Crab Cavities for SuperKEKB

- Parameters for the crab crossing
- Performance of present crab cavities
- Crab cavity for SuperKEKB
- LHC crab cavity
- LHC compact crab cavity
- Summary

Parameters for the crab crossing

	KEKB		*Super-KEKB*	
Strategy	Backup scheme		Adopted as baseline	
Ring	LER	HER	LER	HER
Beam energy (GeV)	3.5	8.0	3.5	8.0
Beam current (A)	2.6 1.62	1.1 0.95	9.4	4.1
RF frequency (MHz)	508.887		508.887	
Crossing angle (mrad)	±11		±15	
βx* (m)	0.33 0.9	0.33 0.9	0.2	0.2
βx, crab (m)	20 85	100 162	100～200	300～400
Required kick (MV)	1.41 0.83	1.44 1.37	1.10 ～ 0.78	1.45 ～ 1.26

200m
1.78MV

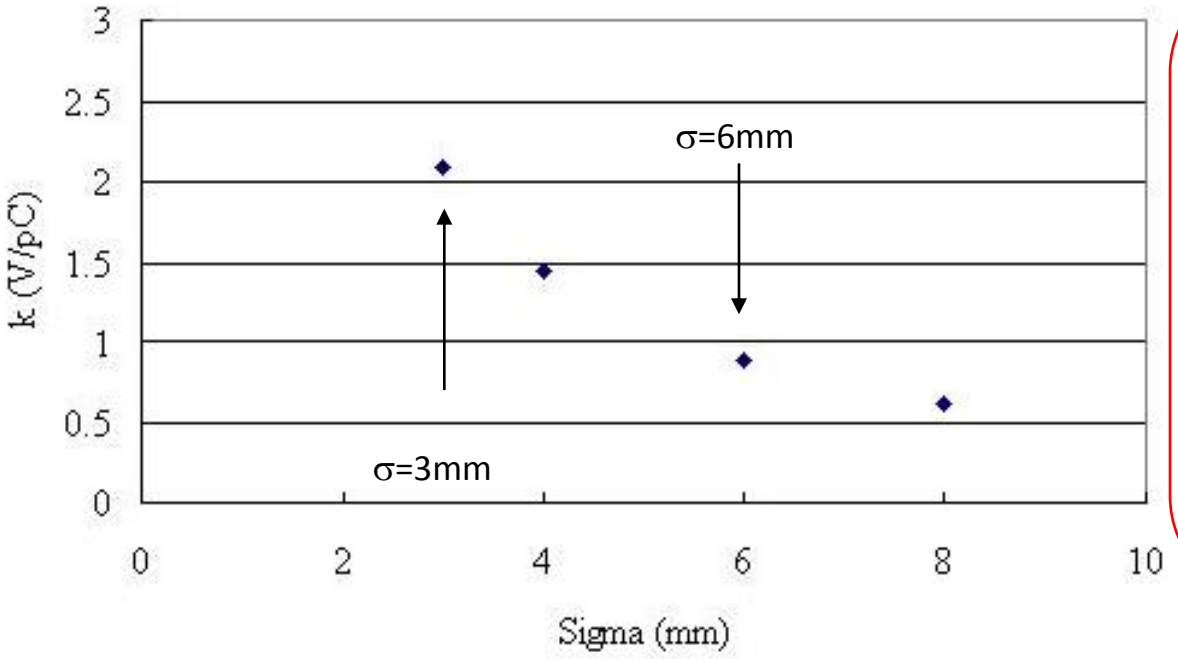
Design value (Local crab scheme)

Present value (global crab scheme)

2 cavities are required for HER.
1 or 2cavities are required for LER.

Loss factor of present crab cavity

The loss factor of the present crab cavity is k=0.877V/pC (σ=6mm).
If σ-3mm, the loss factor becomes k=2.1V/pC.



HOM power for σ=3mm

Wake
K=2.1 V/pC (σ=3mm)
HER 4.1A,5000-bunch Q=71 kW
LER 9.4A,5000-bunch Q=371 kW

Ferrite loss
k=0.3 V/pC (σ=3mm)
HER 4.1A,5000-bunch Q=10 kW
LER 9.4A,5000-bunch Q=53 kW

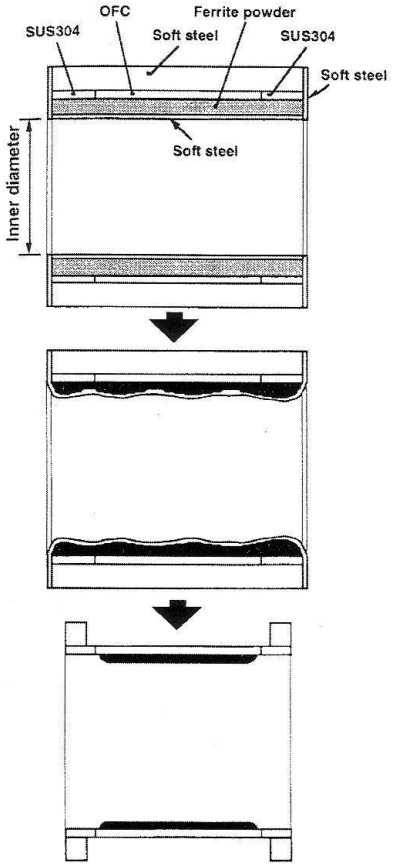
Can present crab cavities be used?
HER : 4.1A HOM dumper should be improved.
LER : 9.4A Very difficult.

Y.Morita

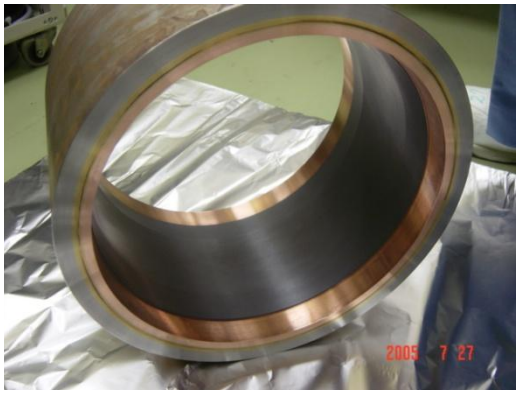
Fabrication of HOM dampers

- Baking of ferrite powder
- Canning of ferrite powder
- HIP 1500 atm, 900 ^{o}C
- Machining of ferrite surface
- UT
- Baking
- Cutting of iron base
- EBW of stainless steel flange
- Winding of copper pipe

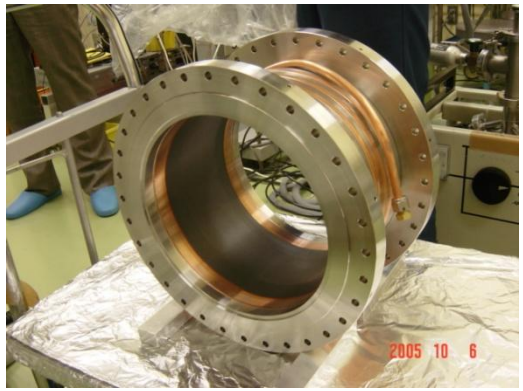
- High power test: up to 10 kW
- Low power test: mode damping test
- Evacuation



T. Tajima



Before Baking



Before high power test

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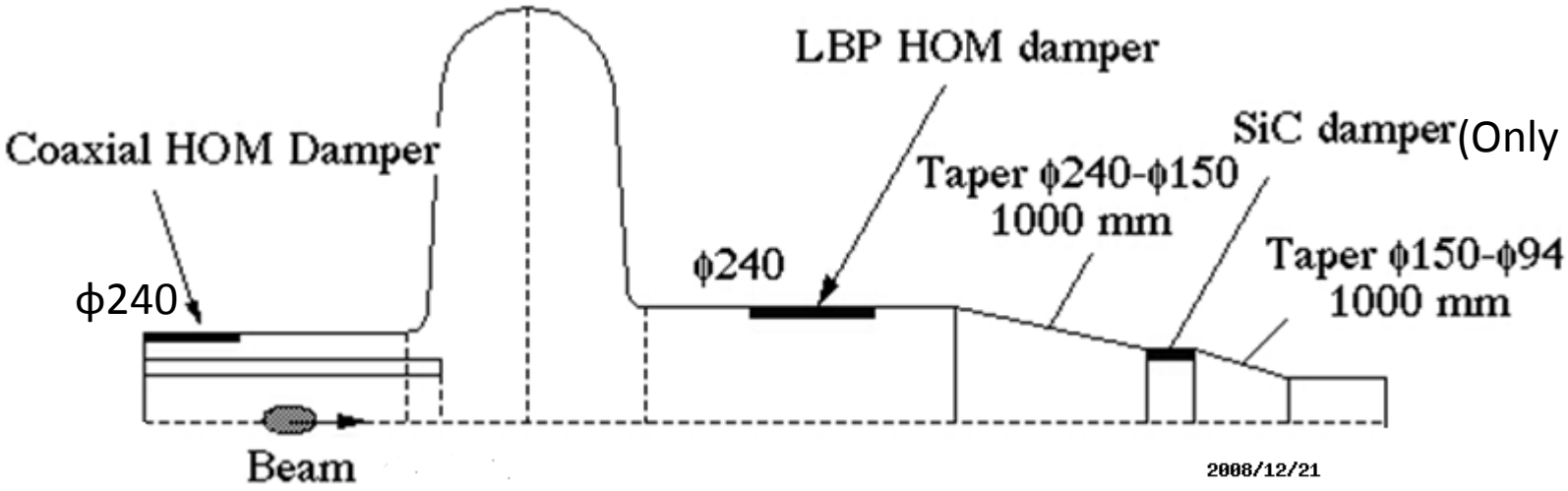
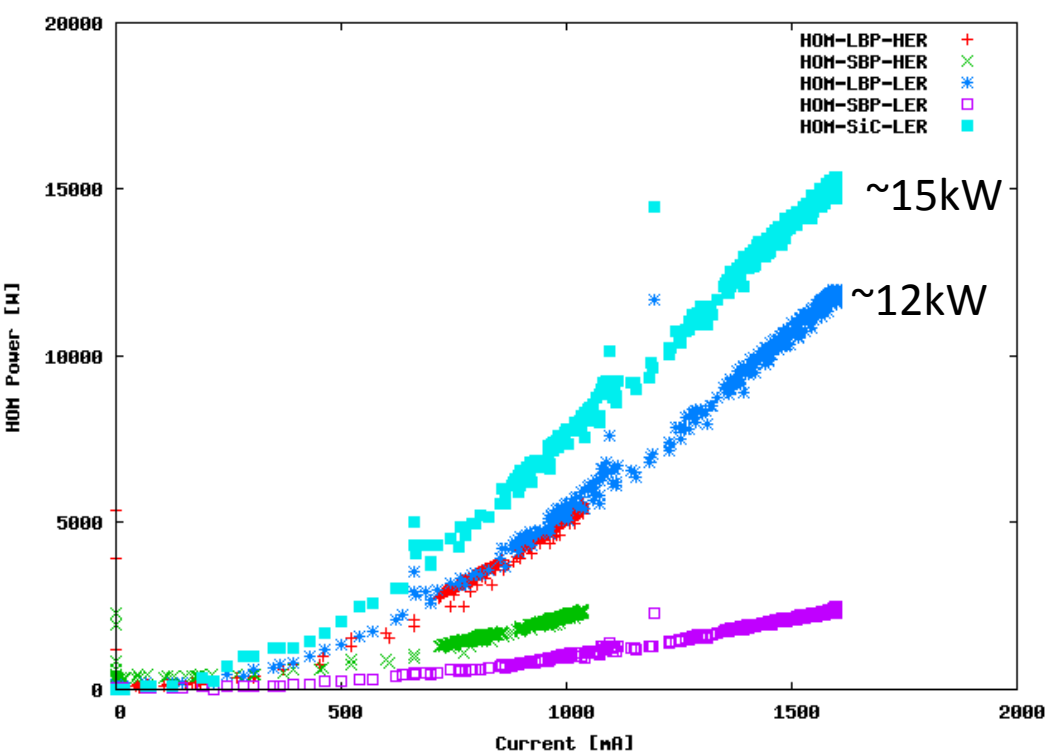
Status of HOM Power

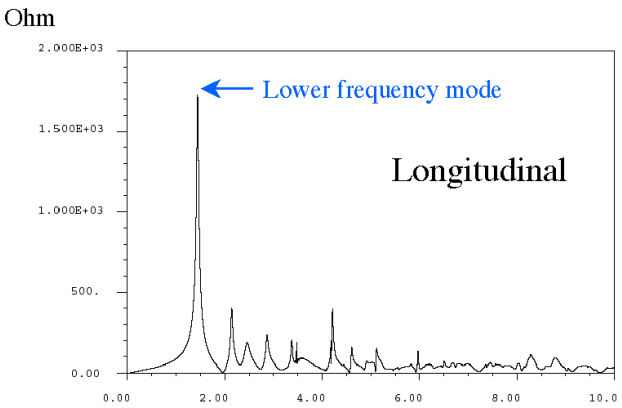


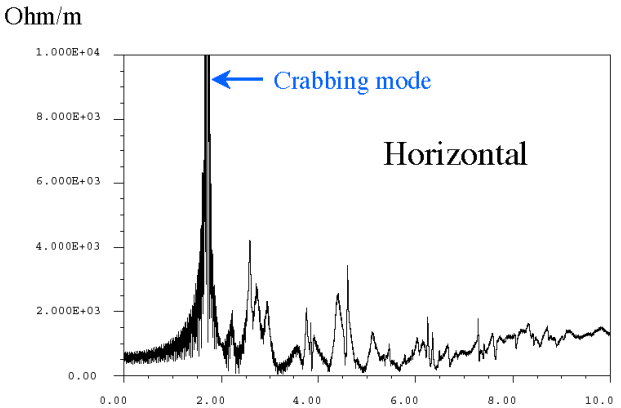
The LBP HOM dumper for LER is absorbed about 12kW at 1.6A of beam current.

Another type HOM dumper and a small taper are attached to LBP of LER cavity. It absorbs some part of HOM power.



Coupling impedance of parasitic modes

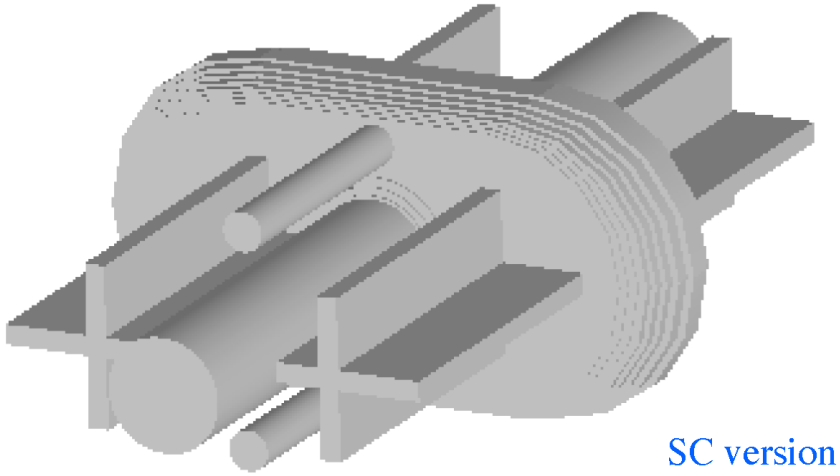




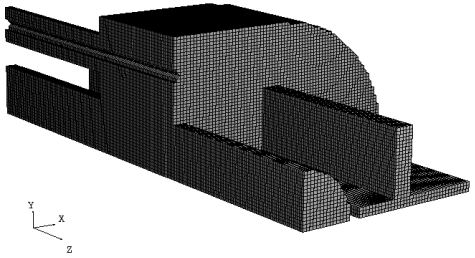
	Original	New(SC)	New(NC)	unit
Highest value of Z_T (H)	25.0	5.6	4.4	kΩ/m
Highest value of Z_T (V)	15.0	3.2	10.1	kΩ/m
Highest (Z// x freq./GHz)	2070	1020	760	Ω GHz
Kloss@3mm	0.73	0.56	0.56	V/pC

2.1 (with taper)

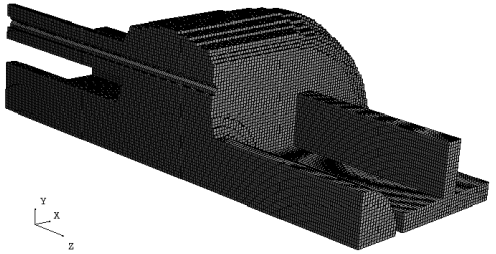
3-D drawing of new crab cavity



SC version



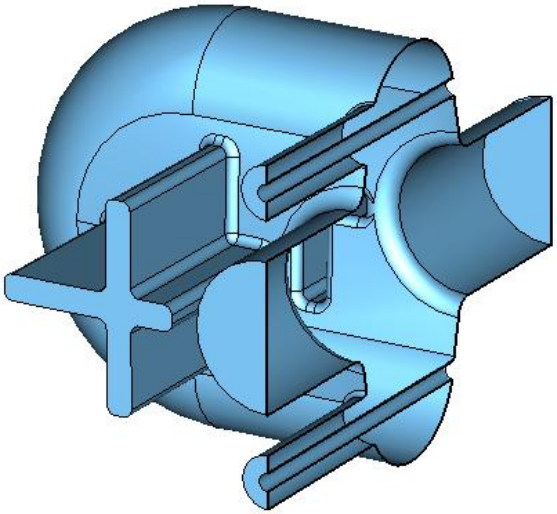
NC version

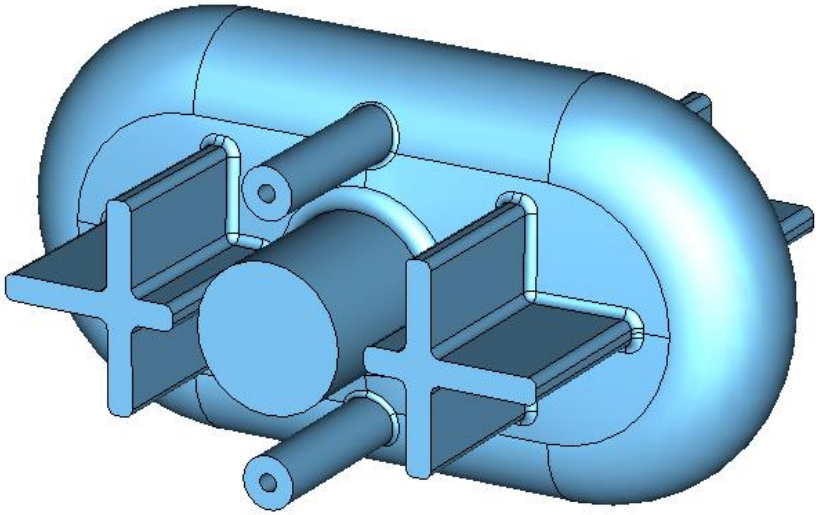


Latest design of the crab cavity for SuperKEKB

New design for SuperKEKB crab cavity was proposed.
It have no coaxial beam pipe tuner to make simple system.

To make heavily dumping, It have coaxial and waveguide type couplers.
To reduce the loss factor, diameters of upstream and downstream beam pipes are same.
No lossy material is exposed to the beam immediately.





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But, it looks very complicated!

Crab crossing in Super-KEKB

1X1 when Beta>250m

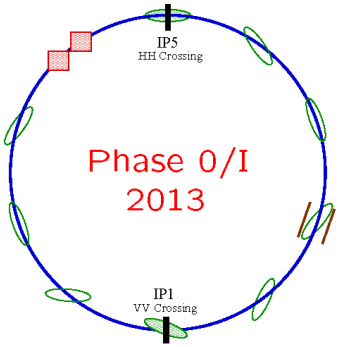
		Original	New design	
		SC	SC	NC
SuperKEKB (LER) βcrab=170m V_{kick}=0.84MV	No. of cavities	1×2	1×2	2×2
	Growth time (horizontal)	0.9ms	8.4ms	4.2ms
	Growth time (longitudinal)	21ms	146ms	73ms
	Total HOM power	214kW	97kW	
SuperKEKB (HER) βcrab=350m V_{kick}=1.34MV	No. of cavities	1×2	1×2	3×2
	Growth time (horizontal)	2.7ms	25ms	8.4ms
	Growth time (longitudinal)	107ms	763ms	254ms
	Total HOM power	44kW	20kW	

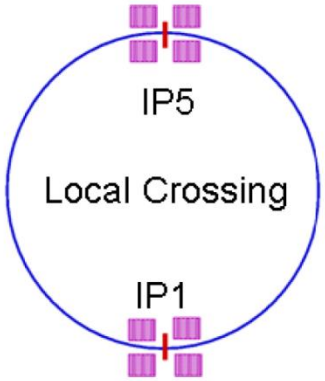
71+10 kW

New crab cavity has advantages for Super-KEKB, especially in LER.
Original crab cavity could also be used in HER, if HOM absorber is OK with 44kW.

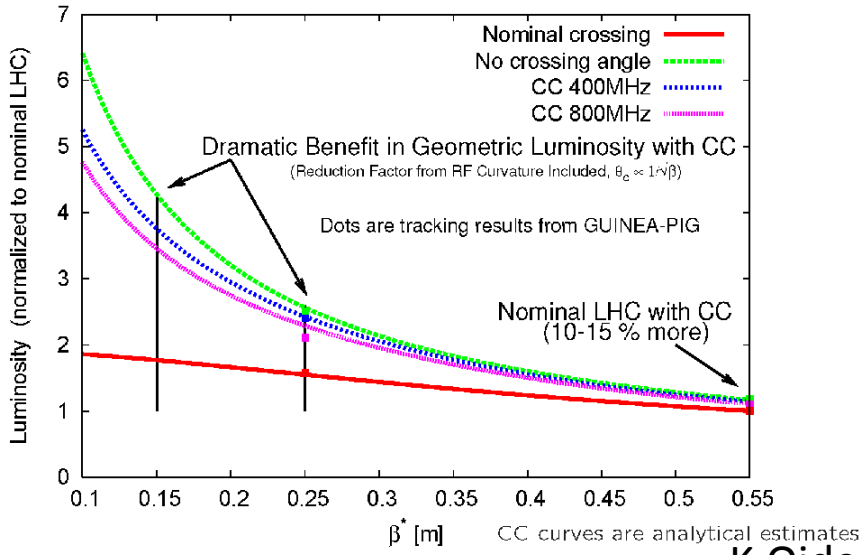
LHC-CC project
as an international collaboration

- Phase 0/I
  - Global crab scheme
  - Feasibility study of the crab crossing
    - LUMI increase ~10%
  - Crab cavity: baseline design by US-LARP
  - Fabrication and cold test: at KEK
    - not yet funded
  - High power tests and beam tests: ?





- Phase II
  - Local crab scheme
  - Increase LUMI by a factor of two
    - With small β^*
  - Need compact crab cavities
  - KEK proposed a new type

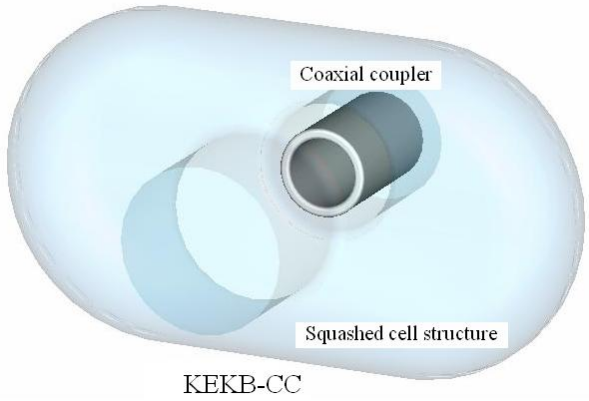


K.Oide

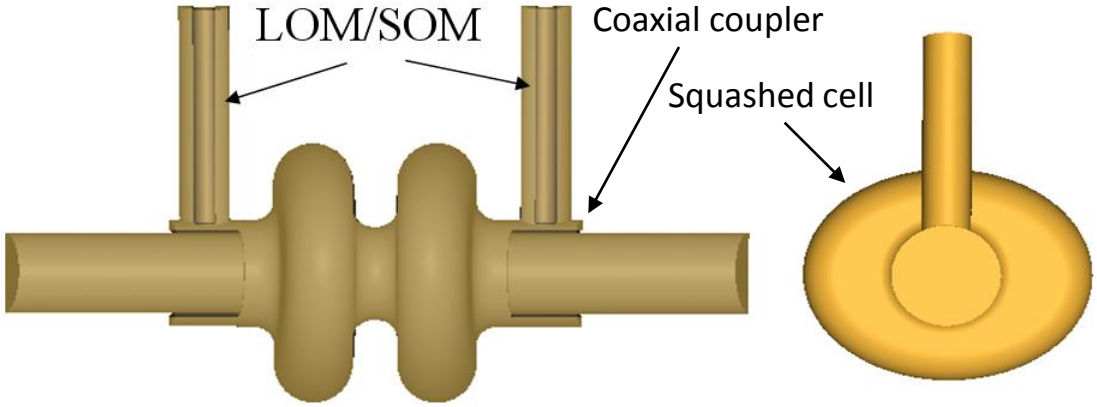
Baseline cavity for phase 0/I

Recently US-LARP proposed a baseline cavity

- The baseline design has similar properties like KEKB-CC
  - Elliptical/squashed cross section
  - Coaxial coupler
- Different properties
  - Two-cell cavity
  - 800 MHz (KEKB-CC: 509MHz)
  - More complicated LOM/SOM/HOM coupler



KEKB-CC



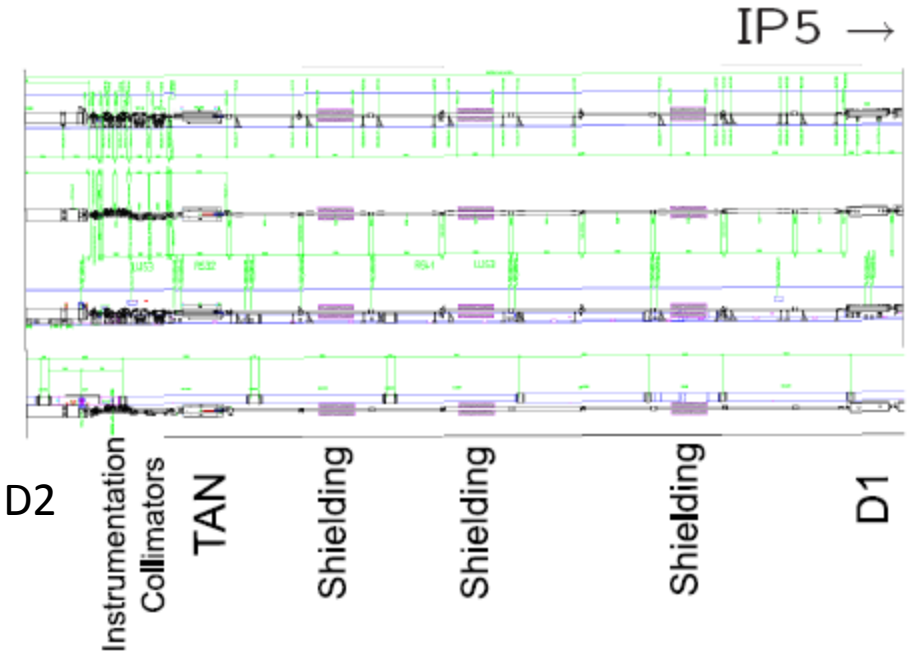
Baseline design, L. Xiao, LARP-CM11, 10/28/08

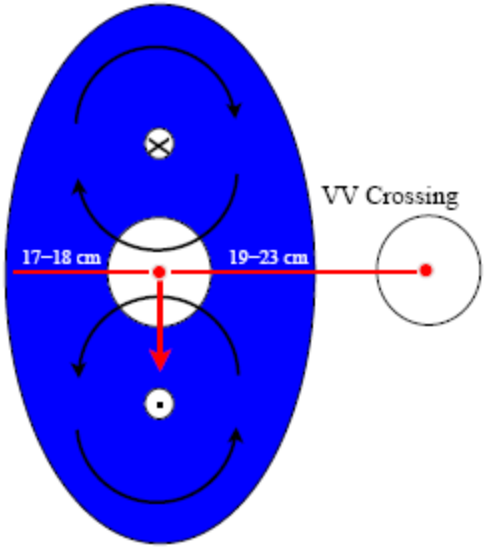
Frequency	800MHz
(R/Q) T	117ohm/cavity
Deflecting Voltage V_T	2.5MV
Deflecting Gradient Ekick	6.67MV/m
Epeak	24.72MV/m
Bpeak	82.75mT
Mode separation (Opt.-SOM)	89MHz

K.Oide

Local scheme: space challenge

- Longitudinal Space ~ 10-15 m (Local, staggered cavities, common cryostat)
- Transverse for nominal ~19 cm, tight margin (VV Crossing)
- Require clever He vessel + integrated cryostat design to accommodate two beams





Y.P.Sun

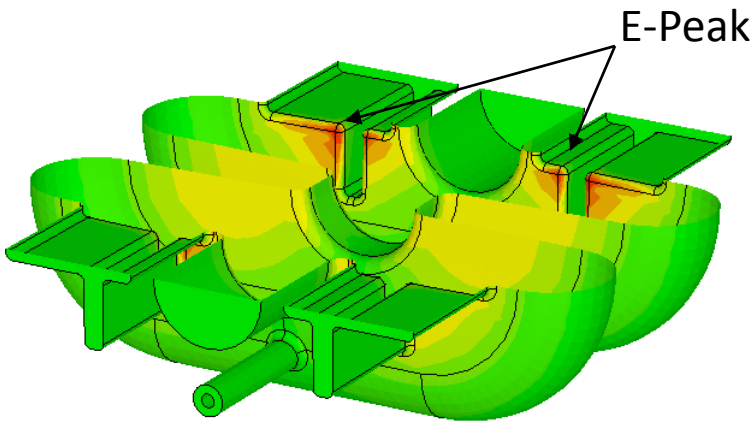
RF parameters

- Compared with the baseline design;
  - Higher peak electric field
  - Lower peak magnetic field
- Loss factor: 0.56 V/pC for σ=3 mm (SKEKB)
  - Low loss factor desired for high current operation

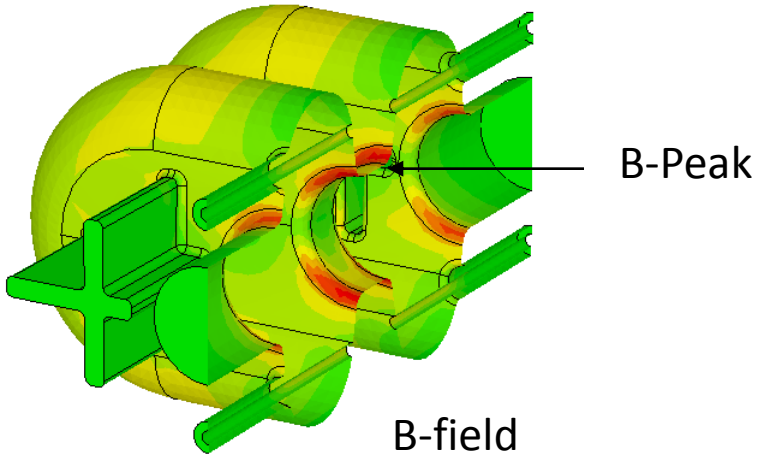
Frequency: 800 MHz

Parameter	At 2.5 MV	At 1MV
Epk (MV/m)	30.5	12.2
Bpk (mT)	69.5	27.8
R/Q (Ω/cavity)	111	
Beam pipe radius (mm)	53.1	
Transverse size (mm)	565	

US-LARP team can analyze multipacting properties of cavity.
This shape is being analyzed by them.



E-field



B-field

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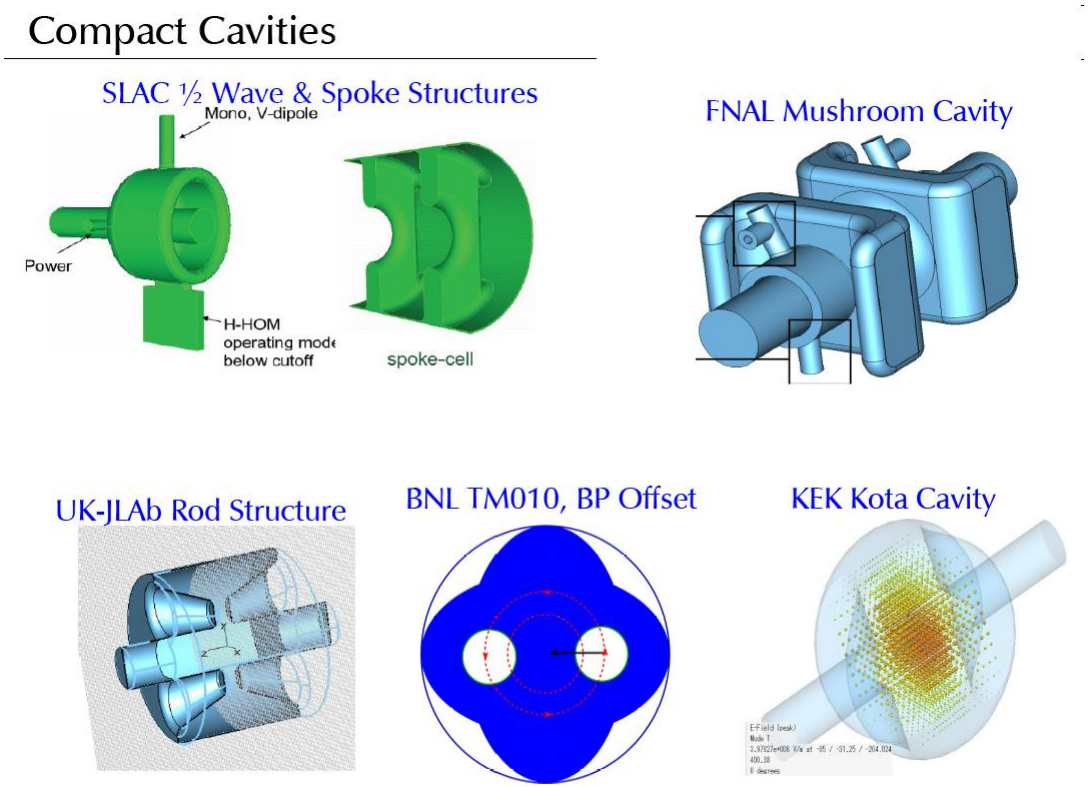
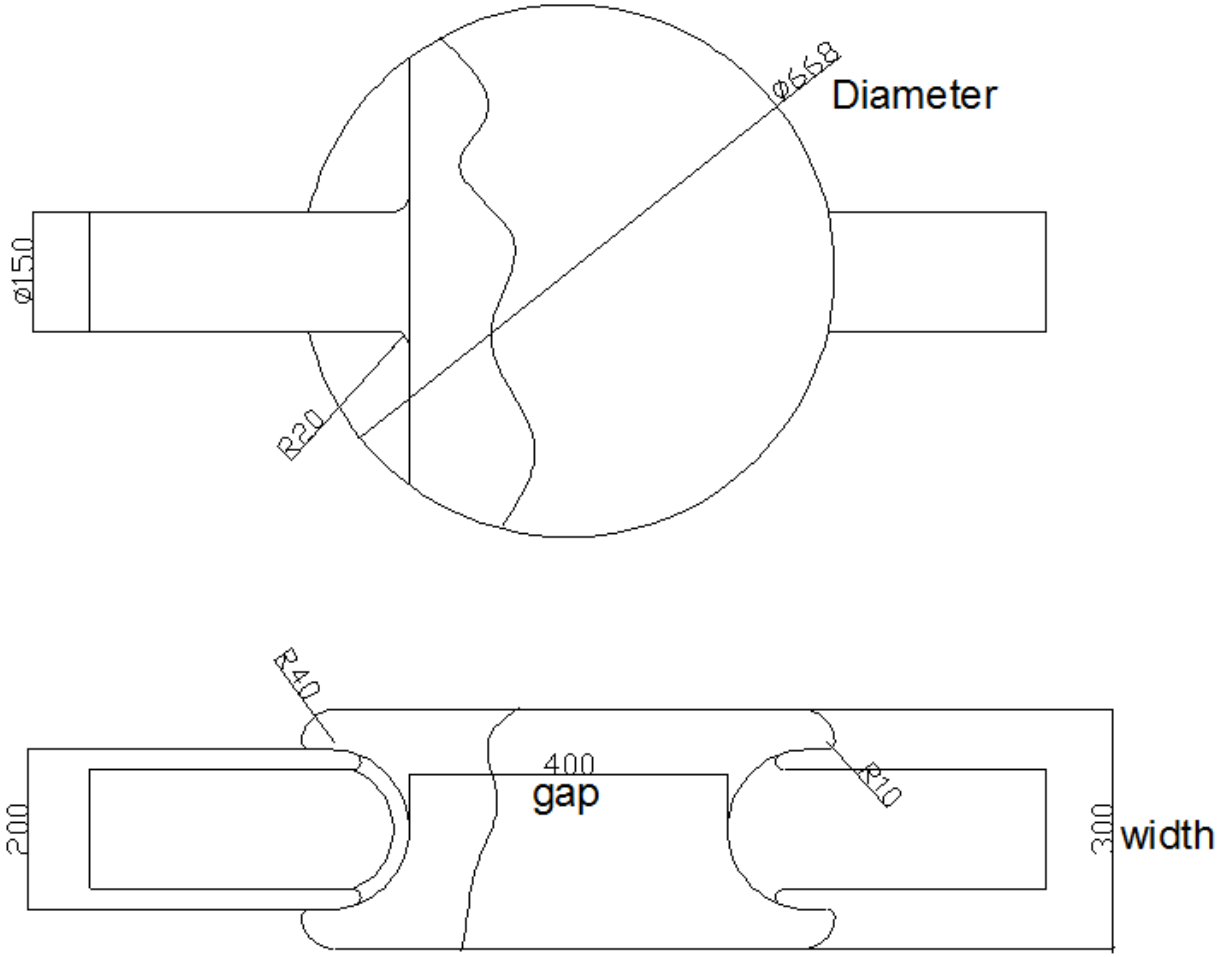
Compact crab cavity

- Compact CC is attractive for the future local crab scheme
- There are many interesting designs (US-LARP, UK-EUCARD, KEK)



Rama Calaga, LARP-CM11, 10/28/08

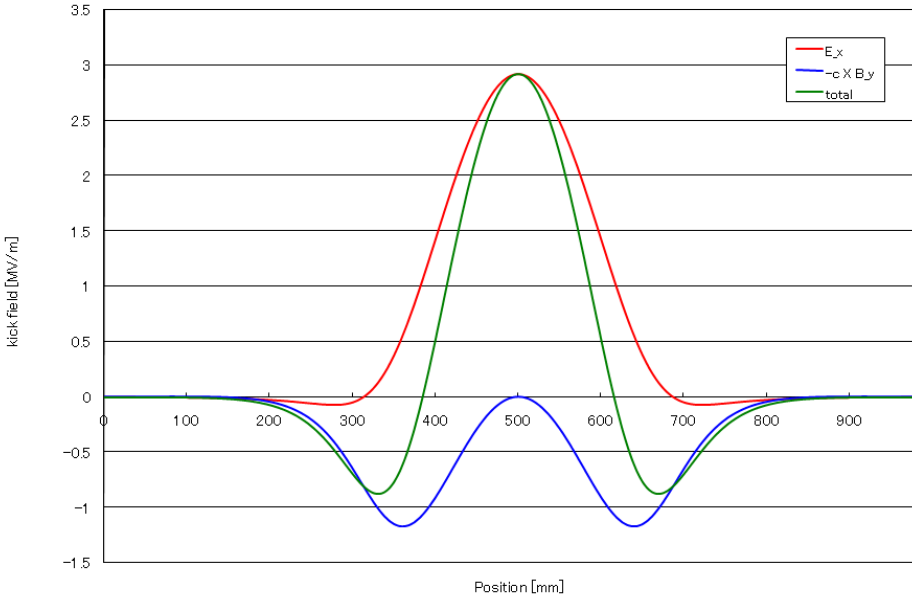
Schematic view of e-crab

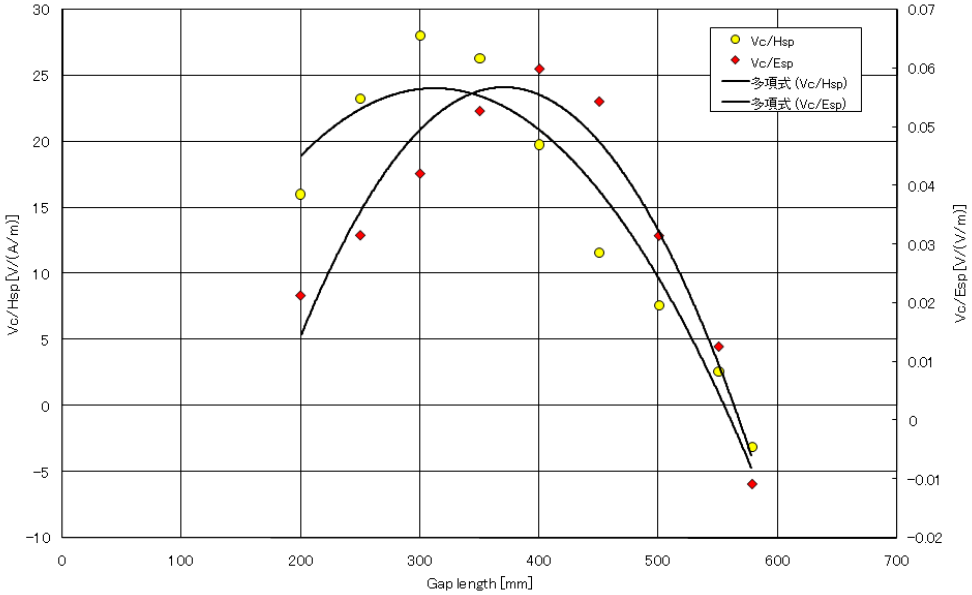


Field distribution of e-crab

This cavity required small beam separation.
Direction of deflection due to electric and magnetic fields are opposite.
Therefore the gap length must be adjusted to make high kick voltage.
If nose cone like structure is omitted, kick voltage almost vanished.
If field emission and multipacting can be suppressed as well as present crab cavity,
it can make about 1MV kick voltage.

It is not considered to apply to SuperKEKB.
It have to consider that this and other compact crab cavity designs can be apply to SuperKEKB





summary

- The present crab can be applied to HER of SuperKEKB.
  (Improvement of HOM absorber is required.)
- New design crab cavity is required to LER of SuperKEKB.
- New design crab cavity was proposed in 2004.
- New crab cavity development is started in collaboration with LHC crab cavity group.
- Modified new design crab cavity is being analyzed by US-LARP.
- Many type of compact crab cavities are proposed, we have to conceder that if they are applicable.