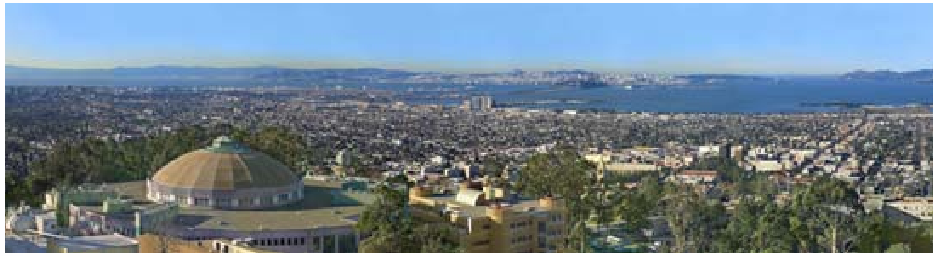
Research Progress Meeting



The SuperB Project

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INFN and University, Pisa

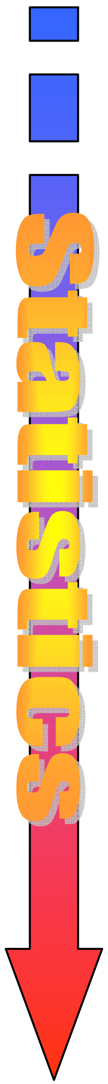
December 6, 2007

Outline

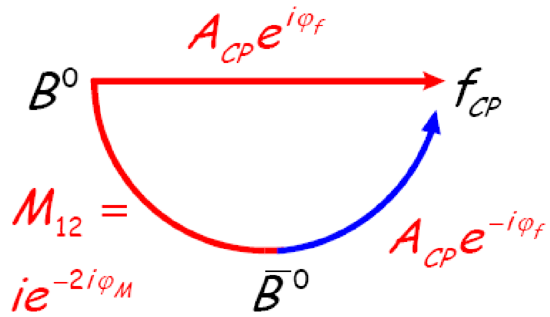
- SuperB physics
- SuperB Accelerator
- SuperB Detector
- Conceptual Design Report
- The Tor Vergata site
- Perspectives

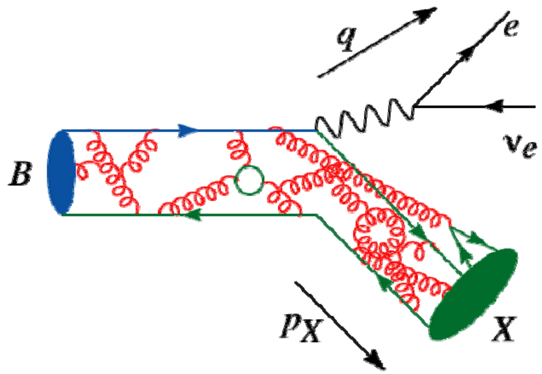
SuperB Physics

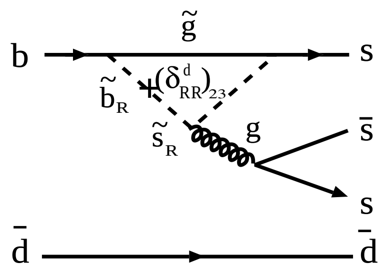
Why flavour physics

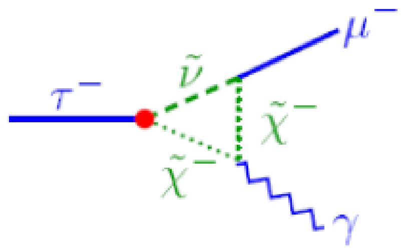


1. Explore the origin of CP violation
   - Key element for understanding the matter content of our present universe
   - Established in the B meson in 2001
   - Direct CPV established in B mesons in 2004
2. Precisely measure parameters of the standard model
   - For example the elements of the CKM quark mixing matrix
   - Disentangle the complicated interplay between weak processes and strong interaction effects
3. Search for the effects of physics beyond the standard model in loop diagrams
   - Potentially large effects on rates of rare decays, time dependent asymmetries, lepton flavour violation, …
   - Sensitive even to large New Physics scale, as well as to phases and size of NP coupling constants





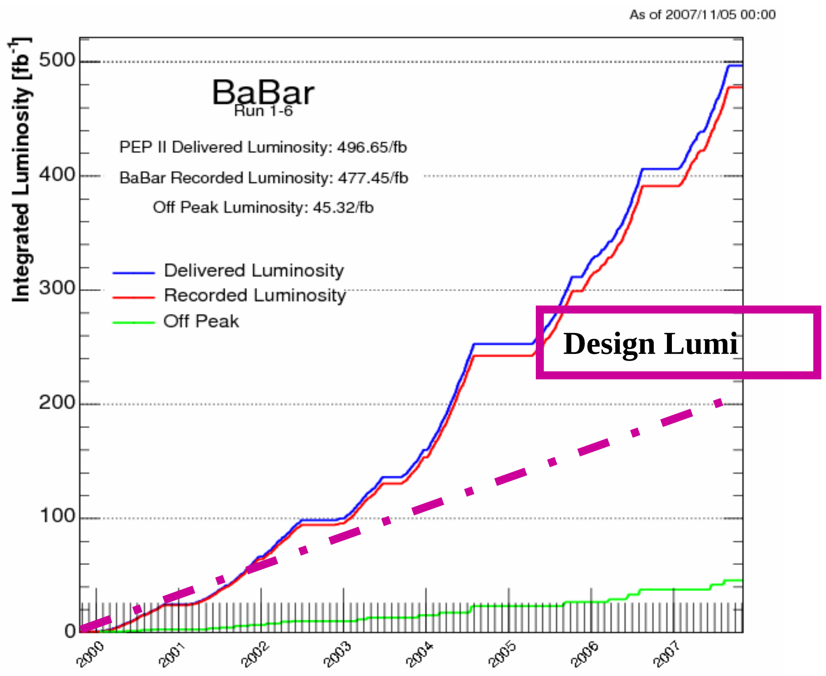


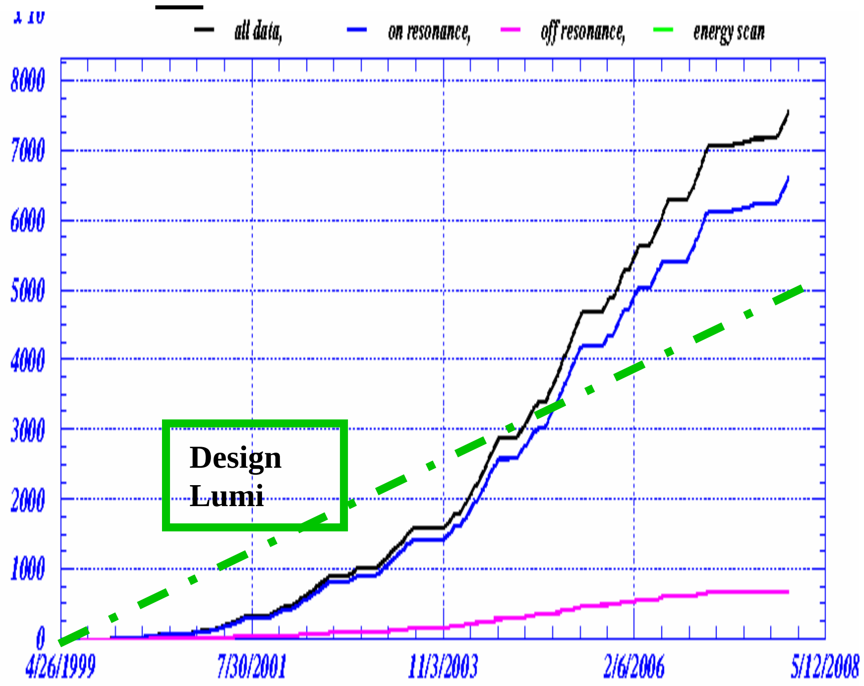


B Factories Success

- Both B-Factories exceeded expectations

Total $\int Ldt$ > 1.2 ab^{-1} → ≈ 1.2 x 10^9 BB ($\tau^+\tau^-$) pairs



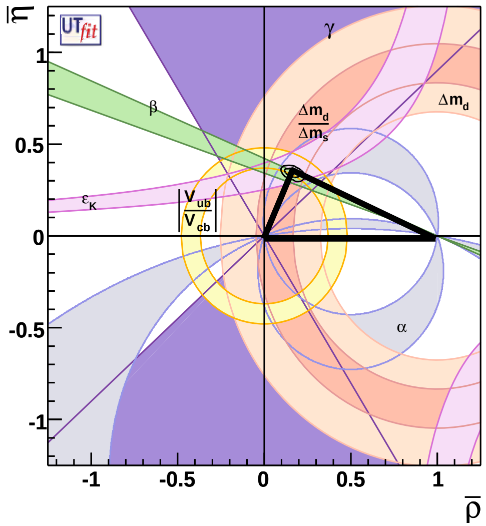


PEP-II (BaBar): 477fb^{-1}
Peak: 1.2 x 10^{34} cm^{-2} s^{-1}

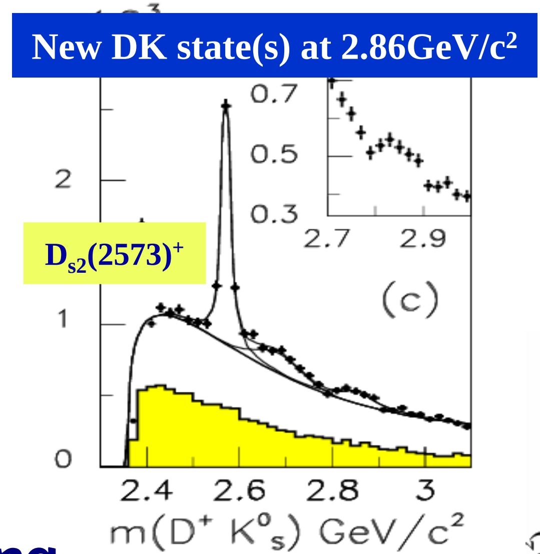
KEK-B (Belle): 754 fb^{-1}
Peak: 1.7 x 10^{34} cm^{-2} s^{-1}

B Factories Results: examples

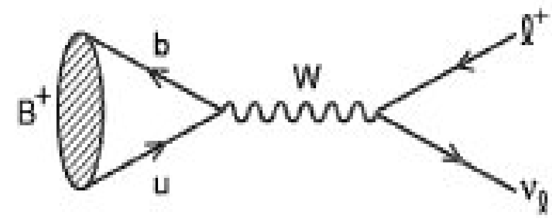
Unitarity Triangle precision measurements

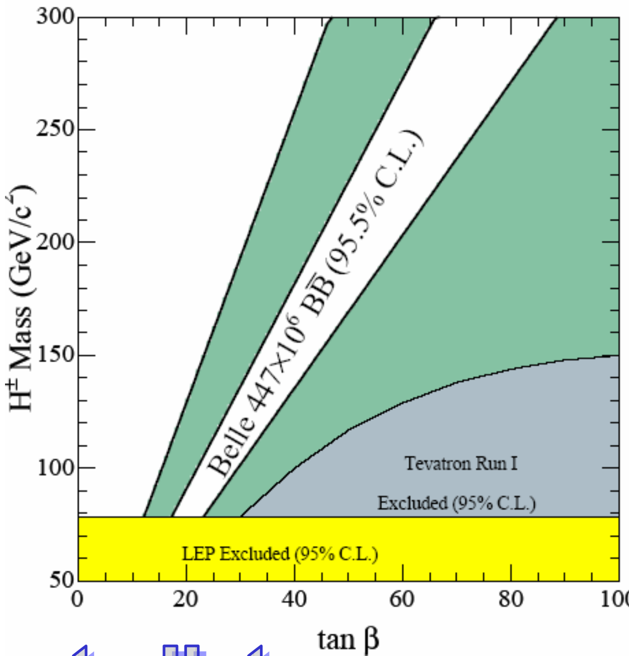


Spectroscopy of new, unexpected states

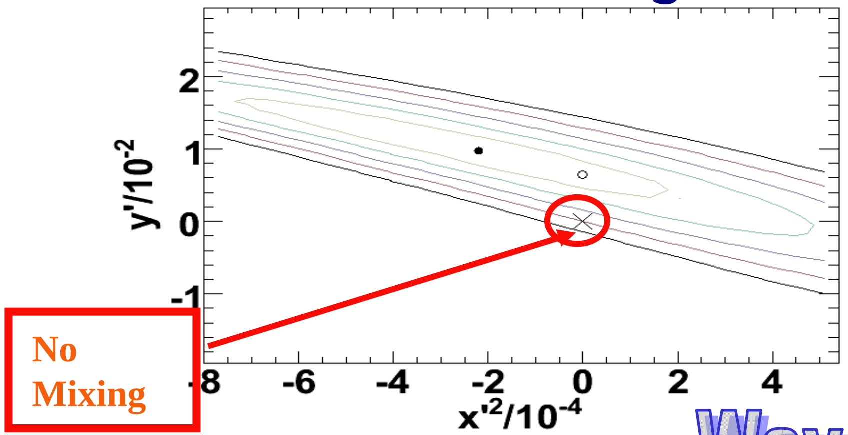


B→τν setting limits on MSSM parameters





D⁰ – D̄⁰ mixing



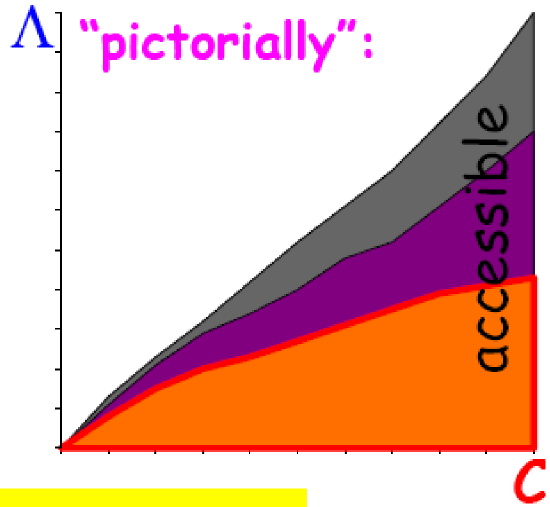
Way too many to list

The next step: New Physics @ SuperB

- We know there must be something beyond SM

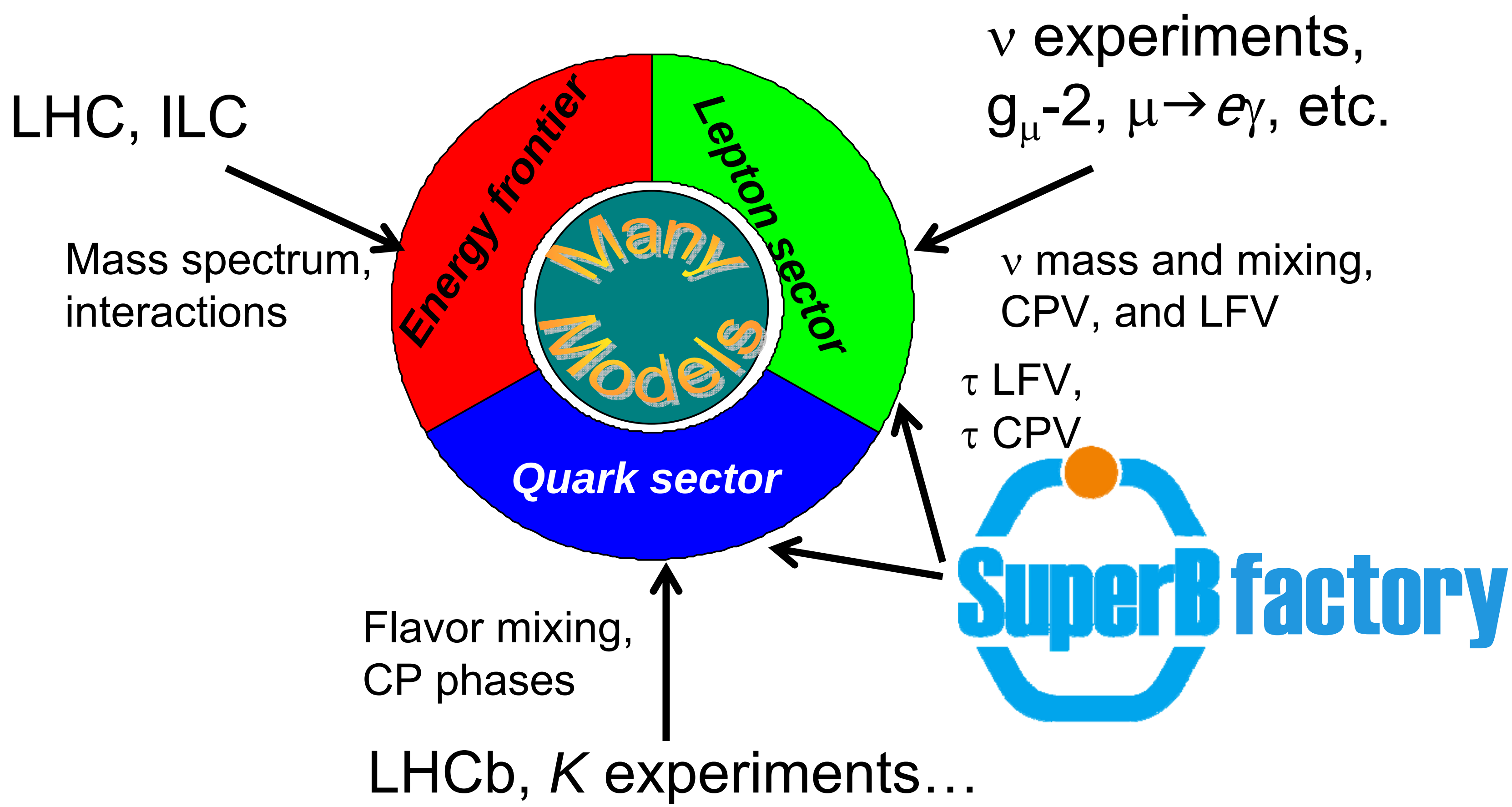
$$\mathcal{L} = \mathcal{L}_{SM} + \Sigma_{k=1}(\Sigma_i\, c_i^k\, Q_i^{(k+4)})/\Lambda^k$$

- NP flavour effects are governed by
  - The scale of the new physics Λ
  - The effective couplings C's
    - Different strengths (ie different interactions)
    - Different patterns (ie dictated by symmetries
- With 5-10x10^{10} bb, cc, $\tau\tau$ pairs we can:



NP(Λ) found at LHC	NP(Λ) not found at LHC
* determine the NP FV and CPV couplings * look for heavier states * study the flavour structure of NP	* look for indirect NP signals * understand where they come from * exclude regions in the parameter space

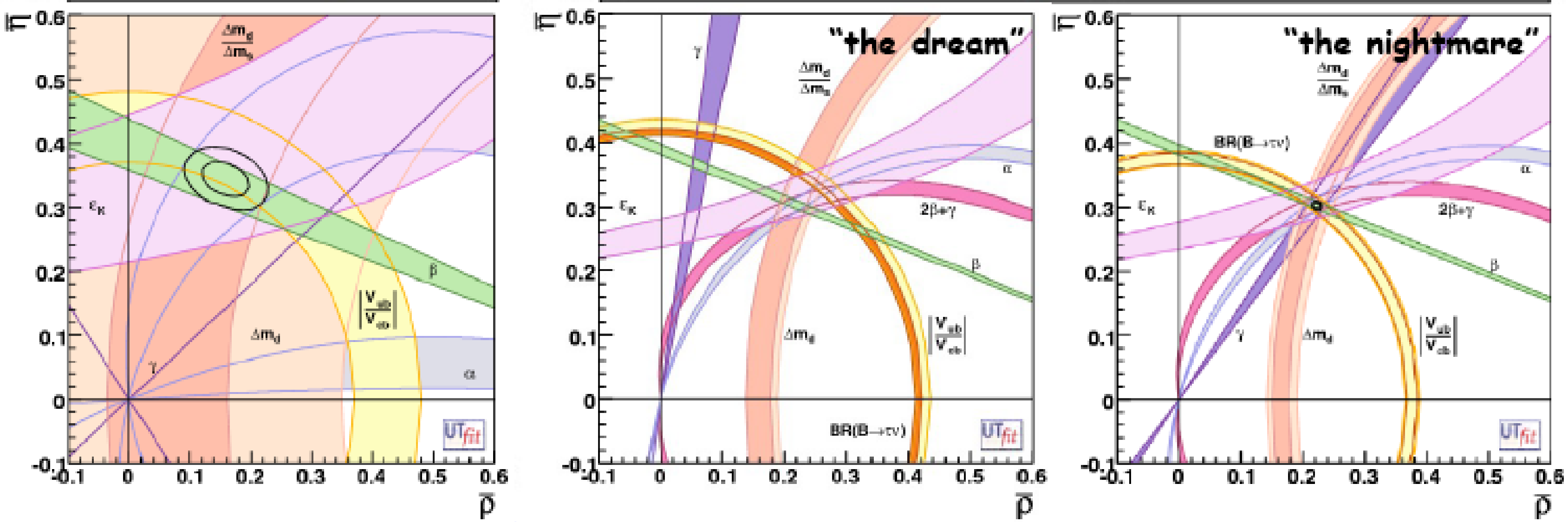
Paths to New Physics



Dozens of observables

Test of CKM paradigm

Today | **With a SuperB** *@ 50 ab-1*



Generalized UT fits:

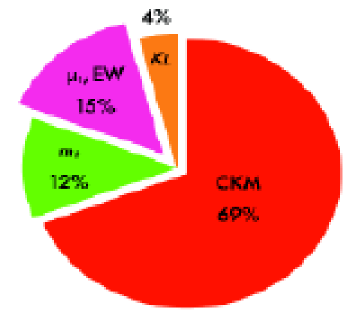
CKM at 1% in the presence of NP!

	today	SuperB
$\bar\rho$	0.187±0.056	±0.005
$\bar\eta$	0.370±0.036	±0.005

- crucial for many NP searches with flavour (not only for B decays!)

$K_L \to \pi^0\nu\bar\nu$

error budget

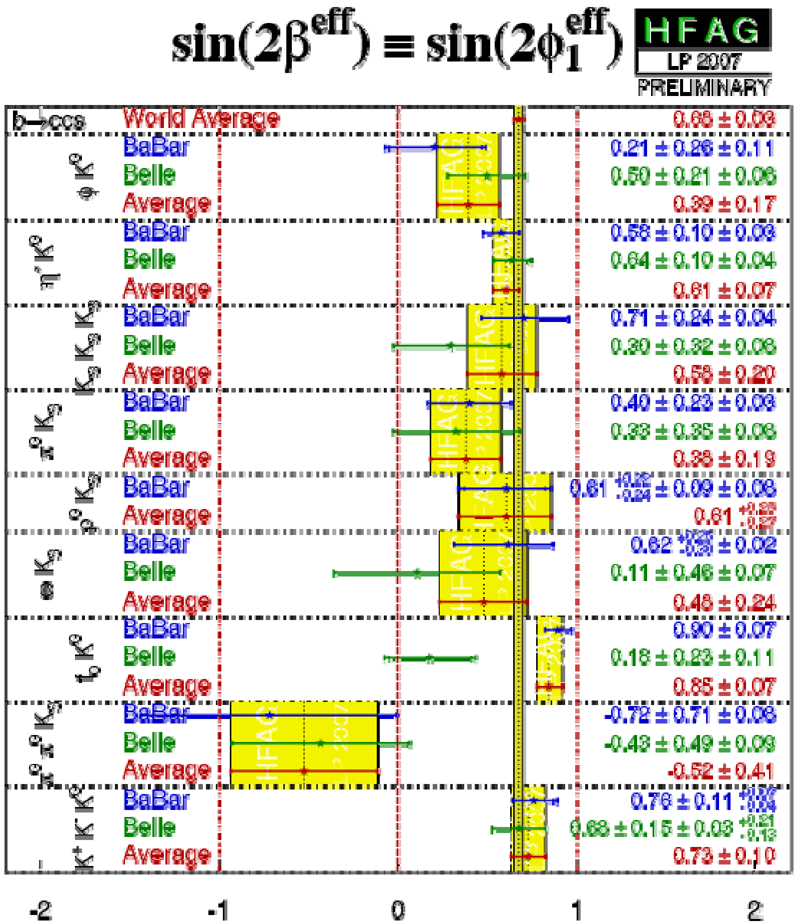


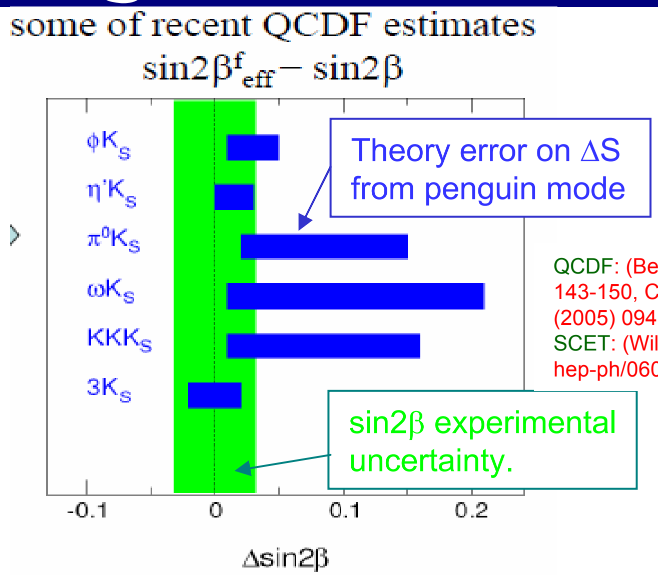
U. Haisch, Kaon '07

Marco Ciuchini SuperB International Review - Frascati, 12 November 2007 Page 10

New Physics in ΔF=1 Penguins

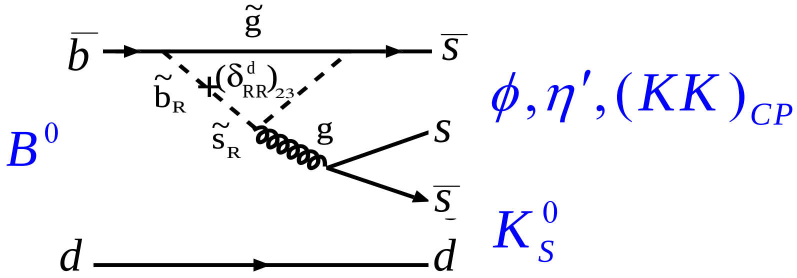
- sin2b in b→s penguin transitions differs from that measured in $b \to c\bar{c}s$ golden modes.





QCDF: (Beneke, PLB620 (2005), 143-150, Cheng et al., PRD72 (2005) 094003 etc.
SCET: (Williamson & Zupan, hep-ph/0601214)

- Theory predicts a positive shift (sign prediction very solid)
- Experiment shows a negative, albeit marginally significant shift
- A discrepancy would be sign of NP phase



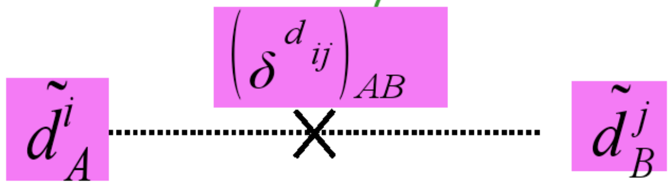
More statistics is needed to sort this out

N.P. sensitivity

An example: MSSM...

...MSSM with non diagonal mass insertion

Let us now consider a MSSM with generic soft SUSY-breaking terms, but dominant gluino contributions only



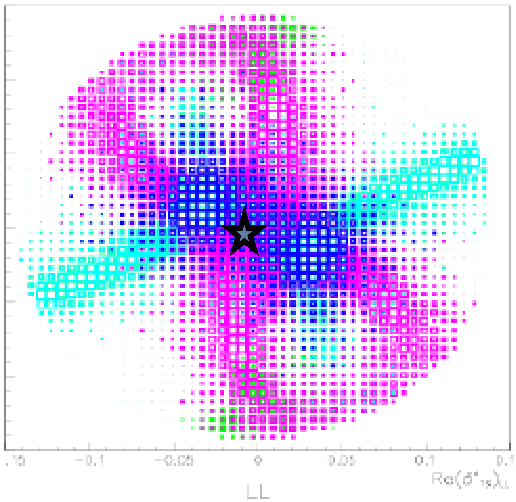
Constraint from Δm_d

Constraint from $\sin 2\beta$ & $\cos 2\beta$

Constraint from $\sin 2\beta$

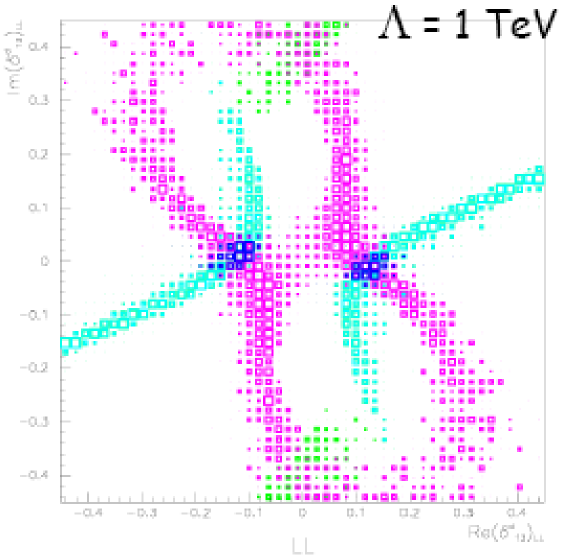
All constraints

★ S.M.



Re $(\delta^d_{13})_{LL}$ vs Im $(\delta^d_{13})_{LL}$

present



superB w. present c.v.

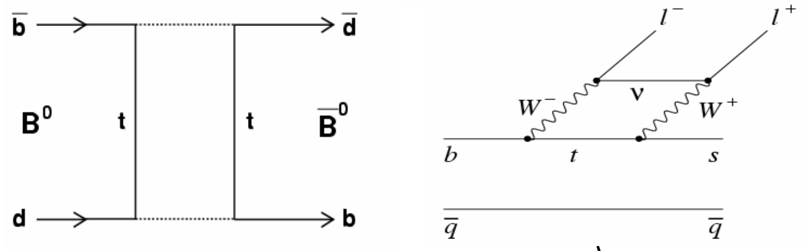
A clear evidence of new physics!!!

Assuming natural couplings in SUSY-MI SB probes scales larger than 20 TeV (and up to ~300 TeV)

NP for ΔF=2 processes

B_d mixing processes can get contribution from NP

They are parametrized by an effective amplitude ratio

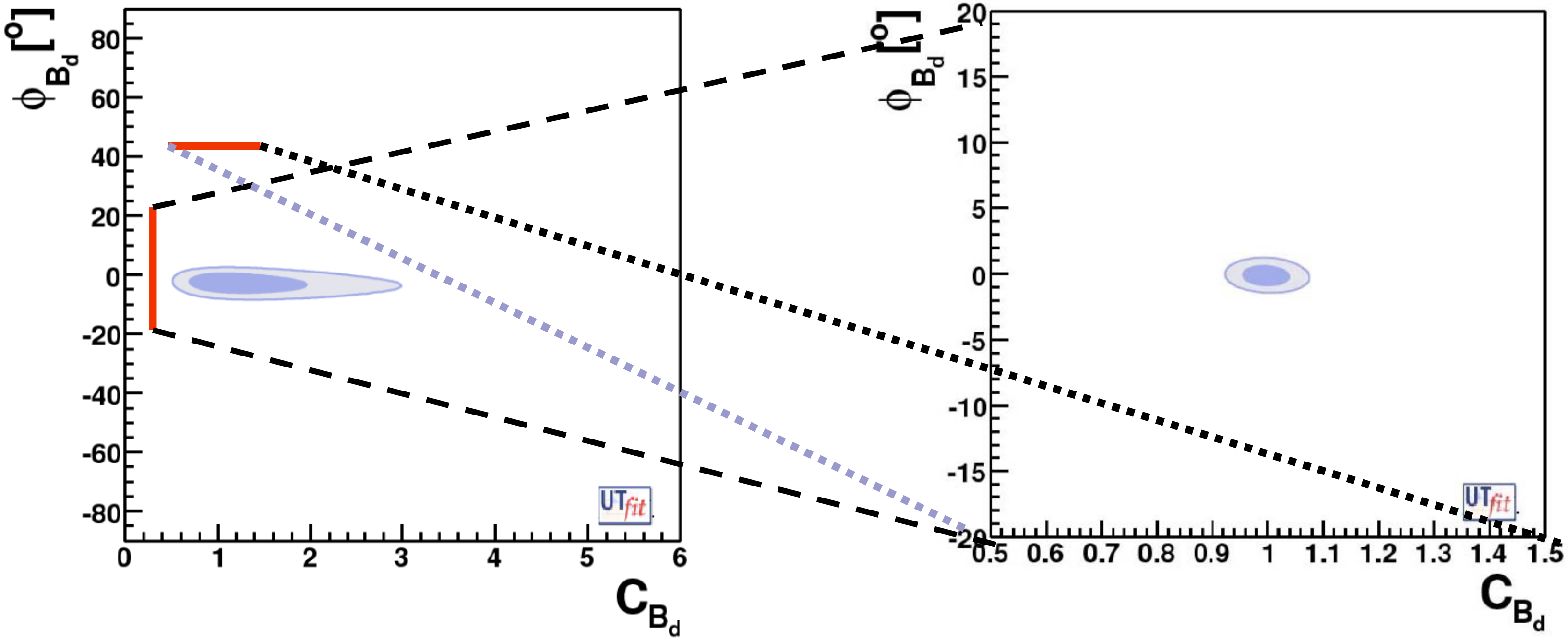


$$C_q e^{i\phi_q} = \frac{\langle B_q^0 | H_{SM+NP} | \overline{B}_q^0 \rangle}{\langle B_q^0 | H_{SM} | \overline{B}_q^0 \rangle} = 1 \text{ (SM)}$$

Huge improvement on limits possible at SuperB.

Now

SuperB with 75 ab^{-1}



Minimal Flavour Violation

- Suppose that there are no new physics flavour couplings(MFV).
  - CP violation comes from SM Yukawa couplings.
  - The top quark contribution dominates the SM.
  - NP contribution is:

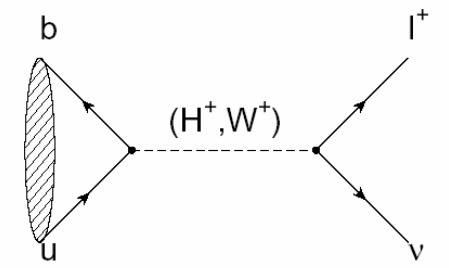
SM Scale ~2.4 TeV

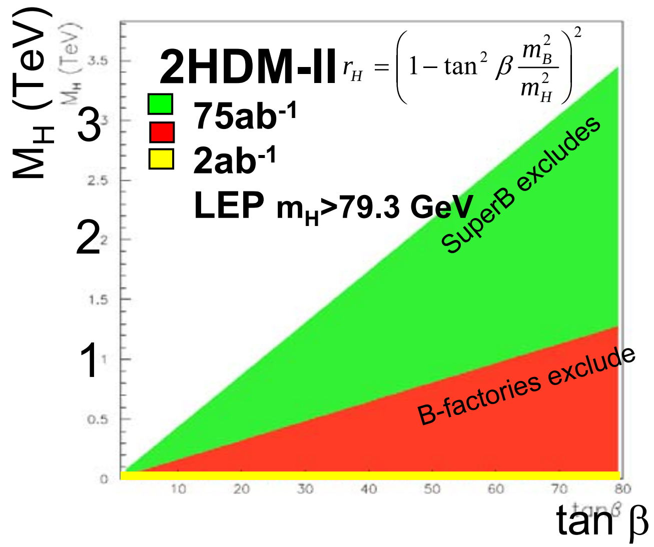
$$\Lambda_0 = Y_t \sin^2\theta_W M_W / \alpha$$

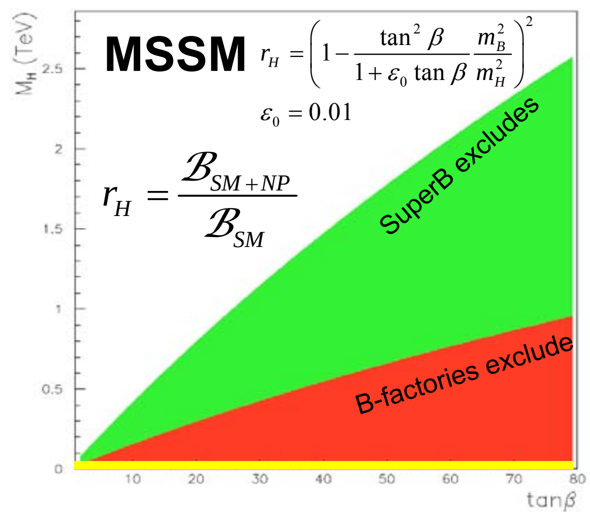
$$\delta S_0 = 4a\left(\frac{\Lambda_0}{\Lambda}\right)^2$$

Real Wilson coefficient $O(1)$ New Physics Scale

  - MFV Includes many NP scenarios i.e. 1HDM/2HDM, MSSM, ADD, RS.
- What is the energy scale that we are sensitive to?
- B→τν Higgs mediated transitions



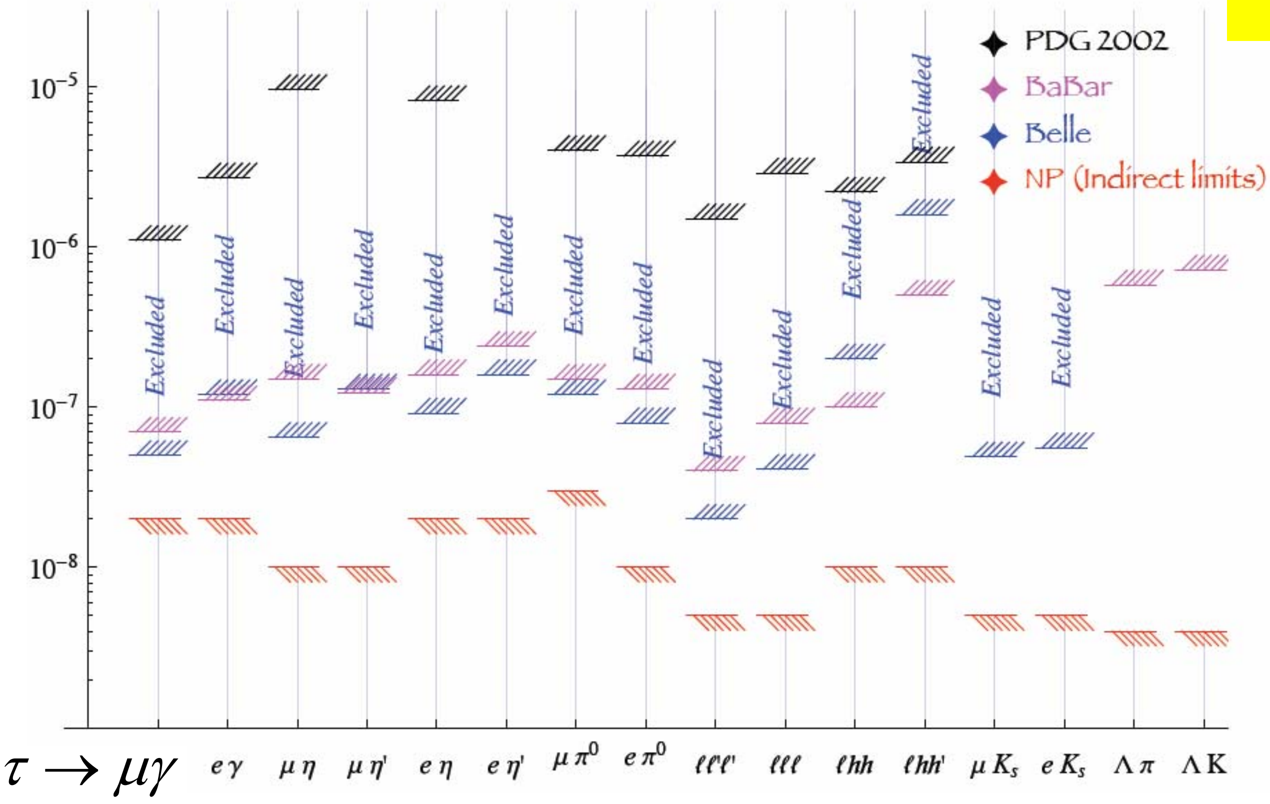




Sensitivity to multi-TeV scale.

Lepton Flavour Violation

- SUSY breaking at low energies should result in LFV : $\tau \to \mu\gamma$, $\mu \to e\gamma$



- τ are an incredibly rich laboratory
- SuperB will produce as many τ's as B's
- Beam polarization possible
- τ magnetic moment measurement

SuperB Sensitivity (75 ab^{-1})

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K^0_S)$	2×10^{-10}

$$B(\tau\to\mu\gamma):B(\tau\to e\gamma):B(\mu\to e\gamma) \sim \lambda^{-6}:\lambda^{-4}:1 \sim 10^4:500:1$$

$$B(\tau\to\mu\gamma):B(\tau\to e\gamma):B(\mu\to e\gamma) \sim [500\text{–}10]:1:1$$

Different models have very different BR patterns

SuperB physics in tables

Observable	B factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	0.12	0.02 (∗)
γ $(B \to DK,\ D \to CP$ eigenstates)	$\sim 15^\circ$	2.5°
γ $(B \to DK,\ D \to$ suppressed states)	$\sim 12^\circ$	2.0°
γ $(B \to DK,\ D \to$ multibody states)	$\sim 9^\circ$	1.5°
γ $(B \to DK$, combined)	$\sim 6^\circ$	1–2°
α $(B \to \pi\pi)$	$\sim 16^\circ$	3°
α $(B \to \rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp,\ D^\pm K^0_S \pi^\mp)$	20°	5°
$\|V_{cb}\|$ (exclusive)	4% (∗)	1.0% (∗)
$\|V_{cb}\|$ (inclusive)	1% (∗)	0.5% (∗)
$\|V_{ub}\|$ (exclusive)	8% (∗)	3.0% (∗)
$\|V_{ub}\|$ (inclusive)	8% (∗)	2.0% (∗)
$BR(B \to \tau\nu)$	20%	4% (†)
$BR(B \to \mu\nu)$	visible	5%
$BR(B \to D\tau\nu)$	10%	2%
$BR(B \to \rho\gamma)$	15%	3% (†)
$BR(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K^0_S \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$BR(B \to K\nu\overline{\nu})$	visible	20%
$BR(B \to \pi\nu\bar{\nu})$	–	possible

Mode	Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$D^0 \to K^+K^-$	y_{CP}	2–3×10^{-3}	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	2–3×10^{-3}	7×10^{-4}
	x'^2_D	1–2×10^{-4}	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	2–3×10^{-3}	5×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}
Average	y_D	1–2×10^{-3}	3×10^{-4}
	x_D	2–3×10^{-3}	5×10^{-4}

	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0 e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}
$D^0 \to e^\pm\mu^\mp$	1×10^{-8}
$D^+ \to \pi^+e^\pm\mu^\mp$	1×10^{-8}
$D^0 \to \pi^0 e^\pm\mu^\mp$	2×10^{-8}
$D^0 \to \eta e^\pm\mu^\mp$	3×10^{-8}
$D^0 \to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+ \to \pi^-e^+e^+$, $D^+ \to K^-e^+e^+$	1×10^{-8}
$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$	1×10^{-8}
$D^+ \to \pi^-e^\pm\mu^\mp$, $D^+ \to K^-e^\pm\mu^\mp$	1×10^{-8}

5-10x improvement

Process	Sensitivity
$\mathcal{B}(\tau \to \mu\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\,\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\,\mu\,\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell K^0_S)$	2×10^{-10}

+ τ FC physics (CPV, ...)

Observable	Error with 1 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}
Γ	0.07 ps^{-1}
β_s from angular analysis	20°
A^s_{SL}	0.006
A_{CH}	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-
$\|V_{td}/V_{ts}\|$	0.08
$\mathcal{B}(B_s \to \gamma\gamma)$	38%
β_s from $J/\psi\phi$	10°

Super Flavour Factory

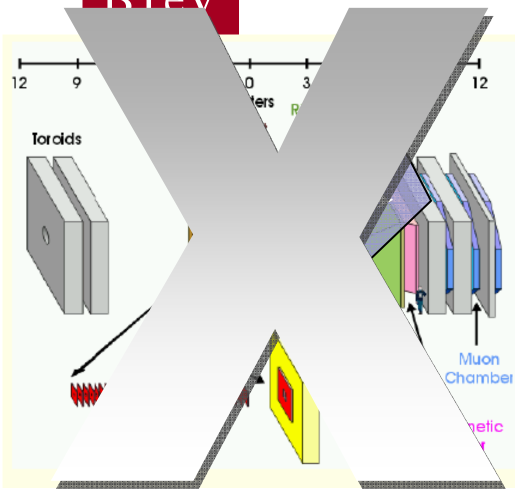
a "treasure chest" of new physics-sensitive observables

Theoretical errors

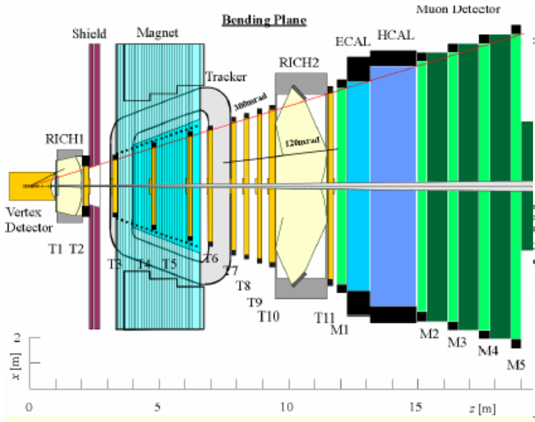
no theory improvements needed	$\beta(J/\psi\ K)$, $\gamma(DK)$, $\alpha(\pi\pi)$*, lepton FV and UV, $S(\rho^0\gamma)$ CPV in $B\to X\gamma$, D and τ decays zero of FB asymmetry $B\to X_s l^+ l^-$	NP insensitive or null tests of the SM or SM already known with the required accuracy
improved lattice QCD	meson mixing , $B\to D(*)l\nu$, $B\to\pi(\rho)l\nu$, $B\to K^*\gamma$, $B\to\rho\gamma$, $B\to l\nu$, $B_s\to\mu\mu$	target error: ~1-2% Feasible (see below)
improved OPE+HQE	$B\to X_{u,c}l\nu$, $B\to X\gamma$	target error: ~1-2% Possibly feasible with SuperB data getting rid of the shape function. Detailed studies required
improved QCDF or SCET or flavour symmetries	S's from TD A_{CP} in b -> s transitions https://agenda.infn.it/getFile.py/access?contribId=6&sessionId=1&resId=0&materialId=slides&confId=163	target error: ~2-3% large and hard to improve uncertainties on small corrections. In addition, FS+data can bound the theoretical error

Flavour Physics of Tomorrow

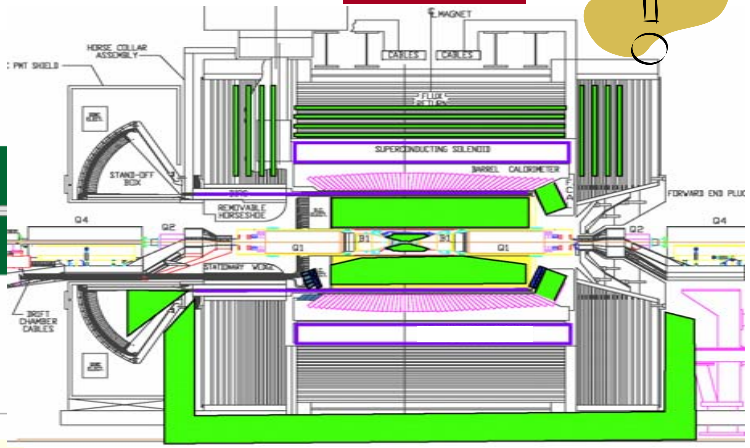
BTeV



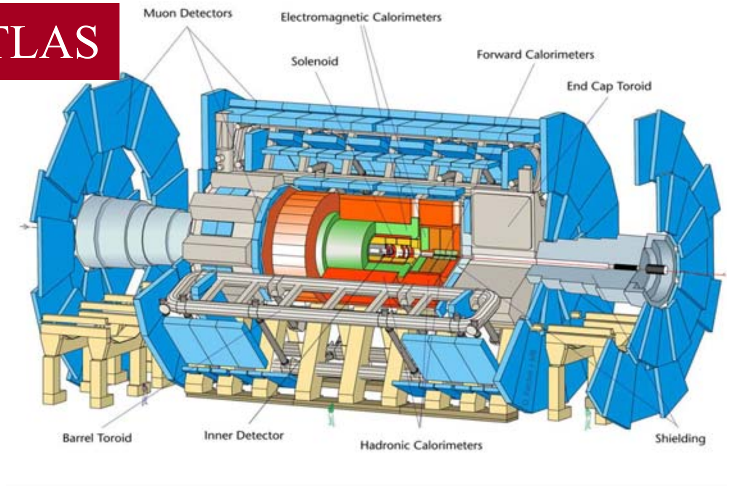
LHCb



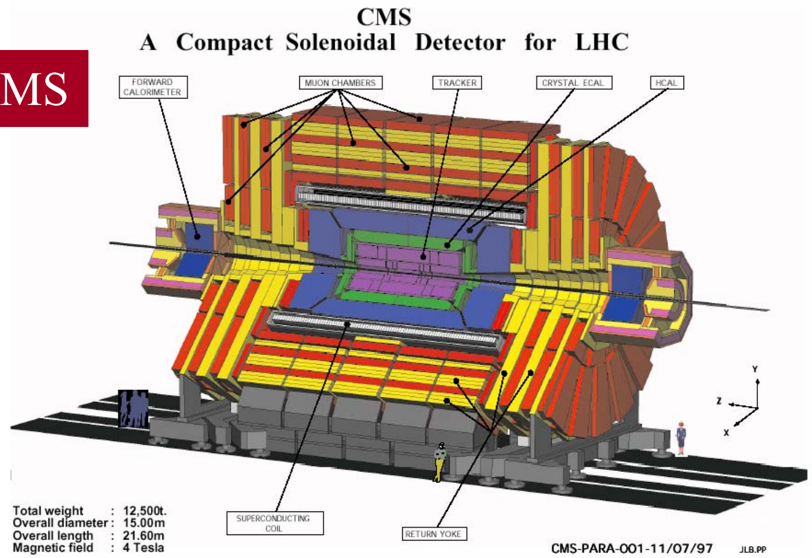
SuperB



ATLAS



CMS

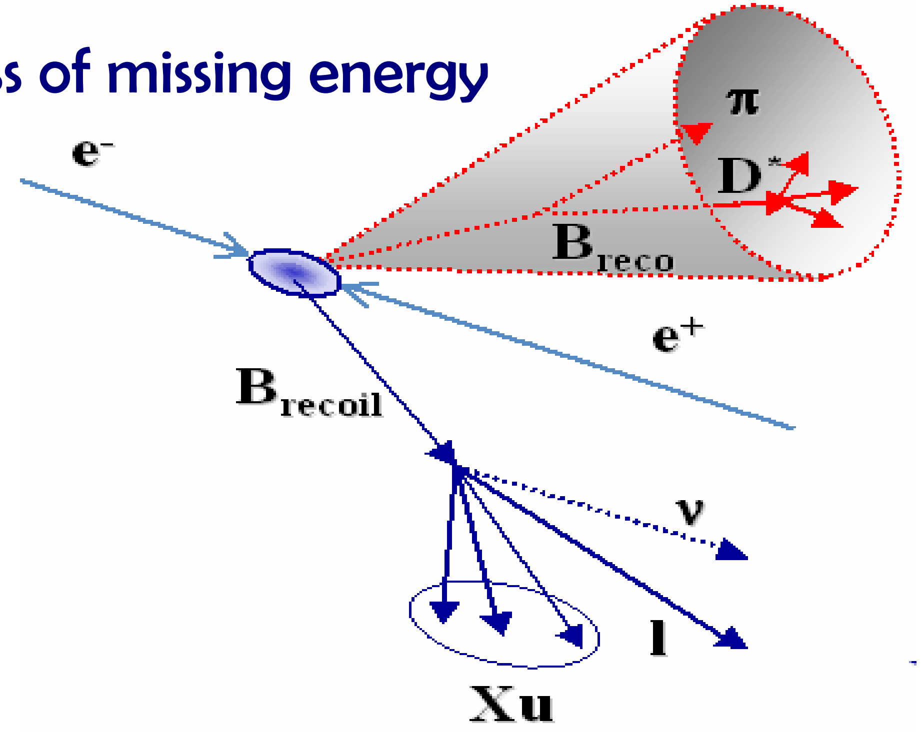


Cross section is not everything

- Hadron machines do have the advantage of an enormously larger B production cross section, BUT…
- SuperB has a super-easy ½ track trigger
- Initial state is coeherent, allowing interference measurements
- SuperB can do τ physics.
- Has access to states with a loss of missing energy

B-Beam Method

- Fully reconstruct one the two Bs in hadronic modes
  - High efficiency: a few per mille
  - > 10^7 recoil Bs in $10ab^{-1}$
- Obtain a pure B Beam on the other side
  - High purity sample
  - Can look at channels with a lot of missing energy.
  - For example BR(B→nothing) measured.



Recoil cinematics well known
Recoil flavor and charge is determined

SuperB and Super LHCb:

- SuperB cannot compete with LHCb on B_s physics.
  - Only time integrated measurements
- Similar sensitivity for many common channels
  - SuperB extrapolation based on Babar/Belle experience
- Unique opportunity for channels with neutrals, ν, inclusive measurements
  - Not accessible at hadronic machines.

Sensitivity Comparison ~2020

S-LHCb 100 fb^{-1} vs SuperB 50 ab^{-1}

•LHCb
•Super B

B_s time dependent analysis only accessible to LHCB

Common

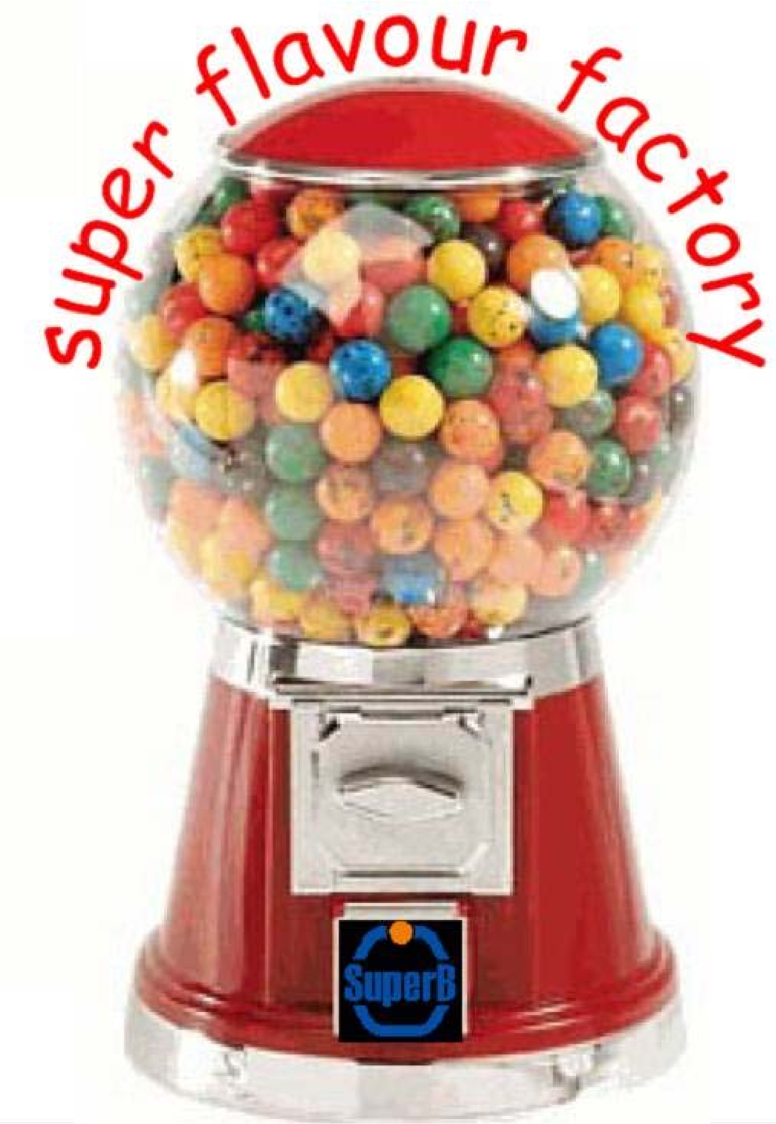
No IP, Neutrals, ν, only accessible to SuperB

Preliminary

CDF an important player, too.

SuperB Physics

- Physics at a Super Flavor Factory collecting 50 – 100 ab^{-1} is exciting:
  - Precision measurements allowing to detec discrepancies from the standard model
    - Theoretical precision allows (or will allow) this in many channels
  - Rare decay measurements
  - Lepton flavour violation
  - Possibility to run at tau/charm threshold
  - Polarized e- beam → τ CPV, EDM, g-2
- 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)
  - SuperB report (hep-ex/0512235)
  - SuperB CDR (INFN/AE-07/02, SLAC-R-85 LAL 07-15)
  - Many documents available at the URL : www.pi.infn.it/SuperB



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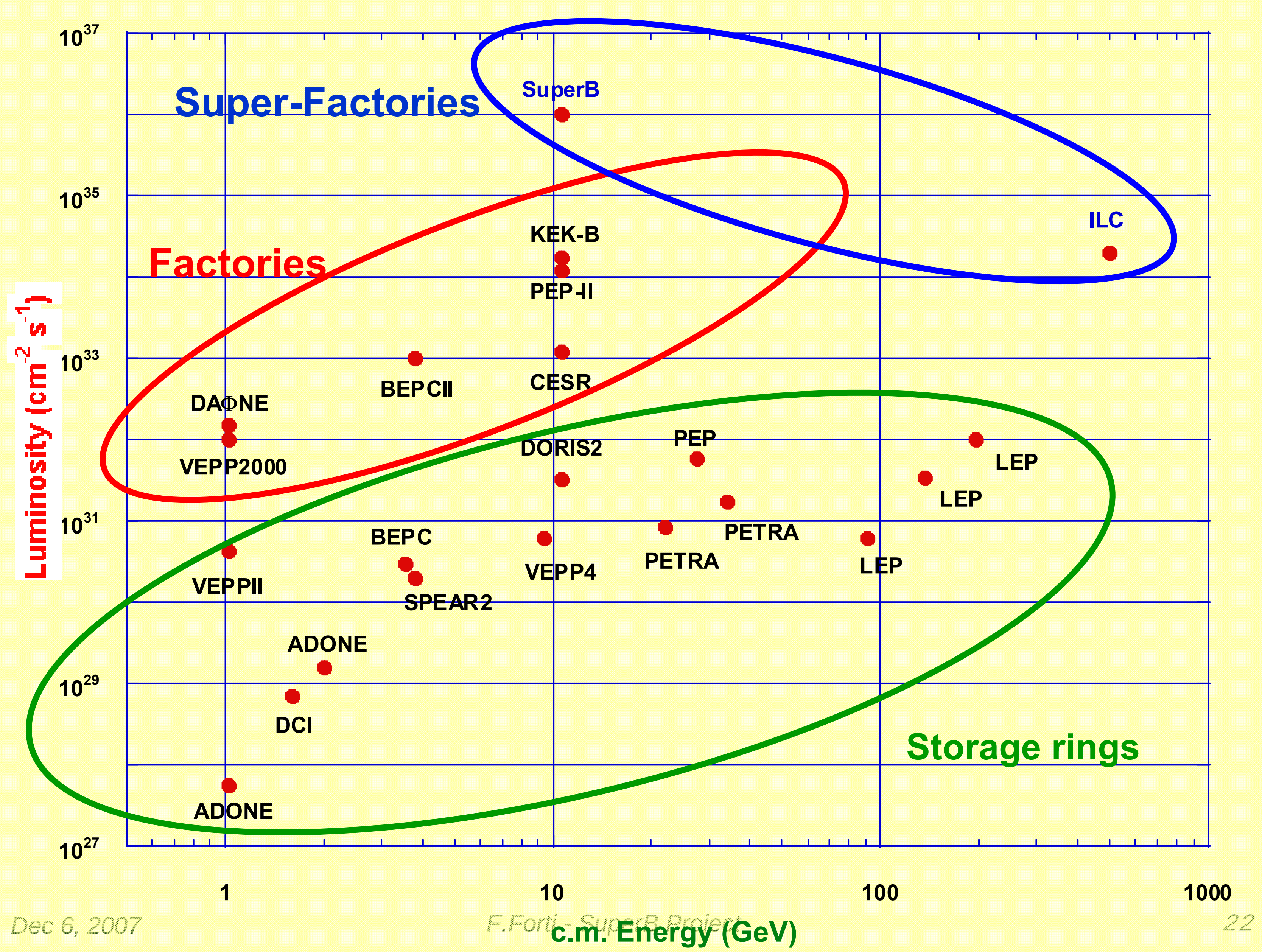
SuperB Accelerator

e+ e- colliders



How to increase L ? (cont)

“Brute force” method

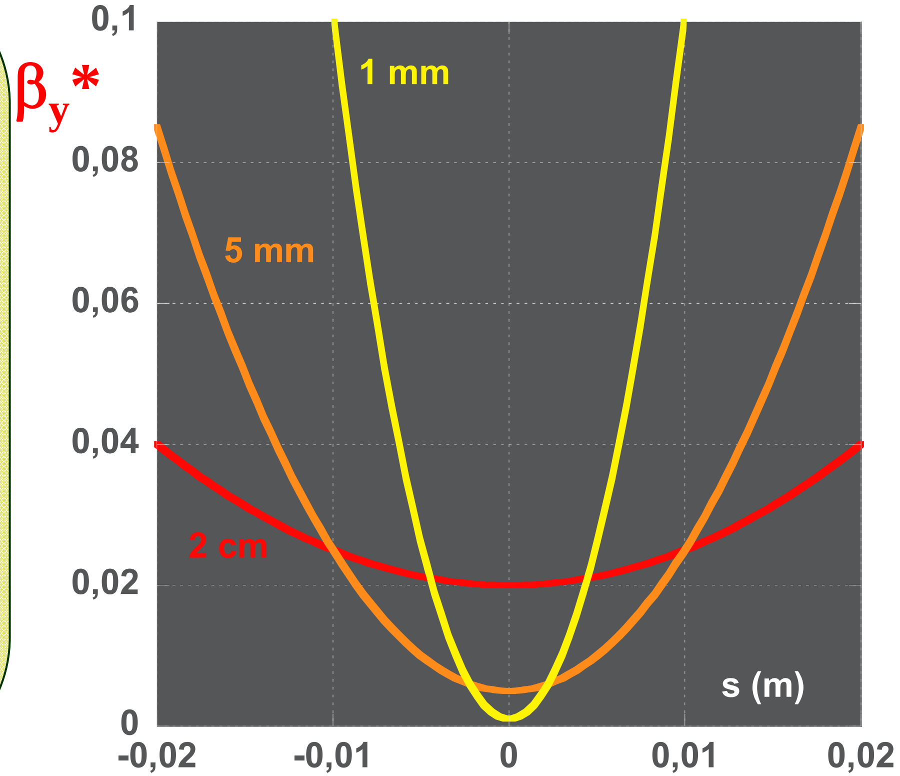
- Increase beam currents
- Decrease β_y^*
- Decrease bunch length

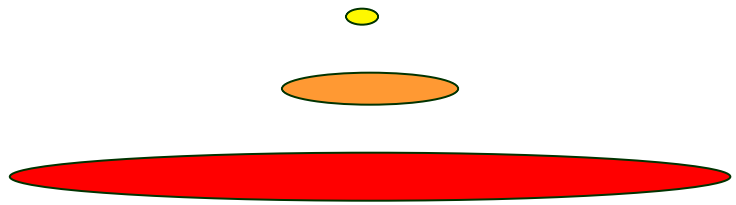
But...

- HOM in beam pipe
  - *overheating, instabilities, power costs*
- Detector backgrounds increase
- Chromaticity increase
  - *smaller dinamic aperture*
- RF voltage increase
  - *costs, instabilities*
- Shorter LER Touschek lifetime

Hourglass effect

To squeeze the vertical beam dimensions, and increase L, β_y at IP must be decreased. This is efficient only if at the same time the bunch length is shortened to ≈ β_y value, or particles in the head and tail of the bunch will see a larger β_y.





Bunch length

Reduced bunch length → increased energy spread → reduced cross section at Y(4S)

A new idea...

P. Raimondi's idea to focus more the beams at IP and have a "large" crossing angle → large Piwinski angle

- Ultra-low emittance (ILC-DR like)
- Very small β at IP
- Large crossing angle
- "Crab Waist" scheme

- Small collision area
- Lower β is possible
- NO parasitic crossings
- NO synchro-betatron resonances due to crossing angle

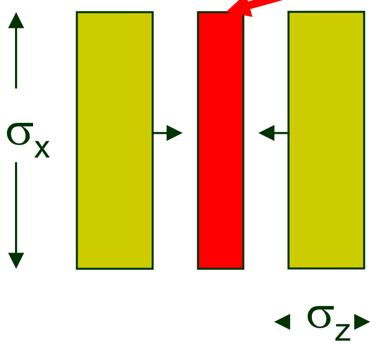
Test at DAΦNE this Fall !!!

Large crossing angle, small x-size

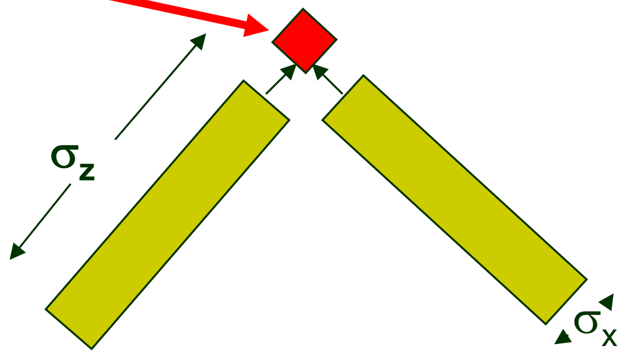
1) Head-on, Short bunches

Overlap region

2) Large crossing angle, long bunches



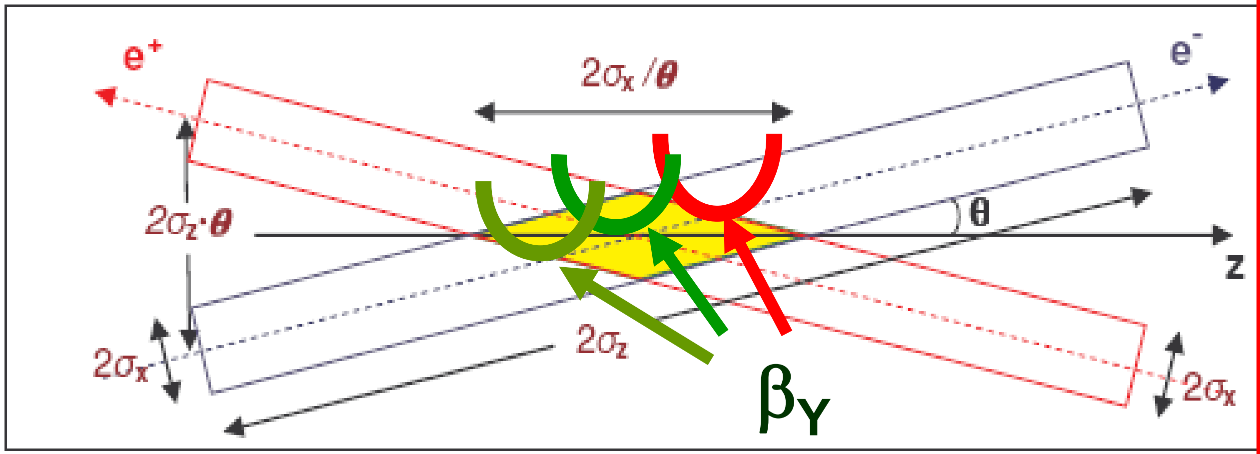
(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



With large crossing angle the x and z planes are swapped

Large Piwinski angle:

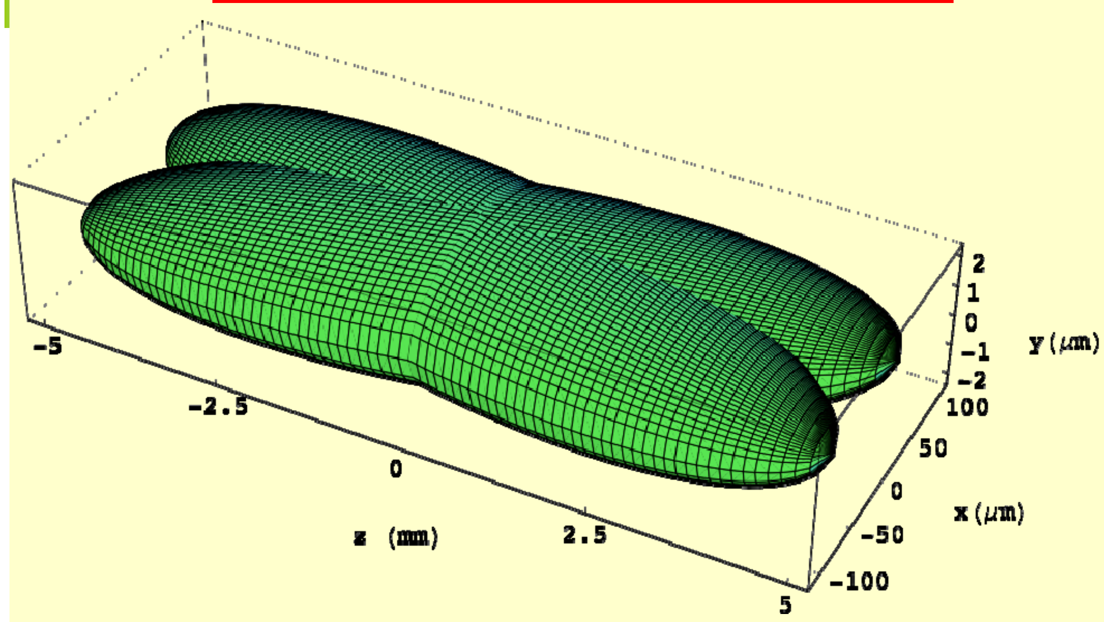
$\Phi = tg(\theta)\sigma_z/\sigma_x$

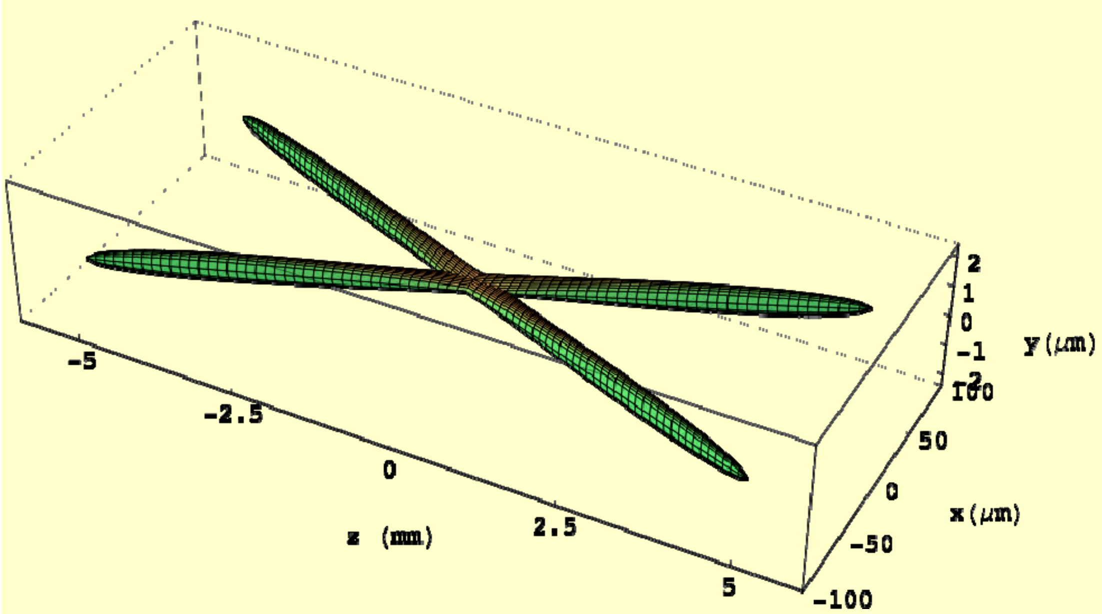


y waist can be moved along z with a sextupole on both sides of IP at proper phase

"Crab Waist"

IP beam distributions for KEKB





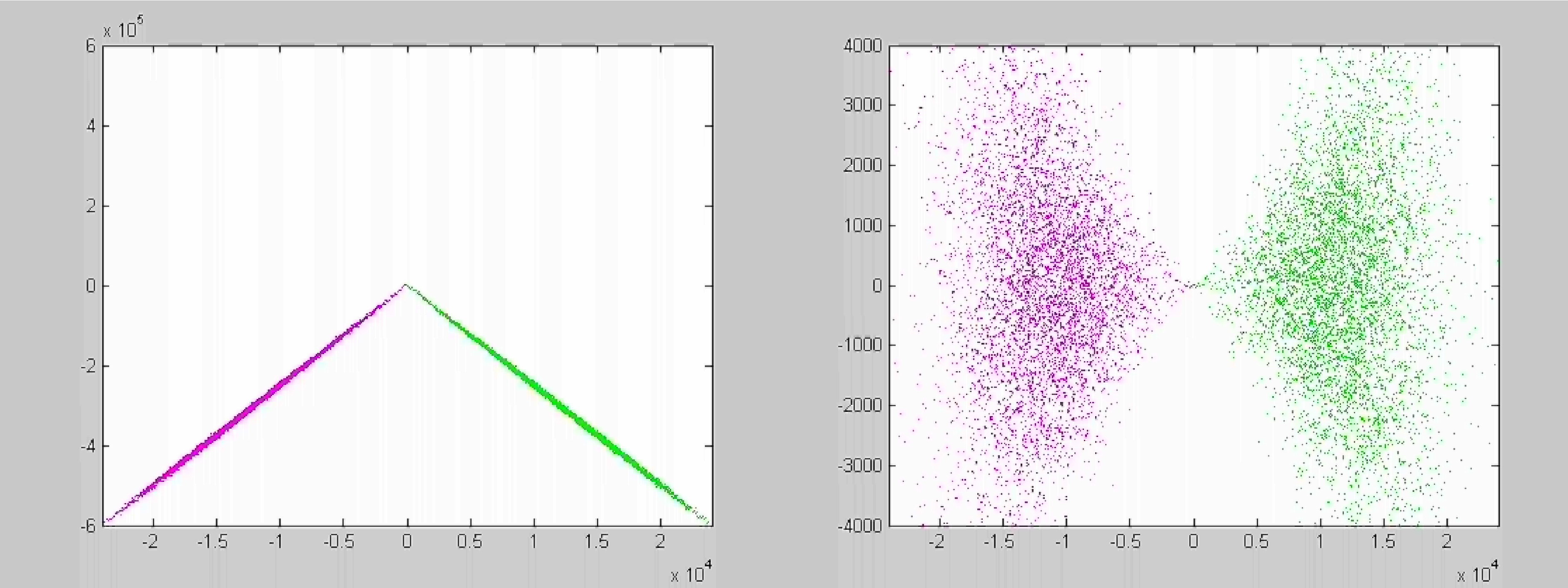
IP beam distributions for SuperB

An example...

	KEKB	SuperB
I (A)	1.7	2.
β_y^* (mm)	6	0.3
β_x^* (mm)	300	20
σ_y^* (μm)	3	0.035
σ_x^* (μm)	80	6
σ_z (mm)	6	5
L ($cm^{-2}s^{-1}$)	1.7×10^{34}	$1. \times 10^{36}$

Here is Luminosity gain

Beam Movies



x 10^5
6
4
2
0
-2
-4
-6
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2
x 10^4
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-2 -1.5 -1 -0.5 0 0.5 1 1.5 2
x 10^4

Comparison with existing machines

	PEPII	KEKB	SuperB
current	2.5 A	1.7 A	2.3 A
betay	10 mm	6 mm	0.3 mm
betax	400 mm	300 mm	20 mm
Emity (sigmay)	23 nm (~100μm)	~ the same (~80μm)	1,6 nm (~6μm)
y/x coupling (sigma y)	0,5-1 % (~6μm)	0.1 % (~3μm)	0,25 % (0,035μm)
Bunch length	10 mm	6 mm	6 mm
Tau l/t	16/32 msec	~ the same	16/32 msec
ζ_y	0.07	0.1	0.16
L	$1.2\ 10^{34}$	$1.7\ 10^{34}$	$1\ 10^{36}$

SuperB Parameters

	Nominal Parameters		Upgrade Parameters		Ultimate Parameters	
PARAMETER	LER	HER	LER	HER	LER	HER
Particle type	e+	e-	e+	e-	e+	e-
Energy (GeV)	4	7	4	7	4	7
Luminosity x 10^{36}	1.0		2.0		4.0	
Circumference (m) (Polarization section 150 m)	1800	1800	1660	1660	1660	1660
Revolution frequency (MHz)	0.167	0.167	0.181	0.181	0.181	0.181
Eff. long. polarization (%)	0	80	0	80	0	80
RF frequency (MHz)	476	476	476	476	476	476
Harmonic number	2856	2856	2634	2634	2634	2634
Momentum spread	7.9E-04	5.6E-04	9.0E-04	8.0E-04	9.0E-04	8.0E-04
Momentum compaction	3.2E-04	3.8E-04	3.0E-04	3.6E-04	3.0E-04	3.6E-04
Rf Voltage (MV)	7	9	10	14	10	14
Energy loss/turn (MeV)	1.16	1.94	1.78	2.81	1.78	2.81
Number of bunches	1251	1251	1251	1251	2502	2502
Particles per bunch x10^{10}	5.52	5.52	5.52	5.52	5.52	5.52
Beam current (A)	1.84	1.84	2.00	2.00	3.99	3.99
Beta y* (mm)	0.22	0.39	0.16	0.27	0.16	0.27
Beta x* (mm)	35	20	35	20	35	20
Emit y (pmr)	7	4	3.5	2	3.5	2
Emit x (nmr)	2.8	1.6	1.4	0.8	1.4	0.8
Sigma y* (microns)	0.039	0.039	0.023	0.023	0.023	0.023
Sigma x* (microns)	9.90	5.66	7.00	4.00	7.00	4.00
Bunch length (mm)	5	5	4.3	4.3	4.3	4.3
Full Crossing angle (mrad)	48	48	48	48	48	48
Wigglers (#) 20 meters each	0	0	2	2	2	2
Damping time (trans/long)(ms)	40/20	40/20	28/14	28/14	28/14	28/14
Luminosity lifetime (min)	6.7	6.7	3.35	3.35	3.35	3.35
Touschek lifetime (min)	13.8	20.6	6.9	10.3	6.9	10.3
Effective beam lifetime (min)	4.5	5.1	2.3	2.5	2.3	2.5
Injection rate pps (100%)	2.6E+11	2.3E+11	5.1E+11	4.6E+11	1.0E+12	9.1E+11
Tune shift y (from formula)	0.15	0.15	0.20	0.20	0.20	0.20
Tune shift x (from formula)	0.0043	0.0025	0.0059	0.0034	0.0059	0.0034
RF Power (MW)	17		25.2		58.2	

Machine summary

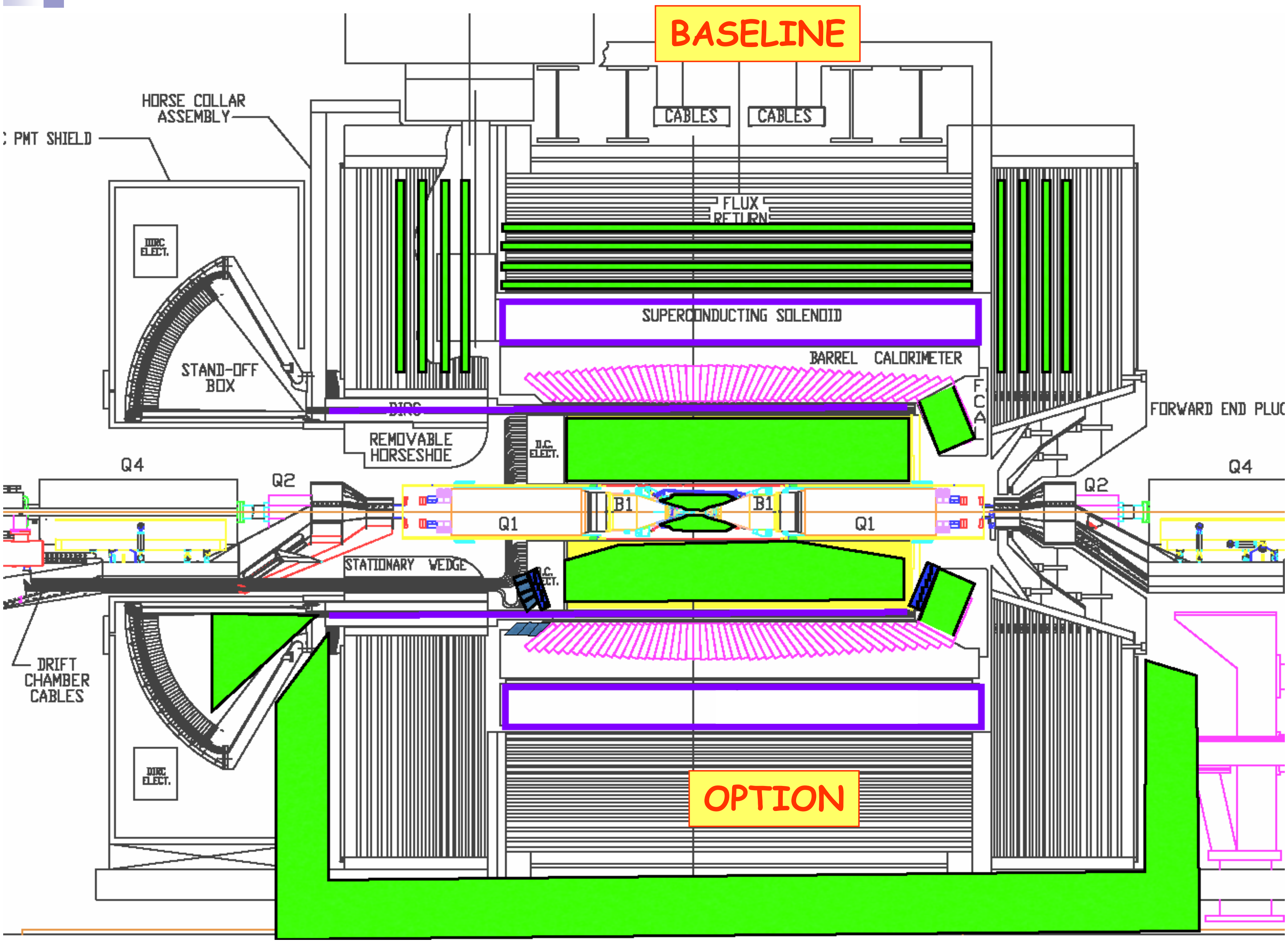
- Present parameter set based on ILCDR-like parameters 3.0 Km long rings studied with ILC OCS (Baseline) lattice scaled to 4 and 7 GeV
  - Same DR emittances
  - Same DR bunch length
  - 1.5 times DR bunch charges
  - Same ILC-IP betas
  - Final focus ILC-like
- Crossing angle and "crab waist" to maximize luminosity and minimize blowup
  - Test will start in Nov 2007 on DAΦNE.
- Design based on recycling all PEP-II hardware, Bends, Quads and Sexts, and RF system
  - Corresponds to a lot of money
- Maximize Luminosity keeping low ΔE and wall power.
  - Total power: 35 MW, as in PEP-II
- Simulations performed in many places and different codes:
  - LNF,BINP,KEK,LAL,CERN,PISA

SuperB Detector

Detector

- Babar and Belle designs have proven to be very effective for B-Factory physics
  - Follow the same ideas for SuperB detector
  - Try to reuse same components as much as possible
- Main issues
  - Machine backgrounds – somewhat larger than in Babar/Belle
  - Beam energy asymmetry – a bit smaller
  - Strong interaction with machine design
- A SuperB detector is possible with today's technology
  - Baseline is reusing large (expensive) parts of Babar (or Belle)
  - Quartz bars of the DIRC
  - Barrel EMC CsI(Tl) crystal and mechanical structure
  - Superconducting coil and flux return yoke.
- Some areas require moderate R&D and engineering developments to improve performance
  - Small beam pipe technology
  - Thin silicon pixel detector for first layer
  - Drift chamber CF mechanical structure, gas and cell size
  - Photon detection for DIRC quartz bars
  - Forward PID system (TOF or focusing RICH)
  - Forward calorimeter crystals (LSO)
  - Minos-style scintillator for Instrumented flux return
  - Electronics and trigger – need to revise Bfactory "½-track" trigger style
  - Computing – large data amount
- More details in:
  - www.pi.infn.it/SuperB/node/159 - SuperB Italy Meeting on detector R&D
  - indico.lal.in2p3.fr/conferenceDisplay.py?confId=167 – Paris workshop (May 9-11)
  - https://agenda.infn.it/conferenceDisplay.py?confId=163 – Review (Nov 12-13)

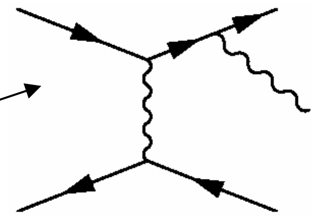
Detector Layout – Reuse parts of Babar (or Belle)

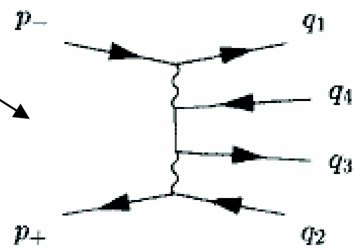


Background

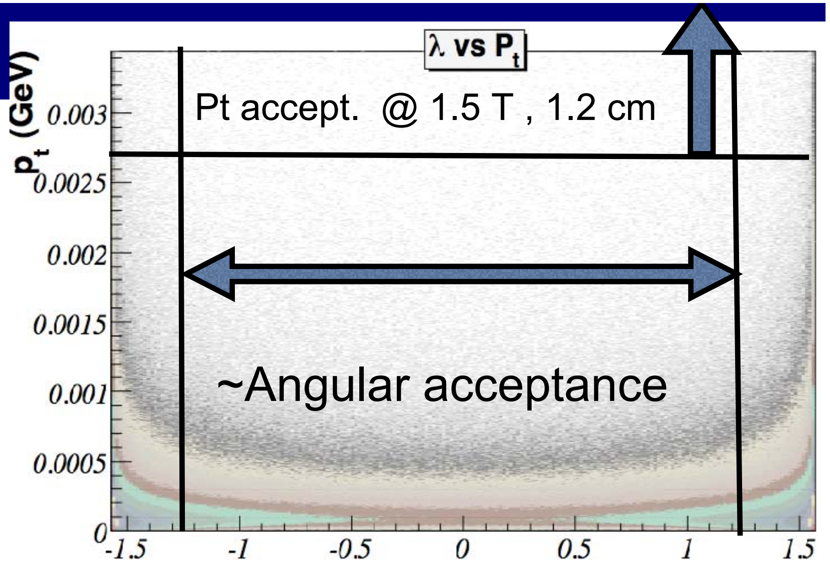
- To be treated with care, but not a huge problem
- Sources: different from PEP-II/Babar
  - Beam-gas: ok because of low current
  - SR fan: can be shielded
  - Touschek
  - QED cross section

	Cross section	Evt/bunch xing	Rate
Radiative Bhabha	~340 mbarn (Eγ/Ebeam > 1%)	~680	0.3THz
e^+e^- pair production	~7.3 mbarn	~15	7GHz
Elastic Bhabha	$O(10^{-5})$ mbarn (Det. acceptance)	~20/Million	10KHz
Υ(4S)	$O(10^{-6})$ mbarn	~2/million	1 KHz





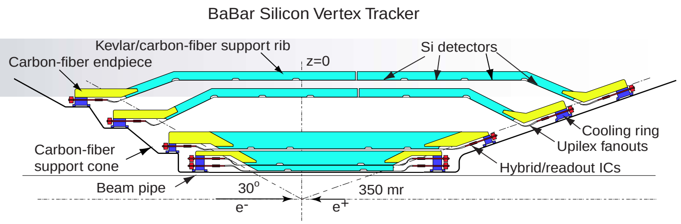
Background rates



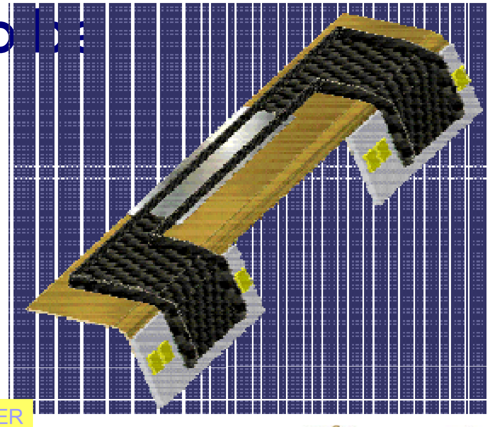
- Pair production
  - Low P_t make magnetic shielding effective
  - Issue for first layer of SVT
  - Rate 15MHz/cm² @ 1.2cm
    5MHz/cm² @ 1.5cm
- Radiative Bhabhas
  - Beamline and shielding design are paramount
  - Showering and backscattering extends to large radius
  - Rate 100kHz/cm² @ R=1.2 cm
- Touschek Background
  - Produced all along the ring, depending on emittance and bunch volume
  - Beam optics and collimator setting essential in controlling this background
  - Rate <10 kHz/cm² @ R=1.2 cm

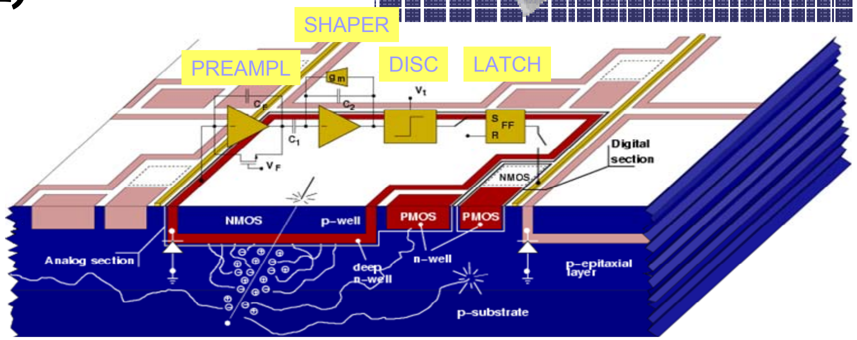
Layer	Flux (Hz/cm2)	X(cm)	Y(cm)	Area (cm2)	time resolution	Occupancy
Pixel @ 1.2cm	15.0E+6	0.005	0.005	0.000025	100.0E-9	3.8E-05
Pixel @ 1.5cm	5.0E+6	0.005	0.005	0.000025	100.0E-9	1.3E-05
Striplets @ 1.2cm	15.0E+6	1.8	0.005	0.009	100.0E-9	1.4E-02
Striplets @ 1.5cm	5.0E+6	1.8	0.005	0.009	100.0E-9	4.5E-03
Strip Layer N	10.0E+3	10	0.01	0.1	100.0E-9	1.0E-04

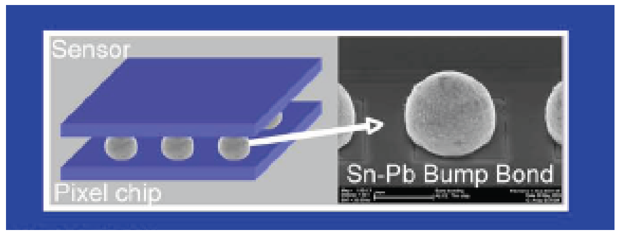
Silicon Vertex Tracker



- The Babar SVT technology is adequate for R > 3cm: use design similar to Babar SVT
- Layer0 is subject to large backround and needs to be extremely thin: > 5MHz/cm2, 1MRad/yr, < 0.5%X_0
  - Striplets option: mature technology, not so robust against background.
    - Marginal with background rate higher than ~ 5 MHz/cm^2
    - Moderate R&D needed on module interconnection/mechanics/FE chip (FSSR2)
  - CMOS MAPS option
    - new & challenging technology:
    - can provide the required thickness
    - existing devices are too slow
    - Extensive R&D ongoing on 3-well devices 50x50um^2
  - Hybrid Pixel Option: tends to be too thick.
    - An example: Alice hybrid pixel module ~ 1% X_0
    - Possible material reduction with the latest technology improvements
    - Viable option, although marginal



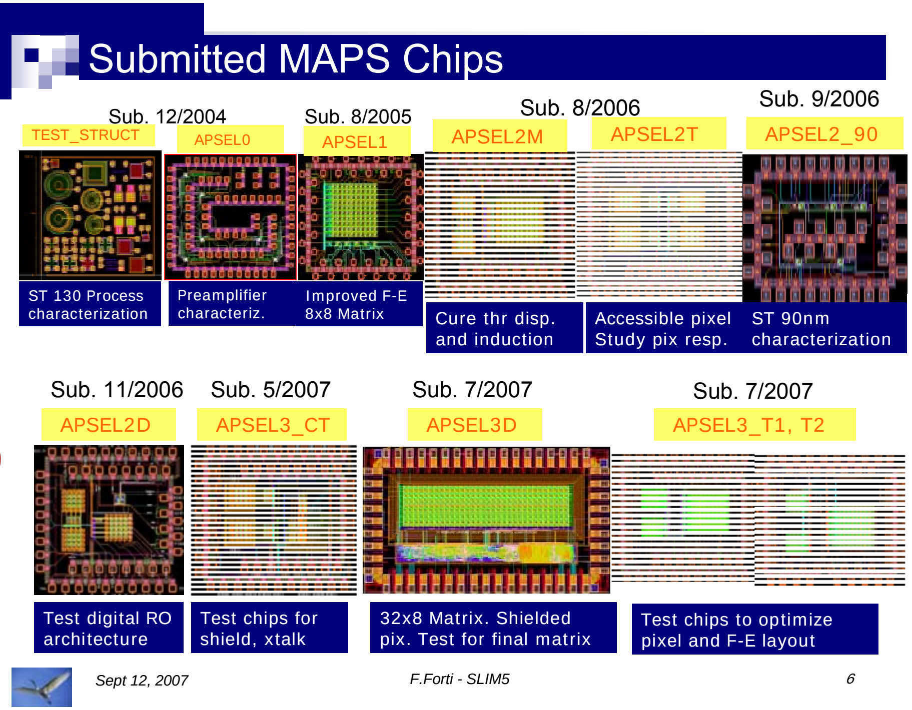


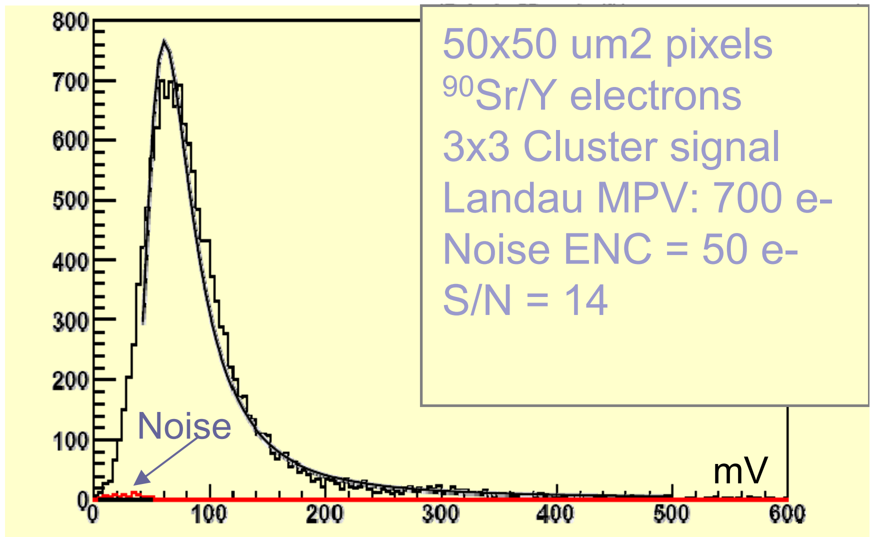


MAPS R&D

Extensive R&D ongoing (and needed):

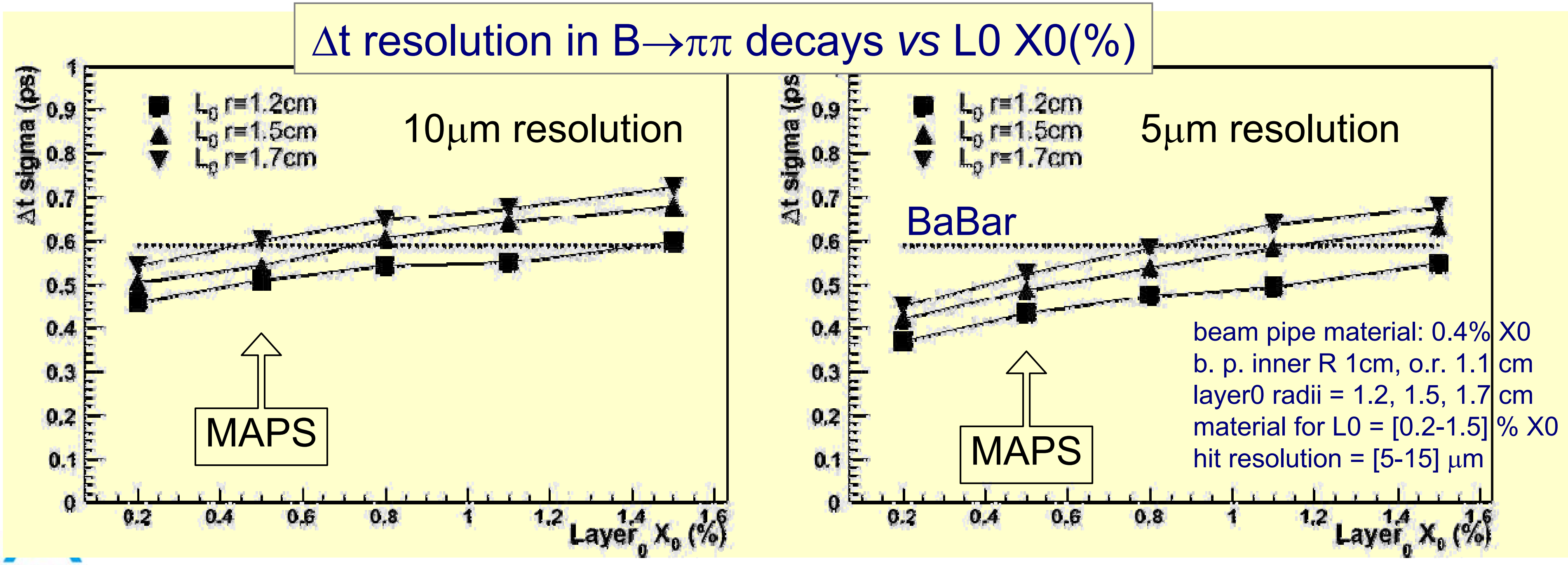
- Fast readout architecture
  - Digital to analog xtalk
  - Architecture scalability (4k→64K)
- Pixel cell optimization
  - Increase S/N (15→30)
  - reduce power dissipation x2
- Radiation hardness
  - Not fully qualified yet. Irradiation program
- Mechanical issues
  - sensor thinning, module design, low mass cooling
- Test Beam foreseen in Sep 2008
  - Prototype MAPS module + striplets





Radius, thickness, resolution

- Technological solutions depend critically on L_0 radius, thickness, resolution
- Fast simulation studies for various decays have been performed
- A full, more detailed reassessment is needed for the TDR.
- MAPS low mass solution would leave more flexibility for radius (ie background) and resolution
- Hybrid pixels will force to use the smallest radius and/or better resolution
- Striplets (same MAPS material) require larger radius, performance marginal

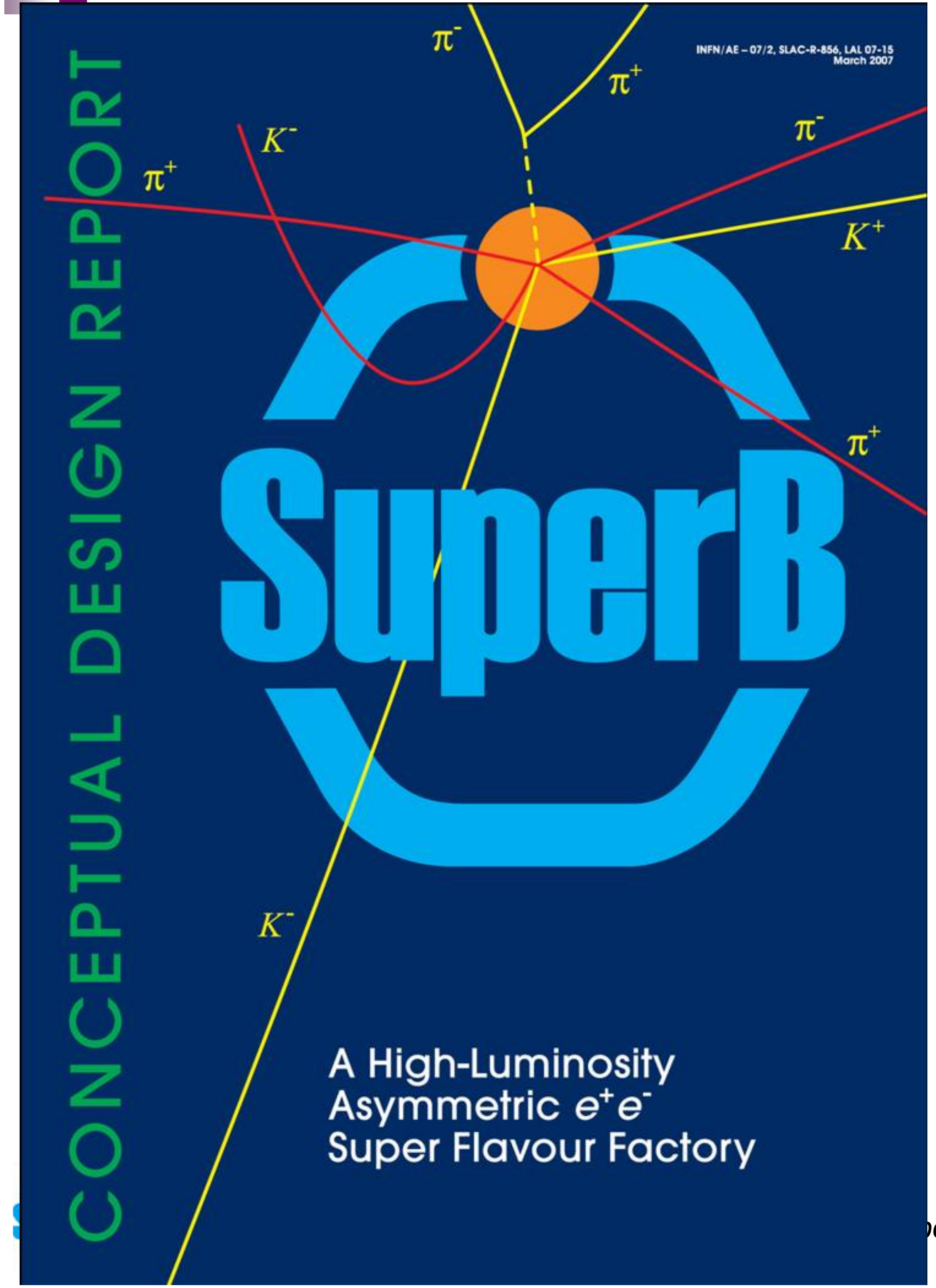


The SuperB Process

The SuperB Process

- International SuperB Study Group formed in Dec 2005 on Physics, Machine, Detector
- International steering committee established, chaired by M.A.Giorgi. Members from
  - Canada, France, Germany, Italy, Russia, Spain, UK, US
  - Regular interaction with Japan, although not formalized
- Regular workshops
  - Since 2005 five workshops held (2 in Frascati, 1 in SLAC, 1 Villa Mondragone, 1 Paris), SuperB Meeting at Daresbury
  - Accelerator retreat at SLAC in 2006 and 2007
  - Physics retreat in Valencia Jan 7-15, 2008
  - Detector R&D Workshop at SLAC Feb 14-16, 2008
- Conceptual Design Report
  - Ready, printed and distributed.
  - Describe Physics case, Accelerator, Detector, including costing
  - International review ongoing
- More information: www.pi.infn.it/SuperB

Conceptual Design Report



The CDR of SuperB is ready!

INFN/AE-07/02,
SLAC-R-856,
LAL 07-15

Available at:

www.pi.infn.it/SuperB

arxiv.org/abs/0709.0451

476 pages

Printed and available

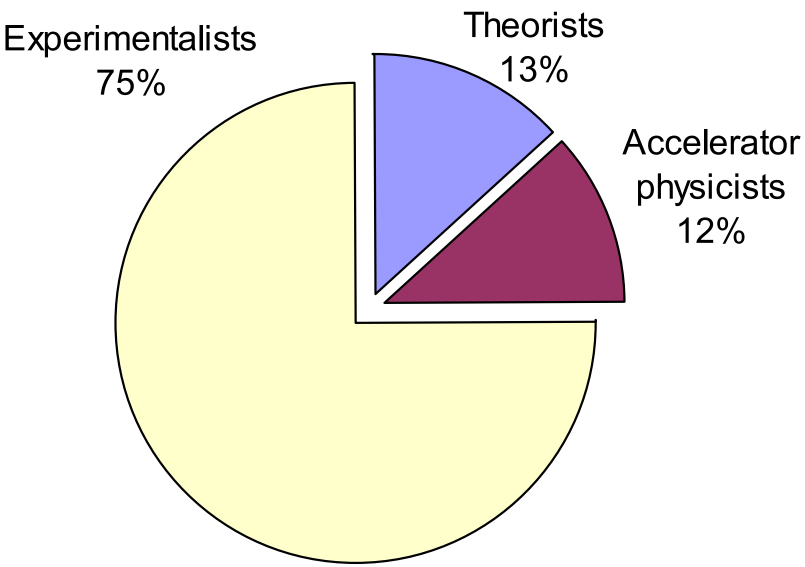
Copies can be requested from Lucia.Lilli@pi.infn.it

CDR Signatures: some numbers

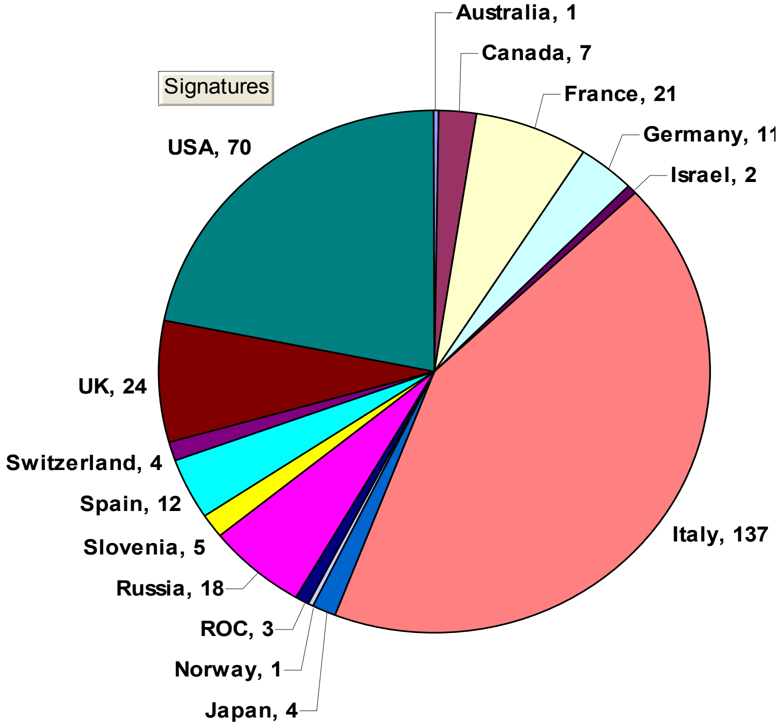
- 320 Signatures; 85 institutions

> The people on the following list have indicated interest in and support for the SuperB project. It includes a subset who have been directly involved with the preparation of this document, as well as individuals who have contributed in other ways or plan on future involvement.

- 174 Babar members
  - 65 non Babar exper.



Signatures breakdown by type



Signatures breakdown by country

CDR Cost Estimate

- A full cost estimate of the SuperB project has been done
  - Based on Babar/PEP-II actual costs
  - Escalated from 1995 to 2007
  - Bottom-up for almost all elements
- Separate new components from reused elements
  - Replacement value of reused components = how much would it cost today to rebuild those components (extrapolated from Babar/PEP-II costs)
  - New costs: everything that's needed today, including refurbishing
  - Transport is not included, but disassembly and reassembly is.
- Keep separate categories:
  - EDIA: engineering, design, inspection and administration (man-months)
  - Labour: technicians (man-months)
  - Materials and Services: 2007 Euros.

Item	*EDIA mm*	*Labor mm*	*M&S kEuro*	*Rep.Val. kEuro*
Accelerator	**5429**	**3497**	**191166**	**126330**
Site	**1424**	**1660**	**105700**	**0**
Detector	**3391**	**1873**	**40747**	**46471**

CDR Review

- An International Review Committee has been appointed by INFN.
  - John Dainton – UK/Daresbury, chair
  - Jacques Lefrancois – F/Orsay
  - Antonio Masiero – I/Padova
  - Rolf Heuer – D/ Desy
  - Daniel Schulte – CERN
  - Abe Seiden – USA/UCSC
  - Young-Kee Kim – USA/FNAL
  - Hiroaki Aihara – Japan/Tokyo
- First meeting with the review committee was in LNF on Nov 12-13(*)
- Interaction with the committee will continue through the first months of 2008.
- The final report foreseen in April 2008
  - After the results of the LNF test of crab waist idea
- CDR presented to ECFA in the summer 2007
  - Very positive reaction
- Presentation to the CERN strategy group expected in spring 2008
  - Coordinates all projects in european HEP for research infrastructure

(*)Slides available at: https://agenda.infn.it/conferenceDisplay.py?confId=163

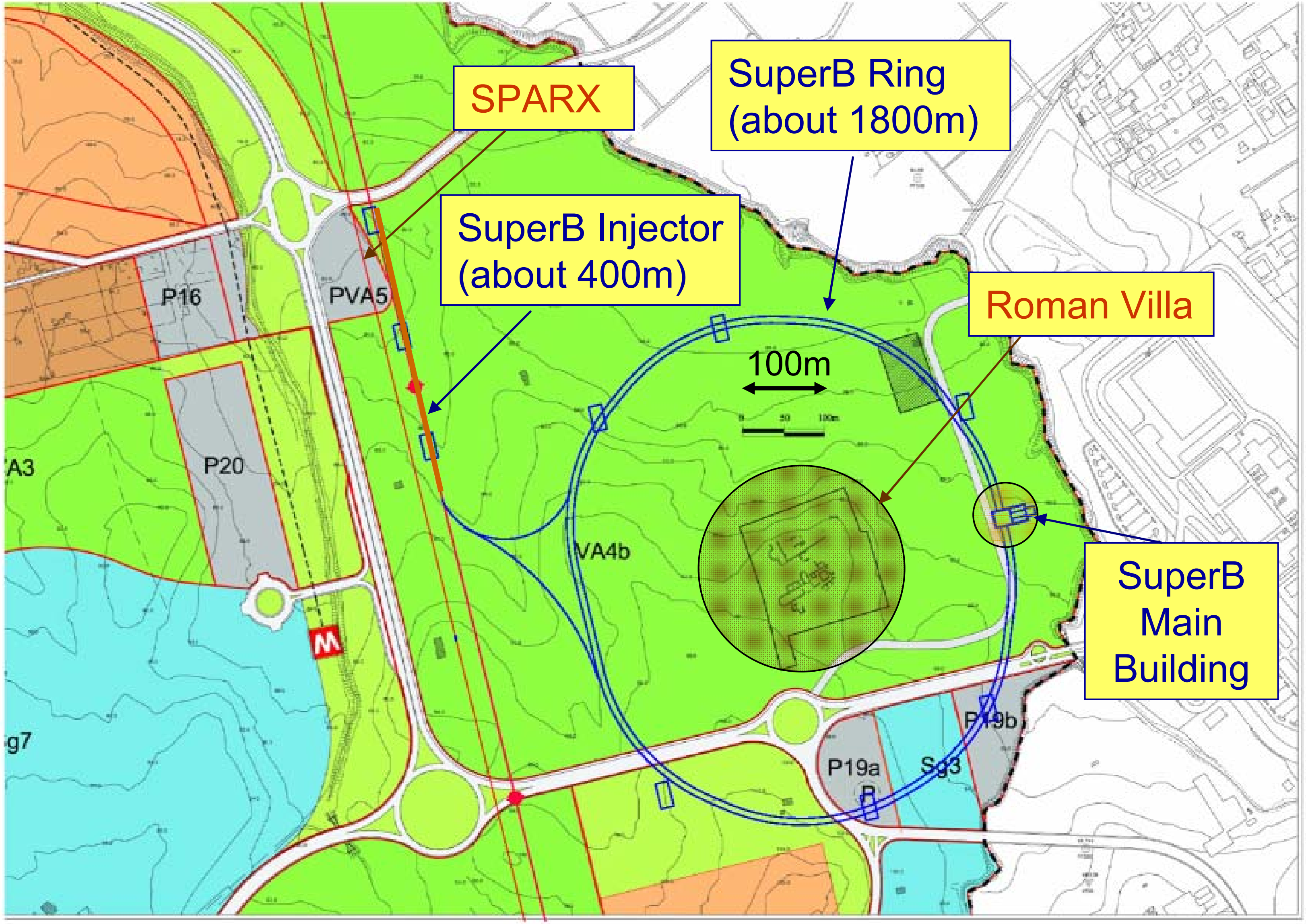
The SuperB Site

Where can we build SuperB ?

- The SuperB conceptual design is largely site independent
- The natural site for SuperB is an existing accelerator laboratory
  - Large sites such as SLAC have different programs at this time
  - KEK has its own adiabatic upgrade plan
  - LNF site is too small to host SuperB
- A possible site is on the Università di Roma Tor Vergata campus
  - Close enough to make use of LNF facilities
  - University with schools of economics, law, engineering, humanities, medicine and science and 41.000 students
  - Big Campus (1,480 acre) with still a lot of available space:a 5000 m2 sport village is also under construction
  - Favorable building codes
  - A FEL project SPARX approved and funded
  - Strong interest of INFN and University
- Setup INFN/Tor Vergata engineering group to prepare feasibility study

SuperB Location

SuperB Footprint



SuperB Summary and Outlook

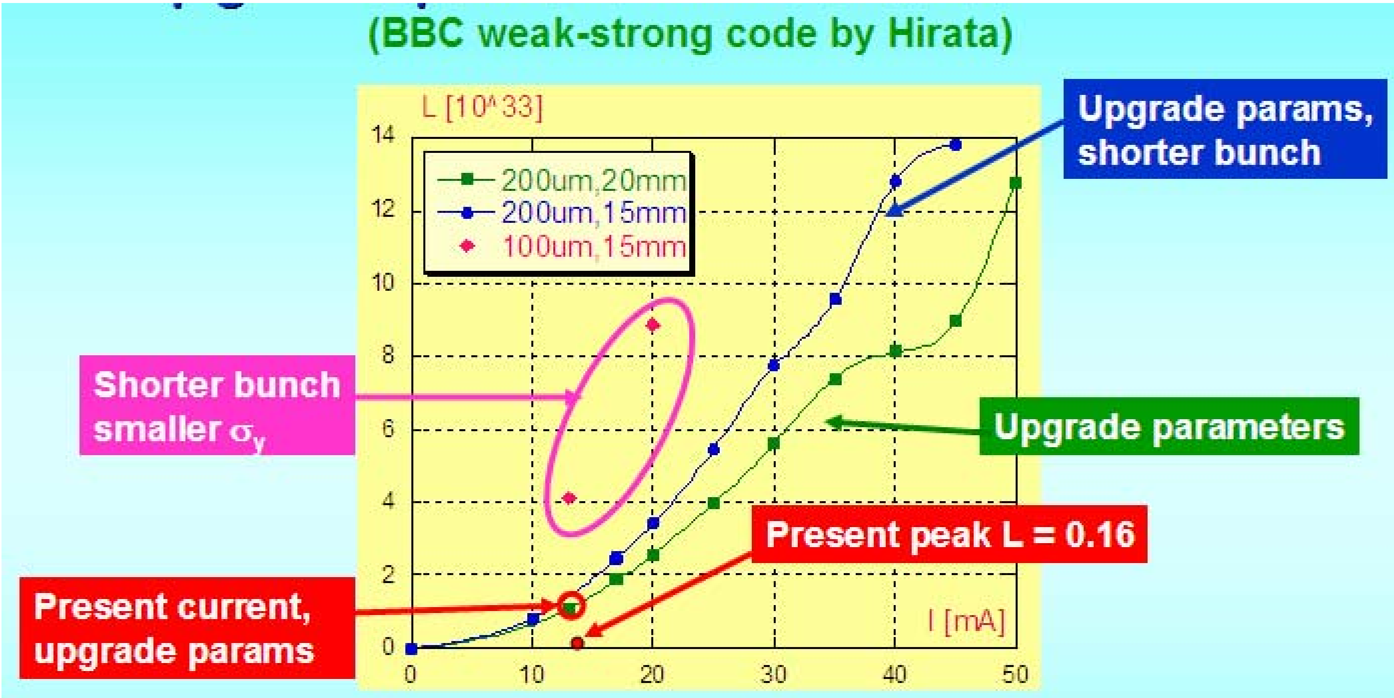
- The physics case for a high luminosity B Factory is clearly established
- The SuperB accelerator concept allows to reach and exceed the 10^{36} threshold
- There is a growing international interest and participation
- A conceptual design report is under review
- R&D is proceeding on various items
- Next steps are:
  - Secure funding sources
  - Formalize SuperB project in 2008
  - Technical Design Report by 2010

Let's start digging...

BACKUP SLIDES

DAΦNE test expected results

- The upgrade of DAΦNE run with a new collision scheme with large Piwinski angle and small beam sizes will allow for peak luminosities in excess of 10^{33} cm^{-2} s^{-1} even without the "crabbing" sextupoles
- The use of "*crab waist*" sextupoles will add a bonus for suppression of dangerous resonances
- Brand new IRs layout and equipments have been designed and constructed and will be ready by next Fall to start commissioning
- The test will have the fundamental function of validating the simulation



How to increase L ?
(example Super-KEKB)

Stored current:

x 3 (HER) / x 5 (LER)

Beam-beam parameter:

x 4

Lorentz factor

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

Classical electron radius

Beam size ratio

Geometrical reduction factors due to crossing angle and hour-glass effect

Luminosity:

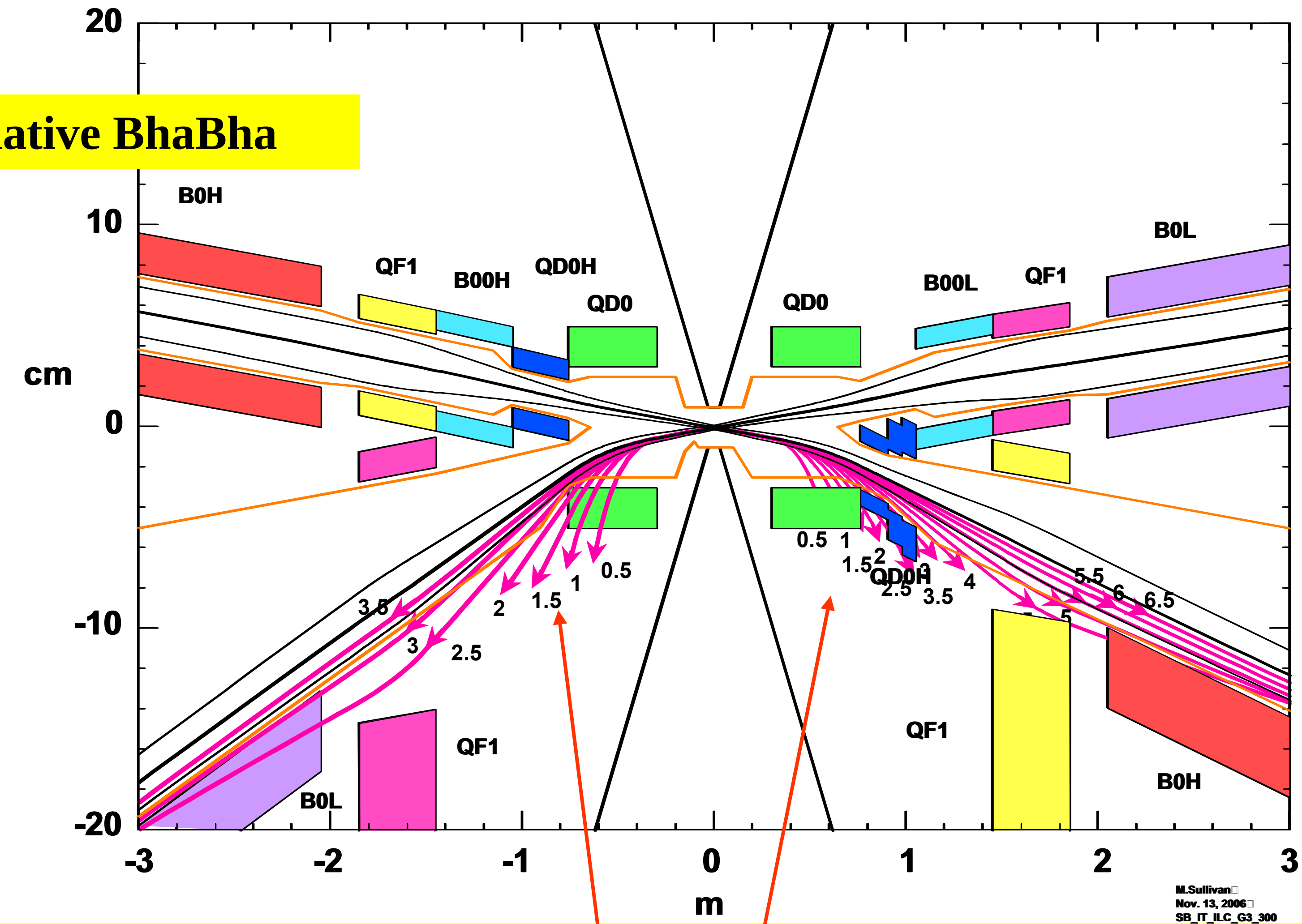
x 50

Vertical β at the IP:

x 0.5

We have an IR design coping with main BKG source

Radiative BhaBha

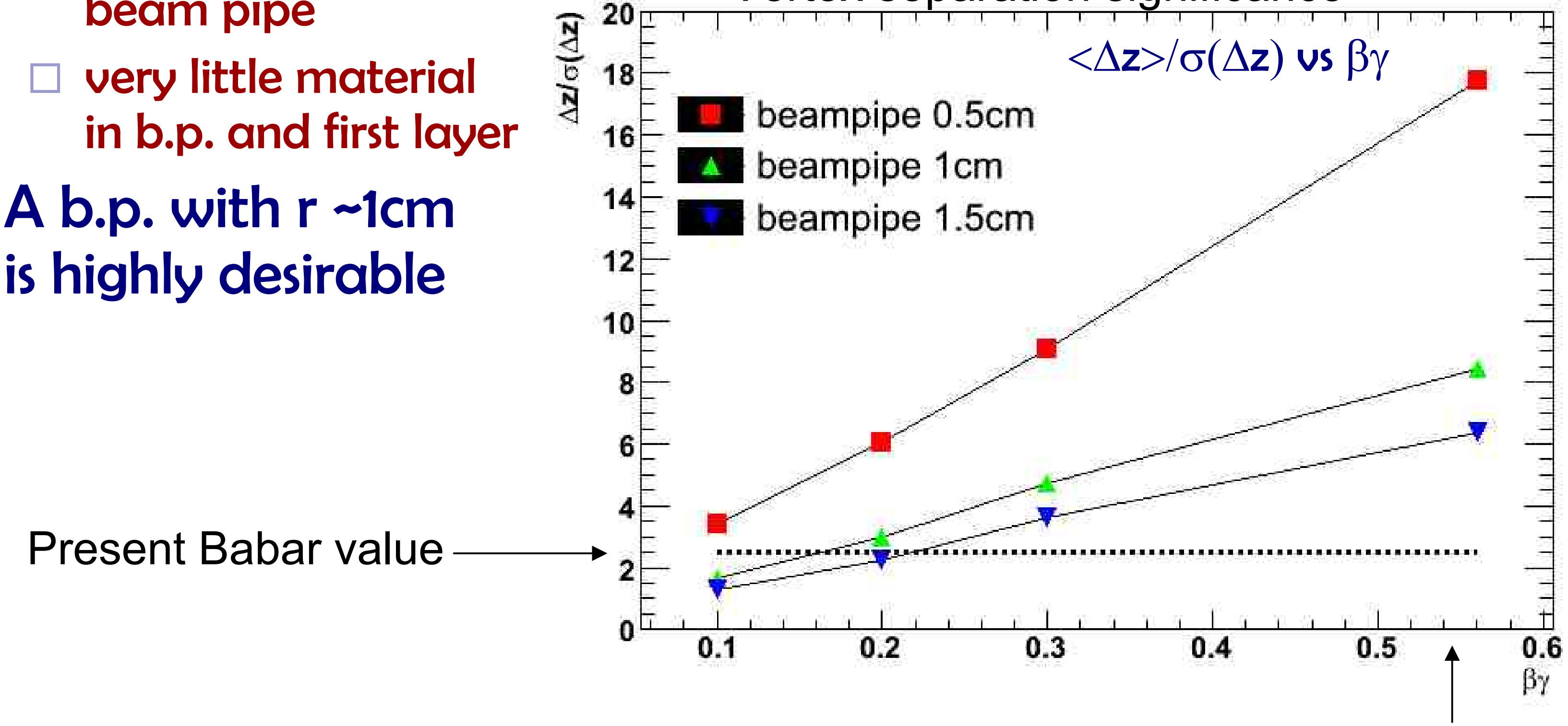


Need serious amount of shielding to prevent the produced shower from reaching the detector.

Asymmetry and beam pipe radius

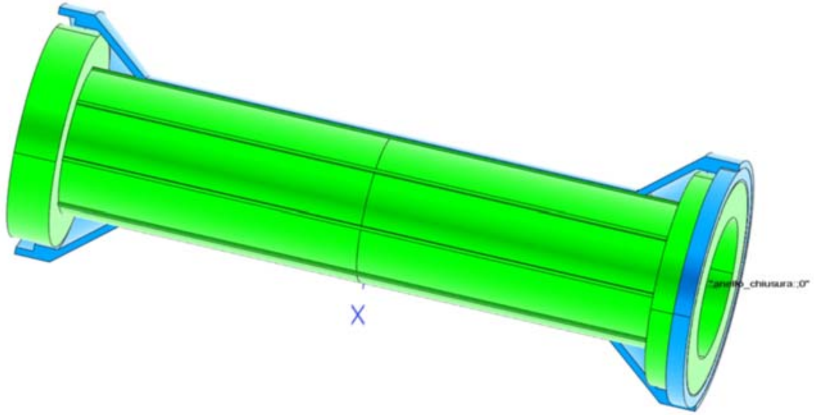
- Lower boost advantegeous for machine design
  - Babar: 9 + 3.1 $\beta\gamma$=0.56 , Belle: 8 + 3.5 $\beta\gamma$=0.45
  - SuperB: 7 + 4 $\beta\gamma$=0.28
- we can afford to have a lower boost only if the vertexing resolution is good:
  - small radius beam pipe
  - very little material in b.p. and first layer
- A b.p. with r ~1cm is highly desirable

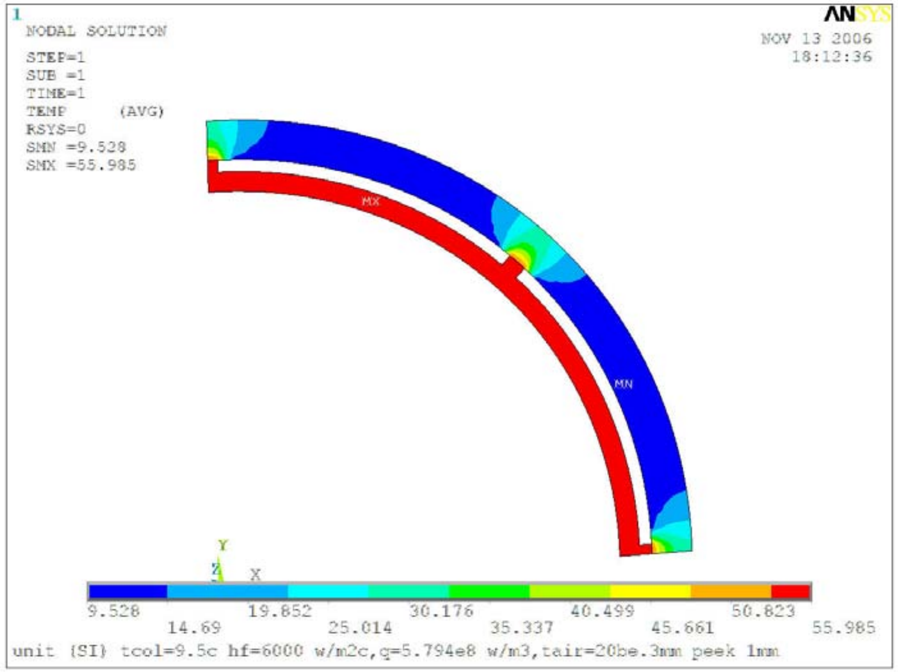
Vertex separation significance



Beam pipe

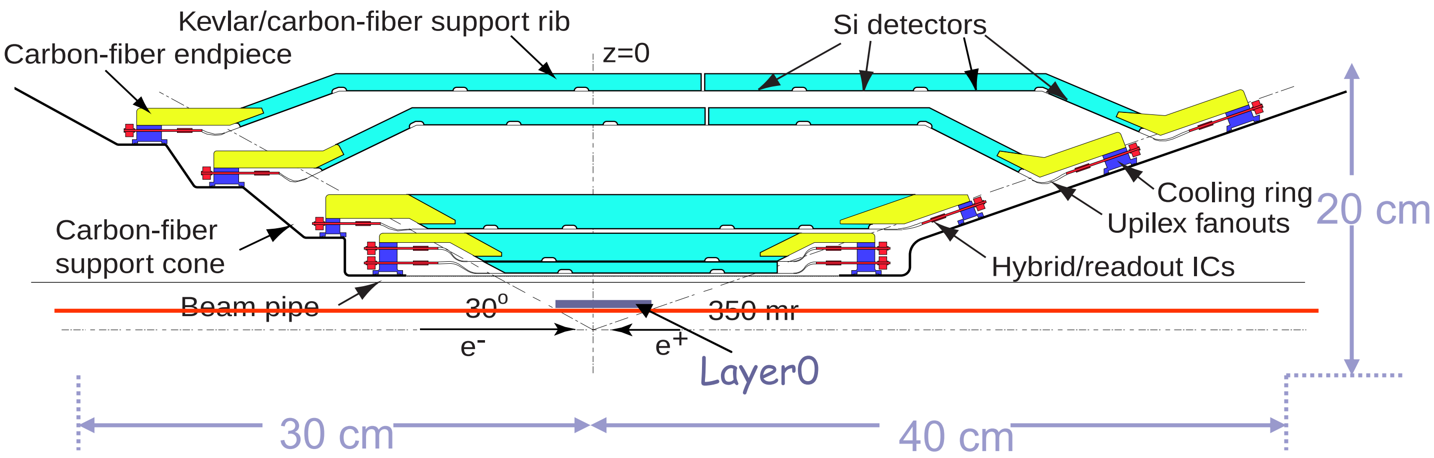
- 1.0 cm inner radius
- Be inner wall
  - ≈ 4um inside Au coating
- 8 water cooled channels (0.3mm thick)
  - Power ≈ 1kW
- Peek outer wall
- Outer radius ≈ 1.2cm
- Thermal simulation shows max ≈ 55°C
- Issues
  - Connection to rest of b.p.
  - Be corrosion
- Outer wall may be required to be thermally conductive to cool pixels



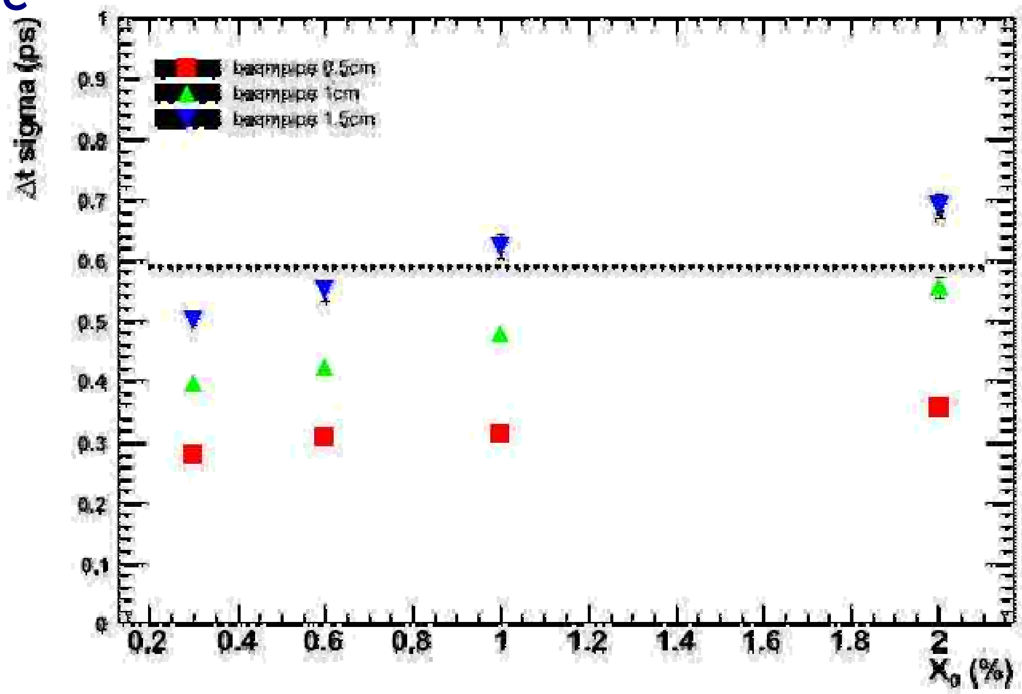


SVT

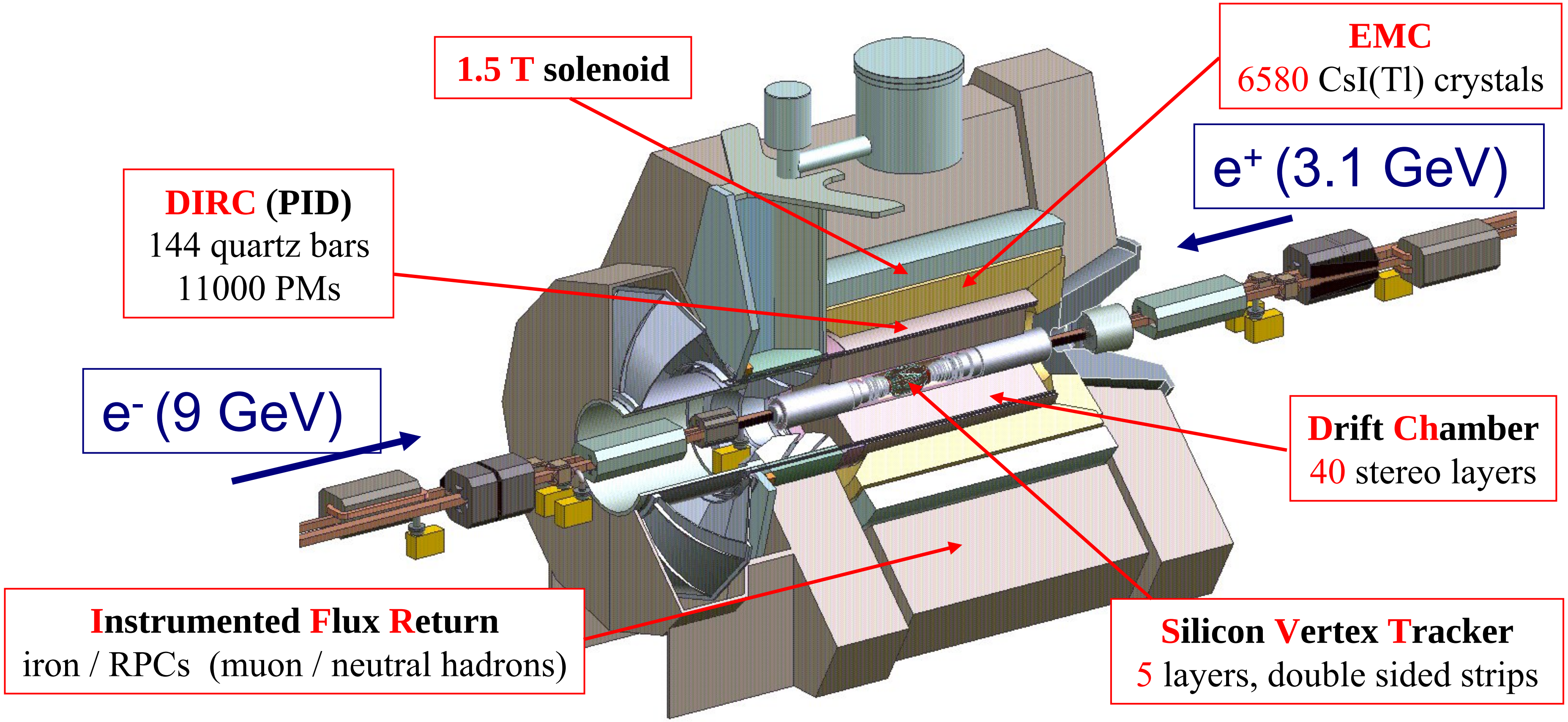
BaBar Silicon Vertex Tracker



- Baseline: use an SVT similar to the Babar one, complemented by one or two inner layers.
  - Question on whether it would possible/economical to add a layer between SVT and DCH, or move L5 to larger radius
- Cannot reuse because of radiation damage
- Beam pipe radius is paramount
  - inner radius: 1.0cm,
  - layer0 radius: 1.2cm,
  - thickness: 0.5% X0



The BABAR Detector



SVT: 97% efficiency, 15 μm z hit resolution (inner layers, perp. tracks)

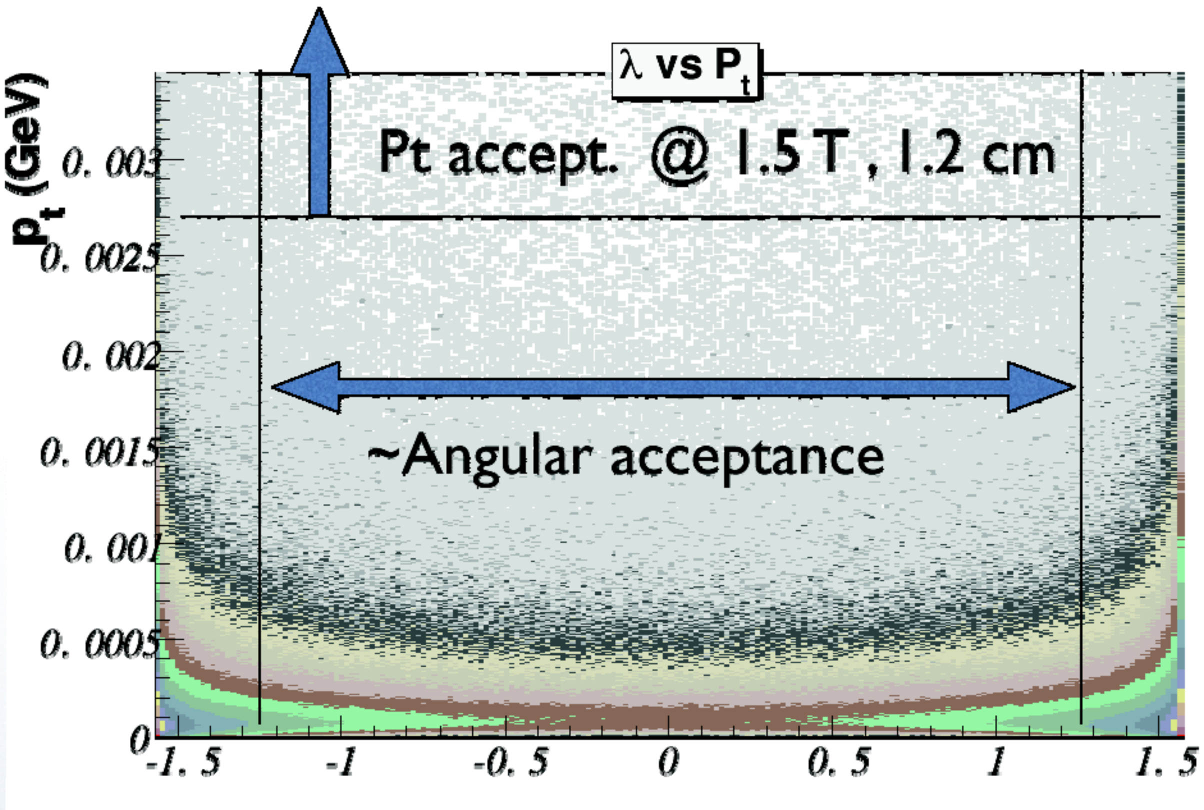
SVT+DCH: $\sigma(p_T)/p_T = 0.13\ \% \times p_T\ +\ 0.45\ \%$, $\sigma(z_0) = 65$ @ 1 GeV/c

DIRC: K-π separation 4.2 σ @ 3.0 GeV/c → 2.5 σ @ 4.0 GeV/c

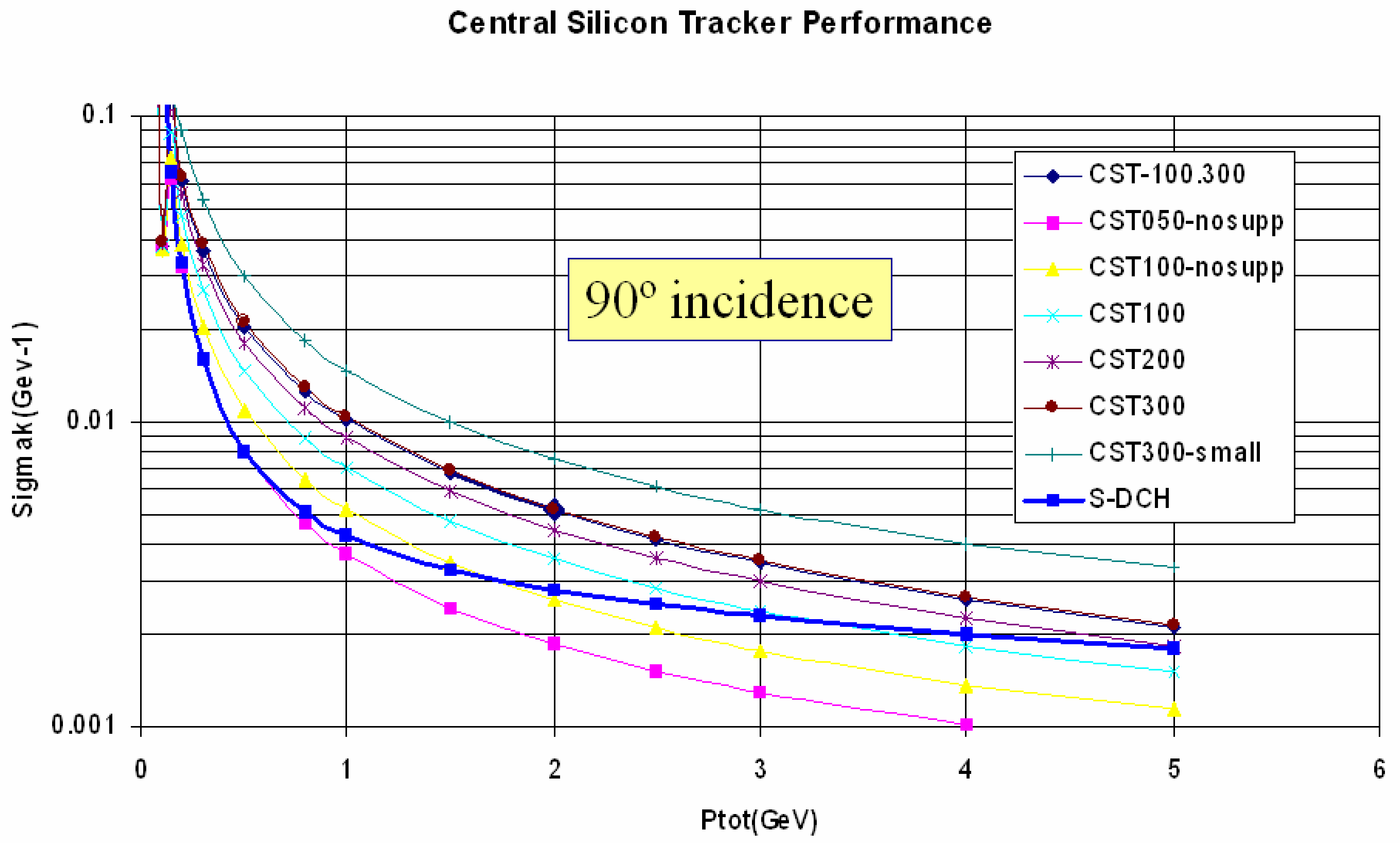
EMC: $\sigma_E/E = 2.3\ \% \cdot E^{-1/4} \oplus 1.9\ \%$

Pair production

- Huge cross section (7.3 mbarn)
- Produced particles have low energy and loop in the magnetic field
- Most particles are outside the detector acceptance



Why not an all-silicon tracker



SuperB Budget

Accelerator and site costs

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
1	**Accelerator**	**5429**	**3497**	**191166**	**126330**
1.1	Project management	2112	96	1800	0
1.2	Magnet and support system	666	1199	28965	25380
1.3	Vacuum system	620	520	27600	14200
1.4	RF system	272	304	22300	60000
1.5	Interaction region	370	478	10950	0
1.6	Controls, Diagnostics, Feedback	963	648	12951	8750
1.7	Injection and transport systems	426	252	86600	18000

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
2.0	**Site**	**1424**	**1660**	**105700**	**0**
2.1	Site Utilities	820	1040	31700	0
2.2	Tunnel and Support Buildings	604	620	74000	0

Note: site cost estimate not as detailed as other estimates.

Detector cost

WBS	Item	EDIA mm	Labor mm	M\&S kEuro	Rep.Val. kEuro
1	**SuperB detector**	**3391**	**1873**	**40747**	**46471**
1.0	**Interaction region**	**10**	**4**	**210**	**0**
1.1	**Tracker (SVT + L0 MAPS)**	**248**	**348**	**5615**	**0**
1.1.1	**SVT**	**142**	**317**	**4380**	**0**
1.1.2	*L0 Striplet option*	*23*	*33*	*324*	*0*
1.1.3	**L0 MAPS option**	**106**	**32**	**1235**	**0**
1.2	**DCH**	**113**	**104**	**2862**	**0**
1.3	**PID (DIRC Pixilated PMTs + TOF)**	**110**	**222**	**7953**	**6728**
1.3.1	**DIRC barrel - Pixilated PMTs**	**78**	**152**	**4527**	**6728**
1.3.1	*DIRC barrel - Focusing DIRC*	*92*	*179*	*6959*	*6728*
1.3.2	**Forward TOF**	**32**	**70**	**3426**	**0**
1.4	**EMC**	**136**	**222**	**10095**	**30120**
1.4.1	**Barrel EMC**	**20**	**5**	**171**	**30120**
1.4.2	**Forward EMC**	73	152	6828	0
1.4.3	**Backward EMC**	42	65	3096	0
1.5	**IFR (scintillator)**	**56**	**54**	**1268**	**0**
1.6	**Magnet**	**87**	**47**	**1545**	**9623**
1.7	**Electronics**	**286**	**213**	**5565**	**0**
1.8	**Online computing**	**1272**	**34**	**1624**	**0**
1.9	**Installation and integration**	**353**	**624**	**3830**	**0**
1.A	**Project Management**	**720**	**0**	**180**	**0**

Note: options in italics are not summed. We chose to sum the options we considered most likely/necessary.

Schedule

- Overall schedule dominated by:
  - Site construction
  - PEP-II/Babar disassembly, transport, and reassembly
- We consider possible to reach the commissioning phase after 5 years from T0.

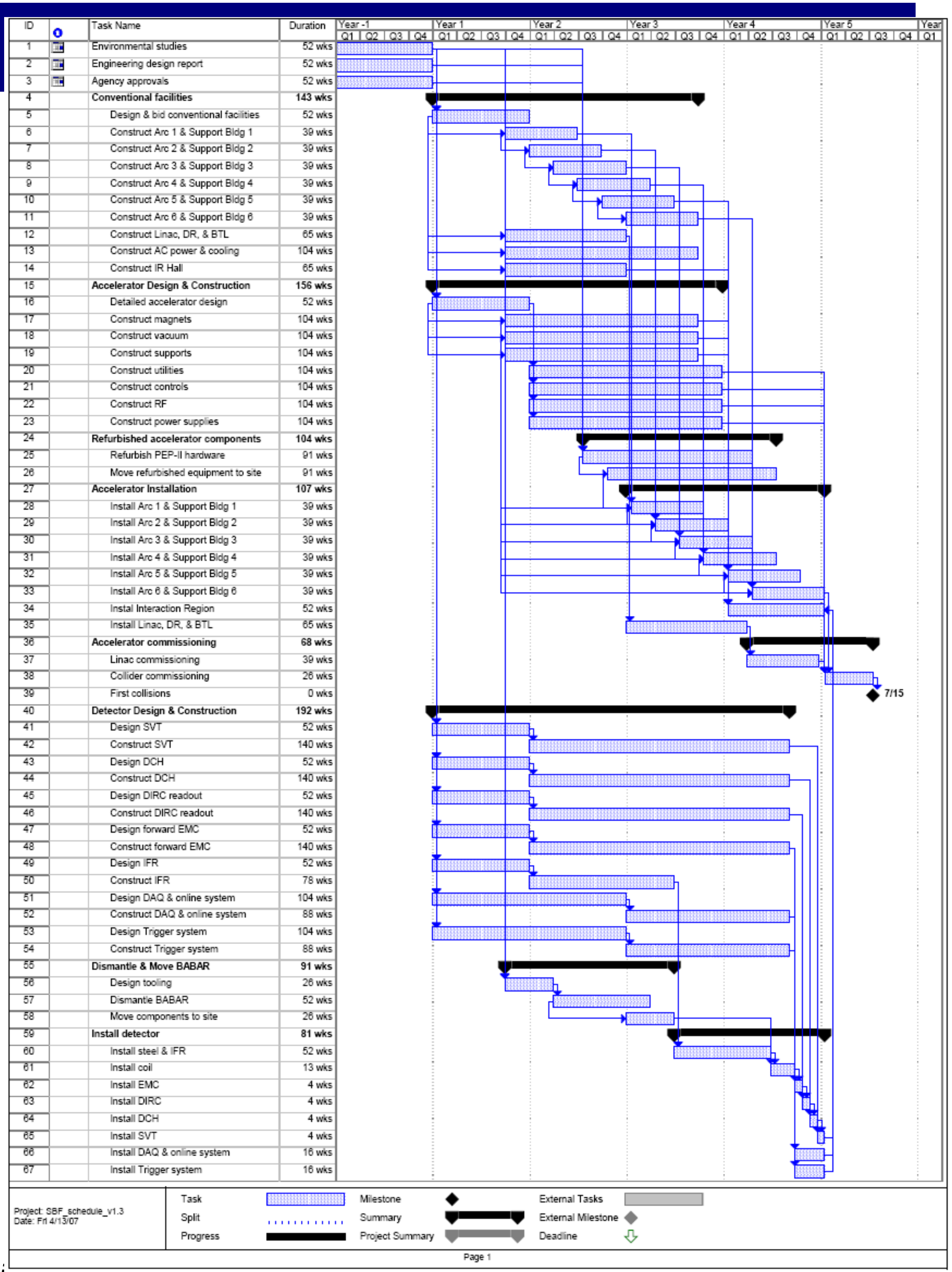


Figure 5-1. Overall schedule for the construction of the SuperB project.

What money ?

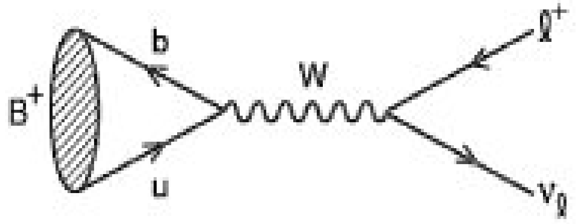
- The SuperB budget model still needs to be fully developed. It is based on the following elements (all being negotiated)
  - Italian government ad hoc contribution
  - Regione Lazio contribution
  - INFN regular budget
  - EU contribution
  - In-kind contribution (PEP-II + Babar elements)
  - Partner countries contributions
- Clearly the SuperB project is inherently international and will need to be managed internationally

The SuperB Physics case

$B^{\pm} \to \tau^{\pm} \nu$

ICHEP06
Browder (Belle)
Sekula (BaBar)

<u>Important</u> as W (suppressed by V_{ub}) can be replaced by charged Higgs, etc



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

SM prediction
$(1.59 \pm 0.40) \times 10^{-4}$
(depends on f_B and V_{ub})

<u>Difficult</u> due to neutrinos in the final state

BELLE: tag with fully reconstructed B mesons (180 channels)

$$BF(B^+ \to \tau^+ \nu_\tau) = (1.79^{+0.56+0.39}_{-0.49-0.46}) \times 10^{-4}$$

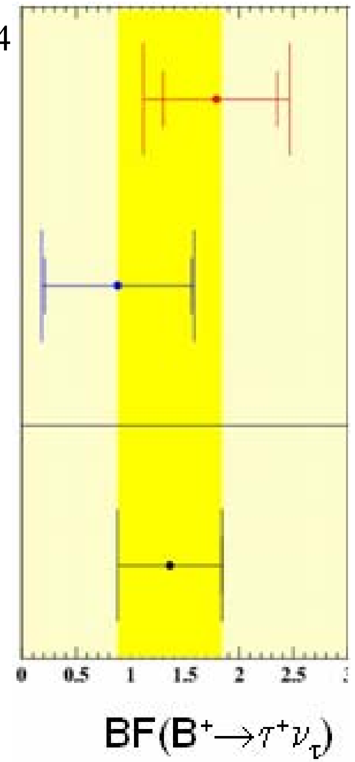
(revised). 3.5 σ significance

BABAR: (new) Tag with B→D(*)lν

$$BF(B^+ \to \tau^+ \nu_\tau) = (0.88^{+0.68}_{-0.67} \pm 0.11) \times 10^{-4}$$

BF<1.80@90%CL

Averaged (1.36 ± 0.48)x10-4



LFV at SuperB to discriminate among models

$A(l_i \to l_j \gamma) = a\,[Y_e Y_\nu^+ Y_\nu]_{ij} + b\,[Y_U^+ Y_U Y_D]_{ij}$

G.Isidori IV SuperB nov 2006

PMNS mixing strucutre [MLFV],
dominant if $M_R > 10^{12}$ GeV $\Rightarrow$ $B(\mu \to e\gamma) \sim 10^{-13}\,(M_R/10^{12}\text{GeV})\,(\Lambda/10\text{ GeV})^4$

CKM mixing structure [~ Barbieri-Hall-Strumia '95]
dominant if $M_R < 10^{12}$ GeV $\Rightarrow$ $B(\mu \to e\gamma) \sim 10^{-13}\,(\Lambda/10\text{ GeV})^4$

The search for $\tau \to \mu(e)\,\gamma$ at B and super-B factories becomes very interesting $\Rightarrow$ best tool to discriminate the two scenarios :

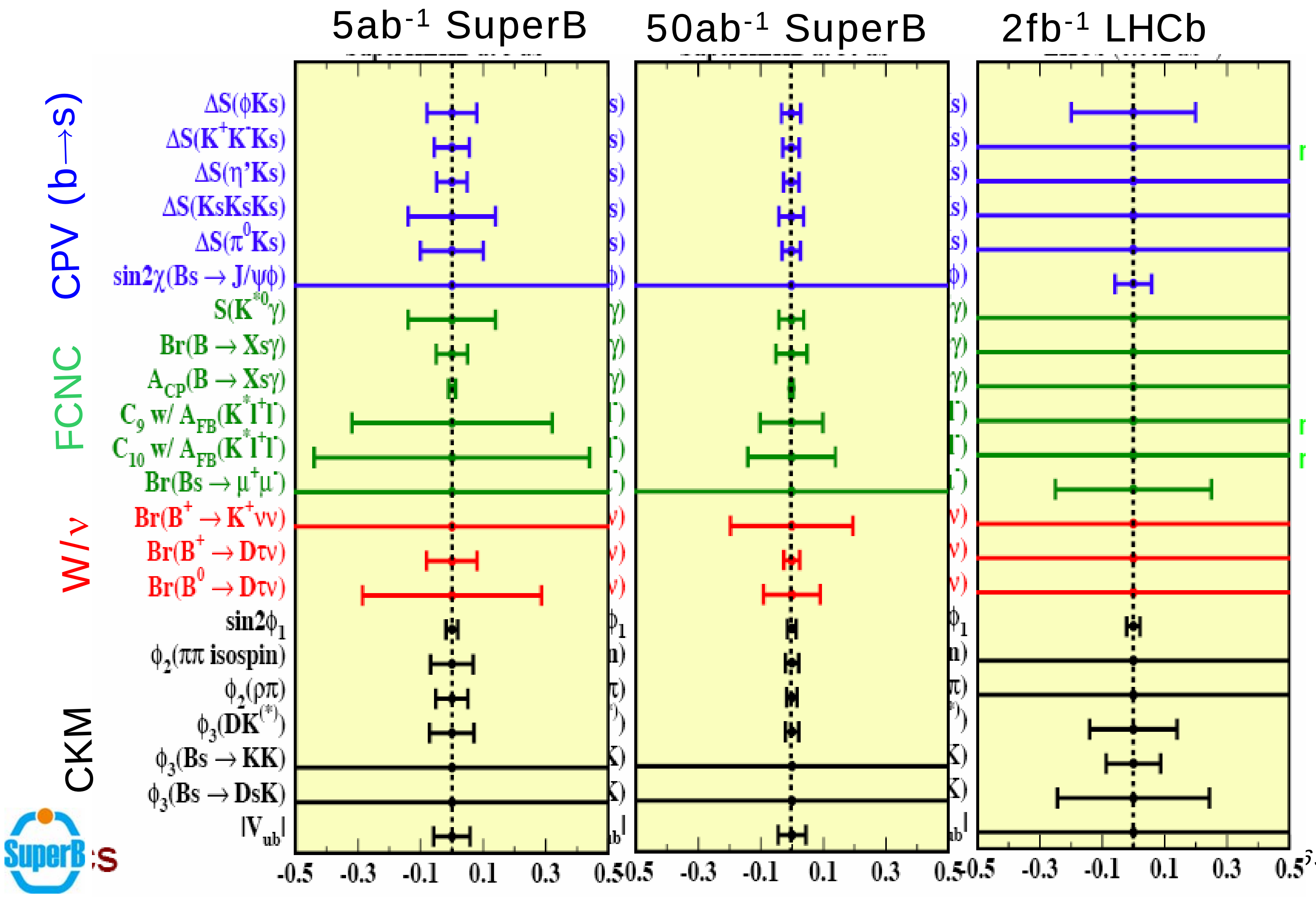
$B(\tau \to \mu\gamma):B(\tau \to e\gamma):B(\mu \to e\gamma) \sim \lambda^{-6}:\lambda^{-4}:1 \sim 10^4:500:1$

SSF <-> MEG

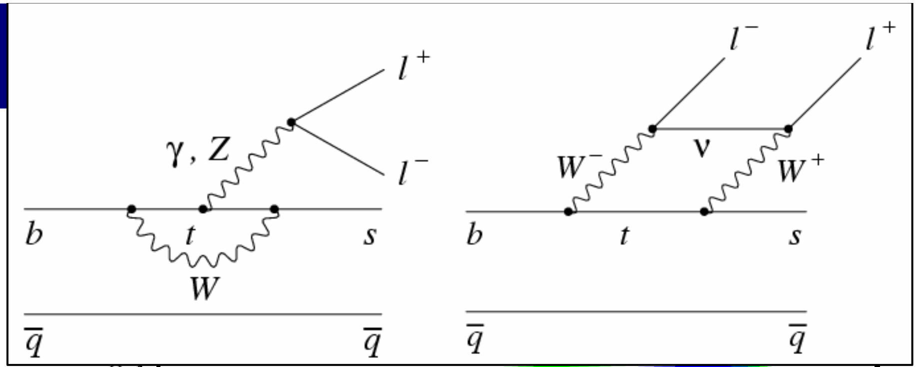
$B(\tau \to \mu\gamma):B(\tau \to e\gamma):B(\mu \to e\gamma) \sim [500\text{–}10]:1:1$

What's in store: Physics reach at SuperB

From '05 T.Iijima talk

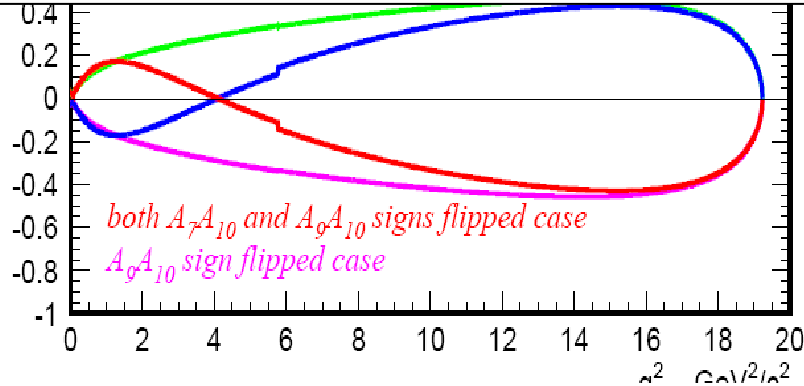


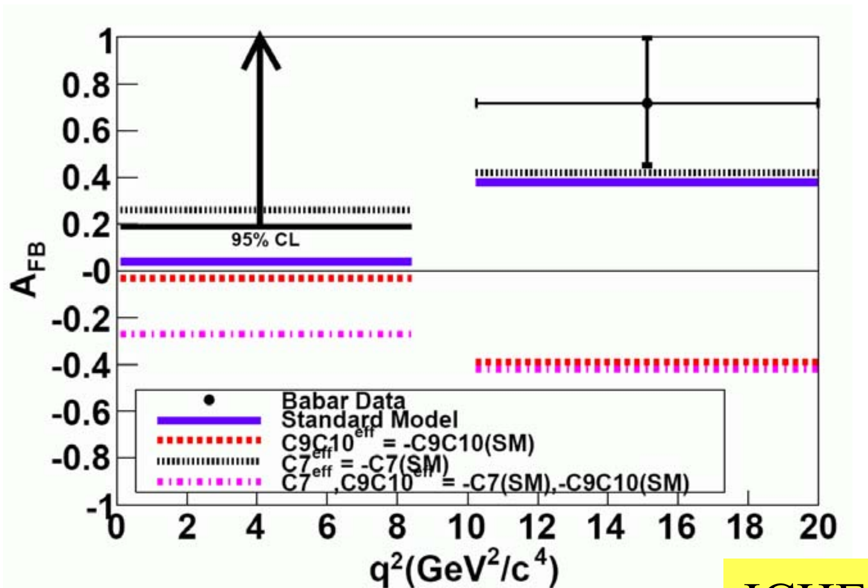
$K^{(*)}l^+l^-$ for NP

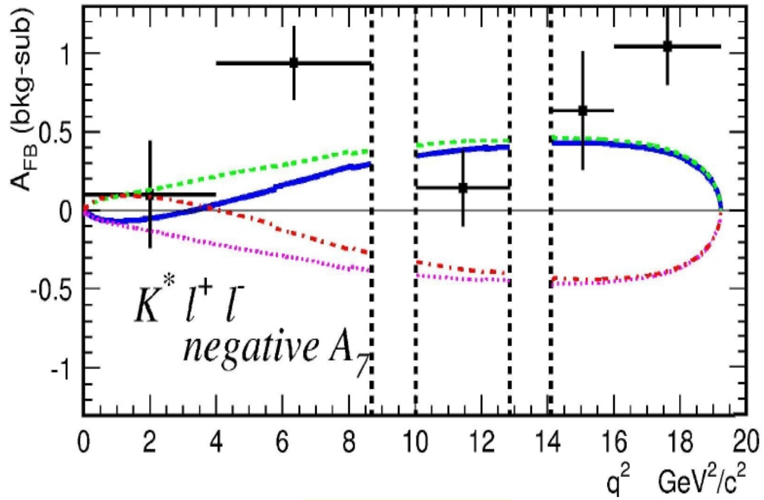


$\ell\ell$ pair forward-backward asymmetry vs q2 is sensitive to NP in the loop, altering the helicity structure

zero crossing predicted with very little theoretical uncertainties





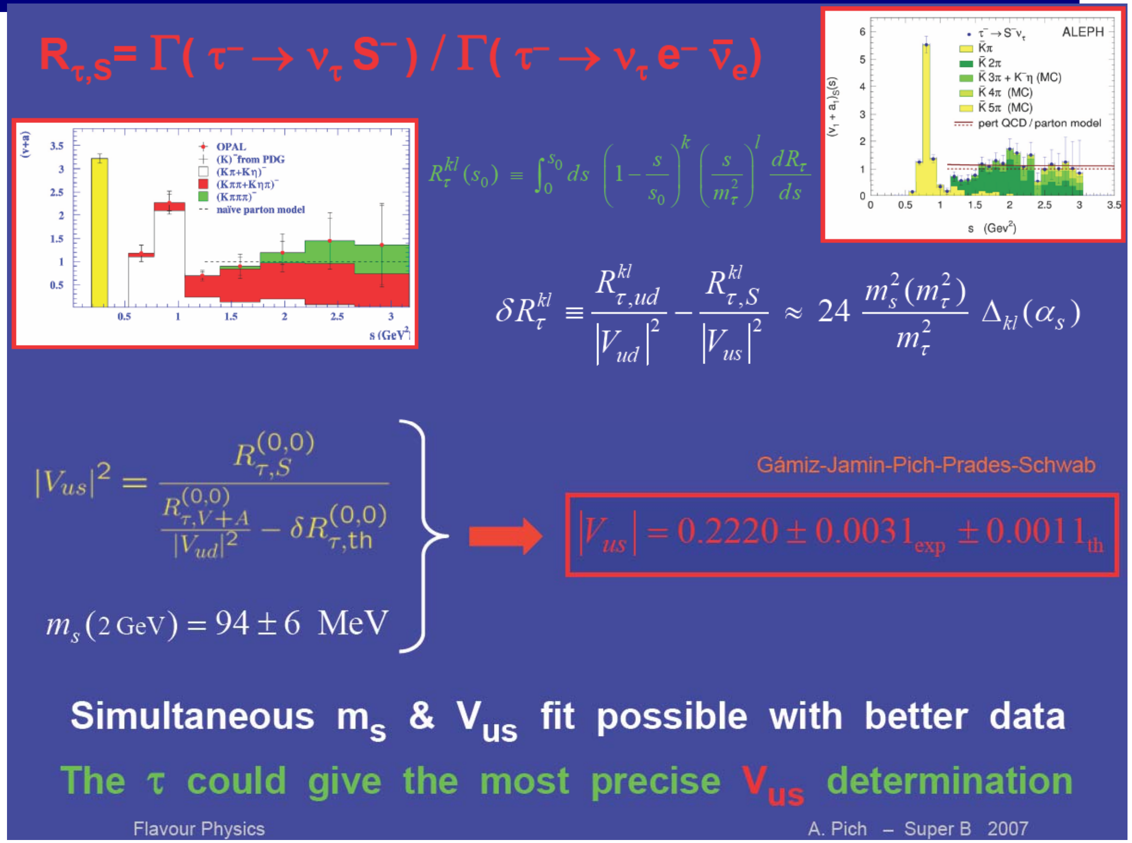


ICHEP06Kovalskyi

τ Richness

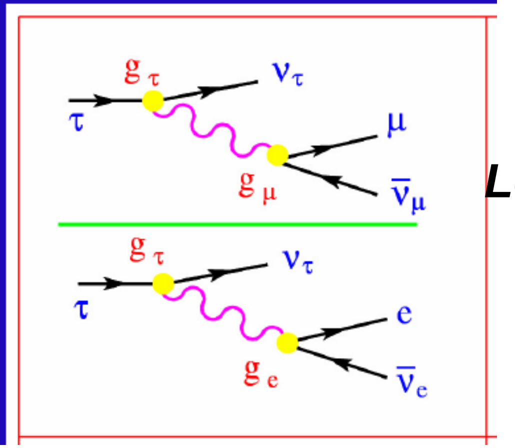
Vus

- τ are an incredibly rich laboratory
- SuperB will produce as many τ's as B's
- Beam polarization possible
- τ magnetic moment measurement

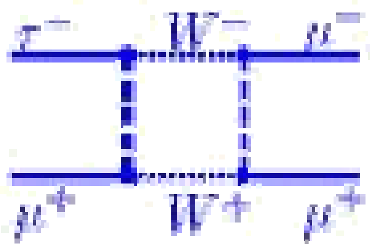


Lepton Universality

$\frac{g_\mu}{g_e}$

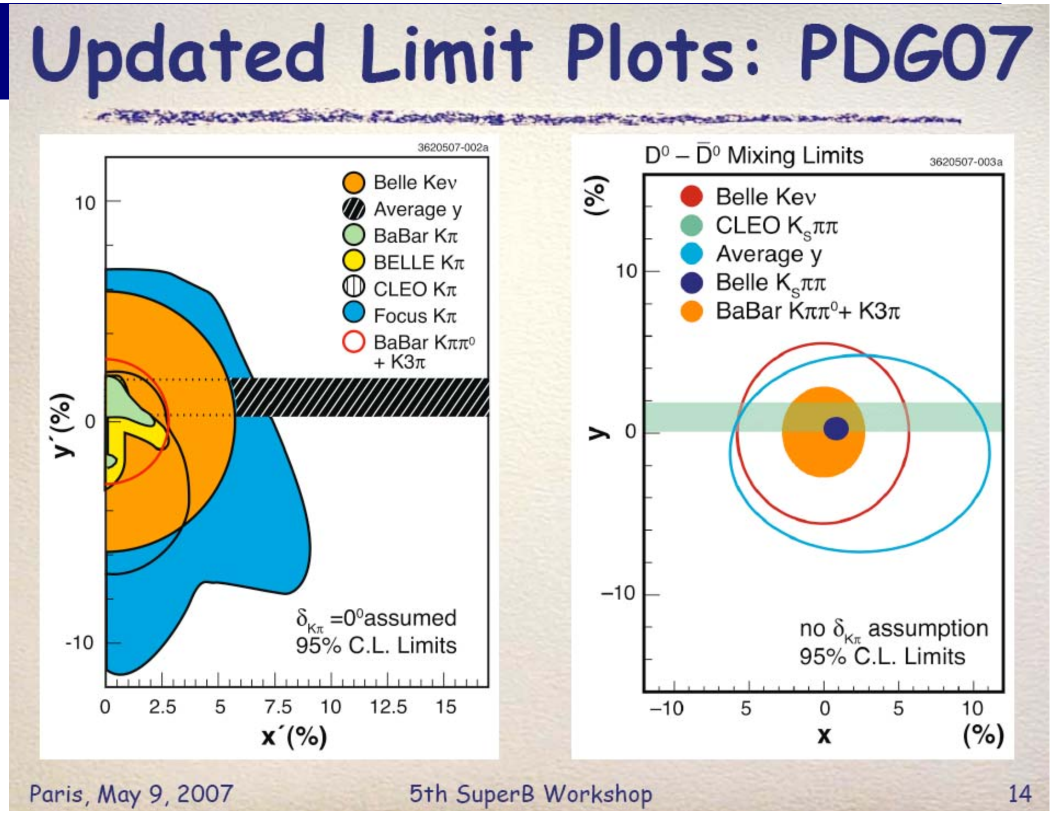


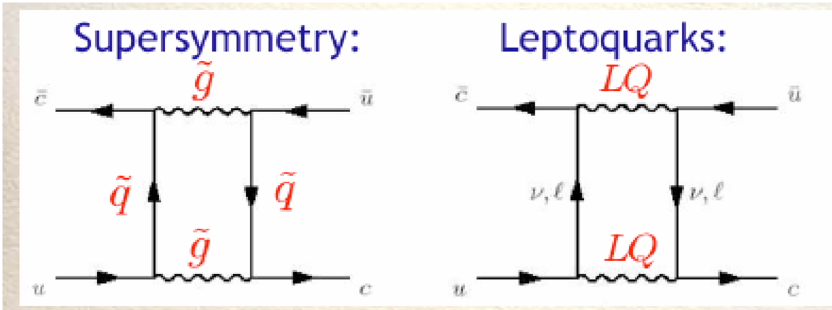
Lepton Flavour Violation direct signal of new physics

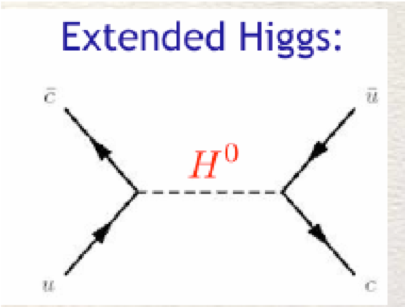


D° mixing

- Recent measurements from Babar and Belle demonstrated Bfactory capabilities in charm physics
- Possibility to measure CP violation in the charm sector







Projected Sensitivity

Exp't / 1 σ	y_{CP} (10^{-3})	y' (10^{-3})	x'^2 (10^{-4})	cosδ
B-factories (2ab^{-1})	2-3	2-3	1-2	-
SuperB (50 ab^{-1})	0.5	0.7	0.3	-
LHCb (10 fb^{-1}) Only B->D*	?	0.7	0.7	-
LHCb (100 fb^{-1}) Prompt D*	?	?	?	-
CLEO-c (750 pb^{-1})	10	-	2-3	0.1-0.2
BESIII (20 fb^{-1})	4	-	0.5-1	0.05
SuperB - 4 GeV (0.2 ab^{-1})	1-2	-	<0.2	<0.05