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Fine-Tuning to Minimize Emittances of J-PARC RF-Driven H^- Ion Source

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- J-PARC 2nd STAGE STATUS
- EXPERIMENTAL SETUP & METHODS
- ROD-FILTER-FIELD (RFF) OPTIMAZATION
- BEAM-HOLE-DIAMETER (Φ_{PE}) OPTIMIZATION
- CONCLUSIONS

* ICIS2015 Poster Presentations on J-PARC-IS
  [A] "Status of the RF-driven H^- ion source for J-PARC linac"
  [B] "Pre-conditioning Procedure Suitable for Internal-RF-Antenna of J-PARC RF-Driven H^- Ion Source"
  [C] "Numerical study of plasma generation process and internal antenna heat loadings in J-PARC RF negative ion source"

J-PARC 2nd Stage Started Oct. 2014
(Routine Operation until June 2015)

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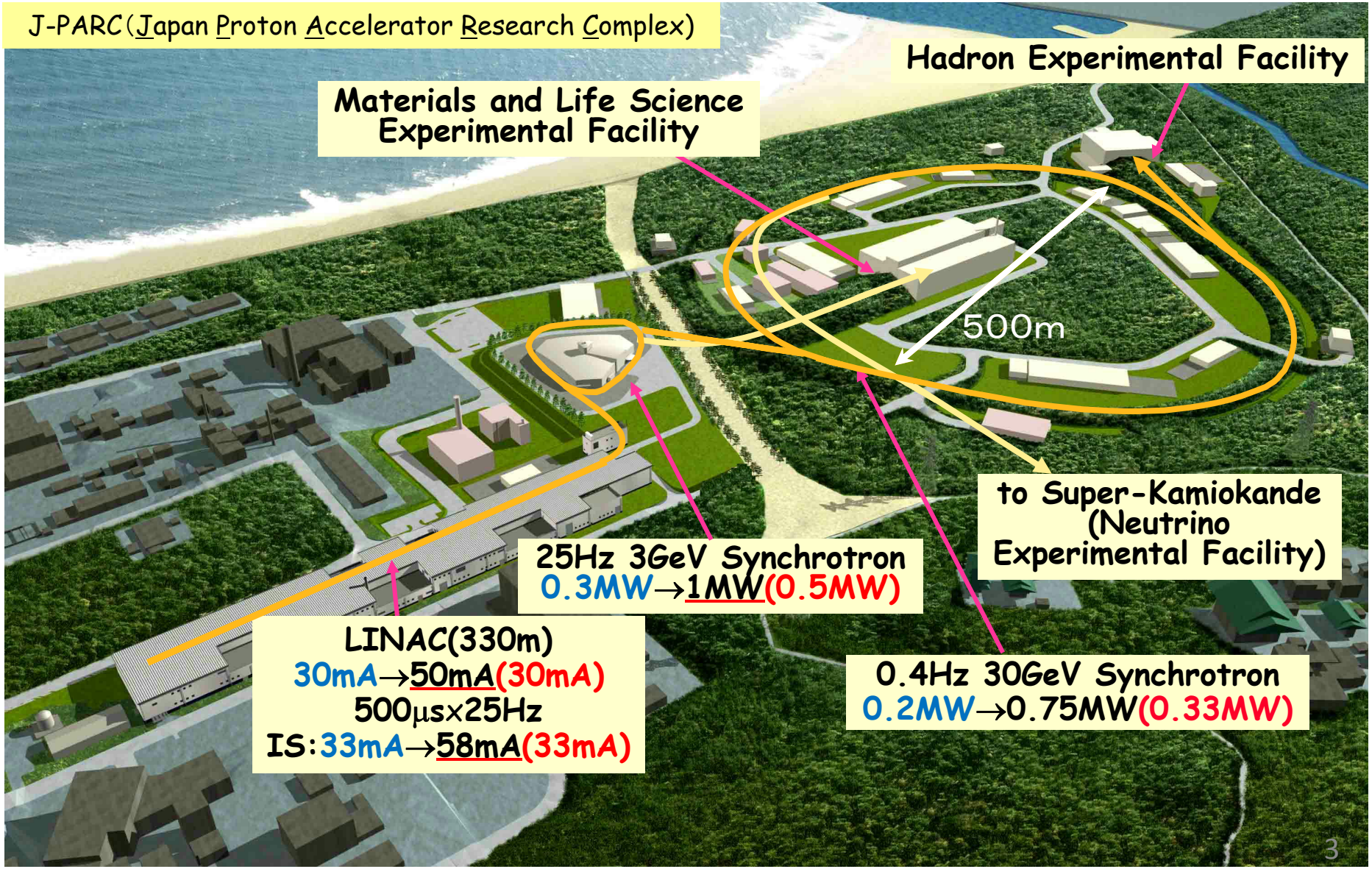

J-PARC RF-DRIVEN H⁻ ION-SOURCE TEST-STAND (IS-TS)

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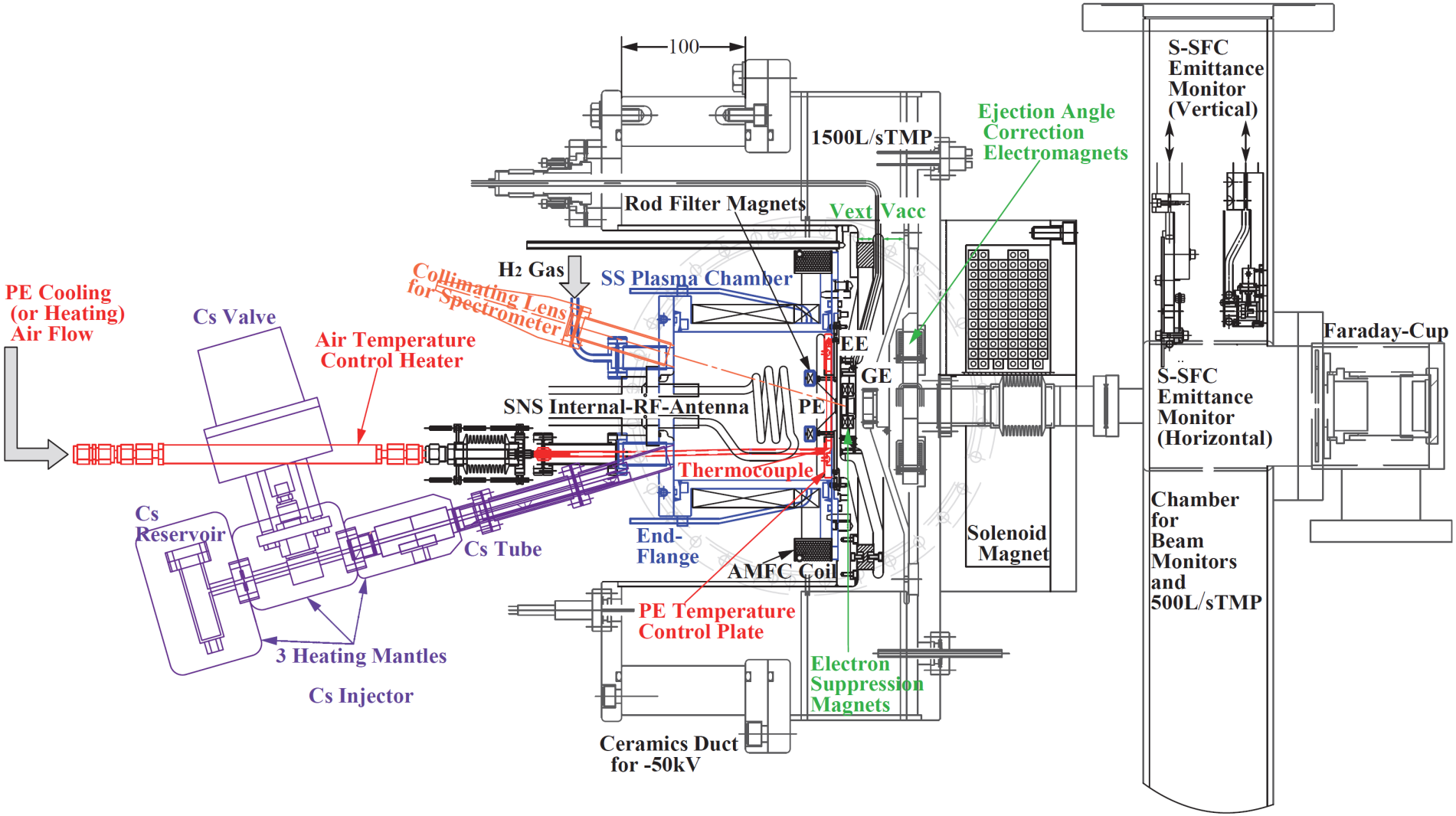

Cross-sectional view of experimental setup of IS-TS.

*Thick PE(16mm-45°:1.5I_{H^-}) , AMFC(1.1I_{H^-}), T_{PE}~60 ° C(0.75$\varepsilon_{msnx/y}$) and so on.

ROD-FILTER-FIELD(RFF) OPTIMIZATION with various triple-gap-lengths (Gs)

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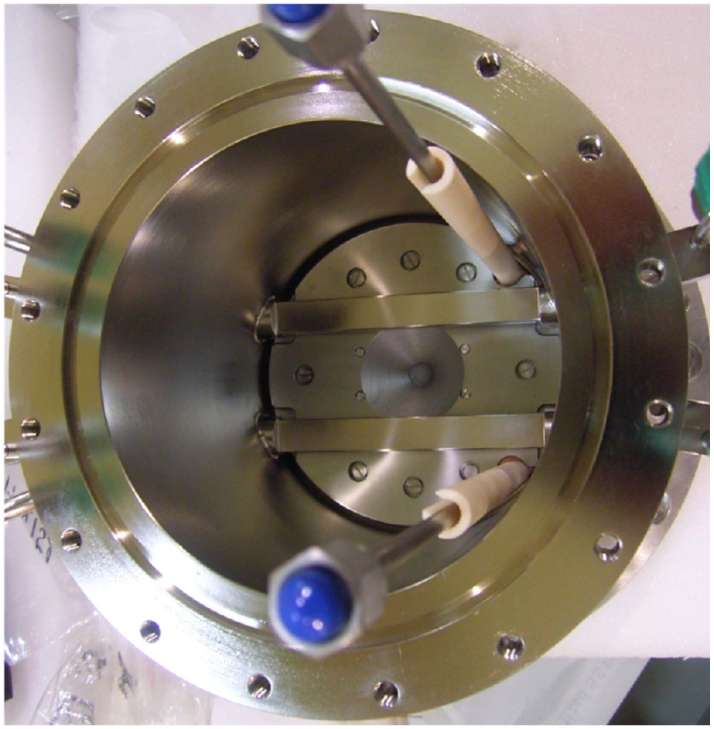
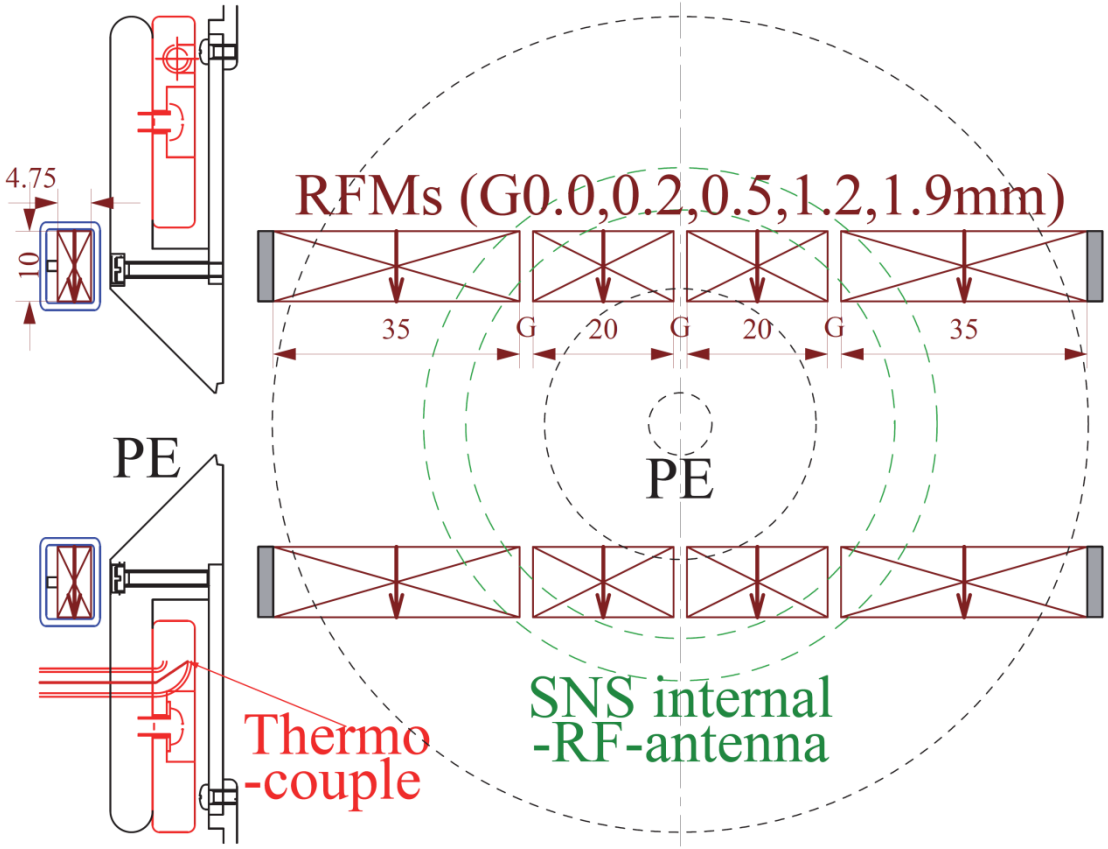


Photo of pipes for RFMs of SS(Stainless-Steel) #2 PCH(Plasma Chamber)



Drawing of RFMs related with Plasma Electrode (PE) and SNS internal-RF-antenna.

ROD-FILTER-FIELD(RFF) OPTIMIZATION with various triple-gap-lengths (Gs)

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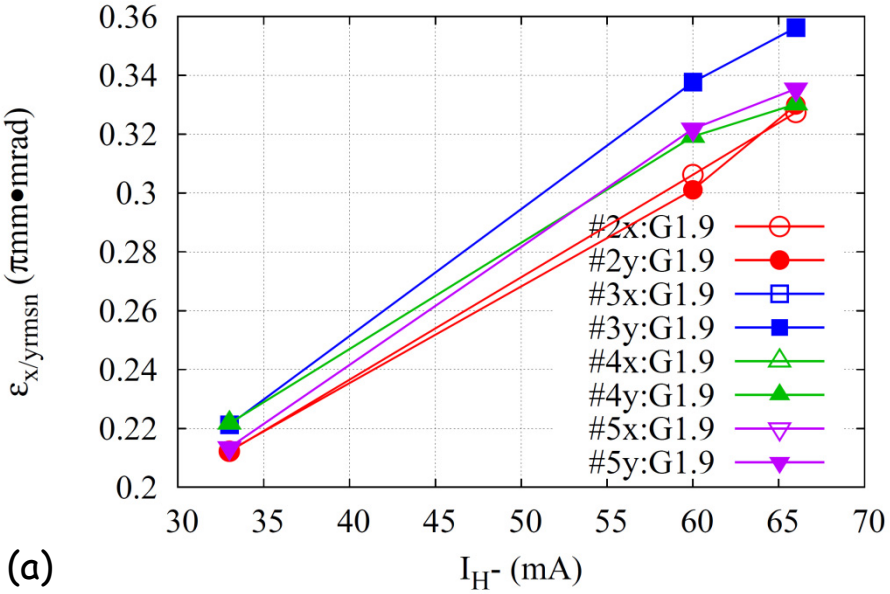
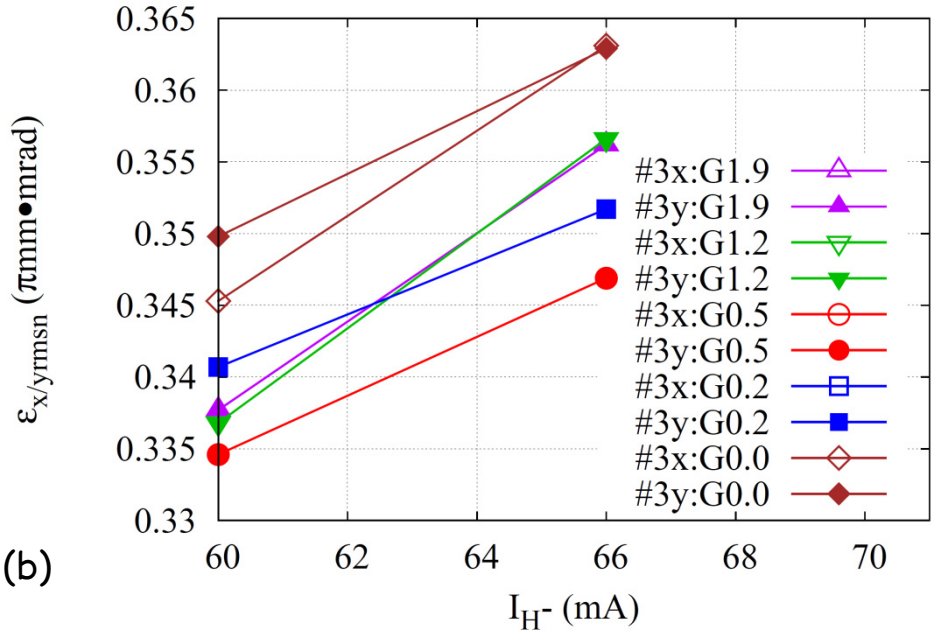


(a)



(b)

(a) Relationships between I_{H^-} & $\varepsilon_{x/yrmsn}$ for #2~#5 PCHs with G1.9mm.

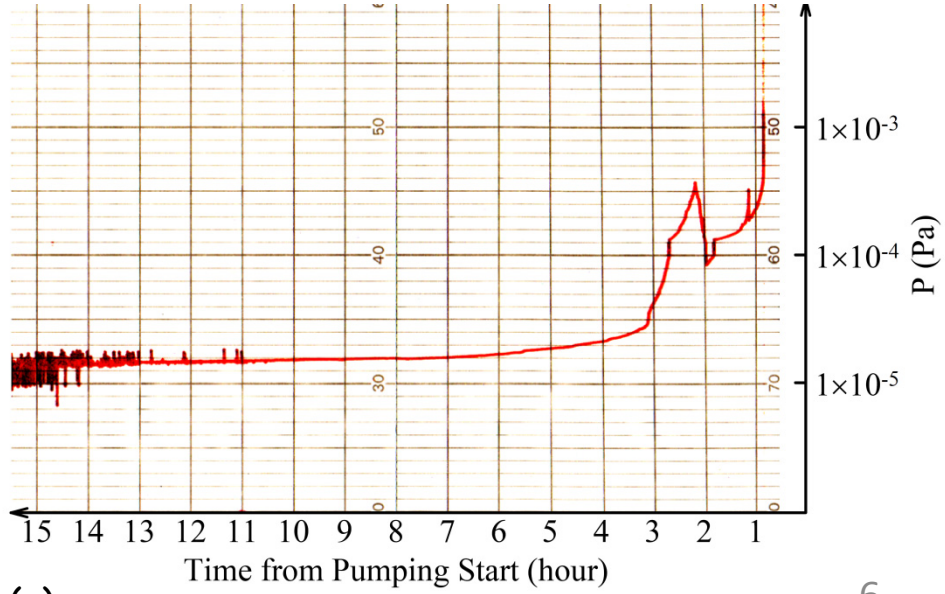
(b) Relationships between I_{H^-} & $\varepsilon_{x/yrmsn}$ for #3 PCH with G0.0,0.2,0.5,1.2 and 1.9mm.

-> Optumum G0.5mm. Still larger $\varepsilon_{x/yrmsn}$.

(c) Relationships between time form pumping start (hour) and vacuum pressure (P) for #3 PCH.

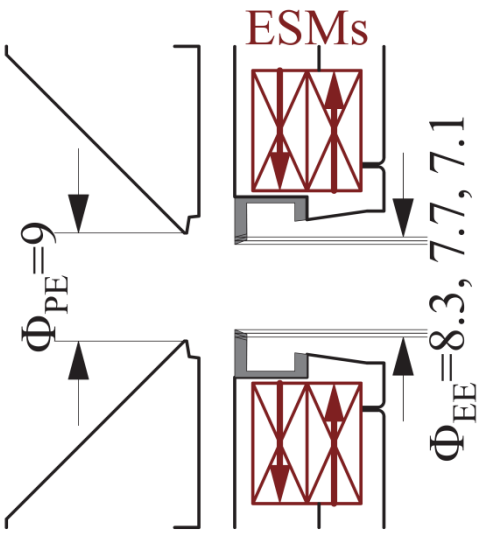
*Spike-nise-like fluctuation (by Ar & N2) of P.

->$\varepsilon_{x/yrmsn}$ seems to be degraded by impurity gasses.

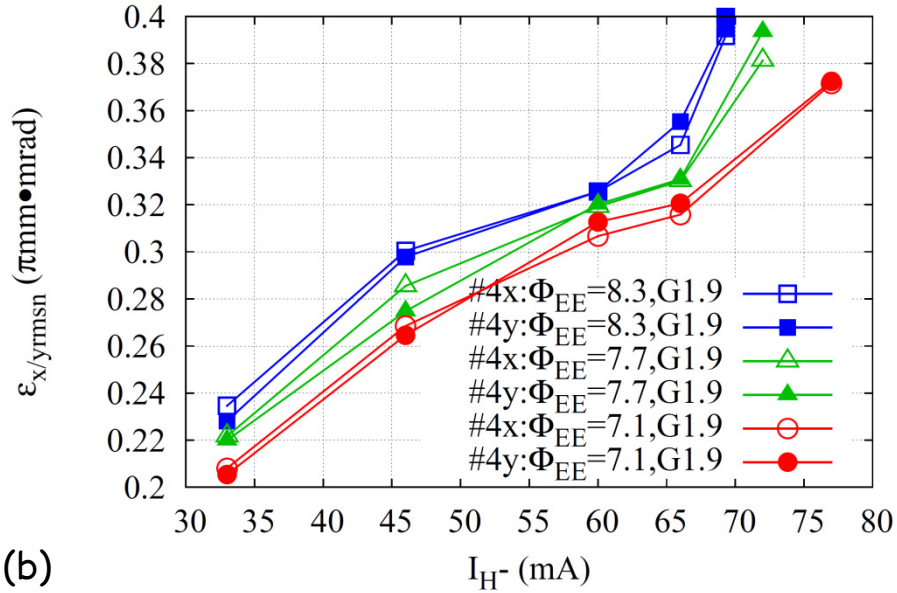


(c)

BEAM-HOLE-DIAMETER OF PLASMA ELECTRODE(Φ_{PE}) OPTIMIZATION



(a)



(b)

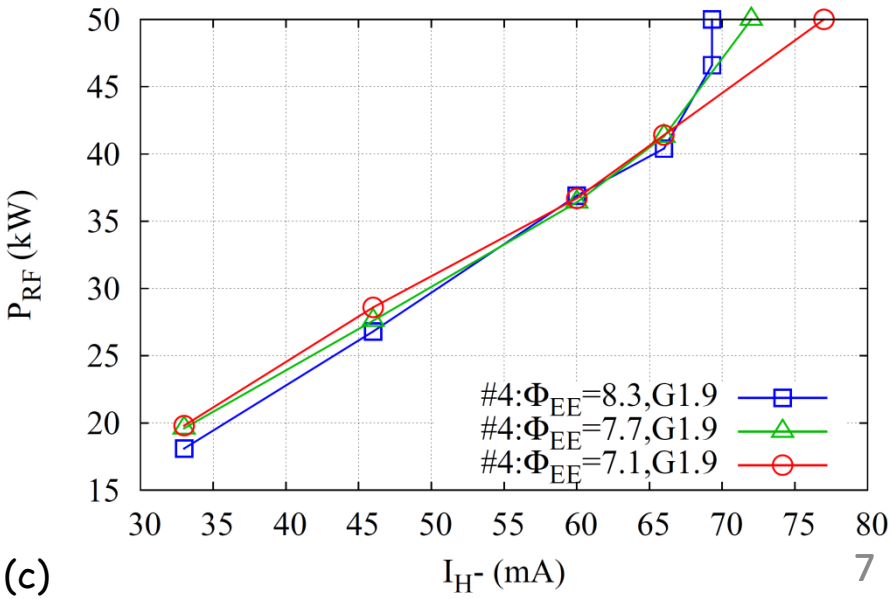
(a) Drawing of Plasma Electrode (PE) and Extraction Electrode (EE).

(b) Relationships between I_{H^-} & $\varepsilon_{x/yrmsn}$ for #4 PCH with Φ_{PE} of 8.3,7.7 and 7.1mm.

(c) Relationships between I_{H^-} & P_{RF} for #4 PCH with Φ_{PE} of 8.3,7.7 and 7.1mm.

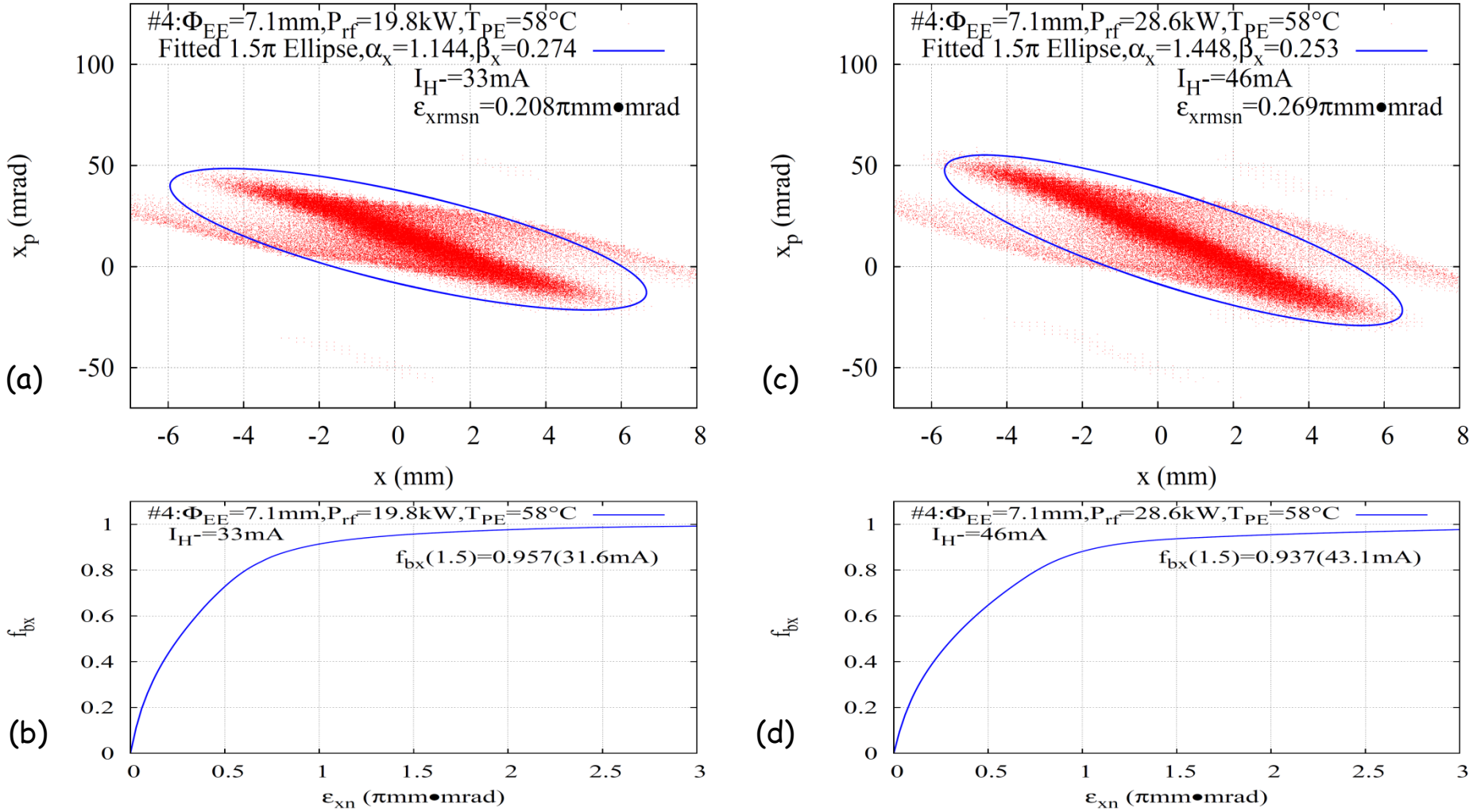
->Smallest Φ_{PE}=7.1mm produced smallest $\varepsilon_{x/yrmsn}$ & highest I_{H^-} for maximum PRF of 50kW.

*Smaller Φ_{PE} will be tested in near feature.



(c)

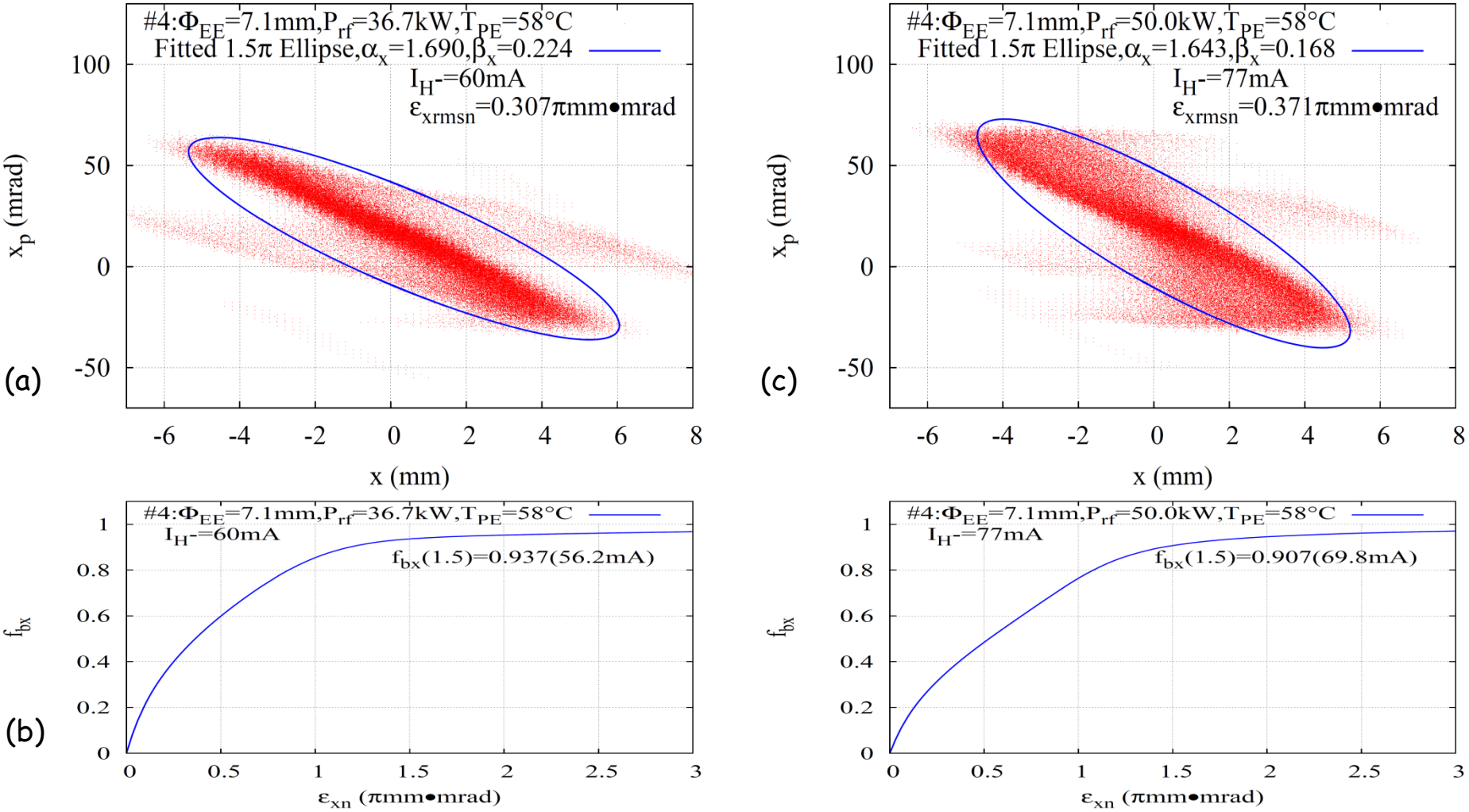
MEASURED HORIZONTAL EMITTANCES with #4 PCH and Φ_{PE}=7.1mm for I_H-=33 & 46mA



Horizontal emittances, fitted normalized 1.5π ellipse (a) and (c) and relationships between normalized emittnaces (ε_{nx}) and included beam fractions (f_{bx}) (b) and (d) with #4 PCH and Φ_{EE}=7.1mm for I_H-=33 & 46mA.

$\varepsilon_{xrmsn(}$(33mA)=0.208πmm•mrad & $\varepsilon_{xrmsn(}$(46mA)=0.269πmm•mrad

MEASURED HORIZONTAL EMITTANCES with #4 PCH and Φ_{PE}=7.1mm for I_H-=60 & 77mA



Horizontal emittances, fitted normalized 1.5π ellipse (a) and (c) and relationships between normalized emittnaces (ε_{nx}) and included beam fractions (f_{bx}) (b) and (d) with #4 PCH and Φ_{EE}=7.1mm for I_H-=60 & 77mA.

$\varepsilon_{xrmsn(}$(60mA)=0.307πmm·mrad & $\varepsilon_{xrmsn(}$(77mA)=0.371πmm·mrad

MEASURED HORIZONTAL EMITTANCES with #4 PCH and I_H-=66mA for Φ_{EE}=7.1 & 7.7mm

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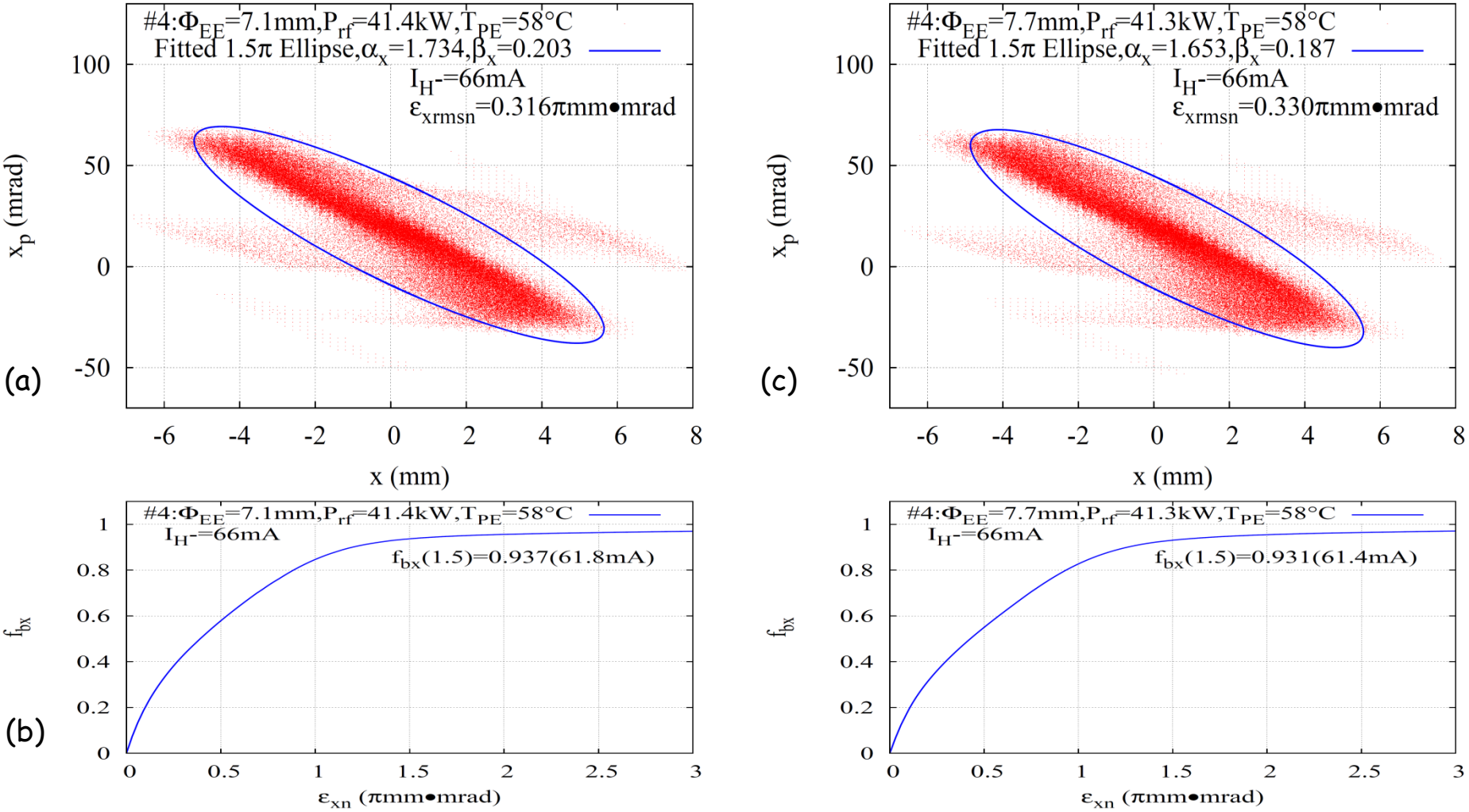
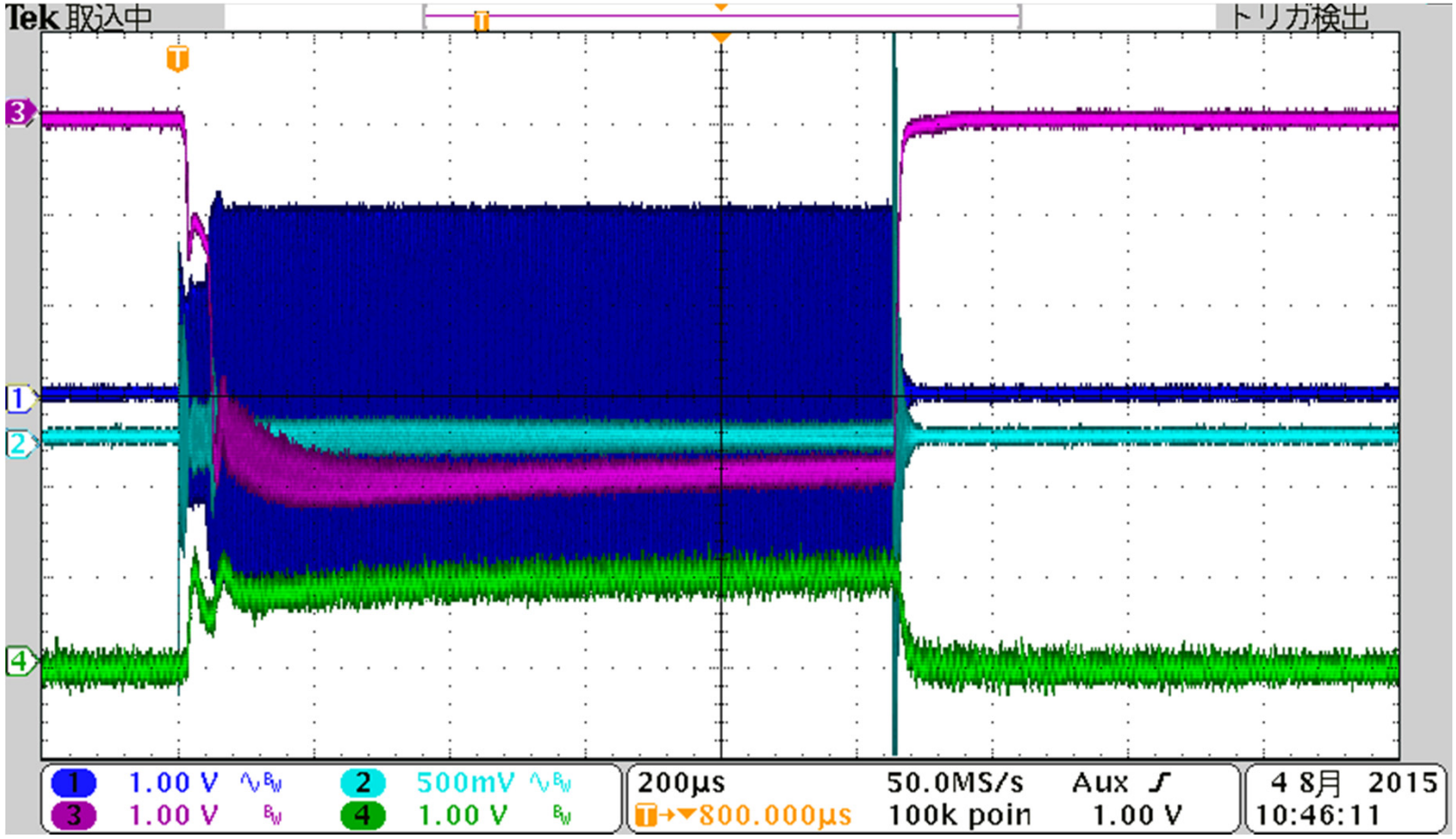


Horizontal emittances, fitted normalized 1.5π ellipse (a) and (c) and relationships between normalized emittnaces (ε_{nx}) and included beam fractions (f_{bx}) (b) and (d) with #4 PCH and I_H-=66mA for Φ_{EE}=7.1 and 7.7mm.

ε_{xrmsn}(7.1mm)=0.316πmm·mrad & ε_{xrmsn}(7.7mm)=0.330πmm·mrad

Measured Waveforms for I_{H^-}=80mA



Measured waveforms of 2MH-RF forward & reflected voltages V_{RFF}(trace1, arb. : P_{RF}=50kW) & V_{RFR}(trace2, arb), H^- ion intensity I_{H^-}(trace3, 20mA/Div. : initial 500µs average of flat top is 80mA) and extraction current I_{ext}(trace4, 100mA/Div.) for #2 PCH with Φ_{EE}=7.1mm & G1.9mm.

ε_{xrmsn} & ε_{yrmsn}=0.394 & 0.394πmm·mrad.

CONCLUSIONS

Triple-gap-lengths (Gs) of 0.5mm for rod-filter-magnets (RFMs) were optimum to minimize the ε_{xrmsn} and ε_{yrmsn} with the #3 PCH.

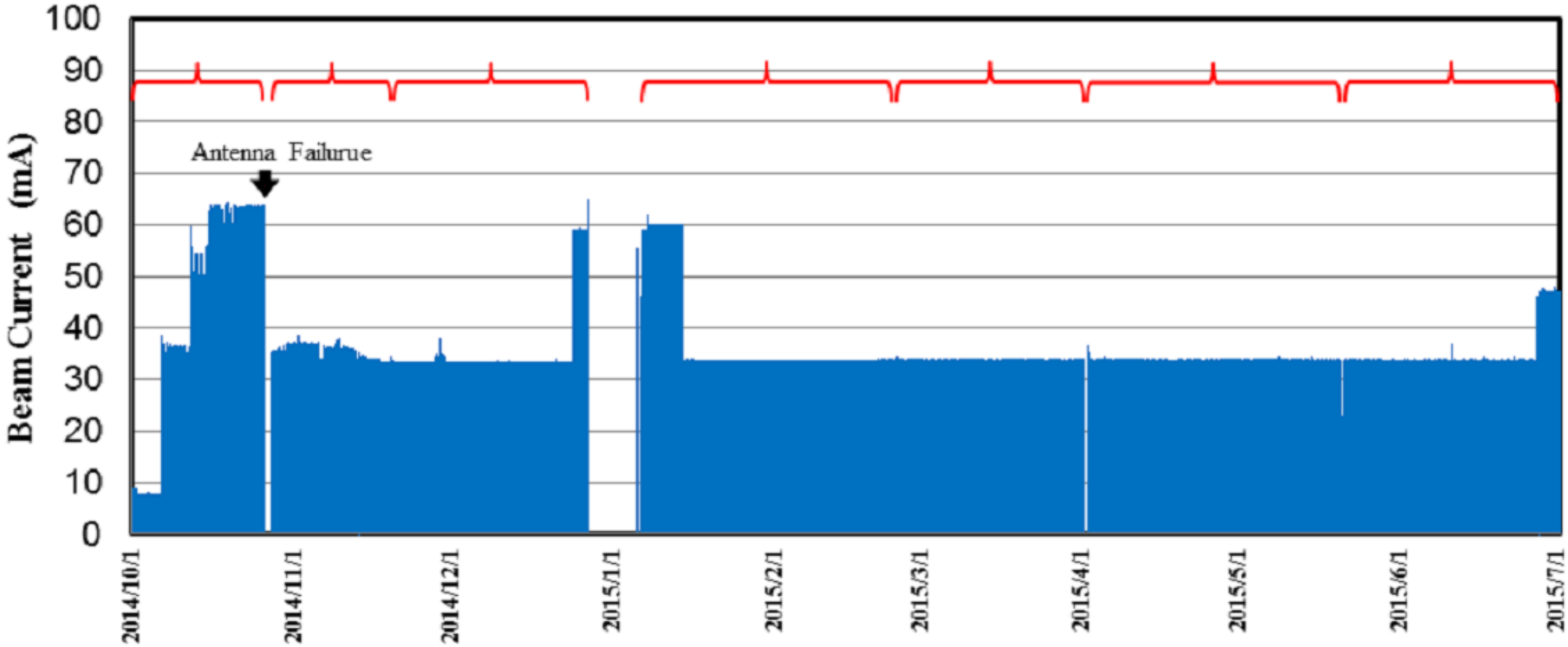
ε_{xrmsn} and ε_{yrmsn} are still higher than those with other PCHs and spike-noise-like fluctuations of vacuum pressure were observed only with #3 PCH, larger degradation of ε_{xrmsn} and ε_{yrmsn} were caused by impurity gases.

Smallest beam-hole-diameter of extraction electrode Φ_{EE}=7.1mm produced not only smallest ε_{xrmsn} and ε_{yrmsn} but also highest I_{H^-} with P_{RF}= 50kW.
*Phenomena are understandable as results of enlarged effective extraction field and more preferable focusing force in extraction gap
->Smaller Φ_{EE} than 7.1mm will be tested in near future.

ACKNOWLEDGMENT

The authors wish to express their sincere thanks to Dr. Martin P. Stockli of the SNS and SNS ion-source group members for their support to purchase internal-RF-antennas and their information on the SNS RF-driven H^- ion-source.

RFFs & ESFs of OFC- & #1-PCHs



Measured rod-filter- and electron-suppression- fields on beam axis.

J-PARC 2nd STAGE REQUIREMENTS

☆J-PARC 2nd Stage Requirements for Source

- Peak Beam Current : 60mA
  within Hor. & Ver. Nor. Emittances of $\varepsilon_{nx/y}$=1.5πmm·mrad
- Beam Flat Top Duty Factor 1.25% (500μsx25Hz)
- Life Time : >1month
- 3 Plasma Chambers(PCHs) Satisfying Requirements for Ope.

○Prototype RF-driven source satisfies all (NIBS2012)

- SNS internal antenna
- Oxygen Free Copper (OFC) PCH

◎J-PARC RF-driven source unitized for rapid IS replacement

- Stainless Steel (SS) PCH (ICIS2013)

At beginning $\varepsilon_{rmsnx/y}$(SS)~0.46 >> $\varepsilon_{rmsnx/y}$(OFC)~0.38
P_{RF}(SS)~41kW >> P_{RF}(OFC)~35kW for I_{H^-}=66mA

Diffs. : Temp. of Plasma Electrode(T_{PE}),Rod-filter-magnets(RFMs)

OPERATION START-UP after PRE-CONDITIONING

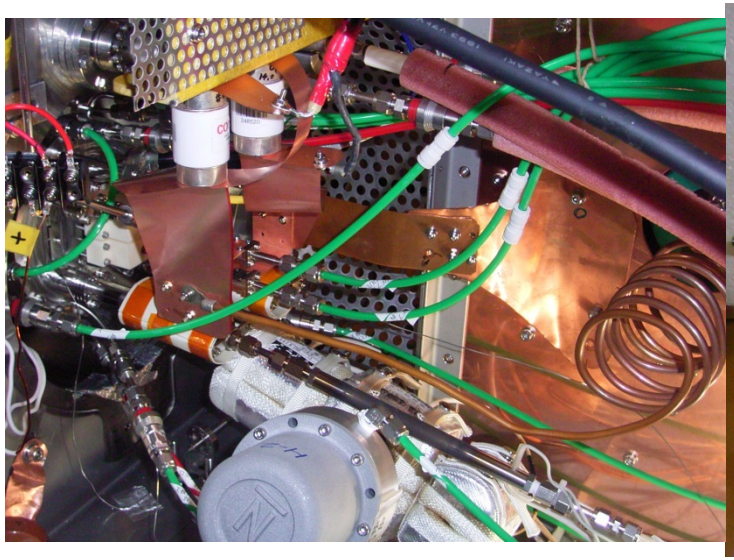


Photo of unitized SS PCH installed on IS-TS with 30MHz-RF matching network and a part of 2MHz-RF matching network

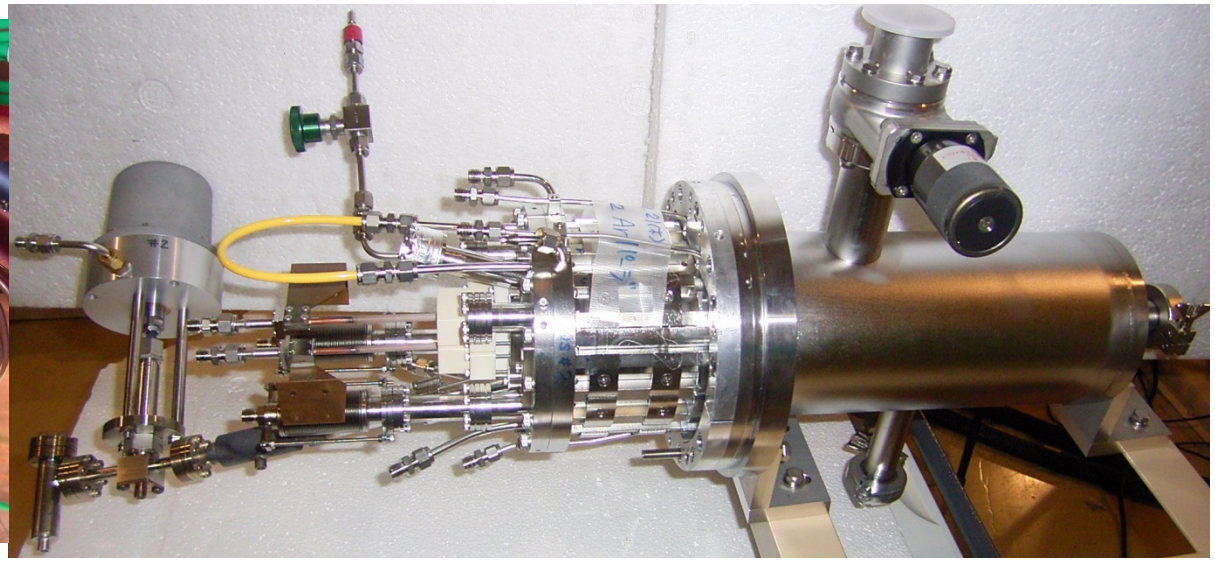
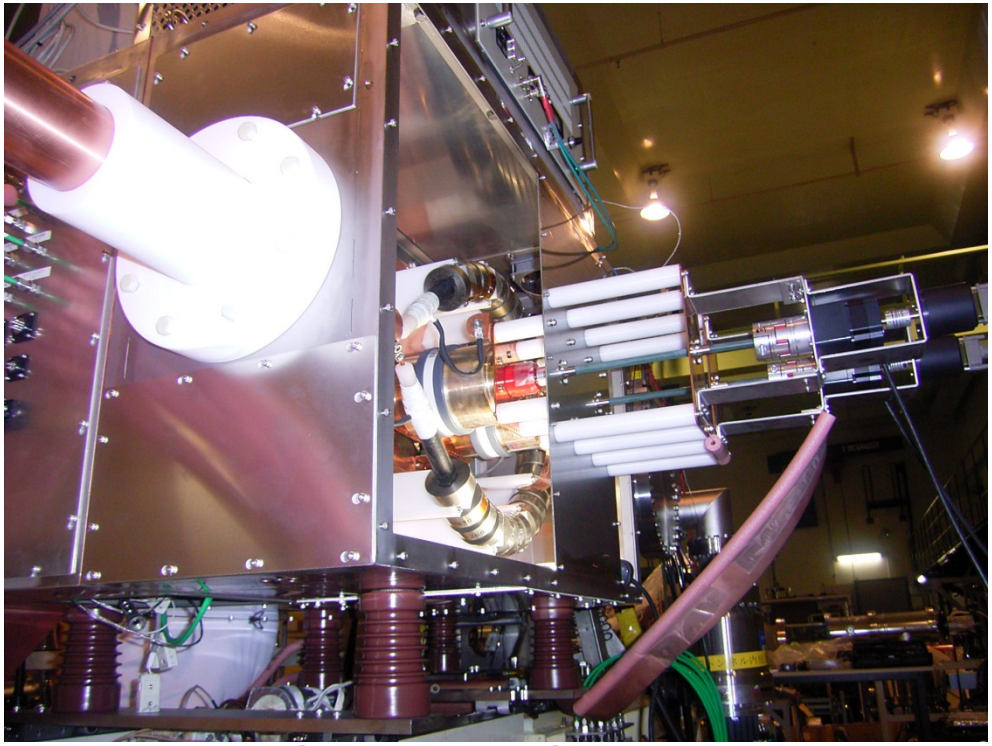


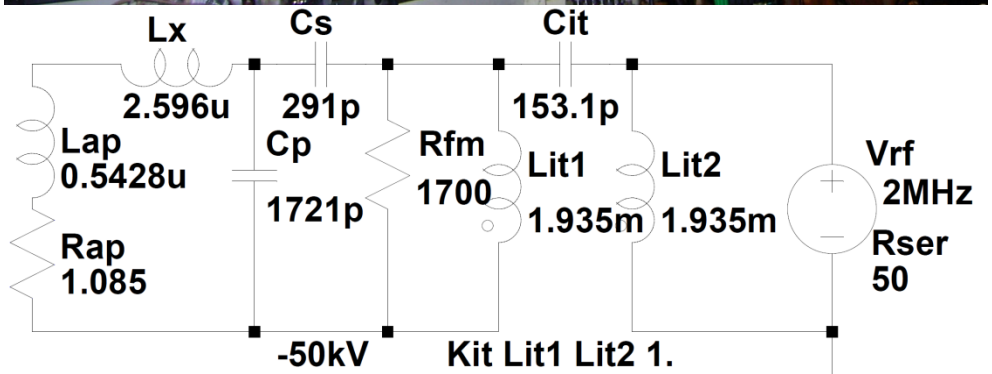
Photo of uitized SS PCH attached on leak-test and preservation chamber with filling Ar-gas inside

FEEDBACK CONTROLS : 2MHz-MACHING

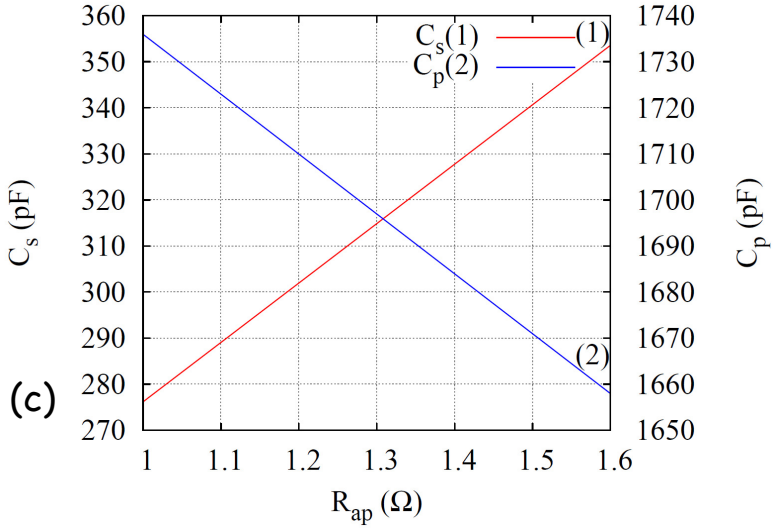
(a)



(b)



(c)



(d)

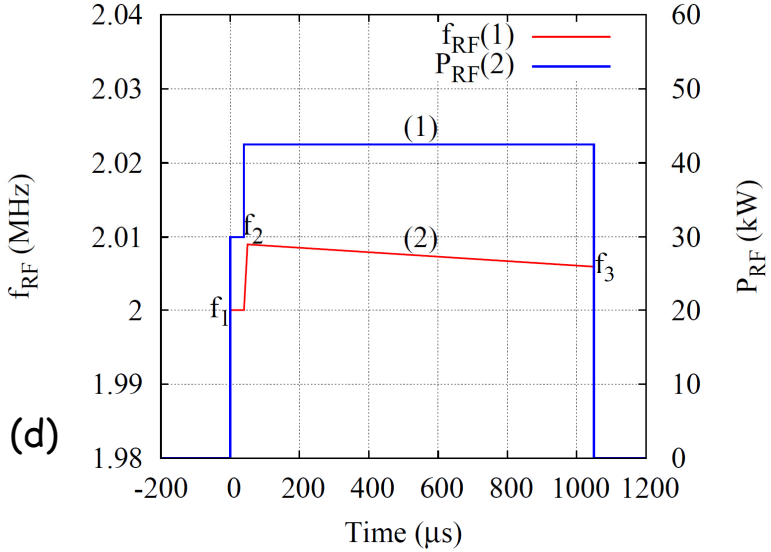


Photo of one-turn isolation transformer & two VVCs for C_S and C_P with pulse motors of 2MHz-RF matching network(a), equivalent circuit used in LTspice IV simulation(b), simulated relationship between R_{ap} and C_S & C_P(c) and timing relationship between time and f_{RF} & P_{RF}(d).

S-SFC EMITANNCE MONITOR
(movable Slit & movable Slit with Faraday Cup)

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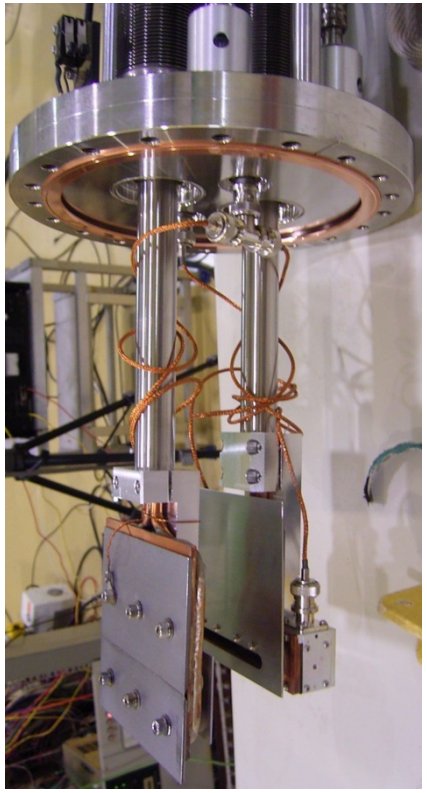
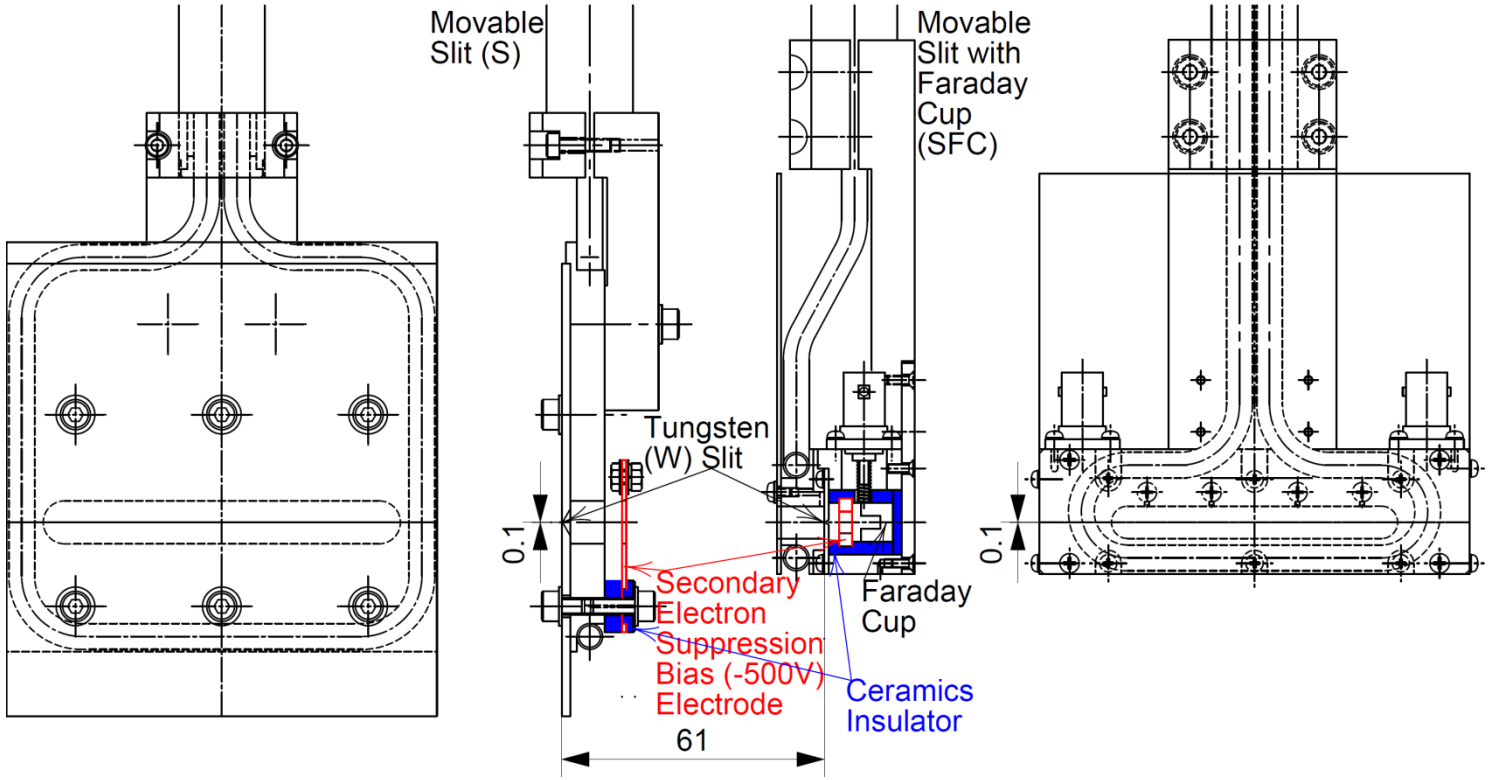


Phot of a set of S-SFC emittance monitor heads.



Drawing of a set of S-SFC emittance monitor heads.