DAΦNE Experience with Negative Momentum Compaction Factor

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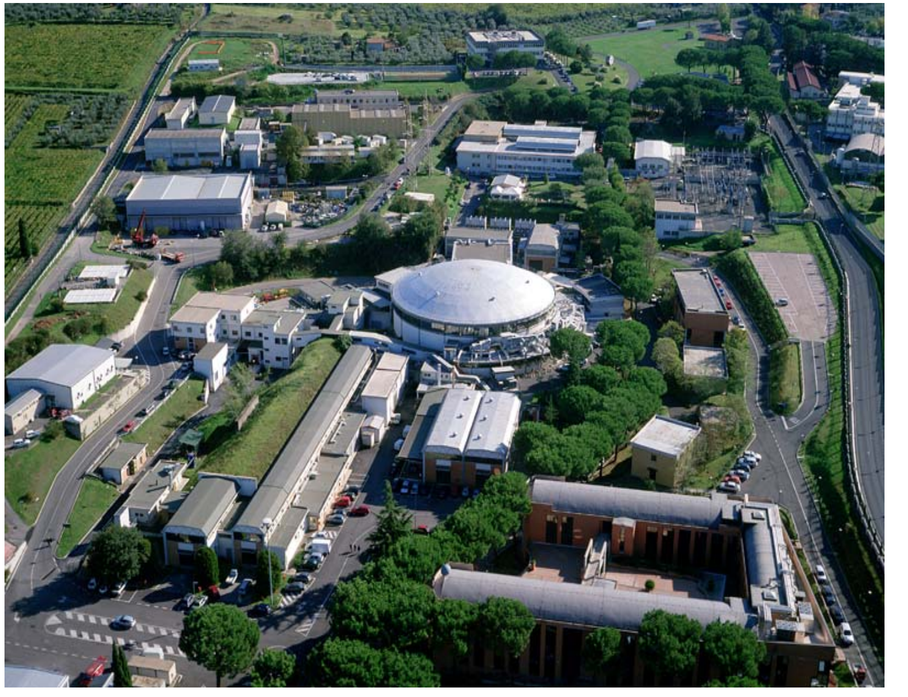
10th European Particle Accelerator Conference
EPAC06, Edinburgh, UK - June 26-30, 2006

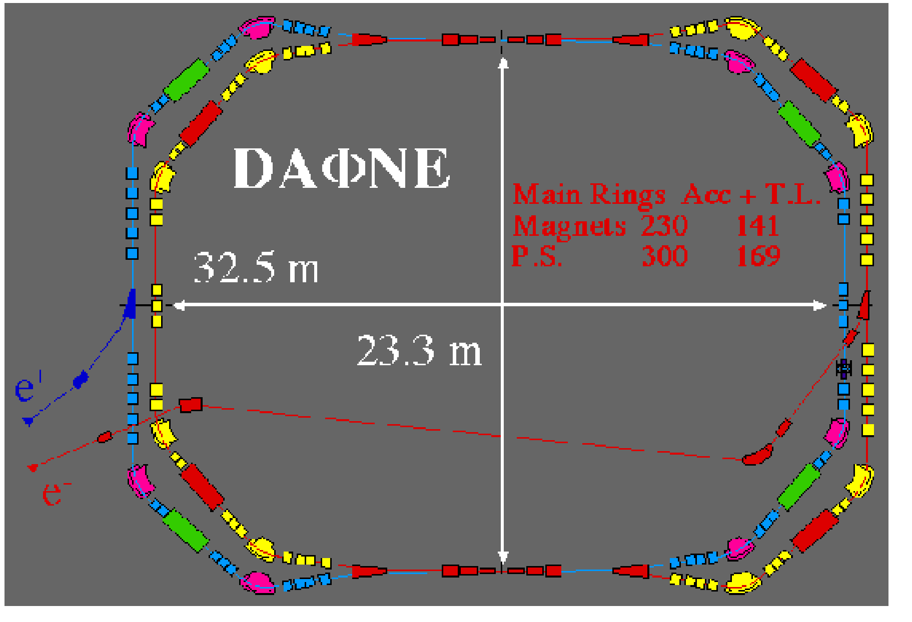
OUTLINE

- DAΦNE and potential advantages of $\alpha_c<0$
- Lattice Modifications
- Beam Dynamics
  a) Bunch Shortening
  b) High Current Multibunch Operation
  c) First Beam-Beam Collisions
- Limitations and Ways to Overcome Them

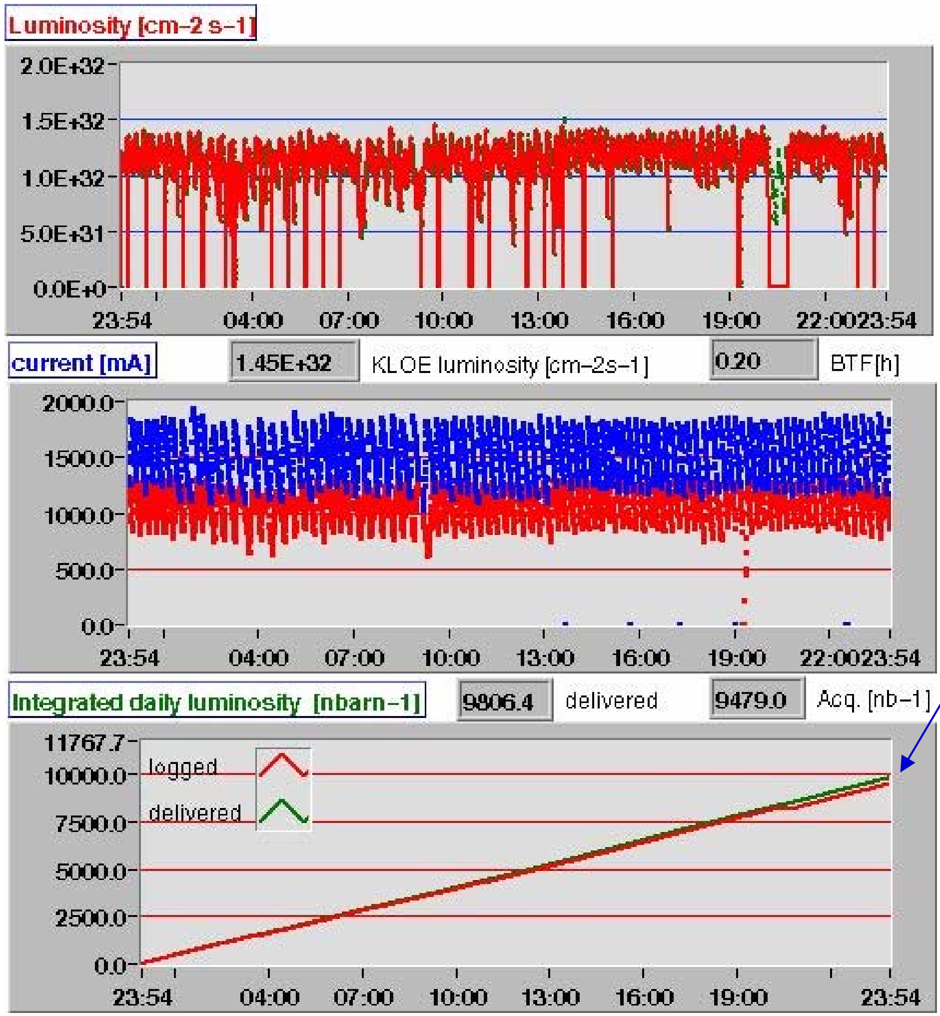
DAΦNE Parameters
(KLOE configuration)

Energy, GeV	0.51
Circumference, m	97.69
RF Frequency, MHz	368.26
Harmonic Number	120
Damping Time, ms	17.8/36.0
Bunch Length, cm	1-3
Emittance, mmxmrad	0.34
Coupling, %	0.2-0.3
Beta Function at IP, m	1.7/0.017
Max. Tune Shifts	.03-.04
Number of Bunches	111
Max.Beam Currents, A	2.4/1.4





Best Daily Integrated Luminosity



10 pb^{-1}/day

A. Gallo et al., "DAΦNE Status Report" → MOPLS028

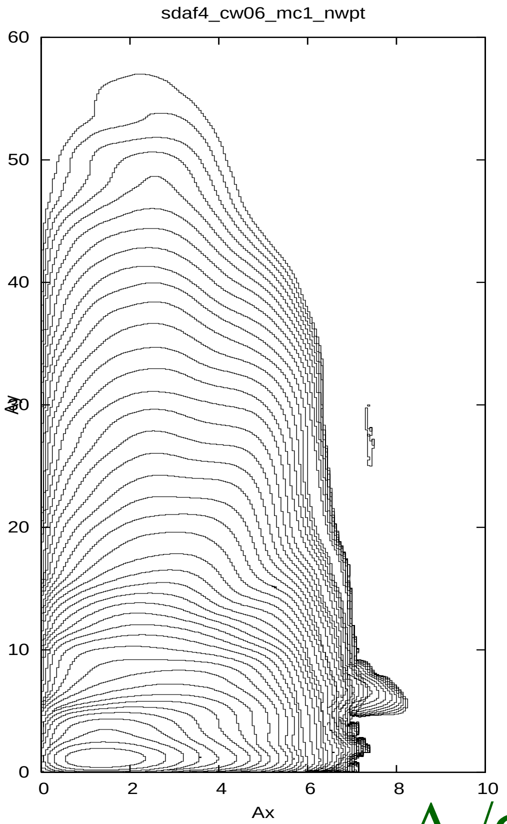
Potential Advantages for a Collider

- Shorter bunch -> Higher luminosity
  - L scales with $1/\sigma_z$ if $\beta_{x,y}$ are reduced proportionally to σ_z
  - Piwinski's angle ('badness factor') $\theta = \phi\ \sigma_z/\sigma_x$ is lower
- Longitudinal beam-beam effects are less dangerous *(V. V. Danilov et al., HEACC 1992)*
  - No coherent and incoherent instabilities
  - Synchro-betatron resonances
- Single bunch is stable with negative 'natural' chromaticity *(100 mA in SuperAco without sextupoles)*
  - Lower sextupole strenghts -> larger dynamic aperture
  - Higher instability thresholds

Beam-Beam Tails in DAΦNE with Crabbed Waist (proposed by P. Raimondi)

$\alpha_c > 0$

A_y/σ_y

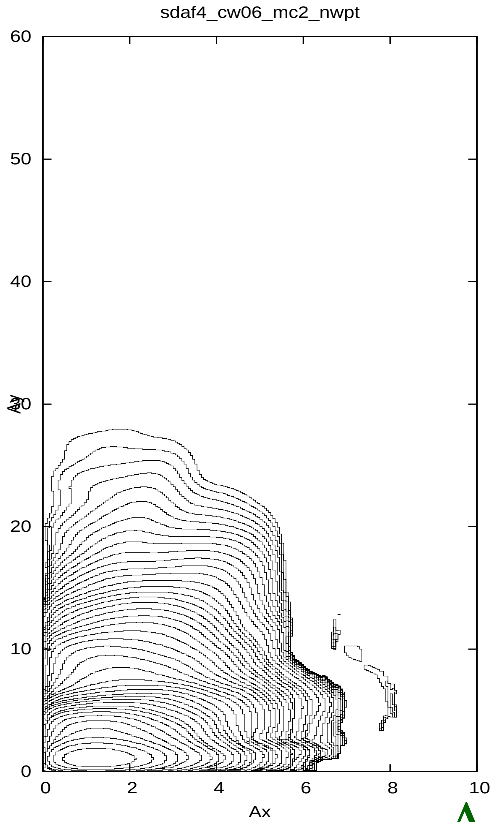


A_x/σ_x

$L = 7.2\text{x}10^{33}\ \text{cm}^{-2}\ \text{s}^{-1}$

$\alpha_c < 0$

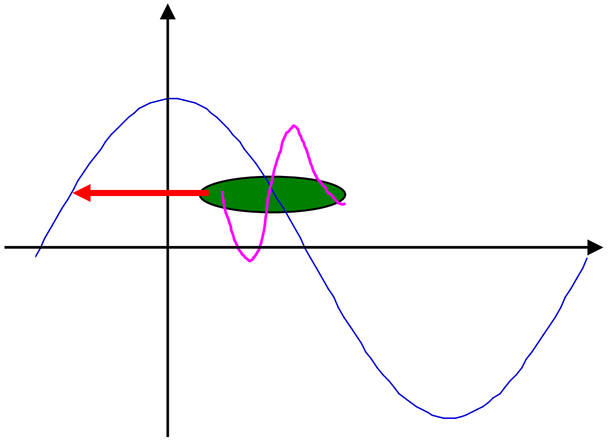
A_y/σ_y



A_x/σ_x

$L = 9.3\text{x}10^{33}\ \text{cm}^{-2}\ \text{s}^{-1}$

Courtesy D. Shatilov



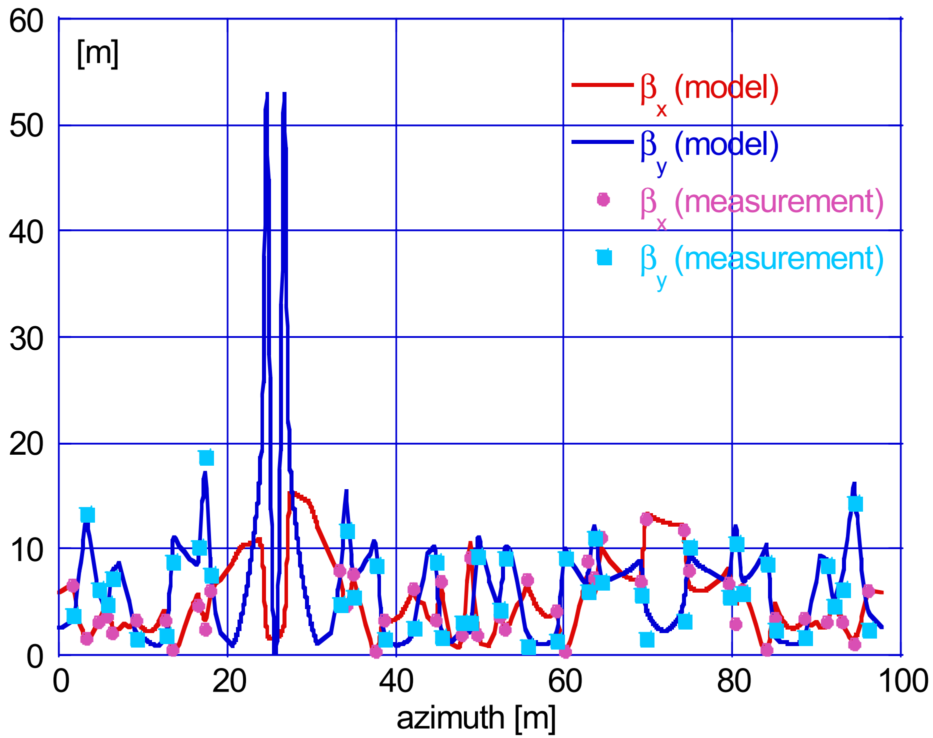
Purpose of Experiment with α_c<0 at DAΦNE

- Prove bunch shortening by wake fields and investigate microwave instability
- Check reliability of the DAΦNE lattice model
- Study high current multibunch dynamics*
- Try beam-beam collisions*

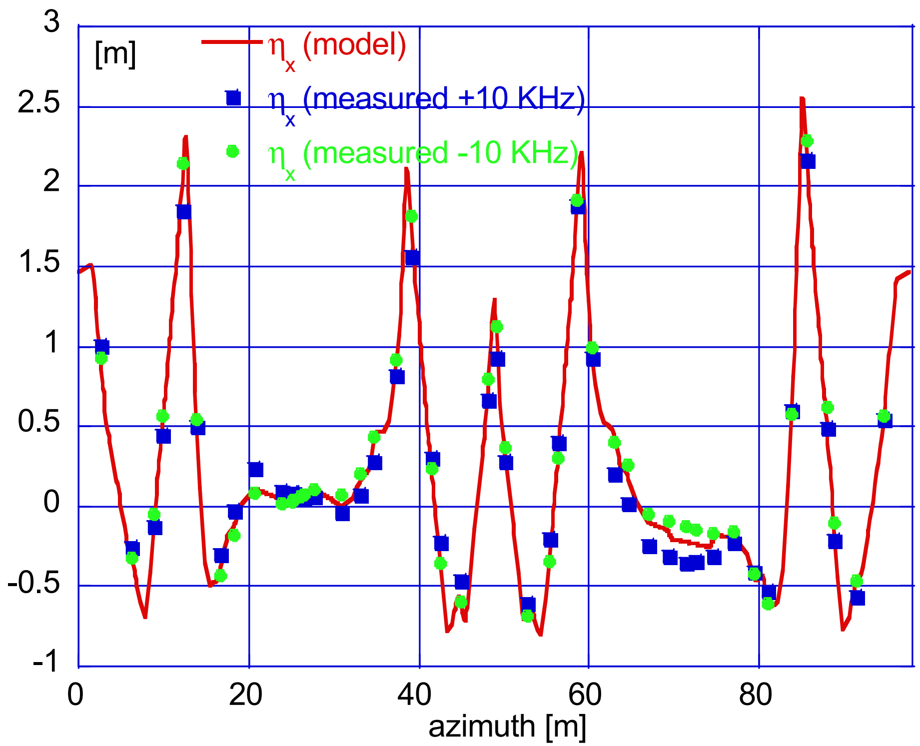
**For the first time*

Positron Ring Optical Functions

Beta Functions

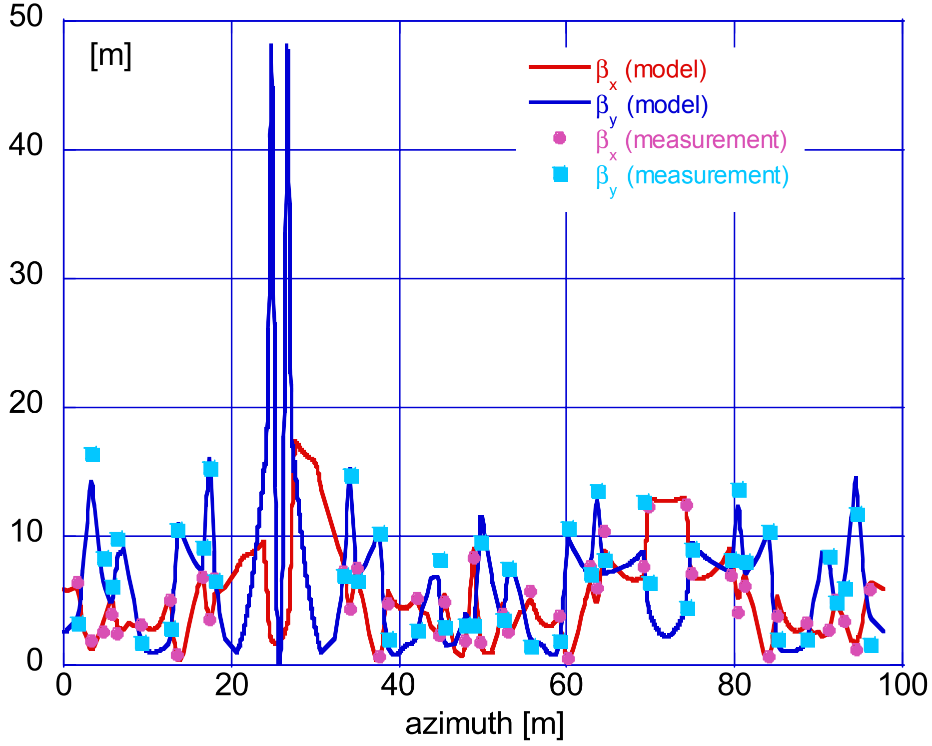


Horizontal Dispersion

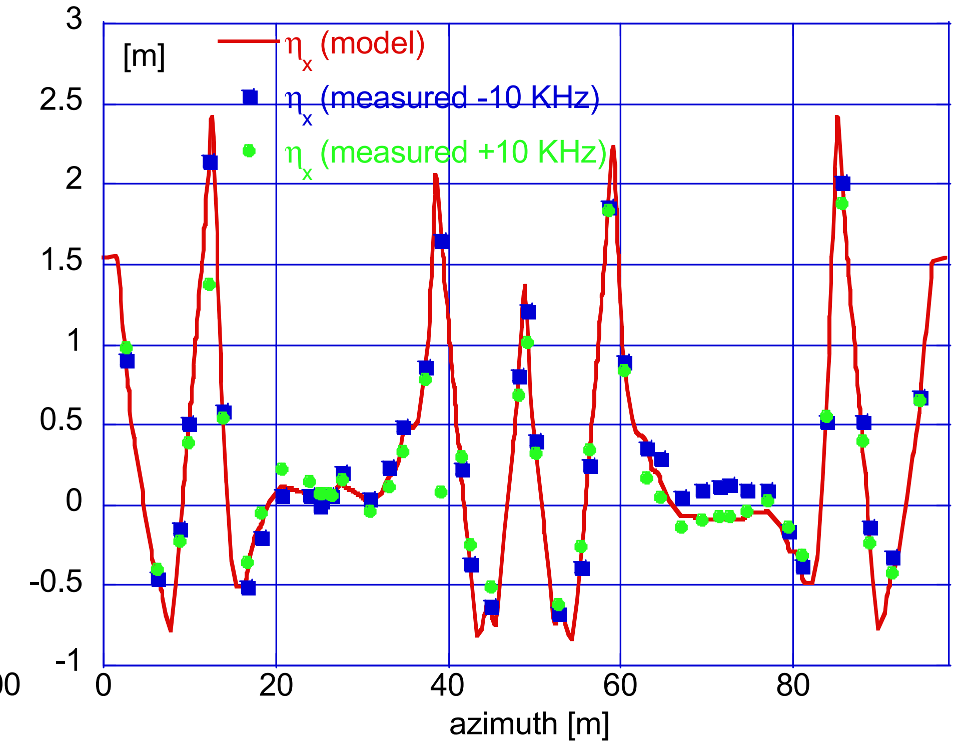


Electron Ring Optical Functions

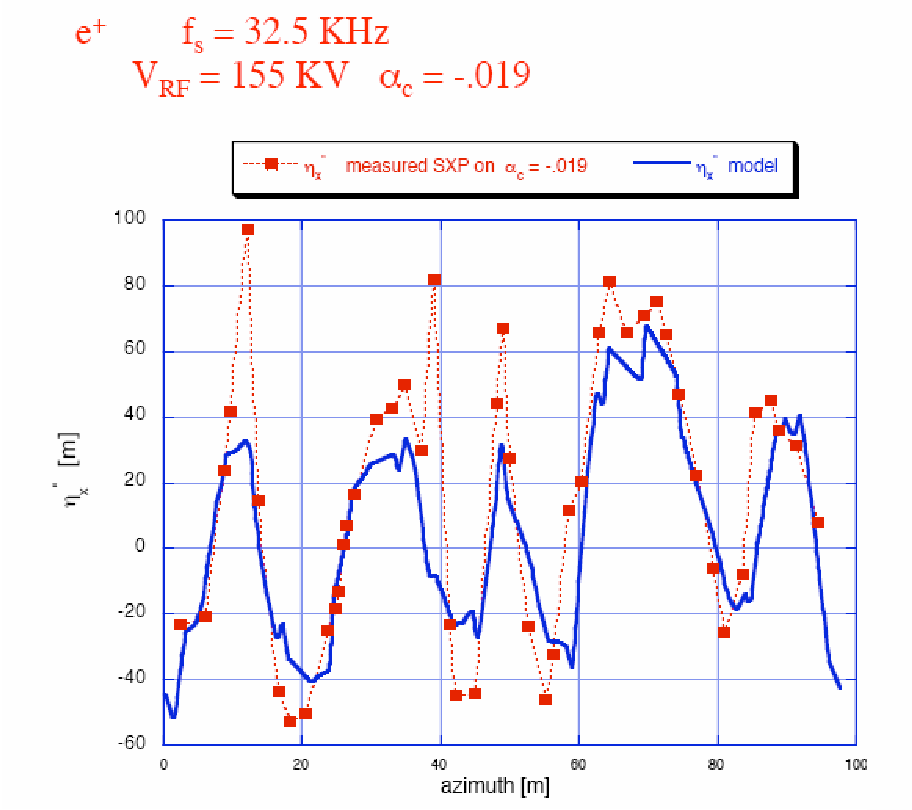
Beta Functions

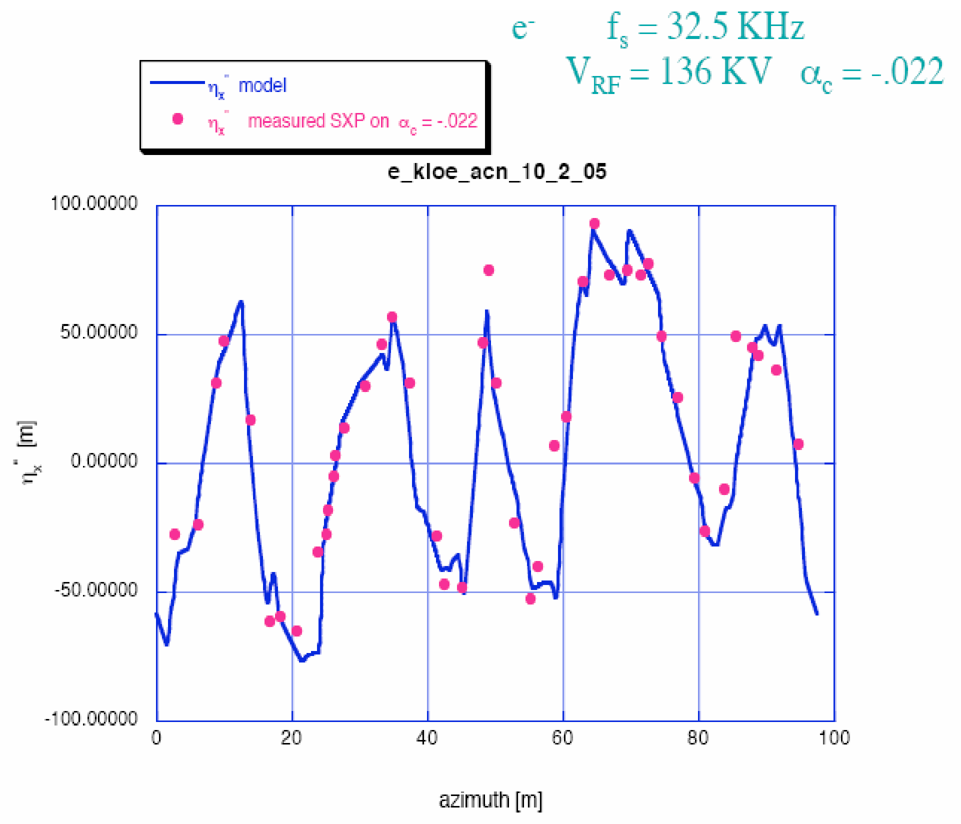


Horizontal Dispersion

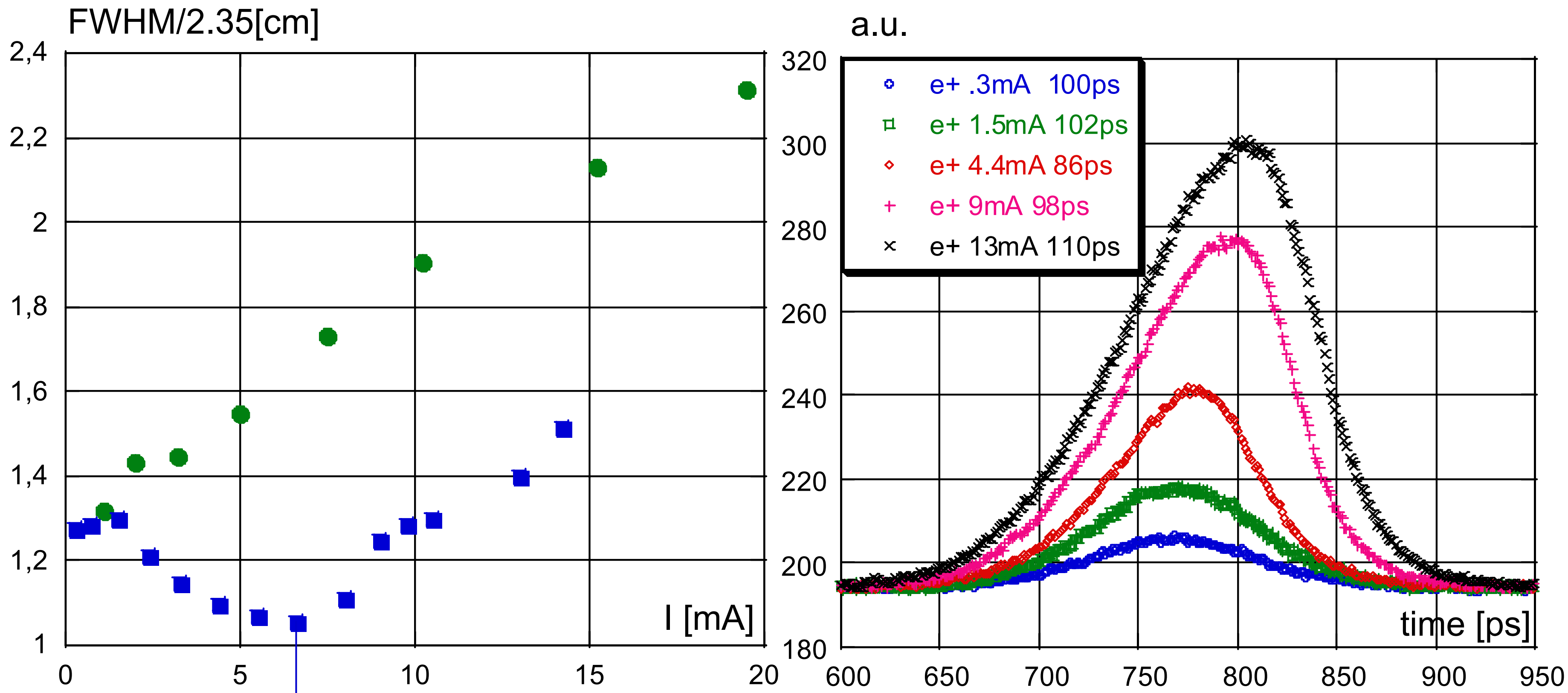


Second Order Dispersion





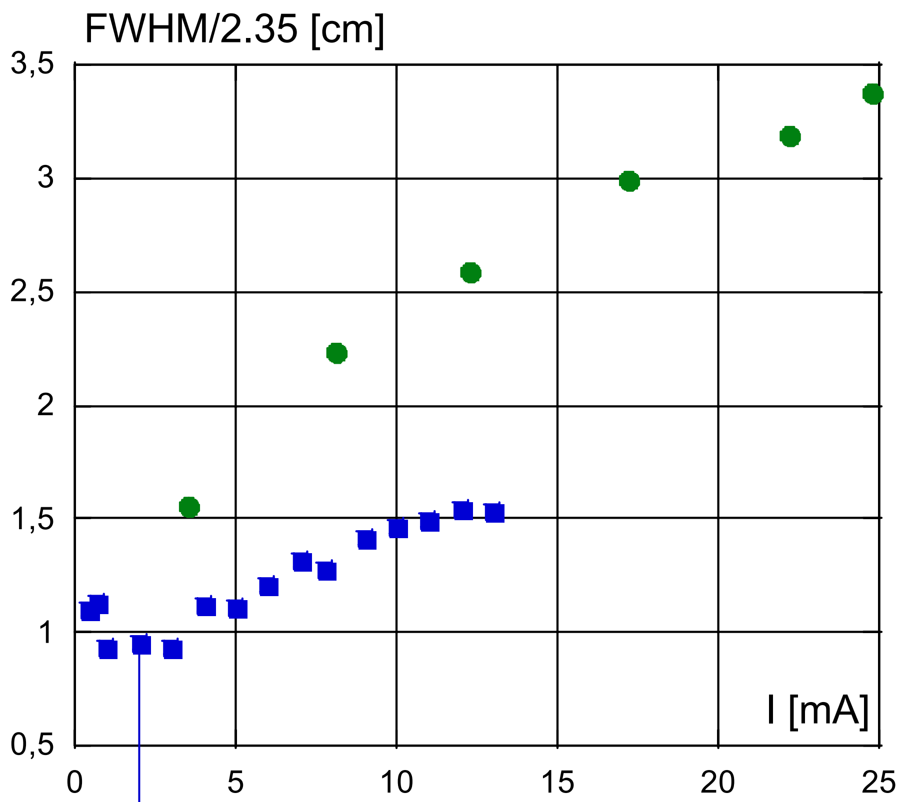
Bunch Shortening in the Positron Ring

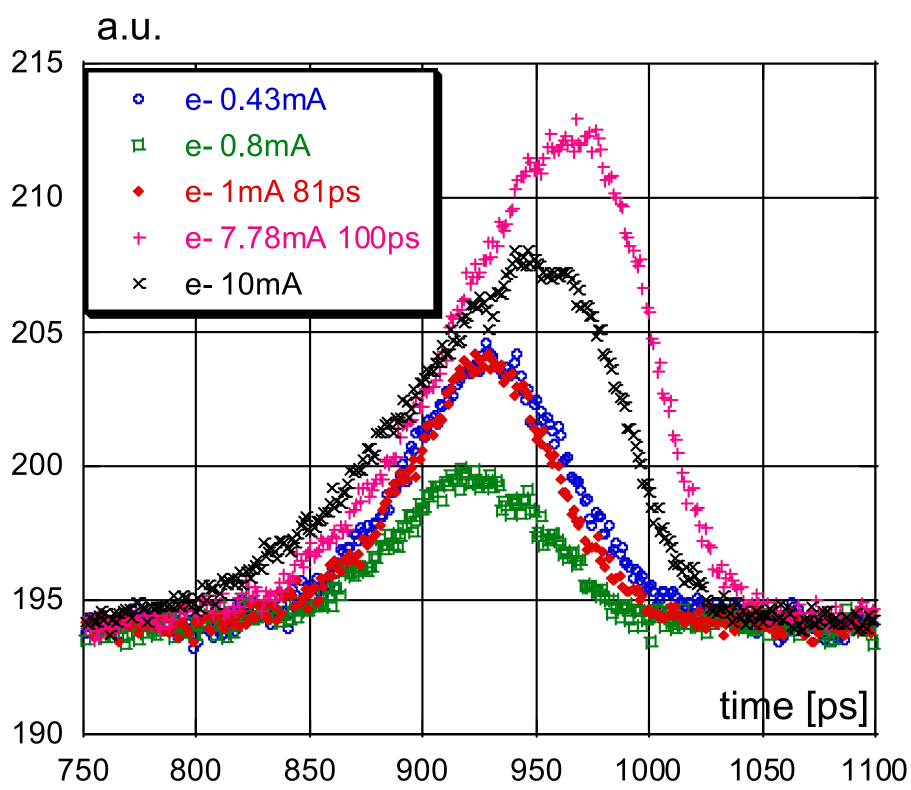


I_{th} = 7 mA at $\alpha_c < 0$

I_{th} = 9 mA at $\alpha_c > 0$

Bunch Shortening in the Electron Ring

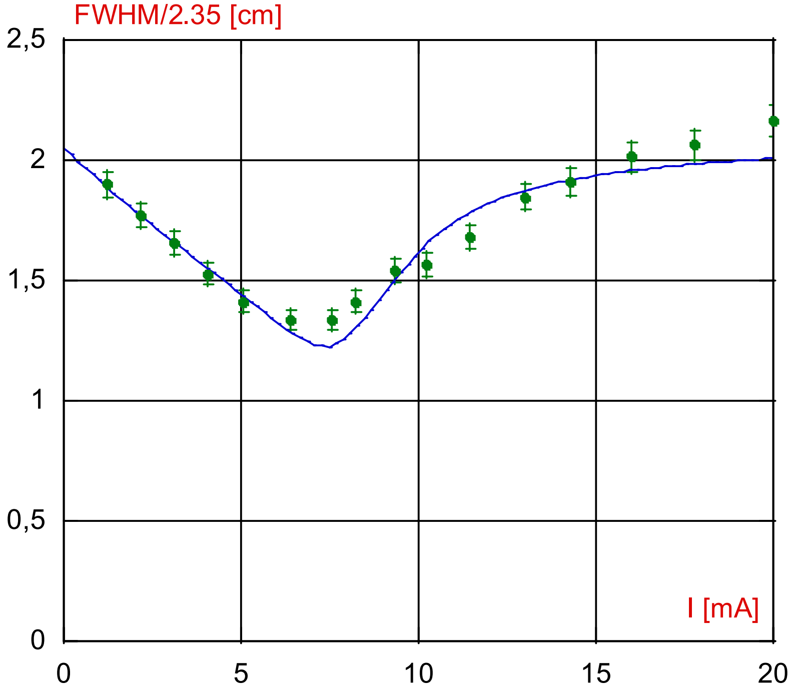




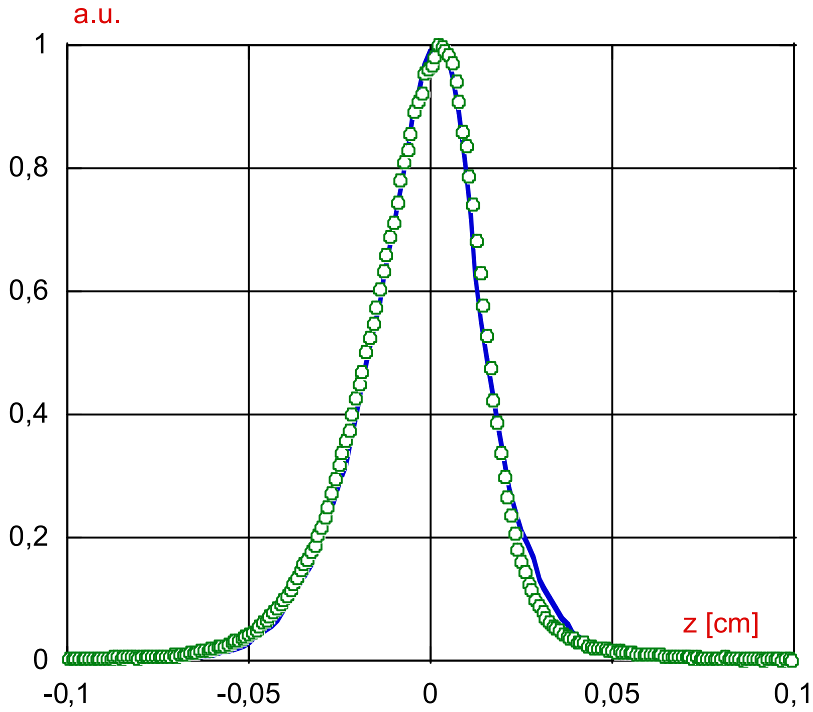
Low microwave instability threshold

COMPARISON with SIMULATIONS

Bunch Length



Charge Distribution at I = 5 mA

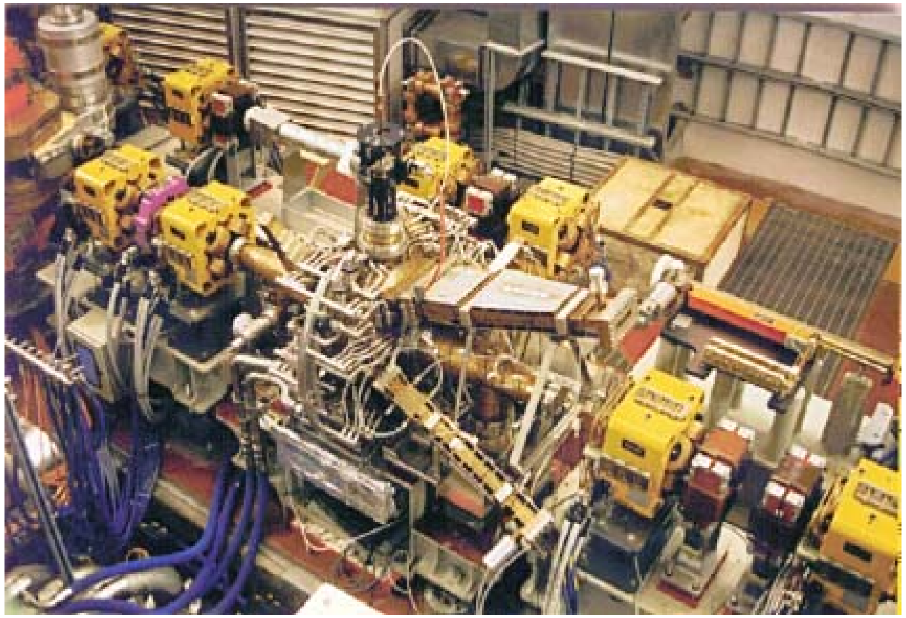


$\alpha_c = -0.036$

Single Bunch (positron ring)

- At I = 15 mA bunch is stable, no evidence of any sidebands
- I > 40 mA is stored in a single bunch with chromaticities $\xi x = -6$ and $\xi y = -2$
- With all sextupoles switched off the lifetime is low due to the wiggler sextupolar components

DAΦNE RF Cavity Tuning



1) *Change of the RF phase by about 170 degree (1.3 ns), since the synchronous phase is on the positive slope of the RF voltage;*

2) *Readjustment of the tuning loop to get a certain initial positive detuning of the accelerating mode.*

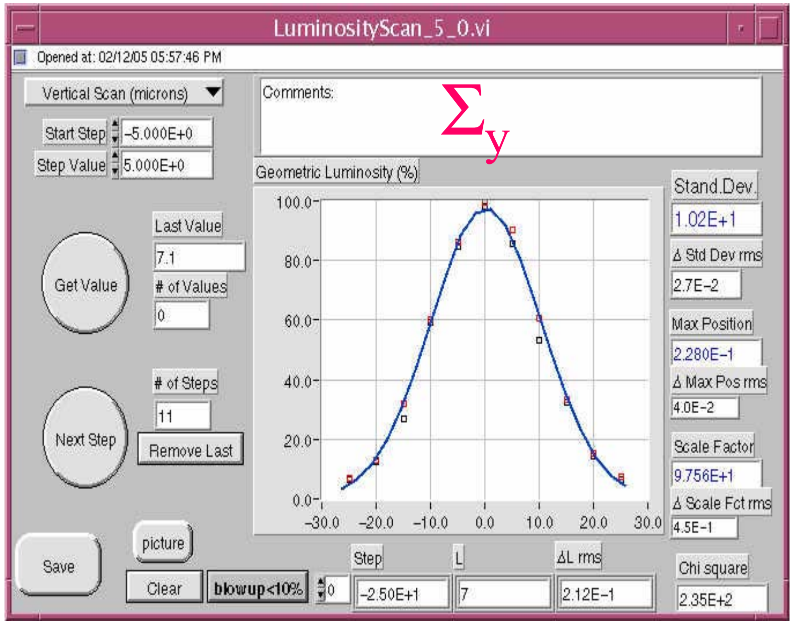
Electron Ring Feedbacks Tuning

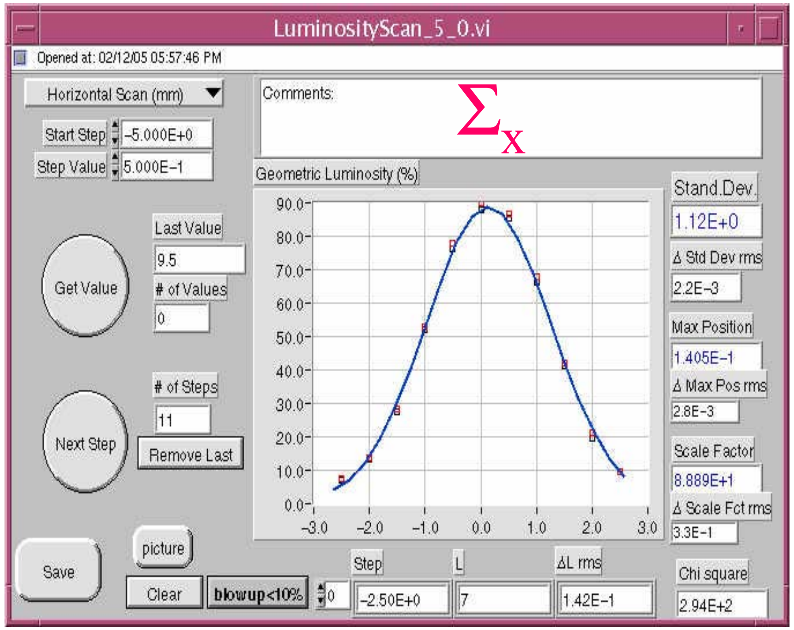
- *All feedbacks off* -> max beam current 400mA in 100 bunches, 16 mA in single bunch
- *Long.feedback* -> "standard" FIR filter (broadband, "low gain"): very good control of motions after frontend and backend retiming
- *Vertical feedback:* necessary only frontend and backend retiming to control motion
- *Horizontal feedback:* no motion
- *All feedbacks on* -> *~1 A stored in 100 bunches,* limited by injection (no instabilities)

Positron Ring Feedbacks Tuning

- *Long.feedback* -> “standard” FIR filter (broadband, “low gain”): very good control of motions after frontend and backend retiming
- *Vertical feedback:* necessary only front-end and backend retiming to control motion
- *Horizontal feedback:* necessary only frontend and backend retiming to damp the horizontal instability
- *With feedbacks on* -> <1 A stored in 100 bunches, limited by injection (no instabilities)

Beam-Beam Luminosity Scan



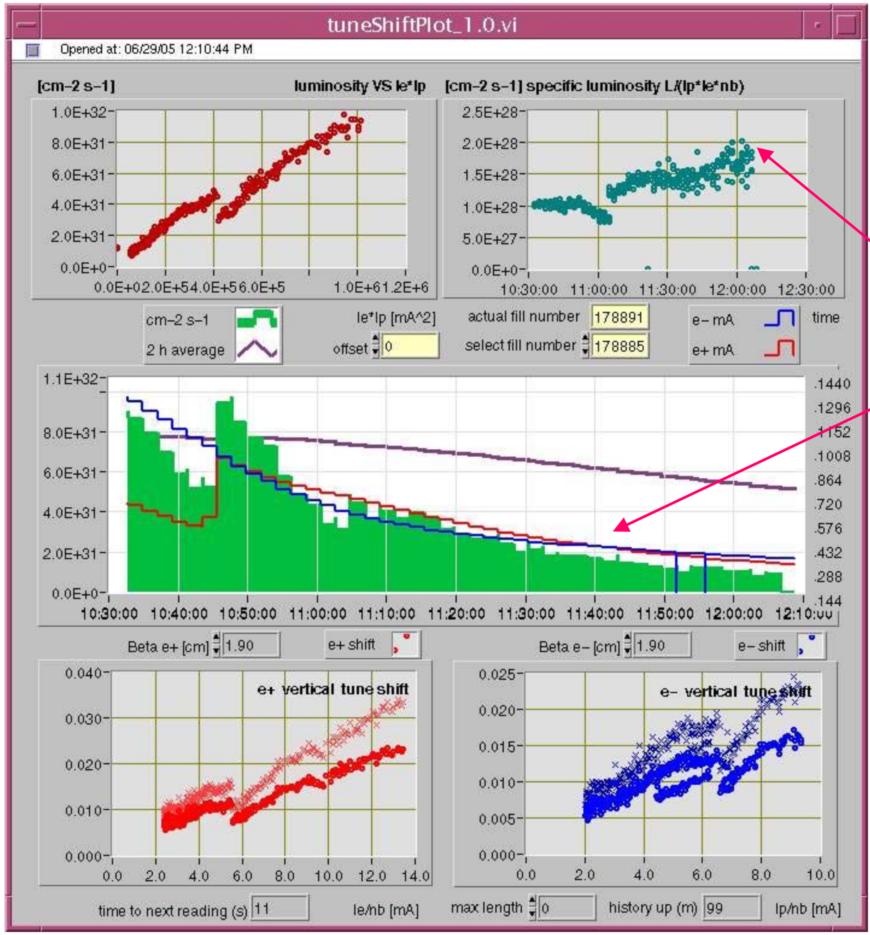


- The best $\Sigma_{x,y}$ achieved → 8.2 µm; 1.0 mm
- Electron coupling → 0.2% (better than now)
- Positron coupling → slightly worser *(shifted sextupole!)*

Luminosity with α_c = -0.02

$\alpha_c > 0$

$\alpha_c < 0$



L = 2.5 x 10^{31} cm^{-2} s^{-1}

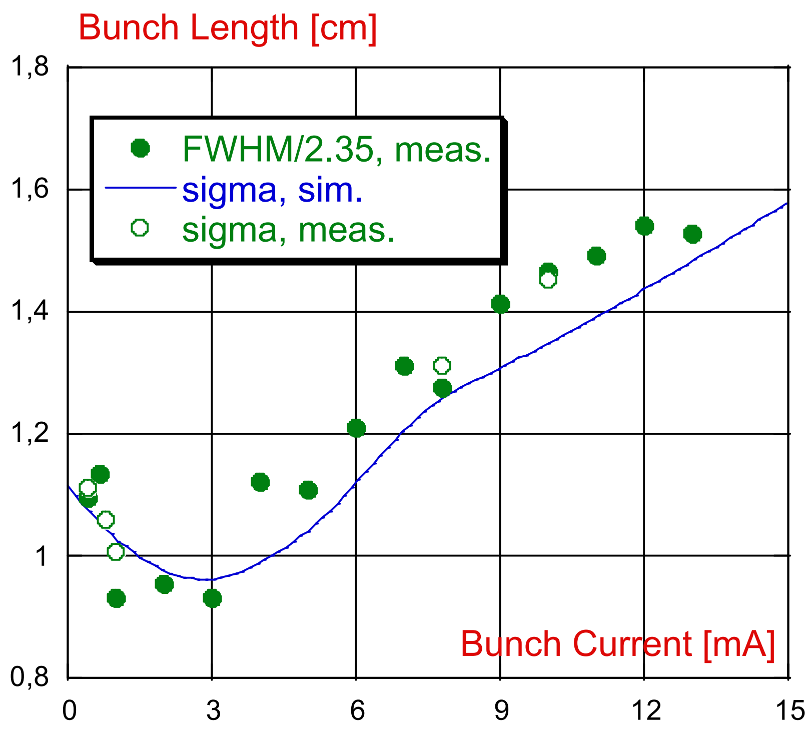
Colliding 300 mA x 300 mA

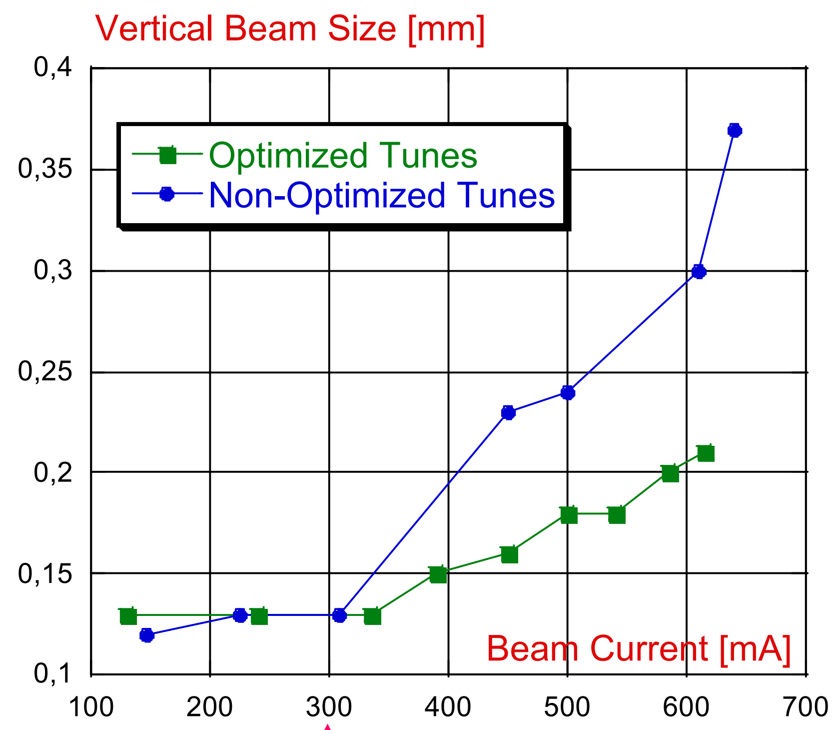
Specific Luminosity

2.5 x 10^{28} cm^{-2} s^{-1} mA^{-2}

Main Limitation

Strong correlation between the longitudinal microwave instability and the vertical size blow up has been found





3 mA x 100 Bunches

Possible Solution

A possible solution to overcome the limitation is to shift the microwave threshold beyond the nominal bunch current

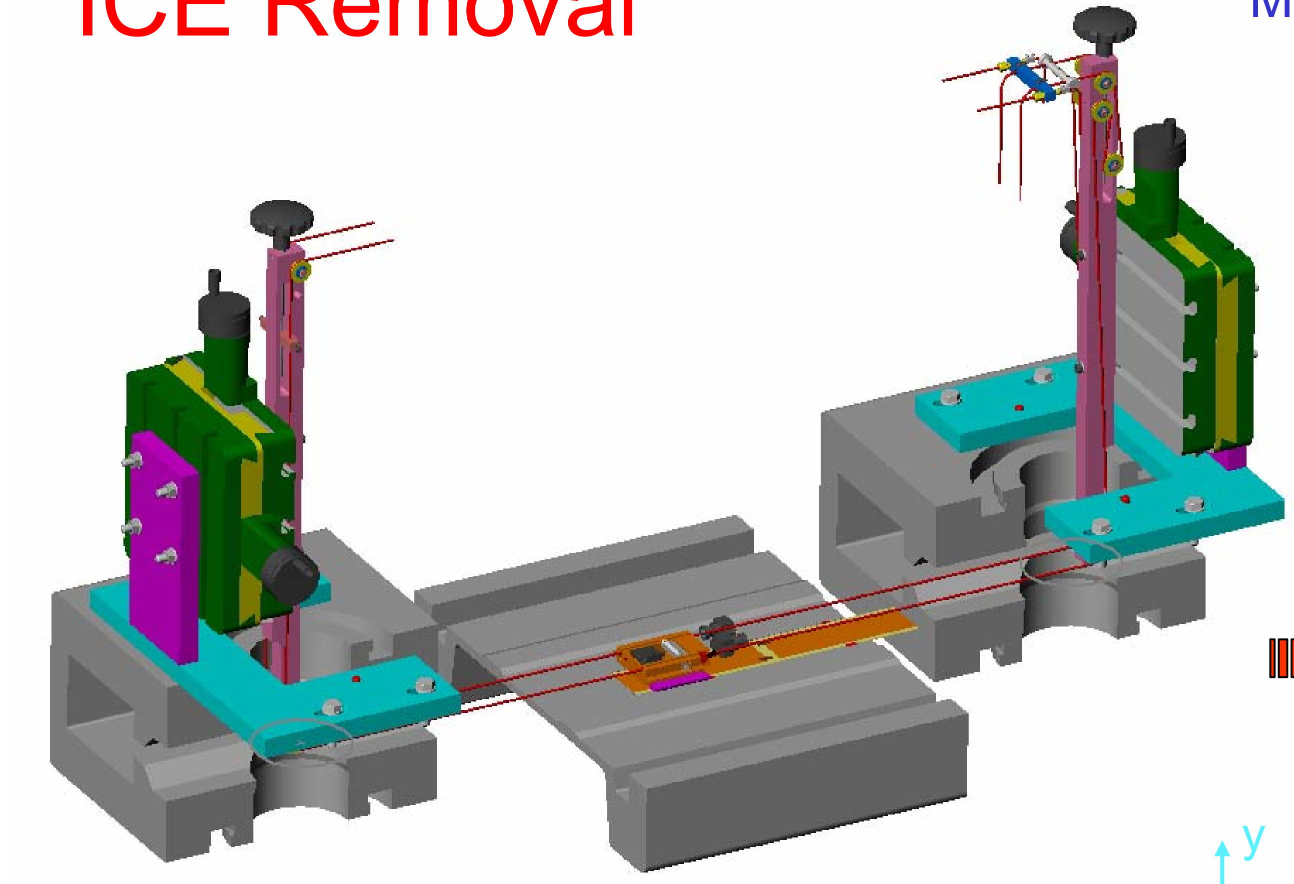
Two ways are under study:

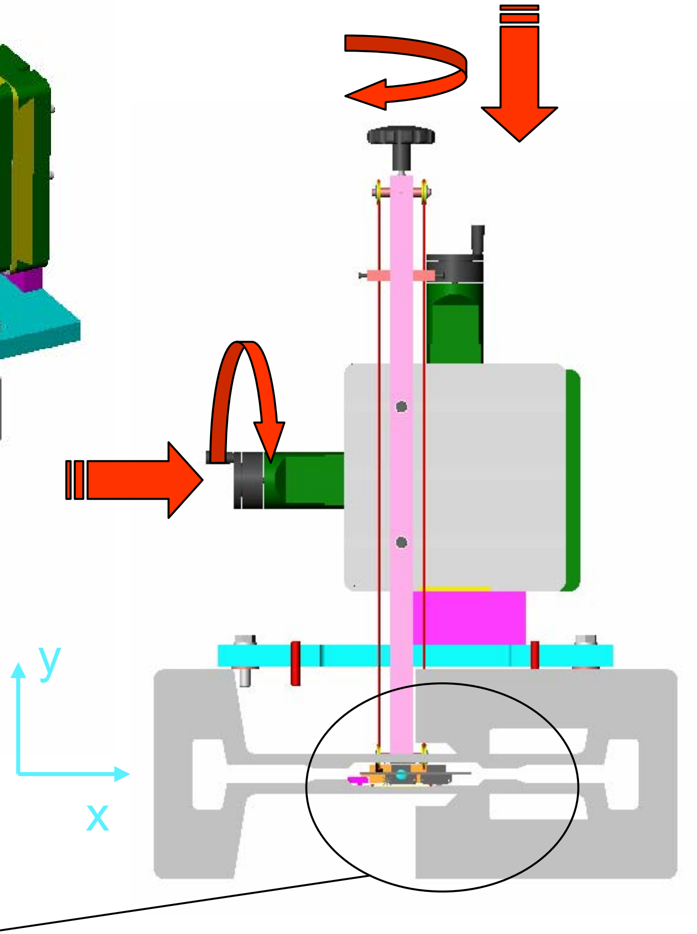
1) Removal of 2 m long ion clearing electrodes in wiggler sections which account for almost half of the electron ring impedance budget;

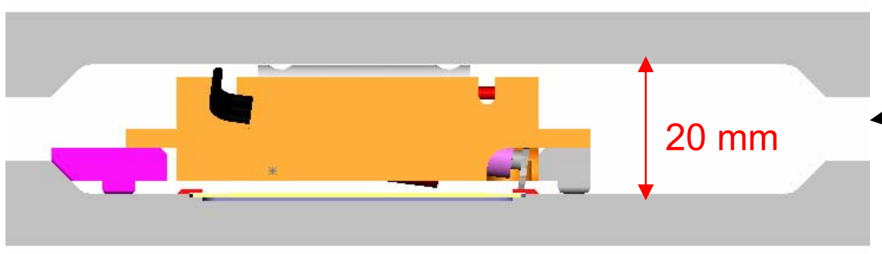
2) Application of collider optics with higher absolute value of the negative momentum compaction factor

ICE Removal

Multipurpose remotized positioning system



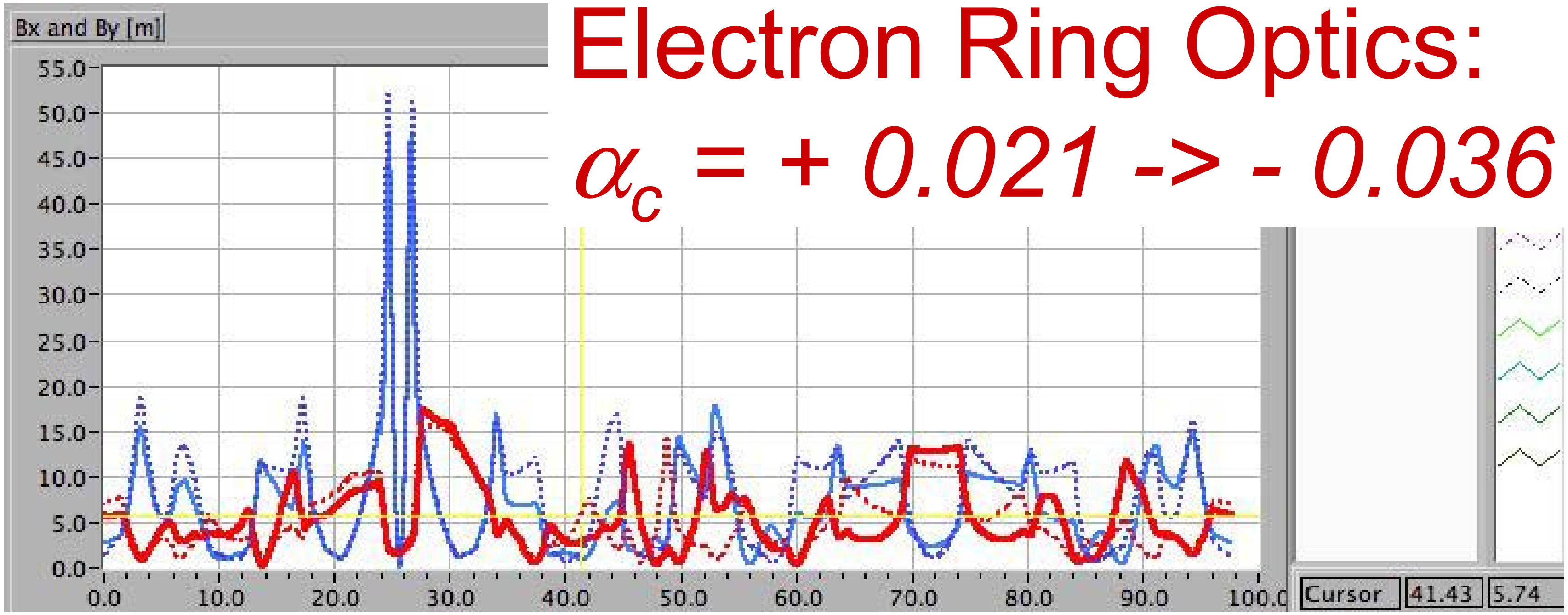


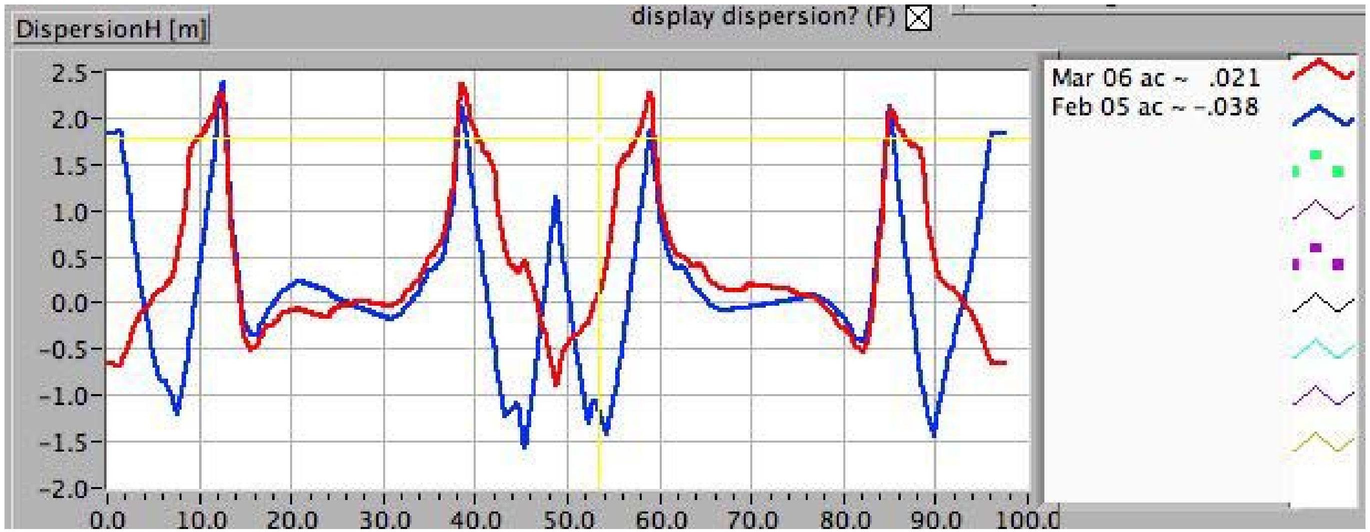


S.R.S. Group S.r.l

Electron Ring Optics:

$\alpha_c = + 0.021 \rightarrow - 0.036$

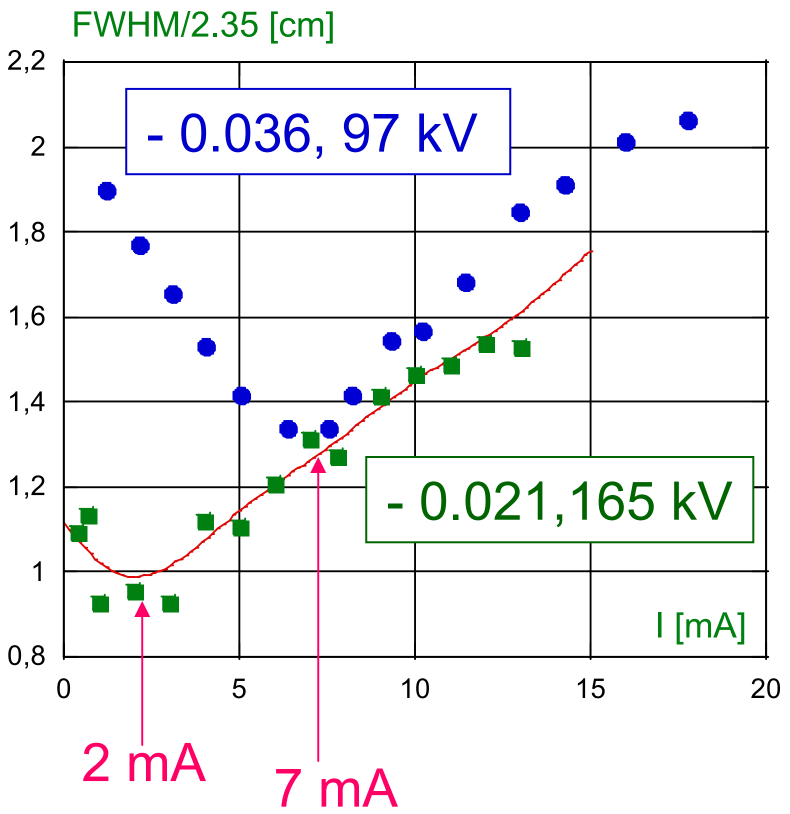


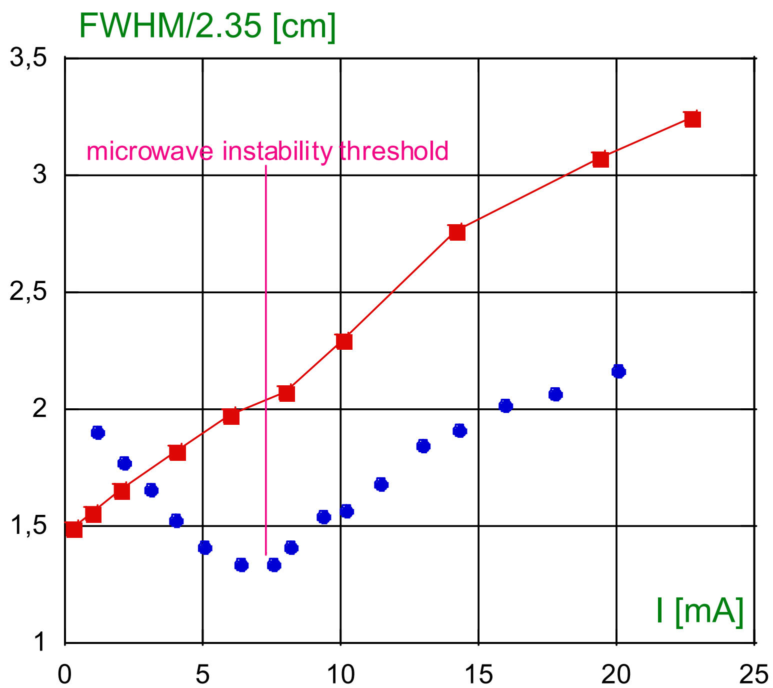


Microwave Instability Threshold Increase

$$I_{th} \propto \alpha_c^{3/2} V_{RF}^{1/2} \rightarrow 3$$

The same threshold with positive and negative α_c





Summary (1)

- DAΦNE optics model has proven to be reliable in providing collider operation with α_c ranging from +0.034 to –0.036
- With $\alpha_c < 0$ bunches shorten as predicted by numerical simulations. High bunch currents can be stored with high negative chromaticities
- No hard limit has been seen in multibunch operation. About 1 A stable beams have been stored in both rings

Summary (2)

- At beam currents up to 300 mA/beam a good specific luminosity has been obtained in beam-beam collisions
- Higher current collisions have been prevented by fast growth of the electron beam vertical size with current (single beam effect)
- We hope to overcome this limitation by reducing the electron ring coupling impedance and/or applying negative momentum compaction optics with higher $|\alpha_c|$.