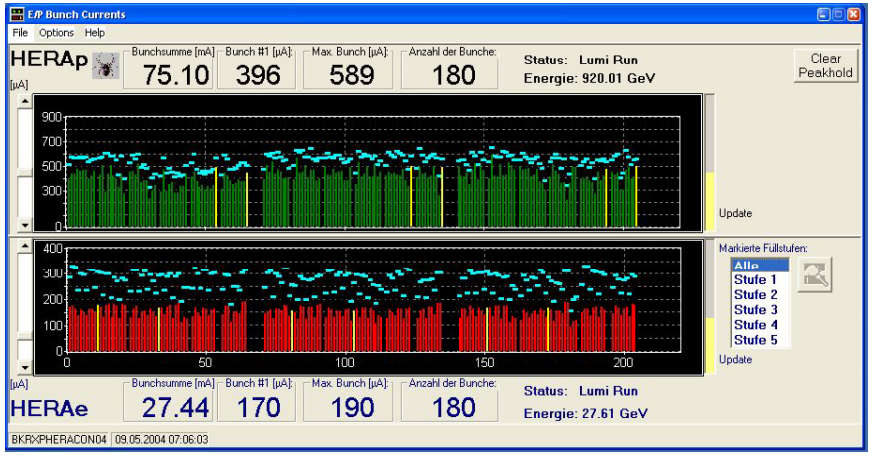
HERA: Sources & Cures of Background Machine Perspective

B. Holzer, DESY-MHE/MPE

I.) Basics:

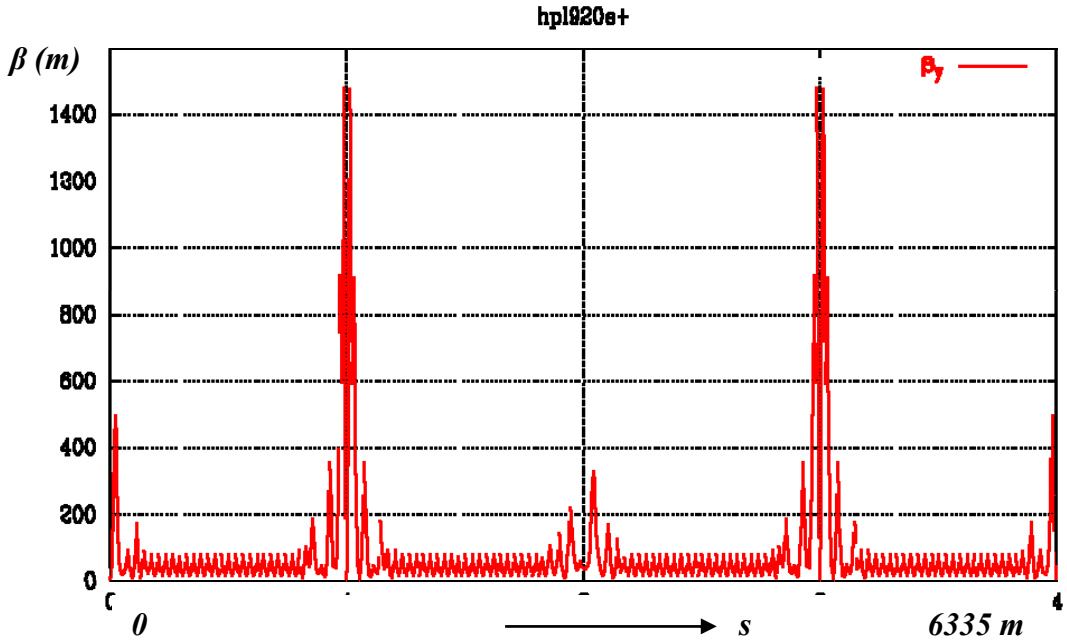
HERA parameters

Injection Energy	*40 GeV*
Flat Top Energy	*920 GeV*
Number of bunches	*180*
Beam current	*100 mA / 45mA*
Part. per bunch	*$7*10^{10}$*



HERA run conditions:

	protons	*electrons*
β_x	*2.45m*	*0.6 m*
β_y	*0.18m*	*0.26m*
ε_x	*5.1 nm*	*21nm*
ε_y	*"*	*3.5nm*
σ_x	*112 µm*	*112µm*
σ_y	*30µm*	*30µm*
Δv_x	*1.1*10 -3*	*3.0*10 -2*
Δv_y	*3.1*10 -4*	*4.9*10 -2*



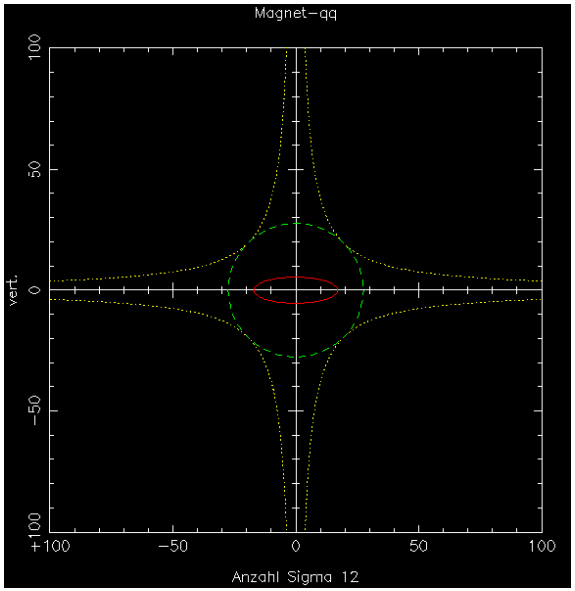
I.) Basics:
Apertures

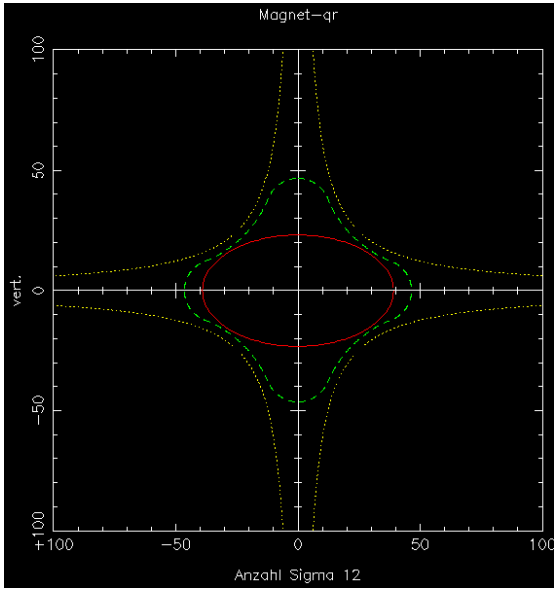
cold section: $r_0 = 27.5mm$

warm section $r_0 \geq 12\ \sigma$
(+/- 130m around IP)

collimators $r_0 \approx 7\text{-}8\ \sigma$

... no additonal safety margin for orbit distortion, dispersion trajectories etc





Apertures and beam envelopes:
12 σ, lumi optics,
cold section
mini beta region

II.) Helmuts Questions:

1.) Are / were machine backgrounds and issue ?
2.) Which type of backgrounds ... ?
3.) How solved ...?
4.) Sources of halo ...?
5.) Scraping useful ?

III.) Communication Machine & Experiments:

four high energy detectors, 300-400 people each ,
4* 400 * 7 questions per person per day --> 10^{10} phone calls in the CCC

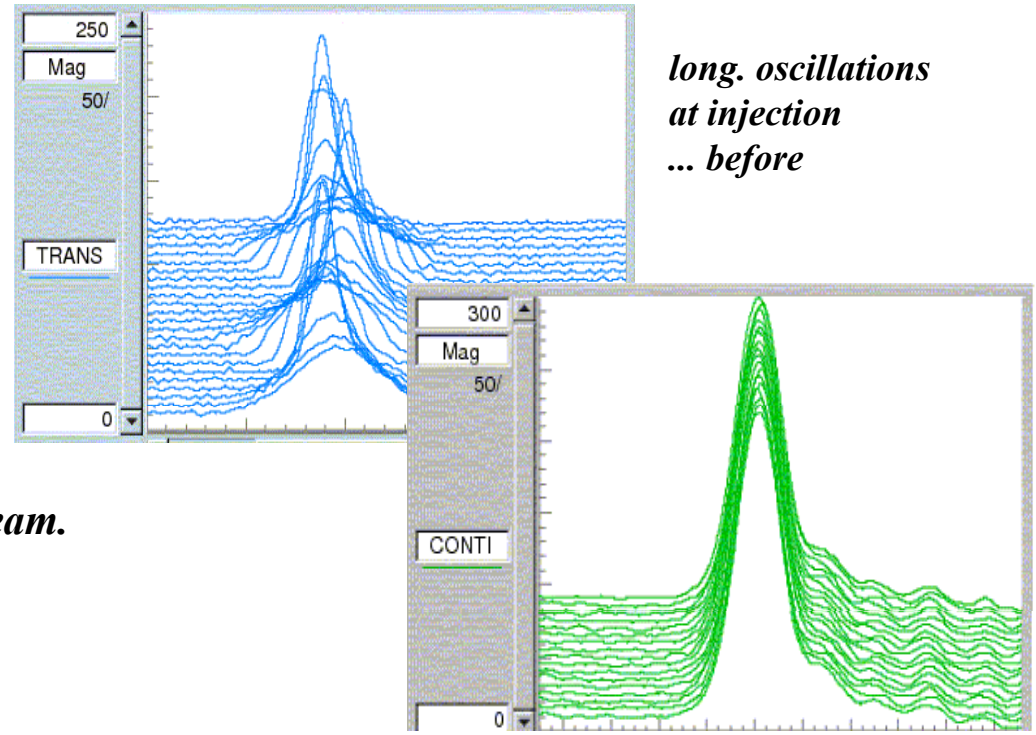
*** 1-2 contact persons per experiment**
*** 1-2 coordinators to clarify the needs / wishes of the 4 experiments**
*** 1 coordinating experiment per week**
*** 1 meeting per week to define the running conditions**

daily "task force meetings" ... were not especially useful.

some experts from the detector part in the CCC for dedicated experiments / tuning procedures / machine optimisation runs was extremly useful ... to understand & improve backgrounds etc.

Aristoteles (384-322 BC):
... a cup of coffee can clarify a lot of misunderstandings.

IV.) Procedures:
Proton Injection



long. oscillations at injection ... before

... and after energy correction

Reproducibility at injection limited,
measure & optimise main parameters on beam.

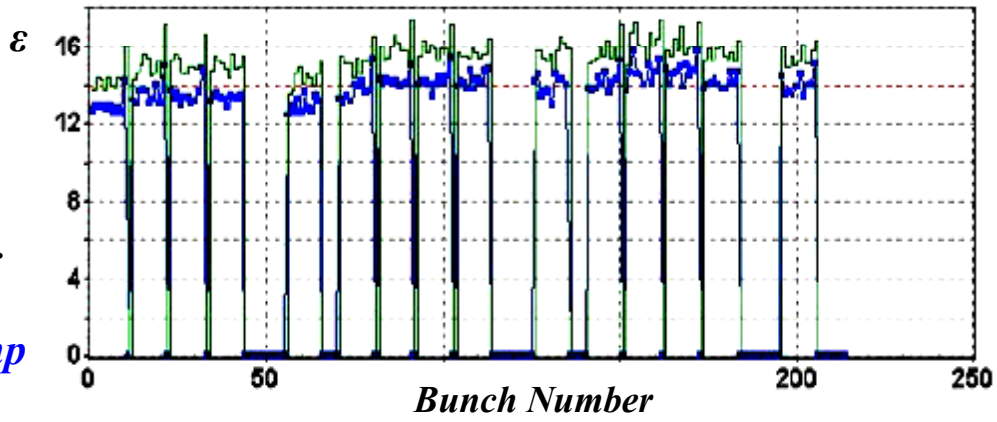
bunch train of 10 pilot bunches
measure and optimise
- E_0, Φ_0,
- Q, Q', κ
- *Orbit*

key issue: beam emittance

problems during acceleration
... rare but possible
problems during luminosity tuning
... very rare but still possible.

measure & judge beam emittance before each ramp

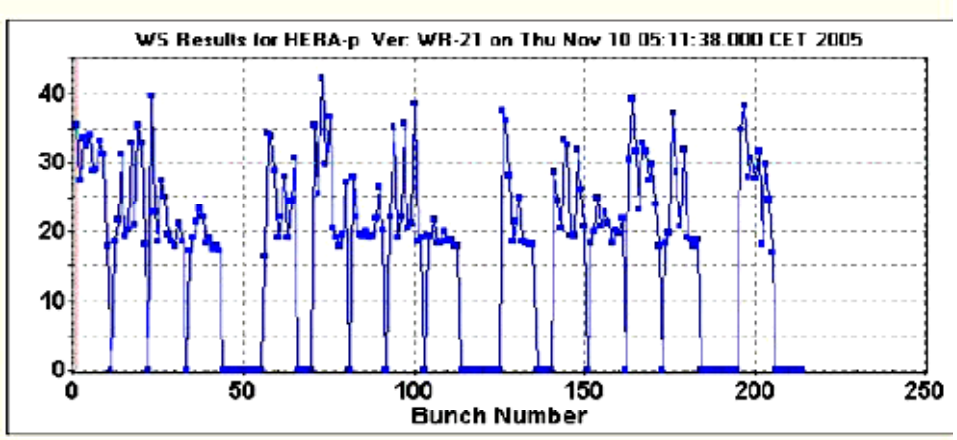
bunch emittance, 2σ, normalised



IV.) Procedures:
Luminosity

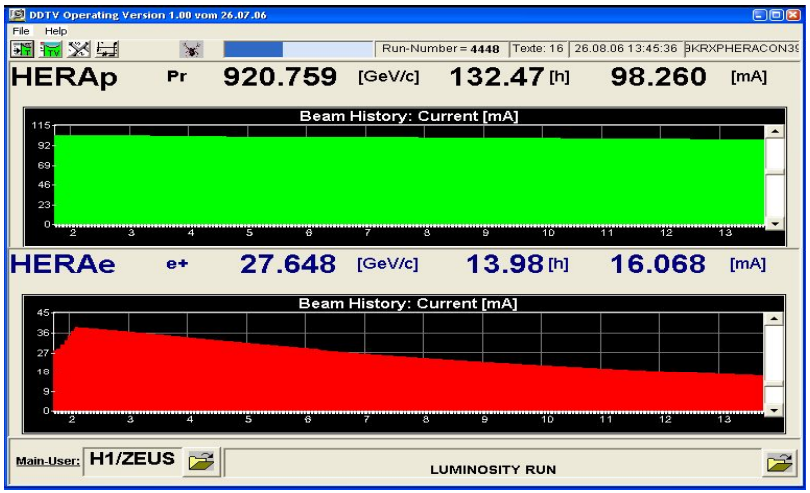
measure emittance before and after each ramp
"... das ist schon die halbe Miete."

never forget: "she is a lady"



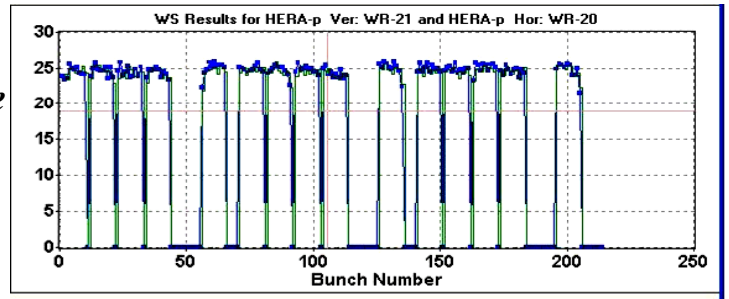
emittance blow up in single bunches during lumi tuning

(s.c. ...?) magnets ... drifting beam parameters
vertex, tune, coupling, chromaticity, orbit
are driving the diffusion rate
most dominant during first 30 minutes

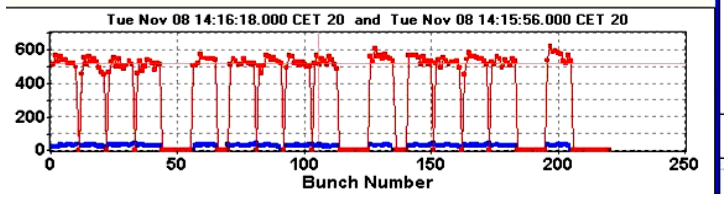


end of a luminosity run
emittance growth during 12 hours

bunch emittance



bunch current



V.) Procedures:

Background Tuning: Machine

measurements:

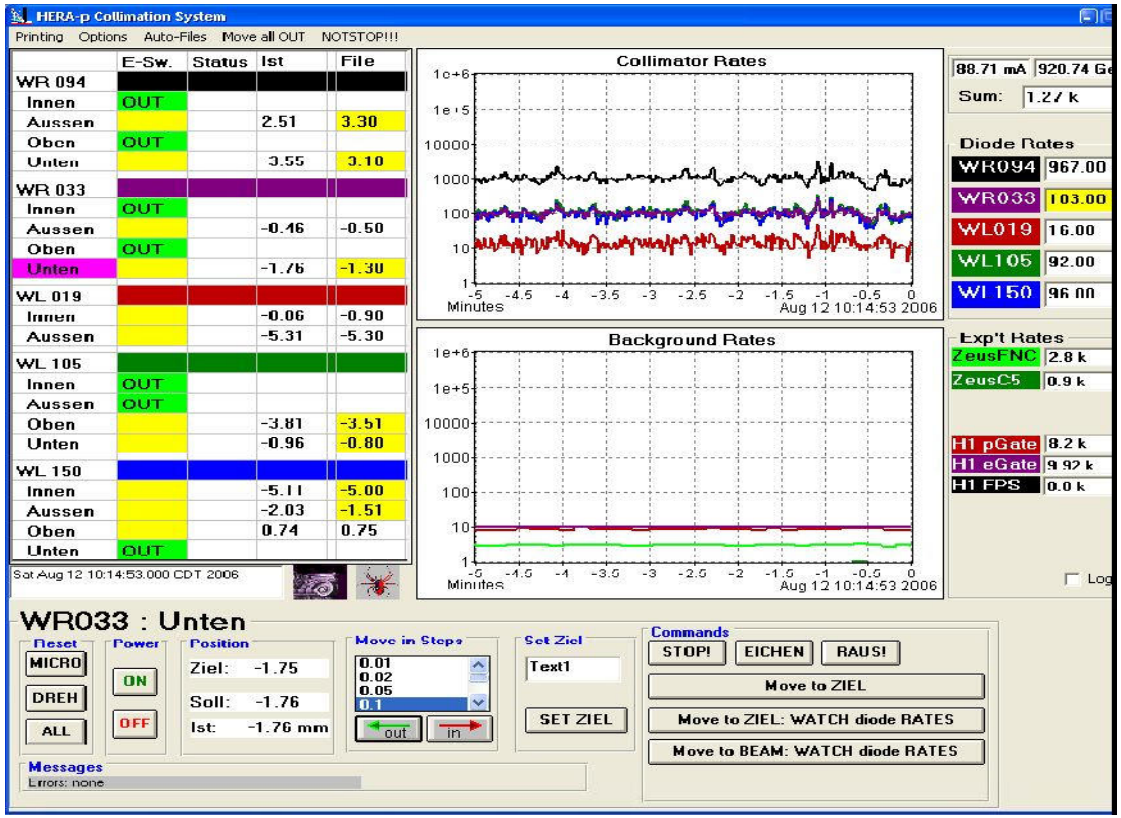
lifetime ... nice but too slowly and unprecise

lifetime during HERA luminosity run

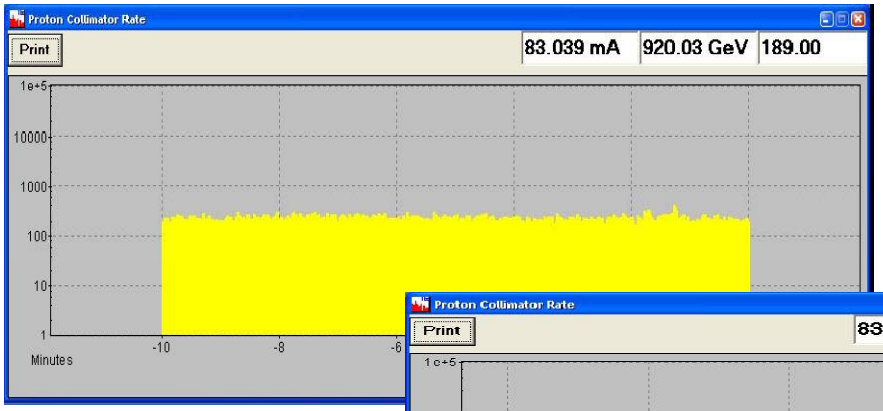
beam loss rates

... fast, excellent for relative changes,

& global beam parameters

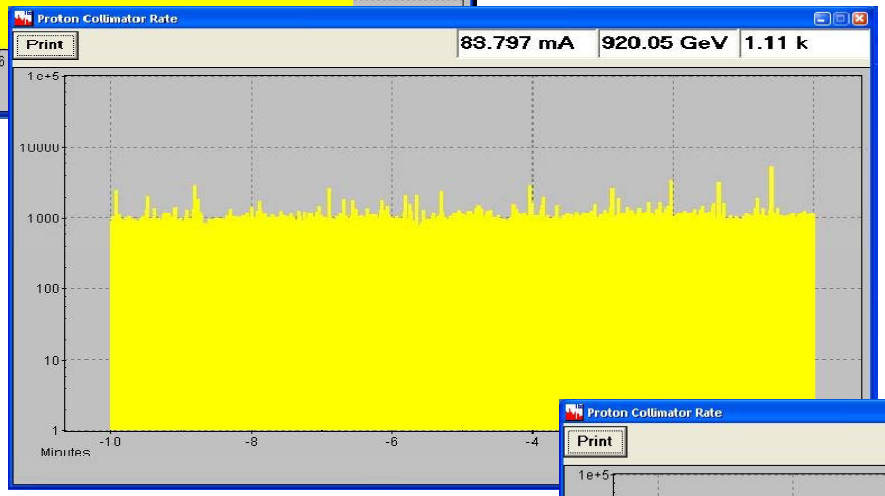


Beam Loss Rates: sum signal



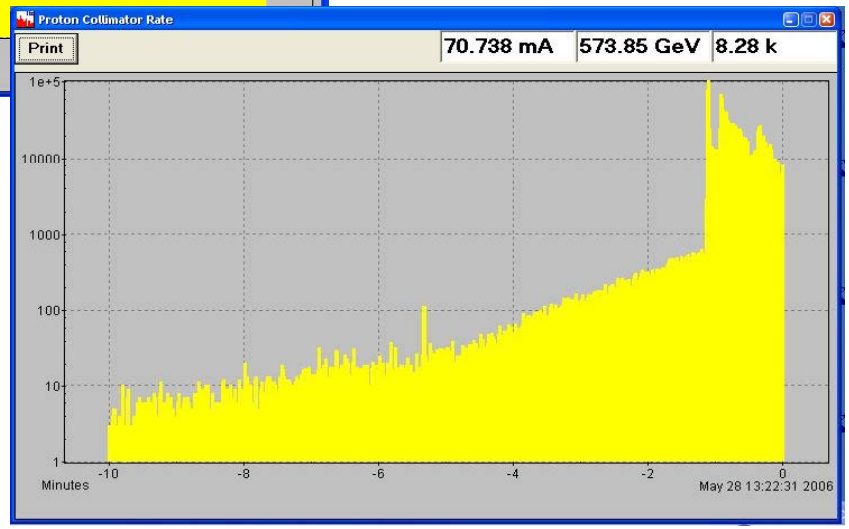
ideal situation:

beginning of a good lumi run



towards the end

... already limiting the data efficiency

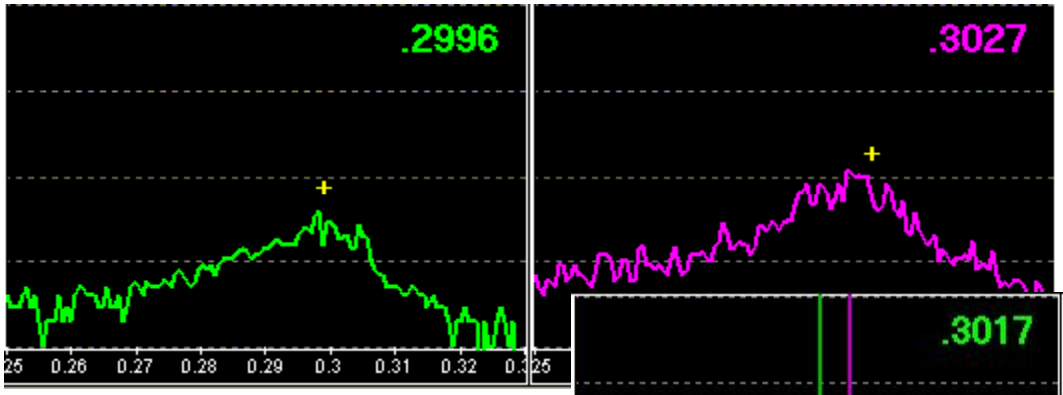


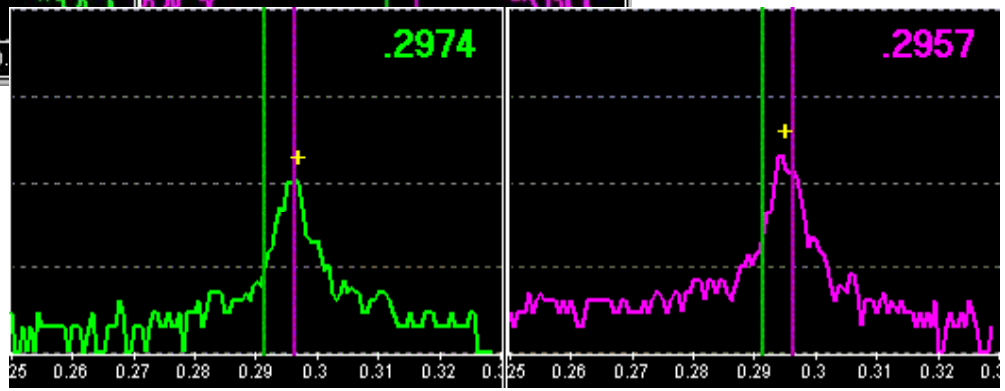
... and in case of trouble (on the ramp)

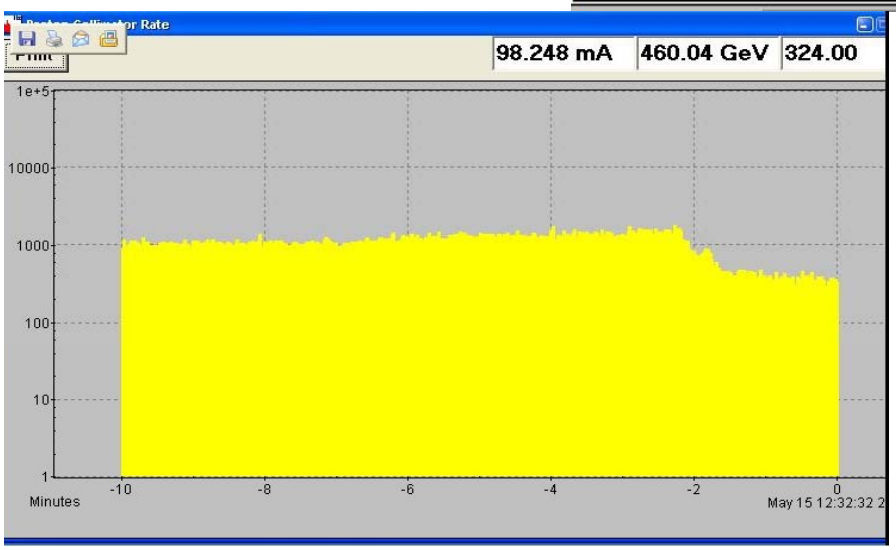
V.) Procedures:

Background Tuning Machine

choose the ideal tune
optimise the coupling
compensate chromaticity
.... on beam

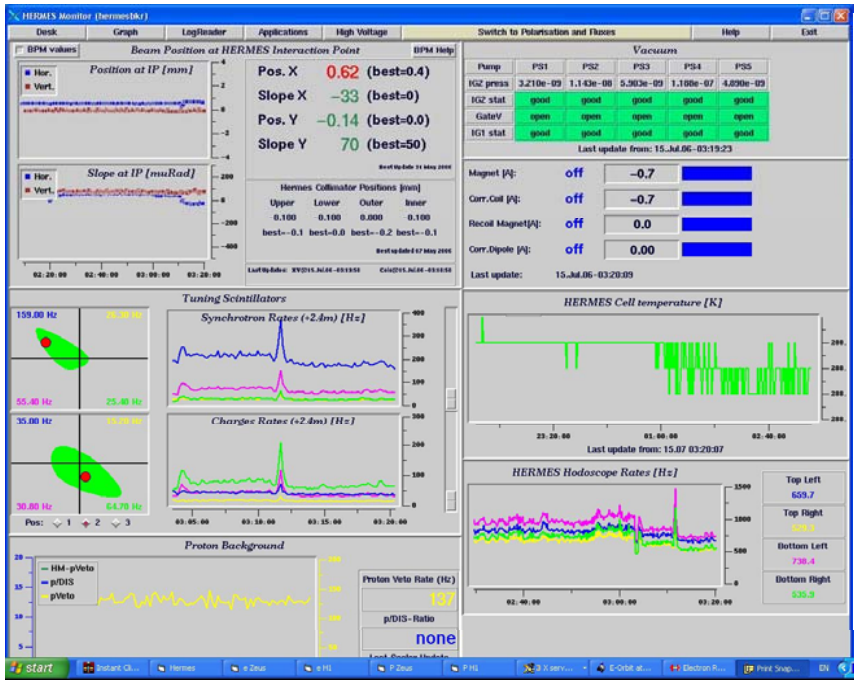




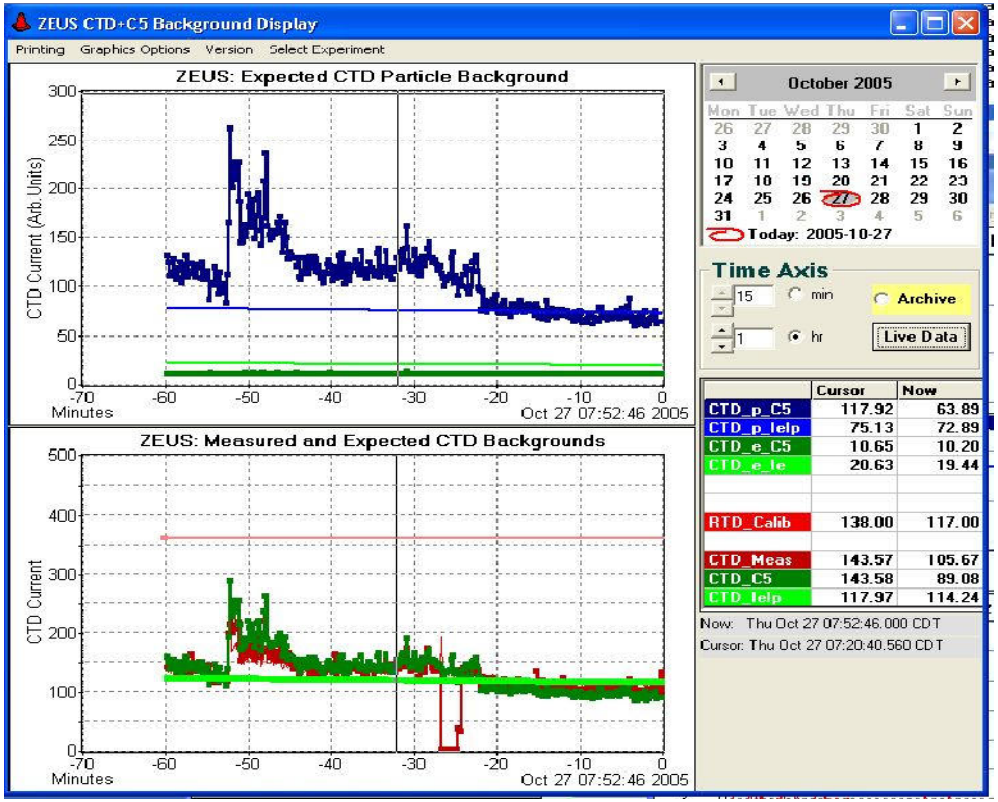


VI.) Procedures:
Background Tuning: Detectors

***Detector Signals** ... slow, very precise, excellent for*
local optimisation & long term tuning



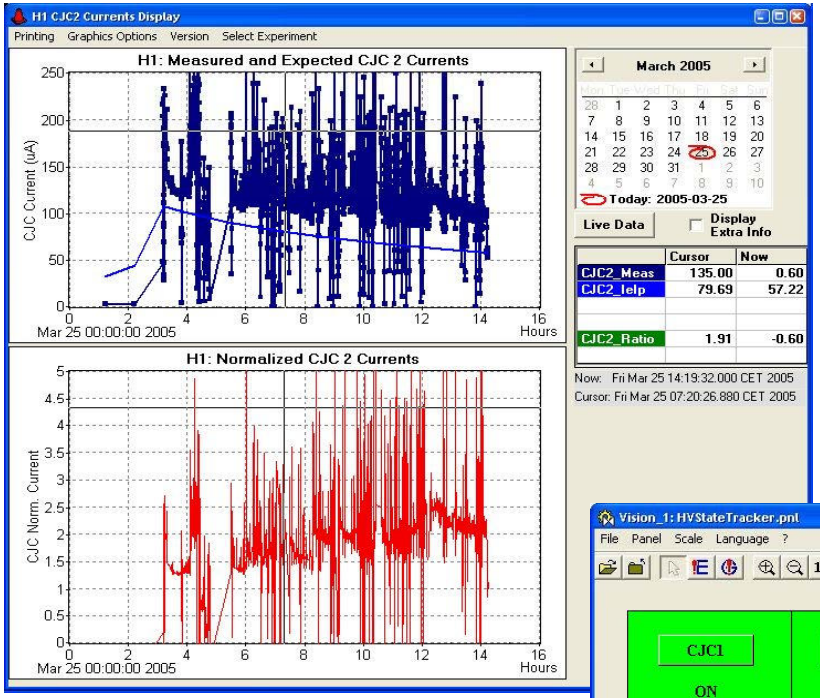
HERMES detector:
main problem synchrotron light & electromagnetic showers
tuning: local orbit ... up to 150m upstream
position & angle at IP



ZEUS detector: ideal situation
direct measure of drift chamber curents
sensitive to hardronic / electromagnetic
showers (via timing)

VI.) Procedures:

Background Tuning: Detectors



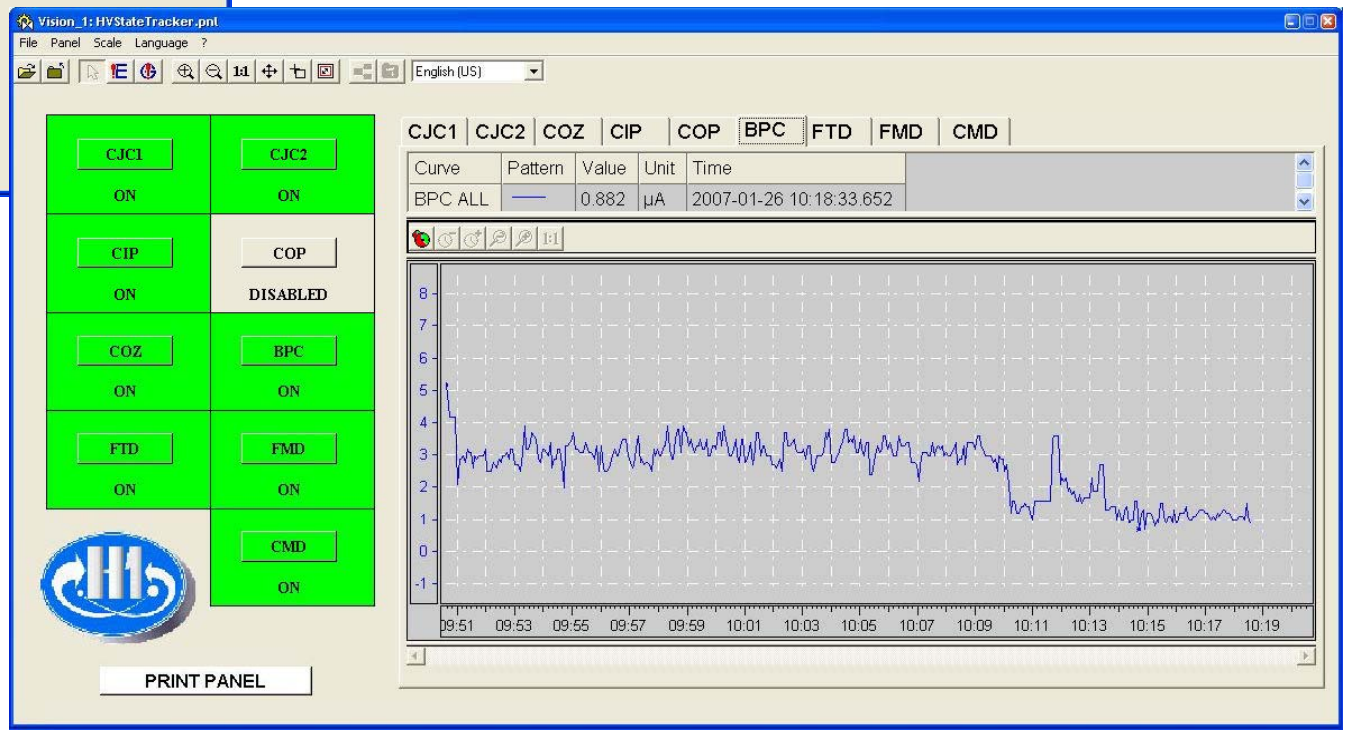
H1 detector: ***drift chamber currents***

a "not so ideal situation"

tuning: ***locally*** *position & angle* ***at IP***

global beam parameters

chromaticity, coupling, *TUNES*



H1 detector:

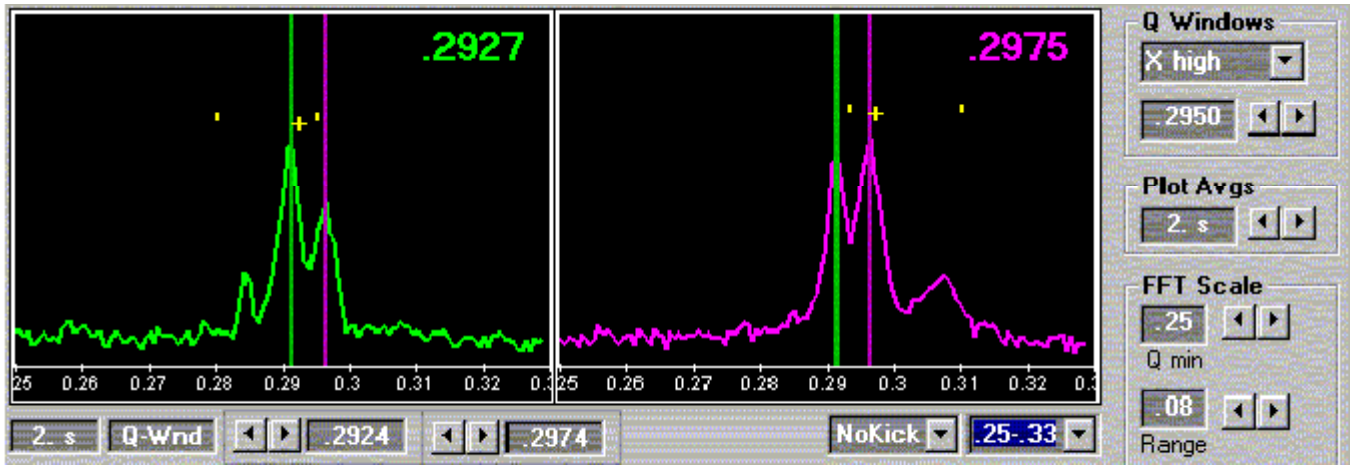
currents of *every sub detector*

available in the CCC

excellent tool *if expert is available*

VII.) Problems & Surprises

there are many tunes ...

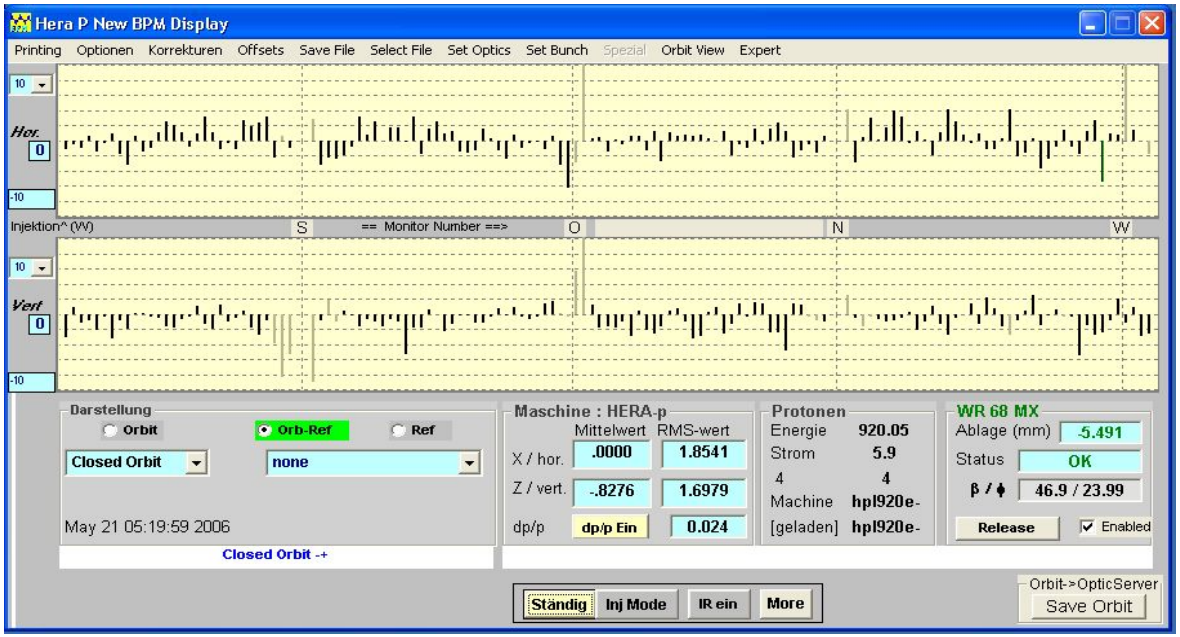


... sometimes we preferred
to switch of the tune stabiliser

spikes, excitations,
beam beam coupling

local Orbit distortions

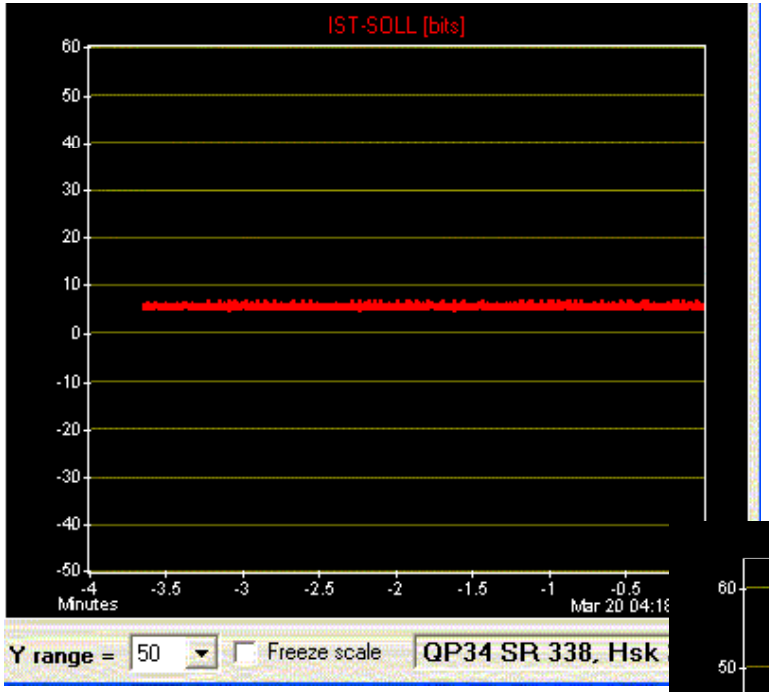
... local orbit corrections by 2-3 mm
can improve the lifetime by 20-30%



VII.) Problems & Surprises

Power supplies

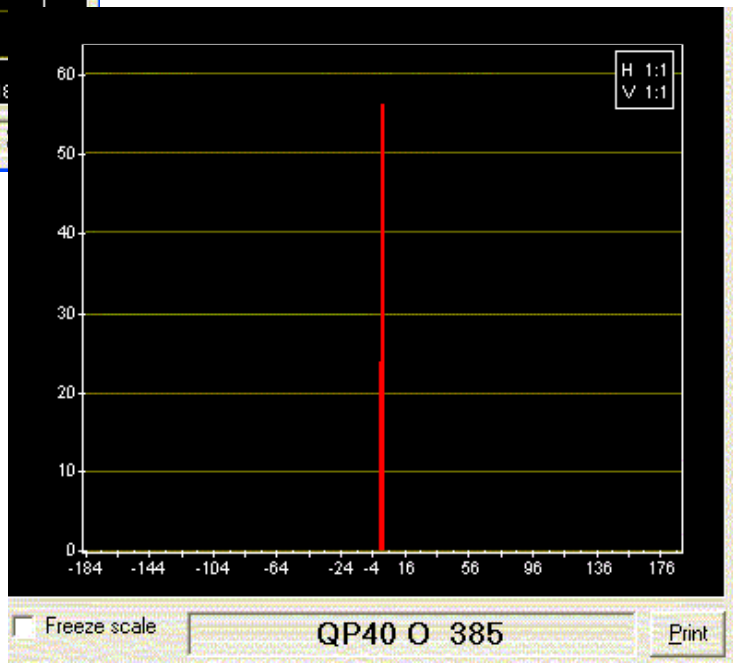
noise and ripple at power supplies



survey and control the current setpoint & read out.

read out & store at any time

freezing the transient recorders triggered by event or operators



HERA tune quads

stable on one "bit"

VII.) Problems & Surprises

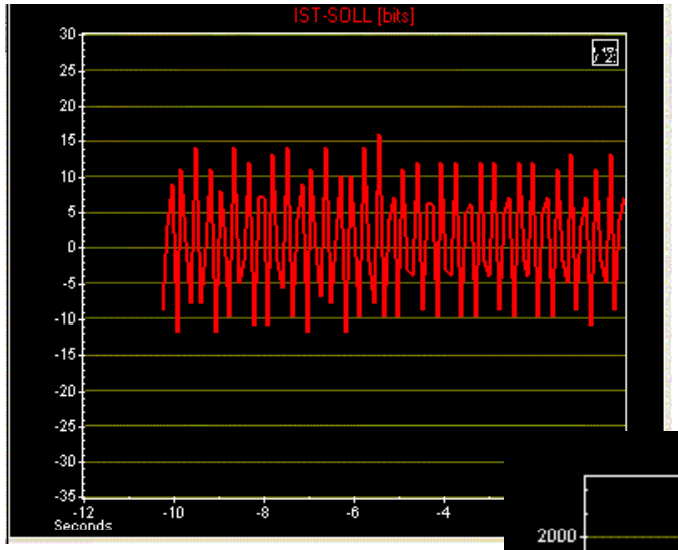
Power supplies

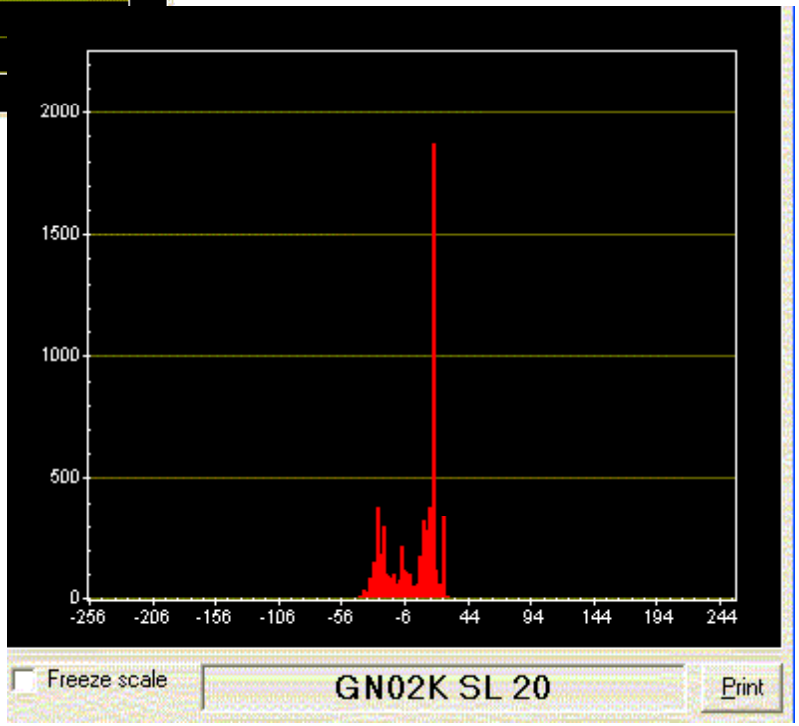
the untold stories ....

chopper supplies running on the tune frequency

broken filter circuits

broken coils (!)



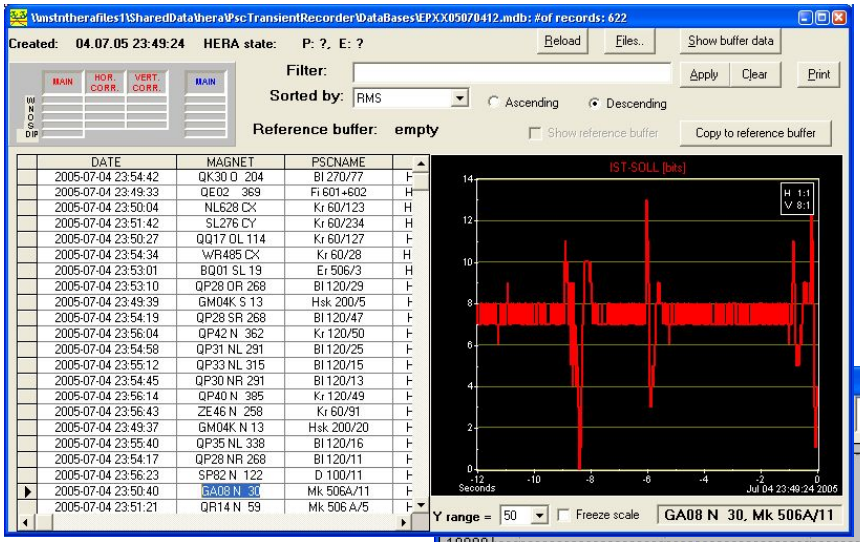


swinging power supply current

increasing diffusion rate
reducing lifetime
... but not toooo severe.

VII.) Problems & Surprises

Power supplies



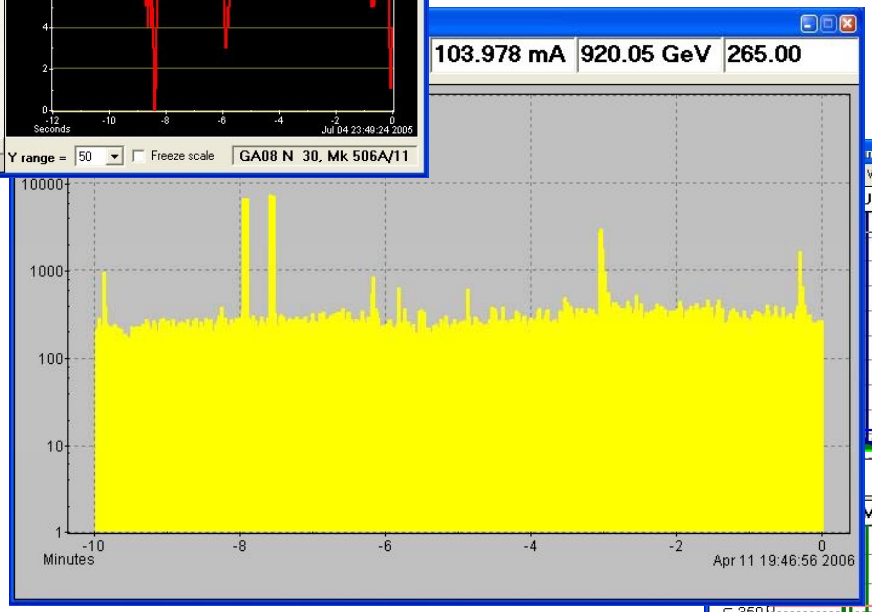
broken electronic in a mini beta quad power supply

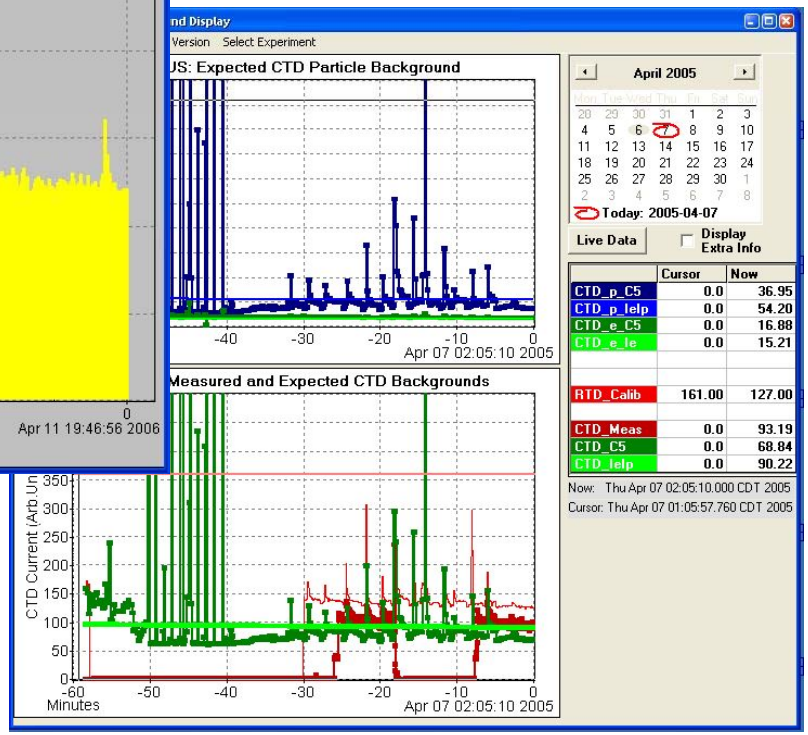
causing spiky magnet current

leading to heavy spikes in the beam background

--> catastrophy ... and not easy to localise.

... the collimator loss rates





... and what the detector people tell us

VII.) Problems & Surprises the RF

DC beam contribution

***broken connection** between rf pre amplifier & main driver in the tunnel*

..."excellent" noise amplification

... driving DC contribution

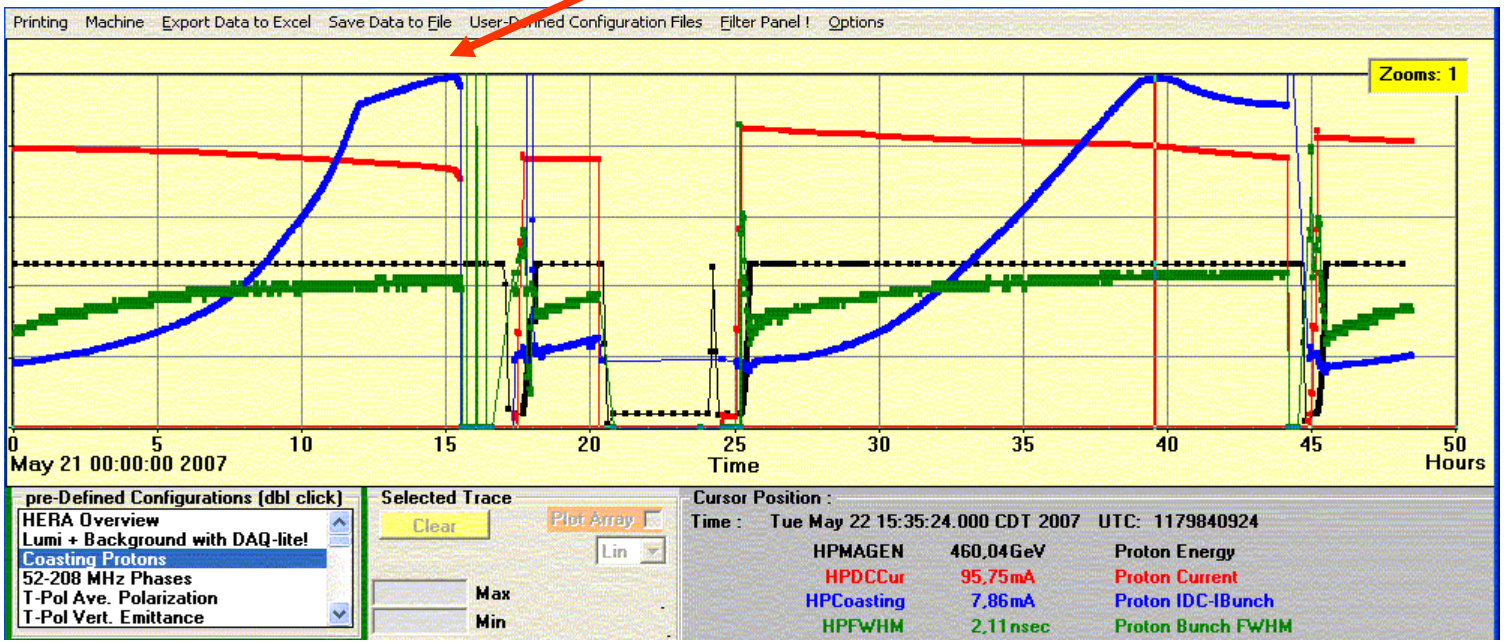
... spoiling several luminosity runs

accumulating up to 20 % DC contribution

... scraping ... did not solve the problem

beam current

DC contribution



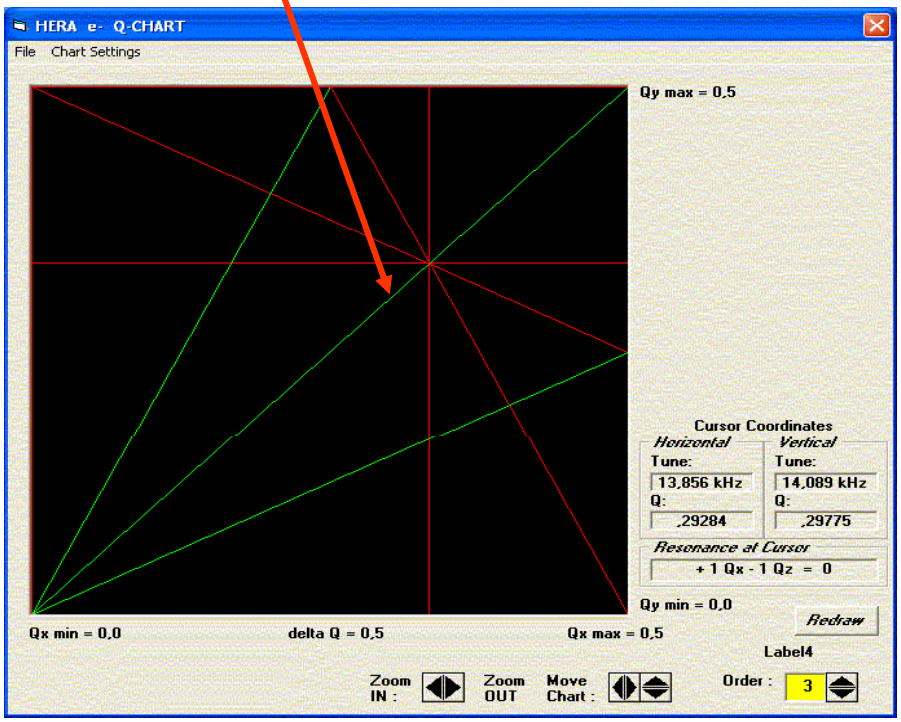
VIII.) The Real Surprises:

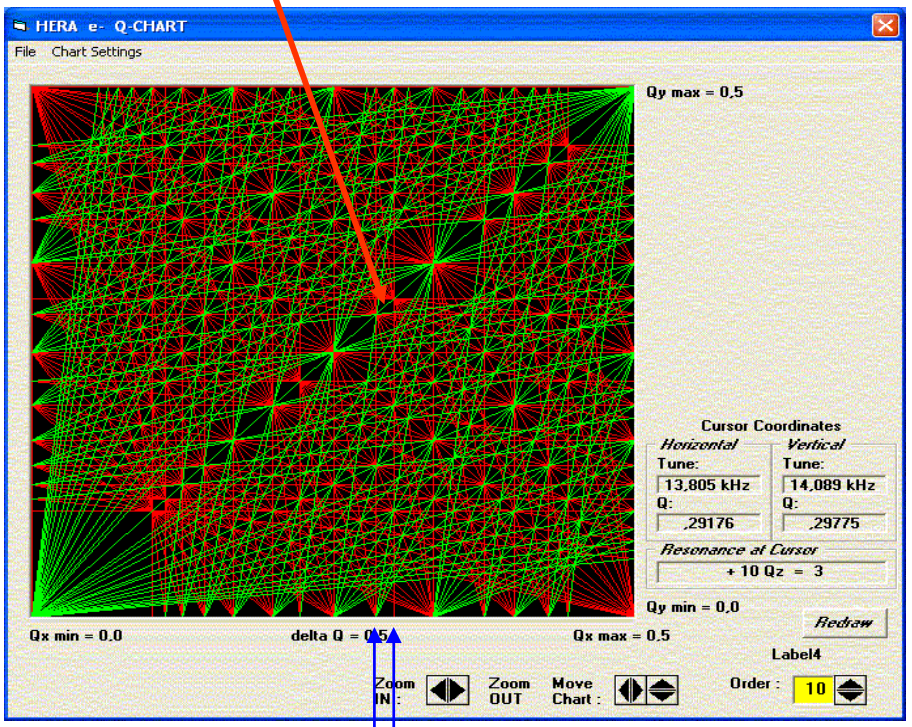
in collision the beam was extremly sensitive to
"wrong" tune settings
non ideal coupling compensation
experiment solenoids
off center collisions
etc ...

HERA Tune ...

never believe in theoretical predictions

ideal tune settings found "on beam" ... or on background !



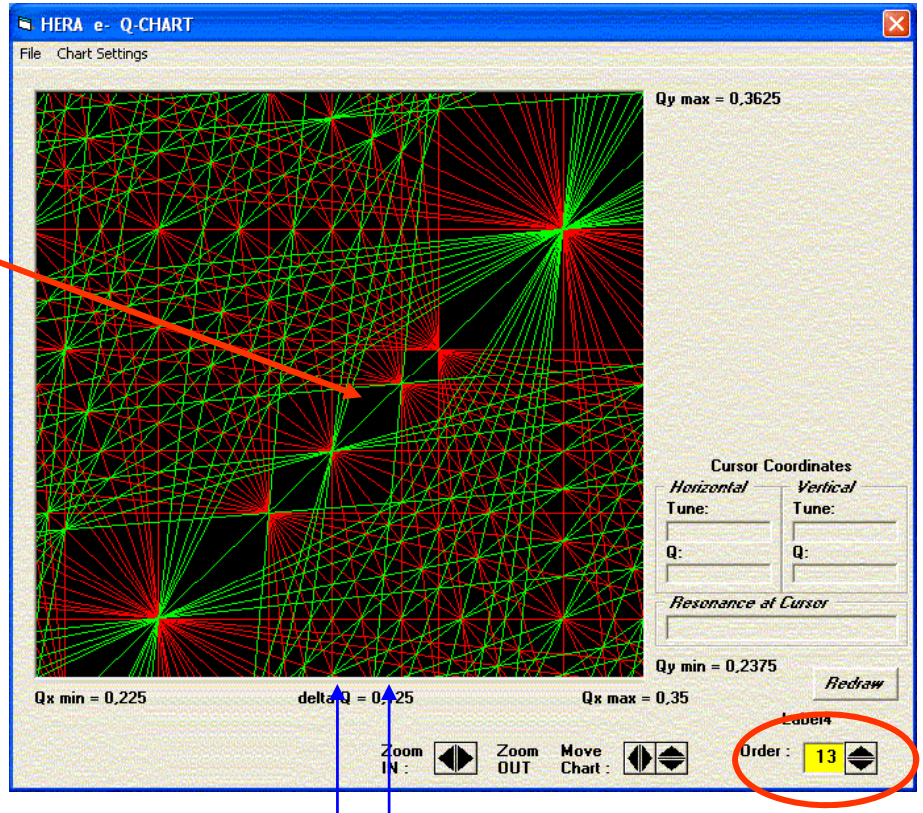


31.0 *31.5*

free space: ≈ 600 Hz

VIII.) the Real Surprises:

HERA Tune ... *ideal value*



problem: significant changes in lifetime
& background by tuning the trim quads
by ≈ 50 bits

nominal current: 100 A
resolution: 16 bit

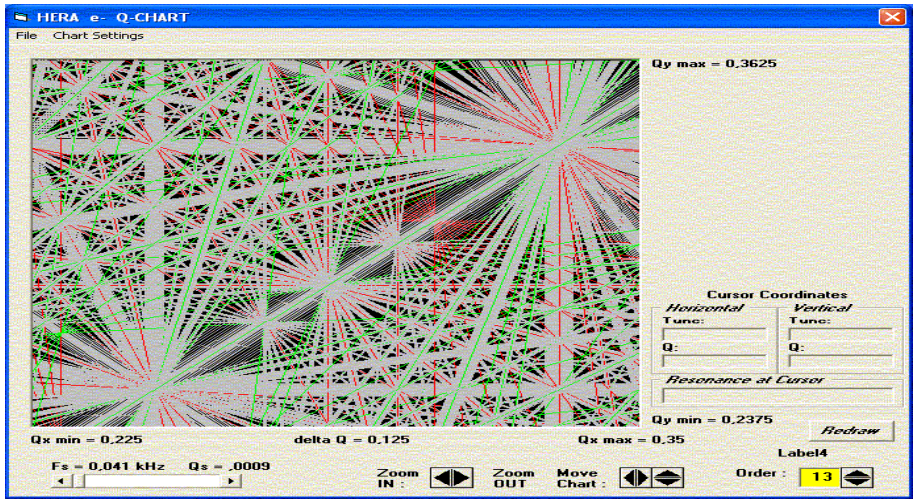
tune change:

$$1\,bit \rightarrow \quad \Delta k = 1.03*10^{-8}\ {}^{1}\!/_{m^2}$$

$$\Delta Q = \frac{1}{4\pi}\int \Delta k \beta dl$$

$$50\,bit \quad \rightarrow \quad \Delta Q = 0.002$$
$$\rightarrow \quad \Delta f = 95\ Hz$$

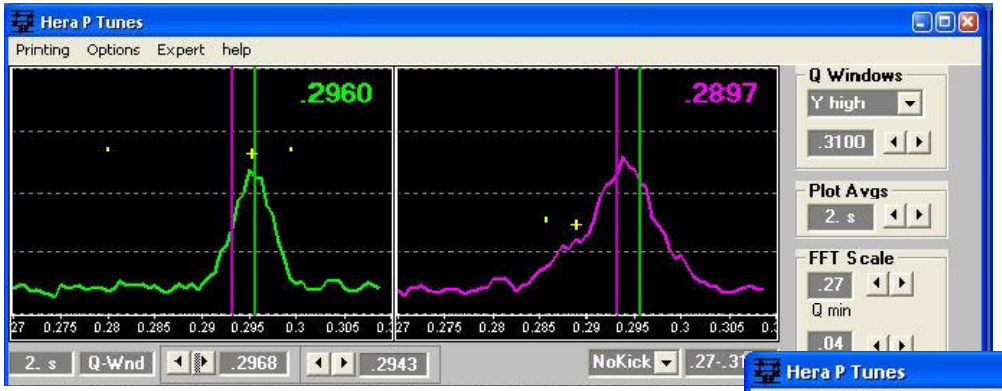
free space: ≈ 600 Hz



The (1 ... 3) real experts:
tune optimisation in single bits !!!

VIII.) the Real Surprises:

HERA Tune ... ideal values can jump



ideal tune values for months

out of the blue ...

ideal tune values interchanged and again stable for months

IX.) Helmuts Questions:

1.) Are / were machine backgrounds and issue ? *YES.*

2.) which type of backgrounds ... ? *most severe: DC current & hadronic spikes*

3.) how solved ...?
Power Supply & RF maintenance
survey & control of ps currents
transient recorders
no solution for external noise.

4.) sources of halo ...? *noise of any kind (transverse & longitudinal)*

5.) Scraping useful ? *No ... yes ... NOOOO !*

Tuning the Background is
** a tedious, time consuming, never ending story.*
** an art of its own,*
... as in the end you have to know & take into account the complete machine and so it is fun.

t.q.m.m.