The Next Generation B-Factories

Michael Roney
University of Victoria

Lake Louise Winter Institute
22 February 2011

Physics Program

Super Flavour Factory Accelerators

The Detectors

Status

Physics program

Overview

- Use a broad set of measurements to observe physics beyond the Standard Model and to elucidate its nature.
- Precision measurements
  - new physics enter in loops
  - interference $\Rightarrow$ asymmetries
- Rare/Forbidden (in SM) decays

Overview

- e^+e^- collider with centre-of-mass near Υ(4S)
  - just above threshold for B-meson pair production – no fragmentation
- Luminosity 100x previous generation e^+e^- collider $\mathcal{L}=10^{34}$ -> 10^{36} cm^{-2} s^{-1}
  - 5-10 x 10^{10} b, c, τ pairs (50-100 ab^{-1})
- Operate with asymmetric beam energies to give boost to CM allowing for time dependent CPV measurements

Overview

- Complements LHC program, both of ATLAS, CMS as well as LHCb
- LHCb is a 'current generation' B Factory
  - Limited by trigger to ~ 1fb^{-1} per year
  - Submitted expression of interest in April 2008 for an upgrade giving x10 as follow-up to a 10 fb^{-1} sample
  - LOI in preparation to upgrade after 5 fb^{-1}
- Focus this talk on 'Next Generation' e^+e^- Super Flavour Factories

Flavour sector gives experimental basis for much of SM parameters that can be:

- determined experimentally with precision
- compared with reliable theoretical predictions

established major pillars of the Standard Model:

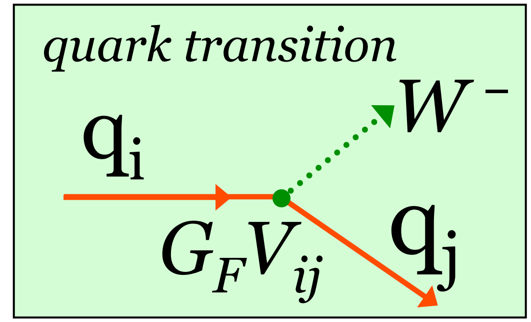
- the particle content
- the weak couplings
- the suppression of flavour-changing neutral current

and constrains Beyond-SM theories

e.g. Minimal Flavour Violation (?)

when new physics is found at the LHC the flavour sector will continue to provide **unique information on the nature of that new physics**

CKM Matrix



In SM weak charged transitions mix quarks of different generations

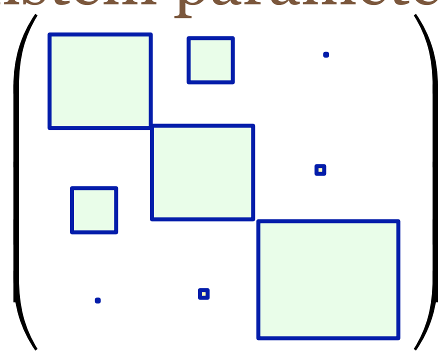
Encoded in unitary CKM matrix

$$\begin{pmatrix} d' & s' & b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Unitarity ➔ 4 independent parameters, one of which is the complex phase and sole source of CP violation in SM

Wolfenstein parameterisation:

$\mathbf{V}_{CKM} =$



$$= \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

CKM Unitarity Triangle

Physics beyond the SM signaled by breakdown of unitarity of CKM matrix

$$\lambda^2 = \frac{|V_{us}|^2}{|V_{ud}|^2 + |V_{us}|^2}; \quad A^2\lambda^4 = \frac{|V_{cb}|^2}{|V_{ud}|^2 + |V_{us}|^2}; \quad \bar{\rho} + i\bar{\eta} = -\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}$$

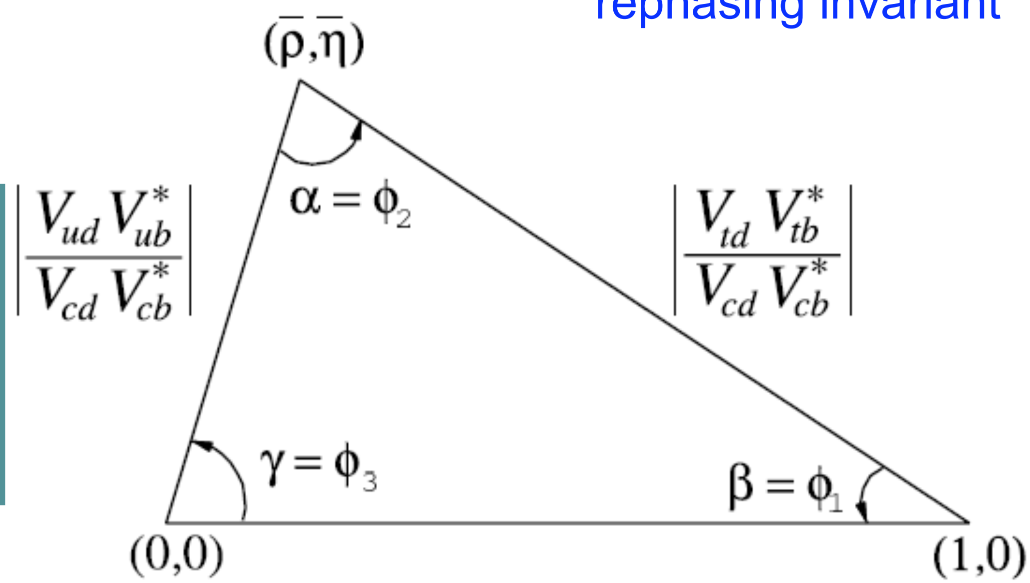
Wolfenstein parameterisation defined to hold to all orders in λ~0.2 and rephasing invariant

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

$$\alpha = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right) \quad \beta = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$$

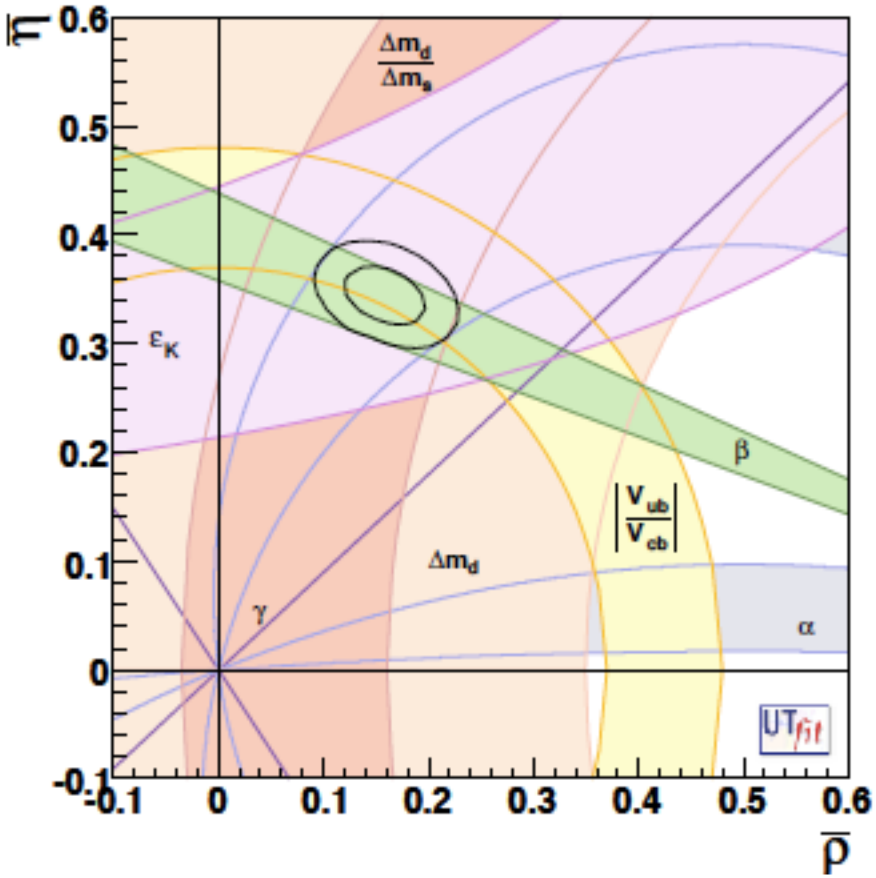
$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right) \quad \beta_s = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*}\right)$$

Area of Δ~CP violation

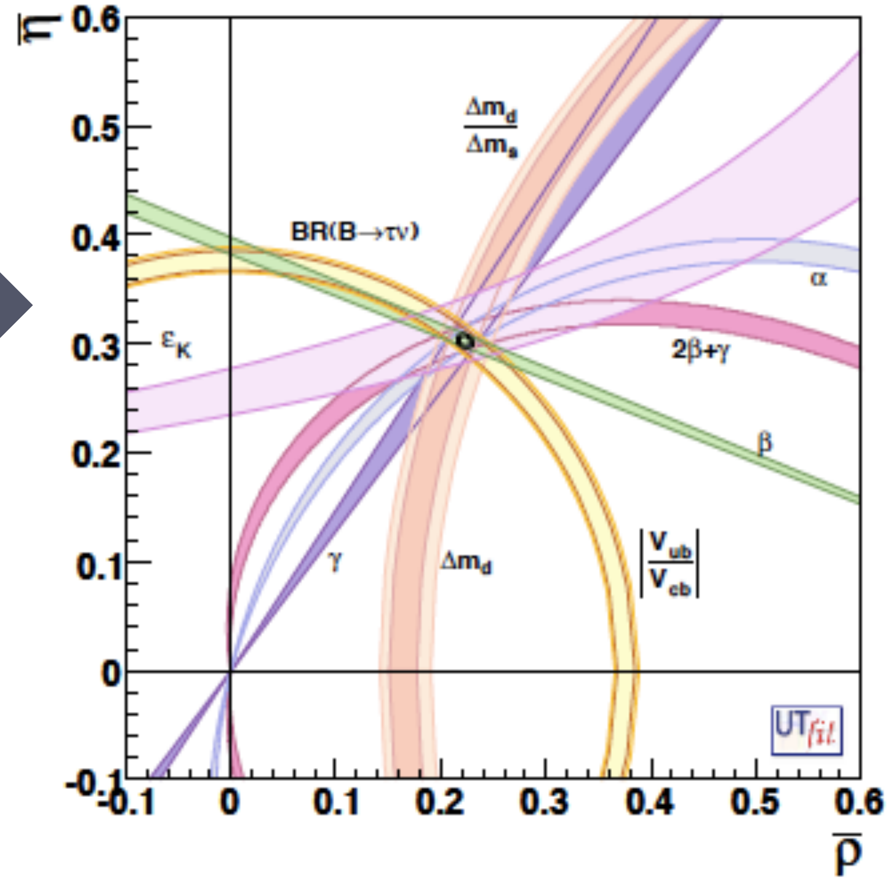


CKM Matrix

$\rho = 0.163 \pm 0.028$
$\eta = 0.344 \pm 0.016$



$\rho = \quad \pm 0.0028$
$\eta = \quad \pm 0.0024$



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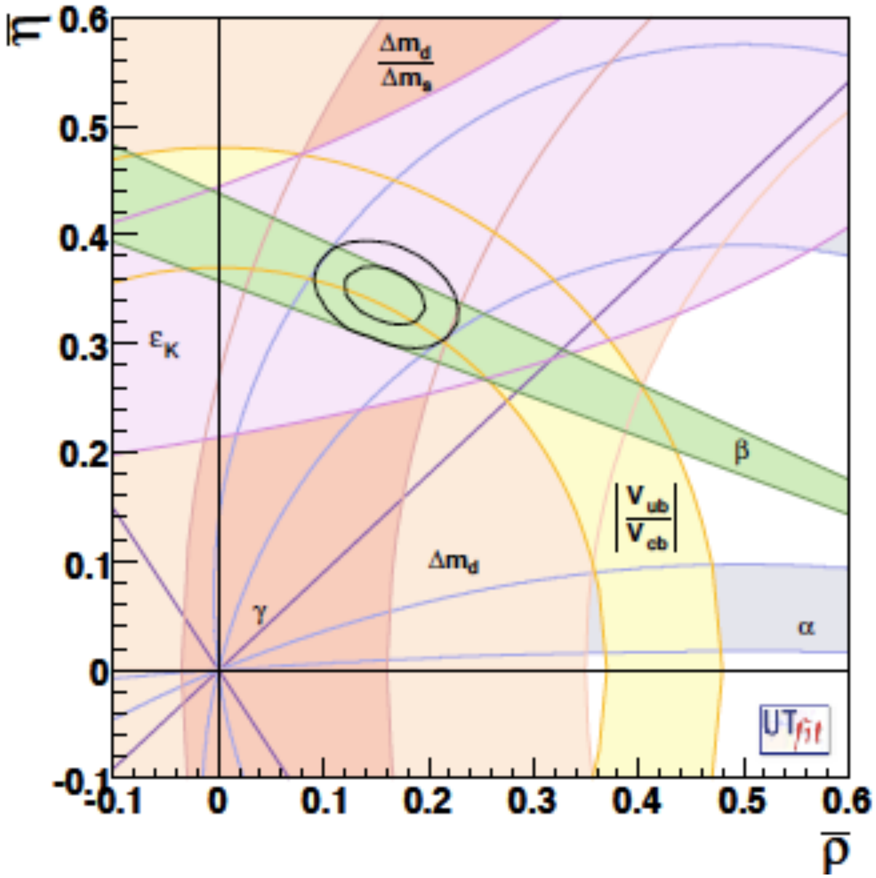
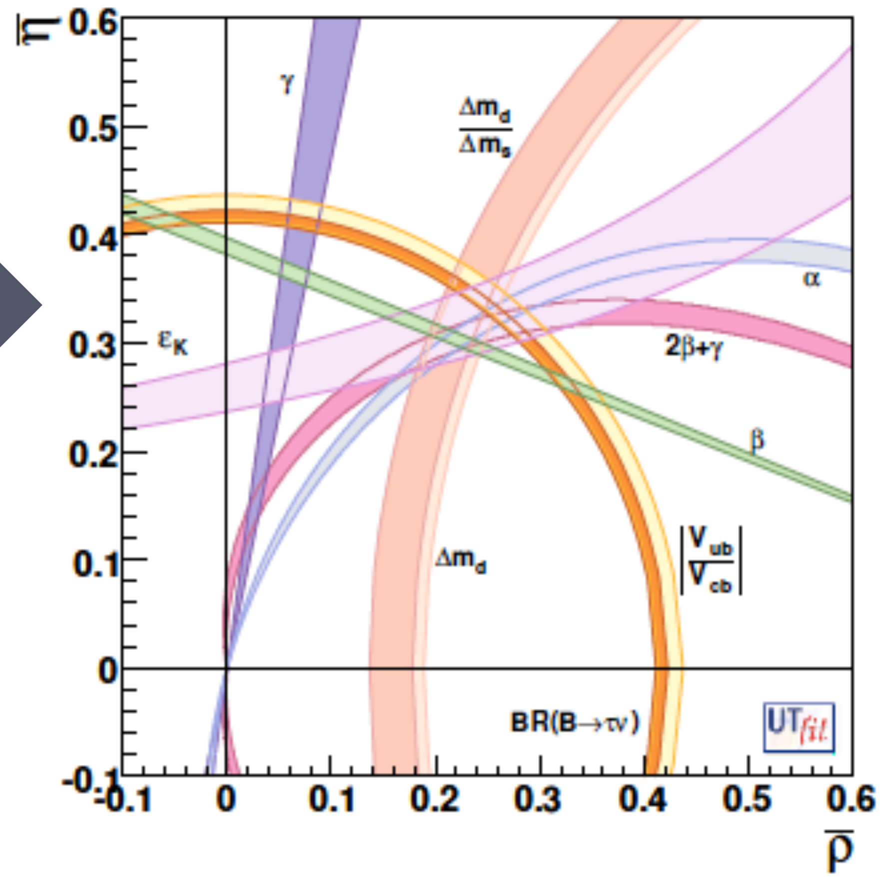


More interesting when SM fails – putting in ρ & η central values c 2008



Physics at Super Flavour Factories

- Test CKM at 1% level
  - CPV in B decays from new physics (non-CKM)
- B-recoil technique for B->K(*)ll, B->τν, B->D*τν
- τ physics: lepton flavour violations, g-2, EDM, CPV
- With polarised beam: Precision EW physics
- Many other topics:
  - ϒ(5S) physics, CPV in Charm, ISR radiative return, spectroscopy…
- Physics motivation is independent of LHC
  - If LHC finds NP, precision flavour input essential
  - If LHC finds no NP, high statistics B and τ decays are unique way of probing >TeV scale physics

Super Flavour Factory Physics Program Summary

B Physics at the $\Upsilon(4S)$

A. New Physics in CP violation
   1. ΔS measurements
B. Theoretical aspects of rare decays
   1. New physics in $B \to K^{(*)}\nu\bar{\nu}$ decays
   2. $\bar{B} \to X_s\gamma$ and $\bar{B} \to X_s\ell^+\ell^-$
   3. Angular analysis of $B \to K^* l^+ l^-$
   4. $\bar{B} \to X_d\gamma$ and $\bar{B} \to X_d\ell^+\ell^-$
C. Experimental aspects of rare decays
   1. $B \to K^{(*)}\nu\bar{\nu}$
   2. $B \to \ell\nu$ and $B \to \ell\nu\gamma$
   3. Experimental aspects of $\bar{B} \to X_s\gamma$
   4. Inclusive and exclusive $b \to s\ell^+\ell^-$
   5. More on $B \to X_{s/d}\ell^+\ell^-$ with a hadron tag
D. Determination of $|V_{ub}|$ and $|V_{cb}|$
   1. Inclusive Determination of $|V_{ub}|$
   2. Inclusive Determination of $|V_{cb}|$
E. Studies in Mixing and CP Violation in Mixing
   1. Measurements of the mixing frequency and CP asymmetries
   2. New Physics in mixing
   3. Tests of CPT
F. Why measure γ precisely (and how)?
G. Charmless hadronic B decays
H. Precision CKM

B Physics at the $\Upsilon(5S)$

1. Measurement of B_s Mixing Parameters
2. Time Dependent CP Asymmetries at the $\Upsilon(5S)$
3. Rare Radiative B_s Decays
4. Measurement of $B_s \to \gamma\gamma$
5. Phenomenological Implications

Super Flavour Factory Physics Program Summary

Electroweak neutral current measurements

Spectroscopy
A. Introduction
B. Light Mesons
C. Charmonium
D. Bottomonium
  1. Regular bottomonium
  2. Exotic bottomonium
E. Interplay with other experiments

Direct Searches
A. Light Higgs
B. Invisible decays and Dark Matter
C. Dark Forces

τ physics
A. Lepton Flavor Violation in τ decay
  Predictions from New Physics models
    LFV in the MSSM
    LFV in other scenarios
  Super$B$ experimental reach
B. *CP* Violation in τ decay
C. Measurement of the τ electric dipole moment
D. Measurement of the τ $g-2$
E. Search for second-class currents

Super Flavour Factory Physics Program Summary

Complementary with LHCb

	Belle or BaBar	SuperB or Belle II	LHCb
	~ 0.5 ab^{-1}	50 ab^{-1}	10 fb^{-1}
$\Delta S(\phi K_S)$	0.22	0.029	0.14
$\Delta S(\eta' K_S)$	0.11	0.020	---
β_s from $S(J/\psi\phi)$	---	---	0.01
$S(K^*\gamma)$	0.36	0.03	---
$S(\rho\gamma)$	0.68	0.08	---
$\Delta B/B(B \to \tau\nu)$	3.5σ	3%	---
$B_s \to \mu\mu$	•	•	5σ @ 6 fb^{-1}
$\tau \to \mu\gamma$ [×10^{-9}]	<45	<8	---
$\tau \to \mu\mu\mu$ [×10^{-9}]	<209	<1	---
α / ϕ_2	11^0	1^0	4.5^0
γ / ϕ_3	16^0	2^0	2.4^0

Advantage:

LHCb

- Modes where the final states are charged only.
- B_s
- B_c, Λ_b
- …..

B factories

- Modes with γ, π^0 .
- Modes with ν .
- τ decays.
- K_S vertex.

Fits - present situation

L. Silvestrini et al.

Is the fit showing some discrepancy ?

	Prediction	Measurement	Pull (σ)
$\sin 2\beta$	0.754±0.035	0.654±0.026	2.3
α	(85±4)°	(94±7)°	1.1
γ	(70±3)°	(73±11)°	<1
Δm_s	$(18.2\pm1.2)ps^{-1}$	$(17.77\pm0.12)ps^{-1}$	<1
$\lvert V_{ub}\rvert$	$(35.8\pm1.1)10^{-4}$	$(37.2\pm2.1)10^{-4}$	<1
B_K	(0.86±0.07)	(0.731±0.036)	1.6
$BR(B\to\tau\nu)$	$(79\pm7)10^{-6}$	$(174\pm34)10^{-6}$	2.7
β_s	(1.08±0.04)°	TeVatron average	2.1
$\Delta\Gamma_s/\Gamma_s$	0.15±0.02	TeVatron average	
A_{SL}^s	$(0.016\pm0.038)10^{-3}$	$(-1.7\pm9.1)10^{-3}$	<1
$A_{\mu\mu}$	$(-0.17\pm0.05)10^{-3}$	$(-9.57\pm2.90)10^{-3}$	3.2

tensions for some observable

- $B\to\tau\nu$ and $\sin 2\beta$ pulls on $|V_{ub}|$ on opposite direction
- MFV cannot improve agreement on $\sin 2\beta$ and B_s
- Large $\tan\beta$ generate effects in wrong direction..

$$\tan\beta < 7.3 m_{H+}/(100\ \mathrm{GeV})$$

And also

$BR(B_s\to\mu\mu) < 26\times10^{-9}$ @95% prob.

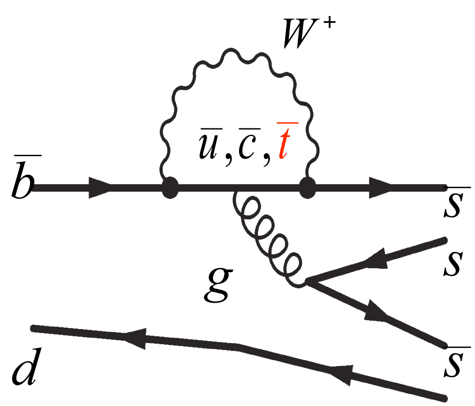
NP probed using many measurements

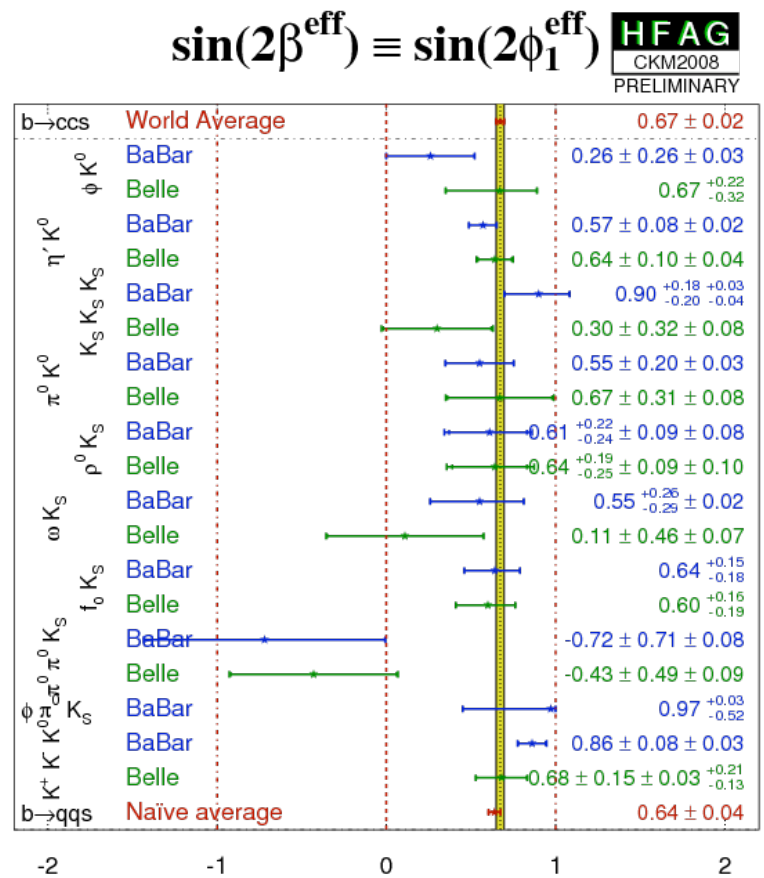
TABLE XXIII: "DNA" of flavour physics effects for the most interesting observables in a selection of SUSY models from Ref. [416]. ★★★ signals large effects, ★★ visible but small effects and ★ implies that the given model does not predict sizable effects in that observable.

	AC	RVV2	AKM	δLL	FBMSSM
$D^0 - \bar{D}^0$	★★★	★	★	★	★
$S_{\psi\phi}$	★★★	★★★	★★★	★	★
$S_{\phi K_S}$	★★★	★★	★	★★★	★★★
$A_{\rm CP}(B \to X_s\gamma)$	★	★	★	★★★	★★★
$A_{7,8}(B \to K^*\mu^+\mu^-)$	★	★	★	★★★	★★★
$A_9(B \to K^*\mu^+\mu^-)$	★	★	★	★	★
$B \to K^{(*)}\nu\bar{\nu}$	★	★	★	★	★
$B_s \to \mu^+\mu^-$	★★★	★★★	★★★	★★★	★★★
$\tau \to \mu\gamma$	★★★	★★★	★	★★★	★★★

Example 1) sin2β from Gluonic Penguins

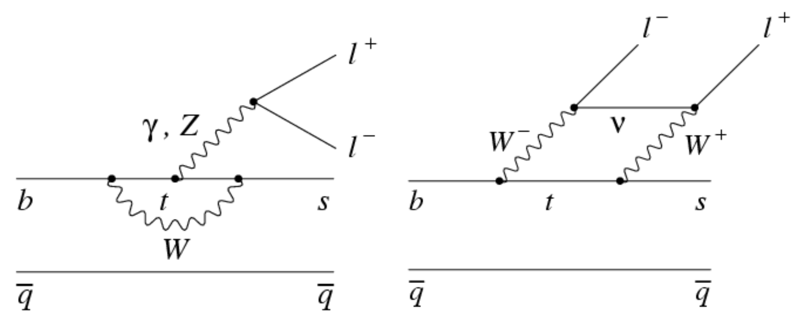
- SM CP asymmetry is sin2β, but new physics in loop with different phase will modify.
- Need to understand QCD effects.
  - calculations
  - many modes

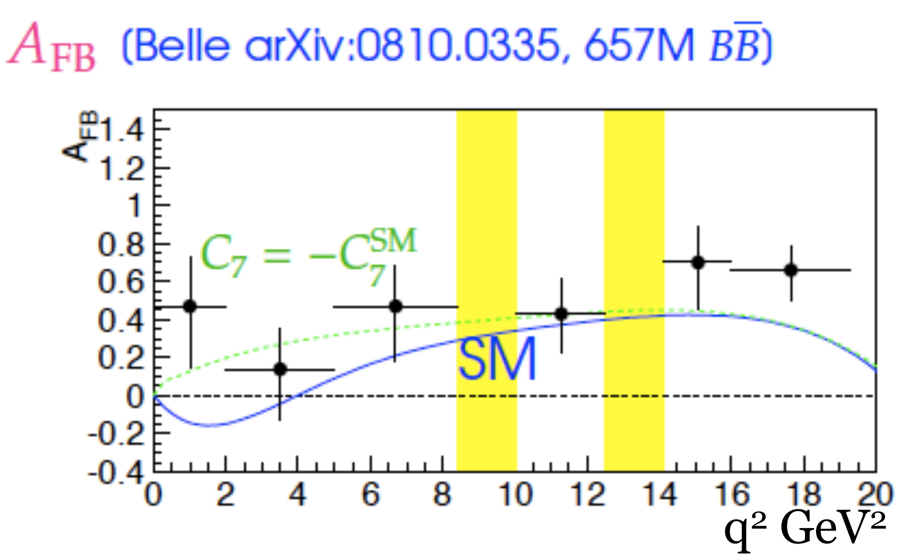


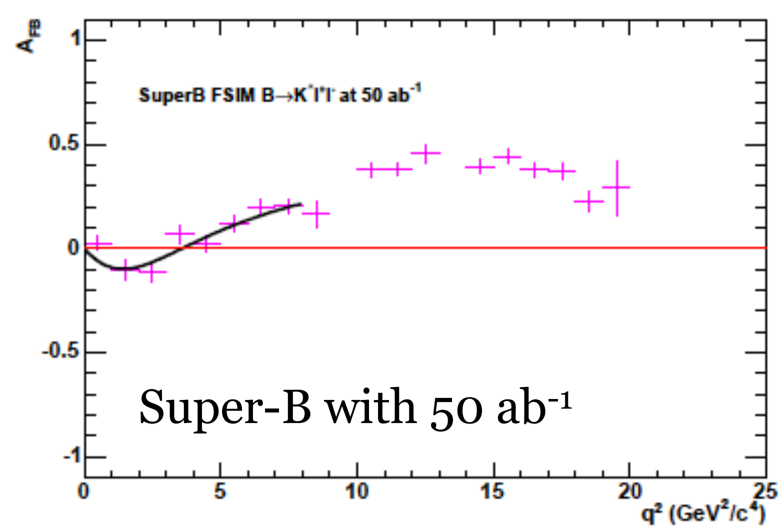


Example 2) Flavour-changing Neutral Currents e.g. $B \rightarrow K^{(*)}\ell^+\ell^-$

- Forward/Backward asymmetry sensitive to new physics.
- Current measurements do not agree well with SM

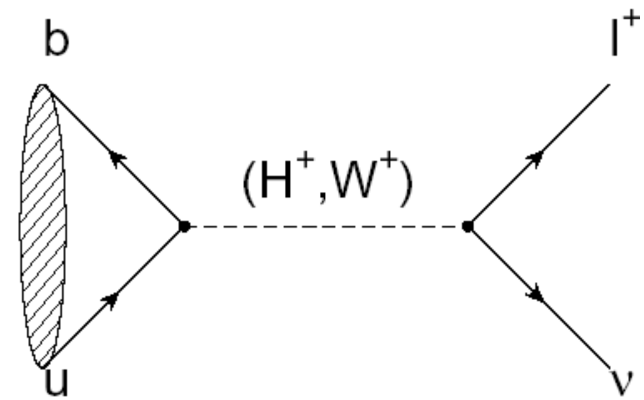






Example 3) Rare Leptonic Decays

- $B^{\pm} \rightarrow \tau^{\pm}\nu$ & $B^{\pm} \rightarrow \mu^{\pm}\nu$ directly sensitive to charged higgs.
- important SM parameters V_{ub} and f_B.



$$BF(B \rightarrow l\nu)_{SM} = \frac{G_F^2 m_B}{8\pi} m_l^2 \left(1 - \frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

the most accessible leptonic B decay

$$BF(B \rightarrow \tau\nu)_{SM} = [1.20 \pm 0.25] \times 10^{-4}$$

$|V_{ub}| = (4.32 \pm 0.16 \pm 0.29) \times 10^{-3}$ From inclusive semileptonic B decays HFAG ICHEP08

$f_B = 190 \pm 13$MeV, From LQCD HPQCD arXiv:0902.1815

$B^+ \to \tau^+ \nu_\tau$ Sensitive to charged Higgs

W. S. Hou, PR D **48**, 2342 (1993)

$$BF(B^+ \to l^+ \nu_l) = BF(B^+ \to l^+ \nu_l)_{SM} \times r_H$$

TYPE II 2HDM

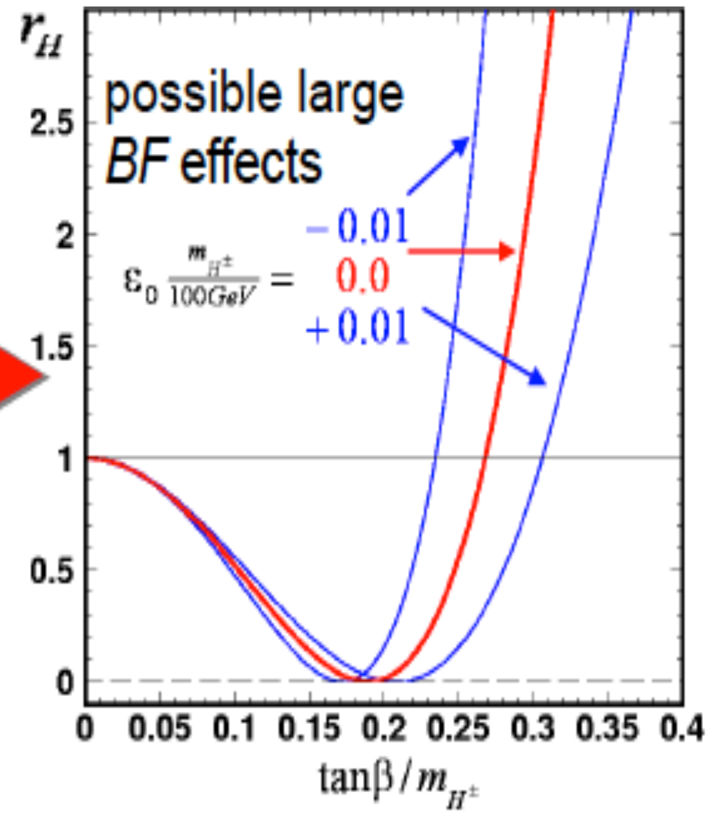
$$r_H = \left(1 - \frac{m_B^2 \tan^2\beta}{m_{H^\pm}^2}\right)^2$$

MSSM

$$r_H = \left(1 - \frac{m_B^2 \tan^2\beta}{m_{H^\pm}^2} \frac{1}{1+\varepsilon_0 \tan\beta}\right)^2$$

e.g. G. Isidori, arXiv:07010.5377

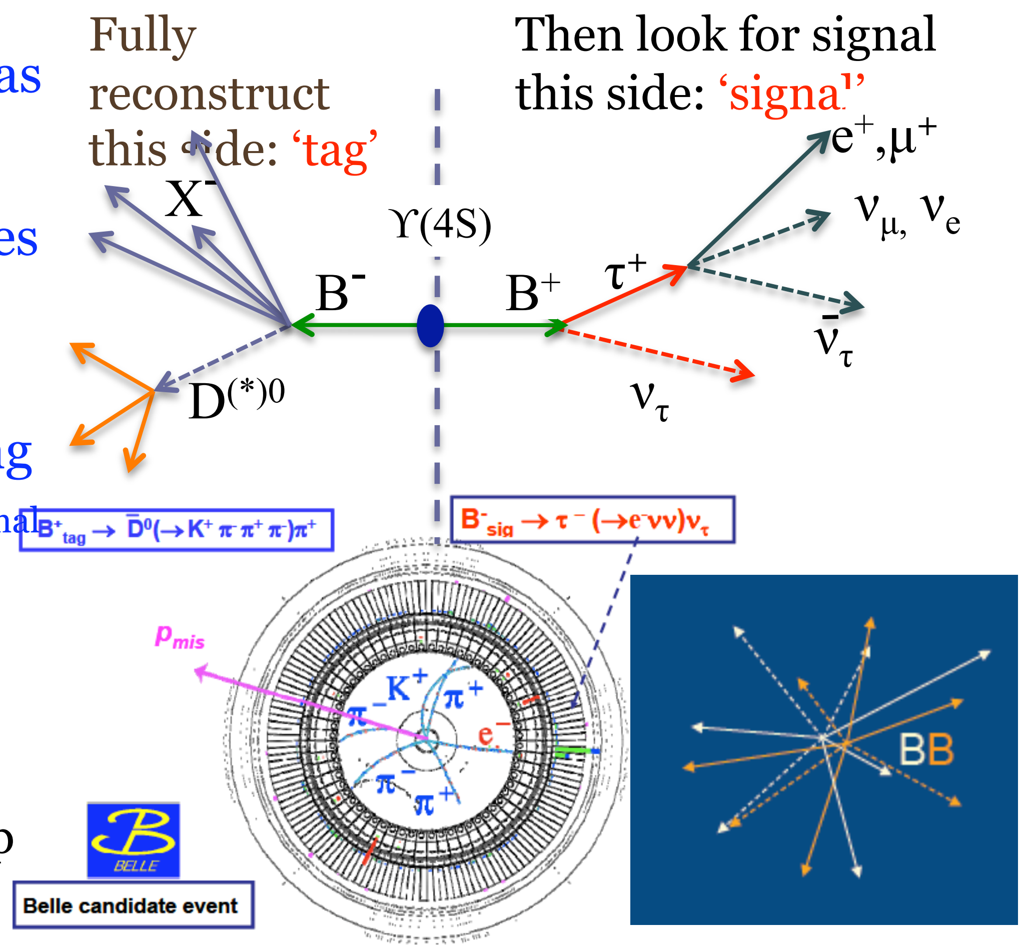
SUSY loop corr.



$B^+ \to \tau^+ \nu_\tau$ Experimental method

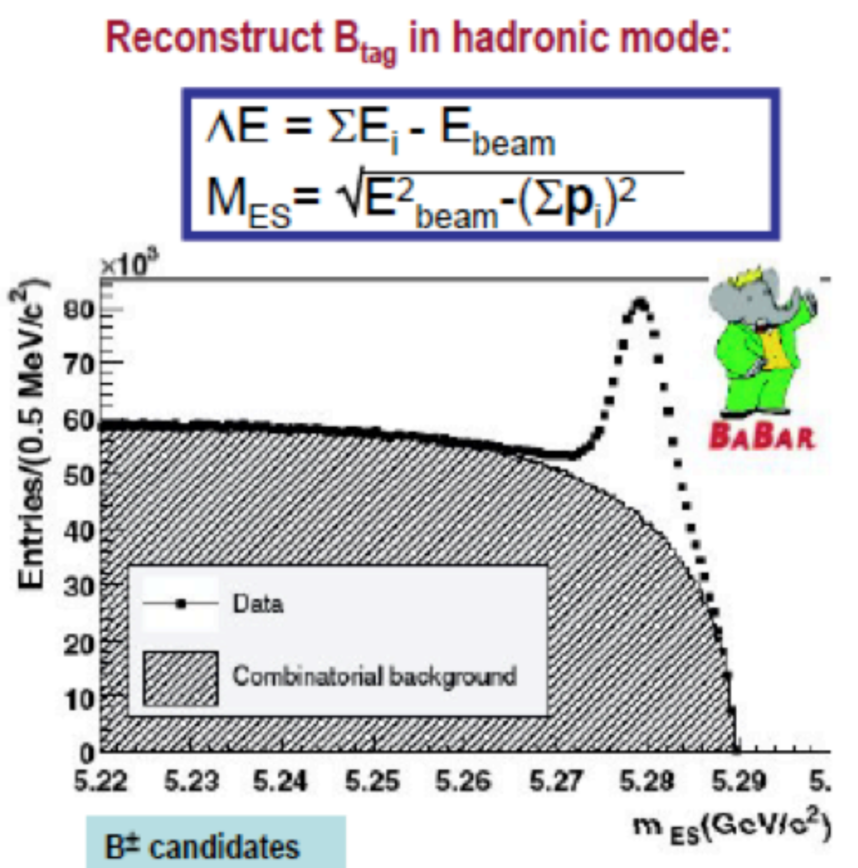
Two approaches to reconstruct the 'tag', which are classified as hadronic or semileptonic

1. select signal candidate and check that remaining particles consistent with B decay (inclusive B_{tag} reco)
2. Reconstruct B_{tag} in exclusive modes and check if remaining particles consistent with B_{signal}

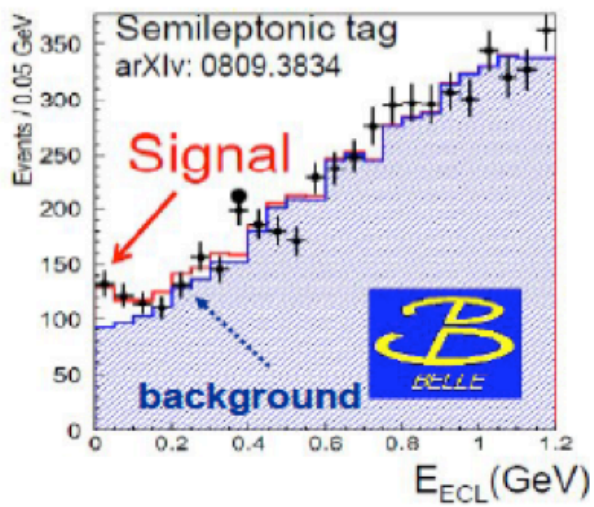


In reality at the Υ(4S) the B^+ and B^- decay products all overlap

Reconstruct event to select B⁻ events from background…



....and look for excess of missing energy associated with the neutrino



D(*)l ν tag

$B^- \to D^{*0} l^+ \nu$, $D^0 l \nu$
$D^{*0} \to D^0 \pi^0$, $D^0 \gamma$
$D^0 \to K^-\pi^+, K^-\pi^+\pi^-\pi^+, K^-\pi^+\pi^0$

657 M $B\bar{B}$

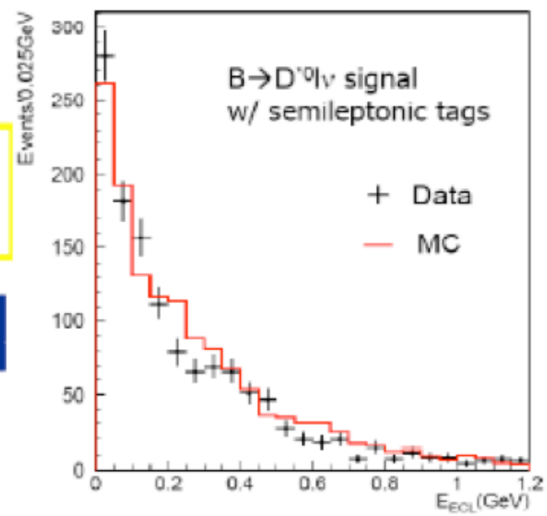
hep-ex/0809.3834

Preliminary

visible products of τ decay

$h = \pi^\pm$, $l = e^\pm$, $\mu^\pm$

$B \to D^{*0} l \nu$ control sample



$N_{sig} = 154^{+36}_{-35}$ (stat) $^{+20}_{-22}$ (syst)

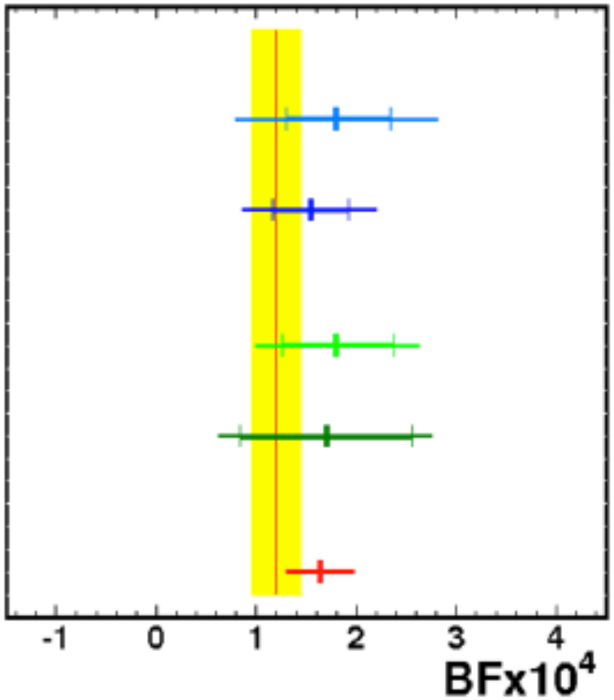
$\Rightarrow \mathcal{B}(B \to \tau\nu) = (1.65^{+0.38}_{-0.37}{}^{+0.35}_{-0.37}) \times 10^{-4}$

3.8σ

Obtained $Br(B^- \to D^{*0} l \nu) = 6.0 \pm 0.2$ (stat) %

$B^+ \to \tau^+ \nu_\tau$ Current Results

$BF(B^+ \to \tau^+ \nu_\tau)$



stat. syst.

$[1.79^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)]\times10^{-4}$ — hadronic tags

$[1.54^{+0.38}_{-0.37}(stat)^{+0.35}_{-0.37}(syst)]\times10^{-4}$ — semileptonic tags

$[1.80^{+0.57}_{-0.54}(stat)\pm0.26(syst)]\times10^{-4}$ — hadronic tags

$[1.7\pm0.8(stat)\pm0.2(syst)]\times10^{-4}$ — semileptonic tags

$[1.64\pm0.34]\times10^{-4}$ HFAG Aug. 2010 — average[1]

Standard Model[2]

Results consistent within uncertainties, but all above the SM prediction

$r_H = 1.37\pm0.39$

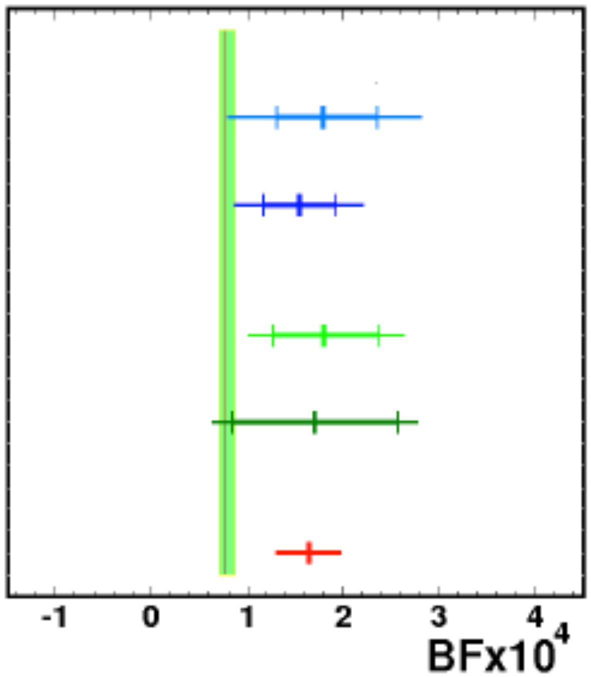
[1] HFAG, http://www.slac.stanford.edu/xorg/hfag

[2] $|V_{ub}|=(4.32\pm0.16\pm0.29)\times10^{-3}$ HFAG ICHEP08

$f_B=190\pm13$MeV HPQCD arXiv:0902.1815

$B^+ \to \tau^+ \nu_\tau$ Current Results

Alternative approach (within SM): extract $BF(B \to \tau\nu_\tau)$ from CKM fit using other flavour observables



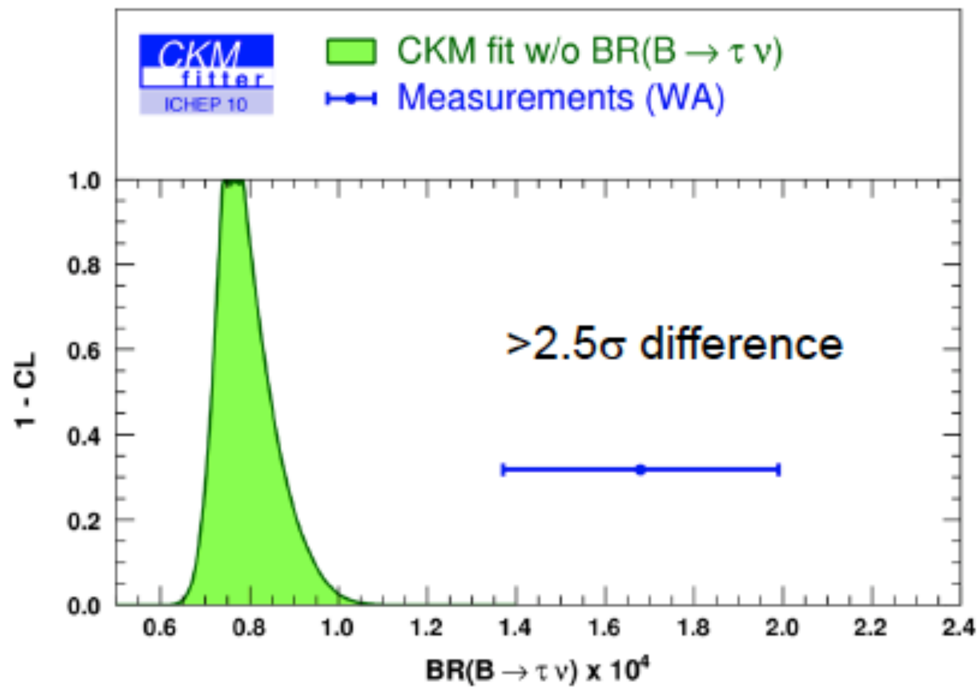
CKM fitter — *output of the CKM fit w/o BF(B→τν) in the input*

$$BF(B \to \tau\nu)_{SM(CKM)} = [\mathbf{0.763}^{+0.114}_{-0.061}] \times 10^{-4}$$

CKM fitter, S. T'Jampens @ ICHEP2010

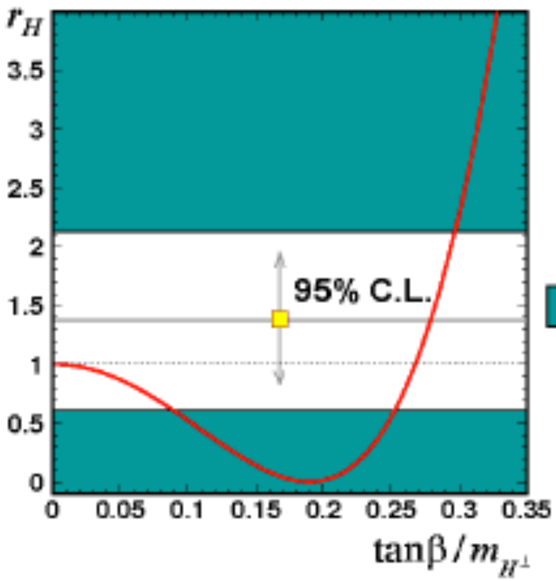
$$BF(B \to \tau\nu)_{SM(UT)} = [\mathbf{0.805} \pm 0.071] \times 10^{-4}$$

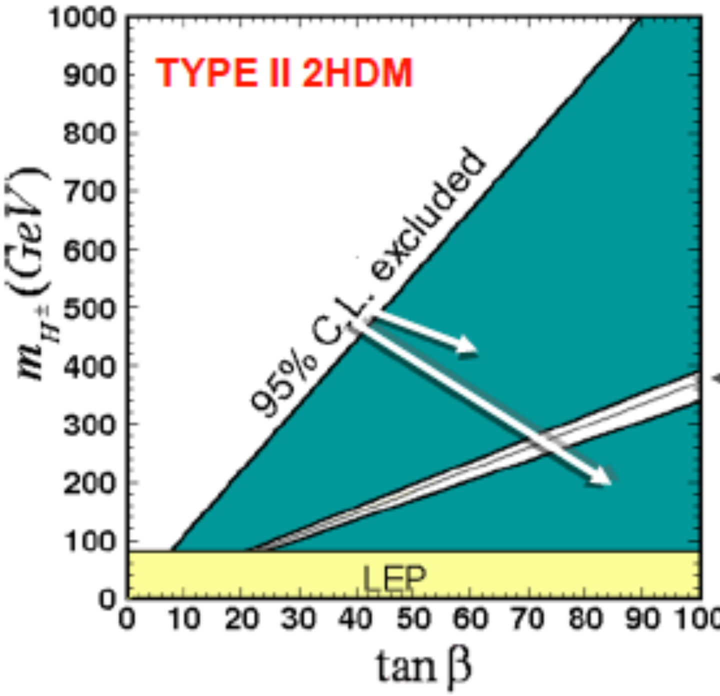
UTfit, C. Tarantino @ ICHEP2010



$B^+ \to \tau^+ \nu_\tau$ Current Results

$r_H = 1.37 \pm 0.39$ (LQCD)





Higgs contribution = double SM contribution

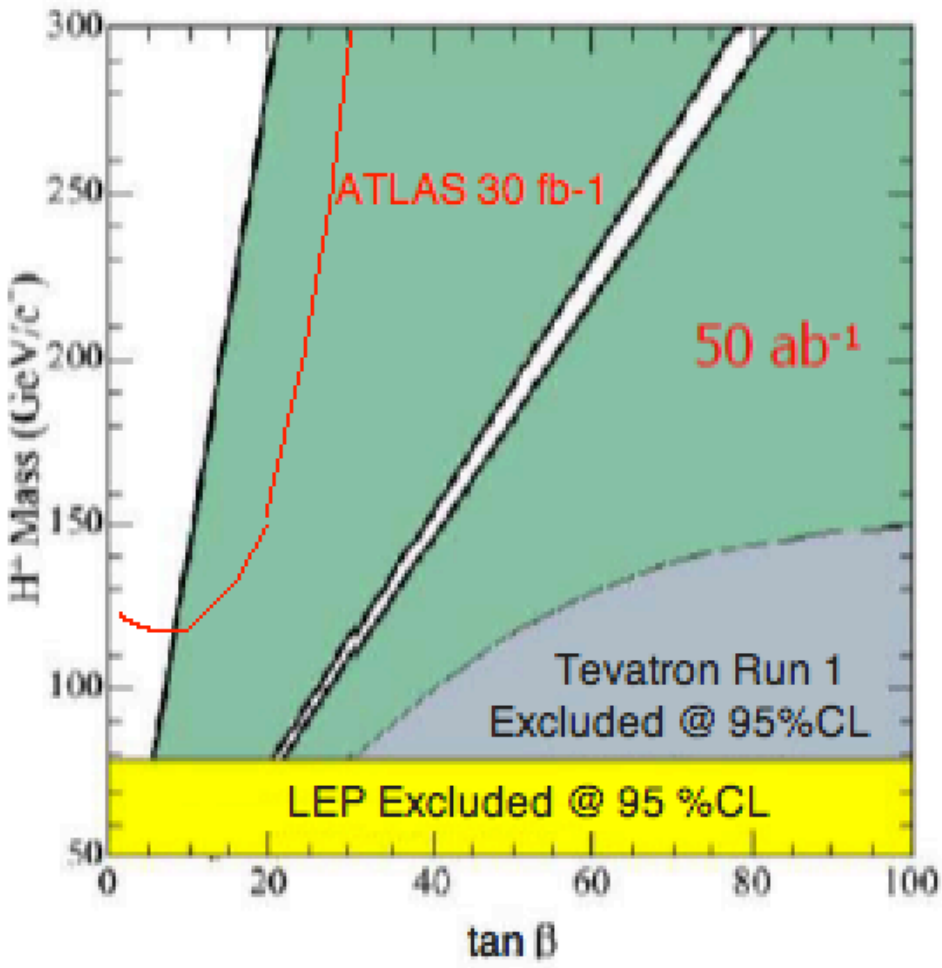
$r_H = 2.14 ^{+0.55}_{-0.48}$ (CKMfitter)

$r_H = 2.04 \pm 0.46$ (UTfit)

Exclude different $\tan\beta / m_{H^\pm}$ regions

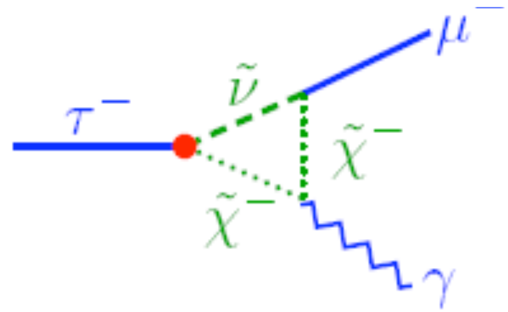
T. Hurth

Limit on Charged Higgs from $B^+ \rightarrow \tau^+ \nu_\tau$ with $50 ab^{-1}$ at Super Flavour Factories



Example 4) Lepton Flavour Violation

- e.g. $\tau^\pm \to \mu^\pm \gamma$ or $\tau^\pm \to \ell^\pm \ell^\mp \ell^\pm$
- Polarization helps suppress backgrounds, mainly $e^+e^- \to \gamma_{ISR}\tau^+\tau^-$ and identify nature of signal if observed



SuperB, 75 ab^{-1}

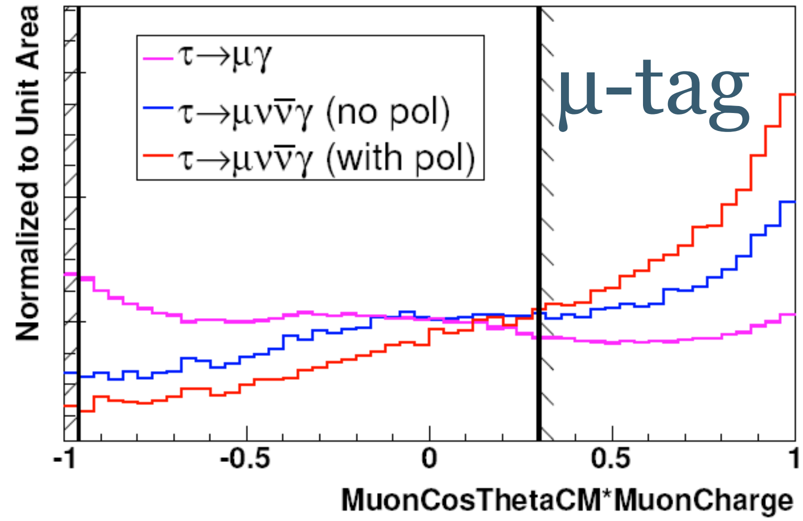
Process	Expected 90% CL upper limit	3σ evidence reach
$\mathcal{B}(\tau \to \mu\gamma)$	2.4×10^{-9}	5.4×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	3.0×10^{-9}	6.8×10^{-9}
$\mathcal{B}(\tau \to \ell\ell\ell)$	2.3–8.2×10^{-10}	1.2–4.0×10^{-9}

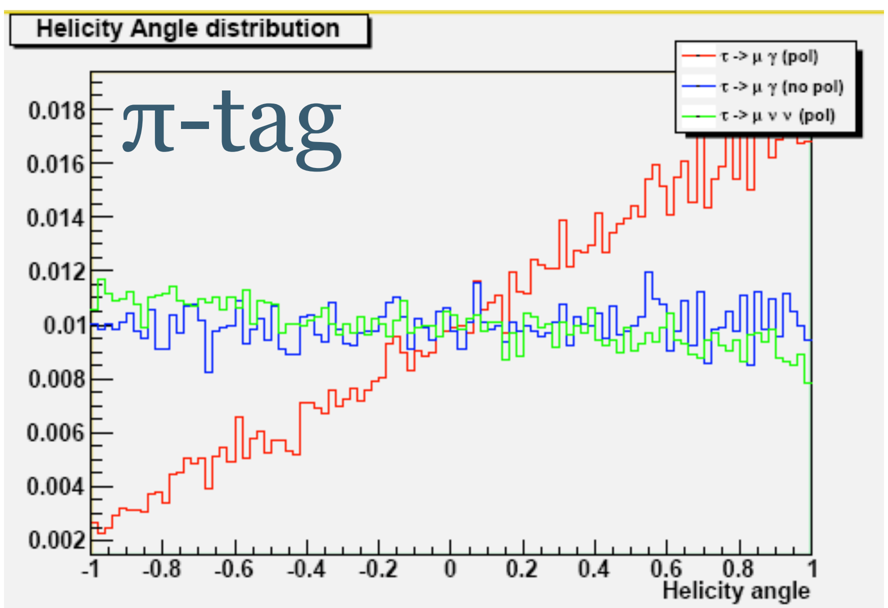
cf 90% cl Limits on $B(\tau \to \mu\gamma)$: $<4.5\text{x}10^{-8}$ (Belle)
$<4.4\text{x}10^{-8}$ (BaBar)

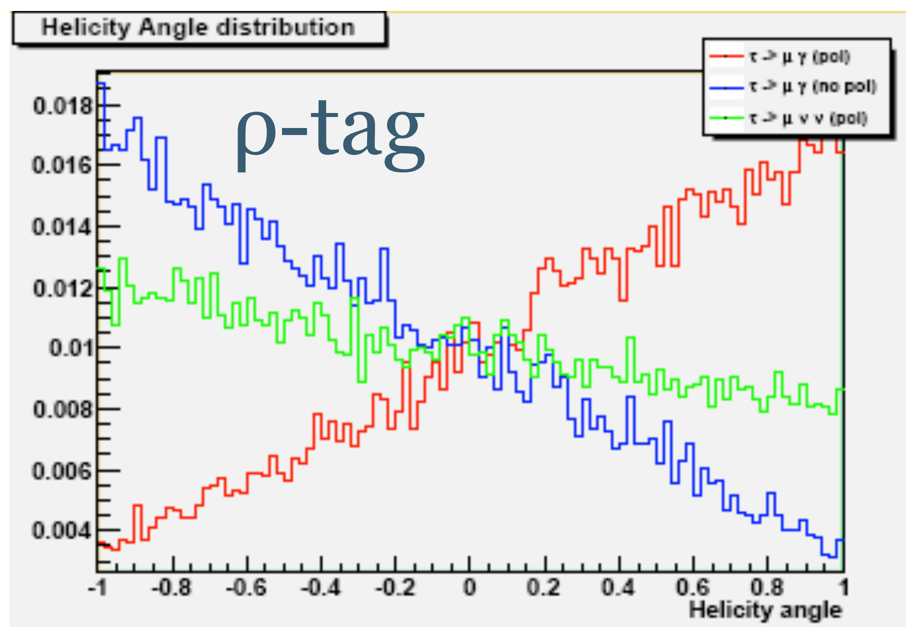
Lepton Flavour Violation

$\tau^{\pm} \rightarrow \mu^{\pm}\gamma$

Signal/Background improvements with polarised beam







Example 5) Polarized Beam provide an impressive Precision EW Program at SuperB

- Measure the difference between cross sections with left-handed beam electrons and right-handed beam electrons

$$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} \propto g_V^f = T_3^f - Q_f \sin^2\theta_W$$

Driven by $\gamma - Z$ interference at $\sqrt{s} = 10.58$ GeV

- same type of measurement as performed by SLD at the Z

$e^+e^- \rightarrow \mu^+\mu^-$ @ $\sqrt{s}$=10.58GeV

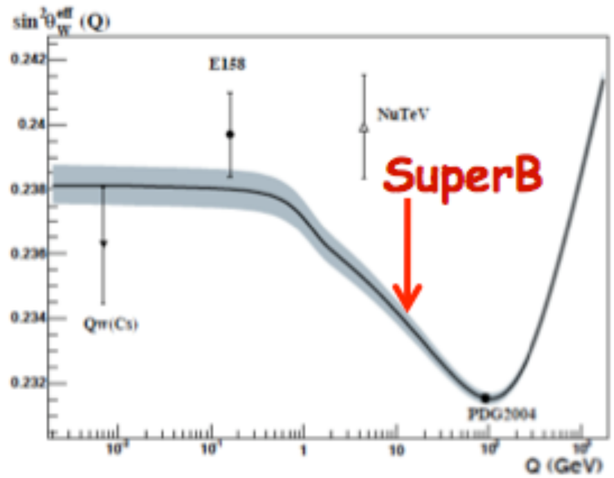
Diagrams	Cross Section (nb)	A_{FB}	A_{LR} (Pol = 100%)
$\|Z+\gamma\|^2$	1.01	0.0028	-0.00051

σ_{ALR} =5x10^{-6} → $\sigma_{(\sin 2\theta eff)}$ =0.00018

cf SLC A_{LR} $\sigma_{(\sin 2\theta eff)}$ =0.00026

relative stat. error of 1.1% (pol=80%)
require <~0.5% systematic error on beam polarisation

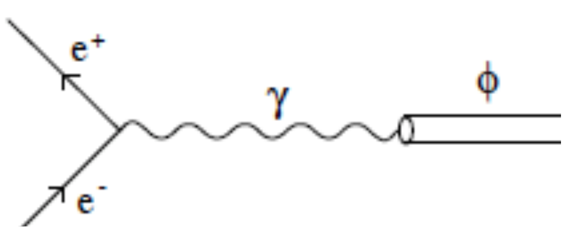
- polarized beam provide measurement of $\sin^2\Theta_W(\text{eff})$ of using muon pairs of comparable precision to that obtained by SLD, except at 10.58GeV.

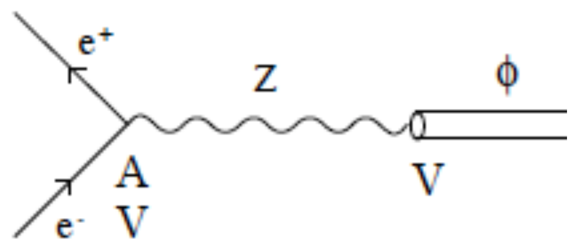


- Similar measurement can be made with taus and charm
- Test neutral current universality at high precision
- Because it depends on gamma-Z interference it is sensitive to Z'
- Measure NC Z-b-bbar vector coupling with higher precision and different systematic errors than determined at LEP with A_{FB}^b and at high precision

So what about Z-b-bbar couplings?

- hep-ph/9512424 (Bernabeu, Botella,Vives)
  - γ-Z interferometry at the Phi factory
  - Assuming only resonance production
  - Same arguments for ϕ ➔Y(4S)





e

$$\sigma(P) = \sigma(P=0)[1 \; + \; \frac{4}{\sqrt{2}} \, (\frac{G_F q^2}{4\pi\alpha}) \, (\frac{g_A g_V^s}{Q_s}) \; P]$$

$$A_{LR} = -\frac{6}{\sqrt{2}}\left(\frac{G_F M^2_{Y(4S)}}{4\pi\alpha}\right) g^e_A g^b_V \langle Pol \rangle$$

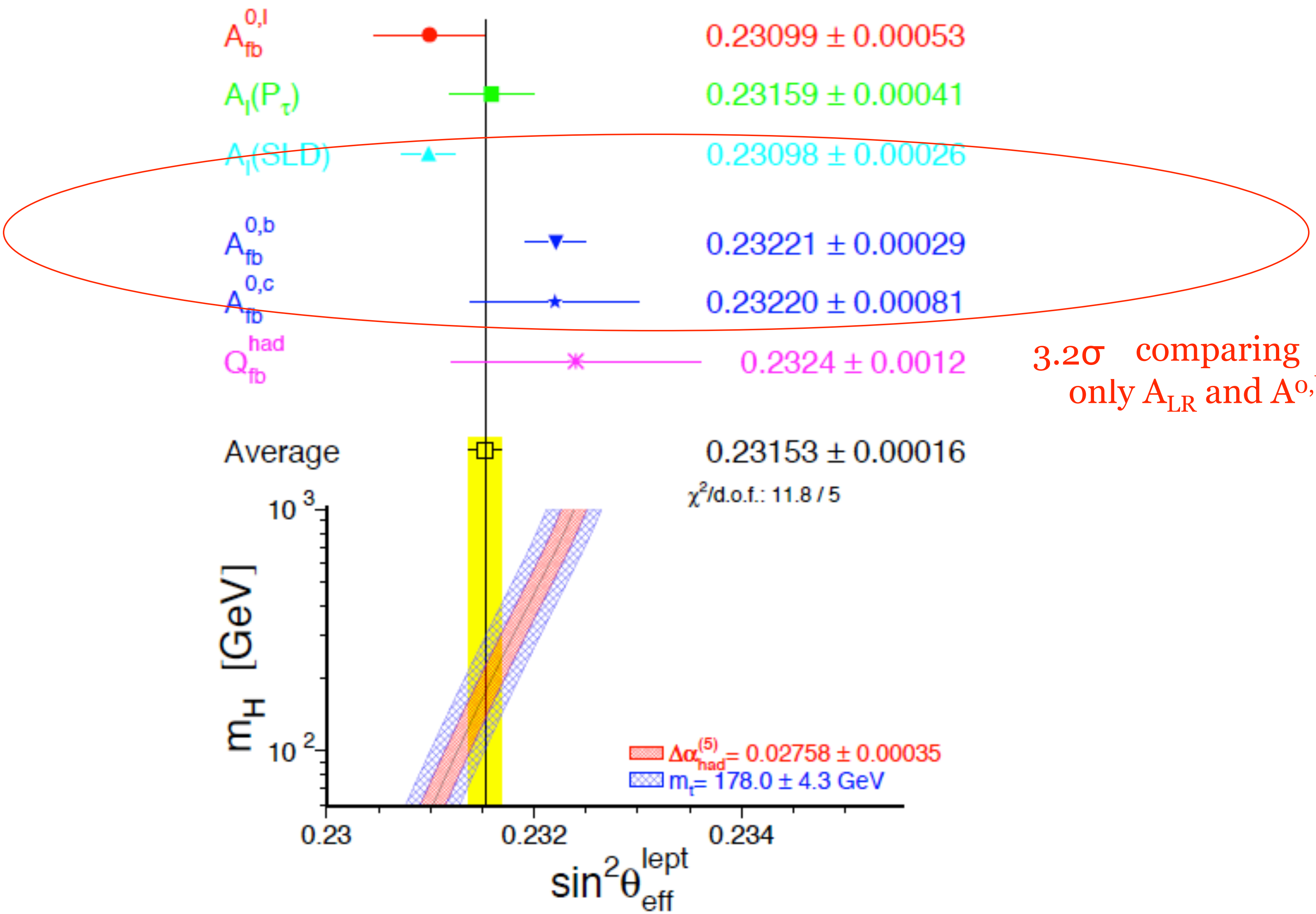
$Q_b=-1/3$; $g^e_A=0.5$

$$\langle Pol \rangle = 80\%; A_{LR} \sim -0.01$$

1 billion reconstructed Y(4S) decays gives A_{LR} to 0.3% stat.
Currently value:

$$g^b_V = -0.3220 \pm 0.0077(2.4\%)$$

- Measurable for all $B^0\ \bar{B}^0$ and $B^+\ B^-$ final states, both resonant and continuum.
- **All** QCD corrections included in the **single** form factor that cancels in the asymmetry.
- Very clean measurement, no **large** theoretical corrections (in progress...)

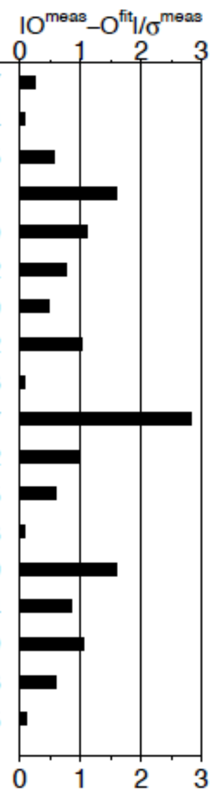


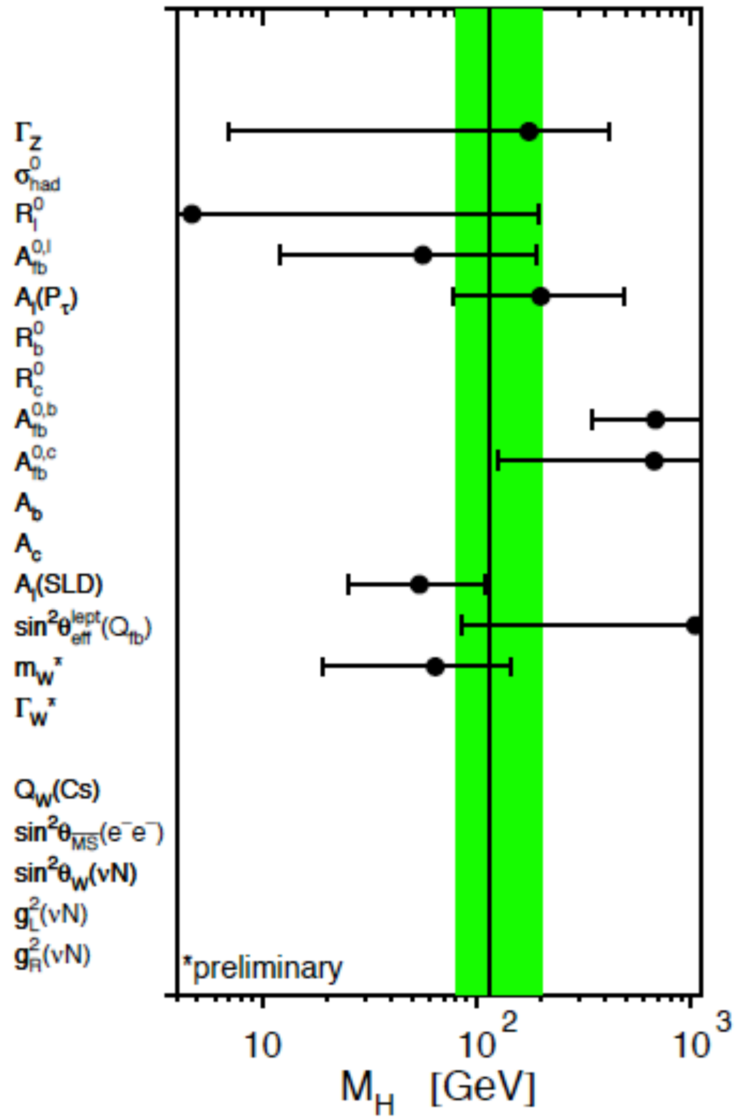
3.2σ comparing only A_{LR} and $A^{0,b}_{fb}$

Z-b-bar

- note: if A_{FB}^{b} is omitted from the SM fit $M_{Higgs}=76\pm^{54}_{33}$GeV low mass Higgs is strongly preferred

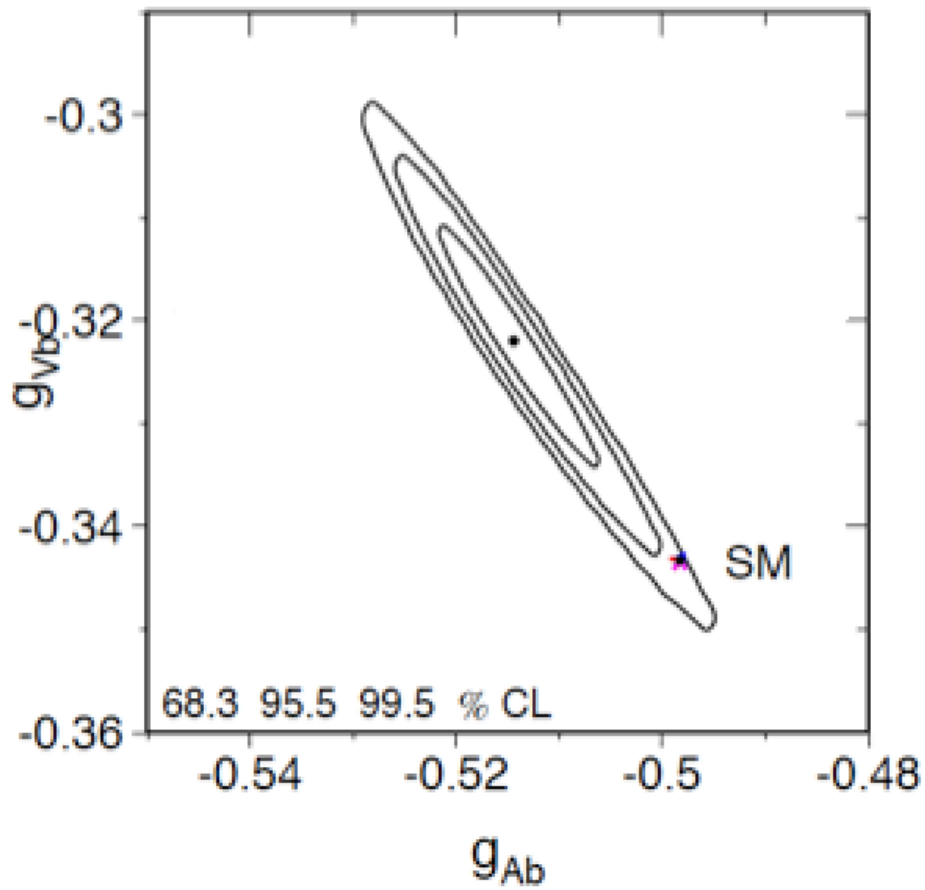
	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ^0_{had} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21562
R_c	0.1721 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.389
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.5





SM expectation & LEP Measurement of g_V^b

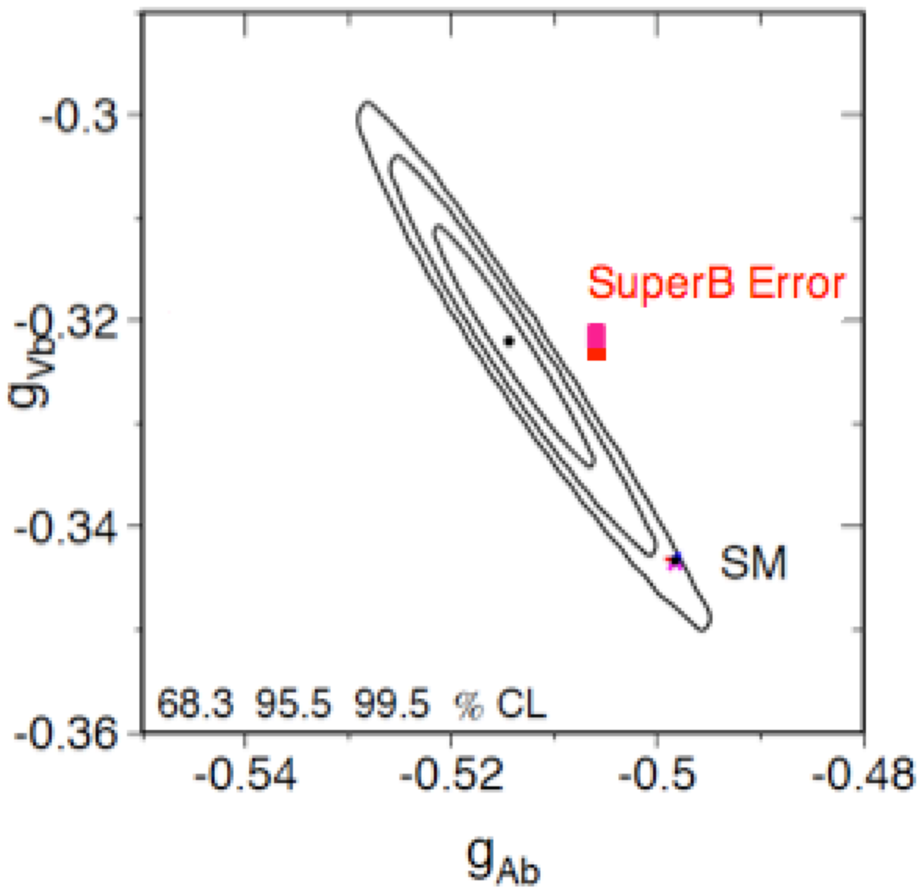
- SM: -0.34372 +0.00049-.00028
- A_{FB}^b: -0.3220±0.0077



SM expectation & LEP Measurement of g_V^b

- SM: -0.34372 +0.00049-.00028
- A_{FB}^b: -0.3220±0.0077

- with 1.0% polarization systematic error and 0.3% statistical error gives SuperB error of ±0.0032



At SuperB no QCD corrections

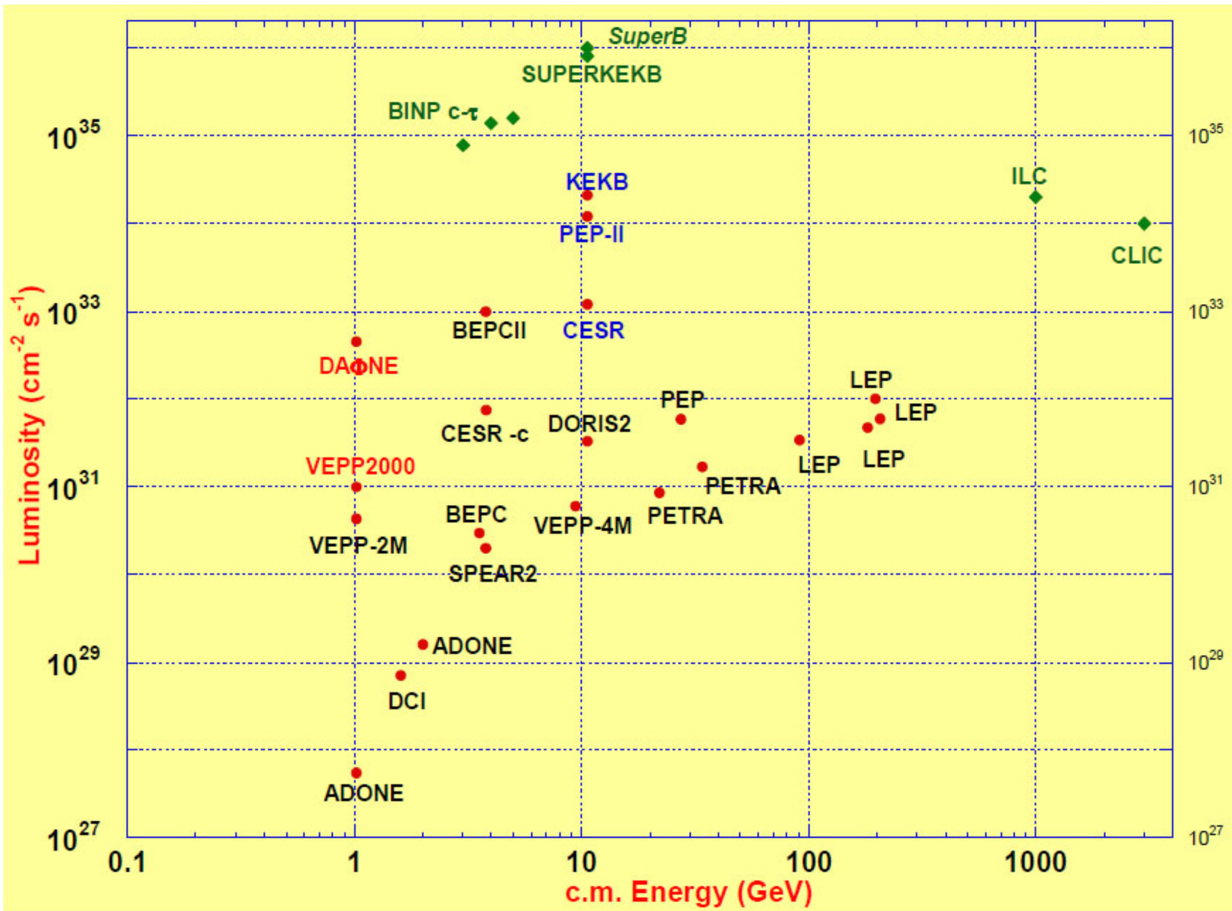
- At LEP QCD corrections were required – hadronization effects, hard gluons, etc
- We think it was done properly at LEP with correctly assessed systematic uncertainties, but…
- An advantage at SuperB over a high energy machine, e.g. Z-factory, is that these corrections do not exist: we are coupling to pseudoscalars with no hadronization

Super Flavour Factory Accelerators

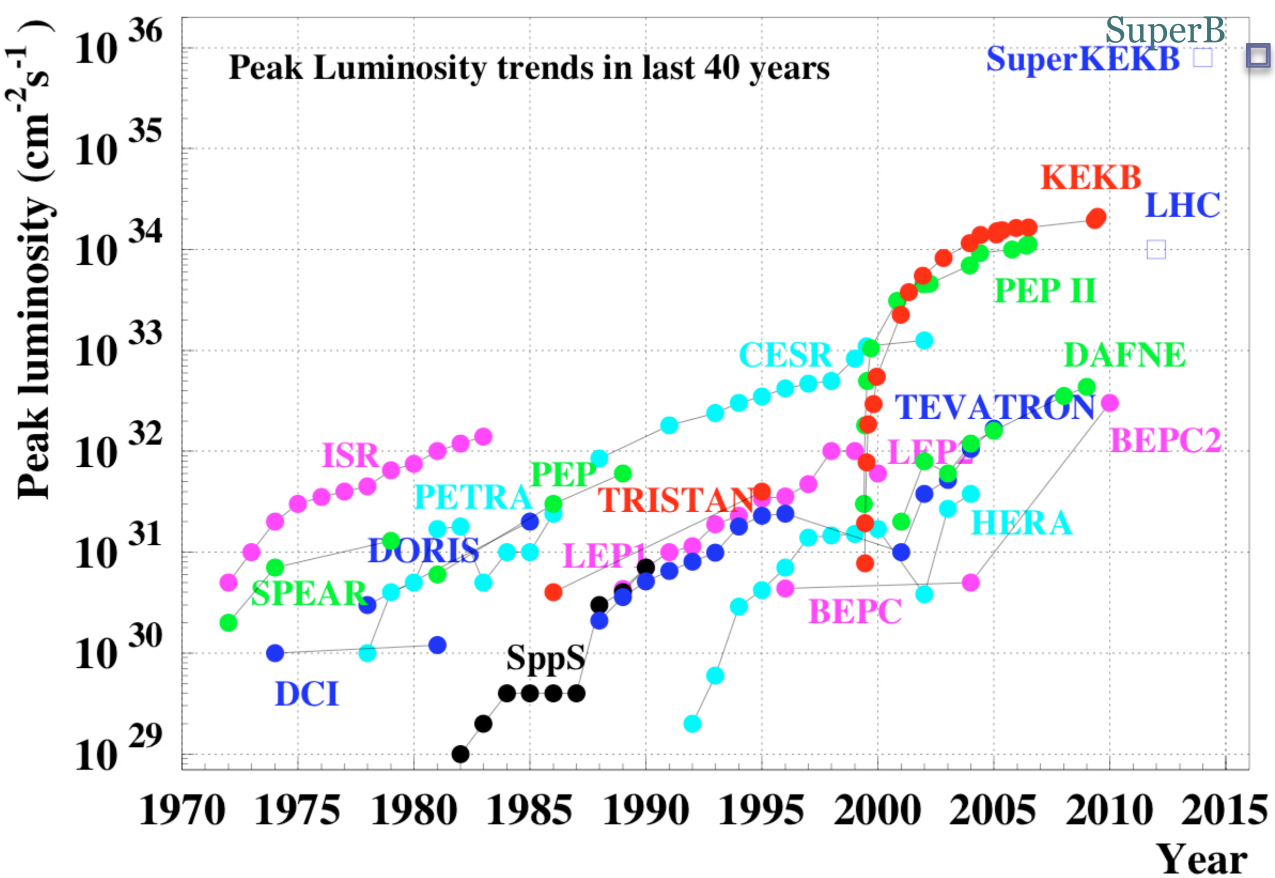
Overview

- Next generation Flavour-physics facility. Primarily will operate at the $\Upsilon(4S)$ ($\rightarrow B\bar{B}$), but with ability to run on Υ (1, 2, or 3S) and above the $\Upsilon(4s)$ and for SuperB at charm threshold.
- Asymmetry e^+e^- collider with luminosity ~100× PEP-II/KEKB, $10^{36}cm^{-2}s^{-1}$, but with comparable beam currents and power.
  - somewhat lower asymmetry, $\beta\gamma = 0.28$ vs 0.56
- For SuperB e- (low energy) beam will be longitudinally polarized ~80%

e+e- Colliders… luminosity vs c.m. energy



Colliders… luminosity trends



How to get to $\mathcal{L}$=10^{36} cm^{-2}s^{-1} …

$$\mathcal{L} = \frac{N^+ N^- f_c}{4\pi\sigma_y \sqrt{(\sigma_z \tan\theta/2)^2 + \sigma_x^2}}$$

f_c	frequency of bunch-on-bunch collisions
$N^\pm$	the number of $e^\pm$ per bunch
σ_x	horizontal rms bunch size (in bending plane)
σ_y	vertical rms bunch size
σ_z	rms bunch length (longitudinal)
θ	crossing angle between beams at IP

reminder of some alternating-gradiant synchrotron features:

$$x(s) = A\sqrt{\beta(s)}\cos(\psi(s)+\delta)$$

x	transverse motion of beam particles
s	path length of particles in beam direction
$d\psi/ds = 1/\beta$	determines phase advance
A,δ	constants of integration

Motion developing with s traces out an ellipse in $\{x, x' \equiv dx/ds\}$ phase space.

πA = Area of ellipse = emittance in case of ensemble of particles.

For Gaussian in both $\{x, x'\}$, define emittance in terms of rms spread of beam: σ_x

$$\varepsilon_x \equiv \pi\frac{\sigma_x^2}{\beta_x}; \text{ similary for vertical direction: } \varepsilon_y \equiv \pi\frac{\sigma_y^2}{\beta_y}$$

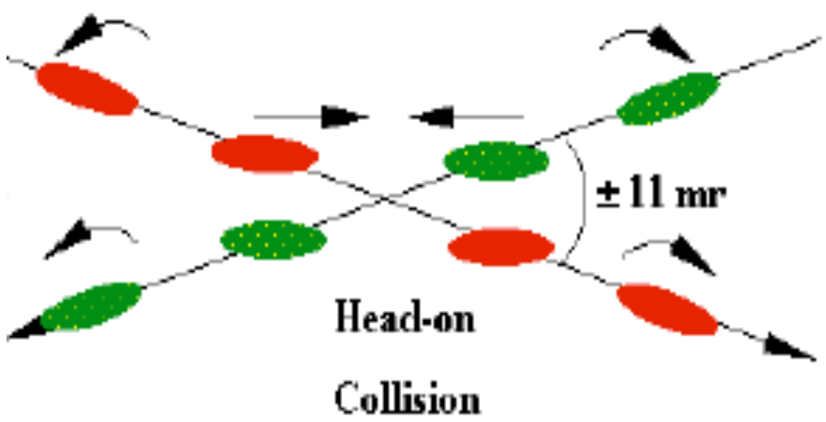
This definition of emittance includes 39% of the beam (1-Sigma in 2D)

Higher luminosity would normally require

$$\text{head-on collisions: } \mathcal{L} = \frac{N^+ N^- f_c}{4\sqrt{\varepsilon_x \beta_x^* \varepsilon_y \beta_y^*}}$$

PEP-II designed with head-on collisions:
required complex IR with magnets inside detector

KEKB designed with ±11mrad crossing angle
installed Crab cavities, ran from Feb 2007



Recall...

... bunch in one beam acts as nonlinear lens to a particle in other beam.

Changes particle's transverse oscillation tune (no. oscillations in closed orbit).

In ensemble, there is a range of tune shifts,

characterised by beam-beam tune shifts by parameters ξ_y and ξ_x.

For beams colliding at a large angle θ in vertical direction

and ~ head-on in horizontal direction:

$$\mathcal{L} \propto \frac{N\xi_y}{\beta_y}$$

$$\xi_y \propto \frac{N\sqrt{\beta_y}}{\sigma_x\sqrt{1+\phi^2}}; \text{ where } \phi = \frac{\sigma_z}{\sigma_x}\tan\left(\frac{\theta}{2}\right) \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2} \text{ is the "Piwinski angle"}$$

What about the bunch length?

RF in the s direction gives longitudinal oscillations

Describe longitudinal motion in terms of $\{z, \delta p/p\}$

where :

z distance the particle leads the "ideal" along design trajectory

$\delta p/p$ energy spread

RF frequency determines the bunch length σ_z

"Hour Glass Effect"

If $\sigma_z >> \beta^*$ generally $\mathcal{L}$ drops because

$\beta(s) \approx \beta^* \times (s/s@IP - 1)^2$ near IP

resulting in particles with $|z| >> 0$ contributing less to $\mathcal{L}$

But higher $\mathcal{L}$ needs small β^* so Hour Glass Effect drives

shorter bunch lengths

Hour glass effect drives shorter bunches, but there are troubles with shorter bunch length

- problems of Higher Order Mode heating – serious operational issue
- coherent synchrotron radiation of short bunches (additional energy losses & instabilities)
- excessive power consumption

Original Super B Factory designs from SLAC and KEK dating to 2001…

$$\mathcal{L} = \frac{N^{+}N^{-} f_{c}}{4\sqrt{\varepsilon_x \beta_x^* \varepsilon_y \beta_y^*}}$$

Try to get to $10^{36}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ by :

- reducing β_y^* - but limited by hour glass effect
- use crab cavities
- increase number of particles per bunch N^- and N^+

Can reach $\mathcal{L}$ ~5-7 x 10^{35} $\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Requires ~100MW of wall power (cf 22MW PEP-II)

Original SuperKEKB design…

- shorten bunches from $\sigma_z = 6.5\text{mm} \rightarrow 3\text{mm}$

$\Rightarrow$ allows β^* to decrease

- decrease ε
- increase beam currents $I^- \times I^+ = 1.2A \times 1.6A \rightarrow 9.4A \times 4.1A$

High currents $\Rightarrow$ High wall plug power $\Rightarrow$ high operating costs

Still didn't reach $\mathcal{L} = 10^{36}\text{cm}^{-2}\text{s}^{-1}$

SuperKEKB design changed SuperB nanobeam design

How to get to $\mathcal{L}=10^{36}\ cm^{-2}s^{-1}$ …

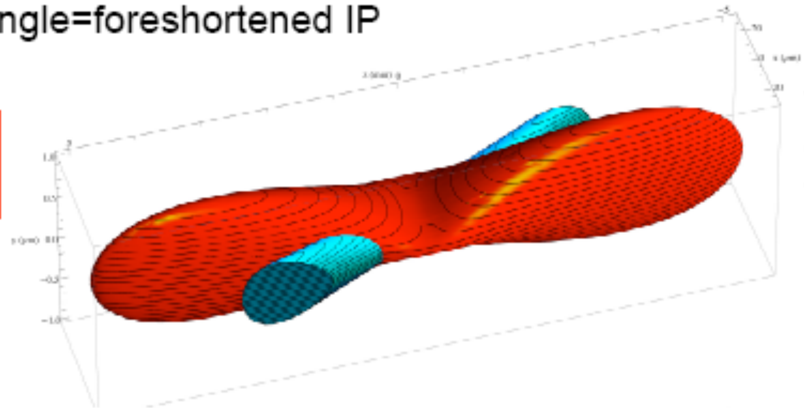
J. Seeman, HEPAP, May 2009

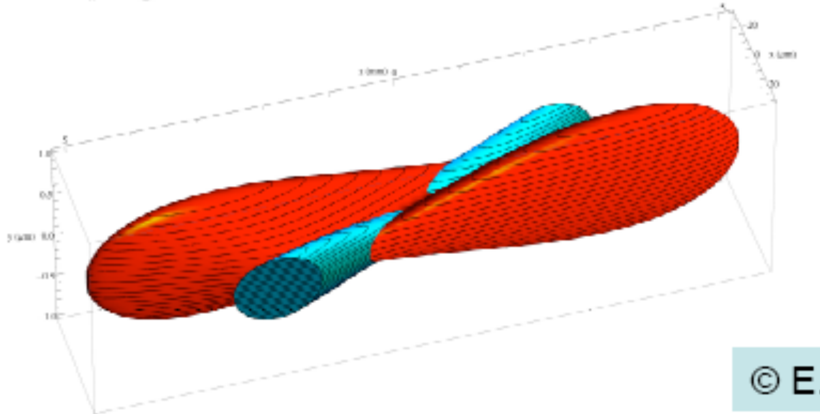
- Crossing angle IR with large Piwinski angle (DAΦNE, KEKB)
- Very low IR vertical and horizontal beta functions (ILC)
- Low horizontal and vertical emittances (Light sources)
- Ampere beam currents (PEP-II, KEKB)
- Crab waist scheme (Frascati, DAΦNE)

Crab Waist – A New Idea invented for SuperB

Pantaleo Raimondi, Frascati

Large "Piwinski" angle=foreshortened IP





Crab Waist – A New Idea invented for SuperB

Waist of one beam aligned with path of other beam

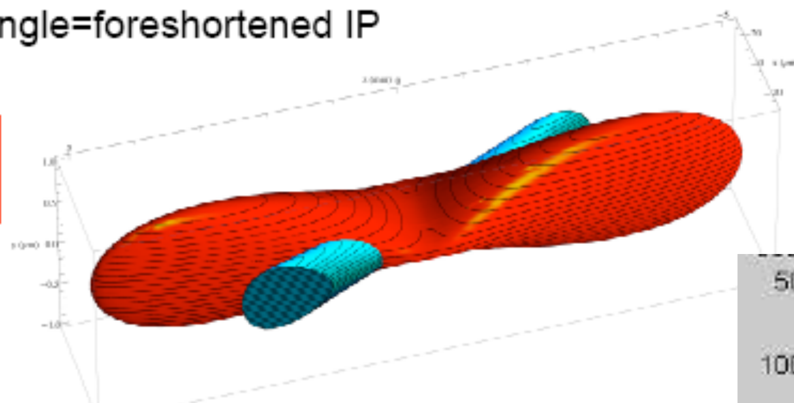
⇒particles at higher ß do not see full field of other beam

⇒no excessive beam-beam parameter due to hourglass effect.

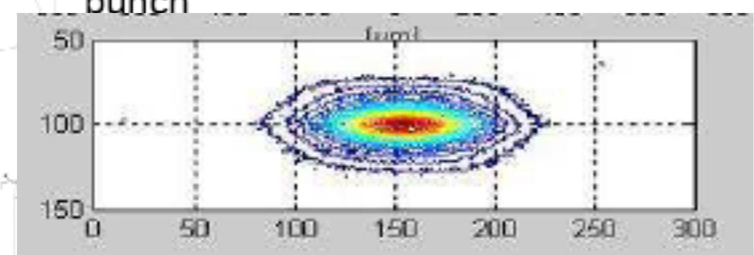
Pantaleo Raimondi, Frascati

Large "Piwinski" angle=foreshortened IP

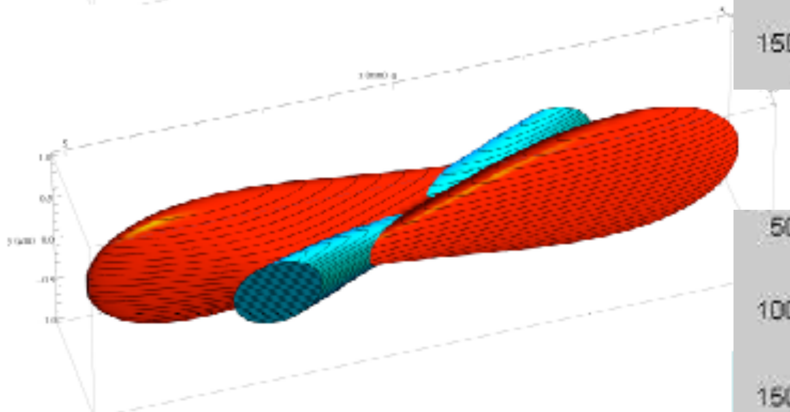
Crab sextupoles OFF



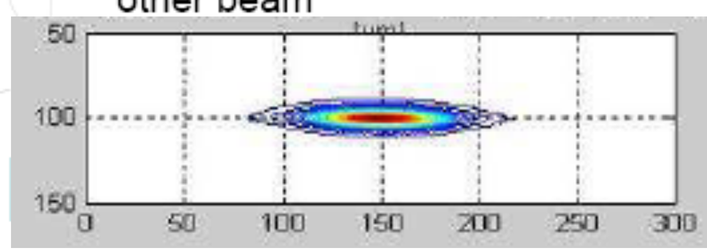
waist line is orthogonal to the axis of one bunch



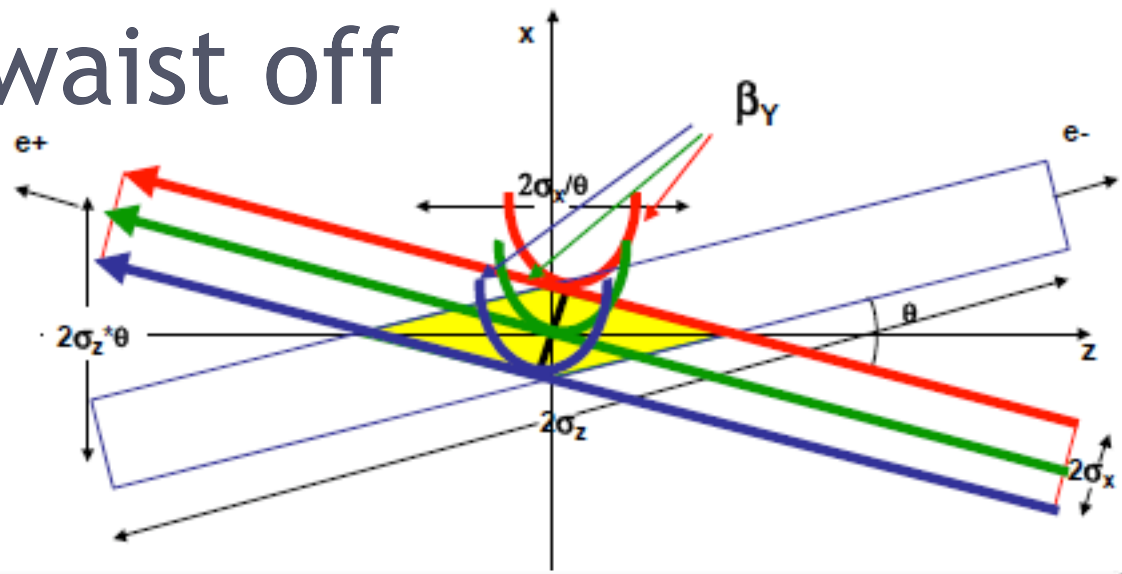
Crab sextupoles ON

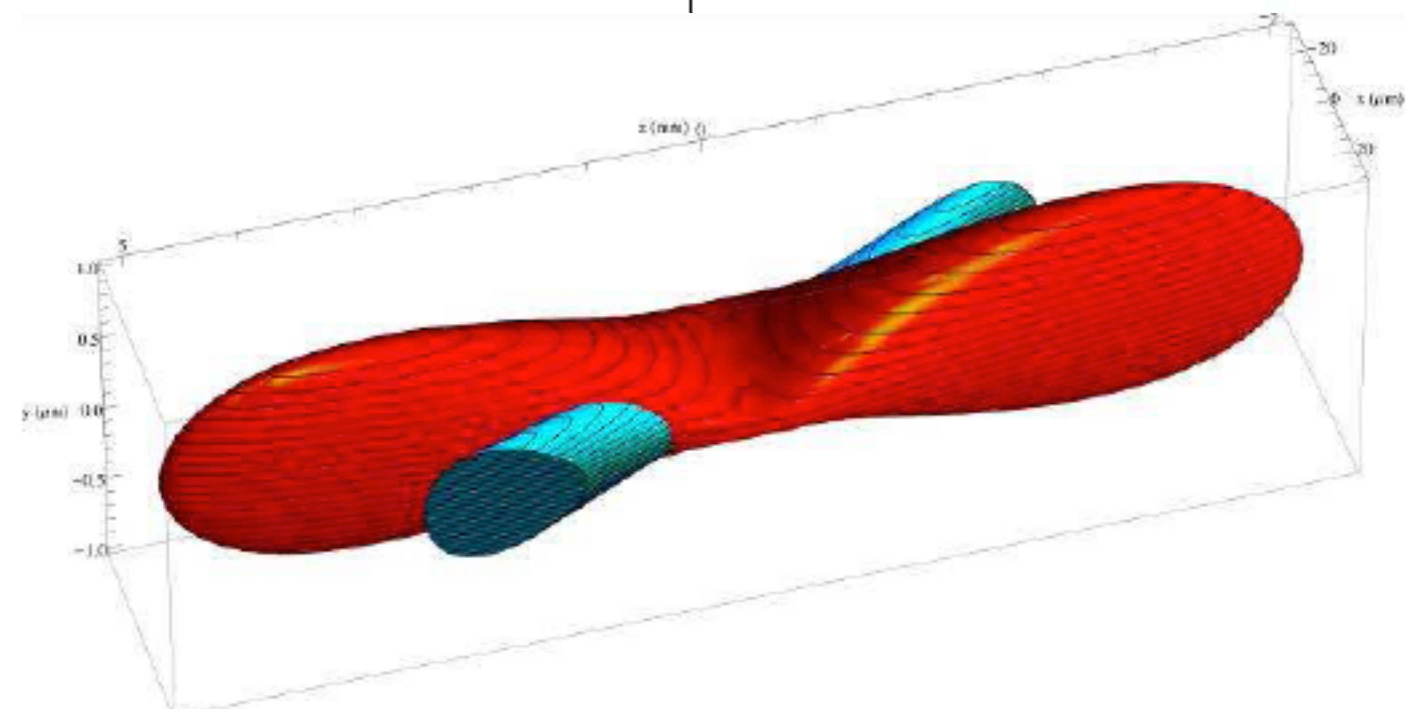


waist moves to the axis of other beam

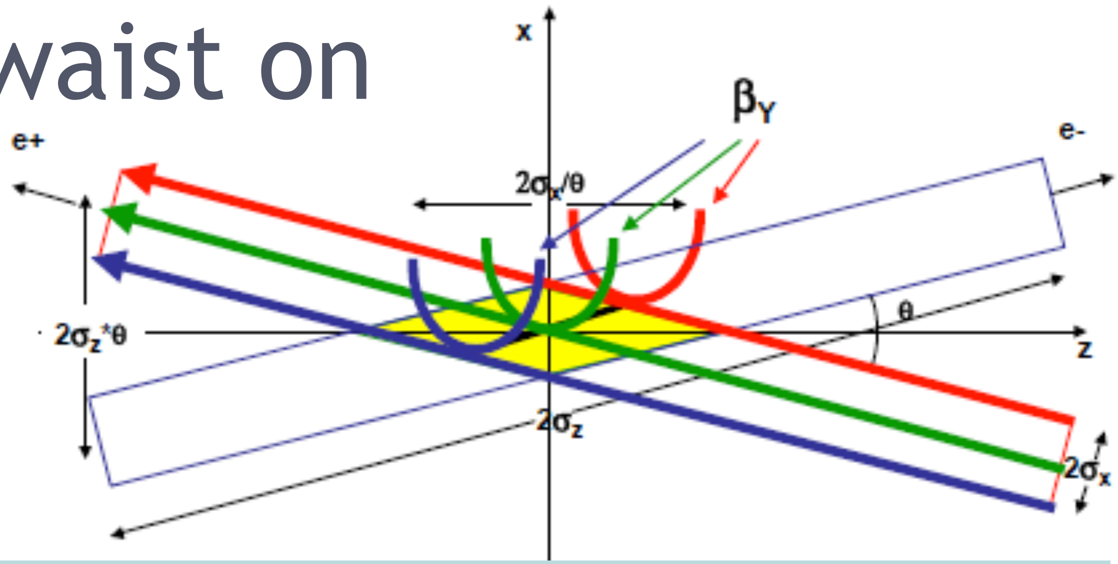


Crab waist off

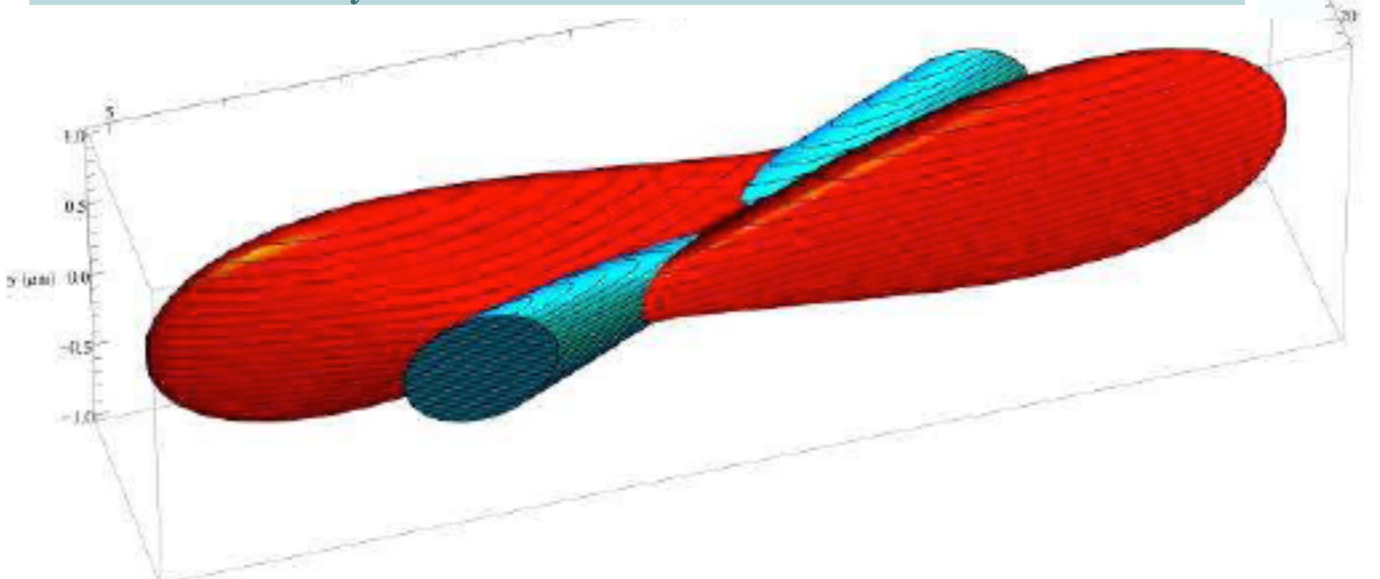




Crab waist on



All particles in both beams collide in the minimum β_y region, with a net luminosity gain



Crab Waist with large Piwinski Angle

Crab waist scheme with large Piwinski angle $\phi \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2} >> 1$

$\Rightarrow$ decrease horizontal rms σ_x and increase crossing angle θ

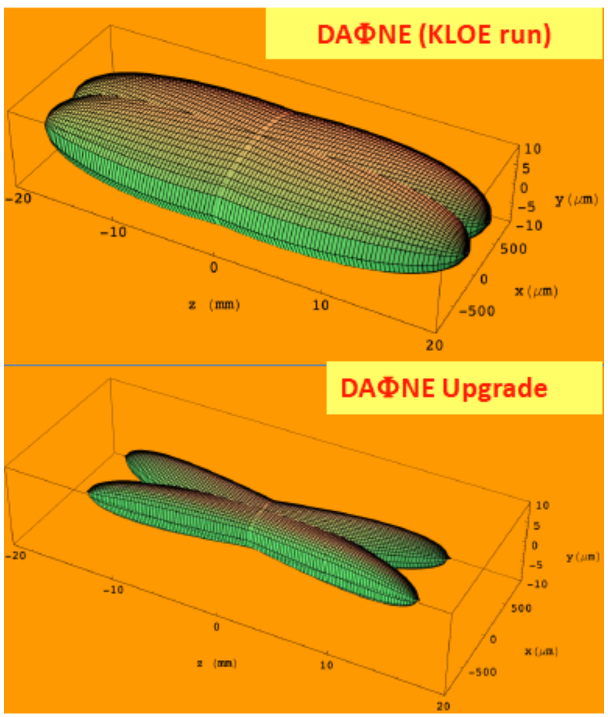
$\Rightarrow$ Overlap area of colliding beams decreases $\propto \frac{\sigma_x}{\theta}$

If β_y^* is comparable to overlap scale

then $\beta_y^* \approx \frac{\sigma_x}{\theta} << \sigma_z$ and we get small β_y^* without small σ_z!

Crab waist Proven at DAΦNE

- DAΦNE e+e- collider at Frascati with Ecm @ Φ (1020 MeV)
- Upgraded to test crab waist scheme
- Crab Waist effectiveness successfully demonstrated in working collider
- Gains of ~ factor of 3 in luminosty



	DAΦNE (KLOE run)	DAΦNE Upgrade
I_{bunch} (mA)	13	13
N_{bunch}	110	110
β_y^* (cm)	1.8	0.85
β_x^* (cm)	160	26
σ_y^* (μm)	5.4 low curr	3.1
σ_x^* (μm)	700	260
σ_z (mm)	25	20
Horizontal tune shift	0.04	0.008
Vertical tune shift	0.04	0.055
θ_{cross} (mrad) (half)	12.5	25
$\Phi_{Piwinski}$	0.45	2.0
L ($cm^{-2}s^{-1}$)	1.5×10^{32}	$>5 \times 10^{32}$

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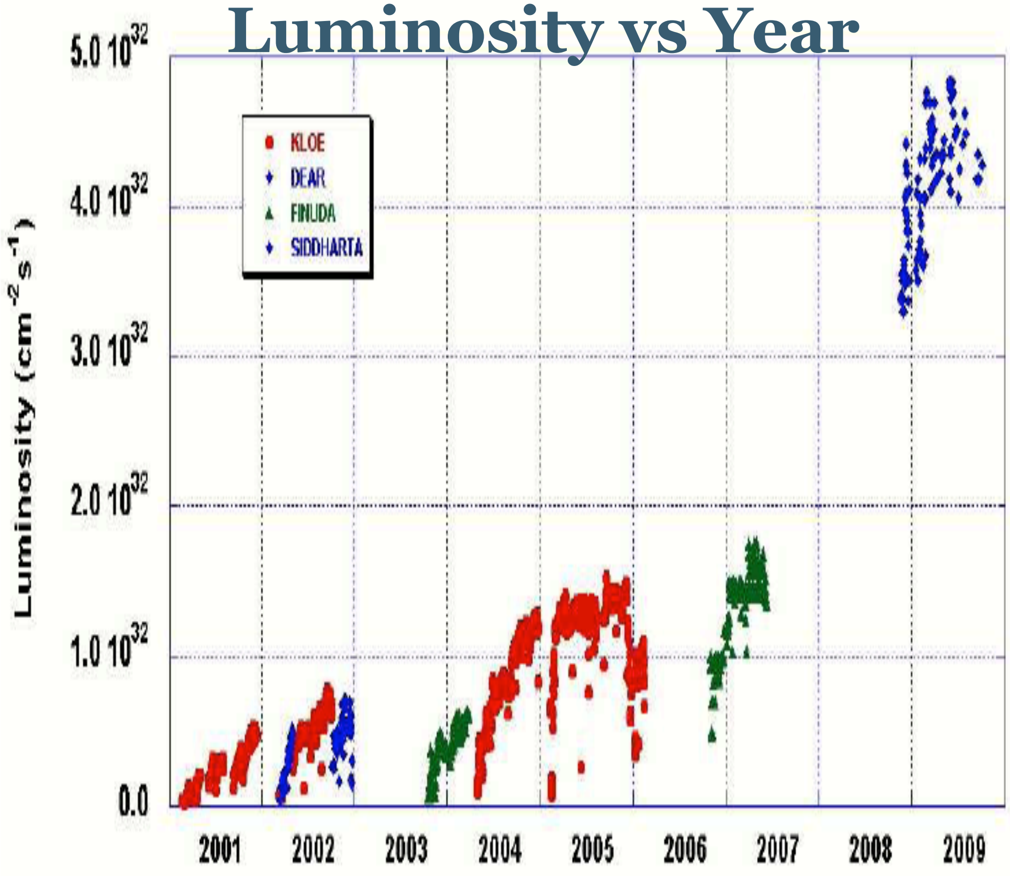
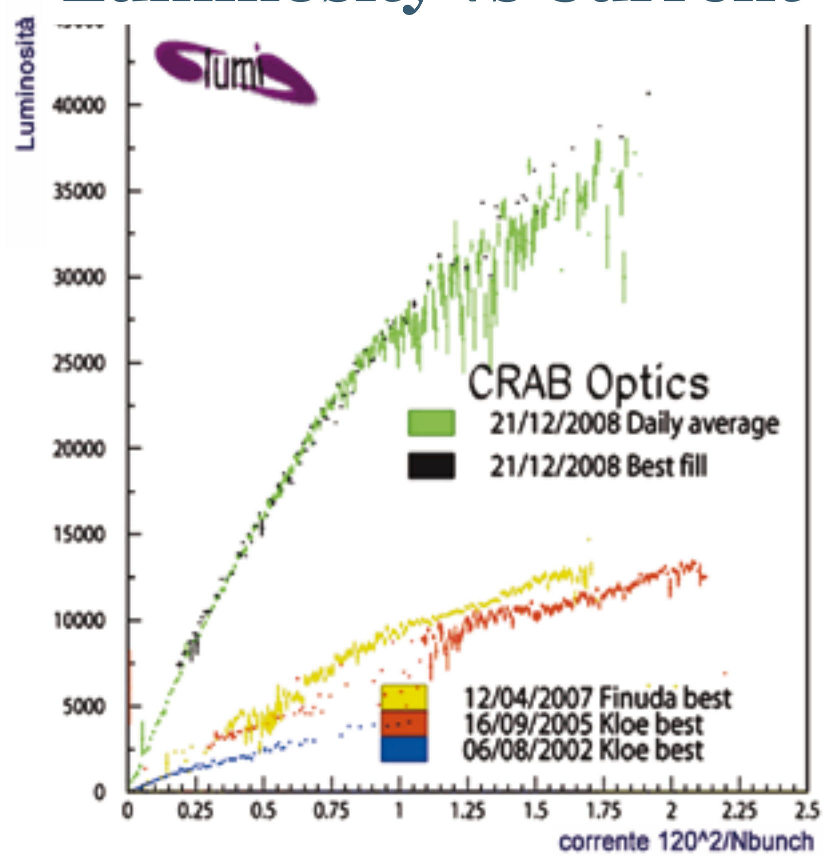
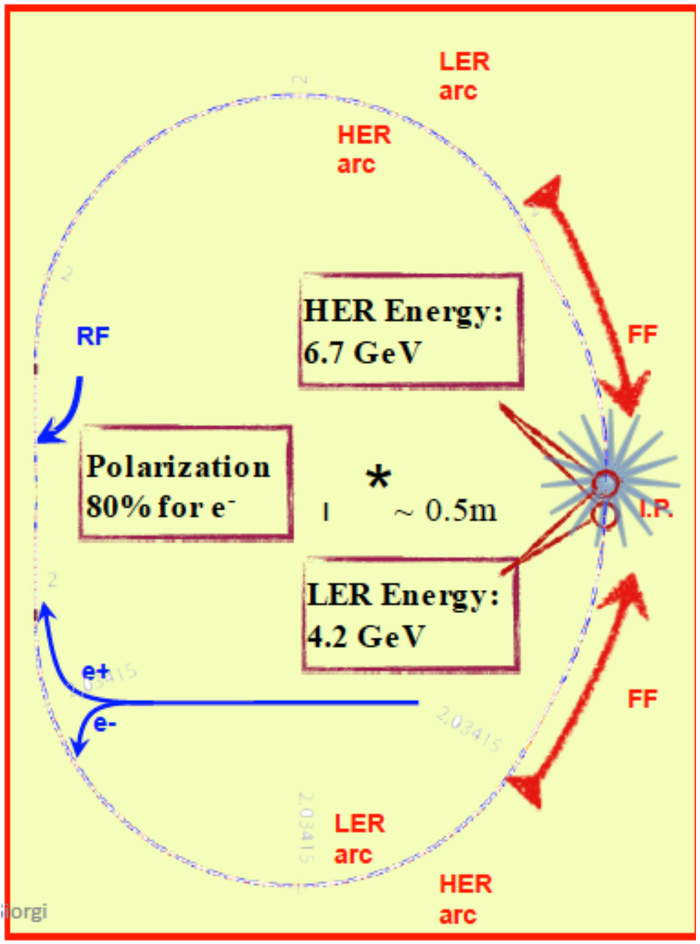
Luminosity vs Year

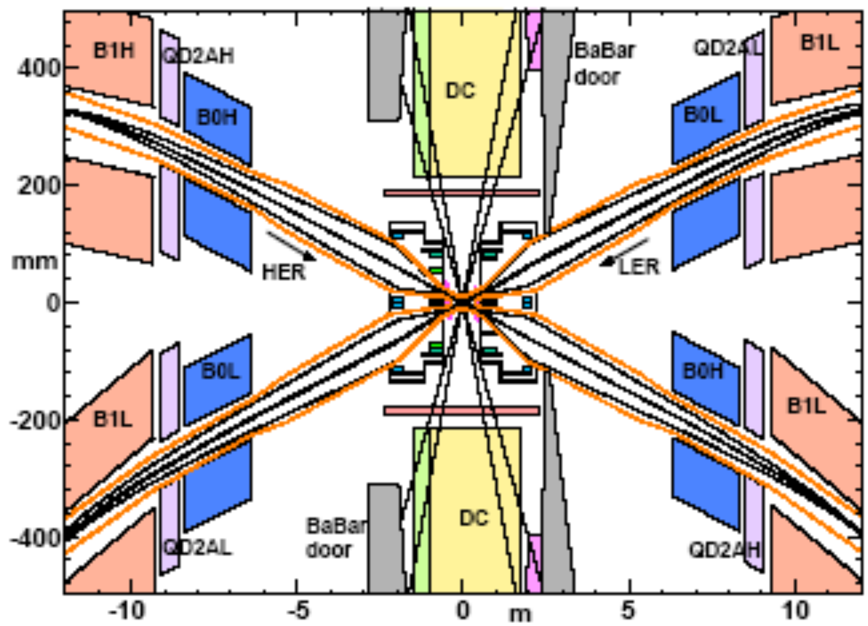


Luminosity vs Current



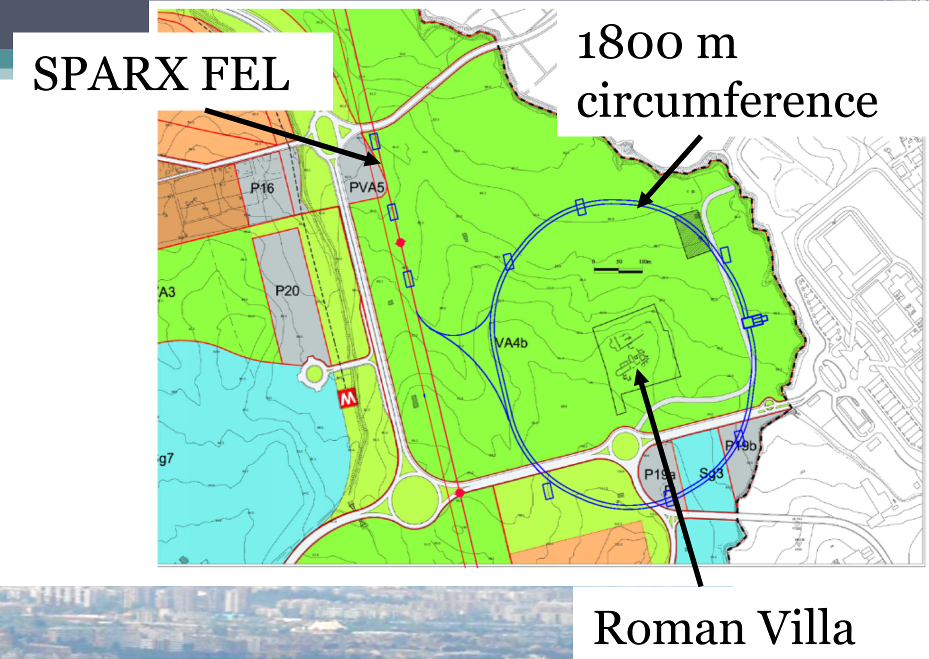
Italian SuperB Collider





Tor Vergata

- U. Rome Campus near Frascati



other option is Frascati lab site

Parameters

Parameter	Units	Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
		HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2}\ s^{-1}$	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

Tau/charm threshold running at 10^{35}

Baseline + other 2 options:
- **Lower y-emittance**
- **Higher currents (twice bunches)**

Baseline:
- **Higher emittance due to IBS**
- **Asymmetric beam currents**

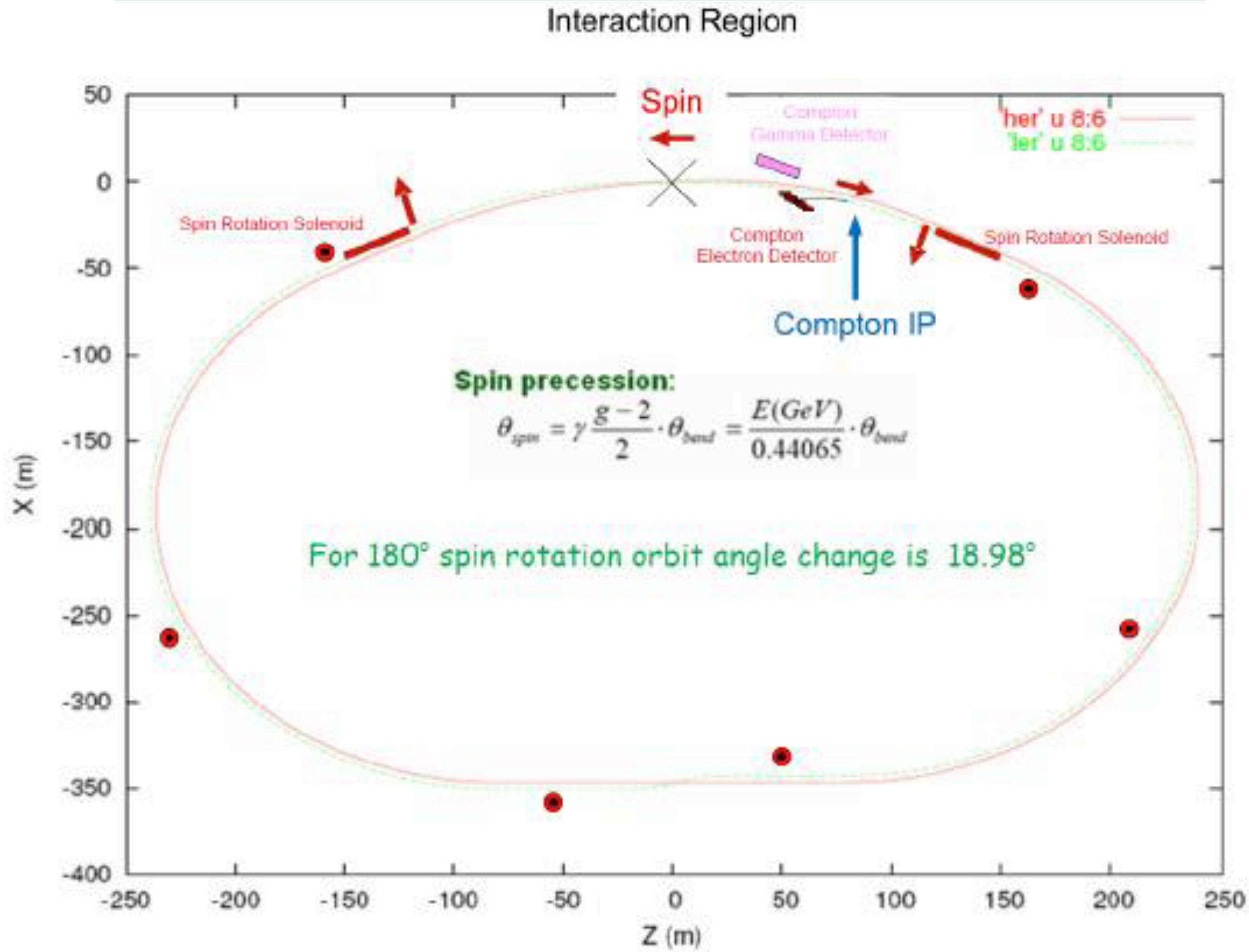
RF power includes SR and HOM

Polarization

- Polarization of one beam (LER) is included in SuperB design.
  - LER chosen because spin rotators scale in strength with energy.
- Longitudinal polarization times and short beam lifetimes indicate a need to inject vertically polarized electrons.
  - The plan is to use a polarized e- source similar to the SLAC SLC source.
- Spin rotators:
  - Solenoids (dipoles will require vertical bending causing unacceptable vertical emittance growth).
- Expected longitudinal polarization with symmetric geometry scheme at IP ~ 80%.
- Need polarimeter to measure longitudinal polarization. Would be nice to be able to measure the transverse polarization as well:
  - We could measure the spin depolarization resonances which would give us a good calibration of the LER beam energy

Italian SuperB Collider

Spin Rotator location for Beam Polarization

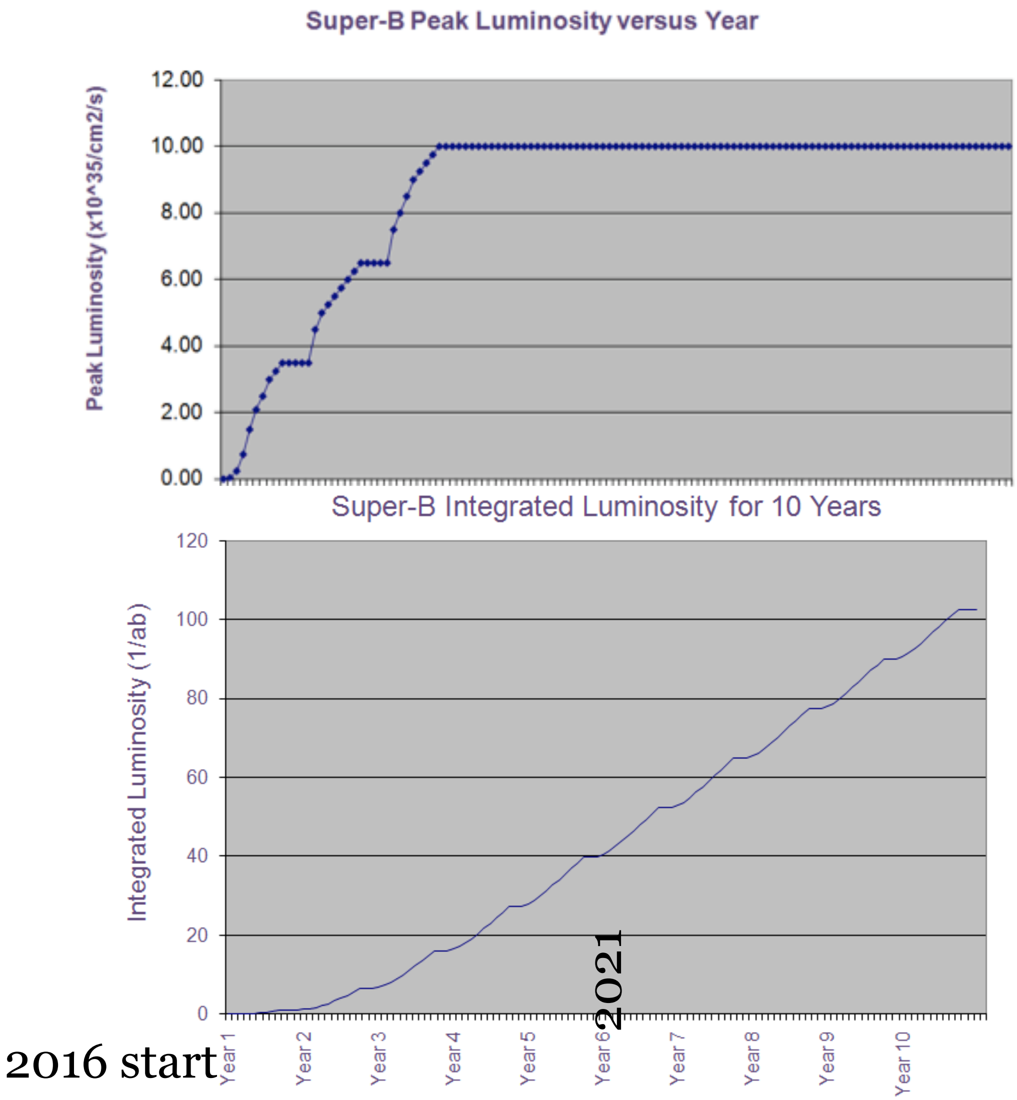


Estimates of Polarization Systematic errors…arXiv:1009.6178

Table 16.4: Systematic errors expected for the polarization measurement.

Item	δP/P
Laser Polarization	<0.1%
Background uncertainty	<0.25%
Linearity of phototube response	<0.25%
Uncertainty in dP (Difference between the luminosity weighted polarization and the Compton IP polarization. Includes uncertainties due to beam energy and direction uncertainties.)	<0.4%
Uncertainty in asymmetry analyzing power	~0.5%
Total Systematic Error	**<1.0%**

SuperB Luminosity Projections



John Seeman

KEKB to SuperKEKB

To get x40 higher luminosity

P. Krizan, CKM 2010

SuperKEKB – upgrade from KEKB

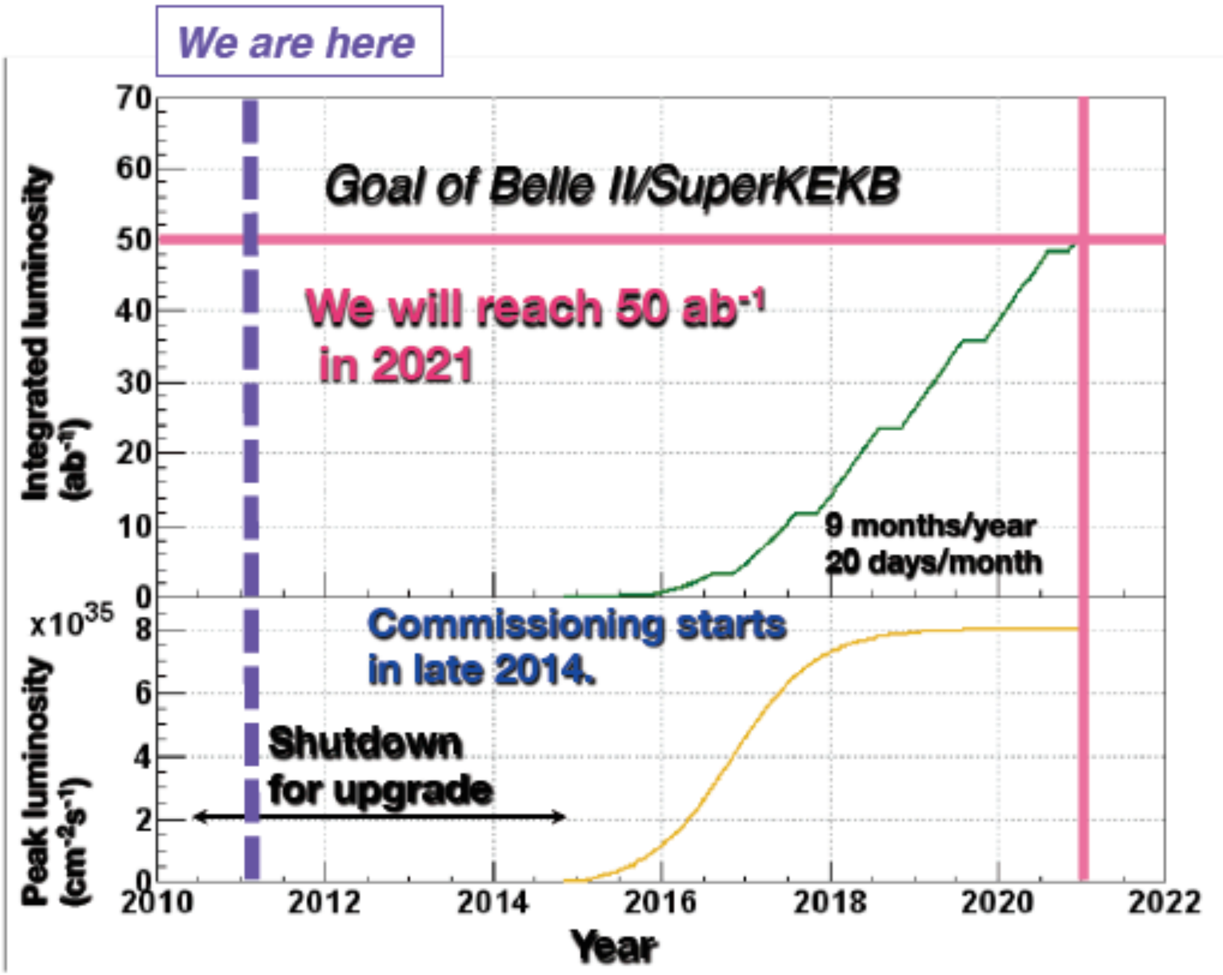
Machine design parameters

parameters		KEKB LER	KEKB HER	SuperKEKB LER	SuperKEKB HER	units
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	5.0	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

M. Iwasaki, ICHEP 2010

SuperKEKB Luminosity Projections

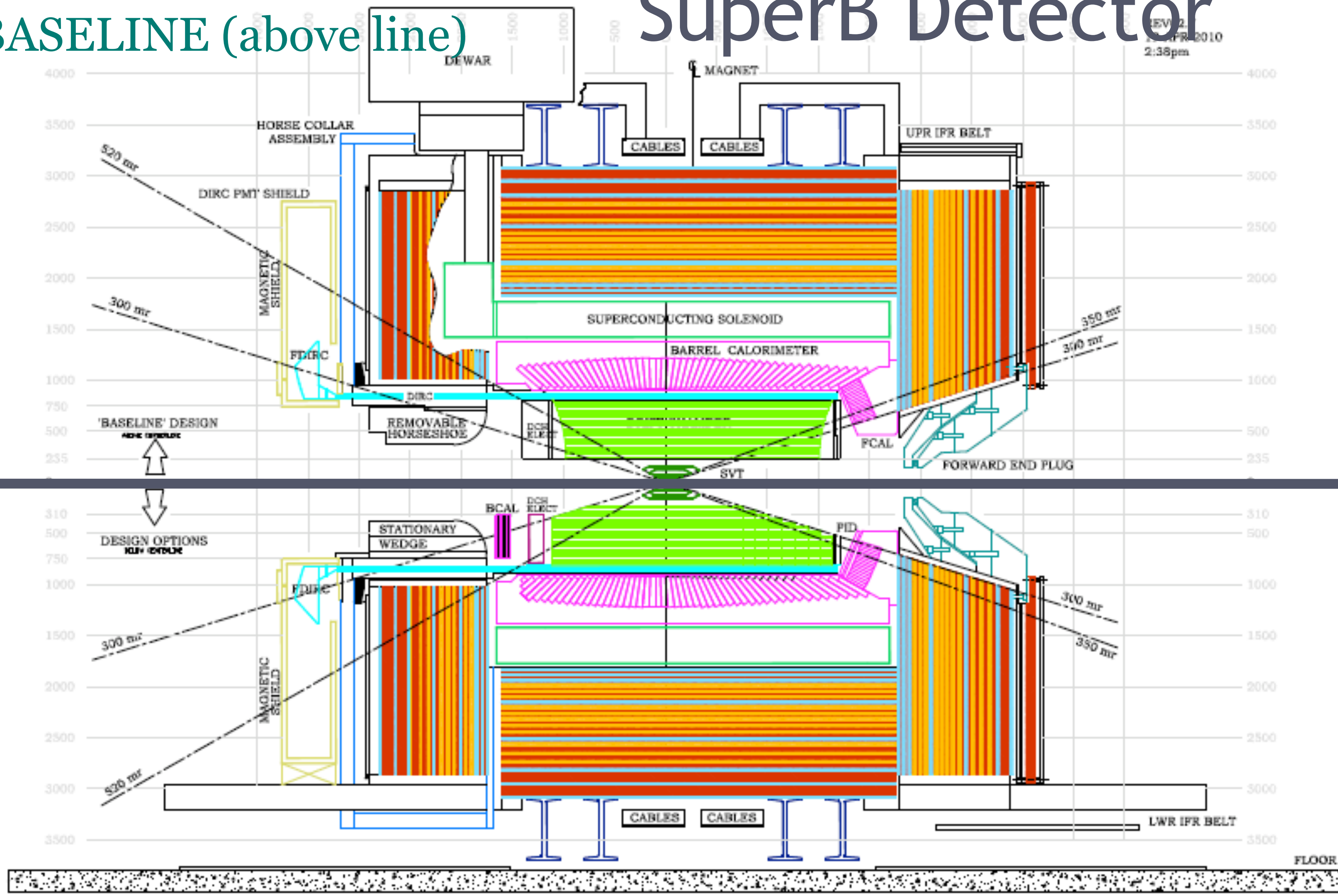


Y. Ohnishi

The Detectors

SuperB Detector

BASELINE (above line)



OPTIONS (below line)

SuperB Detector

- Reuse BaBar components: magnet, DIRC bars, barrel CsI calorimeter.
- Some issues:
  - New silicon; add Layer 0 with smaller beam pipe
  - Need new way to read out DIRC
  - Need new technology for forward calorimeter
  - Possible forward PID
  - Likely backward EMC

More details on SuperB Detector on Thursday

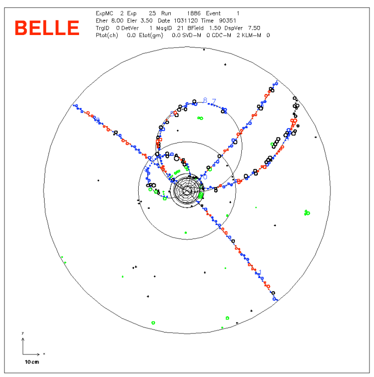
16:30 Drift Chamber Design Optimization Studies for SuperB, Darren SWERSKY

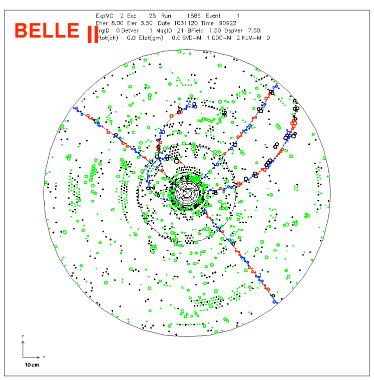
16:45 LYSO Forward Calorimeter, Alessandro ROSSI

17:15 Impact on the SuperB physics reach of the Vertex Detector configuration, Giulia CASAROSA

Belle II detector

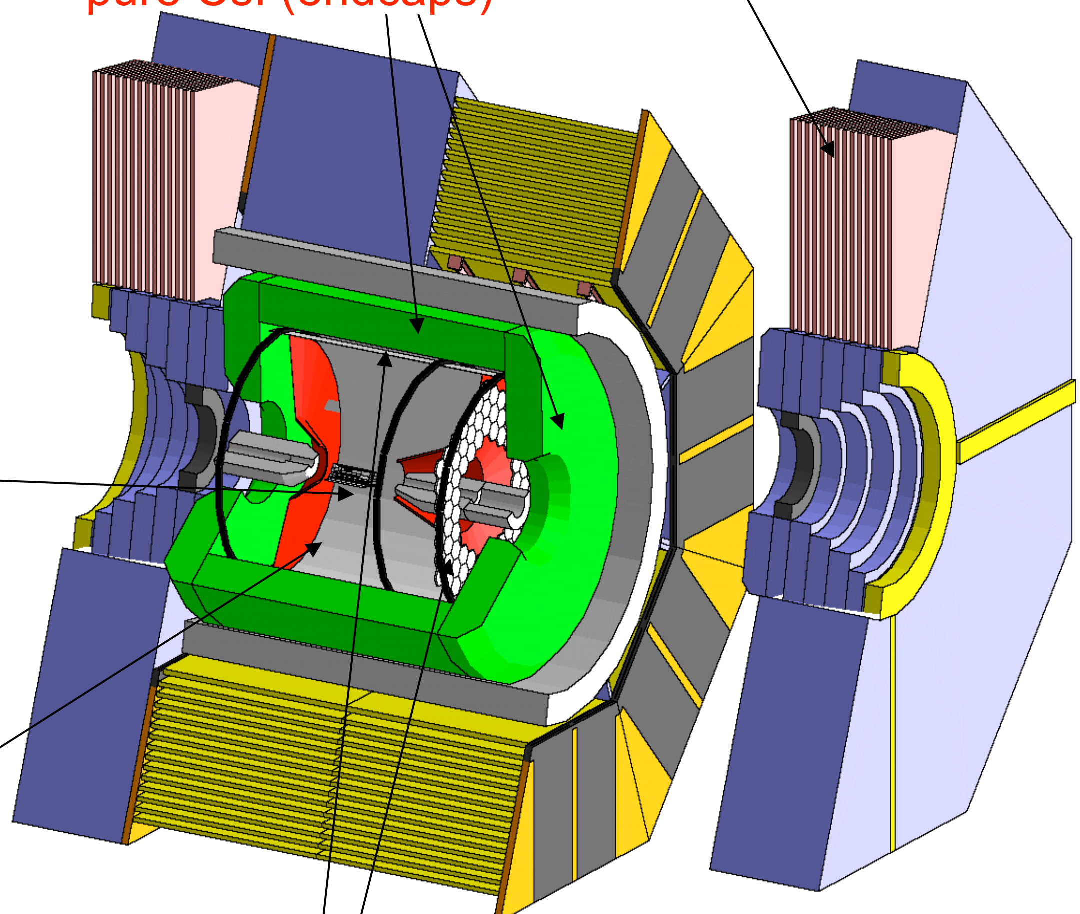
- Deal with higher background (10-20×), radiation damage, higher occupancy, higher event rates (L1 trigg. 0.5→20 kHz)
- Improved performance and hermeticity





Calorimetry:
faster readout
CsI(Tl) (barrel)
pure CsI (endcaps)

μ, K_L: Resistive Plate Chambers (barrel),
scintillators (endcaps)



Vertexing:
2 DEPFET pixel layres
4 double-sided strip layers

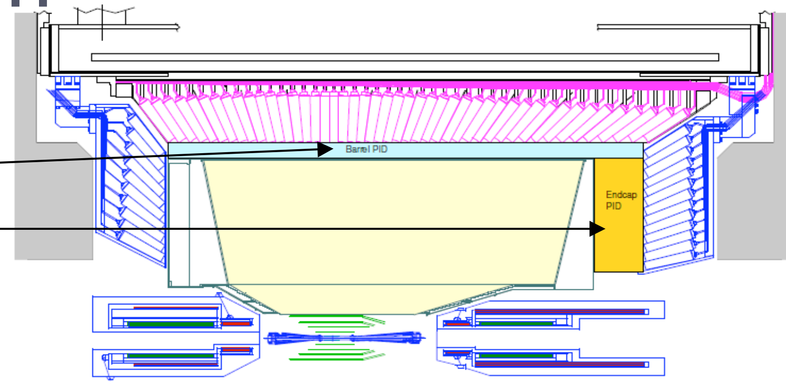
Tracking:
small-cell drift chamber
He-C_2H_6

Hadron identification:
Time-of-Propagation detector (barrel)
Aerogel RICH (forward)

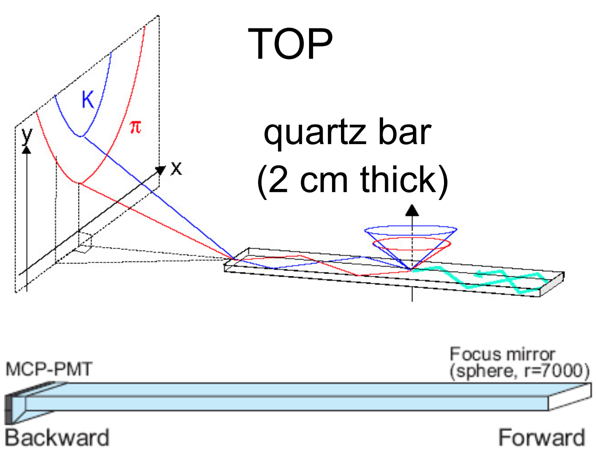
Particle identification

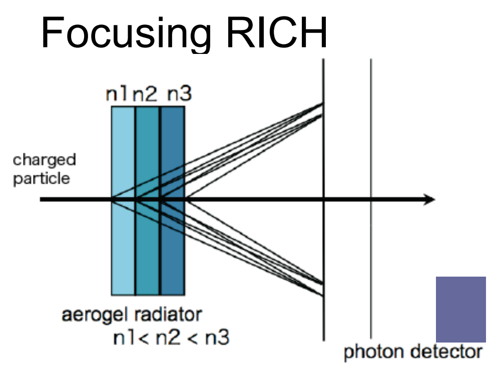
Time-Of-Propagation counter

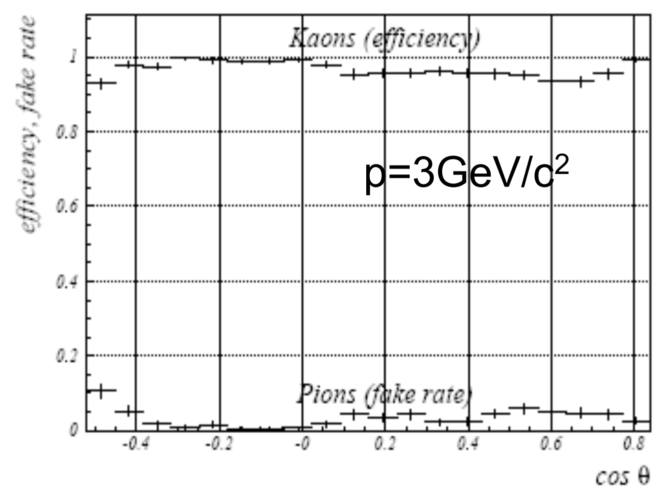
Proximity focusing RICH



- **TOP: reconstructs Cherenkov rings from 3D information from PMTs: x,y coordinates and time of photons propagation**
- **Proximity focusing RICH: measures Cherenkov angle. Inhomogeneous aerogel radiator to improve photon resolution**
- **Improved K/π separation in wide momentum range**







More details on Belle-II and SuperKEKB on Thursday

16:00 Status and Plans for SuperKEKB and Belle II experiment, Hiroyuki NAKAYAMA

16:15 Physics prospects of SuperKEKB/Belle II experiment, Kurtis NISHIMURA

Status and outlook

Mer 14/04/2010

Il Sole 24 ORE

Innovazione. Più spazio all'industria

Gelmini aggiorna il piano nazionale

Eugenio Bruno
ROMA

Un acceleratore di particelle complementare a quello del Cern di Ginevra. Un network dei laboratori di nanotecnologia. Una «fabbrica del futuro» per rilanciare il manifatturiero. Uno studio approfondito nell'epigenetica. Sono alcuni dei «progetti bandiera» che il ministro dell'Istruzione Mariastella Gelmini punta a inserire tra le priorità del programma nazionale della ricerca (Pnr) 2010-2012.

La lista degli interventi su cui il Miur vuole dirottare le prime risorse che il Pnr intercetterà contiene 14 voci. Fermo restando che da qui alla sua ufficializzazione potrebbe anche subire delle modifiche, l'elenco si pre-

SuperB flagship project in the Italian National Research Plan for 2010-2012 of the Italian Ministry of Education and Science

Gli interventi

Progetto	Settore	(milioni)
Super B Factory	Fisica	650
Cosmo - Skymed II generation	Aerospazio	N.D.
Epigenomica	Medicina	N.D.
3N - Network nazionale delle nanotecnologie	Industria	300
Ritmare - Ricerca ita. per il mare	Industria	795
Sintonia - Sistema integrato di telecomunicazioni	Aerospazio	671
Ipi - Invecchiamento e pop. isolate	Medicina	90
Agro Alimentare	Agricoltura	100
L'ambito nucleare	Energia	53,5
Recupero e rilancio della Villa dei Papiri	Beni cluturali	20
Elettra-Fermi-Eurofel	Industria	191
Astri - Astrofisica con specchi a tecnologia replicante italiana	Aerospazio	8
Controllo delle crisi nei sistemi complessi socio-economici	Economica	30
La fabbrica del futuro	Industria	30

SuperB Status (Ministerial approved press release, p1)

The Italian Government Funds the Super-B Accelerator

Friday, 24 December 2010 10:02 Media and press release »

The Ministry for Education, University and Research has decided to select the SuperB project conducted by the Italian National Institute of Nuclear Physics (INFN) as one of its "flagship projects" in Italy over the next few years and has delivered an initial funding for 2010 as a part of a multiannual funding program. Reconstructing the history of the Universe by researching the most infrequent events using high-precision technology. This is the INFN idea underlying the construction of SuperB, the particle accelerator based in Italy and with international involvement, which the Ministry for Education, University and Research has decided to sponsor and finance. A large interest has been expressed in many countries, meanwhile physicists from the United States, Germany, France, Russia, the United Kingdom, Israel, Canada, Norway, Spain, Poland are taking part to the design effort. The purpose of the project is to conduct top-level basic research, developing innovative techniques with an important impact in terms of technology and other research areas. In the words of the ministerial decree, "the project involves entities and Universities, as well as companies in various business sectors. It is expected to have a number of effects on relevant issues for the country, especially as regards the expansion of basic scientific perspectives and specific applications concerning particle detection, advanced simulation techniques, nanometre metrology, and others." Istituto Italiano di Tecnologia (IIT) is cooperating to the project with INFN. It will be in fact possible the use of the accelerator as a high brilliancy light source. The machine will be equipped with several photon channels, allowing the extension of scientific program to physics of matter and biotechnology.

The SuperB project basic assumption is that particle accelerators, smaller than the current "giants", operated at a low energy, can allow excellent scientific results complementary to the high energy frontier.

SuperB Status (Ministerial approved press release, p2)

The crucial element consists in getting particle beams, which are extremely compact, small, short and very dense to collide. SuperB is thus expected to increase by one hundred times compared to the current limit the number of reactions produced in the same unit of time in the laboratory. In this way, through the study of very rare processes, which cause the decay of particles that are already known, it should be possible to account for minute effects not mentioned in the theories.

The quantum leap by SuperB is based on ideas developed in Italy and tested by the accelerator division of the National Laboratories of INFN in Frascati using the machine called *Dafne*. More specifically, the intersection of the beams at an angle is one of the strengths of the project because it allows a set of particles to follow exactly the same path as those moving in the opposite direction.

The experiments and simulations conducted so far show that SuperB will be able to meet the demands of physics and to produce 1000 pairs of B mesons, the same number of lepton τ pairs, and several thousands of D mesons for every second of its full-power operation.

SuperB is expected to have a technological impact in terms of:

- Biology
- Chemistry and the environment
- Microelectronics
- Diagnostics and medical applications
- Innovative materials
- Nanotechnologies
- Cultural heritage

CONTACT INFORMATION:

Prof. Roberto Petronzio
INFN President
Mob. +39335 356843

Umberto Dosselli
INFN Vice pres.
Mob. +39320 9232316

Romeo Bassoli
INFN Communication Office Manager
Tel +39066868162
Mob. +39328 6666766
romeo.bassoli@presid.infn.it
vincenzo.napolano@presid.infn.it

SuperB Approval

- Italian parliament approved 19MEuro for the 2010 first year of the project – in line with the proposed funding profile as proposed in INFN submission.
- Next 50MEuro to come in spring 2011
- Approved funding for construction in 5 years as presented and approved in the official INFN annually updated planning document
  - Aggressive plan with the funding for construction in five years; planning first collisions for physics in 2016

- Site selection decision by INFN to be made this winter – Tor Vergata and Laboratori Nazionali di Frascati (LNF) favoured sites
- U.S. DOE contributing much of PEP-II and BaBar: negotiating details value at a couple of hundred million Euros

SuperB funding profile: INFN Piano Triennale 2010-12

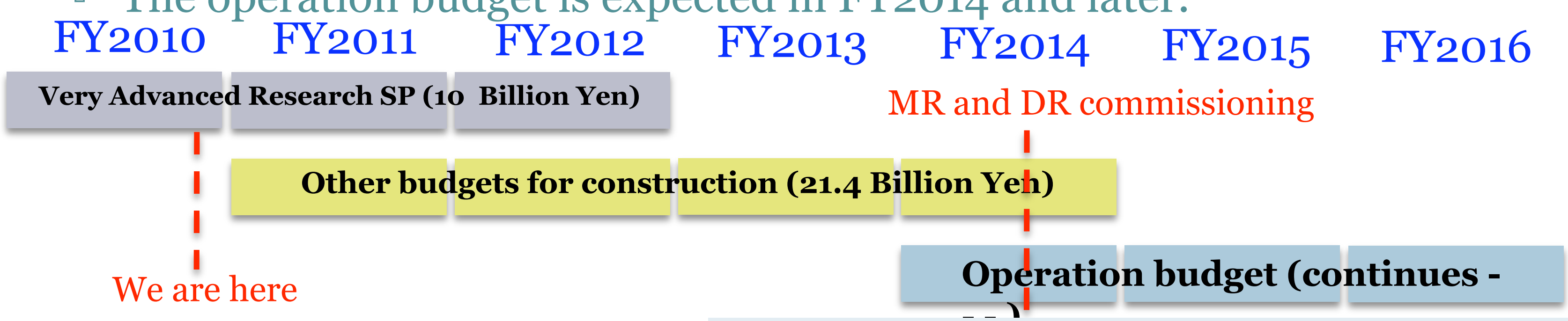
Componenti Super B	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Sviluppo Acceleratore (130 M€) Costruzione infrastrutture, Sviluppo damping rings, Sviluppo transfer lines, Messa in funzione linac, Damping lines transfer lines, Costruzione facility end-user	20	50	60							
Sviluppo Centri Calcolo (43 M€) Sviluppo progettazione costruzione centro di calcolo per analisi dati	5	15	23							
Completamento Acceleratore (126 M€) Installazione componenti negli archi acceleratore, Installazione zona di interazione, Messa in funzione acceleratore				42	42	42				
Utilizzo installazione (80 M€) Costi operazione e manutenzione acceleratore							20	20	20	20
Totale Infrastrutture tecniche **(379 M€)**	25	65	83	42	42	42	20	20	20	20
Overheads INFN **(34.3 M€ equivalente al 9%)**	2.3	5.9	7.5	3.8	3.8	3.8	1.8	1.8	1.8	1.8
Cofinanziamento INFN (150 M€)	15	15	15	15	15	15	15	15	15	15
Costo Totale del progetto (563.3 M€)	42.3	85.9	105.5	60.8	60.8	60.8	36.8	36.8	36.8	36.8

SuperKEKB Milestones this year

- 22 Jun. 2010: A budget of 10 Billion Yen announced
  - The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government. ("KEKB upgrade plan has been approved", Press Release 23 Jun 2010; KEK web site)
- 30 Jun. 2010: KEKB operation was shut down, and KEKB upgrade started
- 24 Dec. 2010: SuperKEKB approved in FY2011 budget
  - The Cabinet of Japan announced the national budget plan of JFY2011 Feb 2011, where SuperKEKB upgrade was approved as requested by MEXT. This will be final decision of SuperKEKB after approval by the Japanese Diet. ("Green light from the Cabinet", M. Yamauchi to Belle II members)

SuperKEKB Budget

- "Very Advanced Research Support Program"
  - MEXT has announced that it will appropriate 10 Billion Yen for three years (FY2010–12).
  - Among this, 7.5 Billion Yen was already appropriated in FY2010.
  - This budget is for upgrading LER vacuum system and LER magnet system.
- Other budgets
  - 21.4 Billion Yen for SuperKEKB construction is expected for FY2011-14.
  - Among this, approval of 4.06 Billion Yen for FY2011 was announced by the Cabinet.
  - They are for various accelerator components and facilities, including DR tunnel, buildings for DR and MR and cooling system.
- Total budget
  - Total construction budget is 31.4 Billion Yen (~ 270 MEuros)
  - The operation budget is expected in FY2014 and later.



Summary

- Extremely broad and exciting physics program with sensitivity to new physics that is complementary to the LHC.
- Flexibility in ways that machines can achieve 100× luminosity with beam currents and power comparable to current facilities
- SuperB and SuperKEKB both approved

Additional slides

Three theory lectures at LLWI-2011 on Flavour:

Monday 21 Feb 08:30 Physics at Future B factories, Martin BENEKE
Thursday 24 Feb 08:30 Flavour Physics, Yosef NIR
Thursday 24 Feb 09:30 Quark Masses, Johann KüHN

Five contributed talks on Next Generation B-Factories (aka Heavy Flavour Factories) in Thursday 24 Feb afternoon session:

SuperKEKB/Belle II
16:00 Status and Plans for SuperKEKB and Belle II experiment, Hiroyuki NAKAYAMA
16:15 Physics prospects of SuperKEKB/Belle II experiment, Kurtis NISHIMURA

SuperB
16:30 Drift Chamber Design Optimization Studies for SuperB, Darren SWERSKY
16:45 LYSO Forward Calorimeter, Alessandro ROSSI
17:15 Impact on the SuperB physics reach of the Vertex Detector configuration, Giulia CASAROSA

In addition: 18 talks on heavy flavour from existing data –
e^+e^- colliders: BaBar, Belle, CLEO-c
Hadron colliders: D0, CDF, LHCb, ATLAS, CMS

~1/3 of LLWI presentations are on heavy flavour topics

Recent publications from proponents of e^+e^- Super Flavour Factories

- SuperB 2010 Progress Reports:
  - Physics arXiv:1008.1541
  - Detector arXiv:1007.4241
  - Accelerator arXiv:1009.6178
- Physics at Super B Factory (Belle-II + theorists)
  - arXiv:1002.5012

Interest of running @ threshold

B. Meadow et al.

PHYSICS

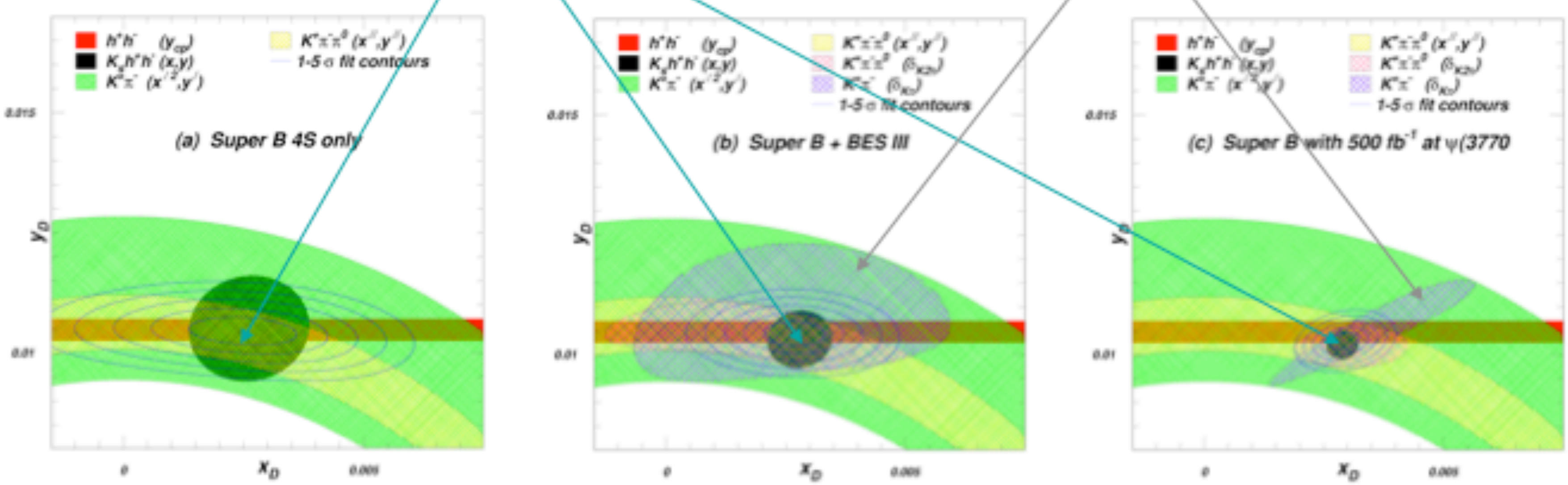
500 fb-1 at *ψ(3770)*

Decays of *ψ(3770)* → *D^0D^0* produce coherent *(C=-1)* pairs of *D^0*'s. Quantum correlations in their subsequent decays allow measurements of strong phases

- Required for improved measurement of CKM γ
- Also required for *D^0* mixing studies

- Dalitz plot model uncertainty shrinks

- Information on overall strong phase is added



Fit	$x \times 10^3$	$y \times 10^3$	$\delta^0_{K\pi\pi}$	$\delta^0_{K\pi\pi\pi^0}$
(b)	$xxx^{+0.72}_{-0.75}$	$xxx \pm 0.19$	$xxx^{+3.7}_{-3.4}$	$xxx^{+4.6}_{-4.5}$
Stat.	(0.18)	(0.11)	(1.3)	(2.9)

Fit	$x \times 10^3$	$y \times 10^3$	$\delta^0_{K\pi\pi}$	$\delta^0_{K\pi\pi\pi^0}$
(c)	$xxx \pm 0.42$	$xxx \pm 0.17$	$xxx \pm 2.2$	$xxx^{+3.3}_{-3.4}$
Stat.	(0.18)	(0.11)	(1.3)	(2.7)

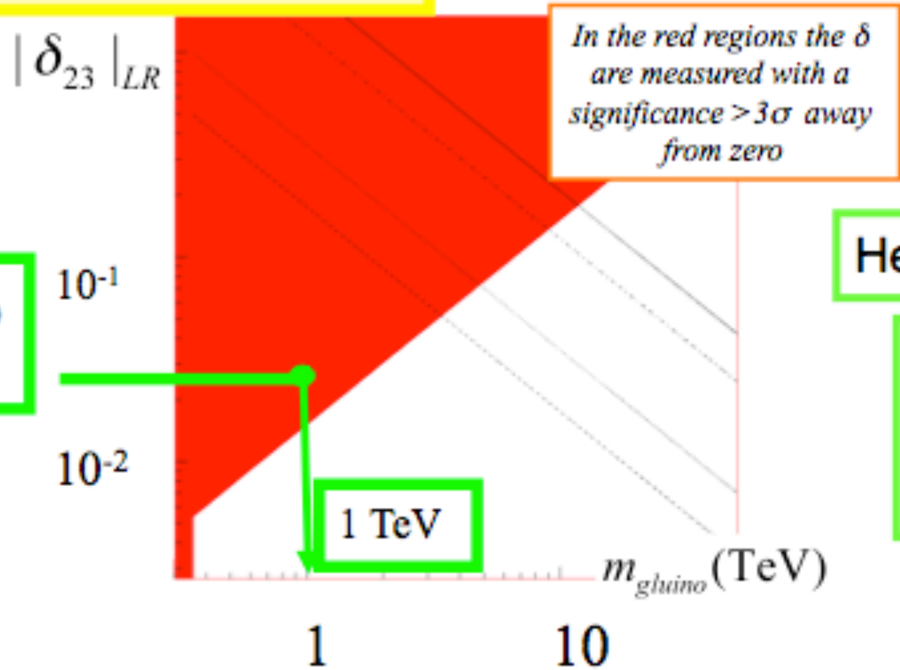
Fit	$x \times 10^3$	$y \times 10^3$	$\delta^0_{K\pi\pi}$	$\delta^0_{K\pi\pi\pi^0}$
(d)	$xxx \pm 0.20$	$xxx \pm 0.12$	$xxx \pm 1.0$	$xxx \pm 1.1$
Stat.	(0.17)	(0.10)	(0.9)	(1.1)

Uncertainty in x_D improves more than that of y_D

MSSM+generic soft SUSY breaking terms

$|\delta_{23}|_{LR} = (0.026 \pm 0.005)$

$\mathrm{Arg}(\delta_{23})_{LR} = (44.5 \pm 2.6)^\circ$



Here the players are :

- $(B \to X_s\, \gamma)$
- $(B \to X_s\, l^+ l^-)$
- $A_{CP}(B \to X_s\, \gamma)$

M. Blanke et al., 0906.5454

ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{Br(\tau^- \to e^- e^+ e^-)}{Br(\tau \to e\gamma)}$	$0.04 \ldots 0.4$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{Br(\tau^- \to \mu^- \mu^+ \mu^-)}{Br(\tau \to \mu\gamma)}$	$0.04 \ldots 0.4$	$\sim 2 \cdot 10^{-3}$	$0.06 \ldots 0.1$
$\frac{Br(\tau^- \to e^- \mu^+ \mu^-)}{Br(\tau \to e\gamma)}$	$0.04 \ldots 0.3$	$\sim 2 \cdot 10^{-3}$	$0.02 \ldots 0.04$
$\frac{Br(\tau^- \to \mu^- e^+ e^-)}{Br(\tau \to \mu\gamma)}$	$0.04 \ldots 0.3$	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{Br(\tau^- \to e^- e^+ e^-)}{Br(\tau^- \to e^- \mu^+ \mu^-)}$	$0.8 \ldots 2.0$	~ 5	$0.3 \ldots 0.5$
$\frac{Br(\tau^- \to \mu^- \mu^+ \mu^-)}{Br(\tau^- \to \mu^- e^+ e^-)}$	$0.7 \ldots 1.6$	~ 0.2	$5 \ldots 10$

LHT models

- LFV: $\tau \to \mu\gamma$ vs $\tau \to \ell\ell\ell$
- semileptonic asymmetries

PDG 2010:

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders

	KEKB (KEK)	PEP-II (SLAC)	SuperB (Italy)	SuperKEKB (KEK)
Maximum beam energy (GeV)	e^-: 8.33 (8.0 nominal) e^+: 3.64 (3.5 nominal)	e^-: 7–12 (9.0 nominal) e^+: 2.5–4 (3.1 nominal) (nominal E_{cm} = 10.5 GeV)	e^-: 4.2 e^+: 6.7	e^-: 7 e^+: 4
Luminosity (10^{30} cm^{-2}s^{-1})	21083	12069 (design: 3000)	1.0×10^6	8×10^5
Time between collisions (μs)	0.00590 or 0.00786	0.0042	0.0042	0.004
Full crossing angle (μ rad)	$\pm11000^\dagger$	0	±33000	±41500
Energy spread (units 10^{-3})	0.7	e^-/e^+: 0.61/0.77	e^-/e^+: 0.73/0.64	e^-/e^+: 0.58/0.84
Bunch length (cm)	0.65	e^-/e^+: 1.1/1.0	0.5	e^-/e^+: 0.5/0.6
Beam radius (μm)	H: 124 (e^-), 117 (e^+) V: 0.94	H: 157 V: 4.7	H: 8 V: 0.04	e^-: 11 (H), 0.062 (V) e^+: 10 (H), 0.048 (V)
Free space at interaction point (m)	+0.75/−0.58 (+300/−500) mrad cone	±0.2, ±300 mrad cone	±0.35	e^- : +1.20/ − 1.28, e^+ : +0.78/ − 0.73 (+300/−500) mrad cone
Luminosity lifetime (hr)	continuous	continuous	continuous	continuous
Turn-around time (min)	continuous	continuous	continuous	continuous

PDG 2010:

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders

	KEKB (KEK)	PEP-II (SLAC)	SuperB (Italy)	SuperKEKB (KEK)
Injection energy (GeV)	e^-/e^+: 8/3.5	2.5–12	e^-/e^+: 4.2/6.7	e^-/e^+: 7/4
Transverse emittance ($10^{-9}\pi$ rad-m)	e^-: 24 (57*) (H), 0.61 (V) e^+: 18 (55*) (H), 0.56 (V)	e^-: 48 (H), 1.5 (V) e^+: 24 (H), 1.5 (V)	e^-: 2.5 (H), 0.006 (V) e^+: 2.0 (H), 0.005 (V)	5 (H), 3 (V)
β^*, amplitude function at interaction point (m)	e^-: 1.2 (0.27*) (H), 0.0059 (V) e^+: 1.2 (0.23*) (H), 0.0059 (V)	e^-: 0.50 (H), 0.012 (V) e^+: 0.50 (H), 0.012 (V)	e^-: 0.032 (H), 0.00021 (V) e^+: 0.026 (H), 0.00025 (V)	e^-: 0.025 (H), 3×10^{-4} (V) e^+: 0.032 (H), 2.7×10^{-4} (V)
Beam-beam tune shift per crossing (units 10^{-4})	e^-: 1020 (H), 900 (V) e^+: 1270 (H), 1290 (V)	e^-: 703 (H), 498 (V) e^+: 510 (H), 727 (V)	20 (H), 950 (V)	e^-: 12 (H), 807 (V) e^+: 28 (H), 893 (V)
RF frequency (MHz)	508.887	476	476	508.887
Particles per bunch (units 10^{10})	e^-/e^+: 4.7/6.4	e^-/e^+: 5.2/8.0	e^-/e^+: 5.1/6.5	e^-/e^+: 6.53/9.04
Bunches per ring per species	1585	1732	978	2500
Average beam current per species (mA)	e^-/e^+: 1188/1637	e^-/e^+: 1960/3026	e^-/e^+: 1900/2400	e^-/e^+: 2600/3600

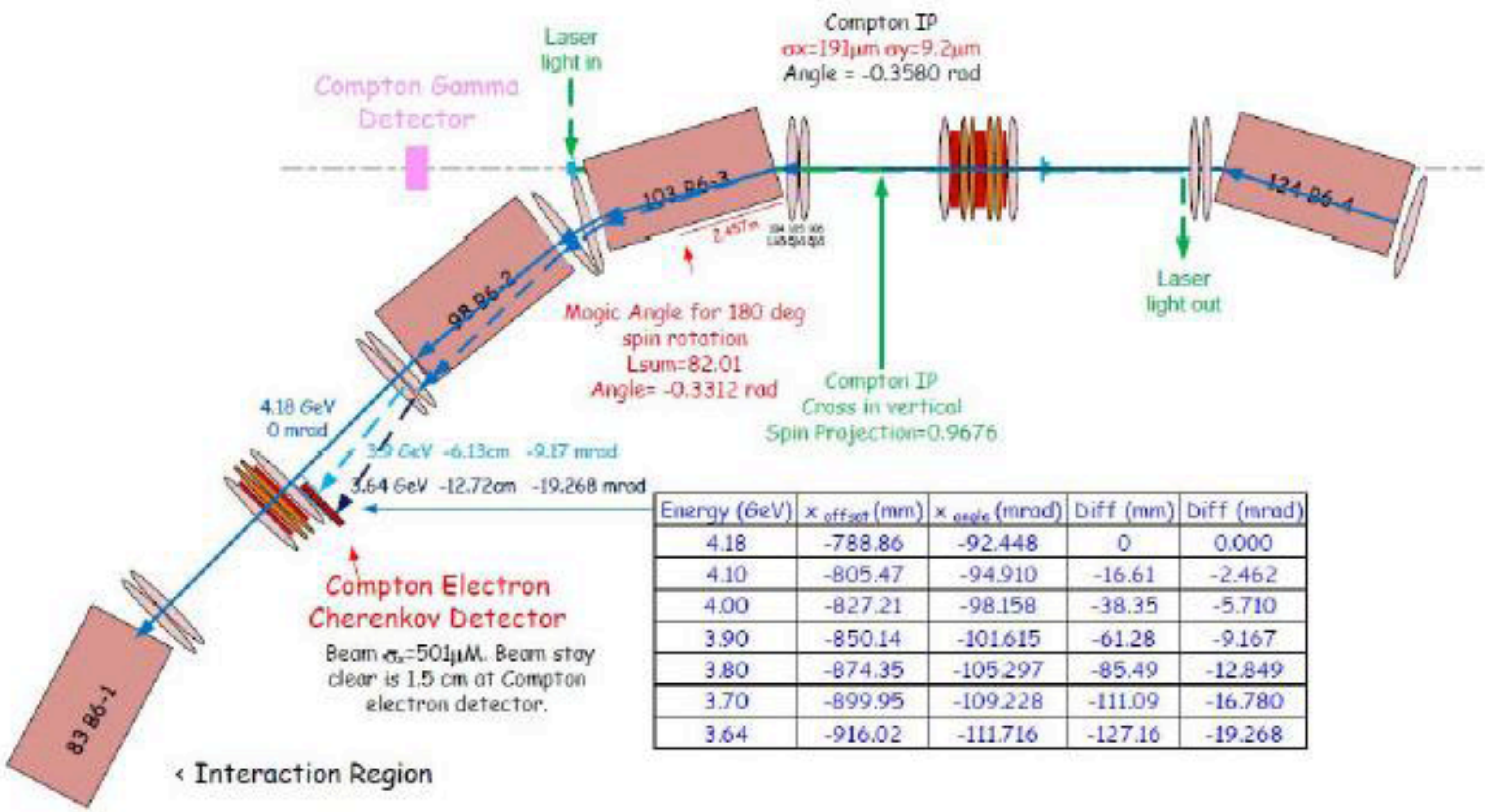
PDG 2010:

HIGH-ENERGY COLLIDER PARAMETERS: e^+e^- Colliders

	KEKB (KEK)	PEP-II (SLAC)	SuperB (Italy)	SuperKEKB (KEK)
Beam polarization (%)	—	—	> 80	—
Circumference or length (km)	3.016	2.2	1.258	3.016
Interaction regions	1	1	1	1
Magnetic length of dipole (m)	e^-/e^+ : 5.86/0.915	e^-/e^+: 5.4/0.45	e^-/e^+: 0.9/5.4	e^-/e^+ : 5.9/4.0
Length of standard cell (m)	e^-/e^+ : 75.7/76.1	15.2	40	e^-/e^+ : 75.7/76.1
Phase advance per cell (deg)	450	e^-/e^+: 60/90	360 (V), 1080 (H)	450
Dipoles in ring	e^-/e^+ : 116/112	e^-/e^+: 192/192	e^-/e^+: 186/102	e^-/e^+ : 116/112
Quadrupoles in ring	e^-/e^+ : 452/452	e^-/e^+: 290/326	e^-/e^+: 290/300	e^-/e^+ : 466/460
Peak magnetic field (T)	e^-/e^+ : 0.25/0.72	e^-/e^+: 0.18/0.75	e^-/e^+: 0.52/0.25	e^-/e^+ : 0.22/0.19

Italian SuperB Collider

Spin Rotator location for Beam Polarization



Energy (GeV)	x_{offset} (mm)	x_{angle} (mrad)	Diff (mm)	Diff (mrad)
4.18	-788.86	-92.448	0	0.000
4.10	-805.47	-94.910	-16.61	-2.462
4.00	-827.21	-98.158	-38.35	-5.710
3.90	-850.14	-101.615	-61.28	-9.167
3.80	-874.35	-105.297	-85.49	-12.849
3.70	-899.95	-109.228	-111.09	-16.780
3.64	-916.02	-111.716	-127.16	-19.268

Figure 16.9: Layout of the Compton polarimeter.