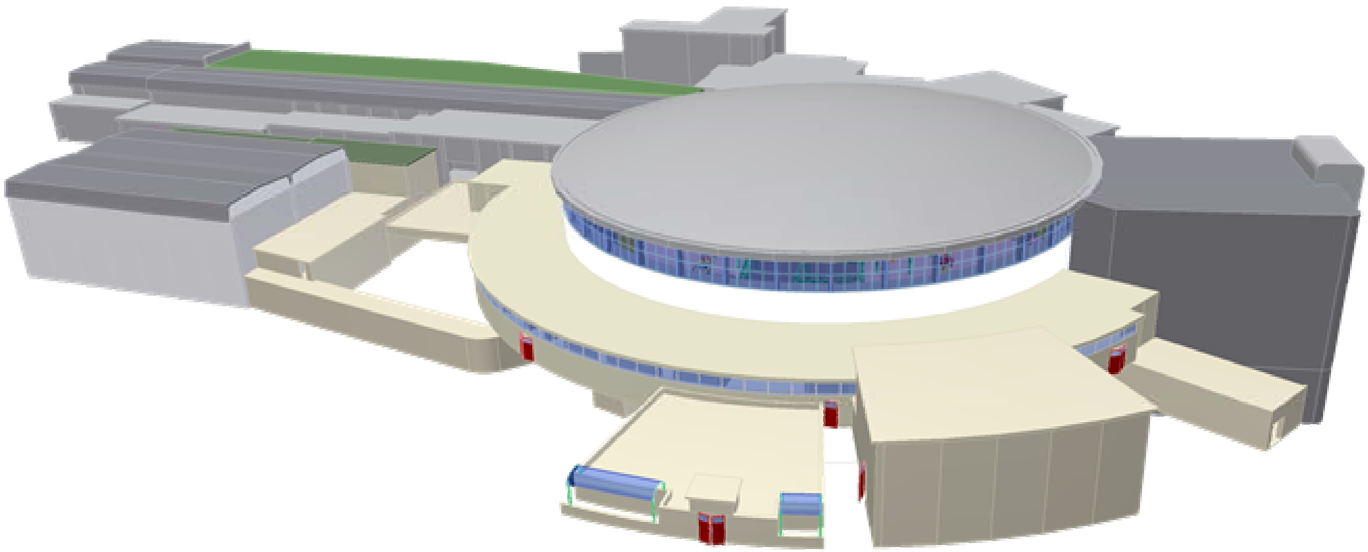
# IMPEDANCE REDUCTION at DAΦNE

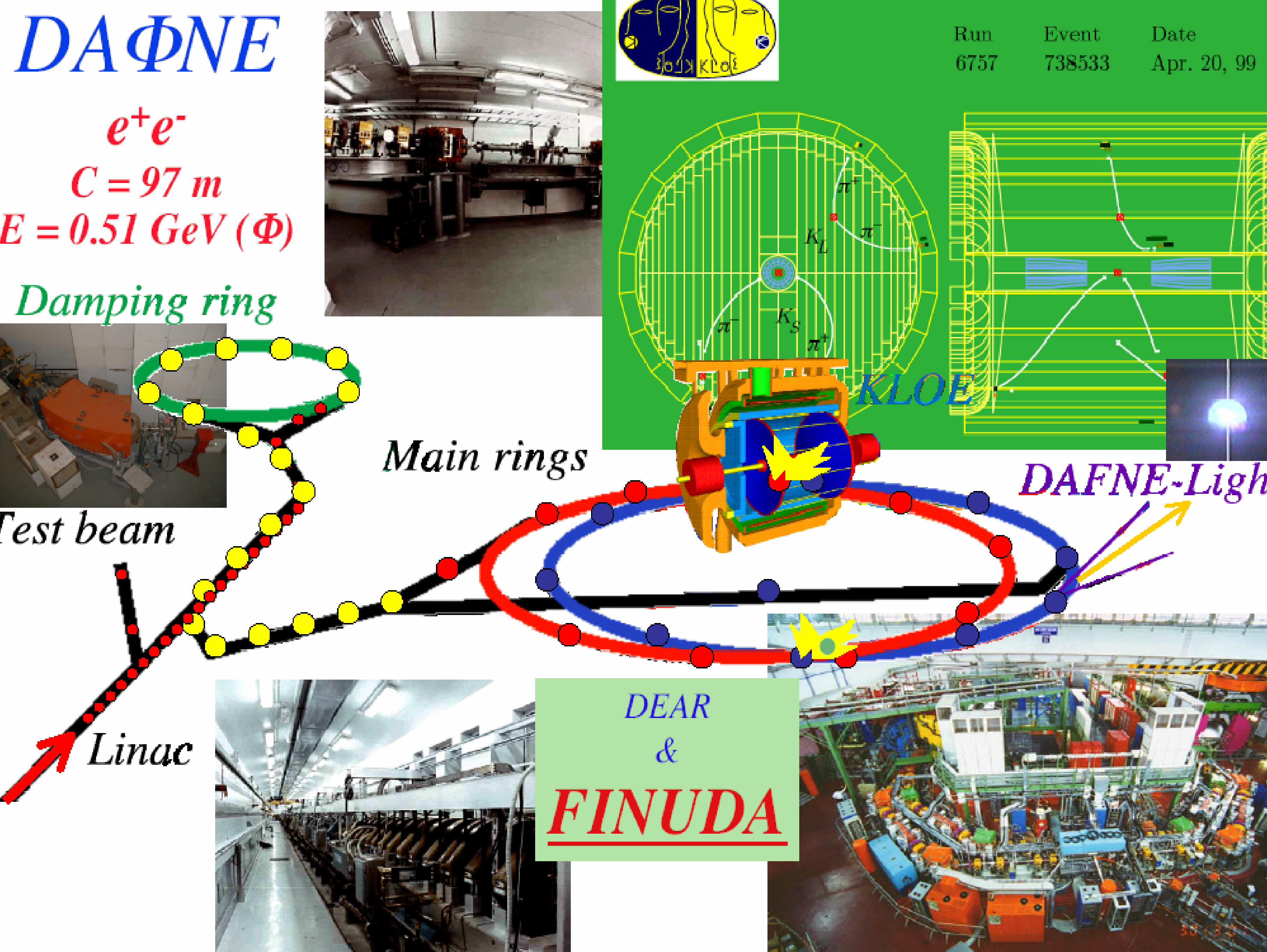
M. Zobov for DAΦNE Team



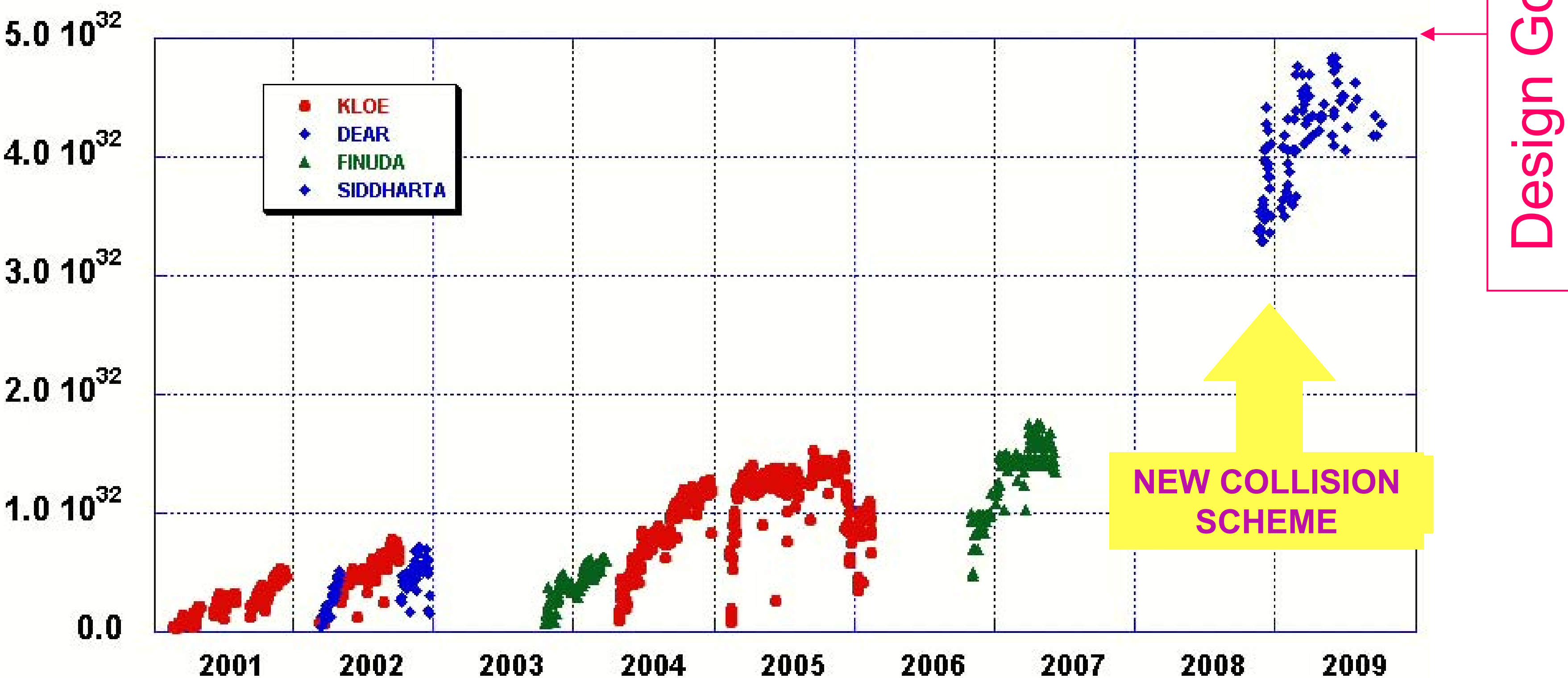
Workshop on Low Emittance Rings (LER2010)
12-16 January 2010, CERN

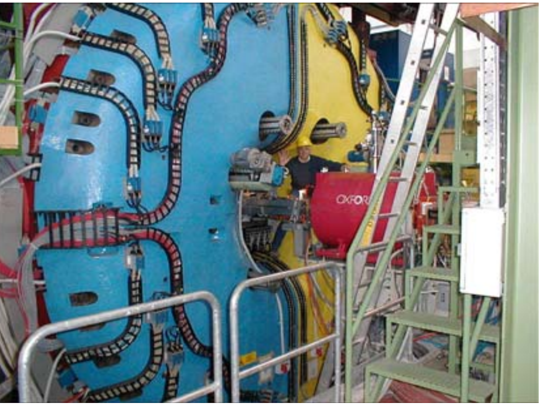
# OUTLINE

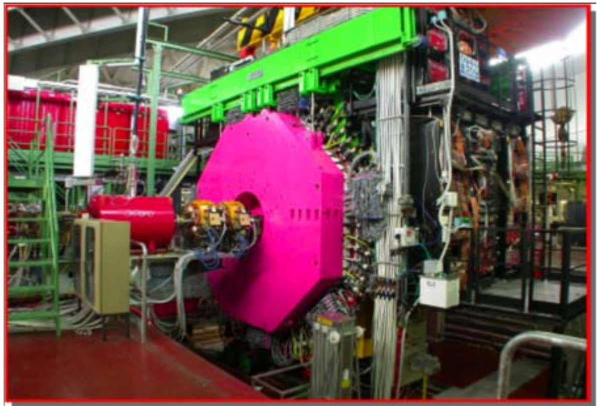
- DAΦNE: brief description and status
- Low impedance vacuum chamber design
- Steps for further impedance reduction
    a) Clearing electrodes removal
    b) Vacuum chamber modifications for DAΦNE upgrade
    c) Some present activities


DAΦNE
e+e-
C = 97 m
E = 0.51 GeV (Φ)
Damping ring
Main rings
Test beam
Linac
Run 6757
Event 738533
Date Apr. 20, 99
KLOE
DAFNE-Ligh
DEAR
&
FINUDA

# DAΦNE Peak Luminosity





# Beam Current Records at Factories

| Parameters | PEP-II | | KEKB | | DAΦNE | |
|---|---|---|---|---|---|---|
| | LER | HER | LER | HER | e+ | e- |
| Circumference, m | 2200 | 2200 | 3016 | 3016 | 97.69 | 97.69 |
| Energy, GeV | 3.1 | 9.0 | 3.5 | 8.0 | 0.51 | 0.51 |
| Damping time, turns | 8.000 | 5.000 | 4.000 | 4.000 | 110.000 | 110.000 |
| Beam Currents, A | 3.21 | 2.07 | 1.70* | 1.25* | 1.40 | 2.45 |

Maximum positron beam current

Maximum currents with SC cavities

Maximum electron beam current

* 2.00 A and 1.40 A without crab cavities

# Broad-Band Impedance

| Parameters | EPA* | DAΦNE |
|---|---|---|
| Circumference, m | 125.7 | 97.7 |
| Energy, MeV | 500 | 510 |
| Z/n, Ω | 21 | 0.34 , 0.44** |
| $Z_T$, MΩ/m | 2.4 | 0.13, 0.16*** |

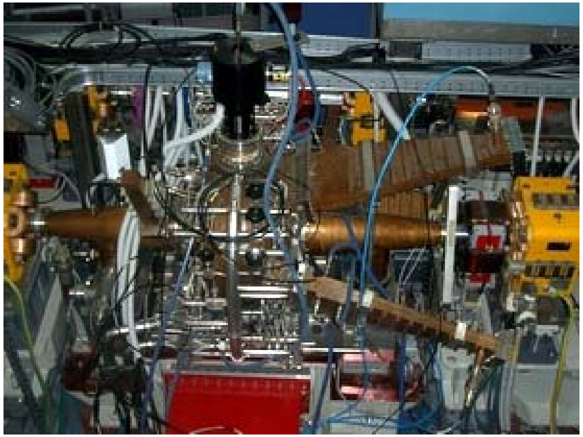

* S. Bartalucci et al., EPAC88, p.672

** F. Marcellini et al., EPAC08, p.1661

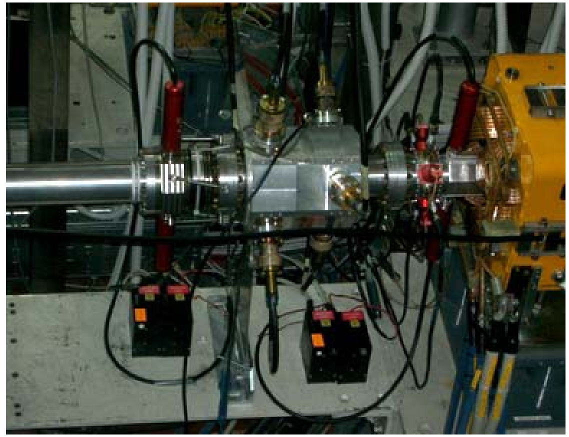
*** A. Ghigo et al., EPAC02, p. 1494


Note that $\dfrac{Z}{n} = \dfrac{Z}{\omega}\dfrac{c}{R}$

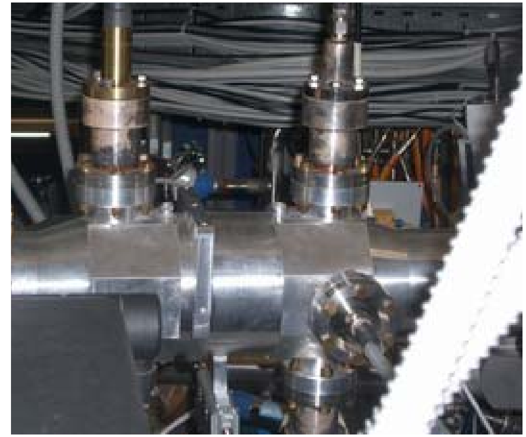
# HOM Damped Vacuum Chamber Elements



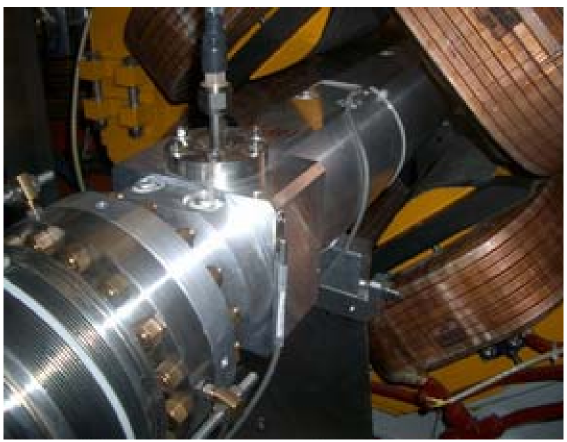
RF CAVITY



LONGITUDINAL KICKER

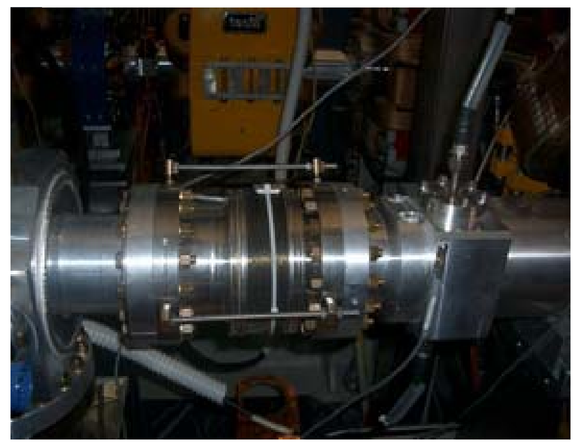


TRANSVERSE KICKER



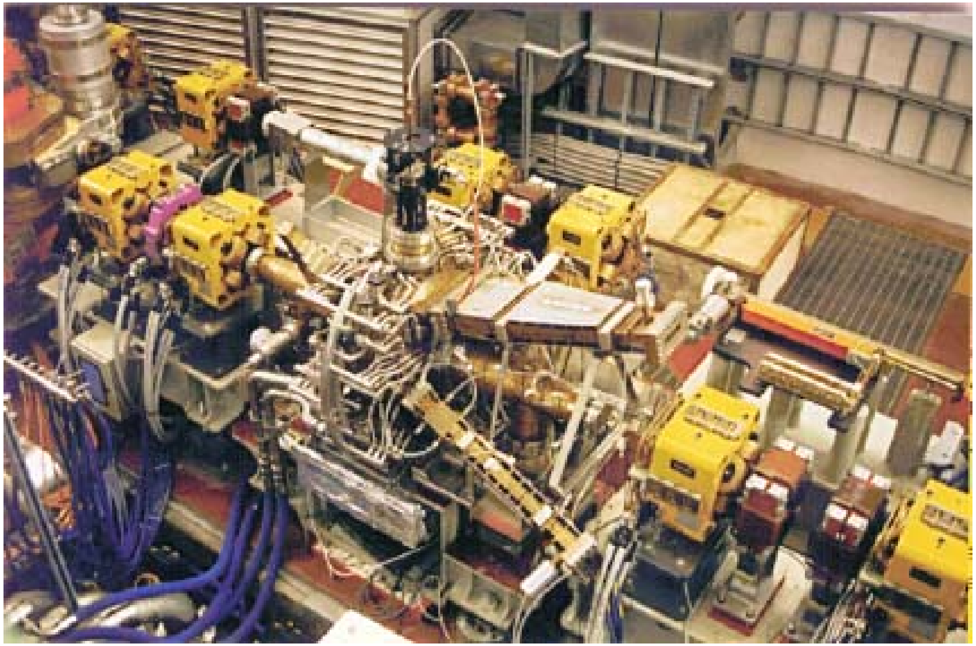
INJECTION KICKER

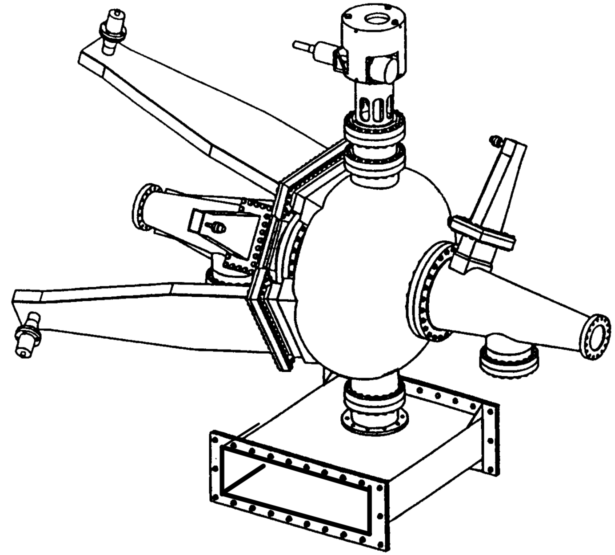
WALL CURRENT & DCCT MONITOR



SHIELDED BELLOWS

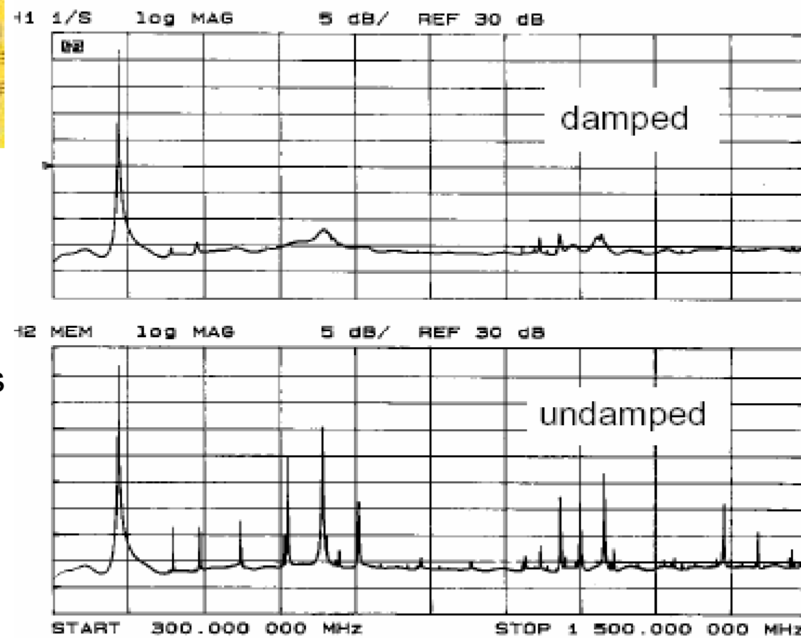
# DAΦNE RF Cavity



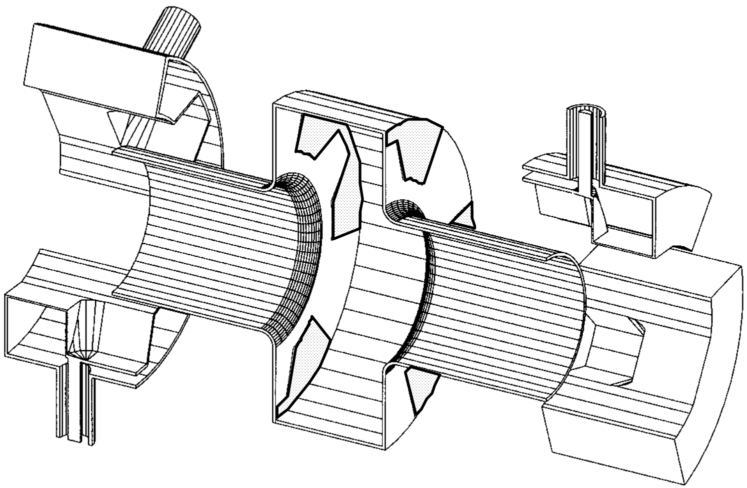


## Principal Design Features

- Rounded body: simple mechanical design, no multipacting
- Long tapers: low broad-band impedance, lower RF losses
- HOM positions far from principal beam harmonics
- No dissipative materials under high vacuum
- Damping waveguides with broad-band transitions to external loadings



# Longitudinal Feedback Kicker



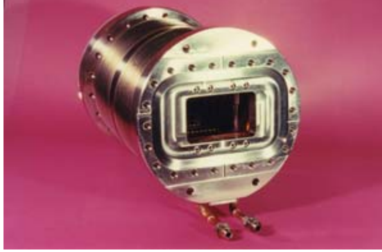
Purpose:
- used to provide correcting longitudinal kick

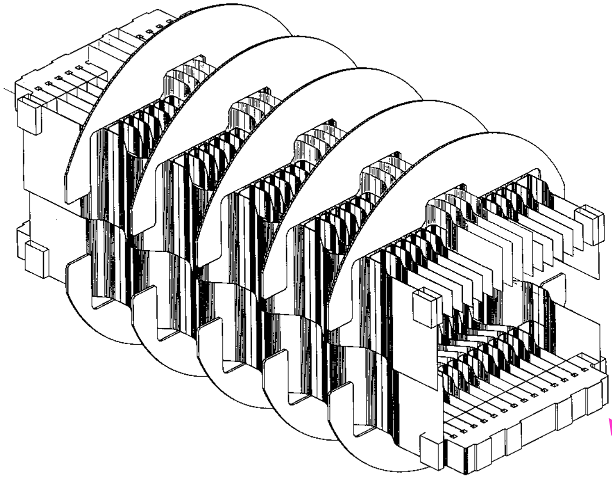
Design Features:
- heavily loaded pill-box cavity
- 6 ridged wave guides rounded to fit cavity shape
- special transitions to coaxial feed through

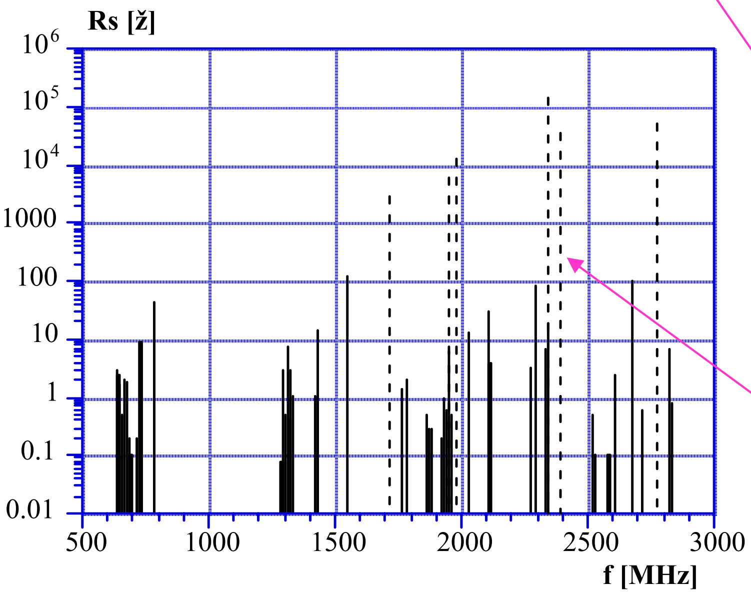
Advantages
- High broad-band shunt impedance
- All HOM are damped

- Publications
  - Part. Accel. 52: 95-113, 1996 (>50 citations in HEP)
- Successful Experience in:
  - DAΦNE, KEKB, PEPII, BESSYII, PLS, SLS, HLS, ELETTRA, KEK Photon Factory, Duke storage ring..

# Long Shielded Bellows

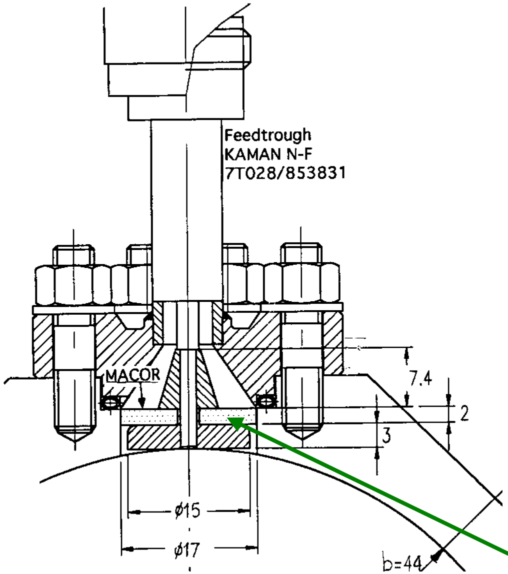


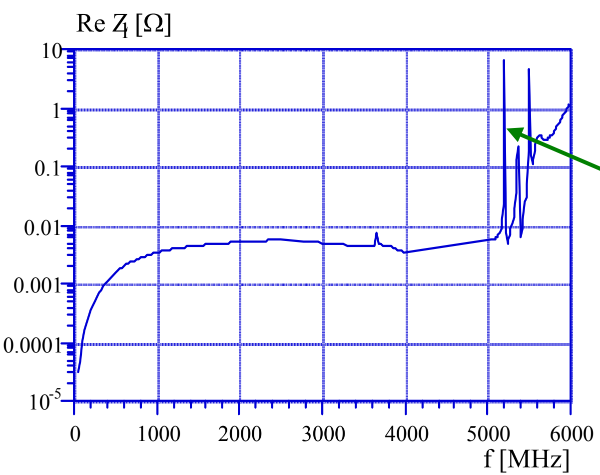





- Purpose and Requirements
  - 8 long bellows are placed between machine arcs and straight sections
  - They must provide 35 mm longitudinal expansion and 10 mm horizontal offset
- Particularities of RF Design
  - No RF sliding contacts since
    - *The contacts can be burned out due to high flowing image currents*
    - *They are a possible source of dust particles created between the sliding surfaces*
  - Parasitic mode impedances are reduced to a harmless level:
    - *To eliminate multibunch instabilities*
    - *To avoid excessive heating of the RF screen*

# Broad-Band Button BPM




- Satisfied Requirements:
  - High sensitivity
  - Broad-band to provide the individual time and transverse offset measurements on a bunch-by-bunch basis, i. e. without "memory"
  - Low coupling impedance
  - No trapped HOM
  - Low power flow in the external cables
- Design Features
  - All the button internal structure has the same characteristic impedance of 50 Ω (no reflections, no HOMs)
  - The first HOM $TE_{111}$ remains beyond the bunch spectrum (at ~ 5.2 GHz)

# Arc Vacuum Chamber

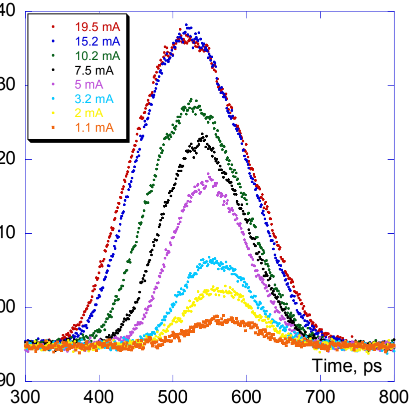
A system of long gradual transitions between different arc vacuum chamber cross-sections is used to minimize the coupling impedance

# Bunch Lengthening in DAΦNE

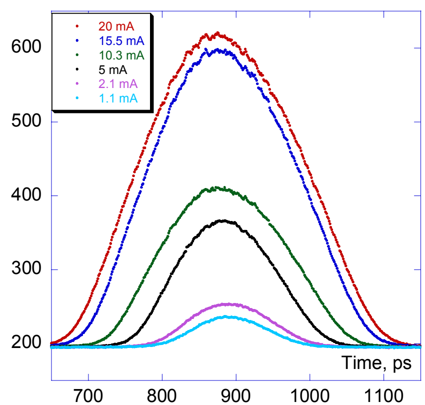
Typical Measured Bunch Distributions

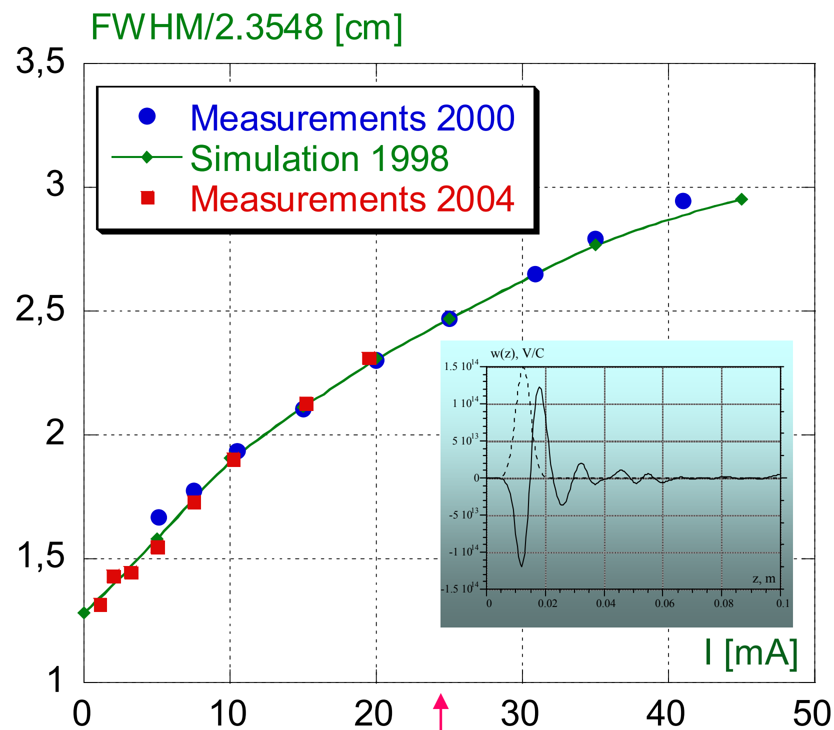
*M. Zobov et al., e-Print: physics/0312072*

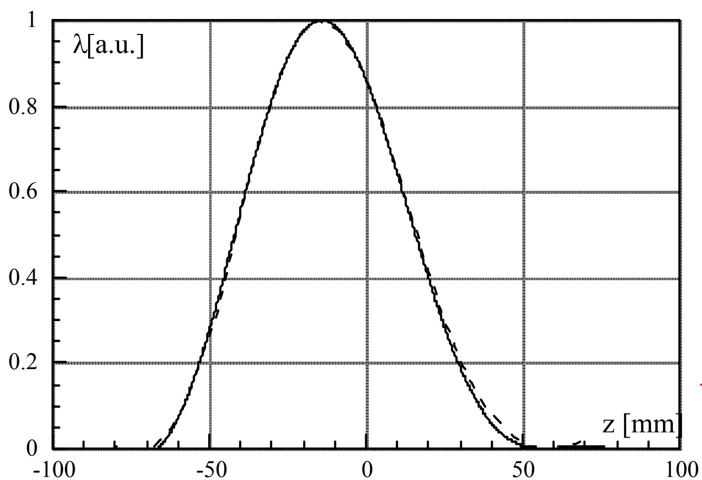
*e+ Ring*




*e- Ring*



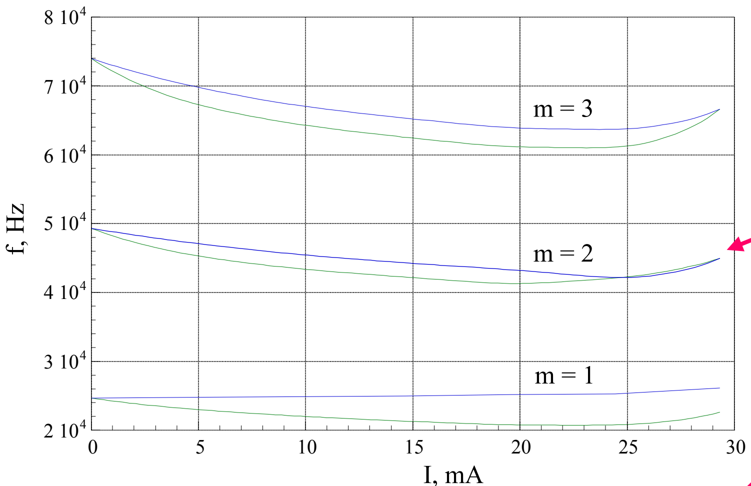



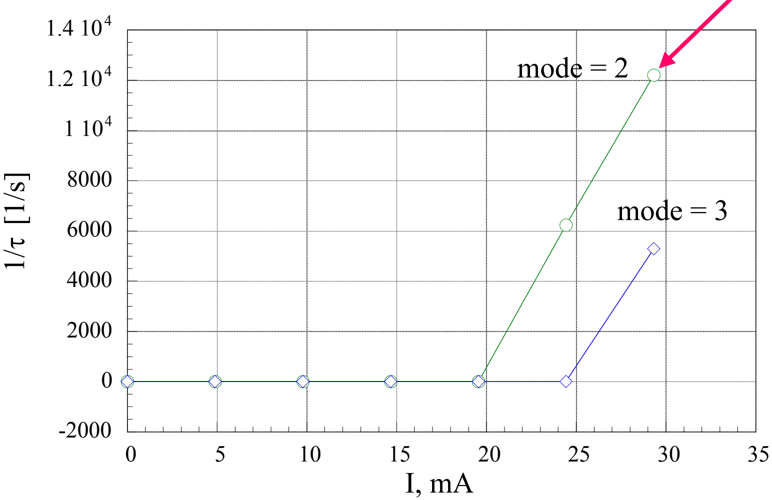




Comparison with Simulations

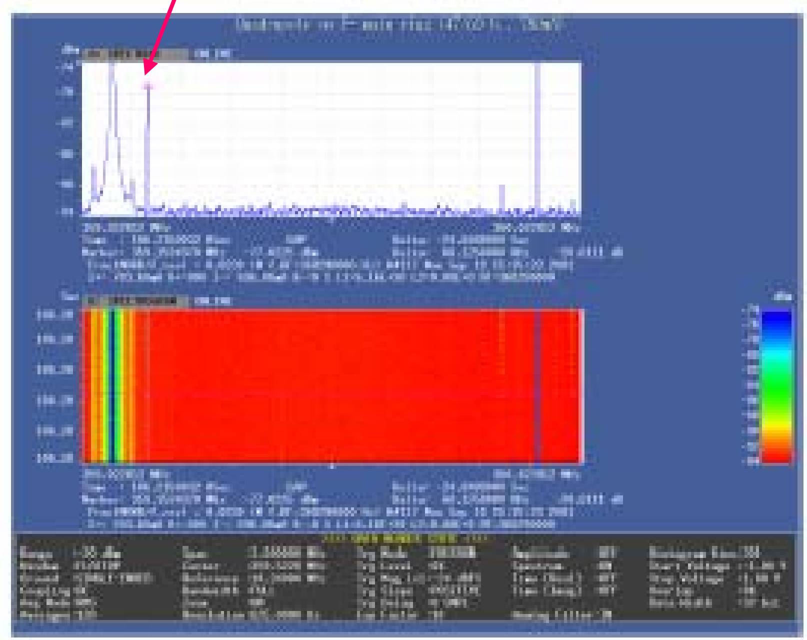
# DAΦNE Quadrupole Instability

*M. Zobov et al., e-Print: physics/0312072*



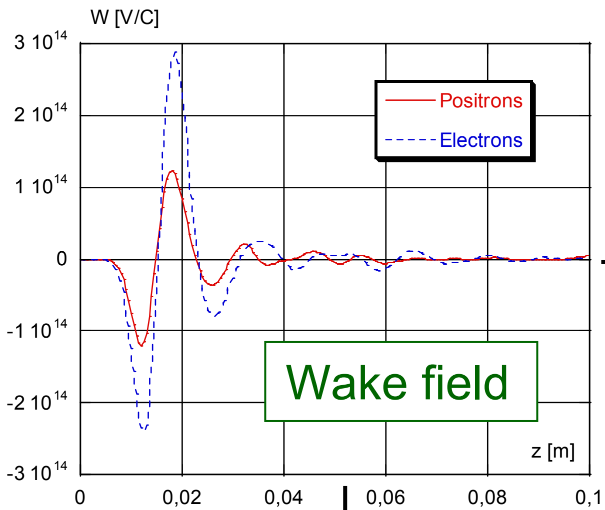

$2f_s$

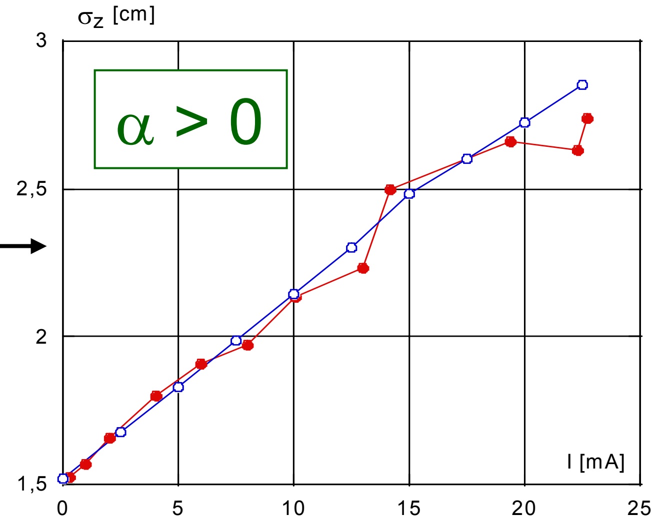


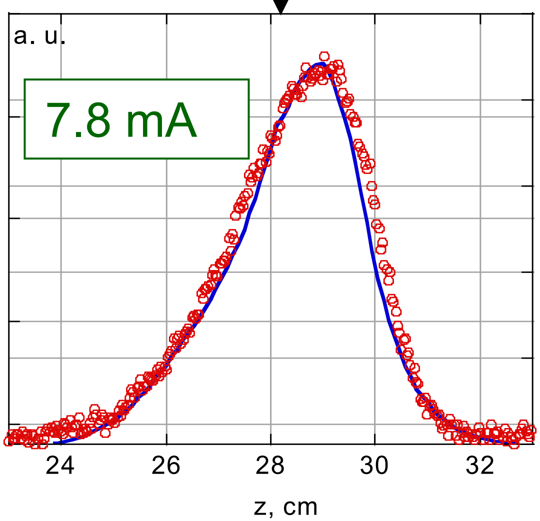
*A. Drago et al., PRSTAB 6:052801,2003*

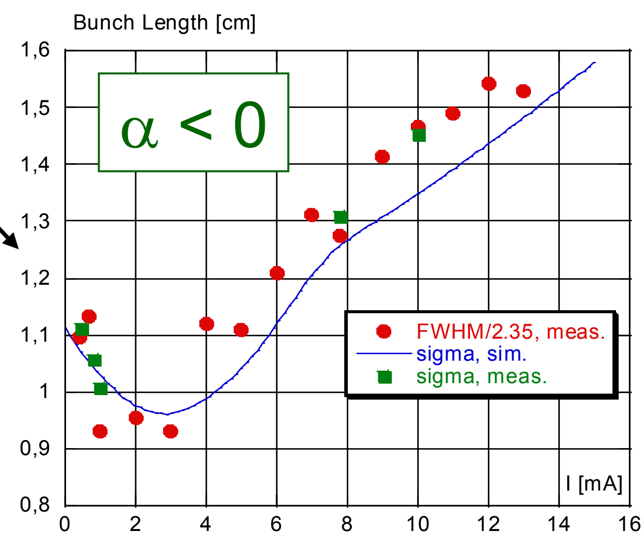
# Bunch Lengthening in Electron Ring

B. Spataro and M. Zobov, DAΦNE Technical Note: G-64, 2005



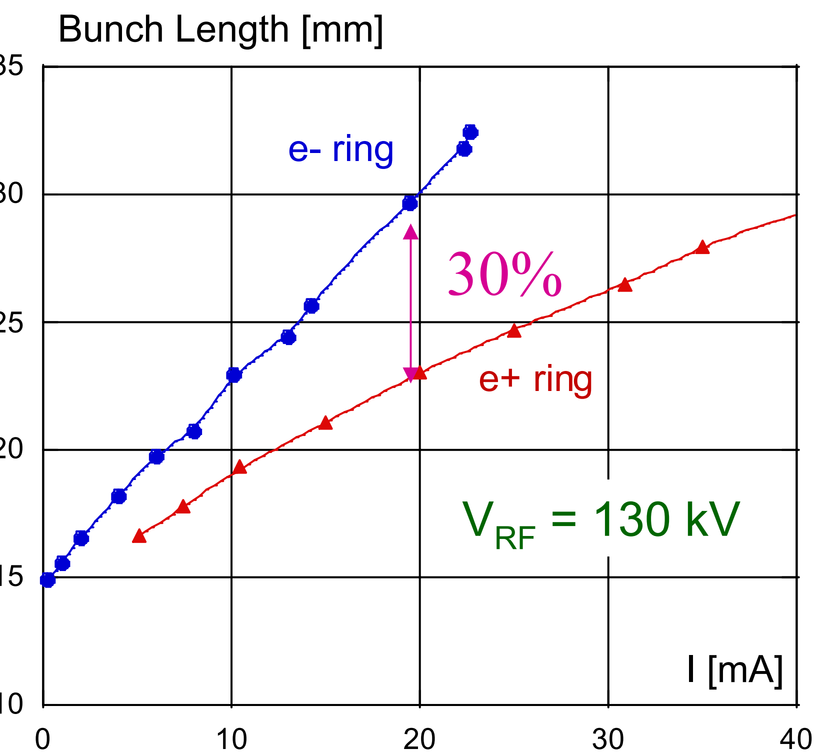



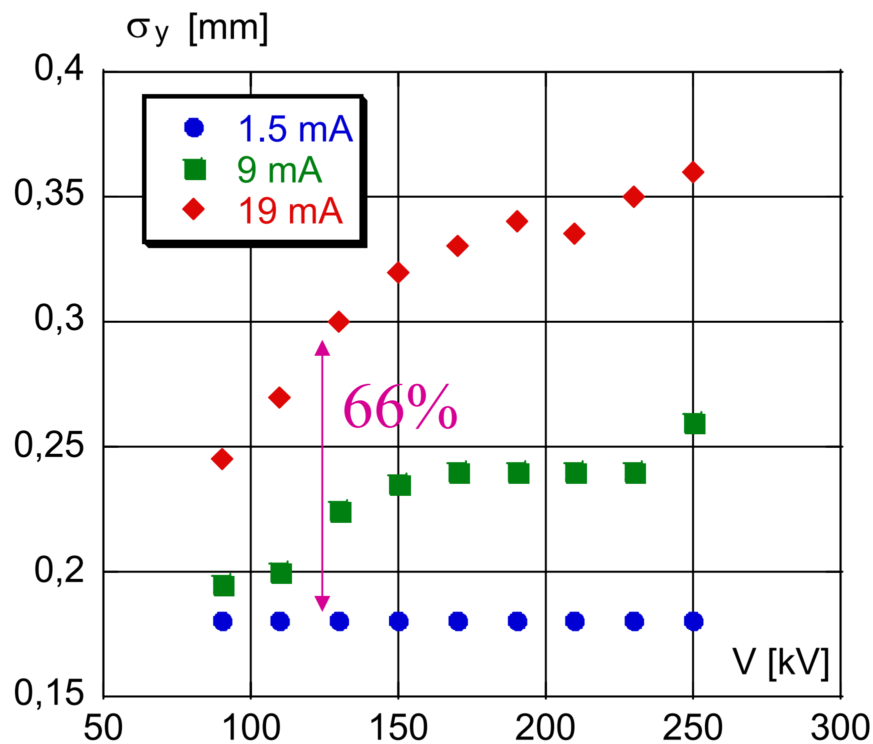



# Impedance Effects in the e- Ring

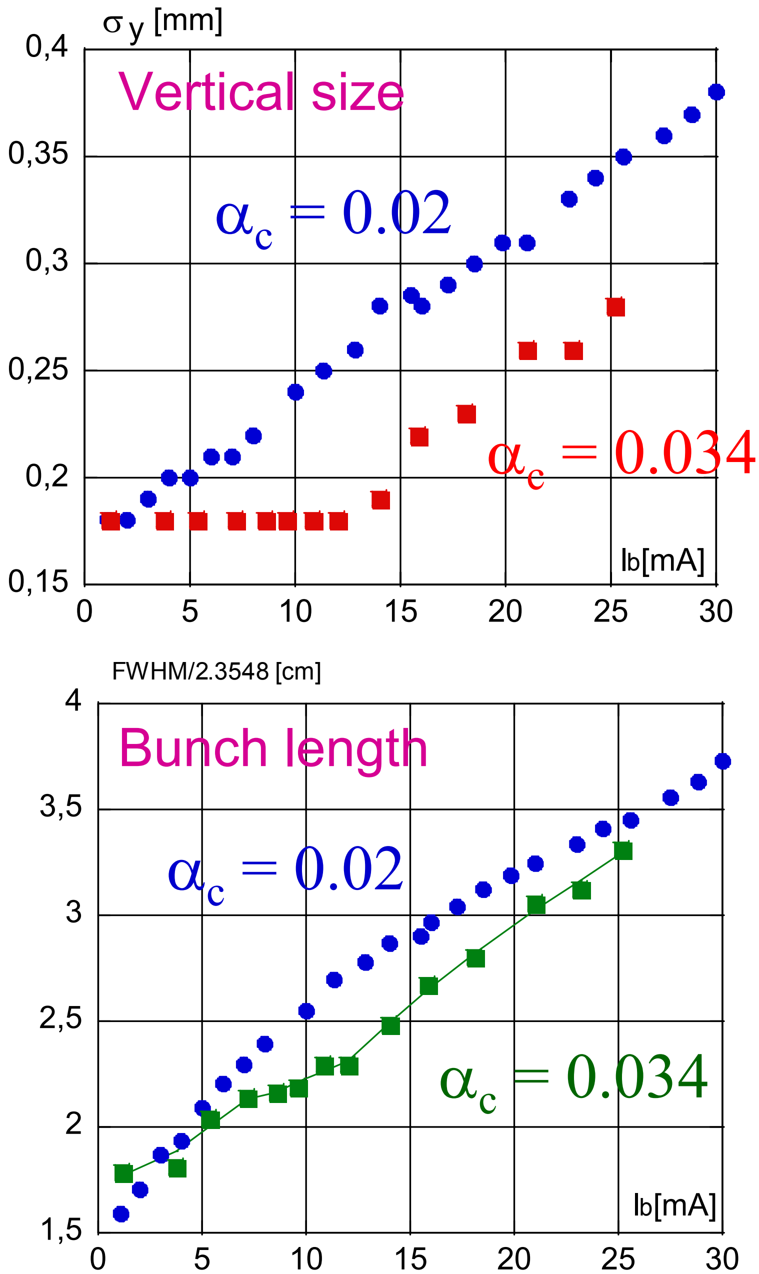
## Stronger Bunch Lengthening




## Vertical Size Blow $f(V_{RF}, I_b)$



# Vertical Size Blow Up




- Single bunch (beam) effect
- It is correlated with the longitudinal microwave instability:

a) The same threshold

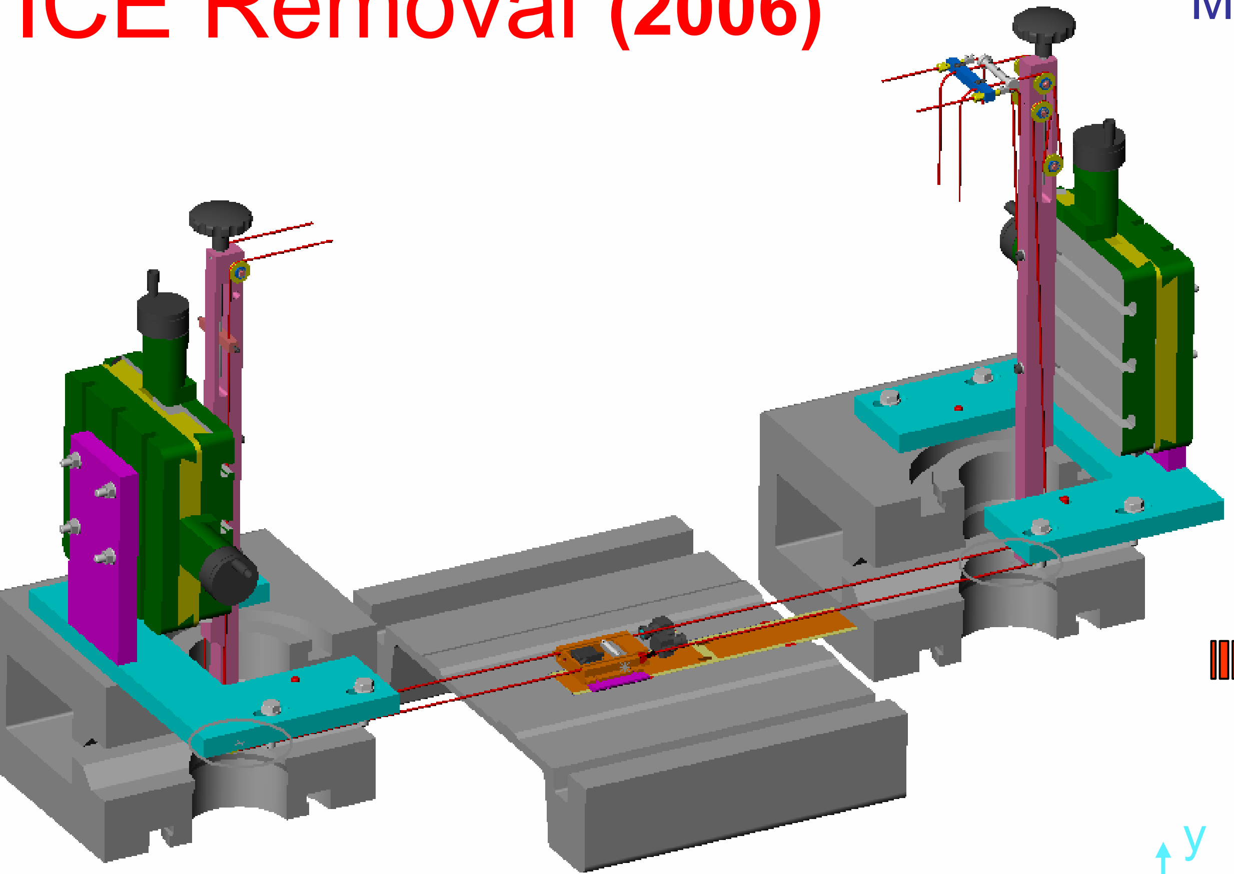
b) The same dependence on RF voltage

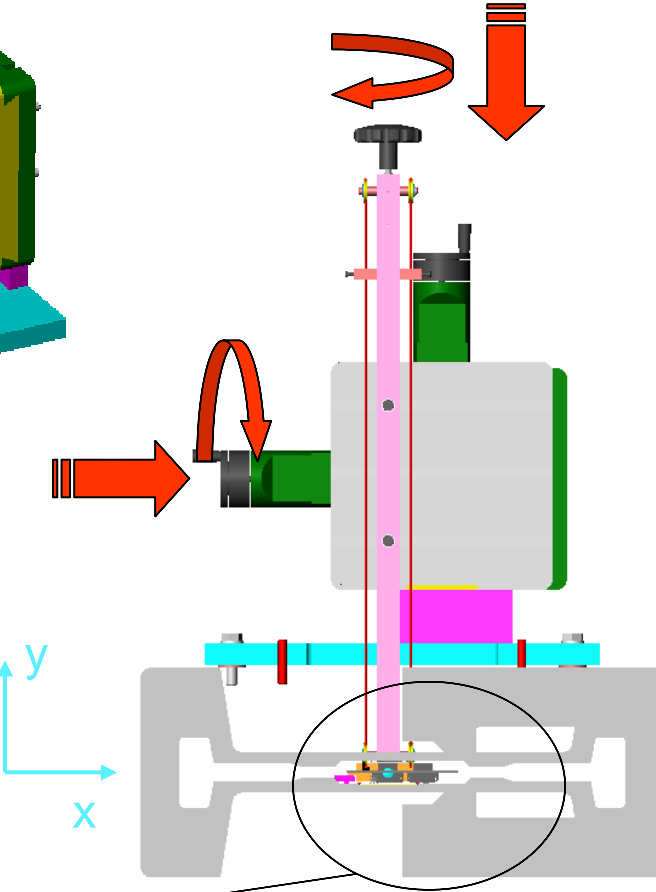
c) The threshold is higher for higher momentum compaction

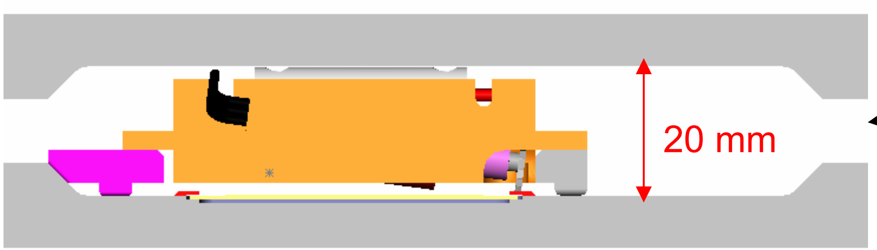
d) More pronounced for e- ring having higher coupling impedance

# ICE Removal **(2006)**

Multipurpose remotized positioning system

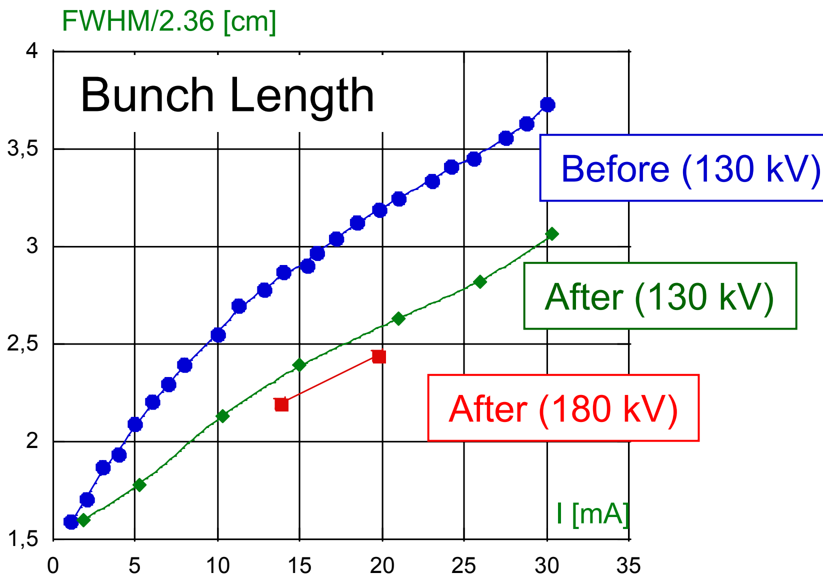





S.R.S. Group S.r.l

# After ICE Removal




1. About 30% e- bunch length reduction
2. Twice higher longitudinal microwave instability threshold
3. No quadrupole instability
4. No single bunch vertical blow up

Geometric luminosity by 50% higher!

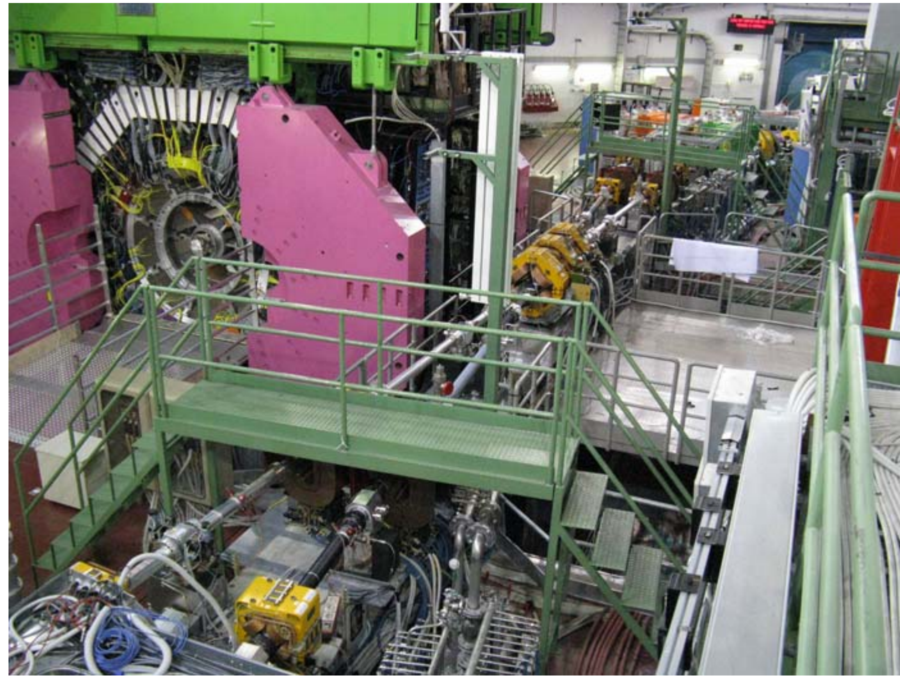
# Vacuum Chamber Modifications in 2007
## (for crab waist collision scheme test)

1. Installation of the new intearction region (main IR)
2. Installation of the new crossing region (second IR)
3. Substitution of the old injection kickers with new ones
4. Substitution of several old bellows with new ones

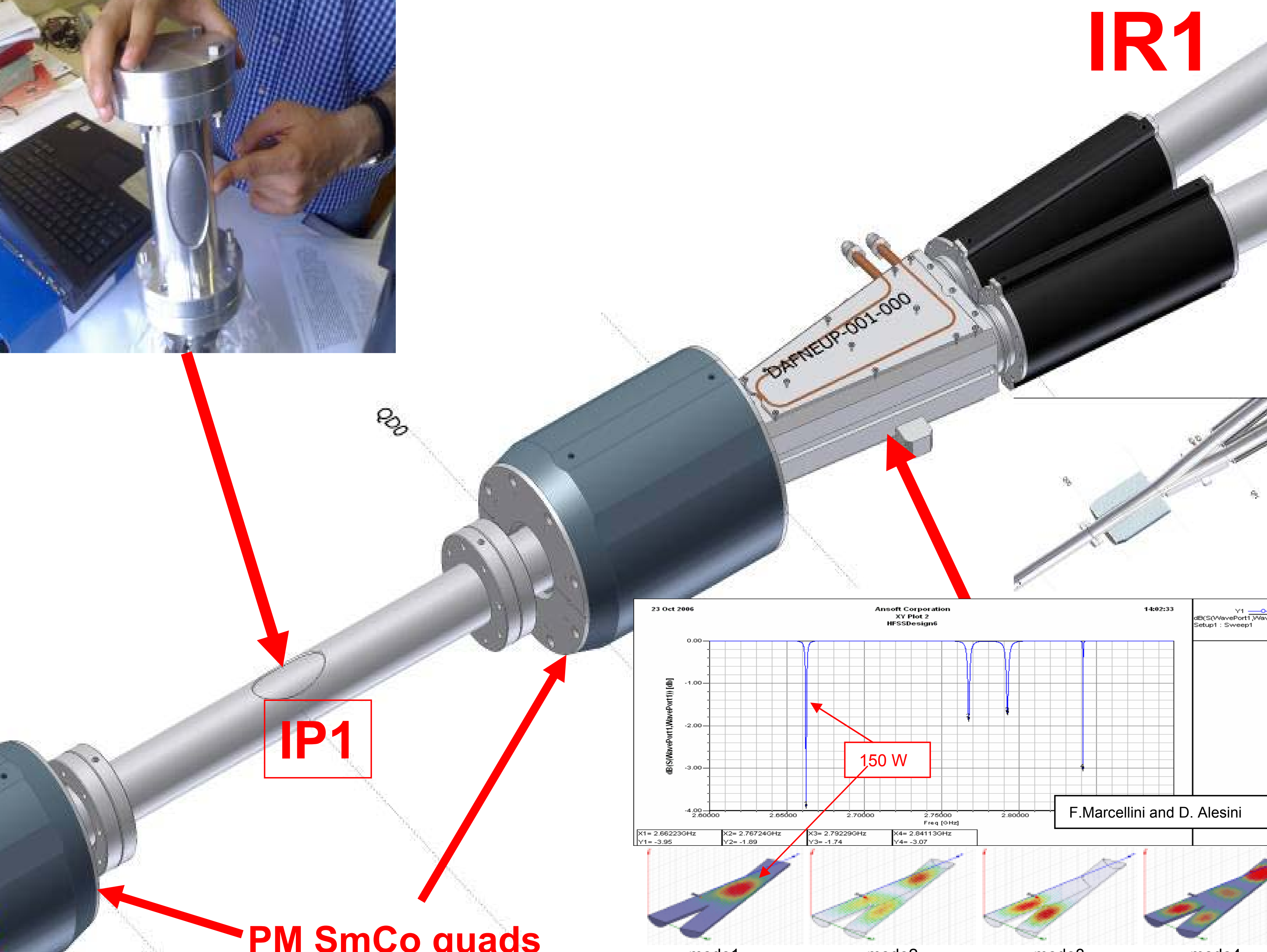

# *Interaction Region layout*

# Modified IR Chambers

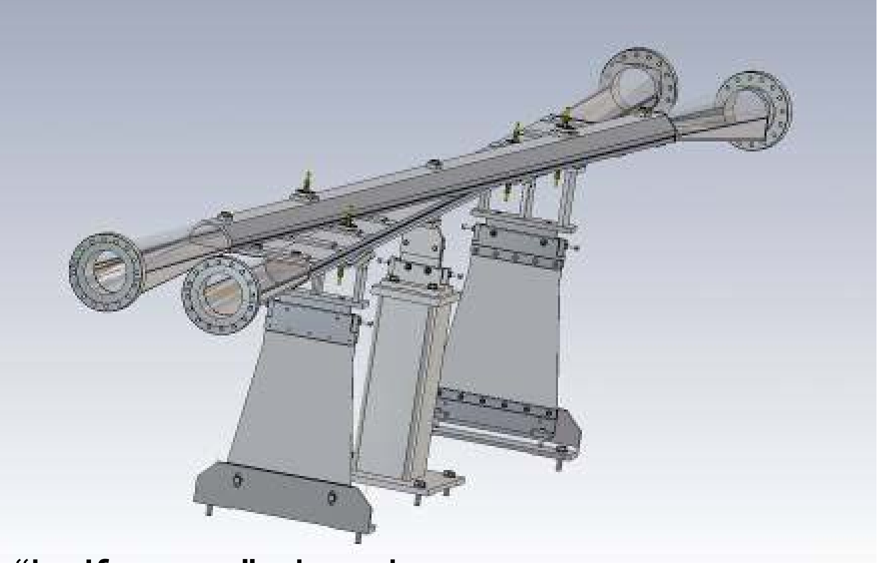
Interaction Region (IR1)



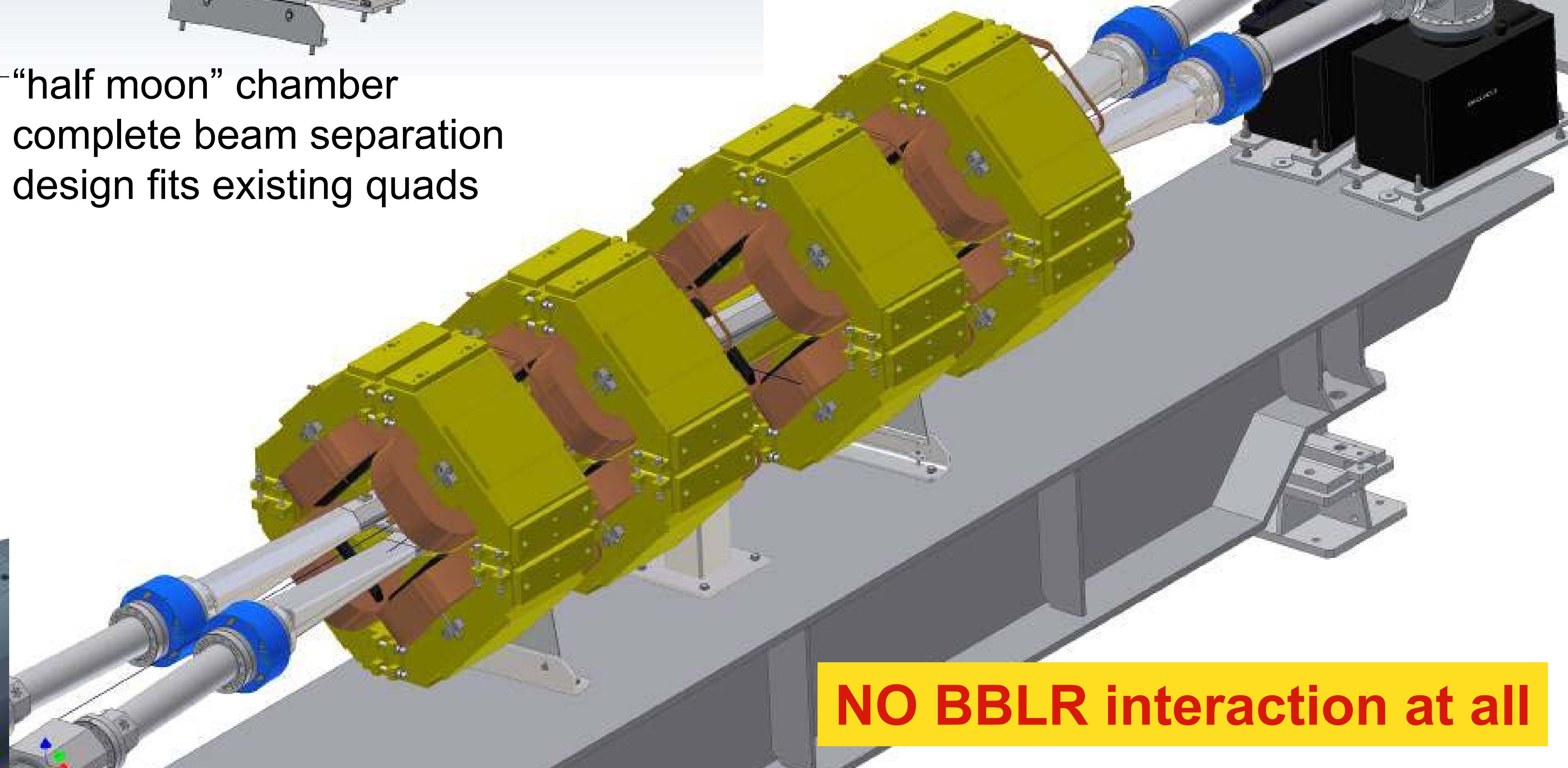
Crossing Region (IR2)


IR1
QD0
DAFNEUP-001-000
IP1
PM SmCo quads
23 Oct 2006
Ansoft Corporation
XY Plot 2
HFSSDesign6
14:02:33
Y1
Setup1 : Sweep1
dB(S(WavePort1,WavePort1)) [db]
0.00
-1.00
-2.00
-3.00
-4.00
2.60000
2.65000
2.70000
2.75000
2.80000
Freq [GHz]
150 W
X1= 2.66223GHz
Y1= -3.95
X2= 2.76724GHz
Y2= -1.89
X3= 2.79229GHz
Y3= -1.74
X4= 2.84113GHz
Y4= -3.07
F.Marcellini and D. Alesini

# DAΦNE upgrade IR2

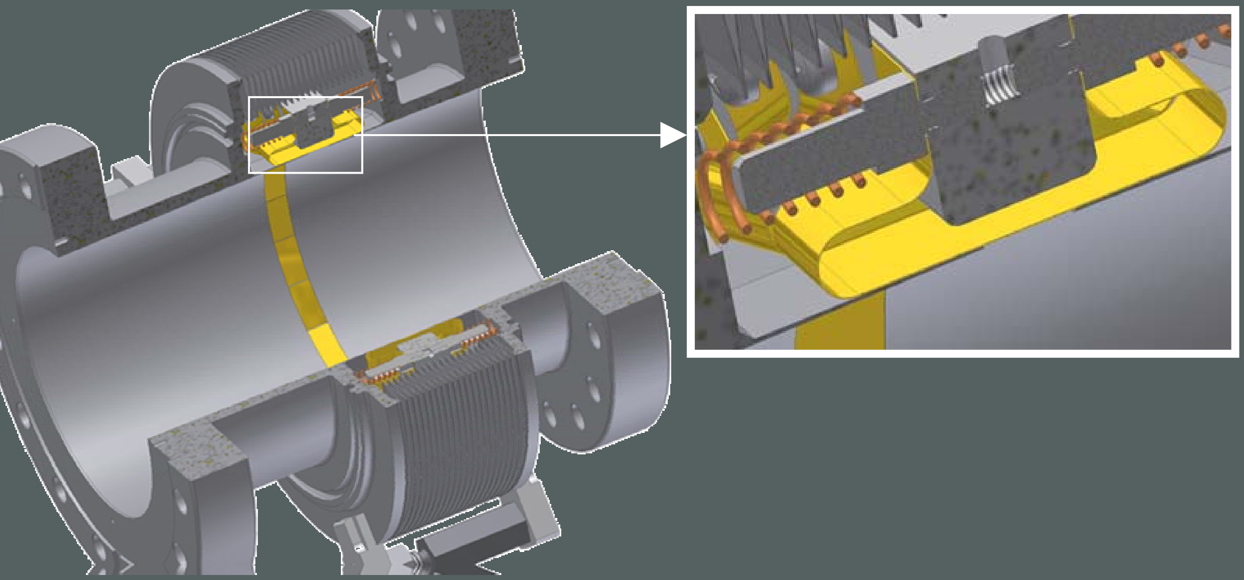


“half moon” chamber
complete beam separation
design fits existing quads



**NO BBLR interaction at all**

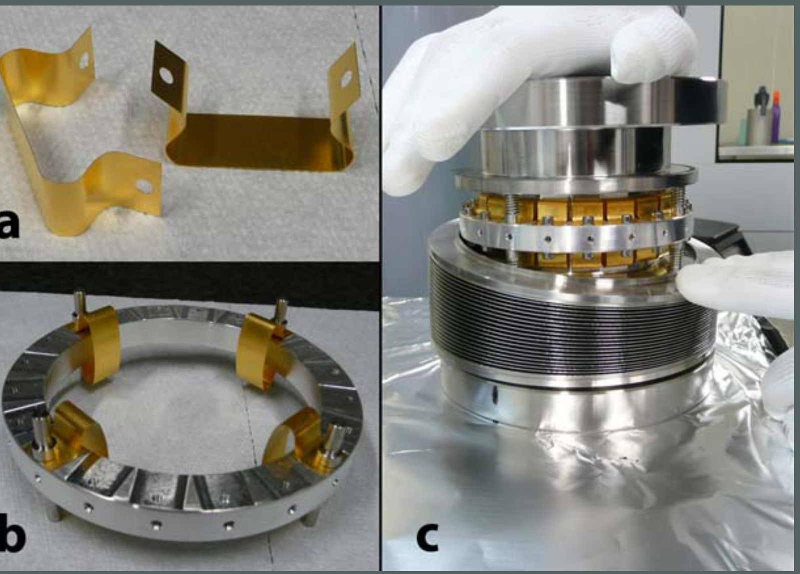
# RAWING OF THE NEW DAFNE BELLOWS



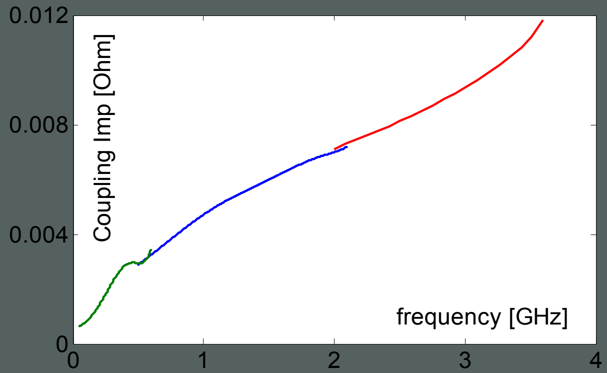
Designed for a circular cross section (ø 88 mm) chamber.

The shield is composed of:

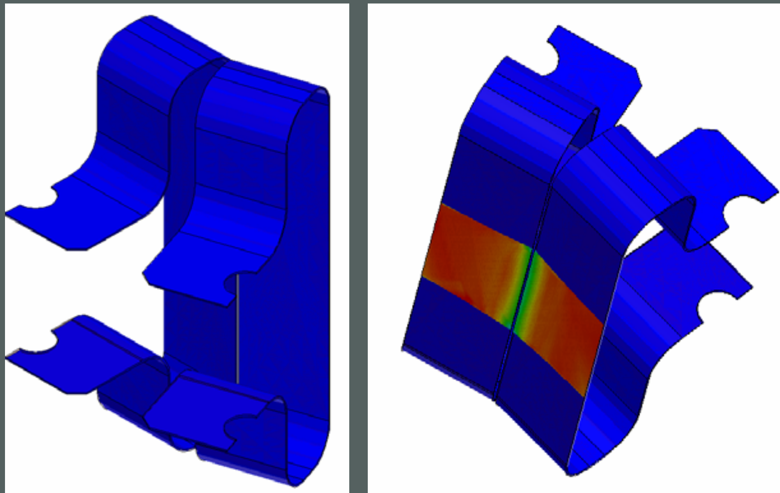
- 2 cylindrical pipes, welded at the bellows ends, give continuity to the beam pipes except for the gap between them.
- 20 Ω shaped, gold-coated, Be-Cu strips, shielding this gap.
- A floating thick aluminium ring where the 20 strips are bolted.




gold coated strip (a), supporting Al ring (b), bellows assembly (c).



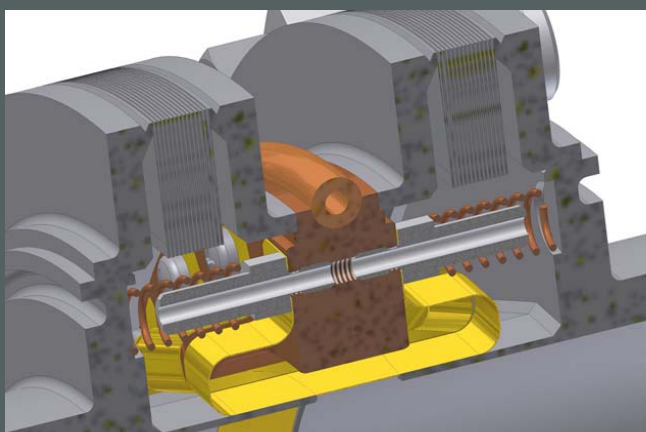

**THE RF SHIELD CAN FIT DIFFERENT BEAM PIPE CROSS SECTIONS**



Tangential magnetic field (current distribution) on the strip surfaces.

Due to the high thermal capacity of the supporting ring, the RF shield has a high thermal strength.

No specific devices to dissipate the power released by the DAFNE beam on the structure.

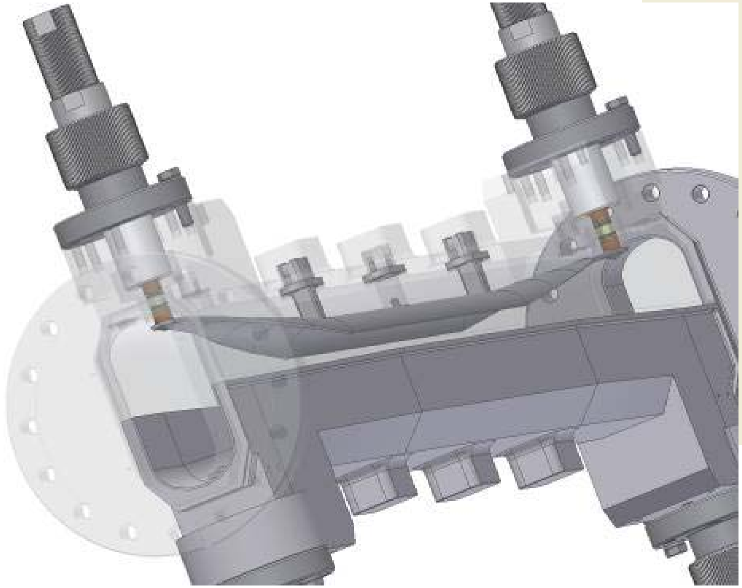


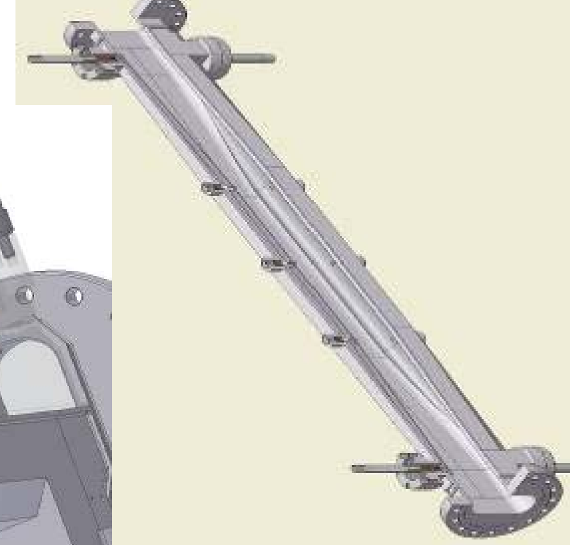
A cooled version of the bellows has been also considered for possible application on different machines.

The bellows convolutions were split in two and an external cooling serpentine is brazed around the supporting ring.

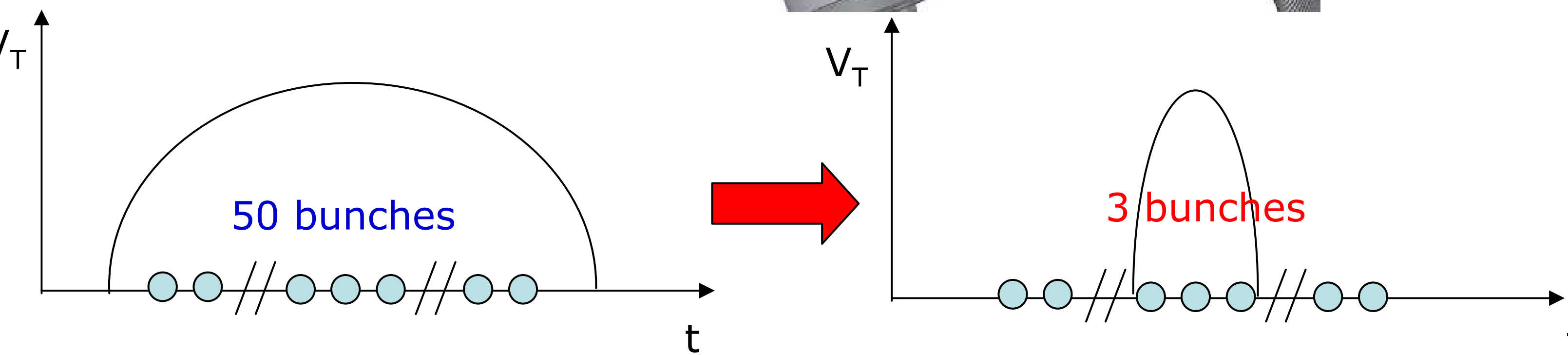
See also: EPAC '08 proceedings TUPP051 and TUPP074

# *New Fast Injection Kickers*





**New injection kickers with 5.4 ns pulse length to reduce perturbation on stored beam**



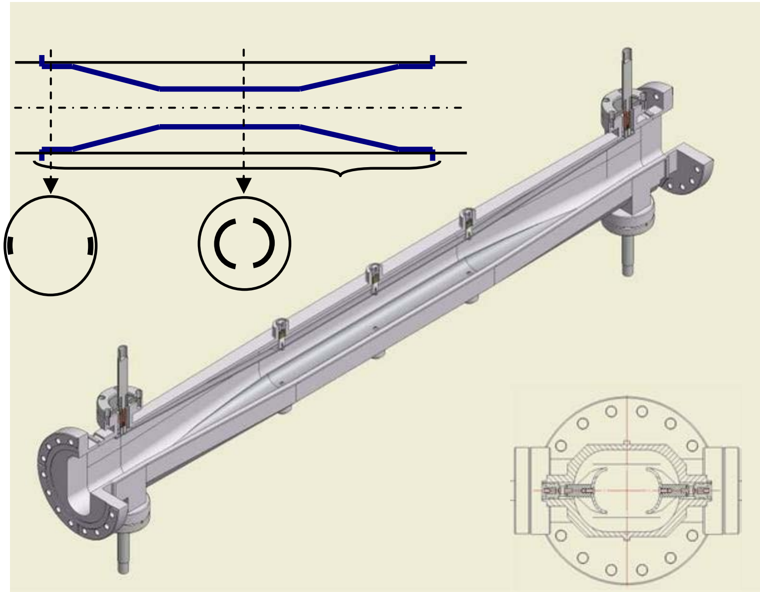

Present pulse length ~150ns

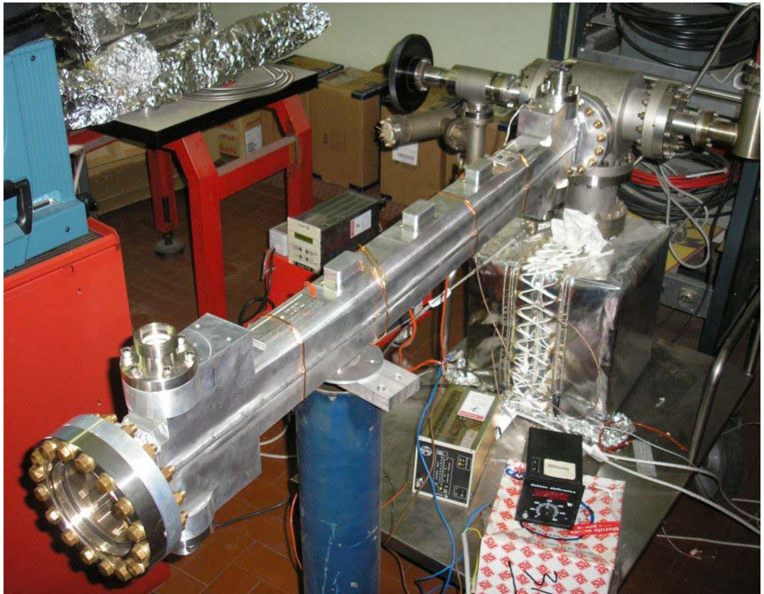
FWHM pulse length ~5.4 ns

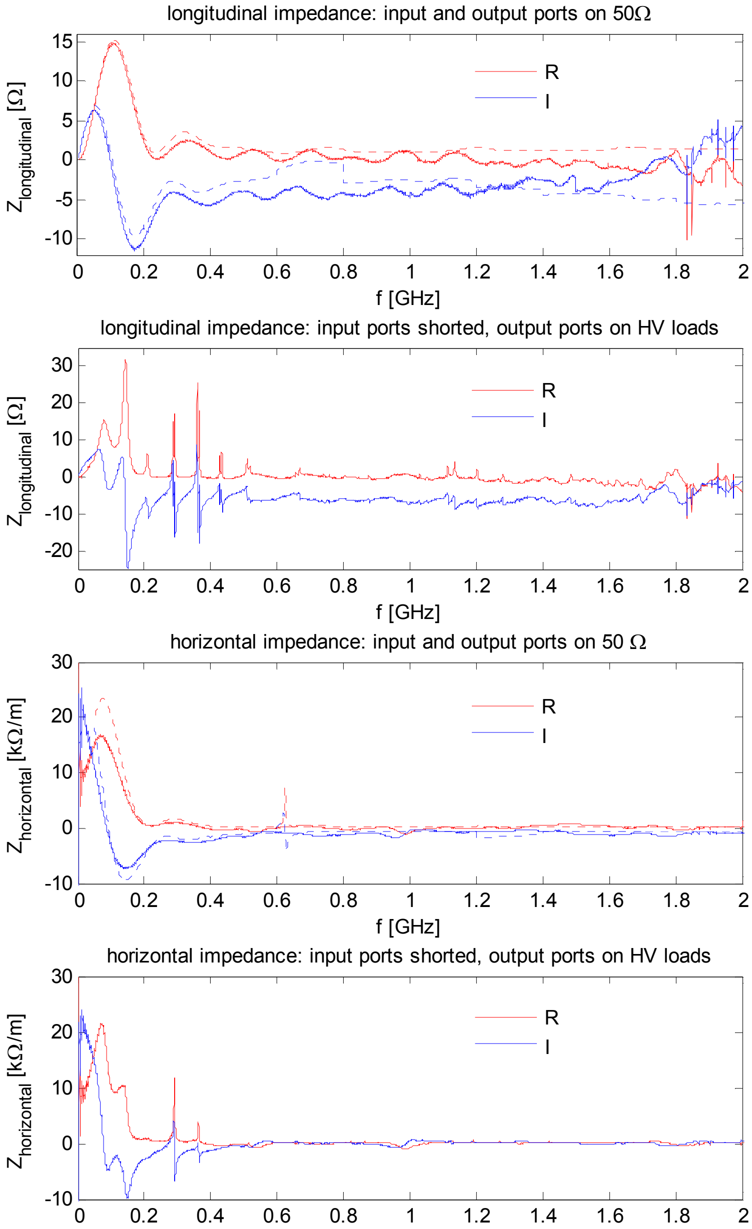
**Benefits:**

- **higher maximum stored currents**
- **Improved stability of colliding beams during injection**
- **less background allowing data acquisition during injection**

# New Injection Kicker Impedance

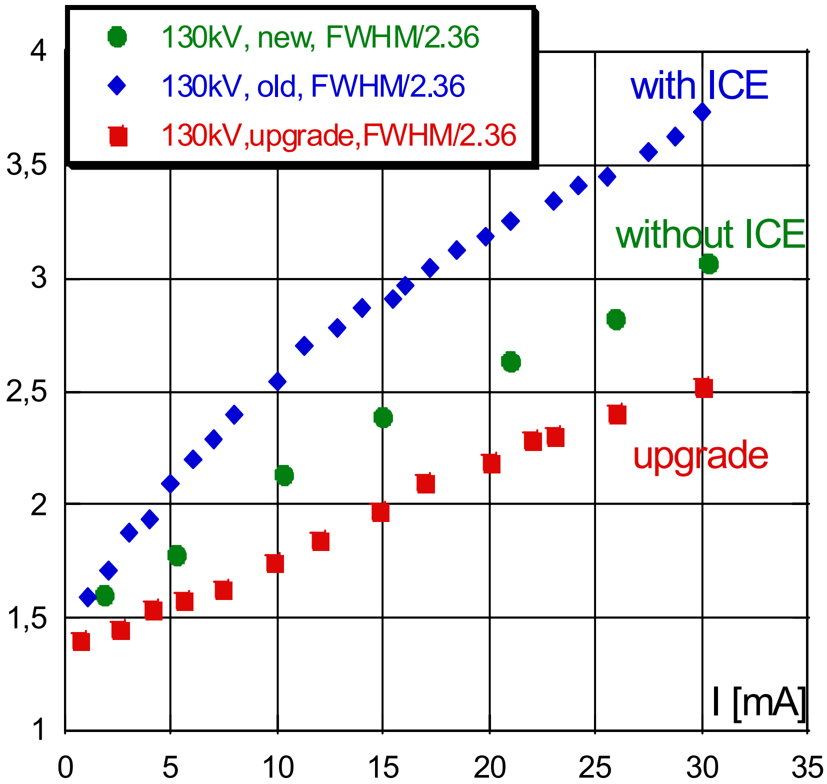




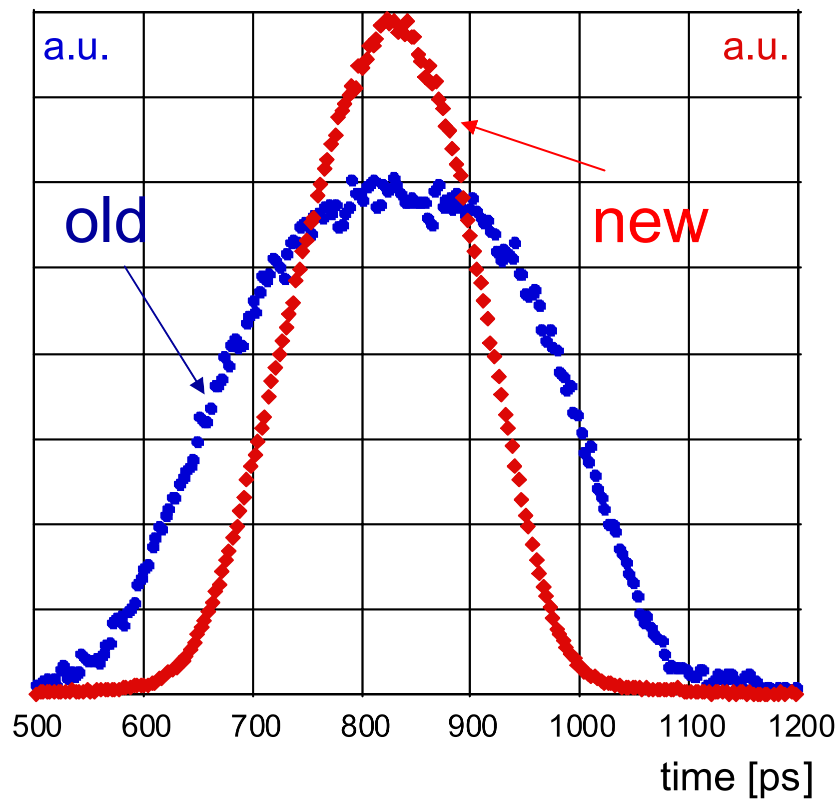


# Bunch Lengthening in Upgraded Vacuum Chamber

## Bunch Length



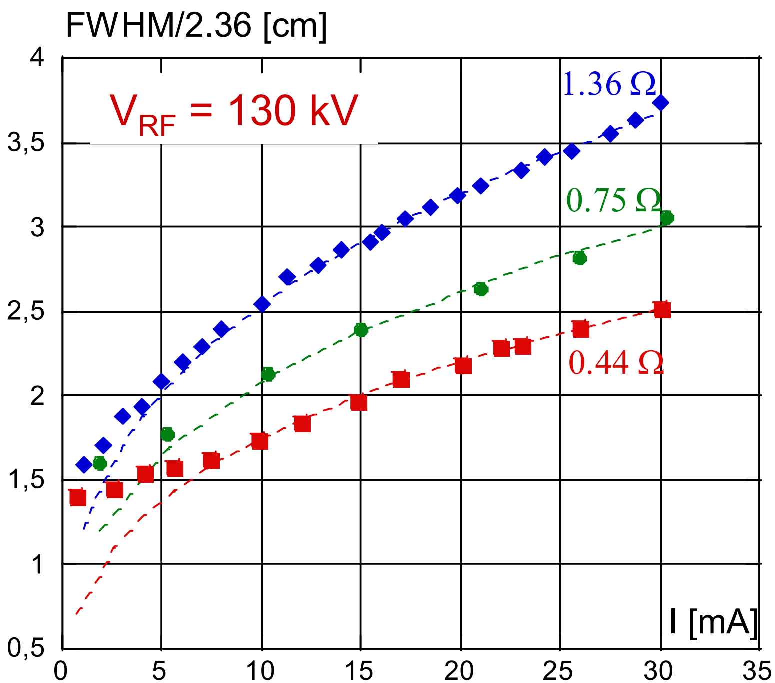

## Charge Distribution



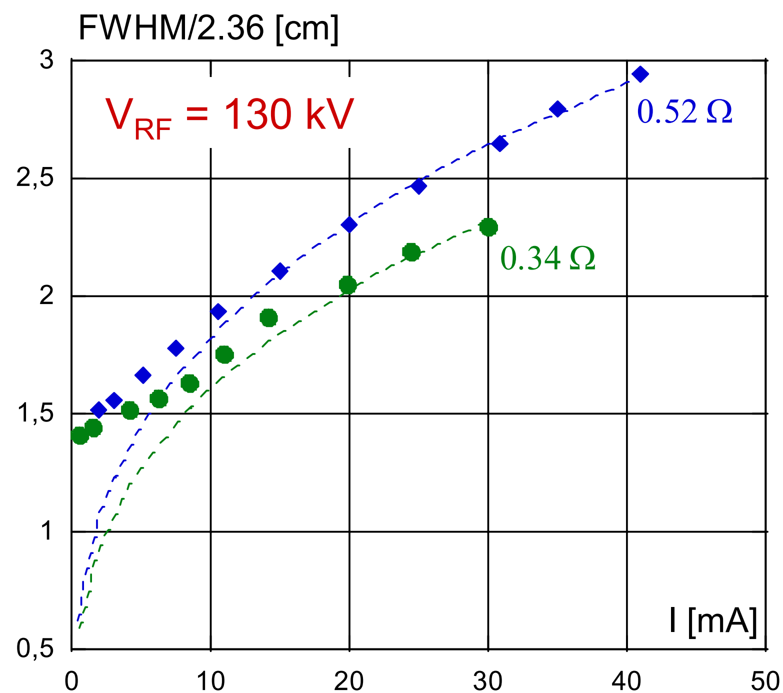
# Broadband Impedance Fit

$$\left(\frac{\sigma_z}{R}\right) \approx \left(\frac{2}{\pi}\right)^{1/6} \xi^{1/3} \left(\frac{Z}{n}\right)_o^{1/3} \quad \text{with} \quad \xi = \frac{\alpha_c I}{\nu_s^2 (E/e)} = \frac{2\pi I}{h V_{RF} \cos\phi_c}$$

A.W.Chao, J.Gareyte, SPEAR-127, PEP-224, December 1976




Electron Ring

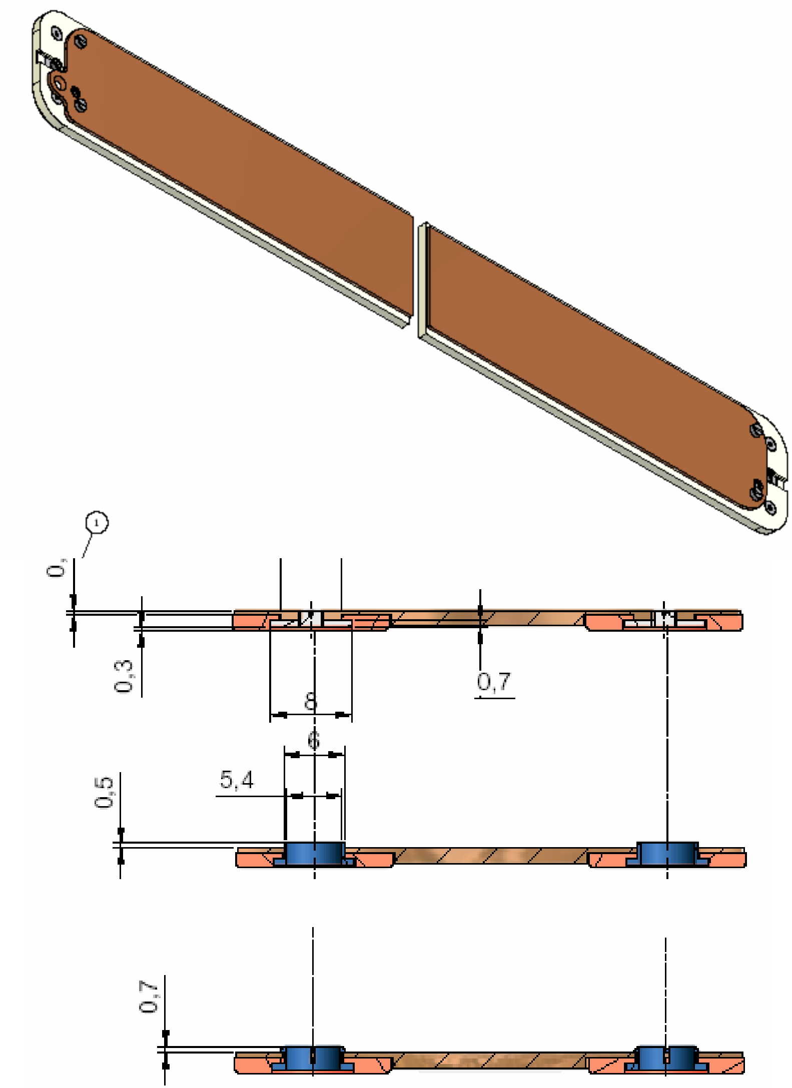



Positron Ring

# Latest Vacuum Chamber Modifications
# (November 2009 – March 2010)

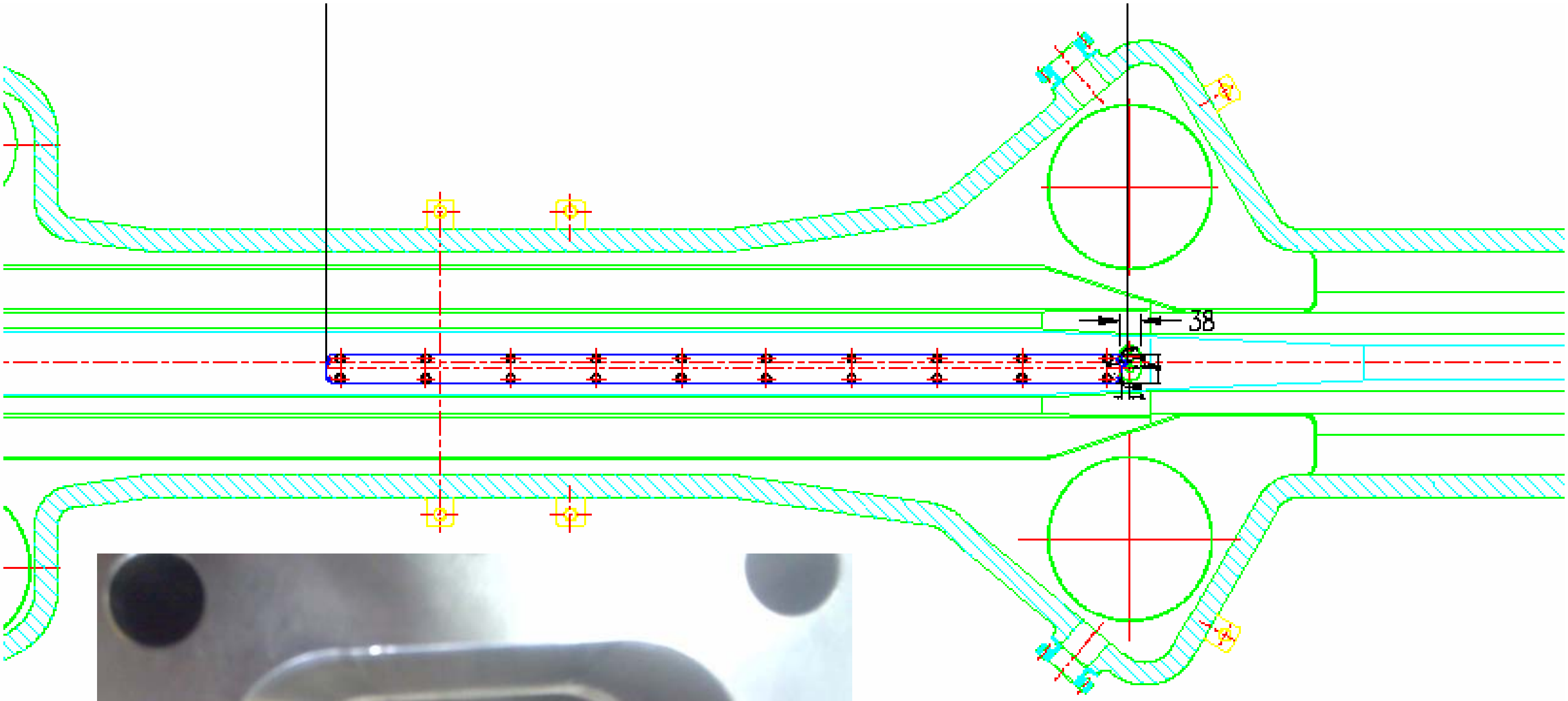
1. Installation of e-cloud clearing electrodes (e+ ring)
2. Removal of remaining ion clearing electrodes (e- ring)
3. New transverse feedback kicker installation
4. Beam dump kicker installation
5. Substitution of old bellows with new ones
6. Modification of beam scrapers
7. Interaction region modifications
8. Other..

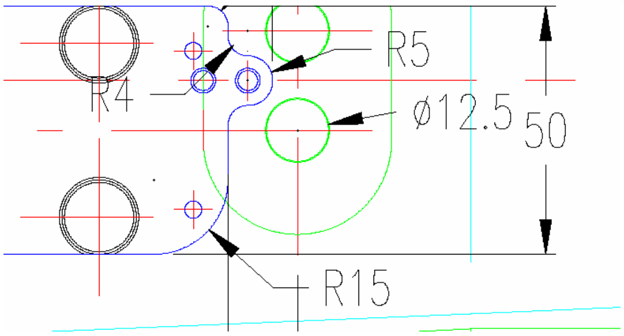
# Clearing electrodes for DAFNE




D.Alesini, M. Zobov, A.Battisti, R. Sorchetti, V. Lollo (LNF)

# Clearing electrodes installation: Wigglers




D.Alesini, M. Zobov, A.Battisti, R. Sorchetti, V. Lollo (LNF)

# Conclusions

Low impedance vacuum chamber design has been one of the key ingredients for achieving the good DAΦNE performance: high colliding beam currents, good peak and integrated luminosity

Thank you!