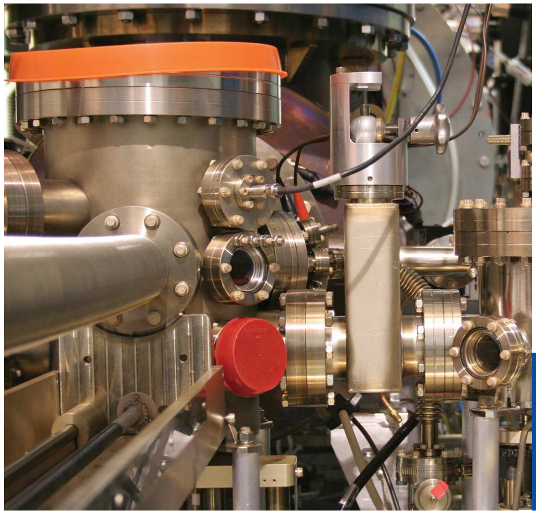


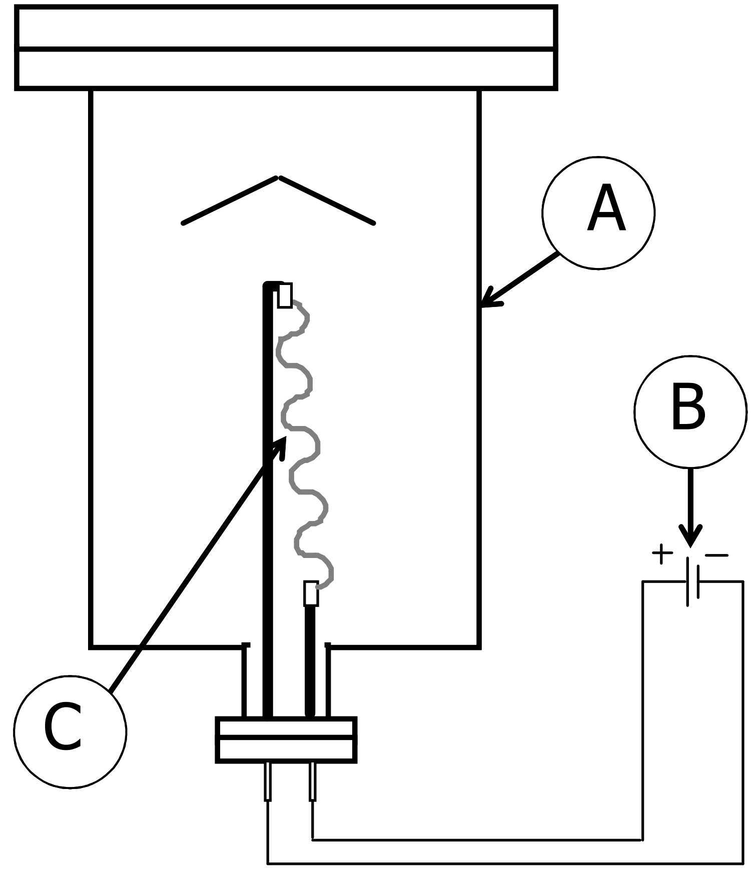
Table of Contents

SESSION 3.2B: Getters

- Getters pump gases by chemically bonding molecules to surfaces upon impingement
- Two definitions of pumping capacities:
  - → Activation capacity
  - → Termination capacity
- Based on activation manner, there are two types of getters:
  - → Titanium sublimation pumps (TiSPs)
  - → Non-evaporable getters (NEGs)
- Both TiSPs and NEGs are widely used in accelerator vacuum systems

Titanium Sublimation Pumps – Basics

- A TiSP simply consists of three basic elements:
  - → A source from which titanium is sublimed (C)
  - → A power supply to heat the source (B)
  - → A surface onto which the titanium is sublimed, and is accessible to the arriving active gas. (A)
- Thus no manufacturer sells a TiSP system, only the Ti sources (and a power supply)



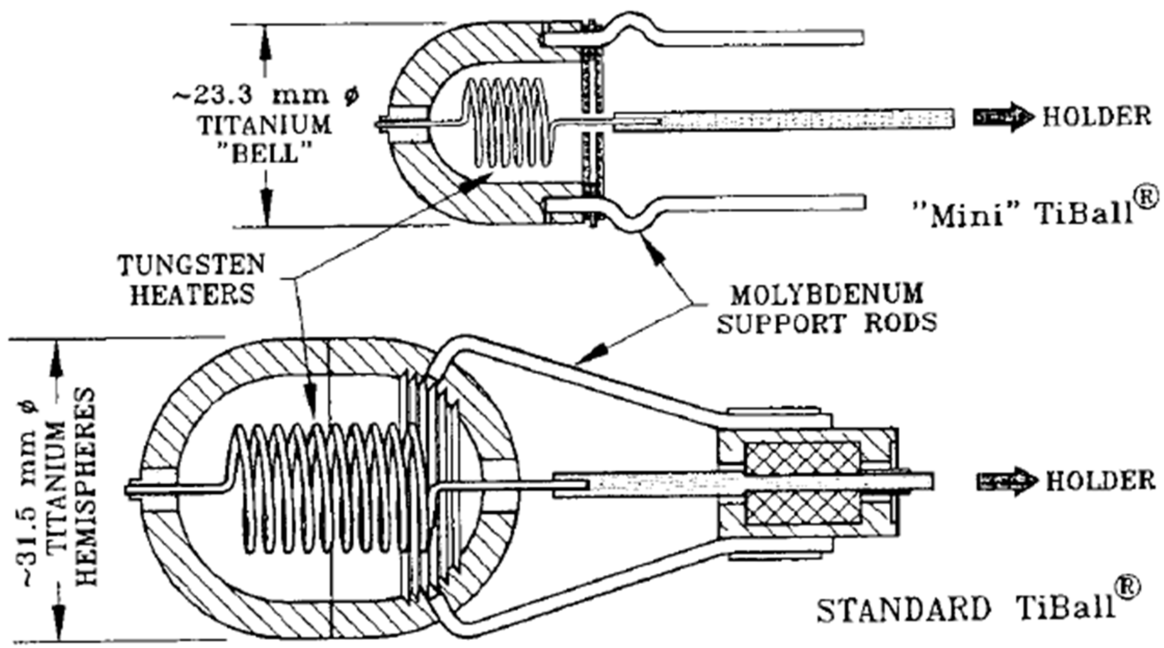
Example of a TiSP System

Titanium Sources – Filamentary Types

- *Filaments made of 85%Ti-15%Mo are most common sources of titanium used in TiSPs.*
- *The filament is resistively heated during sublimation process.*
- *In most cartridges, multiple filaments are loaded.*

Titanium Sources – Radiated Heating

More suitable for very high throughput pumping application.



Varian Vacuum

Ref. "A Radiant Heated Titanium Sublimator," Proc. 5th Int. Vacuum Congress, 1971, JVST 9 (1), 552 (1972)

- ***Sources require operation at some level of standby power to maintain Titanium temperature above 900°C.***
- ***Very inefficient heating, and require relatively high heating power.***

TiSPs – Pumping Speed

A TiSP is simply a surface conductance limited pump. The pumping speed depends on ***unit surface conductance (C_i)*** *to the Ti-covered* ***surfaces (A)*** *and* ***gas sticking coefficient***.

$$\boxed{S_i\left(m^3/s\right)=\alpha_i C_i A=36.24\sqrt{\frac{T}{M}}\cdot\alpha_i A\left(m^2\right)}$$

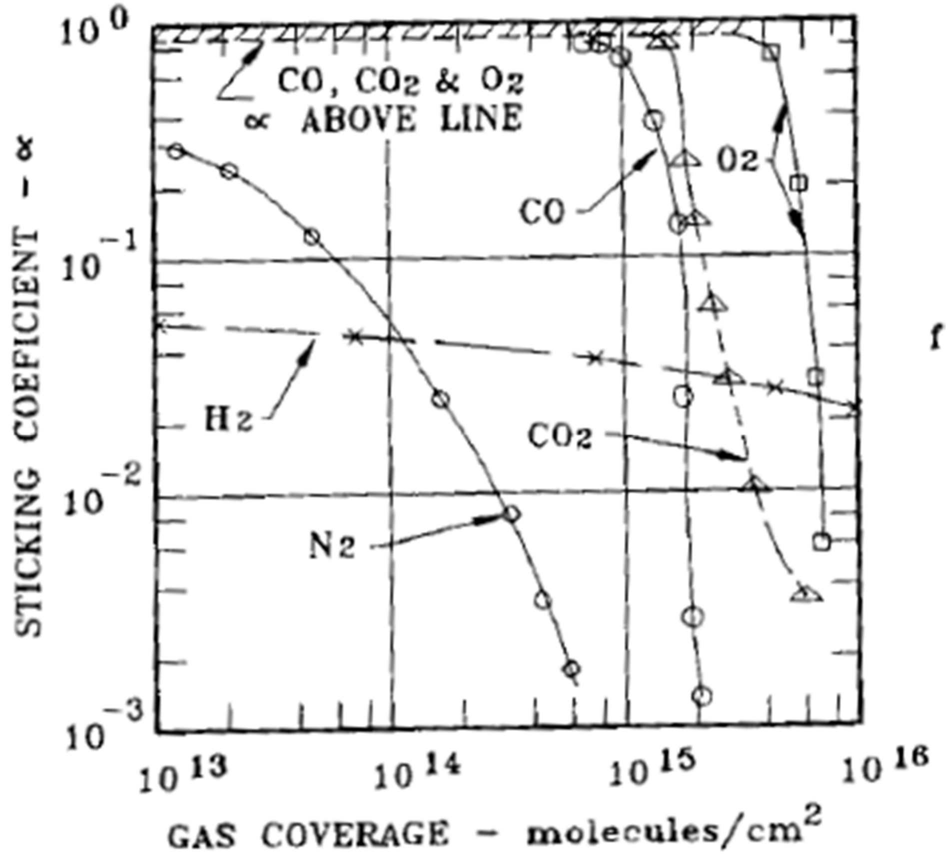
Or

$$\boxed{S_i\left(L/s\right)=3.624\sqrt{\frac{T}{M}}\cdot\alpha_i A\left(cm^2\right)}$$

T – Temperature of gases (Kevin)
M – Gas molar mass
A – Ti covered area (in m^2 or cm^2)
α_i – sticking coefficient for "i" gas molecules

Sticking Coefficient

- ✓ Sticking coefficient is strongly gas reactivity dependent
- ✓ For most active gases, the sticking coefficient decrease with adsorbed quantity, with various behavior, due to surface deactivation.
- ✓ Ti film has very high capacity for hydrogen, indicating 'bulk' diffusion for dissociated H atoms.



Ti layer: ~10^{16} atoms/cm^2

Factors Influencing Sticking Coefficient

- Thickness of Titanium film
- Ratio of pumping speed to Titanium sublimation rate
- Surface temperature at the time of sublimation
- Surface temperature at the time of gas sorption
- Film deposition process (batch or continuous)
- Gas species
- Gas desorption and synthesis at Titanium source
- Partial pressures of gases at time of sublimation
- Contamination of film by some gas
- Effects of film annealing
- Variations of surface and bulk diffusion processes

Pumped or/and Displaced Gases

Pumped Gas	Displaced Gas				
	CH_4	N_2	H_2	CO	O_2
CH_4		no	no	no	no
N_2	yes		no	no	no
H_2	yes	yes		no	no
CO	yes	yes	yes		no
O_2	yes	yes	yes	yes	
α_m	$<10^{-3}$	0.3	0.05	0.85	0.95

This is controversial and probably only true for CH_4 and H_2.

Typical Engineering Values for TiSP

Test Gas	Max. Sticking Coefficient-α_m		Max. Speed[a] (liters/sec-cm^2)		Max. Capacity of Film- x10^{15} (molecules/cm2) [b]	
	300 K	77 K	300 K	77 K	300 K	77 K
H_2	0.06	0.4	2.6	17	8-230[c]	7-70
D_2	0.1	0.2	3.1	6.2	6-11	-
H_2O	0.5	-	7.3	14.6	30	-
CO	0.7	0.95	8.2	11	5-23	50-160
N_2	0.3	0.7	3.5	8.2	0.3-12	3-60
O_2	0.8	1.0	8.7	11	24	-
CO_2	0.5	-	4.7	9.3	4-12	-

a) Speed calculated at RT
b) Wide variations due to film roughness
c) Wide variations due to bulk diffusion into film

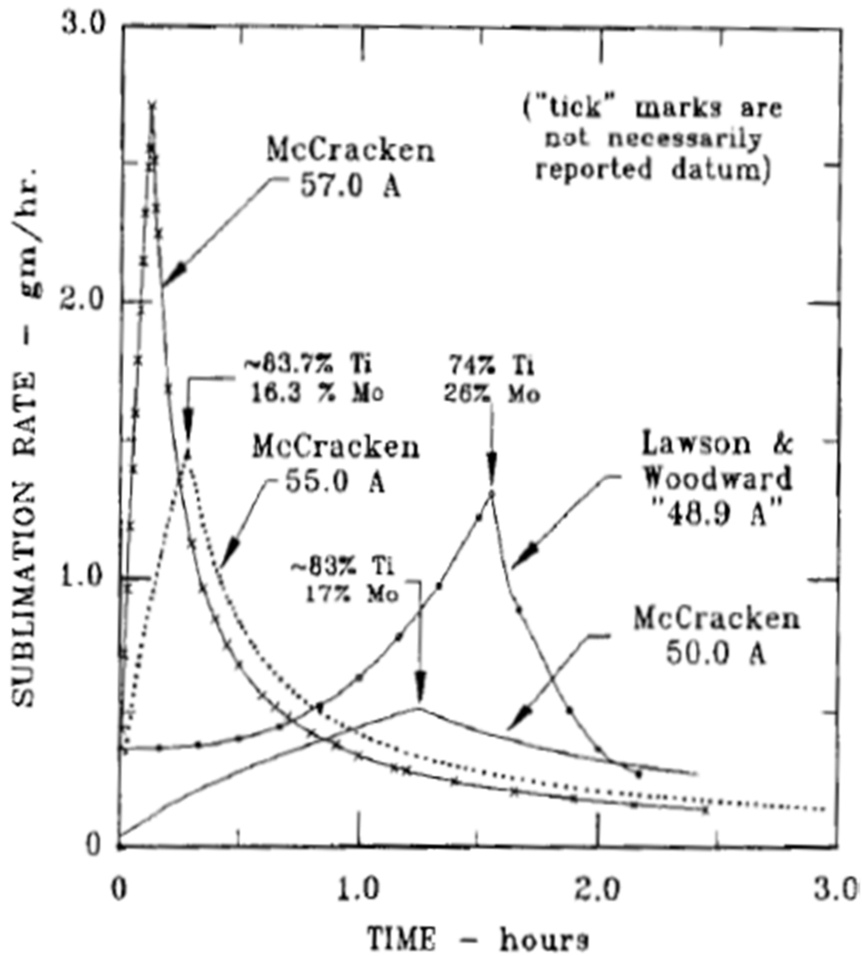
(Ref. "Sorption of Nitrogen by Titanium Films," Harra and Hayward, Proc. Int. Symp. On Residual Gases in Electron Tubes, 1967)

Batch vs. Continuous Sublimation

- For some high gas load, high throughout applications, Ti may be continuously sublimated. In the continuous sublimation mode, proper cooling must considered.
- In most applications, Ti is periodically sublimated as the Ti layer is saturated. This is referred as "batch sublimation". In a batch sublimation mode, the timing of the sublimation is usually rely on independent pressure measurement.
- In batch-mode sublimation, one may choose various control modes: constant current, constant voltage or constant power.

Sublimation Mode – Constant Current

- ***Constant current operation of Titanium filaments produces increases in sublimation rates early in the life of the filament.***
- ***This is probably due to the progressively leaner mixture of Titanium in the filaments.***
- ***Filaments develop rougher surface textures as the mixture changes.***
- ***Rough texture = greater surface area = higher emissivity = lower operating temperature = lower sublimation rates.***



Sublimation Mode – Constant Voltage

- **Constant voltage operation is rarely done.**
- **Constant voltage operation in conjunction with RT cycling produces more predictable sublimation rates**

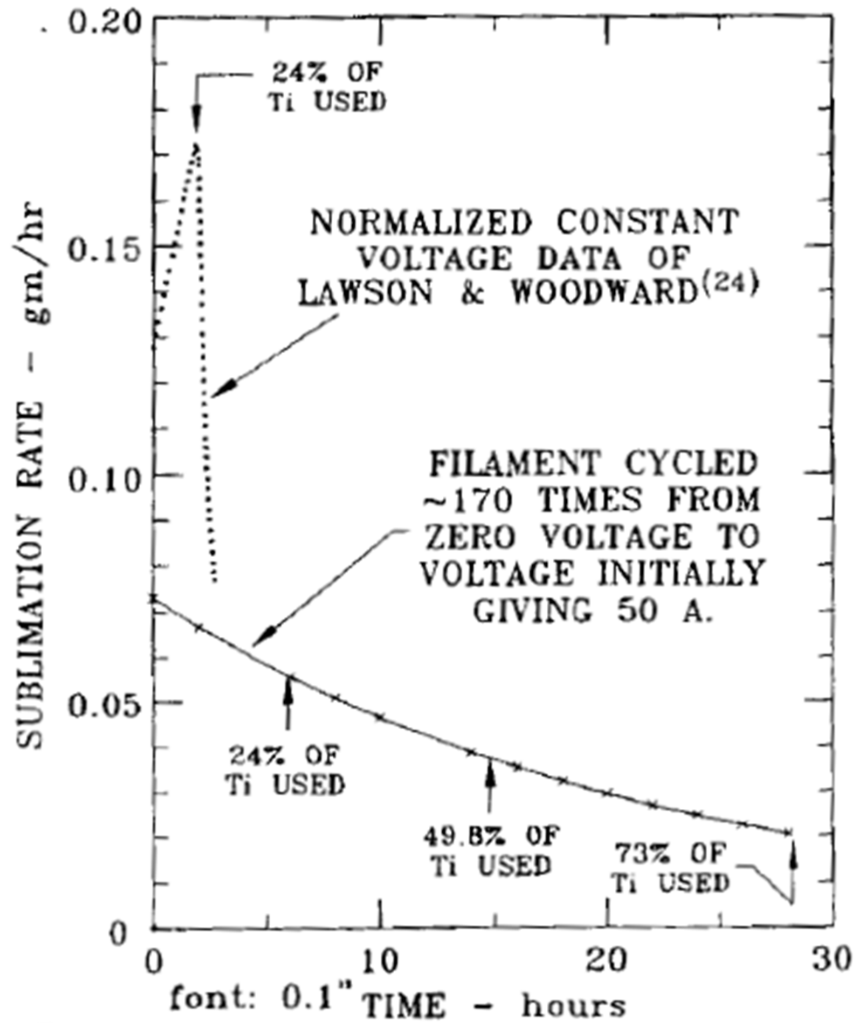
$$R(t) = R_o\ e^{-at}$$

where R_o= initial sublimation rate

a = constant

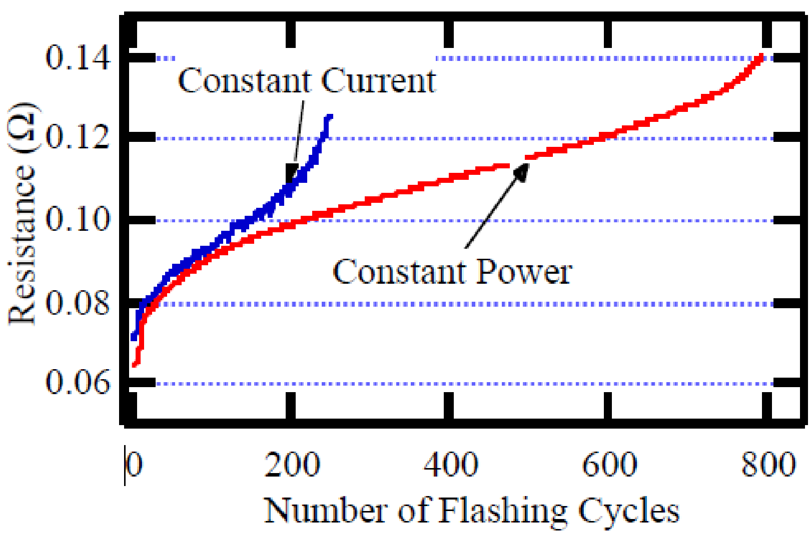
t = cumulative sublimation time

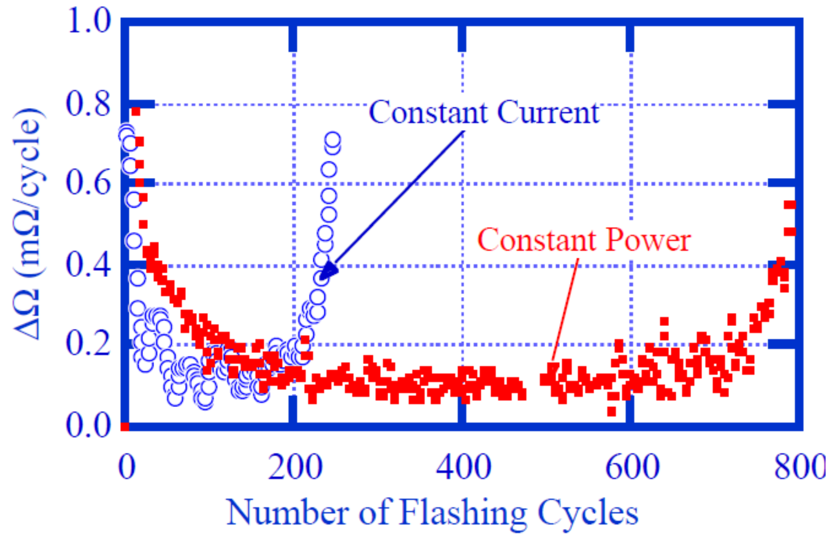
- **Titanium sublimation rates are dependent on Ti and Mo proportions <u>and</u> the number of temperature cycles through the crystalographic transformation temperature.**



Sublimation Mode – Constant Power

- *At CESR, we choose a constant power approach for Ti sublimation (with a LabView® PID controller).*
- *Using resistance change as a measure of sublimation rate, the constant power mode provide very long term stability of the sublimation rate.*
- *Constant power mode also ensures longer lifetime of Ti filament.*



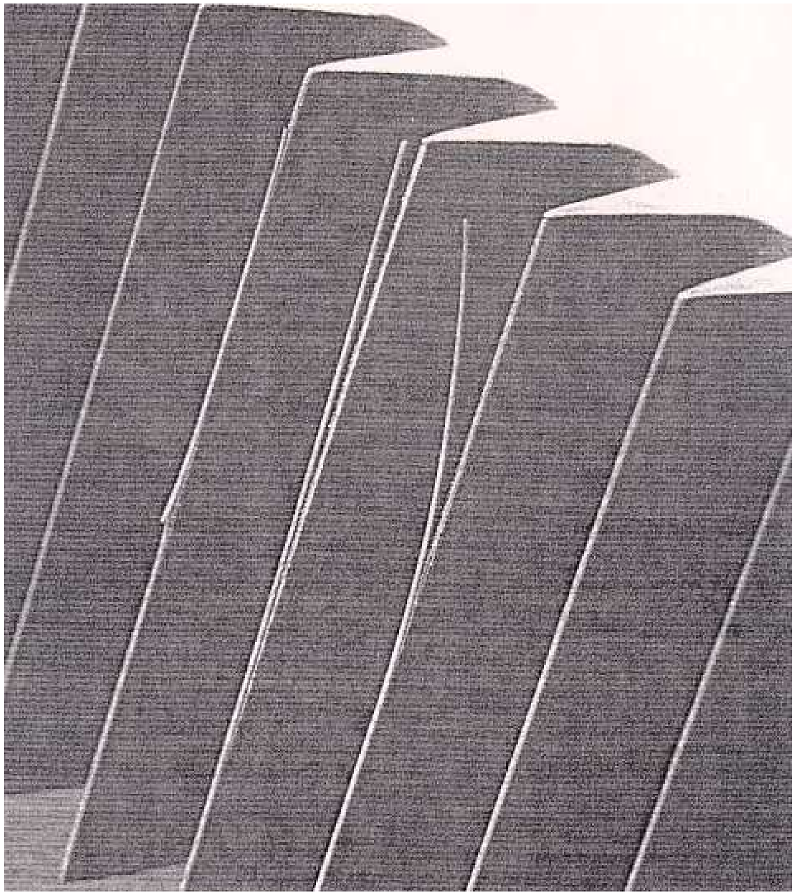


TiSPs for Accelerators – Some Considerations

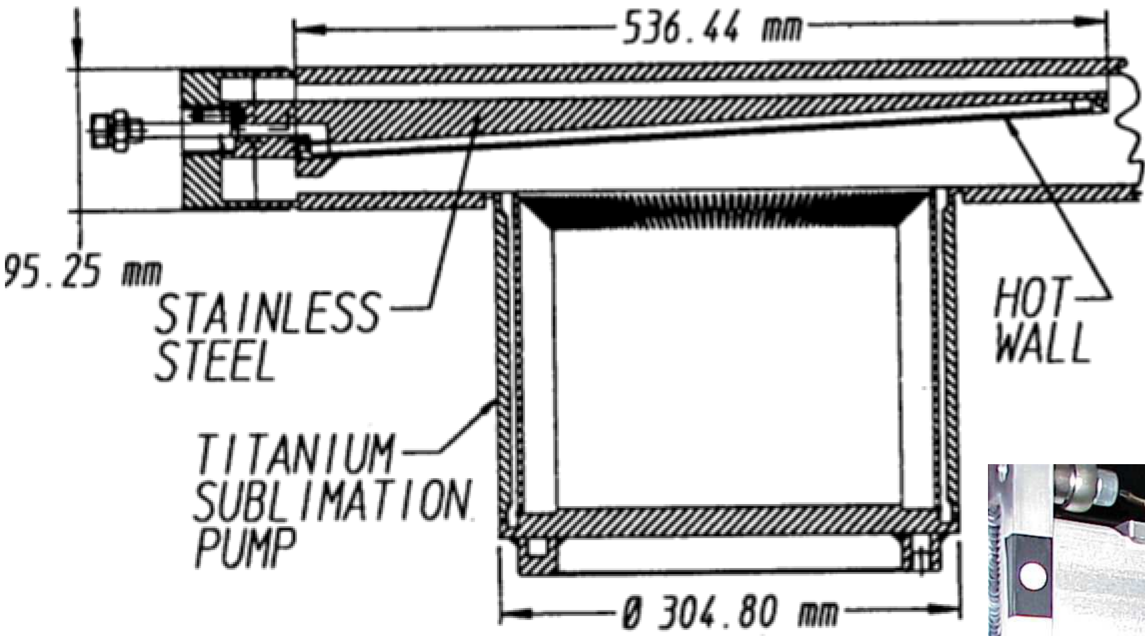
- *Gas throughput must be estimated for use of TiSPs, so that the sublimation period may be reasonable for the accelerator operations. Measures should be taken in design to maximize Ti covered surface area.*
- *Baffles must be in place to block all line-of-sight between the Ti filaments and the particle beam space.*
- *For very long term operations, Ti thin film peeling may be an issue. Orientation of the TiSPs plays a role in minimize particle generations to the beam space.*
- *Ti filaments may become EMI antennae when not properly shielded against short bunched particle beam. Sometime RF filtering in necessary.*
- *Adequate protections (mechanical and corrosive) are important for the electric feedthroughs on the Ti cartridges.*

Peeling of Titanium Films

- As Titanium builds-up on a pumping surface, it will begin to peel.
- A typical thickness where peeling begins is 0.05 mm.
- Peeling produces dust particles and increases surface temperatures during sublimation.
- Because of peeling, pumping surfaces may require periodic cleaning (glass bead blasting and/or chemical cleaning).
- If peeling is a problem, a TSP was probably a bad choice or you are misusing the pumps.

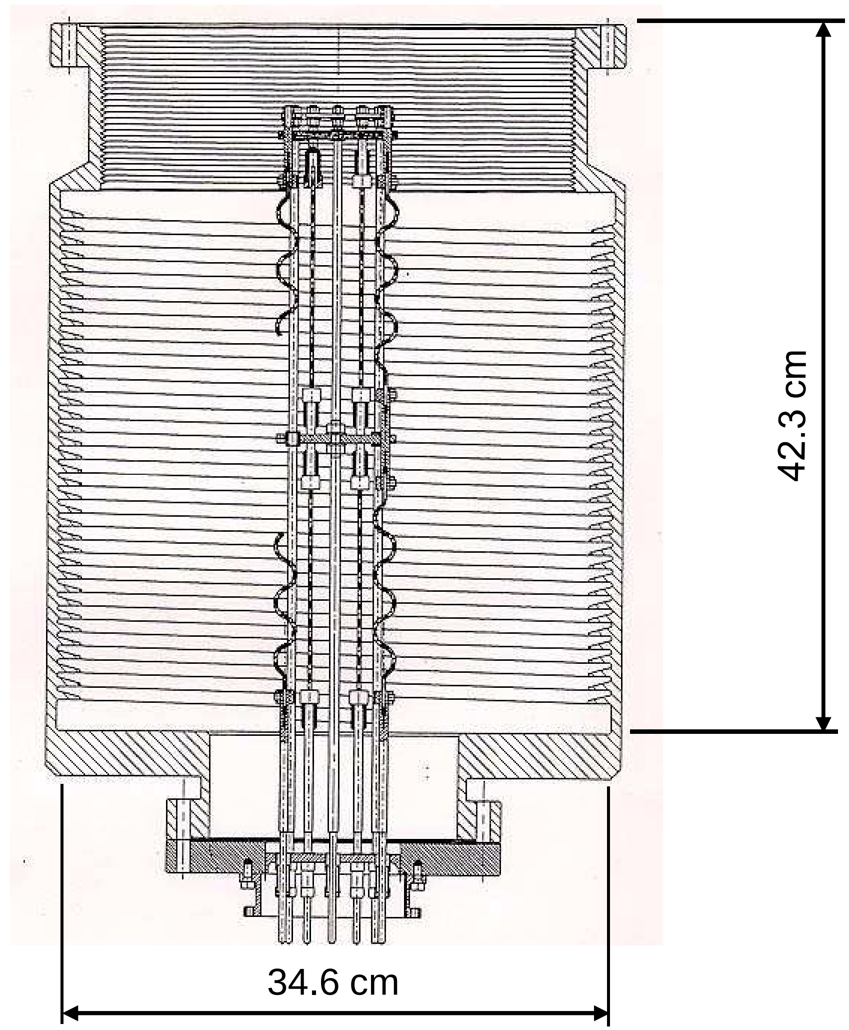


PEP-II LER Arc TSP and Photon Stop



DAFNE Collider TiSP

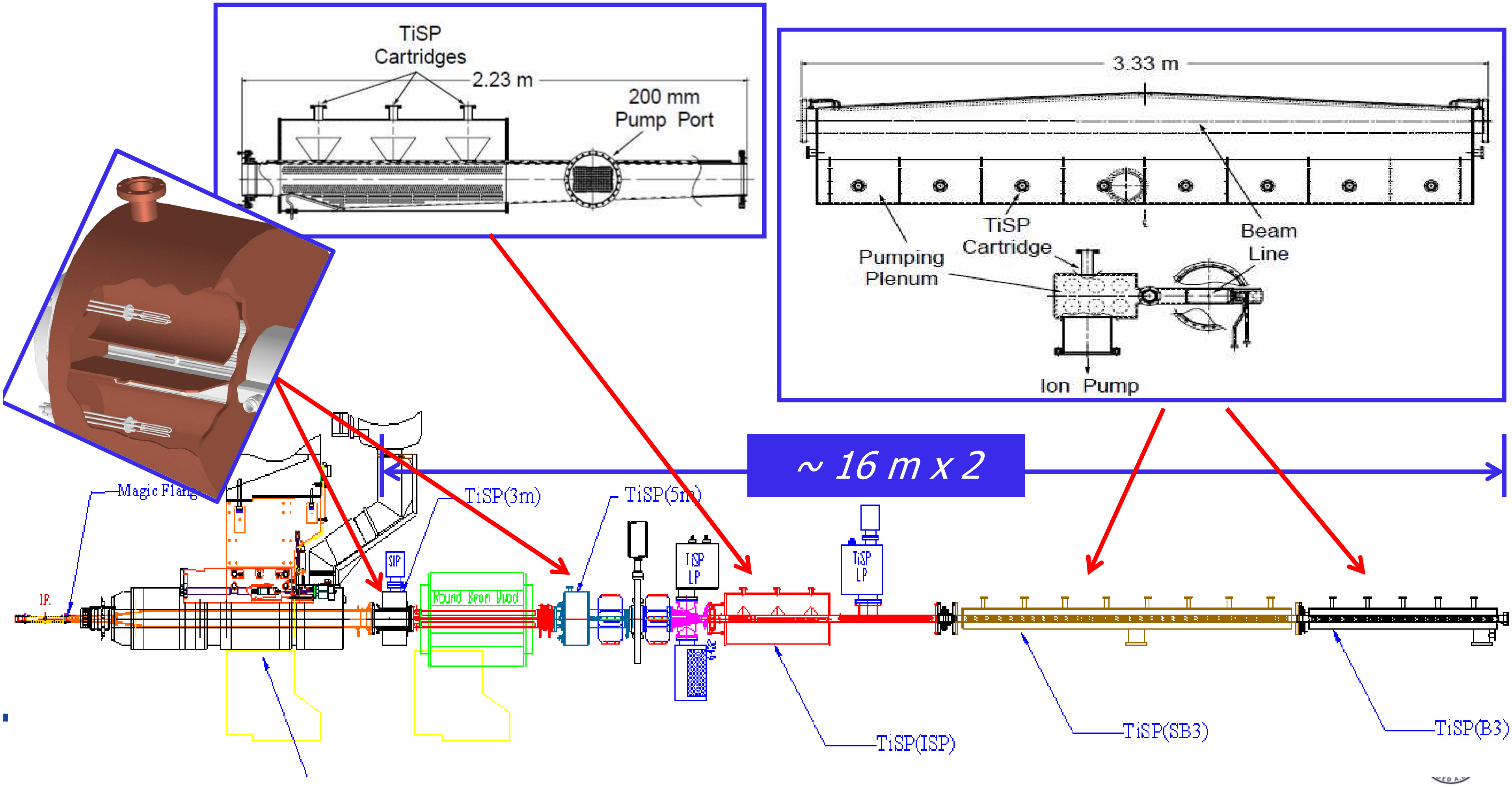
- Used at photon stops
- Specially ordered cartridge with more filaments
- Grooved interior surfaces to increase pumping speed and capacity



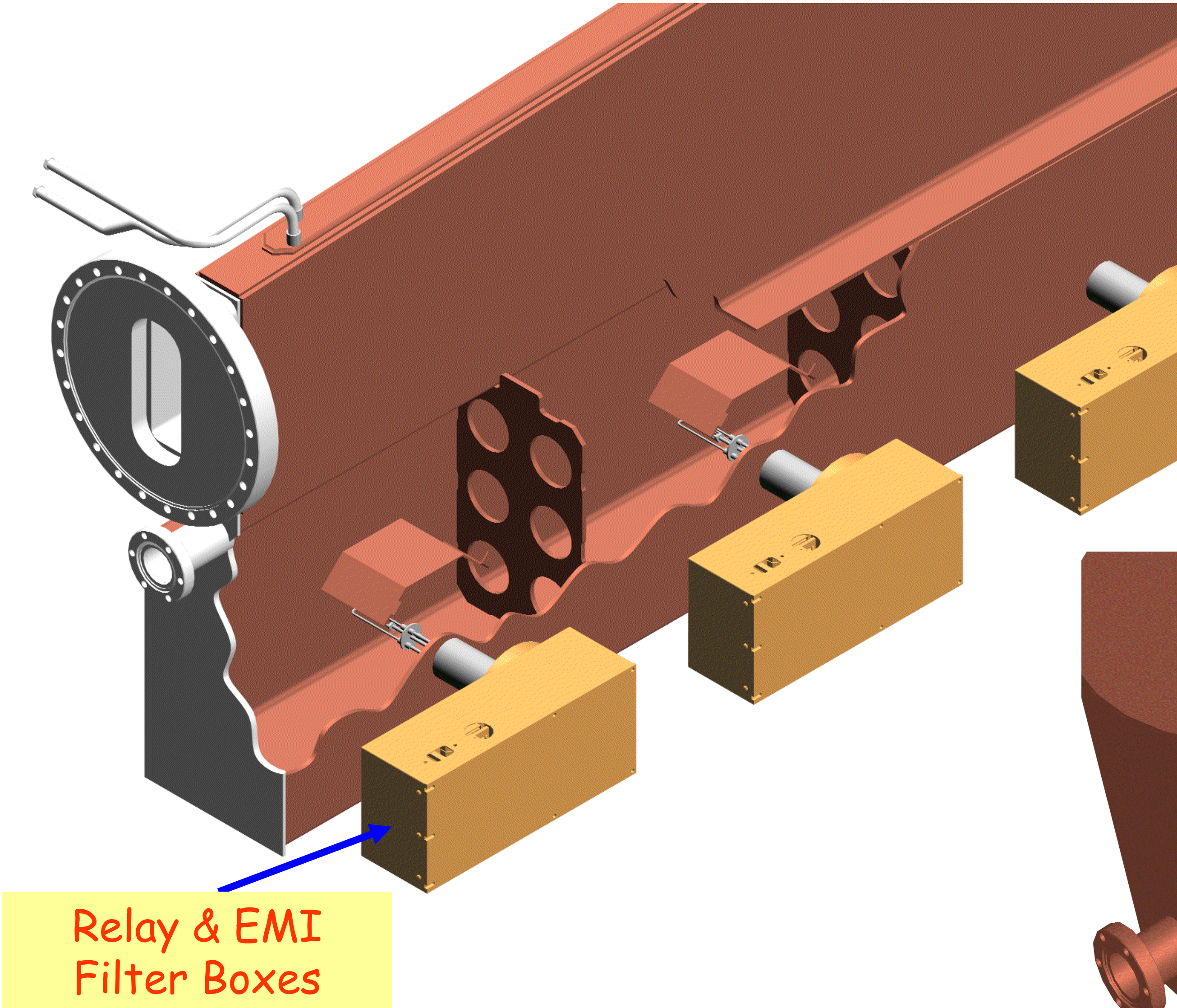
Courtesy: C. Vaccarezza, INFN

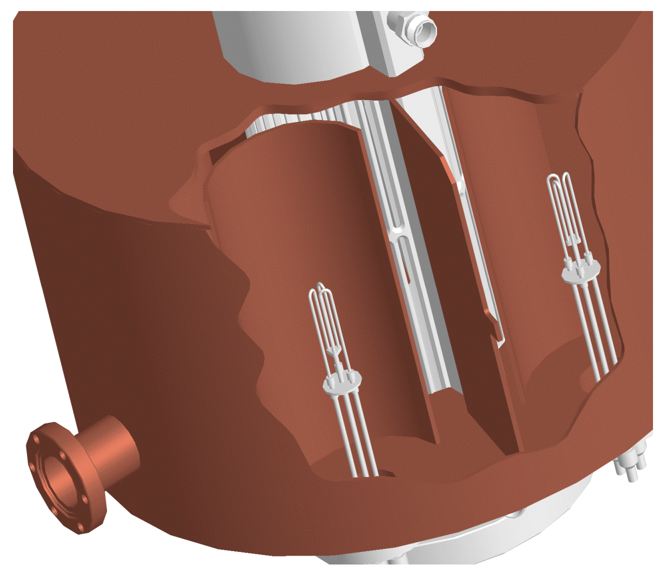
TiSPs in CESR Interaction Region

- During CESR/CLEO III era, distributed TiSPs were implemented as the main pumping system.
- 2X26 TiSP cartridges populated ~32 m. A RF-filter, multiplexing TiSP control system was also deployed.

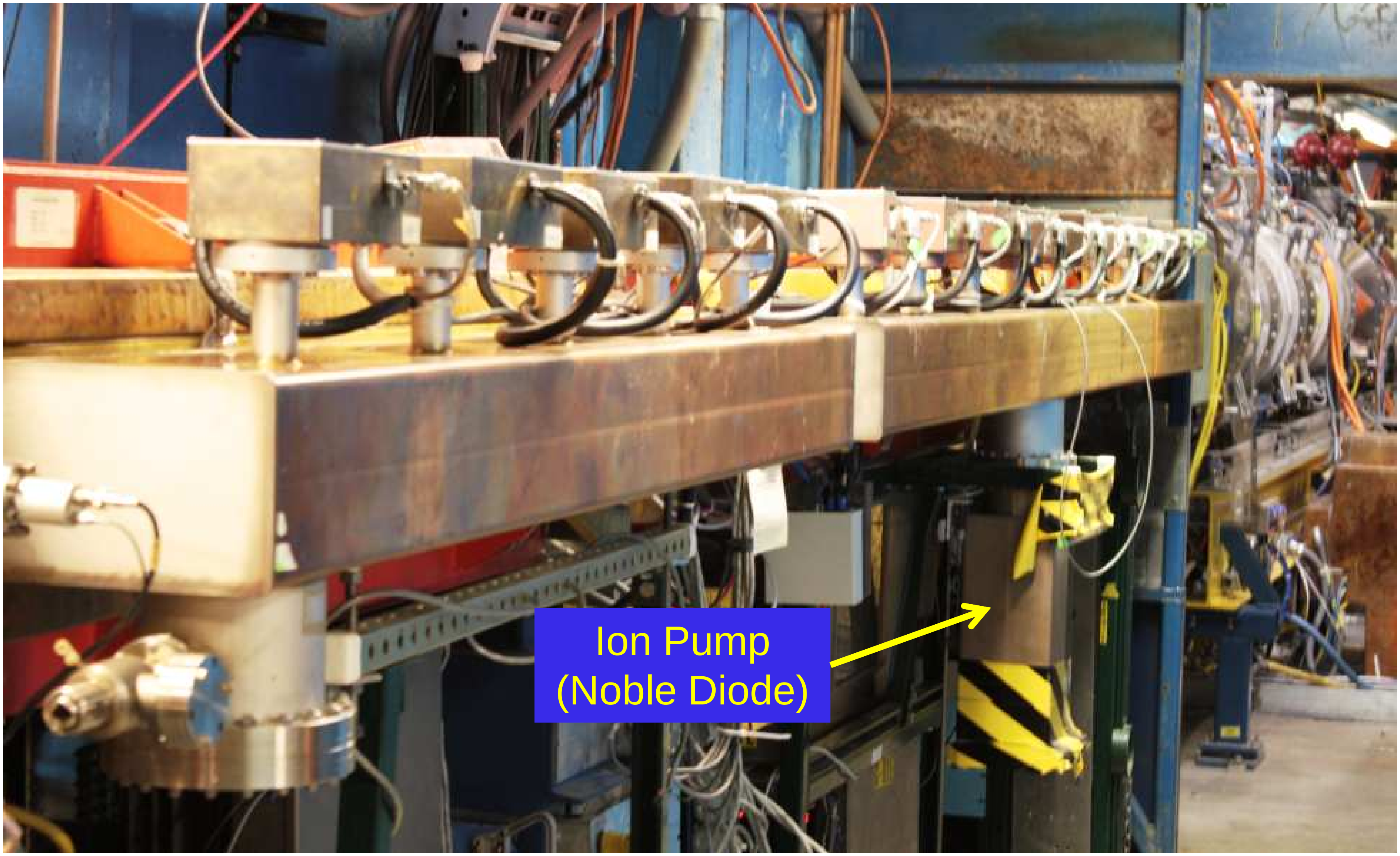


TiSP Chambers in CESR – A Close Look





TiSPs in CESR Interaction Region



TiSPs in CESR IR – Performance History

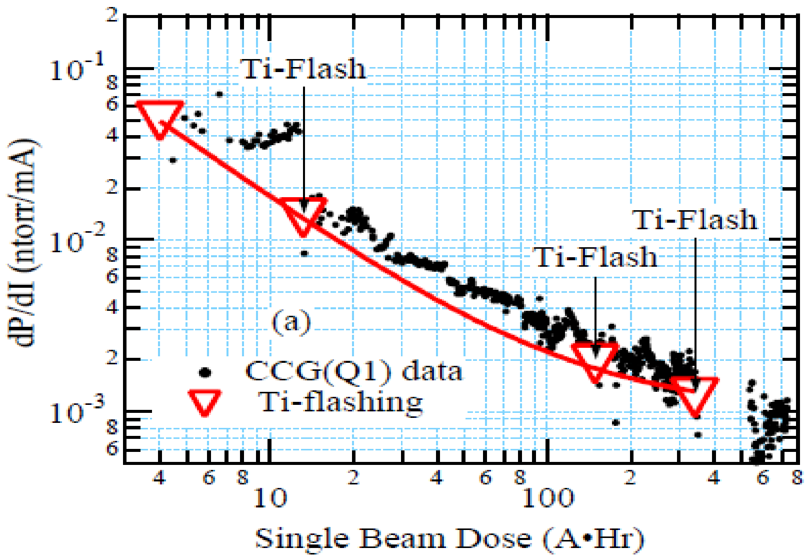
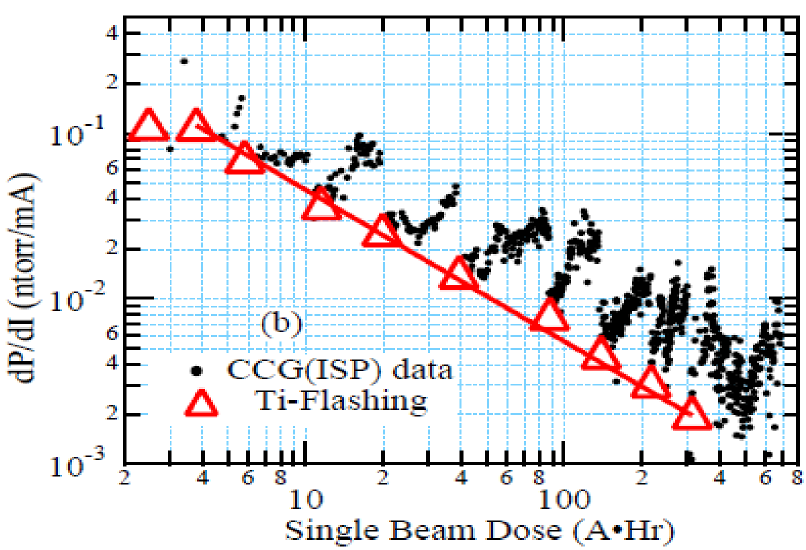
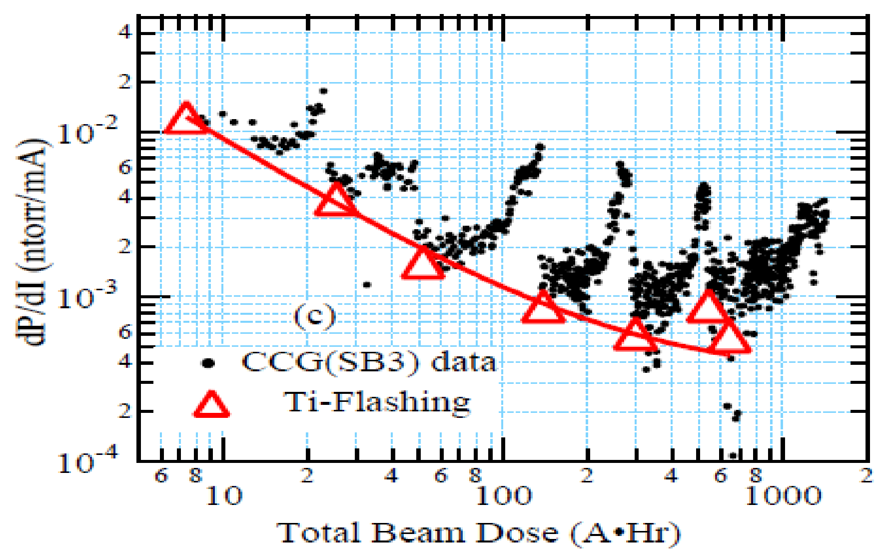


TABLE I. Synchrotron Radiation Flux and Gas Load in the CESR IR for 300 mA $e^{\pm}$ Stored Beams.

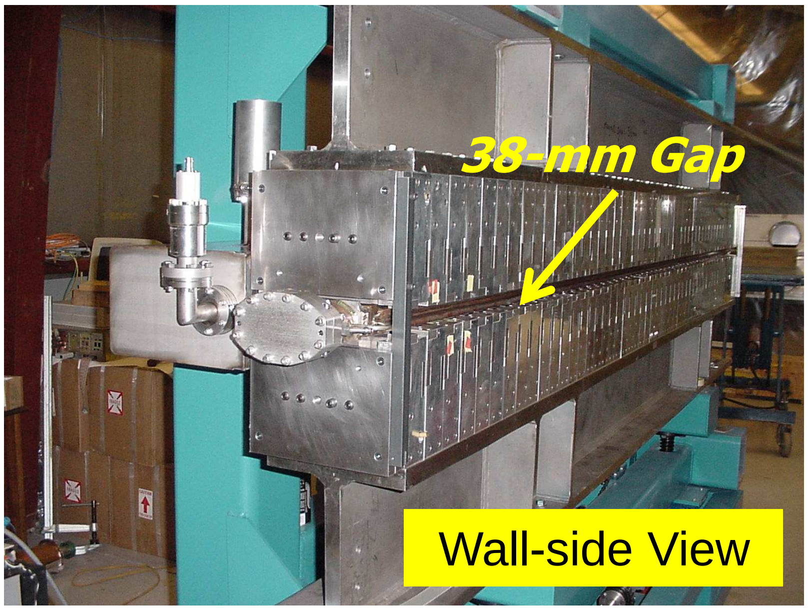
Location	Flux Density (Photon/s/m)	Total Flux (Photons/s)	CO GasLoad [Torr-l/s]
Q1-Pump	$1.3 \cdot 10^{18}$	$2.5 \cdot 10^{17}$	$7.9 \cdot 10^{-8}$
ISP absorb.	$1.1 \cdot 10^{19}$	$1.9 \cdot 10^{18}$	$2.0 \cdot 10^{-7}$
Soft-Bend	$3.3 \cdot 10^{18}$	$3.5 \cdot 10^{18}$	$6.7 \cdot 10^{-7}$
Hard-Bend	$6.9 \cdot 10^{18}$	$2.3 \cdot 10^{19}$	$1.3 \cdot 10^{-6}$

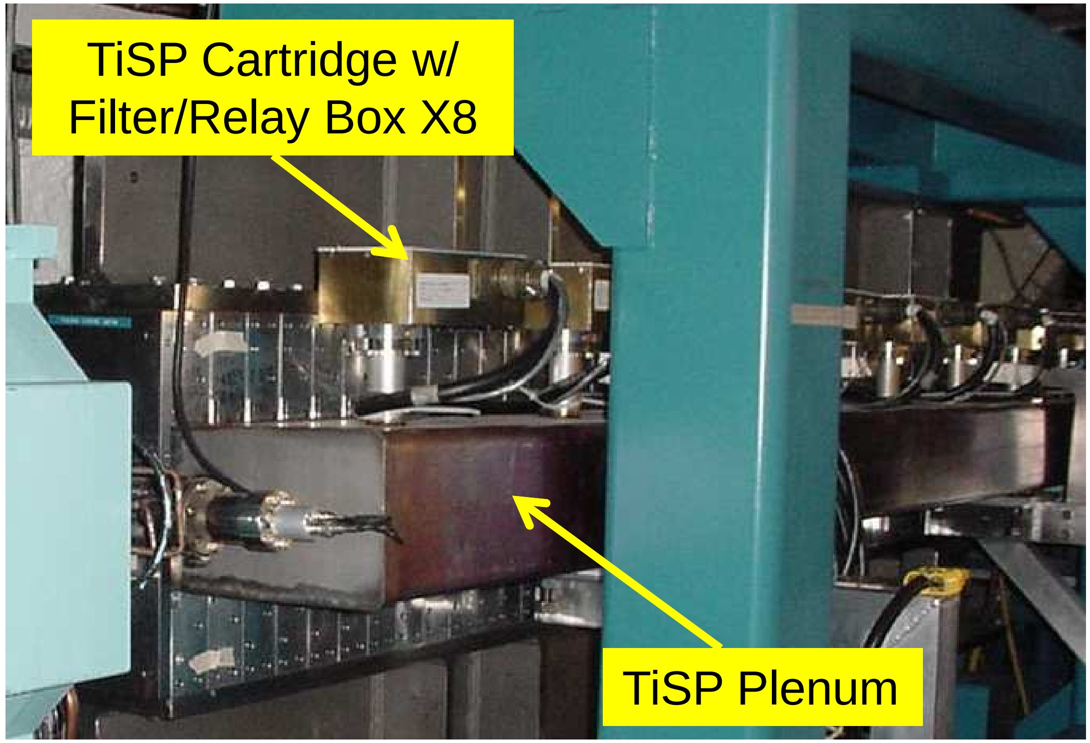


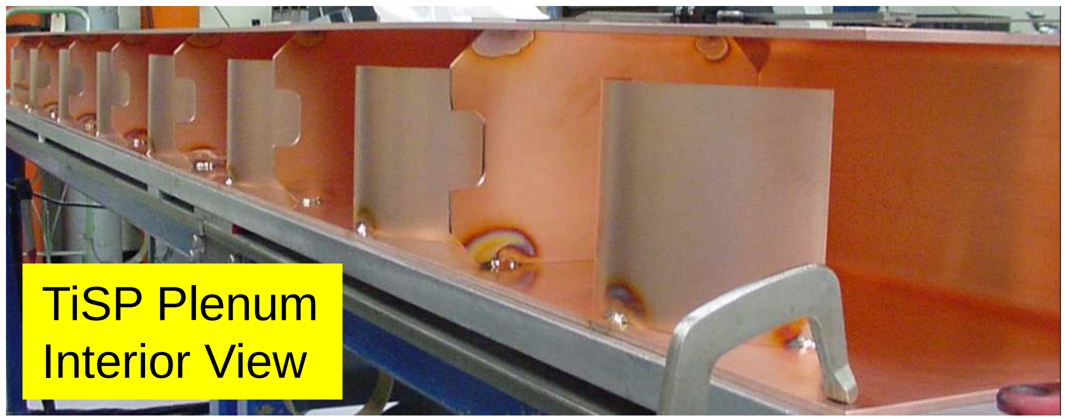


TiSPs in a Wiggler Vacuum Chamber

TiSP was incorporated in narrow gapped wiggler chamber for the CHESS G-line



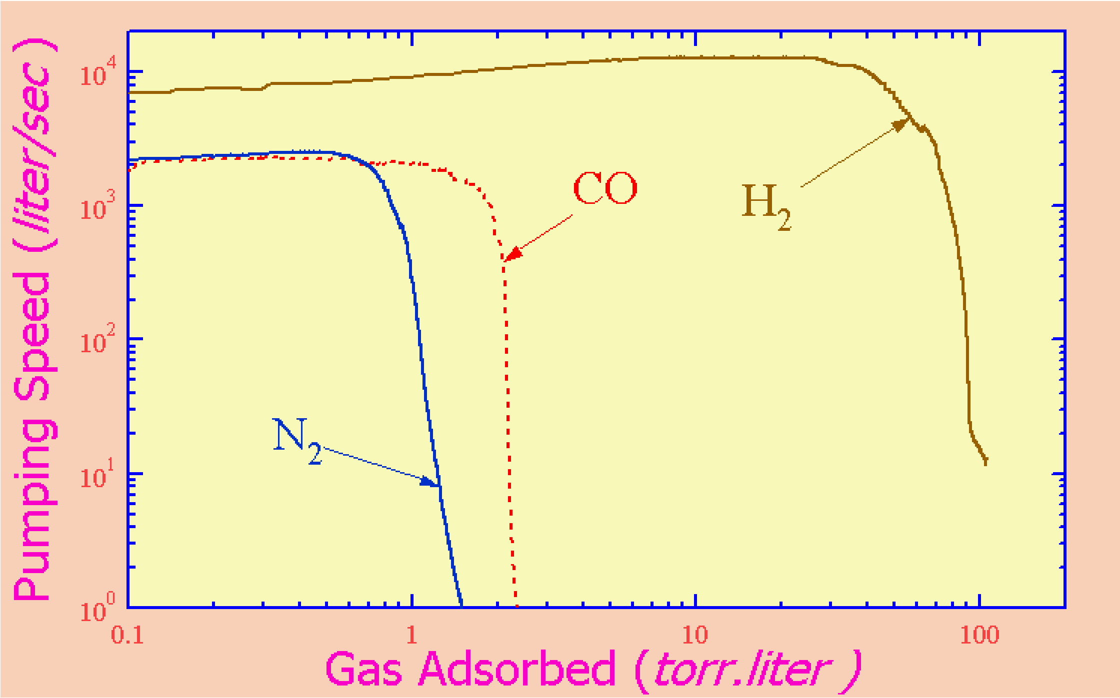


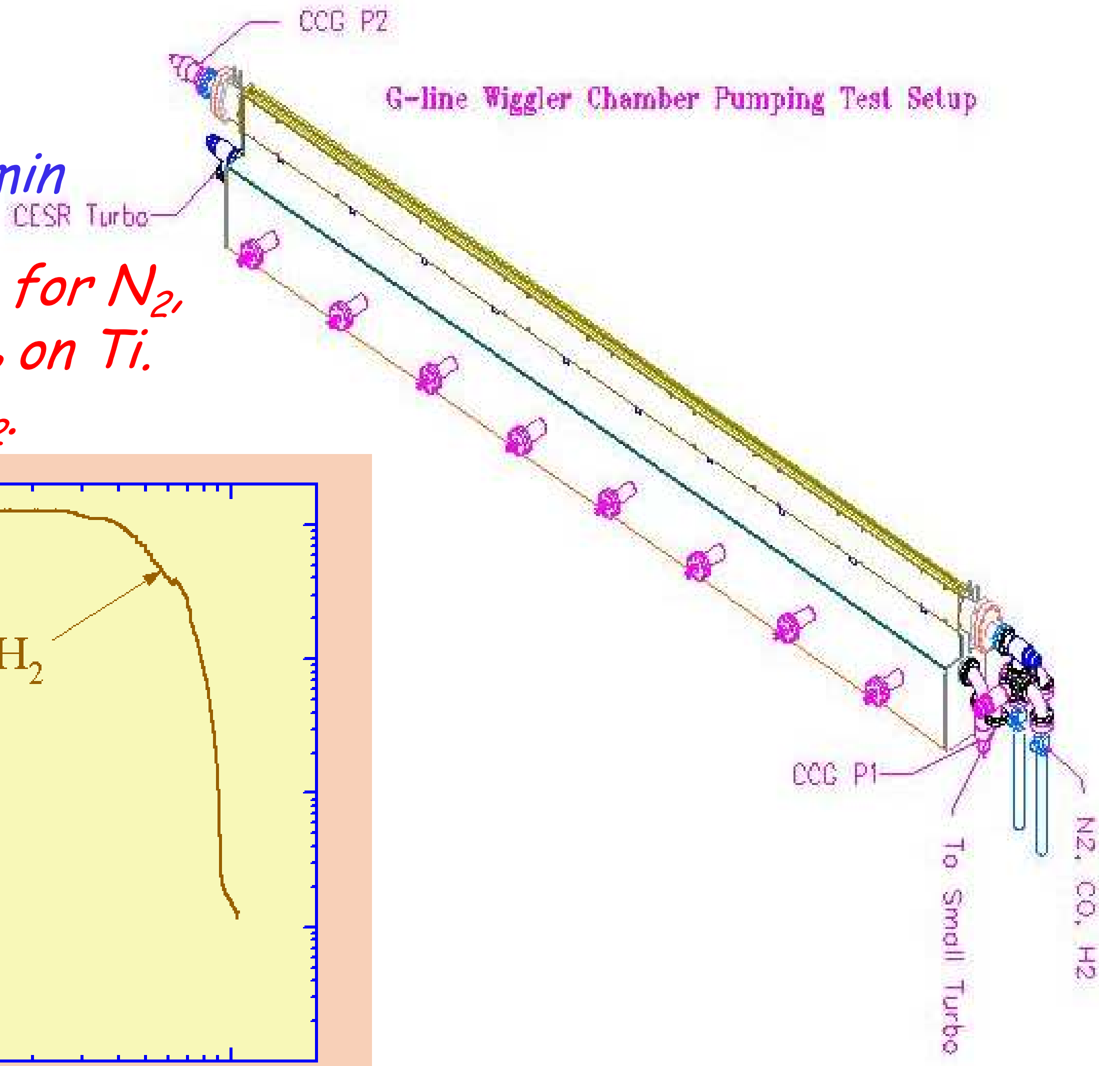


TiSPs in a Wiggler VC – Pumping Speed

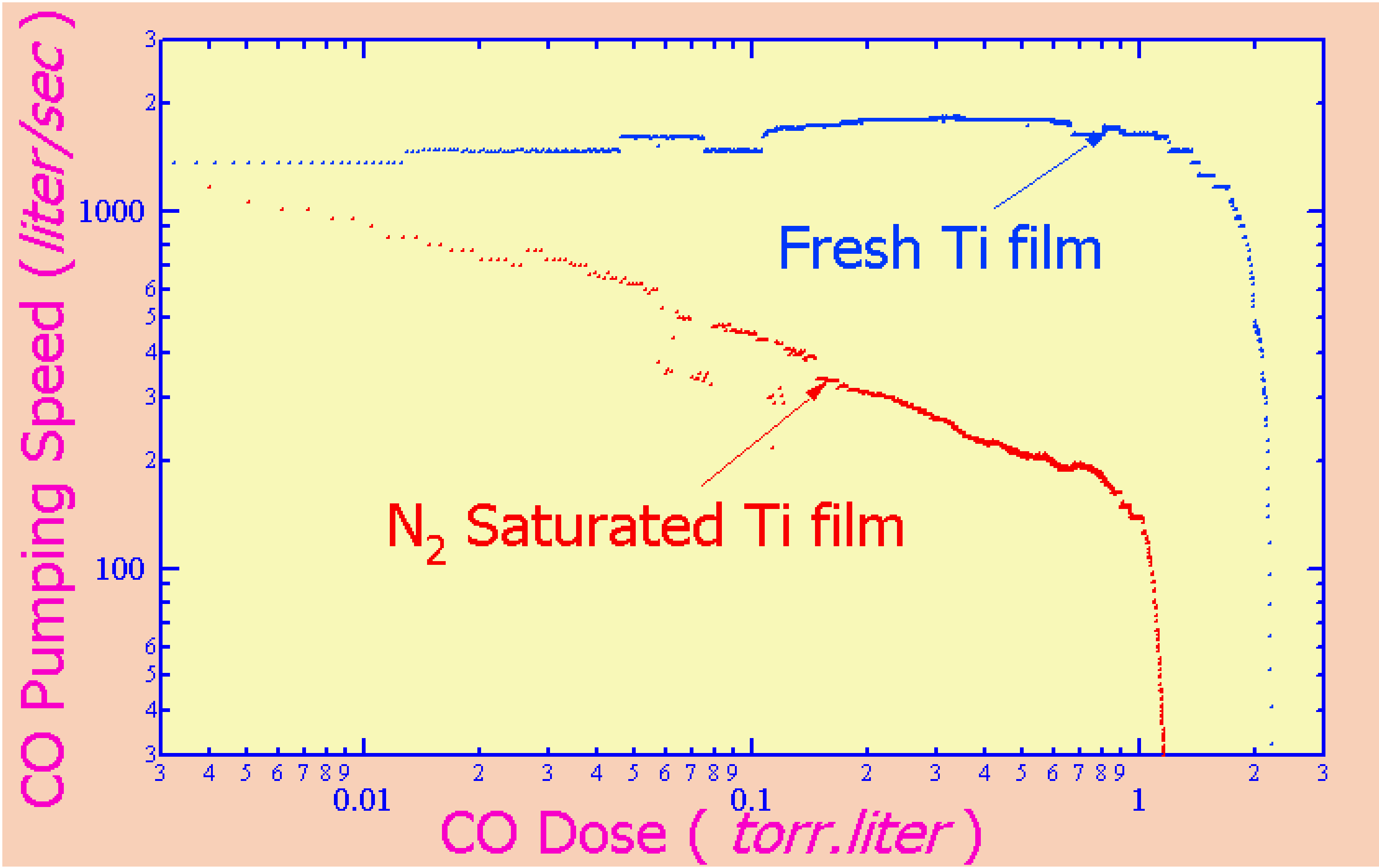
- ✓ *Calibrated leaks used to measure pumping speed*
- ✓ *TiSPs sublimation: 200W-2min*

- ✓ *Twice as capacity for CO as for N_2, indicating dissociation of N_2 on Ti.*
- ✓ *Much higher capacity for H_2.*





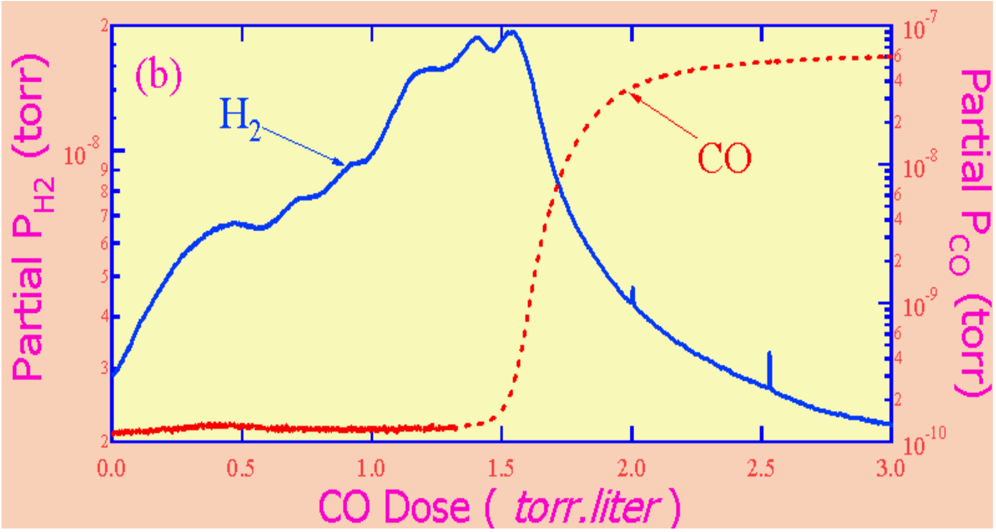
TiSPs Pumping – Another Look

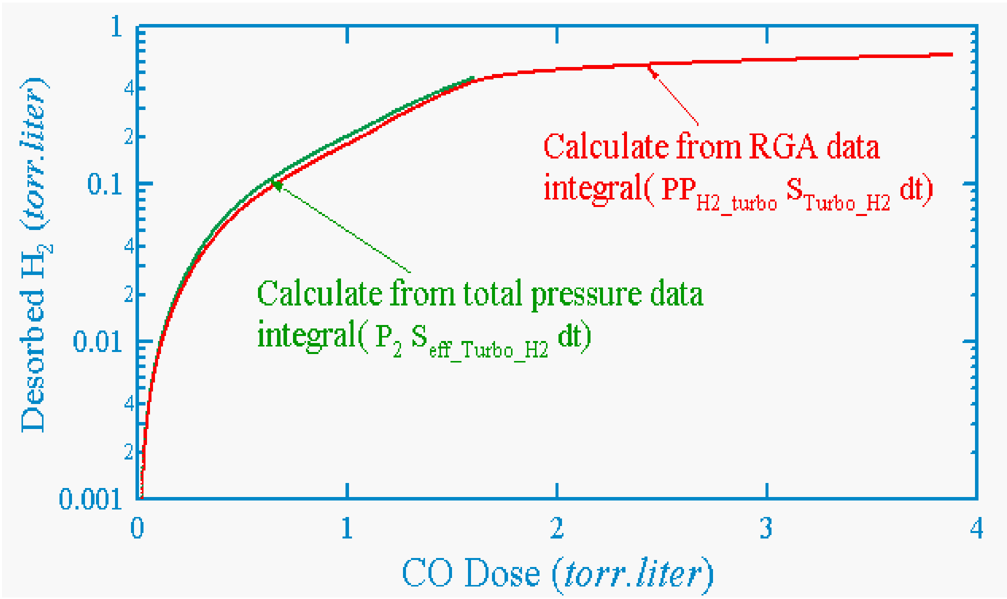


More reactive CO re-arrange adsorbed N atoms on Ti surfaces. Note the (1/2)-capacity for CO

CO Adsorption on Hydrogen-saturated Ti Film

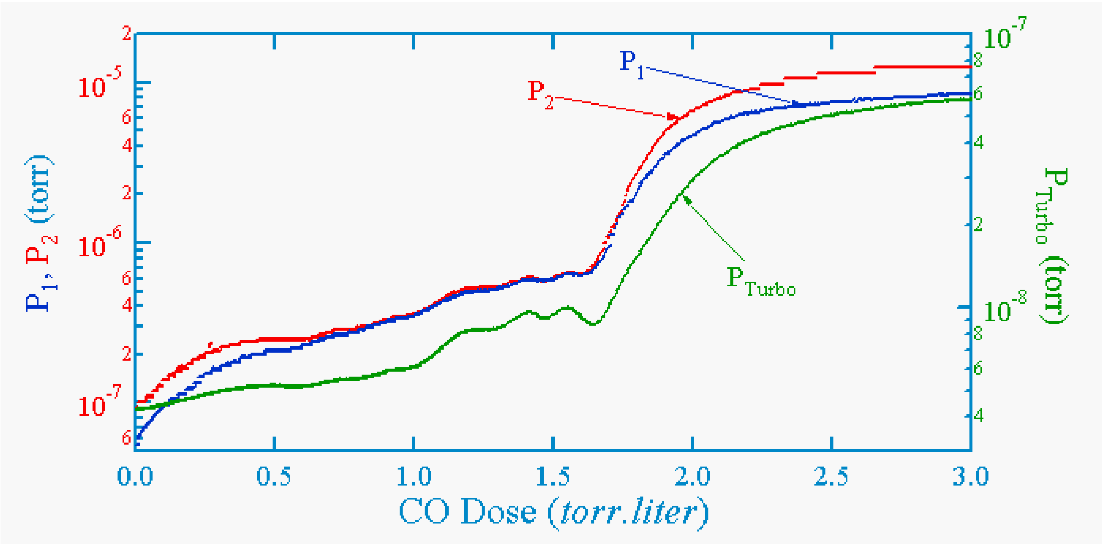
- *After saturating Ti surface with ~ 100 torr-liter H_2, introduce CO.*
- *RGA data clearing indicating further adsorption of CO, and desorption of H_2 simultaneously.*

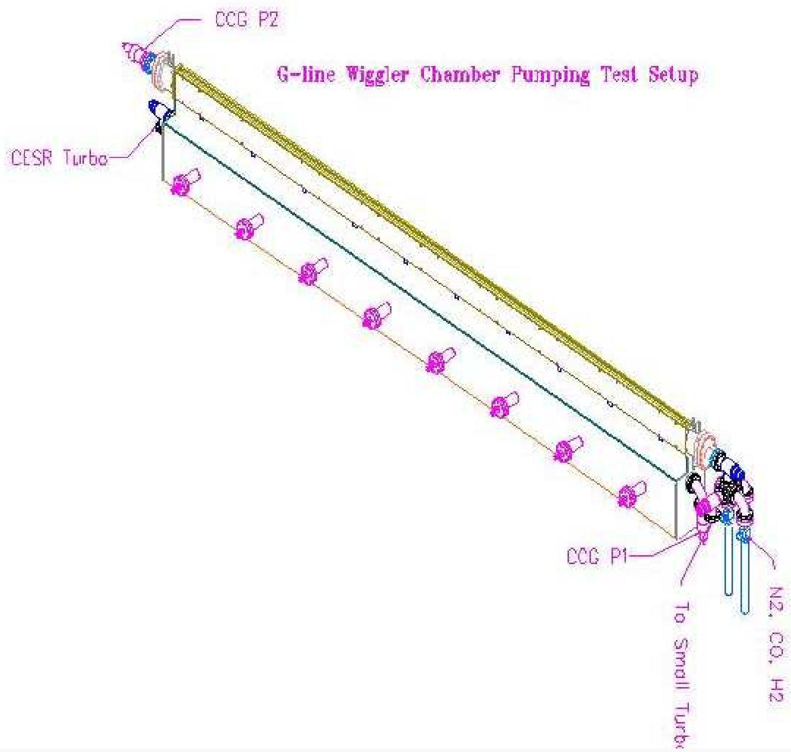




- *Careful quantitative analysis showed CO promoted H recombination desorption.*
- *1.5 torr-liter of CO replaced ~0.7 torr-liter of H_2 !*

Important Partial Pressure Info





Total pressure gauges data. Low sensitivity to replaced H_2 by CO.

RGA data clearly showing CO replacing H_2.