LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

Radiation Cooling of the ILC positron target

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ILC positron target

- Ti alloy wheel
  - **diameter = 1m**
  - **Thickness 0.4 X0 (1.4cm)**
  - **Spinning with 2000rpm**
- Pulsed energy deposition
- peak energy deposition (PEDD) per bunch train:

  Nominal: 67.5 J/g ⇔ ΔT_{max} = 130K
  Lumi upgrade: 101.3 J/g ⇔ ΔT_{max} = 195K
  Fatigue strength in Ti alloy ΔT ~ 425K (240MPa)

- We do not expect thermal shocks
  - **Degradation during irradiation and pulsed heat load should be studied/tested**

Average power deposition 2-7 kW

- TDR: water cooling
- Alternative solutions:
  - **cooling by radiation**
  - **cooling pads (W. Gai)**

Radiative cooling

Length of bunch train on target (2000rpm): ~10cm
Same area of 1m-wheel is hit again after ~6s
→ Time sufficient for heat dissipation and removal ?

Stefan-Boltzmann radiation law:

σ = Stefan-Boltzmann constant
ε = emissivity
A = surface area
G = geometric form factor

$$W = \sigma \varepsilon A G \left(T^4 - T_{cool}^4\right)$$

Estimate:

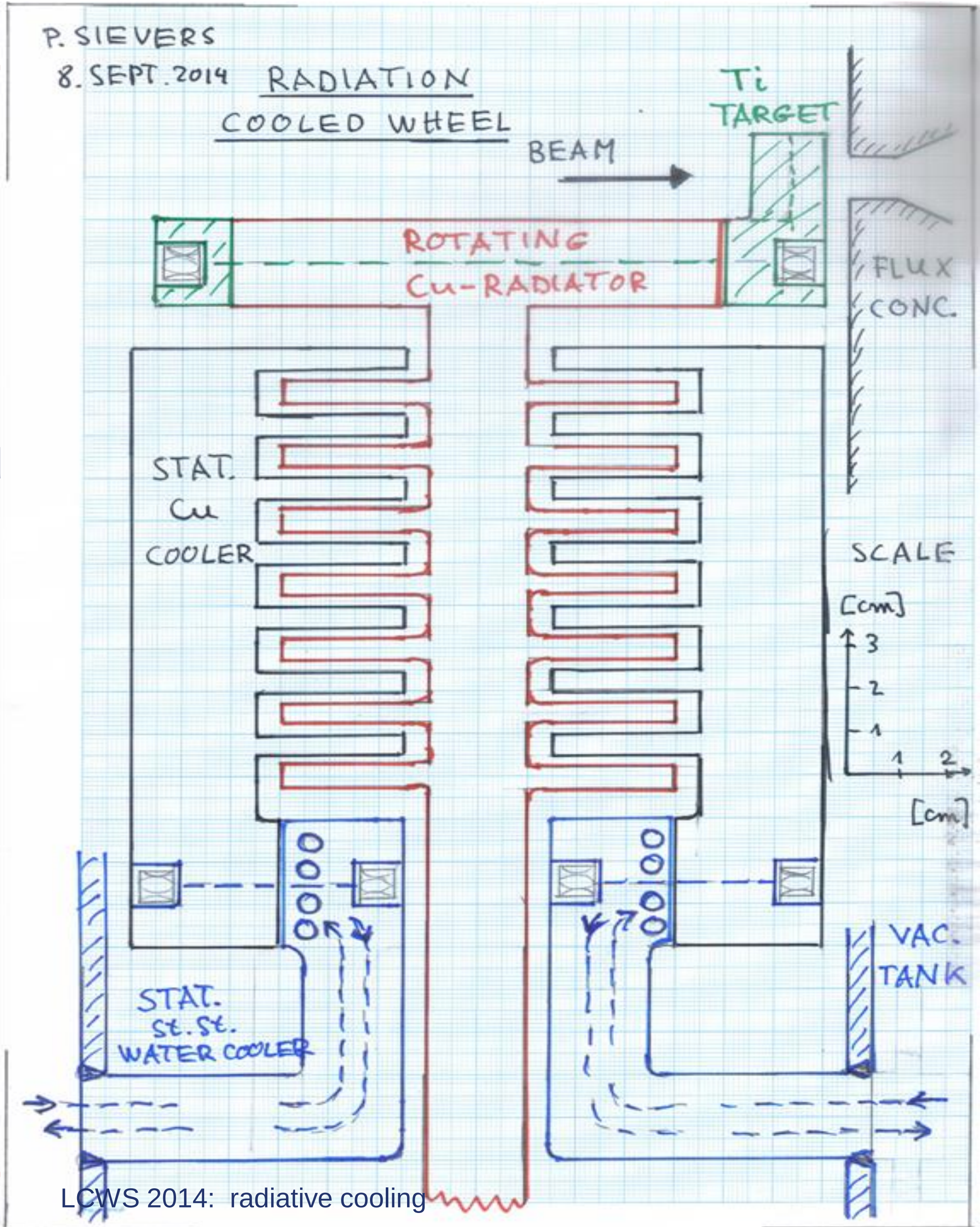
W = 5kW
ε = 0.8
T = 240 C
T_{cool} = 20 C
G = 1

→ We need a surface of A > 1.8m^2

Radiative cooling should be possible

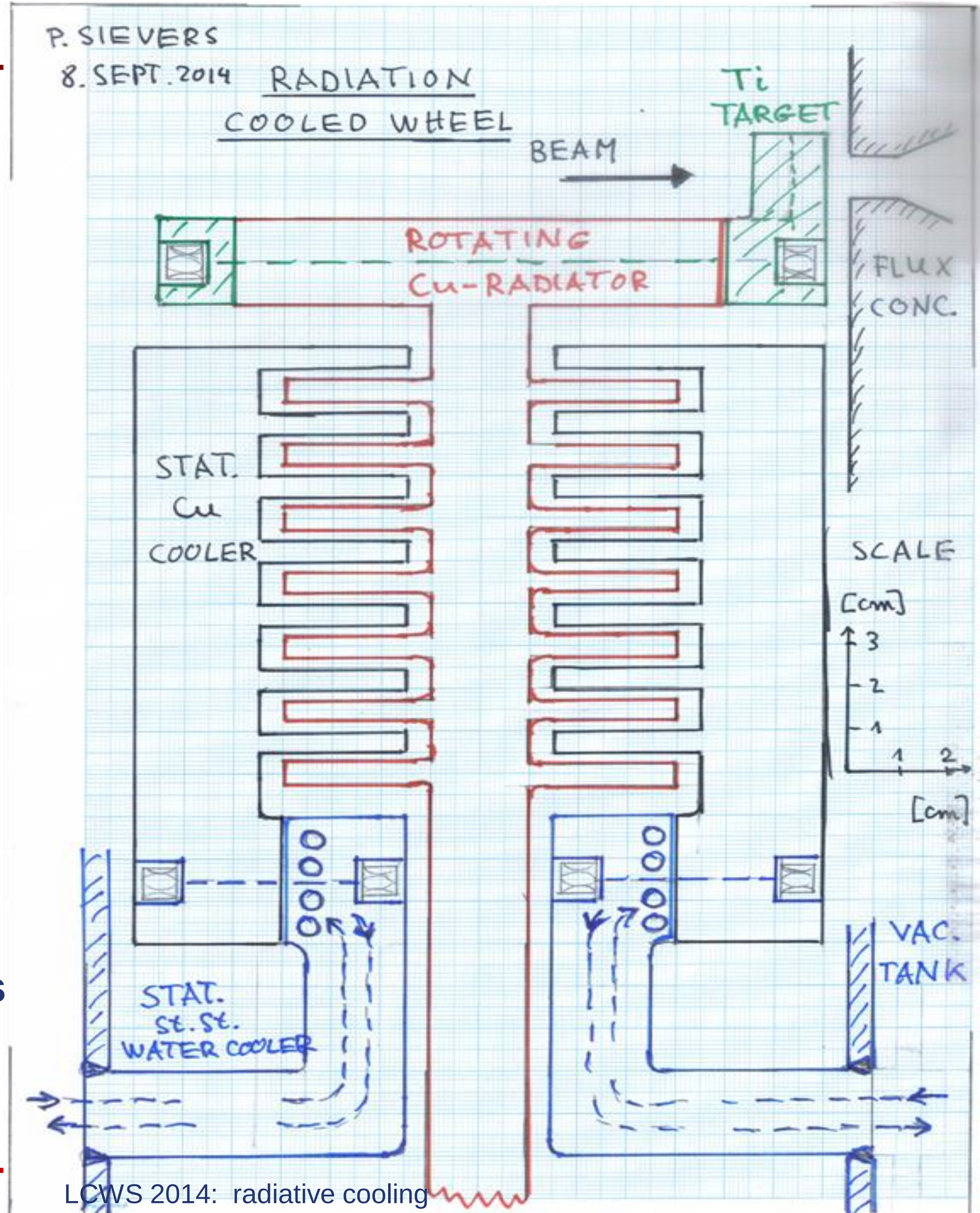
Radiative cooling

- Heat path:
  - **thermal conduction Ti → solid Cu wheel**
  - **radiation Cu wheel → stationary water cooled coolers, placed inside the vacuum**
- Cooling area can be easily increased by additional fins
- thermal contact Ti → Cu is very important
  - **Ti-blocks are clamped by springloaded bolts to Cu wheel → thermal contact, even under cyclic loads of Ti target**



Radiative cooling

- Emissivity
  - **Realistic emissivity**
  - **"corroded" Cu; influence of irradiation on emissivity?**
  - **Coating? (Experience available?)**
- Thermal pulses at rotating radiators are small/negligible
- choice of materials
  - **Cu-alloys (Al-alloys) with high strengths at elevated temperatures are required for the wheel and the radiators**



To be considered in detail

- Average temperature in target and cooling wheel looks ok
- Temperature evolution in the whole system to be considered
- Dynamic temperature distribution at target rim
  - **Temperature ⇔ peak stress values**
  - **can be calculated with existing codes, including radiative cooling**
- Total stress in target rim
  - $\sigma_{static} + \sigma_{dynamic}$
  - **Acceptable limit?**
- Degradation of Ti-target under cyclic thermal load and irradiation must be taken into account
  - **Ti – Cu contact after months of target operation**
  - **Heat transfer coefficient after irradiation**

Mechanical issues

- energy of order 1 MJ is stored in the wheel → Respect safety rules.
- Bearings:
  - **Experience exists over 30 years for the use of magnetic bearings (see Peter Siever's talk at POSIPOL2014)**
  - **Industrial suppliers are SKF/Gemany/Calgary/Canada and KFZ/Juelich/Germany**
  - **Loads above 100 kg with more than 7000 rpm are possible.**
  - **Temperatures of up to 300 oC can be accepted by the bearings.**
  - **Active vibration control of the axis at the magnetic bearings is available**
  - **Thermal barriers should be arranged to prevent heat flowing into the rotation axis.**
- Very precise velocity control is standard

- vacuum
  - **Outgassing must be checked (temperatures ~300 oC) , and if required, differential pumping should be applied**
- monitoring of temperatures
  - **Contactless temperature infrared sensors**
    - Wheel temperature ⇔ sensors placed inside the vacuum close to the rotating wheel
    - Temperature of rotating parts of magnetic bearing and motor
- vibration sensors

Summary

- Radiative cooling is a very promising option
- Scheme will be studied
  - **Ultimate temperature of the target wheel**
  - **Cooling of the chamber**
- Design an experimental mock up in real size which could serve as a systems test of the whole unit.

  → verification of temperature regime and cooling efficiency

  → optimal target + cooling design
- Resources / support

Resources

First estimates (POSIPOL14)

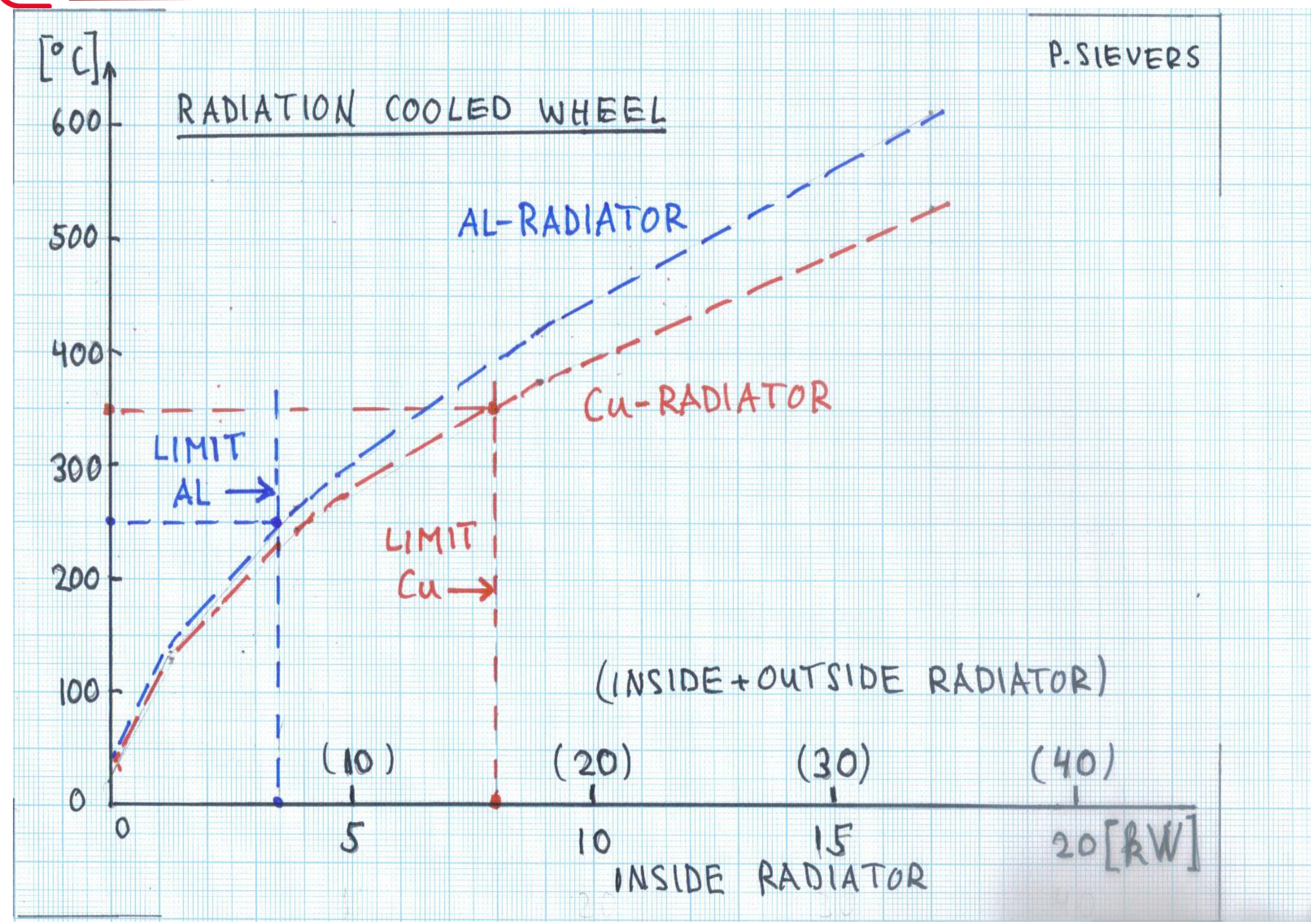
	k€
Vacuum tank, design + manufacture:	170
Wheel design + manufacture	230
Coolers	80
Magn. bearings and motor	170
Instrumentation plus electronics and control	80
Pumps for differential pumping	80
Infrastructure, lab space, safety	70
Dummy run with heaters of rim and water cooling	70
Total	950

Resources (manpower)

Estimate at POSIPOL 2014

	FTE
Initial performance studies (ANSYS, modelling,...)	0.5
Physicist, engineers, designers	3.0
Technicians for assembly, commissioning and test	2.0
total	5.5

backup



P. SIEVERS
RADIATION COOLED WHEEL
[°C]
600
500
400
300
200
100
0
AL-RADIATOR
Cu-RADIATOR
LIMIT
AL
LIMIT
Cu
(INSIDE + OUTSIDE RADIATOR)
(10)
(20)
(30)
(40)
0
5
10
15
20 [kW]
INSIDE RADIATOR

5 kW. 0.4 X_0 Ti Rim + Cu Disk

Target Dimensions:

R = 50 cm

d = **1.48 cm**

w = 3.0 cm

$\epsilon_{Ti} = 0.25$

$\epsilon_{Cu} = 0.9$

P = **5170 W**

T_{max} = **353 °C**

T_{min} = 227 °C

Temperature Distribution