TTF-III Coupler Parts Processing and Multipacting Simulation using Magic

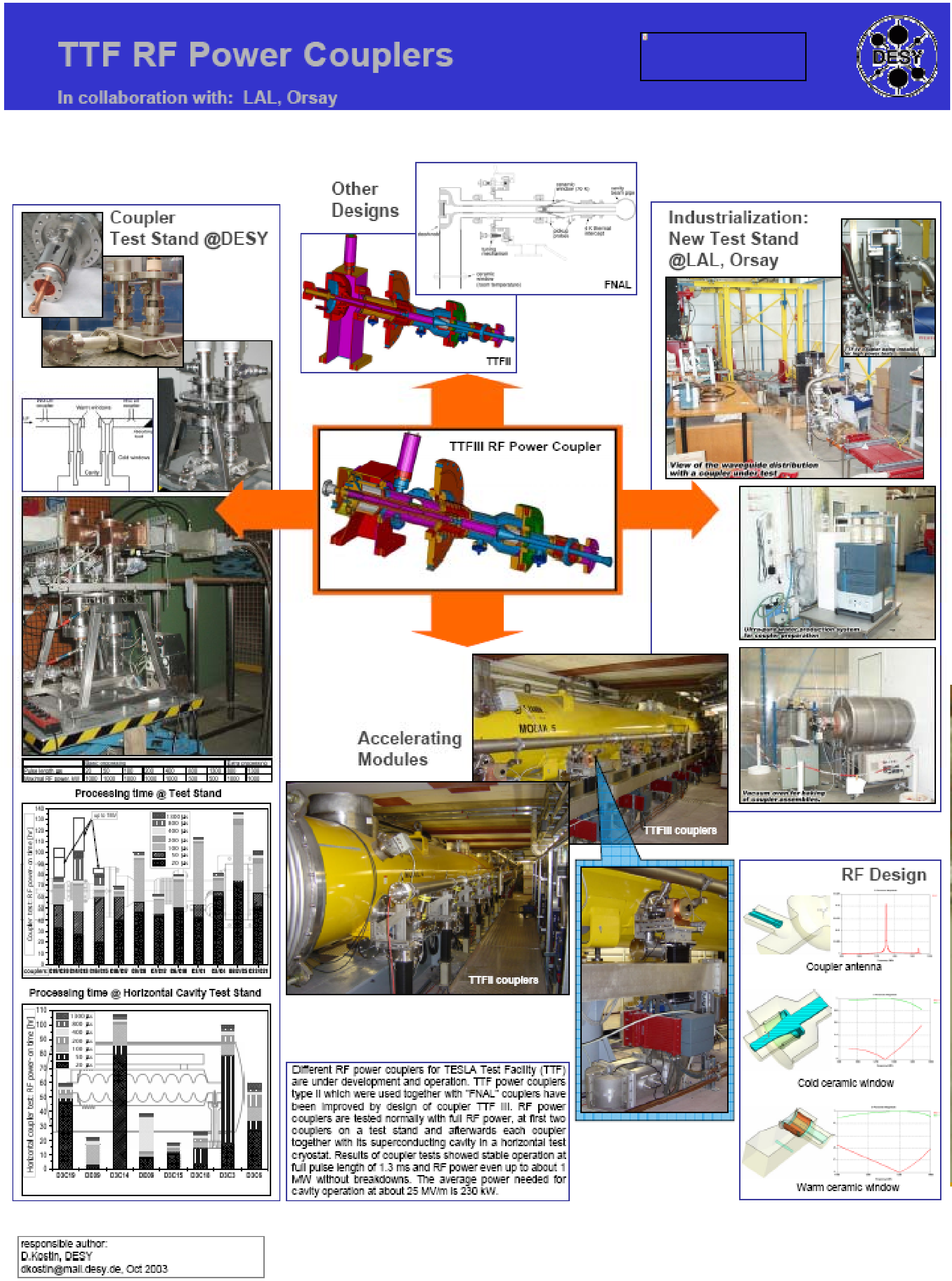
Faya Wang

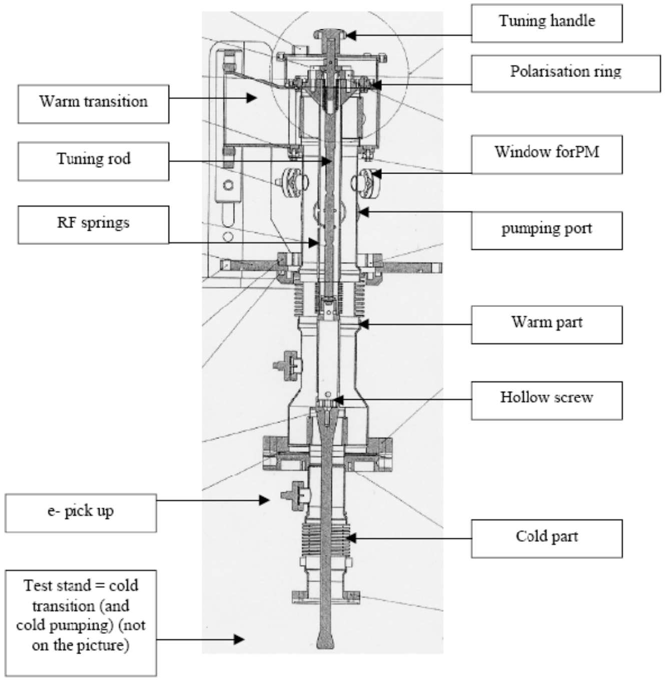
Dec-12 2007

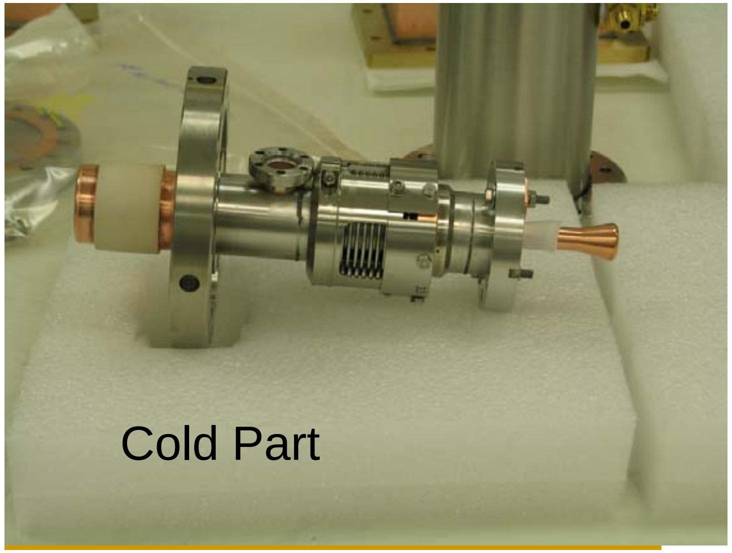
Wake Fest 07 – ILC wakefield workshop at SLAC

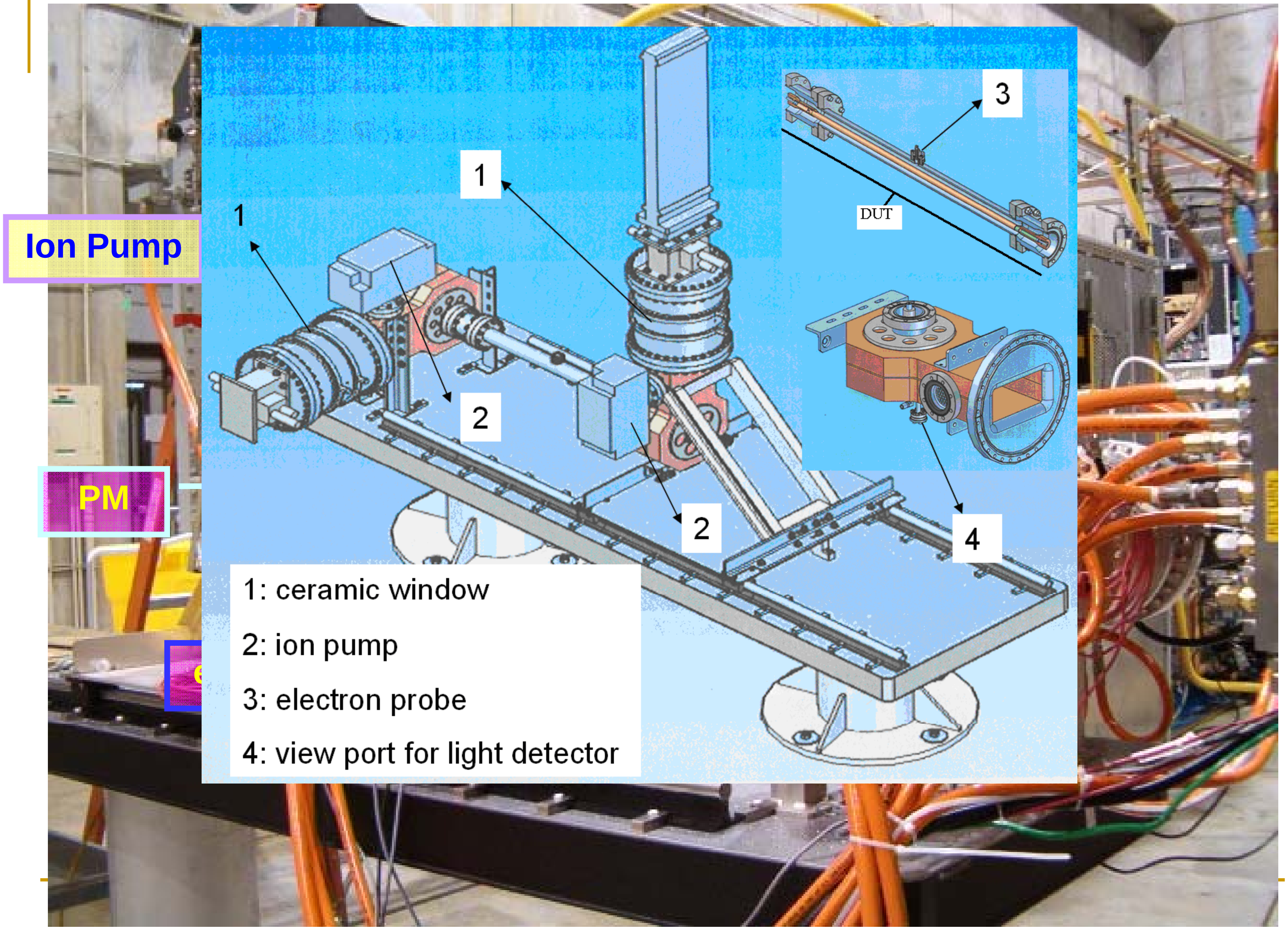
Outline

1. Processing Results with Straight Coax Tube
2. Behaviors of Electron Signal
3. Multipacting Simulation with Magic
4. Multipacting Phase Study
5. Summary


TTF RF Power Couplers
In collaboration with: LAL, Orsay
Coupler Test Stand @DESY
Other Designs
FNAL
TTFII
TTFIII RF Power Coupler
Industrialization: New Test Stand @LAL, Orsay
View of the waveguide distribution with a coupler under test
Accelerating Modules
TTFII couplers
TTFIII couplers
Processing time @ Test Stand
Processing time @ Horizontal Cavity Test Stand
RF Design
Coupler antenna
Cold ceramic window
Warm ceramic window
Different RF power couplers for TESLA Test Facility (TTF) are under development and operation. TTF power couplers type II which were used together with "FNAL" couplers have been improved by design of coupler TTF III. RF power couplers are tested normally with full RF power, at first two couplers on a test stand and afterwards each coupler together with its superconducting cavity in a horizontal test cryostat. Results of coupler tests showed stable operation at full pulse length of 1.3 ms and RF power even up to about 1 MW without breakdowns. The average power needed for cavity operation at about 25 MV/m is 230 kW.
responsible author:
D.Kostin, DESY
dkostin@mail.desy.de, Oct 2003

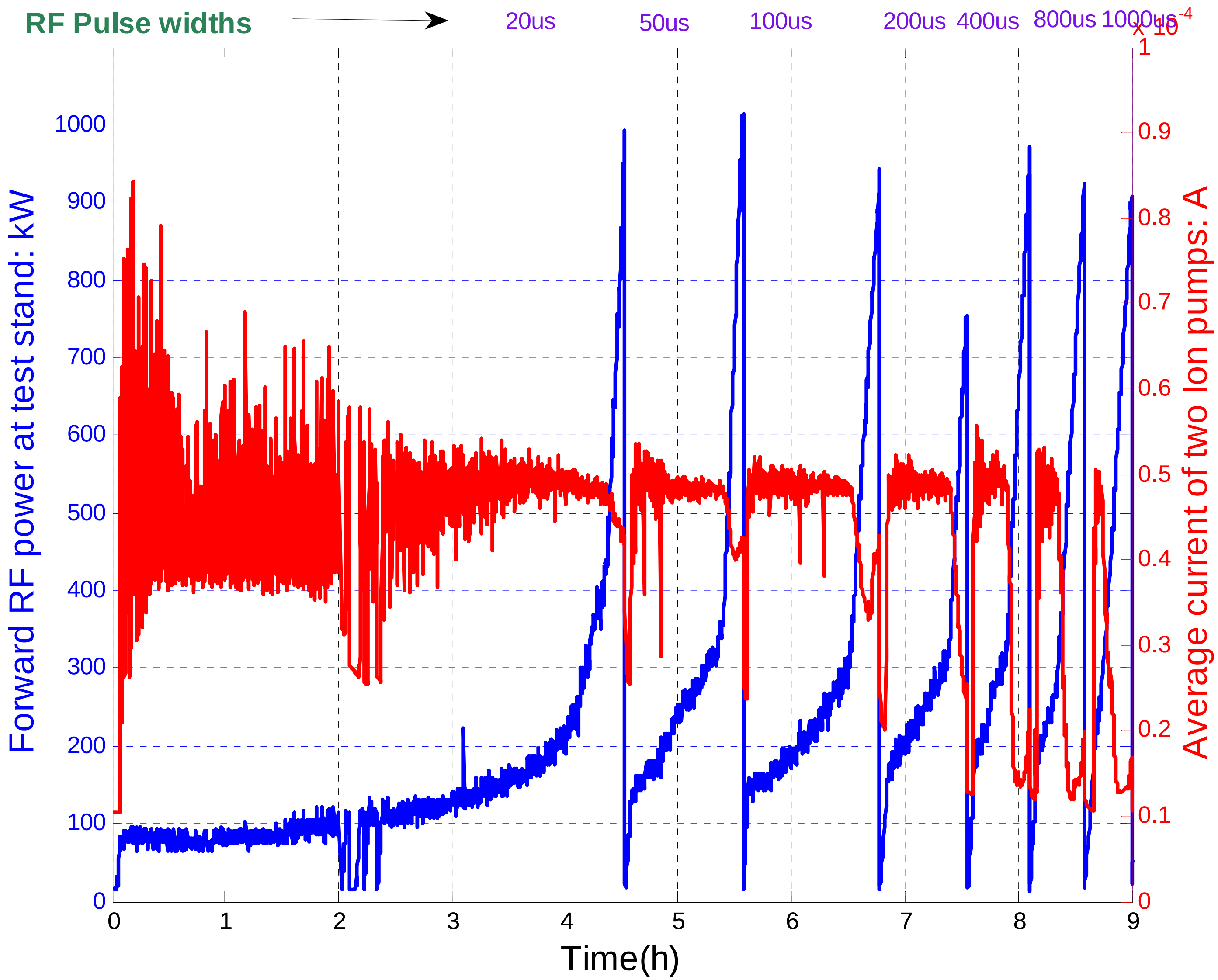

Tuning handle
Polarisation ring
Warm transition
Tuning rod
Window forPM
RF springs
pumping port
Warm part
Hollow screw
e- pick up
Cold part
Test stand = cold transition (and cold pumping) (not on the picture)


Cold Part


Ion Pump
PM
1
1
2
2
3
4
DUT
1: ceramic window
2: ion pump
3: electron probe
4: view port for light detector

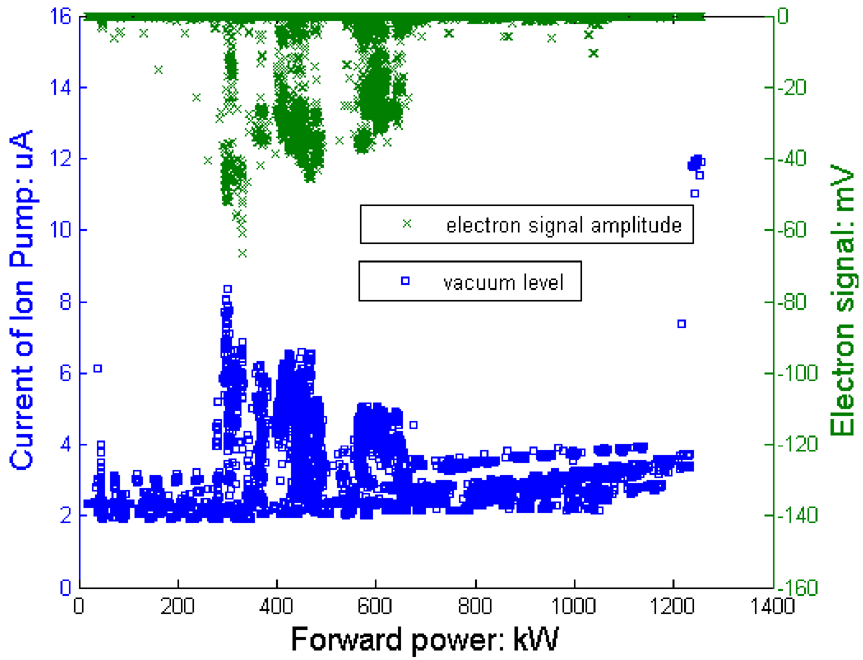
CPC: Coupler Process Cavity

It is the 1st pair of TTFIII coupler built at SLAC and ready to RF process.

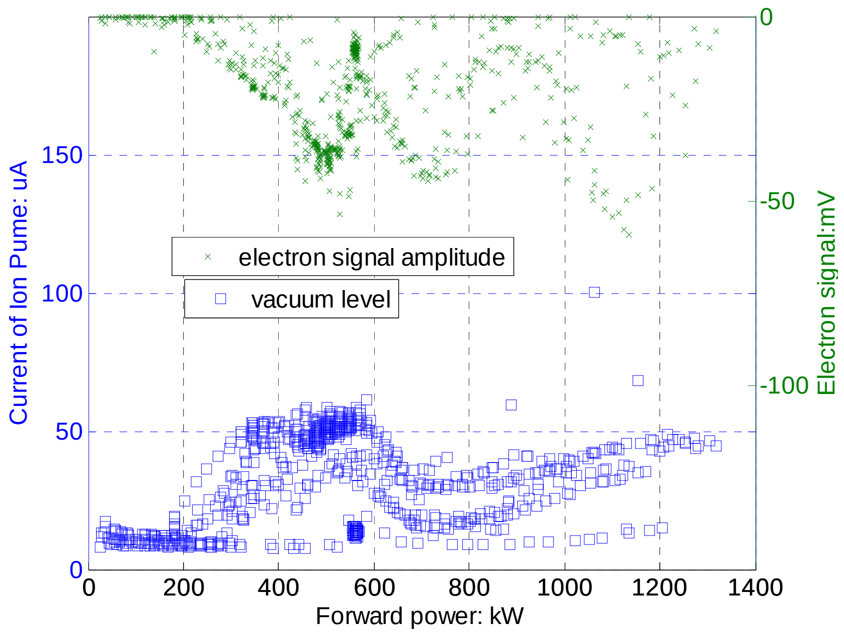


RF Pulse widths
20us
50us
100us
200us
400us
800us
1000us
x 10^-4
Forward RF power at test stand: kW
Average current of two Ion pumps: A
Time(h)
0
100
200
300
400
500
600
700
800
900
1000
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
6
7
8
9

600mm long straight SS coax section test results



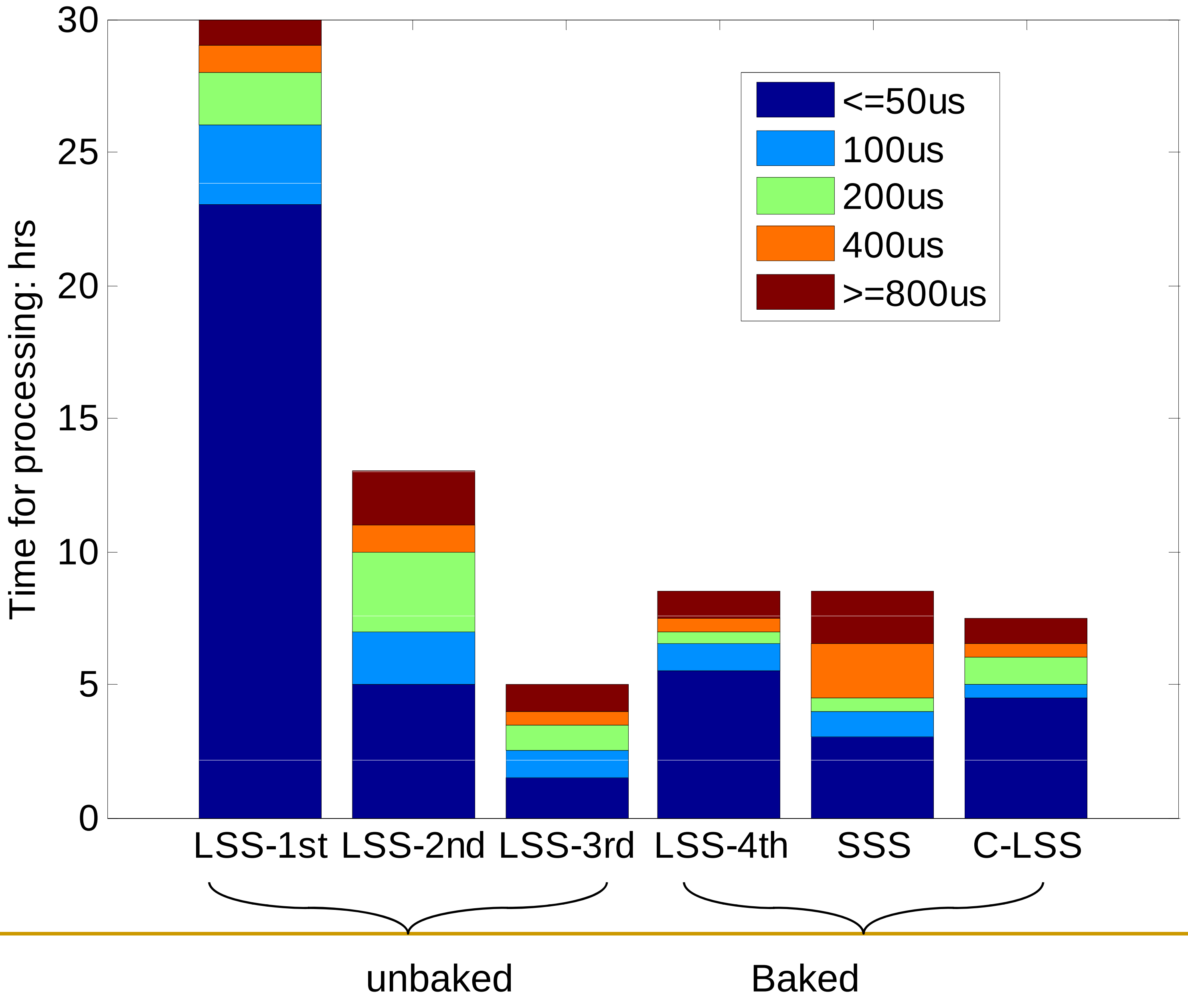
600mm long straight Copper plated SS coax section test results



Strong MP around 300kW!

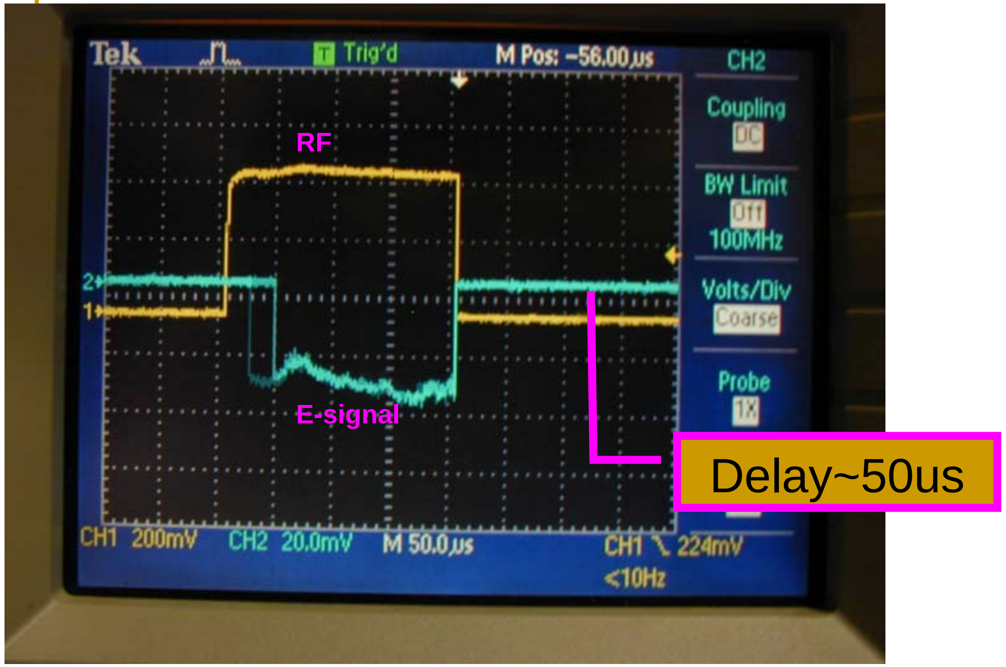
Type	Time:hrs	Disc.
LSS-1st	32	
LSS-2nd	13	After Initial Processing, Vented to N2 and exposed in air for a couple of hours
LSS-3rd	5	After Initial Processing,Vented to N2
LSS-4th	9	Baked at 150 degC in vacuum and bagged in N2 after bake
SSS	9	
C-LSS	8	Copper plated LSS Baked at 400degC bagged in N2

LSS: long section S/S 600mm; SSS: short section S/S: 400mm.



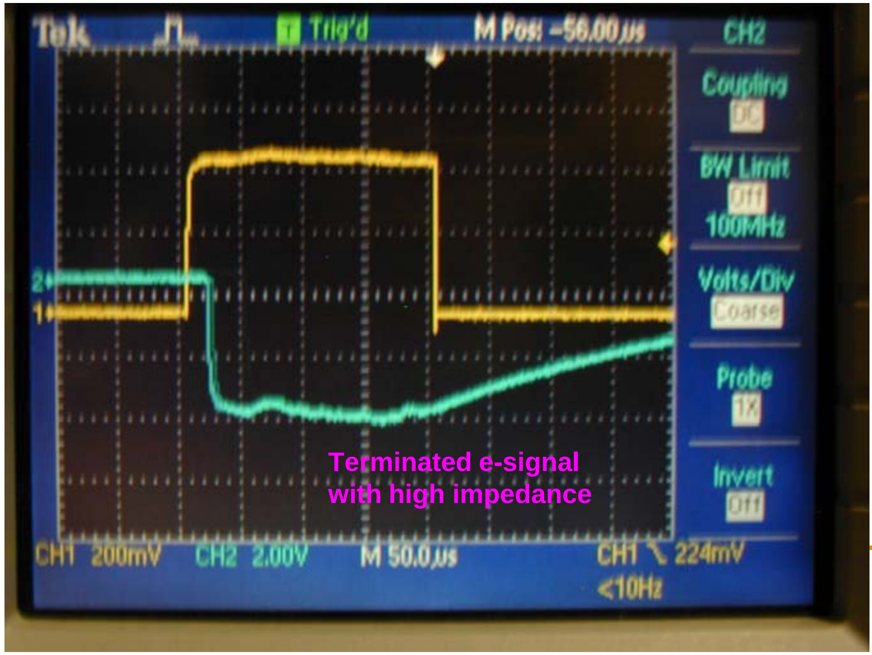
30
25
20
15
10
5
0
Time for processing: hrs
<=50us
100us
200us
400us
>=800us
LSS-1st
LSS-2nd
LSS-3rd
LSS-4th
SSS
C-LSS
unbaked
Baked

Behavior of Electron Signal



1. Delay of electron signal

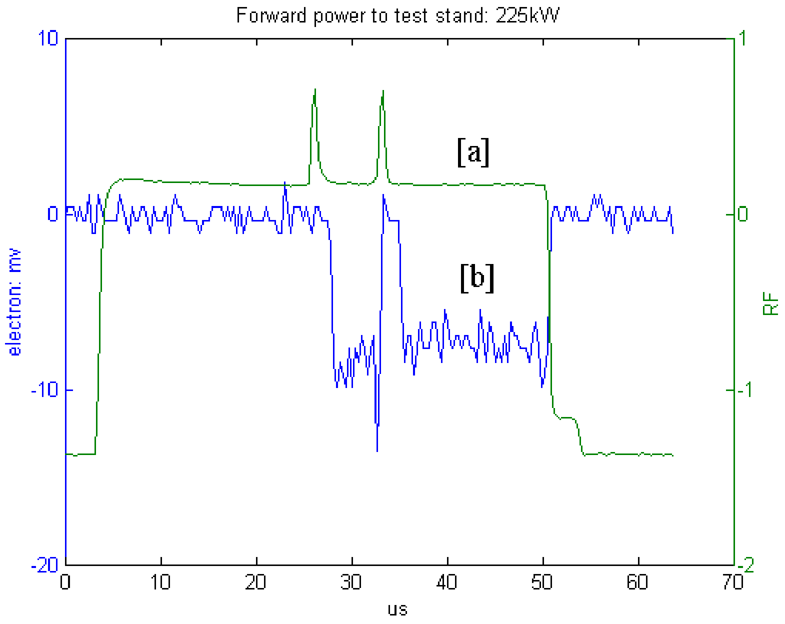
The Dealy time is unstable.



There is insufficient electrons available to seed the onset of multipacting.[1]

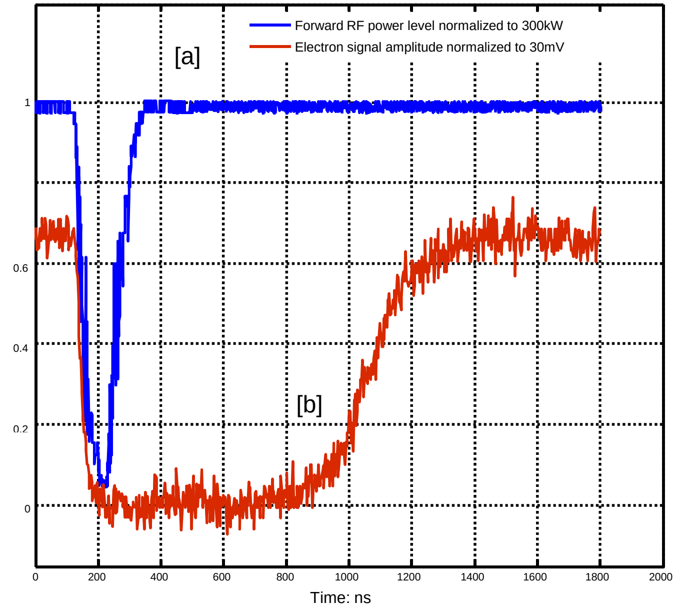
[1] D. Raboso, A. Woode, “A new method of electron seeding used for accurate testing of multipactor transients”, Vol.1, Oct. 1995.

The space charge will disappear in tens of nanoseconds without RF power and build up from the random emission electrons synchronous with RF field.

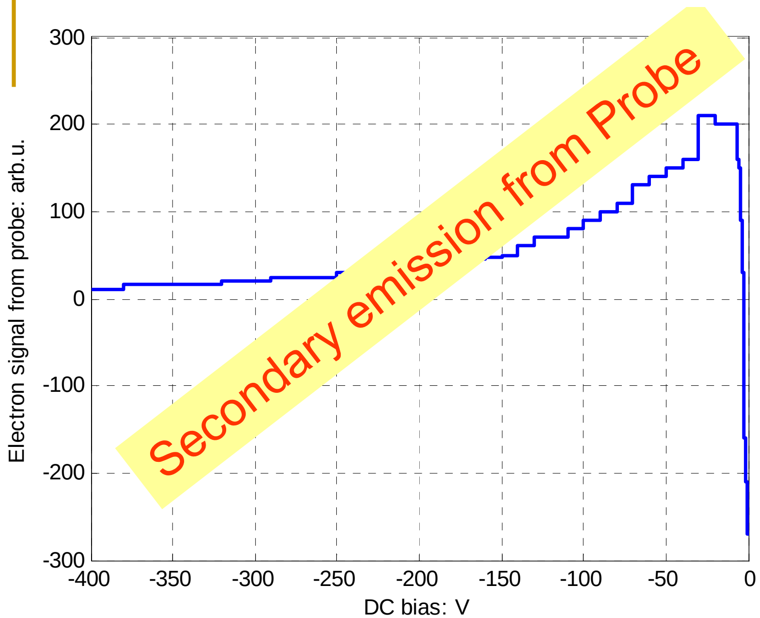


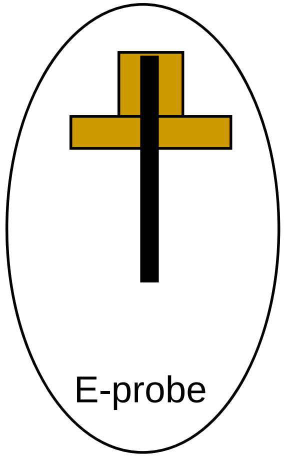
[a] The RF pulse with a 1us high power(3MW) spike;
[b] The multipacting electron signal.

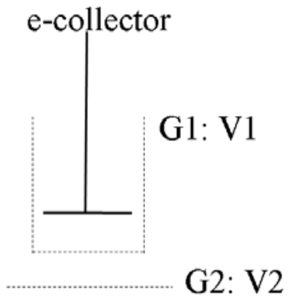
[a] The RF pulse with a 200ns drop;
[b] the multipacting electron signal.



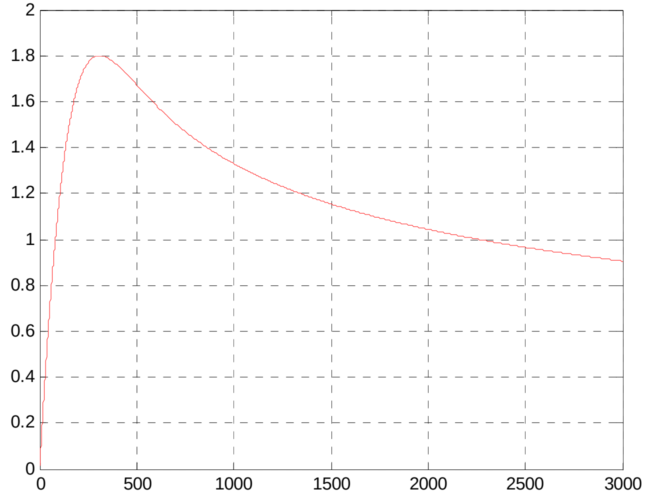
2. Energy of MP Electrons



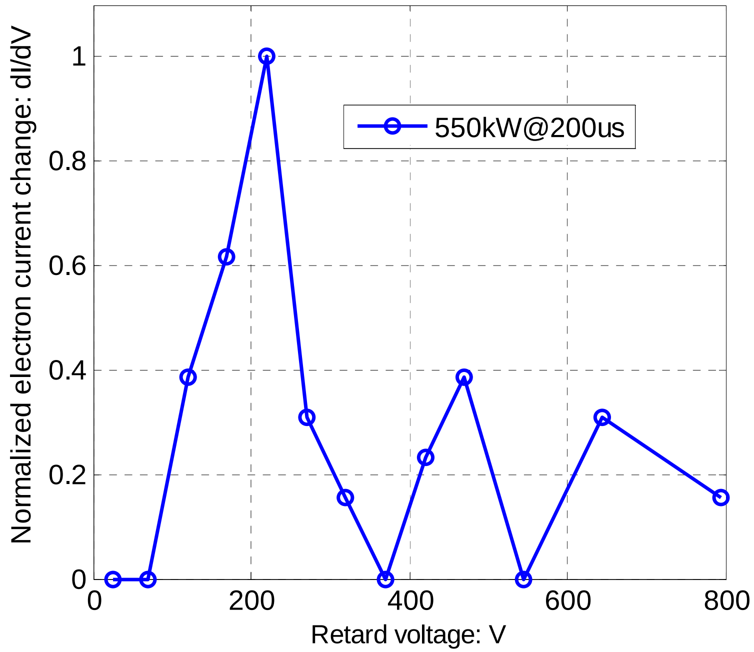




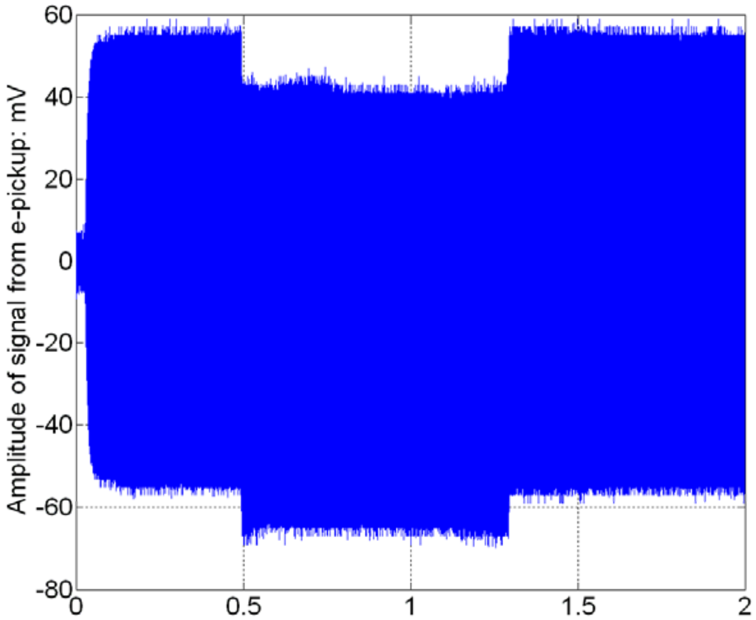
Energy Analysis Probe



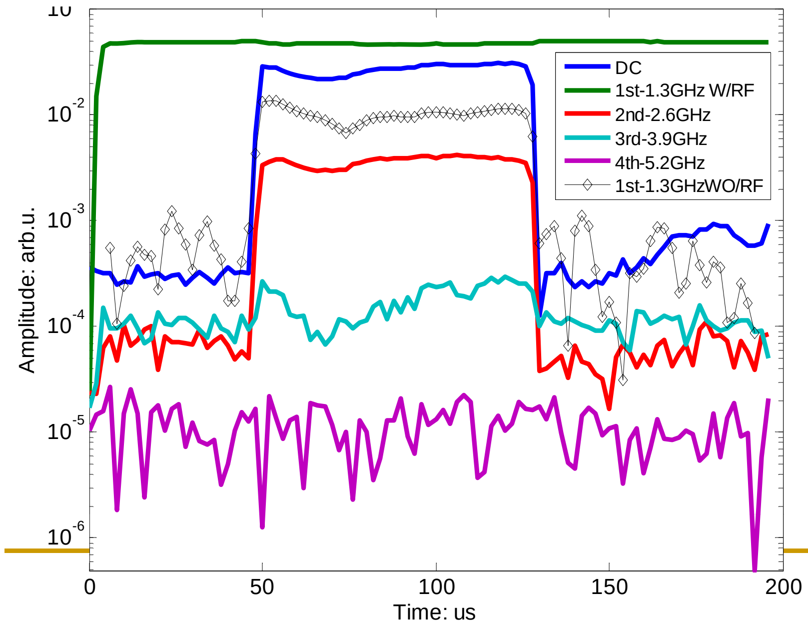
SEY of Copper plated SS



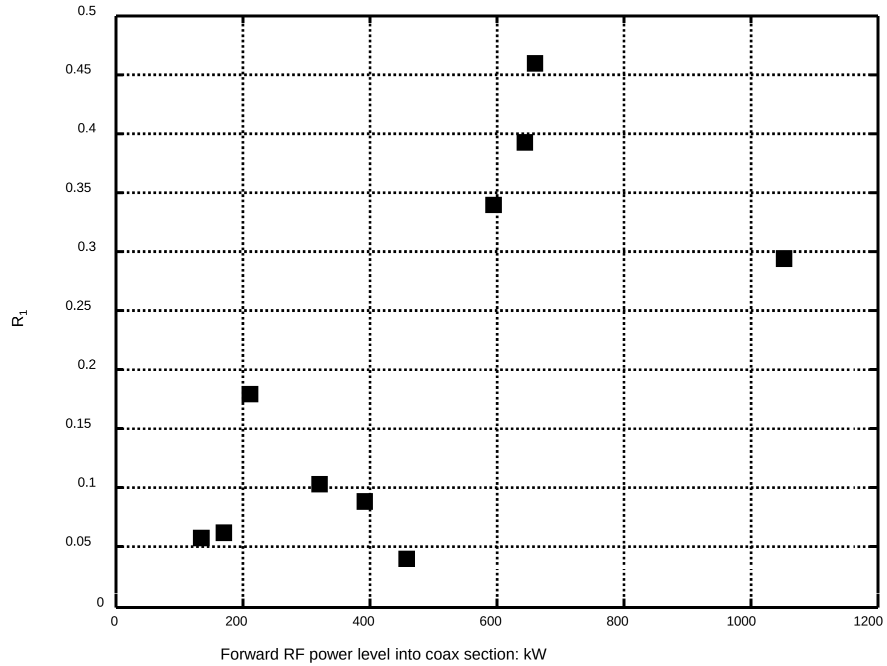
MP electron energy spread measured at 550kW RF power with Copper plated stainless steel coax tube.



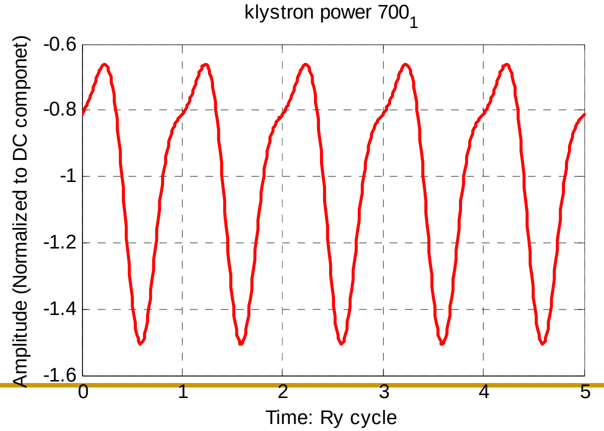
3. Harmonics from e-signal



R1: amplitude of 1st harmonic to DC



Rebuild electron signal

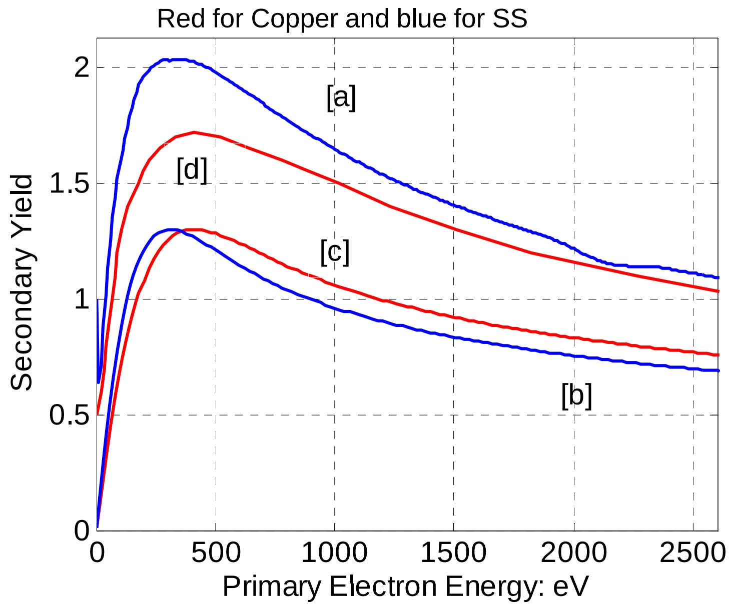


Magic Simulation

24cm coax line OD40mm
ID12.5mm, 1.3GHz RF, TW

Secondary electron energy:

$$f(U_s) \sim \frac{U_s}{(U_s + \Phi)^4}$$

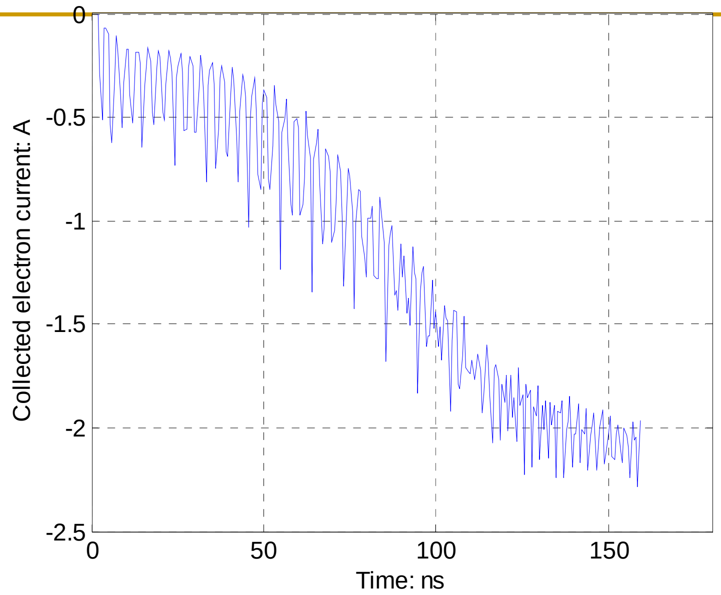


Φ is the work function of material (4.31 for Fe and 4.98 for Cu)

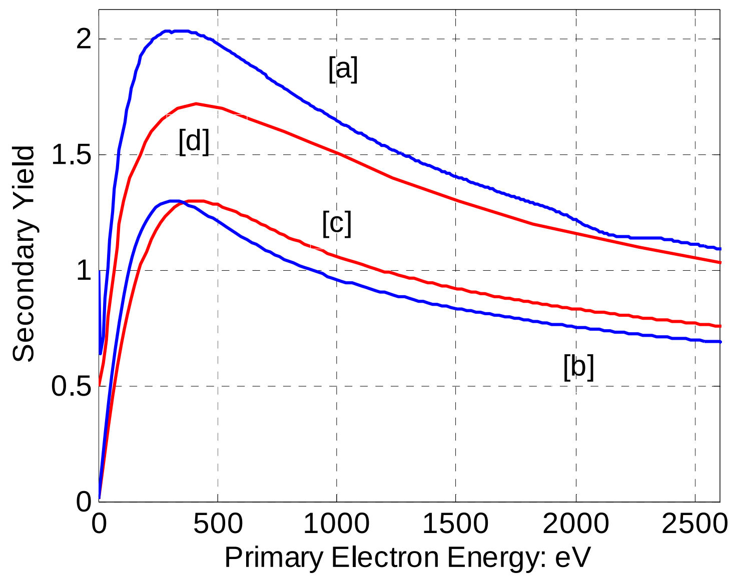
The peak of secondary electron is at $\Phi/3$

Simulation results depends on the Secondary electron distribution

Based on the measured SEY[a,d], it found that the collected electron current by the outside conductor of coax is about hundreds of amperes when the saturation is achieved at hundreds kW RF power in simulation. (few amperes in experiment).
[b c] scaled to the measurement used in simulation.

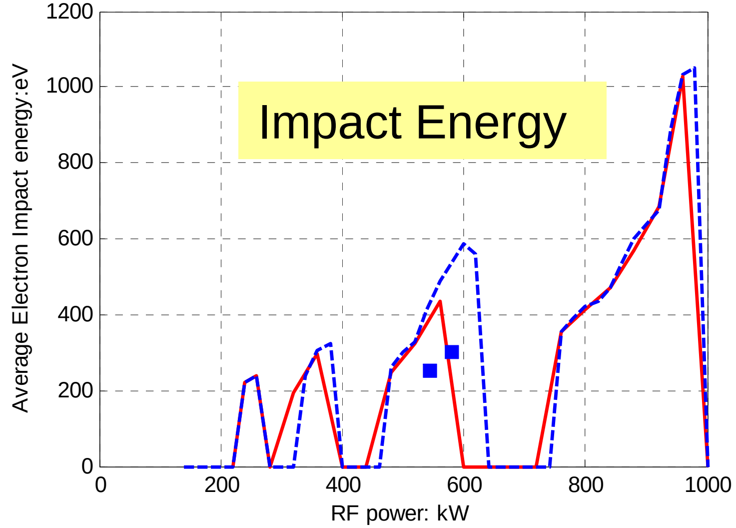


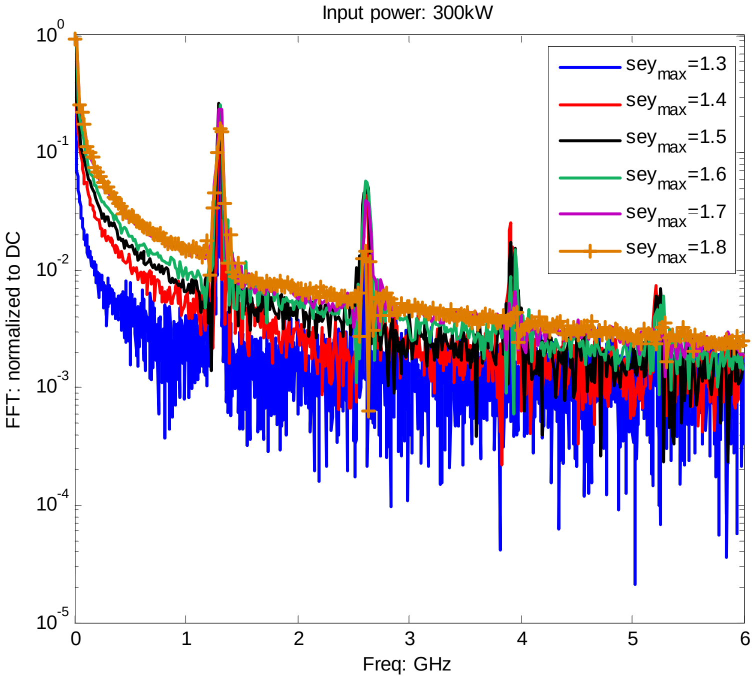
RF power: 500kW. SEY[b]



Buildup time ~ 100ns Simulation

~ 70ns Experiment



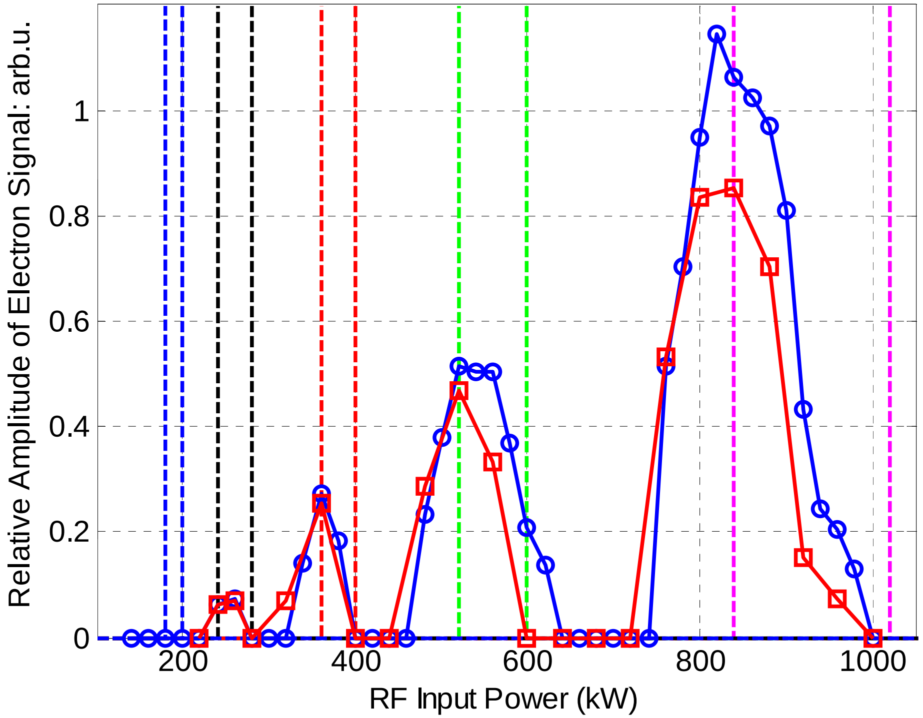


Ratio SEY$_{max}$	R$_1$	R$_2$
1.3	**0.1781**	**0.072**
1.4	0.2593	0.18
1.5	0.261	0.21
1.6	0.2569	0.23
1.7	0.2323	0.17
1.8	0.1596	0.09
EXP	**0.11**	**0.25**
HSW	**1.57**	**0.667**

R2: Amplitude of 2nd harmonic to 1st harmonic.

R1: amplitude of 1st harmonic to DC

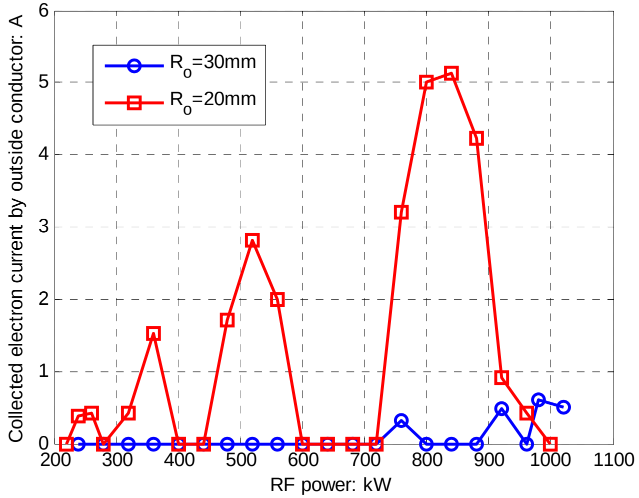
HSW: half-sine wave



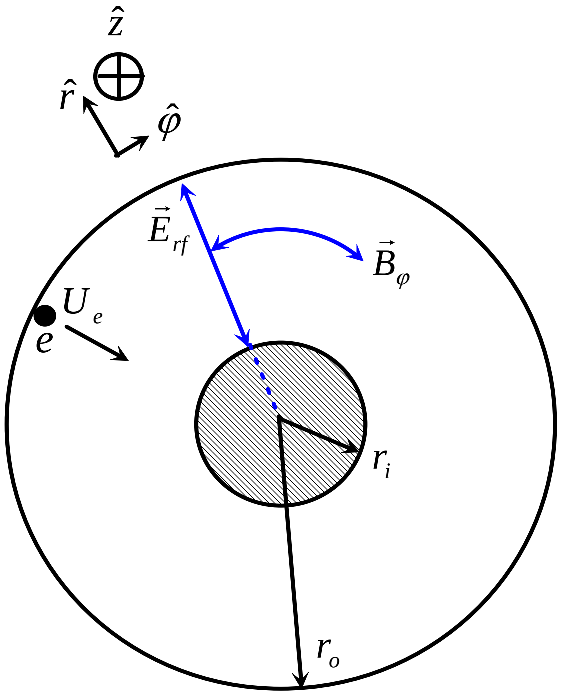
Resonant Mode (indicated by dashed lines) is independent of SEY.

Based on SS SEY

Ro : outside radius of coax



Multipacting Phase Study

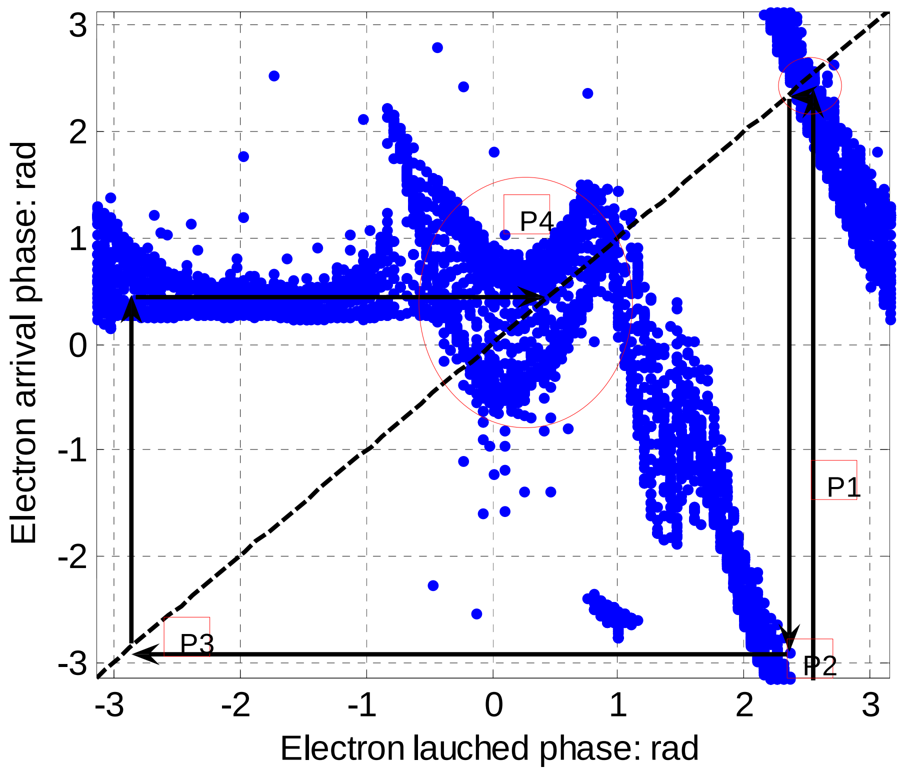


$$\frac{d(m\vec{v})}{dt} = e\vec{v} \times \vec{B}_{\varphi} + e\vec{E}_{rf}$$

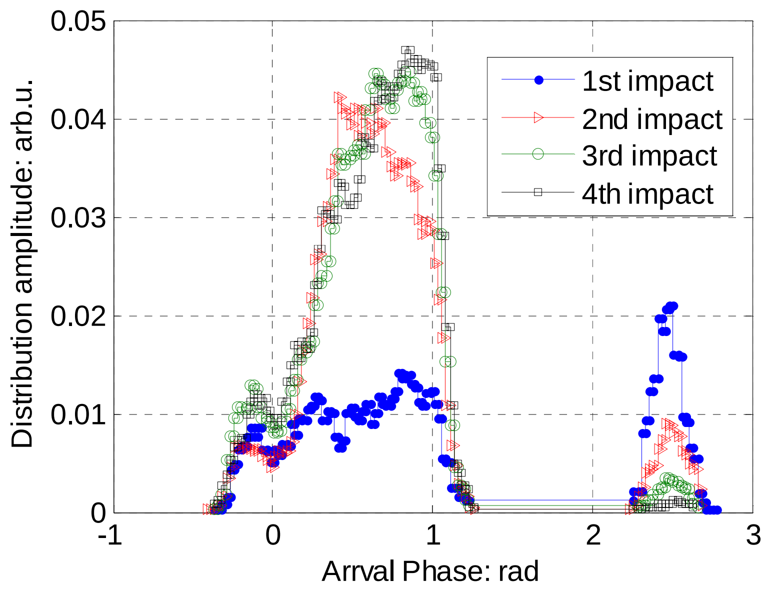
$$U_{rf} = \frac{\sqrt{2PZ_0 \ln(r_o/r_i)}}{\ln(r_o/r_i)}$$

$$\ddot{r} = -\frac{|e|}{m}\frac{U_{rf}}{r}\sin(\omega t + \phi)$$

Coax line OD40mm ID12.5mm, 1.3GHz RF



Resonant phase distribution

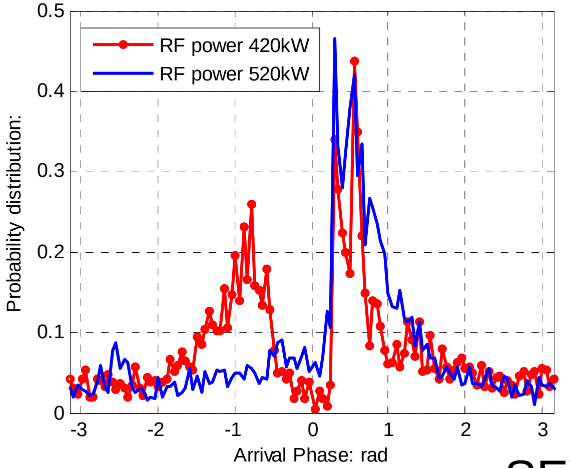


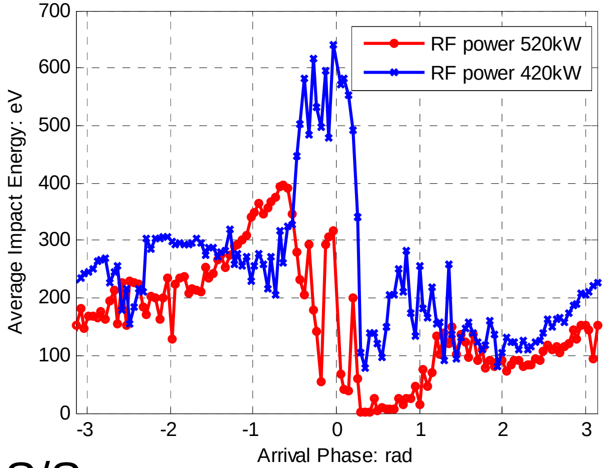
Map of electron lauched phase VS arrival phase

$$\bar{\delta} = \int_0^{2\pi} f(\phi)\delta(U(\varphi))d\phi$$

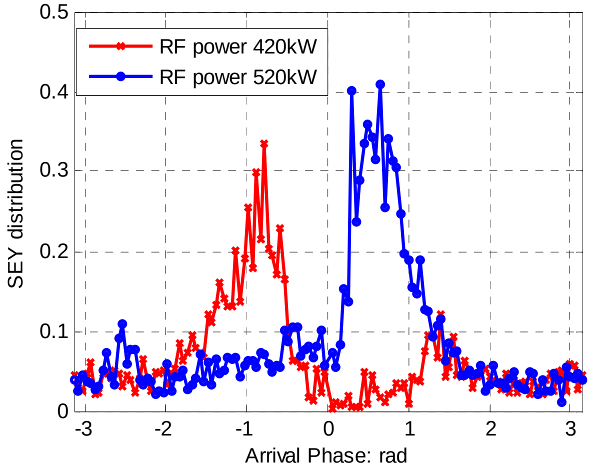
Arrival Phase distribution

Impact Energy distribution





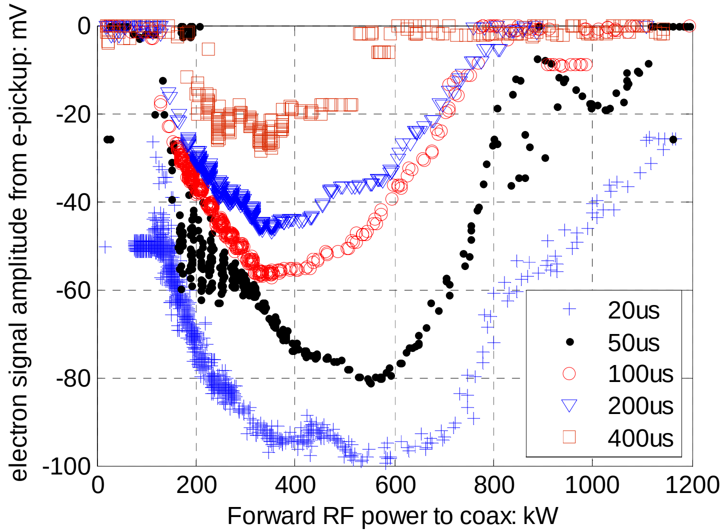
SEYmax=1.3 for S/S



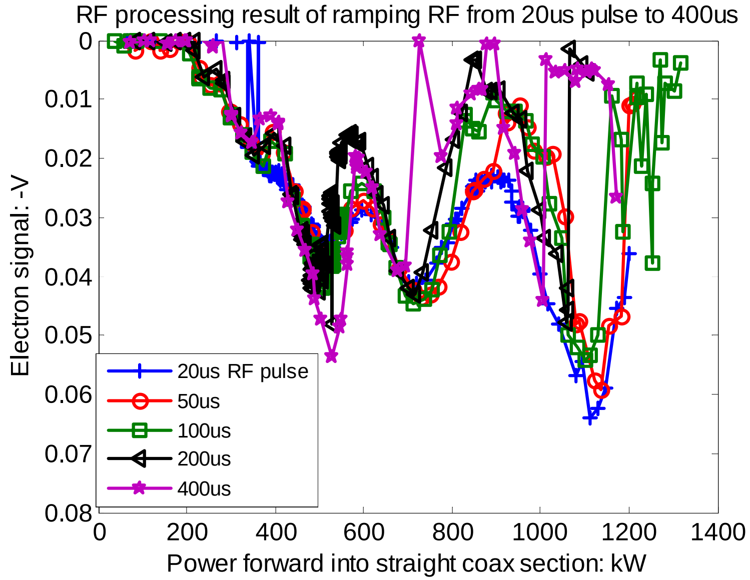
$\bar{\delta} = 0.816$ RF 420kW

$\bar{\delta} = 1.099$ RF 520kW

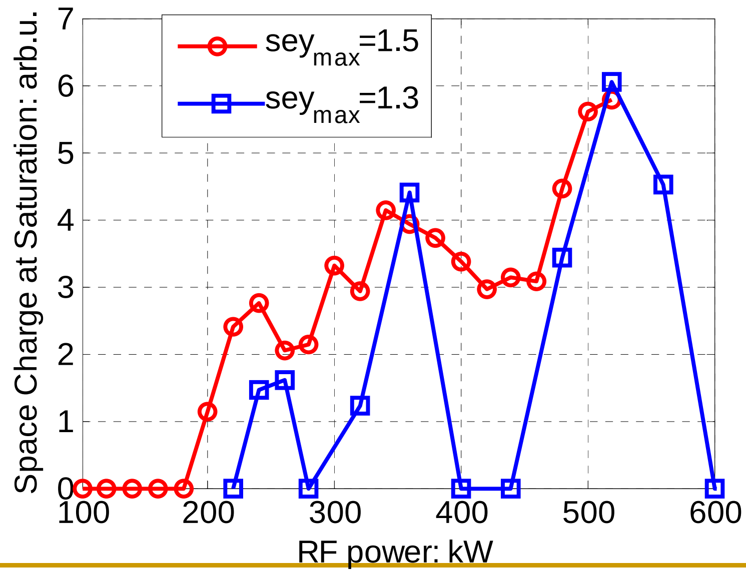
There could be MP with large SEY for the same geometry



Stainless Steel Coax Tube



Copper plated S/S Coax Tube



Magic Simulation

Summary

- There is a strong MP around 300kW for cold coax part of TTFIII.
- Bake and copper plated help to reduce the processing time.
- MAGIC simulation results are in the same range with experimental results.