Introduction,motivation and status of the Superb project in Italy

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Superb workshop
LNF November 11-12, 2005

OUTLINE

- The INFN Super B Group
- Physics at B Factory
- Status of the art
- Few examples of Physics Reach at very High luminosity
- Super B possibilities

INFN Super B group

INFN has setup a roadmap program to evaluate future options and commitments in major physics projects.

Groups (as a sort of advisory bodies) have been setup to collect informations in a coherent way to be presented to the INFN management.

In the area covered by Gruppo I (Particle Physics with accelerators) a group has been setupto study the possibility of a SuperB Factory in Italy .

Structure and How to move on

Marco Ciuchini has been appointed as a theorist member of the group.

I hope to be able to assemble the entire group (Pannel, Thing, COSA?) by the end of next week , of course coordinators of GruppoI are welcome and their contributions based on their experience and wisdom will be particularly valuable.

The report to my understanding should be ready by the end of January 06, that is TOMORROW.

The charge I received was to limit the membership of the group to people of INFN, and that is fine since it will act as an advisory group internal to INFN. However a larger community , from Slac, us in general, Canada, Europe, is interested in the possibility of the SuperB in Italy, they have studied the case in the past few years and volunteered to continue their activity in studying the parameters of the machine and the detector and in supplying all possible information as consulting group to our INFN pannel.

How to move on

Regular weekly meetings of the consulting group have been setup on mondays , they are open and volunteers can freely subscribe!

The group contains machine physicists from LNF and Slac, italian european and US experimental physicists .

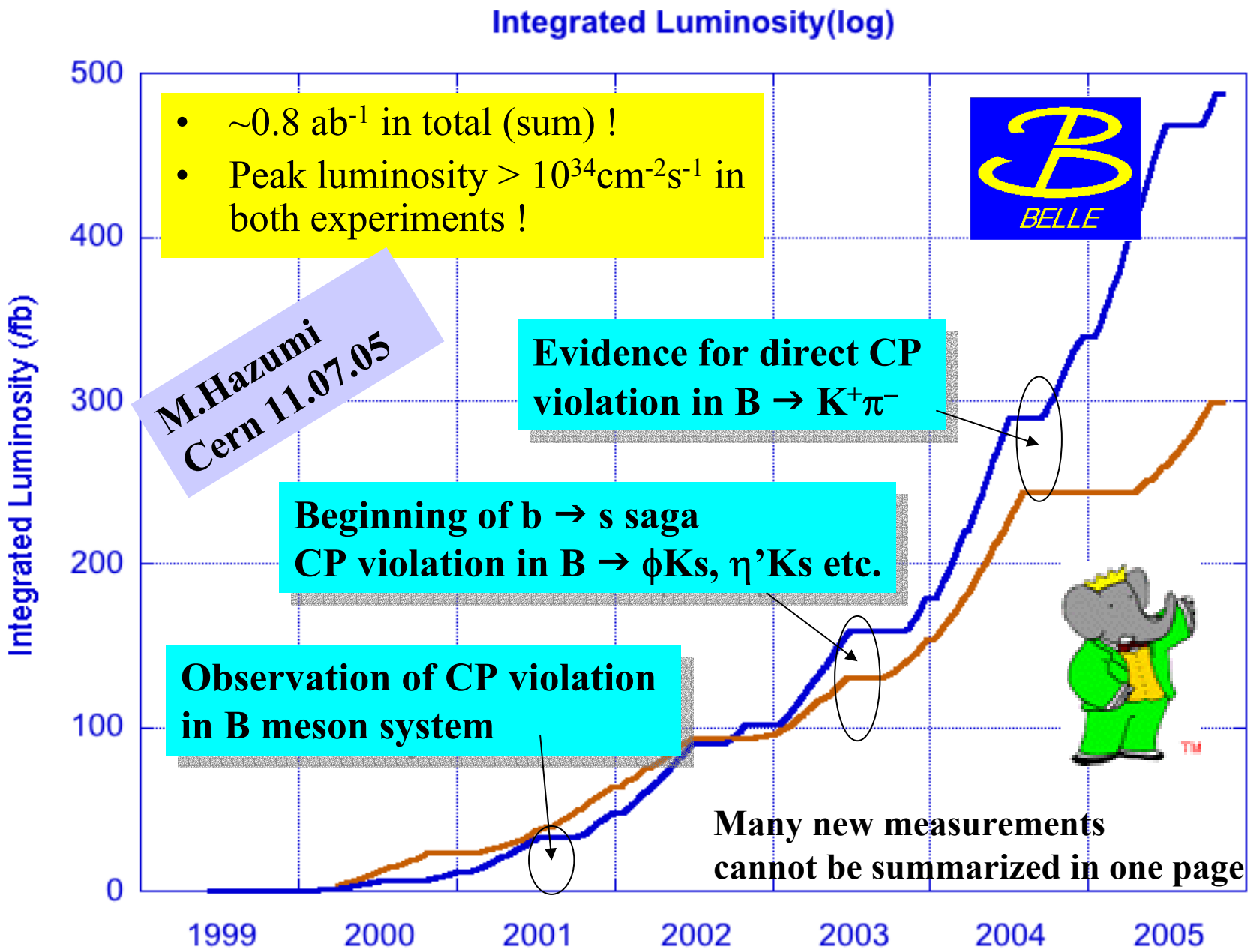
Material will be collected about the machine and the detector and given in real time to our Panel.

We think that the documents on the physics case are already available, so I think that on this subject the task for the panel and in particular for Marco would be somehow easier than the evaluation of the other parameters.

PHYSICS MENU

- Unitarity Triangle sides measurements
  - From (semi)leptonic decays, inclusive or exclusive
  - $|V_{ub}|$, $|V_{cb}|$, $|V_{td}|$

- UT angles precision measurements
  - b→s penguin transitions very sensitive to new physics
  - CPV Asymmetries in B→ϕK_s, $K_s\pi^0$ compared with sin2β.
  - α measurement with B→ππ and ρρ
  - direct CPV
  - γ measurement with B→DK or similar channels.
- Rare decays
  - Exclusive and inclusive $b \to s\gamma$ BFs, direct asymmetries, photon helicities
  - Exclusive and inclusive $b \to s l^+ l^-$ BFs, A_{FB}, CP asymmetries
  - B decays to states with large missing energy, such as $B_{(d,s)} \to \tau^+\tau^-$, $B \to K^{(*)}\nu\nu$, $b \to s\nu\nu$, $B \to D^{(*)}\tau\nu_\tau$, $B \to X_C\tau\nu_\tau$, $B \to \nu\nu$
  - LFV in $\tau \to \mu\gamma$, $\tau \to \mu h$ and similar channels


Integrated Luminosity(log)
Integrated Luminosity (/fb)
500
400
300
200
100
0
1999
2000
2001
2002
2003
2004
2005
• ~0.8 ab-1 in total (sum) !
• Peak luminosity > 10^34cm^-2s^-1 in both experiments !
BELLE
M.Hazumi
Cern 11.07.05
Evidence for direct CP violation in B → K+π−
Beginning of b → s saga
CP violation in B → ϕKs, η'Ks etc.
Observation of CP violation in B meson system
Many new measurements
cannot be summarized in one page

$B^0 \to K^+\pi^-$

BABAR PRL 93 (2004) 131801

$A_{CP} = -0.133 \pm 0.030 \pm 0.009$

4.2σ

Belle Confirmation at ICHEP04

Signal (274M $B\bar{B}$ pairs): 2140 ± 53

$A_{CP} = -0.101 \pm 0.025 \pm 0.005$

3.9σ

Average $A_{CP} = -0.114 \pm 0.020$

$B^+ \to K^+\pi^0$

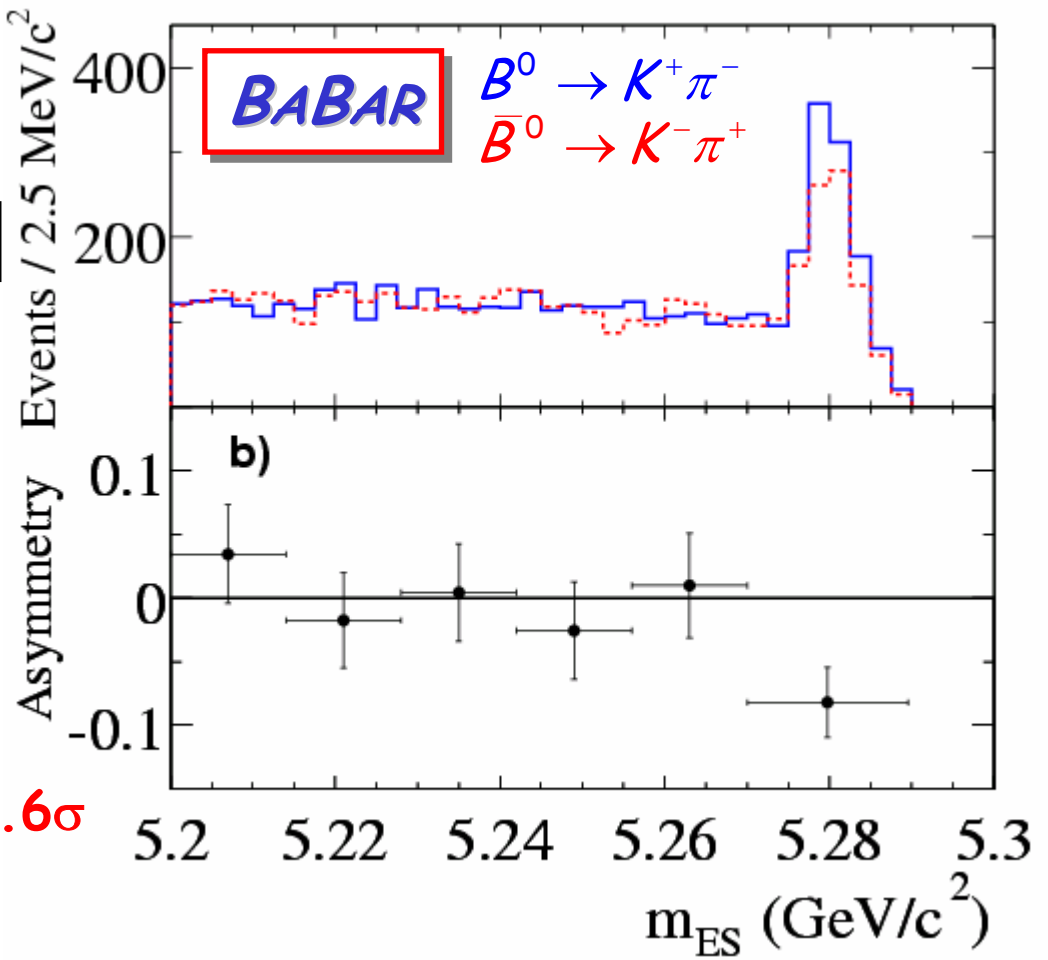
$A_{CP} = +0.06 \pm 0.06 \pm 0.01$ *BABAR*

$A_{CP} = +0.04 \pm 0.05 \pm 0.02$ Belle

3.6σ

Average $A_{CP} = +0.049 \pm 0.040$

Signal (227M $B\bar{B}$ pairs): 1606 ±



Superb

New unitarity triangle with new values

Lp05 new Belle value with 386M $B\bar{B}, J/\psi K^0$

$\sin 2\phi_1 = 0.652 \pm 0.039 \pm 0.020$

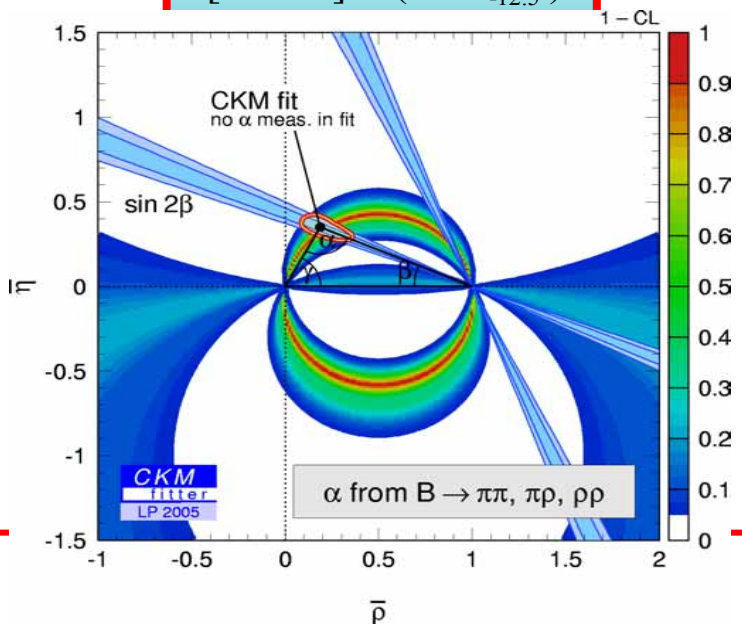
$C = -0.010 \pm 0.026 \pm 0.036$

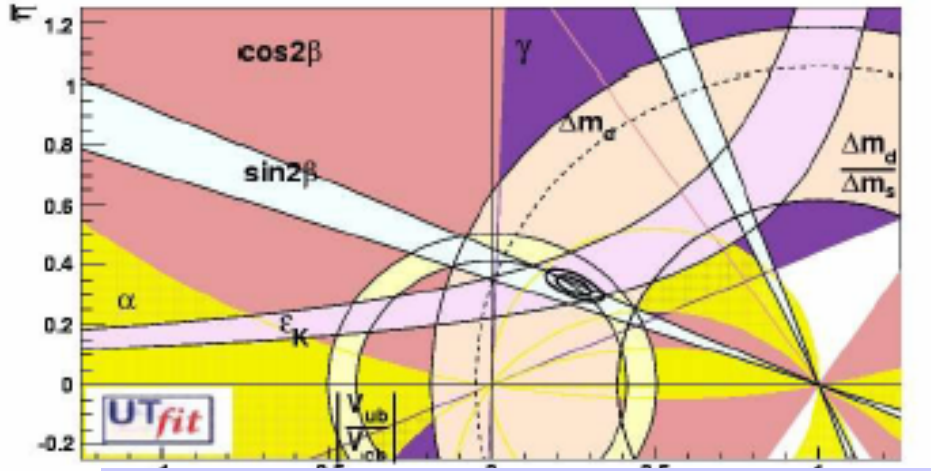
New average values BaBar Belle

Sin2β=0.685±0.032C
=0.016±0.046

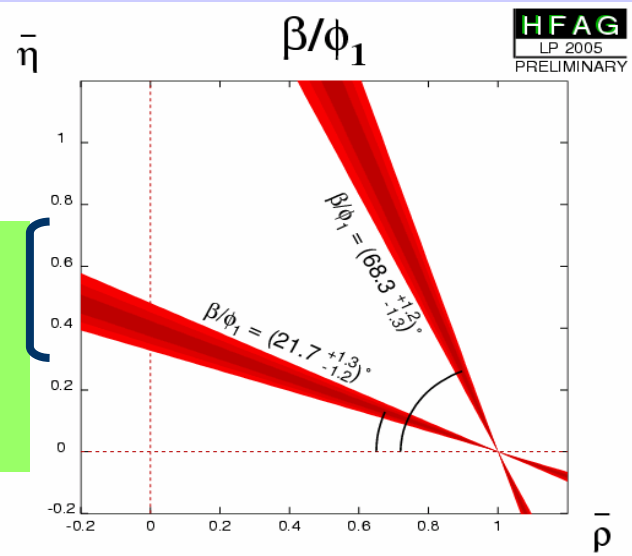
$\alpha[\text{all}] = (99\,^{+12}_{-9})^\circ$

$\alpha[\text{CKM}] = (93.1\,^{+9.6}_{-12.5})^\circ$





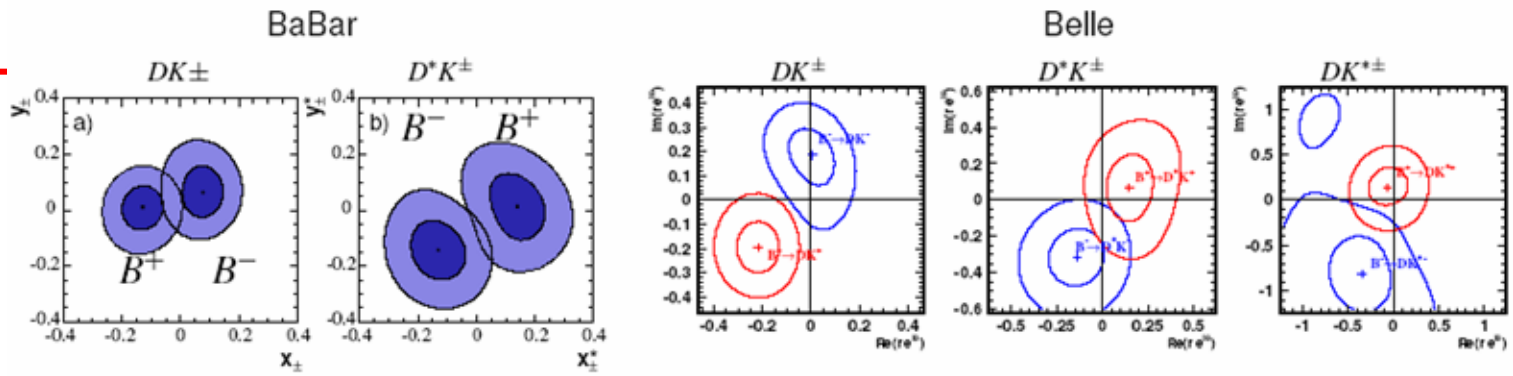
New value of Sin2β vs. UT general fit with new Vub/Vcb value



After Lp 05 Preferred solution

Superb

Including Φ_3/γ mainly from Dalitz analysis



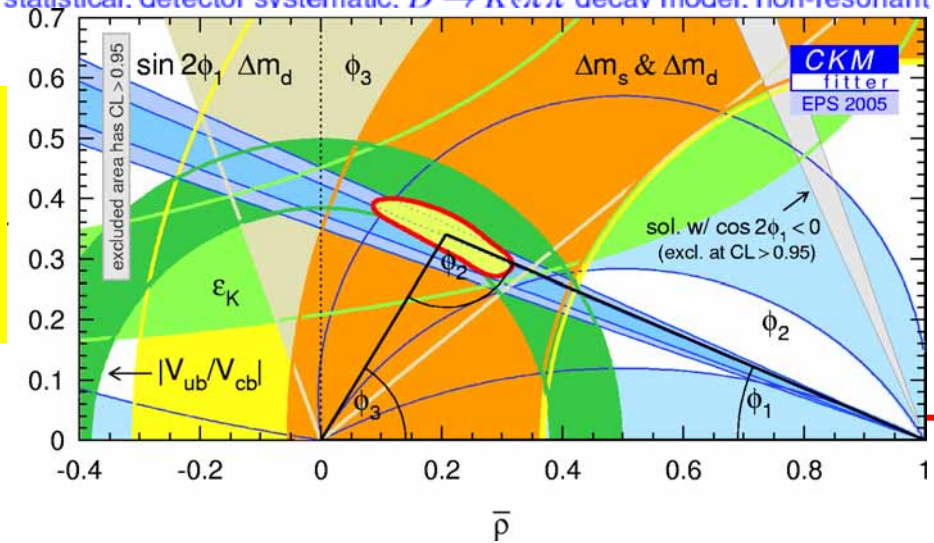
Deviation from origin indicates $r \neq 0$. Difference between B^+ and B^- signifies $\phi_3 \neq 0$ (*CPV*)

	Modes	r	δ (°)	ϕ_3 (°)
BaBar	DK	$0.118 \pm 0.079 \pm 0.034^{+0.036}_{-0.034}$	$104 \pm 45^{+17\ +16}_{-21\ -24}$	
	D^*K	$0.169 \pm 0.096^{+0.030\ +0.029}_{-0.028\ -0.026}$	$296 \pm 41^{+14}_{-12} \pm 15$	
	combined			$70 \pm 31^{+12\ +14}_{-10\ -11}$
Belle	DK	$0.21 \pm 0.08 \pm 0.03 \pm 0.04$	$157 \pm 19 \pm 11 \pm 21$	
	D^*K	$0.12^{+0.16}_{-0.11} \pm 0.02 \pm 0.04$	$321 \pm 57 \pm 11 \pm 21$	
	combined			$68^{+14}_{-15} \pm 13 \pm 11$
	DK^*	$0.25^{+0.17}_{-0.18} \pm 0.09 \pm 0.04 \pm 0.08$	$358 \pm 35 \pm 8 \pm 21 \pm 49$	$112 \pm 35 \pm 9 \pm 11 \pm 8$

Errors: statistical, detector systematic, $D \to K_S\pi\pi$ decay model, non-resonant $DK\pi$

Summer '05

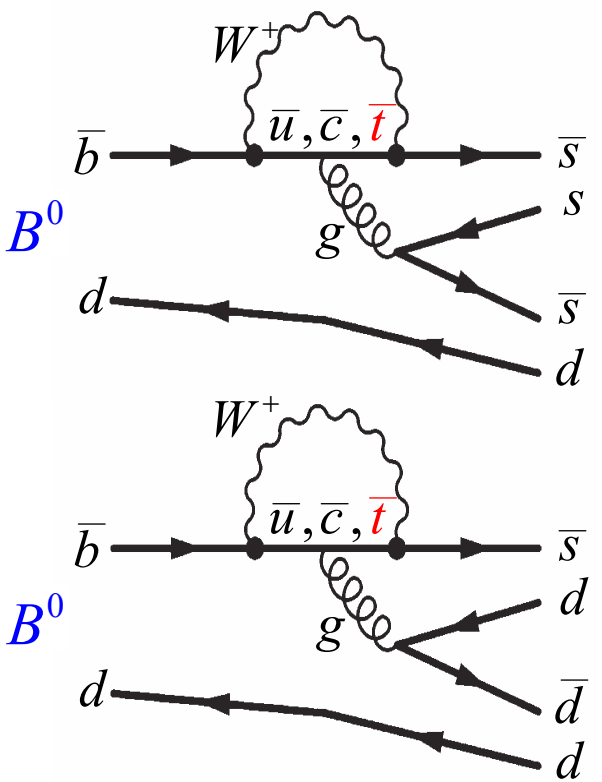
CKM is a success so far…..



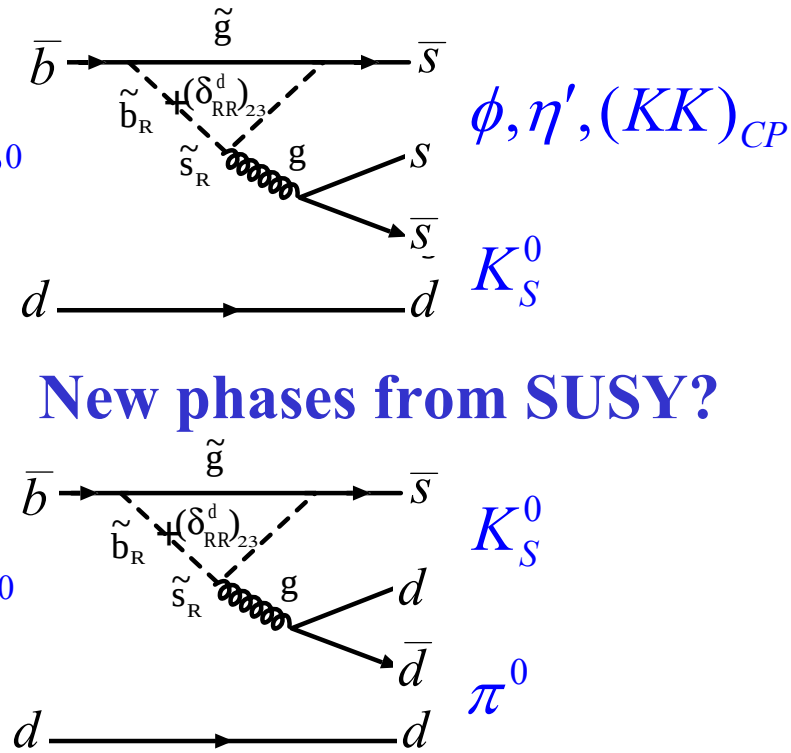
Superb

sin2β and loops

In SM interference between B mixing, K mixing and Penguin $b\to s\bar{s}s$ or $b\to s\bar{d}d$ gives the same $e^{-2i\beta}$ as in tree process $b\to c\bar{c}s$. However loops can also be sensitive to New Physics!

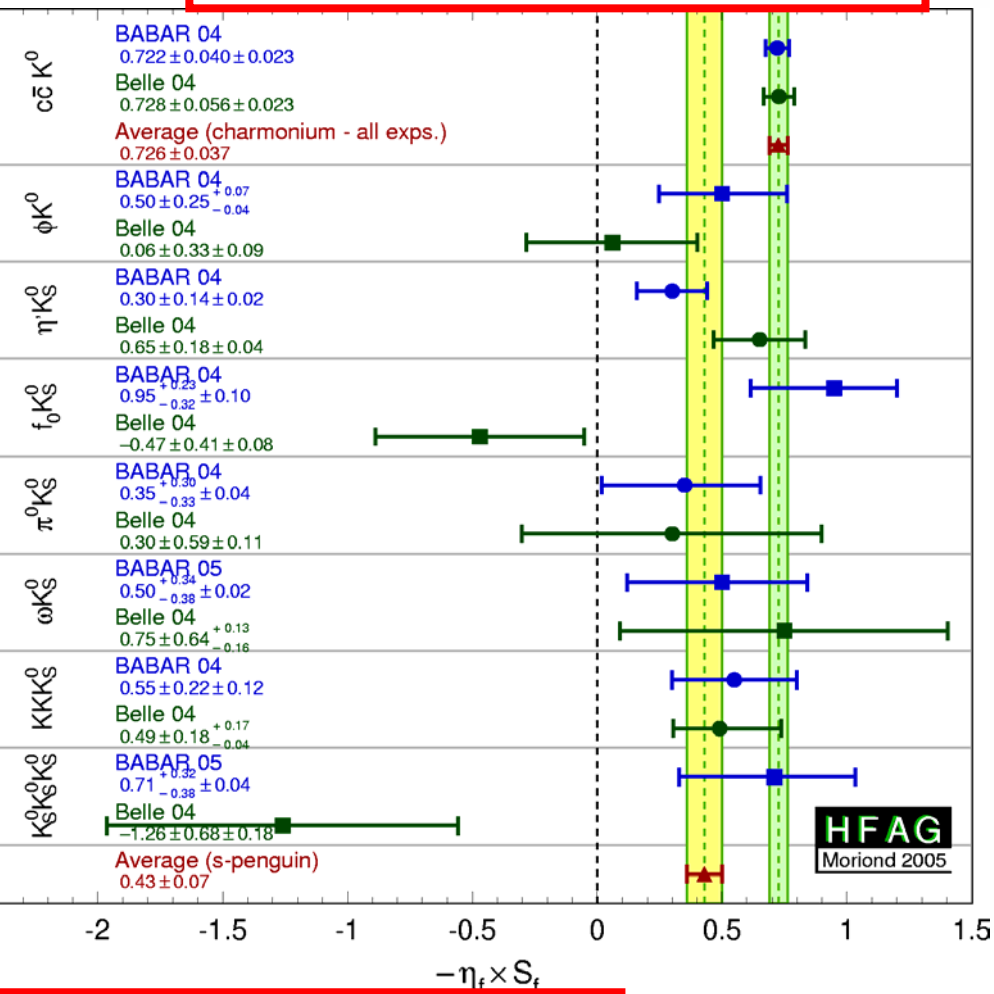


$O(\lambda^2)$
~ 5%
Purely dimensional estimate
$O(\lambda^2/\bar{\lambda})$
~ 20%

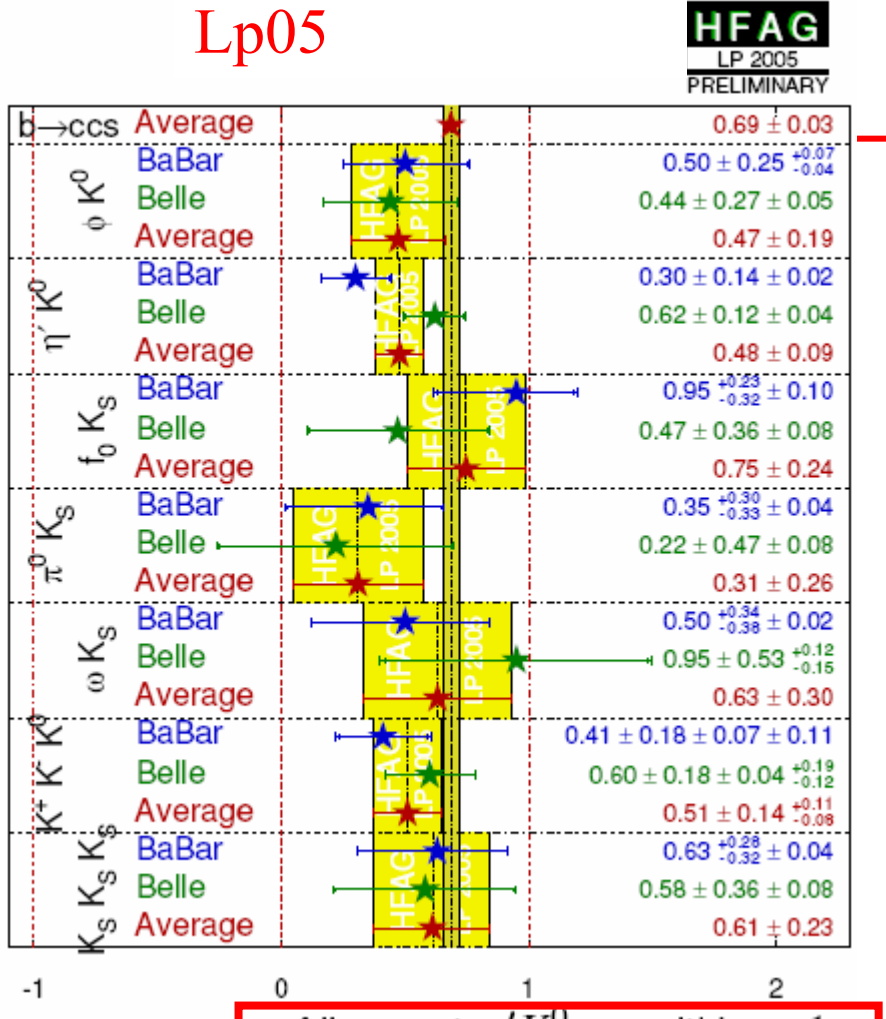


New phases from SUSY?

Winter vs. Summer 05



Lp05



- All except $\eta' K^0$ are within $\sim 1\sigma$
- All except $f_0 K^0_S$ have $\Delta S < 0$

Deviation from SM:
No theory error: 3.7 s
Naïve theory errors: 2.9 s

Superb

New particles

BELLE and BABAR have discovered several new particles in the last couple of years, Thanks to the extraordinary high statistics.

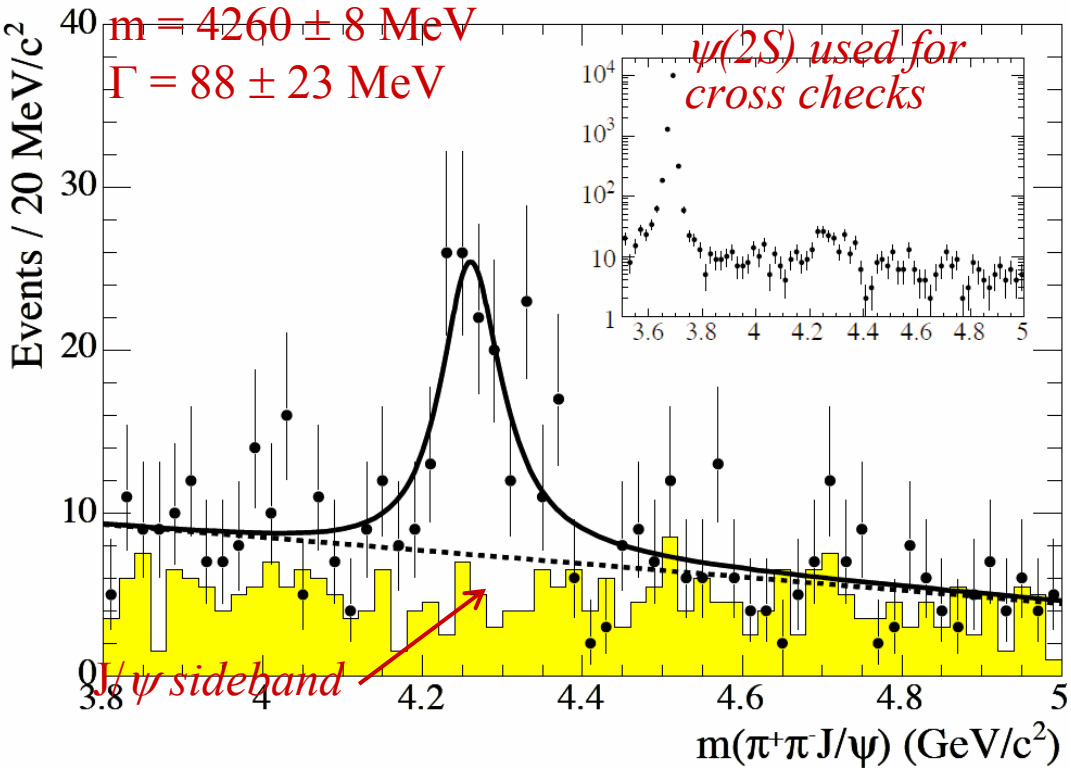
BABAR has first observed $D_s(2317)$ and BELLE the X(3872) and Y(3940) .

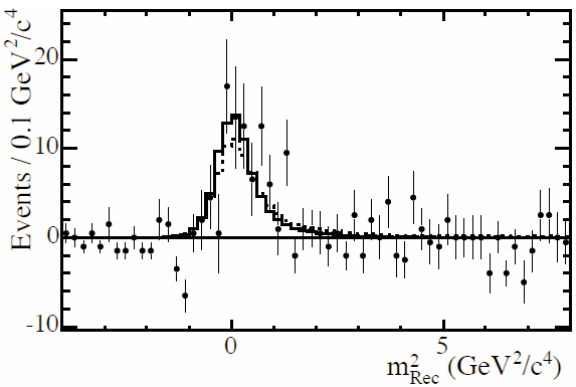
Now a new state…

New Structure Y(4260) in $\pi^+\pi^-J/\psi$ Mass Spectrum

- ISR production: $e^+e^- \rightarrow (\gamma)J/\psi\pi^+\pi^-$

25% of γ's observed





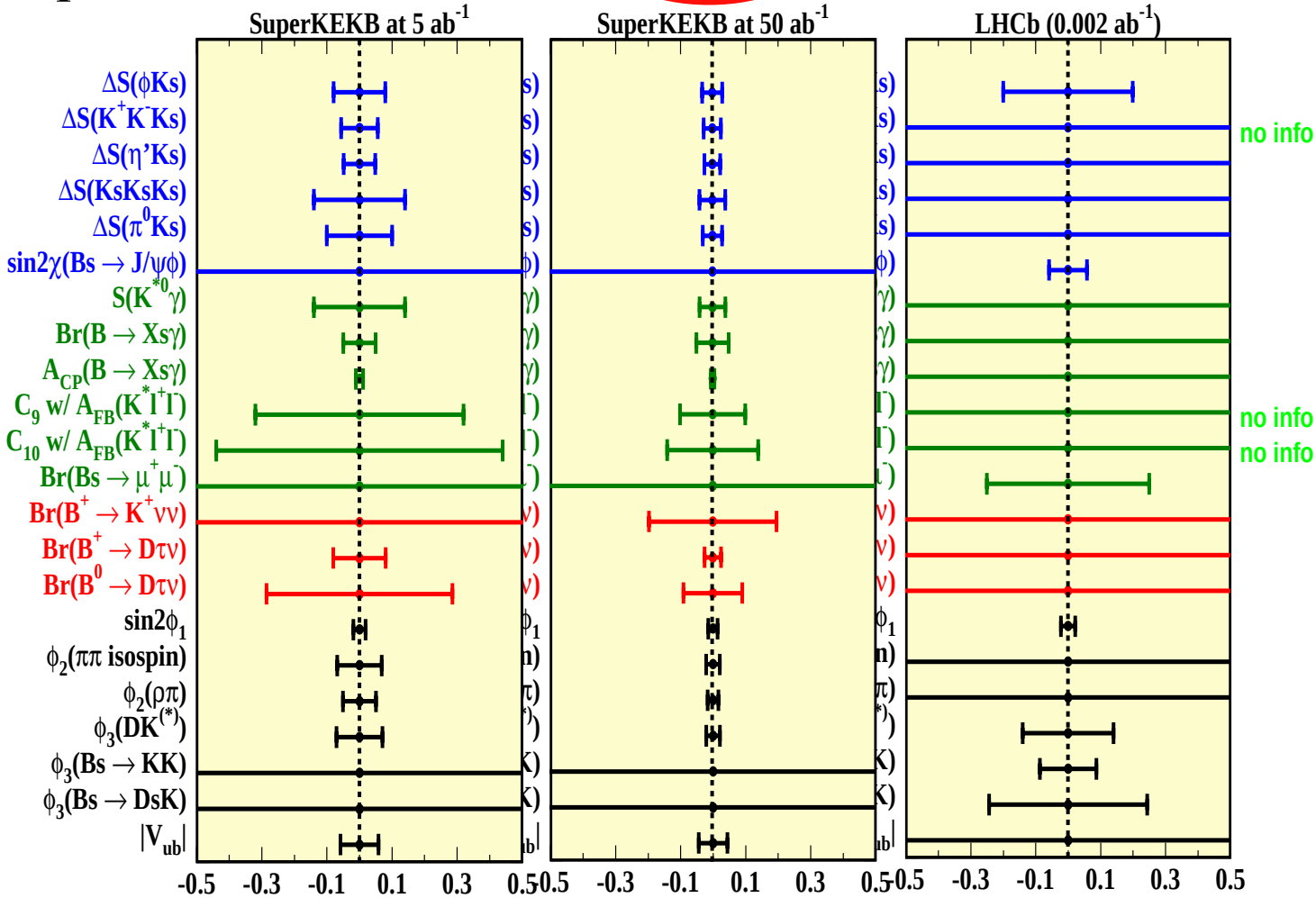
missing mass consistent with γ: Y data, Y MC, and ψ(2S) data

Superb

Comparison with LHCb

		SuperKEKB (5 ab^{-1})	(50 ab^{-1})
CPV (b → s)	$\Delta S(\phi K_S)$	0.079	0.031
	$\Delta S(K^+K^-K_S)$	0.056	0.026
	$\Delta S(\eta' K_S)$	0.049	0.024
	$\Delta S(K_SK_SK_S)$	0.14	0.04
	$\Delta S(\pi^0 K_S)$	0.10	0.03
	$\sin 2\chi(B_s \to J/\psi\phi)$	×	×
FCNC	$S(K^{*0}\gamma)$	0.14	0.04
	$Br(B \to X_s\gamma)$	5%	5%
	$A_{CP}(B \to X_s\gamma)$	0.011	5×10^{-3}
	C_9 w/ $A_{FB}(K^*l^+l^-)$	32%	10%
	C_{10} w/ $A_{FB}(K^*l^+l^-)$	44%	14%
	$Br(B_s \to \mu^+\mu^-)$	×	×
w/ ν	$Br(B^+ \to K^+\nu\nu)$		5.1σ
	$Br(B^+ \to D\tau\nu)$	8%	2.5%
	$Br(B^0 \to D\tau\nu)$	3.5σ	9%
CKM	$\sin 2\phi_1$	0.019	0.014
	$\phi_2(\pi\pi$ isospin)	3.9°	1.2°
	$\phi_2(\rho\pi)$	2.9°	0.9°
	$\phi_3(DK^{(*)})$	4°	1.2°
	$\phi_3(B_s \to KK)$	×	×
	$\phi_3(B_s \to D_sK)$	×	×
	$\lvert V_{ub}\rvert$	5.8%	4.4%

SuperKEKB 5ab^{-1} 50ab^{-1} LHCb 2fb^{-1}

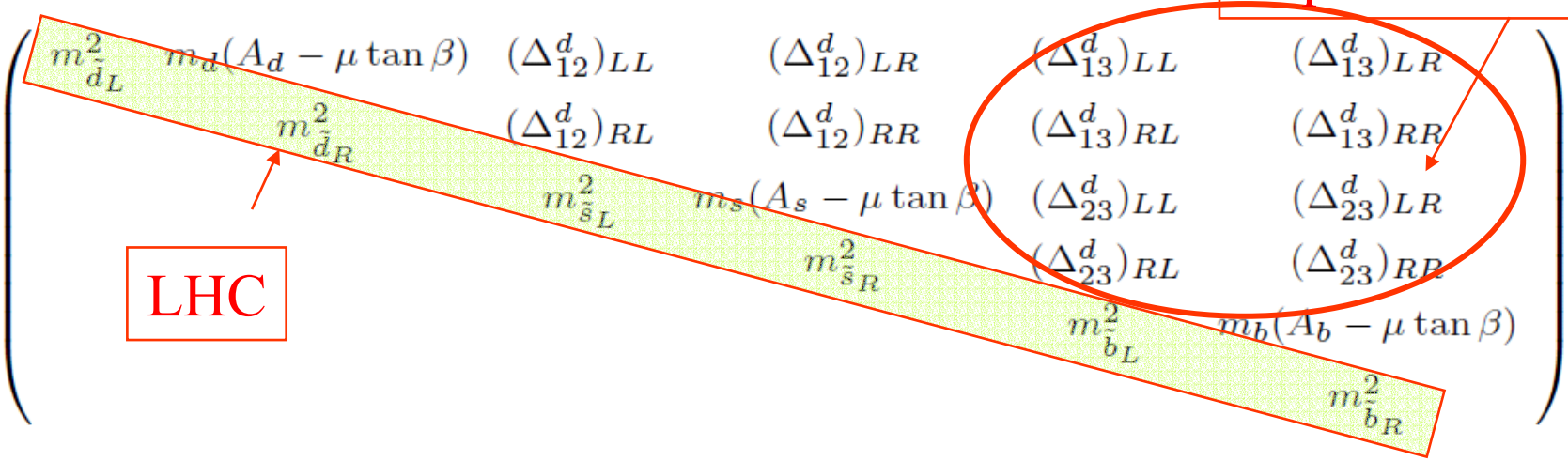


Rare Decays

MEASUREMENT	Goal	3/ab	10/ab	50/ab	100/ab
B($B \to D^* \tau \nu$)	SM: B: 8×10^{-3}	10.2%	5.6%	2.5%	
B($B \to s \nu\nu) K, K^*$	SM:Theory ~5% 1 excl: 4×10^{-6}			~3σ	
B($B \to$ *invisible*)		$<2 \times 10^{-6}$	$<1 \times 10^{-6}$	$<4 \times 10^{-7}$	
B($B_d \to \mu\mu$)		-	-	?	?
B($B_d \to \tau\tau$)		-	-	?	?
B($\tau \to \mu\gamma$) now$< 7\ 10^{-8}$					$<10^{-10}$
B($\tau \to \mu h$) now $< 10^{-7}$					$<10^{-10}$

Complementary information

Super *B* Factory



Assuming all Δ's small and squarks nearly degenerate, we can use mass insertion approximation (MIA):

$$(\delta^d_{ij})_{AB} = \frac{(\Delta^d_{ij})_{AB}}{\tilde{m}^2}$$

Squark mass matrix (*d* sector)

A Super *B* Factory (with 10^{36} BETTER with 10^{37}), early in the LHC era, can provide the means
to eliminate potential models as well as unique information on *CP* phases

Is Physics case solid?

Question :

Is there still a physics case for highly precise flavour experiments in the next decade?

- Evidence for New Physics could be found by ATLAS and CMS in the first few years of LHC operation (2÷5 years?)
- LHC*b* will take data on the same time scale

My view:

It is a solid case if the SuperB is really **SUPER**

($10^{10} \div 10^{11}$ B and τ pair per year well before 2015)

(in the same running period as LHC and before ILC).

3years of Physics Workshop have produced heavy documents

The Discovery Potential of a Super B Factory (Slac-R-709)

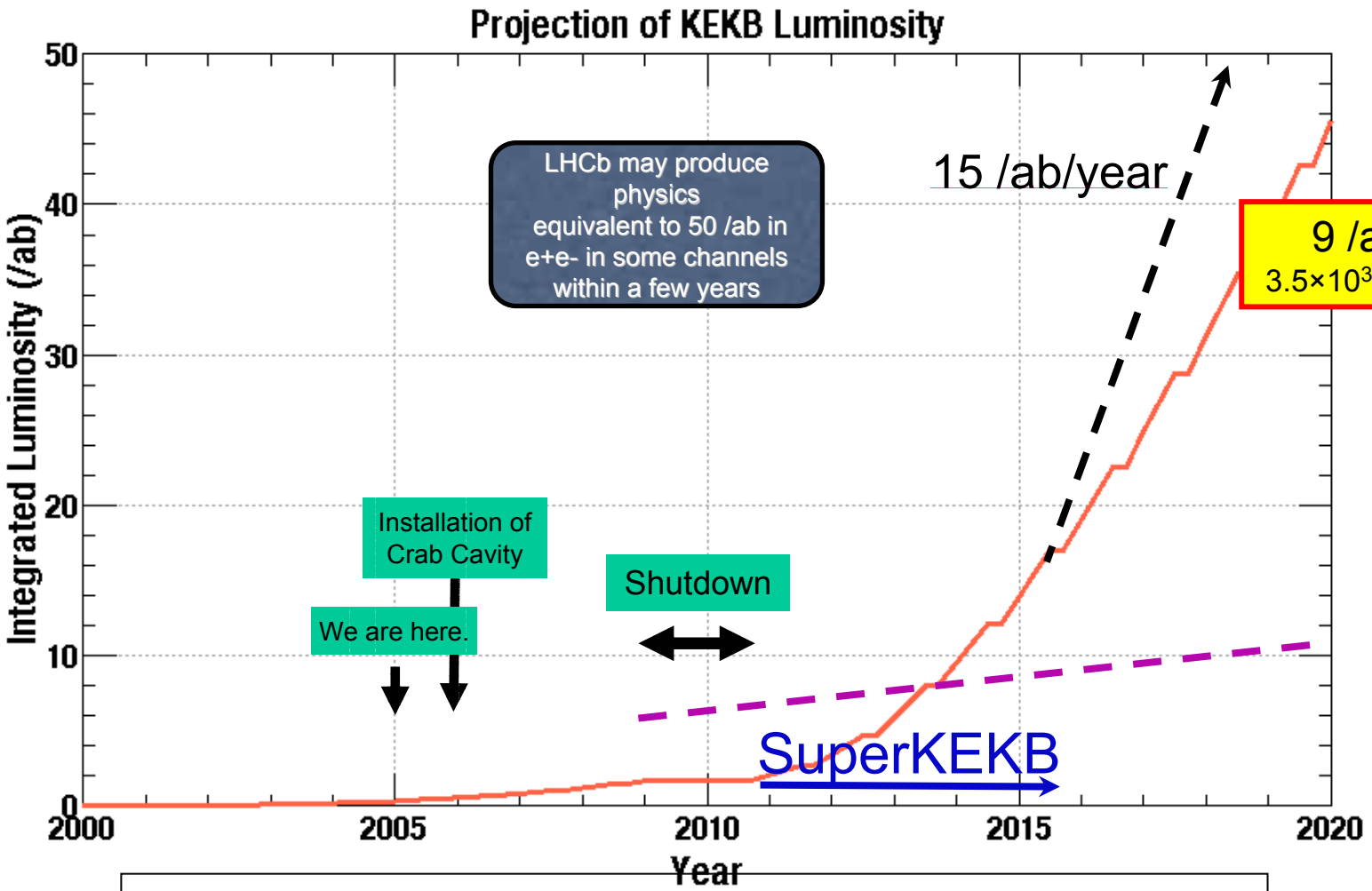
Support of Physics case also in

Letter of Intent for KEK Super B Factory (KEK Report 2004-4)

Physics at Super B Factory (hep-ex/0406071)

Marco Ciuchini will present the potentiality of exploring BSM with a data base at the level of 50 ab^{-1}

SUPER KEKB Project



Shutdown for 18-26 months in 2009-2010 for the upgrade.
0.9 /ab/month in 2020.

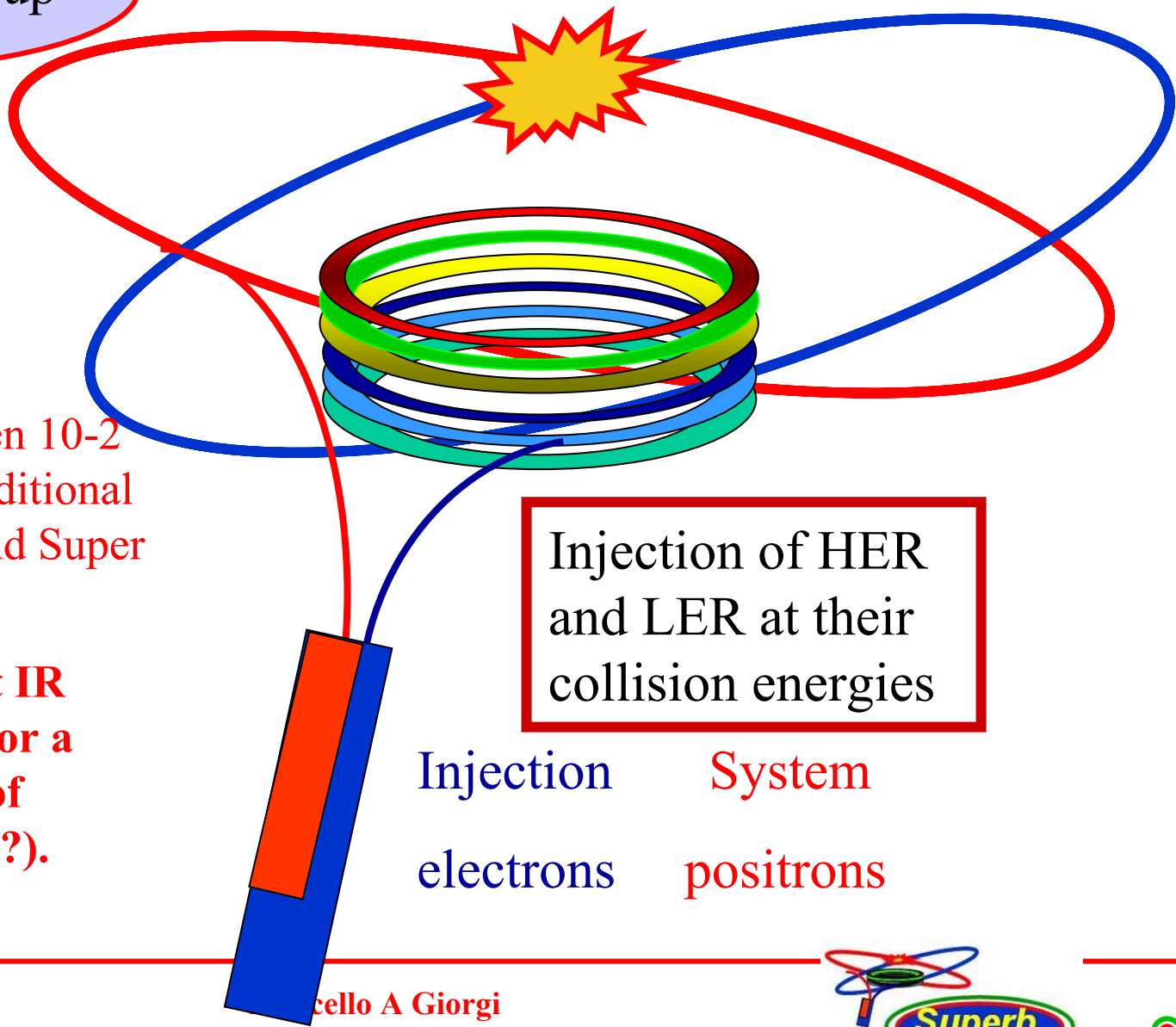
A NEW HERETIC APPROACH

- Basic Idea comes from the ATF2-FF experiment (R&D for ILC)

  In the proposed experiment it seems possible to acheive spot sizes at the focal point of about 2μm*20nm at very low energy (1 GeV), out from the damping ring
- Rescaling at about 10GeV/CM we should get sizes of about 1μm*10nm =>
- Is it worth to explore the potentiality of a Collider based on a scheme similar to the Linear Collider.

(P.Raimondi at Hawaii 05 meeting on Super B)

DR can be piled up



BKG in detector between 10-2 and 10- 3 as in more traditional design as SperKEKB and Super PEPII

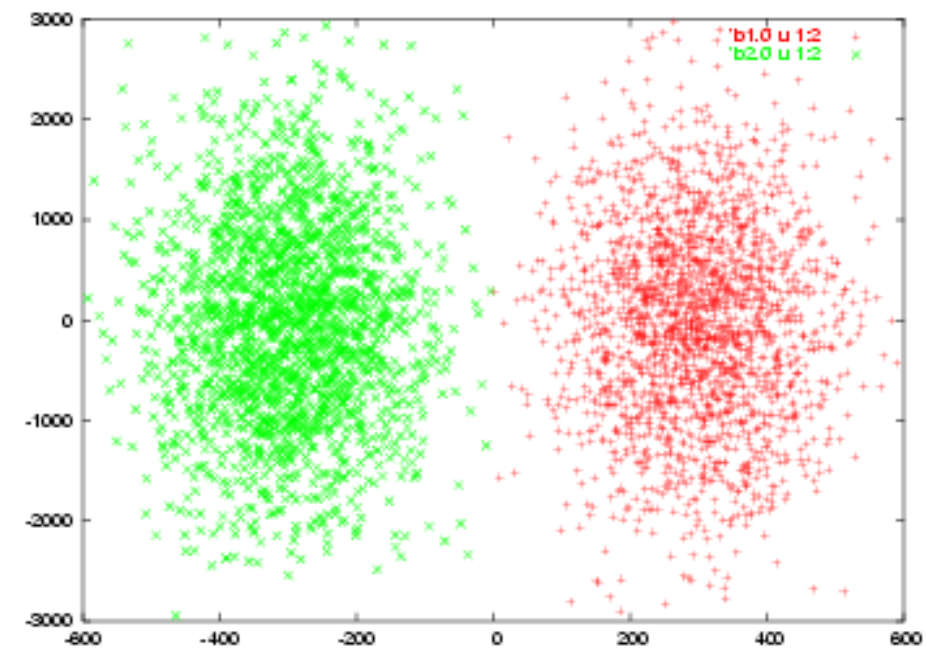
Beam pipe diameter at IR <10 mm (it can allow for a substantial reduction of asymmetry (4+7 GeV ?).

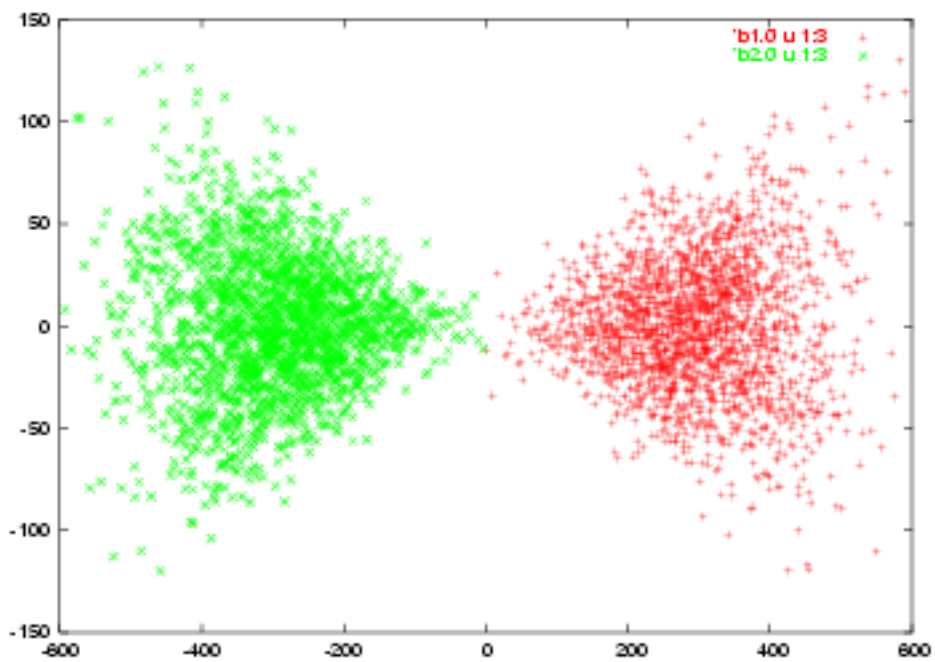
Acceptance up to 99%

Injection of HER and LER at their collision energies

Injection System

electrons positrons





Horizontal Collision

Vertical collision
D. Schulte

Effective horizontal size during collision about 10 times smaller, vertical size 10 times larger

INTRIGUING DESIGN

This idea is based on recycling in Dumping Rings (DR) with wide dynamic aperture the disrupted bunches after their linear collision.

The basic principle was discussed years ago by Amaldi and Coignet, it contains the concept of the separation of a ring (Dumping Ring with high circulating current O(10 Amps)) from the colliding region inside the detector with a low circulating current O(10 mAmps).

What is new now?

The project of ILC is better defined

Many groups in different countries work to the project (R&D is going on) DR are one of critical components.

The DR for Superb could be the same as for ILC.

FRIENDLY ENVIRONMENT

Synergy with ILC project is fundamental.

Superb could be a real scale demonstrator of DR for ILC

A true international enterprise on Superb shared among different regions and agencies (Machine design, Machine construction, Detector design and construction , running the experiment and producing Physics together) could be a marvelous and fundamental test for the future ILC enterprise.

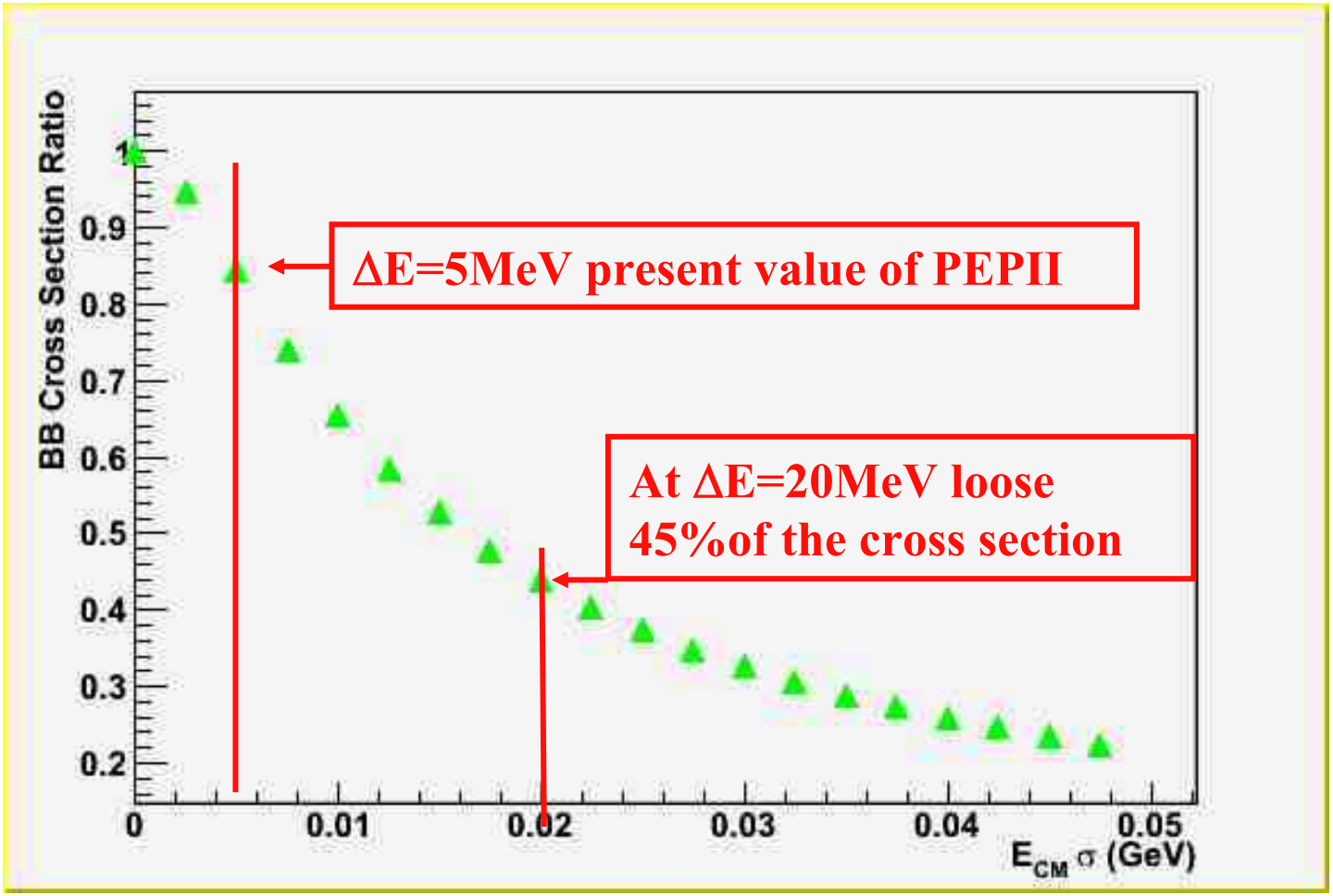
Goals of the Workshop

We expect at the end of this workshop a preliminary list of parameters on machine and detector.
For machine:
The asymmetry parameter $\beta\gamma$ (i.e. Ee-, Ee+),
The Luminosity,
The Energy cms spread ΔE,
The beam pipe radius.
For detector:
Vertex (transparent pixel layer 0 ?)
Tracker (Si or gas?)
Cherenkov and PID in general.
E.M. calorimeter (pure CsI or YLSO in endcaps close to beam)
DAQ

Can WG1 and WG2 end tomorrow with a strawman preliminary design?

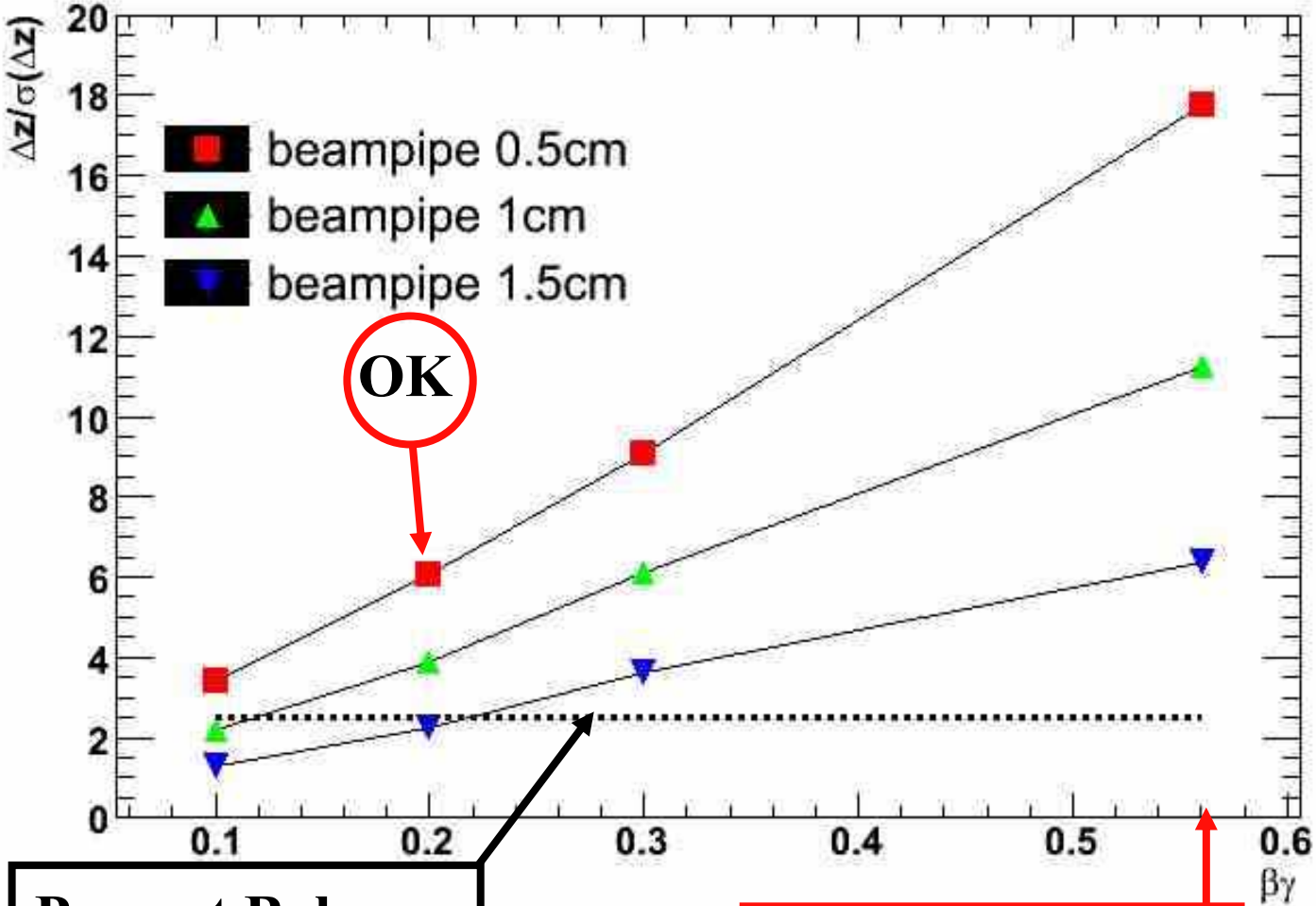
DELTA E issue

For some channels as τ decays, large DE are not affecting to much the physics results. m_{ES} is instead depending on it.



See presentations of N.Neri and M.Pierini

BEAM Energy Asymmetry



Present Babar resolution

Present PEPII βγ

Nicola will discuss in detail the resolution needed in time dependent analysis as functon of βγ

Totsuka's comment V

- **In any case I agree that one super-B factory should be built in the world.**

- And it may be a good idea for you to jointly work for the best scheme of the super-B factory. I understand that there will be a Belle-BaBar joint workshop scheduled in Hawaii in January next year.
  - This will be a great opportunity to start discussing the joint super-B factory.

Conclusion for now

My personal view:

I agree that one Superb must be built.

We at most can afford to build one as the result of a joint international effort.

Synergy with ILC would be essential.

We need creative immagination, a maximum of strength and a lot of hard work .

FROM NOW!

- BACKUPS

OTHER CHANNELS for NP (observables in s/d l+l- decay)

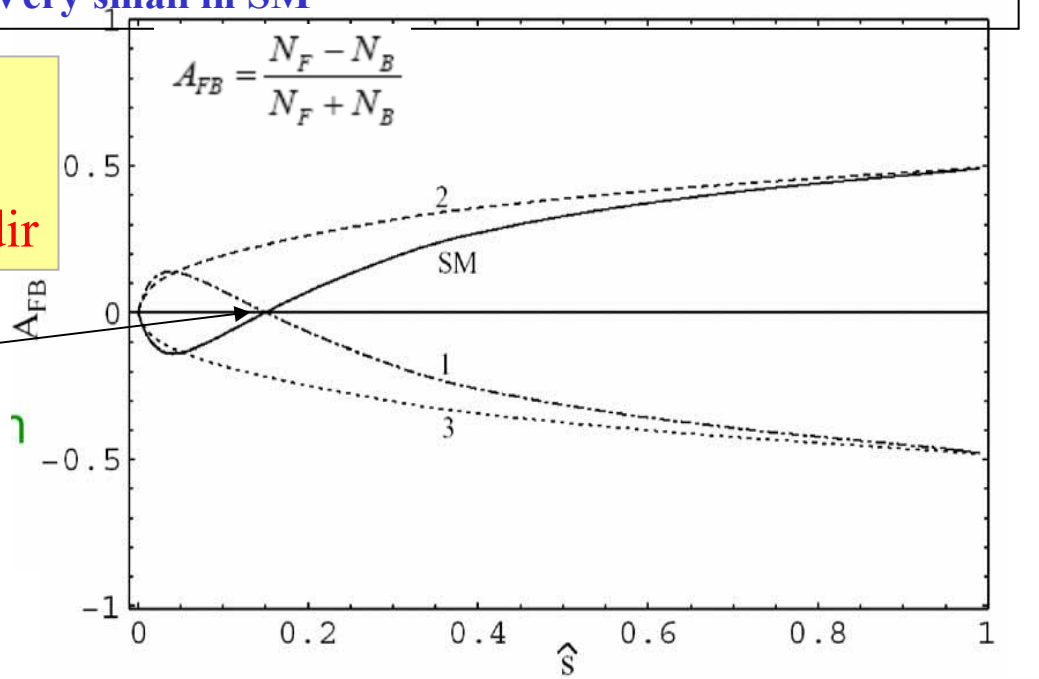
$A_{cp}(B \to s\, l^+ l^-)$	SM: <0.5% (0.05% for K* l^+ l)
$A_{cp}(B \to d\, l^+ l^-)$	SM: ~(4.4+/-4)%
$B(B \to s\mu^+\mu^-)/B(B \to se^+e^-)$	SM: ~1
$A^{FB}(K^* l^+ l^-)$:s_0(zero crossing)	SM predicts with ~5% accuracy
$A^{FB}(K^* l^+ l^-)$:CP asymmetry	Very small in SM

In dilepton rest frame
N_F = when l^+ along b dir
N_B = when l^+ opposite b dir

SM:
S_0 NNLO error = 5%

S_0 = 0.162+/-0.008 ~ C7/C9

$$\hat{s} = (m_{l^+l^-}/m_b)^2$$



$$\hat{s} = (m_{l^+l^-}/m_b)^2$$

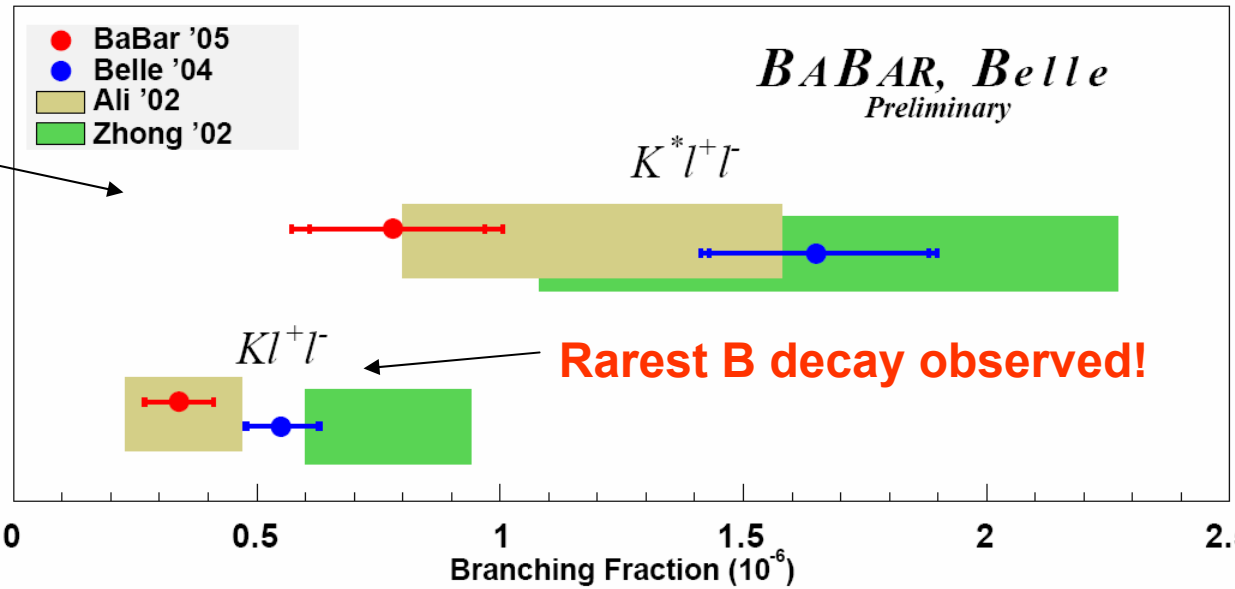
In SM: $A^{CP}_{FB} \sim 0$
Determination of sign of AFB very important.

$B \rightarrow K^{(*)} l^+ l^-$

F.Forti LP05

*Kll, K*ll* branching fractions in range predicted by SM + form factors

theory uncertainty > experimental uncertainty

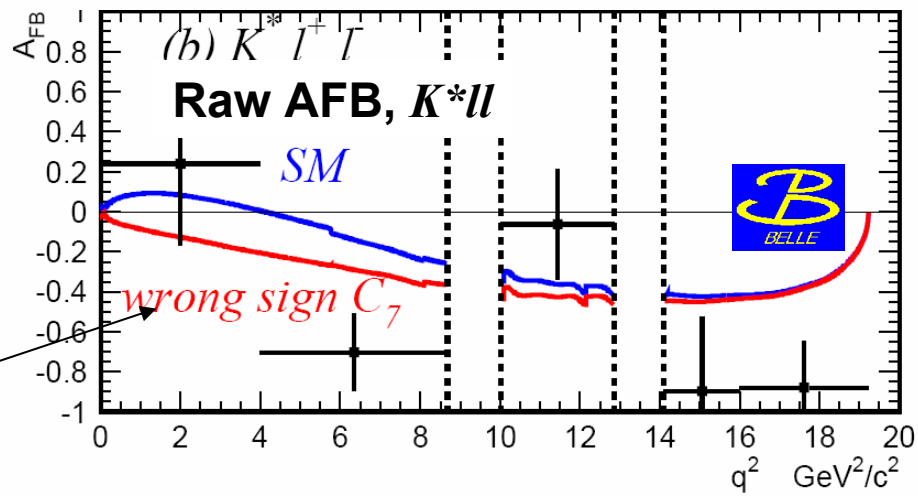


Beyond branching fractions: Asymmetries

A_{CP} consistent with zero

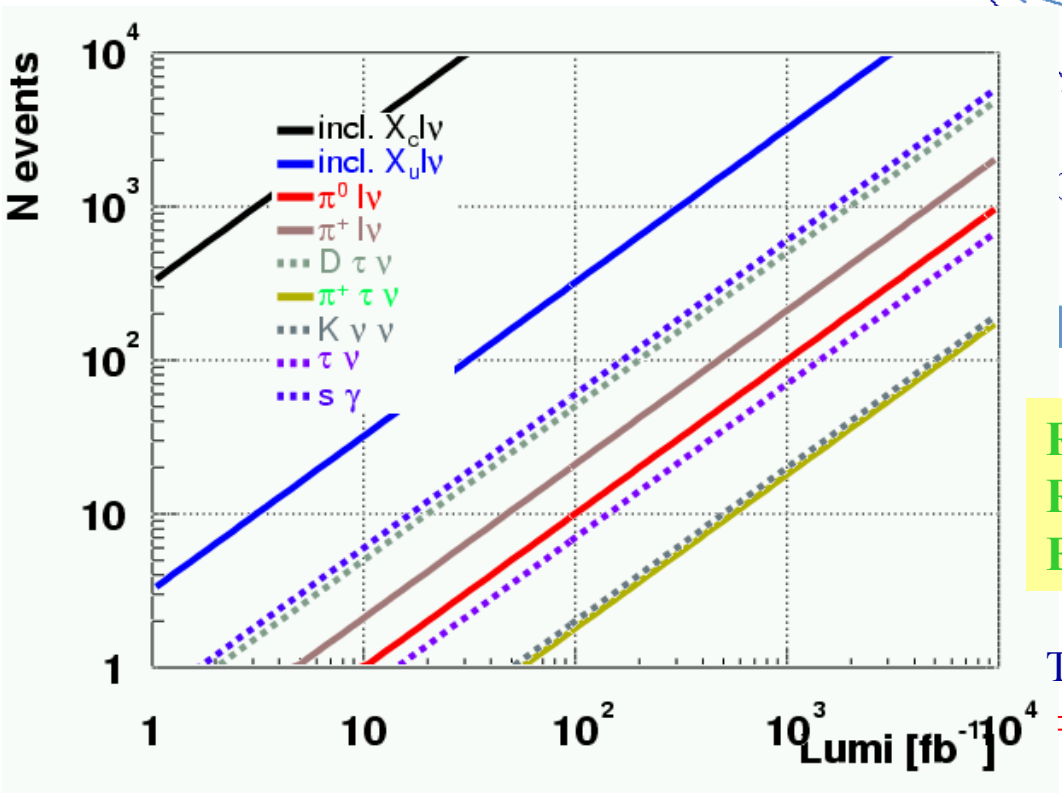
Kμμ/Kee ratio consistent with unity

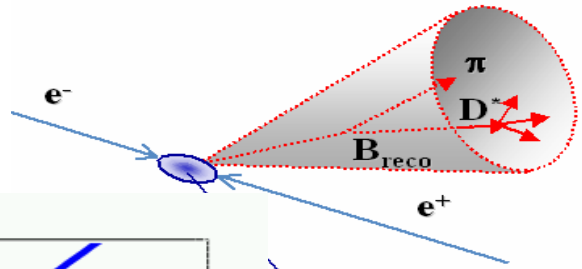
Forward-backward angular asymmetry of lepton pair vs. dilepton mass probes relative size, phase of penguin diagrams

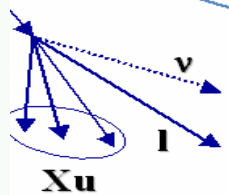


Superb

Recoil Method as pure B beam







- Fully reconstruct one of the two Bs in hadronic modes...
- ...and do it with "high" efficiency

- The remaining of the event is the other B

You have a single B beam!!

Daniele del Re UCSD

Recoil cinematics well known
Recoil flavor and charge is determined
Event closure needed with neutrinos

The final efficiency is ~0.4% (per bb_{bar} pair)
$\Rightarrow$ ~4000 B/fb^{-1} (at 30% purity)
$\Rightarrow$ 1500 B^0/fb^{-1}
$\Rightarrow$ 2500 B^+/fb^{-1}
> 10^7 recoil Bs in $10ab^{-1}$

f_{rev}	s^{-1}	1,36E+05	1,36E+05	1,36E+05	1,36E+05
e		1,60E-19	1,60E-19	1,60E-19	1,60E-19
$4*\pi$		1,26E+01	1,26E+01	1,26E+01	1,26E+01
f_o	s^{-1}	1,20E+02	1,20E+02	1,20E+02	1,36E+05
E	GeV	3,50E+00	3,50E+00	3,50E+00	3,50E+00
γ		6,85E+03	6,85E+03	6,85E+03	6,85E+03
ε_x	nm	1,00E-01	1,00E-01	5,00E-02	2,00E+01
ε_y	nm	0,0010	0,0010	5,00E-02	1,00
β_x^*	µm	1,00E+04	1,00E+04	1,00E+03	1,00E+05
β_y^*	nm	1,00E+05	1,00E+05	1,00E+06	3,00E+06
σ_l	nm	1,00E+05	1,00E+05	1,00E+06	3,00E+06
θ_c	rad	1,00E-02	1,00E-02	1,00E-02	1,00E-02
n_b		3,50E+03	3,50E+03	3,50E+03	3,50E+03
σ_x^*	µm	1,00E+00	1,00E+00	2,24E-01	4,47E+01
σ_y^*	nm	1,00E+01	1,00E+01	2,24E+02	1,73E+03
I^+	A	3,00E+00	1,00E+01	1,00E+01	1,00E+01
I^-	A	6,00E+00	2,00E+01	2,00E+01	2,00E+01
N^+		3,94E+10	1,31E+11	1,31E+11	1,31E+11
N^-		7,88E+10	2,63E+11	2,63E+11	2,63E+11
L_{oo}	$cm^{-2}\ s^{-1}$	1,04E+36	1,15E+37	2,30E+36	1,69E+36
η		1	1	10	1
L_o	$cm^{-2}\ s^{-1}$	1,04E+36	1,15E+37	2,30E+37	1,69E+36
		ATF2	ATF2	ATF2	PEP-II
		crab	crab	round	crab

In this simulation

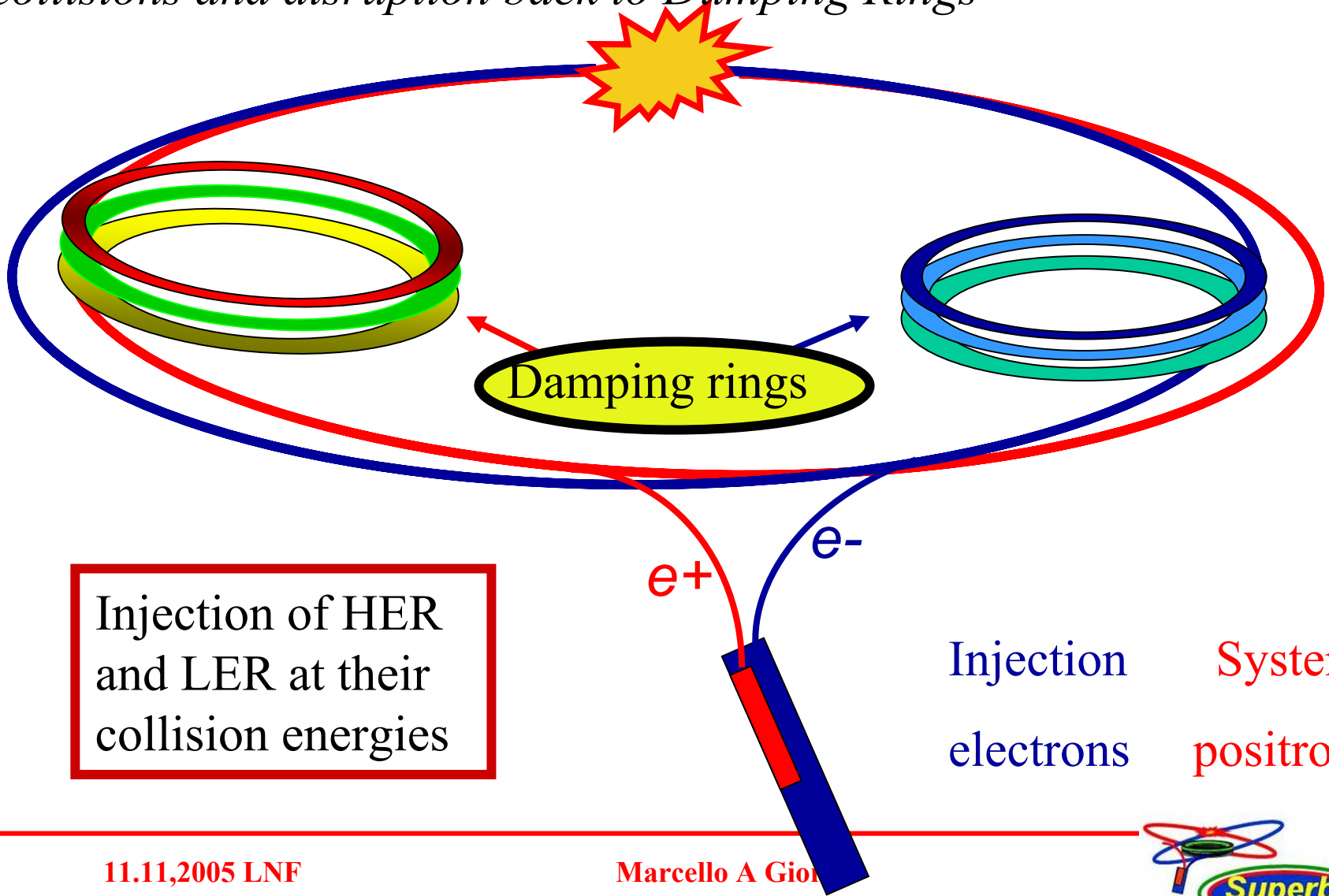
E+=8GeV

E-=3.5 Gev

Sorry Prof. Sanda , not yet 10^{43} but…

Parameter list for a flat and a round beam case
M.Biagini

Bunches are extracted and compressed (as in linear collider), then after collisions and disruption back to Dumping Rings



Injection of HER and LER at their collision energies

Injection System

electrons positrons