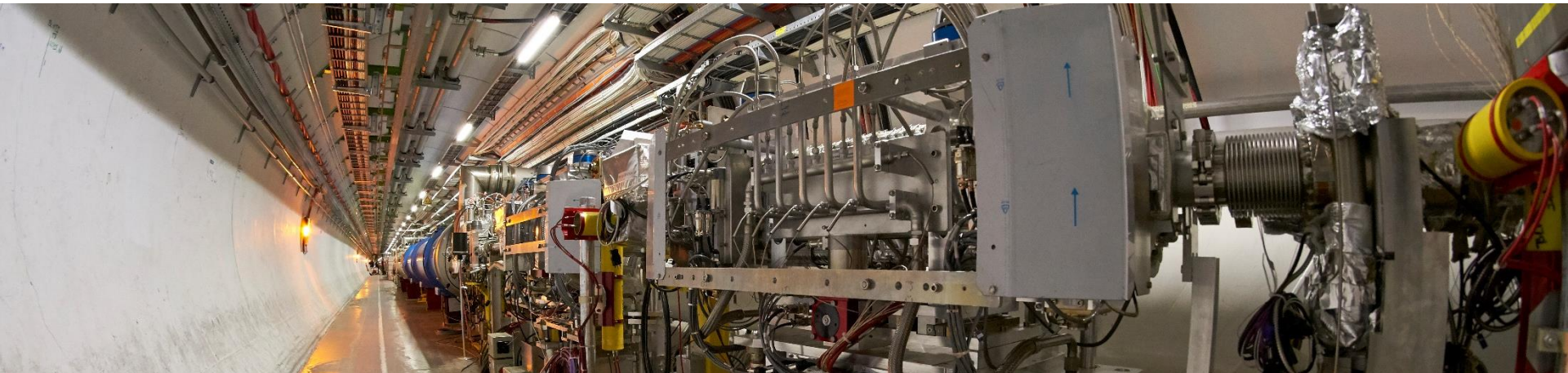
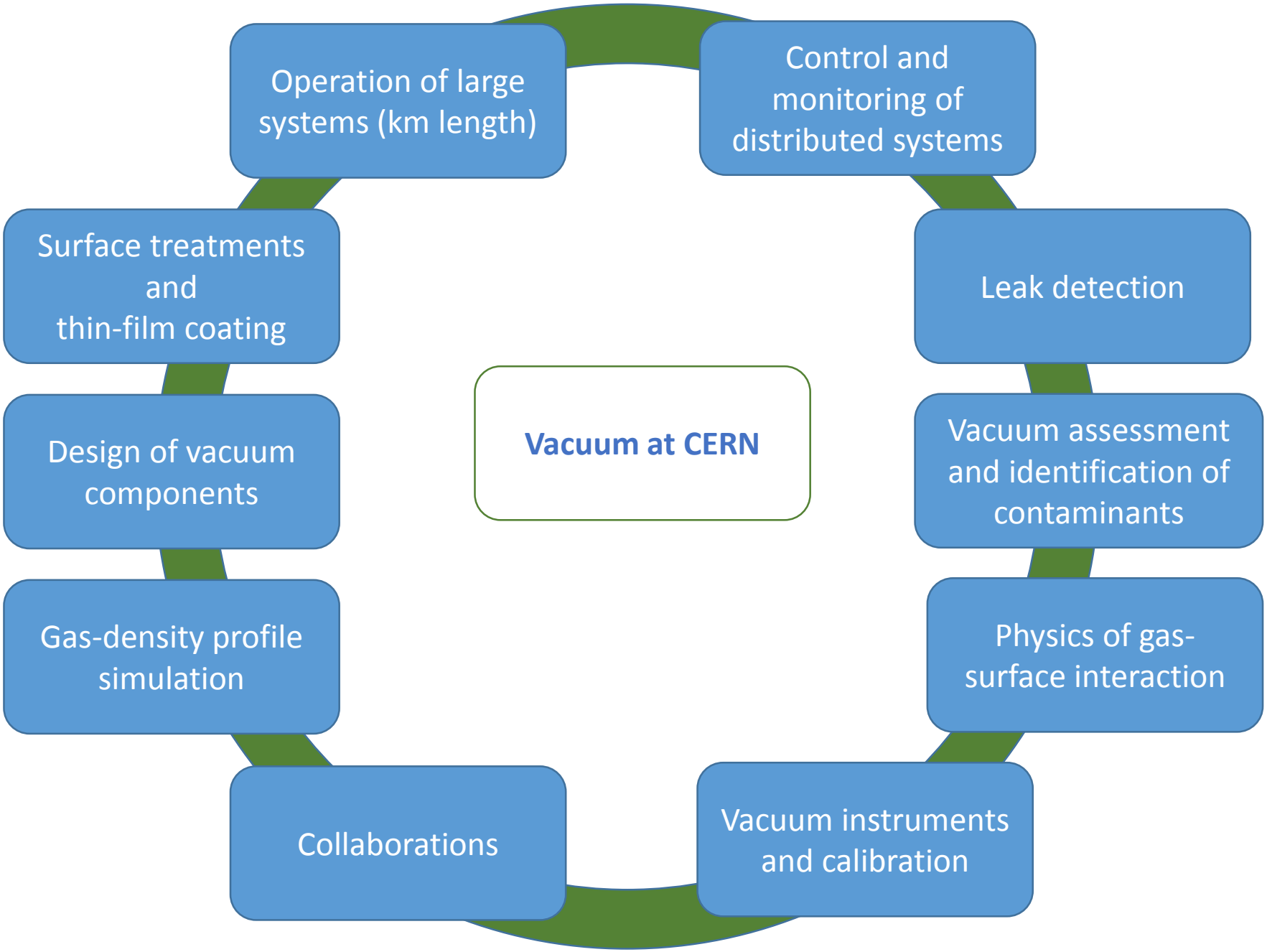
Joint CERN GW meeting

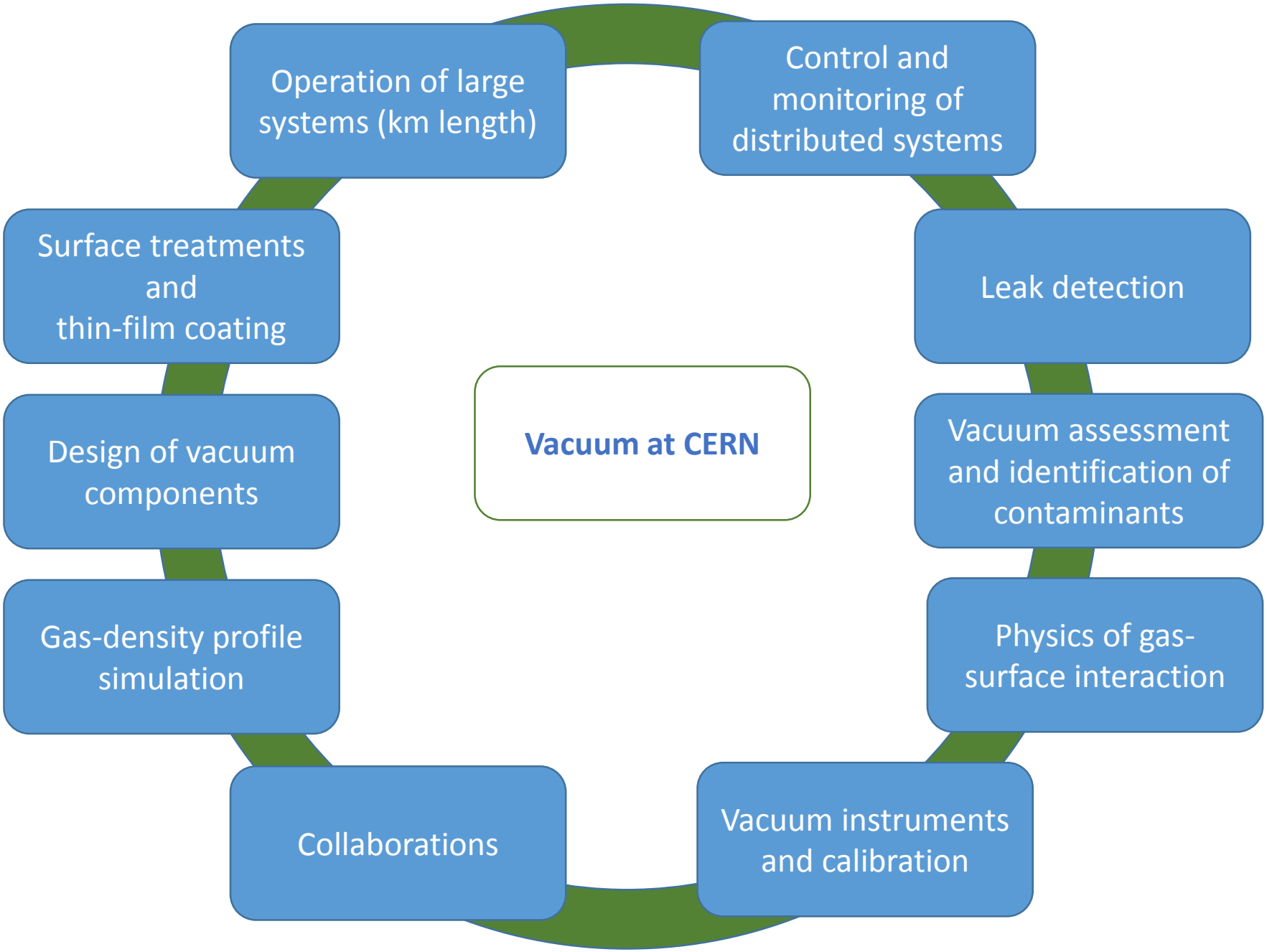
September 1st, 2017

Vacuum Technology at CERN

Paul Cruikshank & Paolo Chiggiato




Vacuum at CERN
Operation of large systems (km length)
Control and monitoring of distributed systems
Surface treatments and thin-film coating
Leak detection
Design of vacuum components
Vacuum assessment and identification of contaminants
Gas-density profile simulation
Physics of gas-surface interaction
Collaborations
Vacuum instruments and calibration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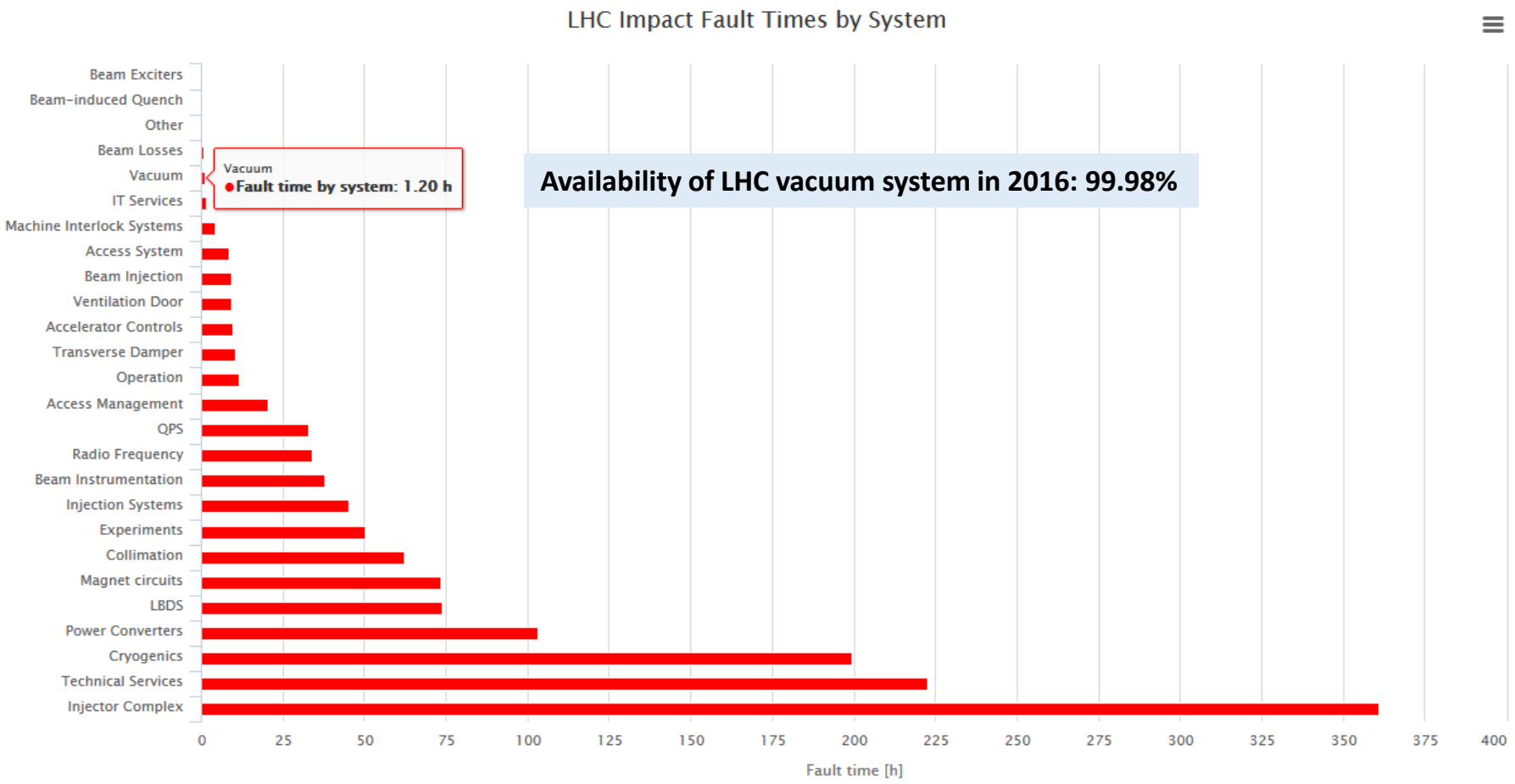

Availability of LHC vacuum system in 2016: 99.98%

LHC Large Hadron Collider SPS Super Proton Synchrotron PS Proton Synchrotron AD Antiproton Decelerator CTF3 Clic Test Facility

AWAKE Advanced WAKefield Experiment ISOLDE Isotope Separator OnLine REX/HIE Radioactive EXperiment/High Intensity and Energy ISOLDE

LEIR Low Energy Ion Ring LINAC LINear ACcelerator n-ToF Neutrons Time Of Flight HiRadMat High-Radiation to Materials

Machine	Type	Year	Energy	Bakeout	Pressure [mbar]	Length
Linacs, Booster, ISOLDE, PS, n-TOF and Antimater						**2.6 Km**
Linac 2	linac	1978	50 MeV	ion pumps	10^{-7}	40 m
ISOLDE	electrostatic	1992	60 keV	_	**10^{-6}**	150 m
REX-HIE ISOLDE	linac	2001-2016	5.5 MeV/u	partly	10^{-7}-10^{-12}	50 m
MEDICIS		2017	_	_	10^{-6}	10 m
Linac 3	linac	1994	4.2 MeV/u	ion pumps	10^{-8}	30 m
LEIR	accumulator	1982/2005	72 MeV/u	complete	10^{-12}	78 m
PSB	synchrotron	1972	1-1.4 MeV	ion pumps	10^{-9}	157 m
PS	synchrotron	1959	26 GeV	ion pumps	10^{-9} -10^{-10}	628 m
AD	decelerator	1999	100 MeV	complete	10^{-10}	182 m
ELENA	decelerator	2016		complete	**10^{-12}**	31 m
PS to SPS TL	transfer lines	1976	26 GeV	_	10^{-8}	1.3 km
SPS complex						**15.7 Km**
SPS	synchrotron	1976	450 GeV	extractions	10^{-9}	7 km
SPS North Area	transfer line	1976		_	10^{-3}-10^{-8}	1.2 km
SPS HiRadMat		2011		_	10^{-8}	1.4 km
SPS to LHC TL		2004/06		_	10^{-8}	2 x 2.7 km
AWAKE	wakefield acc	2017		_	10^{-8}	730 m
LHC						**109 Km**
LHC Arcs (Beam vacuum)	collider	2007	2 x 7 TeV	_	<10^{-8}	50 km
LHC Arcs (insulation vacuum)				_		50 Km
LSS RT separated beams				complete	<10^{-10}	2 x 3.2 km
LSS RT recombination						570 m
Rxperimental areas						180 m
Beam dump lines TD62/68	transfer lines	2006	7 TeV	_	10^{-8}	2 x 720 m
				High Vacuum		**≈ 12**
				UHV-XHV		**≈ 65**
				Insulation vacuum		**≈ 50**
						≈ 127 km

Operation of large systems (km length)

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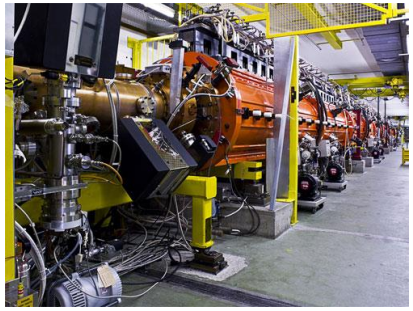
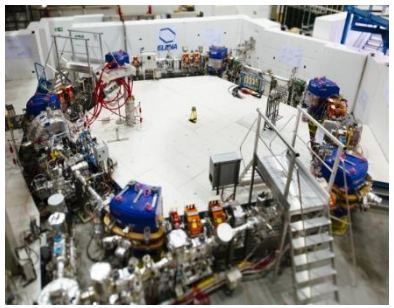


Linac2 <$2 \cdot 10^{-6}$ mbar*

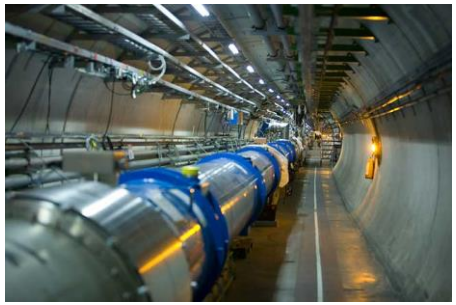
PSB <$5 \cdot 10^{-8}$ mbar*

PS <$2 \cdot 10^{-8}$ mbar*

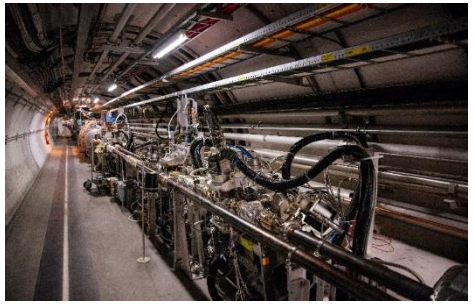


ELENA <$4 \cdot 10^{-12}$ mbar

SPS LSS <10^{-7} mbar*



LHC arcs <10^{-8} mbar



LHC LSS <10^{-10} mbar

Unbaked systems
TMP, ion pumps, Ti sublimators

Cryogenic systems
Cryopumping

Baked systems
Ion pumps, NEG coating

* After 24 h pumpdown

Control and monitoring of distributed systems

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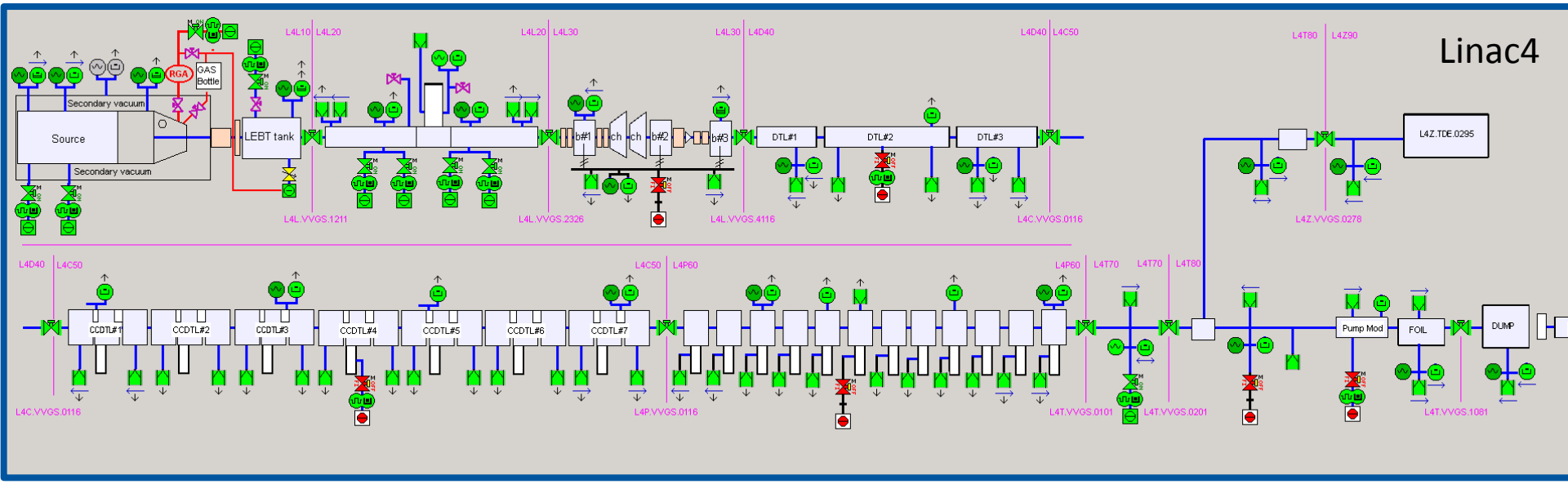
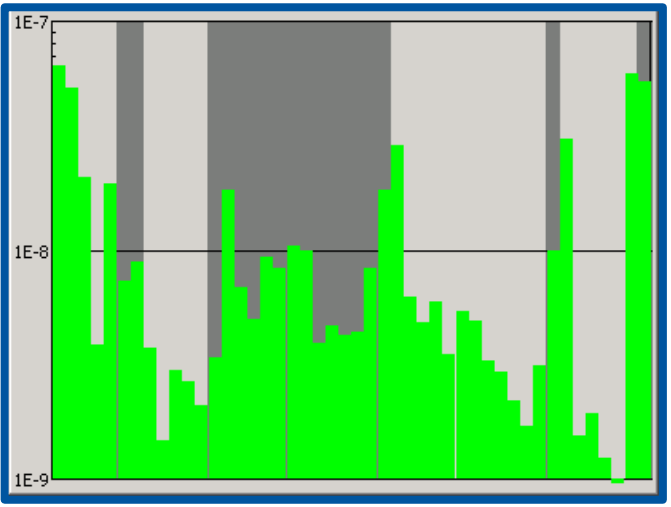
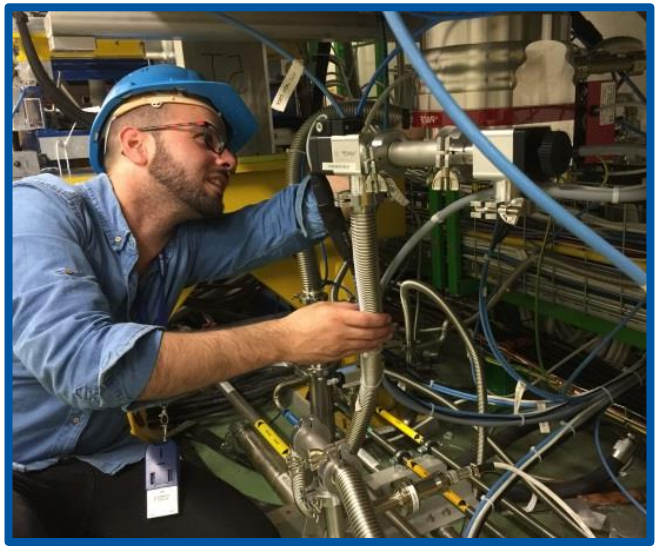
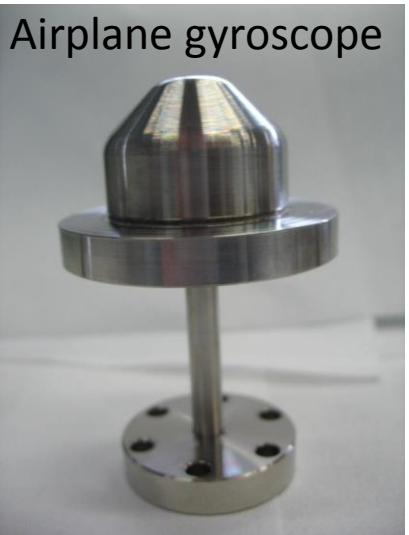
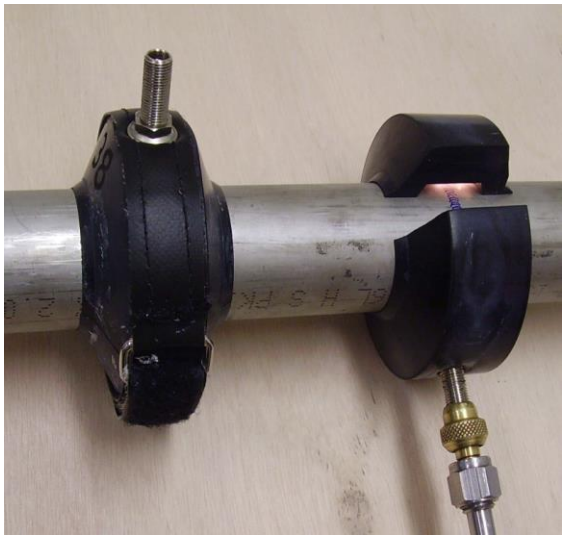






- Expertise in leak detection from 10^{2} to 10^{-15} mbar l s^{-1}
- Leak detection of large volumes (insulation vacuum) and longitudinal localisation
- Tightness assessment of welding during assembly by clam shells
- Alternative method in high helium background by Ne (^{22}Ne)
- Co-operation with manufacturing industry





Vacuum assessment and identification of contaminants

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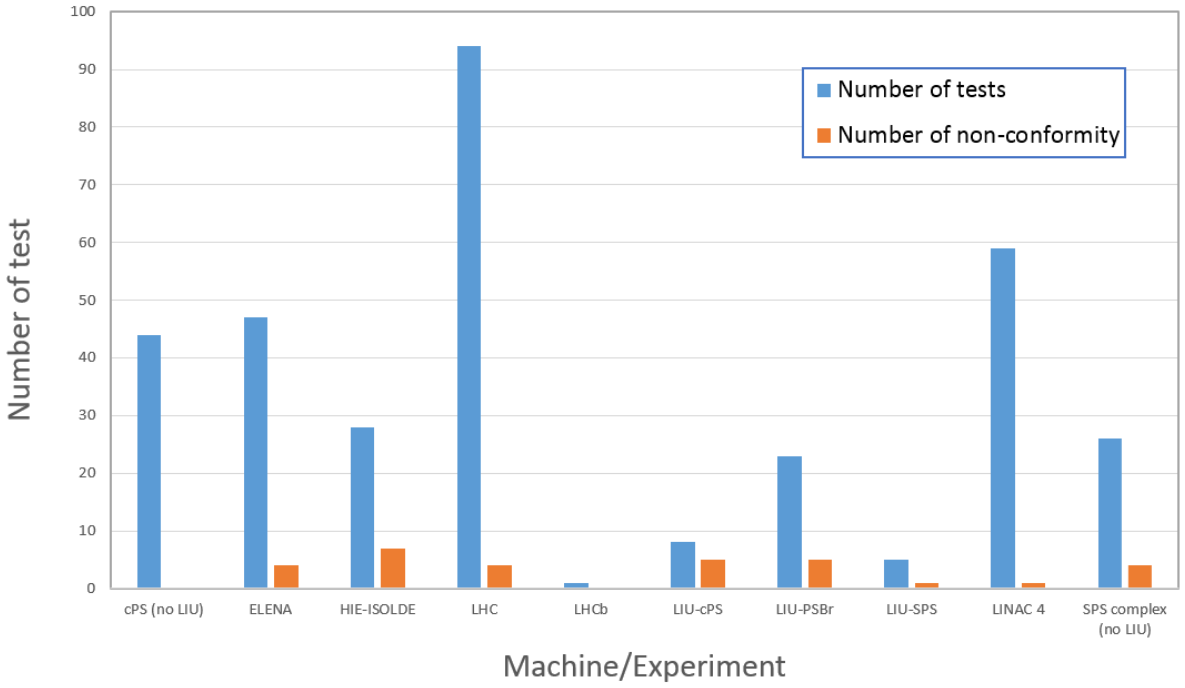
Vacuum at CERN

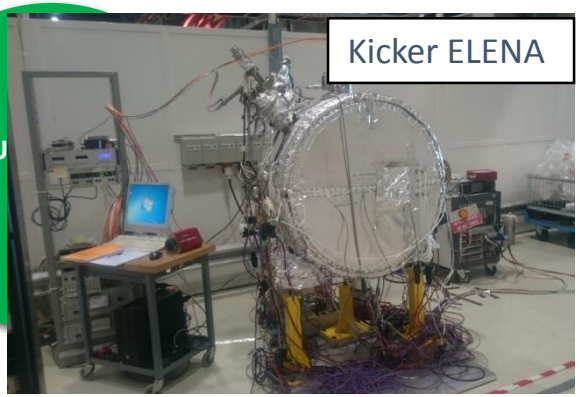
ORGANIC CONTAMINATION

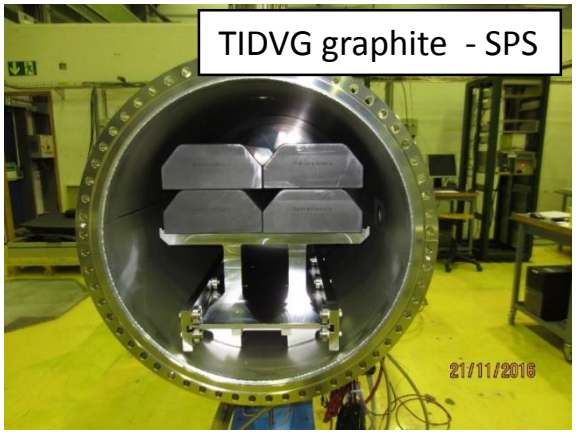
Evaluation of organic contamination by :

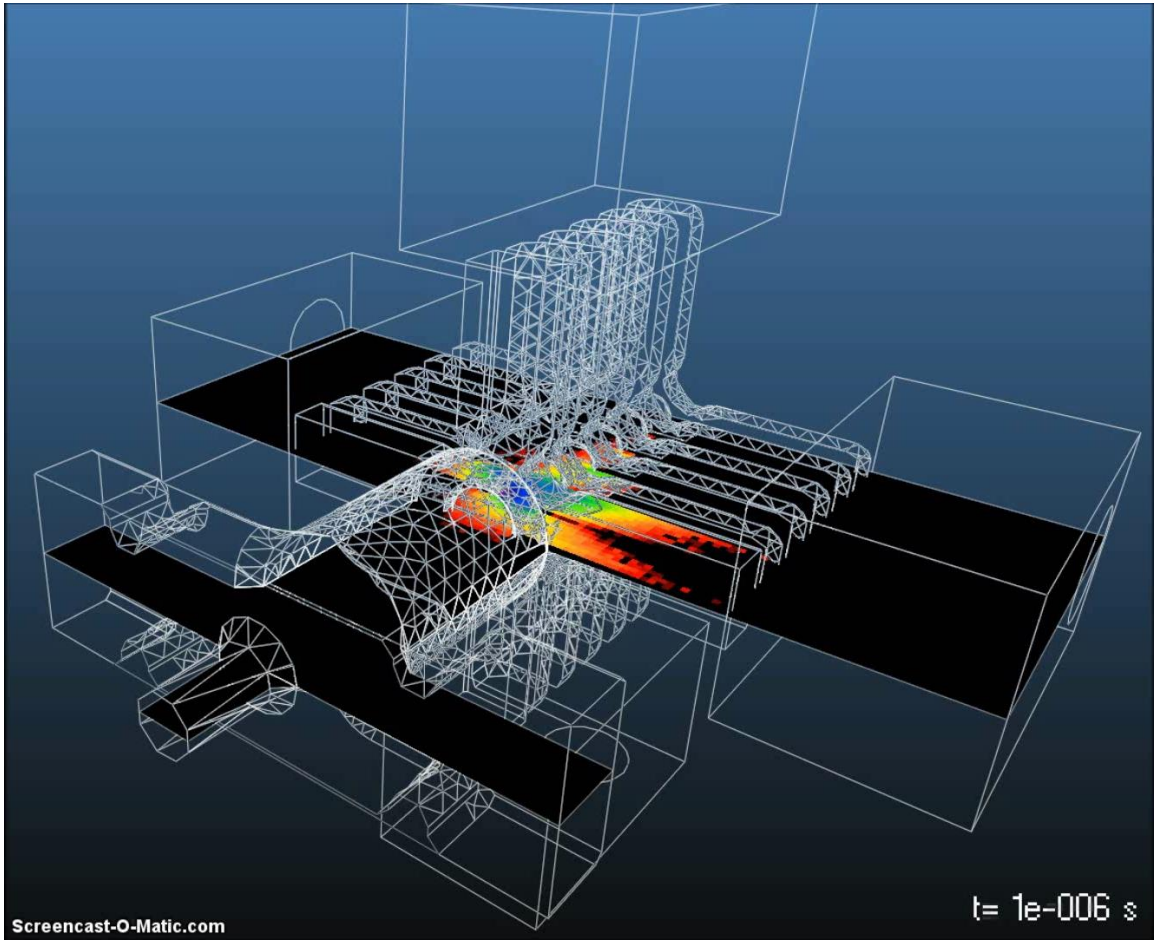
- Fourier Transform Infrared spectroscopy
- X-ray photoelectron spectroscopy
- Residual gas analysis

No test = No installation in beam vacuum









Gas expansion after a spark in a CLIC main cavity

- Molflow+, a Monte Carlo code, is now a standard for vacuum simulation.
- Recent developments have introduced 3D time dependence of gas density, including surfaces at different temperatures.
- Synchrotron radiation distribution is integrated in the code.
- Software and assistance are available and free.

Surface treatments and thin-film coating

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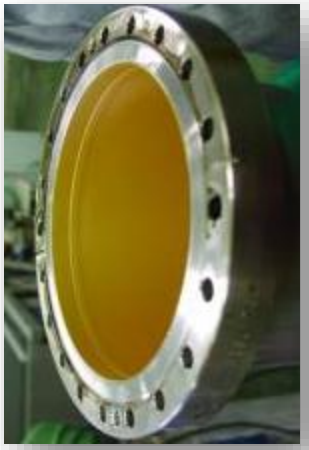
Galvanic treatments

Gold electroplating



LINAC 4

Copper electroplating

Tank LINAC 4

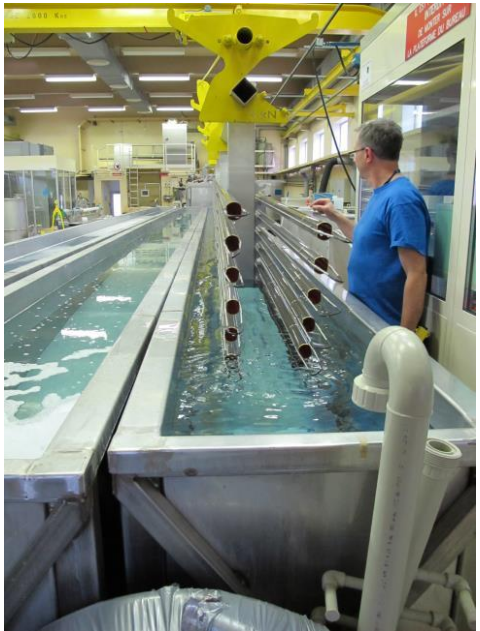
Silver electroplating

LHC TDI

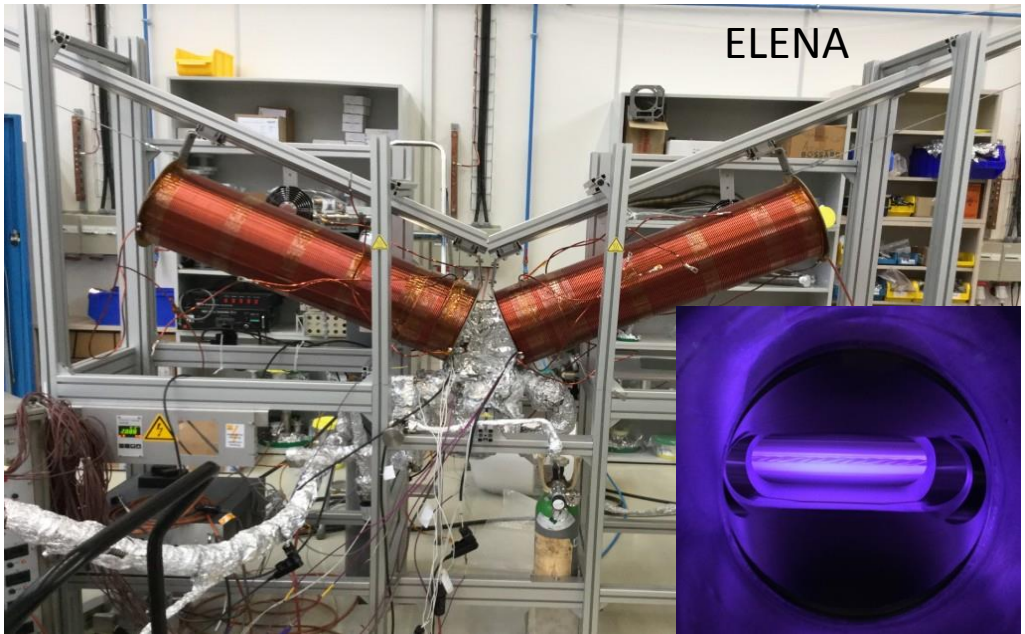
Rhodium electroplating

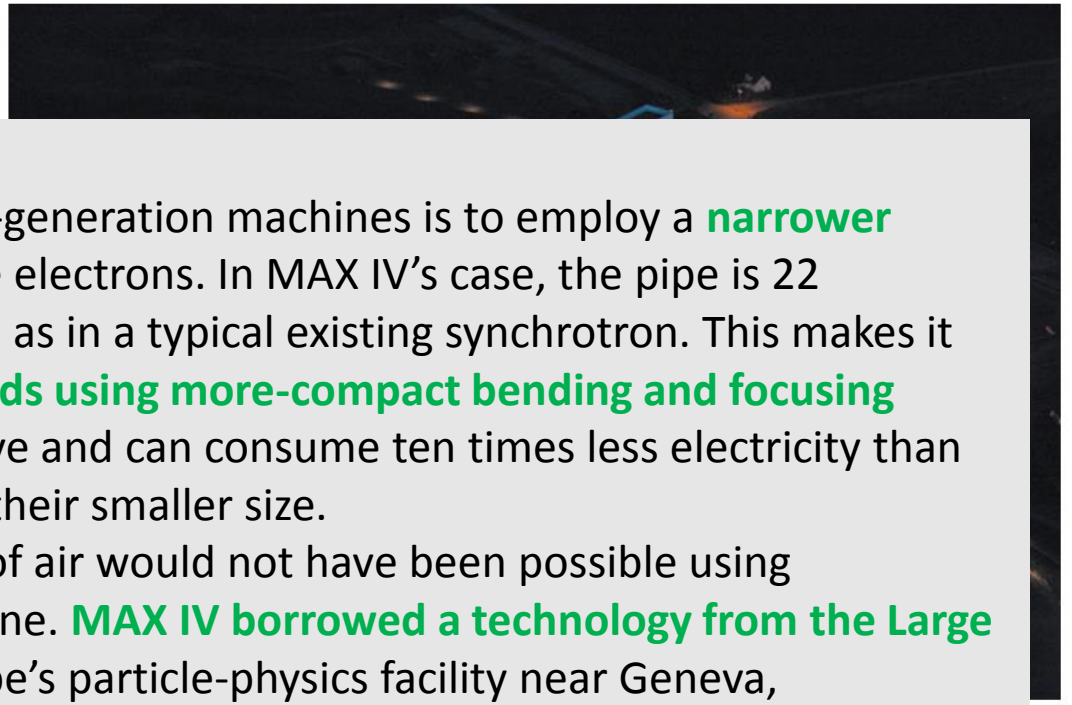
Transition LHCVSR

Surface chemical cleaning



Thin-film coating and plasma simulation





‘The **crucial innovation** in the fourth-generation machines is to employ a **narrower vacuum pipe** in which to circulate the electrons. In MAX IV’s case, the pipe is 22 millimetres across, about half as wide as in a typical existing synchrotron. This makes it possible to **get stronger magnetic fields using more-compact bending and focusing magnets**, which are also less expensive and can consume ten times less electricity than third-generation systems because of their smaller size.

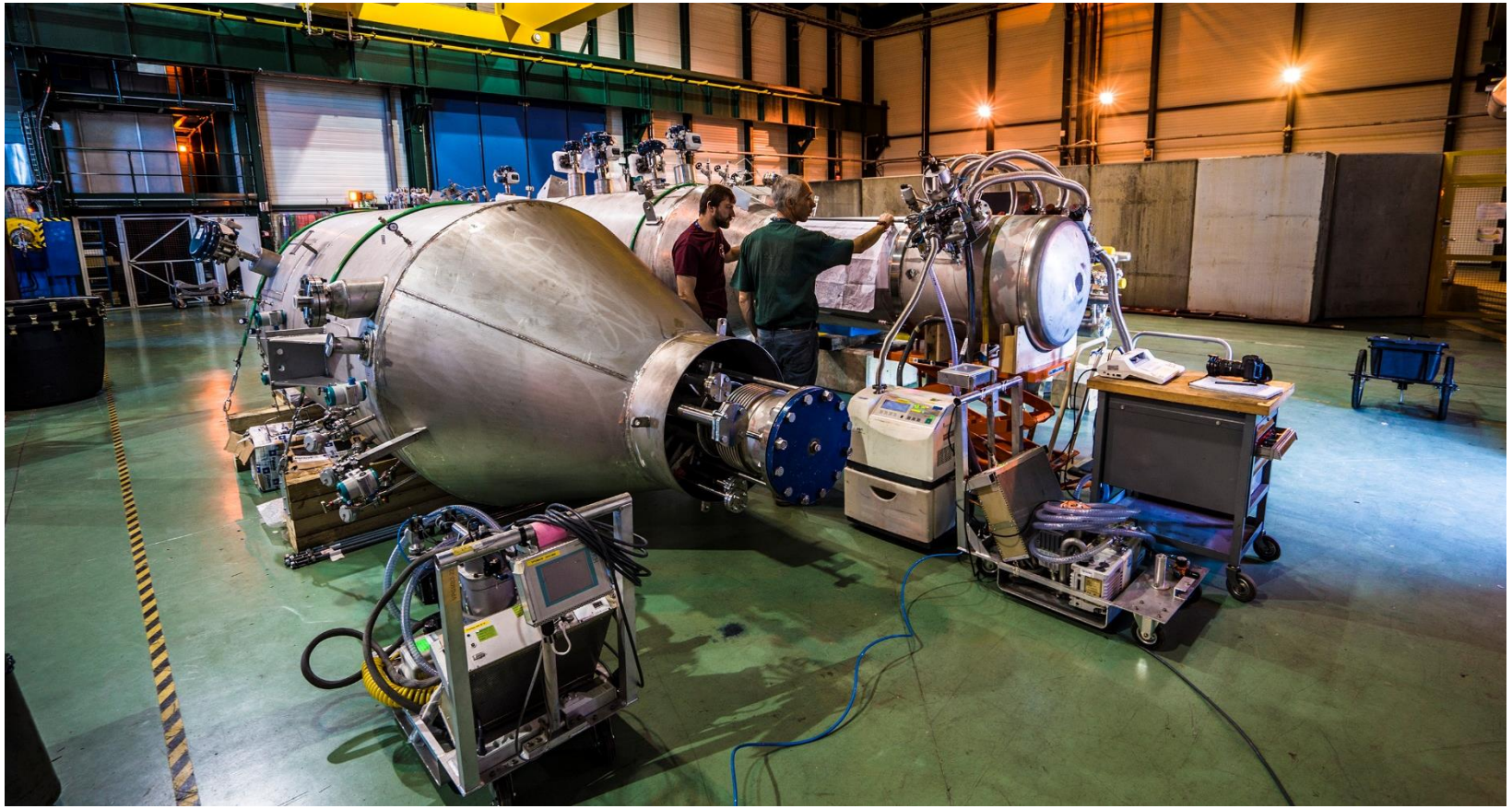
But keeping such a narrow pipe free of air would not have been possible using conventional high-vacuum pumps alone. **MAX IV borrowed a technology from the Large Hadron Collider (LHC) at CERN**, Europe’s particle-physics facility near Geneva, Switzerland, which circulates protons rather than electrons. The LHC’s trick — now adopted by MAX IV — is to coat the inner surface of the pipes with a special alloy that absorbs any gas molecules that happen to bounce around inside the tubes.’

Nature, 3 September 2015, Vol. 525

Swedish synchrotron promises super-bright beams and will open up new avenues for researchers.

Leak Testing of ARIA cryostats at CERN

- ARIA: 350 m cryogenic distillation column for argon purification (^{39}Ar removal) for use in dark matter research
- Service Agreement KN3155 established in 2016 between CERN and Princeton University (DarkSide Collaboration) for the room temperature leak testing of 30 ARIA cryostats, prior to their shipment & installation in a mine shaft in Sardinia.



Collaborations
ITER

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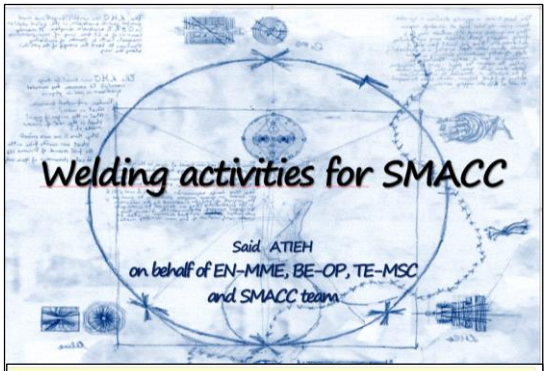
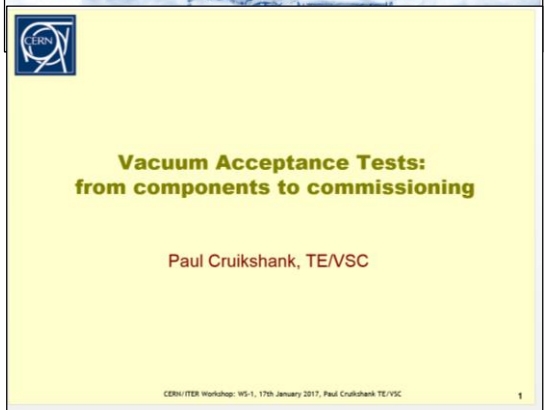
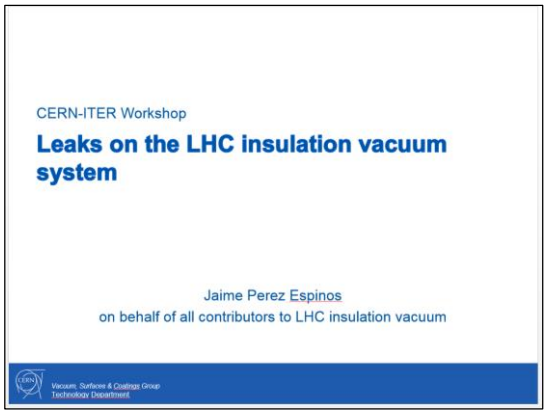
CERN-ITER workshop, Jan 2017

Vacuum at CERN

- Workshop at CERN, with strong presence of ITER field engineers and managers in charge of installation.
- Parallel workshops focused on installations & commissioning of vacuum, cryogenic, magnet & electrical systems.
- TE-VSC presentations on acceptance test strategy and execution, special tooling & vacuum instrumentation, welding QA and non-conformity handling, including visits to vacuum laboratories.







CERN has a wide expertise and experience in vacuum technology.

Through various collaborations, agreements and open exchanges, this knowledge is transmitted outside of CERN.

We are always ready to explore common areas of interest, compatible with our mandate.