HERA
Technological challenges

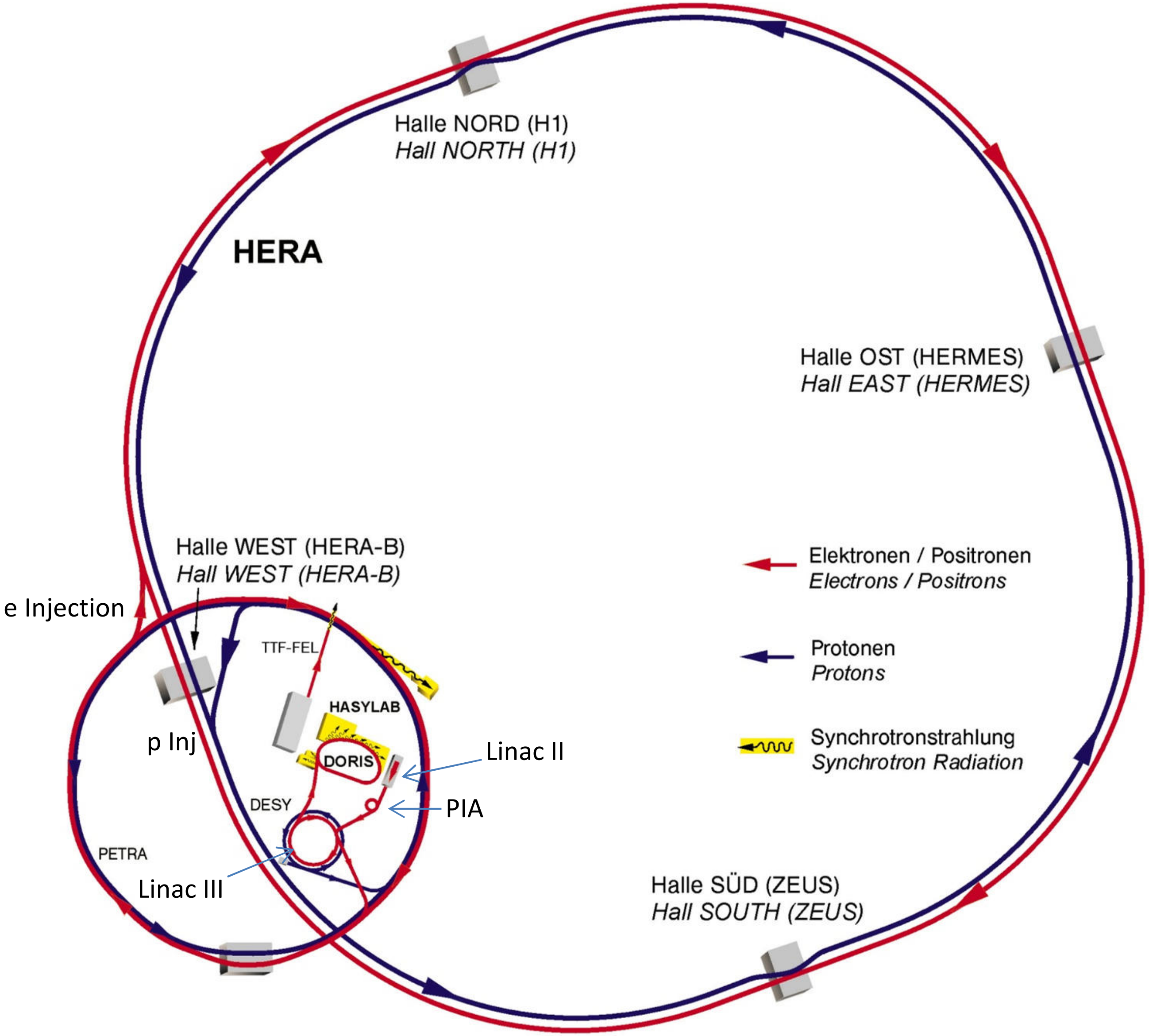
HERA
Technical challenges/problems during operation

Reverence to and admiration for

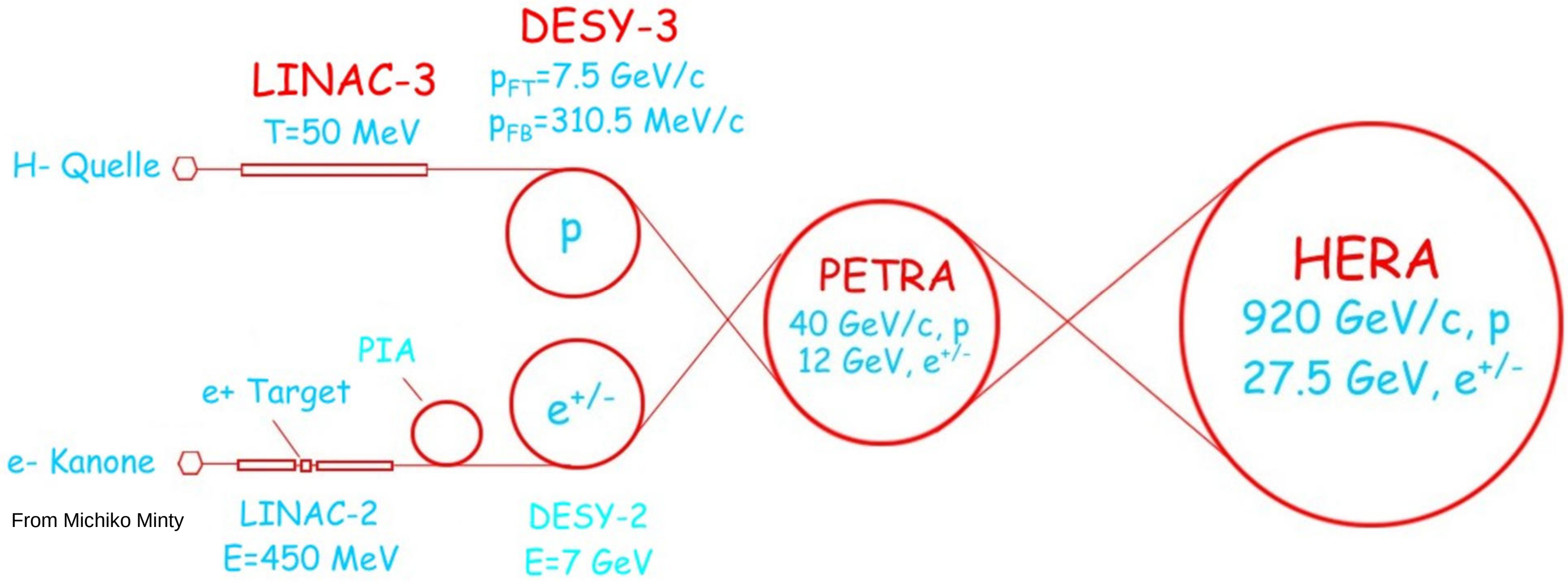
Bjoern H. Wiik

Volker Soergel

HERA was the first facility of its kind.
It was the most complicated accelerator project ever built at DESY
and the operation of the chain of accelerators was demanding



Especially the accumulation of protons in HERA
and the ramp up of the s.c. magnets from 40 to 820/920 GeV
was time consuming and touchy



From Michiko Minty

Many parameters had to controlled: like the frequency of betatron oscillations; the frequency of the p-RF systems to follow the change in the p velocity during ramp up, the length of the proton bunches had to be shortened without producing satellite bunches…….

Any failure or mistake during the ramp up or at the operation energy
would require a complete new cycle and cost at least 1 hour of luminosity operation

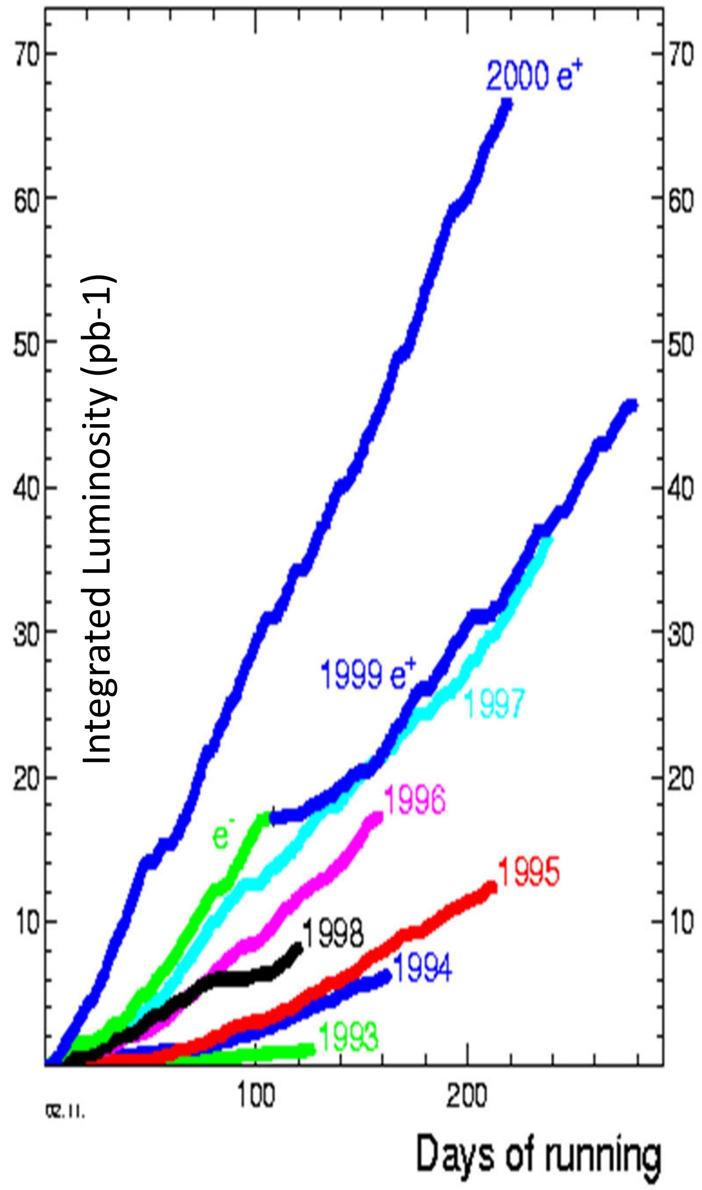
Period 1993-2000

HERA start up in 1993 was tough

- operational efficiency poor
- beam currents far from design
- Many technical failures mainly on conventional systems like water systems, power supplies, and 'warm' magnets

It is worth noting that the superconducting magnet system did not generate many problems contrary to previous suspicions

Integrated luminosity over the years



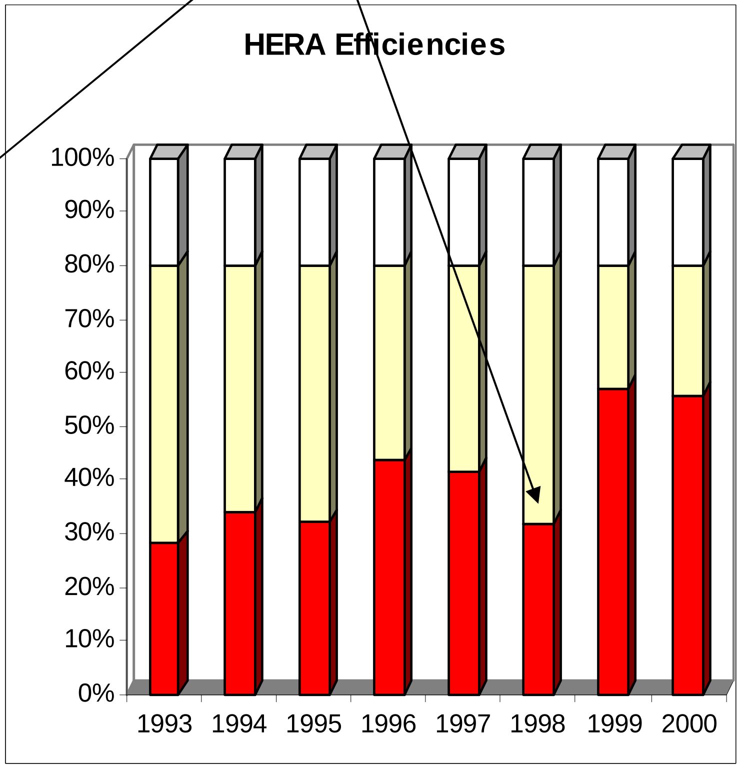
Period 1993-2000

As time went on, performance gradually improved due to:

- **growing experience of the operations crew**

- **increase of mean time between failures** by
  preventive maintenance
  water systems; power supplies
  replacement of unreliable components
  For example:
  new main dipole power supply
  new coils on IR quadrupoles QS
- **lower mean time for repair** by
  requiring spare parts and components
  to be available wherever possible
- **increase of operational efficiency** by
  improved controls on components
  systematic training of operators

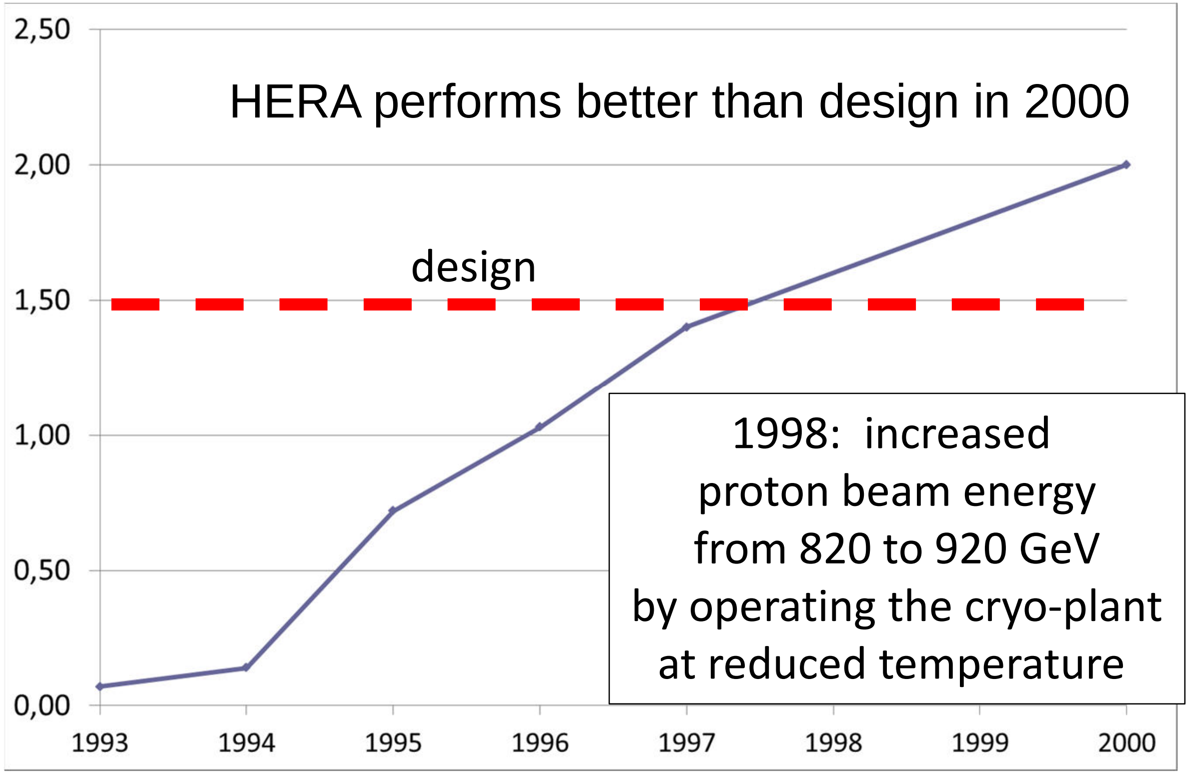
Improvement
Program

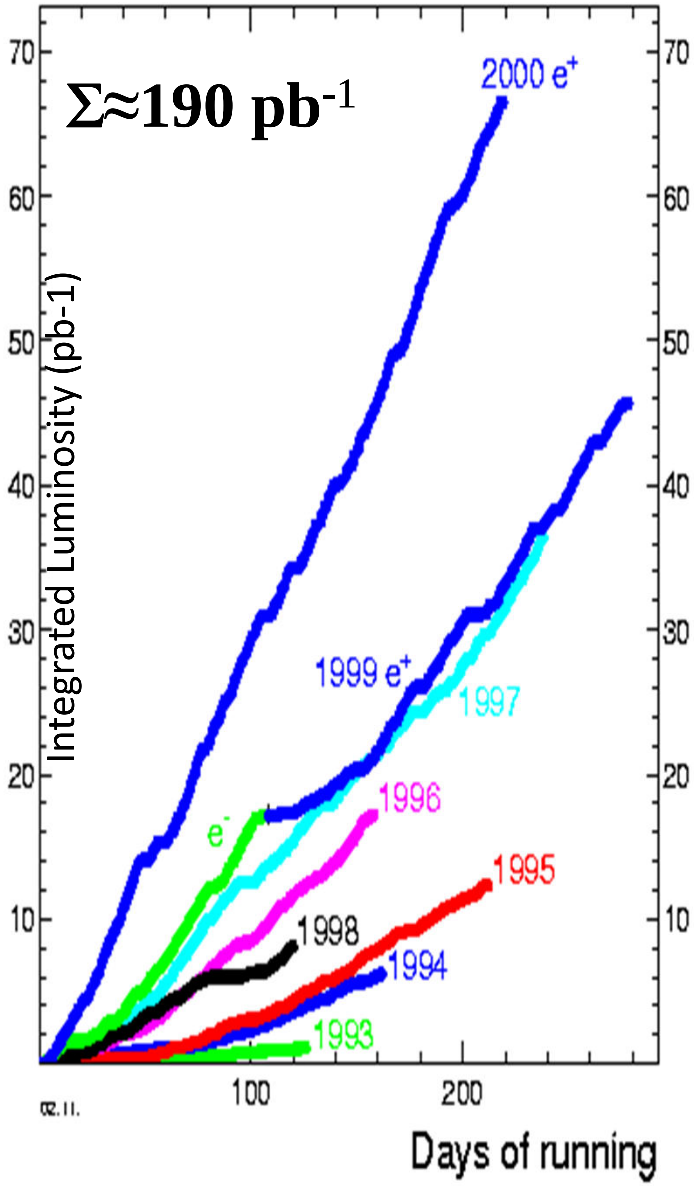


Period 1993-2000

Achievements

$10^{31} \times cm^{-2} \times \sec^{-1}$ The peak luminosity grew steadily





Background in the detectors was not a real issue

Period 1993-2000

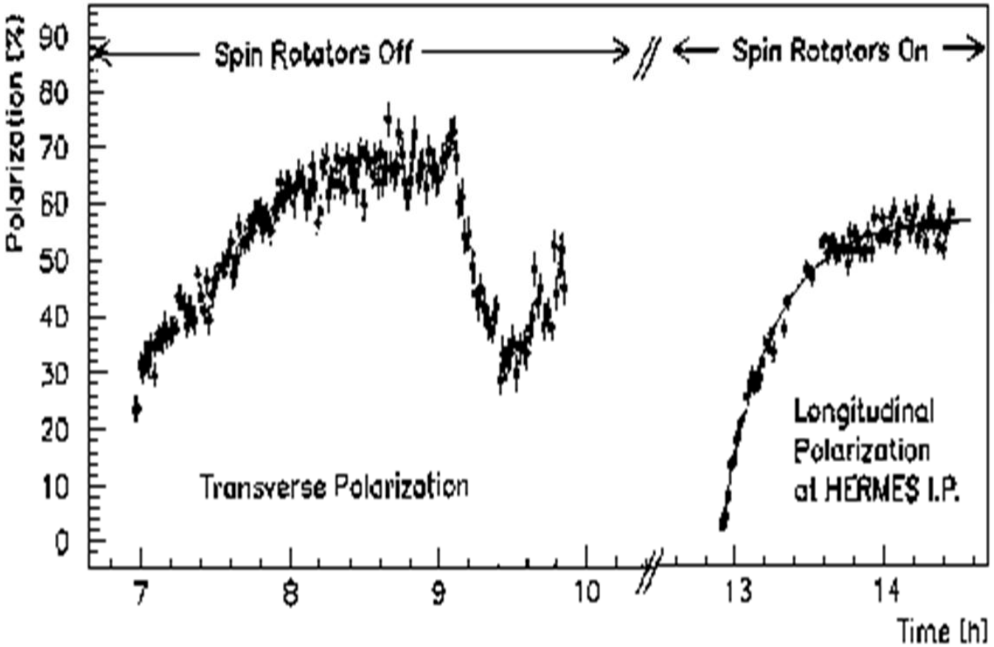
Achievements

1994: to accommodate the internal gas target experiment **HERMES**

spin rotator magnets were installed in the straight section East

HERA 1994: First Longitudinal Spin Polarization was achieved

Longitudinal Electron Spin Polarization



This achievement was due to the late **Klaus Steffen**

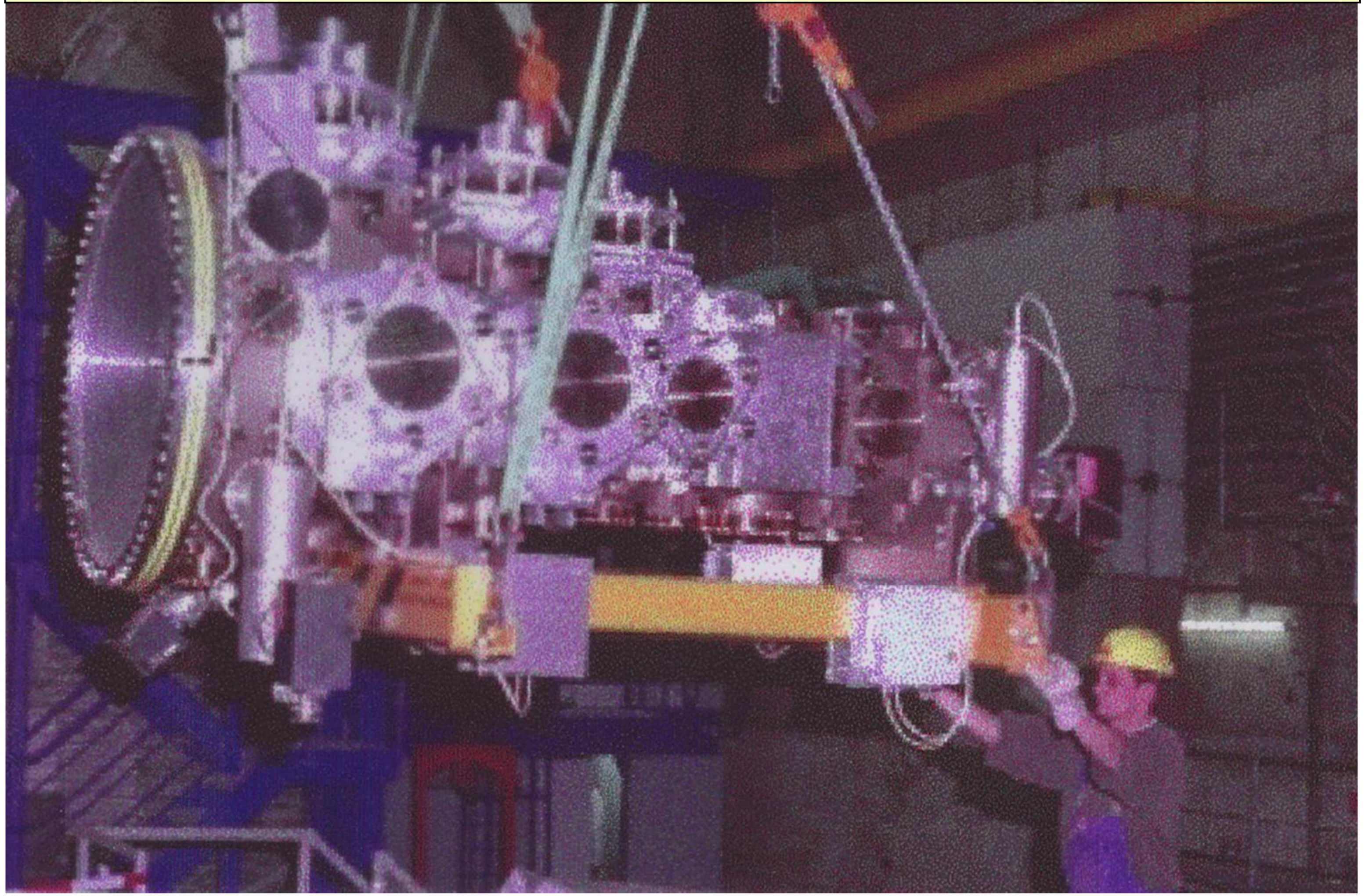
and **Desmond Barber** and the **polarization crew**

50-60% Polarization in Colliding Beam Operation

Period 1993-2000

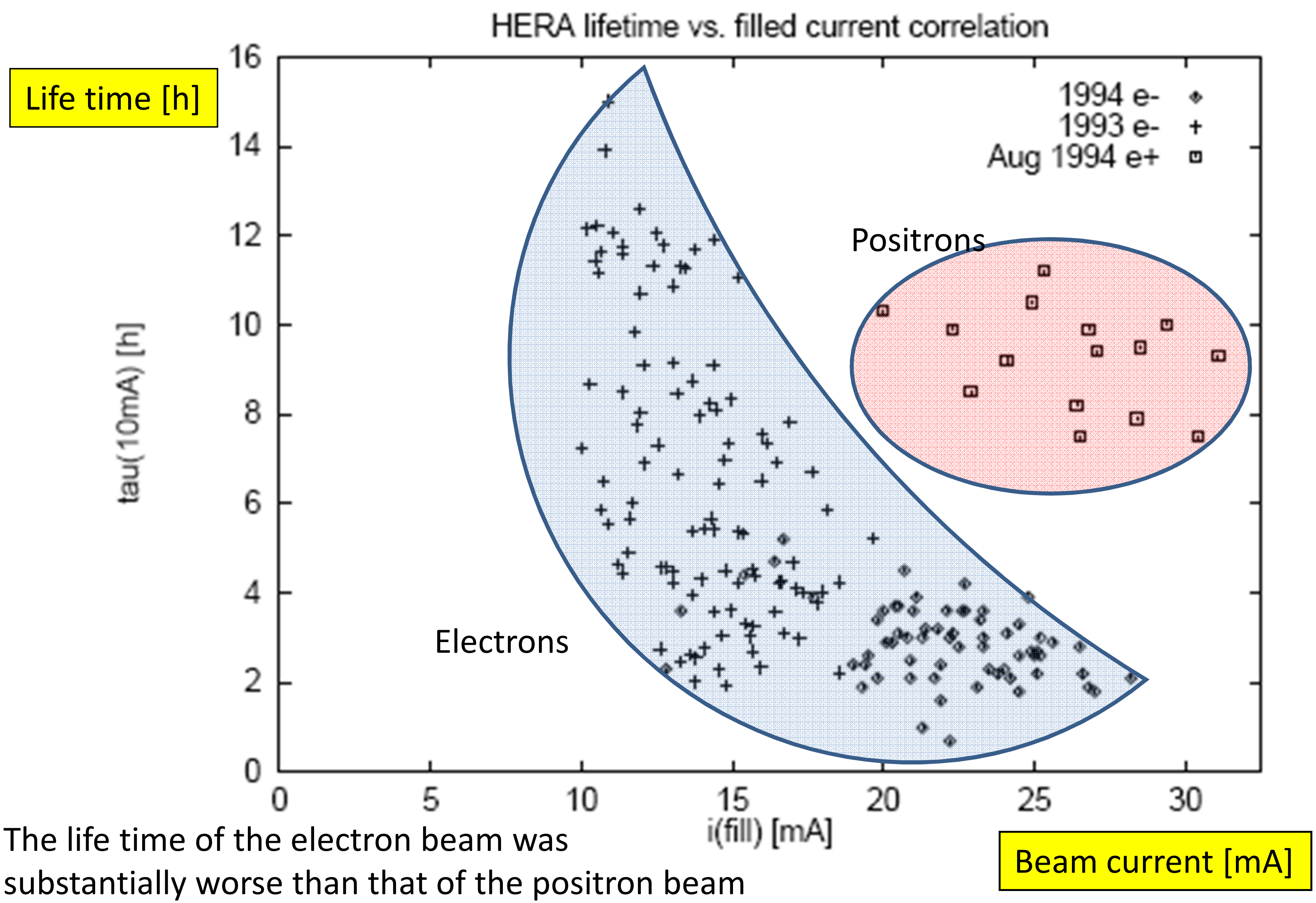
Achievements

1996 HERA-B a large fixed-target-type of detector was accommodated in an already very constrained section of the machine



Example for problems

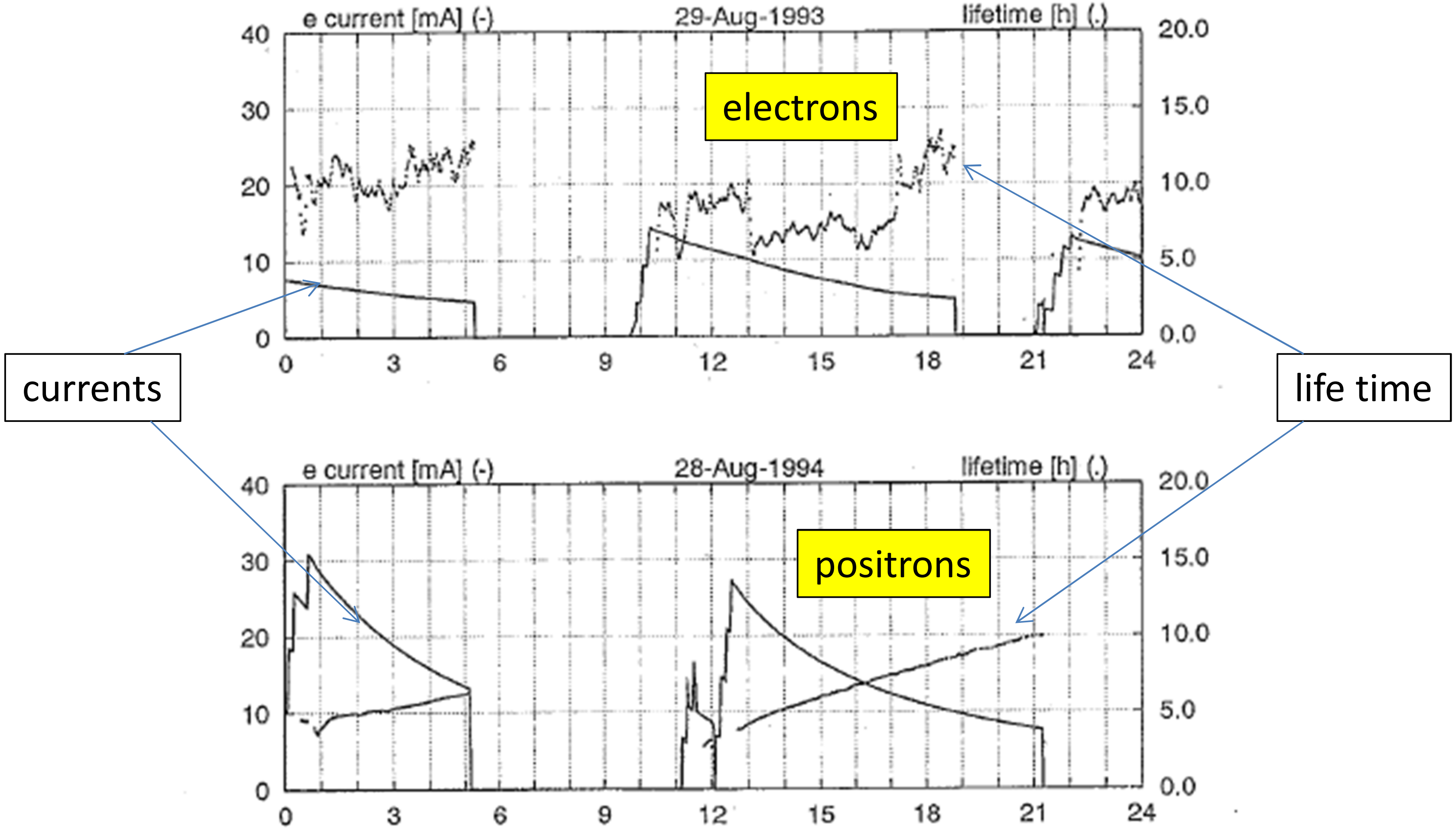
The problem with HERA e^--Lifetime



The life time of the electron beam was substantially worse than that of the positron beam

The problem with HERA e^--Lifetime

life time bumpy



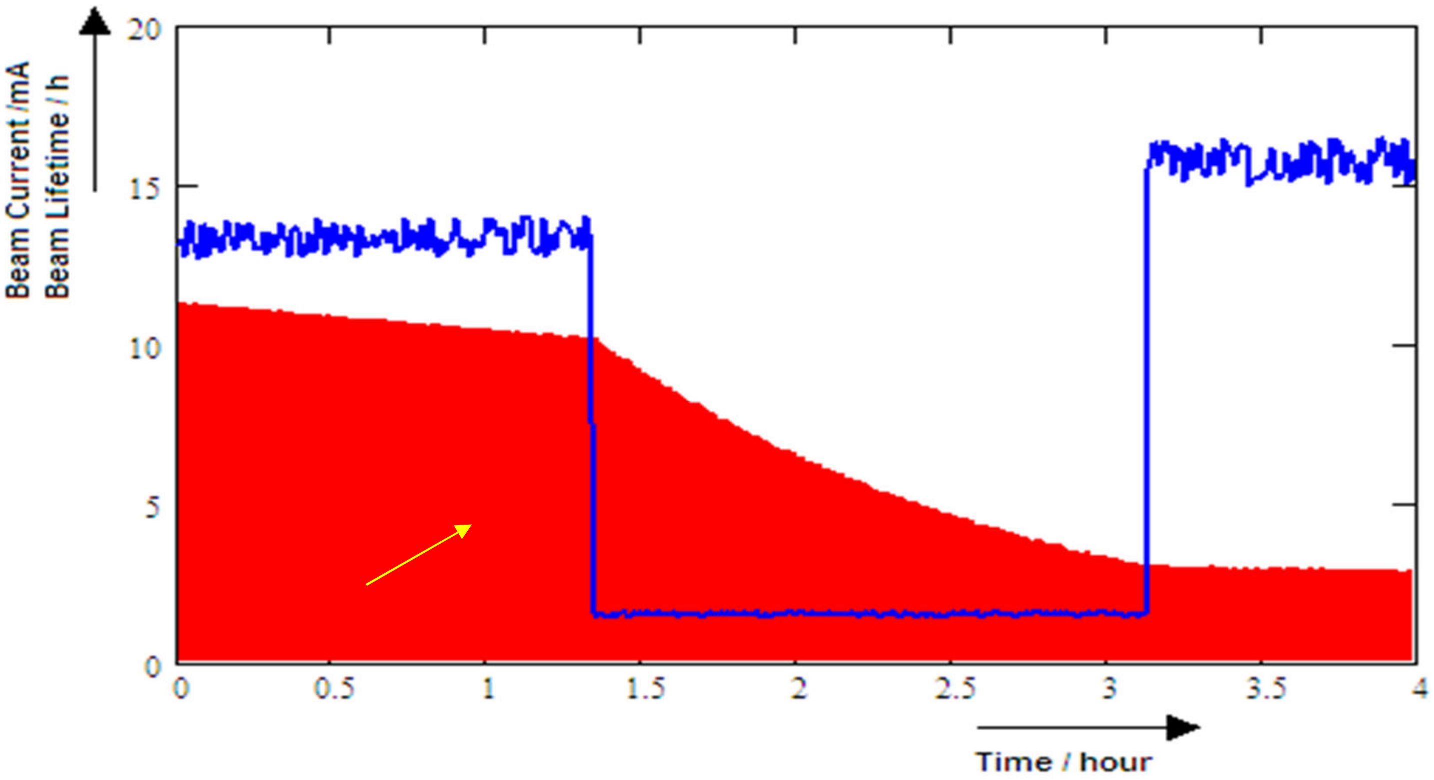
life time development smooth

The problem with HERA e^--Lifetime

occasional sudden long lasting

breakdown of the beam lifetime

above ~10mA beam current



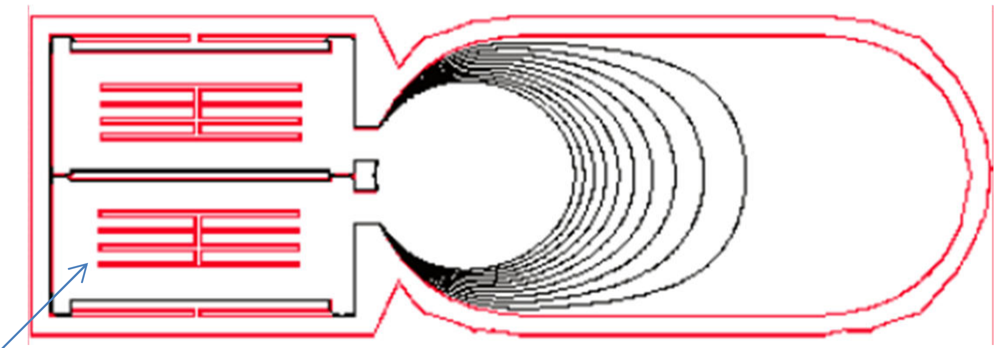
The problem with HERA e^--Lifetime

Experiments and calculations showed that the sudden breakdown of the life time was due to micrometer size **dust** particles, which get ionized by the beam. The positively charged dust particles get pulled into the electron beam and lead to increased losses of beam particles.

Experiments confirm the integrated ion pumps as a major source of dust

By switching the voltage of the pumps on or off breakdowns of the electron life time could be generated

Electron vacuum chamber in dipoles



Integrated
Ion getter pump

Beam area

The analysis of steel sheets of ion pumps showed concrete dust

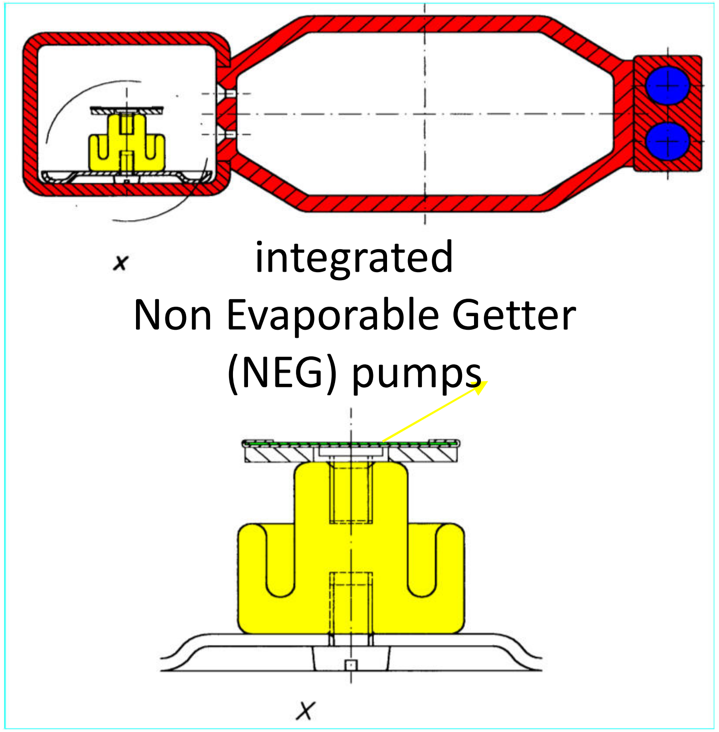
Model: Sheets vibrate due voltage drops f.e. by sparking; dust particles float into the beam region or if charged get pulled along the field lines

The problem with HERA e^--Lifetime

First reaction ➔ Operate with e^+ (1994-1997)

We decided to replace the Ion Pumps in the dipoles by NEG Pumps in the shutdown 1997/1998

Idea: no high voltage; no vibrations; no dust



Successful operation with electrons in 1999

The situation improved **but** there remained dust induced breakdowns of the electron lifetime until the end of the HERA operation

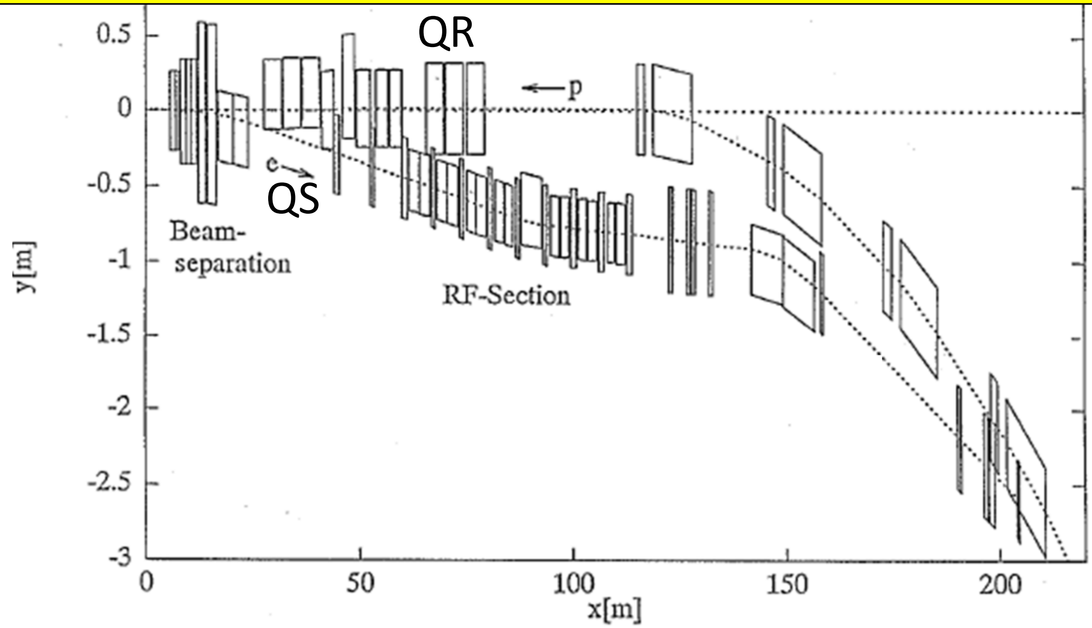
The cause of the dust-events was never really clarified. Laboratory experiments at CERN indicated however, that vibrations of the vacuum chamber may be a dominant mechanism to generate floating dust.

Luminosity upgrade

Already in 1995 studies started to investigate the possibilities
to increase the specific luminosity of HERA

Finally there were two proposals:

1) By **Reinhard Brinkmann** Conservative approach:
First step: Smaller spot size at the IP by increasing the focusing by IR quadrupoles QS and QR as much as possible
Second step: a modification of IR lattice outside the detectors
Projected luminosity increase of 1.9
Low risk, low cost, fast implementation, easy way back




Coordinator of the e-ring until 1995

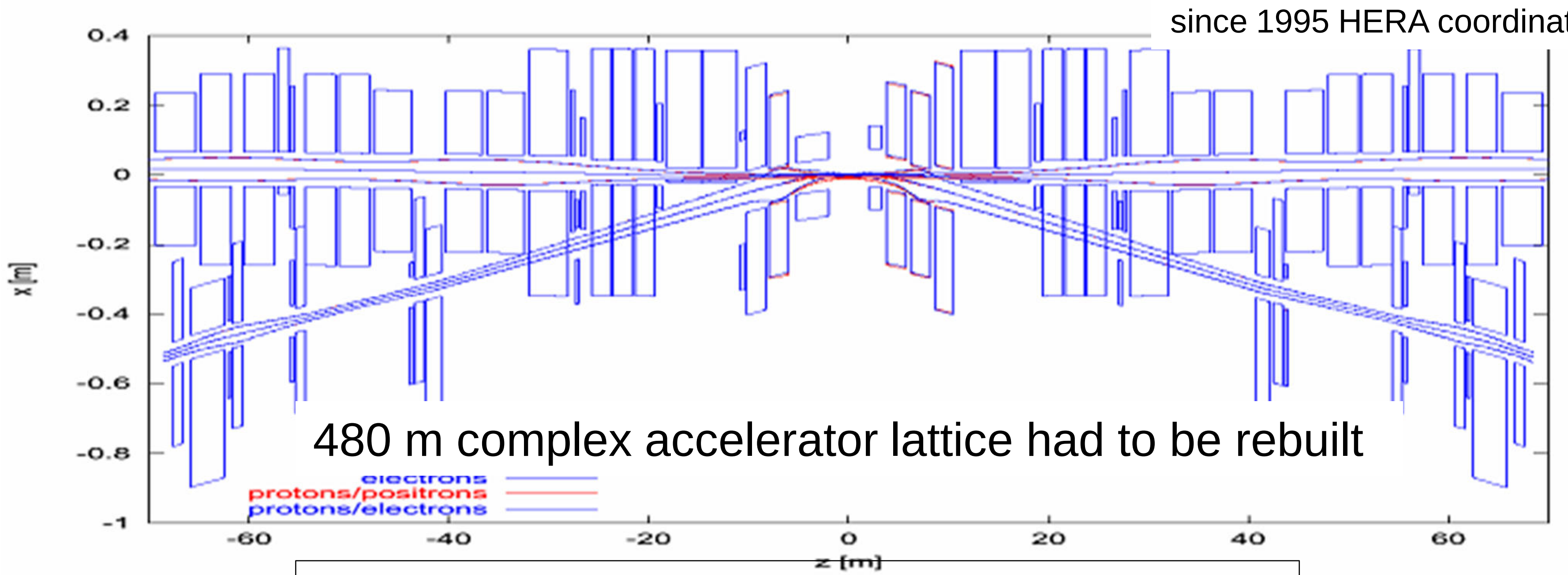
Luminosity upgrade

2) By **Ferdinand Willeke** Radical approach
Completely new layout of the interaction region
SC IR quadrupoles inside the detectors to get smaller spot sizes. Technically very challenging.

Projected luminosity increase of 3.5

Long time needed for a complete rebuilt of IR

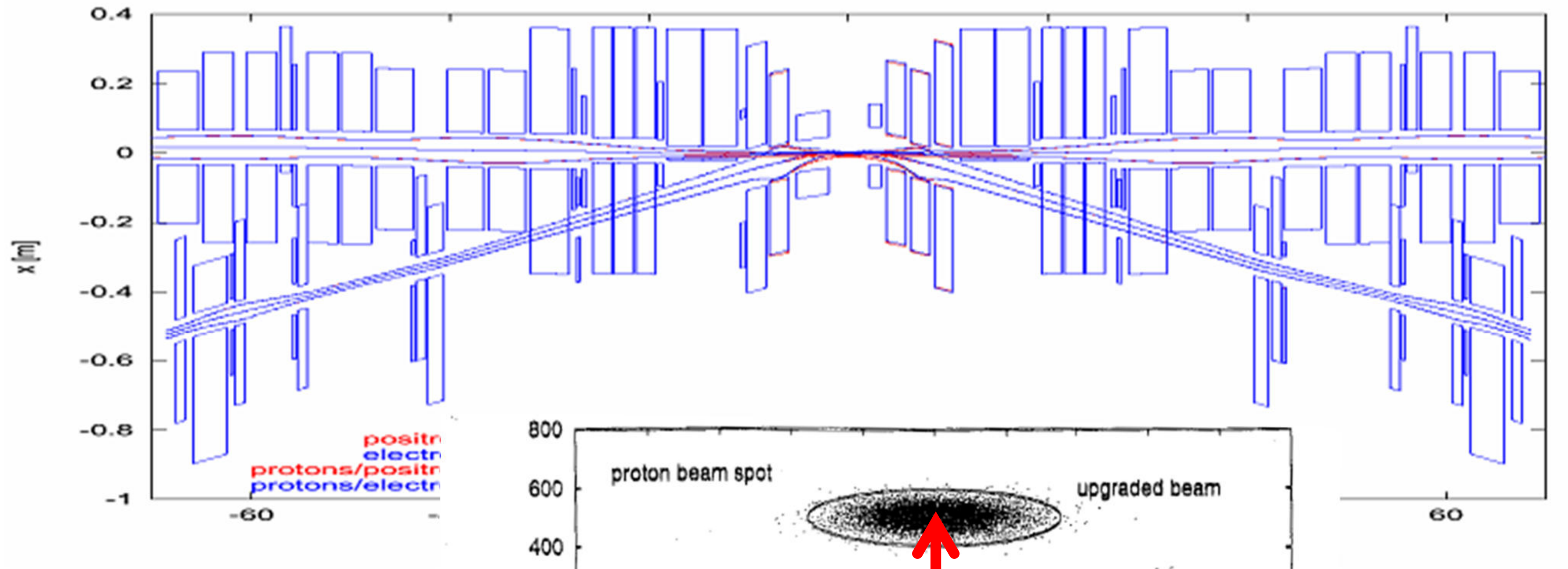
Coordinator of the p-ring
since 1995 HERA coordinator

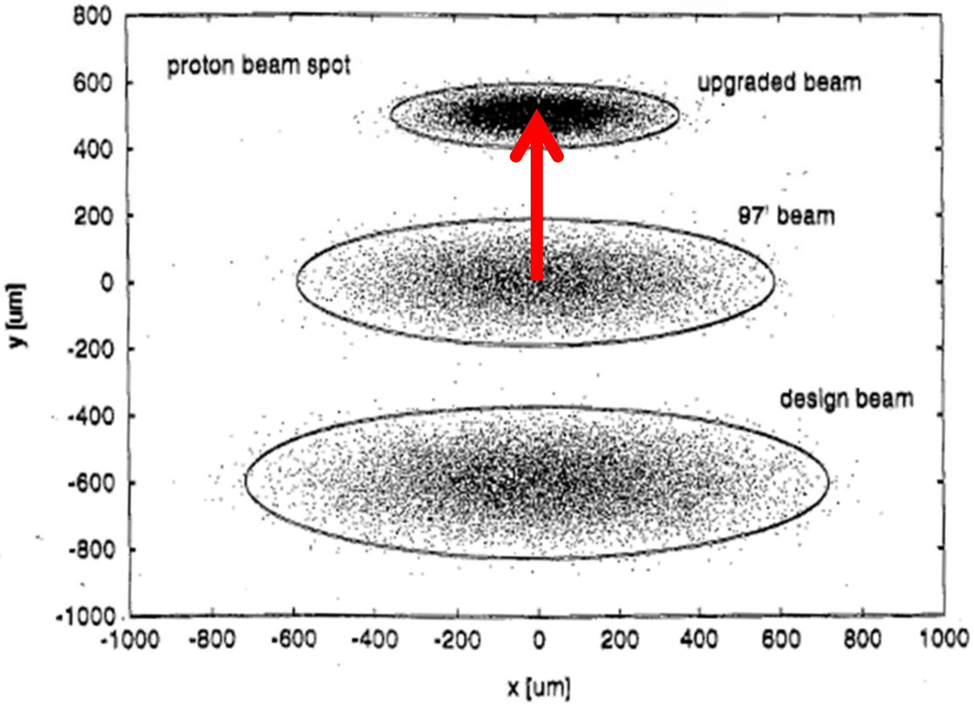


480 m complex accelerator lattice had to be rebuilt

We decided to chose the radical approach

Luminosity upgrade





projected reduction
of the p-beam size
at the IP

Challenges

Very compact super conducting magnets with fascinating new technology (Brookhaven)

OK

Accelerator magnets inside the detector with difficult (weak) suspension, difficult alignment and positioning; interference with solenoid fields; practically inaccessible

!

Very special complicated normal conducting magnets.

OK

No compensation solenoids but non local compensation by skew quadrupoles.

OK

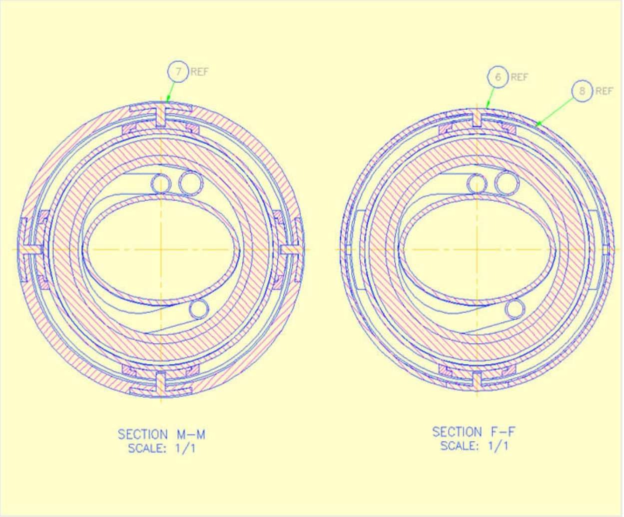
Strong synchrotron radiation generated in the IR

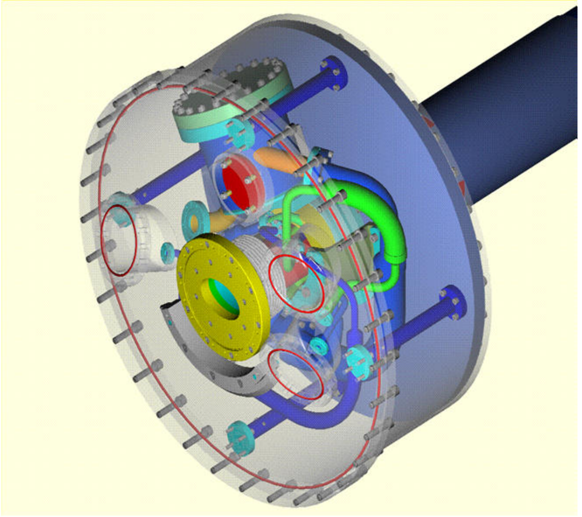
Very complicated beam pipe and collimation system

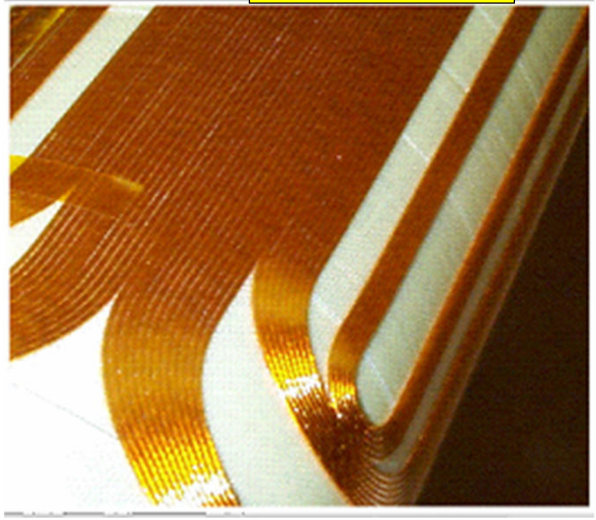
!

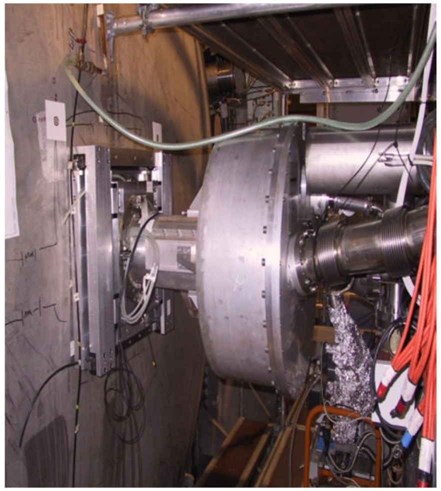
New fascinating Superconducting Magnet Technology
were developed in collaboration with BNL.
Worked as planned!

sc cables
fixed on
flexible foil

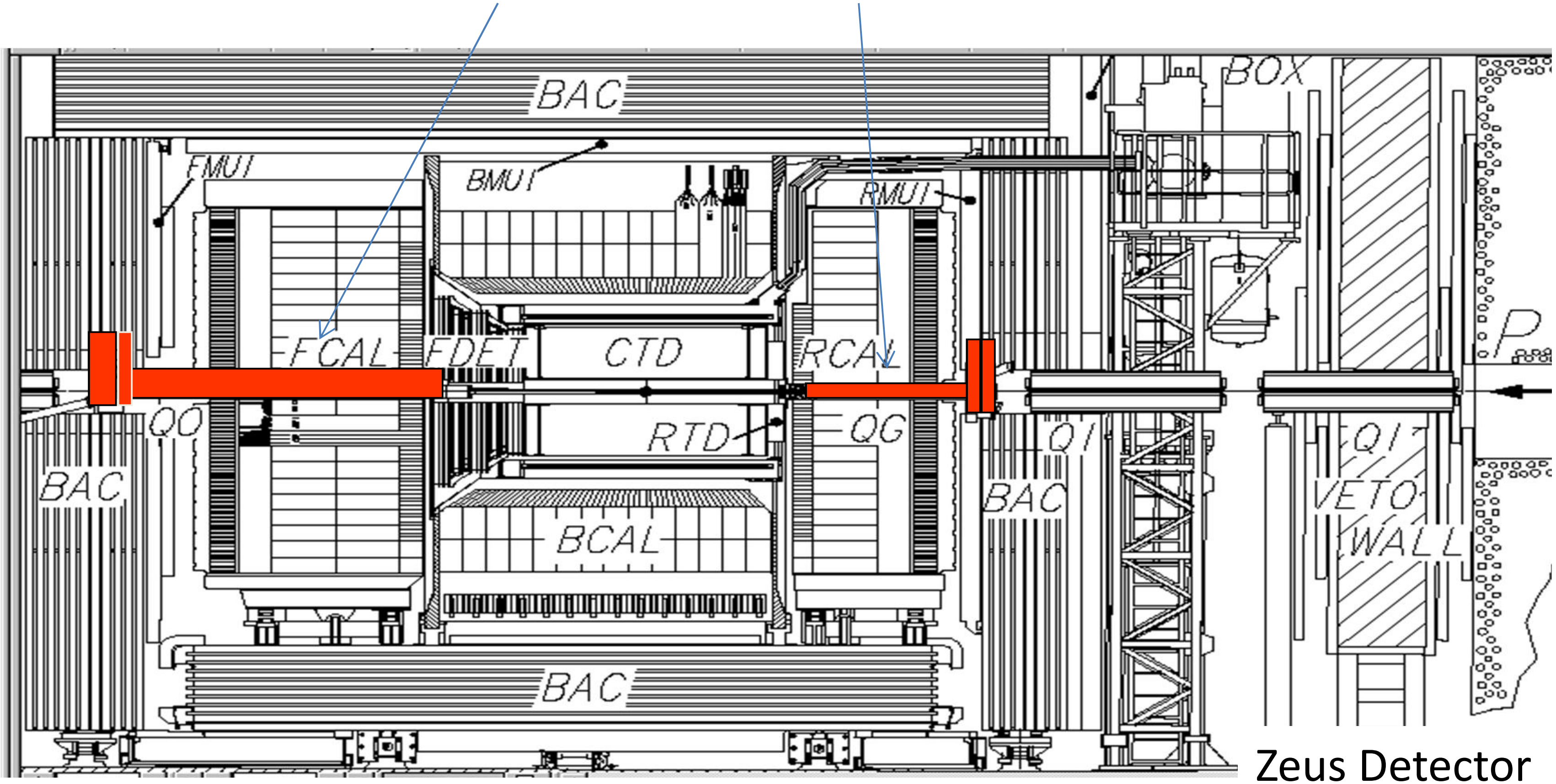






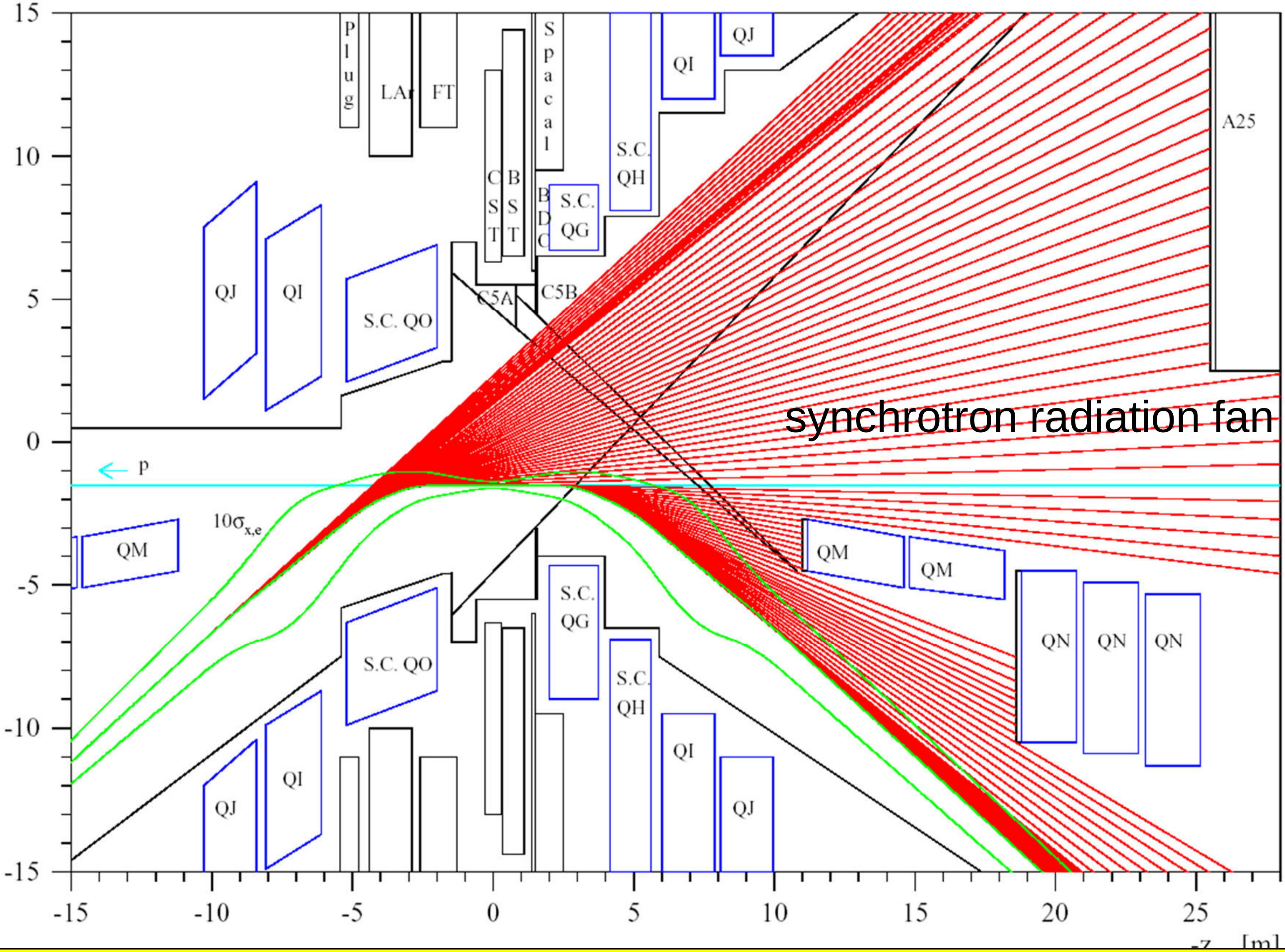


Superconducting Magnets in the Detectors



Zeus Detector

The suspension of the magnets inside the detectors was difficult. Magnets moved when solenoid fields were ramped or due to changing temperature of the support structures. Was finally solved by automated adjustment and beam steering

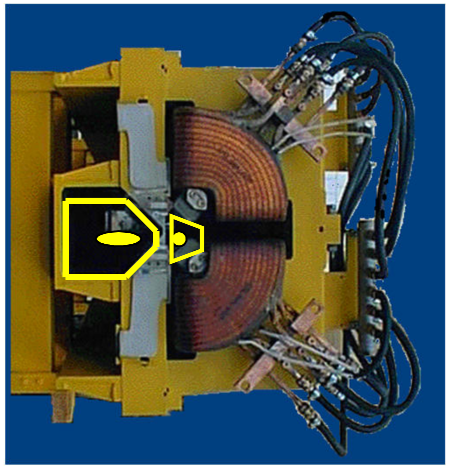


Synchrotron radiation caused severe background problems in the detectors in the beginning. Was finally managed by masking and careful beam steering

Several complicated room temperature magnets to accommodate the proton and electron beams and the synchrotron radiation fan were built and operated successfully

Room Temperature Magnets
designed & produced by EFREMOV, St. Petersburg

GM: Half quadrupole with mirror plate for vertical focussing of the protons



Room Temperature Magnets
designed & produced by EFREMOV, St. Petersburg

p e GN

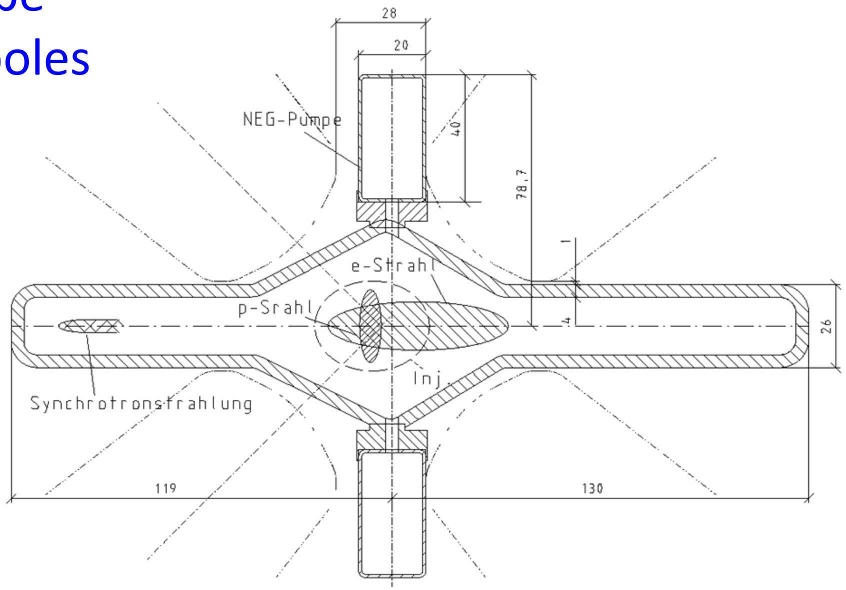
vertical focussing

of the protons

Very complicated
new vacuum system

Examples

3 Beam Pipes
through
GN-type
quadrupoles

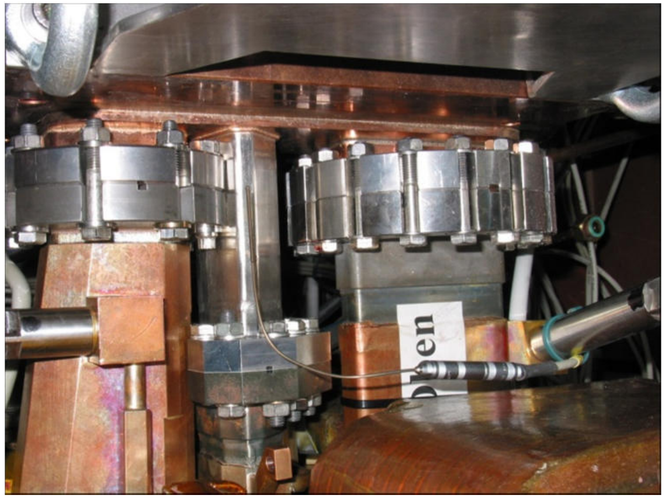


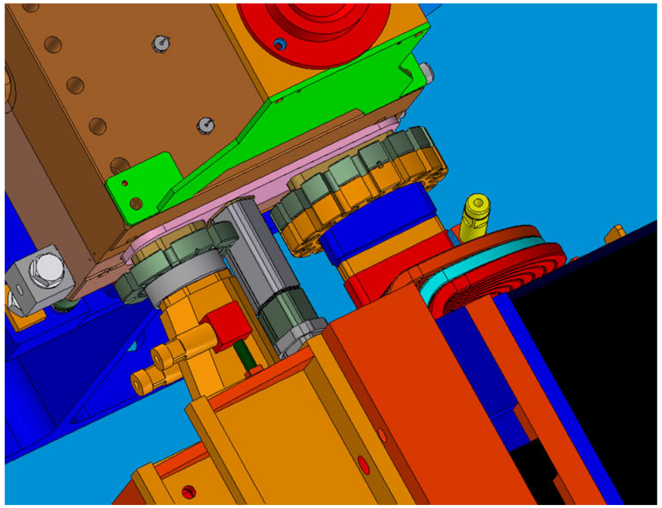
Beam pipe in GI/GJ quadrople magnets

The complicated vacuum system developed leaks during operation mainly due to thermal stresses. The situation improved due to the implementation of refined controls on temperatures and beam position.

Example problems with vacuum system

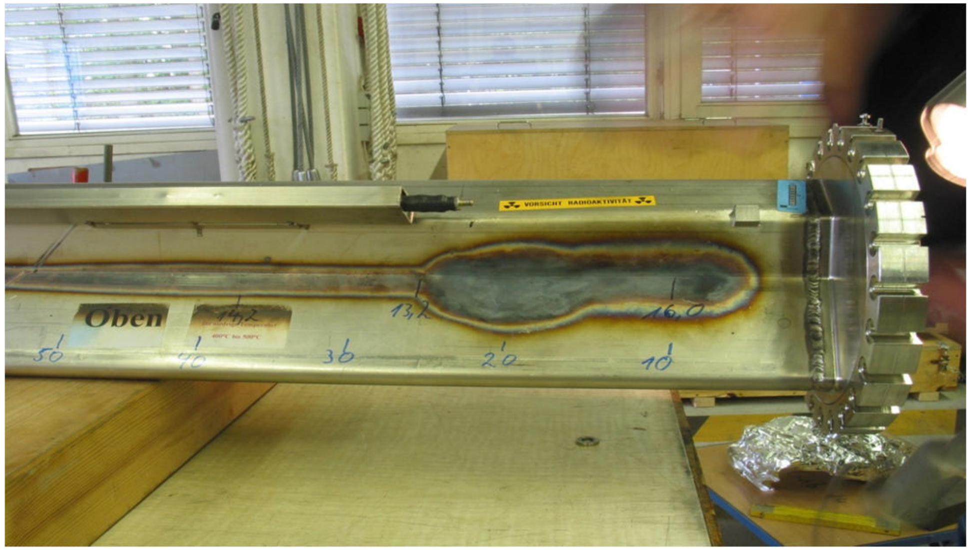
Several severe leaks at flanges at the GI GJ magnets occurred due to sudden temperature changes





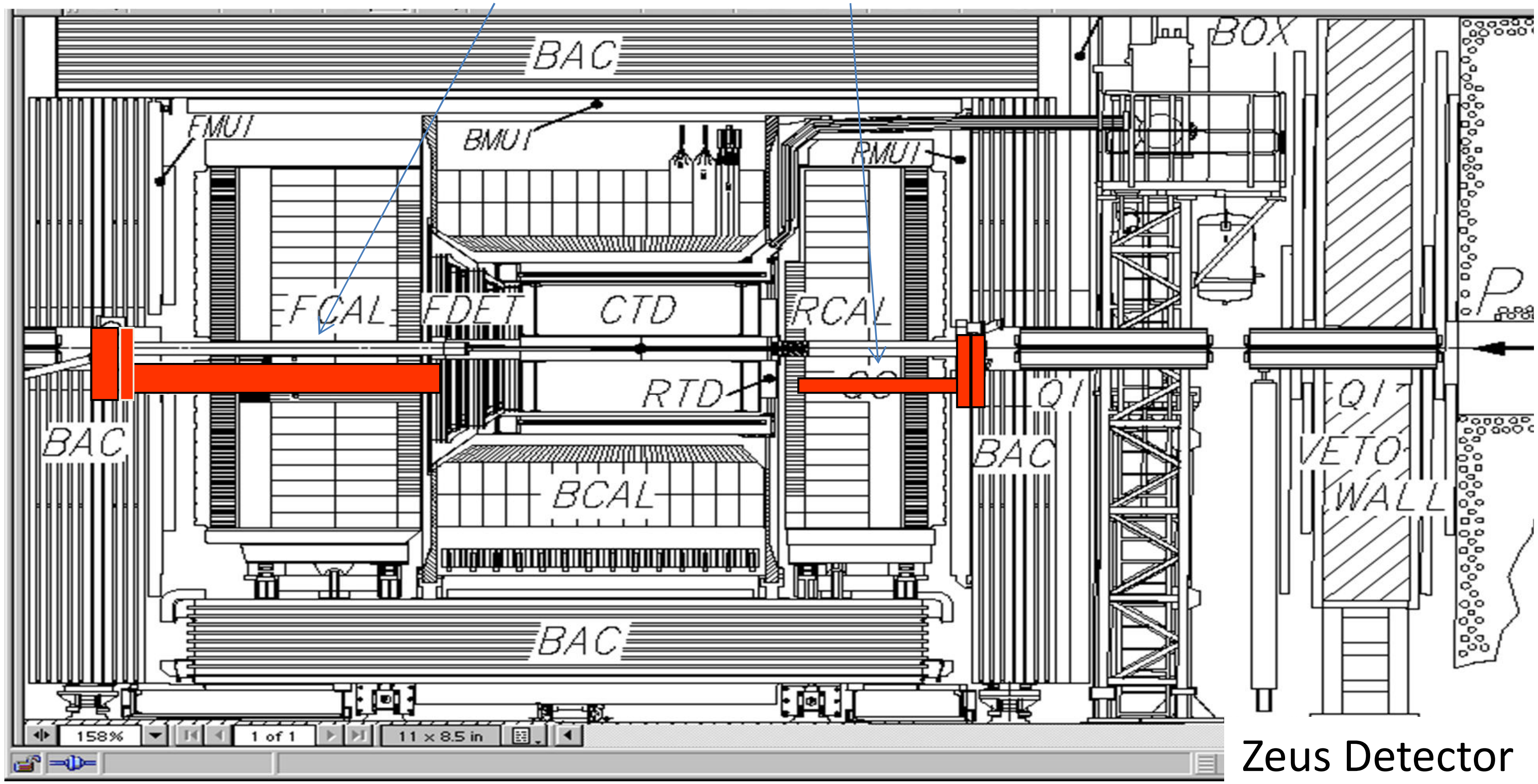
Flange connection NR11m replaced by welding

Only at H1



Vacuum chamber at GI magnet NR 7m molten by synchrotron radiation

Superconducting Magnets in the Detectors

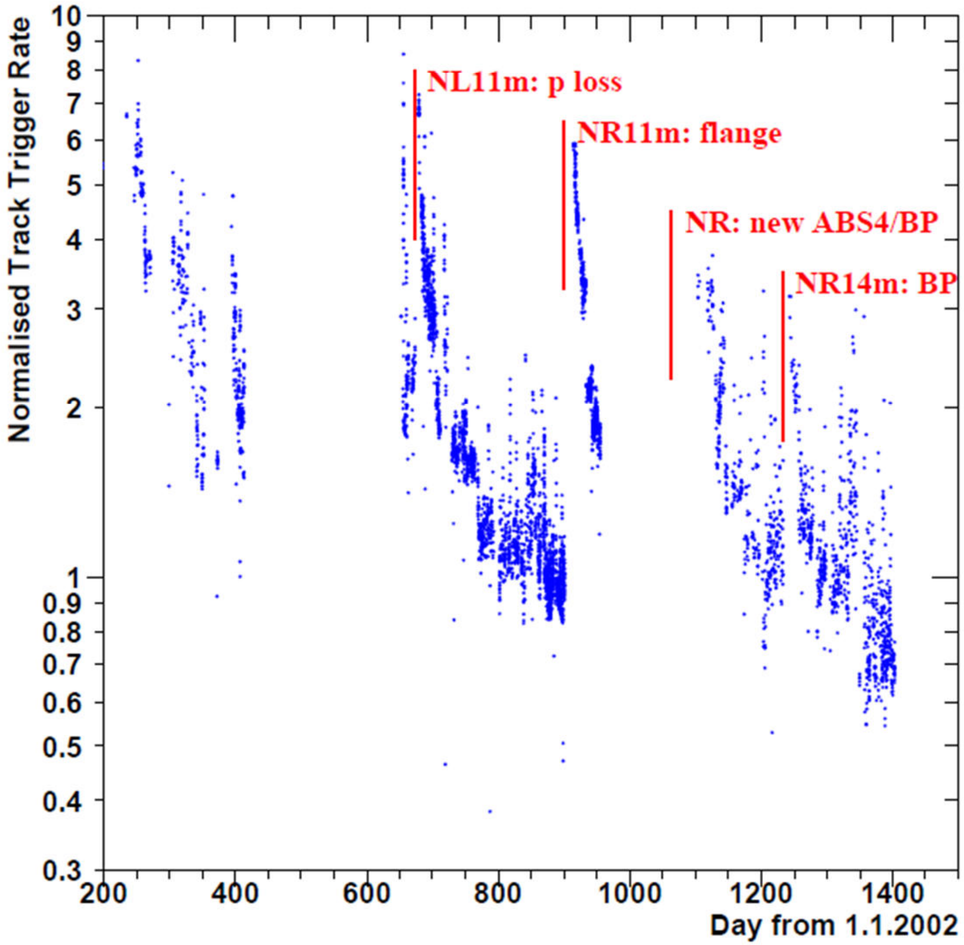


Zeus Detector

Interactions of the proton beam with gas molecules in the IR caused serious background in the detectors.
A full understanding of the background generation was not reached, but the situation improved with time. There was a correlation with the effect, that gas molecules, desorbed from the room temperature parts of the beam pipes, accumulate on the cold surfaces inside the sc magnets.

Proton background at H1 2002 – 2005

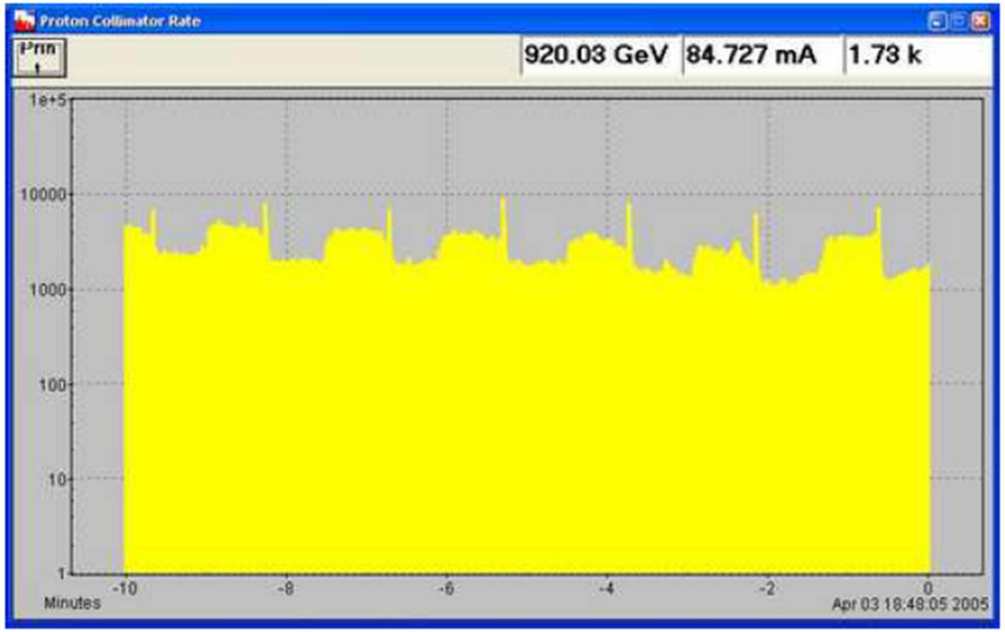
H1 track trigger rate normalized to beam currents:
$\sim$ rest gas pressure.



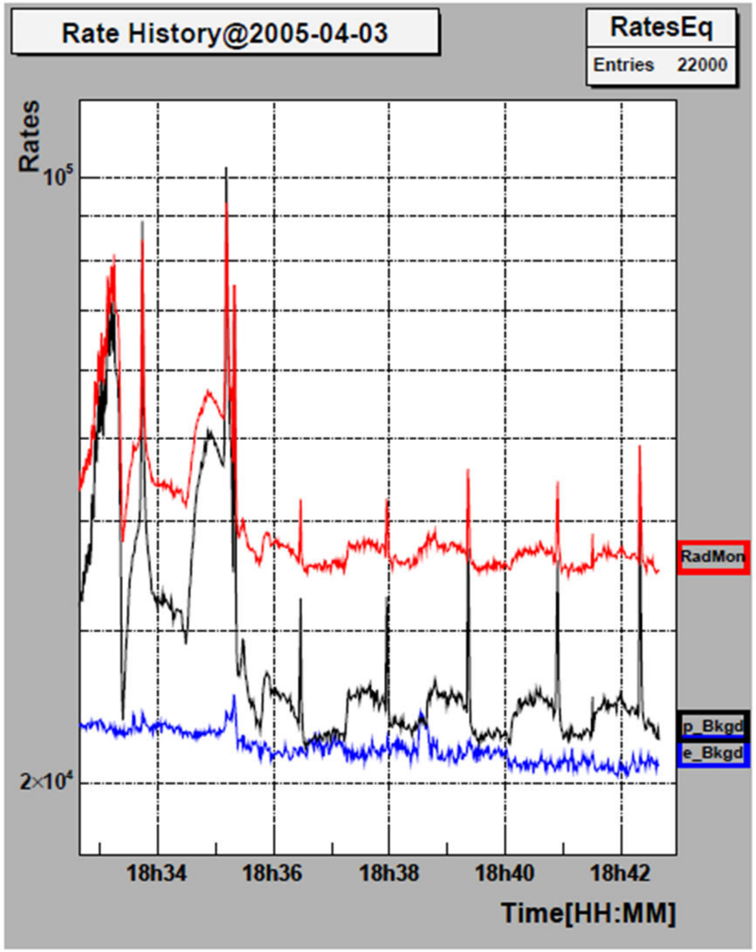
- Gradual improvement during each year.
- Degradation and recovery after each vacuum leak.
- Reached good base level in 2005, with upward excursions due to p beam instabilities.
- Safe chamber operation at full beam currents is possible.

BU magnet short: die Sieben Zwerge

HERA p collimator rates:
7 spikes in 10 min:

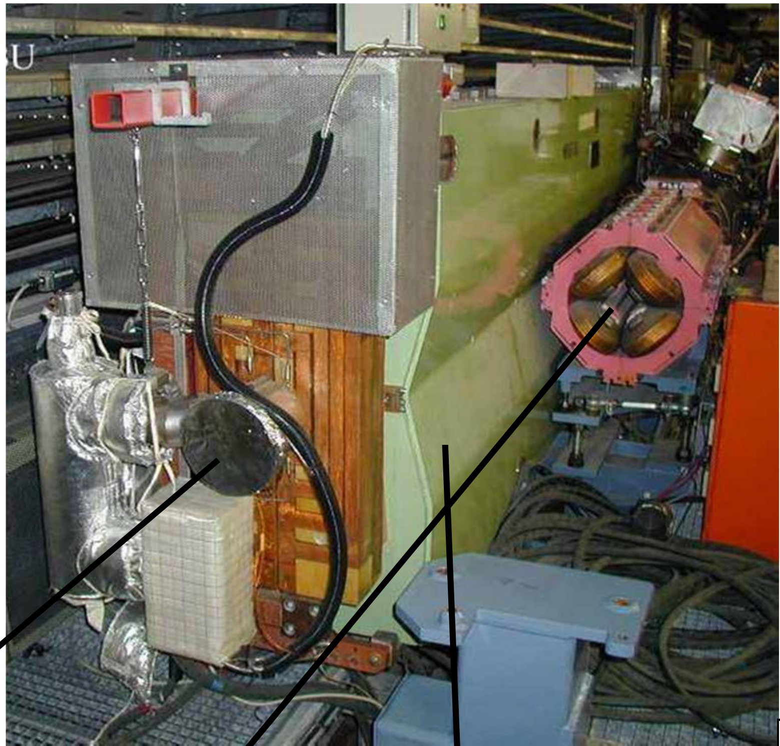


H1 background rate: Same structure seen.



- Chamber operation became impossible.
- Spikes correlated with BU p dipole magnet instabilities.
- 2 coils exchanged in 4 days in April '05.

Coil production was not according to specifications

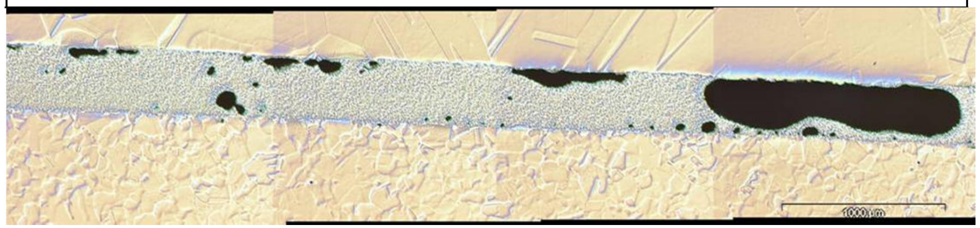


p-Ring

e-Ring

BU dipole magnet

Coils are made from hollow copper bars. At the rectangular joints turbulent water flow created leaks; the leaking water generated shorts in the coil

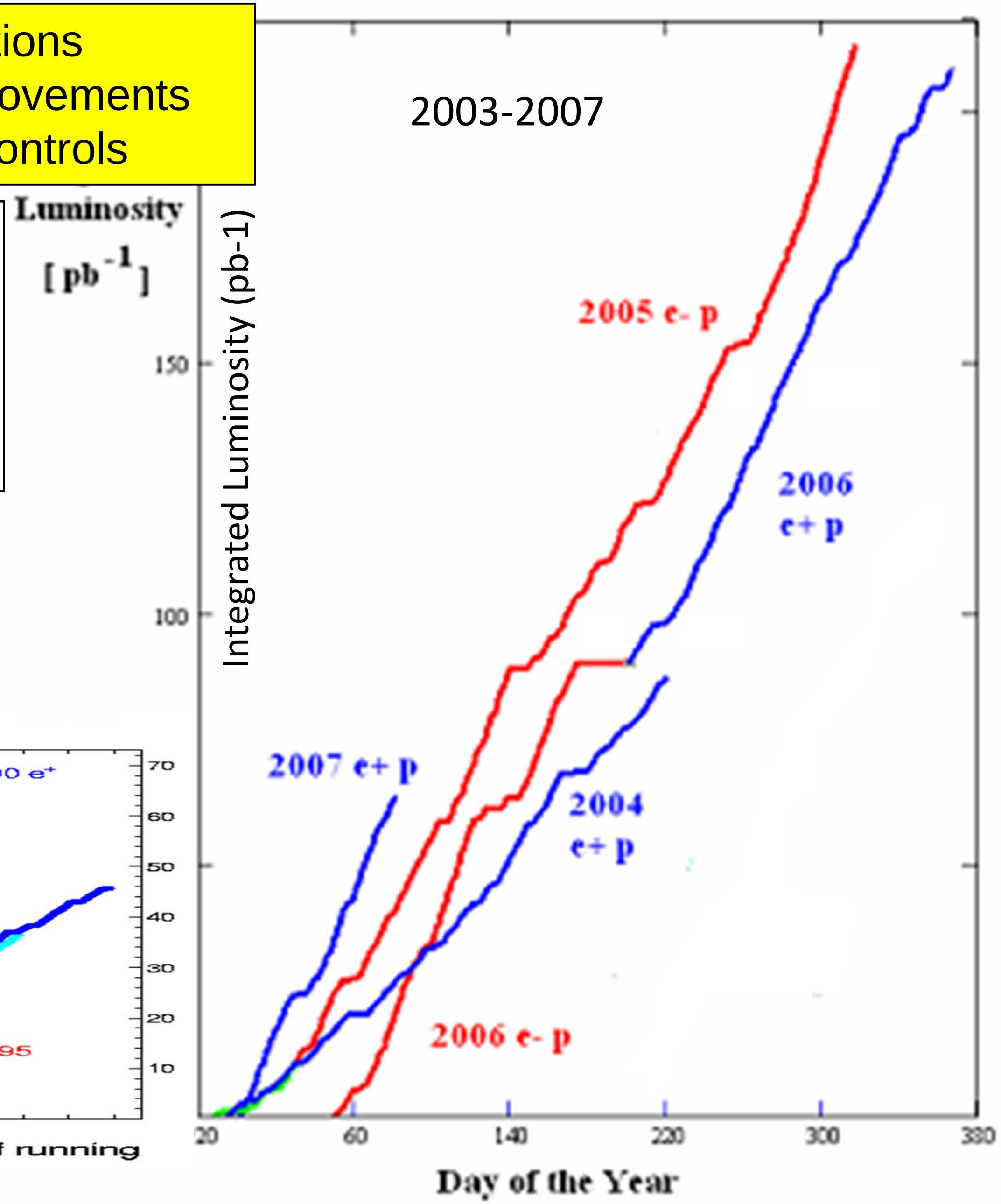


Finally all BU coils were replaced

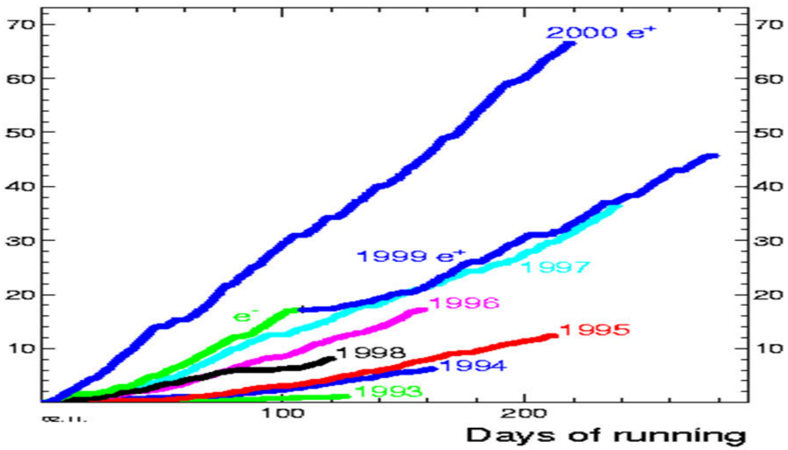
Finally acceptable running conditions were achieved due to many improvements to the accelerator systems and controls

Peak Luminosity of $5*10^{31}$cm-2s-1 reached

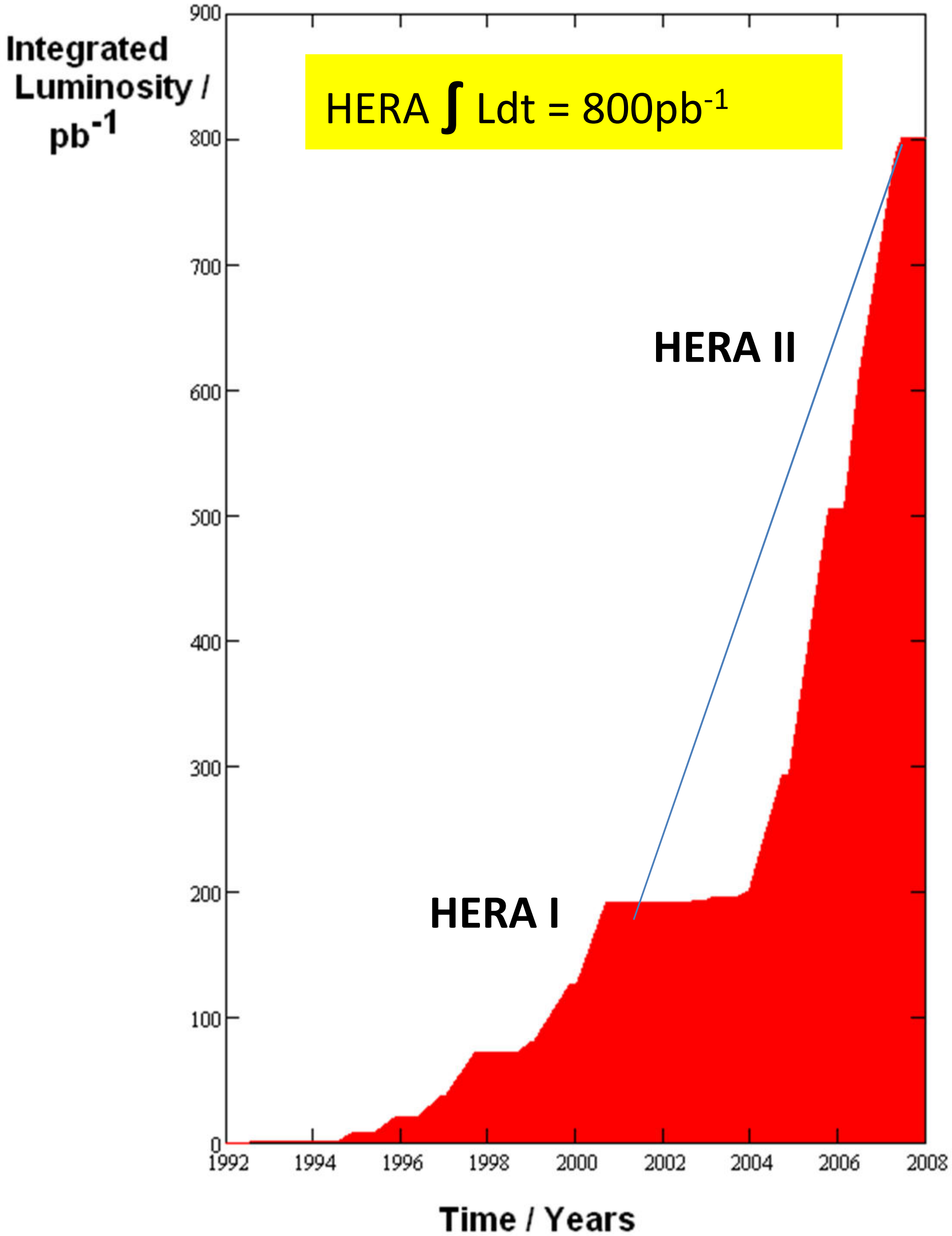
Integrated Luminosity of 600 pb^{-1} accumulated



1993-2000



Conclusions on the HERA Luminosity Production



Most likely we could have gathered a similar amount of integrated luminosity with the more conventional luminosity upgrade proposed by Reinhard Brinkmann

The chosen aggressive upgrade scenario by Ferdinand Willeke would really have paid off if HERA operation could have been continued for a few more years

The achievements and the progress
in the performance of the HERA
were only possible due to the continuous engagement of
the operations crew
the staff of the technical groups
the experimenters from H1, HERA-B, HERMES and ZEUS
and especially Ferdinand Willeke

I would like to thank
the experimenters for the excellent cooperation
over the many years

Discussions were sometimes controversial
but always constructive

In spite of all the hardships
I think it were good years

End