Super$B$
The Super Flavor Factory

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BEACH 2008

June 27, 2008

Is there a motivation to continue e^+e^- flavor physics studies with a Super B factory beyond the *BABAR*/Belle/(LHC*b*) era ?

- Yes – provided that new measurements have sensitivity to New Physics in b, c and τ decay

What size data sample is required to provide this sensitivity ?

- 50-75 ab^{-1} (*BABAR*+Belle total sample is <2 ab^{-1})

What luminosity is required to gather a sample of this size in five years ?

- At least 10^{36} cm^{-2}s^{-1}

Can an asymmetric collider with this luminosity be built ?

- Yes, using an innovative new approach: a low emittance collider, based on concepts developed for the ILC damping rings, and employing a new type of final focus – a "crabbed waist". The machine is called Super$B$

Can a detector be built that can withstand the machine backgrounds ?

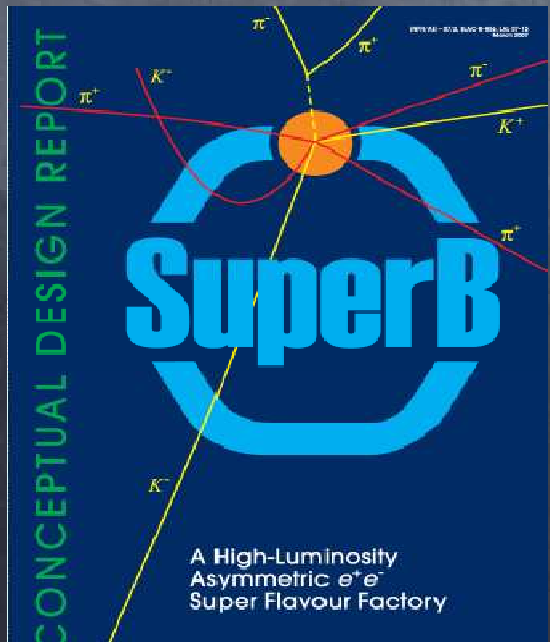
- Yes. The beam currents are less than those at PEP-II and KEKB

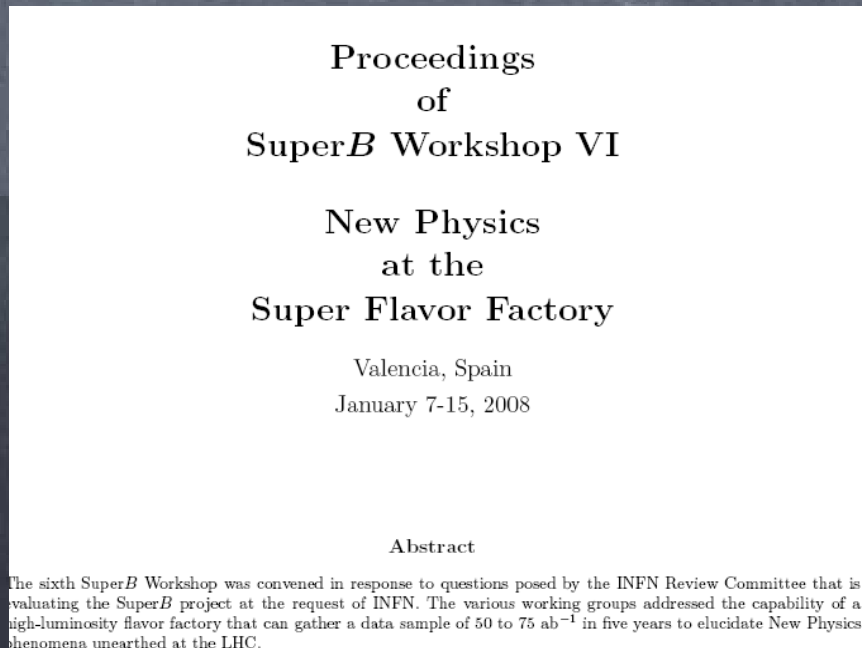
In this era of increasing energy prices, can you pay the power bill ?

- Yes. The wallplug power, 17MW, is less than half that of KEKB (40mw)

- The EPP2010 report regarded flavor physics (or indeed most thi
ve actually know how to measure) as uninteresting
- The recent P5 report is much more realistic
  - It recommends, in Scenario B and above, US participation in an overseas Super B factory
  - There are two proposals on the market
    - SuperKEKB, an upgrade of KEKB, with a luminosity of 1.5×10^{35}
    - Super$B$, a new low emittance collider, with a luminosity of 10^{36}, to be built at Rome II University "Tor Vergata", using many PEP-II compone
  - This talk will concern Super$B$
  - Kay Kinoshita will discuss SuperKEKB tomorrow

320 signers
80 institutions



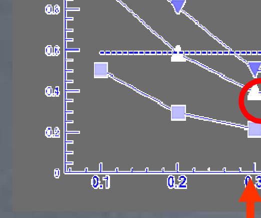

Proceedings
of
Super$B$ Workshop VI

New Physics
at the
Super Flavor Factory

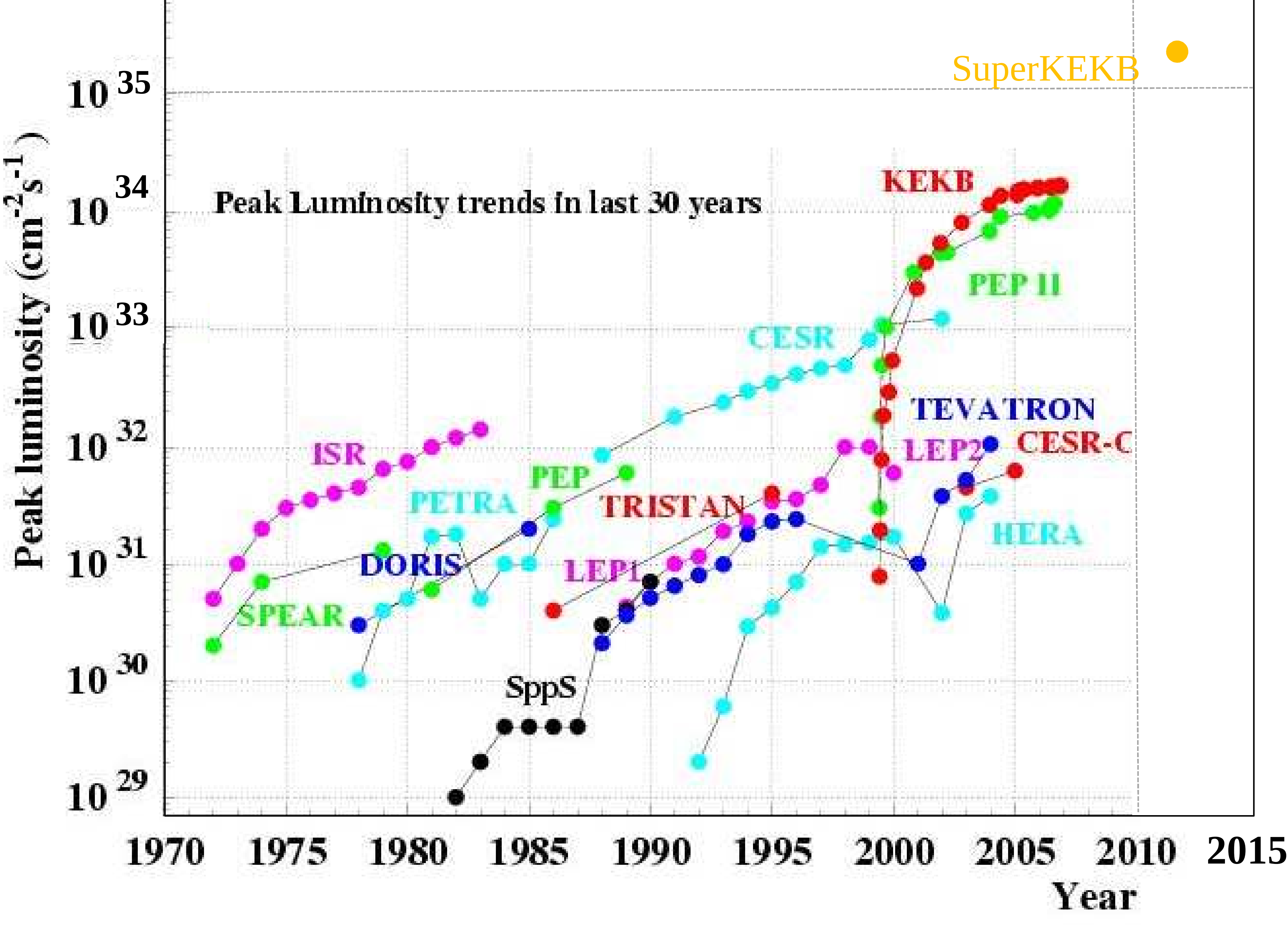
Valencia, Spain
January 7-15, 2008

Abstract

he sixth Super$B$ Workshop was convened in response to questions posed by the INFN Review Committee that is valuating the Super$B$ project at the request of INFN. The various working groups addressed the capability of a igh-luminosity flavor factory that can gather a data sample of 50 to 75 ab^{-1} in five years to elucidate New Physics henomena unearthed at the LHC.



- uper$B$ is a Super Flavor Factory with very high initial luminosity,
  0^{36}, which can be upgraded to 4×10^{36} in a straightforward manner
  t is asymmetric : 4 on 7 GeV
- Aost of the ring magnets can re reused from PEP-II, as can the RF systems,
  any vacuum components, linac and injection components – as well as BABAR as
  asis for an upgraded detector
- he high energy beam can be linearly polarized to ~85% , using the SLC laser
  - This is particularly important for confronting New Physics in τ decays
- he primary E_{CM} will be the $\Upsilon(4S)$, but Super$B$ can run elsewhere in the Υ reg
  d in the charm &tau threshold regions as well, with a luminosity above 10^{35}
  - One month at the $\psi(3770)$, for example, yields 10x the total data sample th
    will be produced by BEPCII
- uper$B$ will be built on the campus of the Rome II University at Tor Vergato
  - There is an FEL already in early stages of construction on the site
  - Tunneling will continue to dig the Super$B$ tunnel, funded by Regione Lazio
- me scales
  - (Successful) conclusion of the European Roadmap process (INFN, ECFA,
    CERN Strategy Group) by the end of 2008, followed by INFN→Ministry
  - TDR effort is beginning: construction 5 years : luminosity in 2015



SuperKEKB
Peak Luminosity trends in last 30 years
KEKB
PEP II
CESR
TEVATRON
CESR-C
LEP2
ISR
PEP
PETRA
TRISTAN
HERA
DORIS
LEP1
SPEAR
SppS
Peak luminosity (cm^{-2}s^{-1})
10^{35}
10^{34}
10^{33}
10^{32}
10^{31}
10^{30}
10^{29}
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year

mbers: H. Aihara, J.B. Dainton (chair), R. Heuer (to Nov 07), Y. K. Kim, J. Lefrançois, A. Masiero, S. Myers (for April 08), T. Nakada (RECFA from April 08), D. Schulte, A. Seiden

nclusions

Strongly recommend continuation of work for 10^{36} cm^{-2} s^{-1} asymmetric e^+e^- collider

Even more concerted effort to fully evaluate physics potential ↔ machine specifications

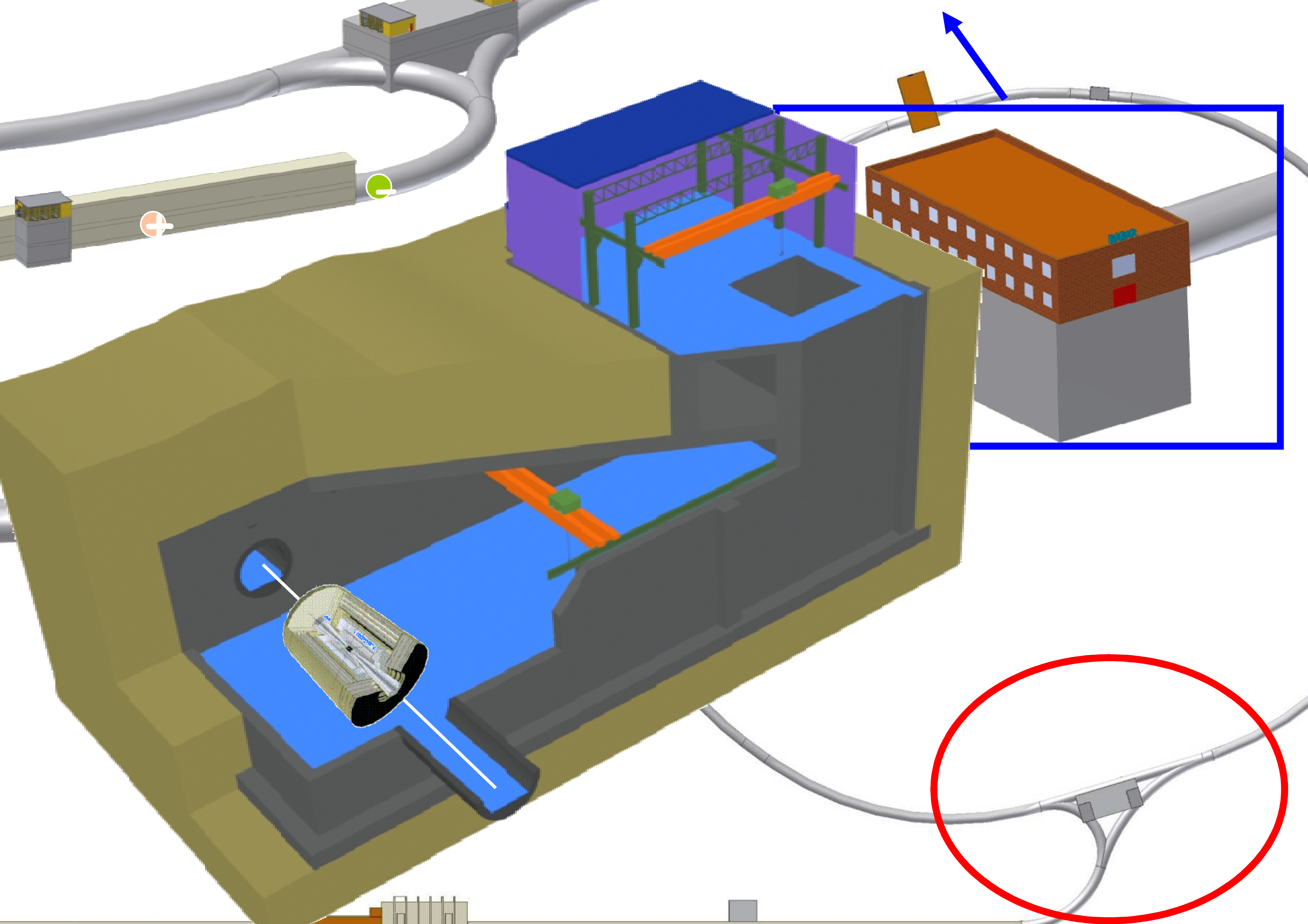
Major design program to establish credibility of machine now critical ← showstoppers ?

Machine Advisory Committee (MAC) now essential

Preservation of detector and PEP2 components

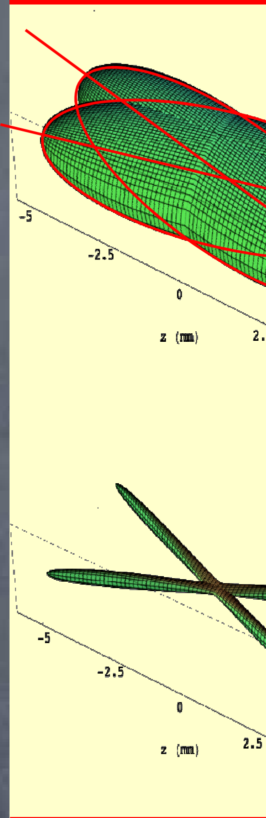
Increasing global involvement if timescale for a TDR is to be met


Due Torri
Google



ER	LER (e+)	HER (e-)	LER (e+)	HER (e-)	LER (e+)	HER (e-)	LER (e+)	HER (e-)
eV)	4	7	4	7	4	7	3.5	8
r x 10^{36}	1.0		2.0		4.0		0.8 (0.4)	
ence (m)	1800	1800						
frequency (MHz)	0.167							
olarization (%)	0	80						
cy (MHz)	476							
n spread ($x10^{-4}$)	7.9	5.6	9.0	8.0				
n compaction ($x10^{-4}$)	3.2	3.8	3.2	3.8				
(MV)	5	8.3	8	11.8	17.5	27		
s/turn (MeV)	1.16	1.94	1.78	2.81				
bunches	1251				2502		5000	
er bunch ($x10^{10}$)	5.52				6.78		12	5
ent (A)	1.85				3.69		9.4	4.1
m)	0.22	0.39	0.16	0.27			3	
m)	35	20					200	
-rad)	7	4	3.5	2			45	
-rad)	2.8	1.6	1.4	0.8			9 (24)	
microns)	0.039	0.039	0.0233	0.0233			0.367	
microns)	9.9	5.66	7	4			42	
gth (mm)	5		4.3				3	
ng angle (mrad)	48						30	
/) 20 meters each	0	0	2	2				
ime (trans/long)(ms)	40/20	40/20	28/14	28/14				
r lifetime (min)	6.7		3.35					
ifetime (min)	20	40	38	20				
eam lifetime (min)	5.0	5.7	3.1	2.9				
ate pps ($x10^{11}$) (100%)	2.6	2.3	5.1	4.6	10	9.1		
y (from formula)	0.15		0.20				0.405	
x (from formula)	0.0043	0.0025	0.0059	0.0034			0.209	
(MW)	17		25		58.2		83	

IP beam dis
for KI



IP beam dis
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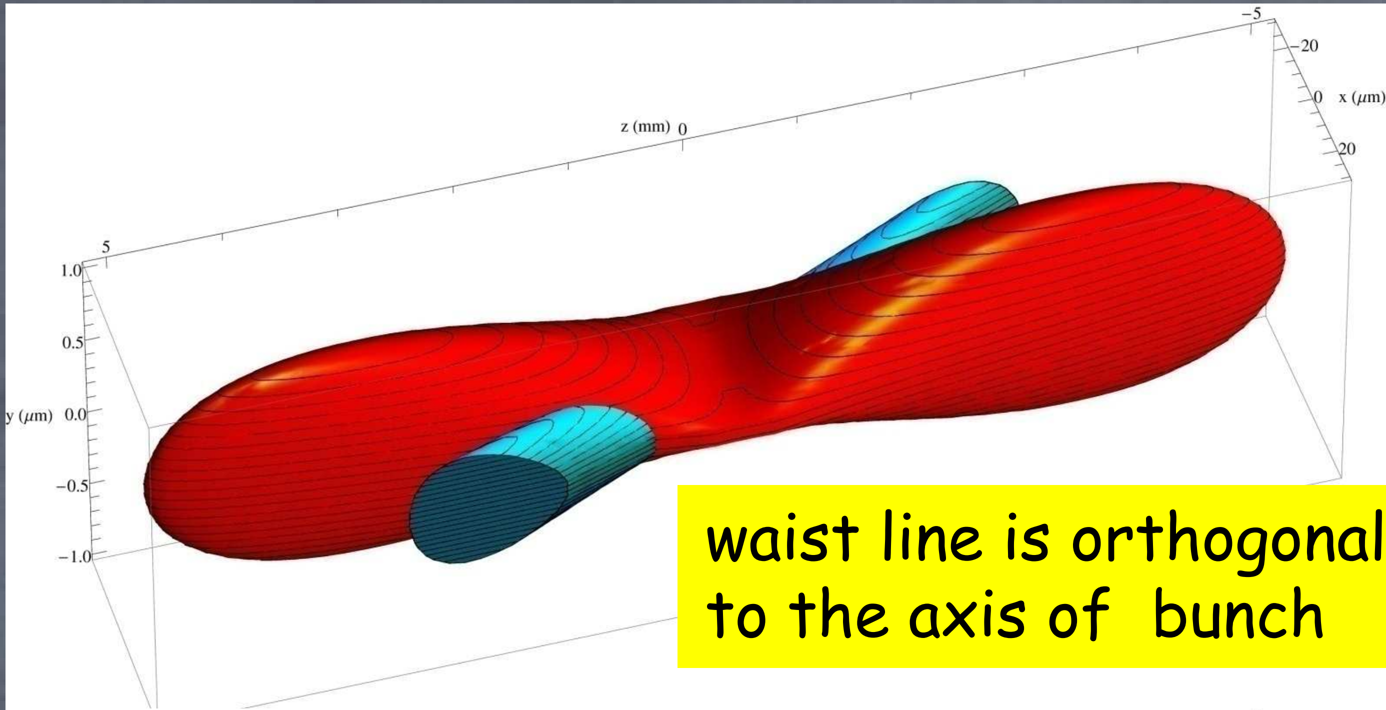
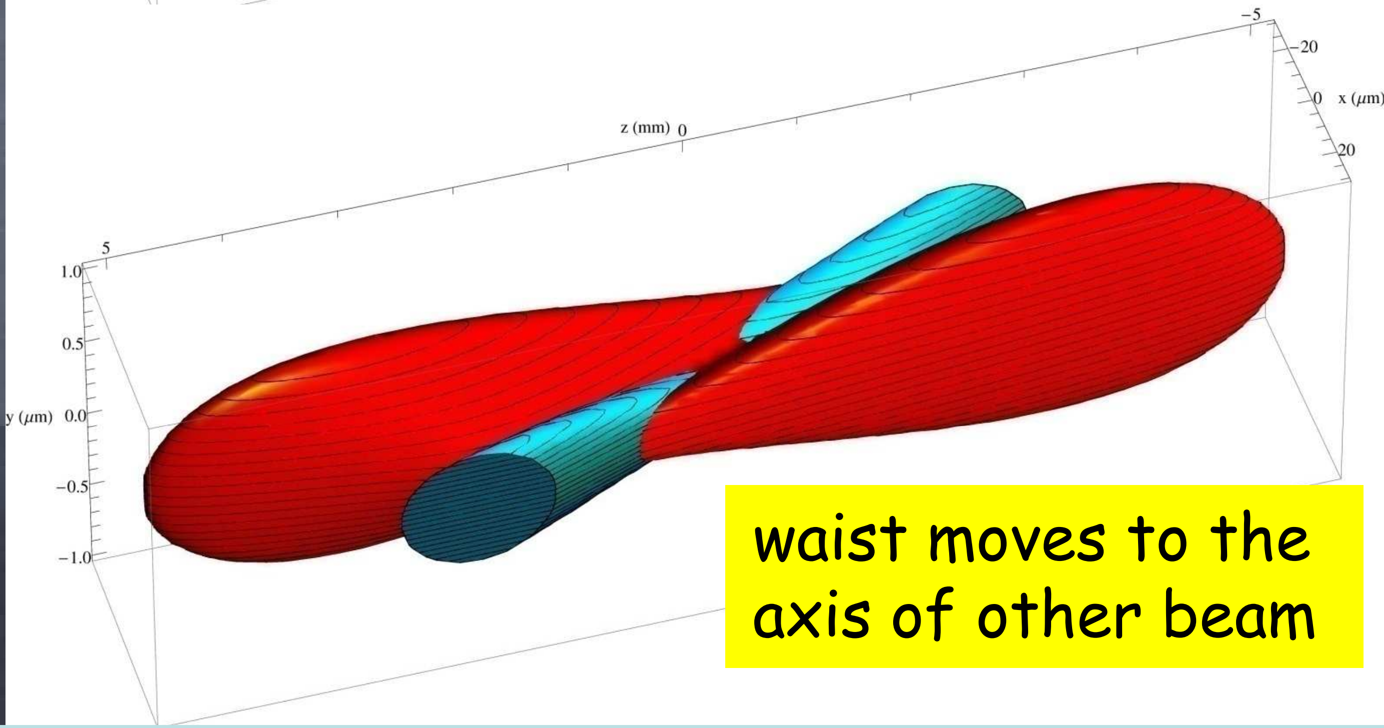
condit

sextupoles OFF



waist line is orthogonal to the axis of bunch

sextupoles ON



waist moves to the axis of other beam

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

E.

erform measurements in the flavor sector such that:

If new particles are discovered at LHC we are able to study the flavor structure of the New Physics

If the New Physics scale is beyond the reach of the LHC, explore the New Physics scale

More specifically

Are there new CP-violating phases in b,c or τ decay ?

Are there new right-handed currents ?

Are there new loop contributions to flavor-changing neutral cur

Are there new Higgs fields ?

Is there charged lepton flavour violation (LFV) ?

Is there new flavor symmetry that elucidates the CKM hierarch

What are the requirements for a detector that can address the questions in a 10^{36} asymmetric e^+e^- environment ?

	0.10	0.02
	0.20	0.04
	0.10	0.02
	0.20	0.03
	0.13	0.02 (∗)
	0.05	0.01 (∗)
	0.15	0.02 (∗)
	0.15	0.02 (∗)
	0.17	0.03 (∗)
	0.12	0.02 (∗)
CP eigenstates)	$\sim 15°$	2.5°
suppressed states)	$\sim 12°$	2.0°
multibody states)	$\sim 9°$	1.5°
bined)	$\sim 6°$	1–2°
	$\sim 16°$	3°
	$\sim 7°$	1–2° (∗)
	$\sim 12°$	2°
	$\sim 6°$	1–2° (∗)
$D^{\pm}K_s^0\pi^{\mp}$)	20°	5°

$\lvert V_{ub}\rvert$ (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 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 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 (†)
$S(K_s^0\pi^0\gamma)$	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%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

		(75 ab^{-1})
$D^0 \to K^+\pi^-$	x'^2	3×10^{-5}
	y'	7×10^{-4}
$D^0 \to K^+K^-$	y_{CP}	5×10^{-4}
$D^0 \to K_S^0\pi^+\pi^-$	x	4.9×10^{-4}
	y	3.5×10^{-4}
	$\lvert q/p\rvert$	3×10^{-2}
	ϕ	$2°$
$\psi(3770) \to D^0\overline{D}^0$	x^2	
	y	
	$\cos\delta$	

Charm FCNC

$D^0 \to e^+e^-$, $D^0 \to \mu^+\mu^-$

$D^0 \to \pi^0e^+e^-$, $D^0 \to \pi^0\mu^+\mu^-$

$D^0 \to \eta e^+e^-$, $D^0 \to \eta\mu^+\mu^-$

$D^0 \to K_S^0e^+e^-$, $D^0 \to K_S^0\mu^+\mu^-$

$D^+ \to \pi^+e^+e^-$, $D^+ \to \pi^+\mu^+\mu^-$

$D^0 \to e^{\pm}\mu^{\mp}$

$D^+ \to \pi^+e^{\pm}\mu^{\mp}$

$D^0 \to \pi^0e^{\pm}\mu^{\mp}$

$D^0 \to \eta e^{\pm}\mu^{\mp}$

$D^0 \to K_S^0e^{\pm}\mu^{\mp}$

$D^+ \to \pi^-e^+e^+$, $D^+ \to K^-e^+e^+$

$D^+ \to \pi^-\mu^+\mu^+$, $D^+ \to K^-\mu^+\mu^+$

$D^+ \to \pi^-e^{\pm}\mu^{\mp}$, $D^+ \to K^-e^{\pm}\mu^{\mp}$

...ysics

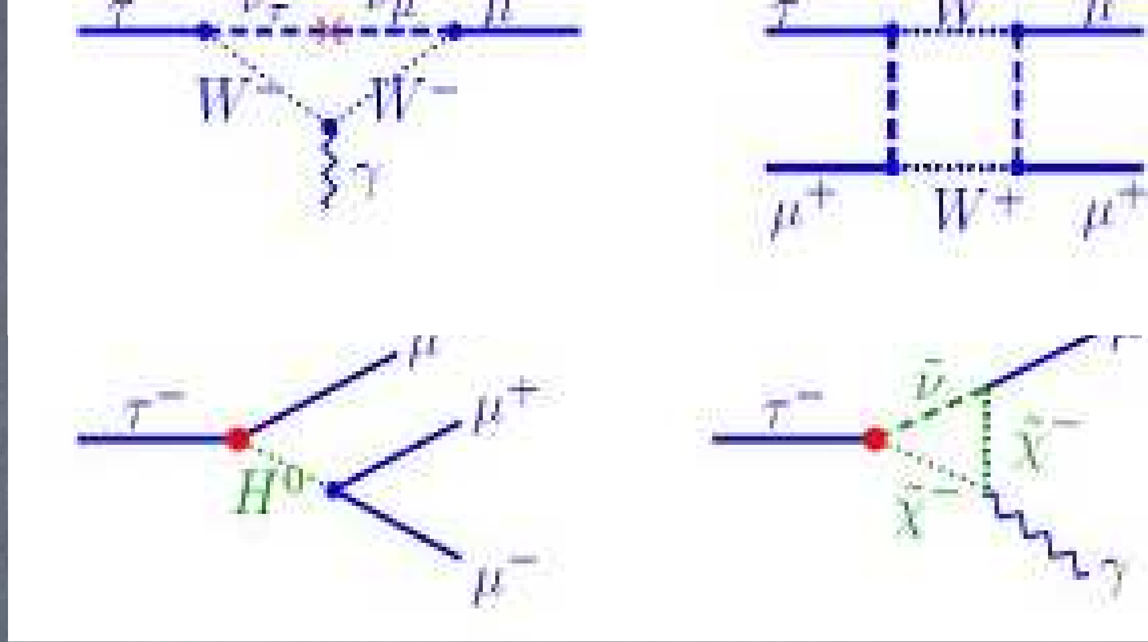
	Sensitivity
$\to \mu\gamma)$	2×10^{-9}
$\to e\gamma)$	2×10^{-9}
$\to \mu\mu\mu)$	2×10^{-10}
$\to eee)$	2×10^{-10}
$\to \mu\eta)$	4×10^{-10}

B_s Physics: $\Upsilon(5S)$

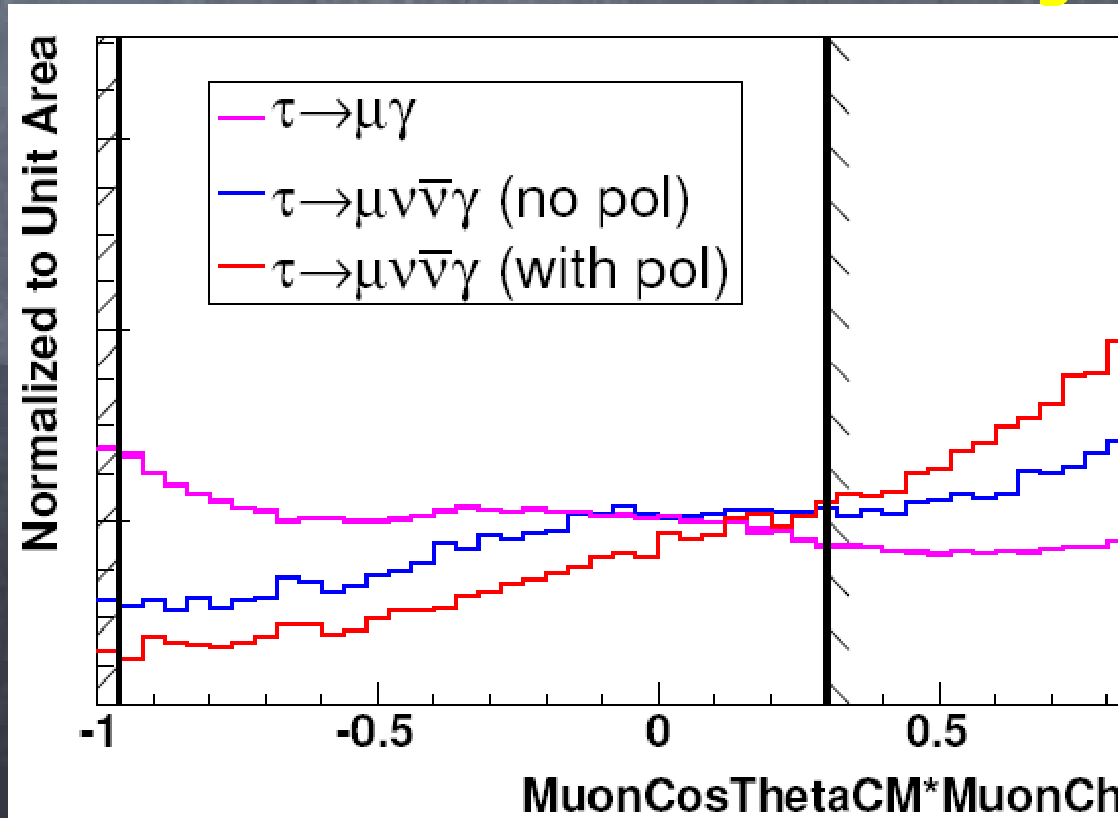
Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s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

epton Flavor Violation

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}
$\mathcal{B}(\tau \to \ell K_s^0)$	2×10^{-10}



polarized e- beam: reduced backgr

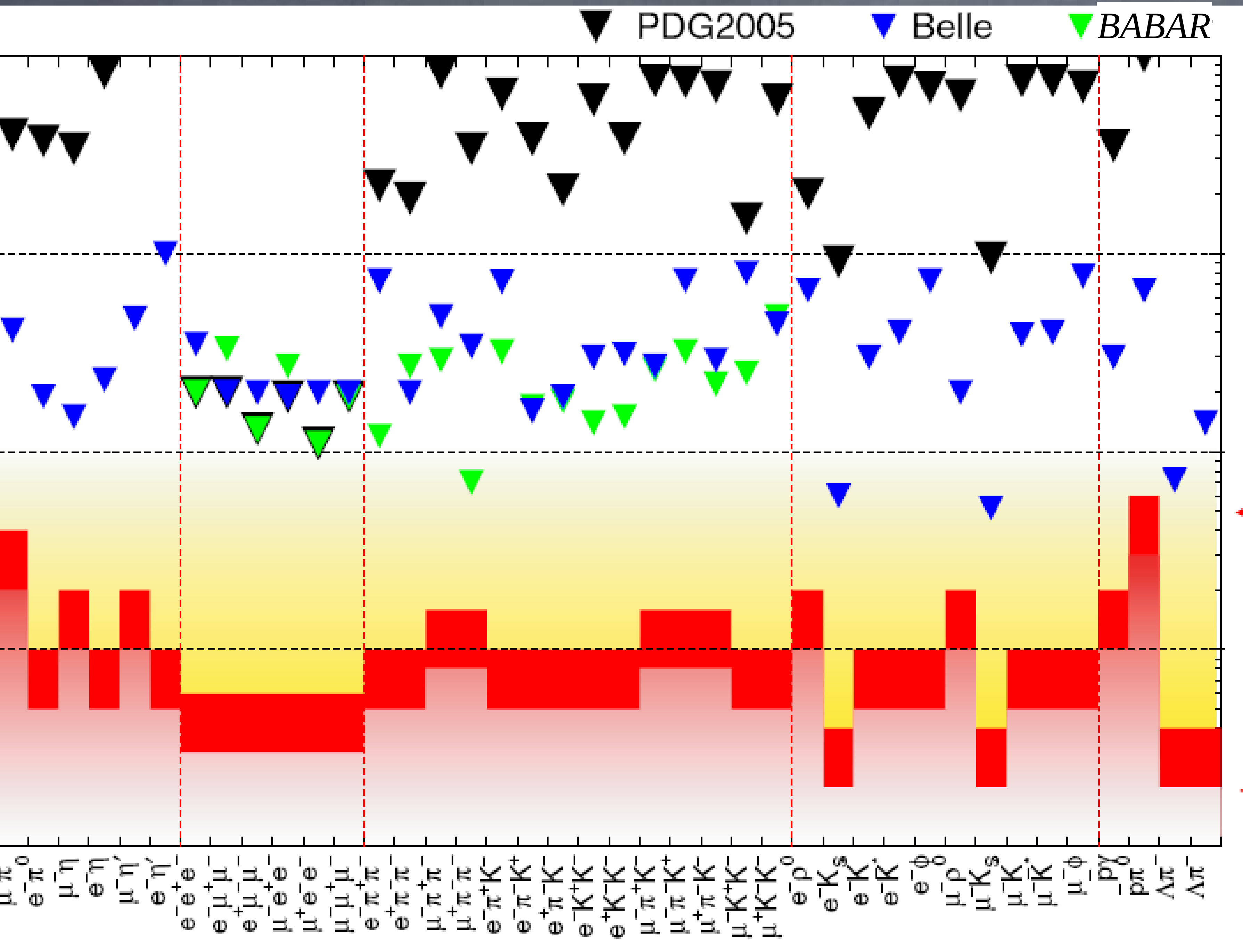


y important order of magnitude

$10^{-8} \to 10^{-9}$

Complimentarity with $\mu \to e\,\gamma$

erB sensitivity directly confronts many New Physics mod



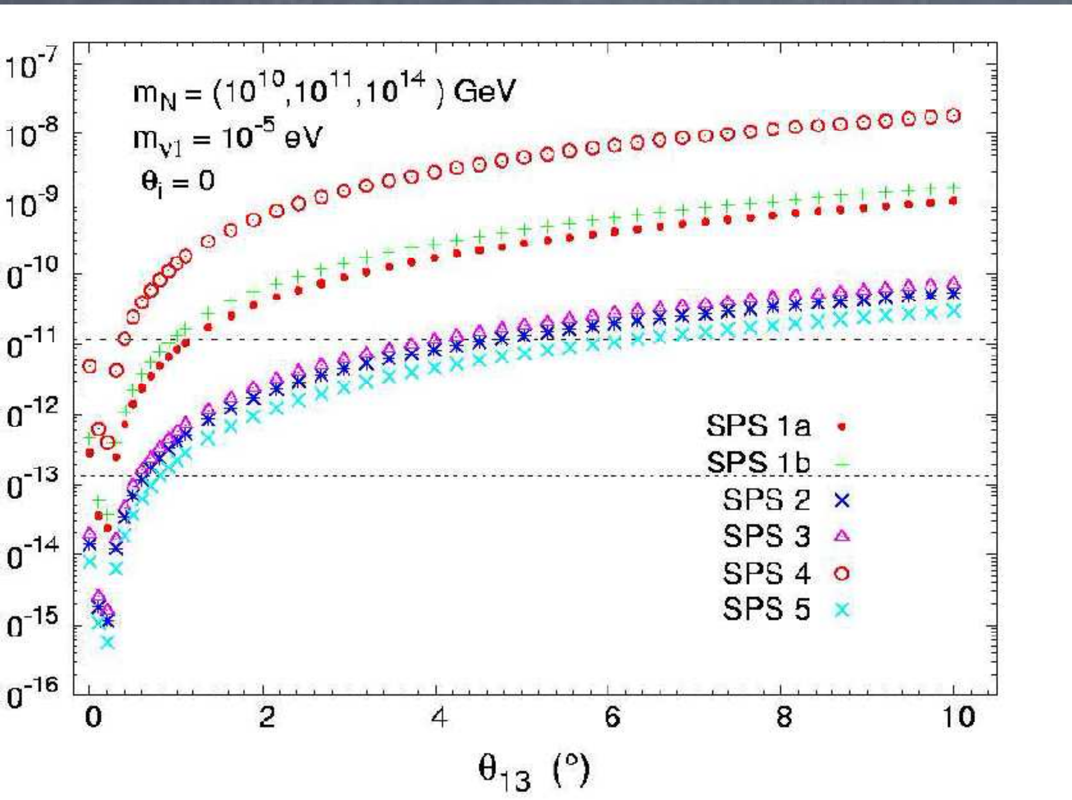
SuperB
sensitivit
For 75 ab

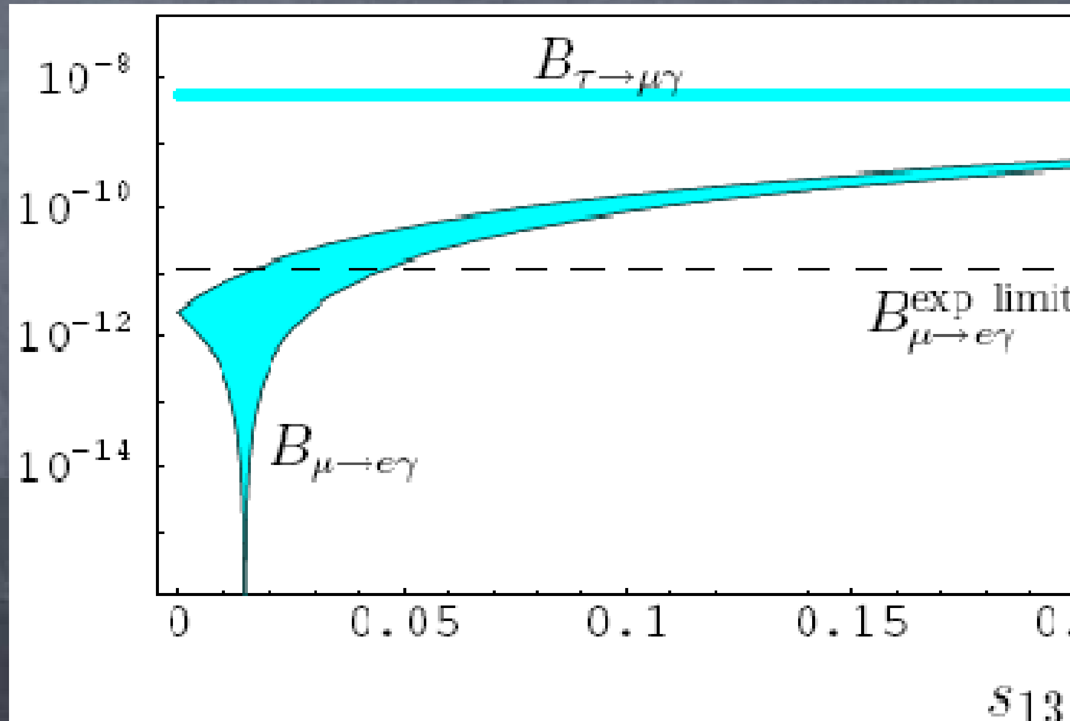
Process	S
$\mathcal{B}(\tau \to \mu\gamma)$	2
$\mathcal{B}(\tau \to e\gamma)$	2
$\mathcal{B}(\tau \to \mu\mu\mu)$	2
$\mathcal{B}(\tau \to eee)$	2
$\mathcal{B}(\tau \to \mu\eta)$	4
$\mathcal{B}(\tau \to e\eta)$	6
$\mathcal{B}(\tau \to \ell K^0_S)$	2

LFV

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

$$10\text{ab}^{-1} : 75\text{ab}^{-1} \Rightarrow \sqrt{\frac{75}{10}} \text{ for } \mathcal{B}(\tau\to\mu\gamma),\ 7.5 \text{ for } \mathcal{B}(\tau\to\ell\ell\ell)$$

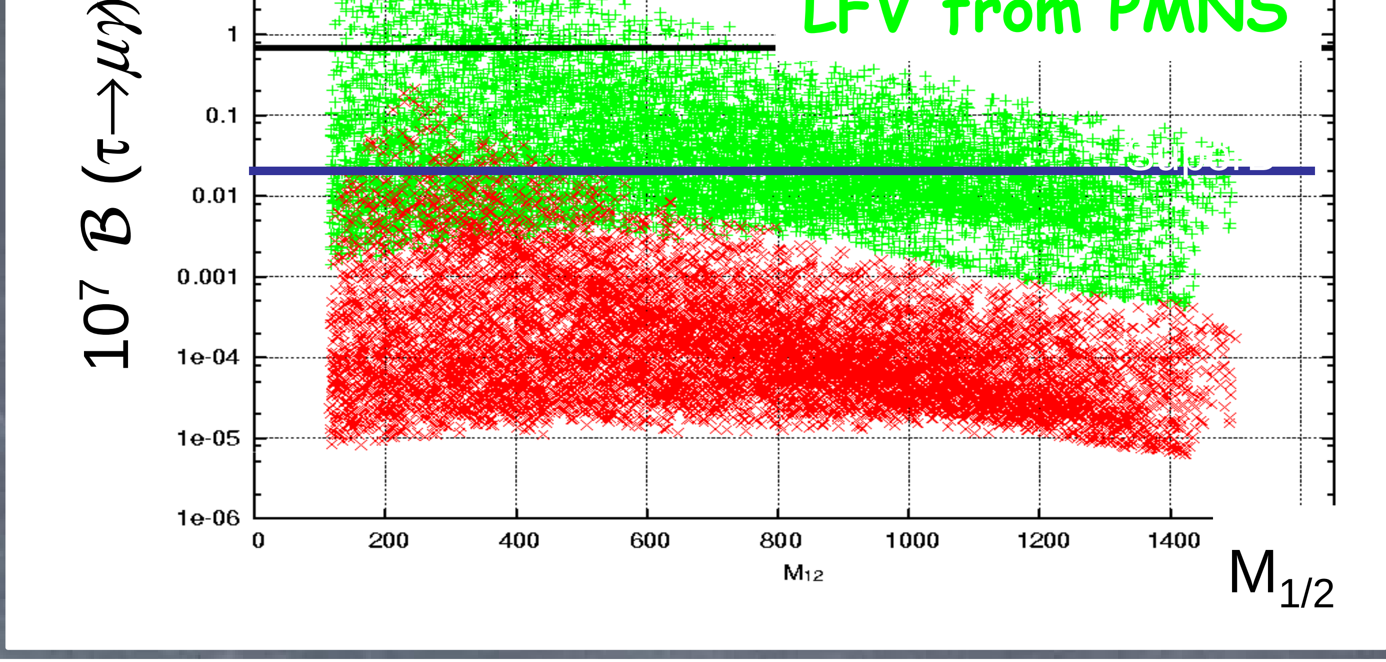




SSM : $\mu\to e\gamma$ vanishes at all SPS points

MVF-NP extensions : $\mu\to e\gamma$ vanishes a
$\tau\to\mu\gamma$ is independent of s_{13}

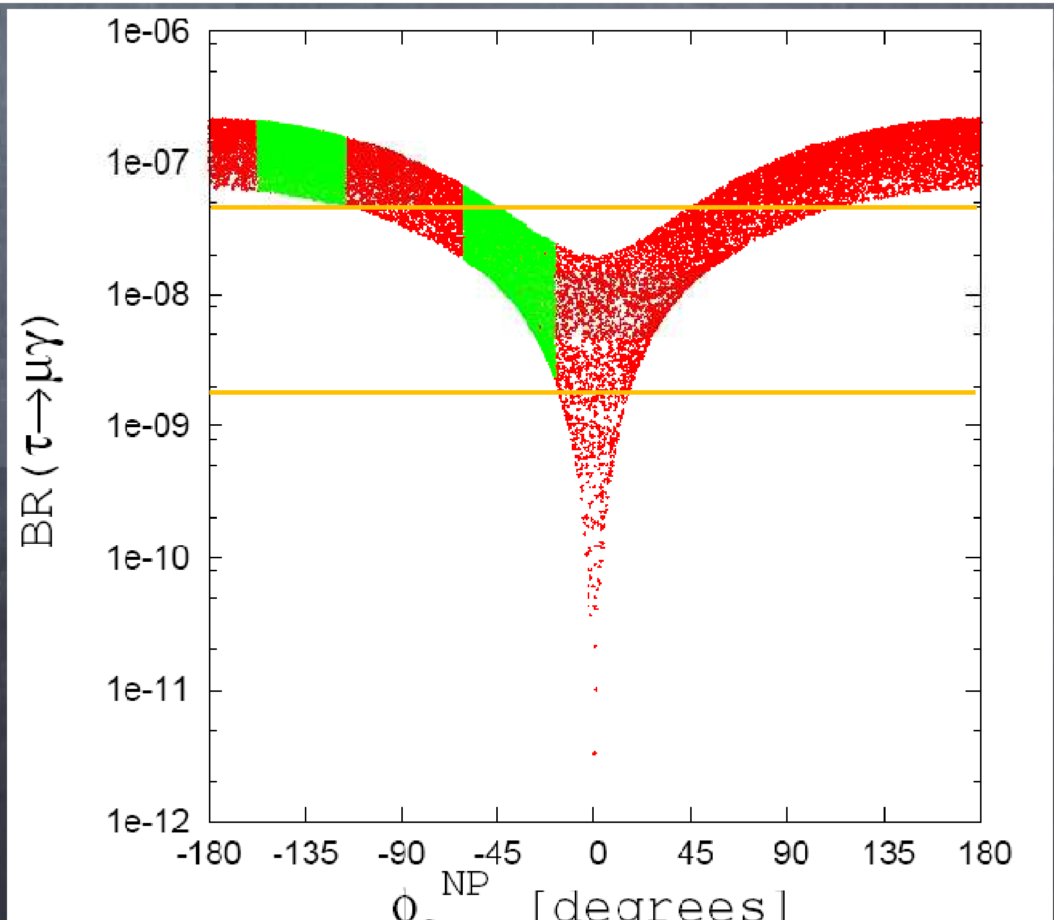
SO(10) MSSM



now

Super

SUSY GUT



now

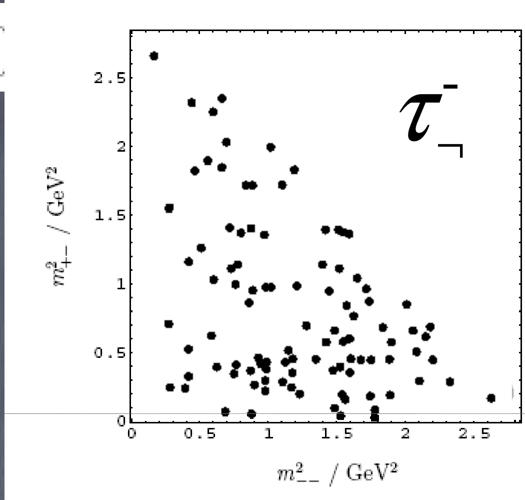
Super$B$

Allowed by Δm_s

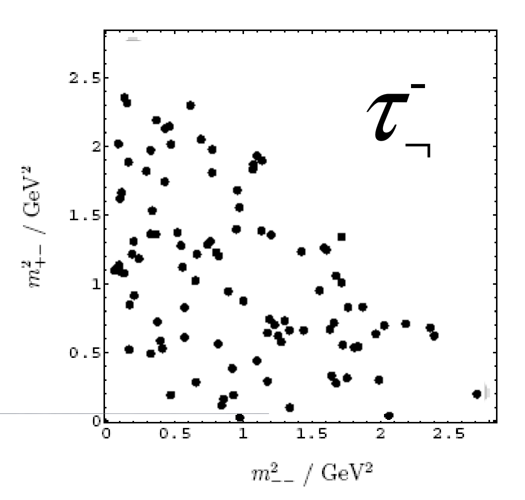
From B_s phase

Recent work :
J.K.Parry, H.-H
hep-ph/0710.5

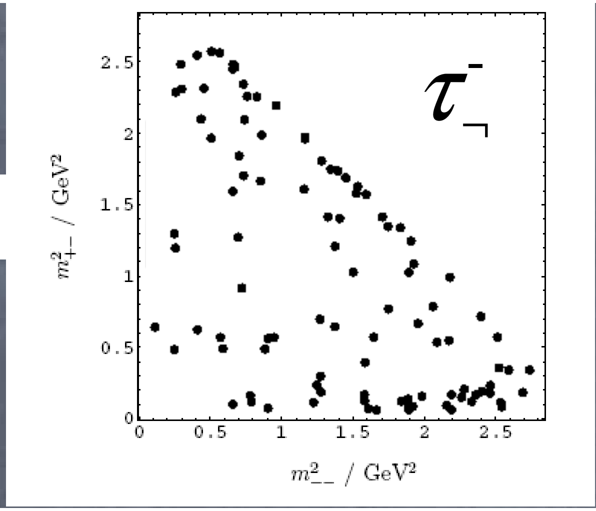
$^{(LL)}$ (left)



$d^2\Gamma_V^{(LL)(RR)}$ (right)

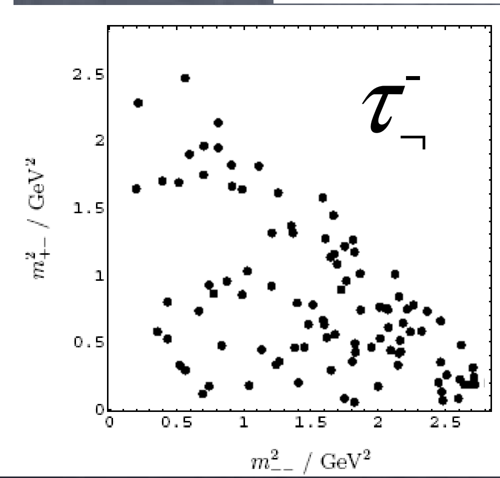


$d^2\Gamma_{\rm rad}^{(LR)}$

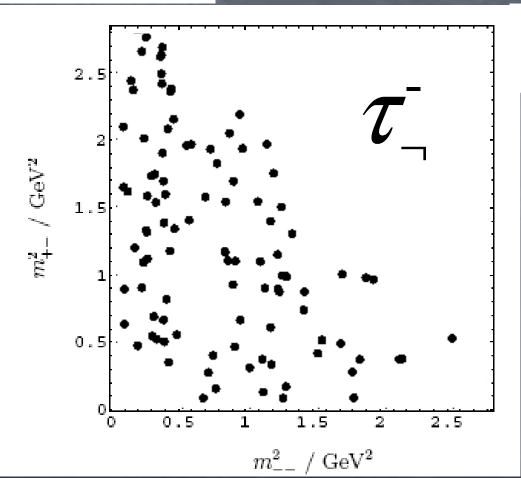


Flipping the helicity of the po
electron beam allows us to
determine the chiral structure
of dimension 6 four fermion
lepton flavor-violating interac

$)^{(LL)}|$ (left)

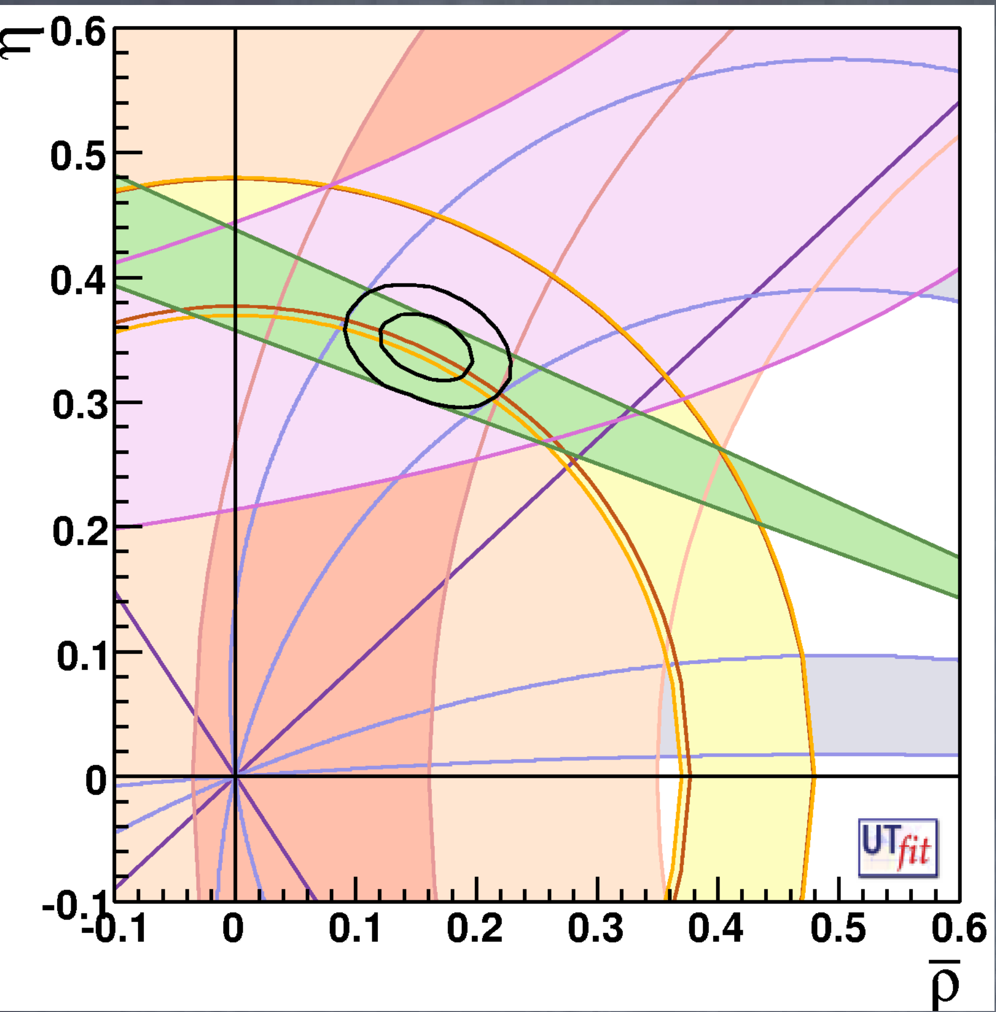


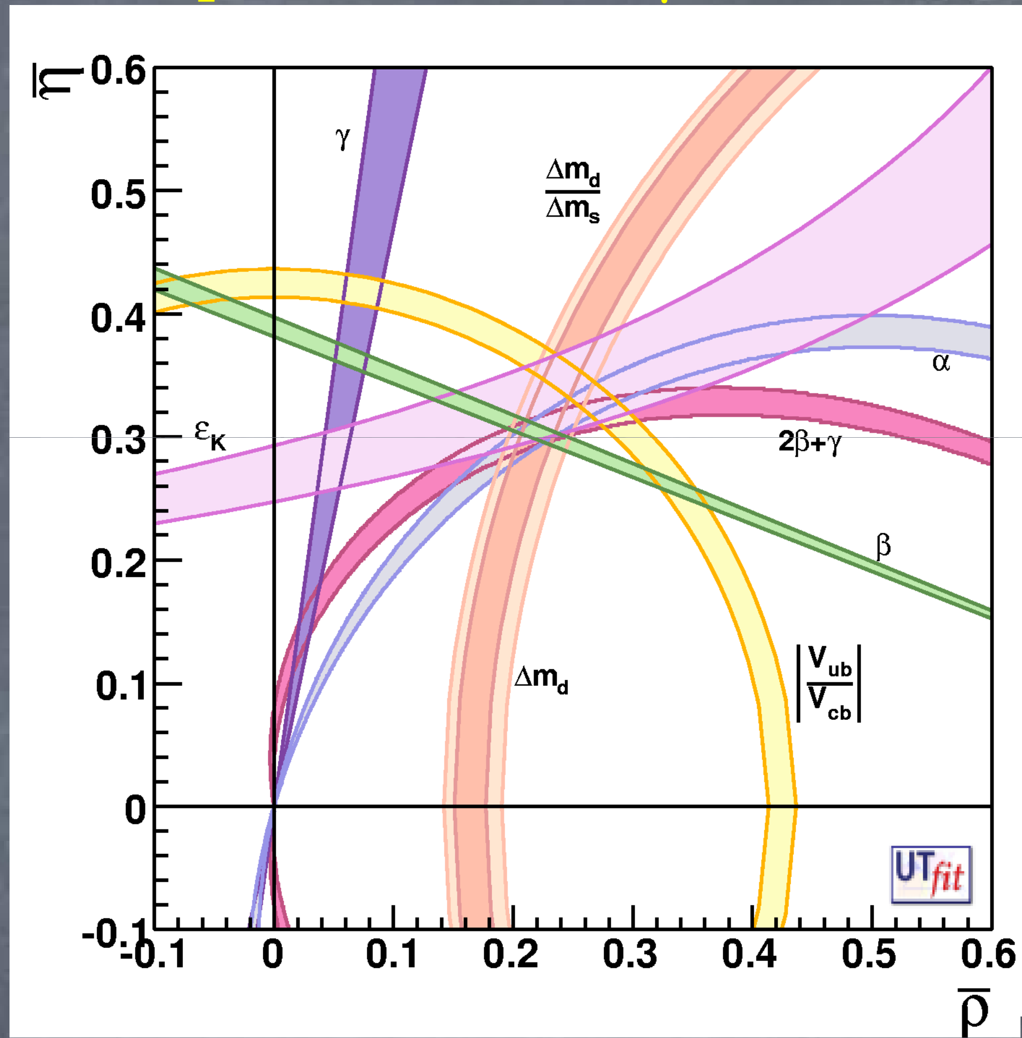
$|d^2\Gamma_{\rm mix}^{(LL)(RR)}|$ (right)



Dassinger, Feldmann, Mannel, and
JHEP 0710:039,2007;

[See also Matsuzaki and Sanda
arXiv:0711.0792 [hep-ph]





$\rho = 0.163 \pm 0.028$

$\eta = 0.344 \pm 0.016$

$\rho = \quad \pm 0.0028$

$\eta = \quad \pm 0.0024$

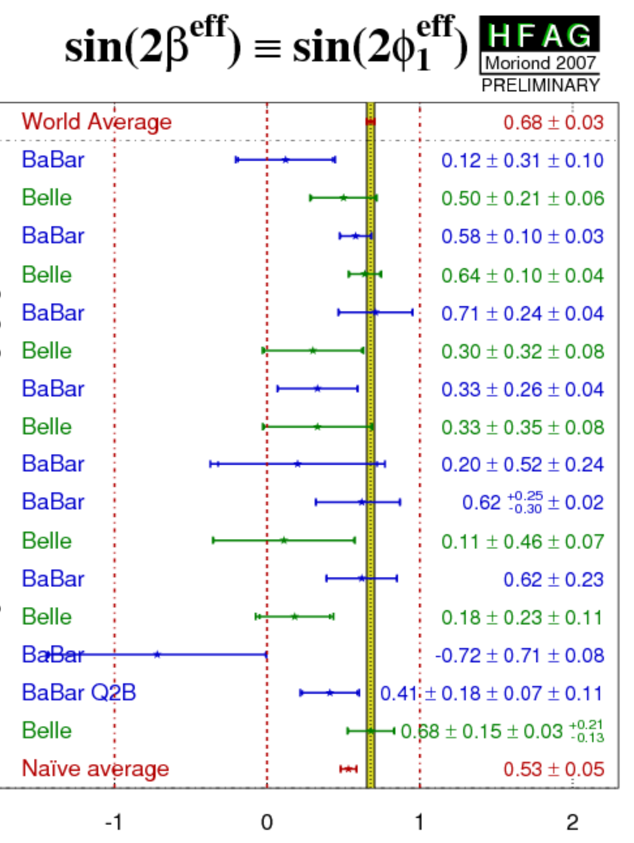
Improving the precision of Unitarity Triangle measurements,
long with reducing theoretical uncertainties, can provide evidenc
for New Physics

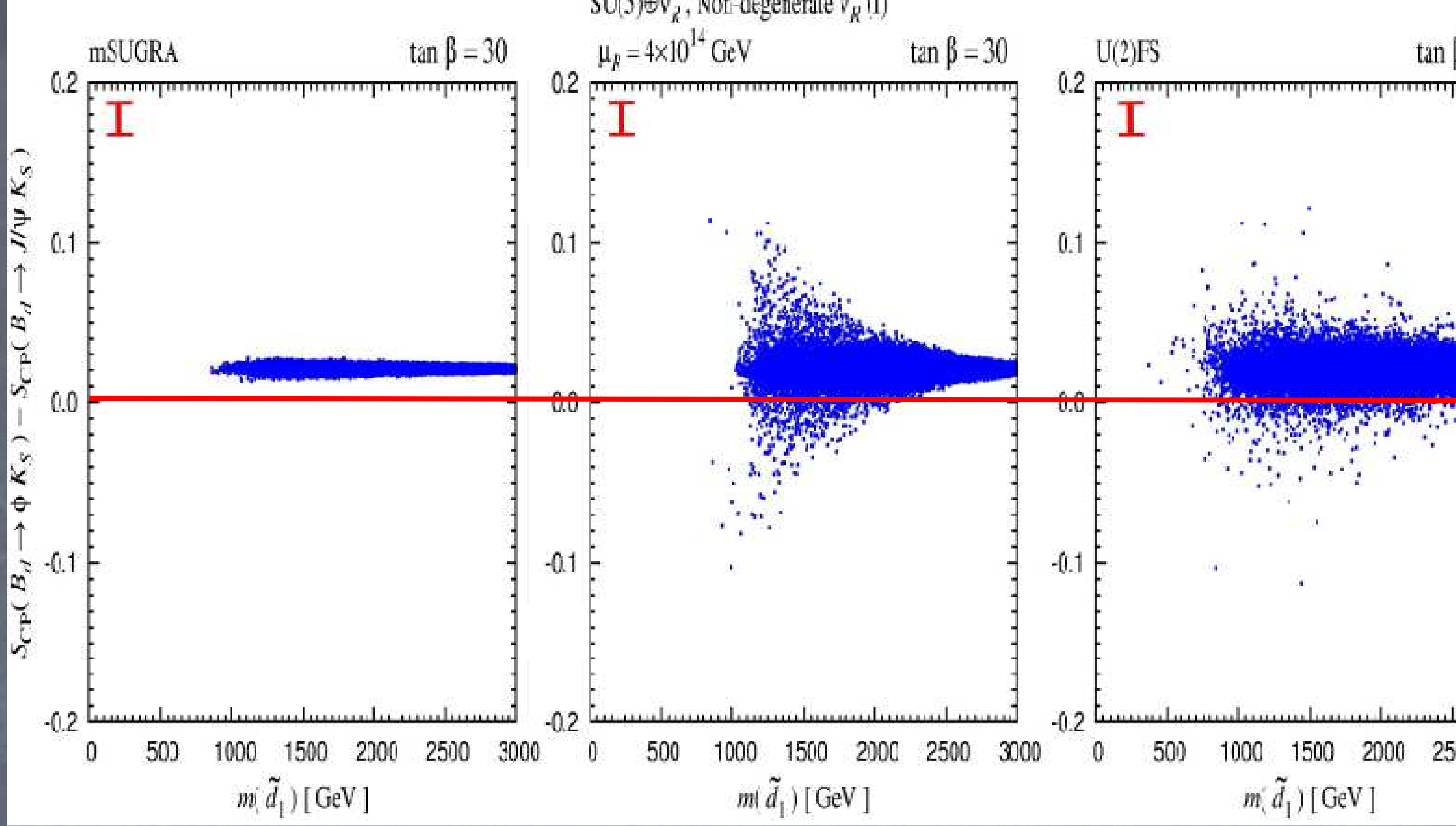
SPS	$M_{1/2}$ (GeV)	M_0 (GeV)	A_0 (GeV)	$\tan\beta$	μ
1 a	250	100	-100	10	> 0
1 b	400	200	0	30	> 0
2	300	1450	0	10	> 0
3	400	90	0	10	> 0
4	300	400	0	50	> 0
5	300	150	-1000	5	> 0

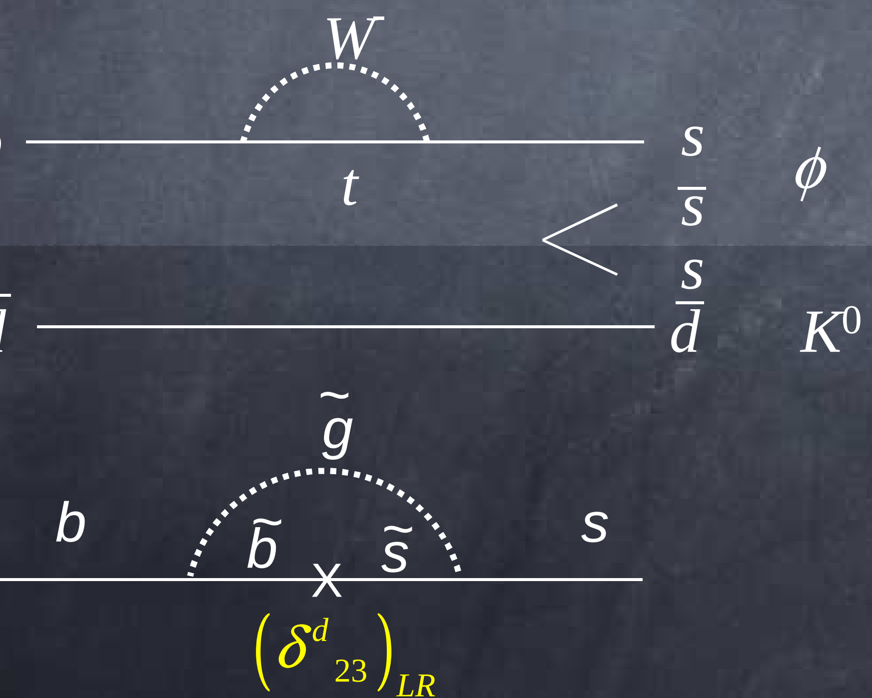
	SPS1a	SPS4	SPS5
$\rightarrow s\gamma)$	0.919 ± 0.038	0.248	0.848 ± 0.081
$\rightarrow \tau\nu)$	0.968 ± 0.007	0.436	0.997 ± 0.003
$\rightarrow X_s l^+ l^-)$	0.916 ± 0.004	0.917	0.995 ± 0.002
$\rightarrow K\nu\overline{\nu})$	0.967 ± 0.001	0.972	0.994 ± 0.001
$\rightarrow \mu^+\mu^-)/10^{-10}$	1.631 ±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

SPS4 is ruled out by ex
value of $B(B\rightarrow s\gamma)$

SPS1a is the least favor
for flavor effects, but
*Super*B and only *Super*
can observe 2σ deviatio
several observables







Many channels can show effects in the range ΔS~(0.0

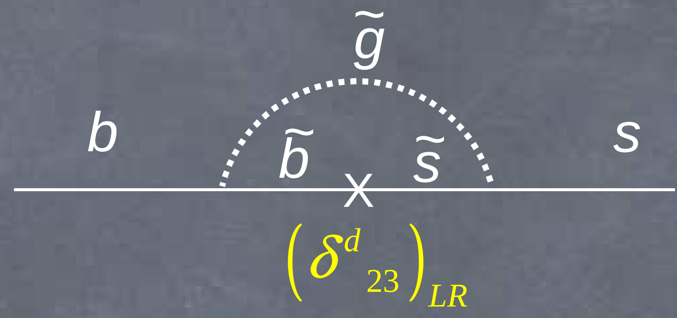
Observable	B Factories (2 ab^{-1})	Super$B$
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	0.12	0.02 (∗)

r-changing NP effects in the squark propagator

P scale SUSY mass $\tilde{m} \sim m_{\tilde{g}}$

avor-violating coupling $(\delta^q_{ij})_{LR,RR,LL} = \frac{(M^2_{ij})^q_{LR,RR,LL}}{\tilde{m}^2}$

(2-3 transitions)



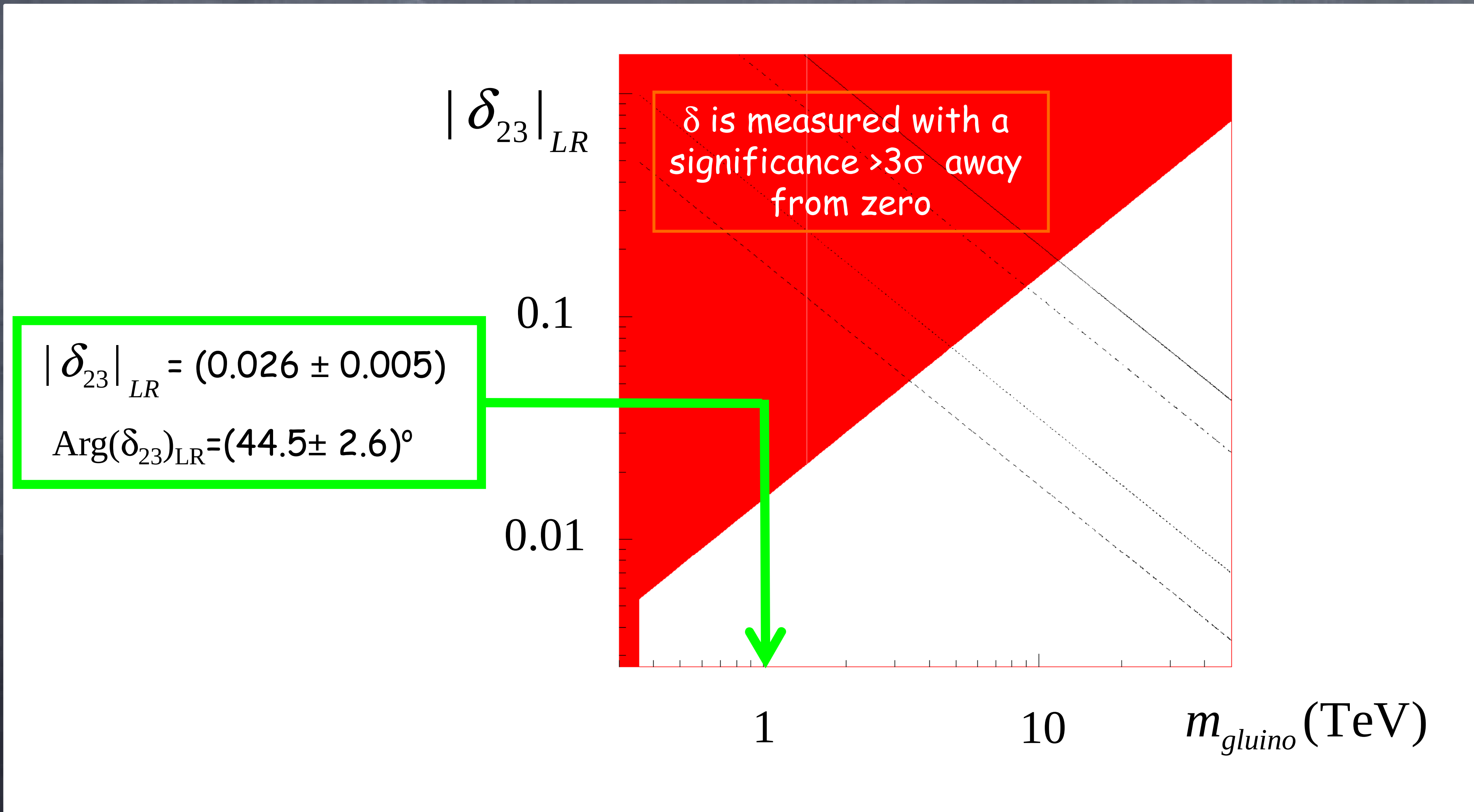
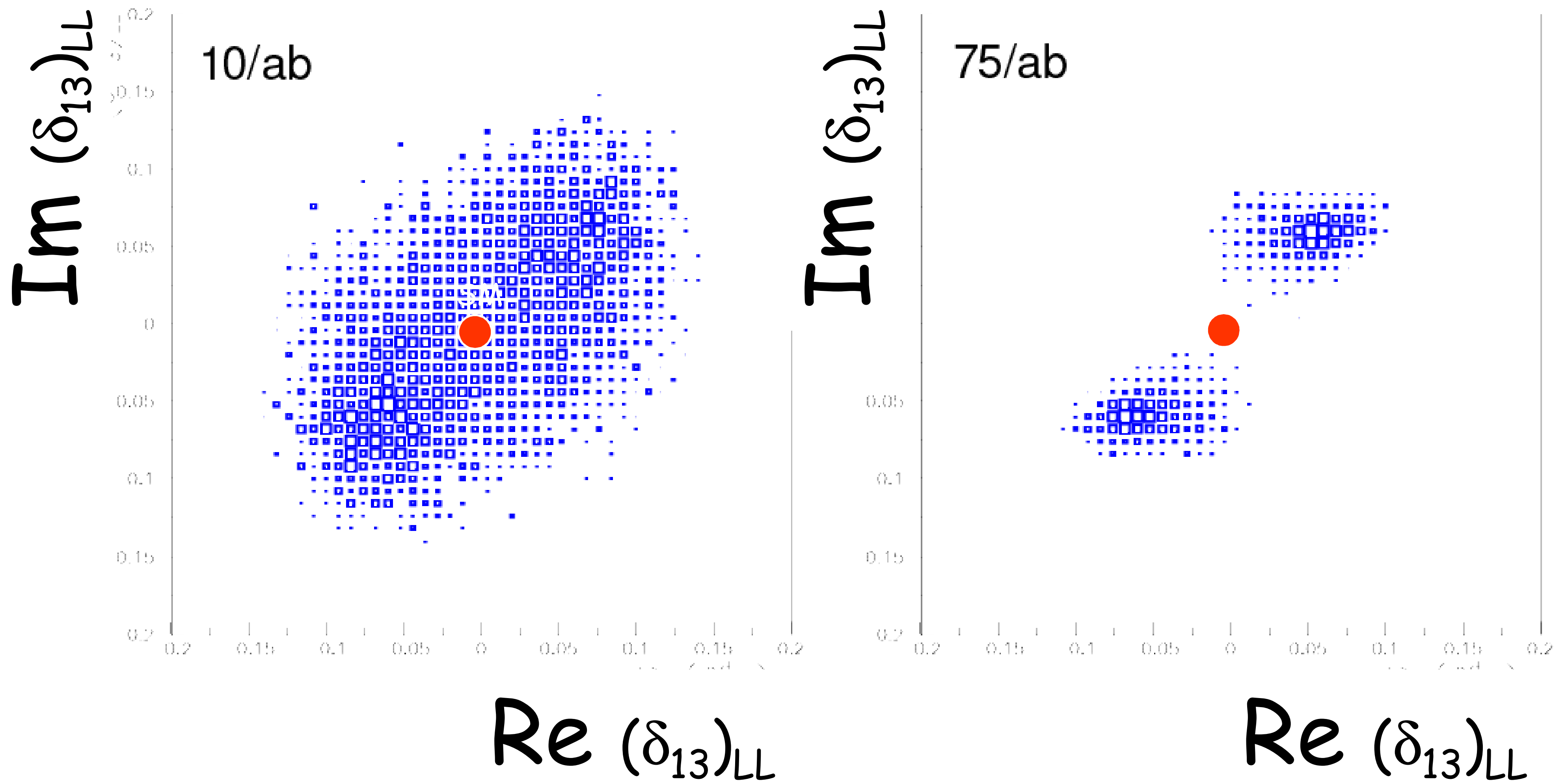
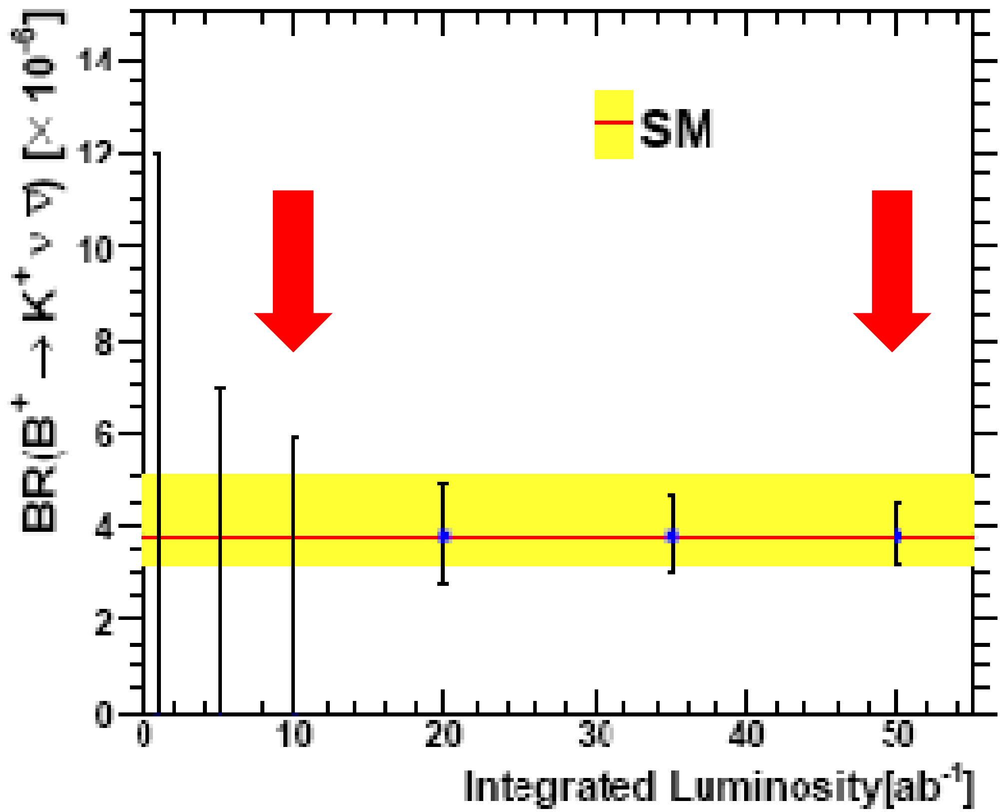


Exhibit A: Determination of coupling [in this case : $(\delta_{13})_{LL}$]

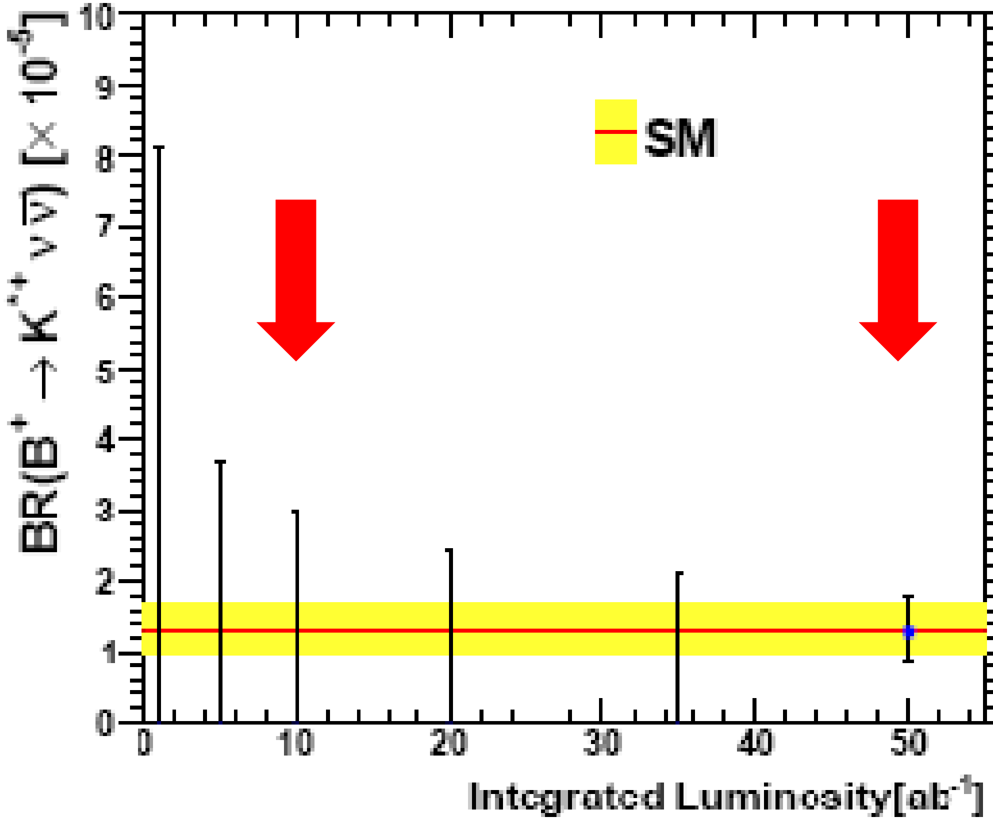
with 10 ab^{-1} and 75 ab^{-1}



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

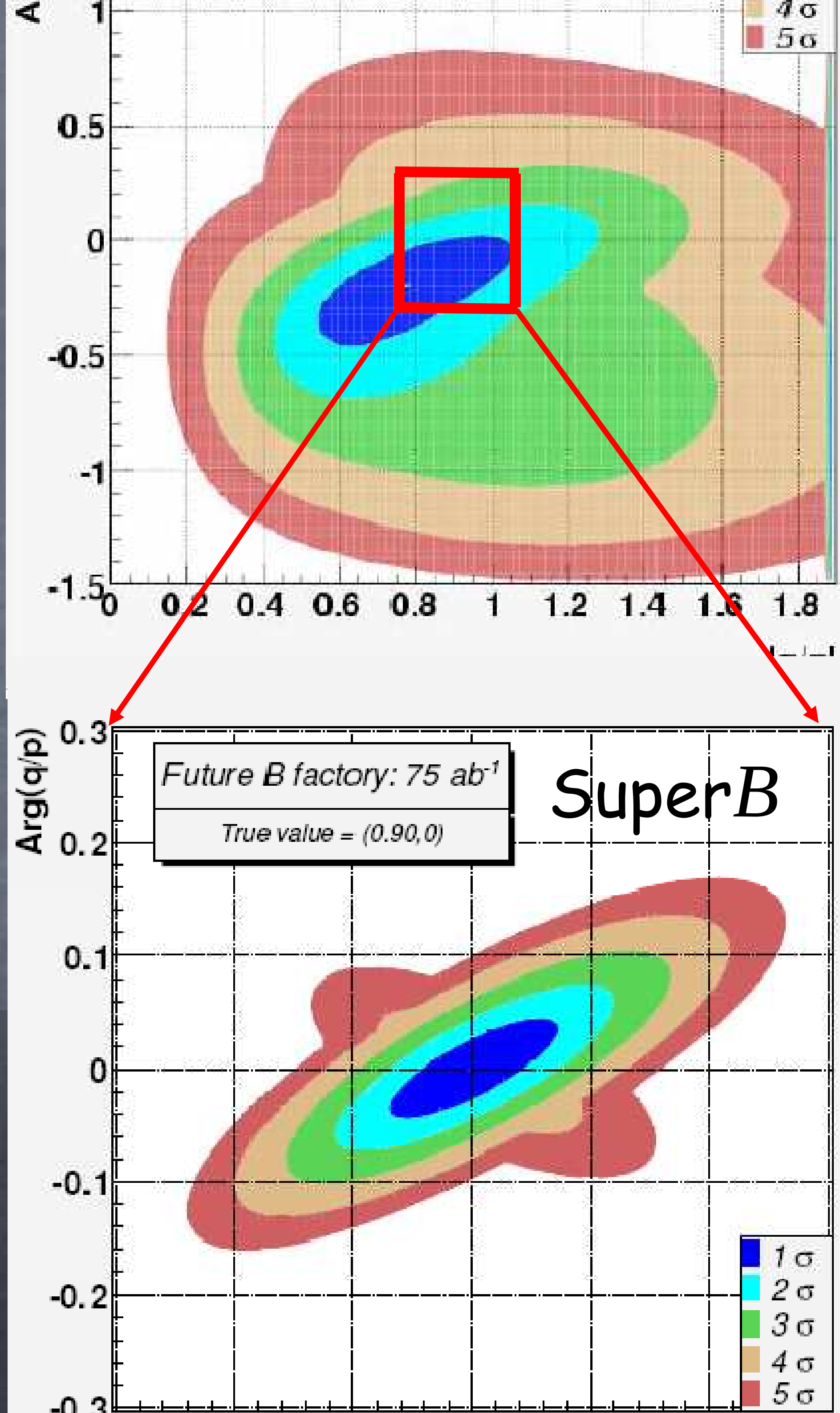


$B^+ \to K^{*+} \nu\bar{\nu},\ (K^{*+} \to K_S \pi^+)$



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

Mode	Observable	$\Upsilon(4S)$ (75 ab^{-1})	$\psi(3770)$ (300 fb^{-1})
$D^0 \to K^+\pi^-$	x'^2	3×10^{-5}	
	y'	7×10^{-4}	
$D^0 \to K^+K^-$	y_{CP}	5×10^{-4}	
$^0 \to K_S^0\pi^+\pi^-$	x	4.9×10^{-4}	
	y	3.5×10^{-4}	
	$\lvert q/p \rvert$	3×10^{-2}	
	ϕ	2°	
$3770) \to D^0\overline{D}^0$	x^2		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$



High statistics flavor physics at an e^+e^- collider will likely provide informatio
crucial to the understanding of new physics found at LHC

- The data sample needed is in the range 50-75 ab^{-1}
- Super$B$, with an initial luminosity of 10^{36} $cm^{-2}s^{-1}$ can provide such a sampl the canonical five years
  - The low emittance crabbed waist design of Super$B$ allows
    - Very high luminosity with a power bill less than existing machines
    - Detector backgrounds that can be coped with using existing technology
    - A longitudinally polarized electron beam that facilitates measurem of or searches for, τ EDM, CPV and anomalous moment
    - The capability of running at lower center-of-mass energies

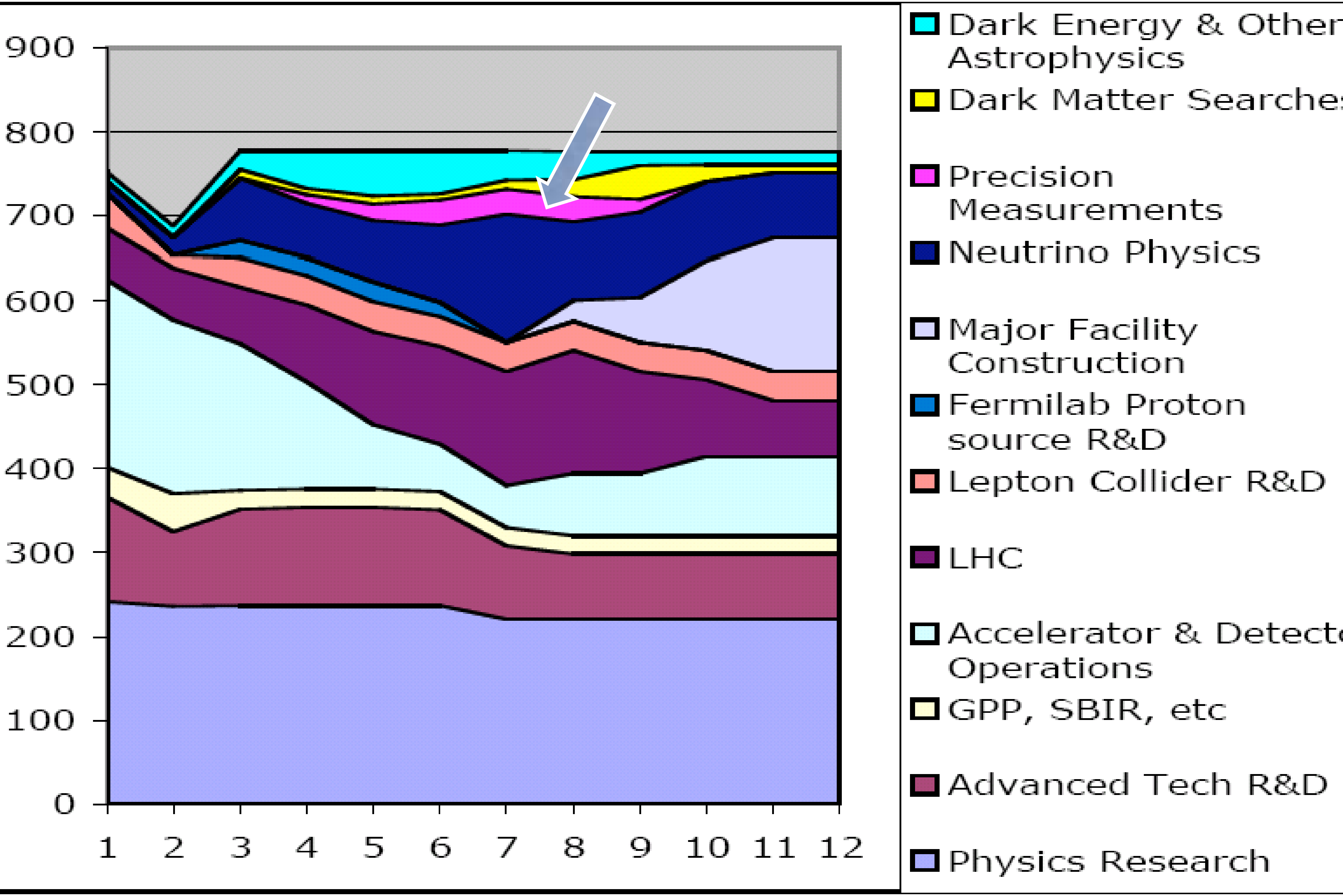
The achievable levels of sensitivity in rare b, c and τ decays allow substantia coverage in the parameter space of new physics

There is, of course, overlap with the programs of LHC flavor experiments su as LHCb, but the e^+e^- environment makes possible a substantial number of ur and important physics objectives, especially in those areas most sensitive to physics, such as LFV, FCNC, decays involving (multi) neutrals, $D^0\bar{D}^0$ mixing and CPV, ...

We are working towards a turn-on date of 2015

High-sensitivity Measurements

- The latest developments in accelerator and detector technology make possible promising new scientific opportunities through measurement of rare processes. Incisive experiments, complementary to experiments at the LHC, would probe the Terascale and possibly much higher energies.
- The panel recommends pursuing the muon-to-electron conversion experiment, subject to approval by the Fermilab PAC, under all budget scenarios considered by the panel.
- The intermediate budget scenario would allow in addition pursuing significant participation in one overseas next-generation B factory.
- The more favorable funding scenario, scenario C, would allow for pursuing a program in rare K decay experiments at Fermilab as well.



900
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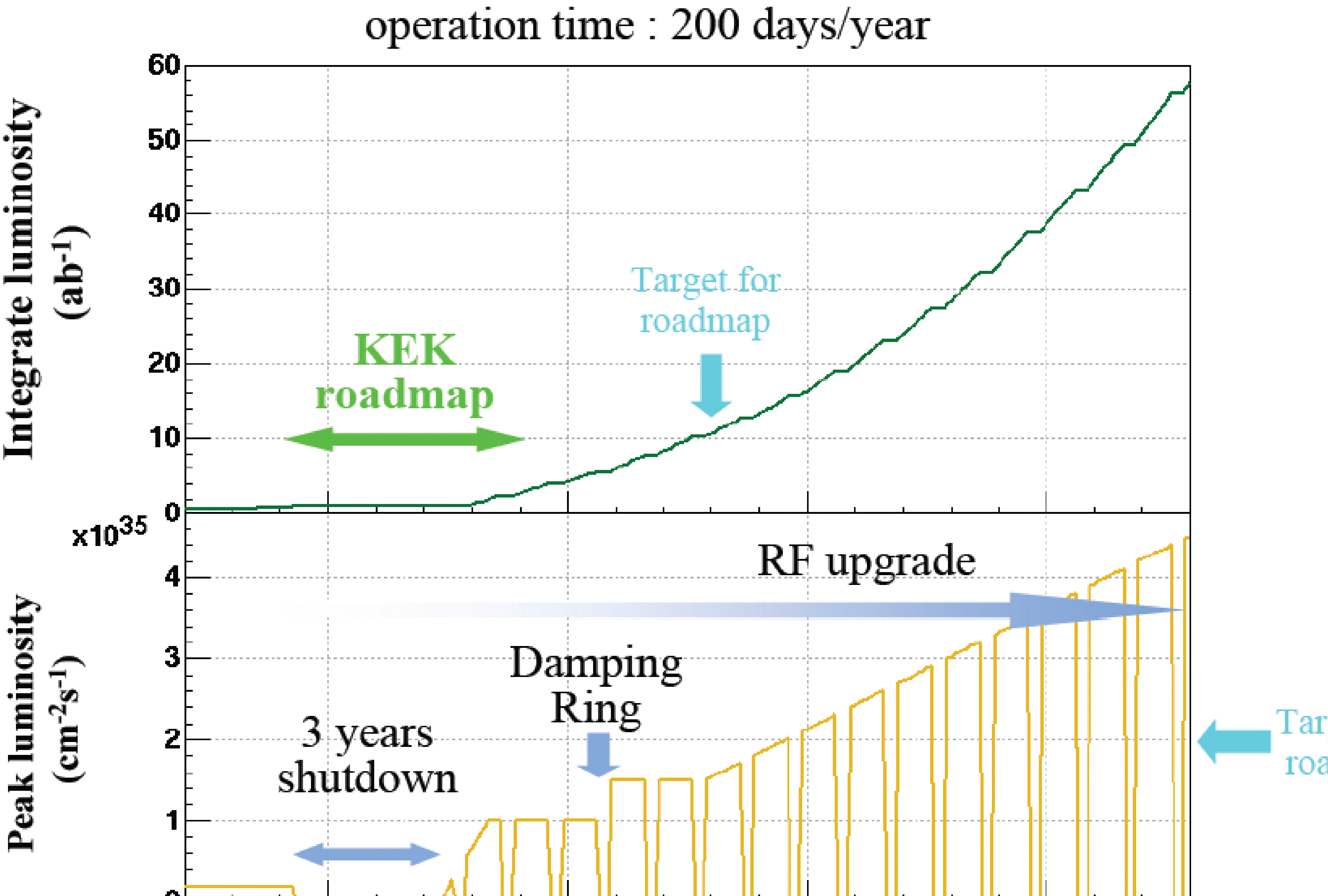
11
12
Dark Energy & Other Astrophysics
Dark Matter Searches
Precision Measurements
Neutrino Physics
Major Facility Construction
Fermilab Proton source R&D
Lepton Collider R&D
LHC
Accelerator & Detector Operations
GPP, SBIR, etc
Advanced Tech R&D
Physics Research

Projected luminosity (preliminary)



SuperKEKB Machine Parameters

SuperKEKB			
Emittance	ε_x	9*	nm
	ε_y	0.045	nm
Beta at IP	$\beta_x{}^*$	200	mm
	$\beta_y{}^*$	3	mm
Beam size at IP	$\sigma_x{}^*$	42	μm
	$\sigma_y{}^*$	367	nm
Bunch length	σ_z	3	mm
Synchrotron tune	ν_s	0.025	
Beam current	I_+/I_-	9.4/4.1	A
#bunches	N_b	5000	
Crossing angle	$2\phi_x$	30 → 0 (crab crossing)	mrad
Beam-beam	ξ_x	0.209	
	ξ_y	0.405	
Luminosity	L	8×10^{35}	$cm^{-2}s^{-1}$

* 24 nm emittance is one of the options because low emittance might be difficult because of beam dynamics issues.
Magnet configuration is same due to lattice flexibility.
In that case, luminosity goes down to 4×10^{35} $cm^{-2}s^{-1}$.

Electric power consumption
45 MW (KEKB)
→ 83 MW (SuperKEKB)