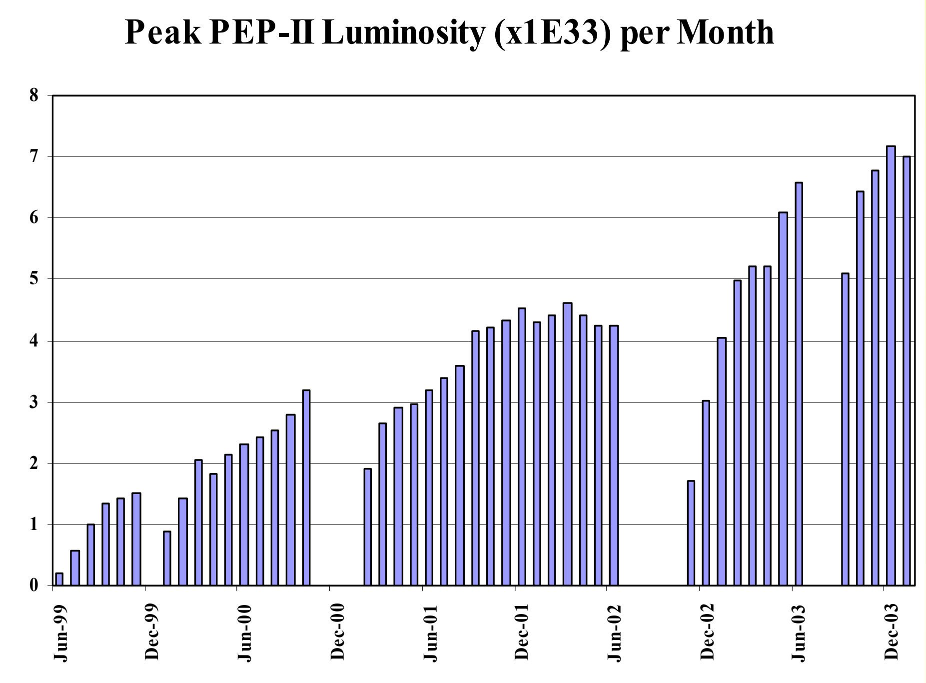
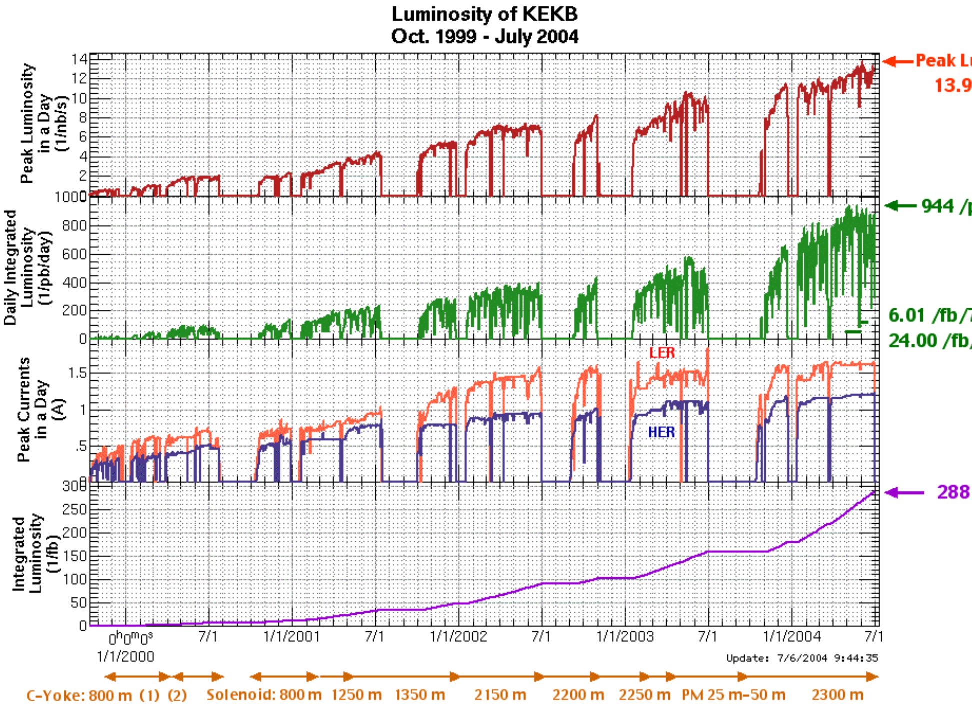
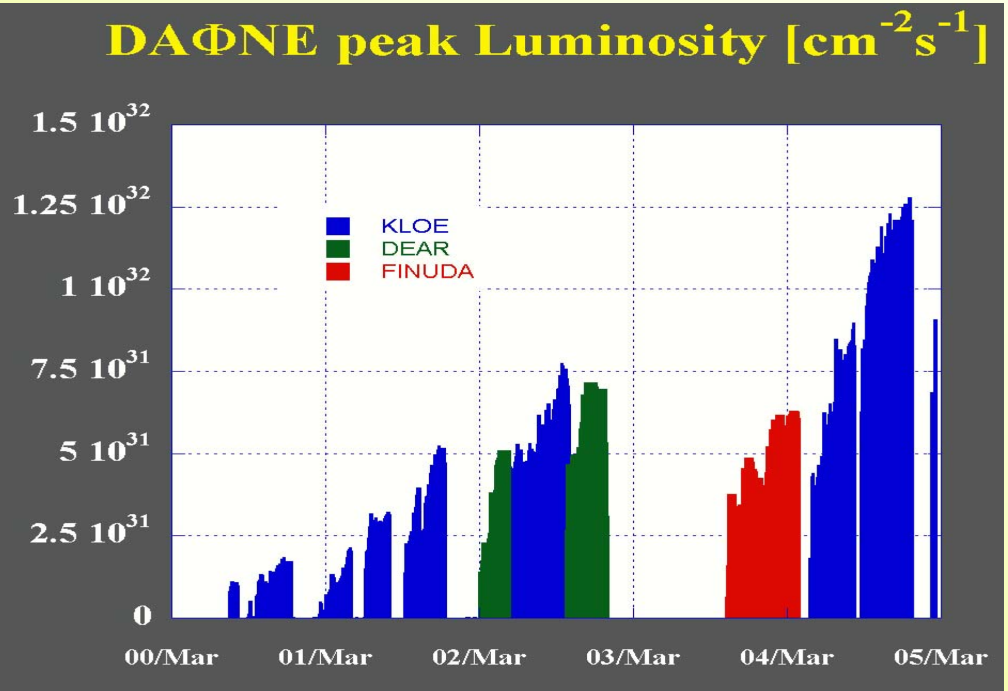
Overview of B and Phi factories and their future

P. Raimondi

La Thuile, March 2nd2005

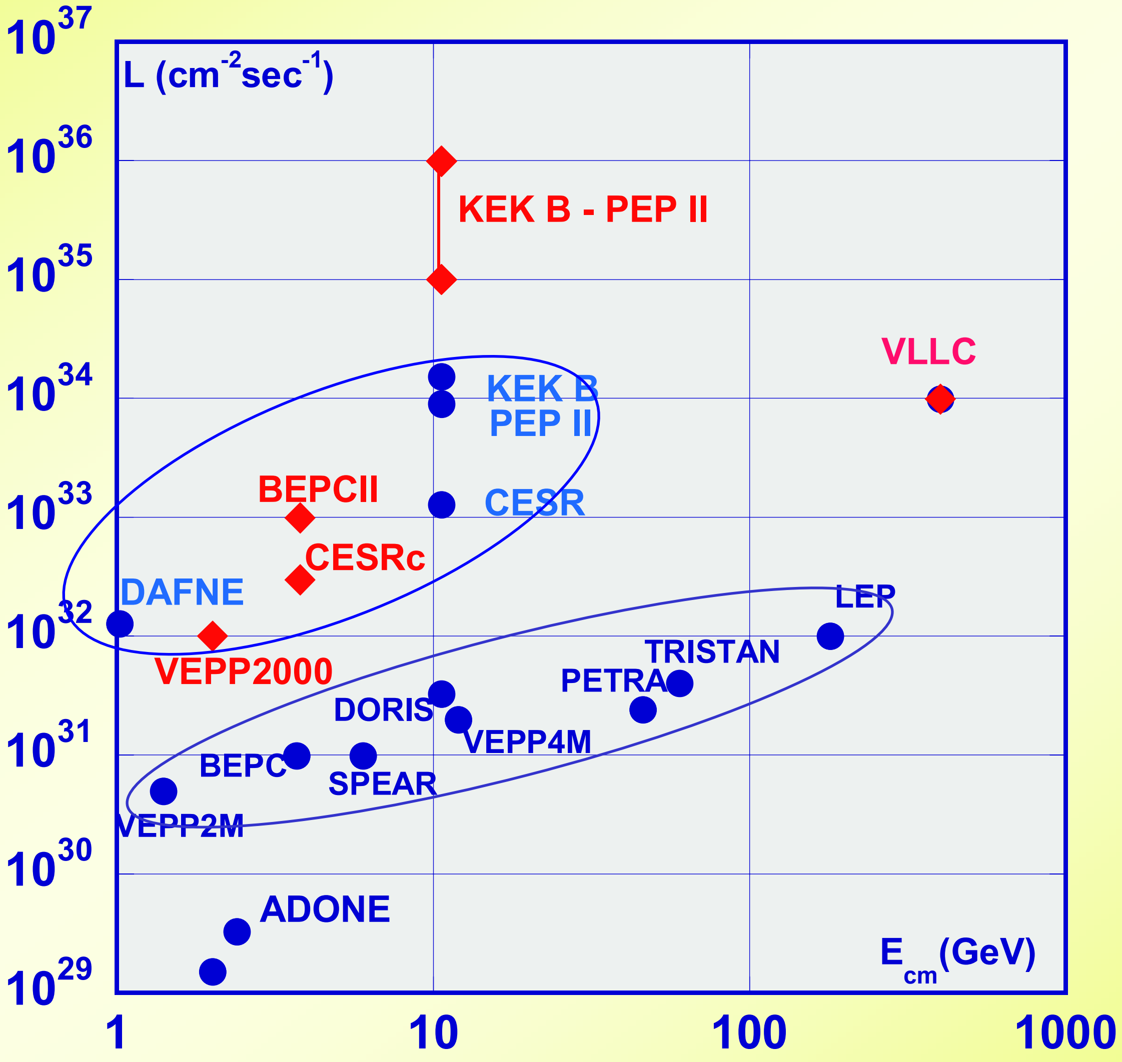






Factories peak luminosities still growing

Lepton Collider Performances: Luminosity vs. Energy



Super PEP2

- Preliminary studies for an upgrade of Pep2 have been made and are still in progress

-However, presently SLAC has decided to focus his HEP on the ILC for the next few years and officially the PEP2 program should be completed at the end of the scheduled physics runs.

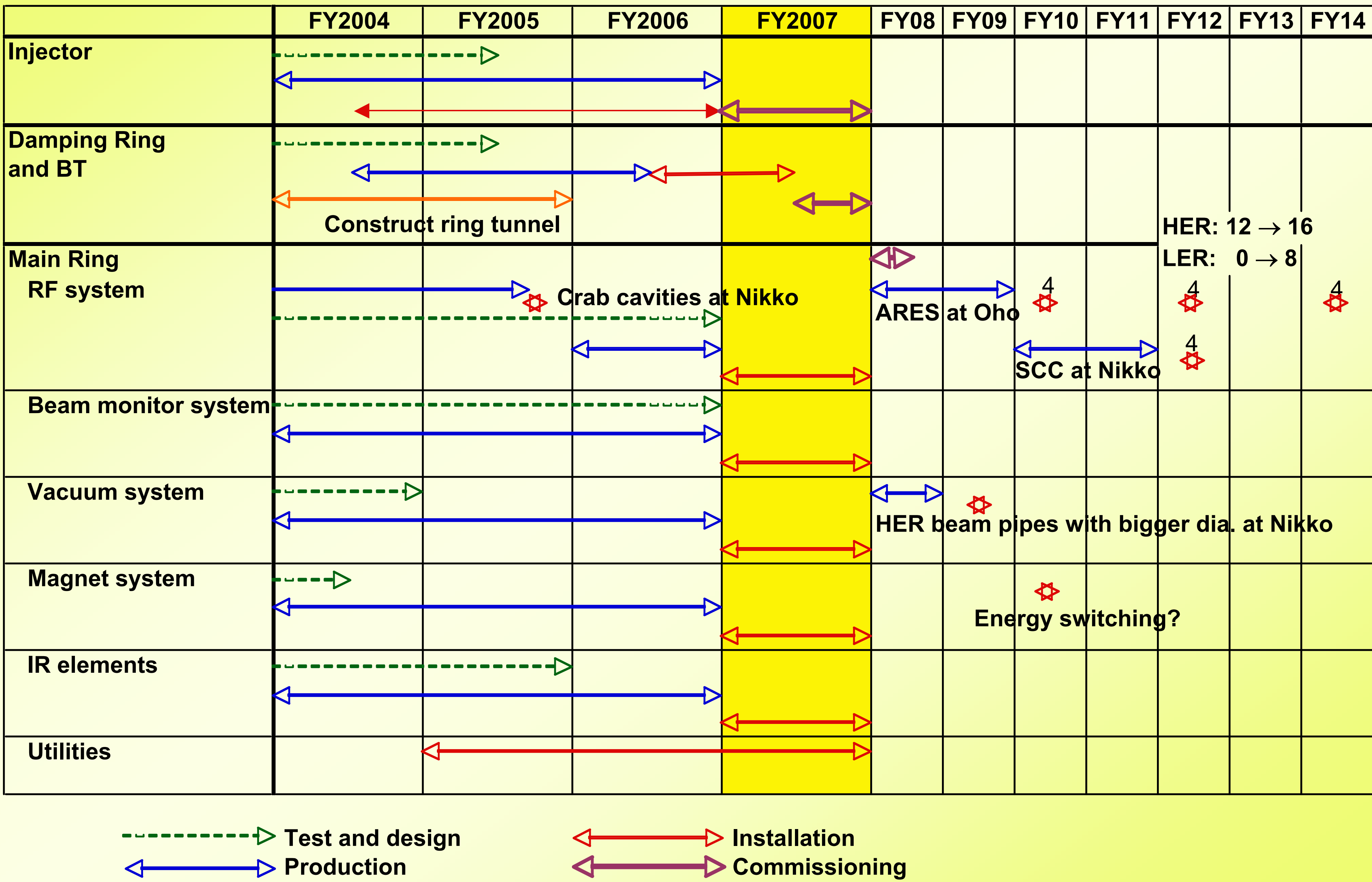
-It is still possible that this will change in the future (budget and power requirements are the most crucial points)

Super KEKB

- **Solid design almost completed for a quasi-adiabatic upgrade aimed at $L=10^{35}$ to be implemented around 2008**

- After that, increasing RF power and beam currents the luminosity could exceed $2\text{-}4*10^{35}$

General Schedule



Strategy

Lorentz factor

Beam current

Beam-beam parameter

$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

Classical electron radius

Beam size ratio@IP
1 ~ 2 % (flat beam)

Vertical beta function@IP

Ratio of luminosity & tune shift reduction factors: 0.8 ~ 1 (short bunch)

Increase beam currents

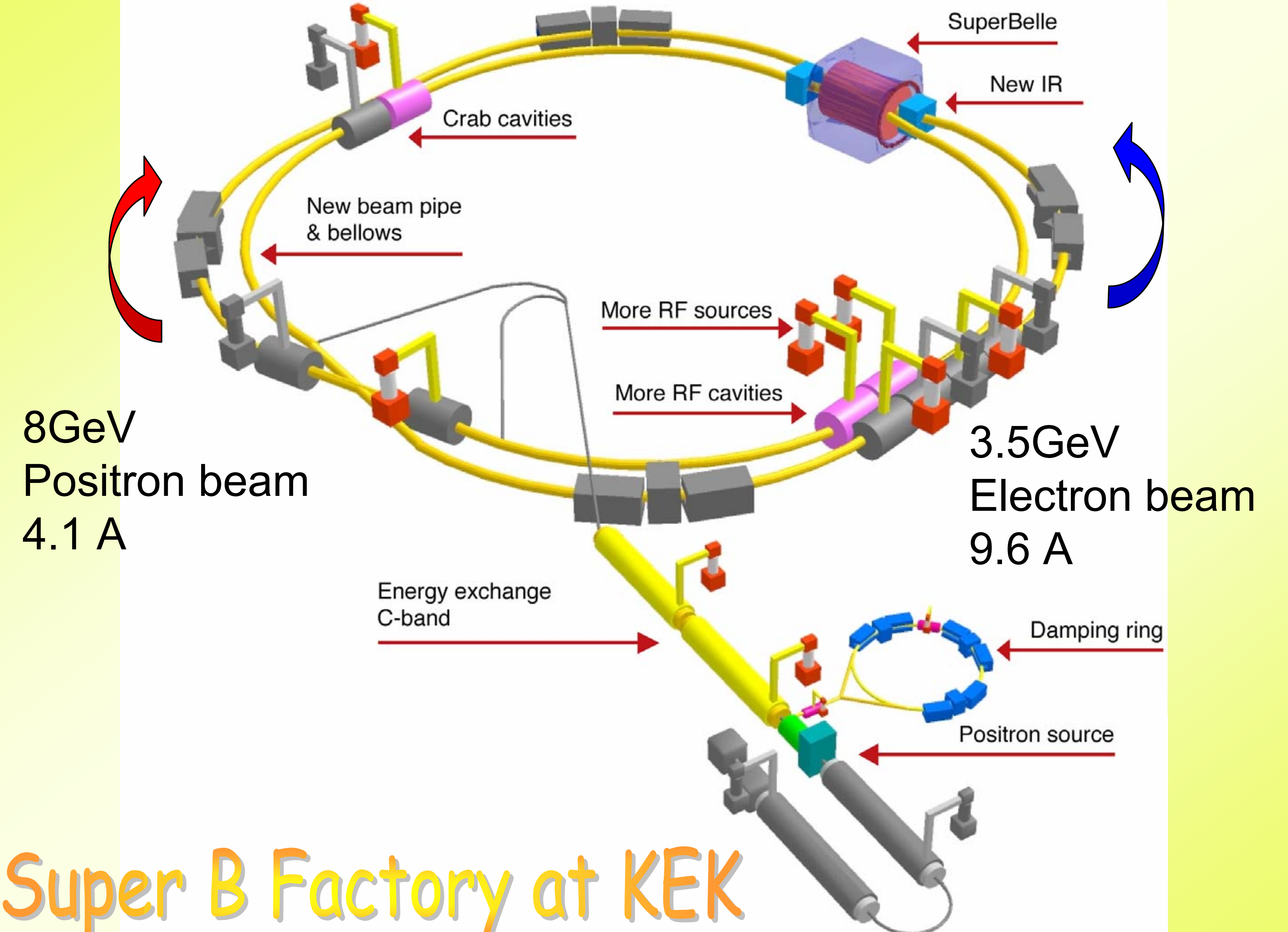
- **1.6 A (LER) / 1.2 A (HER) → 9.6 A (LER) / 4.1 A (HER)**

Smaller β_y^*

- **6 mm→3 mm**

Increase ξ_y

- **0.05→0.14**



Super B Factory at KEK

Machine parameters

Parameters		LER/HER	Unit
Beam energy	E	3.5/8.0	GeV
Beam current	I	**9.4/4.1**	A
Particles/bunch	N	$1.18 \times 10^{11} / 5.13 \times 10^{11}$	
Number of bunches	n_b	5018	
Circumference	C	3016.26	m
Bunch spacing	σ_b	0.6	m
Horizontal β at IP	β_x	200	mm
Vertical β at IP	β_y	3	mm
Bunch length	σ_z	3	mm
Radiation loss	U_0	1.23/3.48	MeV/m
Synchrotron tune	ν_s	0.031/0.019	
Horizontal betatron tune	ν_x	45.506/44.515	
Vertical betatron tune	ν_y	43.545/41.580	

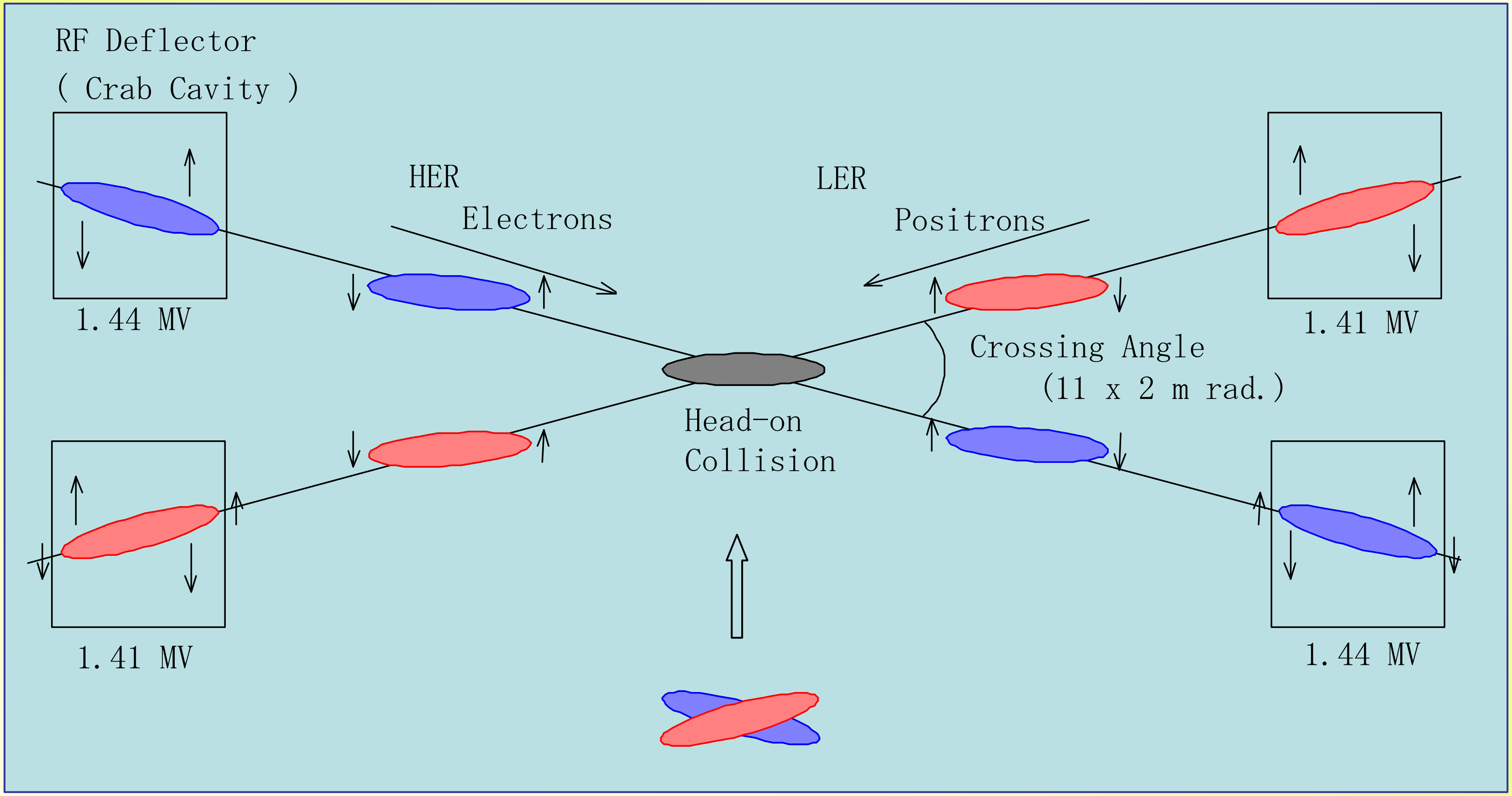
Talk by Ohnishi

Machine parameters

Parameters		*Crab cavities; without/with*				*Unit*
Horizontal emittance	ε_x	30/24				nm
Coupling parameter	κ	6/1				%
Crossing angle	θ_x	30/0				mrad
Luminosity reduction	R_L	0.76/0.86				
ξ_x reduction	$R_{\xi x}$	0.73/0.99				
ξ_y reduction	$R_{\xi y}$	0.94/1.11				
Horizontal beam-beam	ξ_x	0.079/0.137				
Vertical beam-beam	ξ_y	0.051/0.218				
Beam-beam simulation model		S-S	W-S	S-S	W-S	
Vertical beam-beam	ξ_y	0.051		0.14	0.28	
Luminosity	L	1		2.5	5	´10^{35} cm^{-2} s^{-1}

Talk by Ohnishi

Crab crossing scheme



Palmer for LC (1988)
Oide and Yokoya for storage rings :Phys,Rev.A40,315(1989)

Recent simulations by Ohmi showed significant increase of luminosity with crab crossing.

Vacuum System

Beam current increase causes:

Intense Synchrotron Radiation

- 27.8 kW/m in LER, twice as high as in KEKB
- 21.6 kW/m in HER, 4 times as high as in KEKB

→Ante-chamber structure

- Also motivated by need to reduce photo-electron clouds.

Heating due to Higher Order Modes (HOM)

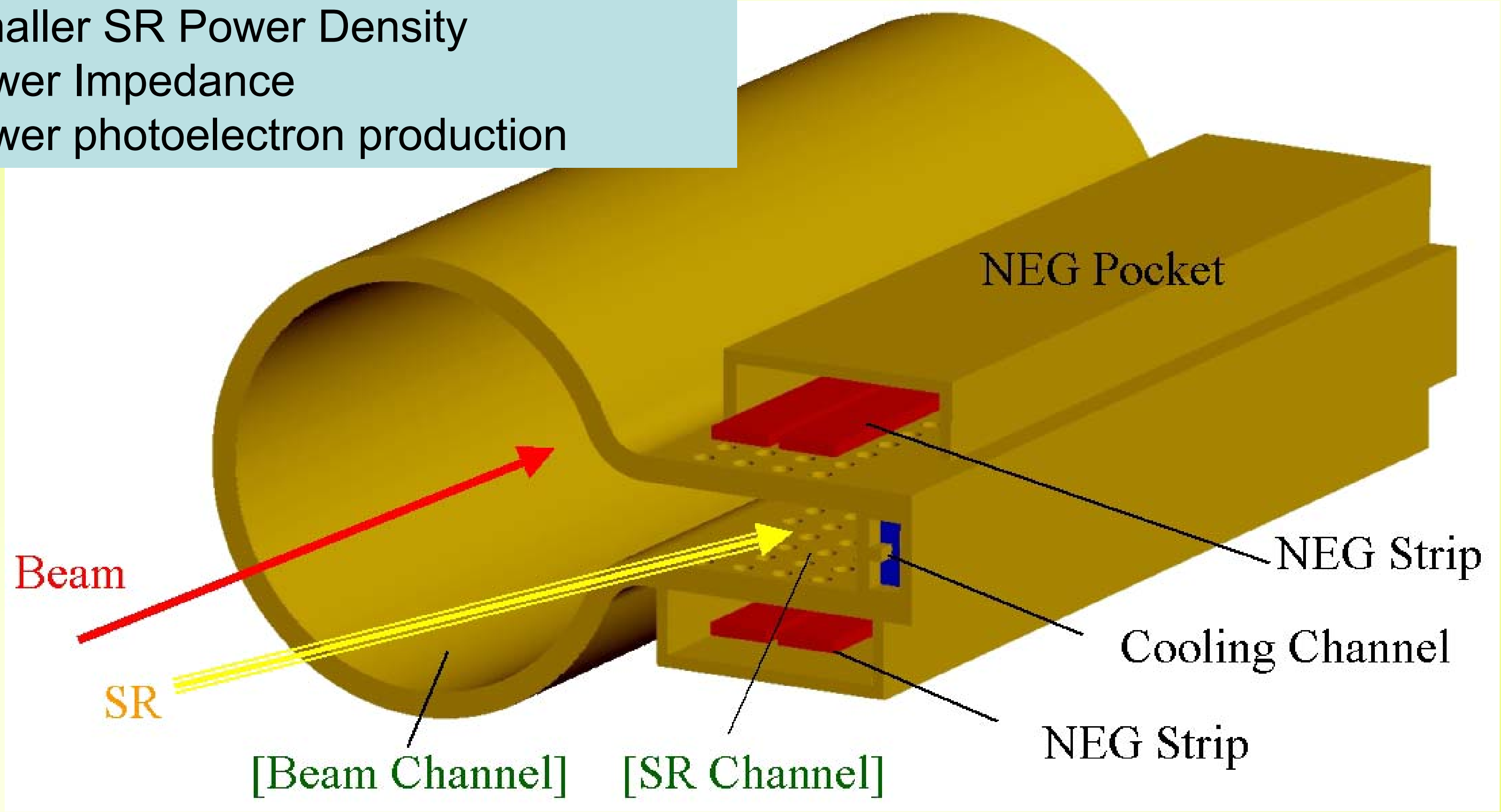
→Design efforts to achieve small loss factor for each vacuum component.

→HOM absorbers near large impedance sources.

Talk by Suetsugu

Vacuum components: Antechamber-type copper duct

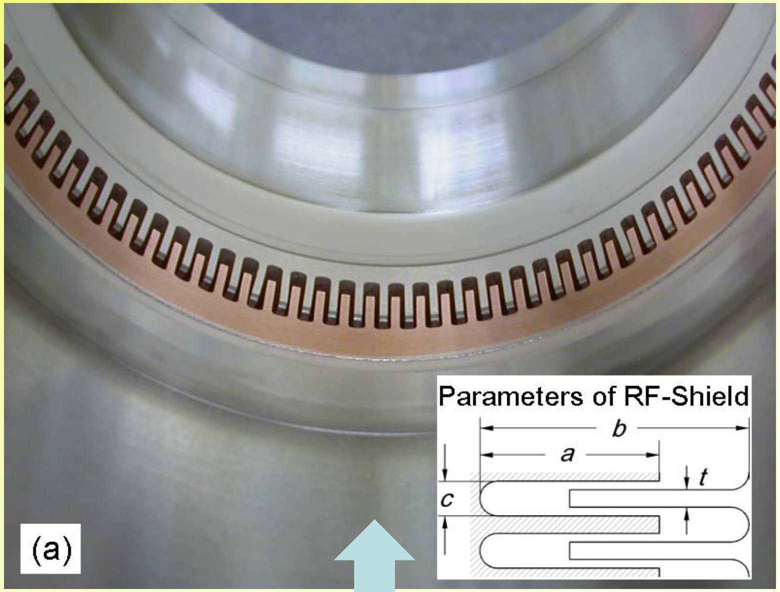
Smaller SR Power Density
Lower Impedance
Lower photoelectron production

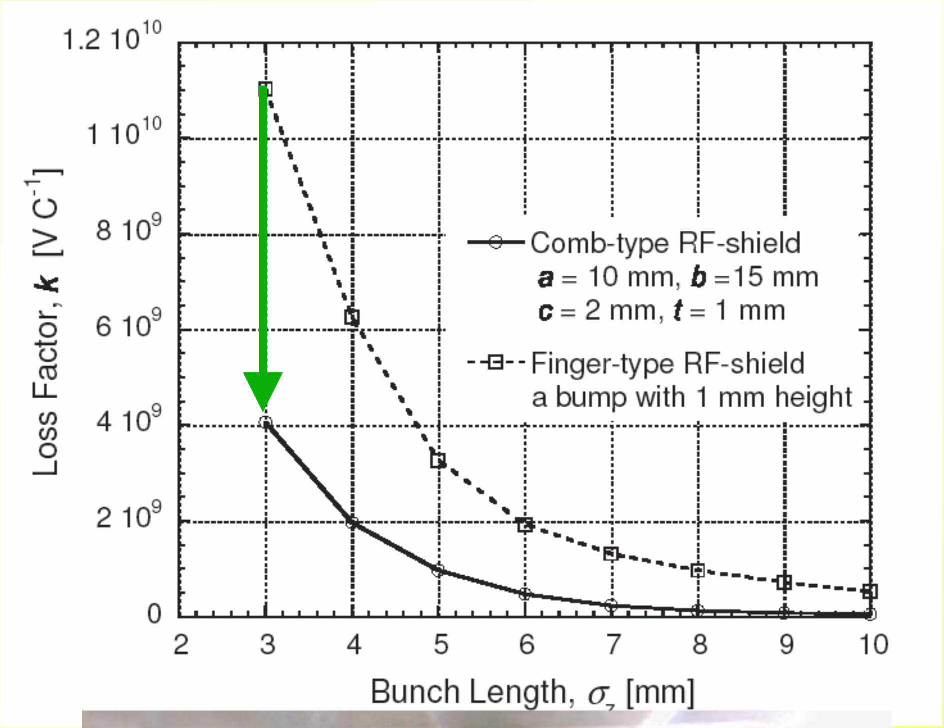


Prototype ducts were installed in the LER (Jan.2004)

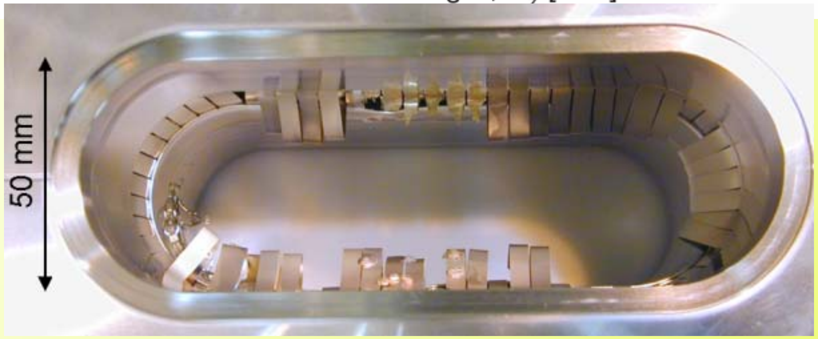
Talk by Suetsugu

Vacuum components: Bellows chamber with comb type RF-shield





- High thermal strength
- Low impedance
- No sliding contact on the surface facing the beam



Comb-type bellows were installed in the LER (2004).

Talk by Suetsugu

RF power Increase

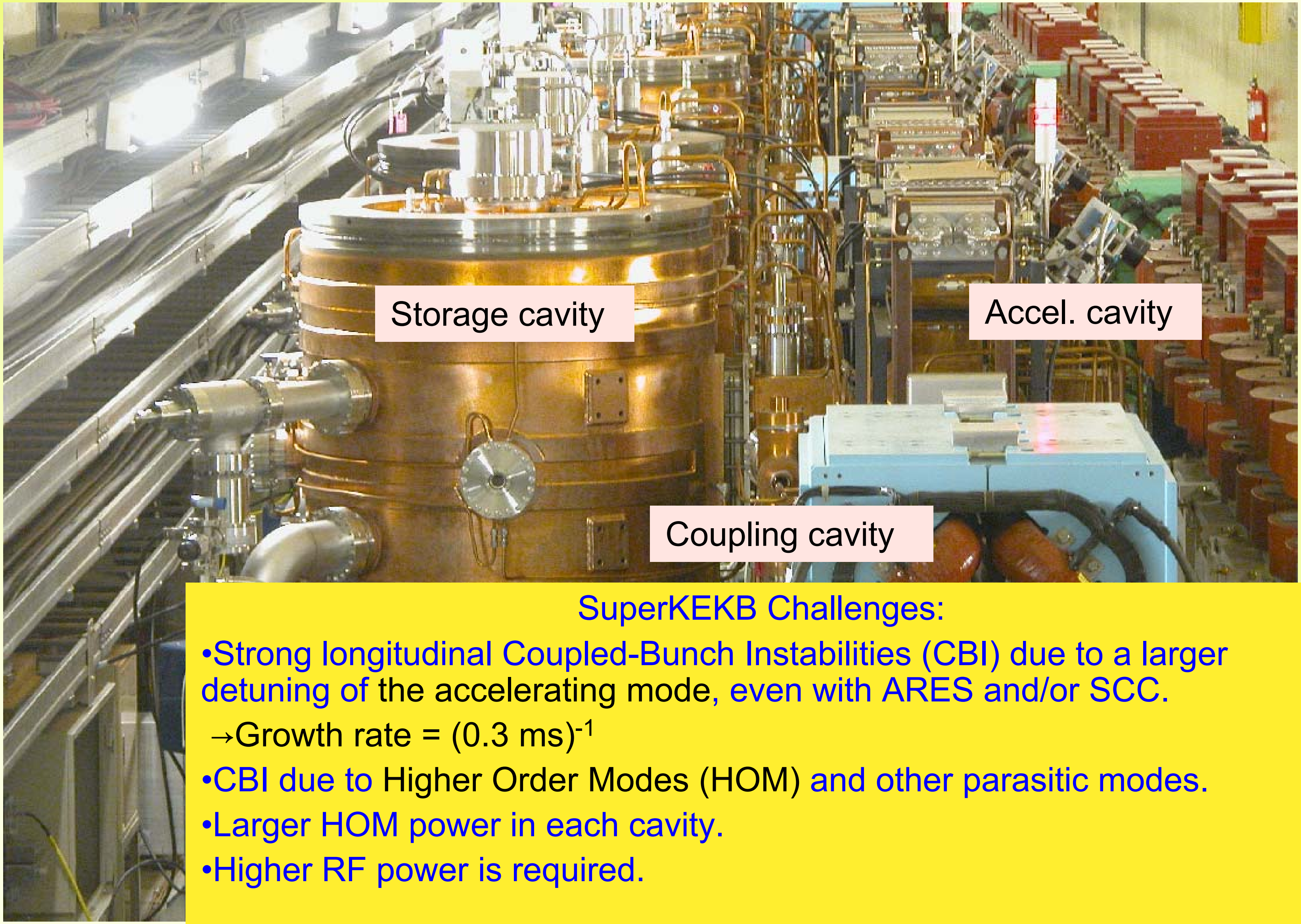
- Required RF power provided to beam is four times as high as those of KEKB.
- The required RF voltage is relatively low.
- The number of cavities should be kept as small as possible to reduce the total impedance in the ring.

↓

- Change to one ARES/klystron configuration.
  - KEKB: two ARES/one klystron
- The input power to each cavity will be nearly doubled.
- The number of klystrons will be more than doubled.

Talk by Ono

ARES (The Accelerator Resonantly coupled with an Energy Storage) Cavity



SuperKEKB Challenges:

•Strong longitudinal Coupled-Bunch Instabilities (CBI) due to a larger detuning of the accelerating mode, even with ARES and/or SCC.

→Growth rate = $(0.3\ \mathrm{ms})^{-1}$

•CBI due to Higher Order Modes (HOM) and other parasitic modes.

•Larger HOM power in each cavity.

•Higher RF power is required.

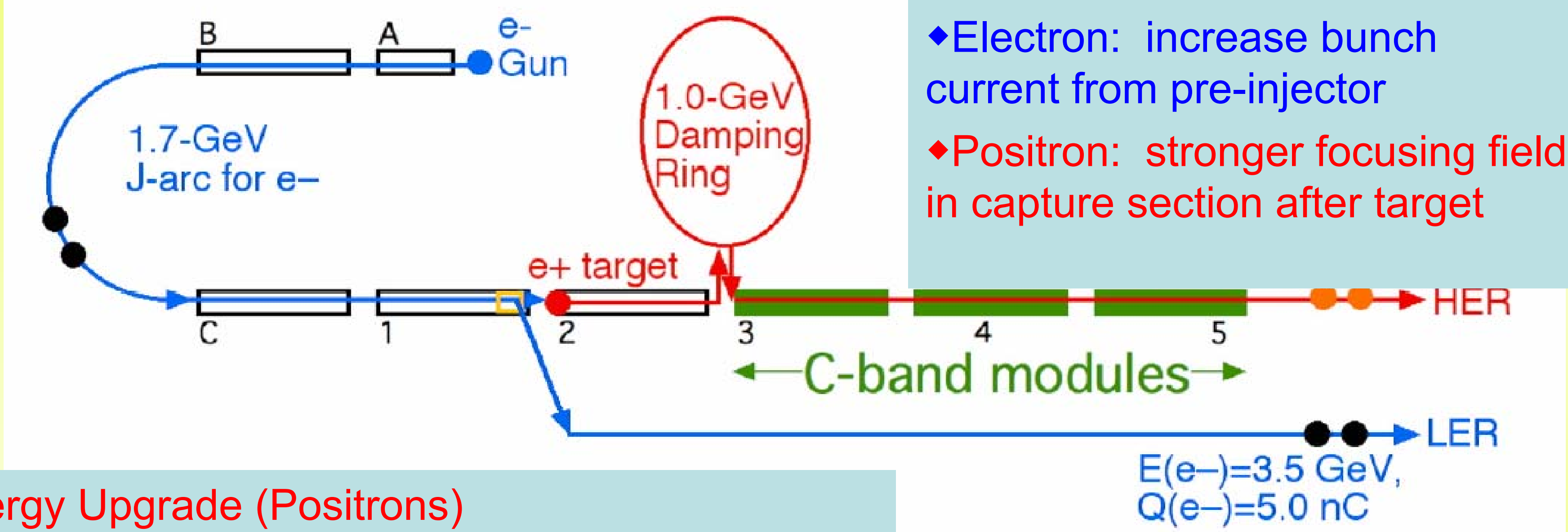
Superconducting Cavity

SuperKEKB challenges:
The expected power load to the HOM absorber is 50 kW/cavity at 4.1 A,
(even) with a larger beam pipe of 220 mmϕ.

HOM damper upgrade may be needed.

Talk by Mitsunobu

Linac Upgrade



Intensity Upgrades

- ◆Electron: increase bunch current from pre-injector
- ◆Positron: stronger focusing field in capture section after target

Energy Upgrade (Positrons)

Replace S-band (2856 MHz) RF system with C-band (5712 MHz) system to double field gradient in downstream section of linac.

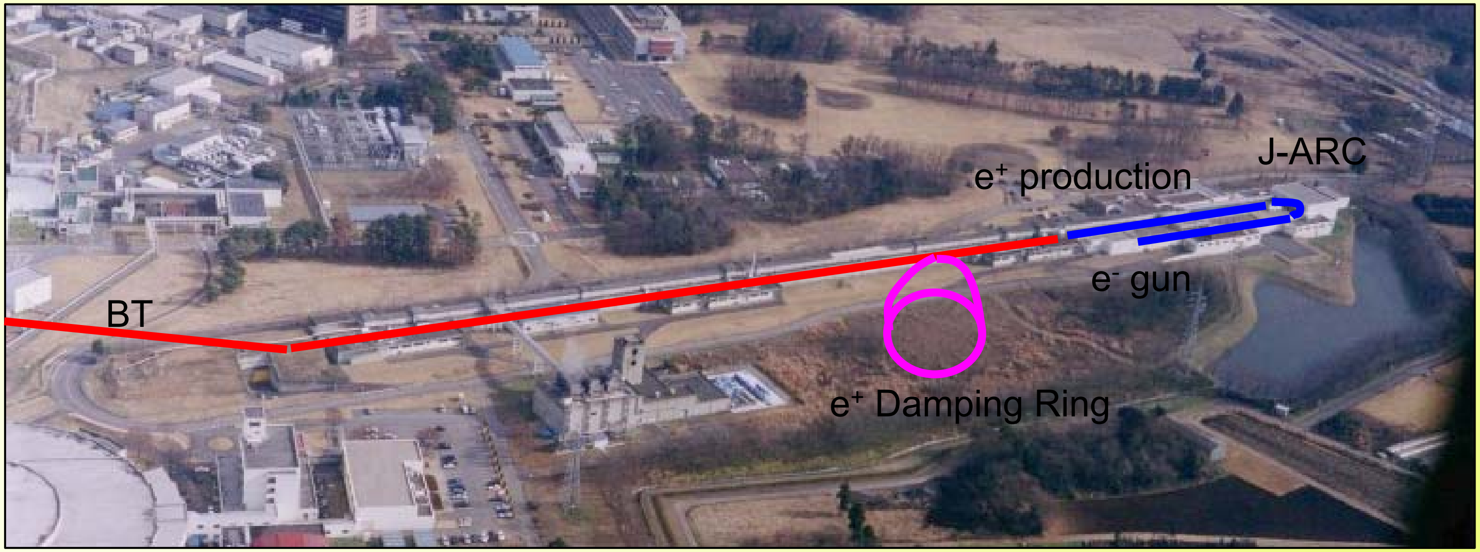
(The present max. energy gain is 4.8 GeV)

Pulse beam kicker installed before positron target for quick switching between beams (50 Hz).

Talks by Michizono, Akemoto, Kamitani, Satoh

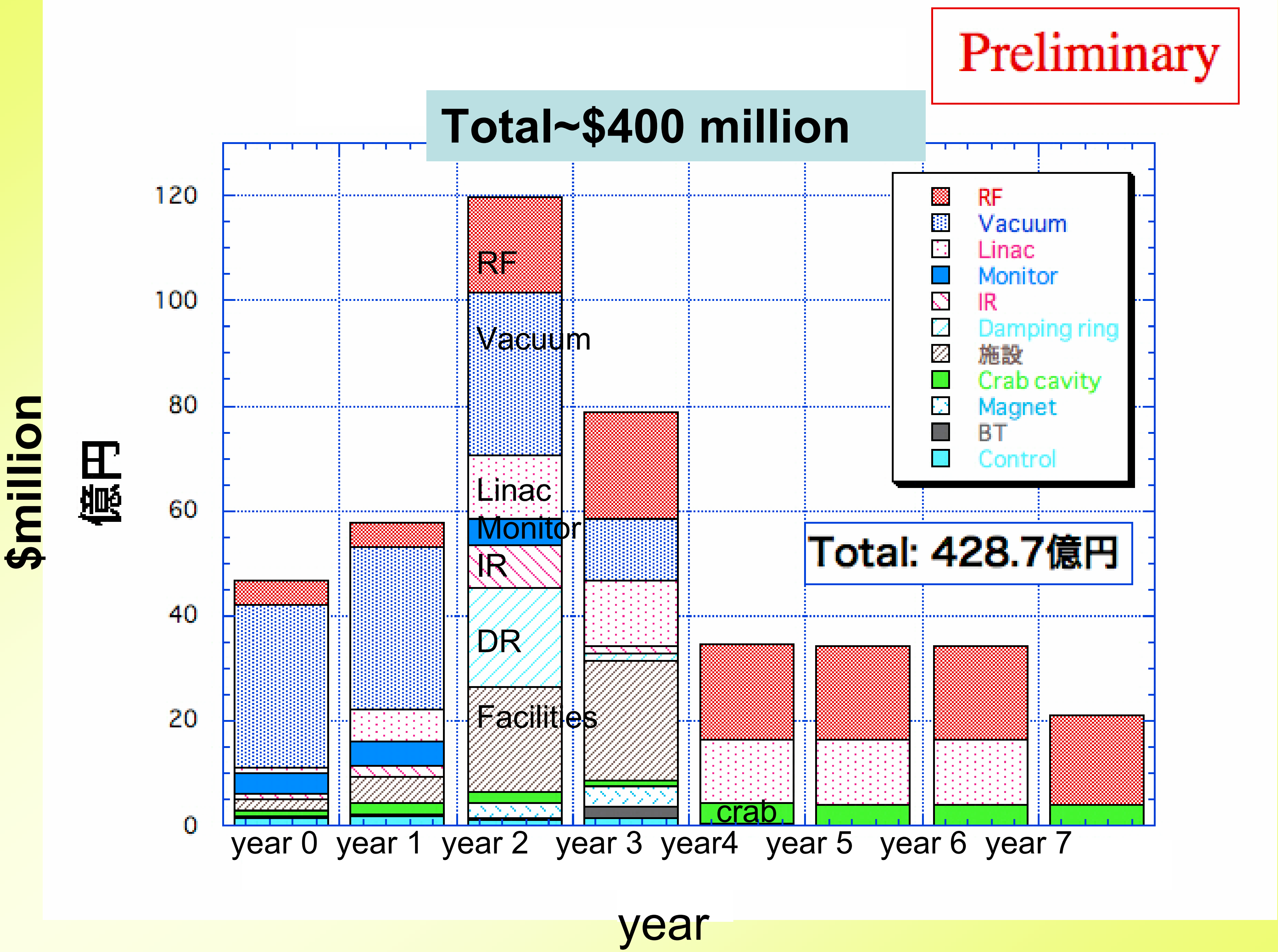
Damping Ring

- Positron emittance needs to be damped, to pass reduced aperture of C-Band section and to meet IR dynamic aperture restrictions.
  - Electron DR may be considered later to reduce injection backgrounds in physics detector, but for now only positron DR considered.
- Damping ring located downstream of positron target, before C-Band accelerating section.



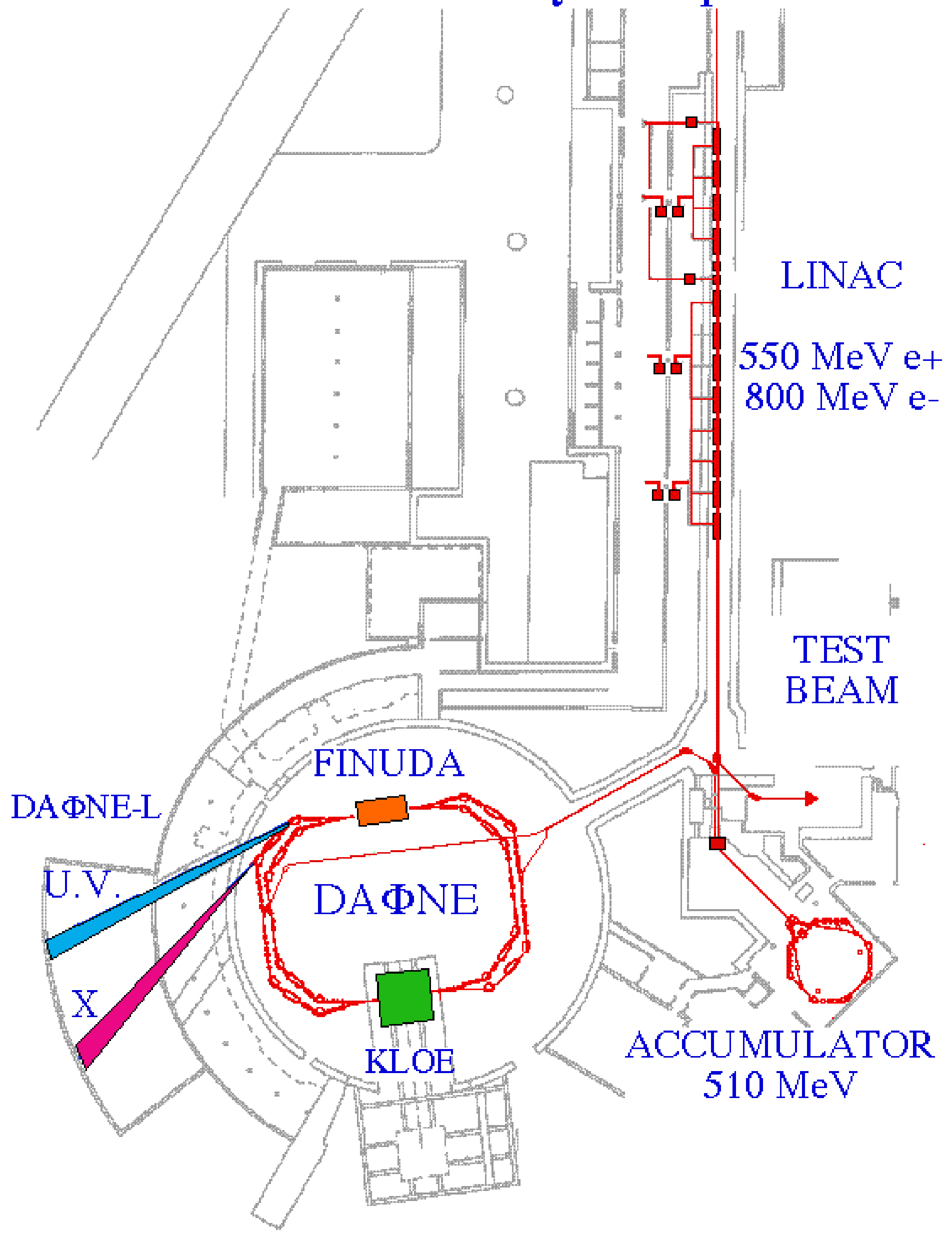
Talk by Kikuchi

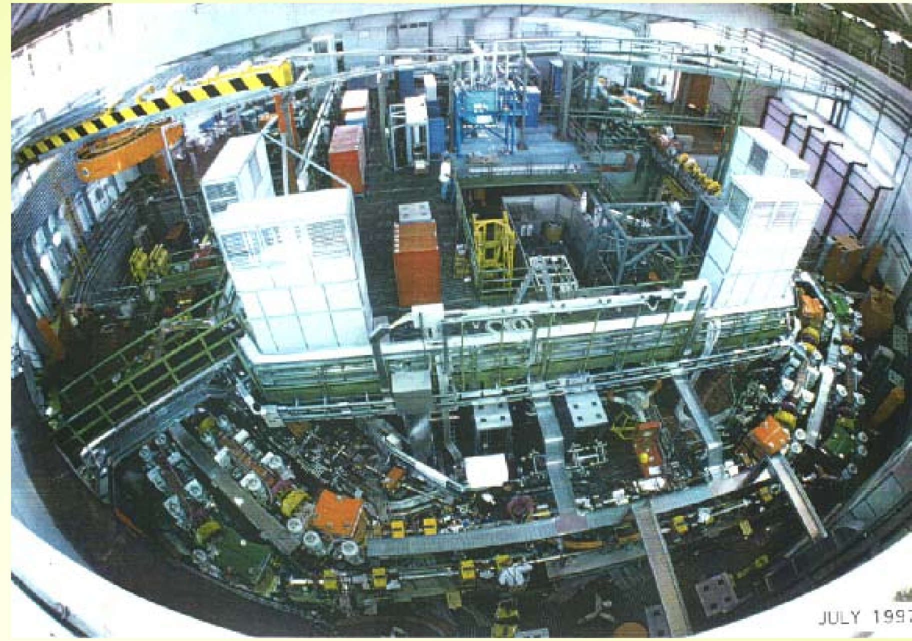
Cost

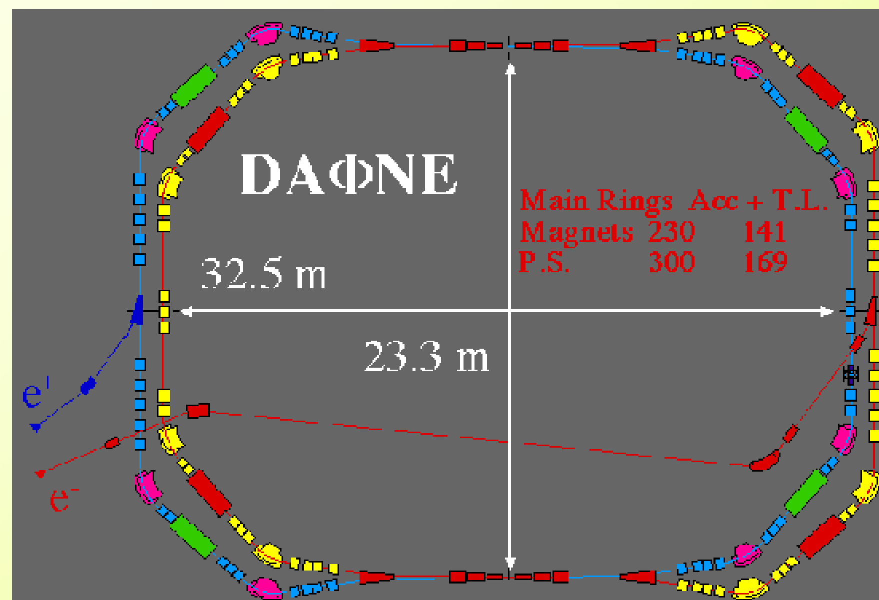


Preliminary
Total~$400 million
Total: 428.7億円
$million
億円
120
100
80
60
40
20
0
RF
Vacuum
Linac
Monitor
IR
DR
Facilities
crab
RF
Vacuum
Linac
Monitor
IR
Damping ring
施設
Crab cavity
Magnet
BT
Control
year 0
year 1
year 2
year 3
year4
year 5
year 6
year 7
year

Frascati Φ–Factory complex







Rough DAΦNE near-future schedule

	2004	2005	2006	2007
KLOE	$>2\ fb^{-1}$ (2004–2005)			
FINUDA			$1\ fb^{-1}$	
SIDDHARTA				$.5\ fb^{-1}$

Possible Future Scenarios

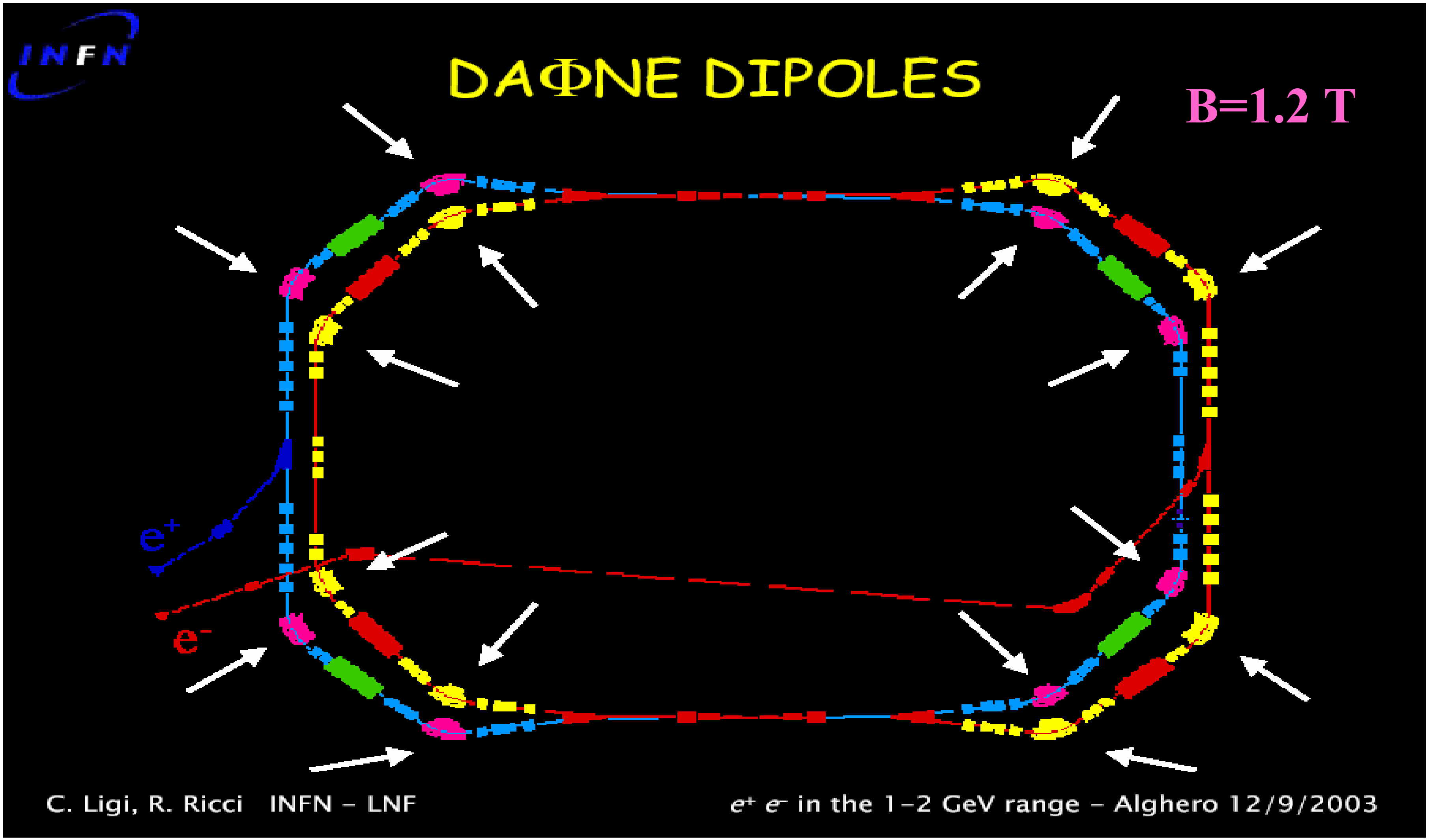
DAFNE2: Minimum change for E upgrade (to 1.1 GeV/beam) – preserve Φ operation

DAΦNE^{UP}: Limited upgrade of the present machine to reach $L > 5 \cdot 10^{32}$ cm^{-2}s^{-1}

SUPERDAΦNE: New Φ-factory for $L > 2 \cdot 10^{33}$ cm^{-2}s^{-1} (optionally 1.1 GeV/beam)

LNF$^{\tau}$: New τ-charm factory for $L > 10^{34}$ cm^{-2}s^{-1} @ 1.9 GeV/beam

Minimum change for E upgrade (to 1.1 GeV/beam) – preserve Phi operation



DAFNE2:
Φ and n-nbar sharing DAFNE

Energy (GeV)	0.51	1.1
Current (A)	1 - 2	1
Luminosity (10^{32})	2	1
N bunches	100	100
I/bunch (mA)	10-20	17
τ damping (msec)	70/40	11/9
Uo (keV)	4.3 / 9.3	64 / 84
τ (h)	<1	> 2

Upgrade of the present machine to reach L = 5-10 · 10^{32} $cm^{-2}s^{-1}$

The upgrade is targeted at a factor 5 luminosity increase at <u>any given current</u>, this means that with the present running conditions DAΦNE^{UP} will deliver a luminosity of about $7*10^{32}$

Basic concepts for the Upgrade

In a tune-shift limited regime the luminosity is almost inversely proportional to both the machine radiation damping time and bunch lenght.

A general strategy to increase the luminosity is to reduce as much as possible the value of these two parameters.

The specific luminosity can be increased by a factor 5 by:

1) reducing the the damping time by a factor > 2

2) reducing the bunch lenght by a factor > 2.5

In order to fully benefict the bunch length reduction, β_y at the IP has to be reduced by the same factor and there will be headroom to decrease β_x as well.

Upgrades Plan

Damping time can be reduced by a factor > 2:

- **decreasing the gap of the DAΦNE wigglers (from 41mm to < 20mm), thus increasing the gap field from 1.7 T up to 2.0 T.**
- **adding wigglers (2 pairs, two meters each) in the second IR region (a superconduting solution could be explored as well)**

Upgrade Plan

Bunch length can be reduced by a factor > 2.5 replacing:

- **all the vacuum chambers (also necessary to decrease the wigglers-gap)**
- **the tapers (now 25% of the total ring impedance)**
- **all the Ion Clearing Electrodes (now responsible for about a 40% bunch lenghtening for e-)**
- **all the bellows (10% of the ring impedance)**
- **the injection and feedback kickers (now 30% of the ring impedance)**
- **the scrapers (10% of the ring impedance)**
- **the feedbacks cavities (15% of the ring impedance)**

The new elements will be redisegned to be "very-low-impedance", the target impedance should be between 2 and 3 times smaller than the present one.

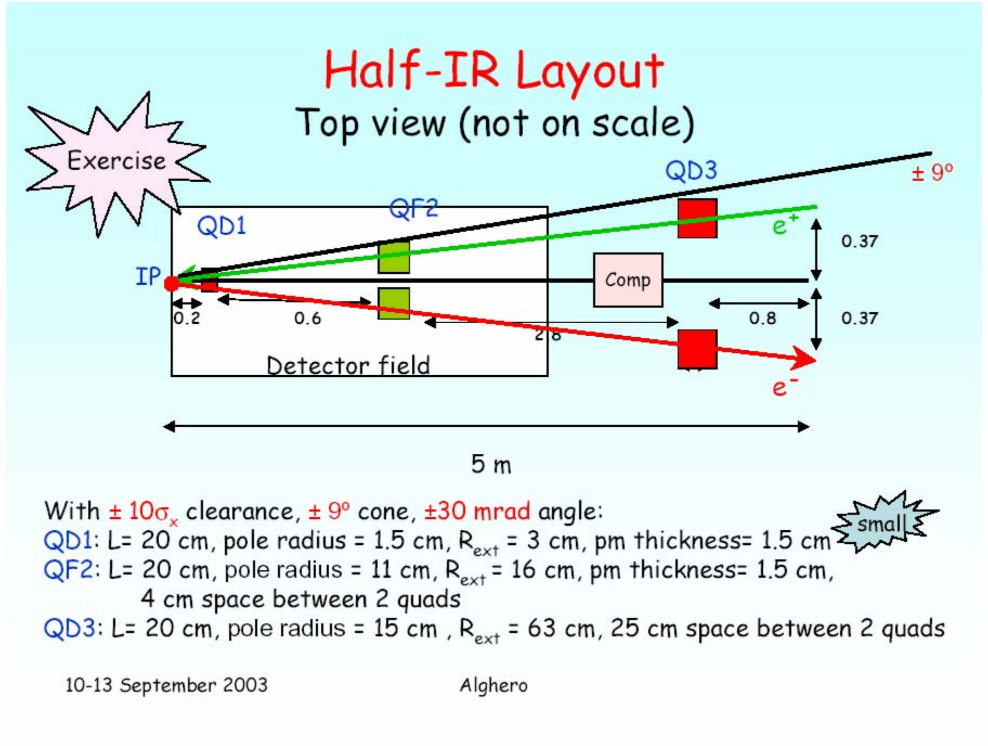
The positron chamber will also have an antichamber to minimize the Electron Cloud that seems a good candidate to explain the present strong horizontal instability and peak current limit for positrons.

Lower impedance will also benefit the beam stability in general.

IR Upgrade

The IR optics, aimed at smaller β_y will be rebuilt with:

- **smaller L*** (= distance between IP and 1st quadrupole)
- **stronger quadrupoles** (PM quads should suffice, although we could explore a SC solution as well)
- optimized geometry to increase the beam separation
- optimized mechanics for the rotation needed for the coupling compensation



Strategy and Logistic for DAΦNE^{UP}

Minimize the down time after the end of the scheduled physics runs and the restart of the operations;

Minimize the recommissioning time;

Minimize the risks of failure;

Minimize the cost;

Optimize just ONE-IR-AND-ONE-ENERGY solution.

DAΦNE^{UP}: Upgrade for the energy up to 2.2GeV/CM or the luminosity > 5 10^{32} @ Φ

	K Physics	Hyper-nuclei	Exotic atoms	
2004 2007	1.5 10^{32} >2 fb^{-1}	10^{32} 1 fb^{-1}	10^{32} 0.5 fb^{-1}	
2008	SHUTDOWN			
2009 2013	> 5 10^{32} > 25 fb^{-1}	> 5 10^{32} 5 fb^{-1}	> 5 10^{32} ???	
	KLOE	FINUDA	SIDDHARTA	
Cost (M€)				20 Accel.

Basic concepts for a brand new Φ-Factory aimed at $L>4*10^{33}$

The general strategy to increase the luminosity in the next generation factories is based on the alredy mentioned concepts:

- reducing the bunch lenght to the (few) mm scale;
- increasing the radiation damping (especially needed in low-Energy collider as a F-Factory);
- increasing the colliding currents (to ≈3 A and beyond);
- increasing the beam-beam limits by improving the machine tuning and/or implementing compensation schemes (such as crab crossing in collider with crossing angle)

The strategy is the same of that illustrated for the luminosity upgrade case, but the design can be much more aggressive on the critical parameters in a brand-new machine.

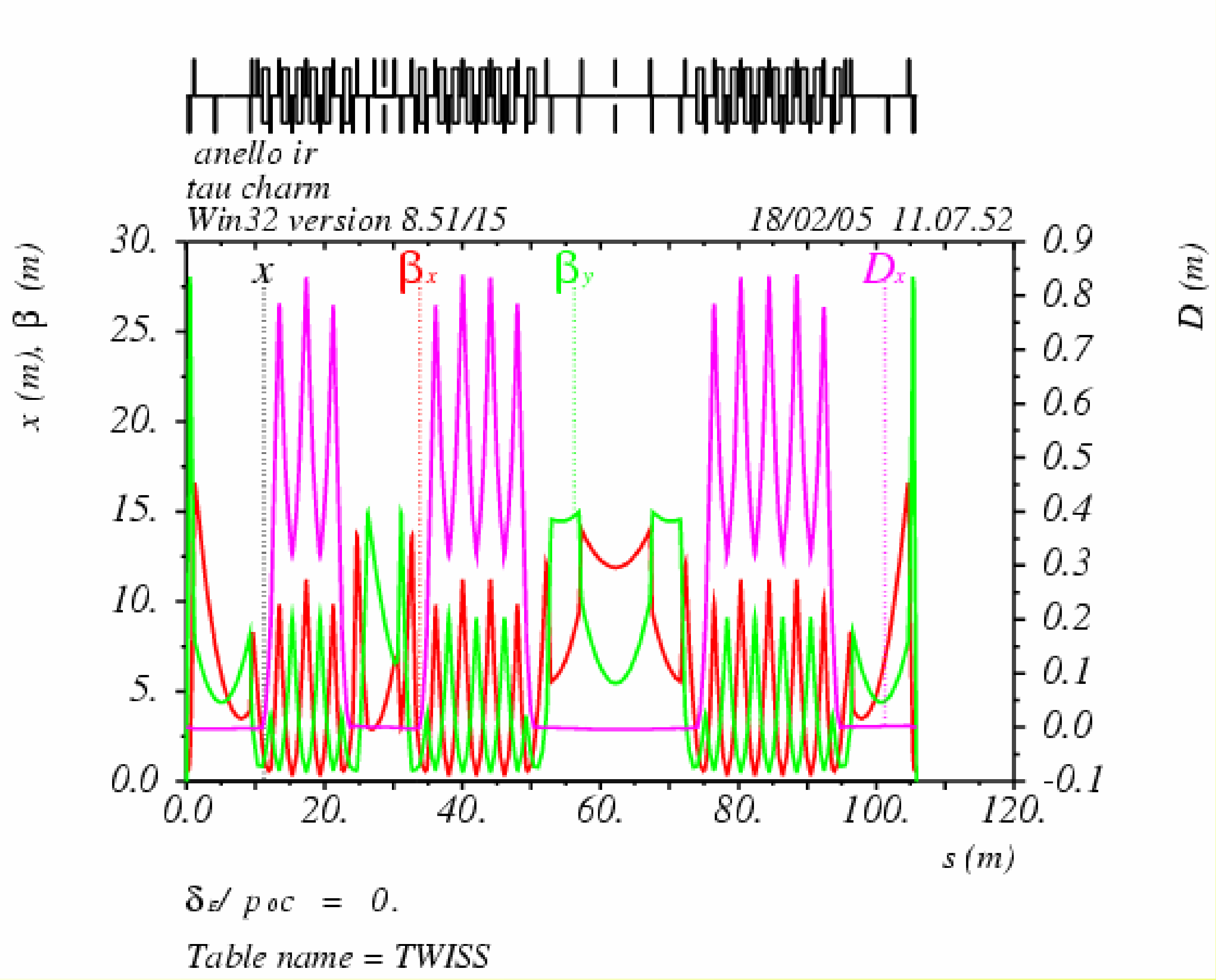
SUPERDAΦNE preliminary parameters

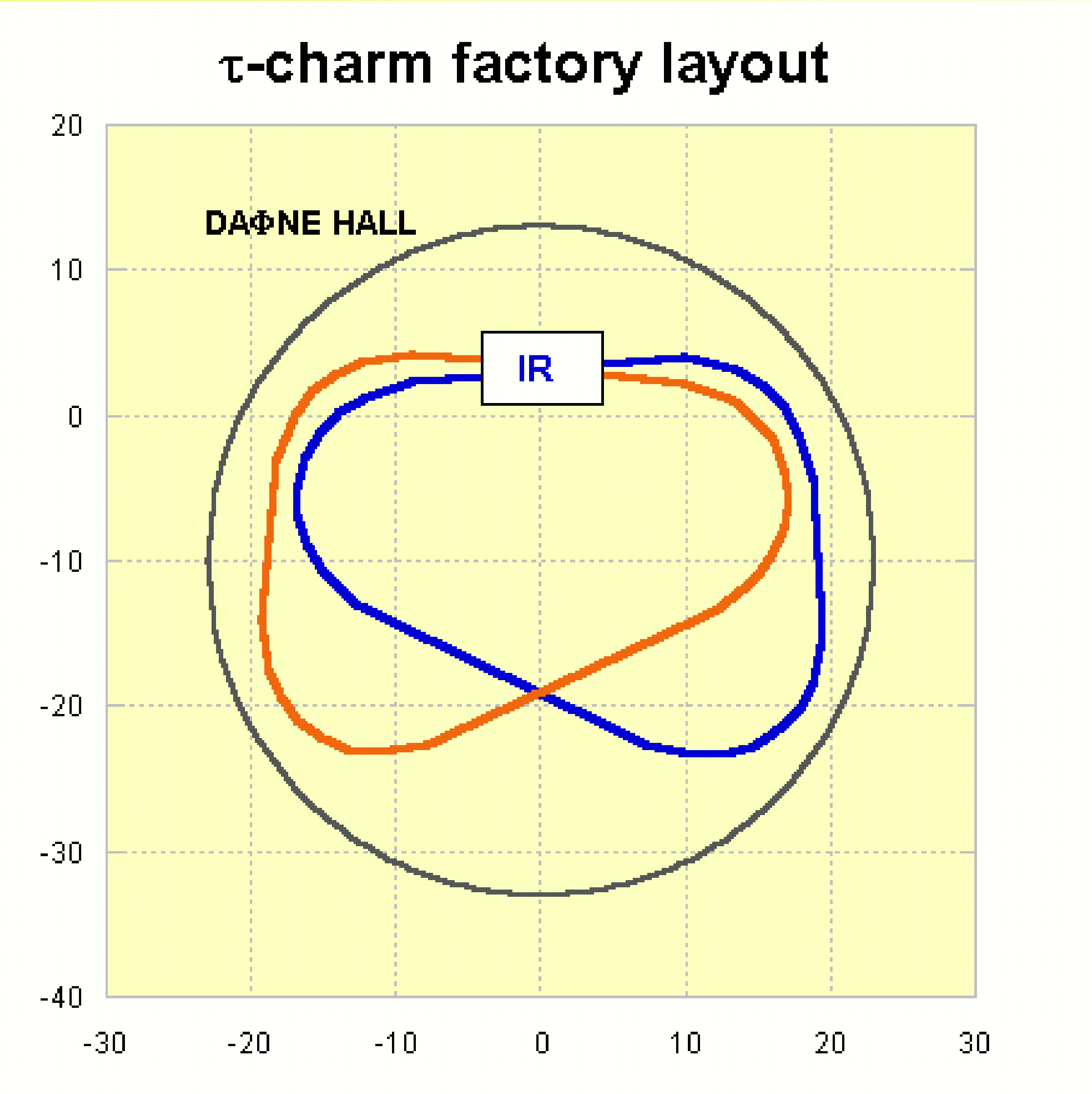
Energy	0.5 GeV	B_{dip} – B_{wig}	1.7 - 4 T
C	100 m	Uo	25 keV
L	2 – 7 10^{33}	V_{RF}	2.7 MV
f_{RF}	500 MHz	V_{3RF}	0÷2 MV
ε_x	3. 10^{-7}	α_c	-0.04 ÷ 0.04
β_x β_y	0.5 m 4 - 2 mm	σ_E/E	5 10^{-4}
κ	0.005 – 0.003	P_{rad}	50 kW
N_{bun}	150	σ_L	2 ÷ 4 mm
$N^{\pm}$/bunch	2.5 10^{10} - 3.5 10^{10} (13 – 18 mA)	I_{th} (@Z/n=0.5Ω)	6.5 mA
ξ_x ξ_y	0.04 0.056 0.05 0.066	I_{tot}	1.9 - 2.7 A

TauCharm factory at LNF: Preliminary parameters

Energy	1.89 GeV	B	1.8 T
C	105 m	Uo	328 keV
L	10^{34} $cm^{-2}s^{-1}$	V_{RF}	2 MV
f_{RF}	500 MHz	V_{3RF}	2 MV
ε_x	1.5 10^{-7} μm	α_c	0.022
β_x β_y	0.5 m - 5 mm	σ_E/E	8.7 10^{-4}
κ	0.003	P_{rad}	900 kW
N_{bun}	160	σ_L	6 mm
$N^{\pm}$/bunch	3.5 10^{10}	I_{th} (@Z/n=0.5Ω)	25 mA
ξ_x ξ_y	0.03 - 0.05	I_{tot}	2.7 A

Lattice of a τ-charm factory fitting the existing DAΦNE building





Time:

Similar to Super-Dafne

Costs

(Order of Magnitude):

100 M€ (Same for SuperDafne)

(new injection system also included)

SUPERDAΦNE: new Φ-Factory for $L > 4\ 10^{33}$ or Tau-Charm Factory

	K Physics	Hyper-nuclei	Exotic atoms	1 ÷ 2.2 GeV physics
2004 2007	$1.5\ 10^{32}$ $>2\ fb^{-1}$	10^{32} $1\ fb^{-1}$	10^{32} $0.5\ fb^{-1}$	
2008	??????			
2009 2010	**SHUTDOWN**			
2011 2015	$>2\ 10^{33}$ $>40\ fb^{-1}$	$>2\ 10^{33}$ $>15\ fb^{-1}$	$>2\ 10^{33}$???	$2\ 10^{32}$ $1\ fb^{-1}$
	KLOE	FINUDA	SIDDHARTA	N-Nbar
Cost (M€)	40 (Accelerator)			+20 (Linac & Dipoles)