Studies of the SPS internal dump (TIDVG) for current and future proton beams

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Outline

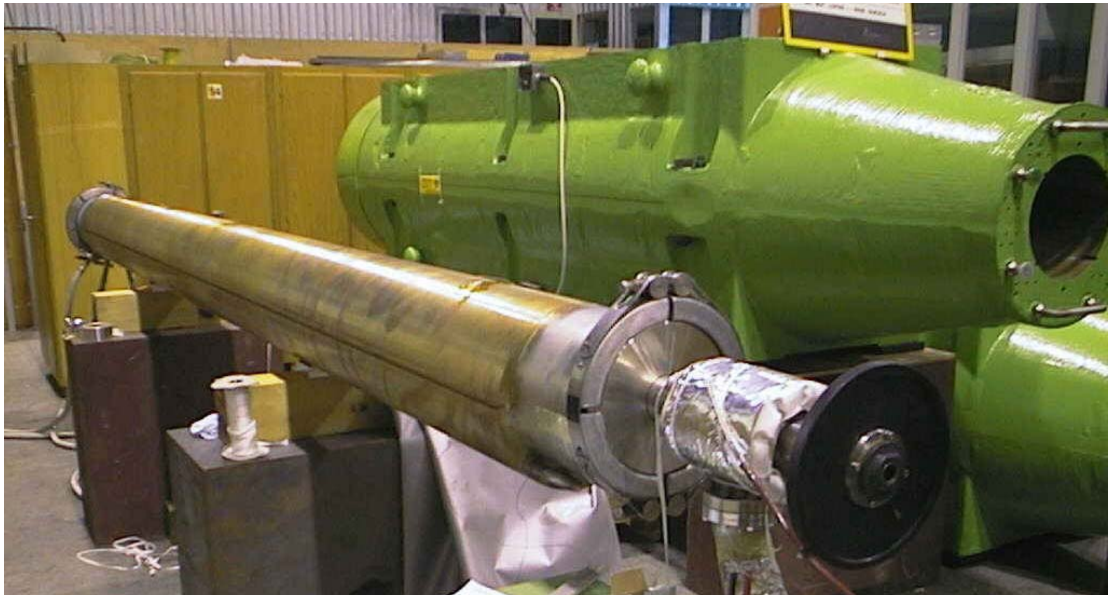
- **A brief overview – The TIDVG & previous study**
- Vacuum outgassing problems during operation
- Performance with current proton beams
- Performance with PS2 beams
- A slightly modified design
- Conclusion and different scenarios

Previous study

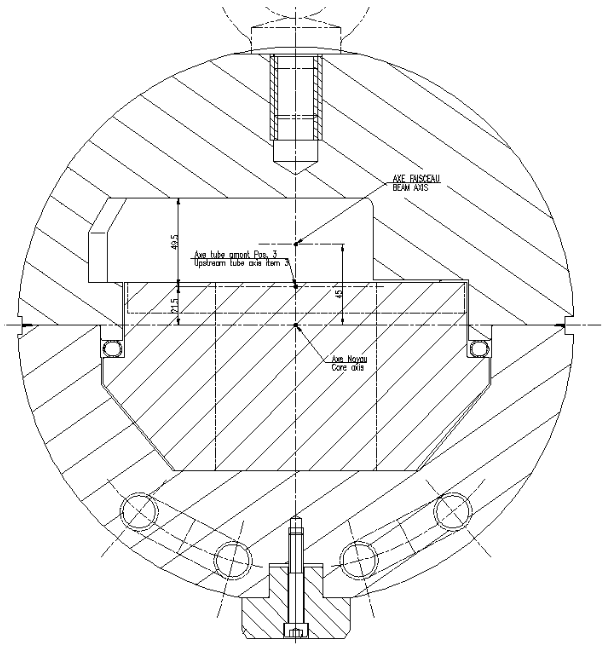
- Conducted by Mattias Genbrugge and presented to SPSU in 2008 by Yacine Kadi
  - Researching the history of the present dump design
  - Exploring causes of the outgassing issue
- This presentation
  - will follow up on the outgassing issue
  - will present the operation limits of the dump (current + PS2 beams)

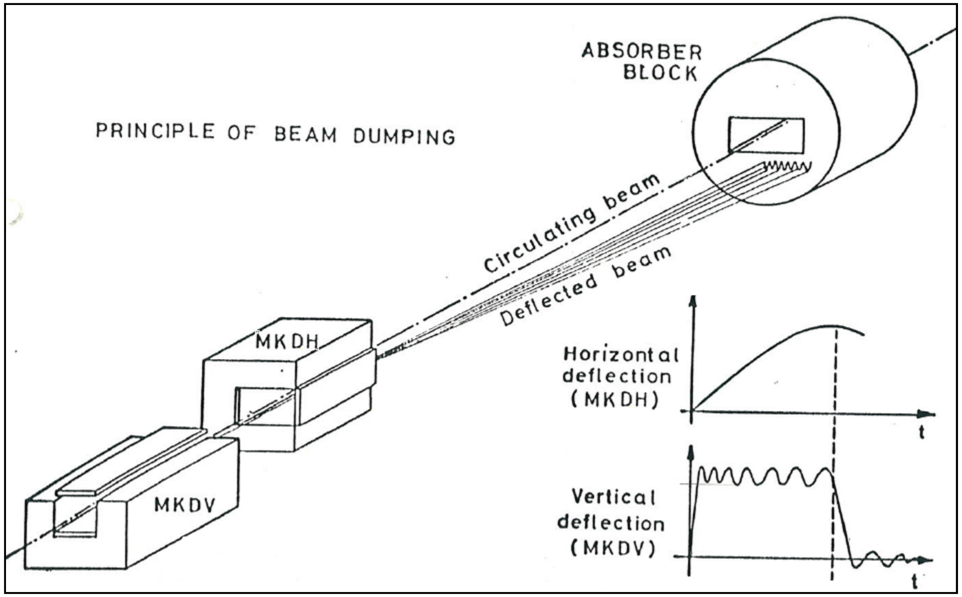
The TIDVG

- The Target Internal Dump Vertical Graphite
  - For energies from 105 to 450 GeV
  - Located in LSS1
  - About 5m long; Core diameter 0.3 meters
  - Installed in cast iron shielding



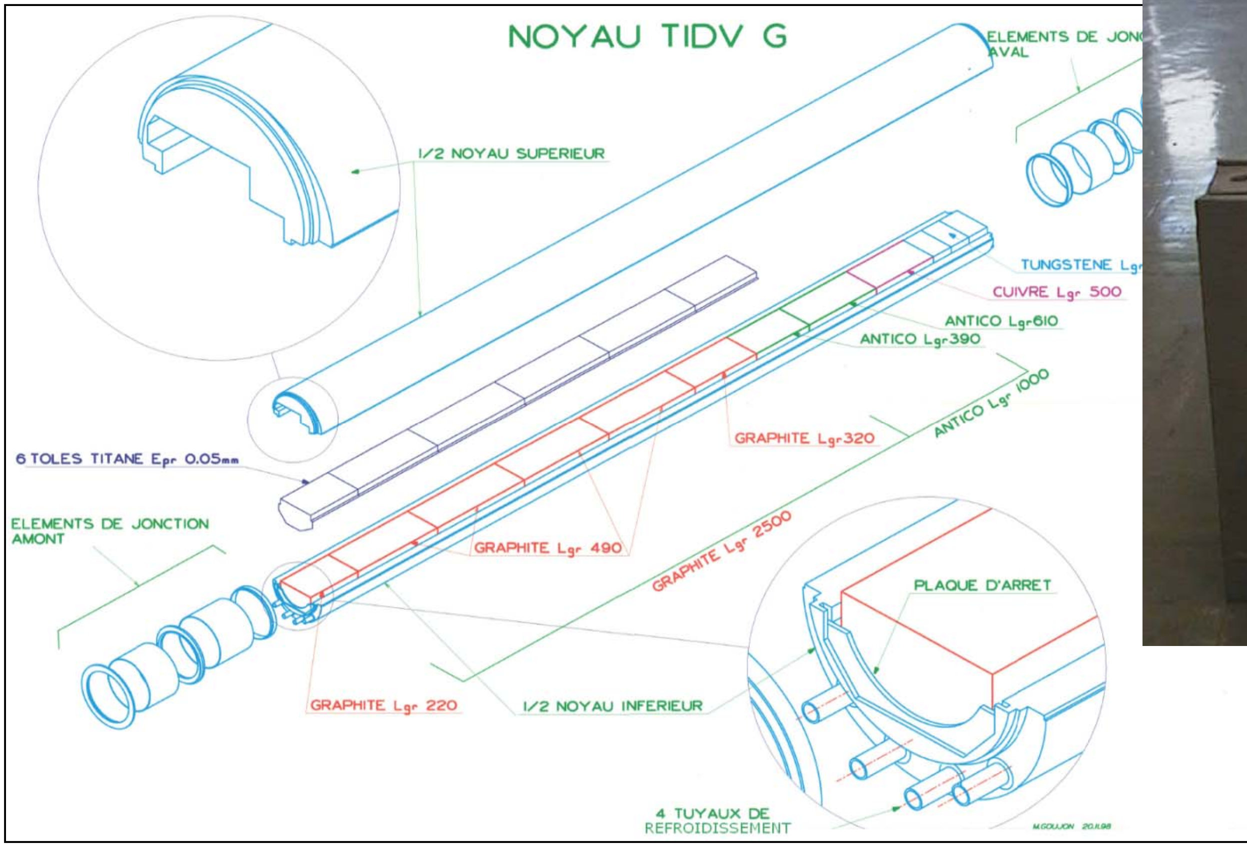
The TIDVG design





•An internal beam dump

The TIDVG design



2.5m Graphite
1m Antico
0.5m copper
0.3m Tungsten

<u>Graphite blocks:</u>
Titanium coating +
Titanium foil

The TIDVG History

- Three Dumps Produced
  - Dump #1 installed in 1999/2000
  - Foil got Damaged and was blocking the aperture
  - Dump #2 was modified (better coating – no foil)
  - Dump #1 replaced by #2 in 2006/2007

  - Dump #3 was not modified (not ready as spare at the moment)
  - Dump #1 Out of order – In Storage (radioactive)

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As presented by Yacine in 2008 (slide by Mattias)

II. Operational Problems

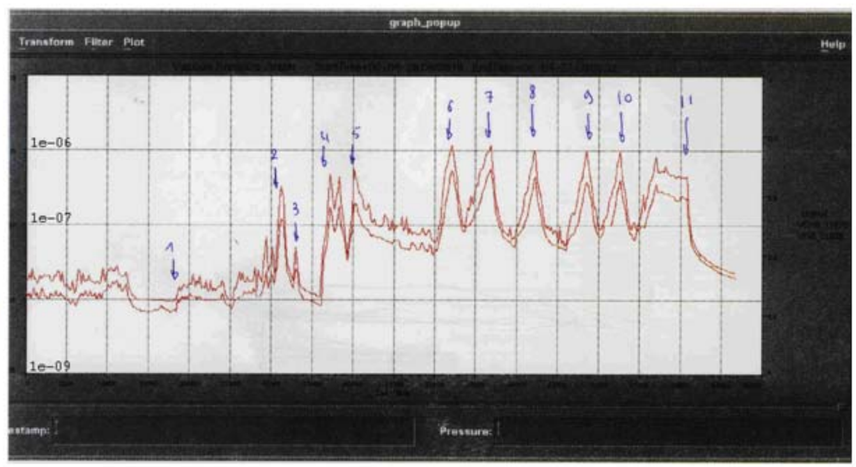
After commissioning in March 2000:

- Pressure peaks from the moment the beam was dumped.

(Repetitive dumping of $9 \, . \, 10^{12}$ protons per cycle at 440 GeV.)

Consequence:

=> Shutdown of the beam due to pressure interlock system.



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Possible causes (as presented in 2008)

- Outgassing originating from: Tungsten or Graphite blocks (Antico and copper are solid metals)
- Outgassing is driven by
  - Temperature
  - Internal concentration of pollutants

- Pressure rise due to e-clouds (presented with a **?**)
  - “No proof! Only hints:”
  - “It is inconclusive until now, but it seems not very likely.”

Looking for the cause of the outgassing

- Significant steps during production and installation of the Dump:
  - Vacuum firing of the graphite (1000°C for 1h) before assembly & welding
  - Bakeout with pressurized water @ 150°C
    - After complete assembly & welding (on surface)
    - After installation (in the tunnel)

Looking for the cause of the outgassing

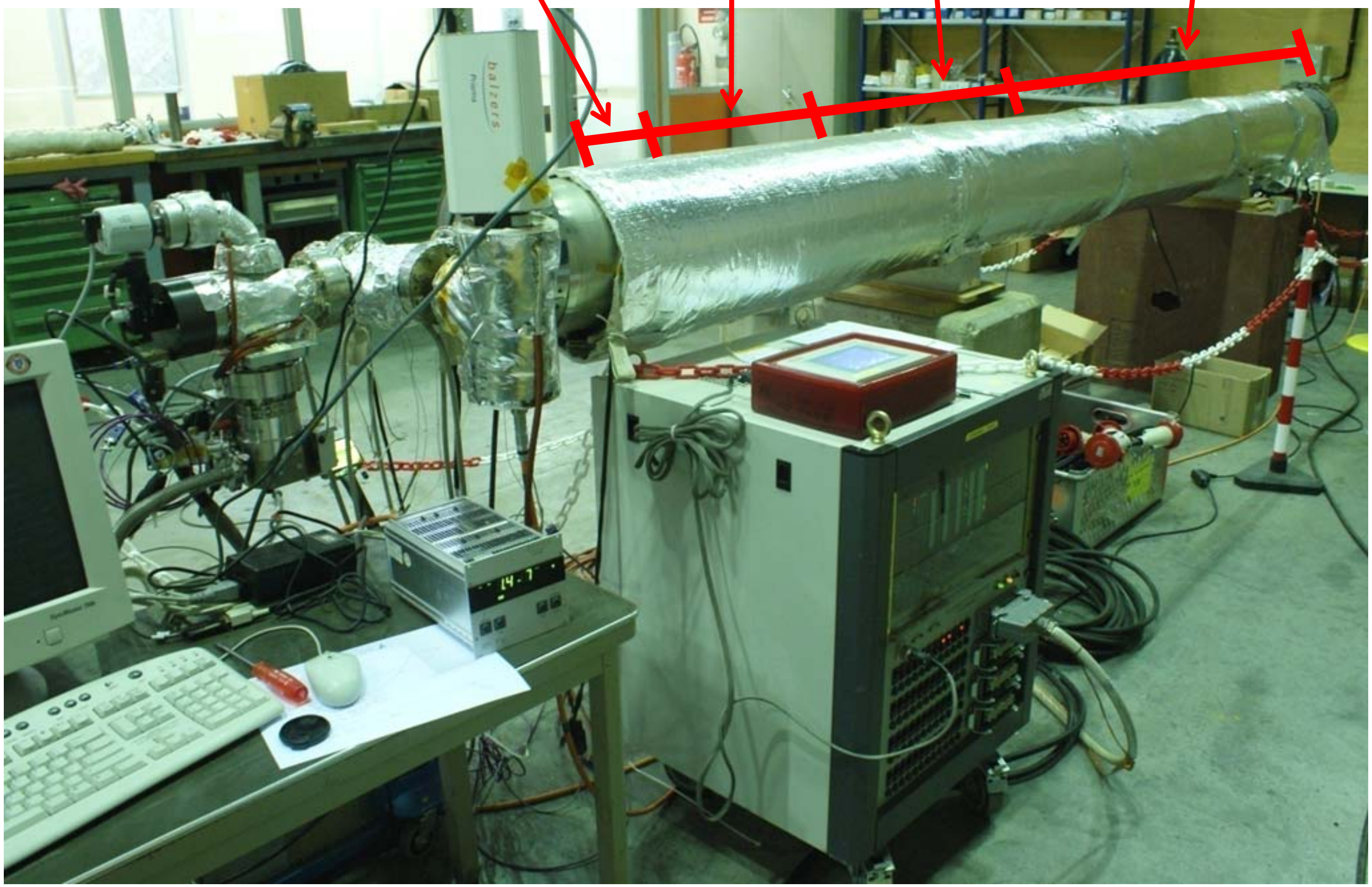
- **Significant observations and actions after installation**
- Dump #1 got conditioned in-situ with beam scraping during MDs
  - Rising the temperature of the Dump and causing the outgassing on purpose (beam scraping)
  - The outgassing rate of the dump got less over time
  - Every dump-cycle is improving the dump (less outgassing)
- After installation of Dump #2 the outgassing during dumps was again high.
  - Dump #2 now in use for ~2 years

Looking for the cause of the outgassing

- Performing a bakeout test in the lab to answer the questions:
  - Is the current bakeout temperature sufficient?
  - How big is the outgassing due to high temperatures?
    - Outgassing of water and/or hydrocarbons?
    - Which material (Graphite or Tungsten) is the origin?

Tests performed with support from TS/VSC for setting up the vacuum & bakeout equipment.

Bakeout test on Dump #3

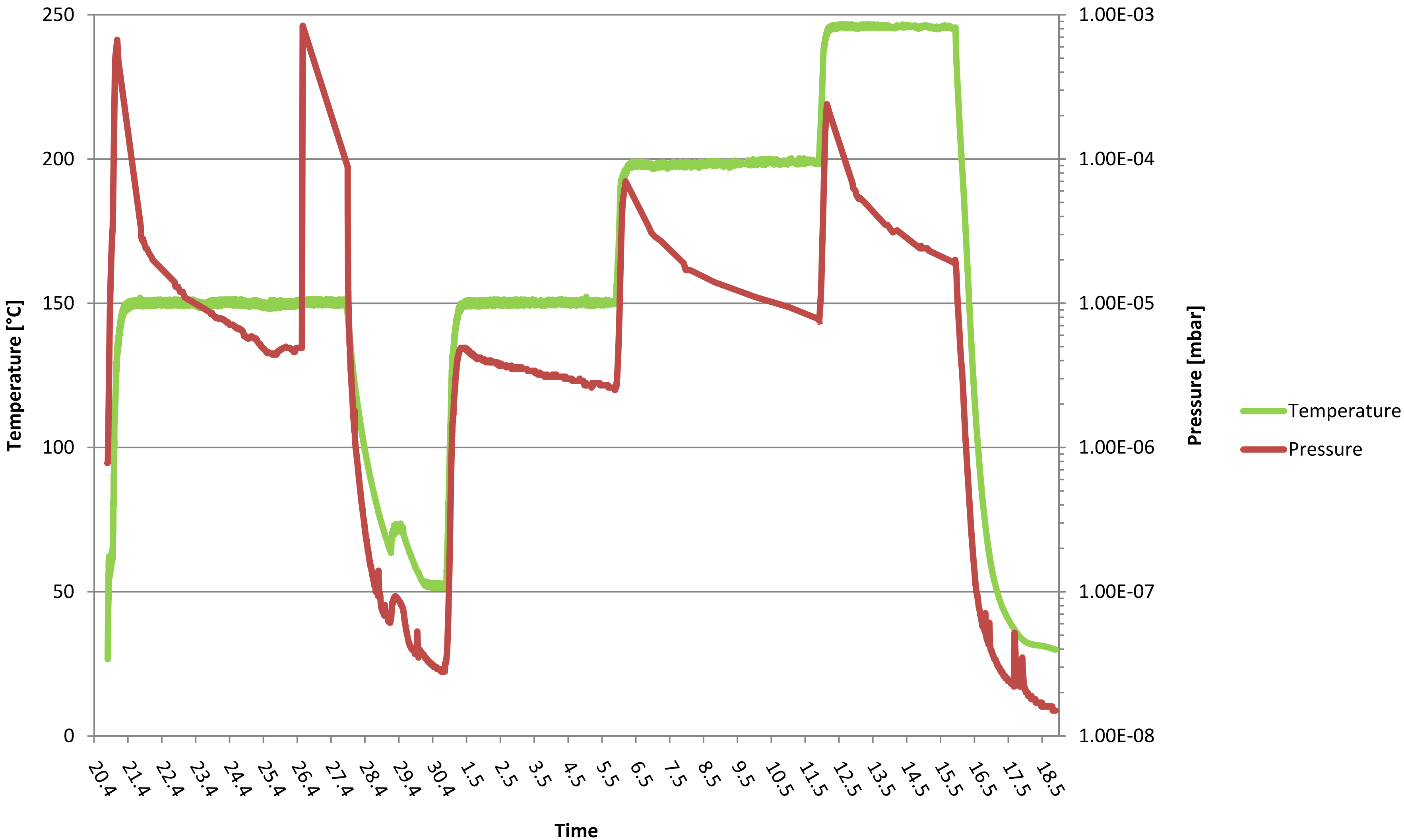


Recording:
- Pressure
- Gas composition
- Temperature (in the vacuum directly on the blocks)

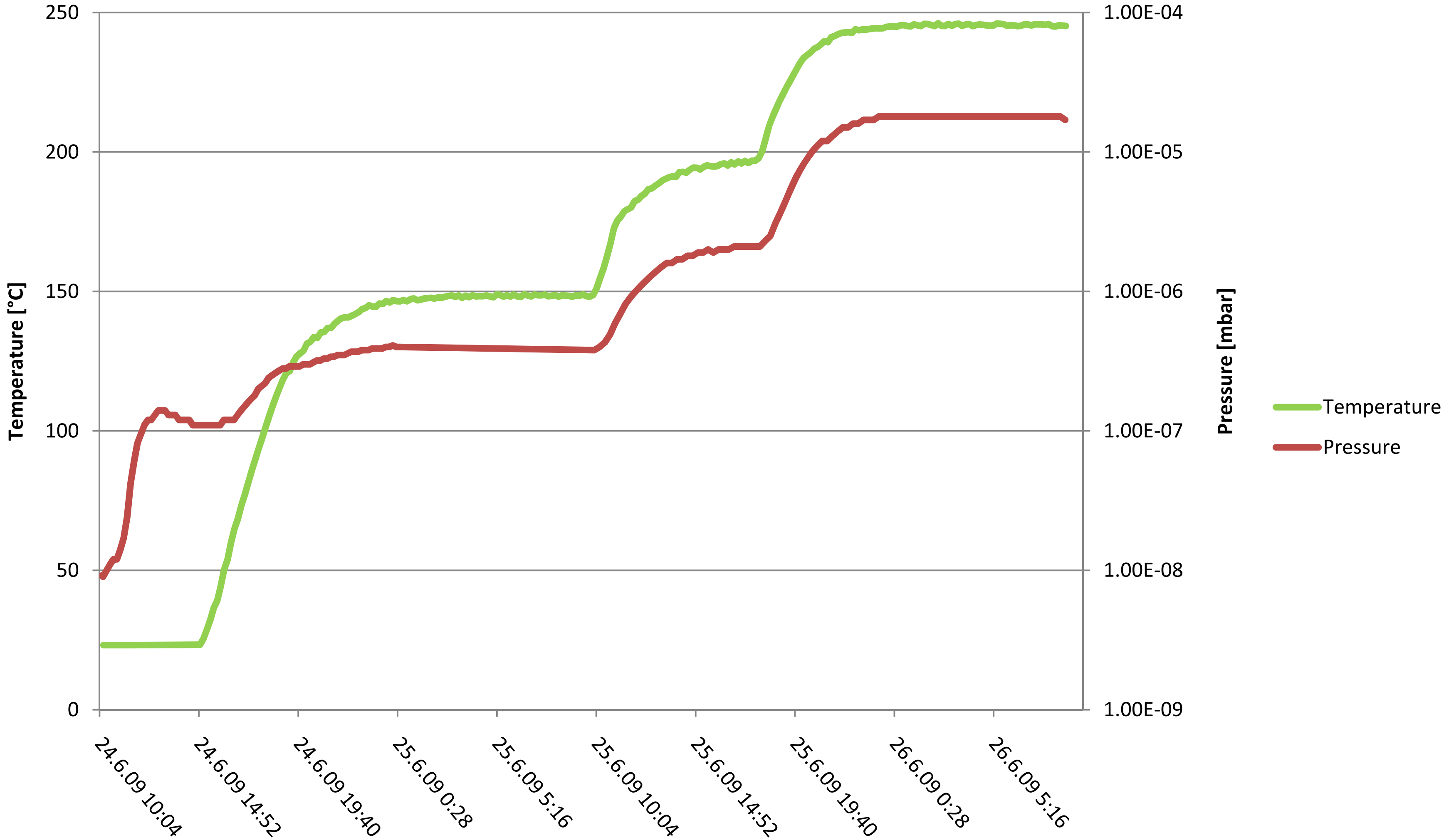
Bakeout test on Dump #3

- Initial conditions:
  - Dump was stored under gas atmosphere (like a proper spare, although not ready to use as spare yet)
  - Dump got opened up and exposed to atmosphere for several months to get a full absorption of water

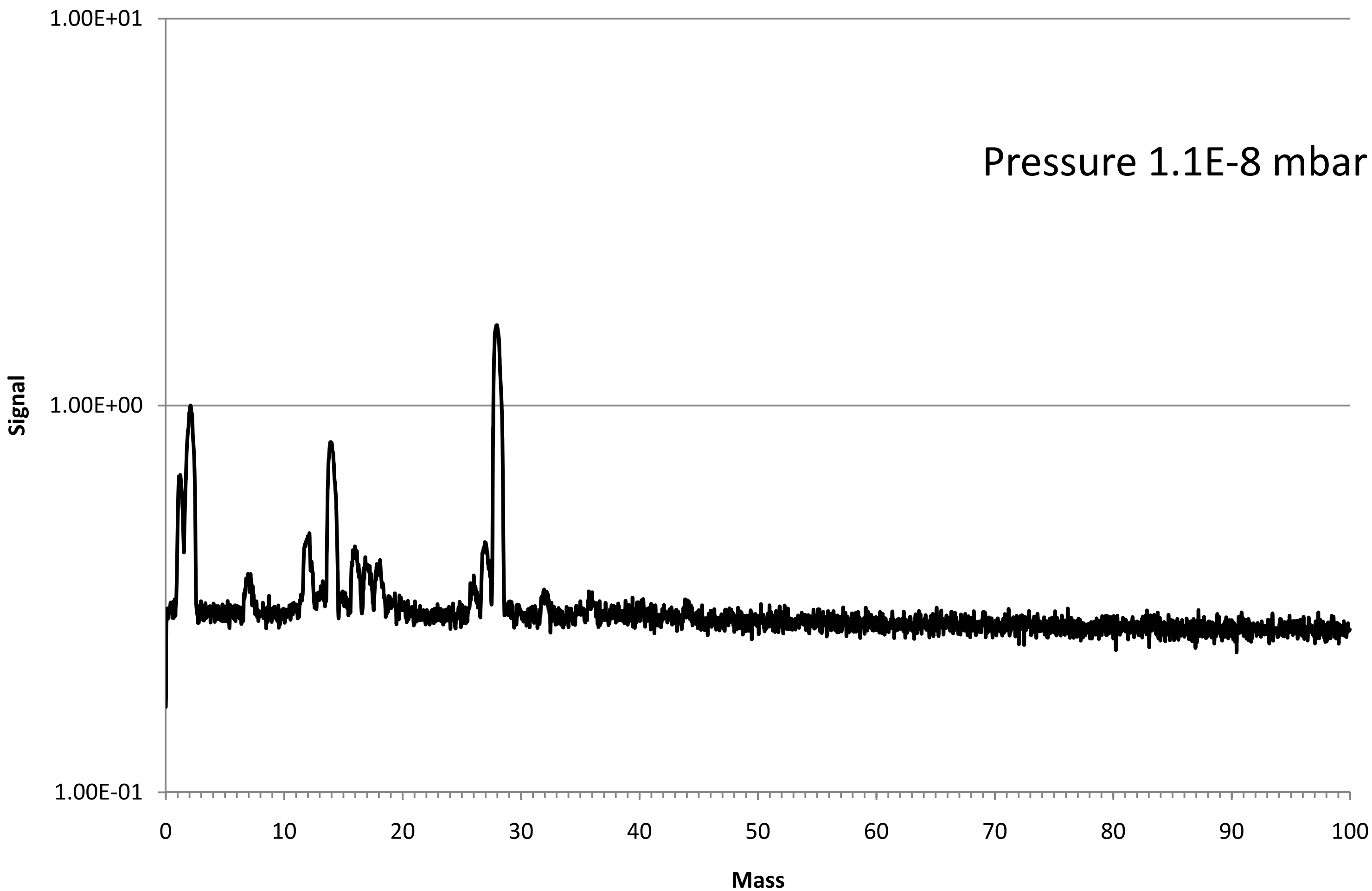
1st long Bakeout cycle



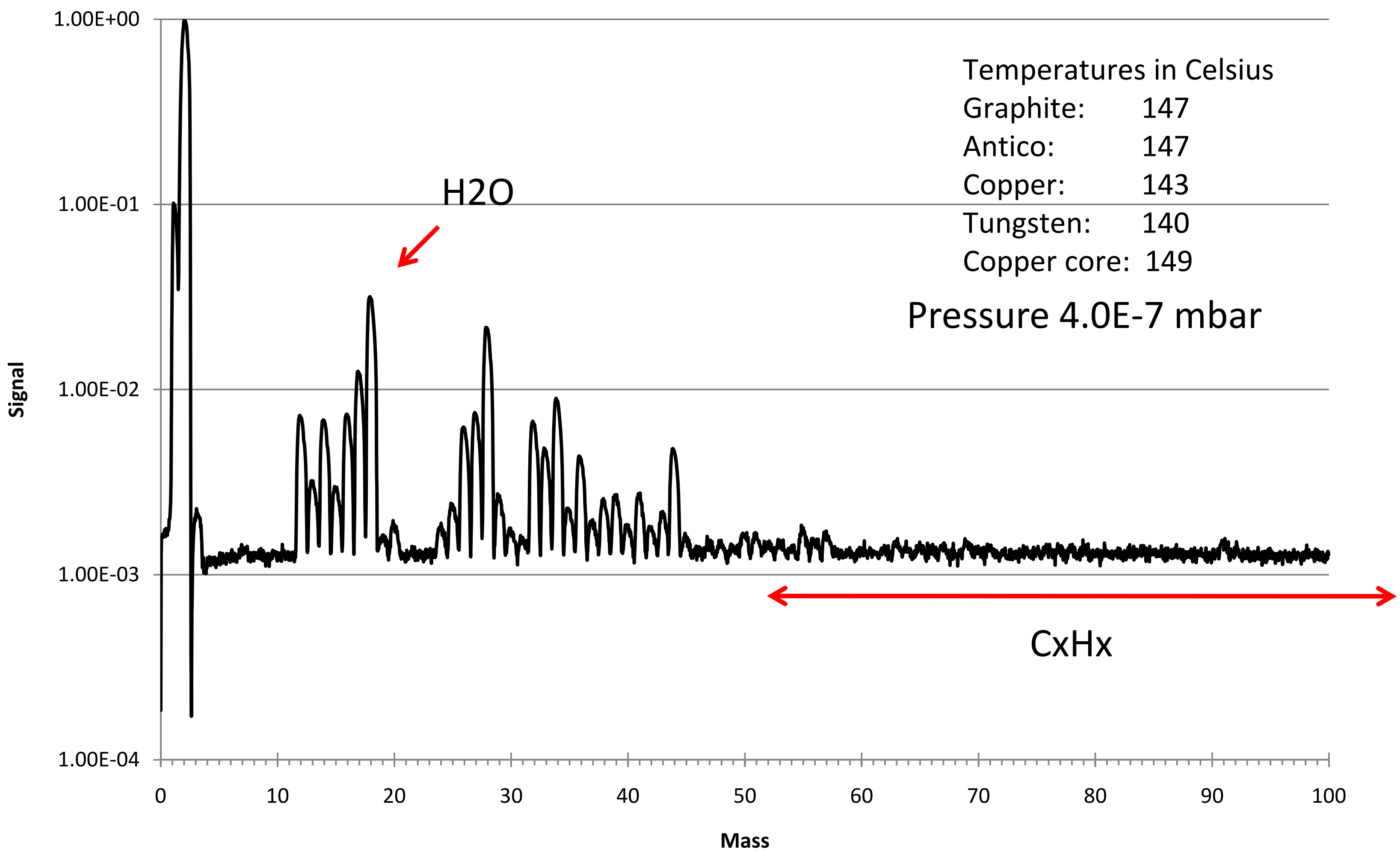
2nd full cycle to get comparative measurements



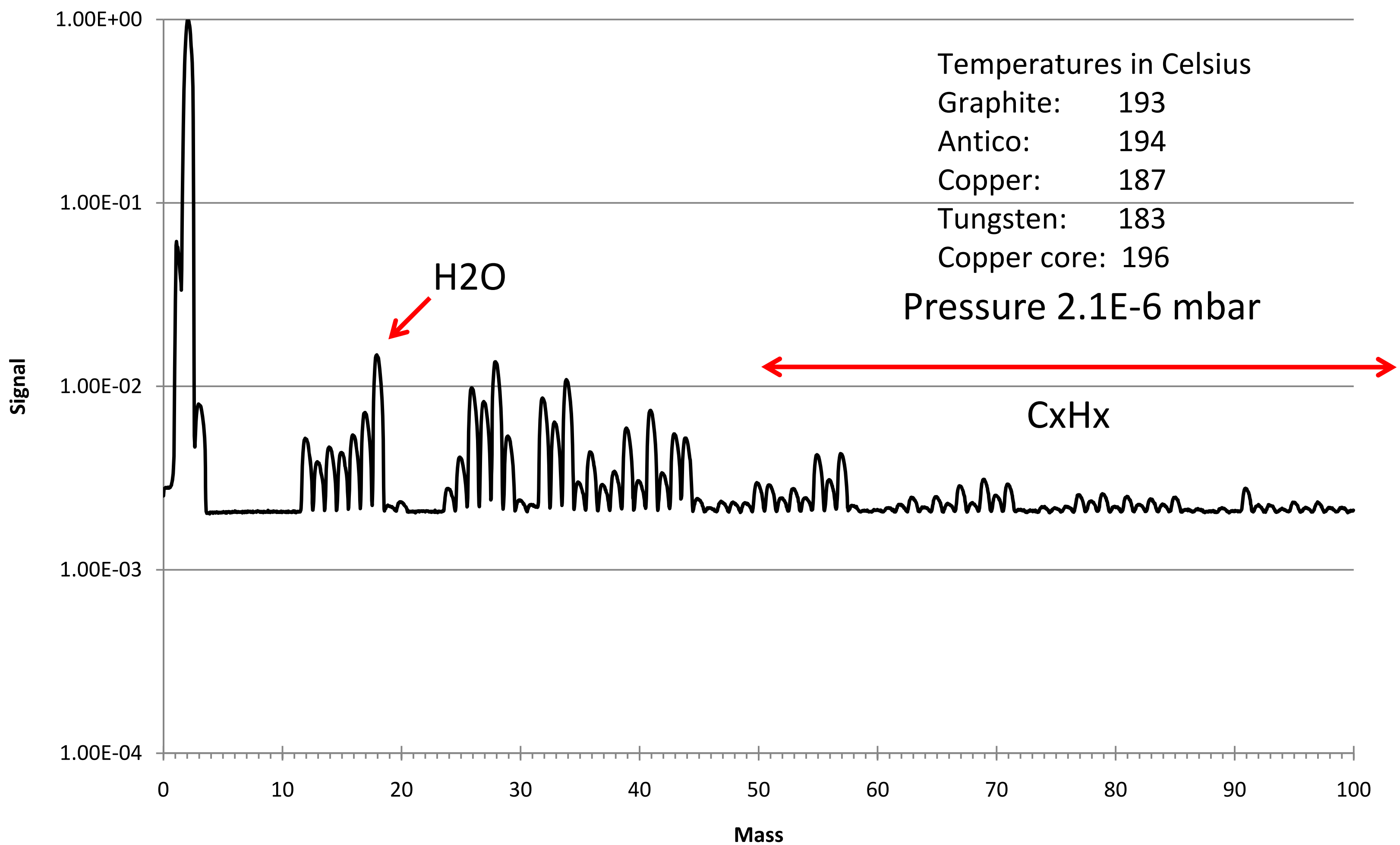
Spectrum at RT between 1st and 2nd cycle



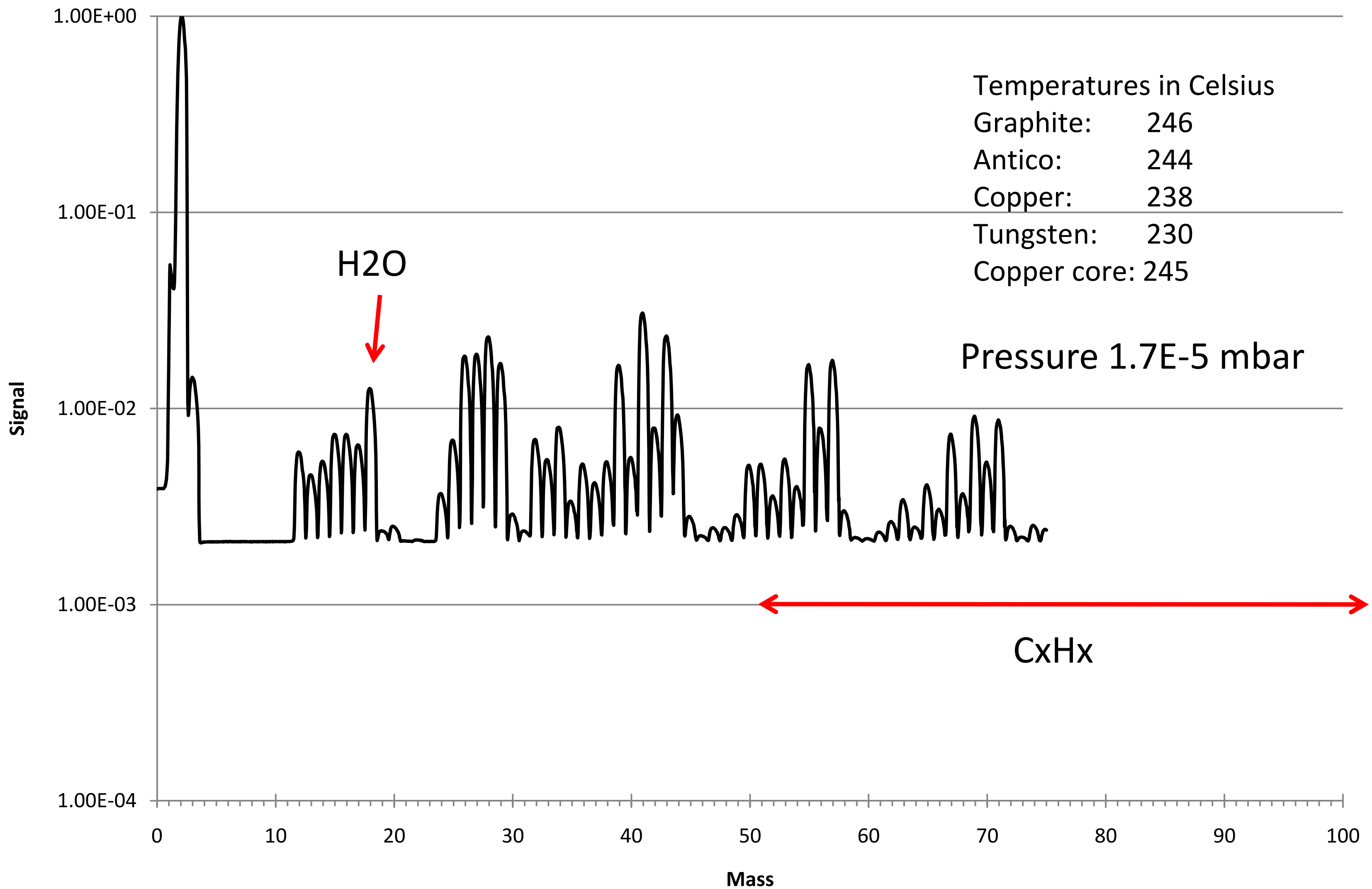
RGA spectrum @ 150°C



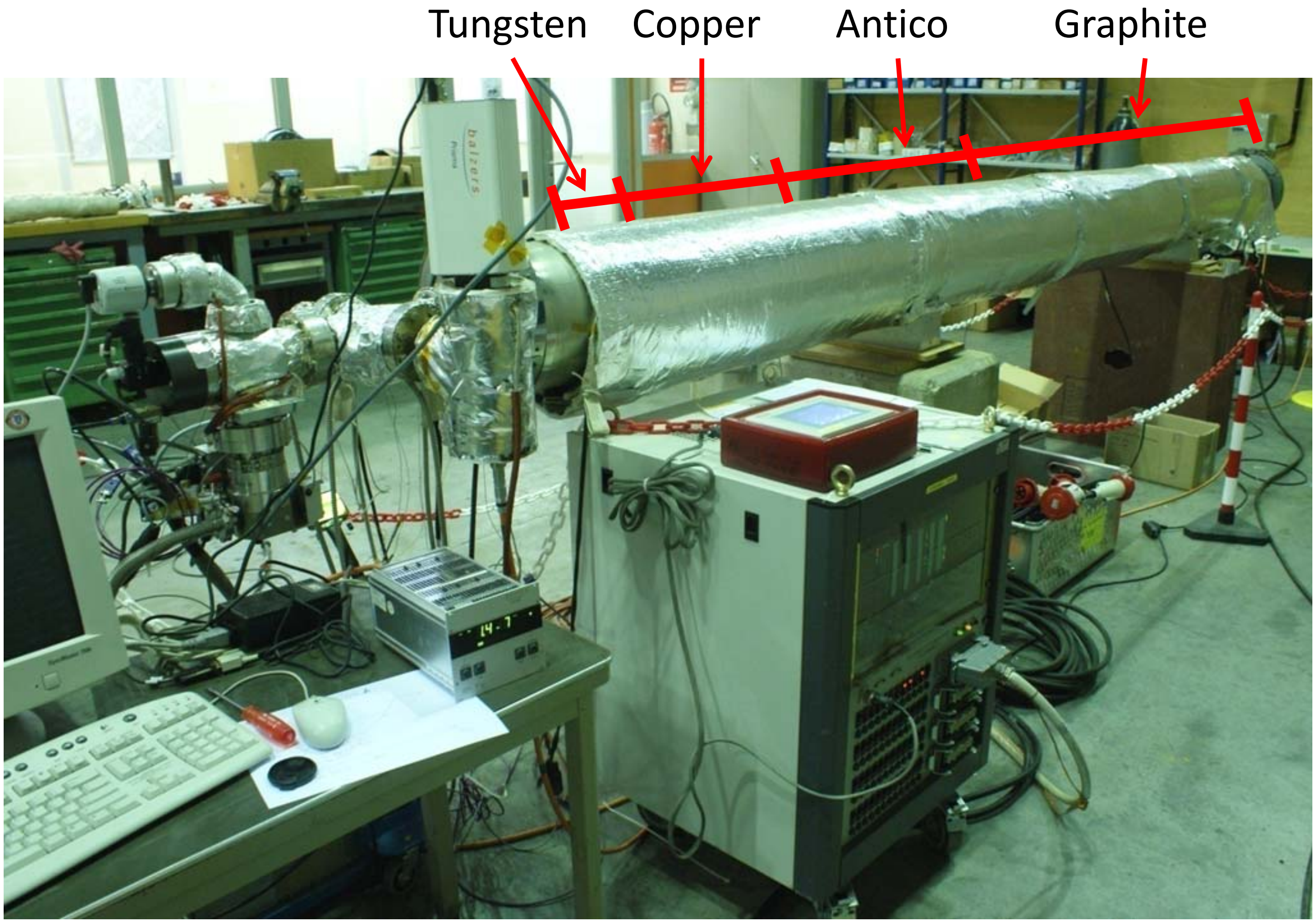
RGA spectrum @ 200°C



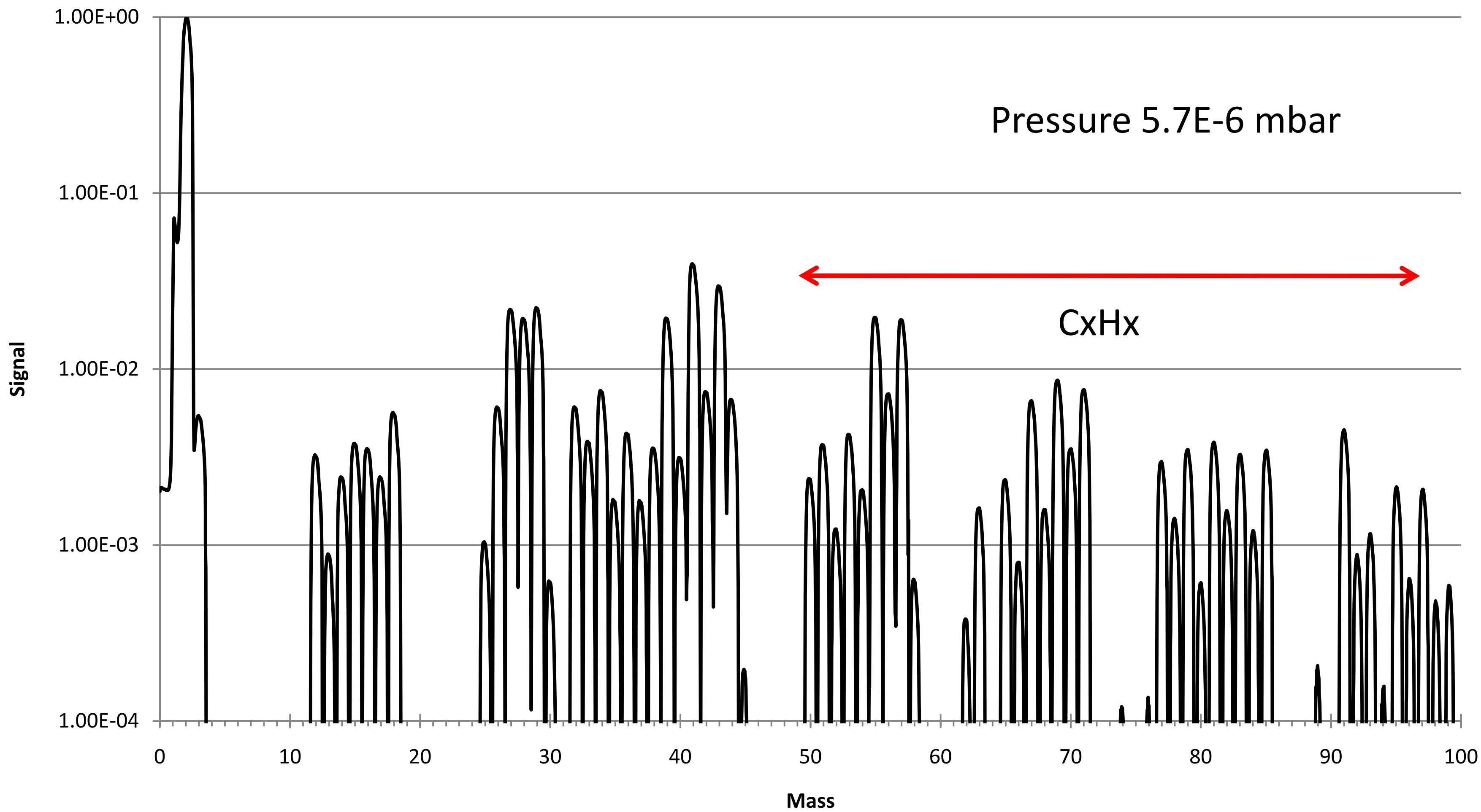
RGA spectrum @ 250°C



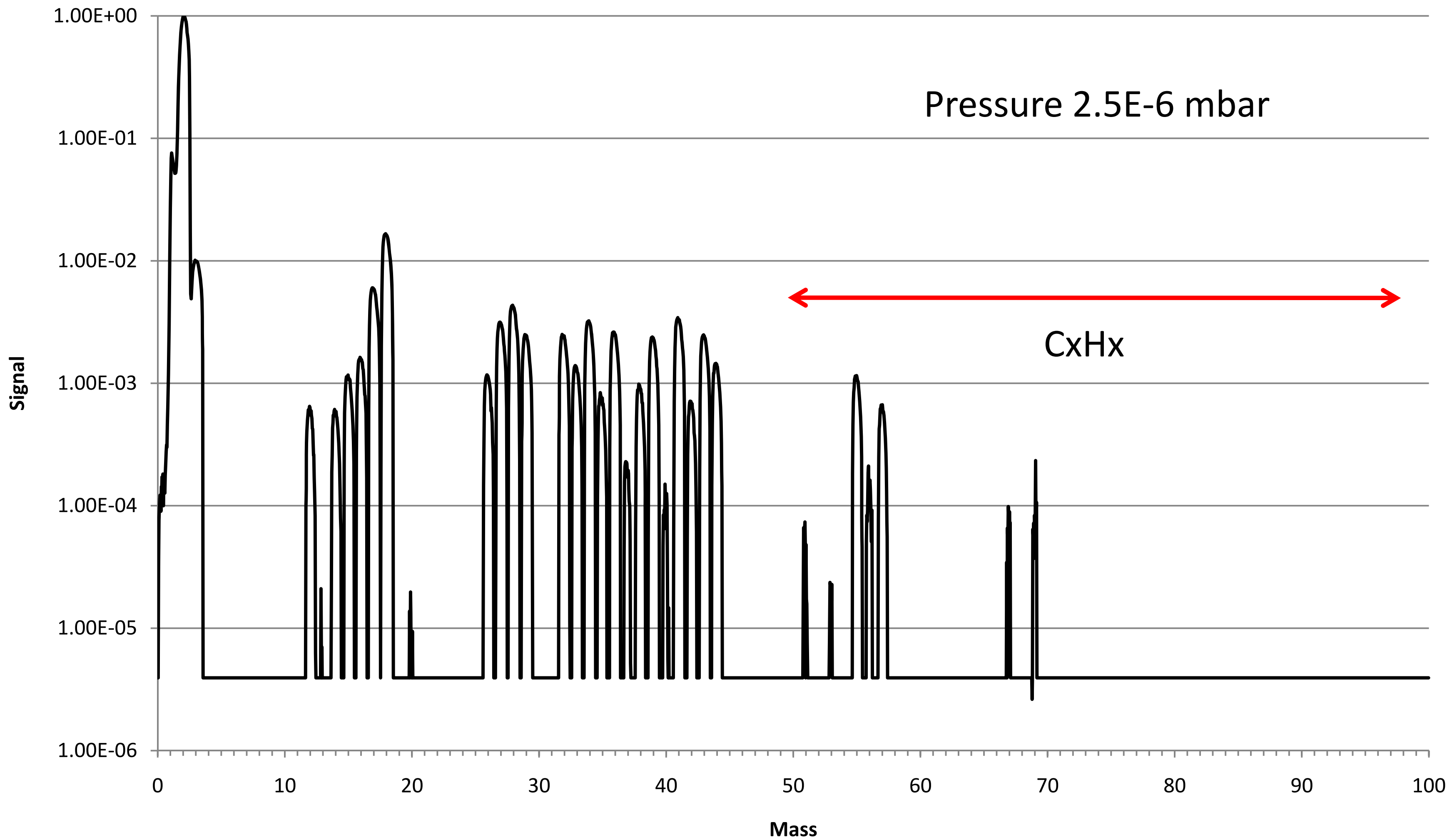
Selective heating of graphite and tungsten



RGA spectrum with graphite @ 250°C; rest @ 150°C



RGA spectrum with Tungsten @ 230°C; rest @ 150°C



Conclusion – Outgassing issue

- Graphite still shows a lot of outgassing after vacuum firing before assembly, and an intense bake out (25 days at 150°C+)
- The present hydrocarbons indicates that the vacuum firing done before assembly was not sufficient!
- Hydrocarbons can not be removed by baking out the graphite in the dump (temperature limitation of the copper core)
- Tungsten seems to be clean from hydrocarbons
- Still a lot of water outgassing present at high temperatures
  - Required time for a water bake out needs to be determined
  - Tests on diffusion coefficient of water in Graphite currently being prepared by TE/VCS Giovanna Vandoni & Florent Bouvier
- Current bakeout @ 150°C is sufficient for water

Proposed actions for dump #3

- Assuring a low outgassing rate of the graphite at high temperatures before assembling the Dump (testing !)
  - When modifying dump #3 cleaning the Graphite blocks with an long vacuum firing (1000°C+ for many hours!) to reduce hydrocarbons
- long bakeout for removing the water (on surface)
- Keep contact with atmosphere as short as possible!
  - Isolating valves for the dump?

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Previous simulations conducted by Mattias Gebrugge

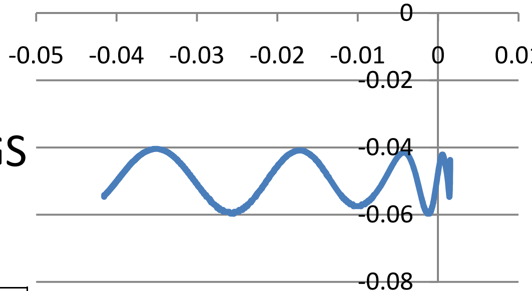
- The goal was to determine the temperature in the materials after a few consecutive dumps
- This information was used to assess if the bakeout temperature (150°C) is sufficient

- The new studies are to determine the limits of the dump during operation!

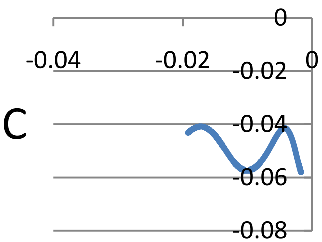
Determining the performance of the TIDVG

- 3D thermal simulation in ANSYS
- Energy deposition in FLUKA (supplied by Roberto Rocca)
- Beam characteristics & dumping patterns

CNGS



LHC

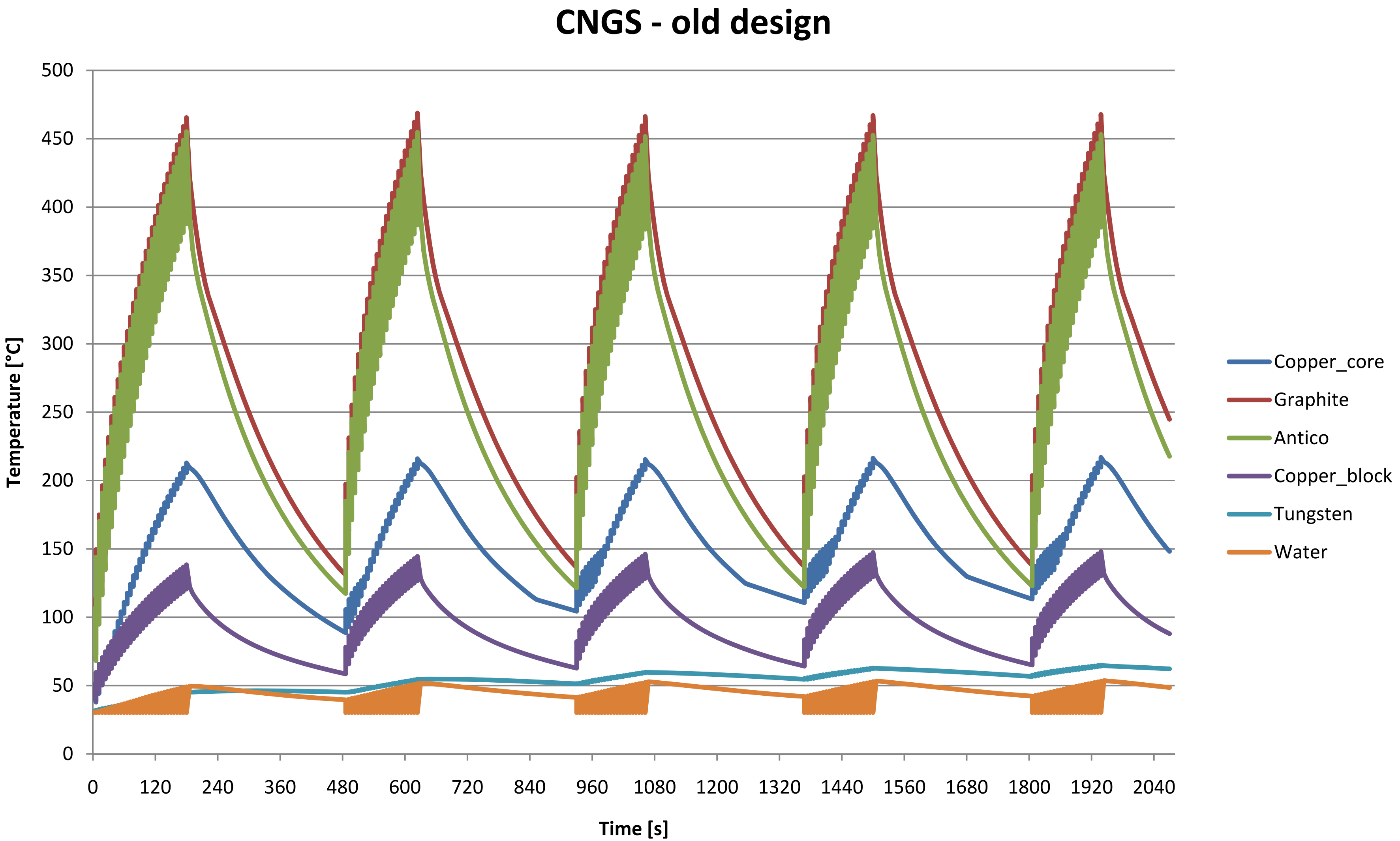


	LHC ultimate	CNGS	PS2_LHC	PS2_CNGS
Total intensity	4.90E+13	4.80E+13	7.00E+13	1.20E+14
Energy [GeV]	450	400	450	400
Repetition time [sec]	21.8	6	4.8	4.8

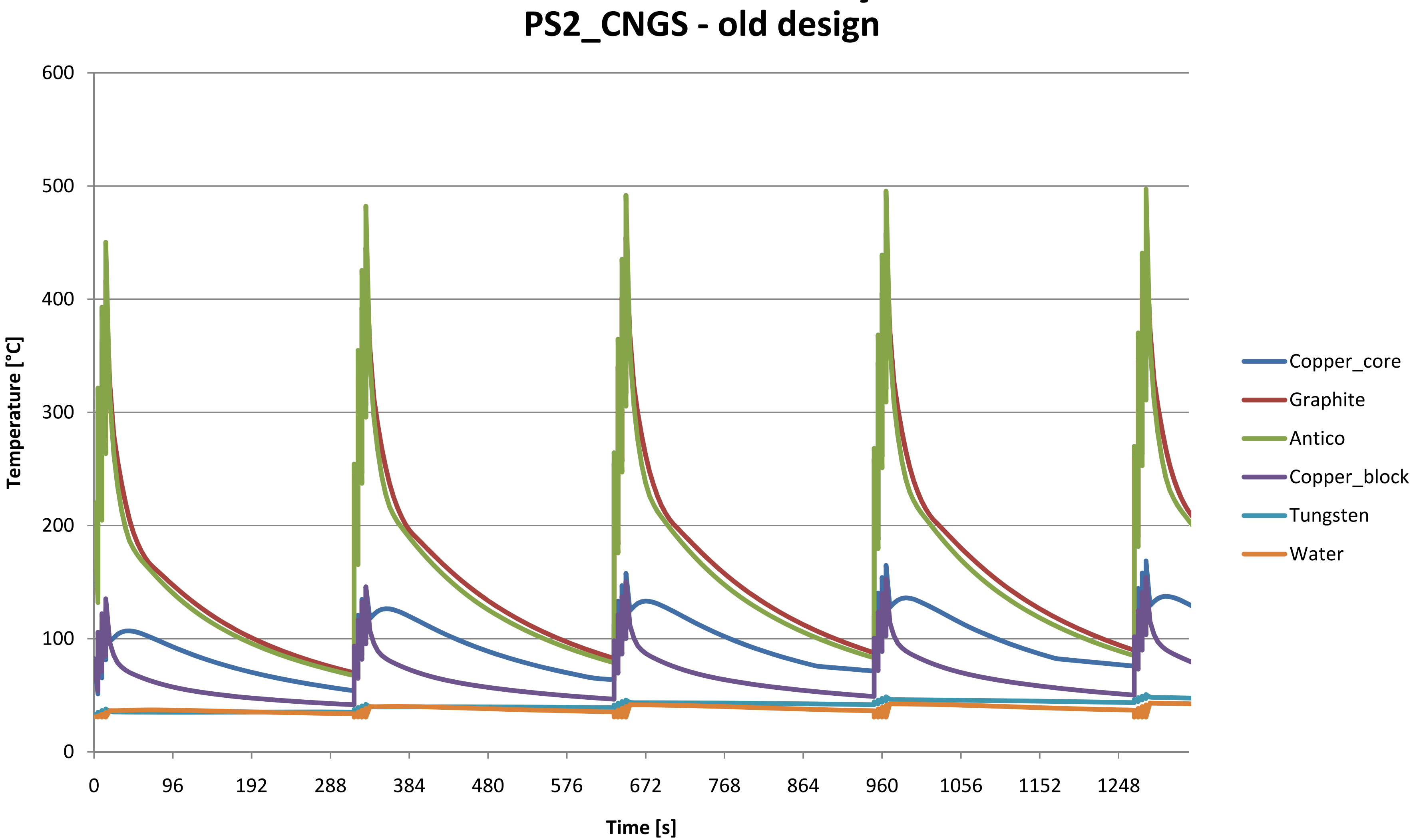
Simulations

- 4 extreme scenarios
  - Continuous CNGS-Beam dumping
  - Continuous LHC-Beam dumping
  - Continuous PS2_CNGS-Beam dumping
  - Continuous PS2_LHC-Beam dumping
  - **Each one followed by 5 minutes cooling**
- Comparison of maximum protons/second to reach steady state
- **Limit:** Temperature of the Antico (aluminum) should not exceed 450°C!

Continuous CNGS-Beam dumping maximum 23 cycles



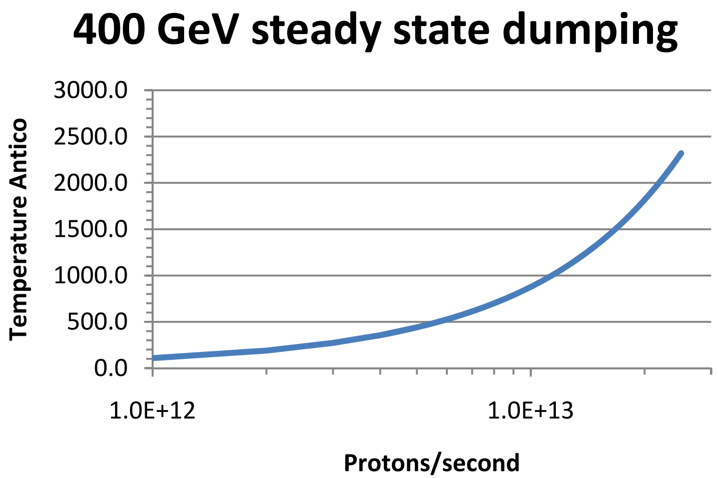
Continuous PS2_CNGS-Beam dumping maximum 3 cycles

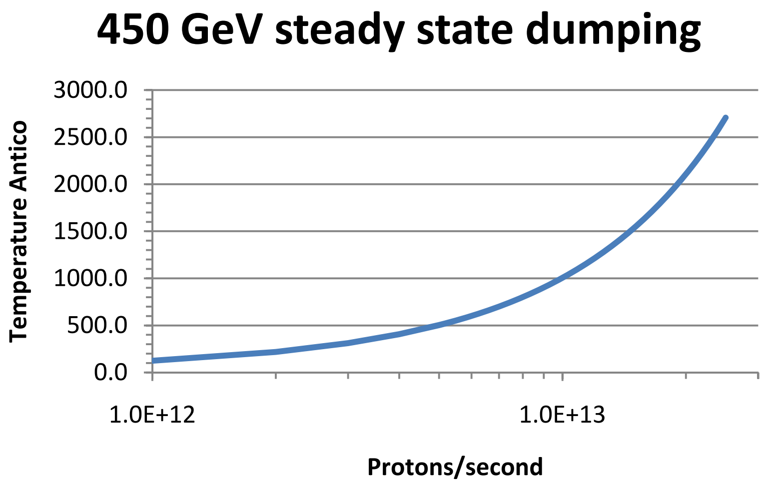


Limits for dumping

	Number of cycles followed by 5 minutes of cooling	
Beam	**Present design**	
CNGS	23	
LHC	steady state	
PS2_CNGS	3	
PS2_LHC	4	

	Maximum Protons/Second to reach steady state	
Beam	**Present design**	
CNGS (400GeV)	4.51E+12	
LHC (450 GeV)	3.93E+12	





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Dump #3 modifications

- Possible modifications that can be done with a reasonable effort when modifying dump #3 to get it ready as spare.
  - Changing composition to:
    - 270cm Graphite (+20)
    - 80 cm Antico (-20)
    - 50cm Copper
    - 30 cm Tungsten

Drawback:
Loss in cleaning efficiency

Particle flux at the end of the dump
Neutrons: +8%
Photons: +11%
Charged particles: +10%

But, currently the dump (not including the shielding) absorbs only 155 GeV/p.

Possible improvements

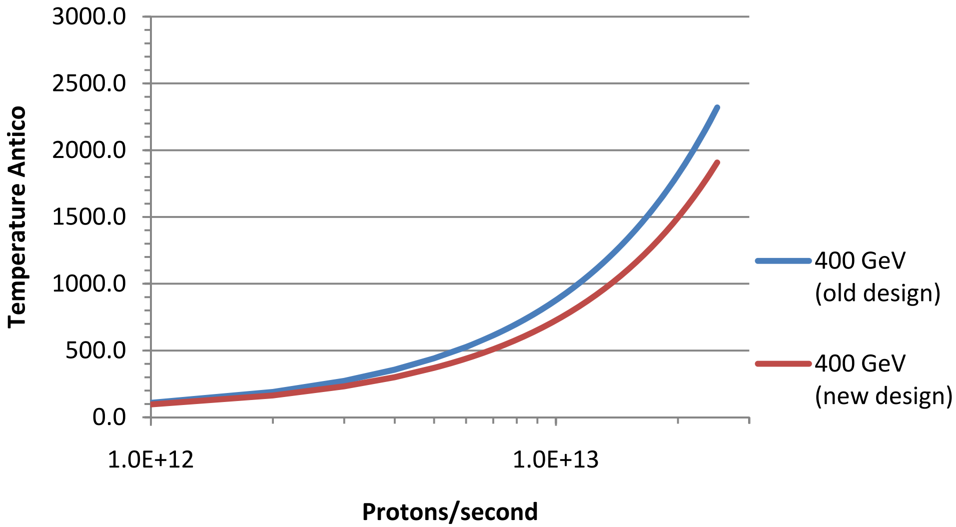
	Number of cycles followed by 5 minutes of cooling		
Beam	**Present design**	**Modification**	**gain**
CNGS	23	38	165.2%
LHC	steady state	steady state	-
PS2_CNGS	3	4	133.3%
PS2_LHC	4	6	150.0%

	Maximum Protons/Second to reach steady state		
Beam	**Present design**	**Modification**	**gain**
CNGS (400GeV)	4.51E+12	5.44E+12	120.6%
LHC (450 GeV)	3.93E+12	4.68E+12	119.1%

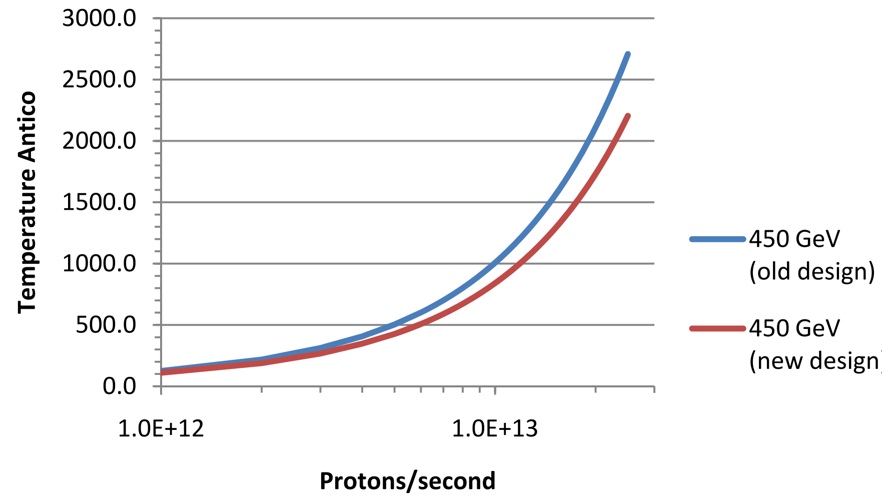
97kW

113kW

400 GeV steady state dumping



450 GeV steady state dumping



Limitations

	Maximum Protons/Second to reach steady state		
Beam	**Present design**	**Modification**	**gain**
CNGS (400GeV)	4.51E+12	5.44E+12	120.6%
LHC (450 GeV)	3.93E+12	4.68E+12	119.1%

	LHC ultimate	CNGS	PS2_LHC	PS2_CNGS
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Maximum proton current for steady state operation			
	CNGS	**PS2_LHC**	**PS2_CNGS**
Present design	2.71E+13	1.89E+13	2.16E+13
Modification	3.26E+13	2.25E+13	2.61E+13
Repetition time [sec]	6	4.8	4.8

Maximum dump intensity 4.5e+13

Any operation below those limits is OK!

	Number of cycles followed by 5 minutes of cooling	
Beam	**Present design**	**Modification**
CNGS	23	38
LHC	steady state	steady state
PS2_CNGS	3	4
PS2_LHC	4	6

Any operation above those limits needs to respect the maximum number of consecutive cycles + cool down time!

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Conclusion
Short-term scenario

- Dump #3 needs to be modified to serve as spare
  - Removal of foil and better Ti coating
  - Intense vacuum firing to clean the graphite
  - Long bakeout in the lab to remove water

  → <u>improving the current Vacuum issues</u>
- Optional:
  - Slight design modification to gain better performance

This can be achieved short-term

Conclusion
Long-term scenario

- A better performance of the dump needs a completely new design
  - This can be achieved with better cleaning efficiency. (TDI for LHC absorbs 200 GeV/proton with the same dimensions)
- About 3 years needed for design and construction
- Costs 0.5-1 MCHF/piece

Further thoughts

- This study was only for the TIDVG!
- Other beam intercepting devices in the SPS
  - TIDH (low energy)
  - TIDP (momentum)
  - TBSJ (injection beam stopper)
  - TBSM (first turn beam stopper)
- Designed in the 70s
- Definite operations limits are not known!

The End