Impedance optimization for eRHIC

A. Blednykh
Accelerator Physicist
June 19, 2019

U.S. DEPARTMENT OF ENERGY | Office of Science
BROOKHAVEN NATIONAL LABORATORY

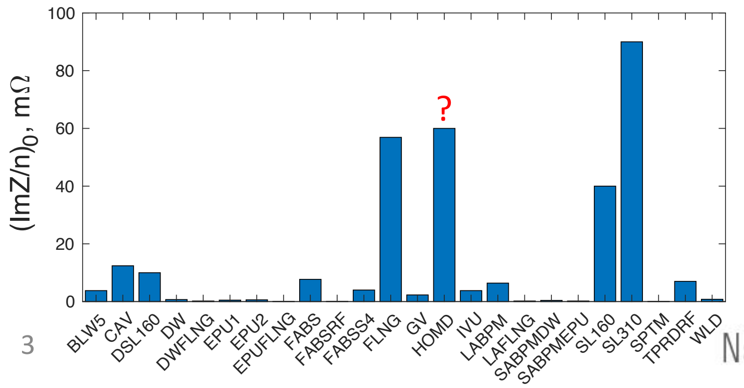
Outlook

- **Impedance modeling and collective effects analysis**
  - **$ReZ_{||}(\omega)$ at high frequencies (microwave instability), $ImZ_{||}(\omega)$ at low frequencies (bunch lengthening)**
- **Beam related heating**
  - **$ReZ_{||}(\omega)$ at low frequencies (vacuum components heating), resistive wall and geometric impedance.**

NSLS-II Impedance Budget $\sum(ImZ_{||}/n)_0$

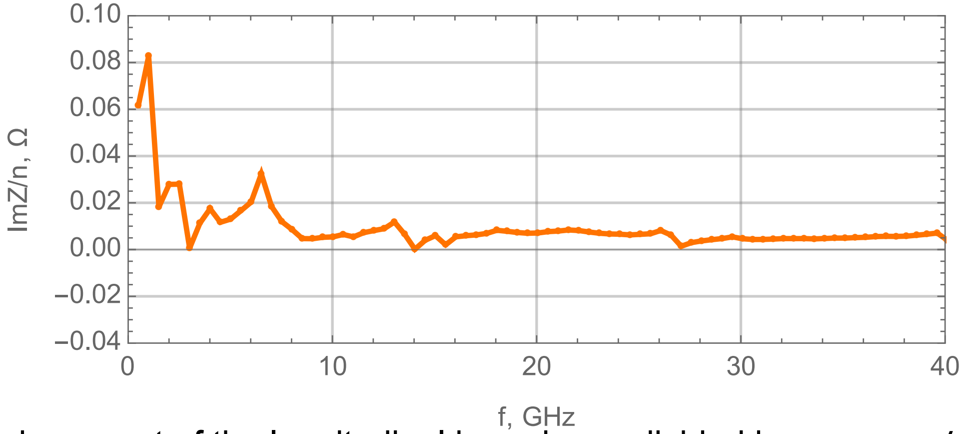
Name of components		Number of components	$\sum(ImZ_{\|\|}/n)_0$ $m\Omega$
Bellows 5in	BLW5	218	3.8
Bellows 6in	BLW6	?	?
Large Aperture BPM	LABPM	237	6.4
Small Aperture BPM (11.5mm x 60mm)	SABPMDW	10	0.4
Small Aperture BPM (8mm x 55mm)	SABPMEPU	3	0.2
Damping Wiggler Chamber (11.5mm x 60mm)	DW	3	0.7
Elliptically Polarized Undulator Chamber (11.5mm x 60mm)	EPU1	2	0.5
Elliptically Polarized Undulator Chamber (8mm x 55mm)	EPU2	2	0.6
Gate Valve (Standard)	GV	61	2.3
Flange Absorber (21mm x 64mm)	FABS	67	7.7
Flange Absorber S4 (21mm x 64mm)	FABSS4	39	4.0
Flange Absorber Rest	FABS2	7	TBD
Stripline (BBF), L=310mm	SL300	2	90
Standard RF Sealed Flanges	FLNG	739	56.9
EPU RF Sealed Flanges	EPUFLNG	4	0.07
DW RF Sealed Flanges	DWFLNG	13	0.2
Direct-Current Current Transformer	DCCT	1	TBD
Kickers Ti-Coated Ceramics Chambers	CCHM	5	TBD
Stripline (TMS), L=160mm	SL150	2	40
In-Vacuum Undulator	IVU	9	3.8
Septum Chamber	SPTM	1	0.05

Name of components		Number of components	$\sum(ImZ_{\|\|}/n)_0$ $m\Omega$
RF Straight Section			
RF HOM Damper	HOMD	2	60
500 MHz RF Cavity*	CAV	2	12.4
RF Tapered Transition	TPRDRF	1	7
RF Flange Absorber (21mm x 64mm)	FABSRF	1	0.1
Medium Aperture Gate Valve (Ø12mm)	MEGV	1	
Medium Aperture RF Sealed Flanges (Ø122.68mm)	MEFLNG	4	
Large Aperture Gate Valve (Ø240mm)	LAGV	2	
Large Aperture RF Sealed Flanges (Ø240mm)	LAFLNG	9	0.2
Large Aperture Bellows (Ø240mm)	LABLW	3	
Welding joints	WLD	240	0.8
Diagnostic Stripline, L=160mm	DSL	1	10
Total:			**308.1**



eRHIC Impedance Budget $\sum(ImZ_{||}/n)_0$

Name of components		Number of components	$\sum(ImZ_{||}/n)_0$ $m\Omega$
Bellows 5in	BLW5	380	
Large Aperture BPM	LABPM	494	
Stripline	SL	18	
Gate Valve	GV	45	
Flange Absorber	FABS	200	
RF Cavity	CAV	23	
RF Tapered Transition	-		TBD
IR Chamber	-		TBD
Pumping Slot	PMPSLT	500	TBD
Crab Cavity			TBD



Imaginary part of the longitudinal impedance divided by $n = \omega/\omega_0$, where $\omega_0 = 2\pi \times 78.186\ kHz$.

Table 3.14: Parameters used for threshold calculation.

Parameter	Value
Energy E [GeV]	10
Revolution period T_0 [μsec]	12.79
Momentum compaction α	1.45×10^{-3}
Energy loss U [keV]	9100
RF voltage V [MV]	41
Synchrotron tune ν_s	0.0815
Damping time τ_x, τ_s [msec]	70, 35
Energy spread σ_δ	5.5×10^{-4}
Bunch length σ_s [mm]	19

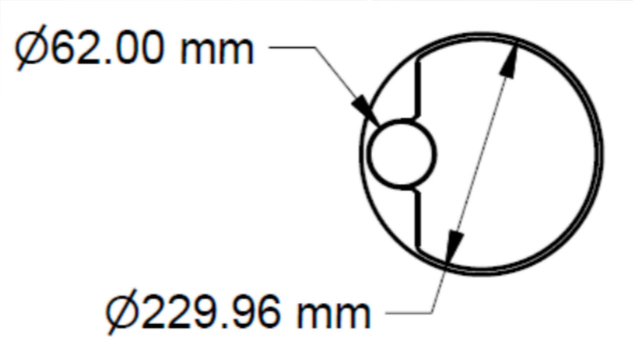
Average Current: $I_{av} = 2.48A$

Number of Bunches: $M = 660$

$$P_{loss} = k_{loss} I_{av}^2 T_0 / M$$

eRHIC (2.5A)	APS-U (0.2A)	KEKB (1A)	NSLS-II (0.4A)
$k_{loss} \times 24620$	$k_{loss} \times 3068$	$k_{loss} \times 4000$	$k_{loss} \times 402$
$\sigma_s = 20mm$	$\sigma_s = 20mm$	$\sigma_s = 4mm$	$\sigma_s = 5mm$
$M = 660$	$M = 48$	$M = 2500$	$M = 1050$

eRHIC Very Rough IR Chamber Design



- The power loss is $Ploss = 22.6\ kW$ for $M = 660$ bunches and $Iav = 2.48\ A$. Most of this heating is a result of the large step transitions which needs to be optimized.

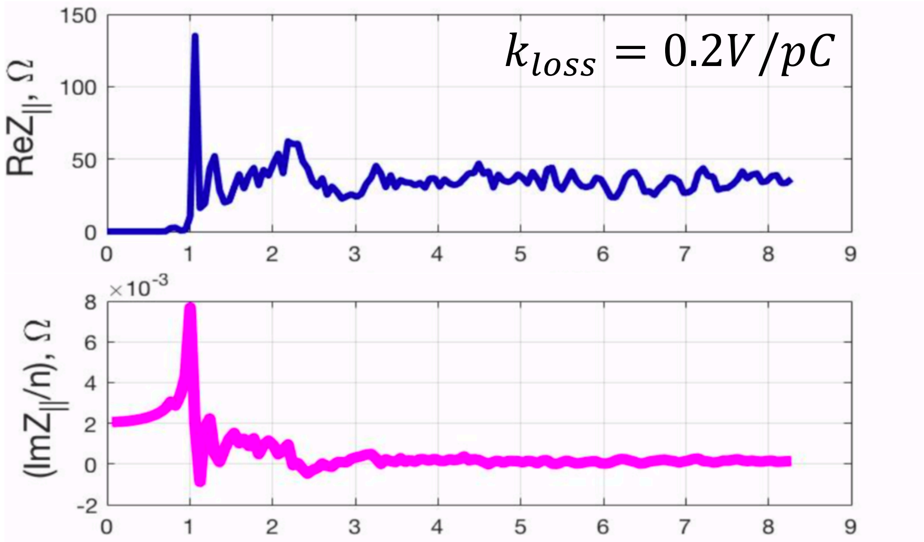
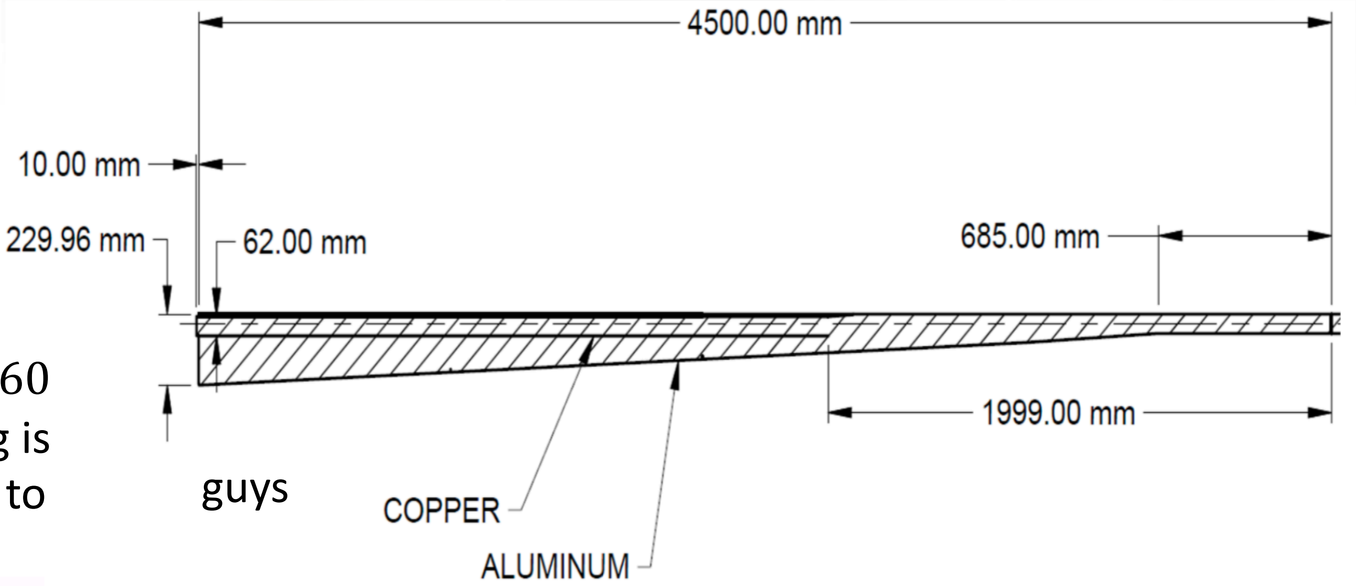
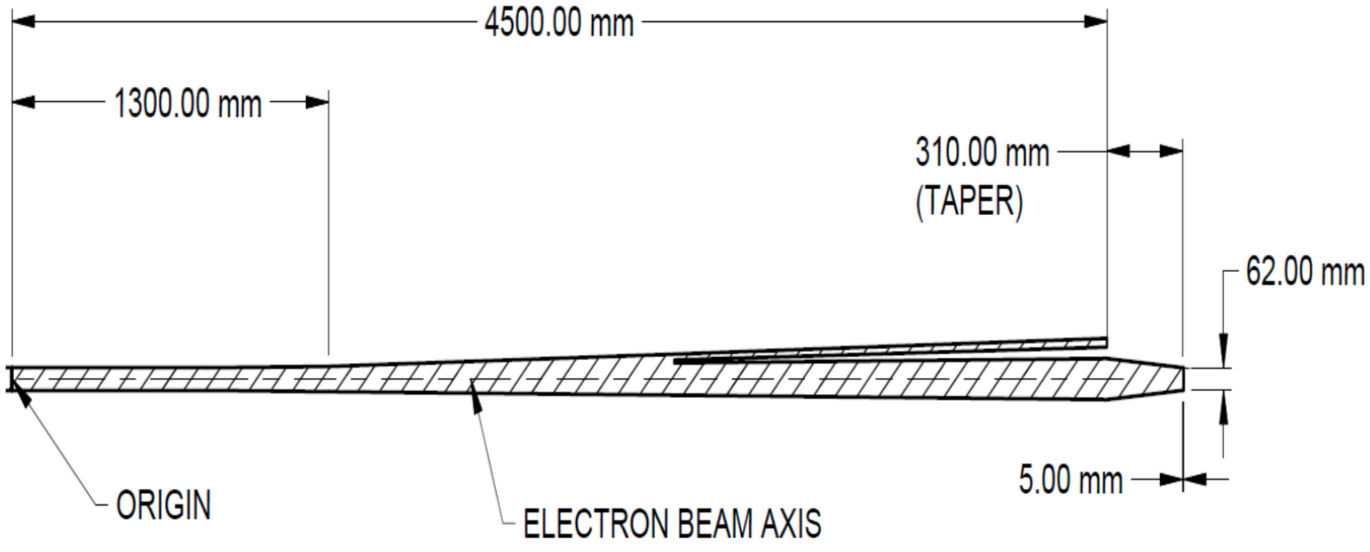
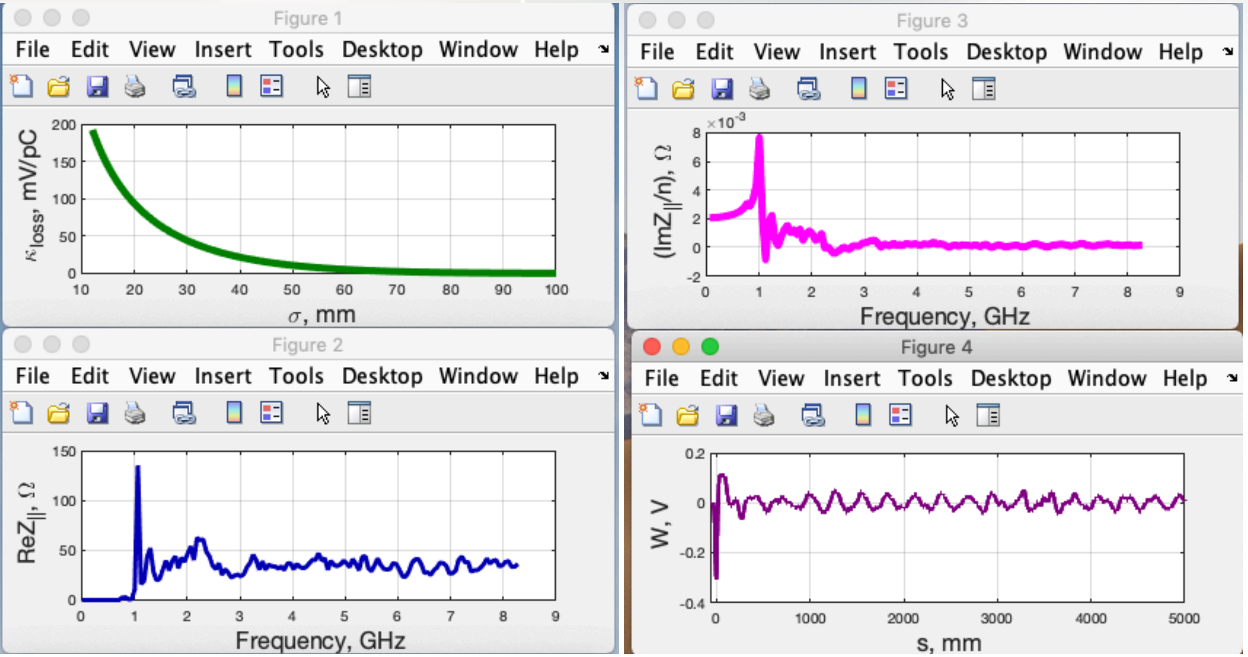


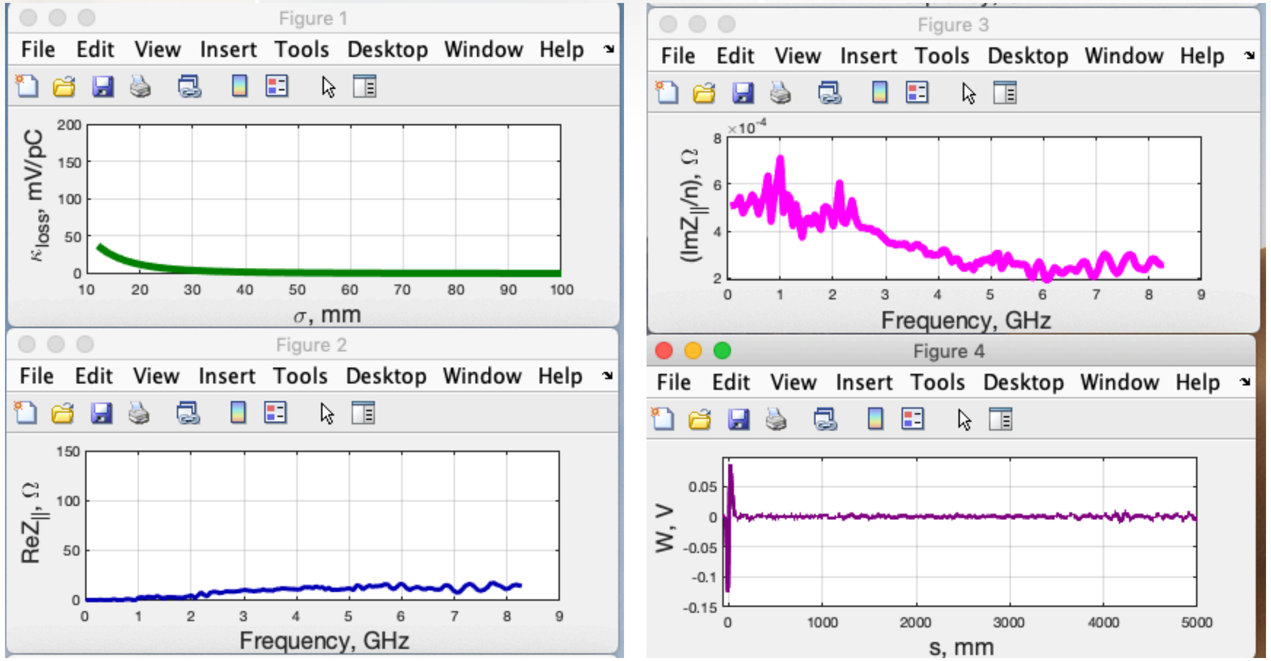
Figure 3.24: Top: Real part of the longitudinal impedance. Bottom: Imaginary part of the longitudinal impedance divided by $n = \omega/\omega_0$, where $\omega_0 = 2\pi \times 78.186\,\text{kHz}$.





eRHIC IR Chamber Updated With Grounded e⁻-Pipe





Version 1.0 (pCDR)

$k_{loss} = 0.2V/pC$ for $\sigma_s = 12mm$

$Ploss\ = 22.6\ kW$ @ $I_{av} = 2.5A$

Version 2.0 (pCDR)

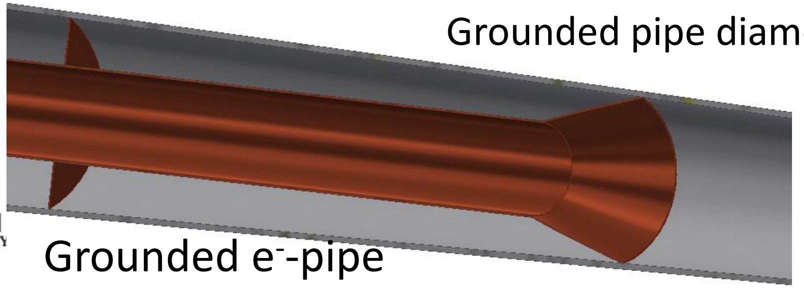
$k_{loss} = 0.038V/pC$ for $\sigma_s = 12mm$

$Ploss\ = 4.5\ kW$ @ $I_{av} = 2.5A$

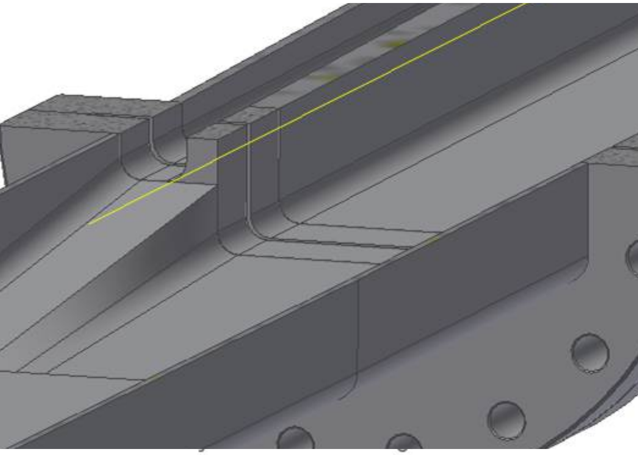
e^- pipe diameter: $\emptyset 62mm$

e^- pipe transition: $L_{tap} = 100mm$

Grounded pipe diameter: $\emptyset 120mm$

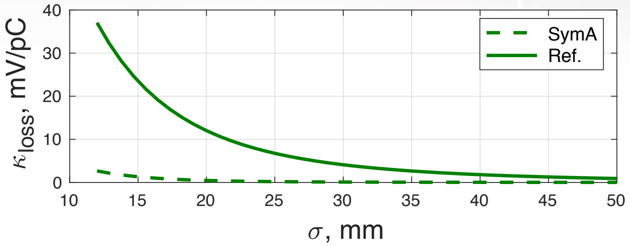


Grounded e⁻-pipe

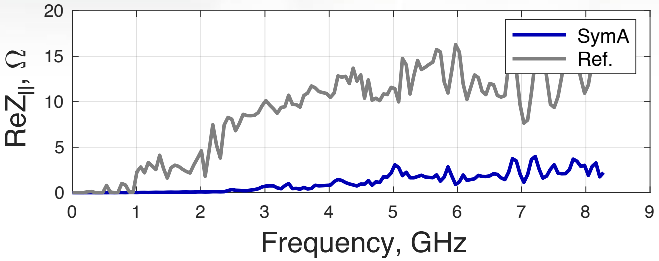


eRHIC IR Chamber Design Studies

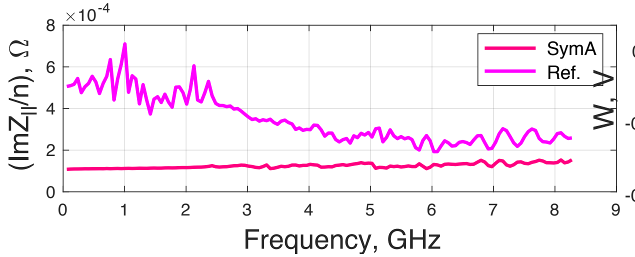
Symmetry A



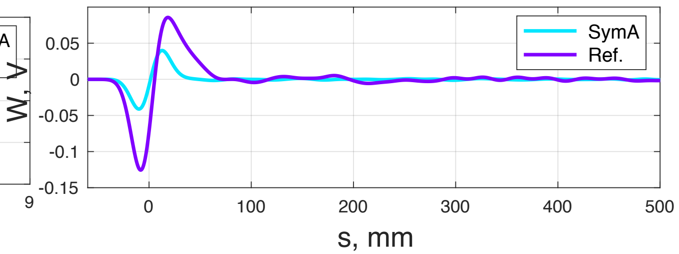
Loss factor vs. bunch length



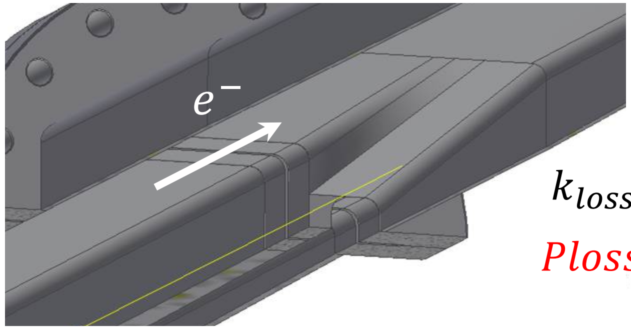
Real part of the longitudinal impedance

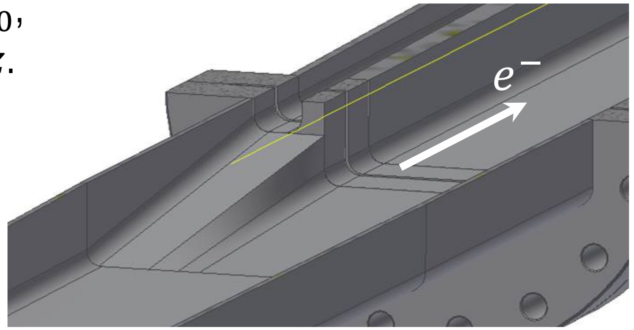


Imaginary part of the longitudinal impedance divided by $n = \omega/\omega_0$, where $\omega_0 = 2\pi \times 78.186\ kHz$.



Longitudinal wakepotential

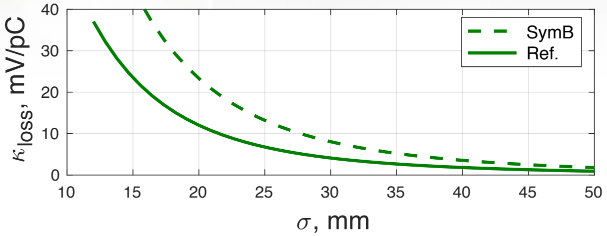




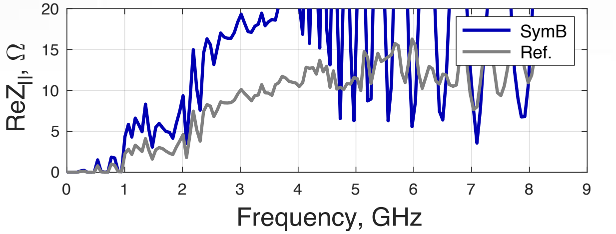
$k_{loss} = 2.9mV/pC$ for $\sigma_s = 12mm$

$Ploss = 346W$ @ $I_{av} = 2.5A$

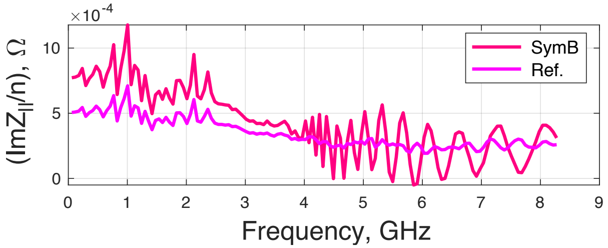
Symmetry B



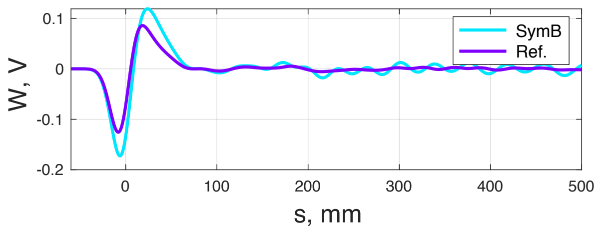
Loss factor vs. bunch length



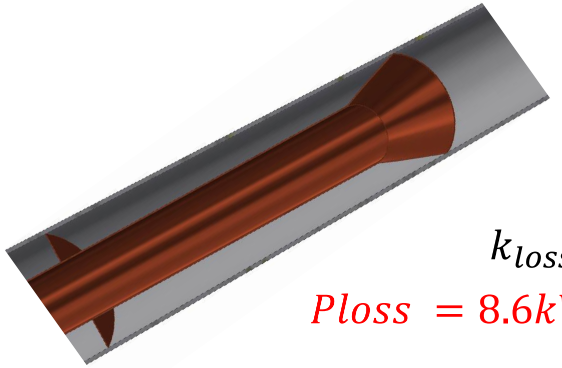
Real part of the longitudinal impedance

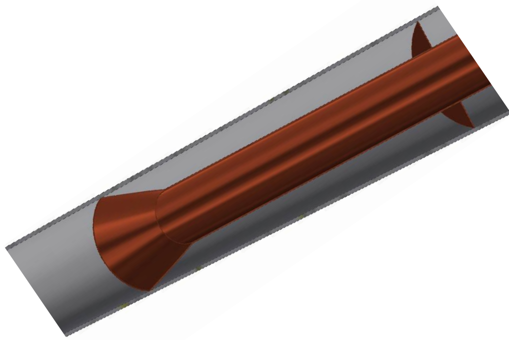


Imaginary part of the longitudinal impedance divided by $n = \omega/\omega_0$, where $\omega_0 = 2\pi \times 78.186\ kHz$.



Longitudinal wakepotential

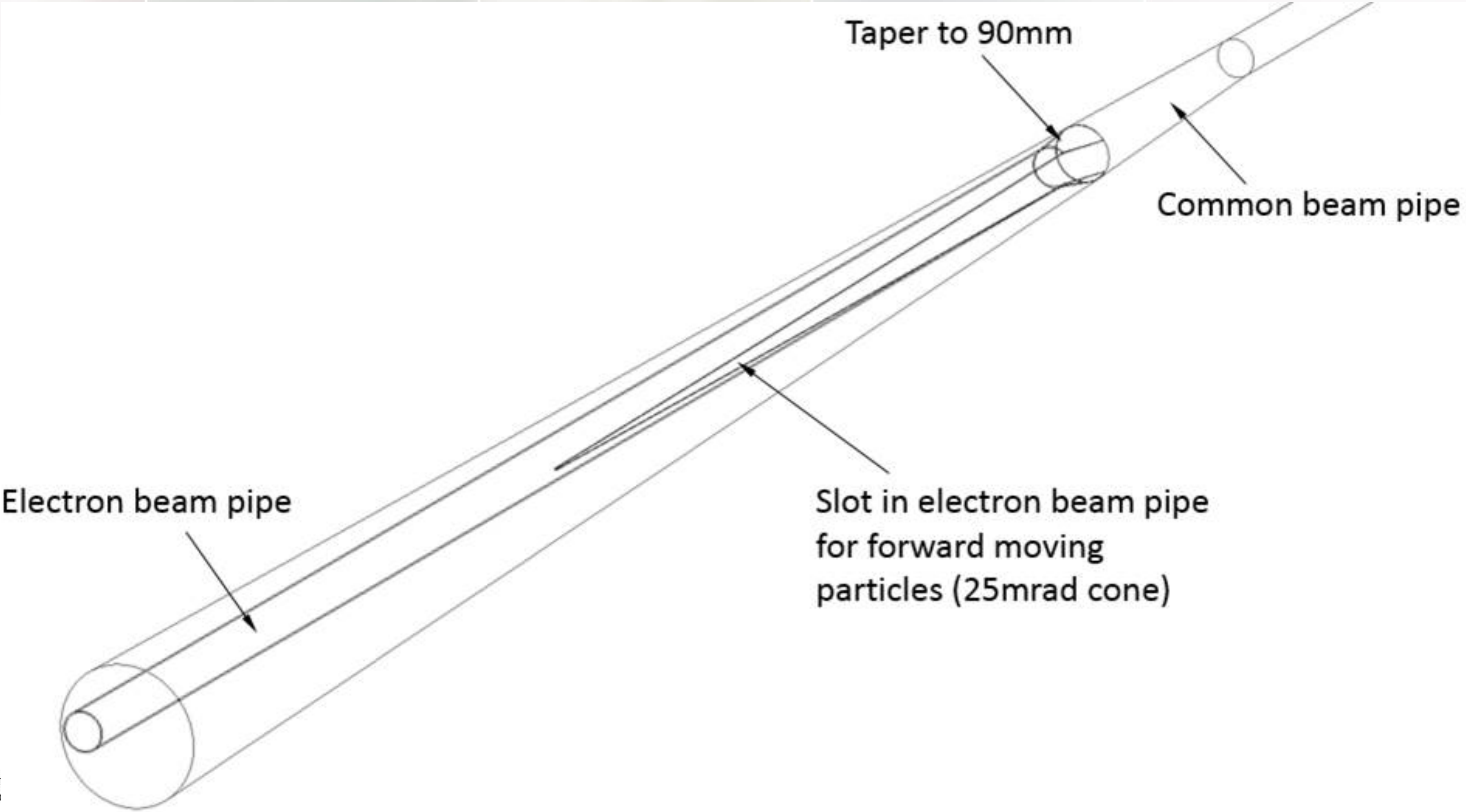




$k_{loss} = 72mV/pC$ for $\sigma_s = 12mm$

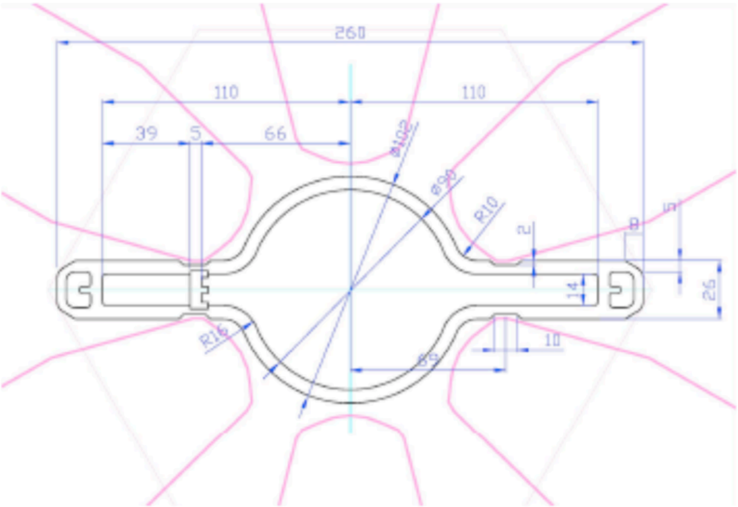
$Ploss = 8.6kW$ @ $I_{av} = 2.5A$

Jul 12, 2019 Updated IR Chamber

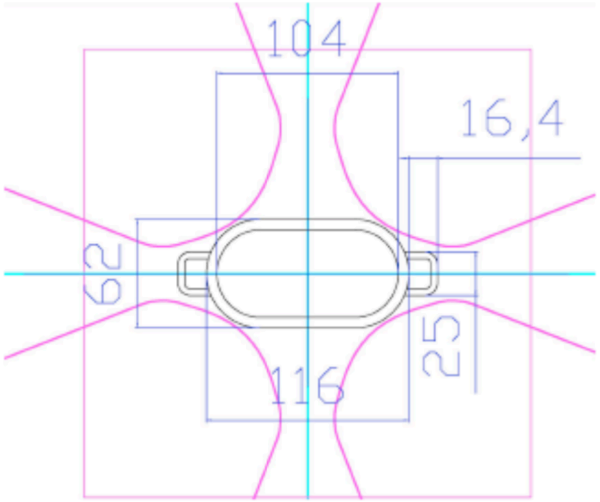


KEKB IR Chamber Design

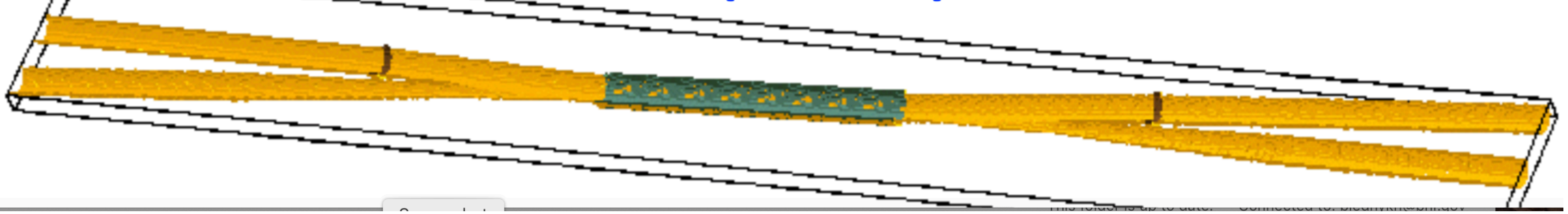
LER typical (~90%)
Aluminum w/ antechamber



HER typical (~70%)
Copper w/o antechamber

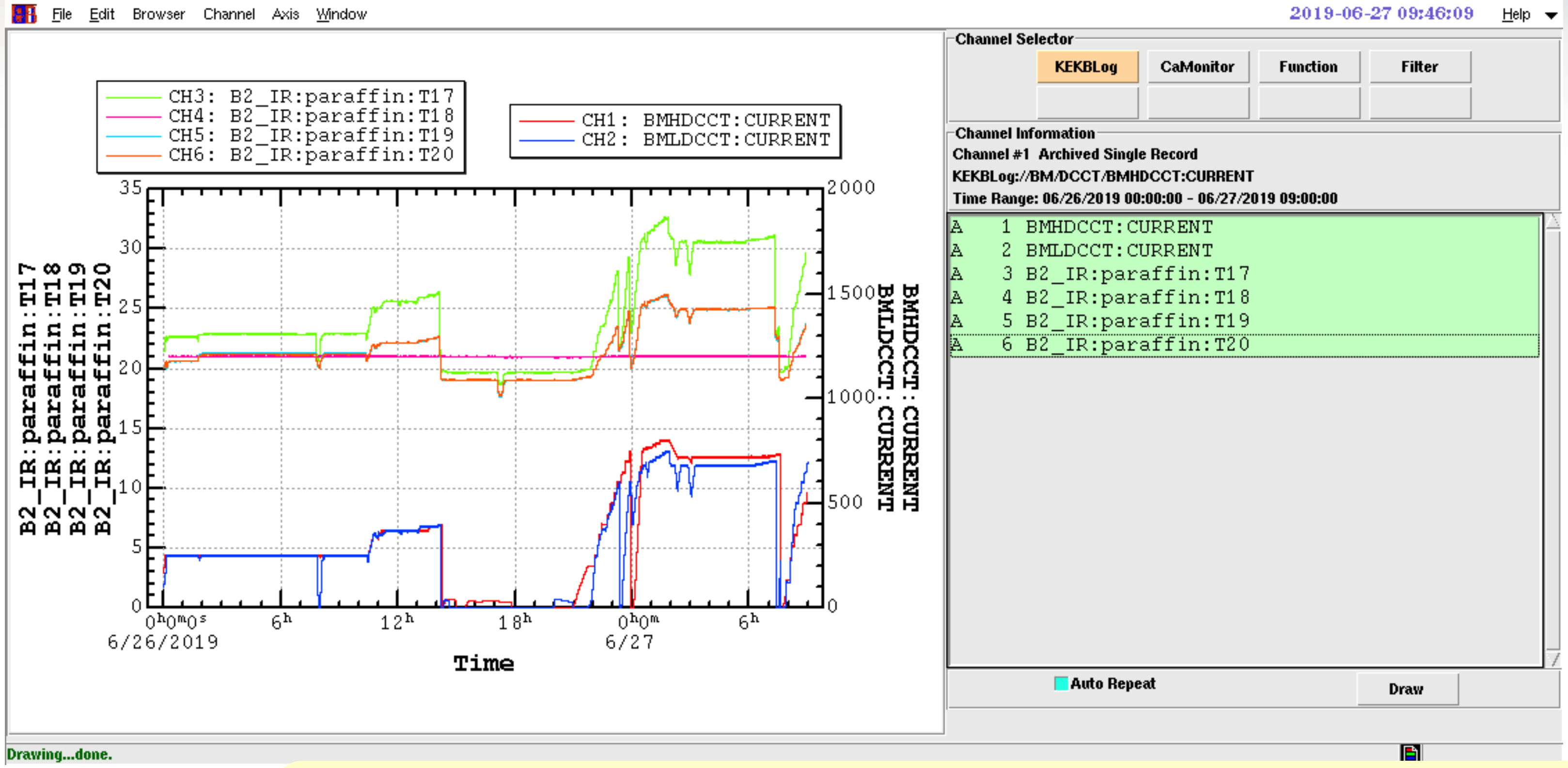


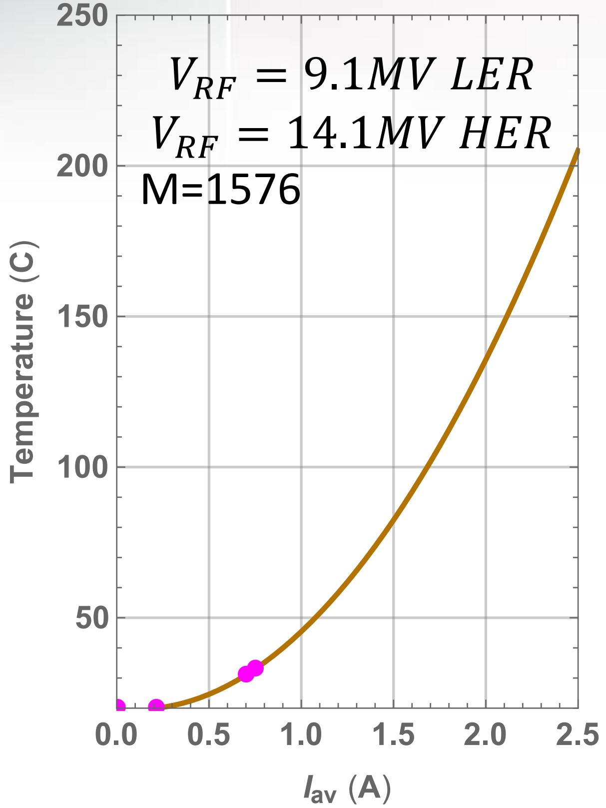
IR (GdfidL)

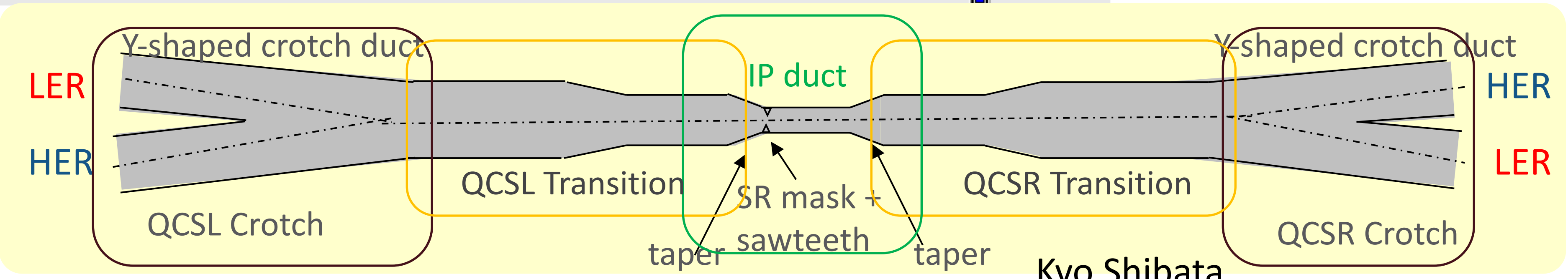


-The SKEKB IR chamber uses as a reference optimized chamber from impedance point of view

SuperKEKB IR Chamber



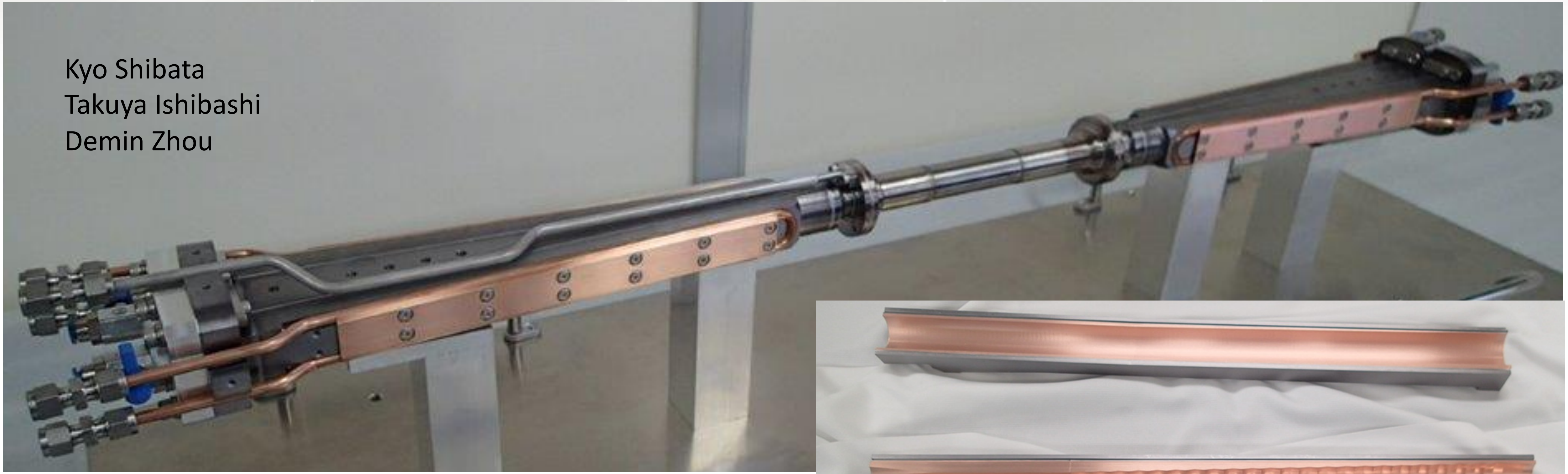


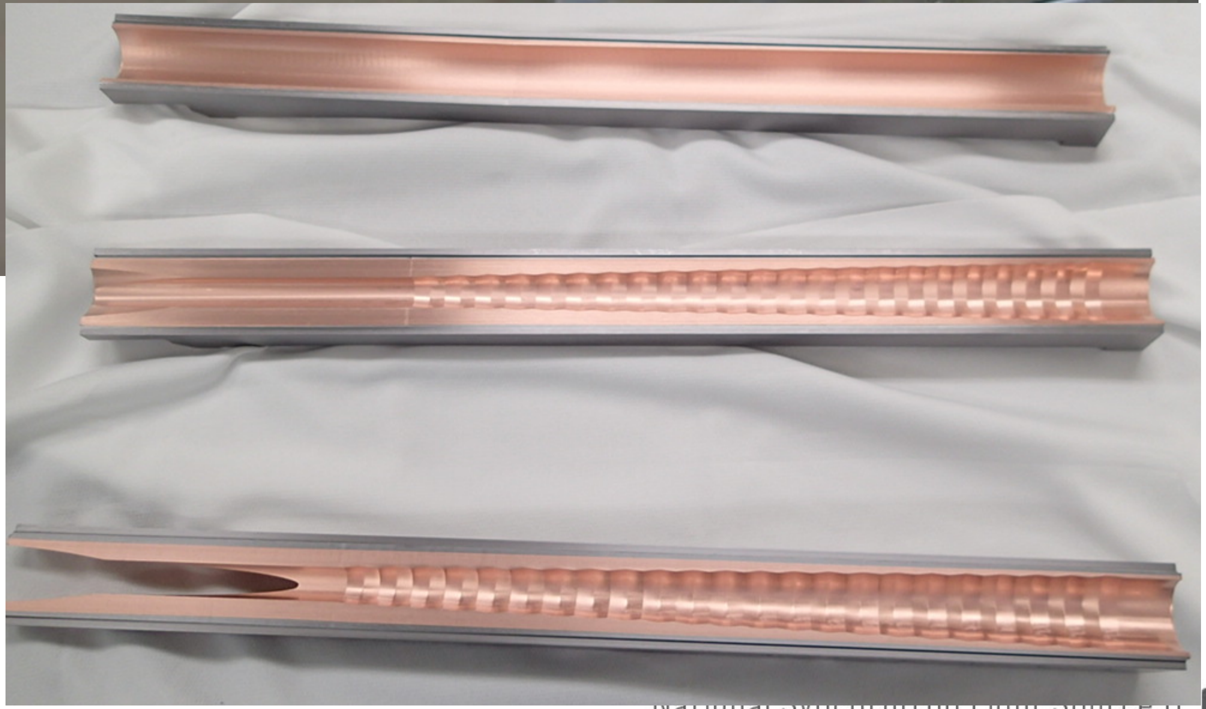


Kyo Shibata

SuperKEKB IR Chamber

Kyo Shibata
Takuya Ishibashi
Demin Zhou





- IP chambers has water (or paraffin) cooling channel with saw tooth structure