HERA Operation and Prospects

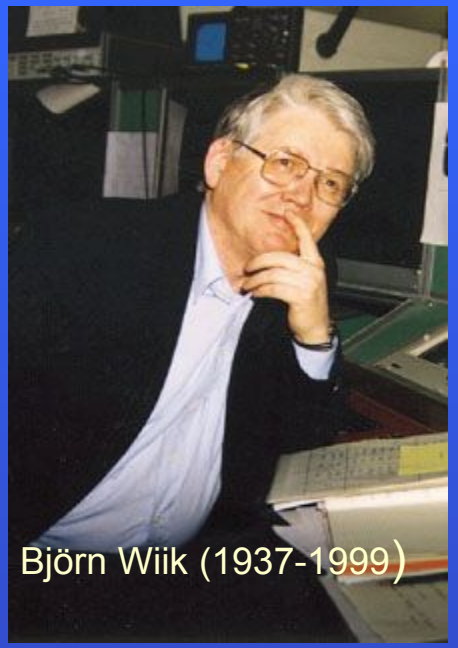
HERA-LHC Workshop Final Meeting

March 22-24 2005

F. Willeke, DESY

HERA overview
HERA I summary
HERA luminosity Upgrade and 2004 proton -e^+
HERA improvement program
present performance
Outlook and conclusions

Lepton-Proton Collider with 320 GeV center of mass Energy

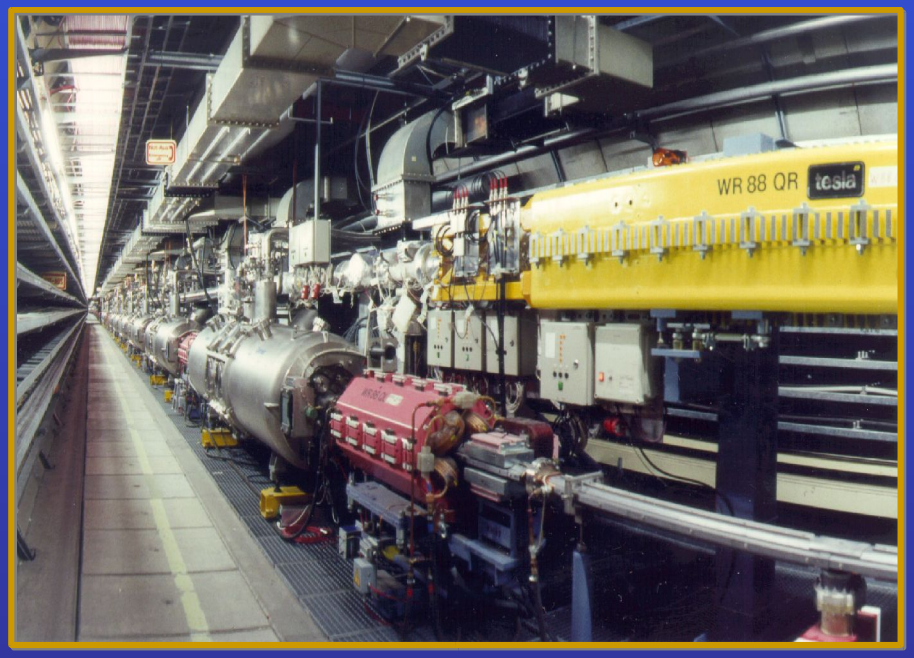

Björn Wiik (1937-1999)

HERA Double Ring Collider

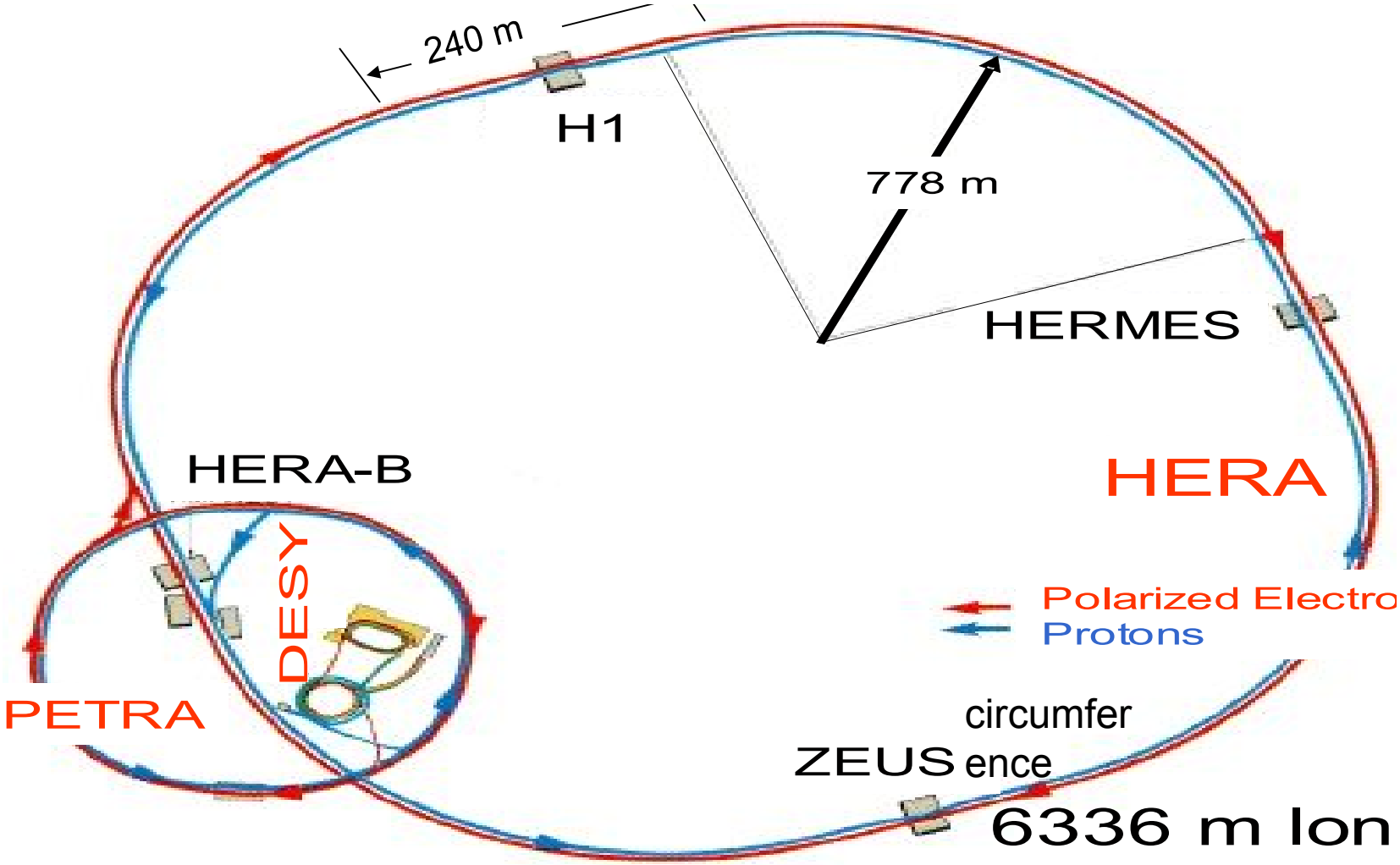
820 GeV Protons (actual 920 GeV)

30 GeV Leptons e^+ or e^- (actual 27.5 GeV)

Spatial resolution 10^{-18}m



HERA Footprint



Milestones

1981 Proposal

1984 Start Construction

1991 Commissioning, first Collisions

5 Start Operations for H1 and ZEUS,

1st Exciting Results with low Luminosity

1994 Install East spin Rotators longitudinal polarized leptons for HERMES

1996 Install 4th Interaction region for HERA-B

1998 Install NEG pumps against dust problem, Reliability Upgrade

2000 High efficient Luminosity production: $100 pb^{-1} y^{-1}$

HERA I: $180 pb^{-1}$ e^+p Precision Measurement on proton structure

2001 Install HERA Luminosity Upgrade, Spin Rotators for H1 and ZEUS

2001/2 Recommissioning, HERA-B physics Run

14 1st longitudinal polarization in high energy ep collisions

2003/4 Start-up of the HERA II Run

HERA I

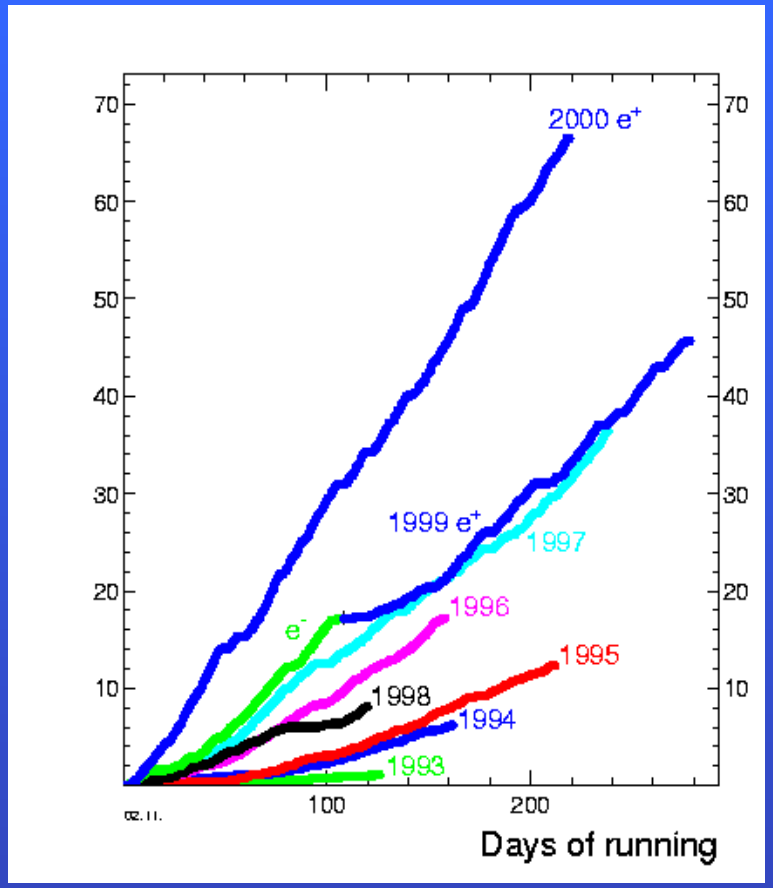
The building, commissioning and efficient operation of the complex HERA accelerator represented a major challenge for DESY, which required a large and continuous effort

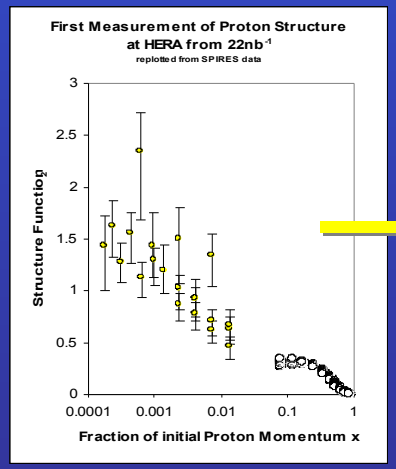
This effort allowed eventually to exceed the planned peak performance with a peak luminosity

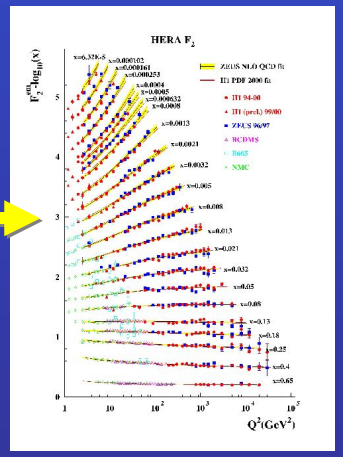
$L_{peak} = 2 \cdot 10^{31}\ cm^{-2}\ s^{-1}$

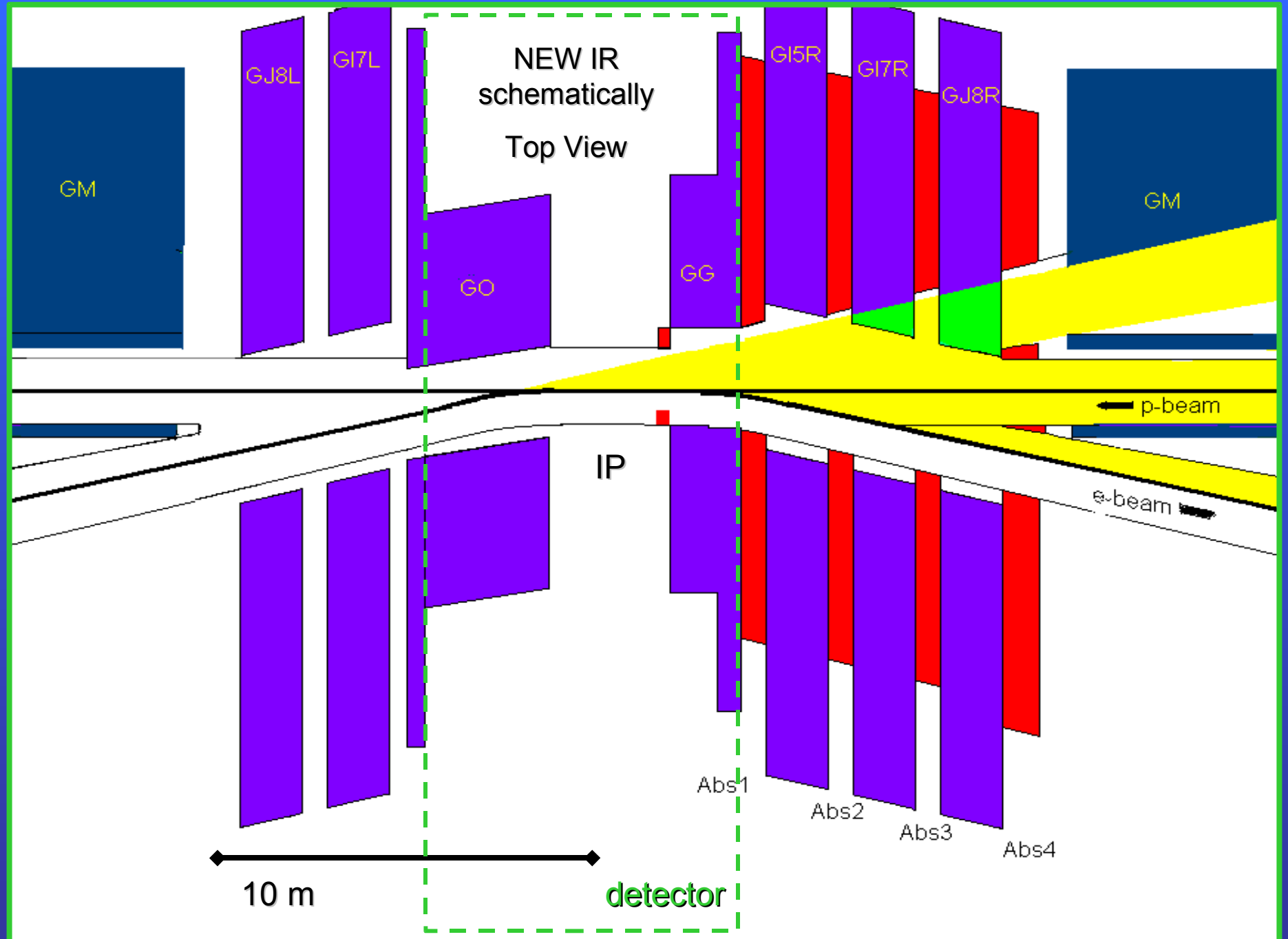
and a Production of $67 pb^{-1}$ in the 200 days of running in 2000.

For more luminosity, a upgrade was performed in 2000-2001 for an increase of a factor of three in peak performance



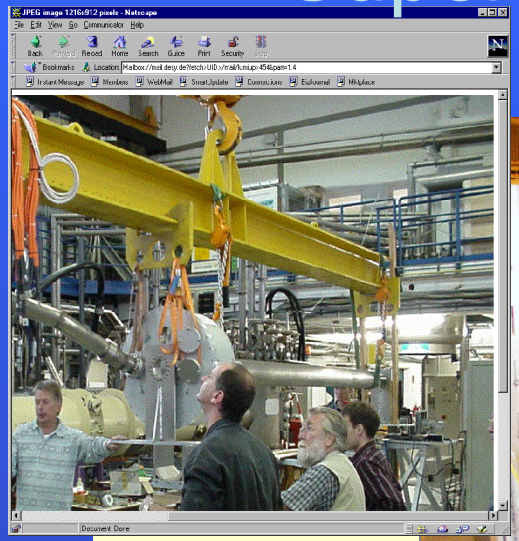


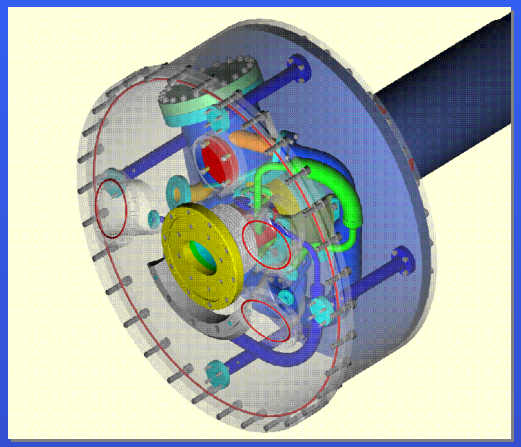



NEW IR
schematically
Top View
GM
GJ8L
GI7L
GO
GG
GI5R
GI7R
GJ8R
GM
p-beam
IP
e-beam
Abs1
Abs2
Abs3
Abs4
10 m
detector

Superconducting Magnets GO/GG

Designed + built in collaboration with BNL





cryostat-wall

He-vessel

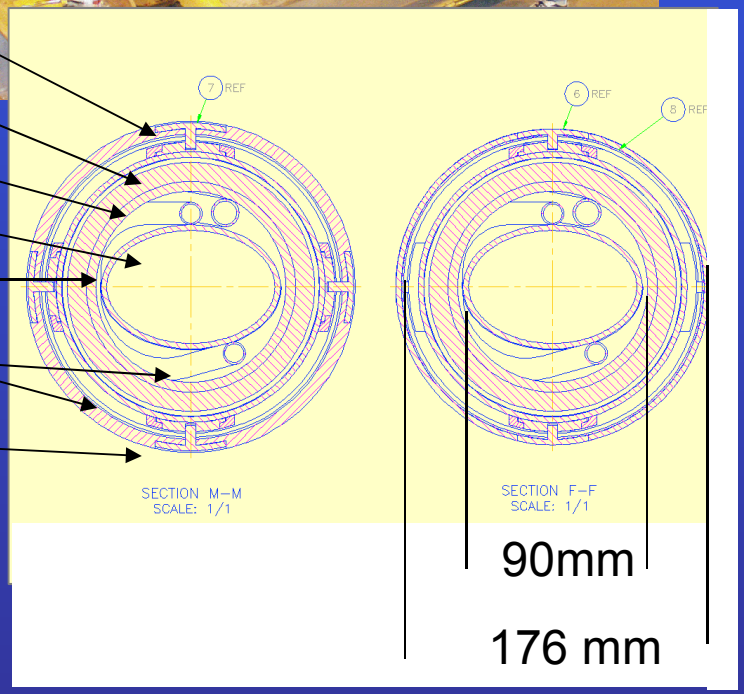
coil

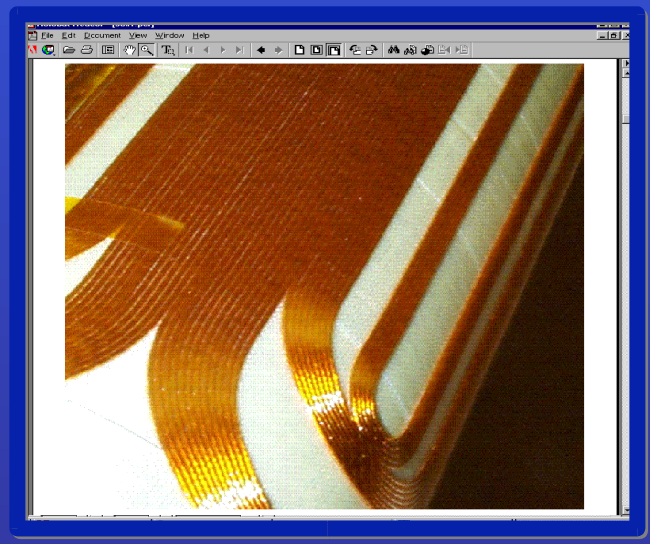
Beam pipe

support tube

insulating vacuum

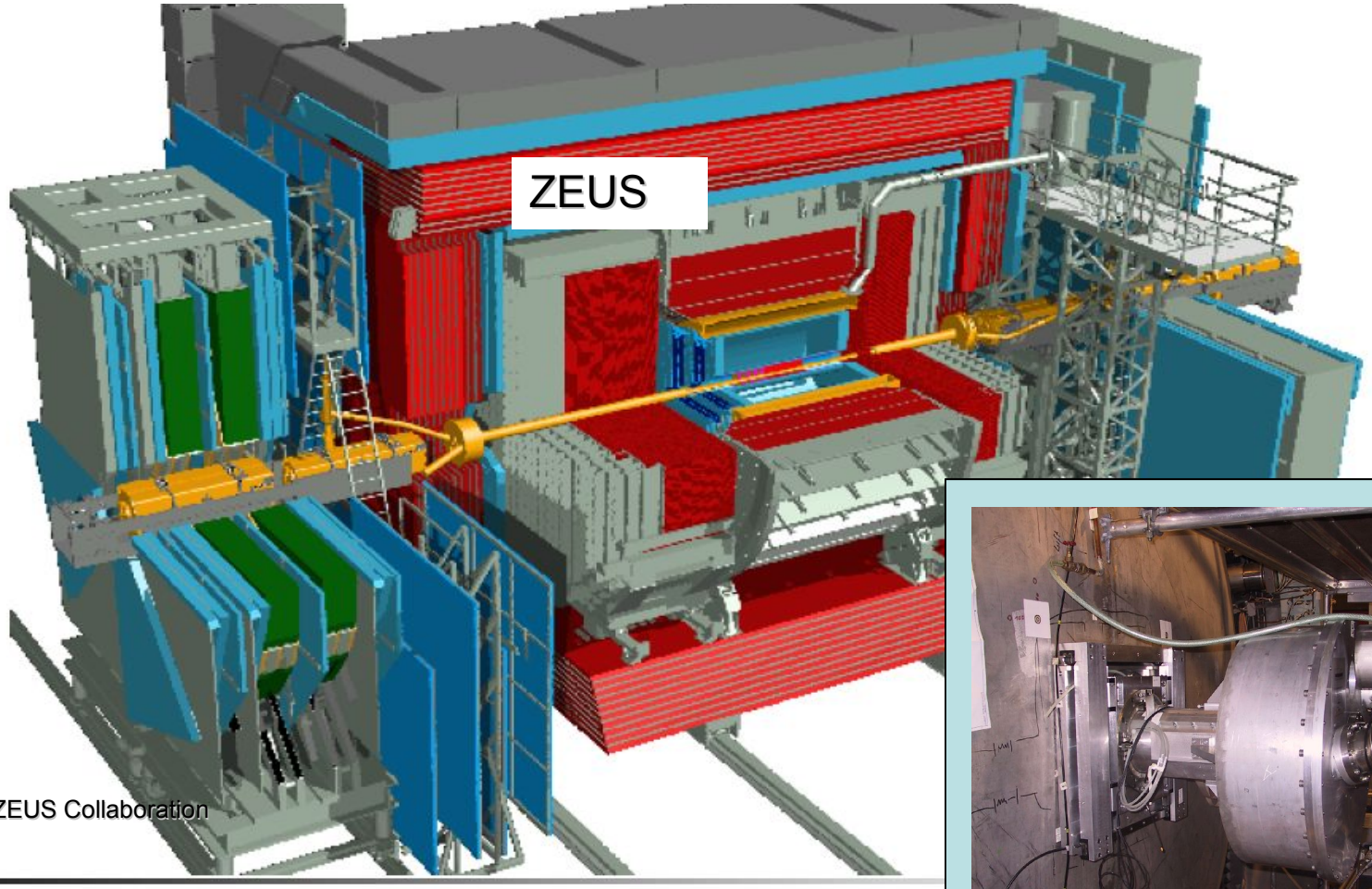
He-supply





serpentine_movie.mov

Superconducting Magnets in the Detectors



Courtesy ZEUS Collaboration

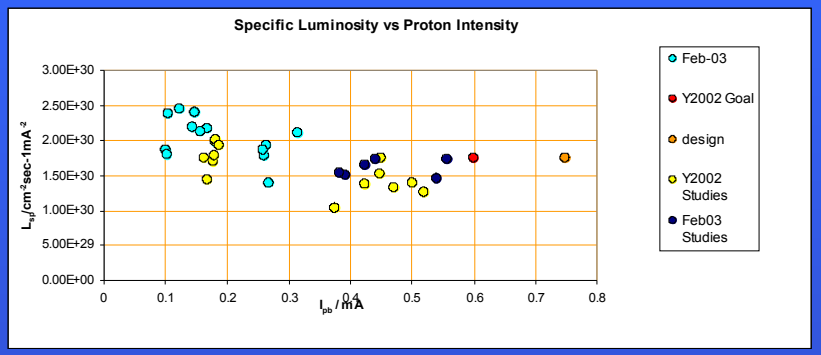
HERA II Luminosity Parameters

$$L = \frac{N_p \cdot I_e}{4\pi e \cdot \varepsilon_N \cdot \sqrt{\beta_{xp}\,\beta_{yp}}}$$

UPGRADE

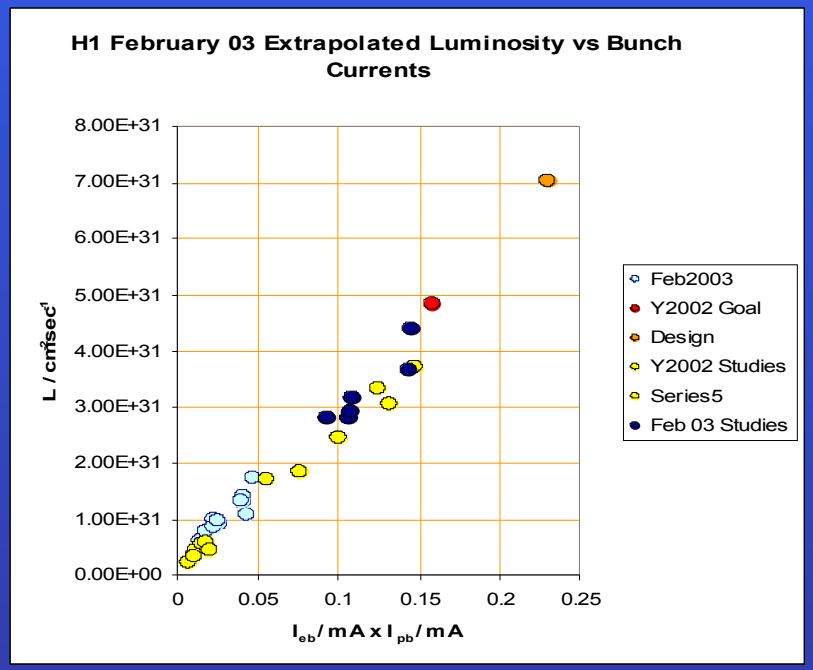
Beam Energies	E_e	= 920GeV/ 27.5GeV
Proton Beam current	I_p	= 100mA
leptons current	I_e	= 50mA
number of protons per bunch	N_p	$= 1 \times 10^{11}$
normalized emittance	ε_N	= 20 μm Proton
beta functions	$\beta_{y,x}$	= 18cm , 2.45m
lepton emittance	ε_e	= 20nm
number of coll. bunches	n_b	= 174
lepton vert. b.-b. tune shift par.	$\Delta_{y,x\,e}$	= 0.045, 0.025
hor./vert. beam size at IP	$\sigma_{x,y,p,e}$	= 114μm/ 30μm
luminosity	L	$= 5 \times 10^{31} cm^{-2} sec^{-1}$

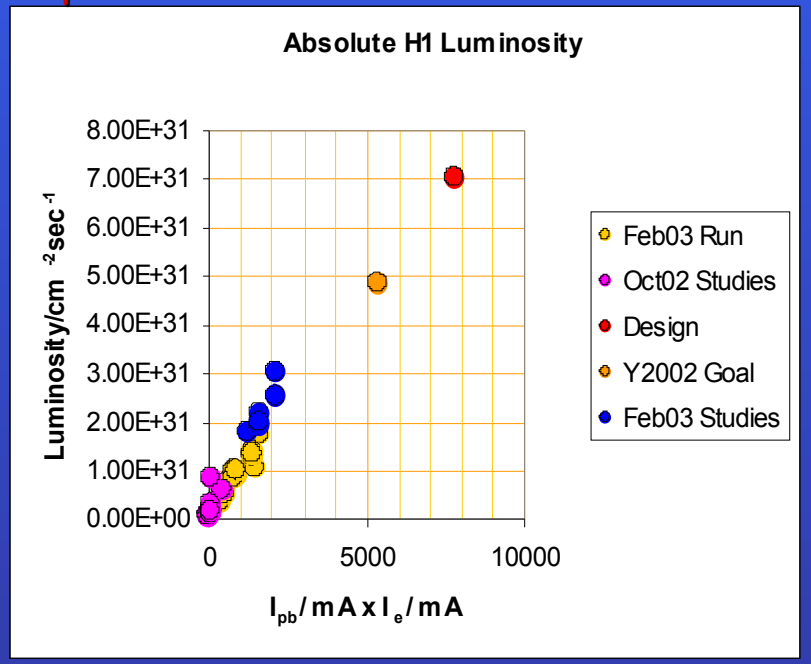
Recommissioning: High Luminosity Demonstrated



Record Luminosity
120 Bunches
$I_p < 70$ mA
$I_e < 35$ mA

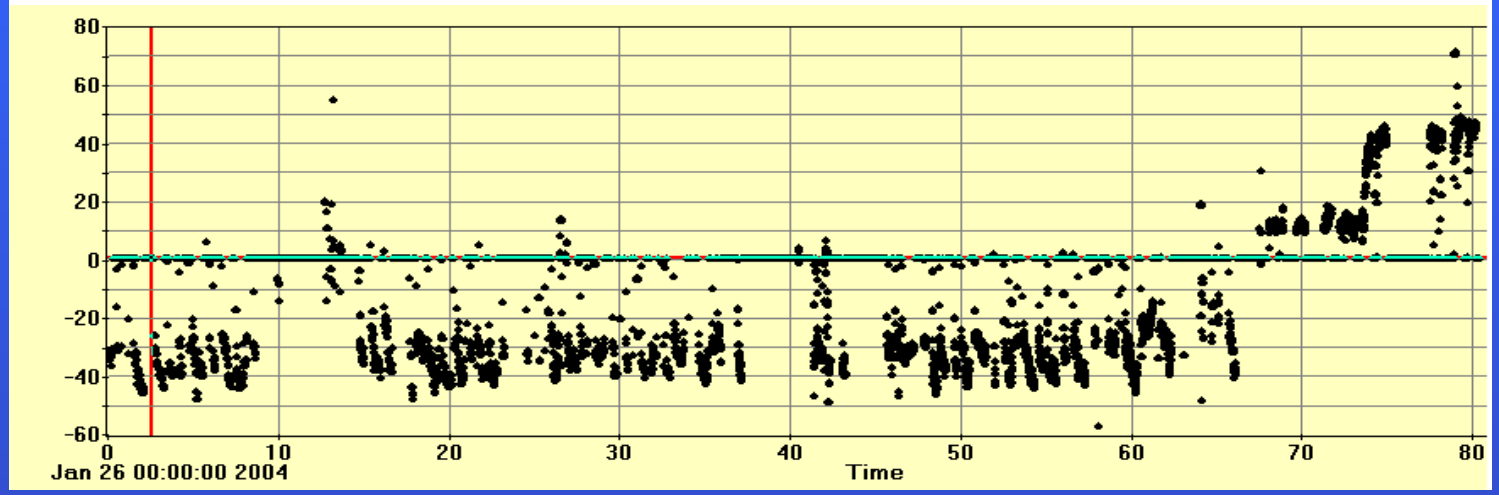
$L_{peak} > 2.7 \times 10^{31}$ cm^{-2}s^{-1}





Conclusion: HERA is able to deliver luminosity as advertised

HERA Longitudinal Polarization



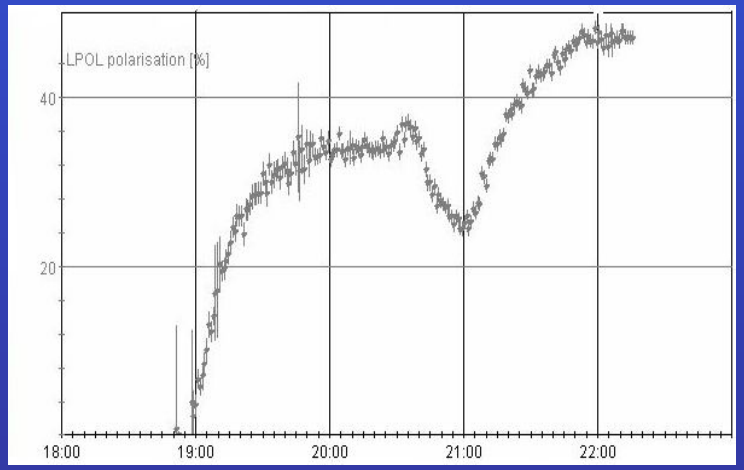
Polarization in collisions: 30-40%
Polarization without collisions up to 50%

Further improvement plans:

Dedicated 2 Polarization Studies
Beam Based alignment
(suffers from lack of resources)

Need better polarization measurement for fast tuning!!
Regular Rotator Flip

Polarization after p-Beam Loss on Feb. 12, 2004

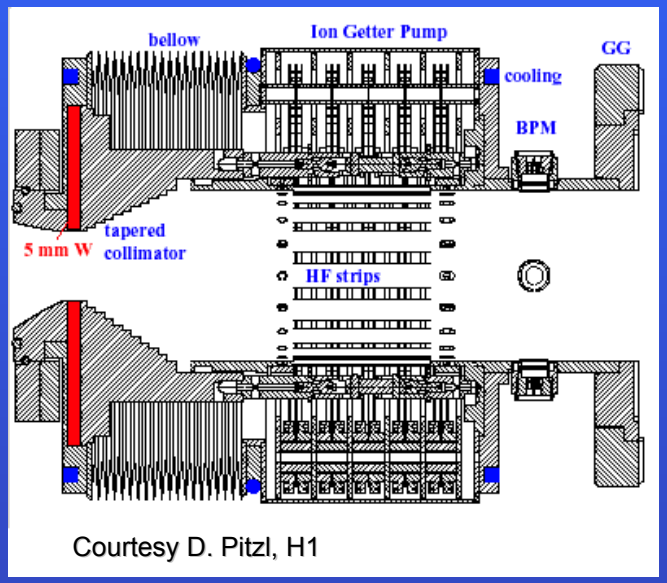


Backgrounds after Luminosity upgrade:

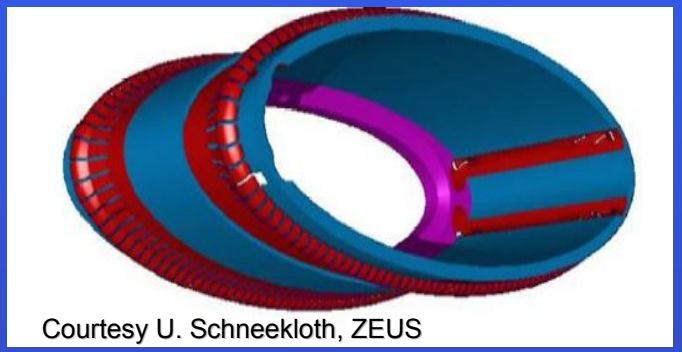
This looked very serious in the beginning and required time to gain understanding and implement counter measures

- Direct Synchrotron Radiation: solved by IR design, SR collimation and sophisticated beam steering procedures
- Indirect (backscattered) synchrotron radiation required improved masking in ZEUS
- e+ particle backgrounds improved with improving vacuum (beam conditioning) and the addition of a pump in a critical location
- proton backgrounds improved with regular beam operation and we are at the point, were this is no issues for ZEUS anymore and almost no issue for H1 anymore

Improvement of synchrotron radiation mask system

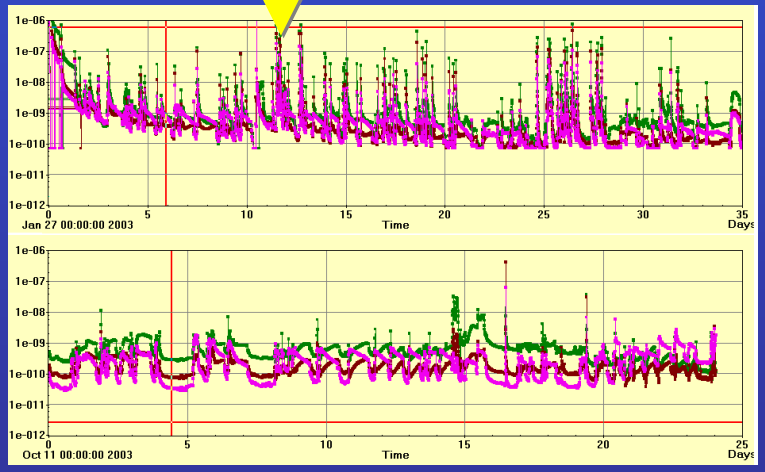


Courtesy D. Pitzl, H1

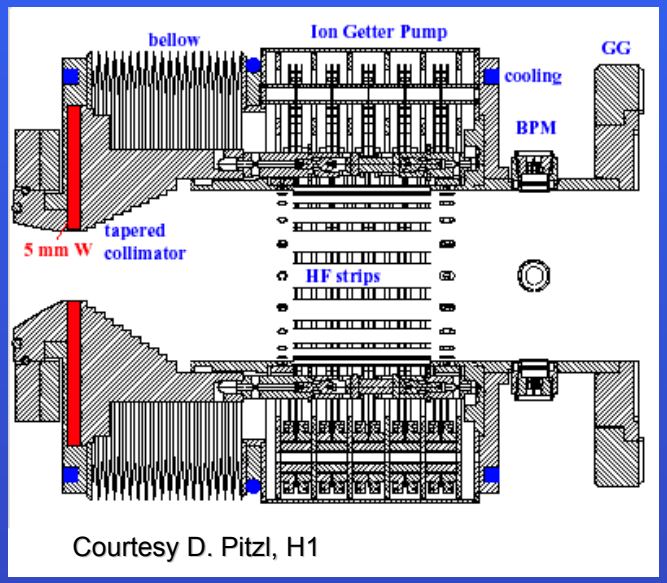

Courtesy U. Schneekloth, ZEUS

before

after



Improvement of synchrotron radiation mask system



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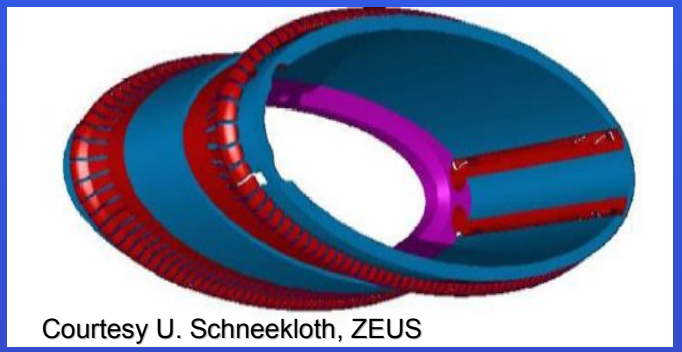
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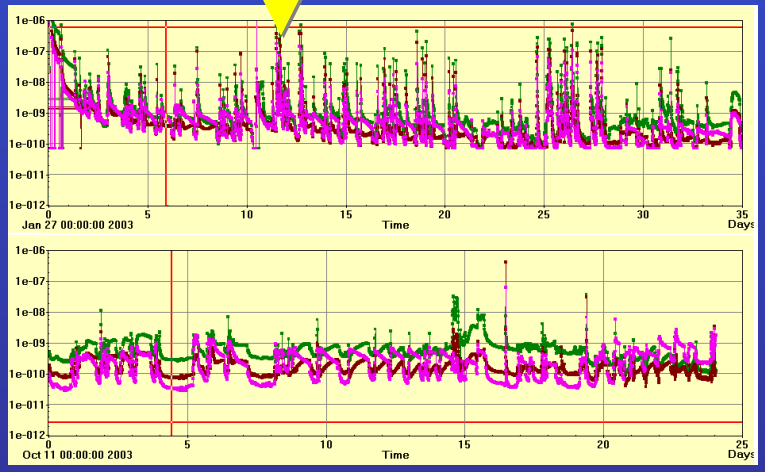
before

after



2004 Running Overview

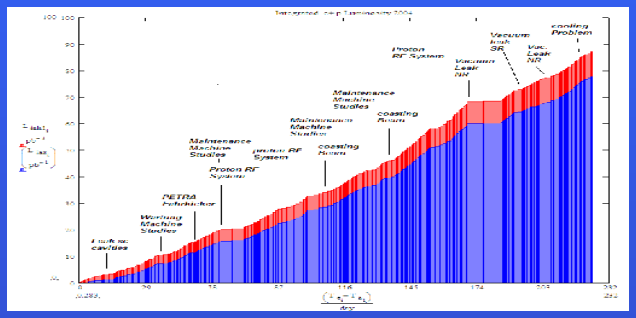
Promising luminosity production in the 2003/2004 Positron Proton run

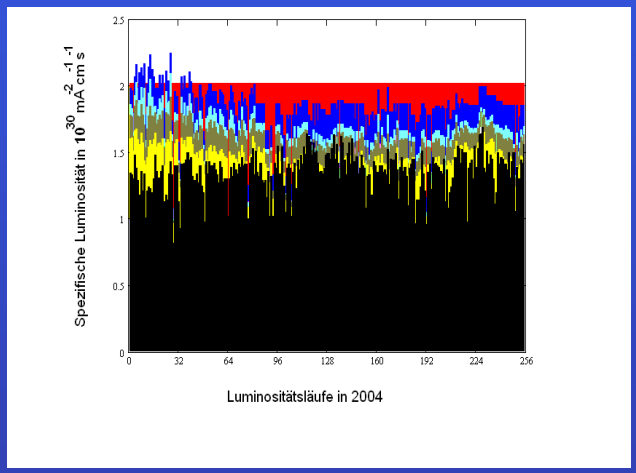
- Peak luminosity L_{peak} up to 3.8 10^{31} $cm^{-2}s^{-1}$
- Production rate of up to 0.8pb^{-1} d^{-1}
- Shortcoming of specific luminosity well understood and improvements underway

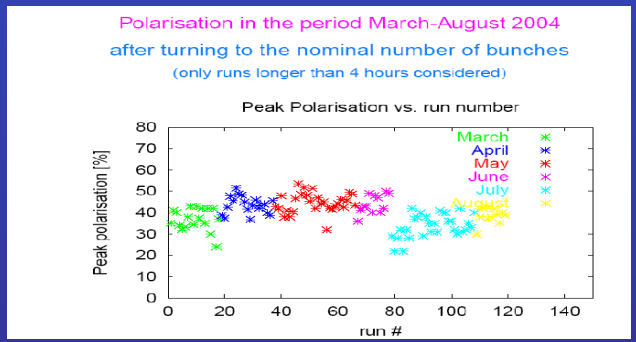
Polarization Satisfactory with up to 50%

Overall Efficiency of operations unsatisfactory, only 40% more efforts are needed

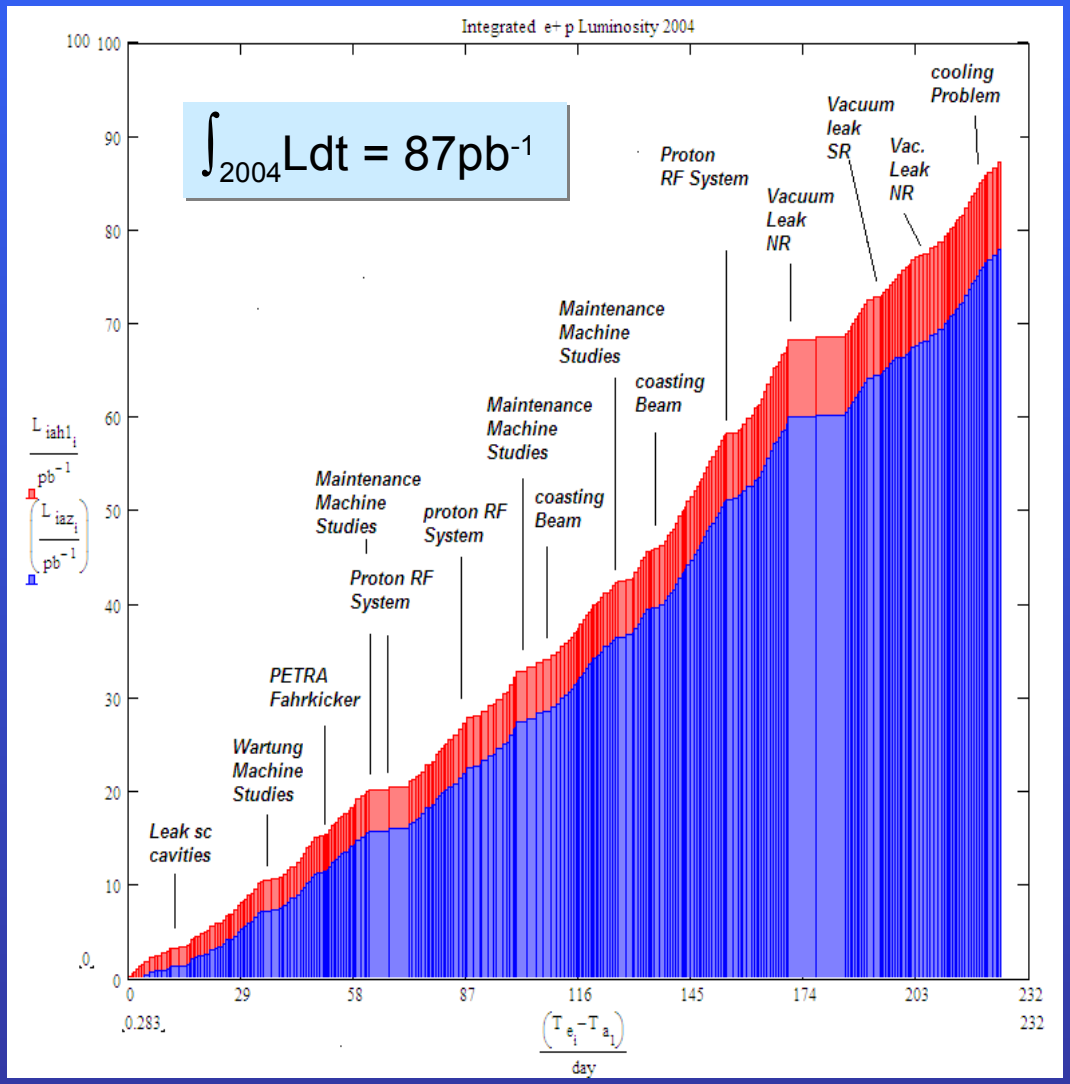
- Better Support of critical components
- Rigorous exchange program for aging and failing components
- Redesign of unsatisfactory components
- Improved operator training program







2004 Luminosity Accumulation



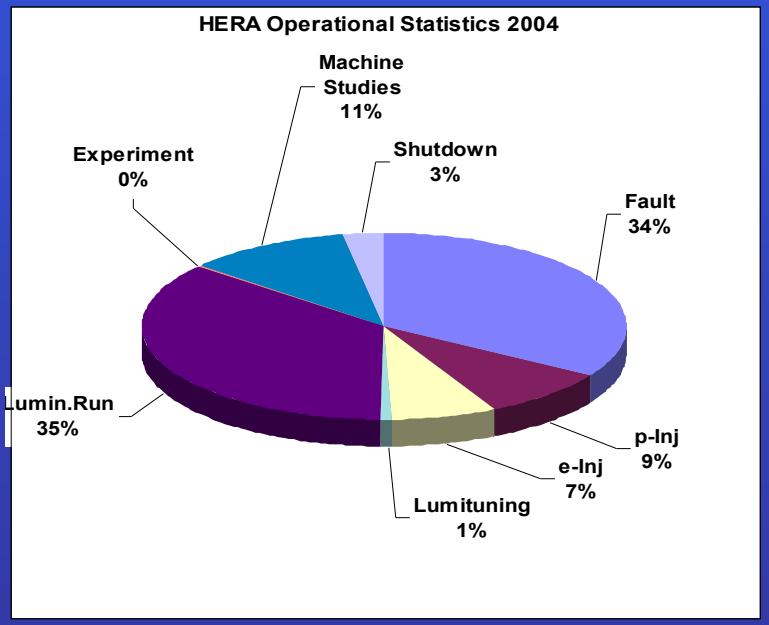
Peak luminosity 1.2 $pb^{-1}d^{-1}$

Best week 0.9 $pb^{-1}d^{-1}$

2004 Average 0.4 $pb^{-1}d^{-1}$

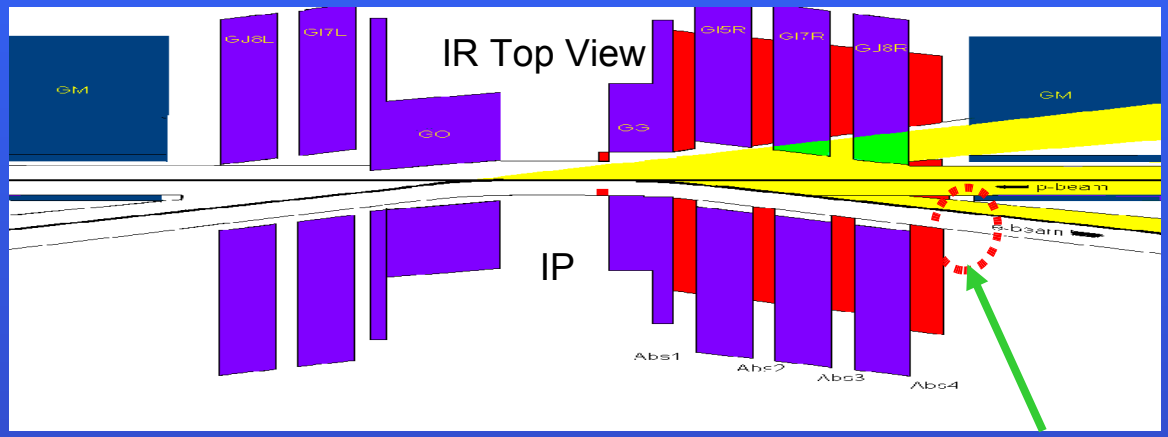
~50 days of operations lost Due to major technical failures

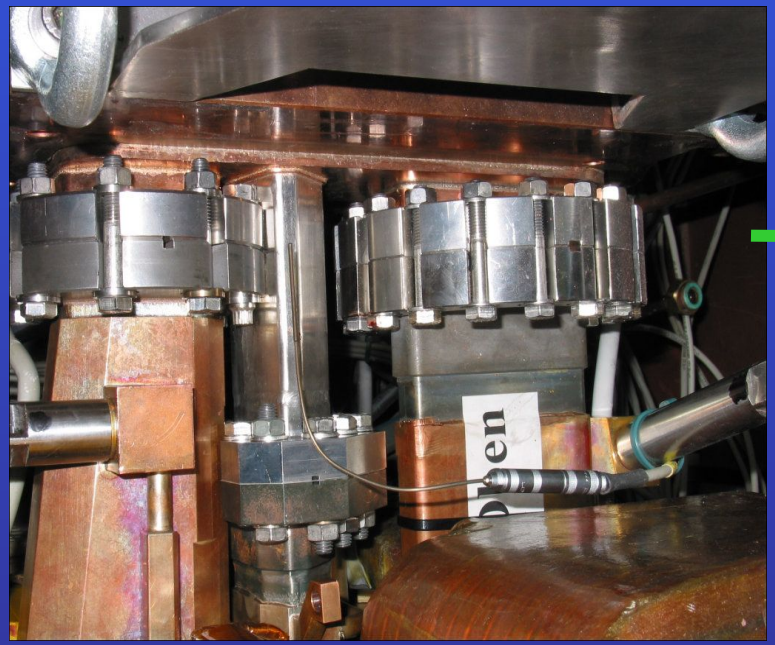
Operational efficiency needs to be improved

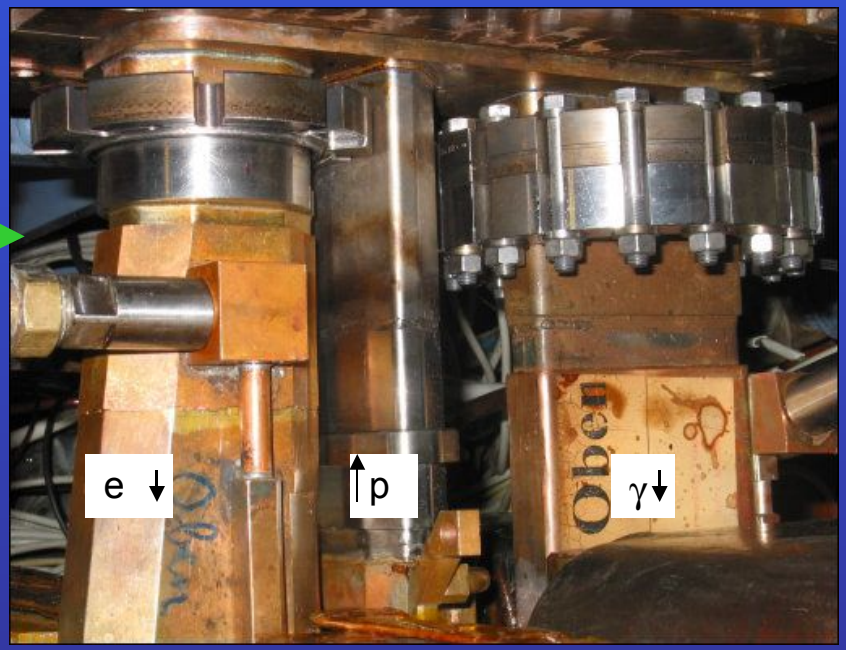


Improving Design Weakness:

Troublesome Flange Connection NR Replaced by Welded Connection





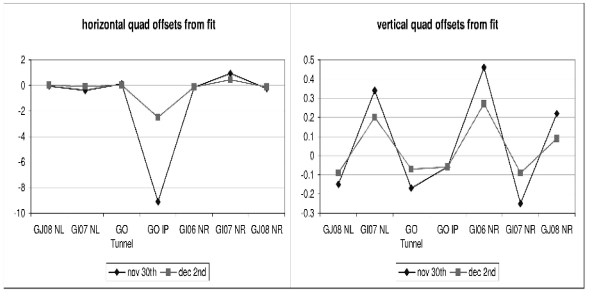


HERA Electron Proton Running

- Switching to Electrons done in several steps starting with recovering from shutdown with positrons … this saved time in the end
- Careful beam based alignment
- Adjusting magnets and H1 detector positions
- Slow start due to problem with 2 GN-type magnets
- Luminosity runs started with 60 bunches in December
- Careful adjustments of files to avoid heating of vacuum components due to increased synchrotron radiation power
- After short holyday break restart with 120 bunches

Ergebnisse des Fits der Quadrupol Offsets im Norden

Magnet	s	x-Offset nov 30th	x-Offset dec 2nd	z-Offset nov 30th	z-Offset dec 2nd
GJ08 NL	-9.2	-0.05	0.03	-0.15	-0.09
GI07 NL	-7	0.4	-0.08	0.34	0.2
GO Tunnel	-5	0.11	0.03	-0.17	-0.07
GO IP	-2.2	-9.1	-2.5	-0.06	-0.06
GI06 NR	4.8	-0.15	-0.12	0.46	0.27
GI07 NR	7.2	0.94	0.43	-0.25	-0.09
GJ08 NR	9.5	-0.26	-0.12	0.22	0.09

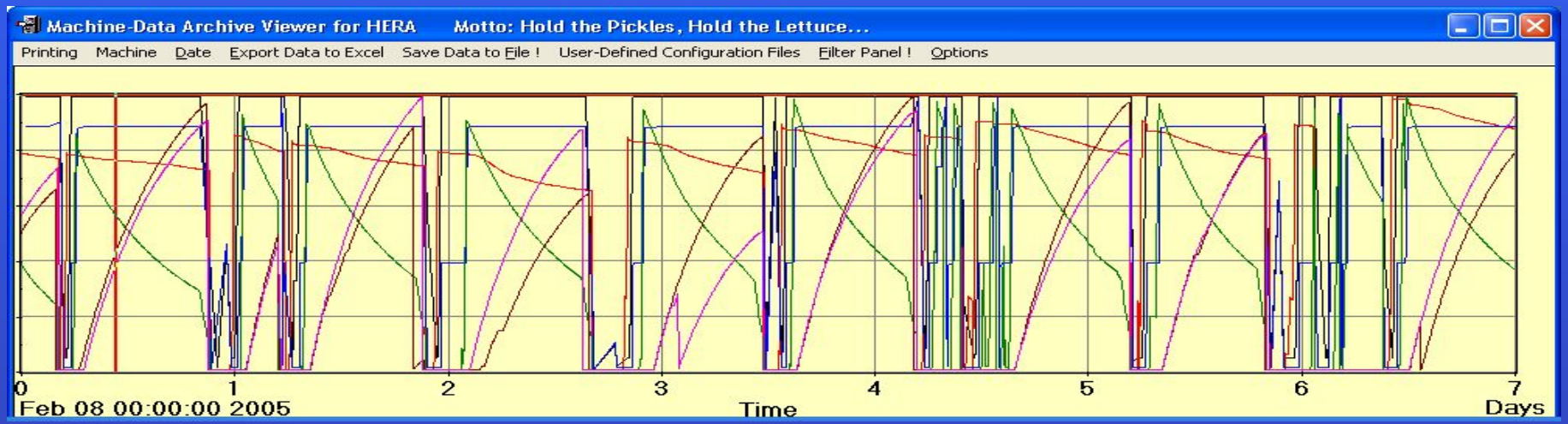


Electron-Proton Run

- Specific Luminosity exceeds design with values of around 2 $\times 10^{30}$ $mA^{-2}cm^{-2}s^{-1}$
- Absolute luminosities comparable with 2004 positron-proton run despite lower beam currents
- Luminosity production rate reaches $1pb^{-1}d^{-1}$
- Vacuum in North IR slowly recovering, now ~1ntorr with beam, H1 cannot turn on with full current
- Additional problem spiky backgrounds …

Example: HERA Week #6

Feb 8-14, 2005



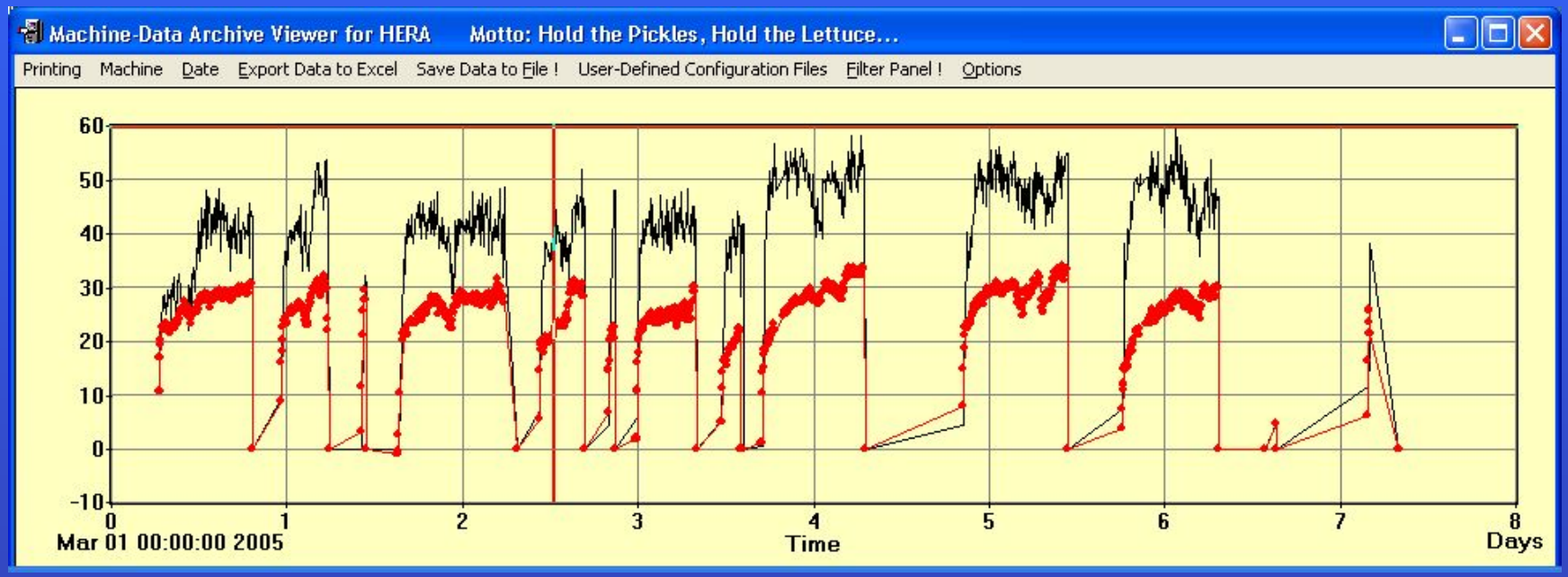
Luminosity production $\int$ Ldt = 6.4 pb^{-1}

Polarization tuning disappointing: 30%

Backgrounds: still critical but somewhat better

Monday: Number of bunches increased from 120 to 150

Polarization 2005

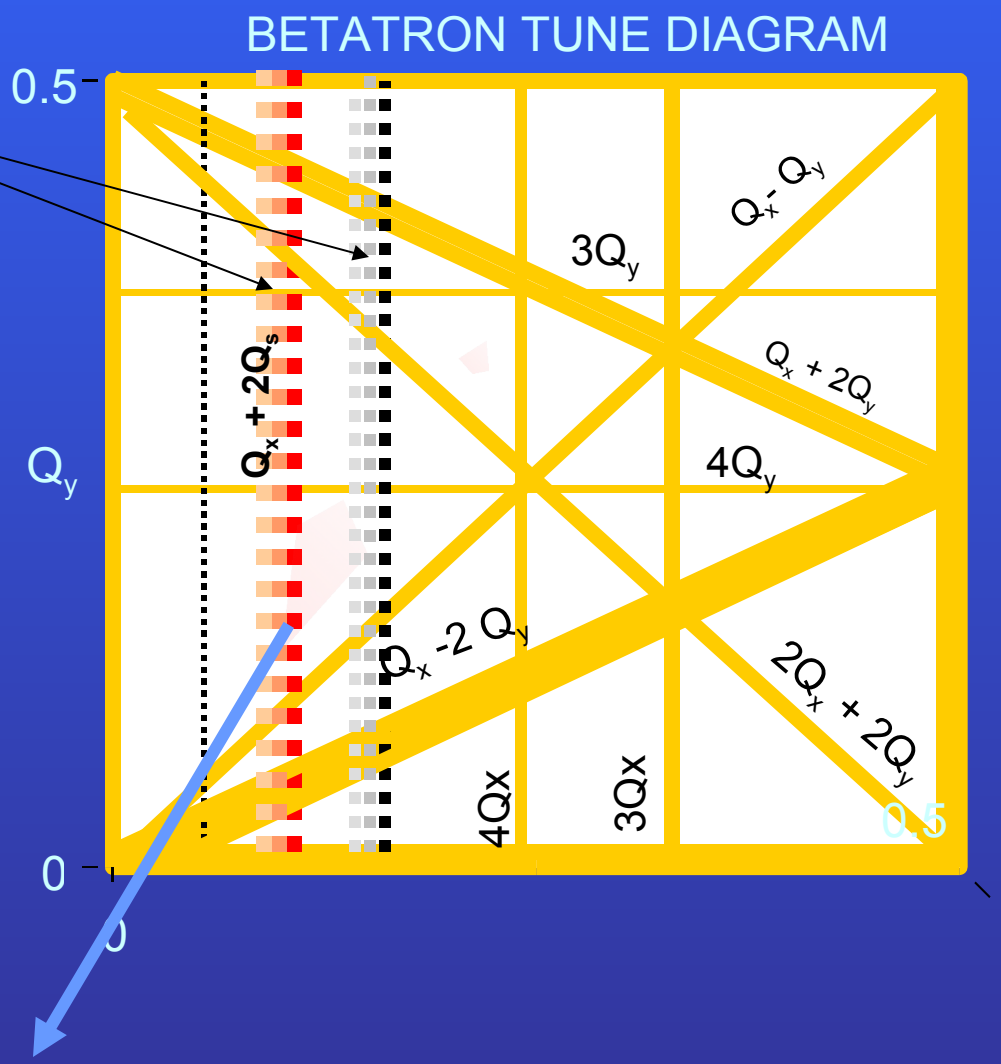


Polarization ~50% but only for non-colliding bunches

Colliding bunches only 30 % Strong beam-beam effects

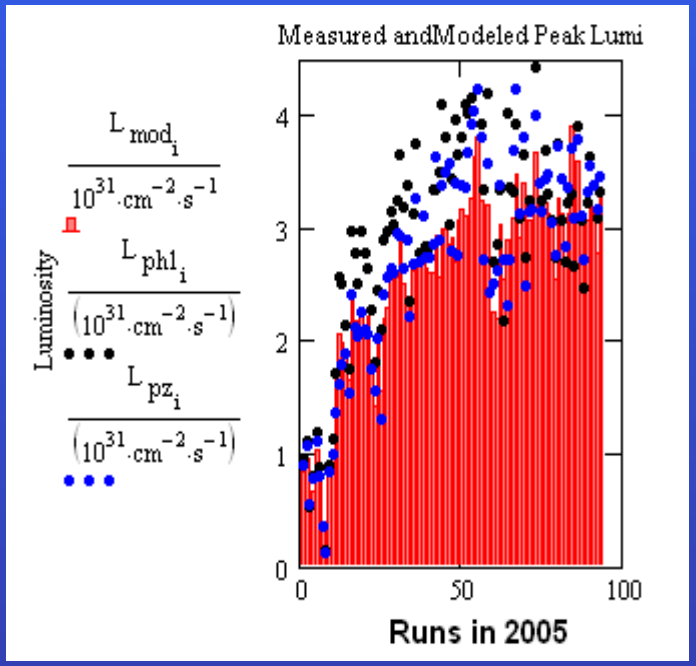
Alternative working point under consideration

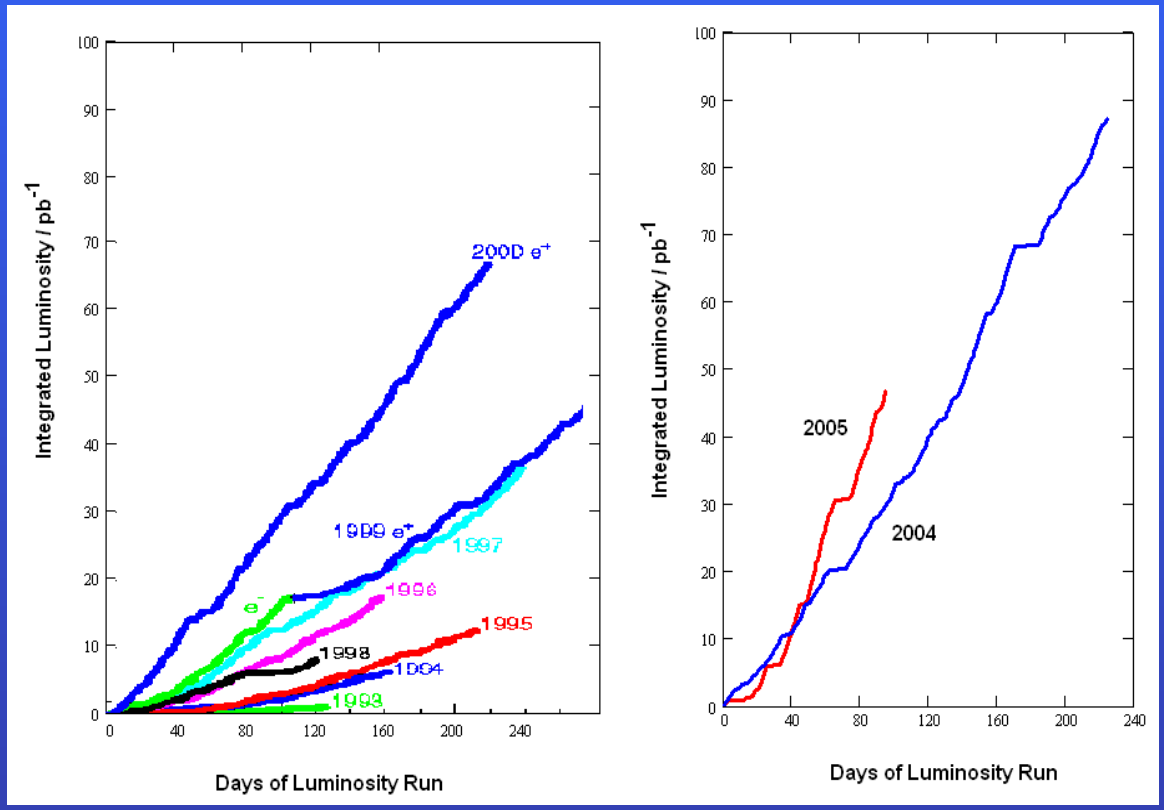
Strong synchro-betatron resonances



HERA I and HERA II Luminosity

Peak luminosity so far
4.5 10^{31} cm^{-2} sec^{-2}





HERA Improvement Program:

rich program with 70 items defined in 2003, program well underway, the most important ones being:

BU Magnet Refurbishing			1.0 M€
Proton RF Systems	Improved low-level controls Suppression of long. Instability	2/2/.5 PJ	0.55 M€
Diagnostics Systems	improved monitors (BPM, SR)	1./0.3/0.1 PJ	0.15 M€
Vacuum System	better pumping in RF sections	0/0.5/1.0PJ	0.5 M€
Power Supply Systems	add'l Ps for spin matching	0 /0.3/0.2 PJ	0.2 M€
e-RF Systems	RF Modulator upgrade	0/0.5/.95 PJ	0.13 M€
Cryogenic Systems	compressor and controls upgr.	0 /0.5/1.5 PJ	0.45 M€
Summe:	**14.6 PJ @ 0.605 M€** (add'l only)		**1.13 M€**

Coil Refurbishing Vertical n.c. BU Dipole Magnet in HERA p

- Needed to bend proton beam upwards at both ends of the IR
- There are 3 Magnets on both sides of the IP in the three IR-s

= 18Magnets

- Magnets develop ground faults because of water leaks of the brazed Cu conductor
- All coils tested so far ~8 have leaks

- Refurbishing program
- This shutdown: 6 Half coils NL replaced
- 8 more coils ordered for later replacements

Low p-Energy Running

Experience: 500GeV p on 27.5GeV e running in 1991 with very low luminosity

Not really an existence proof

Proton energies in the range 400GeV-920GeV should be not problem

Luminosity scales (presumably) as $L \sim E_p^2$

Accelerator Preparation time: 2-3 weeks

Conclusions

- HERA has always been a challenging project which required the full attention of the DESY laboratory. Thanks to the support in the 90-ties, HERA I running was turned into a respectable success and delivered the data for important physics results
- After the luminosity upgrade the background conditions were intolerable, but HERA has now overcome these problems and performed a promising luminosity run in 2004
- The peak luminosity in 2004 was twice as large as in Y 2000
- No unpleasant surprises with 2005 electron proton run, luminosity very good despite reduced intensity
- Longitudinal polarized positrons are delivered routinely to the experiments in 3 IPs
- The challenge is to achieve the Y1999/2000 operational efficiency
- There are good chances that HERA can reach its luminosity goal of $1 fb^{-1}$

  However this requires increased efforts and continuous support of the HERA program by qualified personnel and by the implementation of an ongoing maintenance and improvement program