IPAC11

Beam optics developments for SPS, RHIC, LHC, CLIC and ATF2

R. Tomas, CERN

EPS-AG Sacherer Prize

CERN

RHIC relativistic heavy ion collider

BROOKHAVEN NATIONAL LABORATORY

CLIC

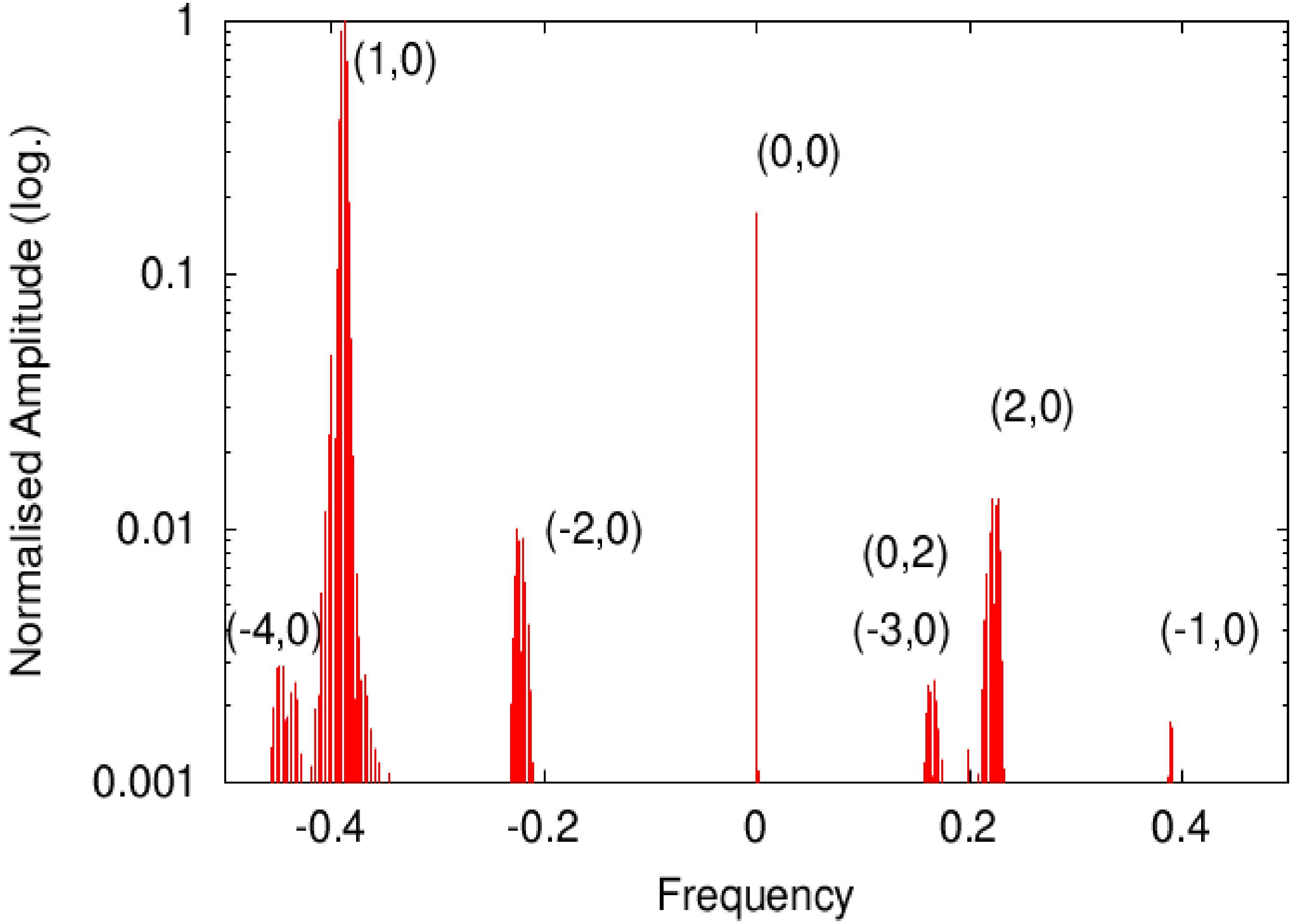
ATF

ACCELERATOR TEST FACILITY

Contents

- LHC: Achieving 10% β-beating
  - Measurement techniques, AC dipole, Local and Global corrections, segment-by-segment technique.
- SPS & RHIC: A journey to the Resonance Driving Terms (RDTs)
  - Longitudinal behavior of RDTs, effects of beam decoherence, local RDTs.
- CLIC & ATF2: Focusing to the smallest possible
  - MAPCLASS, Ultra-low β* proposal in the ATF2.

Spectrum of bunch turn-by-turn motion



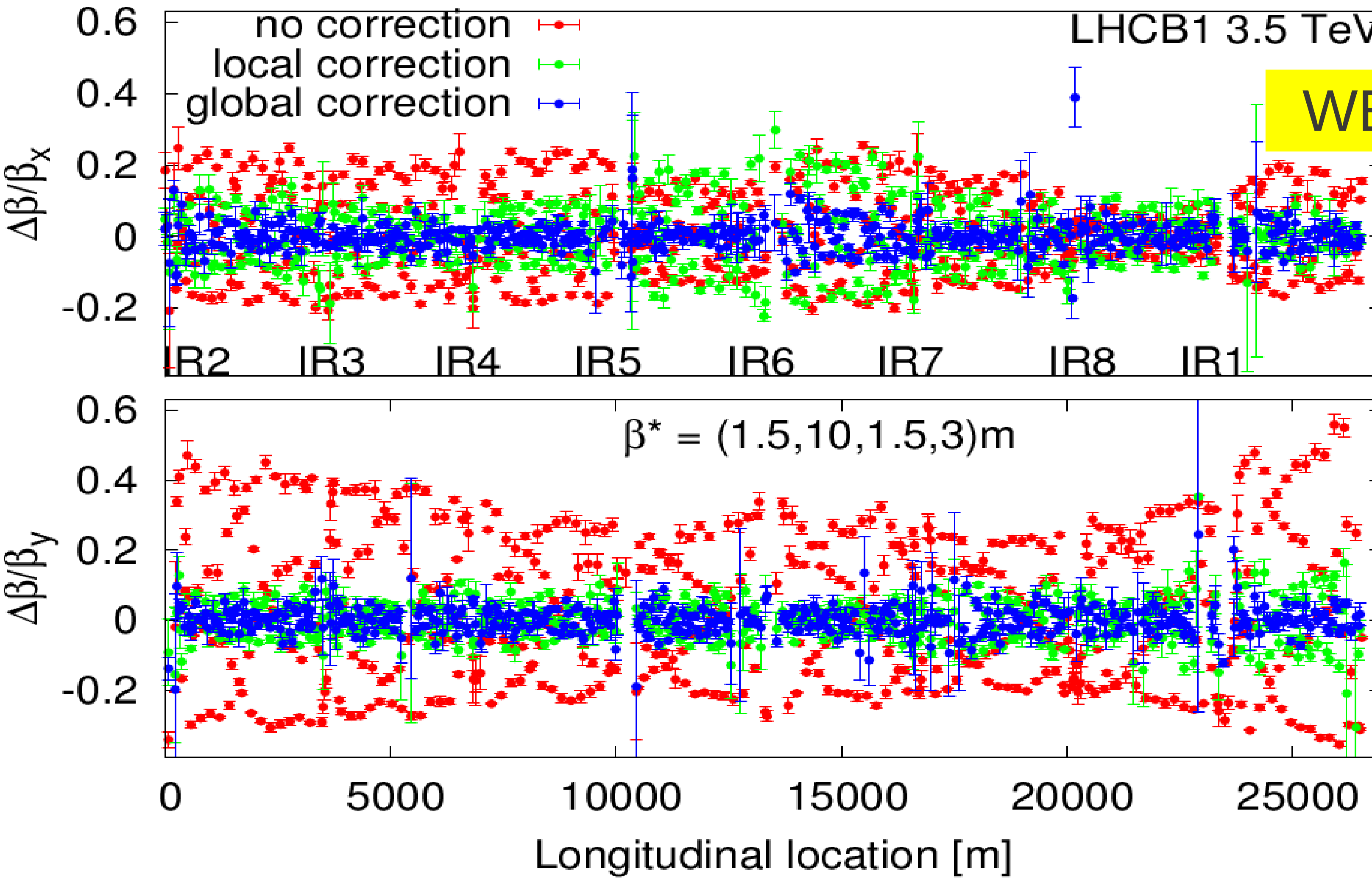
Qx (±1,0)
Linear optics

2Qx (±2,0), (0,0)
Sextupoles

3Qx (-3,0),(±1,0)
Octupoles

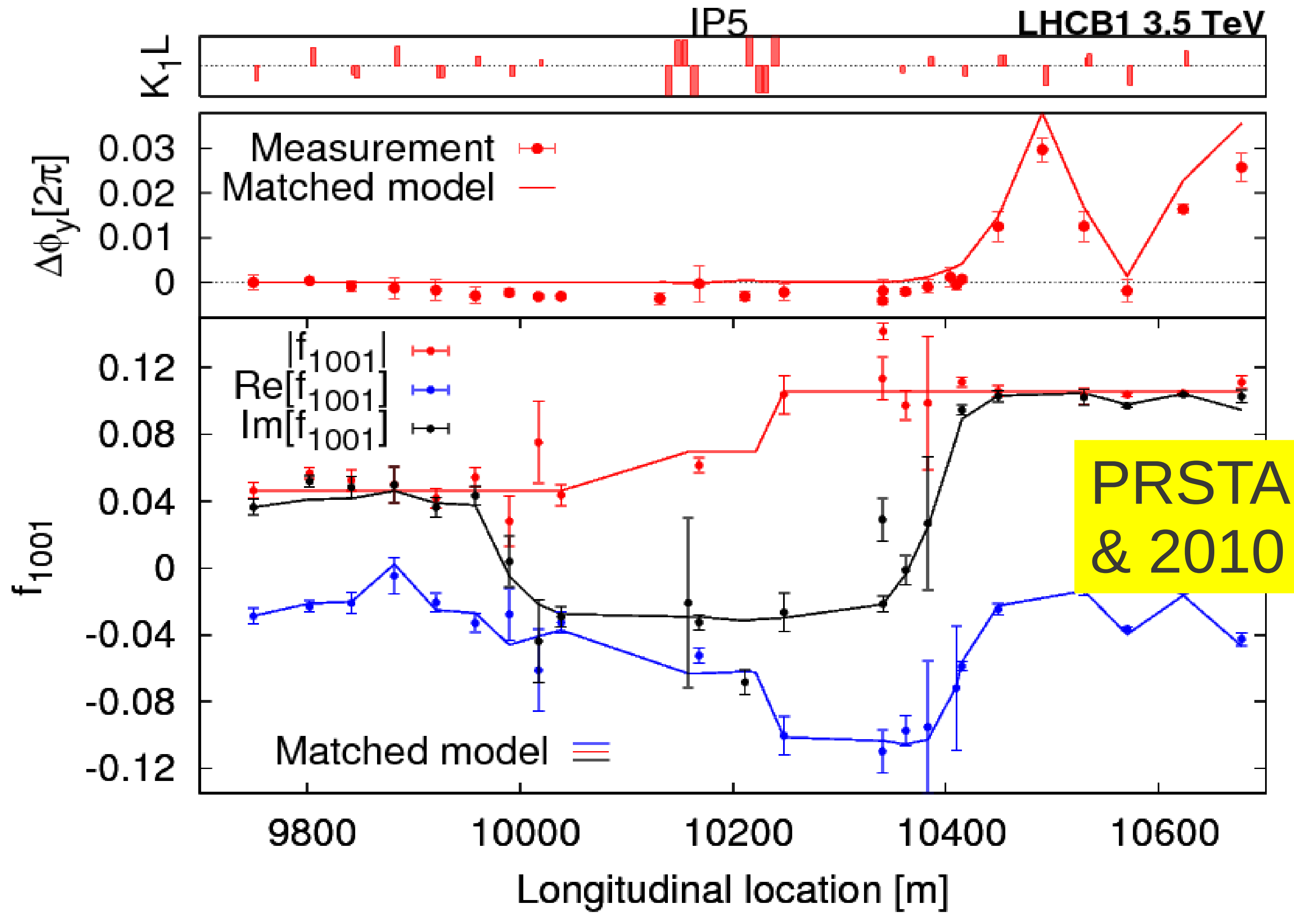
4Qx (-4,0), (0,0)
Decapoles

LHC: Achieving 10% β-beating



WEPC028

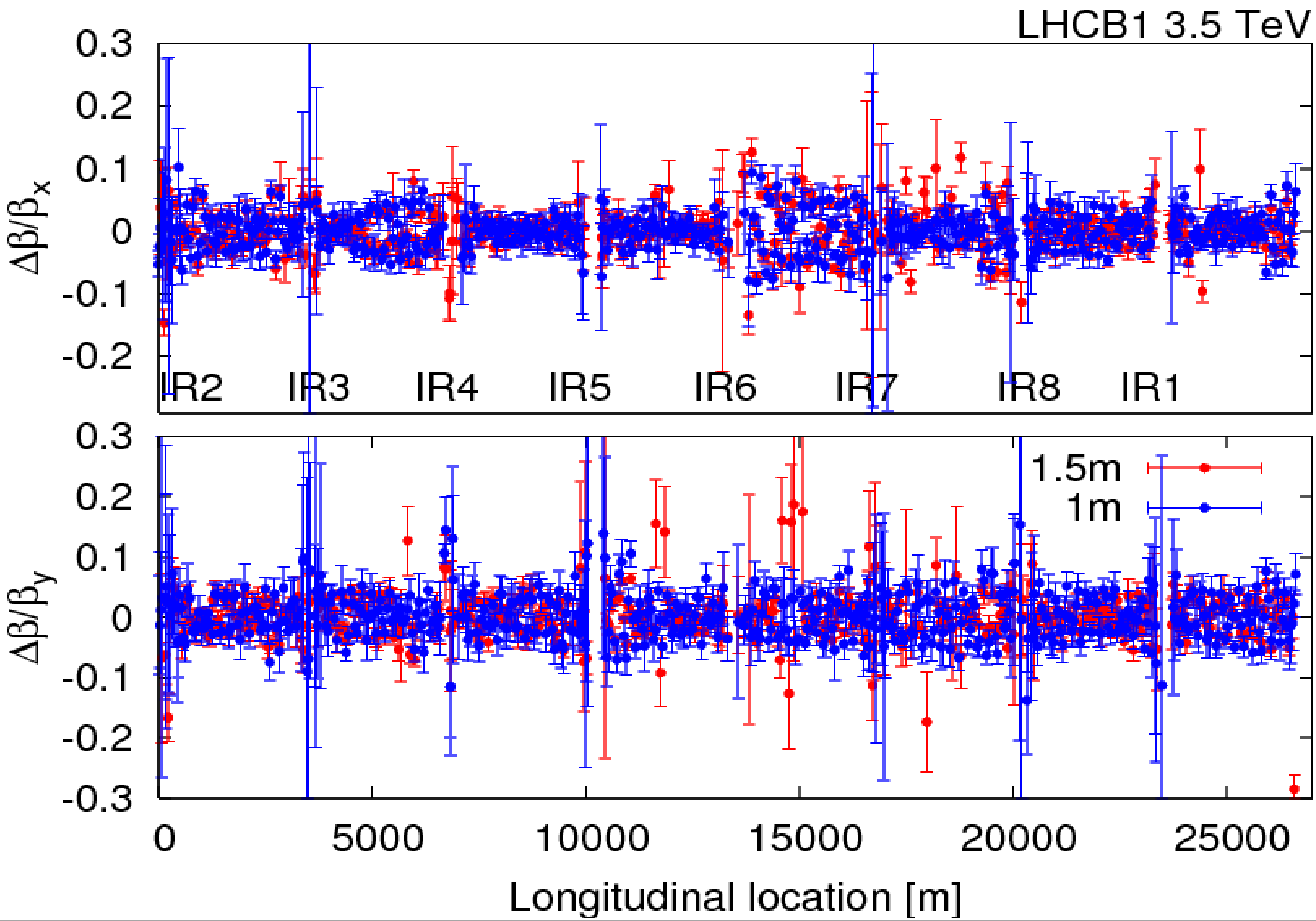
Segment-by-segment technique



PRSTAB 2009 & 2010

Precise local corrections

Commissioning of β*=1m (on-going)

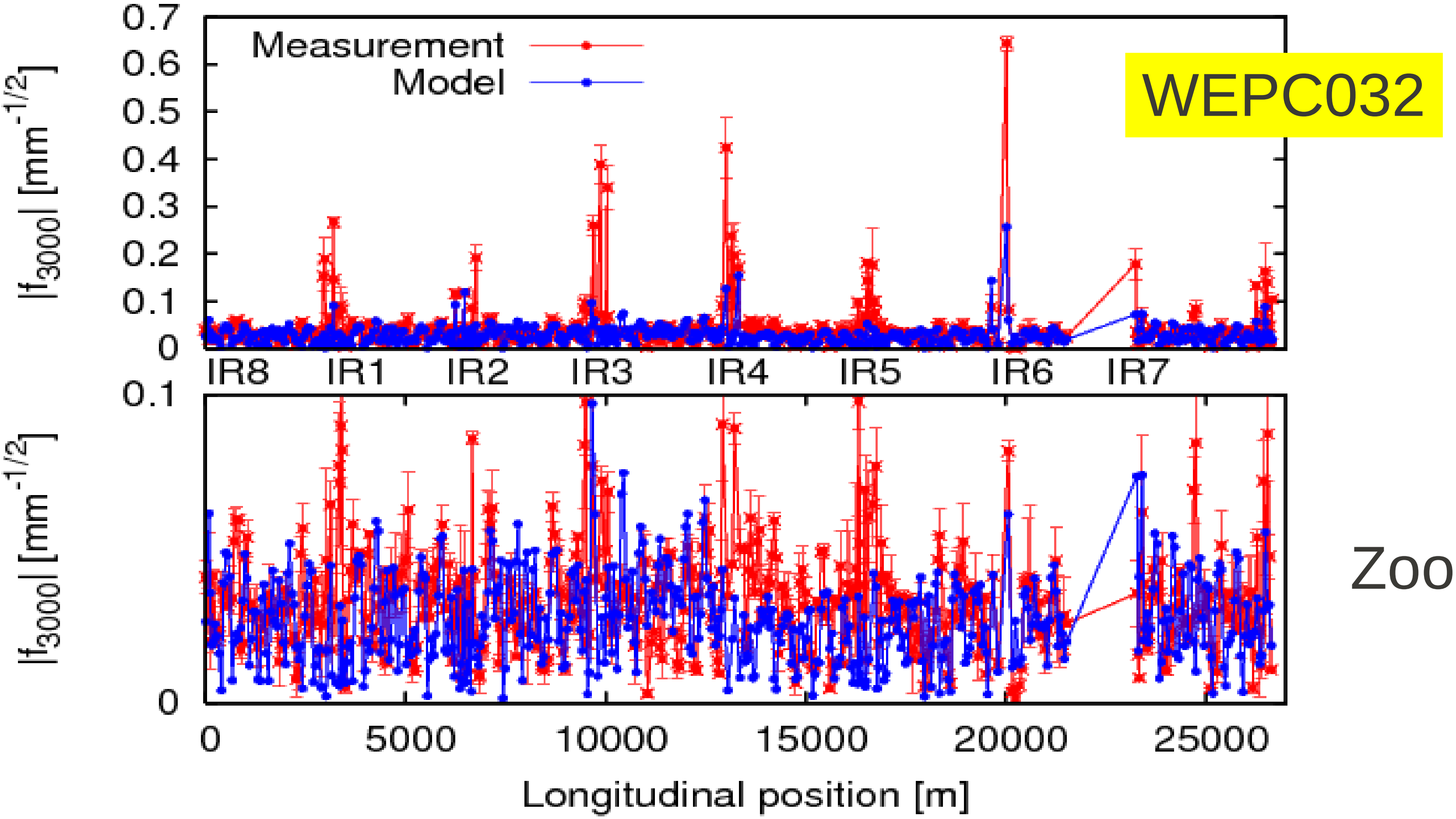


- Same corrections as for β*=1.5m, same β-beat!

10% β-beating in the LHC:
“The cherry on top of the cake”

- Appropriate field quality specifications
- Elaborate magnet model
- Optimized magnet installation (sorting)
- Complete and flexible controls
- Excellent instrumentation (AC dipole, BPMs, etc)

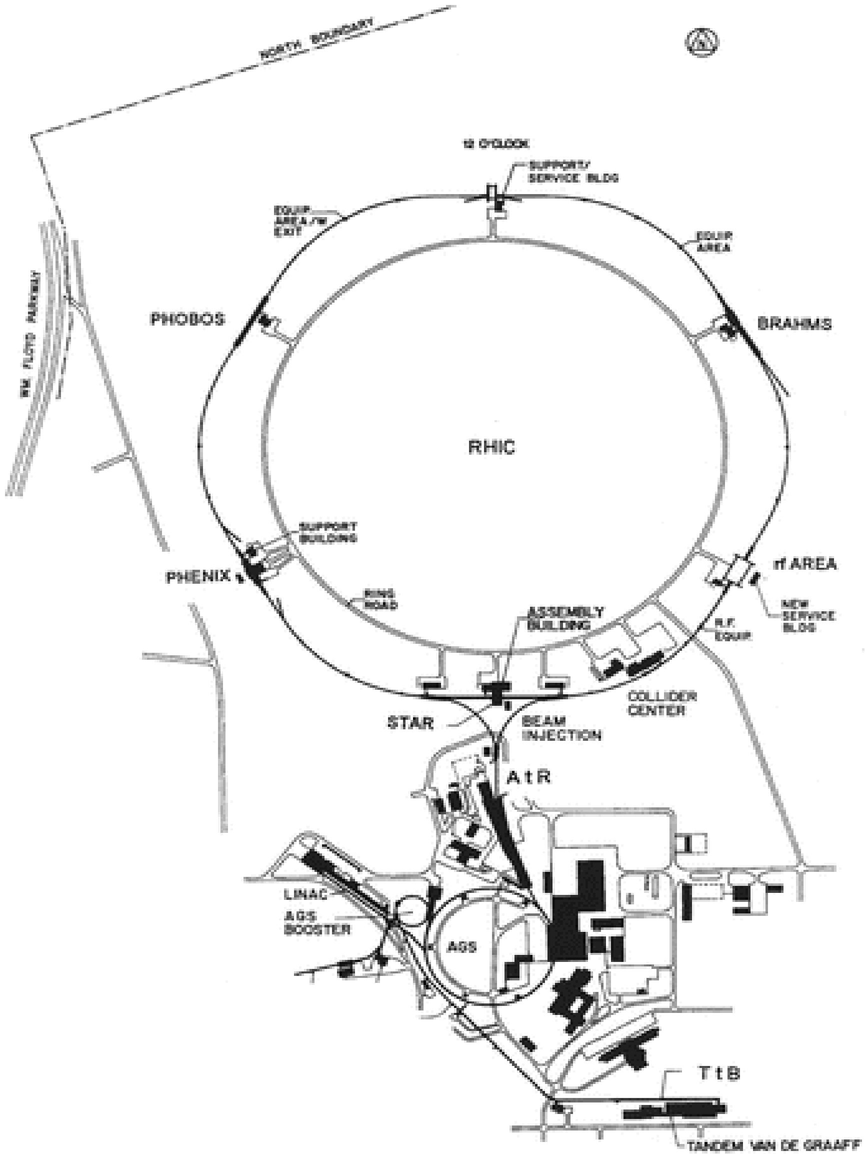
Very first LHC measurement of f_{3000}

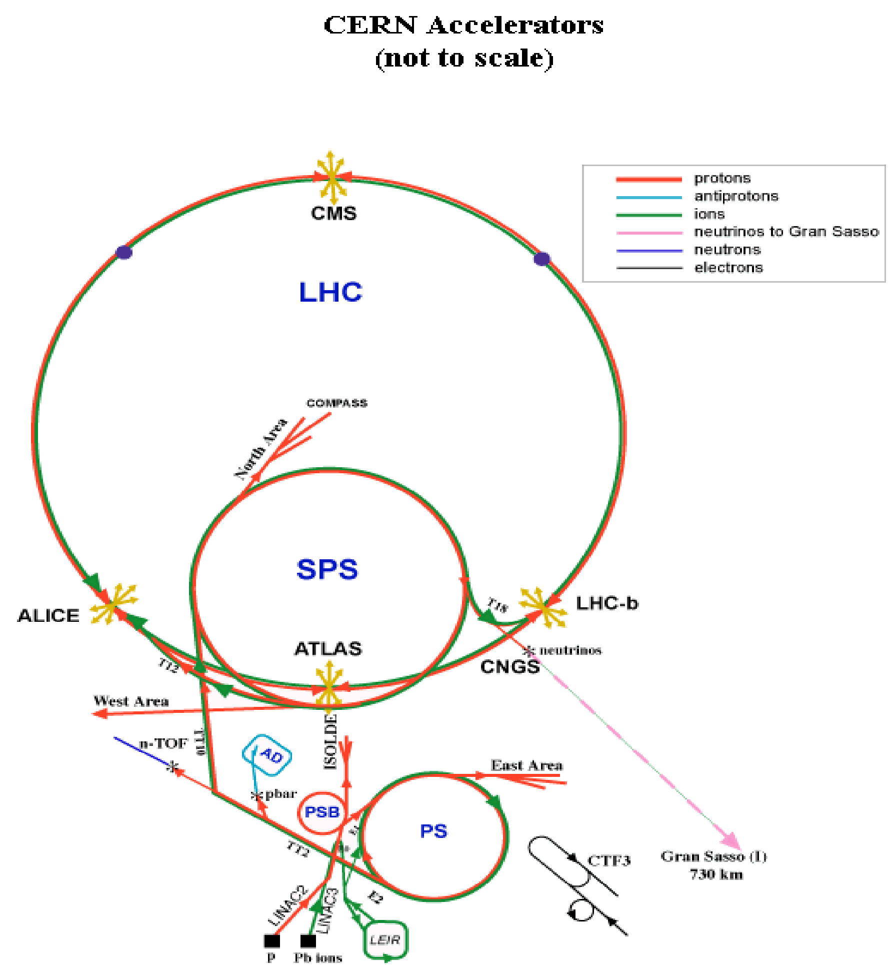


Zoom

Very promising for future adjustments of non-linear beam dynamics in the LHC

RHIC & SPS



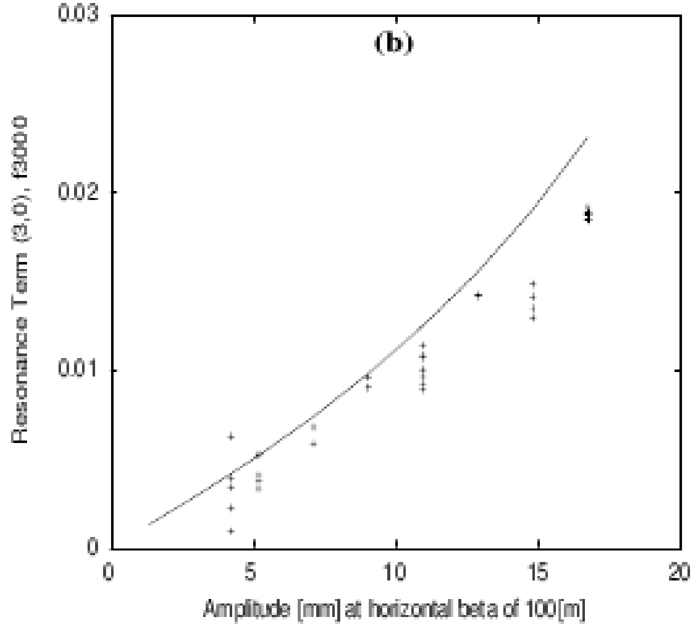


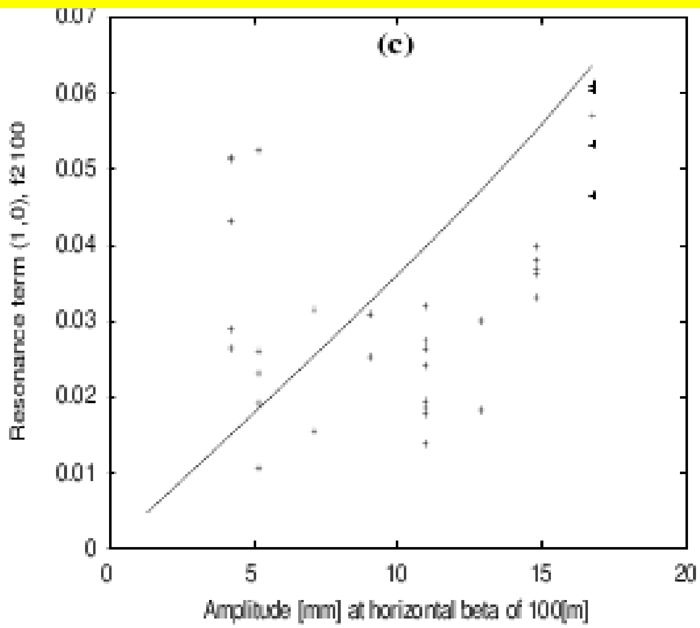
LHC: Large Hadron Collider
SPS: Super Proton Synchrotron
AD: Antiproton Decelerator
ISOLDE: Isotope Seperator OnLine DEvice
PSB: Proton Synchrotron Booster
PS: Proton Synchrotron
LINAC: LINear ACcelerator
LEIR: Low Energy Ion Ring
CNGS: Cern Neutrinos to Gran Sasso

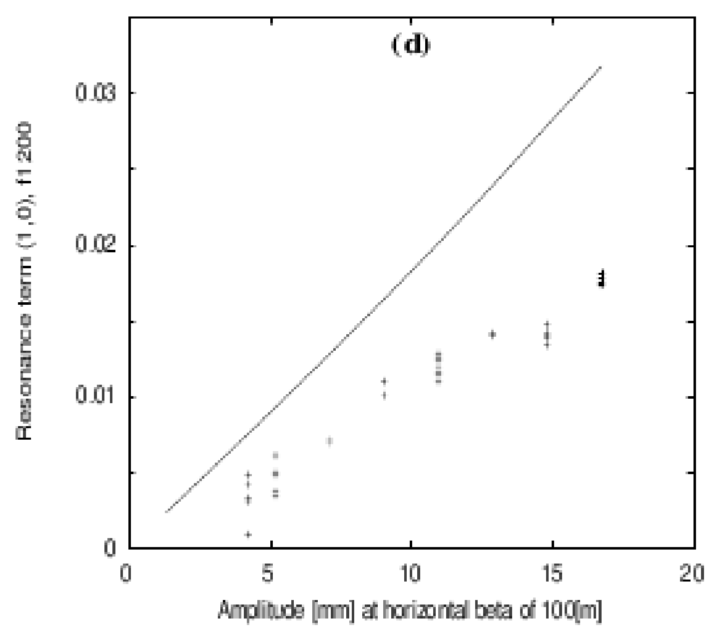
First measurement of RDTs - SPS

R. Bartolini,
L. Leunissen,
Y. Papaphilippou,
F. Schmidt &
A. Verdier.

PAC 1999



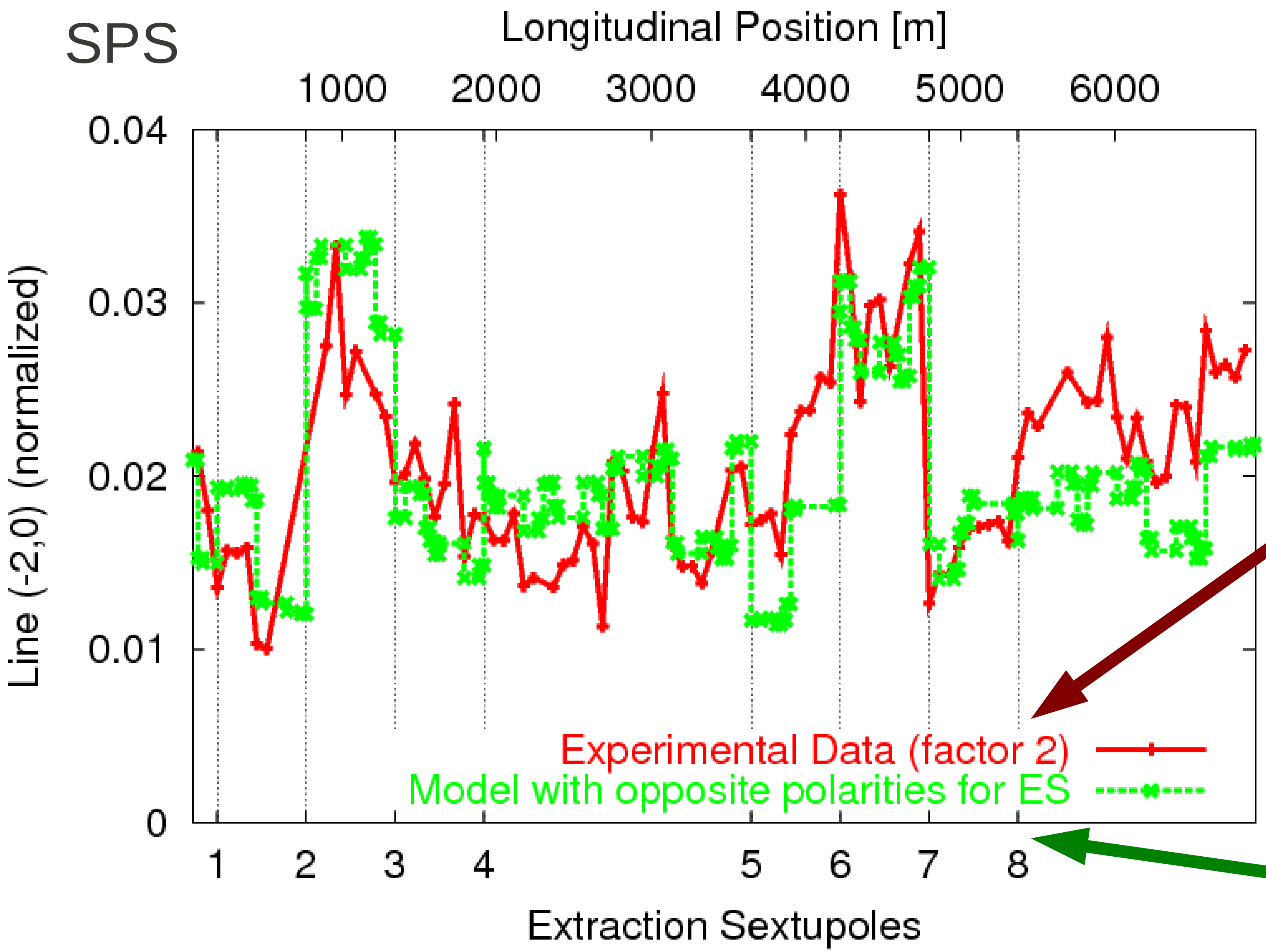




Let's get a PhD student...

First f_{3000} measurement around a ring

SPS



Factor 2?

Opposite polarities!

R. Tomas PhD 2003, supervisors: A. Faus-Golfe, F. Schmidt

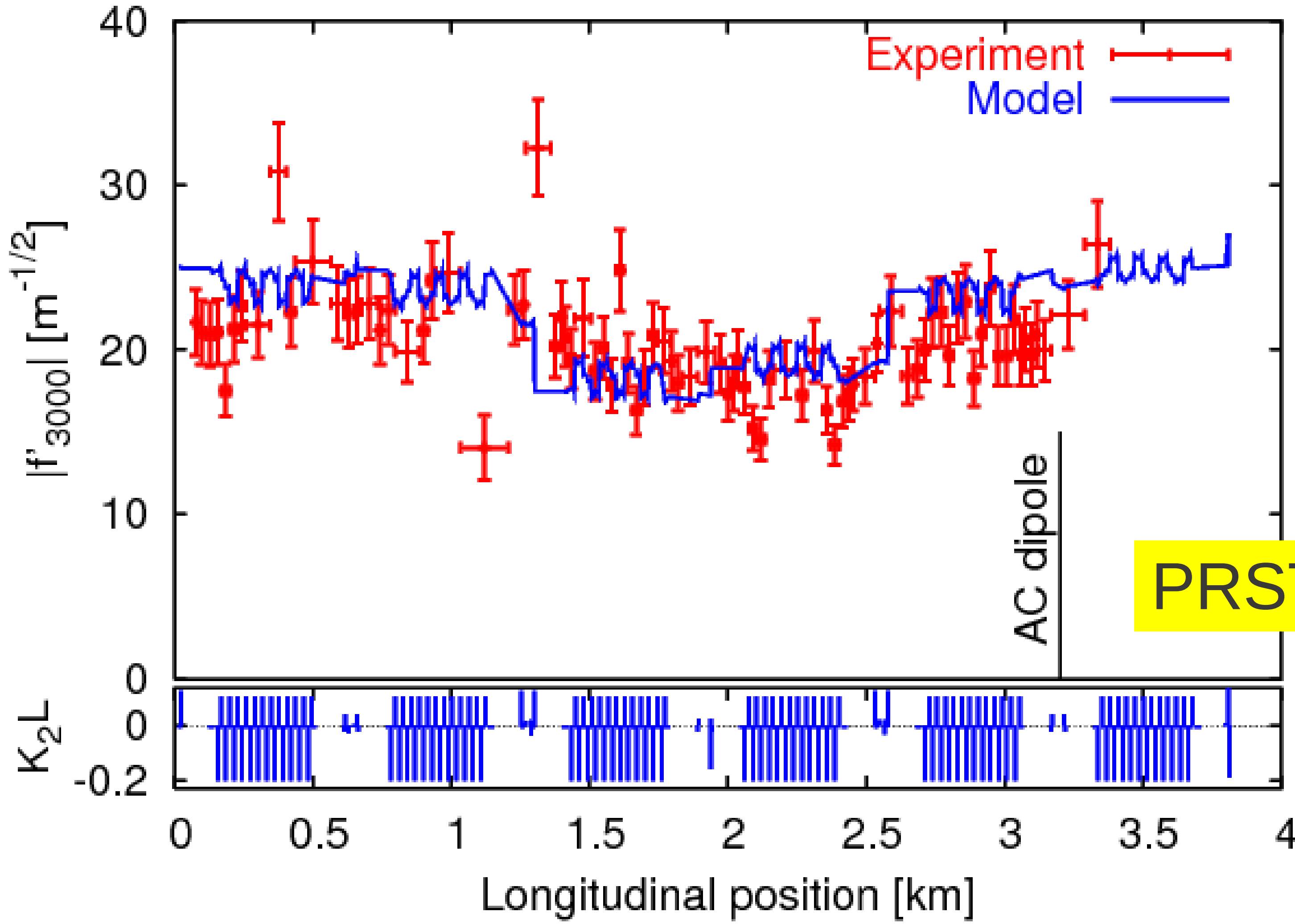
Understanding the RDTs measurement and beyond

- Longitudinal variation:

$$F^{(2)} = A_2 M_1^{-1} A_1^{-1} F^{(1)} - A_2 h_1$$

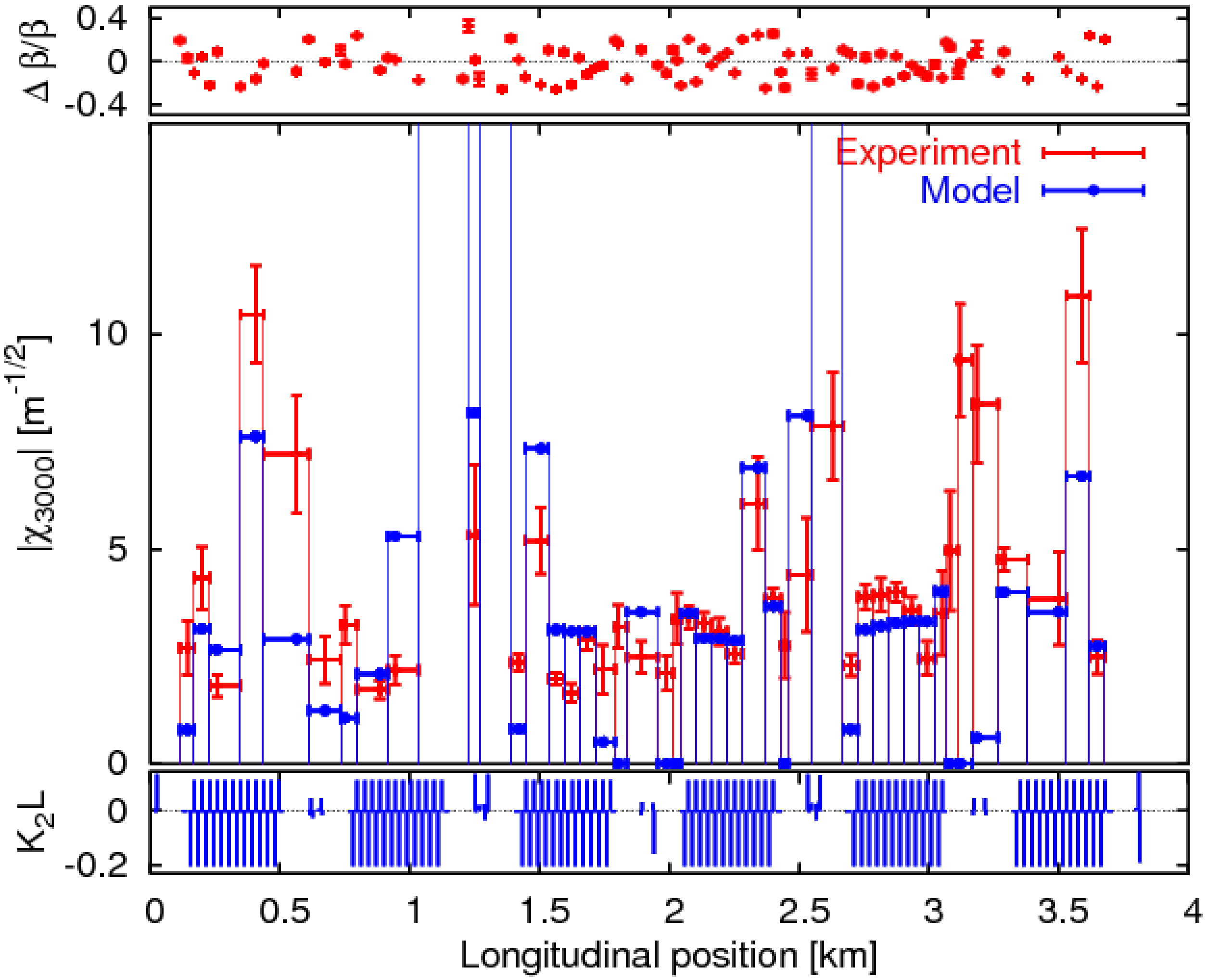
- The SPS extraction sextupoles have opposite polarity to that of the lattice sextupoles.
- Decoherence factors: The spectral line(m,0) is reduced by a factor |m|
- A. Franchi extracted sextupole strengths from RDTs
- R. Bartolini demonstrated sextupolar RDTs correction in DIAMOND (10% lifetime icrease)

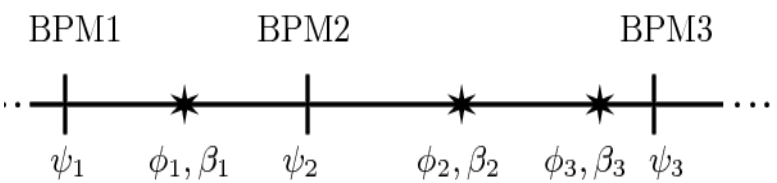
First f_{3000} measurement with an AC dipole - RHIC



PRSTAB 2005

Local RDTs – First RHIC measurement

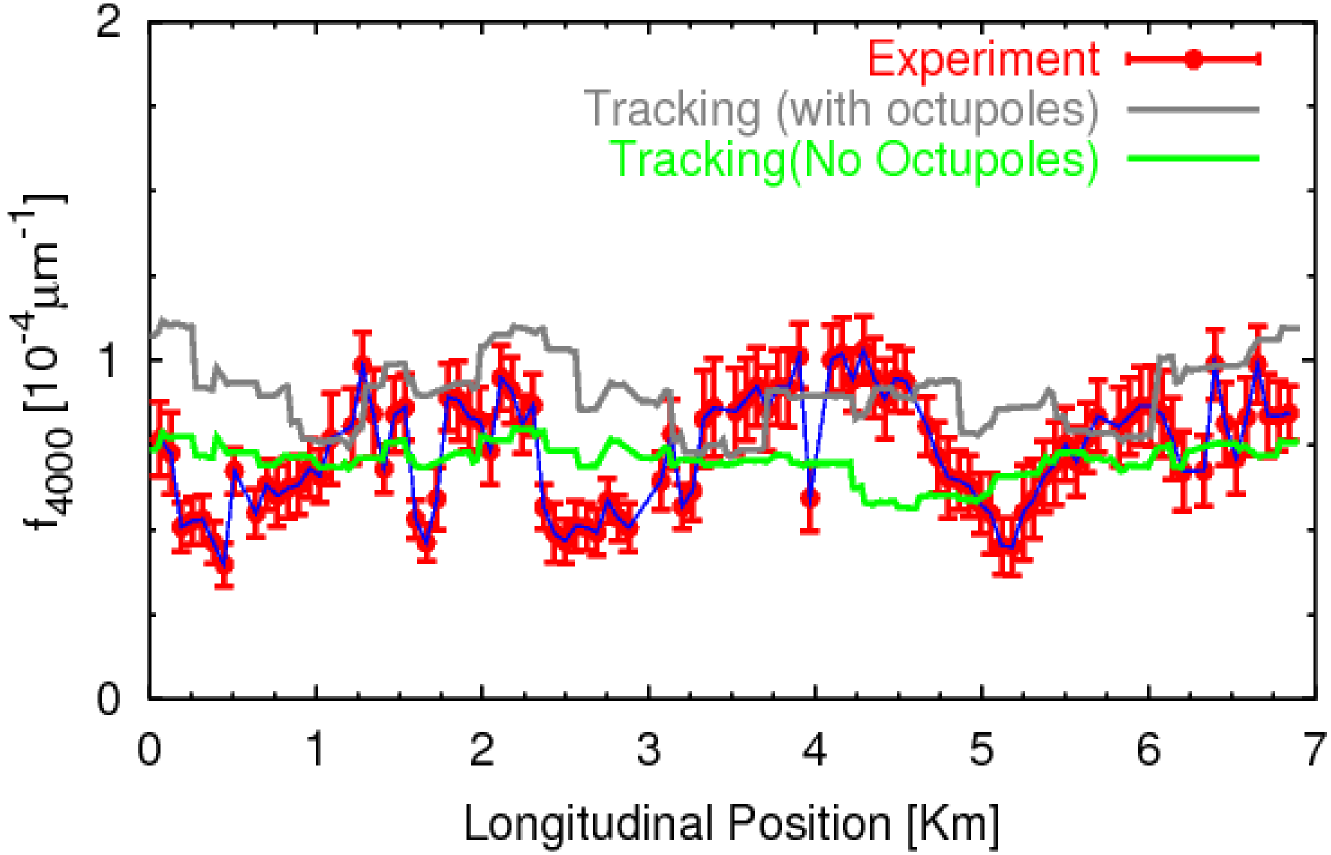




$$\psi_2 - \psi_1 = \pi/2 + \delta_1 \ , \qquad \psi_3 - \psi_2 = \pi/2 + \delta_2$$

$$\chi(N) = \frac{\hat{x}_1(N)}{\cos \delta_1} + \hat{x}_2(N)\big(\tan \delta_1 + \tan \delta_2\big) + \frac{\hat{x}_3(N)}{\cos \delta_2}$$

The challenge: Higher orders

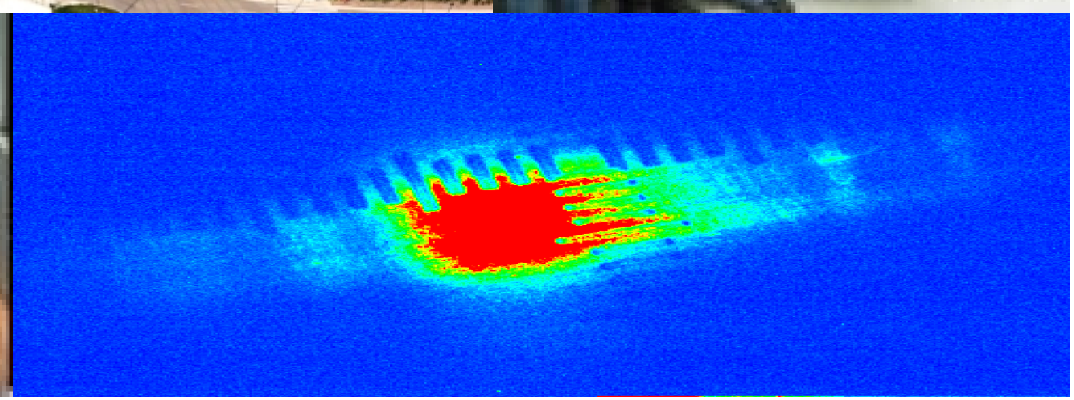


SPS f_{4000}, Q=0.25

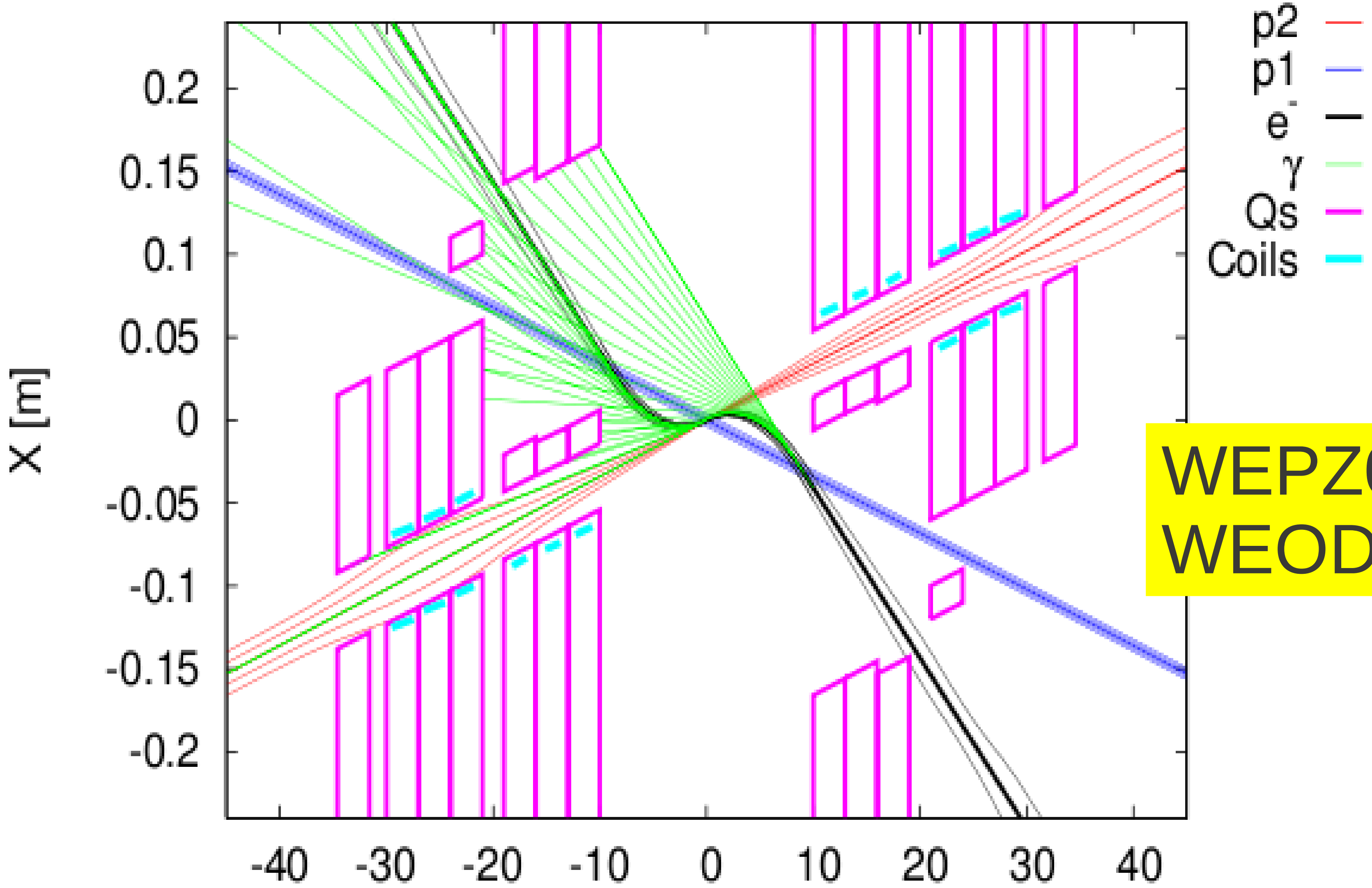
- Small signal, further decreased by decoherence
- Shadowed by “feed-up” and
- BPM calibration (L. Nadolski showed for SOLEIL)

Congratulations to ALBA!



LHeC Linac-Ring IR design



WEPZ013
WEODA03

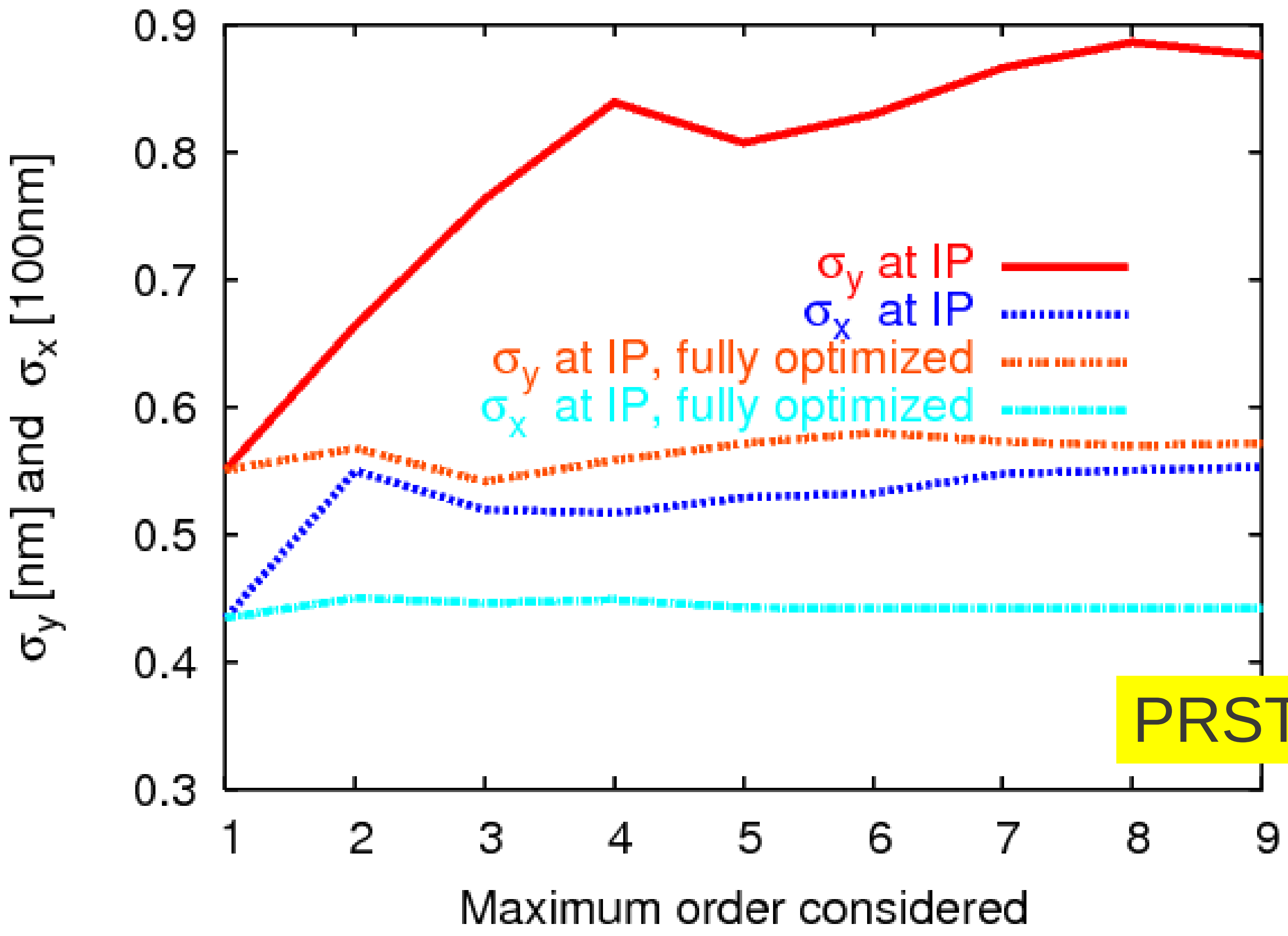
Final Focus optimization

$$x_{IP} = \sum_{jklmn} X_{jklmn}\, x_0^j\, p_{x0}^k\, y_0^l\, p_{y0}^m\, \delta_0^n$$

$$< x_f^2 > \;=\; \sum_{\substack{jklmn \\ j'k'l'm'n'}} X_{jklmn} X_{j'k'l'm'n'} \times \int x_0^{j+j'}\, p_{x0}^{k+k'}\, y_0^{l+l'}\, p_{y0}^{m+m'}\, \delta_0^{n+n'} \rho_0 dv_0$$

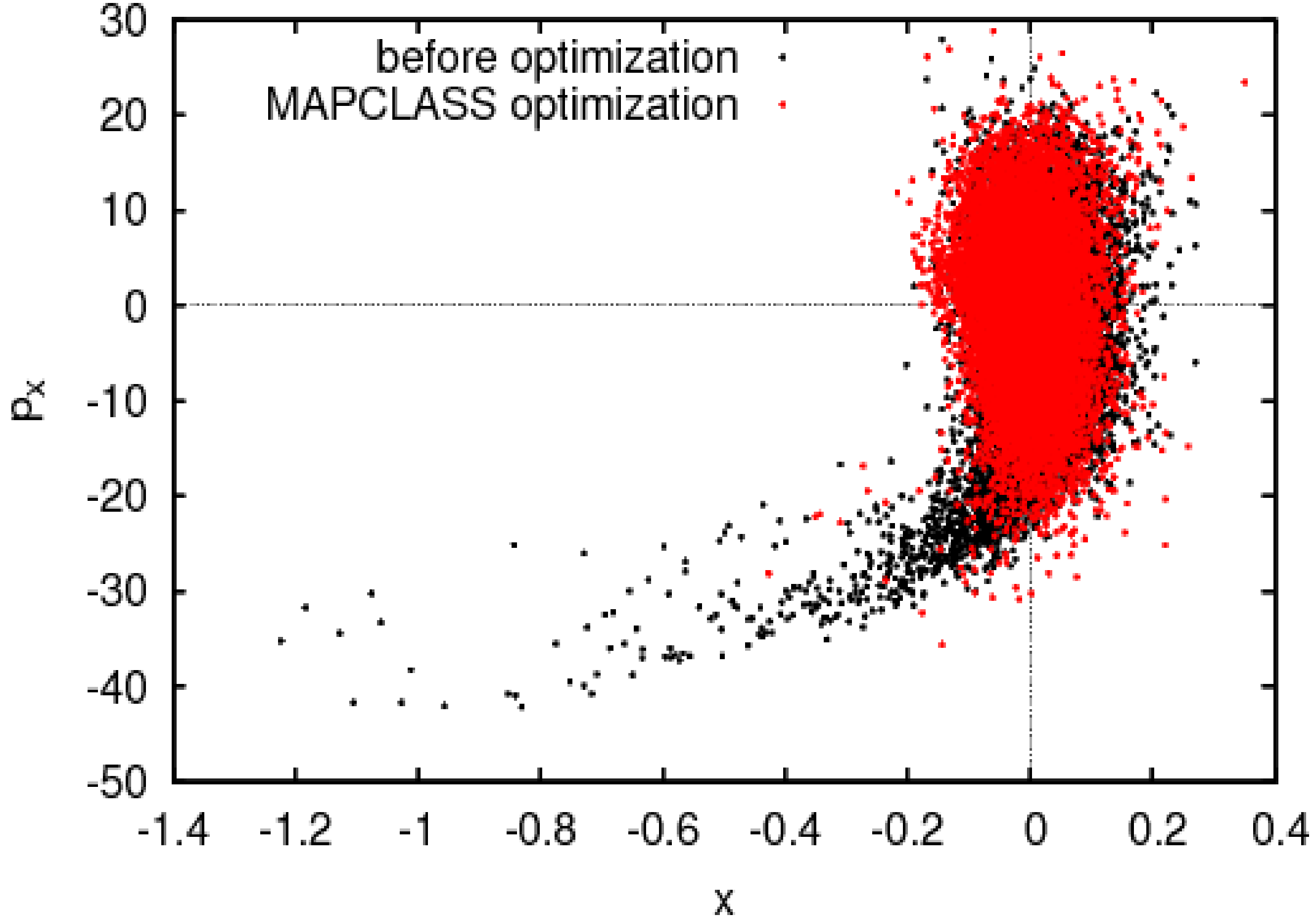
- Lattice description in MADX
- PTC provides $\boldsymbol{X}_{jklmn}$ terms to any order
- MAPCLASS computes IP rms beam sizes
- Higher orders can be matched as β-functions.

CLIC FFS optimization



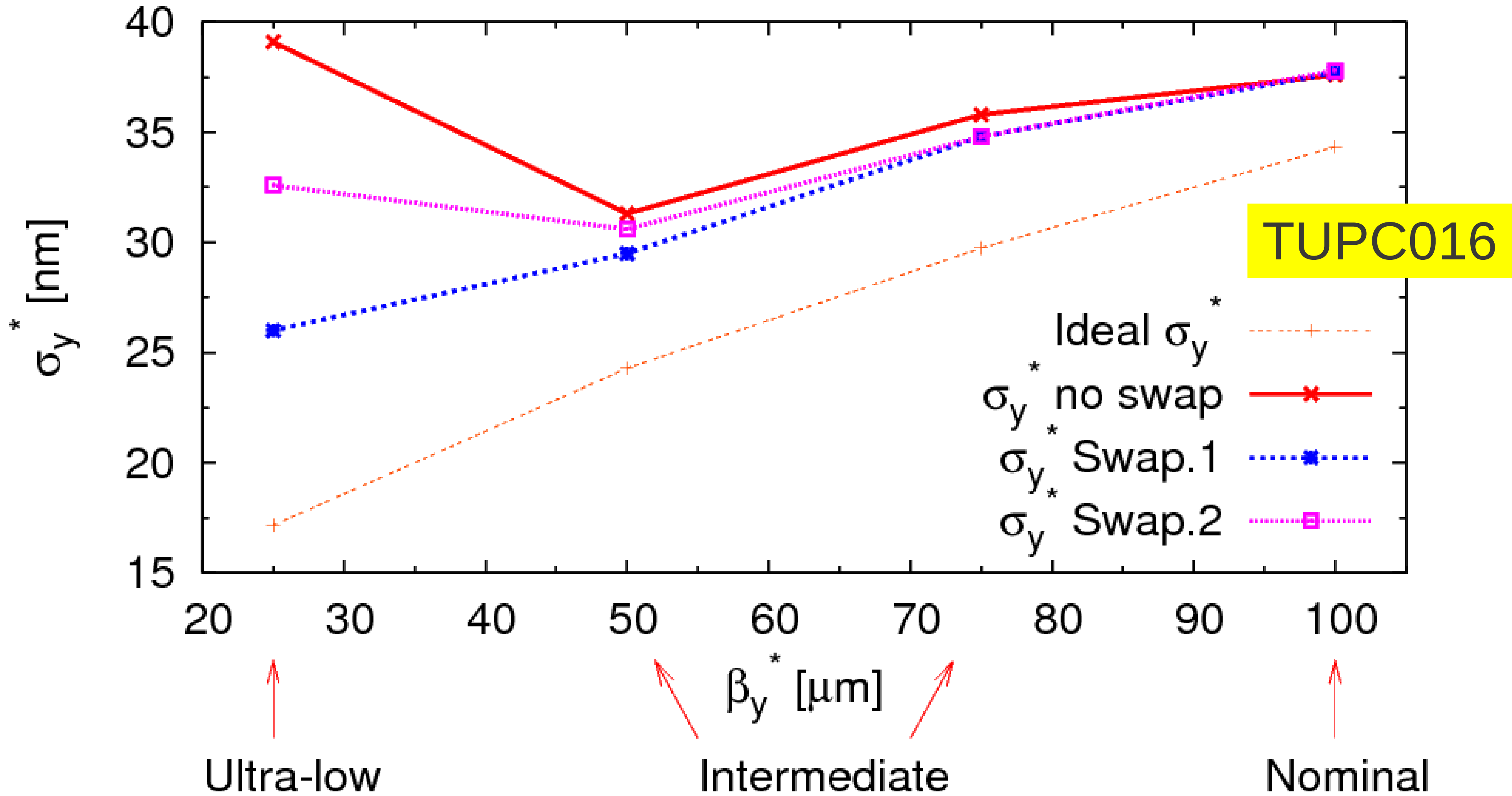
PRSTAB 2006

CLIC FFS optimization



- The “comma” shape disappeared
- Luminosity increased by 70%

Reaching σ^*_y=20nm in ATF2 (or 3)



- Main limitation to reach 20nm is FD field quality: CERN may contribute an accurate quadrupole.

Thanks!

Angeles Faus Golfe, Frank Schmidt, Francesco Ruggiero, Oliver Bruning, Gianluigi Arduini, Giovanni Rumolo, Rama Calaga, Andrea Franchi, Mei Bai, Steve Peggs, Thomas Roser, Wolfram Fischer, Javier Cardona, Masamitsu Aiba, Ryoichi Miyamoto, Massimo Giovannozi, Frank Zimmermann, Giulia Pappoti, Glenn Vanbavinckhove, Mike Lamont, Verena Kain, Laurent Nadolski, Max Klein, Daniel Schulte, Roberto Corsini, Eduardo Marin, Jean-Pierre Delahaye, Junji Urakawa, **etc**

..and to my wife and my other 2011 prize