The SuperB project

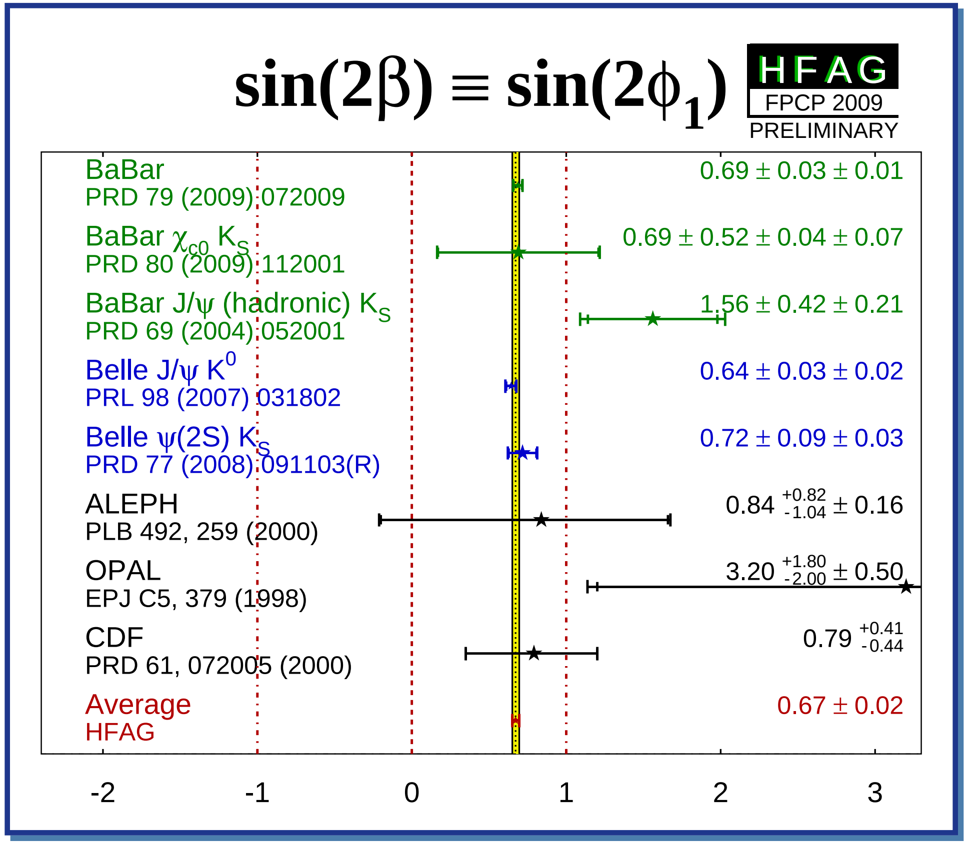
Alberto Lusiani

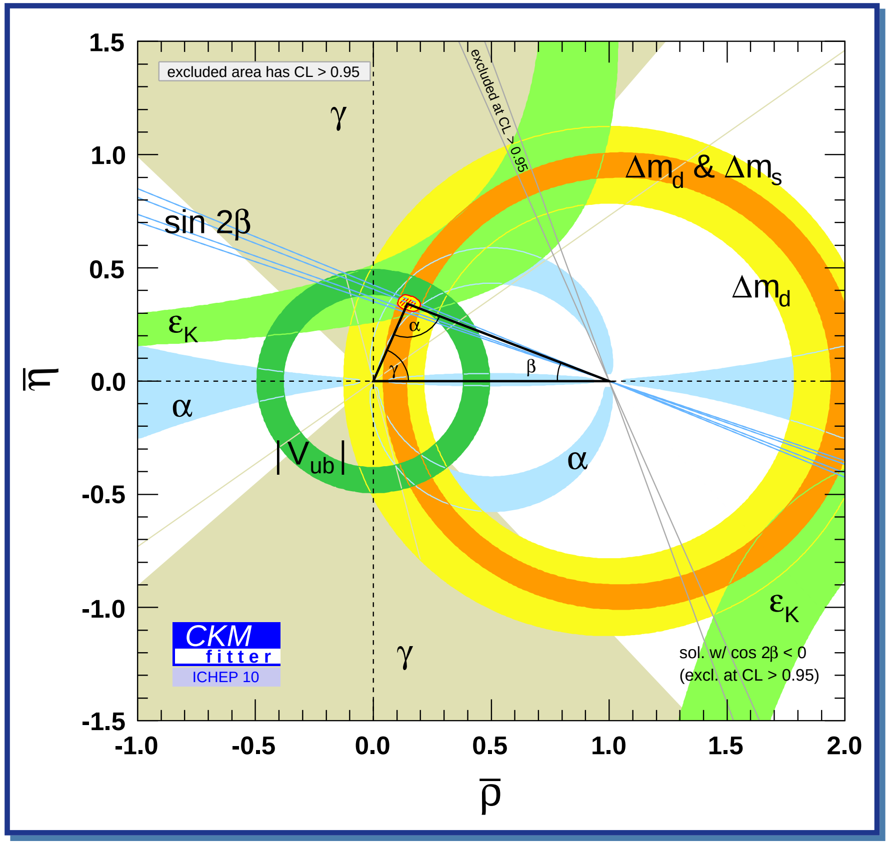
INFN and Scuola Normale Superiore
Pisa

(on behalf of the Super*B* collaboration)

Centro de ciencias de Benasque Pedro Pascual, January 18-21, 2011

B-factories overconstrained Standard Model & searched for New Physics





- **CKM matrix phase main source of CP violation** (2008 Nobel prize to M.Kobayashi & T.Maskawa)
- no evidence (but perhaps few glimpses) of Physics beyond the Standard Model

Physics case for Super*B*

New Physics (NP) expected beyond Standard Model, perhaps at $\Lambda \sim 1$ TeV

Super*B* can search for NP, in a complementary & competivive way with LHC, MEG and other expts

case 1 **LHC finds New Physics (therefore determining Λ)**

- Super*B* can study the flavour structure of NP
- Super*B* can measure the flavour couplings
- Super*B* can search for effects of states even heavier than the LHC direct reach

case 2 **the NP scale is beyond the LHC reach**

- Super*B* can look for indirect NP signals up to $\Lambda \sim 10$ TeV and more

♦ LHCb and MEG have similar abilities but

- some *B* final states are only measurable by Super*B* (with neutrals or missing momentum)
- Super*B* can test tau LFV, *CPV*, EDM, *g*–2
- Super*B* can do useful measurements on entangled charm mesons decays

bottom line: Super*B* provides valuable, unique & complementary tools to advance Physics

The Super*B* project

Super*B* : $\Upsilon(4S)$-peak asymmetric energy e^+e^- Super Flavor Factory which:

- with $L = 10^{36}\,\text{cm}^{-2}\text{s}^{-1}$, can produce $\sim$100$\times$ more *B*s than present B-factories
- has unique and distictive abilities to search for New Physics
- is complementary with LHC (including LHCb), MEG and other experiments

advantages w.r.t. Belle2 (Japanese Super Flavor Factory):

- will provide fruitful competition like it happened between *BABAR* and Belle
- will not be an upgrade of an existing accelerator and is a **modern design for maximum flexibility**
- will use a **80% polarized electron beam**
- will be able to collide at the **Charm threshold** and at

disadvantages w.r.t. Belle2 (Japanese Super Flavor Factory):

- will start later (2-3 years, but better comparison needs planned luminosity evolutions)

Announcement of Super*B* approval in interactions.org

INTERACTIONS.ORG
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Source: INFN
Content: Press Release
Date Issued: 23 December 2010

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The Italian Government Funds the Super-B Accelerator

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

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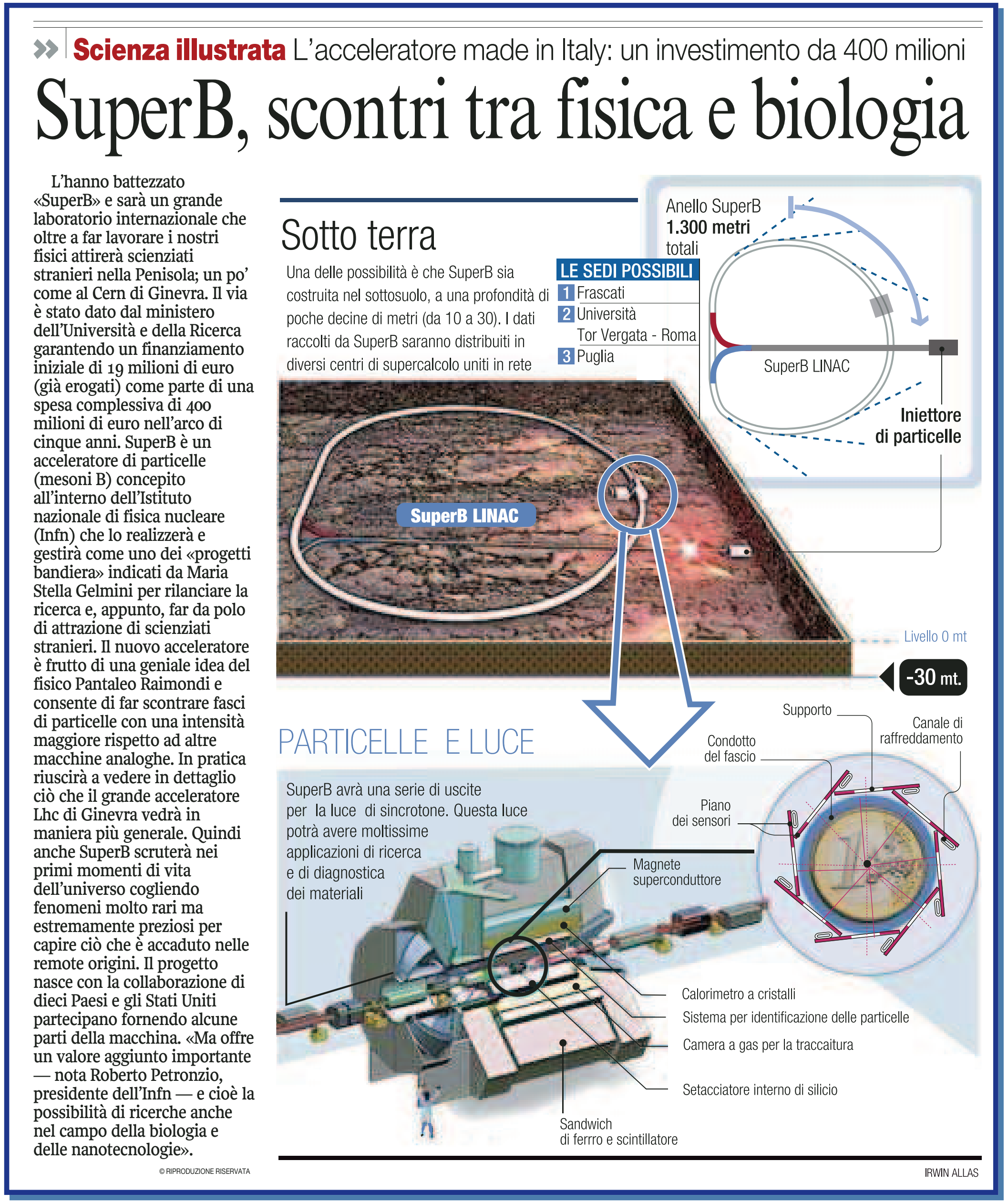


» **Scienza illustrata** L'acceleratore made in Italy: un investimento da 400 milioni

SuperB, scontri tra fisica e biologia

L'hanno battezzato «SuperB» e sarà un grande laboratorio internazionale che oltre a far lavorare i nostri fisici attirerà scienziati stranieri nella Penisola; un po' come al Cern di Ginevra. Il via è stato dato dal ministero dell'Università e della Ricerca garantendo un finanziamento iniziale di 19 milioni di euro (già erogati) come parte di una spesa complessiva di 400 milioni di euro nell'arco di cinque anni. SuperB è un acceleratore di particelle (mesoni B) concepito all'interno dell'Istituto nazionale di fisica nucleare (Infn) che lo realizzerà e gestirà come uno dei «progetti bandiera» indicati da Maria Stella Gelmini per rilanciare la ricerca e, appunto, far da polo di attrazione di scienziati stranieri. Il nuovo acceleratore è frutto di una geniale idea del fisico Pantaleo Raimondi e consente di far scontrare fasci di particelle con una intensità maggiore rispetto ad altre macchine analoghe. In pratica riuscirà a vedere in dettaglio ciò che il grande acceleratore Lhc di Ginevra vedrà in maniera più generale. Quindi anche SuperB scruterà nei primi momenti di vita dell'universo cogliendo fenomeni molto rari ma estremamente preziosi per capire ciò che è accaduto nelle remote origini. Il progetto nasce con la collaborazione di dieci Paesi e gli Stati Uniti partecipano fornendo alcune parti della macchina. «Ma offre un valore aggiunto importante — nota Roberto Petronzio, presidente dell'Infn — e cioè la possibilità di ricerche anche nel campo della biologia e delle nanotecnologie».

Sotto terra

Una delle possibilità è che SuperB sia costruita nel sottosuolo, a una profondità di poche decine di metri (da 10 a 30). I dati raccolti da SuperB saranno distribuiti in diversi centri di supercalcolo uniti in rete

LE SEDI POSSIBILI
1 Frascati
2 Università Tor Vergata - Roma
3 Puglia

PARTICELLE E LUCE

SuperB avrà una serie di uscite per la luce di sincrotone. Questa luce potrà avere moltissime applicazioni di ricerca e di diagnostica dei materiali

IRWIN ALLAS

Corriere della Sera, 18/1/2011

- funding of 400 MEuro reported

Funding figures

- **270 MEuro** in 6 years, starting with 2010
- 19 MEuro already in our hands in December 2010, ∼40 MEuro expected in 2011
- funds from government education and search budget, no increase of Italian science budget
  - all science historical budgets 13% reduced; money used to fund “flagship” projects, incl. Super*B*
  - that made it possible to fund Super*B* in a period of exceptionally tight government budget
  - pending request of money for science (and Super*B*) from outside government science budget
- IIT collaboration to use Super*B* synchroton light for nano- and bio-technology research
- later in presentation: proposed spending profiles

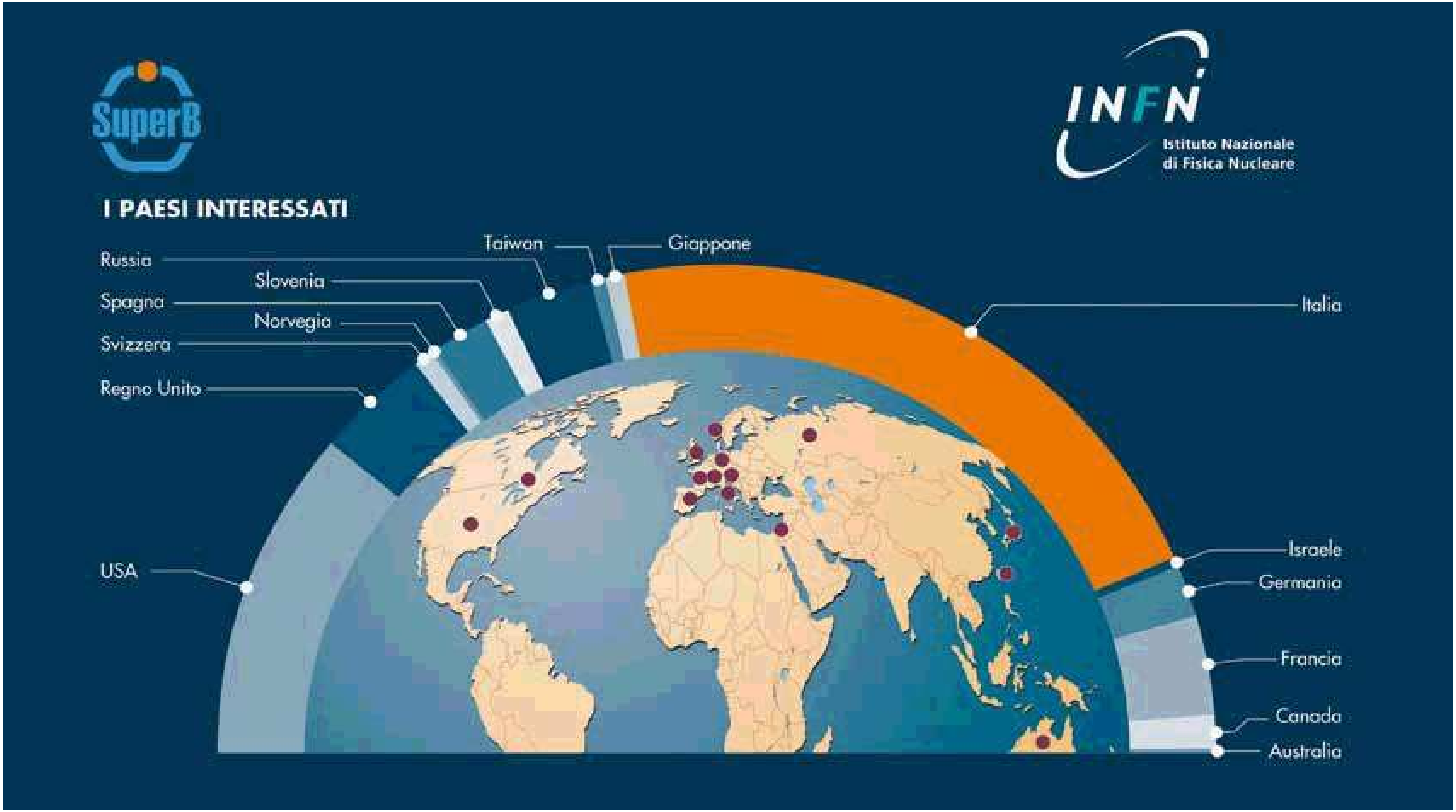
Super*B* proto-collaboration started in 2005

SuperB: A linear high-luminosity B factory, **arXiv:physics/0512235 (2005)**

SuperB Meetings (from INFN Indico web page)

SuperB General Meetings			19
December 2010	XV SuperB General Meeting	Caltech	
September 2010	XIV SuperB General Meeting	Frascati	
May 2010	XIII SuperB General Meeting	Isola d'Elba	
March 2010	XII SuperB General Meeting	LAPP - Annecy	
December 2009	XI SuperB General Meeting	Frascati	
October 2009	X SuperB General Meeting	SLAC	
June 2009	IX SuperB General Meeting	Perugia	
February 2009	VIII SuperB General Meeting	Orsay	
May 2008	VII SuperB General Meeting	Isola d'Elba	
January 2008	VI SuperB General Meeting	Valencia	
May 2007	V SuperB General Meeting	Paris	
November 2006	IV SuperB General Meeting	Monte Porzio Catone	
June 2006	III SuperB General Meeting	SLAC	
March 2006	II SuperB General Meeting	Frascati	
November 2005	**I SuperB General Meeting**	**Frascati**	
Accelerator Meetings			67
Detector			173
Computing Meetings			96
Physics Meetings			13
Steering Committee Meetings			33
International Review Commitee Interactions			4
SuperB Project Board			5
INFN Referee Interactions			8

Expressions of interests for Super*B* (in 2009)

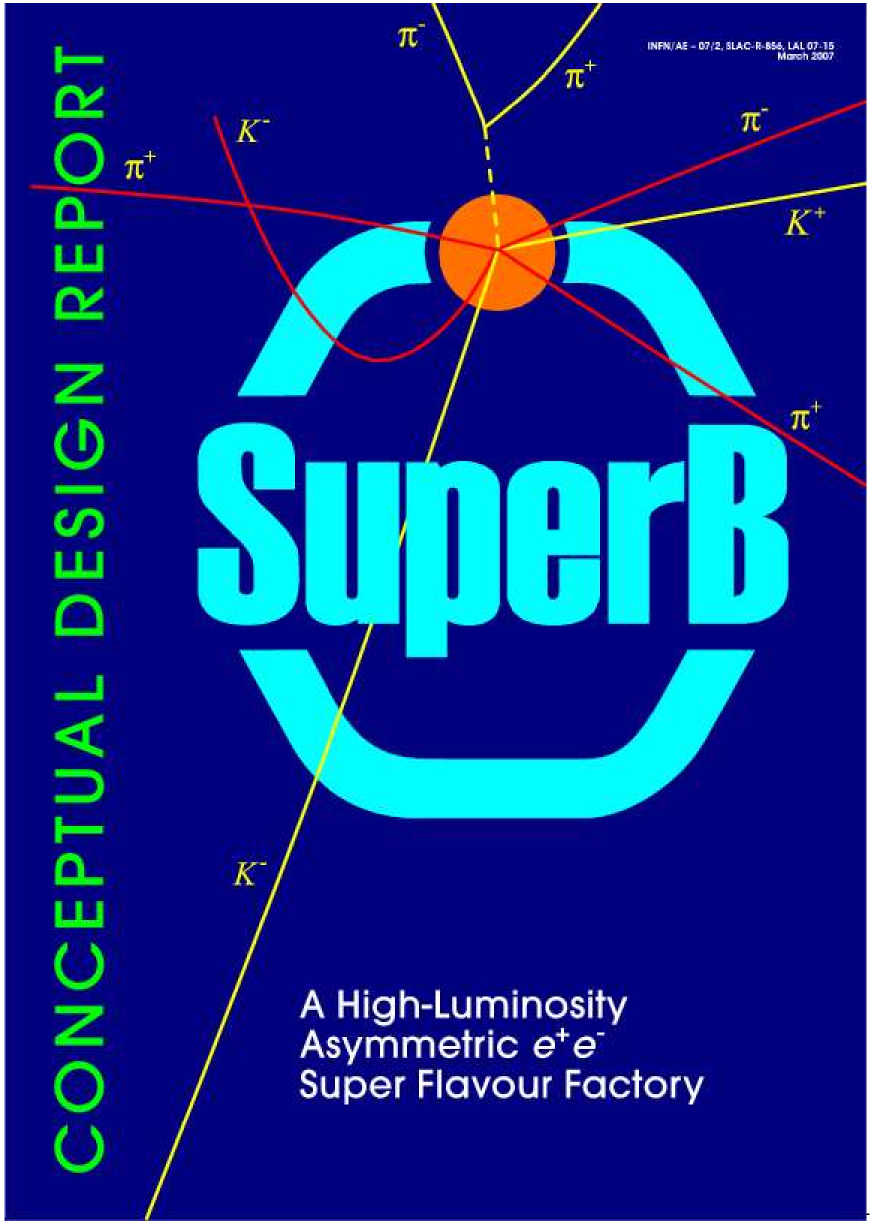


Super*B* collaboration activity

2007	• Conceptual Design Report (CDR) (arXiv:0709.0451v2 [hep-ex])

mid-2010	• accelerator white paper, arXiv:1009.6178v1 [physics.acc-ph]
	• detector white paper, arXiv:1007.4241v1 [physics.ins-det]
	• physics white paper, arXiv:1008.1541v1 [hep-ex]

by Dec 2010	• memorandum of understanding with France, USA, Russia, Canada, Spain
Dec 2010	• after several positive national & international reviews, **Italy funds Super*B***
	• synergies with IIT (synchroton light for nano- and bio-technology)
~now	• select site (panel appointed and working)
	• candidates: Rome/Frascati, Rome/Tor Vergata, Apulia region (Brindisi)
	• prepare European Research Infrastructure Consortium (ERIC)
~end 2011	• Technical Design Report (TDR)
~end 2012	• Physics Book (schedule to be defined)



Conceptual Design Report (2007)

- arXiv:0709.0451v2 [hep-ex]
- 440 pages: Accelerator, Detector, Physics
- cost and schedule of accelerator & detector
- 320 signers from ~80 institutions

White paper

- accelerator: arXiv:1009.6178v1 [physics.acc-ph]
- detector: arXiv:1007.4241v1 [physics.ins-det]
- physics: arXiv:1008.1541v1 [hep-ex]
- **updated costs and schedules**

Super*B*: ~100 B-factories for about the cost of one

- ~100× more intense B-factory using about the same electrical power as *BABAR* &Belle
- ~10×–100× precision improvements in experimental measurements & searches (75 ab^{-1} of data)
- Accelerator
  - ~100× more luminosity than *BABAR* &Belle by using **thinner beams** with **similar currents**
  - since design phase, includes polarized e^- beam, charm threshold ability
  - because of luminosity optimization, reduced beam energy asymmetry w.r.t. *BABAR*, yet ~Belle
  - re-uses part of PEP-II equipment
- Detector is moderately improved *BABAR* detector
  - compensate smaller energy asymmetry with improved vertex detector & resolution
  - faster DAQ and ~100× more powerful computing (mostly provided by technology advancement)
  - re-uses part of *BABAR* apparatus
- ~100× *BABAR* for about the same price, plus garbage recycling, and more

The accelerator

- the most innovative element of Super*B* is the accelerator
- ~100× more luminosity using same power budget: **squeeze beams** or **larger currents & larger ring**
- **larger ring**: less synchroton radiation energy loss but **thicker beam because of less damping**

→ nano-beams (same strategy as ILC)

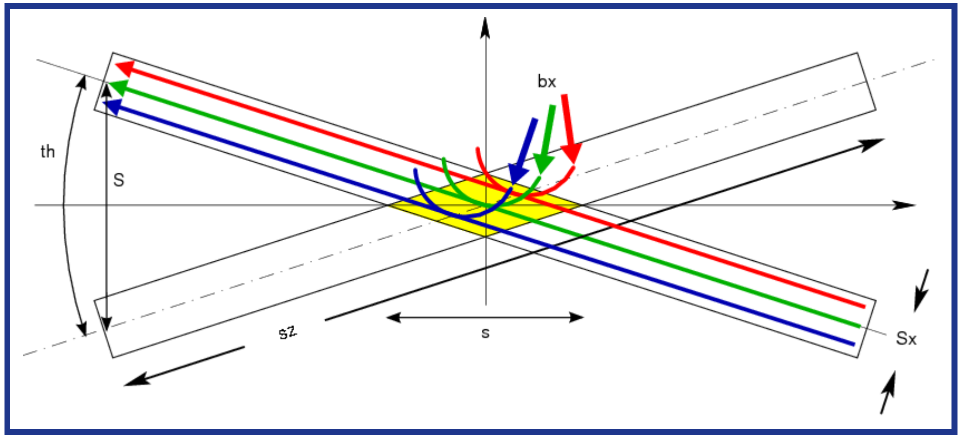
- ~25× thinner beam transverse section $\sigma_x \times \sigma_y$ in storage ring (low emittance)
- ~100× thinner $\sigma_x \times \sigma_y$ at collision (σ_y from ~3 μm to **20–40 nm**) (strong focusing)
- thinner beams → shorter lifetime by factor ~5, i.e. ~5 minutes (need continuous injection)

  however this does not mean significantly higher RF power:
  - to accelerate e^+/e^- one needs 4/7 GeV
  - every 1000 turns, synchroton radiation takes away ~17 GeV, providing beam damping
  - nano-beams have side benefit of moderate increase of background w.r.t. B-factories

Beam-beam effects and instabilities: crab waist scheme

- squeezing beams at the interaction point is not enough, must cope with **beam-beam effects**
- Super*B* approach (P.Raimondi et al.): large Piwinski angle beam crossing and crab waist focusing

Piwinski angle is related to beam crossing angle



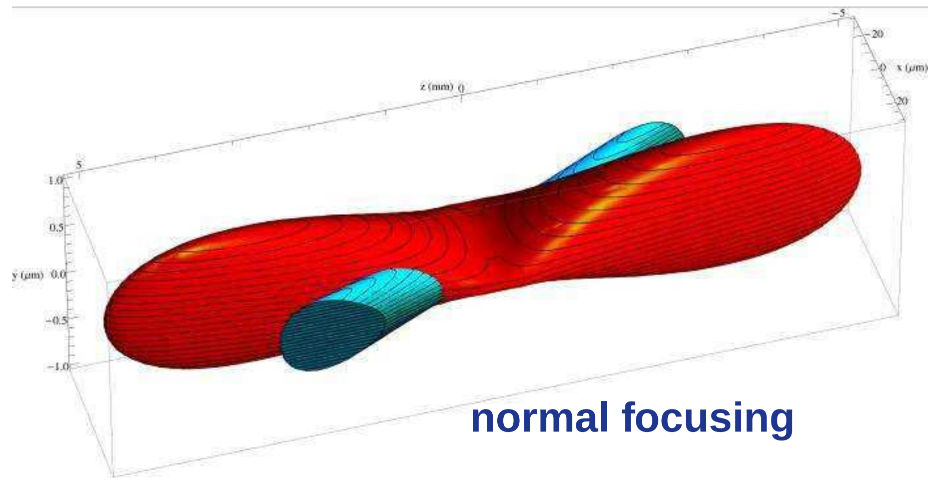
$$L = \frac{N^+ N^-}{4\pi\sigma_y \sqrt{\sigma_x^2 + \tan^2\frac{\theta}{2}\sigma_z^2}} f_c$$

$\sqrt{\sigma_x^2 + \tan^2\frac{\theta}{2}\sigma_z^2} \sim$ beam overlap in xz plane

$$= \sigma_x \sqrt{1 + \left(\tan\frac{\theta}{2}\frac{\sigma_z}{\sigma_x}\right)^2} = \sigma_x \sqrt{1 + \phi^2 (\text{Piwinski})}$$

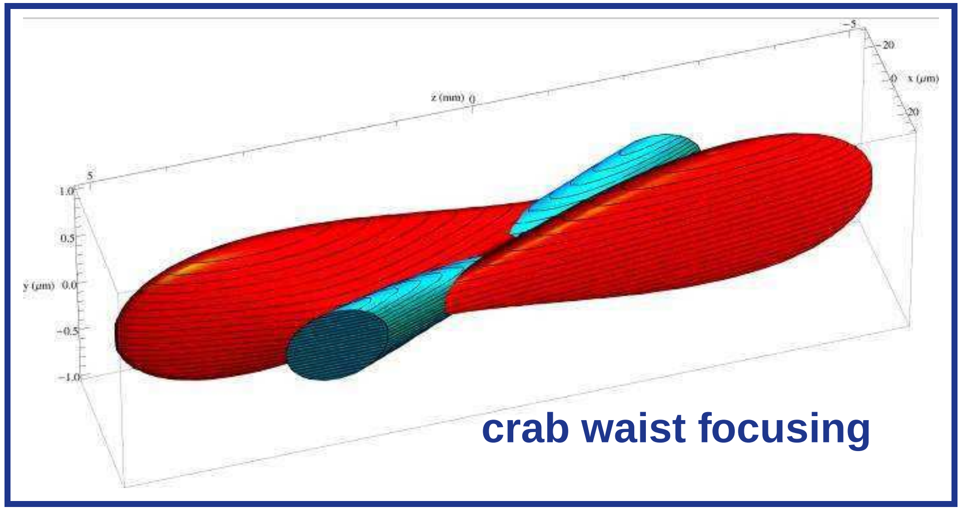
Crab waist scheme

vertical focus waist transverse to same beam



normal focusing

vertical focus waist along other beam



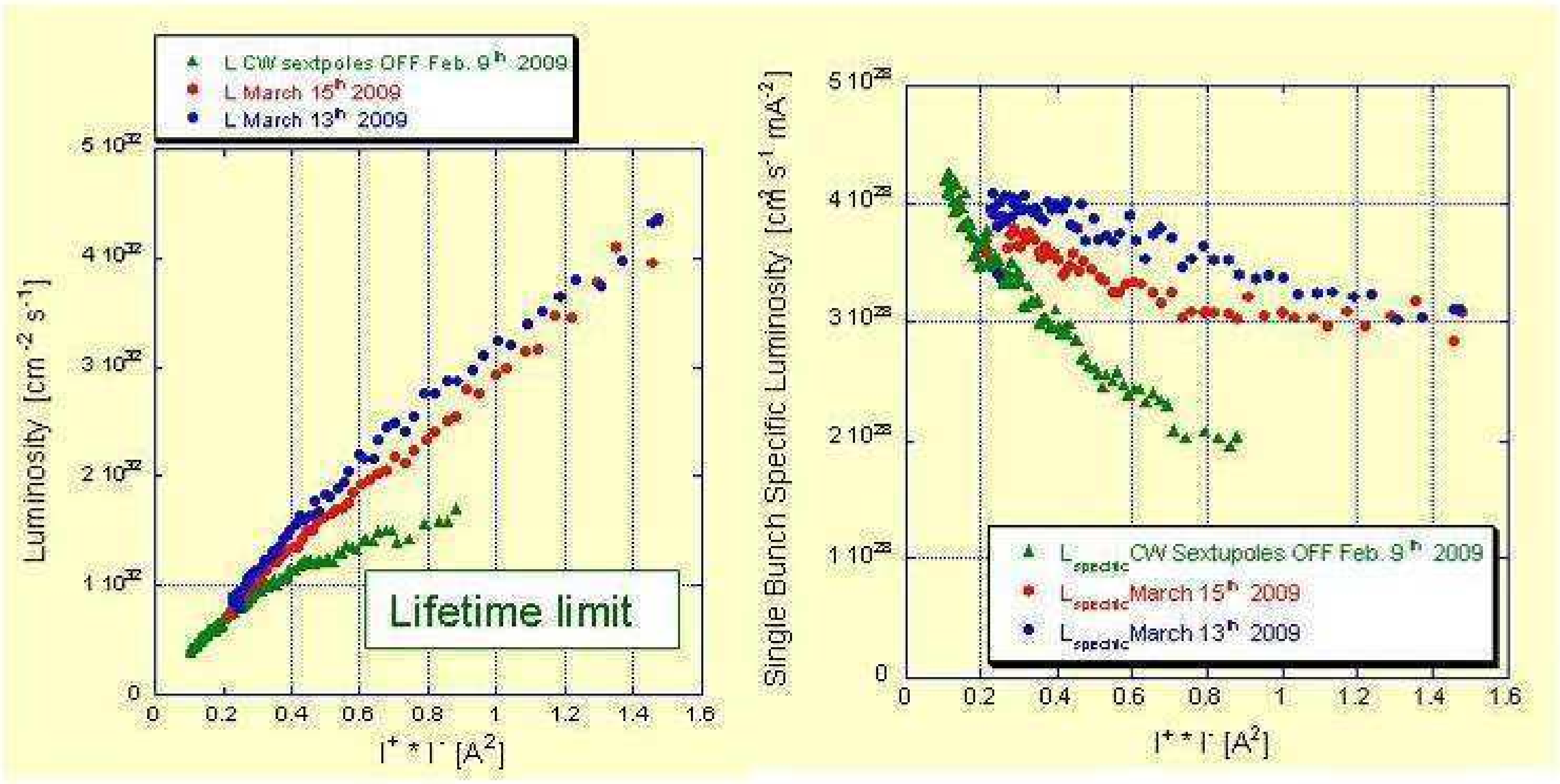
crab waist focusing

- crab waist focusing is obtained with sextupole magnets
- combining crab waist + large Piwiski angle effectively reduces beam-beam luminosity limiting effects

Does the crab waist scheme work? Yes, to the best of our understanding

- accelerator simulations confirm that low enough emittance beams can be accelerated and stored
- accelerator simulations for beam-beam effects confirm that LPA+CW scheme works
- simulation code from different sources (SLAC, CERN, KEK and Frascati) gives similar results
- simulated accelerator operation stable in sizeable parameter space
- **test with Frascati Daϕne** accelerator confirmed predicted 3$\times$ luminosity increase
- details in arXiv:1009.6178v1 [physics.acc-ph] superb accelerator
- also Belle2 seriously considering same scheme

Crab waist scheme successfully tested in Frascati with Daϕne



Present options for accelerator parameters

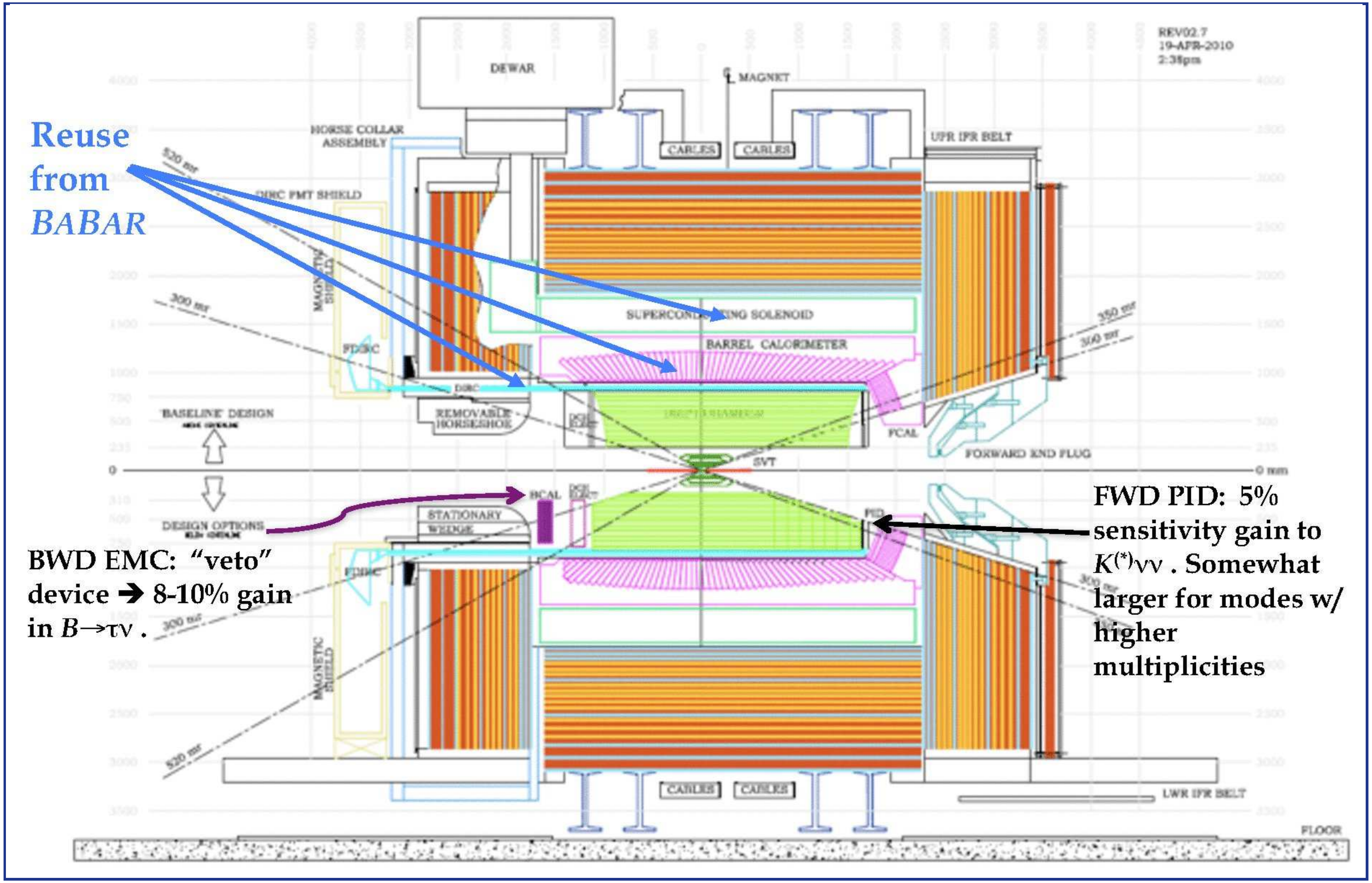
Table 3.1: Super*B* parameters for baseline, low emittance and high current options, and for tau/charm running.

Parameter	Units	Base Line		Low Emittance		High Current		Tau-charm	
		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	
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
Emittance x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
Emittance y	pm	5	6.15	2.5	3.075	10	12.3	13	16
Bunch length (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	MHz	476.		476.		476.		476.	
Revolution frequency	MHz	0.238		0.238		0.238		0.238	
Harmonic number	#	1998		1998		1998		1998	
Number of bunches	#	978		978		1956		1956	
N. Particle/bunch (10^{10})	#	5.08	6.56	3.92	5.06	4.15	5.36	1.83	2.37
σ_x effective	μm	165.22	165.30	165.22	165.30	145.60	145.78	166.12	166.67
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.0254	0.092	0.092
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
Σ_x effective	μm	233.35		233.35		205.34		233.35	
Σ_y	μm	0.050		0.030		0.076		0.131	
Hourglass reduction factor		0.950		0.950		0.950		0.950	
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.097	0.097	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Longitudinal 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	0.17
Momentum compaction (10^{-4})		4.36	4.05	4.36	4.05	4.36	4.05	4.36	4.05
Energy spread (10^{-4}) (full current)	dE/E	6.43	7.34	6.43	7.34	6.43	7.34	6.43	7.34
CM energy spread (10^{-4})	dE/E	5.0		5.0		5.0		5.0	
Total lifetime	min	4.23	4.48	3.05	3	7.08	7.73	11.4	6.8
Total RF Wall Plug Power	MW	16.38		12.37		28.83		2.81	

Super*B* Detector

- similar requirement as B-factories
  - Large solid angle coverage, good lepton ID, $\pi - K$ PID up to 4 GeV
  - resolve B mesons decay time difference
  - good low momentum resolution, good low energy photon energy resolution
- main differences
  - lower machine boost ($\beta\gamma$ = 0.24 vs. $\beta\gamma$ = 0.56 in *BABAR*)
    ⟶ need to improve vertex detector resolution ⟶ SVT layer 0
  - much higher luminosity (and L-scaling background rates)
    ⟶ faster & more robust detectors
    ⟶ open, 100% efficient trigger
- thanks to low currents, can re-use parts of *BABAR* detector

Super*B* Detector



Super*B* Physics reach

- physics reach recently updated in **Super*B* white paper, arXiv:1008.1541v1 [hep-ex]**
- some results assume reasonable progress in QCD lattice computations
- in some cases, experimental measurements, e.g. on charm mesons, can reduce limiting systematics
- fair share of measurements is **not systematically limited** $\longrightarrow$ $\boldsymbol{L = 1 \cdot 10^{36}}$ **worth doing**

Super*B* strong-points:

- *B* physics measurements and searches with π^0, γ or many K^0's cannot be done at LHC
- most tau measurements and searches cannot be done at LHC
- **charm threshold production**: no competitor for measurements based on entanglement
- **beam polarization** allows
  - improved tau physics, with advantages over Belle2
  - even precision electro-weak physics (not presented here, see white paper)

Super$B$ $\Upsilon(4S)$ B Physics reach, 1

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°

† exp. syst. limited

∗ theory syst. limited

most measurements with π^0, γ, ν, many K^0's cannot be done at LHCb

Super*B* $\Upsilon(4S)$ *B* Physics reach, 2

Observable	*B* Factories (2 ab^{-1})	Super*B* (75 ab^{-1})
$\lvert V_{cb}\rvert$ (exclusive)	4% ($*$)	1.0% ($*$)
$\lvert V_{cb}\rvert$ (inclusive)	1% ($*$)	0.5% ($*$)
$\lvert V_{ub}\rvert$ (exclusive)	8% ($*$)	3.0% ($*$)
$\lvert V_{ub}\rvert$ (inclusive)	8% ($*$)	2.0% ($*$)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († $*$)
$A_{CP}(B \to \rho\gamma)$	$\sim$ 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%
$\mathcal{B}(B \to K\nu\overline{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\overline{\nu})$	–	possible

† exp. syst. limited

$*$ theory syst. limited

most measurements with π^0, γ, ν, many K^0's cannot be done at LHCb

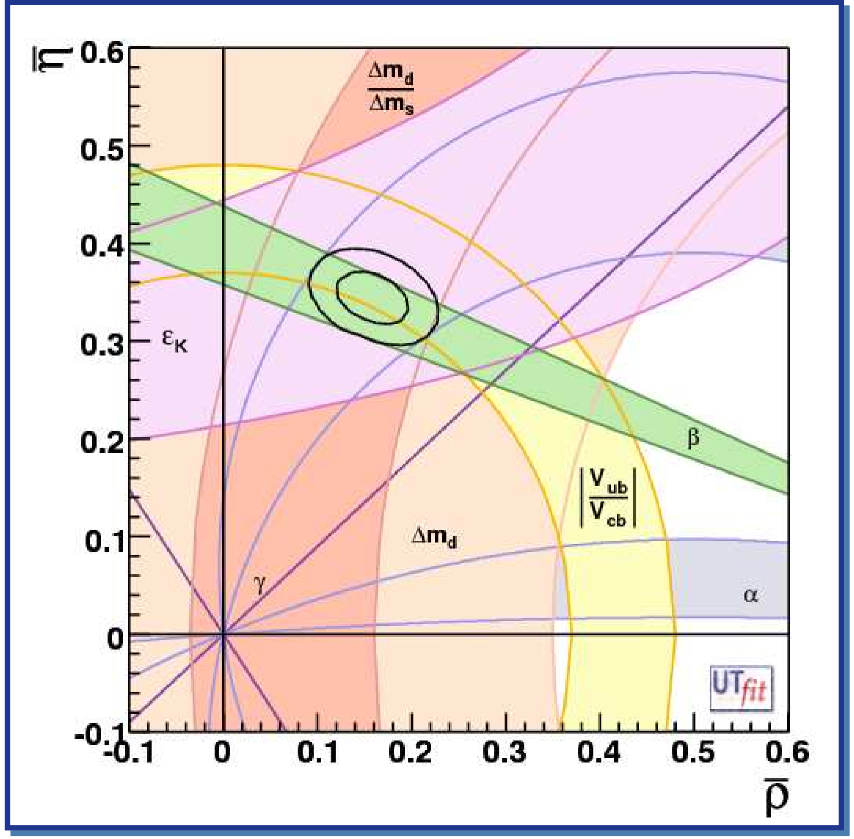
Super*B* $\Upsilon(5S)$ B_s Physics reach

Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A^s_{SL}	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\overline{K}^0$	24°	11°

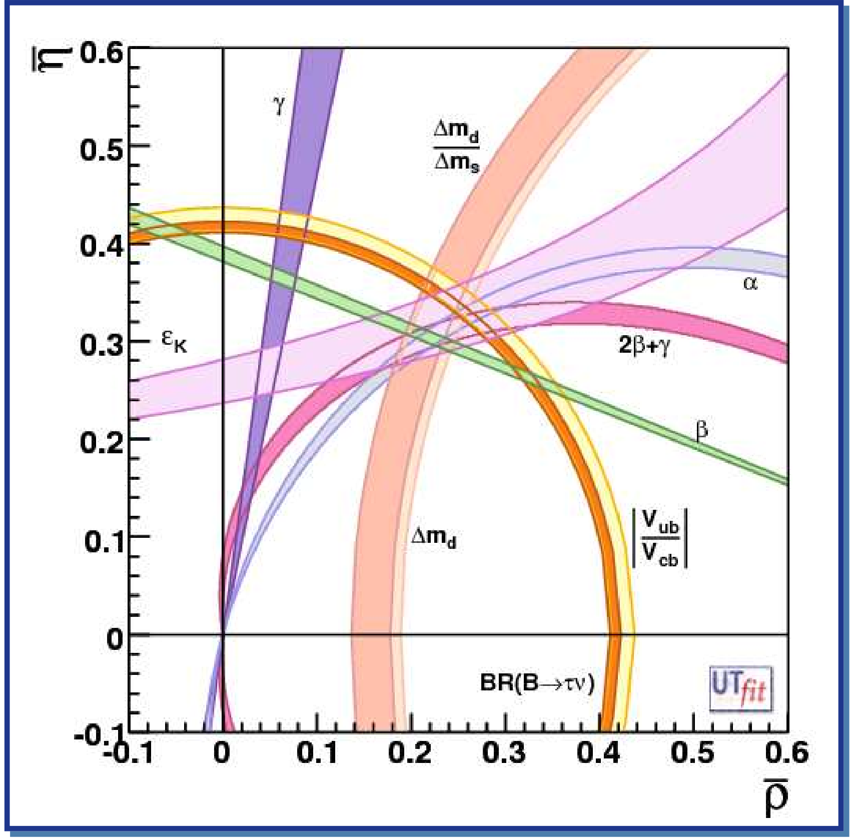
- LHCb in general is more competitive for B_s measurements, but there are a few exceptions

Super*B* *B* Physics reach, CKM fit

2006

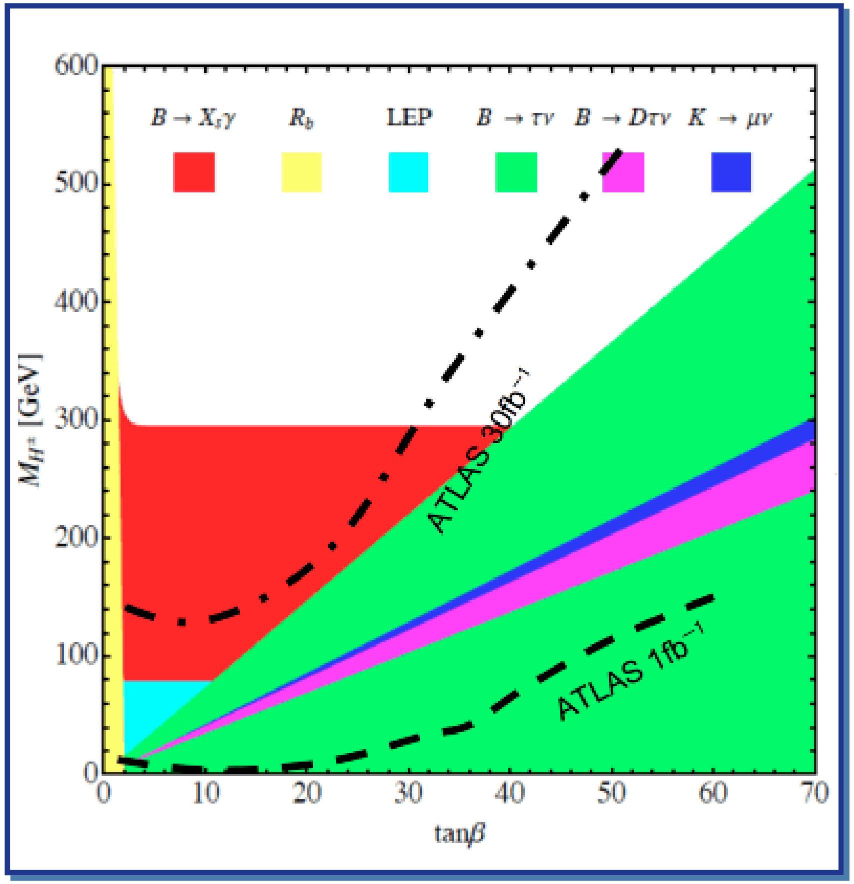


Super*B* & future lattice QCD calculations



- bands show 95% constraints

Super*B* *B* Physics reach, MSSM charged Higgs hunt



- $B \to \tau\nu$ can exclude large MSSM parameters space, competitive with LHC
- ATLAS limits for 1 and 30 fb^{-1} at 14 TeV superposed

Super*B* Charm Physics reach

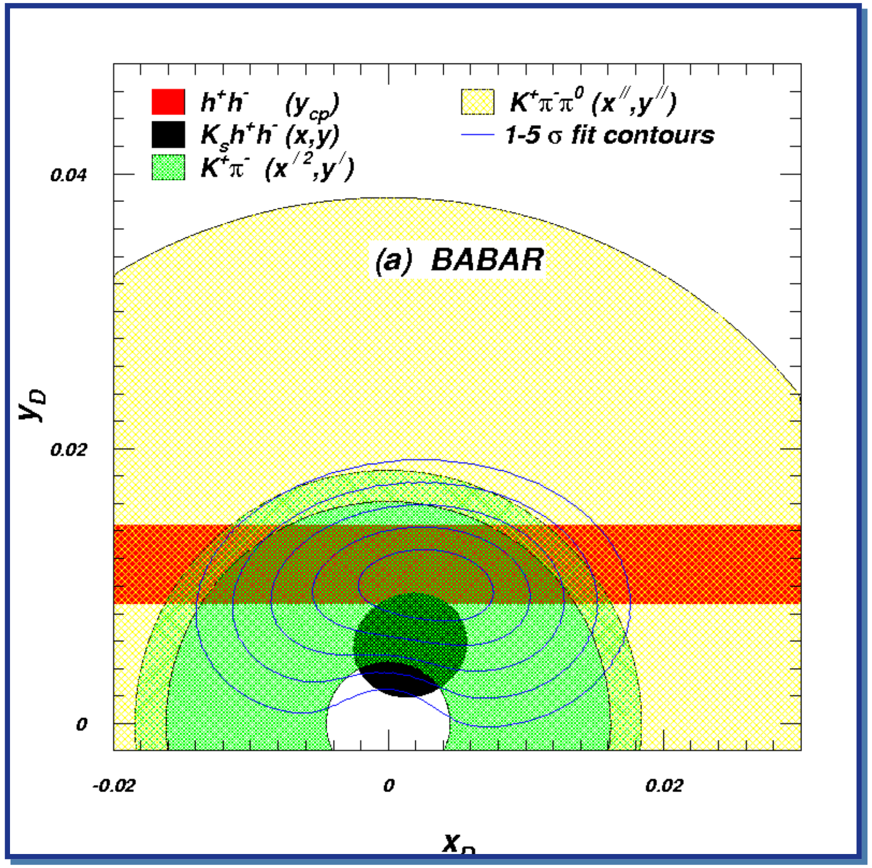
Charm mixing and *CPV*

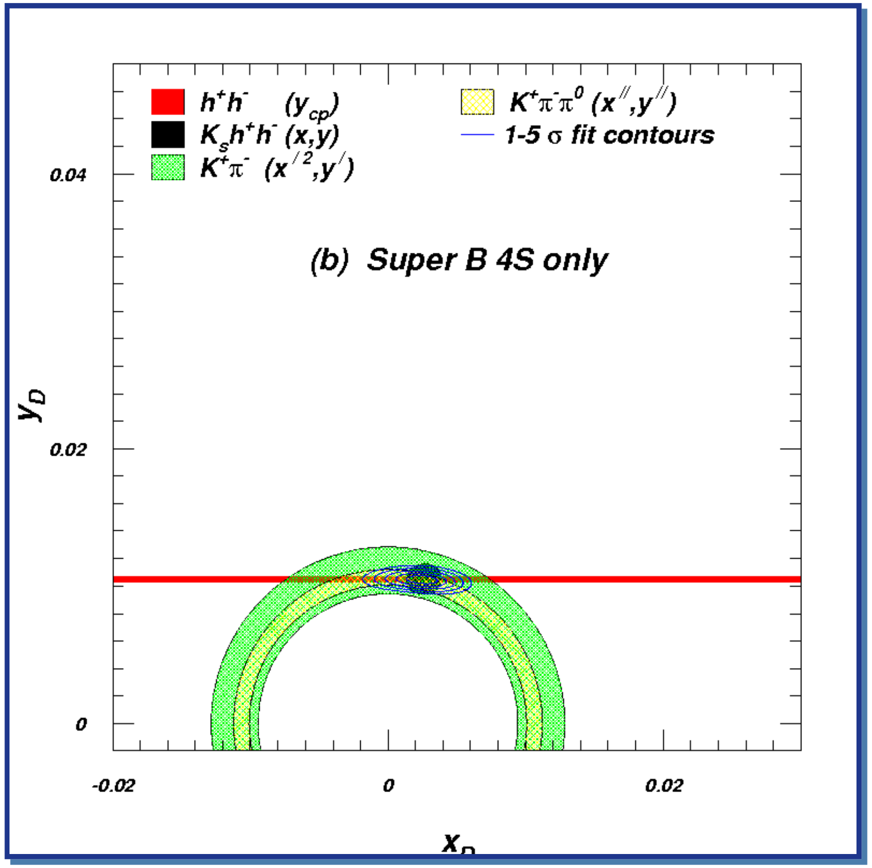
Mode	Observable	*B* Factories 2 ab^{-1}	Super*B* 75 ab^{-1}
$D^0 \to K^+K^-$	y_{CP}	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
$D^0 \to K^+\pi^-$	y'_D	$2\text{–}3 \times 10^{-3}$	7×10^{-4}
	x'^2_D	$1\text{–}2 \times 10^{-4}$	3×10^{-5}
$D^0 \to K^0_S\pi^+\pi^-$	y_D	$2\text{–}3 \times 10^{-3}$	5×10^{-4}
	x_D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

Charm FCNC

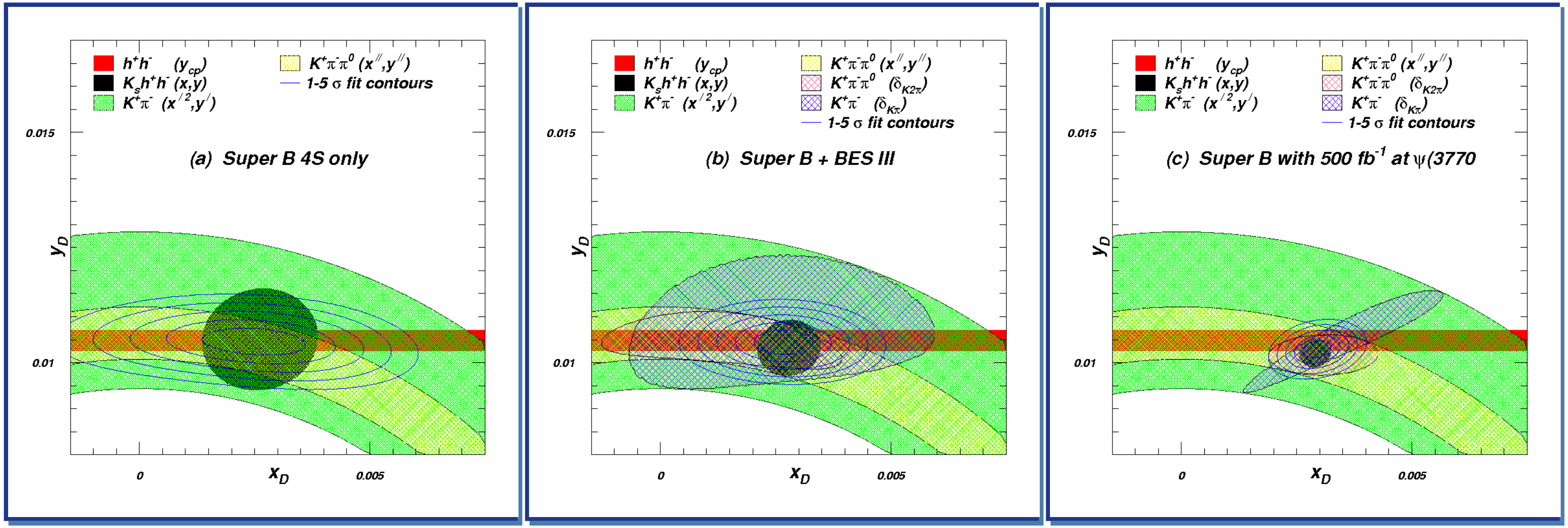
Channel	Sensitivity
$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$	1×10^{-8}
$D^0 \to \pi^0e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$	2×10^{-8}
$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$	3×10^{-8}
$D^0 \to K^0_S e^+e^-$, $D^0 \to K^0_S\mu^+\mu^-$	3×10^{-8}
$D^+ \to \pi^+e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$	1×10^{-8}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

Super*B* D^0–mixing reach, using only $\Upsilon(4S)$ data





Super*B* D^0–mixing reach, using also charm threshold data



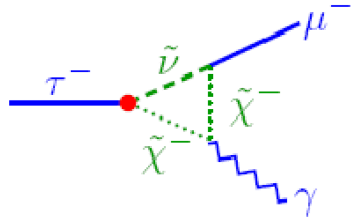
- entangled *D* mesons produced at threshold used to measure Dalitz strong phases

Super*B* Tau Physics NP probes

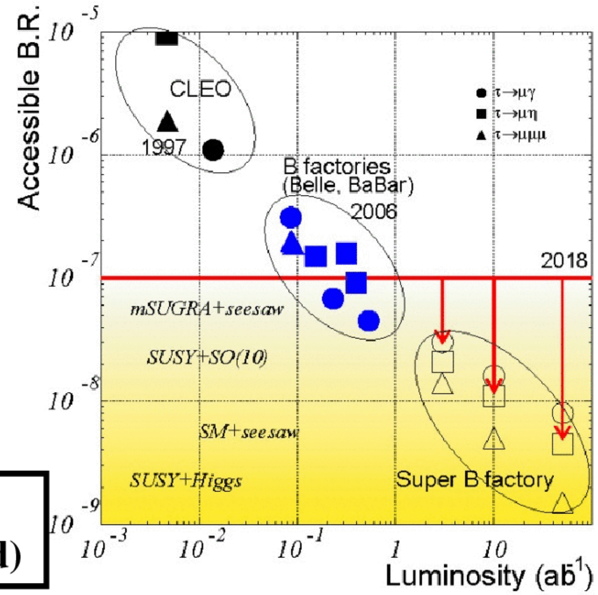
- Lepton Flavor violation in tau decays
  - many NP models predict tau LFV within Super*B* sensitivity
  - unambiguous NP probe, negligible theory uncertainties
  - MSSM-seesaw “naturally” expects some BRs in the sensitivity range of Super*B*
  - Super*B* is complementary with LHC and MEG
    ($\mu \to e\gamma$ can be accidentally suppressed, tau measurements are complementary)
  - best channels: $\boldsymbol{\tau \to \mu\gamma, \tau \to 3\ell, \tau \to \mu\rho, \tau \to \mu\eta}$
- Tau g–2
  - if MSSM explains today's $\Delta a_\mu \approx 3{\cdot}10^{-9}$ discrepancy ⟶ $\boldsymbol{\Delta a_\tau \approx m_\tau^2/m_\mu^2 \cdot \Delta a_\mu \approx 1{\cdot}10^{-6}}$
  - Super*B* sensitivity is in the range of such prediction
- Tau EDM and CPV
  - Super*B* sensitive to some few NP model CPV effects
  - tau EDM constrained by electron EDM upper limit to a range inaccessible by Super*B* despite Super*B* can substantially improve the existing limits
- all: **beam polarization improves precision & helps discriminating NP models**

Lepton Flavour Violation in τ decays

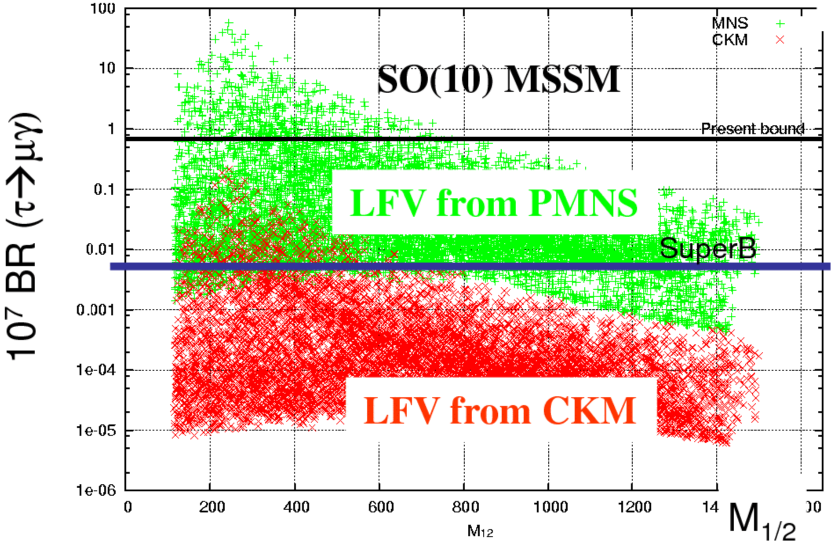
Process	Sensitivity
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to e\gamma)$	2×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}
$\mathcal{B}(\tau \to eee)$	2×10^{-10}
$\mathcal{B}(\tau \to \mu\eta)$	4×10^{-10}
$\mathcal{B}(\tau \to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau \to \ell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



MEG sensitivity μ→eγ ~10^{-13}
(can be accidentally suppressed)



Measurements and origin of LFV



Discrimination between SUSY and LHT

ratio	LHT	MSSM (dipole)	MSSM (Higgs)
$\frac{\mathcal{B}(\tau^- \to e^- e^+ e^-)}{\mathcal{B}(\tau \to e\gamma)}$	0.4...2.3	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{\mathcal{B}(\tau^- \to \mu^- \mu^+ \mu^-)}{\mathcal{B}(\tau \to \mu\gamma)}$	0.4...2.3	$\sim 2 \cdot 10^{-3}$	0.06...0.1
$\frac{\mathcal{B}(\tau^- \to e^- \mu^+ \mu^-)}{\mathcal{B}(\tau \to e\gamma)}$	0.3...1.6	$\sim 2 \cdot 10^{-3}$	0.02...0.04
$\frac{\mathcal{B}(\tau^- \to \mu^- e^+ e^-)}{\mathcal{B}(\tau \to \mu\gamma)}$	0.3...1.6	$\sim 1 \cdot 10^{-2}$	$\sim 1 \cdot 10^{-2}$
$\frac{\mathcal{B}(\tau^- \to e^- e^+ e^-)}{\mathcal{B}(\tau^- \to e^- \mu^+ \mu^-)}$	1.3...1.7	~ 5	0.3...0.5
$\frac{\mathcal{B}(\tau^- \to \mu^- \mu^+ \mu^-)}{\mathcal{B}(\tau^- \to \mu^- e^+ e^-)}$	1.2...1.6	~ 0.2	5...10

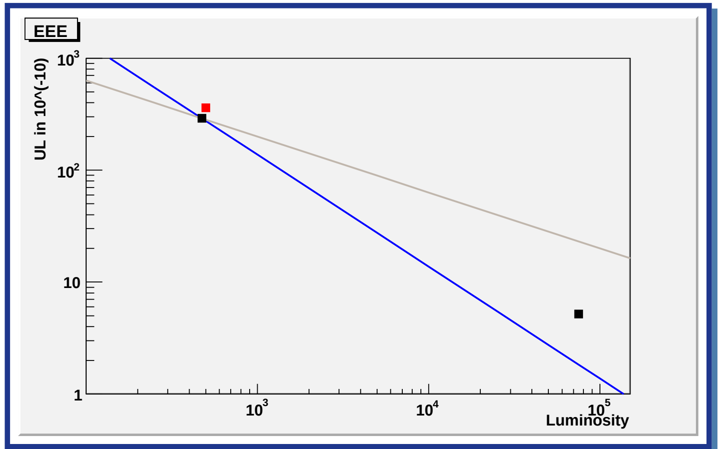
The ratio τ→ lll / τ→ μγ is not suppressed in LHT by α_e as in MSSM

SuperB sensitivity to Tau LFV

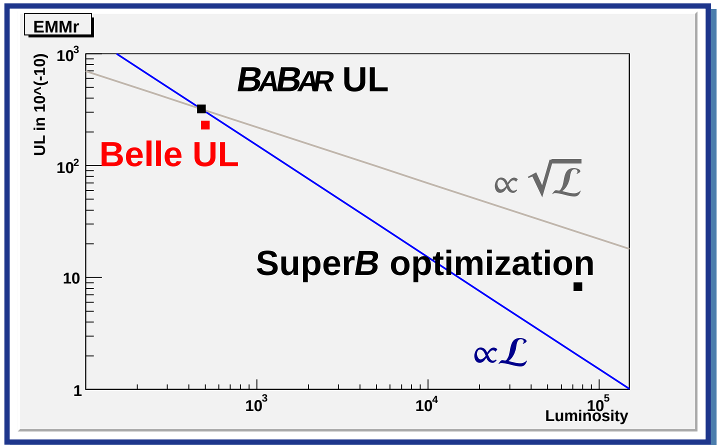
- repeating BABAR analysis insures an improvement of $\sqrt{\mathcal{L}_{\text{SuperB}}/\mathcal{L}_{\text{BABAR}}} \approx \sqrt{150} \approx 12$
- if n. of expected background events ~1 events, improvement of $\mathcal{L}_{\text{SuperB}}/\mathcal{L}_{\text{BABAR}} \approx 150$
- some of previous slide estimates have been refined and updated in the white paper

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

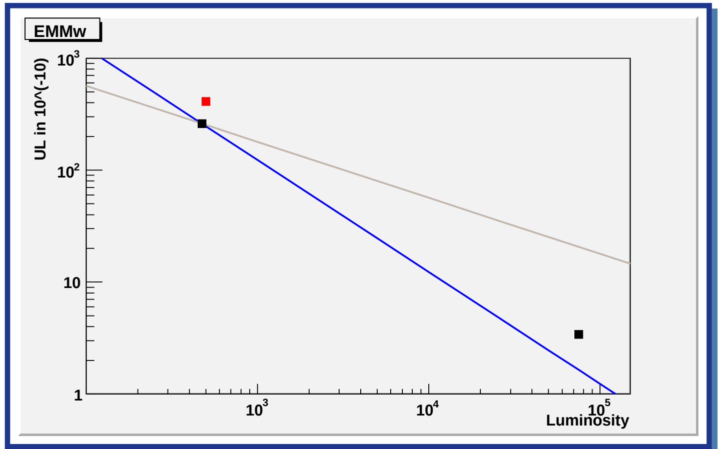
$\tau \to 3\ell$ 90% CM upper limit extrapolations: $\propto \mathcal{L}$ vs. $\propto \sqrt{\mathcal{L}}$ vs. re-optimization



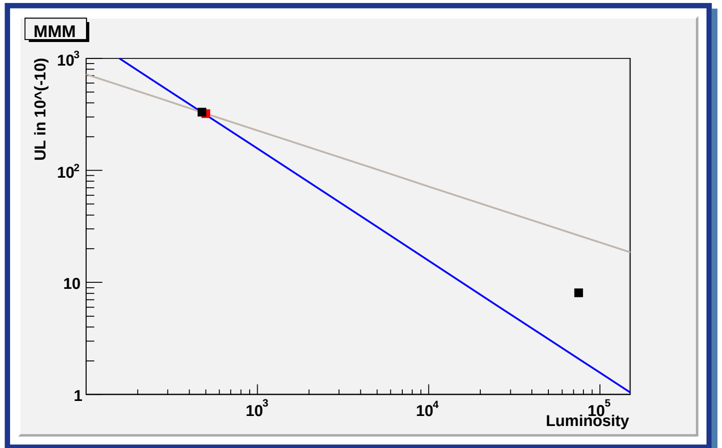
$\tau \to eee$



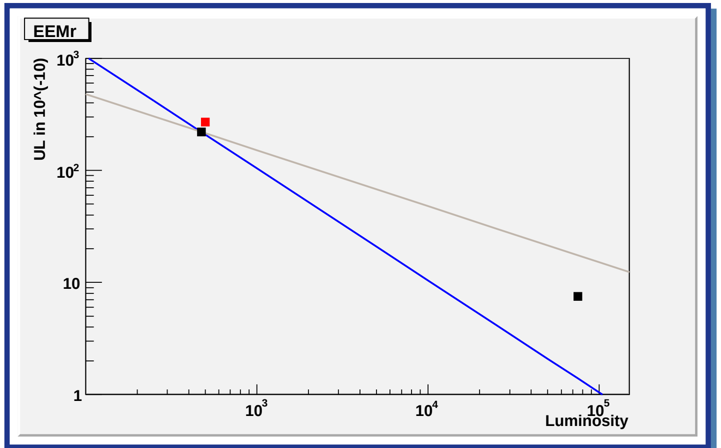
$\tau \to e\mu+\mu-$



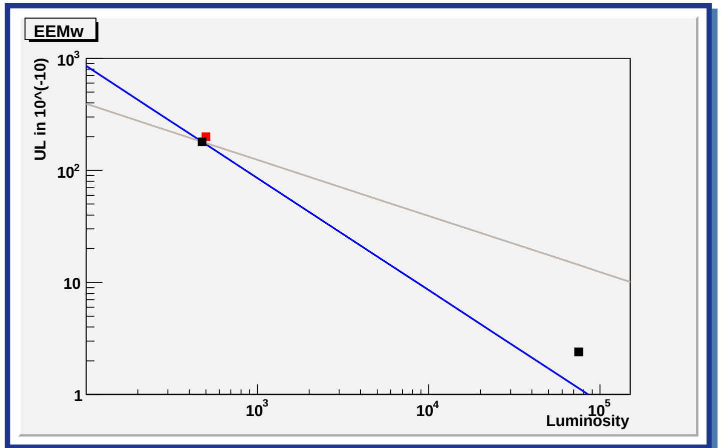
$\tau- \to e+\mu-\mu-$



$\tau \to \mu\mu\mu$

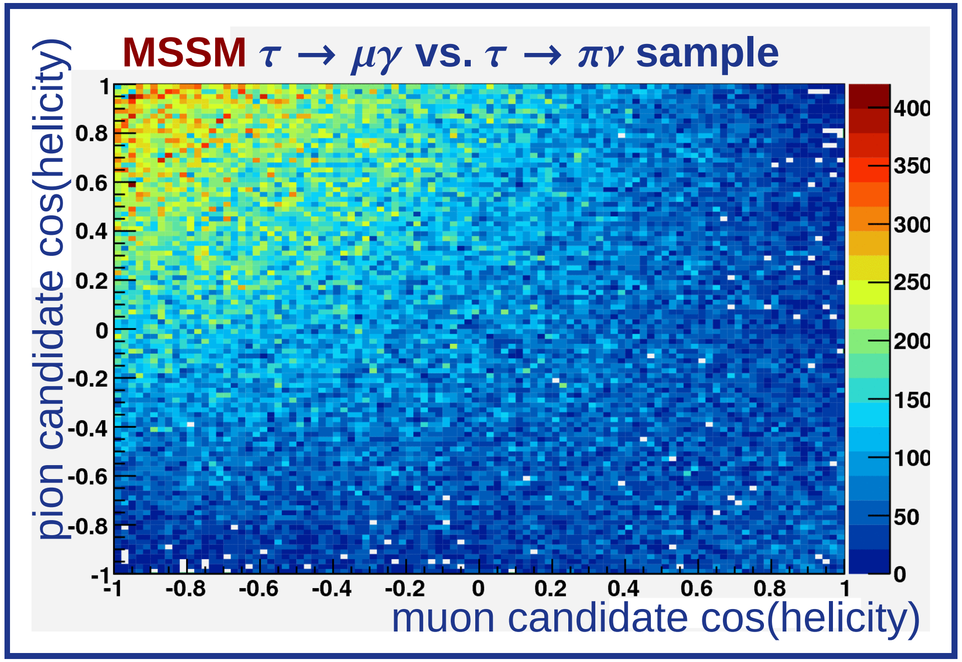


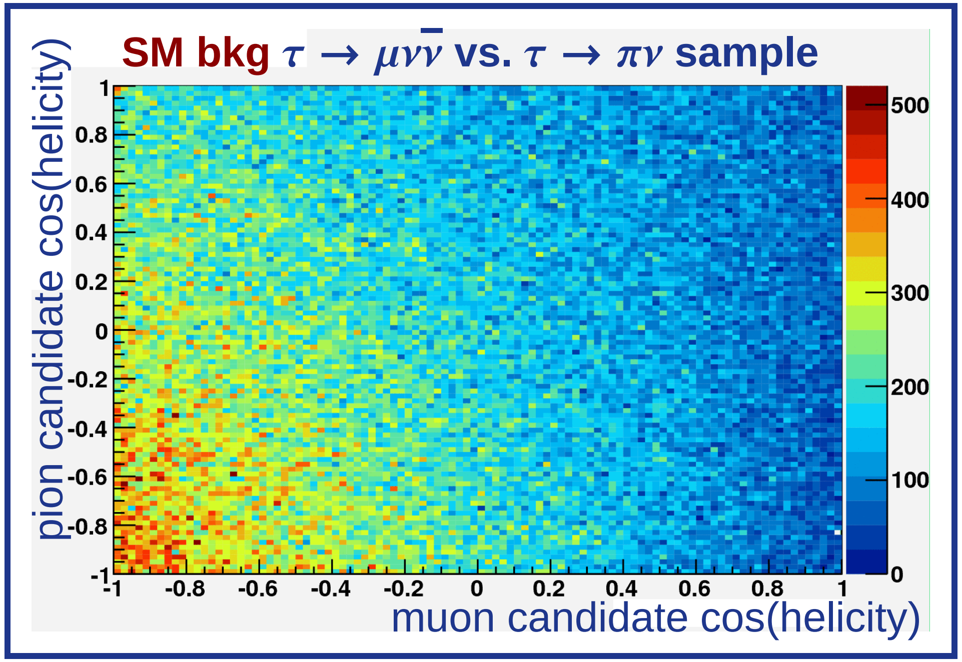
$\tau \to \mu e+e-$



$\tau- \to \mu+e-e-$

Super*B* beam polarization effects on $\tau \to \mu\gamma$ LFV search



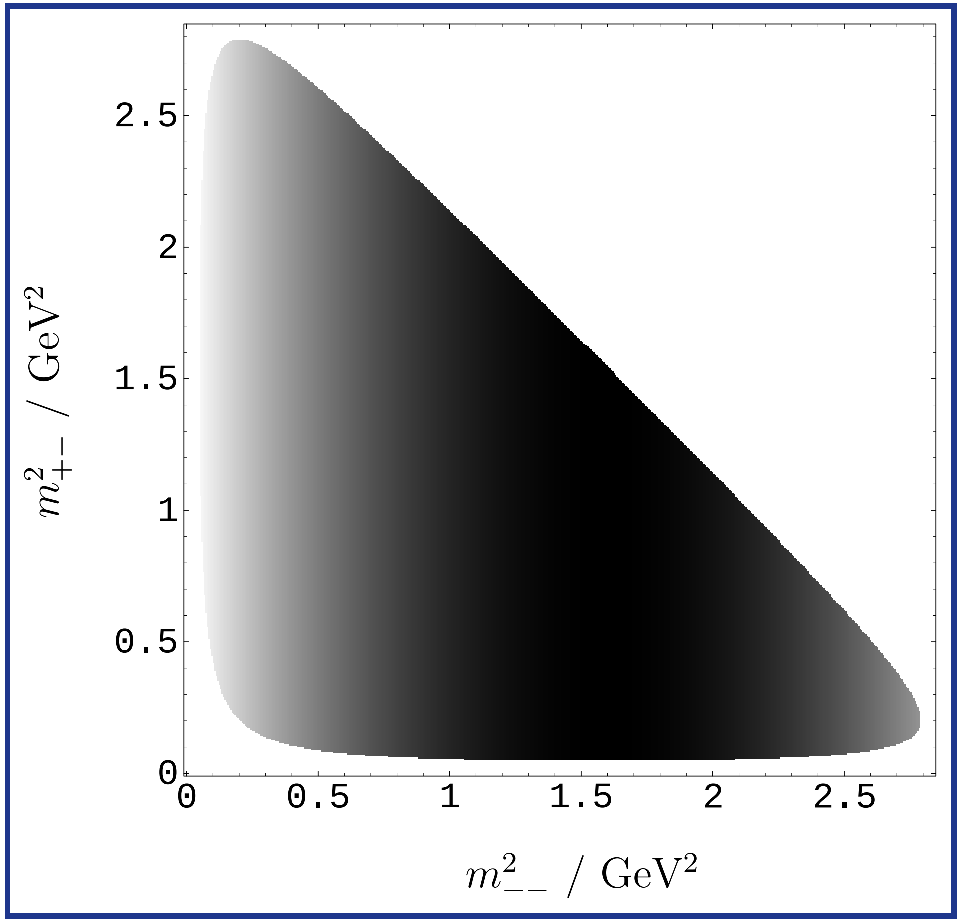


- 80% polarized electron beam
- SUSY LFV spin correlations Tauola decay mode added by S.Banerjee
- Super*B* fast simulation

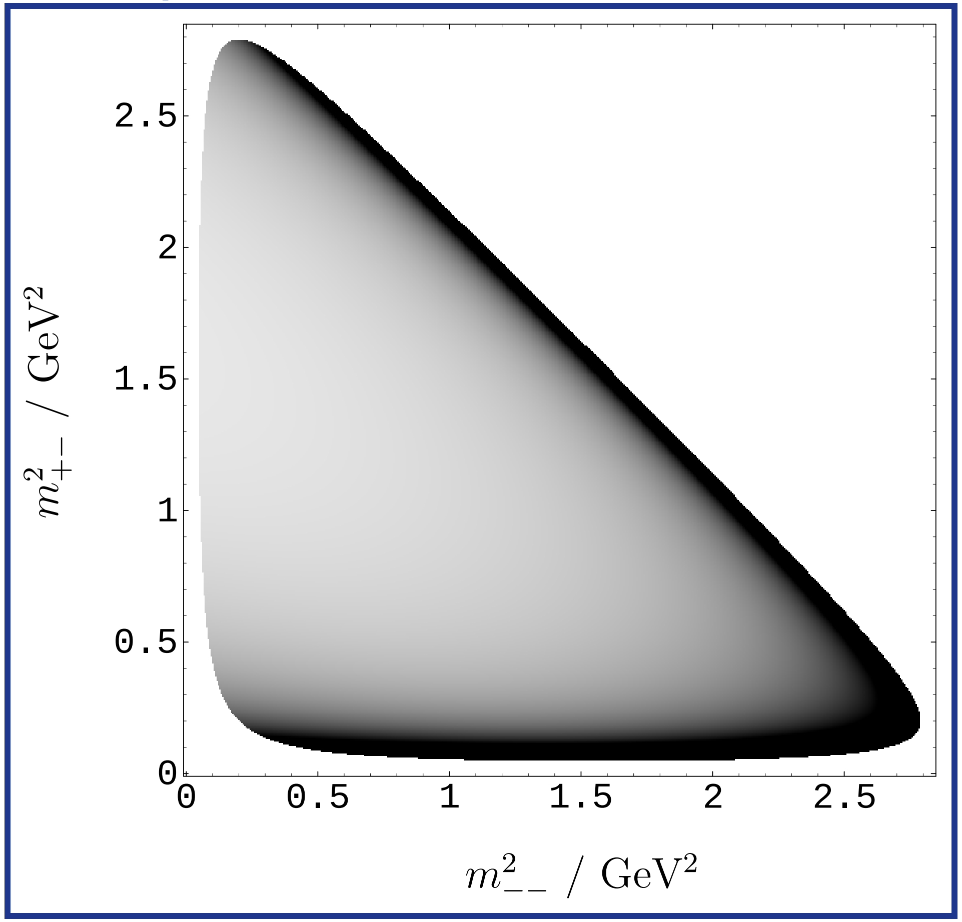
- can improve S/N ratio (assuming LFV NP model)
  - sensitivity improvements being evaluated
- can discriminate between NP models

Super*B* beam polarization effects on $\tau \to 3\ell$ LFV search

4-lepton interaction, all left handed



4-lepton interaction, radiative transition



- plots from S.Turczyk, arXiv:0812.3830 [hep-ph]
- can disentangle different NP models

Tau g–2 at Super*B* with beam polarization

- MSSM would shift muon g–2 by about the presently observed discrepancy $\Delta a_\mu \approx 3{\cdot}10^{-9}$

Δa_μ and Δa_τ for various SPS points						
SPS	1 a	1 b	2	3	4	5
$\Delta a_\mu \times 10^{-9}$	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
(specific parameters can produce Δa_τ as high as $1{\cdot}10^{-5}$)						

- J.Bernabeu et al., JHEP098P1108 estimate Super*B* $\sigma(a_\tau) = [0.75 – 1.7]{\cdot}10^{-6}$
  - Super*B* actually measures $\boldsymbol{a_\tau(q^2)}$ from final state distributions of $e^+e^- \to \tau^+\tau^-$
    - however, Δa_τ from high energy NP contributions is constant for small q^2
  - real part from τ polar angle distribution or transv.&long. polarization
- from tau EDM studies (see next slides) with more realistic assumptions ⟶ Super*B* $\sigma(a_\tau) \sim 2.4{\cdot}10^{-6}$

Tau EDM at Super*B*

- $|d_e| < 1.6 \cdot 10^{-27}$ e cm at 90% CL, 10.1103/PhysRevLett.88.071805 / PDG10
- most NP models expect $|d_\tau| \propto (m_\tau/m_e)|d_e|$
- Super*B* 2010 Physic Report reviews NP models expectations and concludes that:
  $|d_e|$ upper limit → **$|d_\tau^{NP}| < 10^{-22}$ e cm**
- Super*B* actually measures **$d_\tau(q^2)$ form factor** from final state distributions of $e^+e^- \to \tau^+\tau^-$
  - however, high energy NP contributions are constant for small q^2
- beam polarization permits measurements based on single tau distributions
- J.Bernabeu et al., arXiv:0707.1658v1 [hep-ph], estimate Super*B* $\sigma(d_\tau) \approx 7.2 \cdot 10^{-20}$ e cm
  - 100% electron beam polarization, no uncertainty
  - only $\tau \to \pi\nu$, $\tau \to \rho\nu$, no reconstruction uncertainty
- with more realistic assumptions, Super*B* $\sigma(d_\tau) \approx 10 \cdot 10^{-20}$ e cm
  (note that information can be obtained also from the other decay channels)
- extrapolate Belle EDM search, **Phys. Lett. B551, 16 (2003), hep-ex/0210066**
  → Super*B* $\sigma(d_\tau) \approx 17–34 \cdot 10^{-20}$ e cm (both real and imaginary parts)

Tau *CPV* at Super*B*

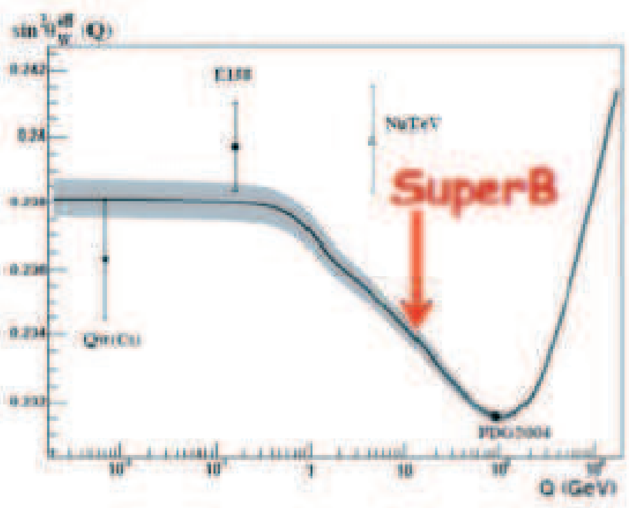
- SM predictions in general very small
  ($\tau^\pm \to K^\pm \pi^0 \nu$ *CP* asymmetry $\mathcal{O}(10^{-12})$, D. Delepine et al., PRD 72, 033009 (2005), hep-ph/0503090)
- small SM *CP* asymmetry in $\tau^\pm \to K_S \pi^\pm \nu$ from *CPV* in $K^0\overline{K}^0$
  $3.3{\cdot}10^{-3} \pm 2\%$ relative, I.I.Bigi & A. I. Sanda, PLB 625, 47 (2005), hep-ph/0506037
- most NP models do not induce measurable tau CPV
- R-parity violating SUSY ⟶ CPV related asymmetries up to 10%, saturating existing limits
  - sizable asymmetries in $\tau \to K\pi\nu_\tau$, $\tau \to K\eta^{(\prime)}\nu_\tau$, and $\tau \to K\pi\pi\nu_\tau$
- CLEO, PRL 88, 111803 (2002), hep-ex/0111095, 13.3 fb^{-1}, $\tau \to K_S\pi\nu$

  ⟶ optimal asymmetry observable $\langle\xi\rangle$ **= (–2.0 ± 1.8)·10^{-3}**
  - data calibration with $\tau \to \pi\pi\pi\nu$
- extrapolating at Super*B*, $\sigma_{\langle\xi\rangle} \approx 2.4{\cdot}10^{-5}$
- beam polarization can provide extra equivalent luminosity (to be studied)

Direct searches

- well defined initial state & clean experimental environment facilitate searches of light particles
- so far undetected **light Higgs** (e.g. NMSSM) can be identified in
  - $\Upsilon(3S) \to \gamma A_1(\to \tau^+\tau^-)$ or $\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$, $\Upsilon(1S) \to \gamma A_1(\to \tau^+\tau^-)$
  - violation of lepton universality in $\Upsilon(nS) \to \ell^+\ell^-$ (unfortunately syst. limited)
  - $A_1 - \eta_b(nS)$ would alter the hyperfine splitting $M(\Upsilon(nS)) - M(\eta_b(nS))$
- dark matter & invisible decays
  - $\Upsilon(3S) \to \pi^+\pi^-$invisible, $\Upsilon(1S) \to \gamma$ + invisible
- dark forces

Precision electroweak measurements

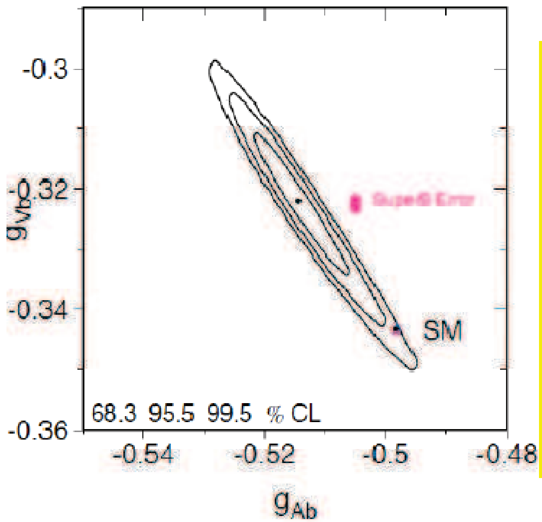


$$A_{LR} = \frac{\sigma(P)-\sigma(-P)}{\sigma(P)+\sigma(-P)} = \frac{16}{\sqrt{2}}\left(\frac{G_F q^2}{4\pi\alpha}\right)\left(\frac{g_A^e\, g_V^b}{Q_b}\right) P$$

- 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...)

⇒ Excellent opportunity to measure g_V & $\sin^2\theta_W$ at SuperB with polarized beams!!

0.5% polarization syst.
0.3% stat. error
→ 0.0021



The L-R luminosity asymmetry has to be very well controlled.Possibly done using monitoring
using Bhabhas
Polarization should be measured better than .05%
luminosity dependent polarization affects systematics

Costs and schedules

- mid-2010 white paper reports cost estimates and proposed schedule for accelerator and detector
- uncertainties from currency rates, not-yet-defined detector responsabilities
- value of recycled components assessed as cost of preplacement from scratch
- INFN 2010-2012 planning report includes proposed spending profiles and INFN budget contributions
- special government budget (270 MEuro) will fund Super*B* accelerator
- Super*B* detector funds will come from INFN & other collaborating institutes
  - provisional 2011 funds already allocated and partially already assigned

Accelerator cost, from accelerator white paper

Table 26.1: Accelerator budget estimate

WBS	Item	Number of units	EDIA (mm)	Labor (mm)	M&S (k€)	Total (k€)	Repl. Value (k€) (not in total)
2.00	Overall SuperB Accelerator total		3159	2852	285350	357476	85760
2.01	Contingency and VAT (50%)		1053	951	95117	119159	0
2.02	Overall Super B Project Sub-total		2106	1901	190233	238317	85760

- to be compared with 270 MEuro funding in 6-years

Accelerator schedule, from accelerator white paper

Table 25.1: Construction schedule

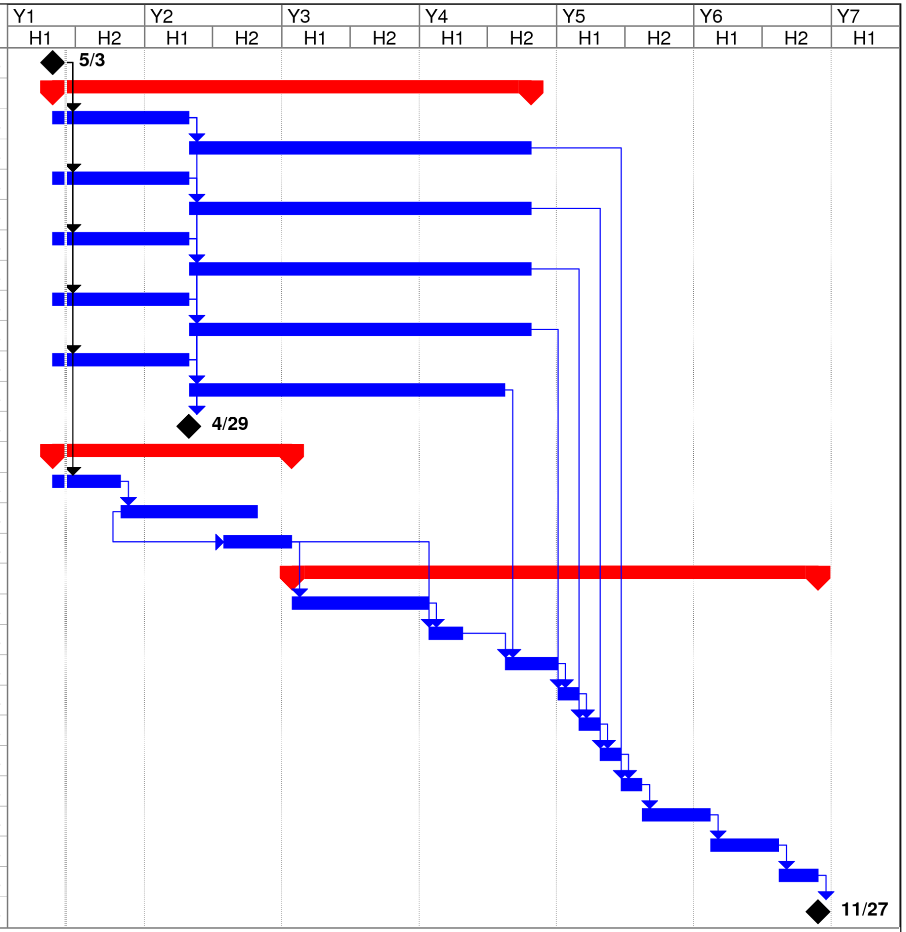
Year	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1	▪ Tunnel design completed ▪ Injector components designed ▪ Ring component studied ▪ Tunnel contracts awarded ▪ Injector components ordered ▪ Ring components designed		▪ Ring tunnel digging started ▪ Injector tunnel digging started ▪ Injector components started manufacturing ▪ Ring components designed ▪ Tunnel digging continued ▪ Injector components are in manufacturing ▪ Ring components orders started	
2	▪ Ring tunnel digging continues ▪ Injector tunnel finished ▪ Injector components start to arrive ▪ Ring components orders finished		▪ Ring tunnel is completed ▪ Injector installation starts ▪ Ring components start to arrive for installation ▪ PEP-II components shipped from SLAC	
3	▪ Injector installation continues ▪ Ring component installation starts		▪ Injector installation is completed ▪ Ring installation continues	
4	▪ Injector checkout starts ▪ Ring installation continues		▪ Injector beam commissioning starts ▪ Ring installation is completed ▪ Ring checkout starts	
5	▪ Ring beam commissioning starts		▪ SuperB beam delivery to detector starts	

Detector cost in kEuro, from detector white paper

1	Super*B* detector	4037	2422	52953	48922
1.0	Interaction region	21	12	860	0
1.0.1	Be Beampipe	10	4	260	0
1.0.2	Tungsten Shield	9	6	540	0
1.0.3	Radiation monitors	2	2	60	0
1.1	Tracker (SVT + Strip + MAPS)	408	442	6444	0
1.1.1	SVT	222	309	4326	0
1.1.2	L0 Striplet option	36	55	542	0
1.1.3	L0 MAPS option	150	78	1576	0
1.1.4	L0 Hybrid Pixel option	156	84	1684	0
1.2	DCH	165	139	3421	0
1.3	PID	116	236	5820	7138
1.3.1	DIRC Barrel (Focusing DIRC)	116	236	5820	7138
1.4	EMC	219	360	12147	31574
1.4.1	Barrel EMC	20	5	205	31574
1.4.2	Forward EMC	171	312	11565	0
1.4.3	Backward EMC	28	43	377	0
1.5	IFR	37	184	1374	0
1.6	Magnet	93	59	3767	10210
1.7	Electronics	994	342	9234	0
1.8	Online System	912	24	2074	0
1.9	Installation and integration	353	624	7596	0
1.A	Project Management	720	0	216	0

Detector schedule, from detector white paper

ID	Task Name	Duration
1	Approval	0 wks
2	**Detector Design & Construction**	**182 wks**
3	Design SVT	52 wks
4	Construct SVT	130 wks
5	Design DCH	52 wks
6	Construct DCH	130 wks
7	Design PID	52 wks
8	Construct PID	130 wks
9	Design forward EMC	52 wks
10	Construct forward EMC	130 wks
11	Design IFR	52 wks
12	Construct IFR	120 wks
13	Detector Technical Design Report	0 wks
14	**Dismantle & Move Babar**	**91 wks**
15	Design Tooling	26 wks
16	Dismantle Babar	52 wks
17	Component transportation	26 wks
18	**Detector Installation & Commissioning**	**200 wks**
19	Installation steel	52 wks
20	Installation magnet	13 wks
21	Installation IFR	20 wks
22	Installation EMC	8 wks
23	Installation PID	8 wks
24	Installation DCH	8 wks
25	Installation SVT	8 wks
26	Commissioning	26 wks
27	Cosmic Ray test	26 wks
28	Commissioning on beam	15 wks
29	**Detector ready for collision**	0 wks



Project: SBF_schedule_v1.2
Date: Fri 6/4/10

Task · Split · Progress · Milestone · Summary · Project Summary · External Tasks · External Milestone · Deadline

Overall schedule and costs, from INFN 2010-2012 plan

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

Final remarks

- Super*B* CDR and white paper contain much more I could introduce here
- Super*B* can do good physics at a reasonable cost
- for many measurements, is competitive & complementary with other experiments
- can provide fruitful competition with Belle2
- has some unique features (luminosity, beam polarization, charm threshold running), which permit distinctive and useful physics accomplishments
- collaboration from Spain is welcome in any topic you prefer
  - physics
  - detector
  - accelerator-related issues (post-docs to be recruited here)