CORRECTION

I said yesterday that ceramic coating of conductor pipe is not broken up to 1mm/m bending…

It is not exactly.

I have not bended a ceramic-coated pipe until broken.
I saw that a 7.5mm*7.5mm hollow conductor of copper ceramic-coated was self-weighted down to about 1mm/m, perhaps, more. And it is not broken.
I do not know the limit.
But I think that ceramic coating is more flexible.

Design of DC-Septum magnets of the injection and extraction system of the Rapid Cycle Synchrotron(RCS) for the J-PARC

14th ICFA mini-workshop on septa devices

平成17年3月1日
ブルックヘブン国立研究所,米国

Member of designing of RCS's septa

日本原子力研究所(JAERI)
島田太平(SHIMADA Taihei)　渡辺真朗　高柳智弘　神谷潤一郎
and
入江吉郎(IRIE Yoshiro)…boss

高エネルギー加速器研究機構(KEK)
藤森寛　五十嵐進　酒井泉　川久保忠通

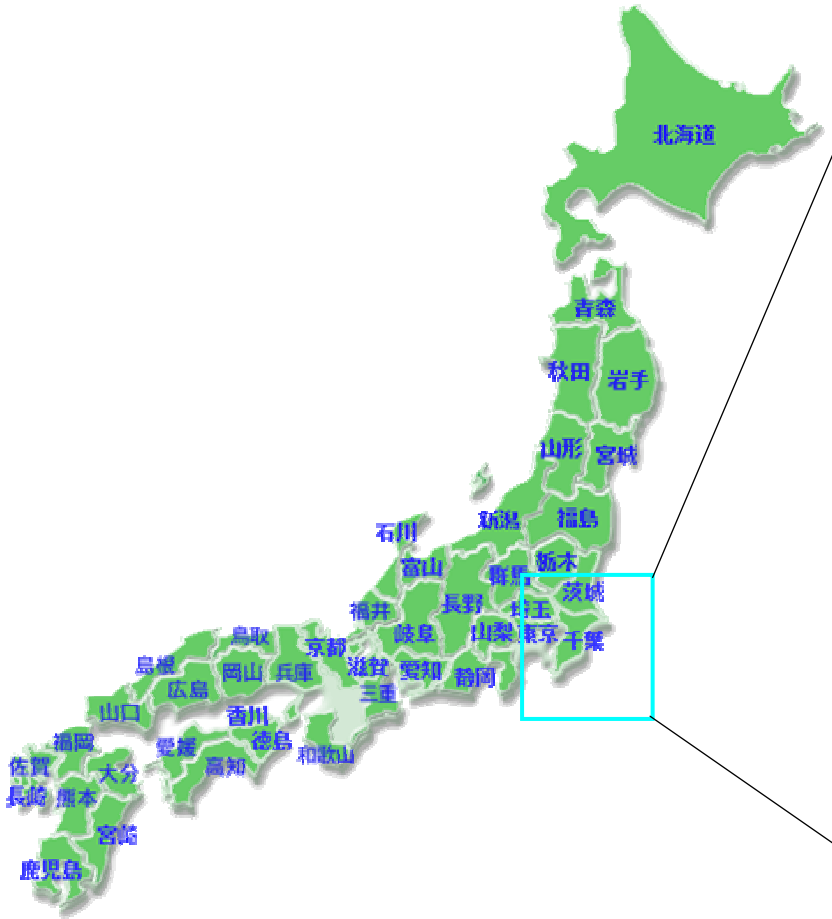
CONTENS

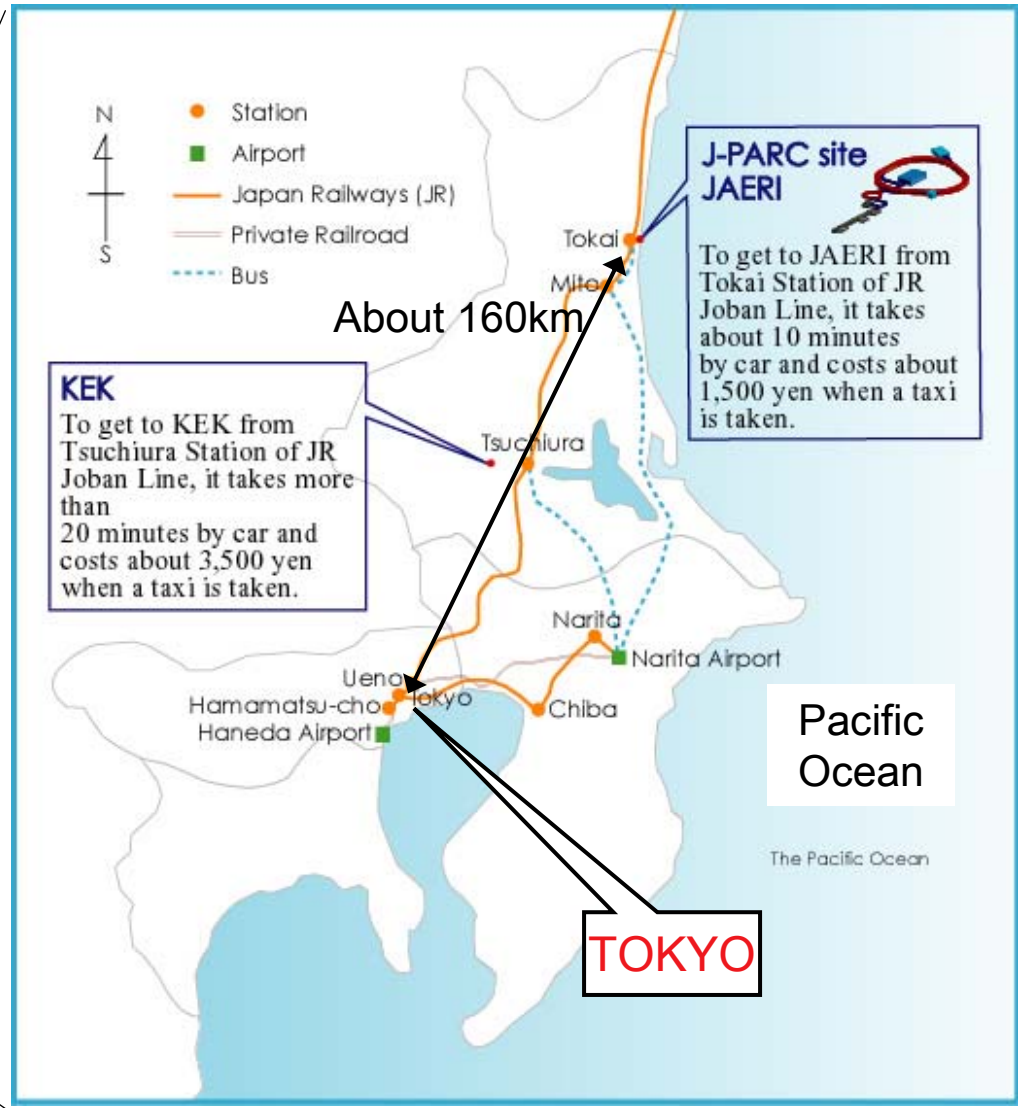
- INTRODUCTION
- DESIGN
- PROTOTYPE
- Concept of coil support and insulation

J-PARC http://jkj.tokai.jaeri.go.jp/index.html

JAERI and KEK Joint Project
Japan Proton Accelerator Research Complex
High Intensity Accelerator Project

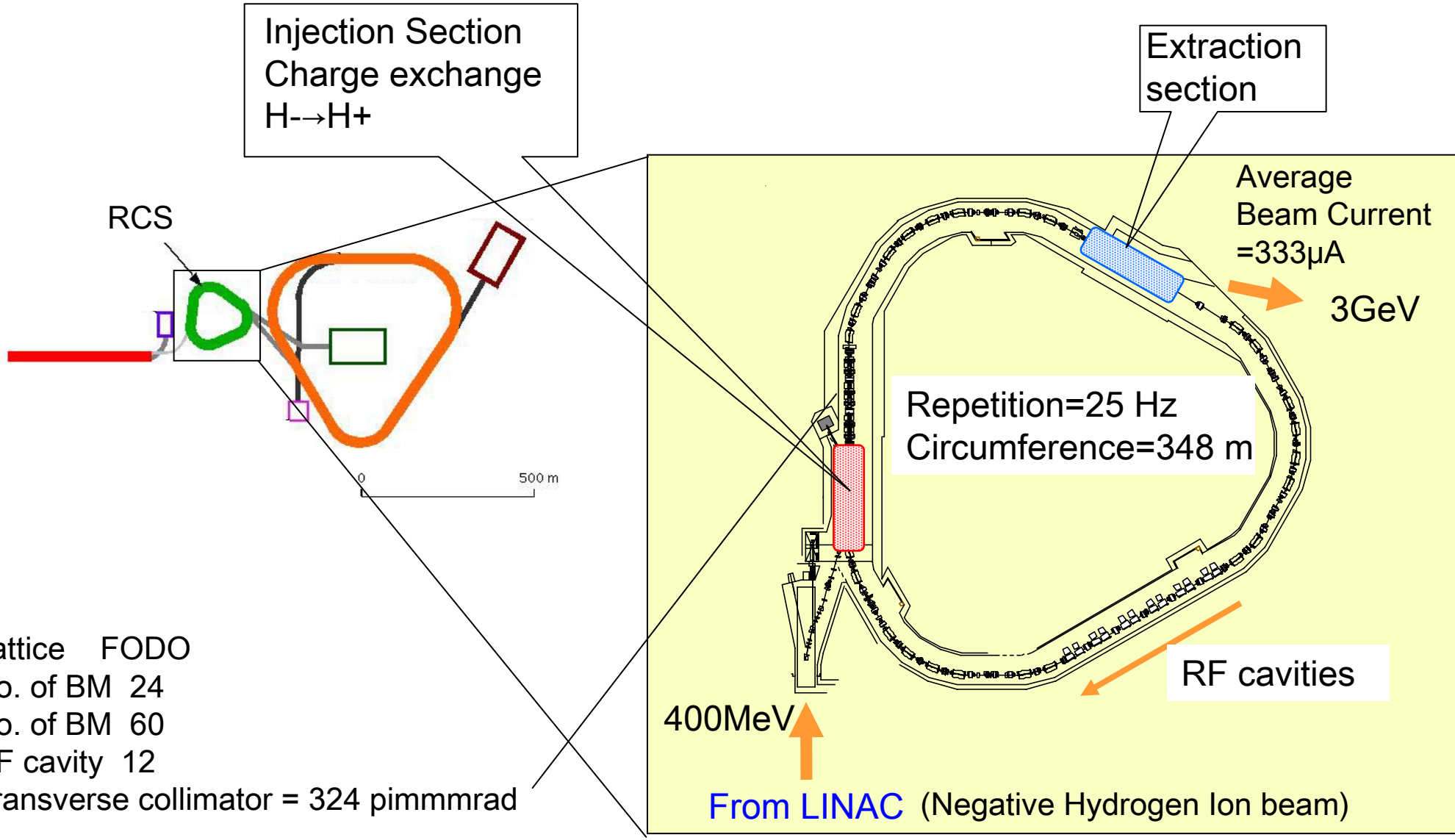
JAERI…Japan Atomic Energy Research Institute
KEK..Ko Enerugi kasokuki Kenkyu kiko





PLAN of J-PARC

RCS Rapid Cycle Synchrotron



Lattice FODO
No. of BM 24
No. of BM 60
RF cavity 12
Transverse collimator = 324 pimmmrad

INJECTION system

High Intensity Machine → Multi-turn Injection (to fill phase space)

Charge Exchange Injection ← Liouville theorem

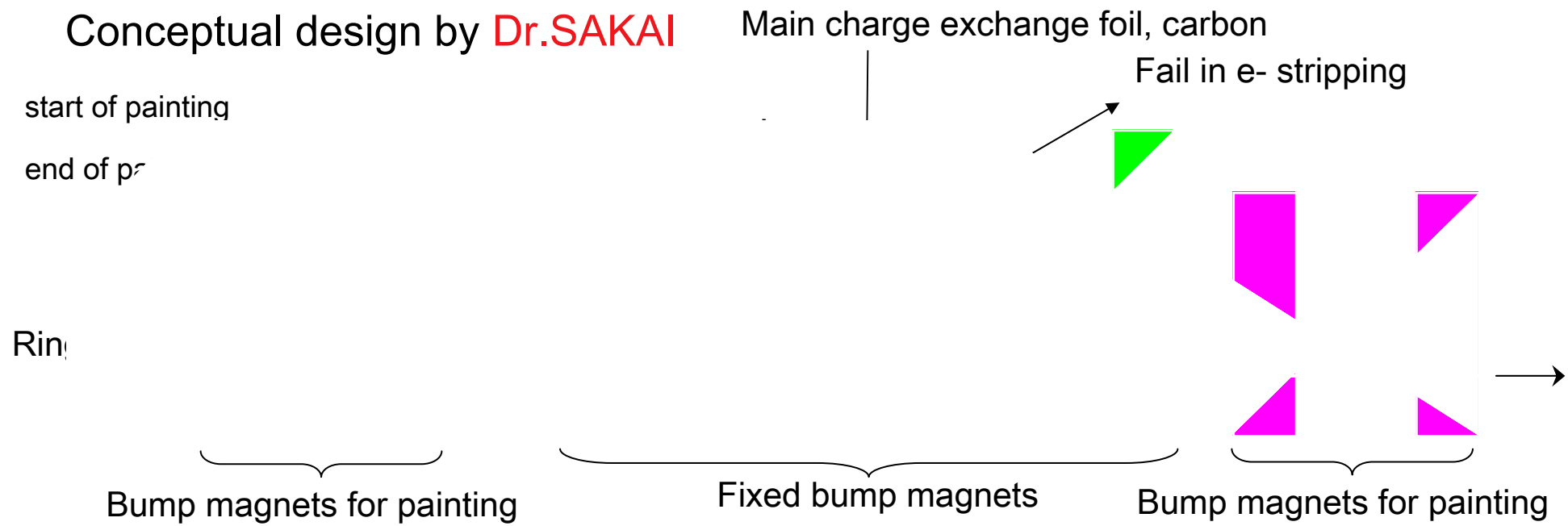
Charge exchange foils (electron stripper, H-→H+) and 4 bump magnets

Phase Space Painting ← Space Charge Effect

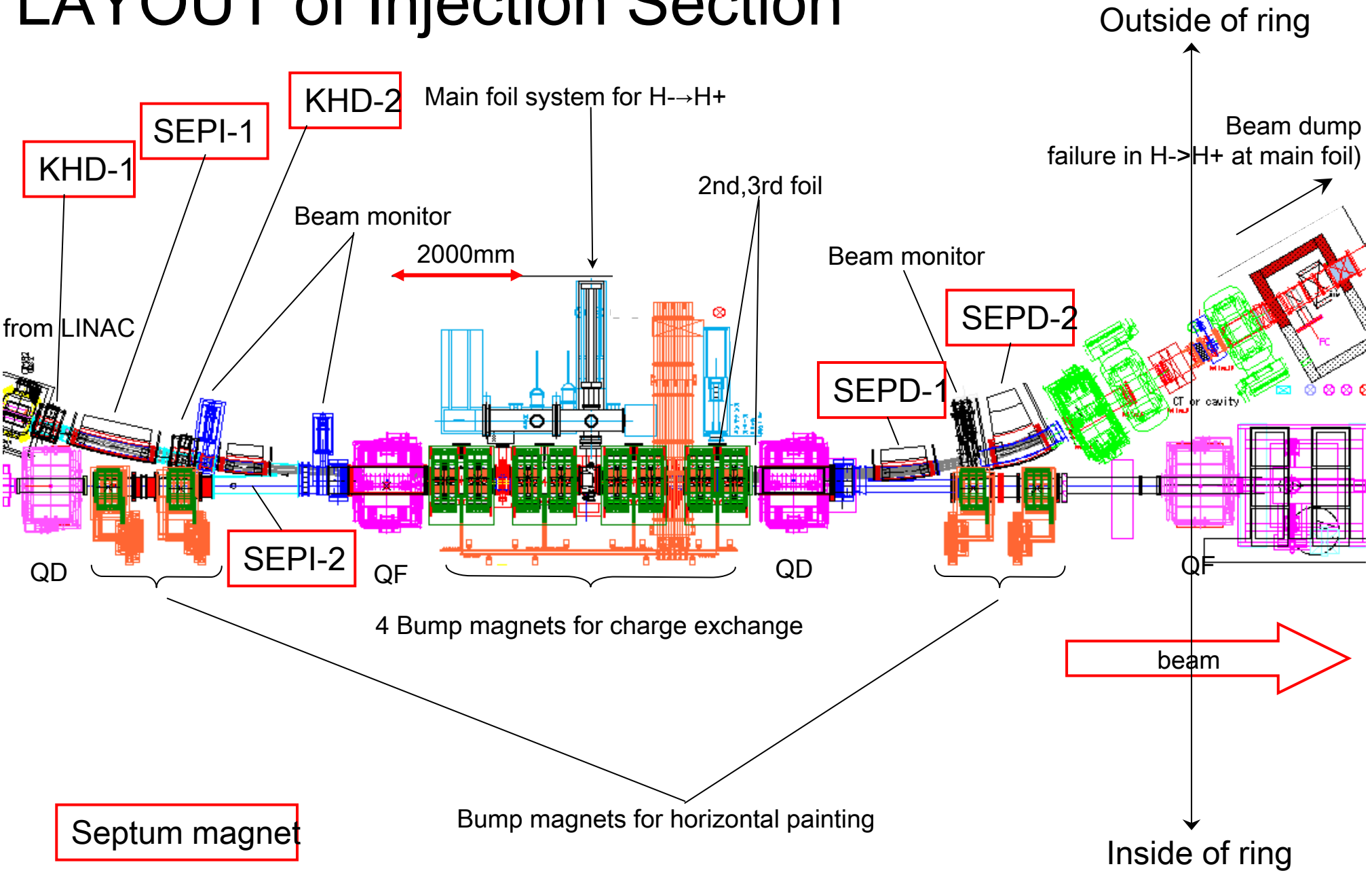
horizontal painting …to move ring orbit using 4 bump magnets in the RCS ring

vertical painting …to move injection line using pulse magnets in the BT line

Conceptual design by Dr.SAKAI



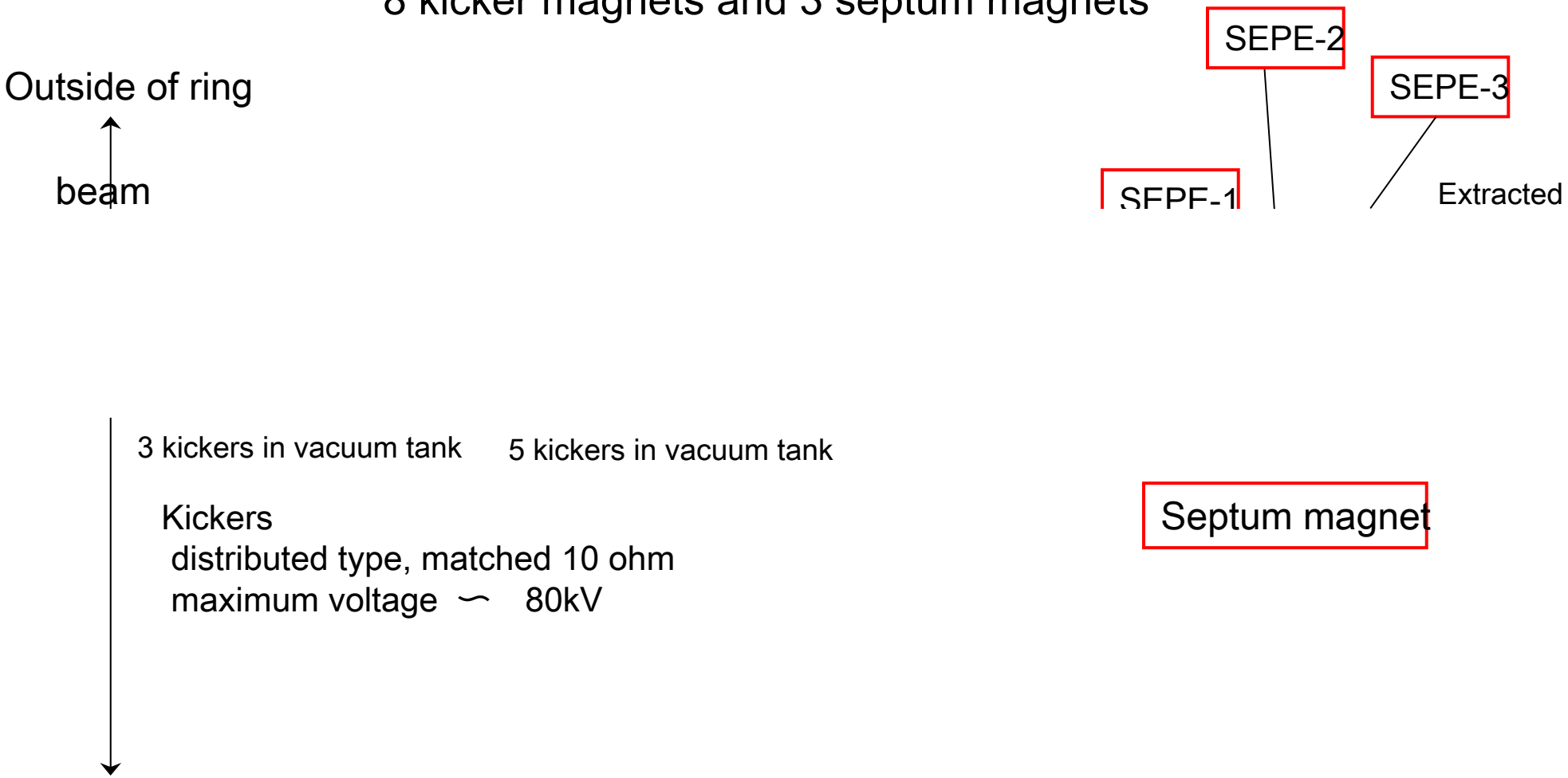
LAYOUT of Injection Section



EXTRACTION system

fast extraction = one turn extraction

8 kicker magnets and 3 septum magnets



DESIGN of SEPTA

RCS = High Power Machine

1) Large aperture to allow the high intensity beam pass through with a low beam loss(≦0.1%).

aperture for injection beam 30 pimmmrad
aperture for extraction beam 326 pimmmrad - collimator aperture

2) Protection against the high radiation (>100MGy/30years in septum coils).

3) High durability to avoid maintenance after high activation.

POLICY

Septum magnets are designed to operate in DC excitation current for mechanical stability
and to use in low voltage to be easy to insulate.

Septum magnets are operated in the air (out of the vacuum),
to avoid an accident of cooling water leaking into the vacuum system of the ring.
(beam runs in vacuum duct)

DESIGN PARAMETERS of SEPTUM MAGNET

		Injection		Dump		Extraction			Injection
	unit	入射用 SEPI-1	入射用 SEPI-2	廃棄用 SEPD-1	廃棄用 SEPD-2	出射用 SEPE-1	出射用 SEPE-2	出射用 SEPE-3	可変偏向 KHD
number of magnets	台	1	1	1	1	1	1	1	2
particle		400Mev,H-	400Mev,H-	400Mev,H+	400Mev,H+	3GeV,H+	3GeV,H+	3GeV,H+	400Mev,H
field strength	T	0.487	0.439	0.501	1.086	0.695	1.402	1.659	0.4195
effective length	mm	1400	800	1000	1000	900	1000	1000	300
gap width	mm	370	348	368	622	336	521	743	406
gap hight	mm	136	136	136	140	223	189	166	160
wave form		DC							DC+AC(3%)
environment		大気中(to operate in air, beam passing in vacuum duct in gap)							
min. septum thickness (duct+coil+shield)	mm	87	45	51	340	34	90	260	91
material of core		電磁軟鉄 JIS SUYP-1 (electromagnetic soft iron; solid)							0.5mm lamination
mass of core	kg	2515	1212	1724	12297	1751	7747	15004	485
magnetic attraction	tonf	3.69	1.67	2.92	21.84	2.28	31.6	57.2	0.71
excitation current	A	6246	5650	6787	5603	11176	12312	11035	1963
turn number of coils	turn	8	8	8	24	10	16	20	24
conductor size	mm2	16*16-φ10 64*16-φ10	16*16-φ10 64*16-φ10	16*16-φ10 64*16-φ10	16*16-φ10 64*16-φ10	19*19-φ8 76*19-φ8	19*19-φ10 76*19-φ10	18*80-φ10	16*16-φ10
max. current density	A/mm2	35.2	31.8	38.2	31.6	48.5	43.6	8.5	14
voltage of coil	V	20	14	19	53	33	28	17	22.3
electro-magnetic force	tonf	1.53	0.68	1.25	6.71	3.17	12.68	16.81	0.26
power loss in coil	kW	127	78	127	295	364	285	185	45
no.of cooling channnel		8	8	8	24	20	16	20	24
cooling of coils		強制循環水直接水冷(water)							
flow rate	l/m	75	75	75	226	189	151	115	40
flow speed	m/s	2	2	2	2	2	2	1.2	2
pressure loss	kgf/cm2	0.77	0.7	0.73	0.75	0.75	0.76	0.32	3.16
temp. rize	℃	24	18	24	19	28	27	23	17

How we determined parameters of coils?

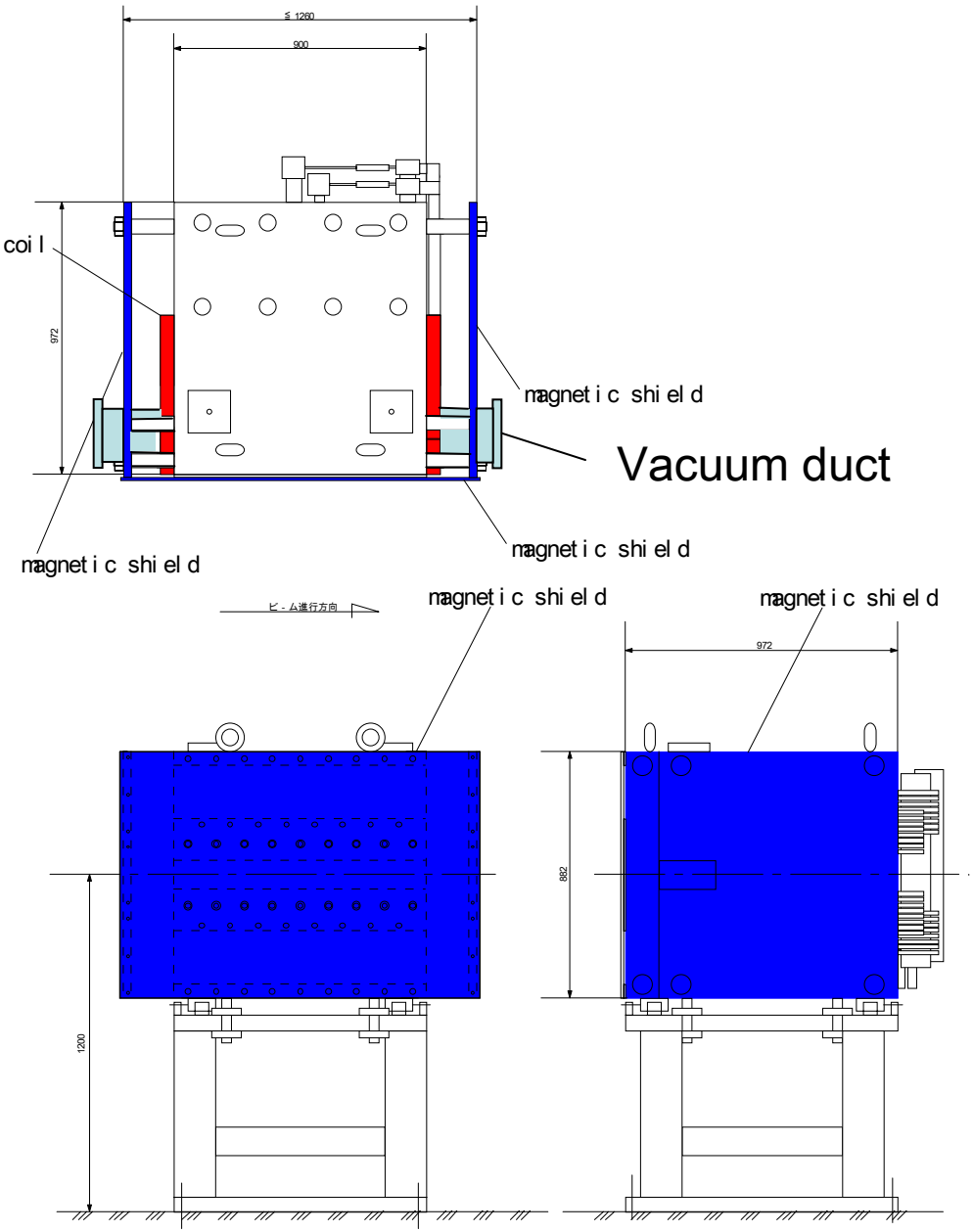
Ex1) SEPI-1,2 SEPD-1,2 have same or near gap height…136,136,136,140mm

Allowed septum thickness of SEPI-1 and SEPD-1 are smallest in them.
We determined their parameters at first.
Allowed space for coil is about 16mm width.
It is need to reduce turn number,
to be low voltage, to be good mechanical stability, to be easy to fabricate…
Durability of coils has priority over the cost of power supplies and power feeds
So we determined number of row of coil to one, i.e. cc
Because square hollow conductor is to be easier to w
we determined height size of conductor to 16mm.
Turn number of coil = gap height / 16mm = 136 / 16 =
Other magnets use the same hollow conductor
because of to use the same parts of cooling channels

Ex2) SEPE-1,2,3

Turn number ratio is fixed to excite them in series
to use near square conductor in SEPE-1,2
to reduce turn number
to reduce cost of power supplies
to reduce cost of power feed
limit of size of hollow conductor

We determined turn no. comprehensively.



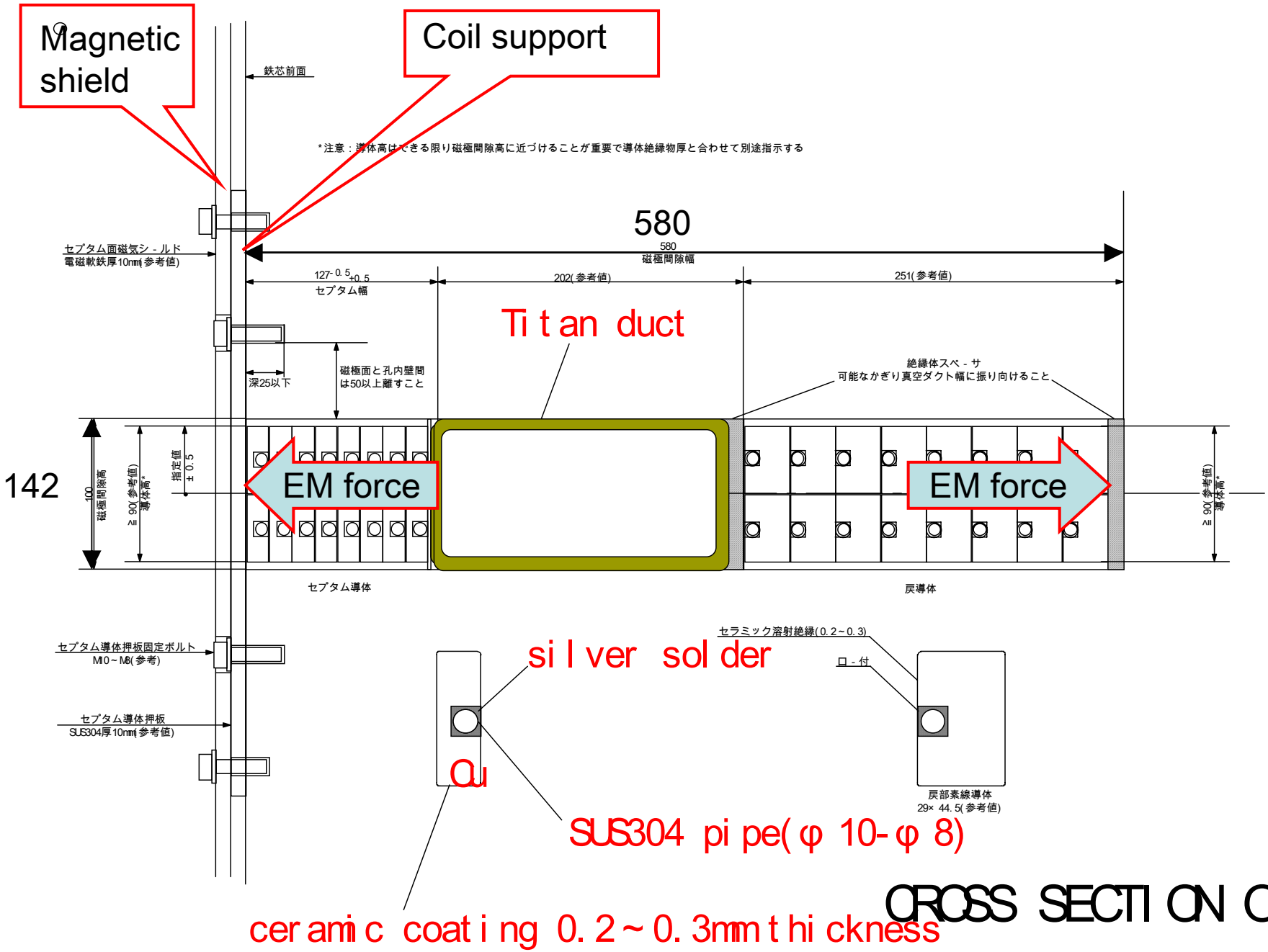
A prototype magnet

gap height	142 mm
magnetic field in the gap	1.13 T
excitation current	12800 A
turn number of coil	10

Ceramic coating is used as the electronic insulation material due to its strength against high radiation (>>100MGy).

All cooling pipes are made of SUS304; non-magnetic stainless steel(SUS304) due to its hardness against erosion and corrosion by the flow of cooling water.

Titanium metal is used as the material of the vacuum duct in the gap because it is its strength against activation.



CROSS SECTION OF GAP

Assembling coils

Cooling pipe (SUS304 stainless steel)
1 water channel / 1 turn φ12-φ10

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White parts are coated of ceramic, sprayed with melting ceramic,Total thickness is 0.2∽ 0 .3mm.

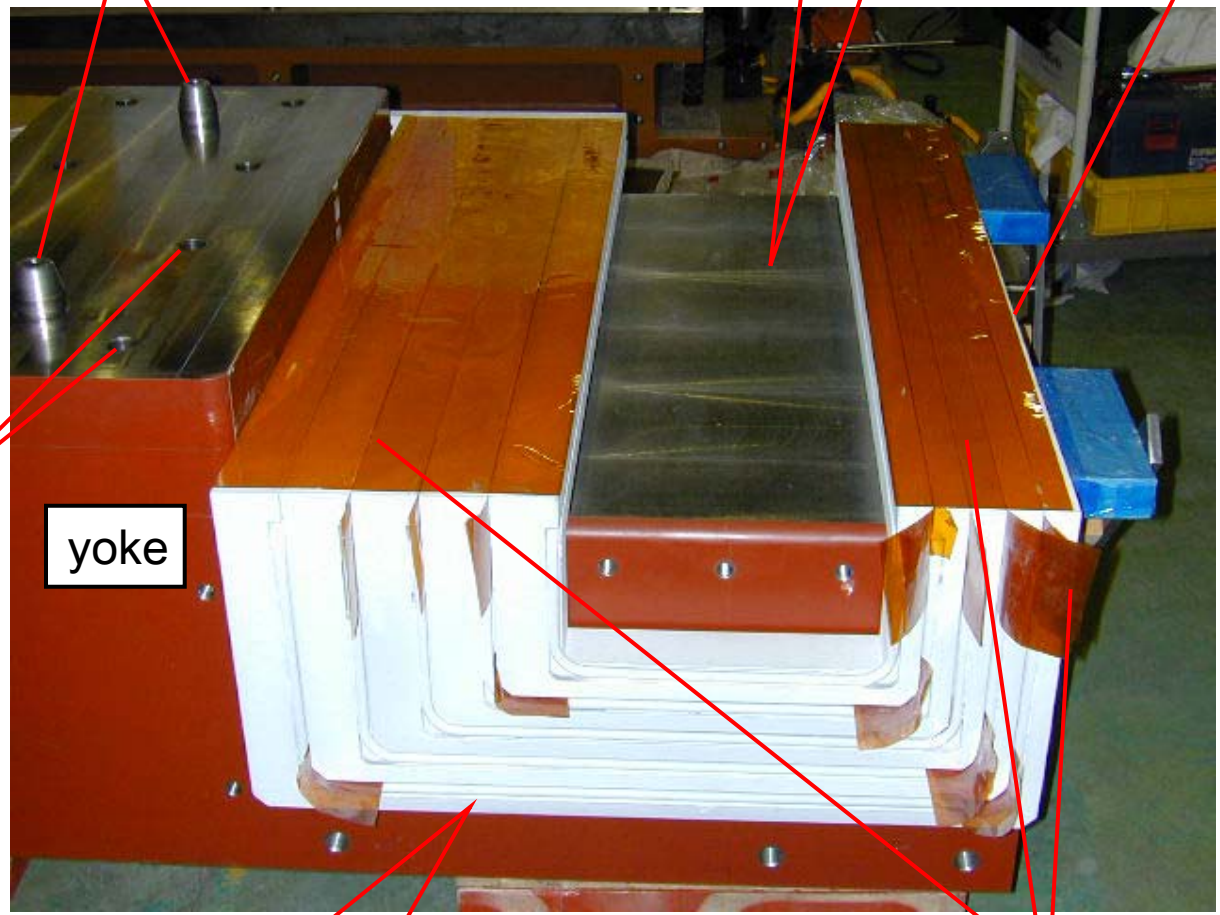
Ceramic coating

Engineers of the company of ceramic coating say

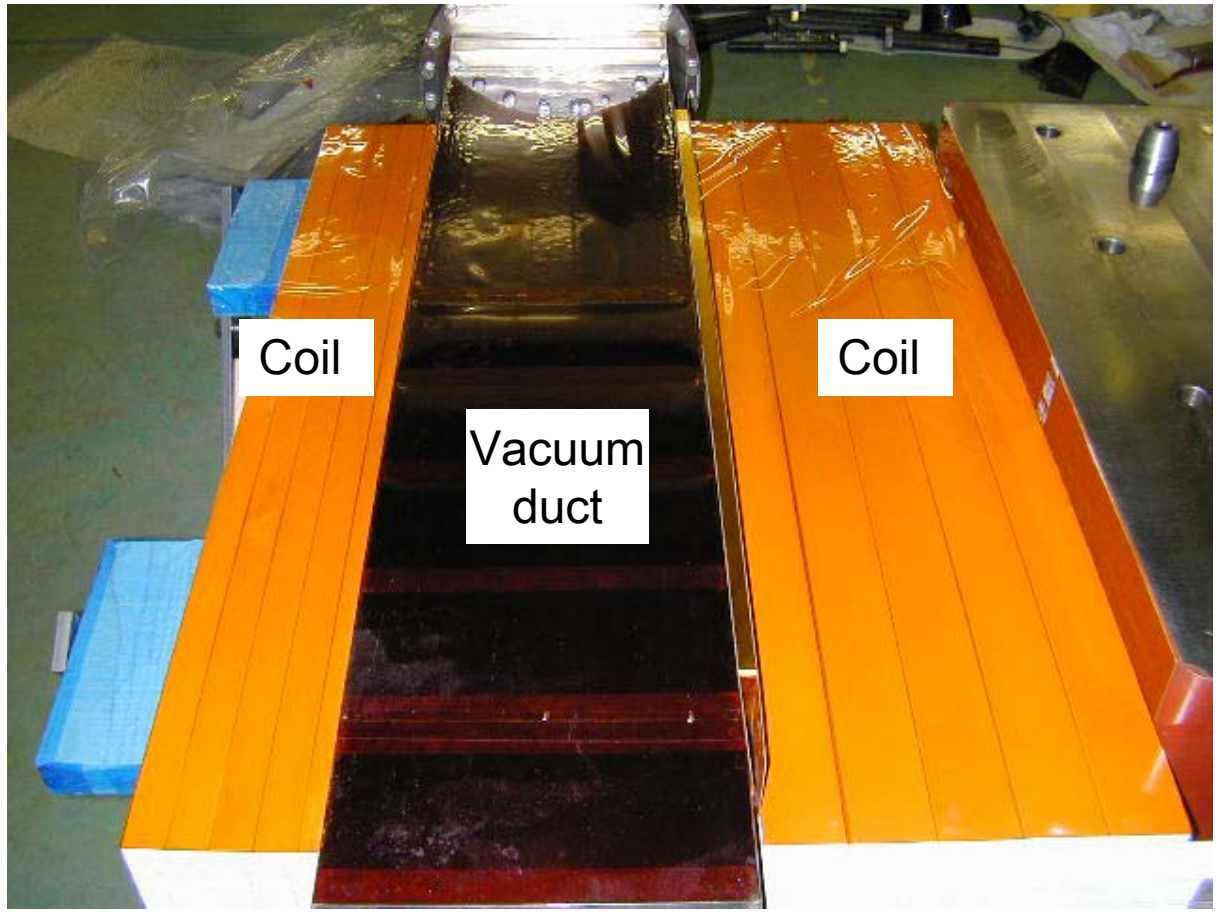
Best thickness is 0.2-0.3mm (10 X 0.02mm)

if less than this, electric insulation becomes uncertain.
if more than this, coating becomes non-flexible, to be apt to crack.

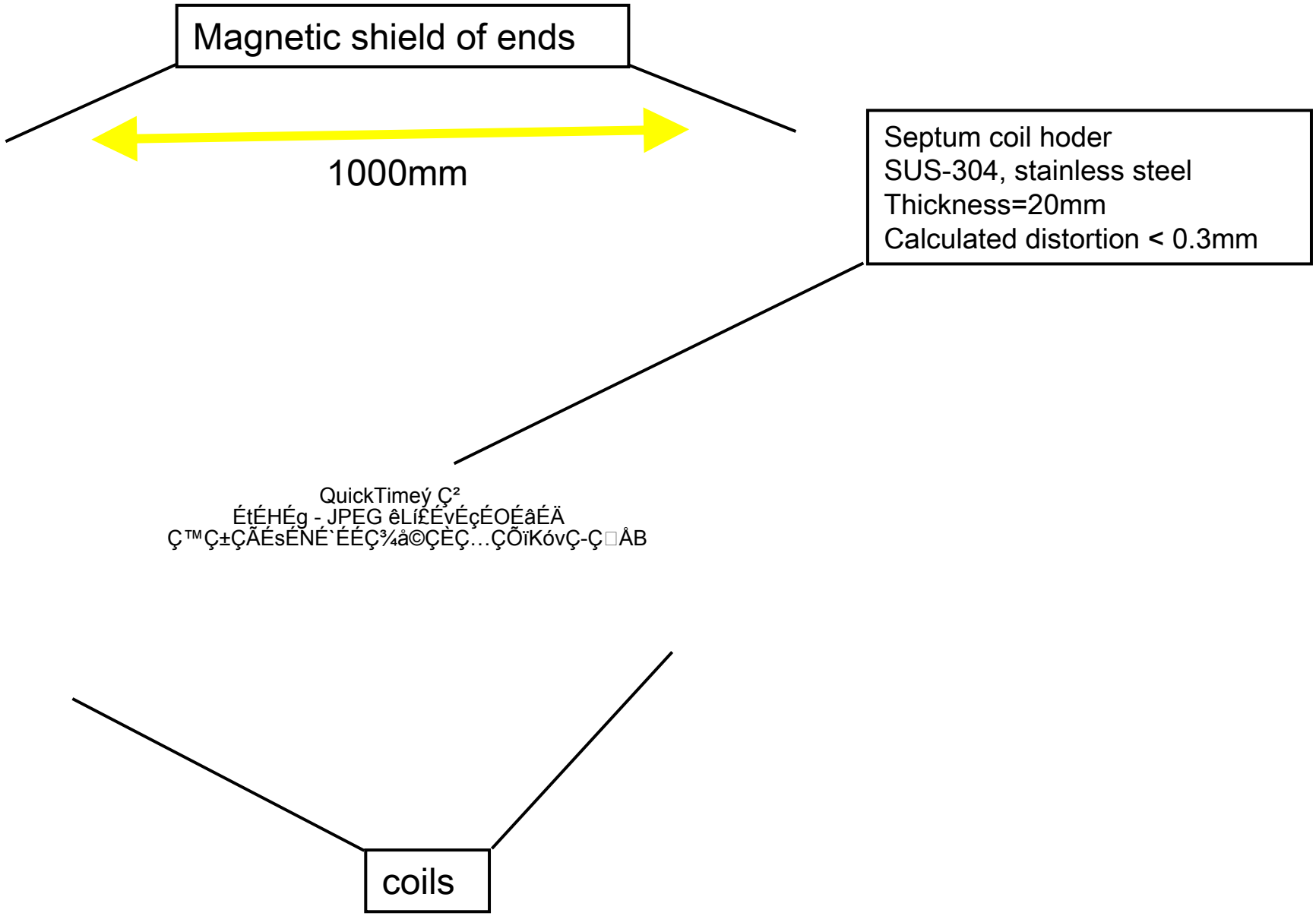
Coils into iron core



Vacuum duct into magnet



End-shield and septum coil holder



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end view, removed magnetic shield

End holder of coils

Concept of coil support and conductor insulation

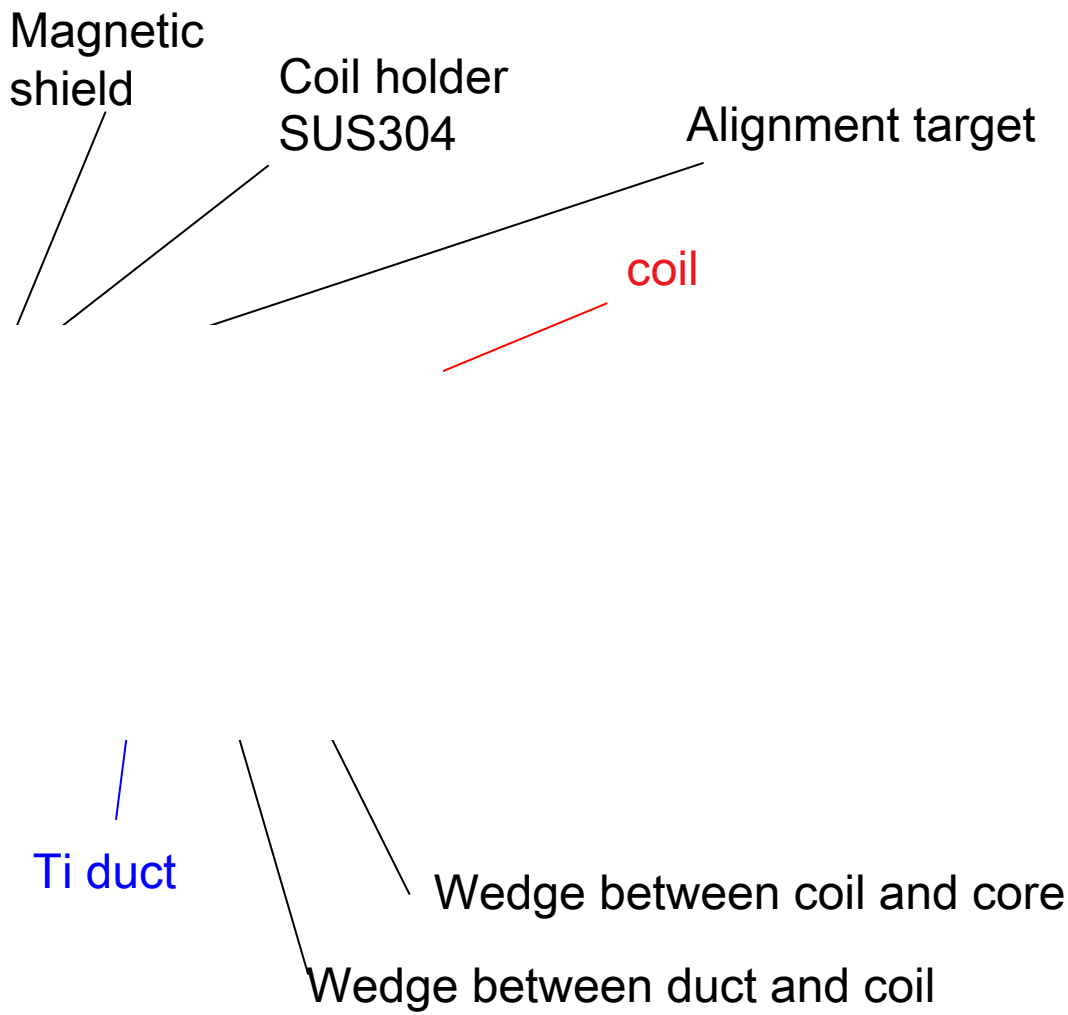
☐Coil supported by sandwiched between coil holder and duct.

Coil is only individually ceramic-coated to insulate.

Ground insulation is none.

We put KAPTON sheets around conductors in order to defend coating
from breaking during assemble work.

We put soft metal, Al sheets between coils and duct,
Between coils and iron in order to slip conductors
As distorting by thermal force or electro-magnetic
Force.



WaveForm of BUMP MAGNETS