Clearing Electrodes in DAΦNE

(Beam Dynamics Aspects)

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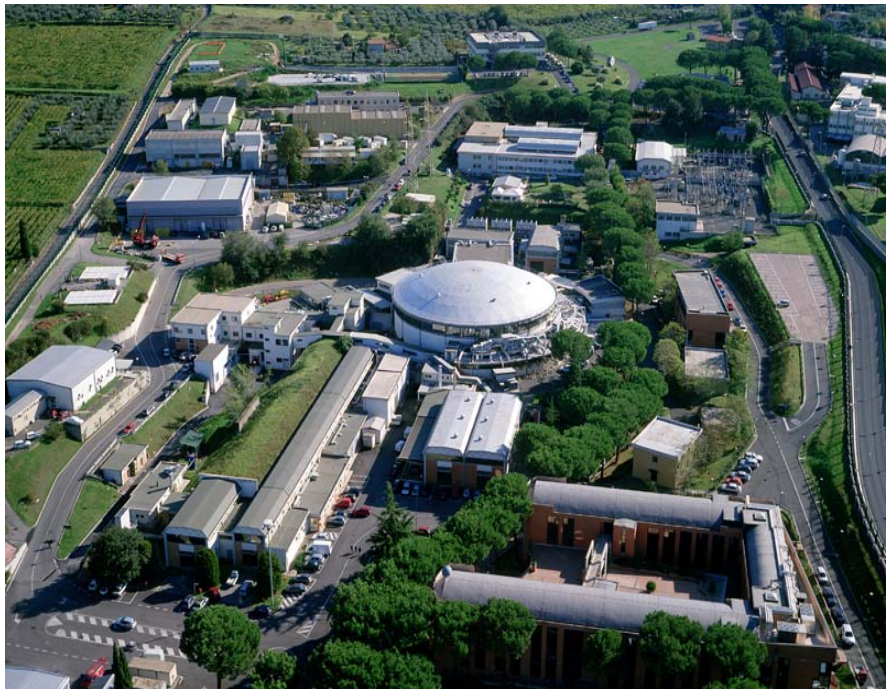
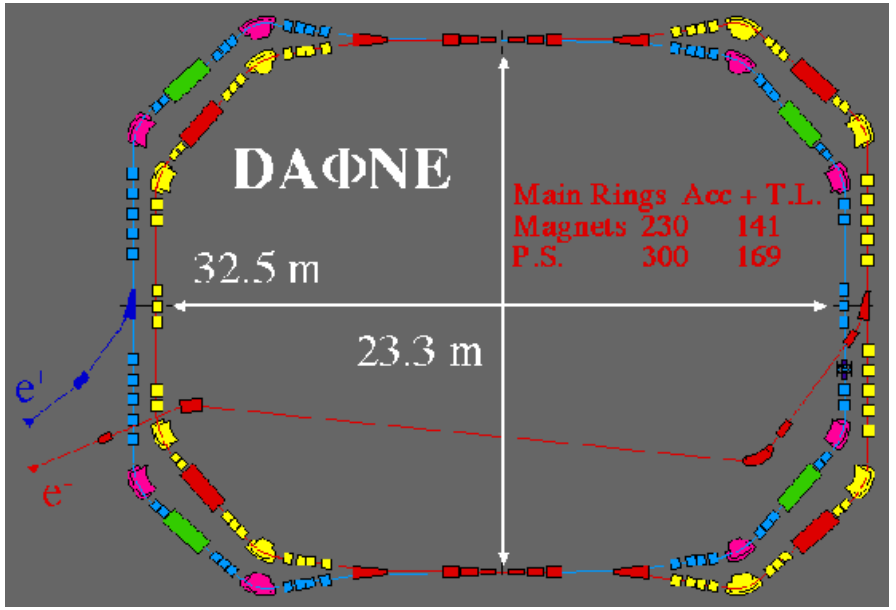
OUTLINE

1. DAΦNE Collider
2. DAΦNE Ion Clearing Electrodes (ICE)
3. ICE Impact on Beam Dynamics
4. ICE Impedance Calculations
5. ICE Impedance Experimental Verification
6. ICE Removal and Results

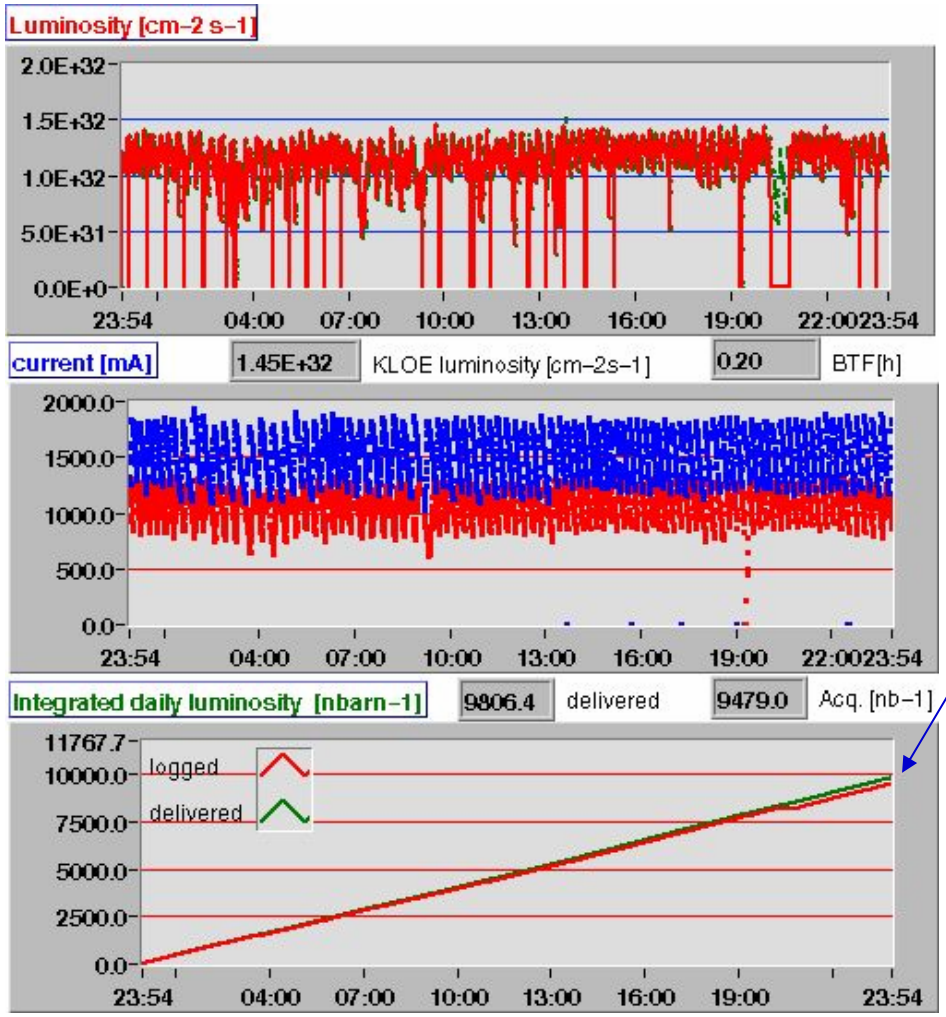
DAΦNE Parameters
(KLOE configuration)

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

$L_{max} = 1.53 \times 10^{32}\ cm^{-2}s^{-1}$

Purpose of Using ‘Invisible’ Electrodes

- To make ICE transparent for the beam as much as possible in order to
  - Avoid the ICE to act as an antenna (Machine Advisory Committee)
  - Eliminate resonant part of the coupling impedance due to mismatch with the external feedthroughs

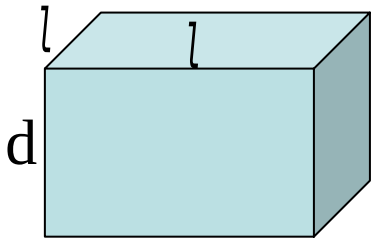
Principal Idea

To use for the ICE a material with a high “resistivity per square”

defines the skindepth

$$R_{\square} = \rho\frac{l}{S} = \rho\frac{l}{dl} = \frac{\rho}{d}$$

defines ICE thickness



R_o does not depend on the the material length and must have high resistivity ρ and small thickness d.

In this case we can expect that the skin depth will be much bigger than the ICE thickness d to provide ICE transparency

ICE Material

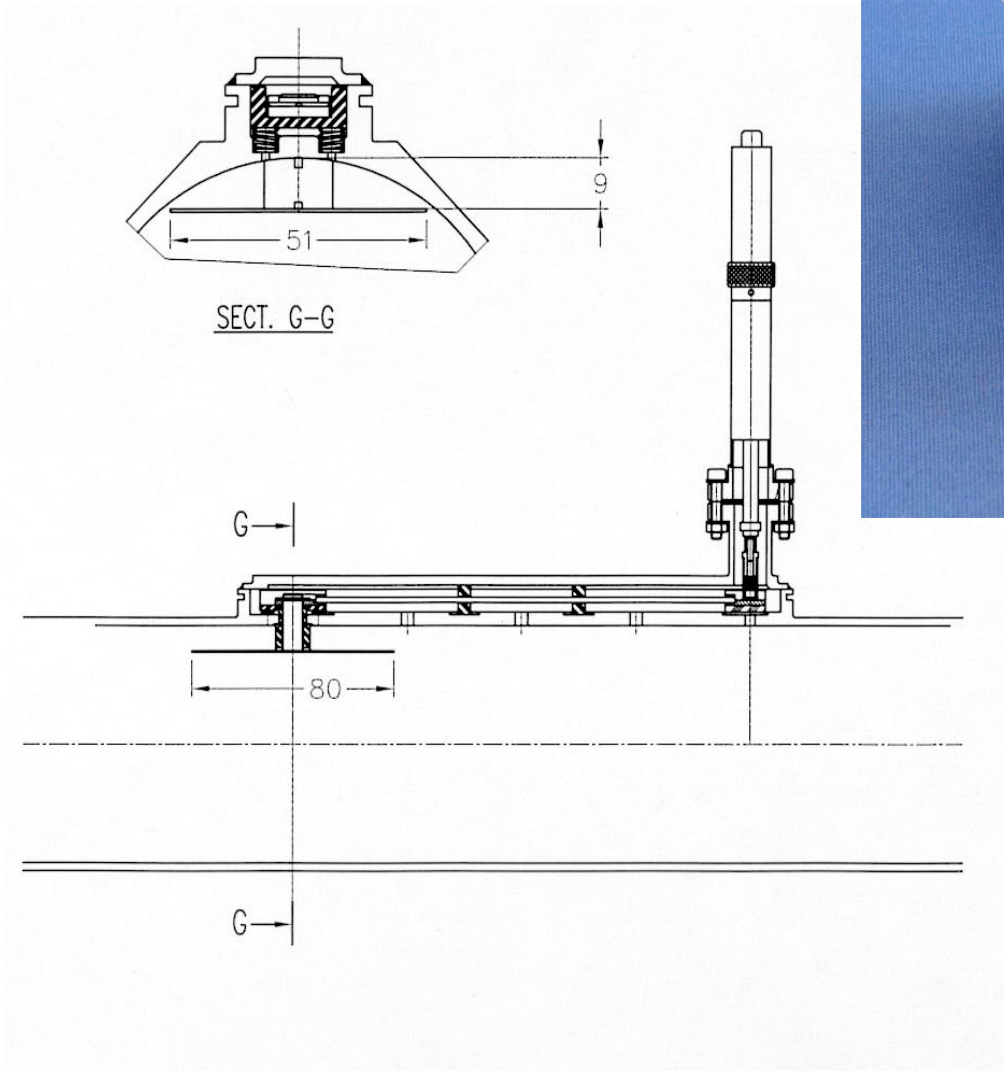
A highly resistive paste with a thickness *d* of 25 μm and the resistivity per square ρ/d of the order of 10^5 is painted on a dielectric material with $\varepsilon = 9$ (alumina)

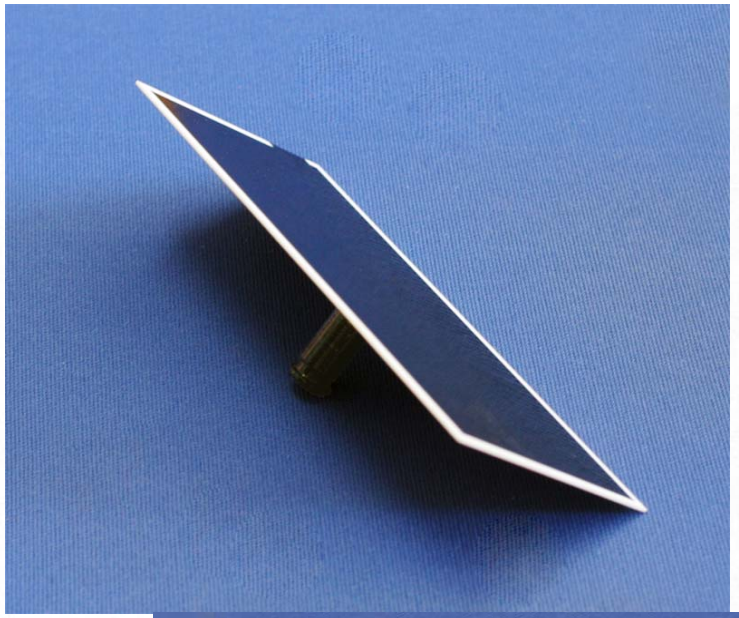
The skin depth estimated at a typical bunch spectrum frequency of 1 GHz is:

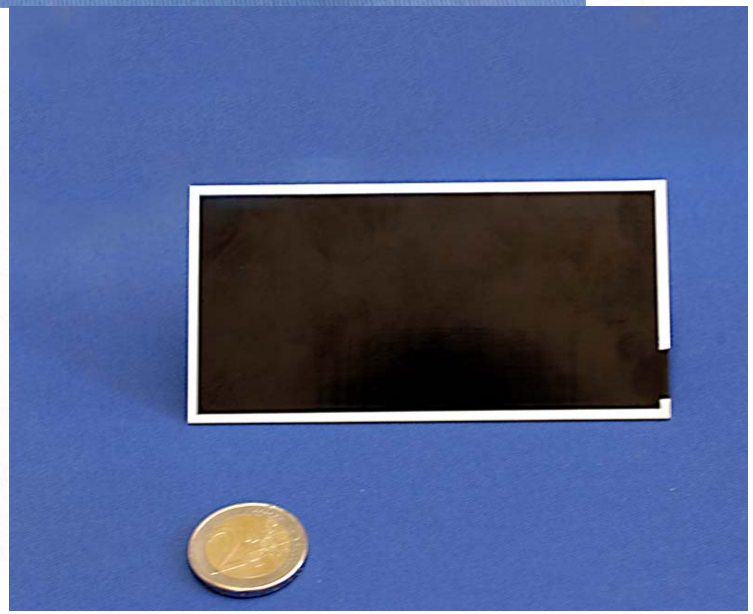
$$\delta_s = \sqrt{\frac{2\rho c}{Z_0 \omega}} = 2.5\times10^{-2} m \rightarrow 1000d$$

i.e. the skin depth is much larger than the layer thickness thus making the layer transparent at RF frequencies

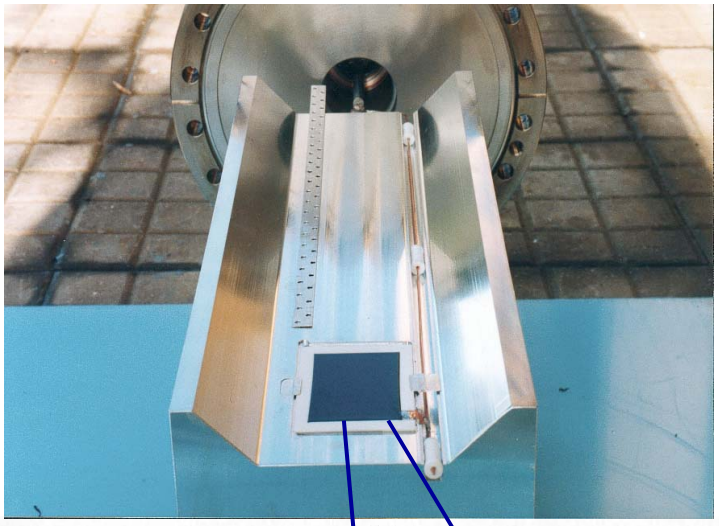
ICE in Straight Sections

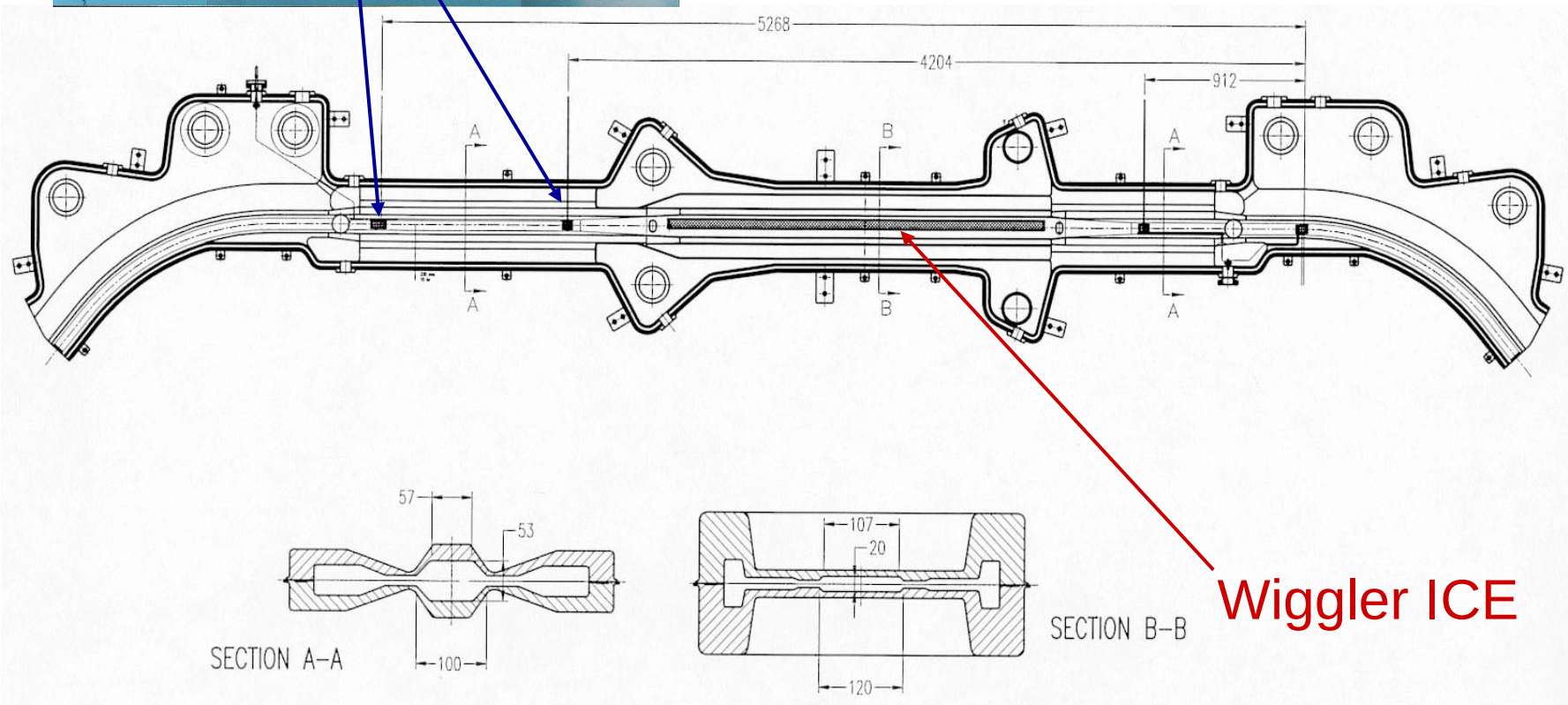






ICE in the Arcs



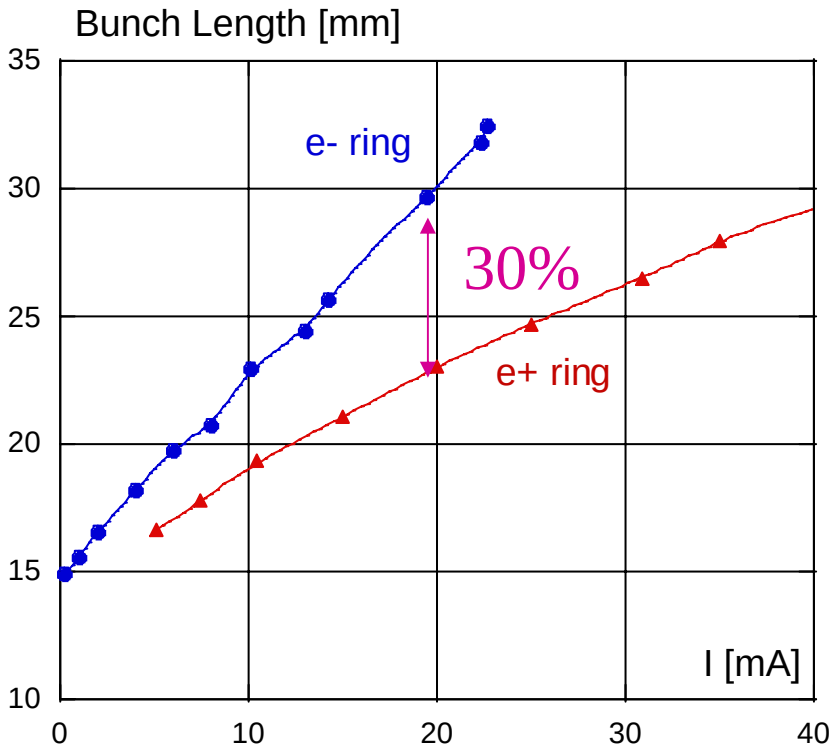


Harmful Effects

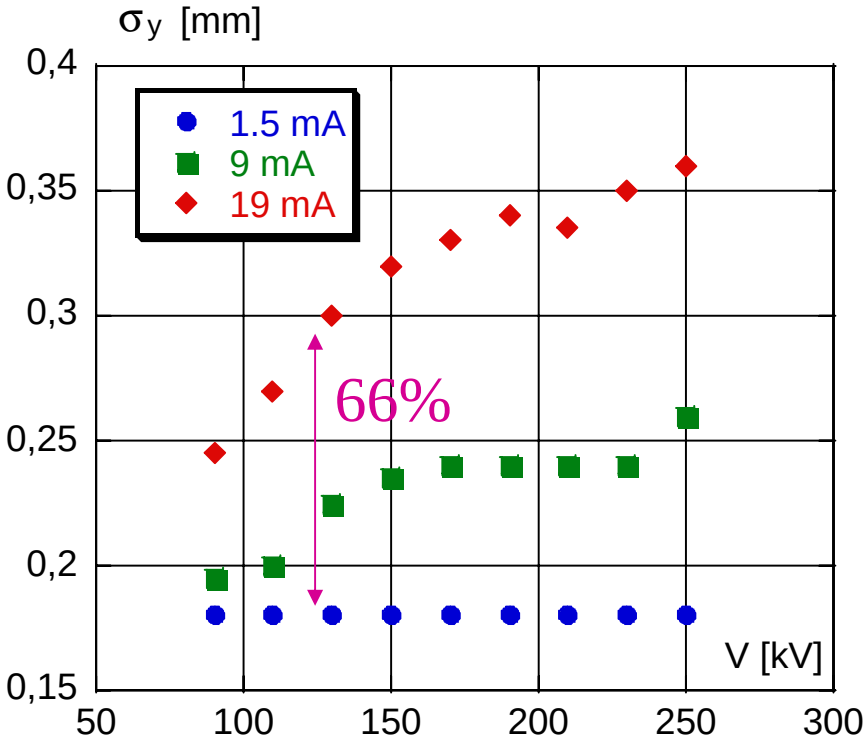
1. Bunch length in the electron ring is by 30% longer than in the positron one
   a) Hour-glass effect → luminosity reduction
   b) Beam-beam resonances are stronger
2. Longitudinal quadrupole instability
   a) Injection saturation
   b) Luminosity reduction
   c) Ineffective feedback operation
3. Vertical beam size blow up beyond the longitudinal microwave instability threshold
   a) Luminosity reduction

Impedance Effects in the e- Ring

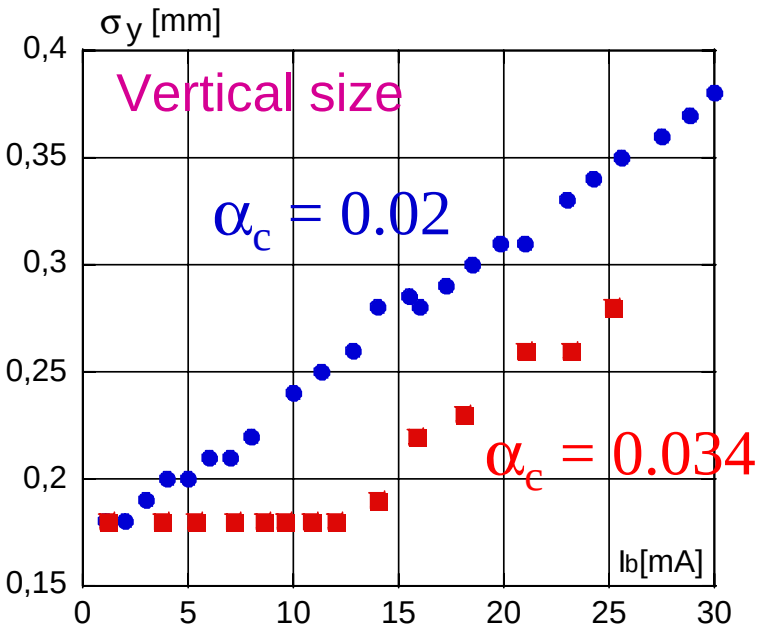
Stronger Bunch Lengthening

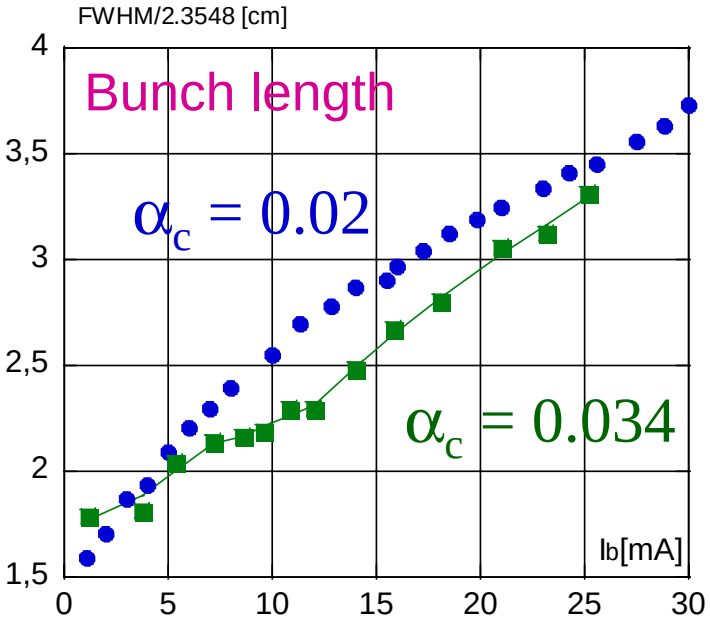


Vertical Size Blow $f(V_{RF}, I_b)$



Vertical Size Blow Up





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

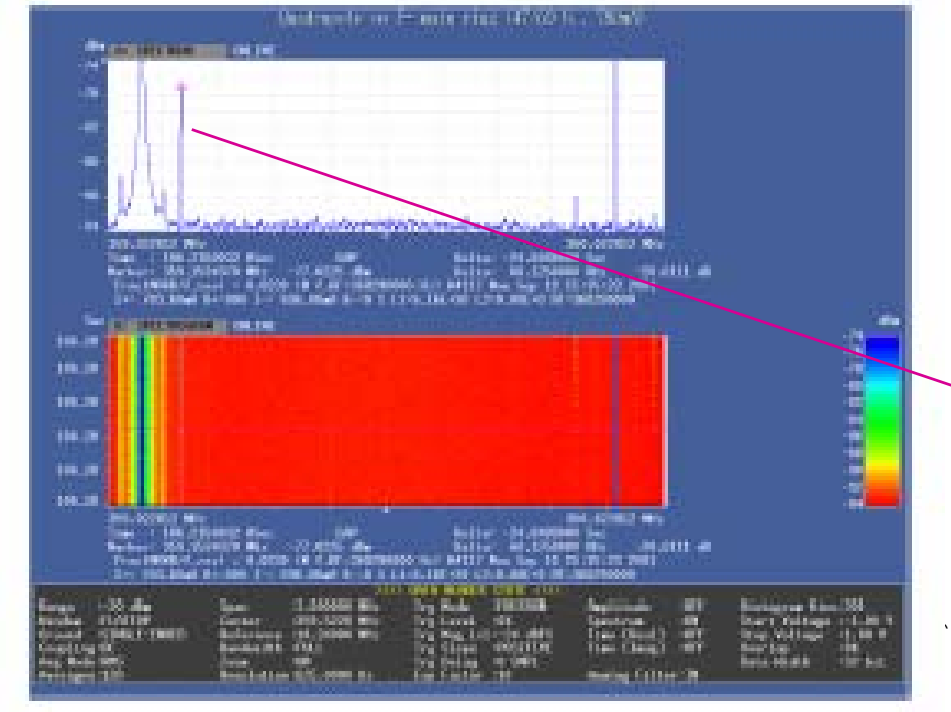
a) The same threshold

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

DAΦNE e- Ring Quadrupole Instability



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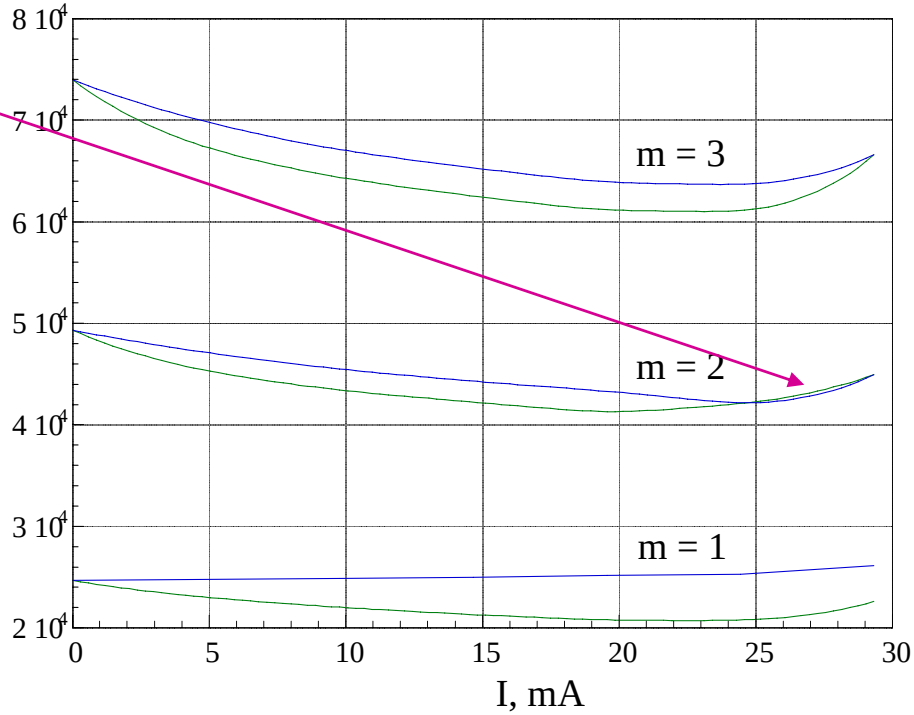
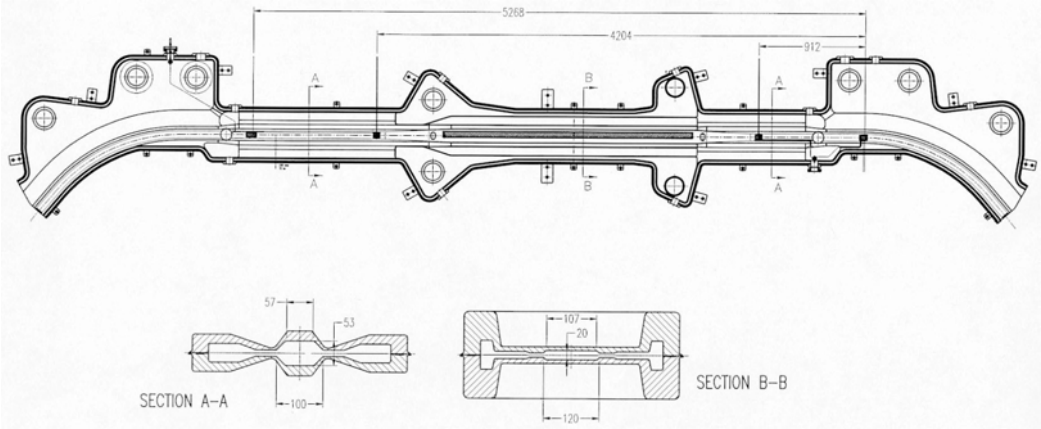
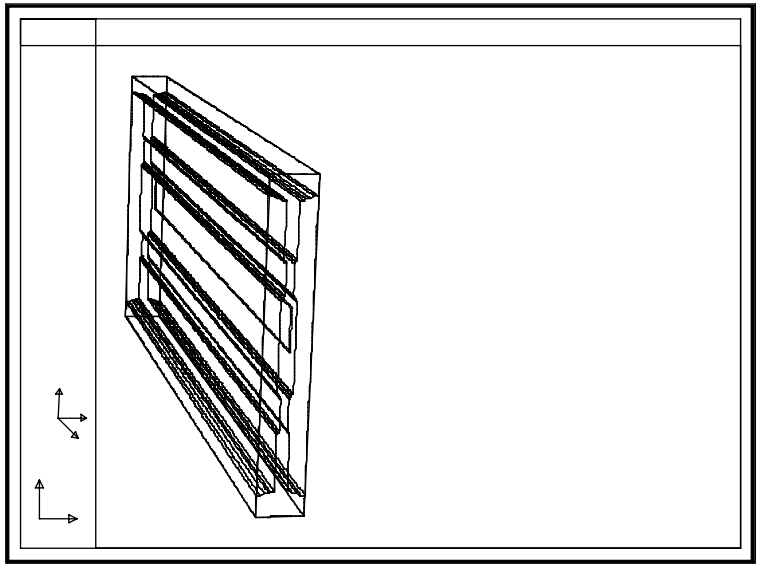
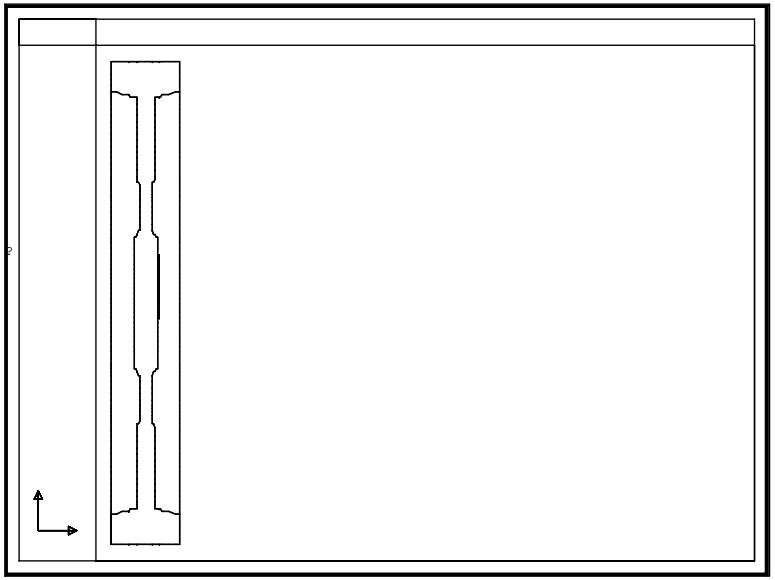
M.Zobov et al., DAΦNE Technical Note BM-3, June 7 1998





Modeling with MAFIA





Impedance Calculations

have shown that the impedance:

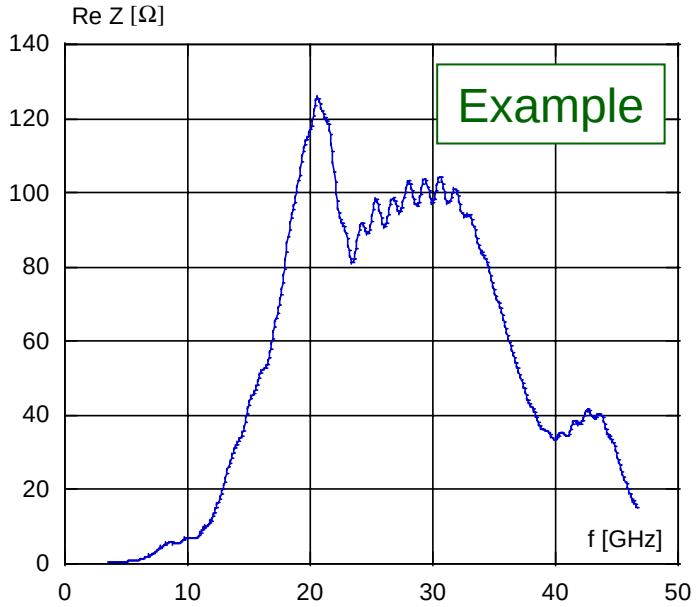
1. scales linearly with the electrode length L
2. scales linearly with the electrode thickness d
3. scales as a square root of material dielectric constant $\varepsilon^{1/2}$
4. dominant impedance contribution comes from 4 ICE in the wiggler sections (>2 m long, very close to the beam)

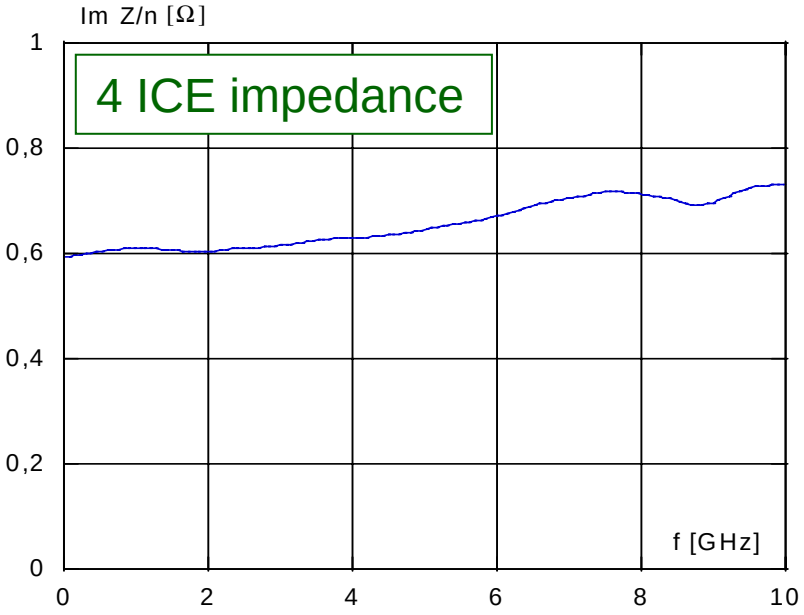
Similar to wake field acceleration in dielectric channels!

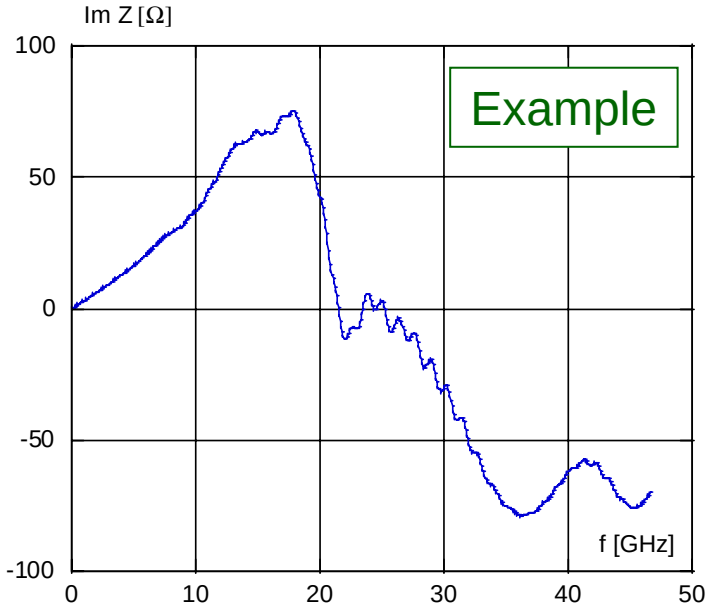
Wiggler ICE Impedance

The impedance:

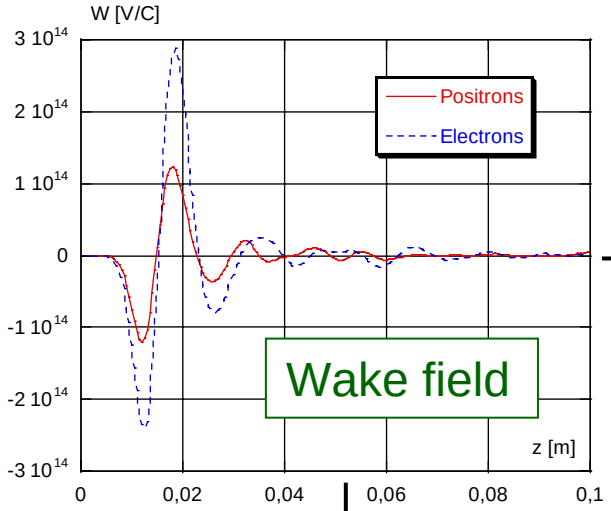
1. Broad-band
2. Extends till rather high frequencies
3. Mostly inductive at low frequencies
4. Accounts for the half of the ring impedance

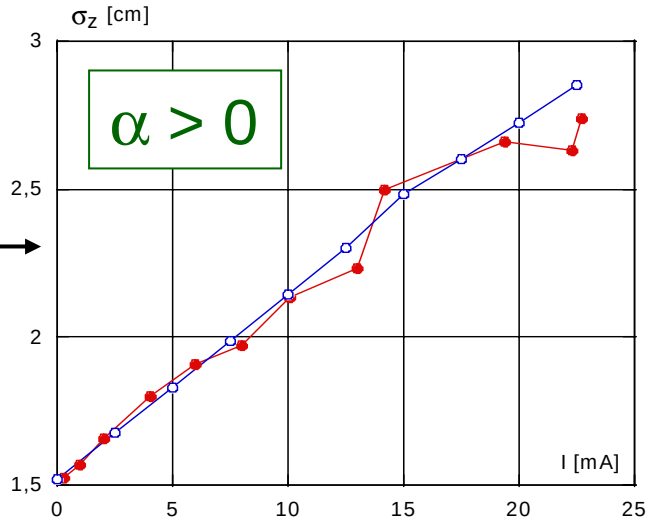


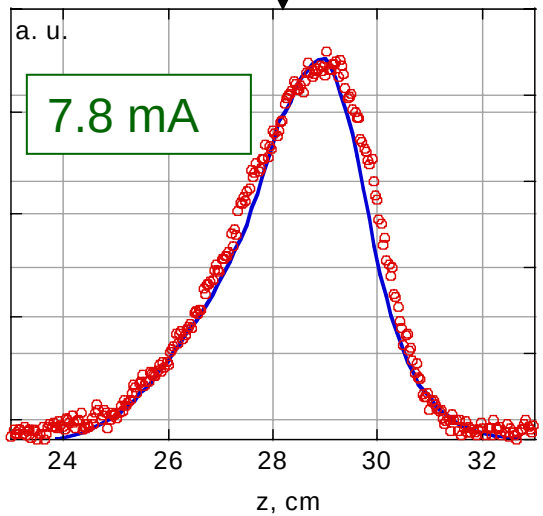


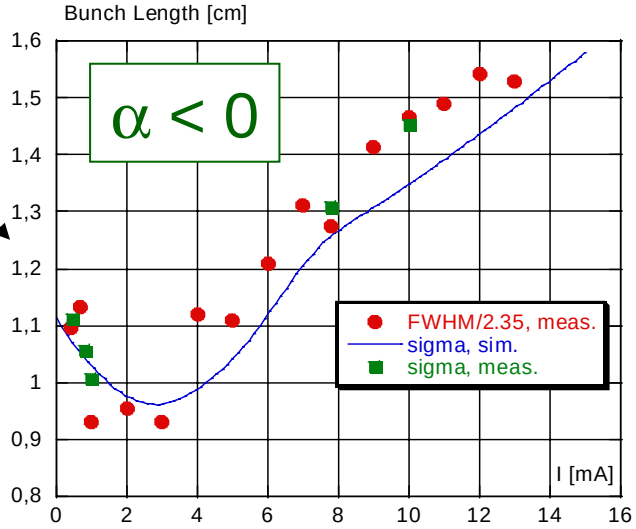


Bunch Lengthening in Electron Ring



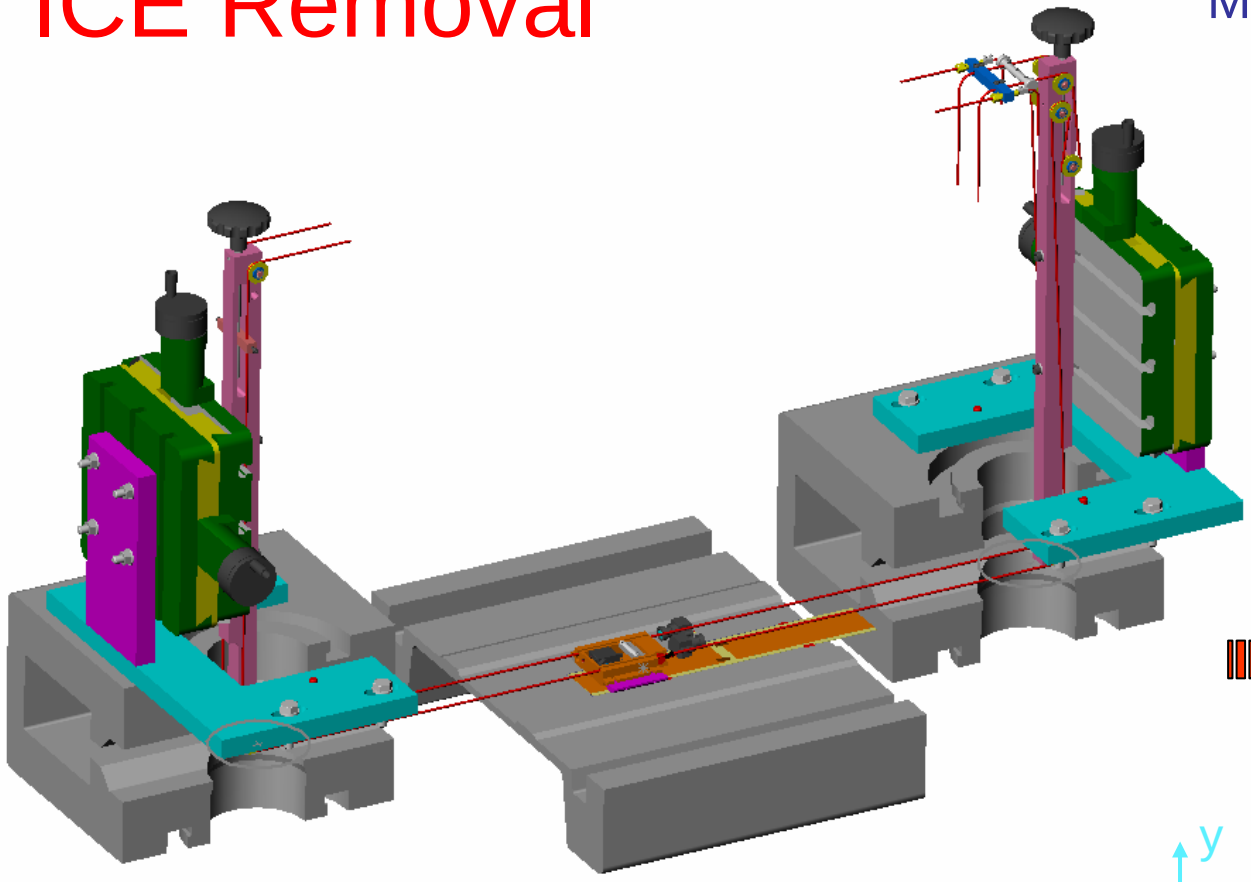


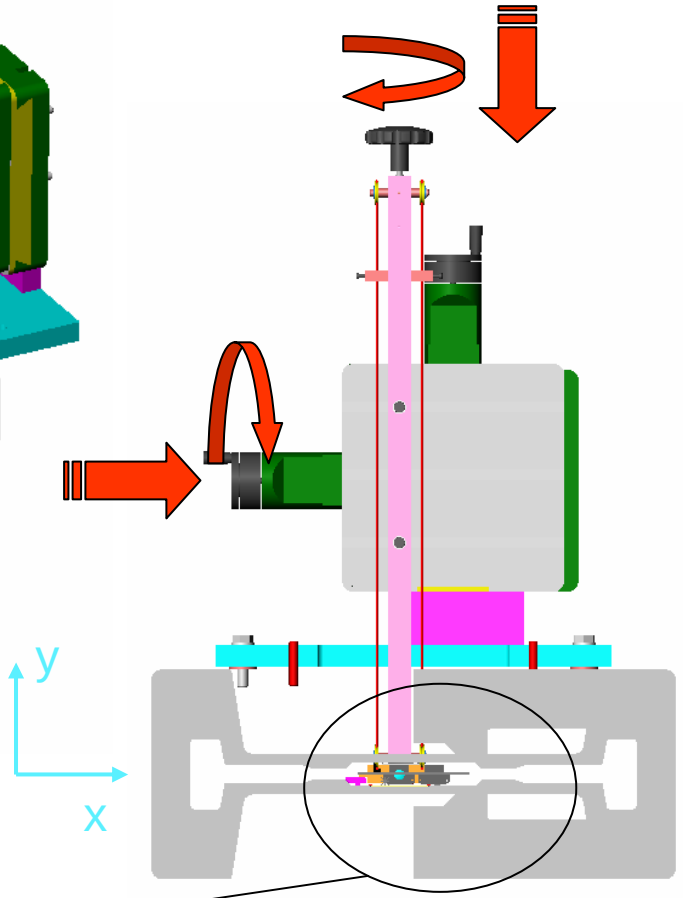


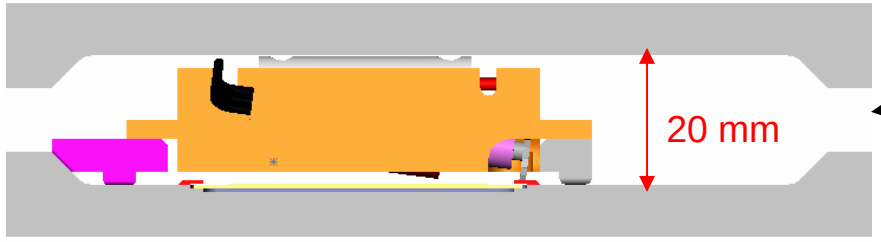


ICE Removal

Multipurpose remotized positioning system

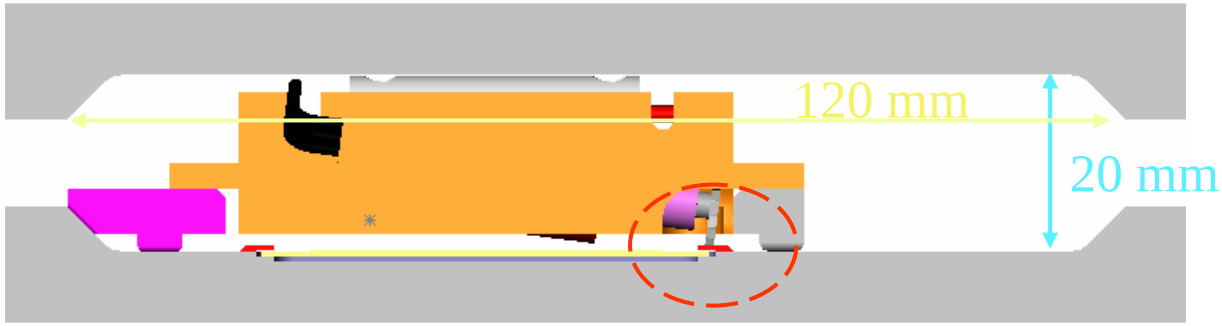


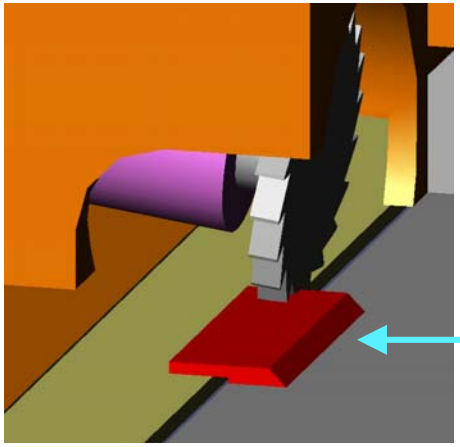




S.R.S. Group S.r.l

Milling machine to cut ICE fingers

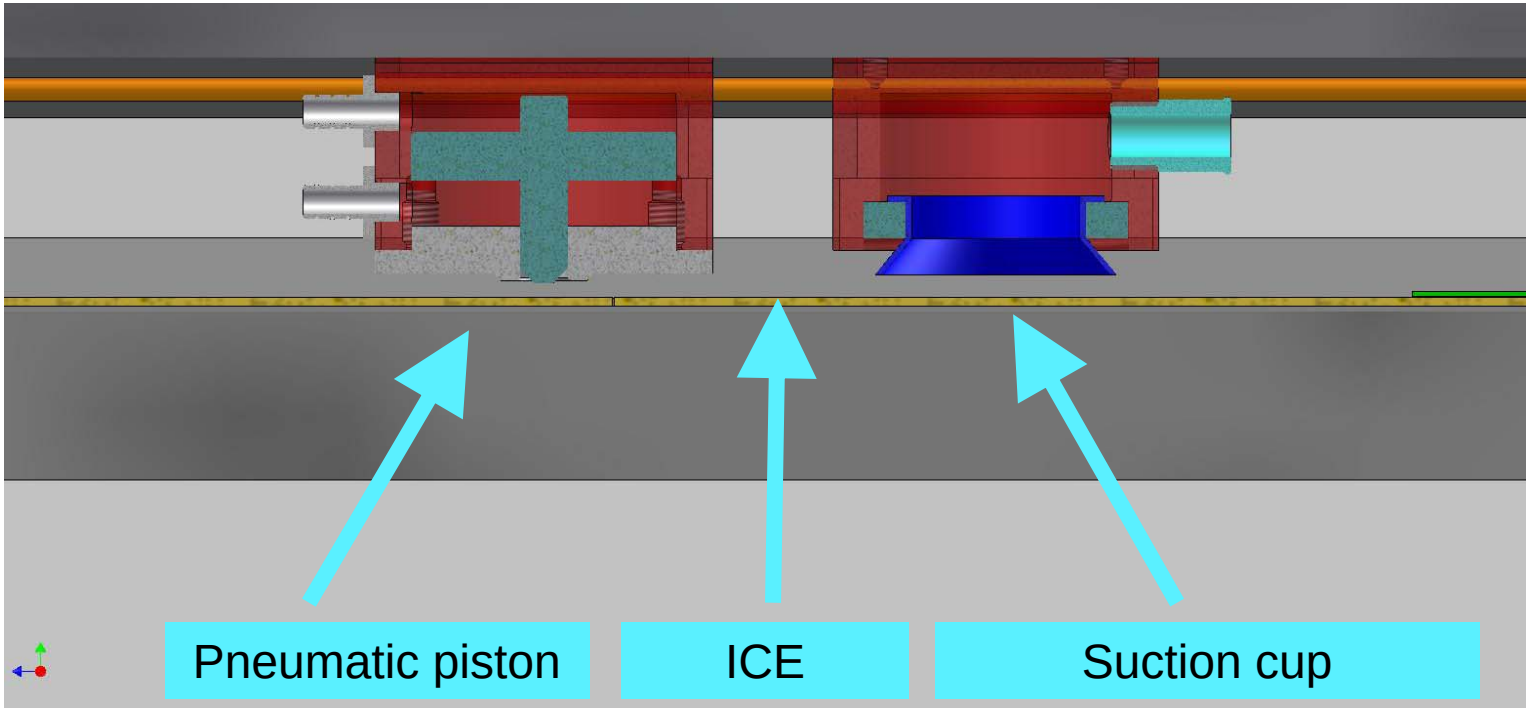


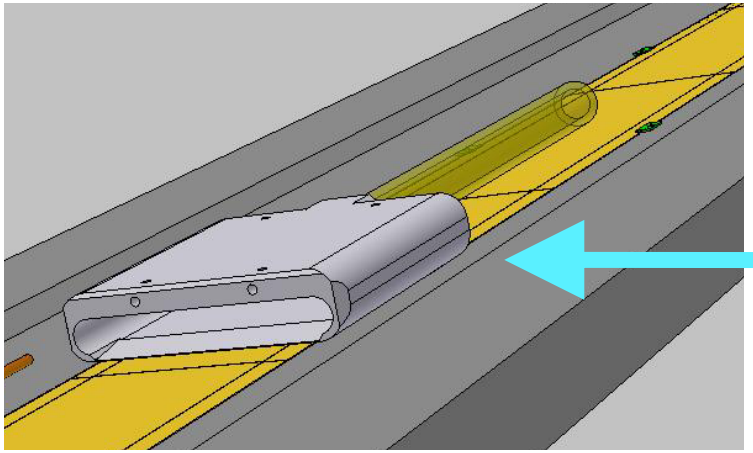


finger

to extract them as a whole

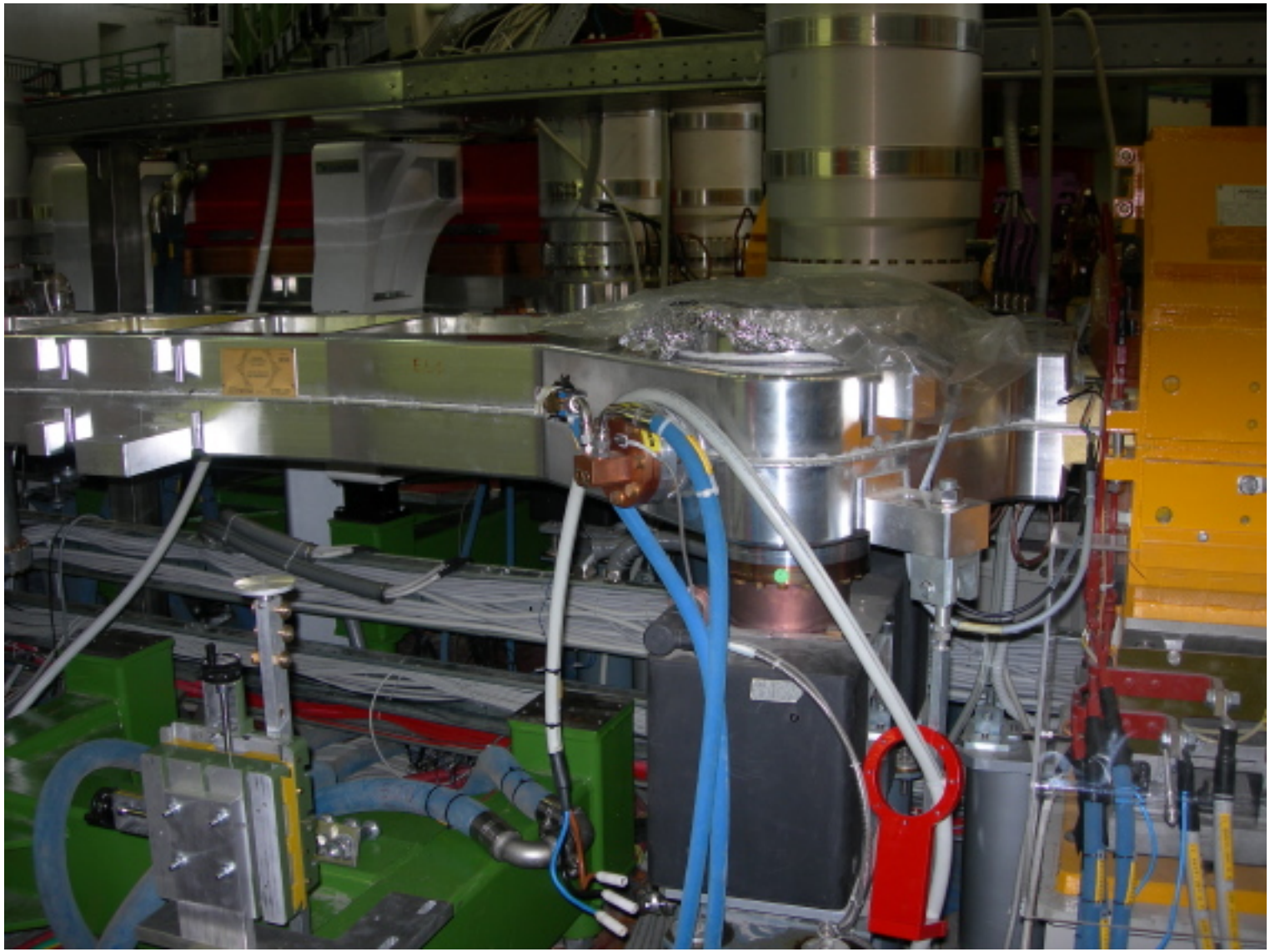
ICE break and removal (backup solution)

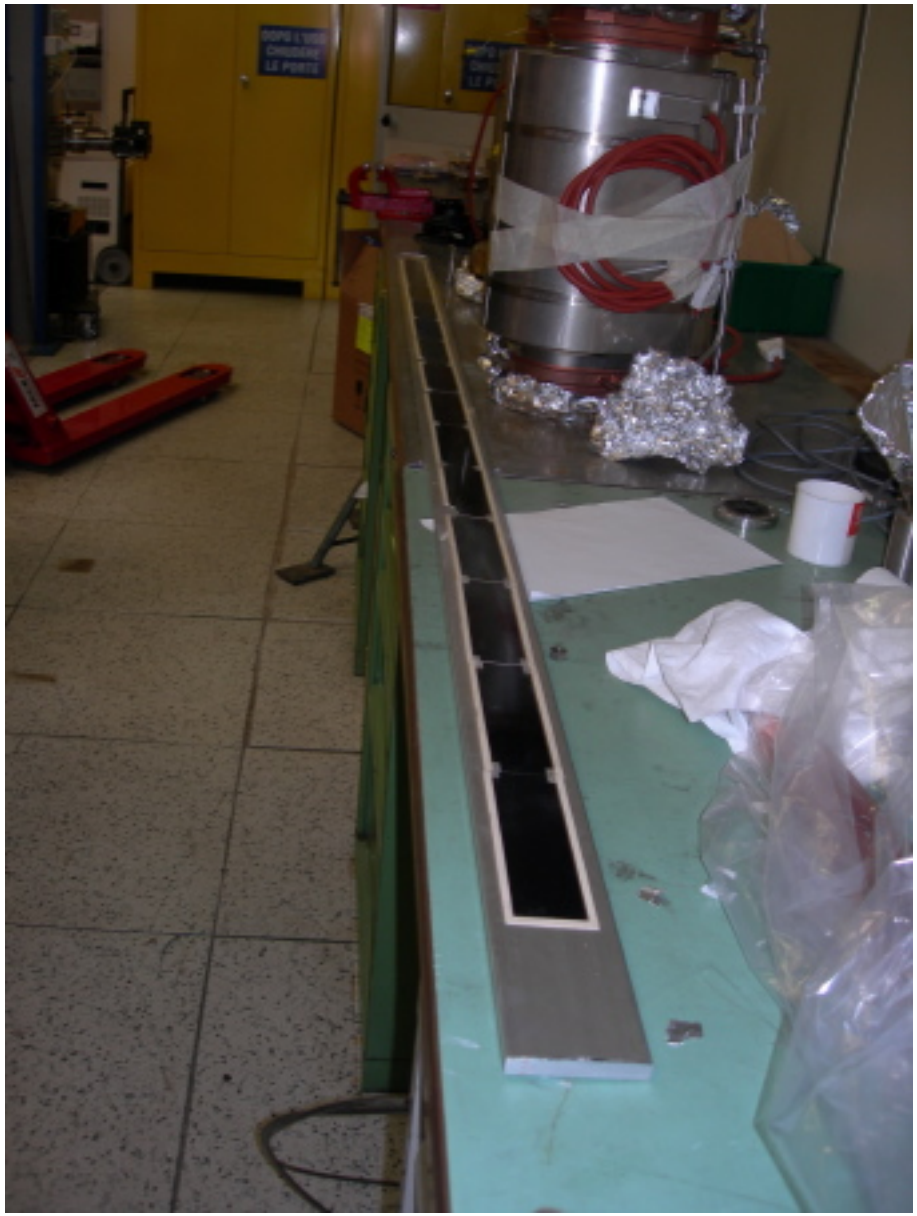




Vacuum chamber cleaning

Extractor fan

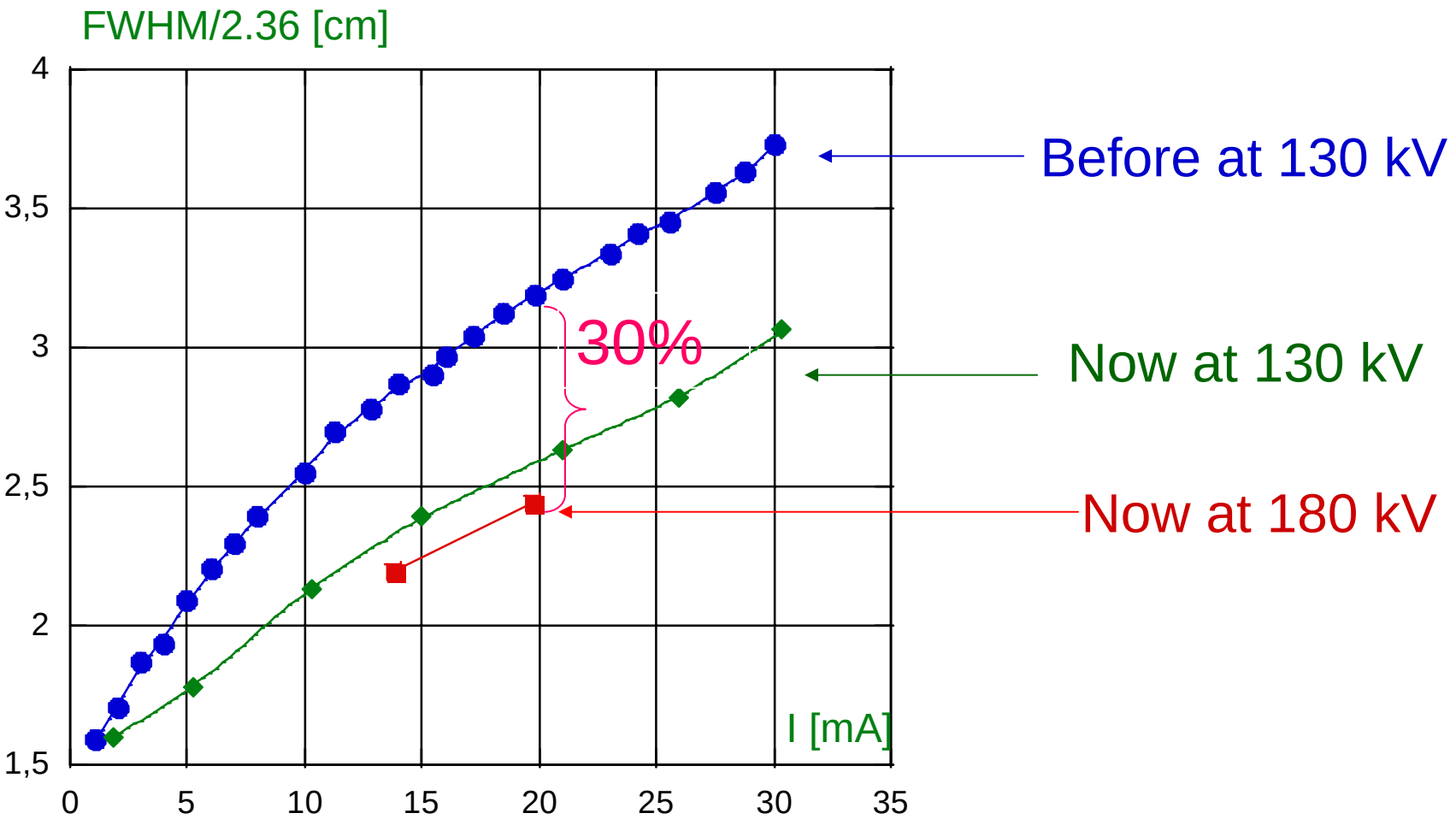




Principal Results

1. Bunches are by 25-30% shorter
2. No quadrupole instability
3. No beam vertical size blow up
4. Geometric luminosity is by 50% higher

Bunch Length Reduction



L_{peak}

FINUDA $L_{peak} = 1.4\ cm^{-2}\ s^{-1}$

Colliding currents

I^- ~ 1.3 A

I^+ ~ 1.0 A

Low-β @ IP2

β_x = 2.1 m

β_y = .019 m

KLOE $L_{peak} = 1.5\ cm^{-2}\ s^{-1}$

Colliding currents

I^- ~ 1.39 A

I^+ ~ 1.18 A

Low-β @ IP2

β_x = 1.7 m

β_y = .017 m

Specific luminosity $L_s = L/n_b I^+ I^-$

$L_s^{Finuda} \sim 1.5\, L_s^{Kloe}$

Conclusions

1. The ‘invisible’ electrodes are good for high current multibunch operations since the resistive layer is transparent for RF fields: no multiple reflections, no high power flowing into external circuits

2. However, the electrodes can give a substantial contribution to the broad-band impedance (due to the dielectic electrode material) and, thus, affect the single bunch dynamics