Vacuum Simulations of the Monitor Spectrometer Detector Chamber

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- Vacuum layout
- Vacuum modelling with MolFlow+
- First results
Vacuum Constraints for TRISTAN

• Phase 0:
The Mon Spec measurements can be made at $1 \times 10^{-9}$ mbar
  • This is less restrictive than the Main Spectrometer

• Phase 1:
  • Pre-Spectrometer (PS) on HV for active neutrino mass measurement requires $p \ll 5 \times 10^{-10}$ mbar. At higher pressure we have Penning discharges.
  • PS on ground potential: higher pressure possible
  • $p > 1 \times 10^{-9}$ mbar: short storage time of trapped electrons
    • high rate of secondary electrons for several seconds (“radon peaks”)
  • fast energy loss of trapped electrons: effect on non-Poisson background?
Vacuum Layout of the Detector Chamber

SAES NEXTORR Z100 NEG + ion getter pump (1000 l/s + 15 l/s)

Bellow DN 100 mm

VAT gate valves DN 100 mm

Pfeiffer HiPace 300 Turbo-molecular pump (300 l/s)

Shared fore-vacuum line: TMP + scroll pump
MolFlow+

- Molecular flow regime
  - Mean free path of molecules is so long that intermolecular collisions can be neglected
  - Monte Carlo simulations of independently flying particles
  - Allows one to calculate pressure, density, conductance, and effective pumping speed of a UHV system
- Geometries can be imported from CAD programs

MolFlow+ allows you to calculate the pressure in an arbitrarily complex geometry when ultra-high vacuum condition is met. The name comes from molecular flow, the condition when the mean free path of molecules is so long compared to the geometry size that collisions can be neglected. In this case, particles fly independently, which makes this physics particularly suitable for Monte Carlo simulations. The first version of this program was written by Roberto KERSEVAN in 1990. In 2008 a new version called MolFlow+ was written, that uses the original algorithm in a modern environment. It uses OpenGL acceleration and can use multiple cores. Further improvements were added in 2012. Geometries can be imported from most CAD programs that support the STL file format.
Monitoring Spectrometer

Steps to import this into MolFlow
1. Simplify the CAD drawing
2. Output CAD drawing into meshes (triangles)
3. Import into MolFlow, “collapse” (combine) triangles into flat polygons (“facets”)
4. Adjust the facets parameters, such as temperature, outgassing, sticking probability, reflectivity, transparency,
5. Run MolFlow simulations
Calculate the conductance across vacuum cover

Step 1

• Blue donut – vacuum cover
• Brown – Detector holder
• Silver rectangular prism - SDD

• Also need to retain the outside cylinder
• Take out the rest of the holding structure for now
Calculate the conductance across vacuum cover
Step 2

Choice in how detail to output the CAD drawing into bunch of triangles
Calculate the conductance across vacuum cover
Step 3

• Collapse triangles into polygons (facets) when importing CAD drawings into MolFlow
• Have to make sure that we don’t lose small but important details of the models in this step
Calculate the conductance across vacuum cover

Allow particles to desorb from this end of cylinder
Particles can also absorb back to this surface

All other facets are perfectly reflective
Green lines show particle path

For realistic simulations, desorptions would mainly come from the PCBs, flat cables, and other parts

Absorptions can be determined either by sticking percentage or pump out rate (depends on facet area)

Count number of particles that hit this end of cylinder, across the vacuum cover
A heat map of hits is shown
Vacuum Cover conductance

Heat map of absorption hits at endcap (UHV side)

Heat map of particles passing through a transparent surface right at the SDD

0.36% conductance
Vacuum Cover conductance

- Particles are leaking through the vacuum cover right at the edge of the SDD
- There is also a gap between the vacuum cover and the holder
- Can also see the hole at the lower right corner for the bond wire
- Actual conductance is smaller than 0.36% with the holding structure taking up space
- Cylinder length, etc. also lower the conductance

Questions to still answer:
- Why is there no leak between the vacuum cover and vacuum chamber inner surface?
- Weird asymmetry (Joachim thinks this is okay)

1475 facets

Can output the hit counts of this mesh into a spread sheet
Phase 0 vacuum sim model

- What we really want is a more complex model of the monitoring spectrometer like this
- Define
  - Effective pump out speed
- What we want to know
  - Given outgassing rate on rough side of vacuum
  - What is the pressure on the ultra-clean side of cover
More realistic simulation – work in progress

Need to simplify this geometry (get rid of screw holes at the very least) for MolFlow sim

- The effective pump out of this space is important
- But true value will be impacted by cabling, etc.
- Simplify geometry with rectangular prisms
  - Do I care about the inside of the cooling block?
  - Bulk (if not all) of outgassing from outside
- Decisions on where and how to include outgassing

Particles get effectively stuck within the SDD holder geometry
Next step: 9 TRISTAN detectors as FPD (phase 1)
Conclusions and Discussions

• First working model available
• More realistic (but with smart simplifications) setup to be implemented
• Adjust simulations to test different gaps between detector, shield, and wall
• Simulation goals:
  • Estimation of conductance to spectrometer vs. effective pumping speed of detector pumps (NEG and TMP)
  • Determine maximum allowed outgassing rate (*this impact other technical designs*)
  • Decision about gap widths and manufacturing tolerances