

Practical Days Vacuum Systems

V. Baglin

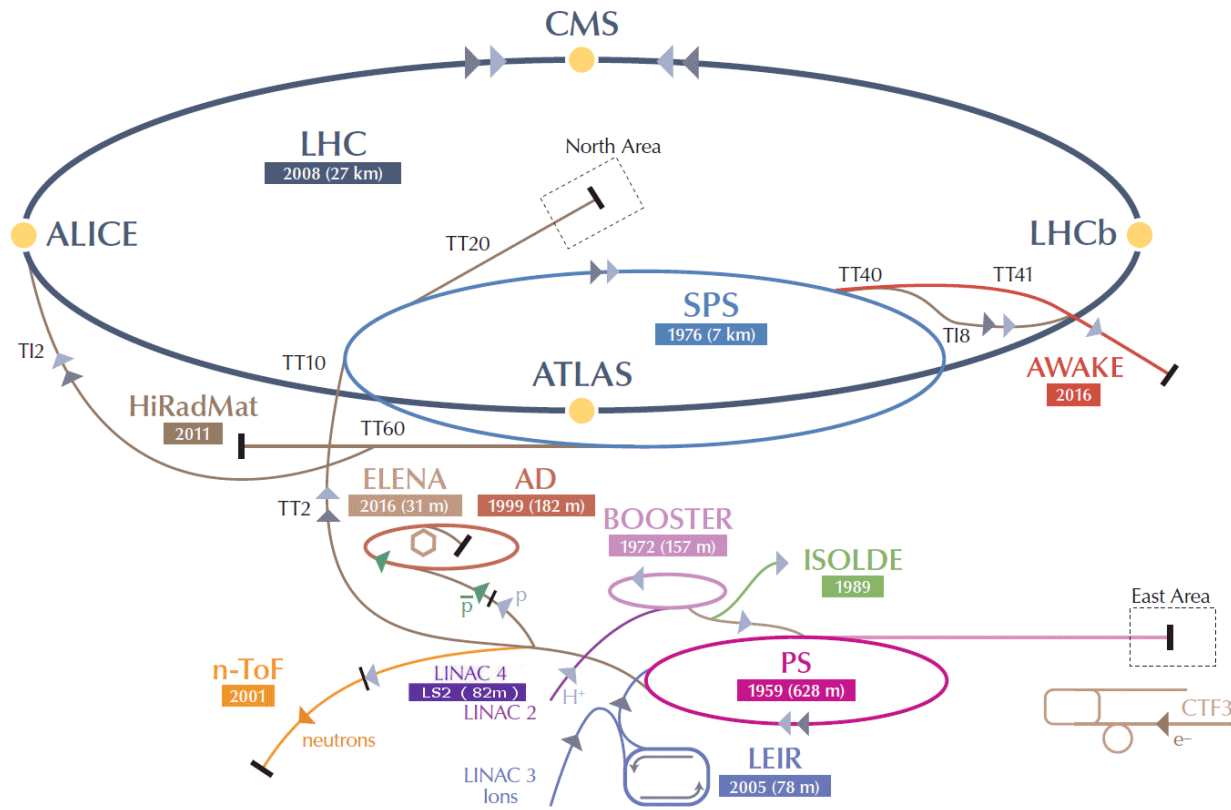
CERN TE-VSC, Geneva



<https://indico.cern.ch/event/1470062/timetable/?view=standard#day-2025-02-17>

11th and 12th March 2025

CERN accelerators complex



CERN vacuum systems

Machine	Type	Year	Energy	Bakeout	Pressure (Pa)	Length	Particles	
Linac, Booster, ISOLDE, PS, n-TOF and AD Complex						2.6 km !		
LINAC 2	linac	1978	50 MeV	Ion pumps	10^{-7}	40 m	p	
ISOLDE	electrostatic	1992	60 keV	-	10^{-4}	150 m	ions: 700 isotopes and 70 (92) elements	
REX-ISOLDE	linac	2001	3 MeV/u	partly	$10^{-5} - 10^{-10}$	20 m		
LINAC 3	linac	1994	4.2 MeV/u	Ion pumps	10^{-7}	30 m	ions	
LEIR	accumulator	1982/2005	72 MeV/u	complete	10^{-10}	78 m	pbar, ions	
PSB	synchrotron	1972	1-1.4 GeV	Ion pumps	10^{-7}	157 m	P, ions	
PS	synchrotron	1959	28 GeV	Ion pumps	10^{-7}	628 m	P, ions	
AD	decelerator	?	100 MeV	complete	10^{-8}	188 m	pbar	
CTF3 complex	linac/ring	2004-09		partly	10^{-8}	300 m	e	
PS to SPS TL	Transfer line	1976	26 GeV	-	10^{-6}	~1.3 km	P, ions	
SPS Complex						15.7 km !		
SPS	synchrotron	1976	450 GeV	Extractions	10^{-7}	7 km	p, ions	
SPS North Area	Transfer line	1976		-	$10^{-6} - 10^{-7}$	~1.2 km		
SPS West Area	Transfer line	1976		-		~1.4 km		
SPS to LHC T12/8 Line	Transfer line	2004/2006		-		2 x 2.7 km		
CNGS Proton Line	Transfer line	2005		-		~730 m		
LHC Accelerator						~109 km !		
LHC Arcs (Beam x2, Magnets & QRL insul.)	collider	2007	2 x 7 TeV	-	$< 10^{-8}$	2 x (2 x 25 km)	p, ions	
LSS RT separated beams				complete		2 x 3.2 km		
LSS RT recombination				complete		~ 570 m		
Experimental areas				complete		~ 180 m		
Beam Dump Lines TD62/68	Transfer line	2006	7 TeV	-	10^{-6}	2 x 720 m		
						High Vacuum	~20 km	~128 km !
						UHV w/wo NEG	~ 57.5 km	
						Insulation vacuum	~ 50 km	

2850 ion pumps, **450** turbomolecular pumps, **325** Ti sublimation pumps,...
6 Km of NEG coated beam pipes, **2750** pressure gauges, **40** leak detectors
and **100** RGAs, **1930** roughing valves and **510** gate sector valves

Intersecting Storage Rings

- Discovery of :
 - Vacuum stability and pressure runaway
 - Beam induced multipacting (electron cloud)
- Developments of laboratory studies and cleaning methods

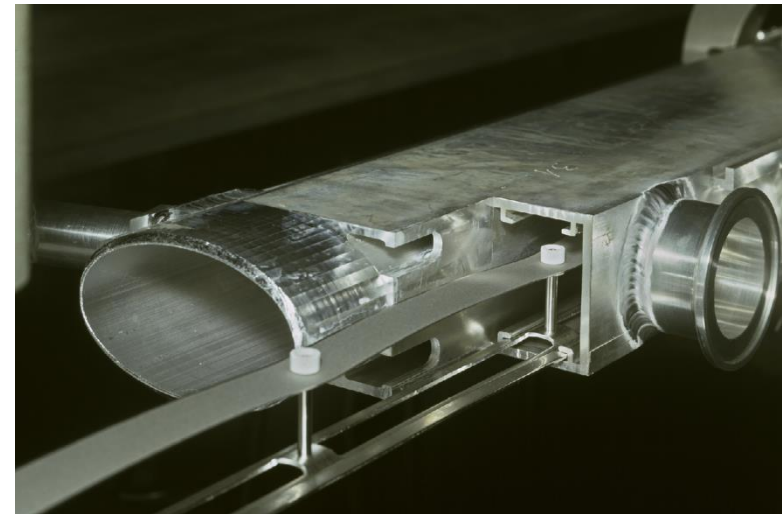
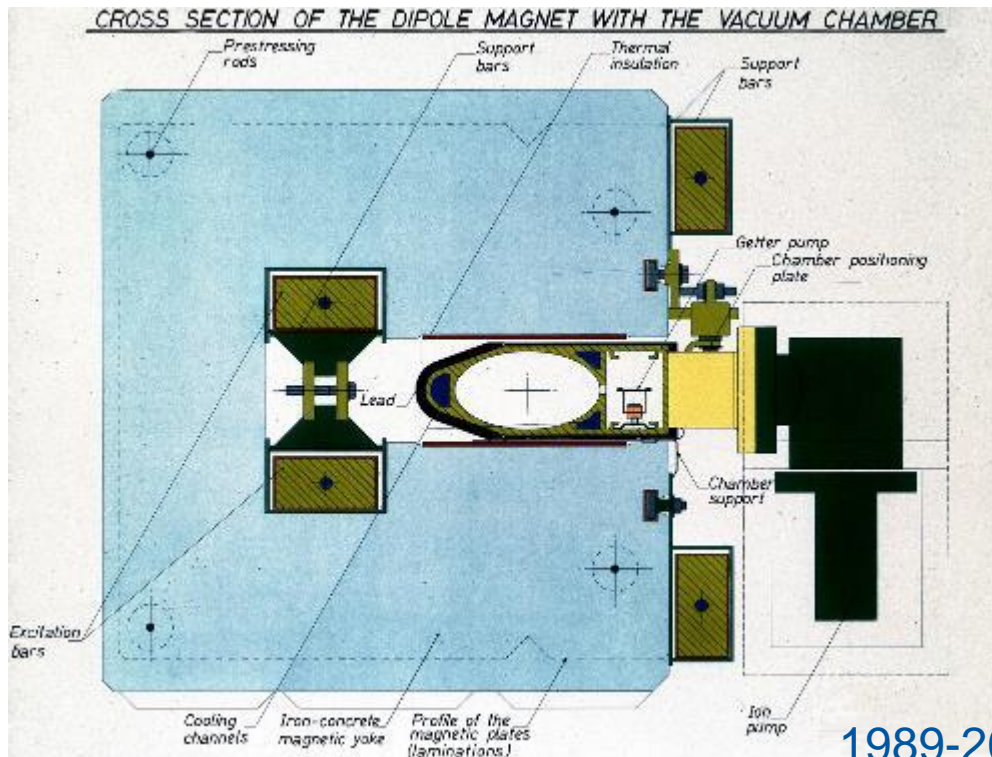


1971-1984

Large Electron Positron Collider

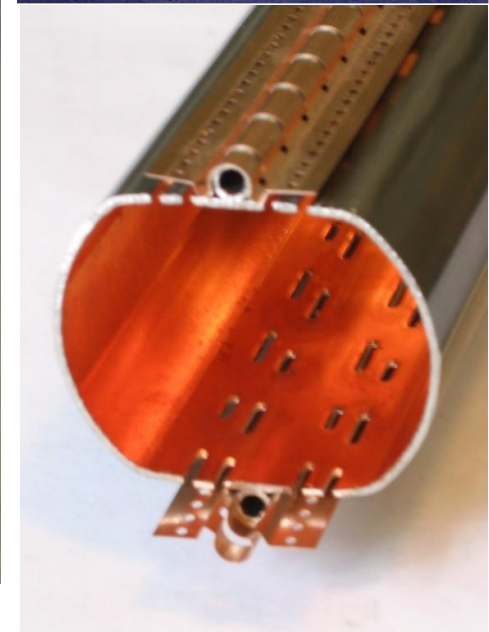
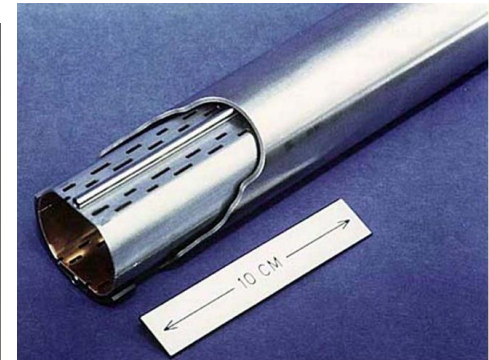
- **Synchrotron radiation** in LEP:
 - From 6 to 660 keV critical energy
 - Gas desorption studies
- Innovative pumping system
 - Antechamber with NEG pumping strip
 - Water cooled and lead shielded

FCC-ee !!



Large Hadron Collider

- Cold bore (CB) at 1.9 K which ensures leak tightness
- Beam screen (BS) at 5-20 K which intercepts thermal loads and acts as a screen



Started in 2008 – to be upgraded by mid-2026-2029 and operated until 2040...

Vacuum, Surface and Coatings group mandate

Design, construction, operation, maintenance and upgrade of high & ultra-high vacuum systems for Accelerators and Detectors.

- Expertise and support on thin-walled vacuum chambers, windows and bellows compensation systems
- Expertise in vacuum sealing and leak-tightness technology
- Expertise in dynamic vacuum phenomena
- Management of the industrial support contract for vacuum work in accelerators
- Expertise in vacuum control systems, vacuum interlocks and monitoring tools
- Simulation of pressure profiles and synchrotron radiation distribution in accelerators

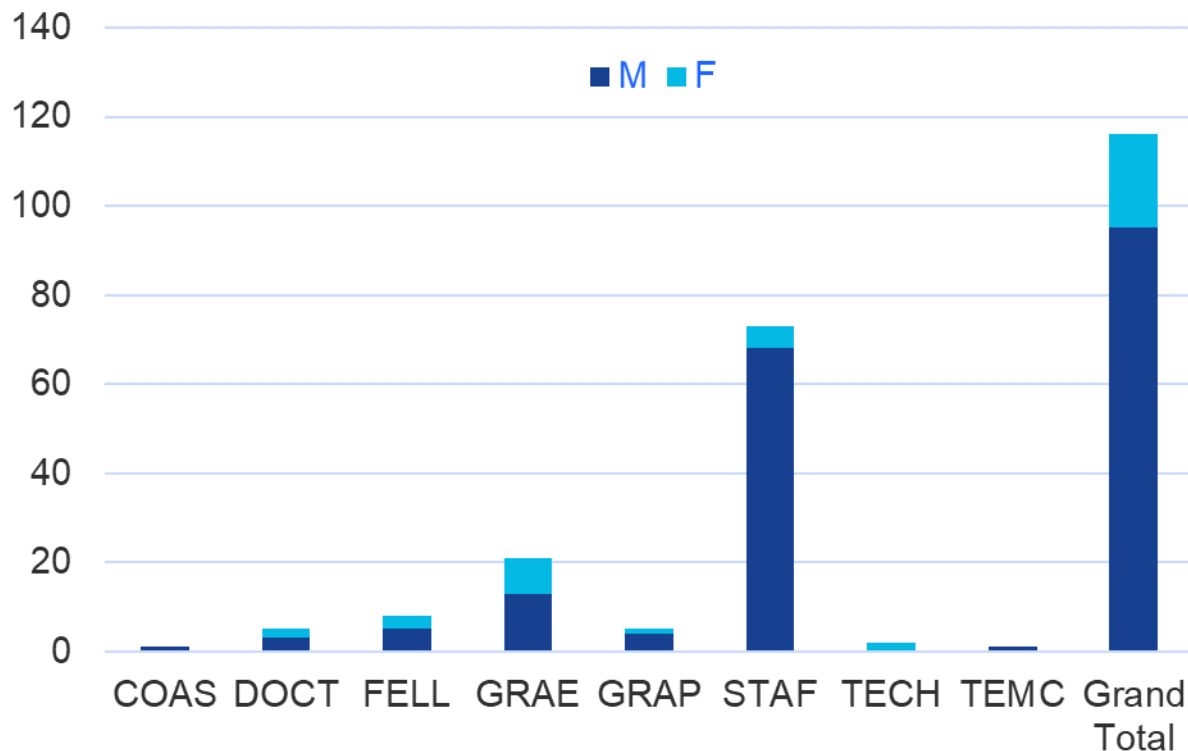
Coatings, surfaces treatments, surface and chemical analysis for Accelerators and Detectors. Expertise and support in the fields of:

- Coatings, electroplating and surface cleaning techniques
- Plasma characterisation and simulation
- UHV characterization and of material and surfaces
- Degassing analysis and treatments

Vacuum, Surface and Coatings group

Design, construction, installation and operation of the CERN accelerator vacuum systems

73+41 = 114 persons in Dec 2024



Several collaborators from different countries and institutes

TE-VSC organisation

Group management
+ 6 sections:

Vacuum studies and measurements

Beam vacuum operation

Design, logistics & methods

Interlock, controls & monitoring

Injector & insulation vacuum operation

Surface, chemistry & coatings

TE – VSC
Vacuum, Surfaces & Coatings group

SECRETARIAT
C. G. [Name]

Group Leader: F. Chappard

GL OFFICE: M. Tazari, J.-L. [Name]

Staff Members:

- Vacuum Studies and Measurements (VSM):** M. Aly, E. Couderc, R. Mestran
- Beam Vacuum Operation (BVO):** C. Collet, S. Collier, J. Chouin, J. Frenk, J. Gasser, K. Geras, J. Heger, A. Kawan, V. Nasser, J. Wenzel, R. Zabus
- Design, Logistics & Methods (DLM):** G. Bader, C. Bucher, H. Ess, A. Kue, M. Ruan, M. Sauer, J. P. [Name], G. [Name], F. [Name], A. Valer
- Interlocks, Controls & Monitoring (ICM):** R. Bayler, A.K. [Name], N. Chakraborty, J. [Name], A. [Name], J. [Name], F. [Name], V. [Name]
- Injectors & Insulation Vacuum Operation (IVO):** F. [Name], M.C. [Name], A. [Name], G. [Name], G. [Name], R. [Name], A. [Name], N. [Name]
- Surface, Chemistry & Coatings (SCC):** R. [Name], C. [Name], F. [Name], Y. [Name], L. [Name], F. [Name], B. [Name], S. [Name], V. [Name], A. [Name], M. [Name], R. [Name], V. [Name], B. [Name], A. [Name], R. [Name], B. [Name], W. [Name]

Students & collaborators: [List of names and photos]

December 2024

Organisation of practical days at CERN

Simulations & Practical work

4 groups of 5 PAX

Meeting in Bat 112/R-034 & 30-1-039

	Tuesday 11 March		Wednesday 12 March	
	Vacuum		Vacuum	
09:30 - 12:30 (3 hours)	Simulation (M. Ady) <u>Group 1</u> (Max 5 PAX)	Practical work <i>Pumping & Leak Detection</i> Instruments calibration (S. Meunier) <u>Group 2</u> (Max 5 PAX)	Simulation (M. Ady) <u>Group 3</u> (Max 5 PAX)	Practical work <i>Pumping & Leak Detection</i> Instruments calibration (S. Meunier) <u>Group 4</u> (Max 5 PAX)
12:30 - 14:00				
14:00 - 17:00 (3 hours)	Practical work <i>Pumping & Leak Detection</i> Instruments calibration (S. Meunier) <u>Group 1</u> (Max 5 PAX)	Simulation (M. Ady) <u>Group 2</u> (Max 5 PAX)	Practical work <i>Pumping & Leak Detection</i> Instruments calibration (S. Meunier) <u>Group 3</u> (Max 5 PAX)	Simulation (M. Ady) <u>Group 4</u> (Max 5 PAX)

Organisation inputs for Simulations

https://molflow.docs.cern.ch/guide/molflow/tutorials/juas/juas_2025/

MolFlow / SynRad documentation molflow-mkdocs repo

Blog Downloads & changelog User guide Gallery/Results Forum (external) About For developers Site admin

JUAS 2025 practical days: Molflow seminar

Vacuum simulations with MolFlow+

CERN, 12 and 14 February 2025

About the course

This course is an introduction to a 3D Monte Carlo simulator for ultra-high vacuum. It is intended for those with little or no previous Molflow experience.

- There will be one exercise where we learn the user interface, and working together, we calculate the effective pumping speed of a NEG cartridge
- In the second exercise, students will solve a more realistic accelerator vacuum problem, also dealing with some common modeling issues

You could help save time in the beginning if you prepared in advance by installing Molflow and downloading the exercise files. Thank you!

Preparation steps

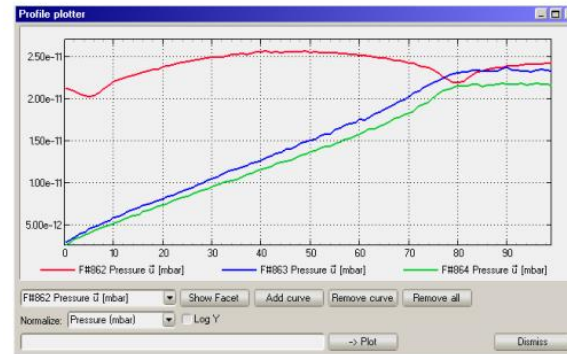
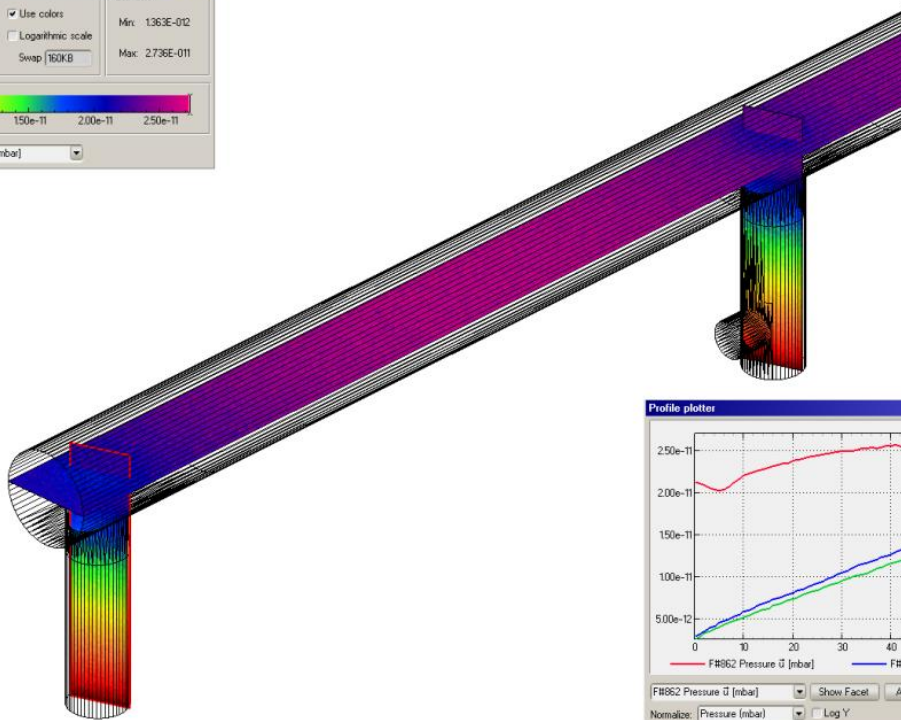
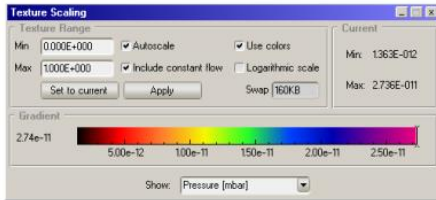
1. [Download](#) the latest MolFlow (as of writing this, Molflow 2.9.27 – choose your OS among the "binaries"). For the tutorial, the easiest is to run the Windows version. Mac or Linux builds are available from the page, but it might be possible that you need to build the solution from source. Note that for each OS, you have instructions on how to install it, below the download links. Check if it runs on your desktop/laptop: if not, get in touch with us on the [forum](#).
2. Download the source files (geometry) from the links below.

Do not forget to bring your laptop & upload Molflow if possible

Simulation

Design of vacuum systems

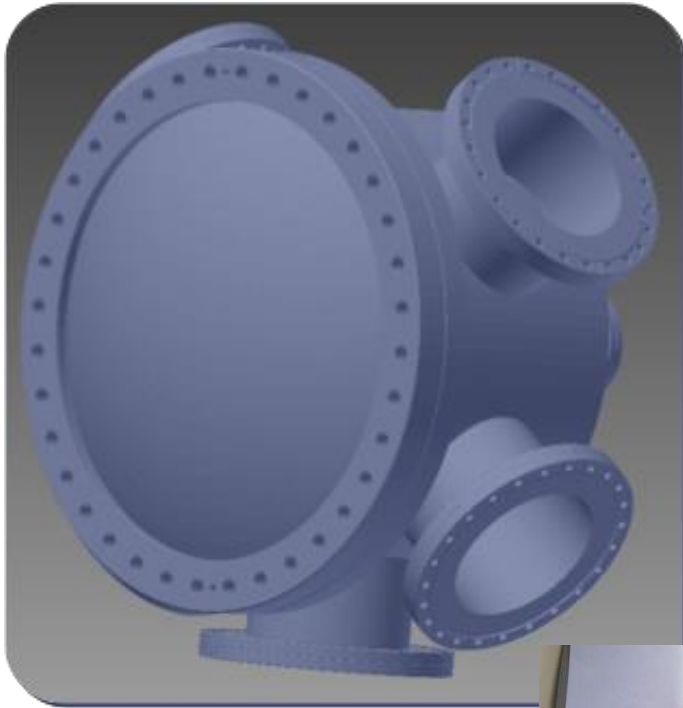
- A test particle Monte-Carlo code for molecular flow
- <http://molflow.web.cern.ch/>
- R. Kersevan – M. Ady



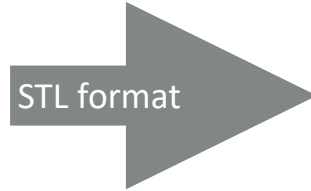
A simple accelerator part with a pumping port

Step 1: creating geometry

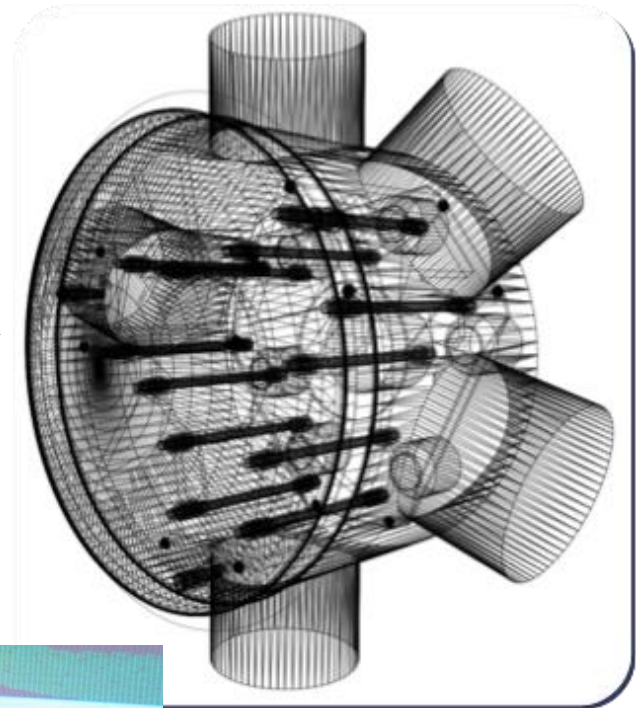
CAD



STL format



Molflow+



Step 2: adding physics

Molflow+ 2.6.39 64-bit (Feb 22 2017) [simple_geo.zip]

File Selection Tools Facet Vertex View Test Time

Profile plotter

V:228 F:139 Dim(5,4,18) Area:216.18

3D Viewer settings

- Rules
- Normals
- \vec{d}, \vec{v}
- Lines
- Leaks
- Hits
- Volume
- Texture

<< View Vertices Indices

Selected Facet (3 selected)

Particles in

Desorption ...

Outgassing (mbar¹/s):

Outg/area(mbar¹/s/cm²):

Particles out

Sticking factor: ...

Pumping Speed (l/s): ...

Sides: 1 Sided

Opacity: 1

Temperature (°K): 293.15

Sum Area (cm²): 13.90576475

Profile: None

<< Adv Details... Coord... Apply

Shortcuts

Simulation

<< Sim Resume Reset

Auto update scene Update

Hits 182.76 Mhit (3.2 Mhit/s)

Des. 2.02 Mdes (34.9 Kdes/s)

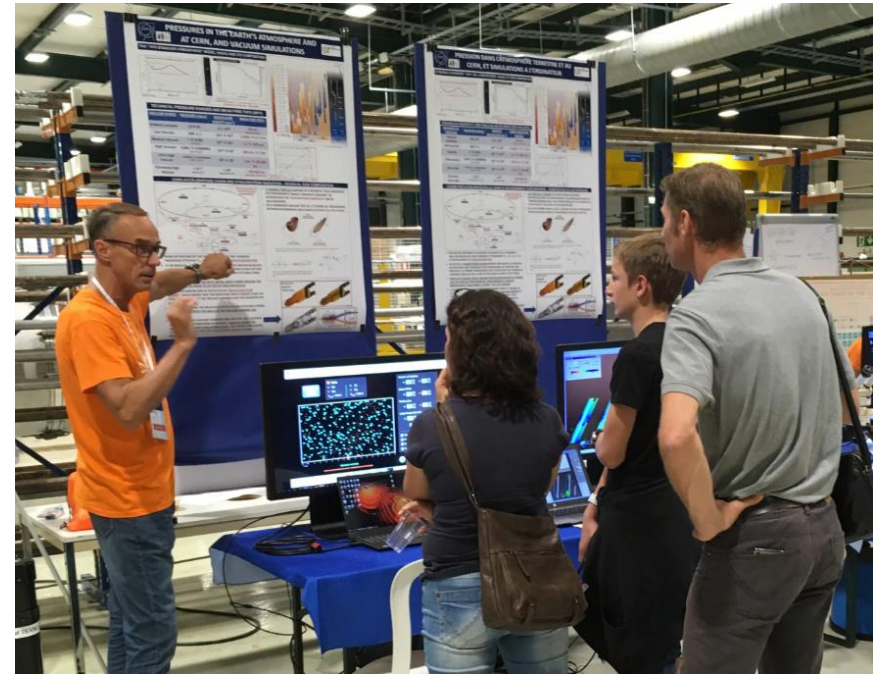
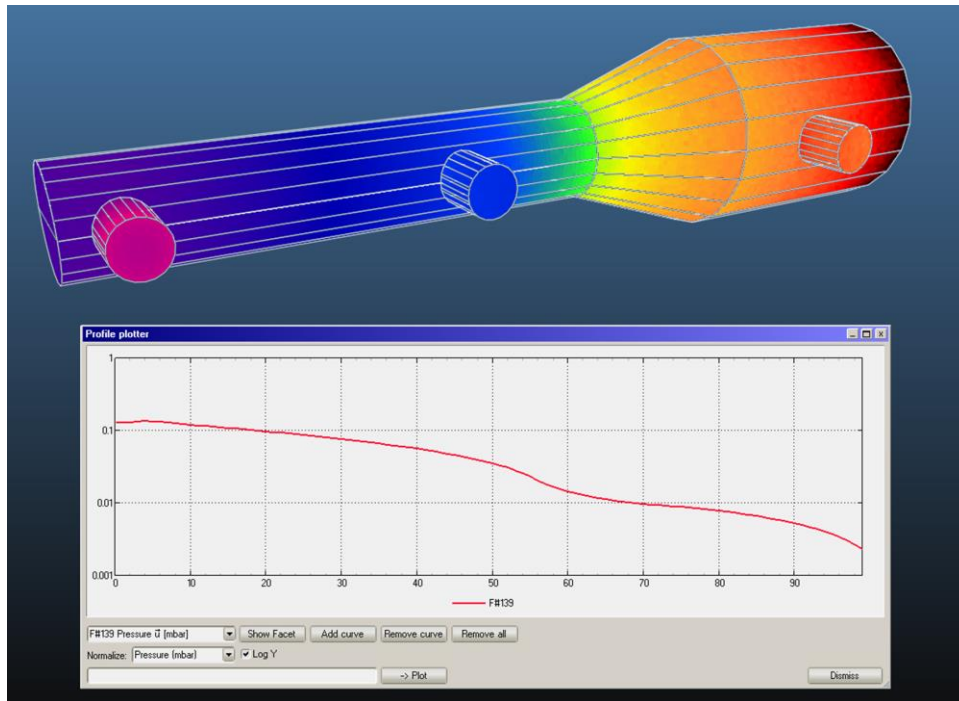
Leaks None

Time Stopped: 00:00:58

#	Hits	Des	Abs
67	6261377	0	0
68	6280336	0	0
69	6294972	0	0

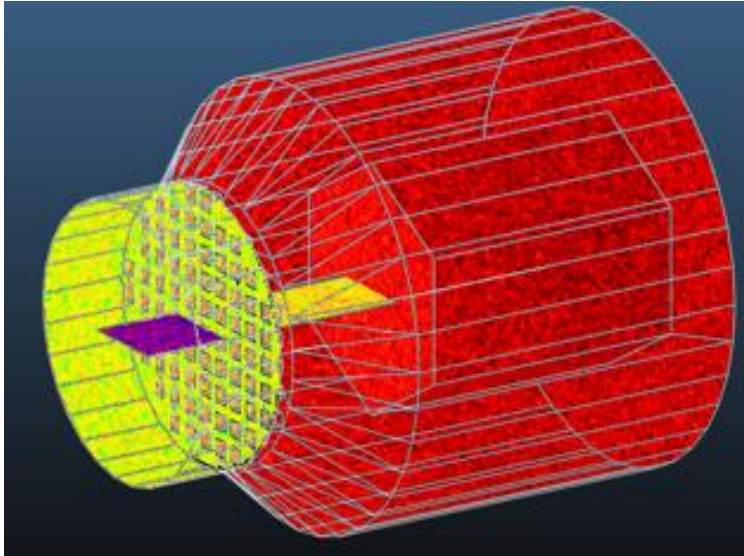
Trans. Prob. Divide by 0

Step 3: simulation and results

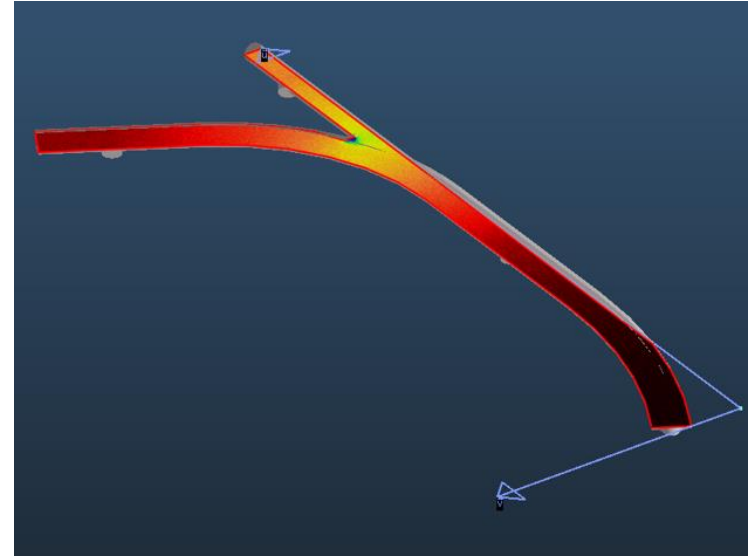


100k molecules

Exercices



Effective pumping
speed of a NEG
pump



Pressure profile in
an accelerator

Practical work



Pump down

- Pump down of a vacuum system:
 - start pumping
 - open roughing valve
 - expected pump down curve



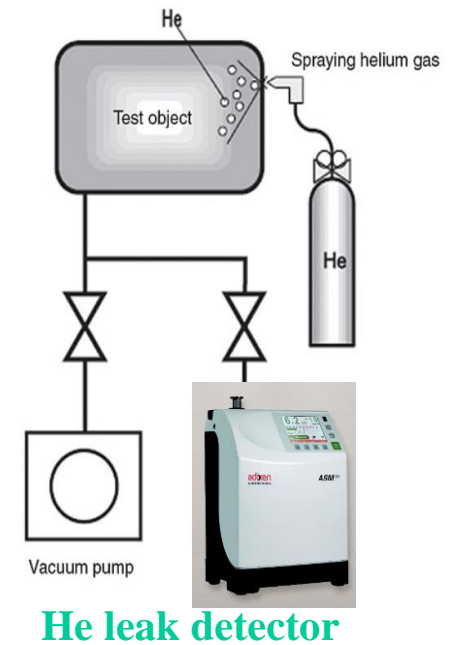
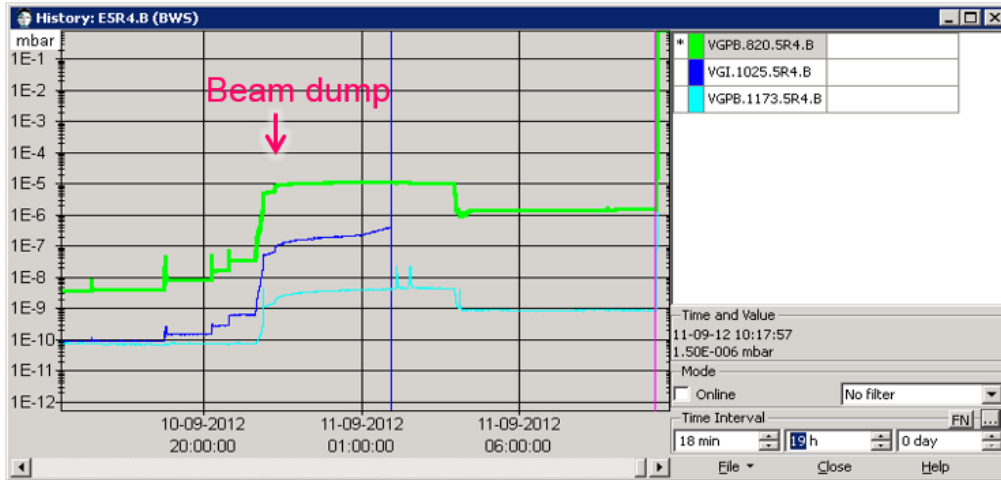
Technical specifications

		nEXT85		nEXT240	nEXT300	nEXT400	
Inlet flange		NW40	DN63 ISO-K or DN63 CF	DN100 ISO-K	DN100 ISO-K or DN100 CF	DN160 ISO-K or DN160 CF	
Inlet pumping speed l/s^4	N ₂	47	84	86	240	300	400
	Ar	44	80	84	230	280	380
	He	61	78	80/78 (D/H)	230	340	390
	H ₂	49/44 (D/H)	60/54 (D/H)	60/54 (D/H)	165	280	325
Compression ratio (D)	N ₂ /Ar	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹
	H ₂	8 x 10 ⁶			3 x 10 ⁵	1 x 10 ⁶	1 x 10 ⁶
Compression ratio (T/H)	N ₂ /Ar	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹	>1 x 10 ¹¹
	He	2 x 10 ⁷	2 x 10 ⁷	2 x 10 ⁷	1 x 10 ⁶	3 x 10 ⁶	>1 x 10 ⁶
	H ₂	5 x 10 ⁶	5 x 10 ⁶	5 x 10 ⁶	1.5 x 10 ⁶	1 x 10 ⁶	1 x 10 ⁶
Backing/interstage/boost ports		NW16		NW25	NW25	NW25	
Vent/purge port		1/8" BSPP	1/8" BSPP	1/8" BSPP	1/8" BSPP	1/8" BSPP	
Critical backing pressure (D/H)	mbar	18		9.5	9.5	10	
Critical backing pressure (T)	mbar	NA		20	20	20	
Water cooled/forced air cooled max. bake out	°C	120 / 115*	120 / 115*	120 / 115*	120 / 115*	120 / 115*	
Recommended backing pump*		nXDS15	nXDS15	nXDS15	RV12/nXDS10	RV12/nXDS10	RV12/nXDS10
Normal rotational speed (rpm)		90,000	90,000	90,000	60,000	60,000	60,000
Start time to 90% speed (sec) D/H (T)		90	90	90	115 (150)	145 (190)	180 (210)
Mass (kg) D/H (T)	ISO	2.9	3.0	3.2	5.7 (6)	5.7 (6)	6.5 (6.8)
	CF		4.4		8.8 (9.1)	8.5 (8.8)	9.5 (9.8)

* a smaller backing pump may be used depending on application.

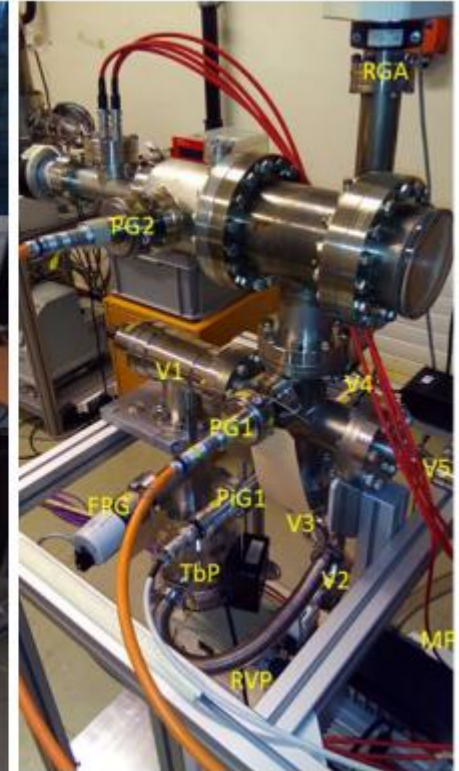
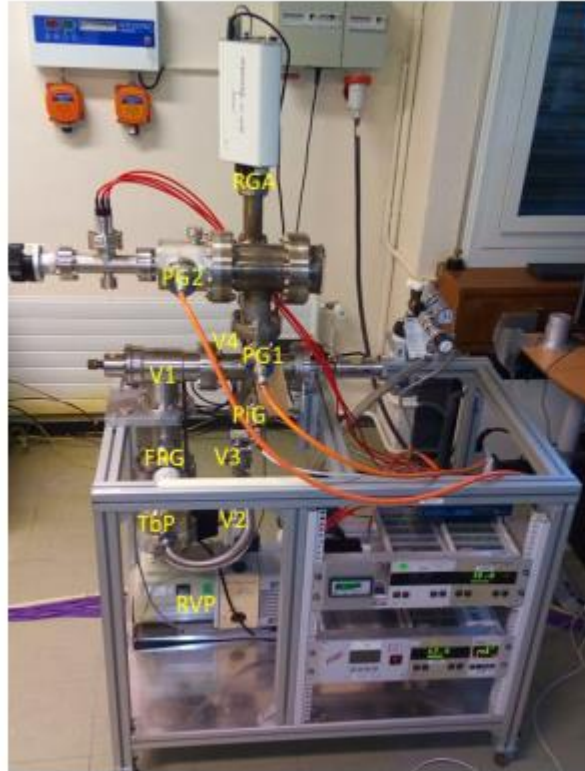
Leak detection

- How to locate / identify leaks in a vacuum system ?



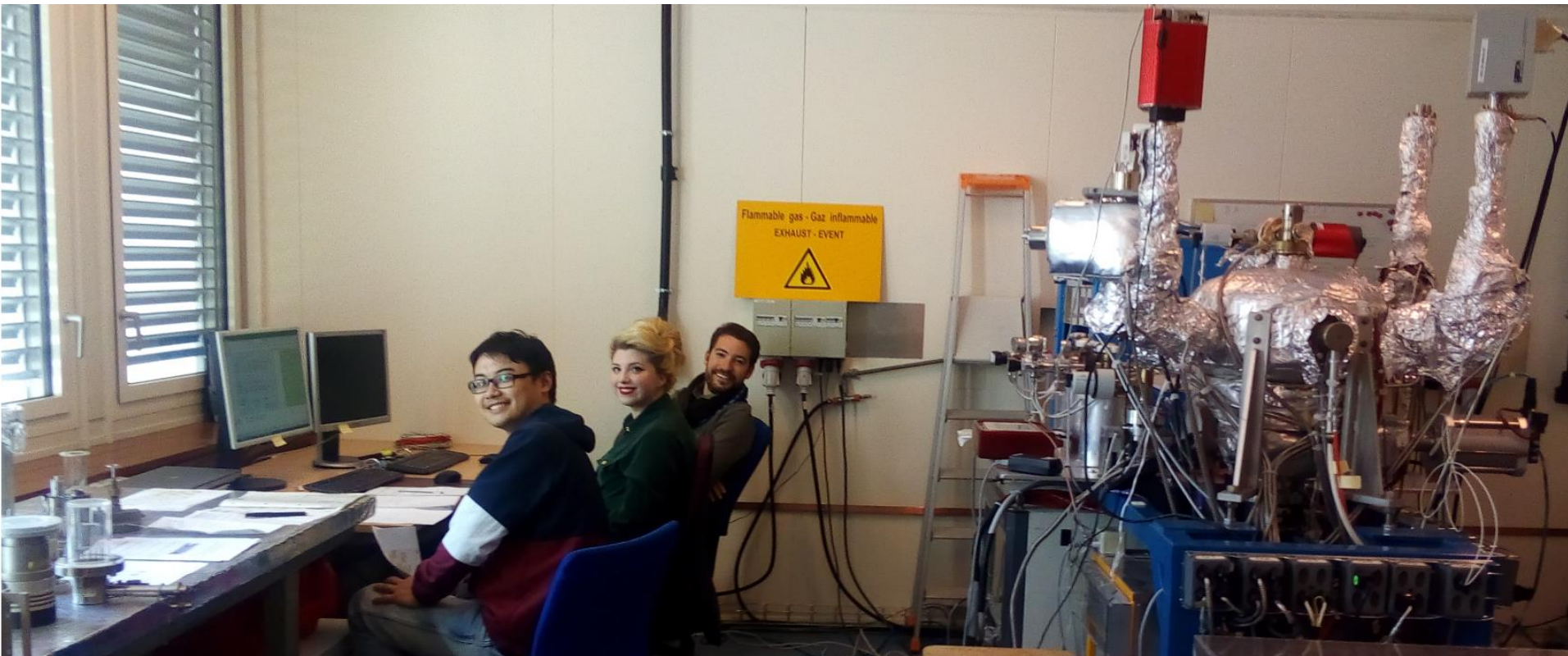
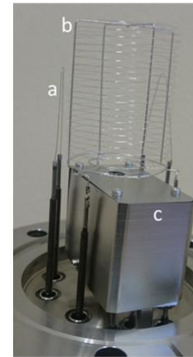
Pumping speed measurement

- Pumping speed measurement



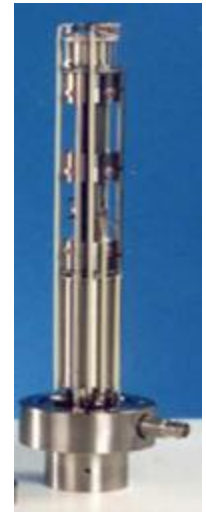
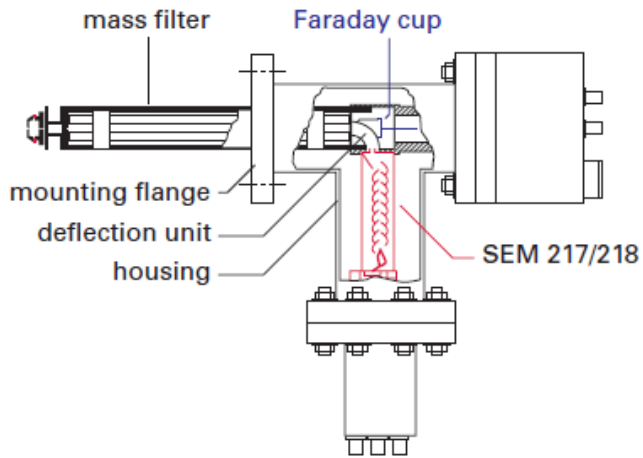
Vacuum gauge

- Vacuum gauges description
- Vacuum gauge calibration
- Gas injections



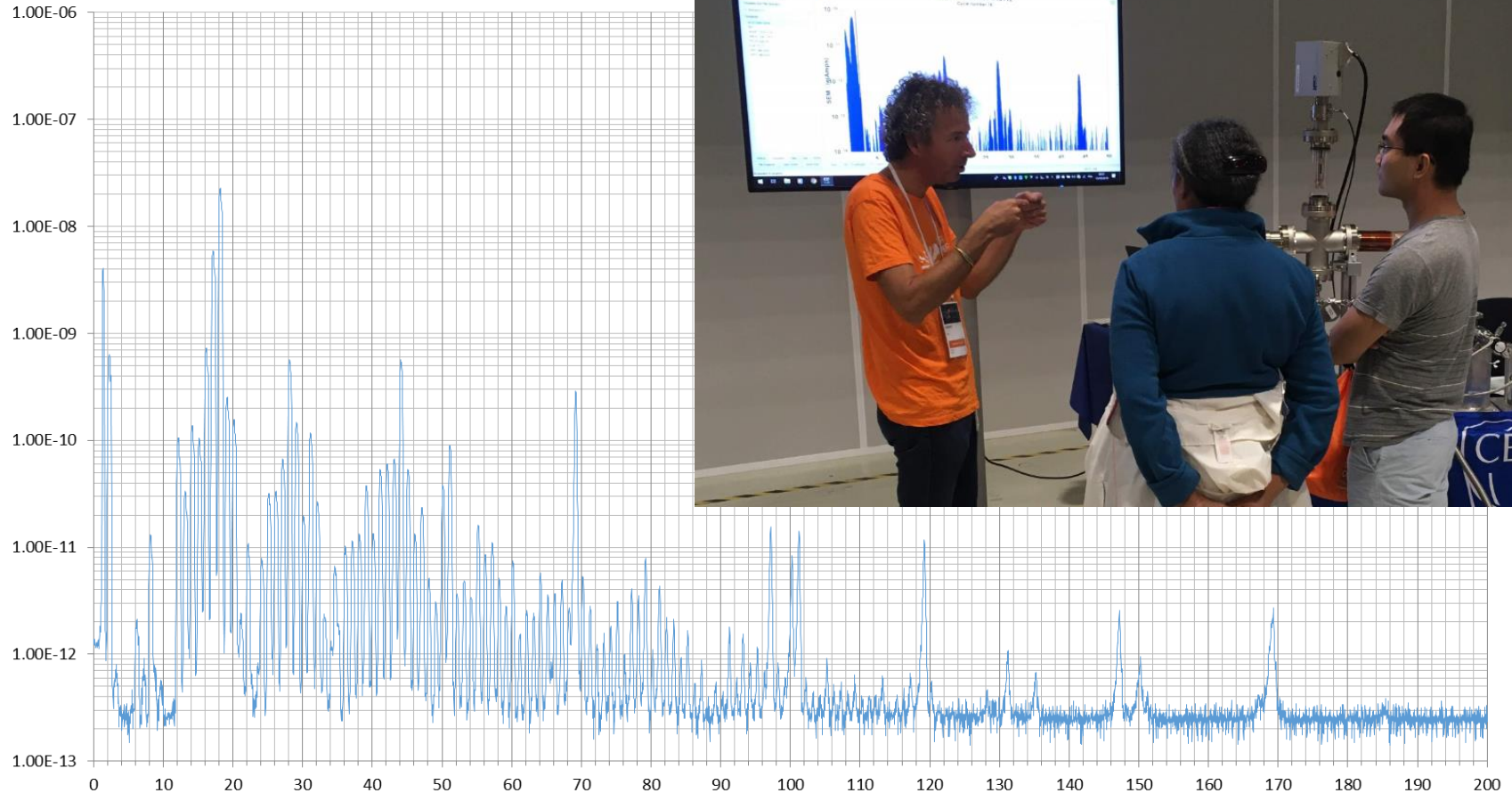
Mass Spectrometry

- Description, operation, limits
- Calibration



Gas analysis

- is my residual gas composition reasonable ?
- Estimation of the partial pressure



**You are welcome to join our group
for the practical days !**



Thank you for your attention !!!



