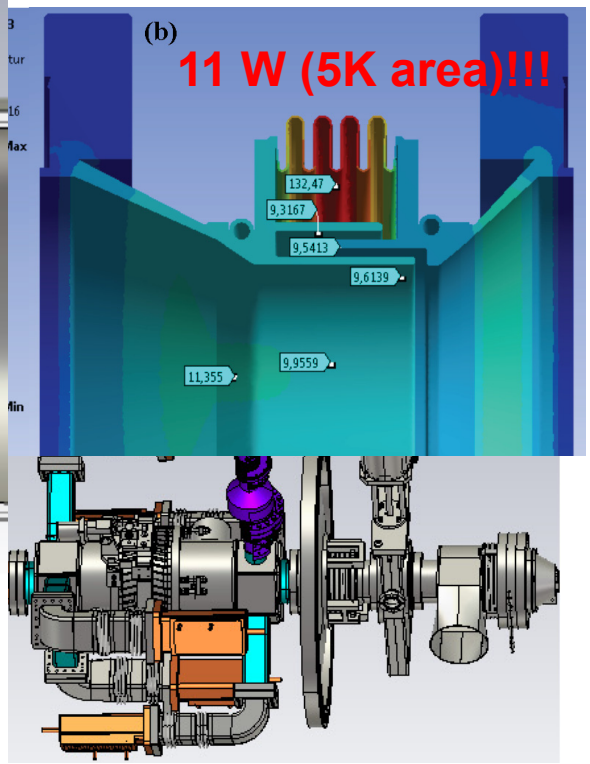


– seven sections for spatial resolution of power loss:

massive copper

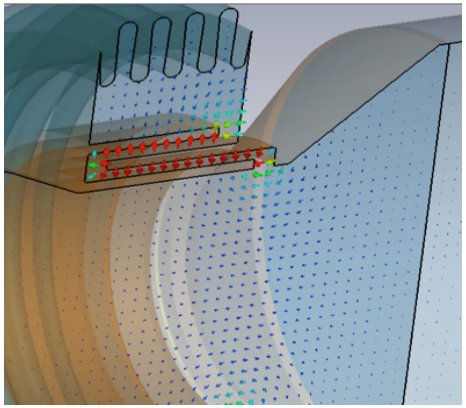
stainless steel

stainless with inner copper coating / plating

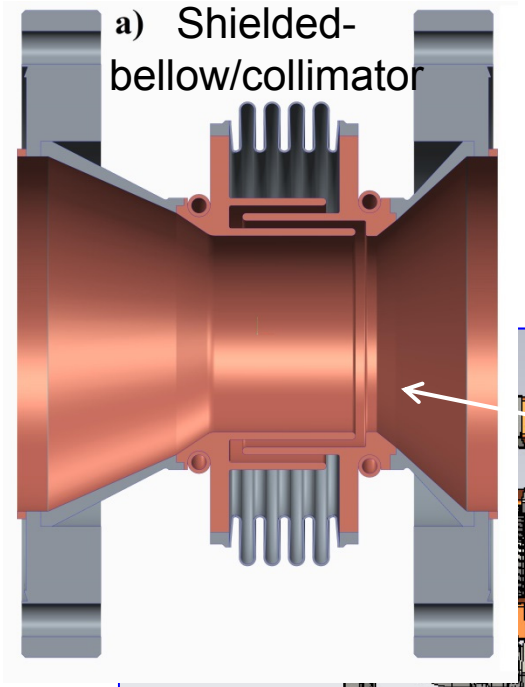


Courtesy of H.W.Glock

- Leaked power fundamental mode cavities (shielding)
- Incident light from synchrotron radiation (upstream magnet section)
- Cover for long. Lateral displacements (.5mm, mech.restriction)
- Avoid heat load transfer to 2K enviroment
- Avoid self resonant modes
- Avoid impedance growth (Wakefields & impedance calculated)

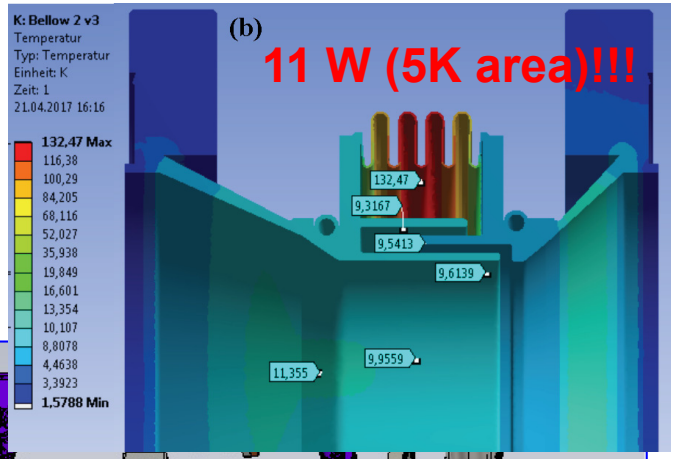


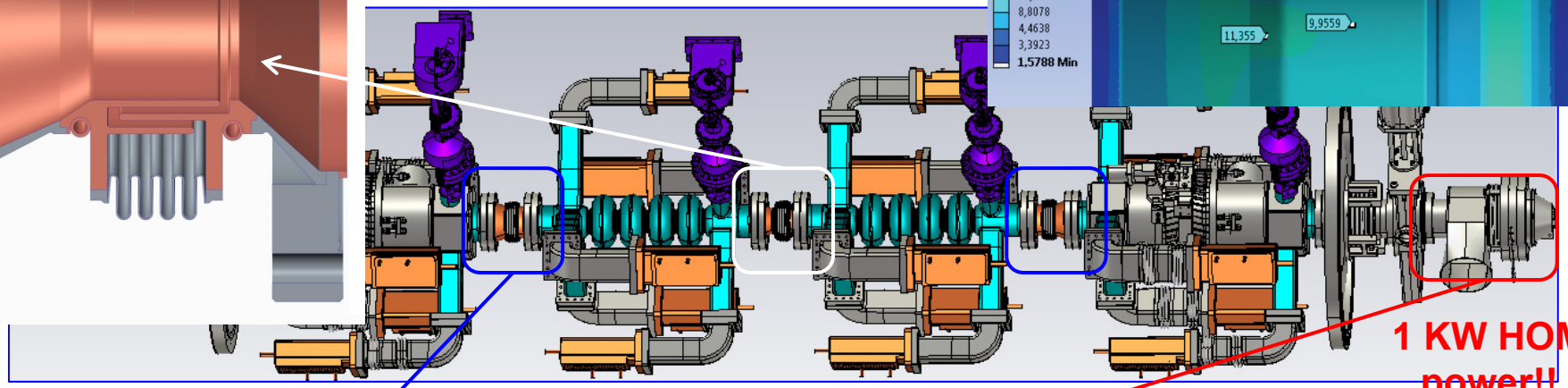
BESSY VSR Cold-String: Just the beginning



Synchrotron Light

89 W !!!

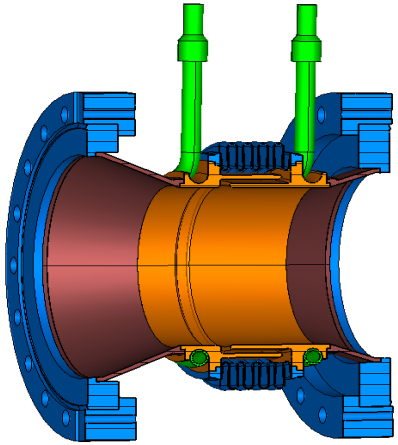




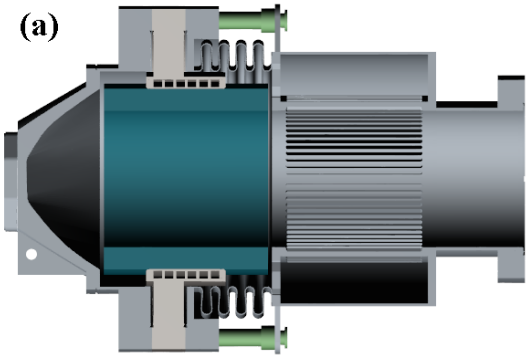
1 KW HOM power!!

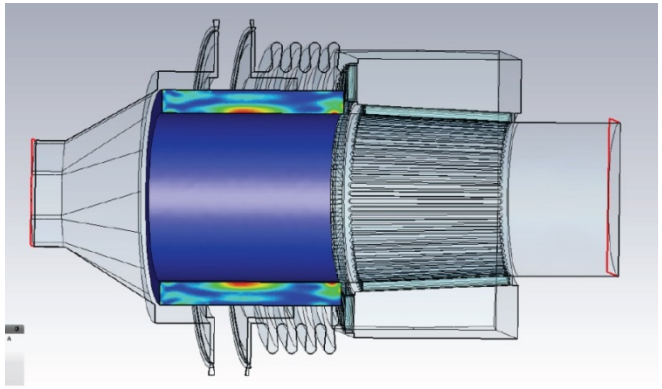
Courtesy of H.W.Glock

Shielded-bellow



Warm BP absorber



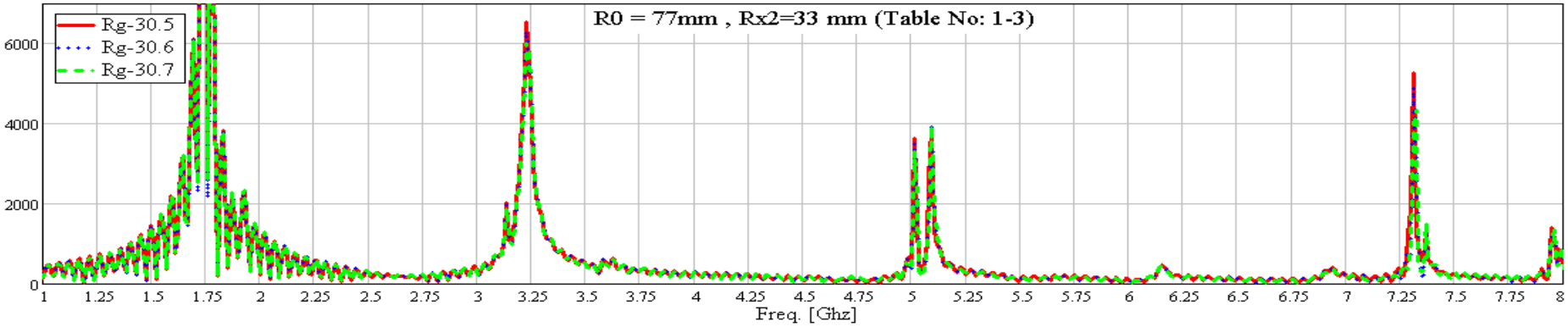


Based on SiC Coorstek SC-95 design developed by Argonne

BESSY VSR Cold-String: Full module analysis

- Full module wakefield studies have been performed
- Concatenation studies in progress with Rostock University (SSC)
- Different orientations analized (available space in the ring)
- Coupler Kicks are under study

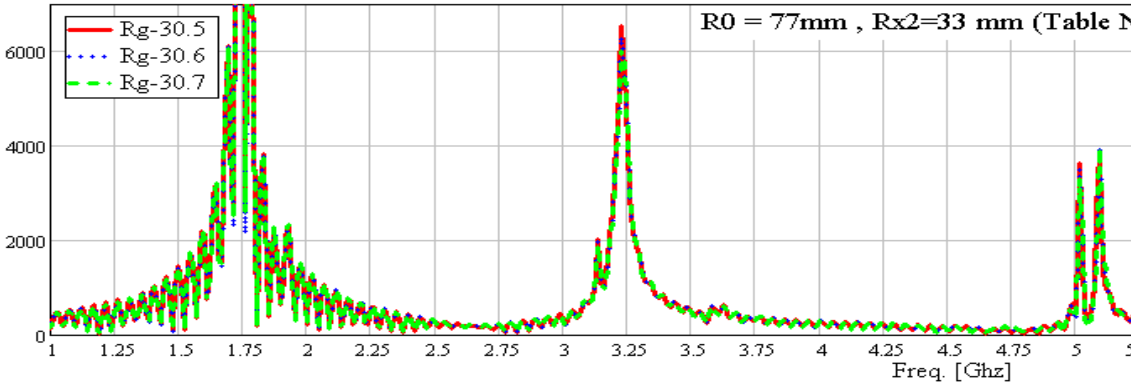
Impedance from Wake run (with Symmetry): Bunch 9mm on-axis, length-20m

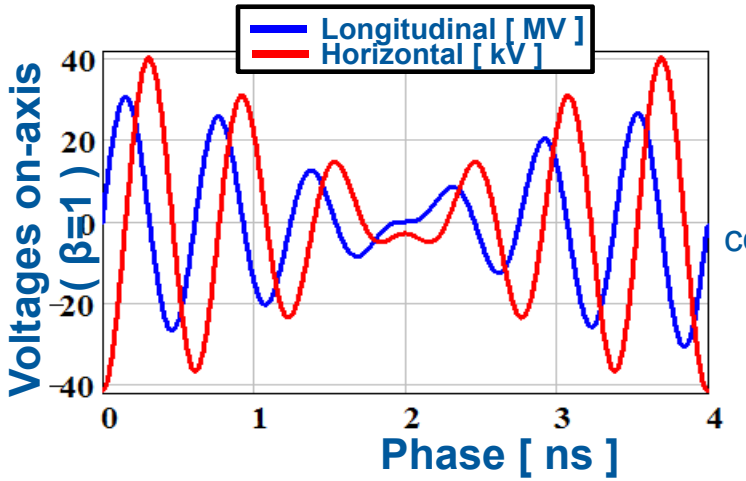


BESSY VSR Cold-String: Full module analysis

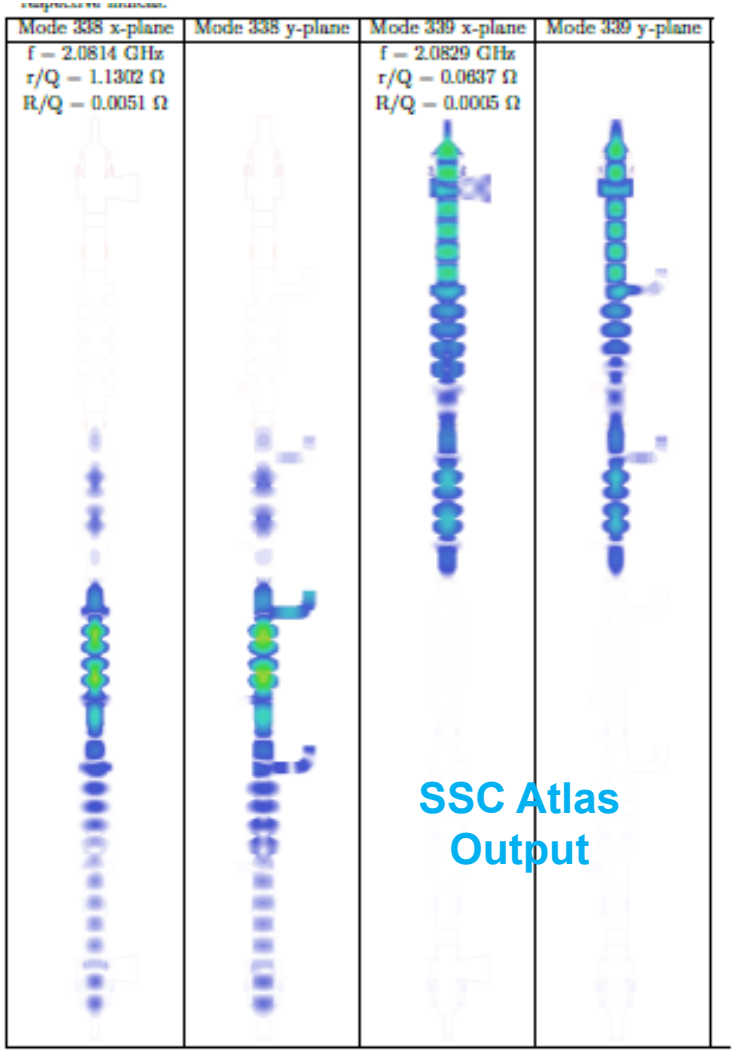
- Full module wakefield studies have been performed
- Concatenation studies in progress with Rostock University (SSC)
- Different orientations analized (available space in the ring)
- Coupler Kicks are under study

Impedance from Wake run (with Symmetry): Bunch 9mm σ



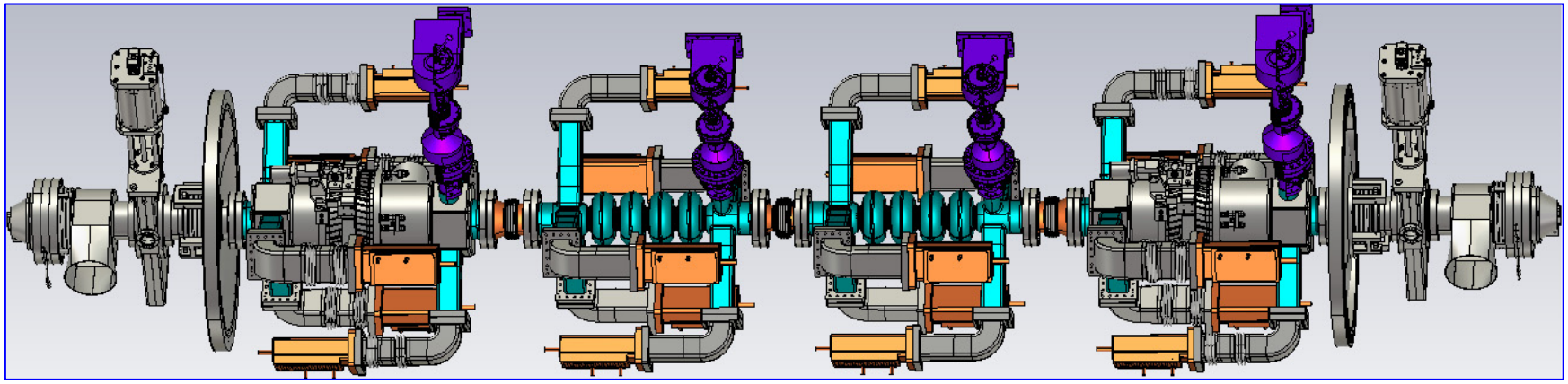


Assymetrical coupler distribution



BESSY VSR Cold-String: Just the beginning

Impedance bugted calculated for the whole string shows impedance under threshold levels

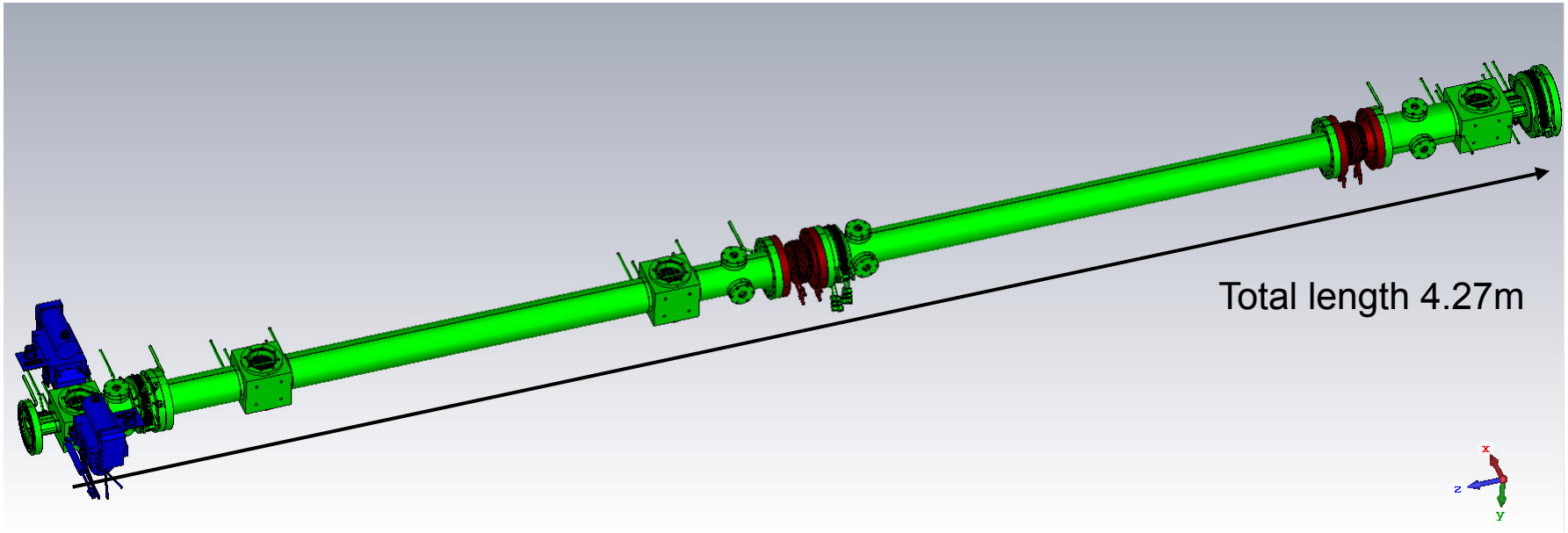


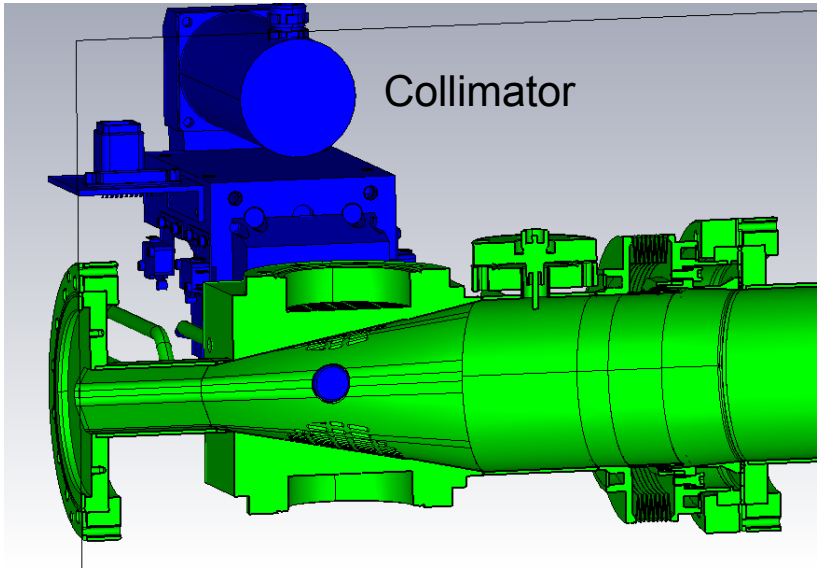
BESSY VSR Cold-String: Just the beginning

Impedance bugted calculated for the whole string shows impedance under threshold levels

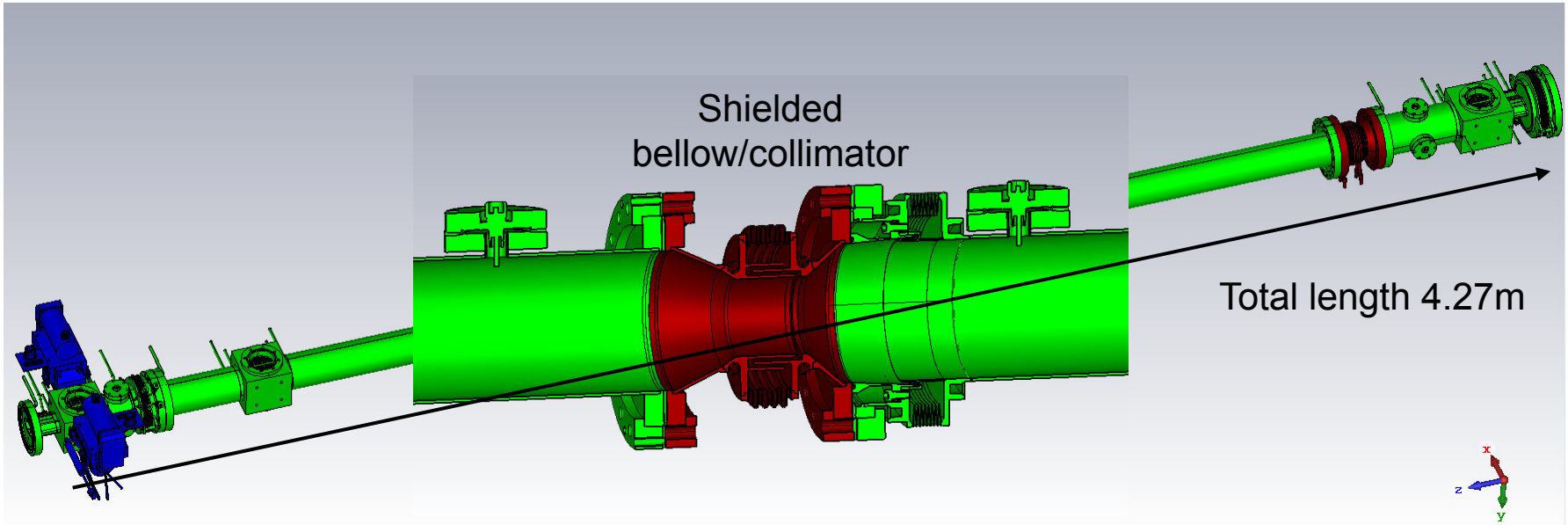
Tests stand for components to be run in BESSY II (shutdown summer 2018)

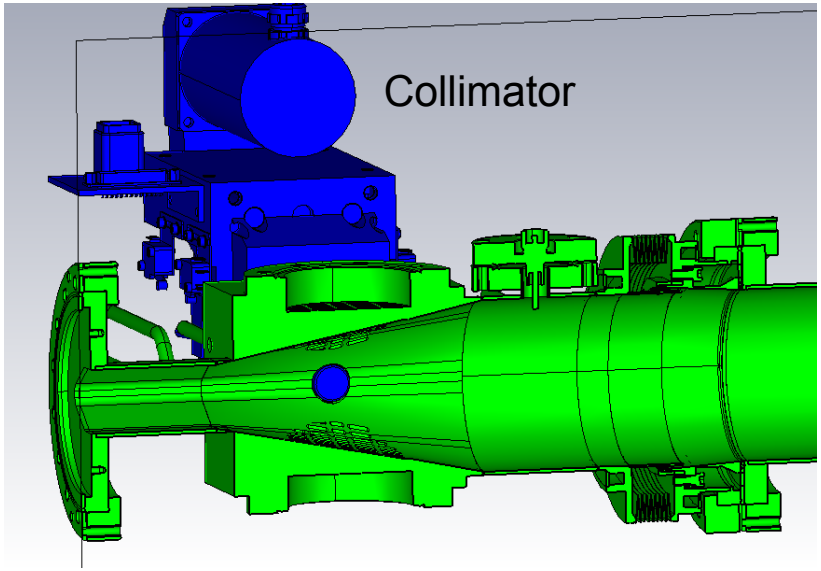
BESSY VSR Components tests

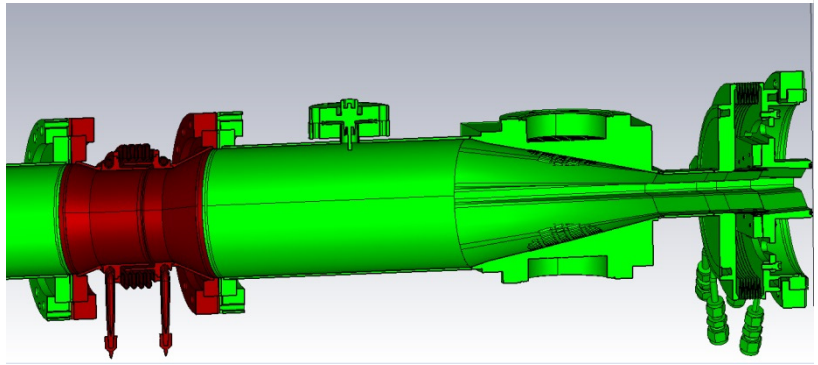




BESSY VSR Components tests

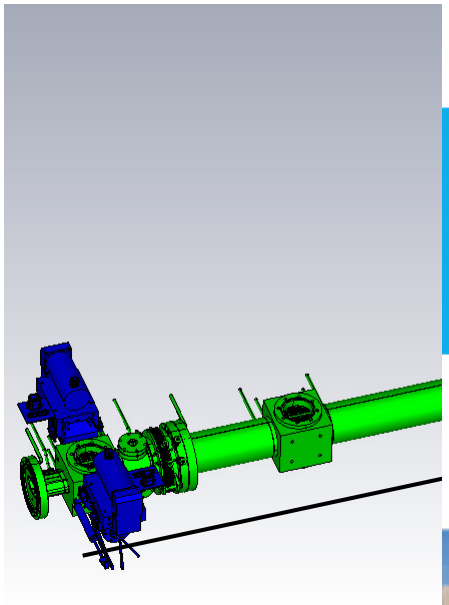


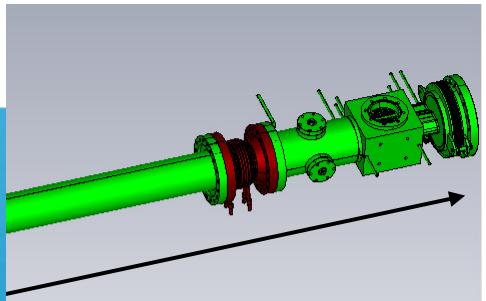




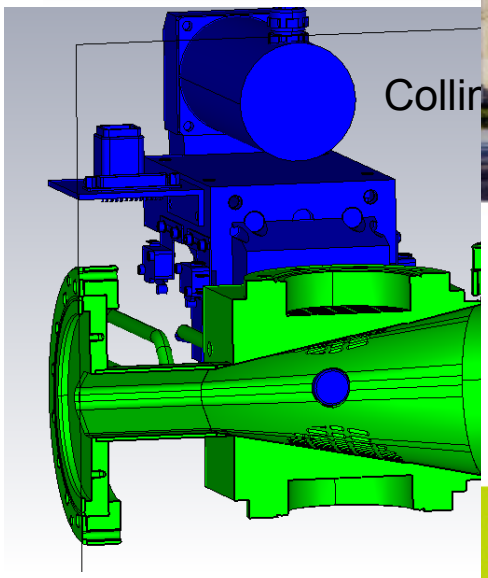
Shielded bellow

BESSY VSR Components tests

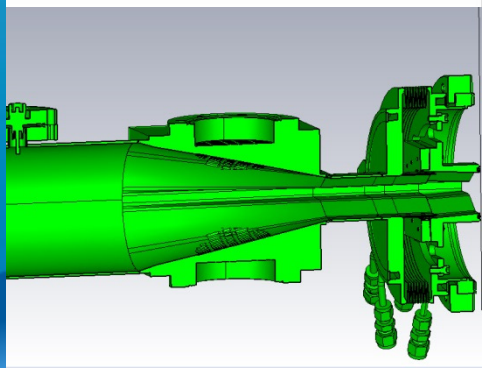




Total length 4.27m



Collir



elded bellow

HZB Helmholtz Zentrum Berlin
BESSY VSR

Workshop on: Operating SRF systems reliably in a "dirty" accelerator

14th -15th September 2017
Helmholtz-Zentrum Berlin

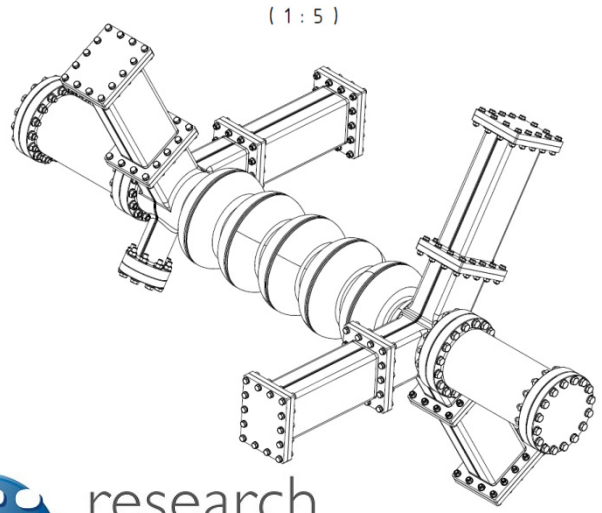
The aim of the workshop is to gather together the expert community to compile experience with "operating SRF in a dirty machine" and develop recipes for the reliable operation of high-voltage SRF. Contributions are invited for all related topics, including dealing with synchrotron radiation, cleanliness and vacuum requirements, long term degradation and mitigation and many more.

Online registration and abstract submission available now.

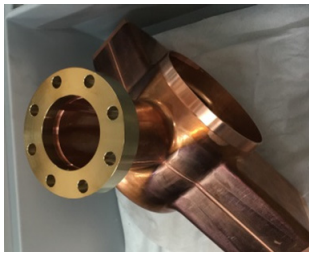
For more information please contact
Dr. Emmy Sharples: emmy.sharples@helmholtz-berlin.de
Website: https://www.helmholtz-berlin.de/events/operating-srf/index_en.html

BESSY VSR: Prototypes

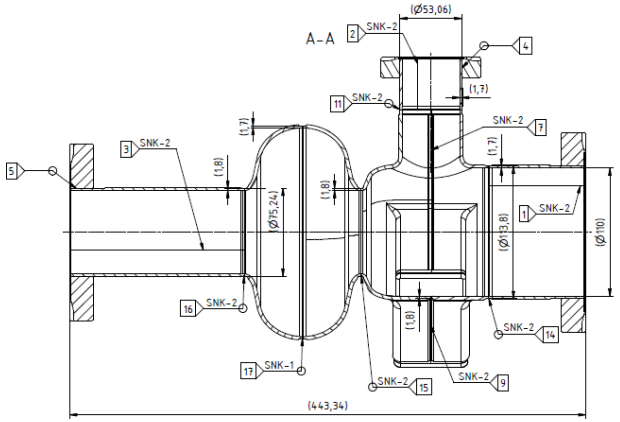
1.5 GHz 5-cell Copper prototype



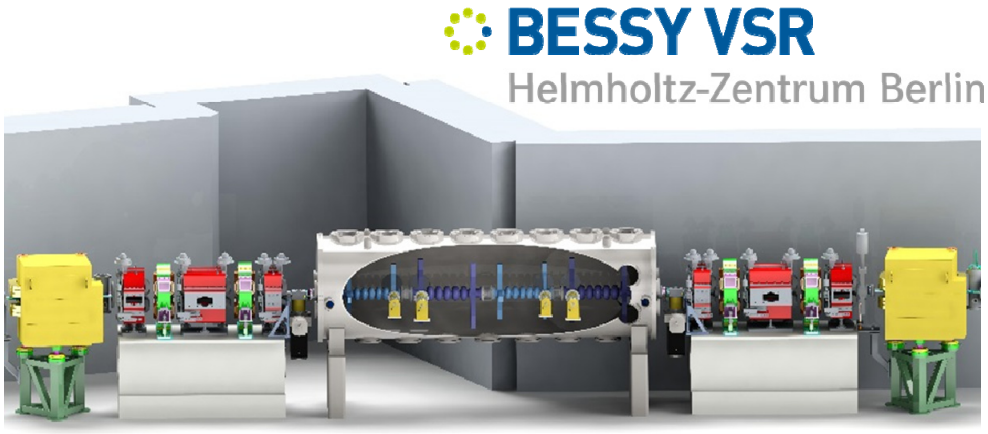
research instruments



1.5 GHz Single-cell Nb prototype



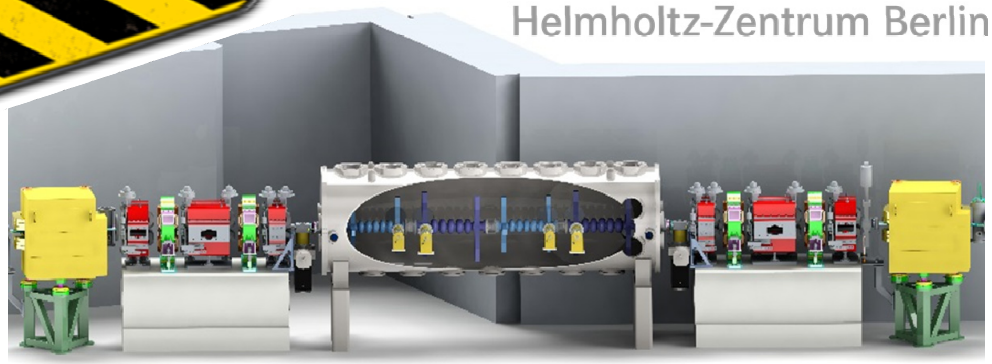
BESSY VSR
Variable pulse length Storage Ring



Thank you for your attention!

BESSY VSR
Variable pulse length **S**torage **R**ing

BESSY VSR
Helmholtz-Zentrum Berlin



Thank you for your attention!