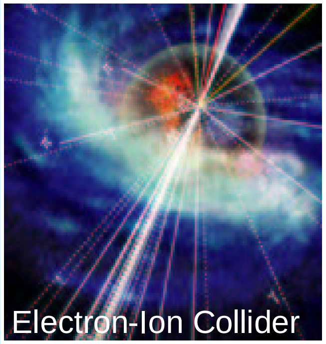
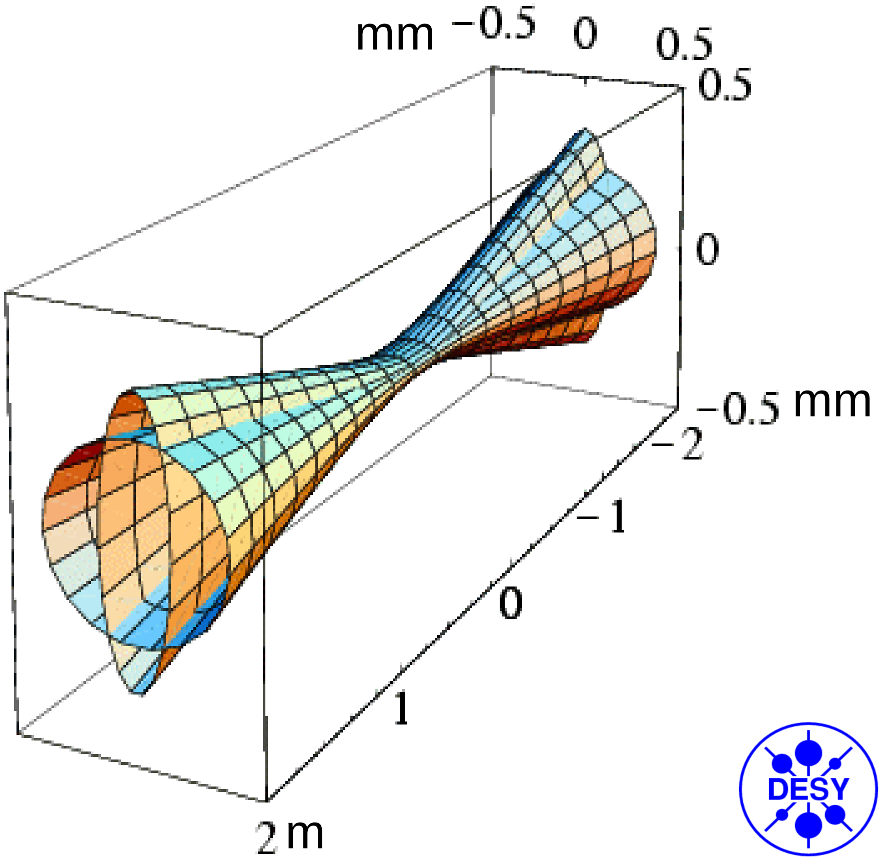


Workshop J-Lab 04

03/15/2004

Beam-Beam Experience in HERA

Georg H.Hoffstaetter
Cornell University
(formerly DESY)

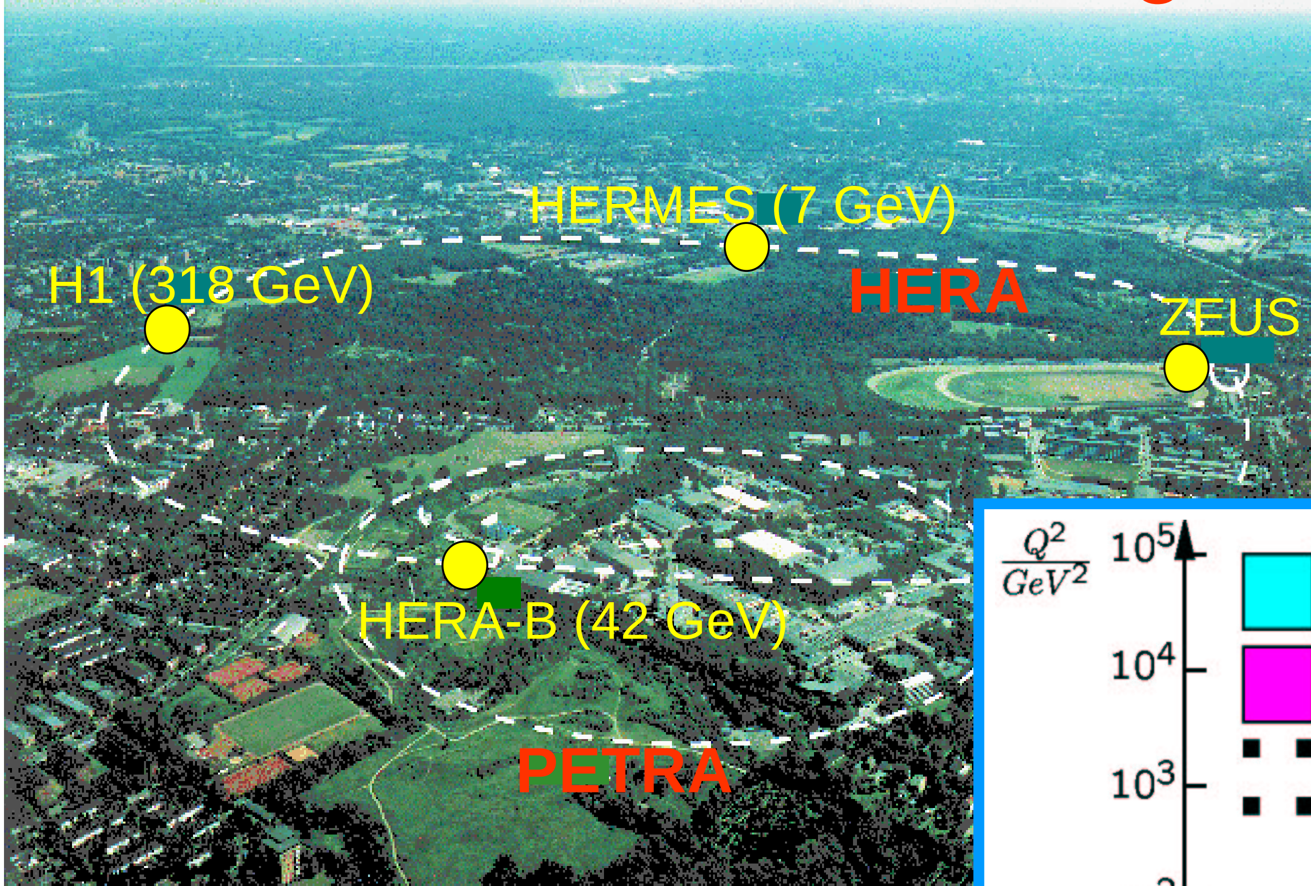


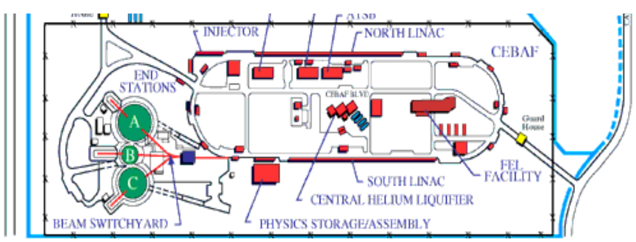
CORNELL

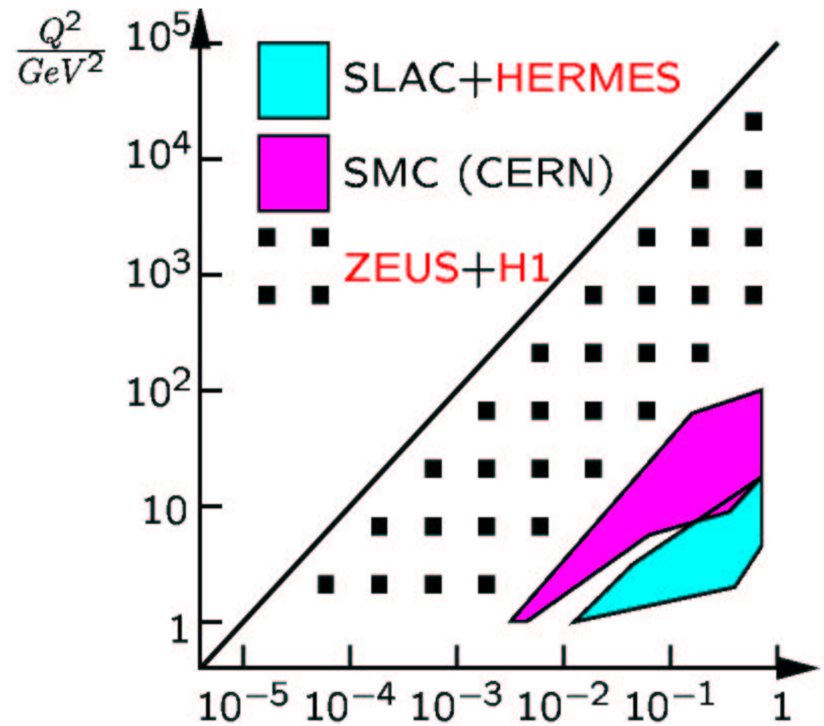
DESY

HERA under Hamburg

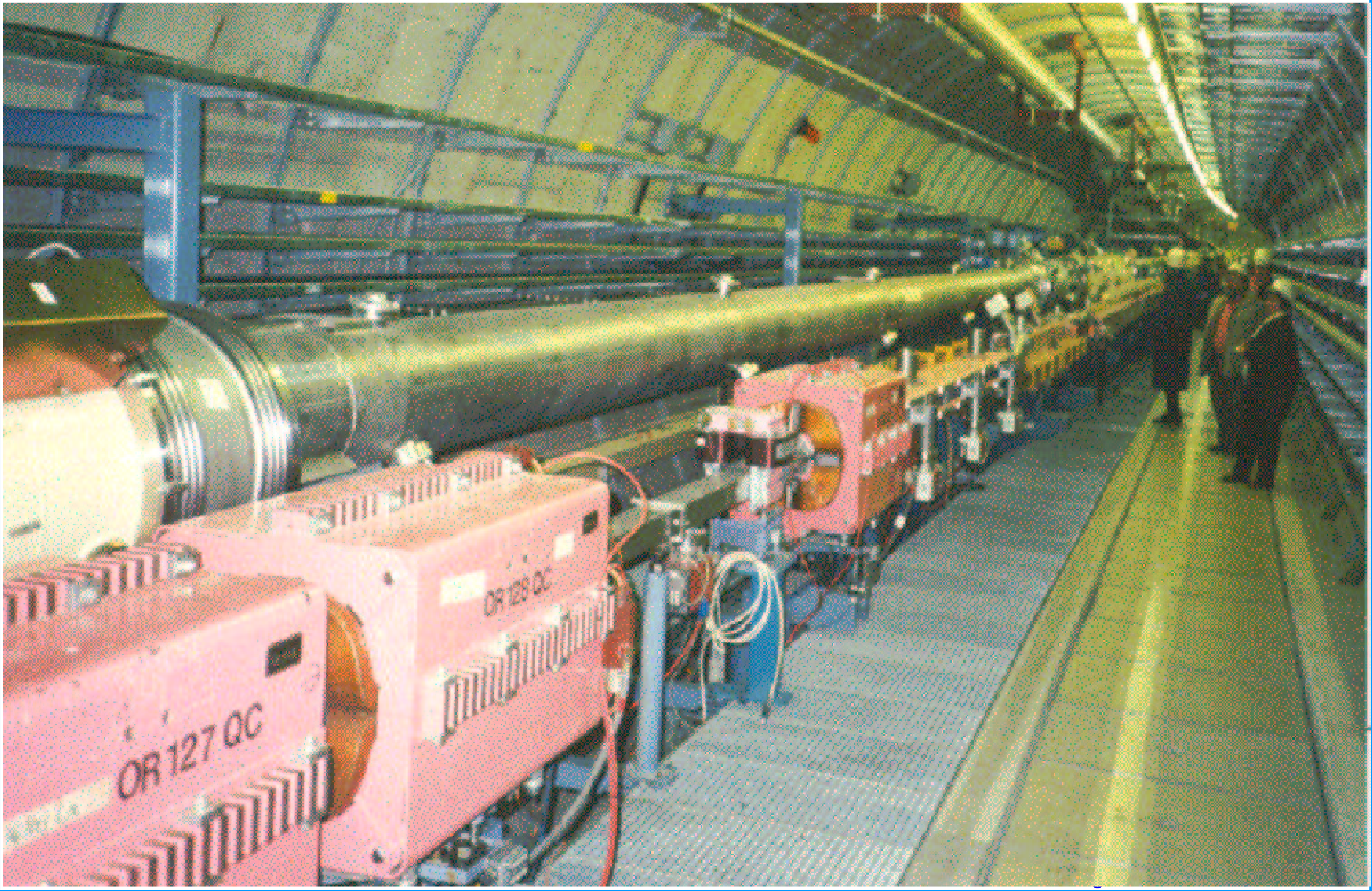
03/15/2004







Superconducting HERA-p + HERA-e



Parameters

Parameter	up to 2000		after the upgrade	
	HERA-e	HERA-p	HERA-e	HERA-p
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_{tot}/n_{col}	189/174	180/174	189/174	180/174
$\beta_x^\star/\beta_y^\star$(m)	0.90/0.60	7.0/0.5	0.63/0.26	2.45/0.18
ϵ_x(nm)	41	$\frac{5000}{\beta\gamma}$	20	$\frac{5000}{\beta\gamma}$
ϵ_y/ϵ_x	10%	1	17%	1
$\sigma_x/\sigma_y(\mu m)$	192/50	189/50	112/30	112/30
σ_z(mm)	11.2	191	10.3	191
$2\Delta\nu_x$	0.024	0.0026	0.068	0.0031
$2\Delta\nu_y$	0.061	0.0007	0.103	0.0009
$\mathcal{L}(cm^{-2}s^{-1})$	$16.9 \cdot 10^{30}$		$75.7 \cdot 10^{30}$	
$\mathcal{L}_s(cm^{-2}s^{-1}mA^{-2})$	$0.66 \cdot 10^{30}$		$1.82 \cdot 10^{30}$	

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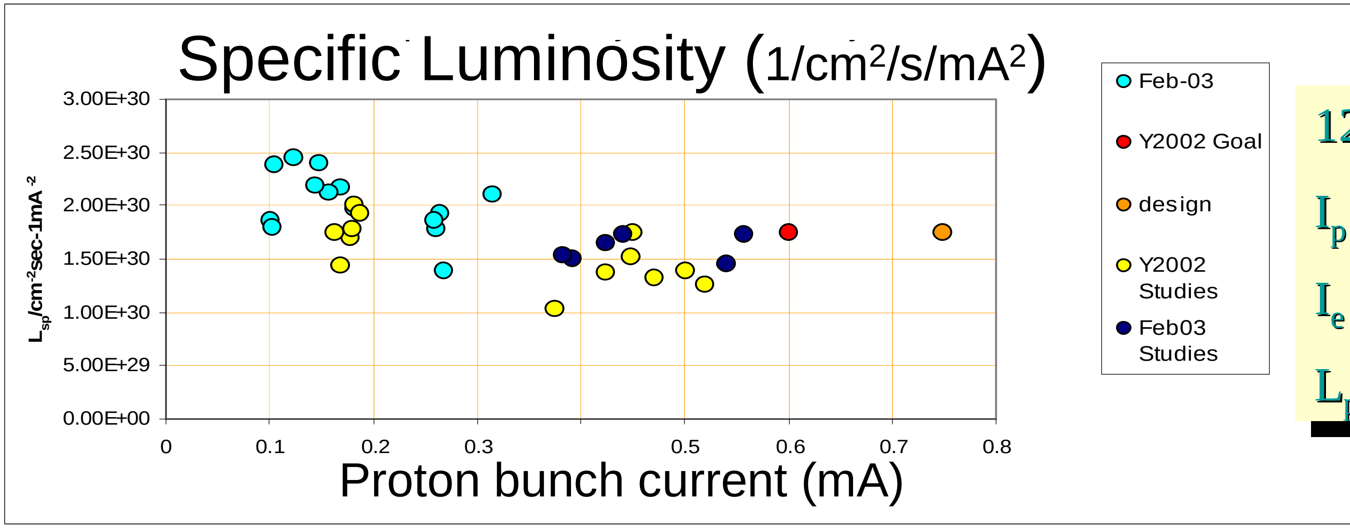
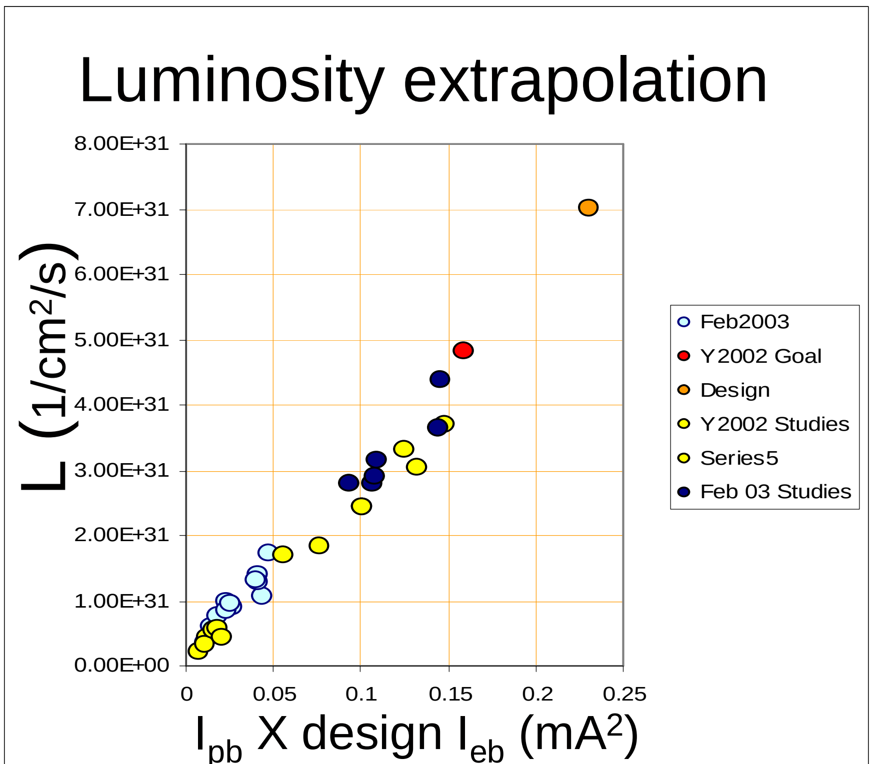


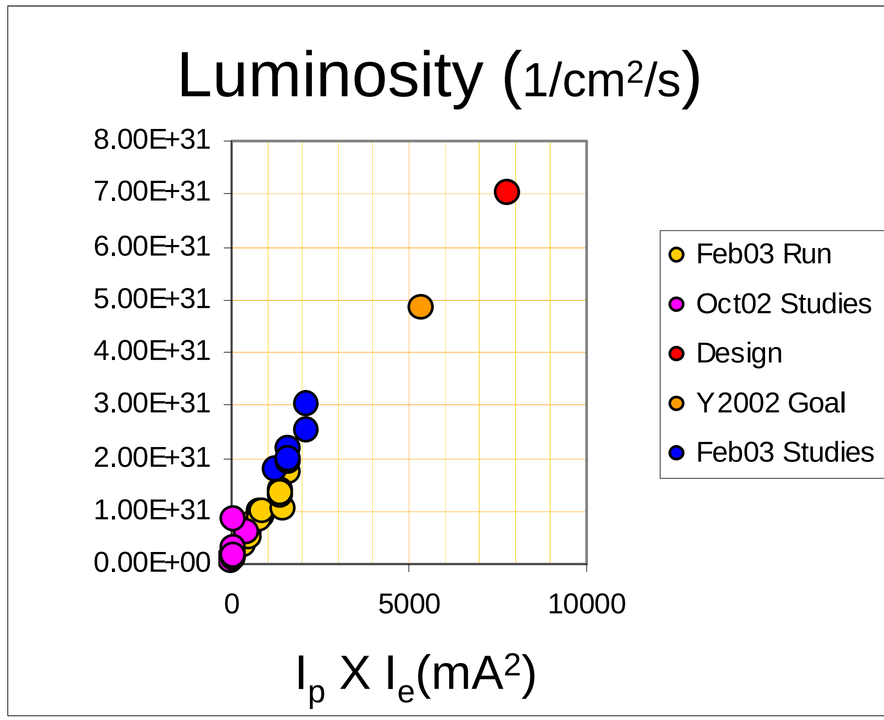
120 Bunches

$I_p < 70$ mA

$I_e < 35$ mA

$L_{peak} < 2.7 \times 10^{31}\ cm^{-2}s^{-1}$





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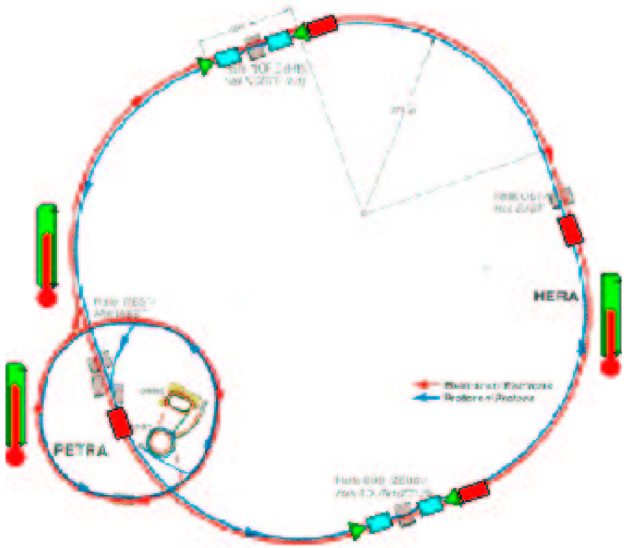
HERA III

Polarized protons in HERA



- Polarimeters
- Flattening Snakes
- Spin rotators
- At least 4 Siberian Snakes

e-A in HERA

- Deuteron acceleration: with same Linac
- Ion Acceleration requires:
  - a new Linac
  - high energy e-cooling
- Luminosity:

$$L_A = L_p \cdot \frac{1}{A} = 7 \cdot 10^{31} \cdot \frac{1}{A}$$

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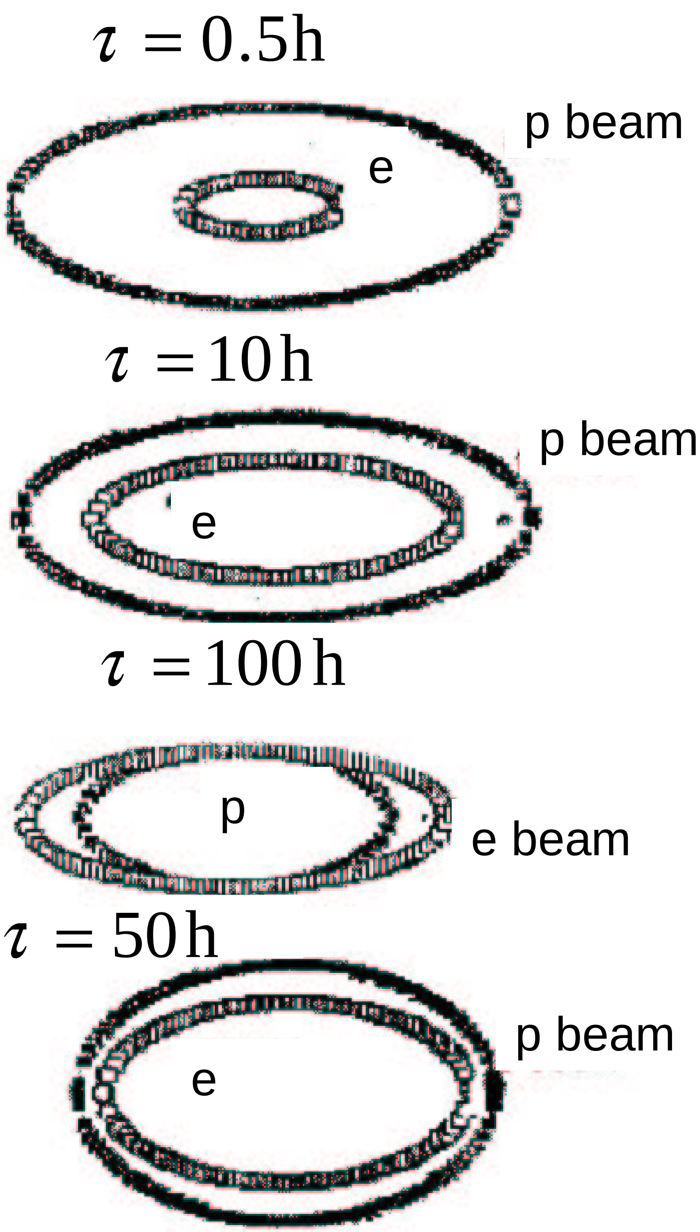
Early experiences



- At the time of HERAs design (1980) there was no experience with high Energy e/p kollision
- Beam sizes have to be matched to let the proton lifetime be long.
- Beams have to meet head on to about 0.1 sigma to avoid bad electron lifetime.
- Proton and electron tunes have to be controlled to about 0.002.
- Tunes were chosen to avoid resonances
  Qx=0.293   Qy=0.297
- Crossing angles were avoided.

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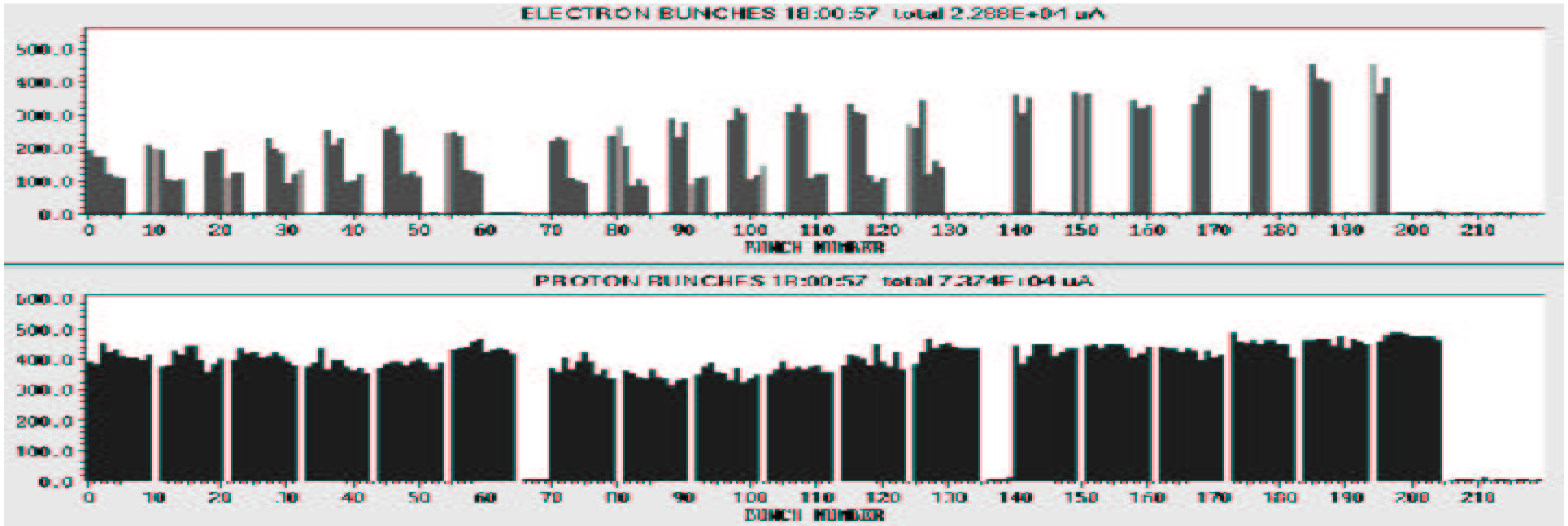
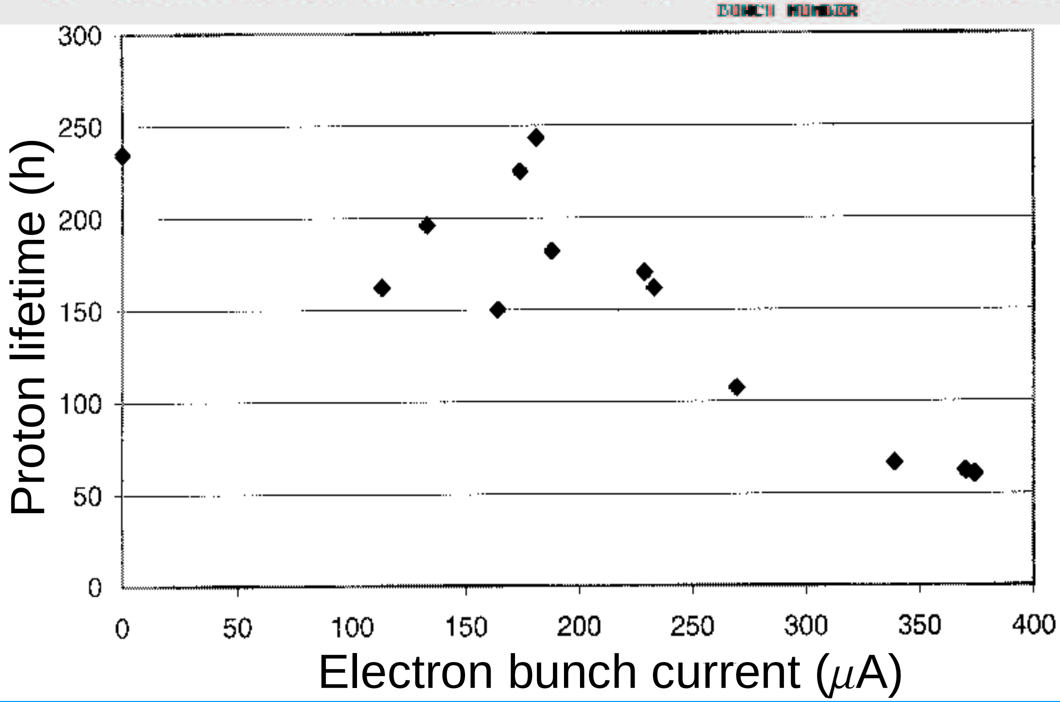
p lifetime drops with e current





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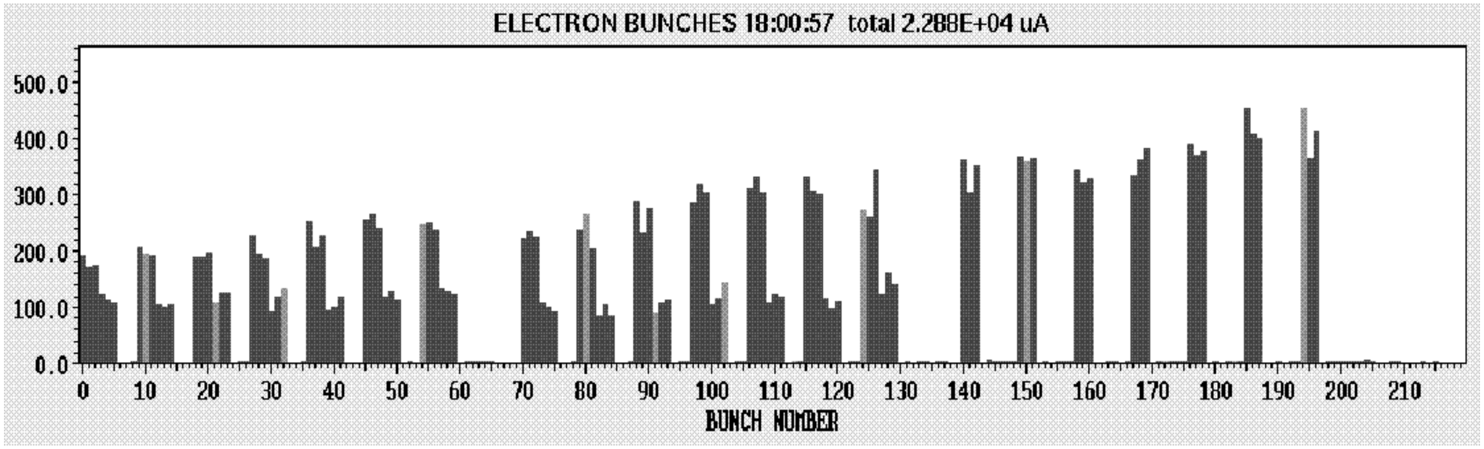
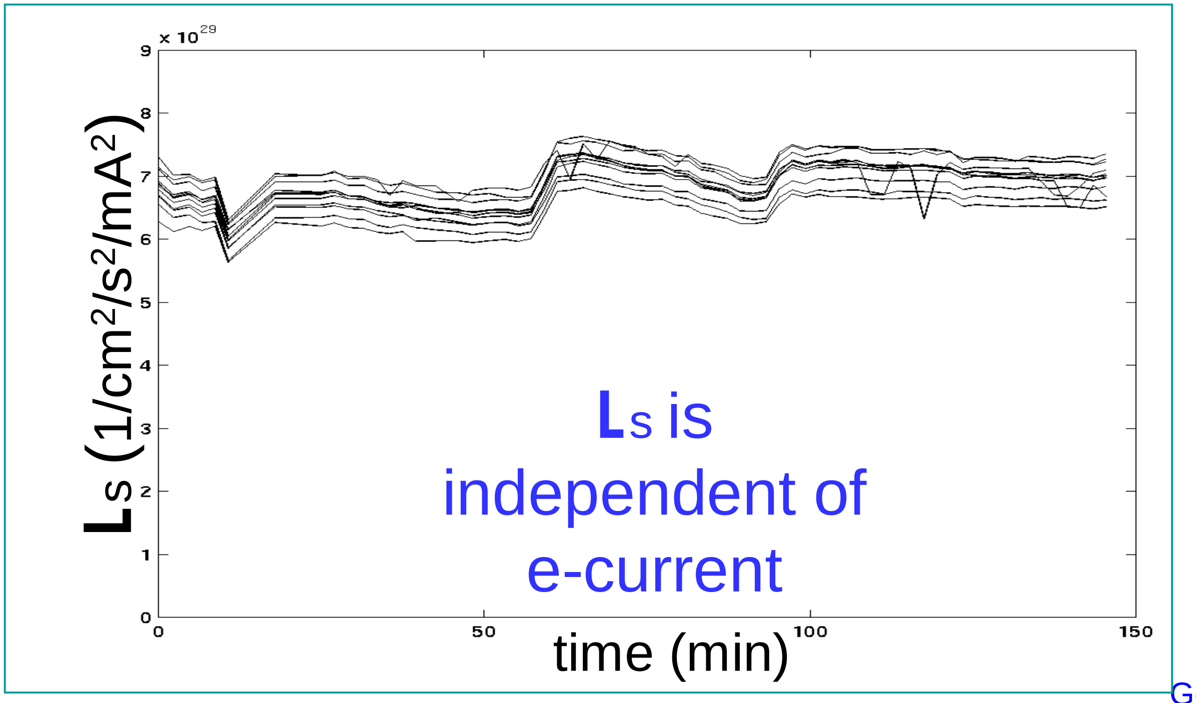
Luminosity for different e currents





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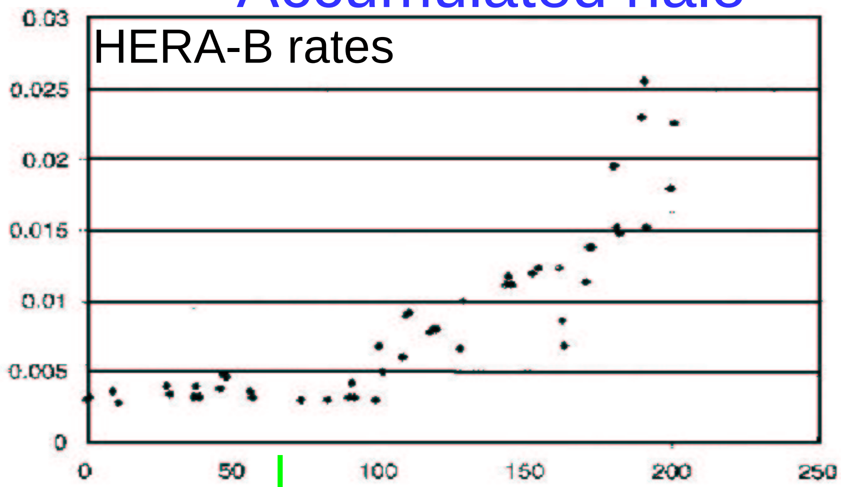
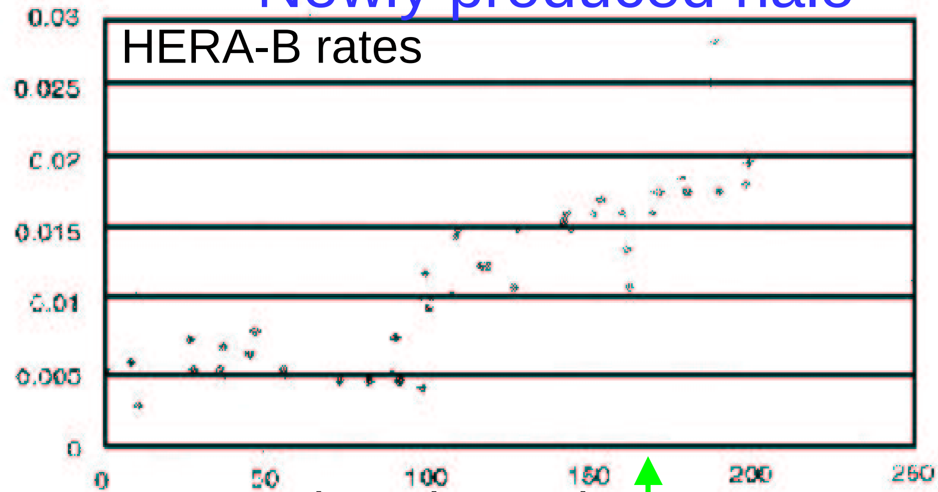
Higher p halo production for higher Ie

Accumulated halo



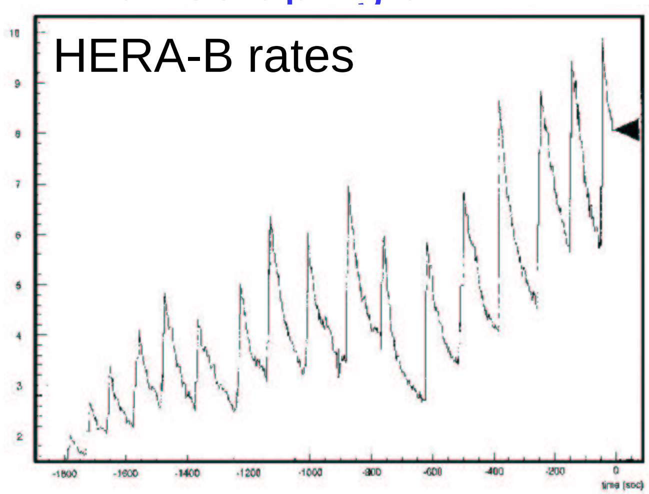
p bunch number

Newly produced halo



p bunch number

Tail scraping at HERA-B



t(s)

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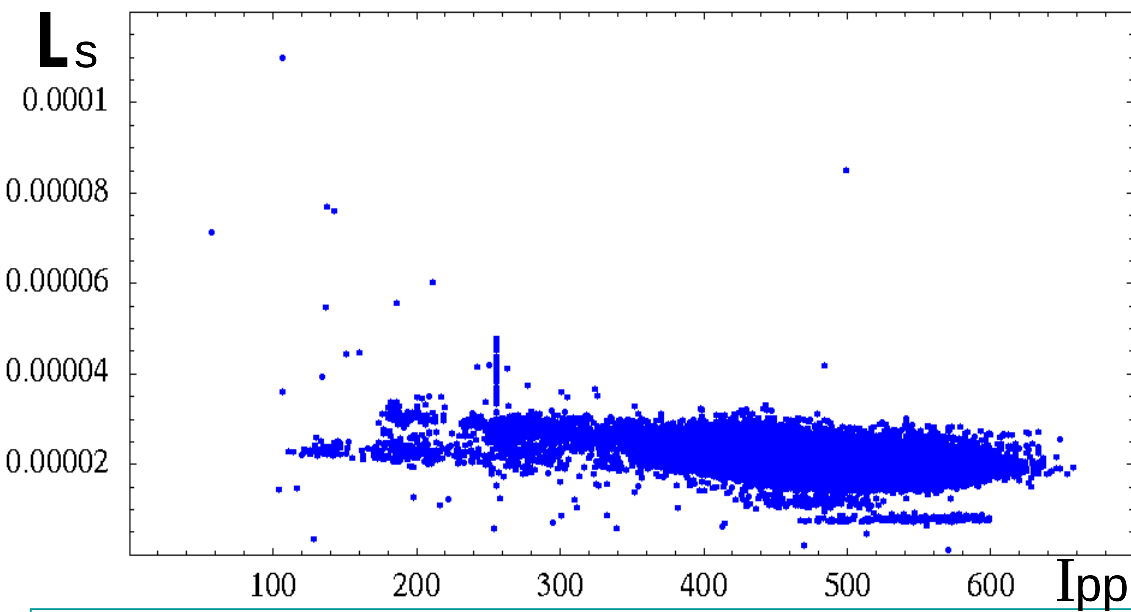
Beam-Beam Force on e



So far no reduction of Ls by the bunch current

β_x^e	β_y^e	$\mathcal{L}_s^{ZEUS}$ (without H1)	$\mathcal{L}_s^{ZEUS}$ (with H1)	$\mathcal{L}_s^{ZEUS}$ $\Delta\Phi \in [0, 2\pi]$	ΔQ_x^e	ΔQ_y^e
0.9m	0.6m	$7.1 \cdot 10^{29}$	$7.0 \cdot 10^{29}$	$[7.00, 7.20] \cdot 10^{29}$	0.0106	0.0311
1.0m	0.7m	$6.78 \cdot 10^{29}$	$7.0 \cdot 10^{29}$	$[6.67, 6.89] \cdot 10^{29}$	0.0118	0.0363
2.2m	0.9m	$5.18 \cdot 10^{29}$	$5.5 \cdot 10^{29}$	$[4.97, 5.42] \cdot 10^{29}$	0.0259	0.0467

b

No reduction of L_s by the second experiment

No reduction of L_s by a larger β-funktionen

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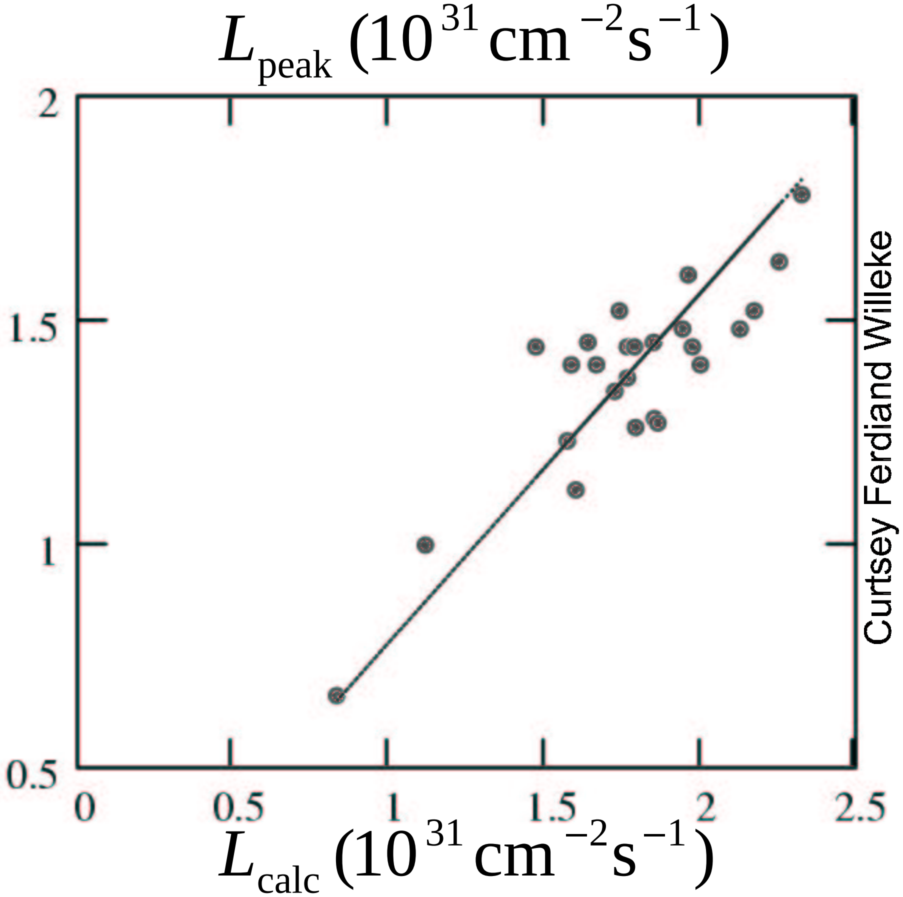
Measures agains drop in L_s

- Moving the electron tune away from the beam-beam enhanced resonance $2Q_y+6Q_x$=integer.
- Change phase advance so that the dynamic beta beat of the two collider experiments H1 and Zeus subtracts.
- Reduce proton emittance grows by switching of electron tune controler PLL during collisions.

Recent lumi scaling

$$\mathcal{L} = \frac{N^p_{ppb} \cdot I^e}{4\pi \cdot e \cdot \epsilon_p} \frac{1}{\sqrt{\beta_{px} \cdot \beta_{py}}} \qquad \begin{pmatrix} \sigma_e = \sigma_p \\ \epsilon_{px} = \epsilon_{py} \end{pmatrix}$$



$$L_{peak} \approx 0.78 \cdot L_{calc}$$

- The luminosity depends on many quantities, many of which could influence the reduction factor.
- One likely possibility would be a dependence on the proton brightness, i.e. the number of proton / emittance

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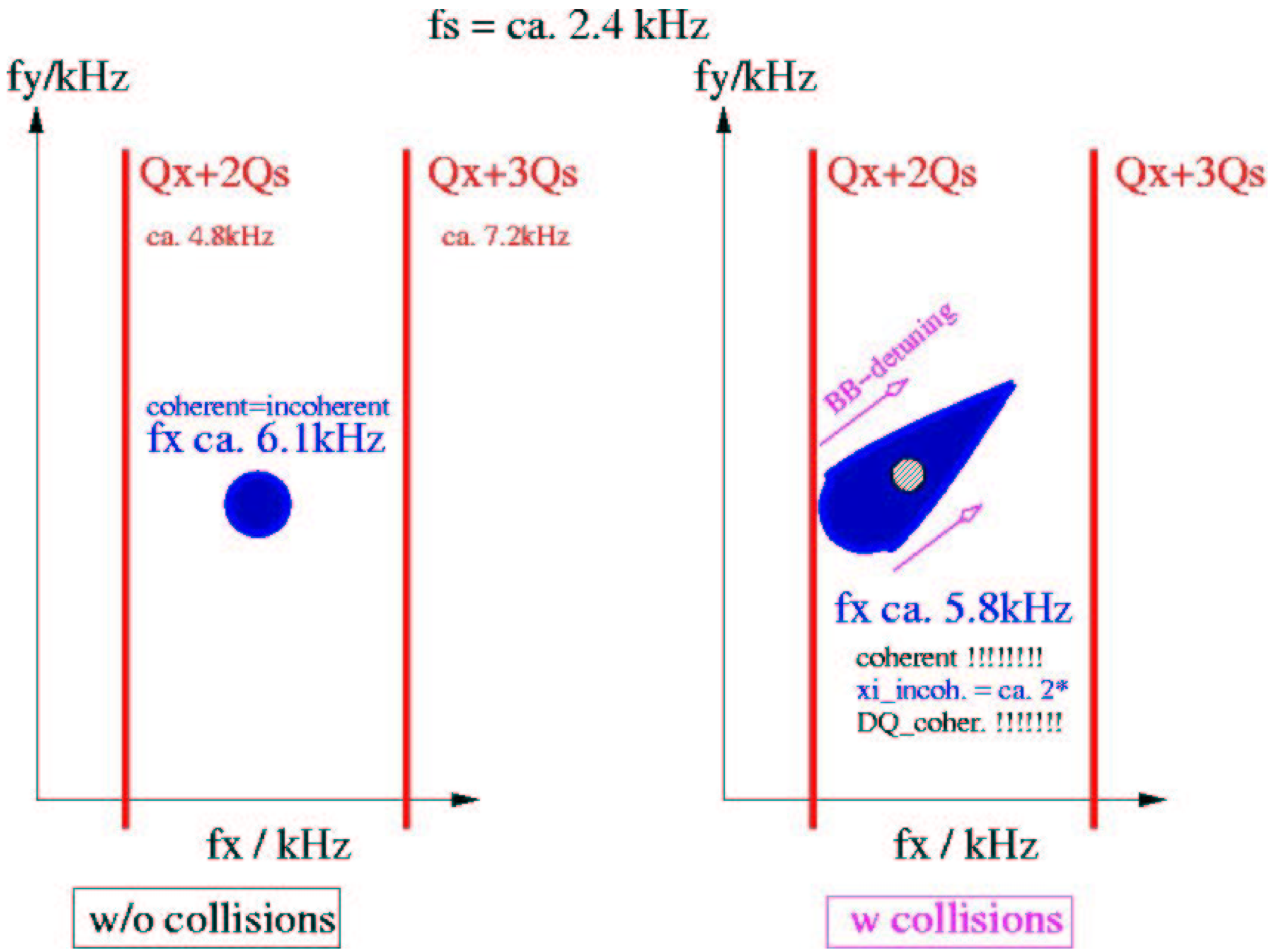
Current operation experience



- The horizontal tune has to be small for good polarization
- Tails of the e-beam on synchro beta resonance leads to proton background
- Core e-tune on synchro beta resonance leads to electron loss

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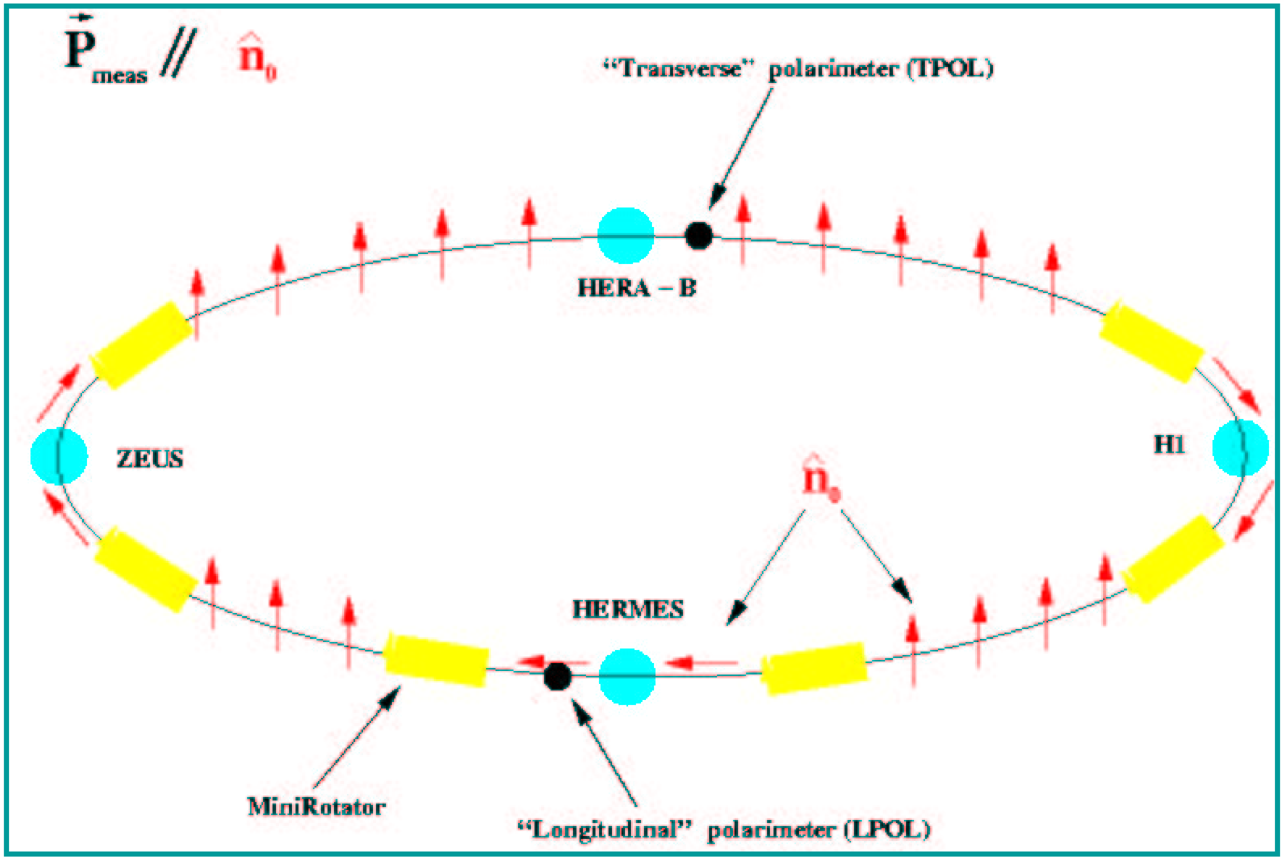
Longitudinal polarization at 3 IRs



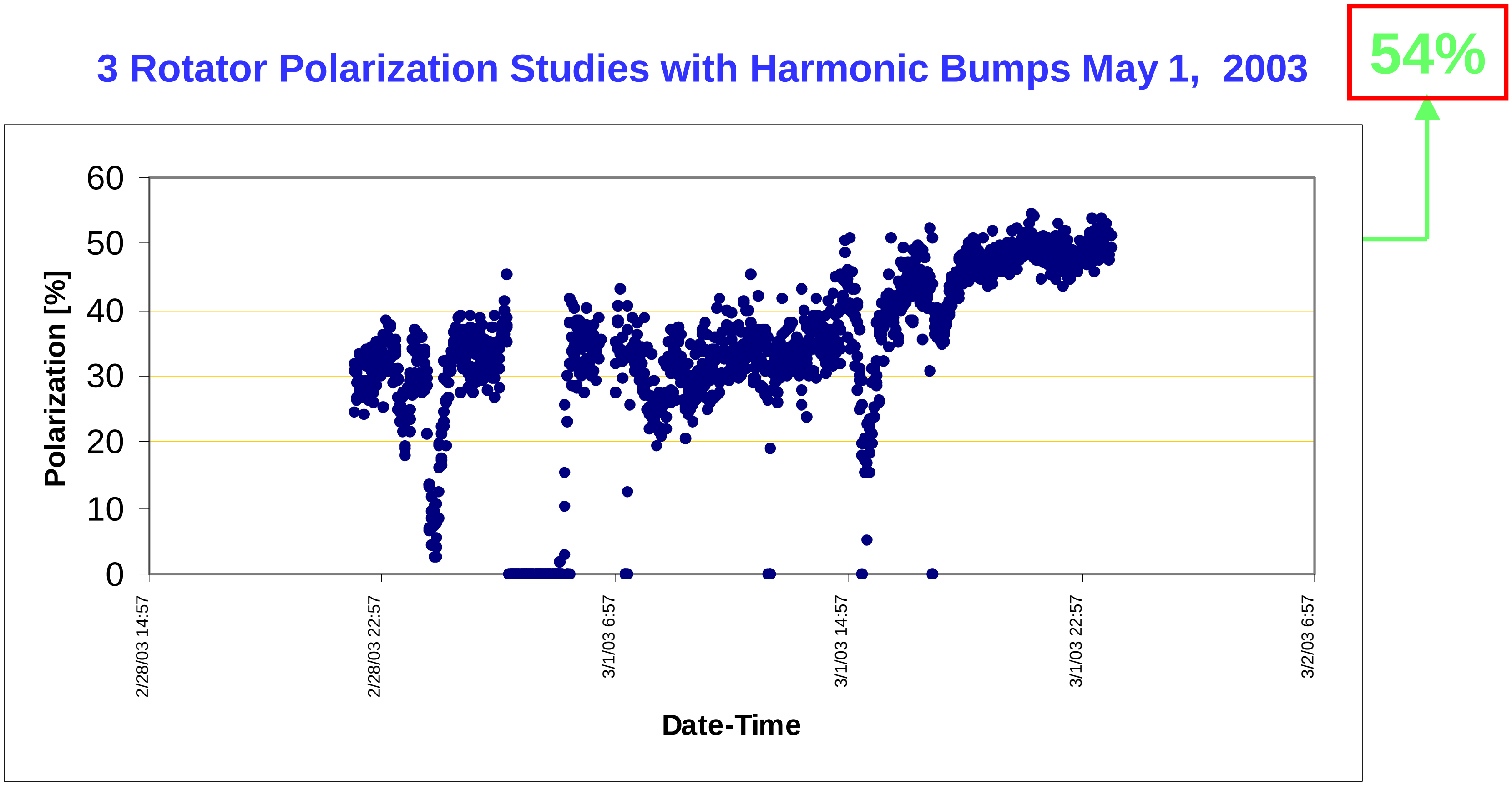
courtesy M. Minty

Goal: longitudinal polarization at ZEUS (new), H1 (new), and HERMES using the new spin rotators

Challenges: The experimental solenoid requires longitudinal polarization at ZEUS & H1, otherwise there is no significant buildup.

First polarization at H1 and Zeus

3 Rotator Polarization Studies with Harmonic Bumps May 1, 2003



51% polarization with e/p collisions was possible with Specific luminosities close to the design:

Luminosity at H1, Lsp = 1.7 (su)   Luminosity at ZEUS, Lsp = 1.4 (su)

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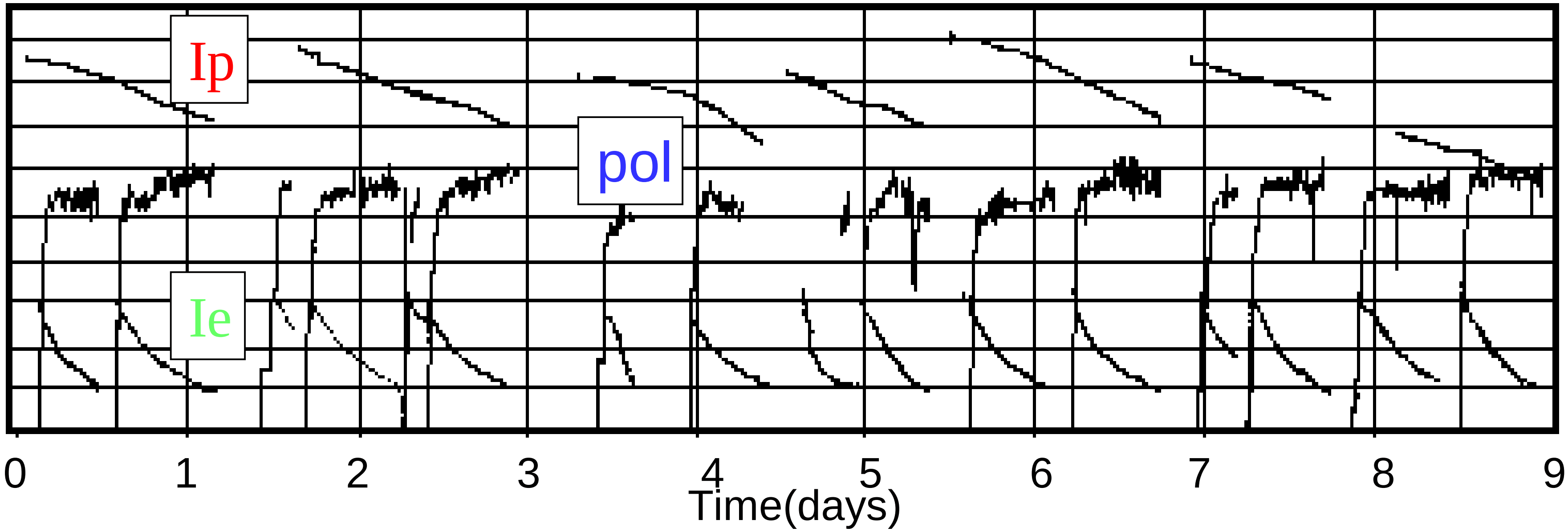
Second e-fills have more polarization



Explanation: The first fill and the refilling procedure have increased the proton emittances and decreased the beam beam force that acts on spins.

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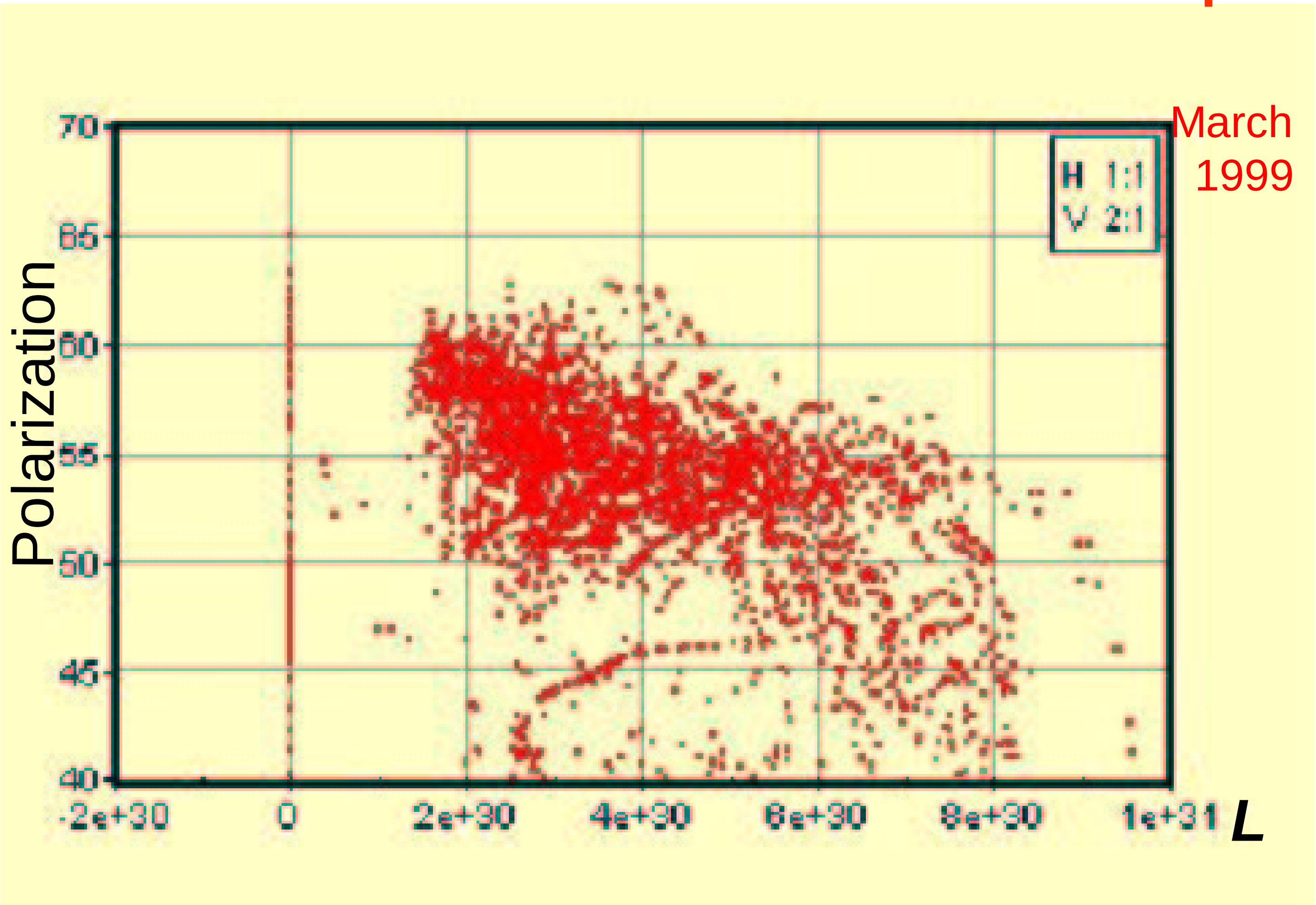
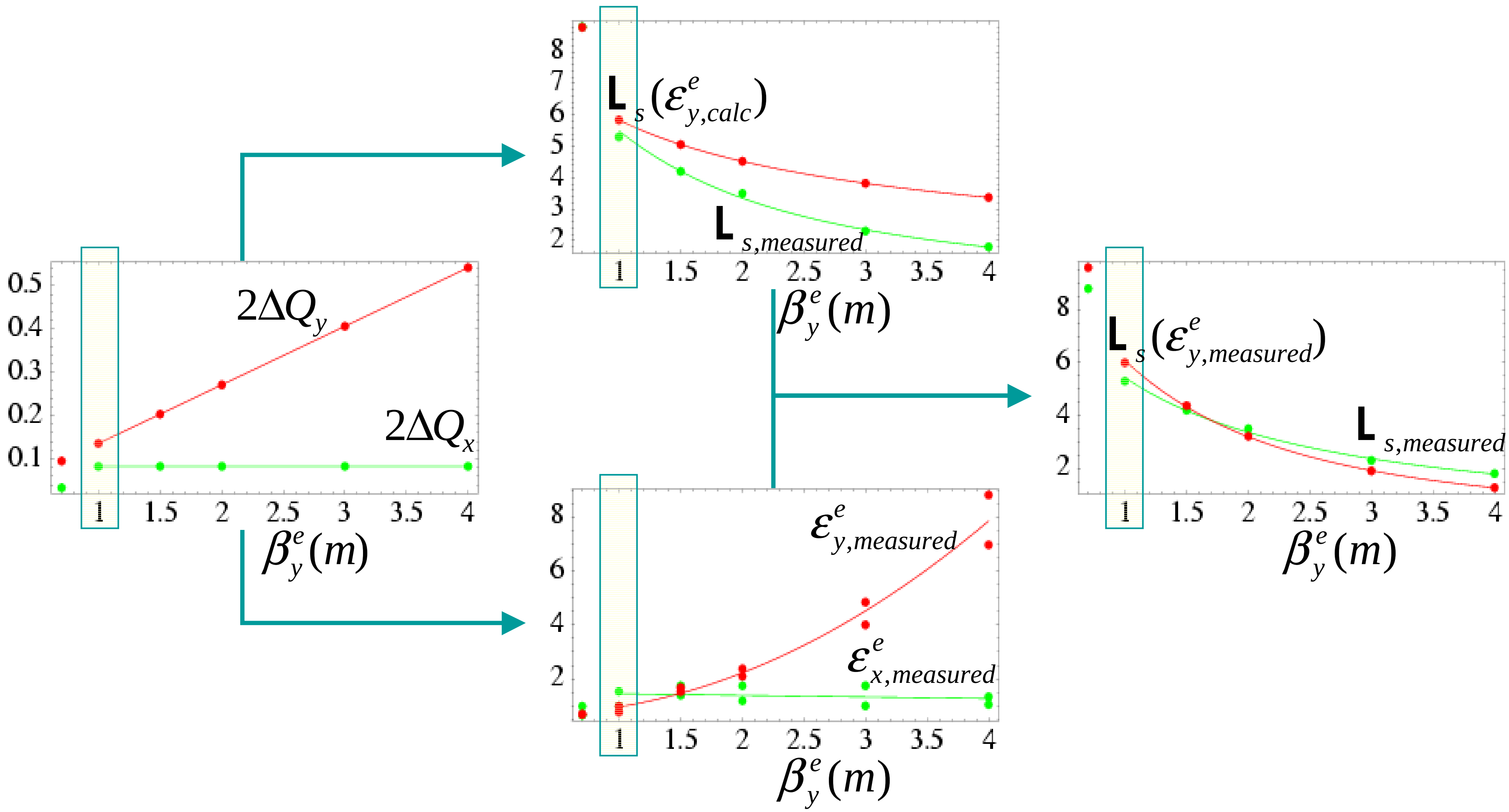
Runs with more lumi have less pol.



Explanation: Runs with more initiall lumi (that is at the time of maximum lumi in this run) have a higher beam beam force than runs with lower initial lumi, given that the initial electron current is about the same from run to run.

Where are the Beam-Beam Limits?



Upgrade and Ip=140mA: emittance starts to grow

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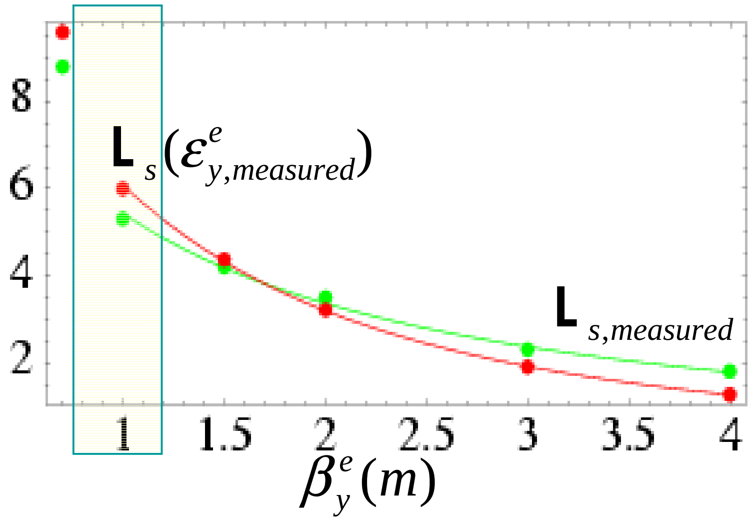
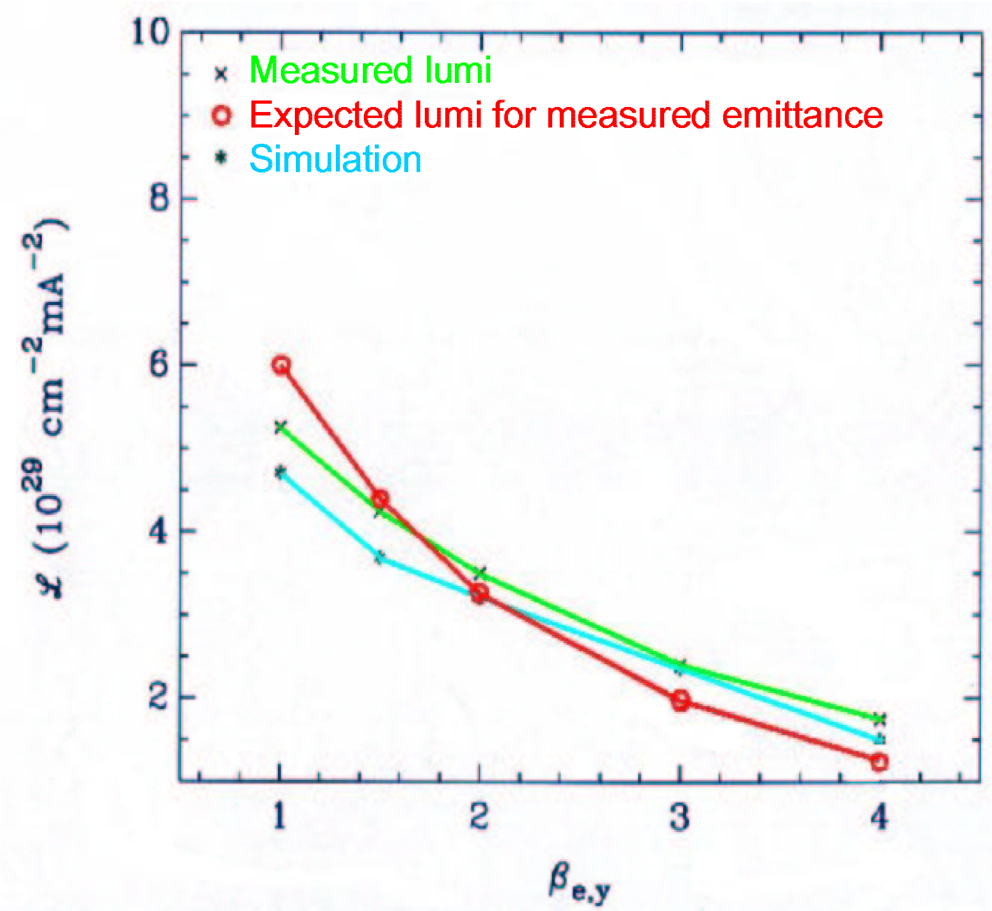
Simulation of large beam beam forces





Dipole modes of Gaussian bunches

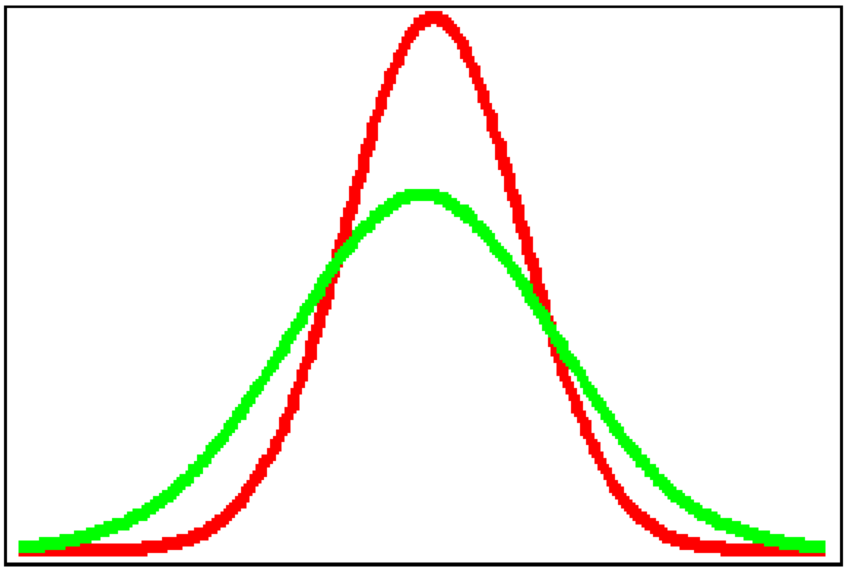
- Beam beam tune shift for one particle in the beam beam field of a Gaussian bunch:

$$\xi_{ex} = \beta_{ex} \frac{r_e}{2\pi\gamma_e} \frac{N_{ppb}}{\sigma_{px}(\sigma_{px}+\sigma_{py})}$$

- Shift in the dipole modes oscillation Frequency of a Gaussian bunch:

$$\Delta Q_{ex} = \xi_{ex} \frac{\sigma_{px}(\sigma_{px}+\sigma_{py})}{\Sigma_{px}(\Sigma_{px}+\Sigma_{py})}$$

Assumption: the bunches remain Gaussian



This approximation is justified for a stiff beam hitting a much less stiff beam when the first beam creates a small beam beam kick.

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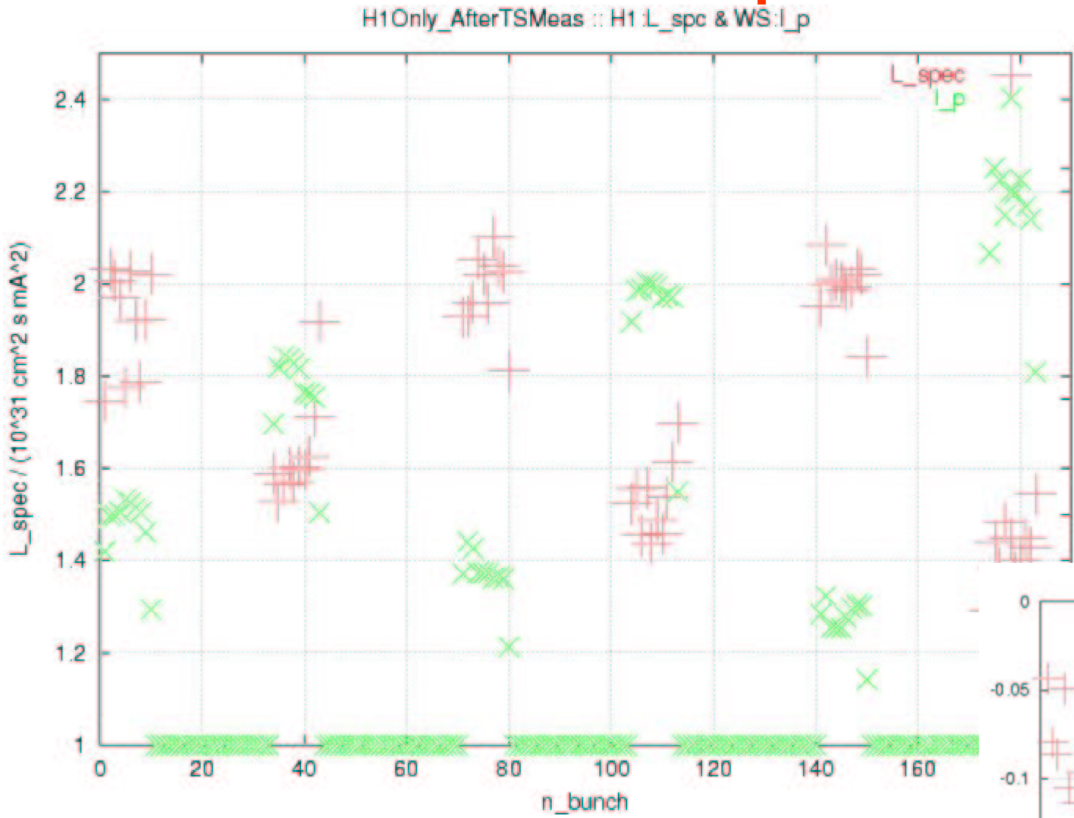
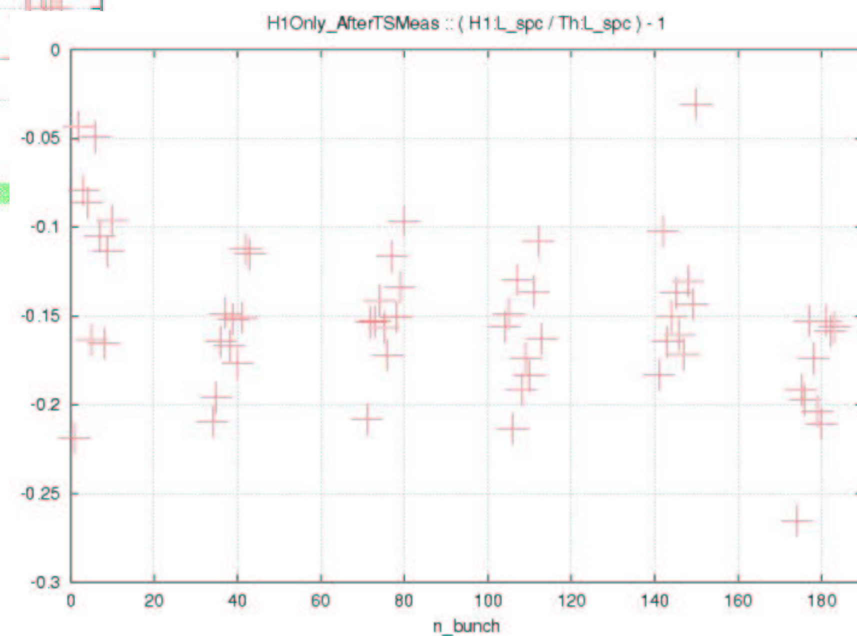
Beam Beam experiments of Feb. 2003



Unexplained lumi change over each bunch train:

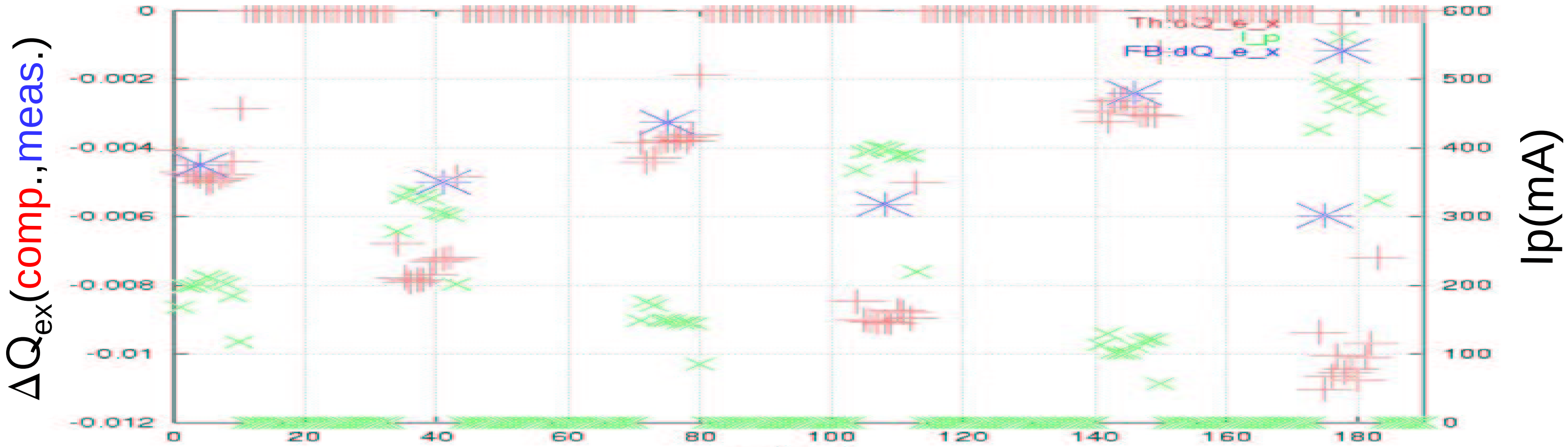


Higher p current

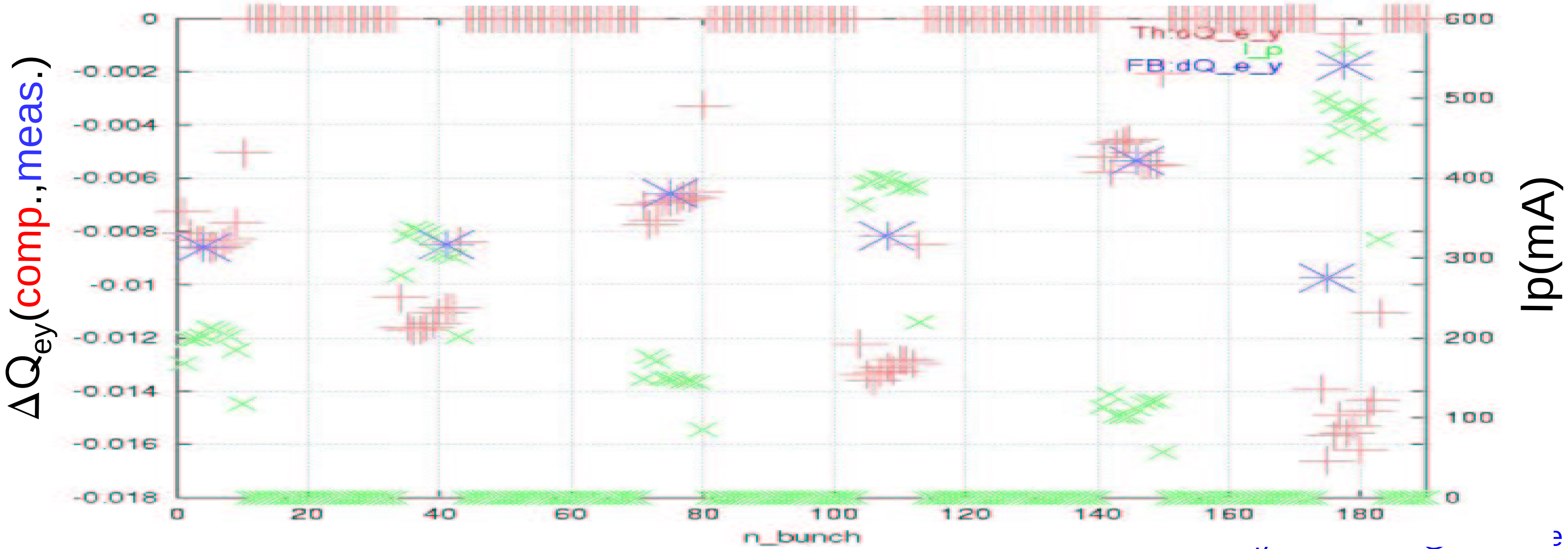
↓

Lower specific luminosity

Beam Beam Tune shifts



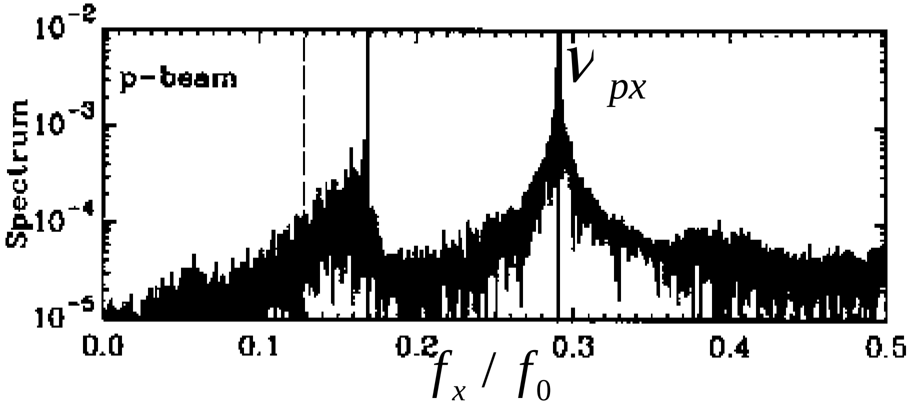
←Bunch number→

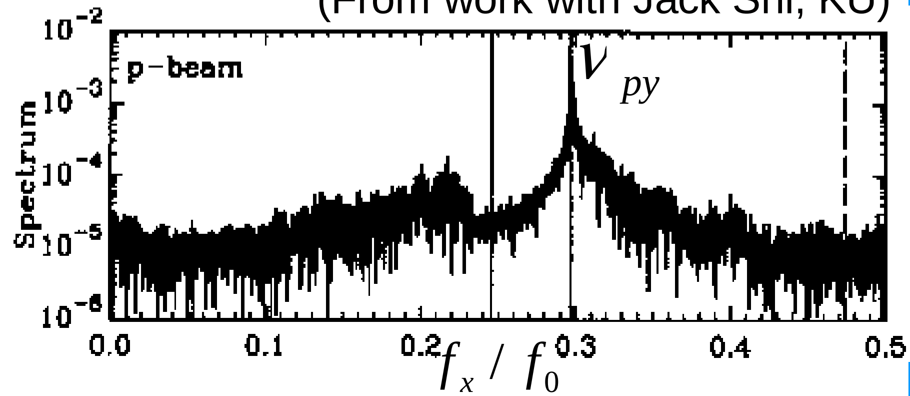


Simulated coherent modes

$$\beta^*_{ey} = 4.0\text{m} + \begin{matrix} \xi_{ex} = 0.041 \\ \xi_{ey} = 0.272 \end{matrix} \rightarrow \begin{matrix} dQ_{ex} = 0.027 \\ dQ_{ey} = 0.082 \end{matrix} \xrightarrow[\text{how ?}]{\text{why?}} \begin{matrix} \Delta\nu^m_{ex} = 0.009 \\ \Delta\nu^m_{ey} = 0.013 \end{matrix}$$

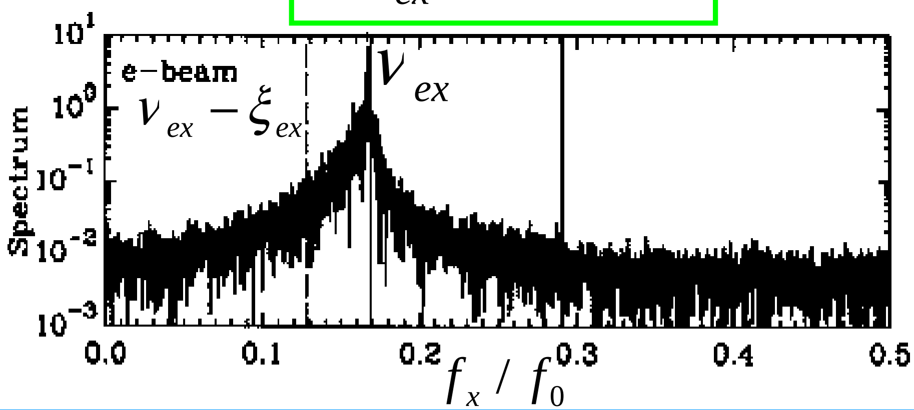
(From work with Jack Shi, KU)

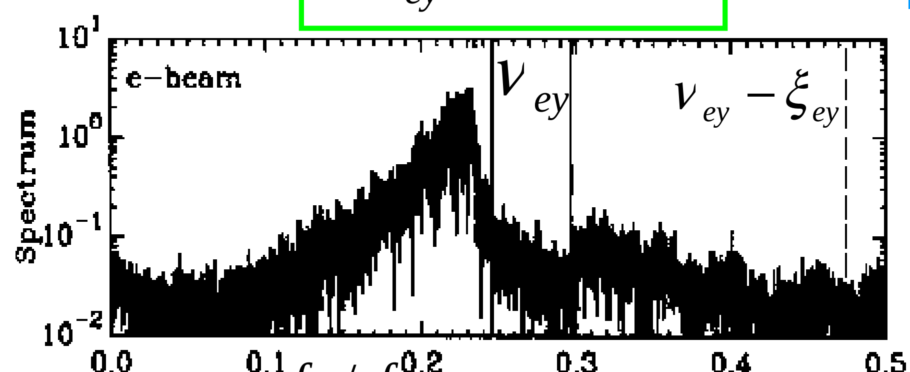




$$\Delta\nu^{sim}_{ex} = 0.003$$

$$\Delta\nu^{sim}_{ey} = 0.013$$





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