DAΦNE upgrade with large Piwinski angle and Crab Waist scheme

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For the DAΦNE Upgrade Team

PAC07, Albuquerque, June 25th

DAΦNE Upgrade Team

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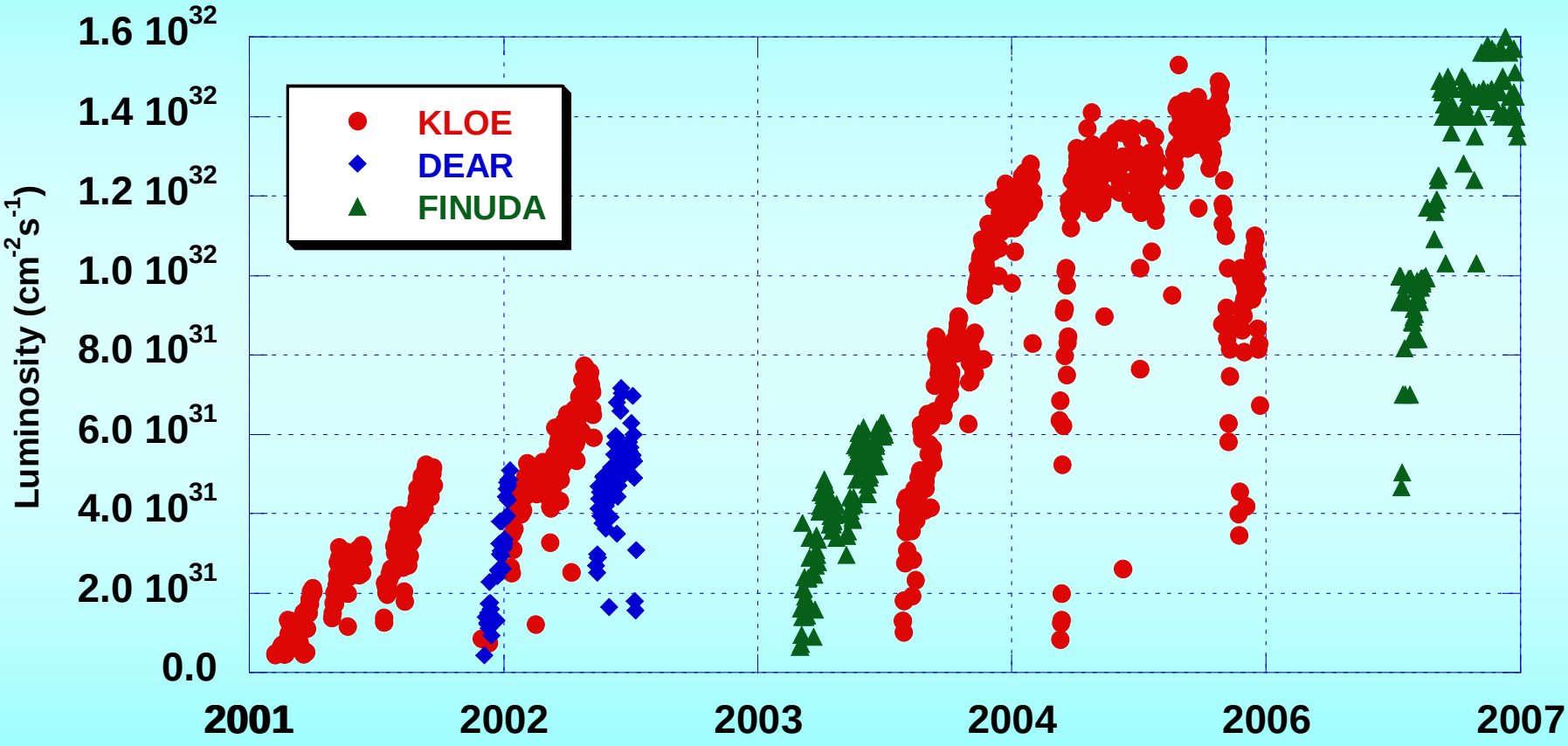
Outline

- DAΦNE performances (TUPAN033, tomorrow)
- Crab waist concept (MOZAKI02, this morning)
- Beam-beam studies (TUPAN037, tomorrow)
- Dynamic aperture studies (FRPMN029, Friday)
- Lifetime & Backgrounds (TUPAN031, tomorrow)
- DAΦNE modifications (TUPAN035, TUPAN036, tomorrow, FRPMN028, Friday)
- Conclusions

DAΦNE performances 2001-2007



Steadily improving performances in terms of luminosity, lifetime and backgrounds

New collision scheme

$$L \propto \frac{N\xi_y}{\beta_y}; \quad \xi_y \propto \frac{N\beta_y}{\sigma_x\sigma_y\sqrt{1+\phi^2}}; \quad \xi_x \propto \frac{N}{\varepsilon_x\left(1+\phi^2\right)}$$

1. Large Piwinski angle ($\theta\uparrow + \sigma_x\downarrow$)

$$\Phi = tg(\theta)\sigma_z/\sigma_x$$

- **Decrease overlap area**
- **Very low horizontal tune shift**

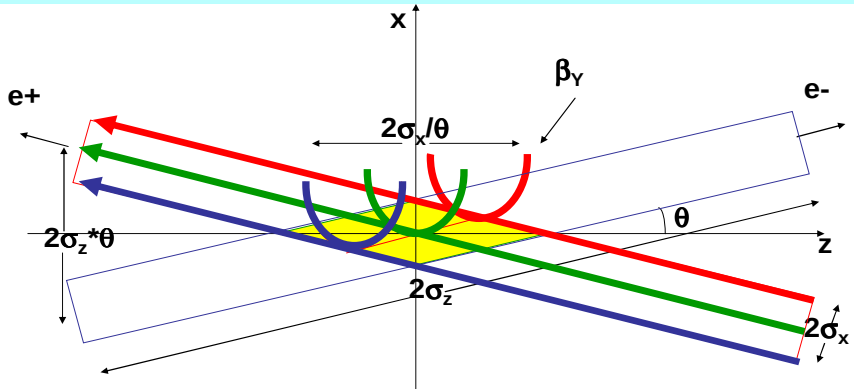
2. Vertical beta comparable to overlap length

$$\beta_y \sim \sigma_x/\theta$$

- **Geometric luminosity gain**
- **Lower vertical tune shift**
- **Vertical tune shift decreases with oscillation amplitude**
- **Suppression of vertical synchro-betatron resonances**

3. Crab waist sextupoles transformation:

between sextupoles β_y is function of X



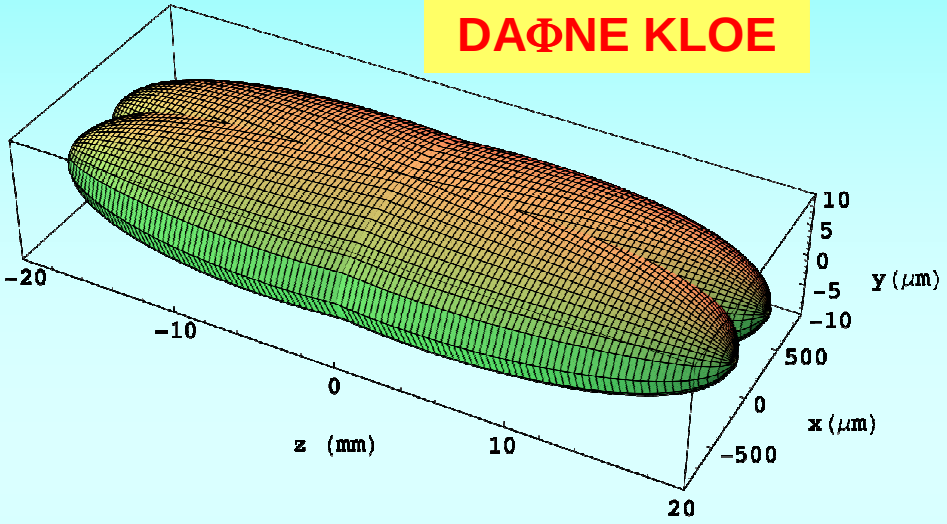
- **No vertical betatron phase modulation by the horizontal betatron oscillations**
- **Suppression of X-Y betatron and synchro-betatron resonances**

... and ...

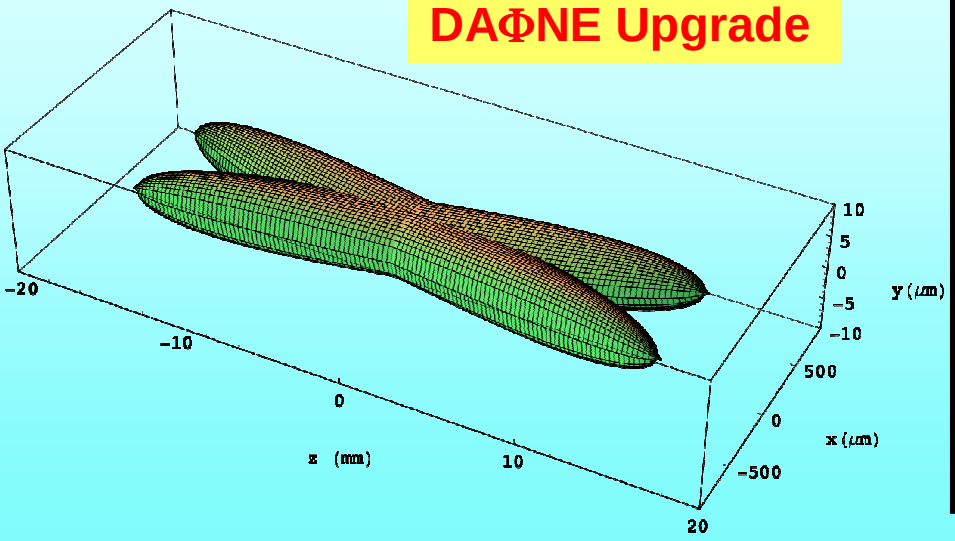
- Higher luminosity with same currents and bunch length:
  1) Beam instabilities are less severe
  2) Manageable HOM heating
  3) No coherent synchrotron radiation of short bunches
  4) No excessive power consumption
- The problem of parasitic collisions becomes negligible due to higher crossing angle and smaller horizontal beam size

DAΦNE Beam distributions @ IP

DAΦNE KLOE



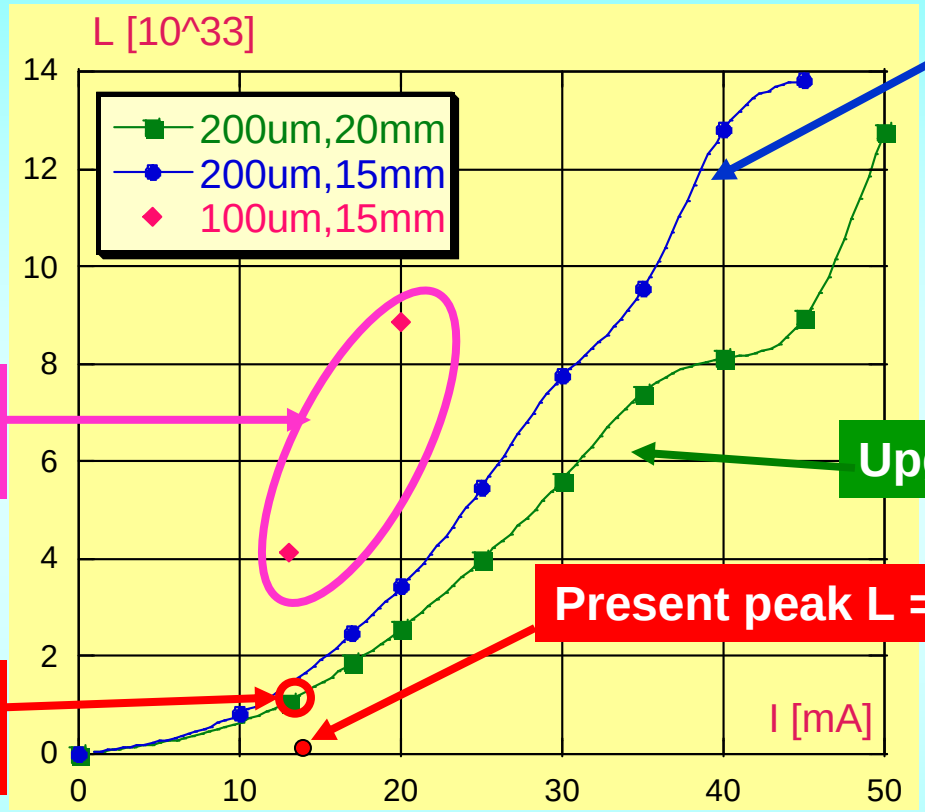
DAΦNE Upgrade



	DAΦNE KLOE	DAΦNE Upgrade
I_{bunch} (mA)	13	13
N_{bunch}	110	110
β_y^* (cm)	1.7	0.65
β_x^* (cm)	170	20
σ_y^* (μm)	7	2.6
σ_x^* (mm)	0.7	0.2
σ_z (mm)	25	20
$\theta_{cross}/2$ (mrad)	12.5	25
$\Phi_{Piwinski}$	0.45	2.5
L ($cm^{-2}s^{-1}$) x10^{32}	1.5	10

Upgrade parameters bb simulations

(BBC weak-strong code by Hirata)



Upgrade params, shorter bunch

Shorter bunch smaller σ_y

Upgrade parameters

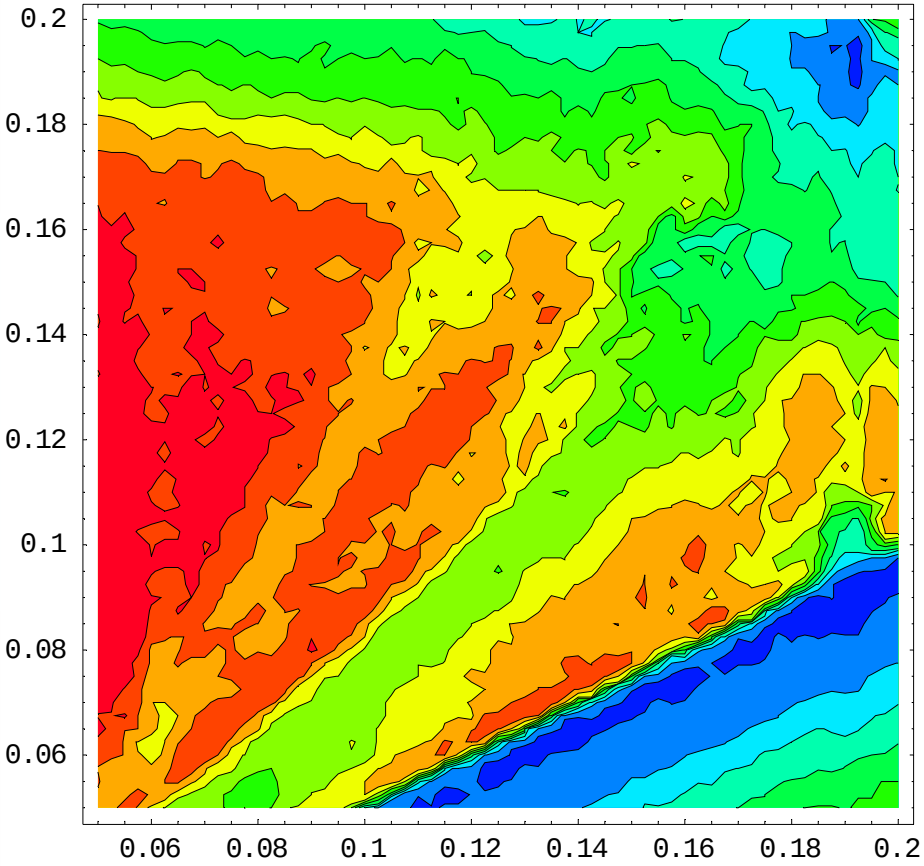
Present peak L = 0.16

Present current, upgrade params

- **With the present DAΦNE beam currents a luminosity in excess of 10^{33} cm^{-2} s^{-1} is predicted**
- **With (2 + 2) Amp more than $2*10^{33}$ cm^{-2} s^{-1} looks possible**
- **Beam-beam limit is way above the reachable currents**

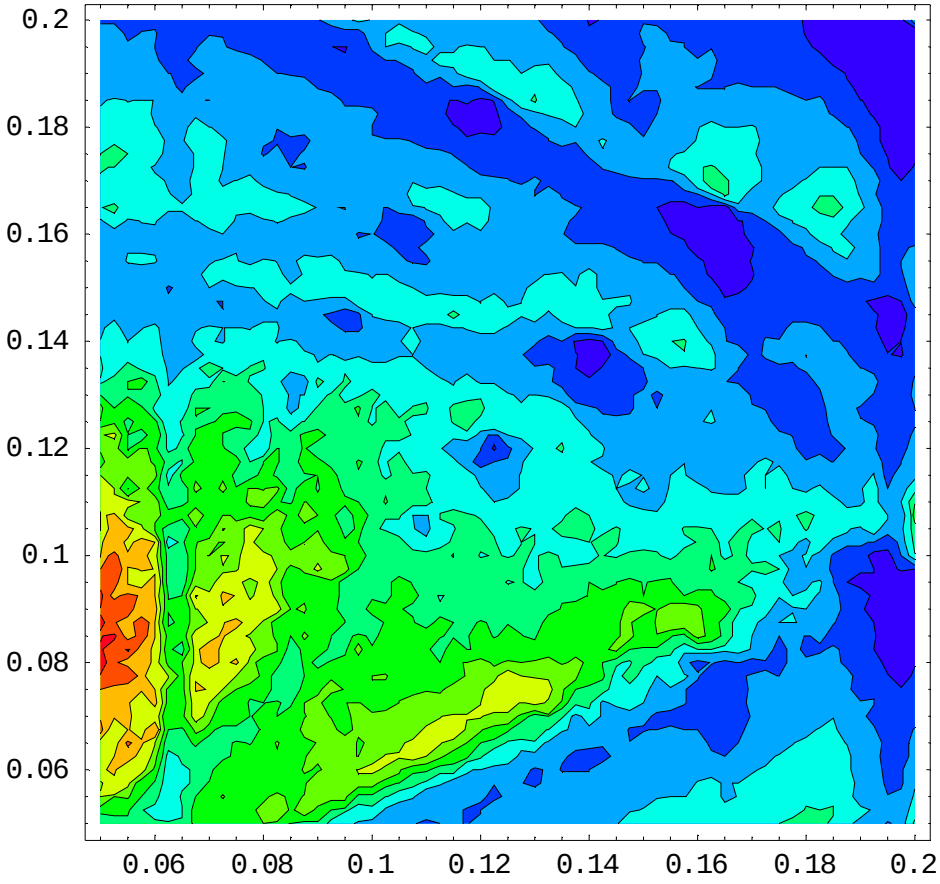
Luminosity vs tunes

Crab ON → 0.6/θ



$L_{max} = 2.97 \times 10^{33}\ cm^{-2}s^{-1}$

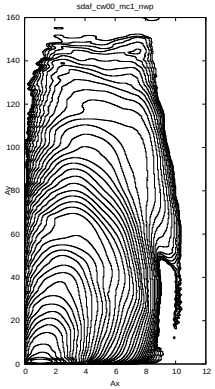
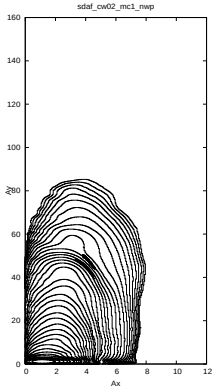
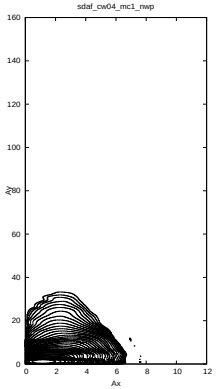
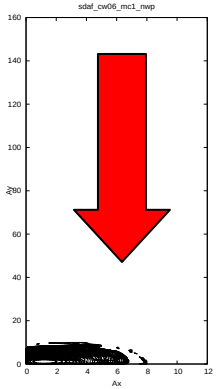
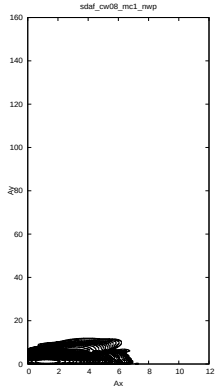
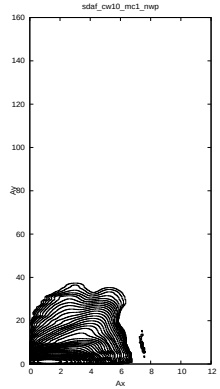
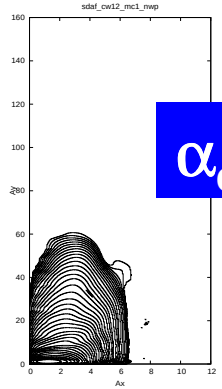
Crab OFF



$L_{max} = 1.74 \times 10^{33}\ cm^{-2}s^{-1}$

Beam-Beam Tails at (0.057;0.097)

(Lifetrack code by D. Shatilov)

$\nu_s \setminus crab$	0.0	0.2	0.4	0.6	0.8	1.0	1.2
0.01							
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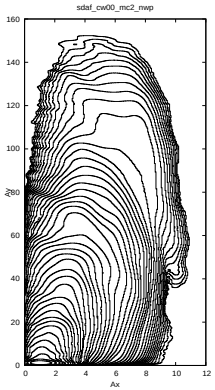
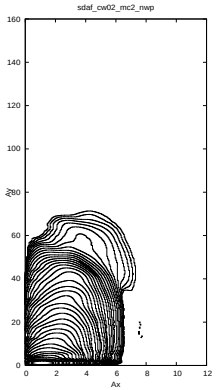
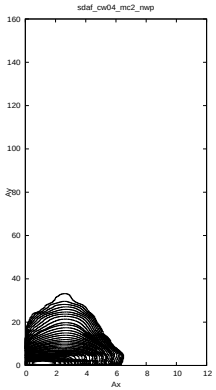
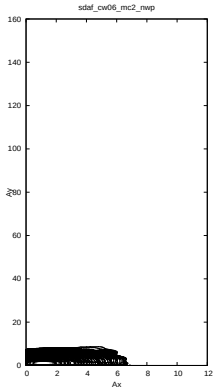
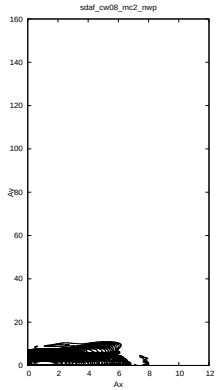
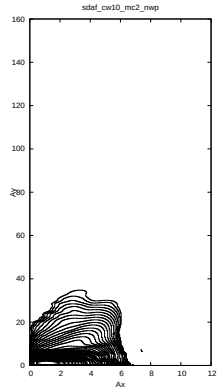
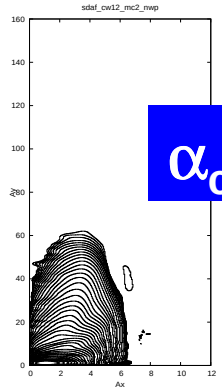
-0.01							
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$\alpha_c > 0$

$\alpha_c < 0$

A_x = (0.0, 12 σ_x); A_y = (0.0, 160 σ_y)

Beam-beam conclusions...

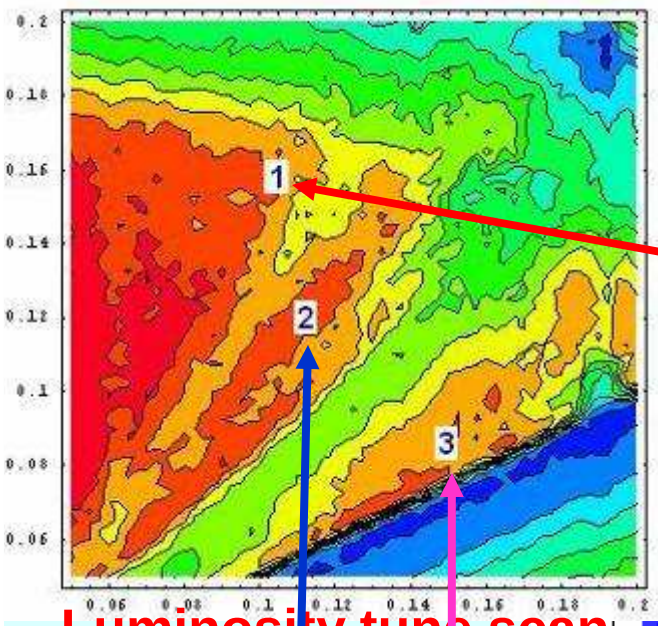
- Simulations show that a luminosity enhancement larger than one order of magnitude is possible in DAΦNE with the large Piwinski angle scheme
- According to the simulations, a luminosity of 10^{33} cm^{-2} s^{-1} can be obtained even without the “crabbing” sextupoles

Dynamic aperture vs tunes

(Acceleraticum code by E. Levichev et al)

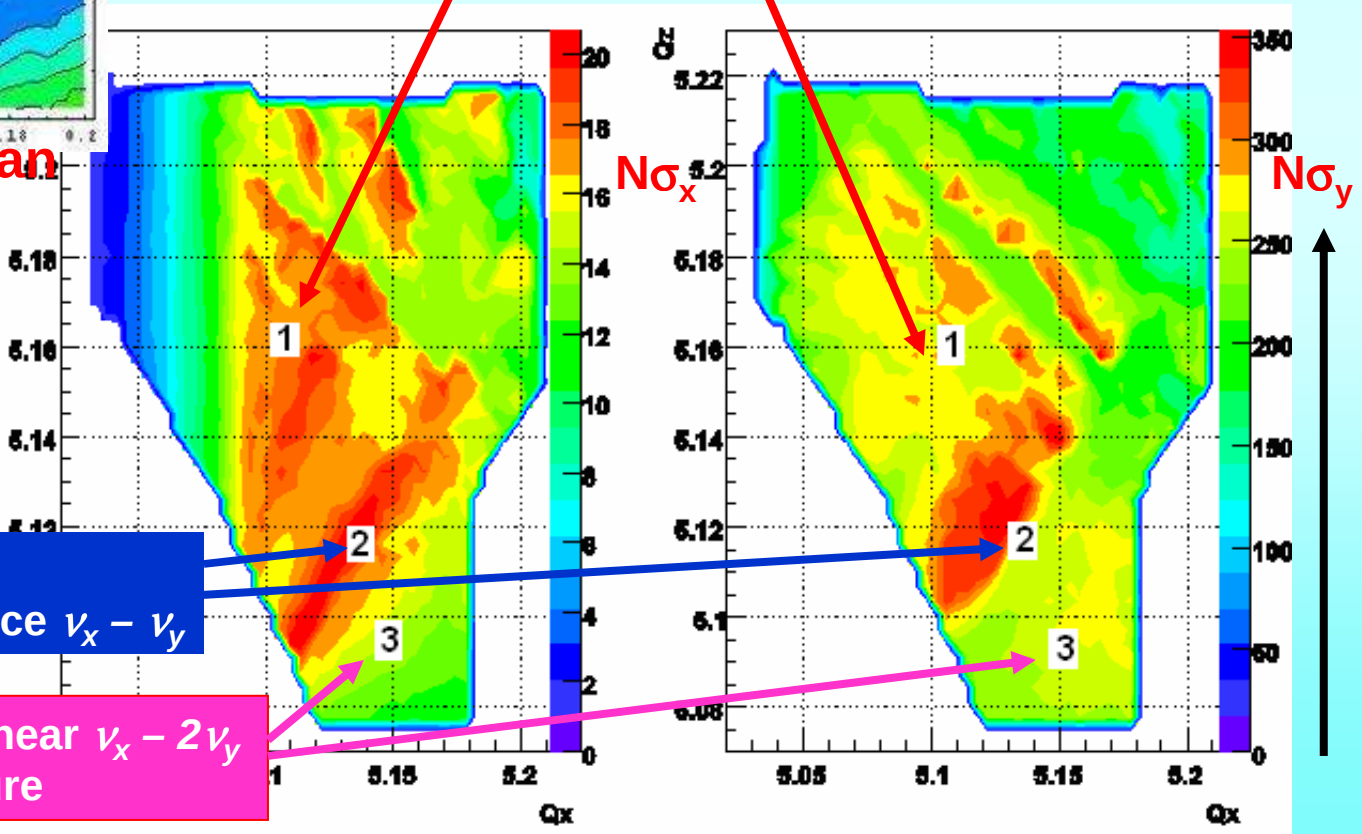
Color indicates the DA size in terms of σ

2 WP with good DA: (5.105, 5.160) and (5.131, 5.116)



Luminosity tune scan

High L and large DA



High L and DA but close to main coupling resonance $\nu_x - \nu_y$

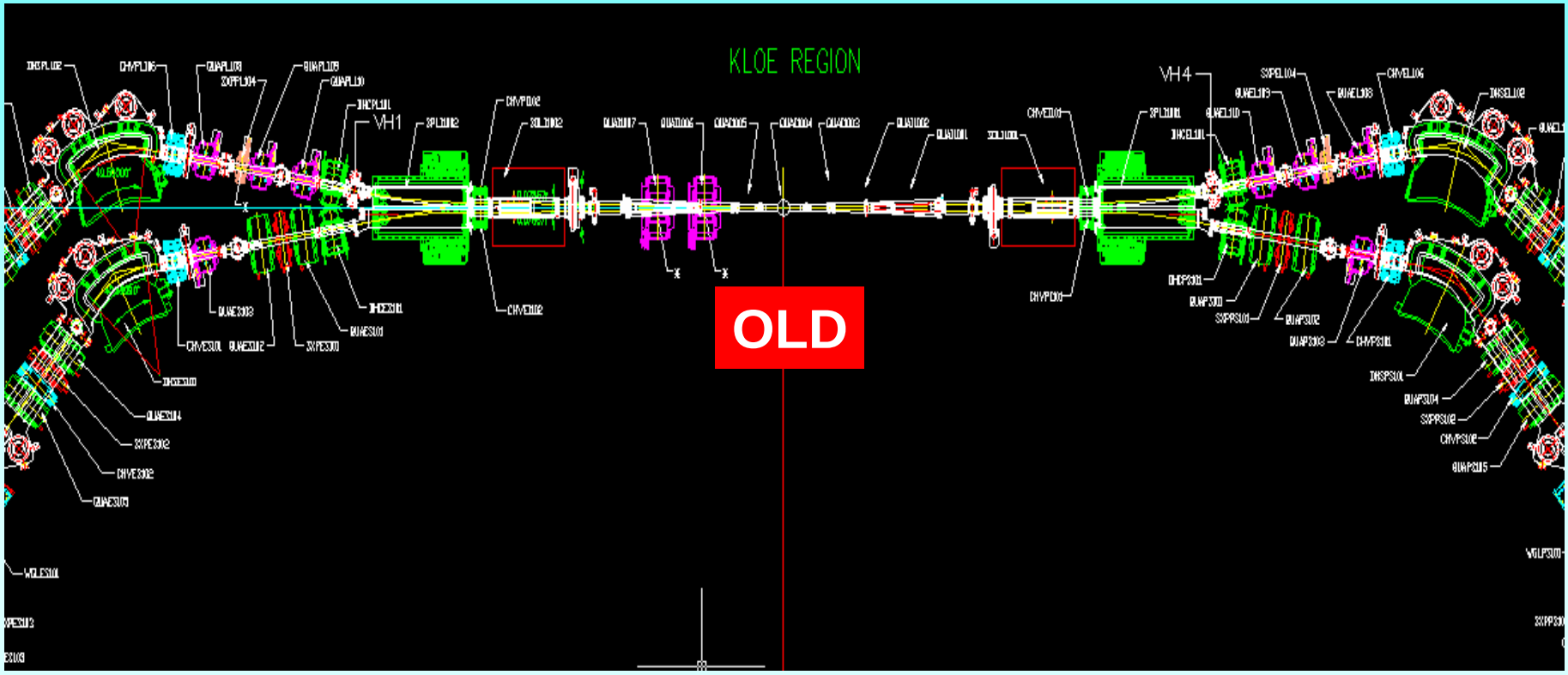
Narrow luminosity ridge near $\nu_x - 2\nu_y$ but small dynamic aperture

Lifetime & backgrounds

- Dominated by the single Touschek scattering
- Simulations of the Touschek effect with the *CW* scheme have been performed
- Particle losses are expected to be quite high mainly due to the smaller aperture, stronger IP doublets
- Longitudinal position of collimators has been optimized but a compromise between losses and lifetime has to be found experimentally
- Design of detector shielding is underway

New Interaction Regions Layout

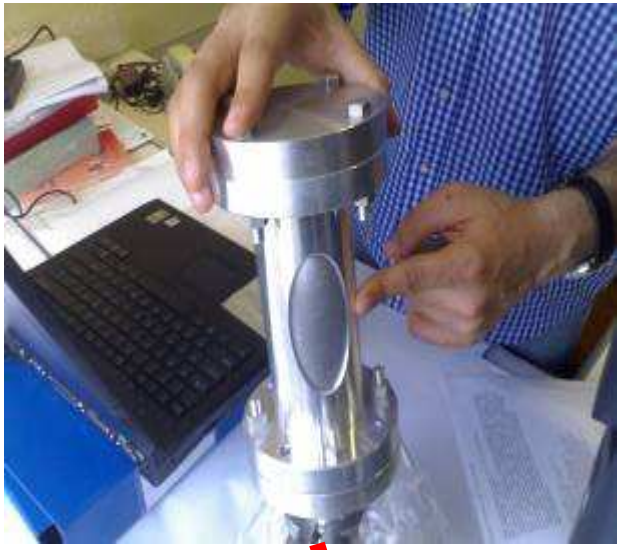
- Splitter magnets removed (both IRs)
- New permanent magnet quadrupoles in IP1
- New vacuum pipe & system for both IRs
- IR solenoids for compensation of detector fields removed
- Some elements (quads, sexts, …) relocated
- New components (kickers, bellows, diagnostics)



Interaction Region layout

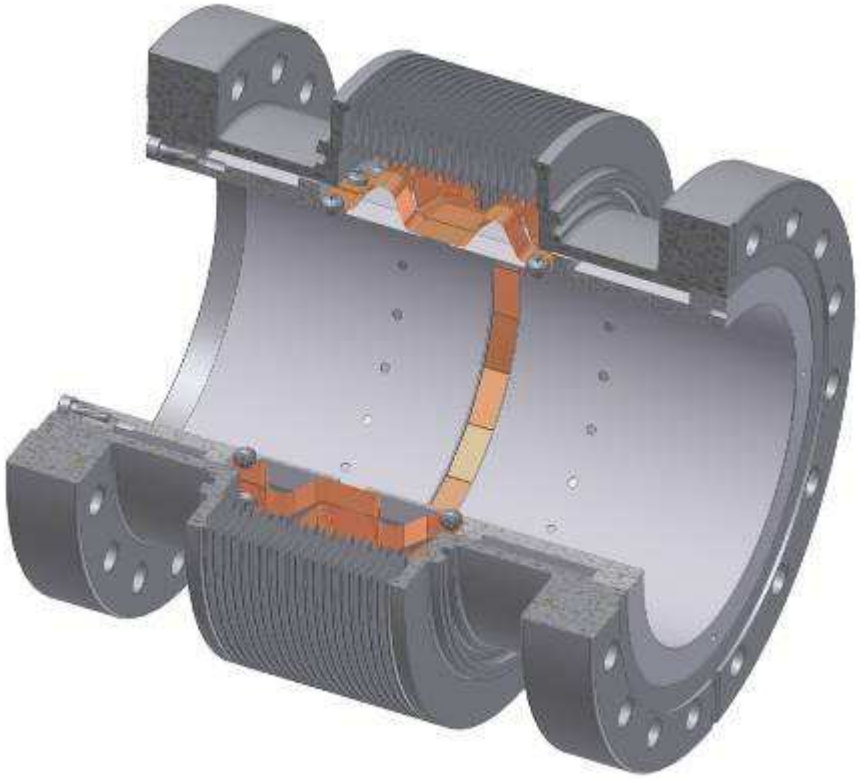
IR1

- Aluminum (cheaper than Be)
- Thin window thickness= 0.3 mm
- Mechanical and vacuum test done
- Construction in progress

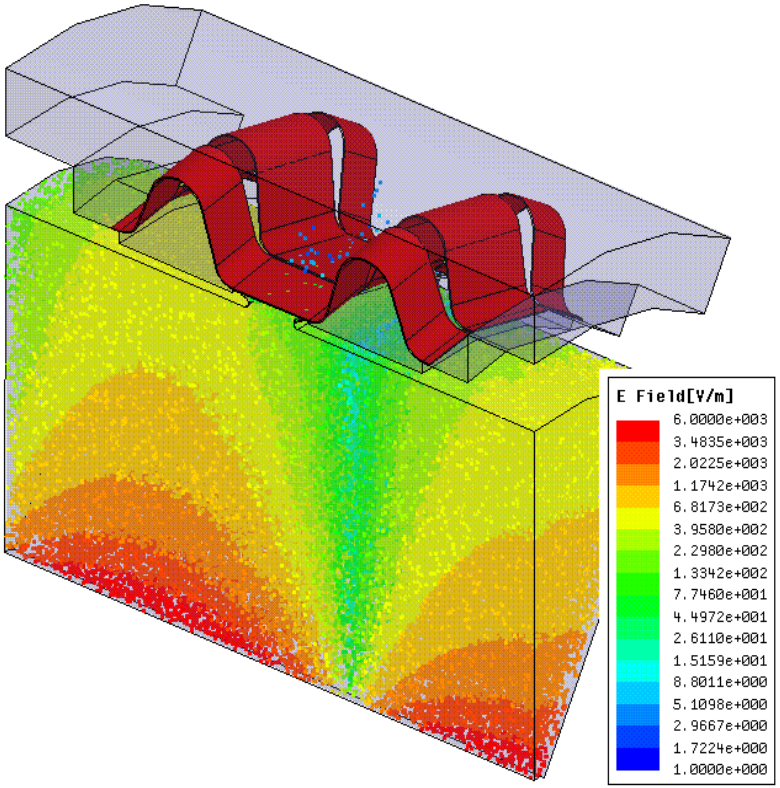


mode1 mode2 mode3 mode4

New shielded bellows

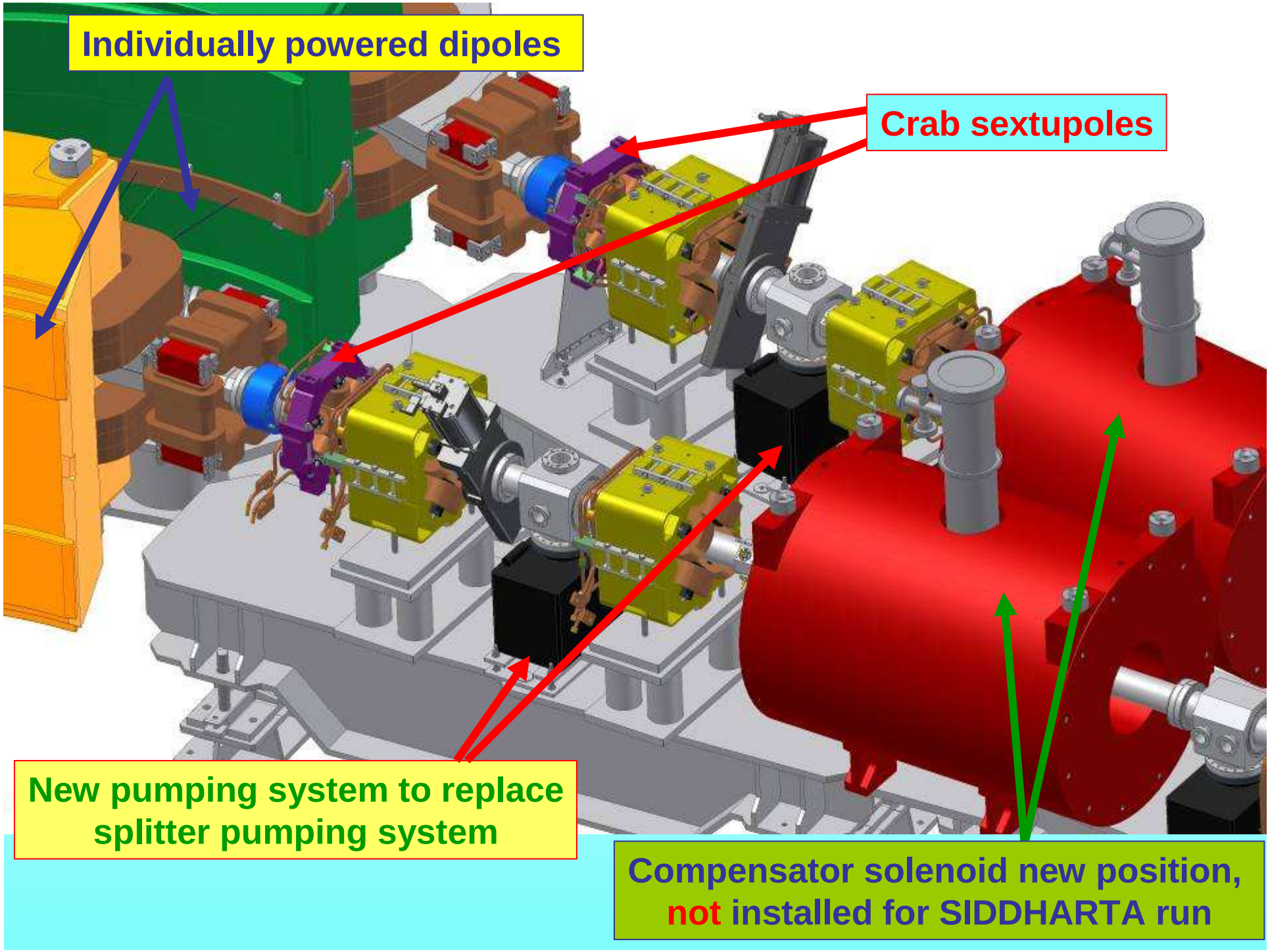


Diameter = 88 mm

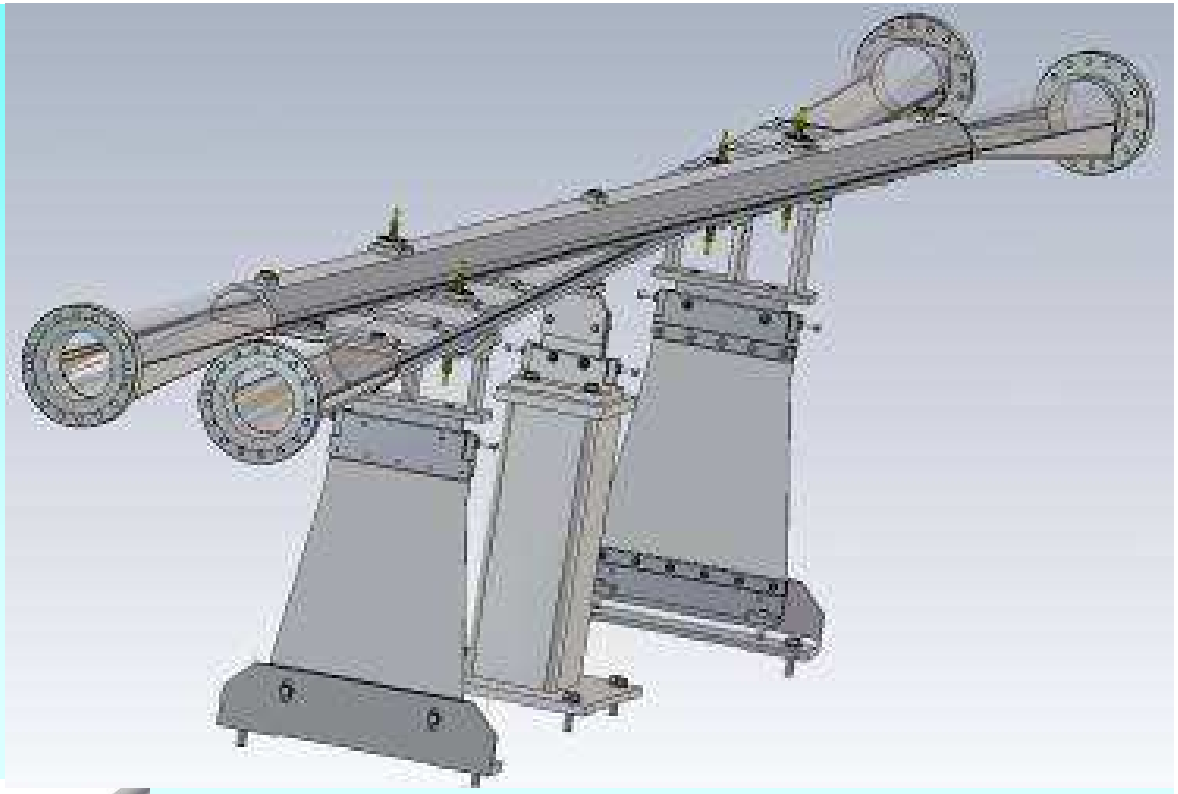


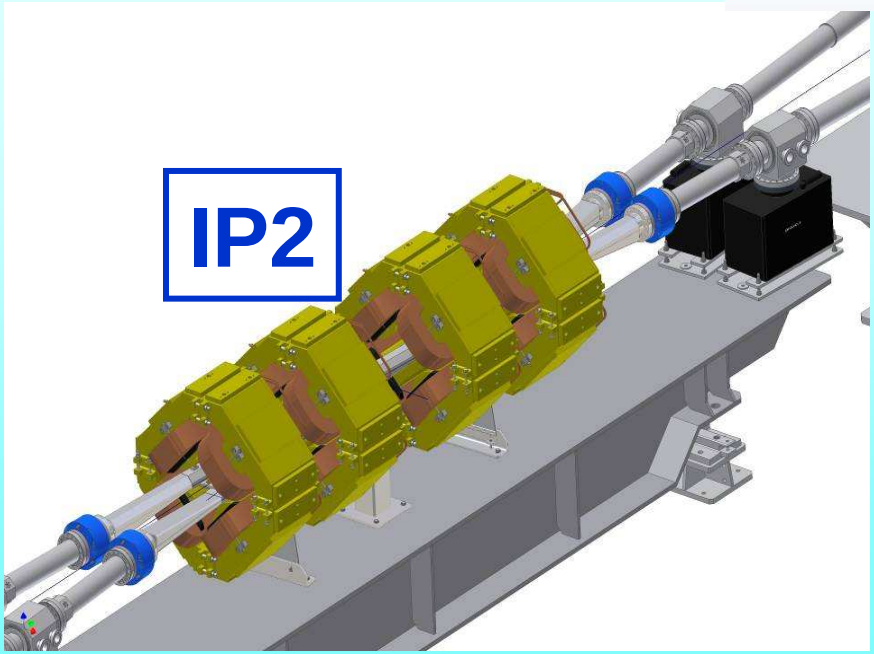
HFSS simulation

- **Beam excited fields in the bellows structure**
- **No significant fields in the volume beyond the shield**


Individually powered dipoles
Crab sextupoles
New pumping system to replace splitter pumping system
Compensator solenoid new position, not installed for SIDDHARTA run

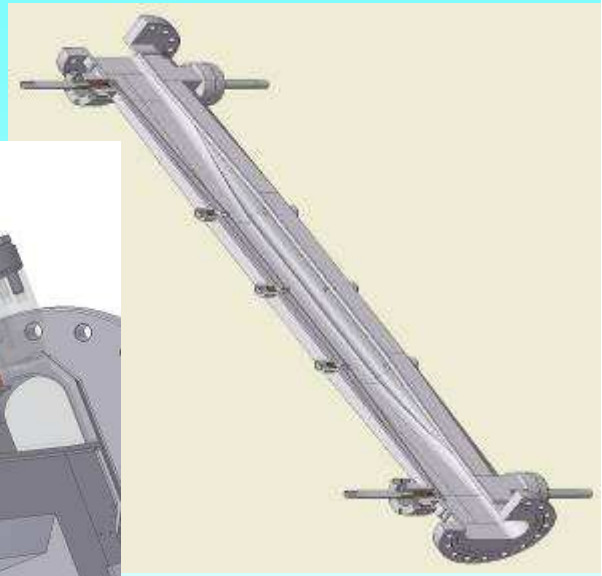
“Half moon” chamber: full beams separation, shape to fit inside existing quads

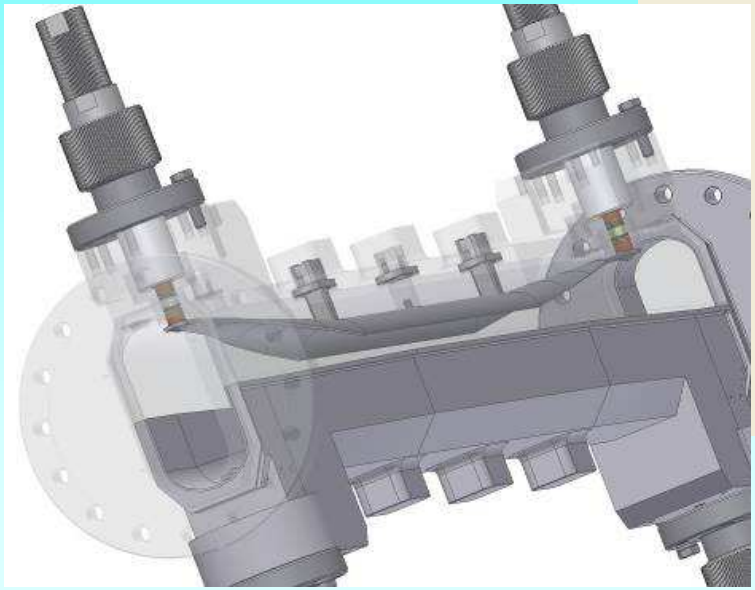




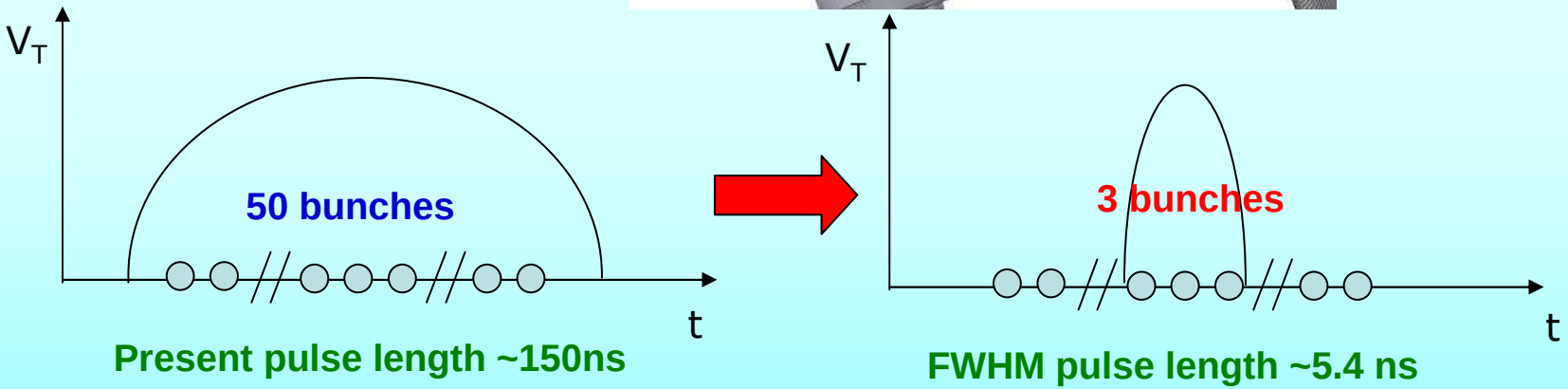
IR2

New Fast Injection Kickers





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



Present pulse length ~150ns

FWHM pulse length ~5.4 ns

Expected benefits:

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

Conclusions (1)

- The upgrade of DAΦNE for SIDDHARTA run with a new collision scheme with large Piwinski angle and small beam sizes will allow for peak luminosities in excess of 10^{33} cm^{-2} s^{-1}
- The use of "*crab waist*" sextupoles will add a bonus for suppression of dangerous resonances
- Brand new IRs layout and equipments have been designed and constructed and will be ready by next Fall to start commissioning
- Beam dynamics studies confirm that operation with the new scheme will be possible

Conclusions (2)

- The demonstration of the practical feasibility of the new collision scheme at DAΦNE will hold the promise of increasing the luminosity of storage ring colliders, as SuperB Factory and LHC, by more than two orders of magnitude beyond the current state-of-the-art, without significant increase in beam current and without reducing the bunch length