The SAES Group

making innovation happen, together

saes getters

What is a getter

- NEG are reactive metals or alloys which capture gases , such as H_2O, CO, CO_2, O_2 and N_2. by a chemical reaction on their active surface.
- The reaction generates carbides/oxides/nitrides on the getter surface: Gases are permanently removed from the vacuum system.
- Hydrogen does not react to form a chemical compound but dissolves in the bulk of the getter forming a solid solution.
- A getter does not pump noble gases as they do not chemically react.

NEG pump features

- NEG need to be heated **under vacuum** : "**ACTIVATION**"

  a) Modest activation temperature : **400-500°C**
  b) short time : ≈ **60 minutes**

- After activation, the pump sorb gases at room temperature without requiring power (**surface adsorption**)

- When the surface capacity is reached (or after a venting), the pump must be reactivated. This can be done many times (>100)

- In presence of high gas load, the pump can be operated at 250-350°C This increases its efficiency to remove molecules since also the bulk getter capacity is used (**surface adsorption + bulk diffusion**).

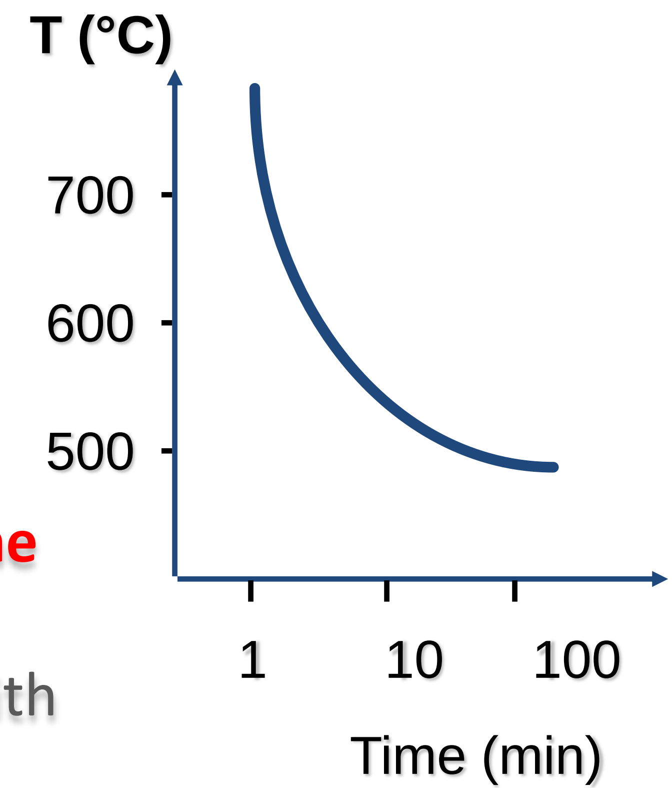
NEG Activation Process

Activation:

- **Diffusion** of surface protective layer

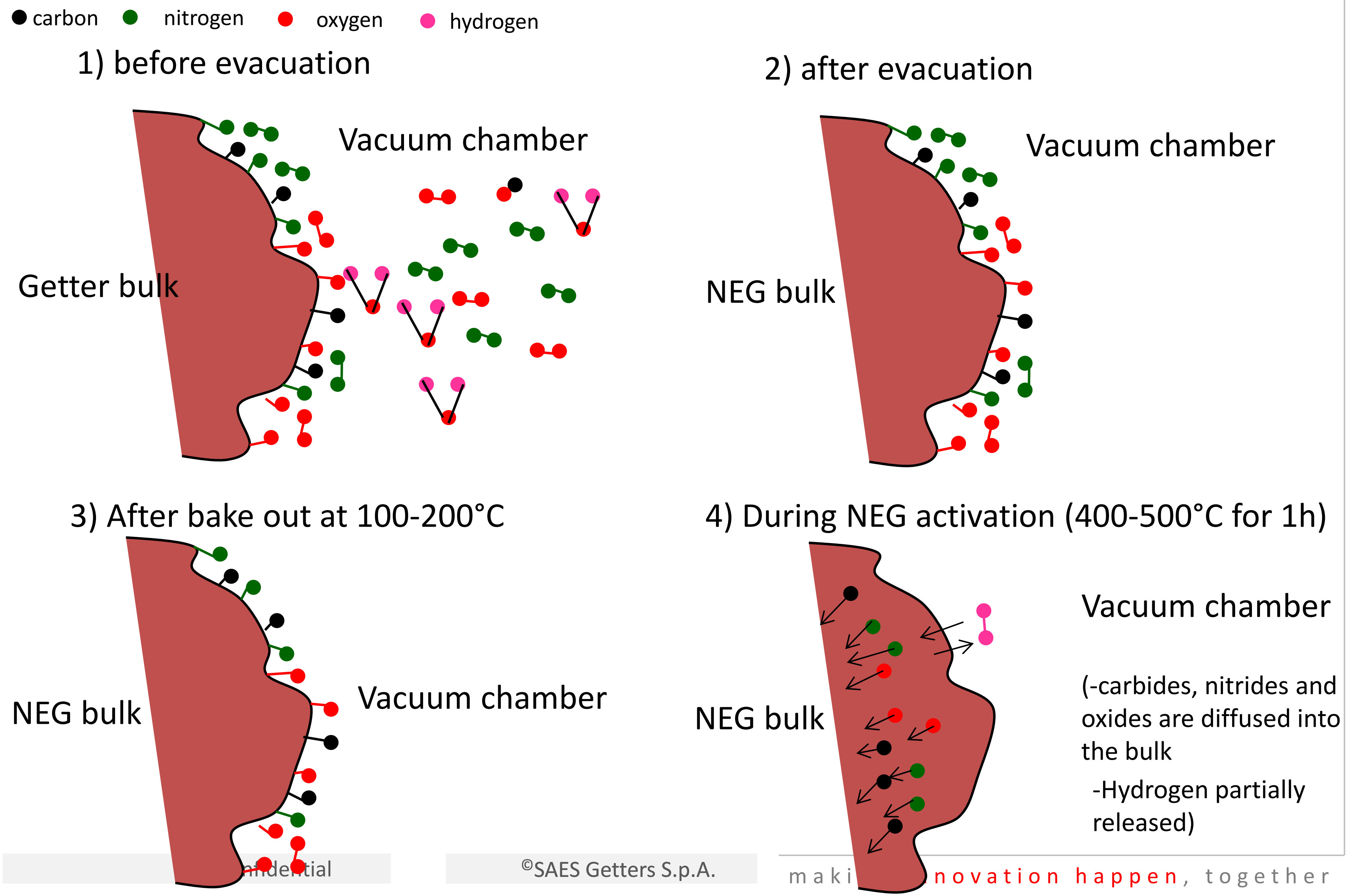
Diffusion phenomena:

- Depend exponentially on the **temperature**: $D=D_o\exp(-E/KT)$
- Depend on the square root of the **time**



Thus, the same effect can be obtained with the increase of temperature or with the increase of time

NEG Activation Process & Adsorption mechanisms

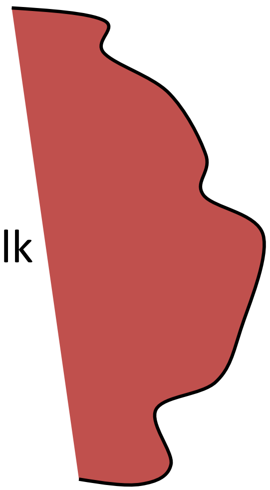


Getter Activation Process & Adsorption mechanisms

● carbon ● nitrogen ● oxygen ● hydrogen

5) after NEG activation

NEG bulk

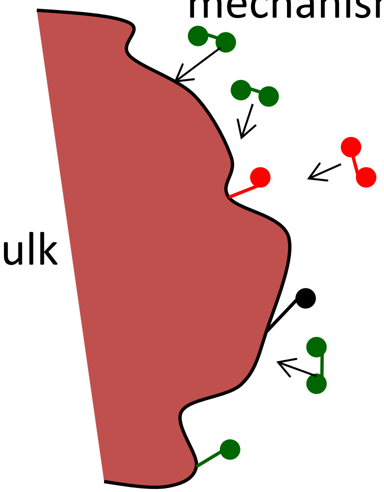


Vacuum chamber

Fresh material to adsorb gases

6) H2O, CO, CO2, N2, O2 gas adsorption mechanism

NEG bulk

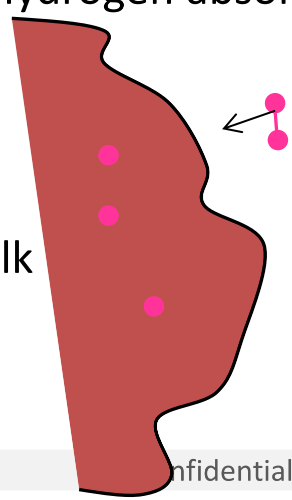


Vacuum chamber

Molecules are dissociated and adsorbed into the getter surface

7) Hydrogen absorption

NEG bulk

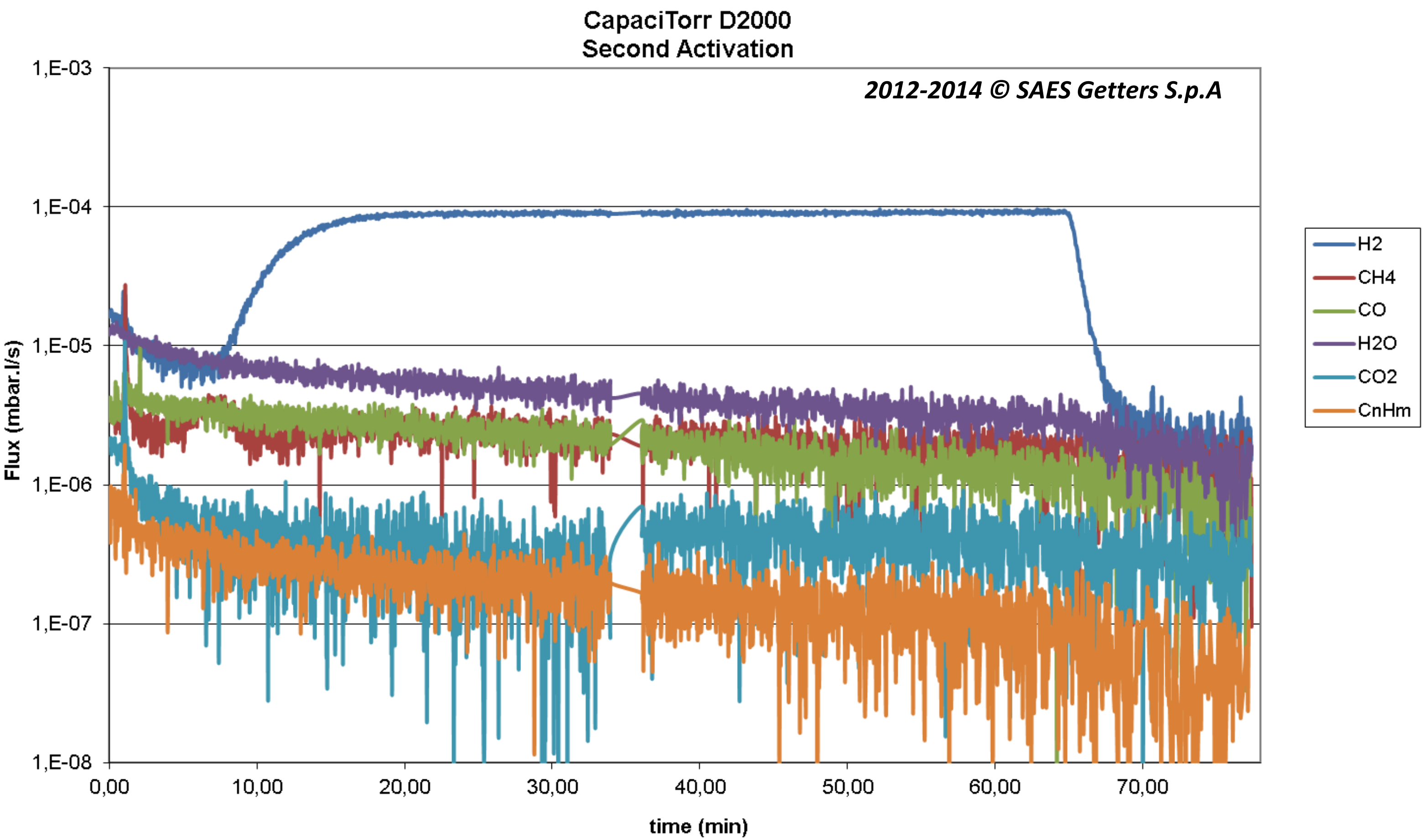


Vacuum chamber

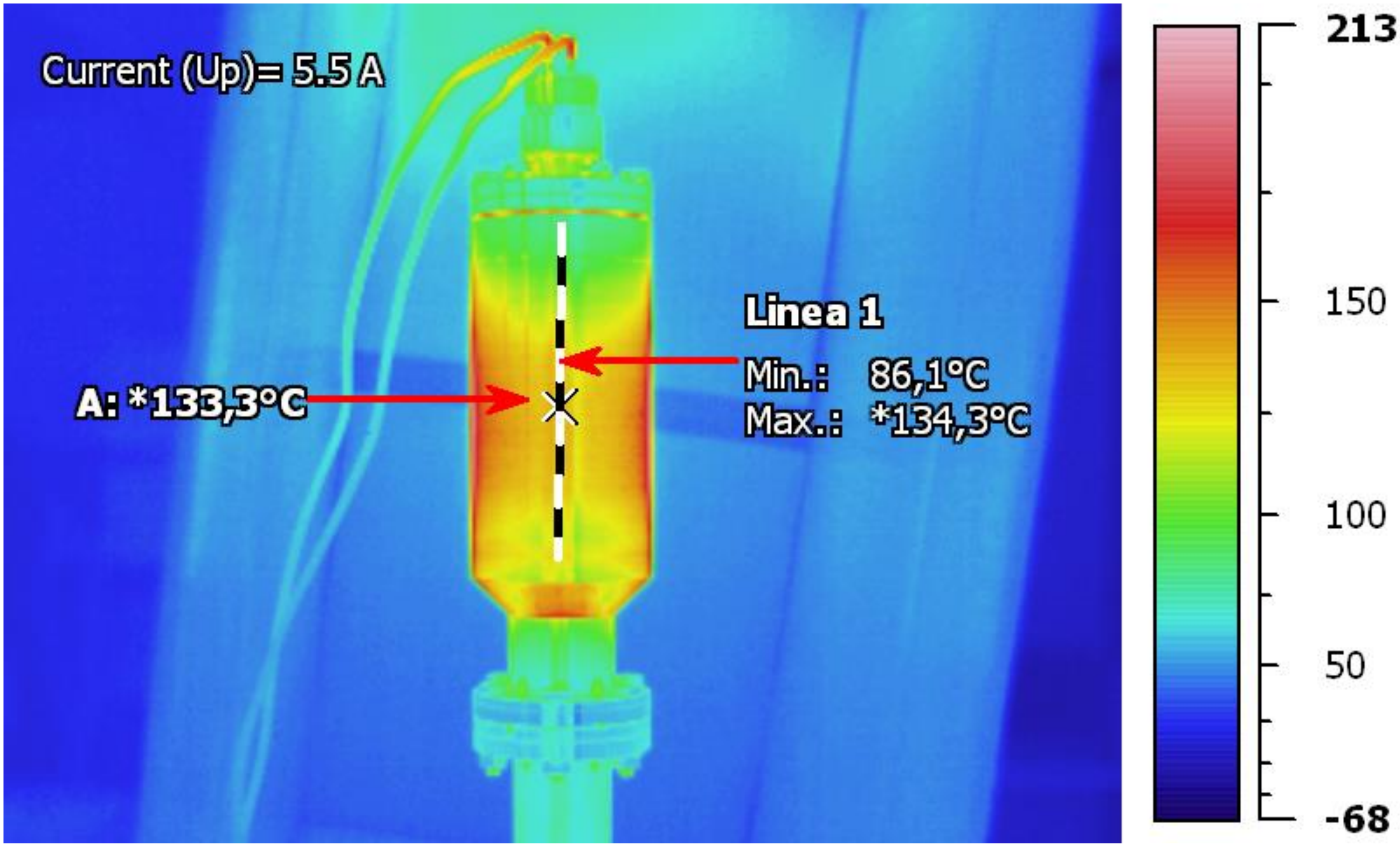
Hydrogen is absorbed into the volume like liquid solution

The getter material can be reactivated more than 100 times!

RGA during NEG activation



CapaciTorr thermal profile during activation



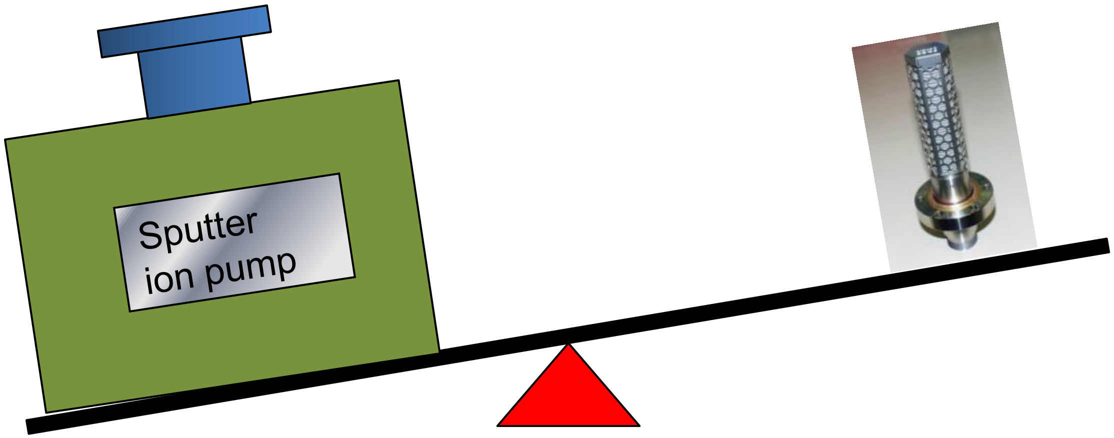
SAES discrete pumping systems

- CapaciTorr and NEXTorr pumps are based on St172 sintered porous disks
- The sintered solution has been developed in the ’90 to improve
  - The pumping speed per m^2 (highly porous materials)
  - The mechanical strength (compressed getter release large amount of particle an is suitable for low vacuum applications where particulate is not an issue)
  - Reduce the H_2 equilibrium pressure

The CapaciTorr® family

	D50	D100	D200	D400	D1000	D2000	D3500
H_2 (l/s)	55	100	200	400	1000	2000	3600
O_2 (l/s)	55	100	200	400	1000	2000	3600
CO (l/s)	30	60	140	340	550	1100	600
N_2 (l/s)	20	40	80	160	400	800	1440
H_2 capacity (Torr.l)	78	135	280	450	1360	2250	3950
CO capacity (Torr.l)	0.1	0.2	0.56	0.9	4	5	12
CO total (Torr.l)	70	120	252	400	1224	2000	3100
Flange	CF35	CF35	CF35	CF35	CF63-CF100	CF100-CF150	CF150-CF200
Weight (kg)	0.3	0.35	0.4	0.8	1-2	2-3	3-4
Total lenght from the flange (cm)	4.4	6.5	8.9	13.2	14.7	19.5	19.5

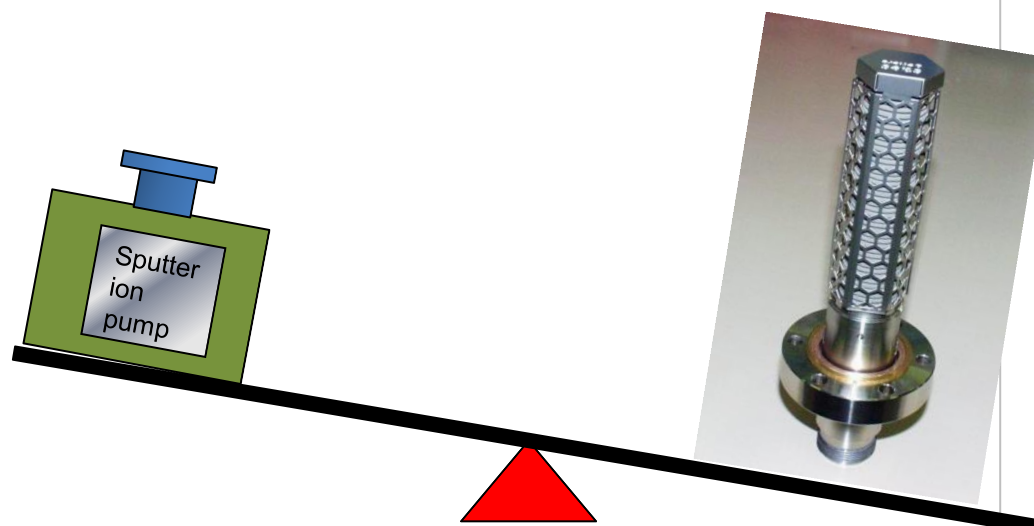
New approach in UHV systems…



Traditional approach

Reversed approach

- UHV-XHV systems can be pumped by a NEG backed by a small SIP.
- saving space (more room to improve the technical design of UHV systems)
- No power consumption at working conditions
- No magnetic interference



Combination of NEG and Sputter-Ion Pumps for Particle Accelerator Vacuum Systems

P. Chiggiato, S. Meunier, I. Wevers
Vacuum, Surfaces and Coatings
CERN, 1211 Geneva 23, Switzerland

A. Bonucci, A. Conte, P. Manini, F. Siviero, L. Viale
SAES Getters SpA, Viale Italia 77, 20020 Lainate (Italy)

Introduction

NEG and sputter-ion pumps are usually combined in particle accelerators to attain UHV pressure specifications. NEG pumps provide very high pumping speed at a reasonable cost for most of the residual gases except CH_4 and rare gases, which amount to less than an hundredth of the total outgassing rate. Sputter-ion pumps remove all gases, though with a lower pumping speed. As a consequence, an optimized design should be based on NEG assisted by sputter-ion pumps for the gases that are not adsorbed chemically.

Outgassing of UHV materials for particle accelerators

Thermal Outgassing		
Materials	Outgassing Rates of gasses pumped by NEG (mainly H_2) [Torr l s^{-1} cm^{-2}]	Outgassing Rates of Gasses Not Pumped by NEG (mainly CH_4) [Torr l s^{-1} cm^{-2}]
Stainless Steel	10^{-12}	$<10^{-14}$
Stainless steel (vacuum fired)	2×10^{-13}	$<10^{-15}$
Copper OFE	10^{-12}	$<10^{-14}$
Aluminium alloys	10^{-13}	$<10^{-15}$

P. Chiggiato et al., Poster VT-TuP6 AVS 58 Conference, Nashville 2011

The next step : NEXTorr® pump

- NEXTorr is a new generation of pumps which combines in a single, very compact and light package, a NEG element and a very small ion pump.

- The getter element provides very large pumping speed and acts as the main pump for the active gases, leaving to the ion pump the task of removing noble gases and CH_4, not pumped by the NEG.

- The integration of the two pumps is optimized to enhance pumping performances. As showed in the previous talk[(1)], the NEXTorr design provides remarkable pumping synergies :

  - **Gases released by the ion pump during the operation are intercepted and removed by the getter element, with a substantial reduction of back-streaming effects.**
  - **Increased pumping efficiency for H_2 , CH_4 and Argon**

A Bonucci et al, "The pumping synergies of integrated NEG and SIP pumps for UHV applications", 57th AVS Conference, 2010.

How it looks like : NEXTorr® D 100-5 pump

Total weight (magnets included)	2,2 kg
Volume	**0,5 l**

	Initial pumping speed (l/s)	
Gas	NEG activated	NEG saturated
O_2	**100**	**3.5**
H_2	**100**	**-**
CO	**70**	**6**
N_2	**40**	**5**
CH_4	**15**	**7**
Argon	**6**	**6**

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The NEXTorr® family

-each NEXTorr pump has a dedicated power supply and cables to activate the NEG and control the ion pump

-the power supply integrates both SIP and NEG parts

The NEXTorr® family

	D100-5	D200-5	D300-5	D500-5	D1000-10	D2000-10
H_2 (l/s)	100	200	300	500	1000	2000
O_2 (l/s)	100	200	300	500	850	1700
CO (l/s)	70	140	200	340	550	1100
N_2 (l/s)	40	80	100	200	320	640
Ar (l/s)	6	6	6	6	10	10
CH_4 (l/s)	13	13	13	13	22	22
H_2 capacity (Torr.l)	135	270	410	680	1125	2250
CO capacity (Torr.l)	0.6	0.8	1.1	1.4	3.2	3.9
CO total (Torr.l)	120	240	360	600	640	780
Flange	CF35	CF35	CF63	CF63	CF100	CF100
Weight (kg)	2.2	2.2	3.1	3.1	6.5	6.8
Total lenght from the flange (cm)	6.0	9.1	7.6	9.0	13.4	18.5

- Diode and noble diode versions are available for all the models

NEXTorr is a patented solution

- SAES has been acknowledged a US patent on a combined NEG and SIP design (US 8,287,247 B). This design is based on arranging a NEG cartridge and a SIP on the opposite side of a mounting flange.
    - The NEXTorr embodies this concept providing in a single integrated pumping device the most performing solution.
    - This also applies to designs based on combined used of a NEG and a SIP as discrete components.

(12) **United States Patent**
Bonucci et al.

(10) **Patent No.:** **US 8,287,247 B2**
(45) **Date of Patent:** **Oct. 16, 2012**

(54) **COMBINED PUMPING SYSTEM COMPRISING A GETTER PUMP AND AN ION PUMP**

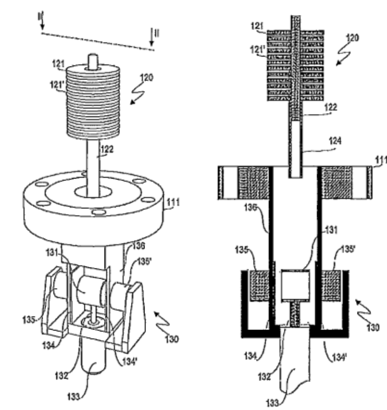
(75) Inventors: **Antonio Bonucci**, Milan (IT); **Andrea Conte**, Milan (IT); **Paolo Manini**, Milan (IT)

(73) Assignee: **SAES Getters S.p.A.**, Lainate (MI) (IT)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,993,638	A *	7/1961	Helmer et al.		417/49
3,327,929	A	6/1967	Dillenbeck et al.		
3,377,499	A	4/1968	Lloyd		
5,221,190	A	6/1993	Romer et al.		
5,324,172	A	6/1994	Manini et al.		
5,993,165	A	11/1999	Lorimer et al.		
6,074,171	A *	6/2000	Giannantonio et al.		417/51
6,149,392	A *	11/2000	Conte		417/51



Quick comment on getter performances: sintered vs compressed disks

- The **performances** of a **getter depends** on a number of reasons including :
  - The **chemistry** (chemical reactivity of the alloy)
  - The **physics** (physical arrangement of the getter material/surface).
  - The **processing** (how the getter material has been processed during manufacturing)
- One of the **first getter used in a NEG pump** was **St 707**. In the **70s SAES developed the SORB AC pump** line using **compressed St 707**. Main drawbacks of compressed powder are:
  - the **surface area and the internal porosity** of the getter element are **small**
  - the getter is prone to **release dust**
- To overcome these limitations, **SAES developed in the 90s** specific sintering processes. The result was the introduction of St 172 (St 707+Zr) and the Capacitorr pump family.

Sintered vs compressed disks (2)

	Compressed	Sintered
Surface area	Low	Very high
Pumping speed (l/s m^2)	Low	High
Pumping capacity (Torr·l m^2)	Low	High
Dust emission	Significant	Marginal
Manufacturing complexity	Simple	High. Sintering is a high temperature process (below alloy melting point) carried out in UHV
Cost	Cheap	More expensive

St 172 is the benchmark for high performances, dust free NEG pumps. However, in low end applications when cost is the main driver SAES provides a full range of compressed powder pumps which can be used and working in the field since 45 years… the point is… compare apples and apples

Exploiting the NEG concept in high vacuum

- Achievement of better vacuum level
- More efficient pumping of hydrogen, water and air
- To reduce the pump down time
- To reduce the baking time or the baking temperature
- To solve specific issues other pumps cannot address (e.g. space, weight, power consumption, vibration, magnetic interference…)

Time between reactivations in high vacuum

CapaciTorr D 400

- Gas to sorb : H_2O at 10^{-8} mbar
- Pumping speed : 300 l/s
- Pump capacity (H_2O) : 10 mbarl
- H_2O sorbed in 1 year: 300l/s*10^{-8}mbar*(365*24*3600)s=94,2 mbar l
- Time between reactivations: 10 mbarl/94,2 mbar l = ~ 1 month

- Gas to sorb : CO at 10^{-8} mbar
- Average pump speed : 100 l/s
- Pump capacity (CO) : 1,2 mbarl
- CO sorbed in 1 year:100l/s*10^{-8} mbar*(365*24*3600)s=31,4mbarl
- Time between reactivations: 1,2 mbarl/31,4mbar l = 14 days

-In high vacuum, NEG pumps operate shorter times before re-activation

-In high vaccum, different approach is required compared to UHV conditions

A further improvement: ZAO ® getter alloy

- A novel family of alloy (Zr-V-Ti-Al) called ZAO® has been developed which has several specific advantages compared to St 172 (currently used in the Capacitorr and NEXTorr product line)

- The ZAO presents the following advantages:

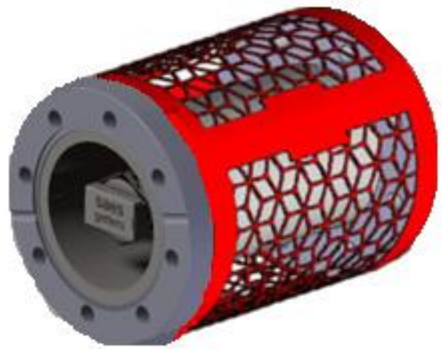
  - **Lower equilibrium isotherm** (even at 200 C the equilibrium pressure of hydrogen is @1×10^{-10} mbar or lower)
  - **Larger capacity** for all active gases
  - Ability to digest gases and withstand **many more reactivation cycles** without loosing significant performances
  - **Better mechanical properties:** disks are intrinsically more robust and higher embrittlement limit.

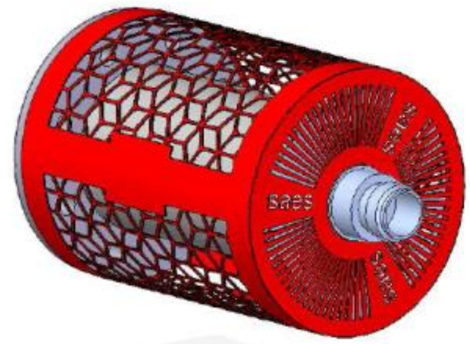
CapaciTorr® HV pumps

- CapaciTorr® pumps based on ZAO® are provided with an integrated housing to keep uniform getter temperature at ≈200°C
- CapaciTorr® HV 200 pump on CF 63 and CF 35 connecting flange can be operated with dedicated power supply
- Larger CapaciTorr® HV pumps can be provided installed in CF150 and CF200 flanges

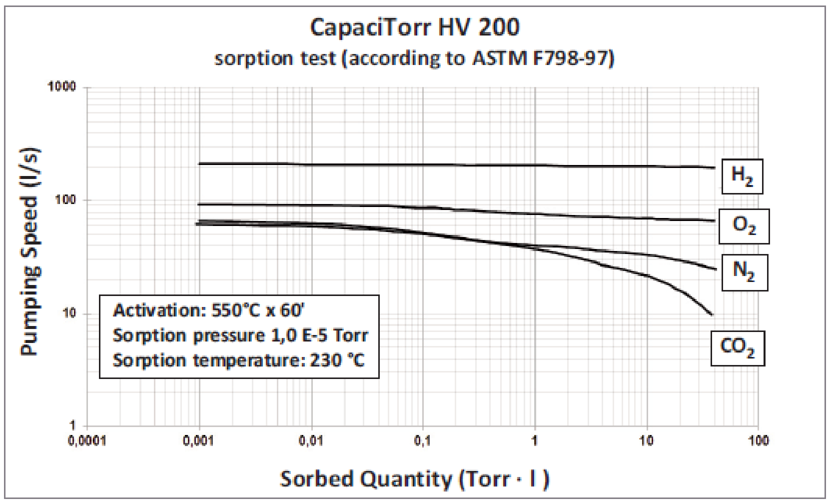
CapaciTorr® HV 200

CF 63 connecting flange





The pump can be also provided in CF35 connecting flange



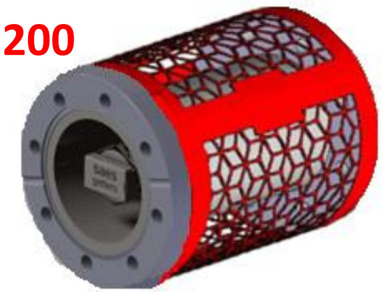
Alloy Type		ZAO®
Alloy Composition		Based on Zr V Ti
Getter Mass (g)		140
Getter Surface (cm²)		432
Pumping speed (l/s) at 200°C	H_2	210
	O_2	90
	CO_2	65
	N_2	60
Sorption Capacity (Torr l)	H_2	2100
	O_2 Single cycle at 200°C	>2000
	CO_2 Single cycle at 200°C	>40
	N_2 Single cycle at 200°C	>200
Number of sorption cycles	>20 cycles	
NOTE: Pumping speed data refer to the initial values. Single run capacity is based on a minimum sorption speed 10% of the initial value. Total capacity is reached after many reactivations.		

-The performances of the CapaciTorr HV pump is defined in terms of number of sorption cycles

-each cycle corresponds to 1 year of operation at ≈10^{-8} mbar

NEG pumps in high vacuum

Capacitorr HV 200



☐ Gas to sorb : CO_2 at 10^{-8} mbar

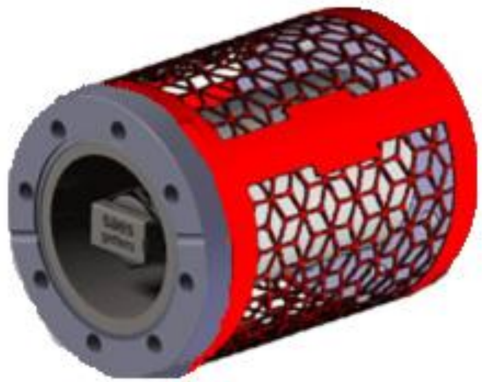
- Average pump speed : 65 l/s
- Pump capacity (CO) : > 40 mbar l
- CO sorbed in 1 year: 65 l/s*10^{-8}mbar*(365*24*3600)s=24 mbar l
- Time between reactivations: 40 mbar·l / 24 mbar l = 1,6 years

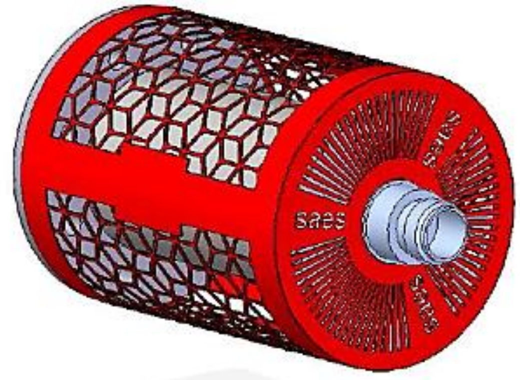
☐ Gas to sorb : N_2 at 10^{-8} mbar

- Average pump speed : 60 l/s
- Pump capacity (N_2) : 200 mbarl
- N_2 sorbed in 1 year: 60 l/s*10^{-8} mbar*(365*24*3600)s=18,8 mbarl
- Time between reactivations: 200 mbar·l / 18,8mbar l = 10,6 years

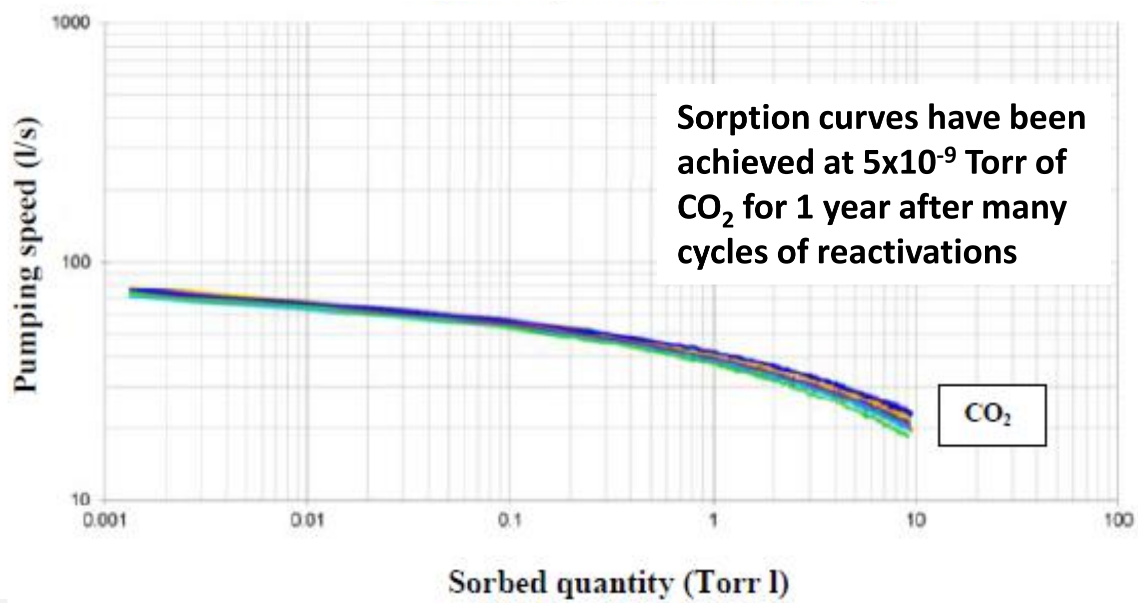
1. **In high vacuum, NEG pumps operate long times before re-activation**
2. **Time between reactivations scales with pressure !!**

CapaciTorr® HV pumps in high vacuum





CapaciTorr® HV 200
Sorption test (according to ASTM F798-97

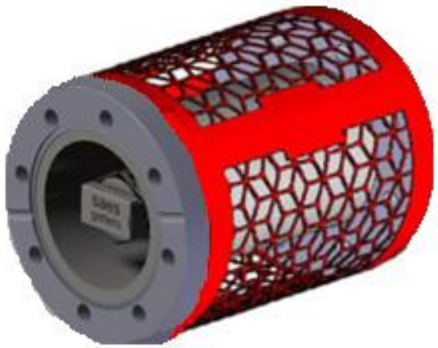


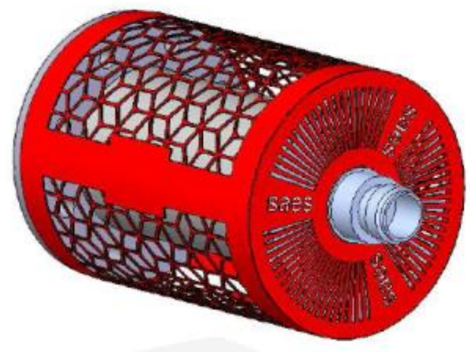
Sorption curves have been achieved at 5x10^{-9} Torr of CO_2 for 1 year after many cycles of reactivations

Ipothesis: pressure @5x10^{-8} Torr with the following reasonable gas composition

- **80% H_2+H_2O**
- **10% CO/CO_2**
- **10% N_2**

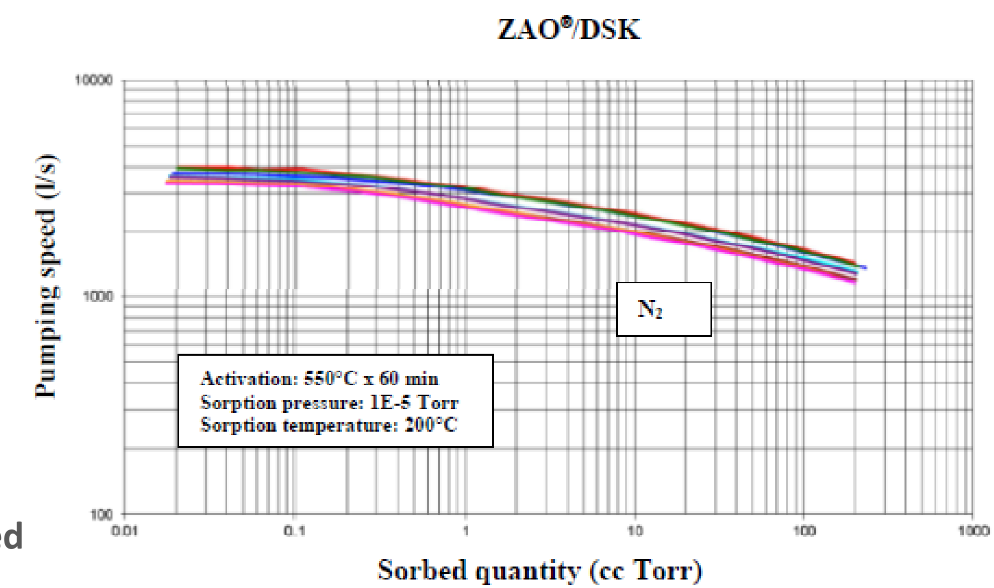
CapaciTorr® HV pumps in large leak rate





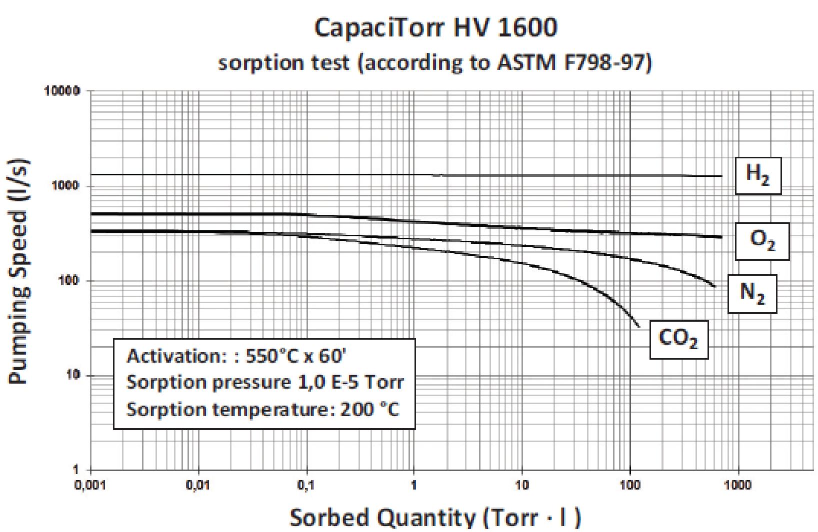
Air leak rate 10^{-7} Torr l/sec

- Pumping speed for O_2 and N_2 120 and 80 l/s respectively
- Capacity at 200 C for O_2 and N_2 2000 and > 200 Torr l respectively
- The sorbed quantity in 1 year of O_2 and N_2 are 0.7 and 2.5 Torr l respectively
- The pump must be reactivated after 100 years!
- After many cycles of reactivations, the pumping characteristics for N_2 are unchanged



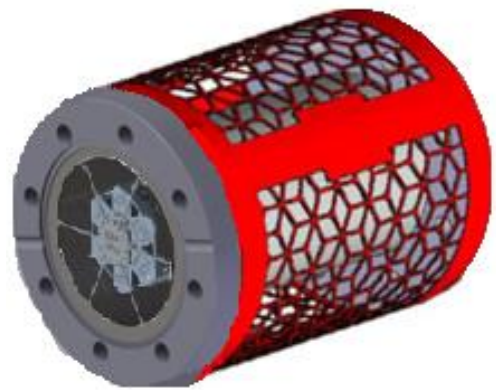
CapaciTorr® HV 1600

CF 150
connecting
flange



Alloy Type		ZAO®
Alloy Composition		Based on Zr V Ti
Getter Mass (g)		700
Getter Surface (cm^2)		1800
Pumping speed (l/s) at 200°C	H_2	1400
	O_2	500
	CO_2	320
	N_2	300
Sorption Capacity (Torr l)	H_2	10500
	O_2 Single cycle at 200°C	>9000
	CO_2 Single cycle at 200°C	>120
	N_2 Single cycle at 200°C	>1500
Number of sorption cycles	>20 cycles	
NOTE: Pumping speed data refer to the initial values. Single run capacity is based on a minimum sorption speed 10% of the initial value. Total capacity is reached after many reactivations.		

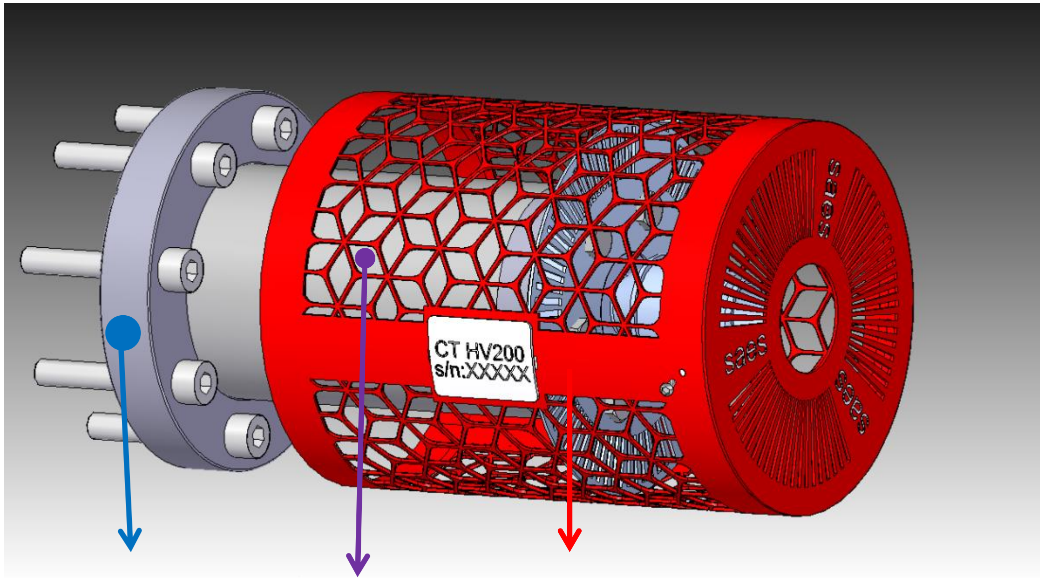
Next development: CapaciTorr® HV 2100



CapaciTorr® HV2100

- Installed in a CF200 connecting flange
- Pumping speed for H_2 ≈2100 l/s, while CO/CO_2 and N_2 in the range of 700 l/s
- Capacities for N_2 and CO/CO_2 for single cycles > 1700 and >170 Torr l respectively

CapaciTorr HV temperature

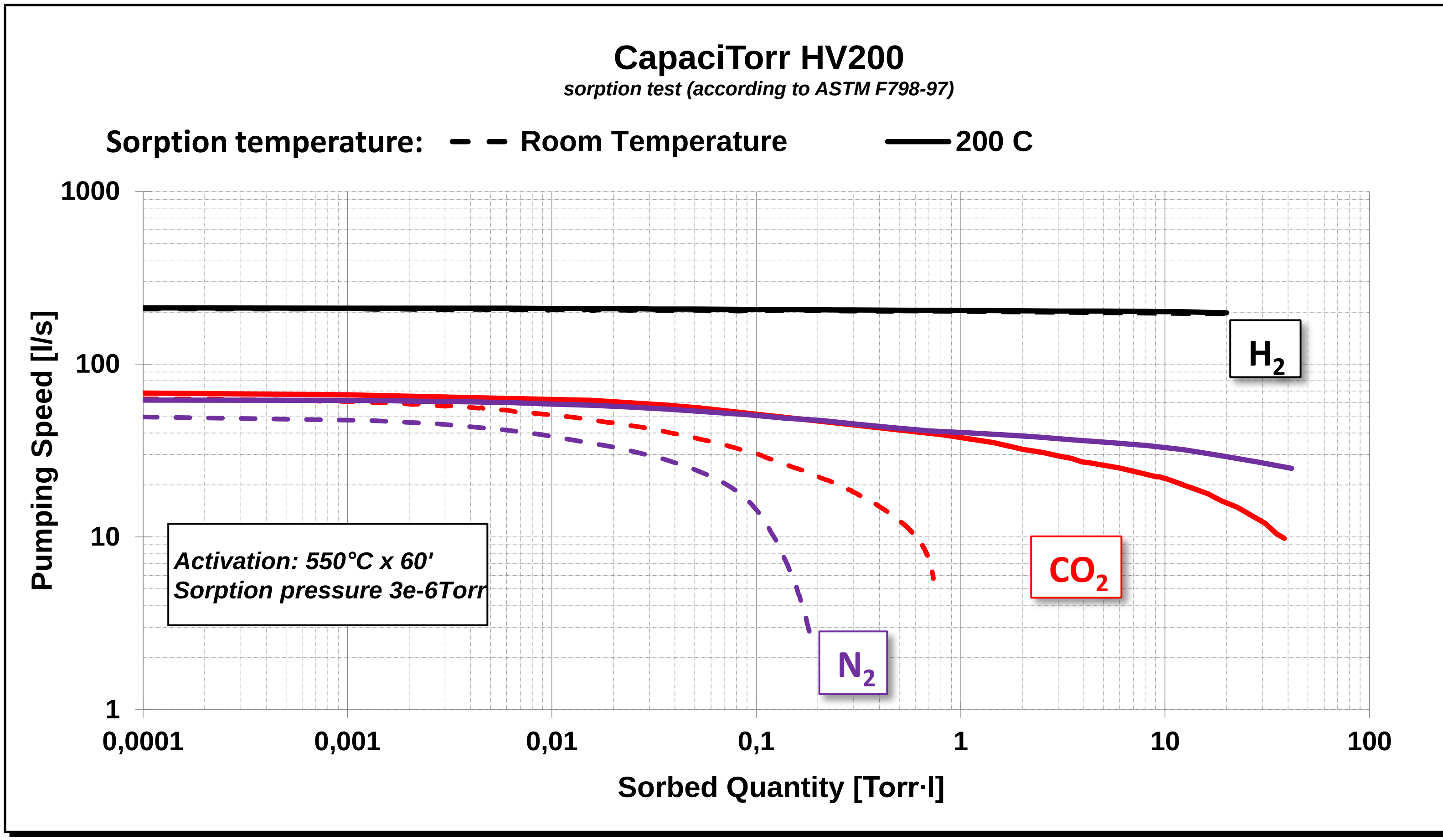


T_1 (flange) T_2 (body) T_3 (external red grid)

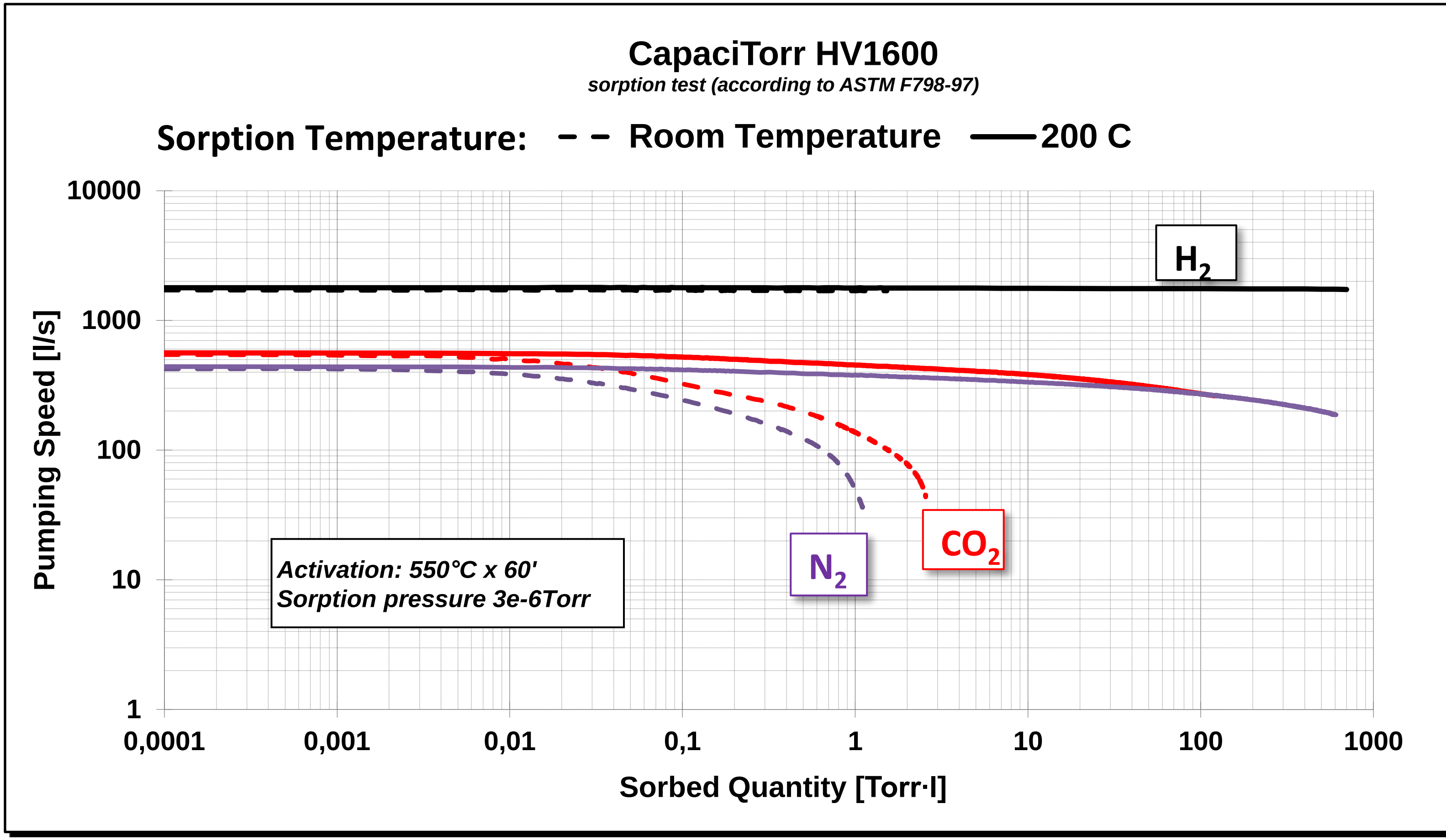
- The external red grid is removable
- Cartridge is replaceable

	T Work. (C)	Power (W)	T_1 (C)	T_2 (C)	T_3 (C)
CapaciTorr HV200	**200**	**8**	**30**	**40**	**RT**
CapaciTorr HV1600	**200**	**50**	**35**	**50**	**RT**

CapaciTorr HV200 at room temperature



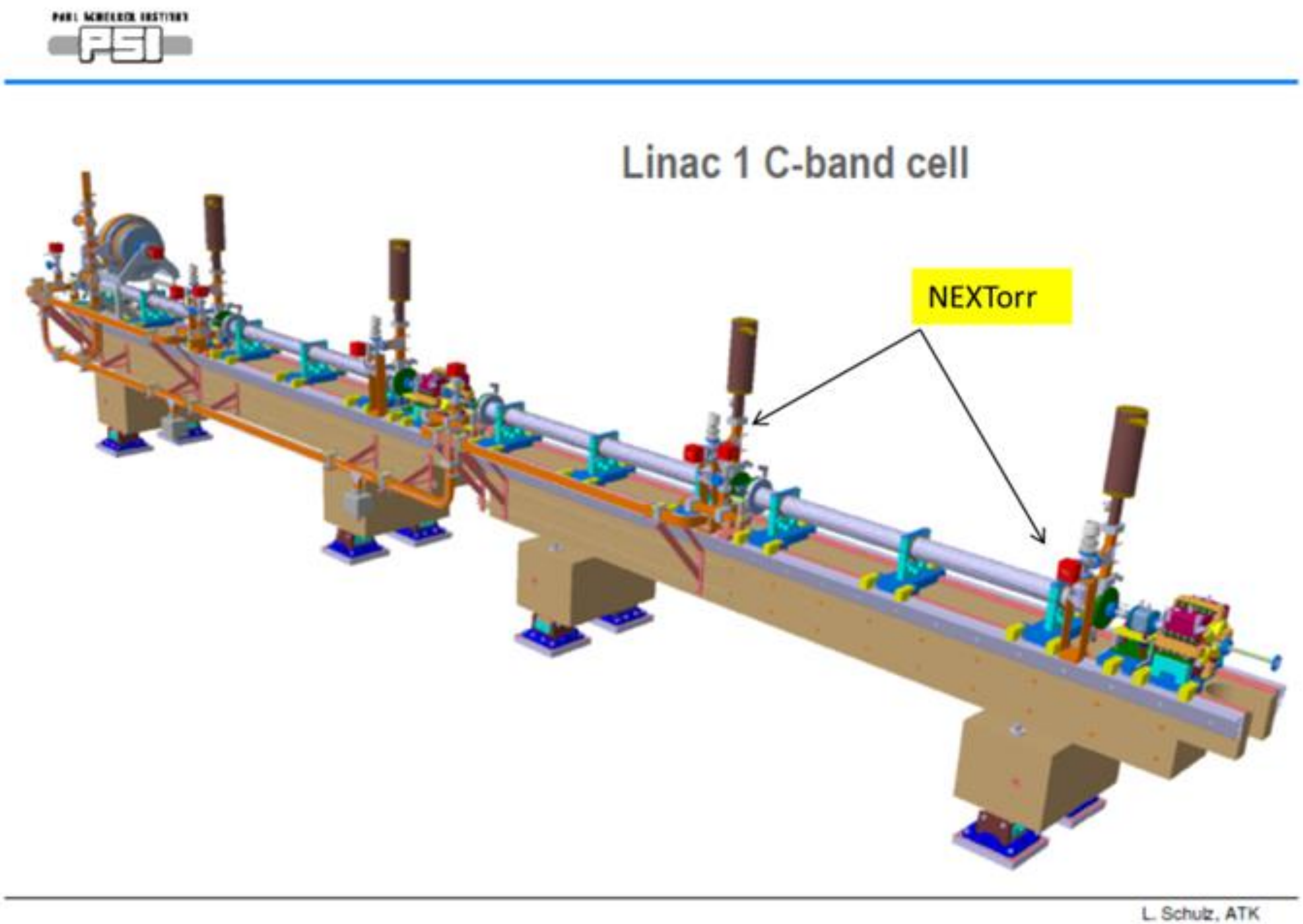
CapaciTorr HV1600 at room temperature



NEG pumps use in UHV-XHV systems

LINAC at SWISS-FEL

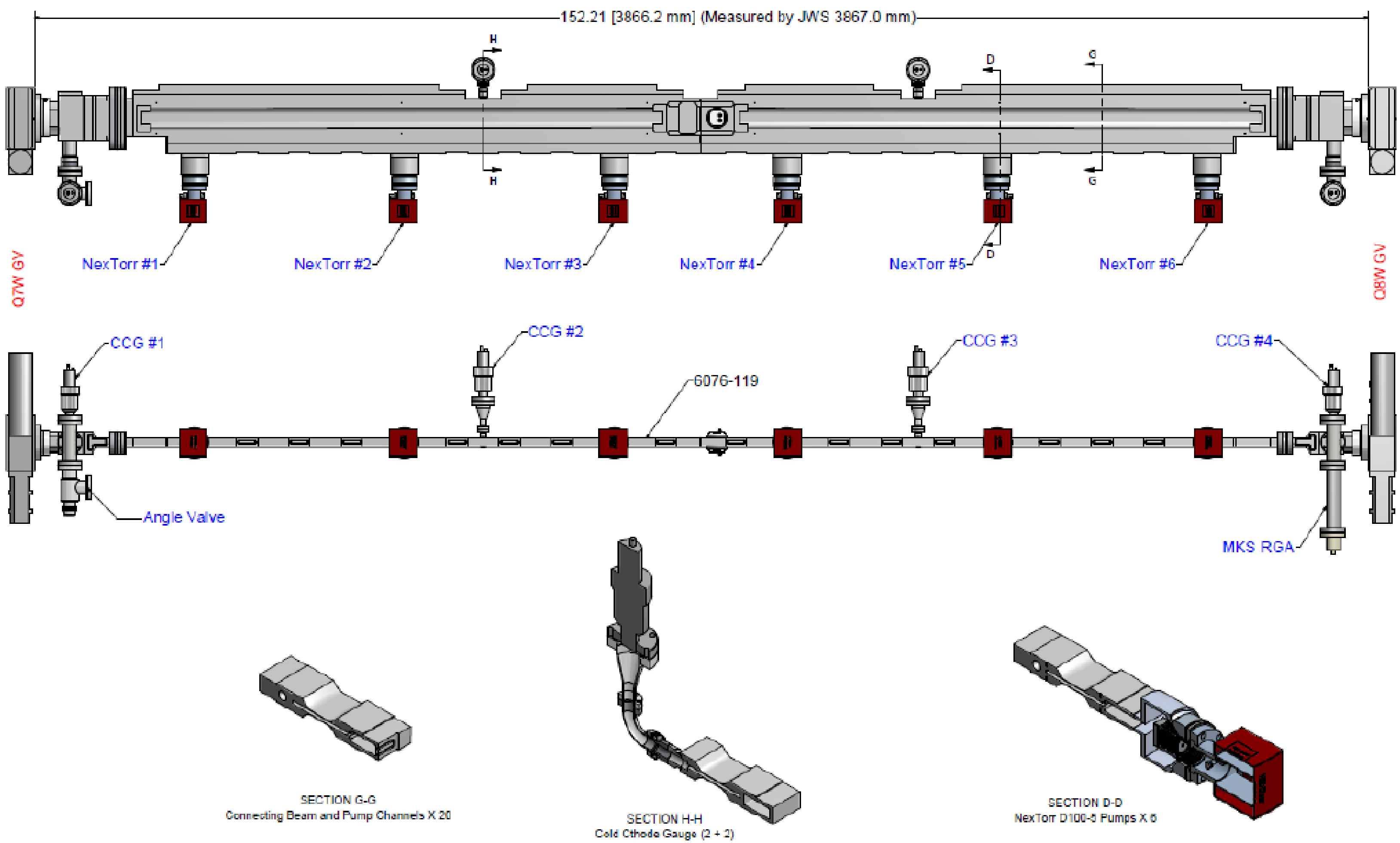
SWISS FEL => 290 NEXTorr ® pumps installed in the LINAC



Courtesy of PSI

Vacuum level 1e-9 Torr

Undulator vacuum test chamber

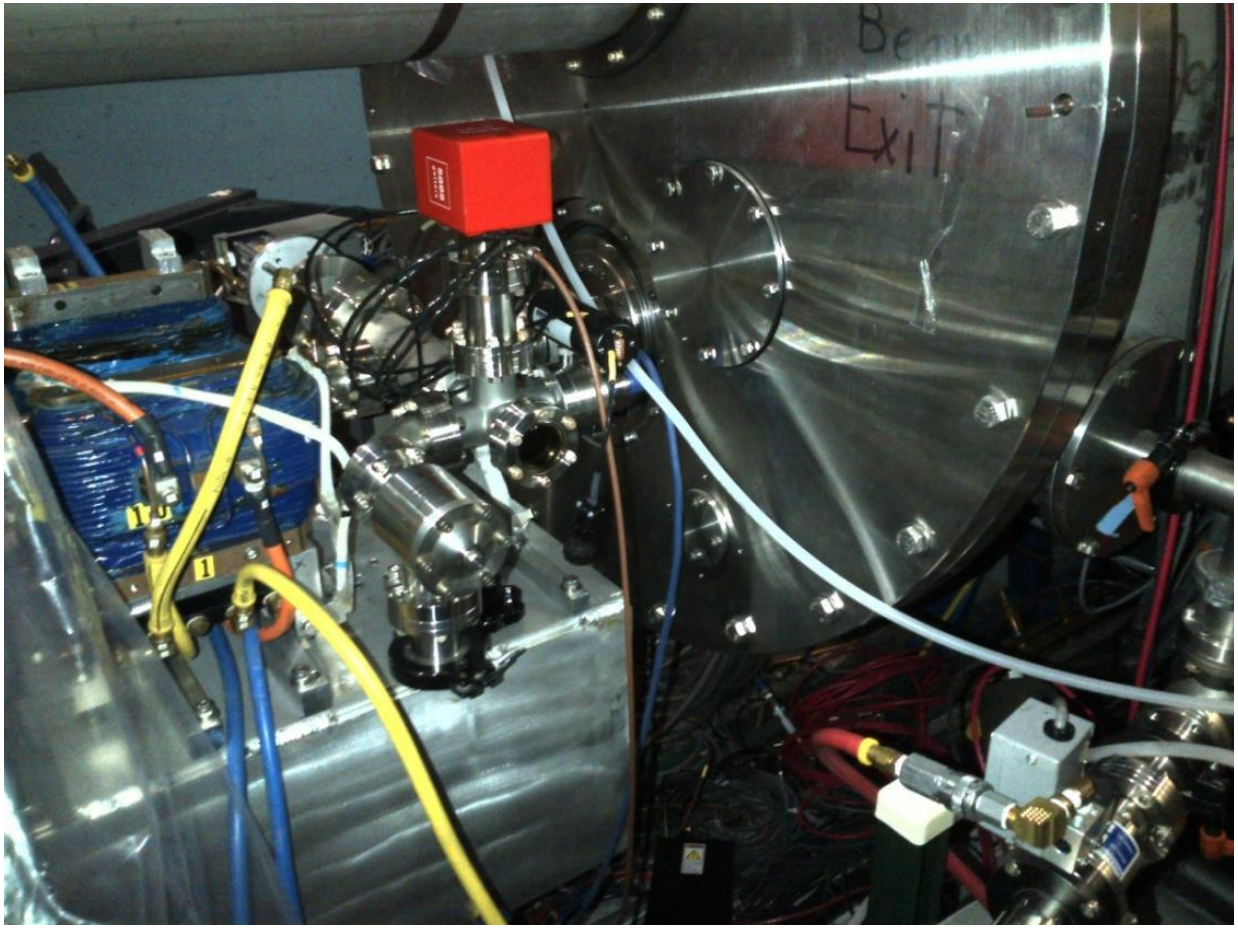


Courtesy of Wilson Lab., Cornell

Vacuum level 1e-10 Torr

RF surpeconducting cavities

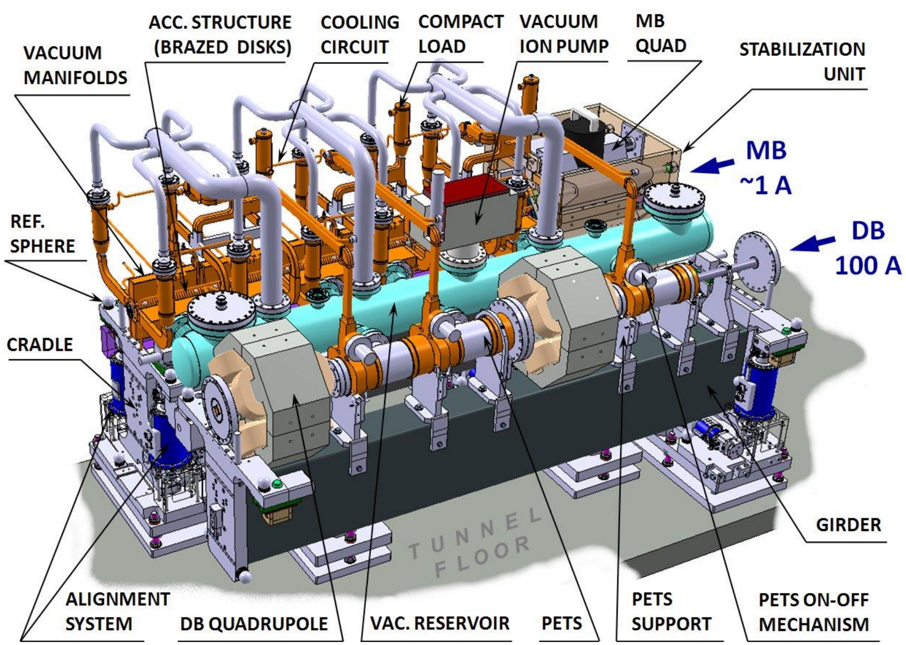
In the warm section, a NEXTorr® D100-5 is under evaluation



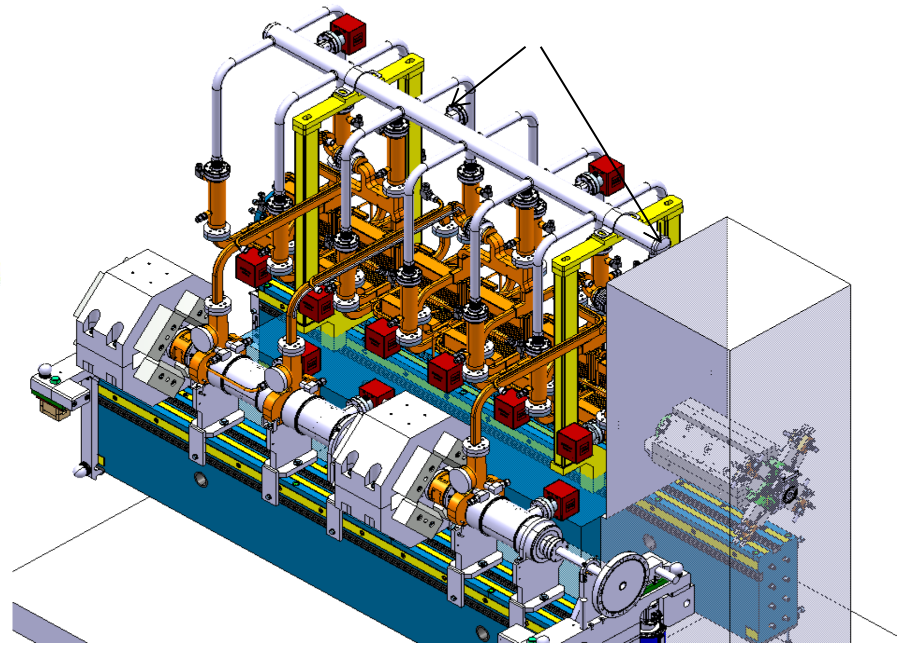
Courtesy of Wilson Laboratory, Cornell – vacuum level 1e-10 Torr

Improving and simplifying the design of the vacuum system (CLIC@CERN)

ION PUMP based system



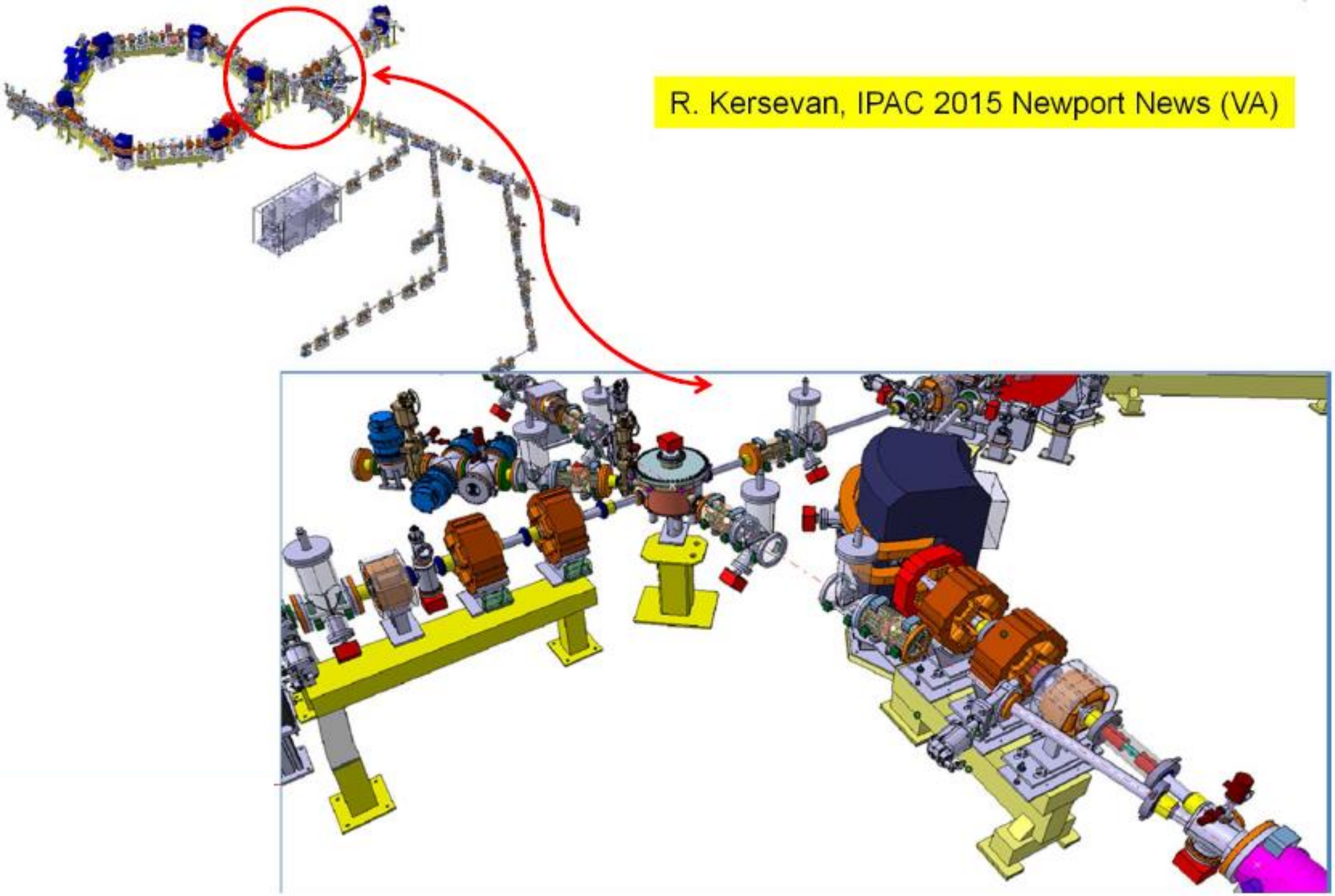
NEXTorr® based system



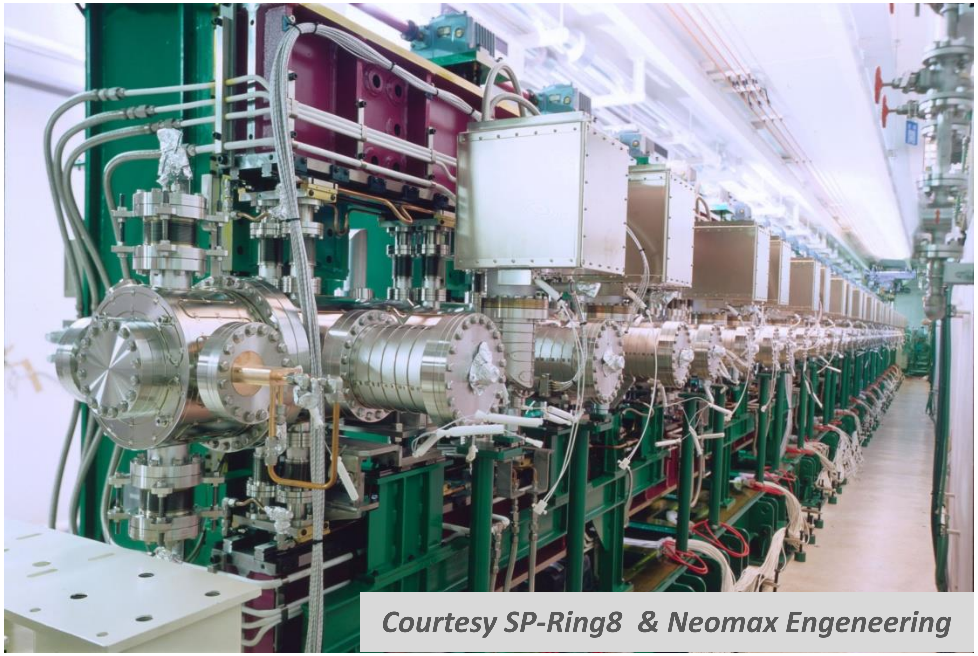
P. Chiggiato et al., poster VT-TuP6 – AVS 58 Conference, Nashville 2011

Elena at Cern: targeting 10-12 Torr

R. Kersevan, IPAC 2015 Newport News (VA)



In vacuum undulators at X-FEL SACLA

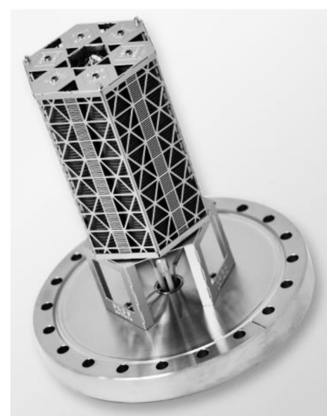


Courtesy SP-Ring8 & Neomax Engeneering

- The same in vacuum undulators have been used in the Taiwan Photon Source
- In the in vacuum undulators at BNL (NSLS-II) CapaciTorr® D3500 are installed. Provide double pumping speed compared to GP® 500

GP® 500

- Used at TPS, SPRING-8
- CF150
- Nominal pumping speed H2 2000 l/s

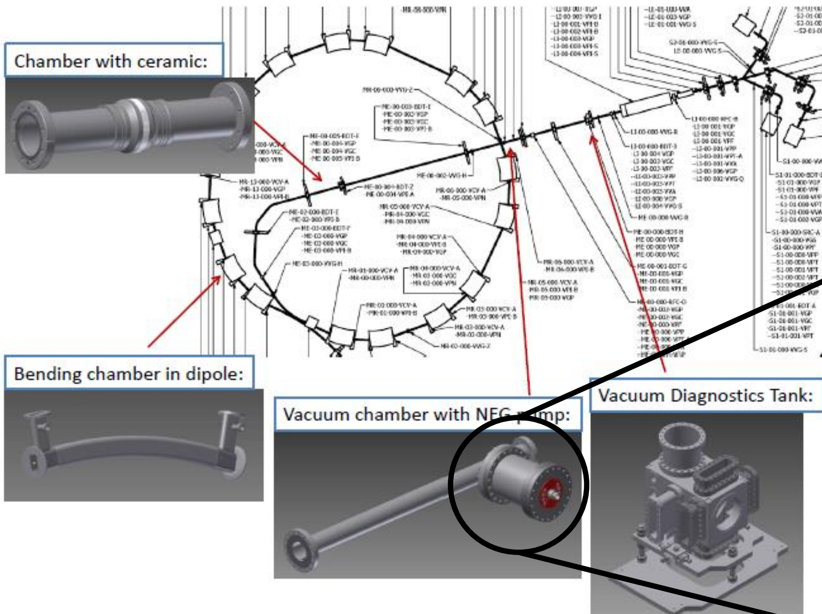


CapaciTorr® D3500

- Used at BNL
- CF150 and CF200
- Nominal pumping speed H2 3600 l/s

Medaustron Medical Accelerators

- In the accelerator and in addition to ion pumps, NEG cartridges will be installed to fasten recovery in case of vacuum venting to atmosphere



CapaciTorr® D2000

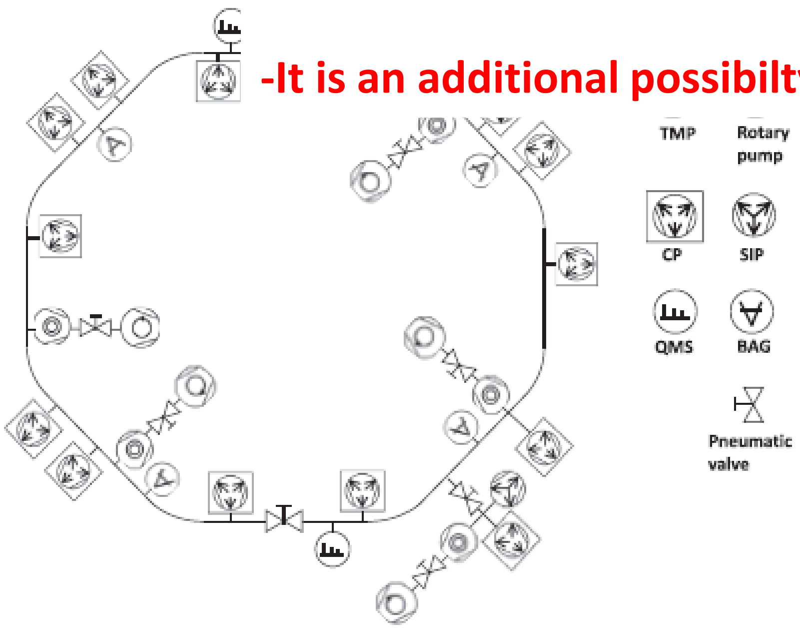
Medaustron Beam Vacuum System: from sources to patient treatment, Proceedin IPAC 2011, J.M. Jimenez et al.

Heavy Ion Medical Machine (HIMM) - China

- CapaciTorr D400-2 was combinaed with ion pump to achieve UHV level $<5x10^{-9}$ Torr
- The possibility to extend the use of this combination in high vacuum (i.e., p>... demons...
- This combination allows to reduce the down-time of the machine after a maintenance or venting
- Bake out time and temperature can be also shorten

-Lower vacuum level allows to use higher beam current providing better characterisics for patient treatment

-It is an additional possibilty for high current retment patient

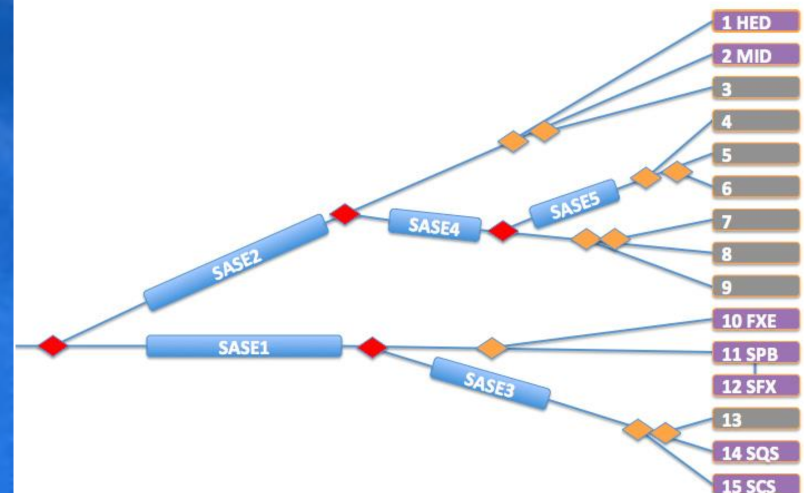


Use of combined sputter ion and NEG pumps in the heavy ion medical machine, vacuum, 114, 108 (2015)

Beam transport area European XFEL

CapaciTorr D 1000

CF63-100



- A CapaciTorr D1000 is under evaluation in combination with a SIP
- The NEG is installed to increase the pumping speed for CO which can be deposited in the mirror

NEG Pump use: Other examples

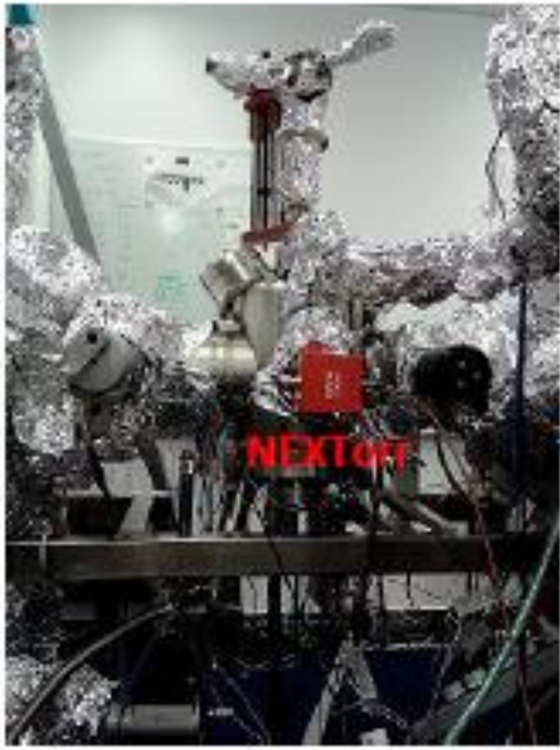
- Fair Project: NEXTorr D500-5, NEXTorr® D2000-10, CapaciTorr® D1000 and CapaciTorr® D3500 under tests
- Tens of CapaciTorr® D2000 in Medaustron medical accelerator
- CapaciTorr® D3500 in the in vacuum undulator at NSLS-II, BNL
- Upgrade of LHC (hundreds of NEG pumps between CapaciTorr® D400, CapaciTorr® D1000 and CapaciTorr® D2000)
- GP® 500 in the in vacuum undulator at the XFEL of SPRING-8
- 300 GP® 500 in the main ring of TPS
- Several hundred of NEG pumps and NEG technology in the SUPER KEK-B
- Tens NEG pumps are used in the COSY project at Juelich
- NEXTorr® positively evaluated at ESRF, TPS, CERN, GSI, ASTEC, ELETTRA, TU Dortmund, Diamond, SUPER KEK B, SPRING-8 …

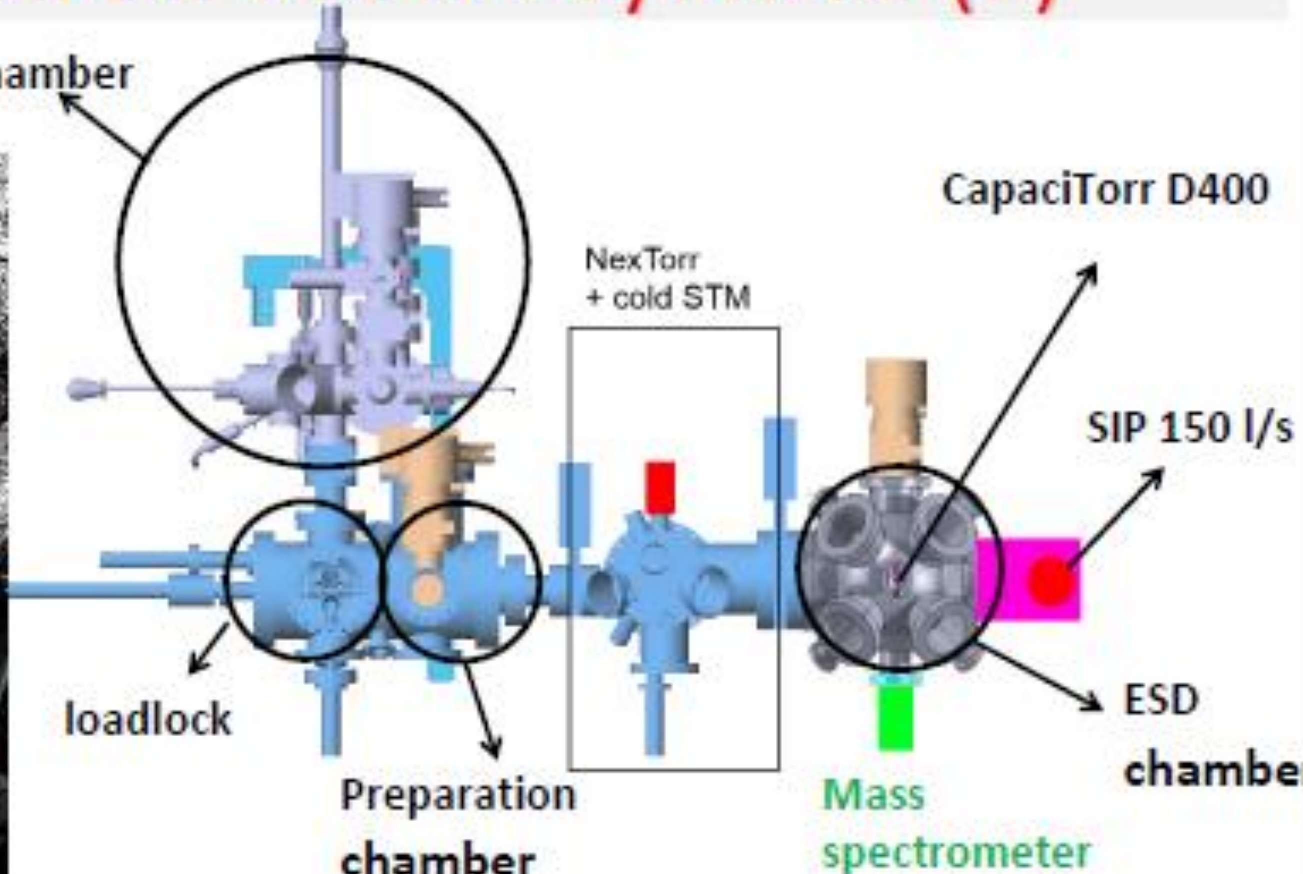
Facility which are using the HV pump

- **JPARC** is using **CapaciTorr HV1600** for the upgrade of the **neutron spallation source**
- **CERN** is using the **CapaciTorr HV2100** for the **ELENA project**
- **FERMILAB** is using the **CapaciTorr HV2100** in the **MICE project**
- **LIGO** project is considering **CapaciTorr HV1600** in the **facility in Louisiana**
- **SLAC** is testing the **CapaciTorr HV1600** in the **mirror chamber** to improve the pumping of long hydrocarbon chains and quickly pumpdown the system
- **Electron microscopes** companies are testing **the CapaciTorr HV200** pump in the **specimen chamber** to fast remove the water entering from the entry lock and environmental microscopes
- In **2016** , first models of **NEXTorr HV will be available**

NEG pumps in surface science

NEXTorr in STM systems (1)

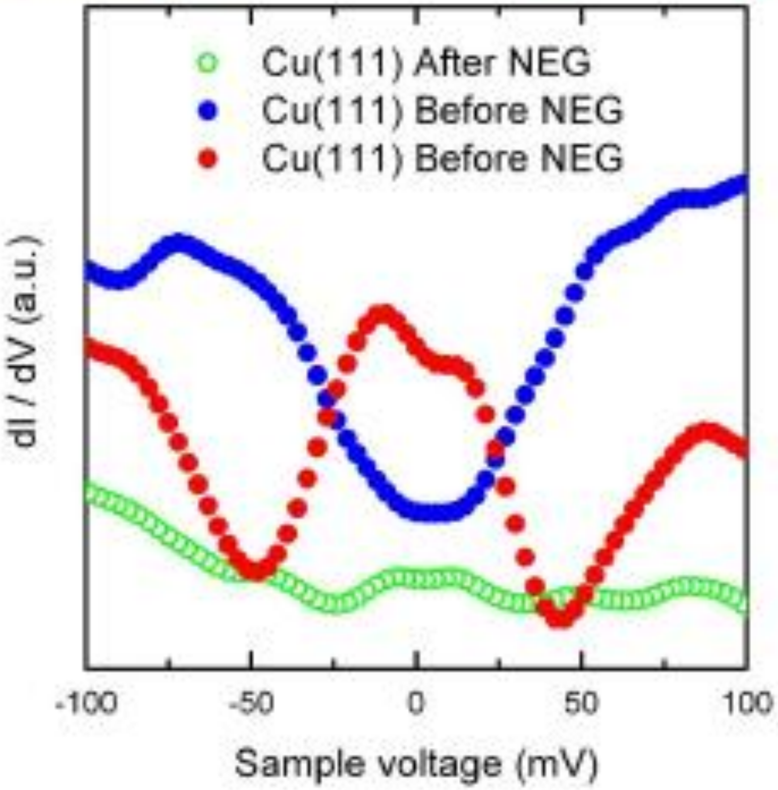




- pressure level in STM chamber below 10^{-10} Torr (pressure indication by NEXTorr SIP)
- pressure level in the ESD chamber close to 10^{-10} Torr
- the NEXTorr D-200 is the only pump present in the STM chamber

Courtesy of University of Hamburg (Dr. Bazarnik, group of Prof. Wiesendanger)

NEG pump in STM systems (3)



front

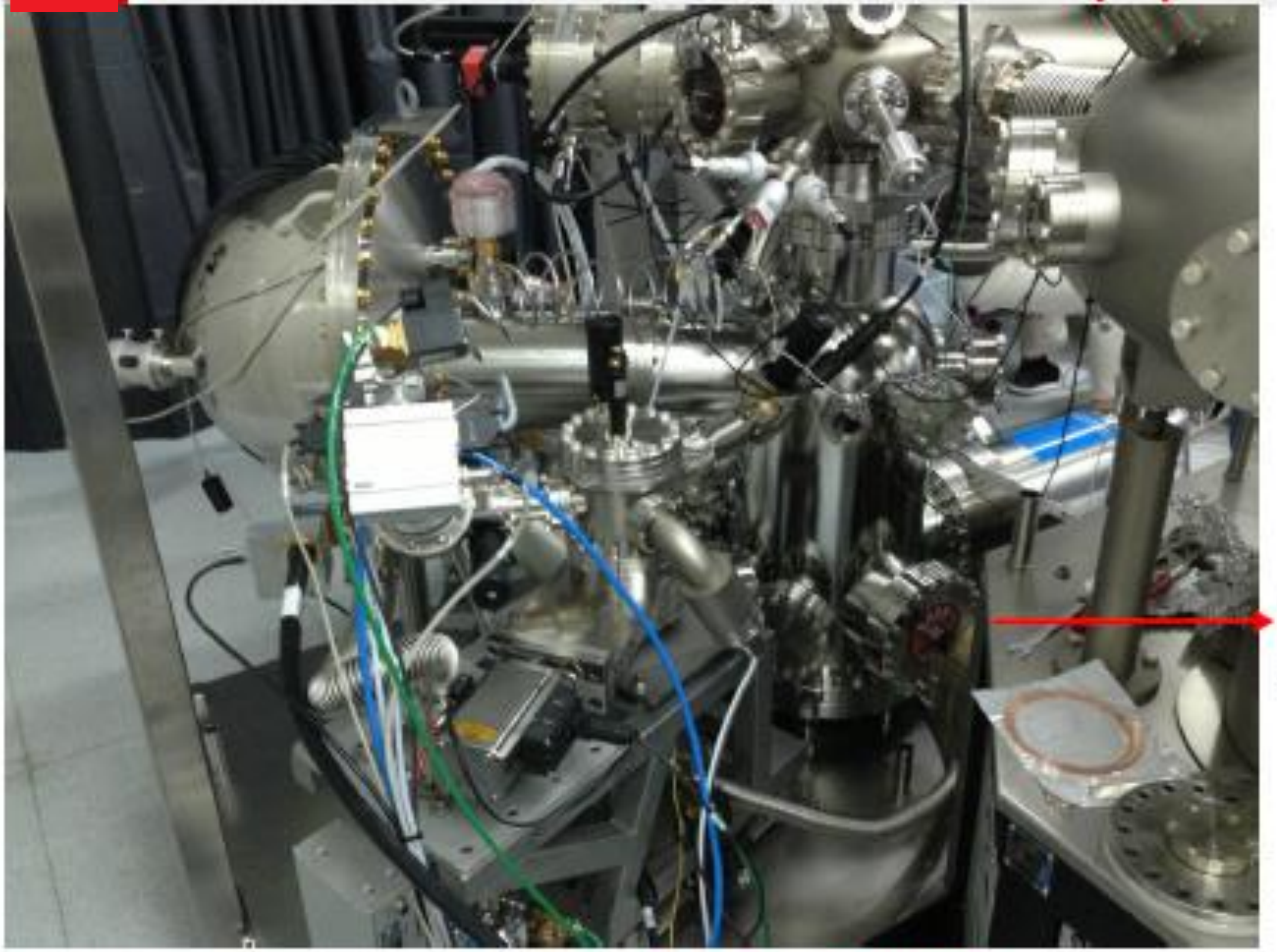
back

NEG pump: CF150 – 1900 l/s H_2

After using NEG pump, the H_2 features close to the Fermi Level disappeared!

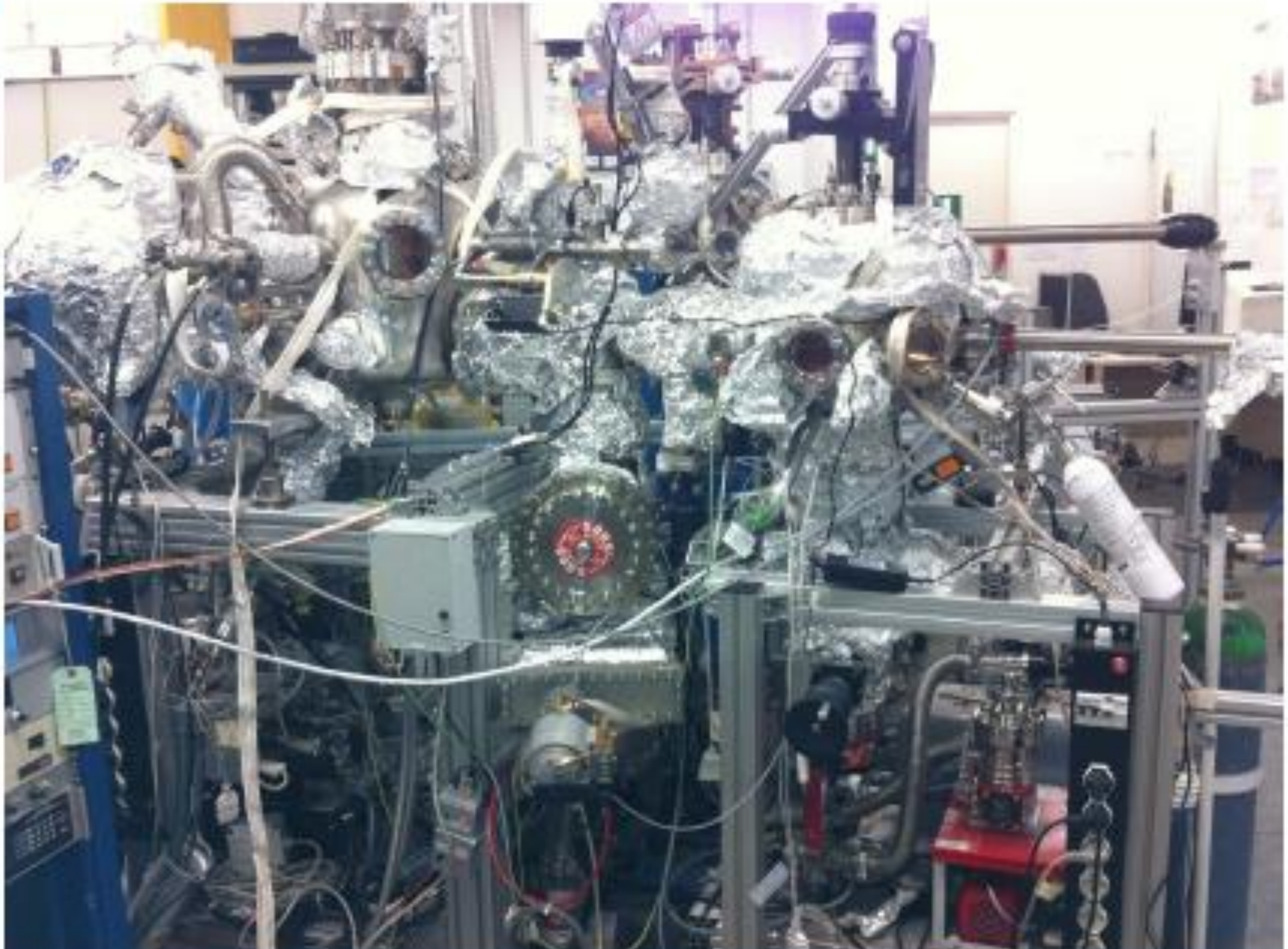
Courtesy of University of Kiel (Dr. Schoeneberg, group of Prof. Berndt)

NEG in ARPES (1)



Capacitorr D-2000: 2000 l/s H_2

NEG in AES



A Capacitorr D-2000 is used in this complex AES system (courtesy of CNR Frascati, Italy)

Other examples (1)

Radial Distribution Chambers (UFO) with a NEXTorr D-500 activated during the baking process, 16h @150°C – 2 days after the baking the P is 6*10^-11 mbar

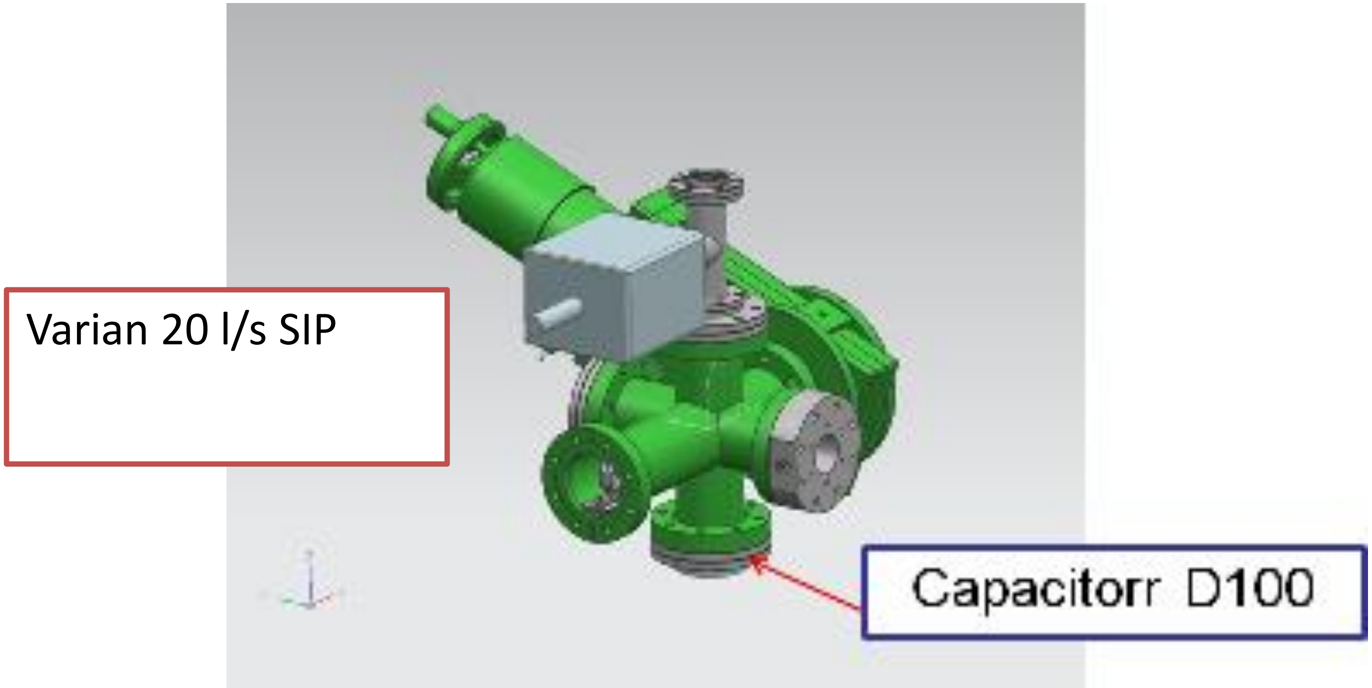
Other examples (2)

NEXTorr D-500 activated after the baking process, 72h @150°C –
Pressure in the 10^-11 mbar range

Courtesy of Elettra (Lab TASC, Trieste – CNR – Ultraspin project, magnetic materials characterization)

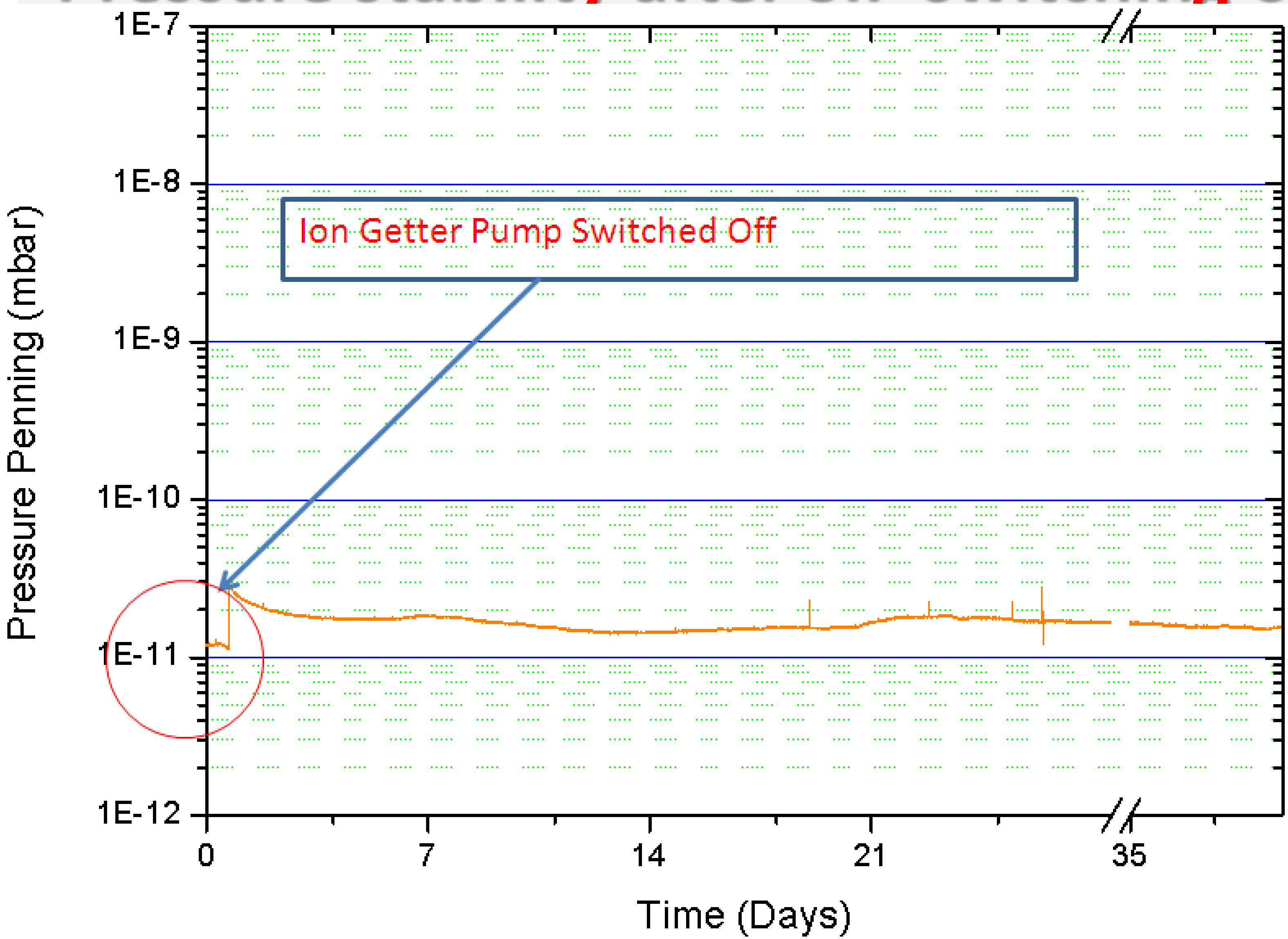
Sample Transfer Suitcases

New pumping system based on NEG and a small ion pump

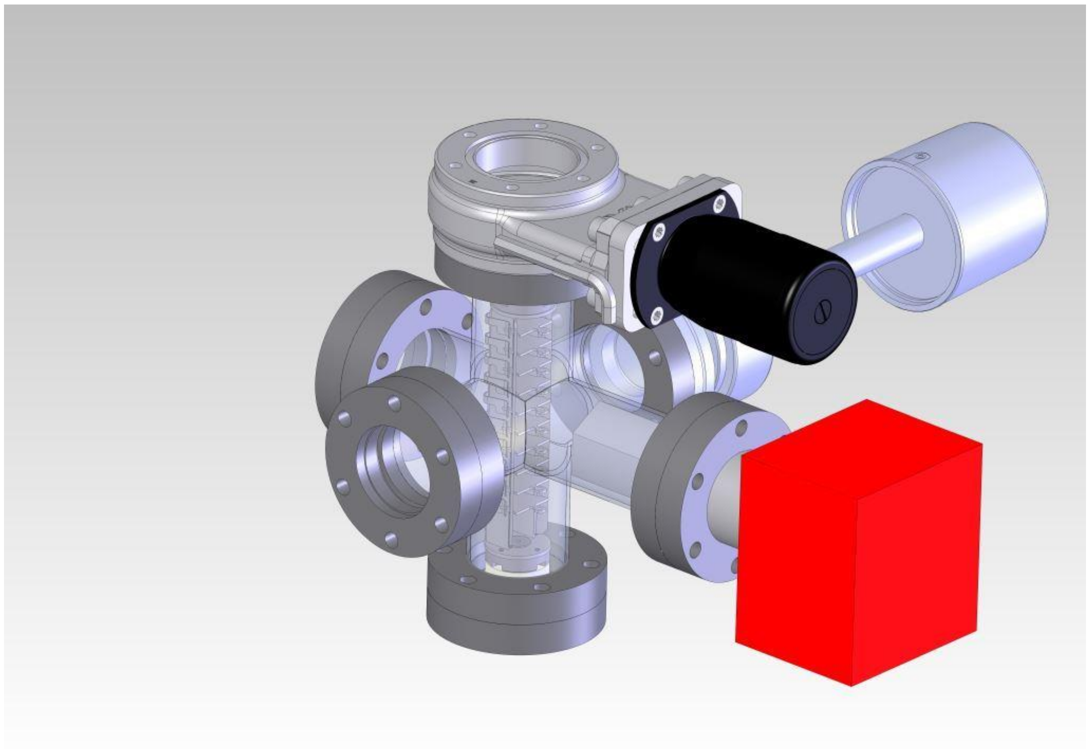


D. Sertore, P. Michelato, L. Monaco, P. Manini and F. Siviero, J. Vac. Sci. Technol. A, 32 (3), 31602 (2014)

Pressure stability after SIP switching off



Suitcase for transportable samples



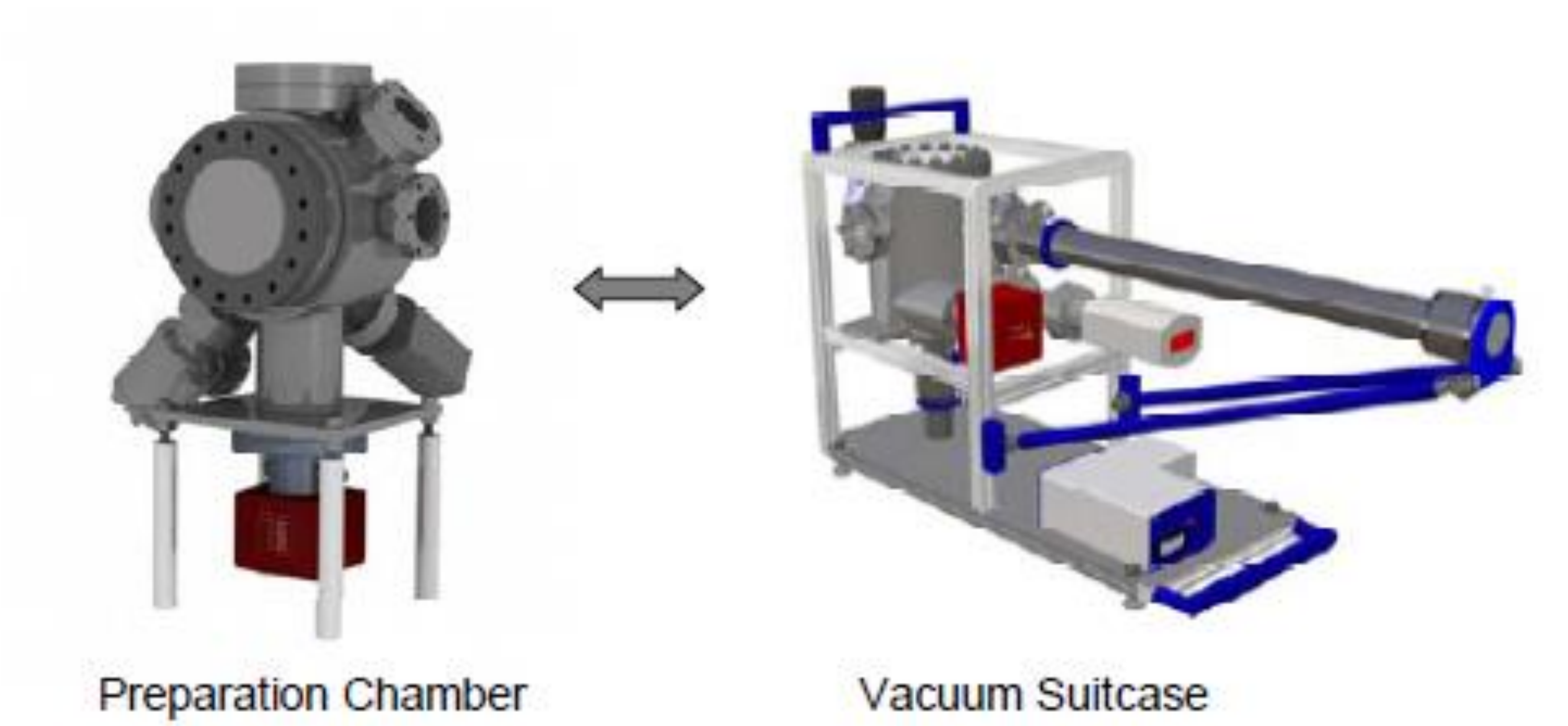
UHV suitcase used to transport perovskites samples under UHV (University of Amsterdam)

Photoinjector-photocathodes applications

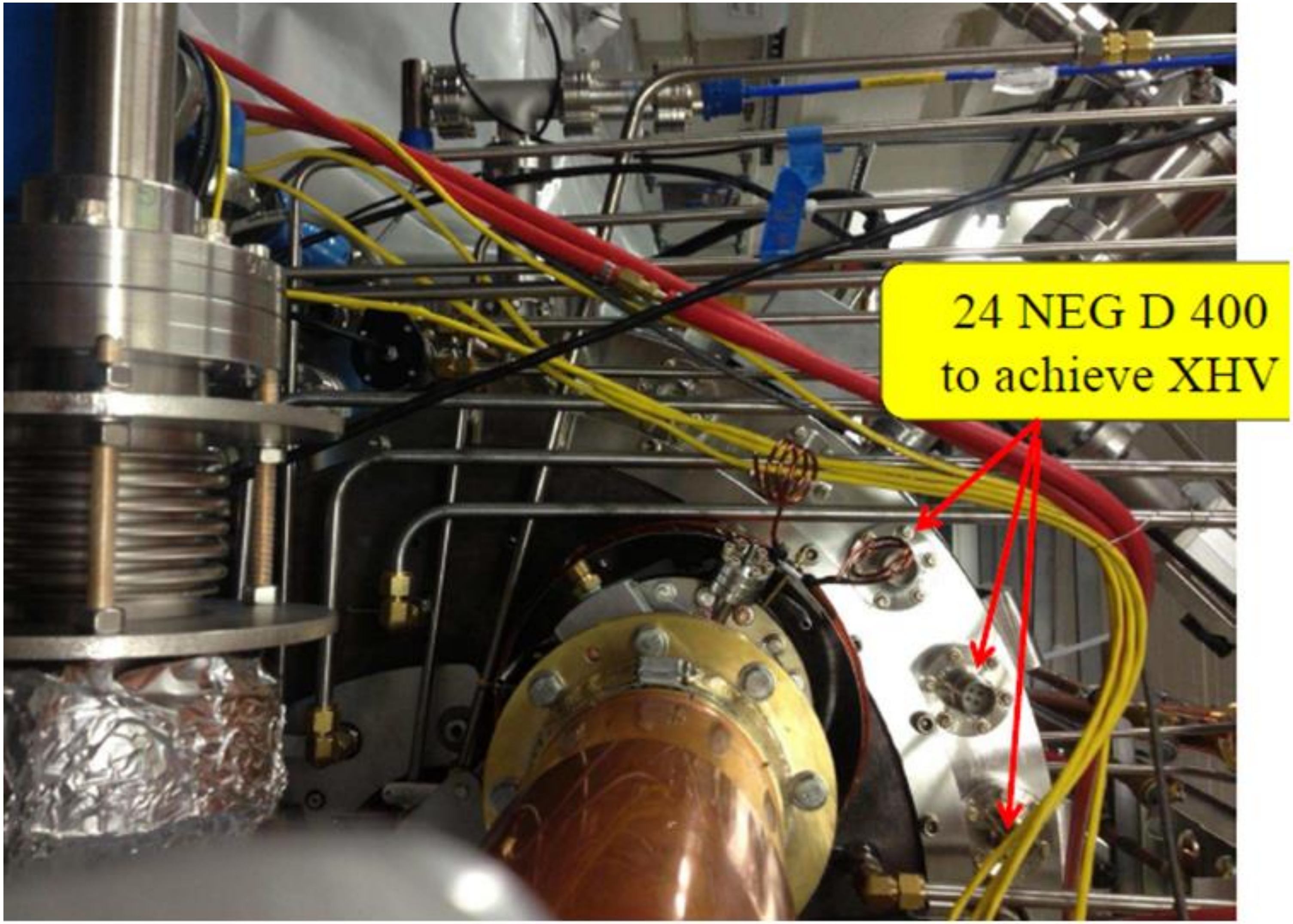
Photocathodes in FEL

- The advent of FEL represented a big opportunities in accelerator facilities in terms of peak photon beam brightness and time resolution compared to Synchrotrons
- In FEL the main aspect is to have large electron gun brightness
- The photocathodes are extremely sensitive to moisture and H2 and their lifetime is strictly depending on the pressure level
- Also the quantum efficiency (ability to produce electrons) strictly depends on the vacuum level

SWISS FEL



APEX photoinjector (LBNL)



FERMI @ ELETTRA project

Poster IVC 2013

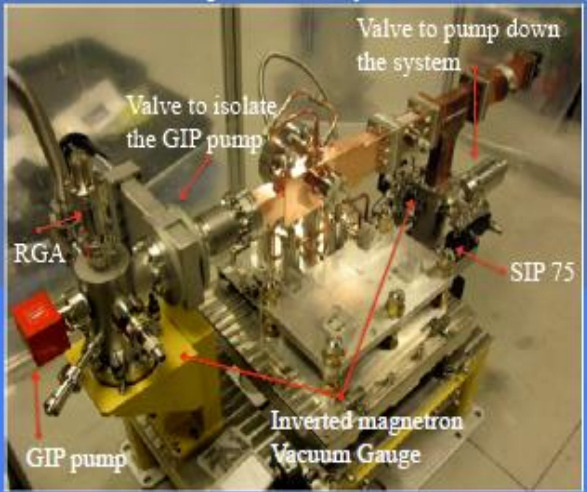
A simplified vacuum system for the new PC gun in the FERMI@Elettra project.

L. Rumiz, I. Cudin, E. Mazzucco, G. Pangon, M. Trovò, F. Zudini.
ELETTRA Sincrotrone Trieste S.C.p.A. - Trieste (Italy).

Corresponding author: Luca.Rumiz@elettra.eu

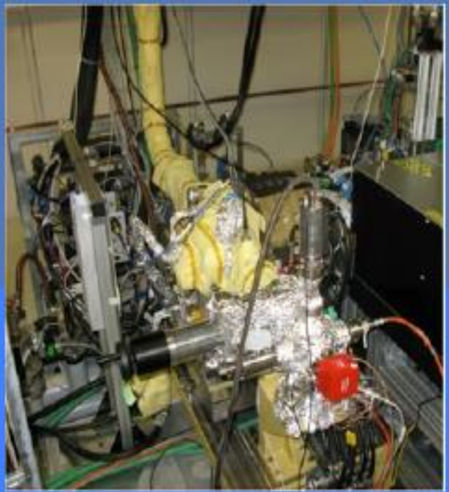
The new PC-Gun

A simpler vacuum system…



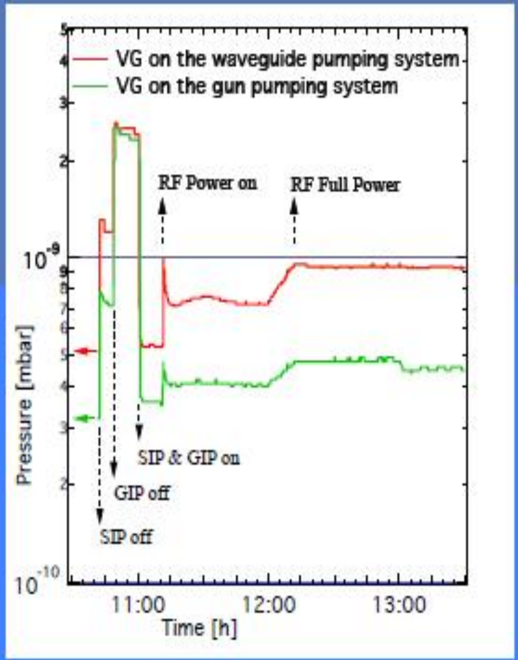
Thanks to our previous experience and to the avaibility of a new compact UHV pump which integrates a NEG and an ion pump, a simpler vacuum system was designed

…after the final installation!



When all auxiliary plants were installed, the space around the gun resulted truly accessible.

Vacuum performance



Switching on & off GIP &SIP: the NEG modules of GIP is able to keep the total pressure in the UHV range .

When it was necessary to upgrade the PC-Gun in order to increase the repetition rate to 50 Hz, it was necessary to change the vacuum system, too. Thanks to a new, compact and light vacuum pump which combines a 200 l/s NEG pump and a 6 l/s diode ion pump together (GIP 200), it is now possible replace effectively 2 large, heavier UHV pumps. The 75 l/s SIP installed on the waveguide and the GIP act as the main pumps of this new gun; the GIP is also an "emergency" pump in case of mains failure, thanks to its NEG module. It can be separated from the gun by a manual gate valve when a gun maintenance or a cathode cleaning process are required. Two inverted magnetron vacuum gauges (VG) are installed, one VG for each gun arm. The whole system is bakeable up to 120-150 °C.
This pumping system is able to keep the pressure in the 10^{-10} mbar range when full power (8 MW) radiofrequency is applied, and in the 10^{-9} mbar range when electrons are extracted from the mirror finished OFHC copper cathode. A quantum efficiency of $5 \cdot 10^{-5}$ e-/ph is usually achieved after a laser or ozone cleaning process. A bunch charge of 500 pC is normally extracted from a spot on the cathode of about 1.2 mm in diameter using a 40μJ pulse of a 260 nm laser.

Thanks for your attention

saes getters

www.saesgetters.com

Multicontroller of NEG pumps: NEG POWER

-NEG POWER can contemporary activate up to 4 NEG pumps, including the Neg elemnts of NEXTorr
-NEG POWER can be remotely controlled through RS232/RS485 and LAN
-touch-screen display

NEG POWER characteristics

- one for all
-

GP series

- GP 50
- GP 100
- GP 200
- GP 500
- GP 500-SP8

CapaciTorr

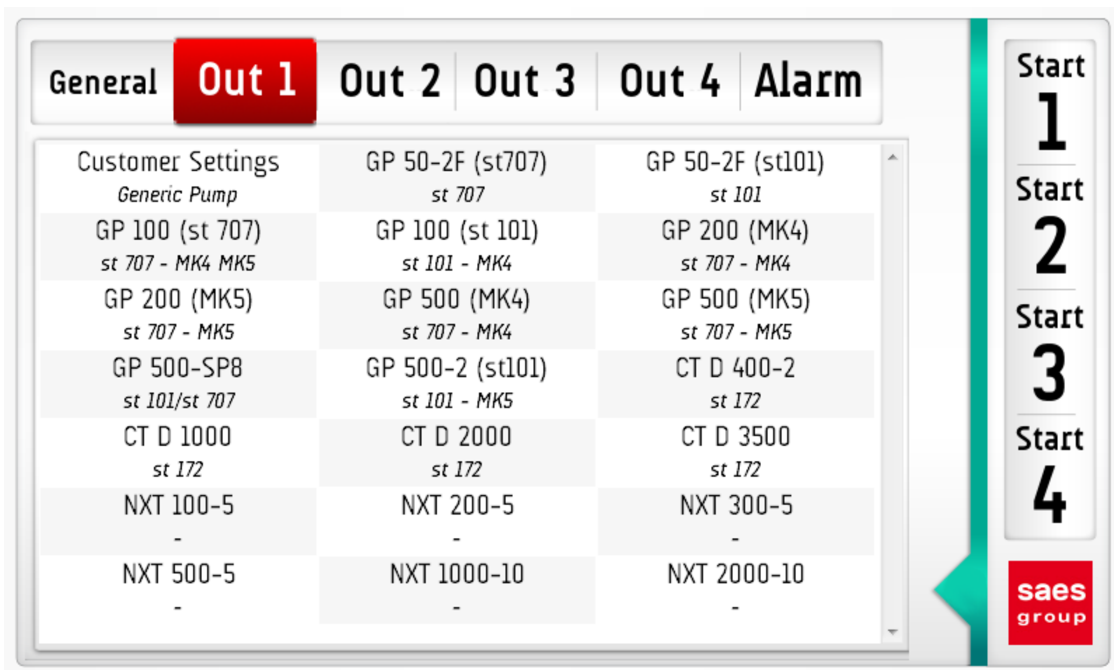
- CT D400-2
- CT D1000
- CT D2000
- CT D3500

NexTorr

- NXT 100-5
- NXT 200-5
- NXT 300-5
- NXT 500-5
- NXT 1000-10
- NXT 2000-10

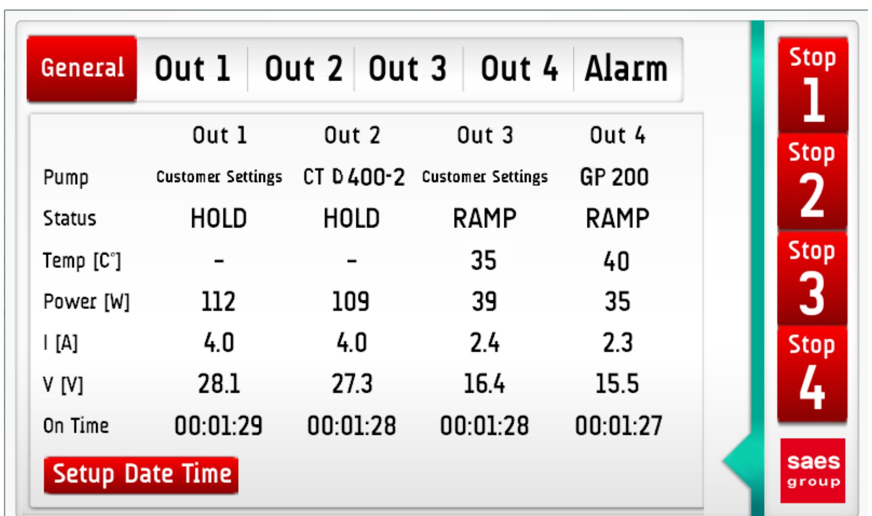
NEG POWER characteristics

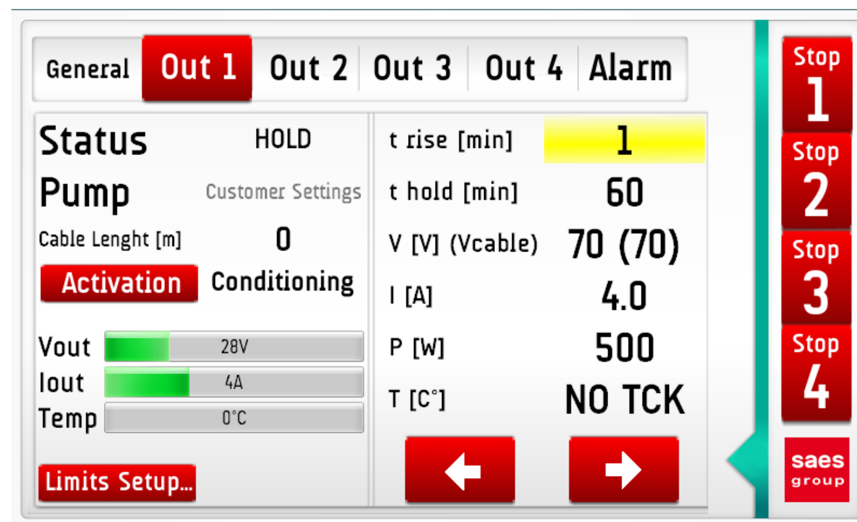
- multicontroller (4 outputs)
- pumps pre-settings



NEG POWER characteristics

- large scale of power : 0-700 W
- settings :
  - rising time, hold time
  - voltage, current, power
  - temperature



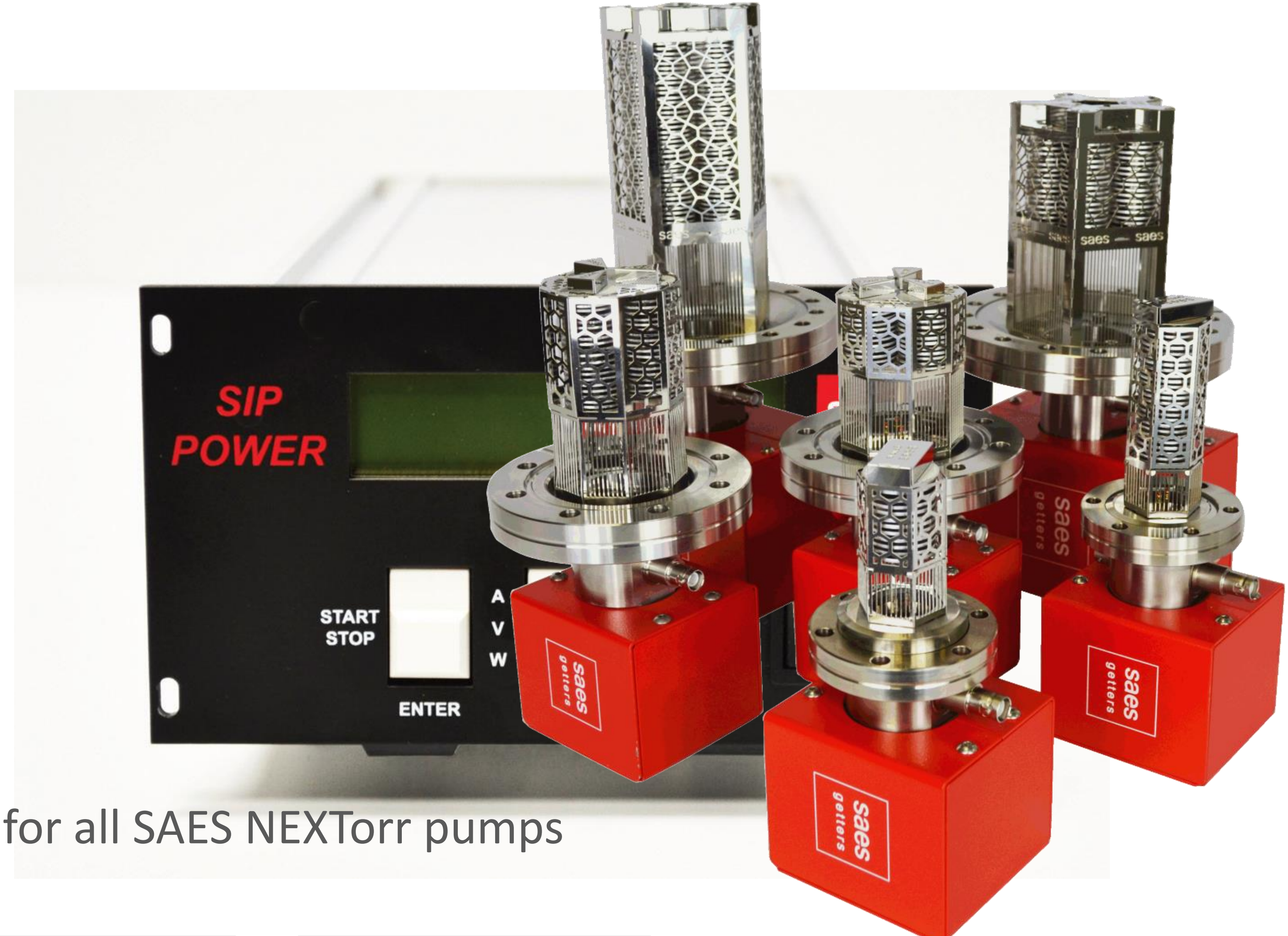


NEG POWER characteristics

- linux PC
- LAN interface and RS232/RS485 interface

NEXTorr ion pump controller: SIP POWER

SIP POWER – the ION pump power supply



- for all SAES NEXTorr pumps

SIP POWER dimensions

- SIP POWER dimensions are Subrack 3U 14 TE

making innovation happen, together

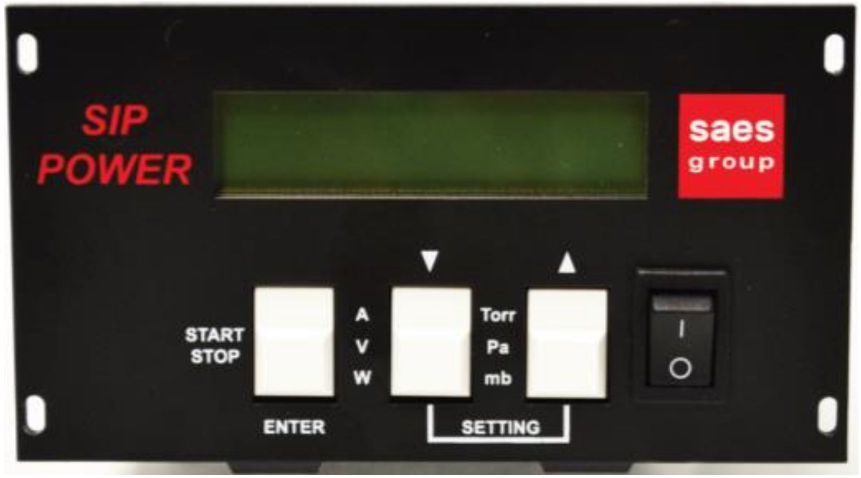
SIP POWER stays in a hand

SIP POWER weight

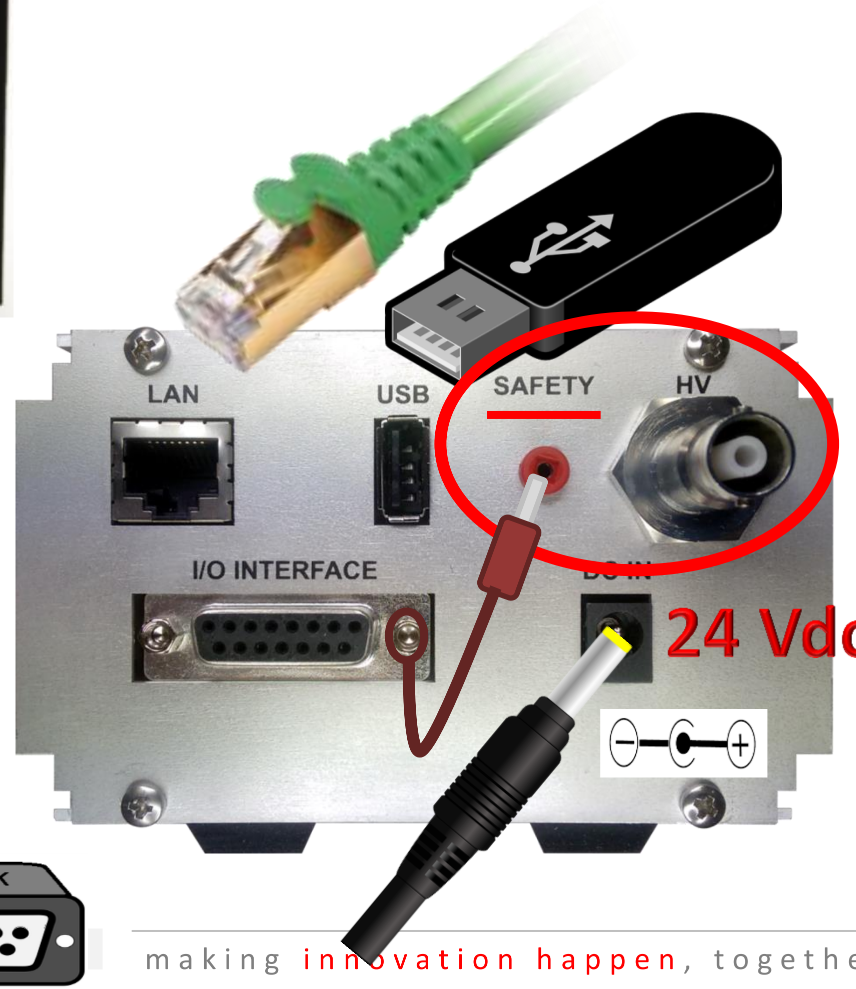
- SIP POWER weigths

just …

SIP POWER connections



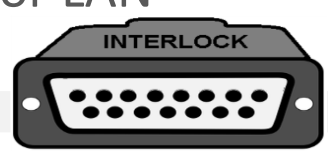
- SIP POWER connections are on the back side



- MAIN INPUT 24 Vdc
- OUTPUT to pump high voltage
- SAFETY pin for HV
- IN / OUT INTERFACE

with INTERLOCK signal

- USB for flash memory
- ETHERNET connector for LAN



SPECIFICATIONS

Complete unit

- Input voltage 24 Vdc
- Maximal input current 2 A
- Weight 1 kg
- Ambient temperature at operation 5÷40 °C
- Relative humidity 20÷80 %

Outputs

- 4× current comparators-switches* on: Z = 13±2 Ω
  positive feeding voltage +5 V / 20 mA
  negative terminal GND
- ** max. voltage between switched off terminals 30 V*
- *max. current through connected terminals 100 mA*

Inputs

- interlock enable input 2–10 mA / 2 kΩ

Communication interface

- Ethernet standard interface
- RS485 38400 Bd, 8 data bits, 2 stop-bit

IP Section

- Pump output (HV) connector BNC (HV)
- Nominal output voltage 5 kV±2 %
- Range of adjustment 1÷6 kV
- Output voltage polarity positive
- Maximum output current 65mA @ 350Vdc
- Obtainable output power 25–35 W

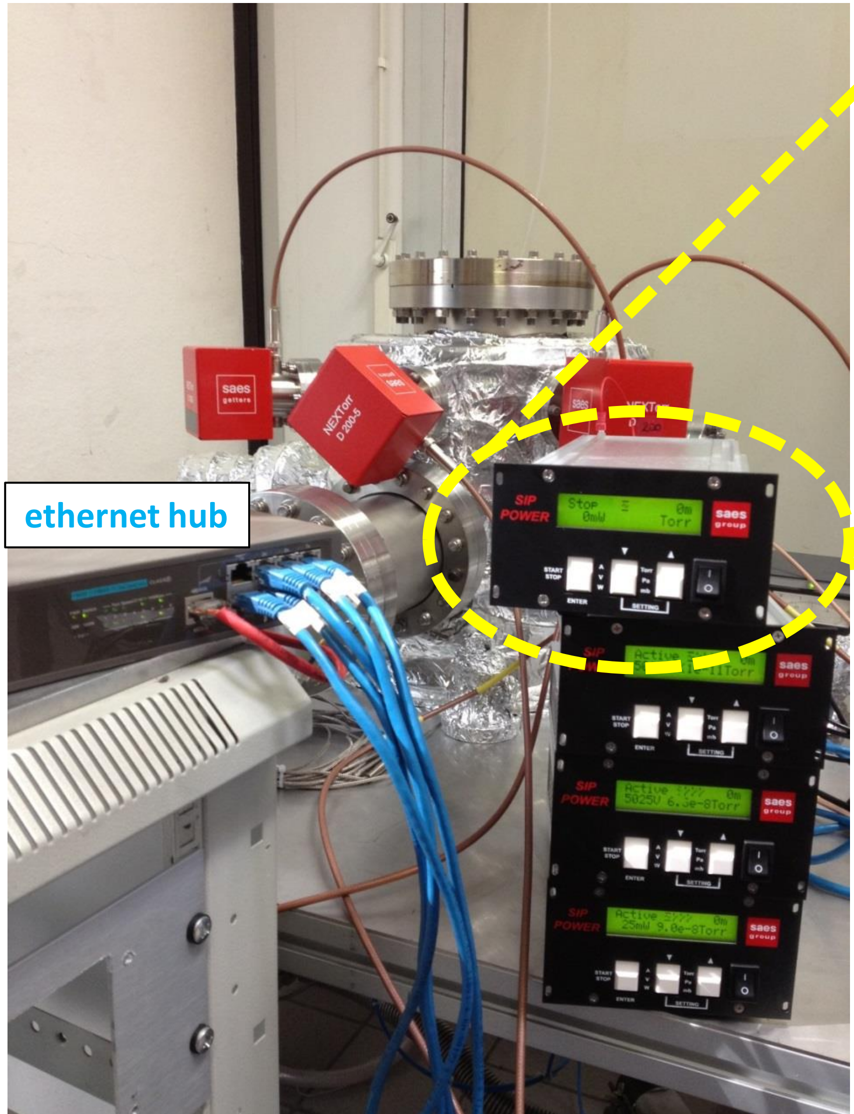
Output Protections

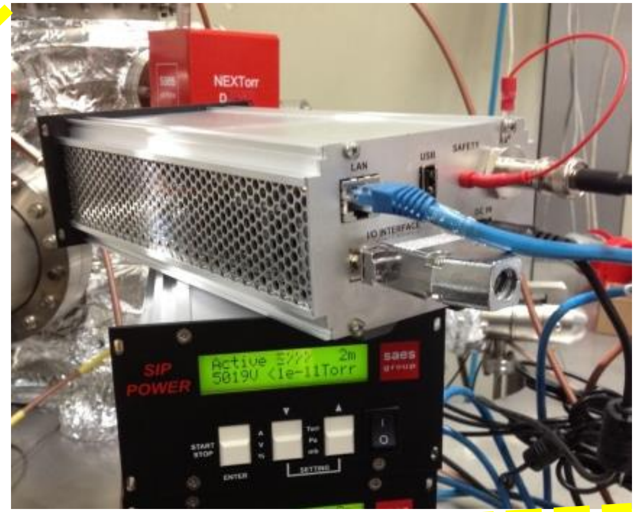
- Current electronically limited at 3.0 A (@ 6kV)

SIP POWER remote controller

rsus multi-controller

SIP POWERs cabling example

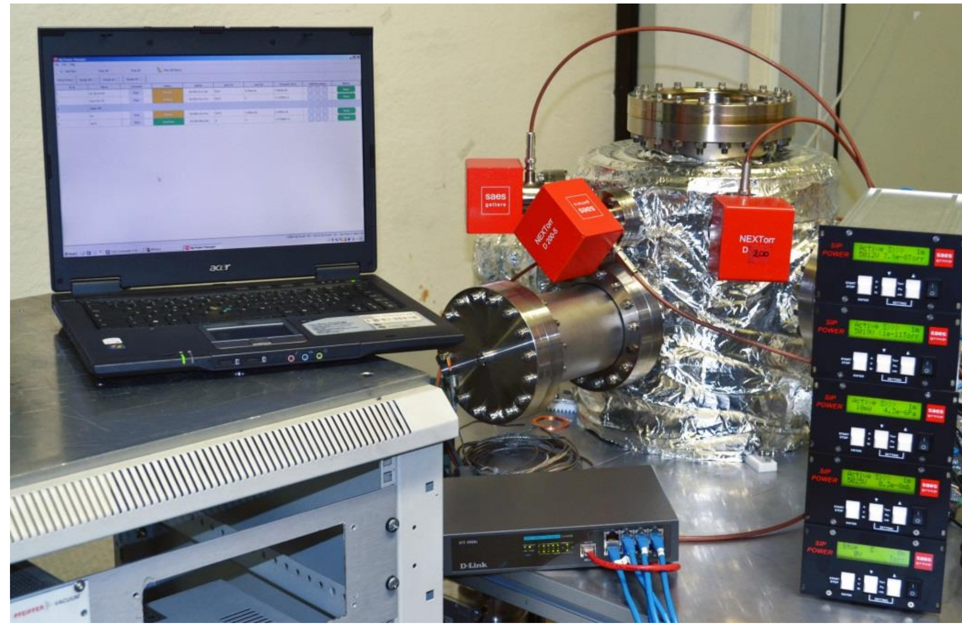




- Example of a vacuum system installing 4 NEXTorr pumps. Every SIP pump is connected to its own SIP POWER controller
- The SIP POWERs are connected through the LAN port to a ethernet hub
- The ethernet hub is then connected to the PC

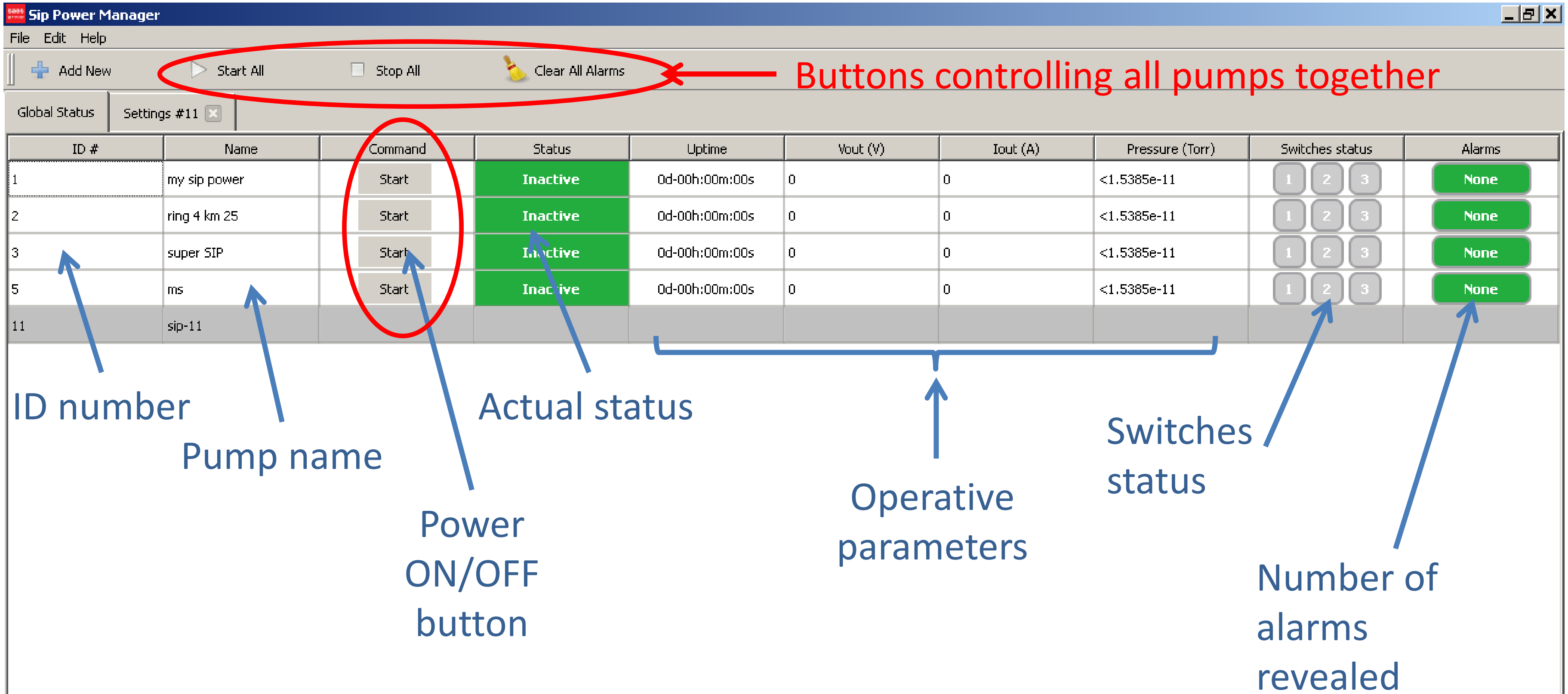
SIP POWER multicontroller : real example

- Many *SIP POWER* power supplies can be remotely controlled by a single PC through ethernet protocol
- The power supplies can be connected to a single ethernet hub that is connected to a PC itself
- A dedicated pc software is used to activate the pumps and monitor their parameters in realtime

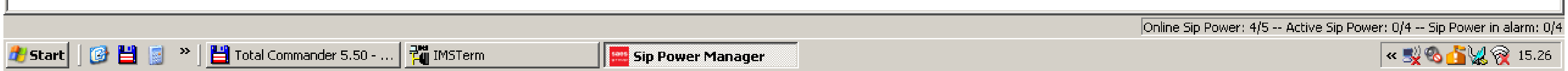


- the SAES PC software is named
  SIP POWER MANAGER
- it can control up to 128 SIP POWERs at the same time

SIP POWER MANAGER software: main screen



- It is possible to select a limited collection of power supplies and control them together
- Multiple instances of the software are allowed on the same pc



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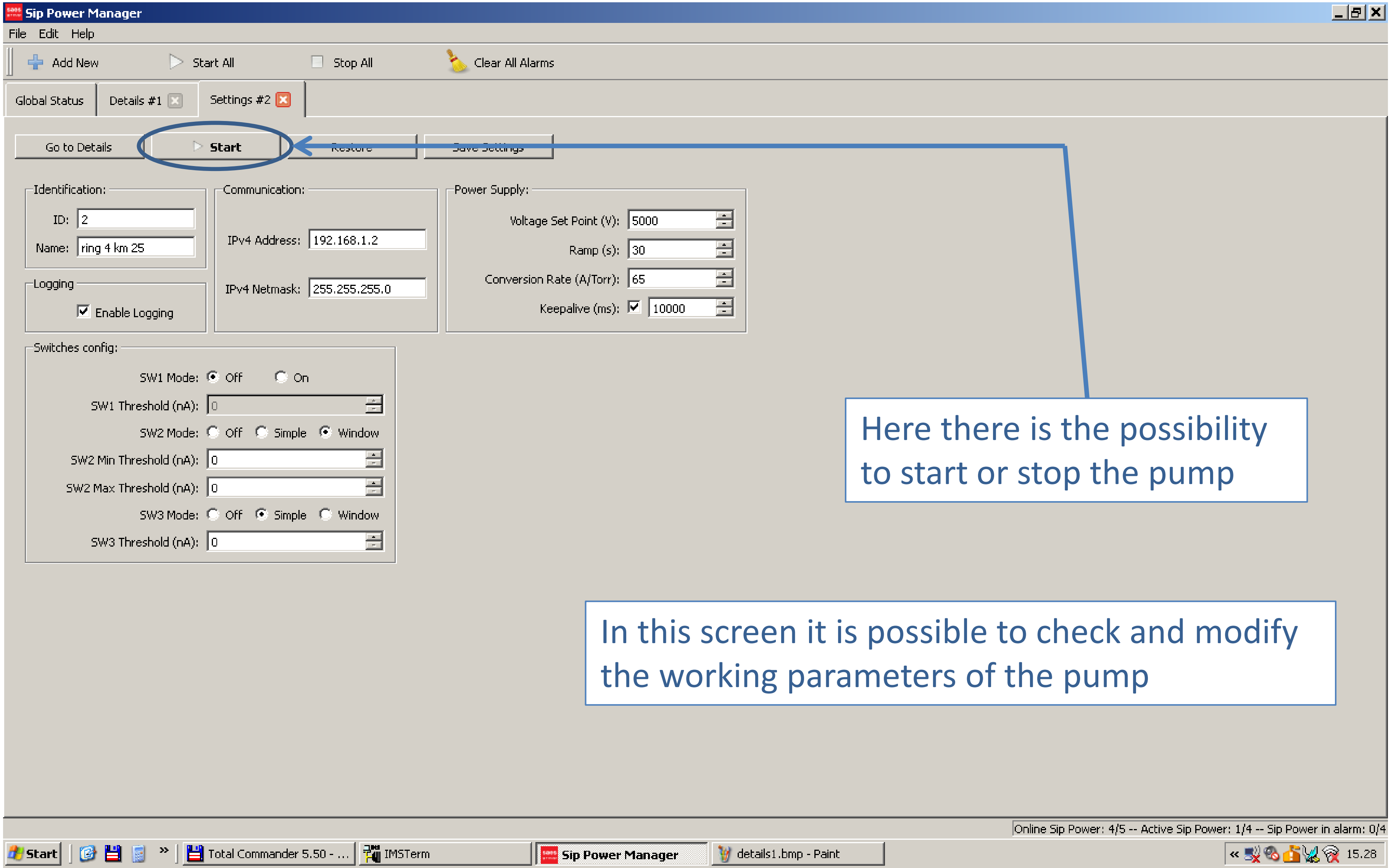
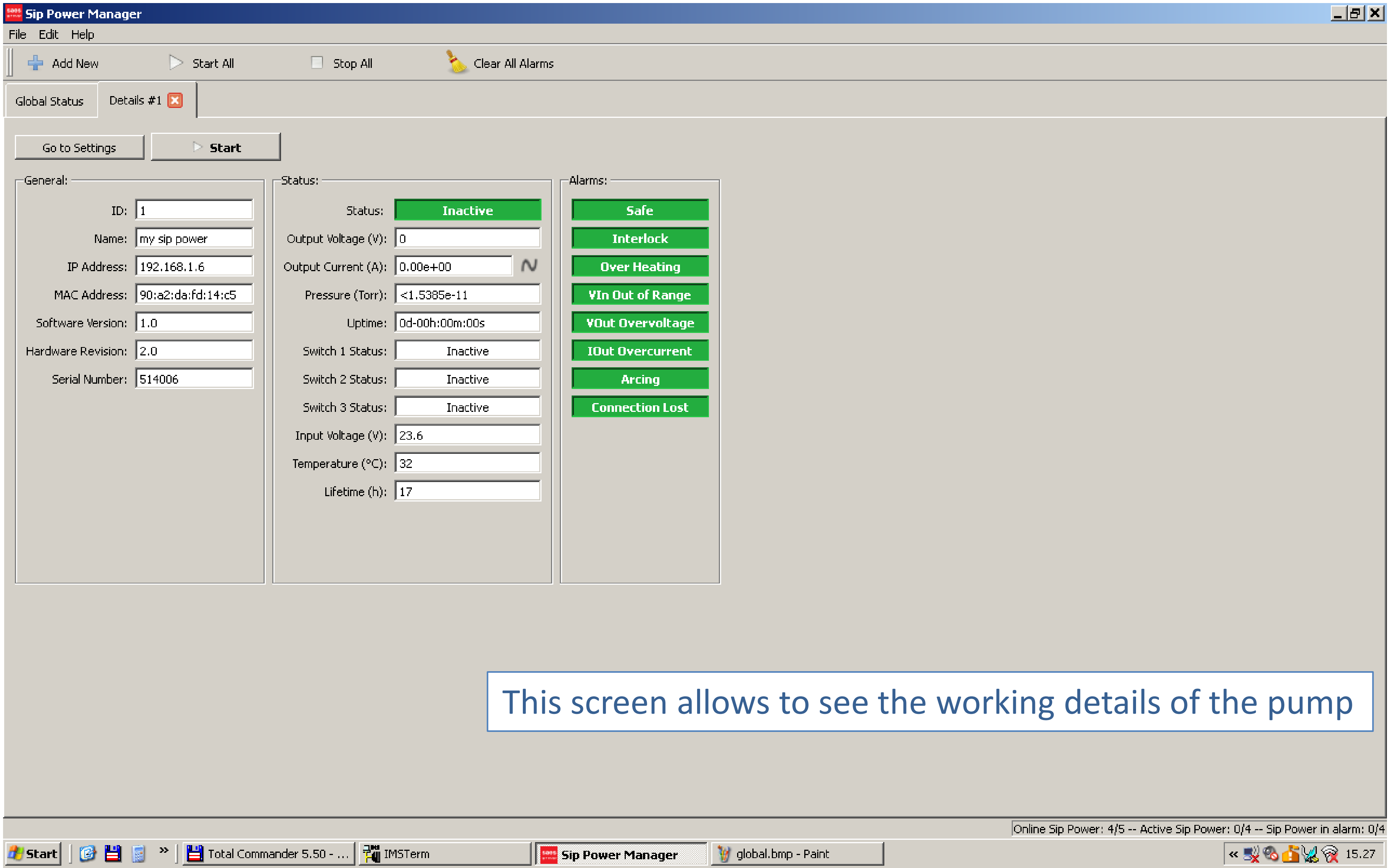
SIP POWER MANAGER software: pump settings screen



Here there is the possibility to start or stop the pump

In this screen it is possible to check and modify the working parameters of the pump

SIP POWER MANAGER software: pump operation screen



This screen allows to see the working details of the pump

NEG pumps and TMP: shorter pump down

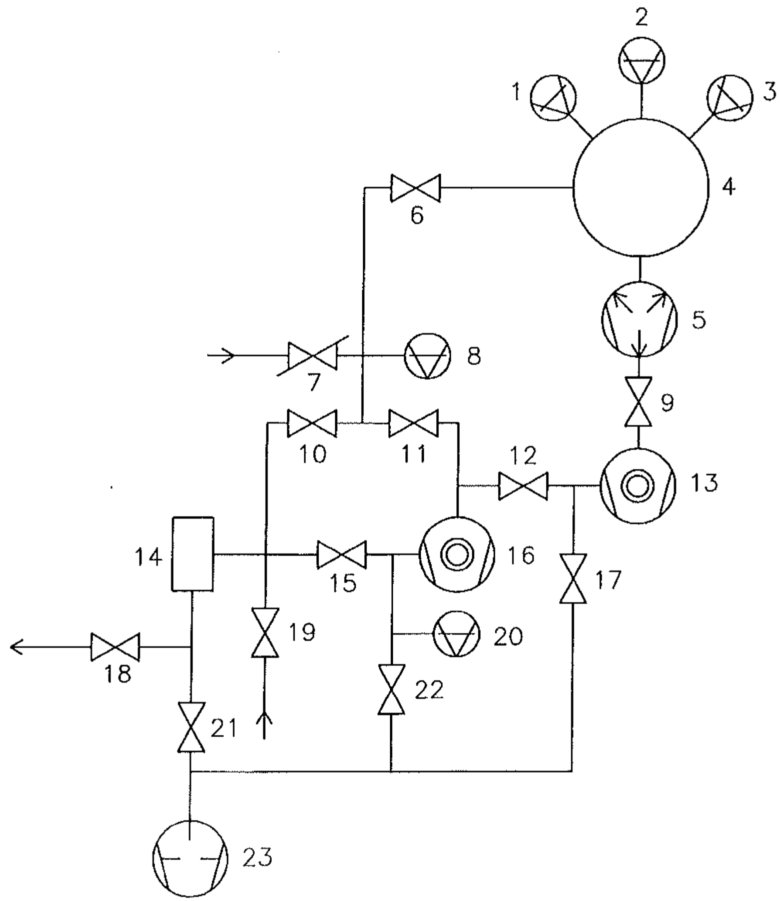


Fig. 1. Layout of the experimental apparatus. 1 = Bayard–Alpert gauge; 2 = extractor gauge; 3 = quadrupole mass spectrometer; 4 = vacuum chamber; 5 = In-line NEG pump; 6, 10–12, 15, 17–19, 21, 22 = valves; 7 = micrometric leak valve; 8, 20 = Pirani gauges; 9 = gate valve; 13 = TMP M; 14 = catalytic trap; 16 = TMP B; 23 = rotary vane pump.

- Chamber of 40 l, 6000 cm^2
- 2 TMPs are installed
  - Nr 13 is 600 l/s
  - Nr 16 60 l/s
- NEG pump is installed of 800 l/s (Nr. 5 in the figure)

R. Giannantonio et al.,
Combination of a getter pump with TMPs in UHV,
Vacuum, 55, 27 (1999)

NEG pumps and TMP: shorter pump down

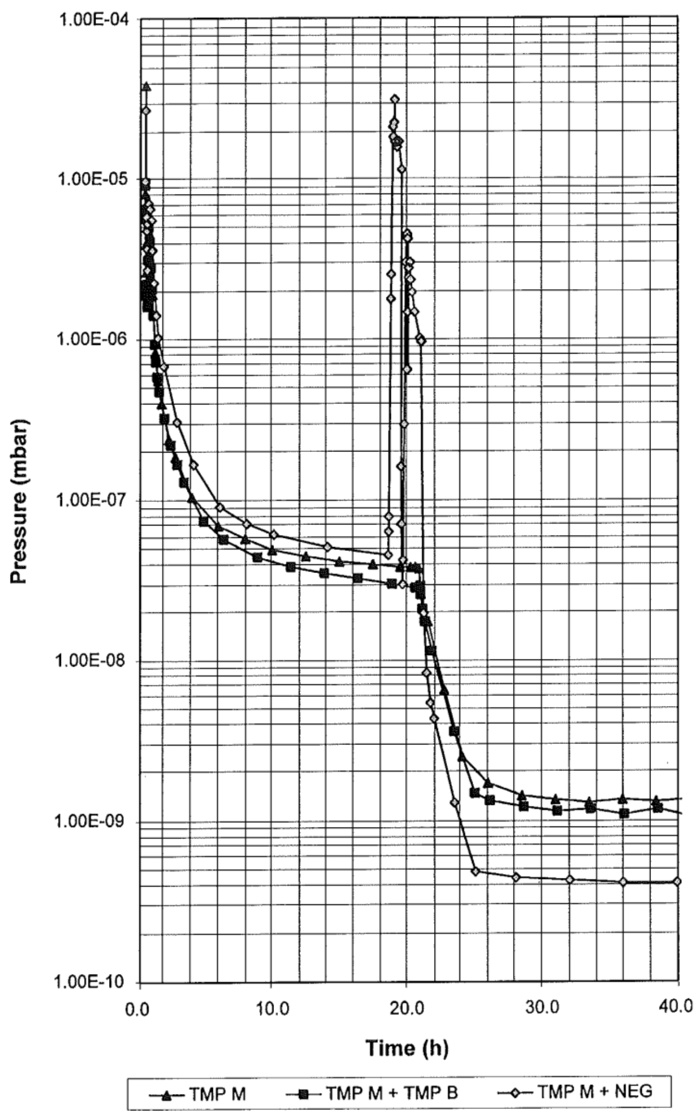
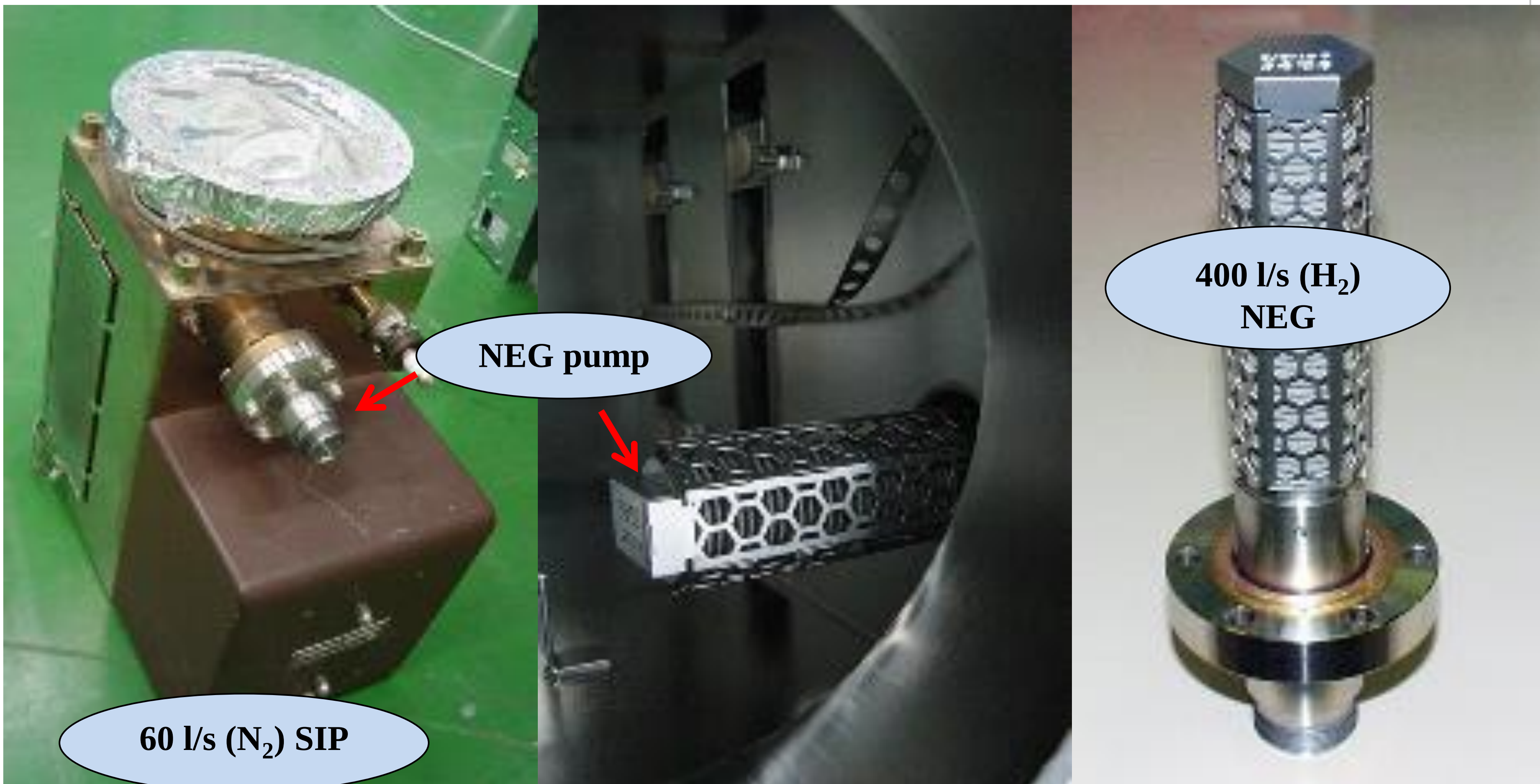


Fig. 4. Total pressure vs. time profiles for different system configurations.

- Use of NEG pump allows to get lower pressure level
- The pressure improvement related to H_2 decrease
- The NEG pump is suitable solution to cope H_2 back streaming

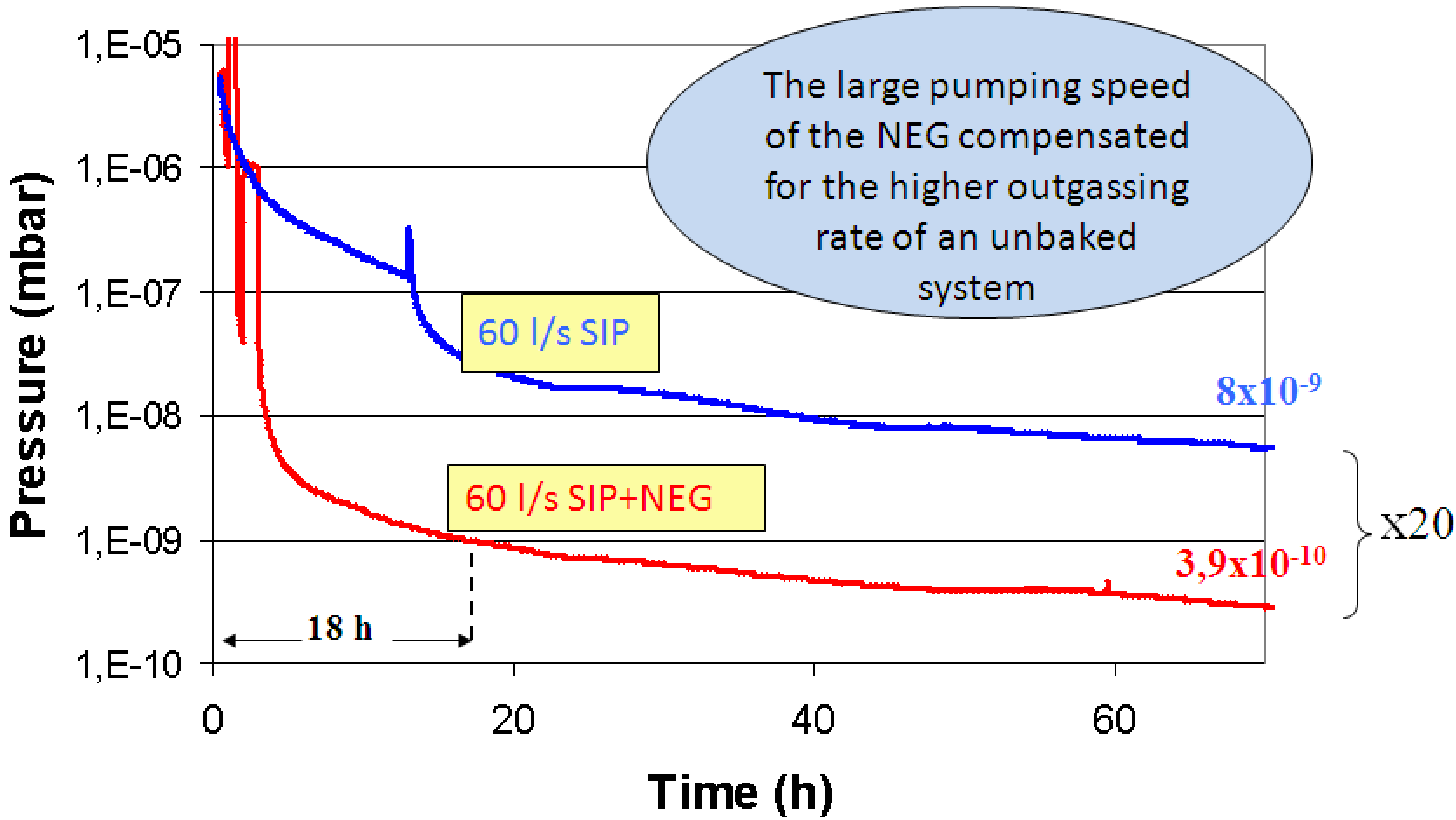
R. Giannantonio et al.,
Combination of a getter pump with TMPs in UHV, Vacuum, 55, 27 (1999**)**

Reducing the SIP size



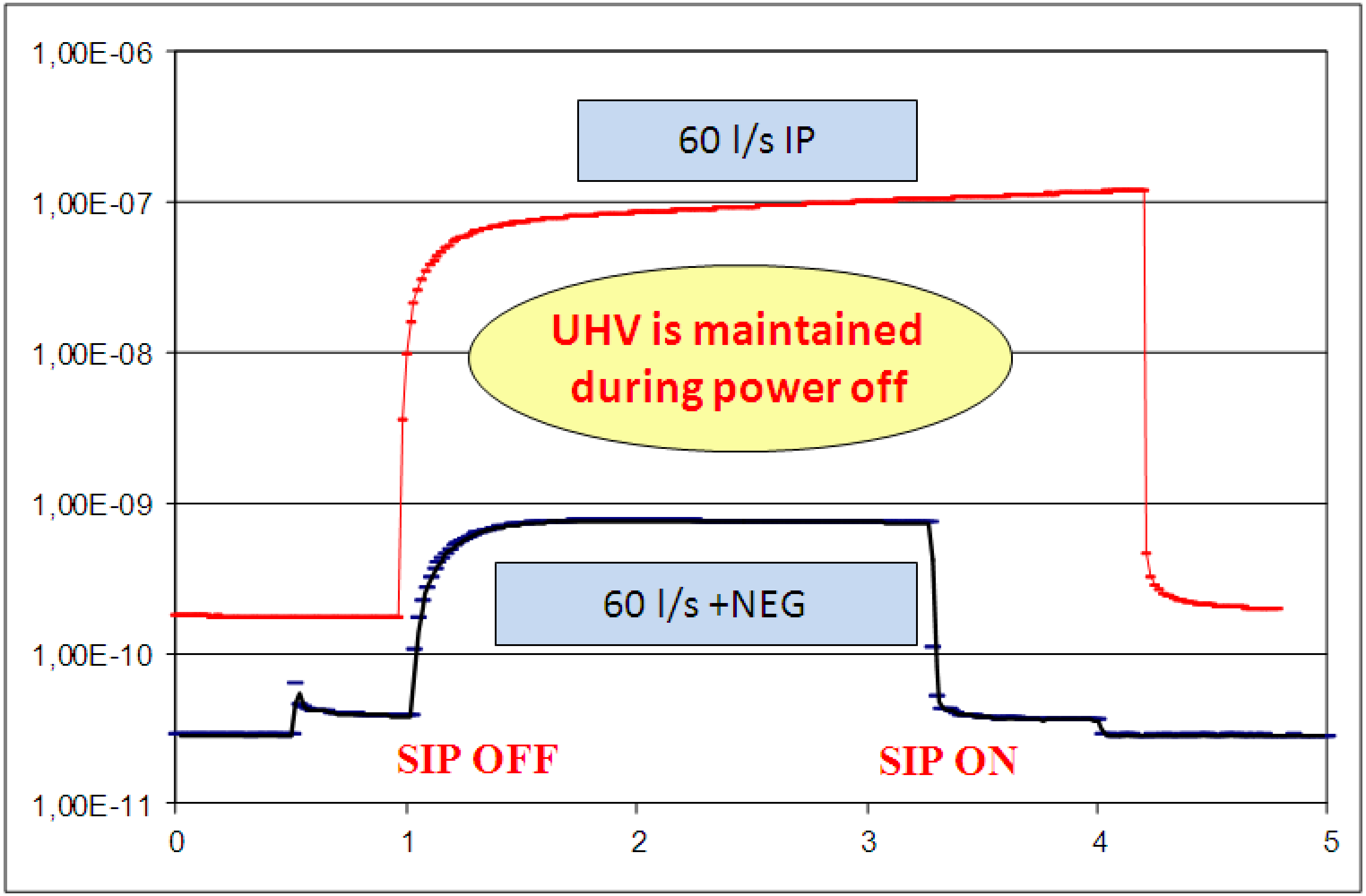
C.D. Park, S.M. Chung and P. Manini, J. Vac. Sci. Technol. A, 29 (1), 11012 (2011)

Shorter pump down (No baking)



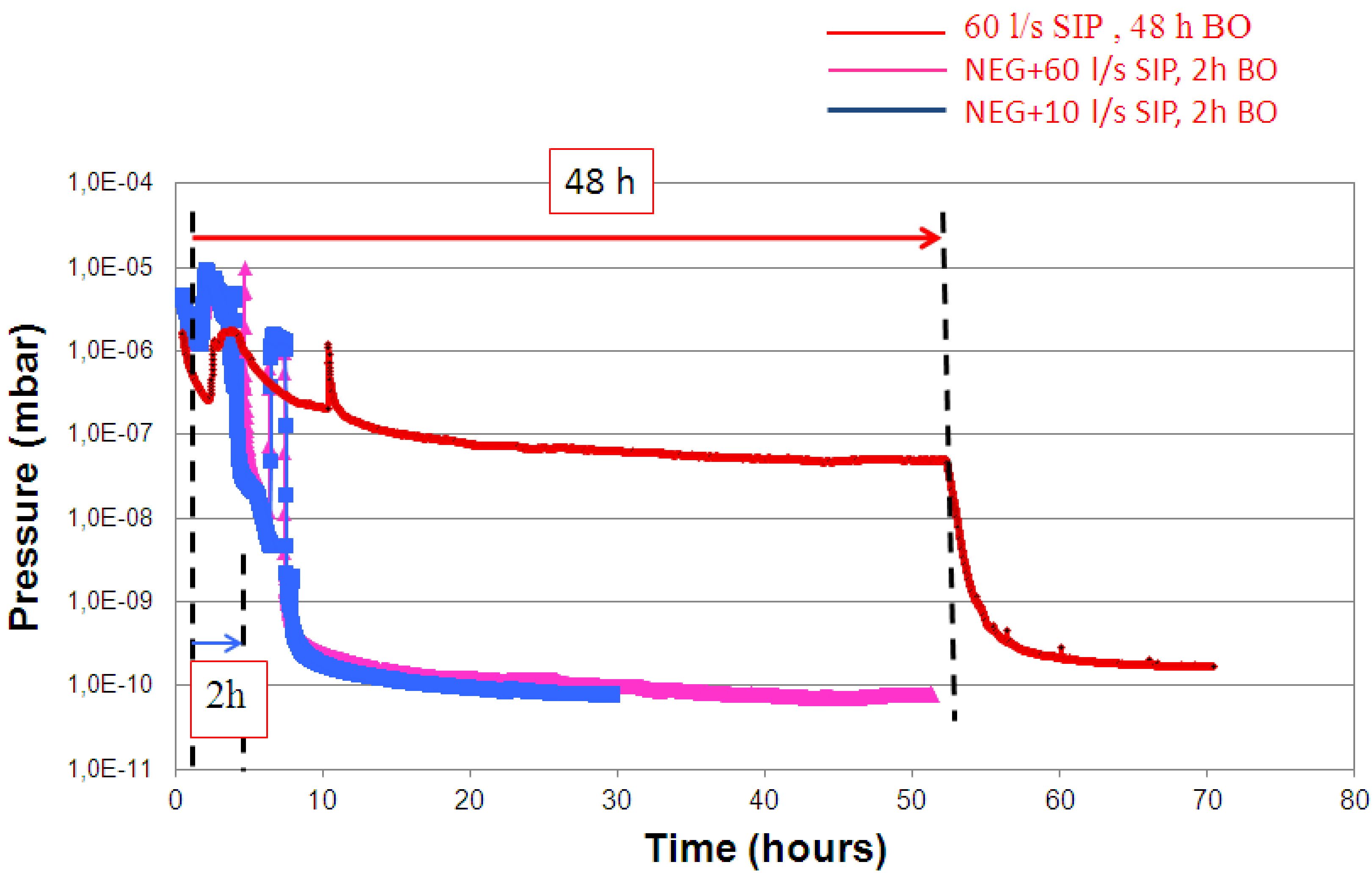
C.D. Park, S.M. Chung and P. Manini, J. Vac. Sci. Technol. A, 29 (1), 11012 (2011)

Rate of Rise tests (ion pump off)



C.D. Park, S.M. Chung and P. Manini, J. Vac. Sci. Technol. A, 29 (1), 11012 (2011)

Reducing the SIP size (2)



C.D. Park, S.M. Chung and P. Manini, J. Vac. Sci. Technol. A, 29 (1), 11012 (2011)

Reducing the SIP size

- In this study no pressure difference was measured when reducing the SIP speed from 60 l/s to 10 l/s, being the NEG the main factor to achieve ultimate vacuum.

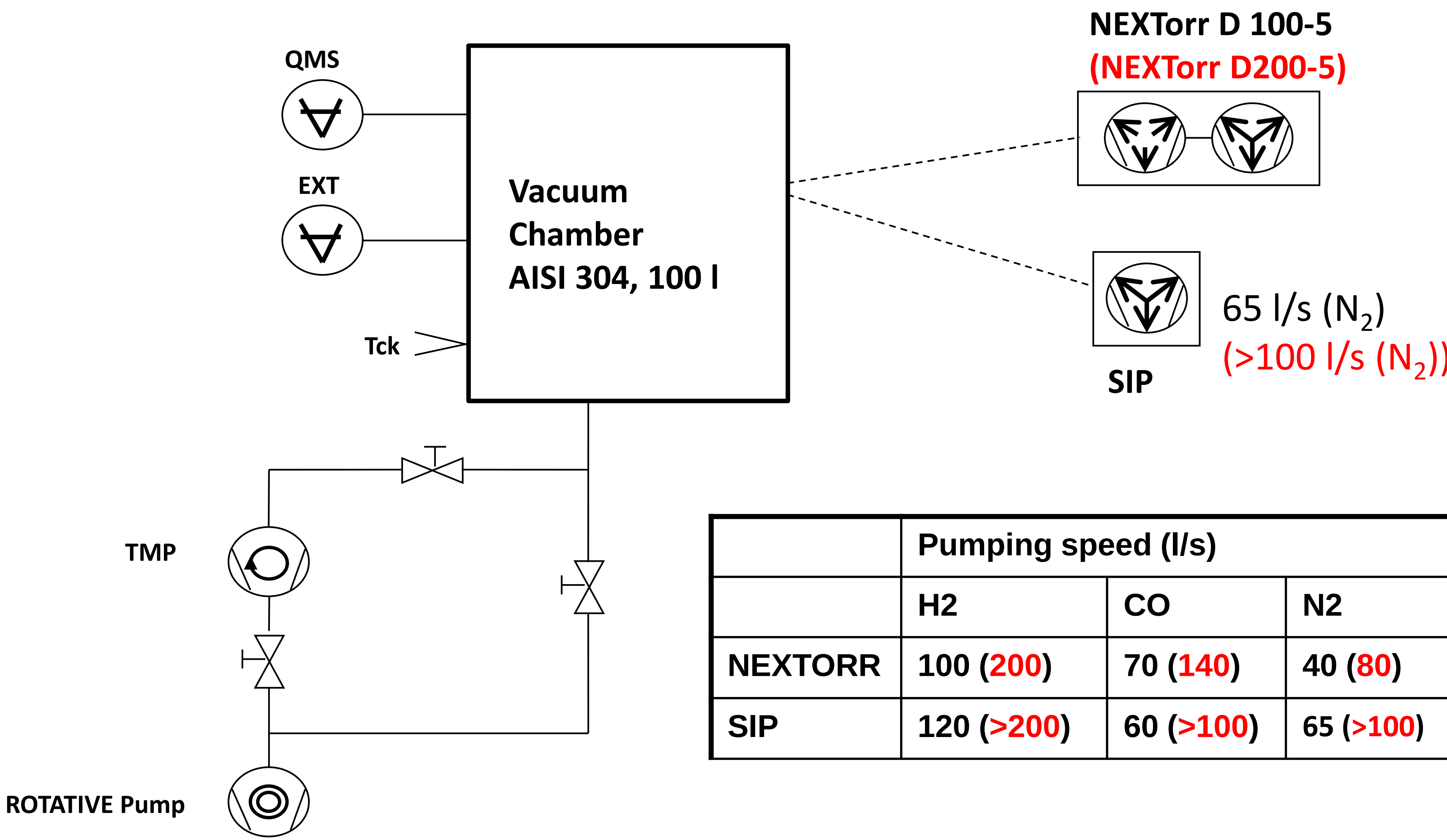
- This is in agreement with Benvenuti and Chiggiato's studies which show that <10^{-13} mbar can be achieved using NEGs as the main pump and leaving to small SIPs the ancillary task of removing CH4 and argon, not pumped by the getter [(1)].

- The same authors also estimated that an ion pump with **≈ 1 l/s** speed for CH_4/Ar is sufficient to remove CH4/Ar down to 10^{-12} mbar in a 1 m^2 leak tight and well conditioned vacuum system[(2)].

- These results are of practical importance since they show that UHV-XHV systems can be pumped by a NEG backed by a small SIP.

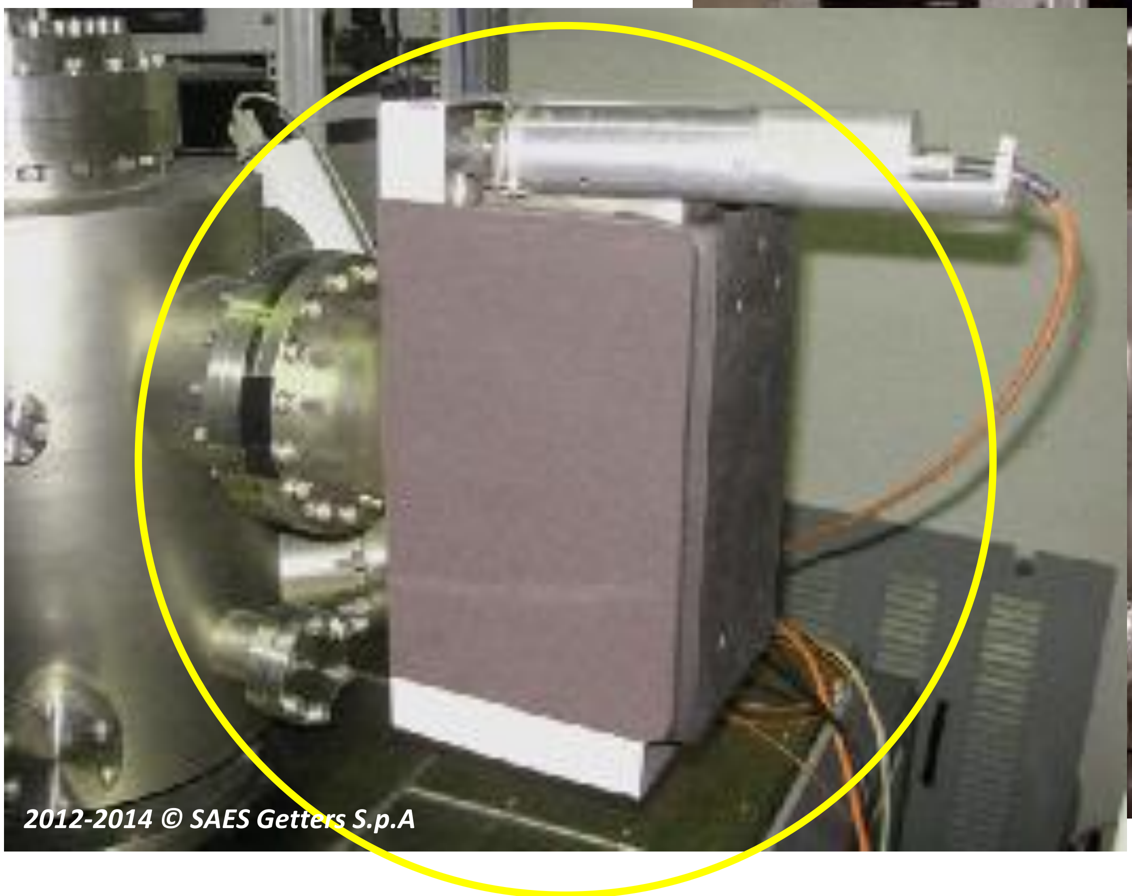
(1) **C. Benvenuti, P. Chiggiato**, J.Vac. Sci. Technol. A 14(6) 3278-82 Nov-Dec. 1996
(2) **C. Benvenuti , P. Chiggiato**, Vacuum 44 (5-7), 507-509, (1993)

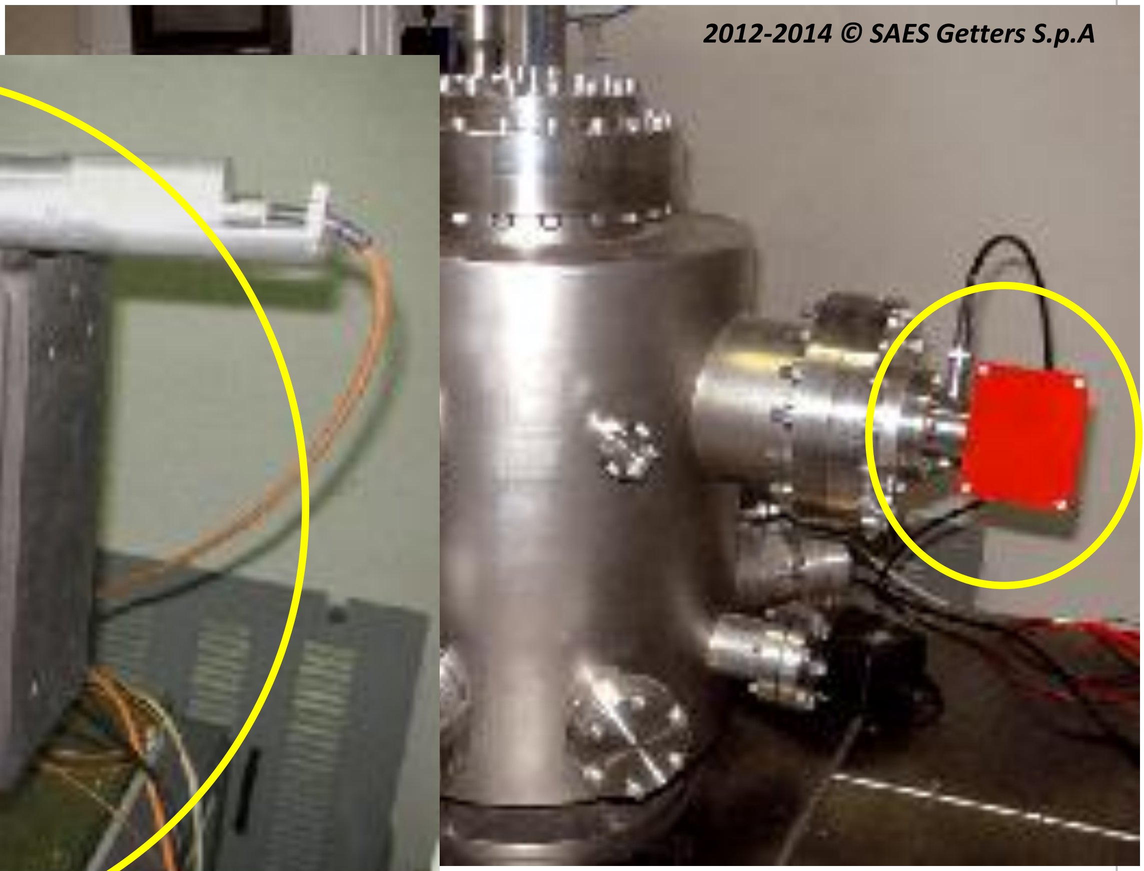
NEXTorr vs SIP: experimental setups



	Pumping speed (l/s)		
	H2	CO	N2
NEXTORR	100 (200)	70 (140)	40 (80)
SIP	120 (>200)	60 (>100)	65 (>100)

NEXTorr D100-5 vs SIP: experimental setup





SIP - 120 L/s (H_2)

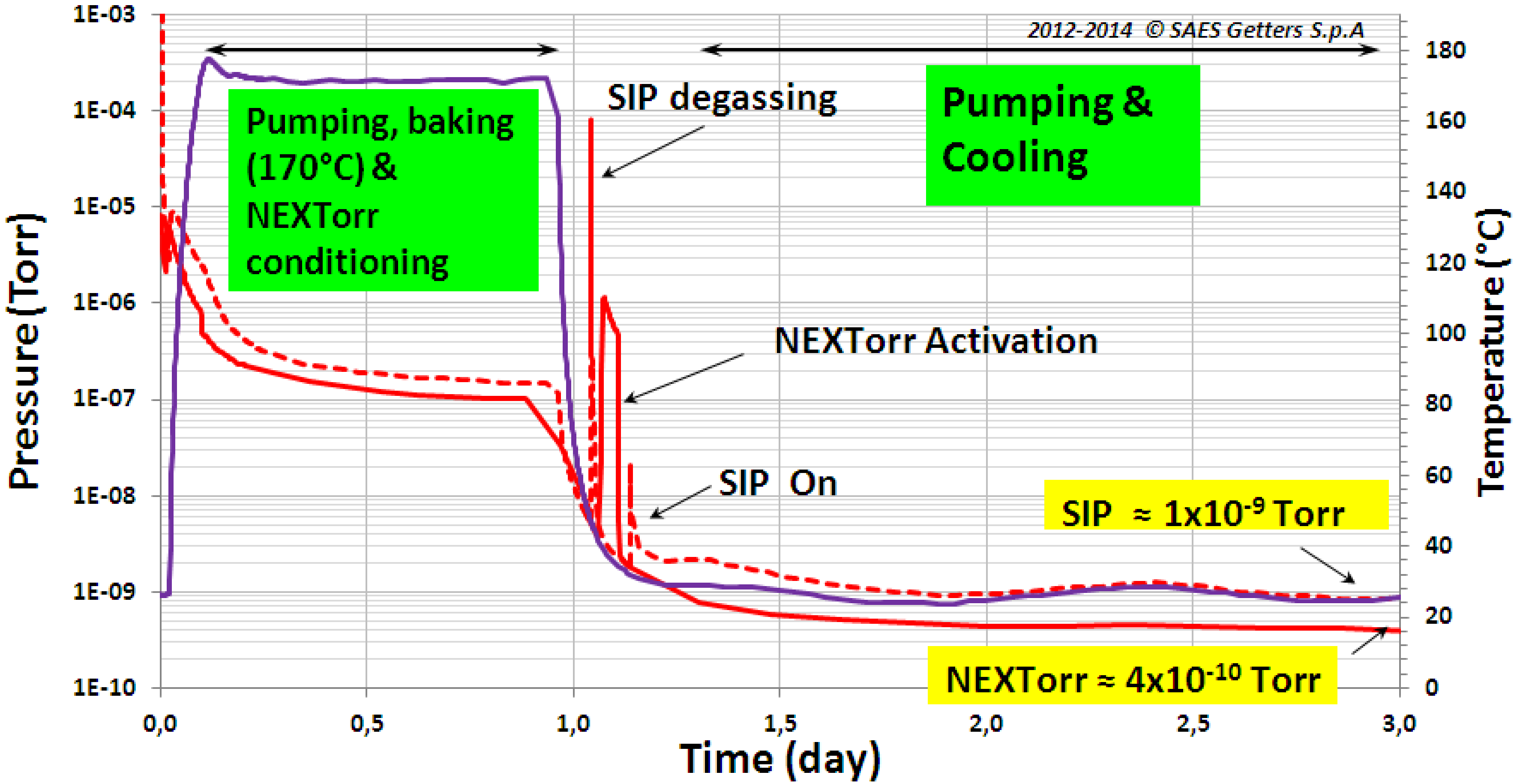
NEXTorr – 100 L/s (H_2)

NEXTorr D100-5: Experimental tests

- Bench baked at 170°Cx24h under pumping. NEG element of the NEXTorr pump kept hot (300°C) during the bake out;
- After bake, pressure recorded for several days.
- Rate of rise test (RoR) carried out to measure the pressure build up in both system in absence of power.

- Two blank runs carried out to measure pressure evolution without the SIP or the NEG.
- Total and partial pressures recorded in all tests with a QMS.

NEXTorr D100-5: Pump down



NEXTorr®: reduced magnetic intereference

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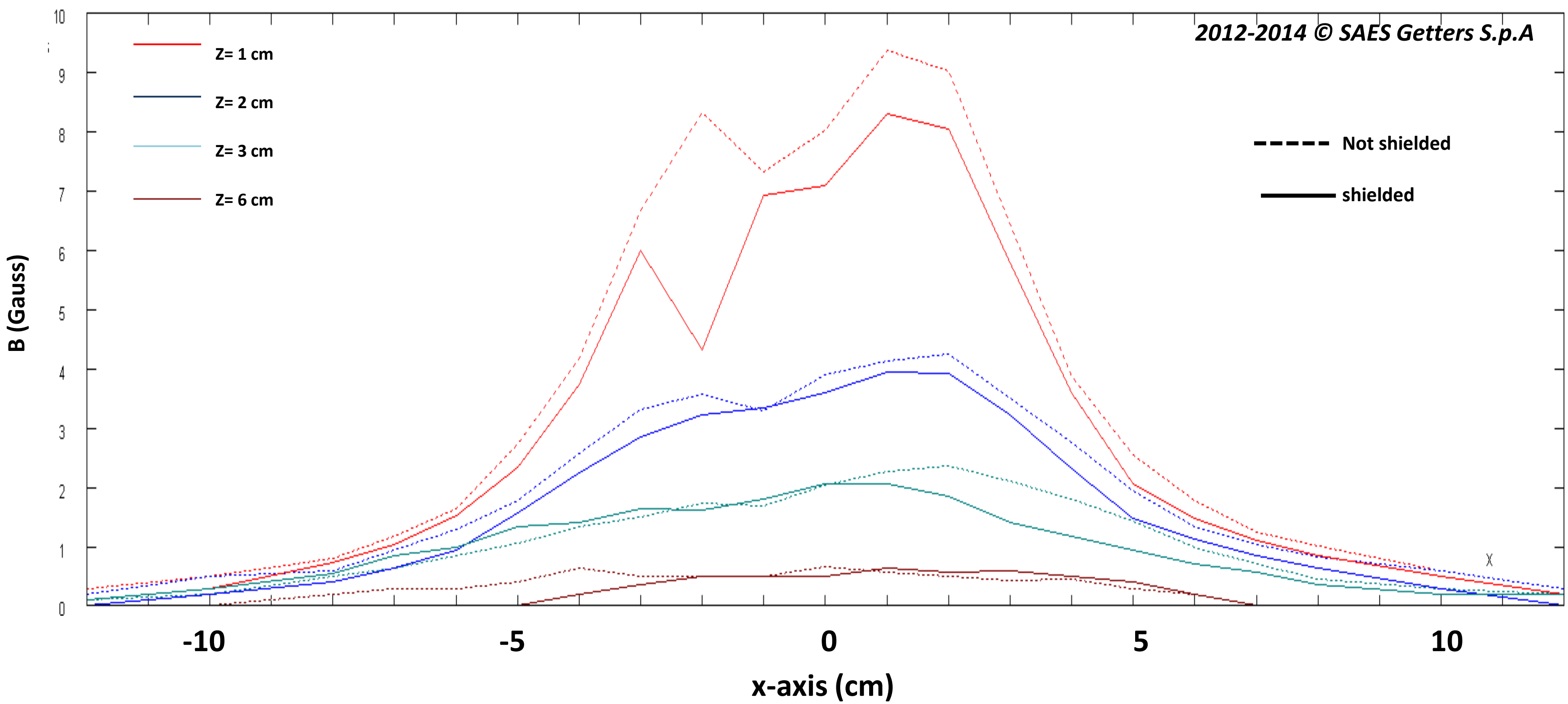
NEXTorr D2000-10 NEXTorr D1000-10 NEXTorr D500-5 NEXTorr D300-5 NEXTorr D200-5 NEXTorr D100-5

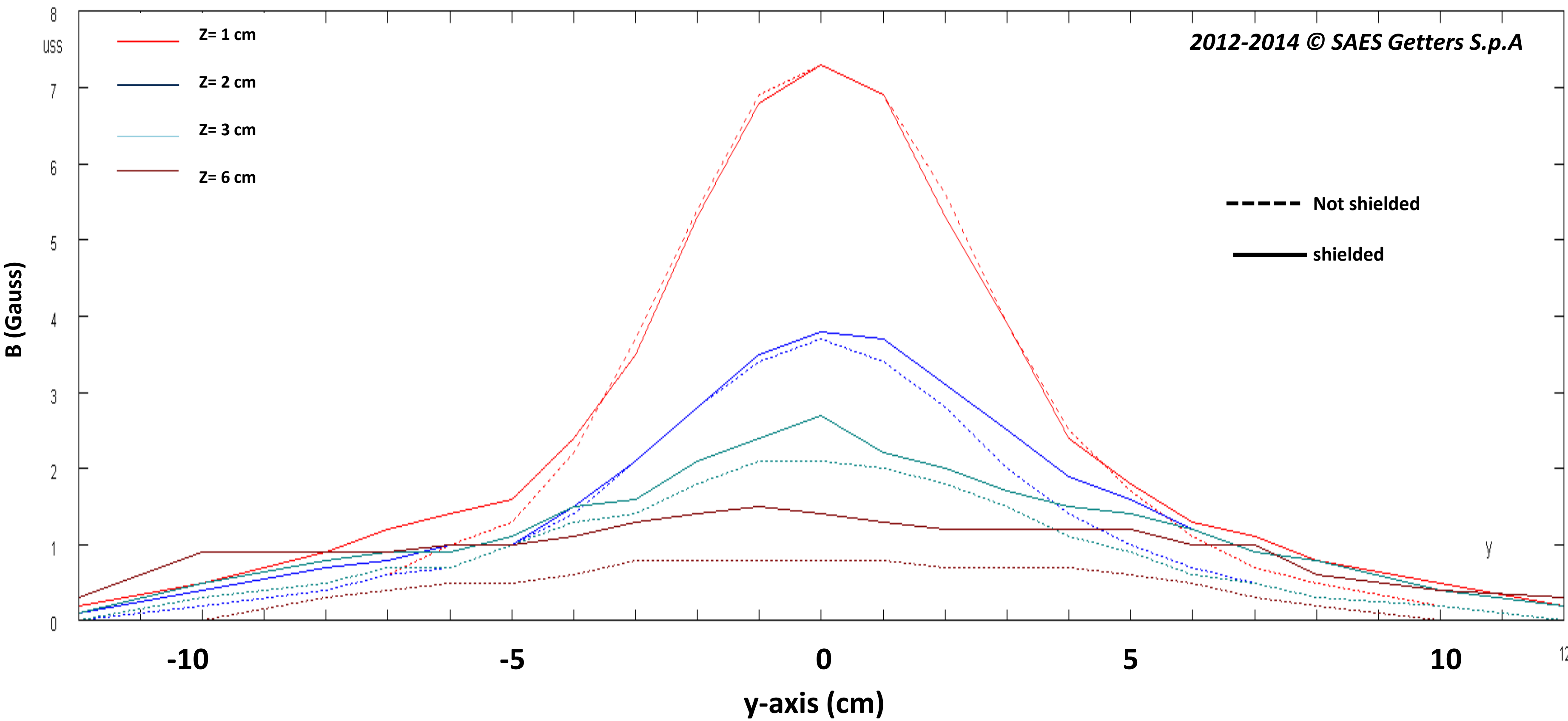
IP-10 IP-10 IP-5 IP-5 IP-5 IP-5

	Ar Pumping speed (l/s)	CH4 Pumping speed (l/s)
IP-05	5	14
IP-10	10	22

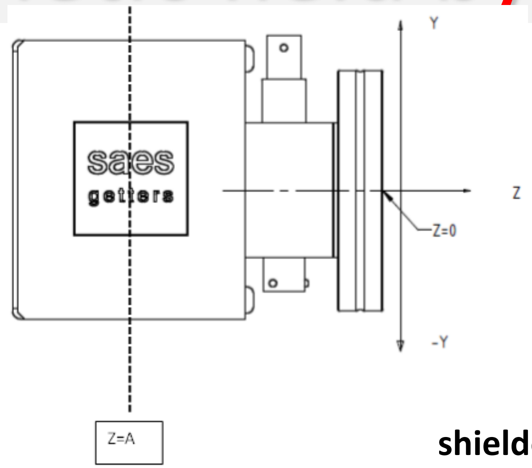
Magnetic field by IP-05 (1)



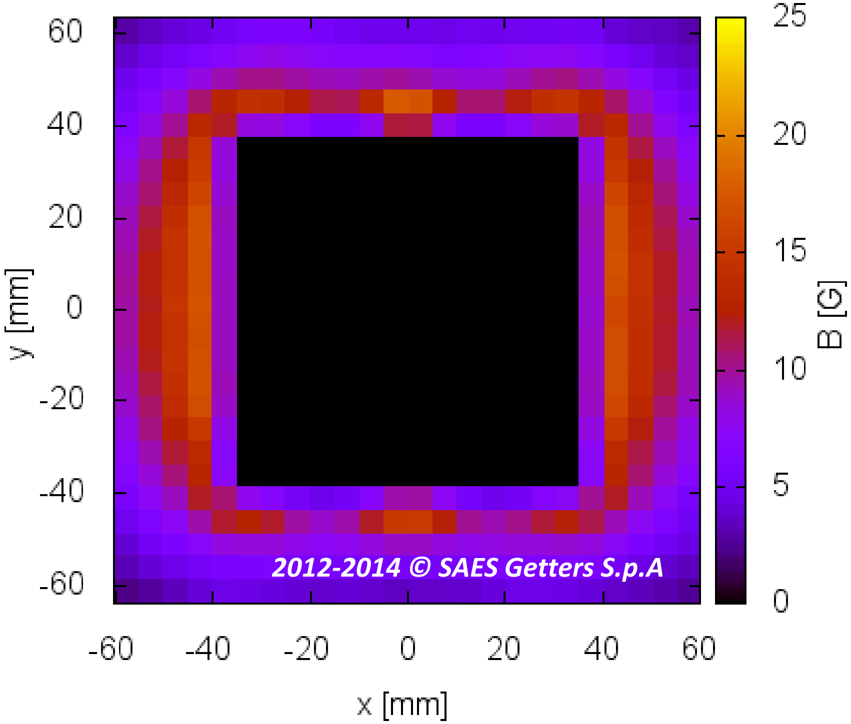
Magnetic field by IP-05 (2)



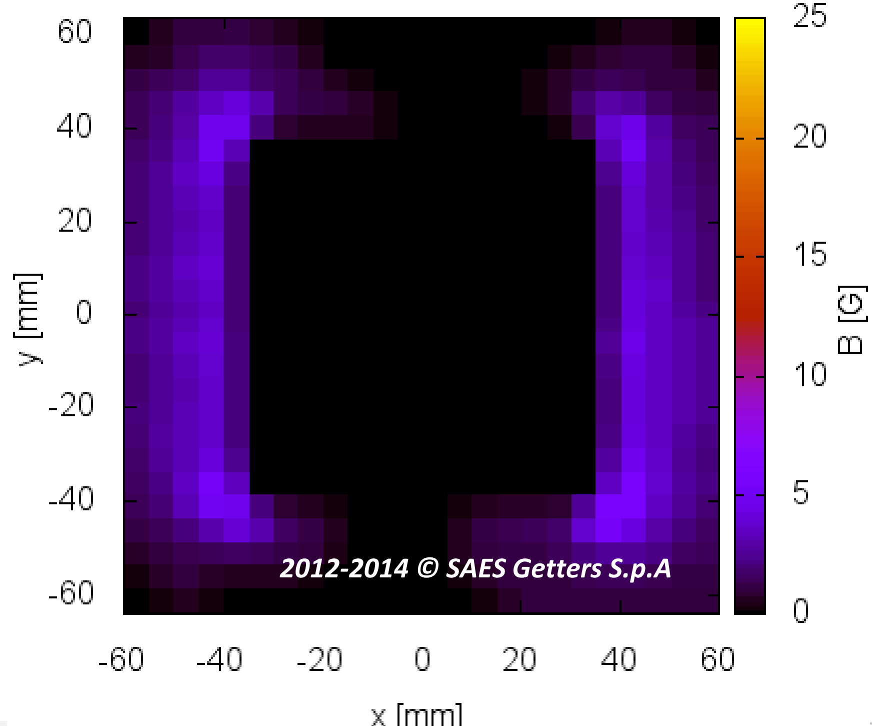
Magnetic field by IP-05 (3)



Not shielded



shielded



Magnetic field by IP-10 (2)