Large Systems Commissioning

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CAS Vacuum in Accelerators

Platja D`Aro, May 21, 2006

Special thanks to O. Gröbner

THE CERN ACCELERATOR SCHOOL

Outline

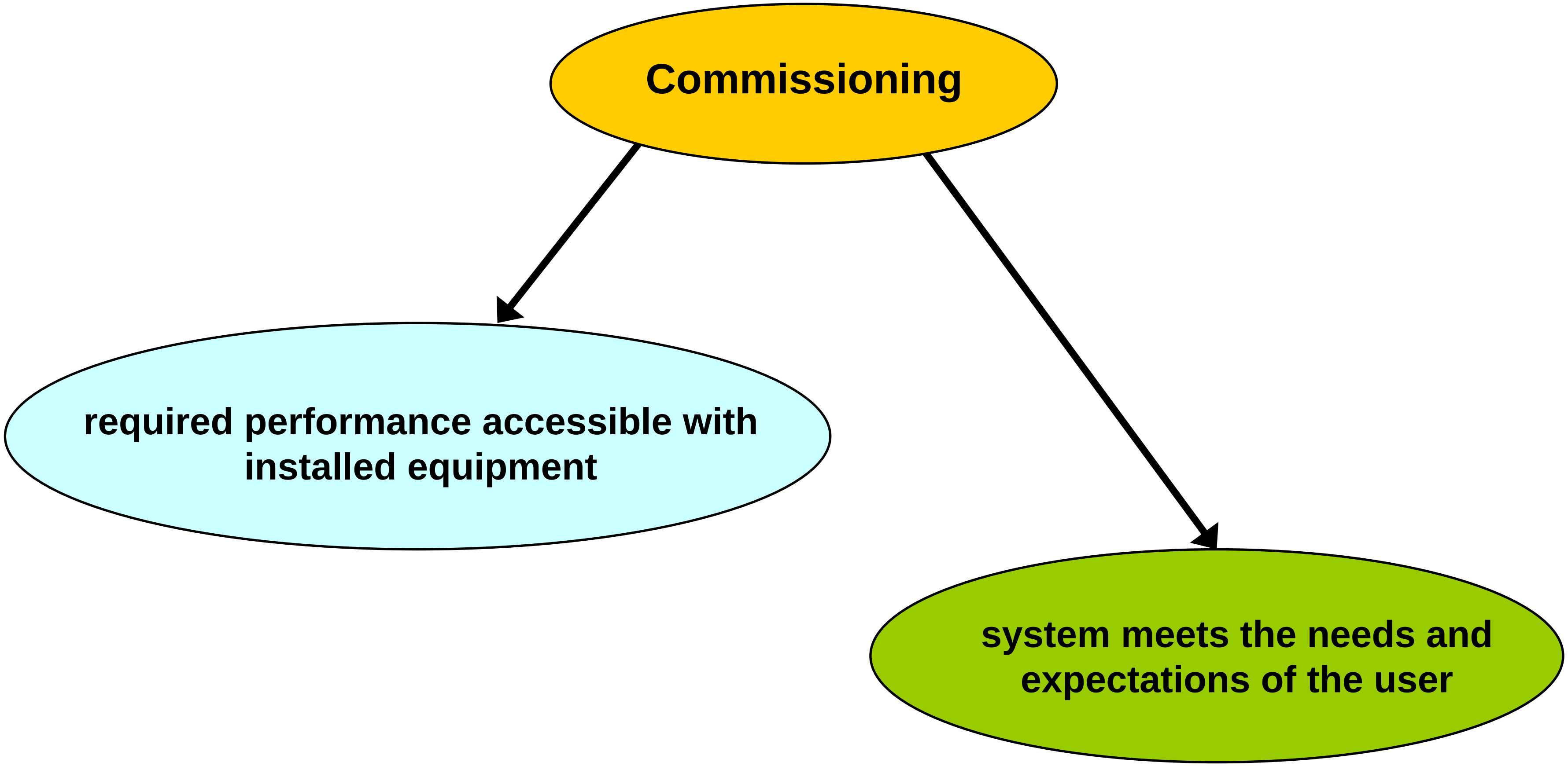
- Introduction
- Pump Down and Leak Check
- Components Check
- Bake Out
- Interlocks/Safety
- Cryogenic Systems
- First Beam
- Concluding Remarks

Introduction

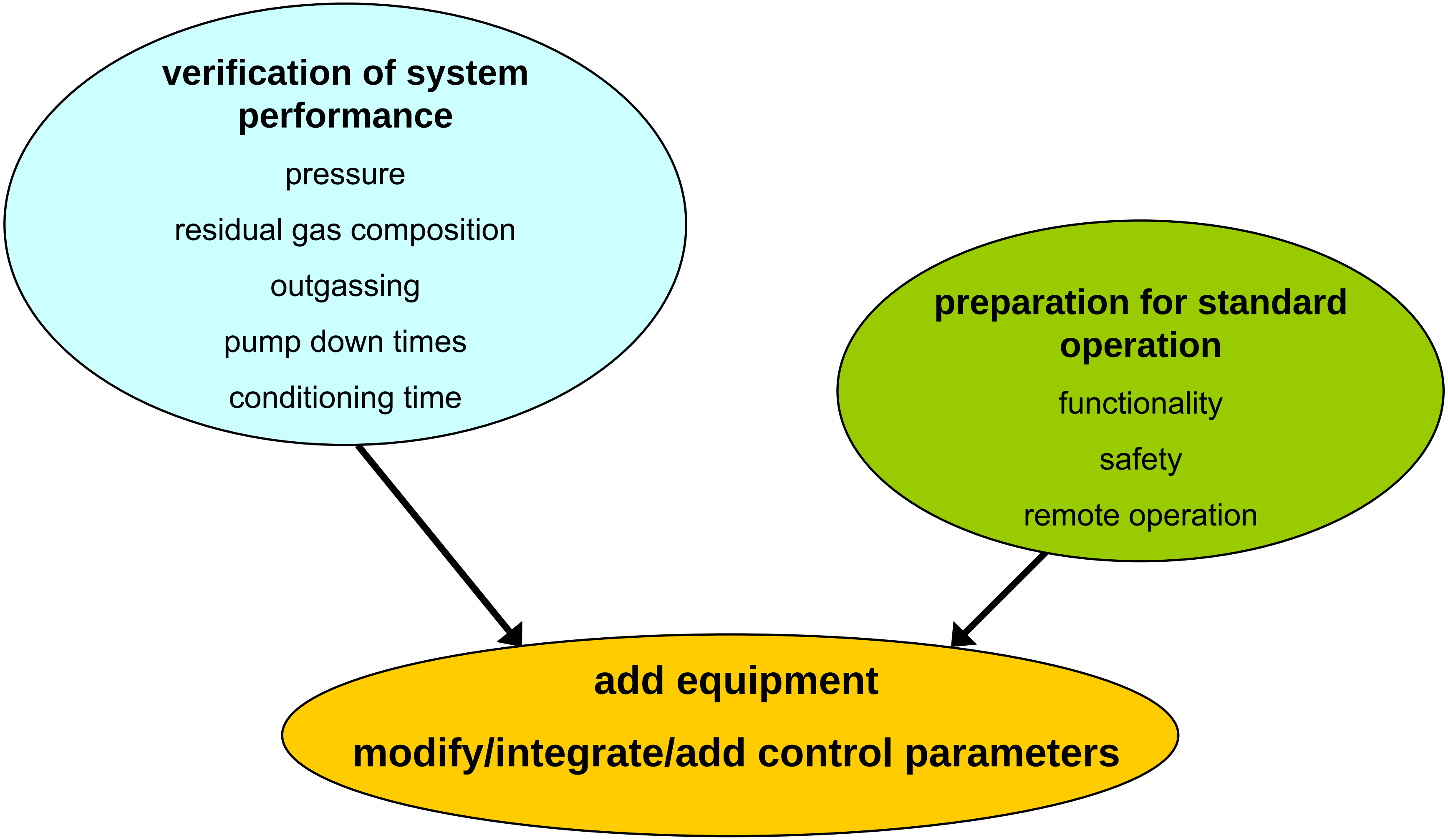
- **Accelerator vacuum system**

beam intensity beam lifetime beam stability	➡	static pressure dynamic pressure beam pipe aperture material rf shielding ....

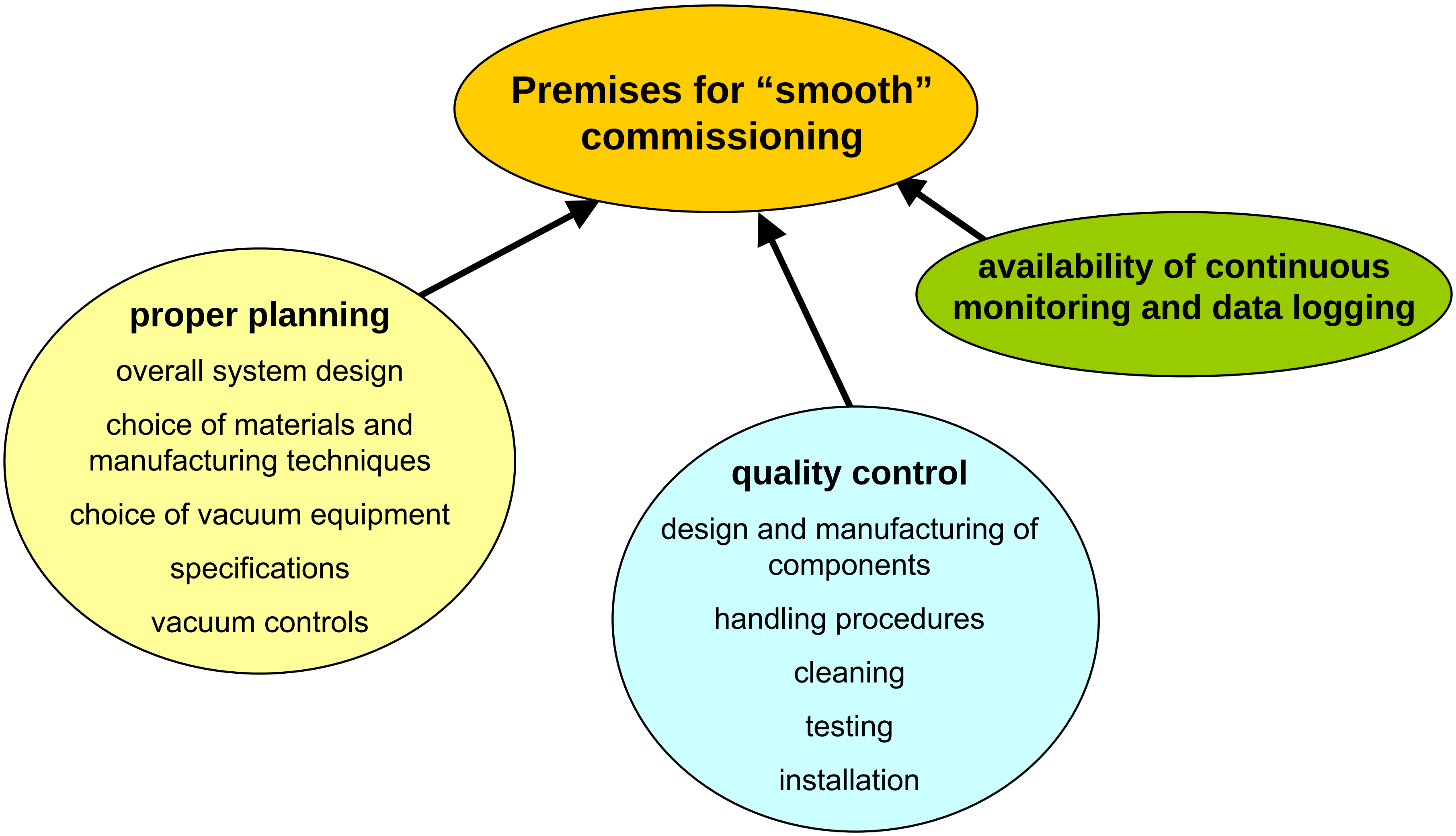
Introduction



Introduction



Introduction



Introduction

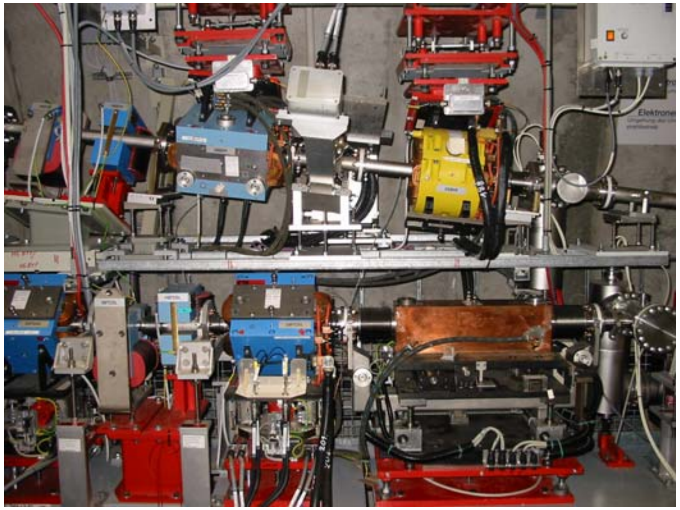
Introduction

- **Large systems**
  - length
  - number of components
  - complexity

Example

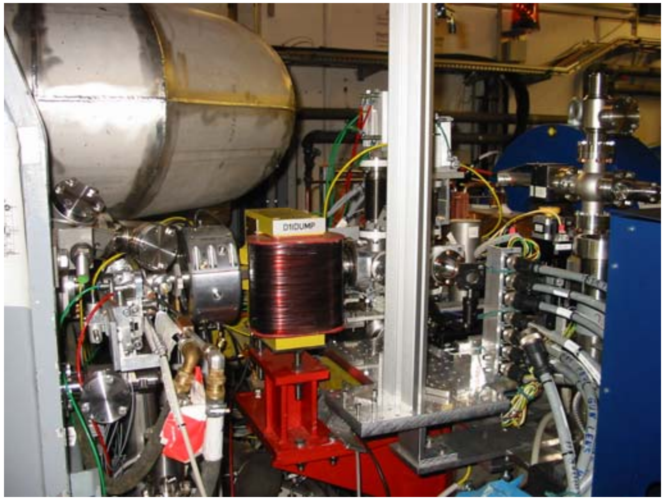
- LEP
  - 27 km circumference
  - ~ 2700 bellows
  - ~ 7000 feedthroughs
  - ~ 2200 pick-up connections
  - ~ 700 gauges
  - 130 sector valves
  - 520 roughing valves
  - 1900 sputter ion pumps
  - 13.000 flanged connections

DESY



TTF/FLASH

Pump Down and Leak Check

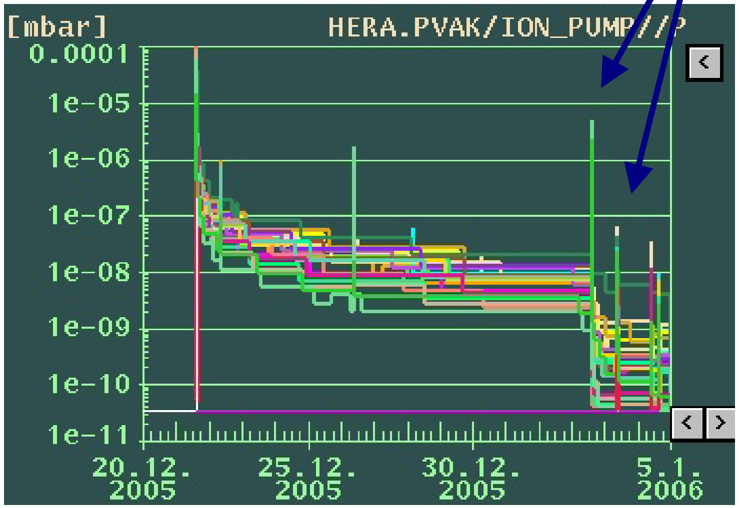


TTF/FLASH

- **Proper fixture of components**
  - loose/fixed points
  - bellows
- **Pressure decay ↪ first hints for leak**
  - check with RGA or pressure rise method
- **Leak Check**
  - gross check $p < 10^{-4}$ mbar
  - fine check $p < 10^{-6}$ mbar
    - flanged connections, ceramics, feedthroughs, windows
  - equipment
    - mobile pump station with leak detector/RGA
  - systematic work necessary
  - switch of sputter ion pumps
    ↪ avoid spoiling with He in case of leak

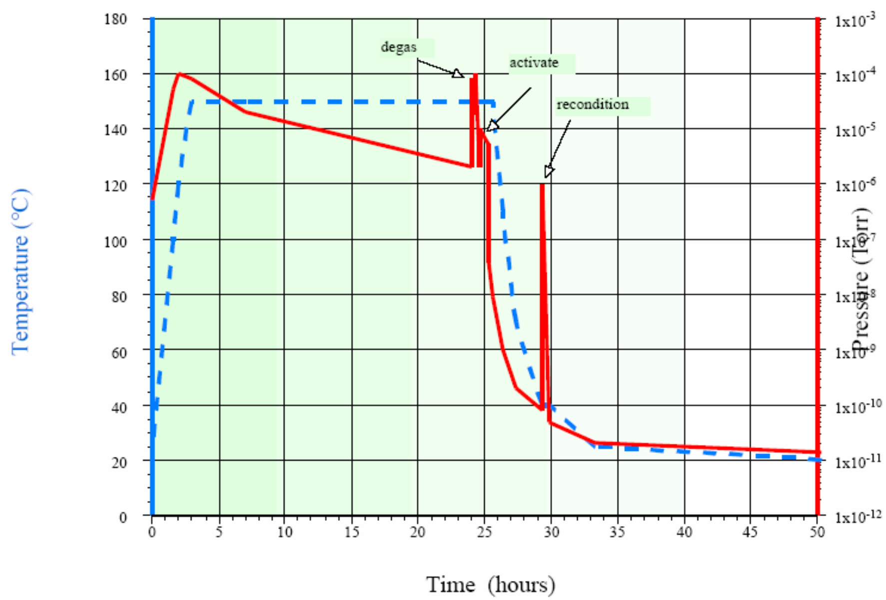
Pump Down and Leak Check

- **Conditioning of vacuum system without beam**
  - activation of titanium sublimation pumps



HERA

  - activation of NEG pumps

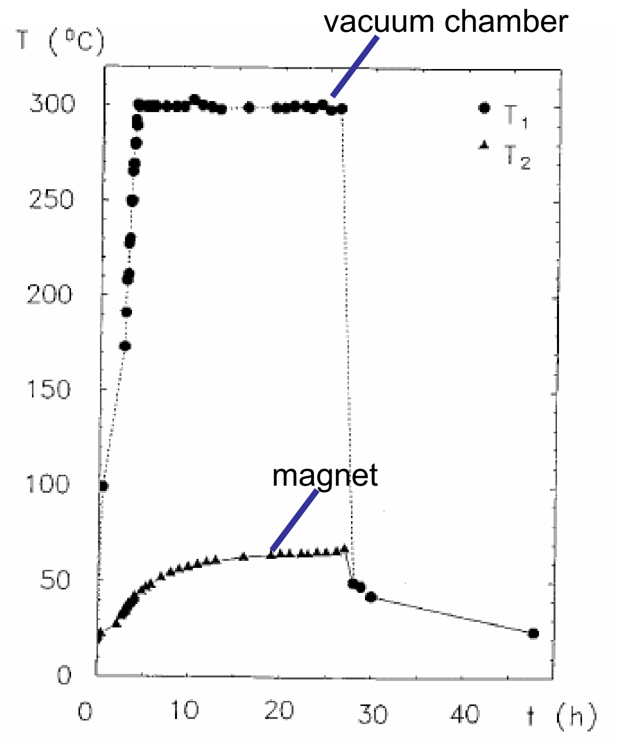


LEP
O. Gröbner

- **Observe behavior of pressure**
  ↳ **repeat leak check if necessary**

Bake Out

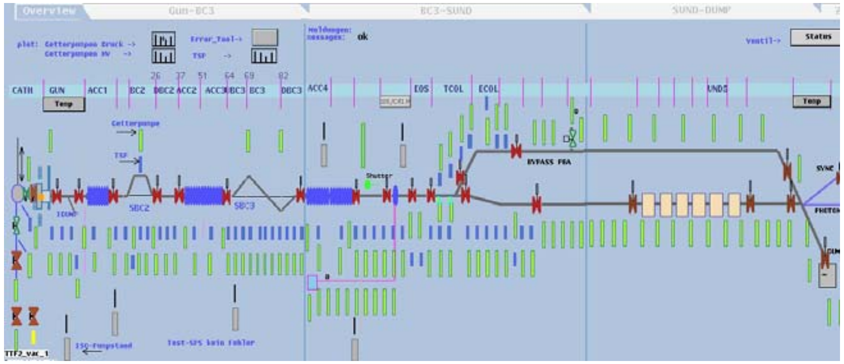
- **System check**
  - equipment (heaters, thermocouples, cabling)
  - functionality ↪ reliable attachment of sensors
  - heating process (ΔT/time, …), automation
  - interlock
    - power failure
    - failure of equipment
    - pressure rise/leak
- **Cooling of critical components**
  - magnets, monitors, etc.
- **During bake out**
  - avoid large temperature gradients
  - check movement of components due to heating
  - observe pressure for leaks

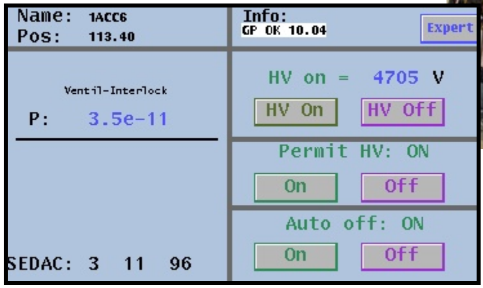


HERA

Components Check

- **Vacuum equipment**
  - correct allocation
    - components ➥ cables ➥ electronics
    - display on computer
  - functionality of pumps, gauges, valves, etc.
- **Vacuum control**
  - remote operation of components
  - functionality
  - add/improve handling options
  - modify/integrate additional parameters

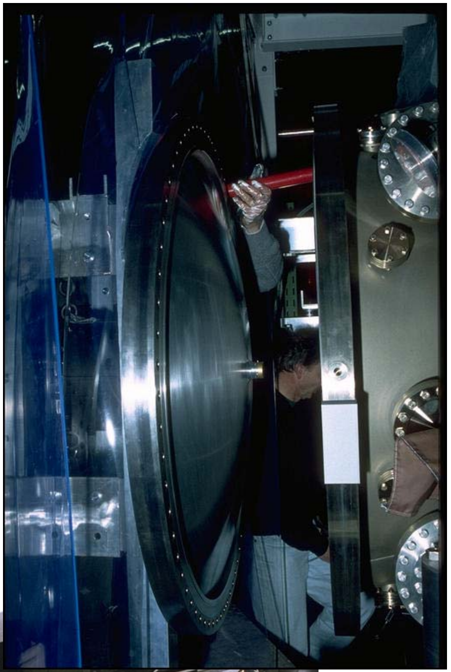




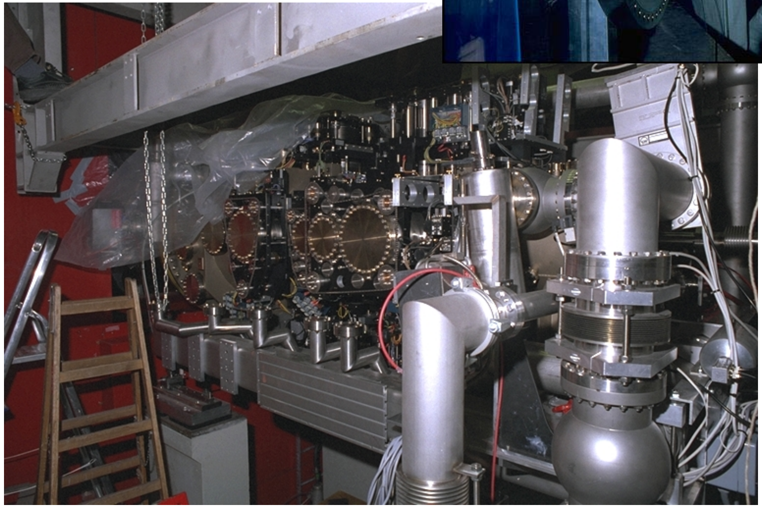
TTF/FLASH

Components Check

- **Movable elements (collimators, diagnostics, …)**
  - correct path length
  - end switches
  - remote operation
    - ➥ check for pressure increase during movements
- **Special equipment of experiments**
  - e.g. gas inlet systems
- **Final alignment**
  - be careful shifting components under vacuum
    - ➥ temporarily unfixed components



HERA-B

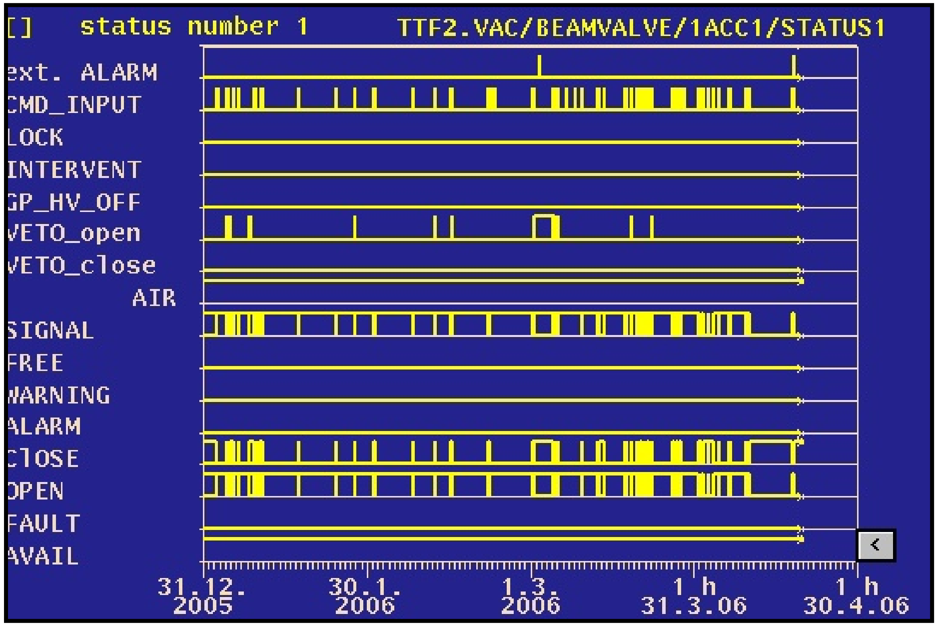


Interlocks/Safety Checks

- **Self safe operation of system**
  - failing of equipment (pumps, gauges)
- **Vacuum interlocks ↪ closing of valves**
  - pressure increase
  - failing of equipment (pumps, gauges)
  - switching off equipment
- **Fast shutters/delay lines**

prepare adequate tools for check-out in advance

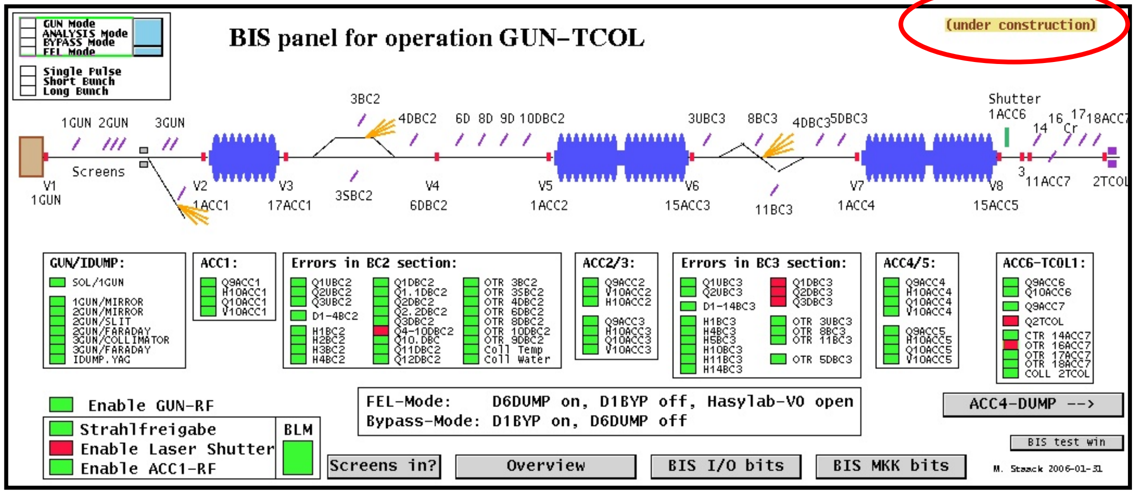
TTF/FLASH



Interlocks/Safety Checks

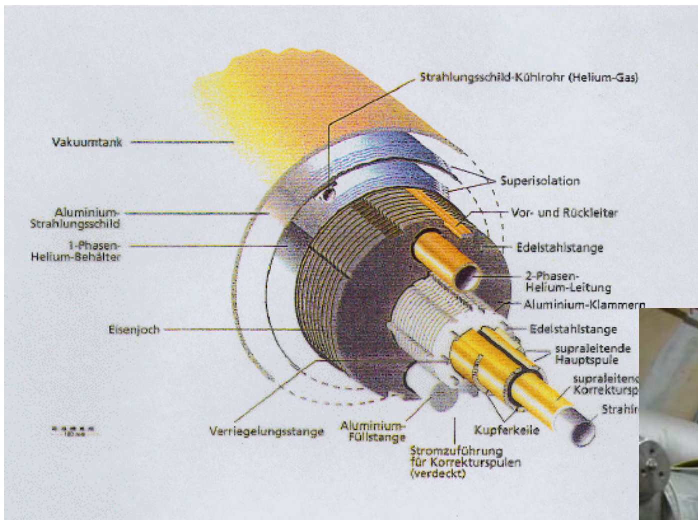
- **Beam interlocks**
  - linear accelerator ➥ stop beam production
  - storage rings ➥ dump beam
- **Different modes of beam operation**
  - injection
  - user beam lines
- **Interlocks connected to other systems**
  - diagnostics
  - experiments

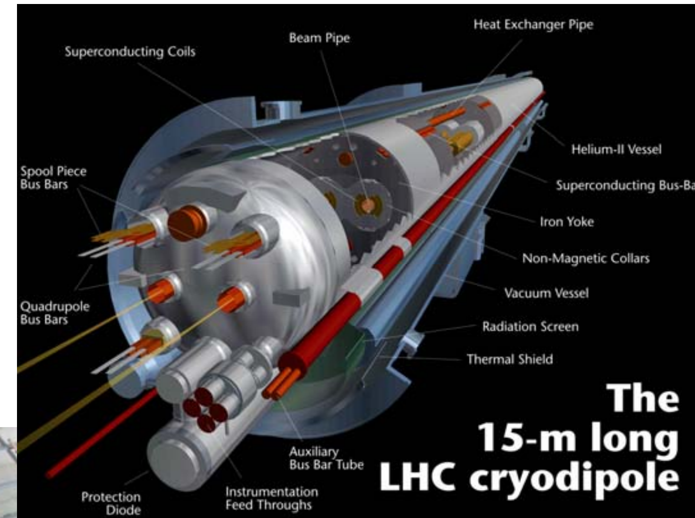
TTF/FLASH



Cryogenic Systems

- **Superconducting magnets**
  - beam pipe partially surrounded by liquid helium
    e.g. Tevatron, HERA, RHIC, LHC

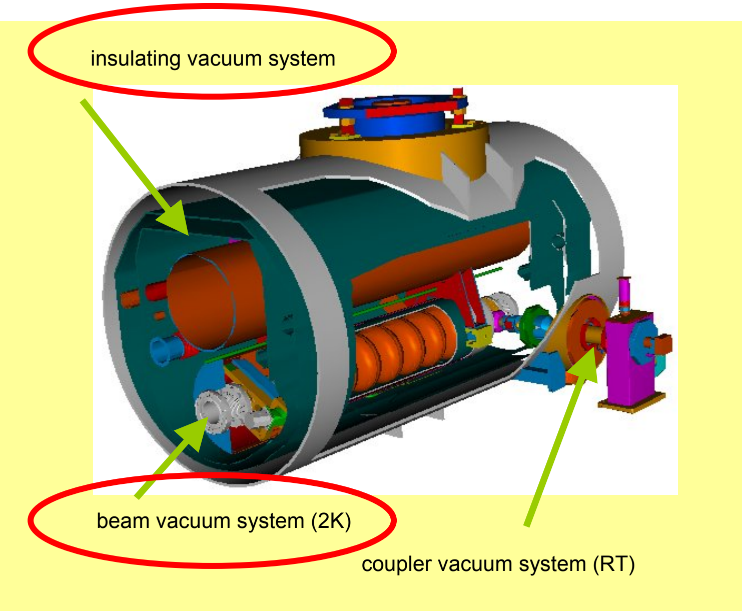




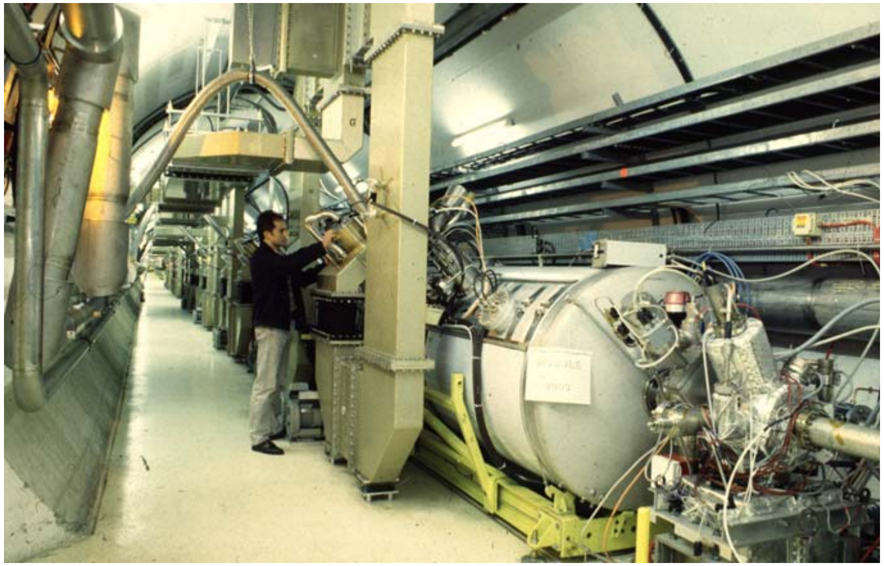
HERA

Cryogenic Systems

- **Superconducting accelerating structures (cavities)**
  - cavities = beam pipe surrounded by liquid helium
    e.g. Tristan, LEP, CEBAF, TTF/FLASH, XFEL, …



TTF, XFEL

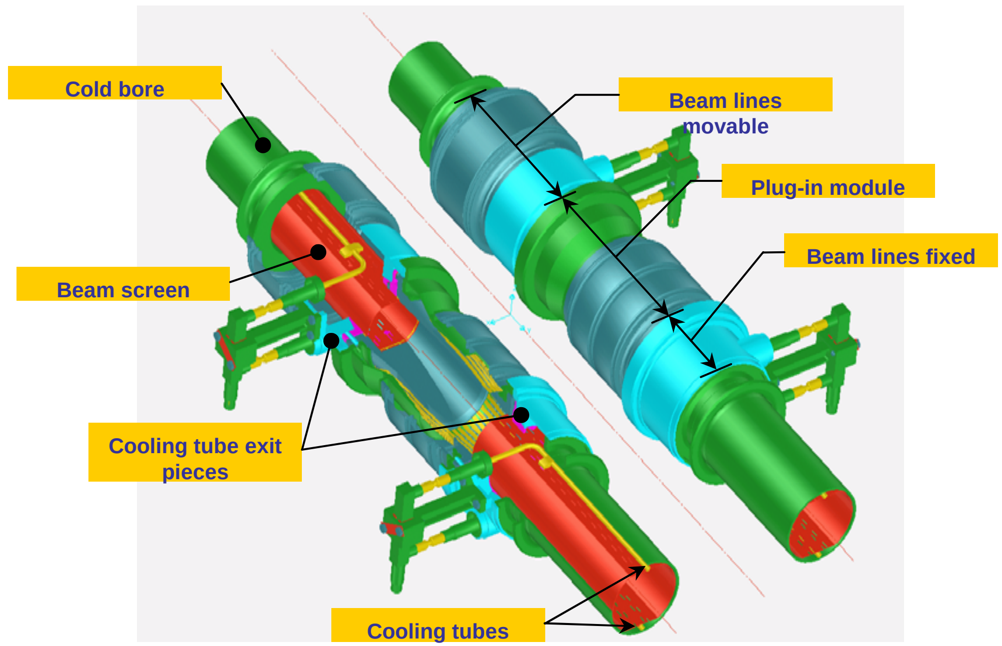


LEP

- **Special insertions for superconducting wigglers, experiments etc.**

Cold Beam Vacuum Systems

- **Leak check of final connections**
  - flanges, in-situ welds
  - no leak check under cold conditions possible
    - extreme care necessary, e.g. integral leak check

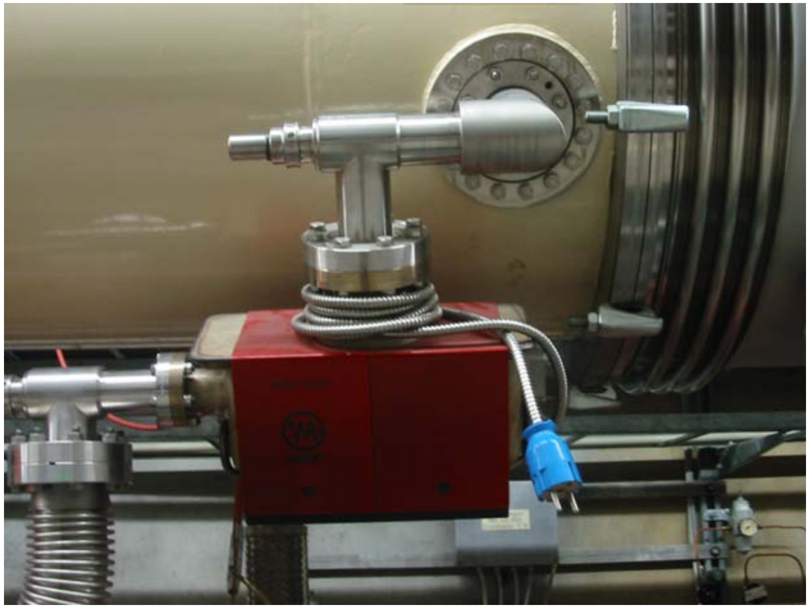


LHC

Cold Beam Vacuum Systems

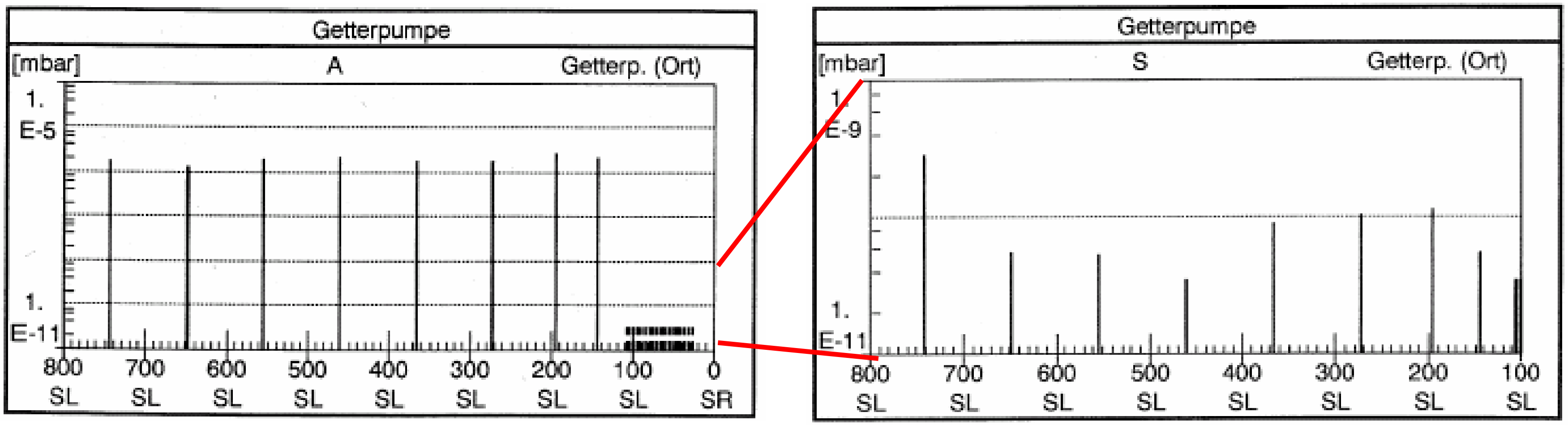
- **Pressure before cool down**
  - permanent pumps (e.g. sputter ion pumps)
    - HERA: $p \sim 10^{-6}$ mbar
  - no active pumping after pump down
    - RHIC $p < 10^{-2}$ mbar

HERA



Cold Beam Vacuum Systems

- **Cool down**
  - beam pipe = cryo pump ➥ pressure drop

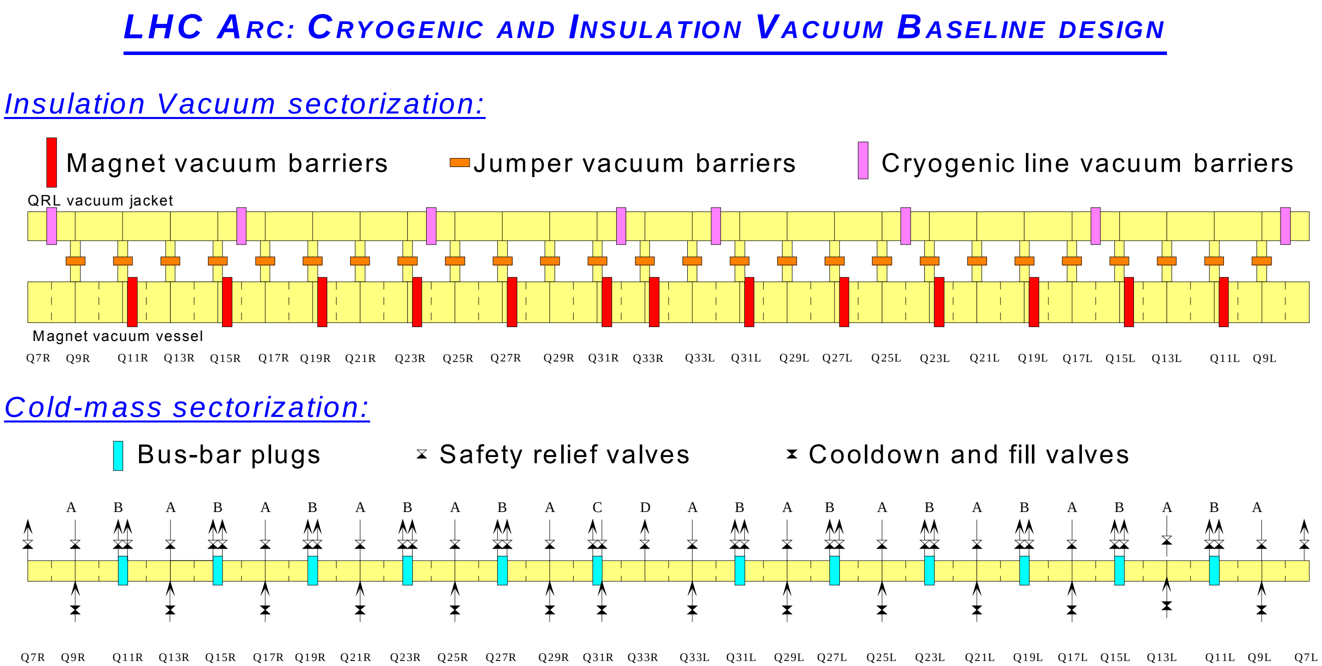


HERA
RT ➥ 4.5 K

- **Measure integral leak rate and wall coverage**
  - release of gas during warm up measured with RGA

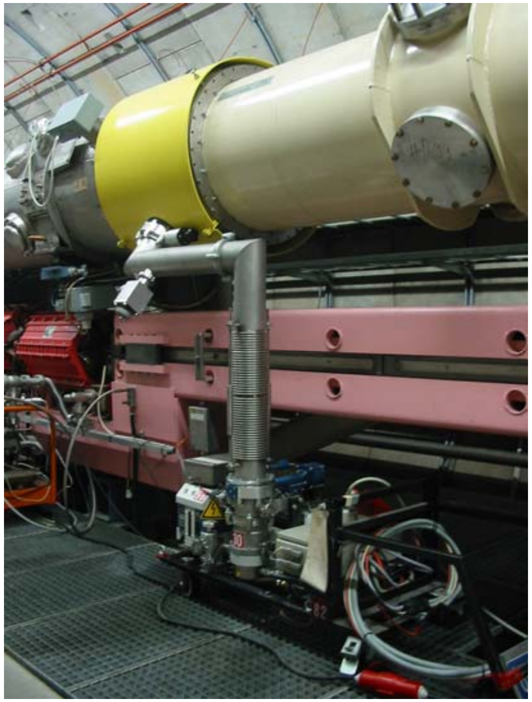
Insulating Vacuum Systems

- **Segmentation**
  - distance of vacuum barriers has increased with time
    - HERA ➥ 20 m
    - RHIC ➥ 500 m
    - LHC ➥ 200 m
  - ➥ larger distance = increased complexity for commissioning

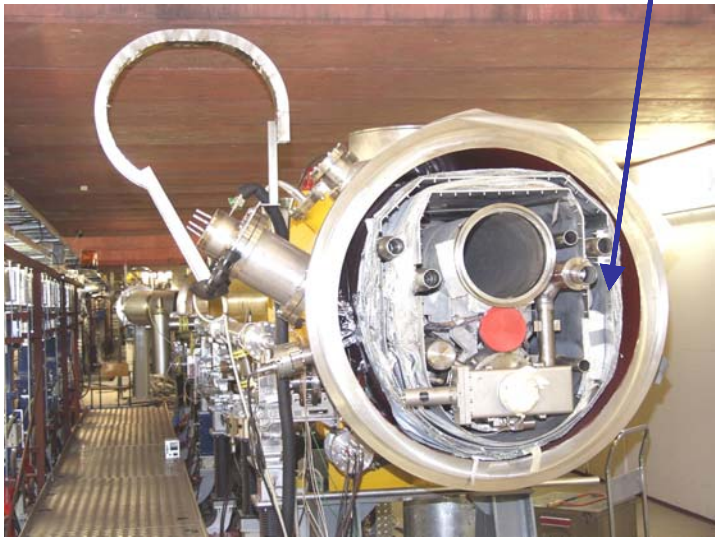


Insulating Vacuum Systems

- **Pump down**
  - equipment
    - start with large roughing pumps
    - sufficient mobile pump stations necessary
  - initial pump down dominated by large amounts of water from super insulating foils
    - be prepared for frequent maintenance of roughing pumps
    - eventually flushing with N_2



HERA



TTF/XFEL

Insulating Vacuum Systems

Example

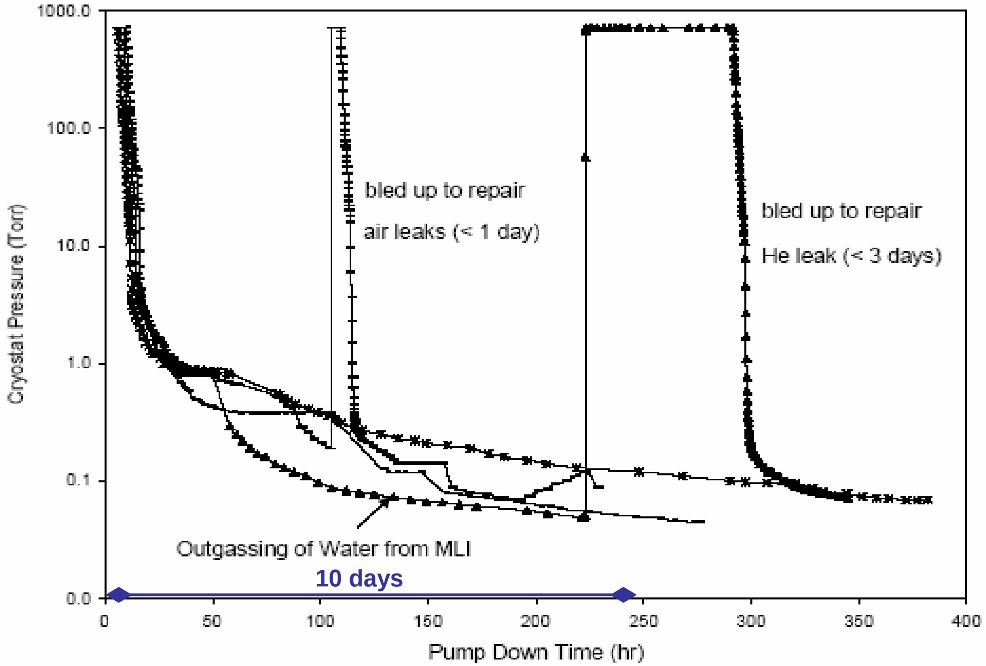


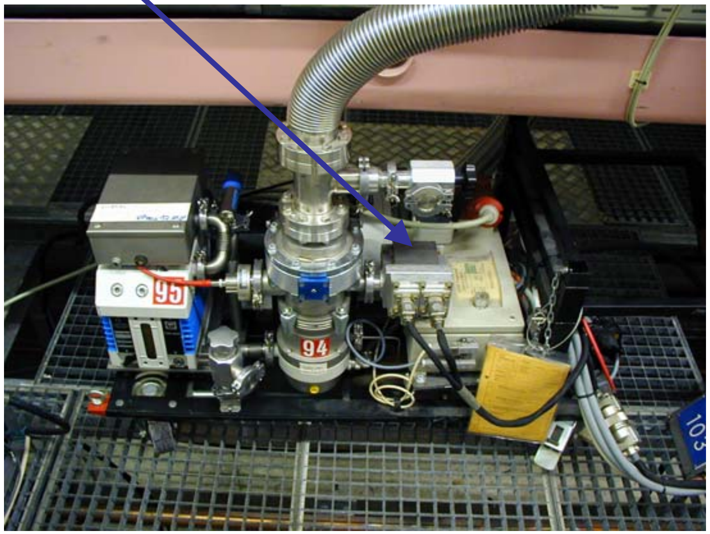
Fig. 6 Pumpdown Curves of RHIC 494m Arc Cryostats

RHIC
D. Hseuh et al.

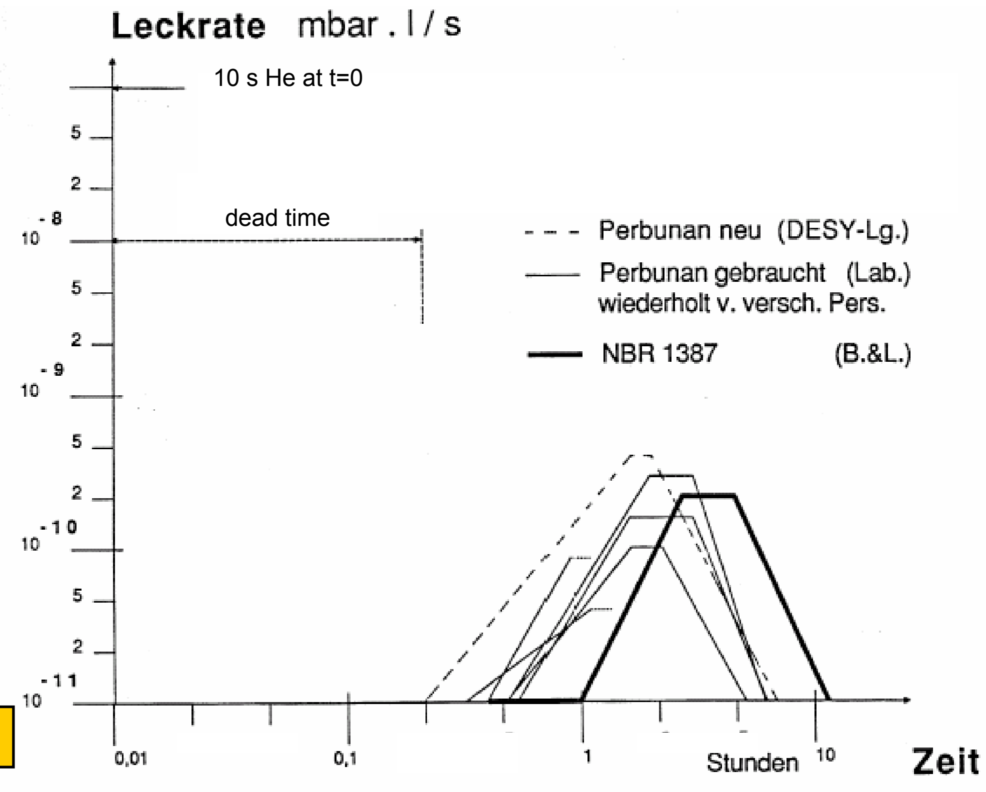
first pump down takes a long time

Insulating Vacuum Systems

- **Leak check of air leaks**
  - equipment ➥ sufficient granularity important
    - leak detectors at mobile pump stations and/or directly attached to tank
      - ➥ base pressure usually not sufficient for RGA
    - gauges
  - He background in tunnel may be significant
    - leaks from cryogenic He supply lines
    - no exhaust line for roughing pumps
      - ➥ HD as alternative to He as tracer gas
  - dead time could be significant
  - large leaks are not exceptional
    - at high pressure small leaks are not detectable
    - needs to repair large leaks first
      - ➥ repeat complete leak check



- **Leak check of air leaks (cont'd)**
  - O-rings
    - permeation determines detection limit for leaks
    - permeation takes time
      - ➥ might simulate leak due to delay in signal

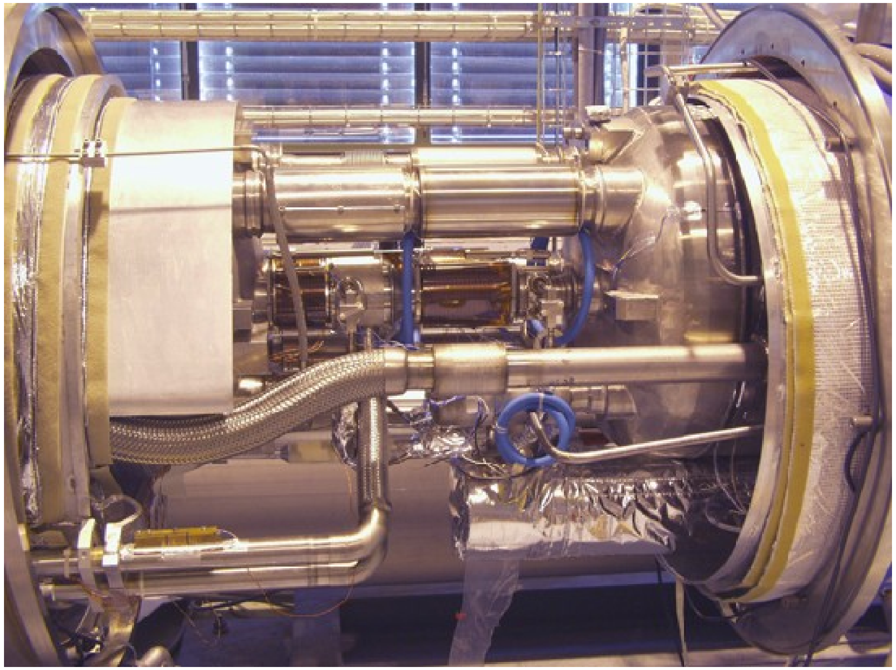


C. Falland (DESY), unpubl.

Insulating Vacuum Systems

- **Leak check of process lines**
  - equipment
    - same as for leak check of insulating vacuum
      - ➥ leak detectors/gauges
    - sufficient He compression in case of He leaks necessary
  - with insulating vacuum pumped down
    - pump out process lines
      - ➥ background level
    - pressurize one line after the other
      e.g. HERA: 15 bar He

LHC



Insulating Vacuum Systems

RHIC/ D. Hseuh et al.

- **Leak check of process lines (cont.)**
  - leak location
    - often not easy to find
      - ➥ sufficient diagnosis mandatory
      - ➥ profile of He signal
    - vent insulating vacuum, open sliding sleeves, check welds, etc.
      - ➥ pressurized with sniffer
      - ➥ pressurized with vacuum tight fixtures

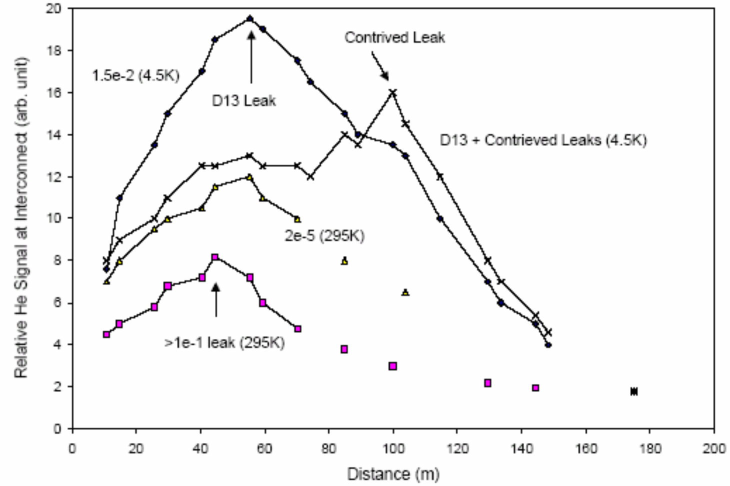
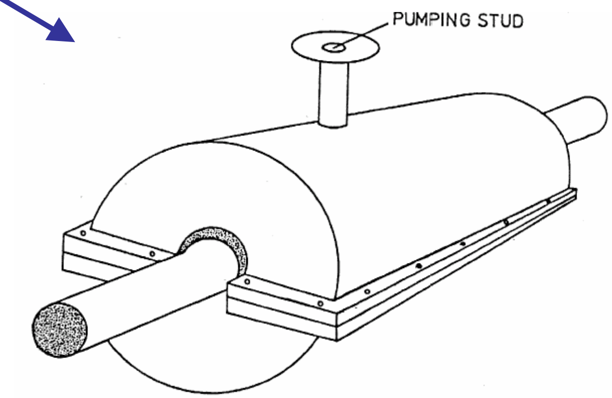


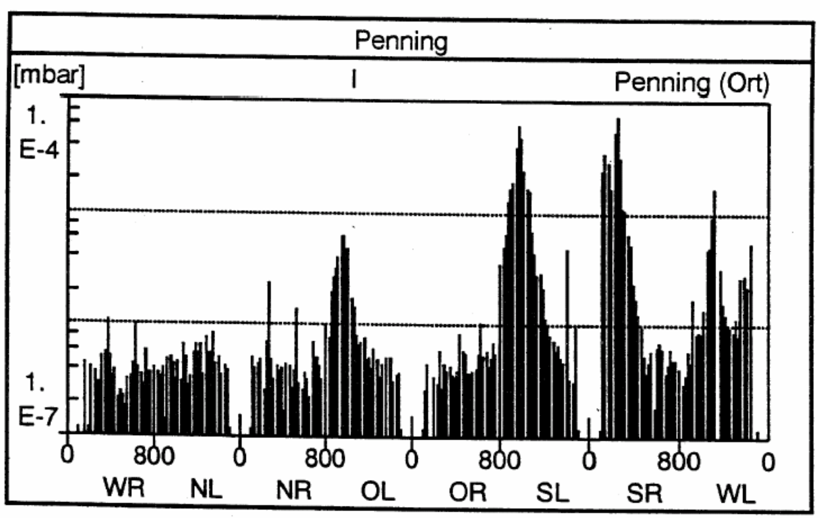
Fig. 7 Helium Pressure Gradients at Interconnects in 494m Arc Cryostats

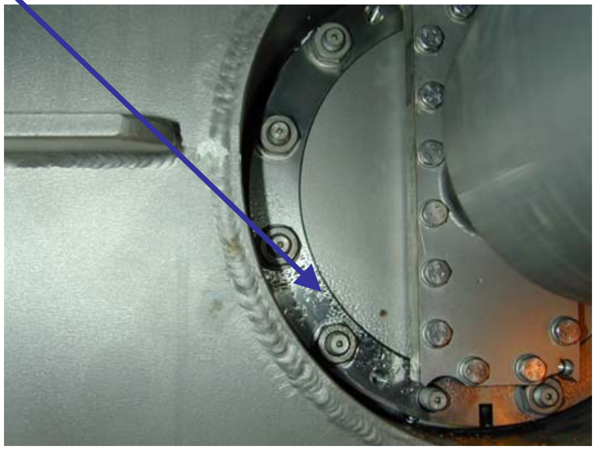
locating and repairing He leaks - difficult and time consuming effort



Insulating Vacuum Systems

- **Cool down**
  - check for movement of components due to shrinkage of materials
  - pressure drop
    - 10^{-3} mbar required before cool down
    - 10^{-6} mbar required for routine operation
      - ↪ remove part of mobile pump stations
  - check for condensation/freezing of water
    - thermal bridges
  - monitoring of He signal
    - leaks from process lines
      - ↪ locate after warm up
      - ↪ cold leaks



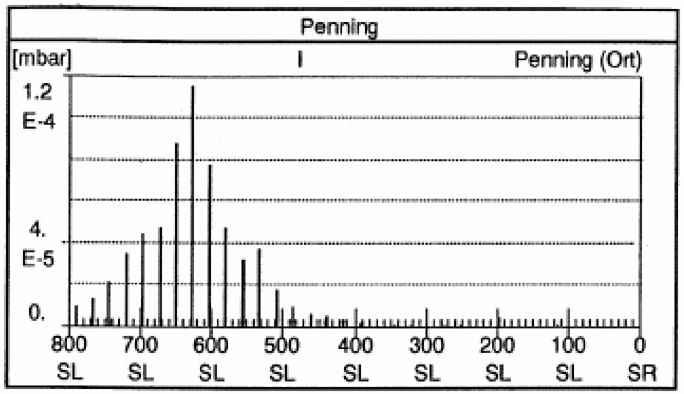


HERA
4.5 K

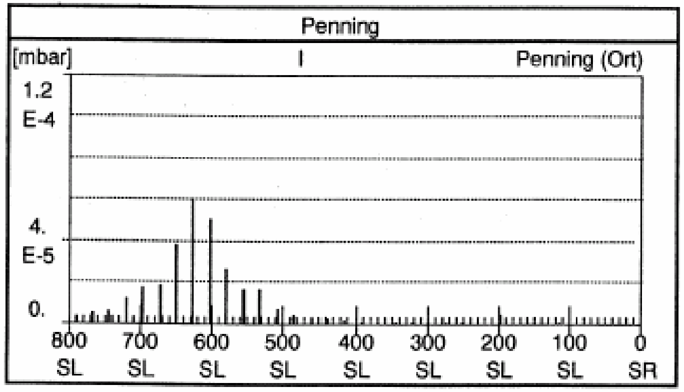
Insulating Vacuum Systems

- **Leaks which can not be localized or repaired**
  - He leaks
    - inside magnets, cavities, …
      - ➥ add pump stations at insulating vacuum
  - air leaks
    - flanges on insulating tanks, …
      - ➥ glue, rubber mastic …

HERA
4.5 K



a) Normal distribution of pump stations and valves open



b) Additional pump station at leaky section

Insulating Vacuum Systems

- **Observe also beam vacuum**
  - during leak check of process lines
  - during cool down
  - ↪ **direct leaks from (liquid) He at sc. cavities/ sc. Magnets**
  - ↪ **leaks against insulating vacuum**
  - ↪ **combined leaks: process lines**

    ↪ **insulating vacuum**

    ↪ **beam vacuum**

  - less critical if leak against insulating vacuum
  - not so nice ↪ He leaking into beam vacuum

    ↪ supply sufficient pumping speed for He

    e.g. sputter ion pump with enhanced He pumping speed

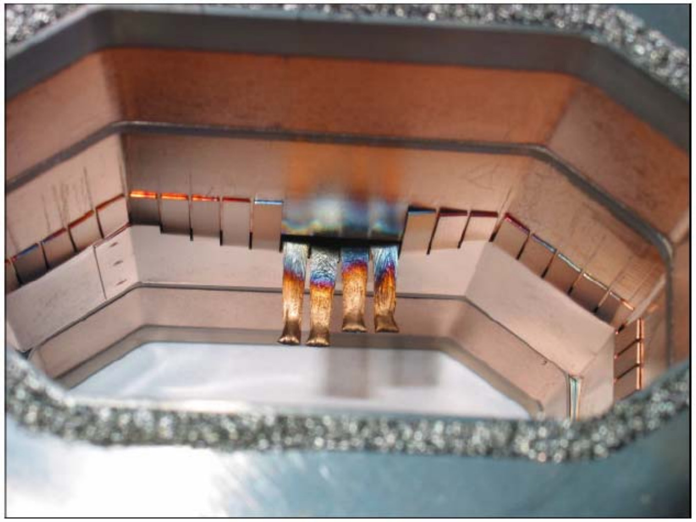
    e.g. charcoal (RHIC)

First Beam

- **First passage of beam …**

  … possible reasons if the beam does not pass

  - closed valves
  - obstacles, e.g. rf fingers
  - …
  - proper functioning of magnets, etc.

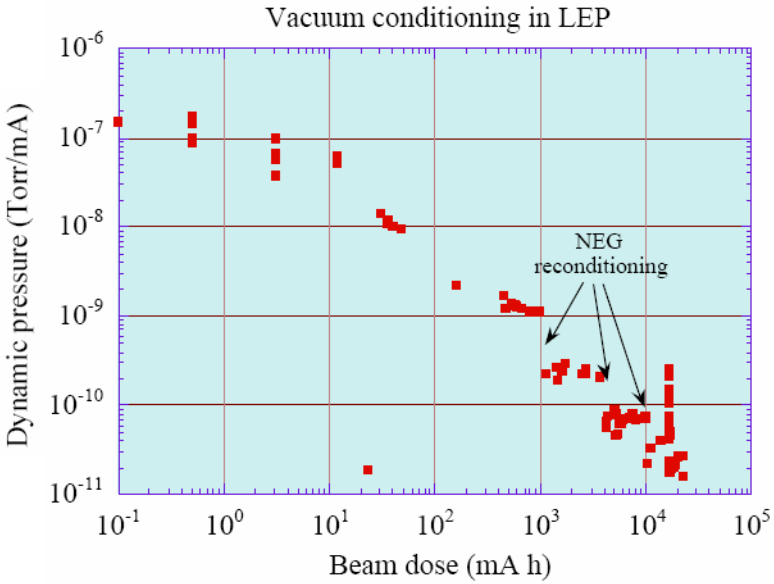


- **Check heating of components**
  - proper rf-shielding
  - proper cooling (synchrotron radiation)

First Beam

- Beam life time
- Beam-gas effects
- Pressure behavior
  - thermal heating
  - photon-induced desorption

- Conditioning of vacuum with beam
  - cleaning of surface ➥ beam scrubbing



LEP
O. Gröbner

Concluding Remarks

Commissioning → (final) proof of correct
layout
design
manufacturing and
installation

- **Sufficient time for systems tests necessary**
  - installation of vacuum system is one of the final steps of accelerator installation
  - time slot often reduced due to delays of preceding steps
  - pump down can not really be speed up

proper planning of commissioning
=
part of vacuum system planning

Courtesy to A. de Zubiaurre Wagner