The *SuperB* Project
an overview

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at

Flavour as a Window to New Physics at the LHC

CERN May 30,2008

A CDR was delivered to the President of INFN in May 2007.

INFN has set up an International Review Committee to evaluate the CDR proposal and in particular the physics program and the machine ideas.

The IRC was lead by J.Dainton and formed byH.Aihara, R.D.Heuer, Y.K.Kim, J.Lefrancois, A.Masiero, D.Schulte, A.Seiden. They met in July 07, November 07, and april 29 and 30 2008.

Meanwhile the project has been presented to ECFA at Manchester during the july 07 conference of EPS and more recently in the RECFA meeting in Lisbon last march 29, 2008.

Rolf Heuer didn't attend the last meeting and the preparation of the report. T.Nakada and S.Myers have participated to the conclusion.

From Manchester ('07) :

to Lisboa ('08) :

ECFA

R-ECFA Meeting PT - Lisbon, 28-29 March 2008

Ecfa has appointed a subcommittee chaired by T. Nakada as a contact group with SuperB

CERN

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First Report
of the International Review Committee[1] (IRC)
for the SuperB Project

Hiroaki Aihara, John Dainton, Young Kee Kim, Jacques Lefrançois, Antonio Masiero, Steve Myers, Tatsuya Nakada[2], Daniel Schulte, Abe Seiden

Roma, May 21st 2008

It will be presented Sunday june 1,2008 y J.Dainton at the general meeting of SuperB starting tomorrow may 31 in the Elba (Italy)

Mainly focused on Physics program with 10 36 , polarization >80%

And possibility of running asymmetric at 4 GeV c.m.s. Energy for charm asymmetry in time dependent analysis.

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Flavour Physics was recently in the front line of the stage thanks to the e+ e- factories.

What in the next decade will e+ e- factories say about new physics and contribute as complementary to LHC and LHCb ?

A LOT!

Providing they can produce more than $5 \cdot 10^{10}$ and 10^{11} b, c and τ pairs in 5 years and from then accumulate $4\text{-}5 \cdot 10^{10}$ more/year.

AND AT WITH A REASONABLE ELECTRICITY BILL!

Luminosity

- For gaussian bunches:

$$\mathcal{L} = f_{\text{coll.}} \times \frac{N_{e+} \, N_{e-}}{4\pi \, \sigma_x \, \sigma_y} \times R_l \quad \text{geometrical Reduction factor}$$

N_e^+ (N_e^-) is the number of positrons (electrons) in a bunch

f_{coll} is the collision frequency

σ_x (σ_y) is the horizontal (vertical) r.m.s. size at the I.P.

R_l is the Luminosity Reduction factor by incomplete overlap: crossing angle and "hour glass" effect.

- TRADITIONAL (brute force): increase the numerator Currents increase: from 1A on 2 A up to 4.1 A on 9.4 A- **Wall Plug Power**, HOM,CSR: hard to surpass $5 \cdot 10^{35}$ cm^{2}s^{-1}
Crab Crossing to increase $\mathbf{R_l}$ and to optimize beam dynamic
- Super$B$: decrease the denominator (same currents as PEP-II)
Bunch sizes: from $\sigma_y = 3\mu$m down to $\sigma_y = 40$ nm Luminosity: 10^{36} cm^{2}s^{-1} (baseline) .
Crab Waist and large **Piwinsky** angle to optimize beam dynamic

It appeared as the solution for the high luminosity at a reasonable wall power
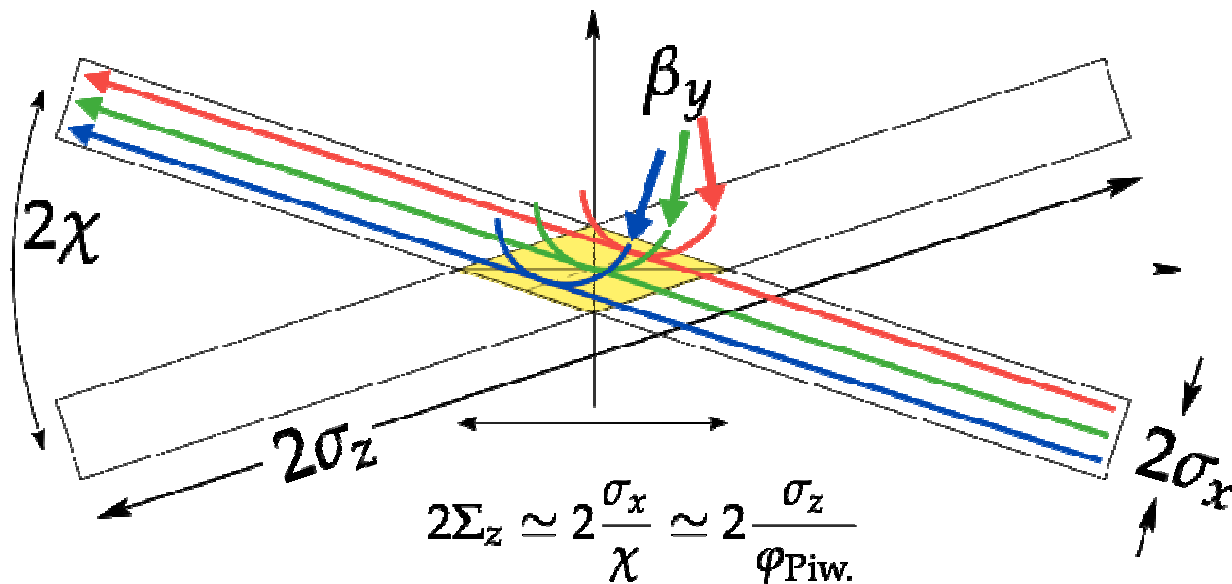
$(\leq 30$ MW as in PEPII)

BUT:

To proceed the validation of simulations was necessary.

The large Piwinski angle scheme and crab waist needed to be tested.

Preliminary results on test are now available

$$2\Sigma_z \simeq 2\frac{\sigma_x}{\chi} \simeq 2\frac{\sigma_z}{\varphi_{\text{Piw.}}}$$

- Crab waist: modulation of the y-waist position, particles collides a same β_y realized with a sextupole upstream the IP.

- Minimization of nonlinear terms in the beam-beam interaction: reduced emittance growth, suppression of betatron and sincro-betatron coupling

- Maximization of the bunch-bunch overlap: luminosity gain
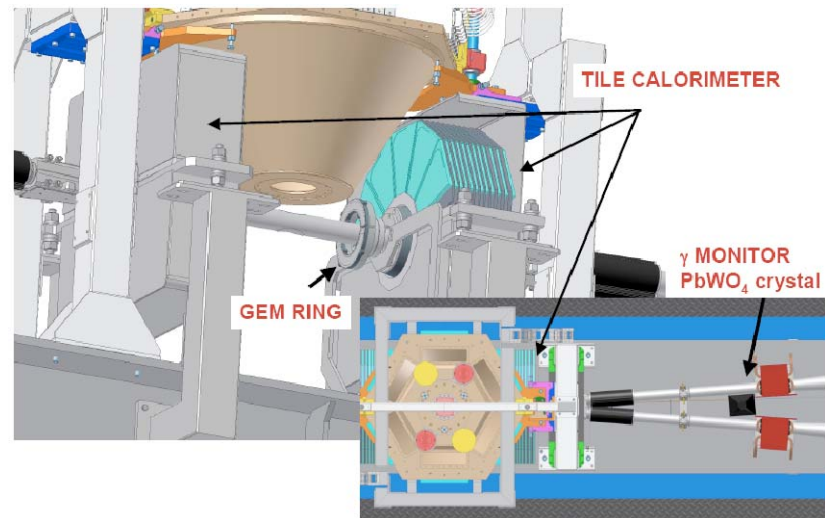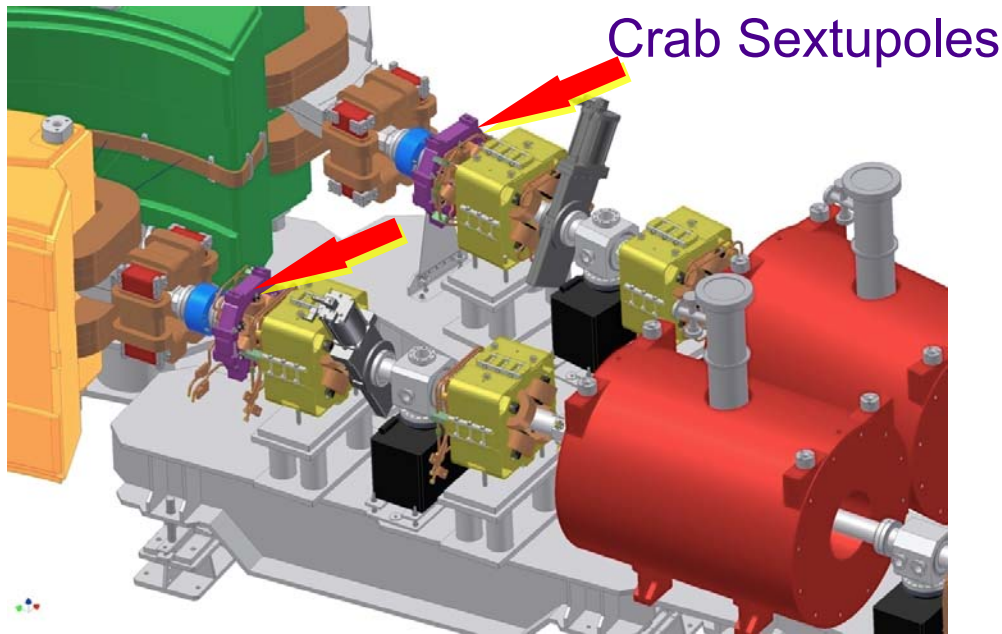
Crab Sextupoles

- Tests undergoing in Frascati right now

- Small angle EMC as luminosity monitor

- Beam crabbing made by 2 pairs of Sextupoles

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DAΦNE test summary

- Crab sextupoles are working very nicely
- Luminosity stable above 1.5×10^{32} reached
- No "hard to fix" problems found so far, but many more than desired
- A lot of "single pieces" are working very nicely, need to put all together at the same time
- Commissioning rate a factor 2 slower than we hoped

Effect of crab sextupoles on luminosity

LUMINOMETERS

A huge work on machine optimization has been done and is still in progress in term of feedbacks systems tuning, background minimization and tuning of the machine luminosity
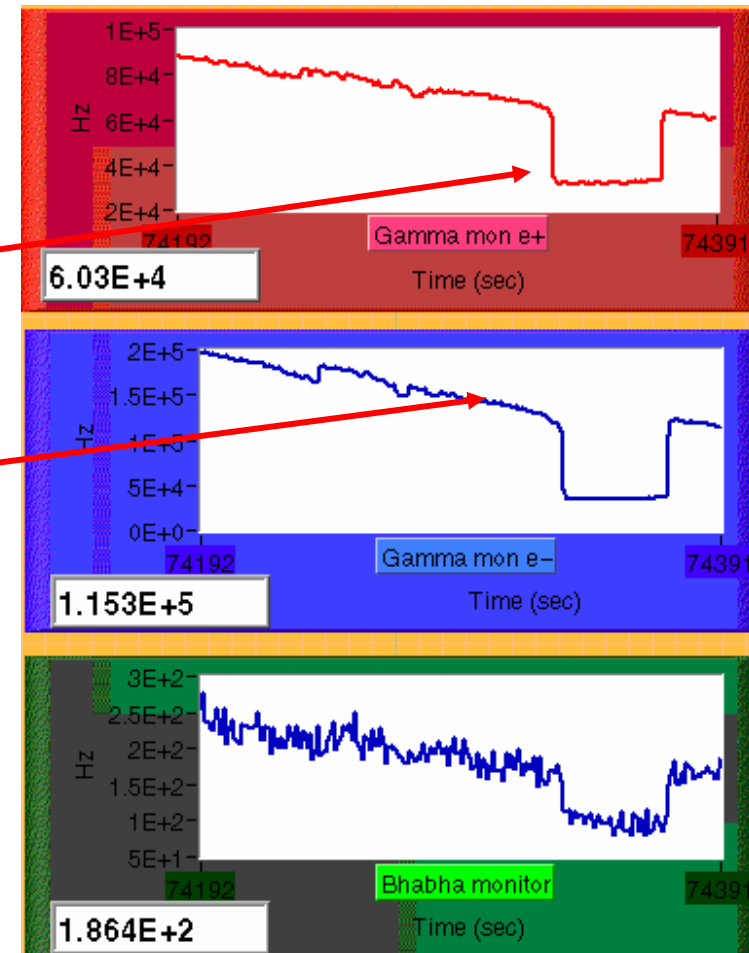
Crab OFF

Crab ON

Transverse beam dimensions at the Synchrotron Light Monitor
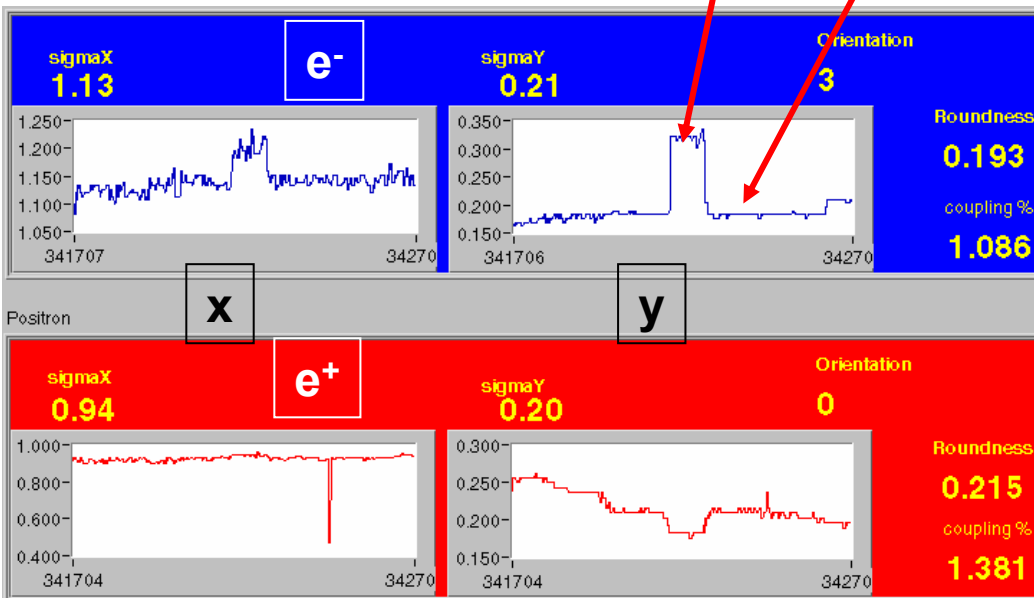
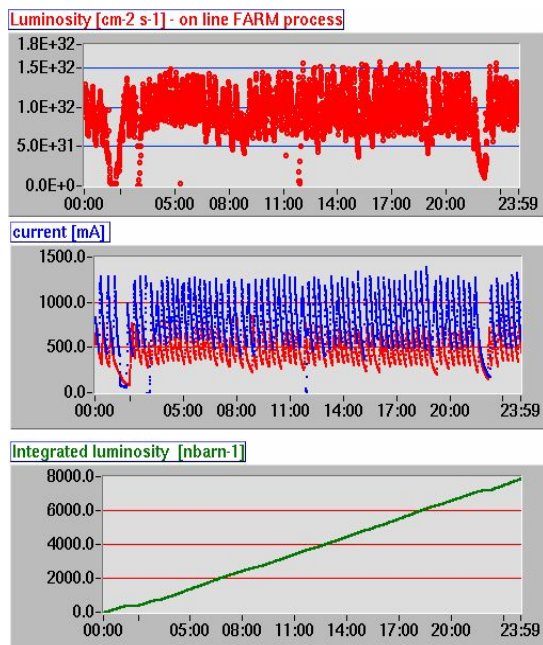**Blow-up in beam sizes and decrease in Bhabha rates observed when crab sexts for one ring OFF (other ring ON)**

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- Specific Luminosity(vs time) does not depends on beam currents
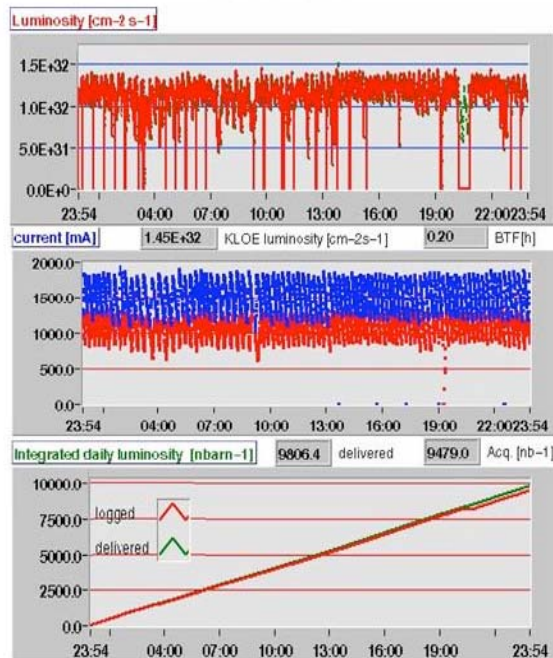
- headrom for luminosity improvements

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Best days

SIDDHARTA

Luminosity [cm-2 s-1] - on line FARM process

current [mA]

Integrated luminosity [nbarn-1]

90 bunches, $\beta_y{}^* = 0.9$ cm, $\beta_x{}^* = 0.26$ m

KLOE

Luminosity [cm-2 s-1]

current [mA] $1.45E+32$ KLOE luminosity [cm-2s-1] 0.20 BTF[h]

Integrated daily luminosity [nbarn-1] 9806.4 delivered 9479.0 Acq. [nb-1]

logged
delivered

111 bunches, $\beta_y{}^* = 1.8$ cm, $\beta_x{}^* = 1.5$ m

FINUDA

FINUDA Luminosity [cm-2 s-1]

current [mA]

Integrated luminosity [nbarn-1]
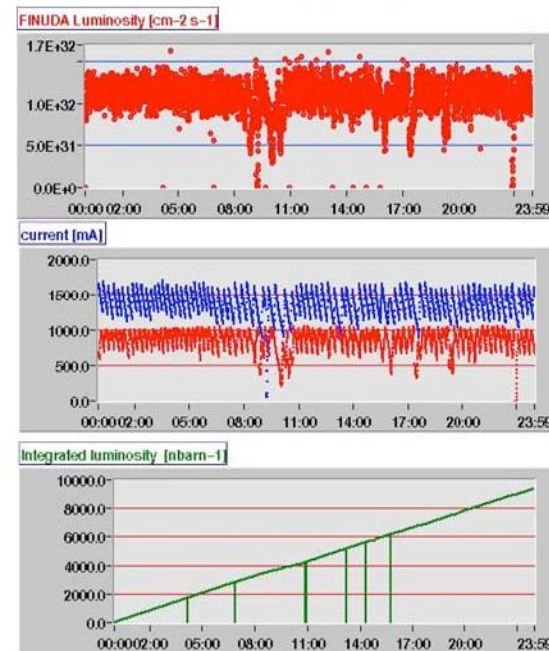
106 bunches, $\beta_y{}^* = 1.9$ cm, $\beta_x{}^* = 2.0$ m

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ISTITUTO NAZIONALE DI FISICA NUCLEARE

Laboratori Nazionali di Frascati

(DRAFT) MEMO for SuperB Steering Committee

PRELIMINARY RESULTS FROM DAΦNE UPGRADE AS A PROOF OF PRINCIPLE OF NEW CONCEPTS FOR *SuperB*

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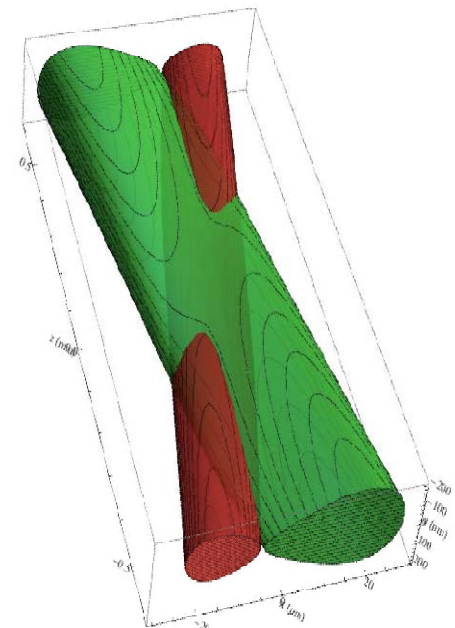
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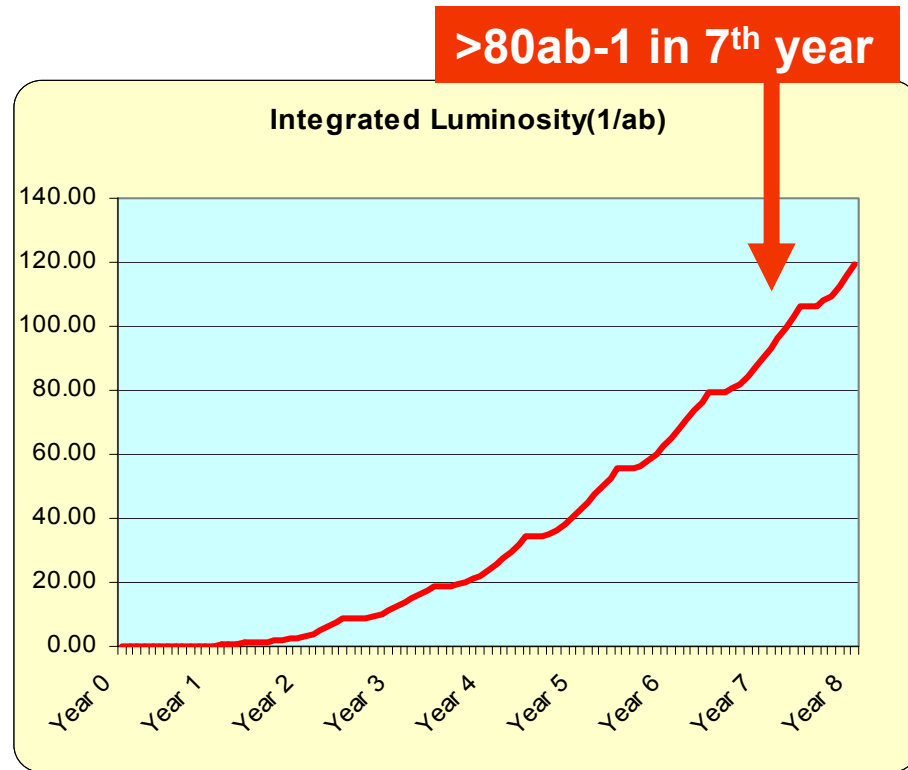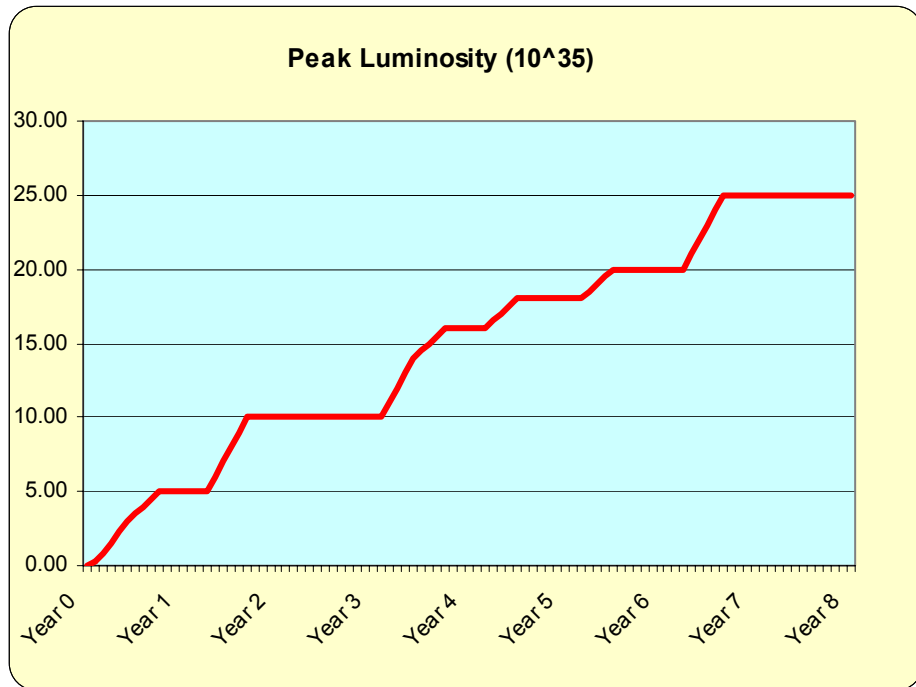| PARAMETER	Nominal		Upgrade	
	LER (e+)	HER (e-)	LER (e+)	HER (e-)
Energy (GeV)	4	7	4	7
Luminosity x 10^{36}		1.0		2.0
Circumference (m)	1800	1800		
Revolution frequency (MHz)		0.167		
Eff. long. polarization (%)	0	80		
RF frequency (MHz)		476		
Momentum spread ($\times 10^{-4}$)	7.9	5.6	9.0	8.0
Momentum compaction ($\times 10^{-4}$)	3.2	3.8	3.2	3.8
Rf Voltage (MV)	5	8.3	8	11.8
Energy loss/turn (MeV)	1.16	1.94	1.78	2.81
Number of bunches		1251		
Particles per bunch ($\times 10^{10}$)		5.52		
Beam current (A)		1.85		
Beta y* (mm)	0.22	0.39	0.16	0.27
Beta x* (mm)	35	20		
Emit y (pm-rad)	7	4	3.5	2
Emit x (nm-rad)	2.8	1.6	1.4	0.8
Sigma y* (microns)	0.039	0.039	0.0233	0.0233
Sigma x* (microns)	9.9	5.66	7	4
Bunch length (mm)		5		4.3
Full Crossing angle (mrad)		48		
Wigglers (#) 20 meters each	0	0	2	2
Damping time (trans/long)(ms)	40/20	40/20	28/14	28/14
Luminosity lifetime (min)		6.7		3.35
Touschek lifetime (min)	13	20	6.9	10.3
Effective beam lifetime (min)	4.5	5.1	2.3	2.5
Injection rate pps ($\times 10^{11}$) (100%)	2.6	2.3	5.1	4.6
Tune shift y (from formula)		0.15		0.20
Tune shift x (from formula)	0.0043	0.0025	0.0059	0.0034
RF Power (MW)		17		25

150m needed for Polarization

Doubling currents with a factor 2 in Wall power we can double the luminosity

LEB HEB

Asymmetric bunch size to optimize beam lifetime (Touschek effect)

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SuperB expected LUMI

Peak Luminosity (10^35)

Integrated Luminosity(1/ab)

>80ab-1 in 7th year

After 7th year integrated Luminosity can grow at rate of ~40 ab^{-1}/year

Physics on CDR (comparisons with 50 ab⁻¹)
More recently update on physics program for 75 ab⁻¹ after the Valencia Physics retreat

Proceedings
of
Super$B$ Workshop VI

New Physics
at the
Super Flavour Factory

Valencia, Spain
January 7-15, 2008

Update on physics (potential discovery of New Physics with a 75 ab-1 in 5 years) for B, Charm, Tau's and new Spectroscopy .

Examine carefully the potential benefits of running at 4GeV c.m.s. Energy and of the Polarization.

Organize the preparation of the simulation tools to evaluate the correct experimental sensitivity to the most relevant physics channels

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- There is a solid case for a SuperB collecting between 50 and 100 ab^{-1} (5.10^{10} -10^{11} B, charm, t pair)
  - Precision measurements allowing to detect discrepancies from the standard model
  - Reduced theoretical uncertainties will allow this in many channels
  - Rare decay measurementsstudy
  - Lepton flavour violation
  - In addition: possibility to run at tau/charm threshold, polarized beam
- Complementarity with LHC has been studied in the CERN workshop Flavour Physics in the era of LHC .
  - (M.Mangano,T.Hurth to be published soon as CERN yellow report)
- See in addition to SuperB CDR:
  - 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)
  - SuperB report (hep-ex/0512235)
  - Many documents available at the URL : www.pi.infn.it/SuperB
  - BUT MORE IMPORTANT……

THE UNEXPECTED DISCOVERY FROM A FRONTIER MACHINE

Mode	Sensitivity		
	Current	Expected ($10\ \mathrm{ab}^{-1}$)	Expected ($75\ \mathrm{ab}^{-1}$)
$\mathcal{B}(B \to X_s \gamma)$	7%	5%	3%
$A_{CP}(B \to X_s \gamma)$	0.037	0.01	0.004–0.005
$\mathcal{B}(B^+ \to \tau^+ \nu)$	30%	10%	3–4%
$\mathcal{B}(B^+ \to \mu^+ \nu)$	not measured	20%	5–6%
$\mathcal{B}(B \to X_s l^+ l^-)$	23%	15%	4–6%
$A_{\mathrm{FB}}(B \to X_s l^+ l^-)_{s_0}$	not measured	30%	4–6%
$\mathcal{B}(B \to K \nu \overline{\nu})$	not measured	not measured	16–20%
$S(K_S^0 \pi^0 \gamma)$	0.24	0.08	0.02–0.03

$B \to X_s \gamma \ and \ B \to X_s \ell^+ \ell^-$ not deeply investigated in the CDR

In CDR all comparisons for 50 ab⁻¹

SuperB

	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathcal{B}(B \to X_s \gamma)$		X		🟢		🟢
$A_{CP}(B \to X_s \gamma)$				X		🟢
$\mathcal{B}(B \to \tau\nu)$	X- CKM					
$\mathcal{B}(B \to X_s l^+ l^-)$				🟢	🟢	🟢
$\mathcal{B}(B \to K\nu\overline{\nu})$				🟢	X	
$S(K_S \pi^0 \gamma)$						
β			X- CKM			X

X The GOLDEN channel for the given scenario

🟢 Not the GOLDEN channel for the given scenario but can show experimentally measurable deviation from SM.
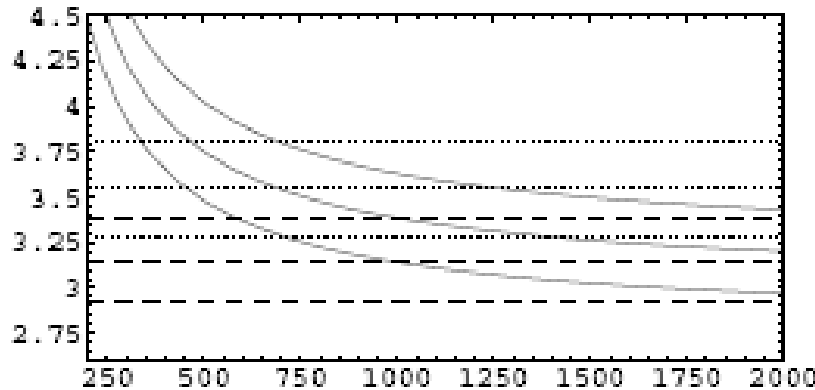
SuperB

$b \rightarrow s\gamma$

FIG. 1: $\mathcal{B}(B \rightarrow X_s\gamma) \times 10^{-4}$ as a function of the charg Higgs boson mass M_{H^+} (GeV) in the 2HDM II for $\tan\beta =$ (solid lines). Dashed and dotted lines show the Standa Model and experimental results, respectively.
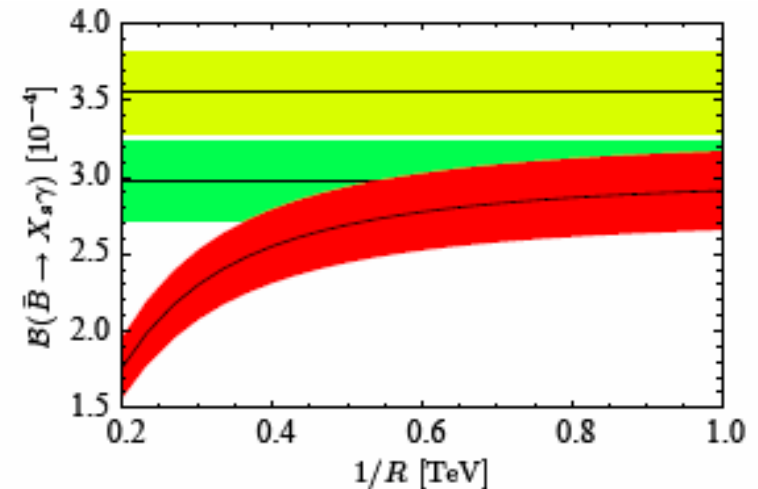

FIG. 2: Branching fraction for $E_0 = 1.6\,GeV$ as a function of $1/R$. The red (dark gray) band corresponds to the LO mUED result. The 68% CL range and central value of the experimental/Standard Model result is indicated by the yellow/green (light/medium gray) band underlying the straight solid line.
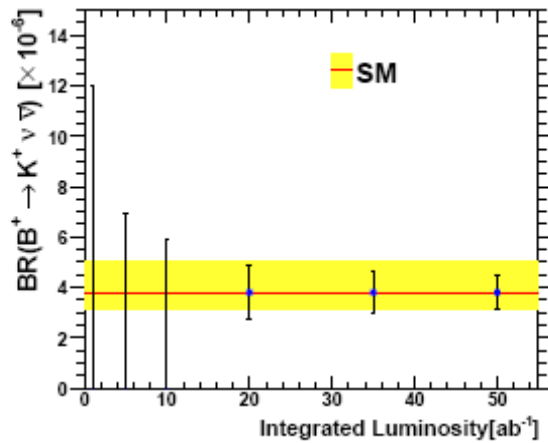
Comparison with charged Higgs mass

2 Higgs-doublet model . Bound on

M_{H^+} = 295 GeV at 95% CL.

Comparison with 1/R in minimal
Universal Extra Dimension model

$$\mathrm{BF}(B \rightarrow X_S\gamma)\Big|_{E_\gamma > 1.6\,GeV} = (3.55 \pm 0.26)\mathrm{x}10^{-4} \mathrm{\ SM} \begin{cases} (3.15\pm0.23)\mathrm{x}10^{-4}\ (\text{Misiak et al.PRL98(2007)}) \\ (2.98\pm0.26)\mathrm{x}10^{-4}\ (\text{Becher and Neubert PRL 98(2007)}) \end{cases}$$

$$B^+ \rightarrow K^+ \nu \bar{\nu}$$

The best UL < 14 10^{-6}

SM BF= 4 10^{-6}
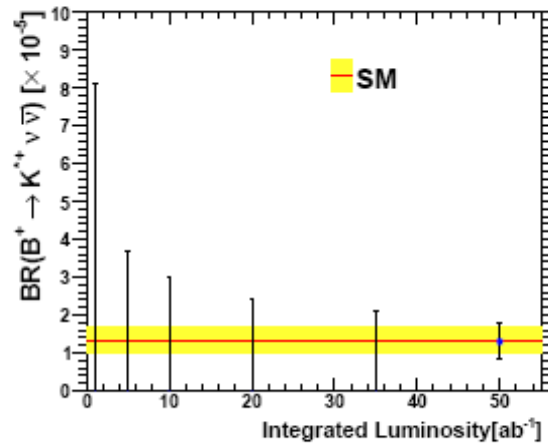
$$B^+ \rightarrow K^{*+} \nu \bar{\nu}, (K^+ \rightarrow K_S \pi^+)$$

FIG. 3: Expected precision of the measurements of the branching fractions of (top) $B^+ \rightarrow K^+\nu\bar{\nu}$ and (bottom) $B^+ \rightarrow K^{*+}\nu\bar{\nu}$ ($K^{*+} \rightarrow K_S\pi^+$) evaluated as a function of the integrated luminosity, assuming efficiencies and backgrounds as in the current BABAR analyses. The bands indicate the range of the Standard Model predictions.

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SNOWMASS points

SPS	$M_{1/2}$ (GeV)	M_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ
1 a	250	100	-100	10	> 0
1 b	400	200	0	30	> 0
2	300	1450	0	10	> 0
3	400	90	0	10	> 0
4	300	400	0	50	> 0
5	300	150	-1000	5	> 0

	SPS1a	SPS4	SPS5
$\mathcal{R}(B \to s\gamma)$	0.919 ± 0.038	0.248	0.848 ± 0.081
$\mathcal{R}(B \to \tau\nu)$	0.968 ± 0.007	0.436	0.997 ± 0.003
$\mathcal{R}(B \to X_s l^+ l^-)$	0.916 ± 0.004	0.917	0.995 ± 0.002
$\mathcal{R}(B \to K\nu\overline{\nu})$	0.967 ± 0.001	0.972	0.994 ± 0.001
$\mathcal{B}(B_d \to \mu^+\mu^-)/10^{-10}$	1.631 ± 0.038	16.9	1.979 ± 0.012
$\mathcal{R}(\Delta m_s)$	1.050 ± 0.001	1.029	1.029 ± 0.001
$\mathcal{B}(B_s \to \mu^+\mu^-)/10^{-9}$	2.824 ± 0.063	29.3	3.427 ± 0.018
$\mathcal{R}(K \to \pi^0\nu\overline{\nu})$	0.973 ± 0.001	0.977	0.994 ± 0.001

SPS4 ruled out by present values of B→sγ. Flavour has a great impact already in MFV!

SPS1a is the least favorable for flavour, but Super*B* can say at the level of 2 σ in several channels as $B \to s\gamma$, $B \to \tau\nu$, $B \to X_S\, l^+l^-$
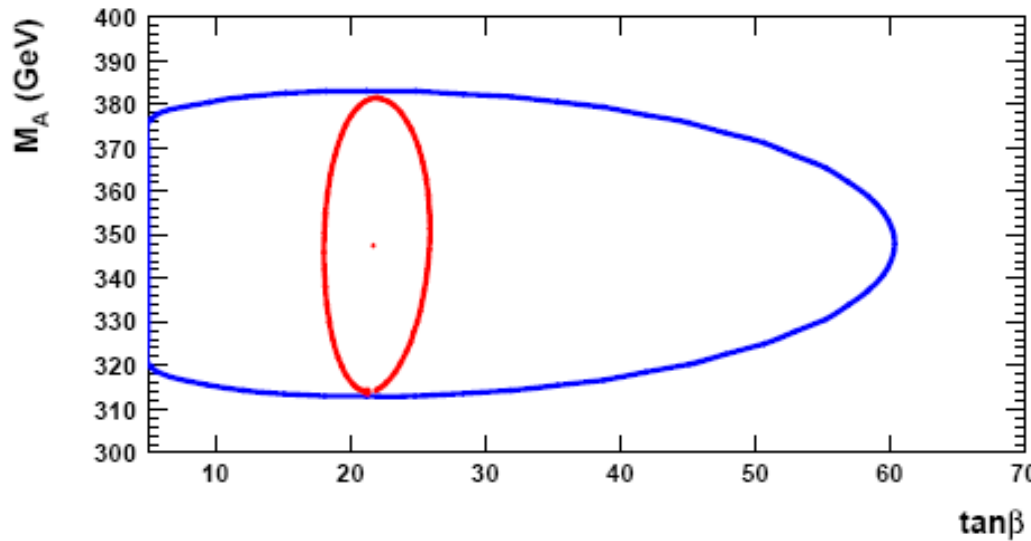
IF LHC DISCOVERS
SUPERSYMMETRY
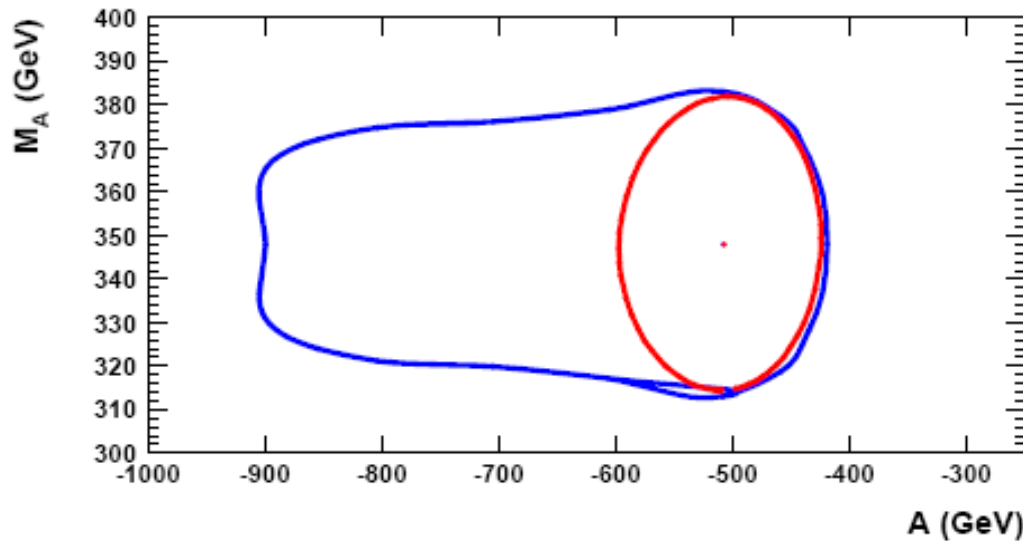
Red are LHC+EW constraints+Super*B*

Blue is LHC alone

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90% CL limits

$Br\ (\tau^- \to e^- \gamma)\quad < \quad 12 \times 10^{-8}$

$Br\ (\tau^- \to \mu^- \gamma)\quad < \quad 4.1 \times 10^{-8}$

$Br\ (\tau^- \to e^- \gamma)\quad < \quad 11 \times 10^{-8}$

$Br\ (\tau^- \to \mu^- \gamma)\quad < \quad 6.7 \times 10^{-8}$
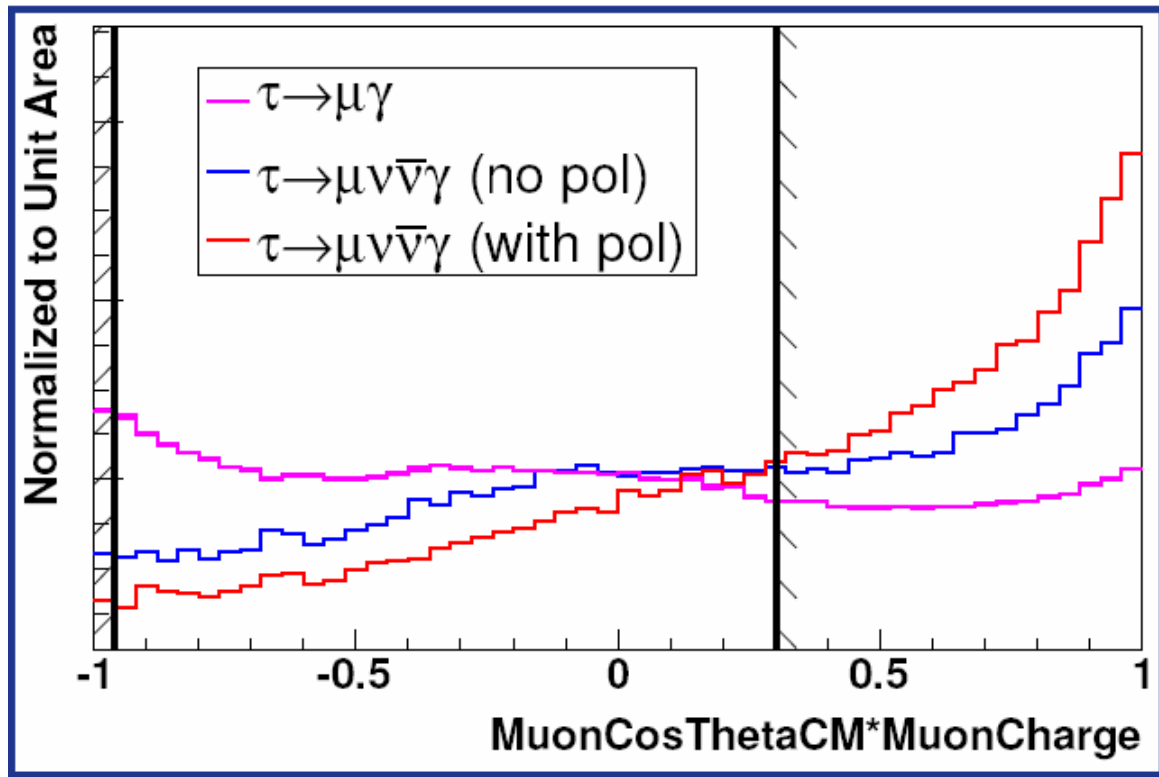
Polarization is only partially used in this estimate. An optimization of the BKG rejection is in progress. But Pol. helps to discriminate models. In some model there is a strong effect on the angular distribution of μ from signal:

(see hep-ph/9604296, Y.Kuno, Y.Okada, $\mu \to e\gamma$ Search with Polarized Muons)

SuperB with 75 ab-1, evaluation assuming the most conservative scenario about syst. errors

SPS	$M_{1/2}$ (GeV)	M_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ
1 a	250	100	-100	10	> 0
1 b	400	200	0	30	> 0
2	300	1450	0	10	> 0
3	400	90	0	10	> 0
4	300	400	0	50	> 0
5	300	150	-1000	5	> 0

♦ NP predictions for experimentally constrained SUSY in a number of standard scenarios
  B.C.Allanach *et al.*, hep-ph/0202233

LFV

	Snowmass points predictions						SuperB	
	1 a	1 b	2	3	4	5	90% UL	5σ disc
BF($\tau \to \mu\gamma$) $\times 10^{-9}$	4.2	7.9	0.18	0.26	97	0.019	1÷2	5
BF($\tau \to 3\mu$) $\times 10^{-12}$	9.4	18	0.41	0.59	220	0.043	200	880

SuperKEKB worse by factor $\sqrt{5}$ for BF($\tau \to \mu\gamma$) and 5 for BF($\tau \to \mu\mu\mu$)

Start with the expt. with μ

$$\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} \approx (3 \pm 1) \times 10^{-9}$$

assume SuperB at $75\,fb^{-1}$, $\boxed{80\%\ e^-\ \text{beam polarization}}$

extend to all tau decay channels

combine 2 measurement methods for $Re\{F_2\}$

studies on simulated events show no limiting syst. effects

	Snowmass points predictions						SuperB
	1 a	1 b	2	3	4	5	exp. resolution
$\Delta a_\mu \times 10^{-9}$	3.1	3.2	1.6	1.4	4.8	1.1	
$\Delta a_\tau \times 10^{-6}$	0.9	0.9	0.5	0.4	1.4	0.3	<1

SuperKEKB, without beam polarization, expected worse by factor ≈ 10, and worse systematics

Make use of all the informations (total x-section,angular distribution, f-b asymmetry. Measure Re and Im parts

Results from Belle

Par.	Stat.	Exp. Syst.	Model Syst.	Total
x (10^{-4})	30.0	8.0	12.0	33.3
y (10^{-4})	24.0	10.0	7.0	26.9
ϵ (10^{-4})	15.0	2.5	4.0	15.7
ϕ (deg)	17.0	4.0	3.0	17.7

TABLE VI: Super$B$ errors with 75 ab^{-1} on relevant mixing and CP violation parameters.

Par.	Stat.	Exp. Syst.	Model Syst.	Total
x (10^{-4})	2.5	1.4	4.0	4.9
y (10^{-4})	2.0	1.7	2.3	3.5
ϵ (10^{-4})	1.3	0.4	1.3	1.9
ϕ (deg)	1.4	0.7	1.0	1.9

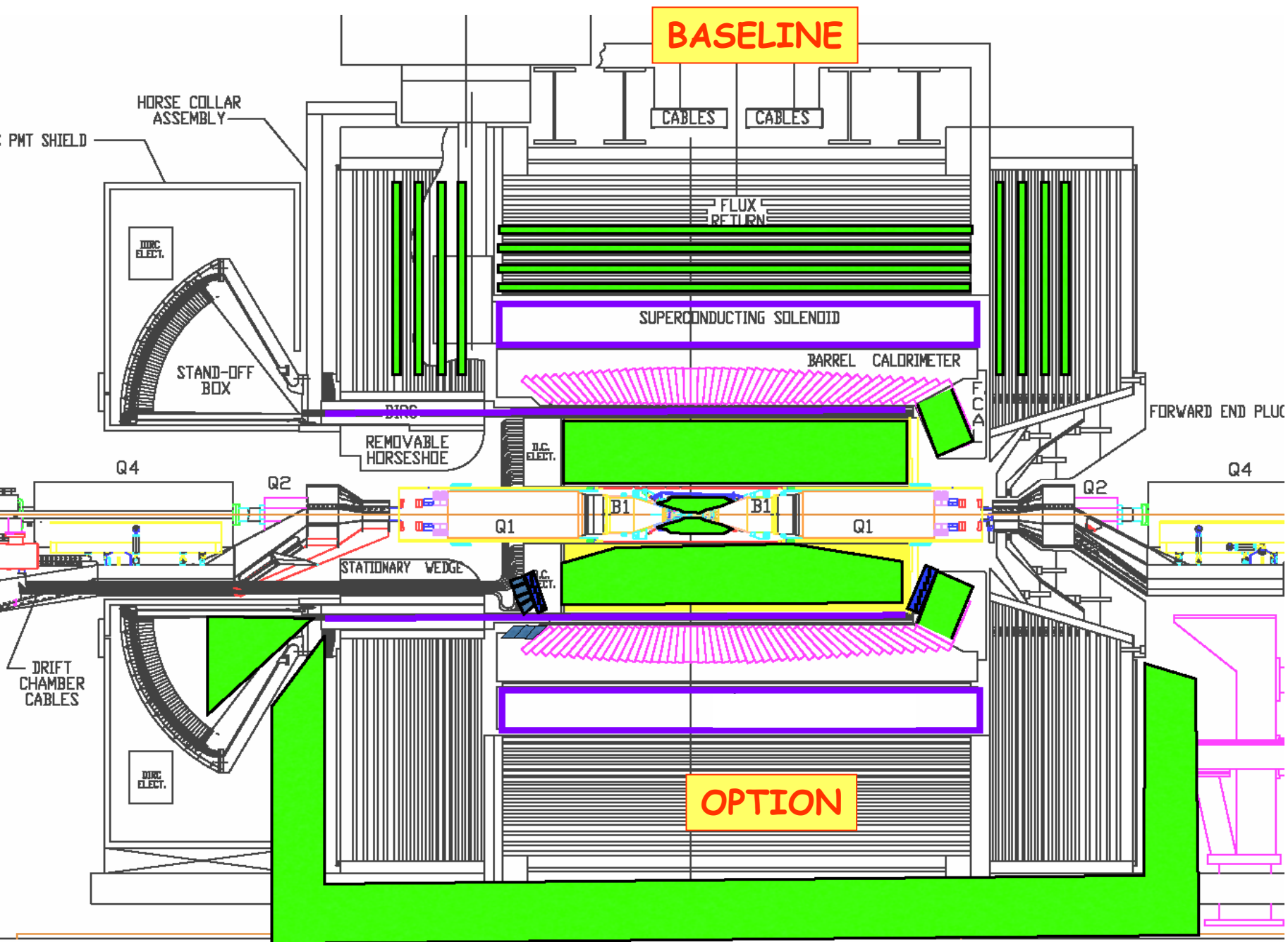CP violation can be studied in high statistics as:

1. Indirect in the mixing
2. Direct in the decay

With very high statistics at Y_{4S} together with tau and B physics

BUT time dependent analysis is needed for CP violation in the interference mixing-decay, for it runs at charm threshold production are needed in asymmetric factory mode .

$D^0 \rightarrow K^+K^-$ and $D^0 \rightarrow \pi^+\pi^-$ can be studied with time dependent analysis and ϕ_f can be extracted.

Detector Layout – Reuse parts of Babar (or Belle)

BASELINE

HORSE COLLAR ASSEMBLY

PMT SHIELD

DIRC ELECT.

FLUX RETURN

CABLES CABLES

SUPERCONDUCTING SOLENOID

STAND-OFF BOX

BARREL CALORIMETER

DIRC

FCA

FORWARD END PLUG

REMOVABLE HORSESHOE

D.C. ELECT.

Q4

Q2

B1   B1

Q1   Q1

Q2

Q4

STATIONARY WEDGE

D.C. ELECT.

DRIFT CHAMBER CABLES

DIRC ELECT.

OPTION

Lots of progress

- R&D technical progress in all detector subsystems
- Started the definition of strategies for Electronics and DAQ design
- Large computing effort for simulation
- Subdetector groups are building up → collaboration

- SuperB is included in the DevDet FP7 proposal
  - Improve infrastructure for detector R&D
  - Mainly focused on improving LNF Beam test facility
  - Electronics and software network

Test beam goals for 2008-2010

- Silicon Vertex Tracker
  - MAPS pixel devices: resolution, efficiency, readout speed
  - Advanced trigger systems (Associative Memories)
- Drift Chamber
  - Cell size, shape, and gas mixture
- Particle ID system (forward system)
  - Radiators (Aerogel, NaF)
  - Photon detector (MCP, MAPMTs, SiPM)
  - Timing for TOF system
- Electromagnetic Calorimeter
  - Forw: LYSO Crystals leakage, resolution, mechanical structure
  - Back: Lead-scintillator calorimeter resolution
- Instrumented Flux Return
  - Scintillator, fibers, photon detector, readout electronics
  - Detection efficiency, time/space resolution
- Integrated slice
  - Track trigger, material in front of EMC, timing for TOF, forward PID options

- Development of both fast (parametrized) and full (Geant4) simulation programs started.

- Reuse Babar code where possible
  - Remove dependencies from private Babar code to allow redistribution to outside Babar
  - Use more modern approach to geometry description (GDML, developed for LHC)

- Fast simulation targeted at physics benchmarking

- Geant4 simulation targeted at backgrounds
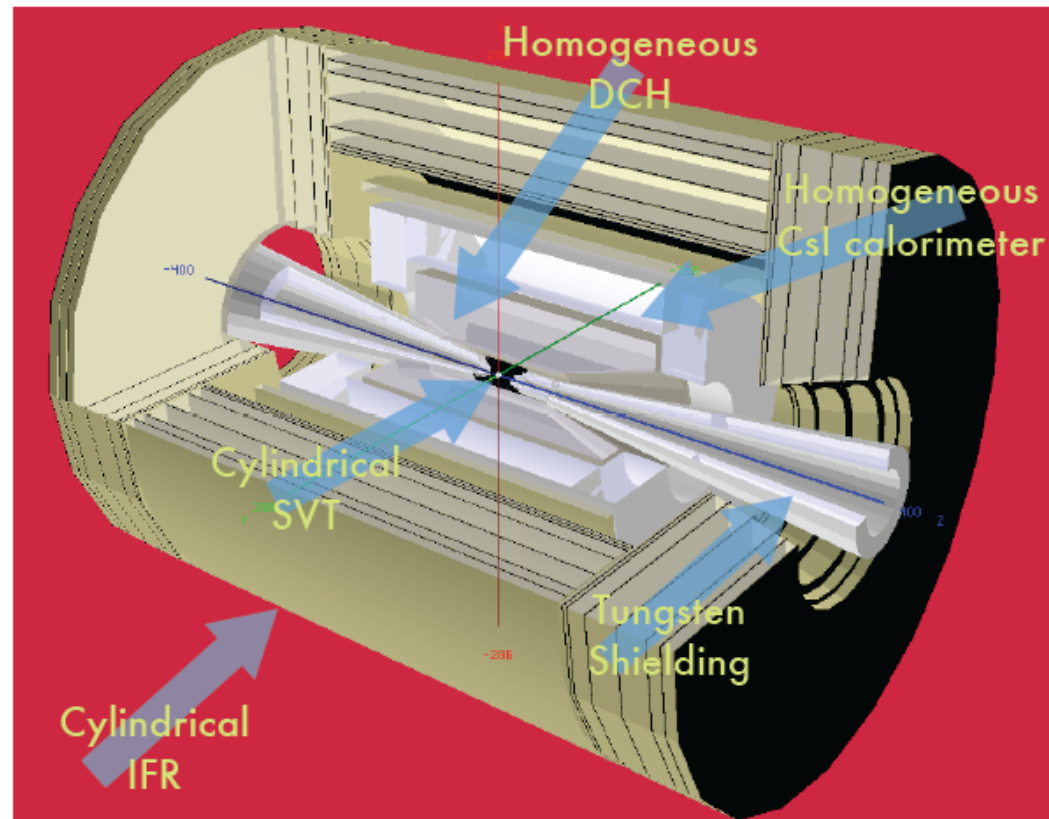
Geant4 Model

Setup the structure for TDR – start now

Move towards forming collaboration- start now

Major goal:

DECISION about the approval by next winter.

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