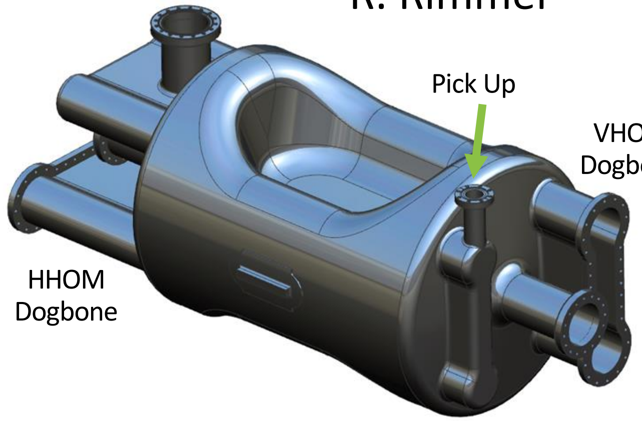
WG11, 12, 7, 9, 13 summary

R. Rimmer, Y. Ohnishi, M. Wendt et. al.

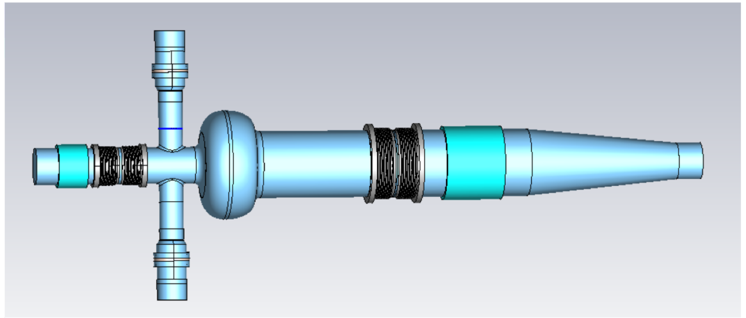
WG11: What’s new in SRF?

WG11: EIC new bunching and crabbing cavities

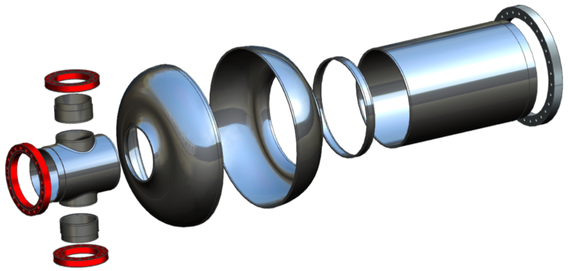
R. Rimmer



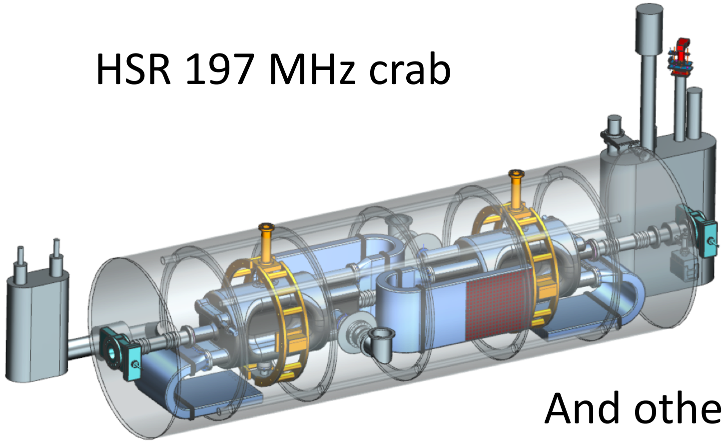
- Prototypes coming soon!

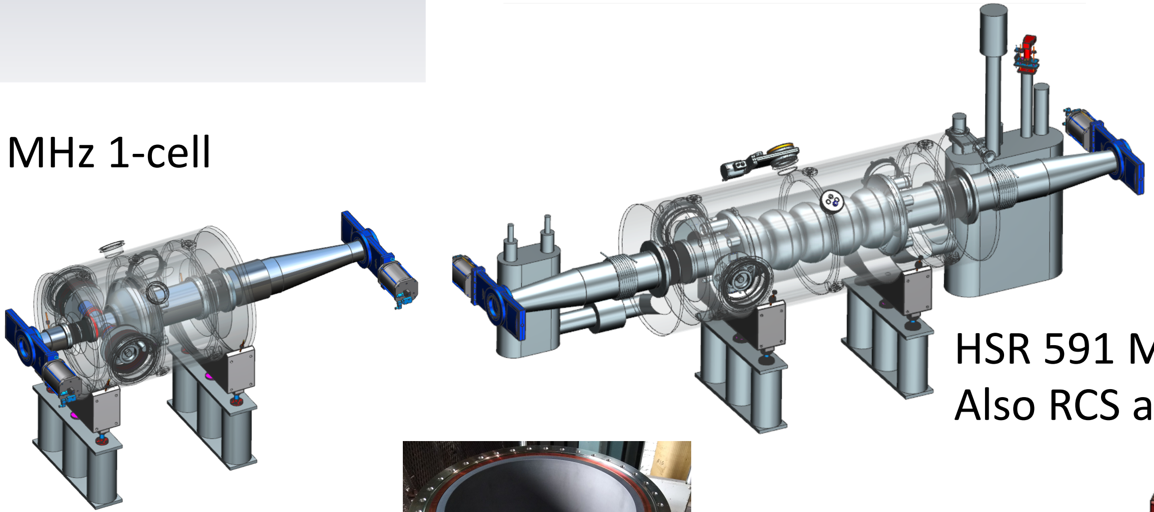


ESR 591 MHz 1-cell



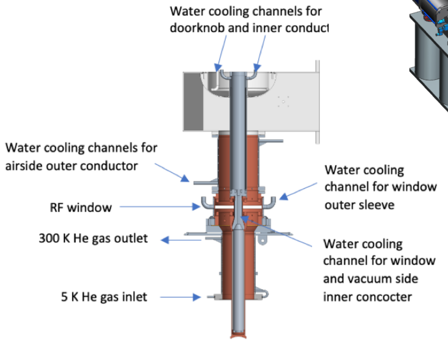
HSR 197 MHz crab



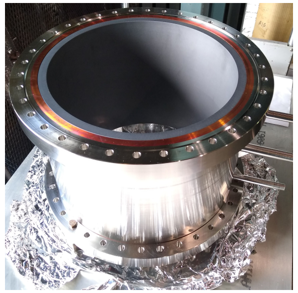


HSR 591 MHz 5-cell
Also RCS and ERL

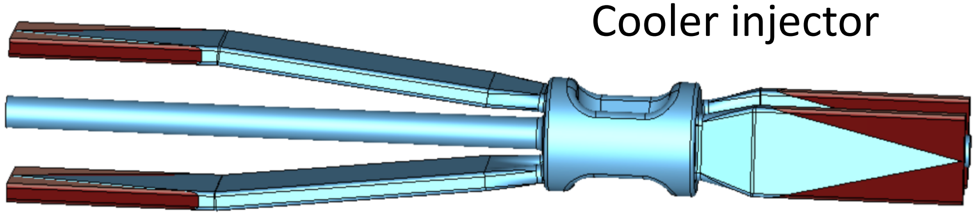
And others!
394 MHz crab
197 MHz QWR
1773 MHz elliptical
Cooler injector



FPC



BLA



WG11: SuperKEKB upgrades and operating experience

Michiru Nishiwaki

High Beam Current-related issues in RF system

- In RF system of SuperKEKB, some systems to cope with instabilities due to large beam current are working well.
- Coupled Bunch Instability (CBI) due to HOM
  - ➢ARES and SCC are designed as HOM-damped structure with HOM absorbers.
  - ➢Additionally, a bunch-by-bunch feedback system is effective.
- Coupled Bunch Instability (CBI) due to accelerating mode
  - μ =-1, -2 and -3 modes
    - ➢New CBI damper system
  - Zero-mode related to Robinson stability
    - ➢Direct RF feedback (DRFB)
    - ➢Zero-mode damper (ZMD)
- Bunch Gap Transient
  - ➢Propose the measures to mitigate the phase difference

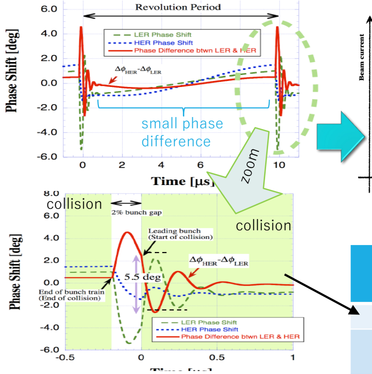
Bunch Gap Transient

T.Kobayashi and K.Akai, Phys. Rev. Accel. Beams 19, 062001, 2016.

Estimation of phase difference between LER and HER ($\Delta\phi_{HER} - \Delta\phi_{LER}$)

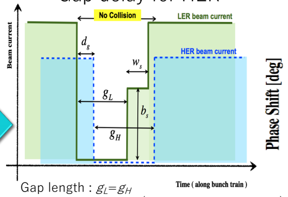
Calculation at design beam currents with 1 gap

Smaller phase difference
→ Smaller loss of luminosity

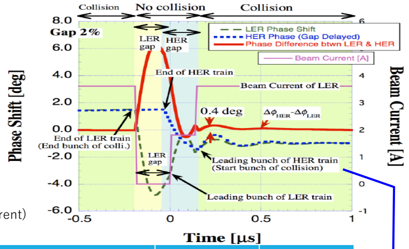


Large phase difference at leading part of collision

Simulation study to mitigate the phase difference
- Change filling pattern at leading part of LER (with step)
- Gap delay for HER



Gap length : $g_L = g_H$
LER step height : b_s (half of nominal current)
HER delay : d_g , LER step length : w_s



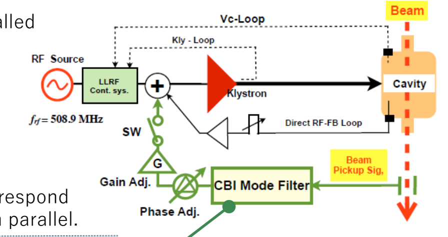
Mitigation Method	Bunch gap $g_L=g_H$	HER delay d_g	Relative phase difference $\lvert\Delta\phi_{HER} - \Delta\phi_{LER}\rvert$ [deg.] Leading Part	Relative phase difference Along Train	Longitudinal displacement @IP (σ_z=5mm)	Rate of num. of colliding bunches
No care	**2%**	**no delay**	**5.5**	**0.9**	**0.44 σ_z**	**-**
HER delay Only	2%	200ns	2.4	0.9	0.19 σ_z	-2%
	3%	300ns	<0.2	1.6	0.13 σ_z	-4%
LER step + HER delay	**2%**	**160ns**	**0.4**	**0.5**	**0.07 σ_z**	**-1.6%**

CBI damper

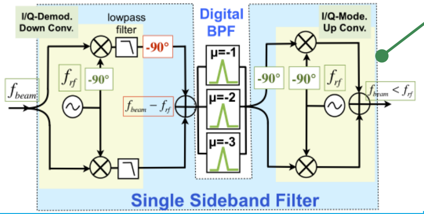
K. Hirosawa et al., Nucl. Instrum. Methods. Phys. Res. A 951, 163044, 2019.

CBI damper system

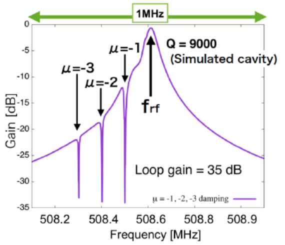
The damper system is installed to ARES station with digital LLRF system.



The damper system can correspond to μ =-1, -2 and -3 modes in parallel.



FB loop test result of the CBI mode filter for a simulant cavity



Frequencies correspond μ =-1, -2 and -3 modes are racked successfully.

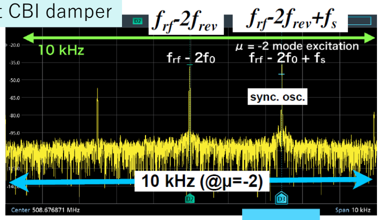
The new CBI damper system is working in SuperKEKB LER and HER.

CBI damper

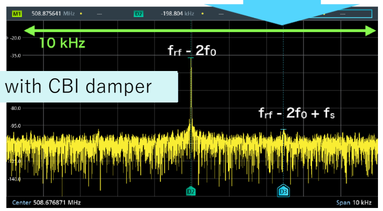
K. Hirosawa et al., Nucl. Instrum. Methods. Phys. Res. A 951, 163044, 2019.

Example of CBI damper operation

without CBI damper



μ=-2 mode was excited purposely by large detuning SCC.



with CBI damper

Peak disappeared by CBI damper.

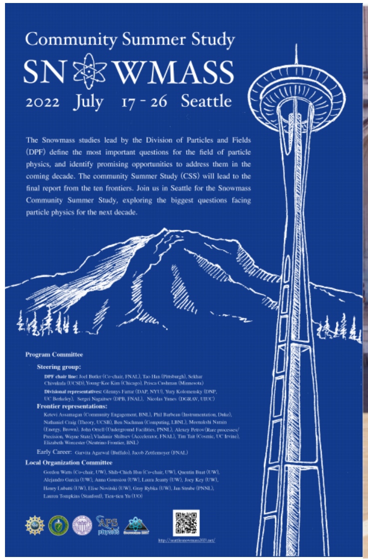
Up to 1.46 A for LER and 1.14 A for HER, CBI is not a problem with this damper systems.

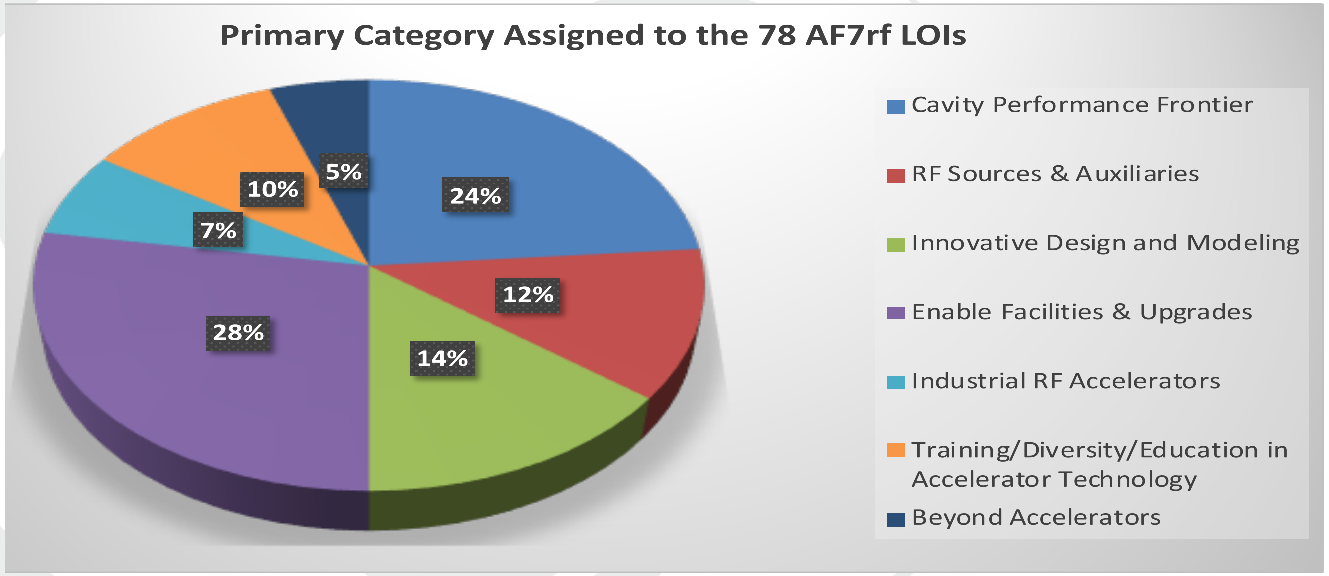
The SRF program in the SNOWMASS 2021 strategy

Snowmass 2021

A.-M. Valente-Feliciano

On behalf of the SRF community





ysics.acc-ph] 25 Aug 2022

August 29, 2022

RF Accelerator Technology R&D

Report of AF7-rf Topical Group to Snowmass 2021

AF7-rf Conveners:
Sergey Belomestnykh[1,2], Emilio A. Nanni[3,4], and Hans Weise[5]

Community Contributors:
Sergey V. Baryshev[6], Pashupati Dhakal[14], Rongli Geng [18], Bianca Giaccone[1], Chunguang Jing[7,8], Matthias Liepe[9], Xueying Lu[7,10], Tianhuan Luo[17], Ganapati Myneni[11,12,13,14], Alireza Nassiri[6,7], David Neuffer[1], Cho-Kuen Ng[3], Sam Posen[1], Sami Tantawi[3,4], Anne-Marie Valente-Feliciano[14], Jean-Luc Vay[17], Brandon Weatherford[3], Akira Yamamoto[15,16]

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JSA

AF7 Recommendations

https://docs.google.com/document/d/1E3NrtnSKeS8XkaBwqoCZO3XQOQC2HRd5t5RiDd34LTk/edit

Key Directions (1)

While the **GARD roadmap continues to serve as a community-developed guidance** for the RF technology R&D, it would benefit from some **mid-course corrections**. Based on the discussions and submitted White Papers, we present the following key directions that should be pursued during the next decade

SRF

- Studies to **push performance of niobium** and improve our understanding of SRF losses and ultimate quench fields via experimental and theoretical investigations;
- Developing **methods for nano-engineering the niobium surface** layer and tailoring SRF cavity performance to a specific application, e.g., a linear collider, a circular collider, or a high-intensity proton linac;
- Investigations of **new SRF materials beyond niobium** via advanced deposition techniques and bringing these materials to practical applications;
- Developing **advanced SRF cavity geometries** to push accelerating gradients of bulk niobium cavities to ~ 70 MV/m for either upgrade of the ILC or compact SRF linear collider;
- Research on application of **SRF technology to dark sector searches**;

Auxiliaries

- Pursuing R&D on **companion RF technologies** to mitigate field emission, provide precise resonance control, enable robust low level RF systems for high gradient and high Q accelerators, etc.;

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https://docs.google.com/document/d/1E3NrtnSKeS8XkaBwqoCZO3XQOQC2HRd5t5RiDd34LTk/edit

Facilities and Workforce

R&D Facilities

To support these key research directions, there is a **need to upgrade and add new capabilities** to the existing R&D and test **facilities to investigate the new concepts** and help integrate them into systems with ready access to researchers. Collaborative efforts at National Laboratories and universities have provided a broad spectrum of sources and manufacturing facilities that has enabled this progress. However, **much of this infrastructure is aging and in need of rejuvenation**. Without **adequate investment** in the facilities, further progress in advancing RF technologies will be hindered.

Workforce

The **workforce** that supports the existing capabilities and facilities **is currently insufficient**. A significant portion of this workforce is approaching the end of their career. **Bringing the next generation of staff into these facilities is a struggle. Additional resources and a strategy are urgently needed for education, training and knowledge transfer**.

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Synergy with European Strategy

- European Strategy for Particle Physics (ESPP) describes strategy for particle physics in Europe and their contributions world-wide (June 19, 2020)
- European National Laboratories Directors Group (LDG) – July 2 (Chaired by Lenny Rivkin)
- Immediate outcome àAccelerator R&D Task Forces reporting to Lab Directors Group(LDG) and CERN Council
- Address the question of what are the most promising Accelerator R&D activities for HEP

5 Targetted Accelerator R&D Expert Panels

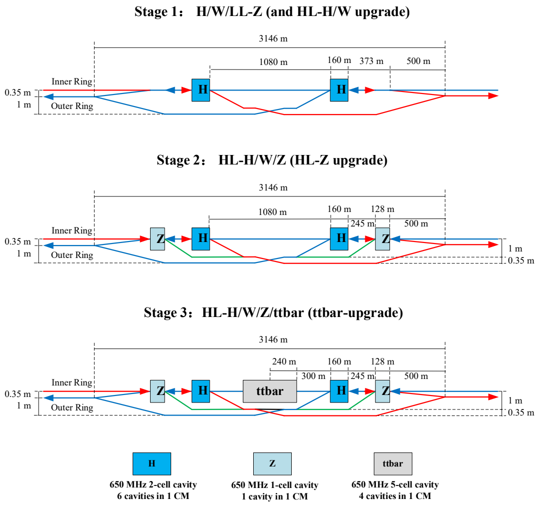
- High-field Magnets (LTS, HTS)
- High-gradient acceleration (plasma / laser)
- High-gradient RF structures
- Muon beams
- Energy-recovery linacs

Snowmass AF participants are active on all the LDG panels

Efforts in the United States for SRF research and development are in synergy with other regions, Europe and Asia coherent with the European Strategy for particle physics document published January 2022

Cavity and Cryomodules Developments for CEPC, Jiyuan Zhai (IHEP)

CEPC TDR New RF Layout



- Higgs first priority. And aiming for all-mode seamless switching in whole project lifecycle without hardware movement
- Maximize performance and flexibility for future circular electron positron collider
- Add center connection line (short black line) for Higgs operation after ttbar upgrade. Need to check if the dipole SR light will hit the cavity after effective shielding.

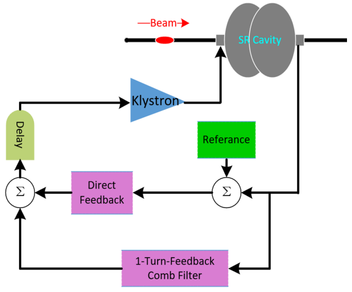
CEPC SRF TDR and Upgrade Hardware Specifications

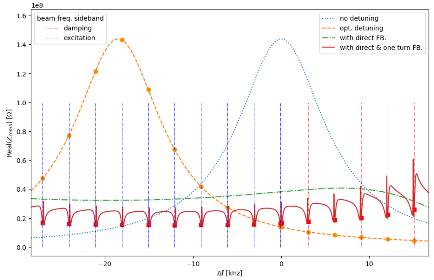
Suitable for 30/50 MW SR per beam	**H, W, Z** high gradient & high Q	**HL-Z** high current & power	**ttbar** very high gradient & high Q
Collider 650 MHz Cavity at 2 K	**2-cell** VT 4E10 @ 22 MV/m HT 2E10 @ 20 MV/m OP 1.5E10 @ 20 MV/m	**HL-Z 1-cell** 1E10 @ 8.7 MV/m **Optional 1-cell for H&Z** VT 4E10 @ 45 MV/m HT 4E10 @ 40MV/m OP 3E10 @ 40 MV/m	**5-cell** VT 6E10 @ 32 MV/m HT 5E10 @ 32 MV/m OP 5E10 @ 28.3 MV/m
Booster 1.3 GHz 9-cell Cavity at 2 K	VT 3E10 @ 24 MV/m HT 3E10 @ 22 MV/m OP 1E10 @ 20 MV/m	1E10@17 MV/m	VT 3E10 @ 32 MV/m HT 2E10 @ 32 MV/m OP 1E10 @ 26.7 MV/m
650 MHz Input Coupler variable	300/500 kW variable	1 MW	300 kW variable
650 MHz HOM Coupler	1 kW	\	1 kW
650 MHz HOM Absorber	5 kW	10 kW	\

8

FM Coupled Bunch Instability in 50 MW Z Mode

Add double comb filter to suppress the dangerous modes.





Couple Bunch Mode Number	Growth rate [s^{-1}]
-1	-7.3
-2	5.0
-3	16.6
-4	26.9
-5	35.3
-6	41.6
-7	45.5
-8	47.0
-9	46.4

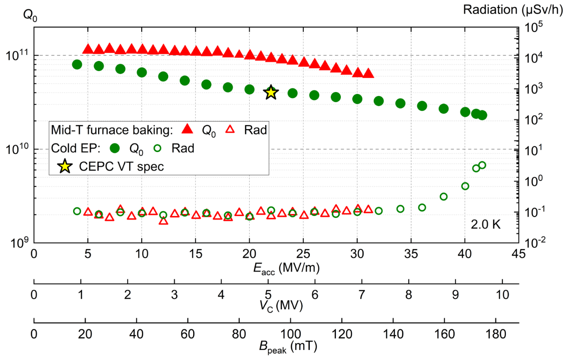
$K = 0.5,\ G = 3.5$

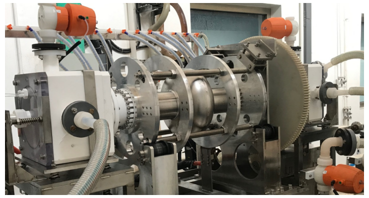
$$H_{\text{dual - comb}}(\omega) = \frac{G\left(1 - e^{-i\omega T_{\text{rev}}}\right)e^{-i\omega(T_{\text{rev}} - T_G)}}{\left[1 - Ke^{-i(\omega T_{\text{rev}} - \nu_s)}\right]\left[1 - Ke^{-i(\omega T_{\text{rev}} + \nu_s)}\right]}$$

$$Z_{\text{cl}}(\omega) = \frac{Z(\omega)}{1 + e^{-i\tau\omega} G e^{i\phi} Z(\omega)[1 + H_{\text{comb}}(\omega)]}$$

In order to bring the growth rate below the half of the synchrotron oscillation frequency (< 50 Hz). We had to add a comb filter alongside the direct feedback loop.

High G High Q 650 MHz 1-cell Cavity

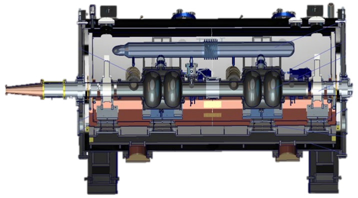


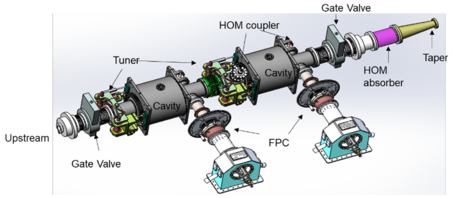


650 MHz 1-cell cavity vertical test
EP treated: 2.3E10@41.6 MV/m@2 K
Mid-T treated: 6.3E10@31 MV/m@2 K

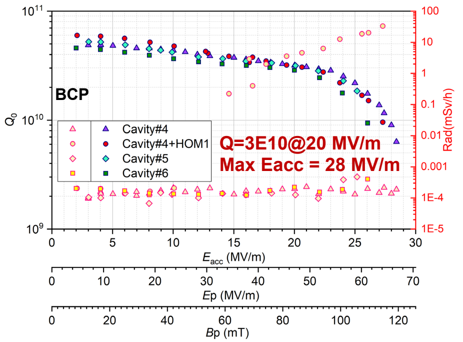
Cavity and Cryomodules Developments for CEPC, Jiyuan Zhai (IHEP)

CEPC 650 MHz Test Cryomodule





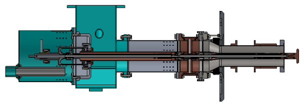
650 MHz 2-cell Cavity Vertical Test with HOM Couplers



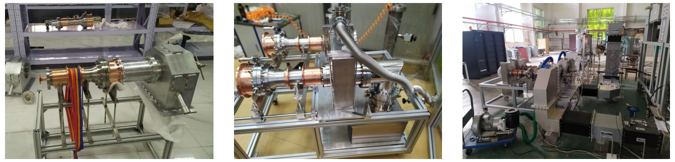
- BCP 650 MHz 2-cell cavities: 2.8E10@22 MV/m (CEPC VT spec: 4E10@22 MV/m)
- Performance no change after install HOM coupler
- EP/heat treatment to further improve gradient and Q

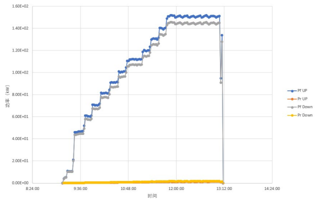
650 MHz High Power Variable Coupler

- 650 MHz **variable couplers** tested to CW TW 150 kW (SSA power limit), SW 100 kW (corresponding to 400 kW TW power at the window, exceeds CEPC spec 300 kW). One of the world highest variable couplers.

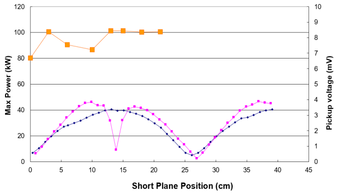


Bellow on inner conductor. Inner conductor water cooling. Outer conductor He gas cooling.

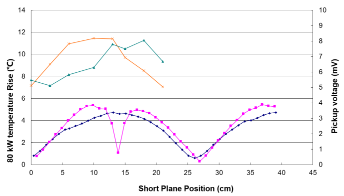




TW high power test to 150 kW



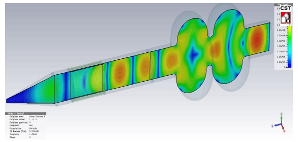
Window SW field and power

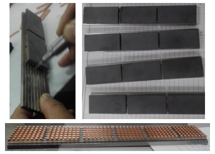


Window SW field and temperature rise

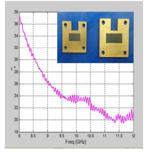
Broadband High Power HOM Absorber

Due to short bunch length thus wide HOM frequency range, **SiC+AlN** composite is chosen for cavity HOM absorbing material. 5 kW high power test show high absorbing efficiency, meet CEPC spec.

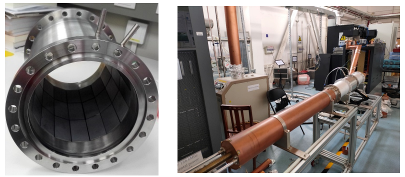


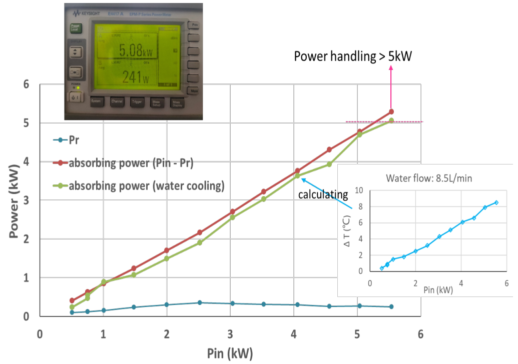


SiC+AlN composite bricks brazed on copper and then on kovar plate

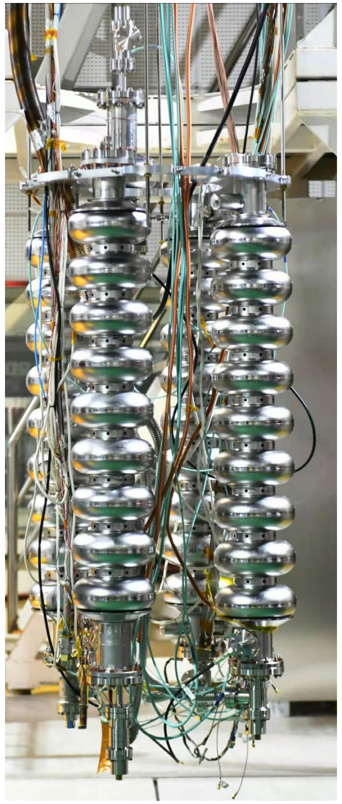


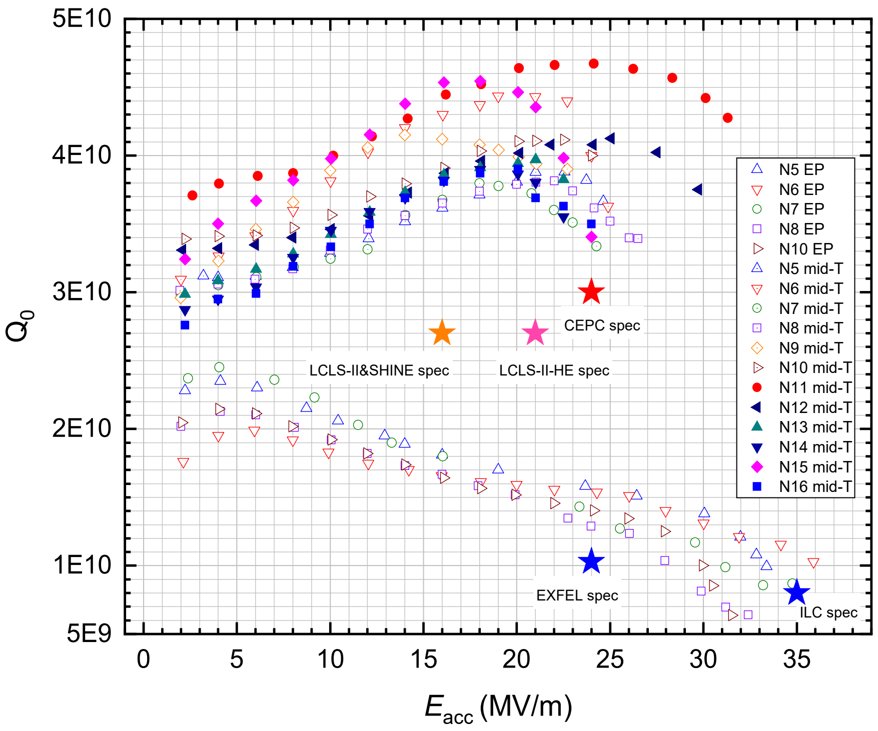
Measured permittivity of SiC+AlN composite (for broadband microwave absorbing)





World Leading Mid-T High Q 1.3 GHz 9-cell Cavity





2 K VT	1st batch average	2nd batch average
E_{acc} (MV/m)	24	27.7
Q_0@16 MV/m	3.8E10	4.1E10
Q_0@21 MV/m	3.8E10	4.1E10

First batch (6 cavities): N5-N10

Second batch (8 cavities): N11-N18 (N11-16 tested)

- Best Cavity (N11): 4.6E10@21 MV/m, 4.3E10@31MV/m
- Q spread due to cool down difference?
- One of the best high Q 1.3 GHz 9-cell cavities and cavity batches in the world.
- Will install to high Q module at IHEP PAPS

RF Developments for HEPS, Pei Zhang (IHEP, CAS)

Civil construction

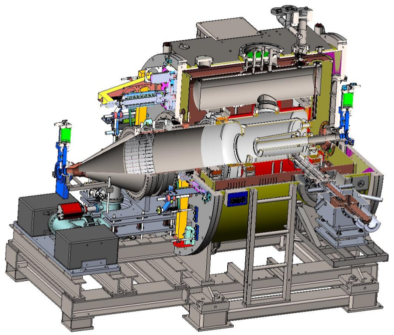
- HEPS civil construction in good shape
- Platform of Advanced Photon Source Technology R&D (PAPS) completed in 05.2021
- First accelerator component installation in 07.2021
- Linac commissioning started in 07.2022 (underway)

HEPS main parameters

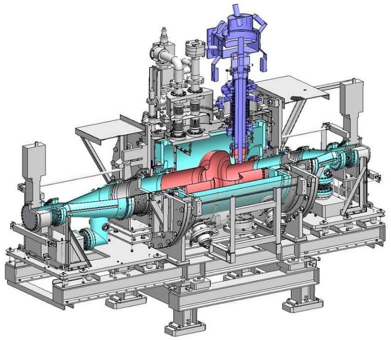
Parameter	Value	Unit
Beam energy	6	GeV
Circumference	1360.4	m
Beam current	200	mA
Lattice type	7BA	-
Number of sectors	48	-
Natural emittance	34.2	pm·rad
Natural bunch length	5.06	mm
Energy loss (bare lattice)	2.64	MeV
Total no. of IDs (Phase I)	14	-
Total beam power	850	kW
Radiation damping time (x/y/z)	10.85/20.62/18.76	ms
RF frequency (main, 3rd harm.)	166.6, 499.8	MHz
Main RF voltage (w/ harm. cav.)	5.16	MV

Y. Jiao et al., *Journal of Synchrotron Radiation* 25, 1611 (2018).

Storage-ring RF: cavities



166.6MHz quarter-wave β=1 SRF cavity (New development)

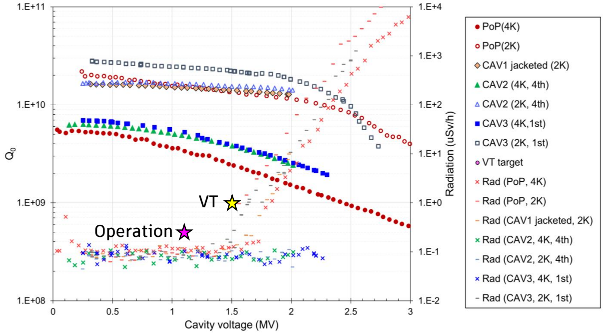


499.8MHz KEKB-type single-cell SRF cavity

Cavities

- In-house developed, contract of 10 bare cavities signed in 10.2020
- Pre-series (3 cavities) production completed in Q1.2022
  - All 3 bare cavities passed VT tests, Cav#1-jacketed VT at 2K
  - Modified BCP implemented to eliminate unwanted traces on the LBP transition

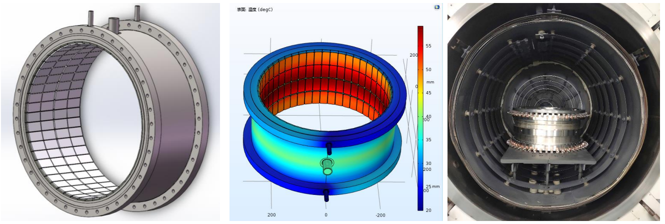
Lowest Rres: ~1.44 nΩ (~1.7 m² Nb surface)



RF Developments for HEPS, Pei Zhang (IHEP, CAS)

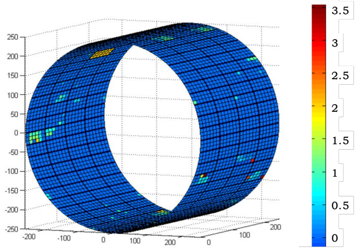
Ferrite HOM absorber

- In-house developed
  - Inner diameter: 505mm
  - 200 tiles, 4 tiles/coupon
- 1 tile peeled off after the 10kW power test
- Brazing fixtures optimized



10kW test

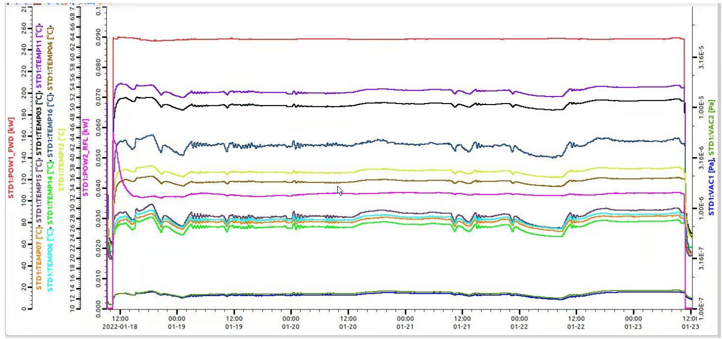
Distance to defects



Fundamental power couplers

- In-housed developed, contract of 10 FPCs signed in 11.2020
- Pre-series (2 couplers) delivered in 07.2021
- High-power conditioning to 250kW CW passed in Q1.2022

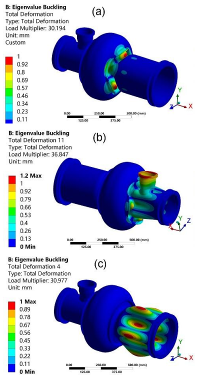
High-power aging for 120 hours at 250kW CW

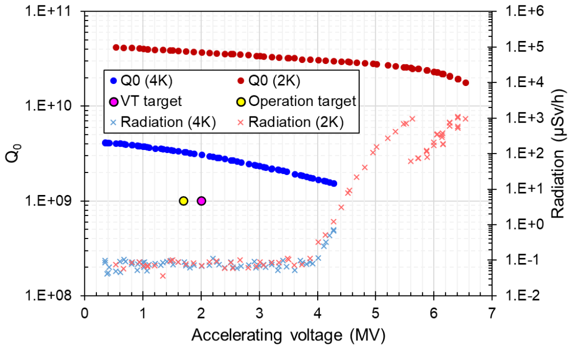


T.M. Huang et al., *Review of Scientific Instruments* 91, 063301 (2020).

500MHz SRF cavities

- Based on BEPCII 500MHz cavity, improved mechanical properties
- All 4 bare cavities delivered in Q3.2022
- CAV#1 (BCP) passed VT

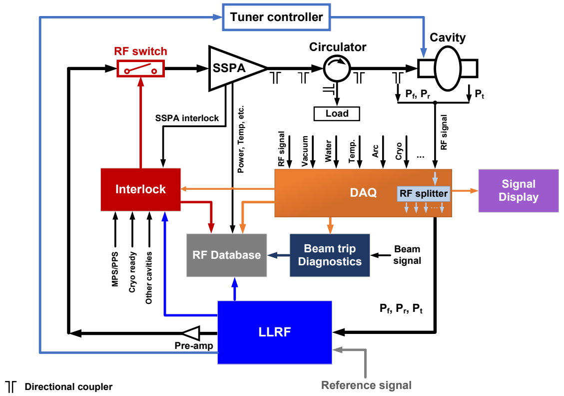




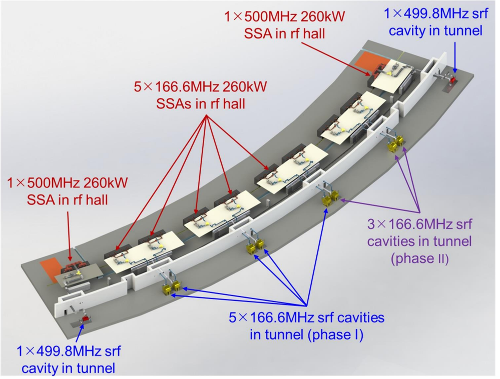
H.J. Zheng et al., *IEEE Trans. Appl. Supercond.* 31, 3500109 (2021).

Integration

RF control layout



SR RF hall

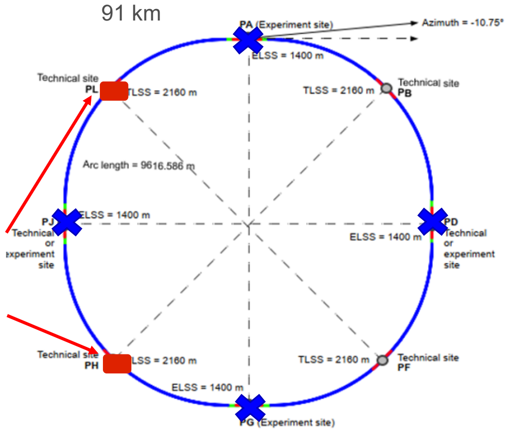


Baseline and Cavity Options for FCCee, Franck Peauger for the FCC RF team

RF system for FCCee

Designed to provide 100 MW of RF power in CW to compensate losses by synchrotron radiation

	Energy (GeV)	Current (mA)	RF voltage (GV)
Z	45.6	1400	0.120
W	80	135	1
H	120	26.7	2.1
ttb	182.5	5	11.3



4 interaction points

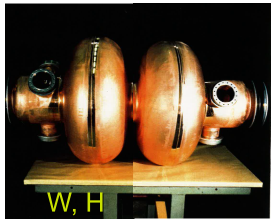
RF systems

TIWG 29/09/2021

3 different types of SRF cavities for the FCC-ee RF baseline

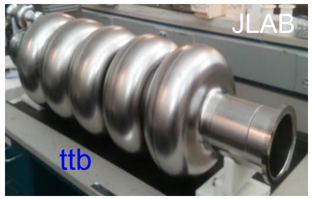
New

400 MHz 1-cell cavities
Nb/Cu

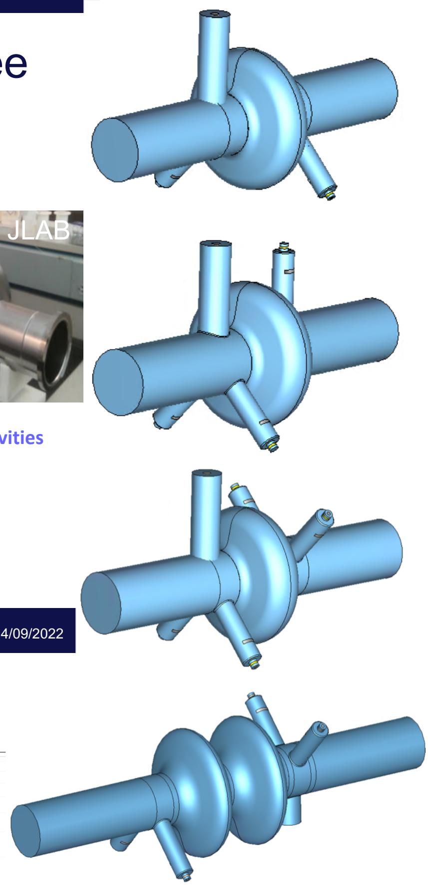


400 MHz 2-cell cavities
Nb/Cu

2-cell is better for W working point
(reduced RF power per cav., improved HOM damping)



800 MHz 5-cell cavities
Bulk Nb

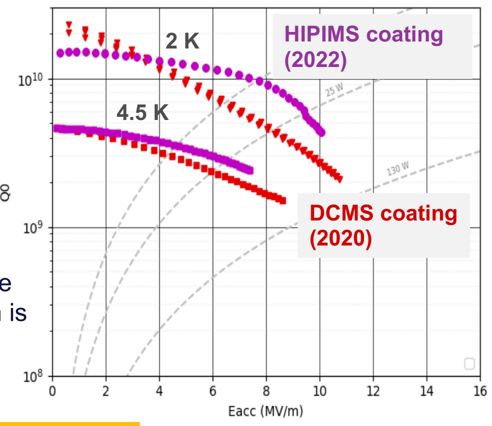


First attempt of HIPIMS coating on a 400 MHz cavity

Reduction Q_0 slope is confirmed

Encouraging result obtained without electropolishing

Test limited by field emission → a new surface preparation in clean room is planned (including HPR)



G. Rosaz, J. Walker,
Y. Cuvet, G. Pechaud

SRF studies with 1.3 GHz single cell cavities

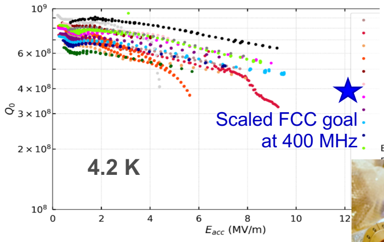
Several types of copper substrates studied
(BM = machined from bulk, W = welded, L = electrodeposited)

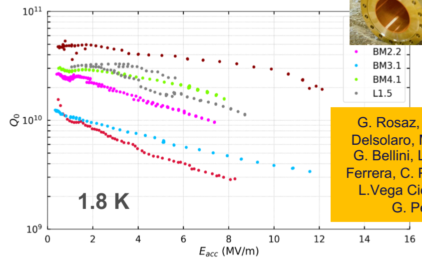
Electropolishing + HIPIMS coating

At 4.2 K, good reproducibility. The tests are stopped are 10 MV/m for administrative limits. Extrapolated at 400 MHz, the **results are already satisfactory.**

At 1.8 K, a large scatter of the results is observed and not yet fully understood. The Q0 slope is cancelled in some cases.

L. Vega Cid, "RF tests of Nb/Cu 1.3 GHz elliptical cavities", presented at the FCC Week 2022, Paris, France, May 2022





G. Rosaz, W. Venturini Delsolaro, M. Garlasche, G. Bellini, L. M. Antunes Ferrera, C. Pereira Carlos, L.Vega Cid, A.Bianchi, G. Pechaud

Baseline and Cavity Options for FCCee, Franck Peauger for the FCC RF team

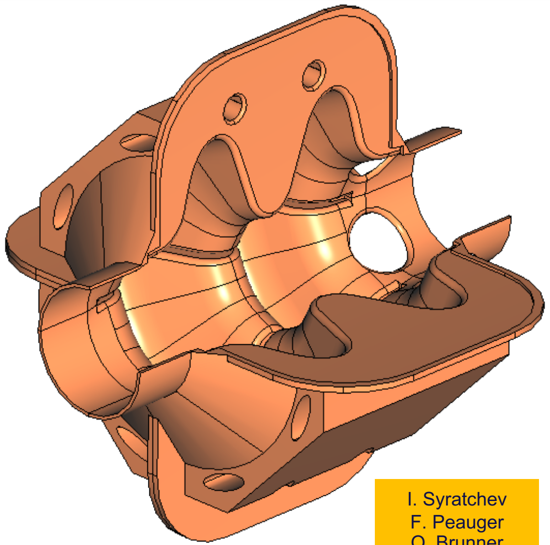
SWELL 2-cell 600 MHz cavity for Z, W, H

SWELL

- Very interesting **alternative cavity option** which would cover three machines (no need to remove cryomodules after operation at Z)
- Highly damped RF cavity for transverse HOMs thanks 4 waveguide slots and coaxial RF lines

E_{acc} = 12.5 MV/m, P_{RF} = 600 kW

- Robust against microphonics and Lorentz forces
- Innovative concept compatible with Nb/Cu technology (open RF structure, easy to coat and inspect)



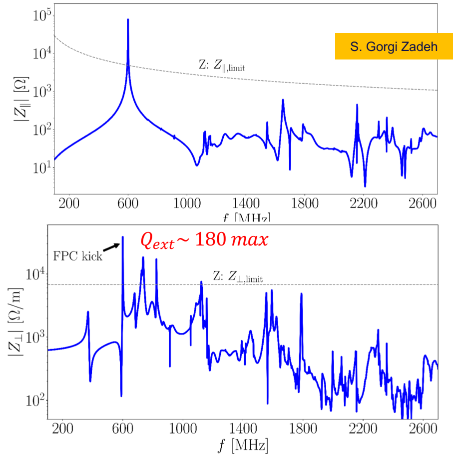
I. Syratchev
F. Peauger
O. Brunner
S. Gorgi Zadeh

F. Peauger et al, SWELL and Other SRF Split Cavity Development, in Proc. LINAC'22, Liverpool, England, Sept. 2022

Impedance and HOM damping of SWELL

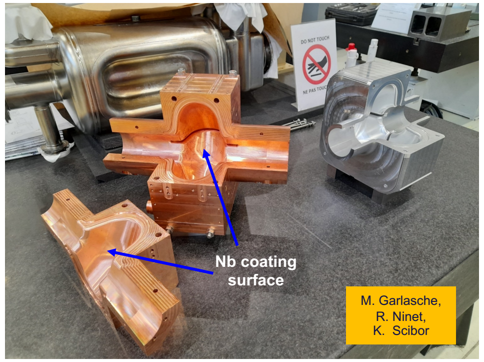
- Longitudinal coupled bunch instabilities due to the FM will be mitigated by direct RF feedback, as performed in the LHC
- Three transverse modes remain above the stability threshold:
  Spike at the FM frequency is due to coupler and tuning plunger asymmetry and can be compensated by alternating their orientation along the accelerator

  For the two other modes at 748 and 830 MHz a bunch-by-bunch feedback system with a damping time of about 100 turns

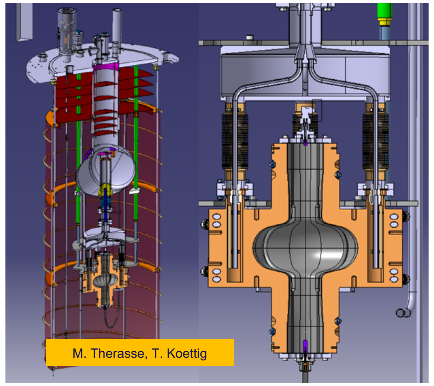


SWELL concept feasibility demonstration

Prototype at reduced scaled (1.3 GHz) successfully machined and ready to be niobium coated



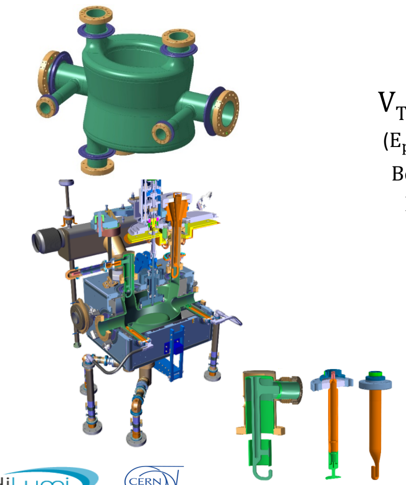
Vertical test at 4.5 K planned in SM18 at CERN in 2023



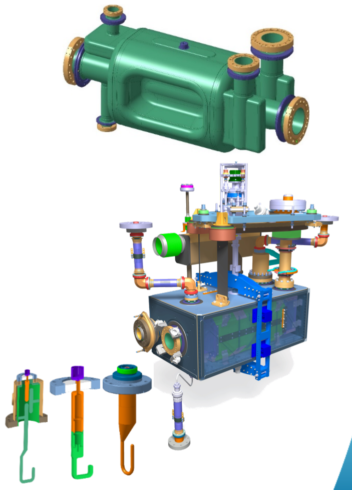
HL-LHC Crab Cavities, Recent Progress, R. Calaga on behalf of HL-LHC WP4

HL-LHC Cavity Geometries

Double Quarter Wave



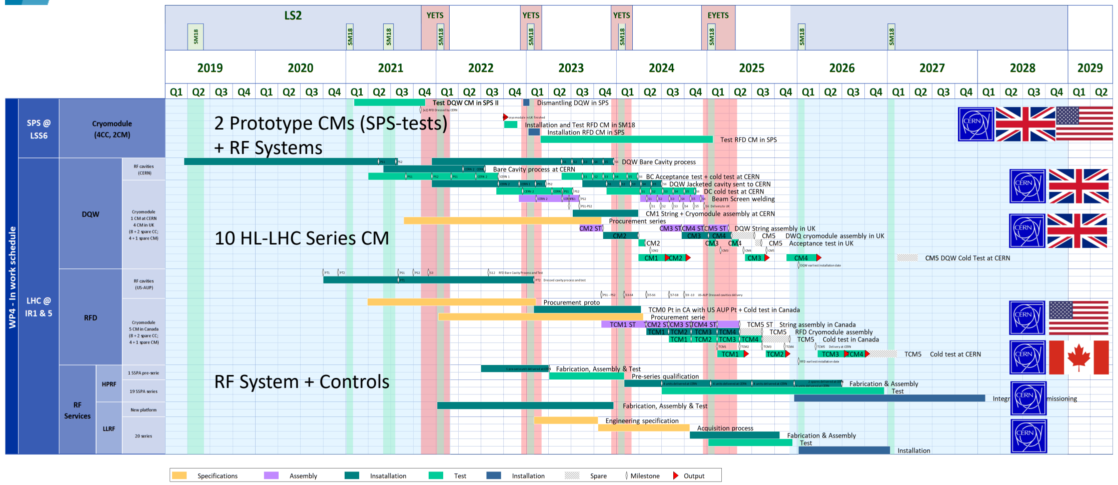
RF Dipole



$$f_0 = 400 \text{ MHz}$$
$$V_T = 3.4 \text{ MV/cavity*}$$
$$(E_p, B_p < 40 \text{ MV/m}, 70 \text{ mT})$$
$$\text{Beam aperture} = 84 \text{ mm}$$
$$\text{RF power} = 40 \text{ kW-CW}$$
$$\text{Operating Temp} = 2 \text{ K}$$

*Engineering spec: 4.1 MV dressed for 20% margin

Masterplan of WP4

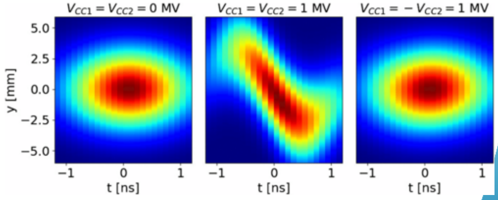


First Demonstration with Hadron

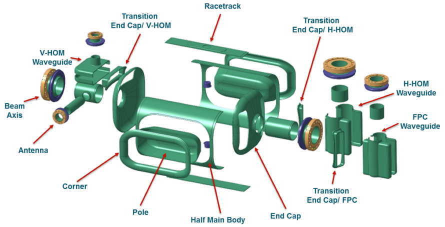
First injection – 12:55, May 23, 2018
Cavity 1 only

Single bunch
$0.2 - 0.8 \times 10^{11}$ p/b

Several experiments with proton beams were performed since 2018 to understand the performance and operational aspects. Experiments continue to date



Cavity Fabrication at CERN



Sub Assemblies

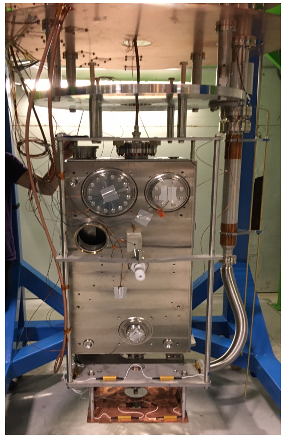
RFD2 Welded

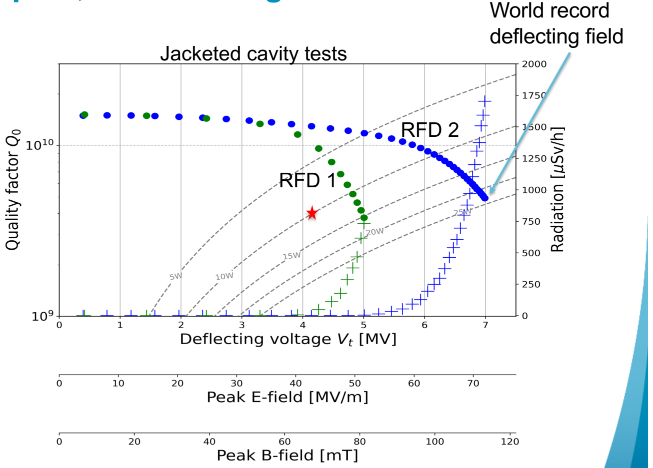
Final weld freq shift

Δf [kHz]	RFD1	RFD2
Expected	+150	+150
Measured	-414	-470

HL-LHC Crab Cavities, Recent Progress, R. Calaga on behalf of HL-LHC WP4

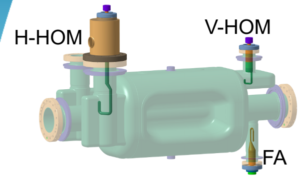
RF Dipole, Cold Testing



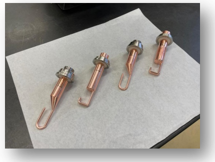


Note: Cavity 1 underwent a 2[nd] light etching ($\sim 30\mu m$) to recover performance

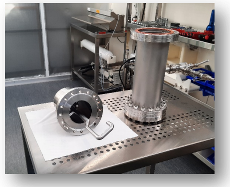
RF Dipole, HOM Couplers



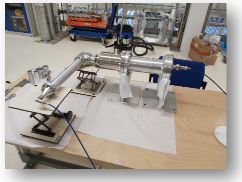
V-HOM & Field Antenna



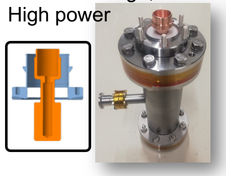
H-HOM, bulk Nb



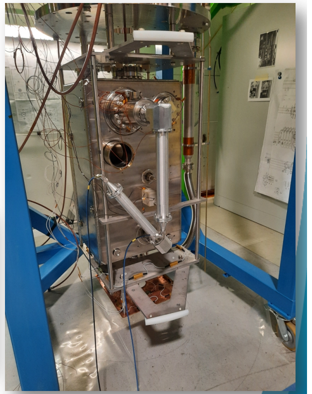
HOM test-box qualification



RF feedthrough, 25 Ω
High power

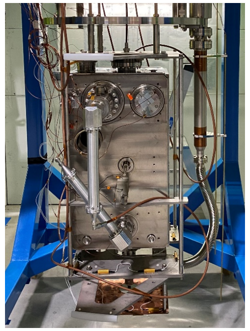


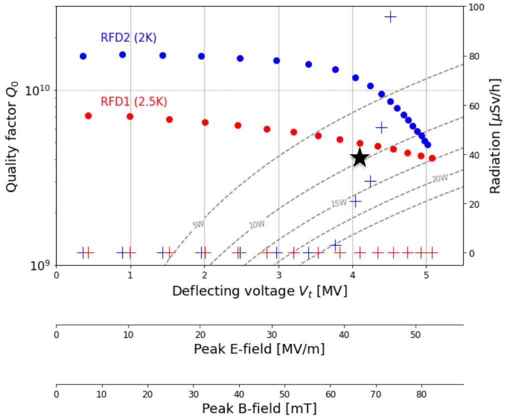
Full Dressed Cavity, 2K test



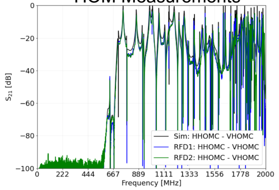
RFD Dressed Cavity with HOMs

CERN-RFD2



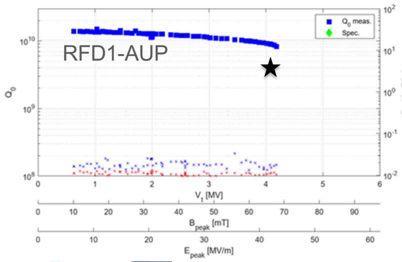


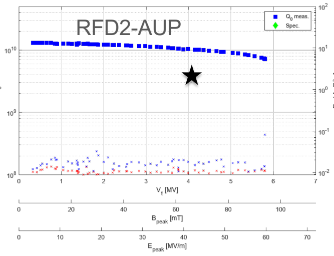
HOM Measurements



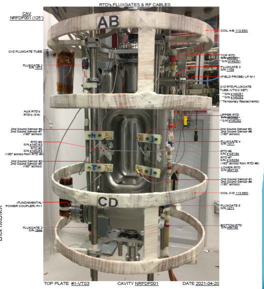
RFD Series (US-AUP & Canada)

- US-AUP will provide 10 fully dressed RFD cavities which will be cryostated at TRIUMF (in-kind)
- Successful completion of industrial RFD prototypes (Zanon) & tested them beyond specification

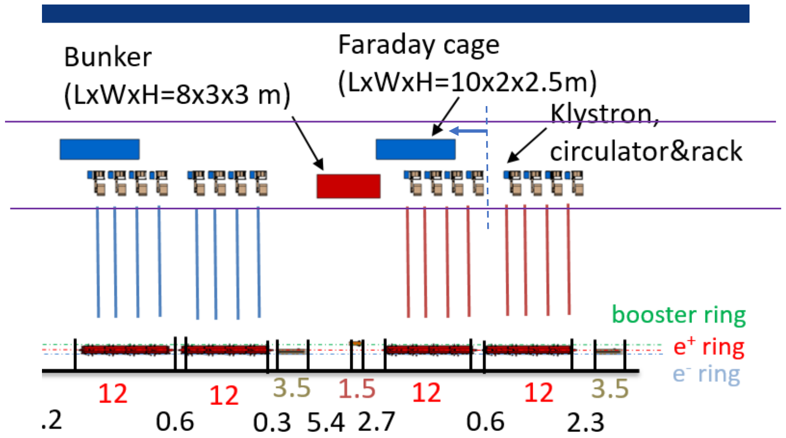


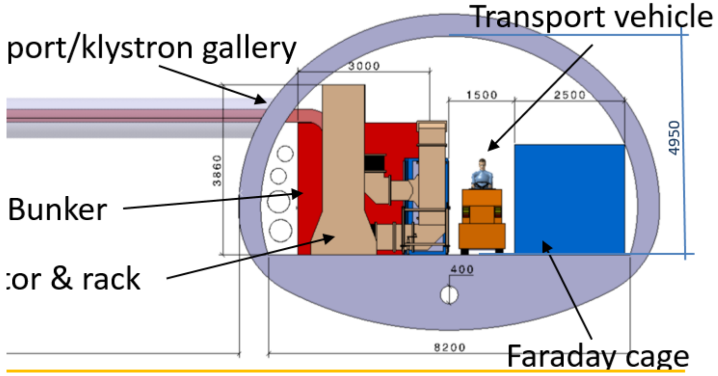


Vertical test stand FNAL

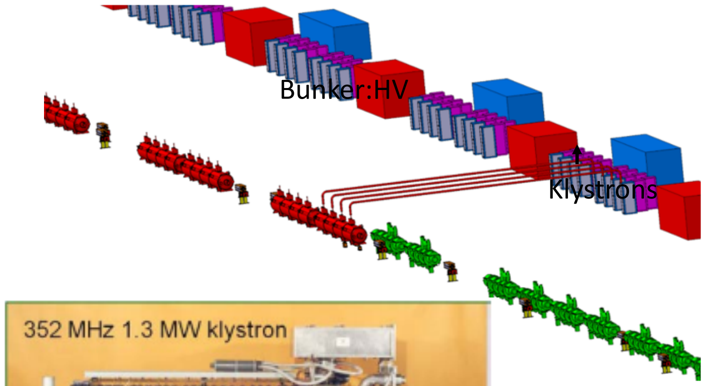


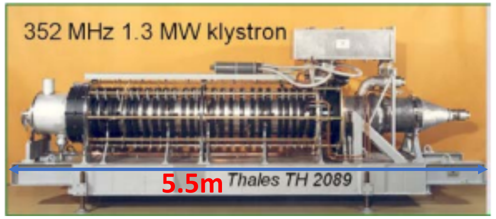
Development progress on TS MBK for FCCee, Zaib Un Nisa (CERN)





FCC_{ee} (Z) accelerator tunnel integration





1.3MW CW, 352MW, 100kV, 20A, eff.=63%.

1. Each Klystron should deliver 1MW @ 400MHz.
2. Preferably, klystron should be placed vertically in the tunn
3. The total length of Klystron should be about 3m.
4. The efficiency of Klystron is targeted at 80%.

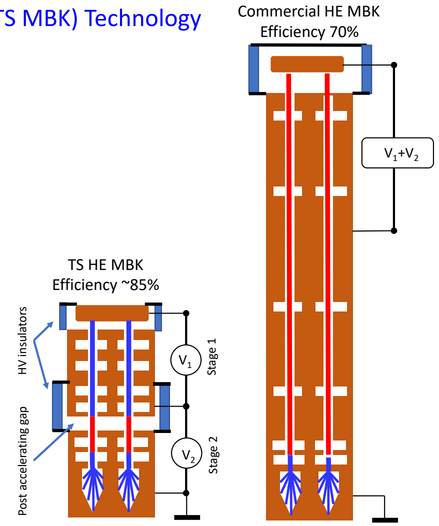
Two-Stage Multi Beam Klystron (TS MBK) Technology

Specific features:

1. Bunching at a low voltage (high perveance). Very **compact RF bunching circuit.**
2. Bunched beam acceleration and cooling (reducing $\Delta p/p$) along the short DC voltage post-accelerating gap.
3. Final power extraction from high voltage (low perveance) beam. **High efficiency.**

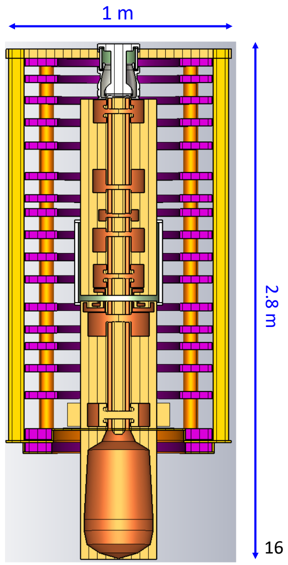
Additional advantages:

1. The second HV stage can be operated in DC mode. Thus simplifying the modulator topology (cost/volume) and increasing the modulator efficiency (in pulsed mode).
2. Simplified feedback for the first stage pulsed voltage. Improved klystron RF phase and amplitude stability.



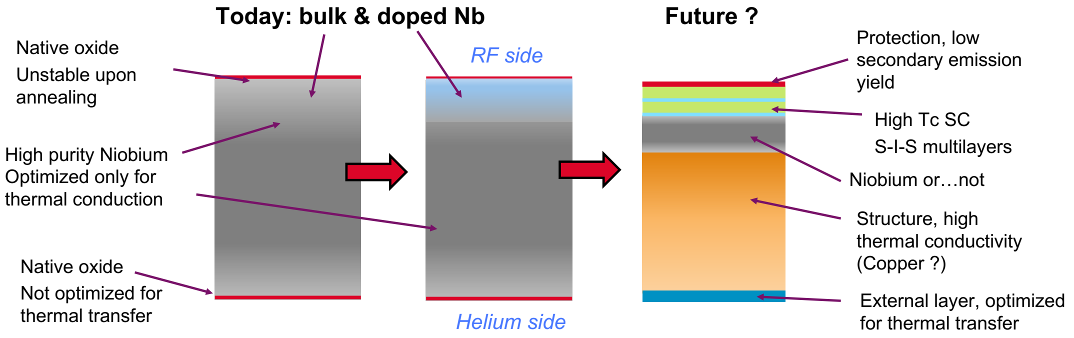
Design Parameters for TS MBK for FCC^{ee}

Parameters	Design Target	KlyC	CST
Frequency (GHz)	0.4	0.4	0.4
Voltage (kV)	58	58	58
First stage (kV)	10-20	11.5	11.5
N beams	10	10	10
Total Current (A)	27	27	27
Output Power (MW)	1.2	1.28	1.2
Efficiency (%)	80	80.6	79
Tube length (m)	<3	--	2.8



Thin films activities in the IFAST program, Claire Antoine (CEA)

Desired: Tailored material for RF cavities



At stakes : COST REDUCTION !!!

- Cooling power (any application); can we go to cryocooling ?
- High accelerating fields => shorter machines ?

Objectives for WP9 (task9.1)
Innovative superconducting cavities

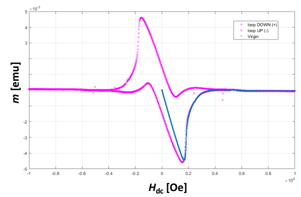
Improve performance and reduce cost of SRF acceleration systems

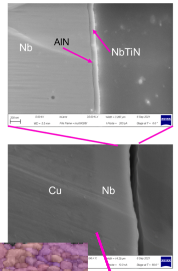
- We aim at building together a global strategy to be able to produce Superconducting RF (SRF) cavities coated with a superconducting films. Not only IFast, (informal) WW collaboration
- It includes pursuing the optimization and the industrialization:
  - Substrates preparation (Nb, Cu), *e.g. PEP, metallographic polishing*
    - Pre-and post treatment *(laser, flash annealing)*
    - The production of seamless copper cavities
  - The optimization deposition techniques: MS, PVD, ALD… to get Nb, NbN, Nb_3Sn, V_3Si… thick films (µm) and/or SIS Multilayers (nm)
- Produce and RF test prototypes of SRF cavities at 6 GHz: Easier to fabricate, handle, dissect to provide fast feedback
- Produce accelerator type 1.3 GHz cavities (feasibility assessment).

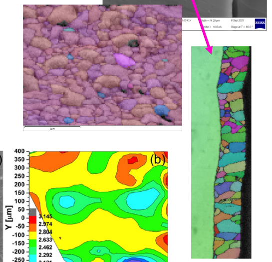
Ifast WP9 : Thorough material characterization needed!

Classical material characterization …

- Opt. and confocal microscopy
- SEM, EDX and EBSD
- Ion beam miller for cross-section
- X-Ray, TEM … advanced characterization techniques
- Superconductivity: Tc, RRR, DC magnetometry, AC susceptibility

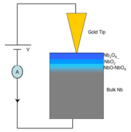


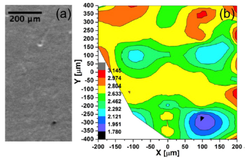




Home made (advanced) characterization tools:

- Flux penetration (@ UKRI, @ CEA) (=> E_{acc})
- Rs on small samples (7.8 GHz cavity @ UKRI)
- SC gap, DOS cartography (scanning tunnel microscope @ CEA)





CONCLUSION

→ Things are going according to IFAST WP9 plan

→ WW: thin films activities = few groups, few resources

→ Coordination and exchanges help to derive maximum benefit

→ Next generation of SRF material is “en route” with already very nice results on samples

→ We hope IFAST WP9 (and collaborators) to bridge the gap between lab R&D and 1rst prototypes development

→ If accelerator community wants SRF technology to evolve*, strong investments are needed in the near future

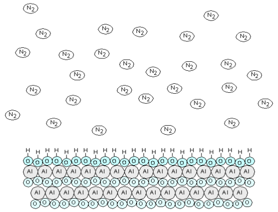
* Change of paradigm, not just mere improvement

Atomic layer deposition for SRF cavities, Thomas Proslier (CEA)

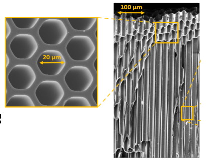
Atomic layer deposition

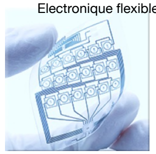
Thin films (≤ 1 µm) synthesis technique based on **self-limiting** surface chemical reactions. Sequential injection of **vapor phase** precursors . Layer by layer growth. Cycles.

$Al_2O_3 = TMA(Al(CH3)_3) + H_2O$

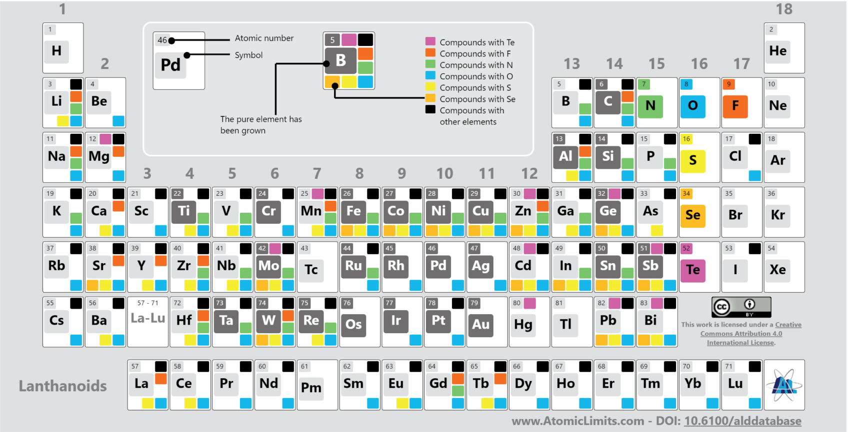


- ➢ *Advantages*:
  - Thickness and composition control down to the atomic level.
  - Pin-hole free films.
  - Excellent conformality on complex-shaped and large area substrates.
  - Large palette of materials.
  - Low temperatures (RT-450°C)
- ➢ *Limits*:
  - Slow deposition (0.3 to 10 Å/min).
  - New materials require new chemistry.
- ➢ *Applications*:
  - Micro-electronic, Photovoltaic, Catalysis, Batteries Detectors…



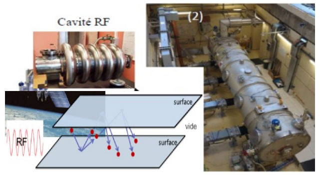


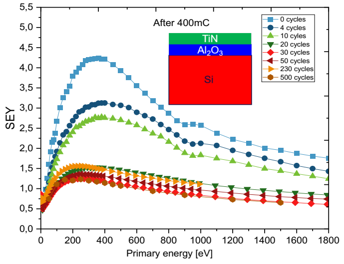
Atomic layer deposition - materials



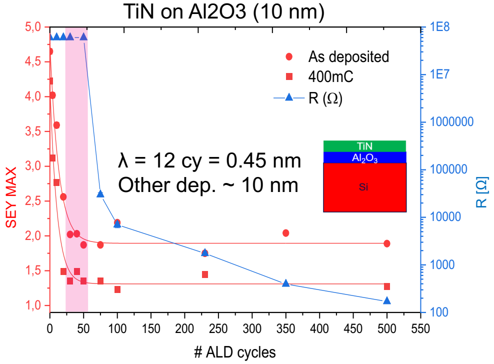
Materials for this project: Al2O3, Y2O3, ZrN, AlN, TiN, NbTiN, NbN, MoN

Secondary electron yield – Mitigate multipacting



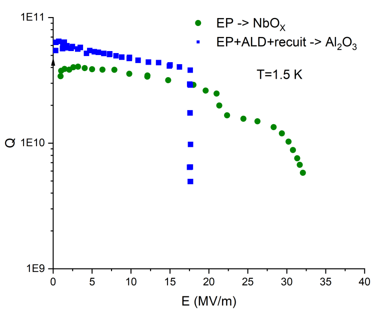


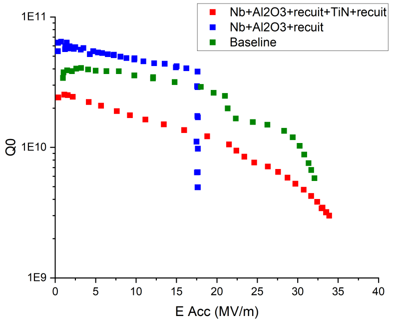
CEA-ONERA



- ➢ Control thickness and chemical composition – uniformity
- ➢ Tune SEY and electrical conductivity
- ➢ Wide variety of substrates (Nb, Cu…)

From coupons to cavities



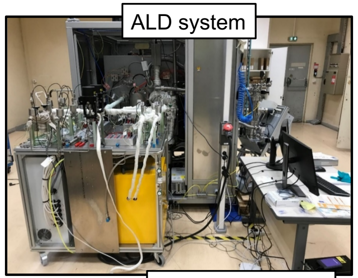


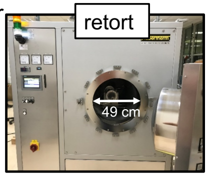
- ➢ Replacing NbOx by Al2O3 increase the Q
- ➢ TiN successfully mitigated the multipacting in RF cavity

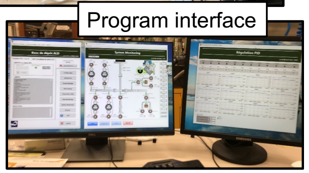
Atomic layer deposition for SRF cavities, Thomas Proslier (CEA)

Cavity dedicated ALD apparatus

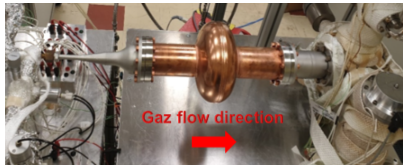
- High vacuum oven:
  - 650°C – 10^{-6} mbar / 900°C 1bar N_2
  - Volume retort: Φ = 49 cm, L= 110 cm (Cavities sizes > 0.6 GHz)
- ALD system:
  - 9 precursor lines (2 gases, 2 liquids, 4 solids, 1 Ultra high temp.).
  - RGA synthesis monitoring.
- Interface and control:
  - Labview program of ALD system and Oven.
  - Automatic synthesis parameter control and monitoring.
- Status:
  - Deposition tests on samples
  - Future: Deposition on cavities

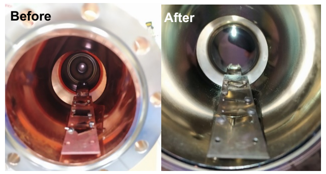






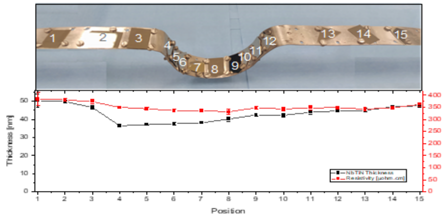
From coupons to cavities

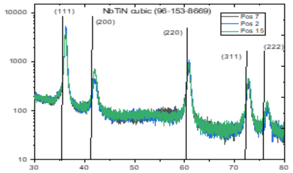




Test 2 : purge 20s

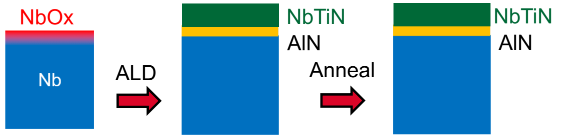
GIXRD diffraction patterns on different samples

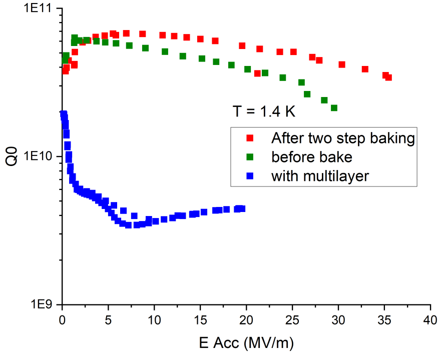


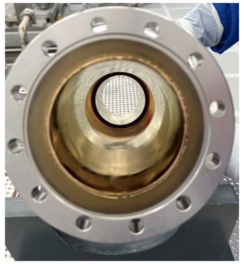


- Optimized deposition parameters on RF cavities
- Homogeneous deposition (thickness, Tc and structure) over 1,3 GHz Nb and Cu test cavity.

From coupons to cavities







- First attempt: Lower Q and Emax
- Unexpected behavior during annealing on SRF cavity.
- Work in progress.

Conclusion-Perspectives

Summary:

- ✓ SEY: ALD of TiN film is promising to reduce multipacting inside RF cavities.
- ✓ Mitigate Multipacting on SRF cavities 1,3 GHz.
- ✓ Growth of NbTiN and the multilayers AlN/NbTiN by ALD with good superconducting properties, homogeneous composition and thickness control over large surface areas (RF cavities).
- ✓ RF Test of multilayer AlN-NbTiN on a SRF cavity.

Future Goals :

- SEY: Test again the Al_2O_3-TiN structure on Niobium RF cavities.
- Multilayer: Test again the NbTiN-AlN structure on Niobium RF cavities.
- Doping: Test ALD doping procedure on SRF cavityies
- New directions:
  - ALD on Copper complementary to HIPIMS: insulating barrier - Nucleation and thermo- currents (CERN collab).
  - ALD for detectors/optics.

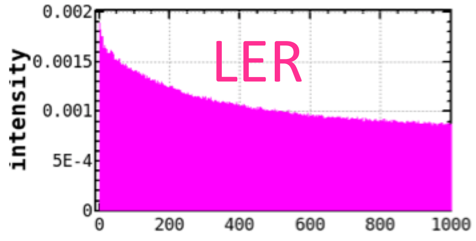
WG12: Infrastructures, Cryogenics, Commissioning & Operation, Yukiyoshi Ohnishi

Y. Funakoshi, "Overview and prospects of the SuperKEKB commissioning"

Message from SuperKEKB: We try to achieve 10^{35} $cm^{-2}s^{-1}$ in one or two years after the first long shutdown (LS1).

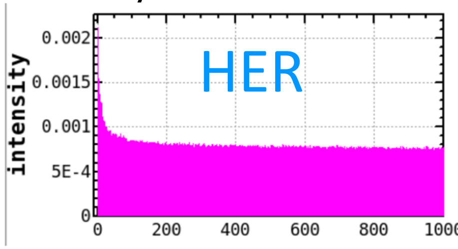
"Sudden Beam Loss" must be solved and higher injection efficiency is necessary to achieve the first milestone.

Injection beam charge measured by TBT- BPM



10ms

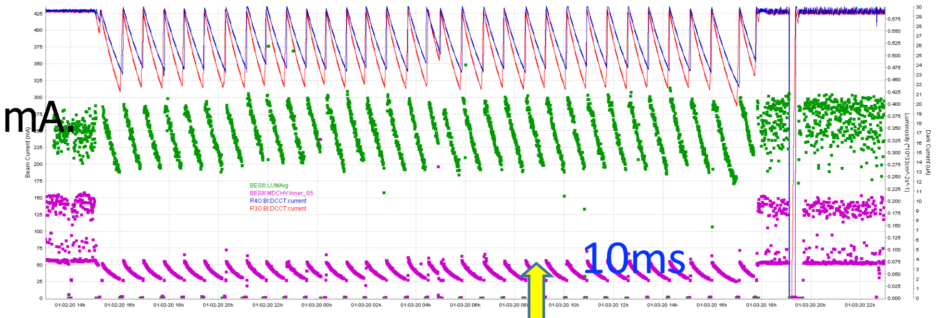
Injection efficiency: ~50%



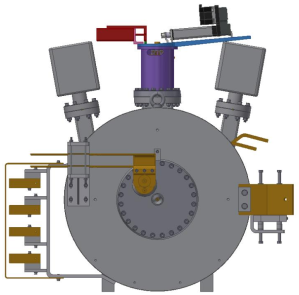
Injection efficiency: ~36%

C. H. Yu, "Commissioning of the top-up injection in the collision operation of BECPII"

The commissioning of top-up injection began from May 7, 2019.
The top-up injection was realized with beam energy > 2.2 GeV and less than 600 mA.
The top-up operation can be 33 % higher luminosity than the decay operation.



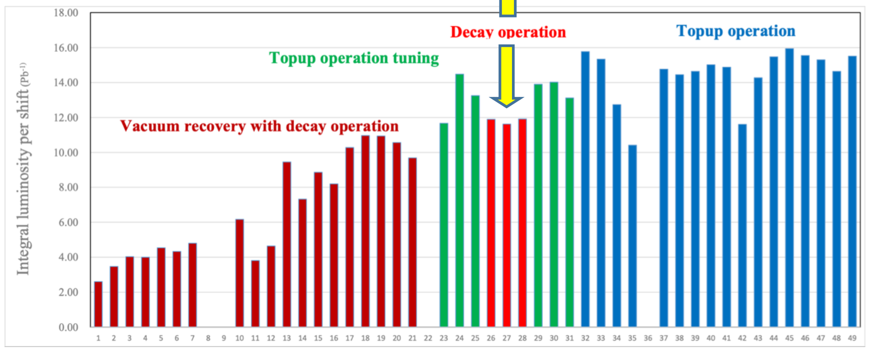
The beam switching time is shortened from 12s to 3.5s.
The drive device is chosen as electric linear actuator for its high stability and reliability.



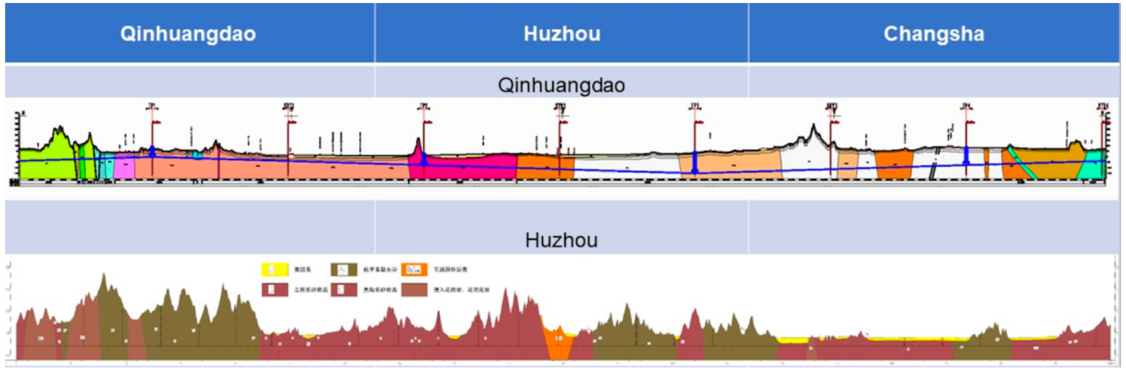
Topup / **Decay**

15.94 pb^{-1} / **11.92 pb^{-1}**

integral luminosity 33% higher

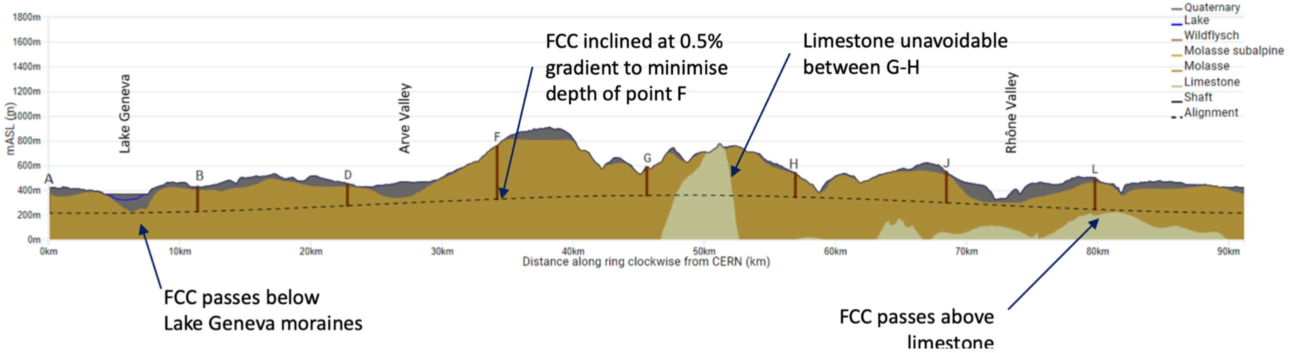


Yu Xiao, "CEPC infrastructure and auxiliary facility"

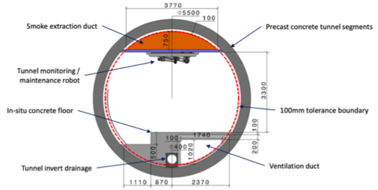


Shaft depth is 100 m - 200 m.
How to choose the site is still open question.

Liam Bromiley, "FC-ee civil engineering and infrastructure studies"



Shaft depth is 140 m - 400 m.



PAPS
Platform of Advanced Photon Source

Rui Ge, "Cryogenics technology development for CEPC in China"

Key technology: 2K JT heat exchanger R&D

Relevant aspects have been considered including the process scheme, layout, and key equipment design.

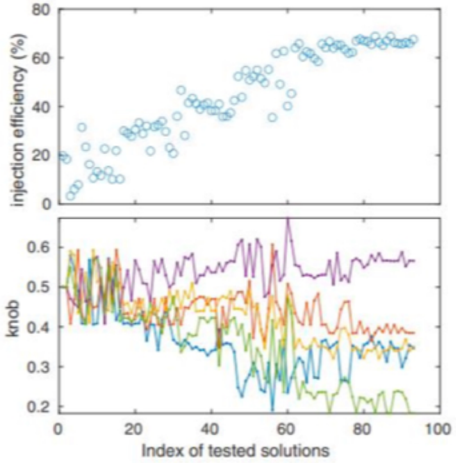
We still need to greatly push forward the work, and complete the TDR design on time.

Xiaobiao Huang, "Methods and experiences of automated tuning of accelerators"

Beam-based optimization: to turn knobs to minimize or maximize the performance measure

Machine is considered a black box.

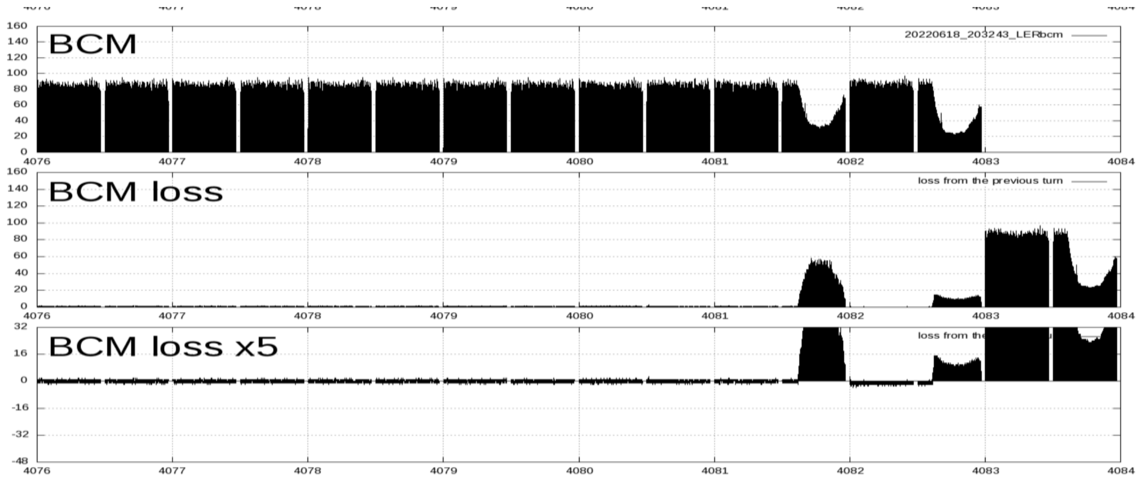
Machine state measurements and knowledge of the system could be used to improve optimization efficiency (depending on algorithms) .



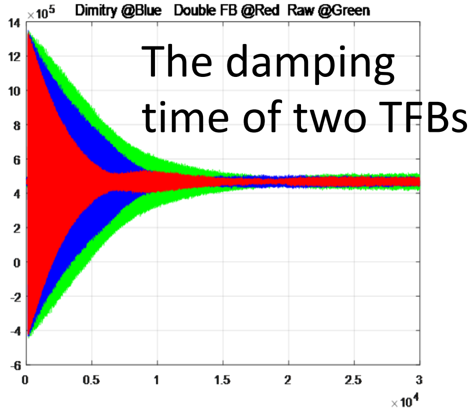
APS DA optimization with MG-GPO

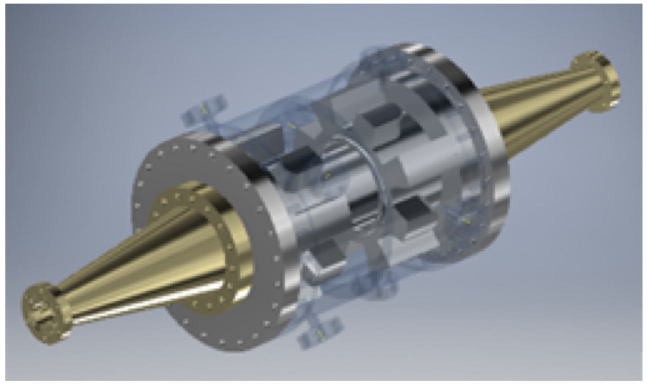
Beam Instrumentation WG7 Summary (selected topics by Manfred Wendt)

- H. Ikeda: SuperKEKB beam instrumentation
  - SR monitors, BLMs
  - Unexplained sudden beam losses
    - Appears in both rings HER & LER
    - Within a single turn
    - High damage potential, collimators, QCS quench, large bg. to Belle-II



- Y. Sui: CEPC beam instrumentation
  - Challenging systems: BxB FB, BPMs, bunch size & length, BxB electronics
  - Yanfeng gave many details on trans. and long. FB, BxB and narrowband
    - To fight resistive wall coupled bunch instabilities and HOM CBI





Pillbox cavity with ridged waveguides type kicker

- D. Gassner: EIC beam instrumentation
  - Challenges: Large scale system - BPMs: quantity, variety, requirements
    Pandemic-related, e.g., chip shortage, raw materials, manpower & staffing
  - BxB BPMs with narrow bunch spacing, 5 & 10 ns, ADC peak detection
  - Crabbing angle measurements

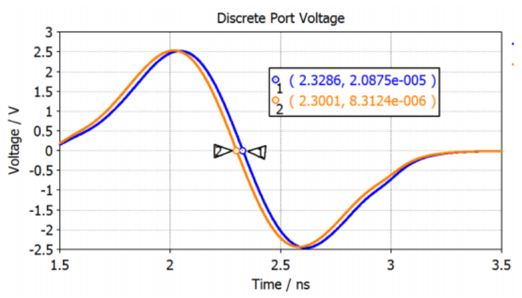


Figure 4: Particle Studio output for the two, opposite, horizontal PUEs when using a 60 mm diameter BPM with 10 mm diameter PUEs with a simulated crabbed bunch input described in Fig. 3.

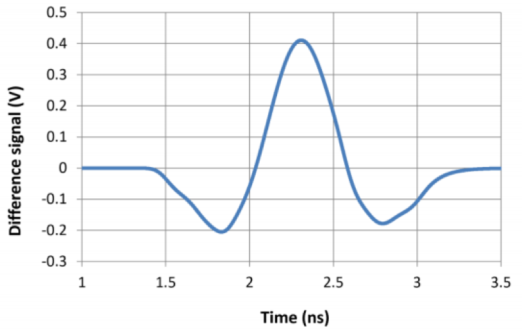
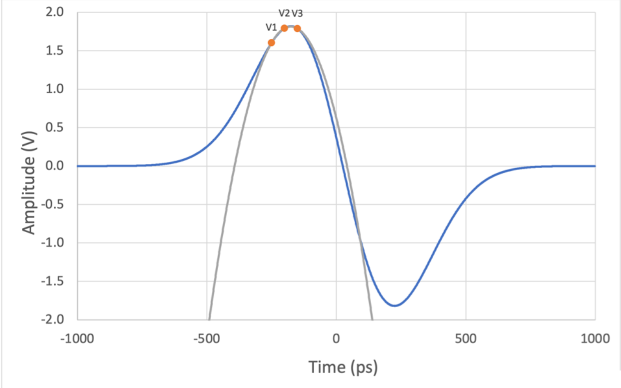
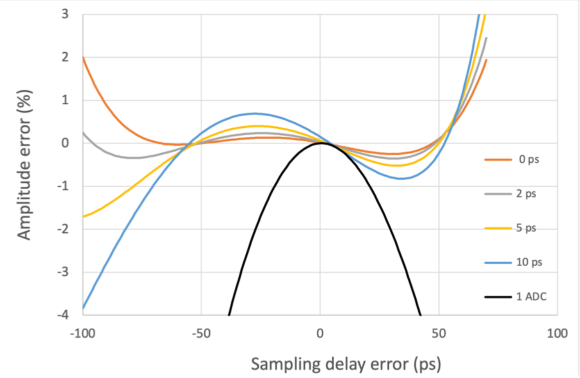


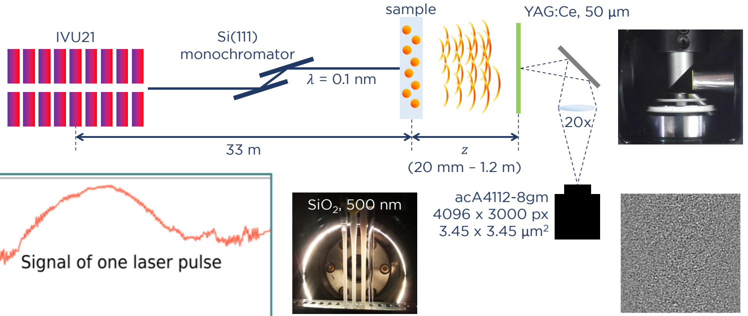
Figure 5: Difference signal obtained by using the simulation output shown in Fig. 4.

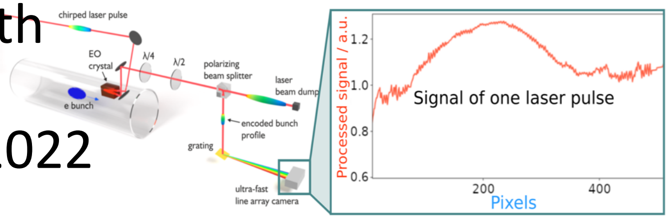


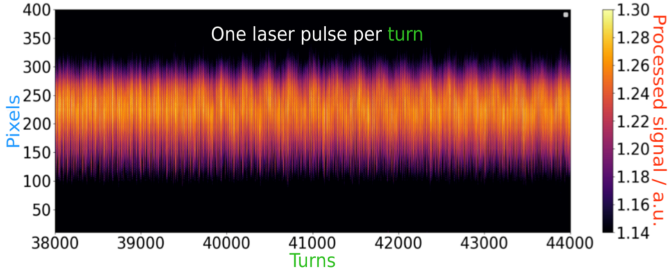


- M. Wendt: FCC-ee beam instrumentation
  - Challenges: BPMs, BLMs, beam size, bunch length
    communication, manpower, budget
  - FCC-ee BI Mini-Workshop@CERN, 21.-22. Nov. 2022
    - Identify FCC-ee BI requirements
      and most critical R&D activities
  - Discussion: BI cost profile for e+/e- collider?
    - 5% of the total costs? With or w/o tunnel costs?

The HNFS setup at NCD (ALBA)







EOS Near-Field at KARA

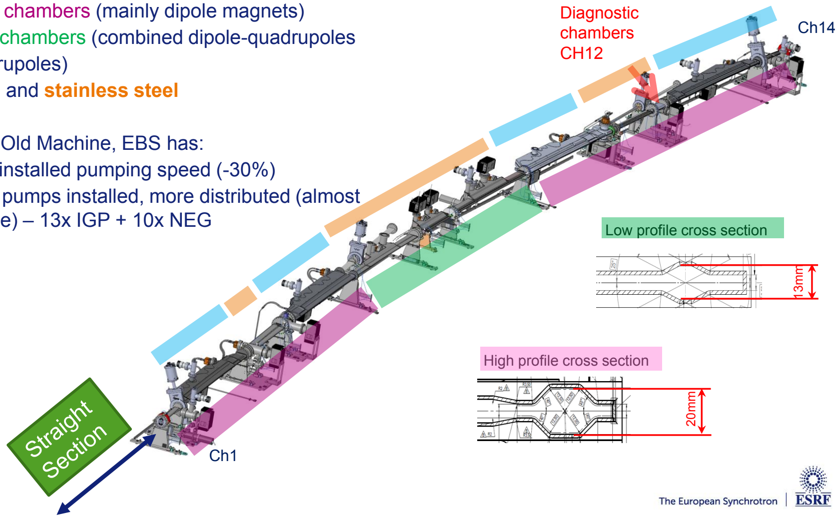
Turn-by-turn single bunch profile measurements

WG9 vacuum , Cristian Maccarrone, ESRF

DESIGN - VACUUM CHAMBERS - ARC

- 12 Chambers per arc
- High profile chambers (mainly dipole magnets)
- Low profile chambers (combined dipole-quadrupoles & HG quadrupoles)
- **Aluminium** and **stainless steel**

- Respect to Old Machine, EBS has:
  - Less installed pumping speed (-30%)
  - More pumps installed, more distributed (almost double) – 13x IGP + 10x NEG



ASSEMBLY – COATING CH1 & CH14 (AND ID CHAMBERS)

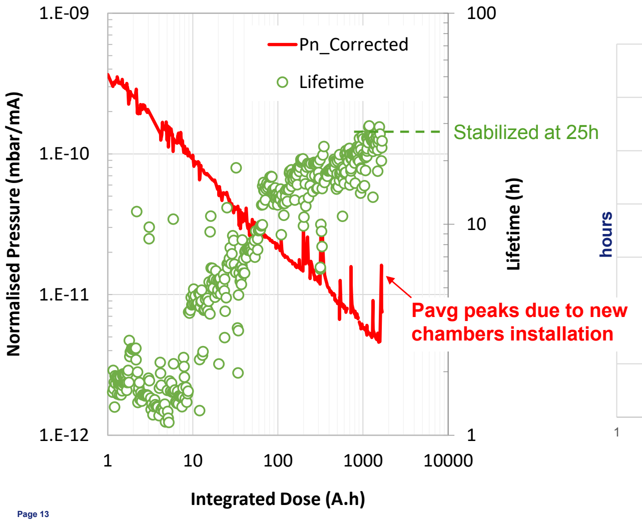
CH-1 and CH-14

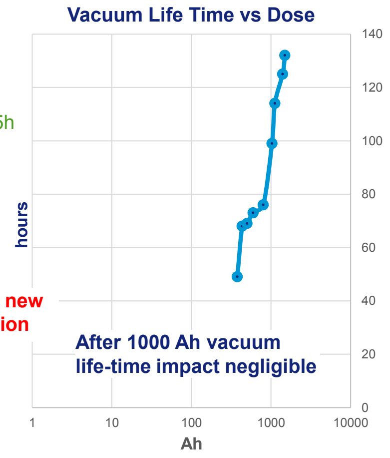
- All chambers (34+34) NEG coated at ESRF
- 2x chambers per run
- One week each run roughly

ID

- All IDs chambers (22) - All 5m long

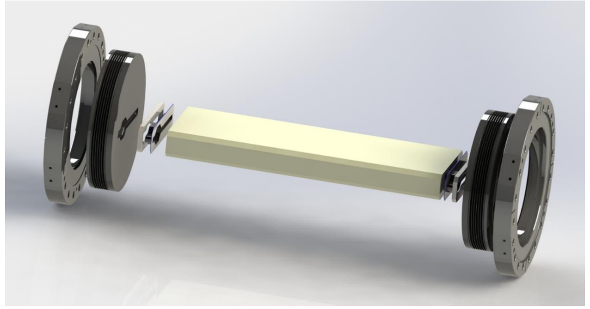
CONDITIONING - LIFETIME

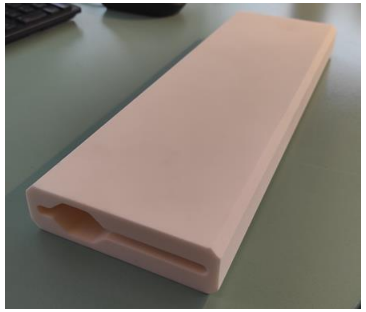




OPERATION – KICKERS' NEW-DESIGN

- No glazing joints (single body)
- Common design for all 4x kickers (today we have one design for K1K4 and one K2K3)
- Production challenging due to internal shape
- **Installation foreseen by summer 2023**

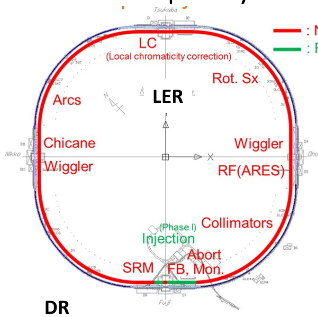


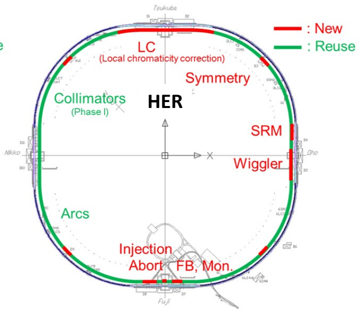


WG9: Status report of vacuum system in SuperKEKB Vacuum, T. Ishibashi KEKB

Vacuum System

- In LER, ~93% of beam pipes and bellows chambers in length, and pumps were renewed.
- In HER, ~82% of them and pumps were reused.
- DR was completely newly constructed.





DR

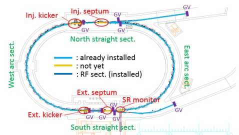
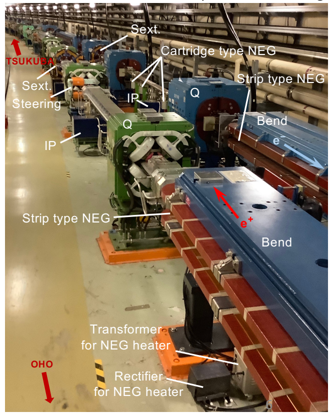


Photo of an arc-section in SuperKEKB main ring

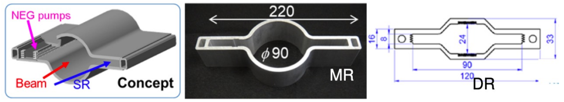


Vacuum System – New Components

[Y. Suetsugu *et al*, J. Vac. Sci. Technol. A 30, 031602 (2012)]

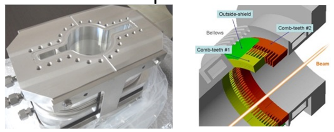
Beam pipes with antechambers

- Effective to reduce photo electrons



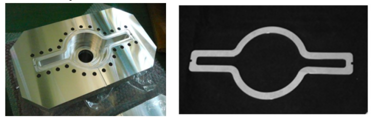
Bellows chambers and gate valves with comb-type RF-shield (MR)

- High thermal strength
- Low beam impedance



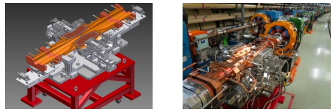
Step-less connection flange (MR)

- No RF-shield finger between flanges
- Adaptable to various cross sections



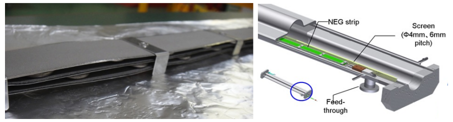
Movable collimator (MR)

- Key component to suppress the detector backgrounds and protect the machine components from beam out of control



Multi-layer of NEG strips ST707 (MR arc) as a main pump

- Installed into an antechamber
- Activation by micro-heaters embedded between the layers
- Ave. pumping speed of 0.14 $m^3 s^{-1} m^{-1}$ for CO including screens between the pump and beam



Vacuum System – New Components (measures against ECE)

- Countermeasures against electron cloud effect (ECE)
  - ECE is a critical issue for the LER and DR. [Y. Suetsugu, "Mitigation of e-cloud effects in SuperKEKB", eeFACT2022, WG4]
  - Based on various R&D results in KEKB and other institutes, various countermeasures were prepared. [Y. Suetsugu *et al*, Phys. Rev. Accel. Beams 22, 023201 (2019)]

Summary of countermeasures for LER (MR)

Sections	L [m]	L [%]	Countermeasure	Material
Drift space (arc)	1629	54	TiN coating + Mag. field	Al (arc)
Steering mag.	316	10	TiN coating + Mag. field	Al
Bending mag.	519	17	TiN coating + Grooved surface	Al
Wiggler mag.	154	5	Clearing Electrode	Cu
Q & SX mag.	254	9	TiN coating	Al (arc)
RF section	124	4	(TiN coating +) Mag. Field	Cu
IR section	20	0.7	(TiN coating +) Mag. field	Cu
Total	3016	100		

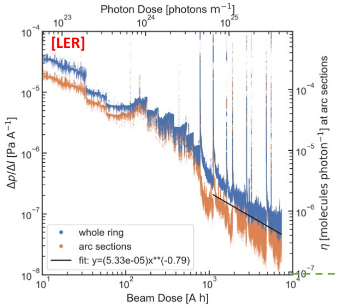
For DR

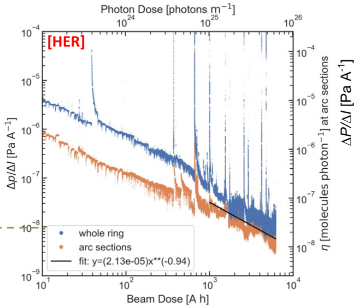
- antechambers with grooved structure at side-wall.
- TiN film coating
- Grooved surfaces on the upper and lower sides of the beam channel (in B-magnets).
- Material: Al

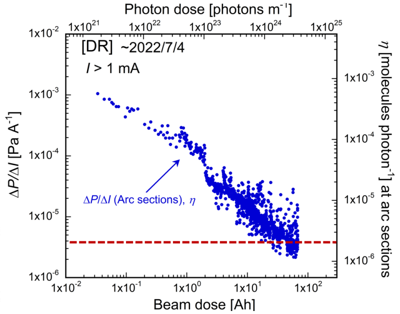
- Expected average e^- density: ~2×10^{10} electrons m^{-3} (MR), ~1.3×10^{13} electrons m^{-3} (DR)
- Less than the threshold estimated by simulations.

Status – Vacuum Scrubbing

- *ΔP/ΔI* vs beam dose (photon stimulated desorption (PSD) coefficient η vs photon dose, 2016-2022).
  - LER: η decreased to less than 3×10^{-7} molecules photons^{-1}, at a photon dose of 3.87×10^{25} photons m^{-1}.
  - HER: η is lower than LER. For arc section (reused beam pipes), η is now 2×10^{-8} molecules photons^{-1}, at a photon dose of 5.74×10^{25} photons m^{-1}. → memory effect
  - DR: η is decreasing steadily. For arc section, η decreased to 2×10^{-6} molecules photon^{-1}, at a photon dose of 3.47×10^{24} photons m^{-1}.



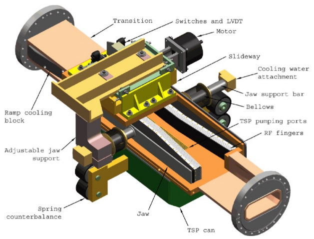




WG9: Status report of vacuum system in SuperKEKB Vacuum, T. Ishibashi KEKB

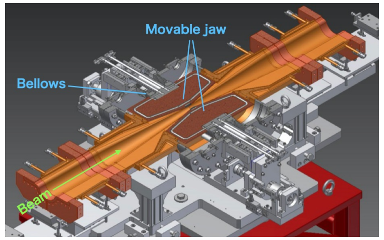
Experiences – Collimator

- We referenced movable collimators for PEP-II in SLAC for the basic design of the SuperKEKB type.
- A collimator chamber has two movable jaws, which are placed the horizontal/vertical direction.
- Part of the movable jaws is hidden inside the antechambers to avoid a trapped mode in gaps between the movable jaw and the chamber.
- The chamber is tapered to the center of the collimator in order to avoid excitation of trapped-modes.
- Materials at the tip of the jaws are tungsten (1st ver.), tantalum (2nd ver.), carbon (low-Z, special ver.), and hybrid (C+Ta, special ver.).

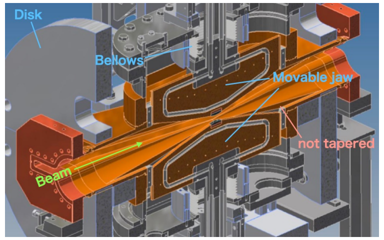


Collimator in PEP-II

[S. DeBarger et al., SLAC-PUB-11752]



Horizontal direction

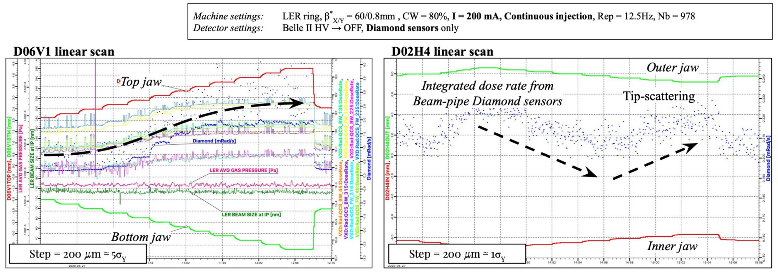


Vertical direction

SuperKEKB type collimator

Experience – Collimator BG suppression

- The SuperKEKB type collimators have been working well as expected up to the beam current of ~1.4 A in LER without abnormal temperature rises and discharges.
- These collimators have been indispensable in terms of the background suppression in Belle II, avoid quenches in final focusing superconducting quadrupole magnets (QCS).

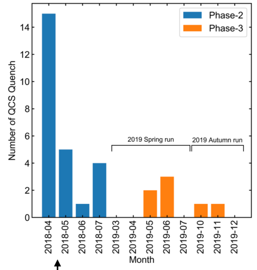


Opening the primary LER V-collimator we see an increase of the IR background rate.

Closing the LER H-collimator we observe an increase of the IR background rate → tip-scattering.

[Andrii Natochii *et al.*, Phys. Rev. Accel. Beams 24, 081001 (2021)]

Number of QCS quenches derived from beam loss in QCS (monthly).



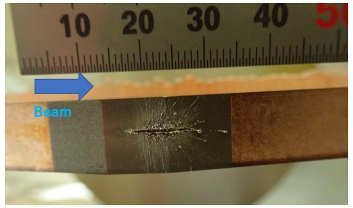
Collimator adjustment was done in earnest

Experiences – Collimator Damage

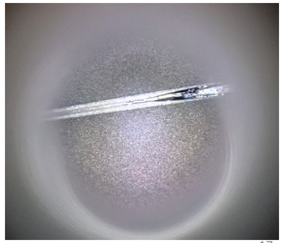
- The collimators have been frequently damaged due to beam hits.
- The source of beam instability that causes damage to the vertical collimators is still unknown (named sudden beam loss). If the collimators are severely damaged, we cannot continue the physics run because of the high background level.
- On the other hand, there are damaged events for known reasons, and that is the damage to a horizontal collimator (D06H3) caused by accidental-firings of injection kickers in LER. As countermeasures against this,
  - Carbon jaws will be installed in D06H3 and used as a spoiler of the crazy beams.
  - D06H1 will move to D06H4 and used as an absorber of the crazy beams.

Damaged jaw of D06H3 in LER due to the accidental-firings

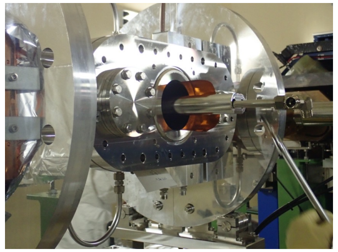
Damaged jaw of D02V1 in LER due to the sudden beam loss

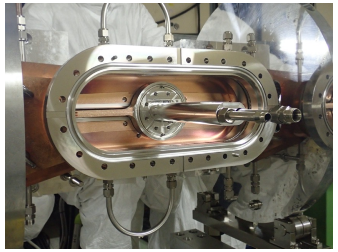


Damaged tip of D09V1 (KEKB type) in HER due to the sudden beam loss

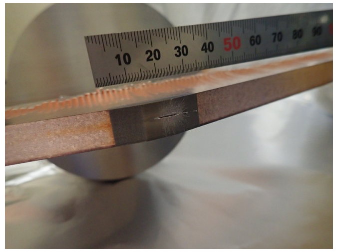


Replacement Work

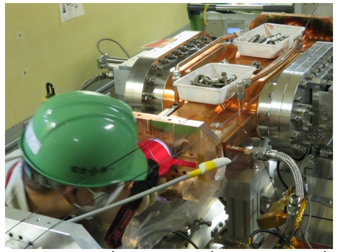




Remove the racetrack type flanges in which the jaws are inserted.



Remove the damaged jaws.

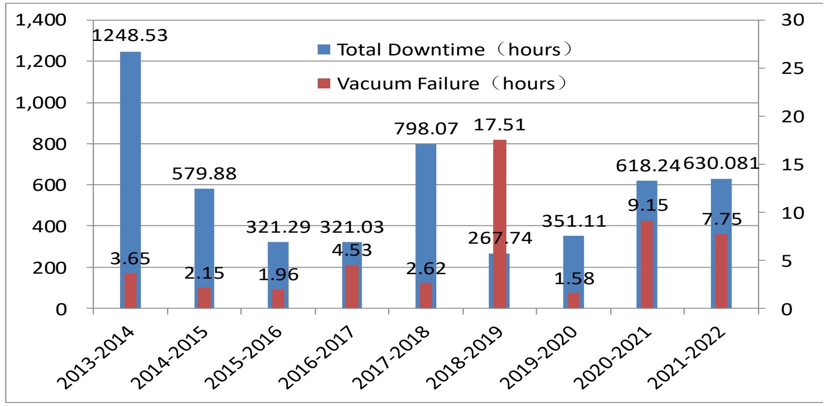


(← this photo shows a cleaning work for D06H3. I was not able to find the photo for D02V1.)

Clean the inside of the flange and chamber to remove deposits such as activated dust.

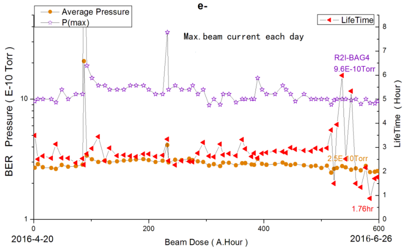
WG9: The operation conditions of BEPCII Storage Ring vacuum system, Guo Dizhou

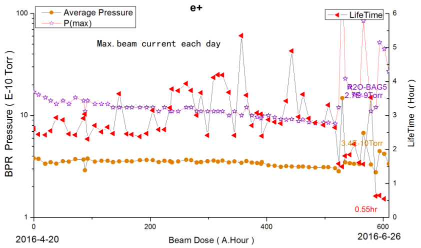
Total downtime and vacuum failure time in recent years

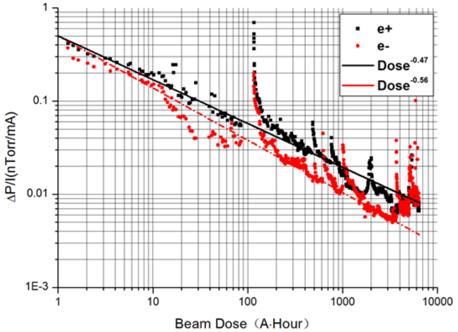


- Since 2013, only a few downtime due to vacuum failure every year, and it is on the decline.
- Several vacuum systems exposed to the atmosphere are due to RF(coupler ceramic), magnet(kicker), beam measurement(DCCT) system failures.

Dynamic pressure operating state of the storage ring



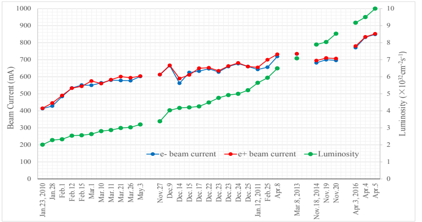


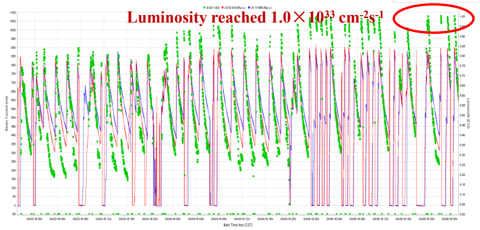


- Pav<6x10^{-10}Torr (1.89GeV)
- The average pressure after each exposed atmosphere is higher, but it can recover quickly.
- The double-ring ΔP/I vs Beam Dose curve showed an exponential decrease (e - (-0.56)/e + (-0.47)).
- Colliding luminosity reached the design target 1.0×10^{33} cm^{-2}s^{-1}。

Luminosity reached 1.0×10^{33} cm^{-2}s^{-1} @1.89GeV 850mA Apr.5.2016 22:29

- April 5, 2016, Colliding luminosity of 1 x 10^{33}cm^{-2}s^{-1},successfully reached the design index. This means the performance of the collider reaches 100 times before the transformation.





2016/04/05 22:29:47

Luminosity	10.00	E32/cm^2/s
	e+	e–
Energy [GeV]	1.8831	1.8831
Current [mA]	849.18	852.31
Lifetime [hr]	1.53	2.30
Inj.Rate [mA/min]	0.00	0.00

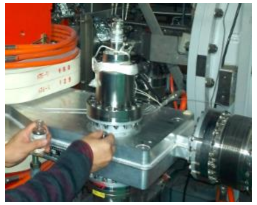
Damage finger of RF bellow:

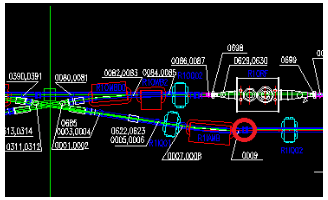
Burnt contact finger

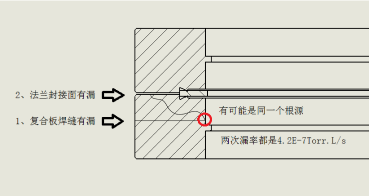
Compressed contact finger

Leak on Al-SST composite plate flange :

- The nearby vacuum was worse from 2×10^{-10}Torr to 1.5×10^{-9}Torr, ion current increased to 8uA.
- The leak was located on weld of Al-SST composite plate flange.

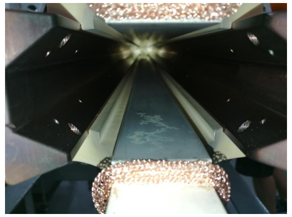


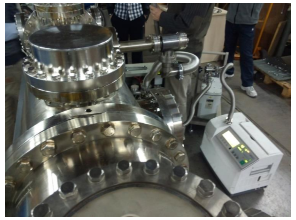


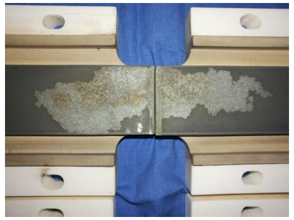


Actually
- We used vacuum glue on weld and flange sealing surface respectively in different time.
- Same leak rate ~ 4.2×10^{-7}Torr .L/s.

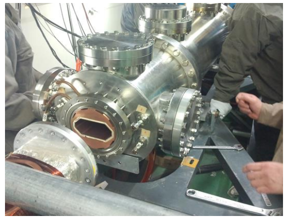
- The faulty kicker was replaced.
- Beam wakefield lead to the failure of coating.







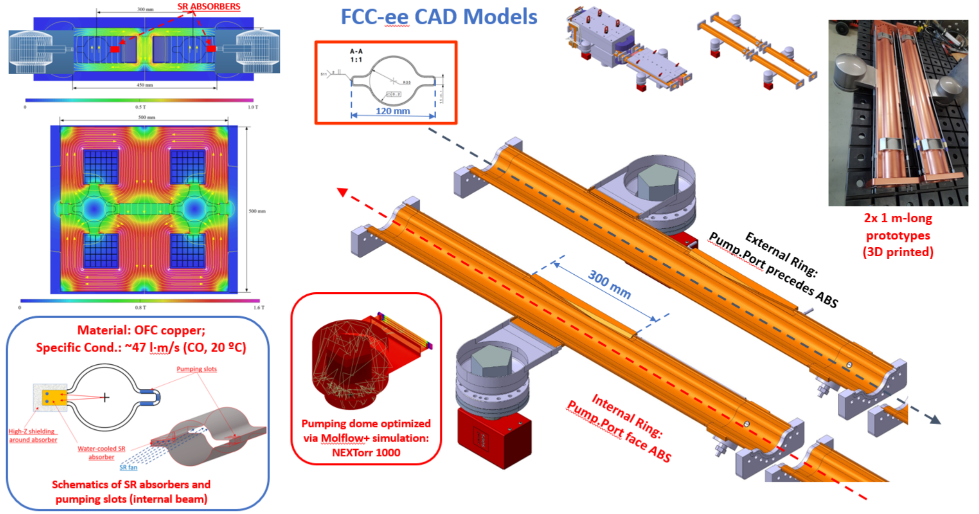
Broken Coating



New Kicker

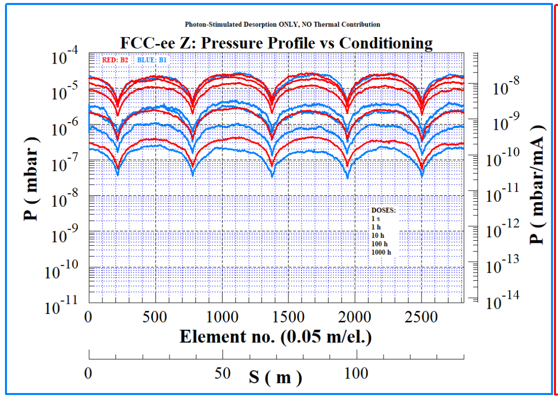
WG9: Vacuum System of the FCC-ee, R. Kersevan, TE Dept., CERN

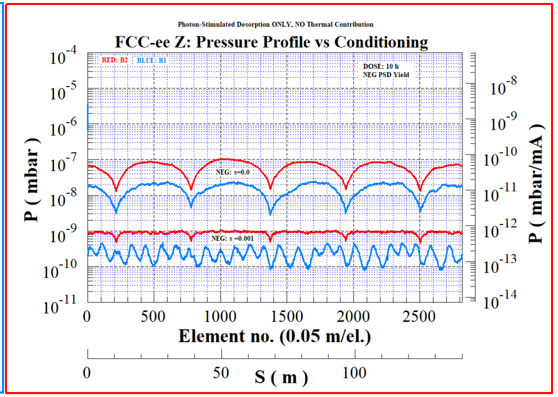
Pumping solutions



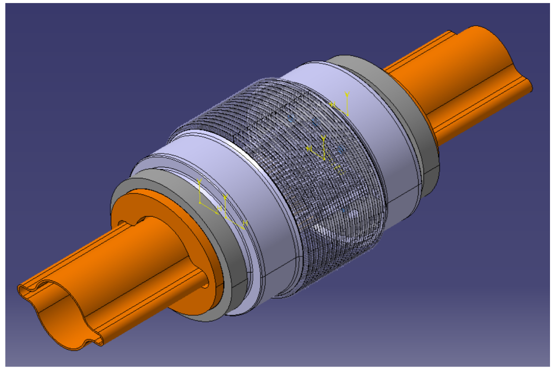
Pressure profiles

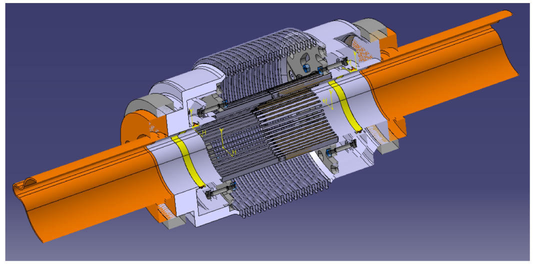
- **We have calculated the PSD pressure profiles for 5 different beam doses, corresponding to times of 1 s, 1 h, 10 h, 100 h, 1000 h. Simulated gas: CO**
- **On the left the case with 5x 100 (l/s) lumped pumps/beam, and no NEG-coating**
- **On the right, the case with NEG-coating, saturated (i.e s=0) and with some residual sticking (*s*=0.001)**





Development of RF contact fingers and bellows

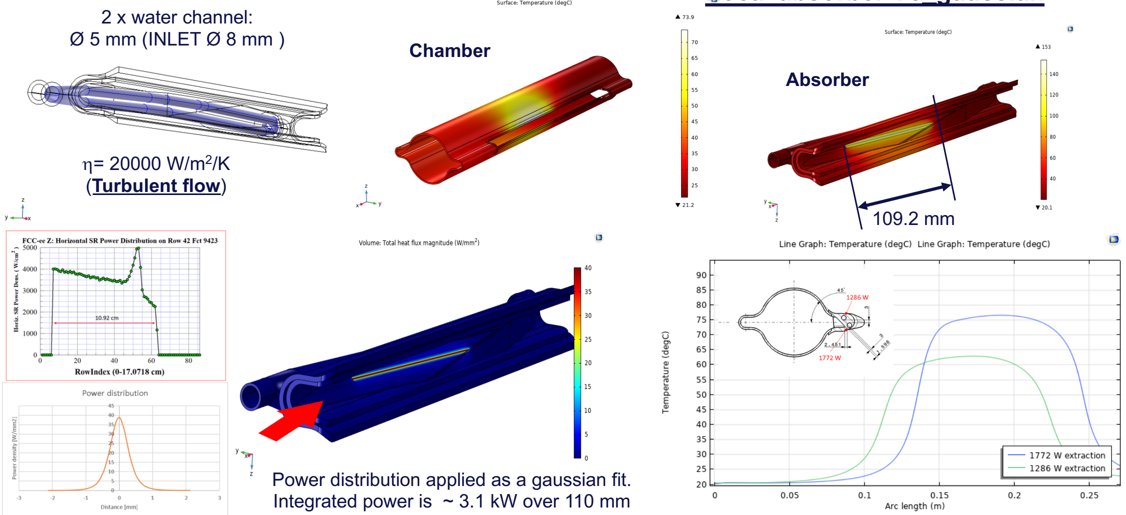




Courtesy S. Rorison, CERN

Thermomechanical analysis SR absorbers (courtesy M. Morrone, CERN)

Local absorber V5_gaussian



Power distribution applied as a gaussian fit.
Integrated power is ~ 3.1 kW over 110 mm

WG9: Vacuum System of the FCC-ee, R. Kersevan, TE Dept., CERN

Prototyping, experiments, as per FCC Week 2021 PRESENT STATUS/PLANS

1. **Design prototype vacuum chambers with and without SR absorber (~ 2 m-long) and test them at light source (KARA/KIT?) UNDERWAY**
2. **Test behavior of thin NEG-coating at light source SCHEDULED EXPERIMENTS TO TEST REFLECTIVITY AT "BEAR" BEAMLINE, ELETTRA LIGHT SOURCE, TRIESTE, Sept-Oct 2022**
3. **Define deposition technique for dipolar ~ 12 m-long vacuum chambers (horizontal sputtering with mole?, other techniques?) DESIGN OF 12 m-LONG COATING BENCHES UNDERWAY**
4. **In-situ measurement of photoelectron yield at light source CONCURRENTLY WITH No.2**
5. **Test other thin-films with potential application to FCC-ee: amorphous carbon (a-C), hydrophobic silicon films (to reduce pump down time without bakeout); test surface texturing techniques (e.g. LASE) WILL PRODUCE SEVERAL 2m-LONG PROTOTYPES FOR KARA's "BESTEX" TEST STAND OR OTHER FACILITY**
6. **Determine material and fabrication technology of SR absorbers and bonding technique to the vacuum chamber (surface power density above 100 W/mm^2 at the ttbar energy) UNDER DESIGN & THERMAL ANALYSIS, SEE NEXT SLIDES**
7. **Design, fabricate, and test bellows with RF fingers, under elongation and misalignment conditions similar to those expected for FCC-ee, BPM blocks SEVERAL DESIGN OPTIONS UNDER ANALYSIS, SEE NEXT SLIDES**
8. **Continue collaboration with FLUKA team (see B. Humann/F. Cerutti), magnet group, tunnel integration working group, and machine optics group (plus MDI) TO BE RESUMED, IMPLEMENTING NEW 92 km LATTICES**

We have come to the conclusion that the aggressive experimental program with large integrated luminosity values within a rather short amount of time (4 yrs for the Z-pole starting from an unconditioned machine) require two things:

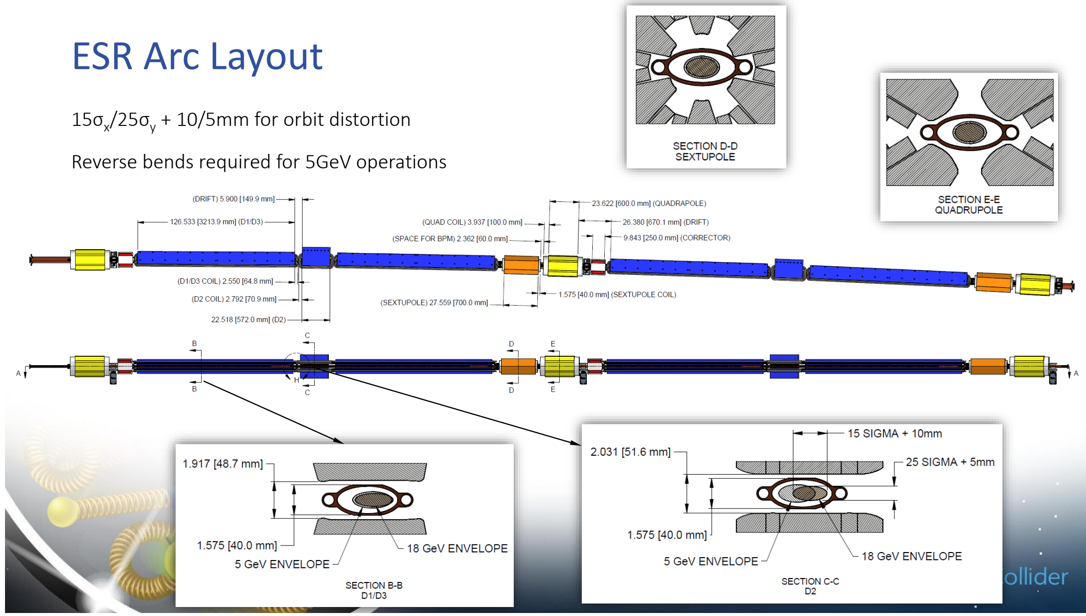
1. **NEG-coating of the chamber**
2. **Localized ("lumped") SR absorbers**

WG9: Vacuum Systems of EIC, C. Hetzel, BNL

ESR Arc Layout

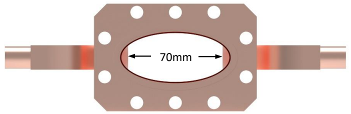
$15\sigma_x/25\sigma_y$ + 10/5mm for orbit distortion

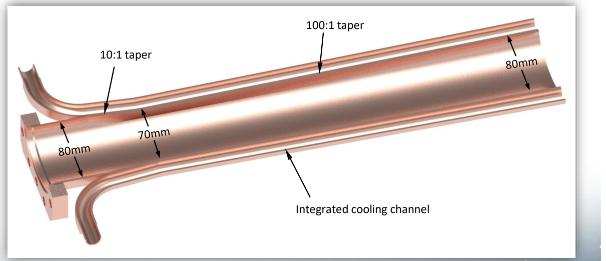
Reverse bends required for 5GeV operations



Integrated Photon Absorber

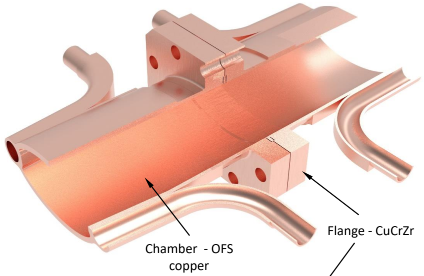
- Mechanical deformation to profile
- Shallow tapers
  - 100:1 on forward side, 10:1 on rear side
- Single layer between heat and cooling water
- Some distortion to vertical profile expected
- Tooling development required

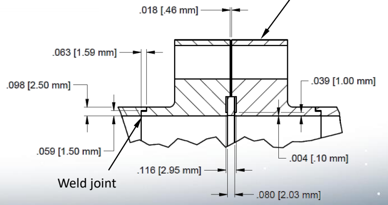




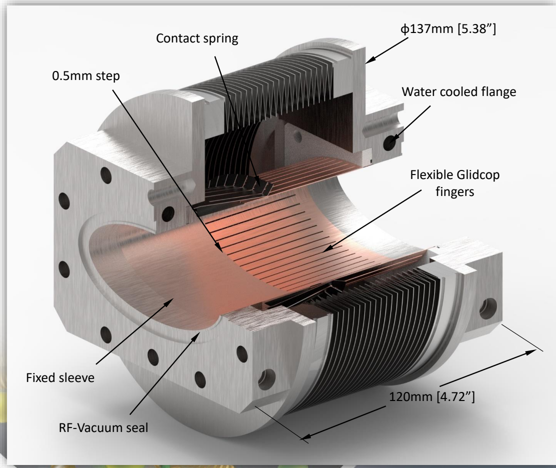
Chamber Flange

- Flanges welded to extrusions
  - Retain hardness of seal surface (R_B = 65 min)
  - ¼ hard copper gaskets (R_B = 25 max)
- Oversized bolt holes
- Common flange geometry
- Final gasket dimension to be developed
  - 'Bulging' of material into beam channel





ESR RF Shielded Bellows Requirements

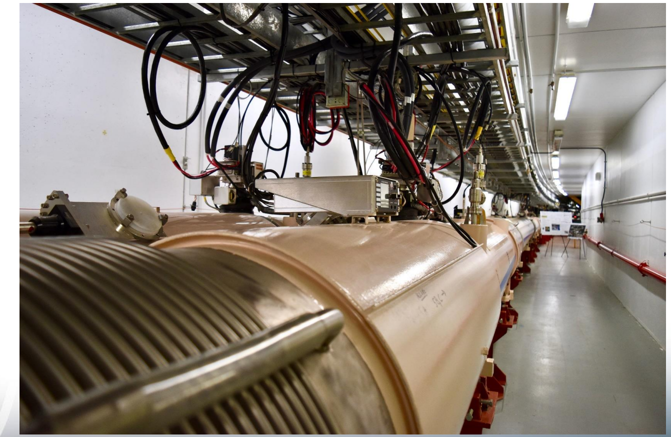


- Combination RF-Vacuum seal
- 30W beam induced heating
- Compact footprint
- Stroke Req: -25/+10mm
  - Cell length variation: +/-5mm
  - Compression: -15mm
  - Extension: +3mm
  - Chamber length: +/-2mm
  - Alignment: +/-1mm
- Radial offset: +/-2mm
- Angular offset: +/-0.5° [8.7mrad]

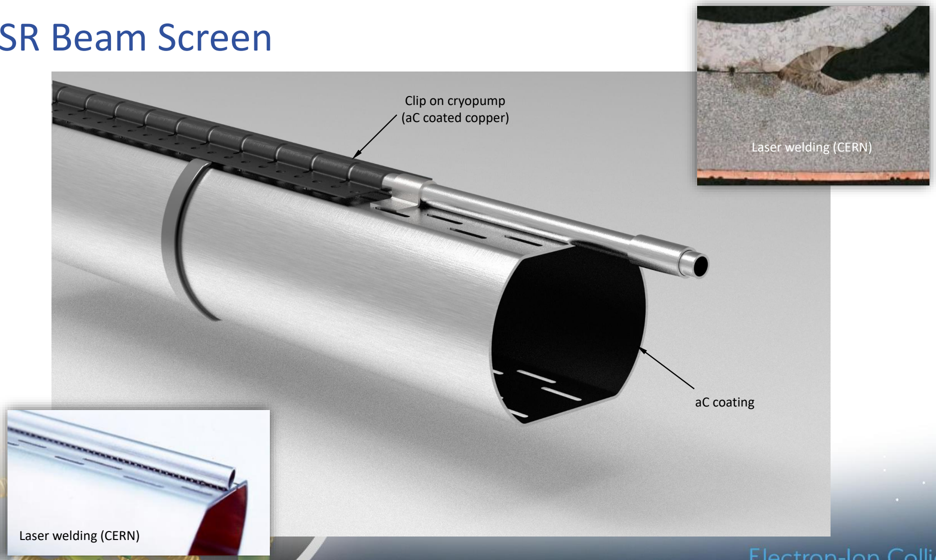
WG9: Vacuum Systems of EIC, C. Hetzel, BNL

Hadron Storage Ring - HSR

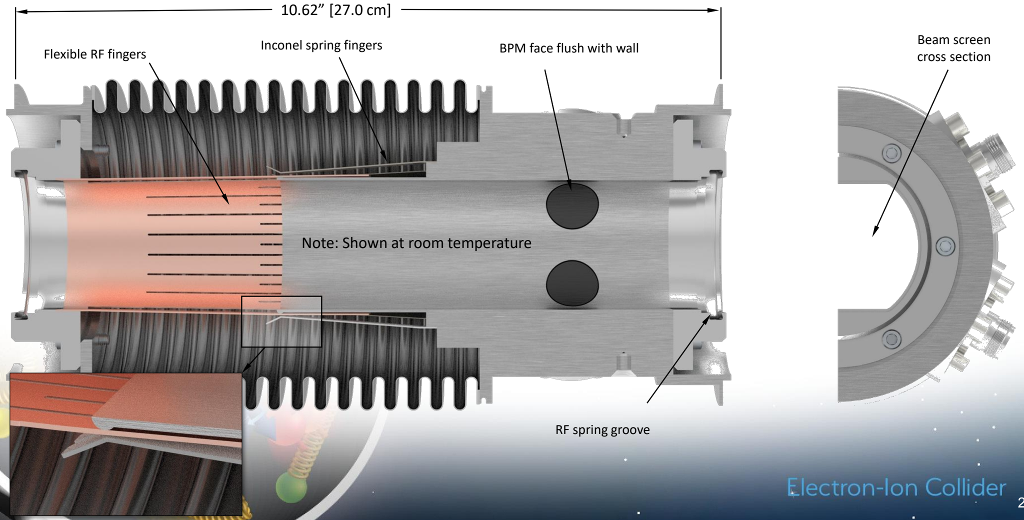
- Beam screen
  - Resistive wall heating
  - Reduction of SEY
- Replace RF bellows
- Replace stripline pickups



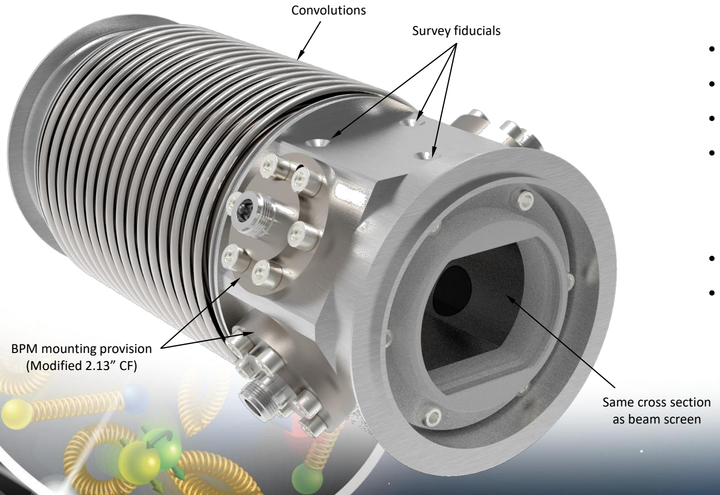
HSR Beam Screen



HSR Bellows/BPM Module



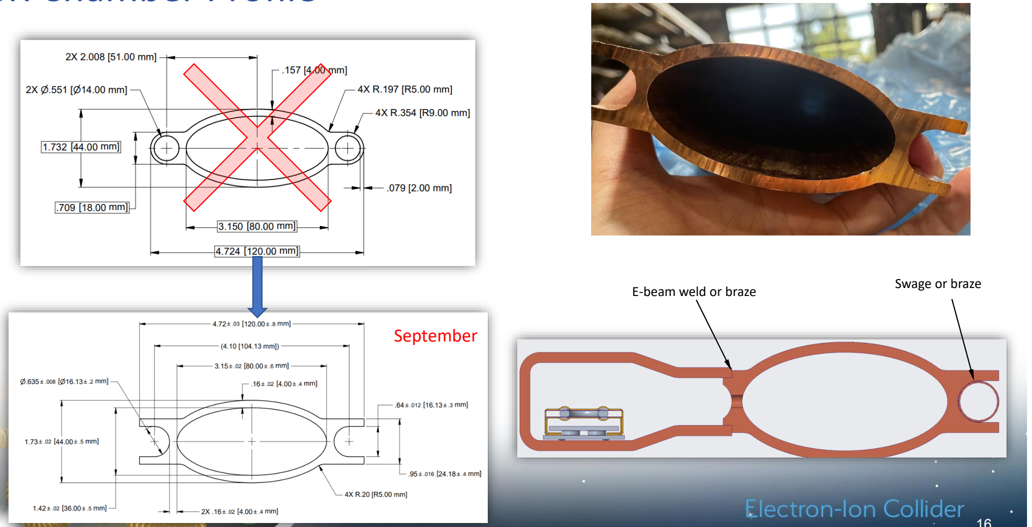
HSR Bellows/BPM Module



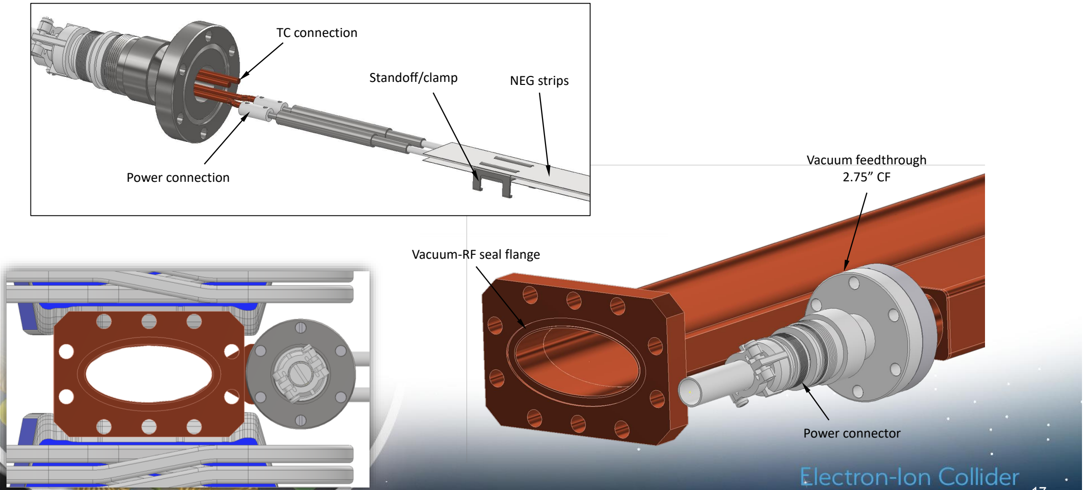
- Fit existing interconnect space
- RF Interface with beam screen
- 30W beam induced heating
- Stroke Req: 50mm
  - Compression (Install): -16mm
  - Extension (cool down): +26mm
  - Interconnect length: +/-4mm
- Radial offset: +/-6mm
- Angular offset: +/-1° [17mrad]

WG9: Vacuum Systems of EIC, C. Hetzel, BNL

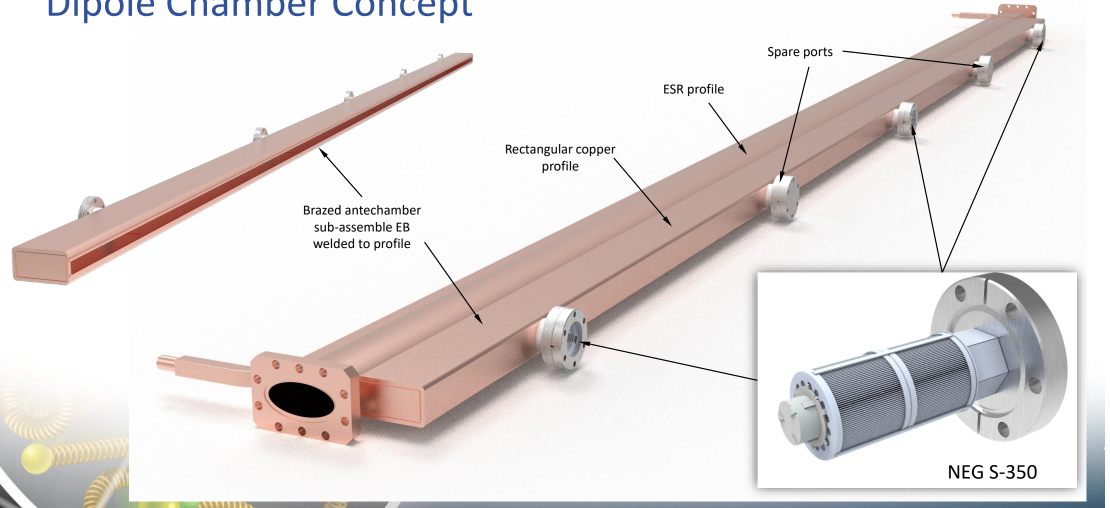
ESR Chamber Profile



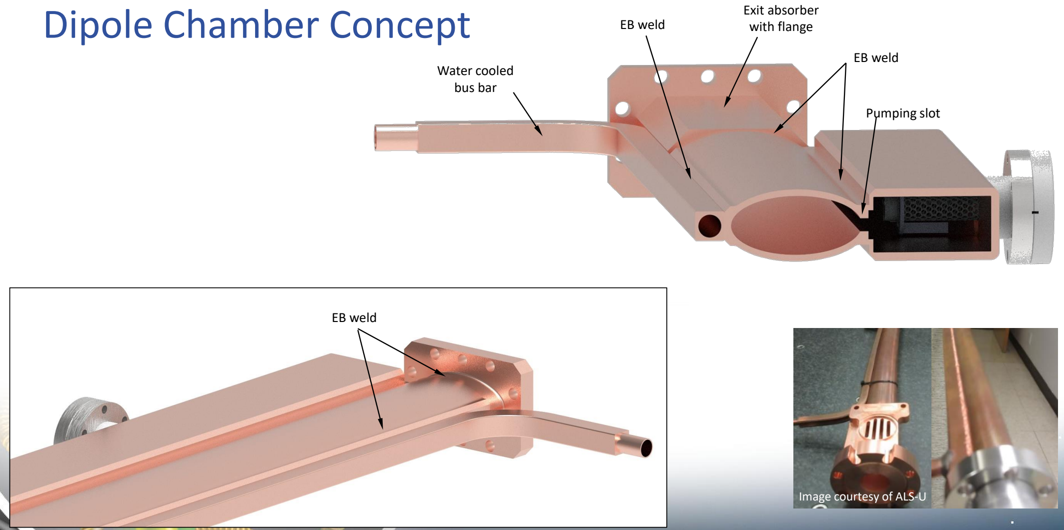
NEG Pump Concept – Resistive Wire Heater



Dipole Chamber Concept



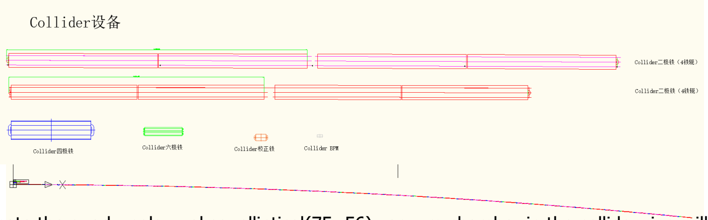
Dipole Chamber Concept



WG9: CEPC Vacuum System, Yongsheng Ma, IHEP

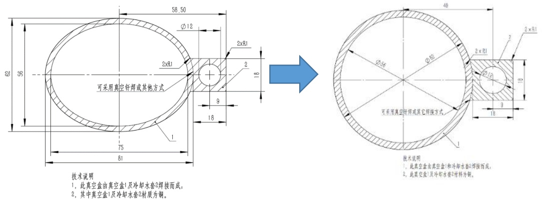
Progress R&D: Vacuum chamber

- Due to the length of the magnet, the maximum length of the vacuum chamber is obout 11.3 meters, and the shortest length is about 3.8 meters.



Wang YW
LI MX

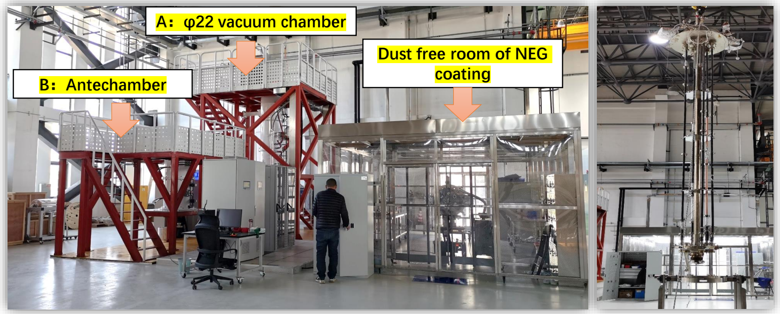
- To eliminate the quadrupolar wakes, elliptical(75×56) vacuum chamber in the collider ring will be replaced by circular chambers with dimeter of 56 mm



NEG coating facility synergy of HEPS

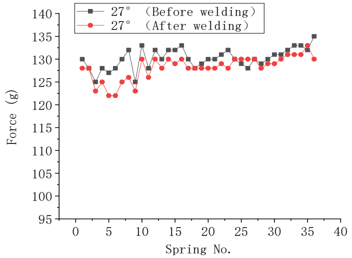
☐ NEG coating of vacuum pipe

A setup of NEG coating which has ability to coat 4 meters long pipe has been built for vacuum pipes of HEPS at location of PAPS. And several test vacuum pipes of 4 meters long, φ22 mm of inner diameter have been coated, which shows that NEG film has good adhesion and thickness distribution. Theoretically, It is easier to be coated of CEPC vacuum pipe, because of the ratio of diameter to length is 56/6000 which is bigger then 22/4000.



R&D of RF shielding bellows

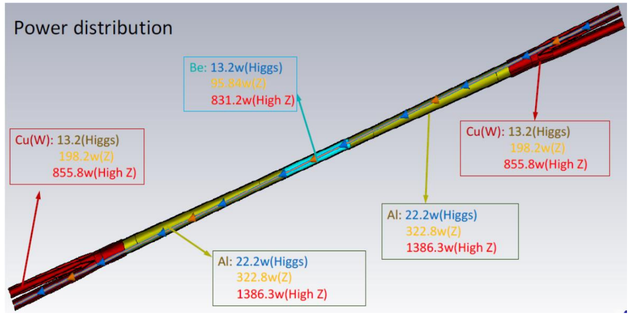
- **Vacuum bellow modules are needed to compensate the mechanical misalignments of the vacuum chambers during installation and to absorb their thermal expansion during the bake-out. In order to reduce the beam impedance during operation with beams these modules are equipped with RF bridges to carry the image current.[1]**
- **The key components experiments such as spring fingers and contact fingers have been carried out. Contact force is uniformly from different fingers and meets the target of 125±25g. The prototypes of RF shielding bellows have been fabricated in local company.**



MDI vacuum

◆Conception design

- OFE copper or Tungsten alloy will be used to made the fork vacuum chamber of MDI
- NEG coating is suggested to the fork vacuum chambers
- Water cooling pipe is designed due to the high thermal load of impedance at high light Z model.

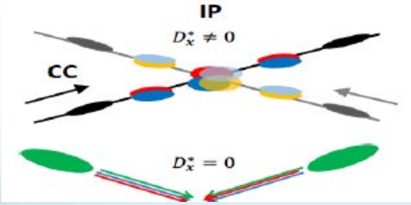


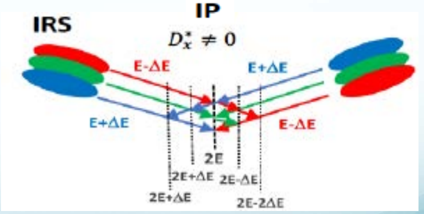
WG13: Monochromatization, Angelas Faus-Golfe, Honping Jiang

Overview of monochromatization in e+e- colliders

Monochromatization in FCC-ee

Given the **FCC-ee IR design**, two **monochromatization schemes** are possible. **Crossing angle** monochromatization scheme featuring **IP dispersion of opposite signs** for the colliding beams with **crab crossing** (**CC**) and without or **integrated resonances scan** (**IRS**).





Summary and perspectives

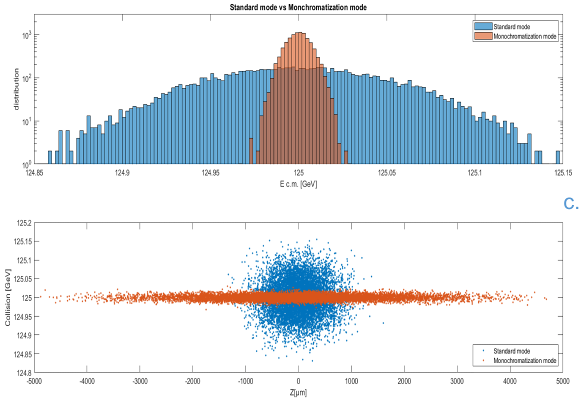
- Monochromatization is a simple conceptual idea but not easy to implement in a collider, if not integrated from the beginning in the optics IR design.
- Given the fact monochomatization has never been tested experimentally, a flexible lattice with two modes of operation with/without monocromatization is advisable.
- Monocromatization optics with IR LOC Dipoles is ongoing.
- New ideas are being investigated.

First optics design for a transverse monochromatic scheme for the direct s-channel Higgs production at FCC-ee collider

The transverse monochromatic scheme

- The transverse monochromatic scheme(Guinea-Pig simulation results)

Monochromatization:
$D^*x=\pm0.2m$
c.m. Energy spread
6.9MeV



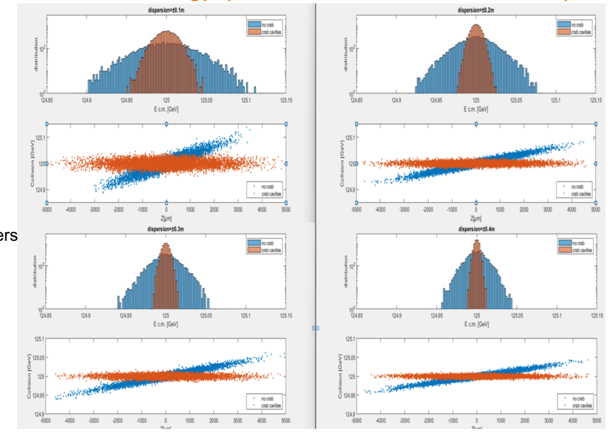
Standard:
$D^*x=0$
c.m. Energy spread
46MeV

The trade-off between luminosity and center-of-mass energy spread

- The monochromatic scheme reduces the c.m. energy spread but decreases the luminosity.

Guinea-pig simulations:
The relationship between luminosity and c.m. energy spread for different D_x^*= 0.1, 0.2, 0.3, 0.4m

The initial beam distribution:
Generated by mathematica with parameters shown in FCC-ee parameters table and different D_x^*



Summary of summaries

- A lot of impressive work since the last eeFACT meeting!
- New and innovative RF solutions are still being developed.
- SuperKEKB and LHC are providing essential lessons.
- Forward planning such as Snowmass and European strategy emphasize R&D, facilities, workforce development, collaborations and energy efficiency.
- New materials and processes are essential for realizing ambitious new projects, R&D now will make that possible (needs funding!).
- High efficiency RF sources are becoming reality, including klystrons and SSA’s
- Beam instrumentation and diagnostics should be planned ahead, not an afterthought.
- Vacuum design relies more and more on advanced materials and coatings. (NEG, amorphous Carbon, beam screens etc.), e.g. ESRF
- Several approaches to Monochromatization, needs more study.
- **Thanks to workshop organizers, speakers and participants!**