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ALS-U
ADVANCED LIGHT SOURCE

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NORTH AMERICAN PARTICLE ACCELERATOR CONFERENCE

The Broad-Band Impedance Budget of the Accumulator Ring in the ALS-U Project*

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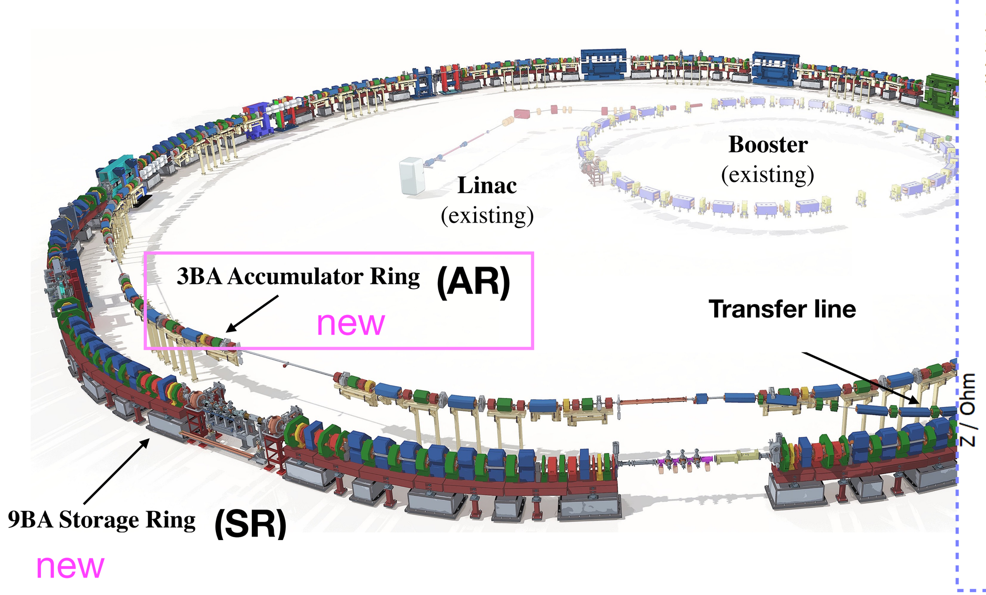
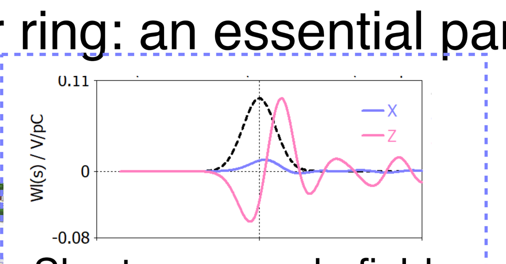
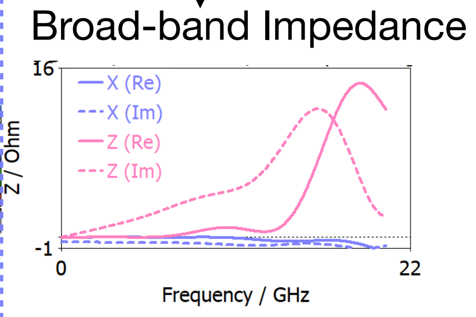
Motivation & Method

- Update of the Advanced Light Source (ALS-U) to 9BA structure, Provide a soft x-ray source 100–1,000 times brighter .
- Short range Wakefield / broad-band impedance is caused by resistive wall + geometric elements, and it's one of the main reason of collective beam instability
- BB impedance study @ accumulator ring: an essential part of accelerator design.





Short range wakefield
↓ FFT
Broad-band Impedance



Optimize for low impedance

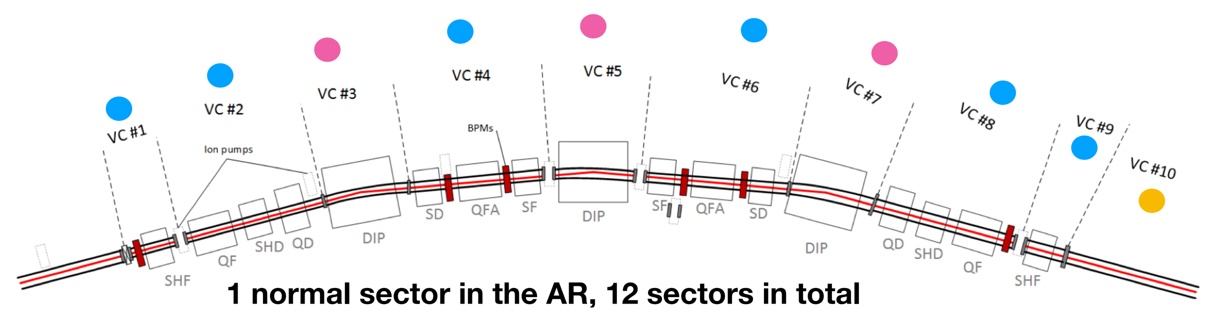
Vacuum design → Impedance modeling → Impedance budget → Beam dynamics

Vacuum design	Impedance modeling	Impedance budget	Beam dynamics
Excel List; track	**3D CST particle studio*** CAD model—> W(s) & Z(w) **Analytical** prediction; cross-check	**Matlab** Data post-processing	**Elegant** Macro-particle simul. **VPF solver** Numerical solver **Analytical** Instability threshold**

*The impedance model will keep updating as rest of the vacuum components are included.

Impedance modeling

Resistive wall



1 normal sector in the AR, 12 sectors in total

chamber type	VC	chamber ID	chamber profile across	total length	material
dipole chamber	3,5,7	14 × 40 mm	ellipse	3m	aluminum
arc section	1,2,4,6,8,9	28 mm	circular	7.8m	stainless steel
straight section	10	47 mm	circular	4.2m	stainless steel

- RW impedance is calculated with analytical formula:

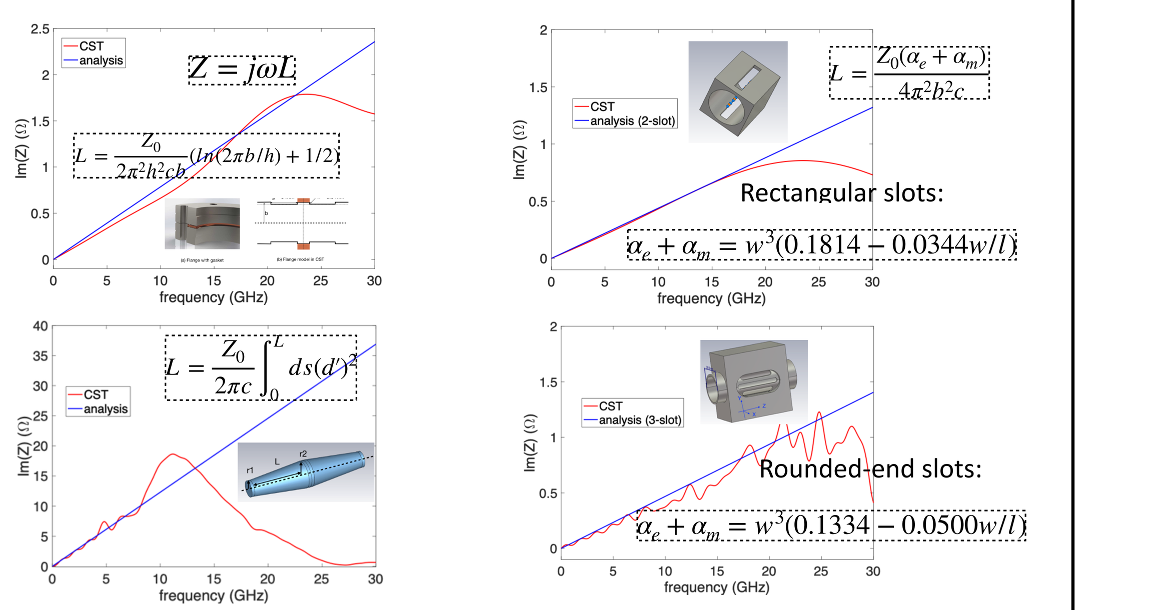
$$Z_{||}(\omega) = \frac{Z_0\delta\omega}{4\pi bc}(\mathbf{sign}(\omega) - i) \times F_{YOKOYA}$$

$$Z_{\perp}(\omega) = \frac{Z_0\delta}{2\pi b^3}(\mathbf{sign}(\omega) - i) \times F_{YOKAYA}$$

Chamber radius: b
Skin depth: $\delta = \sqrt{2/\mu_0\sigma_c|\omega|}$
F_{YOKOYA} : geometric factor, for AR elliptical dipole chamber $F_x = 0.43 \quad F_y = 0.83$

Geometry elements

Per sector (12 sectors in AR)		In the ring	
Component	**Quantity**	**Component**	**Quantity**
Flange	20	RF cavity	2
Pump screen	4	Cavity transition	2
Transition_DA	3	LFB kicker	1
Transition_SA	1	LFB transition	1
BPM	6	Stripline kicker	1
Inline pump	4		
Bellow	7		

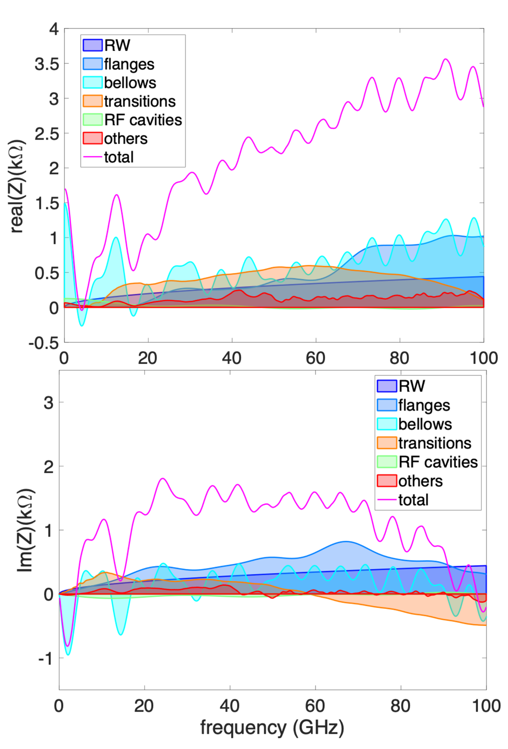


- Majority of the identified AR components have been simulated.
- CST simulation results have been cross-checked with analytical formulas as much as applicable

BB impedance budget

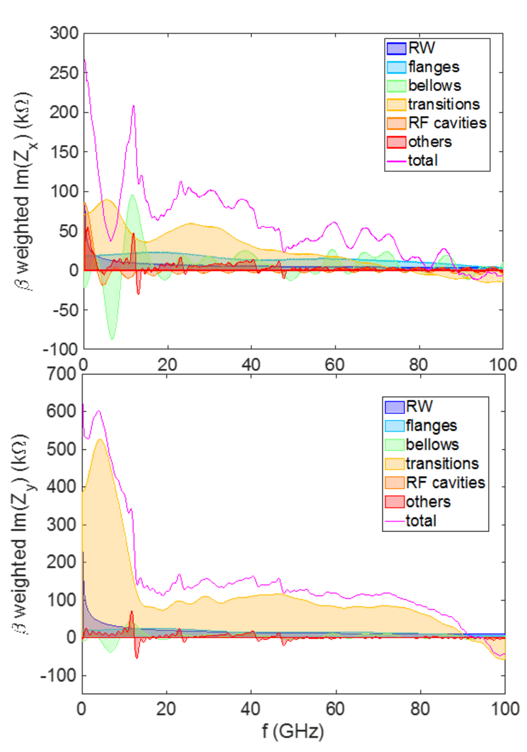
- Longitudinal budget table for nominal 5mm bunch length

Component	Quantity	Sum up		
		Loss factor V/pC	Re(Z/n) mΩ	Im(Z/n) mΩ
Bellow	84	8.148	82.622	21.000
Cavity	2	1.960	19.859	-14.193
Resistive wall	1	1.600	16.232	24.012
Transition SA	12	0.492	4.959	25.311
LFB kicker	1	0.490	4.969	-3.383
Transition_AD	36	0.144	0.660	31.369
BPM	72	0.101	1.022	2.872
Cavity transition	2	0.176	1.796	3.946
Flange	240	0.082	3.129	28.414
LFB transition	1	0.075	0.765	1.620
Arc pump screen	24	0.014	0.142	3.104
Pump screen	24	0.014	0.139	2.340
Stripline kicker	1	0.010	0.087	~ 0.000
Inline pump	48	0.006	0.059	1.545
Ring Total		13.3	136.4	128.0



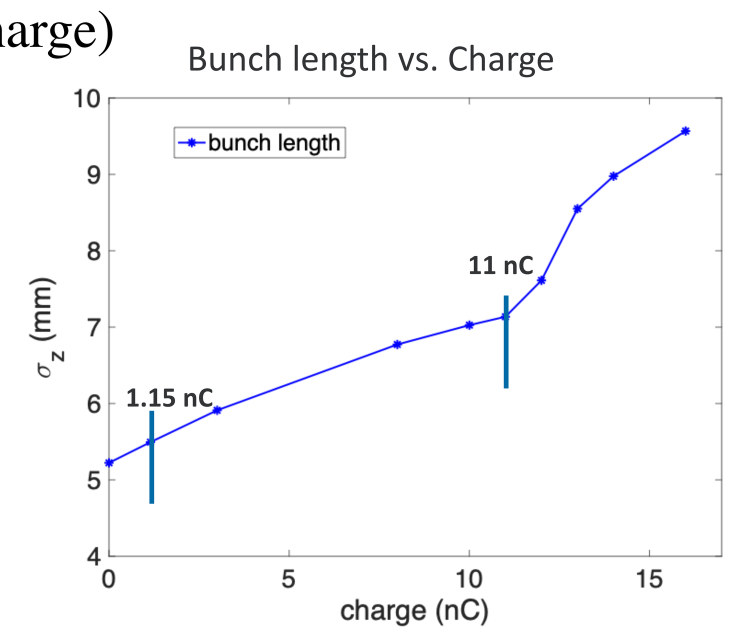
- Transverse budget table for nominal 5mm bunch length & impedance spectrum

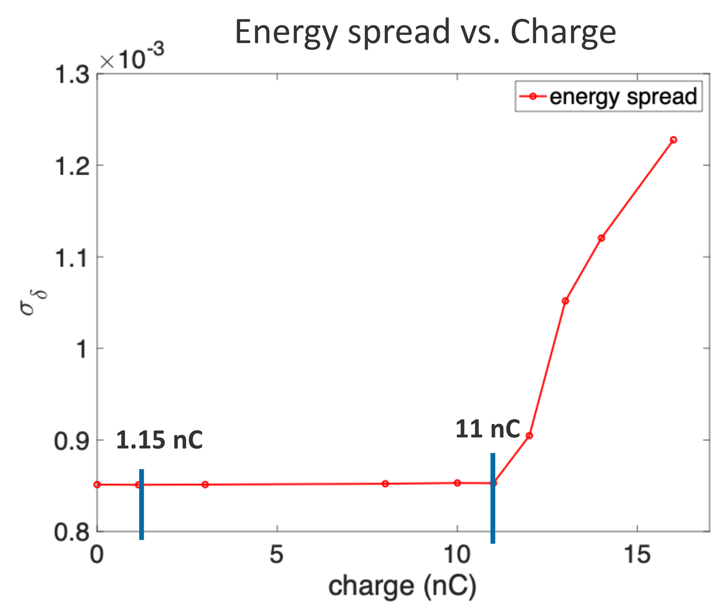
Component	Quantity	Sum up			
		(β^*Z_{eff})x kΩ	(β^*Z_{eff})y kΩ	Tune shift x $*10^{-4}$	Tune shift y $*10^{-4}$
Transitions AD	36	8.74	348.70	-0.068	-2.699
RW_Arc section	1	15.34	28.42	-0.119	-0.220
RW_Dipole chamber	1	1.49	27.74	-0.012	-0.215
Transitions SA	12	58.53	22.83	-0.453	-0.177
Flange	240	20.66	22.40	-0.160	-0.173
Pump screen	48	1.33	17.17	-0.010	-0.133
BPM	72	6.88	10.80	-0.053	-0.084
Inline pump	48	13.31	5.62	-0.103	-0.043
Bellow*	84	10.37	4.49	-0.080	-0.035
Cavity	2	13.83	4.61	-0.107	-0.036
Cavity transition	2	4.61	1.54	-0.036	-0.012
LFB kicker	1	4.52	1.51	-0.035	-0.012
RW_Straight section	1	3.99	1.33	-0.031	-0.010
LFB transition	1	2.04	0.68	-0.016	-0.005
Stripline kicker	1	0.51	0.17	-0.004	-0.001
Ring total		166.18	498.00	-1.29	-3.85



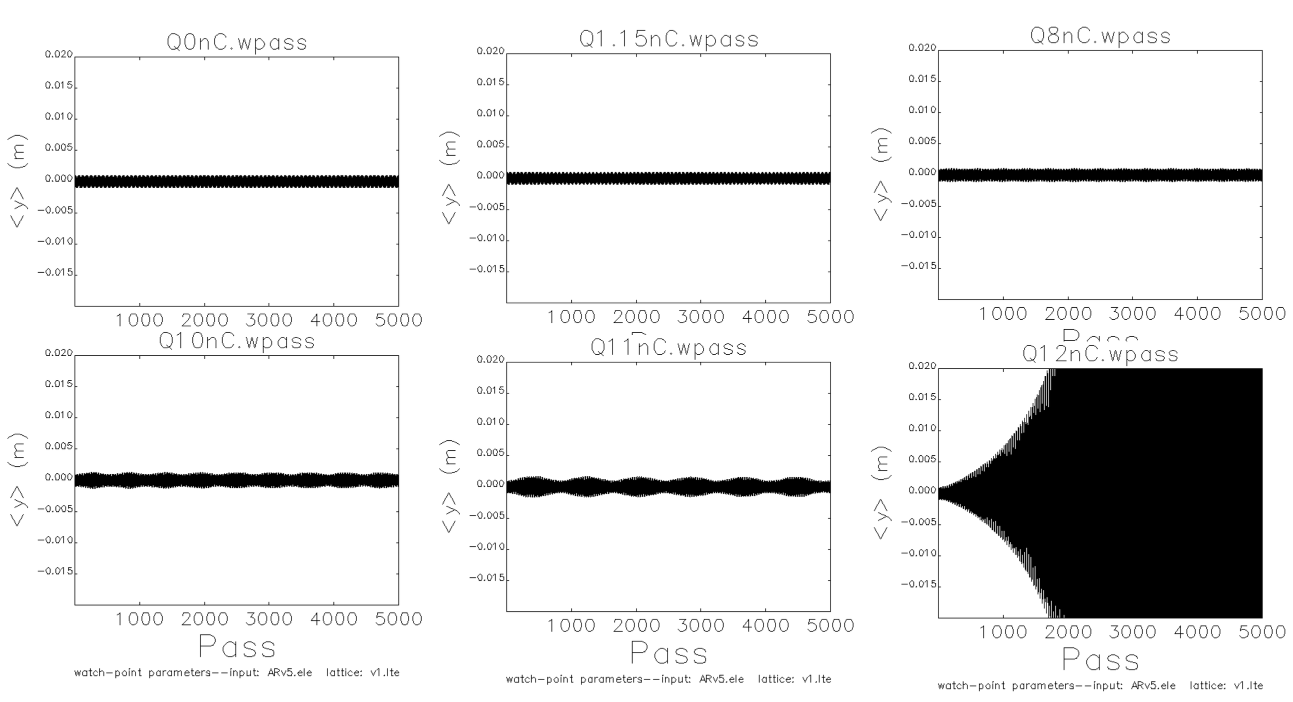
Instability study

- Longitudinal instability study: ELEGANT simulation shows the onset of microwave instability at bunch charge of ~11 nC>>1.15nC (designed charge)





- Transverse instability simulation shows the threshold at charge of ~12 nC



In summary, based on current impedance model, simulation shows that there is a ~10-fold margin between required single bunch charge and the longitudinal / transverse threshold.

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