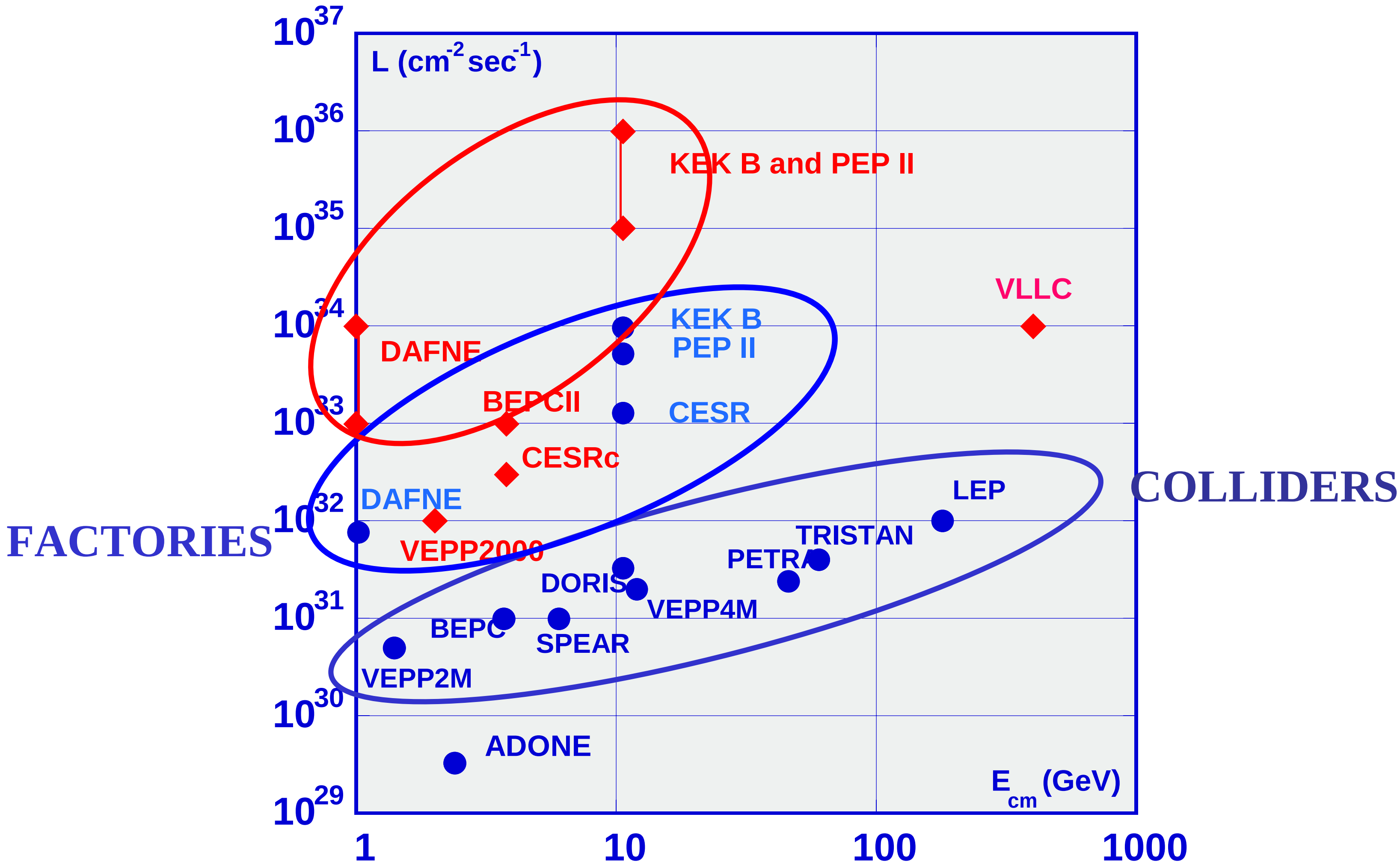
Session:High Luminosity Issues

Part I: Beam-Beam Interaction

Chairpersons: F. Ruggiero, M. Zobov

- Upgrade of Particle Factories — C. Biscari, INFN-LNF
- Negative Momentum Compaction at DAΦNE — M. Zobov, INFN-LNF
- Negative Momentum Compaction at KEKB — H. Ikeda, KEK
- Beam-Beam with Large Crossing Angle — P. Raimondi, LNF-INFN
- Short Bunch at IP — A. Gallo, LNF-INFN
- Study of Beam-Beam Interaction at VEPP-4:
  Tune Plane Appearence and
  Cubic Non-linearity Effect — A. Temnykh, CESR

PAST, PRESENT AND FUTURE



C. BISCARI

Basic concepts:

Luminosity is generally higher for high energy rings for several reasons, some of the more beneficial are:

1) Tune shifts scales with 1/Energy (E) leading to a fundamental linear increase of the luminosity vs Energy

2) Radiation damping-time decrease with $1/E^3$ leading to higher limits for tune-shifts

3) Touschek effect decrease with $1/E^3$

4) Natural bunch lenght shorter

5) Beam stiffer, single and multi bunch instabilities decrease with 1/E

P. RAIMONDI

Beam-beam scalings and constraints

$$L \cong f_{coll} \frac{N^2}{4\pi \cdot \sqrt{\varepsilon_x \varepsilon_y \beta_x \beta_y}} \cdot H \cdot F$$

f_{coll} Bunch collision frequency → fill all buckets, increase RF-frequency

$H \approx 1$ Hourglass factor for $\beta_x, \beta_y \geq \sigma_z$ → Reduce σ_z { $\alpha_c<0$, Strong RF

$F \approx 1$ Crossing angle factor for $\theta_c \sigma_z << \sigma^2$ → Reduce θ_c, Crab-crossing

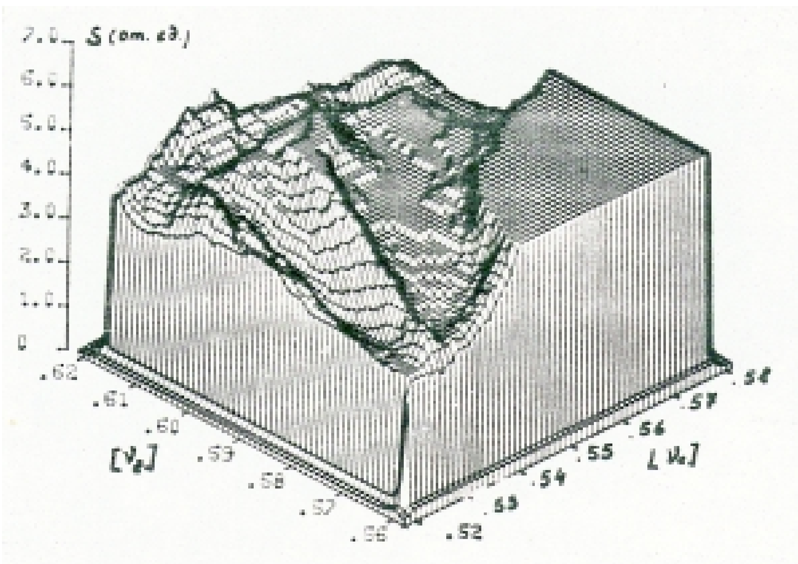
$\Delta Q \propto \frac{N}{\varepsilon} \frac{F}{E}$ Linear beam-beam tune shift → Maximize ΔQ

BB limit: $\Delta Q < \Delta Q_{\max} = g\left(\left(\frac{\tau_{rev}}{\tau_{damp}}\right)^{1/3}, Q, J_z\right)$ → Increase damping, Optimize Q_x, Q_y, Round beams

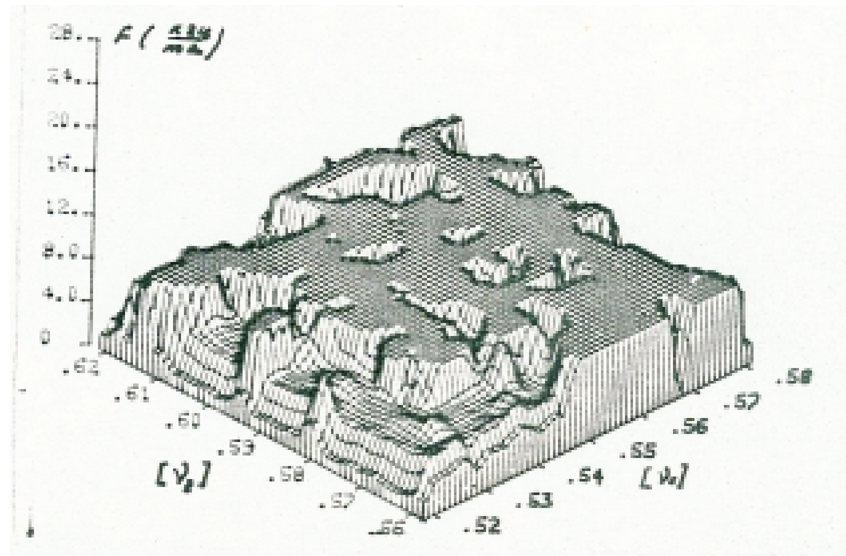
Parasitic BB collisions: $d_{sep} \geq 10\sigma$ → Increase θ_c

Tune plane appearance: beam-beam interaction

Vertical beam size from luminosity (r.u.)



Particle loss rate from positron beam



I+ ~ 6.2mA, I- ~ 10.2mA

$\xi x = 0.015$, $\xi y = 0.060$

A. TEMNYKH, TUNE SCANS AT VEPP-4

Upgrade of Particle Factories

	E_{cm} (GeV)	L_{now}	L_{future}
KEK-B	**10.6**	**1.06 10^{34}**	***10^{36}***
PEP-II	**10.6**	**6.6 10^{33}**	***10^{36}***
CESR	**3-10.6**	**1.3 10^{33}**	***0.15-1.3 10^{33}***
BEPC	**2 – 5.6**	**10^{31}**	***10^{33}***
VEPP2000	**1 - 2**	**_**	***10^{32}***
DAFNE2	***2***	**_**	***10^{32}***
DAΦNE	**1**	**7.8 10^{31}**	***>10^{33}***

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super B factories

	KEK-B		PEP II		
	Super	Hyper	next	Super	Hyper
E + (GeV)	3.5	3.5	3.1	3.5	3.5
E - (GeV)	8.0	8.0	9.0	8.0	8.0
C (m)	3016	3016	2199	2199	2199
L (10^{34} $cm^{-2}s^{-1}$)	10	40-100	2.5 - 4	20	100
β* (m) (h)	30	15	0.5	0.3	0.15
β* (m) (v)	0.003	0.003	0.0065	0.0037	0.0015
ε (n rad) (h)	33	33	44	44	44
ε (n rad) (v)	2	0.33	0.44	0.44	0.44
θ (mrad)	15	0	0 - 4	10	15
ξ (h)	0.068	0.1	0.08	0.10	0.10
ξ (v)	0.05	0.2	0.08	0.10	0.10
N bunches	5018	5018	1700	3400	7000
I+ (A)	9.4	17.2	4.5	11.0	10.3
I - (A)	4.1	7.8	2.0	4.8	2.35
f_{RF} (MHz)	509	509	476	476	952

10^{36} PEP II

Increase n of bunches x 2 : 7000

f_{rf} x2 : 950 MHZ

feedback upgrade (<1 nsec)

lowering β_y nearer quads iP

decrease N+ N-

increase $\theta \sim 15$ mrad

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Light Quark Factories

Collider	VEPP2000	DAFNE 2
status	in construction	design study
E (GeV)	1.	1.
C (m)	24	97
L (10^{32} $cm^{-2}s^{-1}$)	1	1
IPs	2	1
β* (m) (h / v)	0.1 / 0.1	1.5 / 0.025
ε (μ rad) (h / v)	0.136 / 0.136	0.5 / 0.0025
θ (mrad)	0	± 15
ϕ (rad)	0	0.26
σ_z (cm)	3	1.1
N_b (10^{10})	10	3
ξ (h / v)	0.1 / 0.1	0.014 / 0.024
N bunches	1	30
I (A)	0.20	0.45
f_{RF} (MHz)	172	368.3
V (MV)	0.12	0.25

DAΦNE with Luminosity 10^{34}

set of consistent parameters

new → $\alpha_c = -0.23$

$N^{+,-} = 5\ 10^{10}$

$\beta_x = 0.5\,m$

$\beta_y = 4\,mm$

$\varepsilon_x = 0.26\,\mu\,rad$

$\kappa = 0.6\%$

$n_b = 150$

$I_b = 24\,mA$

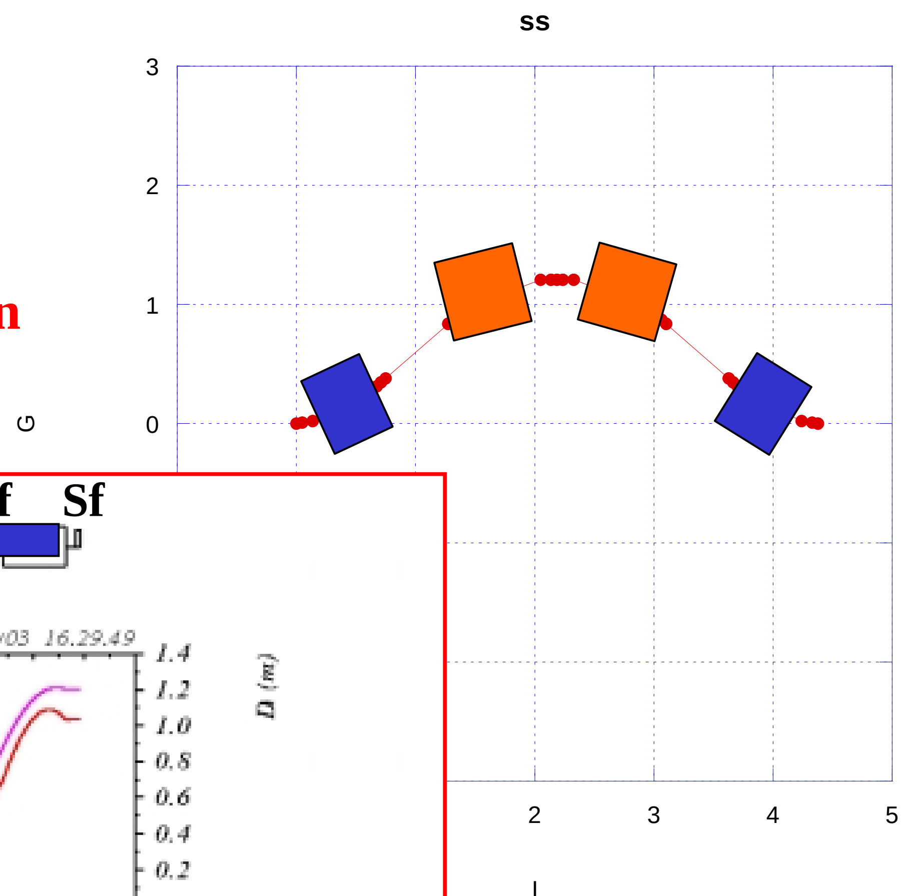
$I_{tot} = 3.7\,A$

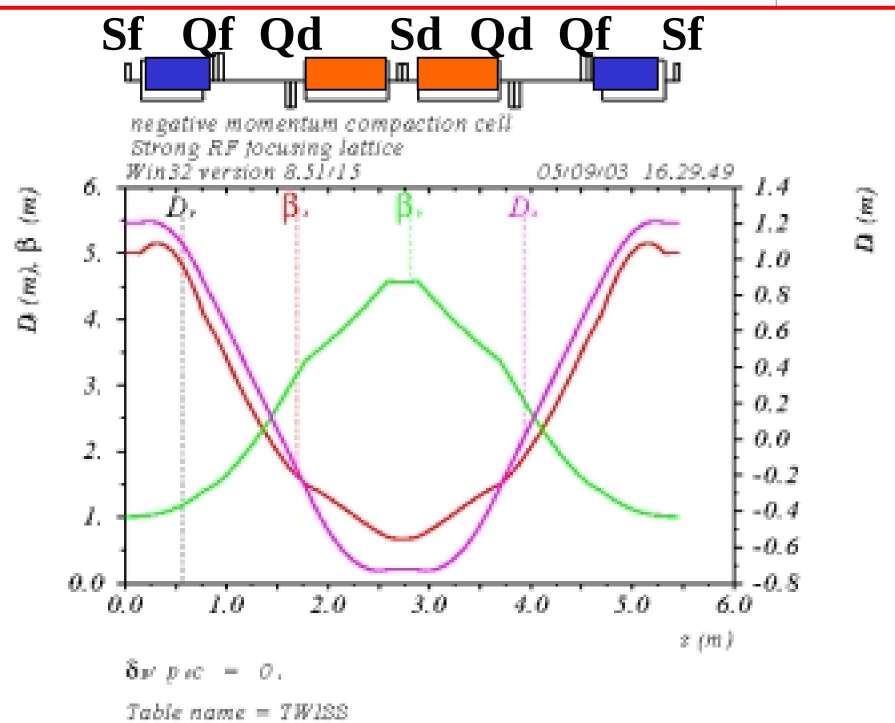
challenges → $\beta_y = 4\,mm$, $I_{tot} = 3.7\,A$

C. BISCARI

HIGH and NEGATIVE MOMENTUM COMPACTION

strong RADIATION emission





Alternating positive and negative bending dipoles

(proposed by Raimondi)

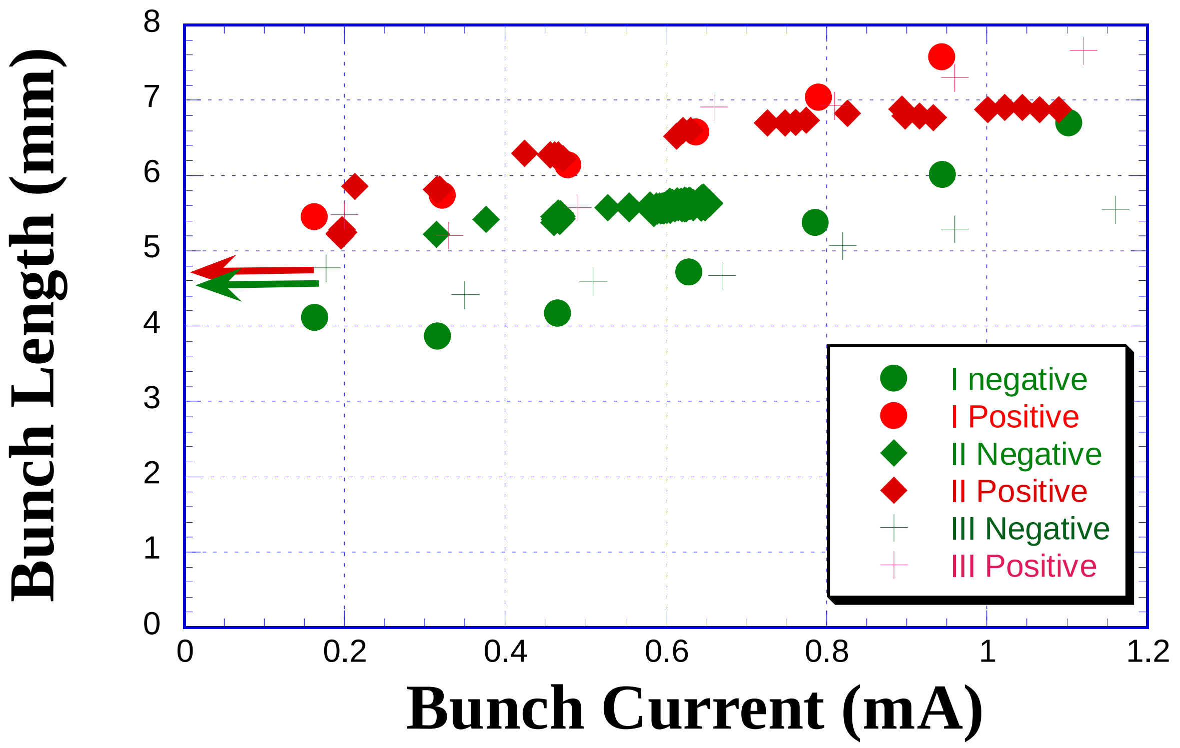
Beam Dynamics with $\alpha_c < 0$

The DAΦNE lattice is flexible enough to provide collider operation with a negative momentum compaction (P. Raimondi). There can be several advantages for beam dynamics and luminosity performance in this case:

- Bunch is shorter with a more regular shape
- Longitudinal beam-beam effects are less dangerous
- Microwave instability threshold is higher (?)
- Sextupoles are not necessary

M. ZOBOV

Negative alfa tests at KEKB



Ikeda, KEKb

Strong RF Focusing ⇨ variable σ_z

A Possible Working Point for a Φ-Factory (E_{ring}=0.51 GeV) with σ_z(IP)=2 mm:

Reference Expressions:

$$\sigma_z(IP) = \alpha_c L \left(\frac{\sigma_E}{E}\bigg|_0 \right) K[\rho(s), \beta_l(s)]$$

with

$$K[\rho(s), \beta_l(s)] = \sqrt{\frac{2+\cos\mu}{6(1-\cos\mu)}}$$

if ***ρ(s)=kost***. and ***R_{56}(s)*** grows linearly in the arcs.

$$\sigma_z(IP) = \sigma_z(RF)\sqrt{\frac{1+\cos\mu}{2}}$$

$$\sigma_z(IP) = 2\,mm;\ \sigma_z(RF) = 10\,mm \ \Rightarrow \mu = 155°$$

$$K[\rho(s), \beta_l(s)] = 0.27 \qquad \frac{\sigma_E}{E}\bigg|_0 = 4.5\cdot 10^{-4};$$

$$L = 100\,m; \qquad \alpha_c = 0.16; \qquad f_{RF} = 500\,MHz;$$

$$V_{RF}(\mu = 180°) = 12.2\,MV;$$

$$V_{RF}(\mu = 155°) = 11.6\,MV;$$

$$\frac{\sigma_E}{E}(\mu = 155°) = 1.1\cdot 10^{-3};$$

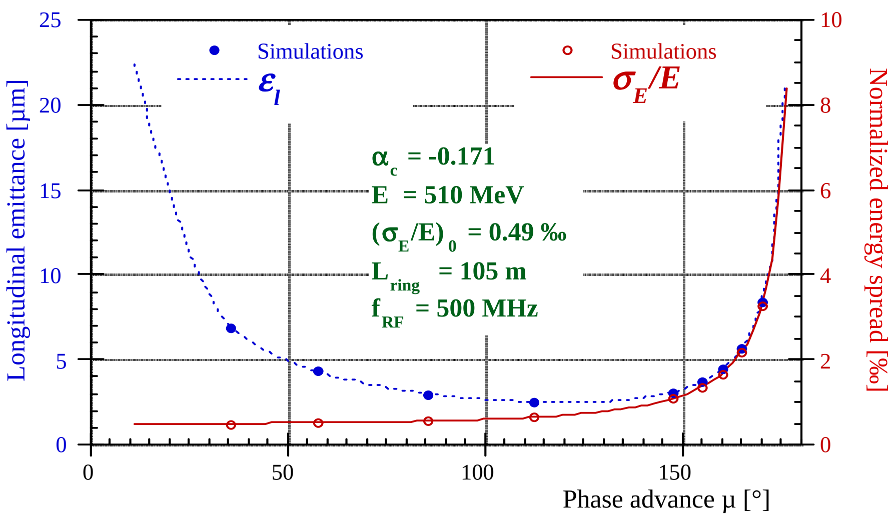
$$\frac{\Delta E}{E}\bigg|_{\max} @\ RF = 4.5\cdot 10^{-3};$$

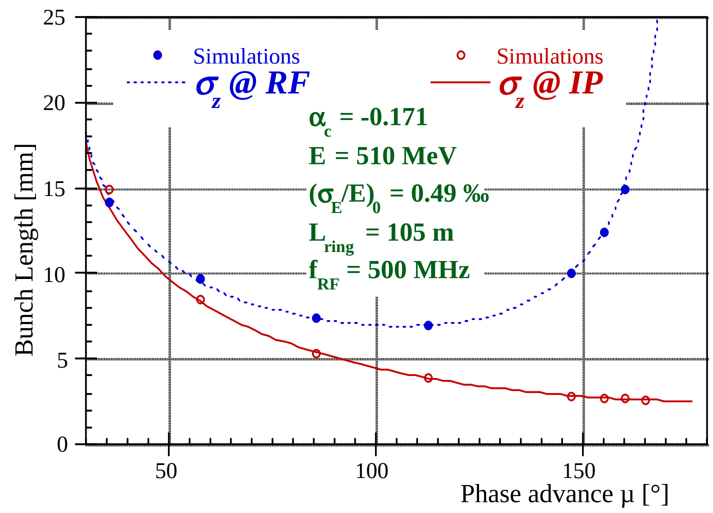
$$\frac{\Delta E}{E}\bigg|_{\max} @\ IP = 1.1\cdot 10^{-2}$$

A. GALLO

Comparison with Numerical Results:

These analytical results have been compared with multi-particle tracking simulations of the bunch longitudinal dynamics in a strong RF focusing configuration. Uniform R_{56} growth and emission rate in the arcs have been assumed in the tracking. The agreement is evident.

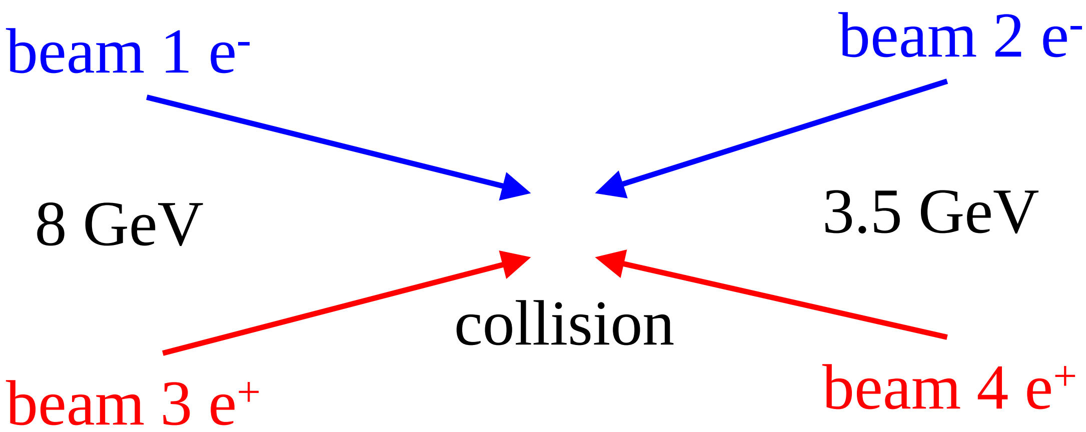




A. GALLO

Other new ideas for high L

- ***collisions with neutralized beams (four beams) + feedback system***



- ***ring against linac***
- ***Monochromators***
- ***Collisions with large crossing angle:***

$E_{cm} = 2E_{beam}\cos(\theta_c/2)$, e.g. $\theta_c/2 = 60°$, $E_{beam} = 1GeV$

Luminosity expectations with large θ_c

Crab crossing case: probably very similar (within a factor 4 around the 10^{34} region) to the low-crossing angle solution, since most of the gains are suppressed by the lenghtening of the interaction length.

Another disadvantage is the need of several MeV of Crab-cavities.

No-Crab crossing case: also very similar to the low-crossing angle solution, since most of the gains are suppressed by the larger horizontal interaction width. However very small tune shifts and micro-betas lead to a new regime of BB interactions, and probably further investigation is worthed.

P. RAIMONDI

Collisions with large X-ing angle

Possible big advantages come from:

-a simpler and more flexible IR design, where l*<0.2m could be possible, togheter with very small aperture, low chromaticity final doublet

-kaons will be boosted, so it might be possible to have the detector decoupled by the IR, with big advantages in the design of collider and detector (see F.Bossi talk)

-reversing the direction of one of the beams, we could increase the Ecm very easily allowing the high energy solution as well

On the opposite side a new detector has to be built, wherease the "standard solution" might require just an upgrade of the existing one.

P. RAIMONDI

CONCLUSIONS

- New ideas to increase luminosity can/will be tested in the near future:
- ❑ Crab cavities (KEK-B)
- ❑ Collisions with round beams (VEPP2000)
- ❑ Negative α_C and strong damping (KEK-B, DAΦNE)
- ❑ Strong RF focussing (CESR?)
- The approach of the DAΦNE machine team is sound: $L=10^{34}$ is already a challenging target
- $L=10^{35}$ needs many combined new ideas/technologies

  ⇒ higher risk and longer time scale