SuperB at Fermilab

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A Super *B* Factory

- Work has been going on for several years on the design of a Super *B* Factory – an asymmetric (7 on 4 GeV) e^+e^- collider running (primarily) at the $\Upsilon(4S)$ resonance – with a luminosity above 10^{36} $cm^{-2}s^{-1}$
  - For comparison,
    PEP-II (9 on 3.1) runs at 10^{34} (design $3x10^{33}$) and
    KEK-B (8 on 3.5) runs at $1.6x10^{34}$ (design $1x10^{34}$)
- The design of a 10^{36} collider has had several phases:
  - Scaling PEP-II and KEK-B up in current and down in β_y^* (Problem: Wallplug power > 100MW)
  - A linear collider design with high disruption (Problem: High power and poor center of mass energy definition)
  - The current design - A low emittance circular collider, based on the ILC damping rings
    - Wallplug power is the same as PEP-II, backgrounds that scale as I are the same, backgrounds that scale as $\mathcal{L}$, such as $ee\gamma$ at small angles, are higher

Physics Motivation

- Search for New Physics effects in rare b,c and τ decays
- Many of the constraints on beyond-the-Standard Model model-building come from flavor physics
  - *CP* violation
  - ^{197}Hg edm
  - $\mathcal{B}(\mu \to e\gamma,\ \tau \to \mu\gamma)$, ...
- With a 10^{36} Super *B* Factory, data samples of 50 to 100 ab^{-1} will see effects of New Physics in b,c and τ decays
  - The pattern of observed effects is diagnostic of, for example, specific models of SUSY breaking
  - Beam polarization can allow search for τ edm in production, *CPV* in decay
  - The sensitivity extends to, and often beyond, the TeV scale

The pattern of deviation from the SM values is diagnostic

	Model	B_d Unitarity	Time-dep. CPV	Rare B decay	Other signals
SUSY EXAMPLES	mSUGRA (moderate tan β)	-	-	-	-
	mSUGRA (large tan β)	B_d mixing	-	$B \to (D)^* \tau\nu$ $b \to s\ell^+\ell^-$	$B_s \to \mu\mu$ B_s mixing
	SUSY GUT with ν_R	-	$B \to \phi K_S$ $B \to K^*\gamma$	-	B_s mixing τ LFV, n EDM
	Effective SUSY	B_d mixing	$B \to \phi K_S$	$A_{CP}(b\to s\gamma)$ $b \to s\ell^+\ell^-$	B_s mixing
EXTRA DIMENSION EXAMPLES	KK graviton exchange	-	-	$b \to s\ell^+\ell^-$	-
	Split fermions in large extra dimensions	B_d mixing	-	$b \to s\ell^+\ell^-$	$K^0\bar{K}^0$ mixing $D^0\bar{D}^0$ mixing
	Bulk fermions in warped extra dimensions	B_d mixing	$B \to \phi K_S$	$b \to s\ell^+\ell^-$	B_s mixing $D^0\bar{D}^0$ mixing
	Universal extra dimensions	-	-	$b \to s\ell^+\ell^-$ $b \to s\gamma$	$K \to \pi\nu\nu$

A Super B Factory compared to LHC*b*

- The LHC will produce large numbers of *b* quarks, and the LHC*b* experiment is specifically dedicated to the study of *B* decays
  - There is, of course, some overlap between the capabilities of LHC*b* and a new, very high luminosity asymmetric e^+e^- *B* Factory

e^+e^- Super *B* Factory	LHC*b*
CPV in $B\to J/\psi K_S$, $B\to\phi K_S$, $\eta' K_S$,…	*CPV* in $B\to J/\psi K_S$
CPV in $B\to K_S\pi^0\gamma$	Most *B* decays that do not include a ν or γ
$B\to K\nu\nu$, $\tau\nu$, $D^{(*)}\tau\nu$ decays	Time-dependent B_s measurements
Time-independent B_s measurements	$B_{s,d}\to\mu\mu$
Inclusive kinematic distributions in $b\to s\mu\mu$, *see*	B_c and *b* baryons
$\tau\to\mu\gamma$ and other LFV decays	
$D^0\overline{D^0}$ mixing	

Programs are complementary

Where are we now ?

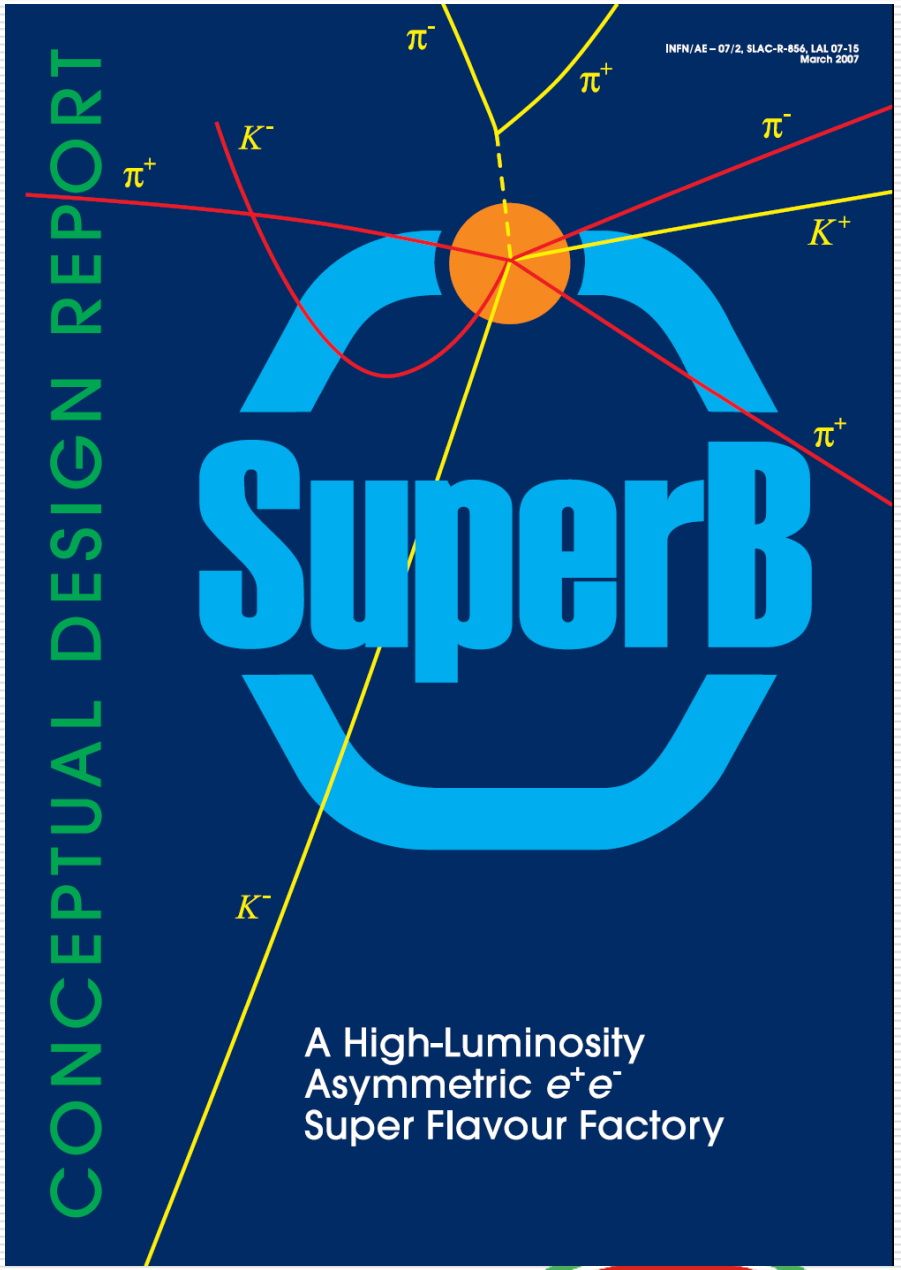
- The low emittance Super*B* design
  - It uses the ILC DR “minimum emittance growth” cell
  - The nominal ILC DR circumference is 6km, the size of the Tevatron ring
- The strategy we have adopted is to scale the design to the circumference of the PEP-II tunnel (2.2 km) and use as many PEP-II components as possible
- The smaller tunnel could be the PEP-II tunnel (unlikely), or a new tunnel near the INFN Frascati laboratory
- The design uses most of the PEP-II magnets and the entire PEP-II RF system
  - An upgrade of *BABAR* is an appropriate detector

The Super*B* CDR is done !

- The CDR

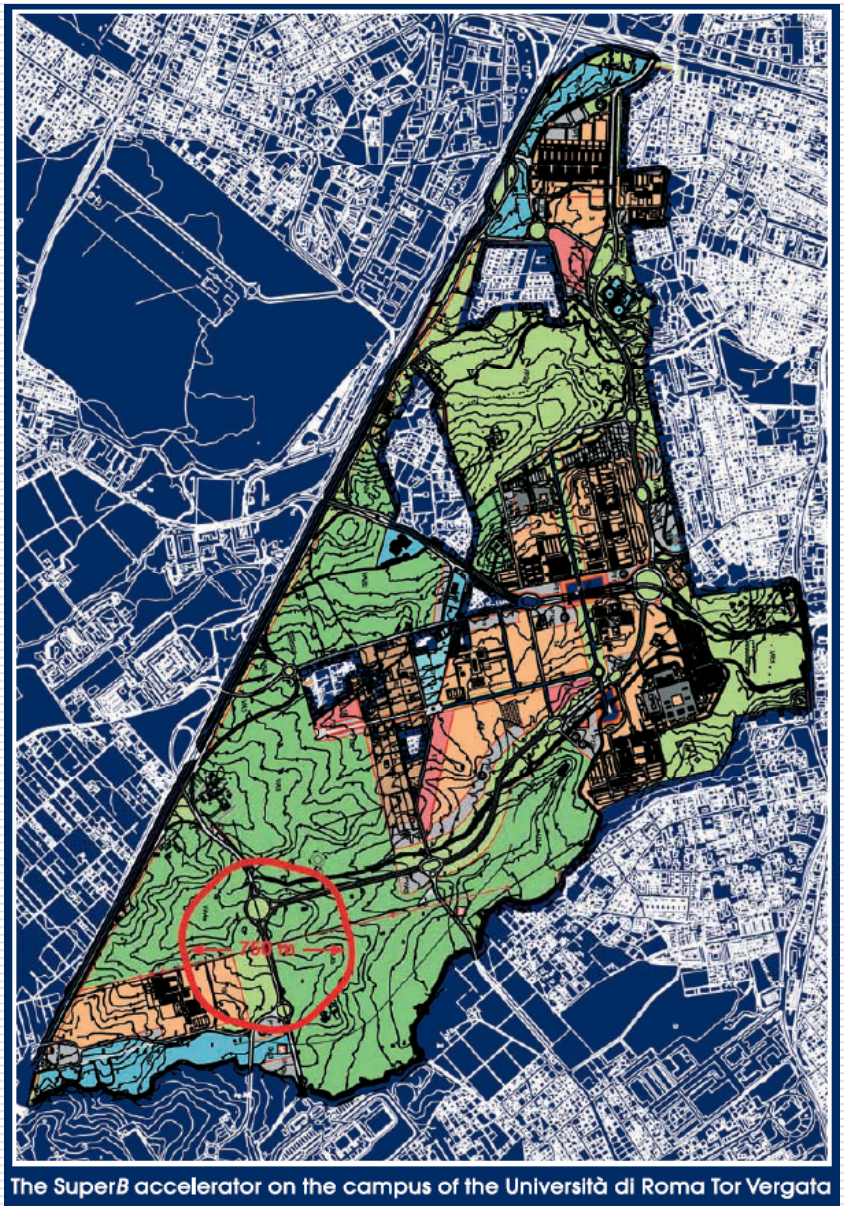
  312 signers
  ~ 260 accelerator+experimental
  ~ 50 theorists

- What use do we make of it?
  - A review committee has been formed by INFN to review the project
  - Work on informing the appropriate European (and non-European) agencies and committees has begun
  - A decision will be made within the next two years



The site of Super*B* on the Tor Vergata campus

- Quite literally a “green field” site
- A lot of work is required
  - Detailed siting study
  - Geological studies for tunnel
  - Ground vibration tests
  - Design and location of support buildings, including the interaction region
  - Provision of utilities
    - Electrical power
    - Chilled water
- Laboratory infrastructure
  - Human resources
  - Engineering
  - Health and safety
  - …….



The Super*B* accelerator on the campus of the Università di Roma Tor Vergata

Super*B* location on the Tor Vergata campus is near INFN Frascati Lab

Super*B* at Fermilab

- There is, of course, a different approach:
  - Build the actual ILC damping rings in the Tevatron tunnel using new components, add a crabbed waist interaction region, and use the complex as a Super *B* Factory while the ILC is being built
- Super*B* can be built on a time scale that would provide an extraordinary midterm physics opportunity of a scale appropriate to Fermilab
  - *BABAR* has ~600 collaborators and has published more than 250 papers and produced ~100 Ph.D. theses
  - Complements the LHC. There will be an ongoing conversation as the details of New Physics are elucidated
- Provides valuable commissioning and operational experience with a low emittance complex prior to ILC

Super*B* at Fermilab

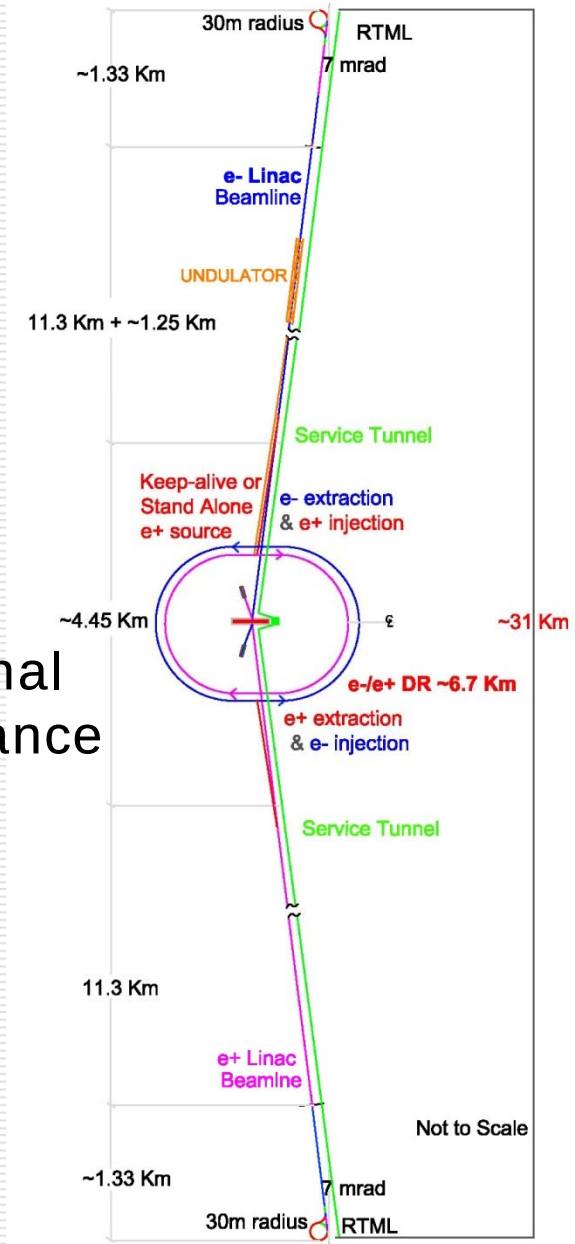
- The Super*B* design can easily be rescaled to the Tevatron tunnel
- The new ILC reference design centralizes the damping rings into a single tunnel
  - Can the ILC arms be built passing through the Fermilab campus?
- Two rings are needed 4 and 7 GeV (ILC nominal is 5 GeV)
  - New dipoles, quads, sextupoles might be required
  - Lots of wigglers (PM or superconducting) needed
  - Would ideally use ILC SC RF system (could start with PEP-II)
- If it were taken as a design constraint, the components of Super*B* in the Tevatron tunnel would be completely reusable as the ILC Damping Rings
  - Does not need the (difficult) fast kickers of the ILC; would be added when Super*B* turns off and ILC commissioning begins
  - The final focus/IR would be specific to Super*B*
  - Polarization components can be developed and incorporated into the ILC DR's

The Super*B* rings resemble the ILC damping rings

Unit	Super*B* LER	Super*B* HER	ILC DRs
Beam energy (GeV)	4	7	5
Circumference (m)	2249	2249	6695
Particles per bunch	6.16×10^{10}	3.52×10^{10}	2×10^{10}
Number of bunches	1733	1733	2767
Average current (A)	2.28	1.30	0.40
Horizontal emittance (nm)	1.6	1.6	0.8
Vertical emittance (pm)	4	4	2
Bunch length (mm)	6	6	9
Energy spread (%)	0.084	0.09	0.13
Momentum compaction	1.8×10^{-4}	3.1×10^{-4}	4.2×10^{-4}
Transverse damping time (ms)	32	32	25
RF voltage (MV)	6	18	24
RF frequency (MHz)	476	476	650

New ILC Reference Design

- The new design has both damping rings in the same tunnel
- Why not build the rings, as soon as possible, in an asymmetric configuration, with a small final focus/interaction region?
  - This allows a strong physics program on an intermediate timescale
  - It focuses accelerator physics efforts directly on the ILC
  - It provides commissioning and operational experience with high current, low emittance damping rings
  - It provides a testbed for work on
    - Injection into a low emittance lattice
    - RF
    - Polarization
    - Fast kickers
    - ……..

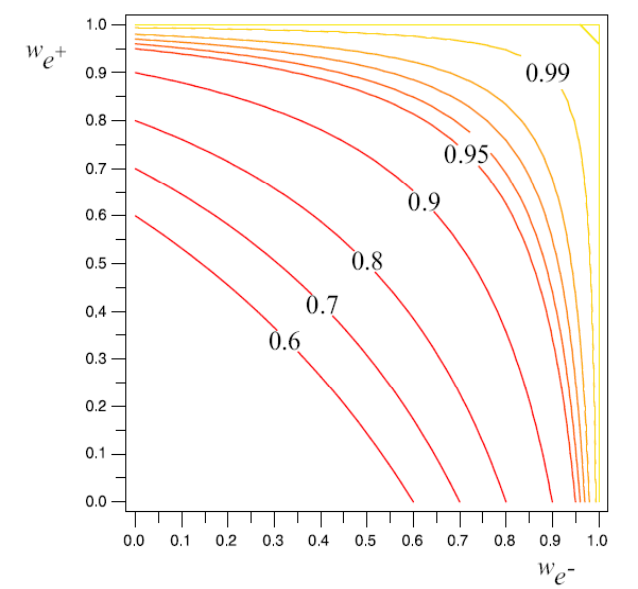


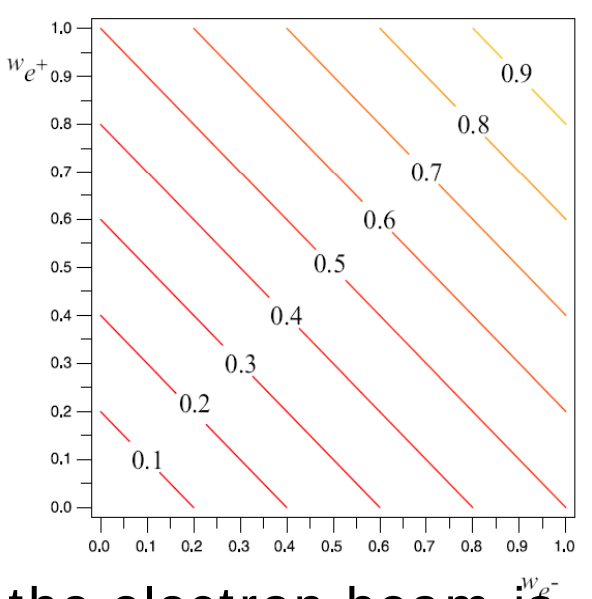
Polarization

- Longitudinally polarizing one or both beams allows search for *T* violation in τ production and/or *CP* violation in τ decay
  - Seeing either of these phenomena is a longshot, but one with a substantial payoff

$$w = \frac{w_{e-} + w_{e+}}{1 + w_{e-} w_{e+}}$$

$$\frac{\mathcal{L}}{\mathcal{L}_0} = 1 + w_{e-} w_{e+}$$





- Longitudinal polarization of the electron beam is straightforward (routine in LSC operation)
- Longitudinal polarization of the positron beam is an interesting R&D project

Super*B* at Tor Vergata. How much?

Costs are presented "ILC-style", with replacement value for reusable PEP-II/*BABAR* components

	EDIA [my]	Labor [my]	M&S [k€]	Replacement value [k€]
Accelerator	452	291	191,166	126,330
Site	119	138	105,700	0
Detector	283	156	40,747	46,471

Value of reusable items from PEP-II and *BABAR*

Disassembly, crating, refurbishment and shipping costs are included in columns to the left

Conclusions

- A Super *B* Factory is an excellent match to the needs of the Fermilab program over the next decade
- It provides a high quality physics opportunity, of the appropriate scale, that would involve quite direct interactions with LHC in unraveling the details of any New Physics discovered there
- It would support a collaboration of the scale of *BABAR* or CDF
- The two rings of Super*B* are essentially the ILC damping rings
  - Construction of these rings would provide focus for ILC R&D, as well as operational experience with a low emittance ring complex
  - Draws on Fermilab's core competence in many relevant areas

- A Super *B* Factory deserves serious consideration as part of Fermilab's future