Why a SuperB Flavour Factory ?

Marcello A. Giorgi

INFN & Università di Pisa

Success of BFactories

Original mission

1)Search for CP violation in B meson decays as predicted in Standard Model

2)Measure precisely at this low energy scale enough quantities to impose constraints on the Standard Model parameters

$\not{CP}$ in b sector has been established by BaBar and Belle (2001)

TRY to open windows on new Physics beyond Standard Model

More precise CKM measurements, Rare B decays, Charm study, Tau rare decays .

3 ways to CP violation

CPV in decay:

$$A_{CP,f/\bar{f}} \equiv \frac{\Gamma(\bar{i} \to \bar{f}) - \Gamma(i \to f)}{\Gamma(\bar{i} \to \bar{f}) + \Gamma(i \to f)} = \frac{\left|\bar{A}_{\bar{f}} / A_f\right|^2 - 1}{\left|\bar{A}_{\bar{f}} / A_f\right|^2 + 1}$$

$$\left|\bar{A}_{\bar{f}} / A_f\right| \neq 1$$

CPV in mixing:

$$|q/p| \neq 1$$

$$A_{SL}(t) \equiv \frac{d\Gamma/dt\left(\bar{P}^0_{phys} \to l^+ X\right) - d\Gamma/dt\left(P^0_{phys} \to l^- X\right)}{d\Gamma/dt\left(\bar{P}^0_{phys} \to l^+ X\right) + d\Gamma/dt\left(P^0_{phys} \to l^- X\right)} = \frac{1 - |q/p|^4}{1 + |q/p|^4}$$

CPV in the interference decay-mixing:

$$\Im m(\lambda_f) \neq 0$$

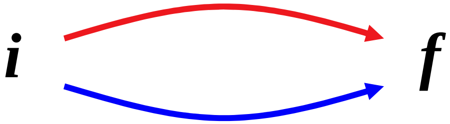
$$\lambda_f \equiv \frac{q}{p} \frac{\bar{A}_f}{A_f}$$

For example: decays to CP eigenstates f_{CP}

$$A_{f_{CP}}(t) \equiv \frac{d\Gamma/dt\left(\bar{P}^0_{phys} \to f_{CP}\right) - d\Gamma/dt\left(P^0_{phys} \to f_{CP}\right)}{d\Gamma/dt\left(\bar{P}^0_{phys} \to f_{CP}\right) + d\Gamma/dt\left(P^0_{phys} \to f_{CP}\right)}$$

Observables: "direct" CP asymmetry

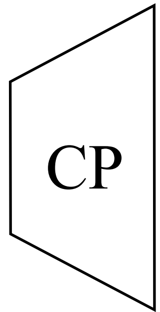
$A_1 = |A_1|$



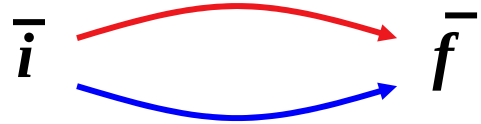
$A_2 = |A_2|\, e^{i\delta}\, e^{i\phi}$

$\delta \to \delta$ (CP-conserving)

$\phi \to -\phi$ (CP-violating)



$\bar{A}_1 = |A_1|$



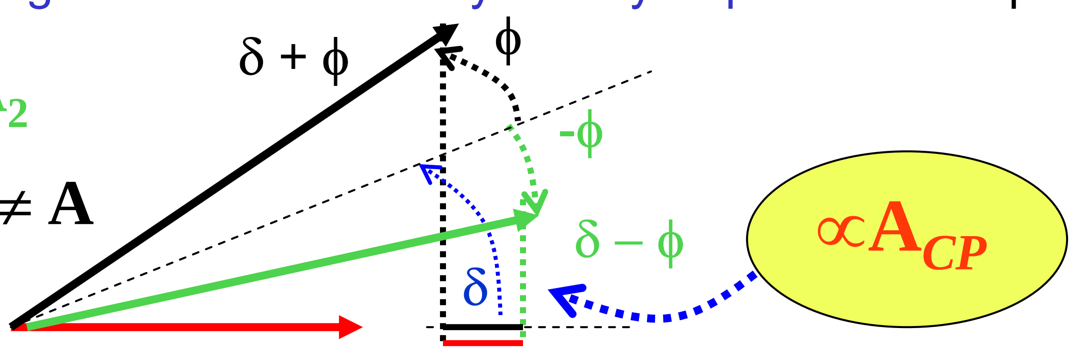
$\bar{A}_2 = |A_2|\, e^{i\delta}\, e^{-i\phi}$

$$A_{CP,f/\bar{f}} \equiv \frac{\Gamma(\bar{i} \to \bar{f}) - \Gamma(i \to f)}{\Gamma(\bar{i} \to \bar{f}) + \Gamma(i \to f)} \propto \sin\Phi \sin\delta$$

Time-integrated "direct" CP asymmetry requires two amplitudes and $\delta \neq 0$:

$A = A_1 + A_2$

$\bar{A} = A_1 + \bar{A}_2 \neq A$



A_{SL} , $|q/p|$, ε_B are related (CPV in mixing)

A_{SL} observable and CP parameters:

$$A_{SL} \equiv \frac{P\left(\overline{B}^0 \to B^0\right) - P\left(B^0 \to \overline{B}^0\right)}{P\left(\overline{B}^0 \to B^0\right) + P\left(B^0 \to \overline{B}^0\right)}$$

$$A_{SL} = \frac{\Gamma_{\Upsilon(4S)\to l^+l^+} - \Gamma_{\Upsilon(4S)\to l^-l^-}}{\Gamma_{\Upsilon(4S)\to l^+l^+} + \Gamma_{\Upsilon(4S)\to l^-l^-}} =$$

← at the B-factories

$$= \frac{|p/q|^2 - |q/p|^2}{|p/q|^2 + |q/p|^2} = \frac{1-|q/p|^4}{1+|q/p|^4} \cong \frac{4\,\mathrm{Re}\,\varepsilon_B}{1+|\varepsilon_B|^2}$$

← equivalent to ε_K in the K system

$$\varepsilon_B = \frac{p-q}{p+q} \quad \Rightarrow \quad \frac{q}{p} = \frac{1-\varepsilon_B}{1+\varepsilon_B}$$

$$\left|\frac{q}{p}\right| = \sqrt[4]{\frac{1-A_{SL}}{1+A_{SL}}}$$

Time dependent rate, flavor mixing and CP,T,CPT

CPV in Mixing -Decay

CPV direct

Time dependent rate:

$dN \propto \exp(-|\Delta t|/\tau_B)\,(\,1 \pm D\,(S \sin(\Delta m \Delta t) - C\cos(\Delta m \Delta t))\,) \otimes R$

D is the mis-tag dilution

R is the time resolution

$$S = \frac{2\,\mathrm{Im}\,\lambda}{1+|\lambda|^2} \qquad C = \frac{1-|\lambda|^2}{1+|\lambda|^2}$$

$$\lambda = \eta_{cp}\frac{q}{p}\frac{\overline{A}_{cp}}{A_{cp}}$$

$\left|\frac{q}{p}\right| \neq 1 \Rightarrow$ CP and T Violation in mixing

$$\lambda_{f_{CP}} = \eta_{f_{CP}}\frac{q}{p}\frac{\overline{A}_{f_{CP}}}{A_{f_{CP}}}$$

$\left|\frac{q}{p}\right| - 1 \approx 4\pi\frac{m_c^2}{m_t^2}\sin\beta \approx 5\times10^{-4}$ SM

CP eigenvalue

$\approx e^{-i2\beta}$ from mixing

Amplitude ratio

$$z = 2\frac{\delta M - (i/2)\delta\Gamma}{\Delta m - (i/2)\Delta\Gamma}$$

z≠0 CP & CPT violation

CPV in Standard Model

$$V = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

CP Violating phase

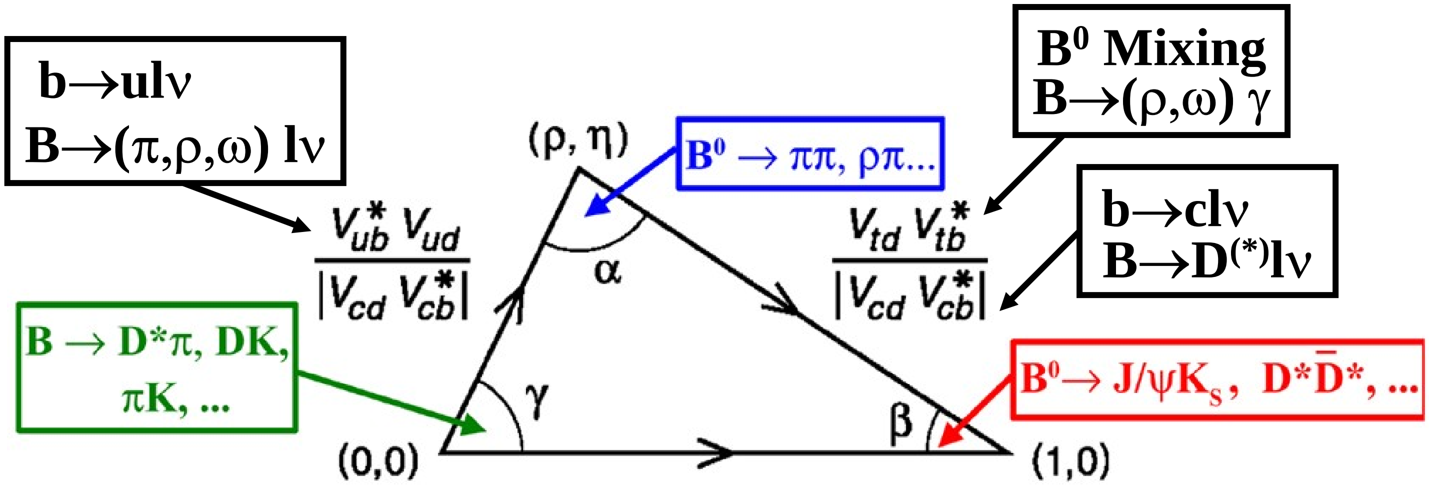
CKM quark mixing matrix

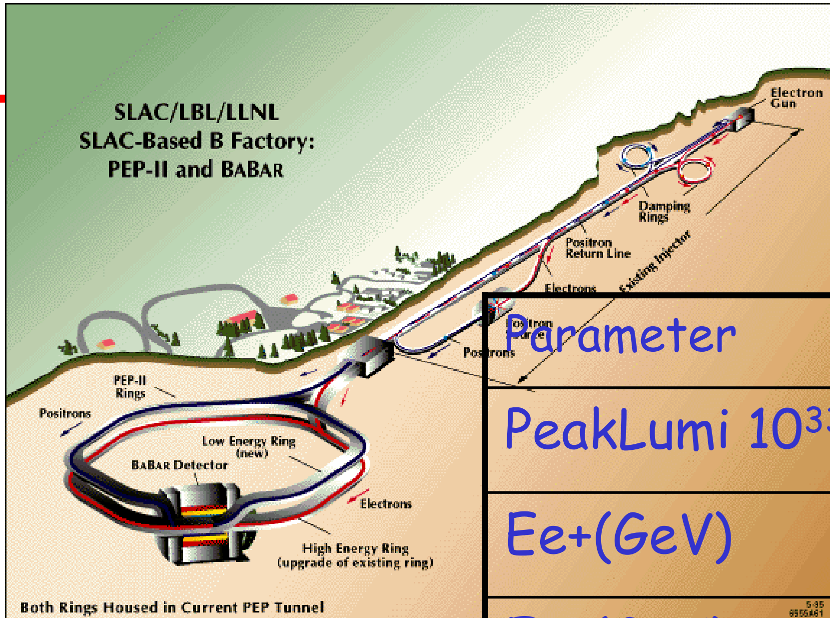
Unitarity

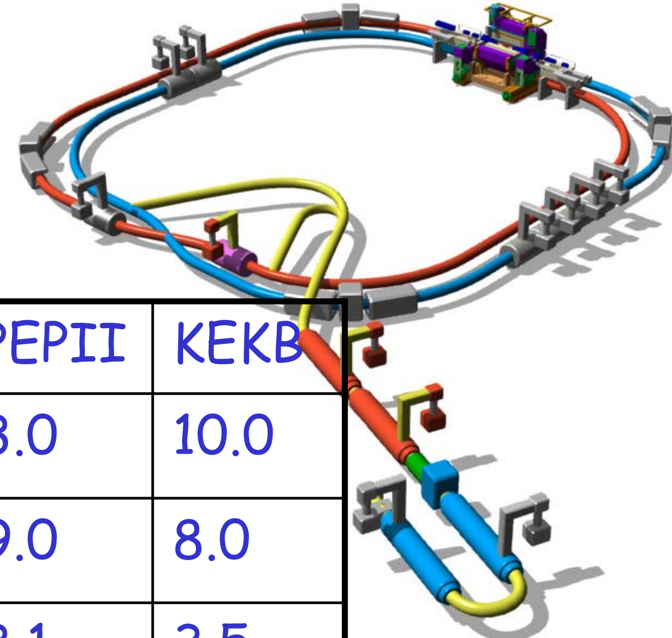
d•s* = 0 (K system)

s•b* = 0 (B_s system)

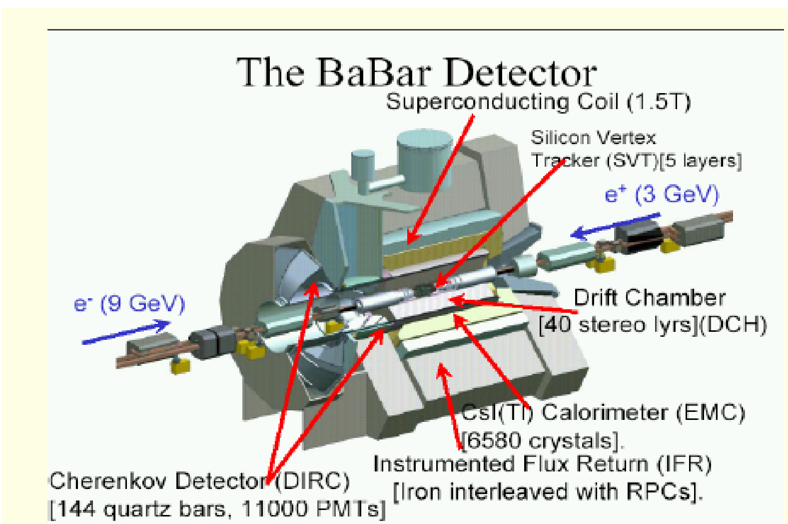
d•b* = 0 (B_d system)

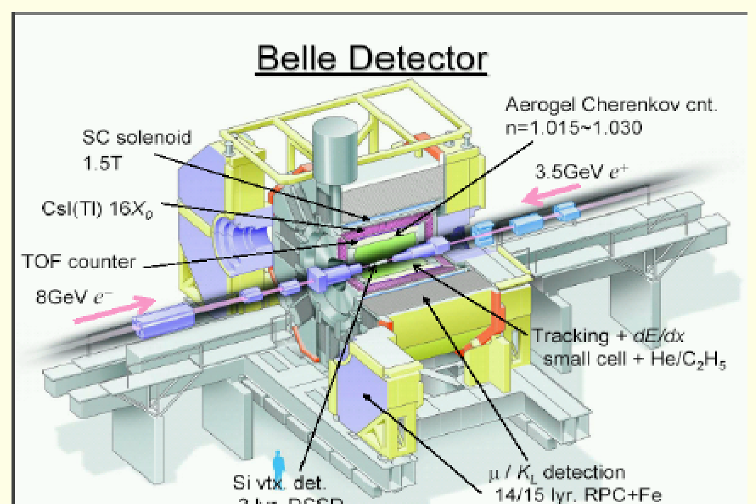






Parameter	PEPII	KEKB
PeakLumi $10^{33} cm^{-2}\ s^{-1}$	3.0	10.0
Ee+(GeV)	9.0	8.0
Ee-(GeV)	3.1	3.5





Peak Luminosities are now

9 10^{33} in PPEPII

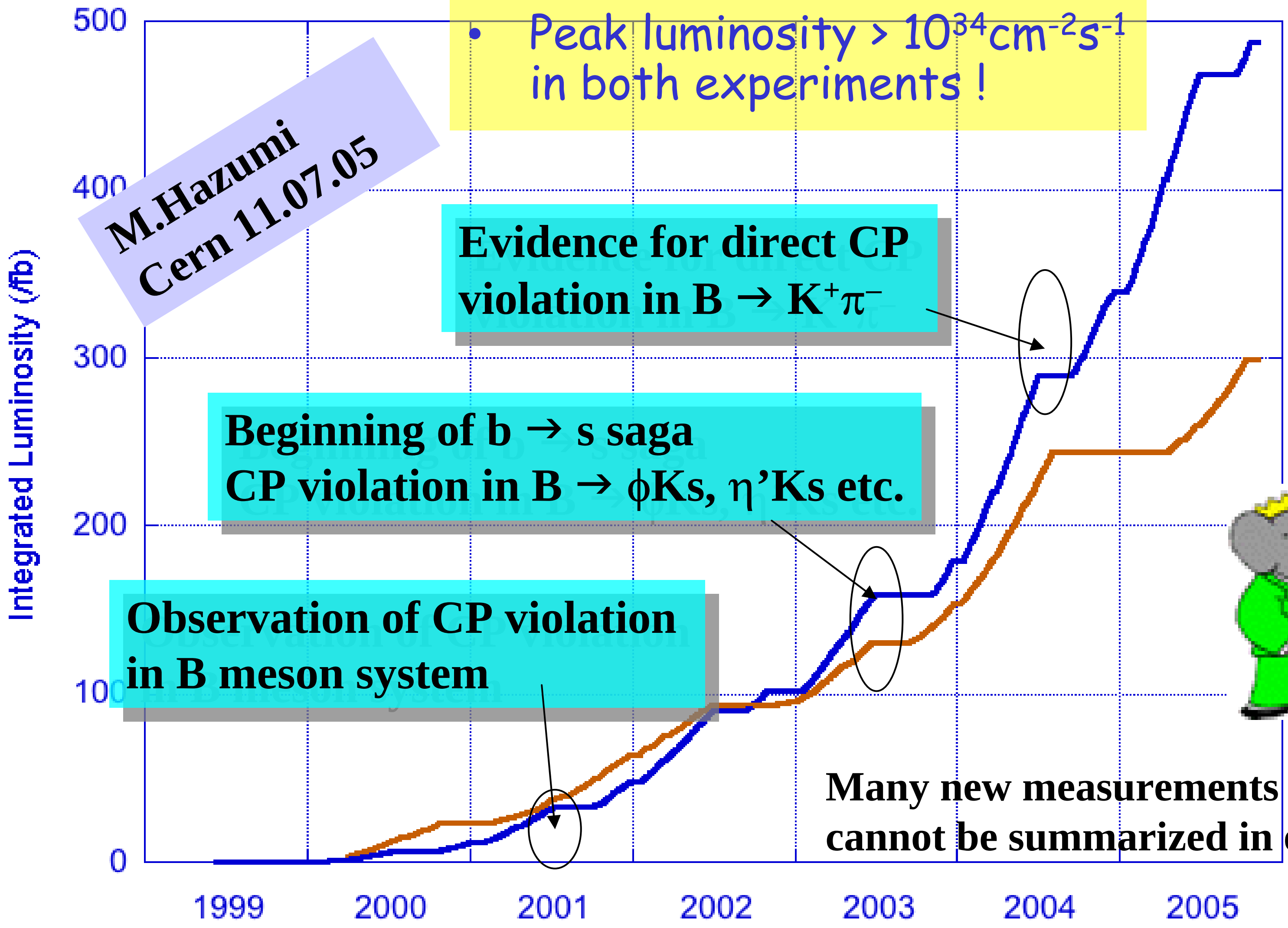
And

14 10^{33} in KEKB

The integrated luminosity doubles every 2 years

Great Success of PEPII and KEKB

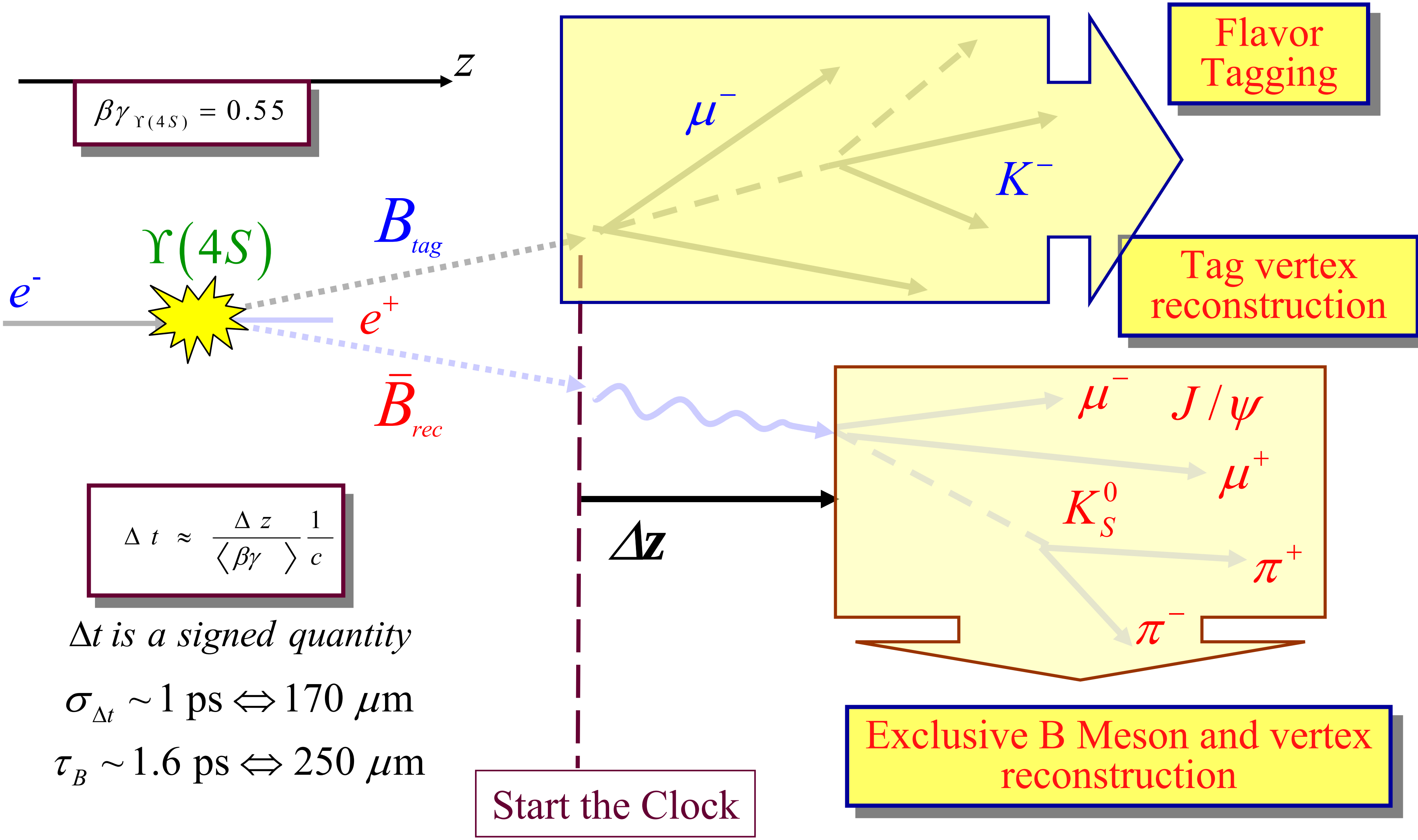
- ~0.8 ab^{-1} in total (sum) !
- Peak luminosity > 10^{34}cm^{-2}s^{-1} in both experiments !



Many new measurements cannot be summarized in one page

Measuring time-dependent CP asymmetries

Tagging performance: Q = 30.5%



$$\Delta t \approx \frac{\Delta z}{\langle \beta\gamma \rangle} \frac{1}{c}$$

Δt is a signed quantity

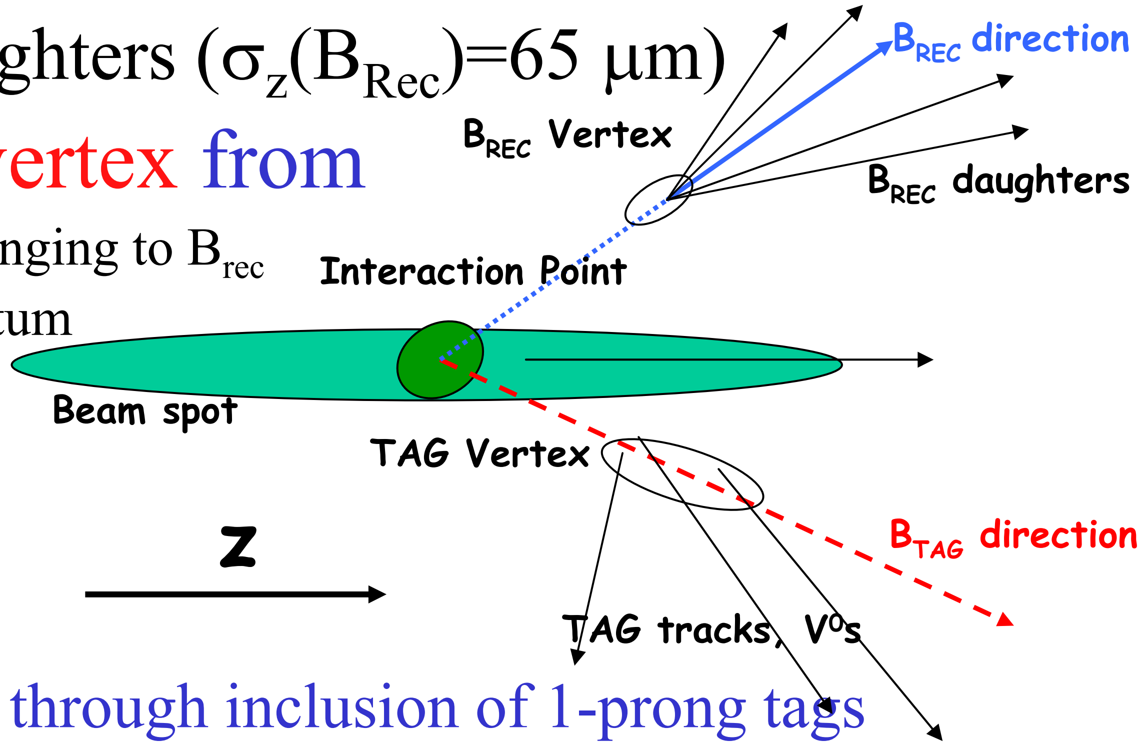
$\sigma_{\Delta t} \sim 1\ \text{ps} \Leftrightarrow 170\ \mu\text{m}$

$\tau_B \sim 1.6\ \text{ps} \Leftrightarrow 250\ \mu\text{m}$

Vertex and Δt Reconstruction

TOOLS!

- Reconstruct B_{rec} vertex from
  - charged B_{rec} daughters ($\sigma_z(B_{Rec})$=65 μm)
- Determine B_{Tag} vertex from
  - charged tracks not belonging to B_{rec}
  - B_{rec} vertex and momentum
  - beam spot and Y(4S) momentum

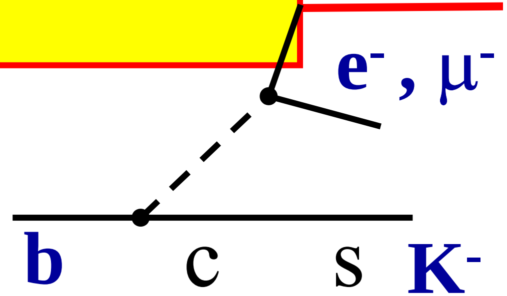


- High efficiency (93%) through inclusion of 1-prong tags
- Average resolution in Δz is 180 μm (<|Δz|> = $\beta\gamma c t$ = 260 μm) corresponding to a Δt resolution of 0.6 ps.
- Δt resolution function measured from data (B_{flav} sample)

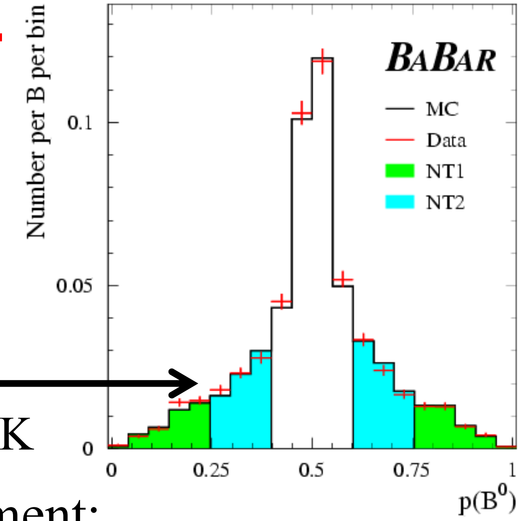
Flavor Tagging

TOOLS!

Hierarchical tagging categories:



- Lepton – charge of lepton
- Kaon – net charge of kaon
- NT1 } exploit information from momentum spectrum
- NT2 } of charged particles, soft π from D*, unidentified l and K



Large B_{flav} sample provide tagging performance measurement:

Tagging category	Efficiency ε (%)	Mistag fraction w (%)	$B^0/\overline{B}^0$ diff. Δw (%)	$Q = \varepsilon(1-2w)^2$ (%)
Lepton	11.1 ± 0.2	**8.6 ± 0.9**	0.6 ± 1.5	7.6 ± 0.4
Kaon	**34.7 ± 0.4**	18.1 ± 0.7	-0.9 ± 1.1	14.1 ± 0.6
NT1	7.7 ± 0.2	22.0 ± 1.5	1.4 ± 2.3	2.4 ± 0.3
NT2	14.0 ± 0.3	37.3 ± 1.3	-4.7 ± 1.9	0.9 ± 0.2
ALL	67.5 ±0.5			**25.1 ± 0.8**

$\sigma(\sin 2\beta) \propto 1/\sqrt{Q}$

TOOLS!

Two kinematical variables are used in BaBar analyses to select B mesons :

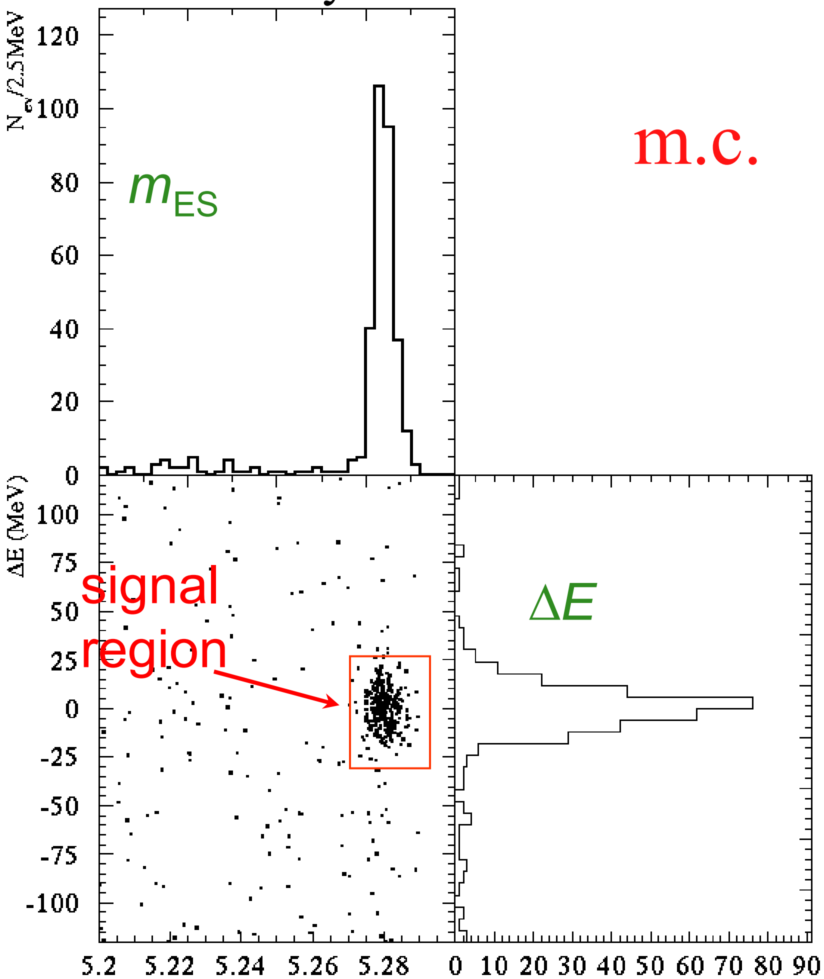
Energy substituted mass

$$m_{ES} = \sqrt{s/4 - p_B^{*2}}$$

the resolution on m_{ES} is 2.6 MeV/c^2 and mainly depends on the E_{beam} uncertainty

$$\Delta E = E_B^* - \sqrt{s}/2$$

ΔE depends on the decay channel(masses of products..), its resolution mainly on tracking



PHYSICS MENU

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

- UT angles precision measurements
  - b→ccs Charmonium B→J/Ψ Ks giving sin2β
  - b→sss penguin also sin2β in SM very sensitive to new physics
  - CPV Asymmetries in $B \to \phi K_s$, $K_s\pi^0$ 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

Direct CPV

No evidence in other channels!!

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

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

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

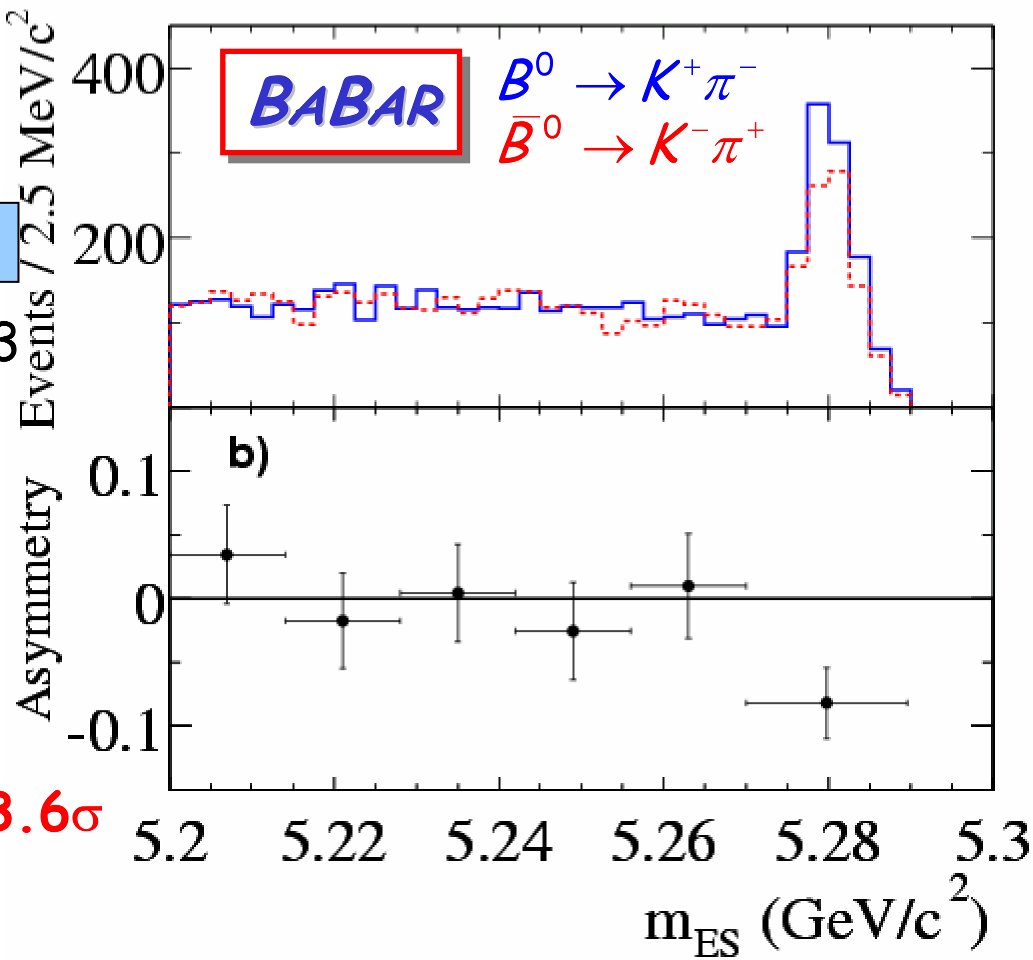
$A_{CP} = +0.06 \pm 0.06 \pm 0.01$ BABAR

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

3.6σ

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

Signal (227M $B\bar{B}$ pairs): 1606 ± 51



CPV in B_d mixing: A_{SL}

Experimental status:
from measurements at LEP, CLEO, BaBar and Belle:

$$|q/p| = 1.0013 \pm 0.0067$$
$$A_{SL} = -0.0026 \pm 0.0034$$
$$\frac{\text{Re}\ \varepsilon_B}{1+|\varepsilon_B|} = -0.0007 \pm 0.0017$$

HFAG, Winter'05 average

Not easy to improve: systematics!

For example, the most recent paper: *BELLE,* hep-ex/0505017:

$$A_{\text{sl}} = (-1.1 \pm 7.9(\text{stat}) \pm 7.0(\text{sys})) \times 10^{-3},$$
$$|q/p| = 1.0005 \pm 0.0040(\text{stat}) \pm 0.0035(\text{sys}).$$
$$\frac{\text{Re}(\epsilon_B)}{1+|\epsilon_B|^2} = (-0.3 \pm 2.0(\text{stat}) \pm 1.7(\text{sys})) \times 10^{-3}$$

BELLE 2005
(78 + 9) fb^{-1}

< 1/5 of the available data !

New unitarity triangle with new values

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

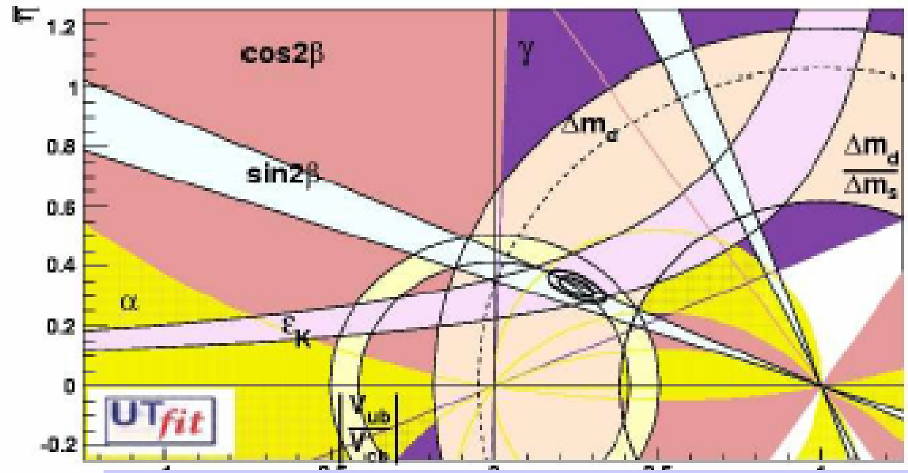
Sin2β=0.652±0.039±0.020

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

New average values BaBar Belle

Sin2β=0.685±0.032

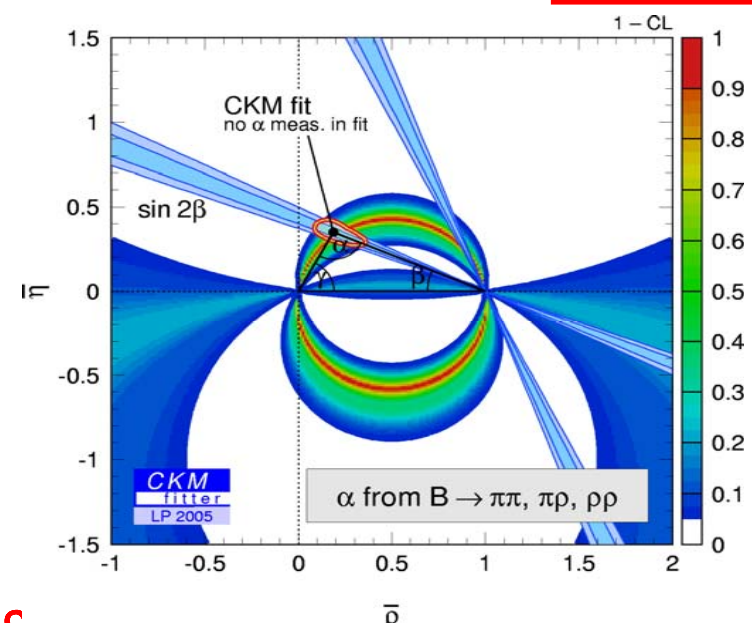
C=0.016±0.046

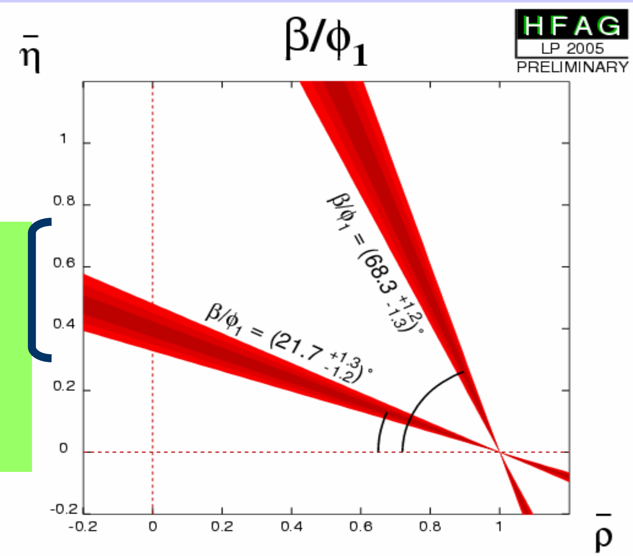


New value of Sin2β vs. UT general fit with new Vub/Vcb value

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

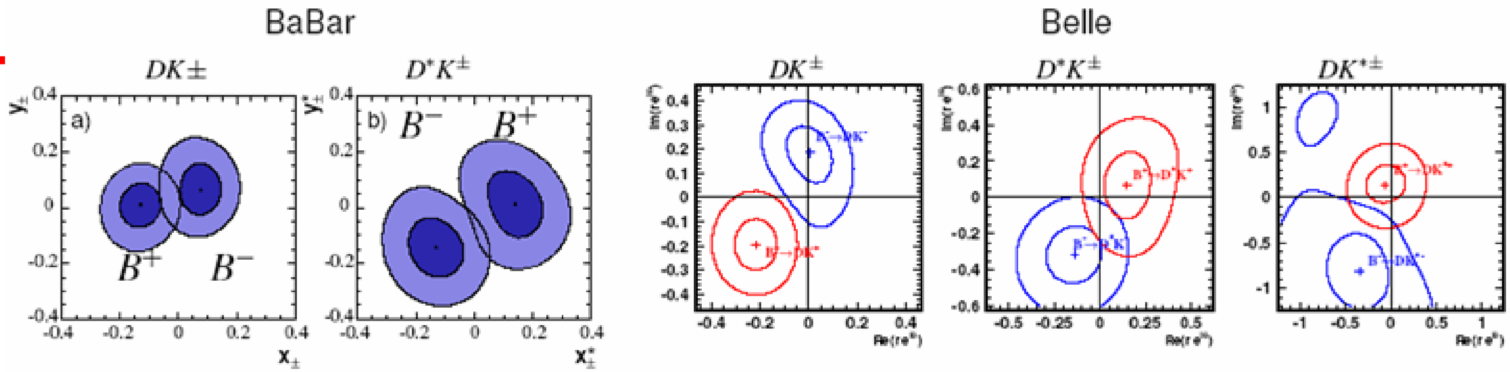
$\alpha[\text{all}] = (99\,^{+12}_{-9})°$





After Lp 05 Preferred solution

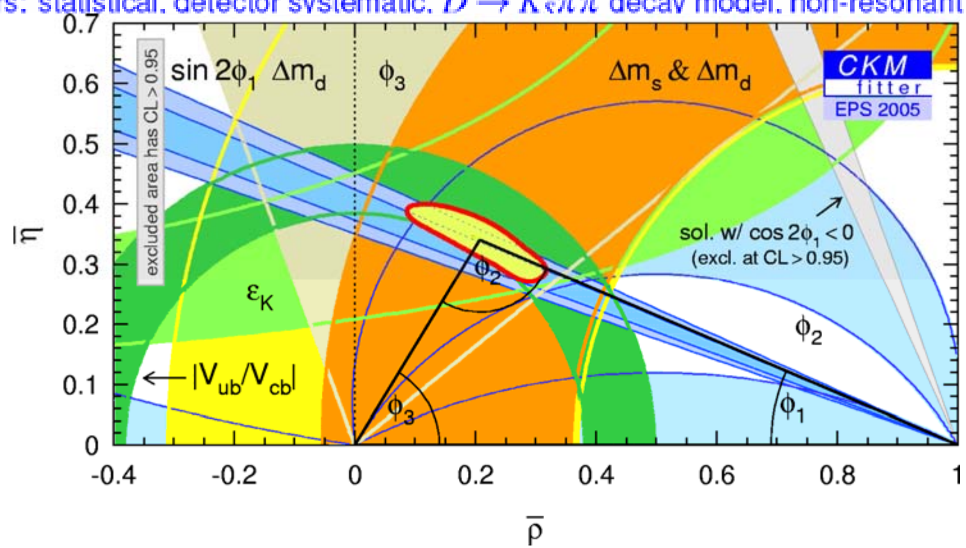
Including Φ_3/γ mainly from Dalitz analysis



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	$0.118 \pm 0.079 \pm 0.034^{+0.036}_{-0.034}$	$104 \pm 45^{+17}_{-21}{}^{+16}_{-24}$	
	D^*K	$0.169 \pm 0.096^{+0.030}_{-0.028}{}^{+0.029}_{-0.026}$	$296 \pm 41^{+14}_{-12} \pm 15$	
	combined			$70 \pm 31^{+12}_{-10}{}^{+14}_{-11}$
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^*	$0.25^{+0.17}_{-0.18} \pm 0.09 \pm 0.04 \pm 0.08$	$358 \pm 35 \pm 8 \pm 21 \pm 49$	$112 \pm 35 \pm 9 \pm 11 \pm 8$

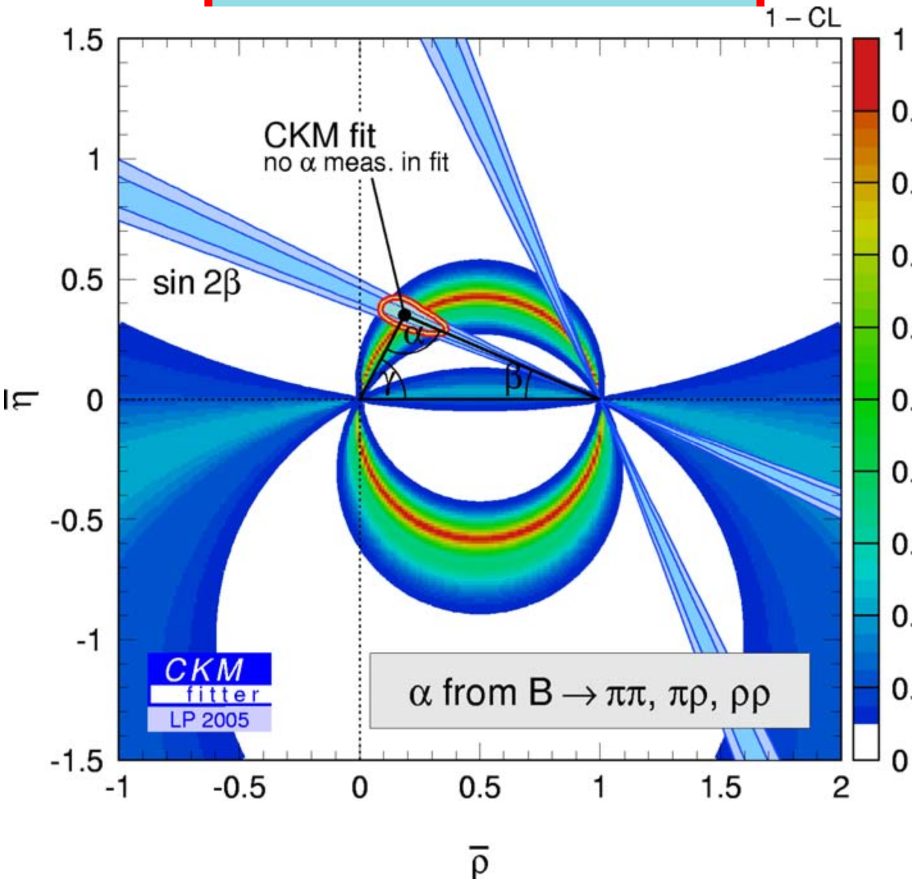
Errors: statistical, detector systematic, $D \to K_s\pi\pi$ decay model, non-resonant $DK\pi$



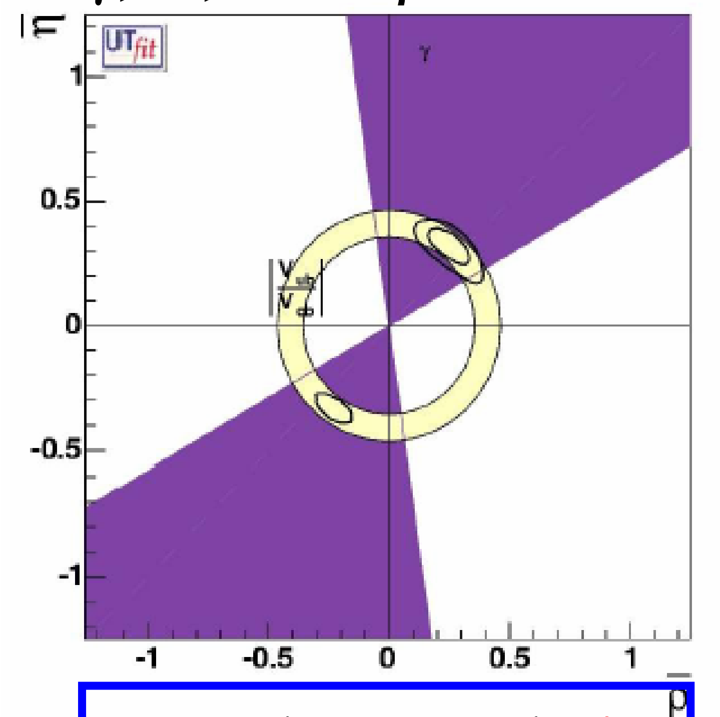
Hints of NP from UT ?

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

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



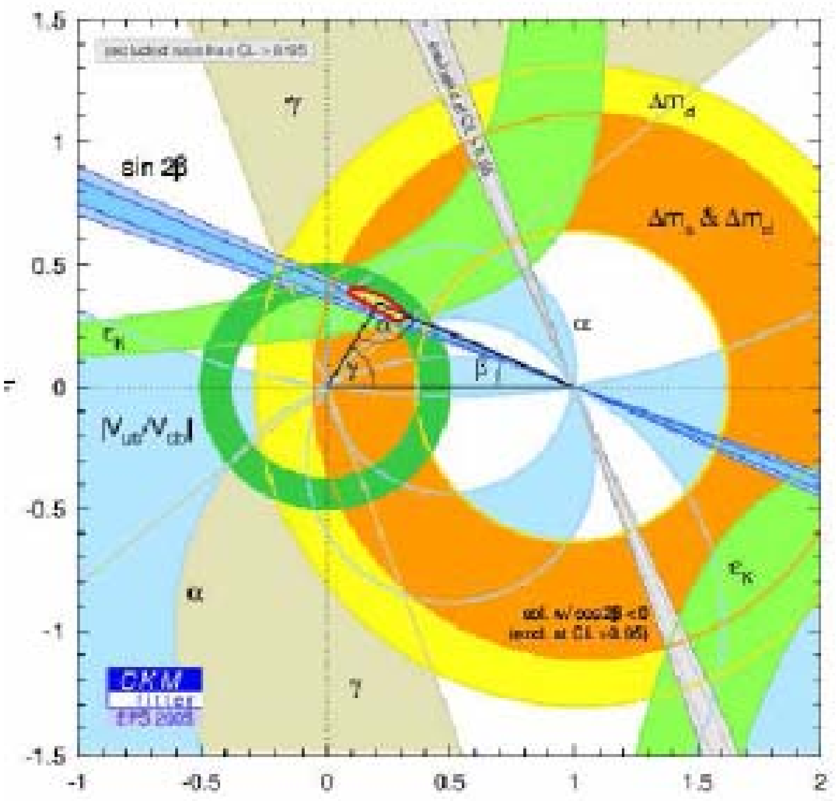
USE: ε, Δm_d, sin 2β, γ, α, cos 2β



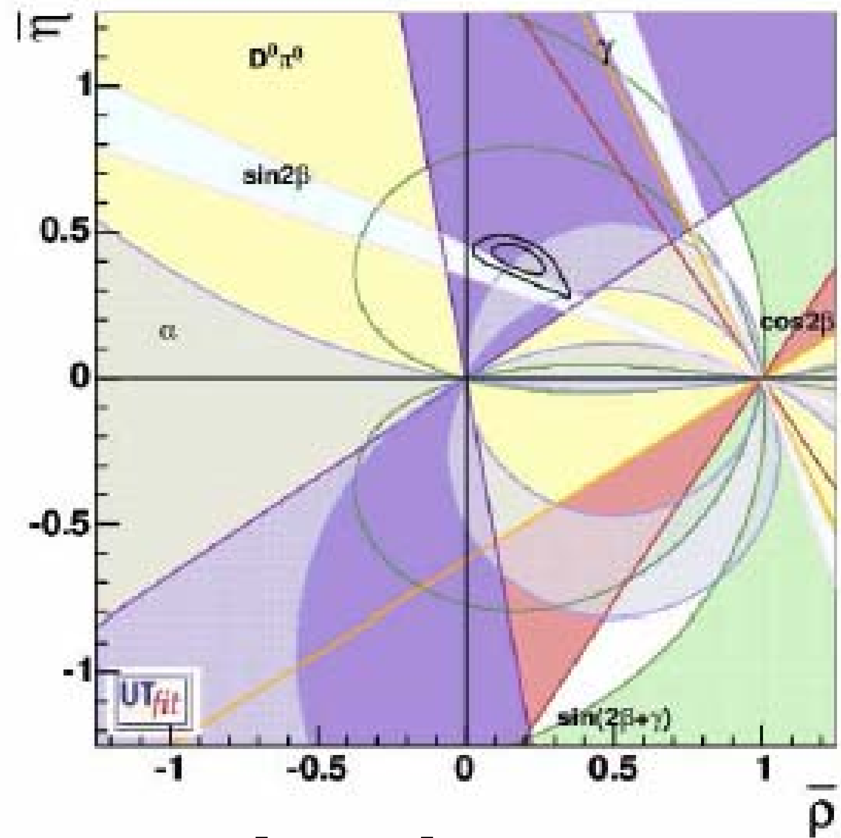
From the general **Fit** : SM at 93% C. L.
NP at 7% C. L.

L.Silvestrini LP05

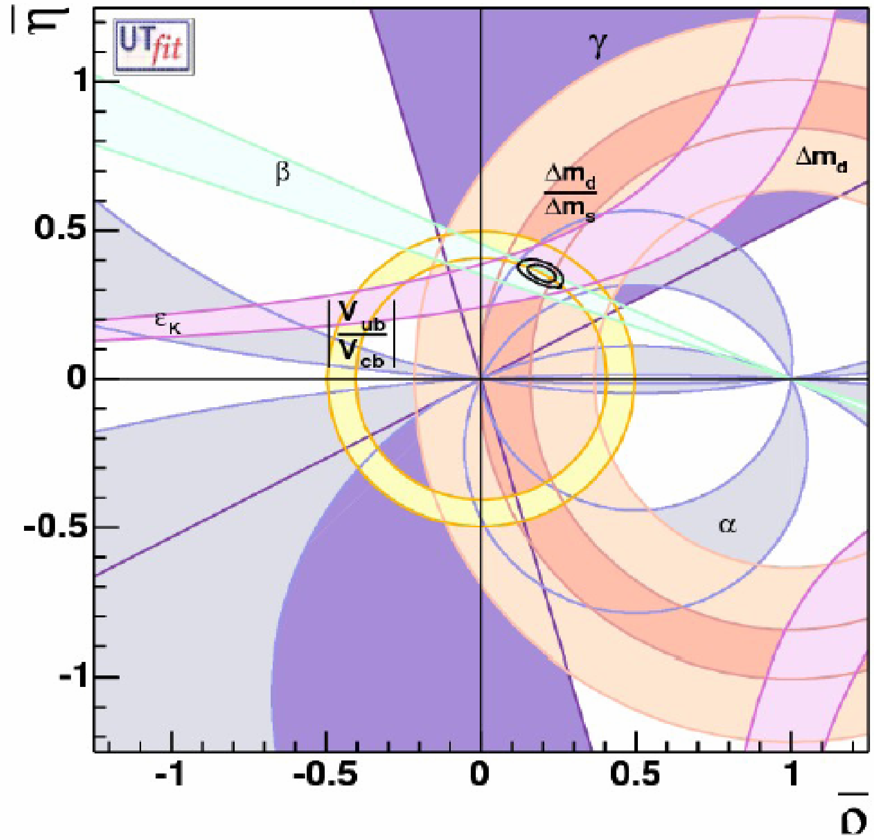
But great success of CKM

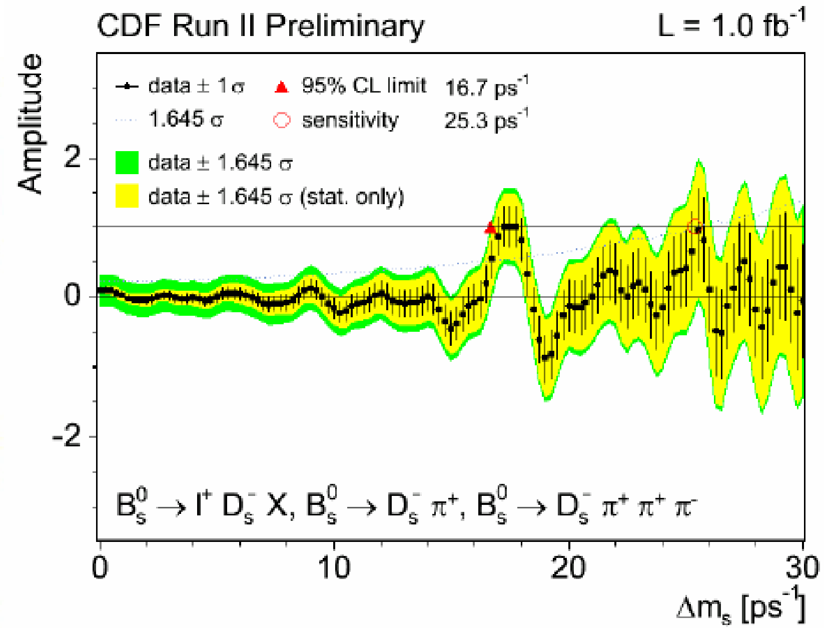


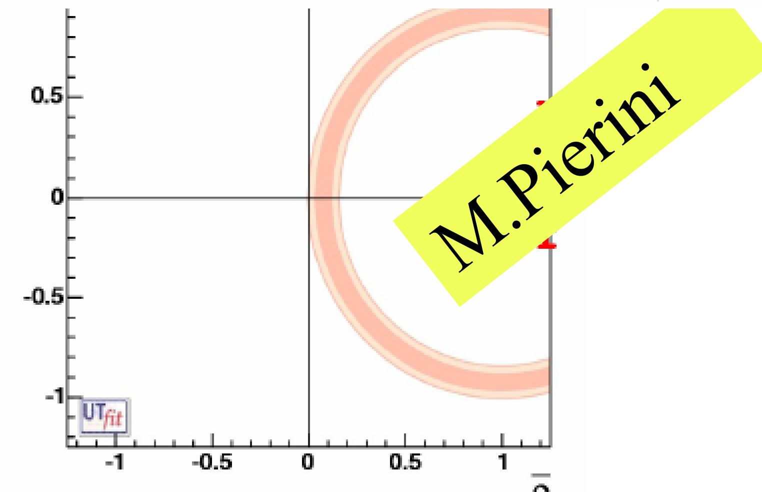
Sides and angles



only angles





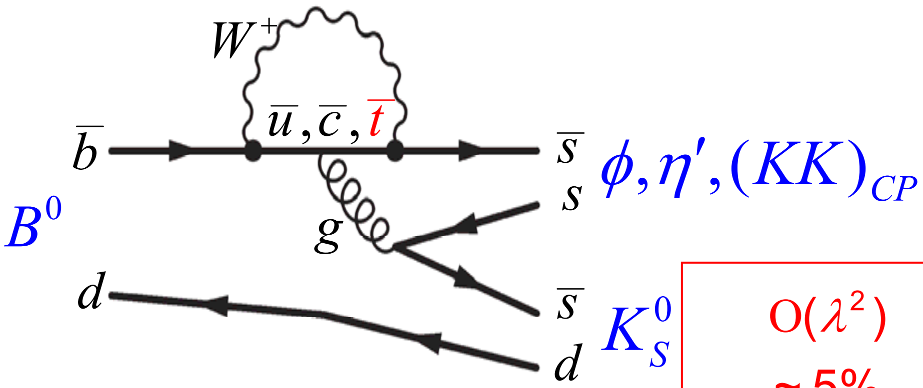


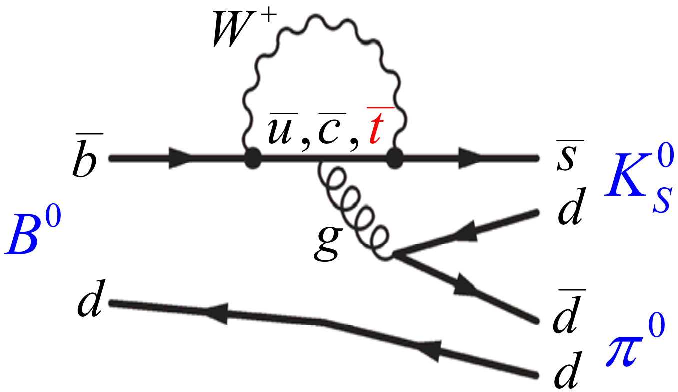
$\bar{\rho} = 0.193 \pm 0.029$
[0.133, 0.248] @ 95% Prob.

$\bar{\eta} = 0.355 \pm 0.019$
[0.318, 0.393] @ 95% Prob.

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!





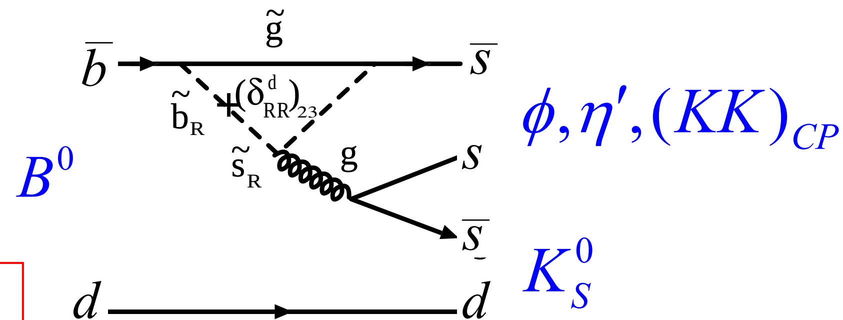
$O(\lambda^2)$

$\sim 5\%$

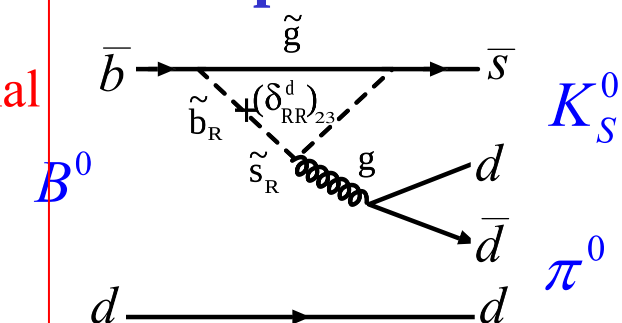
Purely dimensional estimate

$O(\lambda^2 / \bar{\lambda})$

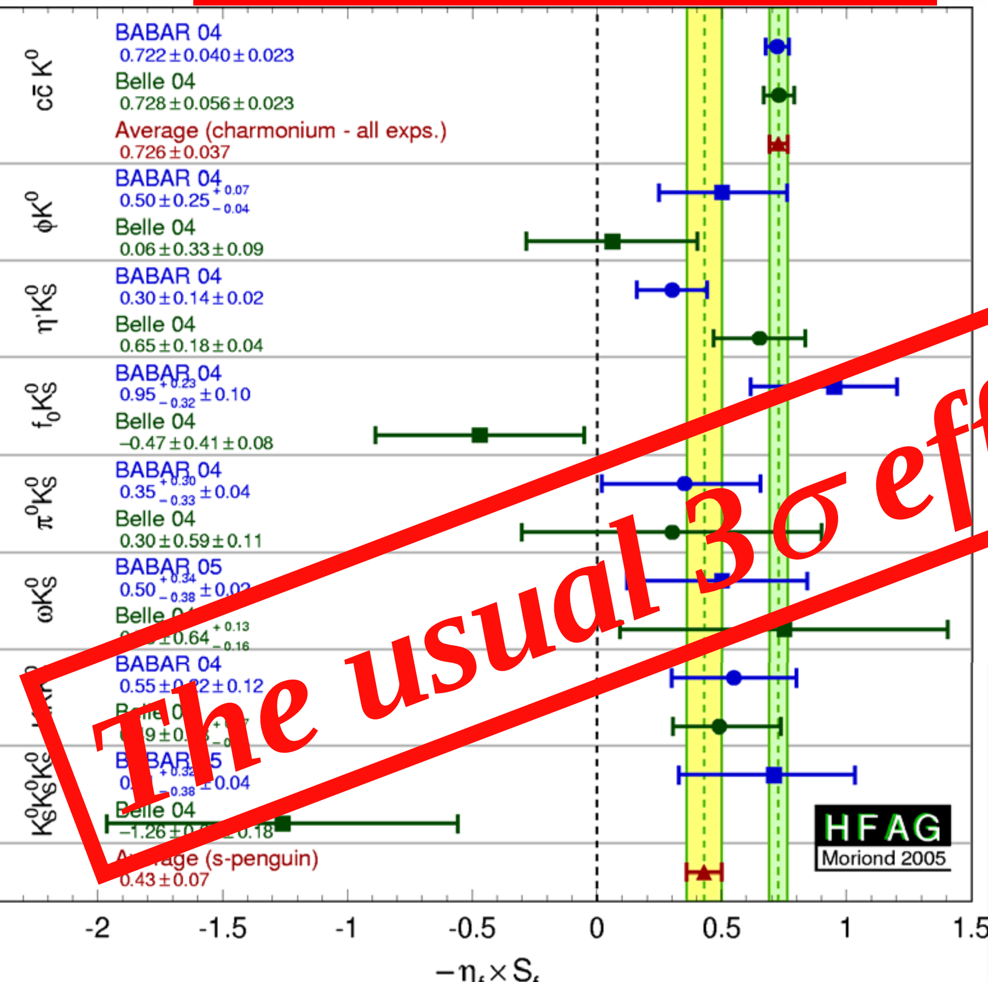
$\sim 20\%$



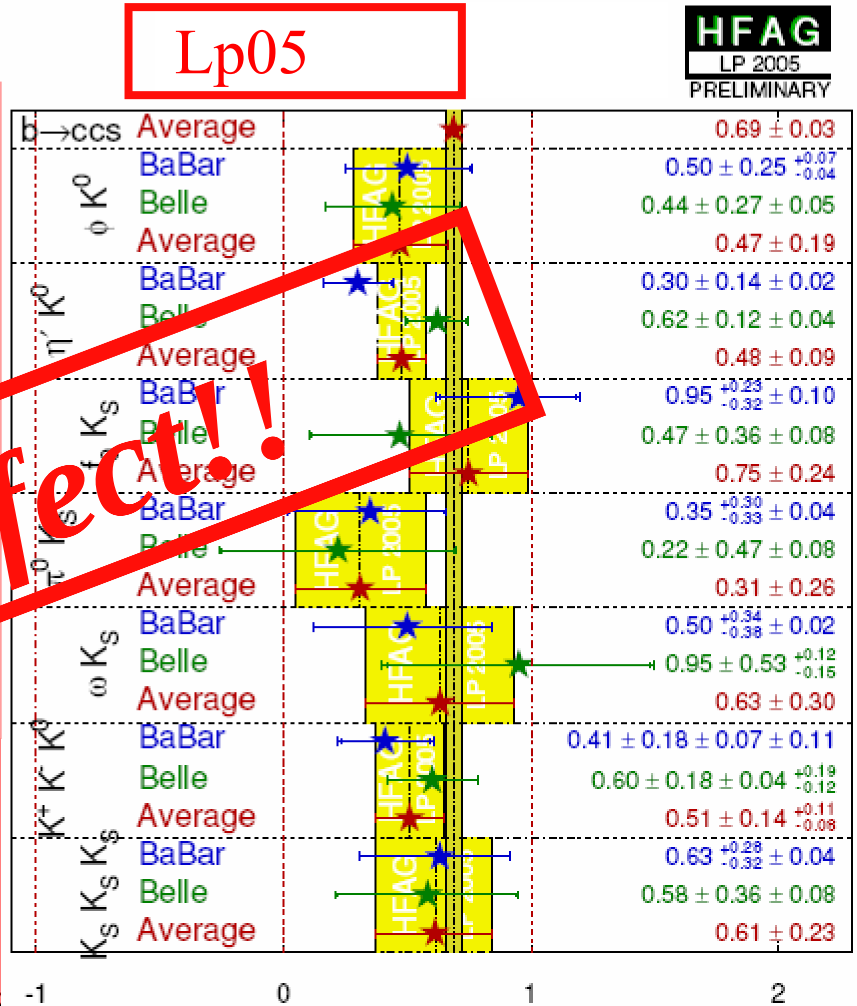
New phases from SUSY?



Before summer05



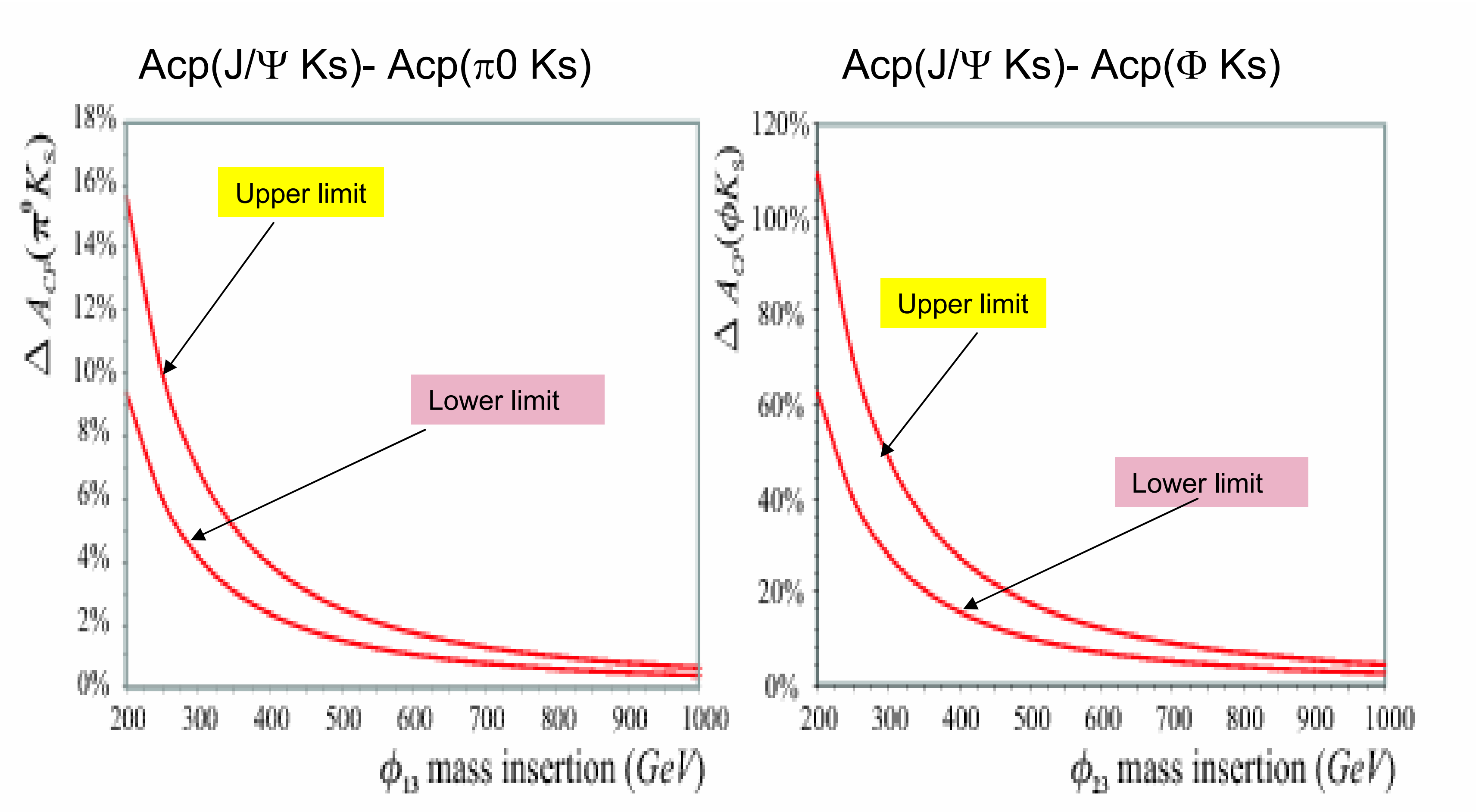
Lp05



The usual 3σ effect!!

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

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



Model independent estimate by
Ciuchini,Franco,Masiero,Silvestrini. PRL**79**,978

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

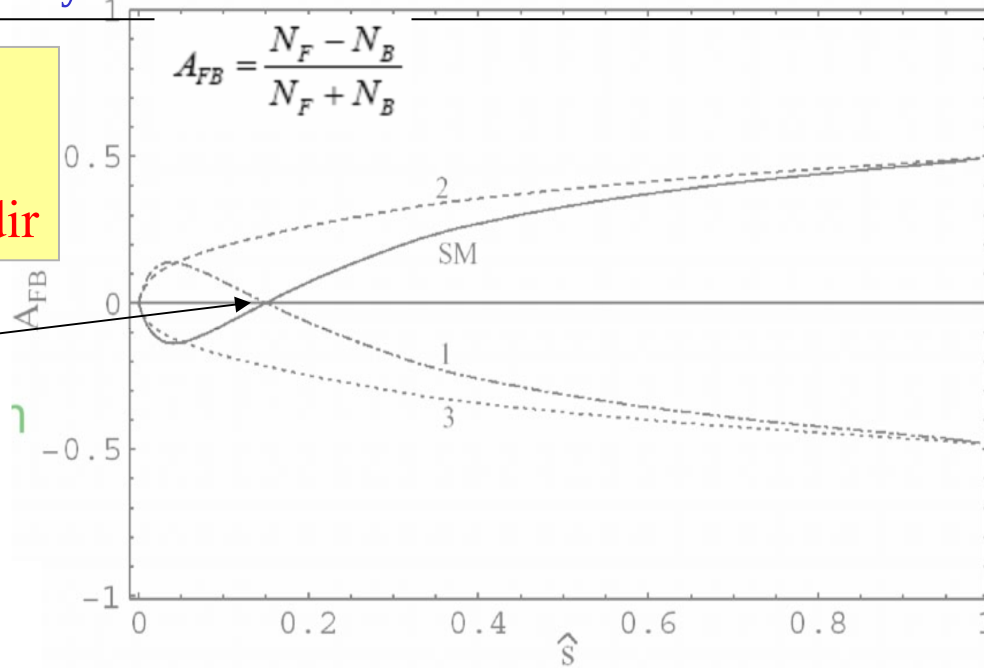
$A_{cp}(B\rightarrow s\, l^+ l^-)$	**SM:** <0.5% (0.05% for $K^*\, l^+ l$)
$A_{cp}(B\rightarrow d\, l^+ l^-)$	**SM:** $^-$~(4.4+/-4)%
$B(B\rightarrow s\mu^+\mu^-)/B(B\rightarrow se^+e^-)$	**SM:** ~1
$A^{FB}(K^*l^+ l^-)$:s_0(zero crossing)	SM predicts with ~5% accuracy
$A^{FB}(K^*l^+ l^-)$:CP asymmetry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

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



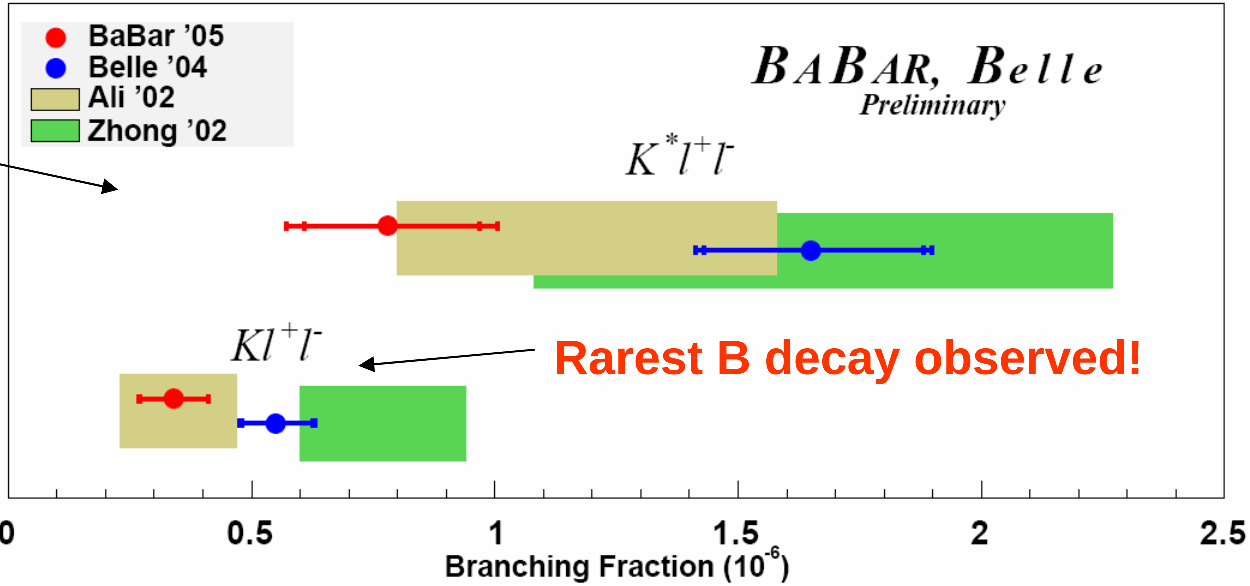
$$\hat{s} = (m_{l^+l^-}/m_b)^2$$

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

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

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

theory uncertainty >
experimental uncertainty

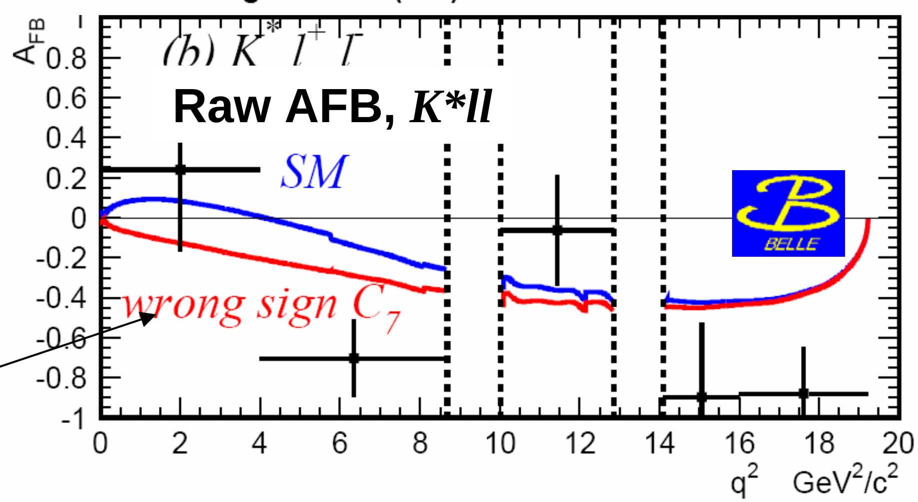


Beyond branching fractions: Asymmetries

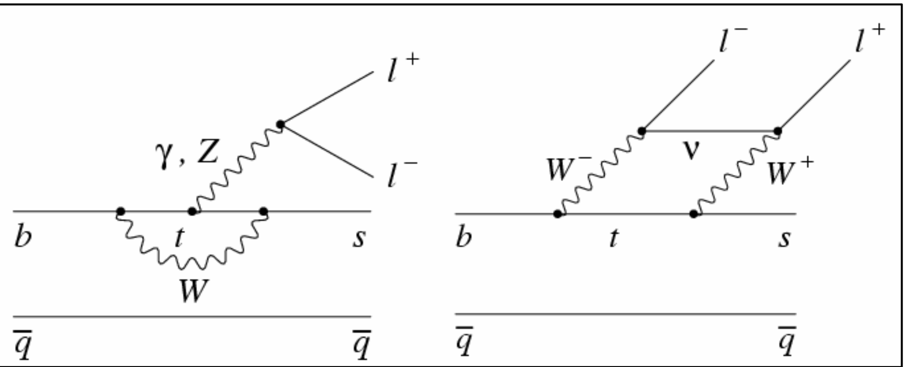
A_{CP} consistent with zero

$K\mu\mu/Kee$ ratio consistent with unity

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



B→K(*)l+l-, Kνν



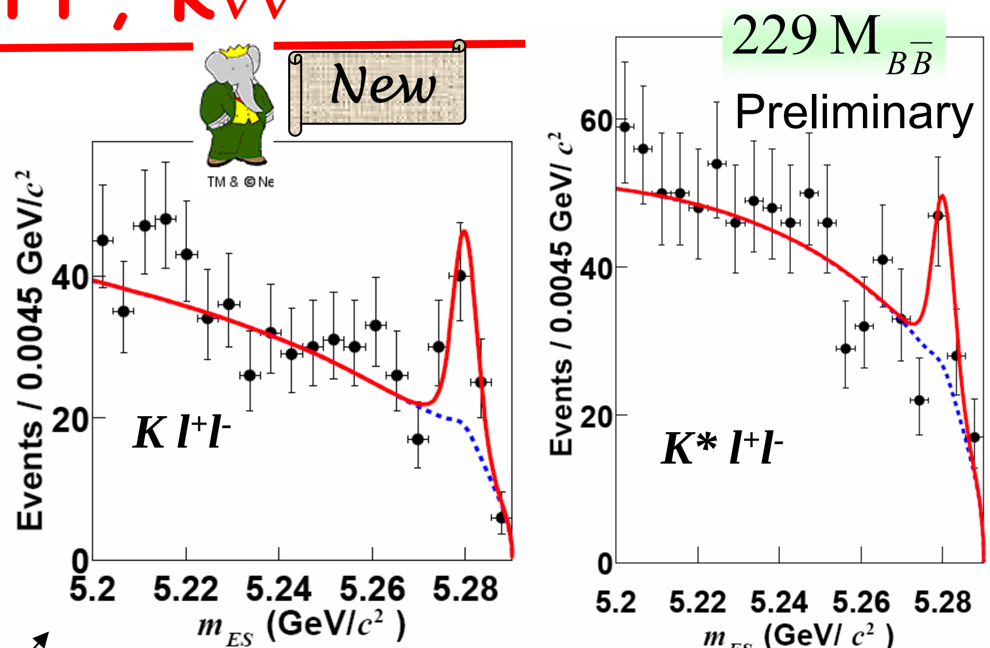
Clean probes of EW scale physics

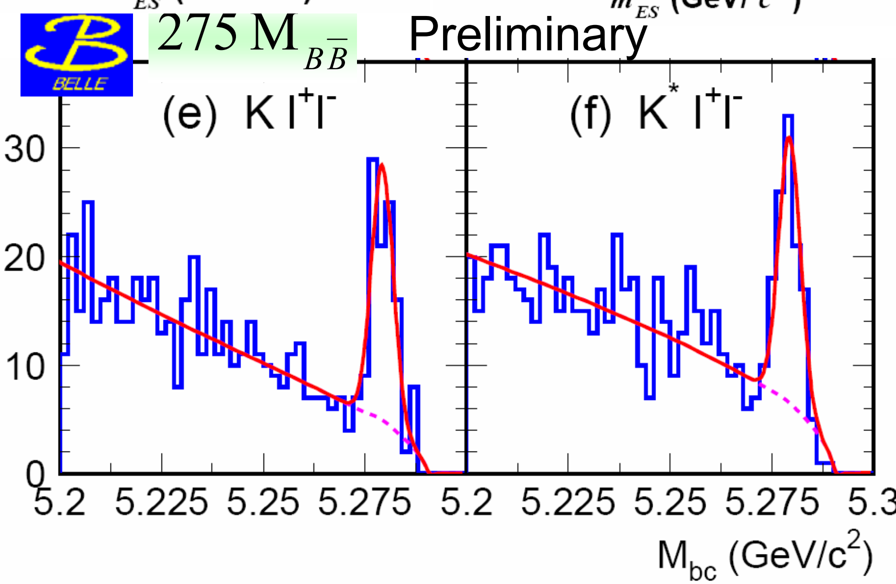
Branching fractions ~ 10^{-6}

Well-established *Kll*, *K*ll* signals for B factories ($l = e, \mu$)

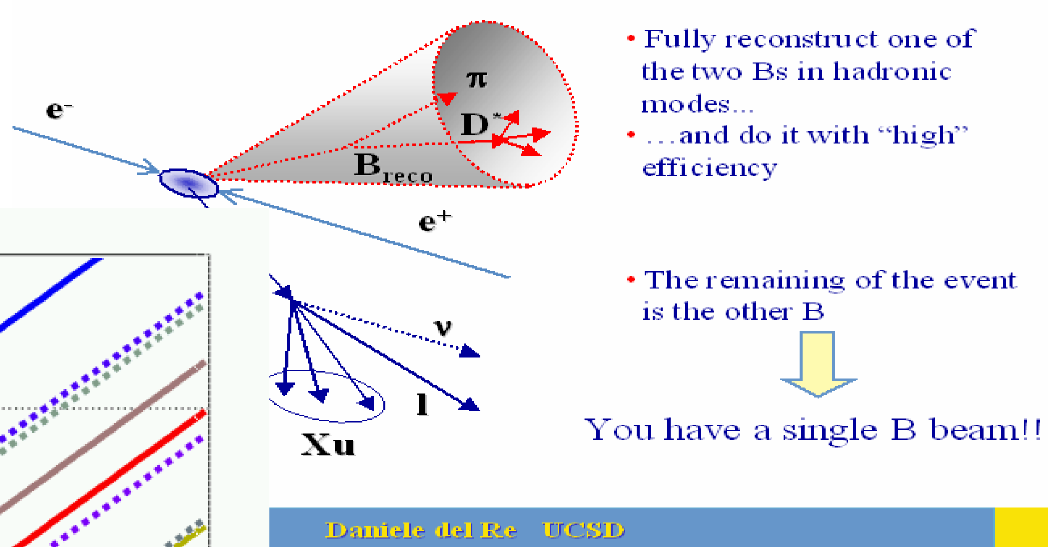
$BF \times 10^6$	$89 M_{B\bar{B}}$	$275 M_{B\bar{B}}$ New
$B(B \to K\nu\nu)$	< 52	< 36
$B(B \to \pi\nu\nu)$	< 100	

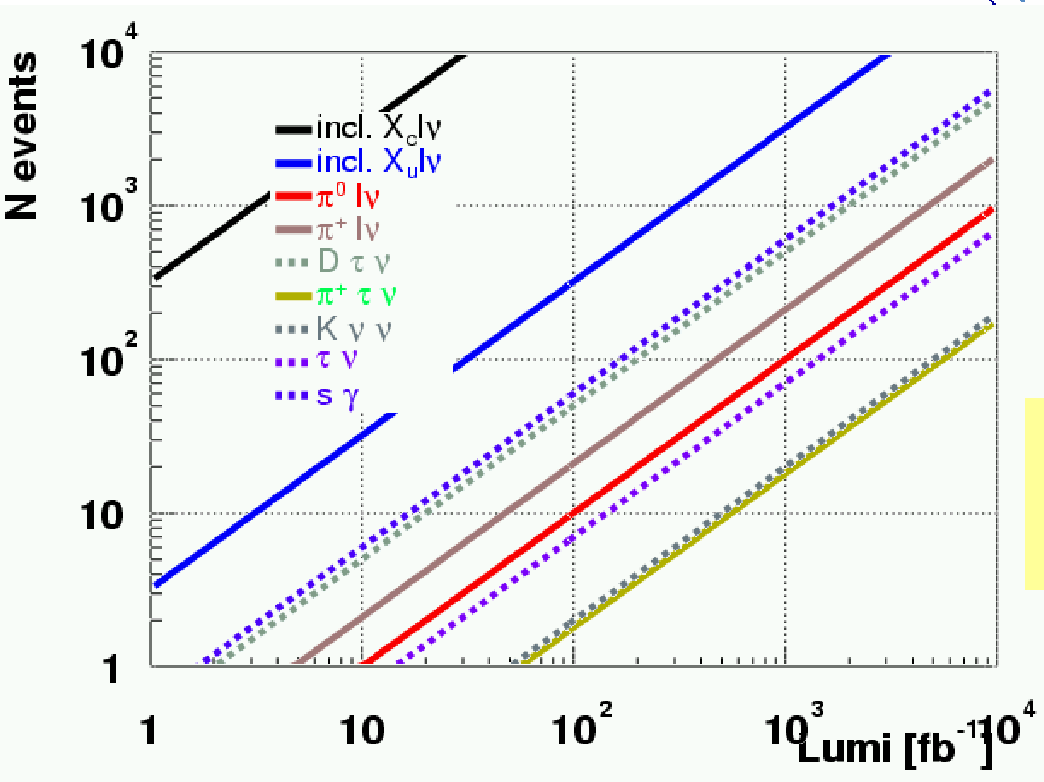
Kνν sensitivity now <10X SM rate





Recoil Method as pure B beam





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}

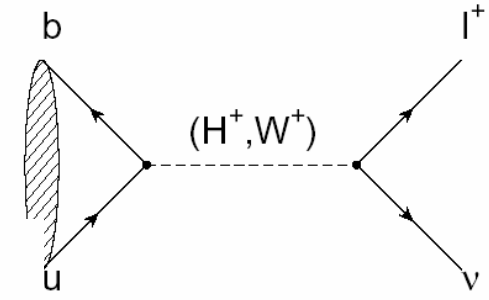
> 10^7 recoil Bs in 10ab^{-1}

Theoretical uncertainties

Measurement (in SM)	Theoretical limit	Present error
$B \to \psi K_S \;\; (\beta)$	$\sim 0.2^\circ$	1.6°
$B \to \phi K_S,\; \eta^{(\prime)} K_S, \ldots \; (\beta)$	$\sim 2^\circ$	$\sim 10^\circ$
$B \to \pi\pi,\; \rho\rho,\; \rho\pi \;\; (\alpha)$	$\sim 1^\circ$	$\sim 15^\circ$
$B \to DK \;\; (\gamma)$	$\ll 1^\circ$	$\sim 25^\circ$
$B_s \to \psi\phi \;\; (\beta_s)$	$\sim 0.2^\circ$	—
$B_s \to D_s K \;\; (\gamma - 2\beta_s)$	$\ll 1^\circ$	—
$\lvert V_{cb} \rvert$	$\sim 1\%$	$\sim 3\%$
$\lvert V_{ub} \rvert$	$\sim 5\%$	$\sim 15\%$
$B \to X \ell^+ \ell^-$	$\sim 5\%$	$\sim 25\%$
$B \to K^{(*)} \nu \bar{\nu}$	$\sim 5\%$	—

Ligeti, ICHEP 2004

$B \to \tau\nu$

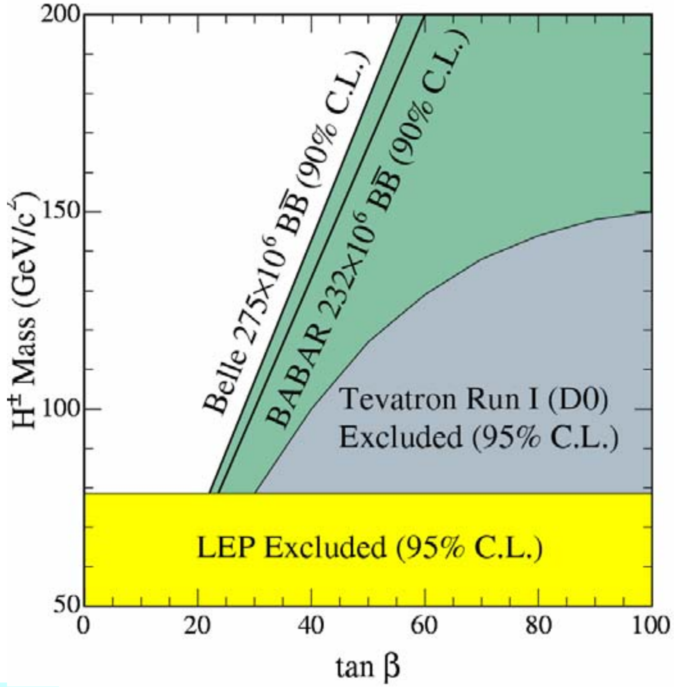


- SM expectation $\mathrm{B}(B \to \tau\nu) = (9.3 \pm 3.9) \times 10^{-5}$

$$\mathcal{B}(B^+ \to \tau^+\nu_\tau) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

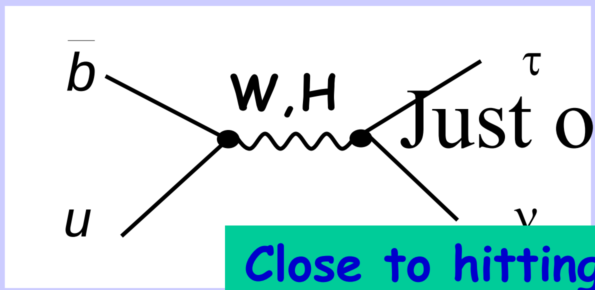
- Direct measurement of f_B (currently only from LQCD)
- $\mathrm{B}(B \to \tau\nu) / \Delta M_{B_d}$ constrains $|V_{ub}|^2 / |V_{td}|^2$

- > 2 ν in the event
  - Use hadronic or semileptonic tag
  - 1 or 3 prong topology
- Can constrain SUSY parameters



$\mathrm{B}(B \to \tau\nu)$	new 232 $M_{B\bar{B}}$	new 275 $M_{B\bar{B}}$
	$< 2.6 \times 10^{-4}$ @90%C.L.	$< 1.8 \times 10^{-4}$ @90%C.L.

B→τν

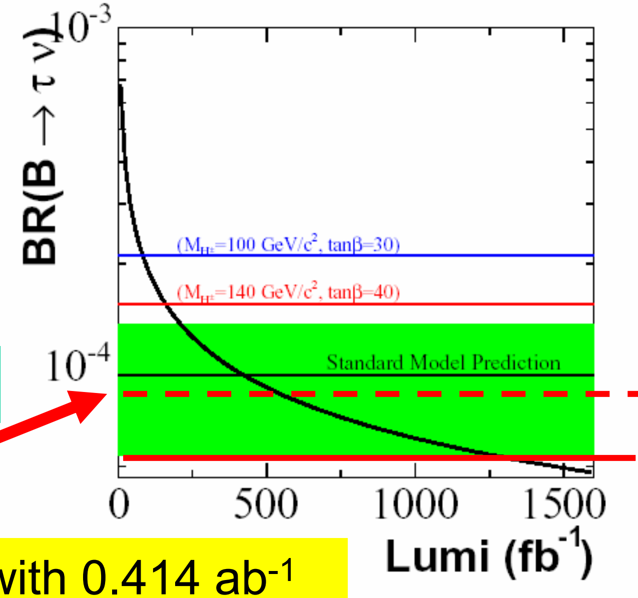


Just one example

Close to hitting the SM prediction

$$\mathcal{B}(B \to \tau\nu) =$$
$$(1.06^{+0.34}_{-0.28}(\mathrm{stat})^{+0.18}_{-0.16}(\mathrm{syst})) \times 10^{-4}$$

SM : B(B→τν)=(1.59 ± 0.40)×10^{-4}



Belle 2006 with 0.414 ab^{-1}

Uncertain regions could be clarified by B-Factories

depends on all other SUSY parameters…

Physics case for very high lumi

On the physics case a lot of documents are available they are the result of three years of Physics workshops in Slac ,in KEK and Joint meetings in Hawaii .

Three years of Physics Workshops have produced heavy documents . See for example:

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

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

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

At the URL :

www.pi.infn.it/SuperB

you can find documents and links to documents

The physics case for a Super Flavour Factory is solid if :

The sample of data available in a few years of running can reach 100 ab^{-1} (10^{11} BBbar, tau and charm pairs)

The running period is overlapped to LHC. (Results from Super Flavour and LHC are largely complementary).

As asked by the president of INFN an international study group has been formed to study the case, to evaluate the solution with time, costs, synergies, footprint of the machine……

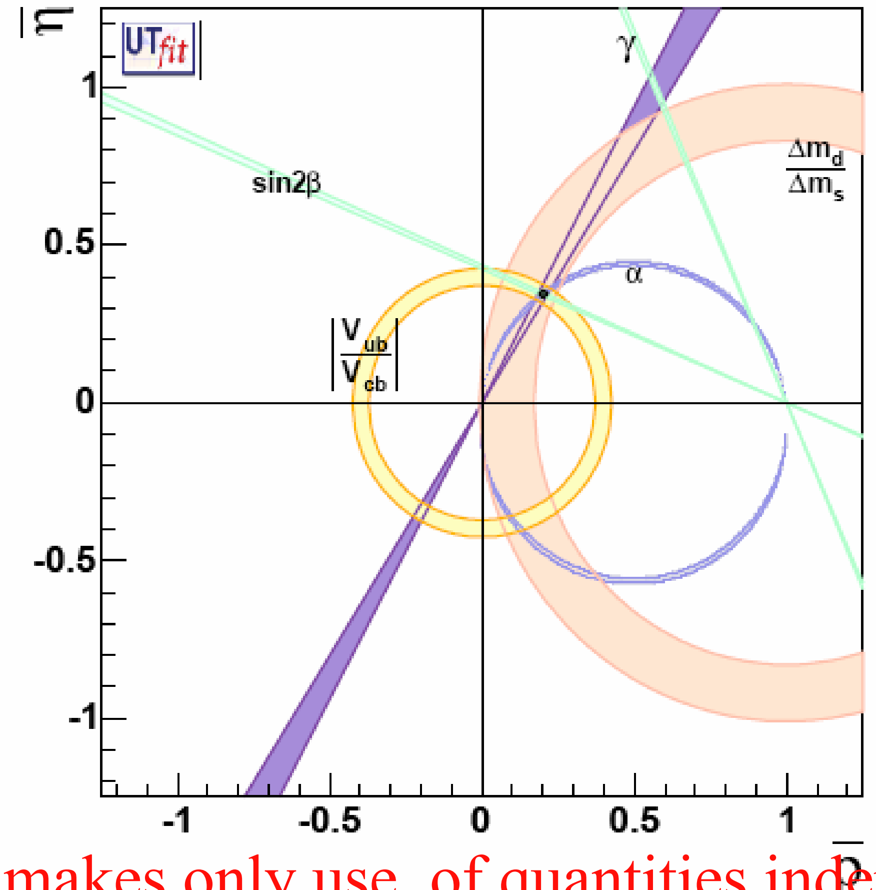
Unitarity Triangle – Sides& Angles

Unitarity Triangle - Sides		e^+e^- Precision		
Measurement	**Goal**	**3/ab**	**10/ab**	**50/ab**
V_{ub} (inclusive)	syst =5-6%	2%	1.3%	
V_{ub} (exclusive) (π,ρ)	syst=3%	5.5%	3.2%	
f_b B($B\rightarrow\mu\nu$)	SM: B~5x10^{-7}			
F_bB($B\rightarrow\tau\nu$)	SM: B~5x10^{-5}	3.3 σ	6 σ	13σ f_b to $\sim$10%
V_{td}/V_{ts} ($\rho\gamma/K*\gamma$)	Theory 12%	~3%	~1%	

Unitarity Triangle - Angles	e^+e^- Precision		
Measurement	**3/ab**	**10/ab**	**50/ab**
α ($\pi\pi$) ($S_{\pi\pi}$, $B\rightarrow$ $\pi\pi$ BR's+ isospin)	6.7°	3.9°	2.1°
α ($\rho\pi$) (Isospin, Dalitz) (syst $\geq$3°)	3, 2.3°	1.6, 1.3°	1, 0.6°
α ($\rho\rho$) (penguin, isospin, stat+syst)	2.9°	1.5°	0.72°
β (J/ψ K_S) (all modes)	0.3°	0.17°	0.09°
γ ($B\rightarrow D^{(*)}K$) (ADS)		2-3°	
γ (all)		1.2-2°	

Theory: α ~1° β ~ 0.2° γ<<1°

UNIVERSAL UT fit with 50 ab^{-1}



Universal fit makes only use of quantities independent of NP contributions within MFV

CP Violation in b→s penguins

Rare Decays – New Physics – CPV (?)		e^+e^- **Precision**		
Measurement	**Goal**	**3/ab**	**10/ab**	**50/ab**
$S(B^0 \to \phi K_S)$	SM: <0.25 (0.05)	*0.08*	*0.05*	*0.02 (?)*
$S(B^0 \to \phi K_S + \phi K_L)$	SM:<0.25 (0.05)			
$S(B \to \eta' K_S)$	SM:<0.3 (0.1)	*0.06*	*0.03*	*0.01*
$S(B \to K_S \pi^0)$	SM:<0.2 (0.15)	*0.08*	*0.05*	*0.04 (?)*
$S(B \to K_S \pi^0 \gamma)$	SM:<0.1	*0.11*	*0.06*	*0.04 (?)*
$A_{CP}(b \to s\gamma)$	SM: <0.6%	2.4%	1%	0.5% (?)
$A_{CP}(B \to K^* \gamma)$	SM: <0.5%	0.59%	0.32%	0.14%
CPV in mixing ($\lvert q/p \rvert$)		<0.6%		

$b \to s l^+ l^-$ precision measurements

New Physics – $K^{(*)}\ l^+l^-$, $s l^+l^-$		e^+e^- Precision			
Measurement	**Goal**	**3/ab**	**10/ab**	**50/ab**	**100/ab**
$\mathrm{B}(B \to K\mu^+\mu^-)/\mathrm{B}(B \to Ke^+e^-)$	SM: 1	~8%	~4%	~2%	~1.5%
$A_{CP}(B \to K^* l^+l^-)$ (all) (high mass)	SM: < 0.05%	~6% ~12%	~3% ~6%	~1.5% ~3%	~1.1% ~2%
$A^{FB}(B \to K^* l^+l^-)$: $\hat{s}_0$	SM: ±5%	~20%	~9%	9%	
$A^{FB}(B \to s l^+l^-)$: $\hat{s}_0$		27%	15%	6.7%	5.0%
$A_{FB}(B \to s l^+l^-)$: C_9, C_{10}		36-55%	20-30%	9-13%	7-10%

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}	~1σ	>3σ	>4σ	>5σ
$B(B \to invisible)$		$<2 \times 10^{-6}$	$<1 \times 10^{-6}$	$<4 \times 10^{-7}$	$<2.5 \times 10^{-7}$
$B(B_d \to \mu\mu)$	$\sim 8 \times 10^{-11}$	$<3 \times 10^{-8}$	$<1.6 \times 10^{-8}$	$<7 \times 10^{-9}$	$<5 \times 10^{-9}$
$B(B_d \to \tau\tau)$	$\sim 1 \times 10^{-8}$	$<1 \times 10^{-3}$	$O(10^{-4})$	?	?
$B(\tau \to \mu\gamma)$ now $< 7\ 10^{-8}$				? →	$<10^{-10}$
$B(\tau \to \mu h)$ now $< 10^{-7}$				? →	$<10^{-10}$

$\tau \rightarrow \mu$ X

The LFV limits on $\tau \rightarrow \mu h$ and $\tau \rightarrow \mu \gamma$ scale with the statistics or with the square root of the statistics?

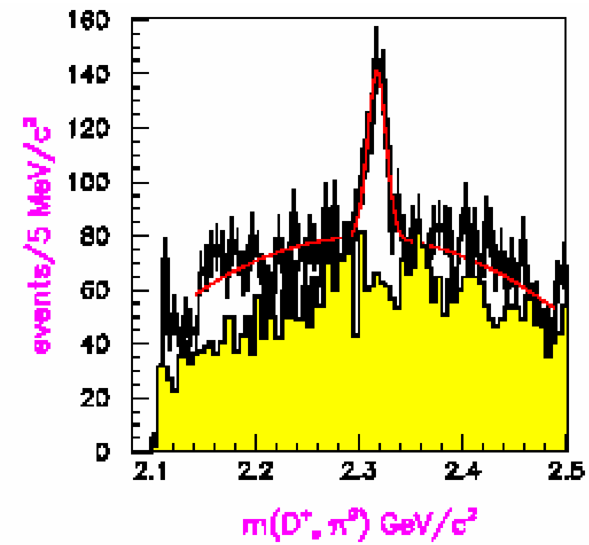
If as we have now in Babar the main source of systematic error is the unidentified background with 2 neutrinos and this background is irreducible

→ the scaling low is the sq uare root?

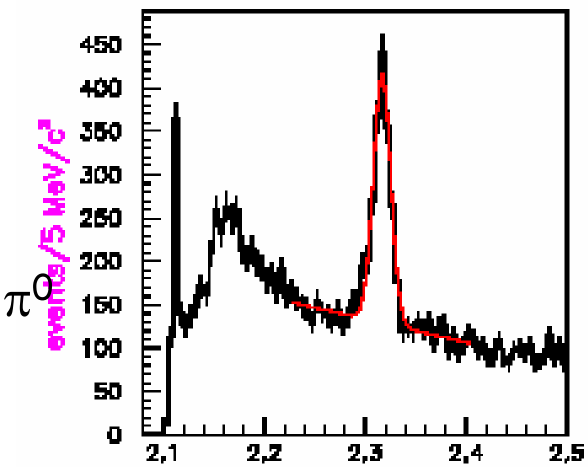
Can this background kept under control as in $\mu \rightarrow e\gamma$?

Can a symmetric machine with very small beam spot (several order of magnitude smaller than in PEPII) and monochromatic taus help in reducing this source of error?

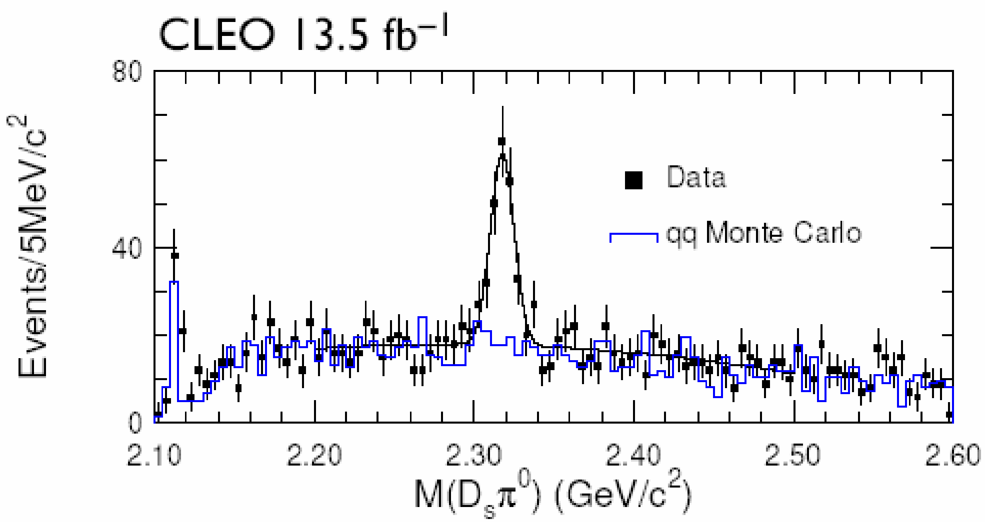
Not only CPV : $D_s(2317) \rightarrow D^+_s(1970)\,\pi^0$:

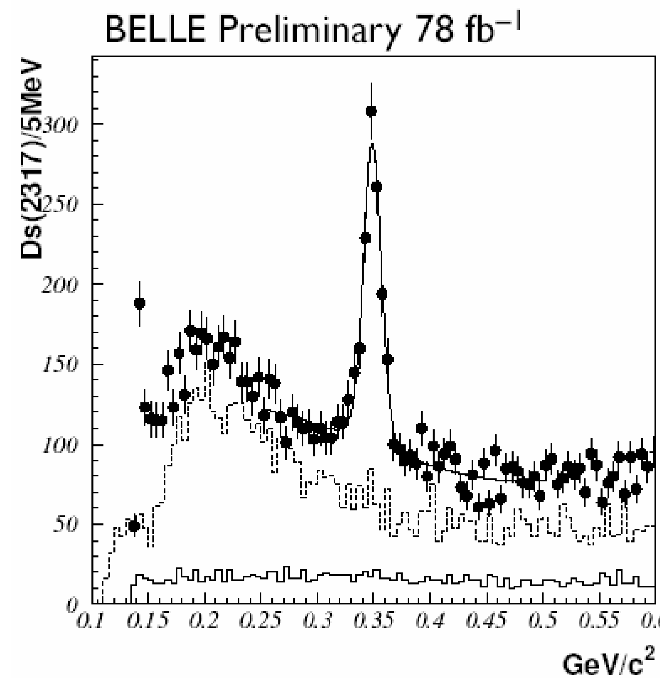


$D^+_s \rightarrow K^+K^-\pi^+$



$D^+_s \rightarrow K^+K^-\pi^+\pi^0$





More recent: Y(4260) in $\pi^+\pi^- J/\psi$ Mass Spectrum

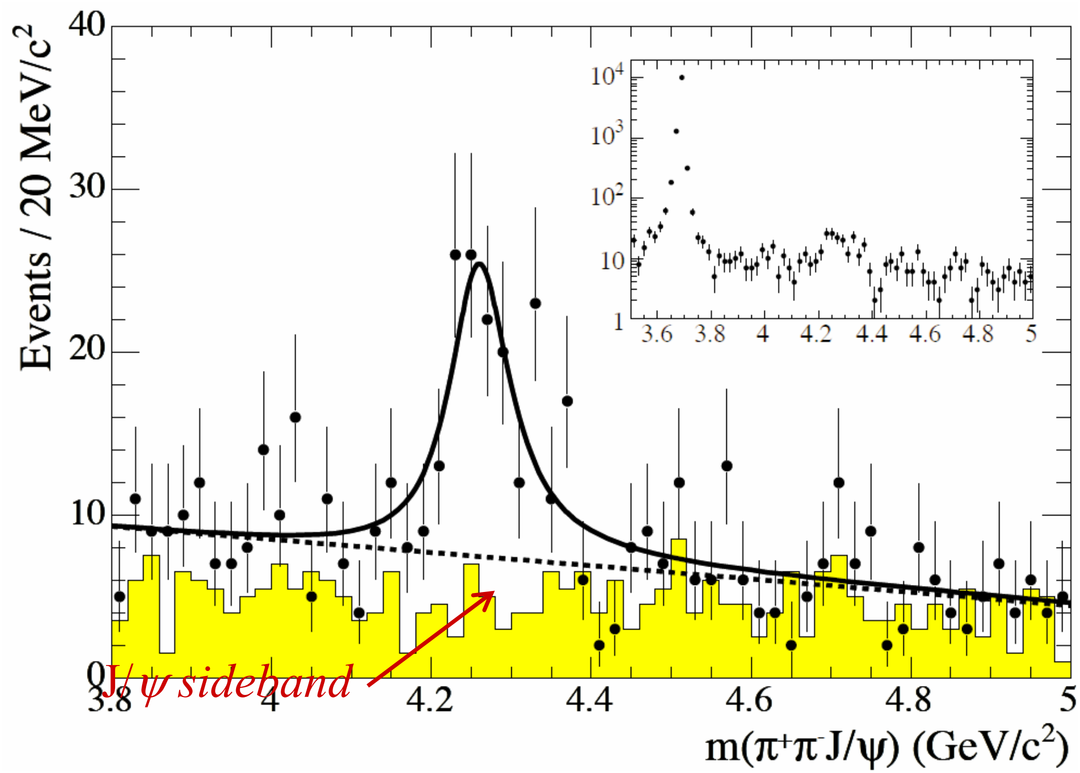
- ISR production: $e^+e^- \rightarrow (\gamma) J/\psi\pi^+\pi^-$

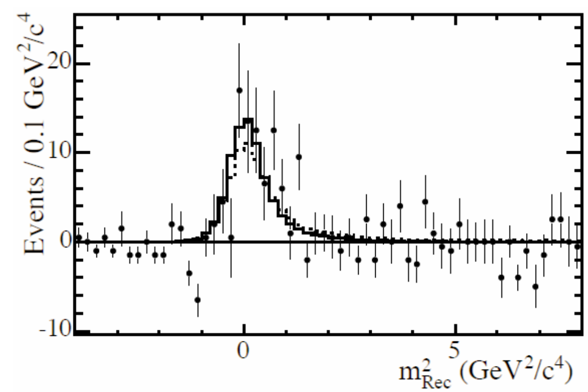
TM & © Ne

25% of γ's observed

$m = 4260 \pm 8$ MeV
$\Gamma = 88 \pm 23$ MeV

$\psi(2S)$ used for cross checks





missing mass consistent with γ: Y data, Y MC, and $\psi(2S)$ data

Also Spectroscopy

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

Rare states have been accessible to Babar and Belle thanks to the very high statistics collected with a luminosity of about 10^{34} cm^{-2} s^{-1} .

More states could be accessible with a luminosity >> 10^{36} cm^{-2} s^{-1}

What kind of Super B Factory?

- Peak Lumi >>10^{36} cm $^{-2}$ s^{-1} to allow 50/ab in a couple of years
- Running period : overlap with LHC and possibly before ILC
- Asymmetric (at least 7+4 GeV)

Options under evaluation:

Possibility to operate symmetric even at lower energy and with at least one polarised beam for τ and charm physics.

Still with at least 10^{35} cm $^{-2}$ s^{-1} .

Traditional machines

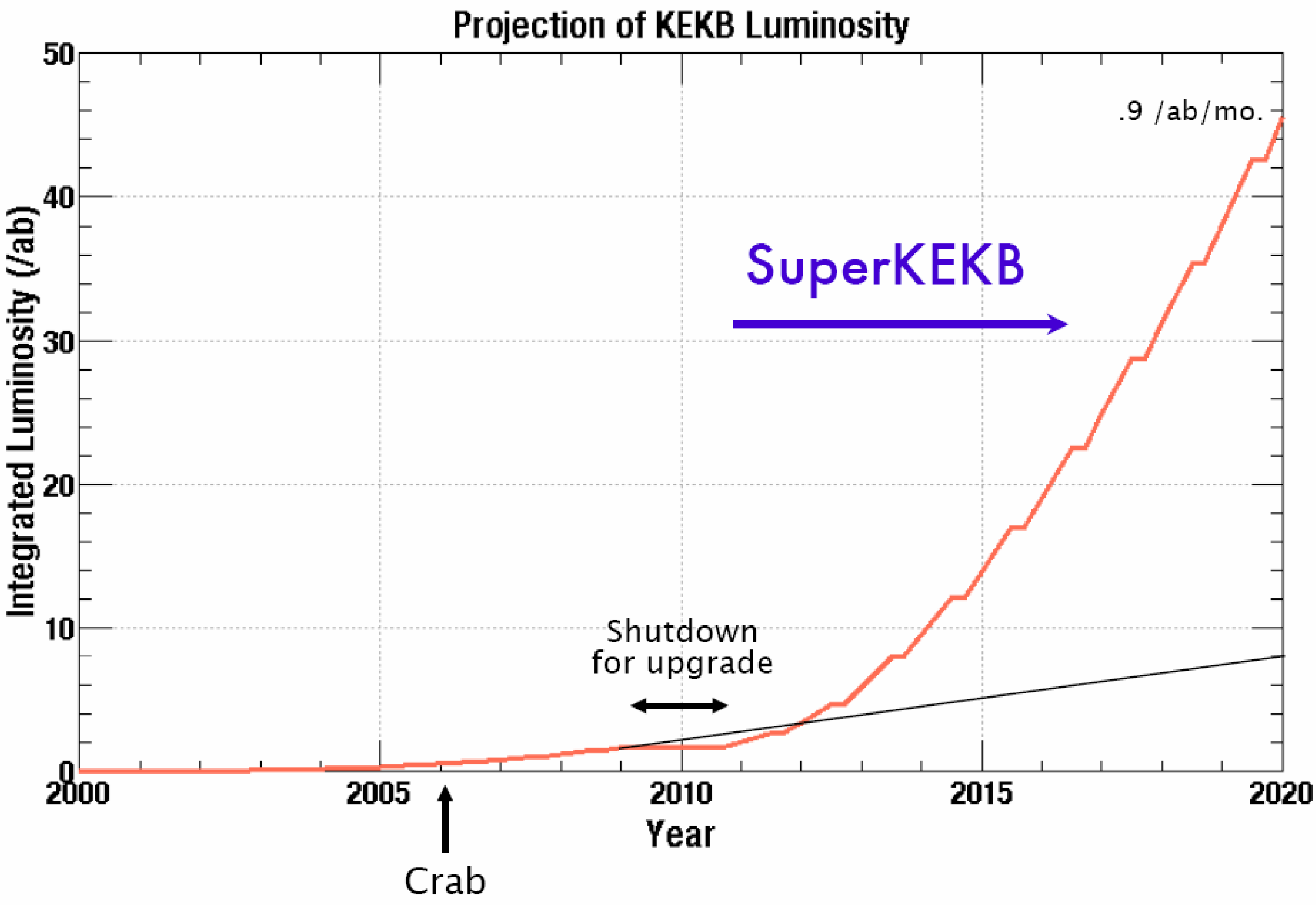
The recipe for high lumi so far is :

- Increase current
- Then increase Background in the detectors
- Increase wall power

Above 5 10^{35} cm $^{-2}$ s^{-1} seems very hard the design of detector with present or near future technology

Wall power jumps soon above hundreds of MW.

Design Peak Lumi 4÷5 $10^{35} cm^{-2} s^{-1}$



Some parameters for comparison with hadron expriments

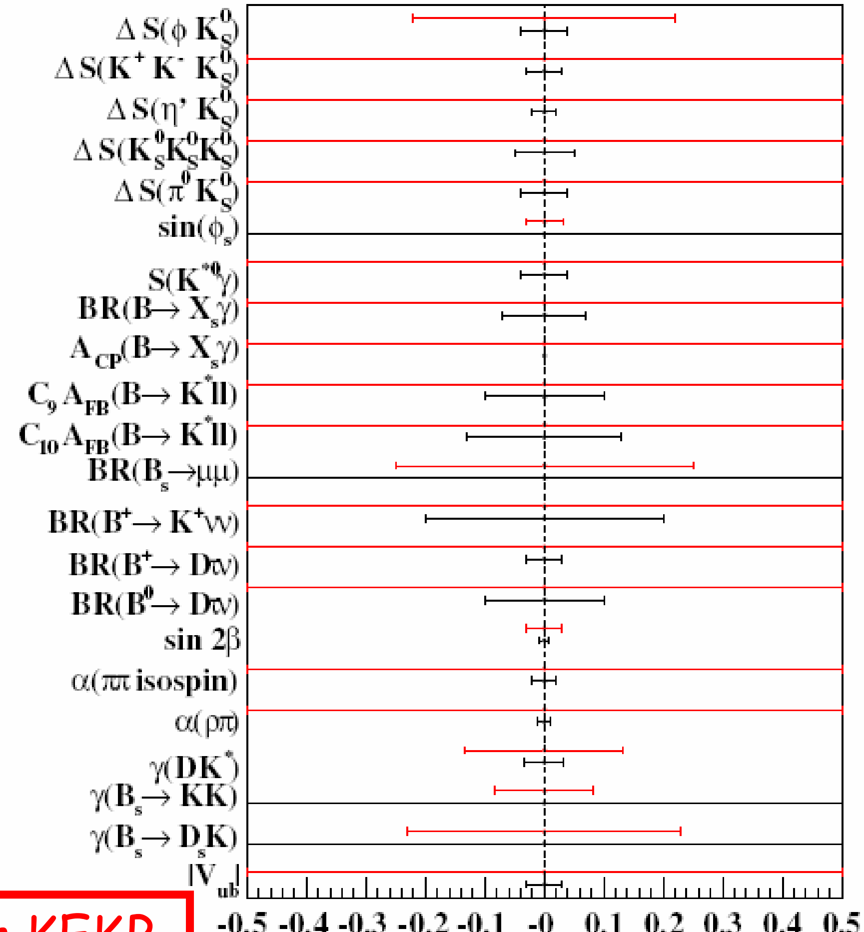
	P.Lumi ($10^{33}cm^{-2}s^{-1}$)	σ_{bb} (10^{-33})	BB (10^{7}/y)	σ_{bb}/σ_{qq}
Bfactories	10	1.1	14	0.3
SuperB	2÷5x1000	1.1	3÷7x1000	0.3
LHC-b	0.15	500000	75x1000	0.005

τ and charm pairs as many as BB in e+e- factories

Comparison to Super B

SuperB (50 ab^{-1}) LHCb (2 fb^{-1})

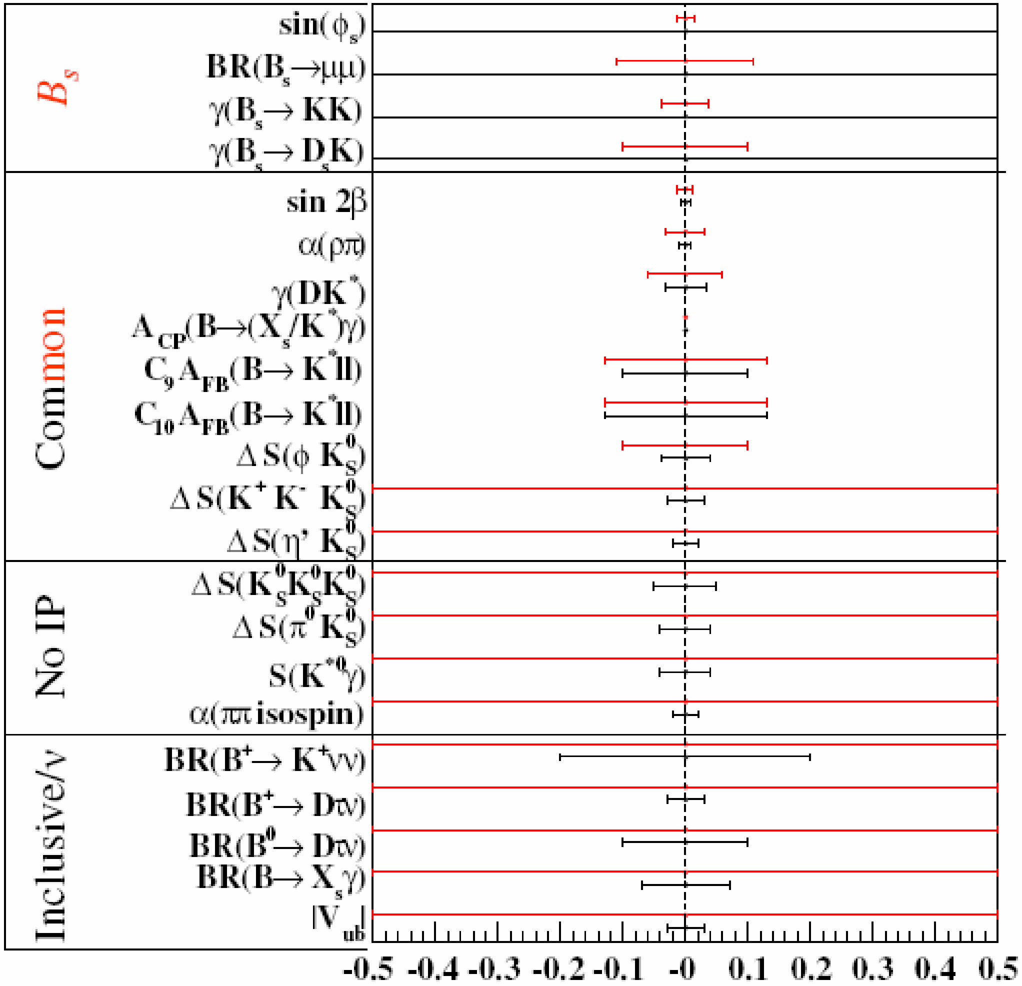
- This was shown by N. Katayama at FCPC a couple of weeks ago
- At first glance I'm working on the wrong experiment!
- But:
  - LHCb ~2010
  - SuperB ~2020
  - Some missing LHCb info



Why? 2020 is the design of Super KEKB

Comparison to Super B

- Added some information on several modes
- Scaled LHCb to 10 fb^{-1} luminosity (~2014) and reordered the measurements
- **Symbiosis!**



Heretic Solution

A new scheme:

the “Linear SuperB”

- 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)

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*π		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

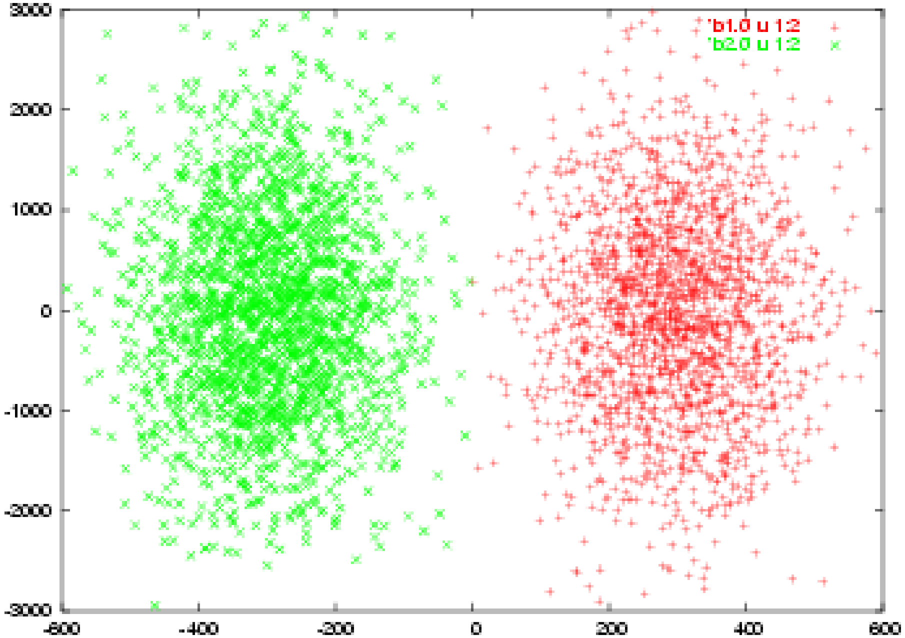
In this simulation

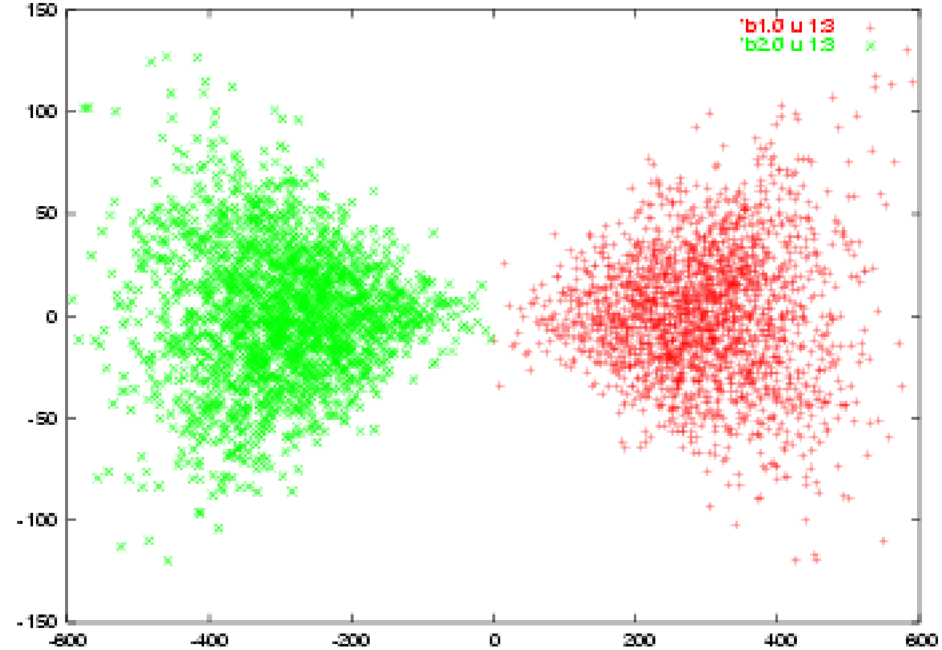
E+=8GeV

E-=3.5 Gev

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

SuperB





Horizontal Collision

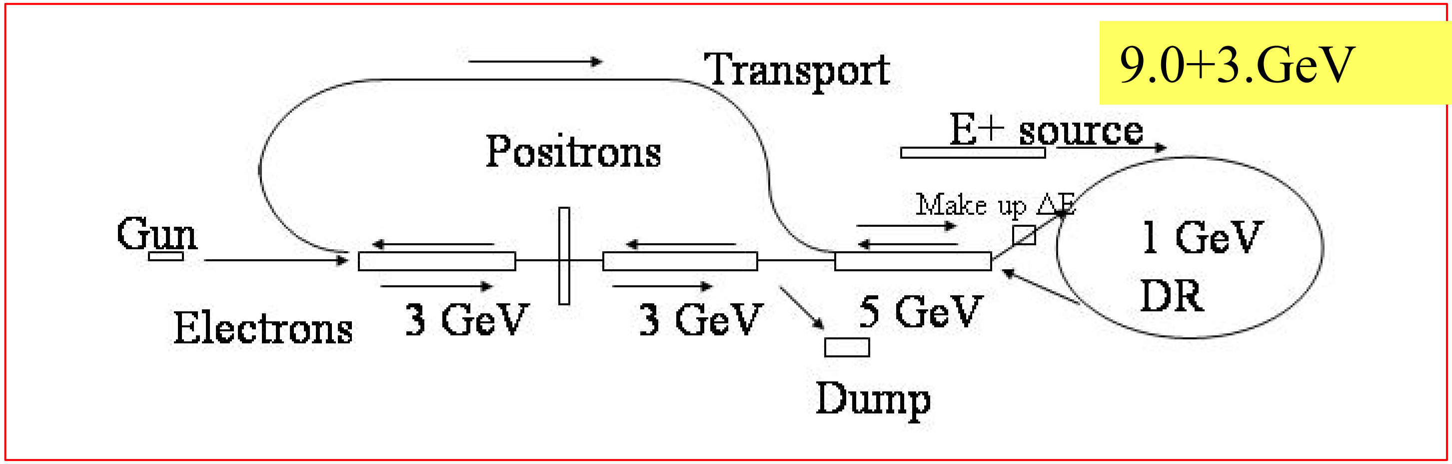
Vertical collision
D. Schulte

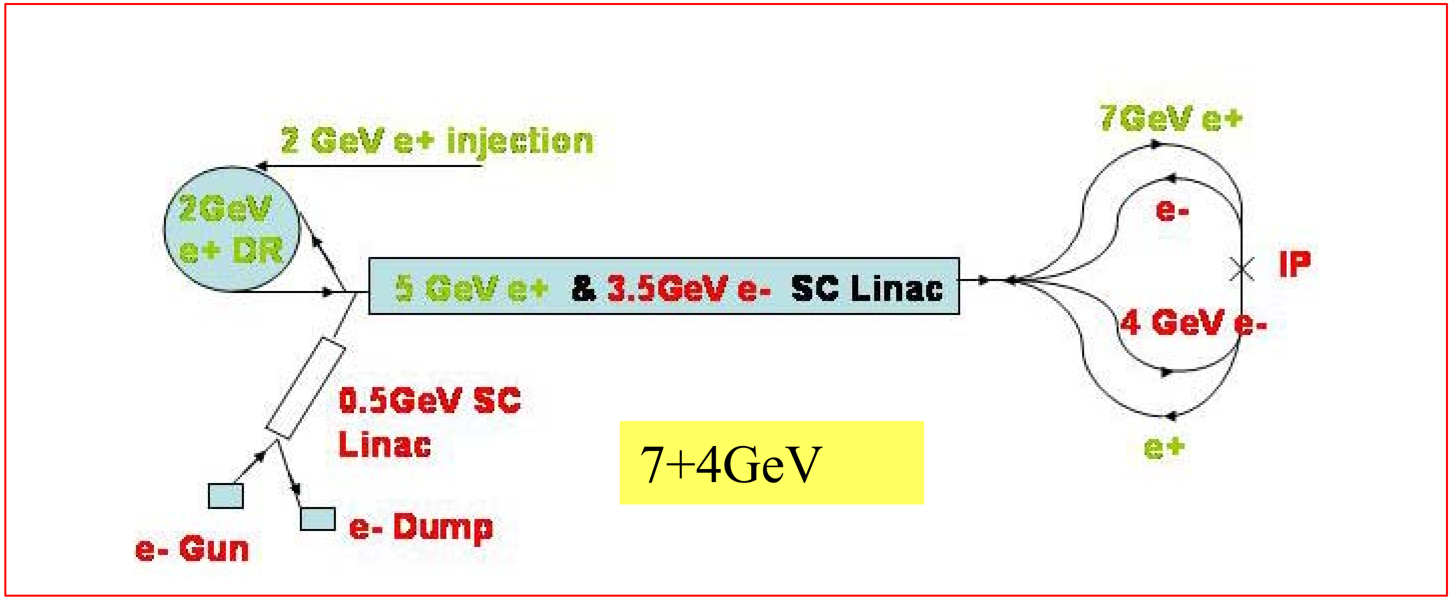
Effective horizontal size during collision about 10 times smaller, vertical size 10 times larger

Basic idea

- Instead of being a limitation, Beam-Beam interaction might actually help to increase the luminosity,but more power in DR.
- Need to find a suitable parameters set: stable collisions, reasonable outgoing emittances and energy spread
- Average current through the detector 10-100 times smaller than in the rings (10-100 mA)
- Experiment looks easy (narrow beam pipe-no Bkgd)
- Damping Rings, even with a parameter set very similar to the ILC ones, have still to handle a lot more current and more radiation from increased damping
- Energy spread in collision is an issue
- WALL POWER 1100 MW!!!!!!!!!

Layouts…


9.0+3.GeV
Transport
Positrons
E+ source
Make up ΔE
Gun
1 GeV
DR
Electrons
3 GeV
3 GeV
5 GeV
Dump

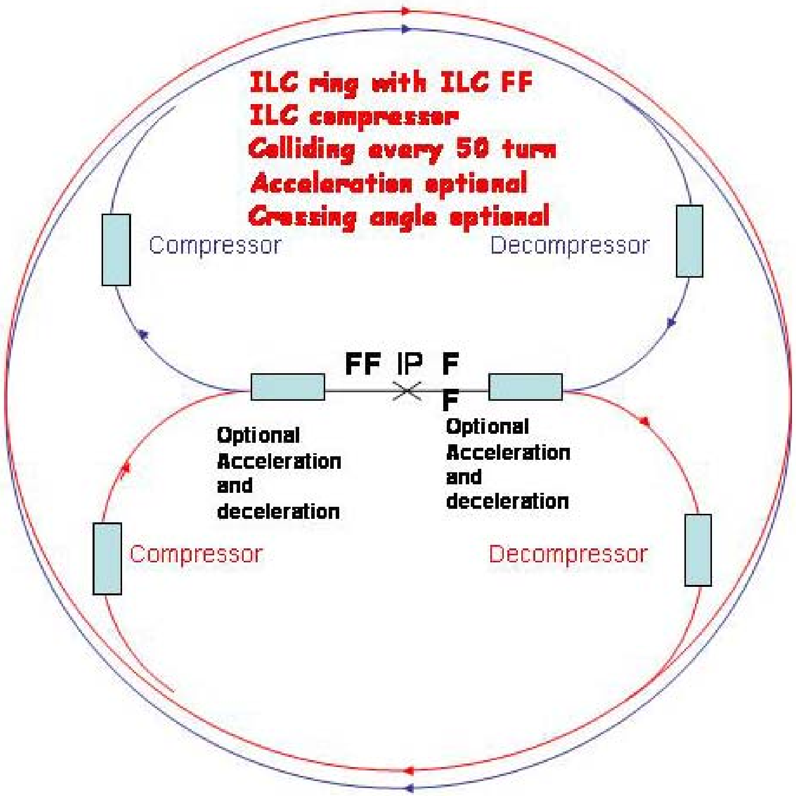

2 GeV e+ injection
2GeV
e+ DR
5 GeV e+ & 3.5GeV e- SC Linac
7GeV e+
e-
IP
4 GeV e-
e+
0.5GeV SC
Linac
7+4GeV
e- Gun
e- Dump

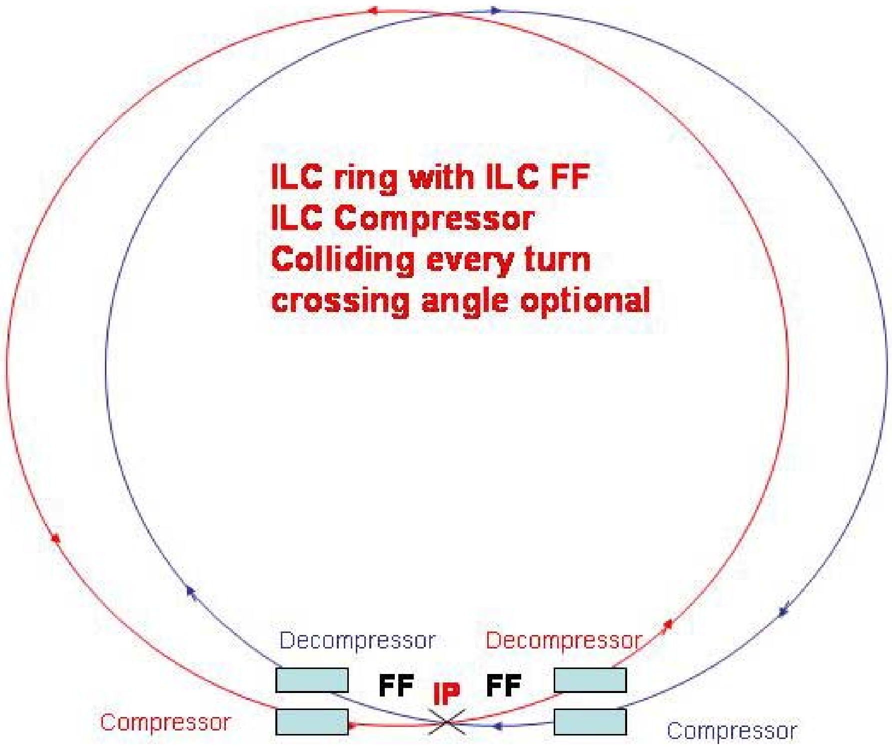
2 solutions

1) ILC DR+ ILC BC + ILC FF

- Acceleration by ILC SC-cavities not a must anymore but a factor 2 in energy gives a factor 2 reduction in energy spread (and a factor 2 down in beam cooling power in the ring)
- Increased collision rate and reduced beam current gives more luminosity, with an optimum for collisions at every turn
- Possible path: to build the machine with the capability to collide with extraction every 50 turns, and then, while at low bunch charge, have the option of increasing bunch charge or collision rate up to every turn…

Solution 1



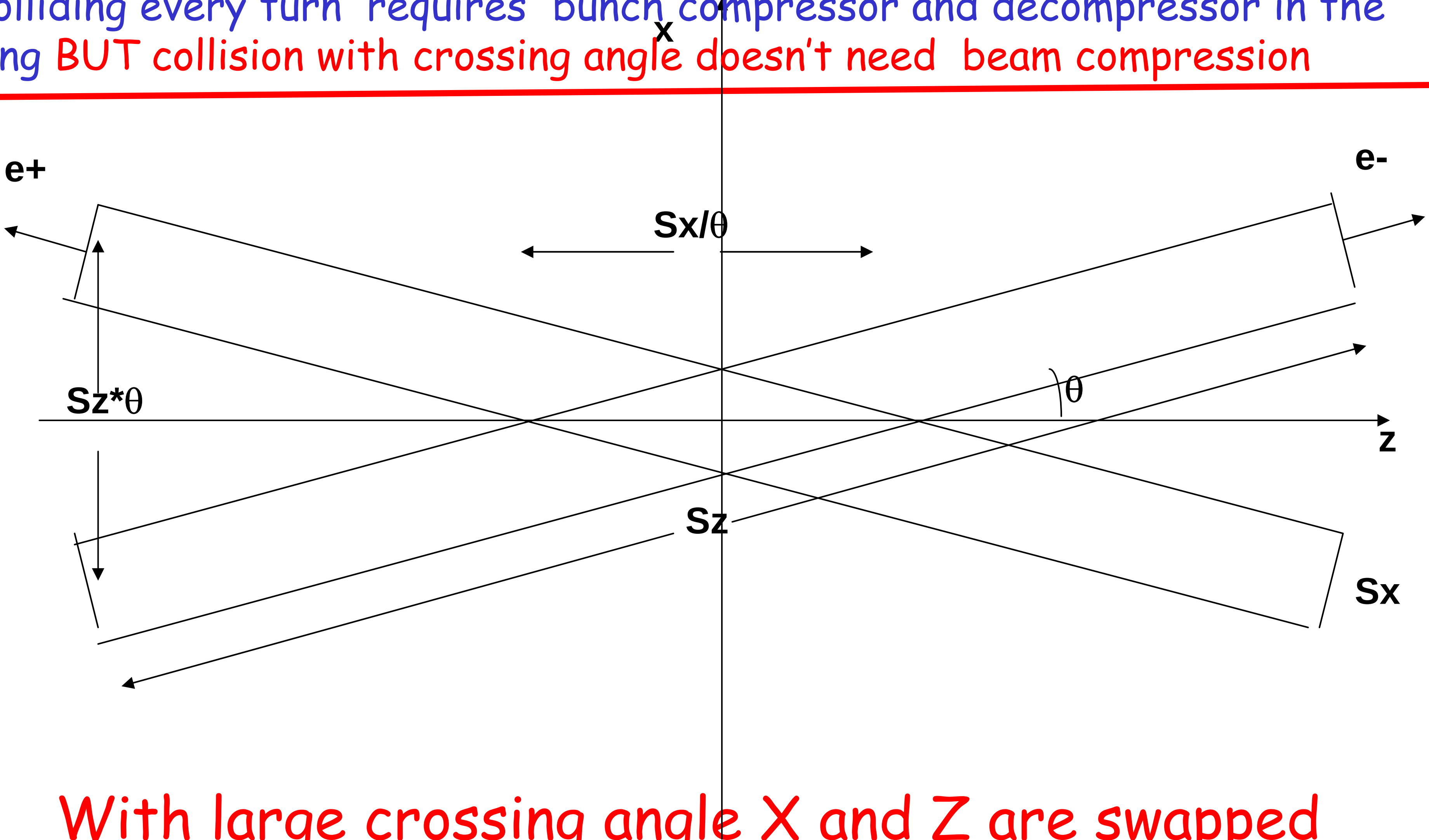


7+4GeV

2) ILC DR+ ILC FF in DR + crossing angle 25mrad

- Bunch Compressor optional, no acceleration
- Requires virtually no R&D
- Uses all the work done for ILC, 100% synergy with ILC
- Rings and FF layouts virtually done, 3km circumference
- IR extremely simplified
- Currents around 1.5A
- Background should be better than PEP-II and KEKB
- Use of "crabbed waist" new idea

Colliding every turn requires bunch compressor and decompressor in the ring BUT collision with crossing angle doesn't need beam compression



With large crossing angle X and Z are swapped

Crab waist

Against the unpleasant 'Long Range Beam Beam' instead of simply increase the x-ing angle (then reduce the lumi) P.R. applies the travel focus idea in the transverse plane since x and z are swapped.

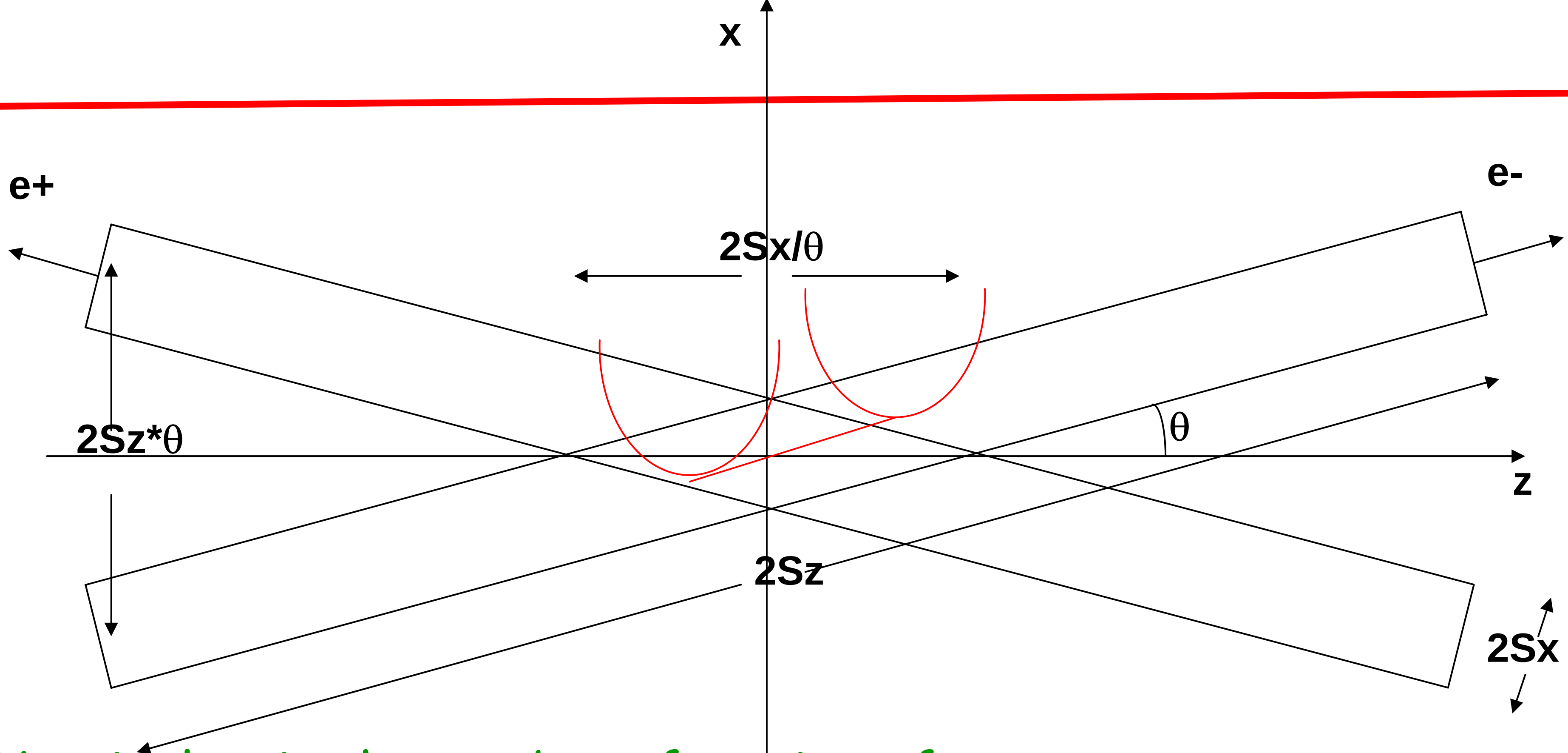
Vertical waist position in z is a function of x:

Zy_waist(x)=x/θ Crabbed waist

All components of the beam collide at a minimum β_y

the geometric luminosity is higher

the bb effects are greatly reduced



Vertical waist has to be a function of x:

Z=0 for particles at $-\sigma_x$ ($-\sigma_x/2$ at low current)

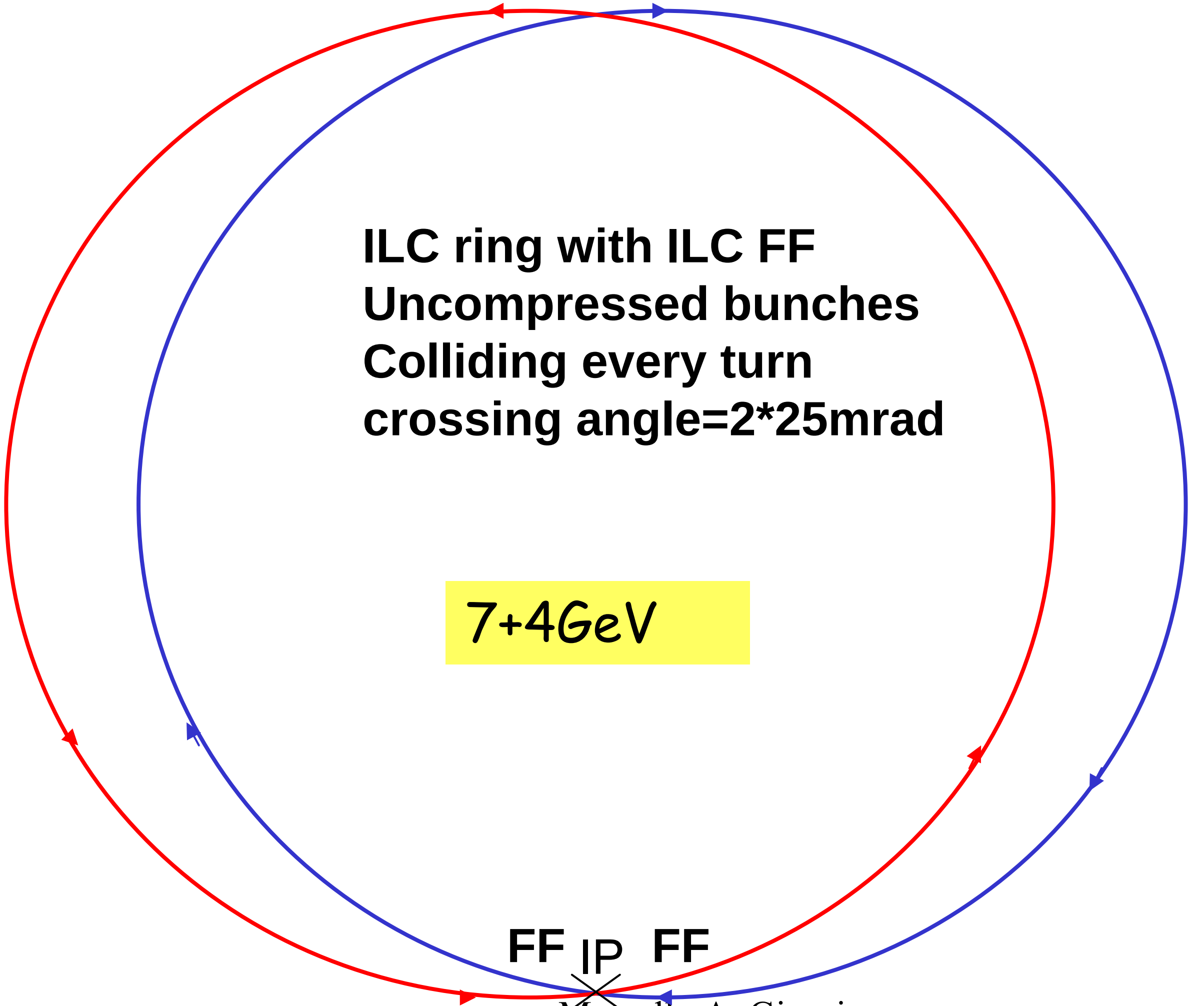
Z= σ_x/θ for particles at $+\sigma_x$ ($\sigma_x/2$ at low current)

Solution 2

ILC ring with ILC FF
Uncompressed bunches
Colliding every turn
crossing angle=2*25mrad

3 Km

7+4GeV



Flat case, Collisions in the Ring, Uncompressed Bunches

$N_{bunches}$=5000, 3Km ring

Crab focus on in vertical plane

X_crossing_angle=2*25mrad

σ_z=4mm σ_e=5MeV $\sigma_{e\_Luminosity}$=7MeV

ε_x=0.4nm ε_y=0.002nm ε_z=4.0μm

Collision_frequency=500MHz

$L_{multiturn}=0.8*10^{36}$ ($L_{singleturn}=1.2*10^{36}$) with $Np=2*10^{10}$

Vertical tune shift as in PEPII! (similar currents but 100 times higher luminosity and 100 times smaller β_y)

Projected $\sigma_x=\sigma_z$*Cross_angle=100μm, as in PEPII!

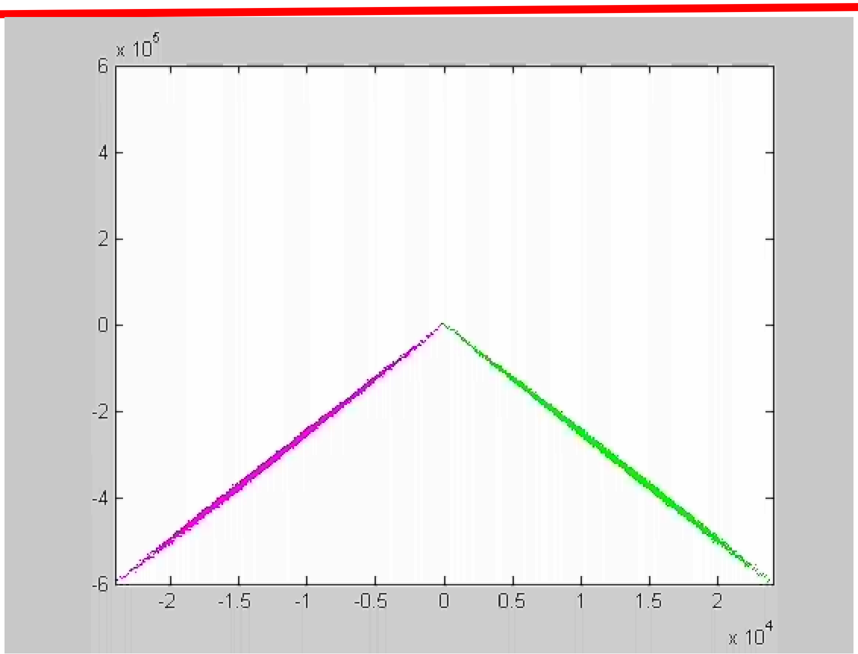
$L=1.6*10^{36}$ with $Np=4*10^{10}$

Luminosity higher with further simultaneous squeeze of β_x and β_y .

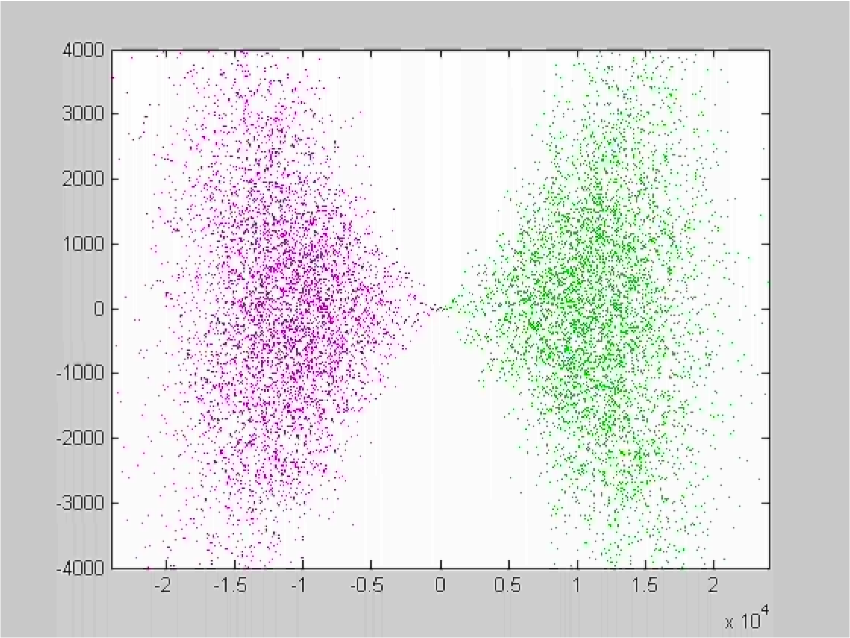
More on 2

- Possibly to operate at the τ with $L=10^{35}$
- To be studied the possibility to run down to Φ
- Total cost about half ILC e^+ DRs (2 e+ 6km rings in ILC)
- Power around 35MW, to be further optimized (goal 25MW)
- Possible to reuse PEP-II RF system, power supplies, magnets, vacuum pumps, etc., further reducing the overall cost
- Needs standard injector system, probably a C-band 7 GeV linac like in KEKB upgrade (already designed) (around 100Meuro)

Result of simulation (Guinea Pig)



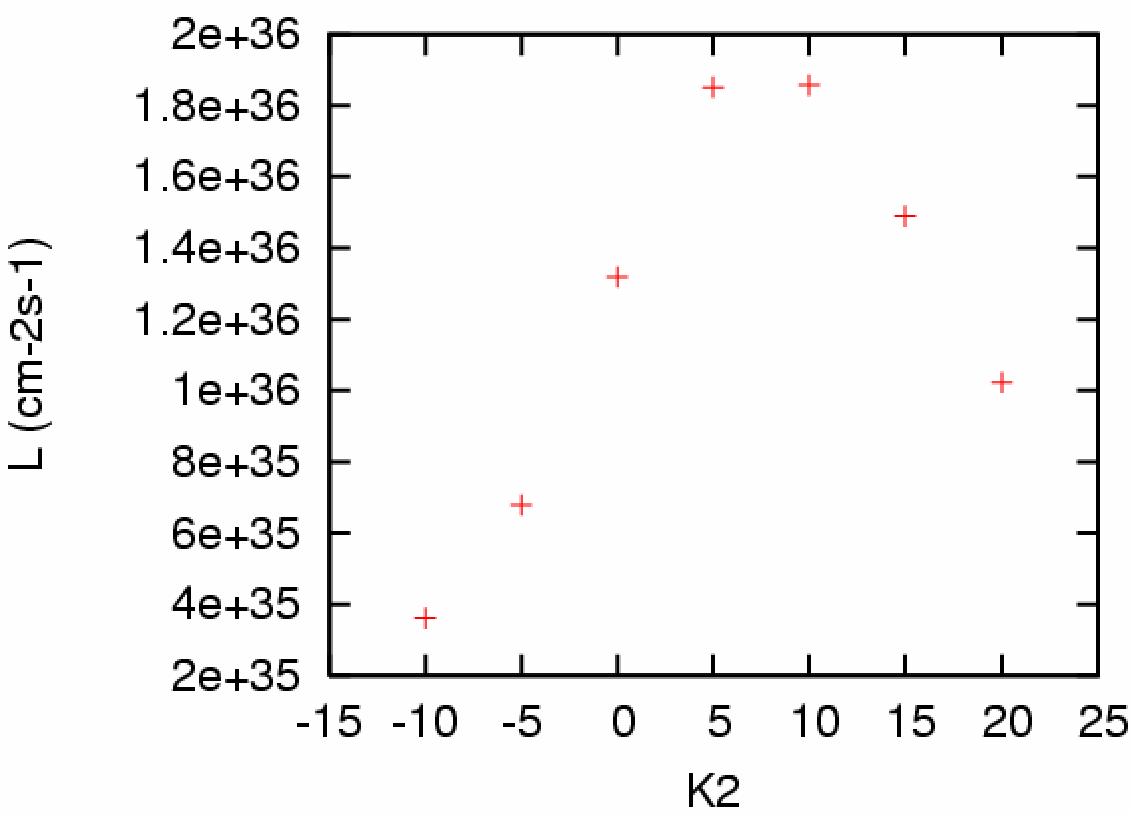
Horizontal Plane



Vertical Plane

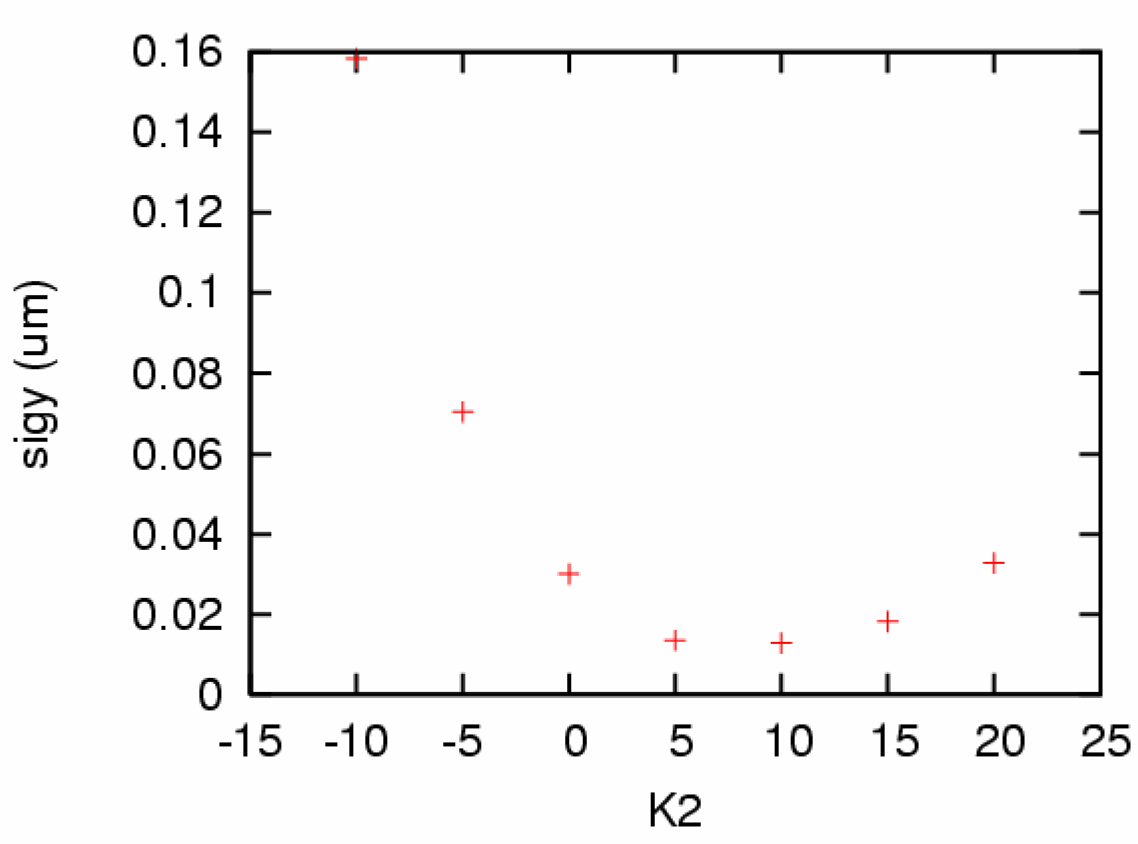
Collisions with uncompressed beams
Crossing angle = 2*25mrad
Relative Emittance growth per collision about $1.5*10^{-3}$
($\varepsilon_{after\_collision}/\varepsilon_{before\_collision}=1.0015$)

SuperB vertical blow-up Ohmi's weak-strong code



K2 is the strength of the sextupolar nonlinearity introduced to have crab waist

SuperB vertical blow-up Ohmi's weak-strong code



Total Wall Power (66% transfer eff.): 34 MW !!

	LER 4 GeV	*HER 7 GeV*
C (m)	3006.	3006.
B_w (T)	1.6	1.6
L_{bend}(m)	5.6	11.2
B_{bend} (T)	0.078	0.136
Uo (MeV/turn)	4.6	7.8
N. wigg. cells	8	4
τ_x (ms)	17.5	18.
τ_s (ms)	8.8	9.
ε_x (nm)	0.54	0.54
σ_E	1.1×10^{-3}	1.45×10^{-3}
I_{beam} (A)	2.5	1.4
P_{beam}(MW)	11.5	10.9

cm σ_E=**0.9**x10^{-3}

0.5x10-3

PLANS:(Possible test in 2007) DAΦNE (M.Zobov, LNF)

- Hirata's BBC code simulation (weak-strong, strong beam stays gaussian, weak beam has double crossing angle)
- $N_p = 2.65\times10^{10}$, 110 bunches
- I_b = 13 mA (present working current)
- σ_x = 300 μm, σ_y = 3 μm
- β_x = 0.3 m, β_y = 6.5 mm
- σ_z = 25 mm (present electron bunch length)
- θ = 2x25 mrad
- $Y_{IP} = y + 0.4/(\theta * x * y')$ crabbed waist shift
- $L_o = 2.33\times10^{24}$ (geometrical)
- L(110 bunches,1.43A) = 7.7×10^{32}
- $L_{equil} = 6\times10^{32}$

Factor 3 above design lumi!

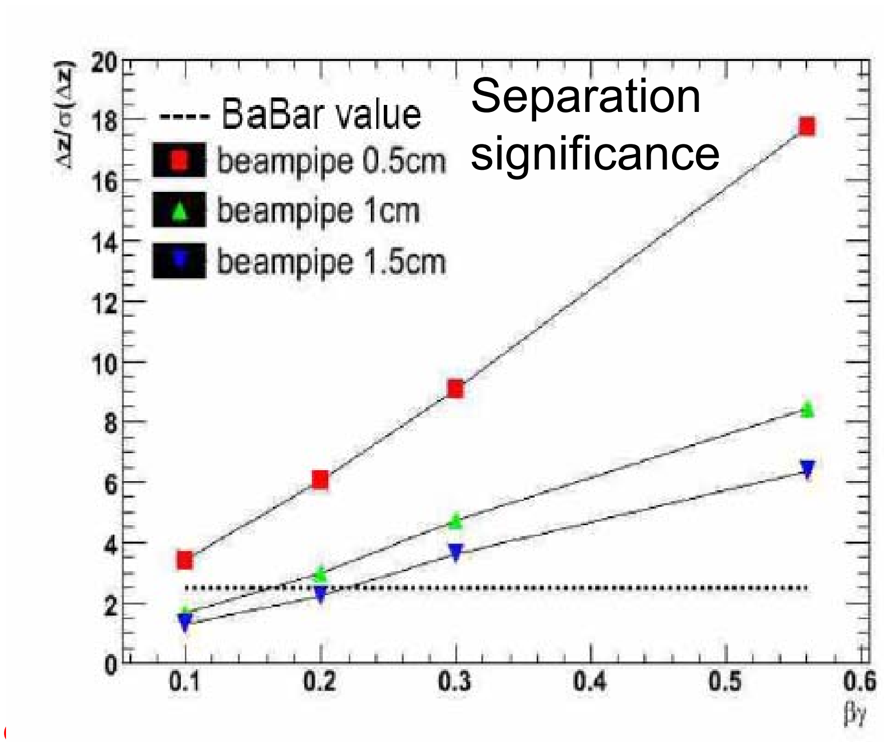
Beam Pipe Radius

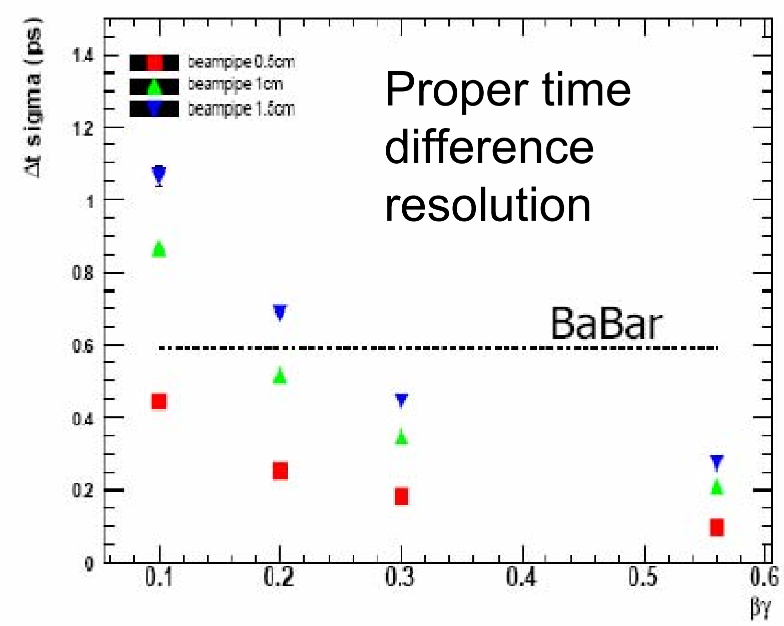
- Small beam pipe radius possible because of small beam size
  - Studied impact of boost on vertex separation (B→ππ)
  - Beampipe hypothesis (no cooling)
    - 5um Au shield to protect from soft photons
    - 0.5cm → 200um Be and 5um hit resolution (0.21% X0)
    - 0.5cm → 300um Be and 10um hit resolution (0.24% X0)
    - 0.5cm → 500um Be and 10um hit resolution (0.29% X0)
  - Rest of tracking is Babar

7+4GeV

Boost βγ=.28

Instead of 0.56





Beam Pipe Thickness

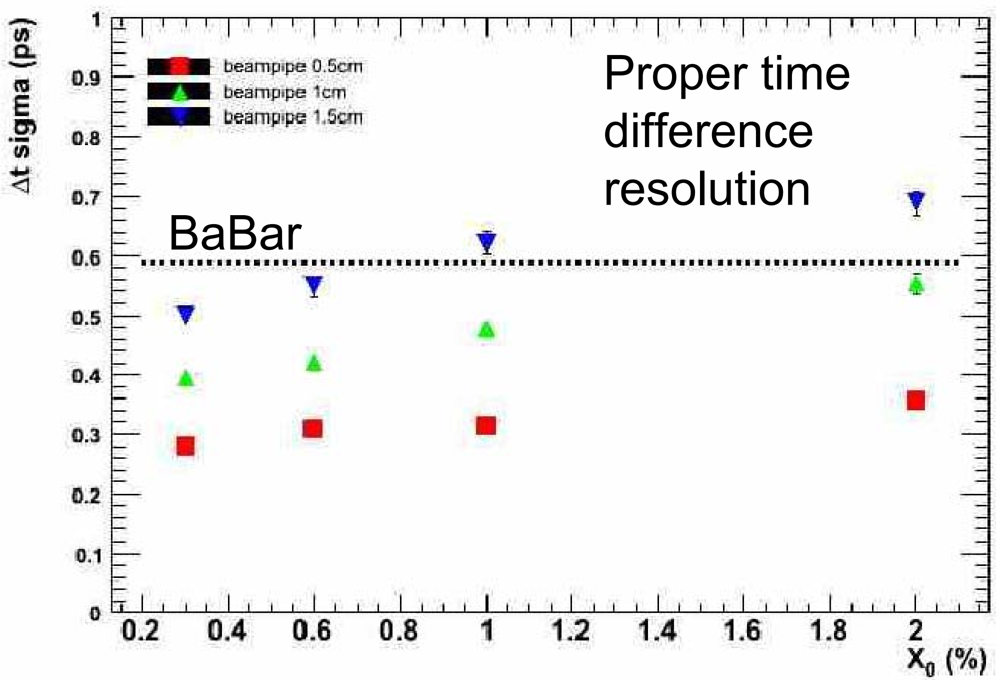
- With 1.5A beam currents the beam pipe will require cooling.
  - Beampipe design is being developed
  - Study effect of beampipe thickness

7+4GeV

Boost $\beta\gamma$=.28

Instead of 0.56

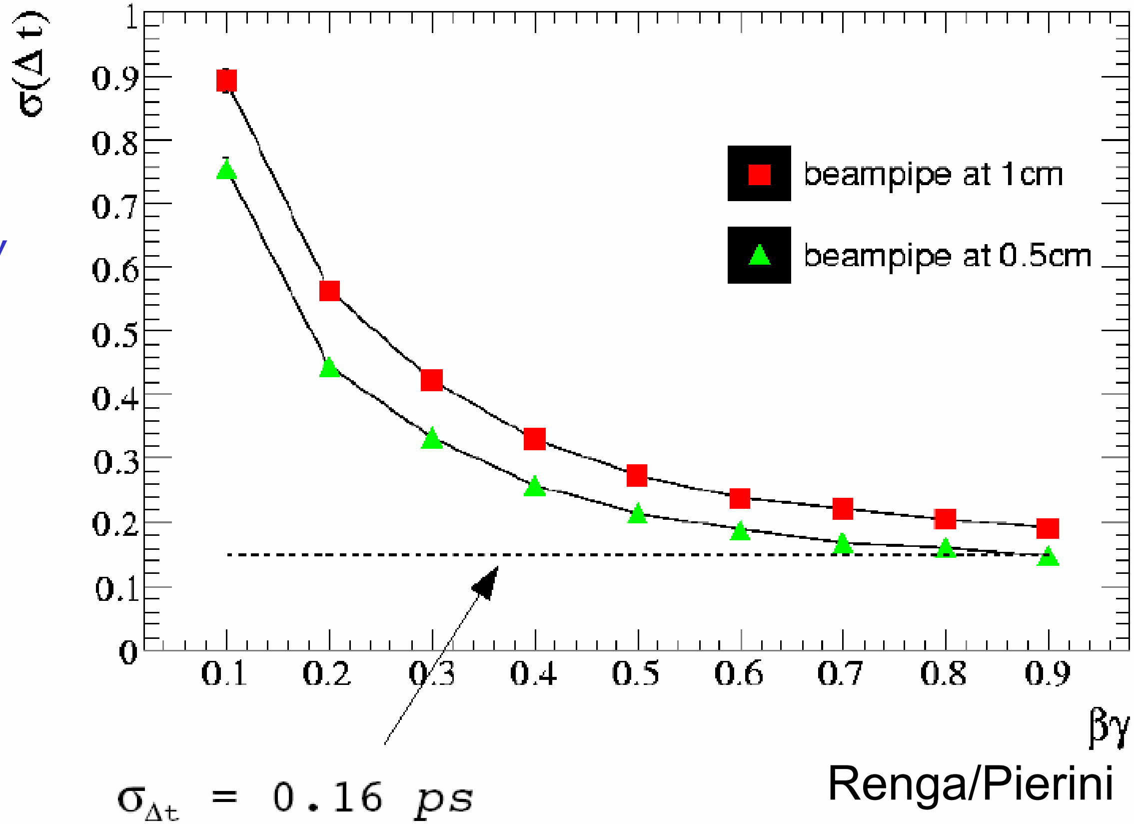
- Assume boost=0.28
- B→ππ decay
- 10um hit resolution
- → 1cm beampipe should allow good performance even with $\beta\gamma$=0.28



Energy (Under Study)

- Is it interesting to run at different energies ?
  - Y(5s): not an issue for the machine
  - oscillation of Bs rapid for TD analysis

- Required resolution very hard to obtain
- Still it might be possible to measure γ through time-integrated measurement branching fractions
- $B_s \rightarrow D\phi$
- $B_s \rightarrow K^+\pi^+\pi^0$

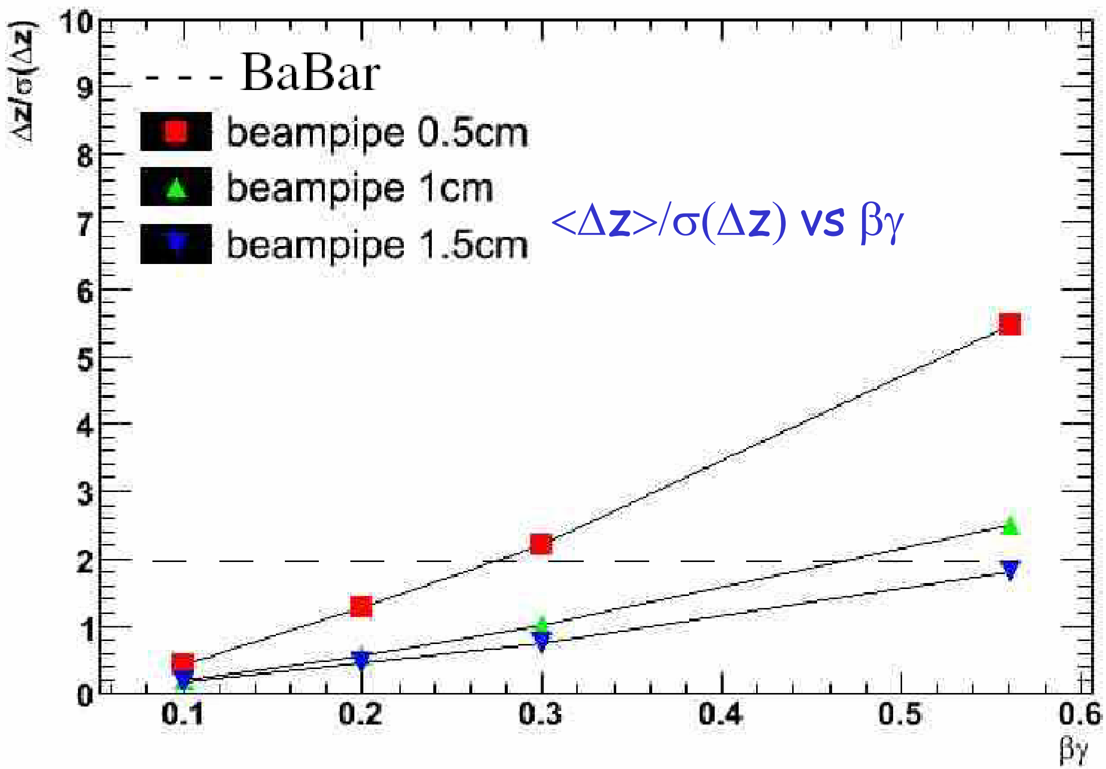


Renga/Pierini

Energy II (Under Study)

full data set
CLEO-c
$0.75\,fb^{-1}$
BESIII
$15\,fb^{-1}$

- Is it interesting to run at the $\tau\tau$ threshold or at the $\psi(3770)$?
  - Luminosity will be around 10^{35}
  - Still more than at tau-charm factories
  - Studies going to on on physics case
    - Absolute D branching fractions, rare decays
    - Form factors
    - Unitarity tests with charm
    - D mixing ? Use coherence of initial state
    - CP violation
- Boosted operation
  - Is there something to be gained to run at low energy with boost ?
  - It might be possible to separate (a little bit) the D vertices



<Δz>/σ(Δz) vs βγ

Detector comments

Detectors don't require a major R&D

Background should be lower than in Babar, even with a smaller radius beam pipe. (from 3cm to 1.cm). Simulations are currently run.

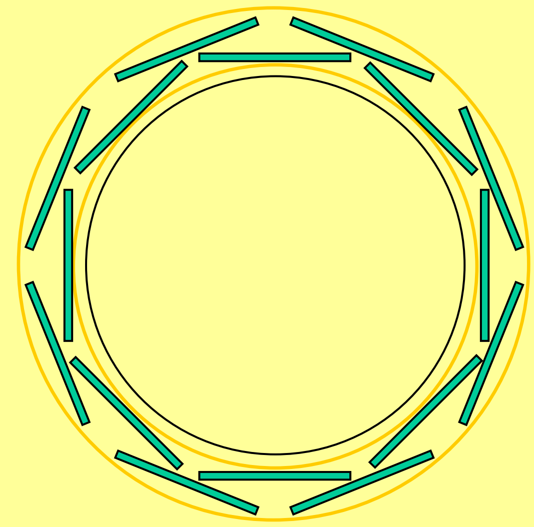
Must be more hermetic than Babar and Belle.

PID in forward/backward

By reducing Lorentz boost higher resolution vertex is needed (MAPS?)

Silicon Vertex Tracker

- Vertexing
  - Two monolithic active pixel layers glued on beam pipe
    - Since active region is only ~10um, silicon can be thinned down to ~50um.
    - Good resolution O(5um).
    - Good aspect ratio for small radius (compared to strips)
    - Improves pattern recognition robustness and safety against background
    - needs R&D: feasability of MAPS, overlaps, cables, cooling



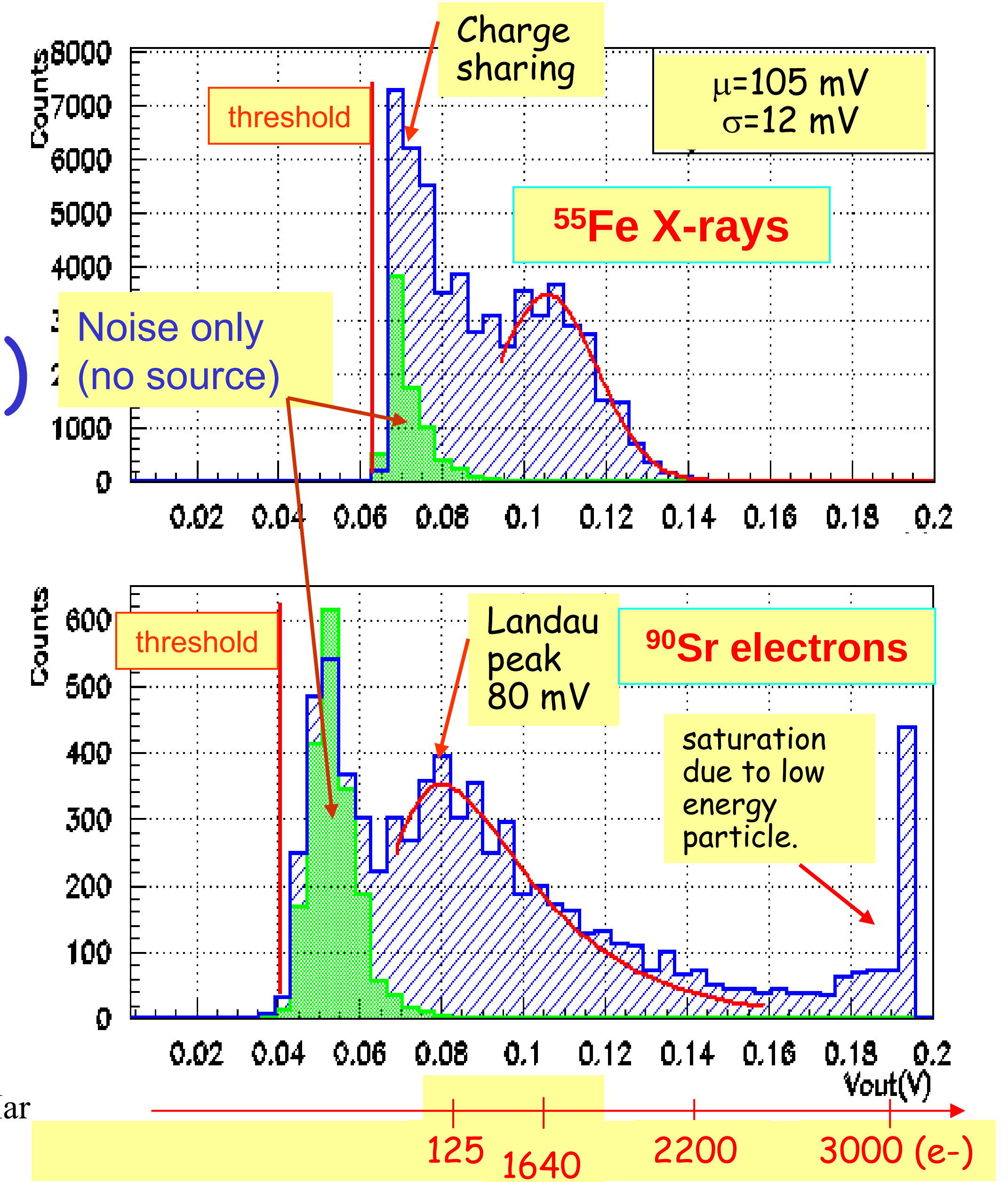
x5 scale with 10mm radius BP, 6mm pixel chip

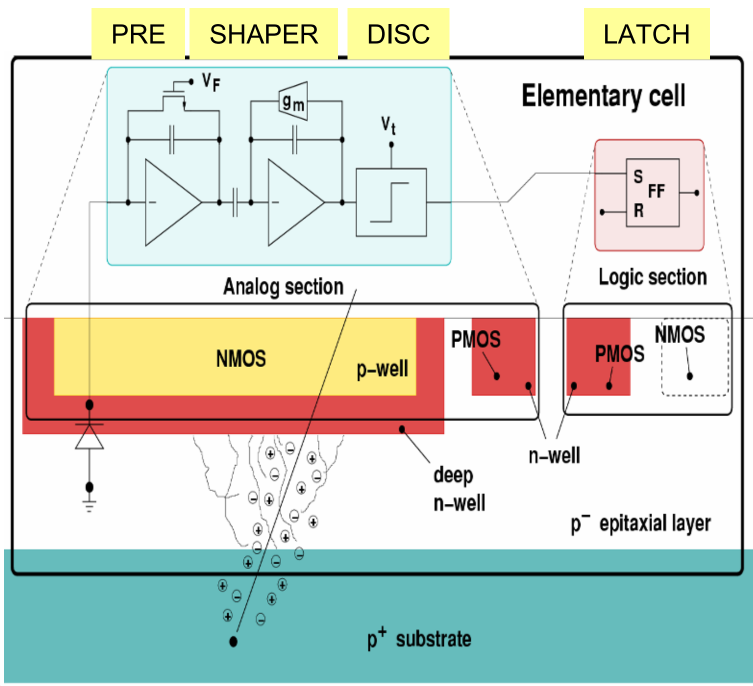
- Quite a bit of R&D going on on MAPS

MAPS R&D II

ST 0.13um triple well technology
Single pixels tested with source
Full signal processing chain

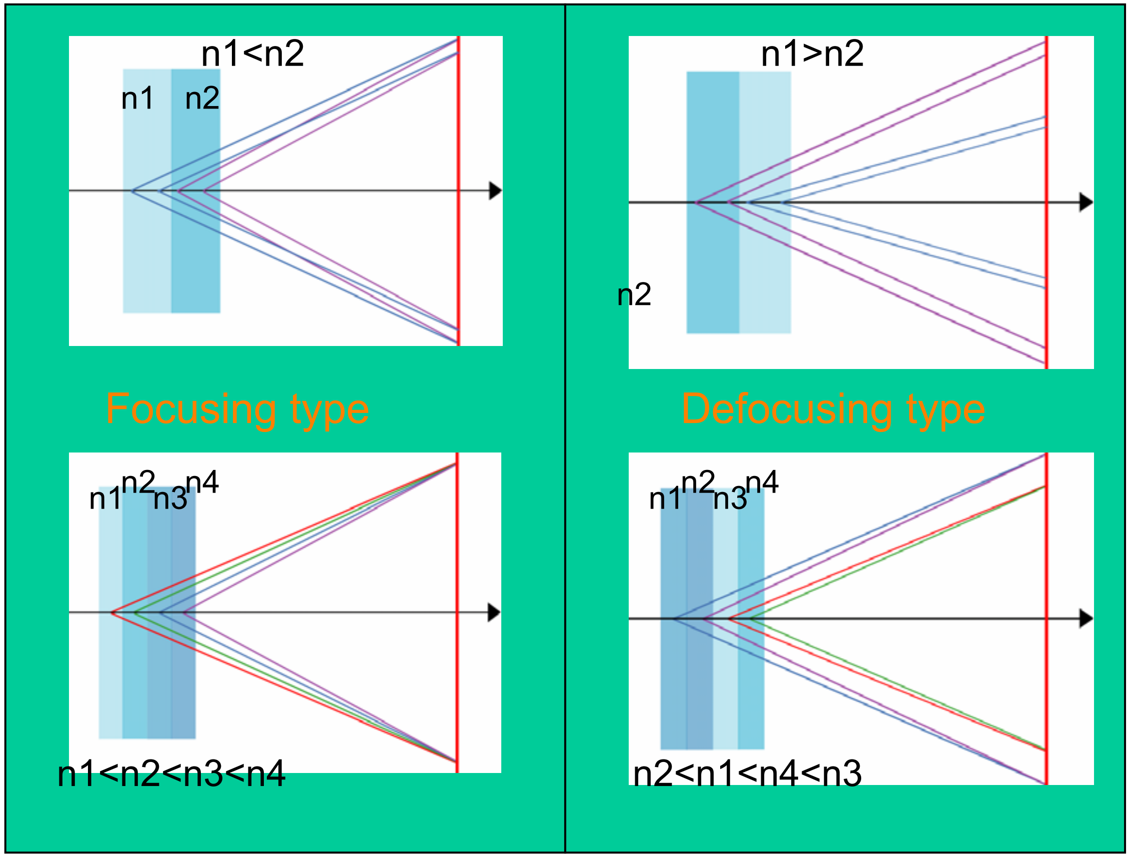
- SLIM chip (Babar collabor.)

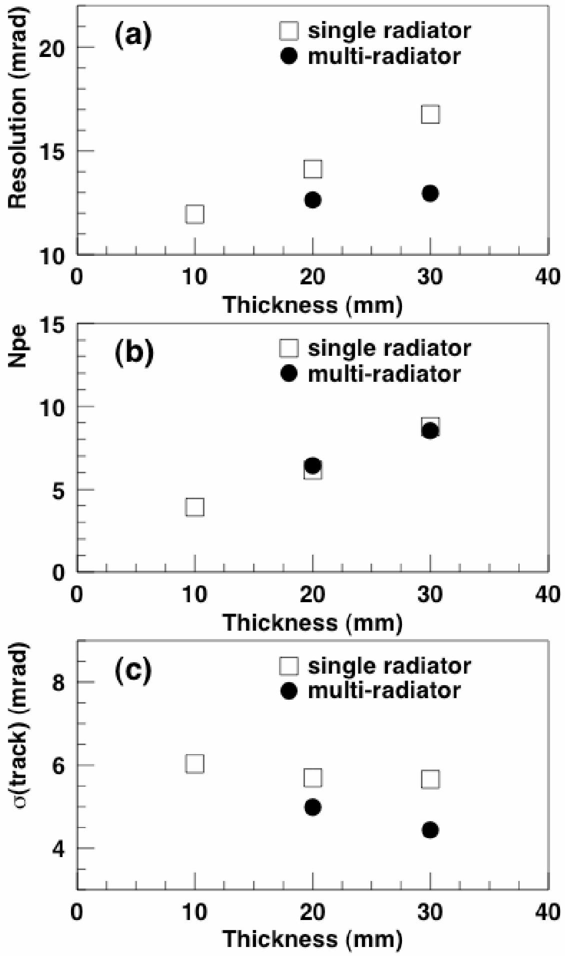




Focusing Aerogel-RICH to cover front/back

- New imaging technique by introducing multiple radiators





Increase Cherenkov photons without loosing single angle resolution due to emission point uncertainty

Take full advantage of controllable index of aerogel

ISTITUTO NAZIONALE DI FISICA NUCLEARE

INFN-AE 05-08
20 Dicembre 2005

Since nov 12,2005

INFN Roadmap Report

SuperB: a linear high-luminosity B Factory

J. Albert,[1] S. Bettarini,[2] M. Biagini,[3] G. Bonneaud,[4] Y. Cai,[5] G. Calderini,[2] M. Ciuchini,[6] G. P.Dubois-Felsmann,[1] S. Ecklund,[5] F. Forti,[2] T. J. Gershon,[7] M. A. Giorgi,[2] D. G. Hitlin,[1] D. W. G. S. Leith,[5] A. Lusiani,[2] D. B. MacFarlane,[5] F. Martinez-Vidal,[8] N. Neri,[2] A. Novokhatski,[5] M. Pierini,[9] G. Piredda,[10] S. Playfer,[11] F. C. Porter,[1] P. Raimondi,[3] B. N.Ratcliff,[5] A. Roodman,[5] J. Seeman,[5] L. Silvestrini,[10] A. Stocchi,[12] M. Sullivan,[5] U. Wienands,[5] and W. J. Wisniewski[5]

[1]*California Institute of Technology, Pasadena, CA 91125, USA*
[2]*Università di Pisa, Dipartimento di Fisica, Scuola Normale Superiore and INFN, I-56127 Pisa, Italy*
[3]*Laboratori Nazionali di Frascati dell'INFN, I-00044 Frascati, Italy*
[4]*Ecole Polytechnique, LLR, F-91128 Palaiseau, France*
[5]*Stanford Linear Accelerator Center, Stanford, CA 94309, USA*
[6]*Università di Roma Tre, Dipartimento di Fisica and INFN, I-00146 Roma, Italy*
[7]*Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom*
[8]*IFIC, Universitat de Valencia-CSIC, E-46071 Valencia, Spain*
[9]*University of Wisconsin, Madison, Wisconsin 53706, USA*
[10]*Università di Roma La Sapienza, Dipartimento di Fisica and INFN, I-00185 Roma, Italy*
[11]*University of Edinburgh, Edinburgh EH9 3JZ, United Kingdom*
[12]*Laboratoire de l'Accélérateur Linéaire, F-91898 Orsay, France*

Abstract

This paper is based on the outcome of the activity that has taken place during the recent workshop on "SuperB in Italy" held in Frascati on November 11-12, 2005. The workshop was opened by a theoretical introduction of Marco Ciuchini and was structured in two working

International study group

An international Study Group was set up coordinated by a steering committee with the aim of preparing a document (CDR) by the end of 2006. Next 2 workshops :

- 14-17june 06 in SLAC
- october 06 in Rome.

M.A.G. coordinator

Members: 1 Canada,2 France, 2 Germany, 2 Italy, 2 Russia, 2Spain, 2 UK, 4 US.

Activity is documented in

http://www.pi.infn.it/SuperB

http://www.pi.infn.it/SuperB