Noble gases flow management in the European XFEL project UHV photon transport beamlines

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MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION
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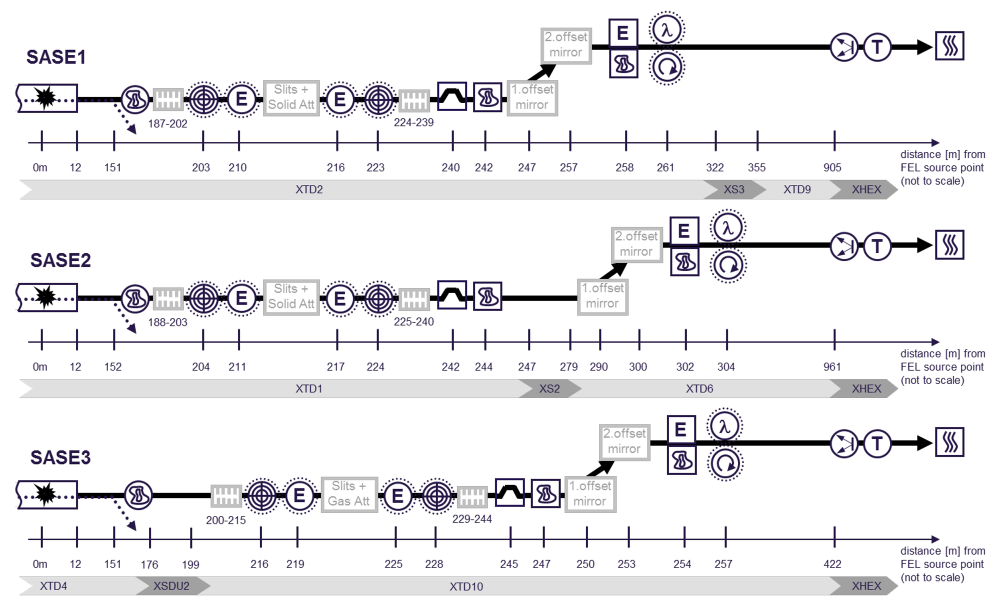
Windowless Gas-Based Diagnostics at the X-ray Beam Transport Systems [1].

Several kinds of gas-based diagnostics devices are developed by the X-ray diagnostics group (WP74) and placed in the beam transport system. These are in particular:

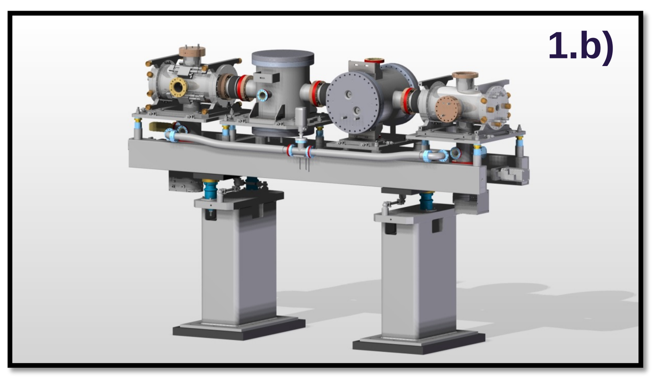
- Gas-based photo-emission spectrometers (**PES**) for spectral analysis [3].
- Gas-based beam intensity monitors (**XGMD**'s) [4].
- Gas-based beam position monitors (**XBPM**'s) [5].

Depending on different requirements, these devices can operate with different gases (Xe, Ne, Ar, Kr and even N_2), running within a pressure range that varies typically from $1\cdot10^{-6}$ mbar up to $5\cdot10^{-4}$ mbar (See R&D activities in WP74 on the explorations of the usable parameter space of these devices.) [2].

Since a windowless system is highly desirable, a differential pumping scheme is mandatory to **provide the required drop in pressure** down to the average beamline values (< $9\cdot10^{-8}$ mbar). This system is able to **reduce** the **flow** of the above mentioned noble gases to the rest of the X-Ray beam transport system and therefore matching the required UHV level with a **maximized optical clear aperture** between pumping stages.



1.a)



1.b)

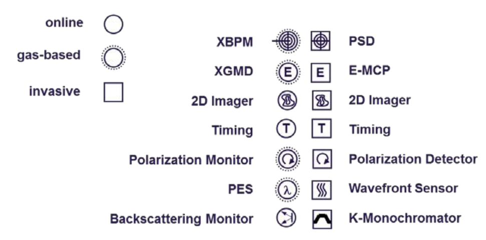


Figure 1a)*: Schematic view of the spatial distribution along the Photon Beamlines of the different diagnostic devices. Notice the recurrence of gas-based devices (all of them windowless) that will require to be differentially pumped.* ***Figure 1b)****: 3D CAD View of a "XGM" (X-Ray Gas Monitor) basic unit including both, vertical and horizontal, XGMD's and XBPM´s modules [2]. (Pictures courtesy of Wolfgang Freund from WP-74):*

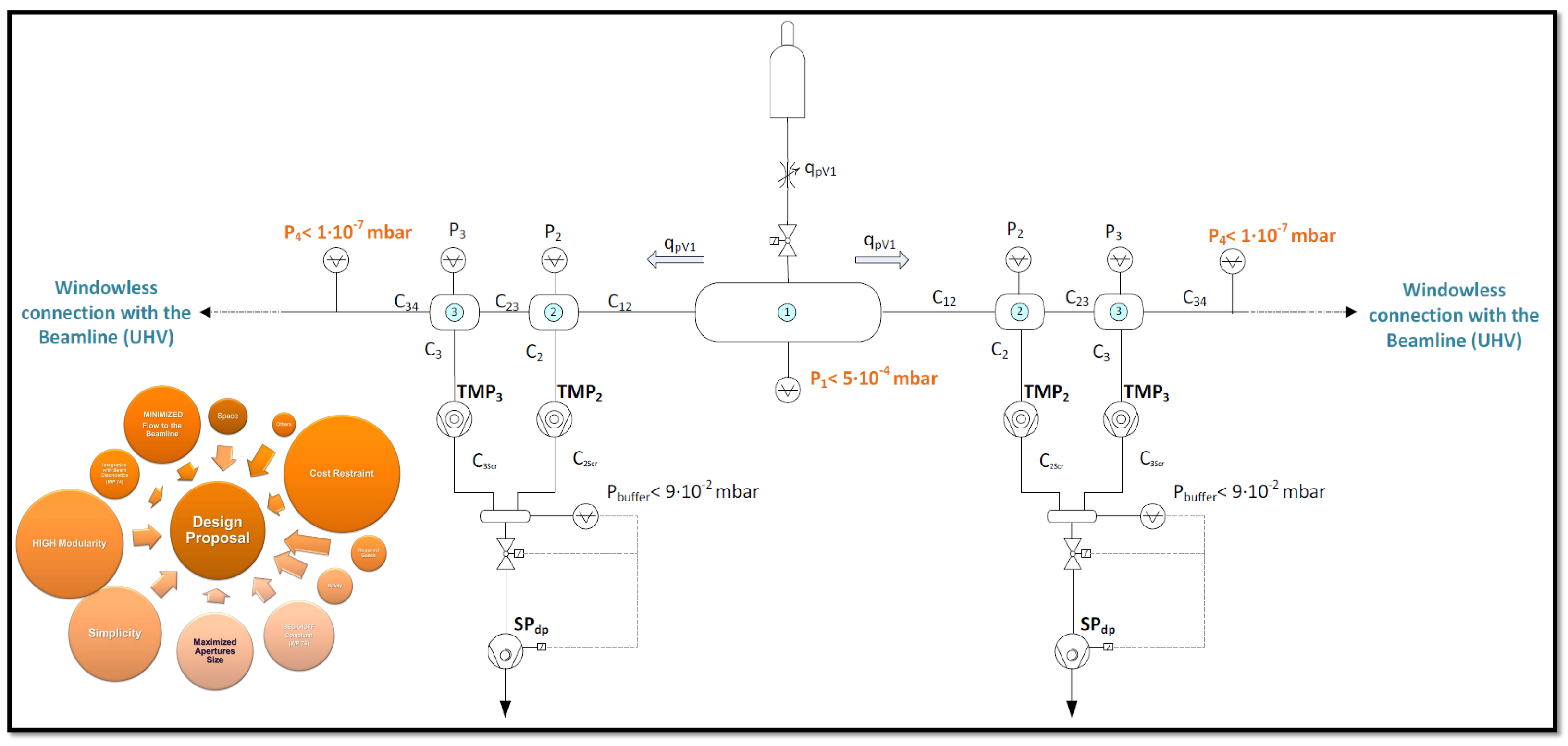
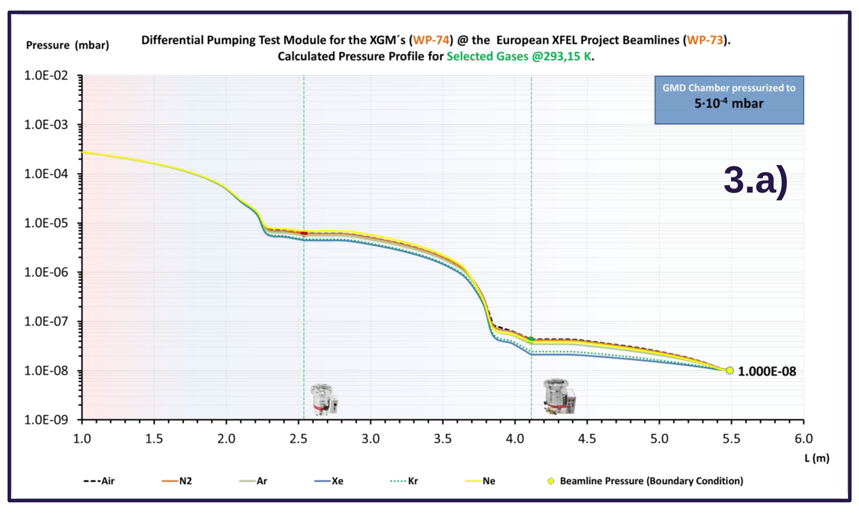
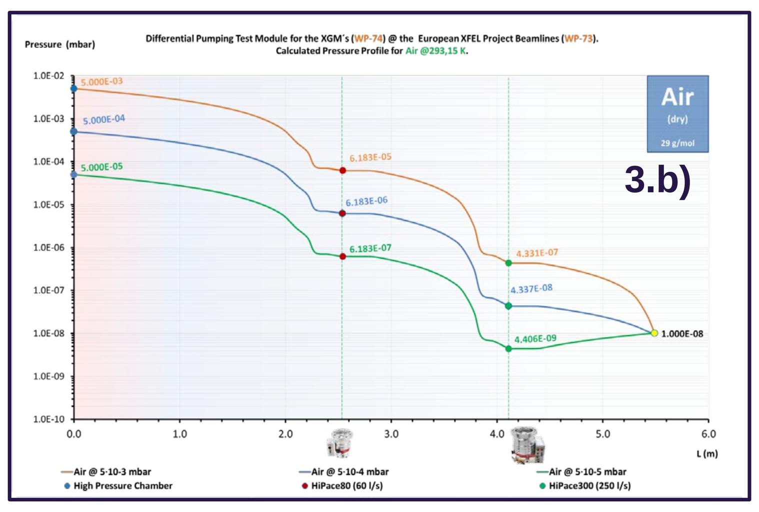


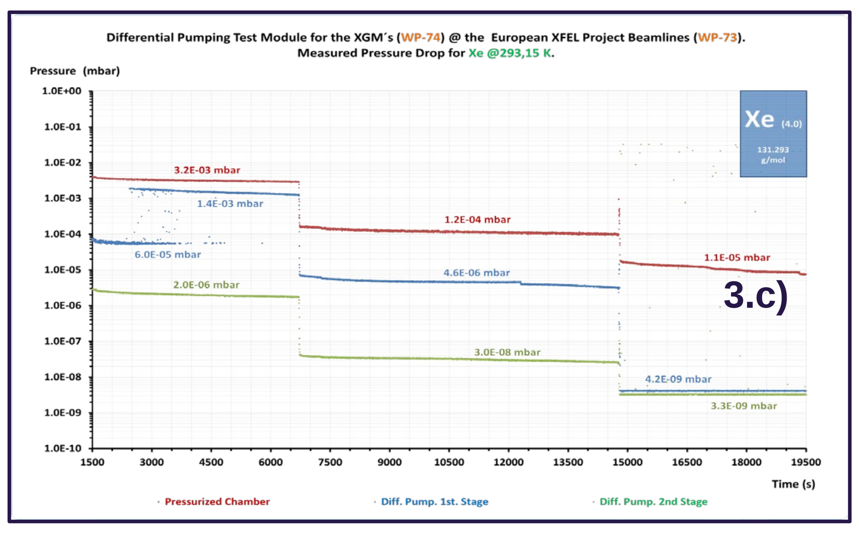
Figure 2*: Simplified overview of the proposed differential pumping design scheme. The graphic shows the use of two pumping stages at each side of the gas based beam diagnostic module. Each of those includes a turbomolecular pump (TMP) and a common forevacuum line ("Buffer") design to safely provide the required compression ratio for each turbo but just using a single Scroll-type pump ("SP") per side. Gas flow directions and interstage conductances are shown as q_{pv}, and C_{ij} respectively.*



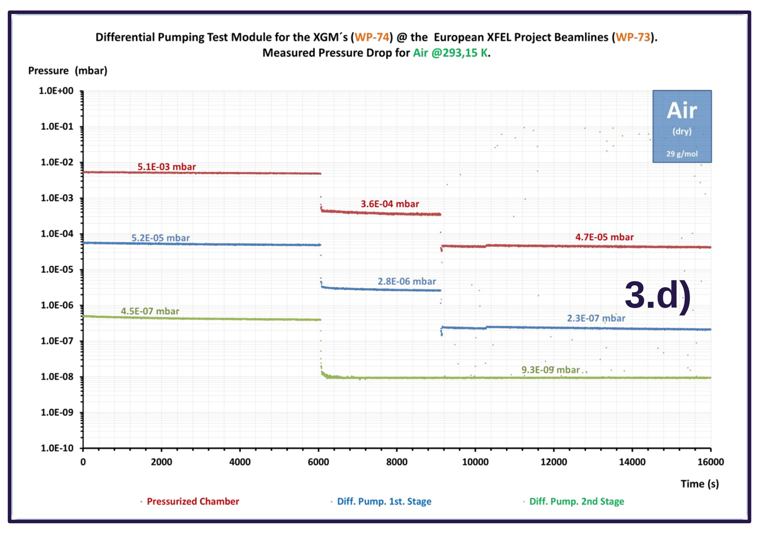
3.a)



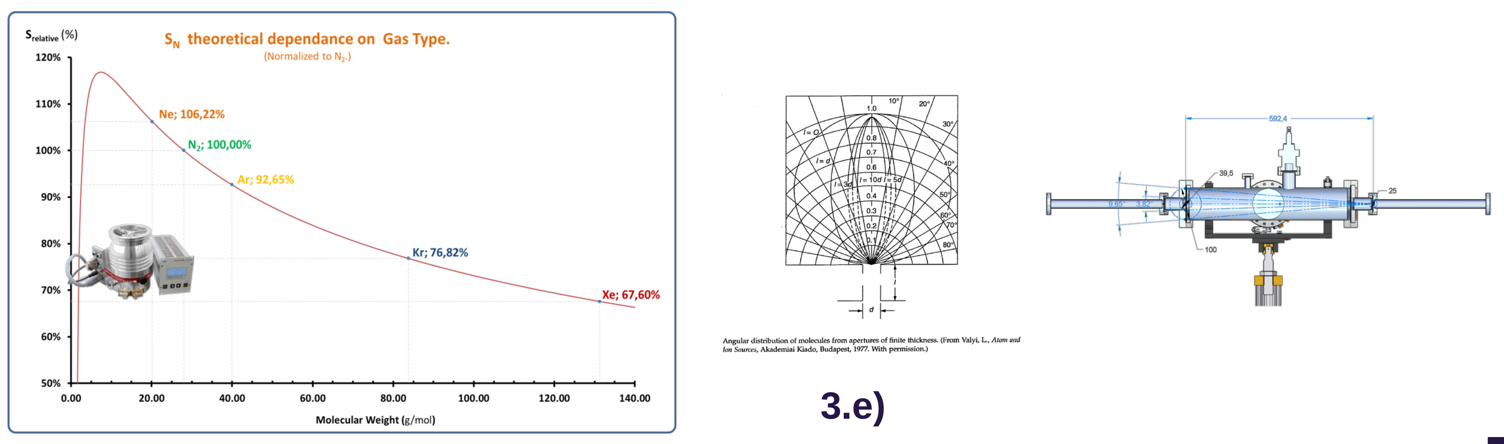
3.b)



3.c)



3.d)



3.e)

Figure 3a*: Pressure drop profile, calculated by the "Matrix-Transfer" Method [6], showing the expected performance differences depending on the gas type. For each element conductance estimation both factors (gas species and sequence of expanding/contracting cross section accordingly to Oatley's / Haefer approach [7].* ***Figure 3b****: Comparison of calculated pressure drop profiles provided by the system for dry air when then pressure in the gas chambers varies from to $5\cdot10^{-5}$ up to $5\cdot10^{-3}$ (stress-test conditions).* ***Figure 3c****: Measured pressure drop profile at different inlet pressures when Xenon is injected in the system (notice instability issue with the pressure gauge of the 1st D-P stage).* ***Figure 3d****: Measured pressure drop profile at different inlet pressures when dry air is injected in the system.* ***Figure 3e****: TMP's theoretical S_{eff} dependence with the gas type at a given temperature (i.e. most probable thermodynamic molecular velocity). In this figure is also shown the expected beaming effect due to the geometrical configuration of the system.*

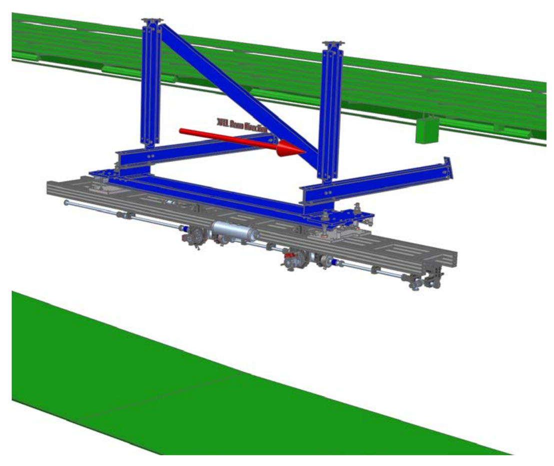
System and Project Description.

Considering the total number of gas-based diagnostic devices along the European XFEL Photon Beamlines (up to 10 assemblies), the diverse installation features of some of them (i.e. beam axis is 2.6 m. above XTD2 tunnel floor level), as well as a clear cost-efficiency orientation of the proposed system, the development of a modular, flexible and adaptive solution, mostly based in "off-the-shelf" UHV components has been considered as the most suitable approach.

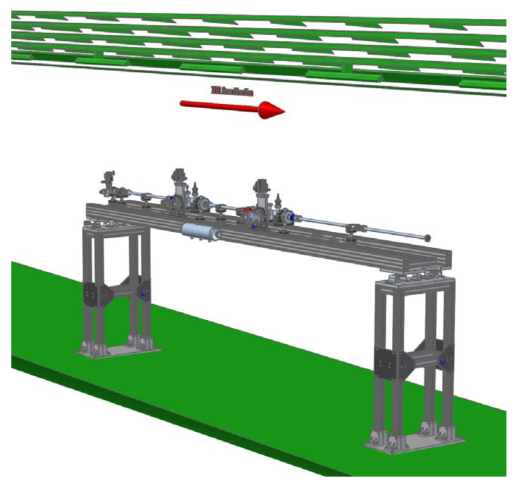
Following this purpose, the developed differential pumping system is based on a reduced number of "*building blocks*": (single-type, all-orientation-enabled pumping chamber design, standard TMP's, common forevacuum system, long-tubes with reduced diameter as conductance limiters between pumping stages, etc, *see figure 2*). In addition, a very challenging restriction was the large optical clear aperture required for most of cases (up to a diameter of 25 mm). On the other hand, installation available space is not a special issue for the majority of those situations. Therefore a narrow, long-pipe solution has been adopted as flow limiting element between pumping stages.

After calculating (*See figures 3.a and 3.b*.) the respective pressure profiles for the different gas candidates (Xe, Ar, Ne, Kr, N_2 and also dry-air) with the theoretical corrected values for both conductances and effective pumping speed in each case, a test-setup was built to explore the design real perfomance space with succesful results (*See experimental data results in figures 3.c and 3.d*).

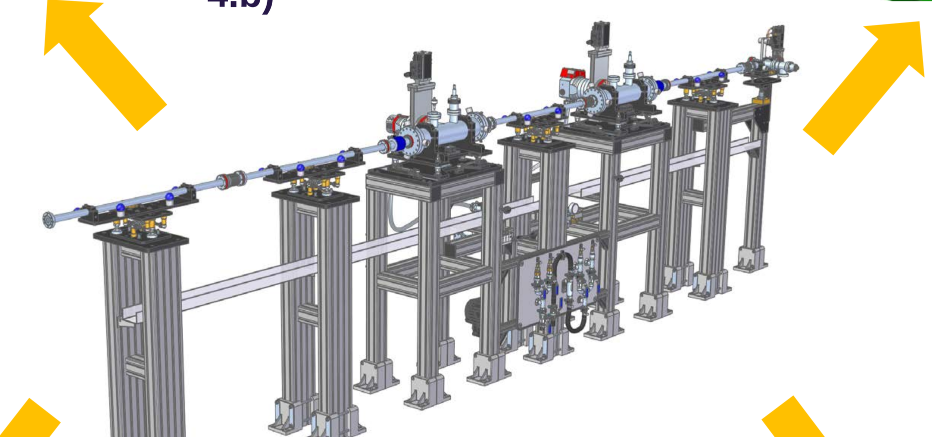
After the subsequent deployment of the project PLC automatic control and equipment protection interlock concepts, the project is now in its last phase which includes the instalation of the 10 assemblies along the different beamline sectors and the joint technical commission with the gas-based diagnostic modules during 2016.



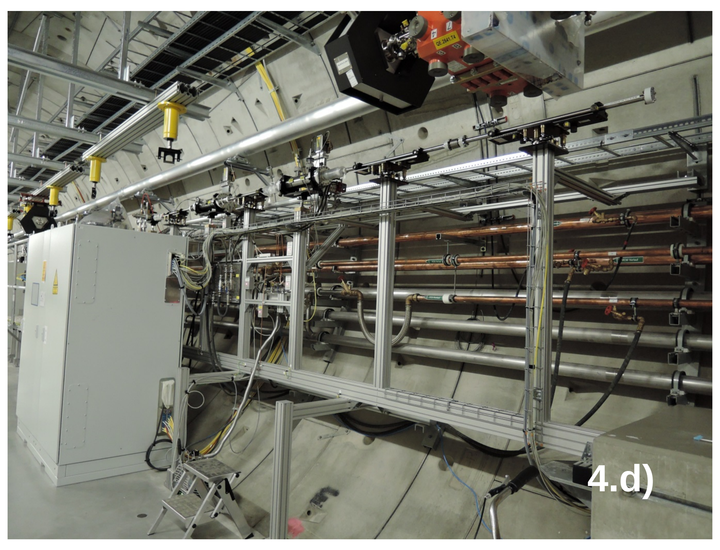
4.b)



4.c)



4.a)



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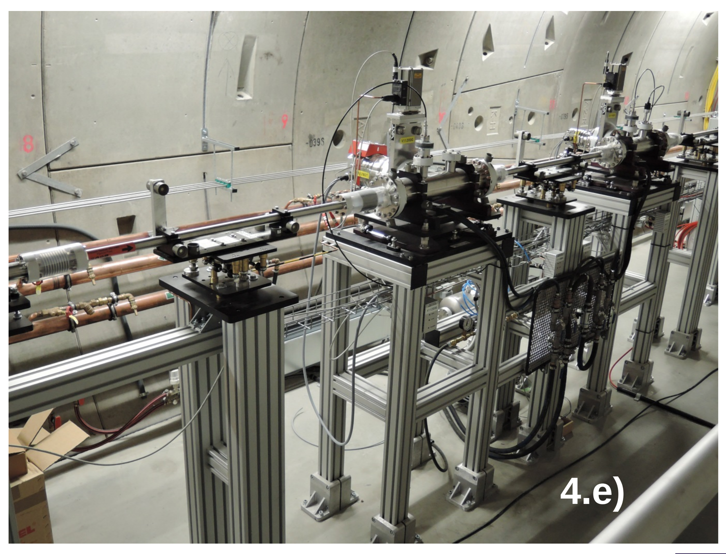

4.e)

Picture 4a*: 3D CAD Model of the reference assembly (for 1,4 m beam axis to floor height).* ***Pictures 4b & 4c****: 3D CAD impressions of the girder mounted variations for respectively "bridge" and "ceiling" assemblies (in collaboration with DESY – ZM1 design group. Supporting structures currently on production).* ***Pictures 4b & 4d****: Actual pictures of the XTD2 and XTD9 tunnels finished installations.*

References.

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