Background Issues in the new HERA Interaction Region

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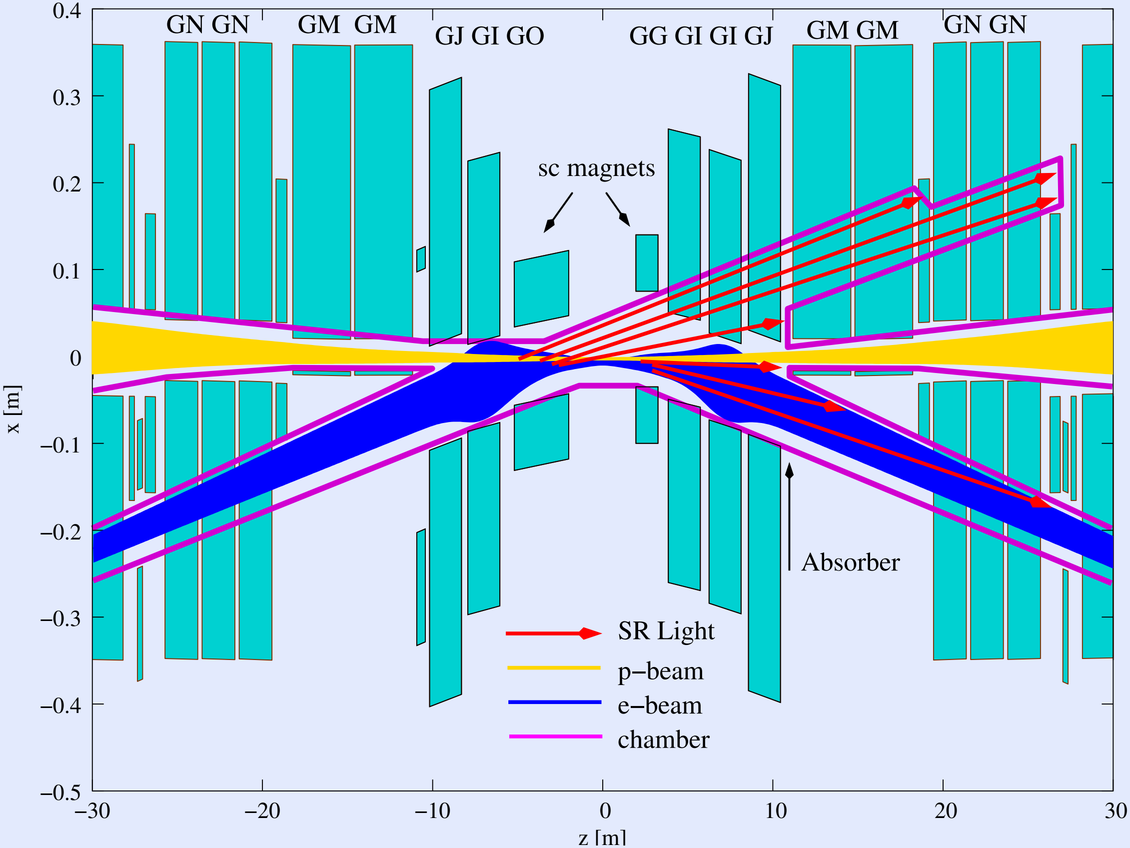
- **Overview on HERA Interaction Region**
- **p-Gas Background**
- **Synchrotron Radiation**
- **e-Gas Background**
- **Recommendations from HERA Experience**

Goal-Parameters for the Upgraded HERA

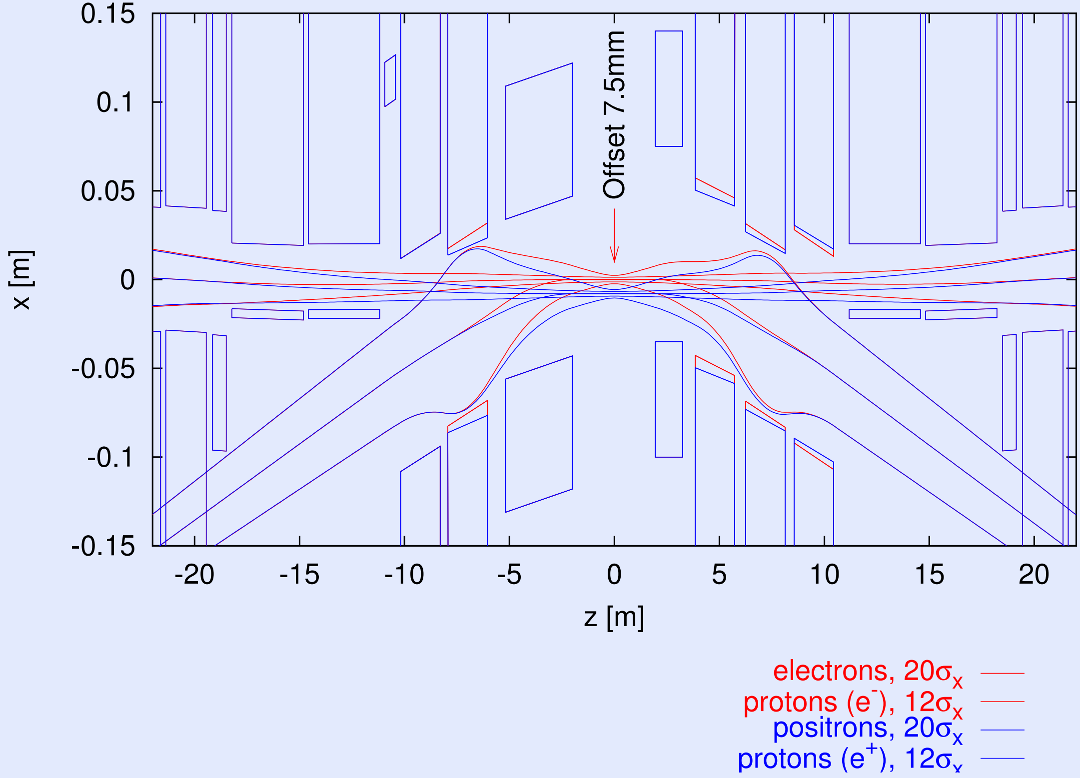
	e-Beam	p-Beam
energy	27.5 GeV	920 GeV
beam current	58 mA	140 mA
emittance	22 nm	$5\,\mu\mathrm{m}\,/\gamma$
emittance ratio	0.18	1
betafunction IP β_x^*	0.63 m	2.45 m
betafunction IP β_y^*	0.26 m	0.18 m
beam size $\sigma_x \times \sigma_y$	$118\mu\mathrm{m}\times 32\mu\mathrm{m}$	$118\mu\mathrm{m}\times 32\mu\mathrm{m}$
tune shift/IP $\Delta\nu_{x,y}$	0.027, 0.041	$0.0017,\ 4.6\cdot 10^{-4}$
aperture	$20\,\sigma$	$12\,\sigma$
Luminosity	$7.00\cdot 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	

$\Longrightarrow$ specific luminosity is raised by factor 2.8

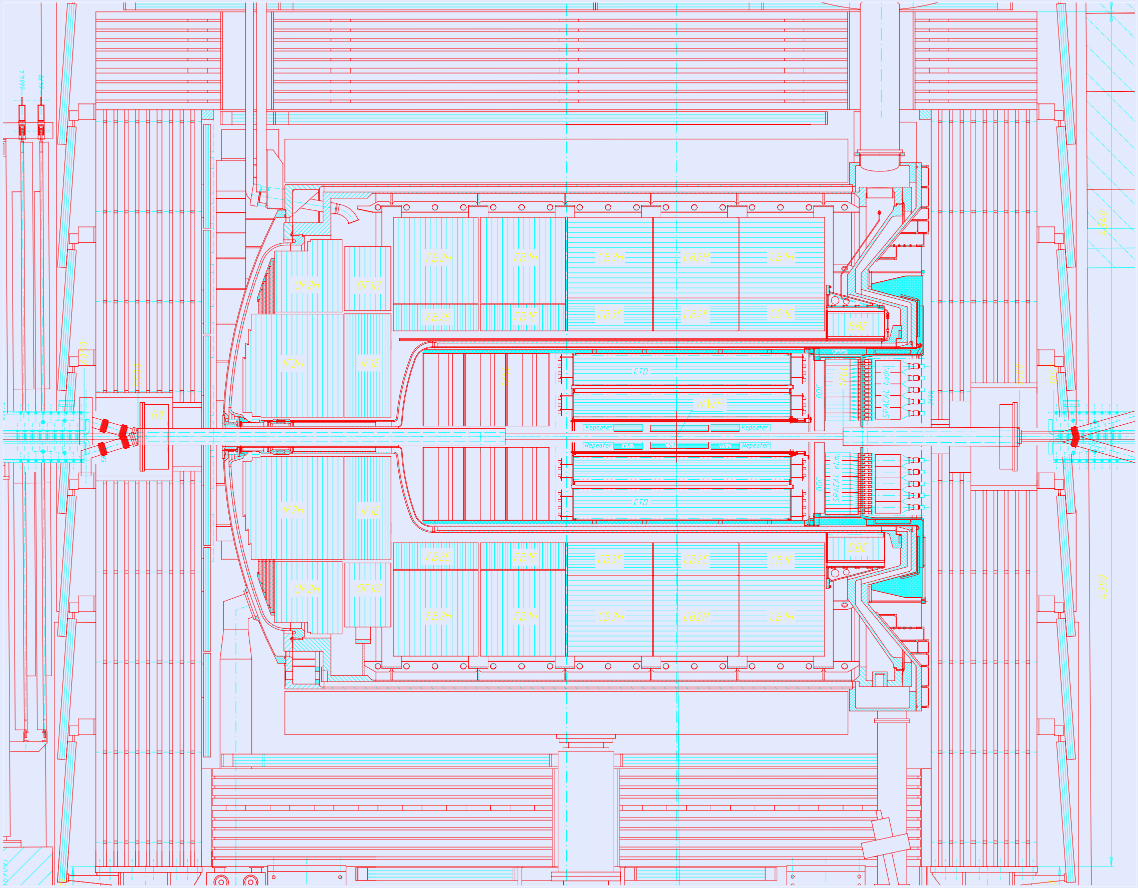
Overview on new IR



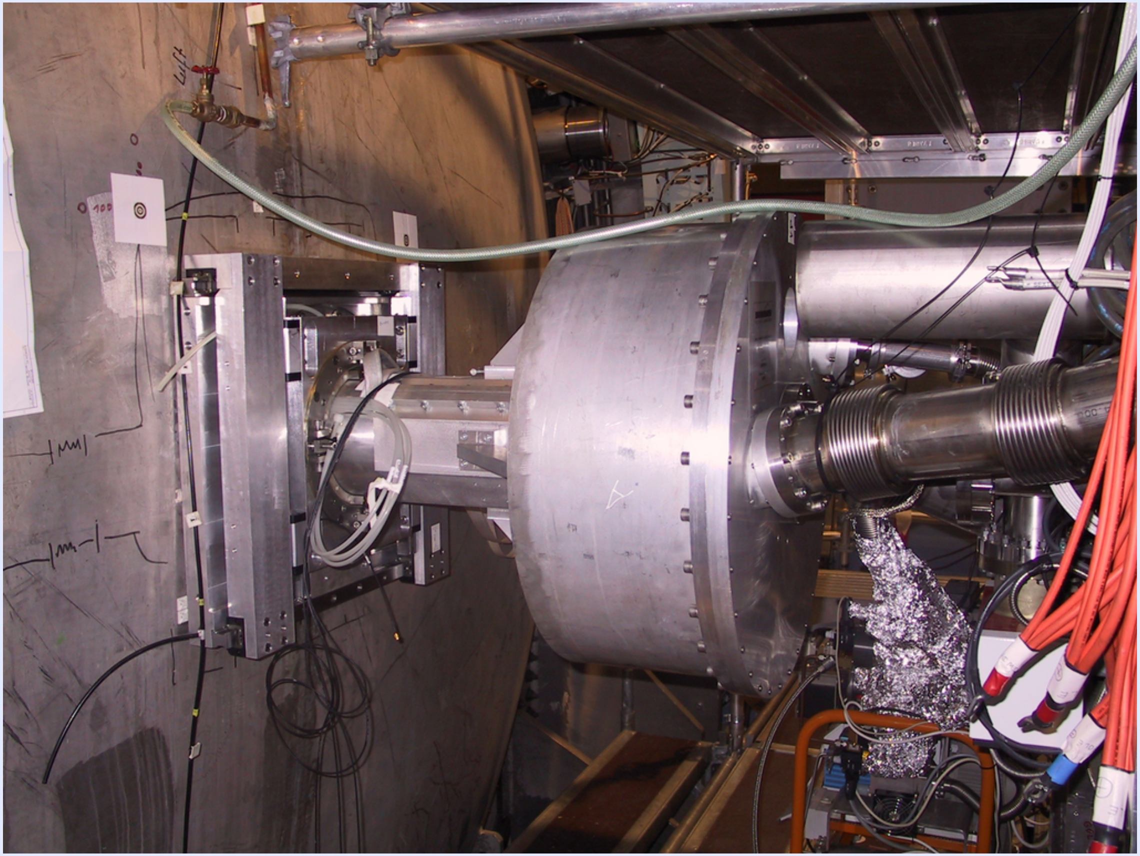
Switching the Lepton Species by Quadrupole Shifting



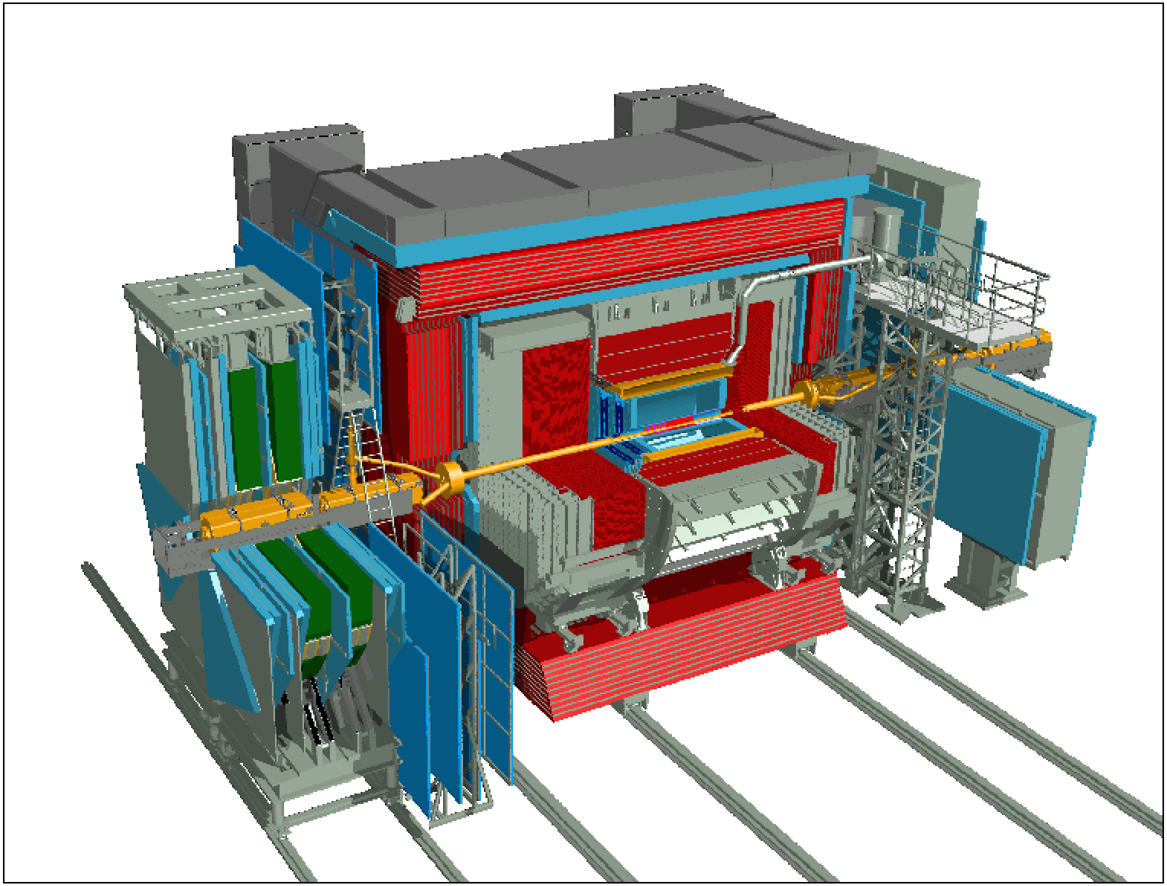
Side View of H1 Detector



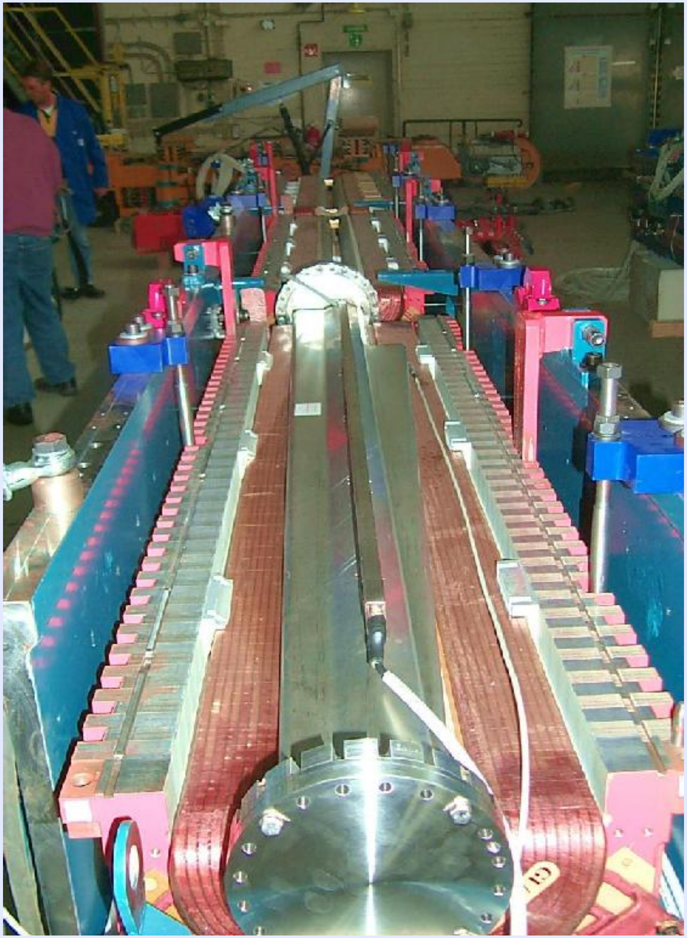
GO magnet in H1



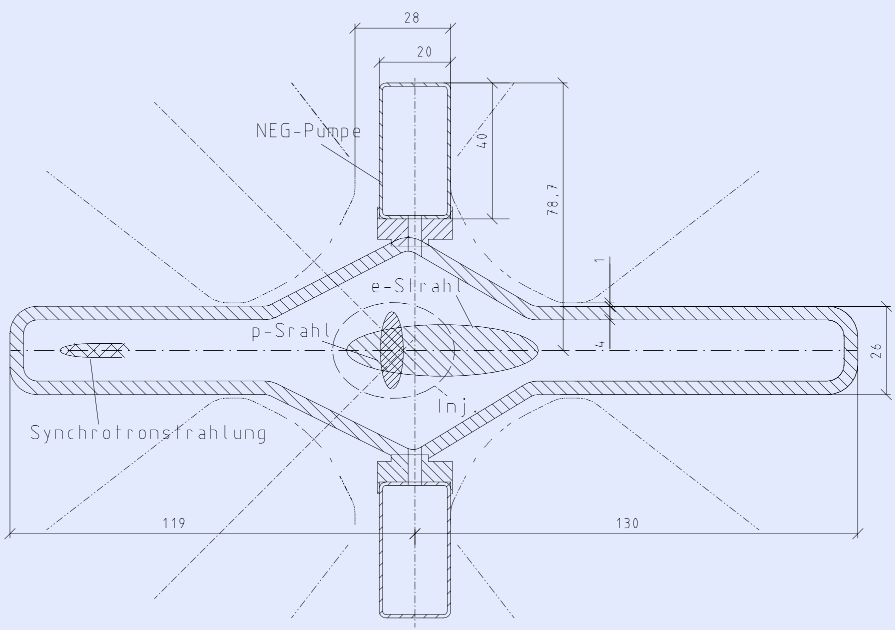
ZEUS Detector



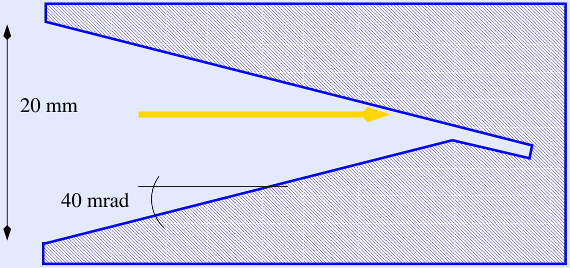
Bridge right
Magnets open



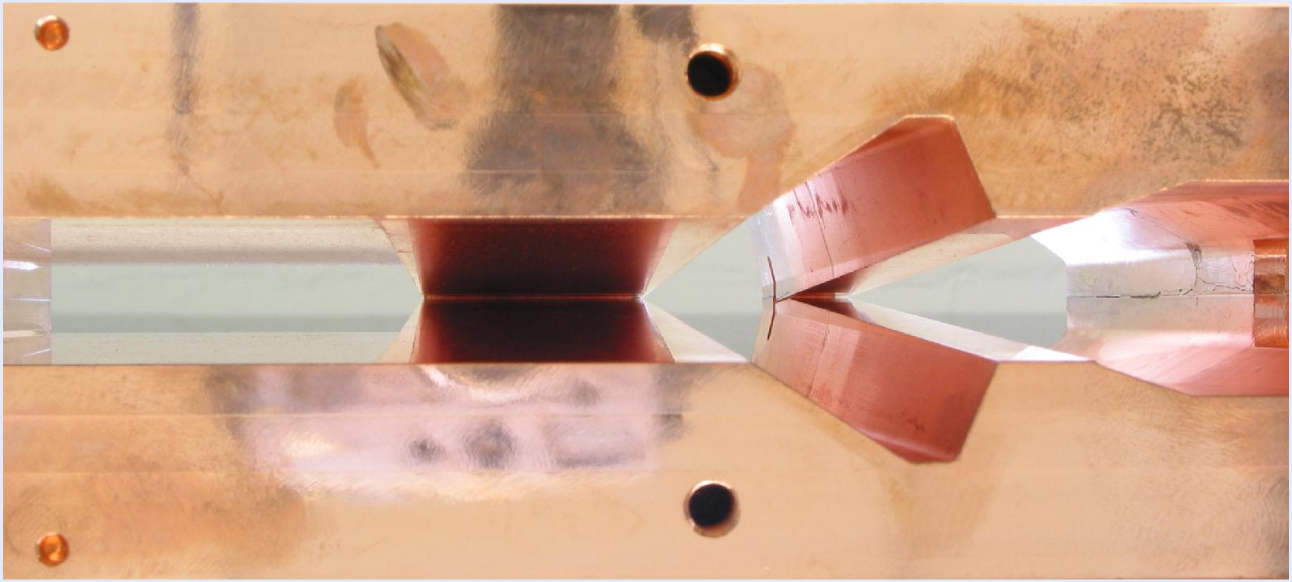
Chamber Cross-Section



Septum Absorber - Beam View



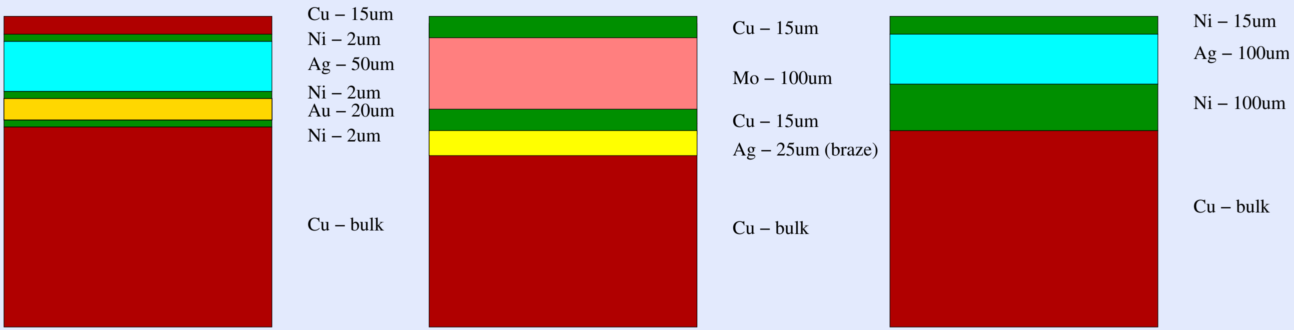
SR Power: $P \approx 6\,\mathrm{kW}$
Crit. Energy $E_c \approx 150\,\mathrm{keV}$ principle:



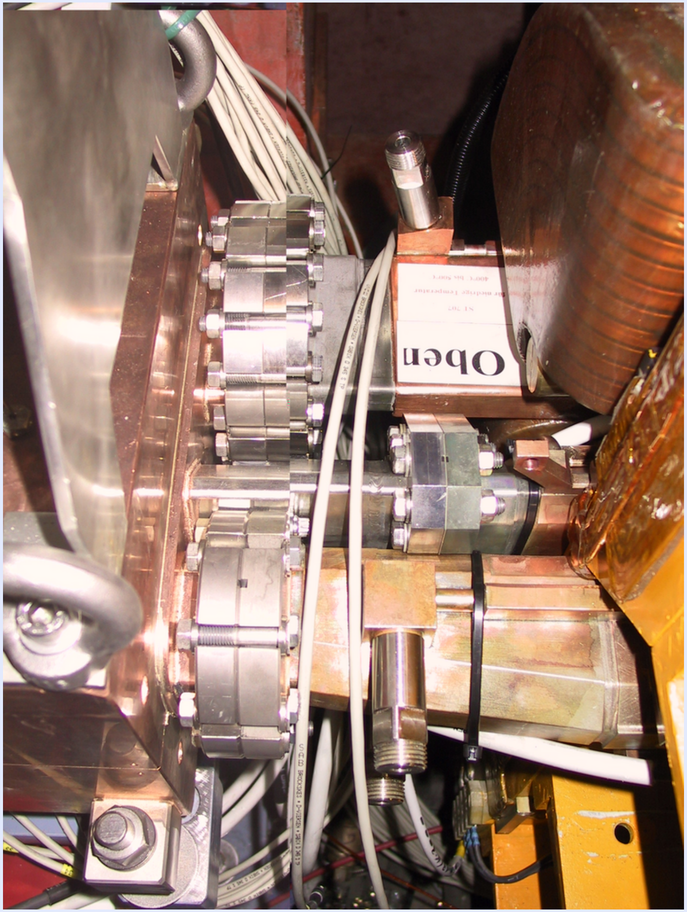
Absorber Coating Under Work

idea: thin low Z layer over thick high Z layer
problem: stability at brazing temperature

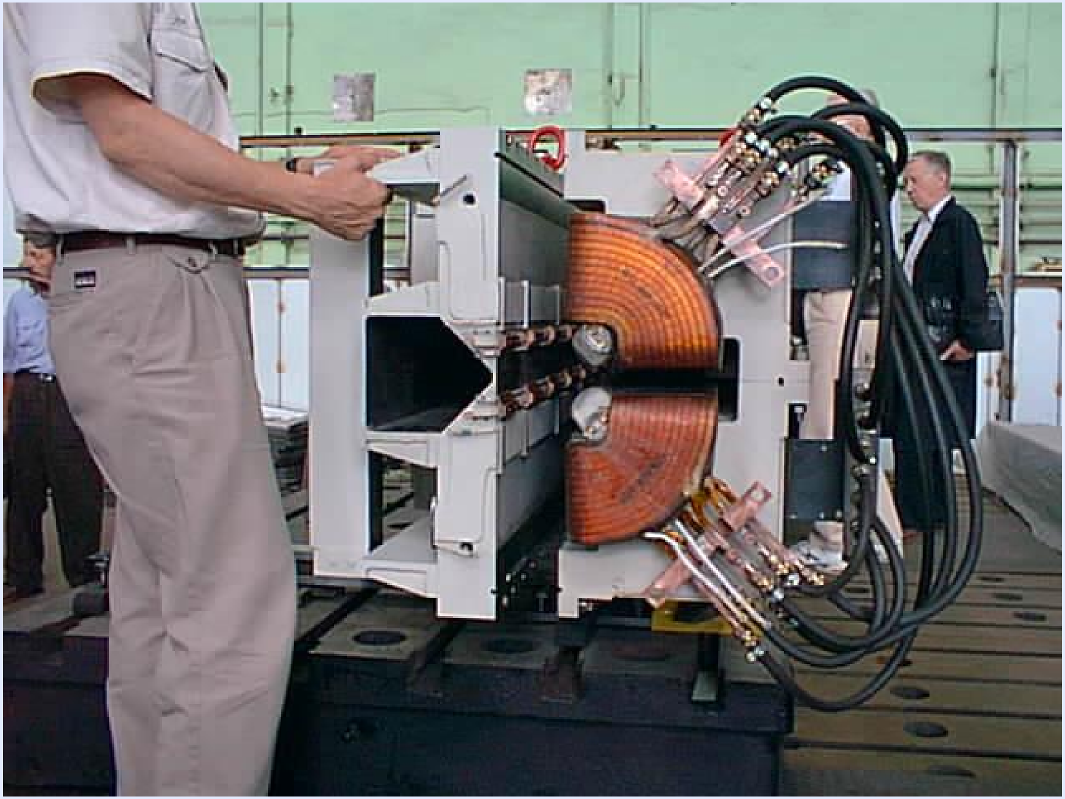
history of sandwich-layers tested



Three Chambers Behind Septum Absorber



Mirror Plate Magnet GM



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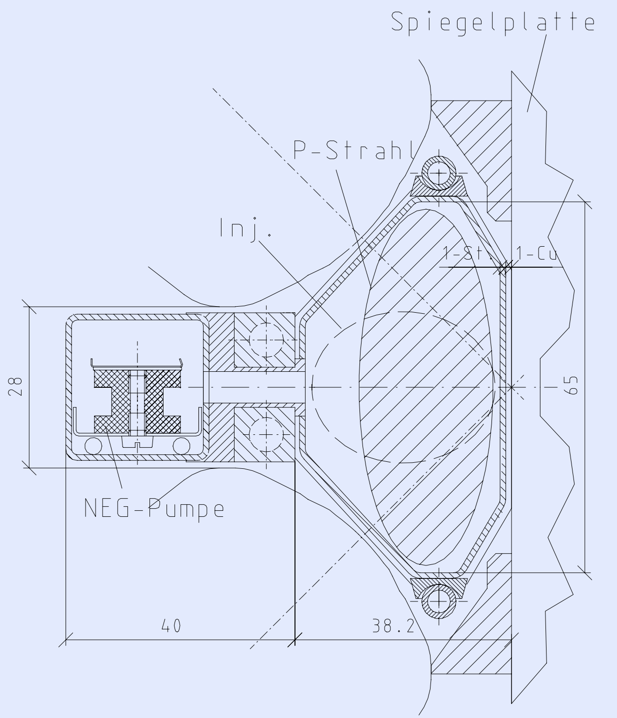
p-Chamber in GM, Septum Magnet



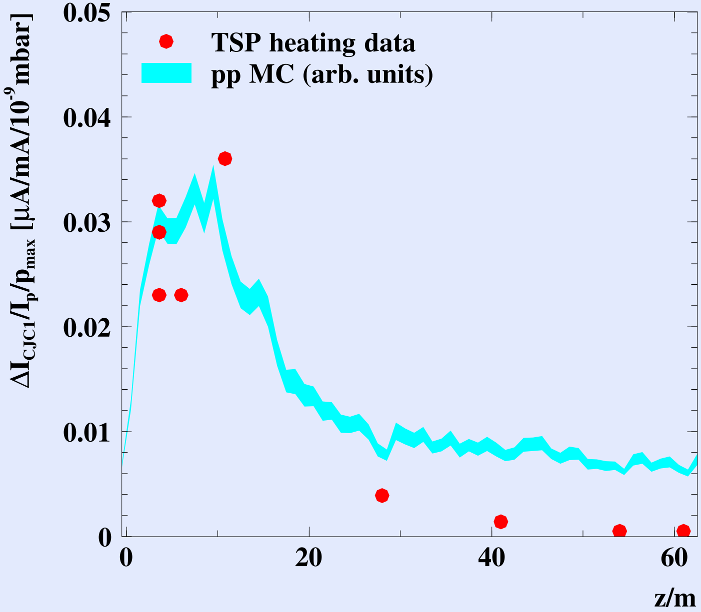
Overview on Types of Backgrounds

we expected (and have evidence for) four types of backgound:

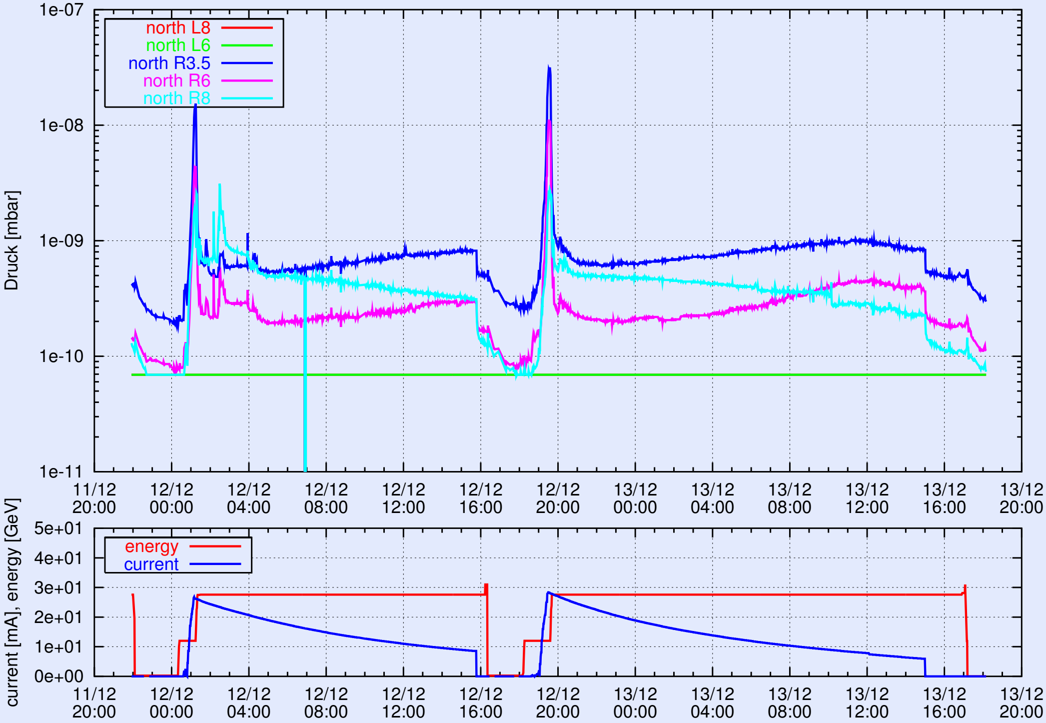
- Proton Halo Losses in low-β quads
  - critical when diffusion/emittance growth from beam-beam effects comes in
  - controlled by two stage collimation system; relative beam size and position
- Proton Gas Scattering
  - lepton-SR induced Pressure Rise!, HOM heating!
  - dominating effect!
- Synchrotron Radiation
  - masking of direct and indirect radiation
  - orbit-control $\rightarrow$ bending in quadrupoles; direction of radiation
- Lepton Gas Scattering
  - wide energy spectrum of scattered leptons
  - momentum collimation

Proton Gas Scattering

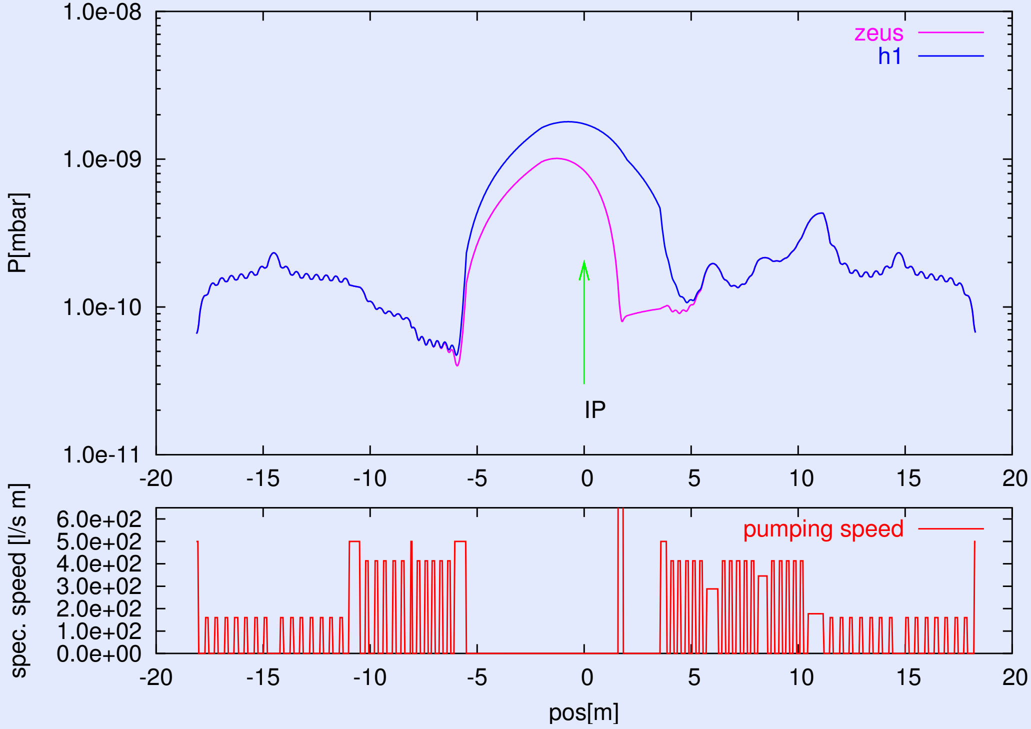
- most sensitive within 20 m from the IP (Monte Carlo)
- verified with artificial pressure bumps (red)
- cross-section with gas species: $\sigma_I \propto A^{\frac{2}{3}}$



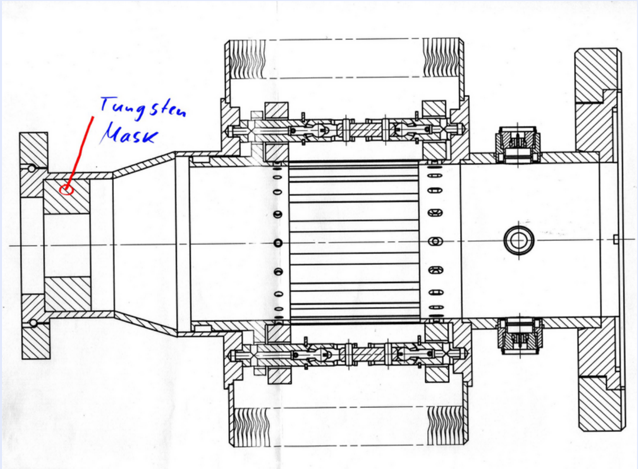
IR Pressure in typical Run

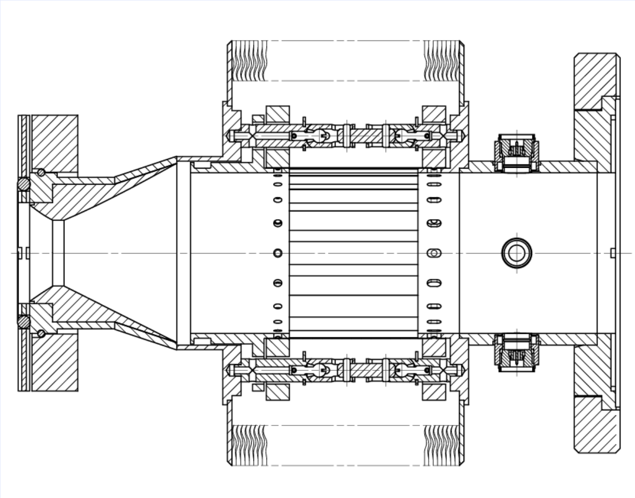


Simulated Pressure Distribution

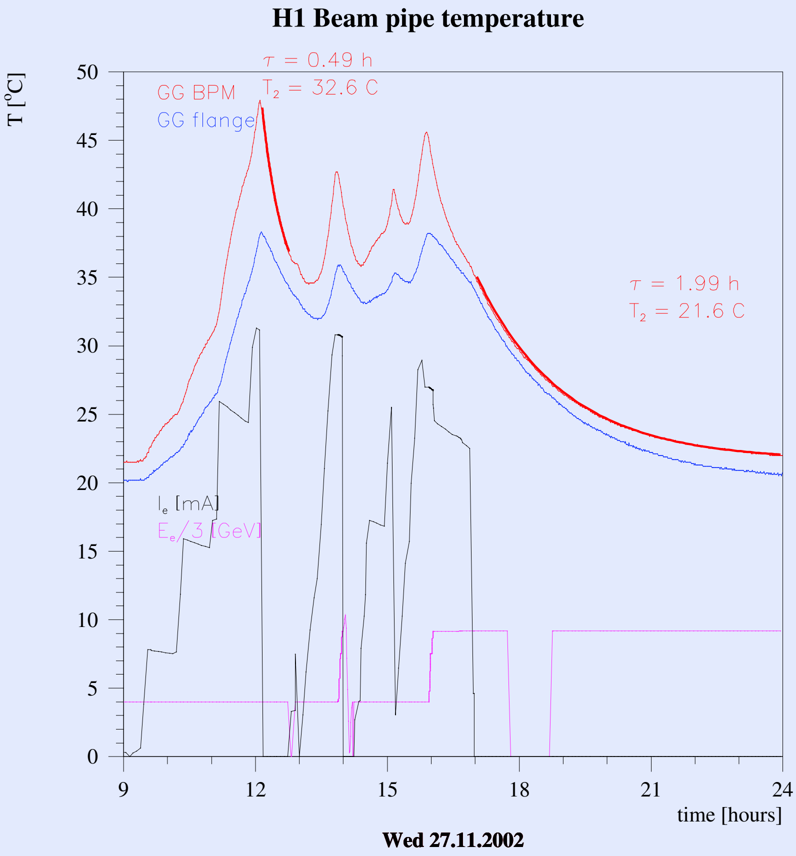


Old and New Radiation Mask in H1

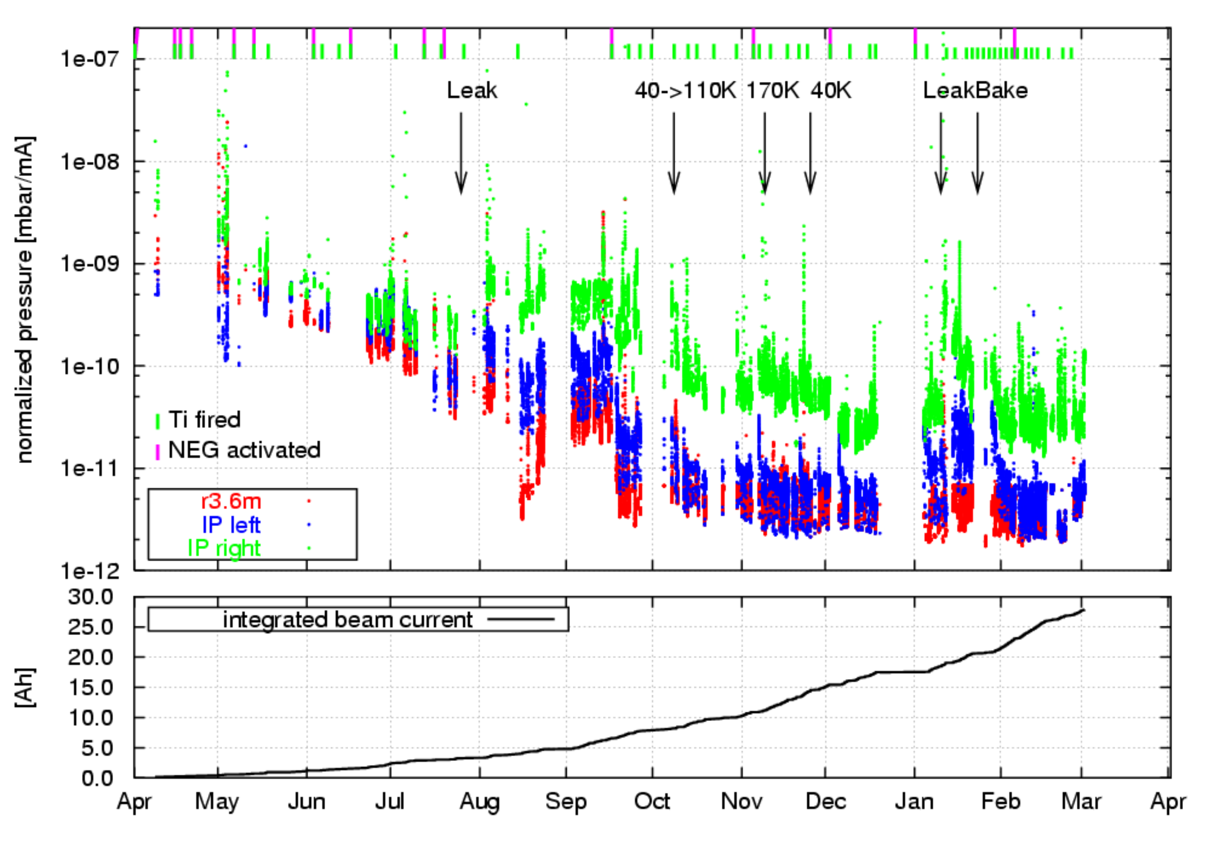




Temperatur GG Flange at H1



Pressure Development 2002/03



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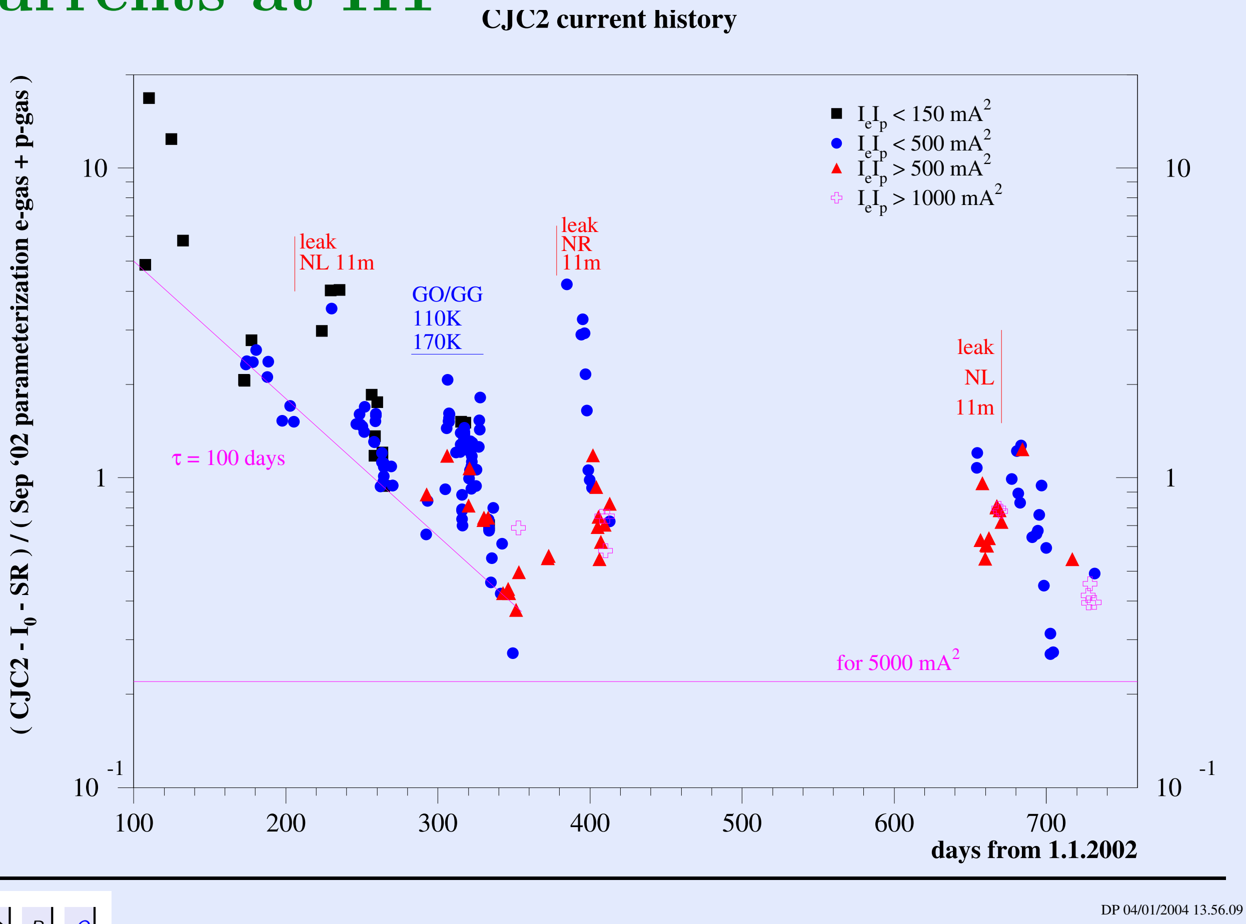
Development of Drift Chamber Currents at H1



Synchrotron Radiation

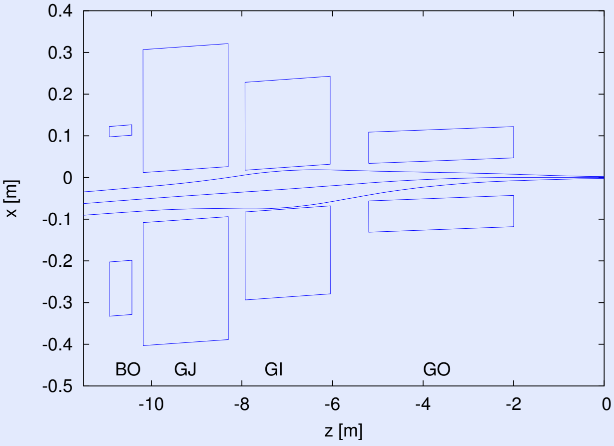
- beam separation and quads produce synchrotron radiation (SR); small powers (10^{-8} of peak density) already problematic!
- orbit mis-steering:
  - wrong direction $\longrightarrow$ photo desorption; back scattering; heating
  - possibly much more power produced; higher critical energy
- orbit control via BPM's, beam based methods
- continuous quad aligment monitoring
- tails in particle beam problematic

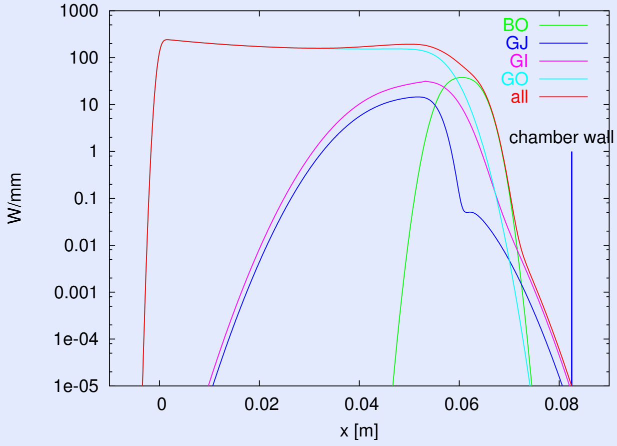
Radiation from Quads is Wider!

phase space distribution of radiation from a thin slice of combined function magnet (γ^{-1} opening angle neglected):

$$\frac{dP}{dl}(x,x',y,y') = \frac{C_0}{4\pi^2\varepsilon_x\varepsilon_y}\left\{\left(\frac{1}{\rho}+Kx\right)^2+K^2y^2\right\}\exp\left(-\frac{\gamma_x x^2+2\alpha_x xx'+\beta_x x'^2}{2\varepsilon_x}\right)\exp(\ldots)$$

step through the beamline and integrate projections of such distributions:





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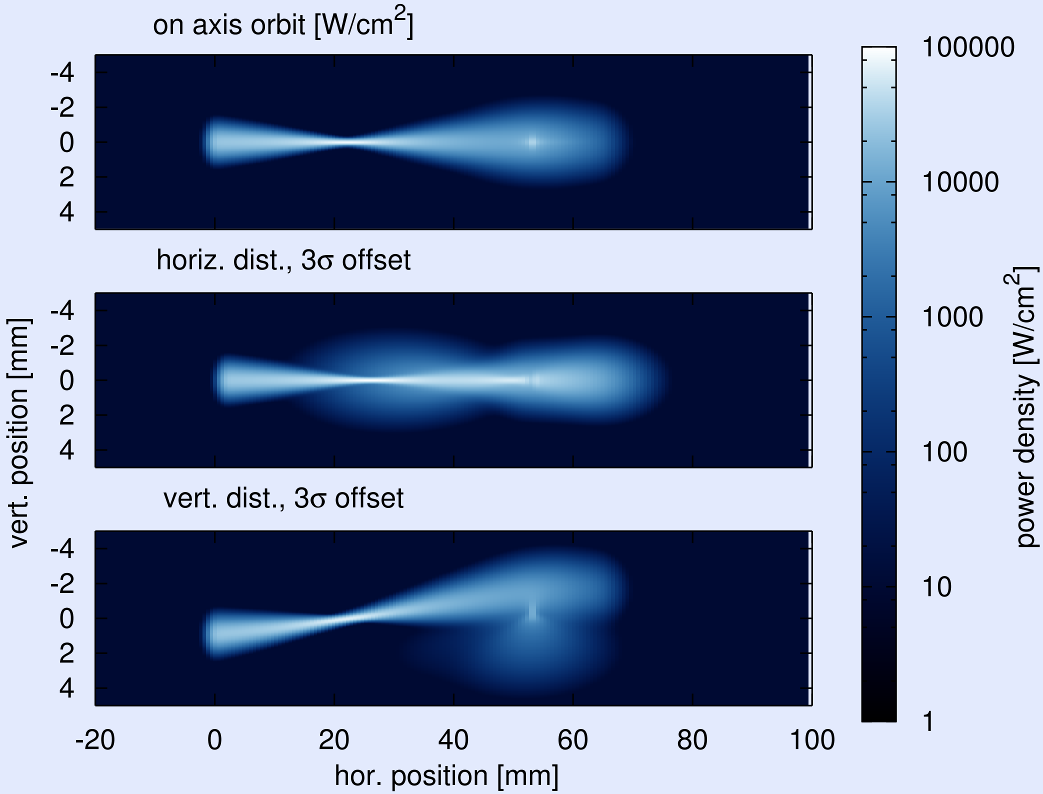
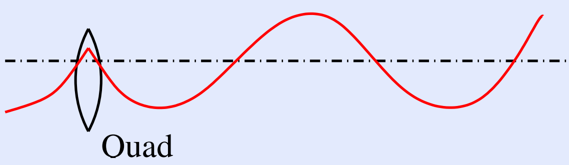
2D Simulation - Nominal and Distorted Orbit

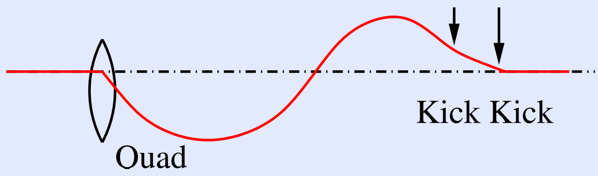
fan projected to 3.5 m right of IP



Beam Based Alignment
Two Methods



difference amplitude around the ring
global optics errors!



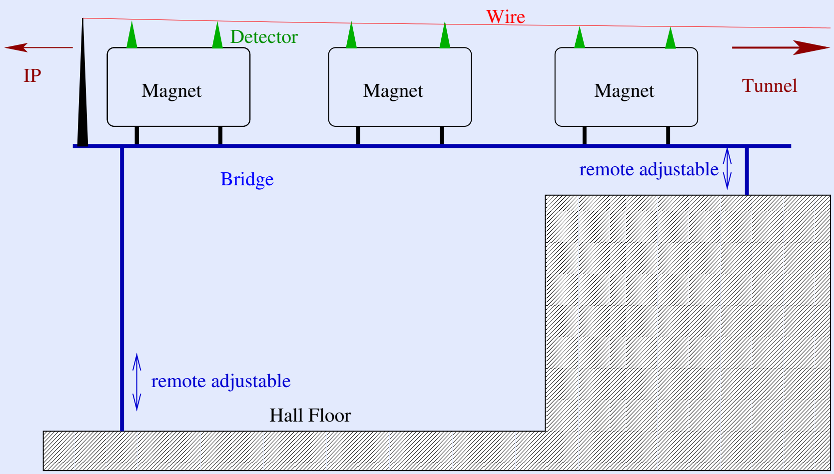
kompensation of kick by two correction coils
calibration of coils! statistics of all monitors contributes

specific problems at HERA:

- nominal offset in x not zero!
  (paper by G. Hoffstätter, F. Willeke)
- coupling in vertical plane
- IR quadrupoles are thick lenses
- advantage: lumidetector fixes IP angle

Stretched Wire Alignment System

- stretched gold-plated wire as reference line
- 100 MHz signal on the wire is detected in BPM-like monitors
- resolution better 1 μm possible; demonstrated at SLAC FFTB
- at HERA complications due to fixation of the wire end point on a magnet support structure



Effects from Electron beam Tails

particle beam tails generate tails in the radiation fan

scraper measurements from HERA-e (A.Meseck, 2000)

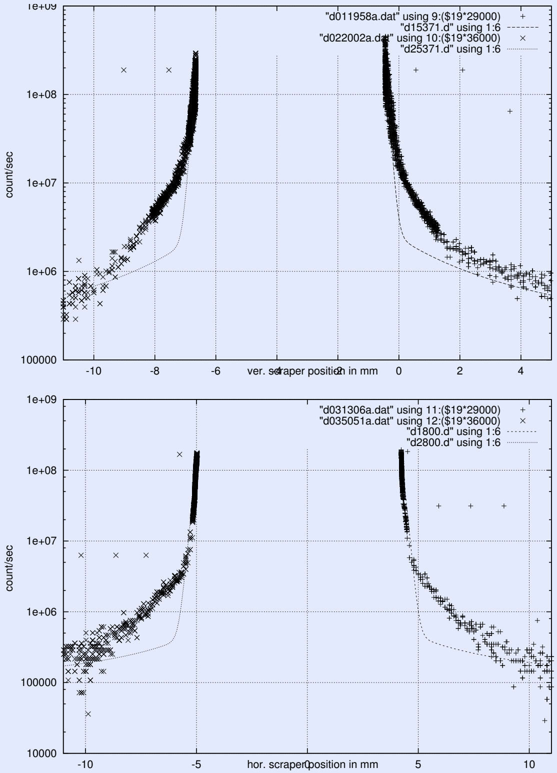
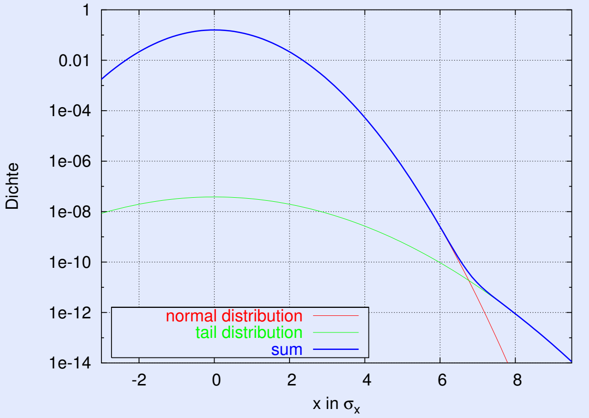


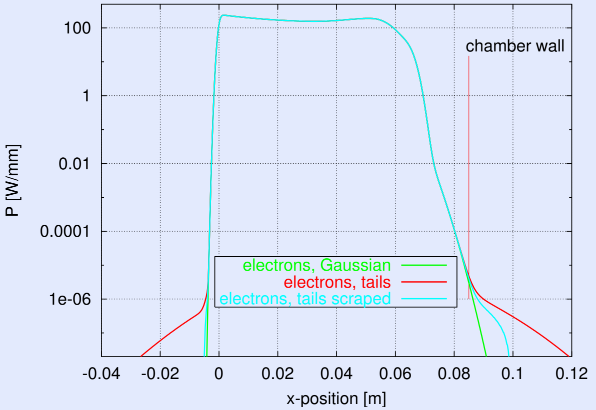
Figure 4.8: Measured (+,×) and the calculated (line) beam loss rates versus scraper position, with the upgrade focusing scheme without beam-beam interaction.

Simulation of the SR Fan including beam tails

beam model distribution



resulting distribution of the fan at +3.5 m



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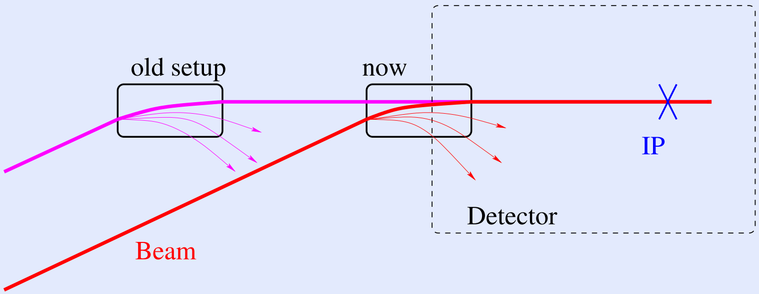
Lepton Gas Scattering

- electrons scatter with residual gas molecules and lose energy; if this happens in the straight section upstream of the detector they get lost preferentially in the separation field
- wide energy range for scattered leptons $\sigma \propto 1/E$
- strong Z dependence for rest gas $\sigma \propto Z^2$
- sensitivity over long distance

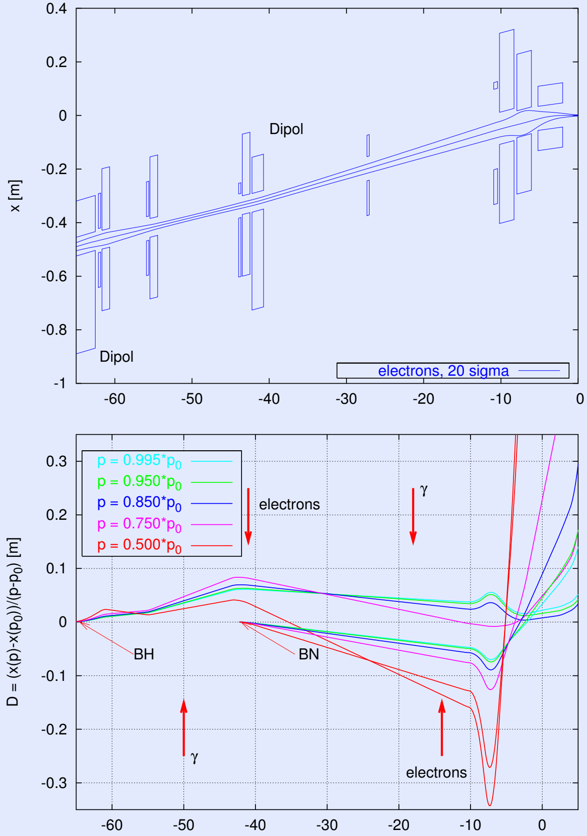
comparison of old new HERA IR



Dispersion Function for Different Energies

problem: scattered particles lose energy; are bent stronger than nominal inside the detector; produce background

remedy: energy collimation; dispersive section

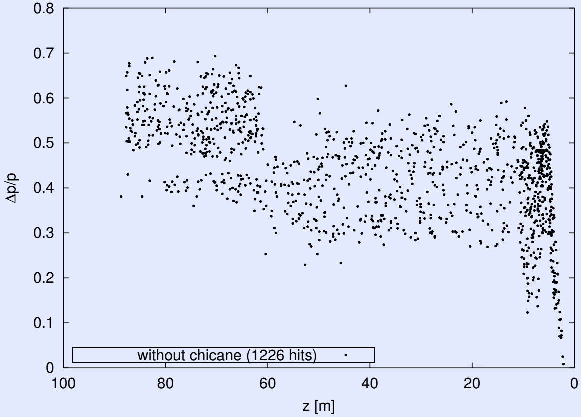


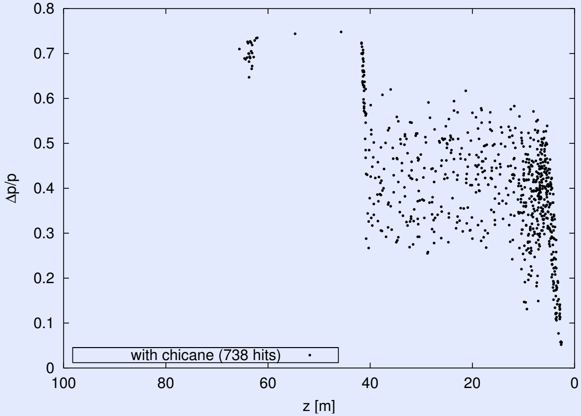
Simulation w/o Energy Collimation

only beam particles that hit detector pipe are plotted

particle energy as function of distance to IP, where the residual gas interaction occurs

(U. Kötz, ZEUS)





Recommendations from HERA Experience

- Synchrotron Radiation
  - careful simulation and prediction of fan locations required
  - error analysis of orbits and magnet positions
  - shielding of critical vacuum components (bellows, flanges)
  - HOM heating produces outgassing!
  - consider effect of beam tails; possibly scraping required
- Beam Gas Background
  - simulation of beam losses from gas scattering (energy loss)
  - consider momentum collimation
  - careful layout of vacuum system at critical locations
  - estimate and prediction of vacuum conditioning