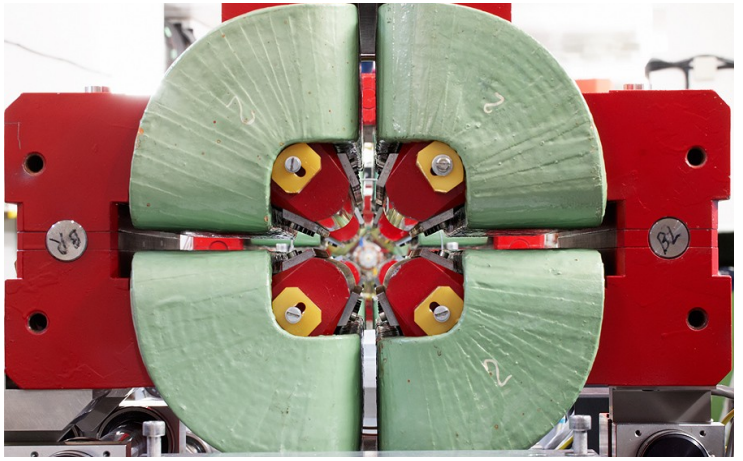
The ATF2 story



Rogelio Tomas (CERN) and Eduard Marin (SLAC)

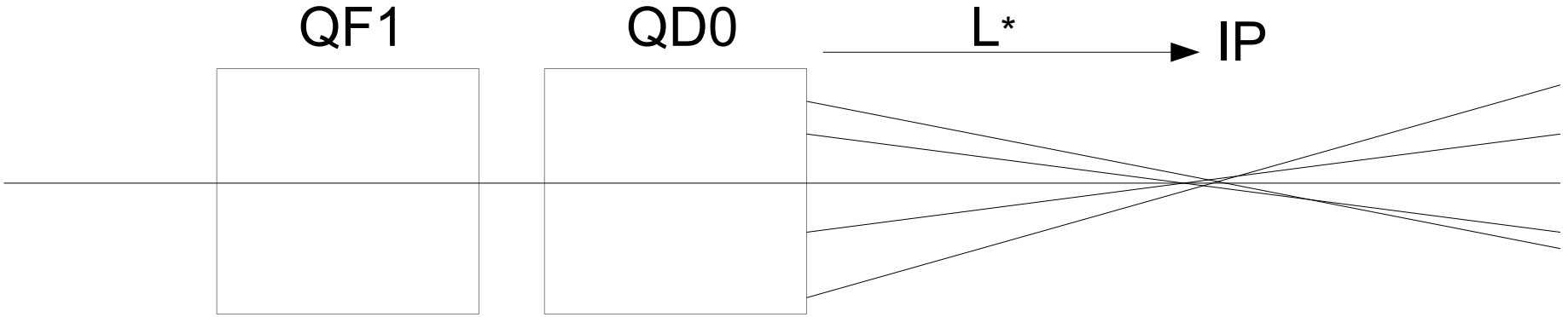
Many thanks to C. Spencer, T. Okugi, G. White,
M. Woodley et al.

Beam Dynamics meets magnets
Darmstadt, December 2013

Contents

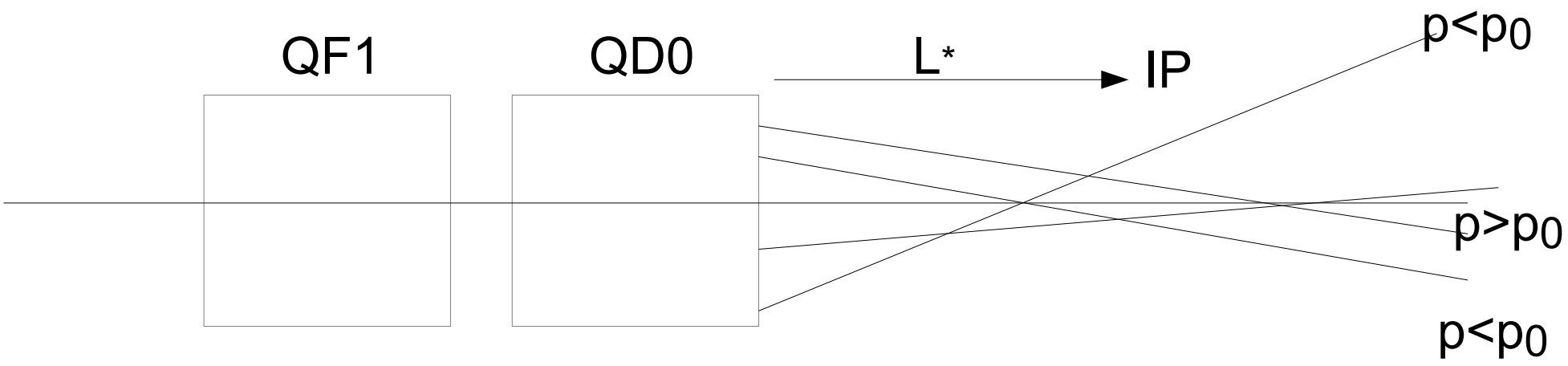
- FFS concepts
- ATF2 goal I
- Nominal optics
- ATF2 challenges
- ATF2 optics and beam size history
- Troubles and solutions
- Lessons learned

FFS concepts: Ideal monochromatic beam



- All particles are focused at the IP
- Beam size is $\sqrt{\beta \epsilon}$

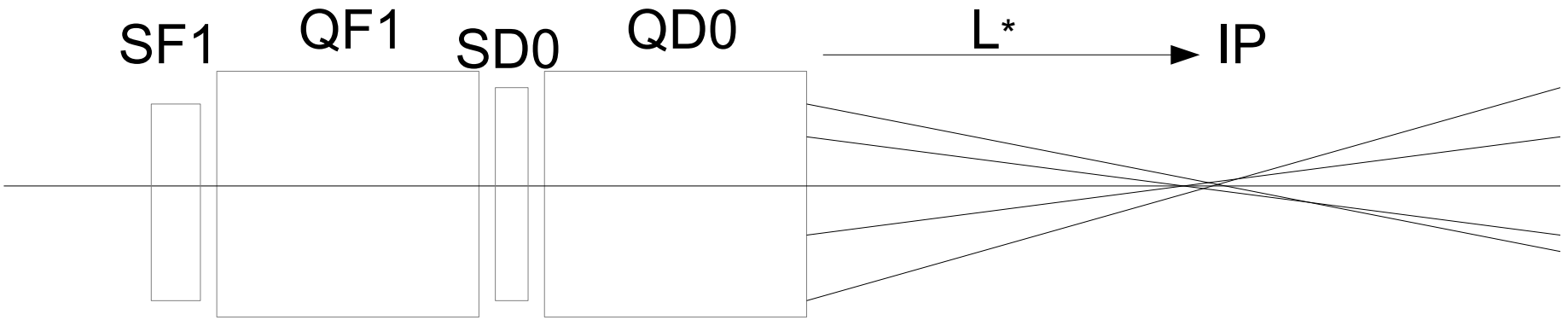
FFS concepts: Chromaticity



- Particles with different energies are focused at different longitudinal locations
- Causing a larger beam size approximately given by

$$\sigma = \xi \Delta p / p_0 \sqrt{\beta \epsilon}$$

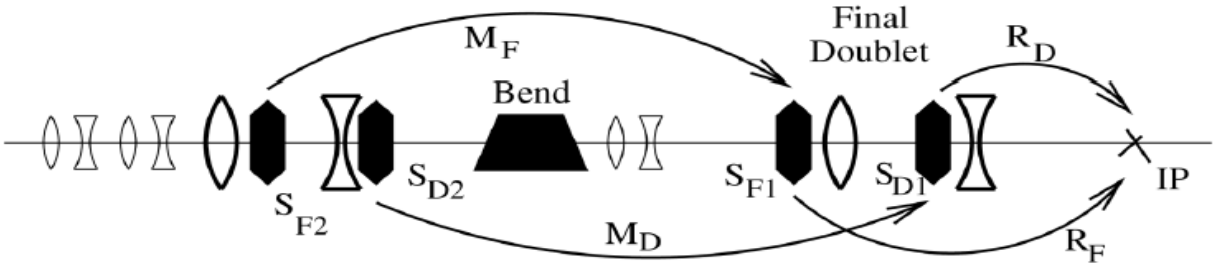
FFS concepts: Local chromaticity correction with sextupoles



Phys. Rev. Lett. 86, 2001

- Introducing sextupoles in the FD minimizes higher order aberrations
- Other sextupoles are used upstream to cancel geometric aberrations
- Beam size is mostly restored to $\sqrt{\beta\epsilon} + aberrations$

ATF2 Goal I



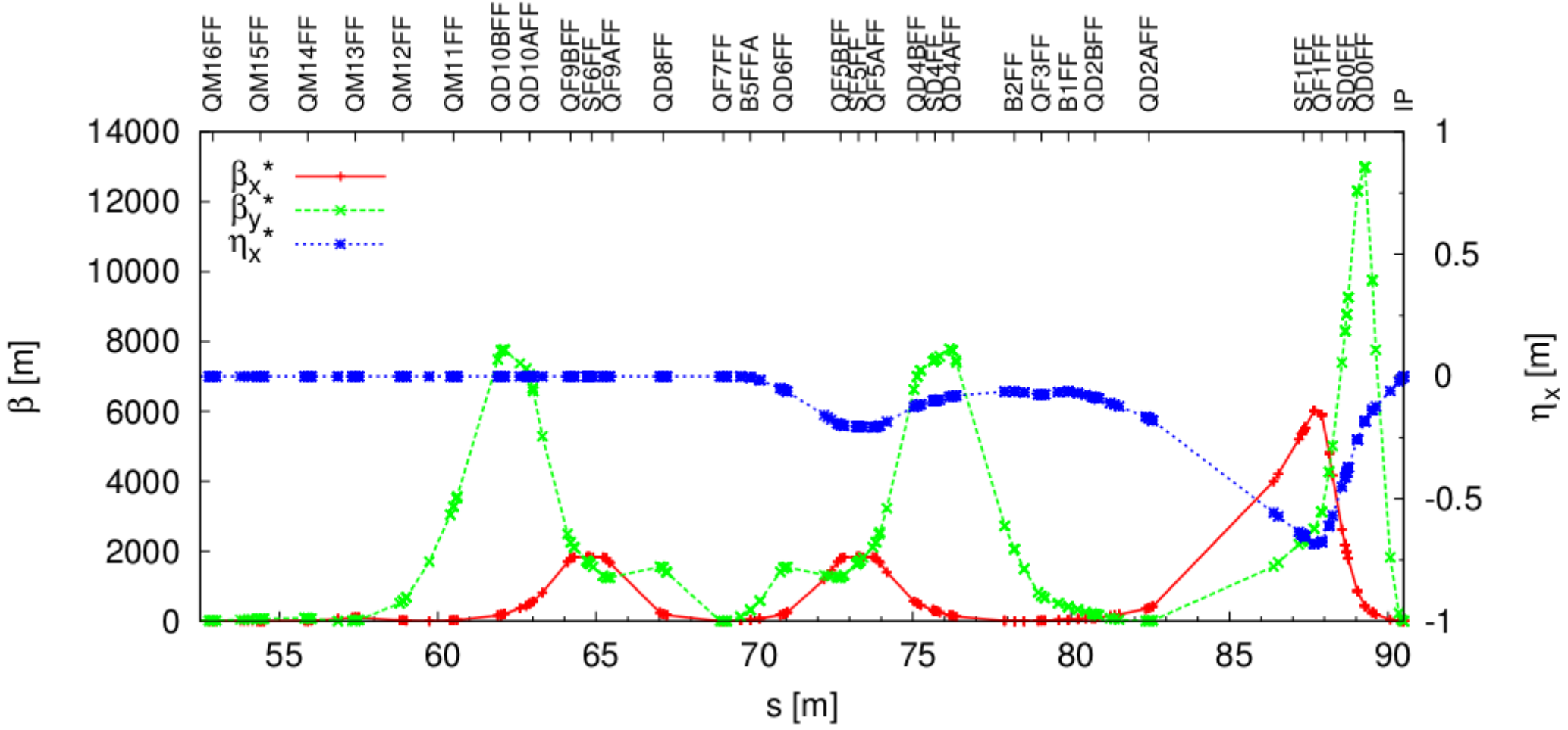
- Demonstrate the feasibility of a Final Focus System based on the local chromaticity correction focusing down to 37 nm.

	σ_y [nm]	β_y[μm]	L* [m]	Chroma, ξ
ATF2 Nominal	37	100	1	10000
ILC	6	480	3.5	7300
ATF2 Ultra-low	22	25	1	40000
CLIC	1	67	3.5	50000

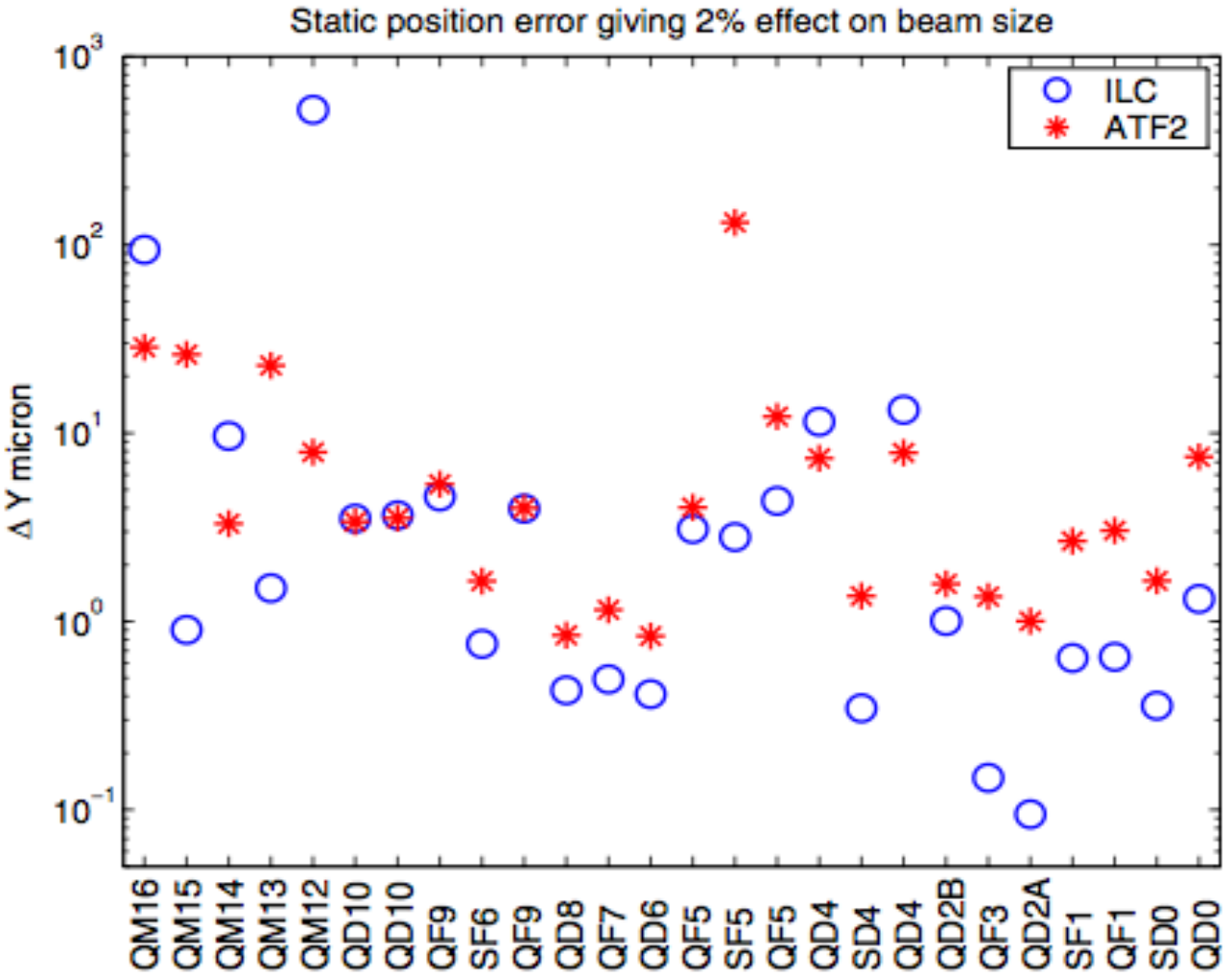
- CLIC study proposes even lower beam sizes!

ATF2 original nominal optics

β_x=4mm β_y=0.01 mm

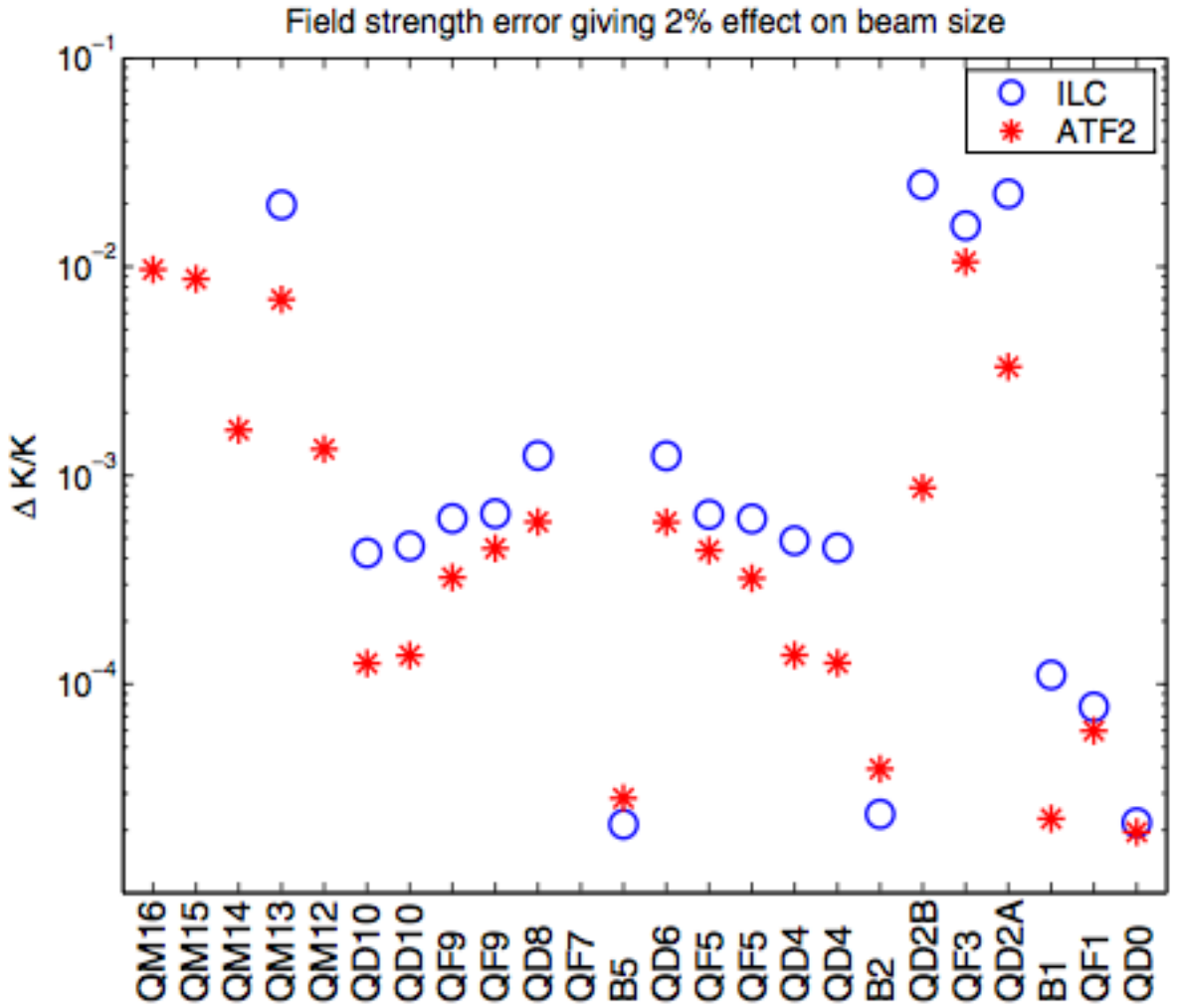


ATF2 challenges: Alignment



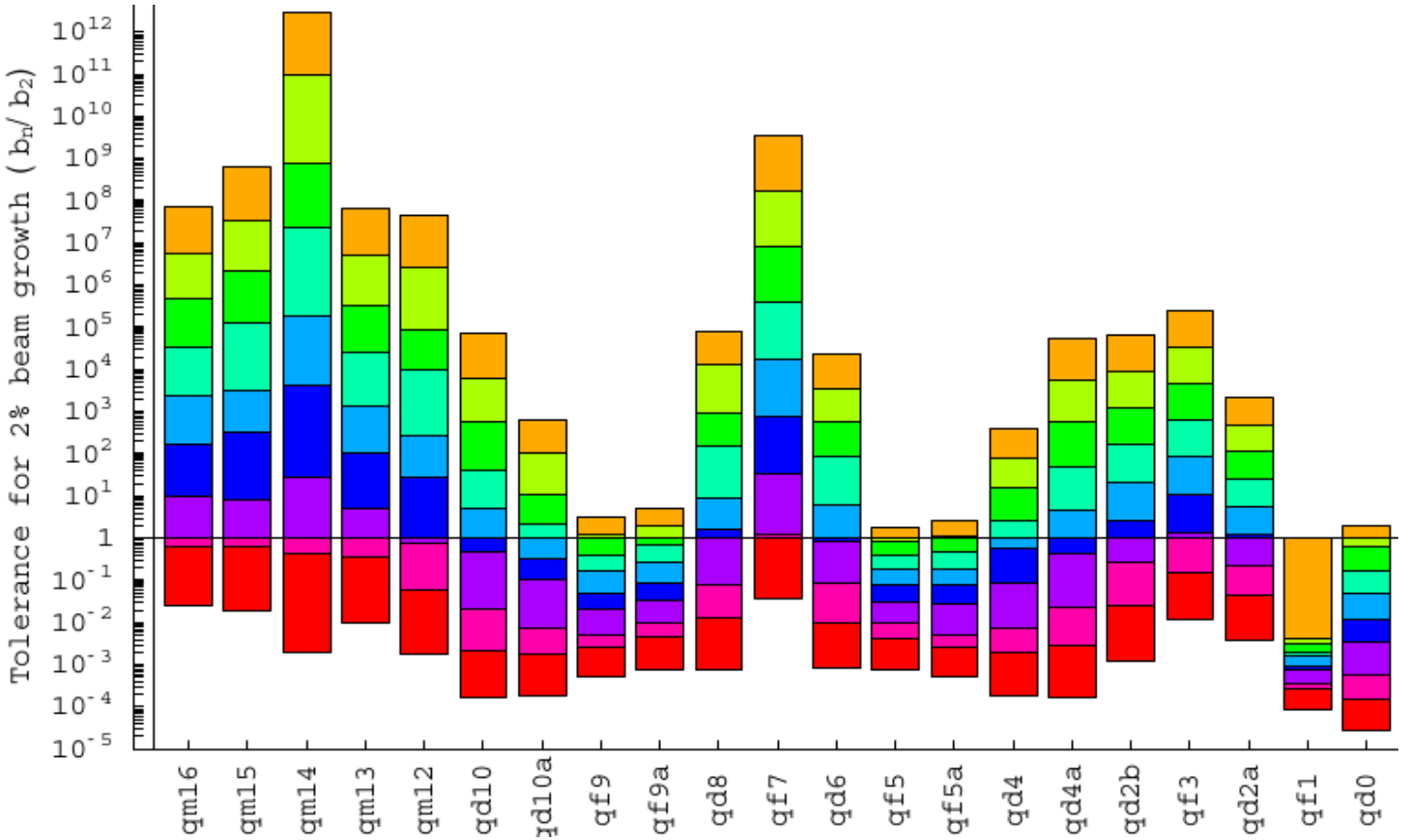
- Micron alignment accuracy ??!!

ATF2 challenges: Quad calibration



- 10^{-5} relative calibration accuracy ??!!

ATF2 challenges: Field quality



These are the quantitative tolerances given for all quads in the ATF2 proposal (SLAC-R-771, 2005)

Table 3.6: Tolerance specifications for the quadrupole magnets.

Order	10	9	8	7	6	5	4	3	2
Normal (10^{-4})	12.0	31.1	5.53	15.7	2.17	5.53	0.516	0.644	0.056
Skew (10^{-4})	4.41	2.66	2.21	1.27	0.941	0.507	0.253	0.117	0.017

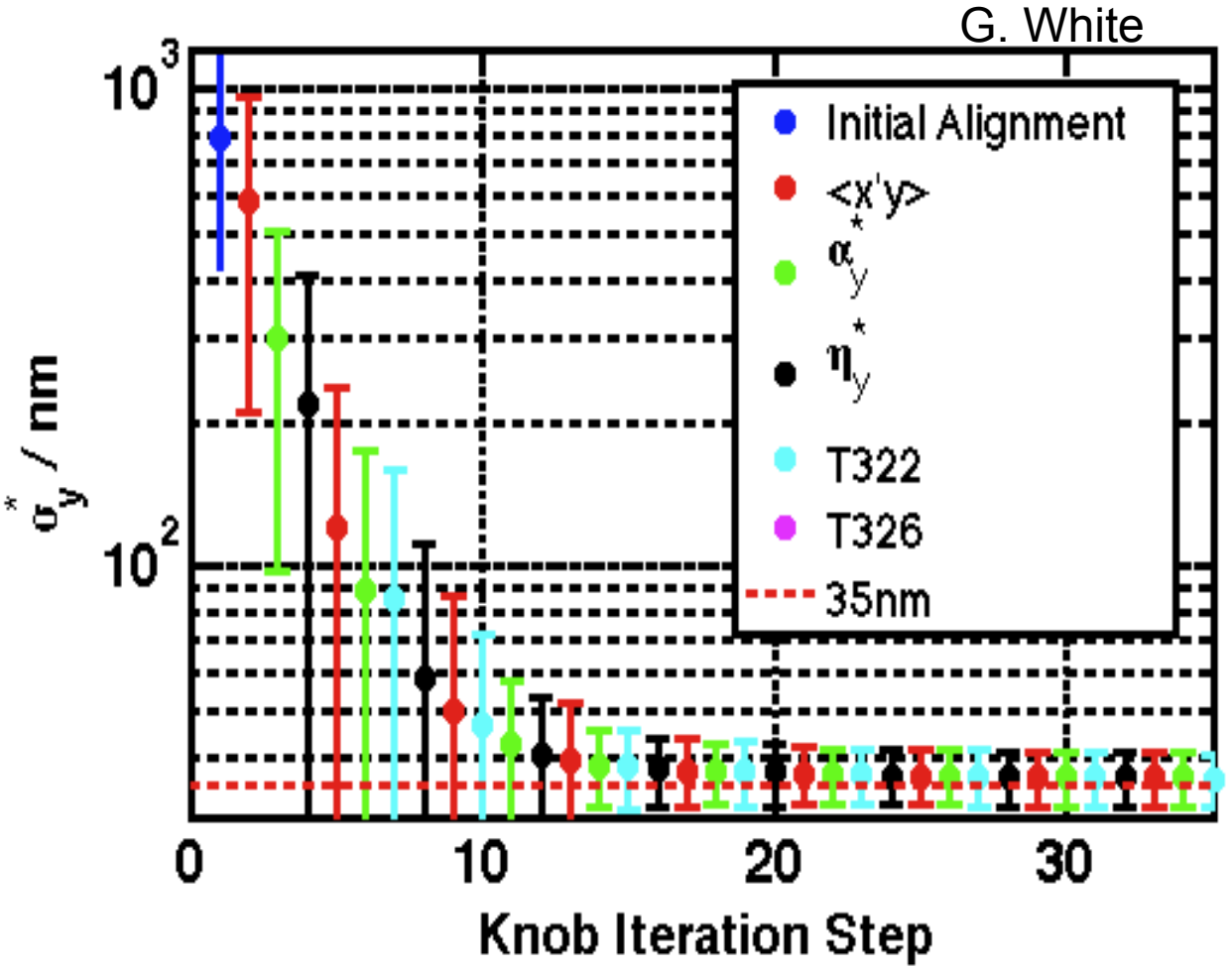
ATF2 challenges: QF1 field quality (more recent)

Tolerances and measurements of magnetic field quality in **10^{-4}** relative units at 1 cm for QF1 **skew** components:

	Sext	Oct	Dec	Dodec
Tolerance	0.09	0.10	0.11	0.11
Measurement	0.28	0.04	0.19	0.76

This newer tolerances are tighter than in 2005 and were not met by QF1!!

ATF2 tuning simulations (excluding multipoles)

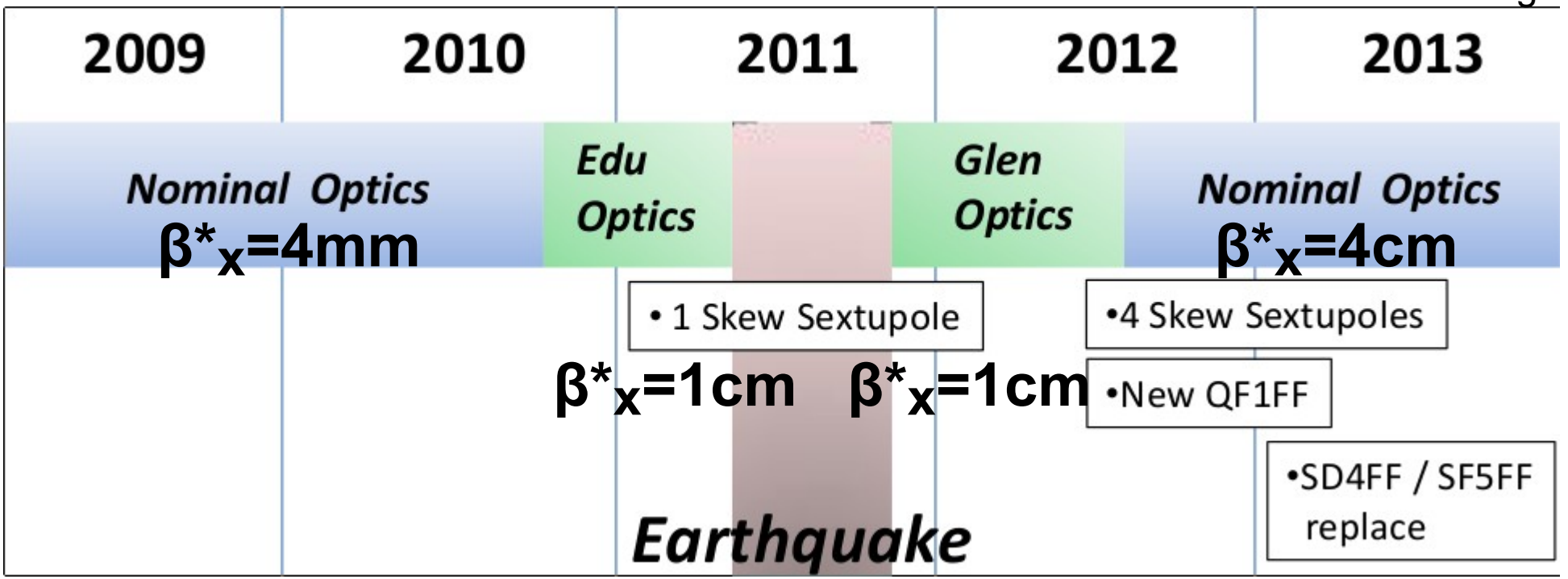


- Tolerances are unachievable
- but we can reduce the beam size step by step using optimized knobs
- Simulations say this works! (again excluding mults)

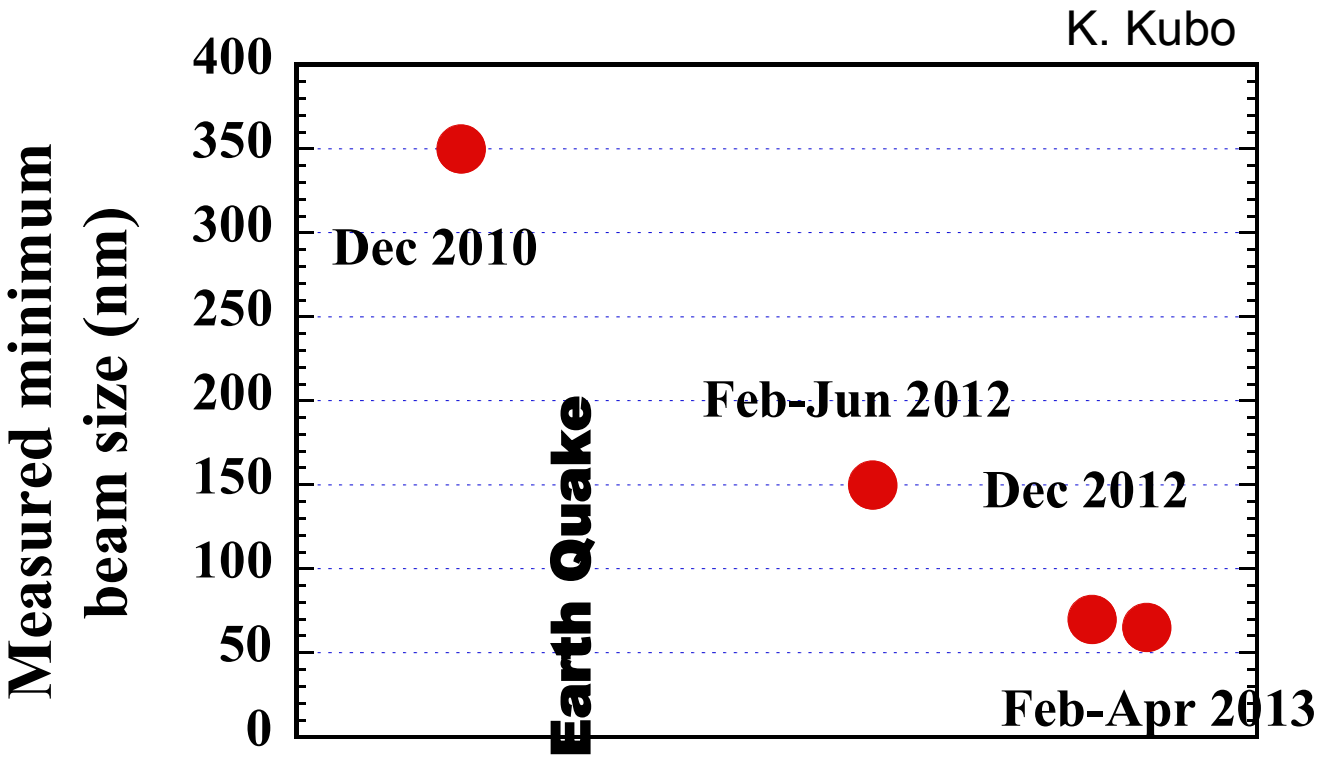
And what do we do with the multipoles?

ATF2 optics history

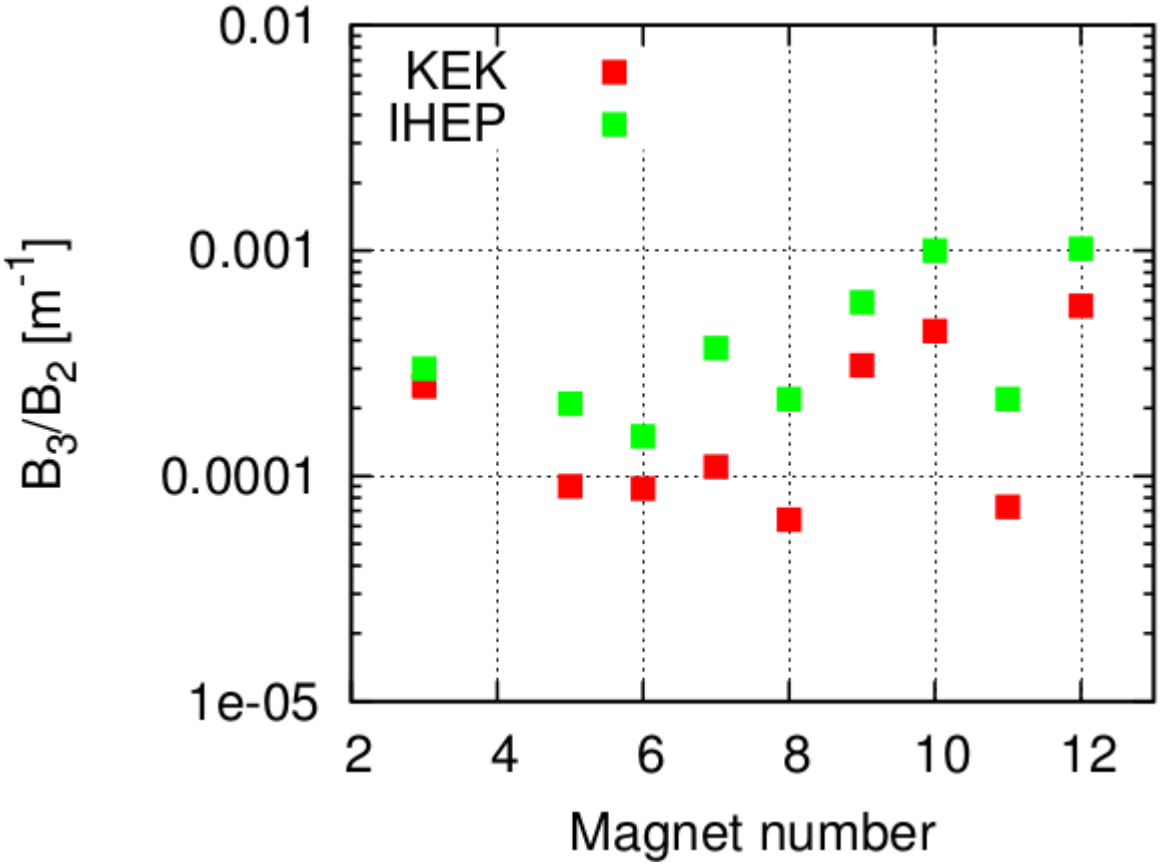
T. Okugi



ATF2 beam size versus time



2007-2011

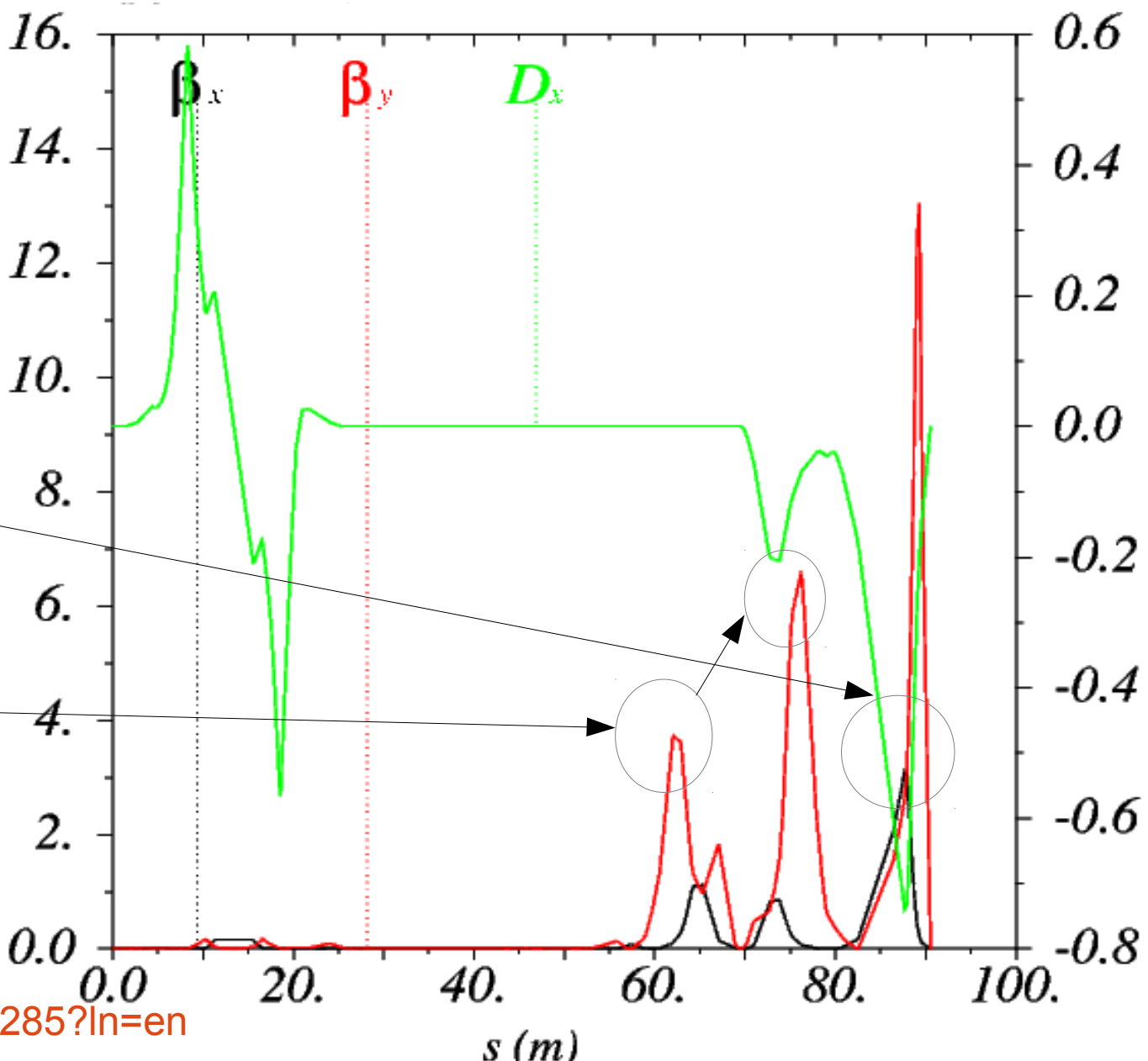


- Large differences in the sextupolar content of quadrupoles from two magnetic measurements

- Feared possible large sextupolar errors. Mitigation was to relax optics by increasing β_x but little!! to avoid spoiling the feasibility demonstration. New skew sextupole installed, SK1.

Dec 2010: Edu's optics

- 1st lattice design considering aberrations, with MAPCLASS
- β^*_x was increased by a factor 2.5, decreasing peak β_x
- Optics tricks were used to mitigate multipolar components



Edu's thesis:

http://cds.cern.ch/record/1504285?ln=en

The new skew sextupole taken from KEKB

SK1 placed between QF5 and QD6

February-March 2012

- Earthquake recovery
- Sextupolar components in quadrupoles from magnetic measurements already clarified by M. Masuzawa:
  http://agenda.linearcollider.org/conferenceDisplay.py?confId=4904
- New optics with similar spirit as Edu's prepared by Glen
- However large xy coupling and huge skew sextupolar aberrations were observed
- Beam size reached 150 nm.
- Limitation was unknown, likely instrumentation.

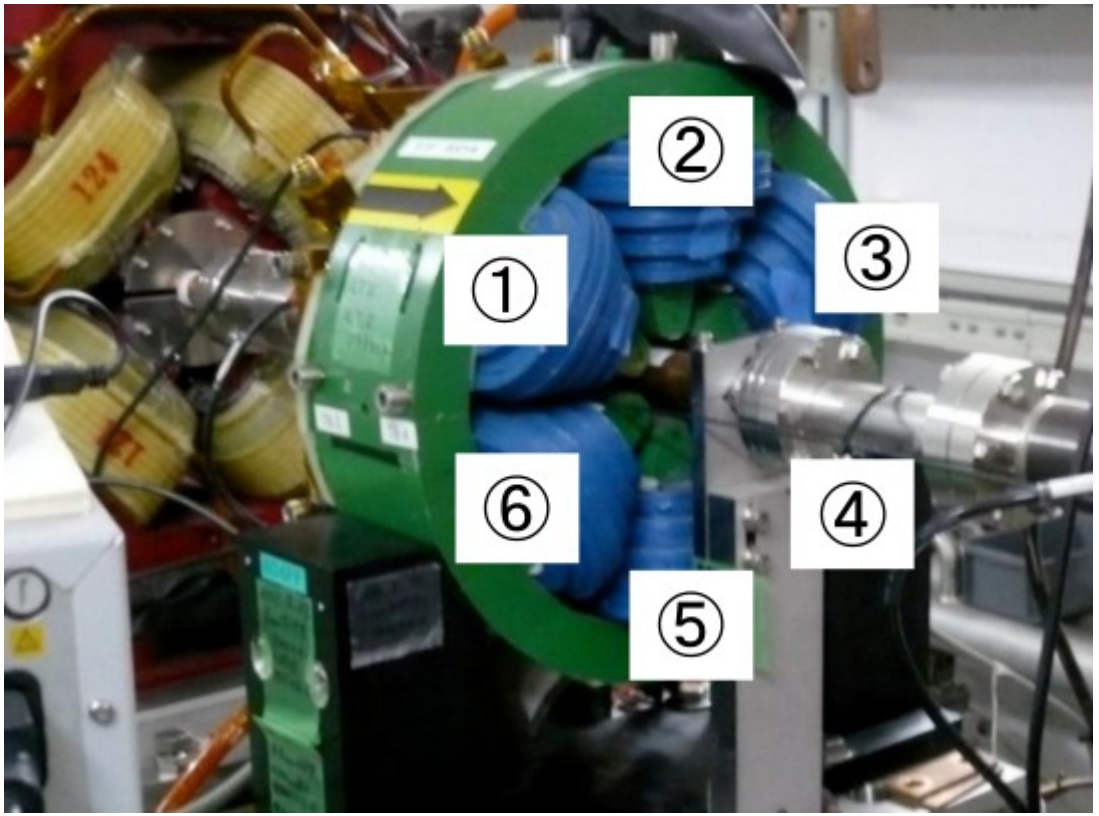
End 2012

- All multipole mitigation measures are taken:
  - QF1 is replaced with a better quality one
  - 4 Skew sextupoles are installed
  - IP β^*_x is increased by a factor 10, to 4cm
- Beam size reaches 73 nm thanks to using 4 new skew sextupoles
- This leads to localizing a problem in SD4FF !
  T. Okugi:

  https://agenda.linearcollider.org/conferenceOtherViews.py?view=standard&confId=5973

SD4FF, the broken sextupole

- SD4FF had lower current in pole 5!
- This generated a skew quadrupole field
- which generated skew sextupole aberrations



2013

- SD4FF is replaced
- Beam size reaches 60 nm
- Candidates for remaining beam size error:
  - Limitations of the IP beam size monitor
  - Beam orbit jitter
  - Remaining multipolar aberrations
- ***Stay tuned for the December run!***

Lessons from ATF2

- Exhaustive evaluation of tolerances in the design phase is needed
  - Although main problem observed so far was a broken sextupole
  - The new QF1 allows to reduce beam size to 26-28 nm!
- Knowledge of magnetic field quality is fundamental
  - This involves good magnetic measurements and
  - A reliable database both for magnet and beam dynamics people (*communication!!!*)
- The unforeseen will happen
  - Beam instrumentation will be fundamental
  - Be ready for compromises, new equipment, etc.