Vacuum Issues in the CKM Veto System

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- Physics motivation for vacuum
- Design of CKM and veto system
- Outgassing and pumping measurements
- Preliminary vacuum design

Real experts:
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7.5.3 Beam Gas Interactions

An interaction of a K^+ with residual gas in the vacuum decay volume can produce a π^+ that falls into the acceptance of the CKM detector. Vertex quality cuts will not assist in rejecting these events. The best protection, of course, is a good vacuum. We assume 10^{-6} torr, which has been achieved in KTeV. Any such interaction will also produce other observable particles, and most beam gas interactions can be rejected on that basis.

The K^+ interaction length in air at 1 atm is about 470 m, so at 10^{-6} torr it is smaller by a factor of $10^{-6}/760 = 1.3 \times 10^{-9}$. Hence, the interaction probability in 30 m is

$$(1.3 \times 10^{-9}) \left(\frac{30}{470}\right) = 8.4 \times 10^{-11}. \quad (25)$$

We have simulated 12,000 beam gas interactions, using FRITIOF to generate K^+ interactions that produce a π^+ with $p > 14$ GeV. Of all K^+ interactions in FRITIOF, 2.5% produce such a π^+. The interactions are generated flat in z between the last vacuum tracker and the first straw tracker. The events are subjected to the standard cuts, with 70 passing. Also, 48% of the interactions produce π^0's for which the veto probability is effectively unity. The effective branching ratio of this background is then:

$$B_{\rm eff} = \left(\frac{1}{\epsilon_{\pi\nu\nu}}\right) \left(\frac{1}{K^+ \text{ decay}}\right) (\text{prob interact})(\text{fract } p_\pi > 14 \text{ GeV})(\text{frac pass cuts})(\pi^0 \text{ rejection}) \quad (26)$$

$$B_{\rm eff} = \left(\frac{1}{0.018}\right) \left(\frac{1}{0.17}\right) (8.4 \times 10^{-11})(0.025) \left(\frac{70}{12000}\right) (0.52) < 2.1 \times 10^{-12}. \quad (27)$$

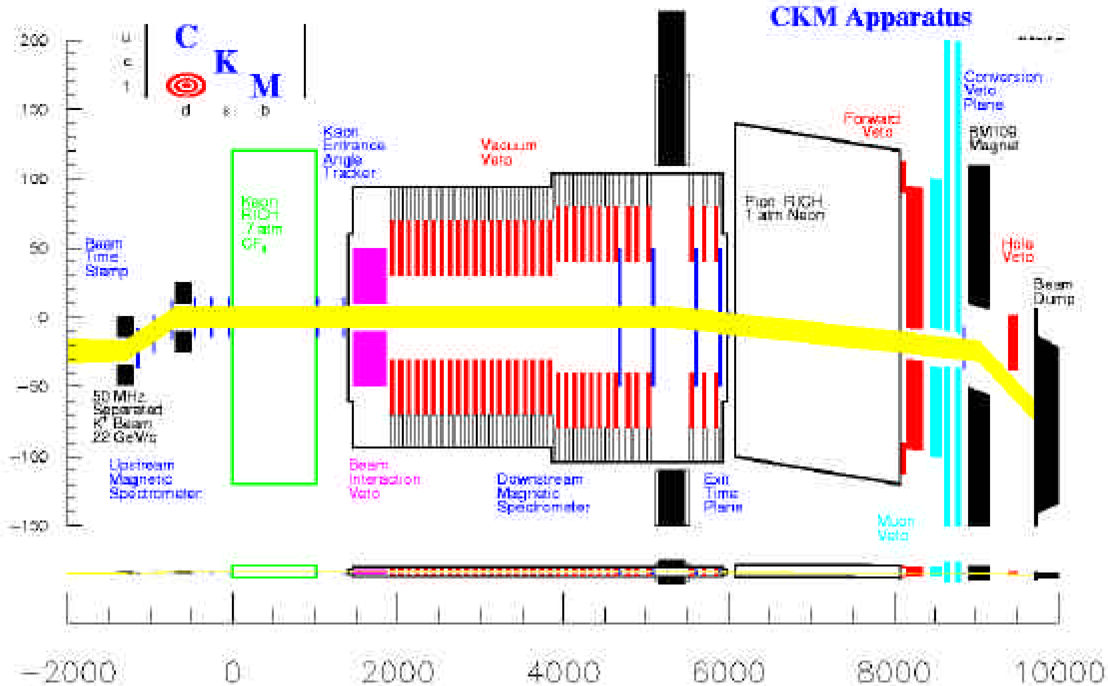
We consider this to be a conservative upper limit since charged hadrons from beam gas interactions will also be used to veto.

7.6 Accidental Background Sources

By accidentals background we mean any process by which two beam particles conspire to fake $K^+ \to \pi^+ \nu\overline{\nu}$. The two beam particles must be close in time, yet one must go undetected. Both K^+ and π^+ will be detected by the beam RICH as well as the beam trackers, so the *a priori* probability is small for conditions to exist for an accidental background event to occur. Even if a K^+ or π^+ enters the decay volume undetected, there is no problem unless it decays. If a π^+ decays, it almost always produces a muon, for which CKM has enormous rejection. The detected K^+ must also decay, since we will veto events with beam particles in-time with $K^+ \to \pi^+ \nu\overline{\nu}$ candidates. We can project the K^+ trajectory from the beam vacuum trackers to the scintillating fiber tracker which spans the beam and make a requirement that no beam particle consistent with a non-decayed K^+ appear. Even if the scintillating fiber tracker suffers some level of inefficiency, the Charged Veto Plane will also have a shot at it, making a complete miss unlikely.

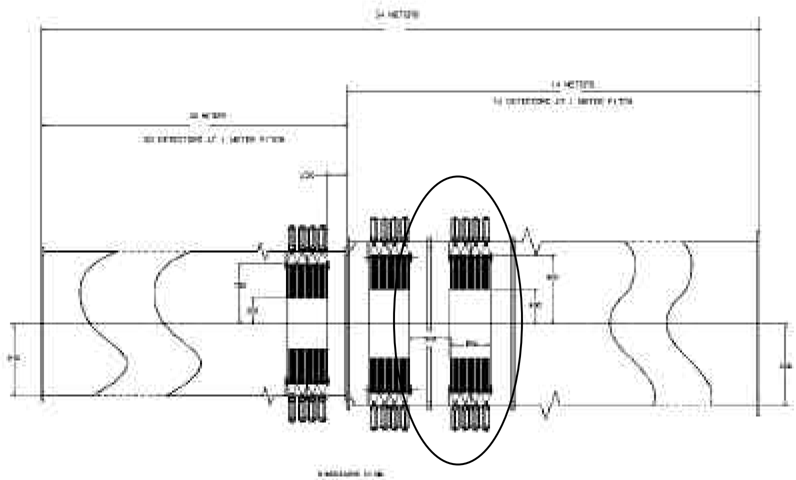
Thus we are led to conclude two K^+ decays are the most plausible candidate accidental background. To be outside the scope of prior estimates, the event must be confused by associating the π^+ from one decay (the undetected K^+) with the the detected K^+, whose decay products must escape completely unnoticed. One can imagine a $K^+ \to \mu^+ \nu_\mu$ decay where the muon is very low-energy in the laboratory. Then the undetected K^+ should decay via $K^+ \to \pi^+ \pi^0$ or $K^+ \to \pi^+ \pi^+ \pi^-$ in order to provide a π^+ candidate. However, one can see from figure 3 that $K^+ \to \pi^+ \pi^+ \pi^-$ cannot produce a π^+ with $p > 14$ GeV, so we will focus on $K^+ \to \pi^+ \pi^0$.

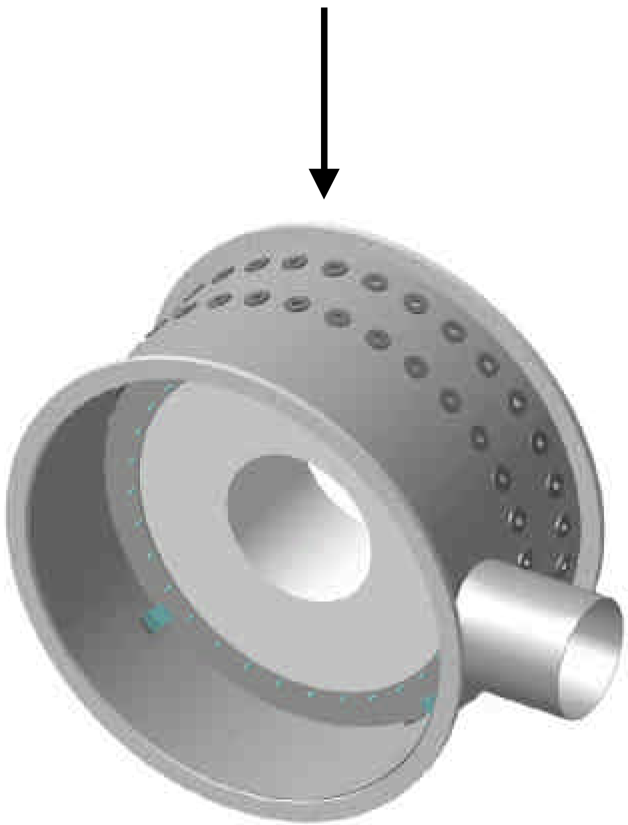
So, we need: (1) the probability of detecting only one of two K^+'s that enter CKM close in time, (2) the probability that one will decay with no observed products, and (3) the probability that



MATERIAL IN VACUUM:

- 34 VVS modules of 2 different sizes
- 4 m long BIVS system
- 29 layers of straw tubes
- 2 Kevlar/mylar windows





Each VVS module is half filled with a stack of 80 layers of 5 mm scintillator and 1 mm lead. There are 16 sections of scintillator in each layer.

Total amount of scintillator for a small VVS module is:

- 1280 scintillator ‘tiles’
- 5×10^5 cm^3 volume
- 2×10^6 cm^2 surface area

A large module has about 20% more scintillator.

Total volume of a small VVS vacuum tank is about 3 cubic meters.


REZHOR

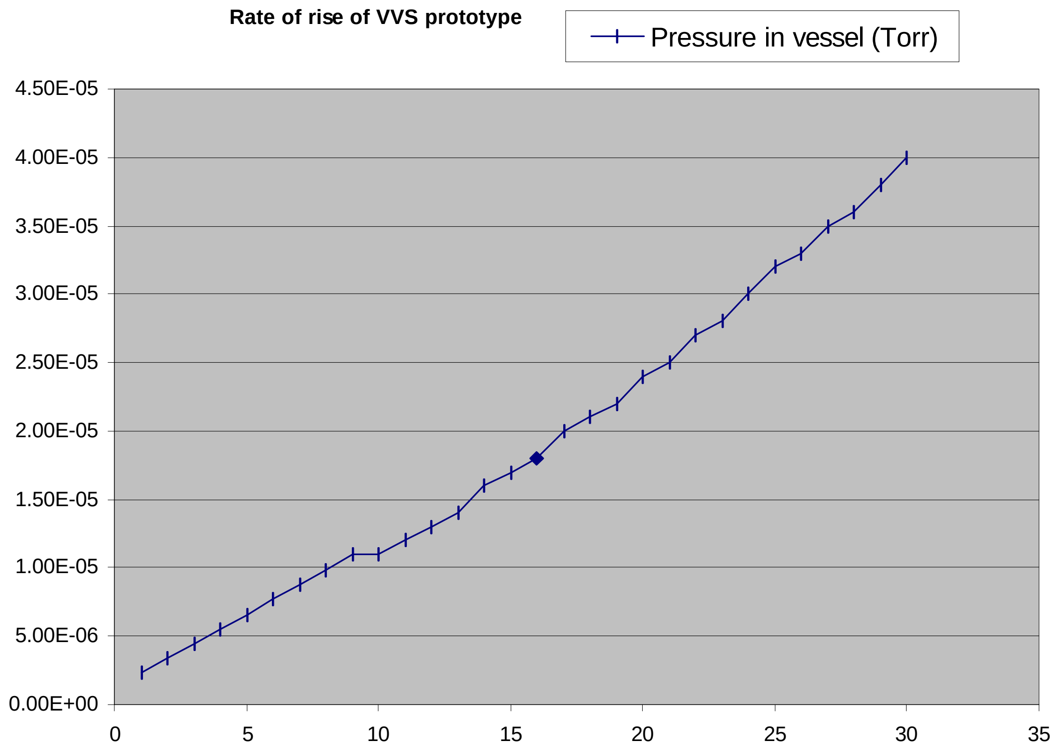
Outgassing rates were determined by 2 groups at Fermilab:

Material	Outgassing rate for 1 tile (1600 cm^2)
Bicron 404	4.7 E-6 Torr-L/sec
IHEP scint	8.5 E-6 Torr-L/sec
Tyvek 1060	8.1 E-9 Torr-L/sec
Lead	1.3 E-9 Torr-L/sec

If these rates scale, then total pumping speed required for outgassing rate from scintillator is on the order of:

$$\frac{(5 \times 10^{-6} \text{ Torr-L/s}) \times (40{,}000 \text{ tiles})}{10^{-6} \text{ Torr}} = 200{,}000 \text{ L/s}$$

However, rate of rise measurements on the 2 sector prototype have shown a significantly lower outgassing rate for a stack of 160 Bicron 404 tiles:



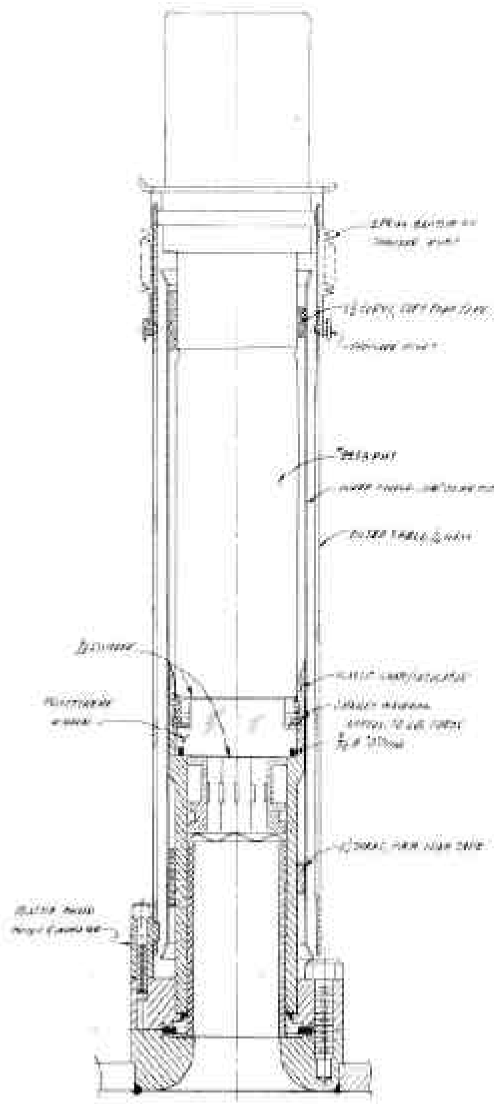
Outgassing rate = (38E-6 Torr) x (600 L) / (30)(60) sec = 1.3 E-5

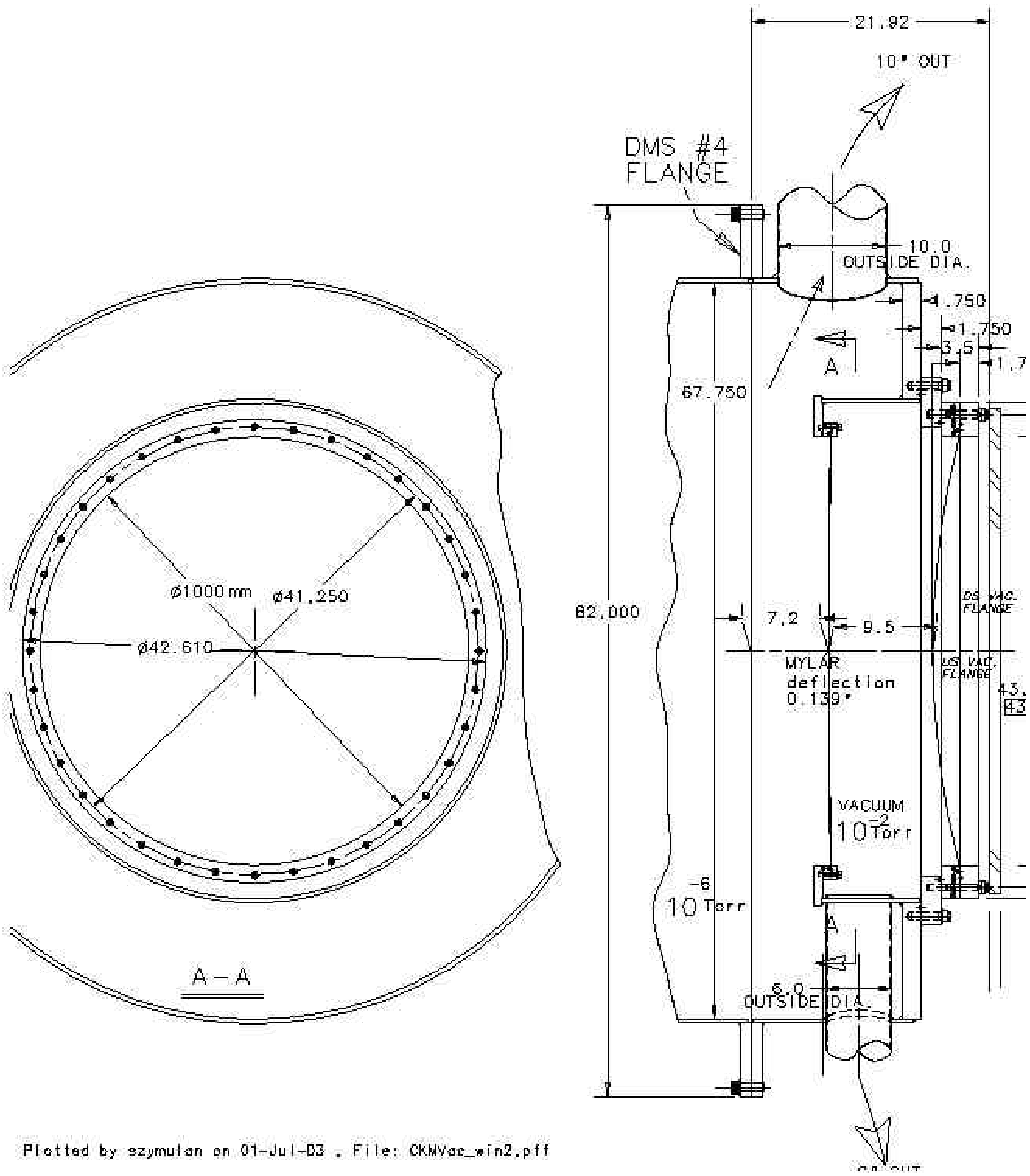
Proposal for PMT window on vacuum vessel and connection to fibers:

- Machined steel housing
- Plastic window with O-ring
- Conflat flange where housing meets vacuum vessel

Prototype used a Delrin housing with a glued window and O-ring (instead of conflat). One glued window failed and had to be reglued

If you use a 2 O-ring design, then diffusion of gas through the extra 2000 O-rings would demand on the order of 4 more TMP's





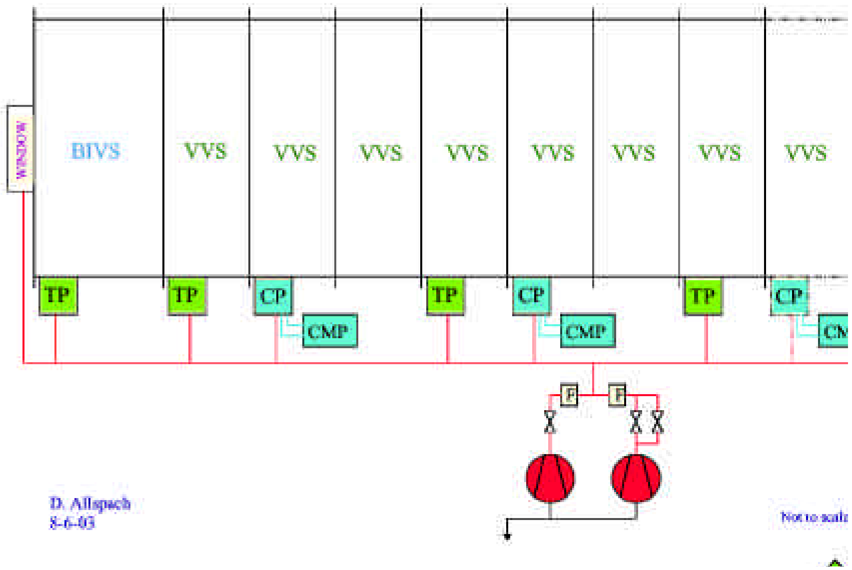
Window design:
- Kevlar primary
- Mylar secondary isolating a rough-pumped buffer

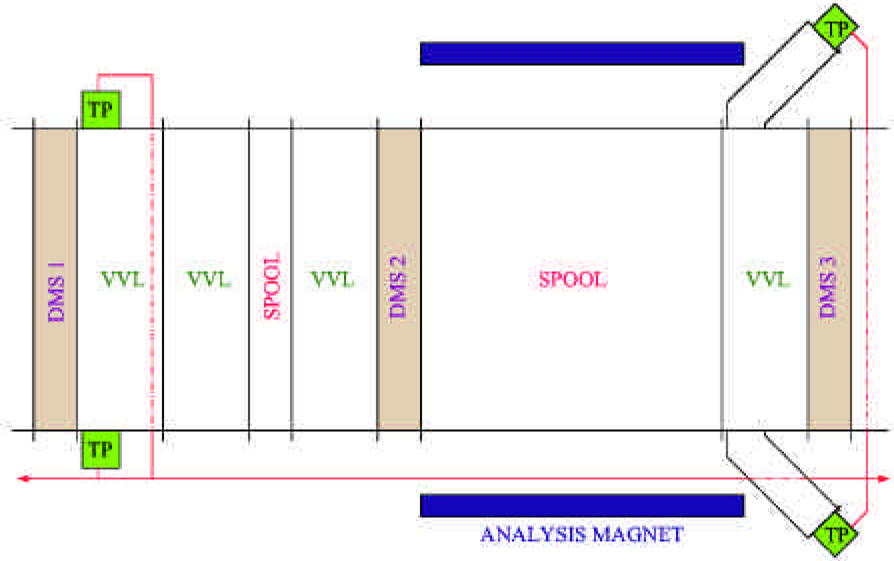
Required thickness for some window materials:

Material	Thickness (mils)	λ (x10^{-3})
Al 6061	45	13
Ti 15-3	10	7
Be SR-200	45	3
Kevlar	23	3

UPSTREAM VACUUM VETO SYSTEM

Conceptual Layout of Vacuum Pumping System





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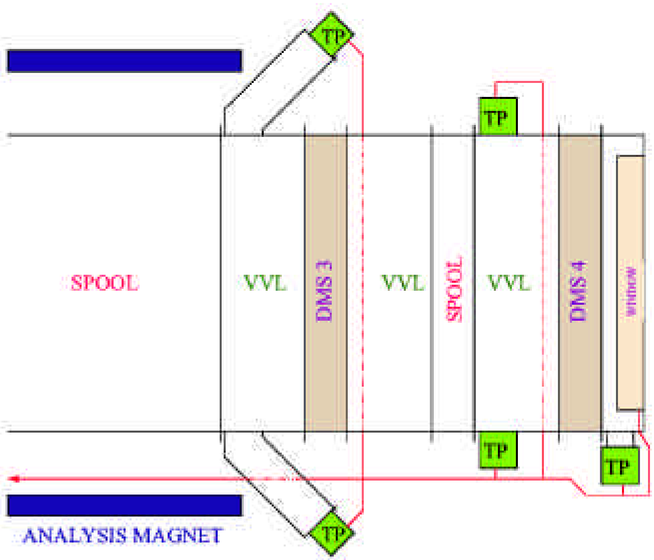
DOWNSTREAM VACUUM VETO SYSTEM

Conceptual Layout of Vacuum Pumping System



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DOWNSTREAM VACUUM VETO SYSTEM

Conceptual Layout of Vacuum Pumping System

The illustrations above assume a hybrid vacuum system consisting of turbo molecular pumps (TP) and cryo pumps (CP) which require compressors (CMP).

The Alcatel model 1600 is one possible TP choice for this system. If chosen, approximately 20 are required including those designated for the DMS region.

A possible cryo pump choice is the Leybold 3000. If chosen, six would be needed.

ALCATEL PUMP OVERVIEW

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6/11/03

•Are magnetically levitated (require < 15 mT magnetic field)
•Clean and dry
•Frictionless, requires no grease
•Maintenance free on clean processes

Failure Modes:
•Normal Shutdowns - unlimited
•Power Failures 1000
•Slow Burst 5 +
•Catastrophic Burst < 5

	Model ATH 1600 M	**Model ATH 2300 M**
Pumping Speed, N2	1500 L/sec nominal	2100 L/sec nominal
Rotational Speed	39,000 rpm / 650 Hz	31,000 rpm / 517 Hz
Vibration Level	0.01 m	0.01 m
Mounting Orientation	any	any
Start-up time	< 6 min.	< 10 min.
Cost per Kit *	$ 25 K	$ 35 K
Cost per L/sec N2	$16.67	$16.67
Cost to Repair **	$ 3400	$ 7500

VVS Design II Vacuum System Cost Estimates for 50/50 Filling Fraction

VACUUM SYSTEM		SYSTEM COST	COST - $ DP
Diffusion Pump System (2) 50,000 L/s DP's (7) 12,000 L/s DP's Includes: LN2 System Water Cooling Instrumentation Roughing System Controls		$ 590K	$0
Turbo + Cryo Pump System (14) Alcatel Model 1600 TMP's (4) Leybold Coolvac 3.0 CP's Includes: Water Cooling Instrumentation Roughing System Controls	Gate Valves for TMP's & CP's	$ 690K	$ 100K
	Gate Valves for CP's only	$ 642K	$ 52K
Turbo + Cryo Pump System (7) Leybold Model 3200 TMP's (4) Leybold Coolvac 3.0 CP's Includes: Water Cooling Instrumentation Roughing System Controls	Gate Valves for TMP's & CP's	$ 651K	$ 61K
	Gate Valves for CP's only	$ 612K	$ 22K