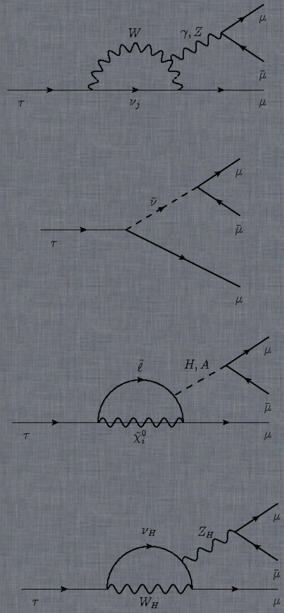
The SuperB factory

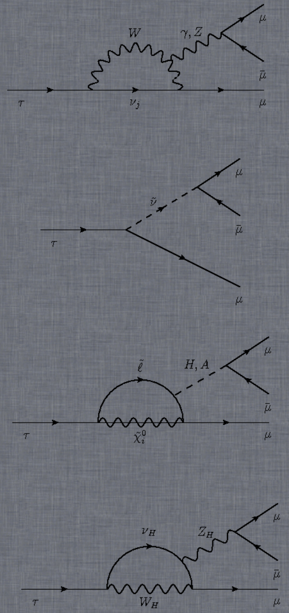
physics prospects and project status

Marcin Chrząszcz

Institute of Nuclear Physics,
Polish Academy of Science,
on behalf of the SuperB collaboration

21^{st} September 2012





W
γ, Z
μ
$\bar{\mu}$
τ
ν_j
μ
$\tilde{\nu}$
μ
$\bar{\mu}$
τ
μ
$\tilde{\ell}$
H, A
μ
$\bar{\mu}$
τ
$\tilde{\chi}^0_i$
μ
ν_H
Z_H
μ
$\bar{\mu}$
τ
W_H
μ

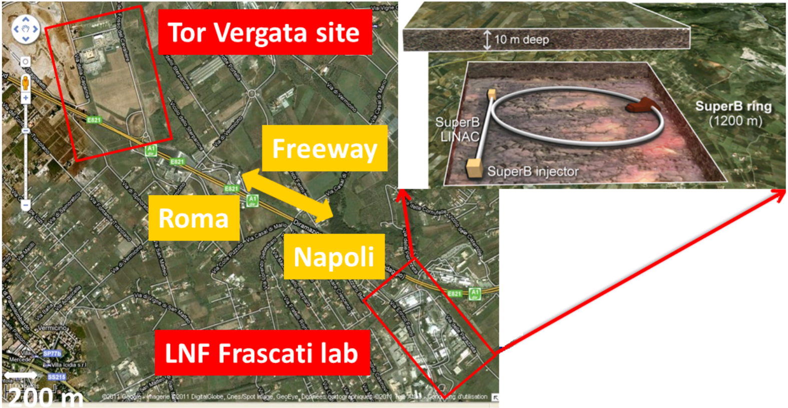
B factories

B factories have contributed to many important physics discoveries over the last decade. They will be succeeded the Super Flavor Factories:

Super Flavor Factories

1. Data $75ab^{-1}$
2. Luminosity $10^{36}cm^{-2}s^{-1}$
3. Flexibility to run on charm threshold with luminosity $10^{35}cm^{-2}s^{-1}$
4. Longitudinal polarization of electron beam 80%
5. Upgraded BaBar detector
6. Start of data taking: 2018
7. $10ab^{-1}$ per year

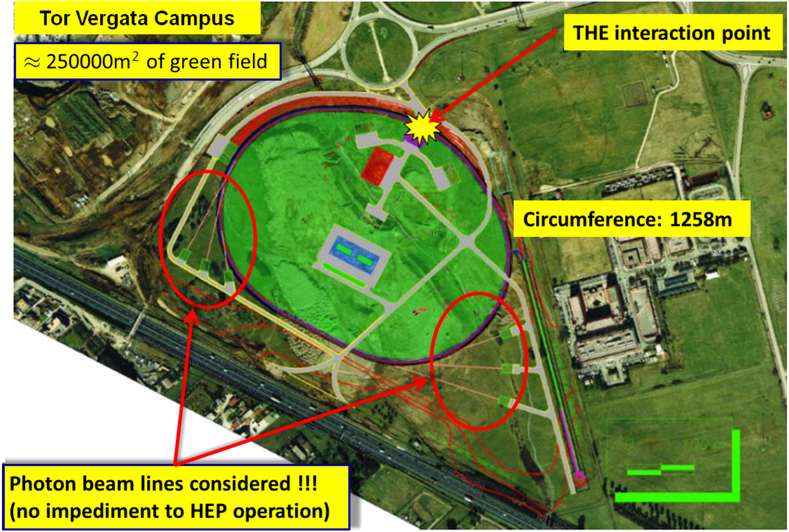
Tor Vegata Site



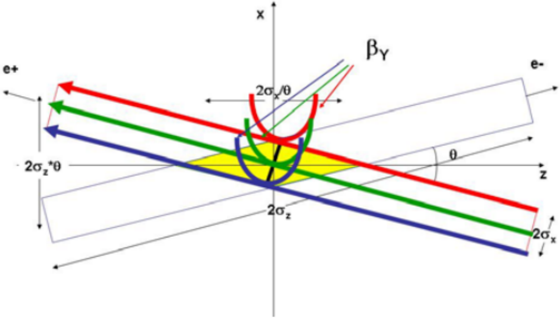
Important dates:

1. TDR: Autumn this year.
2. Colliding beams: June 2018.

Tor Vegata Site

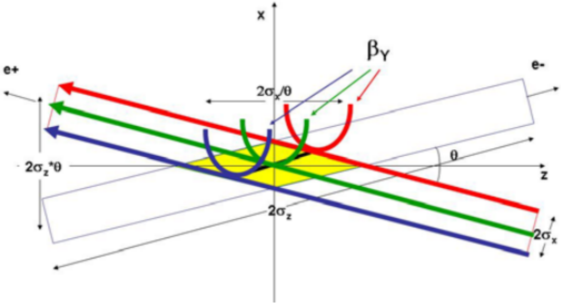


Quest for Luminosity



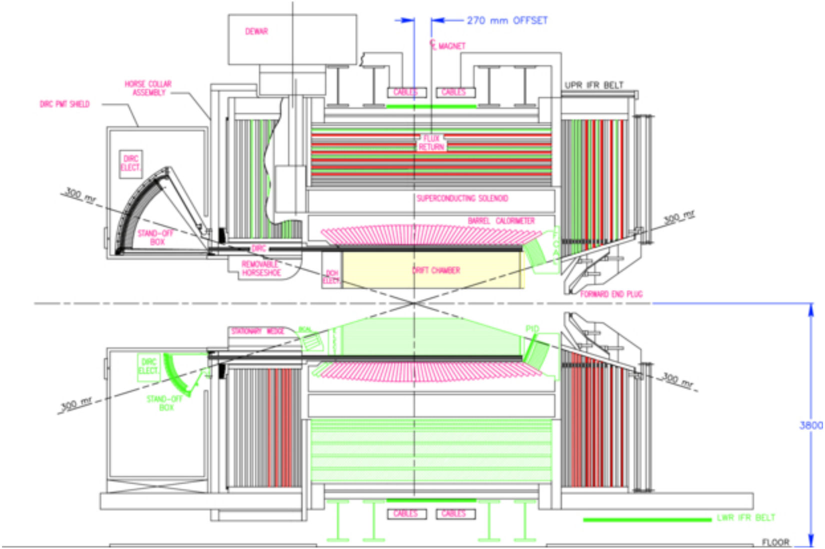
$$L \propto \frac{1}{\sqrt{\beta_y}}, \Phi \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2}$$

Quest for Luminosity

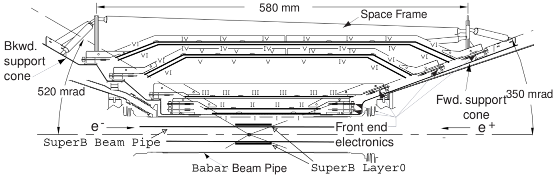


$$L \propto \frac{1}{\sqrt{\beta_y}}, \Phi \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2}$$

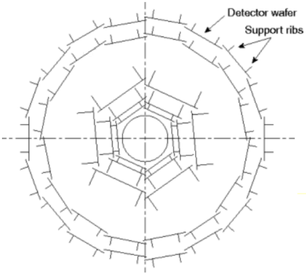
Recycling BaBar



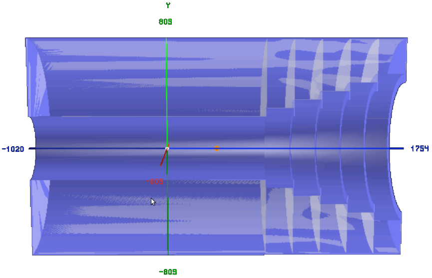
Silicon Vertex Tracker (SVT)



- Five layers(1-5) of double-sided silicon strip detectors
- Radial span $3 - 15$ cm
- Upgraded electronics for faster readout
- Additional Layer 0:
  1. Radius $\approx 1.5 cm$
  2. Low material budget: $X_0 = 0.5\%$
  3. Two candidate technologies: Hybrid Pixels and Double Sided Strip detectors (Striplets)



Drift Chamber (DCH)

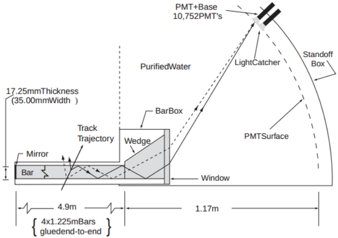


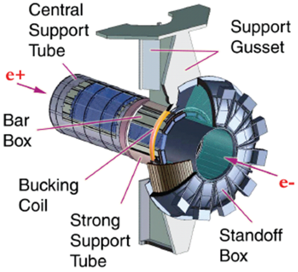
- 40 layers of $\approx 1cm$ cells parallel to beam line
- Provide momentum and $\frac{dE}{dx}$ for low momentum particles ($p < 700MeV$)
- $\approx$ 10000 channels
- Occupancy ($3.5\% - 5\%$)

R&D:

- Geometry
- Gas mixture

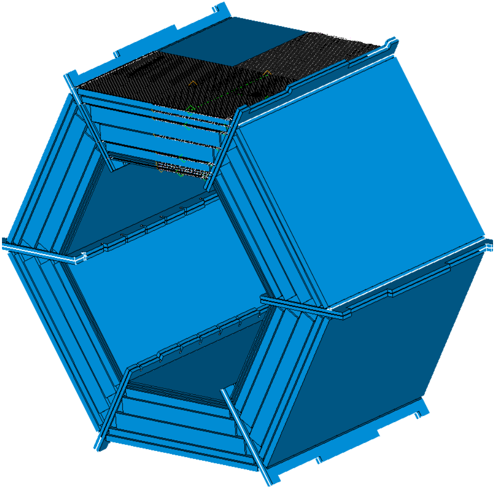
Detector of Internally Reflected Cherenkov Light





- Momentum range $0.7 - 4GeV$
- Radiator: synthetic fused silica
- Photon detectors outside field region
- Radiation hard

Electromagnetic and Hadronic Calorimeter



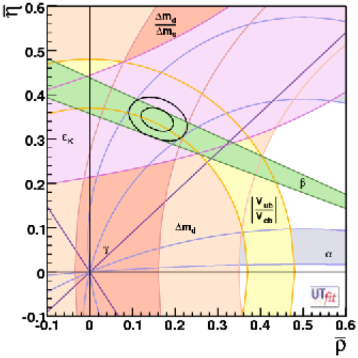
Electromagnetic Calorimeter:

- Coverage $94\% of 4\Pi$
- CsI or LYSO crystals
- Crystal length $16 - 17.5X_0$
- Radiation hard

Instrumented Flux Return:

- Upgrade form TDC to BIRO
- Scintillators
- Iron reused from BaBar
- SiPM

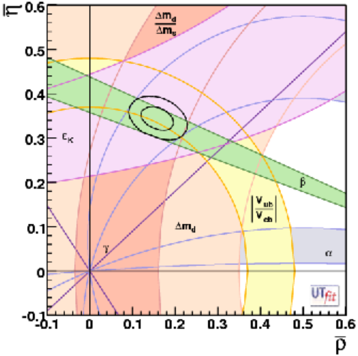
CKM Matrix

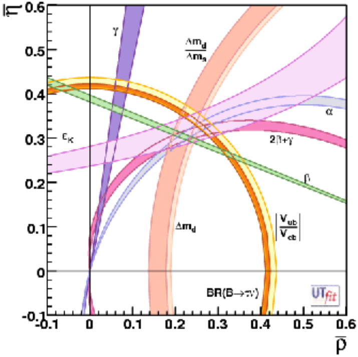


$$\Delta\overline{\eta} = 0.016$$

$$\Delta\overline{\rho} = 0.028$$

CKM Matrix





$\Delta\bar{\eta} = 0.016$

$\Delta\bar{\rho} = 0.028$

$\Delta\bar{\eta} = 0.0024$
$\Delta|V_{cb}|_{incl} = 0.5\%$ $\Delta|V_{cb}|_{excl} = 1.0\%$
$\Delta\bar{\rho} = 0.0028$
$\Delta|V_{ub}|_{incl} = 1.0\%$ $\Delta|V_{ub}|_{excl} = 3.0\%$

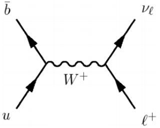
$B \to \tau\nu$

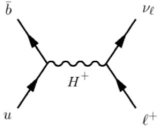
Precise SM prediction:

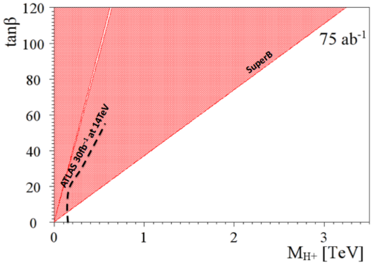
$$Br(B \to l\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 (1 - \frac{m_l^2}{m_B^2}) f_B^2 |V_{ub}|^2 \tau_B$$

In SUSY:

$$Br(B \to l\nu) = \frac{G_F^2 m_B}{8\pi} m_l^2 (1 - \frac{m_l^2}{m_B^2}) f_B^2 |V_{ub}|^2 \tau_B (1 - \frac{tan^2\beta}{1 + \bar{\epsilon} tan\beta} \frac{m_B^2}{m_H^2})$$







Time-Dependent CP (TDCP)

Time-dependent CP analysis can show signs of new physics. One has to study a set of modes:

$b \to s\bar{s}c$, $b \to s$

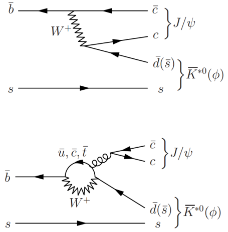
Current experimental results show Δ(SM - Observed):

$\Delta sin(2\beta) = 2.7\sigma$, penguin

$\Delta sin(2\beta) = 2.1\sigma$, tree

Golden modes in SuperB: $B \to J/\psi K^0$, $B \to \eta' K^0$, $B \to f_0 K_s^0$

Mode	Current Precision			Predicted Precision (75 ab^{-1})		
	Stat.	Syst.	ΔS^f (Th.)	Stat.	Syst.	ΔS^f (Th.)
$J/\psi K_S^0$	0.022	0.010	0 ± 0.01	0.002	0.005	0 ± 0.001
$\eta' K_S^0$	0.08	0.02	0.015 ± 0.015	0.006	0.005	0.015 ± 0.015
$\phi K_S^0 \pi^0$	0.28	0.01	–	0.020	0.010	–
$f_0 K_S^0$	0.18	0.04	0 ± 0.02	0.012	0.003	0 ± 0.02
$K_S^0 K_S^0 K_S^0$	0.19	0.03	0.02 ± 0.01	0.015	0.020	0.02 ± 0.01
ϕK_S^0	0.26	0.03	0.03 ± 0.02	0.020	0.005	0.03 ± 0.02
$\pi^0 K_S^0$	0.20	0.03	0.09 ± 0.07	0.015	0.015	0.09 ± 0.07
ωK_S^0	0.28	0.02	0.1 ± 0.1	0.020	0.005	0.1 ± 0.1
$K^+ K^- K_S^0$	0.08	0.03	0.05 ± 0.05	0.006	0.005	0.05 ± 0.05
$\pi^0 \pi^0 K_S^0$	0.71	0.08	–	0.038	0.045	–
ρK_S^0	0.28	0.07	-0.13 ± 0.16	0.020	0.017	-0.13 ± 0.16



$B \to X_s\gamma$

Very important probe for new physics! Current experimental average:
$Br(B \to X_s\gamma) = (3.52 \pm 0.23 \pm 0.09)10^{-4}$
Theoretical prediction from NNLO:
$Br(B \to X_s\gamma) = (3.15 \pm 0.23)10^{-4}$
There are two ways to study this decay:

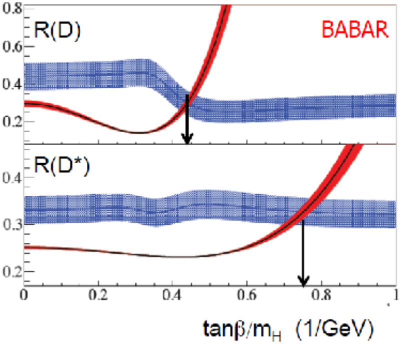
1. Exclusive:
   - The earliest results were done using a large number of exclusive decays, which were fully reconstructed
   - Errors arising from unseen modes
   - Obsolete for SuperB
2. Inclusive:
   - Use tagging to tag the other B
   - No requirements on X_s
   - Disadvantage: Cut on photon energy
   - Effort to keep the cut as small as possible

Experimentally challenging to measure inclusive decays.

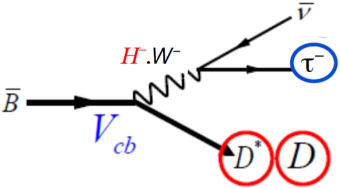
B Rare Decays

$B^{\pm} \to D^{(*)}\tau^{\pm}\nu$

Babar ref. arXiv:1205.5442



Hot decay for SuperB!



Observables:

- $R(\mathrm{D}) = \dfrac{\mathrm{B} \to \mathrm{D}\tau\nu}{\mathrm{B} \to \mathrm{D}\ell\nu}$
- $R(\mathrm{D}^*) = \dfrac{\mathrm{B} \to \mathrm{D}^*\tau\nu}{\mathrm{B} \to \mathrm{D}^*\ell\nu}$

	$R(\mathrm{D})$	$R(\mathrm{D}^*)$
BaBar	0.440 ± 0.071	0.332 ± 0.029
SM	0.297 ± 0.017	0.252 ± 0.003
Difference	2.0σ	2.7σ

$\mathrm{B_s}$ Decays

$\mathrm{B_s}$ is clearly LHCb domain

Short runs at CLEO and Belle showed that $e^+ e^-$ can also contribute in $\mathrm{B_s}$ studies

Observable	Error on $1\mathrm{fb}^{-1}$	Error on $30\mathrm{fb}^{-1}$
$\Delta\Gamma[\mathrm{ps}^{-1}]$	0.16	0.03
β_s from $\mathrm{B_s} \to J/\psi\phi[deg]$	16	6
β_s from $\mathrm{B_s} \to K\overline{K}^0[deg]$	24	11
$\left\lvert \frac{V_{td}}{V_{ts}} \right\rvert$	0.08	0.017

Potentials in SuperB:

1. Decays with neutral particle $\mathrm{B_s} \to J/\psi\eta$, $\mathrm{B_s} \to K^0_S\pi$, $\mathrm{B_s} \to D^*K^0_S$, $\mathrm{B_s} \to \Phi\eta'$
2. Measurements of $\mathcal{B}(\mathrm{B} \to \gamma\gamma)$. SM prediction $\mathcal{B}(\mathrm{B} \to \gamma\gamma) = (2-4) \times 10^{-7}$. NP (SUSY) $\mathcal{B}(\mathrm{B} \to \gamma\gamma) = 5 \times 10^{-6}$.
3. Measurements of semi-leptonic asymmetry. $A^s_{SL} = \dfrac{1 - \left\lvert \frac{q}{p} \right\rvert^4}{1 + \left\lvert \frac{q}{p} \right\rvert^4} = \dfrac{N_1 - N_2}{N_1 + N_2}$

$N_1 = \mathrm{B_s} \to \overline{\mathrm{B}}_s \to D_s^{*-}\ell^+\nu$ $N_2 = \mathrm{B_s} \to \overline{\mathrm{B}}_s \to \overline{D}_s^{*}\ell^-\nu$

Charm Physics

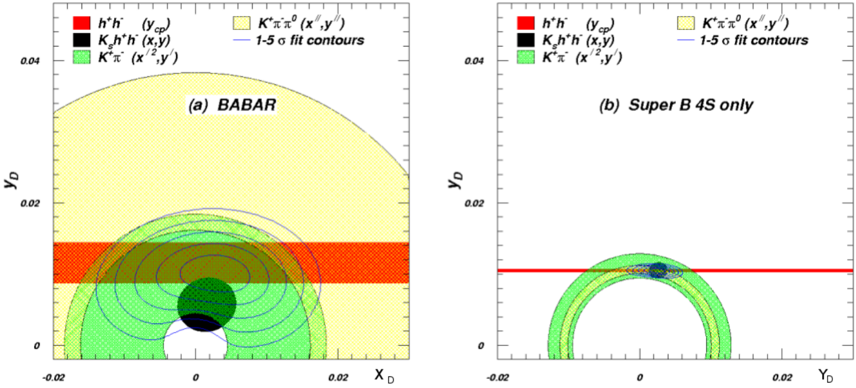
1. Plan for running at $\psi(3770)$ threshold
2. Scenario: Collect 500fb^{-1}
3. D tag possible; other meson can be studied with very small background

Potential improvement from SuperB:

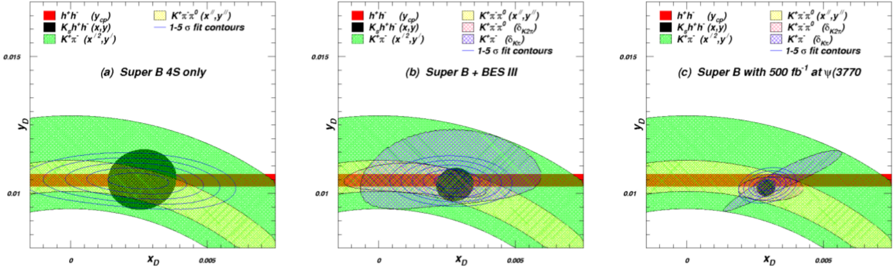
- Improved measurement of the mixing parameters x_D and y_D
- CP violation in $\overline{\mathrm{D}} - \overline{\mathrm{D}}$: $A_{SL} = \dfrac{N_1 - N_2}{N_1 + N_2}$

  $N_1 = \Gamma(\mathrm{D}^0 \to \ell^- \nu \mathrm{K}^+)$,
  $N_2 = \Gamma(\overline{\mathrm{D}^0} \to \ell^+ \nu \mathrm{K}^-)$
- Search for $\mathrm{D}^0 \to \mu\mu$
- Quantum correlations allow one to measure relatively strong phase

Charm Physics

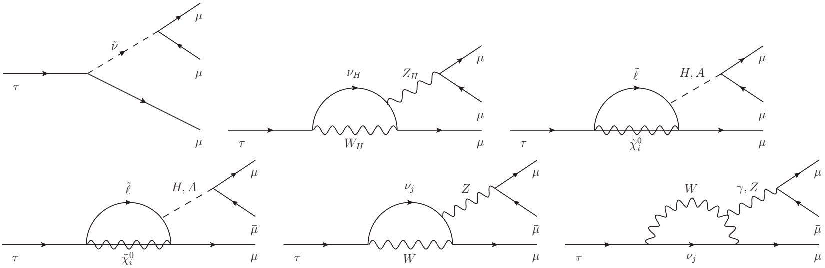


Charm Physics



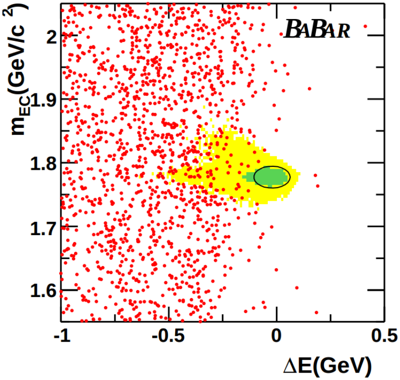
Lepton Flavor Violation (LFV)

- LFV can occur in SM due to neutrino masses
- Any observation is evidence of new physics
- Most promising channels: $\tau \to l\gamma$, $\tau \to lll$.

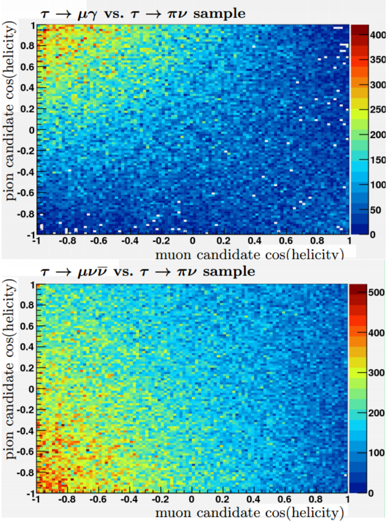


$\tau \to l\gamma$ Sensitivity

- Better tracking resolution, increased $\Delta m - \Delta E$ box by 65%
- Higher photon efficiency
- Increase of geometry acceptance
- Thicker signal peak
- Smaller boost improves the performance of the fit



Polarization



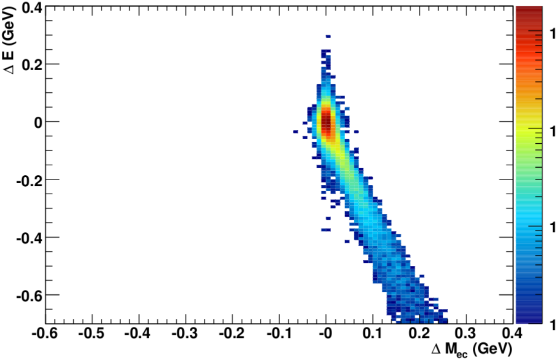
1. SuperB will have polarized electron beam (80%)
2. One can use this information in NP searches
3. Preliminary results:

- Upper limit at 90%: 2.44×10^{-9}
- 3σ observation: 5.50×10^{-9}

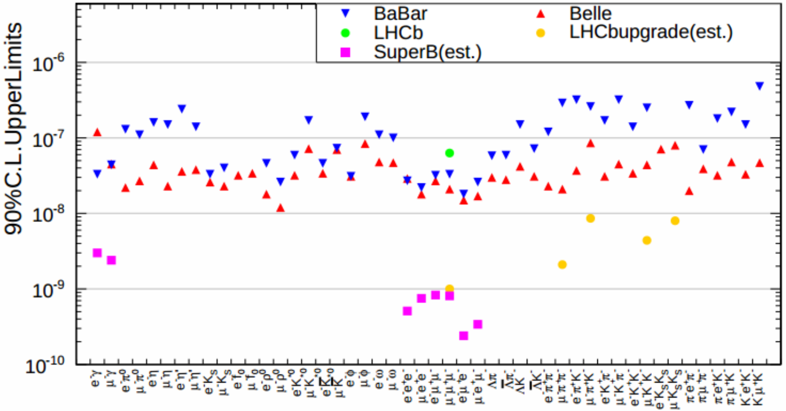
$\tau \to 3\mu$

Current analysis:

- Calculate the thrust axis
- Semi tag the second τ
- Limit obtained (90%)
  $Br(\tau \to 3\mu) = 8.1 \times 10^{-10}$



LFV Summary


BaBar
Belle
LHCb
LHCbupgrade(est.)
SuperB(est.)
90%C.L.UpperLimits
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}

CP Violation

- CP violation has never been observed in τ sector
- SM prediction is negligibly small $O(10^{-12})l$ in $\tau^{\pm} \rightarrow K^{pm}\pi^{0}\nu$.
- Any observation is clear indication of NP
- Very few NP models can explain this:
  1. RPV SUSY
  2. Multi Higgs models
- SuperB can improve sensitivity 75 times compared to CLEO

τ Electric Dipole Moment (EDM)

τ EDM can be measured with single angle differential cross section $e^+e^- \to \tau^+\tau^-$.

- Improvement using polarized beam
- Achievable sensitivity: $10^{-19} ecm$