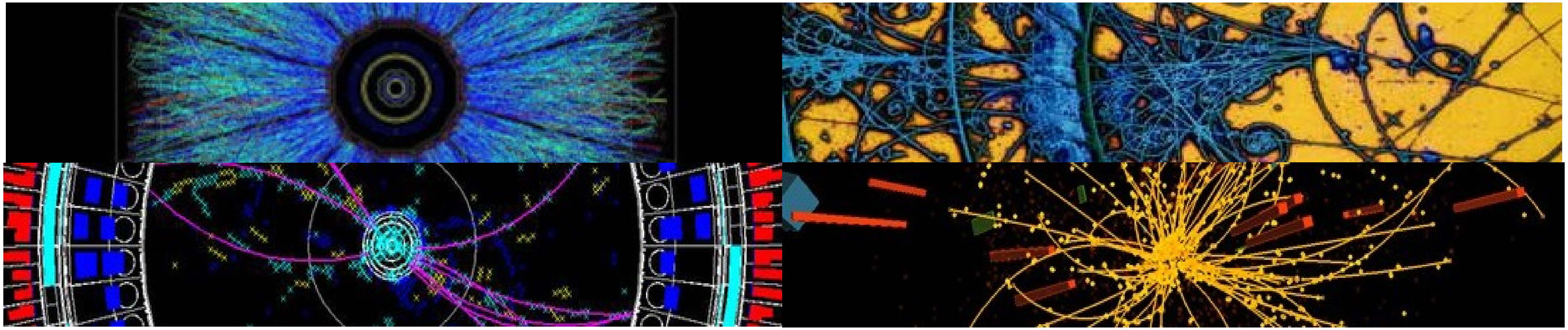
Colliders challenges - *optics*



R. Tomas

Thanks to M. Bai, M. Biagini, R. Calaga, M. Giovannozzi, Y. Luo, R. Miyamoto, T. Pieloni, S. Redaelli, S. Fartoukh, G. Vanbavinckhove and F. Zimmermann

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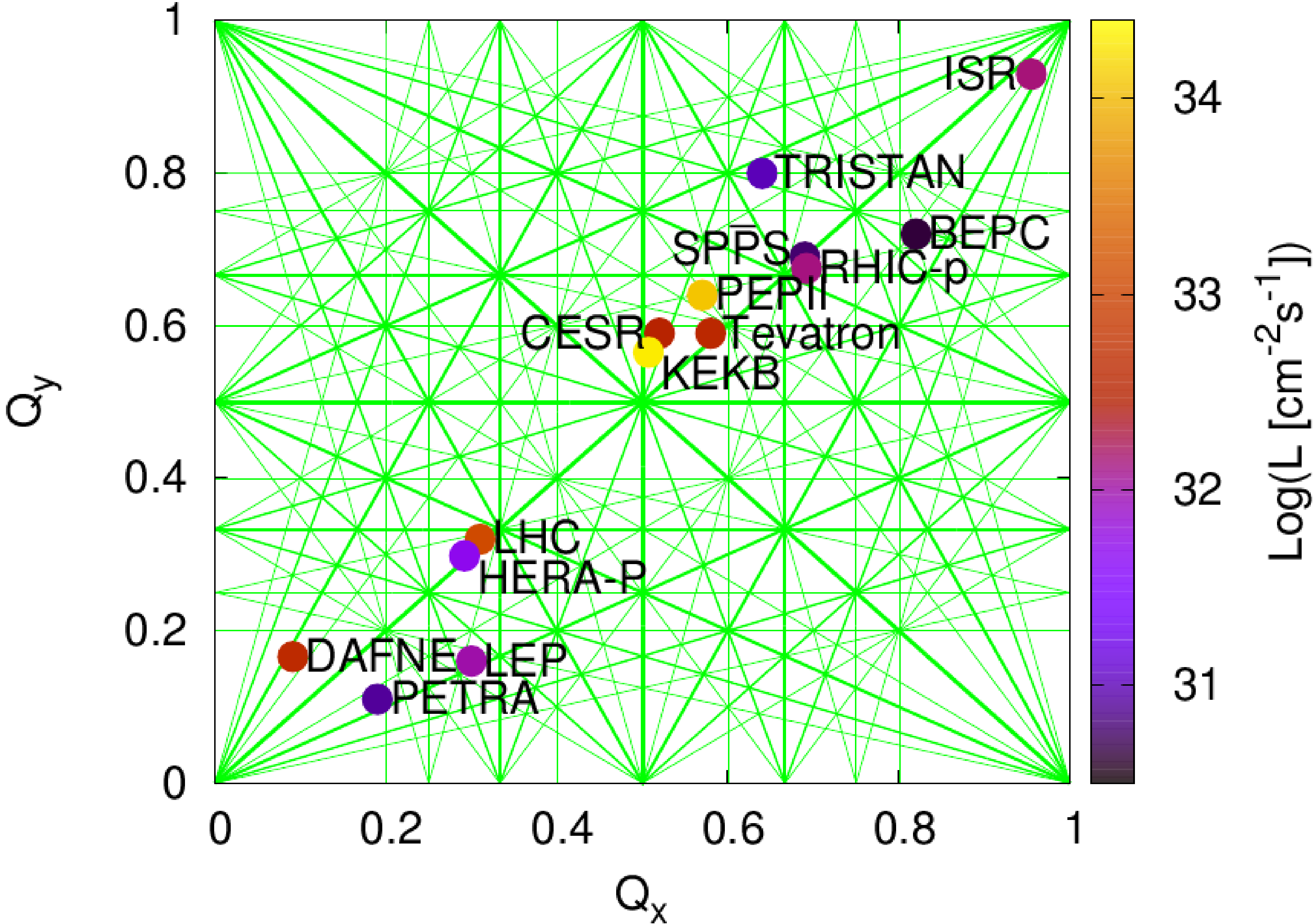
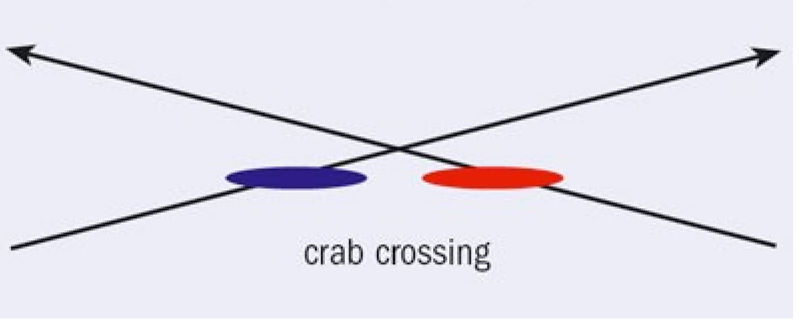
- Some colliders (so far)
- KEKB and the next luminosity record
- SuperB
- LHC, Roman pots and collimation tolerances
- HL-LHC
- Beam-beam compensation schemes
- Optics measurement and correction techniques

Some colliders (in the tune world)

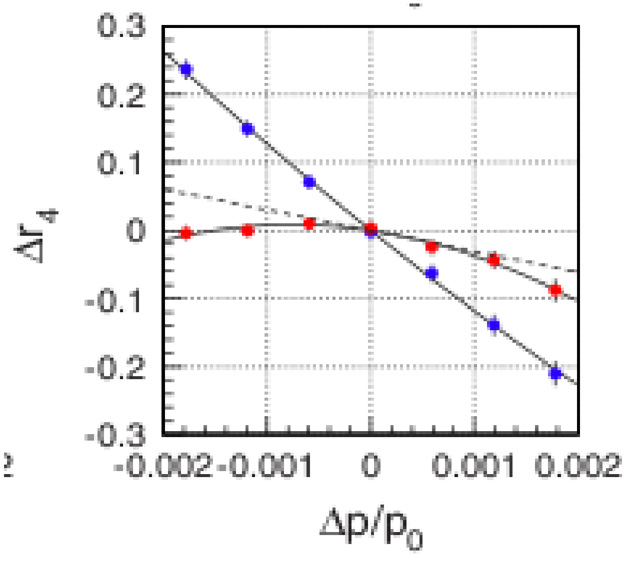


Gold medal for KEKB

- Closest operation to half integer tunes
- Crab cavities for 20% lumi increase



- Measurement and correction of chromatic coupling for another 20% of lumi increase



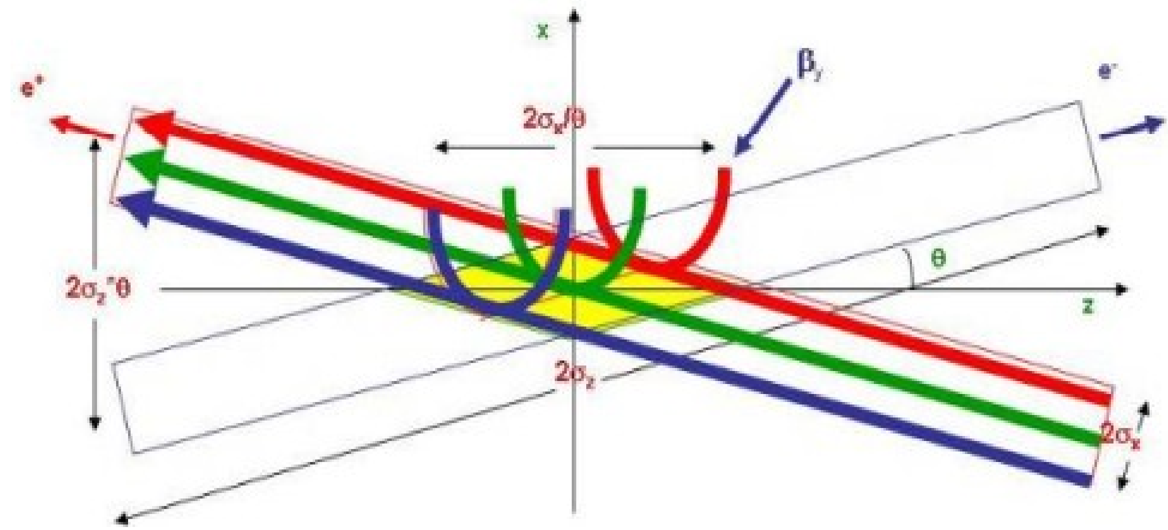
Who will break KEKB lumi record?

- 2014: from simple scaling LHC at 7 TeV might achieve 2-3 10^{34} $cm^{-2}s^{-1}$
  (chance for LHC to become the only hadron collider to beat lepton colliders in the last 20 years)
- 2015: SuperKEKB aims at 8 10^{35} $cm^{-2}s^{-1}$
- 2017: SuperB aims at 10^{36} $cm^{-2}s^{-1}$
- 2020: HL-LHC goal ≤ 10^{35} $cm^{-2}s^{-1}$

Exciting luminosity race!

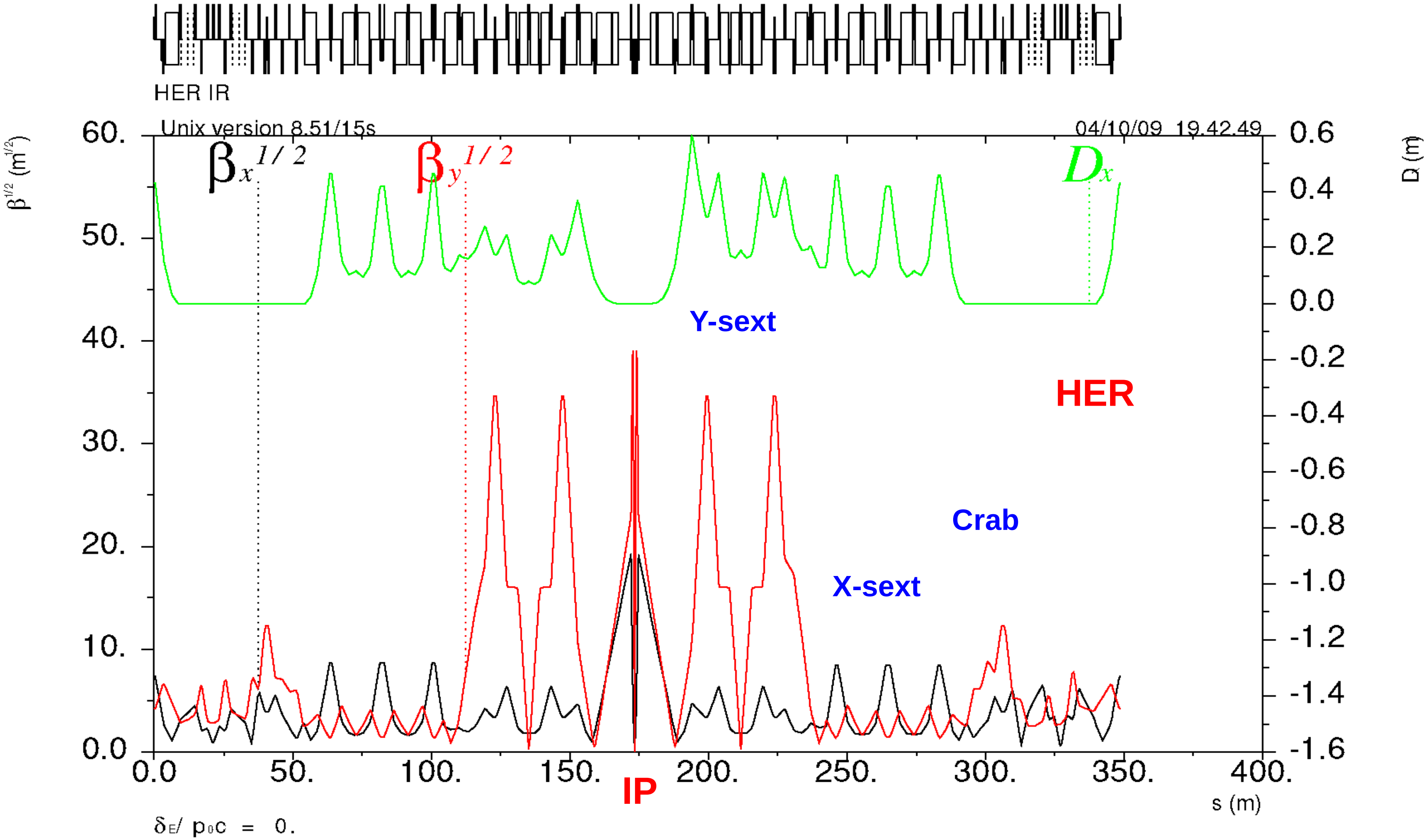
SuperB challenges (M. Biagini)

- Ultra-low emittance lattice
- FFS closer to linear colliders
- Crab waist



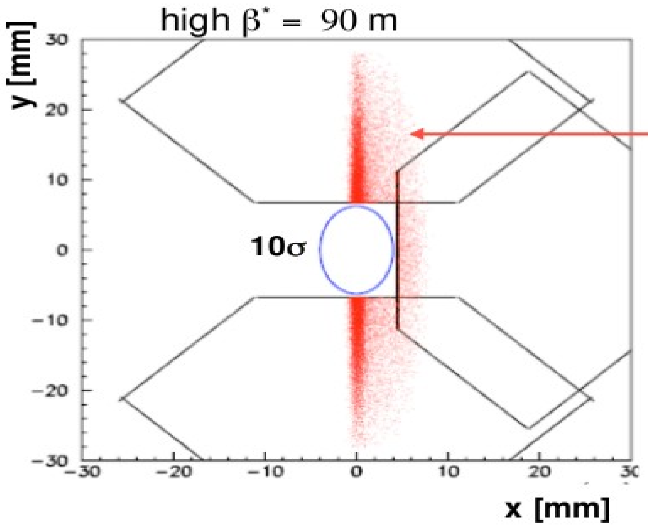
- Beta-beating 3-5% (see LET talk by Simone Liuzzo)
- "... a perfect correction of the crab waist sexts is preferable to avoid a reduction of DA"

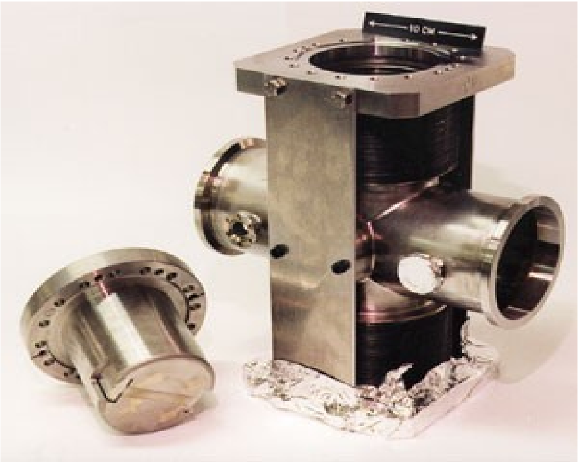
SuperB FFS

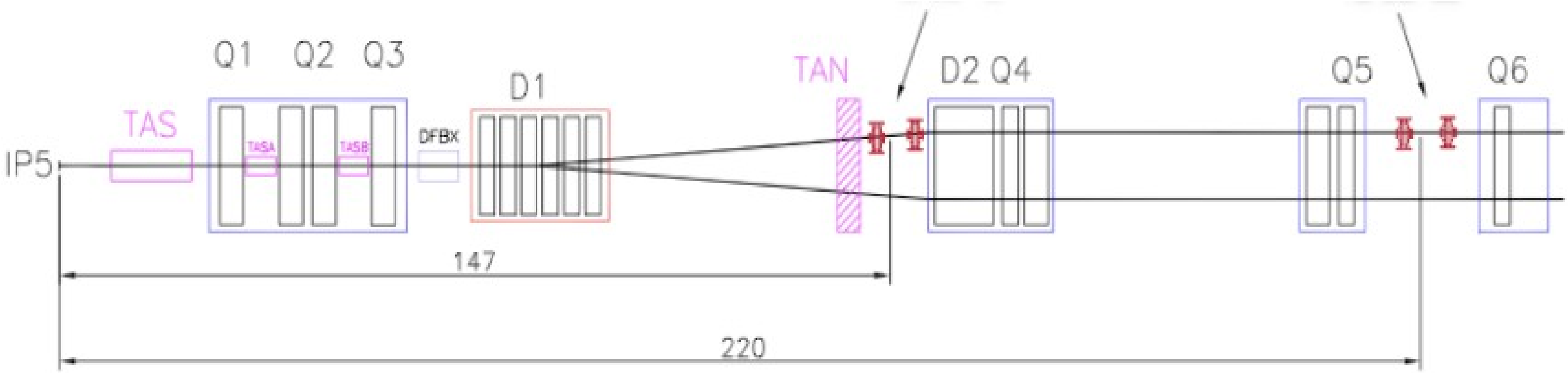


Separate H-V chromaticity correction sections in phase with IP, where the β reach maxima. Works very well in terms of DA and off-momentum twiss parameters.

Requirements from LHC Roman pots



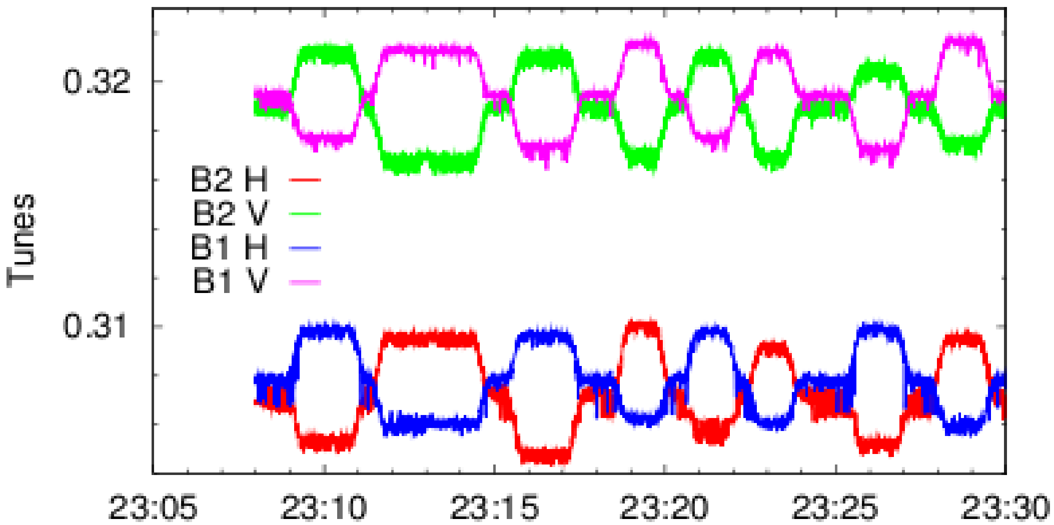




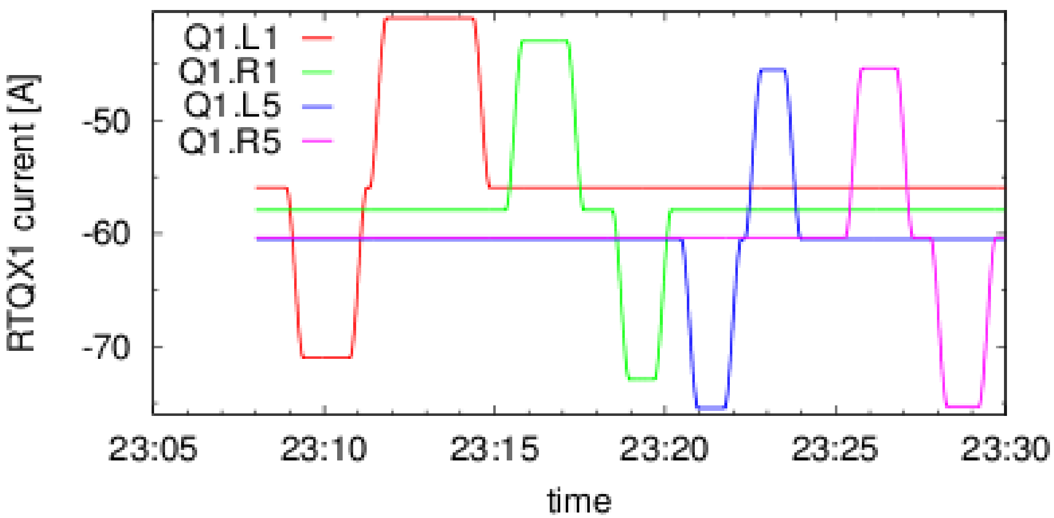
Knowledge of beta-functions better than 1%!

See talk by Hubert Niewiadomski

What was achieved during the 90m LHC Machine Development?



20min of K-modulation gave resolution in beta* between 2% and 9%



Paths to improve resolution:
-Increase modulation depth
-Longer measurement time
-Improve tune resolution
-Combine with AC dipole meas

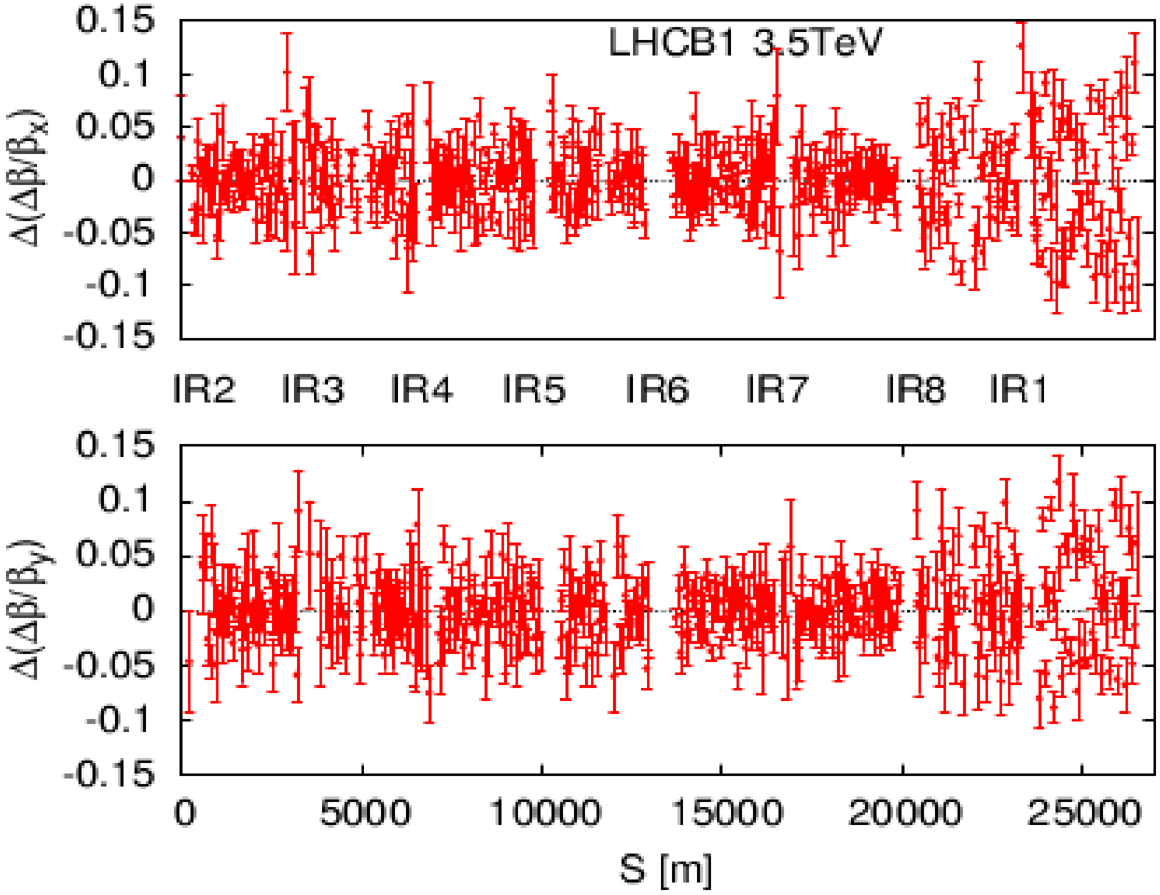
The required <1% seems challenging

LHC collimation tolerances

Parameter	Tolerances		
(n_1/n_2)	Nominal injection (6/7 σ)	Collision (nominal) (6/7 σ)	Collision (relaxed β^*) (7/10.5 σ)
Beam size at collimators	$\approx$ 1.2 mm	$\approx$ 0.2 mm	$\approx$ 0.2 mm
Orbit change	0.6 σ $\approx$ 0.7 mm	0.6 σ $\approx$ 0.12 mm	2.0 σ $\approx$ 0.4 mm
Transient beta beat	8%	8%	80%
Collinearity beam-jaw	50 μrad	50 μrad	75 μrad

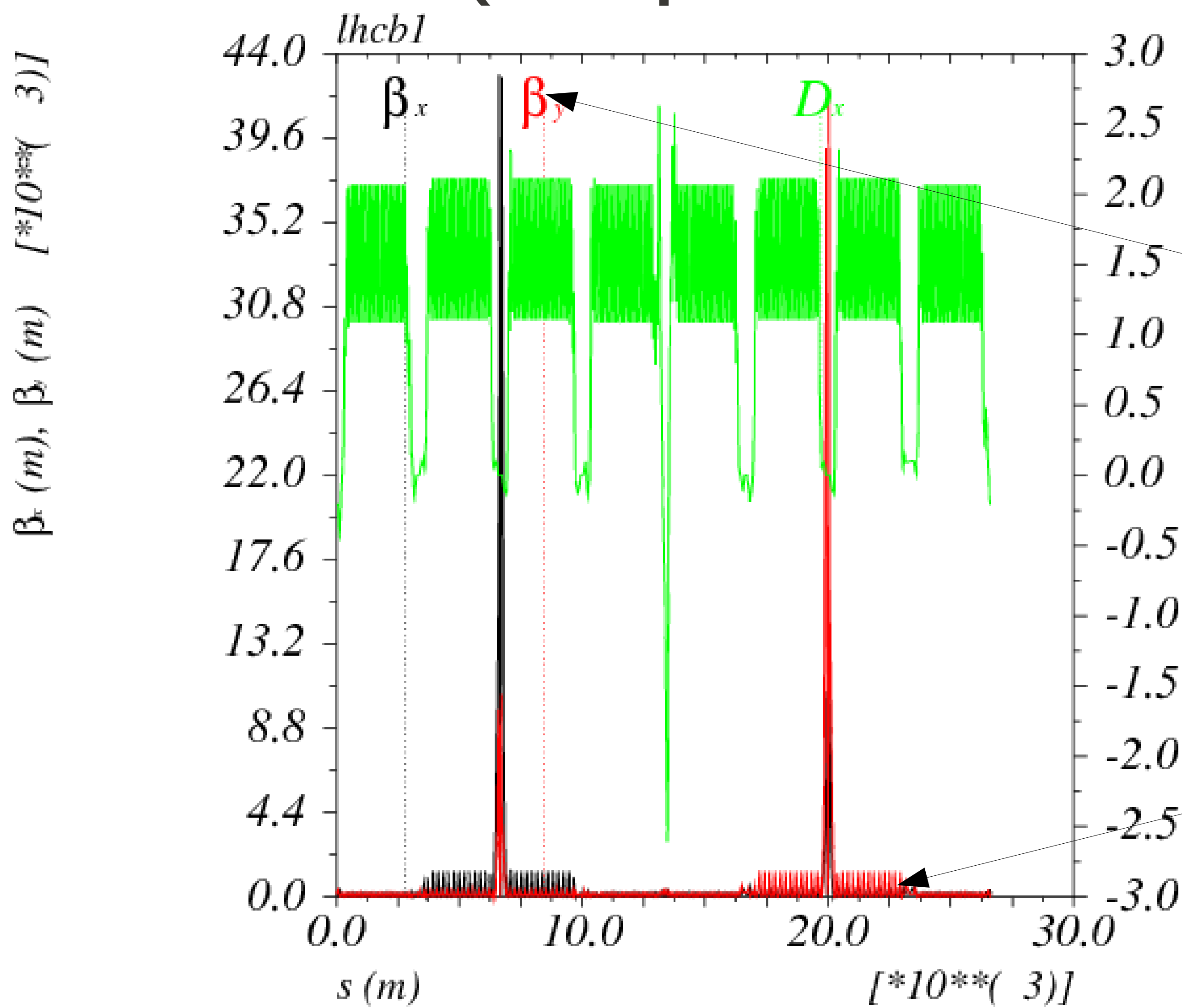
Currently at 3.5 TeV relaxed settings are used n1/n2=5.7/8.5 σ,
But are we ready for nominal settings (trans beta-beat ~ 8%)?

10% variation after a 30 hours fill



10% difference of beta-beating in the beginning and the end of a 30 hours fill (measured in different days) → but 8% tolerance

HL-LHC challenging optics (Stephane Fartoukh)



Max beta~40 km !

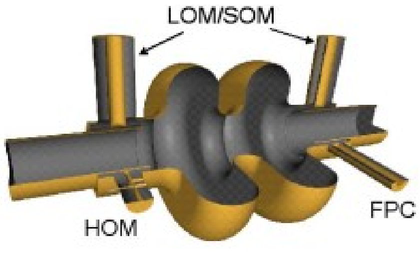
7 km long FFS

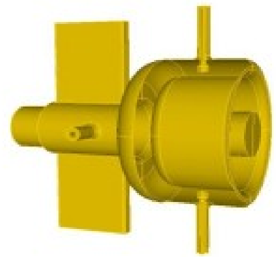
1 km arc beta !

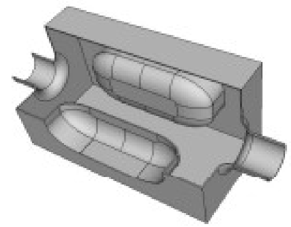
HL-LHC tolerances (Stephane)

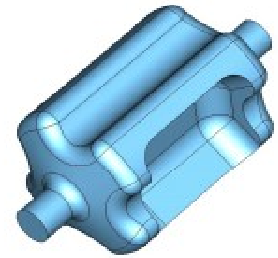
- Required triplet field quality below the traditional 10^{-4}, to a fraction of a unit for the low orders.
- Magnetic field measurements not accurate enough →
- Need precise beam-based optics measurements and corrections
- Combined with appropriate corrections circuits

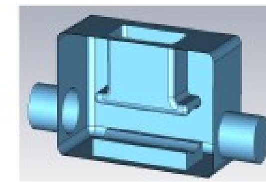
Crab cavities for the HL-LHC (Rama Calaga)

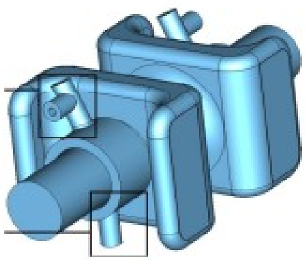


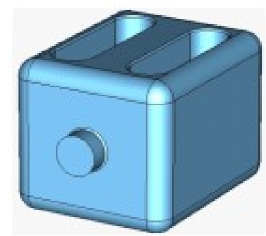


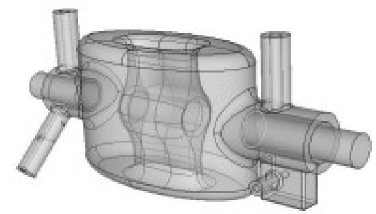


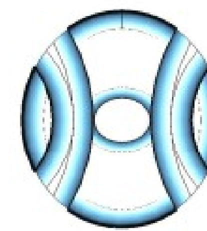


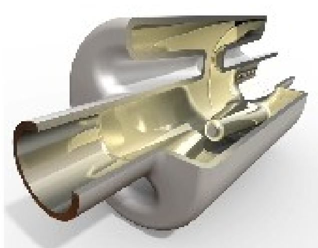


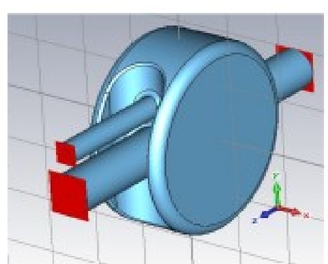


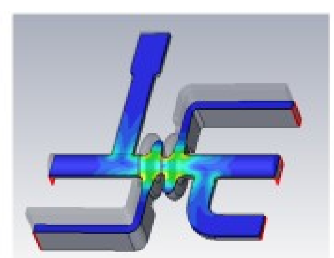


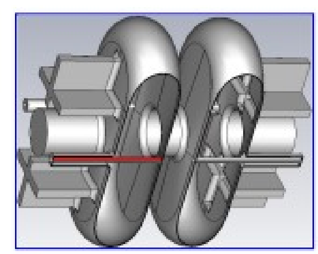


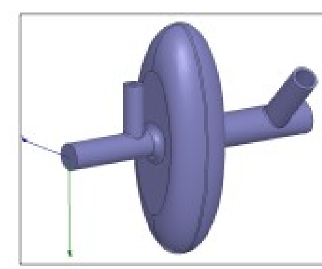






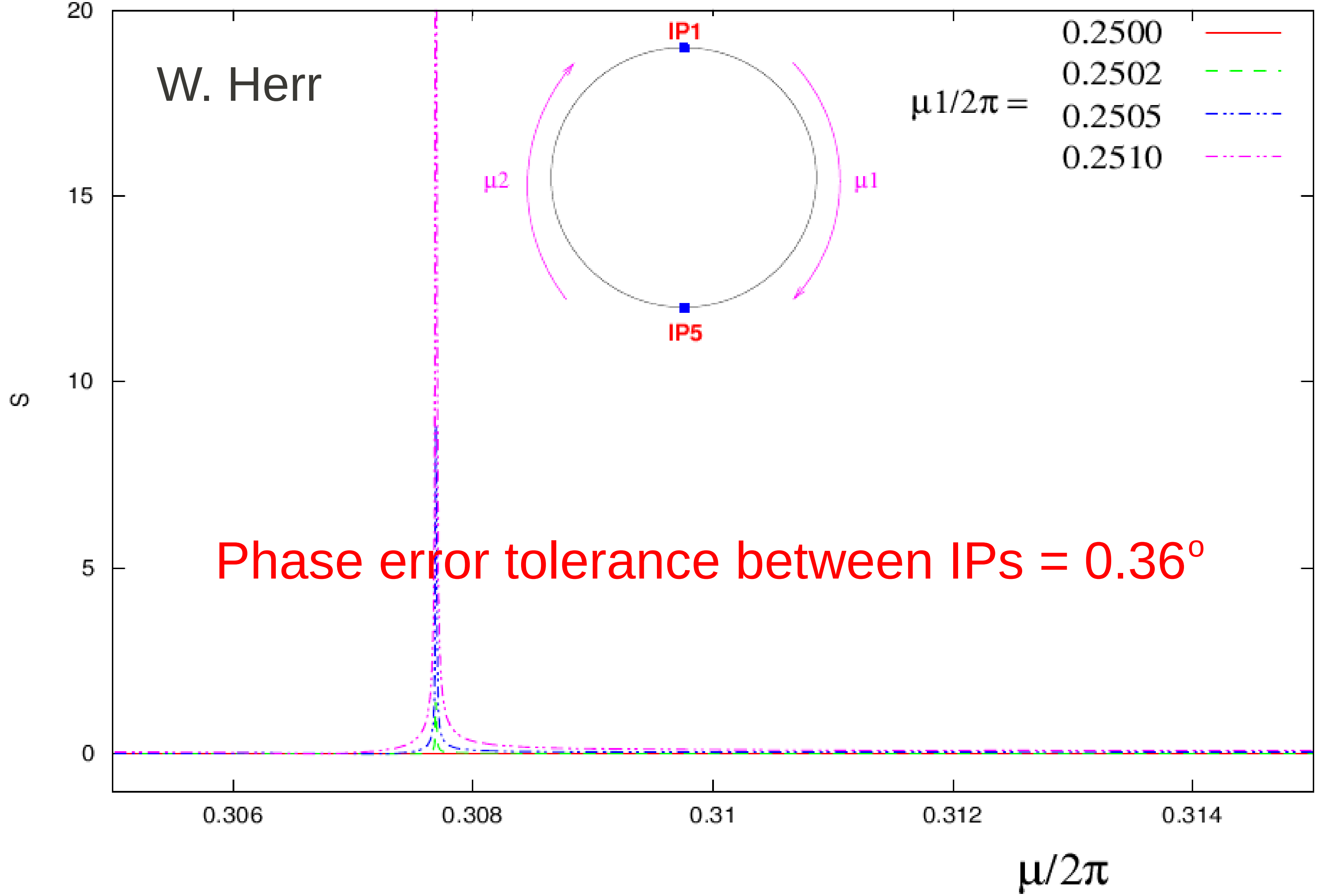




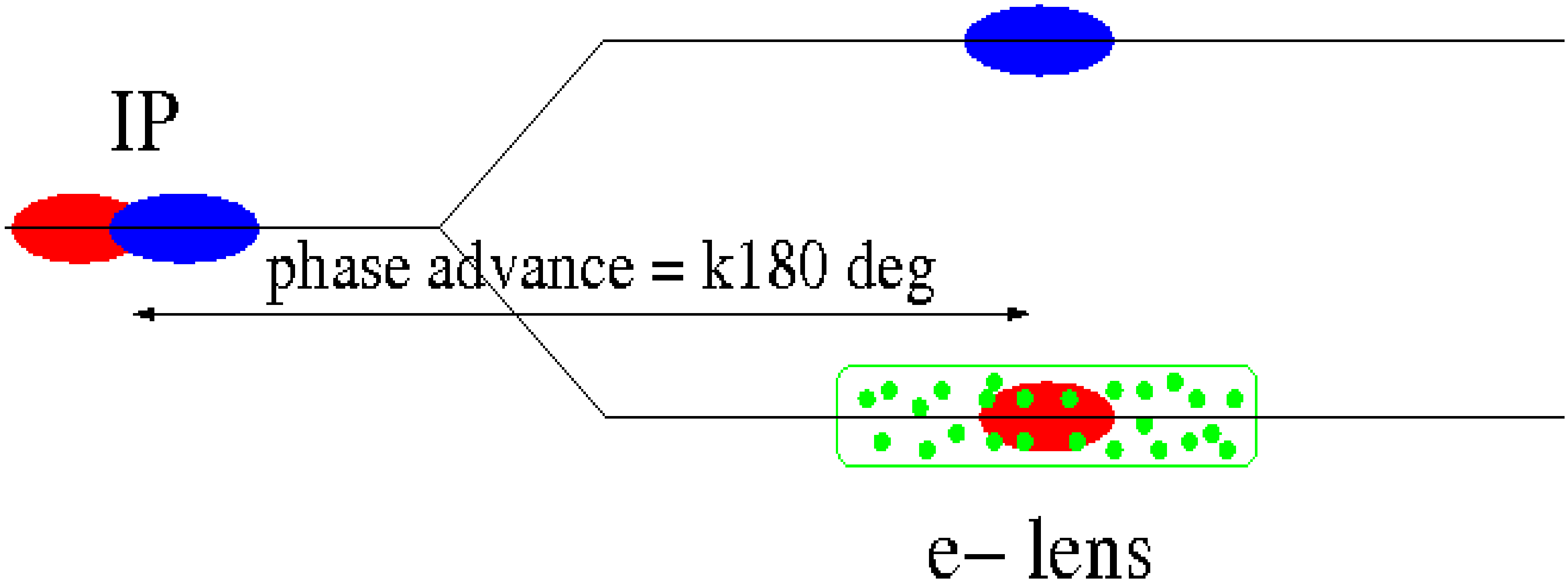


In principle 2 per IP, tolerances?

Beam-beam resonance suppression

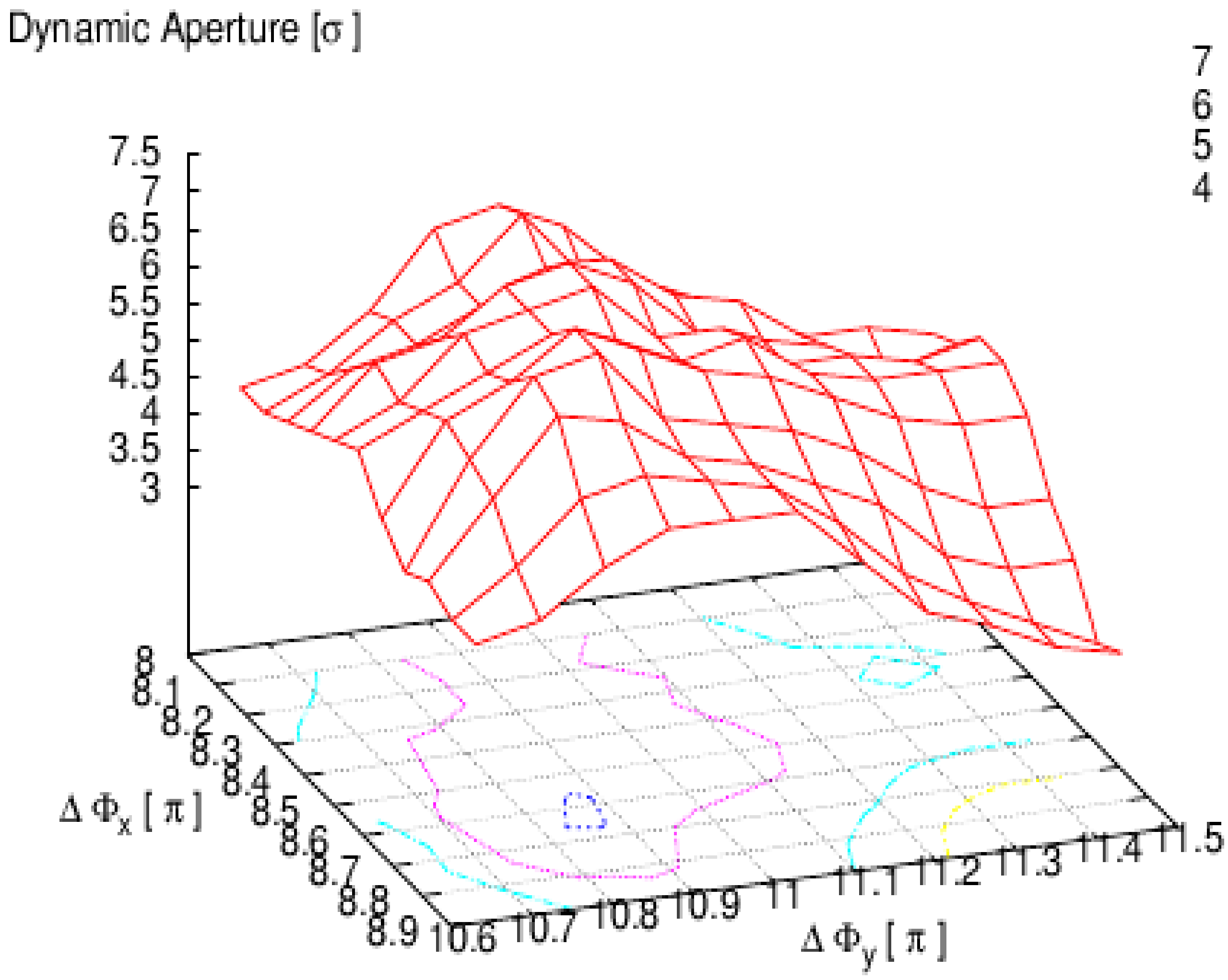


e-lens for head-on compensation



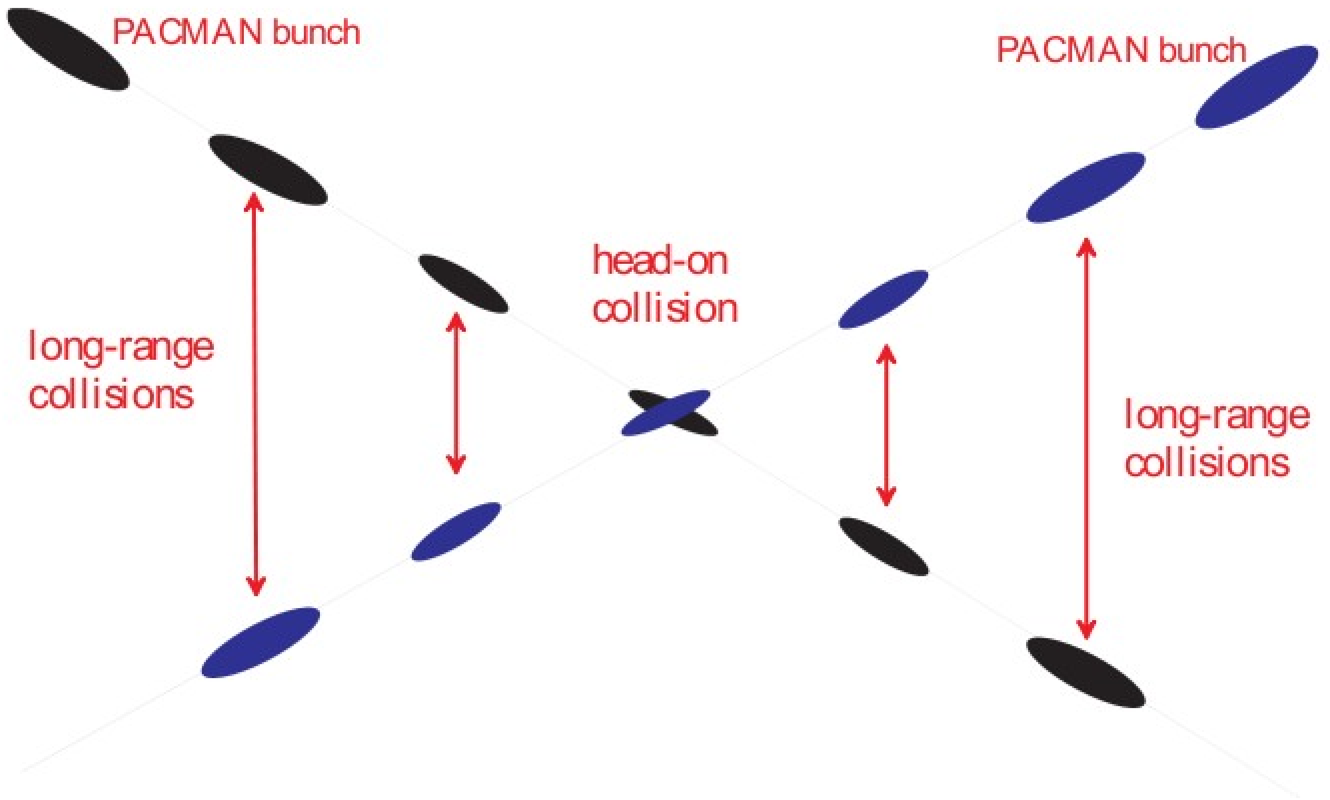
e-lenses can provide the same force as the beam-beam Interaction. Tried in Tevatron, to be tried in RHIC.

RHIC e-lens tolerance (Y. Luo)



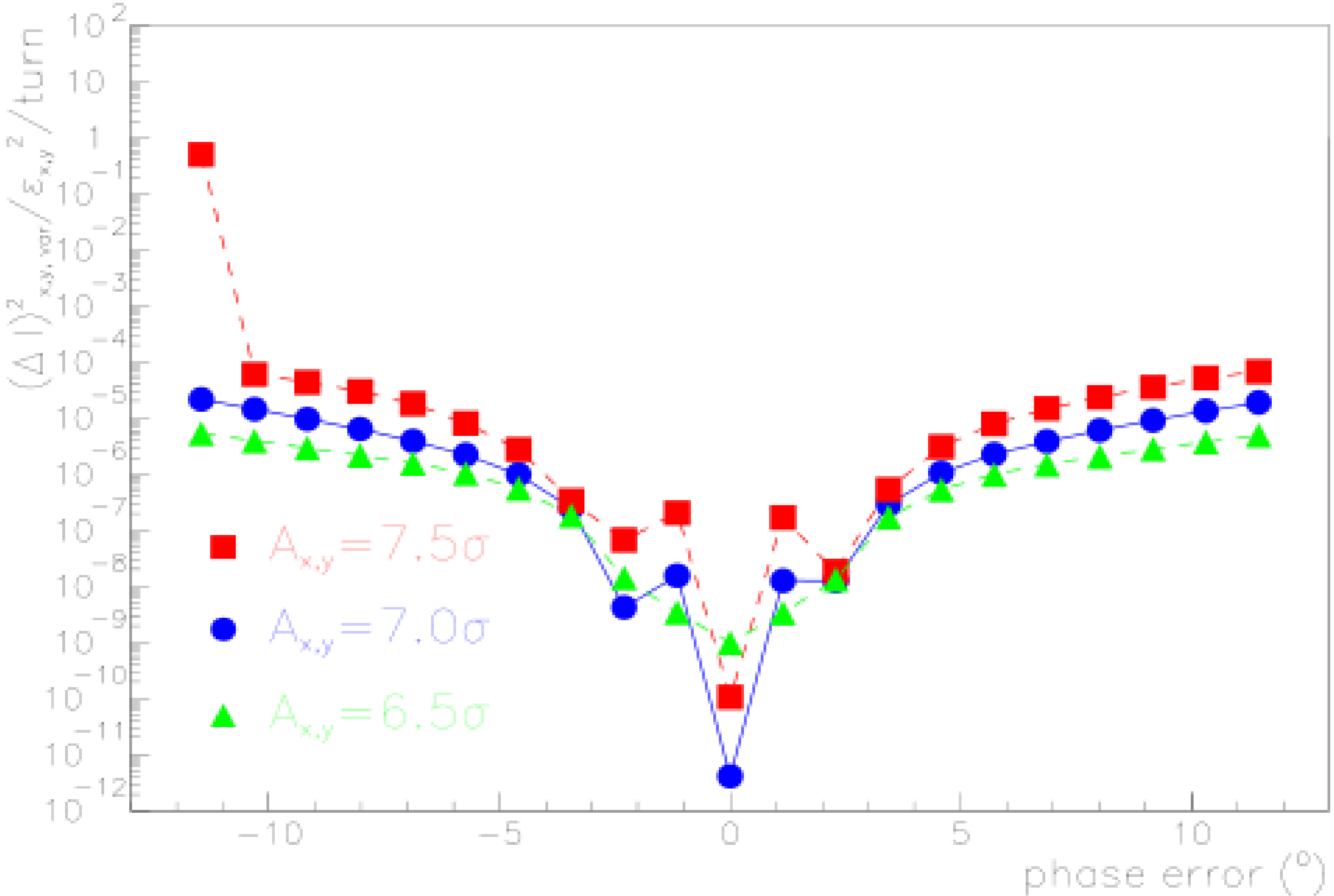
Phase advance error tolerance ~ 18º

Wire for long-range compensation



A wire magnetic field can be used to locally cancel the unwanted long-range interactions. This has been tested in SPS, RHIC and DAFNE.

Tolerance for a single wire in LHC (F. Zimmermann)



10^o error seems OK but the lower the better ($\sim 1^o$)

Popular measurement techniques

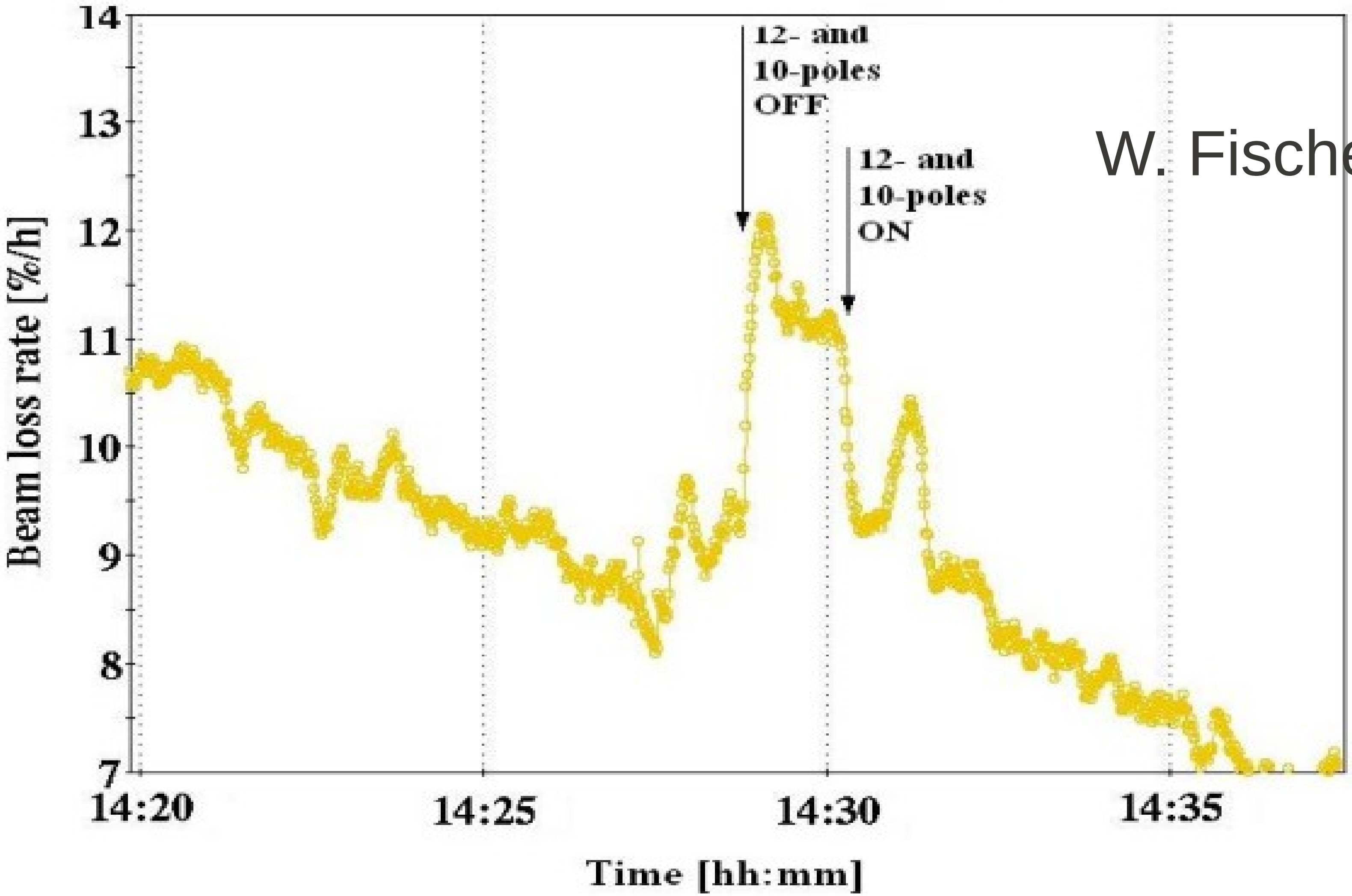
- K-modulation
- Betatron oscillations, free or forced (since ISR)
- Closed Orbit Distortion (KEKB)
- LOCO? (very successful in light sources)

Is the collider optics challenge to reach light source performance?

- DIAMOND and SOLEIL achieved ~1% beta-beating
- DIAMOND measured and corrected varios sextupolar resonances increasing lifetime by 10%
- Differences: number of magnets, BPM resolution, singly powered magnets, etc

RHIC high order correction

W. Fischer et al



Direct optimization of lifetime using 12- and 10-poles IR magnets increased fill integrated luminosity by 4%

Summary and outlook

- Colliders are incorporating a variety of new devices and detectors: crab cavities, crab waist sextpoles, wires, e-lenses, Roman pots,
- plus pushed IR designs,
- yielding unprecedented tolerances in magnetic errors and optics control
- Can colliders achieve 1% beta-beat and 0.3^0 phase-beat? (including dynamic effects)
- Are techniques, magnets and instrumentation good enough?

A possible output of the workshop

Collider	Initial β-beat	Final β-beat	Technique
ISR		15%	K-modulation
PEP II	100%	30%	MIA, resonant excit.
LEP	40%	14%	K-mod, multiturn
HERA	30%	20%	Orbit response
KEKB	80%	20%	Closed orbit distortion
DAFNE		5%	
Tevatron		15%	LOCO, multiturn
RHIC	40%	20%	AC dipole, SBST
LHC	60%	10%	AC dipole, SBST