GRADUAL DAΦNE UPGRADE TOWARDS $L = 6*10^{32}$ cm^{-2} s^{-1}

Catia Milardi
for the Accelerator Division

DAΦNE present plan

KLOE => FINUDA (2nd run) (Apr ÷ Jul 2006)

FINUDA => SIDDHARTA (half 2007)

SIDDHARTA => FINUDA (3rd run) (spring 2008)

During the shutdowns between different experiments several upgrades should be implemented relying on the following ideas …

BASIC IDEAS (1)

Reduce the e^- (and e^+) ring beam impedance will give 30% (up to 80%) luminosity improvement.

How: Shield the Ion-Clearing-Electrodes in the wigglers (e^- ring)

Remove the broken ICE (e^- ring)

Install the new injection kickers and tapers (e^- & e^+ ring)

1) Geometric luminosity increase 20%
2) Beam dynamics luminosity increase (10%)
3) No beam size blow up above the microwave instability threshold 20%
4) Possibility to go closer to integer tunes (20%)
5) Possibility to use optics with negative momentum compaction (50%)

Shielding the Ion Clearing Electrodes in the Wigglers

MOTIVATION:

- Impedance of the DAFNE Main Rings:

$$\left(\frac{Z}{n}\right)_0 \approx 1\,\Omega \qquad e^-$$

$$\left(\frac{Z}{n}\right)_0 \approx 0.54\,\Omega \qquad e^+$$

difference mainly due to Ion Clearing Electrodes in the Wigglers!

- Impedance affects bunch length:

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

$\sigma_z^- \approx 2.7\text{cm}$

$\sigma_z^+ \approx 2\text{ cm}$ measured @ I_b ~ 15 mA

REALIZATION:

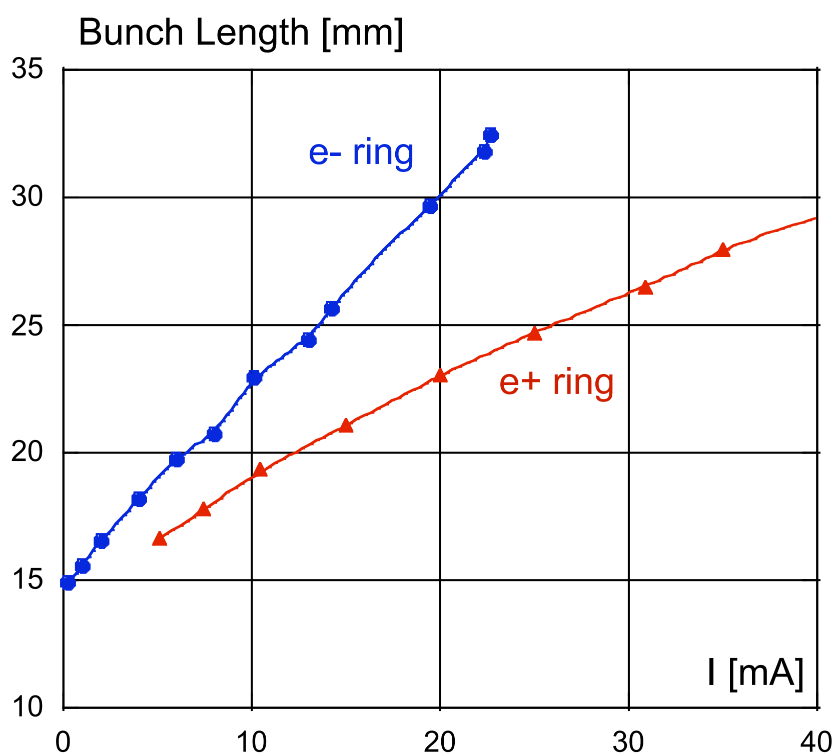
- by means of removable metal plates (CuBe .25 mm thick) covering the ICE

GOALS:

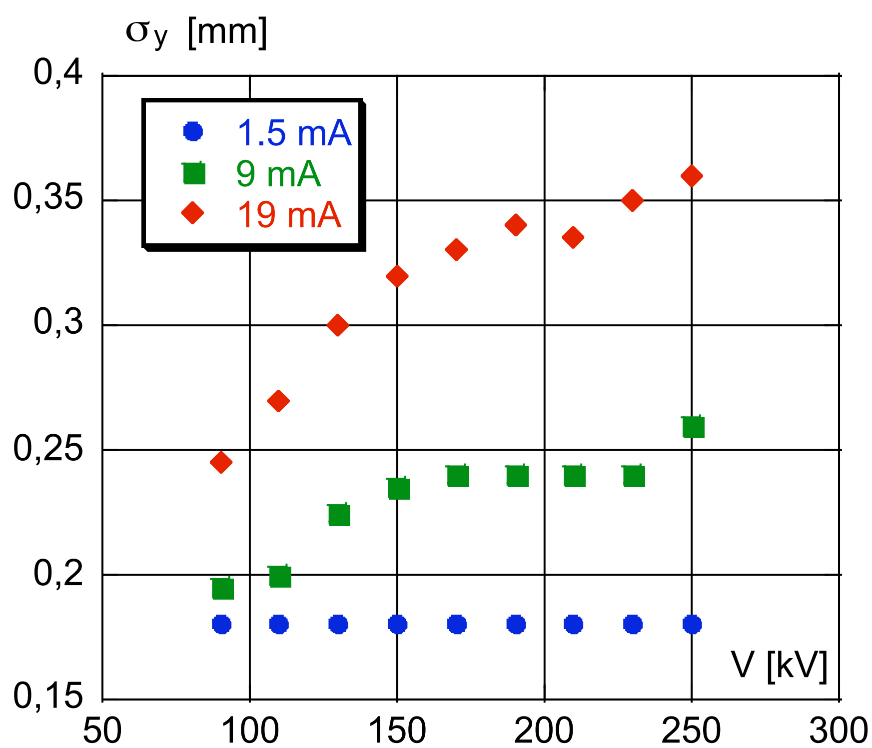
- a factor 2 reduction in e^- ring impedance

Impedance Effects in the e- Ring

Stronger Bunch Lengthening



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



GEOMETRIC LUMINOSITY GAIN

If $\beta_{x,y}$ scale as $\sqrt{(\sigma_z^+)^2 + (\sigma_z^-)^2}$

Conditions	σ_z (e^-), cm	σ_z (e^+), cm	Gain, %
Normal operations	3.0 (meas.)	2.1 (meas.)	0
Low Impedance	2.3	2.1	18
Low Impedance Negative α_c	1.4 (sim.)	1.3 (sim.)	92

BASIC IDEAS (2)

Increase the Positron Beam Current to 2Amps.

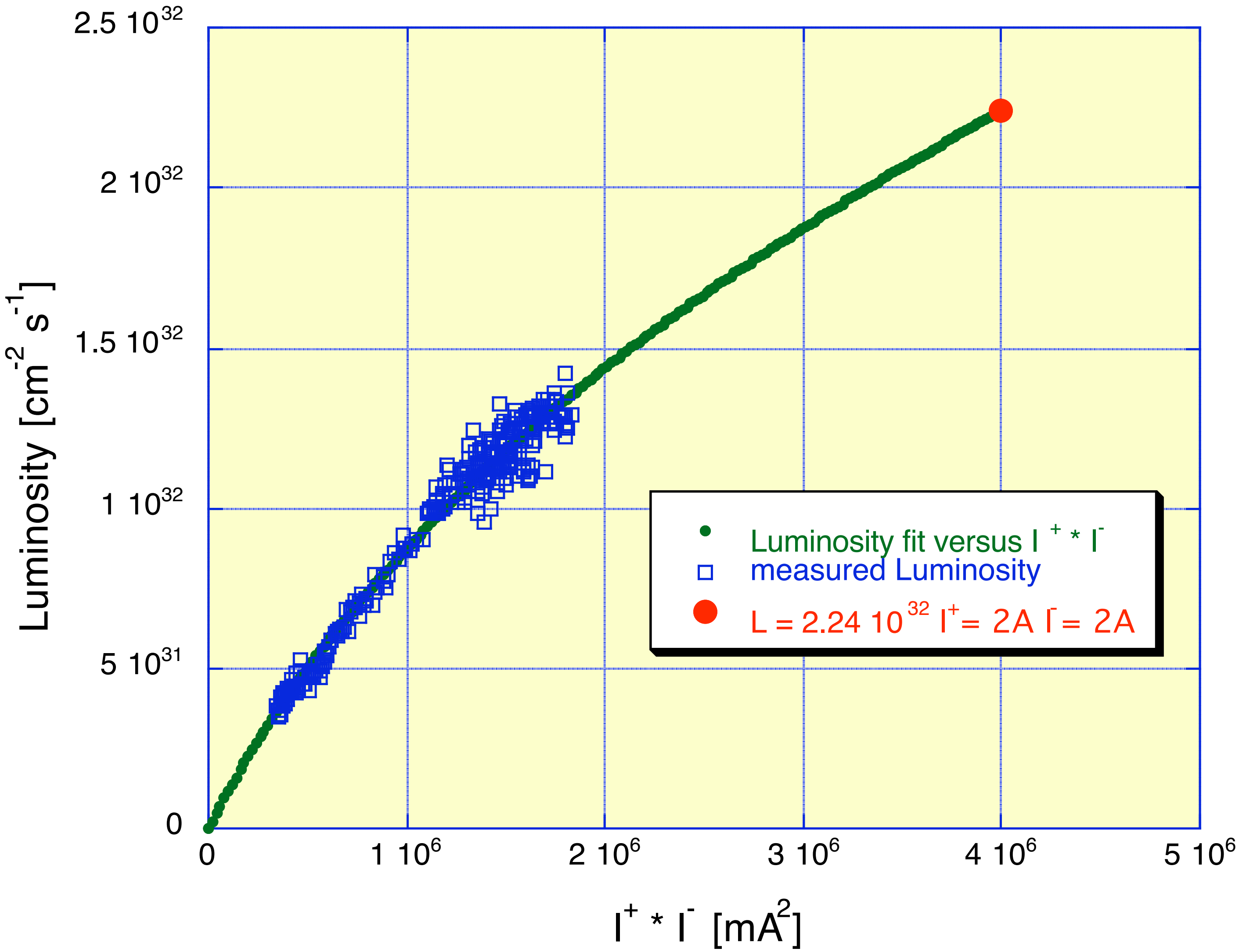
How:

1) New injection kickers *(less beam impedance, less beam excitation)*

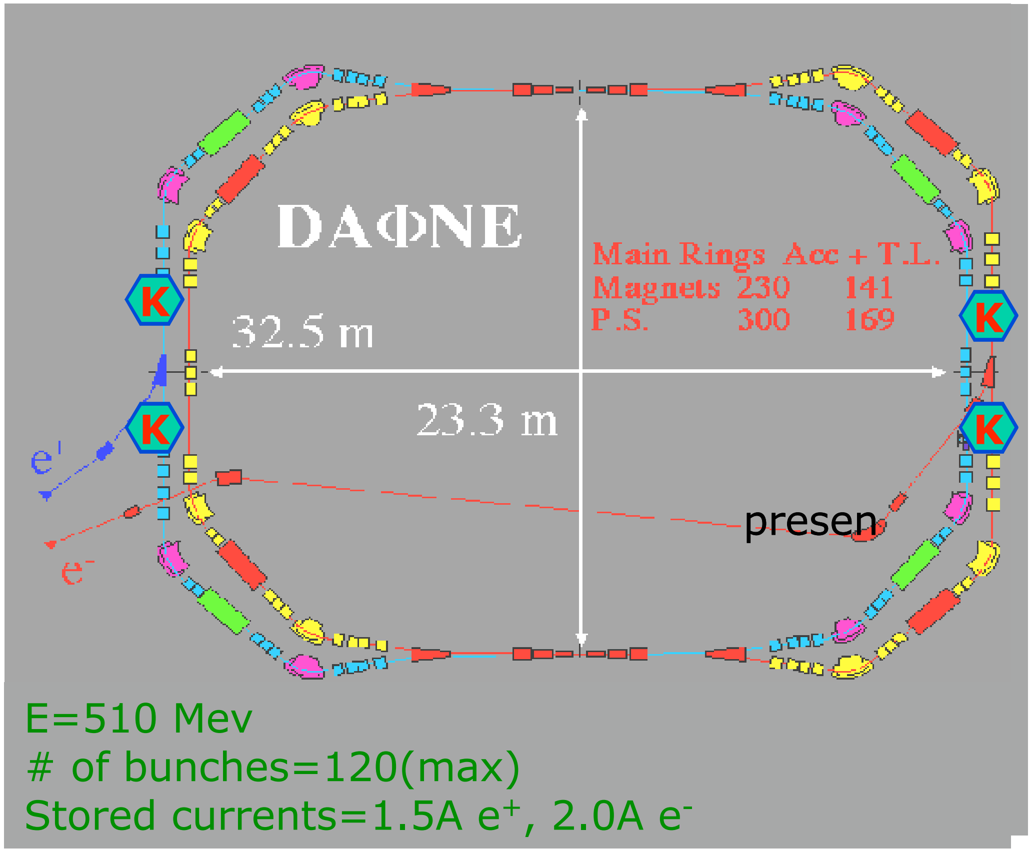
2) Ti-coating against electron cloud

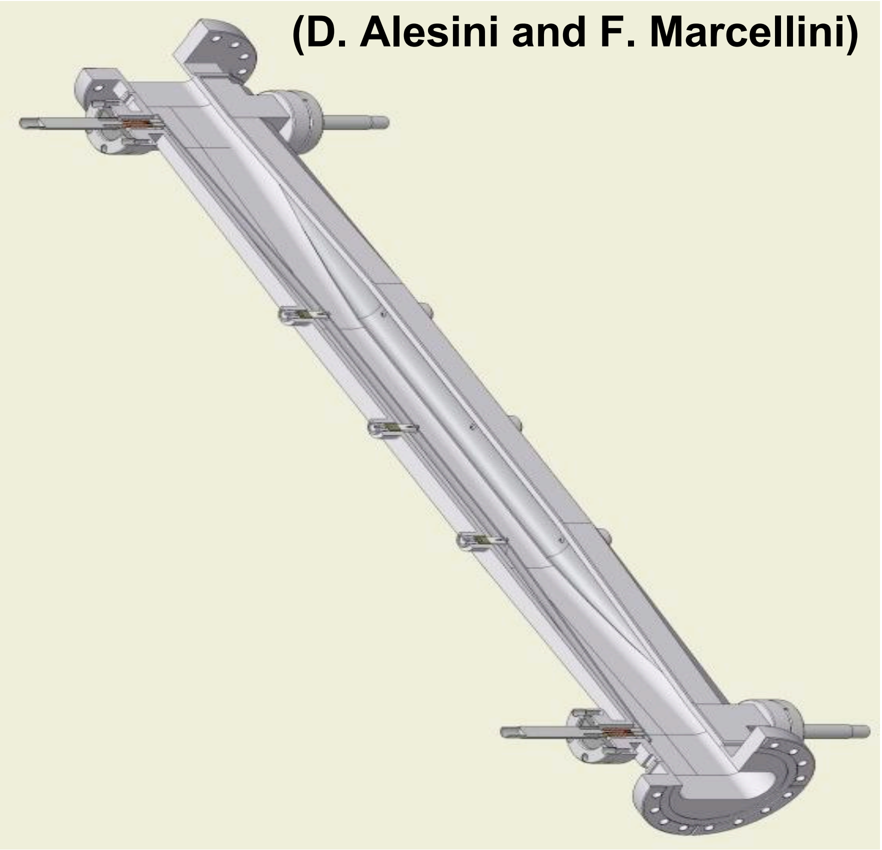
3) New transverse feedbacks *(one experimental sample is already running at DAΦNE)*

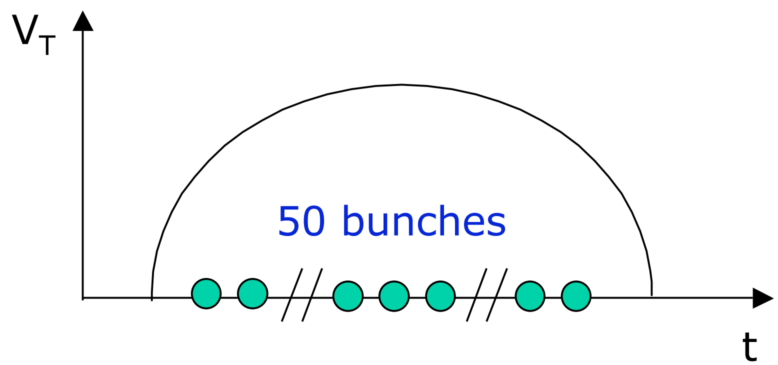
Luminosity gain increasing the currents of the colliding beams



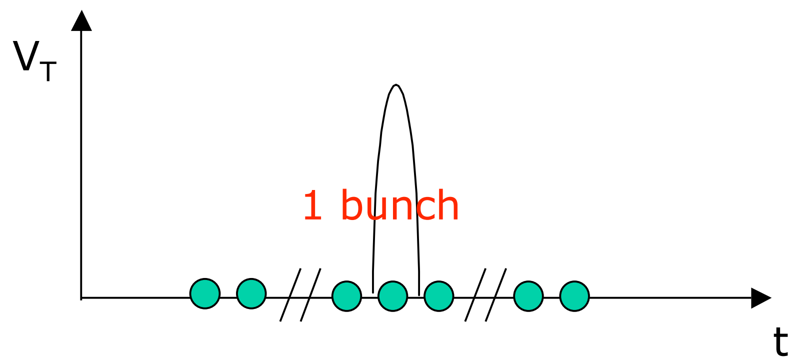
NEW DAFNE INJECTION KICKERS







present pulse length ~150ns
(old kickers)



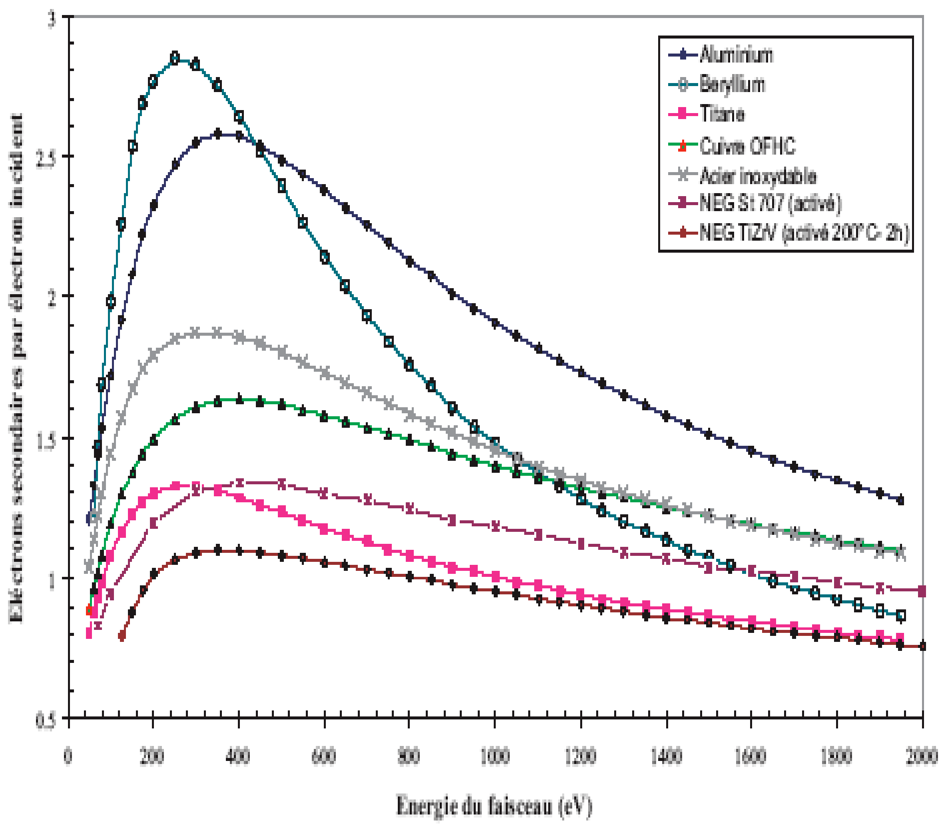
aimed FWHM pulse length ~5.4 ns

SLAC-TN-03-052 \ revised 27th August 2004
LCC-128

Secondary Electron Yield Measurements of TiN Coating and TiZrV Getter Film

F. Le Pimpec, F. King, R.E. Kirby, M. Pivi
SLAC, 2575 Sand Hill Road, Menlo Park, CA 94025

9th October 2003



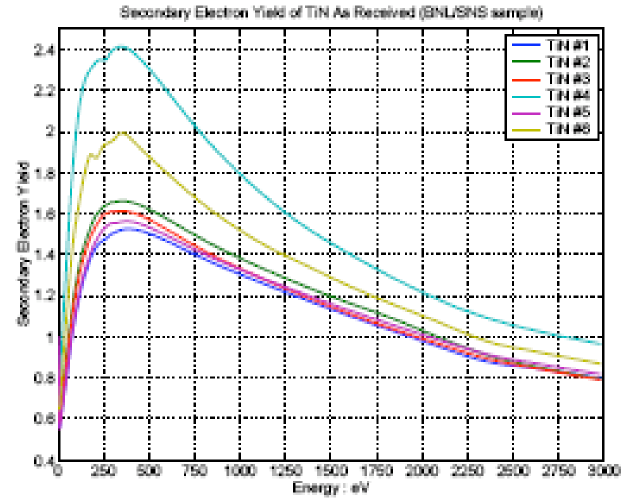


Figure 12: SEY of different TiN sample for electron energy be-

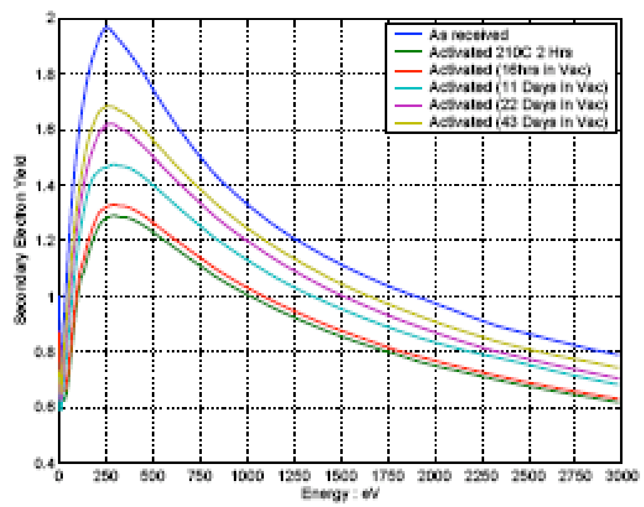


Figure 14: SEY of TiZrV after different process, electron energy between 0-2980 eV

BASIC IDEAS (3)

- Feedback upgrades [A.Drago]

The present low energy DAFNE shifts have pointed out the major limits of the beam dynamics control.

What we need is:

I) More e- feedback **power** **(+750W)** to better control the longitudinal instabilities and avoid the beam-beam in-collision blow-up's (e- beam)

II) More feedback **selected gain** to control the transverse instabilities using the new SLAC-KEK modules FPGA based (e+ in both planes, eventually e- in both planes)

III) Complete **remote** control & monitoring of feedbacks and beam dynamics to give a faster and better diagnostics from outside DAFNE control room (e+/e- beam)

- Possibly 25-30% increase in peak luminosity and 30-35% in integrated

BASIC IDEAS (4)

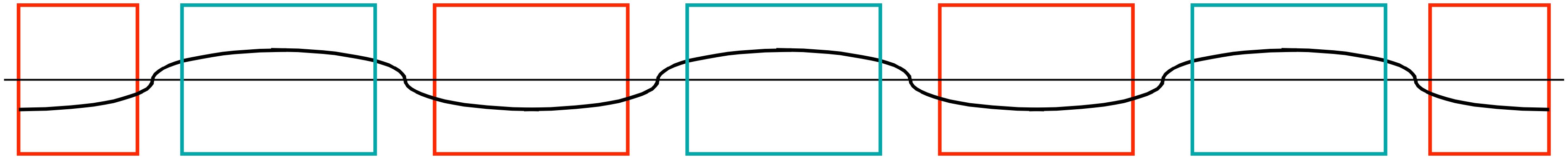
Increase the Lifetime.

How:

1) Wigglers modifications will give a factor 2 (up to 4)

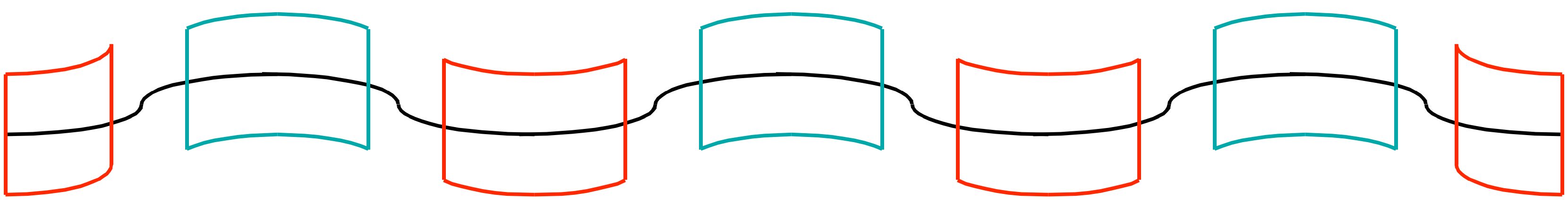
2) Parasitic crossings compensation with current-carrying wires *(first trial successful).* Lifetime independent from the other beam current.

Wiggling wiggler
(under study)



Motivation:

Build wiggler poles symmetric with respect to the beam orbit



Multipole budget
(with respect to standard wiggler)

Quadrupole	**25%**
Sextupole	**55%**
Octupole	**15%**

Goals:

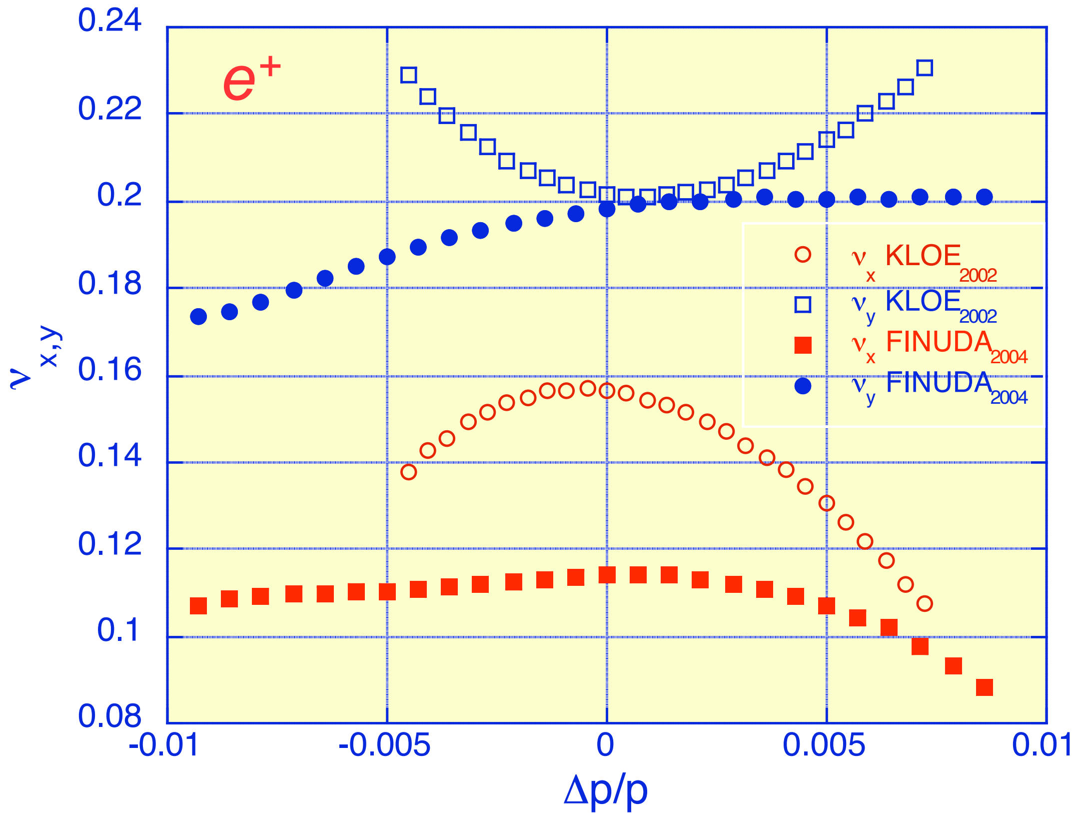
- increase $\mathcal{L}_{\mathrm{int}}$
- increase $\mathcal{L}_{\mathrm{peak}}$

- Magnetic Measurements show:
  - 3rd order term reduced by 2.5
- Tests using the beam
  - confirm magnetic measurements
  - show a factor 2 in the energy acceptance

$$\nu_x = \nu_{x0} + m_{1x}\frac{\Delta p}{p} + m_{2x}\left(\frac{\Delta p}{p}\right)^2$$

$$\nu_y = \nu_{y0} + m_{1y}\frac{\Delta p}{p} + m_{2y}\left(\frac{\Delta p}{p}\right)^2$$

	m_{2x}	m_{2y}
KLOE 2002	-882	823
FINUDA 2004	-194	-144

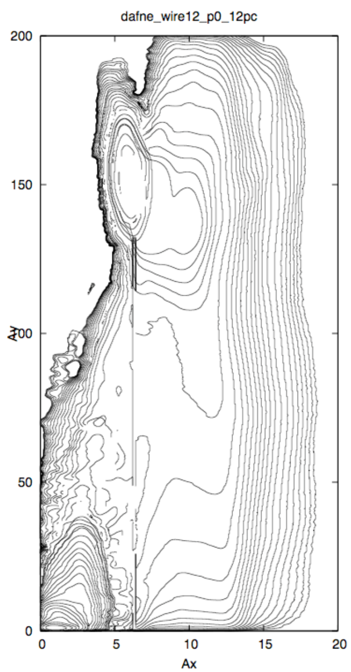


Parasitic Crossings compensation in the DAFNE Interaction Region

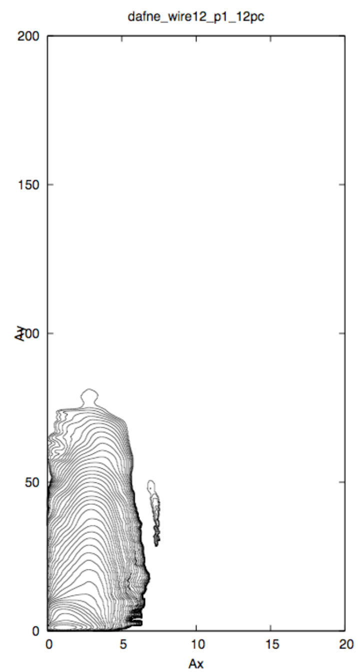
MOTIVATION:

- In the DAFNE Irs the beams experience 24 Beam Beam Long Range interactions limiting the maximum storable current.
- Numerical simulations show that BBLR interactions can be compensated by current-carrying windings

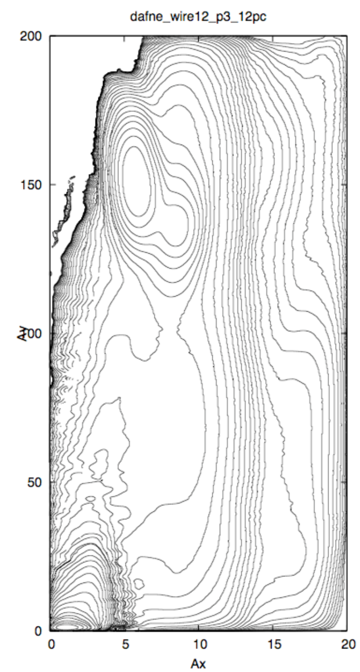
Particle equilibrium density in the transverse space of normalized betatron amplitude



Windings OFF



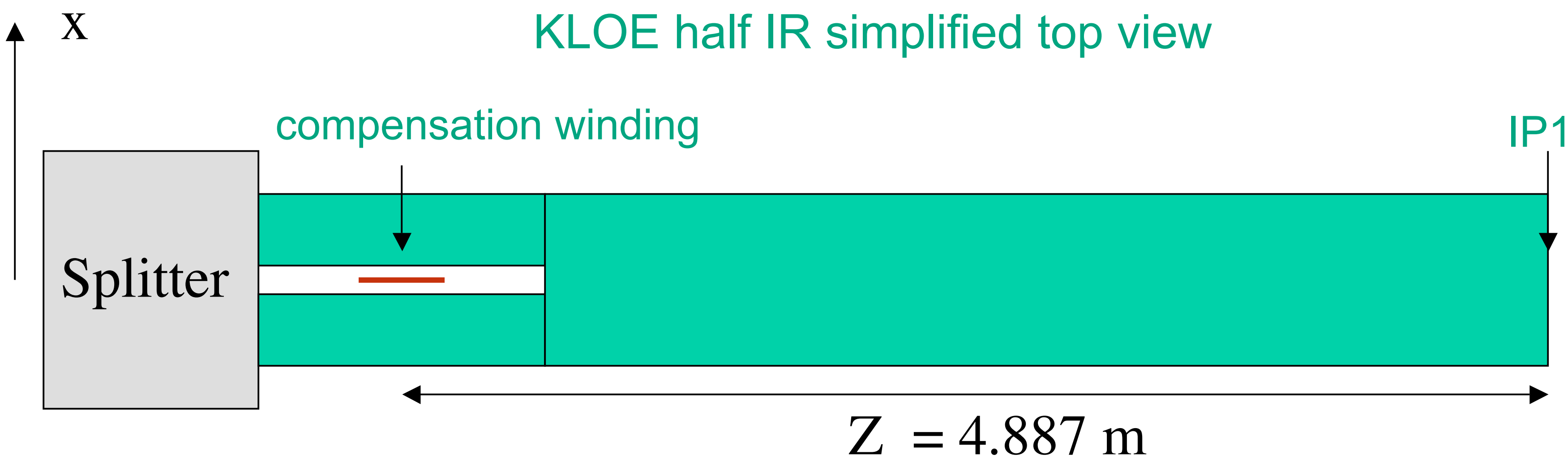
Windings ON

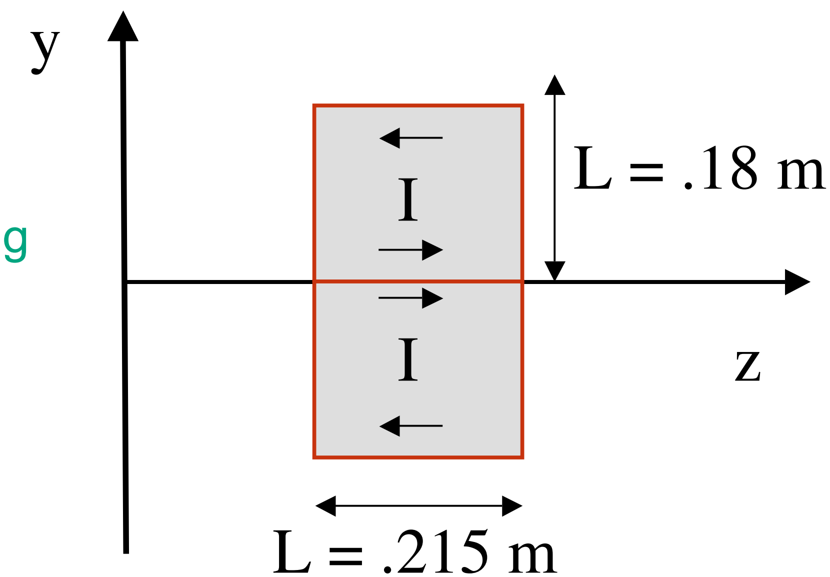


Windings ON (wrong polarity)

REALIZATION:

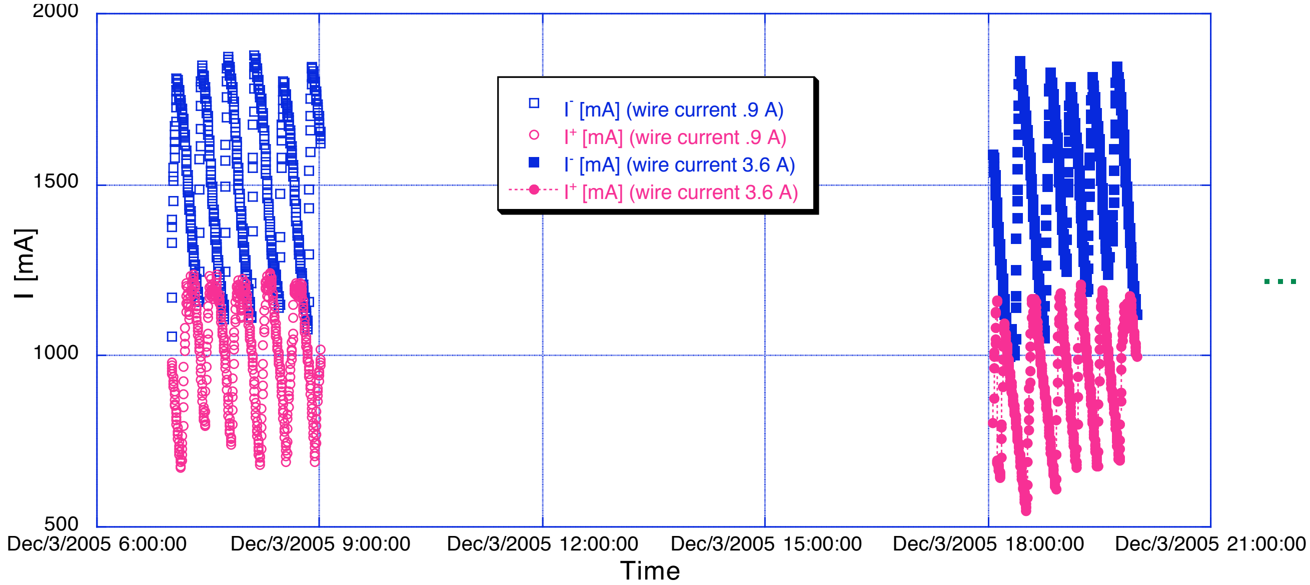
- Windings installed in the KLOE Interaction Region



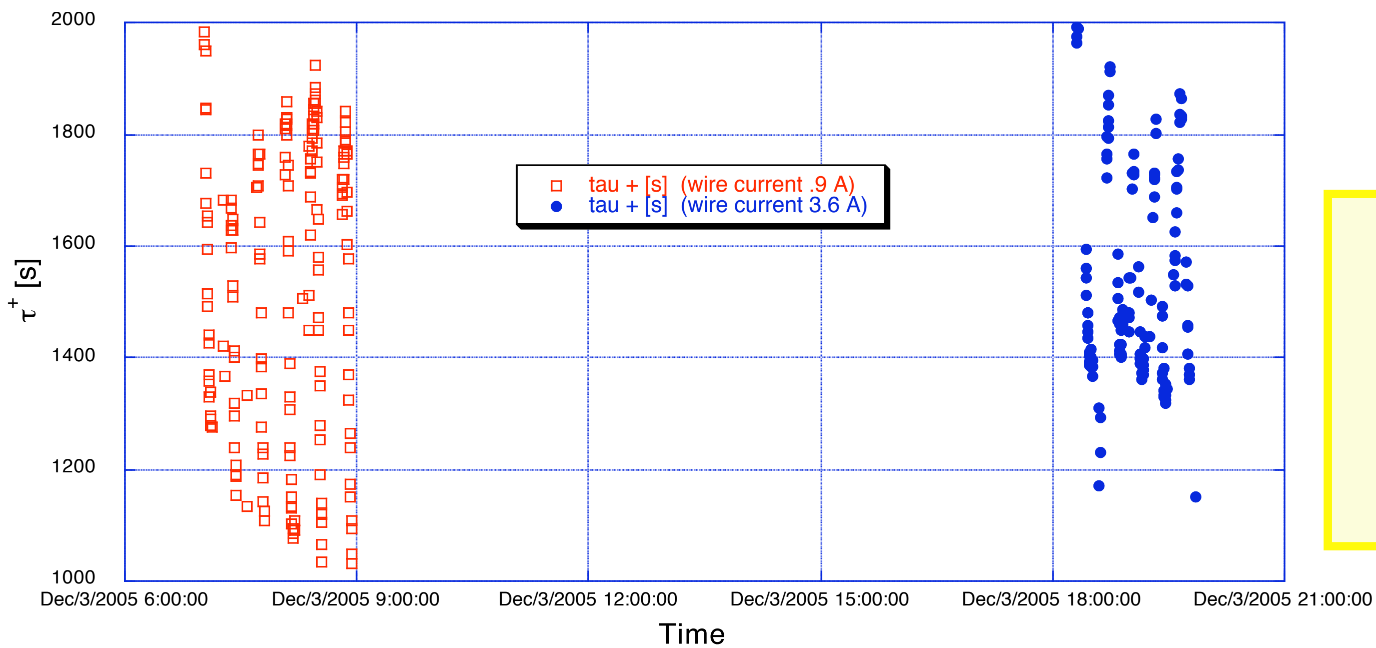


compensation winding
(20 coils)

First results from BBLR compensation windings



... with the same currents



τ^+ improves

τ^+ affects:

- I^+_{MAX}
- $\mathcal{L}_{int}$
- background

BASIC IDEAS (5)

Decrease coupling, betay,chromaticity,bb-parasitic crossing. How:

New interaction region for Dear and Finuda2. Low betay peak, earlier separation of beam lines. QFs on separate lines.

1) Geometric luminosity increase 20%
2) Beam dynamics luminosity increase 10% (20%)

BASIC IDEAS (6)

Remove the horizontal crossing angle.

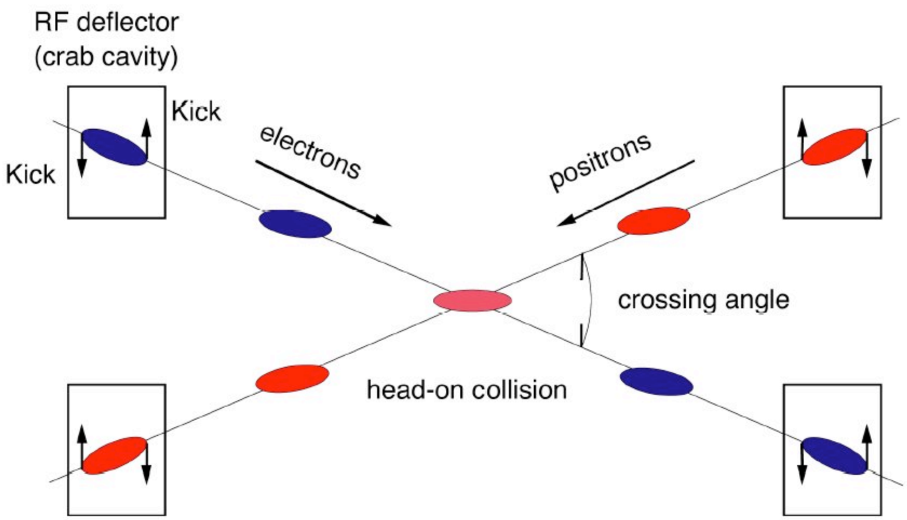
How:

Install 1 crab cavity per ring.

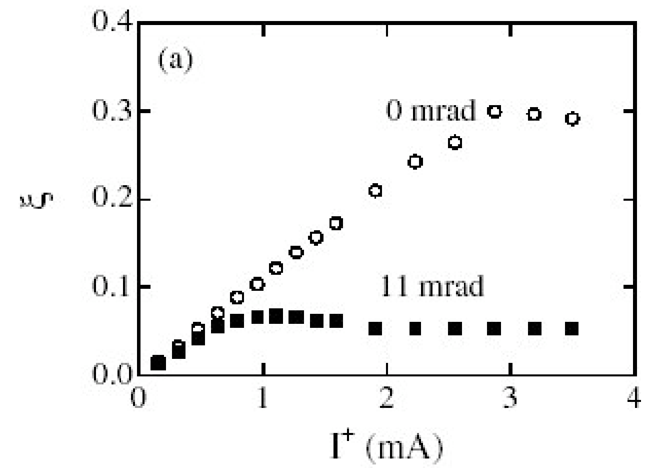
Geometric luminosity increase 10%

Beam dynamics luminosity increase 20% (70%)

Crab crossing system for DAFNE: luminosity increase

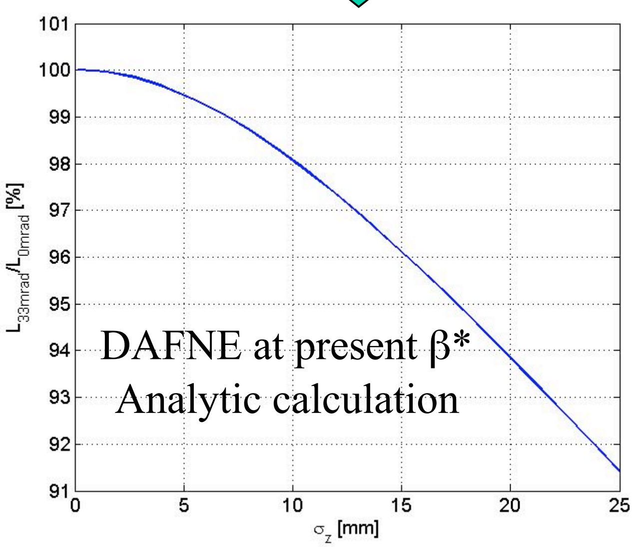


Studies on B-factories optimization shown that the beam-beam effects are weaken by the crab crossing. An increase in luminosity up to a factor of 2 is expected (K. Ohmi, PRST-AB, 2004)



weak-strong simulations

The crab crossing optimizes the geometrical superposition of the colliding bunches

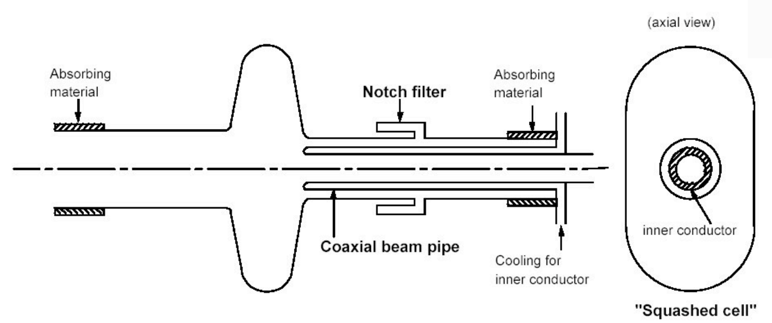


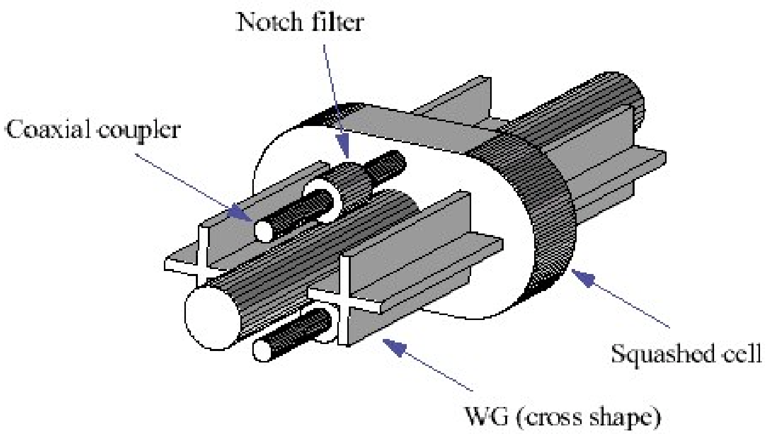
DAFNE at present tunes LIFETRAC simulations

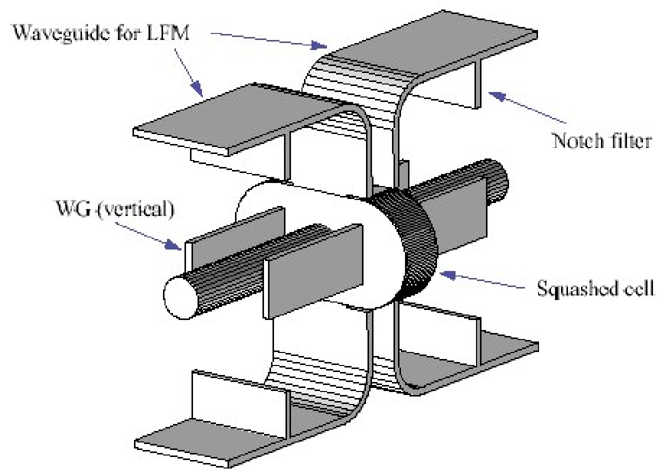
	I [mA]	L/L_0
ϕ_{crab}=0 mrad	6	0.88
ϕ_{crab}=15 mrad	6	0.69
ϕ_{crab}=0 mrad	10	0.75
ϕ_{crab}=15 mrad	10	0.43

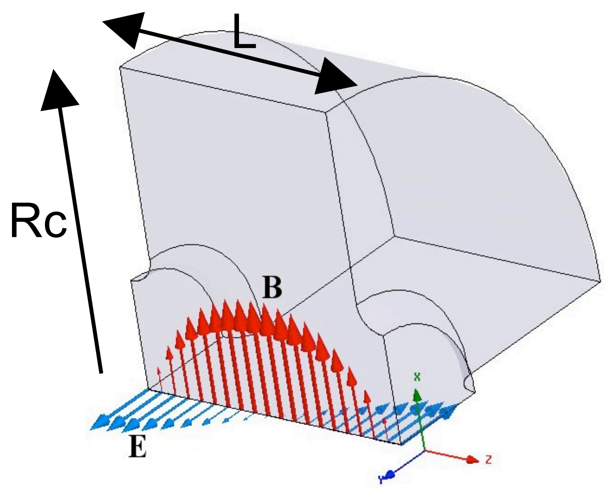
Crab crossing system for DAFNE: RF cavities

Different approaches to damp the HOM and LFM can be adopted (see K. Akai designs, KEK)









Frequency of operation [MHz]	Main dimensions [cm] (pillbox case)	
	L	Rc
368 (found. harmonic)	~40	~ 47
736 (2nd harmonic)	~20	~ 23
1104 (3rd harmonic)	~14	~ 16
1472 (4th harmonic)	~10	~12

Crab crossing system for DAFNE: power requirements

In the single crab cavity scheme the crabbing angle is related to the tranverse kick voltage by:

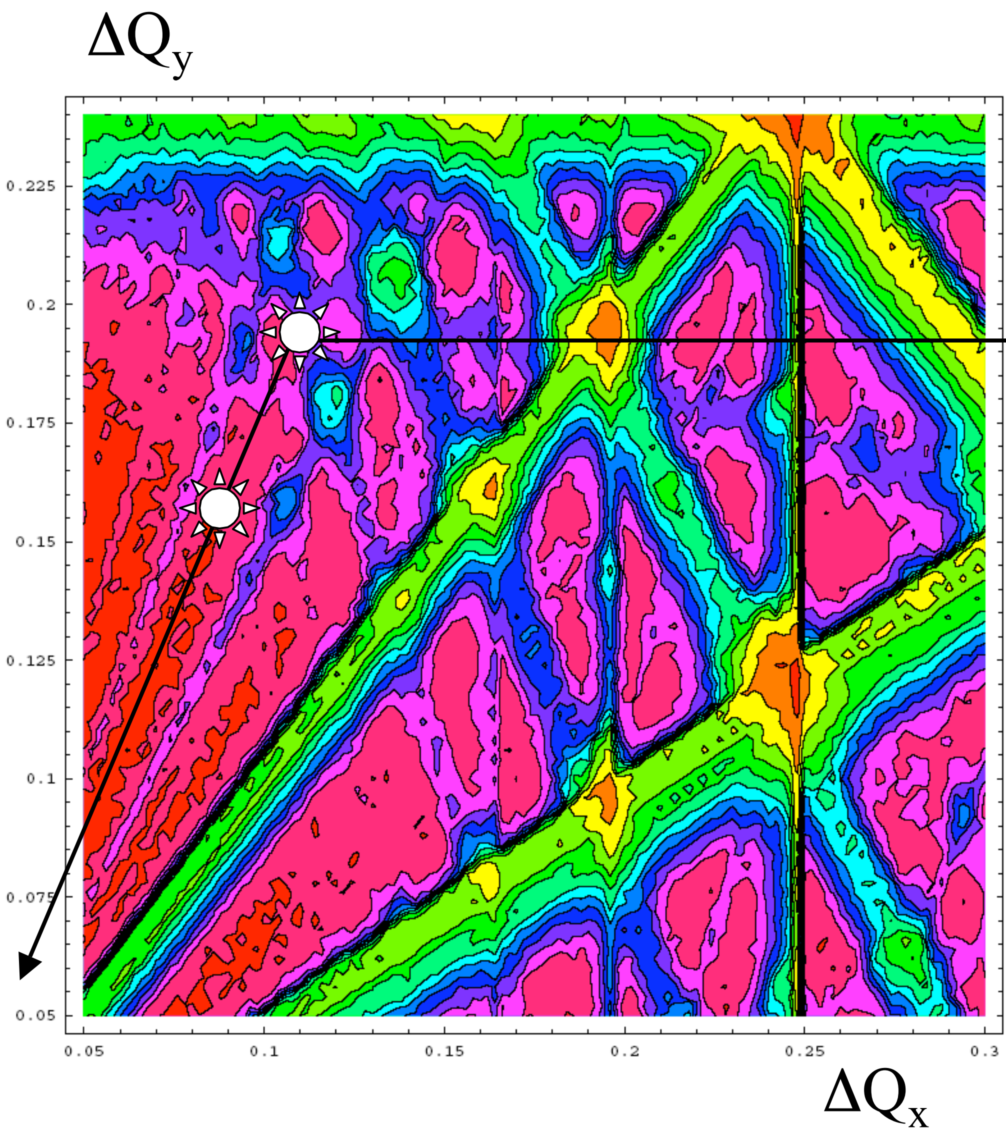
$$\phi_{crab} = \frac{\pi\sqrt{\beta_{IP}\,\beta_{cav}}}{\lambda_{RF}\sin(\pi\,Q_x)}\frac{eV_\perp}{E}\cos\left(\left|\phi_{IP} - \phi_{cav}\right| - \pi\,Q_x\right)$$

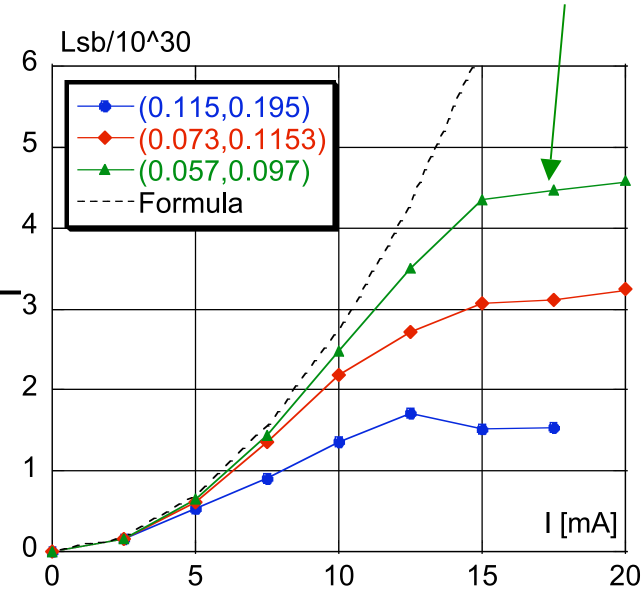
obtained for a longitudinally rigid bunch. A small correction is needed to take into account the synchrotron oscillation. The optimal betatron phase advance between the crab cavity and the IP is $n\pi + \pi Q_x$. In the DAFNE case the IP and the crab cavity have to be kept almost in phase. The main parameters for a DAFNE crab crossing system based on one 3rd harmonica crab cavity per ring are reported in the table.

ϕ_{crab}	β_{IP}	β_{cav}	λ_{RF}	Q_x	$eV_\perp$	R_s	P_{RF}
15 mrad	1.5 m	9 m	0.27 m	0.15	80 keV	0.8 MΩ	4 kW

Budgetary cost evaluation:	1 HOM damped 3rd harmonic crab cavity:	100 k€
	1 5 kW, 1100 MHz RF power source:	120 k€
	RF controls + contingency:	30 k€
	TOTAL	**250 k€/ring**

Working Point Choice, 30%





Going closer to the integers we hope to improve both the peak luminosity and lifetime

This is possible with the new wigglers since DA is satisfactory at low tunes!

M.Zobov

RF Quadrupole
(Innovative idea under study)

Introduces a betatron tune modulation between the head and the tail of the bunch producing:

- Enhancement in the Transverse Mode Coupling Instability threshold representing the main limitation to the maximum storable current I
- Reduce the effective betatron function seen from the colliding beams according the formula:

$$\beta_{eff} = \frac{\beta^*}{\sqrt{2}}$$

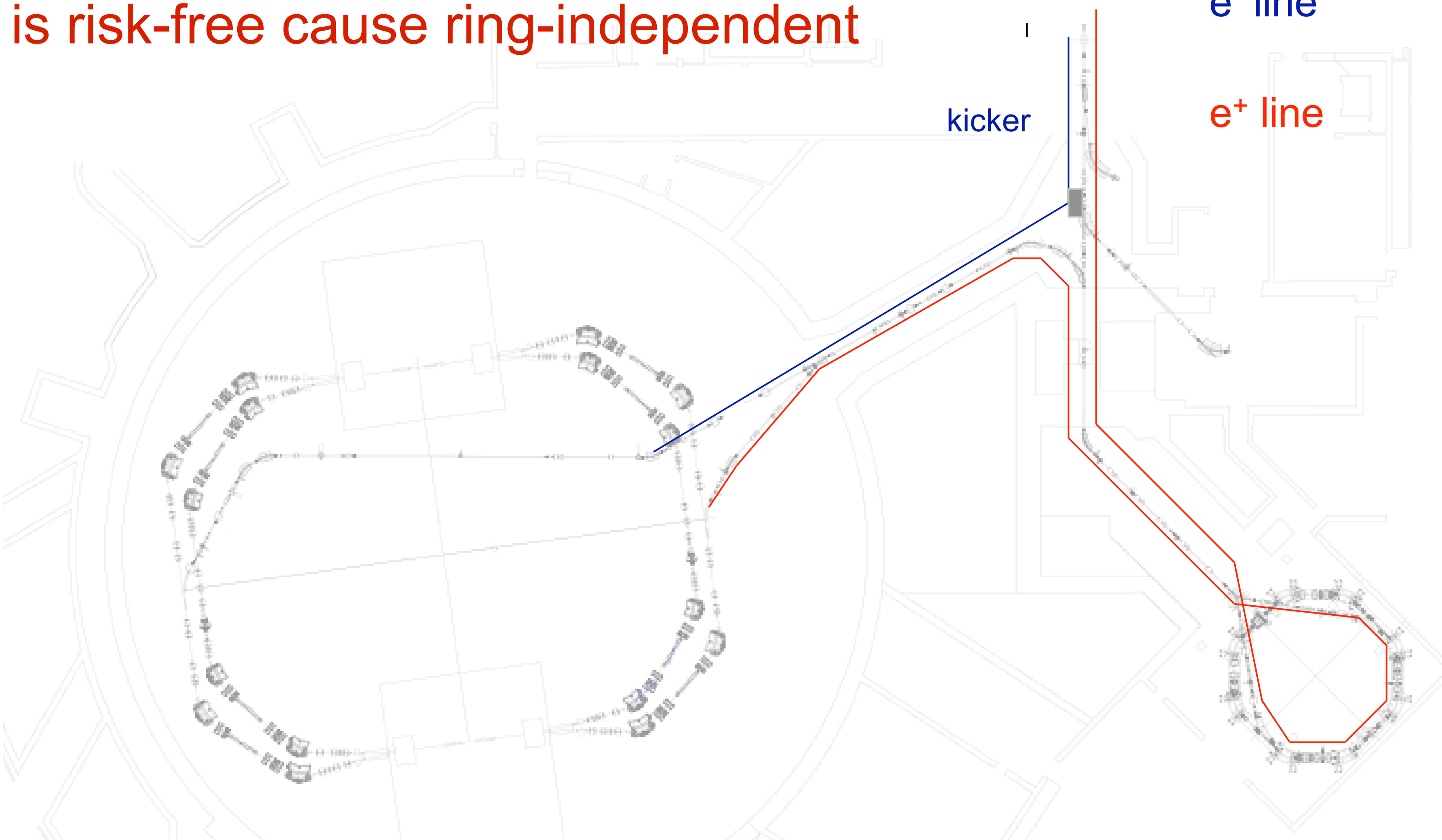
Luminosity *L* is: $$L \propto \frac{I}{\beta_{eff}}$$

BASIC IDEAS (7)

The transfer line upgrade, working very hard (needs dedicated manpower and resources) could be made during last shutdowns, or most likely will be part of the dafne2 upgrades.

Transfer Lines Upgrade

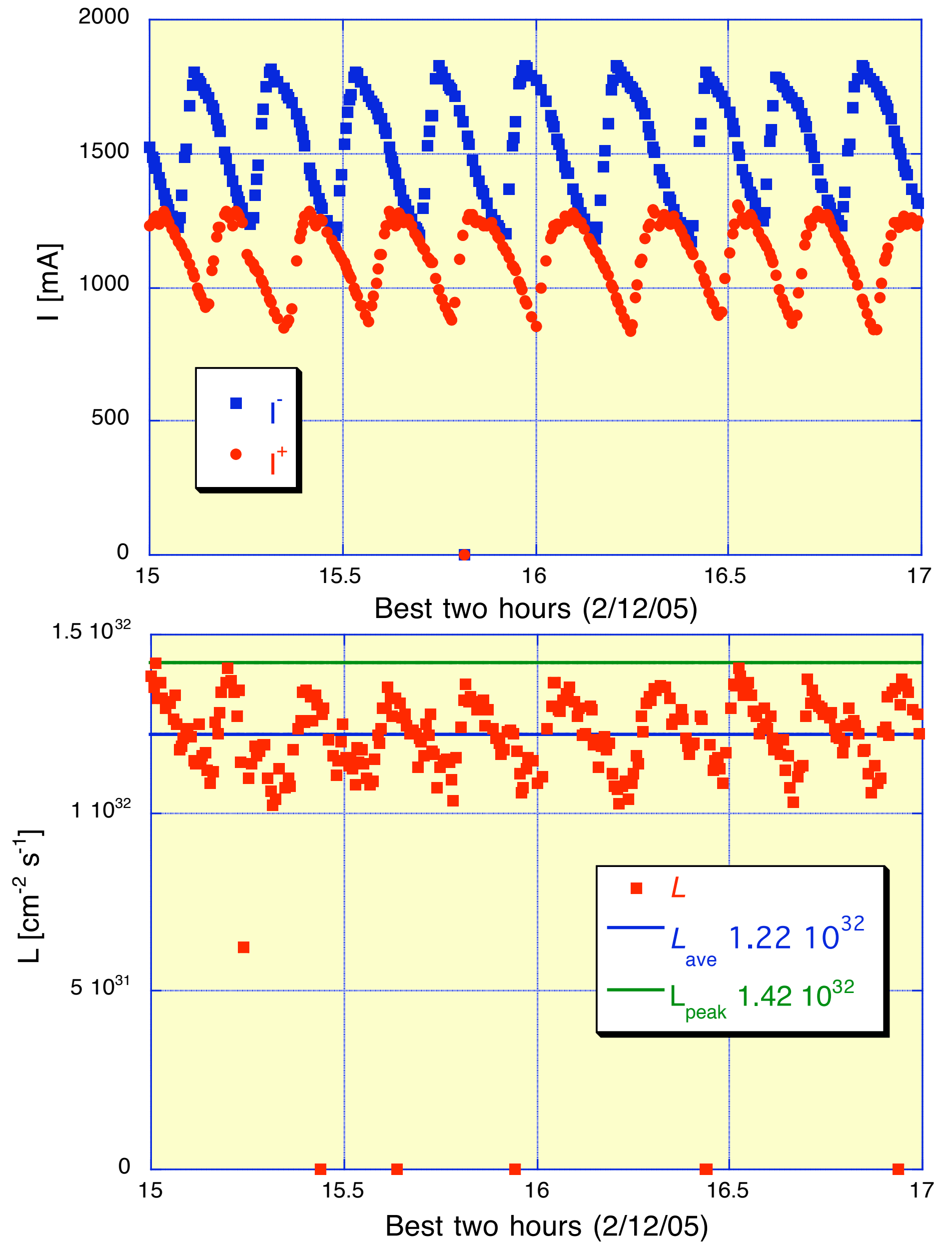
It is risk-free cause ring-independent



Motivation:

e^+ e^- continous injection in collision

Luminosity rate 440 nb^{-1}/h



Luminosity gain:

$$\frac{L_{peak}}{L_{ave}} \sim 20\%$$

In a tipical shift

$$\frac{L_{peak}}{L_{ave}} \sim 30\%$$

Other gains:

- L_{peak} 20% cause both currents will be maximized simultaneusly
- L_{peak} 10% more efficient tuning at L_{peak}

Upgrades tentative implementation

ICE shielding & removal
Ti coating
Longitudinal FBK
Injection kickers ??

KLOE -> FINUDA
shutdown (Apr ÷ Jul 2006)

Injection kickers

Christmass shutdown
2006 ÷ 2007

New IR
FBKs
Modified Wigglers

FINUDA -> Siddharta
shutdown (half 2007)

New IR
RF quadrupoles ??
Crab Cavity ??
Transfer Lines ??

Siddharta -> FINUDA
shutdown (spring 2008)

Luminosity projections for finuda 3rd run

Starting from $1.5*10^{32}$, 2 fb^{-1}/year

$1.95*10^{32}$	(2.6 fb^{-1})	by ICE shields & removal + 30%
$2.73*10^{32}$	(3.6 fb^{-1})	by higher positron current +40%
$3.55*10^{32}$	(4.7 fb^{-1})	by new interaction region + 30%
$4.44*10^{32}$	(5.9 fb^{-1})	by feedback upgrades + 25%
$4.44*10^{32}$	(6.7 fb^{-1})	by wigglers linearization
$5.77*10^{32}$	(8.4 fb^{-1})	by crab cavities + 30%
$6.92*10^{32}$	(10. fb^{-1})	by transfer lines upgrade +20%
$8.99*10^{32}$	(12.8 fb^{-1})	by waist modulation (RF quads) +30%

In the projections only the conservative, high likelihood estimates are considered.

All modifications are worldwide top of the line accelerator physics.

All the investments done so far are used as a base for excellent and essential physics

All proposed improvements can be achieved if resources, man power and machine development time can be allocated!