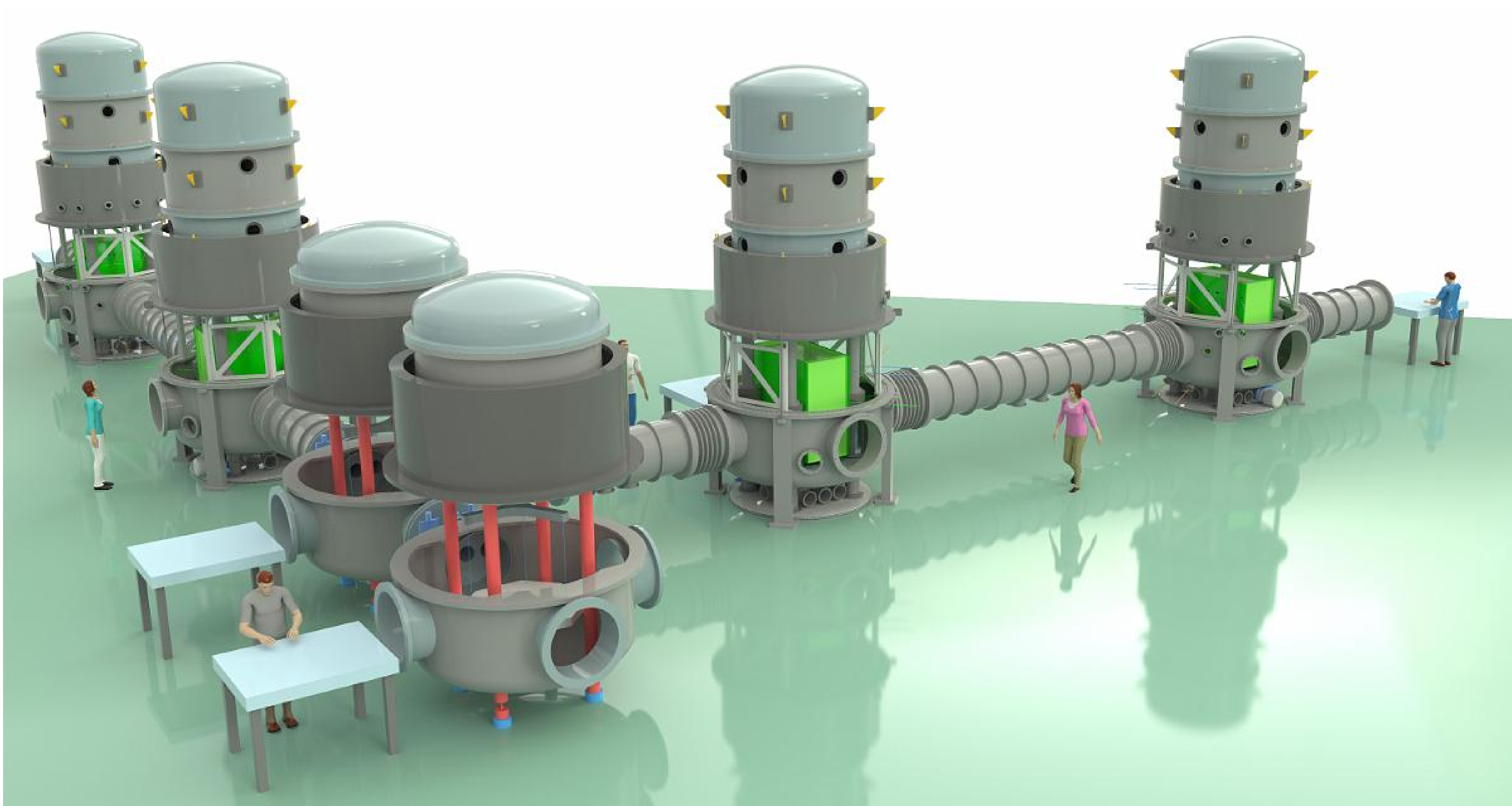
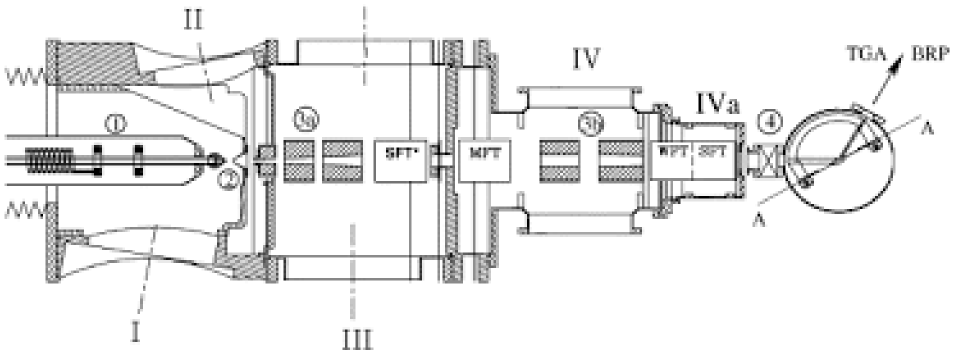
Vacuum technology, plans ETpathfinder

H.J. Bulten



My background in vacuum(+cryogenics) technology

- Not a vacuum technician, just a physicist with vacuum experience
  - particle-physics background, experiments with among other things atomic beam sources:
    - nuclear-polarized hydrogen/deuterium beams injected in storage rings: Nikhef-AmPS polarized electron beam, IUCF cooler facility, on-call expert for the source at DESY with the Hermes experiment
      - Atomic beams, different pumps, cryogenics inside vacuum.
    - developing and testing the microstrip GAS chamber - a detector facing the DESY beam
    - design of the RF box around the LHCb vertex locator : a box in the primary vacuum, housing the silicon tracker, with corrugated walls at 7 mm from the LHC beam.
      - RF wake fields, differential pumping, thin-walled boxes, UHV environment, stepper motors in vacuum, NEG coatings, plastic deformation Al
- some experience with turbo pumps, getter pumps, cryopumps, NEG coatings
- some cryogenic experience.
- currently chair ETpathfinder work package 4: vacuum and cryogenics.

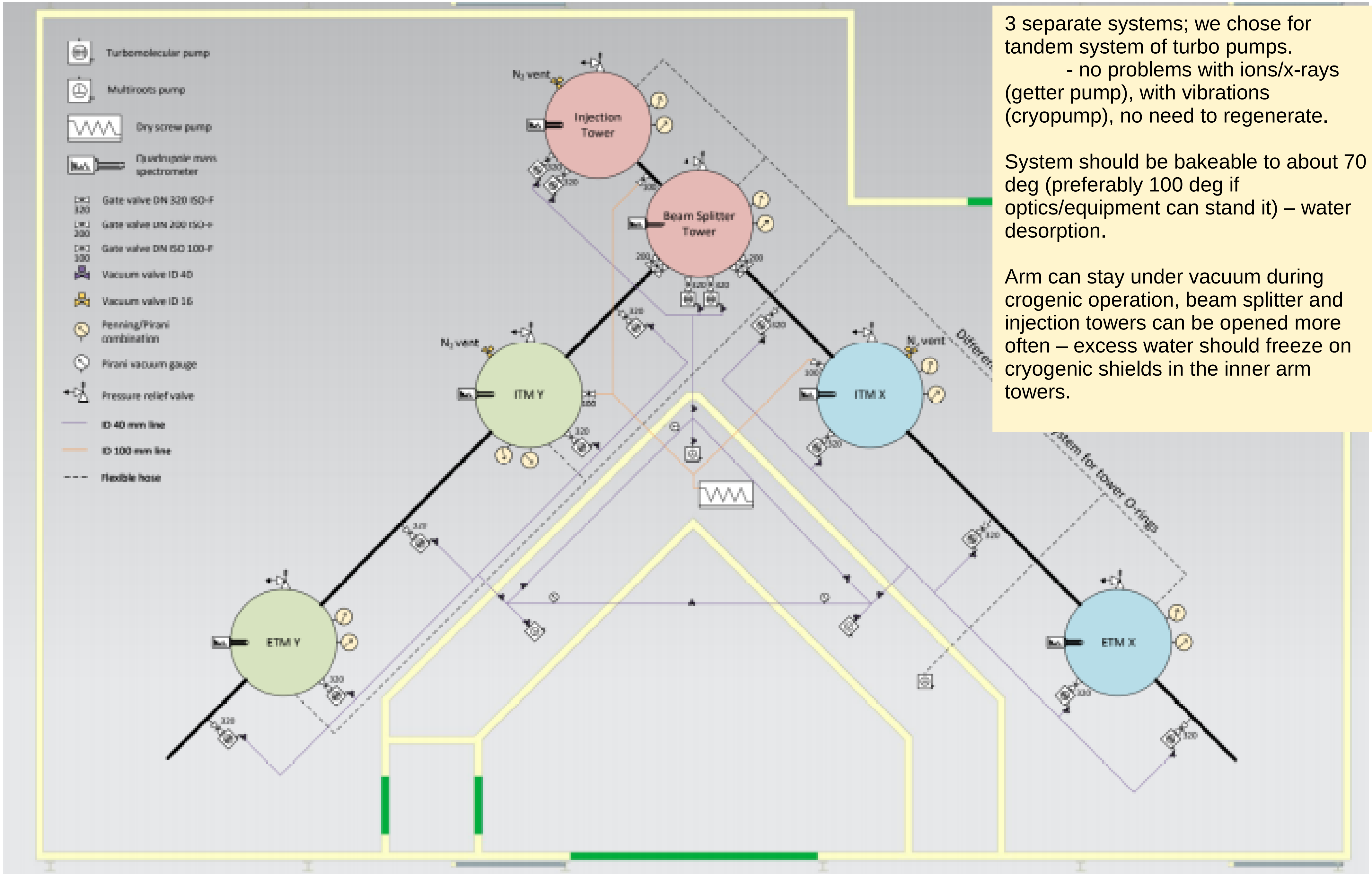


Hermes Atomic beam source: hydrogen or deuterium gas is dissociated with a strong RF field and passes a cooled (20K) nozzle to form a jet in vacuum. A set of strong sextupole magnets focuses the electron spin of the atoms and hyperfine transitions are made in-flight. The beam with selected nuclear-polarized state is injected into a t-shaped storage cell around the axis of the 35 GeV DESY polarized positron beam.

ETpathfinder plans wrt. vacuum

- We aim to minimize ice build-up on the mirror for ETpathfinder
- Vacuum should be compatible with ET vacuum in the tower section; we do not attempt to reach <1e-10 mbar in the arms
- We try to start with a base vacuum around 1e-9 mbar in the input/end towers before cooling down; about 100-1000 times better than currently realized in the Virgo/KAGRA end towers. Not sure if that is realistic considering the cabling/equipment in the tower, but it is our ambitious start goal.
  - Maybe unrealistic because of cabling/stepper motors: we will test the outgassing of 1 LVDT/actuator coil set-up in the coming months
  - we will not use MLI foil - hygroscopic and impossible to pump on.
    - if this is needed for ET then the foils should be enclosed in a sealed Al casing - too complicated for ETpathfinder
  - we will have separate cooling chains for inner and outer cryogenic shields - will try to freeze water on outer shield while heating the inner shield to further reduce ice build-up
  - we can moderately “bake” the system to 70 deg. to reduce water load after vacuum breach
  - we will have RGAs installed in all towers to monitor partial pressures.
- developed numerical modeling to predict water migration in the system: surface binding and ray-tracing of particles (also hydrogen outgassing is parametrized).
  - Raytracing to obtain travel times and conductances; tracking the hydrogen in the walls and the water/dissociated water on the surface to obtain time-dependent adsorption and desorption.
  - model calibrated with outgas measurement chamber at Nikhef.
- we will aim to model and measure water migration; ice build-up and water loss from the LN2-cooled outer cryogenic shield.
- ETpathfinder has 800-mm diameter beam pipe; possibility to test small-scale ET-prototype sections (e.g. a NEG coating section; or a thin-walled carbon steel pipe to measure H/H2O outgassing)
  - this is not an immediate plan of us but the facility is designed so that such future studies are possible
- ETpathfinder will use turbo pumps in tandem; we avoid getter pumps since we are not sure about charging/pollution by sputtering etc and since we will probably have to break vacuum regularly. We will not use cryopumps for noise reasons.

ETpathfinder - design



3 separate systems; we chose for tandem system of turbo pumps.
- no problems with ions/x-rays (getter pump), with vibrations (cryopump), no need to regenerate.

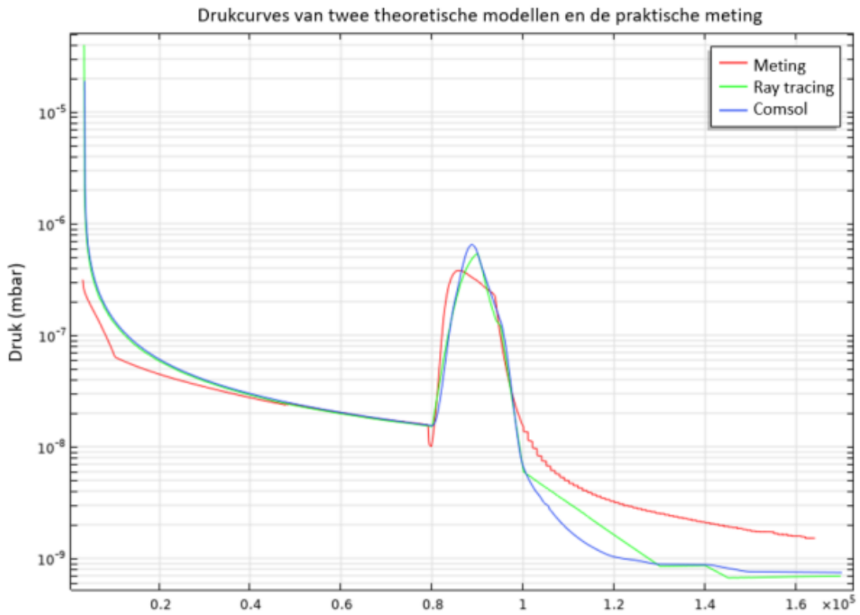
System should be bakeable to about 70 deg (preferably 100 deg if optics/equipment can stand it) – water desorption.

Arm can stay under vacuum during crogenic operation, beam splitter and injection towers can be opened more often – excess water should freeze on cryogenic shields in the inner arm towers.

Vacuum modeling

- Both Comsol and molflow are not capable of tracking the outgassing rate as a function of history of the surfaces. Nevertheless, we can compare the simulation model with Comsol and molflow for steady-state, and in the case of Comsol for surfaces with outgassing rates that are linear wrt the coverage.

- Since the simulation for the full ETpathfinder setup with 6 shield walls around the payload was too time-consuming, the model has been tested against a simpler set-up, the Nikhef outgas chamber (Vera Erends, minor project Mechanical Engineering). Results are reported in NeVac Oct 2020 (the Dutch journal on vacuum technology).



Pressure as a function of time. Comparison of measurement (red), this simulation (green) and Comsol simulation (blue) for 2 days of pumping, where the temperature was increased from 300K to 340K for 3 hours after 1 day. In this simulation code and Comsol, a distribution of binding energies between 0.75 and 1.1 eV was chosen for different parts of the surface. The discrepancy between 100,000 and 130,000 seconds for between Comsol and this simulation is due to a different assumption for the temperature. The excess pressure in the measurement is due to hydrogen gas (as was apparent from the RGA).

Outgas chamber at Nikhef. Samples can be brought in at the bottom and raised to the top chamber. Both chambers are pumped with a small turbo pump (56 l/s), the top chamber contains a stabil-iongauge and a Prisma-Pro 200 RGA. The chamber can be heated to 120 deg. by air.
From Nov. on we have a larger outgas setup with dual turbopumps (350 l/s) and better heating blankets.