
CERN

Practical Days
Vacuum Systems

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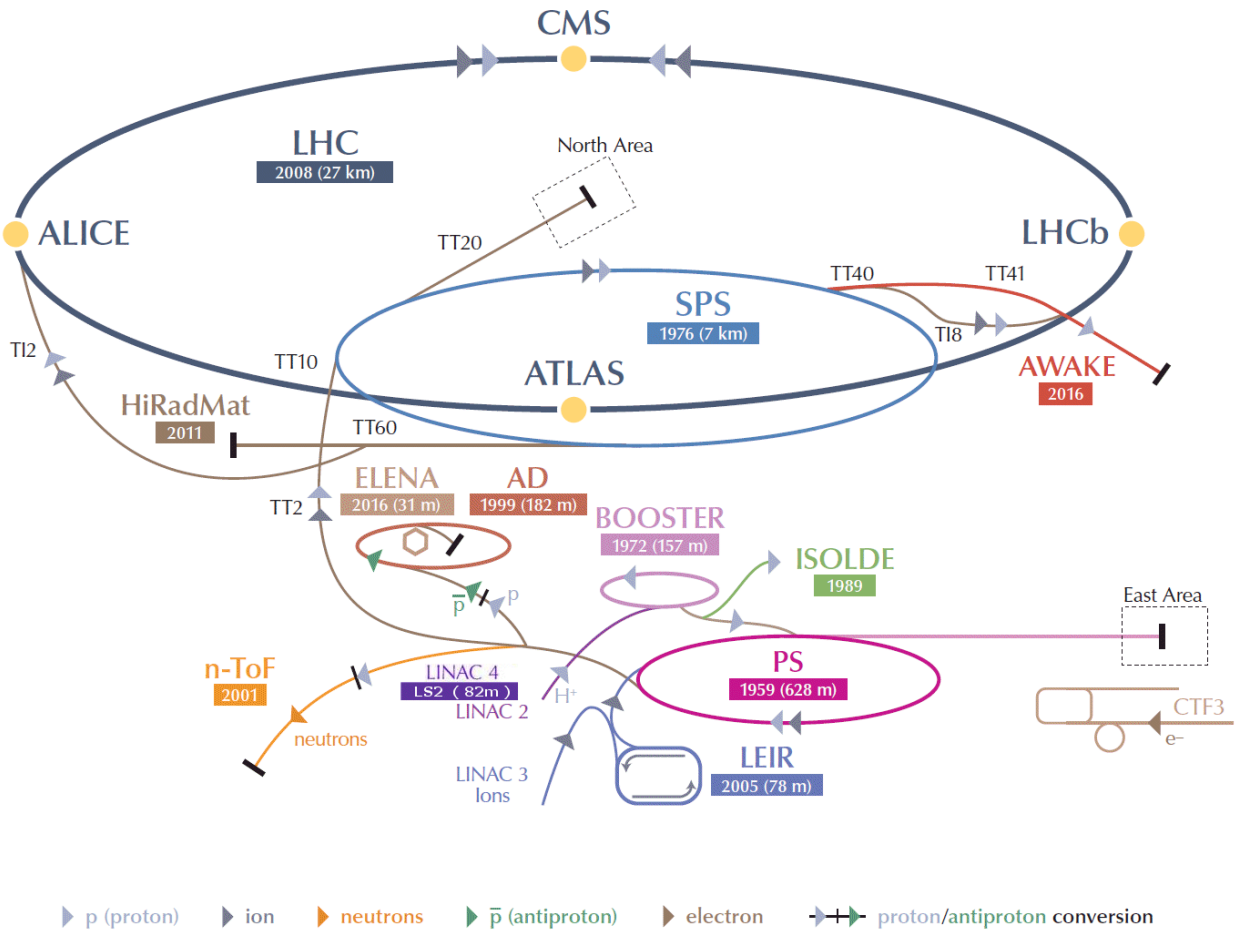
https://indico.cern.ch/event/1470062/timetable/?view=standard#day-2025-02-17

11th and 12th March 2025

CERN accelerators complex



CERN vacuum systems

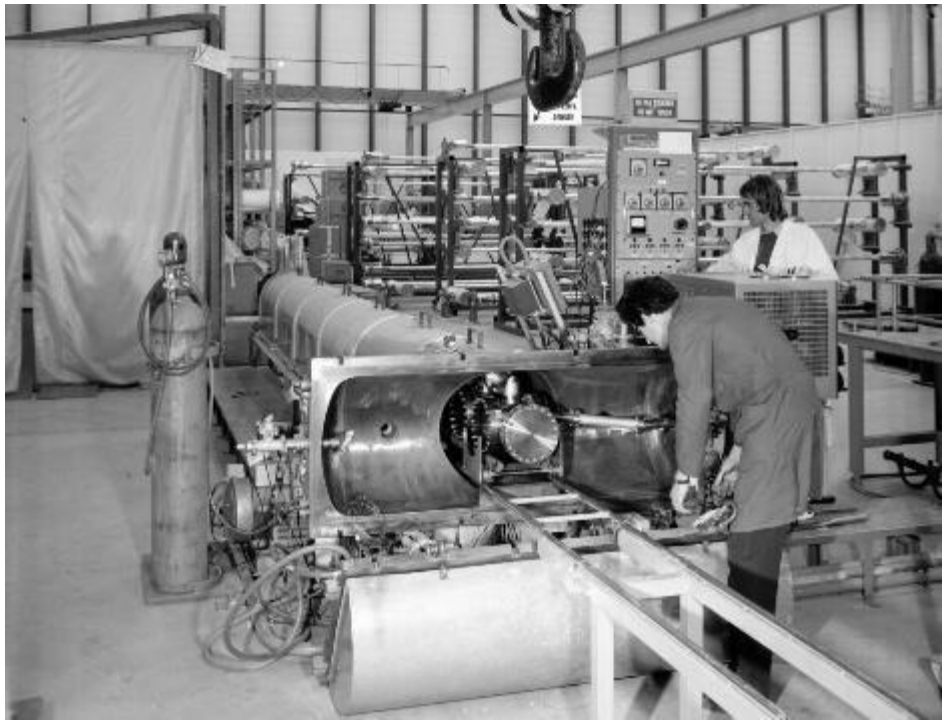
Machine	Type	Year	Energy	Bakeout	Pressure (Pa)	Length	Particles
Linac, Booster, ISOLDE, PS, n-TOF and AD Complex						**2.6 km !**	
LINAC 2	linac	1978	50 MeV	Ion pumps	10^{-7}	40 m	p
ISOLDE	electrostatic	1992	60 keV	-	10^{-4}	150 m	ions: 700 isotopes and 70 (92) elements
REX-ISOLDE	linac	2001	3 Mev/u	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 TI2/8 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 × 7 TeV	-	< 10^{-8}	2 x (2 x 25 km)	p, ions
LSS RT separated beams				complete		2 × 3.2 km	
LSS RT recombination						~ 570 m	
Experimental areas						~ 180 m	
Beam Dump Lines TD62/68	Transfer line	2006	7 TeV	-	10^{-6}	2 × 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



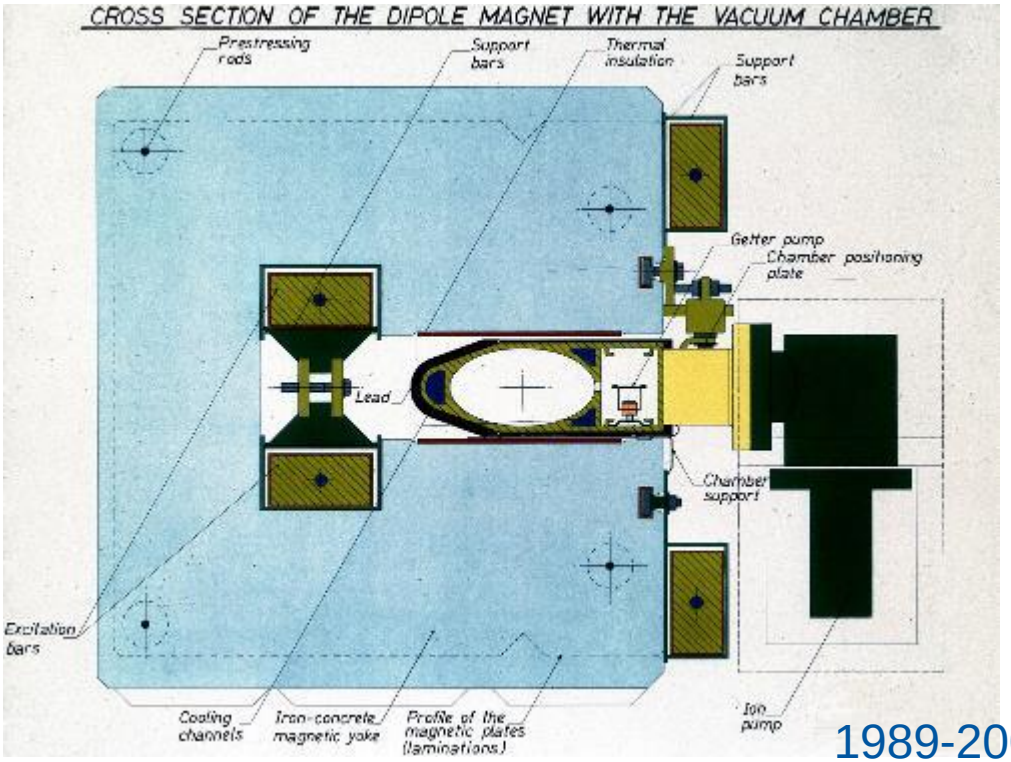
1971-1984

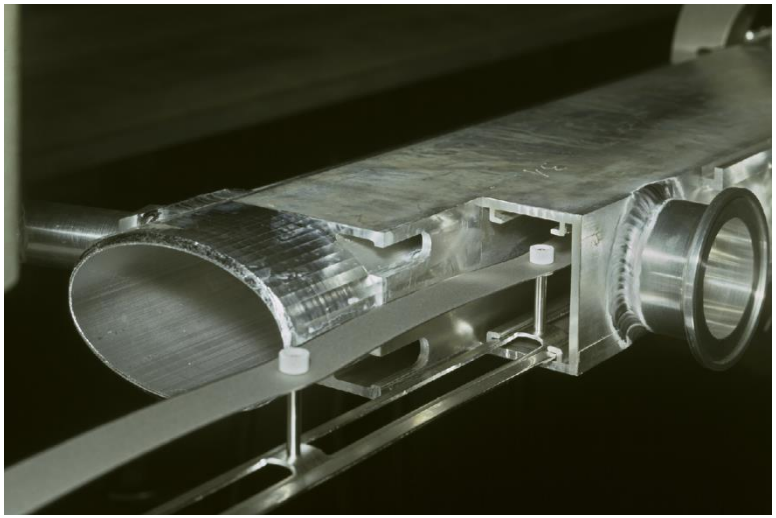
Large Electron Positron Collider

- Synchrotron radiation in LEP:
  - From 6 to 660 keV critical energy
  - Gas desorption studies

FCC-ee !!

- Innovative pumping system
  - Antechamber with NEG pumping strip
  - Water cooled and lead shielded

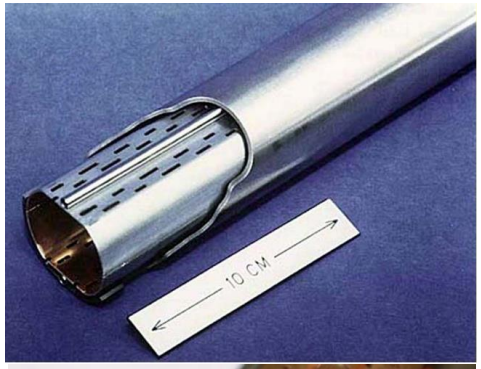




1989-2000

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

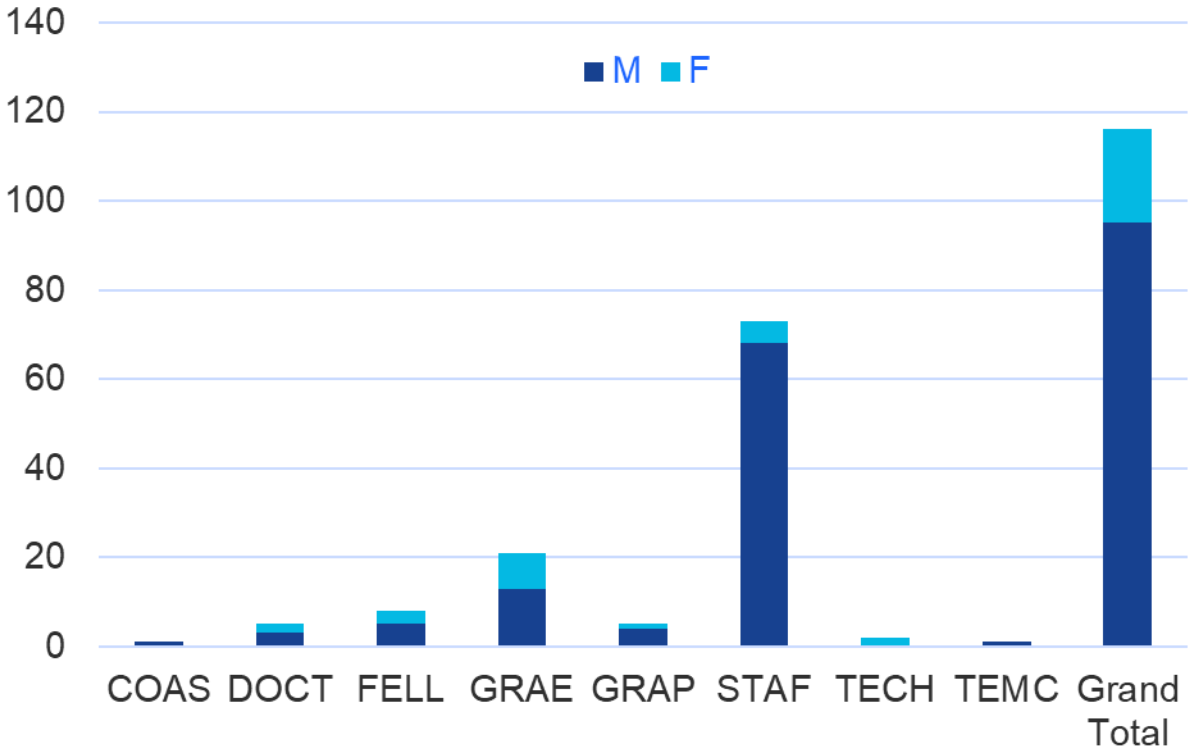
Coatings, surfaces treatments, surface and chemical analysis for Accelerators and Detectors. Expertise and support in the fields of:

- 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

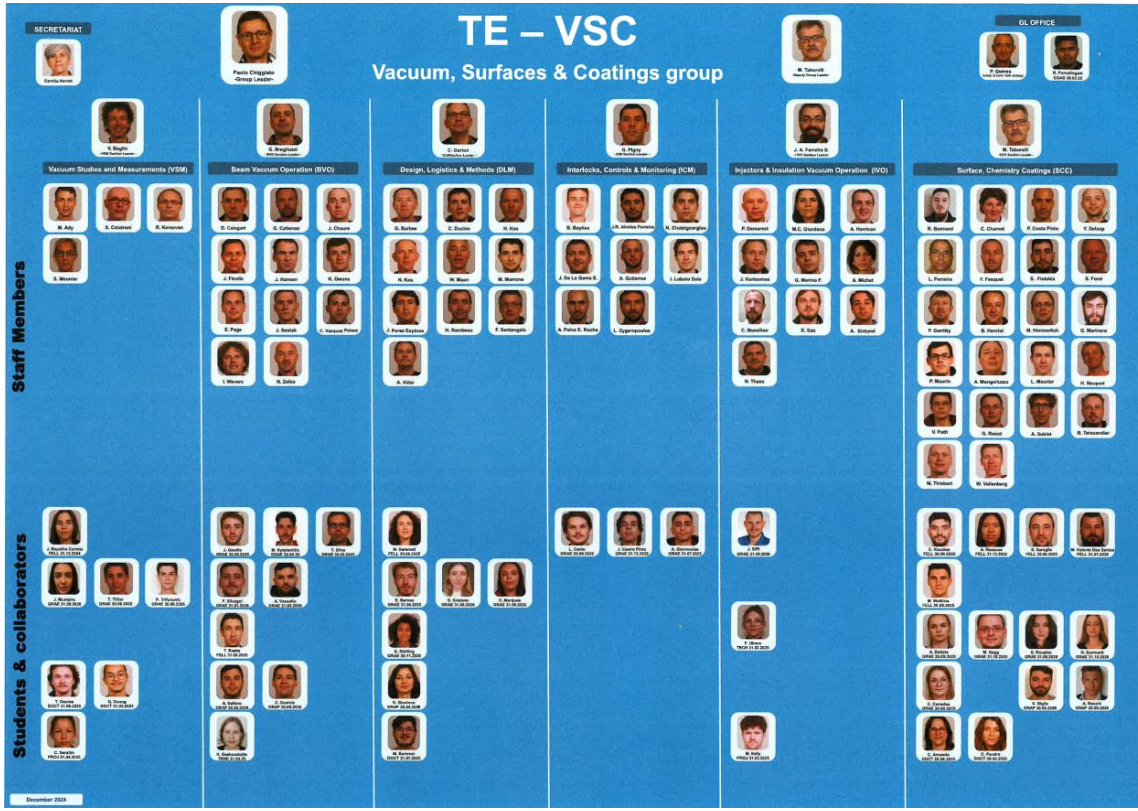
Beam vacuum operation

Design, logistics & methods

Interlock, controls & monitoring

Injector & insulation vacuum operation

Surface, chemistry & coatings



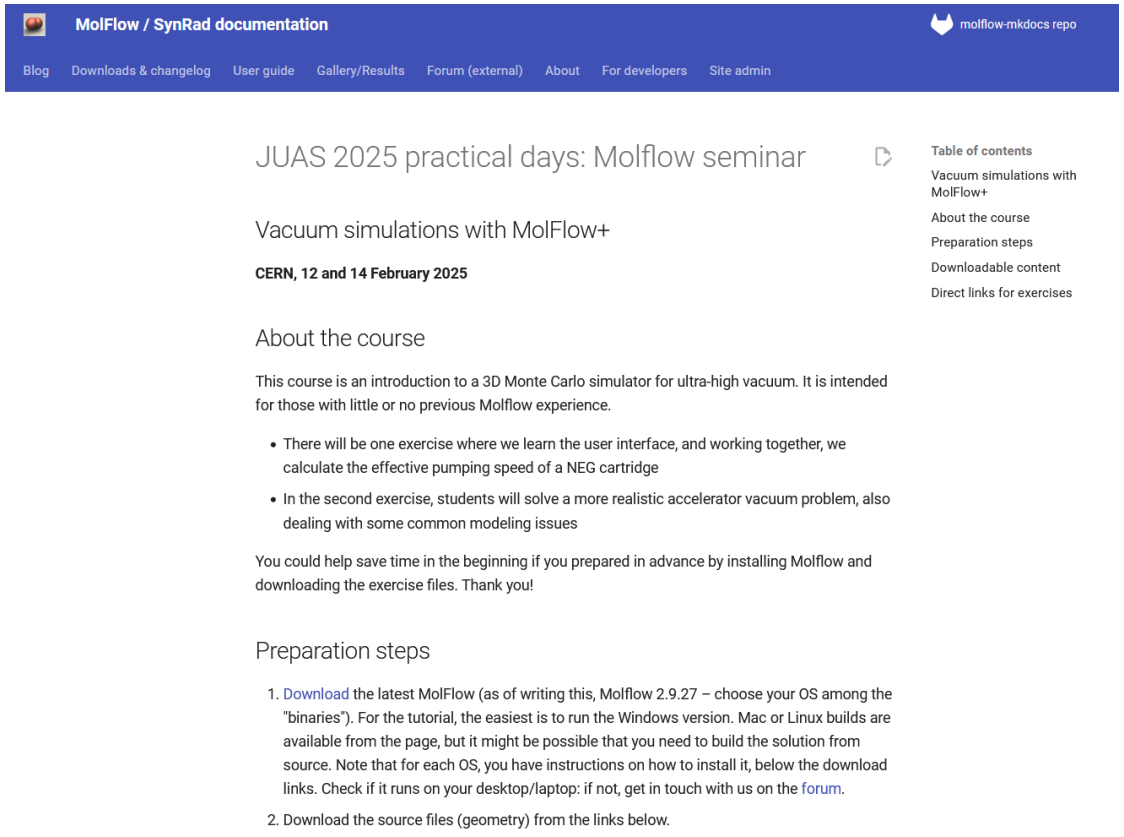
Organisation of practical days at CERN

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) Group 1 (Max 5 PAX)	**Practical work** *Pumping & Leak Detection* Instruments calibration (S. Meunier) Group 2 (Max 5 PAX)	**Simulation** (M. Ady) Group 3 (Max 5 PAX)	**Practical work** *Pumping & Leak Detection* Instruments calibration (S. Meunier) Group 4 (Max 5 PAX)
12:30 - 14:00				
14:00 - 17:00 (3 hours)	**Practical work** *Pumping & Leak Detection* Instruments calibration (S. Meunier) Group 1 (Max 5 PAX)	**Simulation** (M. Ady) Group 2 (Max 5 PAX)	**Practical work** *Pumping & Leak Detection* Instruments calibration (S. Meunier) Group 3 (Max 5 PAX)	**Simulation** (M. Ady) Group 4 (Max 5 PAX)

Organisation inputs for Simulations

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

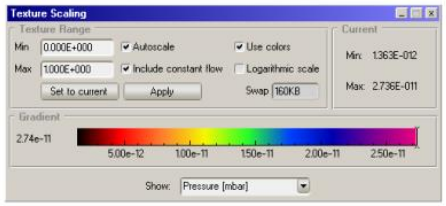


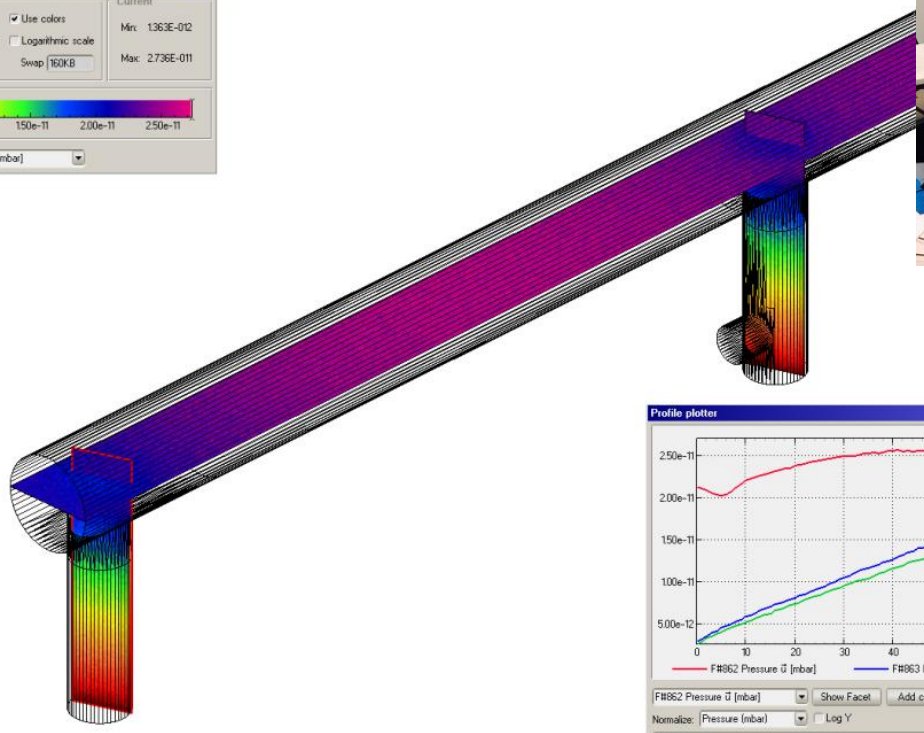
Do not forget to bring your laptop & upload Molflow if possible

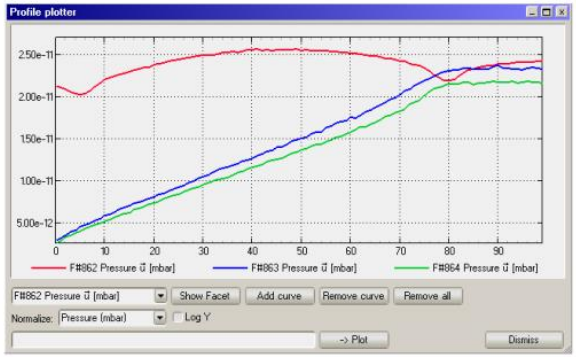
Simulation

Design of vacuum systems

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





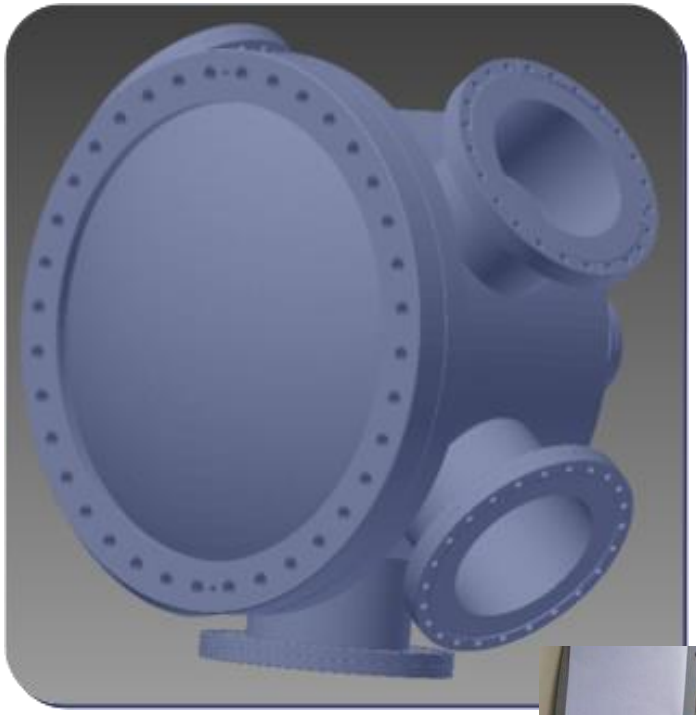


A simple accelerator part with a pumping port

Step 1: creating geometry

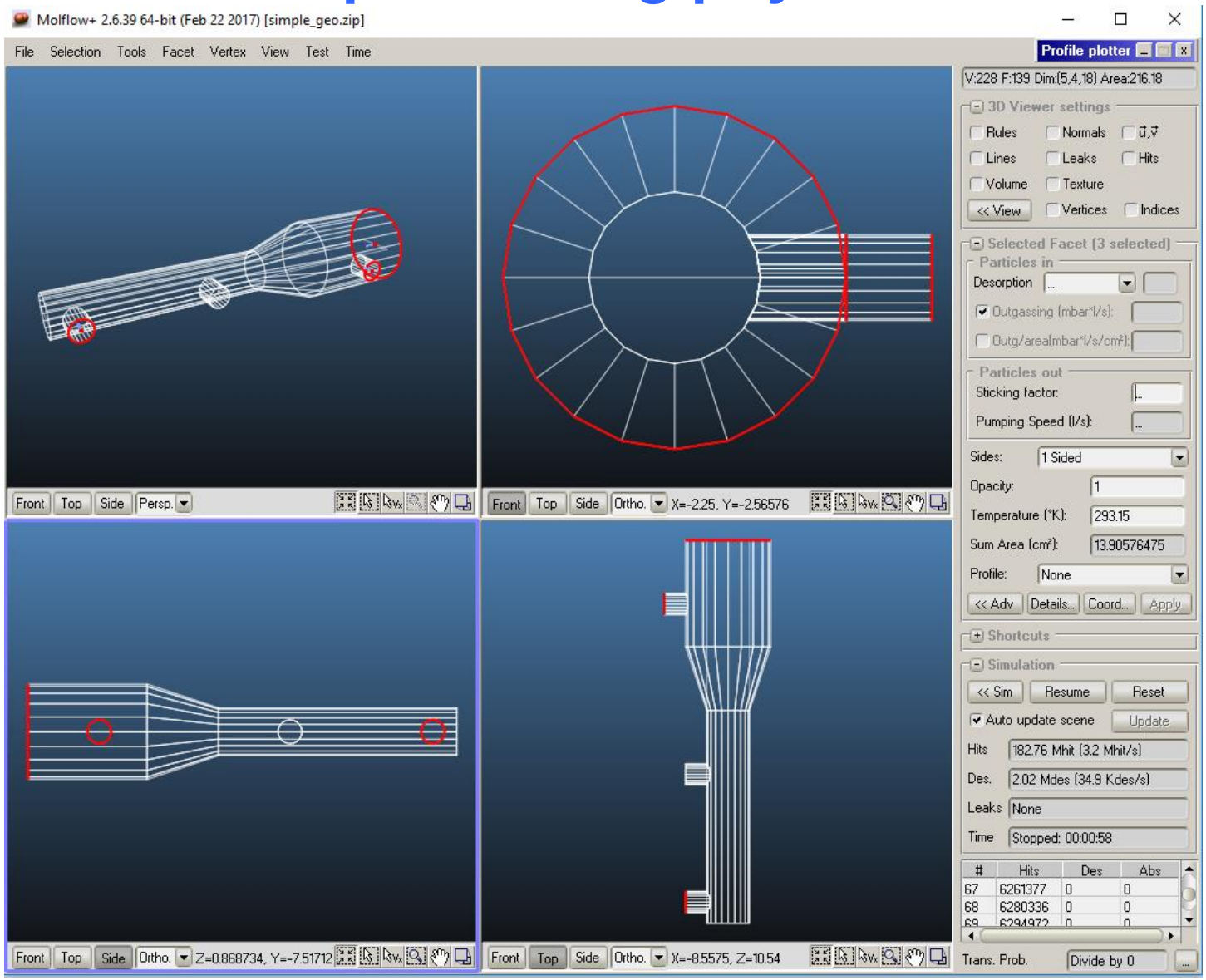
CAD

Molflow+

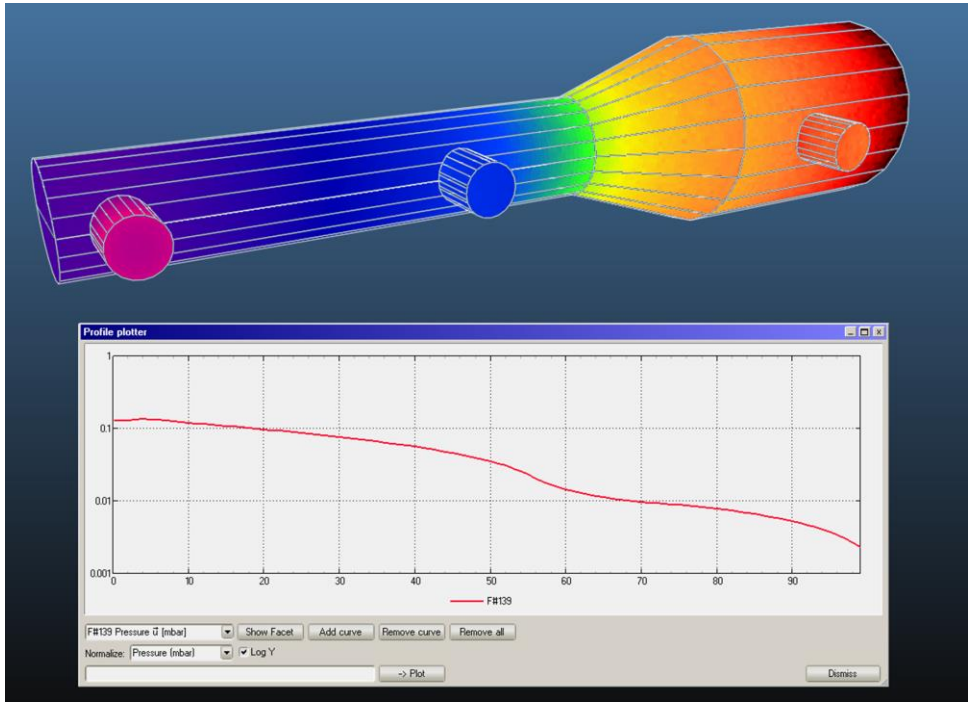


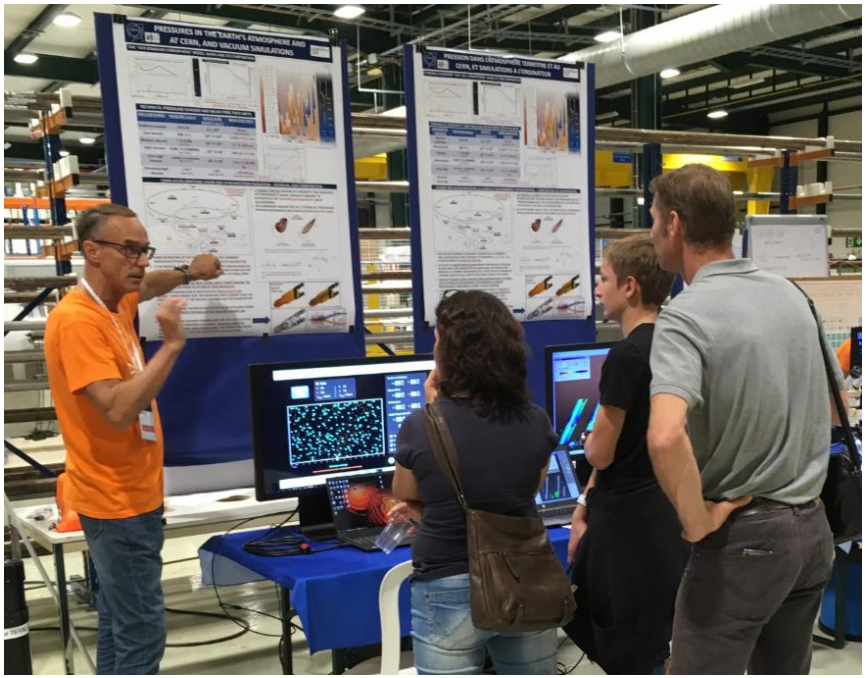
STL format

Step 2: adding physics



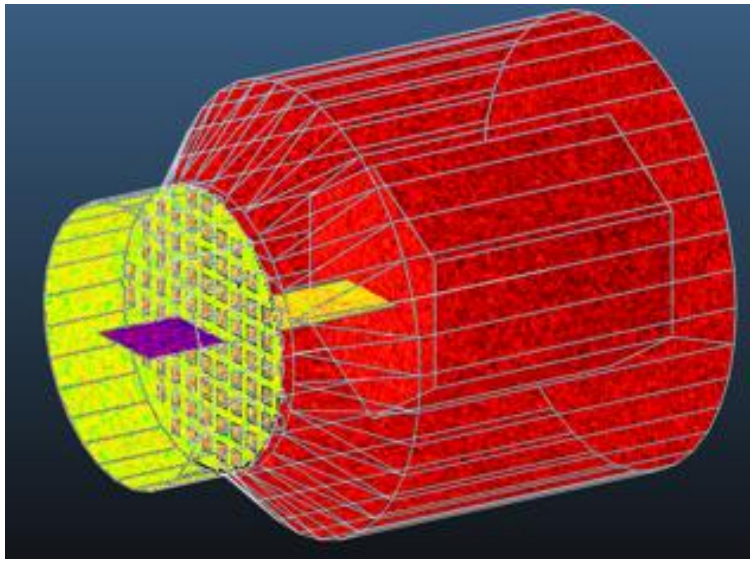
Step 3: simulation and results



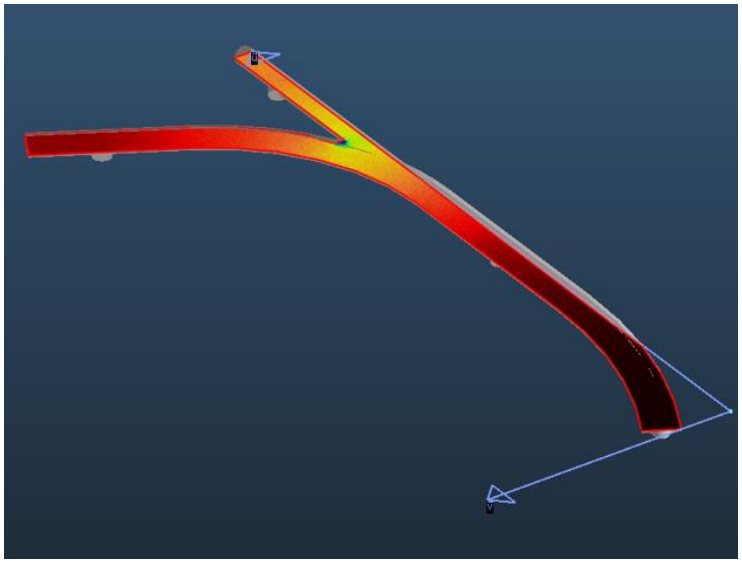


100k molecules

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

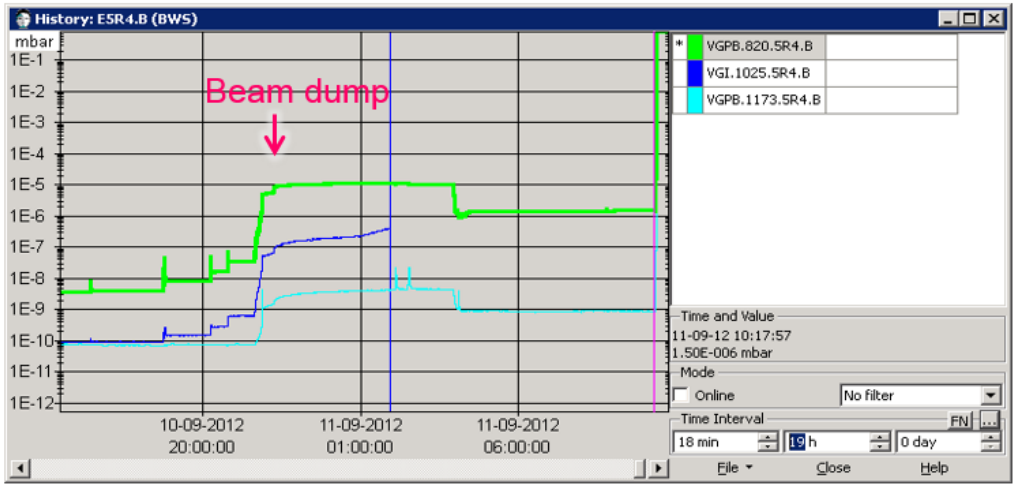
Technical specifications

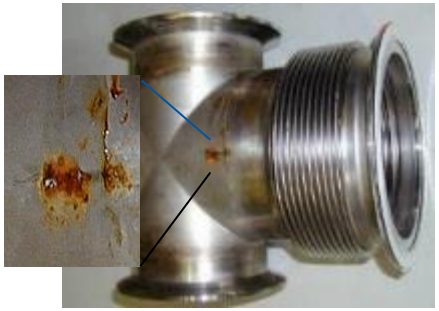
		nEXT85			nEXT240	nEXT300	nEXT400
Inlet flange		NW40	DN63 ISO-K or DN63 CF	DN100 ISO-K	DN100 ISO-K or DN100 CF	DN100 ISO-K or DN100 CF	DN160 ISO-K or DN160 CF
Inlet pumping speed ls⁻¹	N_2	47	84	86	240	300	400
	Ar	44	80	84	230	280	380
	He	61	78	80/78 (D/H)	230	340	390
	H_2	49/44 (D/H)	60/54 (D/H)	60/54 (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}
	He	8 x 10^6			3 x 10^5	1 x 10^6	1 x 10^8
	H_2	2 x 10^5			1 x 10^4	5 x 10^4	5 x 10^5
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 10^8	3 x 10^8	>1 x 10^8
	H_2	5 x 10^5	5 x 10^5	5 x 10^5	1.5 x 10^4	1 x 10^5	1 x 10^5
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	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*	120 / 115*
Recommended backing pump*		nXDS15	nXDS15	nXDS15	RV12/nXDS10i	RV12/nXDS10i	RV12/nXDS10i
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)

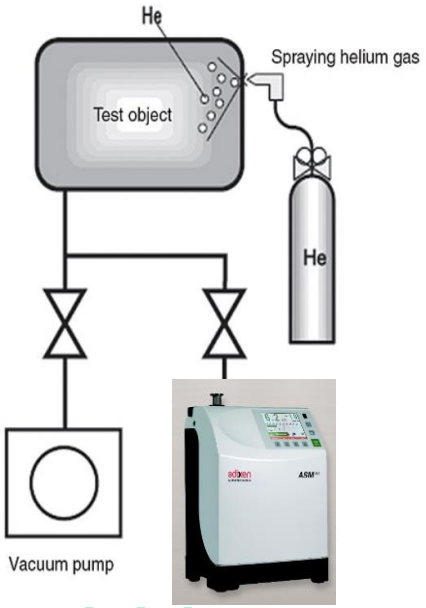
* a smaller backing pump may be used depending on application.

Leak detection

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



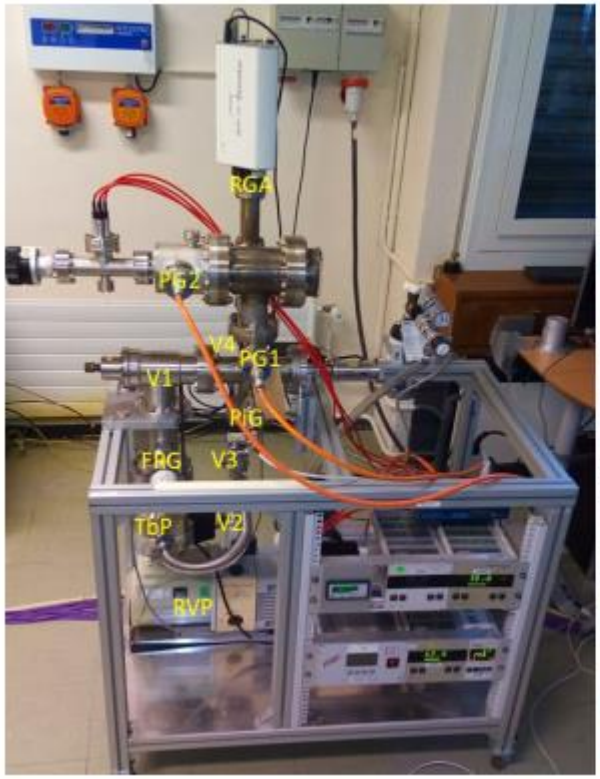


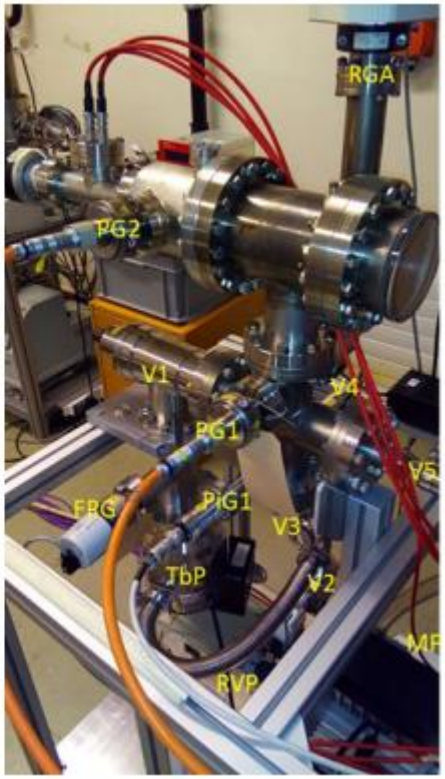


He leak detector

Pumping speed measurement

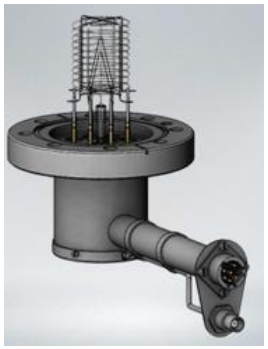
- Pumping speed measurement

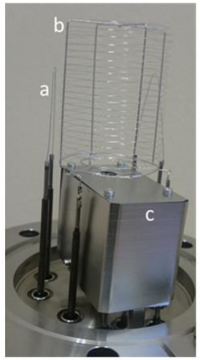


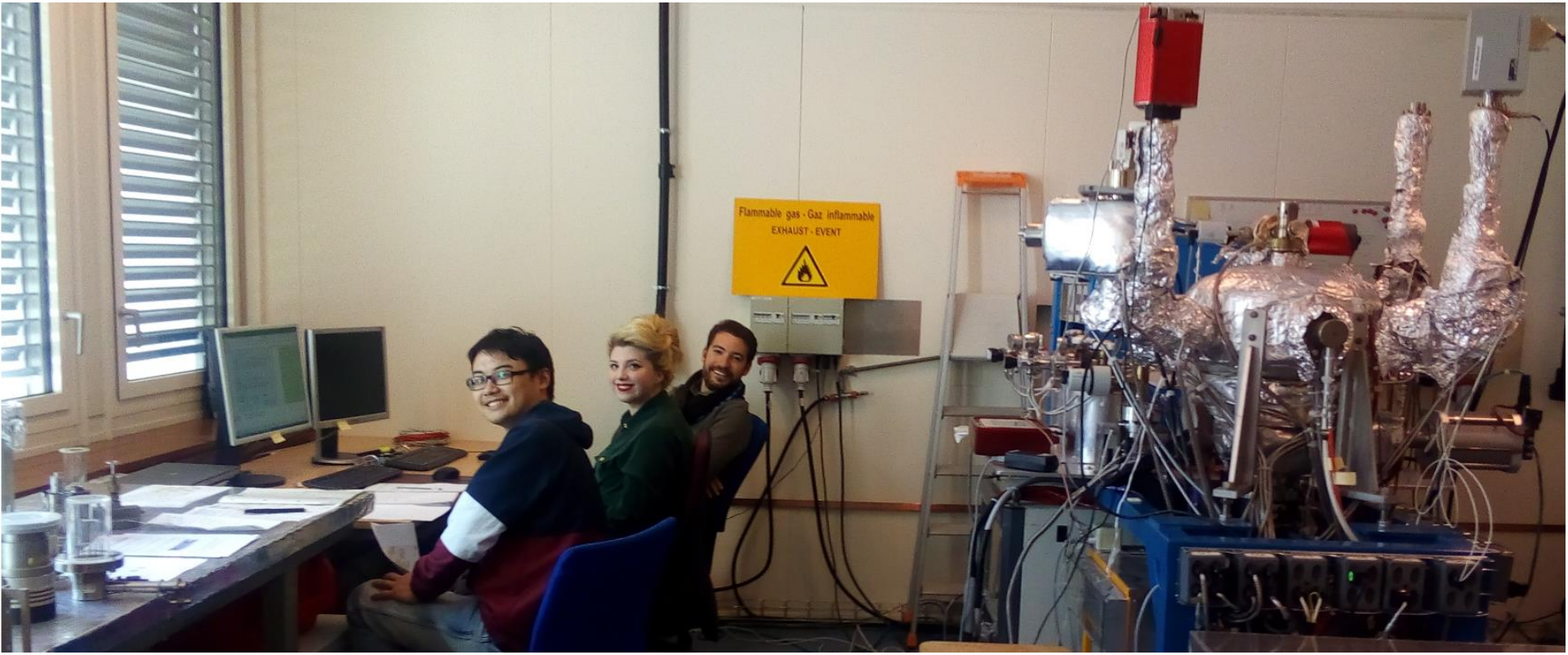


Vacuum gauge

- Vacuum gauges description
- Vacuum gauge calibration
- Gas injections

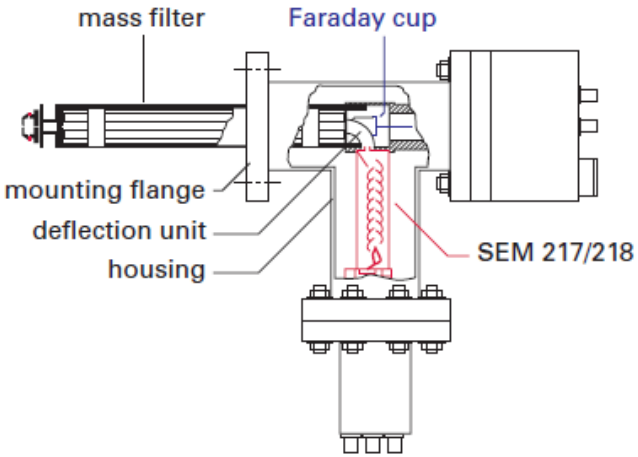






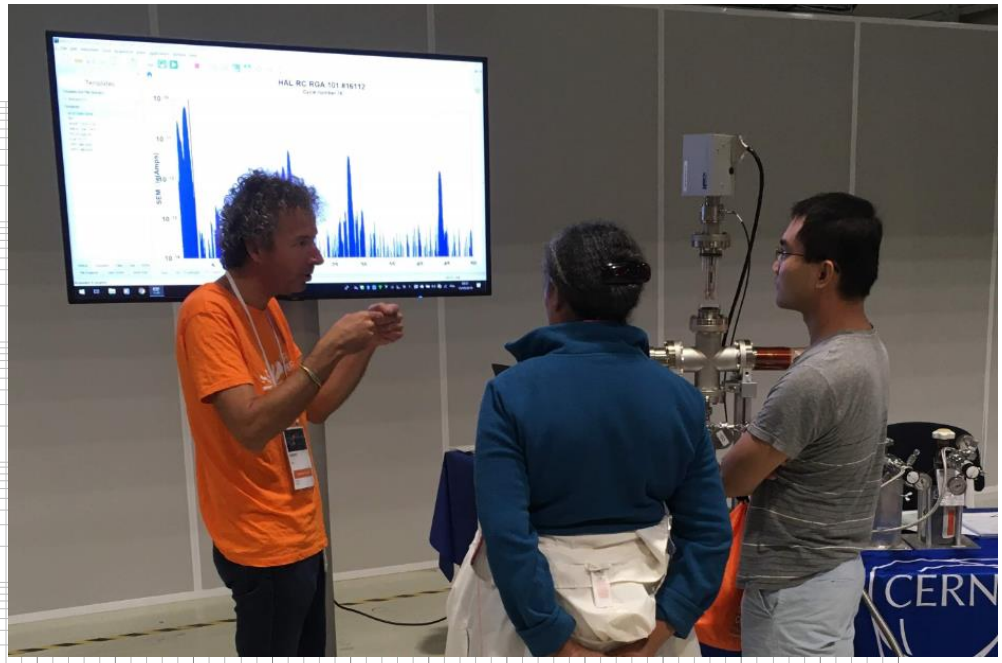
Mass Spectrometry

- Description, operation, limits
- Calibration



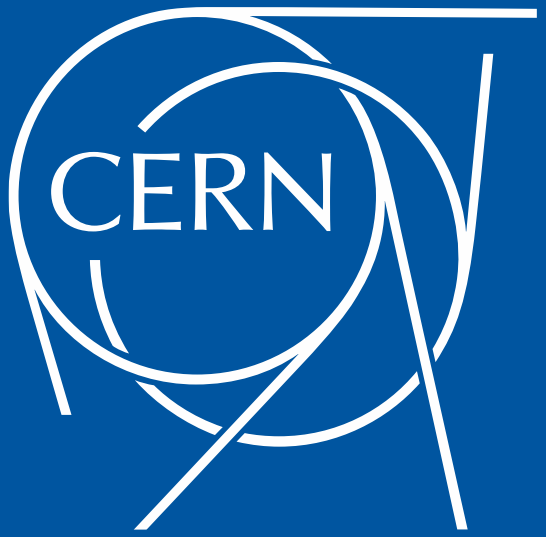
Gas analysis

- 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 !!!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