Vacuum System for GBAR antiproton trap

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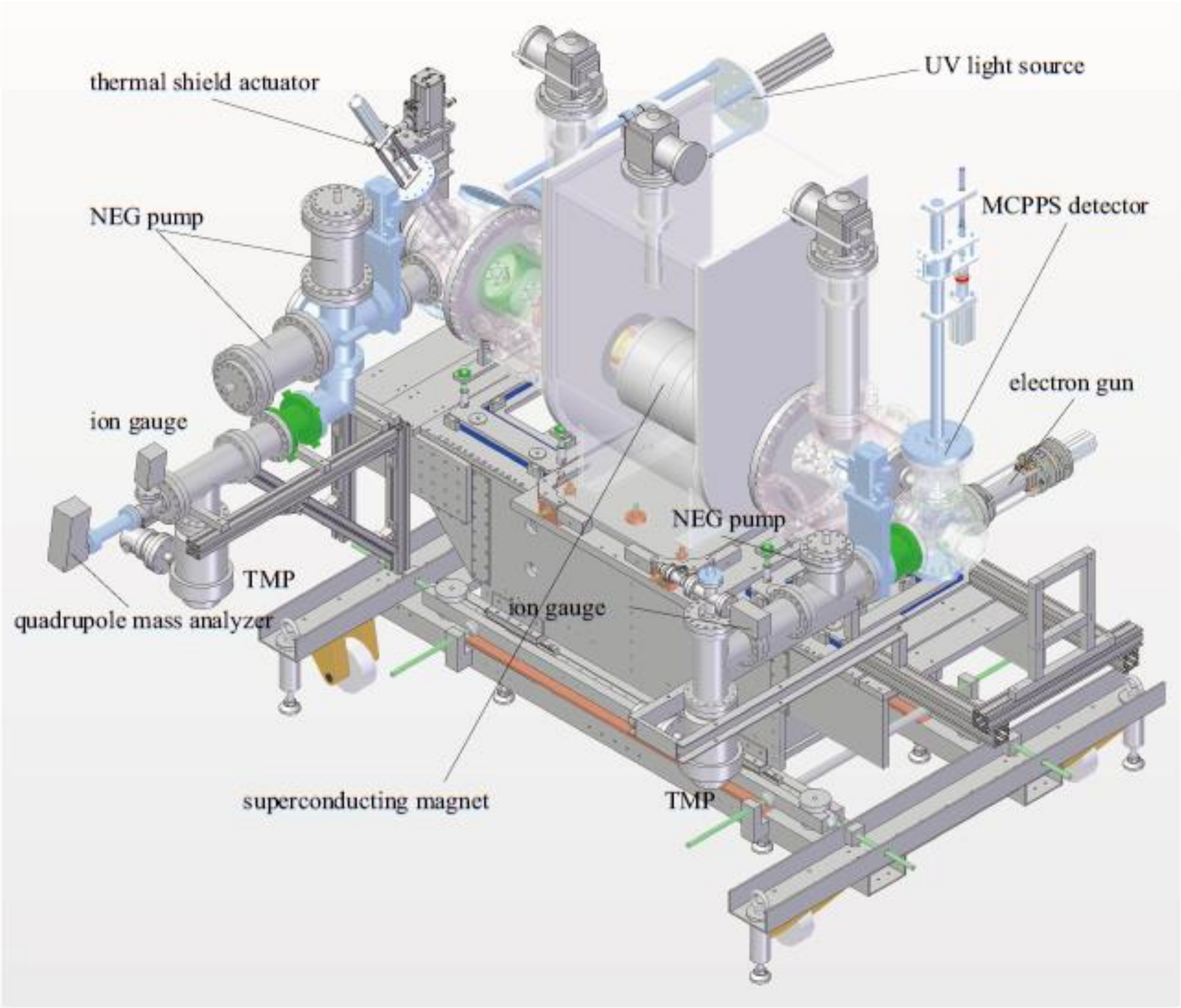
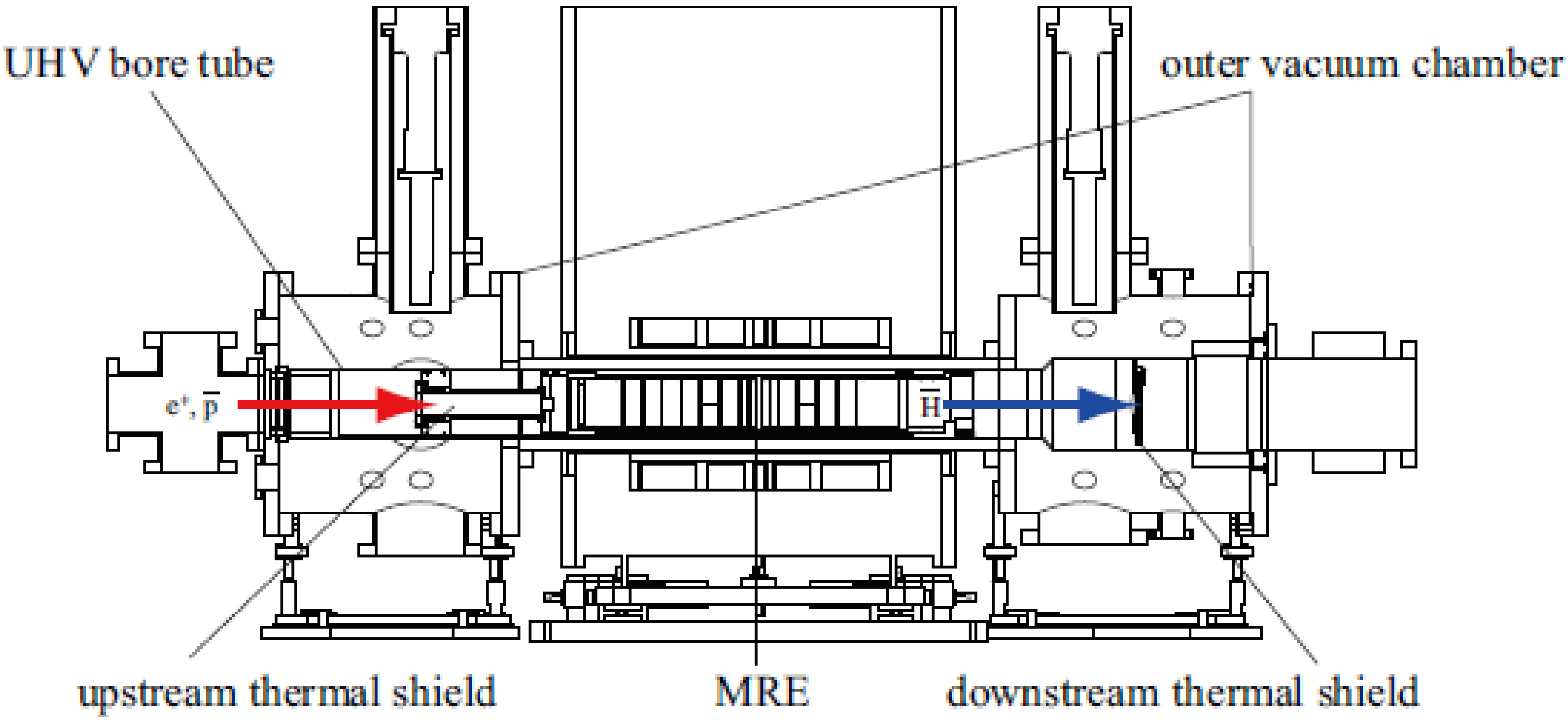
Contents

1. Cusp Trap
2. Musashi Trap
3. Why UHV is needed
4. UHV Pumps
5. UV Light Source
6. Schematic Drawing of GBAR Antiproton Trap

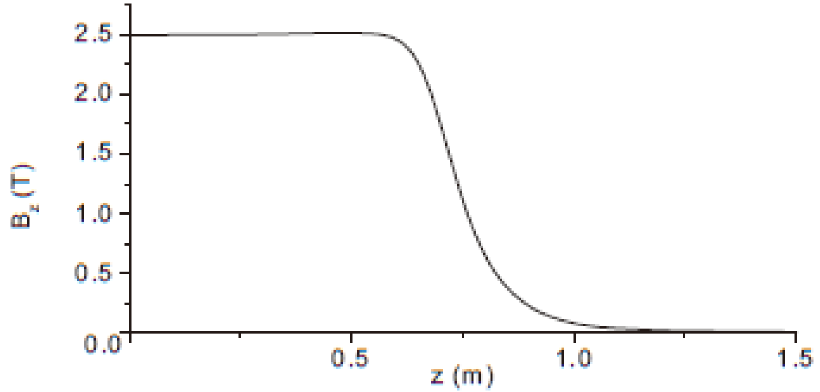
Cusp trap

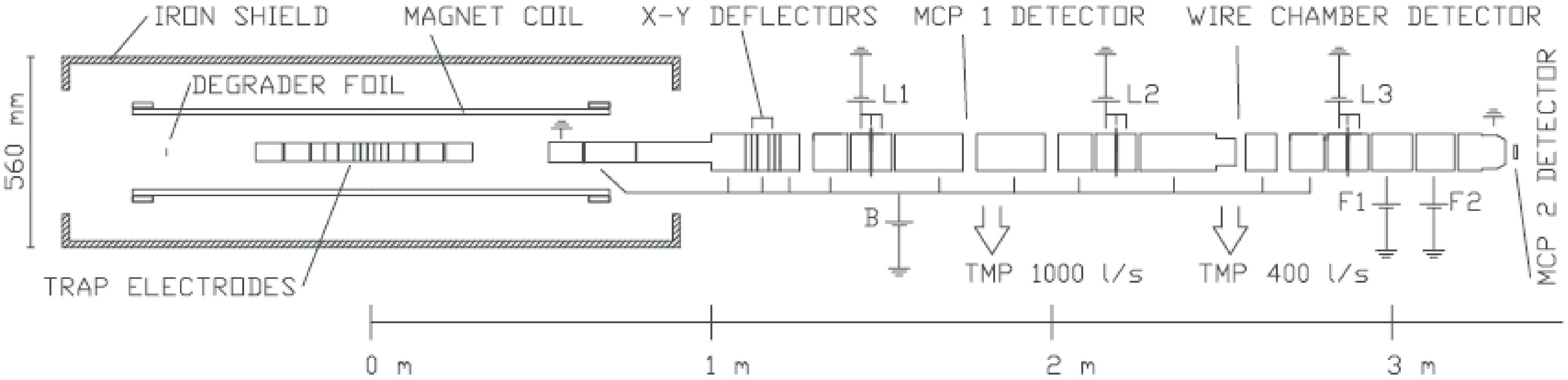

thermal shield actuator
UV light source
NEG pump
MCPPS detector
electron gun
ion gauge
NEG pump
TMP
quadrupole mass analyzer
ion gauge
superconducting magnet
TMP

A cross sectional drawing of the cusp trap



Musashi Trap

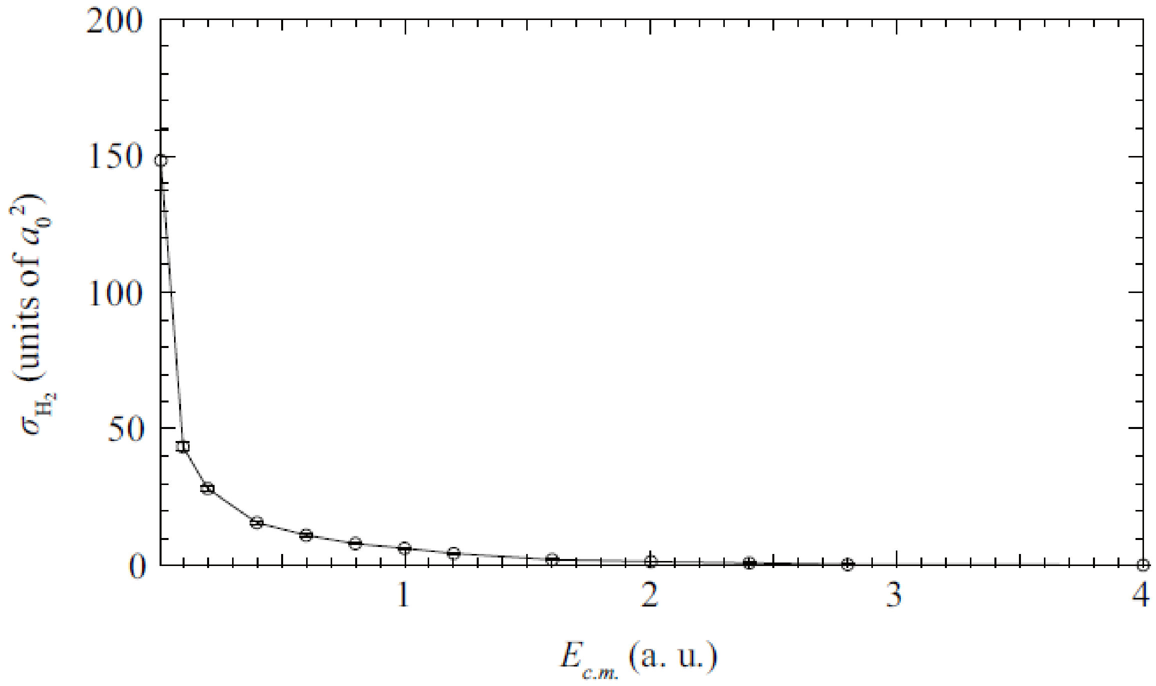




Why UHV is needed

Collision frequency : $\nu_{H_2} = \sigma_{H_2} v n (/\mathrm{s})$

Cross section of hydrogen molecule and antiproton :



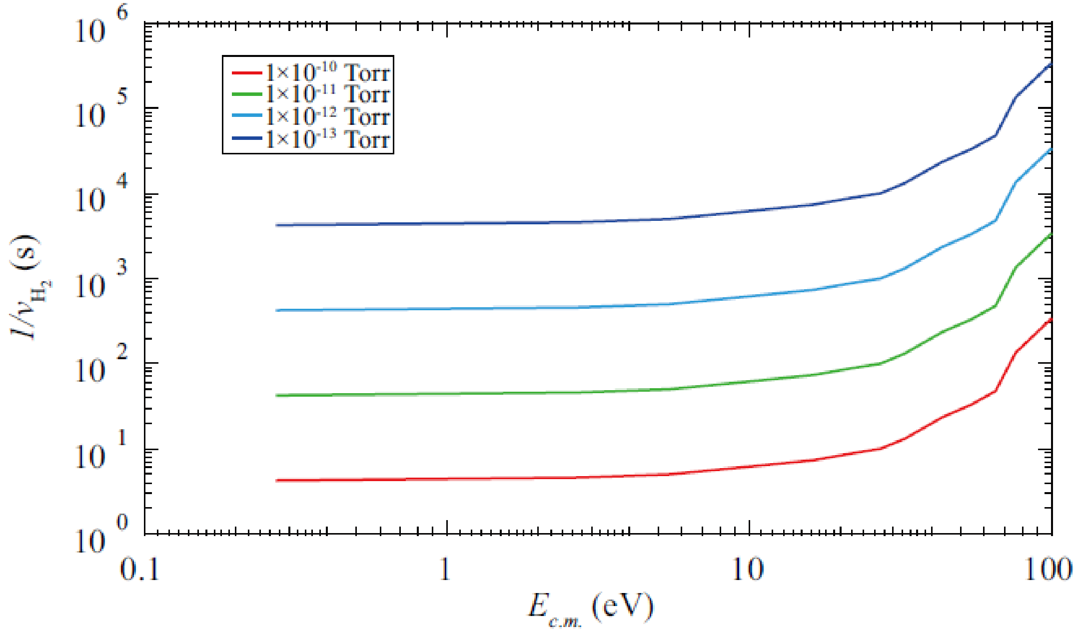
J.S. Cohen. Molecular effects on antiproton capture by H_2 and the states of $p\bar{p}$ formed. *Physical Review A*, 56(5):3583, 1997.

$a_0^2 = 2.5\text{x}10^{-21}\ (m^2)$

a. u. $= 931.494\ (MeV/c^2)$

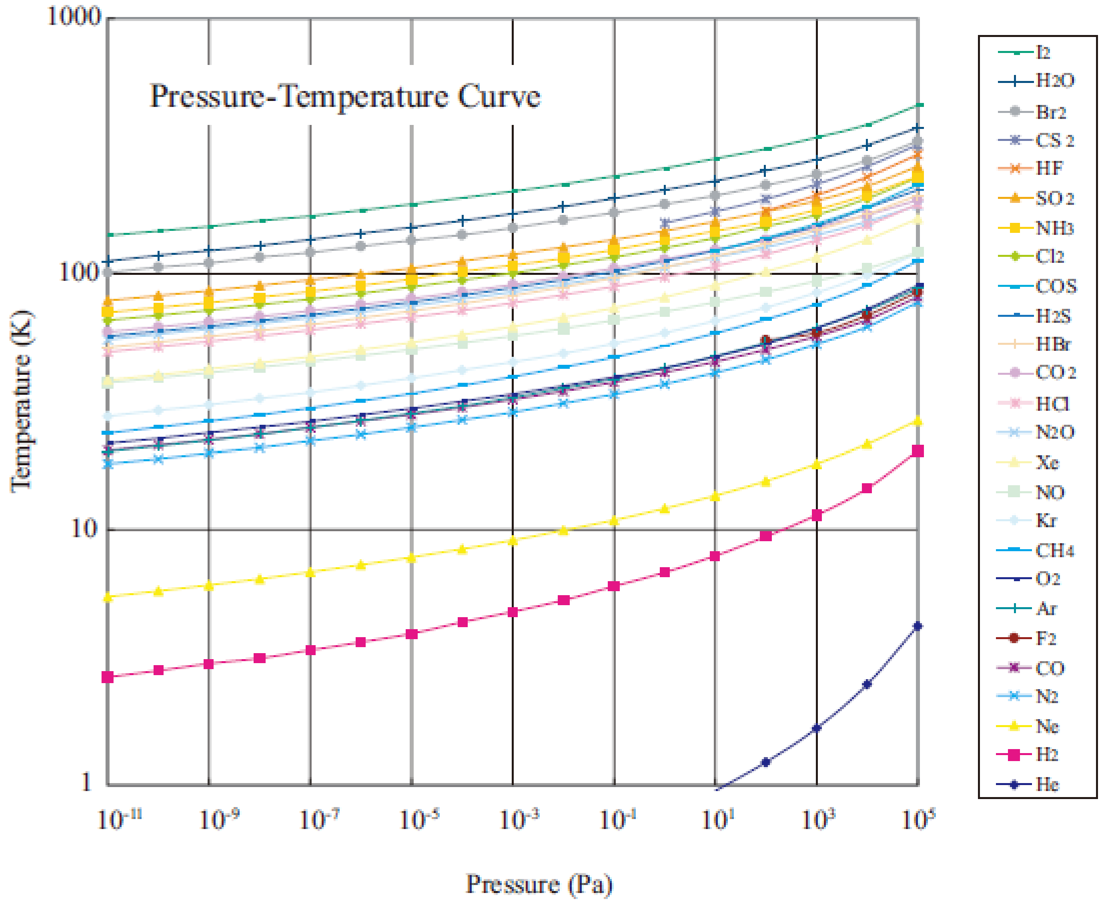
Number density of the hydrogen molecules : n = N/V = P/kT

Mean free time($1/\nu_{H_2}$) of antiproton for several different hydrogen pressures



Considering typical operation period for the production of antihydrogen atoms in the present work is 100s, pressure of hydrogen gas should be kept under 10^{-12}Torr.

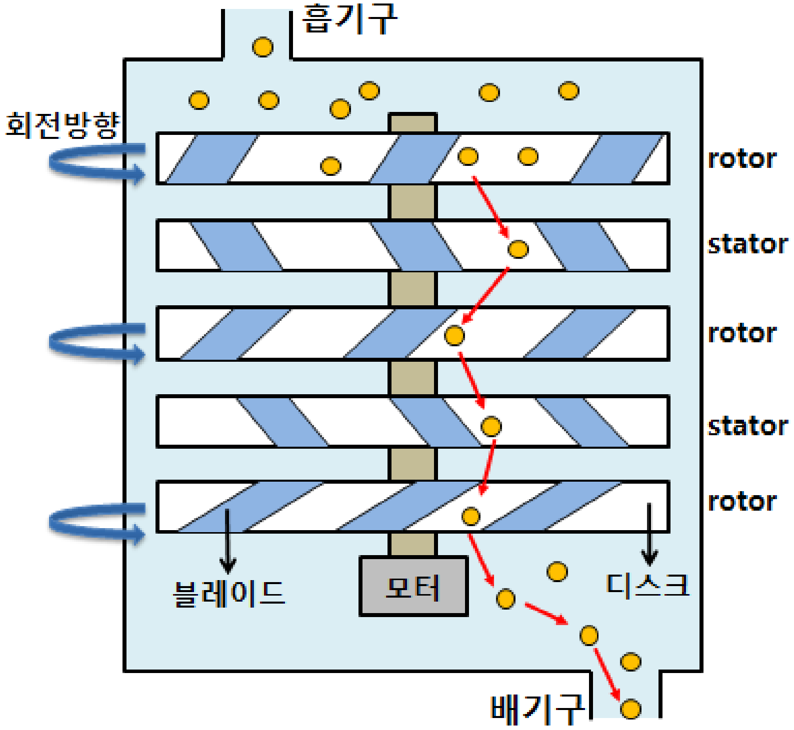
Relation between temperature and vapor pressure of various gases



Evacuating Process of Cusp Trap

1. Use TMPs as roughing pump and evacuate the chamber down to 10^{-10}Torr.
2. Cool the bore tube down to 4K to freeze all residual gases but hydrogen.
3. Use NEG pumps, which has large pumping speed for hydrogen, to evacuate hydrogen.

TMP(Turbo molecular pump)



Clean mechanical compression pump.

The only purely mechanical vacuum pump that can reach pressures of less than $5x10^{-10}$Torr.

Ideal for uses where a vacuum relatively free of hydrocarbons is a must.

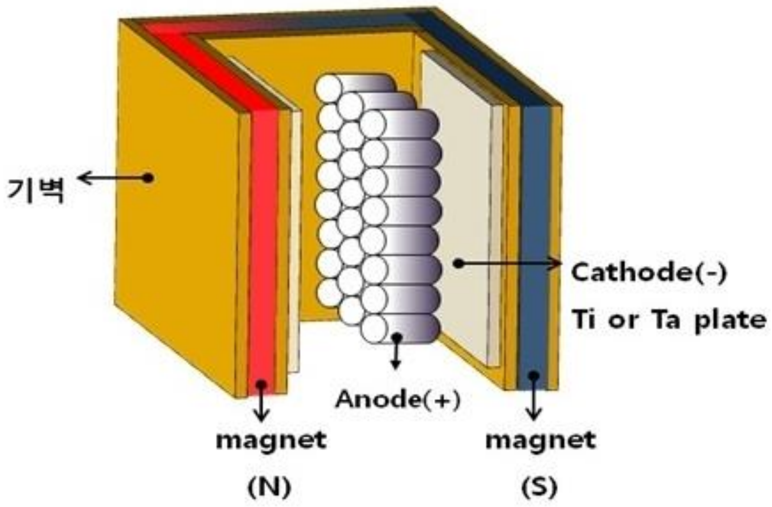
The turbo pump cannot exhaust directly to atmosphere. Though usually backed by a rotary mechanical pump.

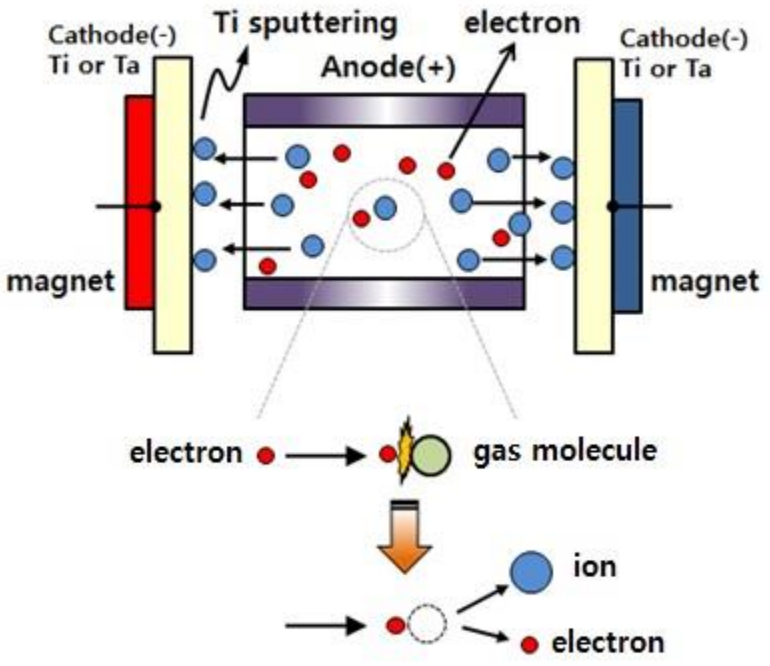
Contribute little vibration to the operating system.

Non-Evaporable Getter(NEG pump)

Non evaporable getters (NEG), based on the principle of metallic surface sorption of gas molecules, are mostly porous alloys or powder mixtures of Al, Zr, Ti, V and Fe. They help to establish and maintain vacuums by soaking up or bonding to gas molecules that remain within a partial vacuum. This is done through the use of materials that readily form stable compounds with active gases. They are important tools for improving the performance of many vacuum systems.

Ion pump





An ion pump (also referred to as a sputter ion pump) is a type of vacuum pump capable of reaching pressures as low as 10^{-10} Torr under ideal conditions. An ion pump ionizes gas within the vessel it is attached to and employs a strong electrical potential, typically 3–7 kV, which allows the ions to accelerate into and be captured by a solid electrode and its residue.

List of vacuum pumps and gauges(Cusp)

description	manufacturer	type
Main TMP	Shimadzu	TMP-303M
backing TMP	Varian	V-81
backing rotary vane pump	Edwards	RV5
NEG pump	Saes	CapaciTorr D400-2
Nude ion gauge	Yamamoto	VX-200B
full range gauge (B-A ion/Pirani)	Pfeiffer	PBR 260

Upstream side

description	manufacturer	type
Main TMP	Shimadzu	TMP-303
backing TMP	Varian	V-81
backing rotary vane pump	Edwards	RV5
NEG pump $\times$ 2	Saes	CapaciTorr B1300-2 MK5
quadrupole mass analyser	Anelva	M-066QG
full range gauge (B-A ion/Pirani)	Pfeiffer	PBR 260

Downstream side

TMP-303M

Turbo molecular pump		TMP-303LM	TMP-303LMC	TMP-303M	TMP-303MC
Inlet flange		VG100 / ICF152 / ISO100B / ISO100C			
Outlet flange		KF25			
Cooling method		Water		Cooling fan	
Ultimate pressure (after baking) (Note1)		10^{-8} Pa order	10^{-7} Pa order	10^{-8} Pa order	10^{-7} Pa order
Maximum allowable inlet pressure (N_2 continuous exhaust)		200 Pa		1.3 Pa	
Maximum allowable outlet pressure		400 Pa		40 Pa	
Pumping speed (Note 2)	N_2	320 L/s			
	He	340 L/s			
	H_2	320 L/s			
Compression ratio	N_2	1×10^9			
	He	8×10^4			
	H_2	1×10^4			

Rated speed		45000 rpm	
Start-up time		5 minutes or less	
Mounting position		In any desired direction	
Bake-out temperature at an inlet flange		120 degrees C. or less	
Vibration level (by Shimadzu's method)		0.012 µm or less (0-peak)	
Recommended flow rate of purge gas		20 to 30 mL/min (Note 3)	
Recommended pumping speed of backing pump in case of gas purge		200 L/min or more	
Environmental Temperatures		0 to 40 degrees C.	
Admissible ambient magnetic field	Radial direction	3 mT	
	Axial direction	15 mT	
Water	Flow rate	1 to 3 L/min	-
	Pressure	0.2 to 0.5 MPa	
	Temperature	5 to 30 degrees C.	
Mass		14 kg	

NEG pump-Saes 社 CapaciTorr D400-2, B1300-2 MK5

Typical Pump Characteristics

Alloy Type		St 172®
Alloy Composition		ZrVFe
Getter Mass(g)		45
Getter Surface (cm^2)		380
Pumping Speed (l/s)	H_2	400
	CO	180
Sorption Capacity (Torr l)	H_2	900
	CO Room Temperature	0.9
	CO Total	400

Note: Pumping speed data refer to the initial values of the pump without the pump body. CO capacity based on speed below 20 l/s.

CapaciTorr D400-2

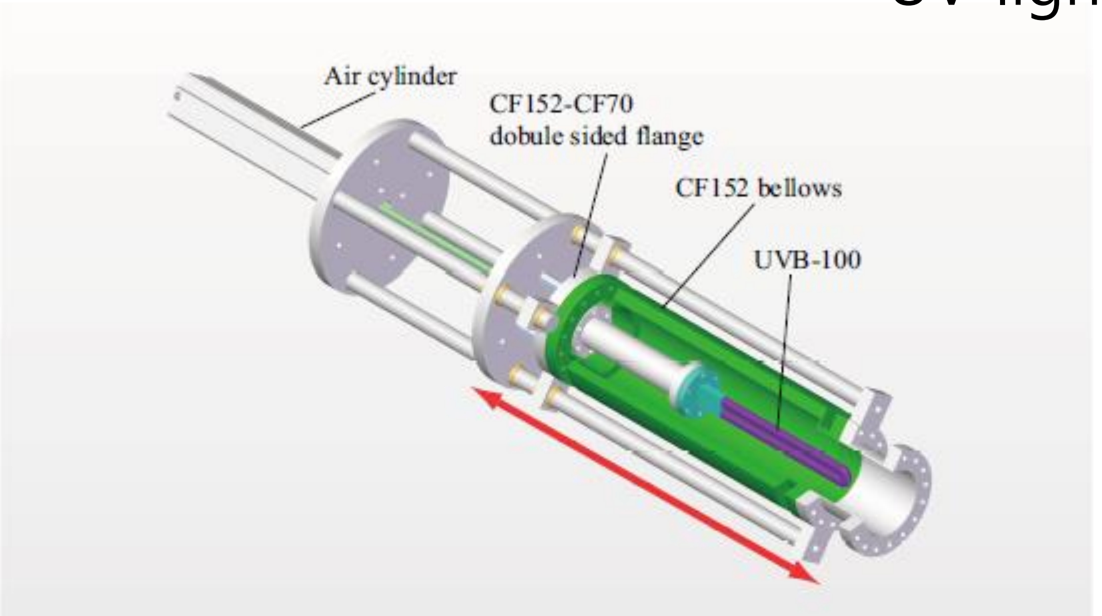
Typical Pump Characteristics

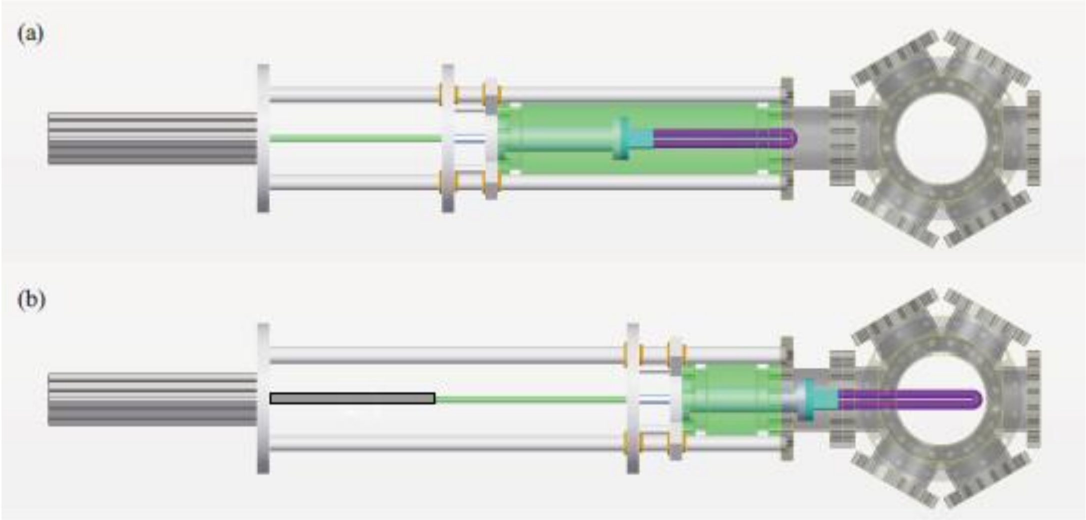
Alloy Type		St 185®
Alloy Composition		TiV
Getter Mass(g)		560
Getter Surface (cm^2)		5530
Pumping Speed (l/s)	H_2	1300
	CO	1000
Sorption Capacity (Torr l)	H_2	18000
	CO Room Temperature	6
	CO Total	5400

Note: Pumping speed data refer to the initial values of the pump without the pump body. CO capacity based on speed below 50 l/s.

CapaciTorr B1300-2 MK5

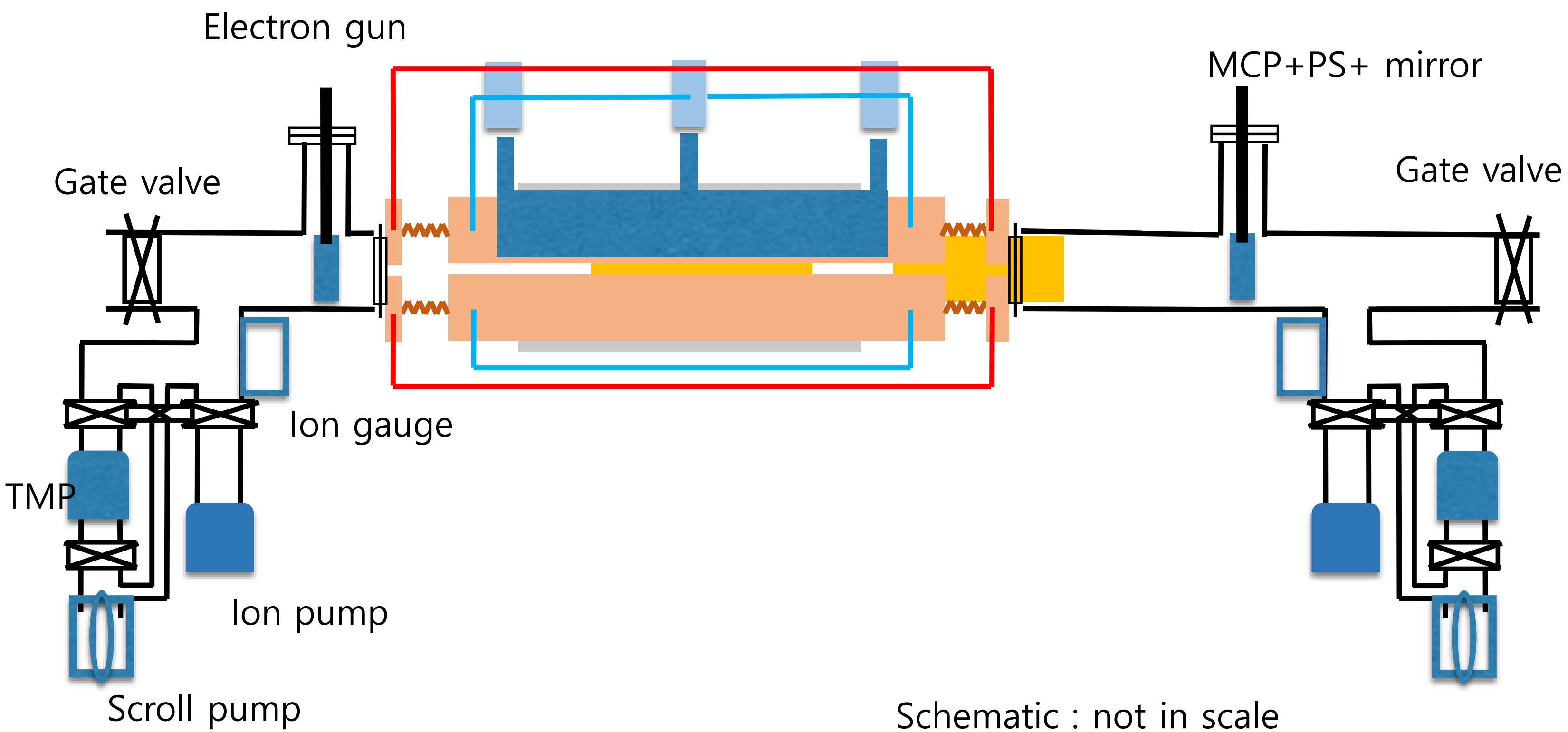
UV light source





RDB instruments, UVB-100

GBAR antiproton trap-Vacuum



Schematic : not in scale

Thank You

Reference

Enomoto, Y. *Antihydrogen production in cusp trap*. Diss. Ph. D. thesis, RIKEN Advanced Science Institute, Hirosawa, Wako, Saitama 351-0198, Japan, 2011.

黒田直史. *Accumulation of a large number of antiprotons and production of an ultra-slow antiproton beam*. Diss. 東京大学, 2004.