H1 and ZEUS after the Luminosity Upgrade of HERA

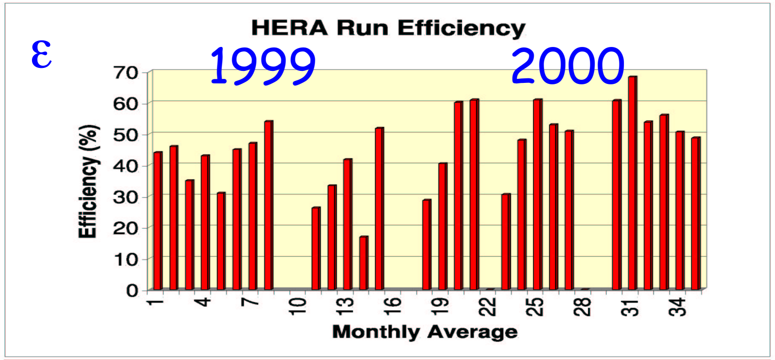
- HERA I

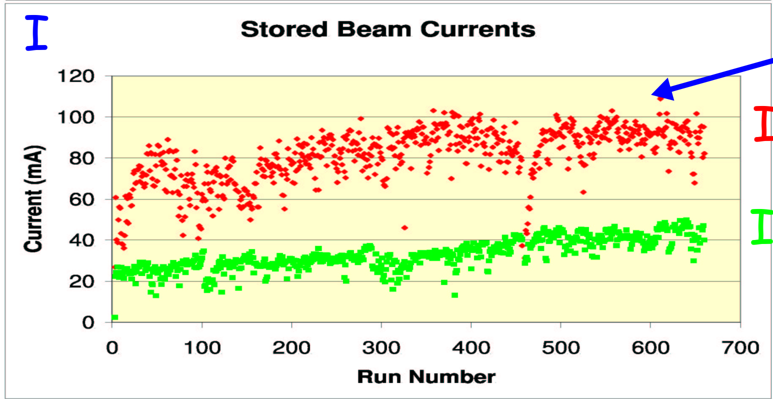
- HERA luminosity upgrade
  - Concept
  - Problems
  - Status

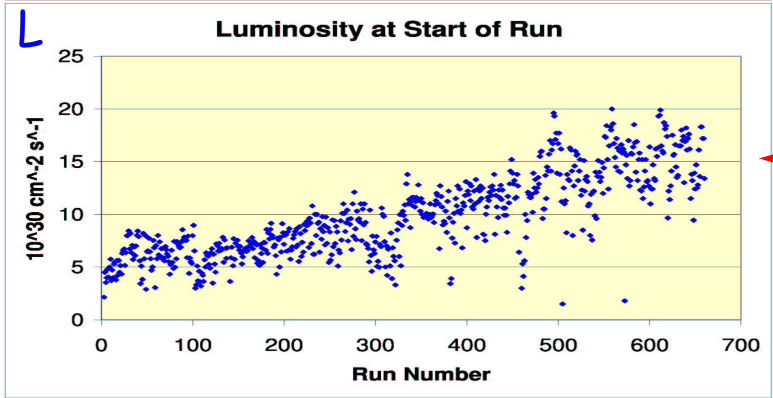
- Detector upgrades of H1 and ZEUS

- Outlook

HERA I Performance until end of 2000

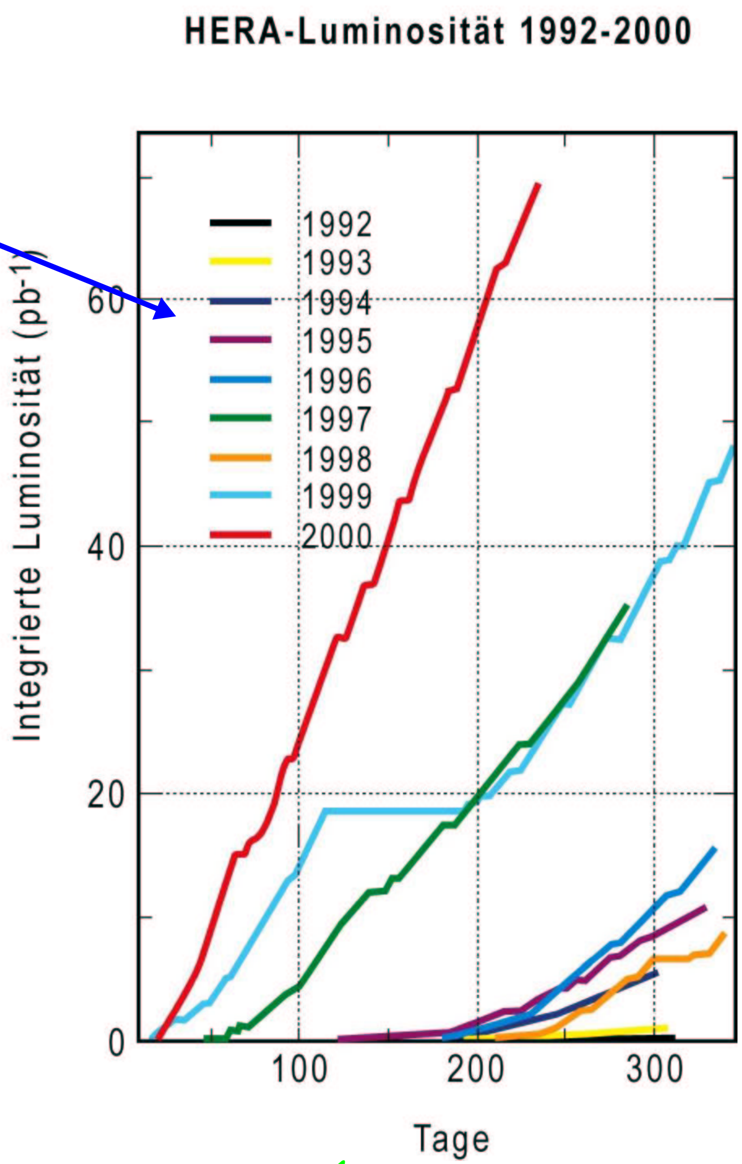






- ever increasing performance since 1992
- some saturation reached in 2000

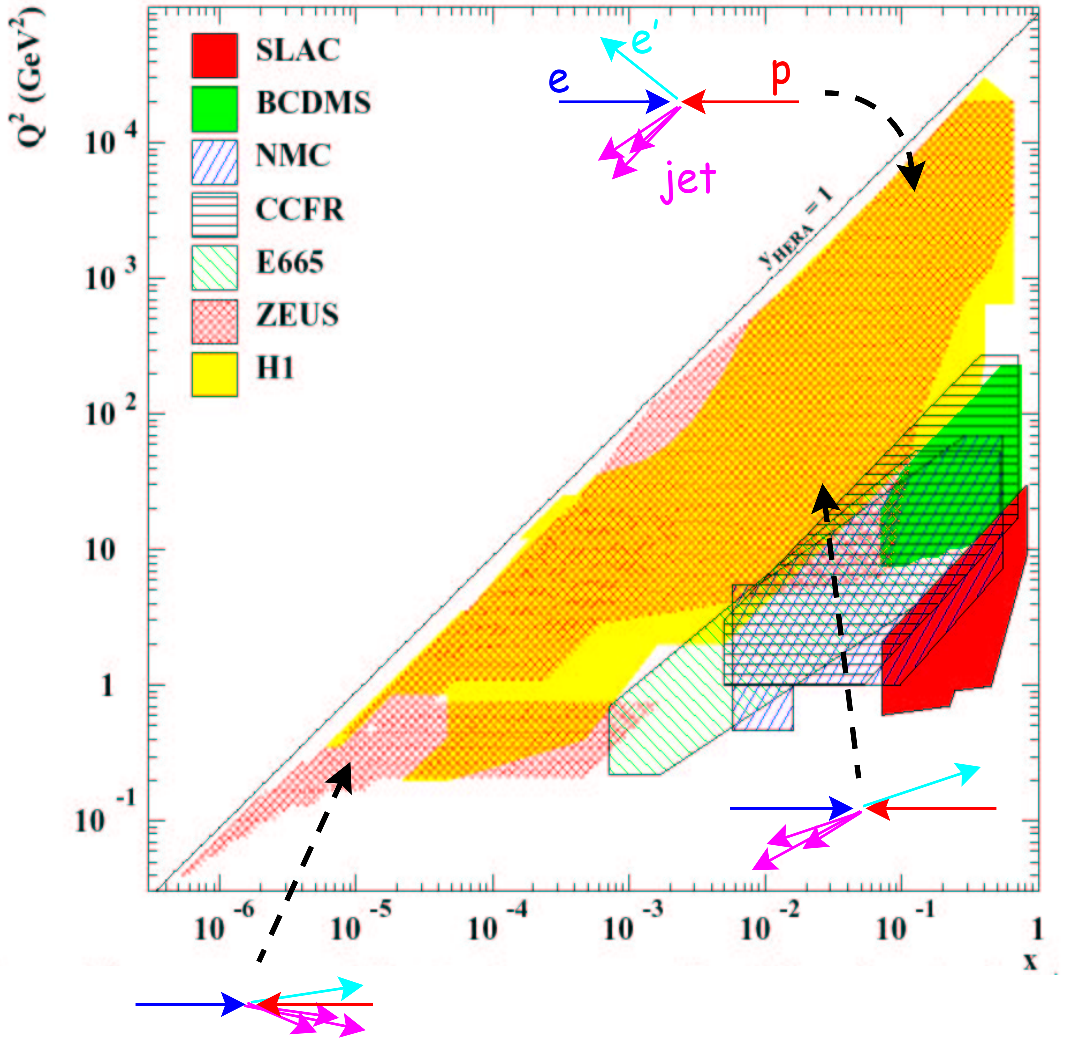
Design value



120 pb^{-1} per experiment

Kinematic Range and Highlights from HERA I

Significant increase in kinematic range beyond fixed target experiments



Highlights from HERA I (1992-2000)

- proton structure & QCD
- low x physics
- photon structure
- physics beyond the Standard Model

HERA II

- Luminosity upgrade
- Spin rotators for ZEUS and H1 ⇒ longitudinally polarized electrons/ positrons
- H1 and ZEUS detector upgrades

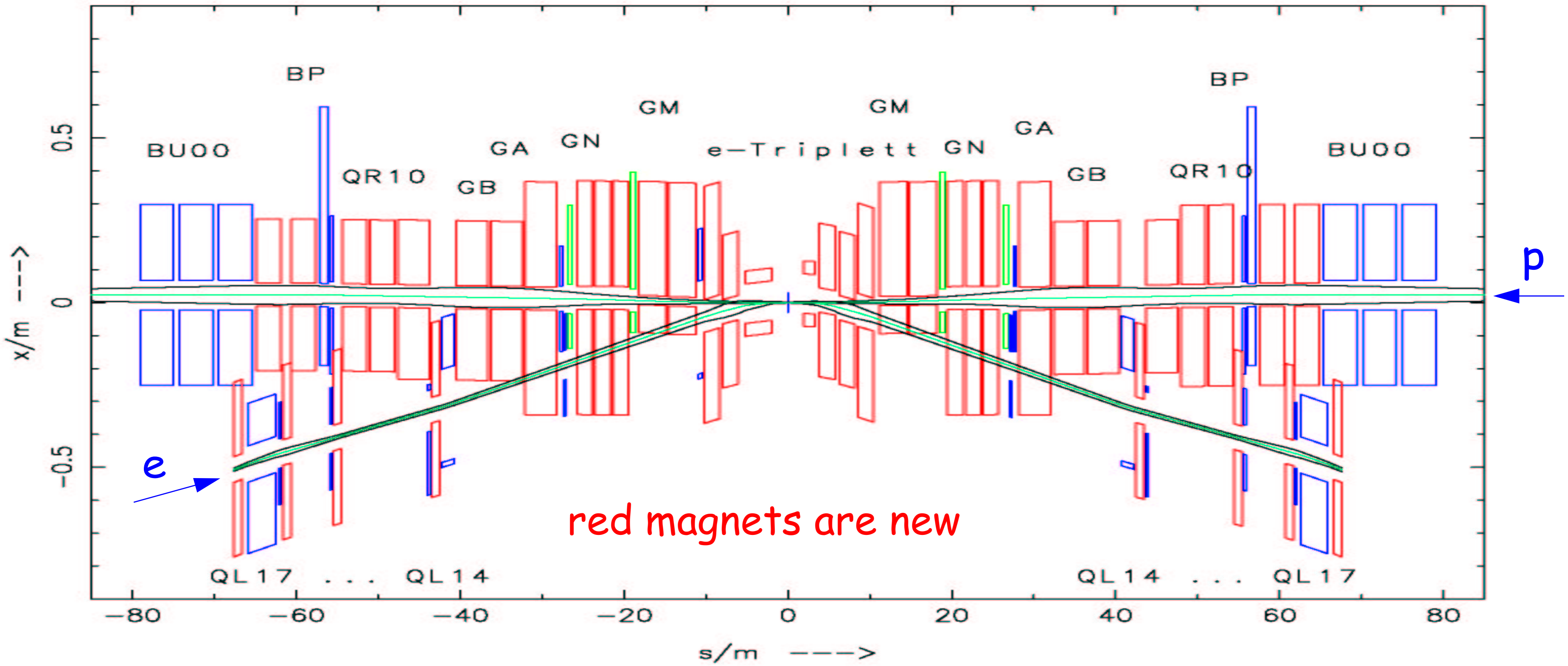
Physics at HERA II

- Searches
  - high pt leptons
  - stop
  - LQ, CI
  - ν^*, e^*
- High x, high Q^2
  - xF_3
  - uZ, dZ couplings
  - u,d densities
  - W_R
- High x, low Q^2
  - F_L
  - α_s
- QCD
  - jets
  - bottom
  - charm
- Diffraction

In order to complete HERA program need

- integrated luminosity of 1 fb^{-1}
- shared ≈ equally between
  - e^-p and e^+p
  - and with both polarisation states

Concept of new Interaction Regions



Stronger focusing of protons by moving proton quadrupoles closer to IR : 26m → 11m ⇒

- early beam separation by superconducting magnets inside detectors
- reduced e-bending radius: 1200 m → 400 m
  ⇒ increased synchrotron radiation power: P_{tot} = 28 kW @ 58mA , $E_{crit} \leq$ 150keV
- radiation has to pass the detector and is absorbed at 12, 19 and 25 m behind the experiments

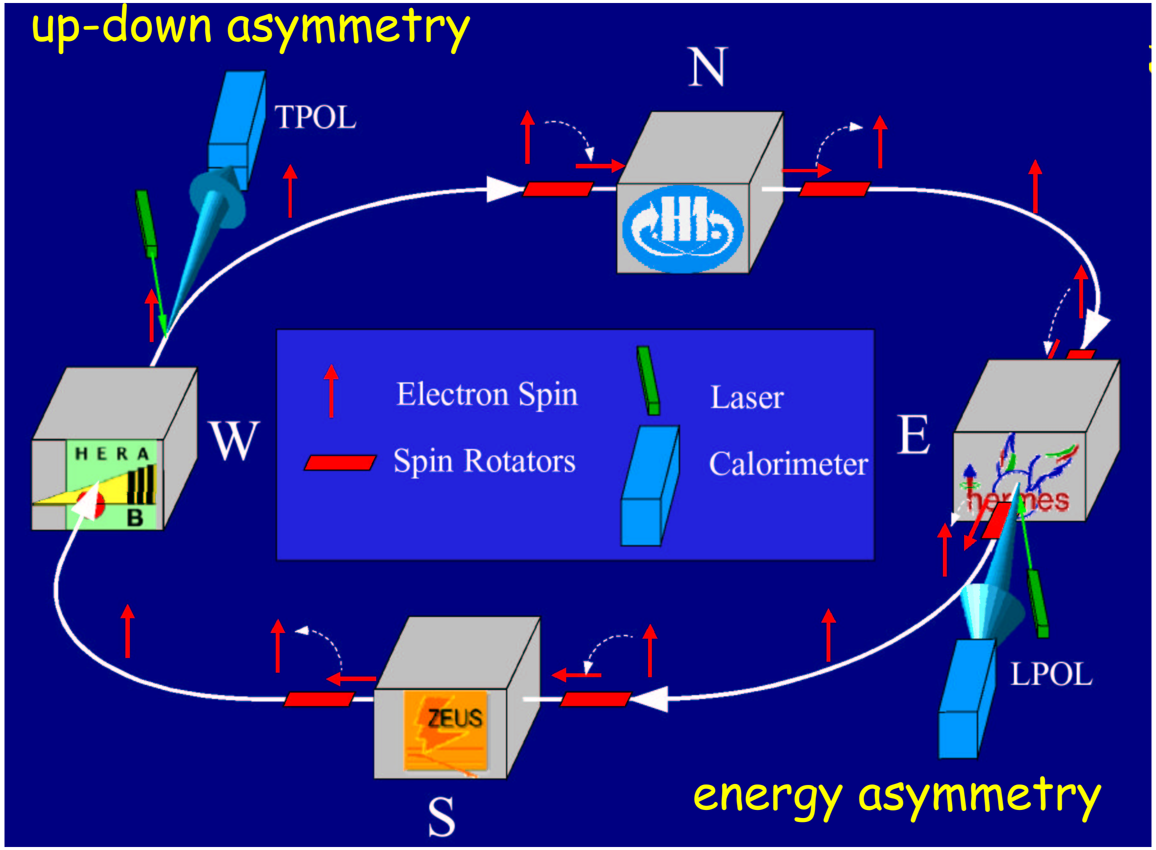
HERA Parameters after the Upgrade

Parameters	before Upgrade		after Upgrade	
	e-ring	p-ring	e-ring	p-ring
E [GeV]	27.5	920	27.5	920
I [mA]	50	100	58	140
N_{ppb} [10^{10}]	3.5	7.3	4.0	10.3
n_{bunch}	174	174	174	174
β_x^* [m]	0.90	7.0	0.63	2.45
β_y^* [m]	0.60	0.5	0.26	0.18
ε_x [nm]	41	5000/γ	22	5000/γ
$\varepsilon_y / \varepsilon_x$	10%	1	18%	1
σ_x ; σ_y [μm]	190 ; 50	190 ; 50	120 ; 30	120; 30
σ_z [mm]	12	130	12	130
$\Delta\nu_x$	0.012	0.0013	0.027	0.002
$\Delta\nu_y$	0.03	0.00035	0.041	0.0005
L [$cm^{-2}s^{-1}$]	**1.5 x 10^{31}**		**7 x 10^{31}**	

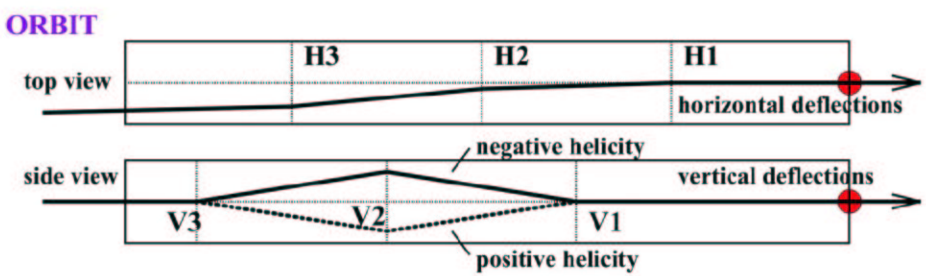
New machine components:

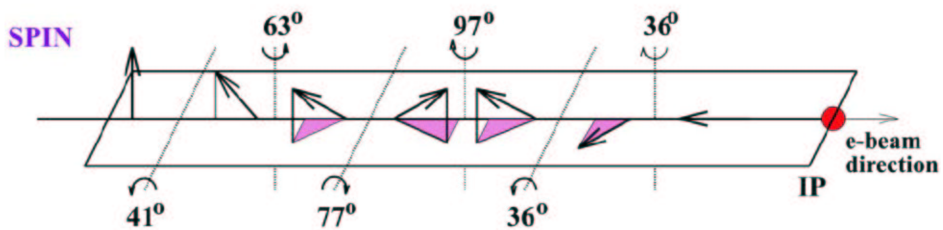
- 448 m new vacuum beam pipe
- 4 superconducting magnets
  - BNL, Brookhaven
- 54 new normal conducting magnets
  - Efremov Institute, St. Petersburg
- 2 spin rotators

Spin Rotators in HERA

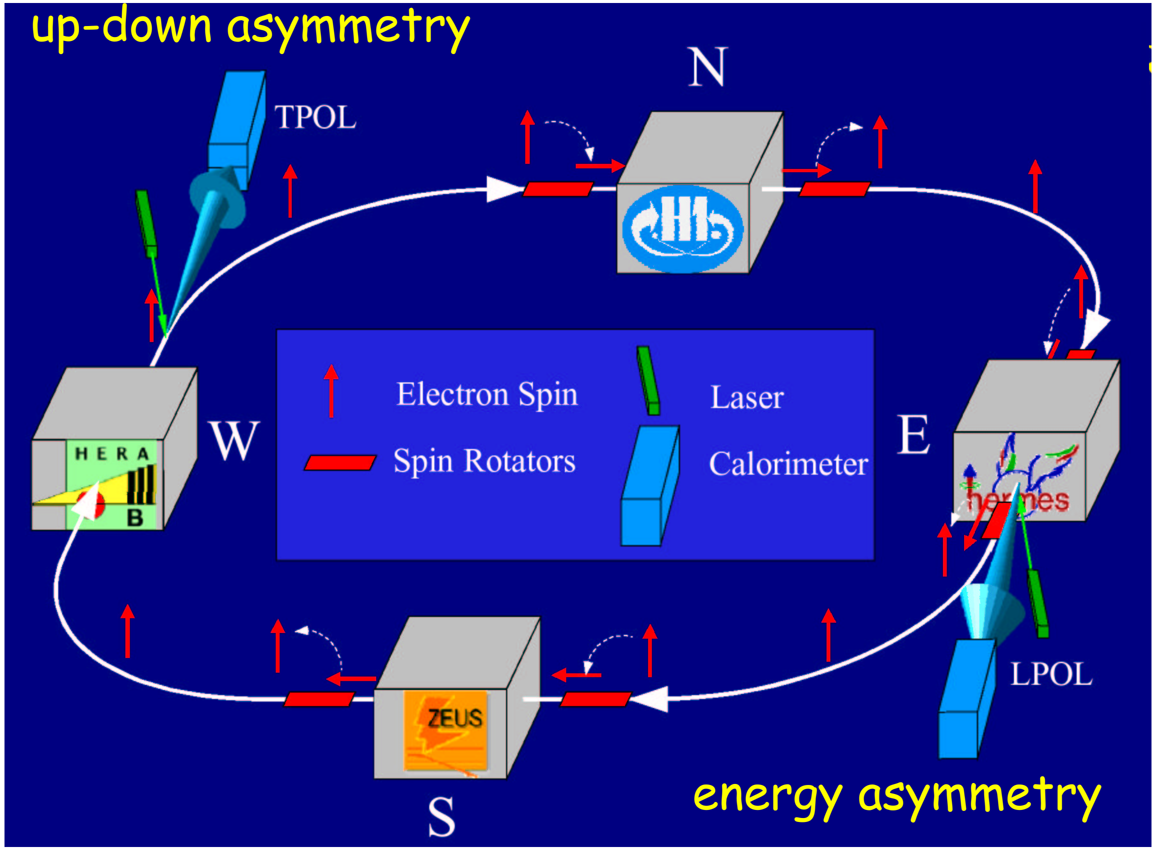


Rotator down → positive helicity

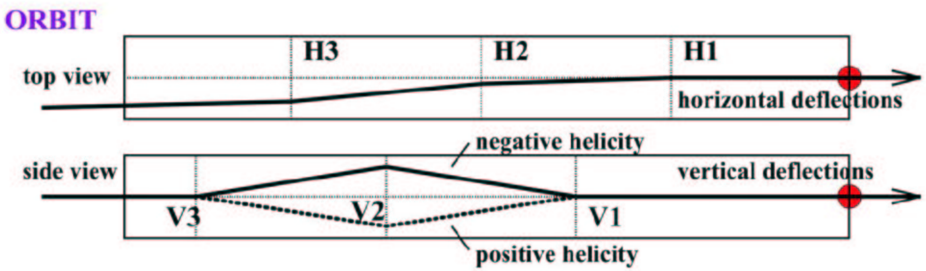


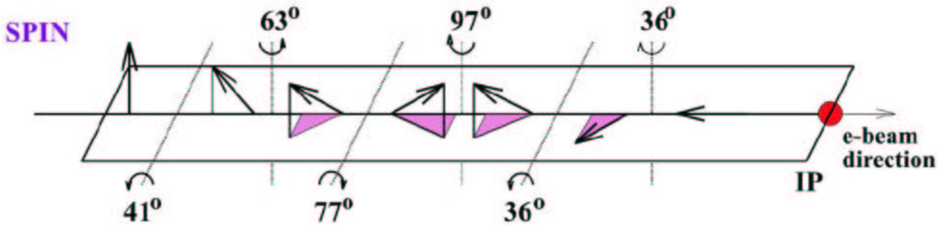


Spin Rotators in HERA

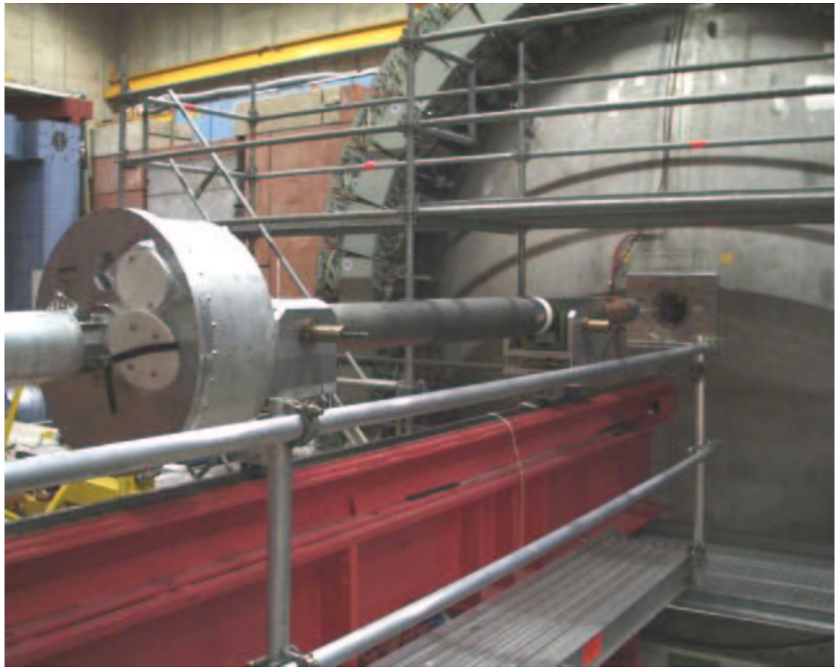


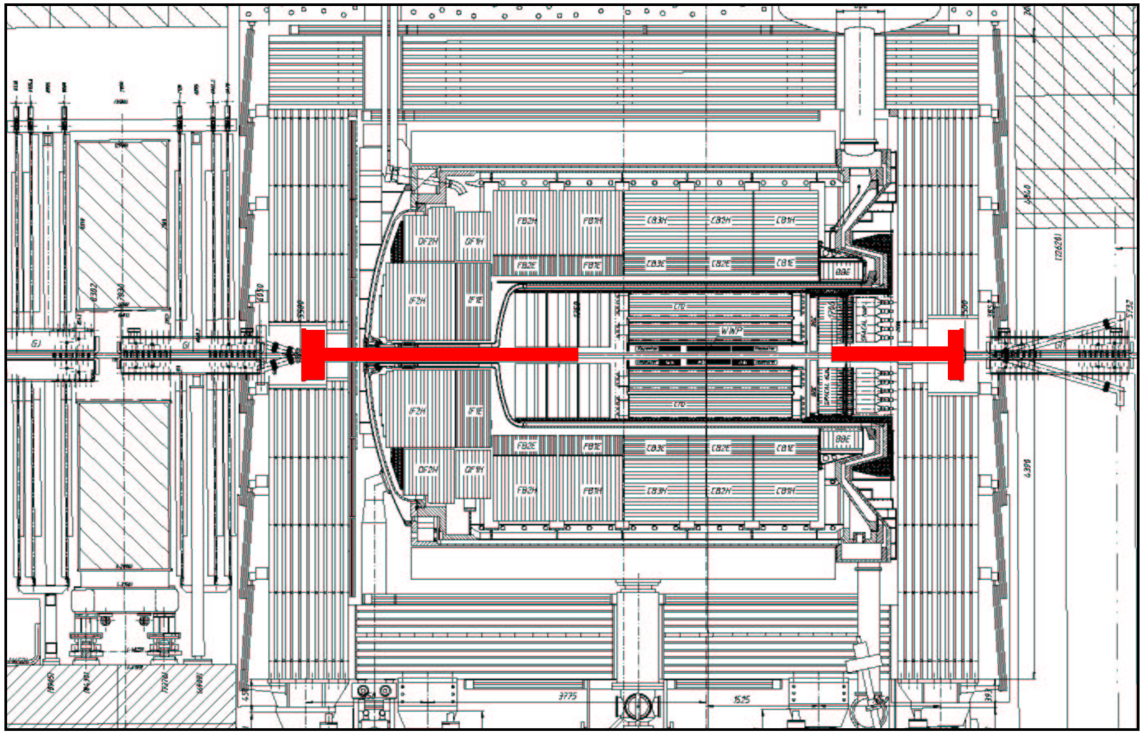
Rotator up → negative helicity

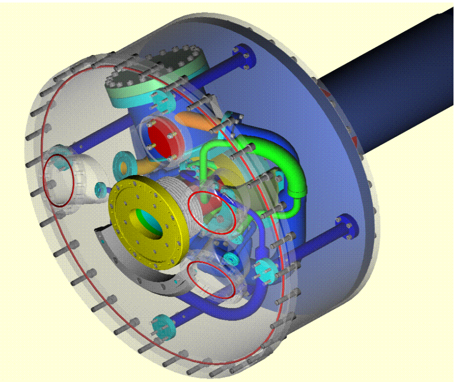




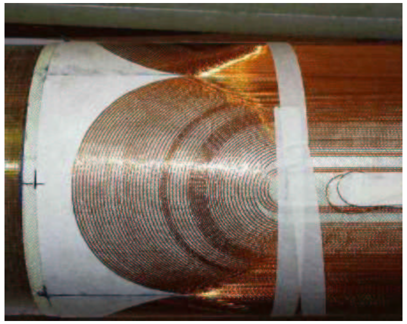
New Superconducting Magnets in the Experiments







end can with
He supply lines



superconductor
positioning precision
0.01mm

- combined function magnets including dipole, quadrupole, skew dipole, skew quads, sextupole
- very tight space requirements (ø <180 mm)
  ⇒ super conducting magnets
- designed and constructed at BNL
- complicated movable supports needed inside detectors (forces on LAr cryostat)

Achievements and Status

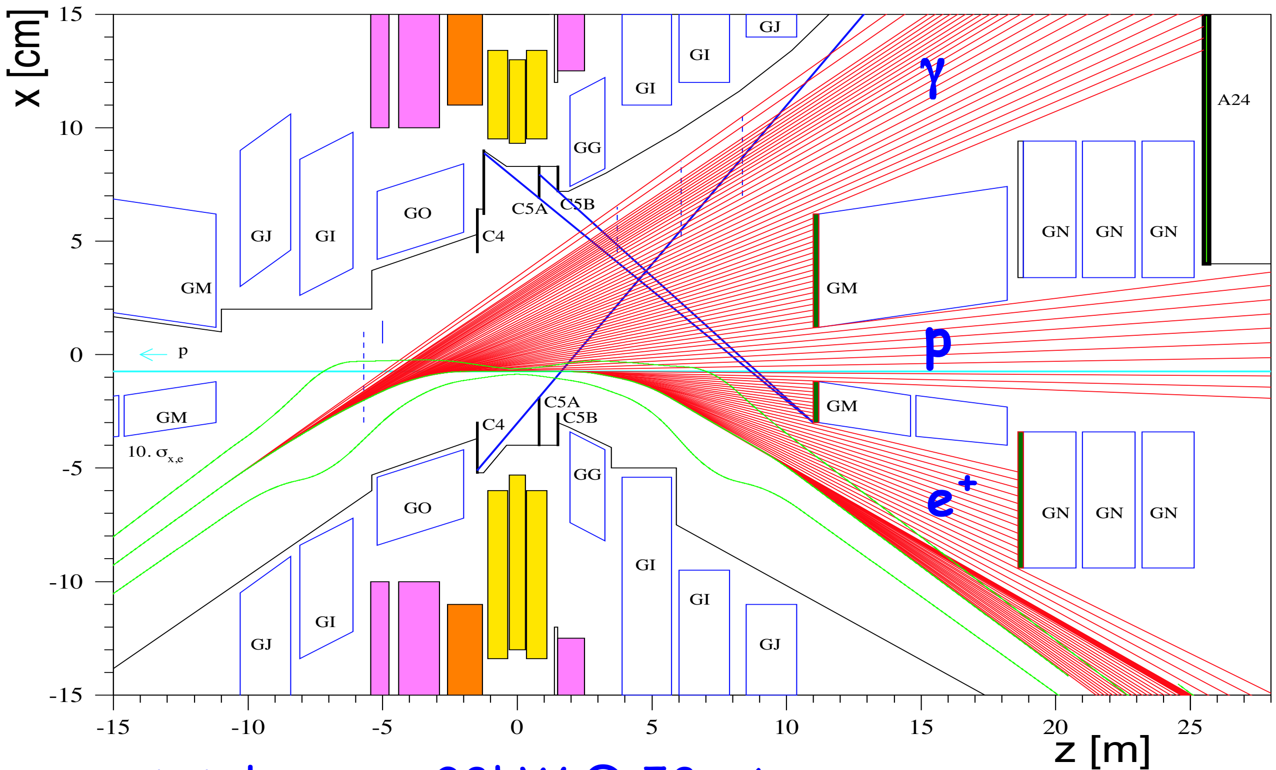
Sep 00 – Jul 01	Shutdown for installation
Aug-Sep 01	Recommissioning of both HERA rings
Oct 01	Luminosity commissioning
Nov-Dec 01	Background studies, beam based alignment: $I_{e+} < 2mA$ – aperture limitation identified
Jan-Mar 02	Installation of additional collimators, widen tight apertures
Mar-Apr 02	Restart ep operation
Apr 02 - now	Colliding beams with increasing intensities Accelerator & background studies, beams for HERAb/Hermes

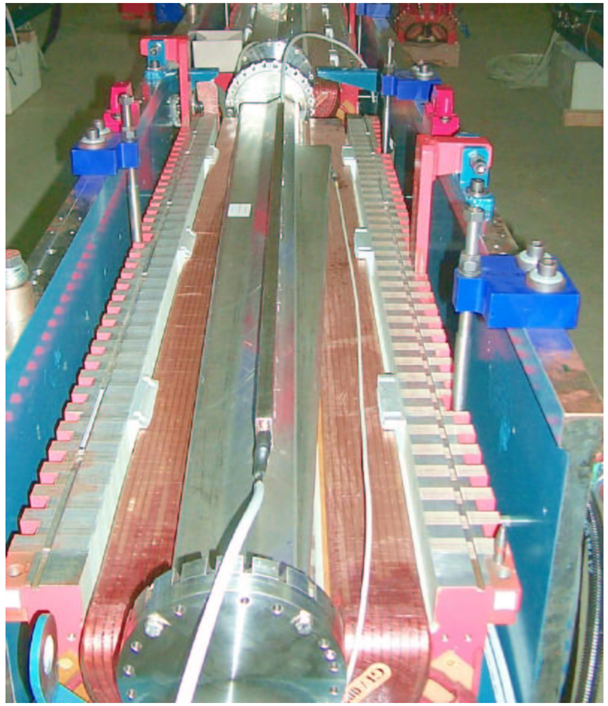
– background in sensitive detector components (tracker & Si) limits beam currents to $I_p \times I_{e+} \approx 600\ mA^2$ (design 8000 mA^2)

– reach design specific luminosity at low bunch currents

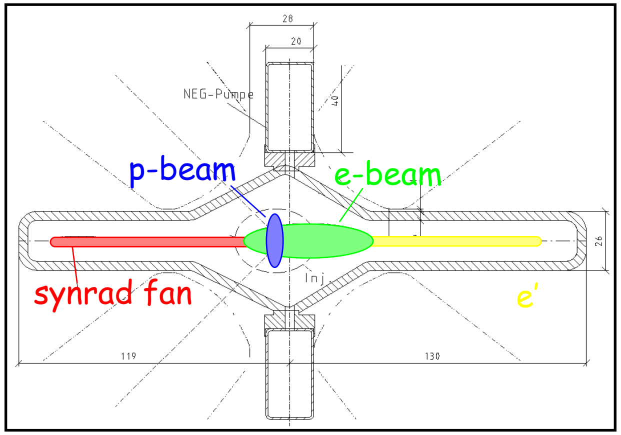
– reach $L = 8.9\times10^{30}\ cm^{-2}s^{-1}$ (design $7\times10^{31}\ cm^{-2}s^{-1}$)

Challenge: Synchrotron Radiation





Need rather complicated beampipe (steel) to accomodate 3 different beams

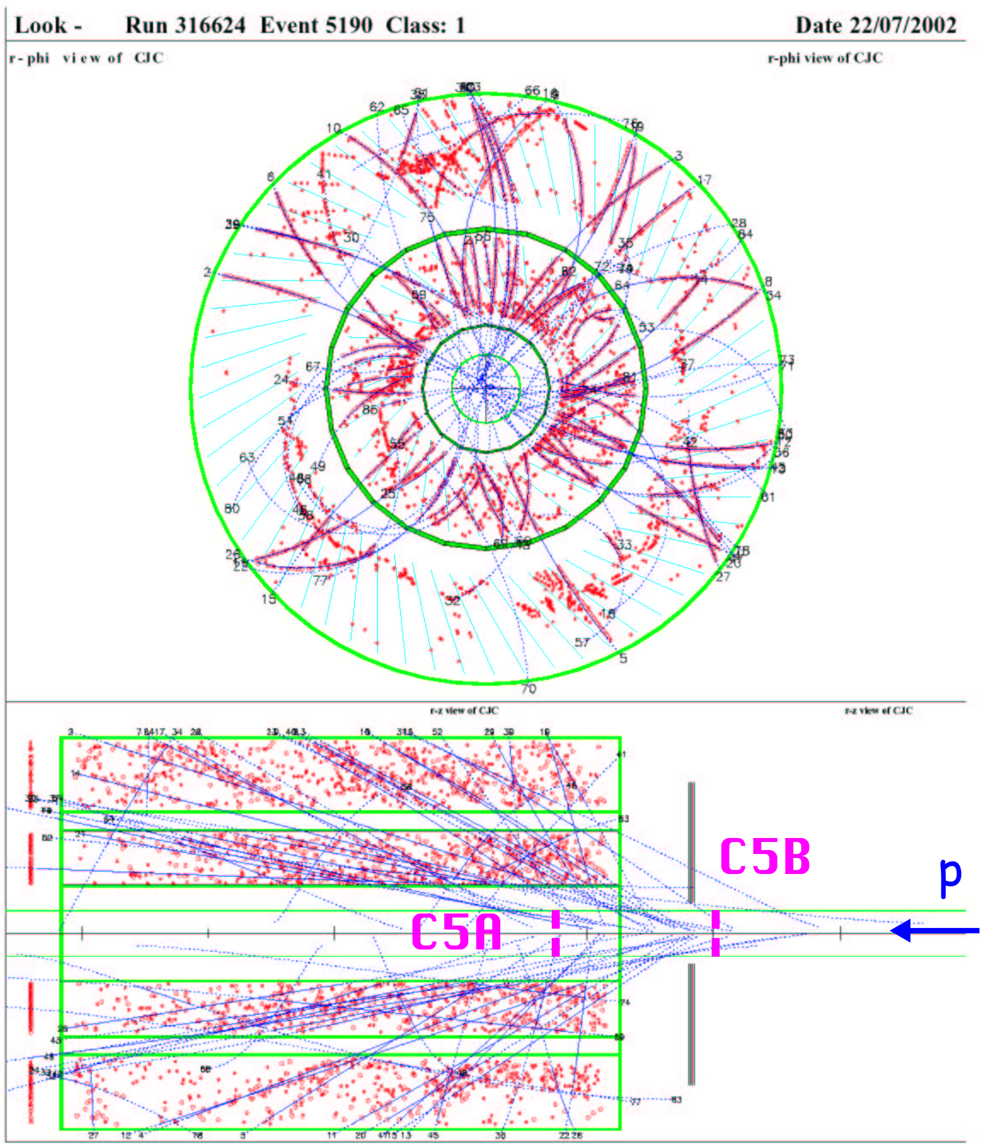


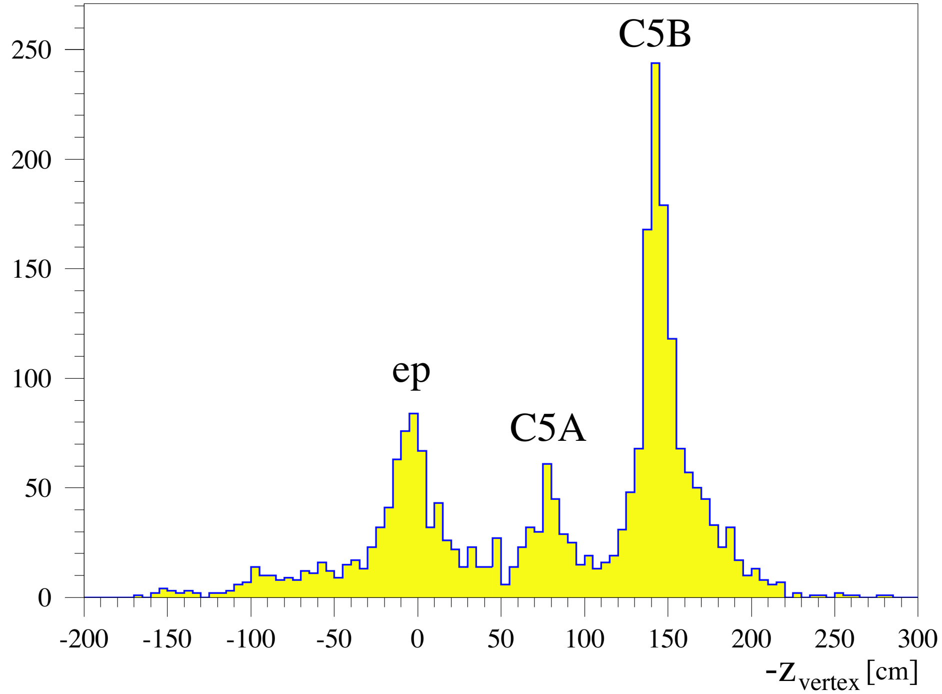
total power: 28kW @ 58mA

Concept:

- no hits of direct synchrotron radiation on beam pipe
- use combination of downstream absorbers (12, 19, 25m)
- and integrated collimators to shield against backscattered synchrotron radiation

Challenge: Proton Background

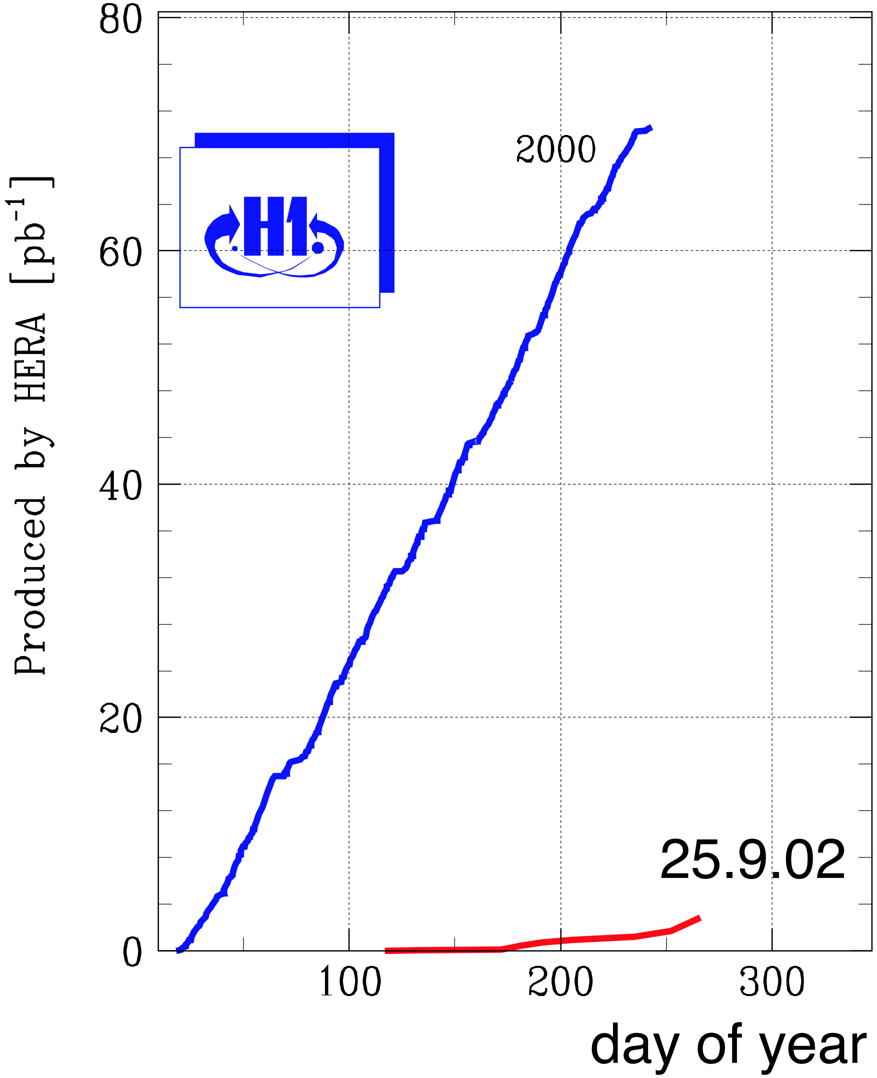




Mechanism:

- desorption by synchrotron radiation ⇒ dynamic pressure increase p-upstream
- debris of p-restgas interactions hits aperture limitations (ie synchrotron masks C5A & C5B)
- tolerable I_{CTD} @ HERA design currents requires ≈ 5 x better vacuum around IPs

Where do we stand ?



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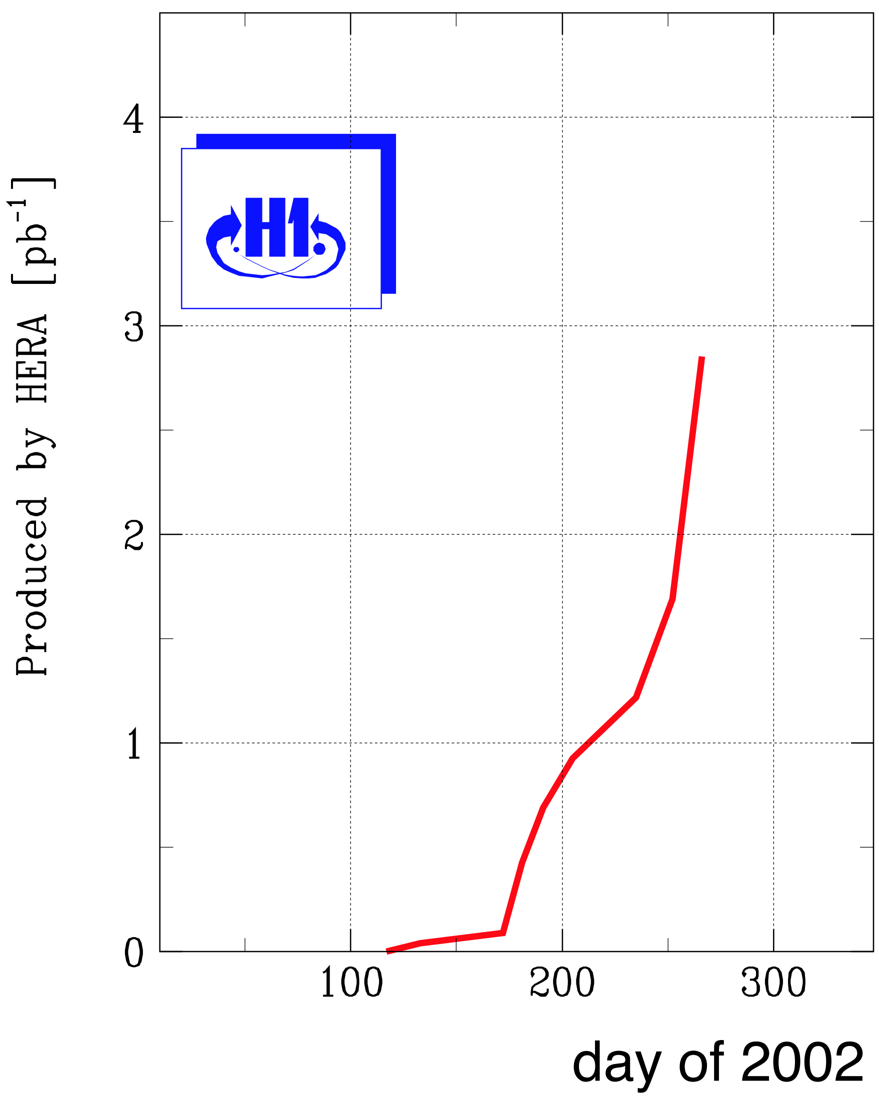
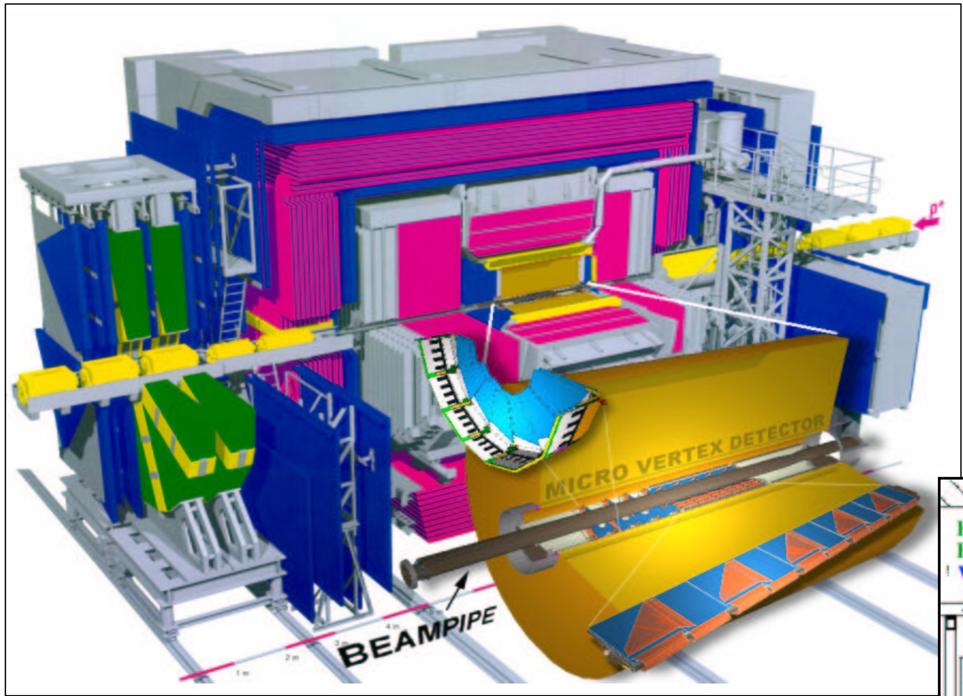


Detector Upgrades



Many upgrade projects

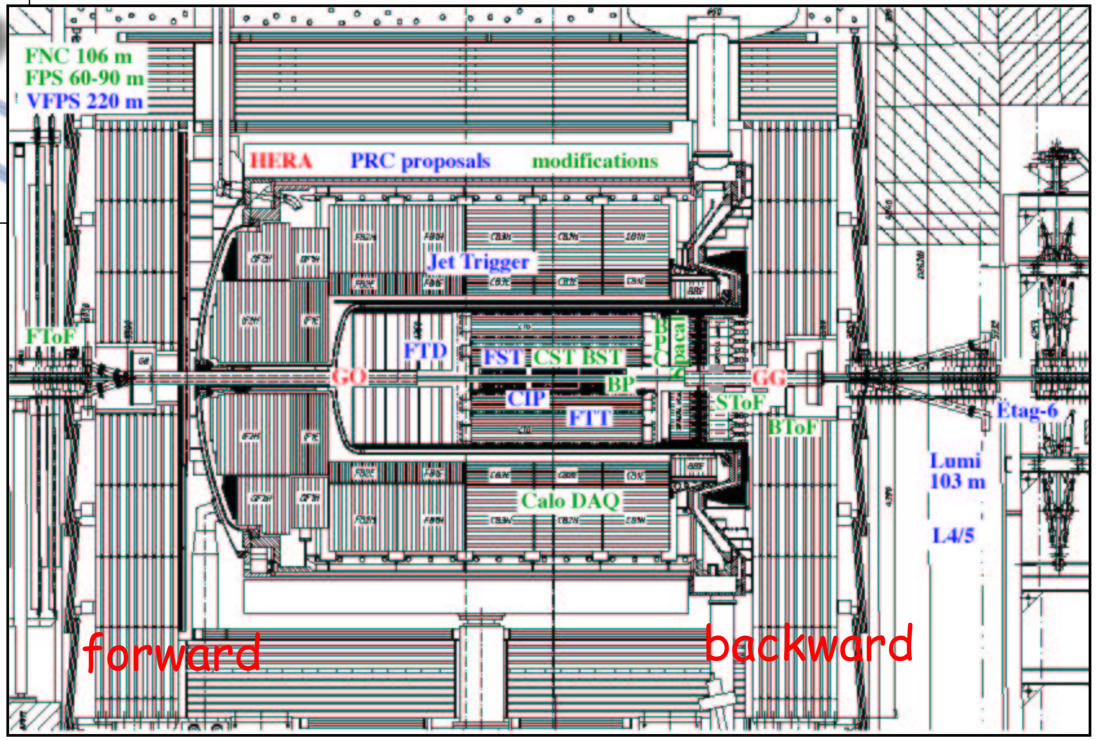
with emphasis on enhanced capabilities for

- tracking (in forward direction)
- triggering (data taking rate ≈ constant)

Mandatory for H1 & ZEUS:

luminosity detector upgrade

- see high load of synchrotron radiation
  ⇒ need radiation hard γ detector
- cope with bunch to bunch pile up



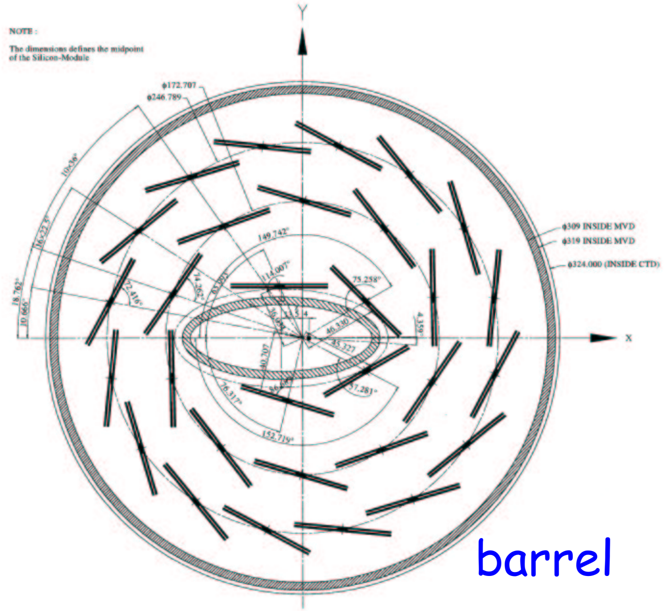
ZEUS Micro Vertex Detector MVD

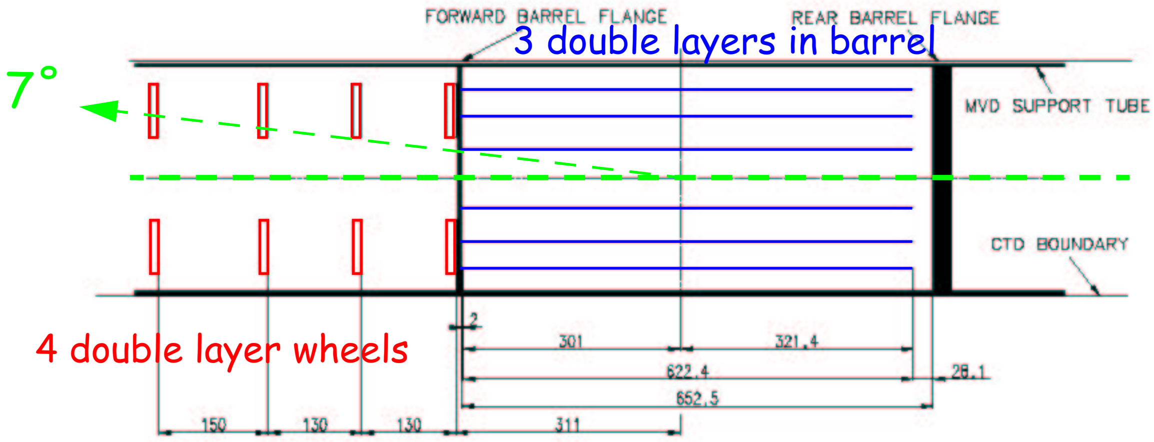
Design goals

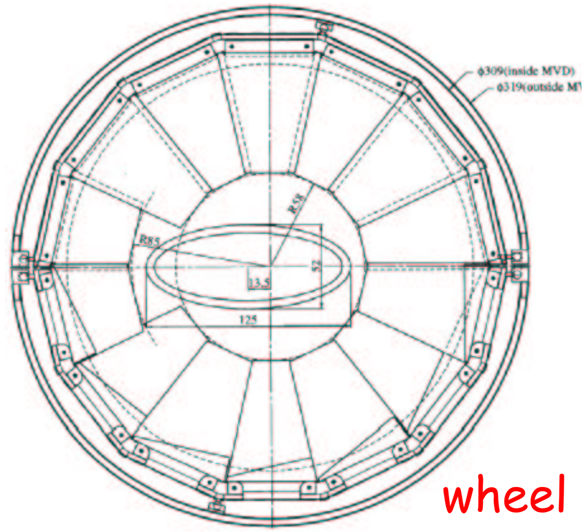
- three spatial measurements per track in two projections
- polar angle coverage 10°-170°
- <20μm intrinsic hit resolution for normal incidence
- impact parameter resolution ≈100 μm for p > 2GeV
- high efficiency (>97%)

Constraints

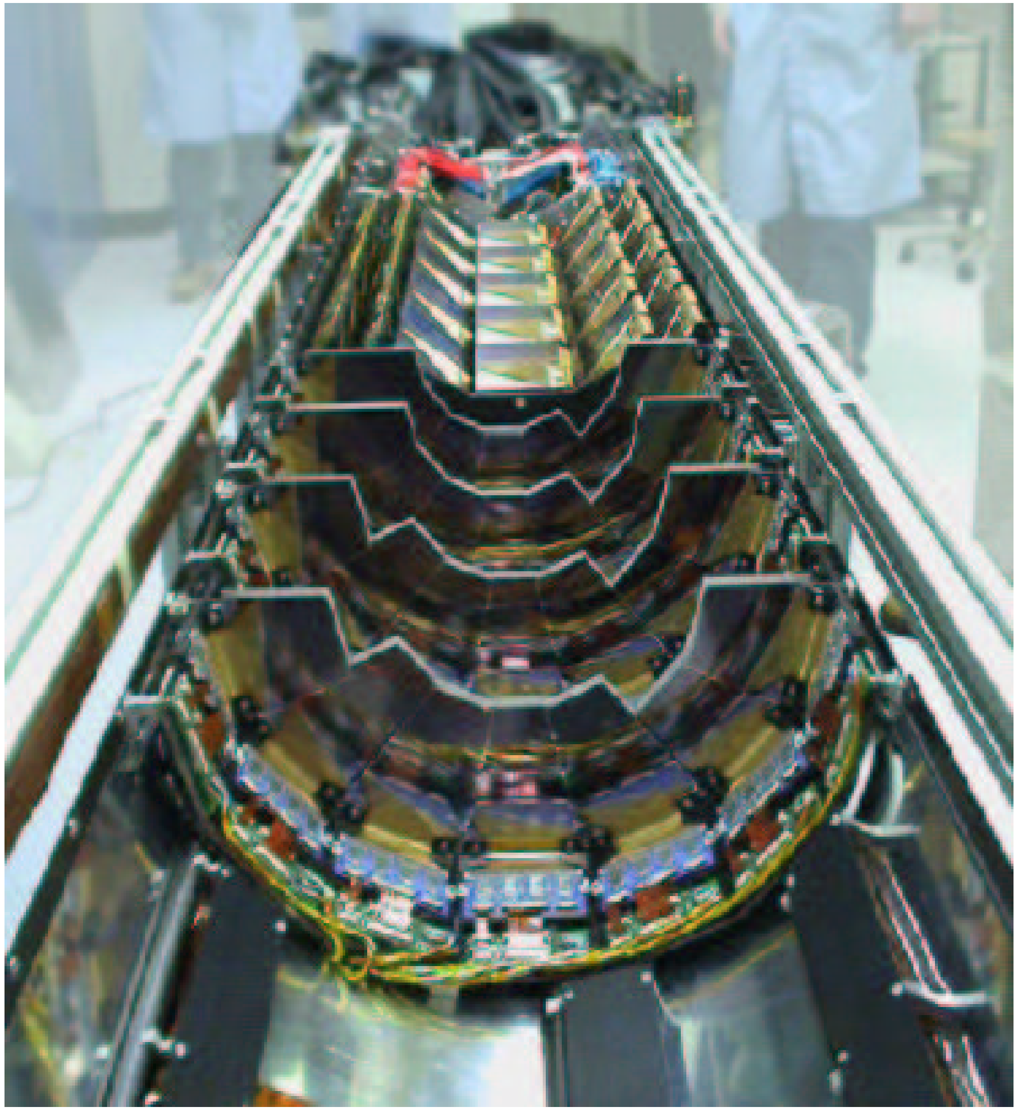
- elliptical beam pipe
- CTD inner diameter 320mm
- 96 ns bunch crossing time

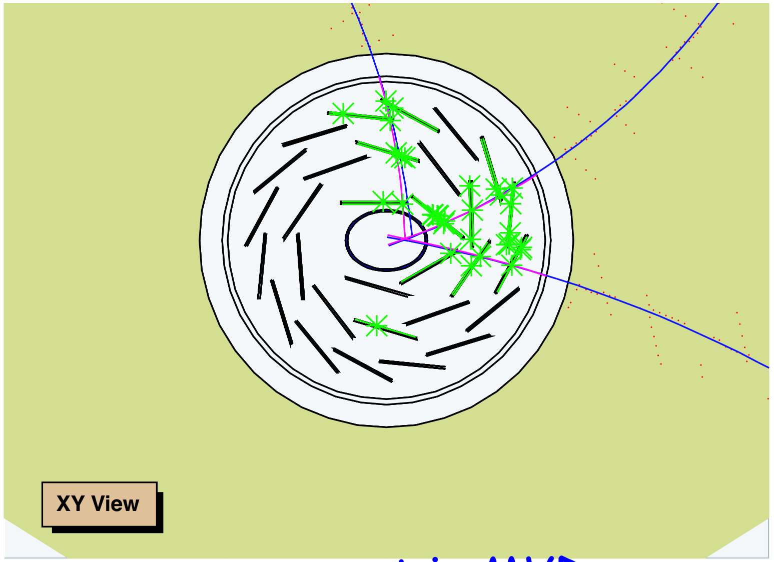




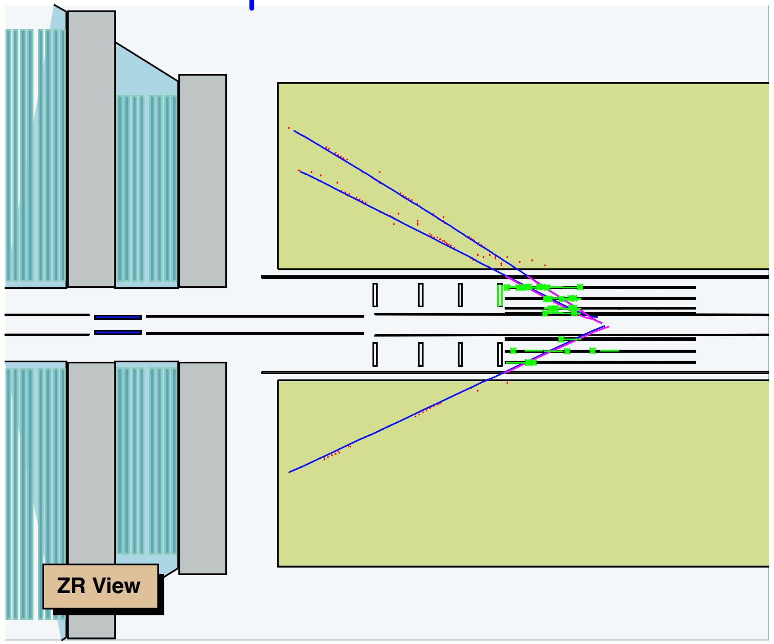


ZEUS Micro Vertex Detector MVD





ep event in MVD

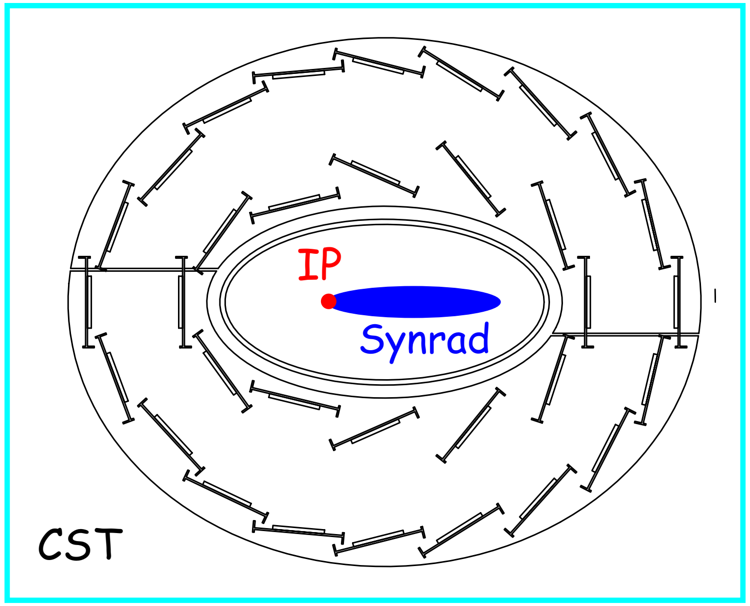


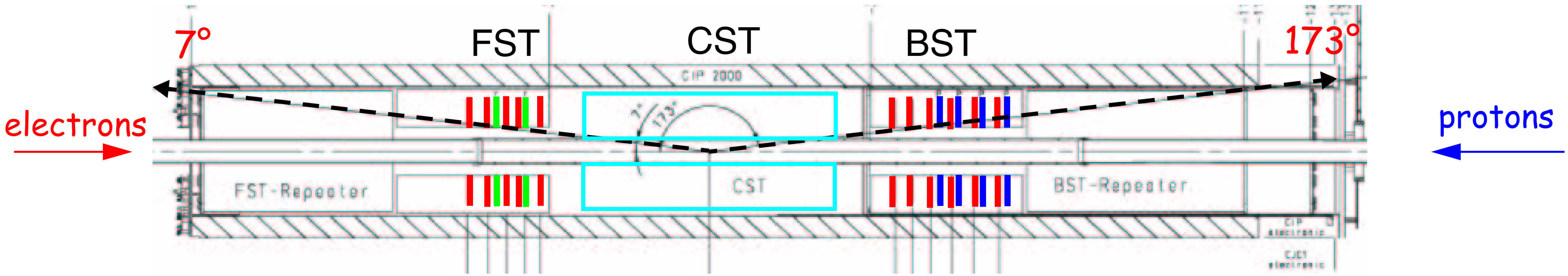
H1 Silicon Detector Upgrade

H1 successfully operates CST and BST since 1997

Upgrade

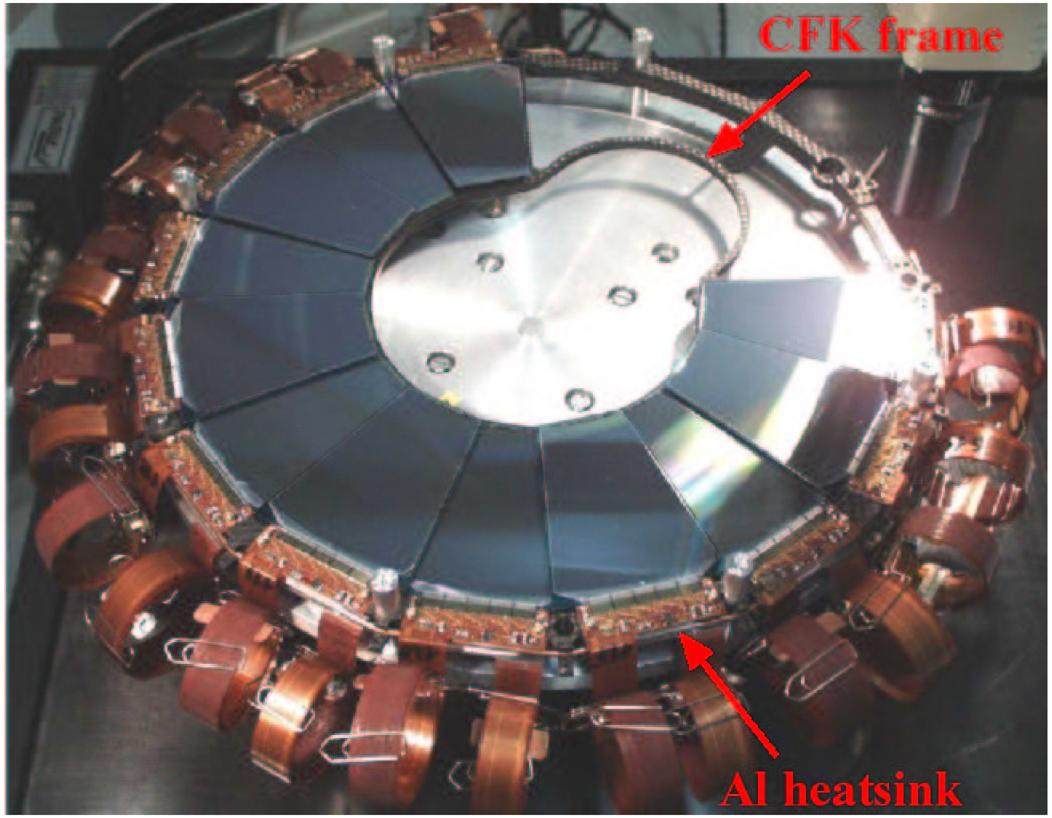
- adapt to new elliptical beam pipe geometry
- *backward region BST*
  - rearrange existing BST: 6 u/v planes
  - add 4 planes with pad detectors for triggering
- *central region CST*
  - radiation damage observed
  - radiation hard readout electronics for CST
- *forward region FST* ⇐ *new*
  - add 5 u/v planes
  - add 2 r planes

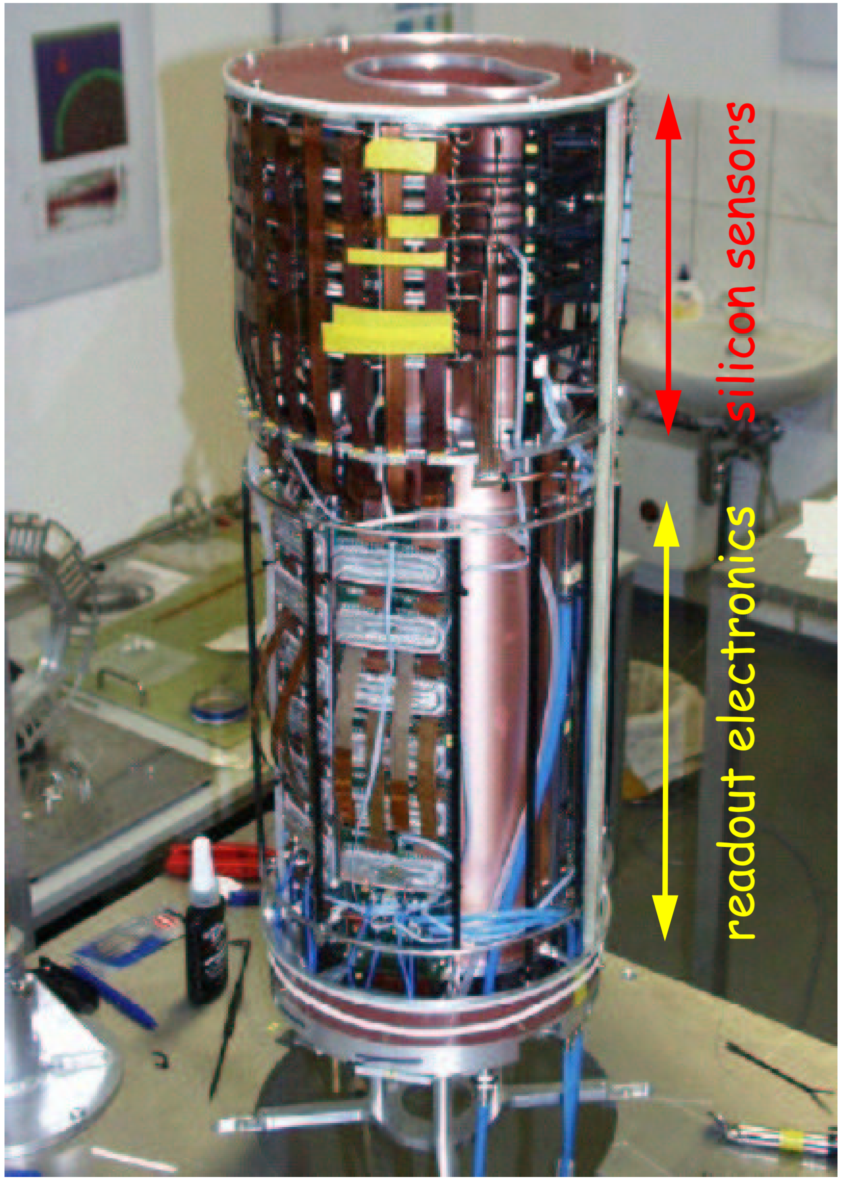




H1 Forward Silicon Tracker FST

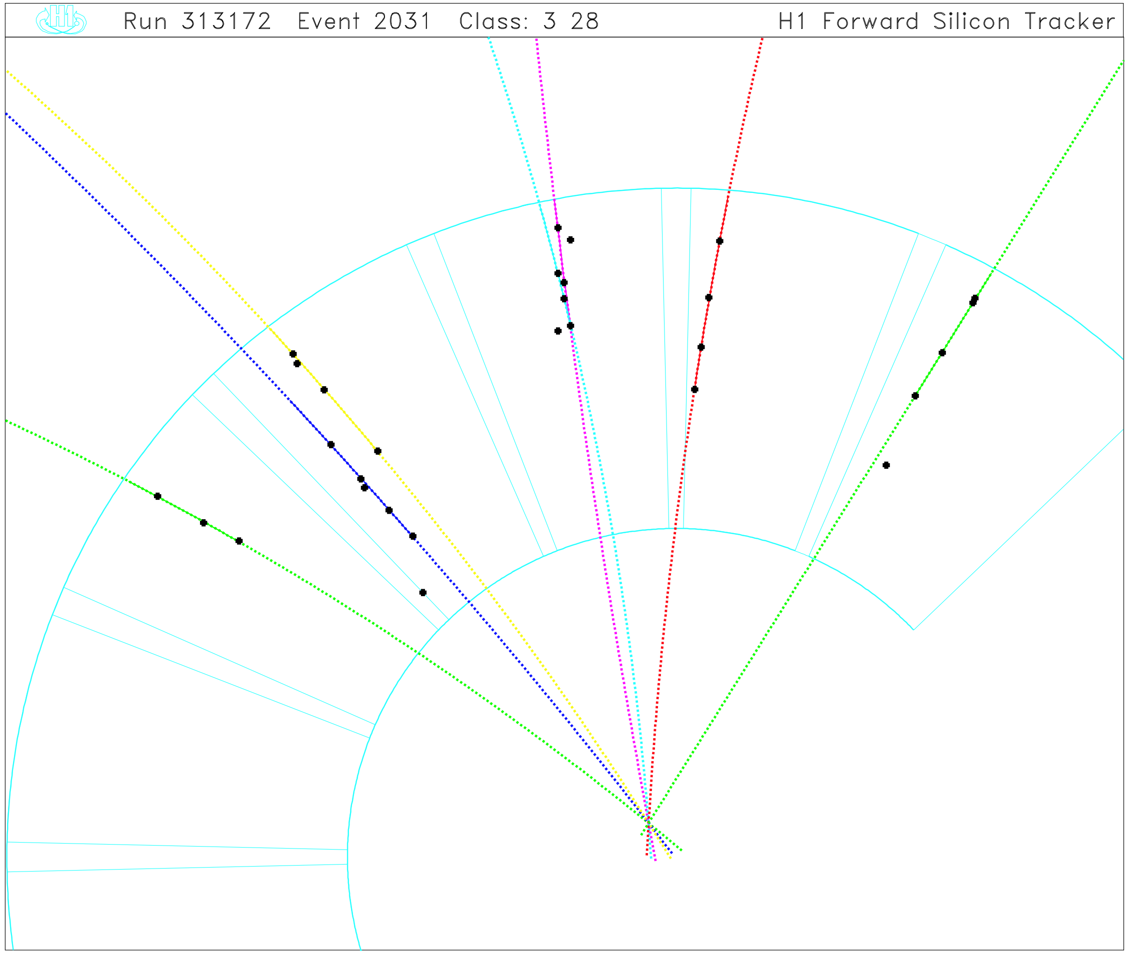
single wheel

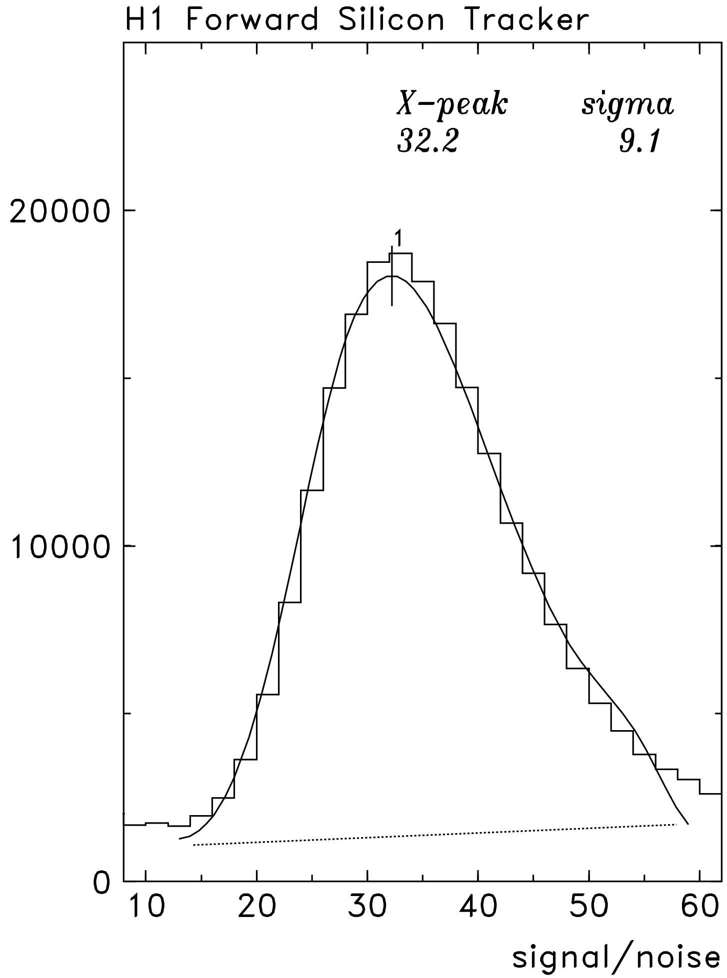




full detector

FST Performance





- excellent S/N
- next step: alignment

Triggering at HERA II

HERA Upgrade:

- higher background from synchrotron radiation and particle background
- larger physics event rates but output rate ≈ constant (high E_T scales are safe)

Need also improvements for trigger:

- higher redundancy → better background rejection

  H1: replace central inner proportional chamber CIP by new one with 5 instead of 2 layers
  optical readout of of 8500 pads for L1 (2.3μs) decision

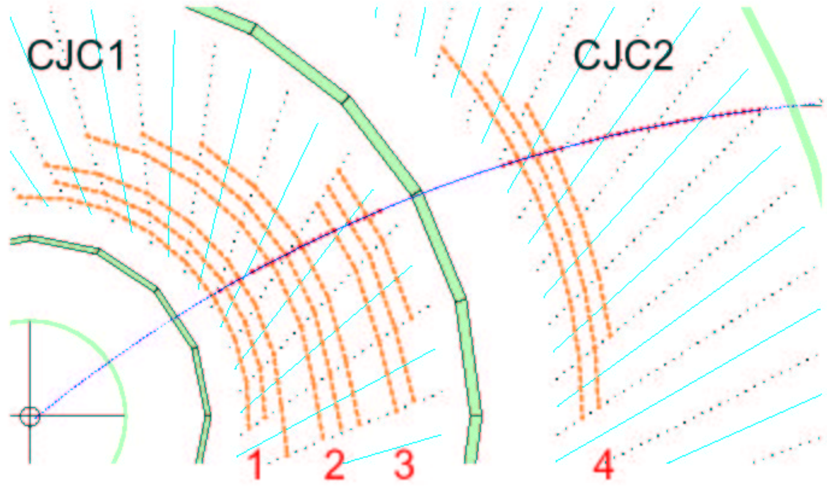
- higher selectivity

  ZEUS General Track Trigger (GTT): new second level trigger based on PC farm, input from:
  - micro vertex detector MVD
  - central track detector CTD
  - straw tube tracker STT

  H1 Fast Track Trigger (FTT)
  - input from Central Jet Chamber CJC

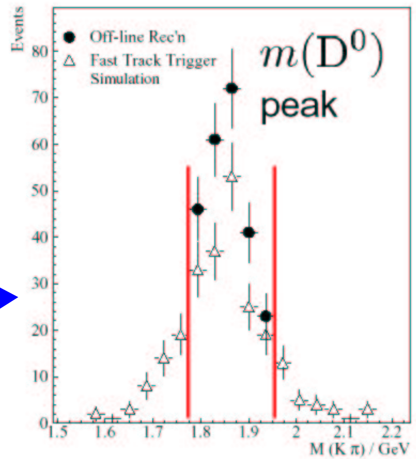
Fast Track Trigger FTT

- Level 1: 2.3 μs
  - signal digitization
  - finding track segments from hits
  - coarse track linking for L1 trigger signal
- Level 2: 22 μs
  - track segment linking
  - fitting track parameters (3D)
  - trigger decision based on basic event properties
- Level 3: ≈100 μs (processor board farm)
  - identification of particle decays

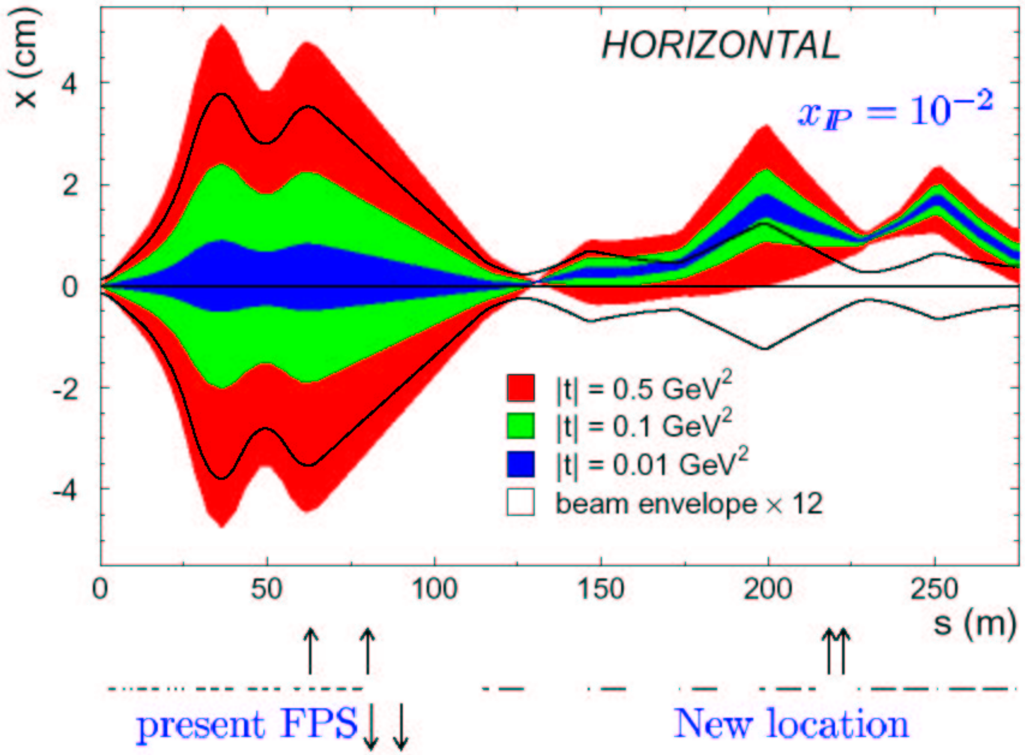


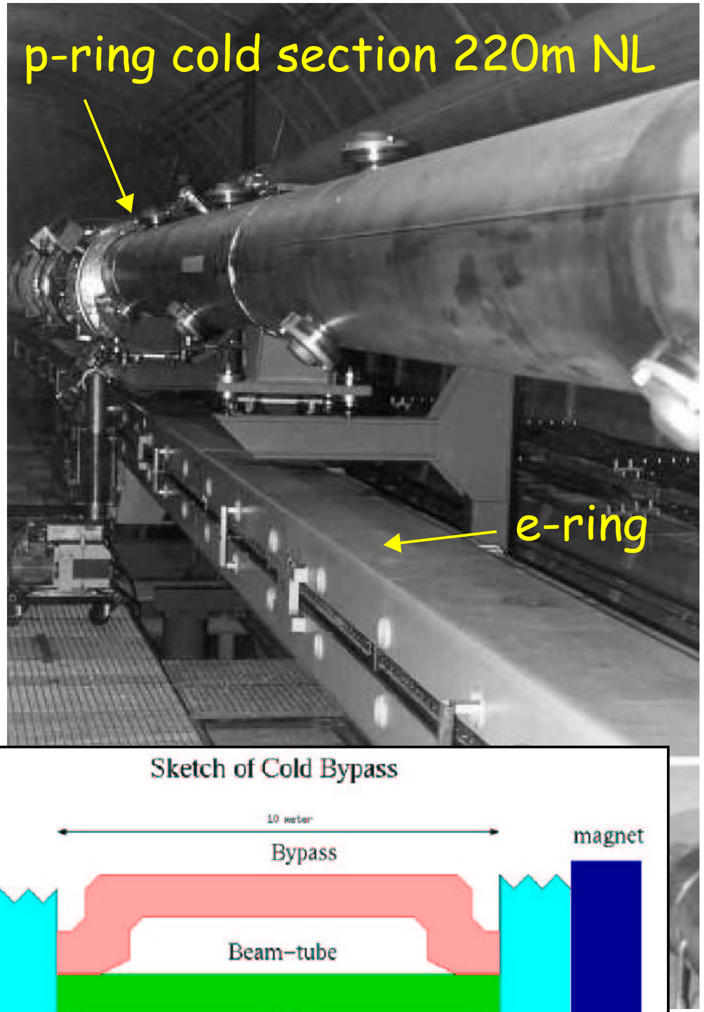
$r - \Phi$ view of the central drift chamber

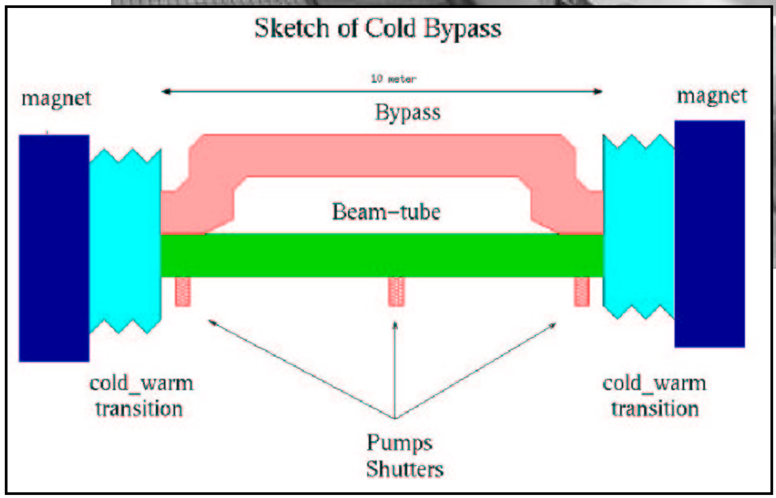
- makes extensive use of content addressable memories (CAM)
- only possible with new generation of programmable electronics
  - high density FPGAs
  - DSPs
- performance approaches offline reconstruction in precision



H1 Very Forward Proton Spectrometer VFPS







- measure diffractively scattered protons
- use proton bending magnets as spectrometer
- 2 Roman pots with fibre trackers
- high acceptance for small x_P and $0 \leq t \leq 0.5\,\mathrm{GeV}^2$
- ready for installation spring 2003

Summary & Outlook

Ambitious luminosity upgrade project finished

- after difficult start up HERA running reasonably well
- experiments presently still suffer from severe background preventing HERA to operate at design currents
  - synchrotron radiation → optimise shielding & absorber coating
  - proton background → improve vacuum: beam scrubbing (need 30Ah), better pumps

Next steps

- demonstrate design specific luminosity at design bunch currents
- demonstrate longitudinal polarisation with new spin rotators
- exploit further measures to reduce backgrounds
- take 5-10 pb^{-1} (polarised ?) until 1.3.2003

Shutdown 2003

- implement modifications for background reduction
- repair of several detector components
- install Very Forward Proton Spectromater VFPS
- install new LPOL

2003-2006 collect 1 fb^{-1} of data