The H1 detector at HERA

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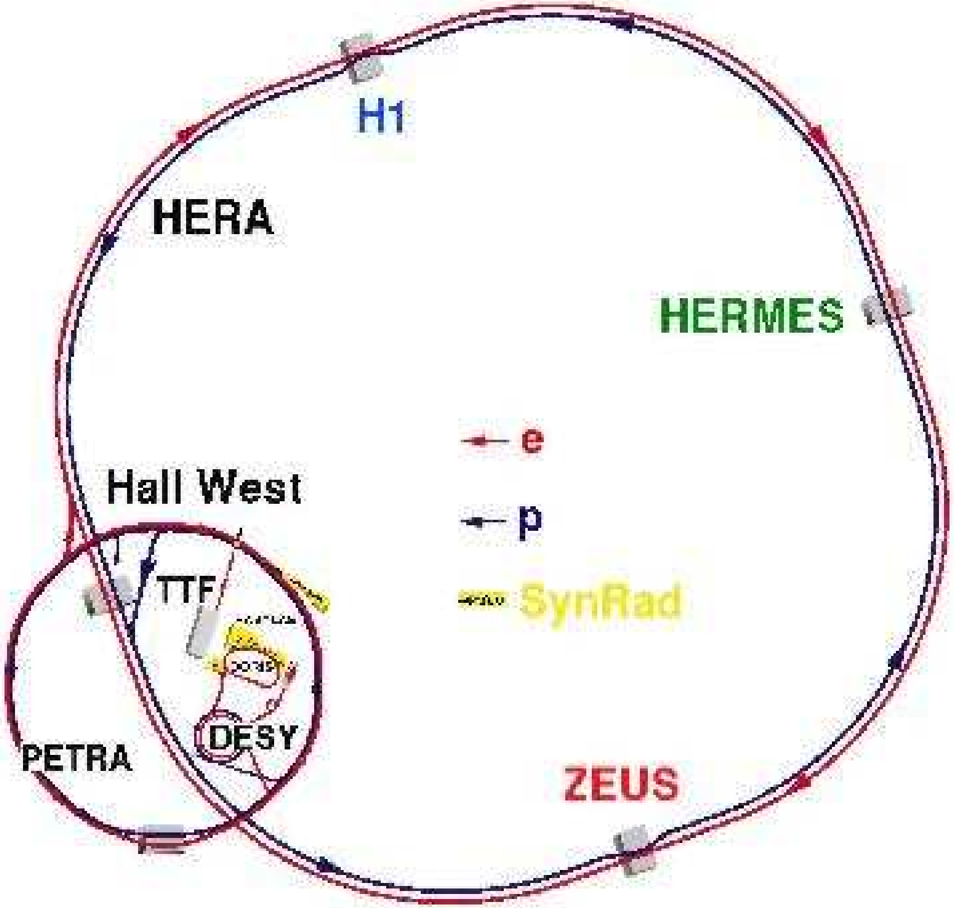
- HERA and H1
- H1 components and performance
- Working at H1

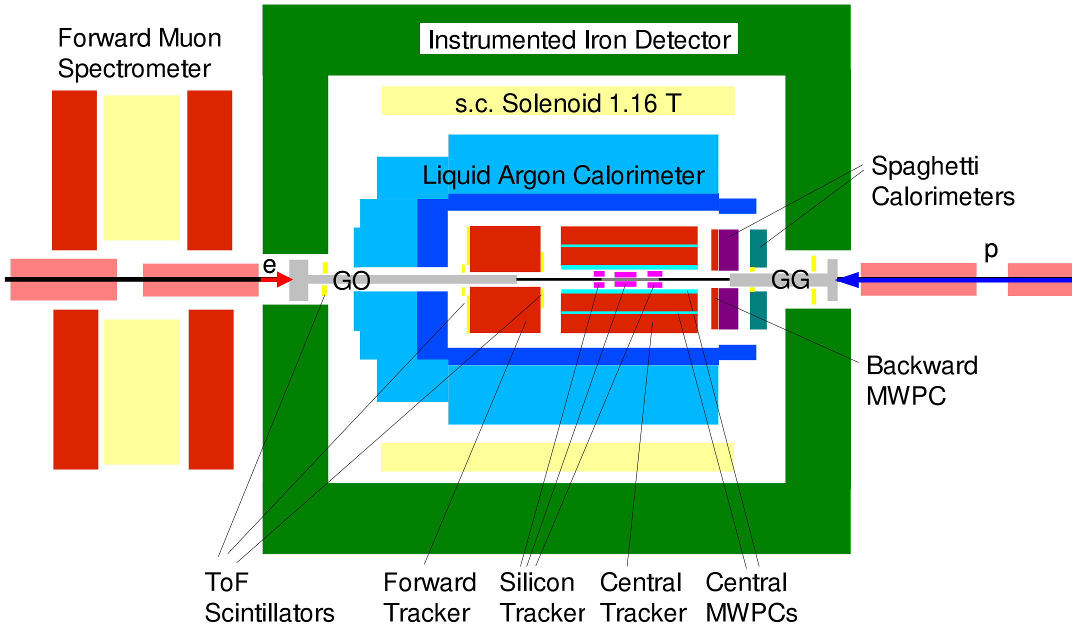
The Hadron Elektron Ring Anlage in Hamburg

- Preaccelerators: e and p linacs, DESY II, III, PETRA.
- HERA-p: 6.336 km proton storage ring.
- 920 GeV, 110 mA.
- Superconducting dipoles at 5.5 T.
- HERA-e: 6.336 km e^+ or e^- storage ring.
- 27.6 GeV, 50 mA.
- Design peak luminosity $5 \cdot 10^{31}$/cm^2/s.
- Two ep interaction points: H1 and ZEUS.
- One eA polarized gas jet target experiment: Hermes.



The H1 Detector

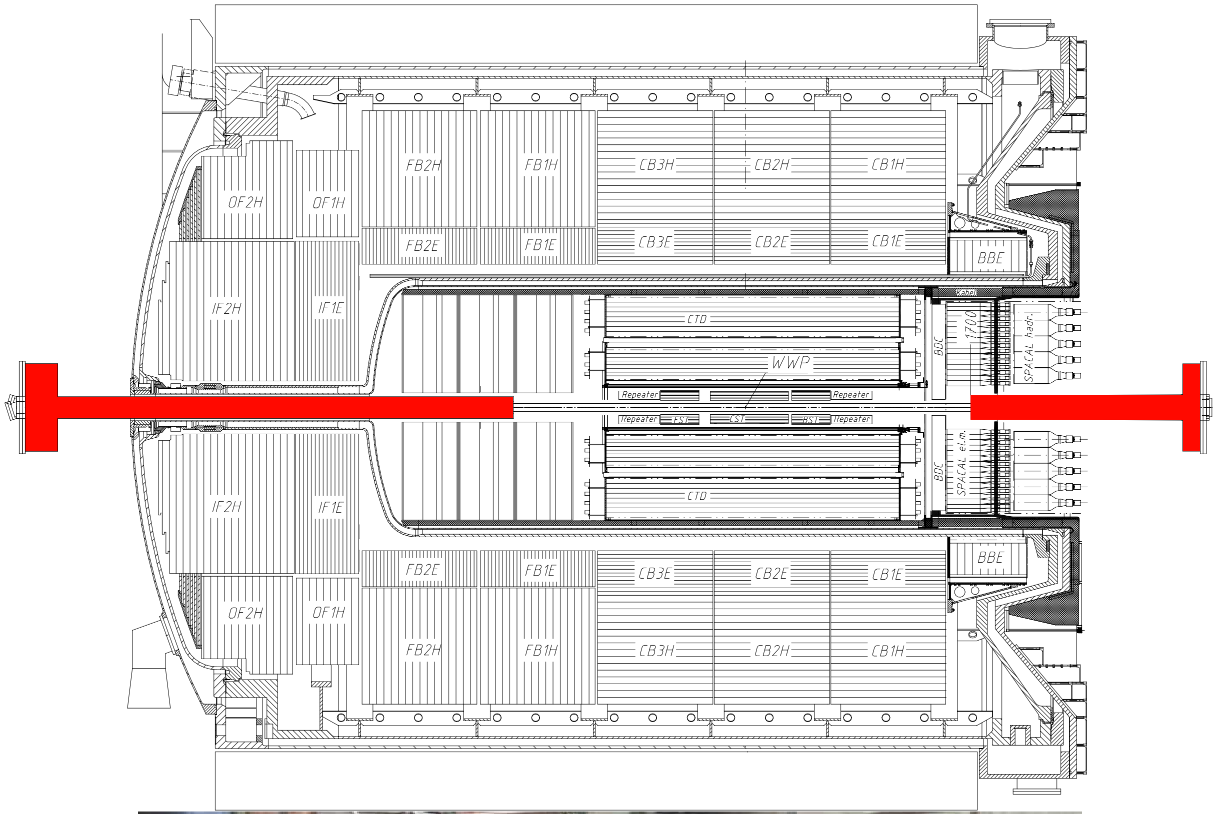
- Large superconductiong solenoid.
- 500 t Liquid Argon Calorimeter, hermetic in central and forward region, good EM resolution.
- Precision 8 t lead-fiber Spaghetti calorimeter in the backward region.
- Drift chamber tracking in the central and forward region.
- Silicon tracking and vertex detectors in forward, central, and backward region.
- Muon detectors: streamer tubes in the iron yoke, drift chambers around a forward toroid magnet.
- Tunnel systems: luminosity detector, forward neutron and proton detectors.



H1 history

1985	Letter of Intent	1997	$24.5\,\text{pb}^{-1}$ e^+
1986	Technical Proposal	1998	$4.5\,\text{pb}^{-1}$ e^-
1989–1991	Installation	1999	$14.8 + 23.4\,\text{pb}^{-1}$ e^- and e^+
1992	Luminosity run: $0.025\,\text{pb}^{-1}$	2000	$56.8\,\text{pb}^{-1}$ e^+
1993	$0.52\,\text{pb}^{-1}$ e^-	2001	Luminosity upgrade:
1994	$3.65\,\text{pb}^{-1}$ mainly e^+		Superconducting e magnets in H1
1994/95	Detector upgrade:		new Luminosity detector
	SpaCal		new Forward Silicon
	Central Silicon detector		improved Forward Tracker
	Backward Silicon detector		new Track trigger
	Forward Neutron Calorimeter		new Calorimeter trigger
	Forward Proton Spectrometer	2002	Background problems
1995	$5.5\,\text{pb}^{-1}$ e^+	2003	Improved vacuum system
1996	$9.6\,\text{pb}^{-1}$ e^+	2004	Luminosity run

Superconducting beam magnets inside H1



- Tight space in LAr cryostat: $\emptyset < 18\,$cm.
- Design and construction by BNL, USA.
- Superconducting magnets without iron.
- Combined function magnets: 5 coils for e focussing and ep separation.
- Movable supports inside H1.
- Stability requirement $< 0.1\,$mm fulfilled.

Silicon Tracking

New elliptical excentric beam pipe: BeAl, 1% X_0

FST:

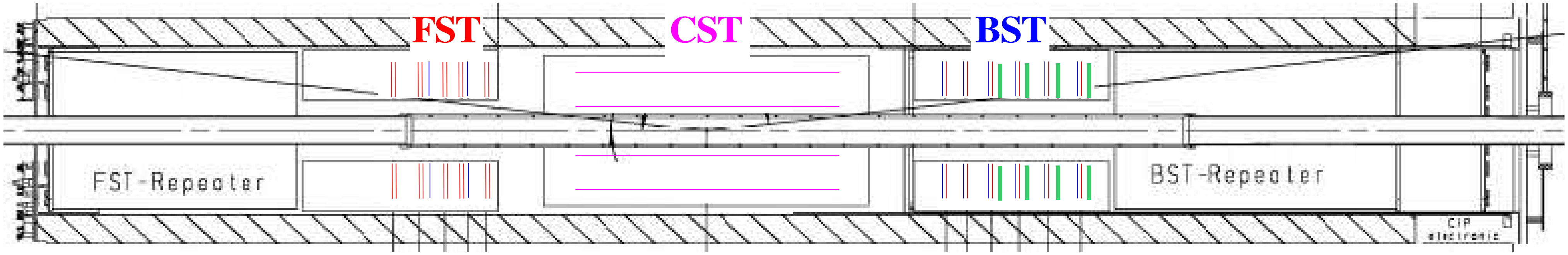
- New forward silicon tracker covering $7^o - 17^o$.
- 12 planes with strips in 3 projections.
- S/N = 32 for single-metal planes.

CST:

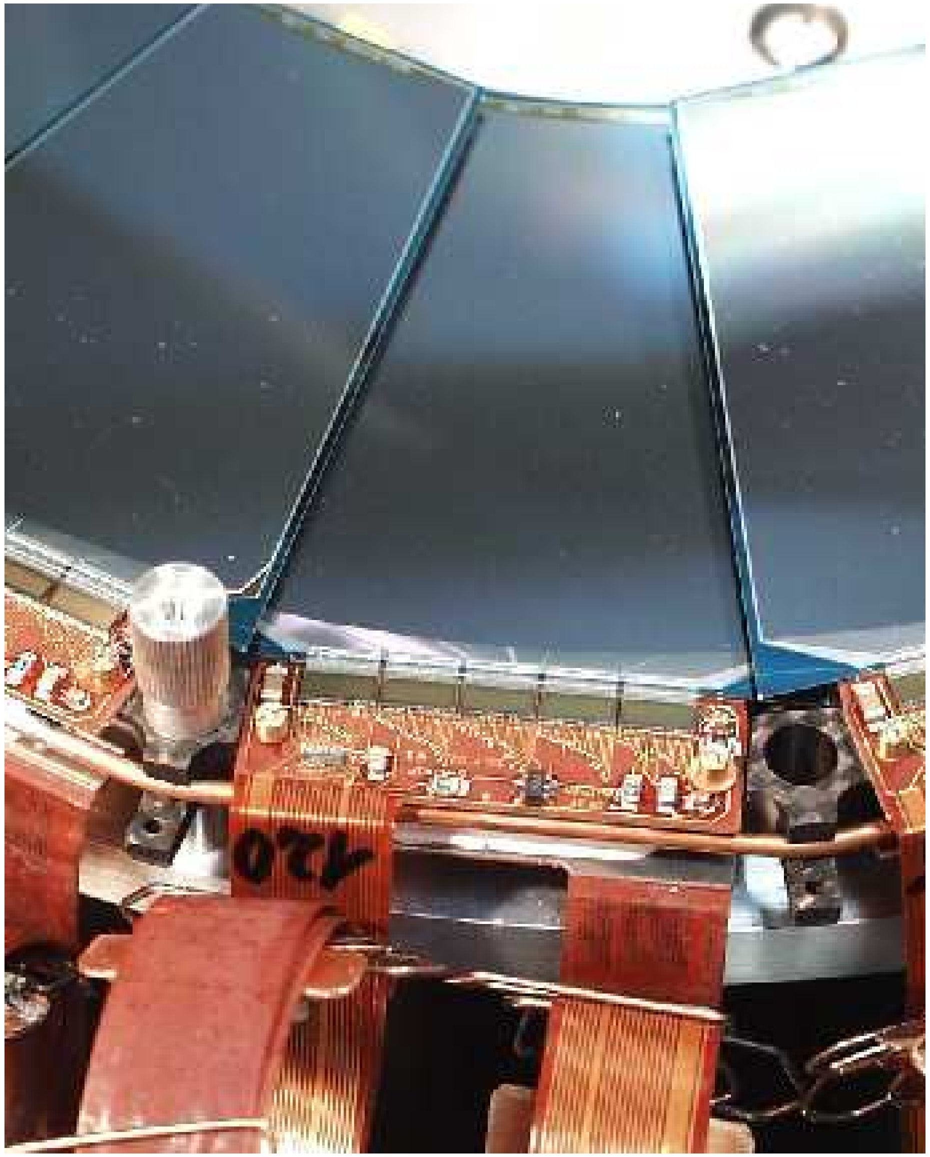
- 2-layer Si vertex detector for c and b-tagging operational since 1997.
- Adapted to elliptical beam pipe shape.
- Use radiation hard readout chips (DMILL).

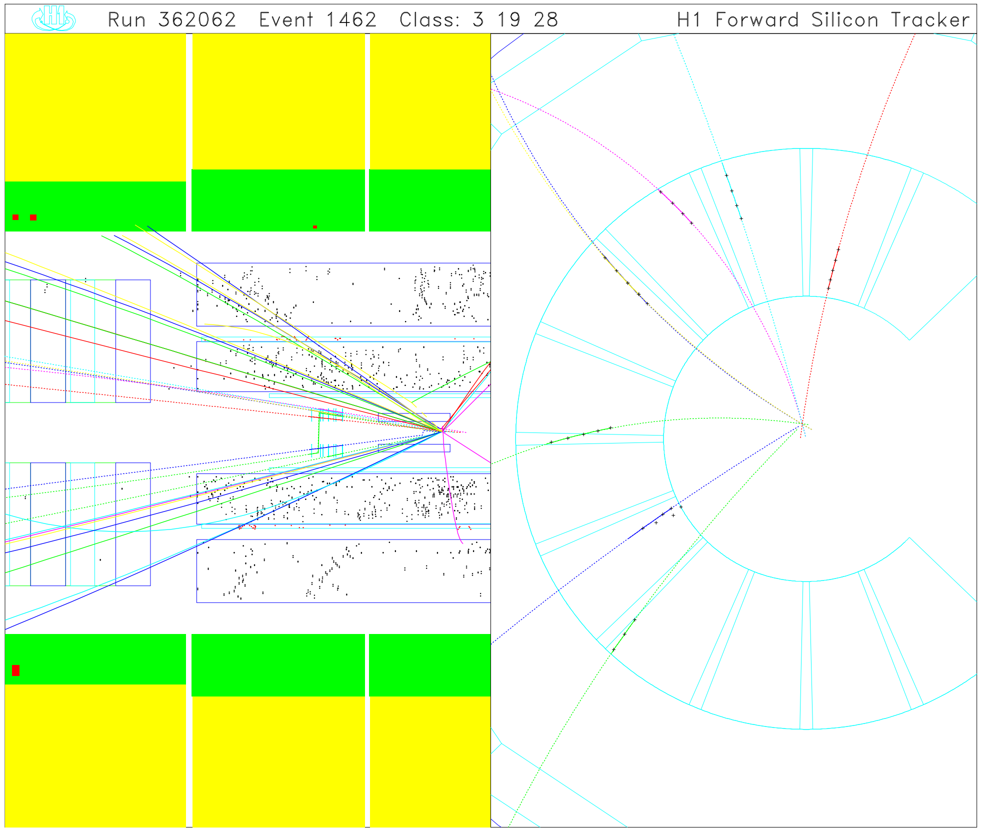
BST:

- 12-plane backward silicon for low-angle tracking operational since 1997.
- Adapted to new geometry.
- 4 Si pad planes for triggering.

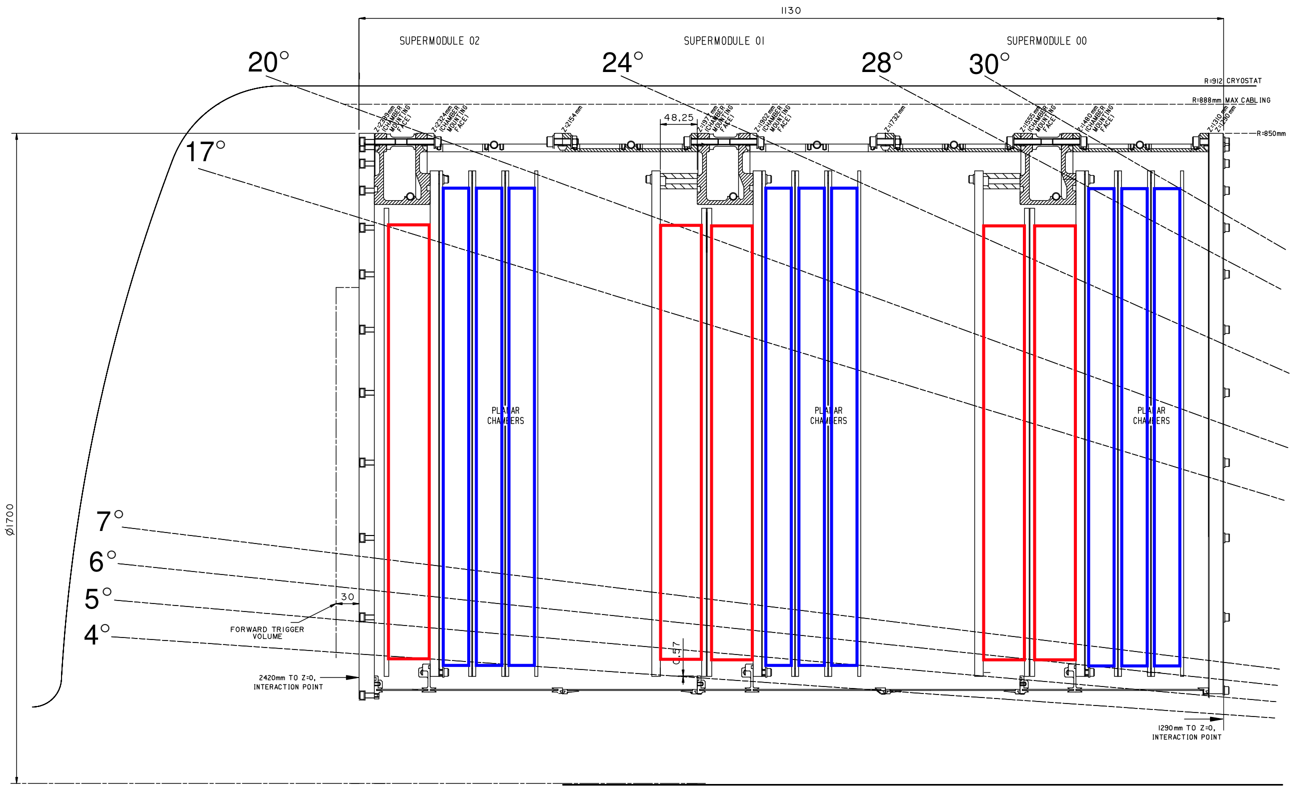


Forward Silicon Tracking



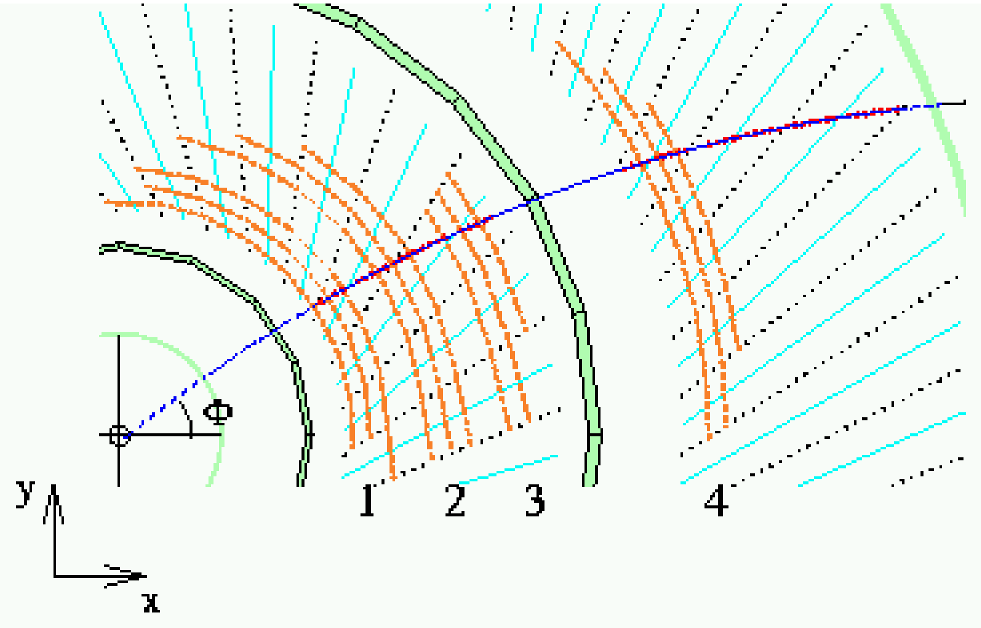


H1 for HERA II: Forward Tracking

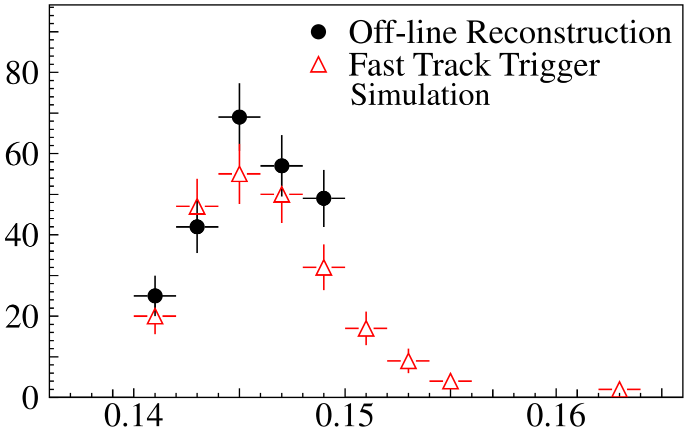


- Reduce material in old Forward Tracker.
- Re-use 9 planar chambers, 4 wires deep.
- Added 5 planar chambers, 8 wires deep.
- Total 14 chambers with 76 wires in 5 projections.
- Covering 7^o – 28^o, full overlap with FST.
- In operation, calibration and alignment in progress.

Fast Track Trigger

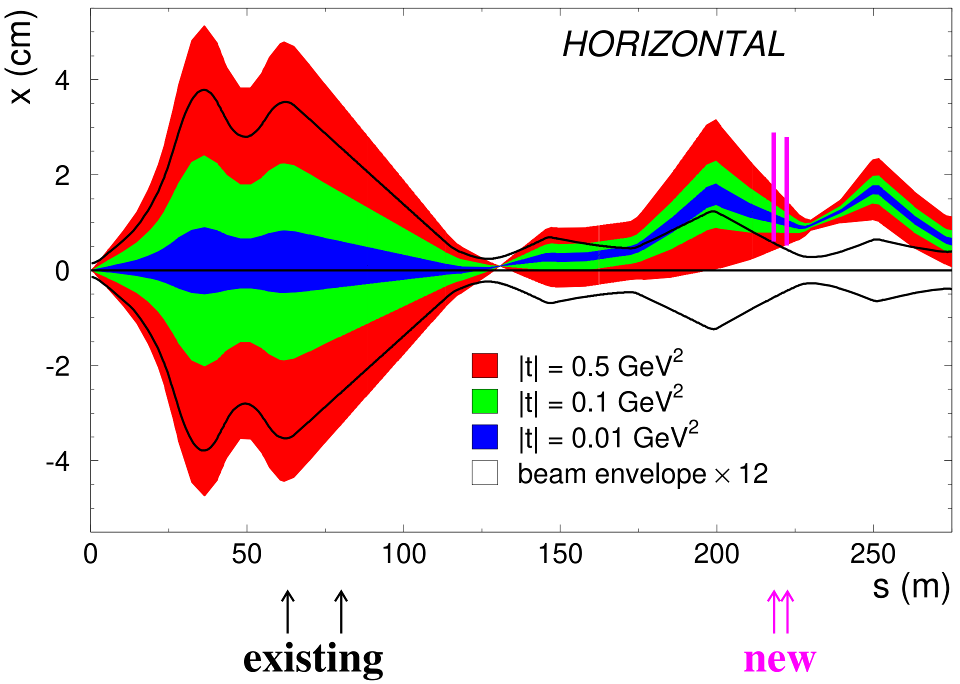


$D^\star$ finder ΔM:



- Use 12 of 56 wire layers in the Central Jet Chamber.
- Independent FADC, pipeline, hit finding.
- Coarse track finding in $r-\phi$: 2.2 μs with content addressable memory in large FPGAs.
- Refined track finding and beam-spot constrained 3-D track fit: 22 μs with DSPs.
- Invariant mass calculation: 100 μs with PowerPC CPUs.
- Status: all hardware operational and within specifications.
  Track linking code being finished.

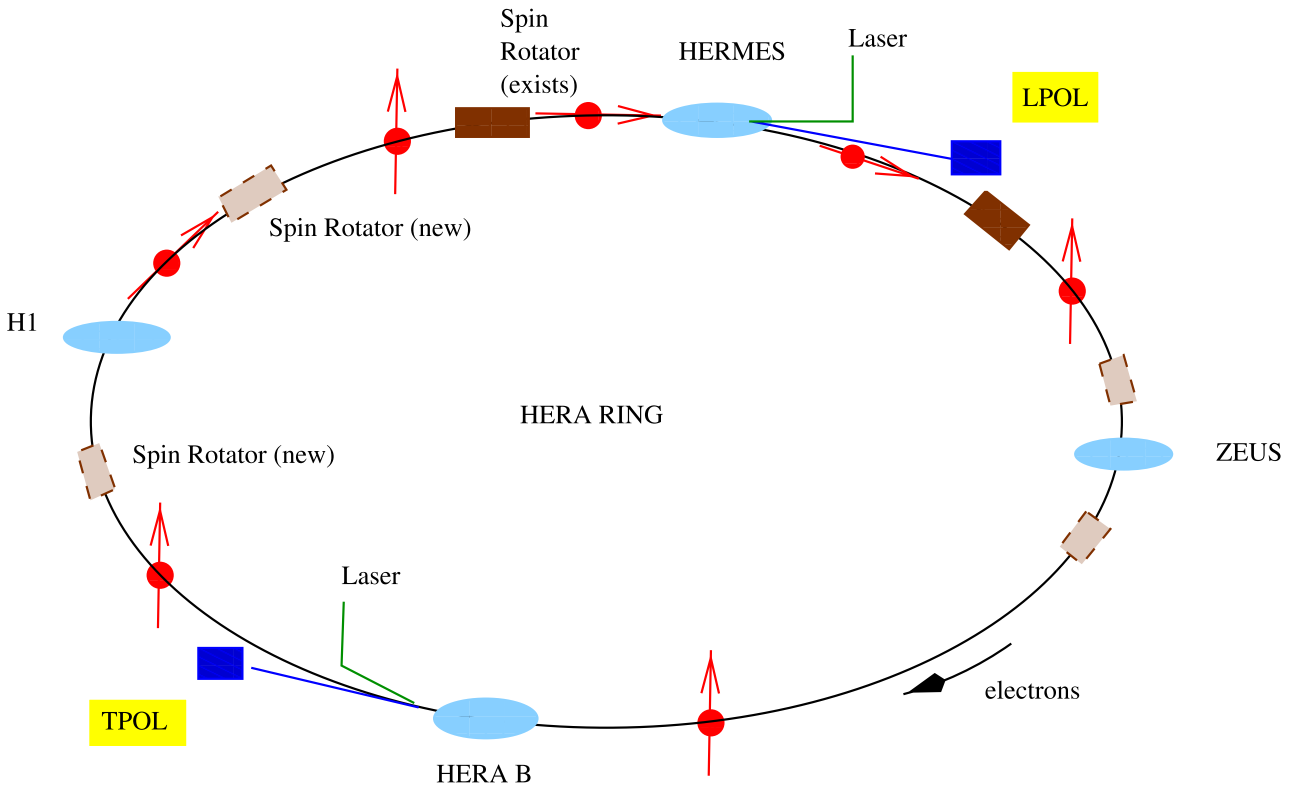
Very Forward Proton Spectrometer



Proton envelopes for $E_p/E_{\text{beam}} = 0.98$ ($x_{\mathbb{P}} = 0.02$).

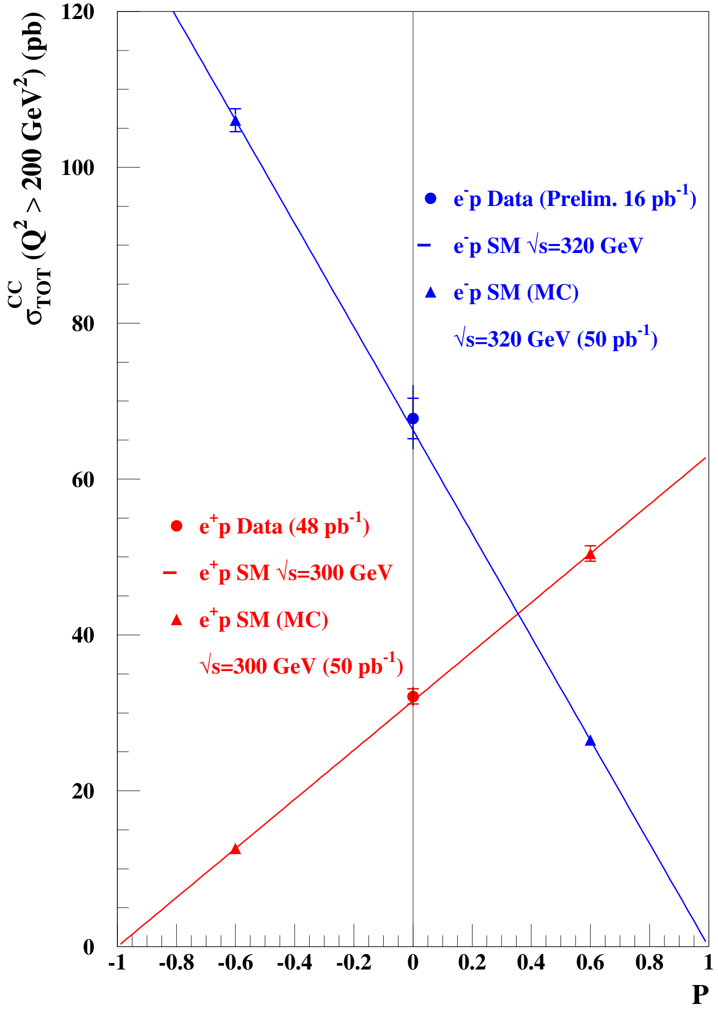
- Measure diffractively scattered protons
- Use first proton bending magnets as spectrometer.
- 2 Roman pots with fiber tracking at 220 m from IP.
- Optimized for acceptance in $x_{\mathbb{P}} = 0.005$ to 0.03 and in $|t|$ from 0.5 GeV^2 down 0.
- A cold bypass for He supply lines and new warm beam pipe are installed.
- Commissioning of the detectors is in progress.

Polarization



- Sokolov-Ternov spontaneous build-up of transverse polarization by synchrotron radiation: $\tau_{\mathrm{pol}} \approx 25\,\mathrm{min}$.
- Spin Rotators use $g-2$ precession to get longitudinal polarization at IP.
- Polarimeters use asymmetries in Compton backscattered polarized laser light.

Polarised $e^{\pm}p$ charged current cross section

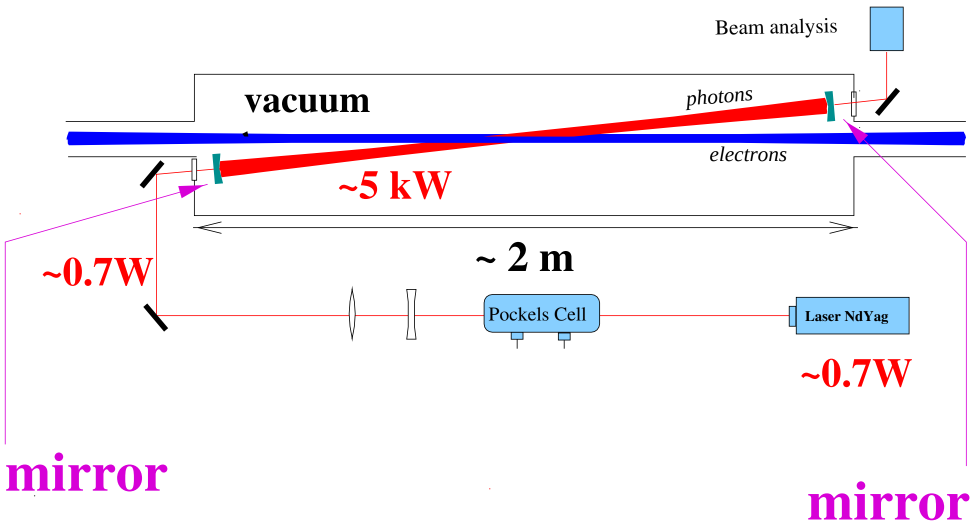


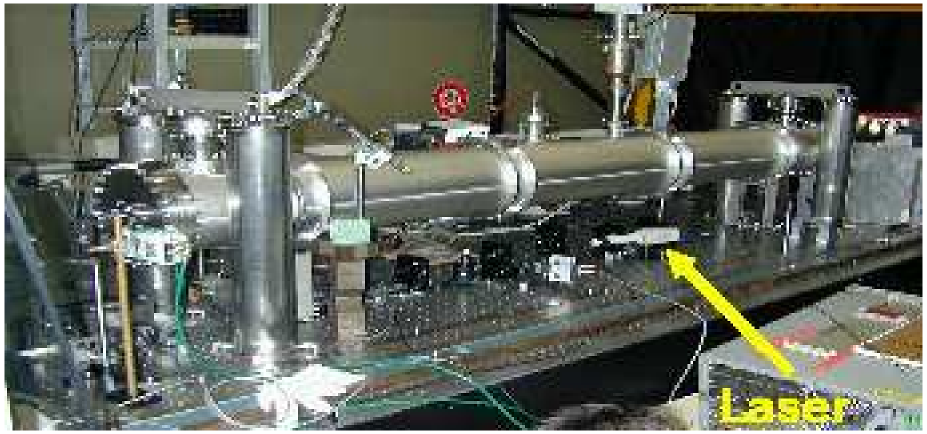
$$\frac{d^2\sigma^{CC}}{dx\,dQ^2} = (1 \pm P)\,\frac{G_\mu^2}{2\pi}\left[\frac{M_W^2}{Q^2 + M_W^2}\right]^2 \cdot \left[u + (1-y)^2\,\bar{d}\,\right]$$

Classic test of the electroweak Standard Model in the space-like region.

- 'Correct' polarisation enhances the Standard Model cross section, e.g. for parton density determination at high x.
- 'Wrong' polarisation suppresses the Standard Model 'background' for searches.

A new polarimeter





- Longitudinal polarimeter upgrade: Fabry-Perot laser cavity
- Goal: $\sigma_P/P = 1\%/\text{bunch}/\text{min}$ statistical
- $\sigma_P/P < 0.5\%$ systematic
- Uses a low power polarized laser beam coupled to a resonant cavity with gain 8000.
- Requires high quality optical mirrors and precision alignment with active feedback.
- A calorimeter 30 m away measures Compton-scattered photons their energy asymmetry for two laser polarzations.
- Installed, commissioning in progress.

H1 sociology and finances

- Personnel:
  - Currently 212 physicists from 34 institutes in 13 countries.
  - Authors (includes PhD students): currently 315
  - Engineers and technicians: about 20 full-time equivalents.
  - New collaborators are highly welcome!

- Operation Cost: 1.45 M€ in 2004 shared by funding agencies
  - Electricity
  - Computing
  - Gas, cryogenics
  - Electronics maintenance

H1 data taking

- ep bunch crossings occur every 96 ns (10.4 MHz) at HERA.
- Bremsstrahlung $ep \to ep\gamma$ has few MHz rate, used for luminosity monitoring.
- Beam-gas and halo background rate is a few 10 kHz.
- The level 1 trigger decides within 2.2 μs to keep an event, based on calorimeters, drift chambers, and muon and tunnel detectors.
- The highest physics trigger rate is about 1 kHz, leading to 2.5% deadtime.
- The trigger rate is reduced to 40–50 Hz on level 2 (20 μs) and level 3 (200 μs).
- Readout of the entire H1 detector takes 1.3 ms, leading to 6% deadtime.
- The raw data are processed on a processor farm, with online calibration and full reconstruction in 0.3 s per event.
- A level 4 filter applies physics selection criteria and reduces the event rate to less than 10 Hz for tape storage.
- H1 records about 10^8 events per year, which take about 15 TB of storage space.
- Immediate data quality checks are done by subdetector experts and physics working groups.

Working in Hall North

- Two persons are on shift for 8 hours, 6 shifts in one week, once or twice per year.
- Safety instructions and dosimeters are mandatory for work in the H1 hall.
- Installation of new components must not interfere with data taking.
- A 6 week shutdown is schedule for mid August until end September 2004.

Doing a physics analysis in H1

- Physics analysis is organized in five working groups: DIS, Diffraction, Jets, Heavy Quarks, and Rare processes.
- Data are stored at DESY. The H1 computing cluster and batch farm can be accessed from outside institutes.
- Physics analysis can be done in modern object-oriented analysis framework (C++), which includes the best tools for particle identification, jets, vertexing...
- The H1 detector is modelled in great detail using the GEANT 3 package.
- Physics processes are simulated using various Monte Carlo generators.
- Monte Carlo mass production is done centrally in H1.
- Simulated events are processed by the same reconstruction programs as the real data and are available in the same format.
- Physics analyses are presented regularly at monthly working group meetings
- An H1 physics plenary may approve a result as 'preliminary', which can be shown at conferences.
- Drafts of papers circulate in the working group, then in H1, are refereed, and finally sent for publication (10 per year on average).

Summary

- H1 is one of the major particle physics detectors in operation (next to ZEUS, CDF, D0, Star, Phenix, BaBar, Belle).
- The routine data taking in the HERA II phase has just started, and will continue at least until mid 2007.
- The goal is to accumulate $1\,\mathrm{fb}^{-1}$, roughly equally shared between e^+ and e^-, left and right polarized.
- H1 is fully operational, with excellent performance of all major components.
- A continuous upgrade and renewal programme is ongoing, where your institute wants to modernize the the gas system for the central and forward drift and multiwire proportional chambers.
- In addition, participation in data taking and physics analysis is highly welcome!