XFEL Beam Dumps

- Technological Issues -

EIFast-XFEL Workshop, DESY, 9/10 May 2006
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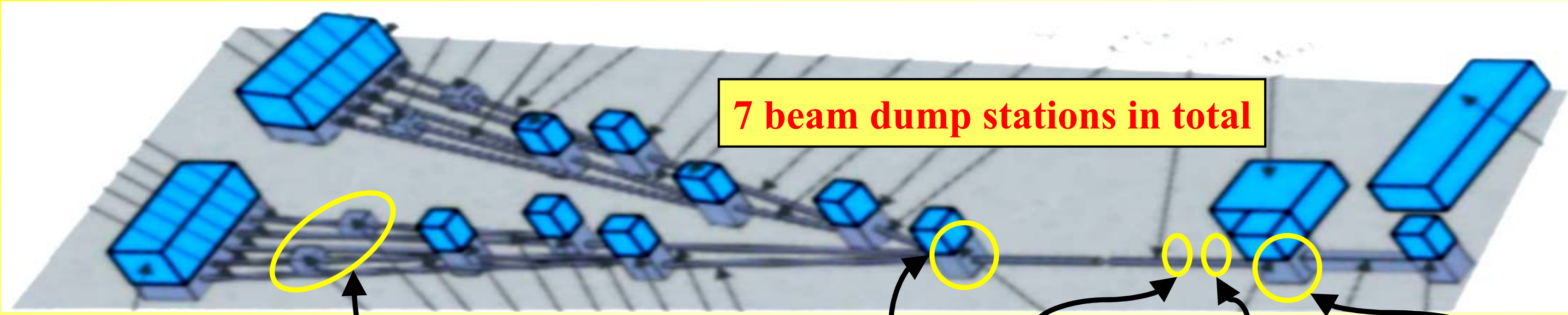
A. Introduction

B. Dump Issues

C. Window Issues

D. Possible Industrial Contributions

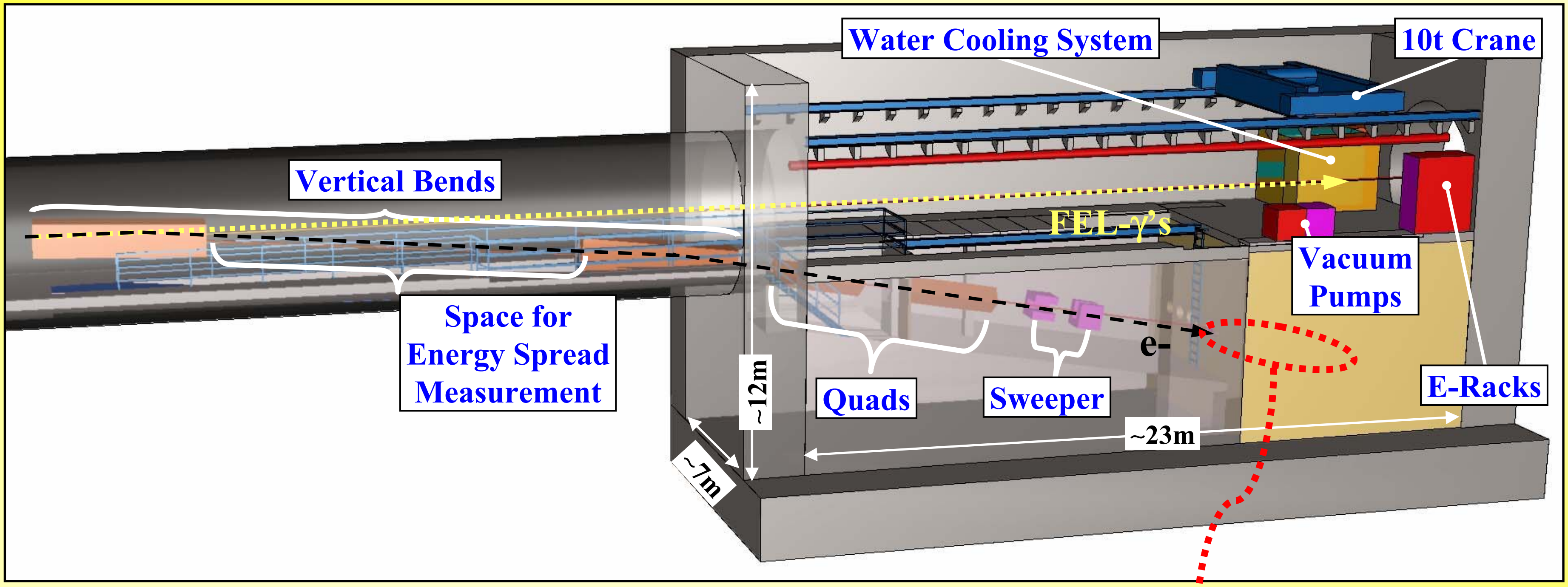
Introduction: locations & parameters



Quantity & Type of Dumps	3 x MAIN		1 x BC2	1 x BC1	2 x INJ
Location & Purpose	XSDU1,2	Final Beam Abort	XTL Tuning of BC's		XTIN Tuning of INJ's
	XS1	Linac Commissioning Emergency Dump Bunch Pattern			
E_0	≤ 25 GeV		≤ 2.5 GeV	≤ 500 MeV	≤ 300 MeV
N_t	$\leq 2.5 \cdot 10^{13}$ e- = 4 μC				
I_{ave}	≤ 40 μA		*)	*)	≤ 40 μA
P_{ave}	≤ 300 kW		*)	*)	≤ 12 kW
Beam Preparation	σ ≥ 2mm slow circular sweep with Rs=5cm		*)	*)	*)

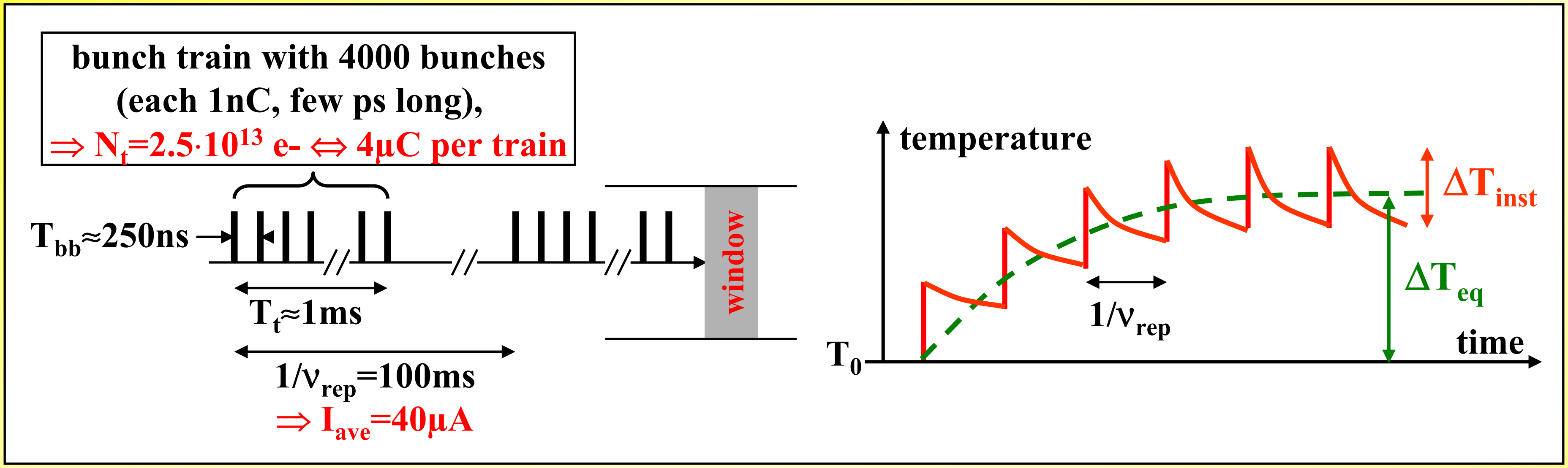
*) to be discussed

Introduction: MAIN dump building



Exit Window
&
Absorber (in Concrete Shielding)

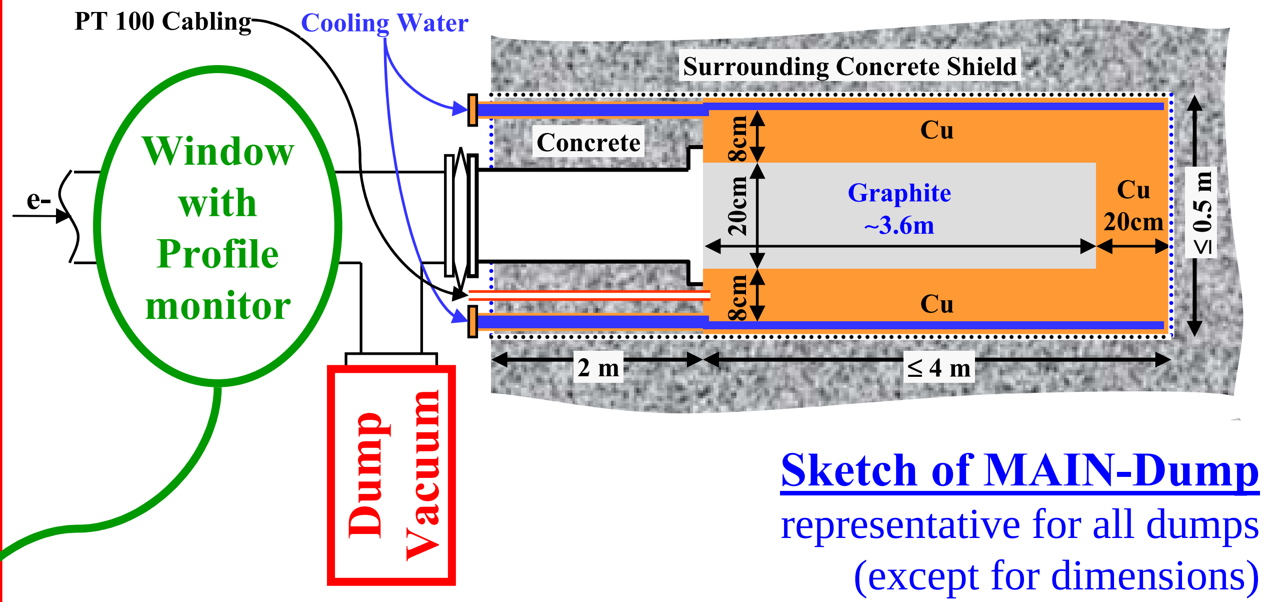
Introduction: pulsed beam → pulsed heating



Graphite will be used as a base material for dump and window

- good thermal and mechanical properties especially in cyclic load applications
- low density → moderate power dissipation per unit length

Introduction: dump & window



Sketch of MAIN-Dump

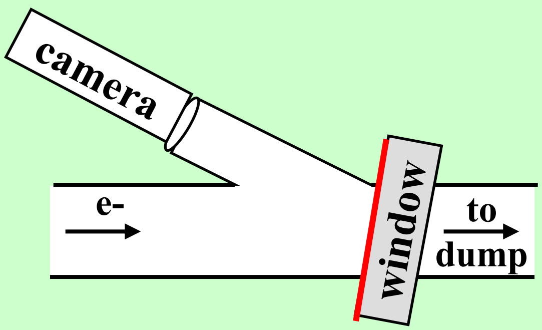
representative for all dumps (except for dimensions)

Window with integrated OTR-monitor

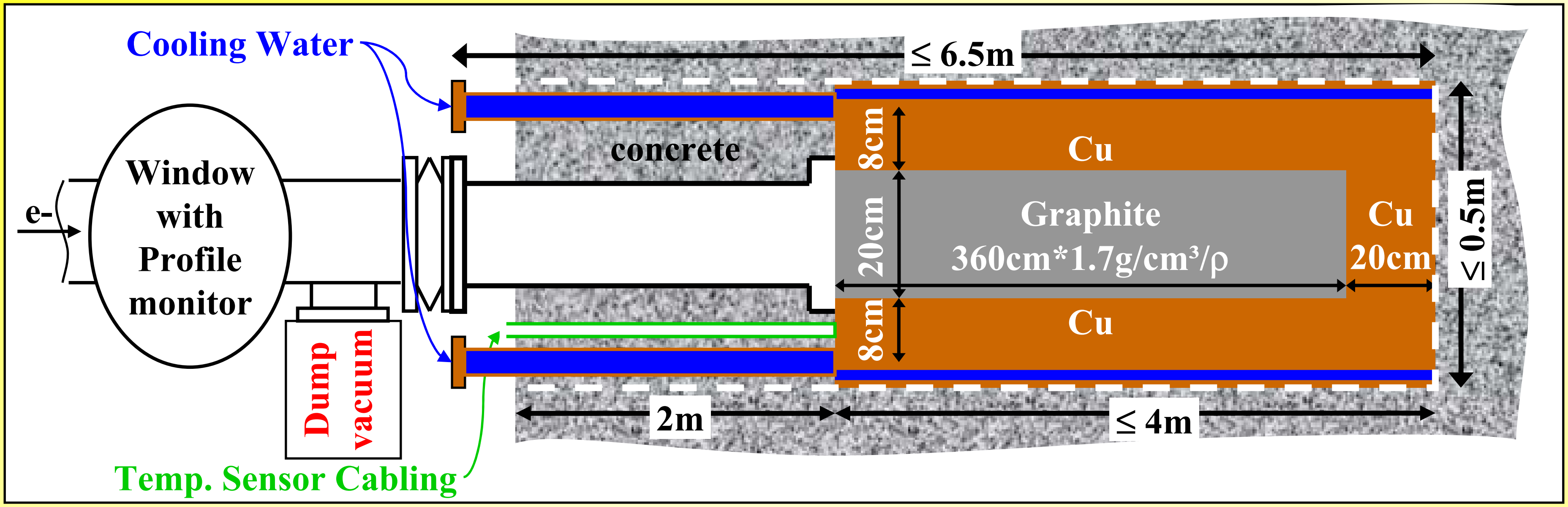
1 tilted window

1 camera

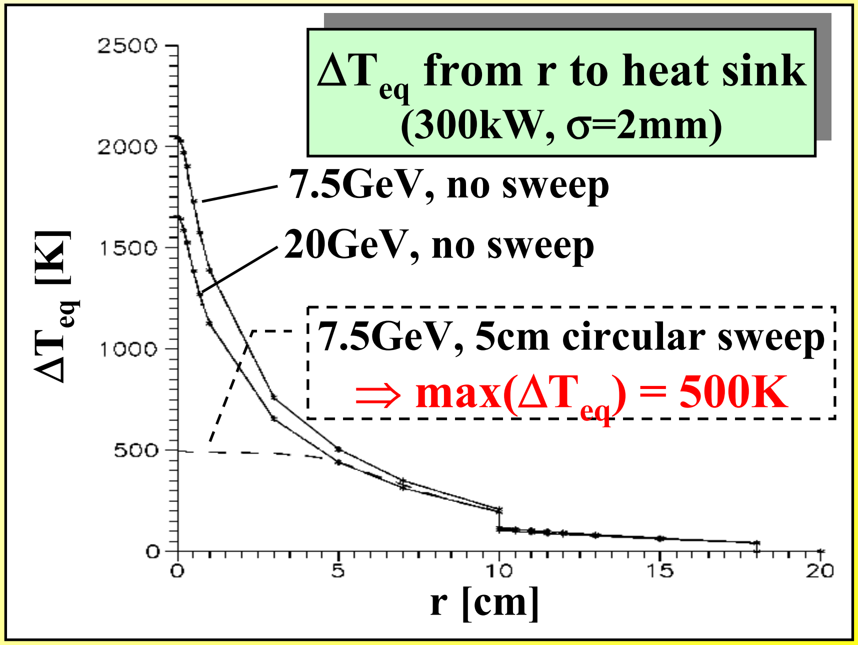
reflecting surface



MAIN Dump: conceptual layout

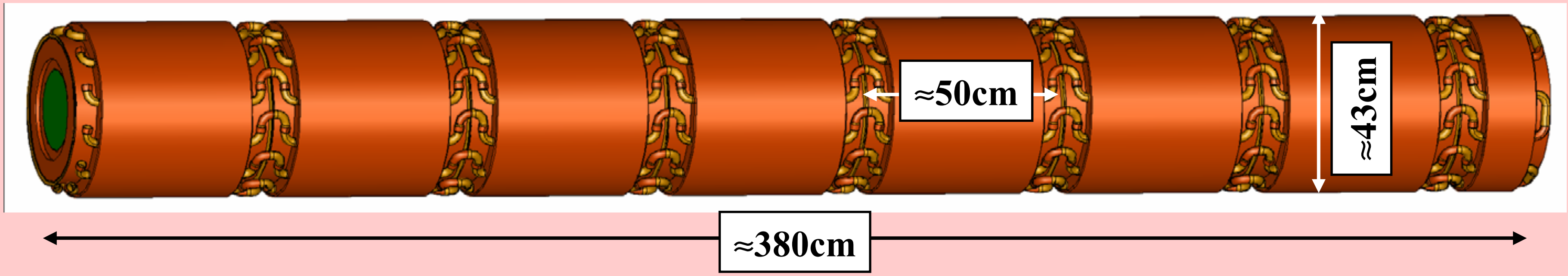


- dump module: Ø ≤ 0.5m, L ≤ 6.5m, m ≤ 7t
- C-core fully under vacuum
  → allows T ≥ 500°C w/o oxidation risk
- Cu acts as vacuum vessel
  → water piping outside vacuum
- max(dP/dz)= 1.8kW/cm (7.5GeV/300kW)
  = 1.6kW/cm (20GeV/300kW)
- max(ΔT_{inst}) ≈ 200K (25GeV/2.5·10^{13}e-, σ=2mm)



MAIN Dump: preliminary technical layout (1)

C-Cu Dump w/o 2m Front Part



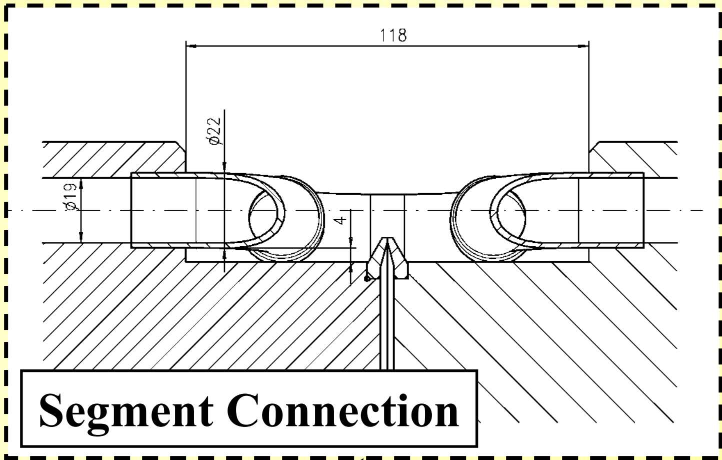
Basic Ideas

- split up long C-Cu device into longitudinal segments, which are welded together
  → modular assembly
- outer support structure (not drawn) to strengthen the module
- C-Cu connection not trivial, due to different therm. exp. ($\alpha[10^{-6}/K]$: C: 5-8, Cu: 16)
  → stress calc. to define length of C blocks and way of manufacturing the C-Cu joint
  brazed contact is favoured, since good heat transfer is vital
- copy technical solution also for INJ and BC dumps with modified dimensions, i.e.
  MAIN: radial layout A
  INJ, BC: radial layout B, different length easy to achieve due to modular design
  → same technical dump layout at all dump stations

MAIN Dump: preliminary technical layout (2)

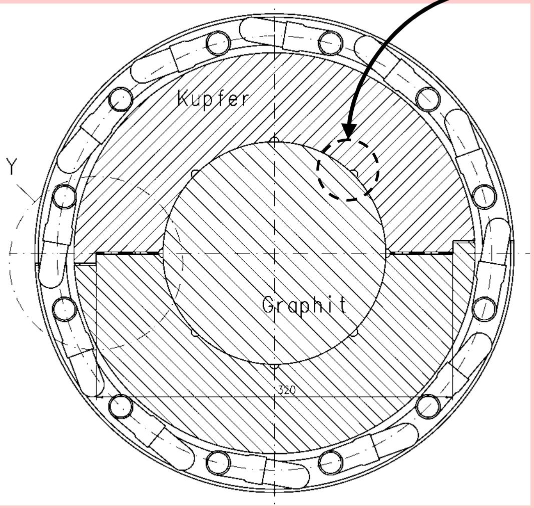
- **brazed C-Cu boundary for good thermal contact**
  2 Cu halves pressed with clamps on C during braze, to avoid expansion gap at brazing temperature
  Does this work ?

- **pumping slits between C / Cu**
  "open" graphite surface ≈1-2m²

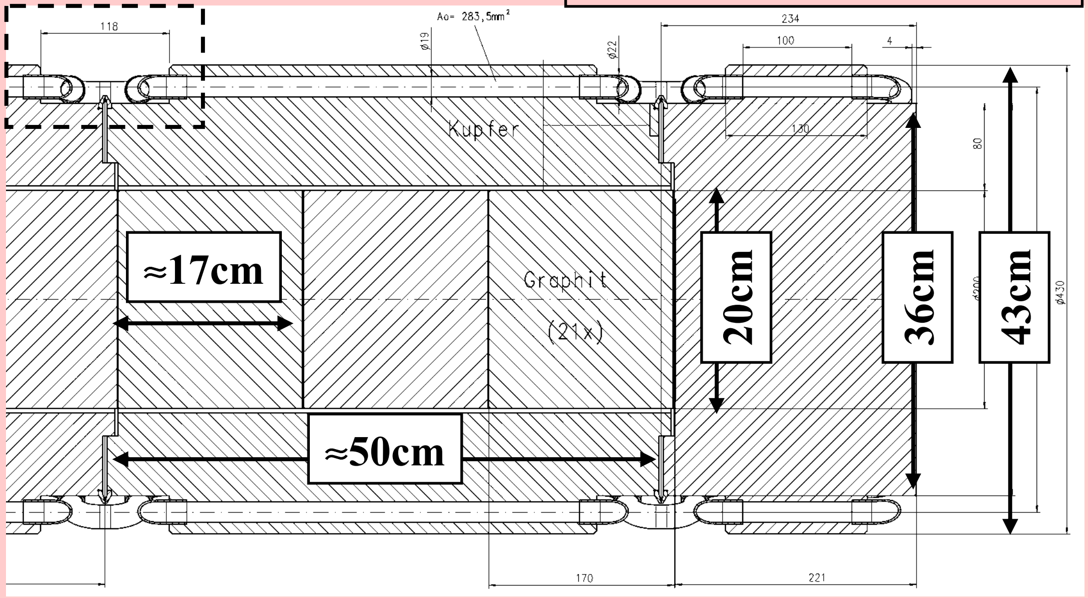


Segment Connection

Cross Section



Middle & End Segment



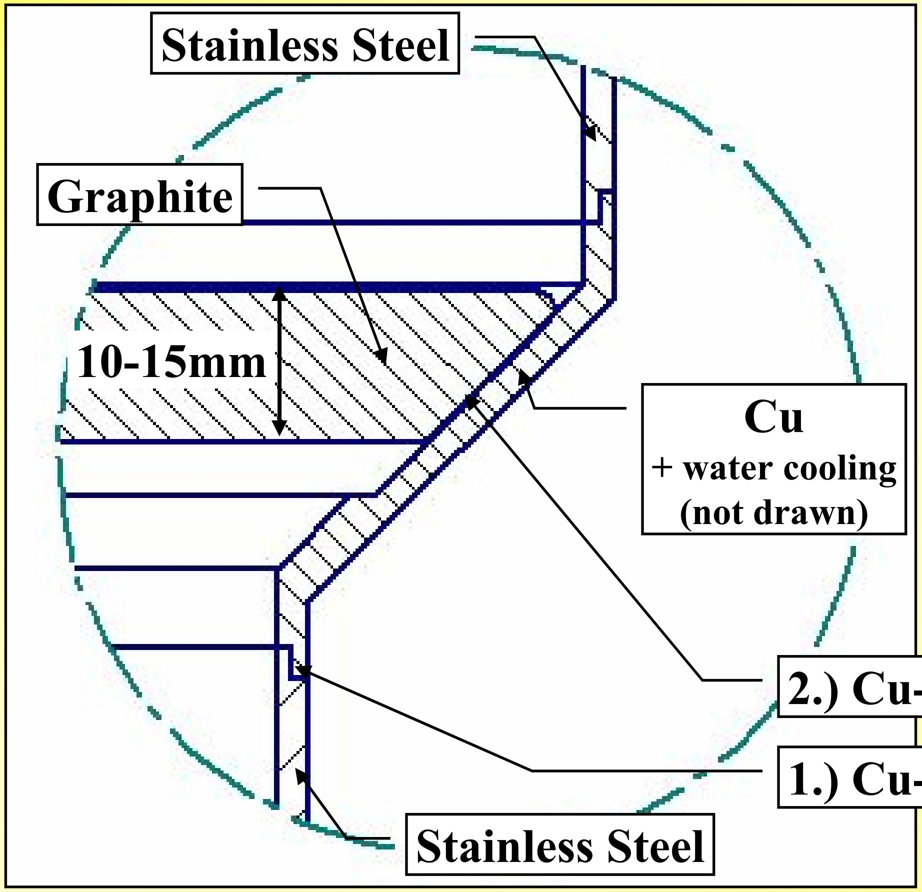
Window: basic layout

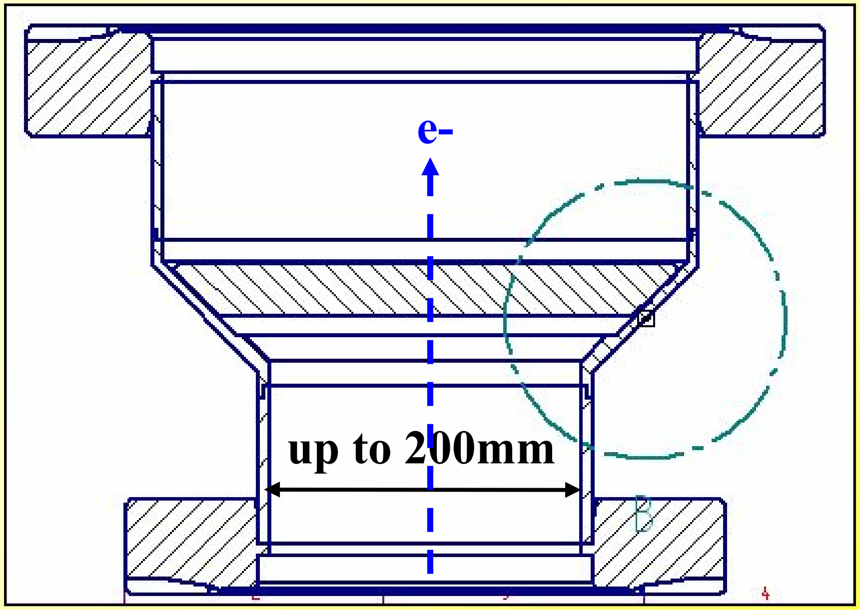
Concept: pure C-window with suitable thin (few µm) coating, that fulfills being:

leak-tight, cyclic stress resistant, no insulator, solderable, clean, optical reflecting

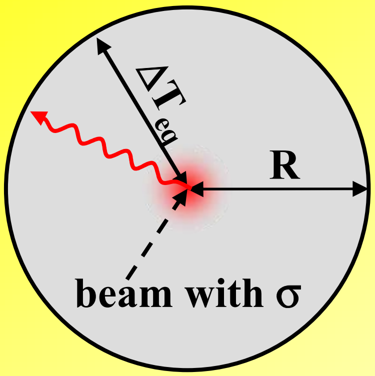
So far: graphite has good thermal & mechanical properties, C-Cu braze works fine

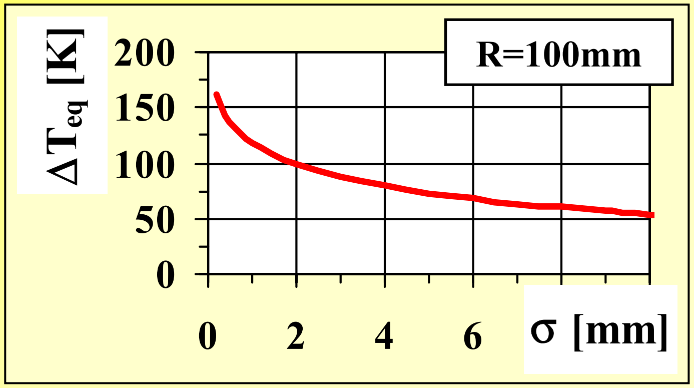
Goal: find suitable coating without degrading the window operation limits too much





Window: heating





<u>equilibrium heating</u> $\propto I_{ave} \cdot \rho / \lambda$

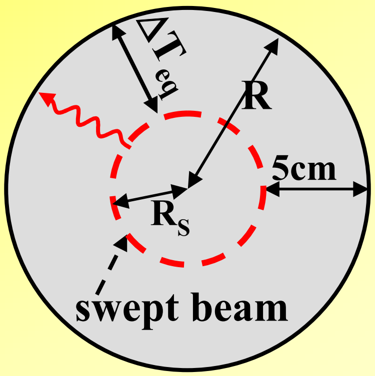
for graphite:

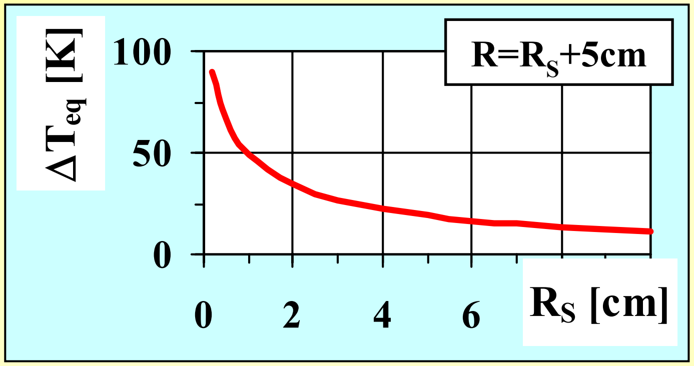
λ=0.7W/cm/K

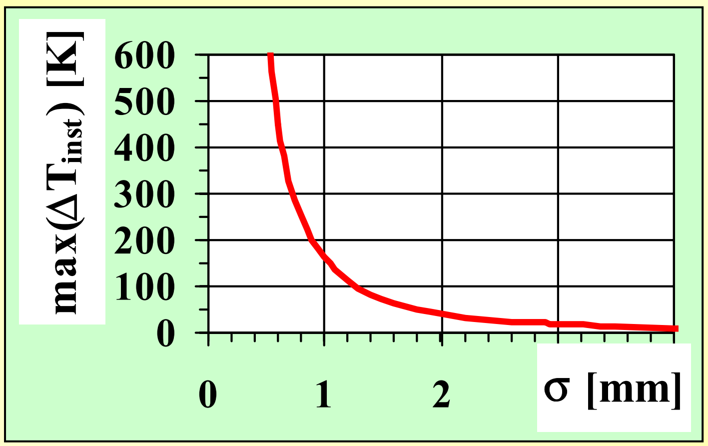
ρ=1.7g/cm^3

I_{ave}=40µA

average heating of graphite window even without sweep no problem







<u>instantaneous heating</u> $\propto N_t \cdot 1/c \cdot 1/\sigma^2$ **(!)**

for graphite:

c=0.7J/g/K

N_t=2.5·10^{13}

reasonable operation with beam size $\sigma \geq$ 1mm

Window: coating

50µm foil of brazing material (Ag-Cu-Ti)
brazed on one surface of graphite
and
polished afterwards

- **leak tight**
- **clean surface**
- **polished surface with high reflectivity ~80%**

Possible Industrial Contribution

Subsystem Dump involves no Mass Production (7 stations + spare),
but requires long term reliable Components,
which undergo cyclic Stress in the Presence of Neutron Irradiation

Industry can contribute at the unsolved key questions (listed by decreasing priority)

1) **Feasible technical design of C-Cu dump with reliable long term thermal contact (based on our technical layout or alternative approach)**
2) **Remote handling procedure for dump module exchange (vacuum-, water-, electrical-connections; vehicle for dump movement; ...)**
3) **Window design/proposal with alternative materials (e.g. ceramics)**
4) **Tests to investigate the operation limits of coated window (energy density, lifetime, ageing effects, work hardening of the coating, ...)**

A lot of very good Research & Engineering Work !

Thanks

for your Attention

Vacuum: graphite properties

<u>Cleanliness</u> (MVP measurement, 10mm thick uncoated NW63/100 graphite FE879 window)

- **no particles detected at vacuum particle counter 20cm apart from graphite surface, while other side was flooded with 1bar N_2**
- **20 counts level when knocking on setup (not sure whether it comes from window)**

<u>Desorption</u> (MVA measurement, graphite FE779)

- **specific desorption rate at 20°C: $\approx 8 \cdot 10^{-10}$ mbar·l/s/cm^2 after 10h**
  $\approx 8 \cdot 10^{-11}$ mbar·l/s/cm^2 after 100h

<u>Leak Tightness</u> (measurement,10mm thick uncoated NW63/100 graphite FE879 window)

- **measured leak rate against 1bar N_2: $\approx$ 0.4mbar·l/s**
  $\Rightarrow$ conductance $\approx 4 \cdot 10^{-4}$ l/s resp. permeability $\approx 6 \cdot 10^{-3}$ cm^2/s (d=1cm, A=63cm^2)
  (conductance = permeability * area/thickness)

$\Rightarrow$ graphite

• is a suitable material to be used in clean vacuum systems

• has to be sealed with suitable coating to make it leak tight for window applications