Minutes of a meeting on vacuum aspects of the PS/RF 40 MHz (LHC) prototype cavity (PE-2232/LHC/PS, IT 2232/LHC/PS)

Date: Wednesday, 5 October. 1994

present: C. Burnside/AT, W. Fritschi/MT, E. Jensen/PS, S. Milner/MT, F. Pedersen/PS, M. Van Rooij/AT

aim: Clarification of vacuum requirements for the 40 MHz prototype cavity.

The experiences of the vacuum group in the PSB and other indications lead to requirements of pumping speeds to be installed higher than originally estimated (cf. meeting of 11 January, 1994). Very large and heavy ion pumps (1000 l/s) were brought into the discussion, but with these the overall design would have to be revised, a) because the fraction of the surface covered with holes would be non-negligible for RF considerations, and b) the cavity with these pumps mounted on it would be very difficult to handle in the limited space of the PS tunnel.

The following questions were considered in this meeting:

1. The dependence outgasing - surface area - pumping speeds - vacuum level.
2. How many pumps are really required? How to be grouped around the cavity?
3. How is the efficiency of these pumps reduced due to Tee junctions (manifolds)?
4. What can be done for in situ bake out (lamps, wire, jacket, required power, tolerable temperature)? What is gained, what is necessary?

Required pumping speeds

The design of the vacuum equipment for this cavity aims at the future requirements in the PS ring, i.e. a partial pressure of non-hydrogen gases below 10^{-9} mbar . M. van Rooij states that for non-bakeable equipment, cleanliness and high pumping speeds are the main issues. With an estimated surface of the bellows of $3\ \mathrm{m}^2$, and an (optimistically) estimated outgasing rate of $10^{-11}\ \mathrm{mbar}\cdot\mathrm{l}/\left(\mathrm{s}\cdot\mathrm{cm}^2\right)$, a pressure of 10^{-9} mbar would require a pumping speed of $300\ \mathrm{l/s}$ at the location of the bellows. It is not easy to estimate to what pumping speed at the circumference of the cavity this would correspond, due to conductance of the gap region etc. The inner surface of the cavity is approximately $10\ \mathrm{m}^2$. The pumping speed into the beam chamber upstream and downstream of the cavity was estimated to be $50\ \mathrm{l/s}$ each.

To get an idea of the required pumping speed of the ion pumps, which have to bring the vacuum level down to 10^{-8} mbar <u>before</u> the sublimation pumps can start to operate, C. Burnside proposed a scaling from the vacuum equipment of the RFQ of Linac 2. With $1\ \mathrm{l/s}$ per $10\ \mathrm{cm}^2$ surface, one reaches 10^{-8} mbar there. Inserting the ratio of inner surfaces, this would correspond to $14000\ \mathrm{l/s}$ in our case (!) - with the ion pumps only!

Another estimate comes from a calculation made by M. van Rooij some time ago, but then with slightly different geometrical parameters (cavity diameter 1900 instead of 1600 mm, bellow surface $5\ \mathrm{m}^2$ instead of the more realistic $3\ \mathrm{m}^2$). Van Rooij will provide the actualized numbers later, but they will approximately confirm the above estimate.

The actual vacuum level in the PS ring is already below 10^{-8} mbar , the worst point is notably the 114 MHz cavity in SD10, a cavity which is somewhat similar to the 40 MHz cavity. This is now equipped with two ion pumps of $400\ \mathrm{l/s}$ each, and no sublimation.

Soft baking:

Ion pumps for 14000 l / s are practically impossible to install. The only way out seems to be (soft) baking. One gains 1 to 2 orders of magnitude in the outgasing rate of the baked surfaces.

Two different regions were considered separately: the short circuit mechanism and the cavity itself.

Short circuit mechanism: The bellows inside the short circuit mechanism a) have a total surface of about $3\ m^2$ which is a substantial contribution to the total inner surface, b) are located in a region which is not easily accessible with vacuum pumps, and c) are in fact the beam pipe, i.e. the region where the good vacuum is required. For these reasons, the bakeout of this area seems to be most important.

Although not originally considered, soft baking (up to 150 °C) seems to be relatively easy to obtain, putting a slim baking jacket onto the cylindrical outer cover of the mechanism. An easily mountable/demountable jacket has to be foreseen (clip-on), since the space between the mechanism and the inner electrode of the cavity is very limited (even smaller than in the test stand), and needed to access the bolts near the gap. Another way to obtain soft baking would be forced hot air heating. A fan would have to be provided for cooling purposes in any case. In both cases temperature control is necessary. 150 °C must not be exceeded, otherwise the ball bearing would suffer. On the other hand, at 180 °C baking would be ideal from the vacuum point of view, requiring about 2 h. With every 10 °C, the baking time would increase by a factor of 2, bringing us to 8 h at 150 °C, which seems reasonable.

Cavity: Different methods for soft bakeout were mentioned: Heating jacket around the cavity, quartz lamps, filament heating, and gas discharge.

Heating jacket: Standard technique, but cumbersome for mounting/demounting equipment. Expensive, but it has to be studied how much isolation will actually be necessary to get to approximately 150 °C with reasonable power.

Quartz lamps: about 4 quartz lamps of each would be inserted through special flanges into the cavity. A good location would be above the gap region, and equally distributed around the cavity. The lamps shall be moved out during RF operation, and valves would have to be foreseen. Advantage: the inside of the cavity would be heated directly.

Filament heating: One could consider a single filament in azimuthal direction, somewhere in the middle of the cavity. This would, like the quartz lamps, heat the inside of the cavity. Due to the azimuthal direction, the perturbation of the RF is probably small, but this has not been studied thoroughly.

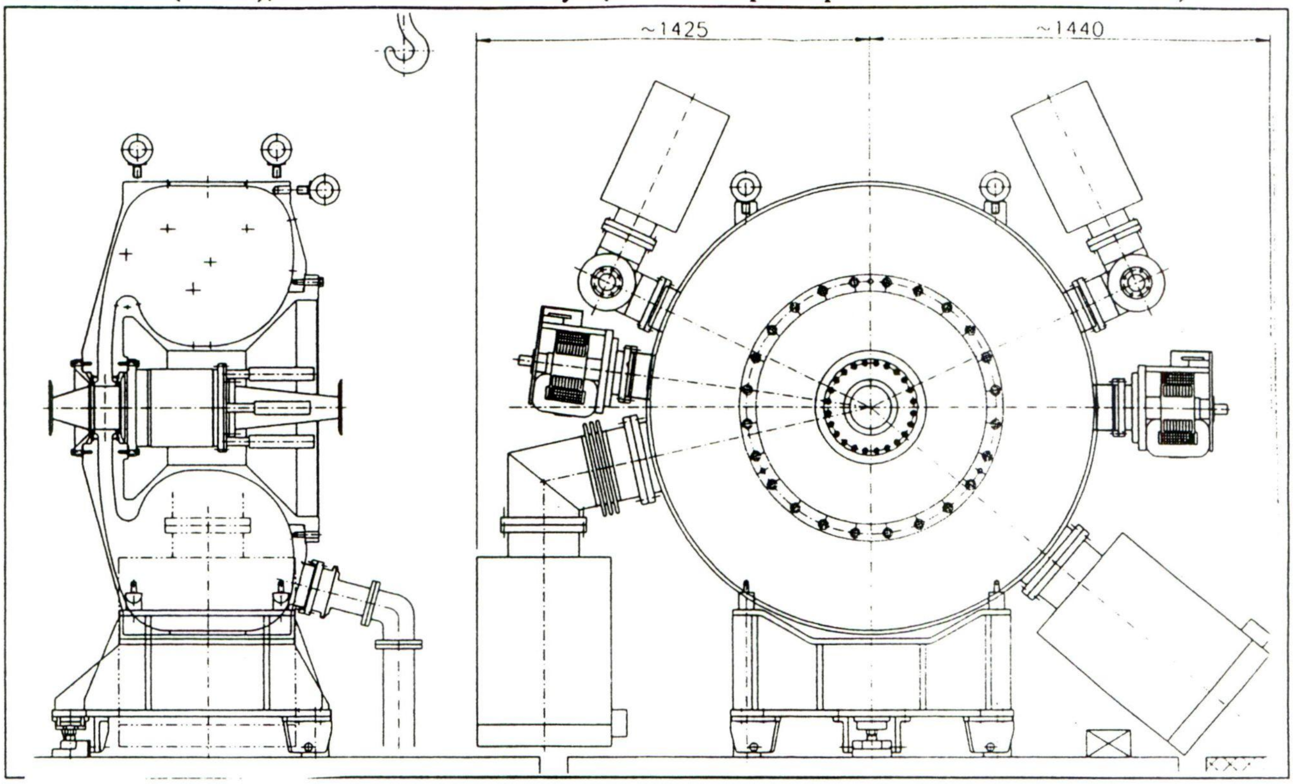
Gas discharge: Would require an additional (DC) electrode in the cavity. Some gas (Ar for example) at low pressure (10^{-2} mbar) would be discharged with a DC voltage. This method has good cleaning effect, but would have to be studied in more detail.

Efficiency of elbows (manifolds)

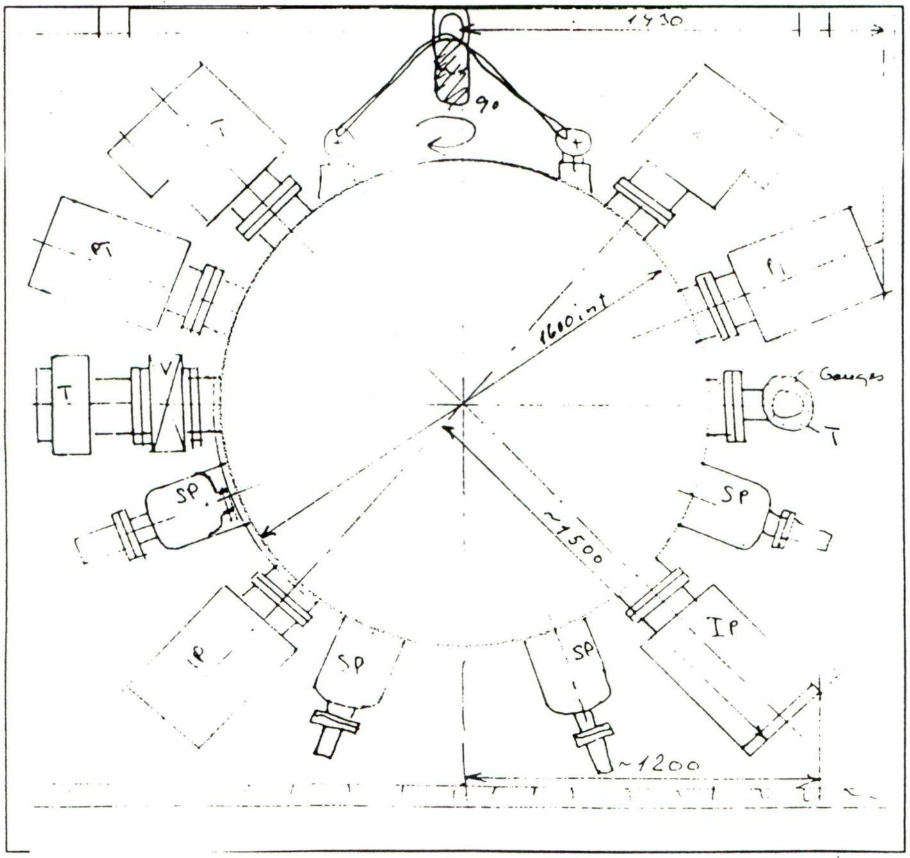
In the design proposals so far, the ion pumps are mounted not directly to the cavity wall, but on a manifold. This has the advantage that each manifold equally can be equipped with a sublimation pump. M. van Rooij states that about 30 % pumping speed are lost with such a manifold due to the reduced conductance.

S. Milner's proposal

Fig. 1 shows a study by W. Fritschi of the cavity with 2 ion pumps of 400 l / s each (top) and 2 ion pumps of 1000 l / s each (bottom), mounted in 2 different ways. (Note the RF power port has moved to the side wall!)

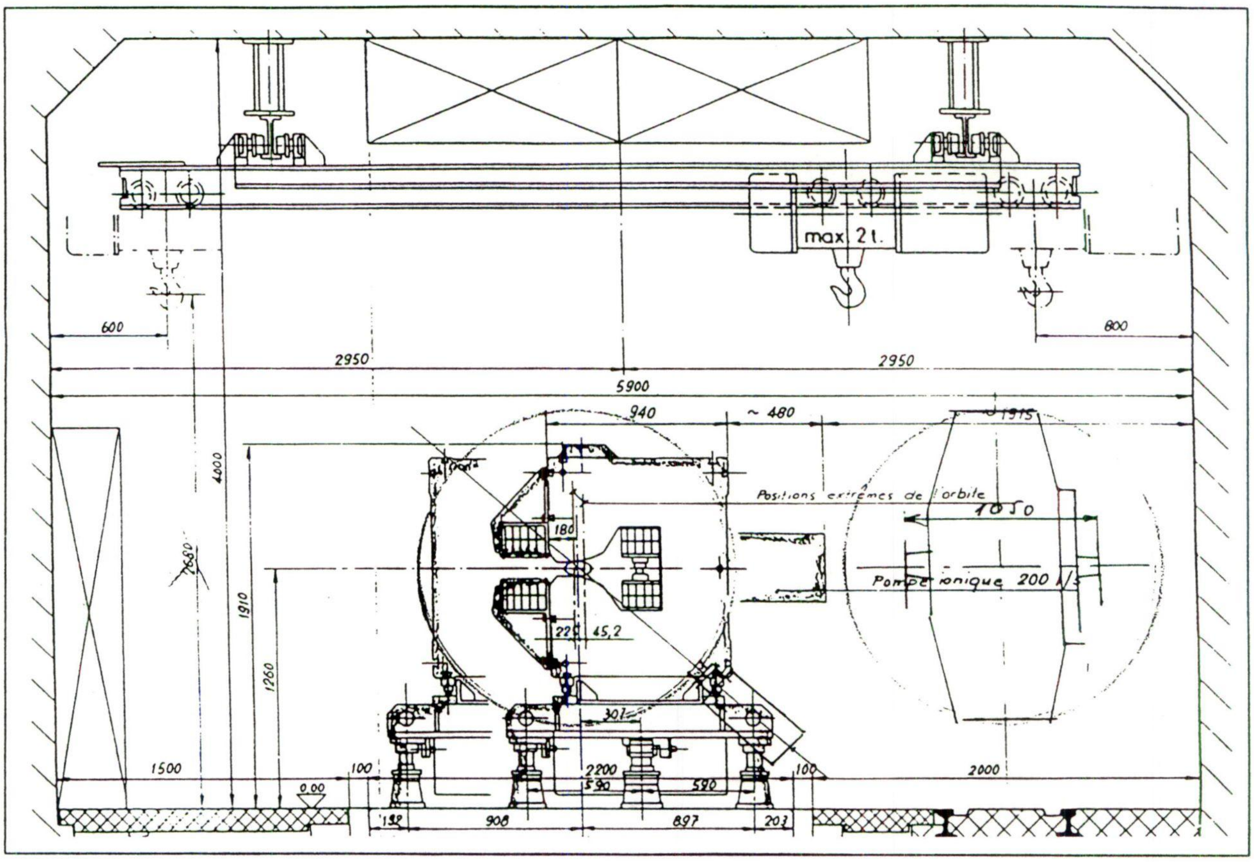


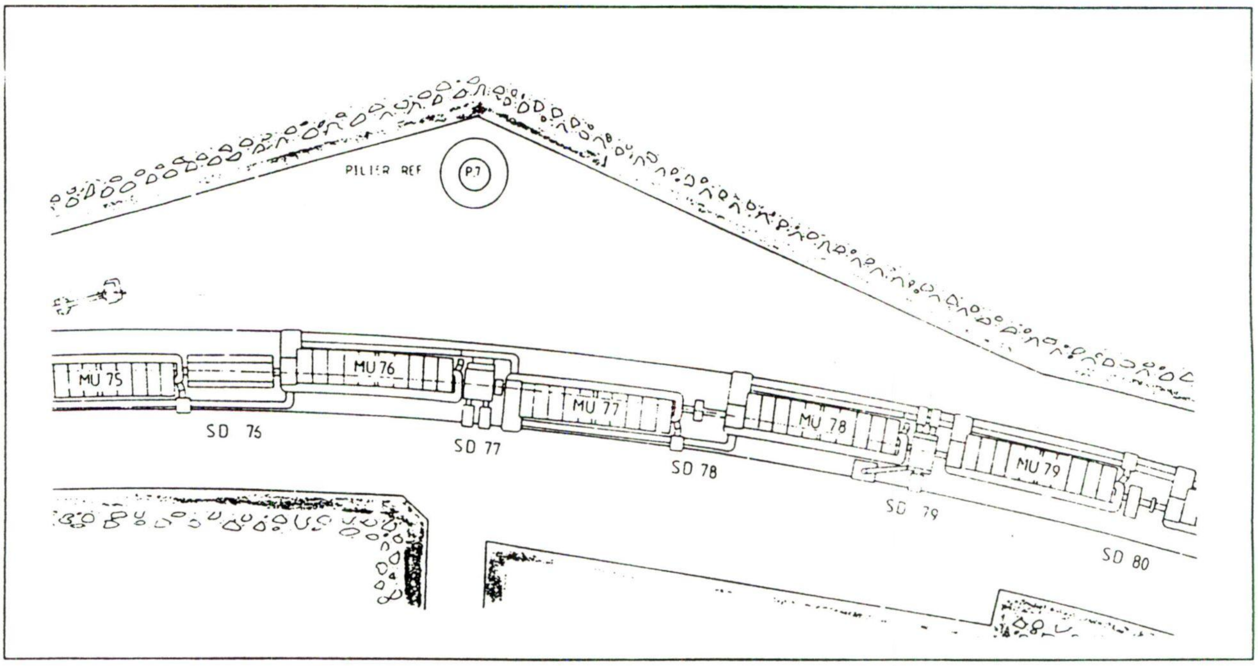
Sten Milner pointed out that it would be impossible to transport the cavity through the PS tunnel and position it in the ring with the large ion pump units on it. For this reason, and to gain on the pumping efficiencies mentioned above, he proposes a different scheme where no elbows are used and all pumps are mounted directly onto the cavity. The proposal is sketched in Fig. 2.



The proposal was generally approved by the vacuum experts. E. Jensen will have to estimate the diminution of the Q factor of the cavity by the large number of openings in the outer cavity wall.

S. Milner further points out that special equipment has to be constructed to handle the cavity: a girder to suspend the cavity on two cranes (each crane is limited to 2 t), with the possibility to turn it in front of the short section.





Even with this (slim) construction, the possibility to transport the cavity through the PS tunnel has to be verified in detail (cf. Fig. 3). There is a niche at the inside of the tunnel near SD77 and SD78 (cf. Fig. 4), but it must be checked during the shutdown in week 43/44 whether this is usable.

Valves?

It would be helpful to have a vacuum sector "cavity", i.e. to provide valves at both ends. This was judged unnecessary when the construction was initiated. It would not be impossible to reconsider it for a later cavity, but for this prototype, the changes of the actual design though would be too expensive.

Erk Jensen