Accelerator Technical & Operation Review (ATC/ABOC Days)
Session 4: MTTR & spare policy for the LHC injectors & experimental areas

Vacuum System of the LHC Injectors and Beam Transfer Lines

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Main Topics

- **Introduction**
- **Reliability of the vacuum systems**
  - Critical vacuum components, instrumentation & controls
  - Mitigation measures
- **Spare policy for all accelerators**
- **Vacuum Piquet Service**
- **MTTR**
- **Conclusions**

Introduction (1/2)

- **CERN accelerators have different vacuum systems with a wide variety of:**
  - Mechanical design
    - Flanges
    - Bellows
    - Magnets & Beam instrumentation types
    - Infrastructure
  - Required vacuum performances
    - UHV with or without NEG coatings
    - High vacuum with low or huge pumping speeds
  - Safety aspects
    - Accessibility
    - Radiation dose rates

Introduction (2/2)

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
REX-ISOLDE	linac	2001	3 Mev/u	partly	10^{-5} - 10^{-10}	20 m	and 70 (92) elements
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	
PS to SPS TL	Transfer line	1976	26 GeV	-	10^{-6}	~1.3 km	
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						**83.6 km !**	
LHC Arcs (Beamx2, Magnets & QRL insul.)	collider	2007	2 × 7 TeV	-	< 10^{-8}	4 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
UHV w/wo NEG	~ 57.5 km
Insulation vacuum	~ 50 km

Reliability of the vacuum systems (1/5)

- **Vacuum systems failures result from:**
  - Leaks induced by:
    - Mechanical fatigue e.g. welded bellows and welded SPS dipole chambers
    - Thermal fatigue induced by beam losses e.g. transition pieces
    - Corrosion of vacuum components like bellows and feed through resulting from the combination of humidity and radiations (SPS North Area TDC2, SPS TWC cavities, PS Booster feed through)
    - Beam impacts onto the vacuum chambers, bellows, transition pieces, etc.
  - Radiation induced damages to:
    - The sector valves switches and pneumatic
    - The ion pumps and gauge cables and connectors
  - Failure of the vacuum instrumentation e.g. gauges and their controllers
    - ☞ Most of the gauges are radiation hard i.e. passive gauges
    - ☞ Gauge controllers suffer from current cuts

Reliability of the vacuum systems (2/5)
Critical vacuum components, instrumentation & controls

- **Vacuum components**
  - Bellows are thin and:
    - Sensitive to corrosion
    - ☞Not exposed to beam losses since of higher diameters than the pipes
  - Thin windows are sensitive to:
    - Corrosion
    - Mechanical fatigue after several venting
  - Feed through are sensitive to corrosion in presence of humidity & radiations e.g. PS Booster being investigated extensively
    - ☞Corrosion can be avoided by a local heating ⇨ cost implications
  - Sector valve ⇨ switches and pneumatics are damaged by radiations
    - ☞Repairs are delicate and time consuming (~ 4 h)

Reliability of the vacuum systems (3/5)
Critical vacuum components, instrumentation & controls

- **Instrumentation**
  - Ion pumps provide the interlocks to close the sector valves
    ⇨ cables are damaged by radiations and shortcuts inside the pumps
  - High (Pirani) and low (Penning) pressure gauges provide the interlock for opening of the sector valves
    ⇨ their controllers suffer from mains cuts
- **Controls & Monitoring**
  - Machine protection is made by hardware systems. Then, failures of Controls & Monitoring will not stop the operation with beams
    ⇨ In case of a sector valve closure, an intervention will be required…
  - IT is provided by 3 WINDOWS Servers housed in the IT Dpt Control Room and a spare LINUX machine with 3 Servers (SPS, LEIR & LHC) in the CCC rack

☞ **A standardization of all accelerators Controls & Monitoring tools is in progress**

Reliability of the vacuum systems (4/5)
Mitigation measures

- **Vacuum components**
  - ☞ Leaking components or connection can be varnished if the leak is accessible and smaller than 10^{-6} mbar.l/s
  - ☞ Bigger leaks or inaccessible leaks requires the exchange of the leaking component or seal
  - ☞ Differential pumping could be an option… implemented in 2007 in LINAC 2
- **Sector valve**
  - ☞ If the switches which provide the valve status or if the pneumatics are damaged by radiations, then, the valve will be opened and disconnected from both Control & compressed air to avoid any closure until the next access (min. 4 hours required)
    ⇨ Implications to the machine protection has to be accessed
- **Instrumentation**
  - ☞ Instrumentation controller or cards can be easily exchanged
- **Controls & Monitoring**
  - ☞ Not required for the operation… can be fixed without impacting the operation
  - ☞ Spare LINUX server is available in case the WINDOWS servers crash…
  - ☞ 4 VAC-ICM Staff can intervene on PLC chassis

Reliability of the vacuum systems (5/5)
Example of shutdown consolidation activities

- **LINAC 2&3**
  - New Control & Monitoring system based on PLCs technology (LHC, SPS & LEIR type)
  - Replacement of all ion pumps power supplies
  - Source maintenance, pumps maintenance and installation of additional pumping speed when required
- **PS, PSB & AD**
  - Global leak detection of all sectors – repairs if required
  - Maintenance & replacement of the sublimation pumps, fixed pumping stations, instrumentation, sector valve compress air circuits and ion pumps cables and connectors
  - Maintenance of the Console Manager supervision
  - PSB: modify the sectorisation around the wire scanners to reduce the bake out downtime when repairing a wire.
- **ISOLDE**
  - Maintenance of gas collection system & upgrade of its associated instrumentation
  - Maintenance & consolidation of primary & turbo pumps: 4 turbo pumps replaced by new ones
  - Upgrade of the ISOLDE control system
- **SPS consolidation during shutdowns**
  - Leak detection & instrumentation checks
  - Exchange of ion pumps faulty cables and connectors
  - Removal of all electrical safety non-conformities on ion and sublimation pumps

Spare policy for all accelerators (1/2)

- **Vacuum components except sector valves**
  - ☞ Impossible to have spares for all vacuum chambers, transition pieces and bellows ready to be used due to the large variety of components ⇨ Storage and cost problem !
  - – Basic components like tubes, shaped tubes, flanges (except enamel flanges), bellows are available ⇨ LEIR case shall be worked out e.g. bellows and DFH chamber
  - ☞ If a vacuum component is found to be leaking, then, a new component has to be manufactured by assembling the basic components together, vacuum cleaned and leak detected before becoming available…
  - ☞ Availability of transfer line windows is not known ⇨ action with AB-ATB
  - – Already planed corrective actions
    - Manufacture additional spare chambers e.g. MBN type for the SPS North Area
    - Design & manufacture new transfer line windows
- **Pumps**
  - – Ion & sublimation pumps are available for all types
  - – Old turbo pumps need to be replaced by new pumps e.g. case of LINAC 3 source ⇨ new control & cablings are required

Spare policy for all accelerators (2/2)

- **Sector valves**
  - ☞Spare sector valves are available
  - ☞ Spare parts are available for all types of sector valves to allow in situ repair of switches and pneumatics
- **Instrumentation, Controls & Monitoring**
  - ☞Spares are available for all machines
    - New spare for the new type of controls (PLC based) ⇨ 3 spare PLC masters are available
    - Recuperated racks for the old fashion controls (PS, PS Booster & AD machines)
    - Sector valve racks: 2 by machine
    - Ion pump power supplies: 10 by machine (compatible SPS/LHC)
    - Gauges & controllers: all types are available ⇨ shared between machines
  - ⇨ISOLDE instrumentation need to be replaced by a more recent one

Vacuum Piquet Service (1/2)

- **Formal Piquet Service**
  - Two independent Piquet Services were providing the vacuum mechanical & leak detection support
    - PS Complex – 1 staff at a time
    - SPS Complex – 1 staff at a time
  - One “Control & Vacuum Interlocks” Piquet Service for PS & SPS Complex – 1 staff at a time
- **Piquet Services were available as soon as the beams were injected in the accelerators i.e. from April to mid-November**
- **When an access was required for example in the SPS, the PS Piquet was ensuring the “2nd person” and “vice-et-versa”**

Vacuum Piquet Service (1/2)

- **New CERN-Wide Accelerator Piquet Service**
  - ☞ Vacuum Piquet Service changes to take into LHC operation constraints: longer run (limit of 9 weeks for stand-by), optimisation of resources, need of an expert support and technical opportunity for Staff

☞ **Vacuum Group will provide two types of support to operation:**

- Piquet Service
  - 2 staffs on stand-by in order to be able to access underground areas
  - Duty: After being called by the CCC, analyse the cause of the incident and try to fix it using the remote ac[illegible]m control system or directly on the hardware in the surface building or in the tunnel.

    In case of difficulties to fix the problem or if a risk to the person or to the material has been identified, the staff on stand-by can call the Experts for advise.
- Expert support ("Piquet libre", not on stand-by !)
  - A list of Experts by systems is accessible to the staff on stand-by
  - Help expected: After being called by the staff on stand-by (we shall avoid the direct call from the CCC), the Expert will give advise to the stand-by team and will intervene on site if required to fix the problem. If the problem can not be fixed, he will report to the CCC.

In case of a major mains cuts, priorities will have to be defined !

1			Only LHC Cryo
2	09.01.2008	16.01.2008	
3	16.01.2008	23.01.2008	
4	23.01.2008	30.01.2008	
5	30.01.2008	06.02.2008	
6	06.02.2008	13.02.2008	
7	13.02.2008	20.02.2008	
8	20.02.2008	27.02.2008	
9	27.02.2008	05.03.2008	
10	05.03.2008	12.03.2008	
11	12.03.2008	19.03.2008	
12	19.03.2008	26.03.2008	
13	26.03.2008	02.04.2008	
14	02.04.2008	09.04.2008	
15	09.04.2008	16.04.2008	
16	16.04.2008	23.04.2008	LHC Cryo + Injectors with beams
17	23.04.2008	30.04.2008	
18	30.04.2008	07.05.2008	
19	07.05.2008	14.05.2008	
20	14.05.2008	21.05.2008	
21	21.05.2008	28.05.2008	
22	28.05.2008	04.06.2008	
23	04.06.2008	11.06.2008	
24	11.06.2008	18.06.2008	
25	18.06.2008	25.06.2008	
26	25.06.2008	02.07.2008	
27	02.07.2008	09.07.2008	
28	09.07.2008	16.07.2008	
29	16.07.2008	23.07.2008	
30	23.07.2008	30.07.2008	
31	30.07.2008	06.08.2008	
32	06.08.2008	13.08.2008	
33	13.08.2008	20.08.2008	
34	20.08.2008	27.08.2008	
35	27.08.2008	03.09.2008	
36	03.09.2008	10.09.2008	
37	10.09.2008	17.09.2008	
38	17.09.2008	24.09.2008	
39	24.09.2008	01.10.2008	
40	01.10.2008	08.10.2008	
41	08.10.2008	15.10.2008	
42	15.10.2008	22.10.2008	
43	22.10.2008	29.10.2008	
44	29.10.2008	05.11.2008	
45	05.11.2008	12.11.2008	Injectors & LHC with beams
46	12.11.2008	19.11.2008	
47	19.11.2008	26.11.2008	
48	26.11.2008	03.12.2008	
49	03.12.2008	10.12.2008	
50	10.12.2008	17.12.2008	
51	17.12.2008	24.12.2008	Only LHC Cryo
52	24.12.2008	31.12.2008	
1	31.12.2008	07.01.2009	
2	07.01.2009	14.01.2009	
3	14.01.2009	21.01.2009	
4	21.01.2009	28.01.2009	

MTTR
Failures classified by increasing beam downtime

- **Sector valve problem**
  - Undefined position or valve is closed and can not be opened
    - Control can access the valve:
      - YES: less than 1h
      - NO: ~2 h
    - + Pneumatic or switch problem ⇨ need to access the valve in the tunnel: 2-3 h
- **Vacuum instrumentation failure**
  - Valve can not be opened due to a gauge problem: 1-2 h
- **Mains cut**
  - IT infrastructure is available (Profibus, Ethernet, servers…):
    - YES: < 3 h
    - NO: 3-5 h
  - ☞ Vacuum pumps and instrumentation have to be restarted manually, one-by-one !
  - ☞ Old electronics suffer from the cuts (even short cuts) ⇨ The amount of failures is always the "cerise sur le gateau"…!
- **Leak on vacuum or machine (beam instrumentation, magnet, etc.) components**
  - Leak can be varnished (localization included): 3-4 h
  - Leak can not be varnished, spare component is available:
    - YES: Max. 8h
    - NO: 2-3 days to manufacture a new vacuum component

MTTR
Factors inducing additional delays to an intervention

- **Access to the tunnel is required**
  - Radiation VETO has to be removed: 1 h
  - Transportation of mobile pumps, leak detectors & vacuum tooling to the spot: 1-2 h
  - Accessibility of mobile material (e.g. case of TI2/TI8, TT41, North area…): 2-3 h
    ⇨ requires venting of other beam lines & removing vacuum components
- **Design not optimised for vacuum**
  - Type of flanges (quick connect chain clamps or Conflat® flanges): +20 min/flange
  - Welded connection instead of flanges ⇨ grinding shall be avoided: few hours
  - Bake out is required e.g. porous materials (graphite, C-C, BN, ferrites…): 3-4 days
  - Water circuit leaking into the beam vacuum e.g. TIDVG in the SPS: days or weeks !
- **Other constraints**
  - Survey is required: limited impact < 1 h
  - Several machines have vacuum problems ⇨ resources & logistic limitations ⇨ radiation dose levels could forbid using additional resources from the Vacuum industrial support contract (dose rate > 2 mSv/h)
  - High radiation dose rates e.g. SPS Extractions & internal dump, North area (TCC2, TDC2), ISOLDE target, PS septum area, PS internal dump…
    ⇨ requires a cool down time ! Several days !
  - Corrosion on bellows ⇨ leaks reappear after venting / pumping cycle ! Several weeks !
  - Spare component not available: several days or weeks !

Conclusions

- Apart from the transfer line vacuum windows which availability and responsibility has to be followed up actively, all spare components or subcomponents are available
- Unique Piquet service will have to gain experience
  ⇨ no impact is expected on the accelerator operation
- Consolidation of PS and PS Booster has to continue to standardise the vacuum controls & monitoring tools
- Other consolidations will be proposed for evaluation e.g. heating of feed through in SPS BA4 extraction and PS Booster to avoid corrosion, corrosion problems in SPS North Area, new ISOLDE control system

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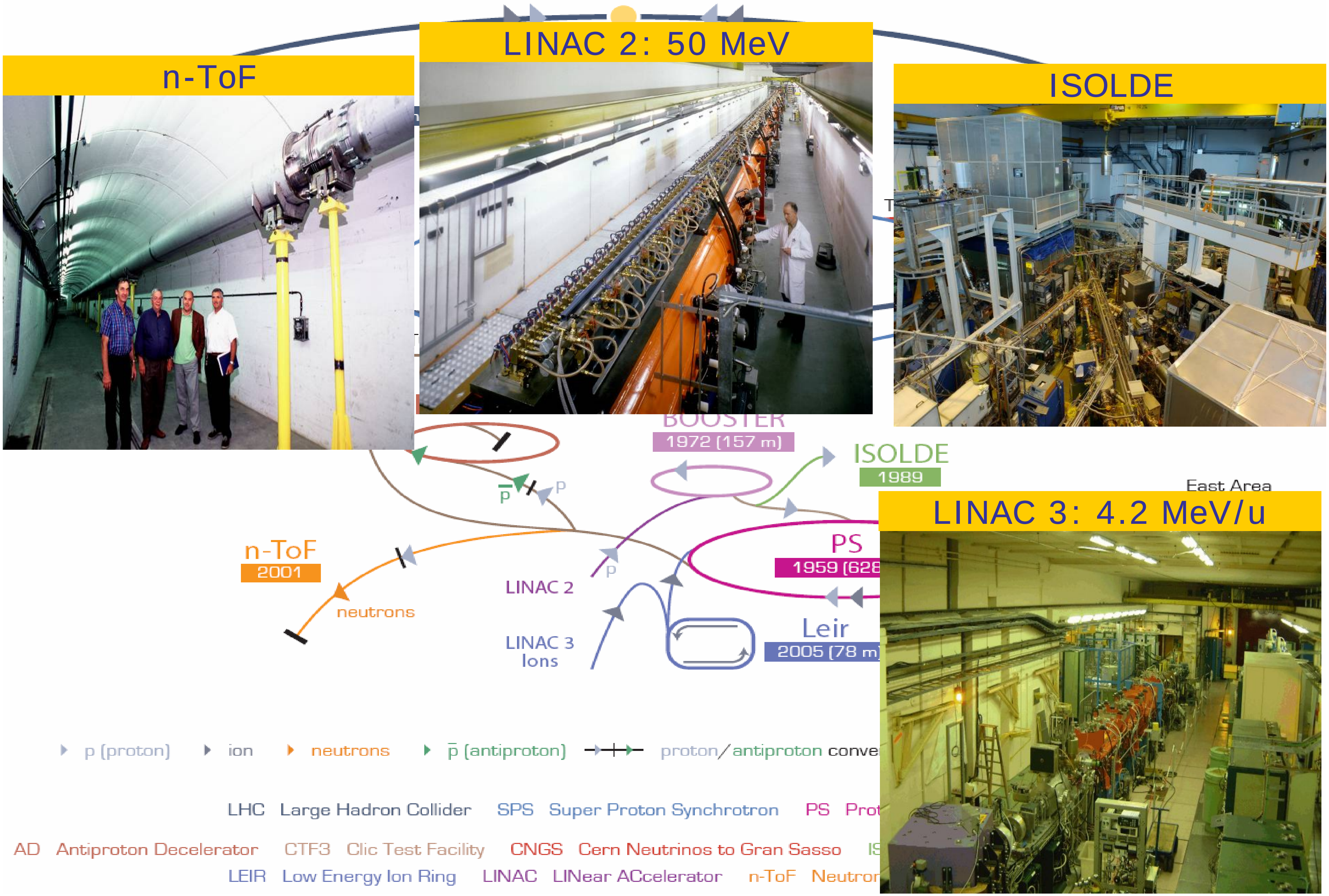
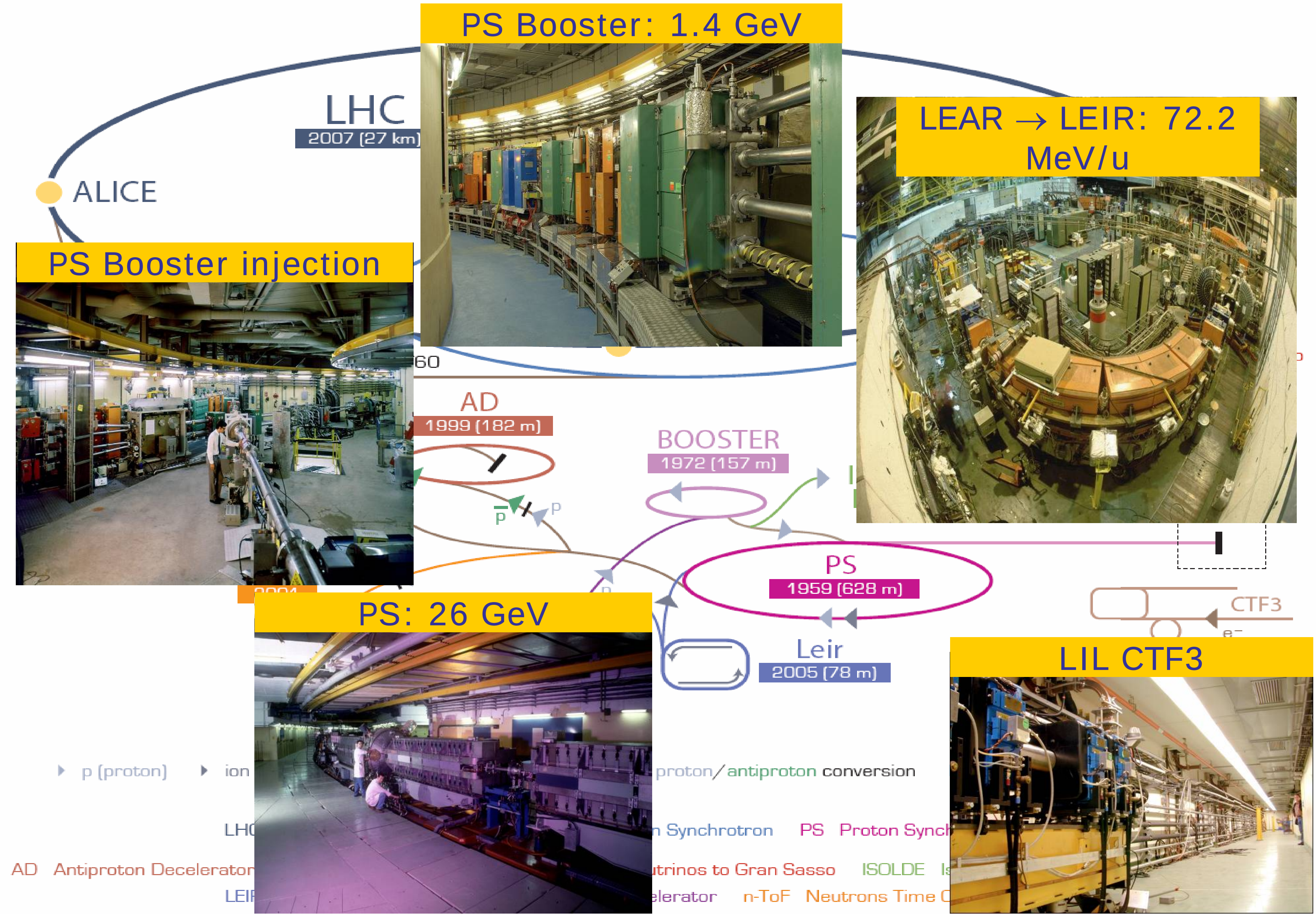
CERN Accelerator Complex

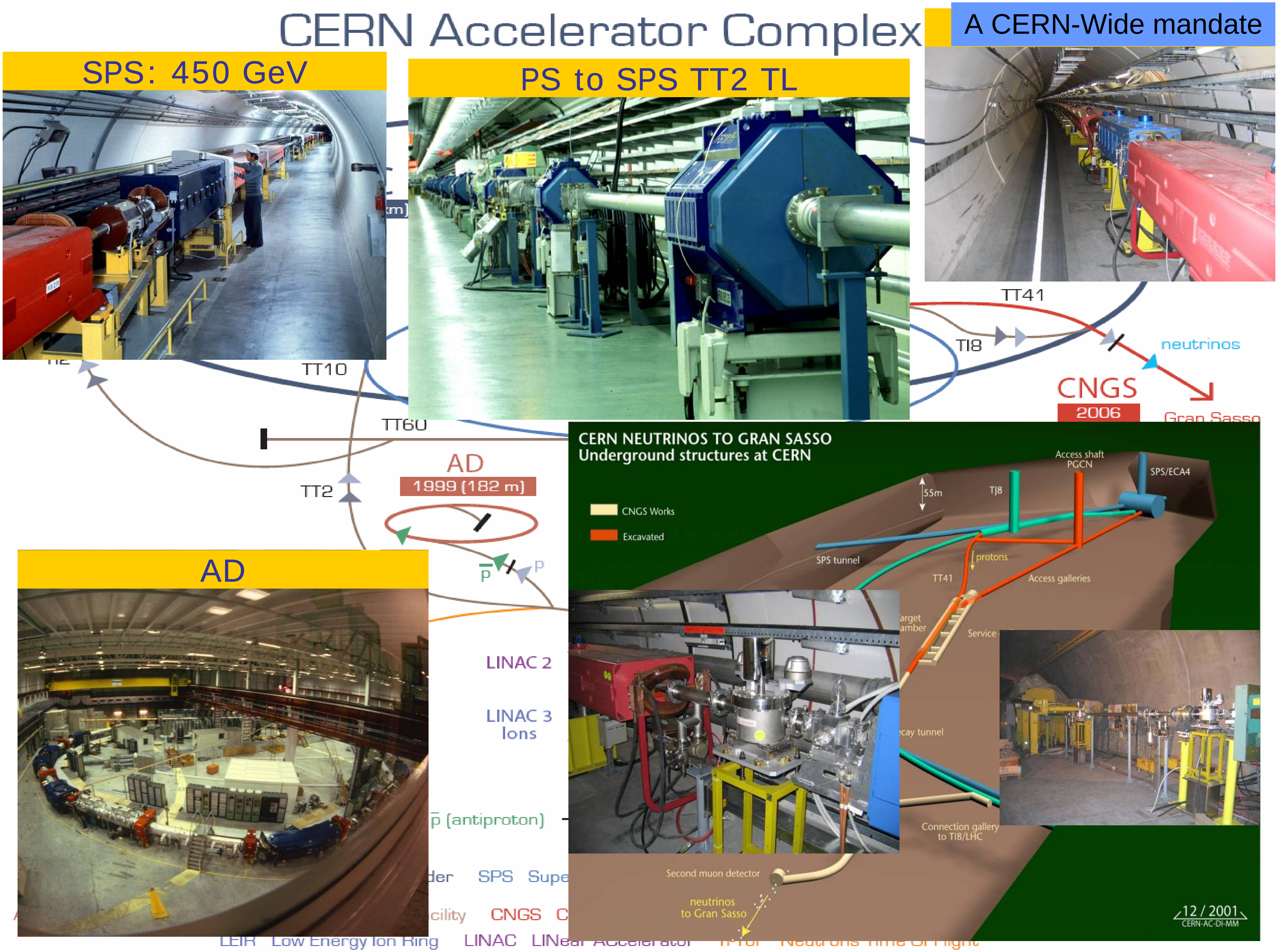
A CERN-Wide mandate



CERN Accelerator Complex

A CERN-Wide mandate





CERN Accelerator Complex
A CERN-Wide mandate
SPS: 450 GeV
PS to SPS TT2 TL
TT41
TI8
neutrinos
CNGS
2006
Gran Sasso
TT10
TT60
AD
1999 (182 m)
TT2
AD
LINAC 2
LINAC 3
Ions
p̄ (antiproton)
SPS
CNGS
LEIR Low Energy Ion Ring
LINAC LINear Accelerator
CERN NEUTRINOS TO GRAN SASSO
Underground structures at CERN
CNGS Works
Excavated
Access shaft
PGCN
SPS/ECA4
55m
TJ8
SPS tunnel
protons
TT41
Access galleries
Service
Connection gallery
to TI8/LHC
Second muon detector
neutrinos
to Gran Sasso
12 / 2001
CERN-AC-DI-MM

CERN Accelerator Complex

A CERN-Wide mandate

SPS to LHC Transfer Lines
(TI2 & TI8)