



# HHF effects simulation with intense pulsed ion beam (IPIB)

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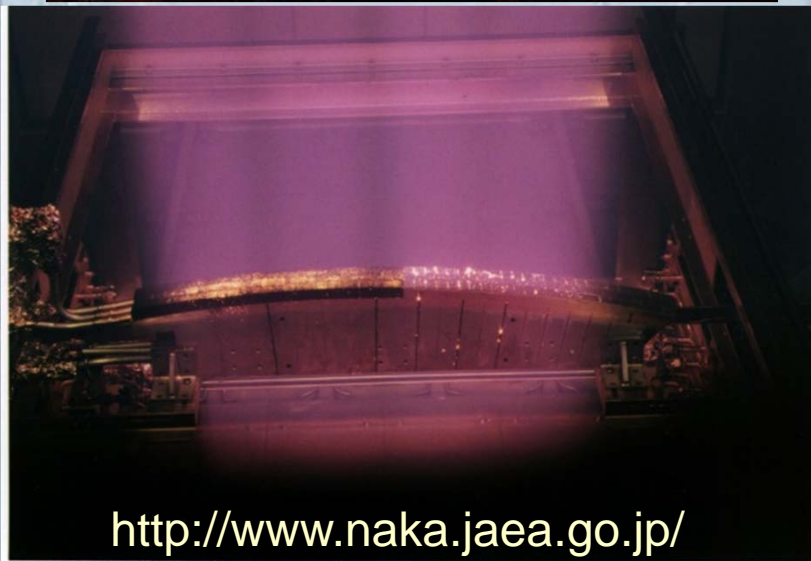
# Outline

- Introduction
- Difference on parameters between transient HHF in TOKAMAK and IPIB irradiation
- Transient thermal dynamic process analysis
- First round of IPIB irradiation of W

## GLADIS in IPP, Germany



[http:// www.ipp.mpg.de/](http://www.ipp.mpg.de/)

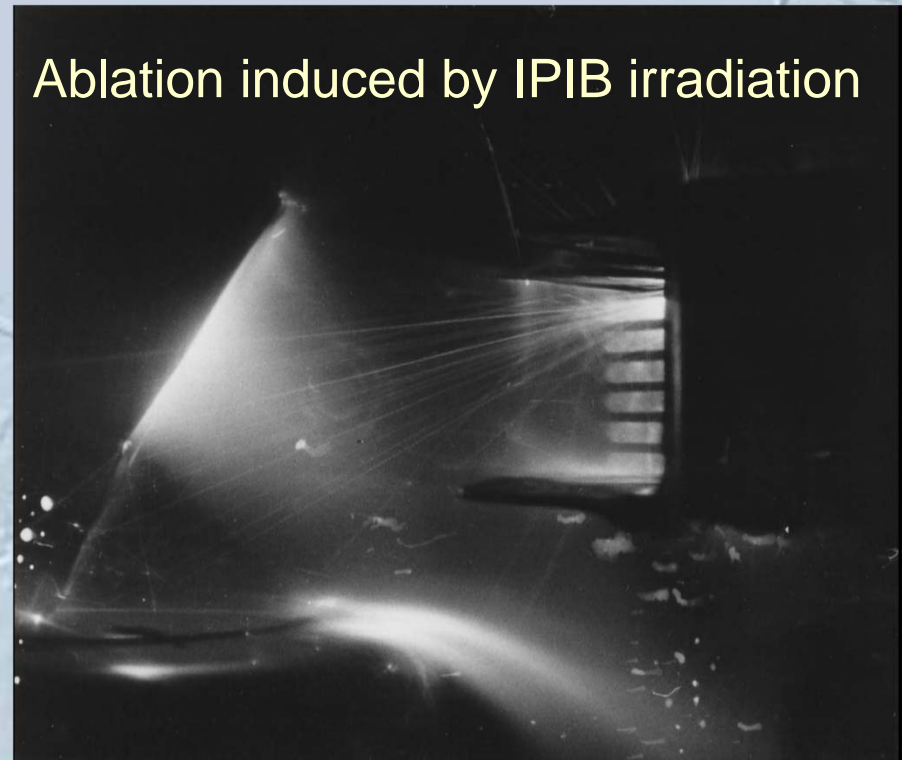


<http://www.naka.jaea.go.jp/>

## PBEF in JAEA, Japan

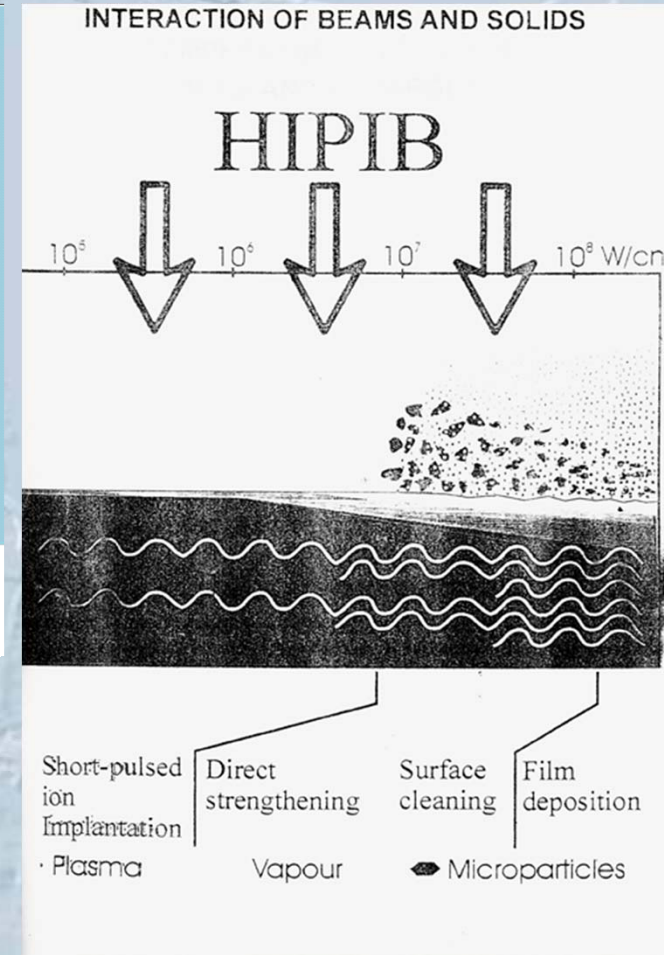
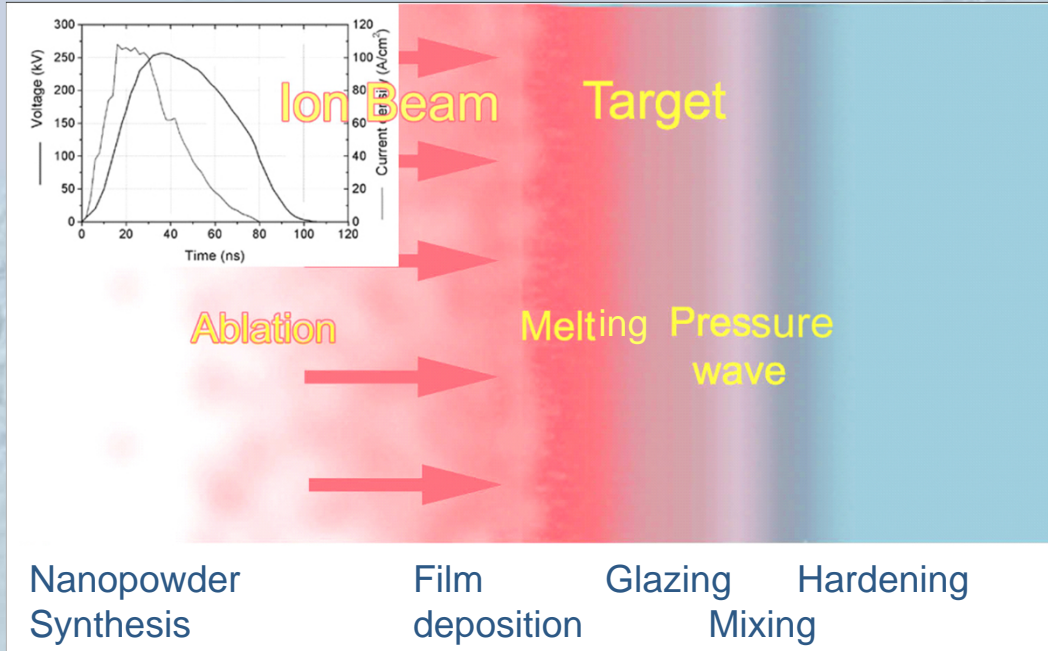
## TEMP in HVI, Russia

Ablation induced by IPIB irradiation





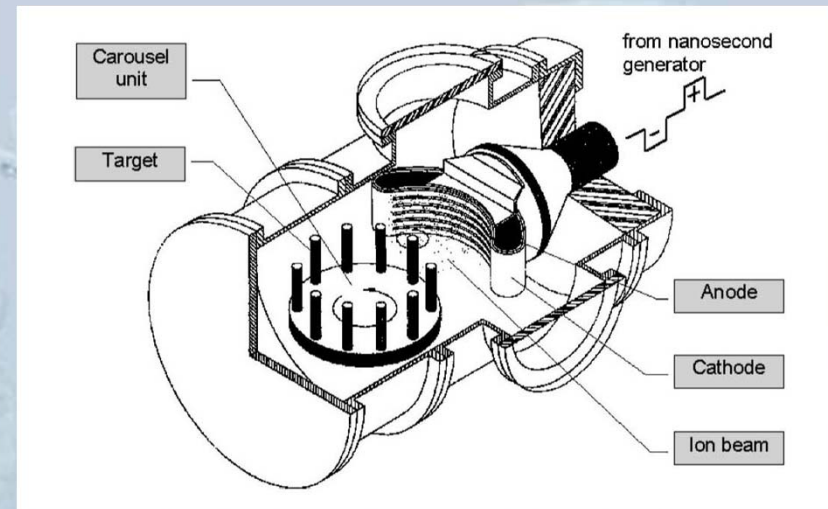
# IPIB and material interaction





# TEMP II accelerator based on Max-Plank generator and magneto insulated ion diode

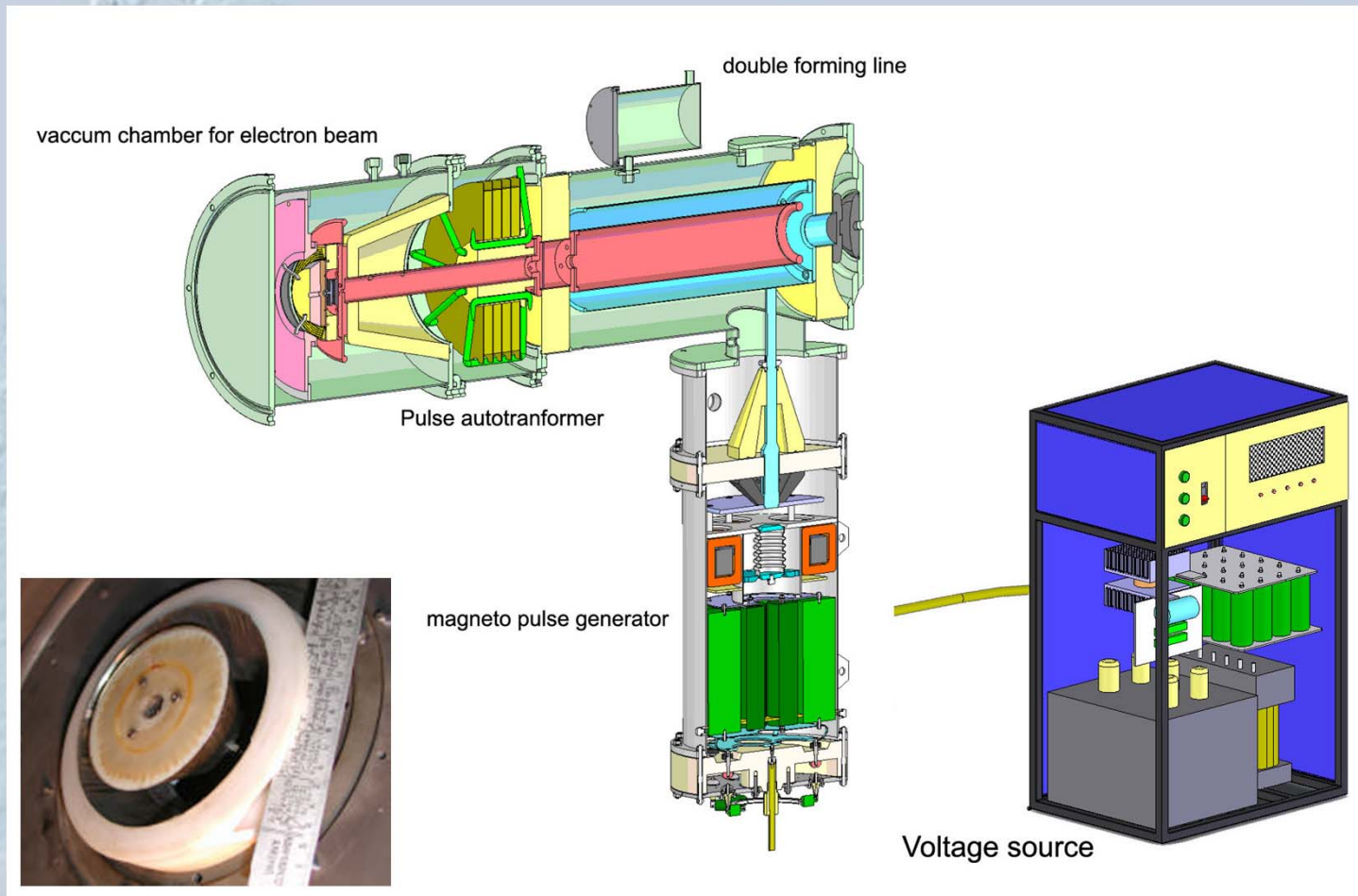
250-350 kV, 40-300 A/cm<sup>2</sup> , 70 ns, 0.1Hz





# New IPIB accelerator: based on high-voltage magneto-pulse generator and ion diode

300-450 kV, 40-400 A/cm<sup>2</sup>, 80 ns, 1Hz





# Comparison of parameters of TEMP series (based on magneto isolated diode) with GLADIS, PBEF and transient HHF in TOKAMAK

	Output Power MW	$P/S$ GW/m <sup>2</sup>	$E/S$ per pulse MJ/m <sup>2</sup>	Ion energy keV	Pulse duration ms	$P/V$ 10 <sup>6</sup> GW/m <sup>3</sup>
TEMP		1~2×10 <sup>4</sup>	10 <sup>-4</sup> ~0.1	200~400	<10 <sup>-4</sup>	6.7~6×10 <sup>4</sup>
GLADIS	2.2	(5~65) ×10 <sup>-3</sup> *		55 *	1~3×10 <sup>3</sup> *	0.03~0.3
PBEF	1.5			50	10 <sup>6</sup>	
ELM I		1.7~6.7	0.5~4 †	3 †	0.3~0.6 †	90~340
Disruption		2.0~4.3	2~13 †	10 †	1~3	54~116

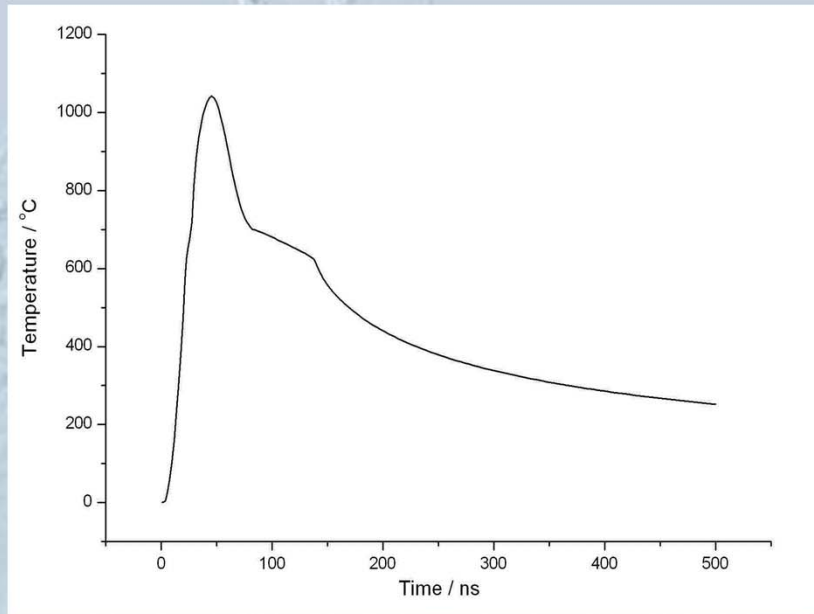
\* H. Greuner et al. / Fusion Engineering and Design 75-79 (2005) 345-350

† <http://www.naka.jaea.go.jp/>

‡ B. Bazylev, et al, FEC2006

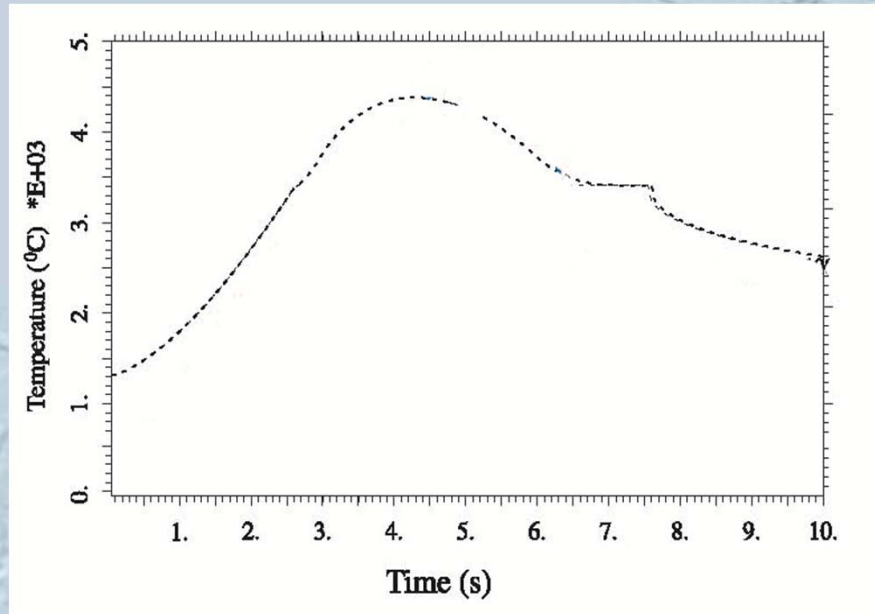


$$C_V \rho \frac{\partial T}{\partial t} = S(x, t) + \frac{\partial}{\partial x} \left( \lambda \frac{\partial T}{\partial x} \right)$$



Time dependence of temperature on Al target surface irradiating by IPIB

Code: STDIPIB



Time dependence of temperature on W target surface under type I ELM

Code: RACLETTE

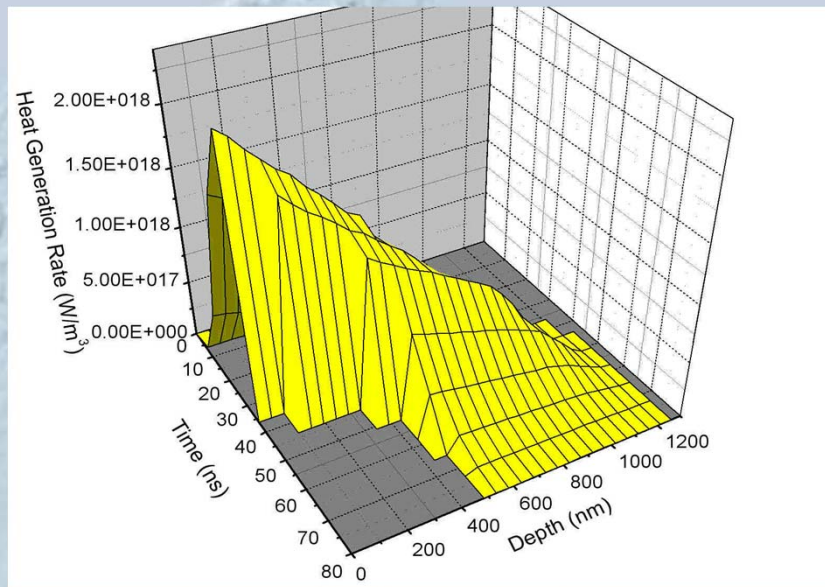
*G Federici, et al., Plasma Phys. Control. Fusion 45 (2003) 1523*





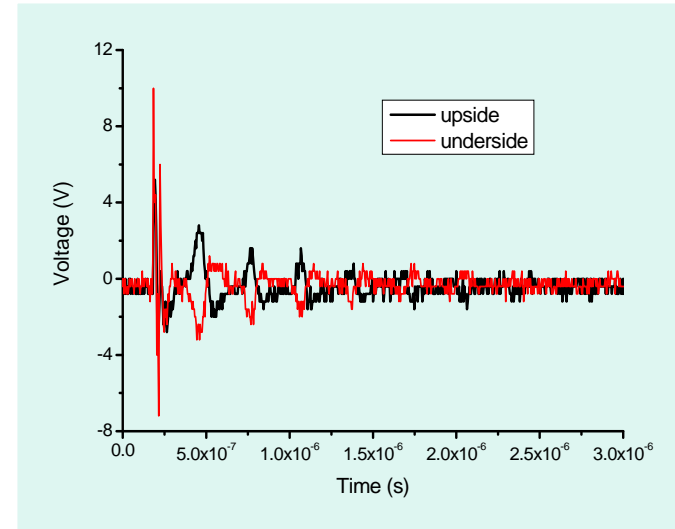
# STDIPB Calculation results

IPIB : 300keV 100A/cm<sup>2</sup> C<sup>+</sup>  
Target : Pure Al

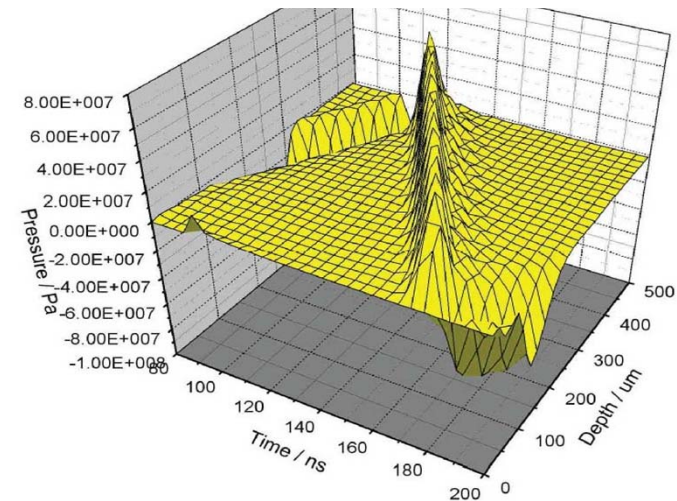


Heat source

In this case, about 15% of deposited energy is carried off by the pressure wave and dissipates in whole the target rapidly.



Experimentally measured pressure wave in Al target induced by 450 keV, 430 A/cm<sup>2</sup>, 50 ns C<sup>+</sup> beam irradiation



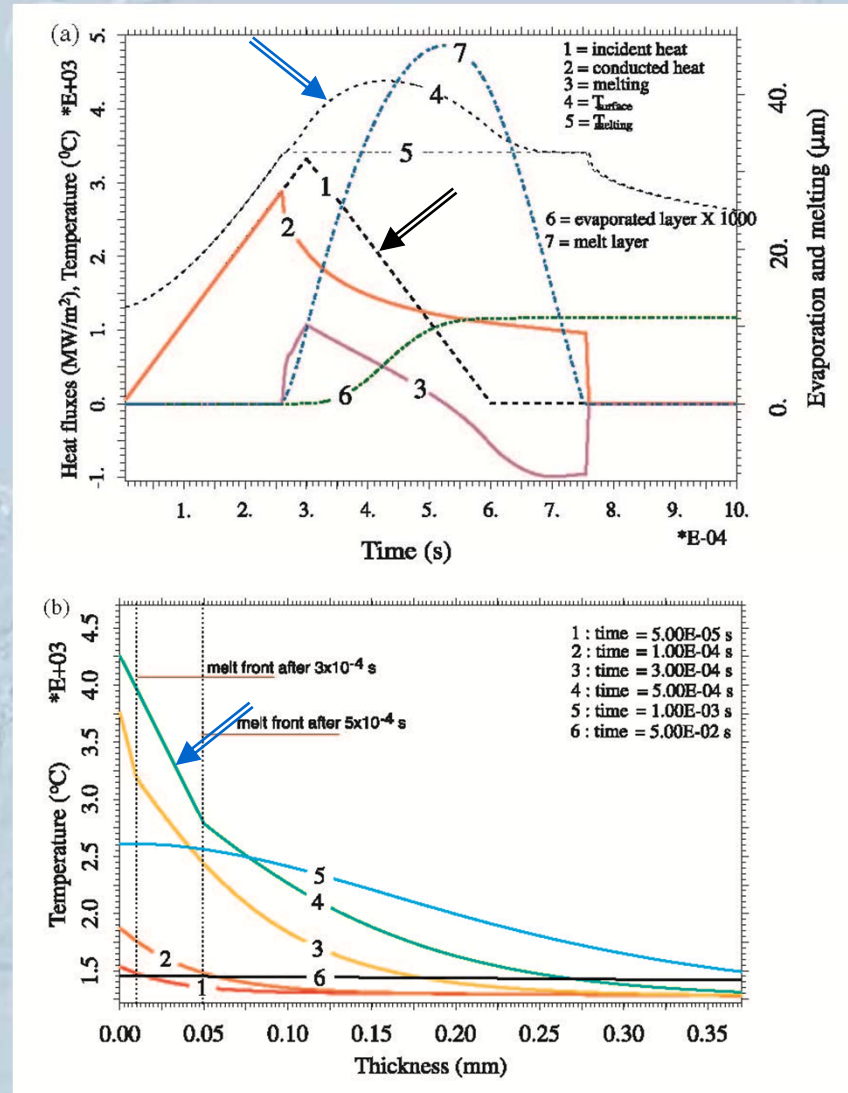
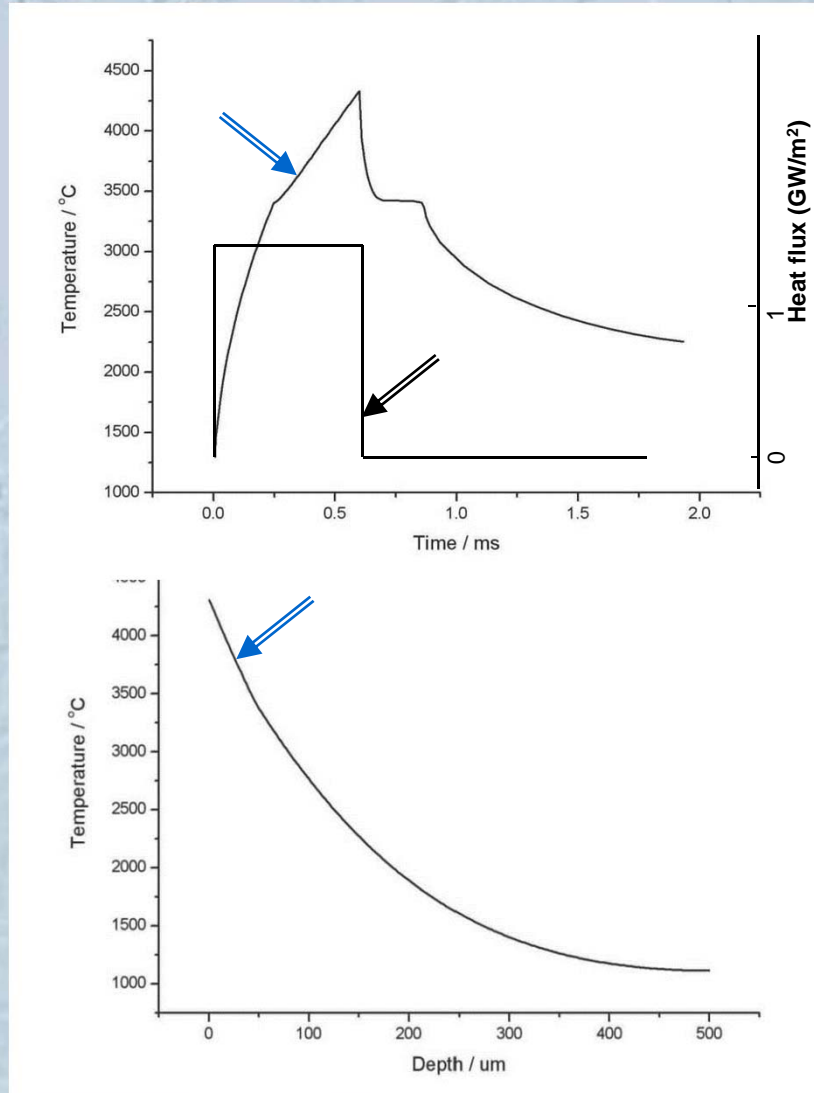
pressure wave



# Comparison between two codes

## STDIPIB

## RACLETTE





# First round of IPIB irradiation

## Beam parameters

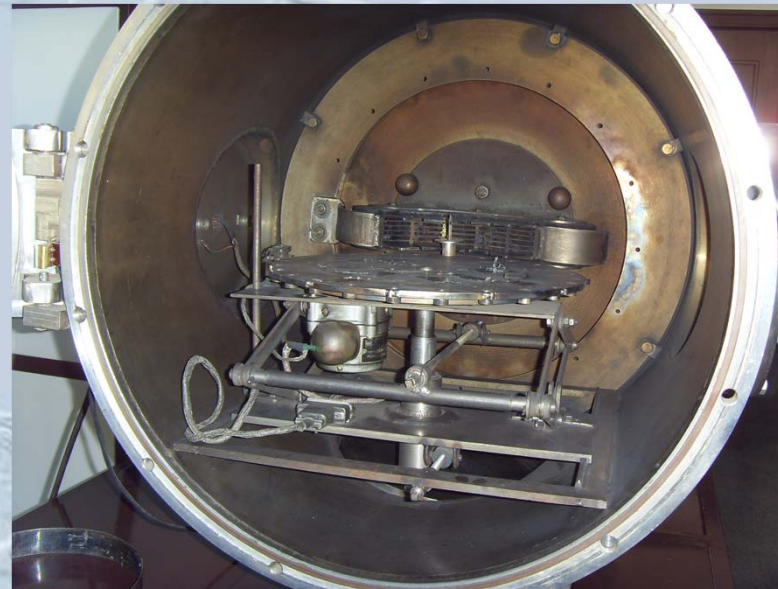
$V_{\text{acc}}$ : 240kV

$j_{\text{peak}}$ : 170A/cm<sup>2</sup>

$\rho_{\text{peak}}$ :  $3.6 \times 10^3$  GW/m<sup>2</sup>

Pulse duration: 70ns

Pulse times: 20



## Expected ones

$V_{\text{acc}}$ : 300kV

$j_{\text{peak}}$ : 250~300 A/cm<sup>2</sup>

$\rho_{\text{peak}}$ :  $(7.5 \sim 9) \times 10^3$  GW/m<sup>2</sup>

Pulse duration: 70ns

Pulse times: 50~100

Target: pure W

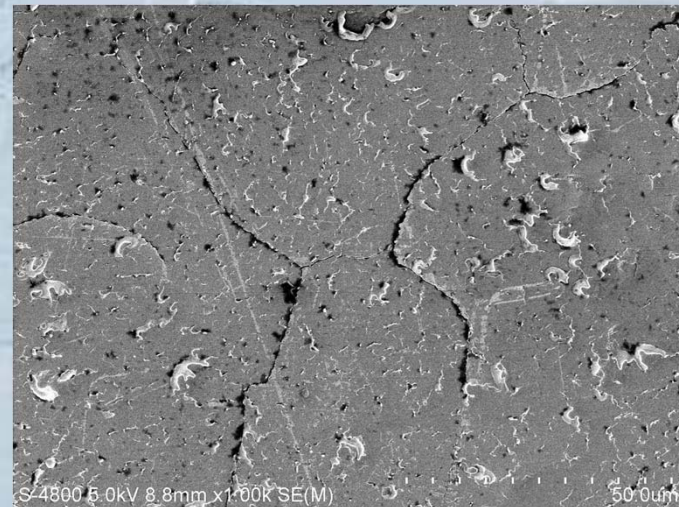
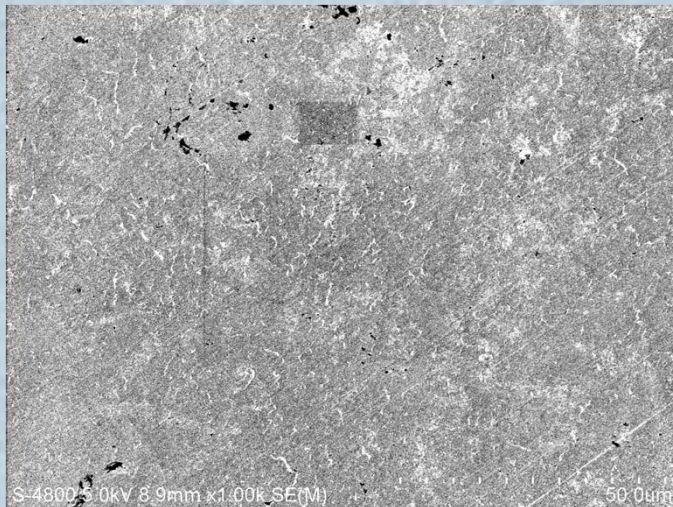
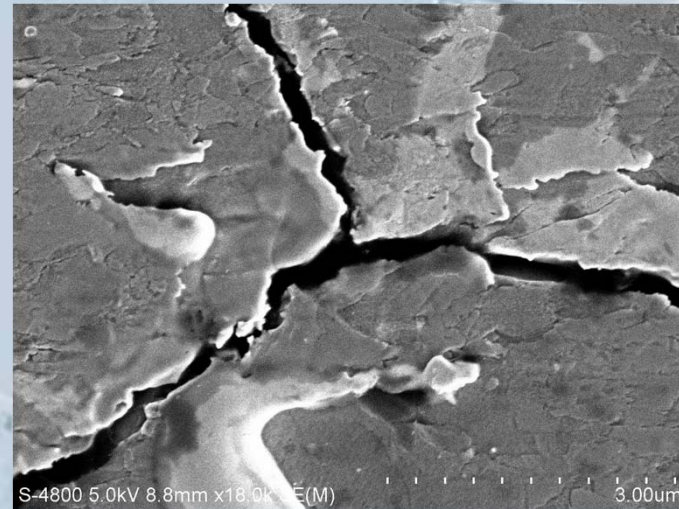
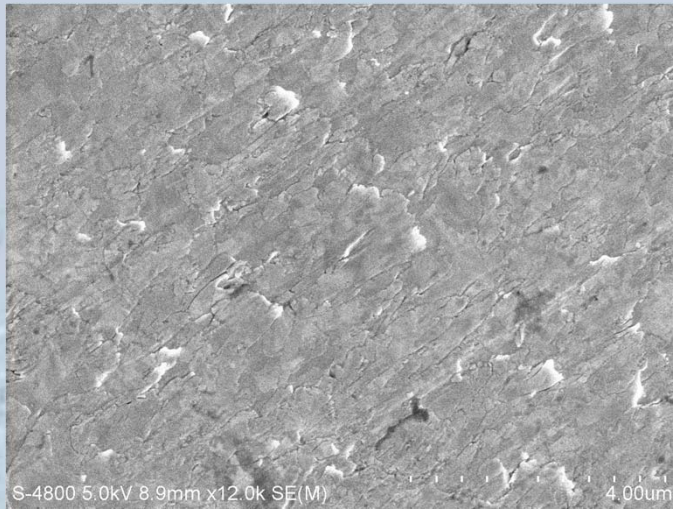
Weight loss:  $<10^{-4}$  g/cm<sup>2</sup>



# Morphology under SEM

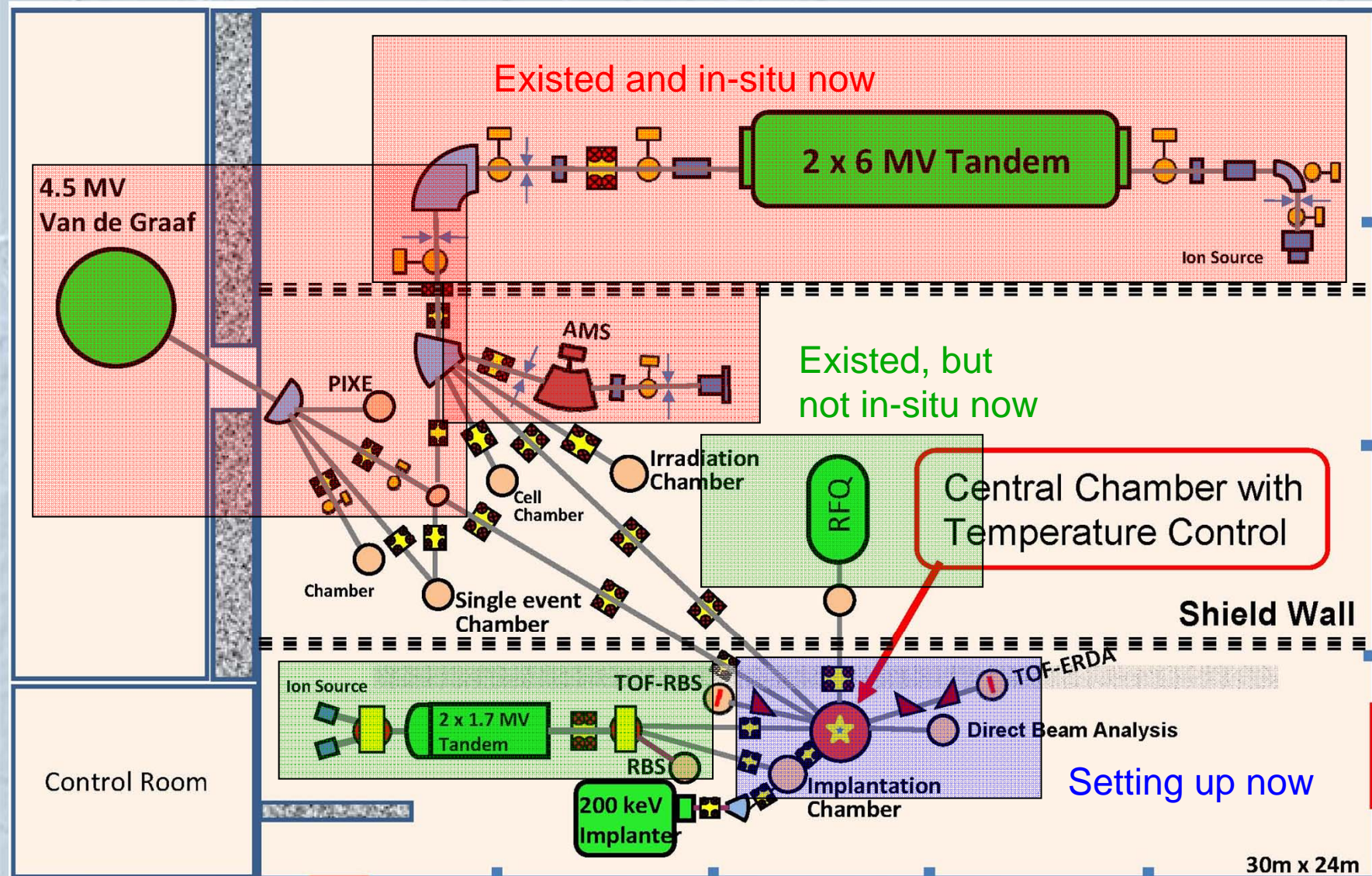
original

After IPIB irradiation





# PKU Multi-Beams System (in 3~5 years)



30m x 24m



# PKU accelerator facility



**4.5MV Van de Graaff**



**2x6MV tandem**



**1MeV RFQ  
accelerator**



**Accelerator Mass  
Spectroscopy**



**2x1.7MV tandem**



**ECR ion source**



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*DANKKE!*

谢谢！