Summary on vacuum requirements and design options

Y. Suetsugu, KEK

- Three talks were presented;

(1) Vacuum requirements (L. Keller)
(2) A Basic Design of IR Vacuum system (Y. Suetsugu)
(3) IR Vacuum Systems First Thoughts (O. Malyshev)

Vacuum requirement_1

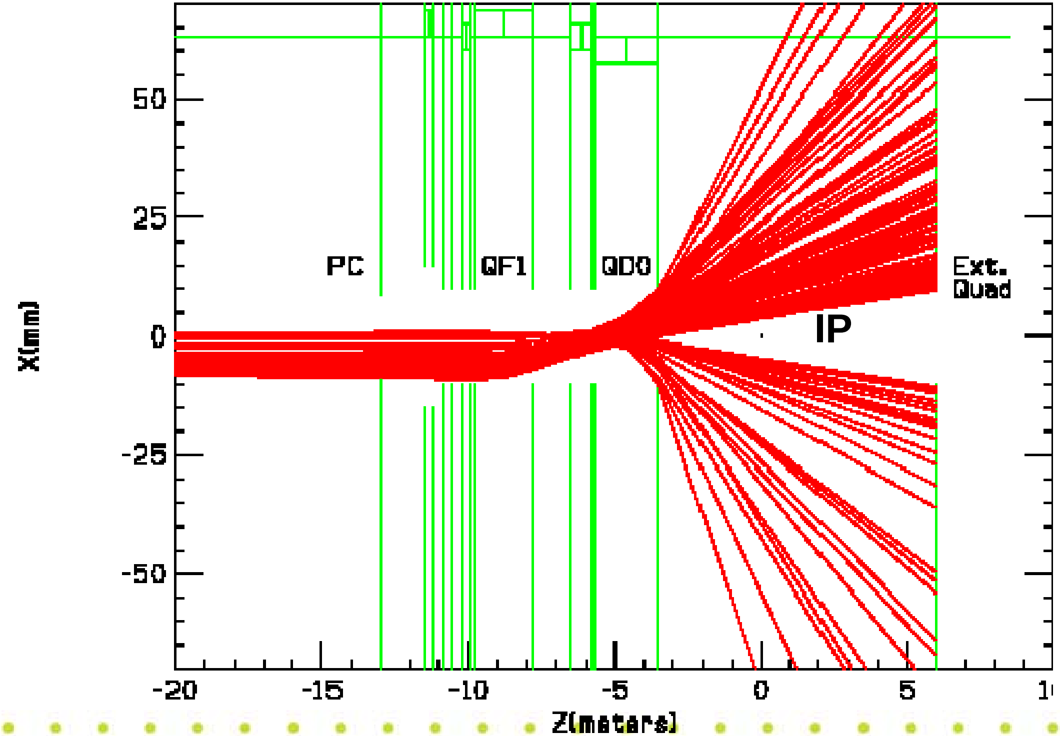
- Study of background from beam-gas scattering

Beam-Gas Bremsstrahlung Electrons Hitting Beyond the Final Doublet

Cut: Outside 10 mm at entrance to 1st extraction line quad

Average Energy = 100 GeV

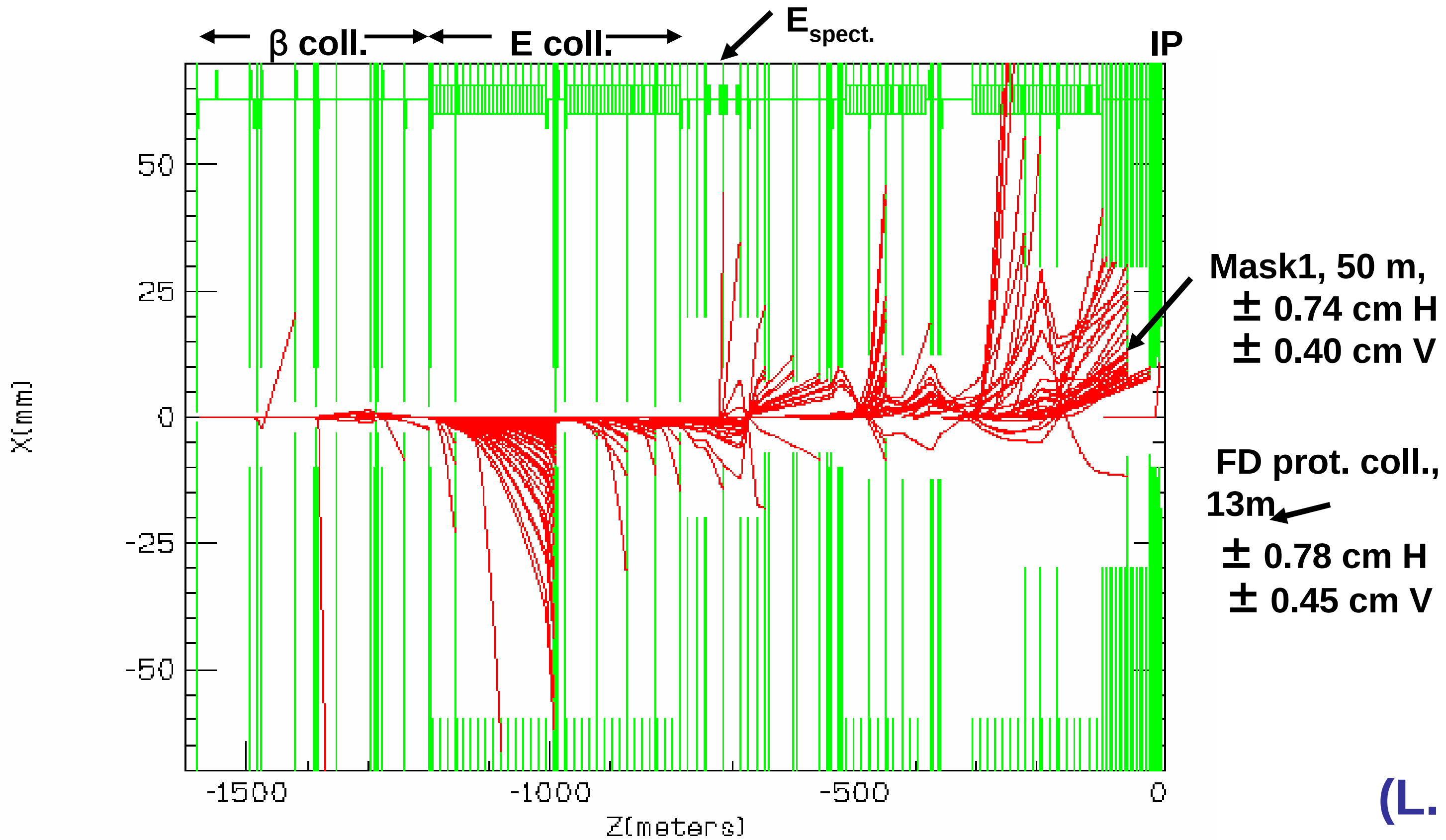
Origin is inside 200 m from the IP



(L. Keller)

Vacuum requirement_2

Loss pts. of 150 random beam-gas brem. trajectories in the BDS using LP TURTLE



(L. Keller)

Vacuum requirement_3

Summary of Hits/bunch and Hits/160 bunches (TPC) – both beams, 10 nTorr

Hits/bunch — Hits/160 bunches (TPC)

Hit Location	GEANT3 Beam-gas brem (charged)	TURTLE Beam-gas brem (charged)		TURTLE Beam-gas brem (photons)		TURTLE Coulomb (charged)	
	Hits	Hits	<E>	Hits	<E>	Hits	<E>
FD Prot. Coll. (13 m) |x| > 0.74 cm |y| > 0.45 cm Origin 0-800m from IP	0.22 35	0.17 27	235 GeV	0.056 9.0	~50 GeV	0.009 1.4	250 GeV
Inside F.D. (10 – 3.5 m) (QF1 to QD0) Origin 0-100m from IP	0.014 2.2	0.006 1.0	~100 GeV	0	-	0	-
IP region (± 3.5 m) (R > 1 cm at Z = 6.0 m) Origin 0-200m from IP	0.04 6.4	0.02 3.2	~100 GeV	0	-	0	-

GEANT3 simulations show that only hits in the IP region (± 3.5 m) cause problems for the vertex detector

(L. Keller)

Vacuum requirement_4

<u>What are the vacuum specs between the QD0's ?</u>
(where there is no room for pump installation)

1. We have seen that 1 nT out to 200 m is conservative, but near the IP, it could be one to two orders of magnitude higher from a bremsstrahlung standpoint. What about electro-production of hadrons?

2. **Electro-production of hadrons in gas near the IP (± 3.5 m)**

σ_{tot} ~ 2 mb => ~ 5x10^{-5}/BX @ 10 nT

Lumonosity bkg.: gamma-gamma at L_{max} ~ 0.5/BX

Therefore the near-IR pressure requirement is not determined by the beam-gas background rates

(L. Keller)

Vacuum requirement_5

Conclusions

160 bunches

1. At 10 nTorr within the IP region there are 0.02–0.04 hits/bunch (3-6 hits TPC) at an average energy of about 100 GeV/hit originating inside 200 m from the IP. Some of these cause intolerable background in the vertex detector, so to reduce this background to less than 1% per bunch crossing, the pressure specification inside 200 m from the IP is 1 nTorr.

2. At 10 nTorr, on the FD protection collimator 13 m from the IP, there are 0.21 charged hits (33 hits TPC) at an average charged energy of about 240 GeV/hit and 0.06 photon hits/bunch (9 hits TPC) at an average photon energy of about 50 GeV/hit originating inside 800 m from the IP. This leads to a conservative pressure specification of 10 nTorr in the BDS from 200 to 800 m.

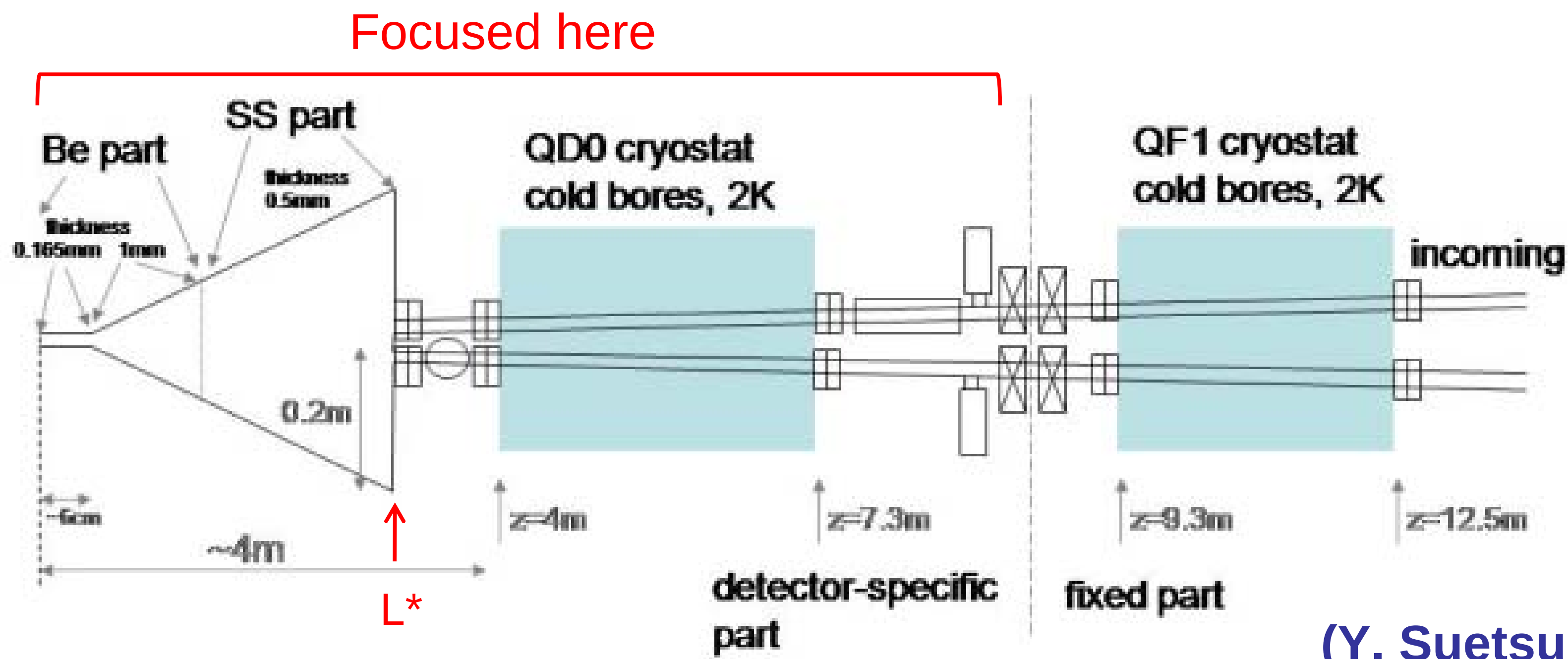
3. From a particle background standpoint, within the IP region between the QD0 quadrupoles, the pressure can be greater than 1 nTorr since luminosity backgrounds will be dominant in this region.

ILC-NOTE-2007-016

(L. Keller)

- Required pressures
  - **For z < L* : 1 ~ 10 x 10^{-7} Pa (= 1 ~ 10 nTorr)**
  - **Up to 200 m from IP: ≤1x10^{-7} Pa (= 1 nTorr)**

(by L. Keller, 15/8/2007)



(Y. Suetsugu)

Basic design_2

- The first consideration by O. Malyshev (2007/8/16)
  - **Very reasonable design.**
  - **NEG coating at z < L* should be effective.**
- However,
  - **Baking *in-situ* at 180 - 200 °C is indispensable to make use of the NEG coating.**
  - **Is it available?**
    - Dangerous to the detector circuit.
    - Mechanical strength?
  - **Is the capacity of the NEG-coating sufficient?**
- How about a system without *in-situ* baking?
  - Is it possible?

(Y. Suetsugu)

Basic design_3

- Assumptions
  - **Pre-baking before assembling should be done.**
  - **The chambers should be treated carefully after the pre-baking to avoid any contamination.**
  - **Water should be kept away as much as possible.**

  - **Thermal gas desorption rate without baking:**
    - After 10 hours evacuation:

      CO: 2×10^{-7} Pa m^3 /s/m^2 (~ 2×10^{-10} Torr l /s/cm^2)

      H_2: 2×10^{-6} Pa m^3 /s/m^2 (~ 2×10^{-9} Torr l /s/cm^2)
    - After 100 hours evaculation (after 4 days)

      CO: 2×10^{-8} Pa m^3 /s/m^2 (~ 2×10^{-11} Torr l /s/cm^2)

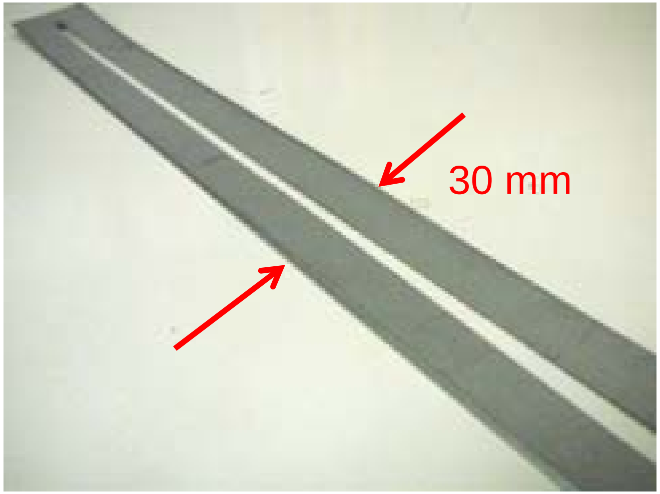
      H_2: 2×10^{-7} Pa m^3 /s/m^2 (~ 2×10^{-10} Torr l /s/cm^2)
    - About 20 times larger than those after baking (O. Malyshev)

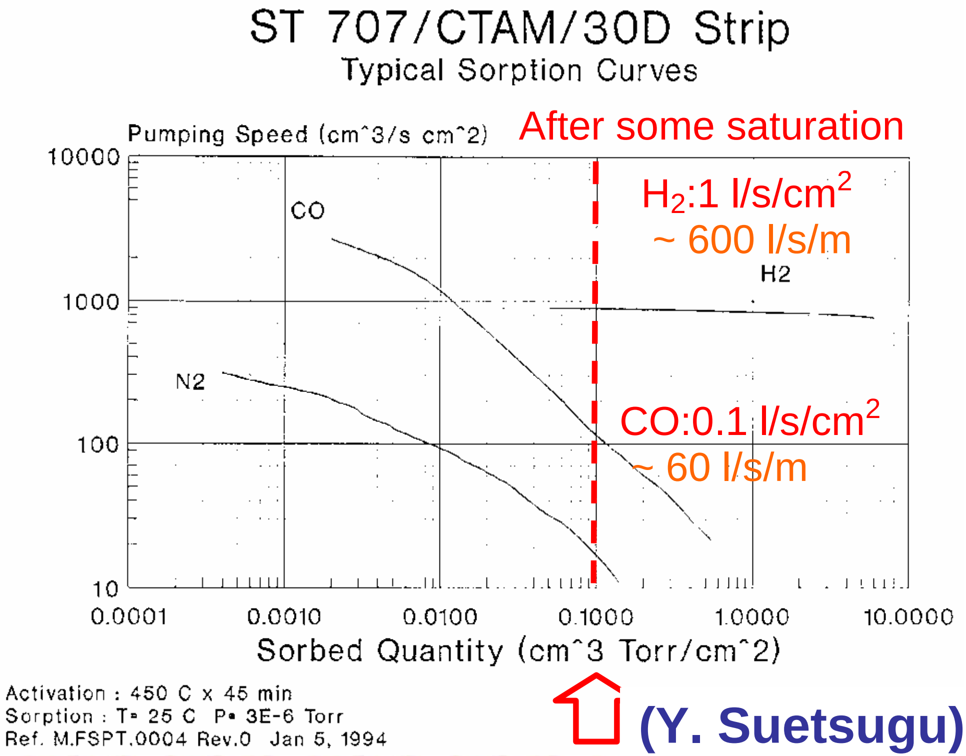
(Y. Suetsugu)

Basic design_4

- Assumptions
  - **Distributed pumping to effectively evacuate these conductance-limited beam pipes**
  - **Use NEG strip : ST707 (SAES Getters), for ex.**

St707 NEG strip





(Y. Suetsugu)

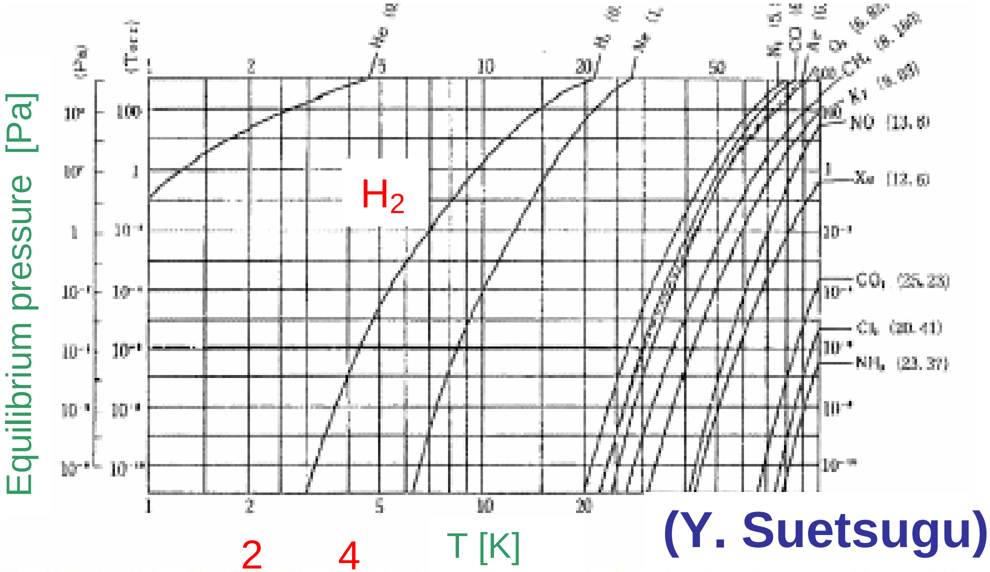
Basic design_5

- Assumptions
  - **QD0 = Cryopump (at *T* = 2 K[?])**
  - **Pumping speed**

A: Area
P_{eq}: Equilibrium pressure
m: mass of gas molecule
T: Temperature
C_g: Sticking coefficient

$$S = \frac{1}{4}\bar{v} A C_g \left\{ 1 - \frac{P_{eq}}{P}\sqrt{\frac{T}{T_s}} \right\} = \sqrt{\frac{kT}{2\pi m}} A C_g \left\{ 1 - \frac{P_{eq}}{P}\sqrt{\frac{T}{T_s}} \right\}$$

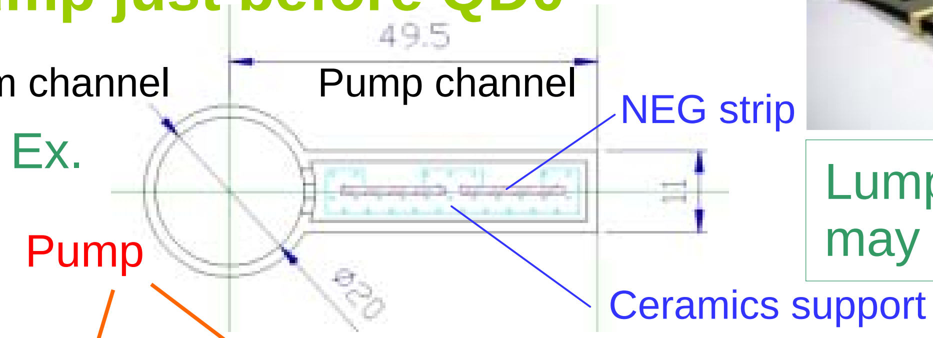
  - $P_{eq} \ll P$
  - $C_g = 0.1$
  - **As a first approx.**
  - $S_{H2} = 3.6\ \mathrm{m^3/s/m^2}$ $= 036\ l\mathrm{/s/cm^2}$
  - **If** $r = 10$ **mm,** $S_{H2} = 0.22\ \mathrm{m^3/s/m}$ $= 220\ l\mathrm{/s/m}$



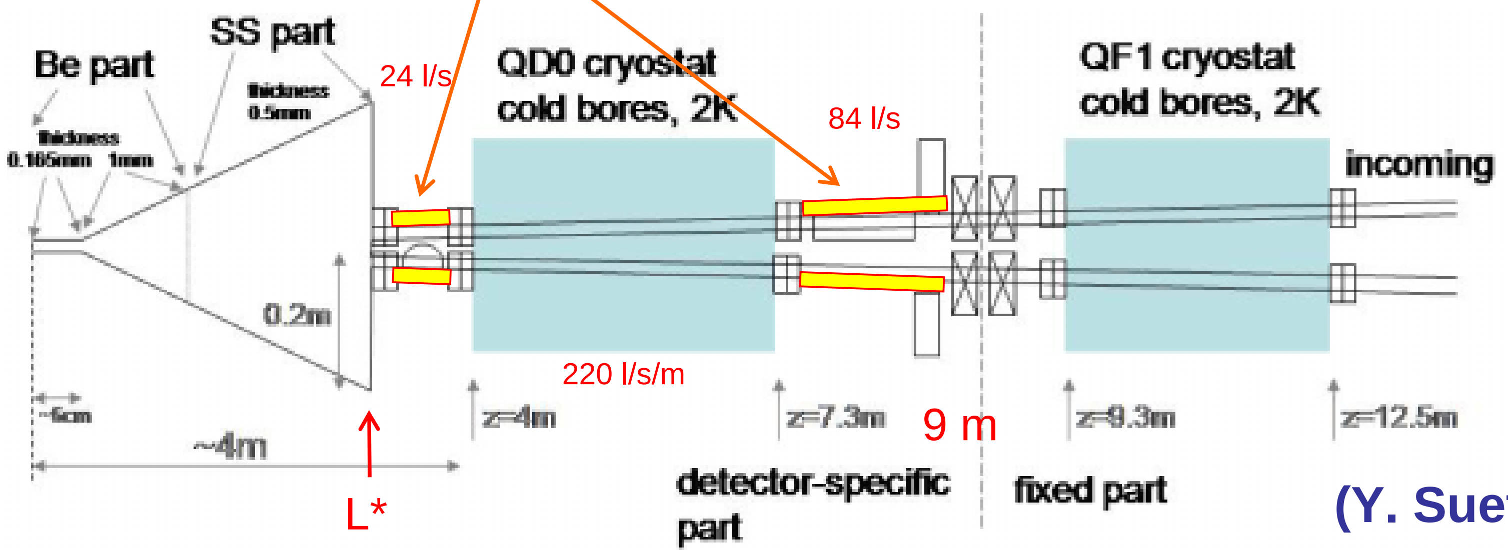
(Y. Suetsugu)

Basic design_6

- If no pump at cone region (z < L*)
  - NEG pump just before QD0



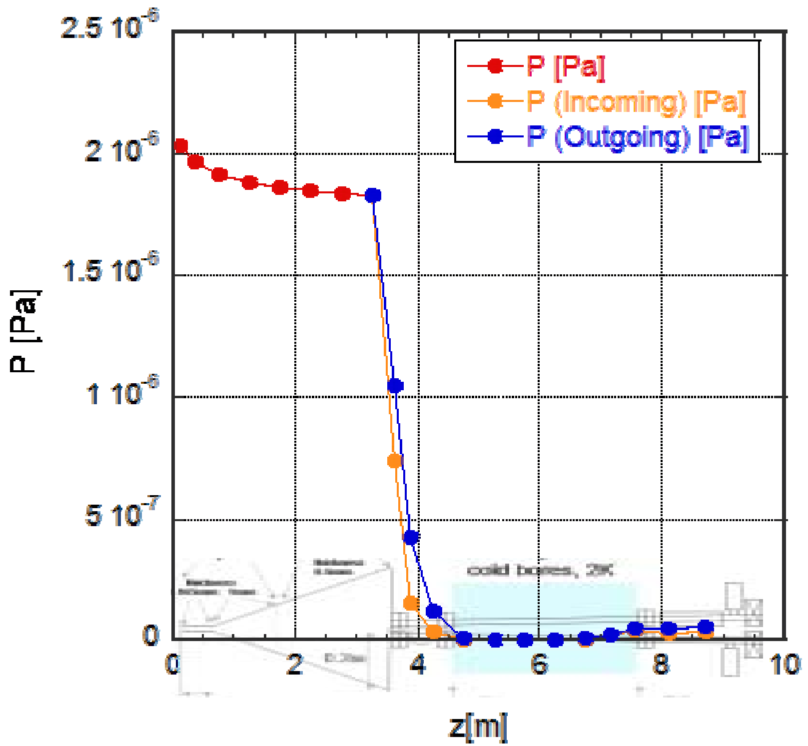
Lumped pump may be OK



(Y. Suetsugu)

- Pressure distribution after 100 hours evacuation
- Calculated by a Monte Carlo code

No pump at cone



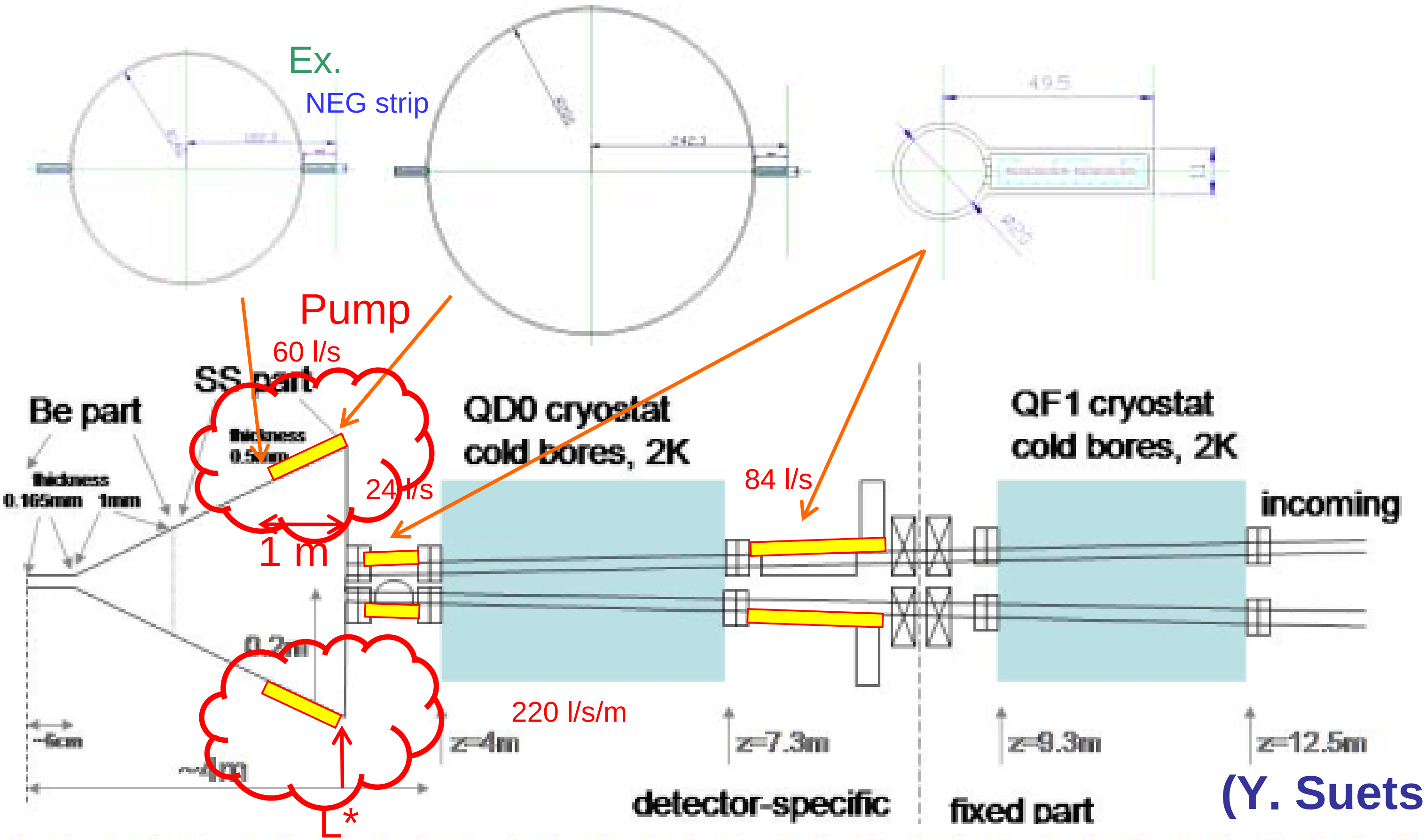
– $Q = 2x10^{-8}$ Pa m^3 /s /m^2 for CO

– P (z < L*) > $1x10^{-6}$ Pa!

Some pumping are required at z < L* !

(Y. Suetsugu)

- For example, NEG pumps at the last 1 m of cone



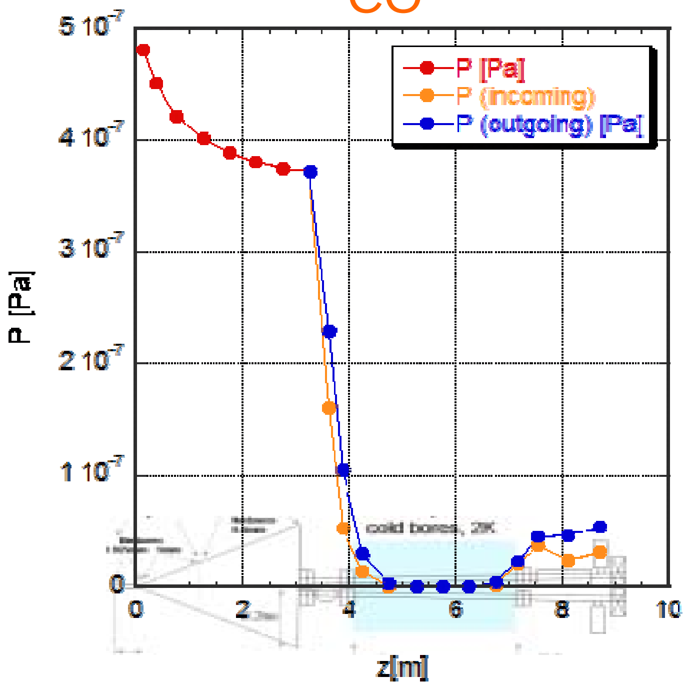
(Y. Suetsugu)

Basic design_9

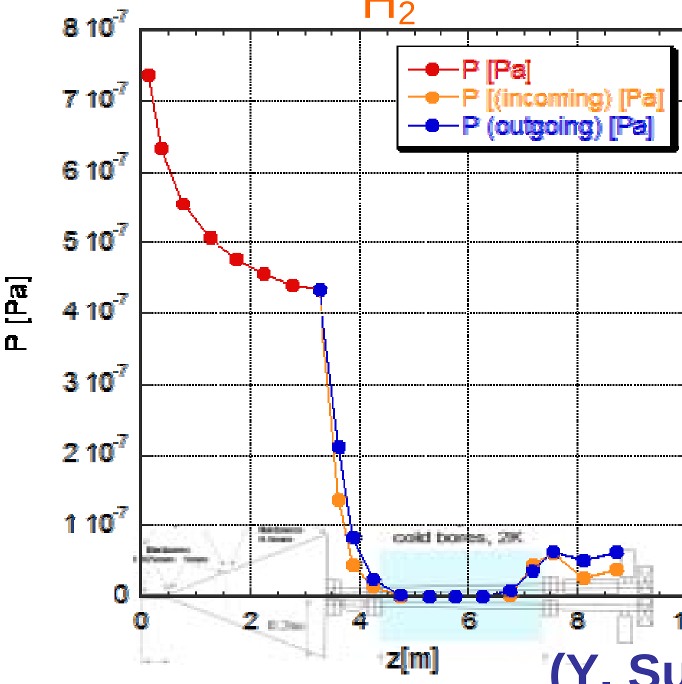
- Pressure distribution after 100 hours evacuation
  - $Q = 2\times10^{-8}$ Pa m^3 /s /m^2 for CO
  - $Q = 2\times10^{-7}$ Pa m^3 /s /m^2 for H_2

P < 1 x10^{-6} Pa !

CO

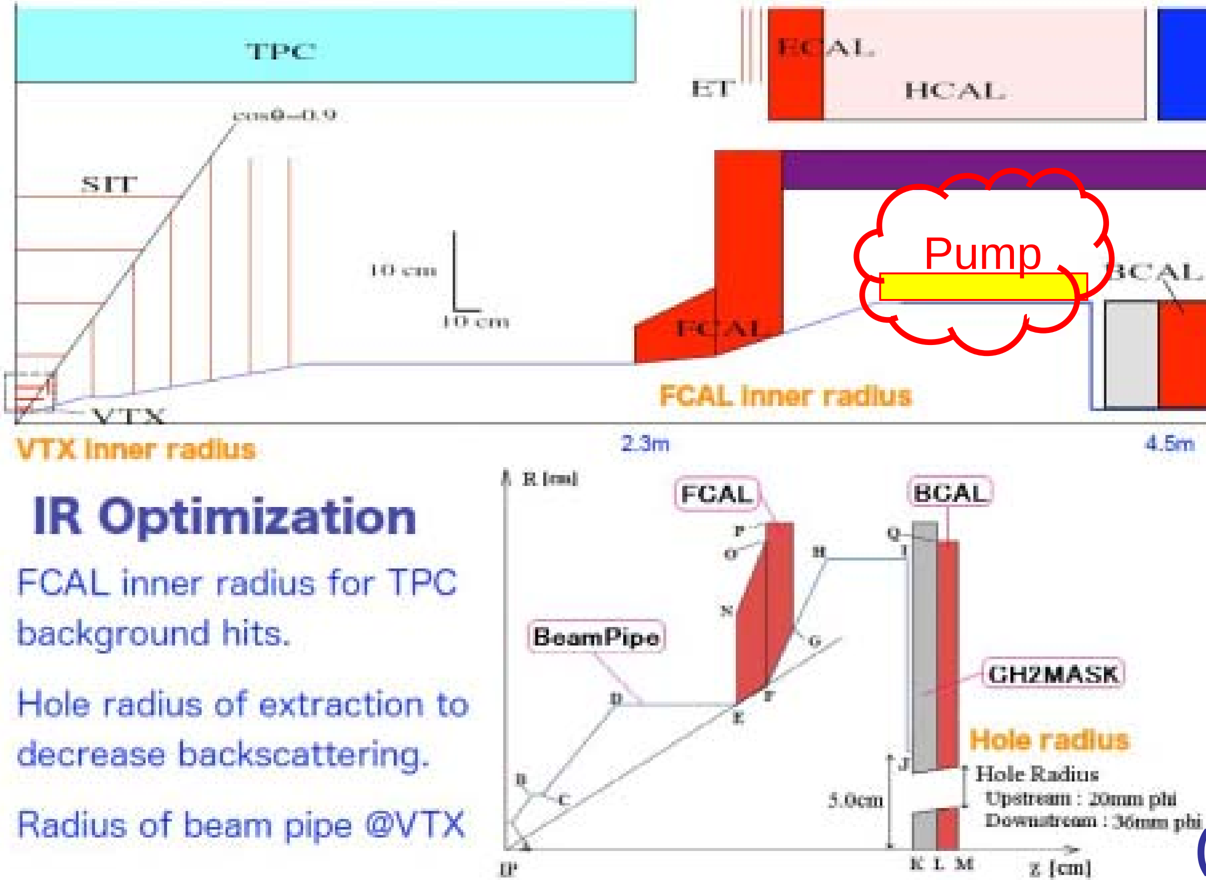


H_2



(Y. Suetsugu)

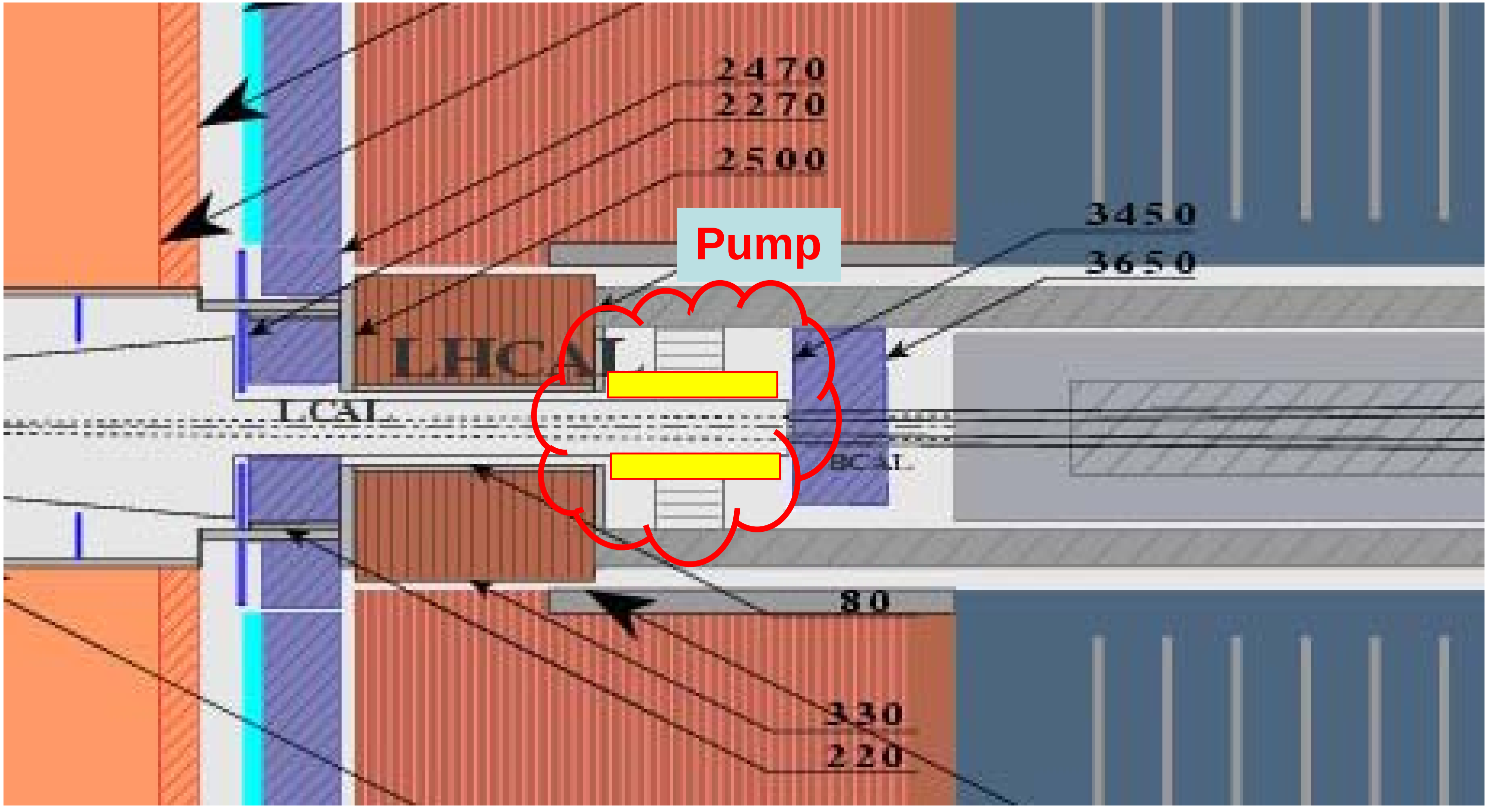
- Possible for GLD



(Y. Suetsugu)

Basic design_11

- for LDC



N. Meyners

(Y. Suetsugu)

Basic design_12

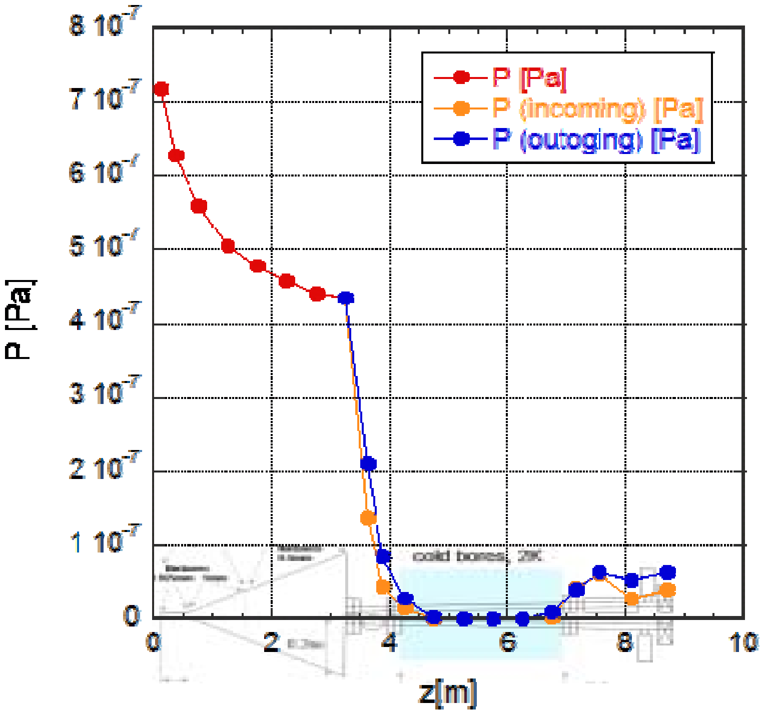
- Gas desorption by SR
  - Problem as Malyshev-san said
- – **Information from T. Maruyama-san (8/2/2007)**
  - SR from beam halo (halo rate ~ 10^{-3})
  - At extraction line, average photon energy = 7 MeV, power = 60 mW, from 3.5 m to 6.5 m
  - Photon density is about $2x10^{10}$ photons/s/m
  - If $1x10^{11}$ photons/s/m and $\eta = 0.1$ are assumed,
  - Q_{photon} = $4x10^{-11}$ Pa m^3/s/m @ 293 K ~$1x10^{-10}$ Pa m^3/s/m ~$1x10^{-9}$ Pa $m^3/s/m^2$
  - $\boxed{\text{Still below the thermal gas desorption.}}$
  - Similar order of gas desorption by e^-/e^+.

(Y. Suetsugu)

Basic design_13

- Q_{photon} = 1x10^{-9} Pam^3/s/m^2 for QD0 (2 K)

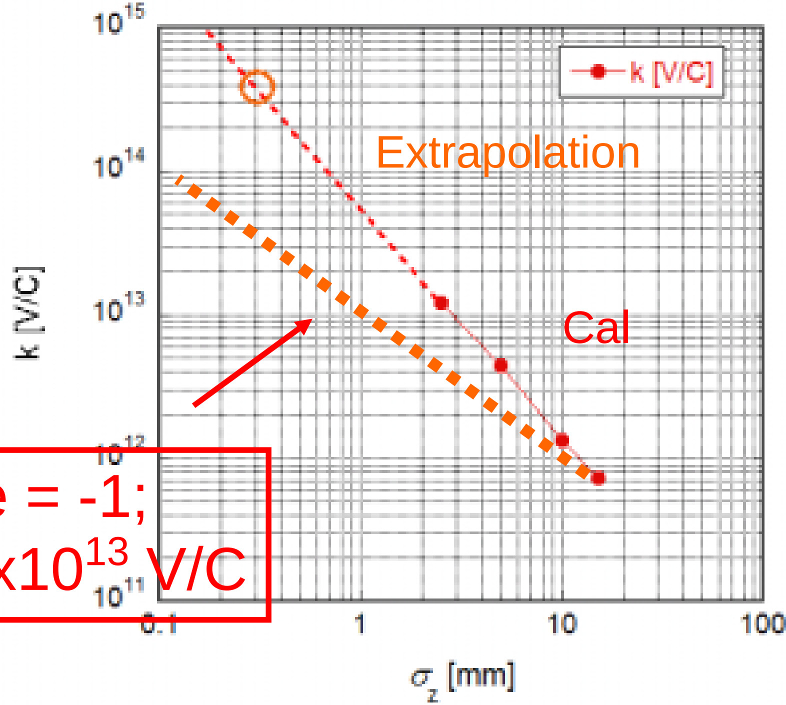
H_2, Q_{photon} = 1x10^{-9} Pam^3/s/m^2



No problem

(Y. Suetsugu)

- Heating by HOM
  - **Loss factor, *k*, of a simple cone**
  - **~4×10^{14} V/C @σ_z = 0.3 mm**
  - ***q* = 3.2 nC, 5400 bunch,**
    5Hz : *I* = 8.6×10^{-5} A
  - ***P* = *kqI* x2 = 220 W**
  - **Other components?**
    - SR crotch?

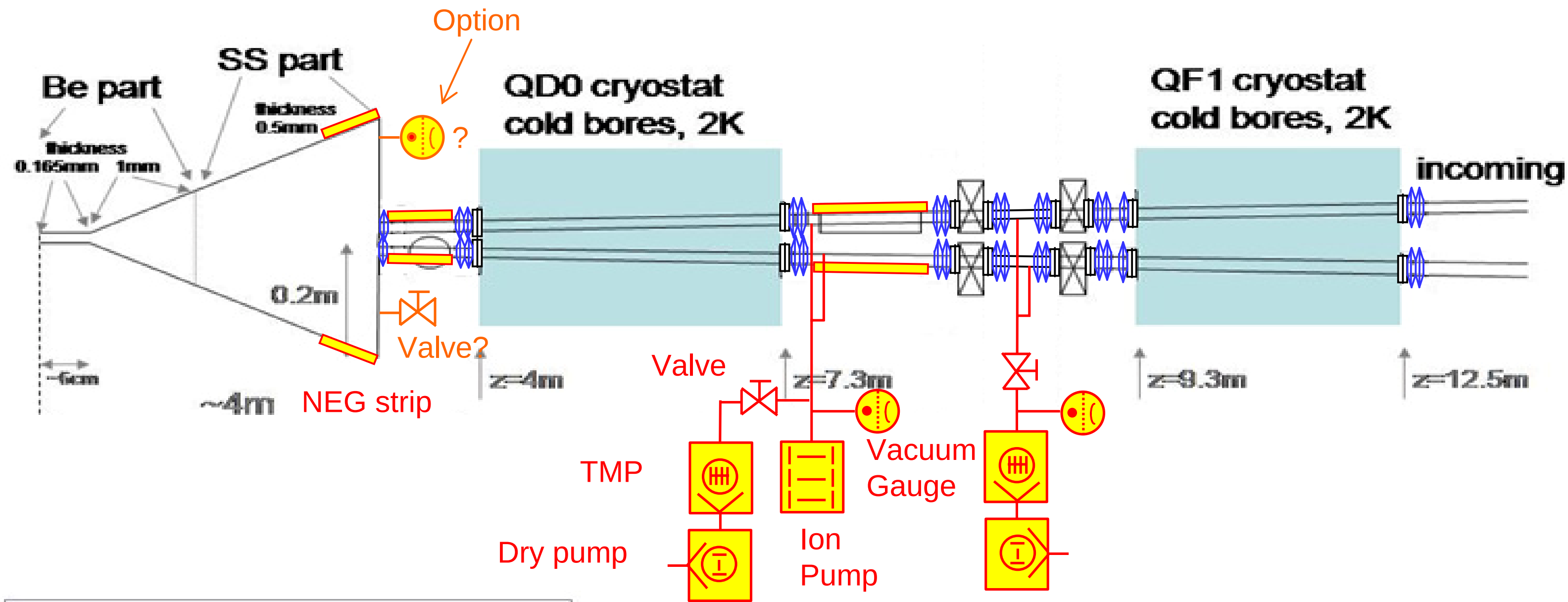


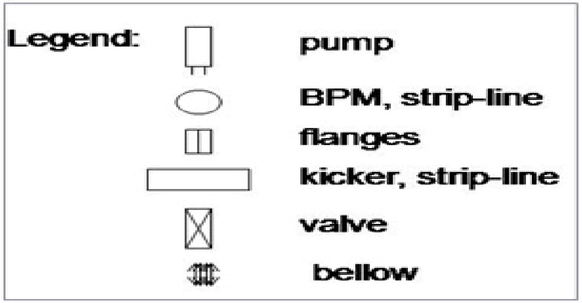
Slope = -1;
k = 4×10^{13} V/C

Air cooling ?
Water cooling may be safe.

(Y. Suetsugu)

- Layout of pumps





Apertures typically r=1cm in incoming beamline, and r=1.2cm+0.08cm*Z(m) in the outgoing beamline

Be-SS connection is permanent

(Y. Suetsugu)

IR Vacuum_1

- Be cone vacuum chamber (half):
  - **A=~2 m^2**
  - **Reachable thermal desorption rate** after 24 hrs bakeout at 250°C and weeks of pumping:
    - η (H_2) = 10^{-11} Torr·l/(s·cm^2)
    - η (CO) = 10^{-12} Torr·l/(s·cm^2)
  - **Total thermal desorption:**
    - Q(H_2) = $2 \cdot 10^{-7}$ Torr·l/s; Q(CO) = $2 \cdot 10^{-8}$ Torr·l/s
  - **Required pumping speed for P=10^{-9} Torr:**
    - S(H_2) = 200 l/s; S(CO) = 20 l/s
  - **Available tube conductance (2 tubes: R=1 cm, L=0.5 m) is very low:**
    - U(H_2) = 15 l/s; S(CO) = 4 l/s

(O. Malyshev)

IR Vacuum_2

Be cone

- Reachable pressure without a beam:
  - $P = Q / S_{eff,}$ $S_{eff} < U$
  - $P(H_2) > 10^{-8}$ Torr; $P(CO) > 5 \cdot 10^{-9}$ Torr
  - **Lower desorption can be reached by longer bakeout**
  - **Larger pumping speed S_{eff}, requires a pump connected directly to a Be vessel**
  - **In-build SIP in a magnetic field of a detector**
- Present layout does not allow reaching the required pressure without long bakeout at 250°C and weeks of pumping by using conventional technology even for thermal outgassing only, i.e. with no beam.

(O. Malyshev)

Be cone

- In presence of the beam
- Photon, electron, ions, lost positron and electron stimulated desorption

- Q = $\Sigma(\eta_i \Gamma_i)$, where
  - η **is desorption yield, number of desorbed gas molecules per impact photon or particle**
  - i **is an index associated with each kind of impact particle**
  - Γ **is a number of photon or particle hitting a surface per second**

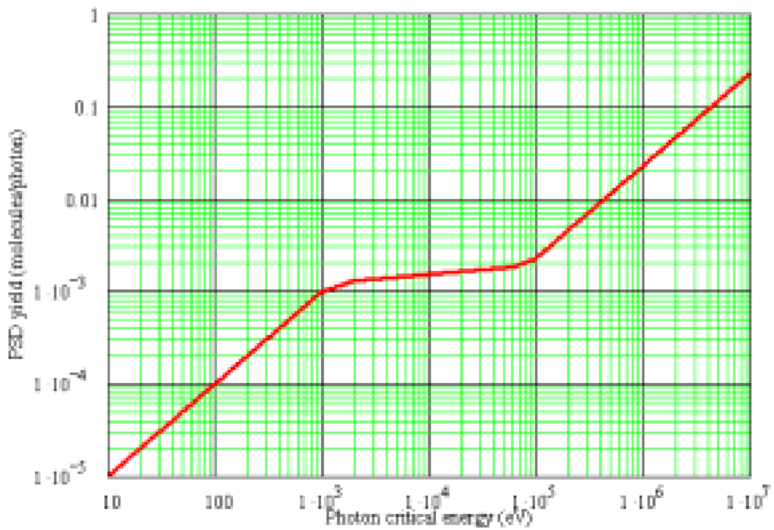
(O. Malyshev)

IR Vacuum_4

PSD at Be cone

The 'critical' energy of photon near IR is ε_c ~ 0.5 MeV.
Photon flux $\Gamma=10^9$ γ/s (calculated by Dr. Takashi Maruyama)

- PSD yield at ε_c ~1 MeV is not well studied (LEP data only, for Al and SS)
- Beam conditioning studied at DCI at ε_c up to ~20 keV
- Initial desorption yield for Be at ε_c = 500 eV (Foerster et al, JVSTA 10(1992),p. 2077):



  - $\eta = 4\cdot10^{-3}$ H_2/γ, $\eta = \mathbf{1\cdot10^{-3}}$ CO/γ, $\eta = \mathbf{8\cdot10^{-4}}$ CO_2/γ, $\eta = 2\cdot10^{-4}$ CH_4/γ
  - **Coefficient due to photon energy = 100**
  - **Total photon stimulated desorption is less than thermal:**
    - $Q(H_2) = 1.2\cdot10^{-11}$ Torr·l/s;
    - $Q(CO) = 2\cdot10^{-12}$ Torr·l/s

η = 0.1~0.4

(O. Malyshev)

IR Vacuum_5

The 'peak' energy of e^+/e^- near IR is ε_c ~ 1-2 MeV.
Flux of e+/e- I=$8.5 \cdot 10^8$ e^{+-}/s (calculated by Dr. Takashi Maruyama)

ESD at
Be cone

- ESD yield at ε_c ~1 MeV is not studied
- Initial desorption yield for Ti at E = 3 keV after bakeout at 300°C for 24 hrs (M.-H. Achard, private communication):
  - $\eta = 0.1$ H_2/e, $\eta = 0.02$ CO/e, $\eta = 0.02$ CO_2/e, $\eta = 0.01$ CH_4/e.
  - **Coefficient due to e^+/e^- energy is unknown, probably the same as for photons (~100)**

η = 2~10

  - **Total e^+/e^- stimulated desorption is also less than thermal:**
    - $Q(H_2) = 3 \cdot 10^{-10}$ Torr·l/s;
    - $Q(CO) = 5 \cdot 10^{-11}$ Torr·l/s

(O. Malyshev)

IR Vacuum_6

Be cone

Solution is the NEG coated vacuum chamber:

- **1-μm TiZrV coating**
- **Activated by bakeout for 24 hrs at 180°C**
  - Even bakeout for 24 hrs at 160°C is very beneficial
  - Inductive heating of thin Be wall (tbd)
- **Pressure without a beam is below 10^{-13} Torr**
- **Low photon, electron and other particles induced gas desorption**
- **Low secondary electron emission**
- **Pumping speed:**
  - $S(H_2) = 0.5$ l/(s·cm^2), $S(CO) = 5$ l/(s·cm^2)
  - Does not pump C_xH_y and noble gases

(O. Malyshev)

PSD
Between cone and QD0

The 'critical' energy of photon near IR is ε_c ~ 0.5 MeV.
Photon flux Γ=~7·1010 γ/(s·m) (calculated by Dr. Takashi Maruyama)

- Estimated pressure raise due to photon stimulated desorption is much larger than thermal:
  - **$P(H_2) = 1.5\cdot10^{-8}$ Torr; $P(CO) = 3\cdot10^{-9}$ Torr**
- e^+/e^- stimulated desorption may lead to an order of magnitude larger pressure raise.

=> these tubes must be also NEG coated and activated

(O. Malyshev)

IR Vacuum_8

QD0 cold bore

- Required vacuum:
  - **10^{-9} Torr at RT => $3.2 \cdot 10^{13}$ molecules/m^3**
- d=21-36 mm, L=3 m
- Gas density with no beam is negligible at T=2 K (except for He).
- $\boxed{\text{Gas density with a beam increase due do:}}$
  - **Photon, electron, ions, lost positron and electron stimulated desorption inside the cold bore.**
  - **Gas from the cone and connecting tube!**
  - **Desorbed gas cryosorbed and accumulated on the cryogenic walls**
  - **Accumulated molecules will be desorbed by photon, electron, ions, lost positron and electron.**
  - **=> Gas density is growing with time**

(O. Malyshev)

IR Vacuum_9

QD0 cold bore

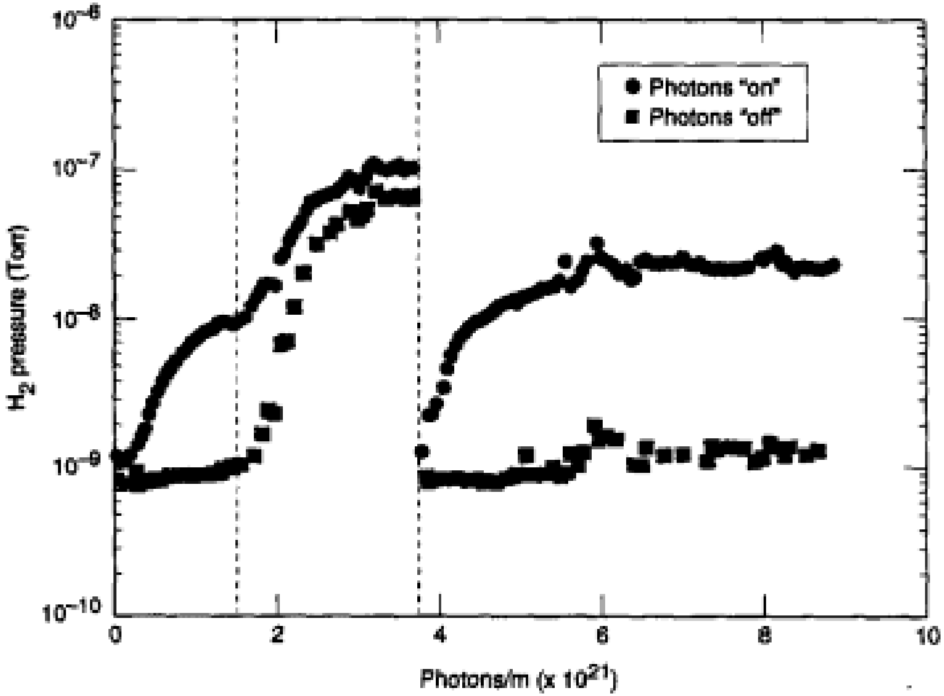


FIG. 1. Room-temperature RGA H_2 pressure measured at the center of the 4.2-K beam tube vs integrated photon flux with photons on and photons off. The raw pressure difference "on" minus "off" has been normalized to 1×10^{16} photons/m/s. The vertical dashed lines correspond to features discussed in the text.

- Experiment was performed with photons with ε_c = 300 eV

Investigation of synchrotron radiation-induced photodesorption in cryosorbing quasiclosed geometry

V. V. Anashin, O. B. Malyshev, and V. N. Osipov
Budker Institute of Nuclear Physics, Novosibirsk, Russia

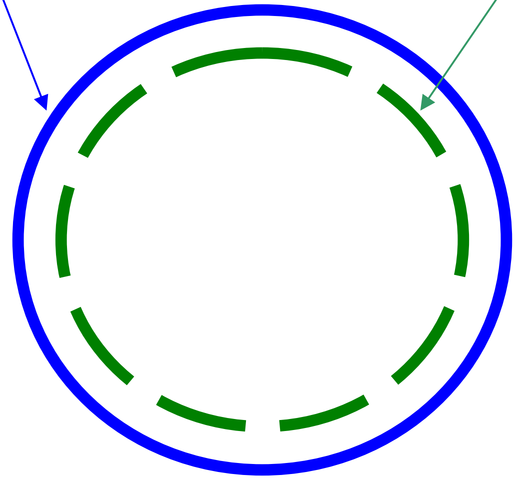
I. L. Maslennikov and W. C. Turner
Superconducting Super Collider Laboratory, Dallas, Texas 75237

2917 J. Vac. Sci. Technol. A 12(5), Sep/Oct 1994

(O. Malyshev)

IR Vacuum_10

- Cold bore with a liner or a beam screen (alike SSC or LHC)



QD0 cold bore

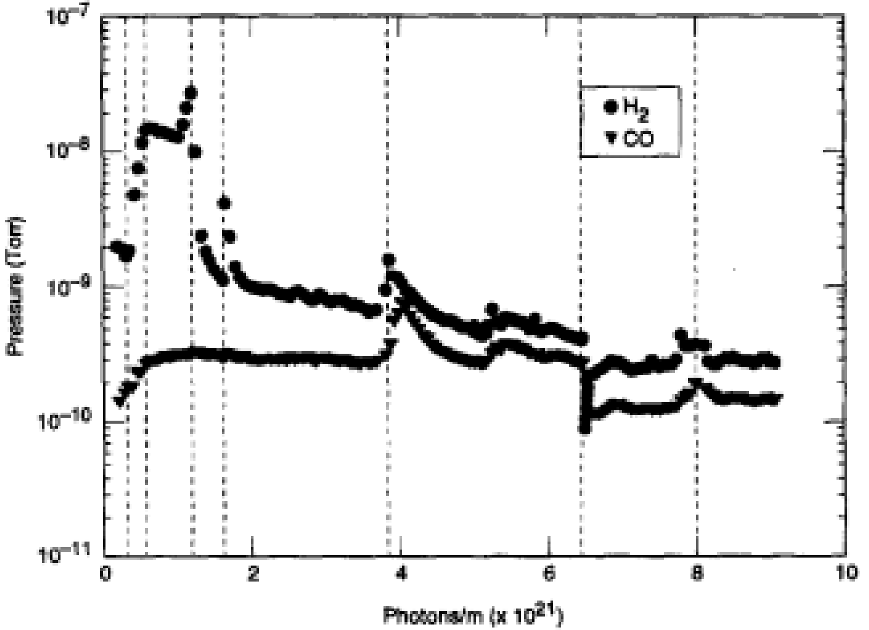
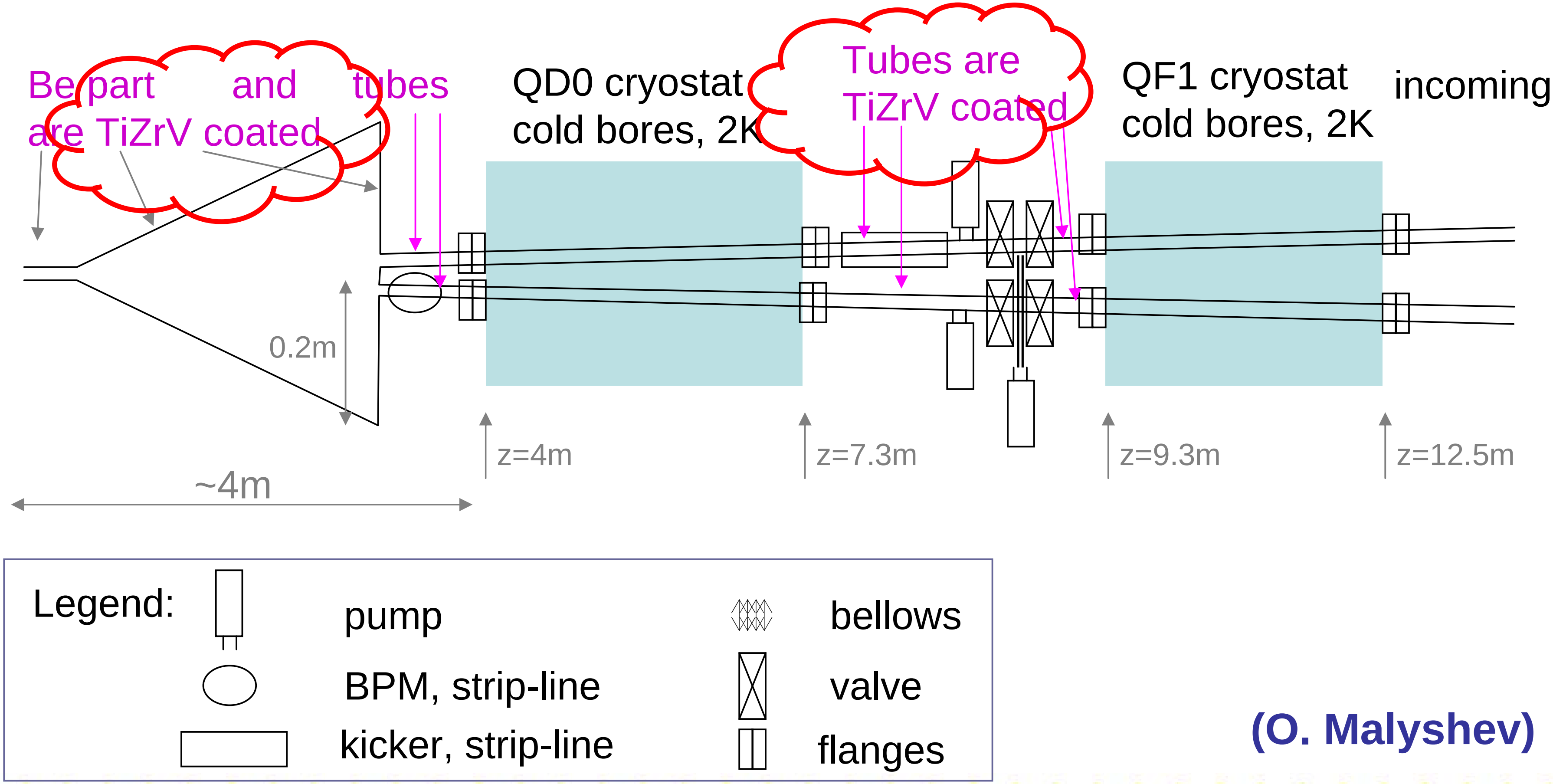


FIG. 2. Room-temperature RGA H_2 and CO dynamic pressures measured at the center of the liner configuration. Dynamic pressure is normalized to 1×10^{16} photons/m/s.

(O. Malyshev)

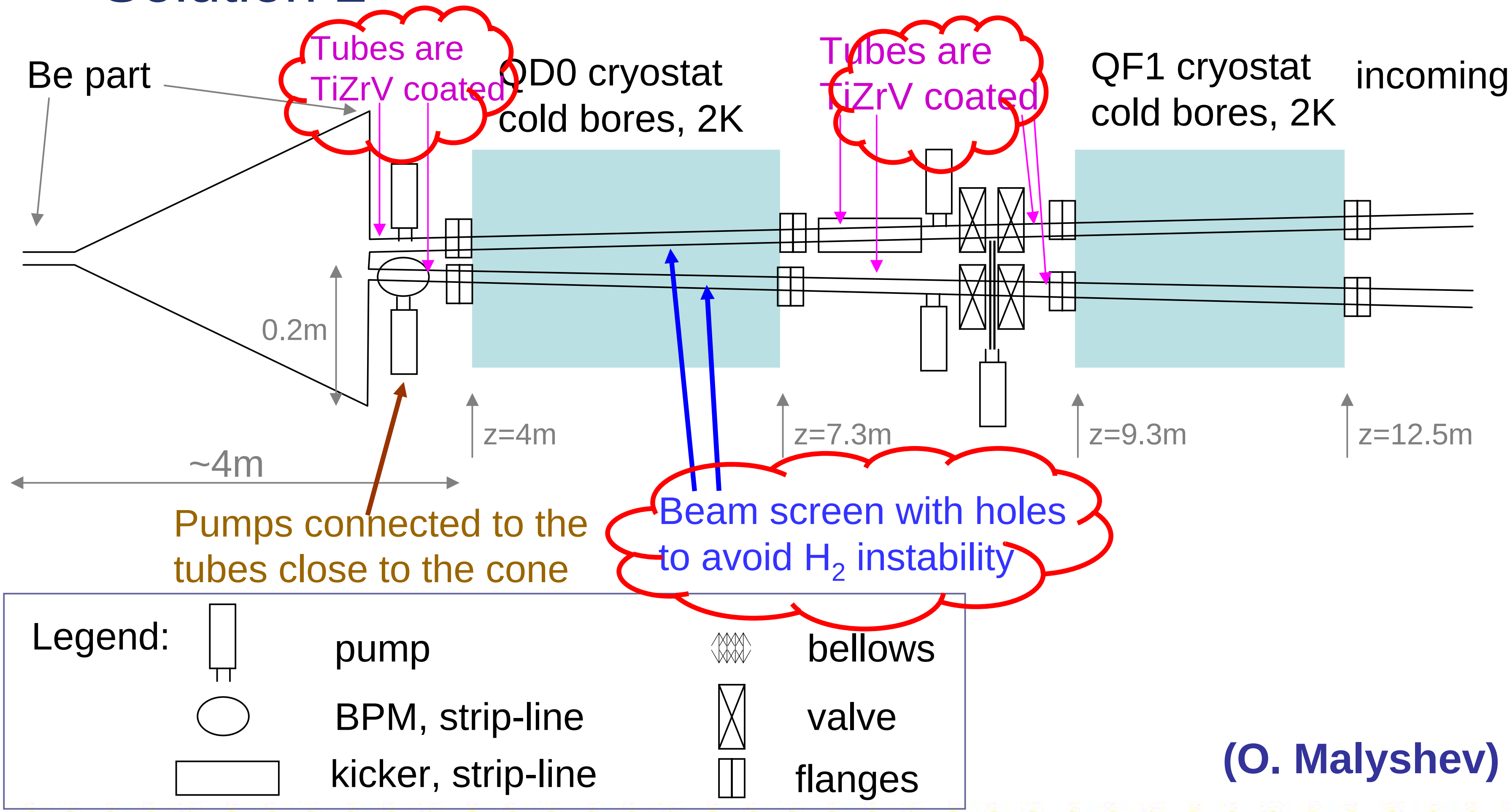
IR Vacuum_11

- Solution 1



(O. Malyshev)

- Solution 2



(O. Malyshev)

Summary_1

- Basic concepts of the vacuum system around IP has been proposed.
- It is a great step for the engineering design of ILC IR.
- At the same time, several important issues were recognized.

Issues_1

- Pumping scheme at z < L* (Cone) depends on the required pressure;
  - **If P >10 nTorr is OK,**
    - No baking and no pump are OK
  - **If 10 nTorr > P >1 nTorr is OK,**
    - No baking is OK, but some pumps are required
  - **If P < 1 nTorr is required,**
    - NEG coating and baking are required.

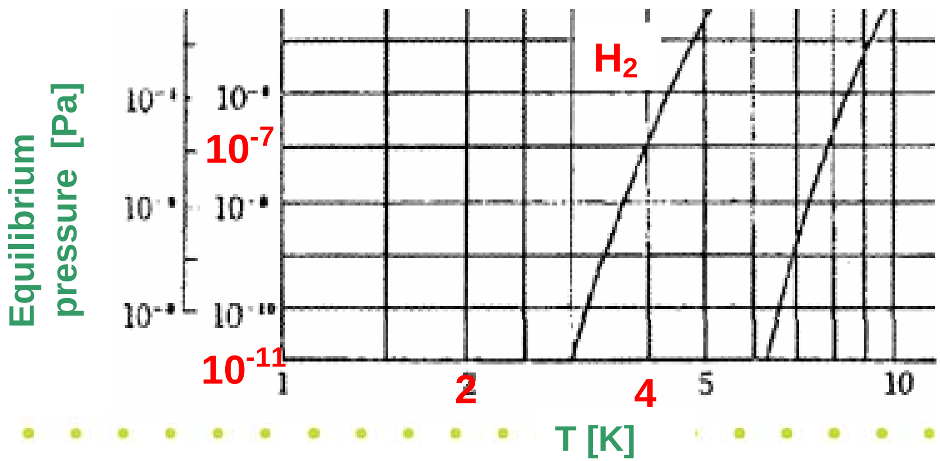
- Other room temperature region needs pumps (distributed or lumped pumps or NEG coating)

Issues_2

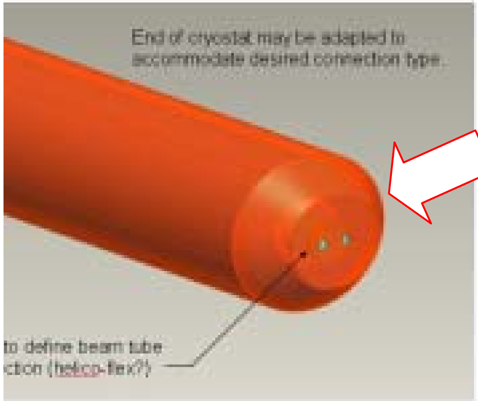
Comment

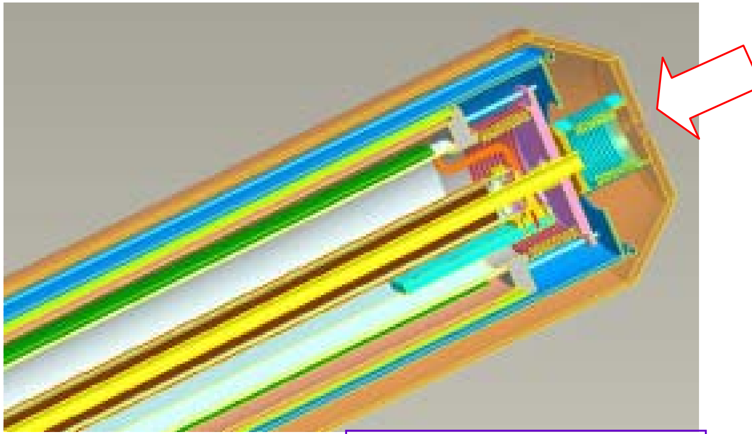
- Pumping system design also depends on;
  - **How long we can wait until the pressure decreases to the allowable level.**
    - Days or weeks?
    - Strategy of push-pull
  - **How often we have to exposure the beam pipe to air**
    - Capacity of NEG coating
- We need a typical operation pattern.

- Gas desorption by photons, e^-/e^+, ions in QD0
  - H_2 may pile up → Beam screen (O. Malyshev)
  - H_2 comes by PSD and also adjacent pipes
  - But, more quantitative study should be done.
  - Also, how about for the case T=2 K?
    - The situation should be quite different between the cases of 4.2 K and 2 K (Equivalent pressure is different by orders)
    - Beam screen may protect 2 K cold Bore



- Heating by HOM
  - **Cone**
    - ~100 W?
  - **Cavity? at the front of QD0**
    - Heat load to cryostat?
  - **RF shielding of bellows?**
  - **HOM absorber?**
  - **Water cooing?**



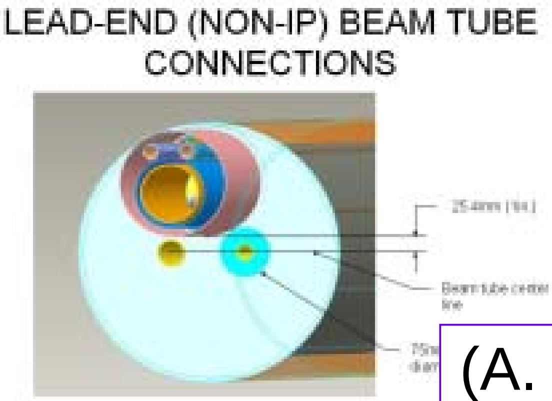


(A. Marone)

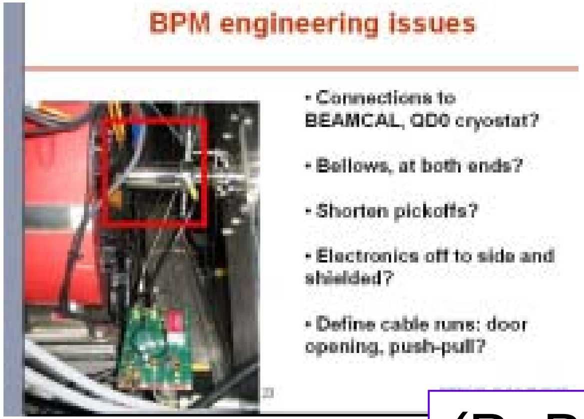
Issues_5

- Electron Cloud Instability (e+ beam)?
  - **NEG coating will decrease the secondary electron yield and effective to cure ECI**
    - NEG coating also works as an effective pump
  - **If not, solenoid ? (at drift space)**

- Number and location of flanges and bellows
  - To be accessible
  - Size of flange
  - Sealing
    - Helico flex?
  - Number of bellows
  - → Alignment
    - At both ends of kicker
  - RF-shield?
    - Heating
  - How to connect?



(A. Marone)



(P. Burrows)

Summary_2

- These issues can be solved in the further study, I am sure.
- The design of vacuum system should proceed in corporation with those of magnet (Cryo-module), FB kicker and BPM etc.

Thank you !