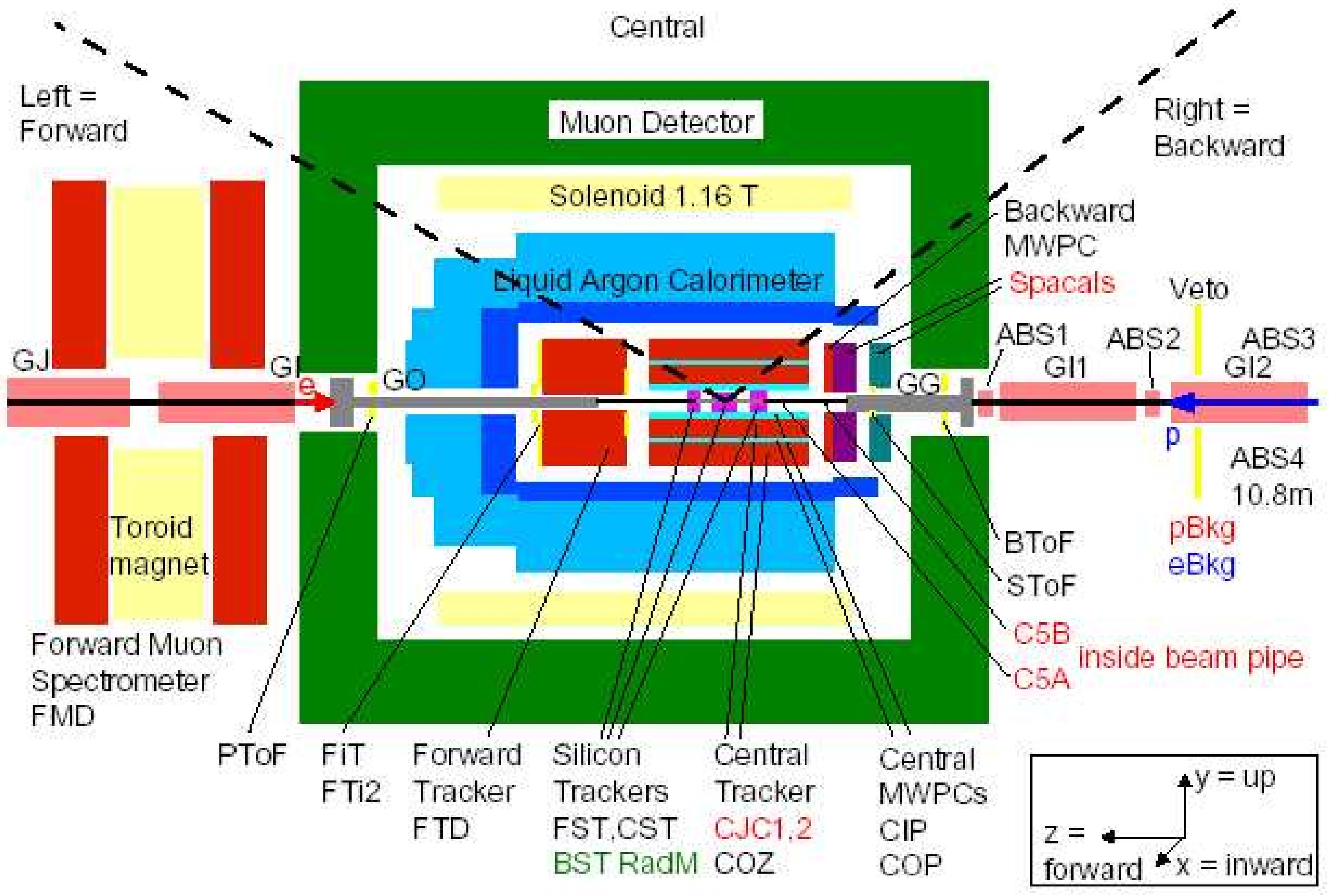
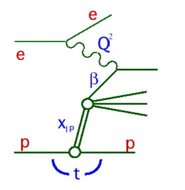
Upgrades for high luminosity HERA running

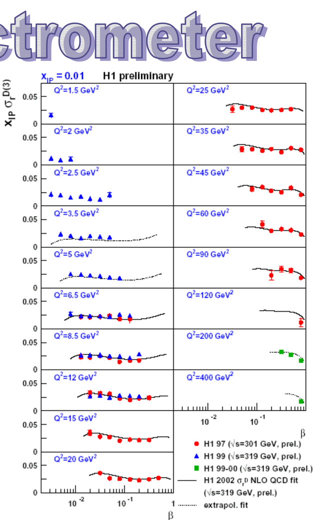


The H1 detector with some of the 25 upgrade projects undertaken and beam line elements for the HERA high luminosity upgrade of the electron-proton interaction region

Very Forward Proton Spectrometer

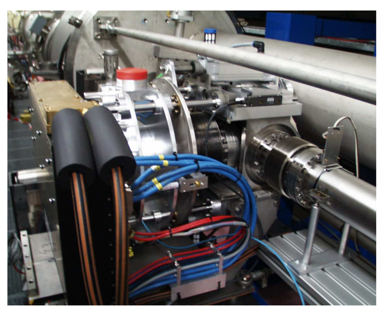
HERA studies have demonstrated that the colour neutral exchange responsible for diffraction, (the “pomeron”, IP) is composed of quarks and gluons.



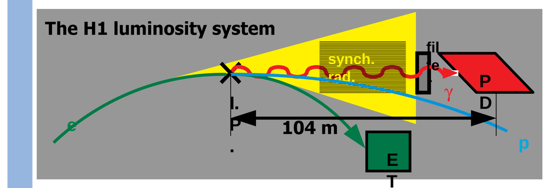


The gluons dominate and IP structure evolves according to the same QCD equations that govern proton structure (see right).

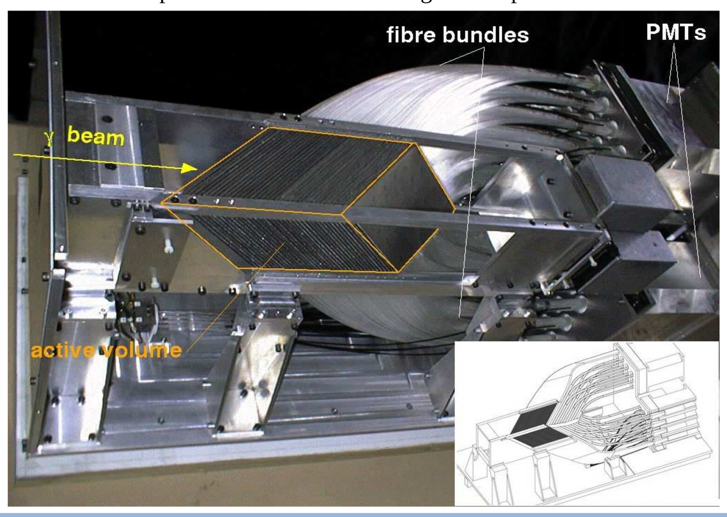
Most diffractive studies rely on the presence of a “rapidity gap” in the diffractive final state. Detecting the diffracted proton and measuring its four momentum would reduce systematic errors and make possible new measurements. This is the task of the Very Forward Proton Spectrometer, recently installed 220m from H1 on the proton beam line. The VFPS will allow H1 to profit fully from the HERA luminosity upgrade in the study of diffraction. The photo shows one of four Roman Pots, containing scintillating fibre detectors and a scintillating tile trigger system. These can be inserted to within a fraction of a millimetre of the HERA proton beam.



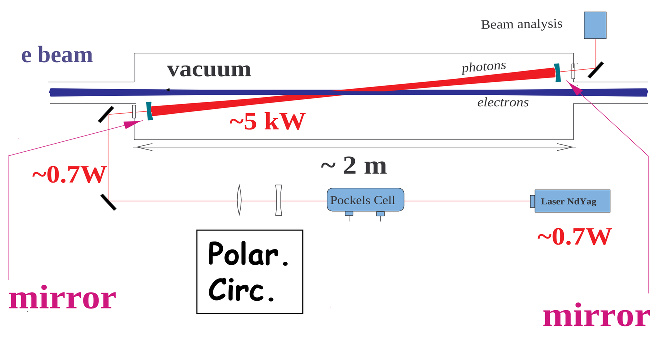
Luminosity System



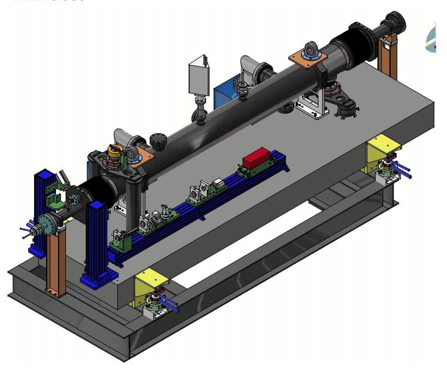
The factor of five increase in the luminosity following the HERA upgrade has implications for the photon (PD) and electron (ET) detectors of the luminosity measurement apparatus. The increase in the rate of the Bethe-Heitler events ($ep \rightarrow e\gamma p$) used for the luminosity measurement implies that, at design luminosity, photons with energy $E_\gamma > 0.5$ GeV hit the photon detector at a rate of 170 MHz. The stronger bent of the positron beam also results in a higher synchrotron radiation dose. These considerations led to the design of a new radiation hard tungsten/quartz-fibre photon detector, the fibres being orientated at the Cherenkov angle with respect to the positron beam. A new fast histogramming data acquisition system was also developed that will be used for both the new photon detector and the longitudinal polarimeter.



Fabry Perot Polarimeter

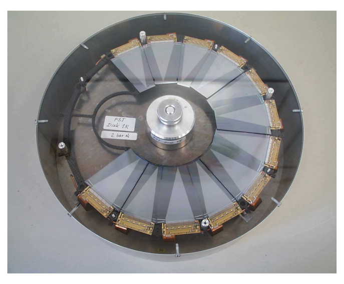


H1 has installed a new polarimeter which aims at measuring the longitudinal polarisation P of the 27.6 GeV electron beam via Compton scattering off 1.165 eV photons. The cross section is calculable in QED and depends on P and on the circular polarisation of the laser beam. Large laser power results in a high statistical accuracy enabling a bunch by bunch determination of the polarisation to 1% per minute.



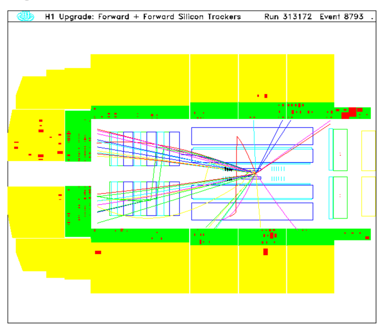
Schematic view of the new polarimeter with Fabry Perot cavity. With the laser frequency tuned to resonance conditions a gain of 7000 was measured as expected. The new “LPOL” will be operated during the HERA II phase.

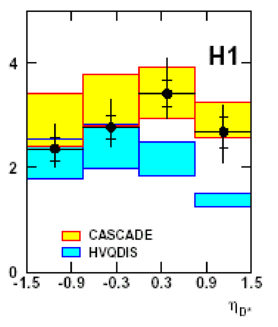
Forward Tracking



The Forward Silicon Tracker (FST) consists of 12 single sided silicon sensor planes (S/N = 32) measuring tracks in three projections covering the polar angle range 7° < θ < 17°. The elliptical and excentric beampipe limits the azimuthal acceptance. New drift chambers in the forward track detector (FTD) now provide up to 76 measurements over the same angular range.

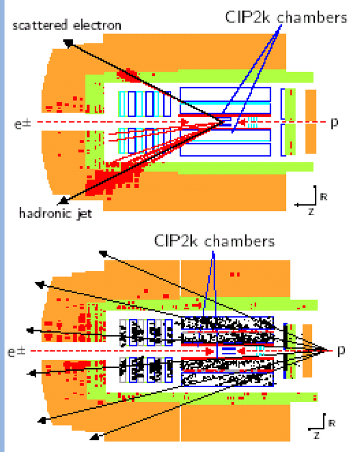
Data from running in 2002, such as the event shown here, provide first hints of the physics opportunities that will be provided by efficient forward tracking. These include the investigation of QCD radiation patterns closer to the proton, up to pseudorapidities η ~ 2.8, than has been possible to date, e.g. by studying charm quarks produced in gluon splitting.





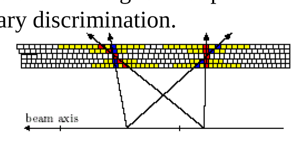
Current measurements suggest that NLO QCD calculations (HVQDIS) do not describe the data in the forward region (η > 0), whereas approaches based on the CCFM equation (CASCADE) are more successful. Forward charm data will aid progress towards an understanding of gluon radiation in this complex region.

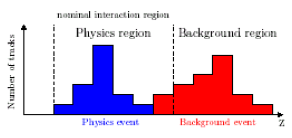
Central Inner Proportional Chamber

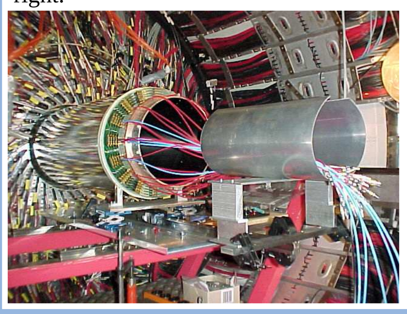


The increased luminosity of the upgraded HERA collider represents a challenge for the trigger systems of H1. Efficient data taking requires good discrimination between background and signal as soon as possible after collisions have occurred. One signature that allows separation is the position of the event vertex. Signal events, e.g. the high Q^2-event above left, are seen to come from the ep interaction point, whereas a large proportion of background events, below left, originate upstream of H1. The Central Inner Proportional (CIP) chambers are designed to provide the necessary discrimination.

The 5-layer proportional chambers of the CIP allow the position of the event vertex along the beam axis to be reconstructed, as illustrated on the right.

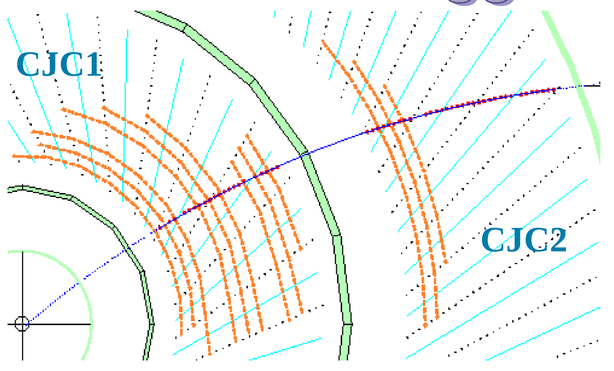






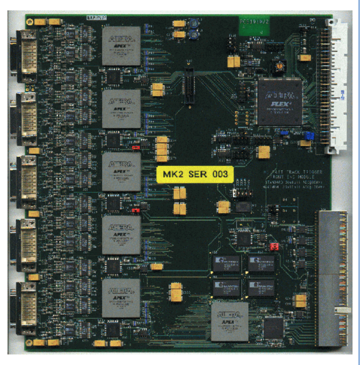
Following teething troubles with the electronics, caused by cooling problems, the CIP has now been repaired and installed within H1, photo left, ready for data taking in September 2003.

Fast Track Trigger



4 trigger layers formed out of three layers of wires each. The wires are readout at both z ends to enable three-dimensional track reconstruction.

The new Fast Track Trigger is designed to reconstruct tracks and resonances (D*) within the first 3 levels (L1-L3) of the multi-stage H1 trigger system. Using a subset of wires of the central jet drift chamber (CJC) the FTT reconstructs tracks down to 100 MeV momentum within the L2 latency of ~23µs. To reach high momentum resolution (of ~5% at 1GeV) dedicated algorithms are implemented using high density FPGA’s. Track fits are done in DSP’s. At L3 commercial processor boards are used to reconstruct invariant masses. The system will be used in the high luminosity data taking from fall 2003 onwards.

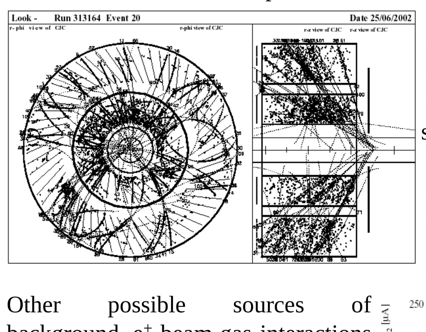


Level 1 reconstruction of hits (Qt) and of r-ϕ-tracks on ~30 FEM boards with five Altera APEX 20K600E FPGAs

Backgrounds at HERA II

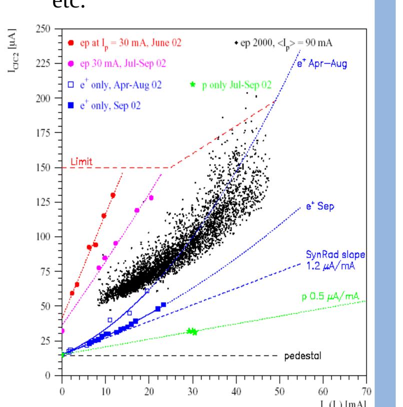
Increased Backgrounds Following HERA Upgrade

Following the HERA upgrade the H1 drift chamber currents were higher than acceptable. The rate of events in which an energetic proton had interacted in the material upstream of the detector was observed to be high.



Simulations and background studies with the HERA machine confirmed that source of these events was the diffractive scattering of protons 2 to 20 m upstream of H1 off the residual gas in the beam pipe. The scattered protons then interacted in the material of collimators etc.

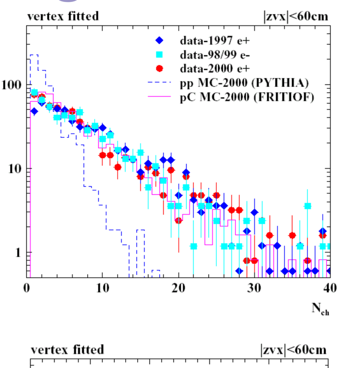
Other possible sources of background, e^+ beam-gas interactions and scattered synchrotron radiation (SR), were found to be significant but less important. The size of the various effects is shown by the plot of the contributions they make to the CJC current, obtained from e^+ only, p only and colliding beam studies. The CJC current caused by a p current I_P = 30 mA increases with increasing e^+ current as the resulting SR desorbs gasses from the beampipe surfaces, worsening the vacuum.

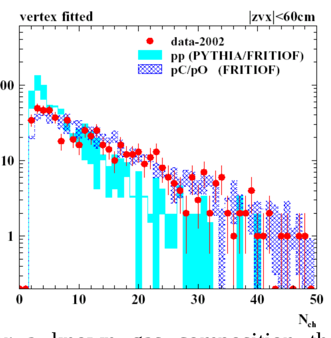


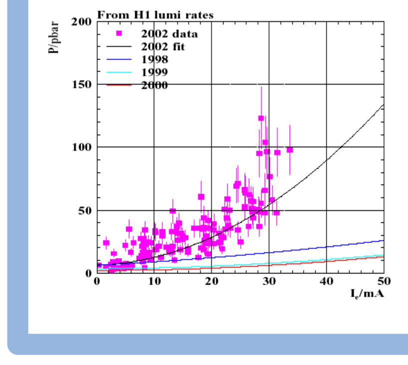
Backgrounds from all sources were observed to decrease with time as the HERA vacuum improved, but they did not reach an acceptable level.

Proton Background

One possible cause of the increase of the p-induced background compared to running before the HERA upgrade is a change in the composition of the residual gas. The charged multiplicities of p-gas events recorded before and after the upgrade in the central drift chamber were compared with the expectations for pN interactions with various nuclei, N. The expectations were calculated using MC simulations which include the effects of H1 and of the HERA beam line. No evidence for a change of the gas composition was found. A slightly increased multiplicity was observed as is expected for a given species *A* following the upgrade due to changes in the distribution of the material in the detector and beamline.

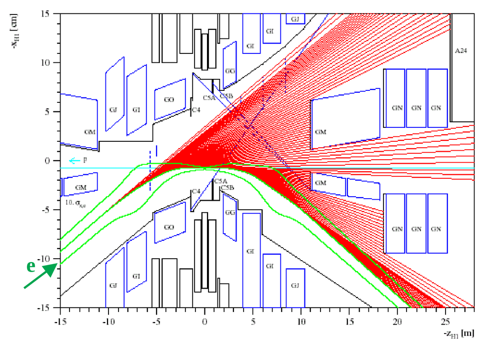






For a known gas composition the Bethe Heitler scattering rate as measured by the H1 luminosity detector determines the pressure in the interaction region. The pressure was found to be significantly higher in 2002 than in previous years. A non-linear component in the current dependence hints to HOM heating besides photodesorption effects.

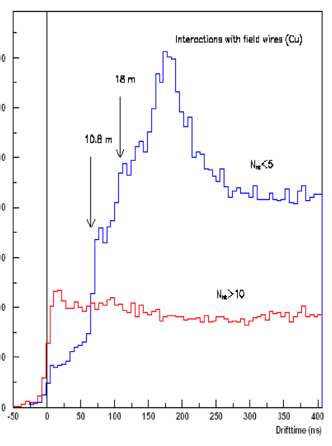
Positron Background



Schematic view on the H1 interaction region. The positron beam, now bent near the IP, emits synchrotron radiation which causes desorption of gases. Beam steering has to ensure that no collimator or beam pipe wall is hit before 10.8m distance from the IP.

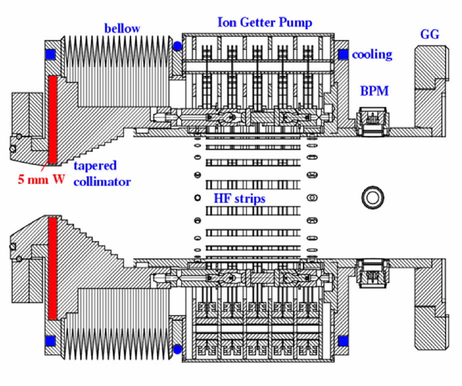
Drift time distribution for events from lost positrons (red) and from synchrotron radiation events (blue). The arrows indicate the arrival time due to backscattering at upstream collimators (data from single electron bunch fills).

While the effect from only synchrotron radiation on the background is tolerable, it causes a dynamic increase of pressure during ep operation.



Prospects

During the HERA shutdown 2003 a number of measures was realised to combat the beam induced background - with further pumps (in the GA e chambers left at 30m and at C5), improved cooling (GI/GJ magnets right), improved shielding and RF screening. Refined diagnostics on radiation, temperature, gas composition etc. was installed both in the machine and the experiment. Gains are expected from steady operation.



New C5 collimator installed in H1 at -1.5m from IP with integrated getter pump and tapered geometry reducing higher order mode (HOM) heating effects.

Reduced backgrounds enabling high current operation, large positron beam polarisation, as achieved for the first time in February 2003 (below), and an improved apparatus will lead the H1 experiment to its second phase with sensitive searches and precision tests of QCD.