

# Development of 10-MeV L-band Electron Linac for CESC\*

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## ◆ Introduction

- **L-band traveling-wave electron linac**
- **Irradiation applications**
- **10 MeV and average 30 kW**
- **Single klystron (pulsed 25 MW)**
- **Single accelerating column**
- **Vertical mount**

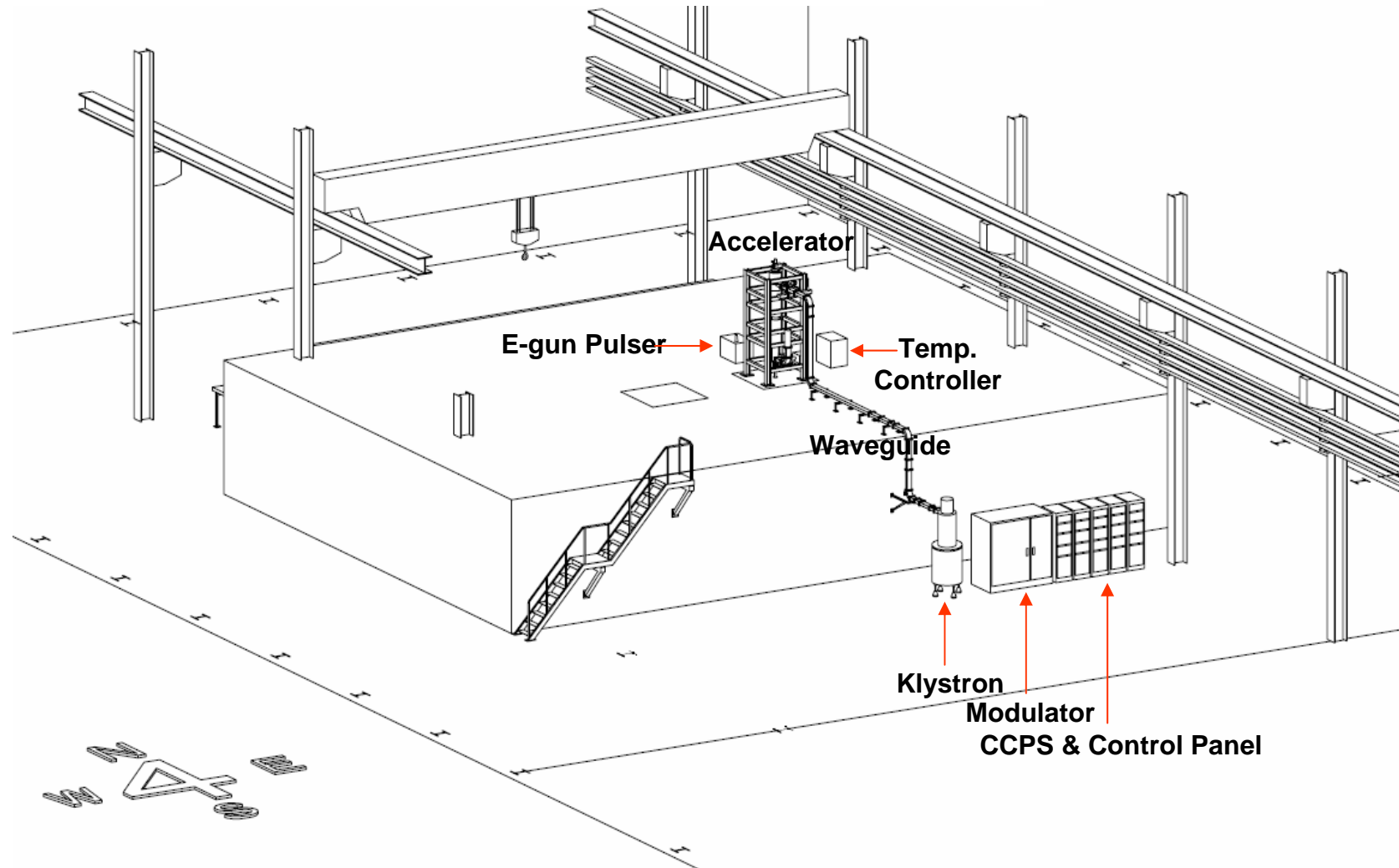
# ◆ Accelerator Parameters

RF System Parameter	
Operating Frequency	<b>1.3 GHz</b>
Pulsed RF Power	<b>25 MW</b>
Pulse Length	<b>7 <math>\mu</math>s</b>
Repetition Rate	<b>350 Hz</b>
Average RF Power	<b>60 kW</b>
E-gun Parameter	
High Voltage	<b>80 kV</b>
Pulsed Beam Current	<b>1.6 A</b>
Pulse Length	<b>6 <math>\mu</math>s</b>

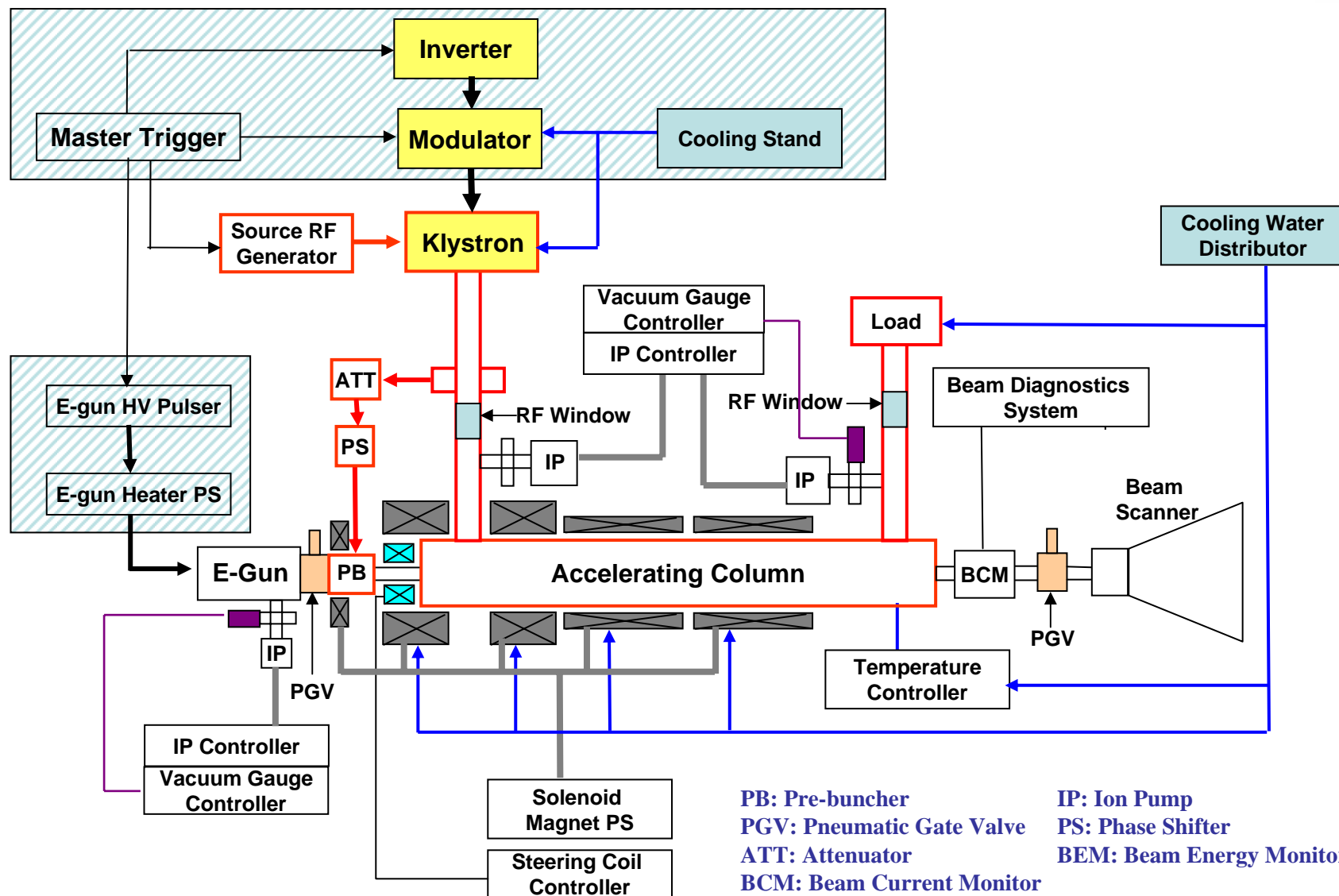
Beam Parameter	
Beam Energy	<b>10.7 MeV</b>
Pulsed Beam Current	<b>1.4 A</b>
Beam Transmission Rate	<b>90%</b>
Average Beam Power	<b>35 kW</b>
Accelerating Structure Parameter	
Type of Structure	<b>Constant-impedance</b>
Shape of Cell	<b>Disk-loaded</b>
Operating Mode	<b><math>2\pi/3</math> mode</b>
RF Filling Time	<b>0.8 <math>\mu</math>s</b>
Operating Temperature	<b><math>40^{\circ}\text{C} \pm 1^{\circ}\text{C}</math></b>
Average Accelerating Gradients	<b>4.2 MV/m</b>
Beam Loading Factor	<b>- 4.7 MeV/A</b>
Temperature Shift Factor	<b>- 2.3 MeV/<math>^{\circ}\text{C}</math></b>

# ◆ System Layout

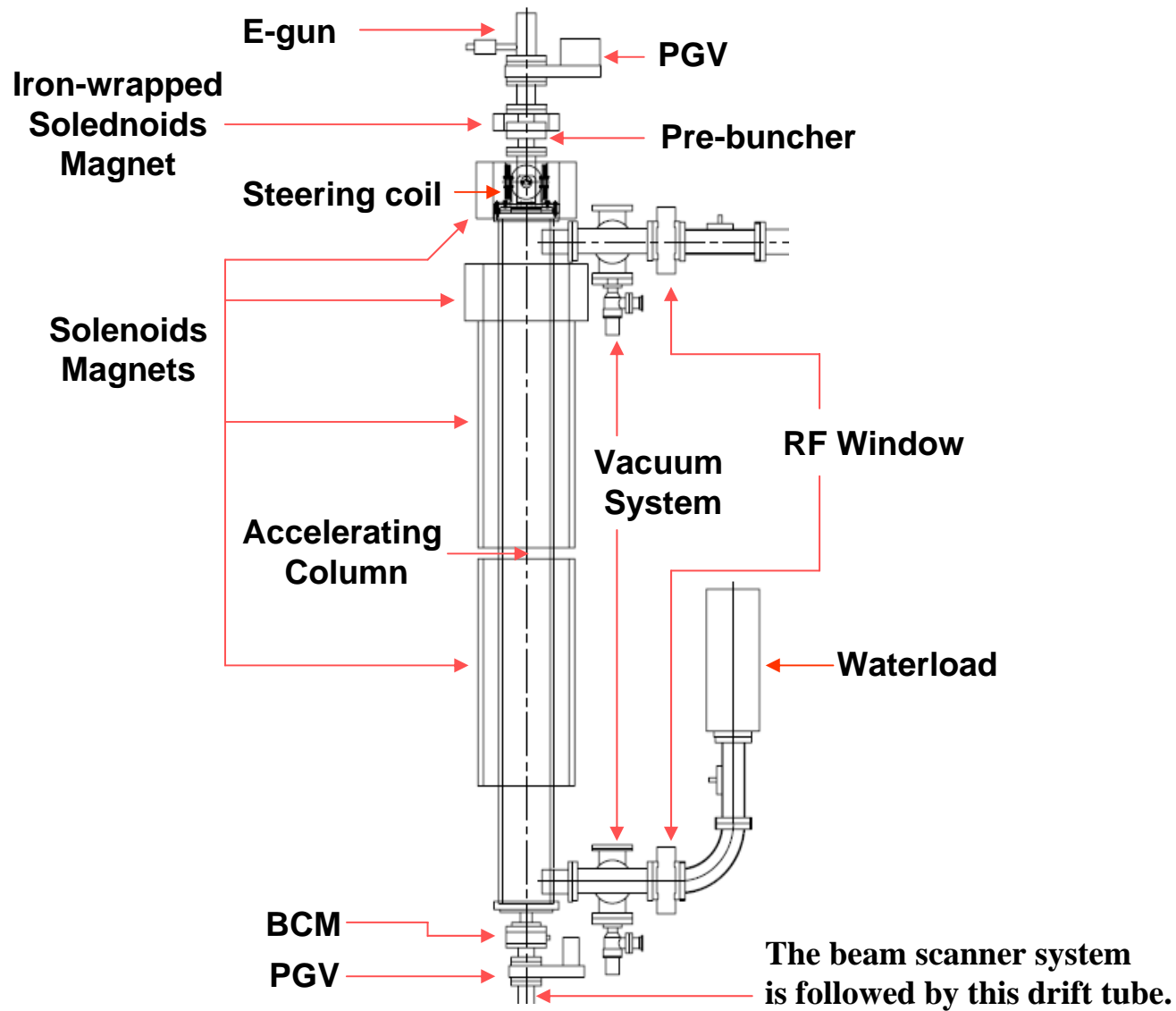
To be installed at CESC (Cheorwon Electron-beam Service Center)



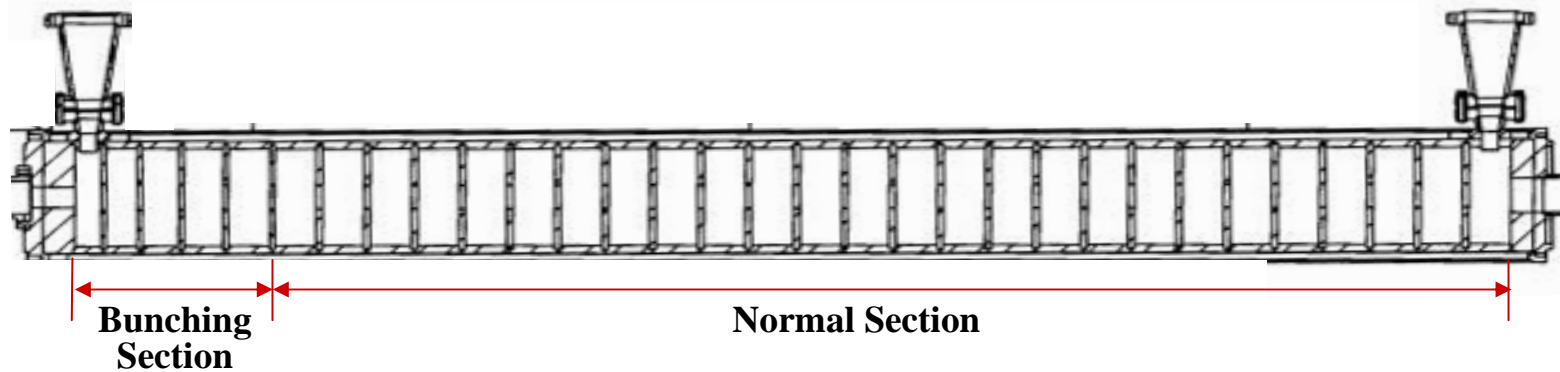
# Schematic Diagram of Linac System



# ◆ Beamline Configuration

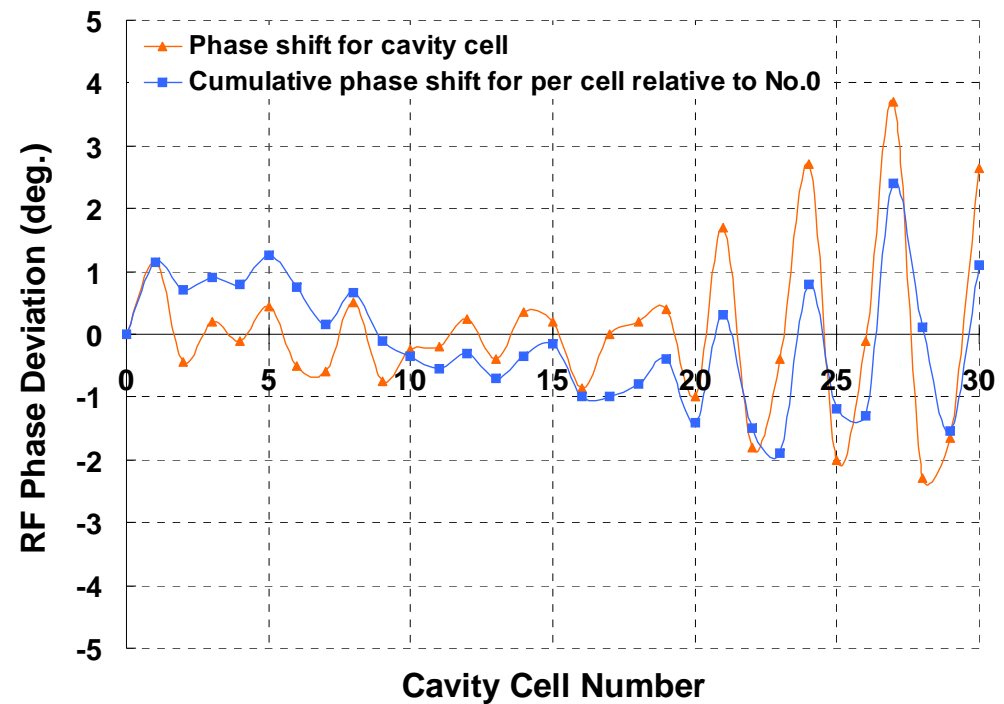


# ◆ Accelerating Column



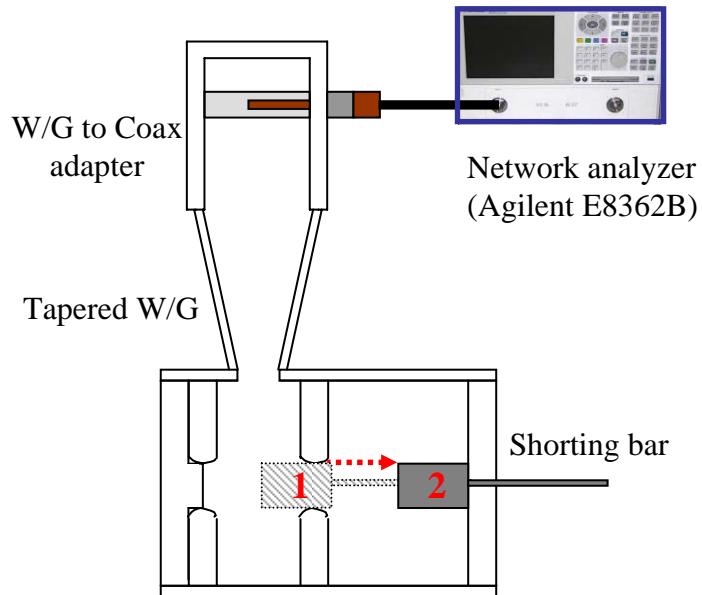
Cell Characteristics

Cell	Phase velocity / c	Attenuation Coefficient (Nep/m)
1 <sup>st</sup> buncher	0.65	0.0538
2 <sup>nd</sup> buncher	0.75	0.0489
3 <sup>rd</sup> buncher	0.88	0.0442
4 <sup>th</sup> buncher	0.92	0.0431
5 <sup>th</sup> buncher	0.98	0.0415
Normal	1.00	0.0623



# RF Couplers

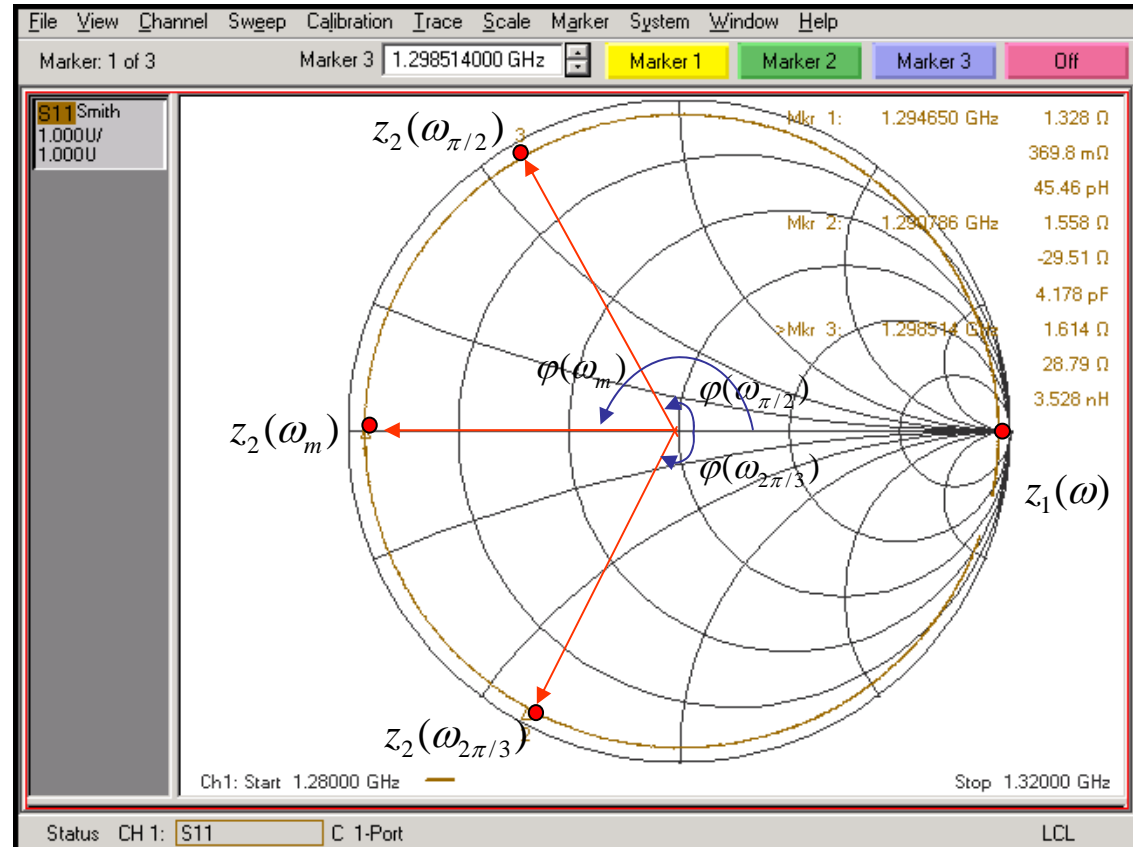
**Measurement Setup**  
(Khyll's method on TRwave coupler)



$$\omega_m = (\omega_{\pi/2} + \omega_{2\pi/3}) / 2$$

	Input coupler	Output coupler
$\varphi(\omega_{\pi/2})$	120.1°	117.7°
$\varphi(\omega_m)$	179.2°	179.4°
$\varphi(\omega_{2\pi/3})$	-119.9°	-120.6°

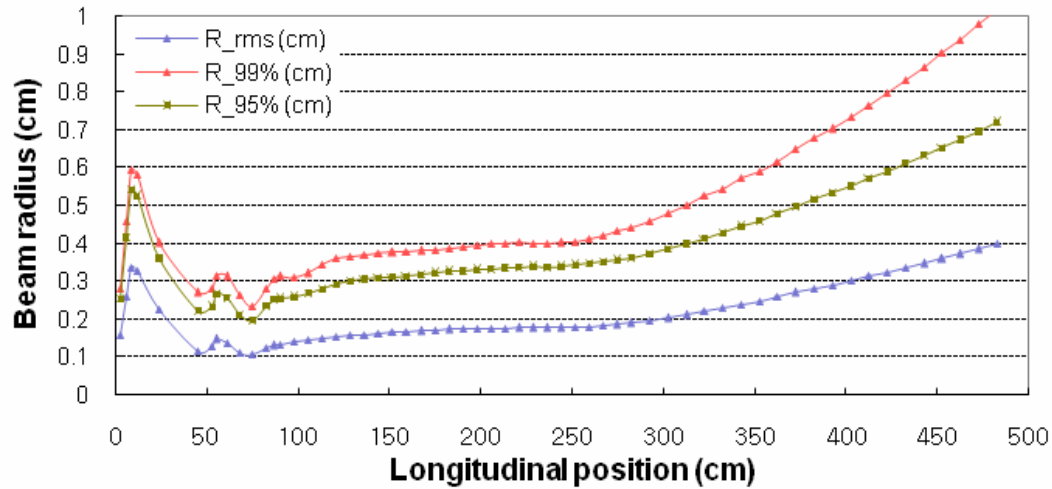
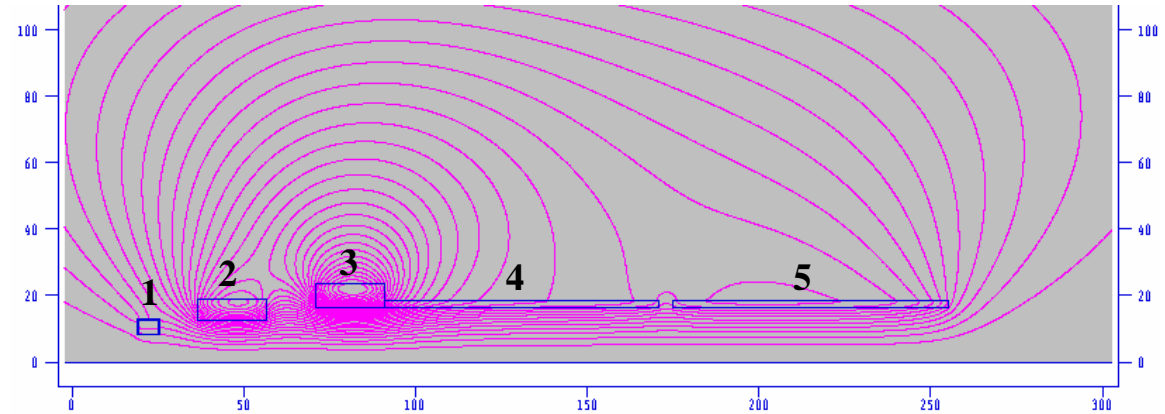
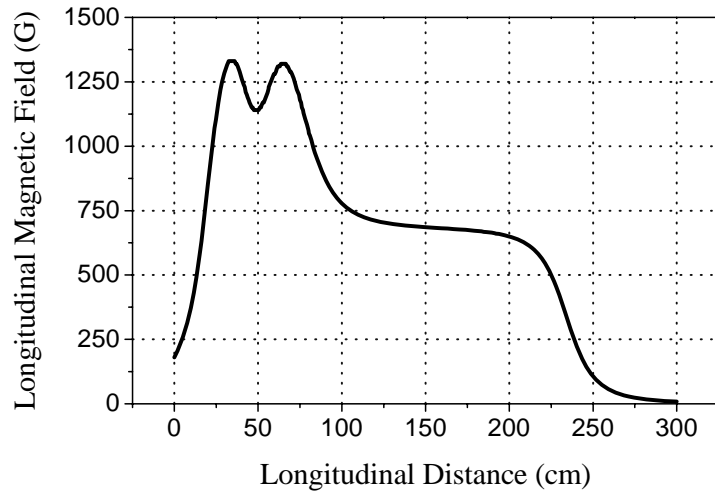
**Impedance Smith-chart**





# ◆ Focusing Solenoids

Longitudinal B-field

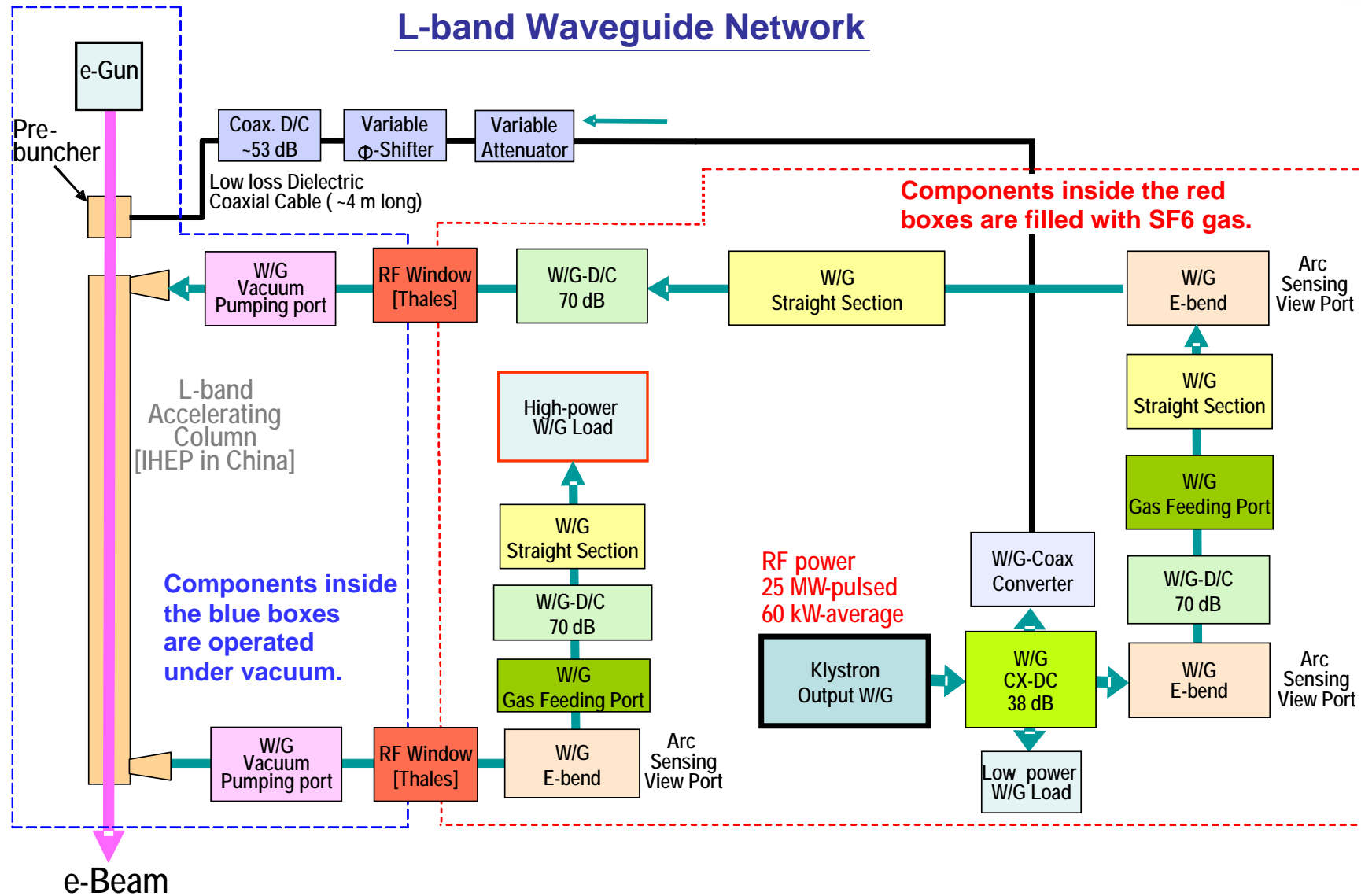


Solenoids Characteristics

Solenoids	Ampere-turn	Current (A)
1	2000	3.6
2	32000	32
3	36000	32
4	44000	32
5	44000	32

Powered by single DC power supply

# Waveguide Network with Coax Line



# ◆ Klystron

## Thales TV2022D Tube



## Specifications

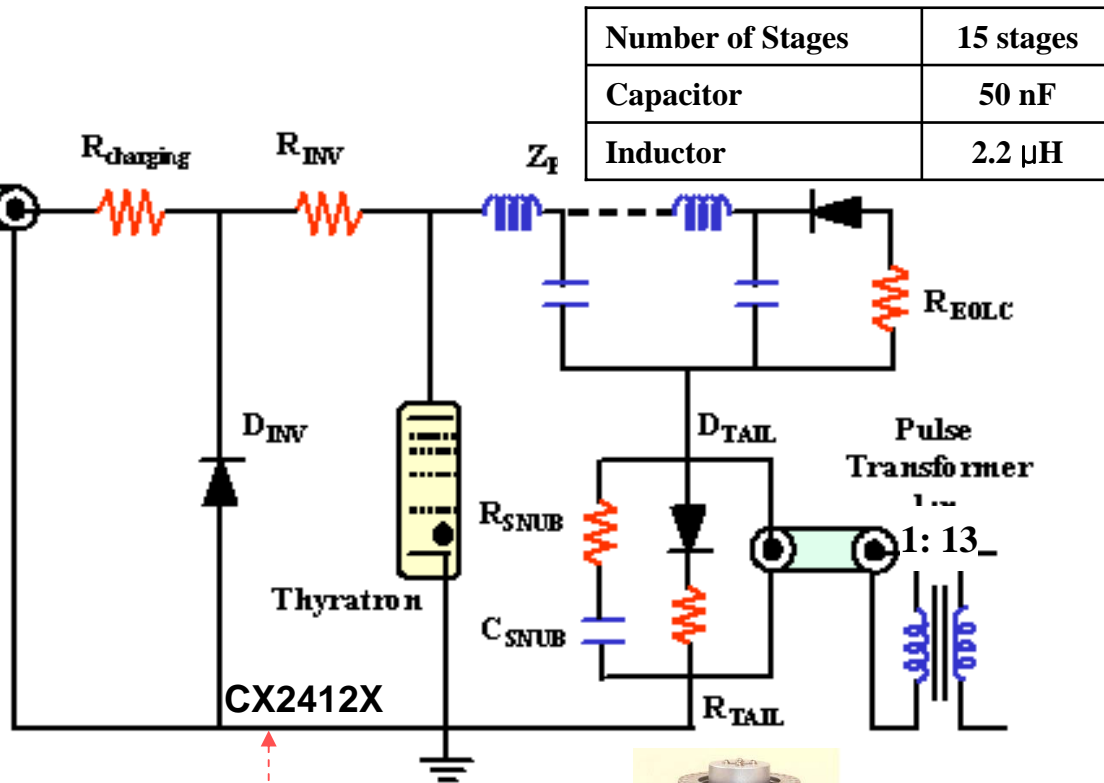
Frequency	1.3 GHz
RF output peak power	30 MW
RF output average power	60 kW
Peak drive power	300 W
RF pulse duration	7 us
Cathode voltage	264 kV
Beam current	230 A
Perveance	1.7 $\mu$ Perv
Heater	28 V / 25 A

## 1 : 13 Pulse Transformer



# Pulse Modulator

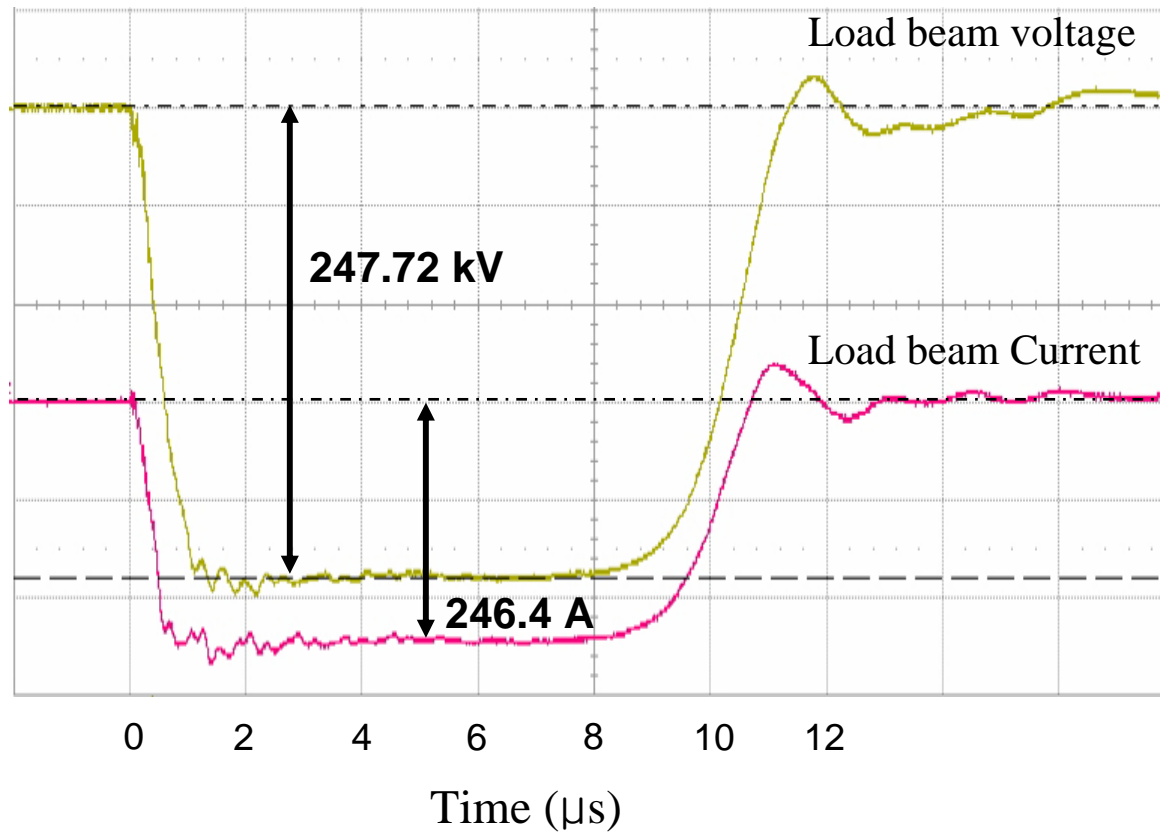
Peak Charging Rate	33 kJ/sec
Output Voltage	45 kV
Average Output Power	30 kW
Number of Units	8 units



Peak forward voltage	50 kV max
Peak forward current	15 kA max
Average anode current	15 A max



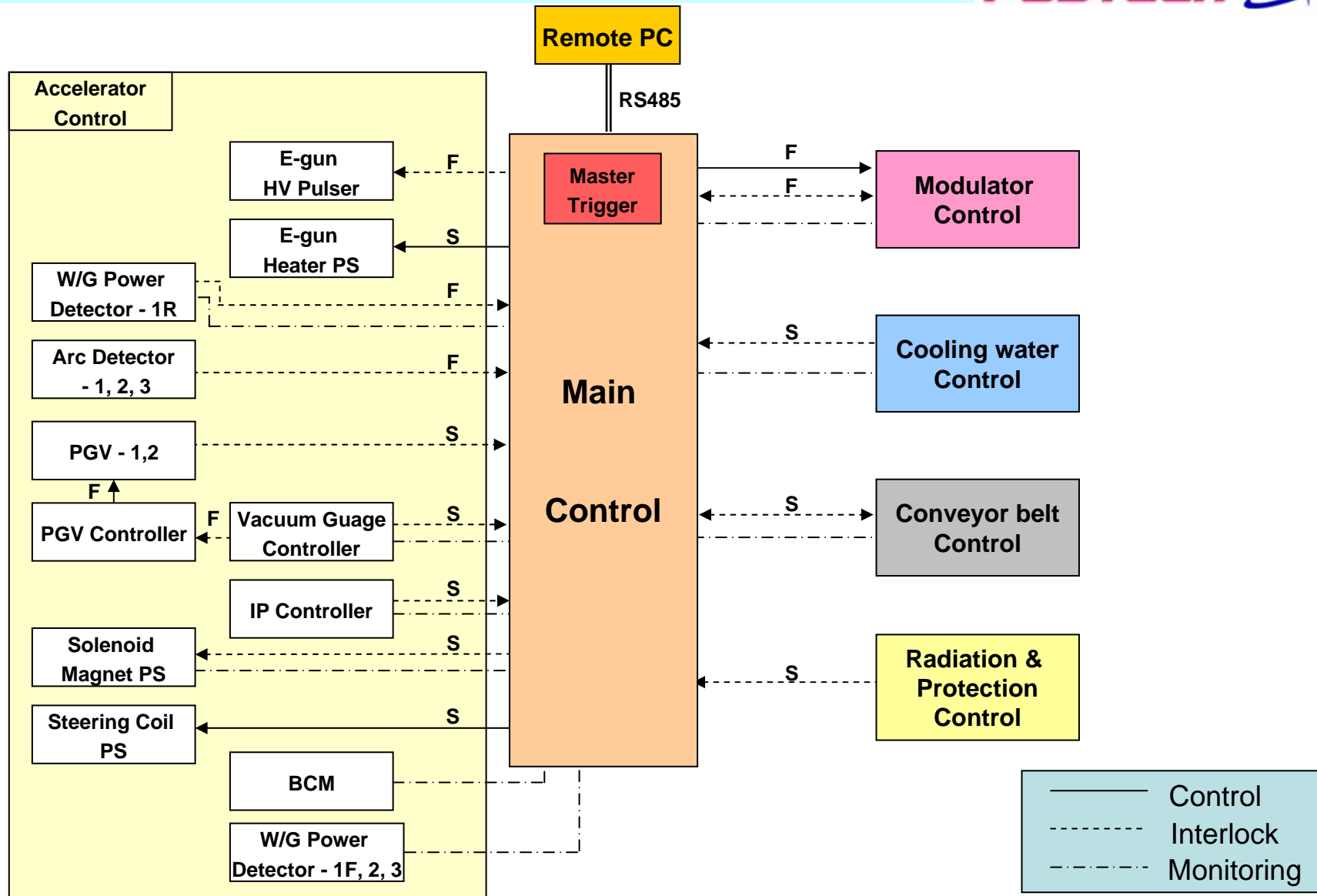
# ◆ High-voltage Pulse Test



## Test Result

Load Impedance	1 kΩ
Load Voltage	247.72 kV
Load Current	246.4 A
Charging Voltage	42 kV
Pulse Width (70 %)	9.3 μs
Repetition Rate	10 Hz

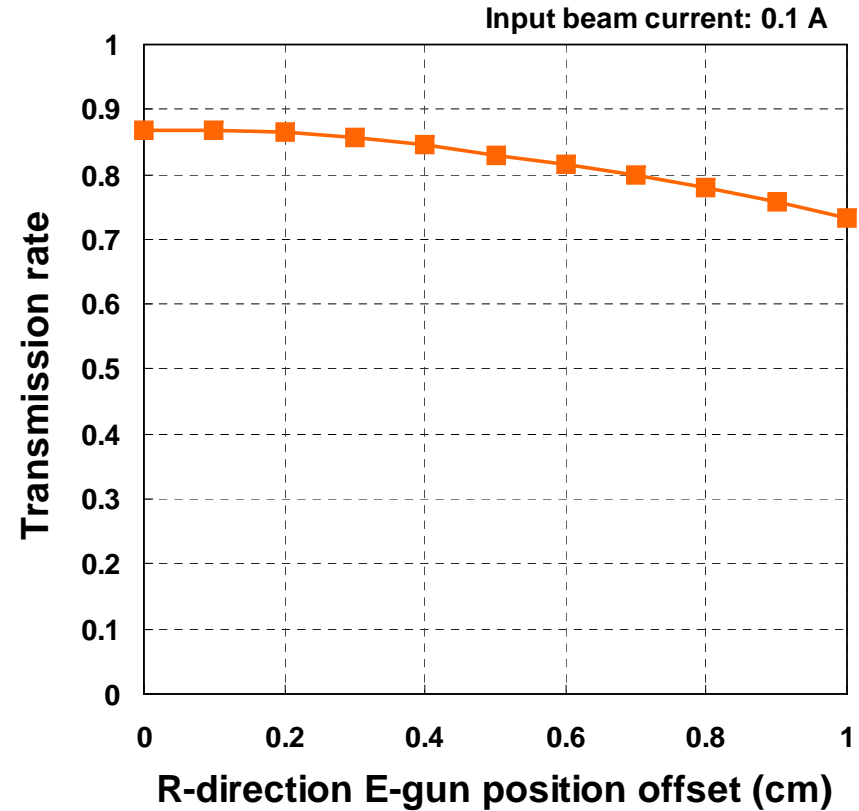
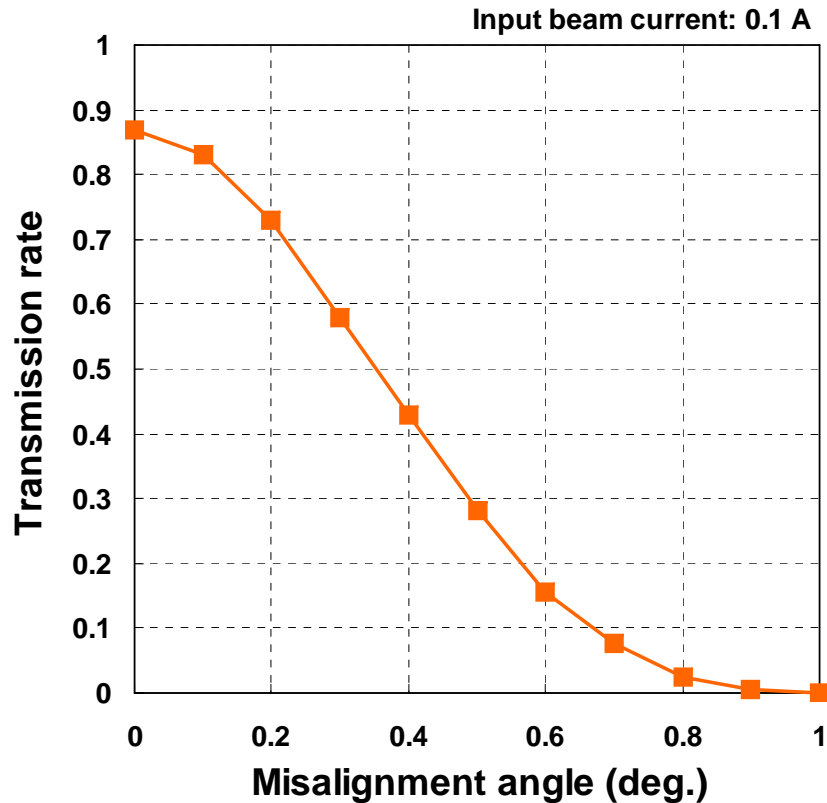
# Control System



# ◆ Beam Commissioning Scenario

Step	Steering Coils	Solenoids	Input RF Power (into acc.)	Input Current (A)	Pre-buncher	Remarks	Goal (transmission)
1. Initial Condition	off	off	off	0.1	off	Check the output beam current.	
2. Alignment Check	on	off	off	0.1	off	Search the max. transmission condition of the steering coils. Find the offset rate.	87%
3. Solenoids On	re-adjust	on	off	0.1	off	Turn on the solenoids. Adjust the steering coil refer to the simulation result.	100%
4. RF On	on	on	to 12 MW	0.1	off	Raise the input power Until the output beam energy is 10 MeV.	85%
5. Nominal Current	on	on	12 MW	to 1.6	off	Raise the input current at the operation condition.	86%
6. Nominal RF Power	on	on	to 25 MW	1.6	off	Raise the input power until the output beam energy at the operation condition.	77%
7. Operation Condition	on	on	25 MW	1.6	on	Obtain the optimum condition by the commissioning of the pre-buncher.	89%

# ◆ Beam Commissioning – Alignment Check



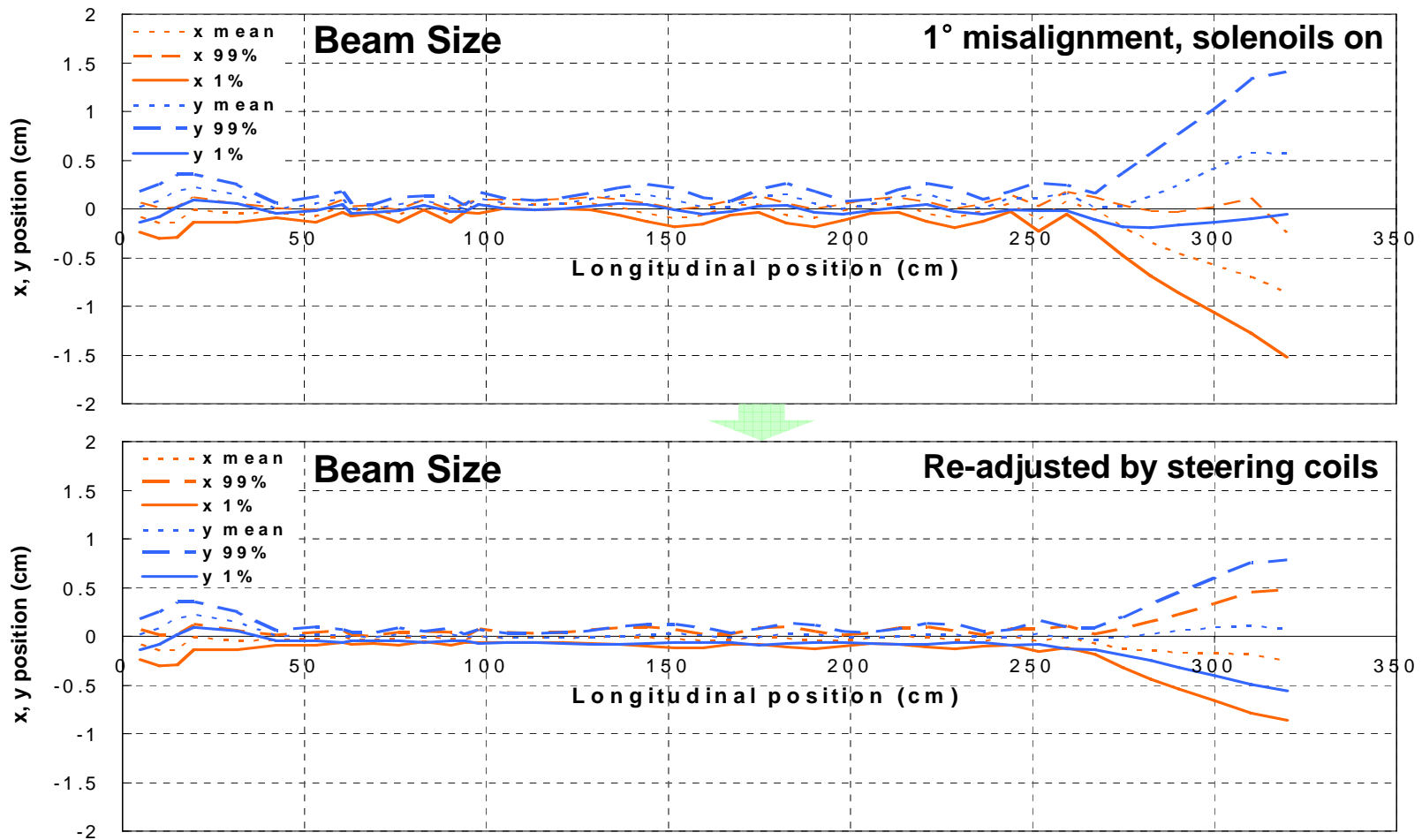
Initial condition: **no power, no solenoid, no pre-bunching,**  
operation the E-gun emitting 0.1 A only

1° misalignment  $\Rightarrow$  no output beam

Steering coils  $\Rightarrow$  find the value of the misalignment



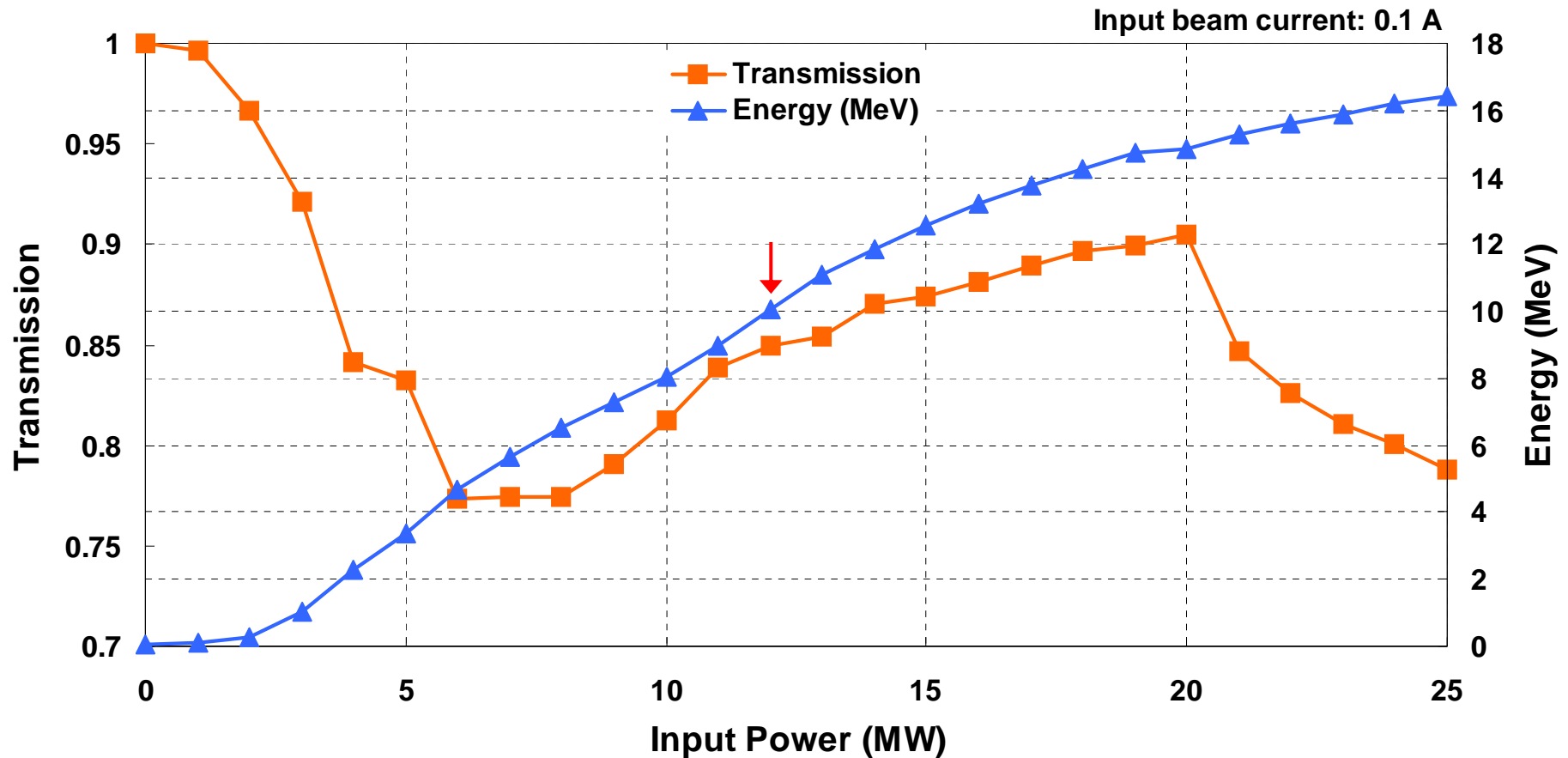
# ◆ Beam Commissioning – Solenoids On



Focusing by solenoids  $\Rightarrow$  100% transmission

Re-adjusted by steering coils refer to simulation result  $\Rightarrow$  Optimum condition

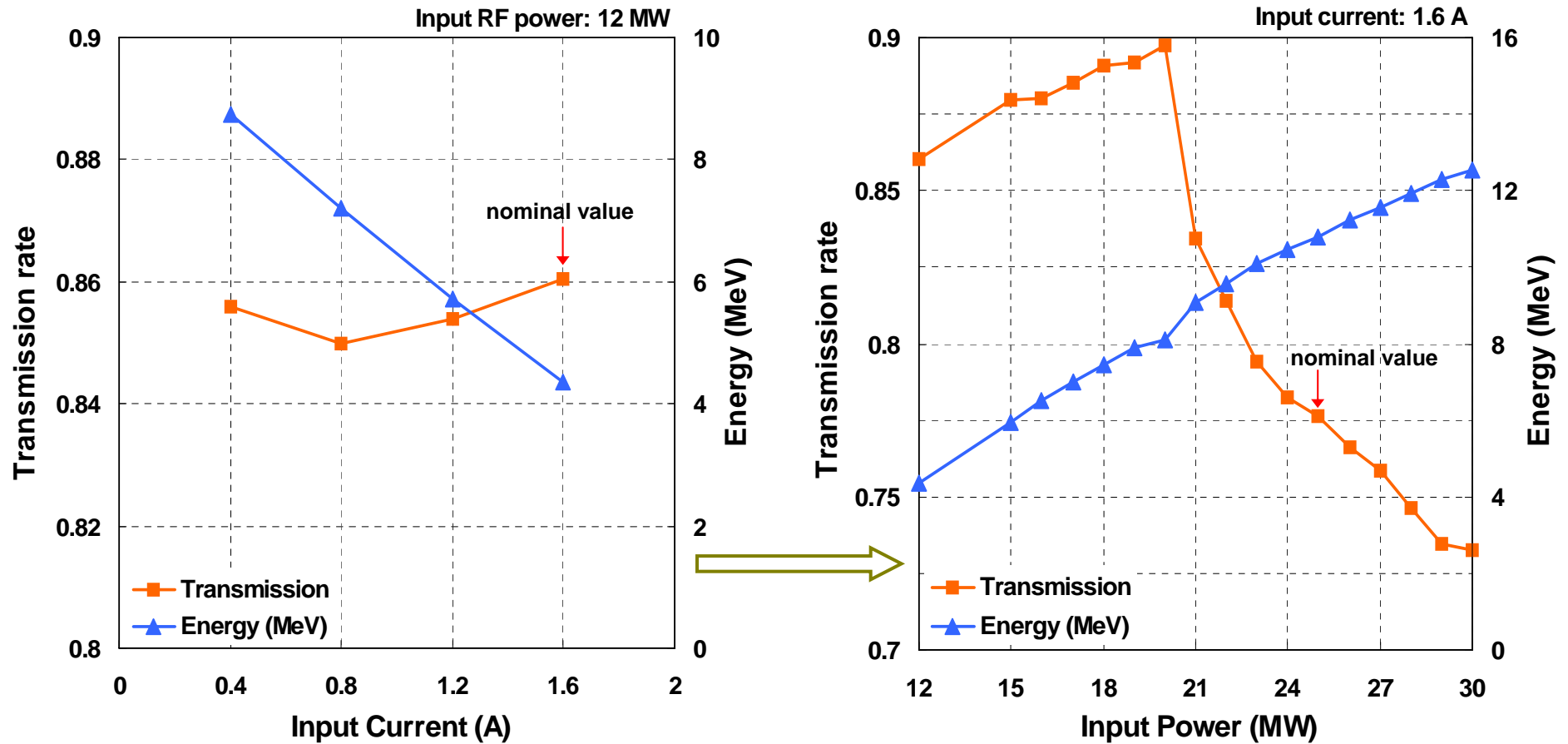
# ◆ Beam Commissioning – RF On



Raise the RF power at **12 MW**

: Beam energy limited by 10 MeV due to neutron production

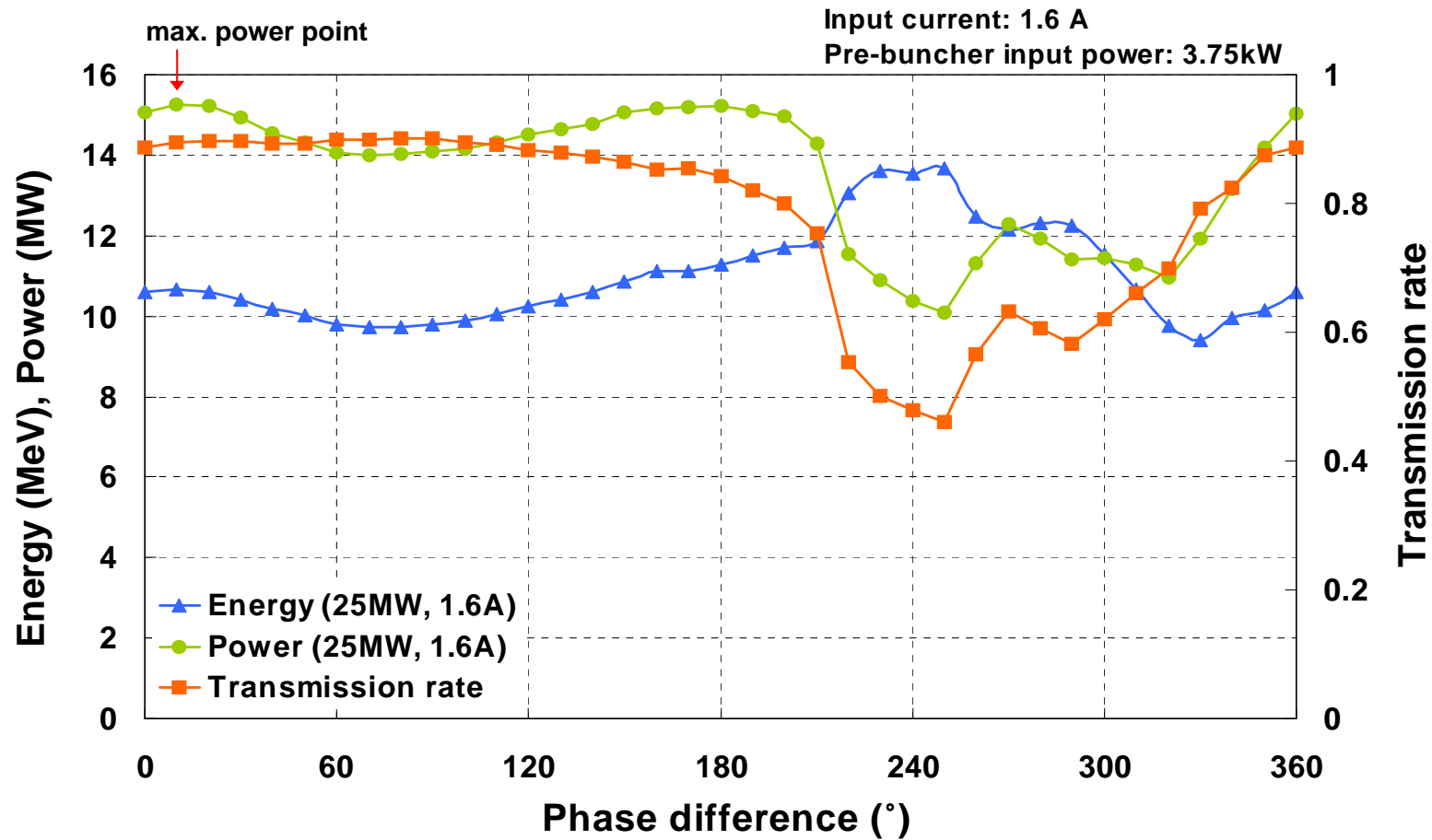
# ◆ Beam Commissioning – Nominal Condition



Raise the input current to nominal value: **1.6 A**

Raise the RF power to nominal value: **25 MW**

# ◆ Beam Commissioning – Operation Condition



Scanning the transmission rate during change the pre-buncher phase

Pre-buncher optimizing  $\Rightarrow \Delta\phi_{PB} 10^\circ$ , **transmission 90%, 10.7 MeV**

# ◆ Current Status and Plan

## Klystron & Modulator

- Fabrication and Assembling finished.
- PFN to be tuned for the flat-top requirement.
- Installed at the CESC site. →

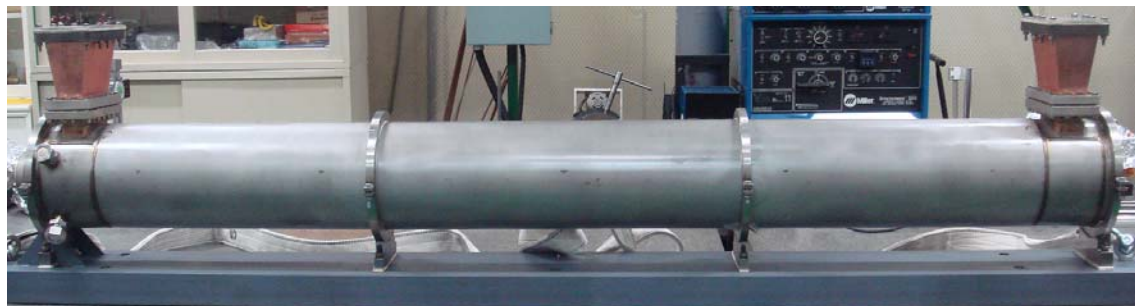


## Waveguide and Coaxial-line

- Ready to installation.

## Accelerating Column

- Delivered to Pohang. →
- Beamline also to be assembled.



## Under Development

- Beam Scanner
- Cooling System
- Control System

**Commissioning is planned this year.**