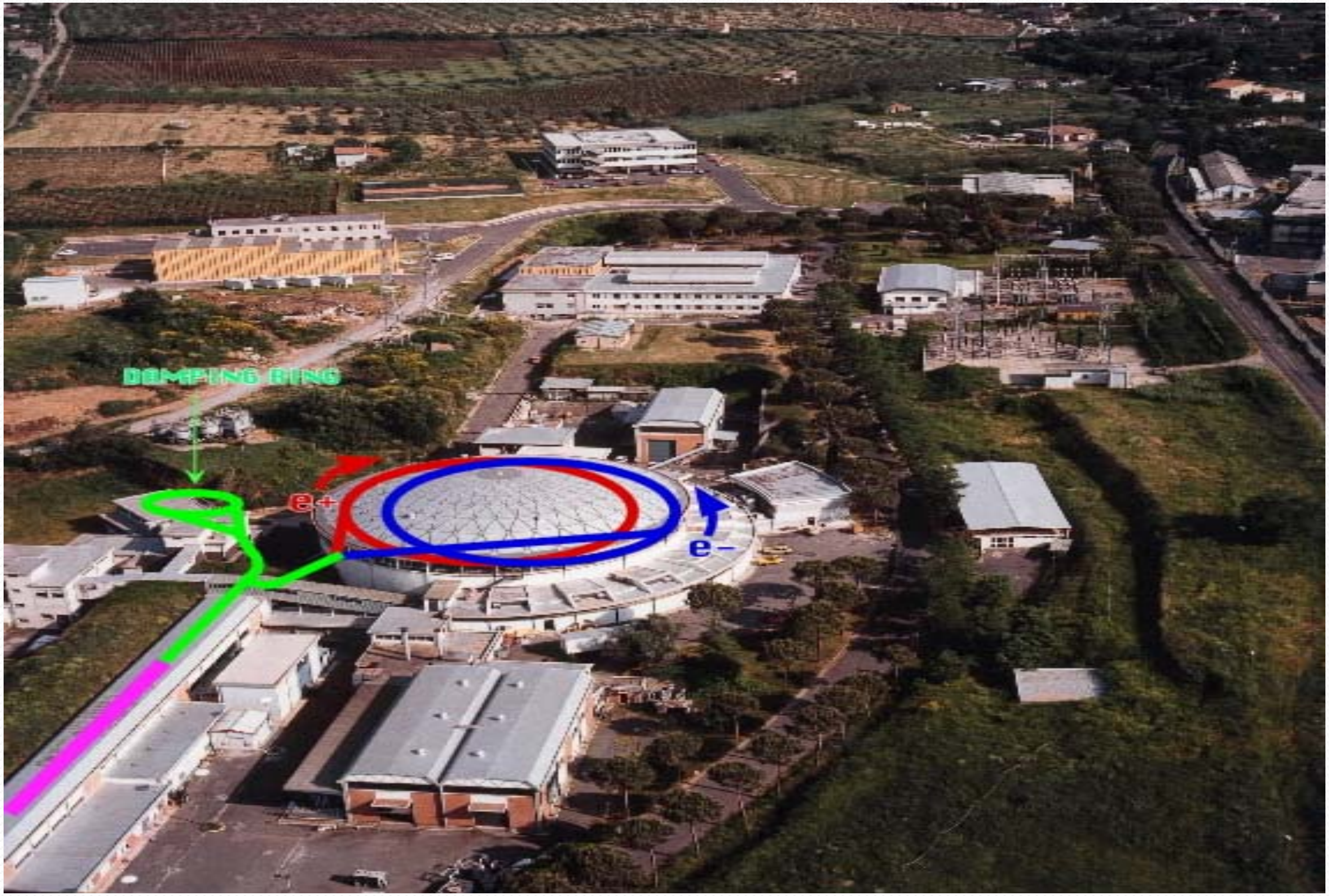
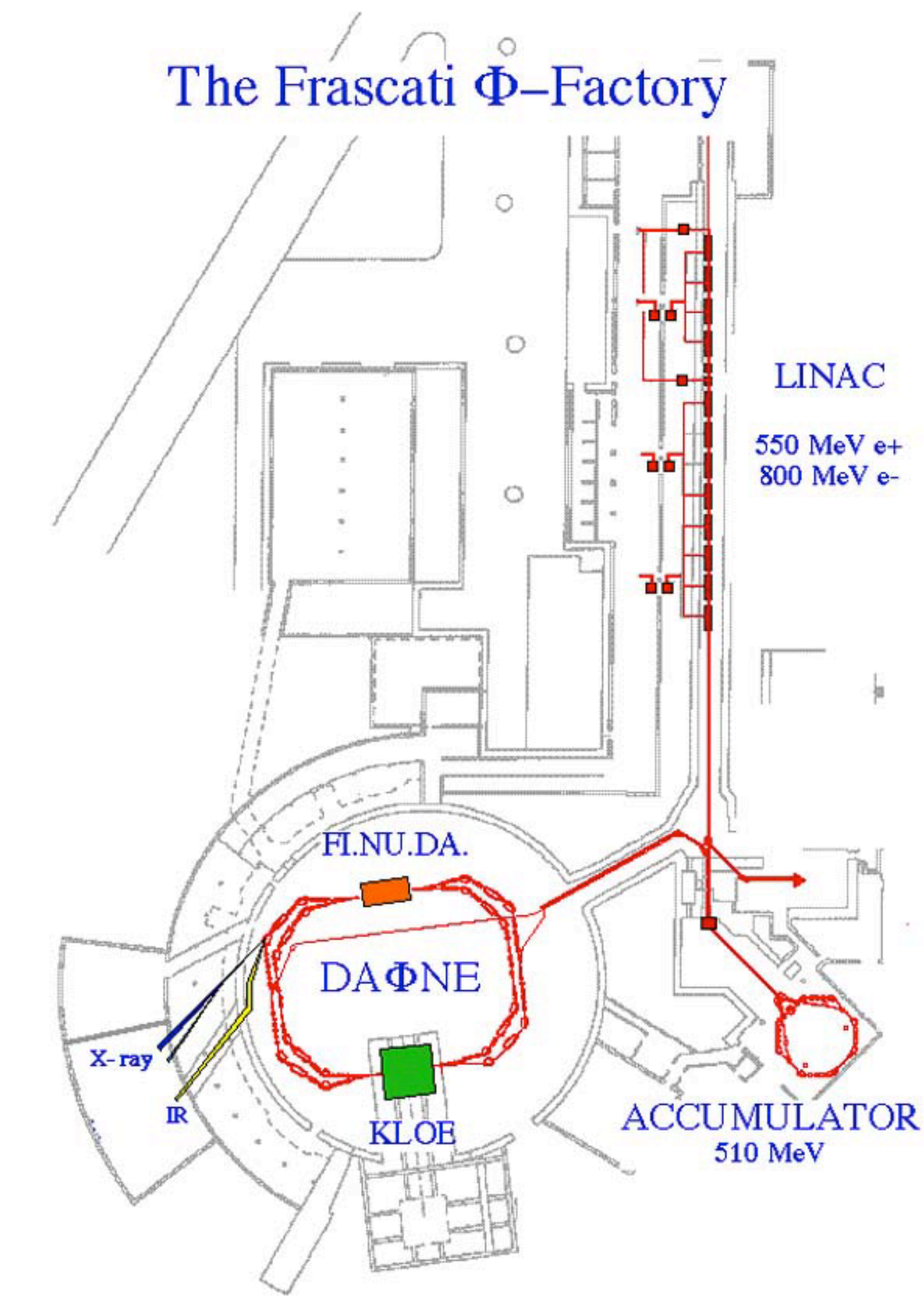
Circular colliders
The DAΦNE Φ-Factor
Part II

M.E. Biagini, INFN-LNF
Corso di "Teoria degli acceleratori"
per dottorato Universita' di Roma II
Scuola per Dottorato LTLI
LNF, 16 Giugno 2014

DAΦNE Φ-Factory (E_{cm} = 1.02 GeV)

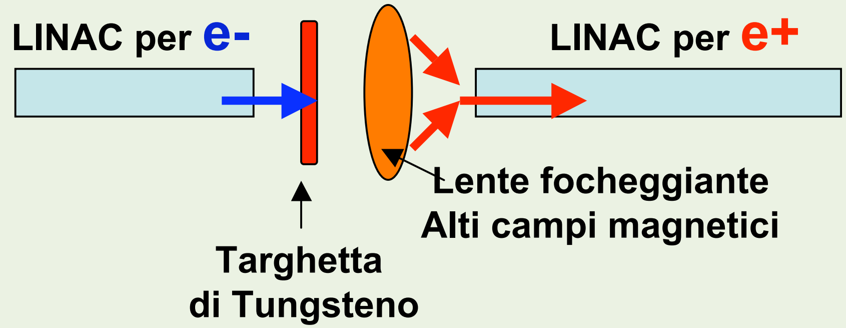


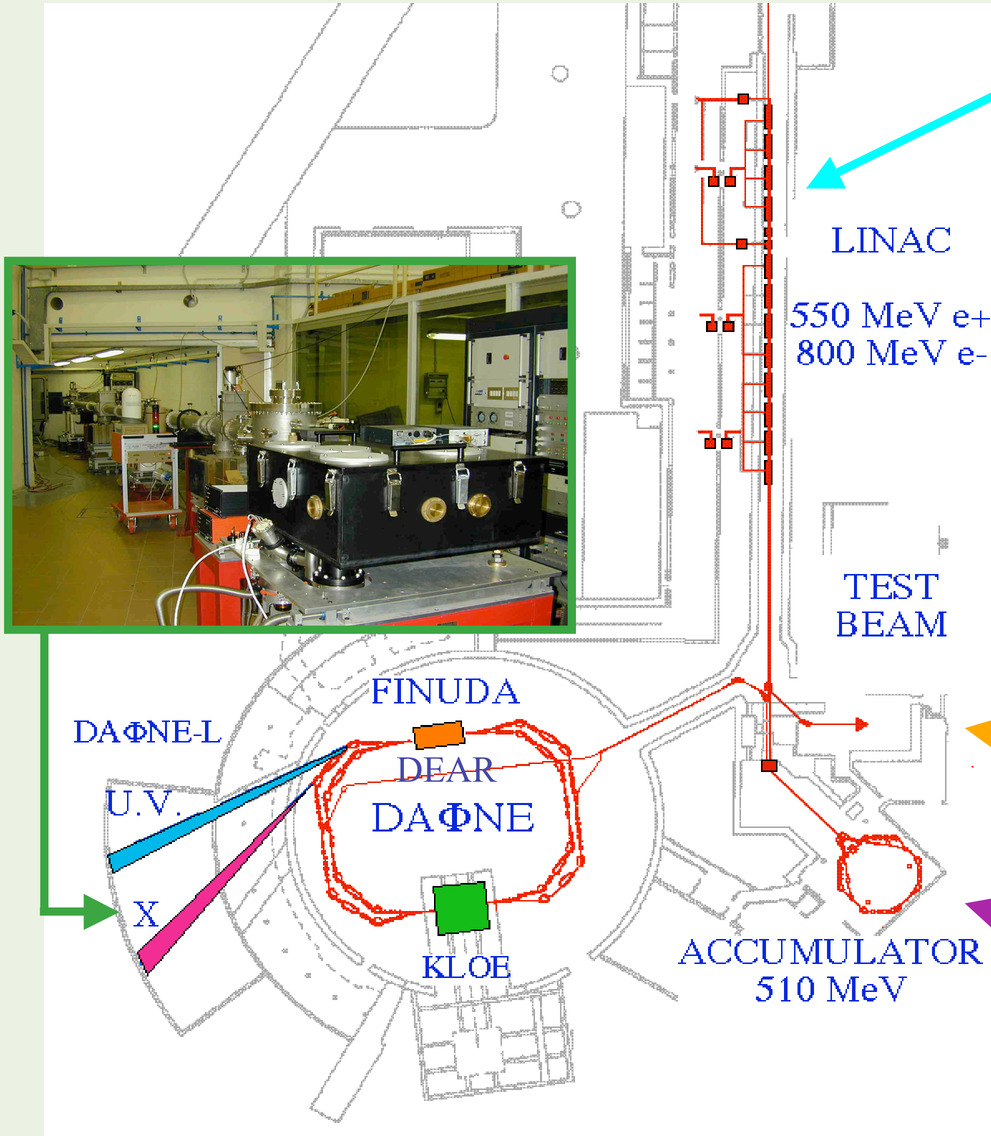


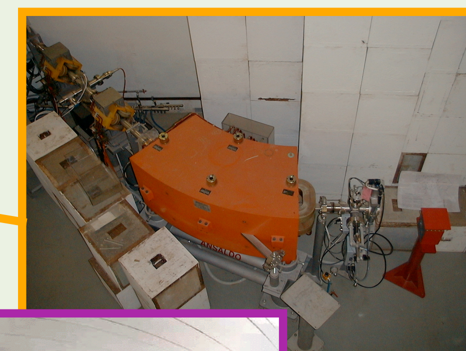
DAΦNE complex is:
(1) LINAC
(2) Accumulator
(3) Two main Rings
(4) Four beam lines for synchrotron light users

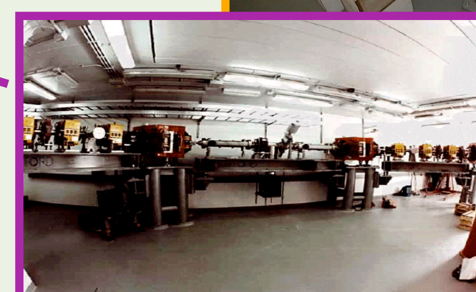
It was completed in 1997 and first collisions happened in March 1998

Il complesso di acceleratori DAΦNE





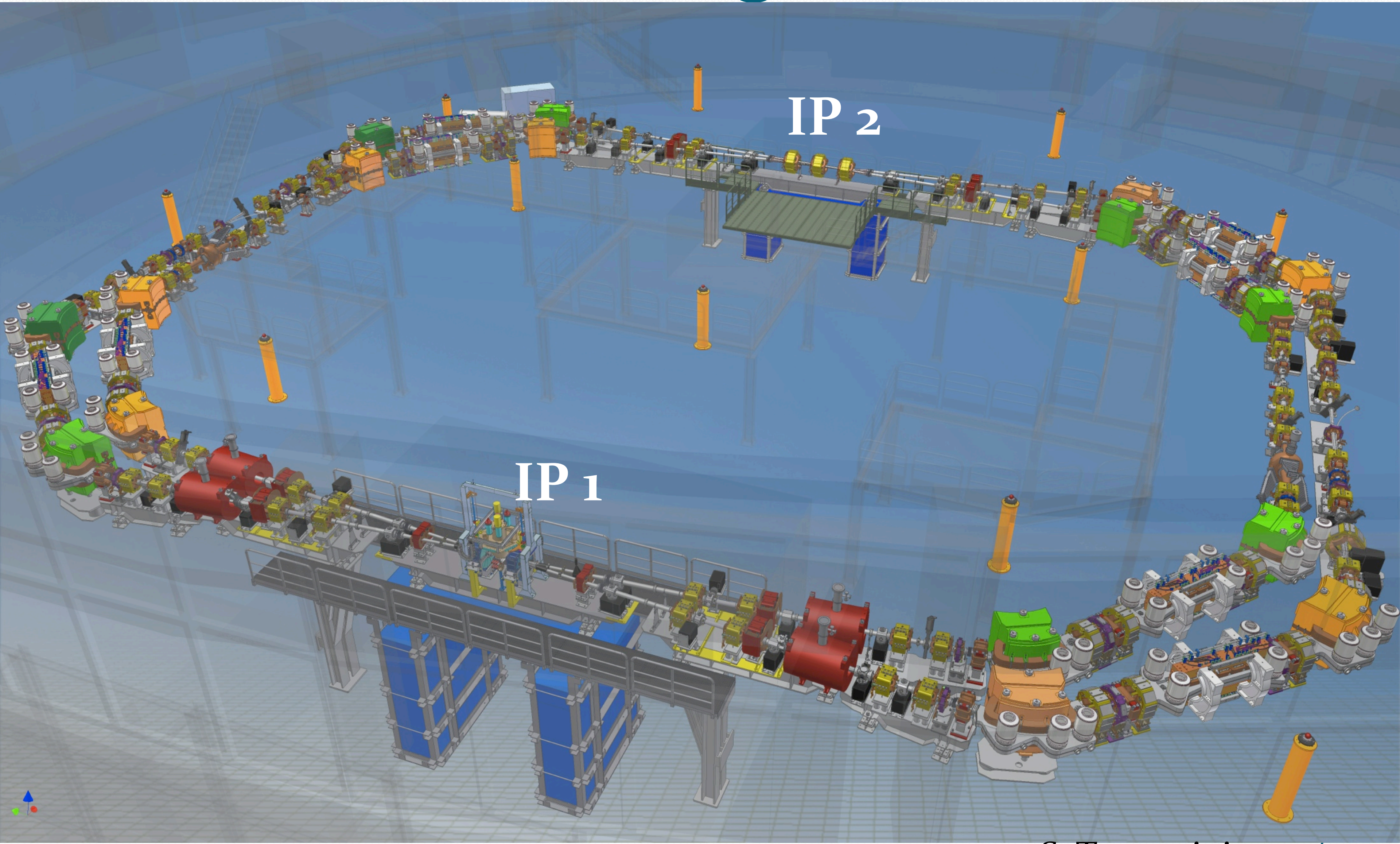




DAΦNE Linac

- Can produce and accelerate electrons (up to 800 MeV) and positrons (up to 510 MeV)

DAΦNE Main Rings



DAΦNE Features

- Electron/positron collider for production of the Φ resonance at high intensity
- Beam Energy: 0.51 GeV
- Center of mass Energy: 1.02 GeV
- High beam current (> 2 A electrons, 1 A positrons)
- Wigglers to increase beam radiation and damping
- Beam lines for synchrotron light users from dipole and wiggler

DAΦNE parameters

		DAFNE 100 bunches	
Parameter	Units	e+	e-
L Measured	$cm^{-2}\ s^{-1}$	1.70E+32	
Energy	GeV	0.51	0.51
Circumference	m	97.59	
X-Angle (full)	mrad	51.4	
β_x @ IP	cm	27	27
β_y @ IP	cm	0.9	0.9
Coupling (full current)	%	3.5	1.9
Emittance x (from model)	nm	280	280
Emittance y	pm	10850	6289
Bunch length (full current)	mm	12	13
Beam current	mA	890	960
Buckets distance	#	1	
RF frequency	Hz	3.69E+08	
Revolution frequency	Hz	3.07E+06	
Harmonic number	#	120	
Number of bunches	#	100	
N. Particle/bunch	#	1.81E+10	1.95E+10
Piwinski angle	rad	1.07	1.12
Tune shift x		0.0208	0.0224
Tune shift y		0.0308	0.0233
Longitudinal damping time	msec	17	17.0
Energy Loss/turn	MeV	0.009	0.009
Momentum compaction		1.90E-02	1.90E-02
Energy spread (full current)	ΔE/E	6.00E-04	6.00E-04
SR power loss	MW	0.01	0.01
RF Wall Plug Power (SR only)	MW	0.03	

Luminosity strategy with 2 rings

- Small IP beta function $\beta_y{}^*$
- High number of particles per bunch N_{part}
- More colliding bunches N_b
- Large beam emittance (area) ε_x
- High bb tune shift parameters $\xi_{x,y}$
- Crossing angle θ ← **To avoid parasitic crossing**
- Small Piwinski angle $\Phi = \sigma_l tg(\theta/2)/\sigma_x < 1$

➡ *small crossing angle* $\theta < \sigma_x/\sigma_l$

To reduce synchro-betatron resonances

Changing the approach…

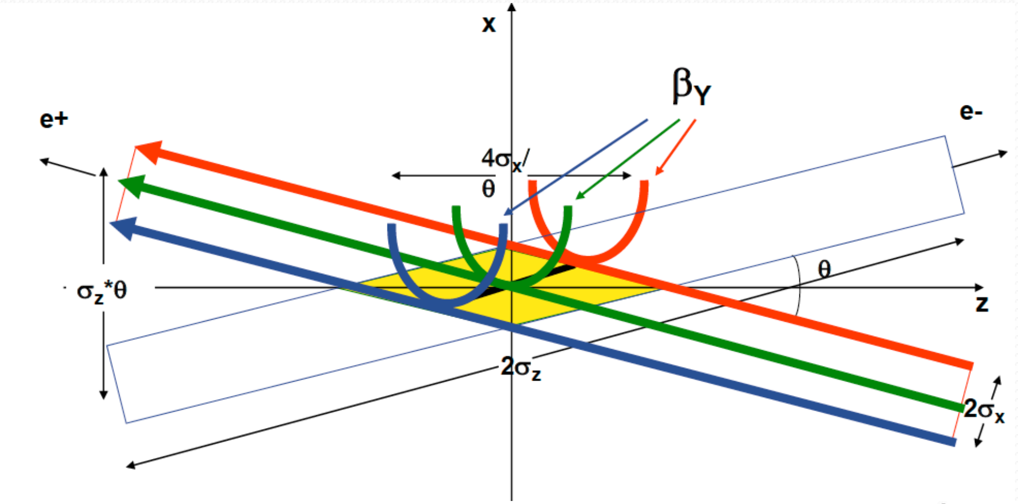
- Less than 10 years ago the "brute force" (increasing currents) was the only approach to higher luminosity
- P. Raimondi (LNF) studied a new collision scheme with larger crossing angle and lower IP beam sizes (*Large Piwinski Angle*) **PLUS** a couple of "*crab sextupoles*" to twist the IP waist and cure x-y and synchro-betatron resonances raising from the angle. Tested at DAΦNE
- Adopted by all Factory projects after 2008

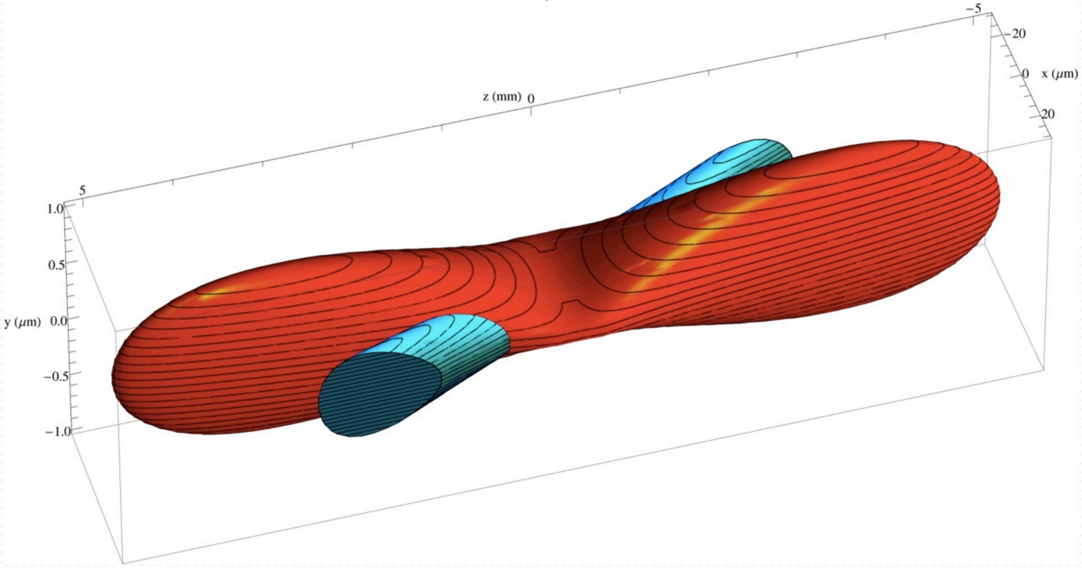
		Present KEKB LER/HER	High-current LER/HER	Nano-beam LER/HER	
Stored currents	I	1.8 / 1.4	9.4 / 4.1	$\sim 3/1.5$	A
Vert. beam-beam param.	ξ_y	$\lesssim 0.09$	~ 0.3	~ 0.1	
Vert. β at the IP	β_y^*	6	3 / 5	~ 0.2	mm
Hor. emittance	ε_x	~ 18	~ 18	~ 1	nm
Vert. beam size at the IP	σ_y^*	~ 1	~ 1	~ 0.05	μm
Crossing angle	θ_x	22	0 (crab)	~ 60	mrad
Luminosity	$\mathcal{L}$	1.8	~ 50	~ 80	10^{34} cm^{-2} s^{-1}

Oide, Progress of Theoretical Physics, Vol. 122, No. 1, July 2009

Crab sextupoles OFF

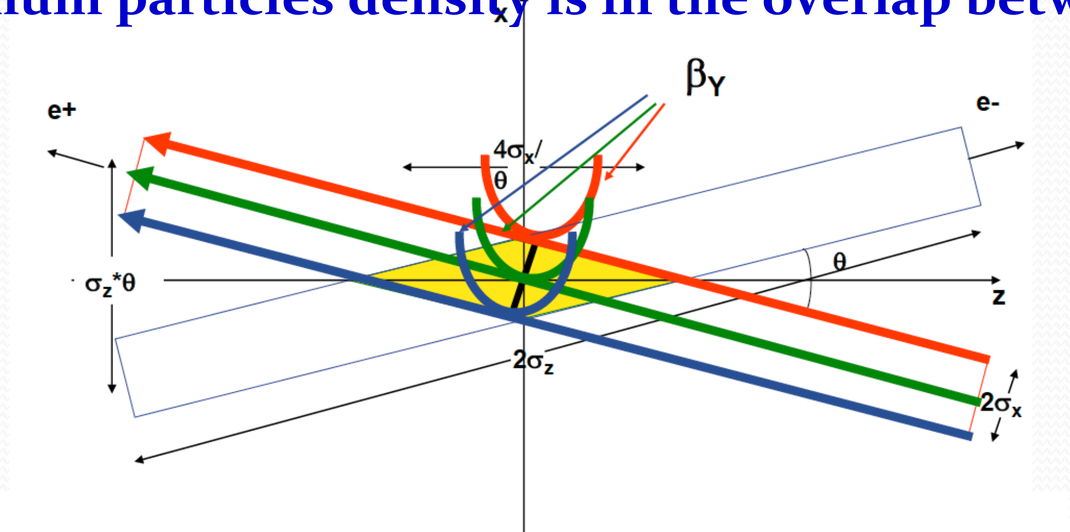
Minimum β_y is orthogonal to the other beam axis

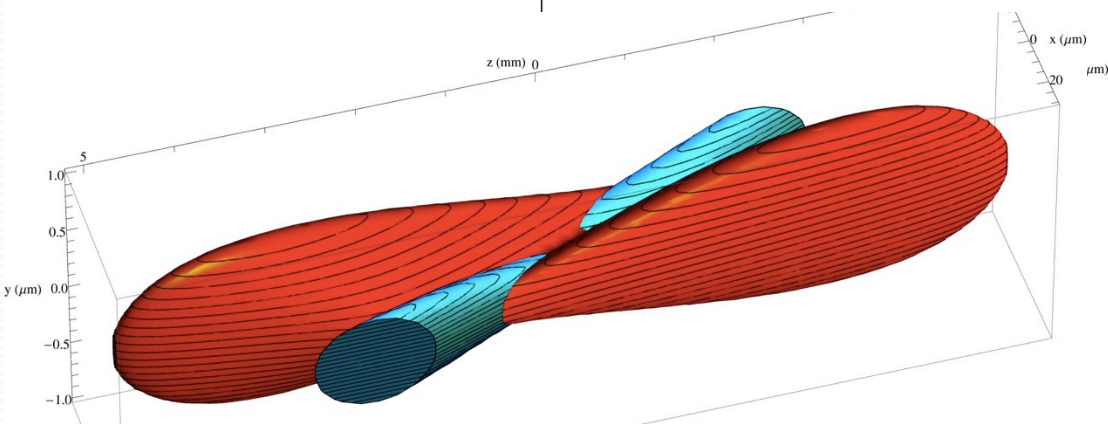




Crab sextupoles ON

Minimum β_y moves parallel to the other beam axis
→ Maximum particles density is in the overlap between bunches





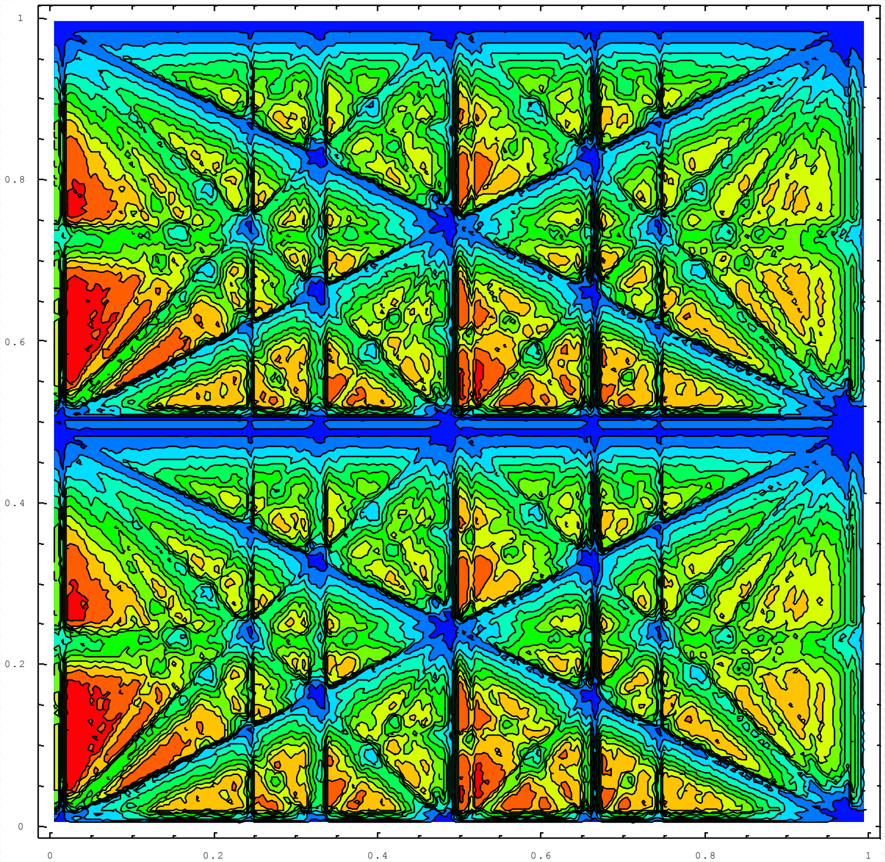
All particles in the 2 beams collide in the di minimum β_y region with a luminosity gain

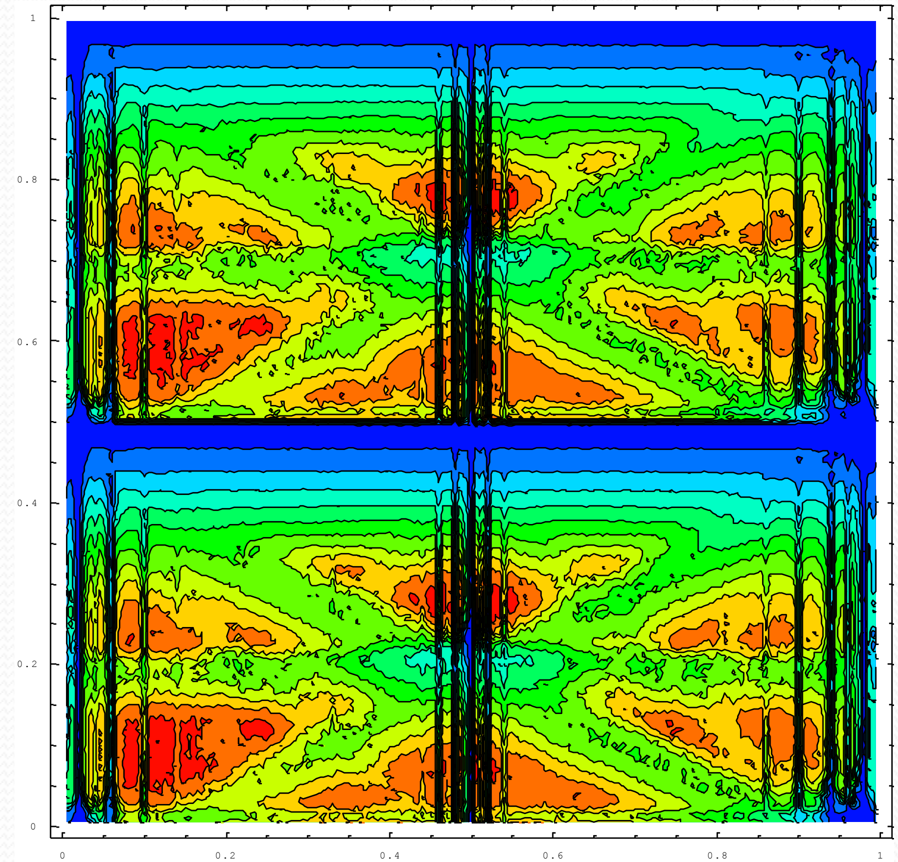
Beam-beam simulations

- *Beam-beam interaction* simulations show that introducing the *crab sextupoles* X-Y and synchro-betatron resonances due to the large crossing angle are suppressed, with consequent beam stability and no vertical *blow-up*
- In the following plots Luminosity (higher in Red) is plotted in the tunes plane (Q_x, Q_y). The Blue lines show the "resonances" to be avoided
- This allows to choose the ring "*working point*" with maximum theoretical Luminosity

X-Y Resonance Suppression

Much higher luminosity!





Typical case (KEKB, DAΦNE etc.):

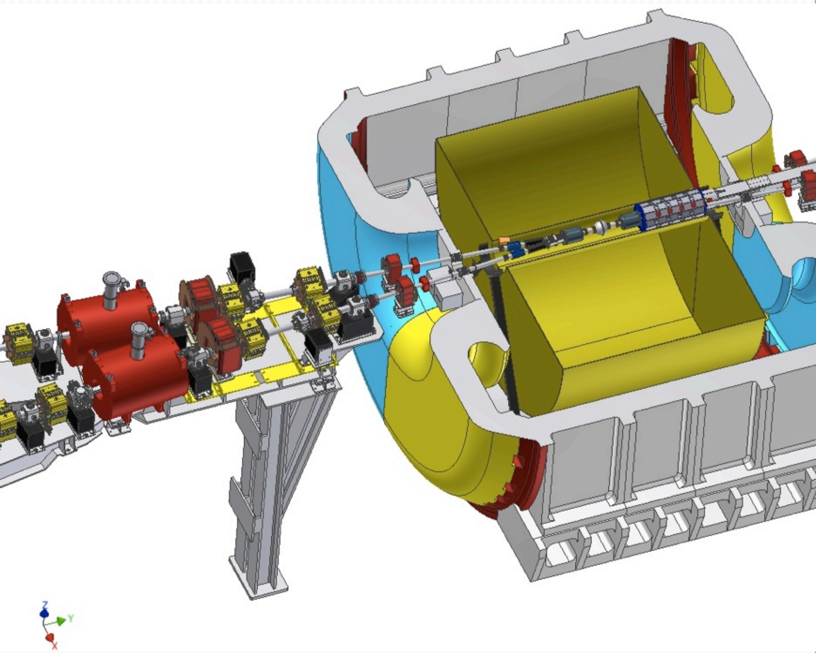
1. low Piwinski angle $\Phi < 1$
2. β_y comparable with σ_z

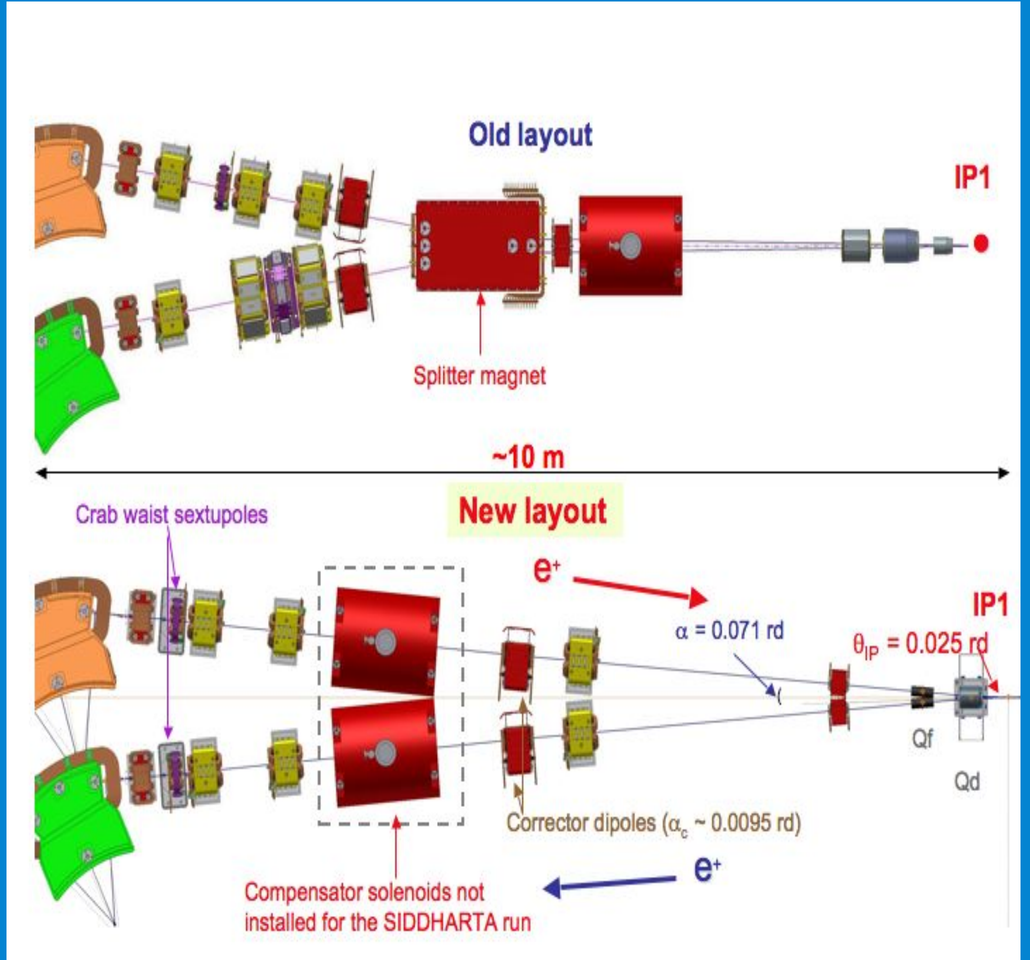
Crab Waist ON (DAΦNE upgrade):

1. large Piwinski angle $\Phi >> 1$
2. β_y comparable with σ_x/θ

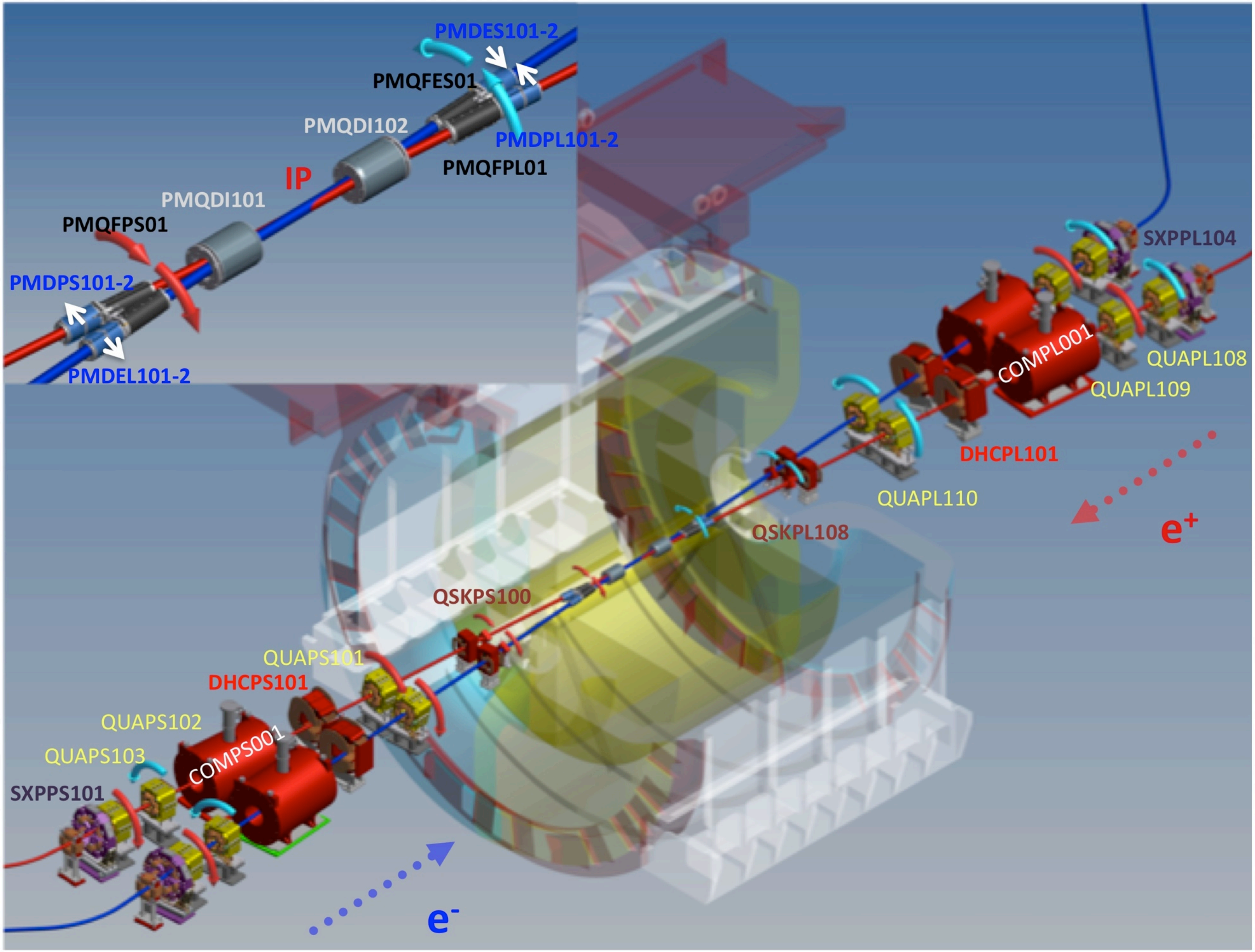
New DAΦNE Interaction Region for LPA&CW scheme

KLOE IR





P. Raimondi, Aprile 2010



Courtesy S. Tomassini