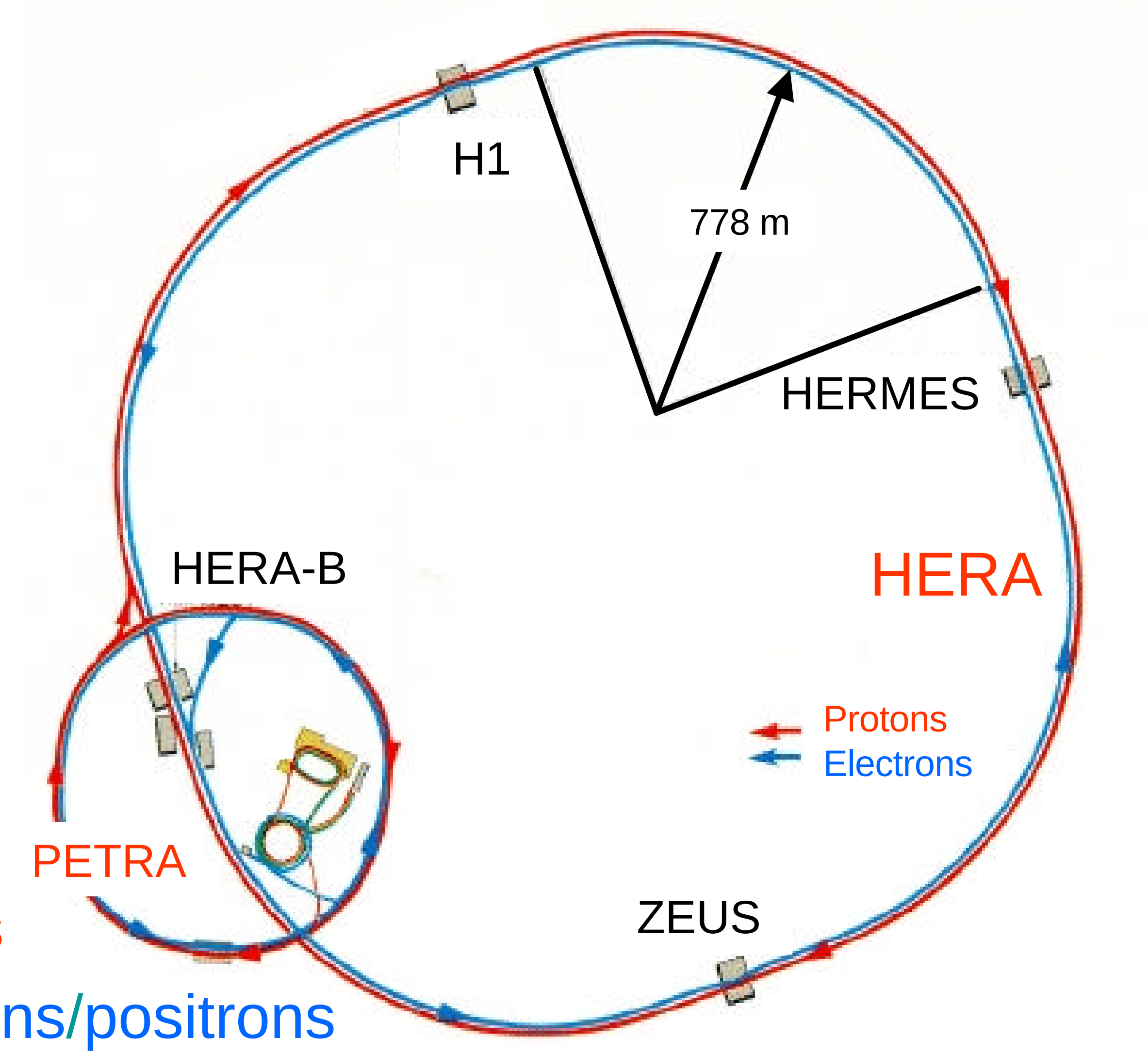
Future HERA High Luminosity Performance

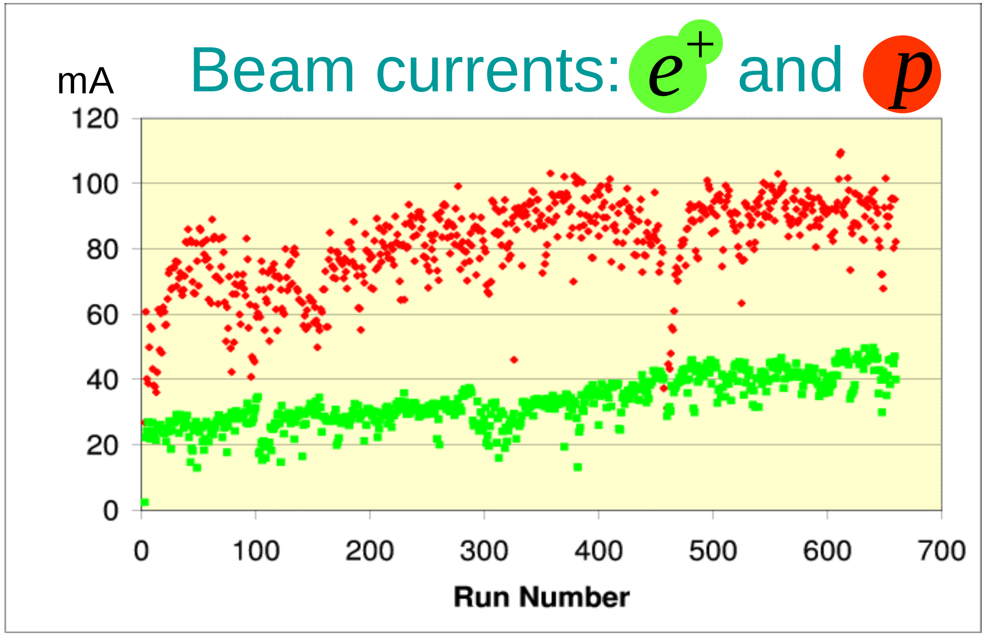


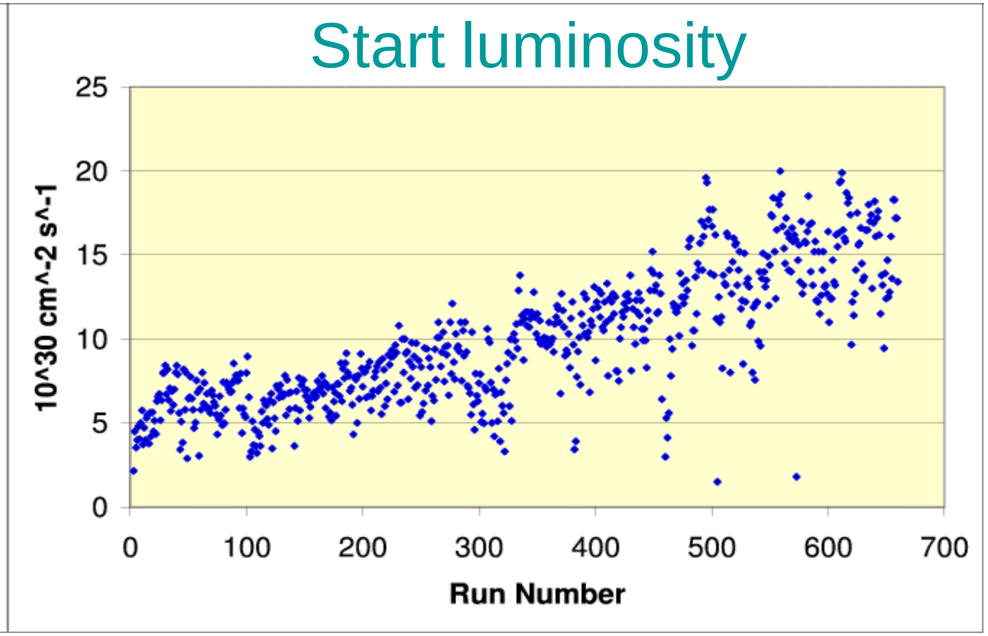
29 March
2001

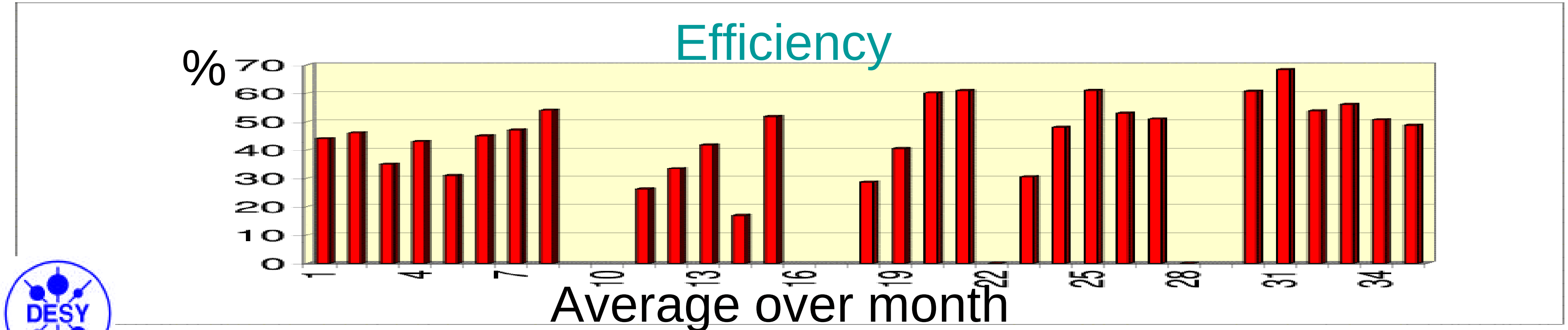
Georg H. Hoffstaetter
and Ferdinand Willeke
(DESY, Hamburg)

6336 m long
920 GeV protons
27.5 GeV electrons/positrons

HERA: Improvements 1999/2000



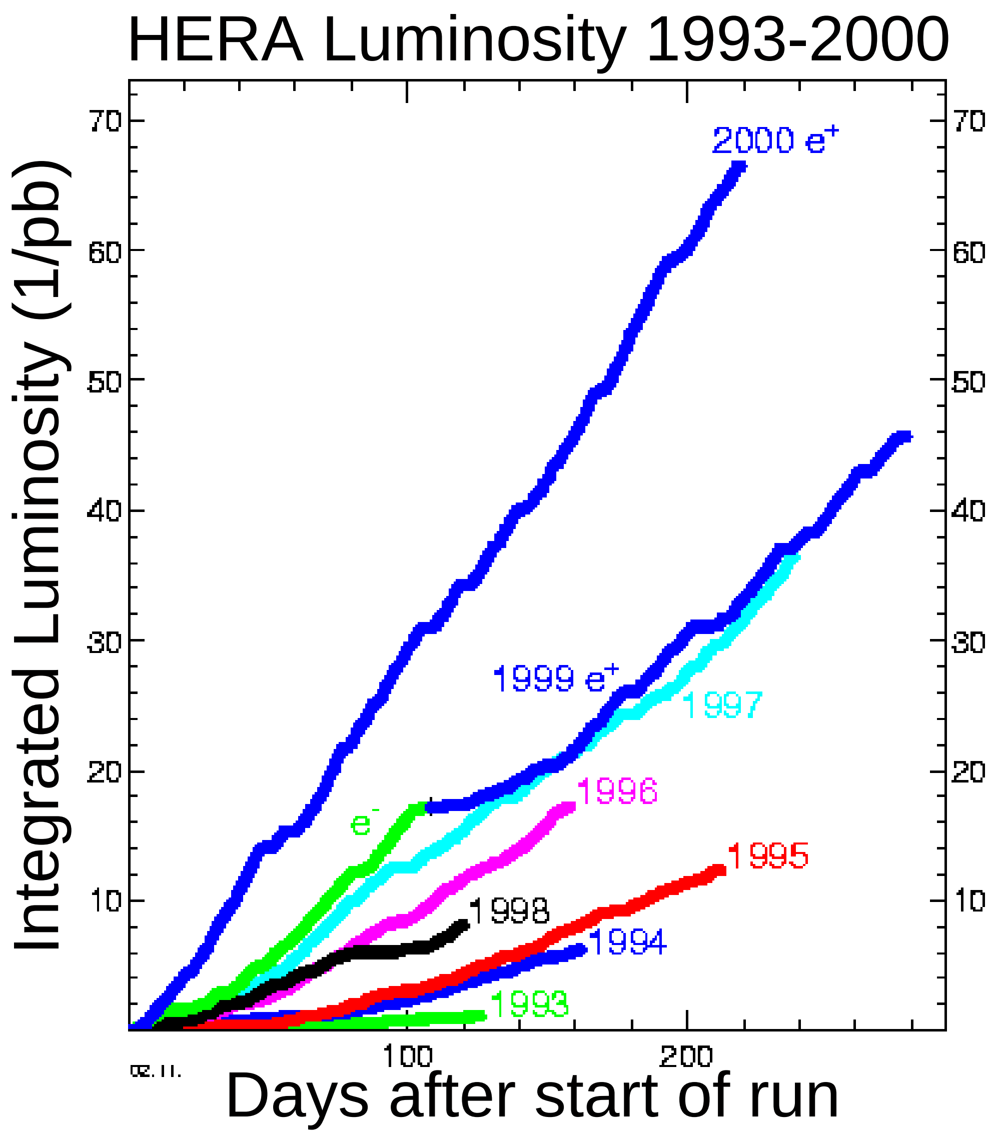




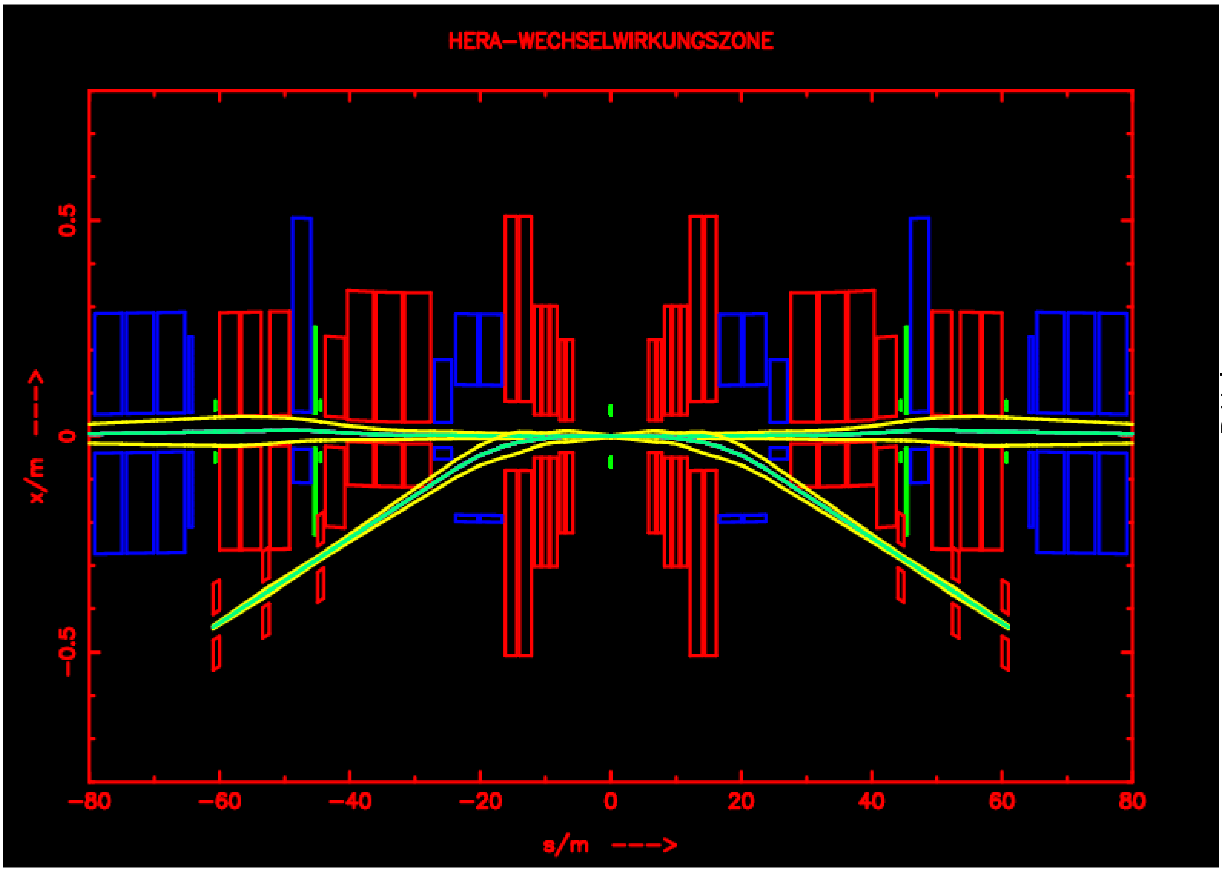
Development of the Luminosity

Linear increase of the integrated Luminosity

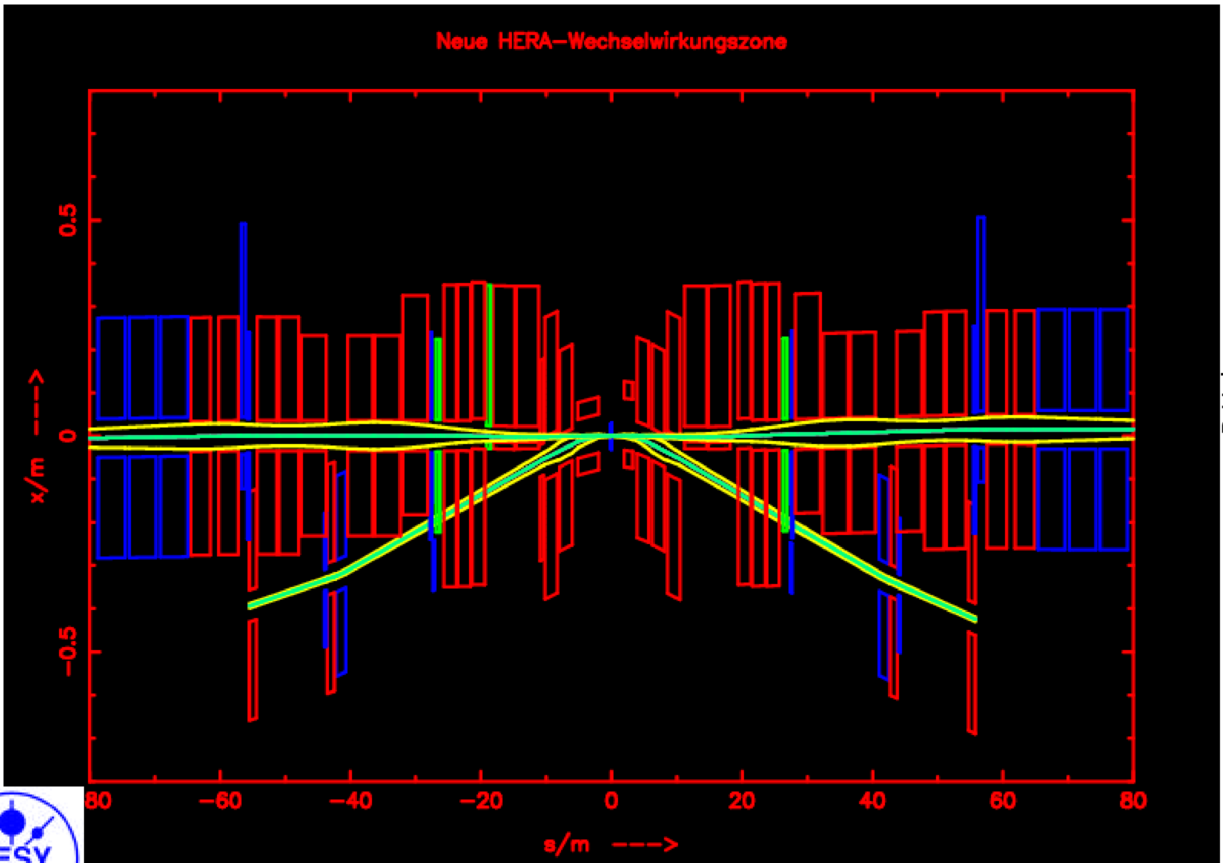
The time for a luminosity upgrade of HERA has come



The Detector Region



courtesy B.Holzer



courtesy B.Holzer

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Superconducting Magnet GO

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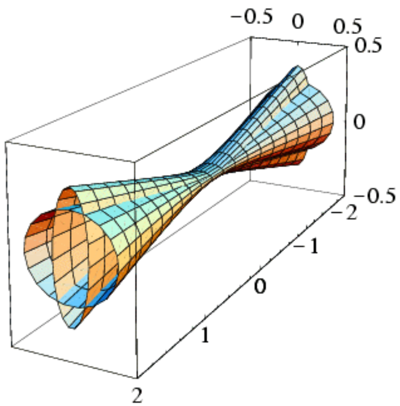
Potential Problems

Focusing:

- Dynamic Aperture OK?
- Polarization OK?, Luminosity OK?
- Can HERA be handled well?

f_{RF} increase:

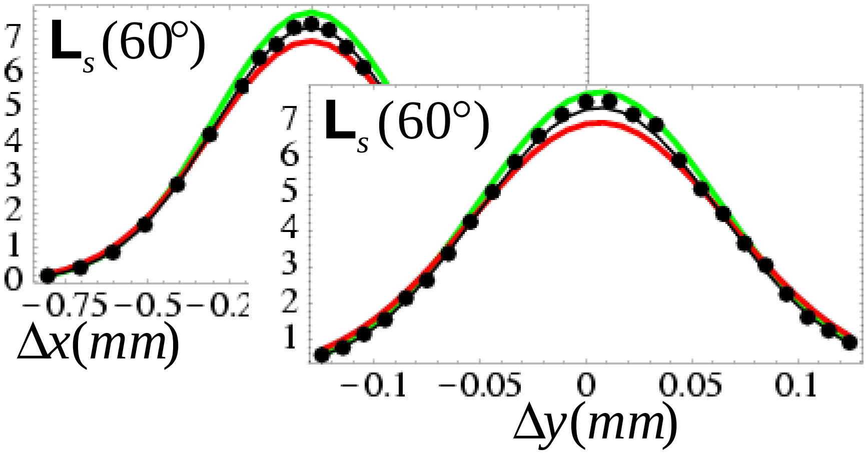
- Polarization OK?, Luminosity OK?

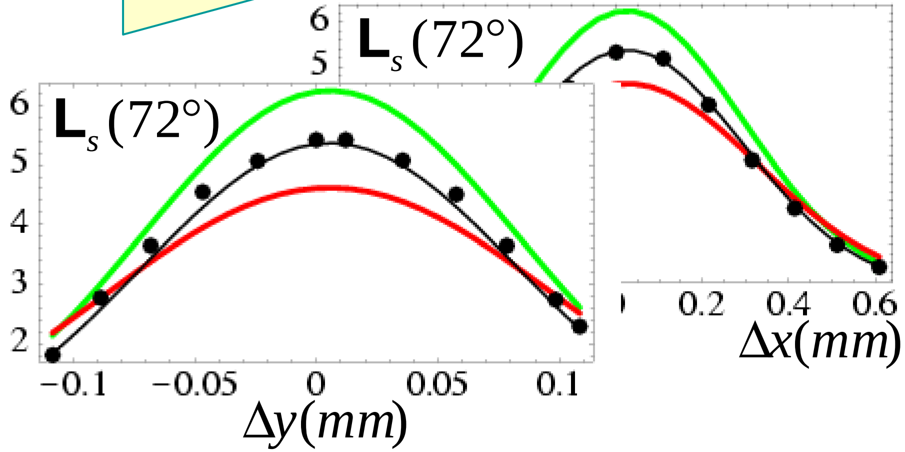


- Too strong beam-beam force on p?
- Too strong beam-beam force on e?

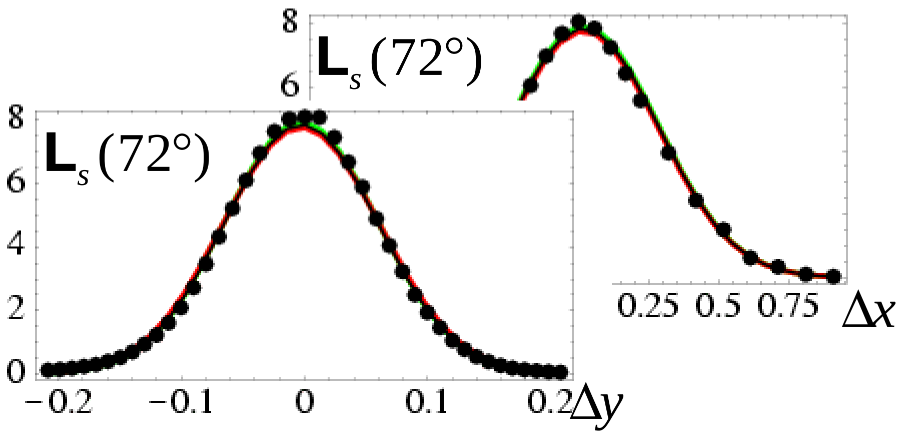
Emittance and Lumi for 72° Optic

- The Luminosity was initially too small: → Lumiscan



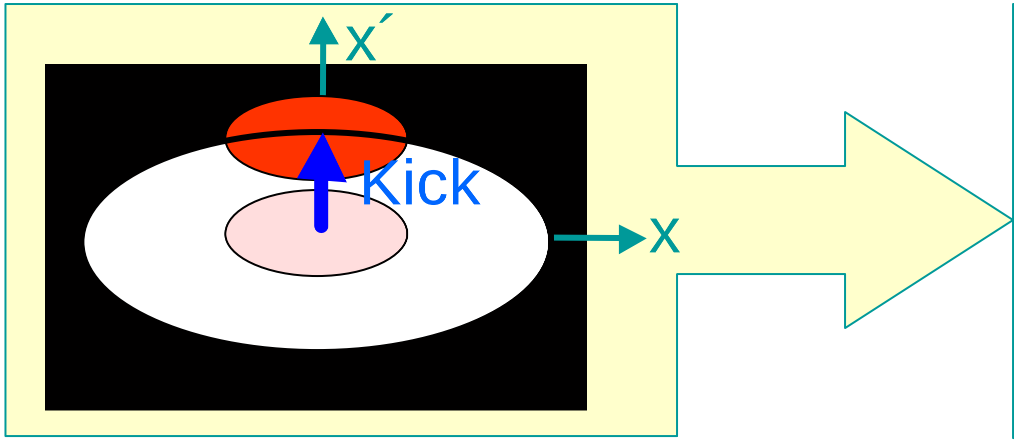


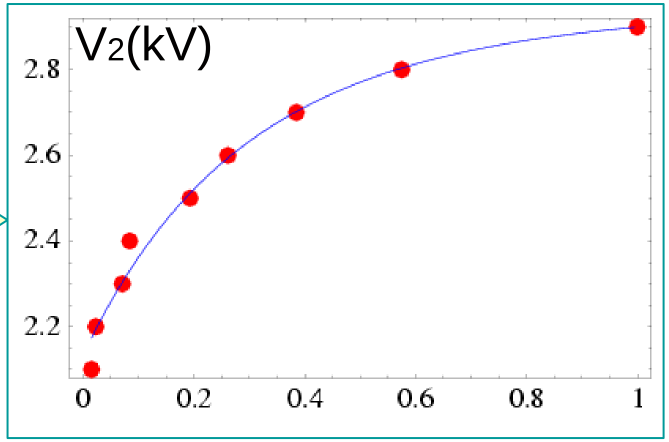
Bunch has no product distribution: $r(x)\,r(y)$ ⇨ coupling



- Luminosity with 72° is large as expected

Dynamic Aperture for 72° Optic

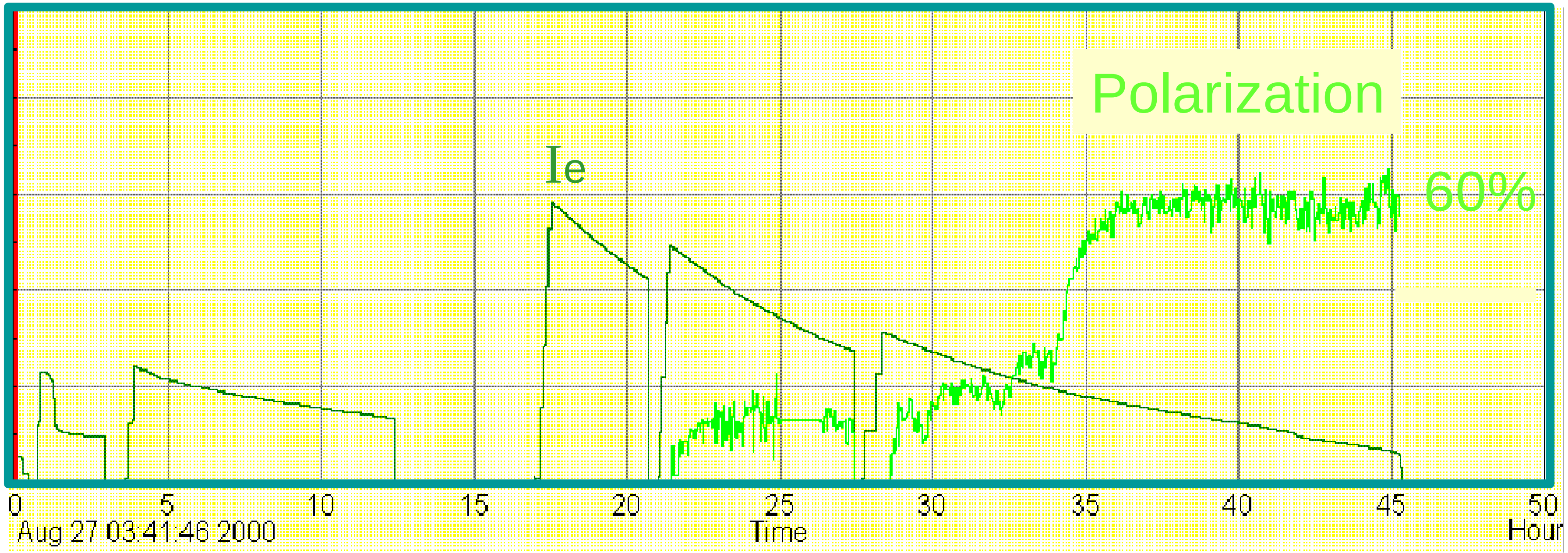




Optics	Date	V_2	DA	DA_{rel}	RF shift
72° luminosity	3 Jul.1999	2.70kV	3.4πmm mrad	10.0σ	0Hz
72° luminosity	3 Jul.1999	2.76kV	3.5πmm mrad	10.2σ	0Hz
72° luminosity	3 Jul.1999	2.66kV	3.3πmm mrad	9.8σ	0Hz
72° luminosity	3 Jul.1999	2.77kV	3.6πmm mrad	12.7σ	300Hz
72° luminosity	3 Jul.1999	2.74kV	3.5πmm mrad	12.6σ	300Hz
72° luminosity	3 Jul.1999	2.82kV	3.7πmm mrad	10.4σ	0Hz

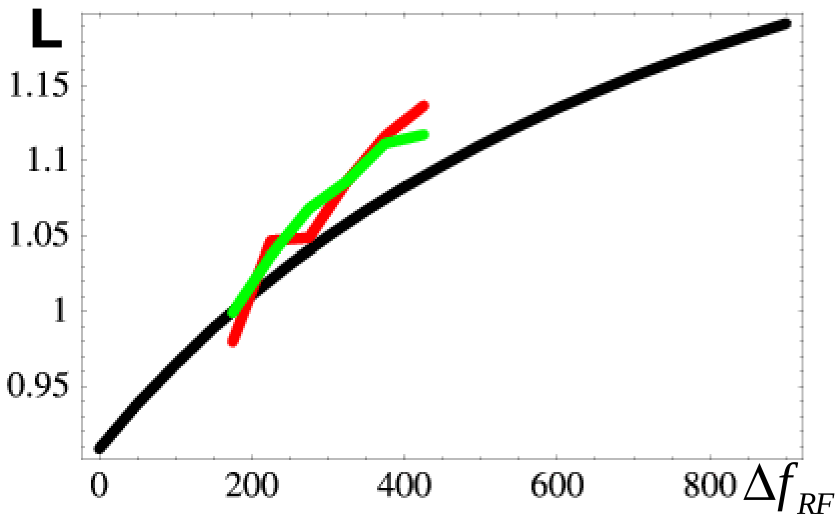
The kick where half the current is lost leads to a satisfactory dynamic aperture.

Polarization for 72° Optic

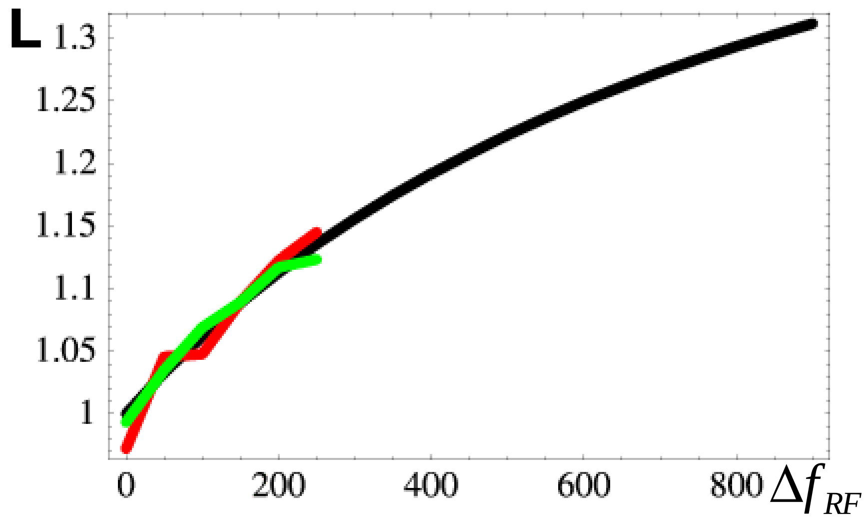


- Polarization was in the spin matched 72° optic quickly brought to 63% (one day).
- Harmonic bumps were immediately effective
- Decoupling bumps worked well

Luminosity for f_{RF} Increase



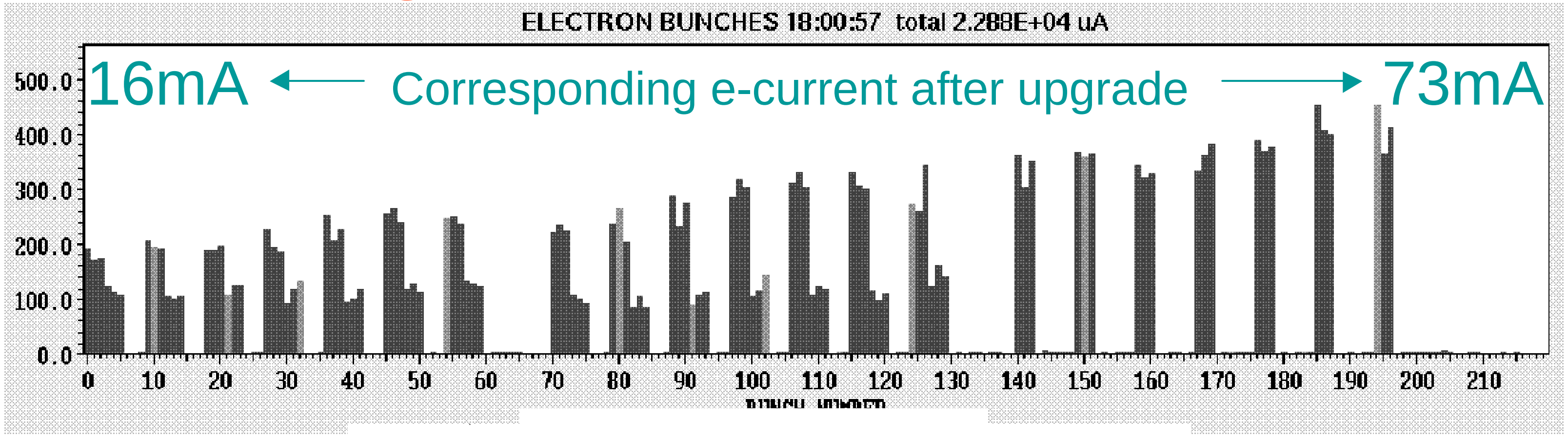
$f_{Zentrum} \approx 0Hz$

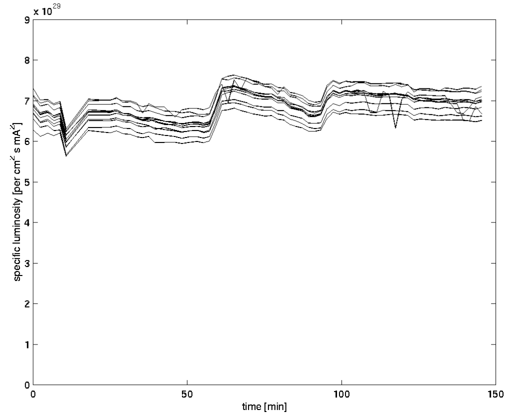


$f_{Zentrum} \approx 175Hz$

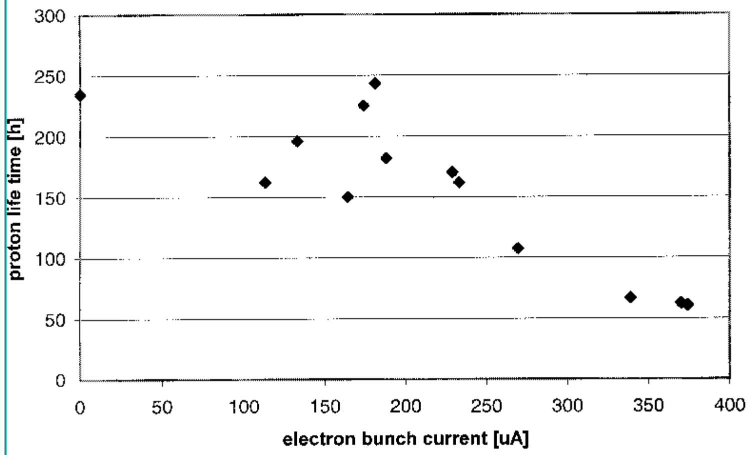
- 6 more measurements indicate $f_{Zentrum} \approx 175Hz$
- For the center frequency $f_{Zentrum} = 175Hz$, the luminosity is increased as expected

Too Strong Beam-Beam Force on p?

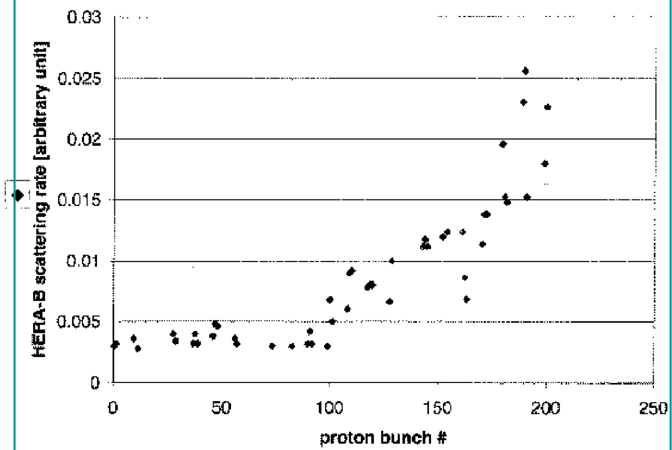




L_s is independent of e-current

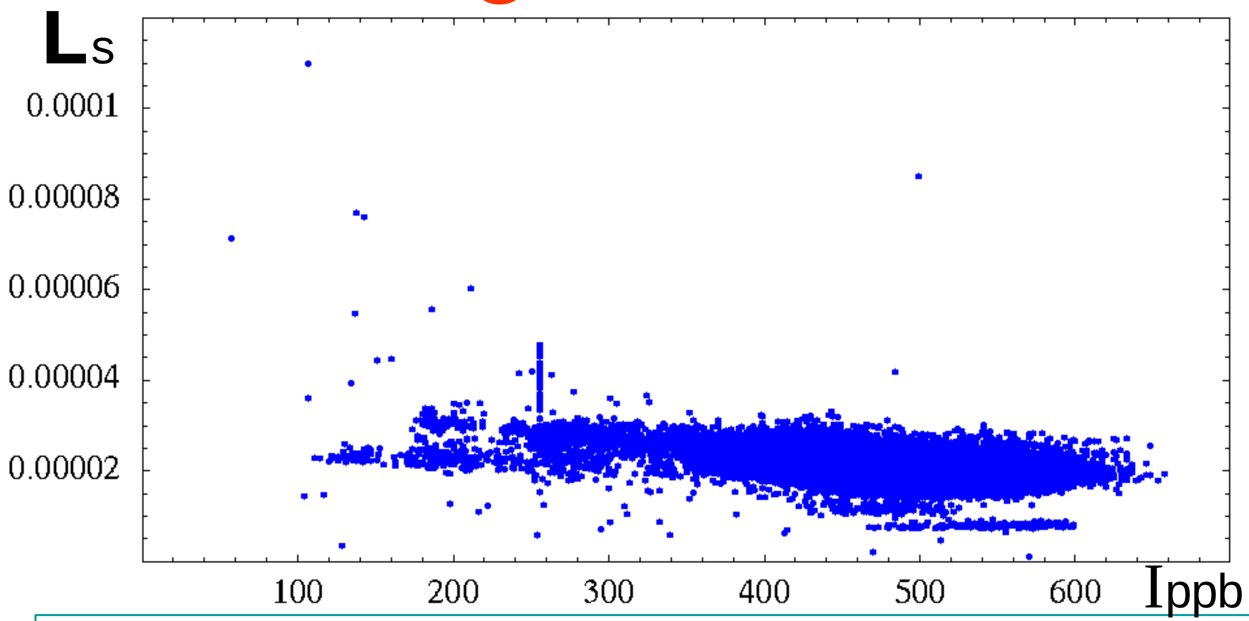


T_p depends on e-current



Tails depend on e-current

Too Strong Beam-Beam Force on e?



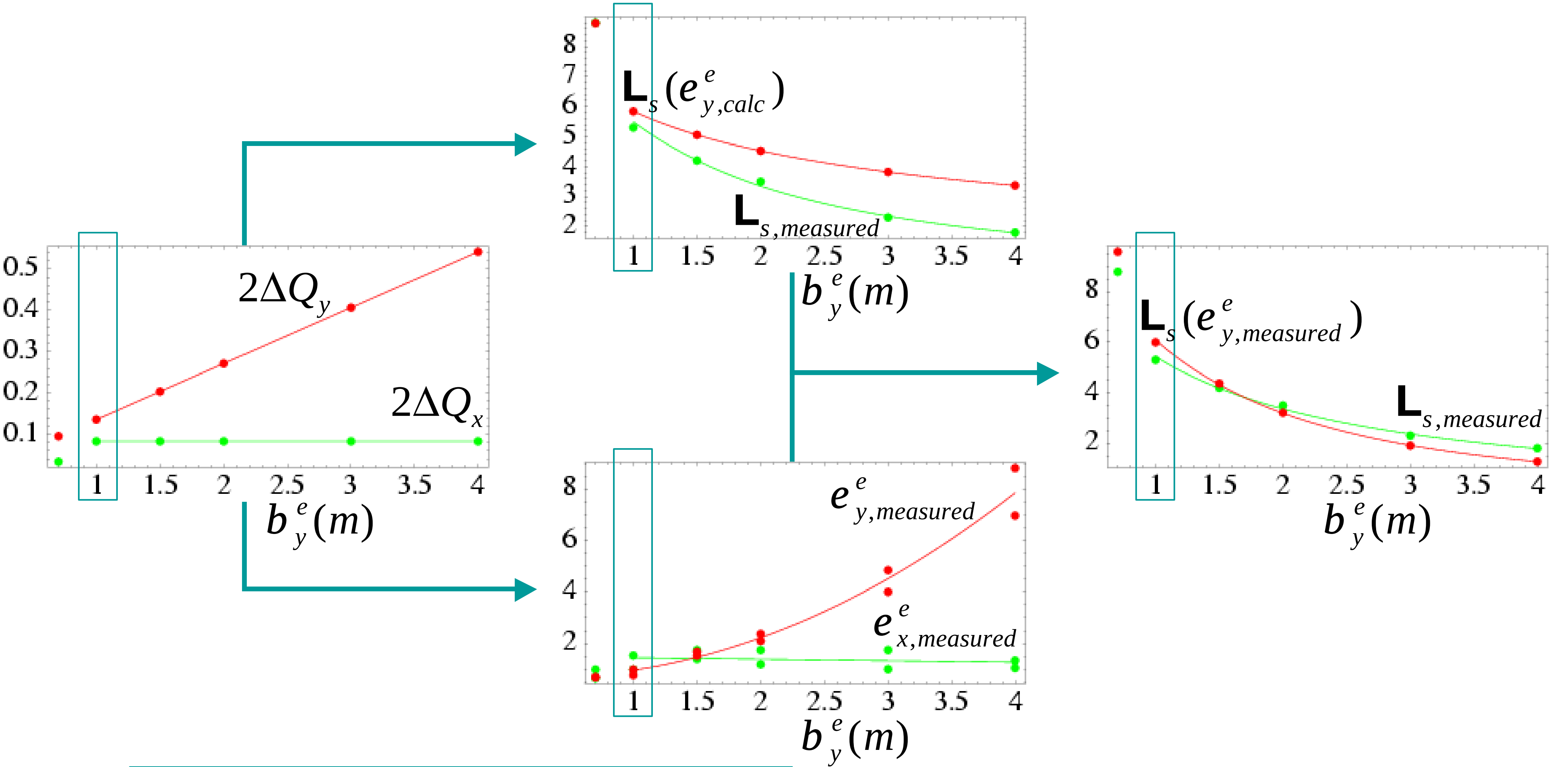
So far no reduction of **L**s by the bunch current

β_x^e	β_y^e	$\mathcal{L}_s^{ZEUS}$ (without H1)	(with H1)	$\Delta\Phi \in [0, 2\pi]$	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

No reduction of **L**s by the second experiment

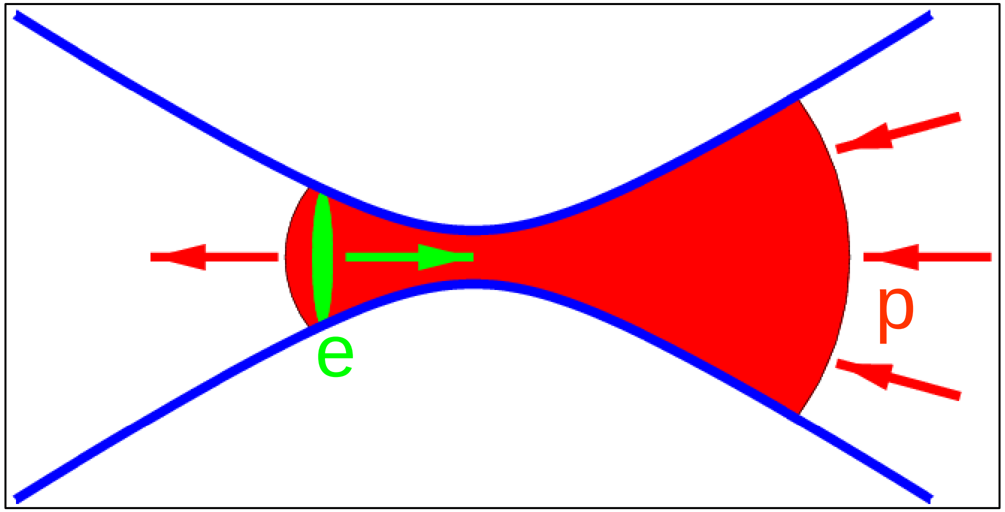
No reduction of **L**s by a larger b-funktionen

Where are the Beam-Beam Limits?



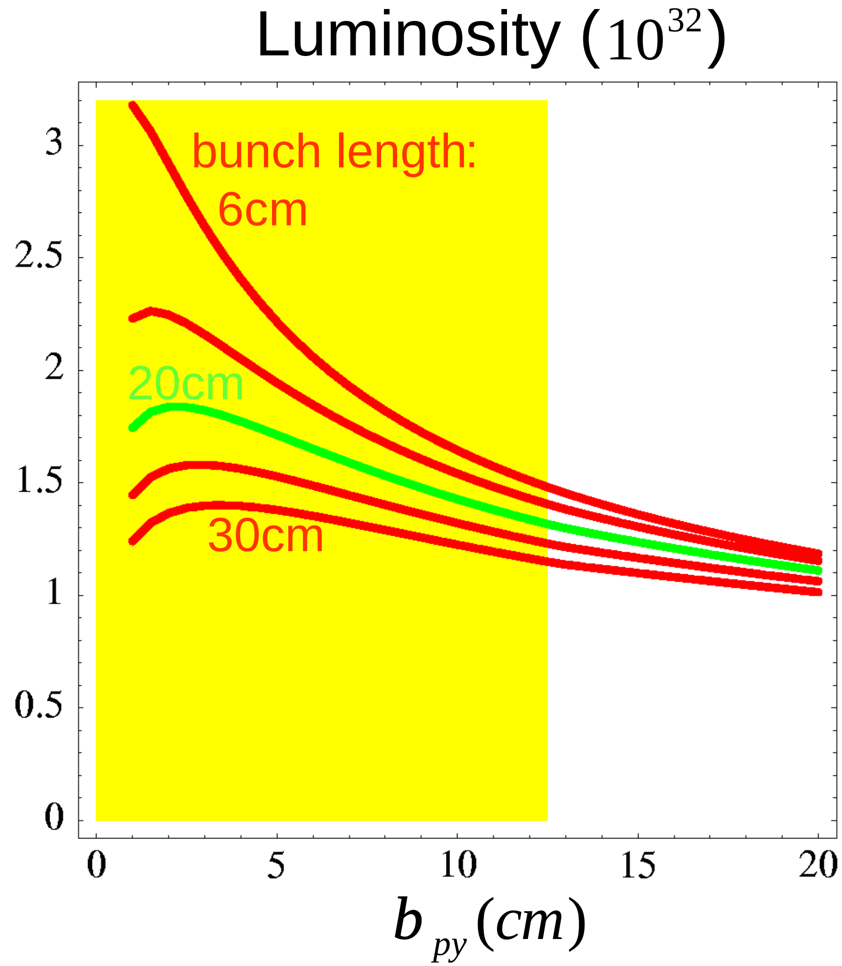
Upgrade and Ip=140mA: emittance starts to grow

Lumi Reduction by Hourglass Effect

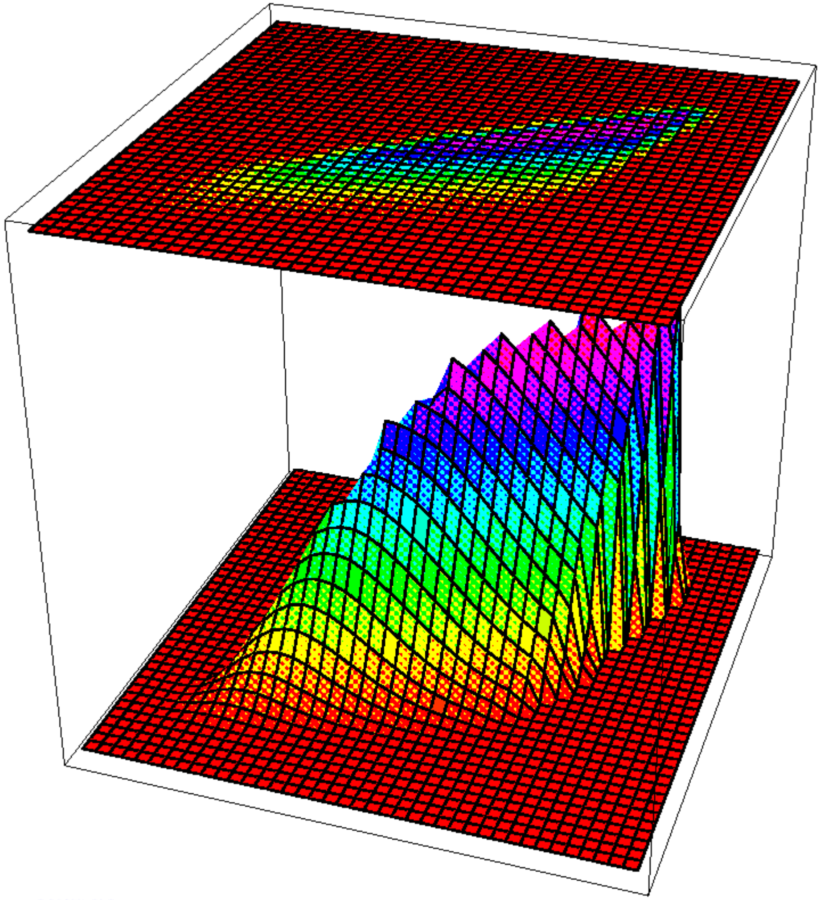


Length 19cm: $\frac{L(b_{py} = 12.5cm)}{L_0} = 1.75$

12cm: $\frac{L(b_{py} = 12.5cm)}{L_0} = 1.9$



Tune Shift with Bunch Length Effect



How will the tune shift parameters change and have these been analyzed by accelerator experiments ?

	$\Delta\nu_{x0}$	$\Delta\nu_x(5)$	$\Delta\nu_{y0}$	$\Delta\nu_y(5)$
initial p	0.0016	0.00081	0.00044	0.00011
ultimate p	0.0022	0.00060	0.00059	0.00147
studies p	0.0022	0.0017	0.00061	0.00080
initial e	0.024	0.024	0.045	0.044
ultimate e	0.034	0.036	0.069	0.070
studies e	0.041	0.041	0.085	0.083

Resonances with Bunch Length Effect

	initial	ultimate	studies
$\delta(4Q_{ex}+2Q_{ey})$	0.00020	0.00031	0.00045
$\delta(2Q_{ex}+8Q_{ey})$	0.000012	0.000018	0.000036

(10^{-8})	δ_0^i	δ_{max}^i	δ_{max}^u	δ_{max}^s
$\delta(10Q_{px})$	175	175	230	220
$\delta(8Q_{px}+2Q_{py})$	73	73	97	99
$\delta(6Q_{px}+4Q_{py})$	43	55	65	60
$\delta(4Q_{px}+6Q_{py})$	24	55	60	44
$\delta(2Q_{px}+8Q_{py})$	14	65	68	32
$\delta(10Q_{py})$	22	251	300	68
$\delta(14Q_{px})$	3.1	3.1	4.1	4.1
$\delta(12Q_{px}+2Q_{py})$	2.9	2.9	3.8	3.7
$\delta(10Q_{px}+4Q_{py})$	4.4	4.4	5.8	5.8
$\delta(8Q_{px}+6Q_{py})$	5.9	5.5	5.8	5.3
$\delta(6Q_{px}+8Q_{py})$	2.6	7.0	6.0	4.3
$\delta(4Q_{px}+10Q_{py})$	1.2	8.8	8.0	3.2
$\delta(2Q_{px}+12Q_{py})$	0.37	8.5	6.6	1.4
$\delta(Q_{py})$	0.33	22	22	1.7

How will the resonance strength change and have these been analyzed by accelerator experiments ?

All large resonance strength are due to the proton bunch length

Nominal and Ultimate Parameters

	p	e
Energy–p/e	920 GeV	27.5 GeV
Emit. hor/vert	$5/5\pi$ mm mrad	20/3.4 nm
β^* at IP hor/vert	2.45/0.18 m	0.63/0.26 m
Aperture hor/vert	$12/12\ \sigma$	$20/20\ \sigma$
p per bunch and e-cur.	$1.03 \cdot 10^{11}$	58 mA
Tune shift hor/vert	0.0016/0.0004	0.034/0.051
Bunch Length	191 mm	10.3 mm
Luminosity	$0.74 \cdot 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$	

p	e
$3.5/3.5\pi$ mm mrad	20/2.7 nm
1.7/0.125 m	0.42/0.17 m
$10/10\ \sigma$	$12/12\ \sigma$
0.0017/0.0005	0.047/0.069
$1.3 \cdot 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$	

- The performance goal of HERA is not unrealistic and should not be too hard to achieve.
- A shortfall of beam intensity in the short term can be compensated.