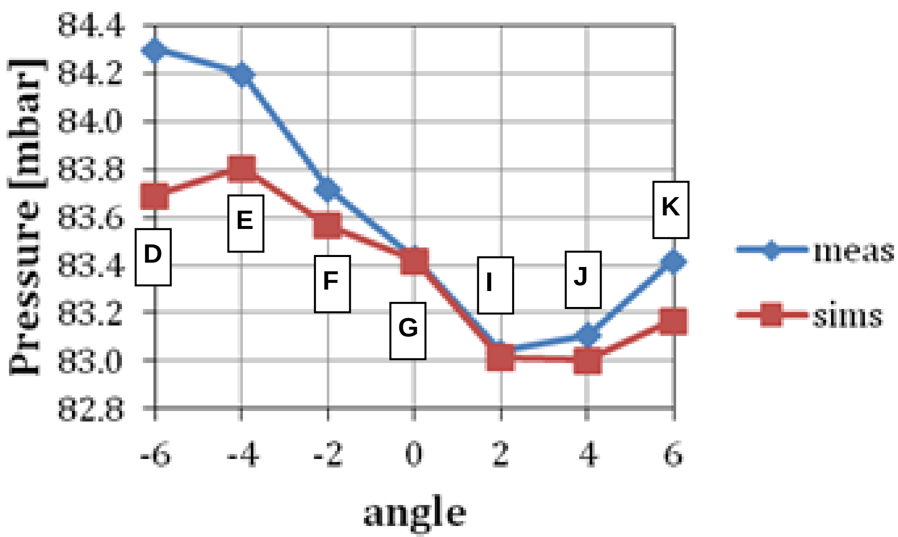
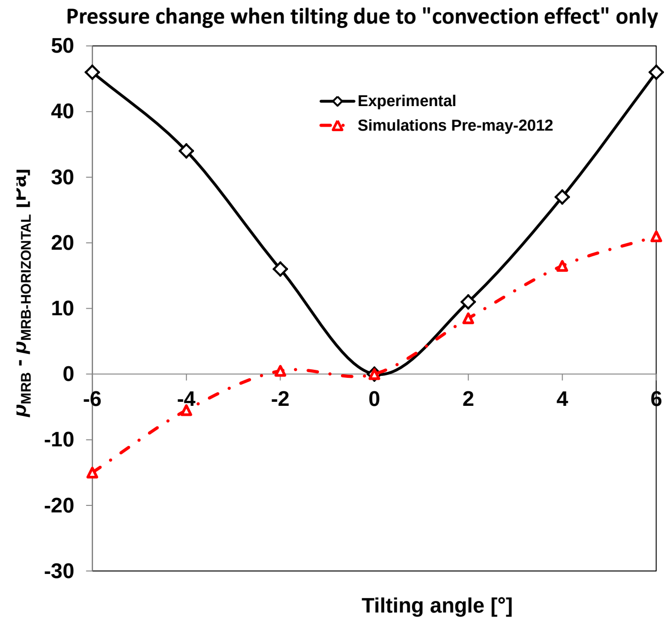
CFD Simulations for CAST
1. Status of CFD simulations

- Enrico Da Riva -
CERN (EN/CV/PJ)

49th CAST Collaboration Meeting, Geneva 24/26 September 2012

Tracking of actual tilting process



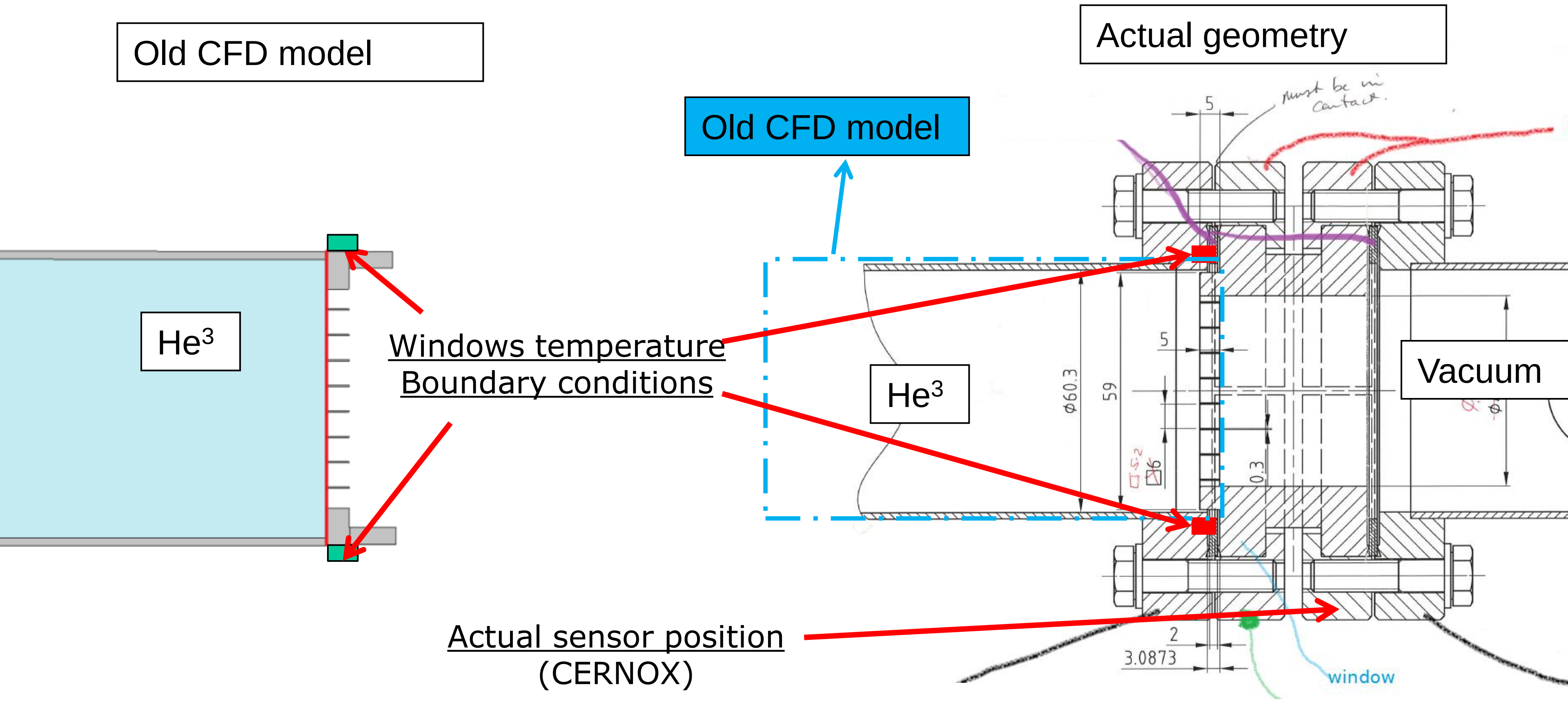


Pressure change during actual tilting is due to:

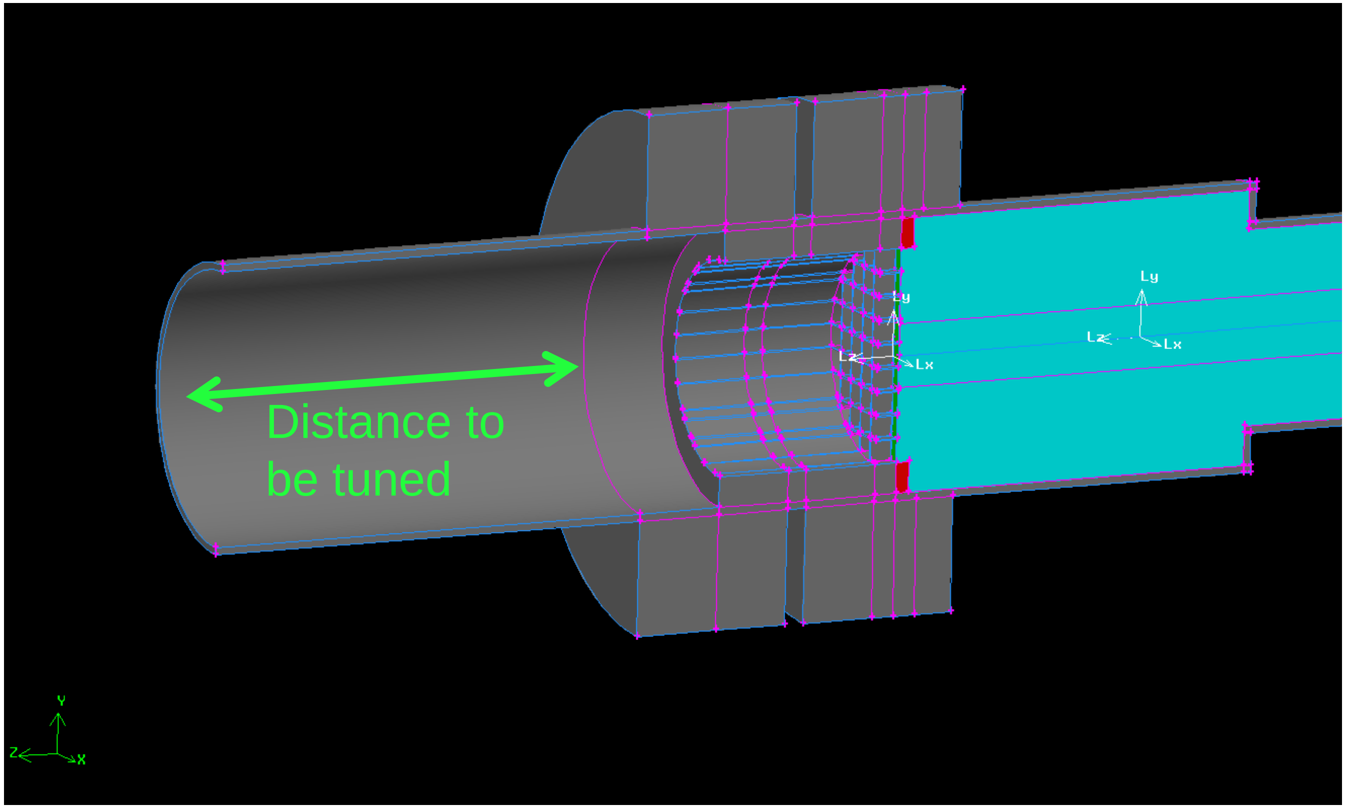
1. MAGNET TEMPERATURE CHANGE: pressure change depends on $(\delta p/\delta T)_\rho$; density doesn`t change since the mass distribution is not affected; no need of CFD simulations to predict this phenomenon (provided that the right Equation of State is used).
2. HYDROSTATIC: pressure change depends only slightly on the mass distribution, can be easily computed with enough accuracy without CFD (see second part of the presentation).
3. CONVECTION EFFECT: pressure change due to the change of the He3 mass distribution, can be computed only through CFD.

- ❑ Previous CFD simulation could somehow reproduce the experimental trend (left plot) because the first 2 phenomena could be predicted.
- ❑ However the prediction of the pressure change due to the CONVECTION EFFECT was wrong (right plot).

Geometry and b.c. update

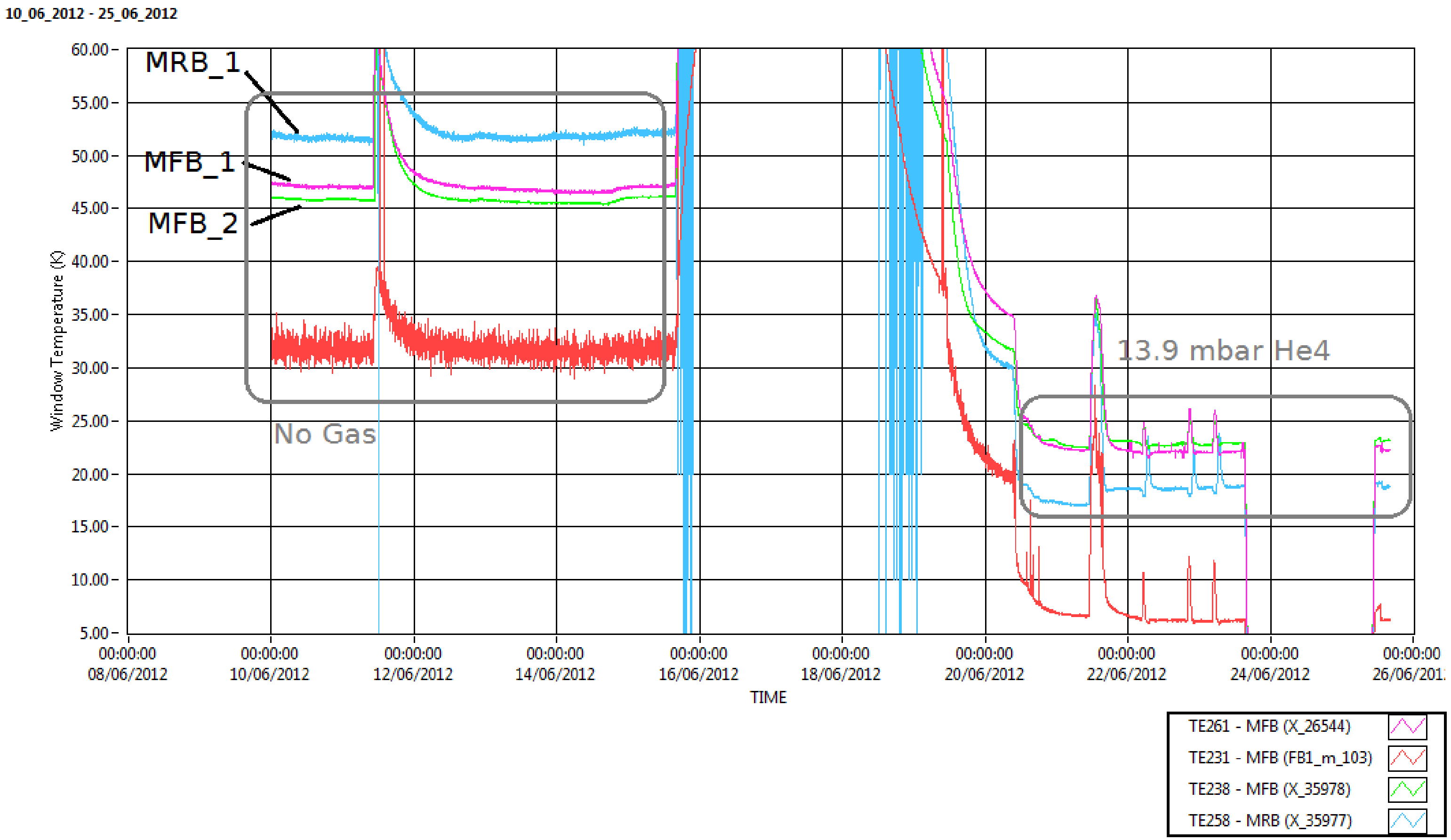


Updated CFD model



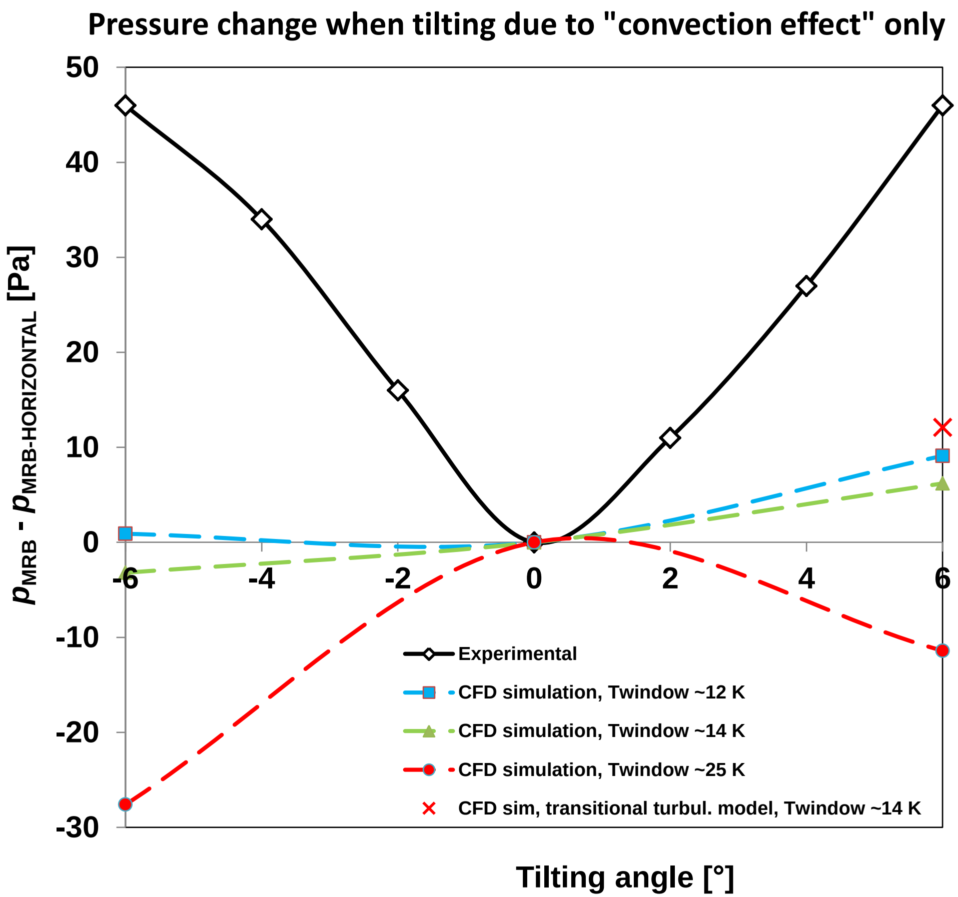
- Flanges and vacuum pipe added to the model up to the thermal shield.
- Symmetry plane still used.
- Distance between the flange and the thermal shield must be tuned using experimental temperature data without gas.
- Experimental windows temperature not used anymore as boundary conditions; new b.c.: cryostat temperature + thermal clamp temperature (70 K).
- Pressure and windows temperature are a result of the simulations.

Tuning of the CFD model



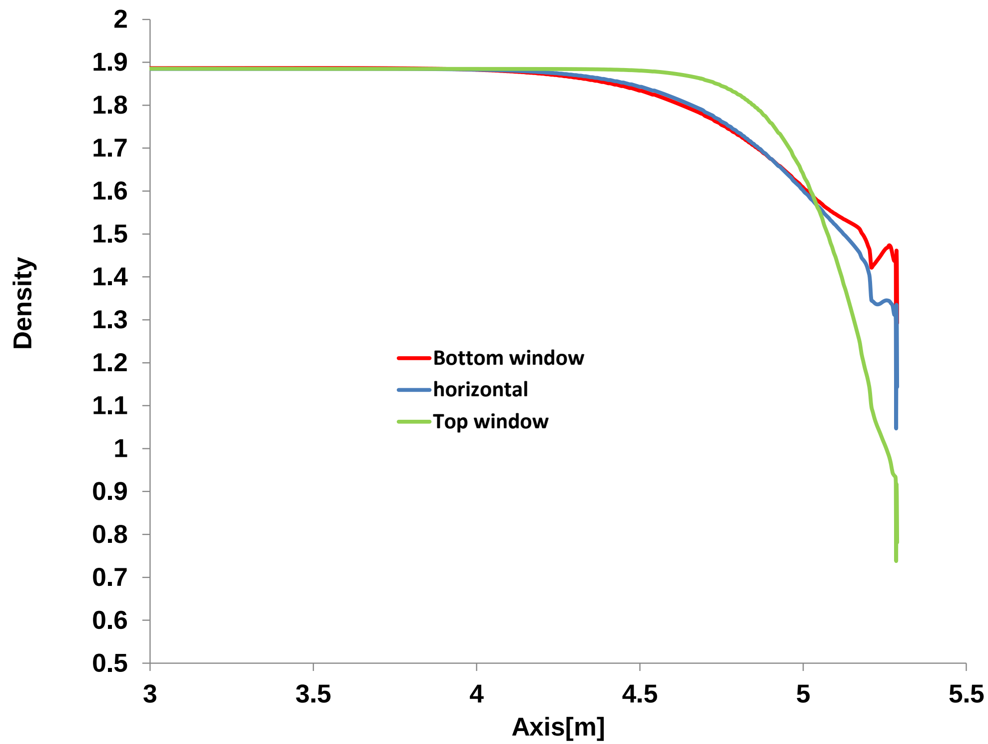
- Tests have been run without gas.
- Tuning of the CFD model has been difficult, since several temperature measurements inconsistencies were found (see backup slide).
- Direct access to the probes needed to better understand experimental data.

Updated CFD model results



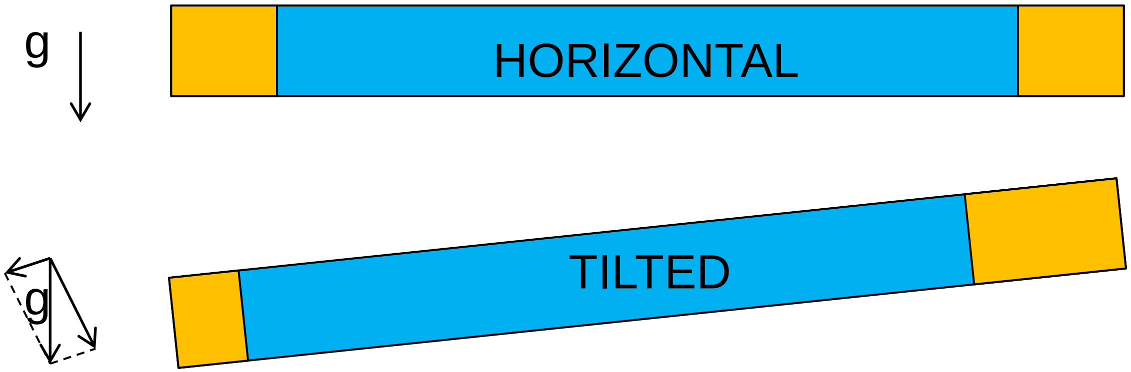
- CFD simulations have been run with different tunings corresponding to different temperatures of the windows.
- Results of pressure change due to <u>CONVECTION EFFECT</u> only are now qualitatively closer to the experimental “V-shape”.
- CFD simulations with tuning corresponding to colder windows (~12K) show a pressure increase when tilting, the ones with warmer windows (~25K) show a pressure decrease when tilting.

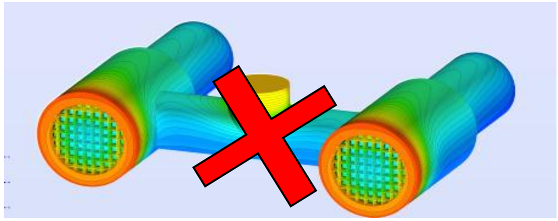
Example of density profile



- When tilting, the gas at the bottom end is colder and slightly more mass is stored there.
- Gas stratification occurs at the top window: moving from the center to the top, the almost-constant density region extends further closer to the window, followed by an abrupt density drop.
- The coherent-density region is shifted upwards, however less mass is globally stored in the upper end of the magnet (in the present example @ 83 mbar).
- Globally (top + bottom), less mass is stored at the ends; this difference in mass is pushed to the center where pressure and density increase.

CB pipes connection





- Pressure change when tilting is due to the fact that the gas volumes at the windows change temperature and density in a different way.
- Simple way to imagine it: one of the two extremities expands more than the other → push the vapor inside the CB → pressure increases.
- In the present model the pipe connection was not included, hence the total number of moles available at the extremities for contraction/expansion is underestimated.

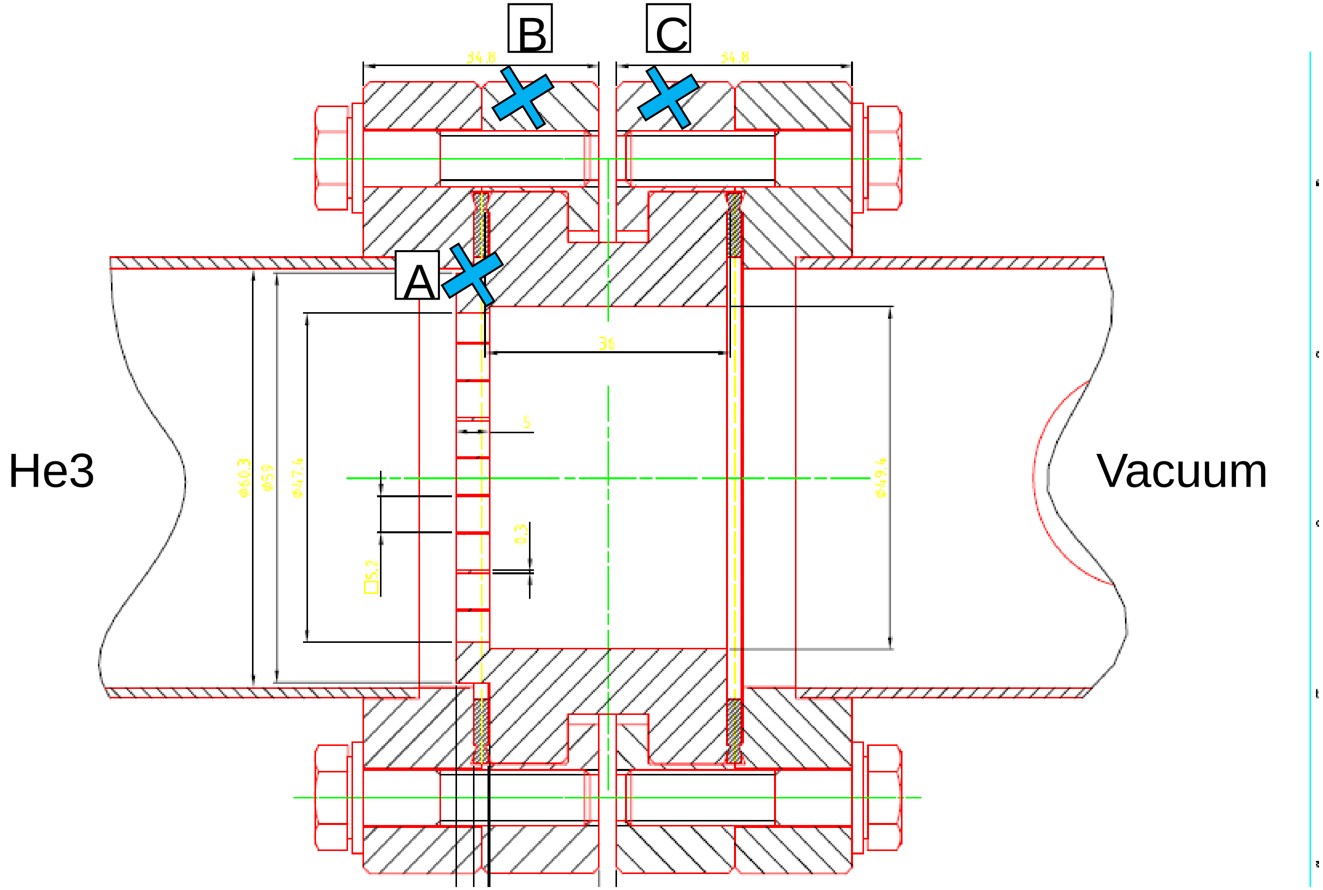
- Adding the connection is expected to enhance the pressure change when tilting.

CONCLUSIONS

- Being able to predict the pressure change when tilting due to the "CONVECTION EFFECT only" would be a proof of CFD simulations reliability.
- The old (i.e. before May 2012) CFD model could not predict this phenomenon.
- The CFD model have been updated adding the flanges and the vacuum pipe up to the thermal shields.
- Accurate windows temperature measurements during test runs without gas are essential to "tune" the updated CFD model, but several temperature measurements inconsistencies have been found.
- The experimental window temperature measurements during tracking are not used anymore as boundary conditions; they are now a result of the simulation.
- The predictions of the updated model are now qualitatively closer to the experimental values, but the pressure increase when tilting is underpredicted.
- Adding to the CFD model geometry the connection pipes between the CBs is expected to enhance the predicted pressure change when tilting.

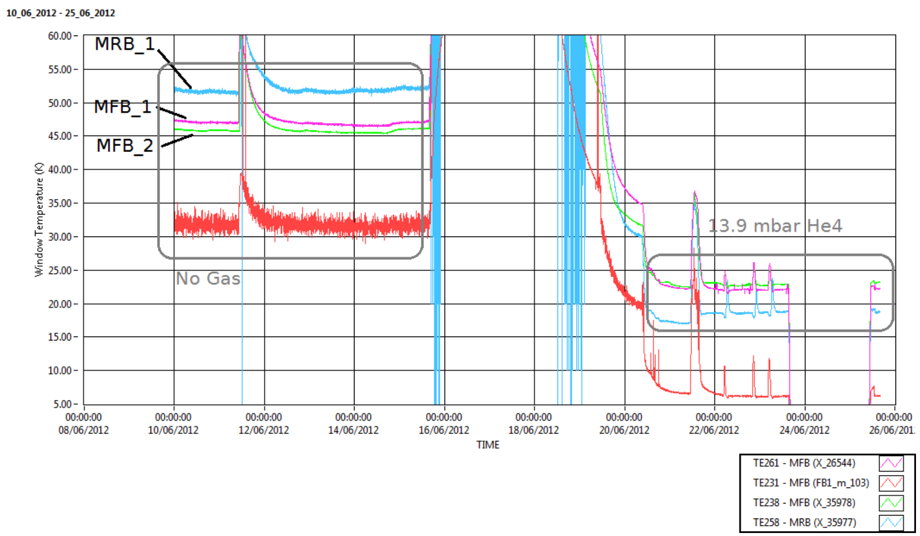
Back up slides

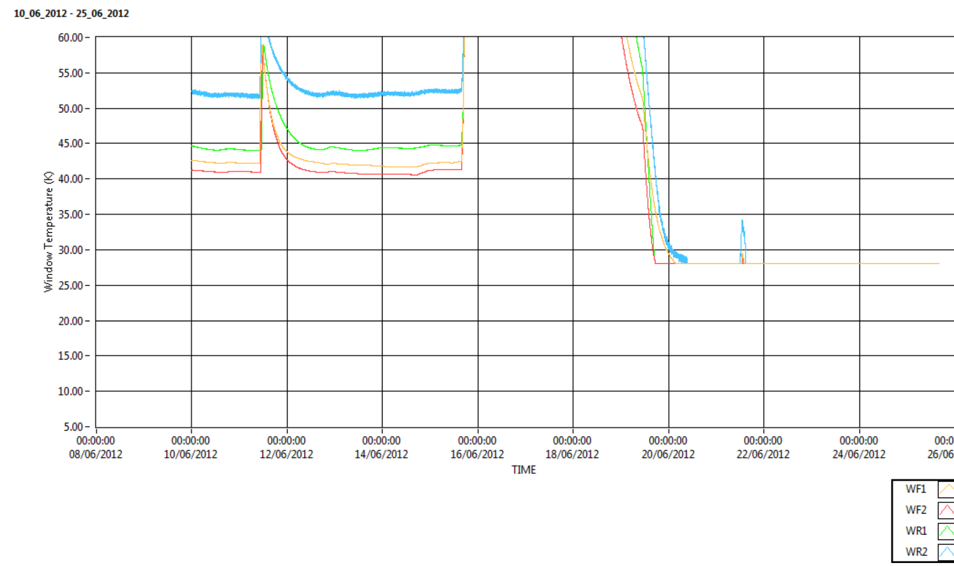
Temperature sensors position



- A: Position in the old simulations, now discarded
- B: PT100 sensors, not used during tests (not suitable for T < 28 K)
- C: cryogenics CERNOX sensors (T_{MFB1}, T_{MFB2}, T_{MRB1}) [T_{MRB2} assumed broken]
- Vertical position unknown (there may be some difference due to stratification)

Window temperature inconsistency





- With gas at 83 mbar, MFB is ~10K hotter than MRB.
- Without gas, MFB is ~5K colder than MRB.
- The PT100 sensors WR1 and WR2 display ~7 K difference without gas.
- Position of the sensors is not completely known.
- A CERNOX sensor @ MRB side is broken.
- Possible causes of inconsistency: poor thermal clamping of probes, wrong/not accurate calibration, wrong cabling.

CFD simulations *(EDMS 1184174 v.1)*

Influence of magnet temp. (cases B1, B2)

Influence of tilting only (cases C1, C2)

Tracking of real tilting process (cases D, E, F, G, I, J, K)

Case #	N_T [mol]	T_{Mag} [K]	$T_{W\text{-}MFB1}$ [K]	$T_{W\text{-}MFB2}$ [K]	$T_{W\text{-}MRB1}$ [K]	θ [degree]	P_{CB} [mbar]
A	18.887	1.758	19.0	16.6	11.2	0	83.39
B1 B2		1.778 1.738	19.0	16.6	11.2	0	84.39 82.25
C1 C2		1.758	19.0	16.6	11.2	-6* +6*	
D		1.765	20.2	17.8	10.5	-6	84.30
E		1.766	20.2	18.0	10.5	-4	84.20
F		1.761	19.9	17.3	10.7	-2	83.72
G		1.759	19.1	16.5	11.0	0	83.43
I		1.750	18.9	16.2	11.8	2	83.04
J		1.749	18.9	16.0	12.8	4	83.11
K		1.752	18.8	16.0	14.1	6	83.42

* positive tilting means MRB above MFB