Physics Prospects for the SuperB Factory

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Overview

- SuperB at a Glance
- Physics Prospects
- Accelerator, Detector
- Timeline, Funding
- Further Reading

SuperB at a Glance

- **Asymmetric e^+e^- collider**
- E_{e-} ~7 GeV, E_{e+} ~4 GeV
- **Clean e^+e^- initial state**
- >90% 4π acceptance in CMS
- ~80% polarized electrons
- Data-taking starting ~2017
- **E_{CMS}: psi(3770) up to Υ(5S)**
  - psi(3770): coherent ccbar
  - Υ(4S): coherent bb (B_u , B_d)
  - Υ(5S): coherent bb (B_s)
  - all E_{CMS} : $\tau^+\tau^-$, continuum light quark (udsc) production
- **Luminosity ~10^{36} cm^{-2} s^{-1}** →
- Synchrotron light source?

- psi(3770): ~1 ab^{-1} (few months)
- Υ(4S): ~75 ab^{-1} (~6 years)
- Υ(5S): ~1 ab^{-1} (few months)

CKM Unitarity Triangle

$$V_{\mathrm{CKM}} \equiv \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

- is a 3 × 3 unitary matrix
  - parameterized by three mixing angles
  - and the CP-violating KM phase*

$$V = \begin{pmatrix} c_{12}c_{13} & s_{12}c_{13} & s_{13}e^{-i\delta} \\ -s_{12}c_{23}-c_{12}s_{23}s_{13}e^{i\delta} & c_{12}c_{23}-s_{12}s_{23}s_{13}e^{i\delta} & s_{23}c_{13} \\ s_{12}s_{23}-c_{12}c_{23}s_{13}e^{i\delta} & -c_{12}s_{23}-s_{12}c_{23}s_{13}e^{i\delta} & c_{23}c_{13} \end{pmatrix},$$

where $s_{ij} = \sin\theta_{ij}$, $c_{ij} = \cos\theta_{ij}$, and δ is the phase responsible for all CP-violating phenomena in flavor-changing processes in the SM.

- It is known experimentally that $s_{13} \ll s_{23} \ll s_{12} \ll 1$, and can write V_{CKM} to $\mathcal{O}(\lambda^4)$ using the Wolfenstein parameterization**

$$s_{12} = \lambda = \frac{|V_{us}|}{\sqrt{|V_{ud}|^2 + |V_{us}|^2}}, \qquad s_{23} = A\lambda^2 = \lambda\left|\frac{V_{cb}}{V_{us}}\right|$$

$$s_{13}e^{i\delta} = V_{ub}^* = A\lambda^3(\rho + i\eta) = \frac{A\lambda^3\boxed{\bar\rho + i\bar\eta}\sqrt{1 - A^2\lambda^4}}{\sqrt{1-\lambda^2}[1 - A^2\lambda^4\boxed{\bar\rho + i\bar\eta}]}$$

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* N. Cabibbo, Phys. Rev. Lett. **10**, 531 (1963).
M. Kobayashi and T. Maskawa, Prog. Theor. Phys. **49**, 652 (1973).
L. L. Chau and W. Y. Keung, Phys. Rev. Lett. **53**, 1802 (1984).

** L. Wolfenstein, Phys. Rev. Lett. **51**, 1945 (1983).

CKM Unitarity Triangle

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

- unitarity of the CKM matrix imposes $\sum_i V_{ij}V^*_{ik} = \delta_{jk}$ and $\sum_j V_{ij}V^*_{kj} = \delta_{ik}$
- these can be represented as triangles in a complex plane
- the most commonly used unitarity triangle arises from

CKM Unitarity Triangle

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

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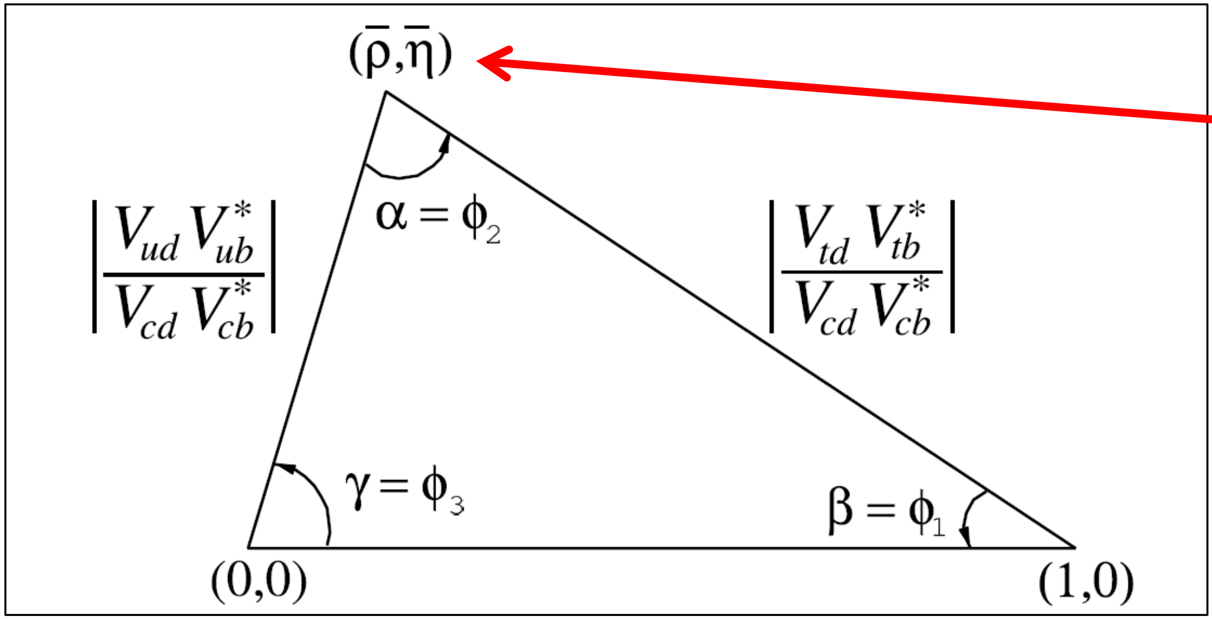
- these can be represented as triangles in a complex plane
- the most commonly used unitarity triangle arises from

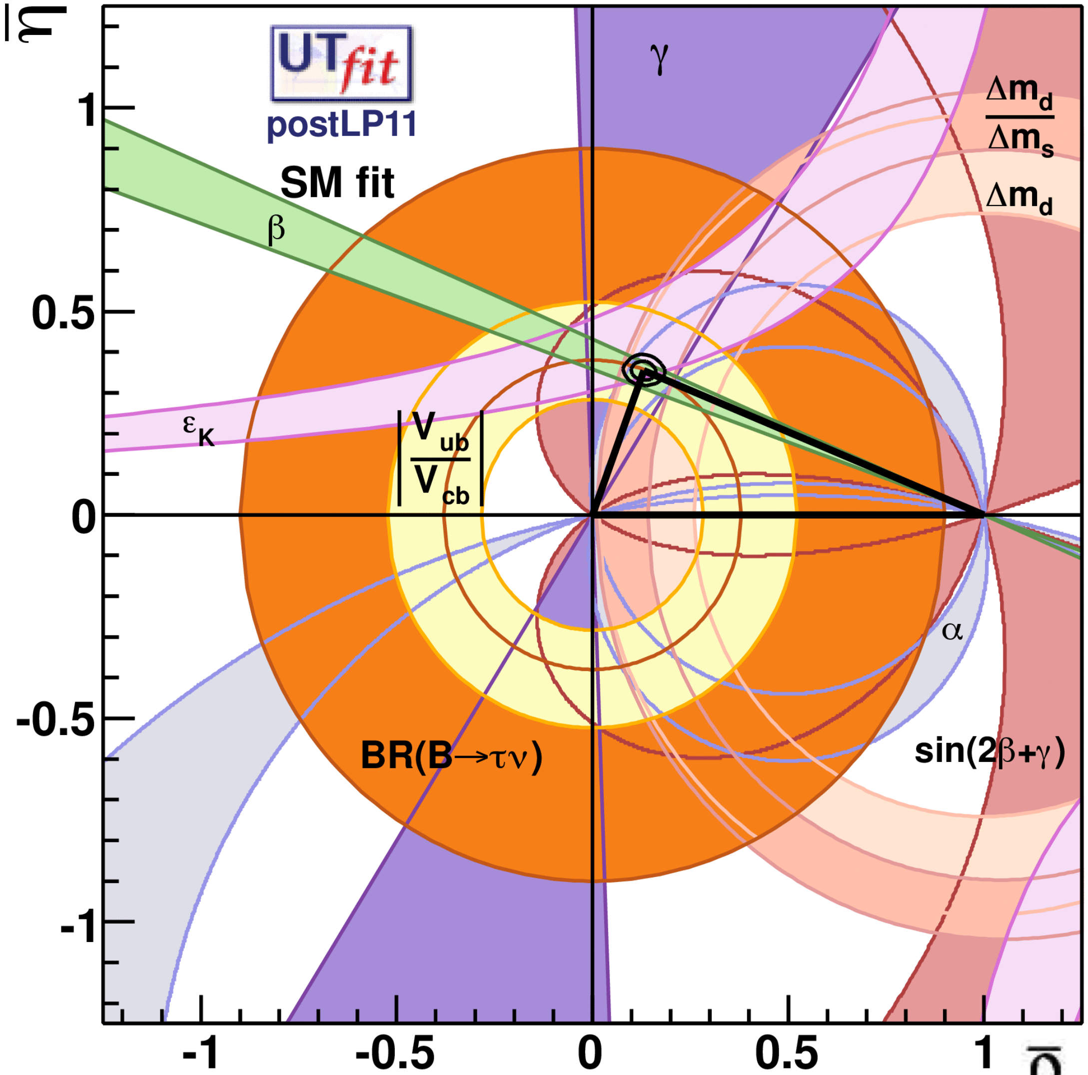
$$\boxed{V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0}$$



$$\bar\rho + i\bar\eta = -(V_{ud}V_{ub}^*)/(V_{cd}V_{cb}^*)$$

CKM Unitarity Triangle Experimental Constraints

- Status of the UT after LP2011 from the combination of all results

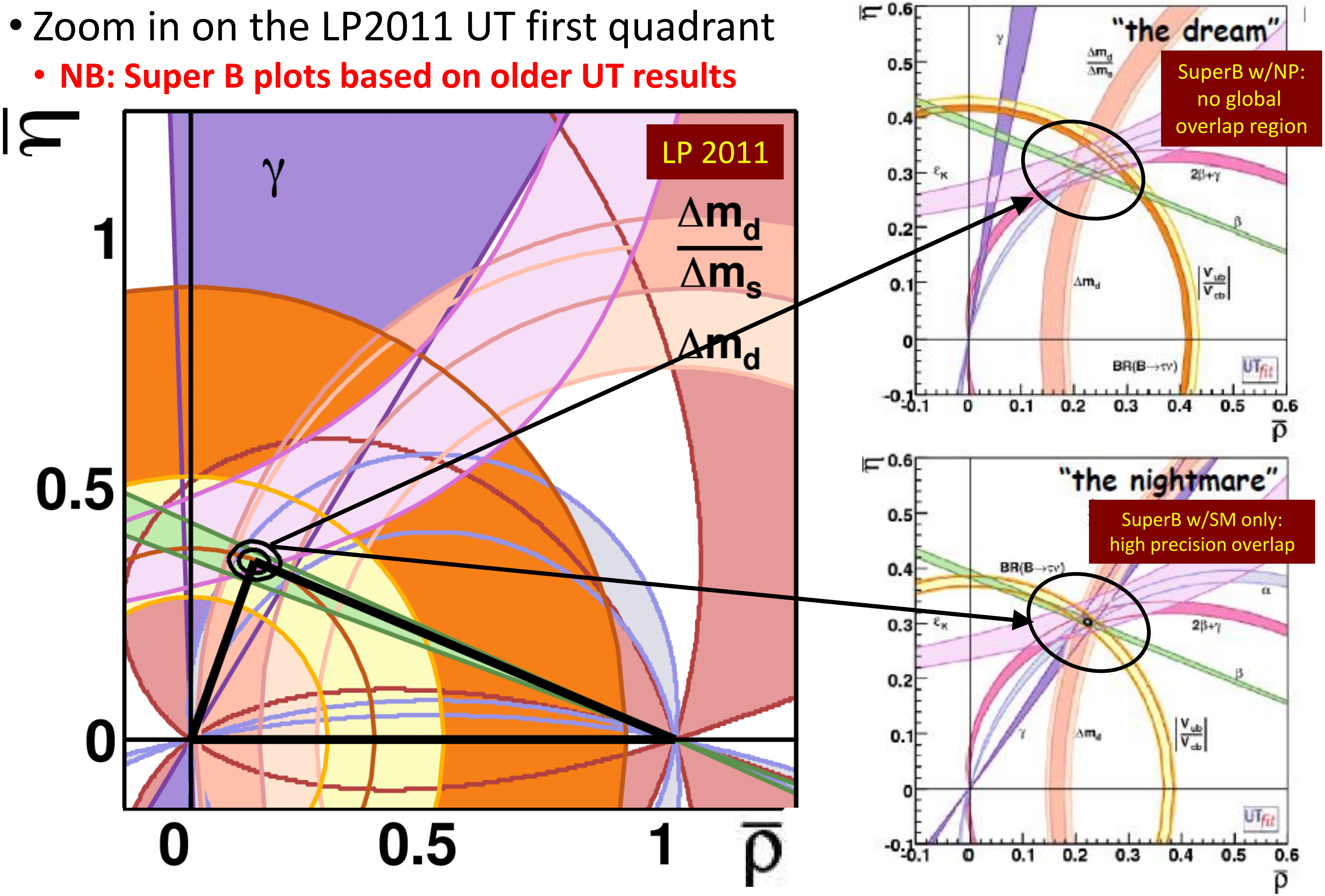


http://www.utfit.org/UTfit/ResultsSummer2011PostLP

- **The game is to over-constrain the UT by finding disagreement on the triangle's closure by using independent measurements of the UT sides and angles**
- **The Babar/Belle physics program resulted in confirmation of the KM mechanism as the source of CPV in the SM**
- **2008 Nobel Prize to KM**

Physics Prospects: CKM Unitarity Triangle After SuperB

- Zoom in on the LP2011 UT first quadrant
  - **NB: Super B plots based on older UT results**



LP 2011

SuperB w/NP: no global overlap region

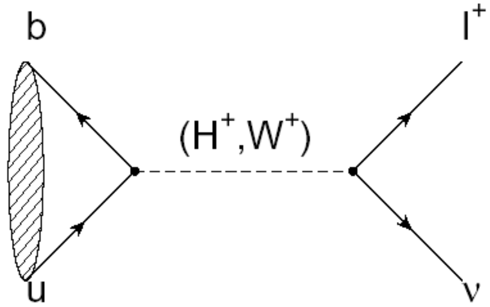
SuperB w/SM only: high precision overlap

Physics Prospects: Rare Decays, $B^+ \to \tau^+ \nu$

$$\mathcal{B}_{\tau\nu} = \frac{G_F^2 m_B m_\tau^2}{8\pi}\left[1-\frac{m_\tau^2}{m_B^2}\right]^2 f_B^2\, ||V_{ub}||^2 \tau_{B^+}\, r_H$$

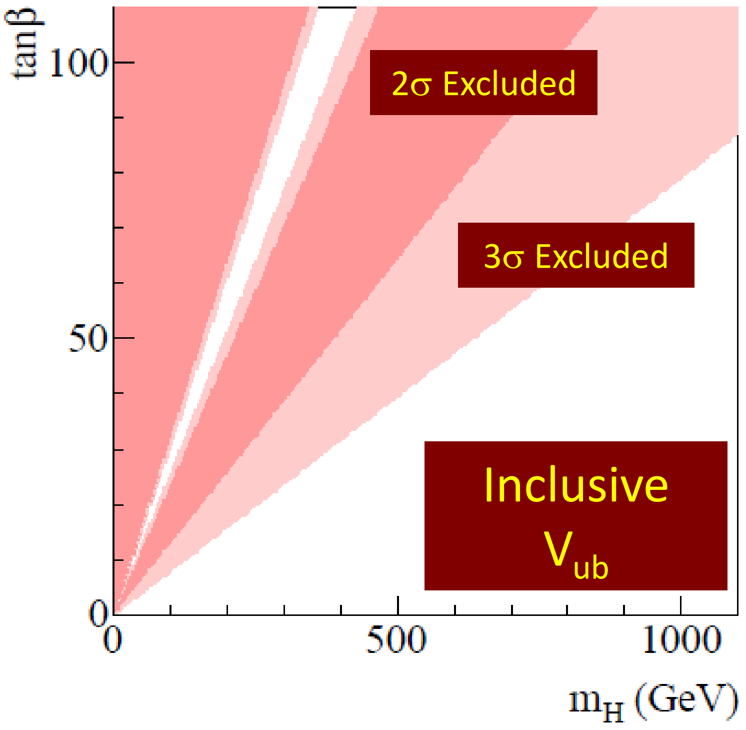
$$r_H = \frac{B_{SM+NP}}{B_{SM}} = \left(1-\frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

lattice, CKM inputs

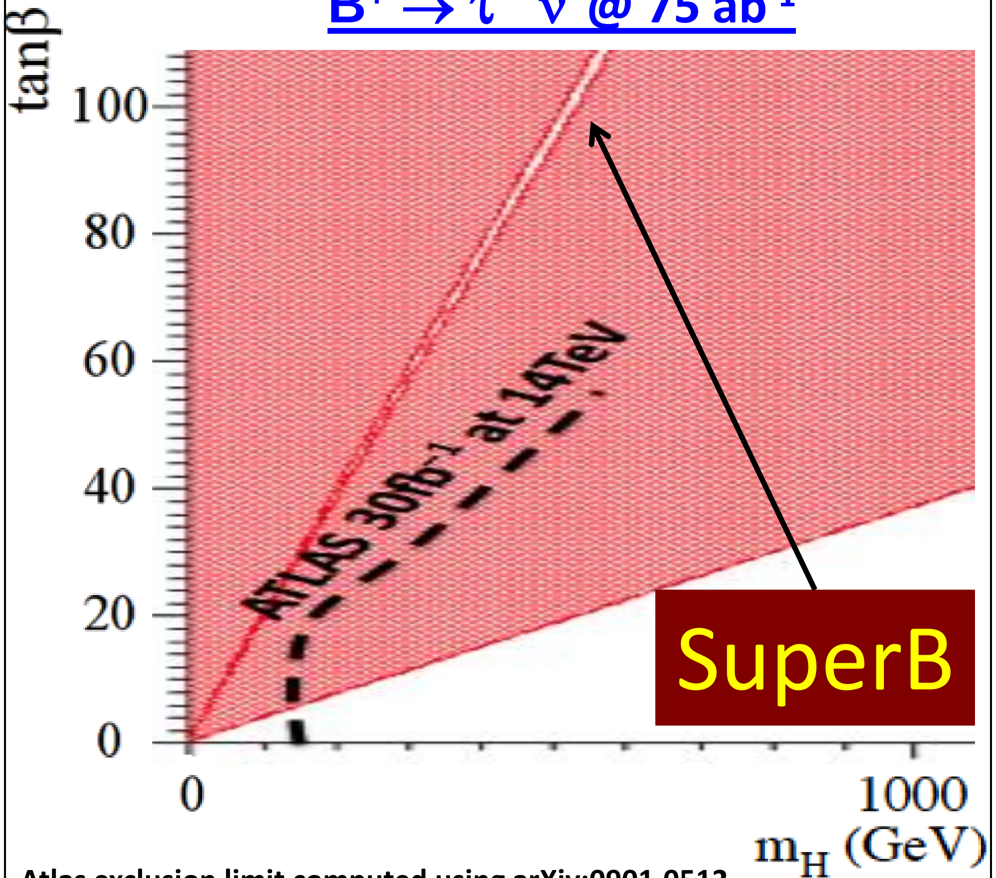


$B^+ \to \tau^+ \nu$ @ Babar (~0.5 ab^{-1})

Final Babar $B^+ \to \tau^+ \nu$ result using full dataset will be released in 1-2 weeks!



$B^+ \to \tau^+ \nu$ @ 75 ab^{-1}



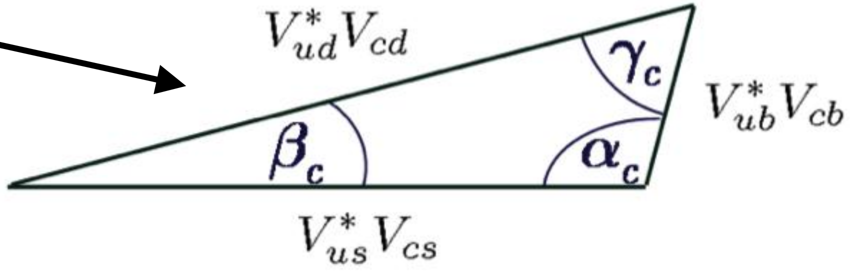
Atlas exclusion limit computed using arXiv:0901.0512

Physics Prospects: Charm Physics

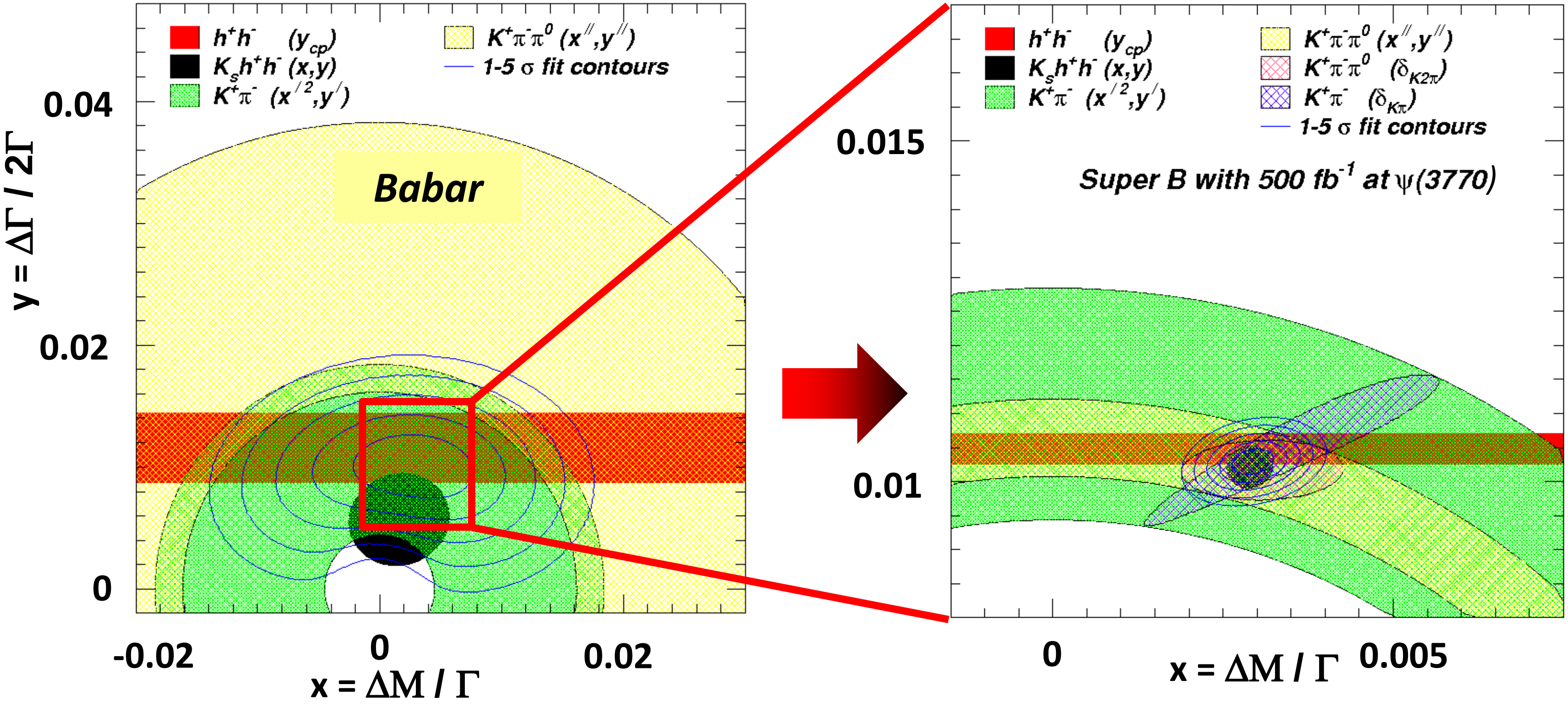
- SuperB will measure charm UT,

$$V_{ud}^* V_{cd} + V_{us}^* V_{cs} + V_{ub}^* V_{cb} = 0$$

$$\text{SM:} \begin{cases} \alpha_c &= (111.5 \pm 4.2)^\circ &= \arg\left[-V_{ub}^* V_{cb}/V_{us}^* V_{cs}\right] \\ \beta_c &= (0.0350 \pm 0.0001)^\circ &= \arg\left[-V_{ud}^* V_{cd}/V_{us}^* V_{cs}\right] \\ \gamma_c &= (68.4 \pm 0.1)^\circ &= \arg\left[-V_{ub}^* V_{cb}/V_{ud}^* V_{cd}\right] \end{cases}$$

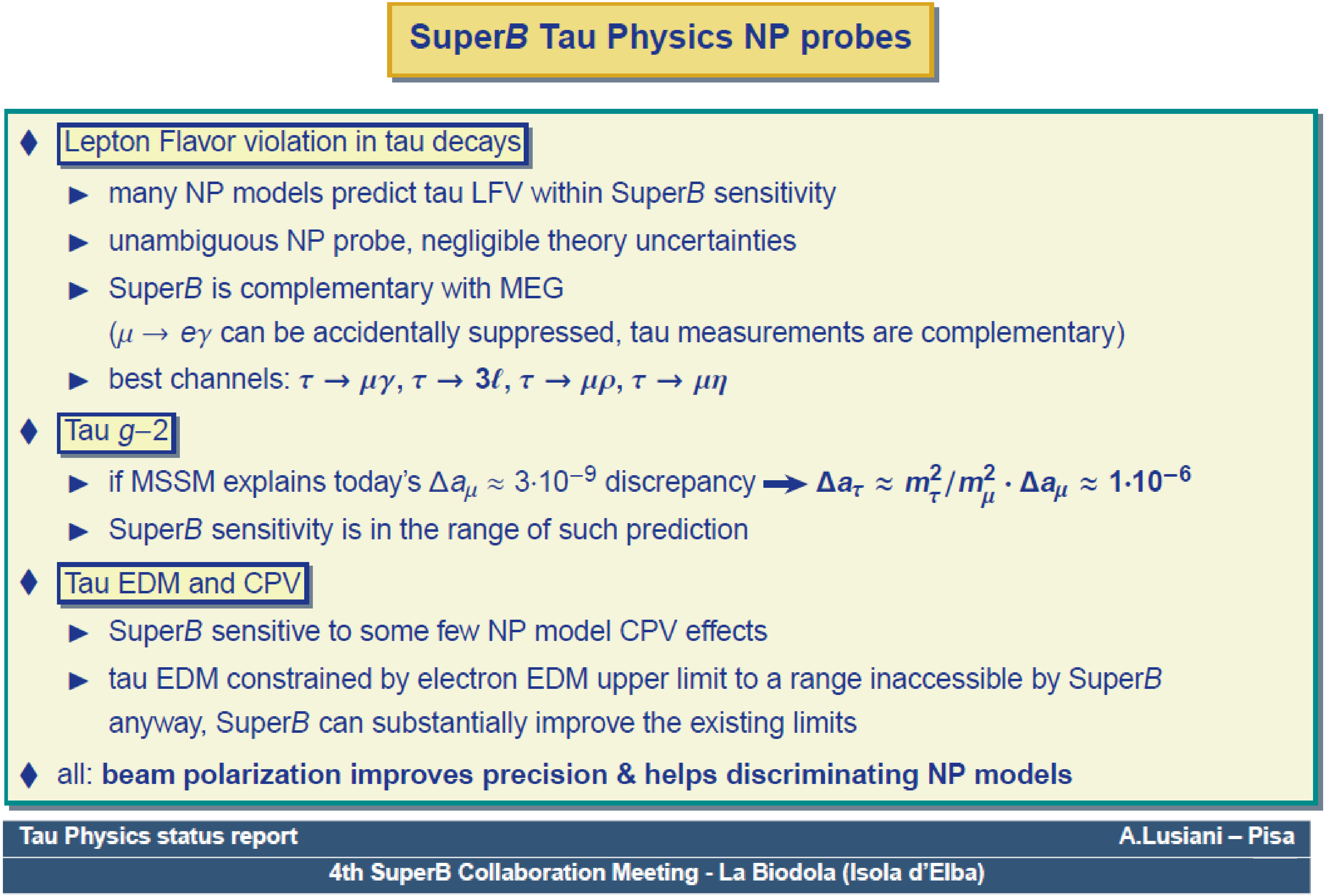


- Coherent production at charm threshold will allow precision measurements of mixing parameters (x,y) and strong phases (δ)



Physics Prospects: Tau Physics

Courtesy of A. Lusiani, Pisa, as shown at the most recent SuperB Collaboration Meeting (Elba, 1-4 June 2012)



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
  - Super*B* is complementary with MEG
    ($\mu \to e\gamma$ can be accidentally suppressed, tau measurements are complementary)
  - best channels: $\tau \to \mu\gamma$, $\tau \to 3\ell$, $\tau \to \mu\rho$, $\tau \to \mu\eta$
- Tau *g*–2
  - if MSSM explains today's $\Delta a_\mu \approx 3{\cdot}10^{-9}$ discrepancy → $\Delta a_\tau \approx m_\tau^2/m_\mu^2 \cdot \Delta a_\mu \approx 1{\cdot}10^{-6}$
  - 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* anyway, Super*B* can substantially improve the existing limits
- all: **beam polarization improves precision & helps discriminating NP models**

Tau Physics status report A.Lusiani – Pisa

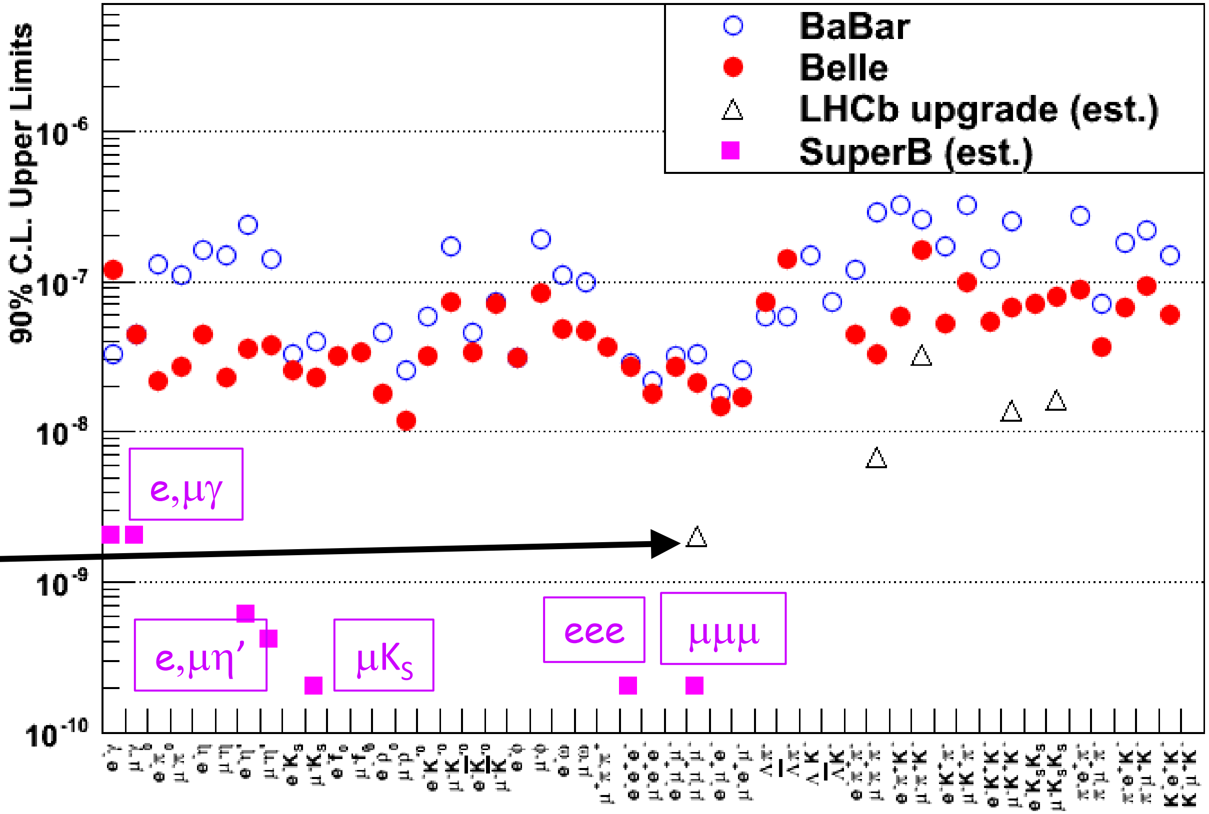
4th SuperB Collaboration Meeting - La Biodola (Isola d'Elba)

Physics Prospects: Tau Physics

- SuperB will search for transitions $\tau \rightarrow \mu$ and $\tau \rightarrow e$
- e^- polarization can help in suppressing backgrounds in some modes

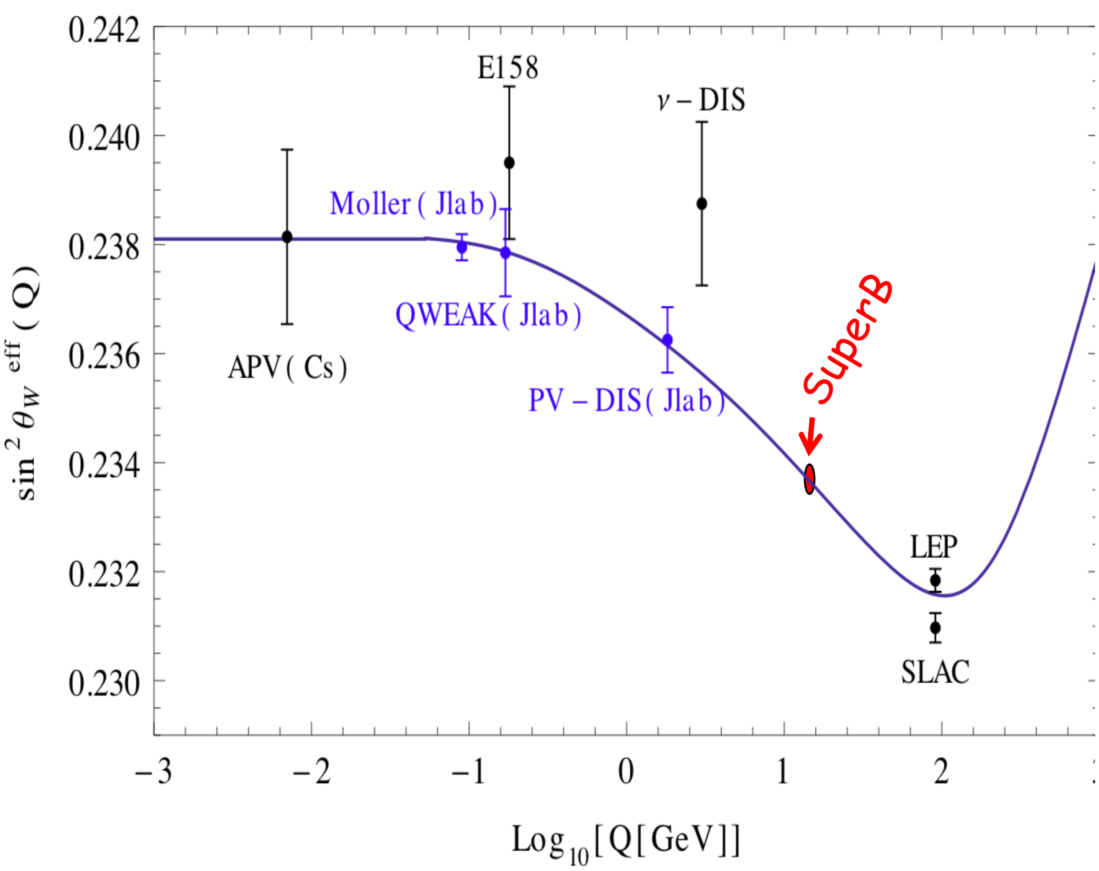
- Searches in final states with little-to-no background can improve by more than two orders of magnitude over Babar

- Can hadron machines compete?
  - No! according to LHCb upgrade projections
  - Yes! according to W. Marciano's talk yesterday ($10^{-10} – 10^{-11}$) ?



Physics Prospects: Precision Electroweak Physics

- $\sin^2\theta_W$ can be measured with polarised e^- beam
- $\sqrt{s}=\Upsilon(4S)$ is theoretically clean, c.f. Z pole b-fragmentation at LEP/SLC
- Simply need to measure event rates for left and right polarized beams



Plot adapted from W. Marciano's talk yesterday

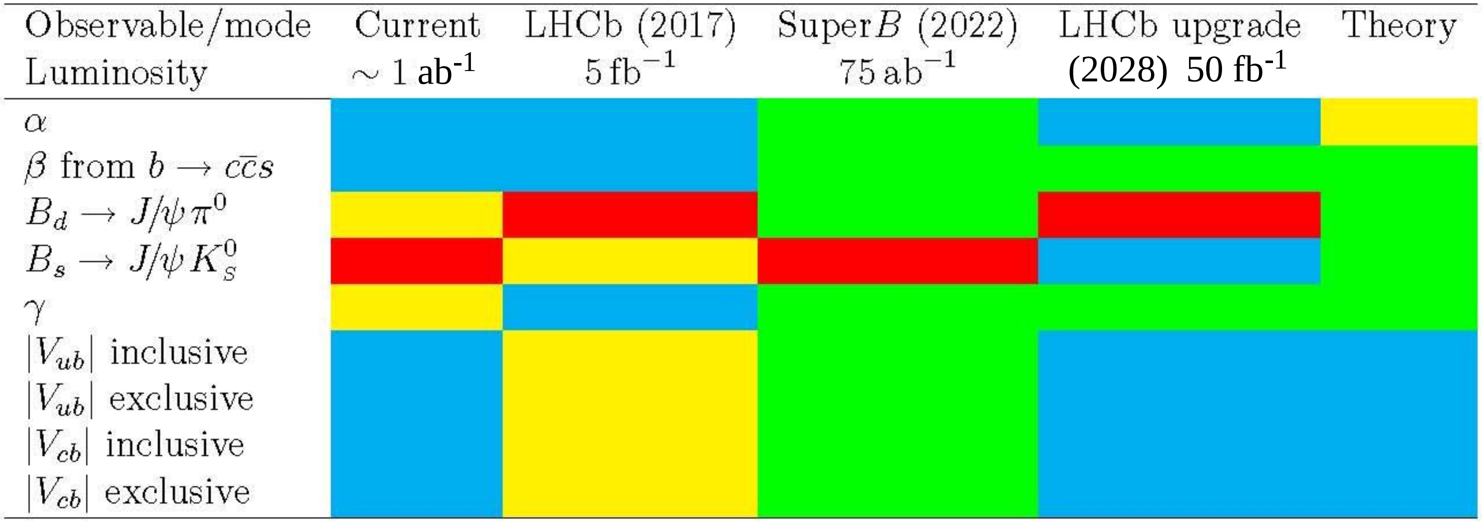
- Measure LR asymmetry in

$$
\begin{aligned}
e^+e^- &\longrightarrow b\bar{b}\\
e^+e^- &\longrightarrow c\bar{c}\\
e^+e^- &\longrightarrow \tau^+\tau^-\\
e^+e^- &\longrightarrow \mu^+\mu^-
\end{aligned}
$$

- Done at the $\Upsilon(4S)$ to the same precision as LEP/SLC at the Z-pole, also can have point at charm threshold
- **Precision is driven by the polarization measurement**
- Complements lower energy measurements

Complementarity: CKM Golden Modes, SuperB vs LHCb

- Can make a straightforward comparison of the relative precision of CKM observables measured at SuperB (75 ab^{-1}) versus existing measurements, along with expectations from near-future LHCb (5 fb^{-1}) and after the LHCb upgrade (50 fb^{-1})



Observable/mode Luminosity	Current $\sim$ 1 ab^{-1}	LHCb (2017) 5 fb^{-1}	Super$B$ (2022) 75 ab^{-1}	LHCb upgrade (2028) 50 fb^{-1}	Theory
α	🟦	🟦	🟩	🟦	🟨
β from $b \to c\bar{c}s$	🟦	🟦	🟩	🟩	🟩
$B_d \to J/\psi \pi^0$	🟨	🟥	🟩	🟥	🟩
$B_s \to J/\psi K_S^0$	🟥	🟨	🟥	🟦	🟩
γ	🟨	🟦	🟩	🟩	🟩
$\lvert V_{ub}\rvert$ inclusive	🟦	🟨	🟩	🟦	🟦
$\lvert V_{ub}\rvert$ exclusive	🟦	🟨	🟩	🟦	🟦
$\lvert V_{cb}\rvert$ inclusive	🟦	🟨	🟩	🟦	🟦
$\lvert V_{cb}\rvert$ exclusive	🟦	🟨	🟩	🟦	🟦

LHCb can only use ρπ

β theory error B_d

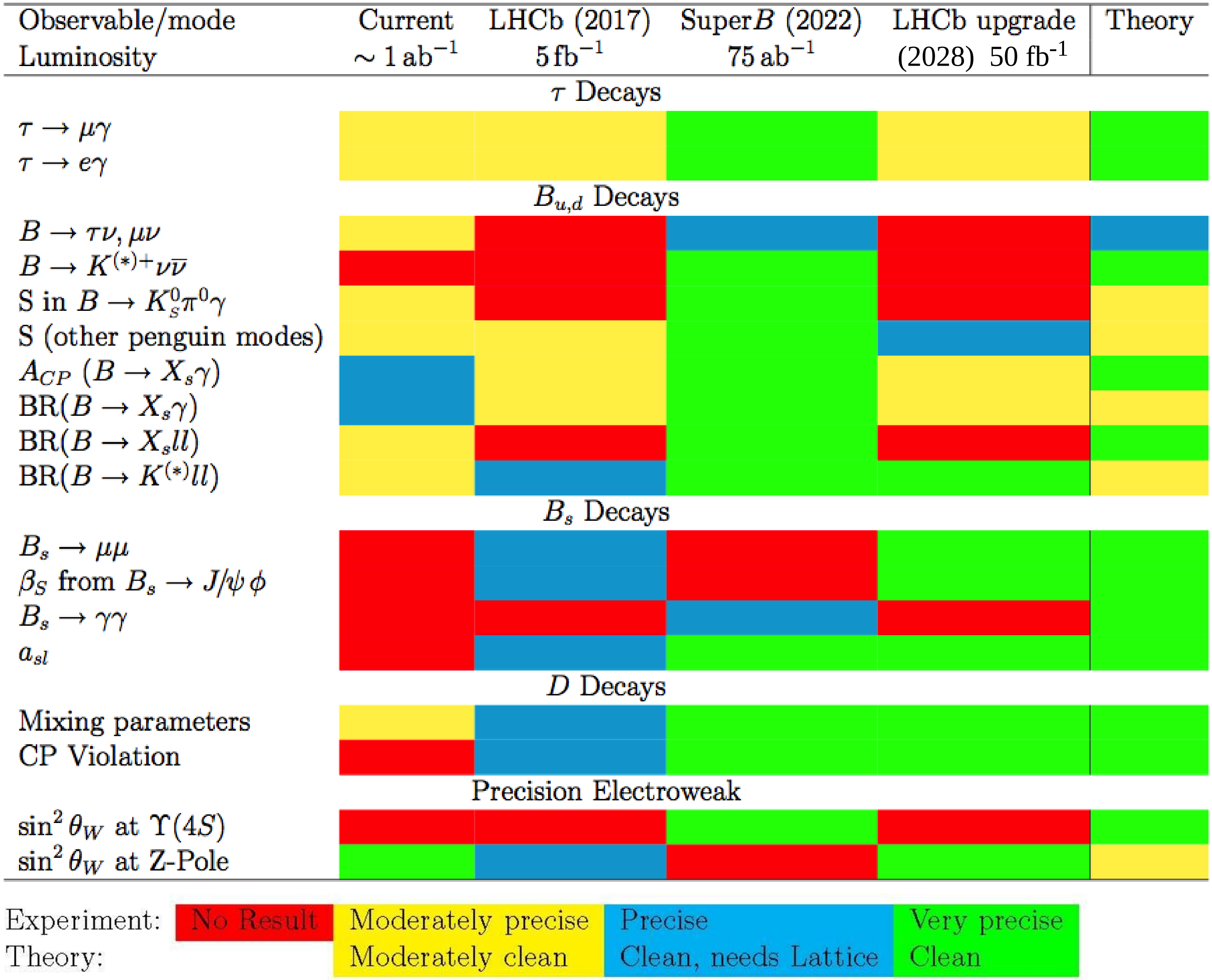
β theory error B_s

Need e^+e^- environment to do high-precision measurements with semileptonic B decays

	🟥	🟨	🟦	🟩
Experiment:	No Result	Moderately precise	Precise	Very precise
Theory:		Moderately clean	Clean, needs Lattice	Clean

Complementarity: Golden Modes in General, SuperB vs LHCb

- **A selection of other interesting modes/observables**

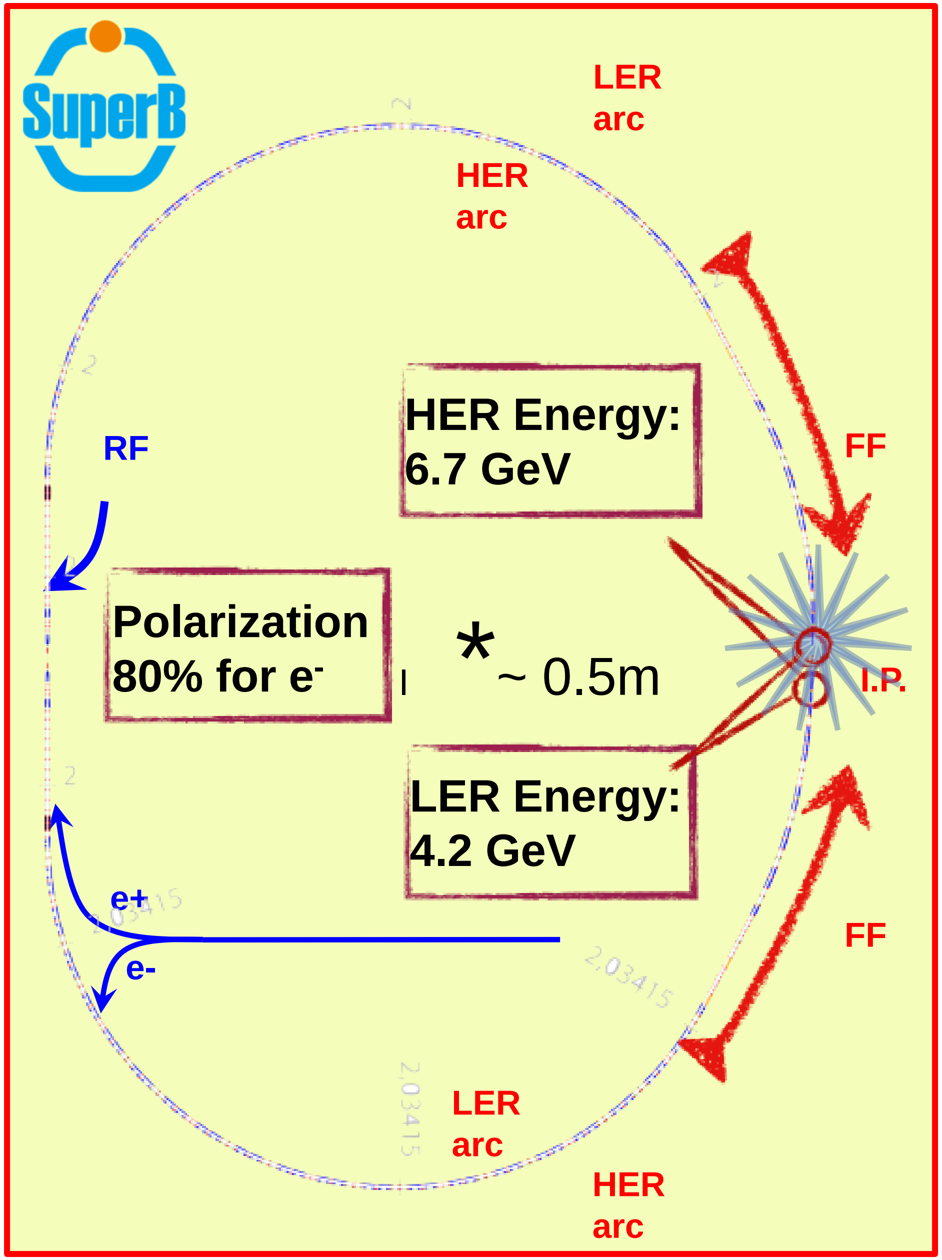


Observable/mode Luminosity	Current $\sim 1\,\mathrm{ab}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super*B* (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade (2028) $50\,\mathrm{fb}^{-1}$	Theory	
		τ Decays				
$\tau \to \mu\gamma$ $\tau \to e\gamma$	🟨	🟨	🟩	🟨	🟩	**SuperB benefits from polarised e^- beam**
		$B_{u,d}$ Decays				
$B \to \tau\nu, \mu\nu$	🟨	🟥	🟦	🟥	🟦	**Very precise with improved detector**
$B \to K^{(*)+}\nu\overline{\nu}$	🟥	🟥	🟩	🟥	🟩	**Stat. limited, angular obs. OK @ $75\mathrm{ab}^{-1}$**
S in $B \to K^0_S\pi^0\gamma$	🟨	🟥	🟩	🟥	🟨	**Right handed currents**
S (other penguin modes)	🟨	🟨	🟩	🟦	🟨	**SuperB measures many more modes**
A_{CP} $(B \to X_s\gamma)$	🟦	🟨	🟩	🟨	🟩	**Tagged analyses, low systematics**
BR$(B \to X_s\gamma)$	🟦	🟨	🟩	🟨	🟨	
BR$(B \to X_s ll)$	🟨	🟥	🟩	🟥	🟩	**Inclusive analyses only possible @ e^+e^-**
BR$(B \to K^{(*)} ll)$	🟨	🟦	🟩	🟩	🟨	**LHCb limited to μμ only**
		B_s Decays				
$B_s \to \mu\mu$	🟥	🟦	🟥	🟩	🟩	
β_S from $B_s \to J/\psi\,\phi$	🟥	🟦	🟥	🟩	🟩	
$B_s \to \gamma\gamma$	🟥	🟥	🟦	🟥	🟩	
a_{sl}	🟥	🟦	🟩	🟩	🟩	
		D Decays				
Mixing parameters	🟨	🟦	🟩	🟩	🟩	**SuperB exploits coherent production**
CP Violation	🟥	🟦	🟩	🟩	🟩	
		Precision Electroweak				
$\sin^2\theta_W$ at $\Upsilon(4S)$	🟥	🟥	🟩	🟥	🟩	**Theoretically clean**
$\sin^2\theta_W$ at Z-Pole	🟩	🟦	🟥	🟩	🟨	**b fragmentation limits interpretation**

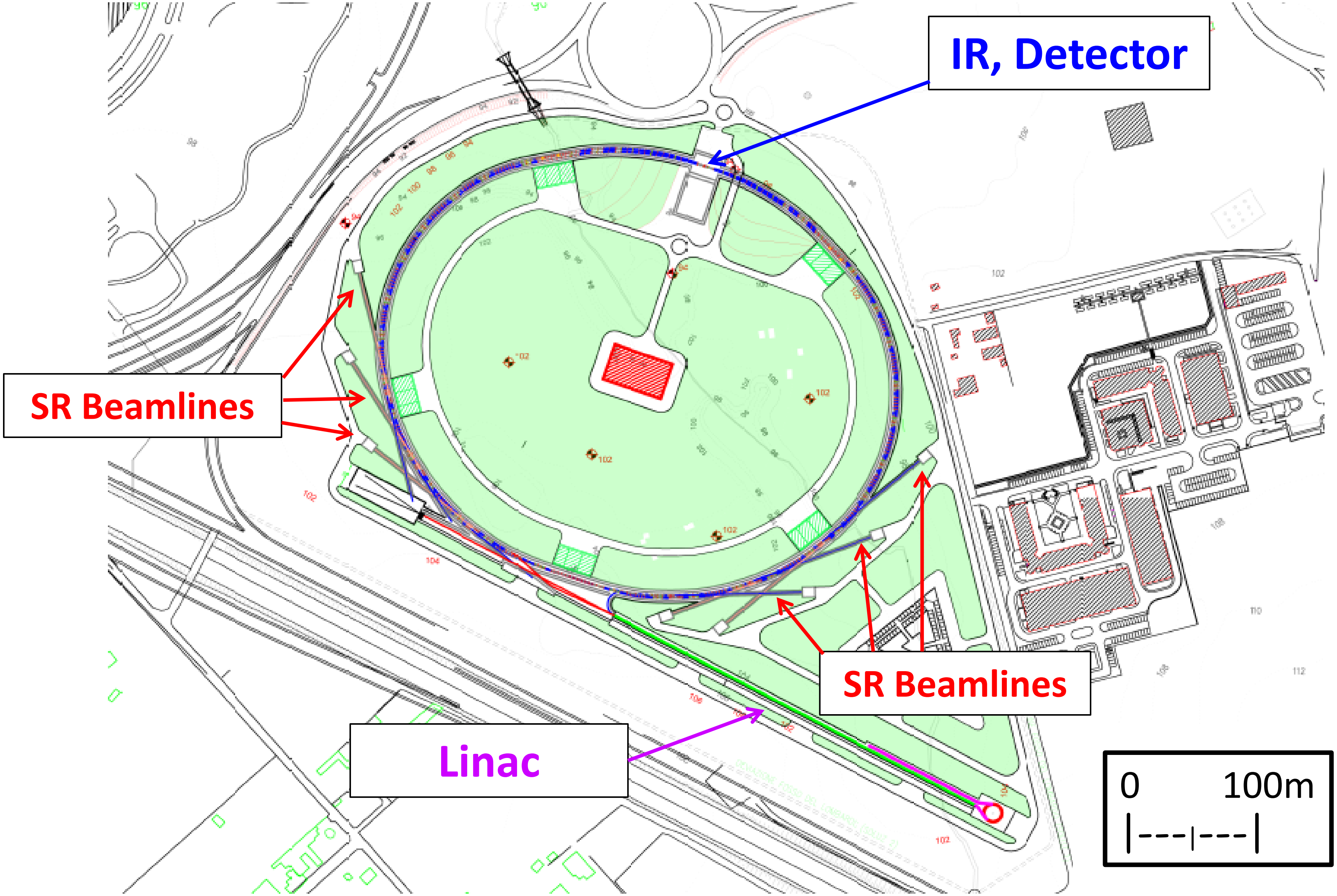
	🟥	🟨	🟦	🟩
Experiment:	No Result	Moderately precise	Precise	Very precise
Theory:		Moderately clean	Clean, needs Lattice	Clean

The Accelerator Scheme

- **General strategy:**
  - Very small emittance (ILC-DR)
  - Small β* at IP
  - **Crab waist technique**
  - Large crossing angle
  - Currents similar to present accelerators
- **Advantages:**
  - Small collision area
  - No parasitic crossings
  - No synchro-betatron resonances
  - Moderate backgrounds
- **Possible to reuse many components from PEP-II**



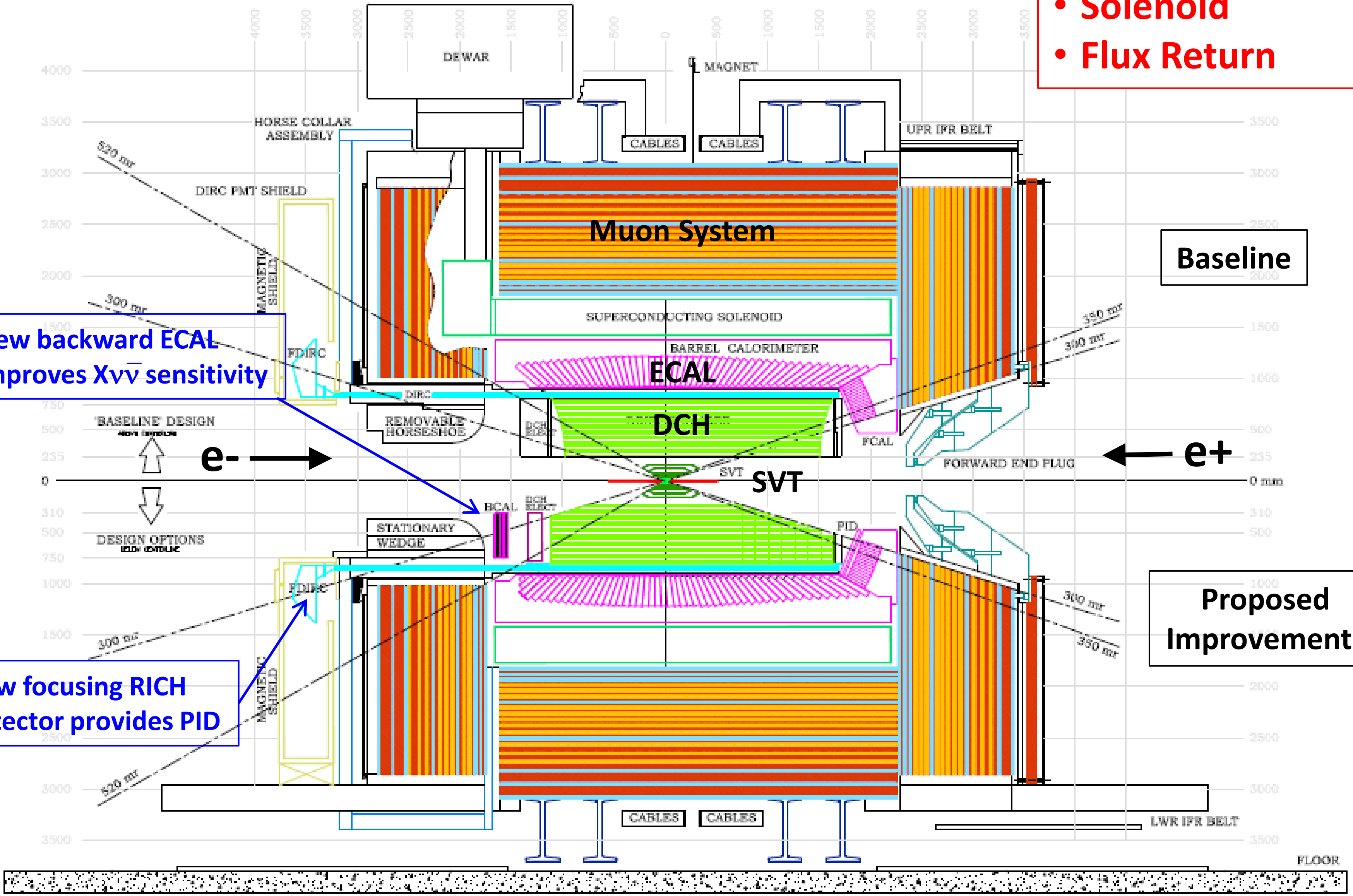
The Accelerator Complex at the Tor Vergata Campus (near Rome)



The SuperB Detector

Large pieces of BaBar will be reused in the SuperB detector:

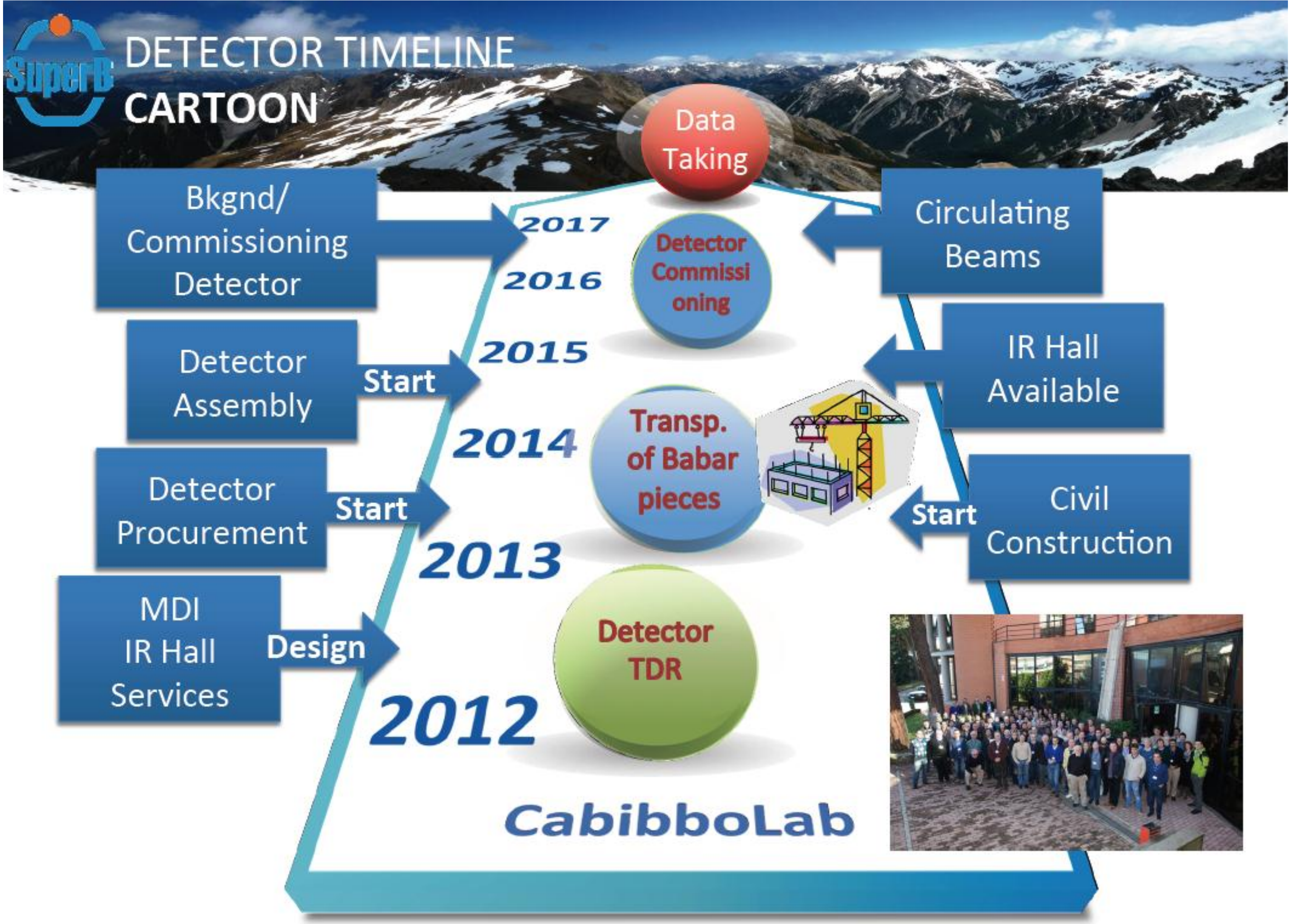
- Barrel, FWD ECAL
- Solenoid
- Flux Return



New backward ECAL improves $X\nu\bar{\nu}$ sensitivity

New focusing RICH detector provides PID

The SuperB Timeline



DETECTOR TIMELINE
CARTOON

Data Taking

2017
2016
2015
2014
2013
2012

Bkgnd/ Commissioning Detector

Detector Assembly Start

Detector Procurement Start

MDI
IR Hall
Services
Design

Detector Commissioning

Transp. of Babar pieces

Detector TDR

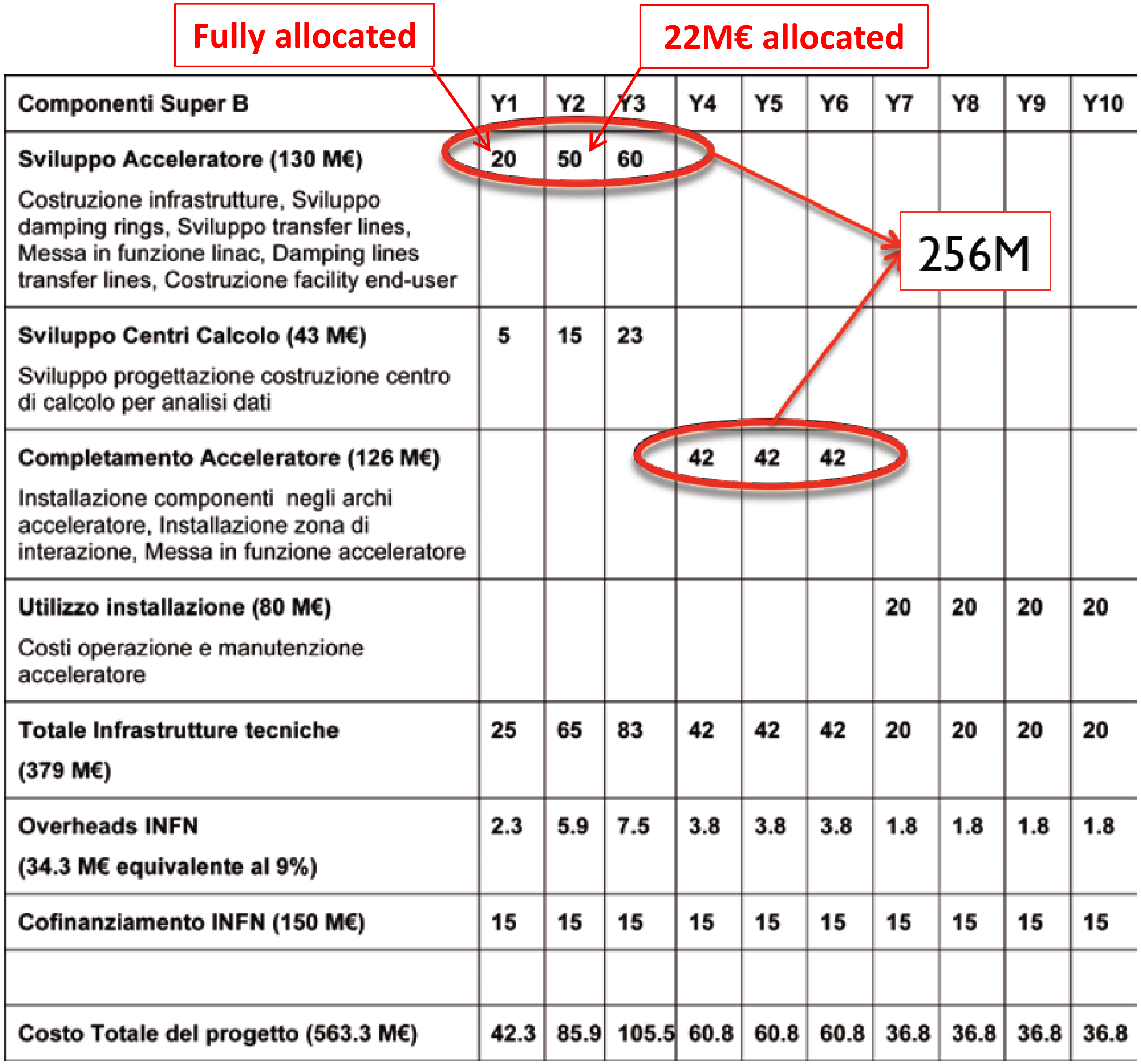
Circulating Beams

IR Hall Available

Civil Construction Start

CabibboLab

Funding in the INFN Multi-year Plan



Fully allocated

22M€ allocated

256M

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

Funding for accelerator and infrastructure

Computing funding from special funds for south development

Detector funding inside ordinary funding agency budget.

In addition, we re-use parts of PEP-II and Babar, for a value of about 135M€

Further Reading

Technical Design Report on target for completion in Sept-Oct 2012

Conceptual Design Report:
arXiv:0709.0451

Valencia Physics Workshop Report:
arXiv:0810.1312

Detector White Paper:
arXiv:1007.4241

Accelerator White Paper:
arXiv:1009.6178

Physics White Paper:
arXiv:1008.1541

Impact Document:
arXiv:1109.5028

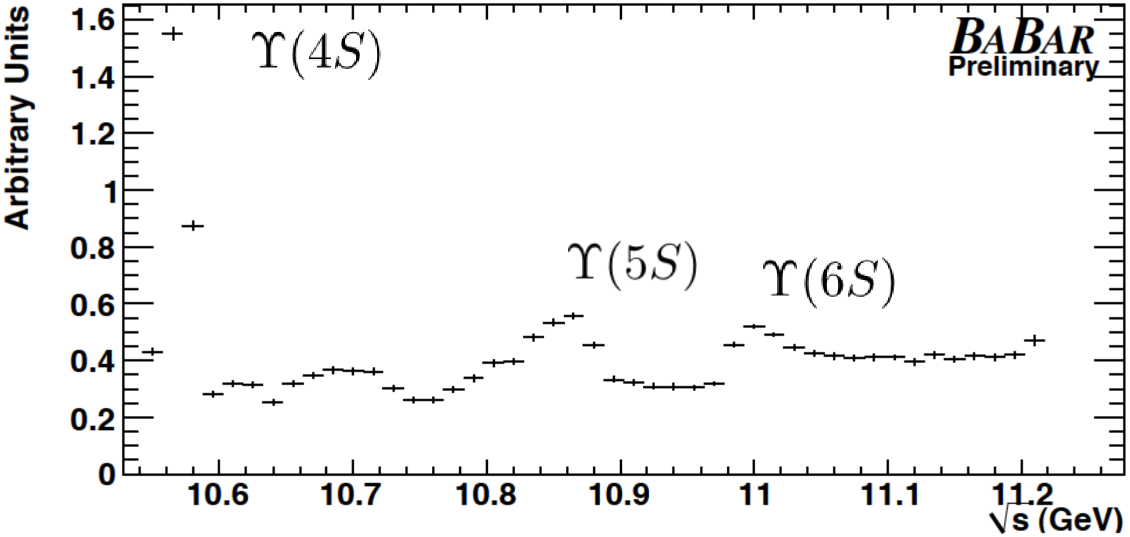
Recent Review:
arXiv:1110.3901

BACKUP SLIDES

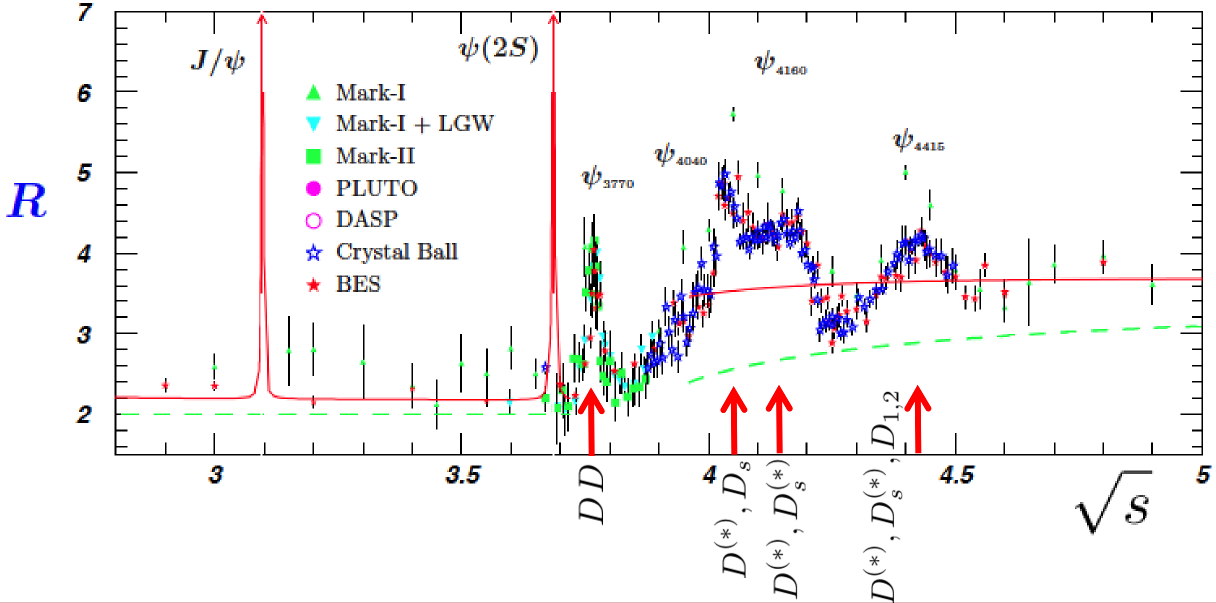
The Projected SuperB Dataset

- Physics dictates **75 ab^{-1} at the Υ(4S)** + **0.5-1 ab^{-1} at/near ψ(3770)**

- At Υ(4S): **~75 x10^9 B, D and τ pairs**
- Will also **run at the Υ(5S)** and above, as well as off-resonance running
- **~80% e- polarization will improve S:B in studies of LFV in the tau sector**



- At ψ(3770): **few x 10^9 D pairs**
- Also will run at nearby resonances
- Total 0.5 ab^{-1} collected in several months running



Tau physics at Super*B*

LFV Decays

- ♦ clean and unambiguous New Physics probe
- ♦ complementary to muon LFV (MEG,. . .)
- ♦ no real competition but Belle II
  - ▶ advantage of beam polarization

Tau *g*–2

- ♦ $(g{-}2)_\mu$: $\sim 3\sigma$ exp vs. th discrepancy
- ♦ precise SM and CMSSM predictions
- ♦ no real competition but Belle II
  - ▶ advantage of beam polarization

CPV in tau decay

- ♦ precise and clean SM prediction
- ♦ most NP models below our sensitivity
- → can probe some specific models
- → set new much improved limits
- ♦ beam polarization may help

Tau EDM

- ♦ severely constrained from electron EDM
- ♦ no real competition but Belle II
  - ▶ advantage of beam polarization

plenty of precision physics also possible

Outline of work done

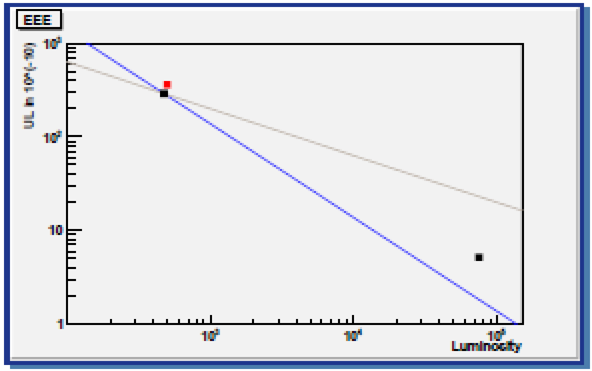
Super*B* physics documents

- arXiv:1109.5028v2 [hep-ex] The impact of SuperB on flavour physics
- arXiv:1008.1541v1 [hep-ex] SuperB white paper: Physics
- arXiv:1007.4241v1 [physics.ins-det] SuperB white paper: Detector
- arXiv:0810.1312 [hep-ex], Valencia Jan 2008 Workshop Proceedings

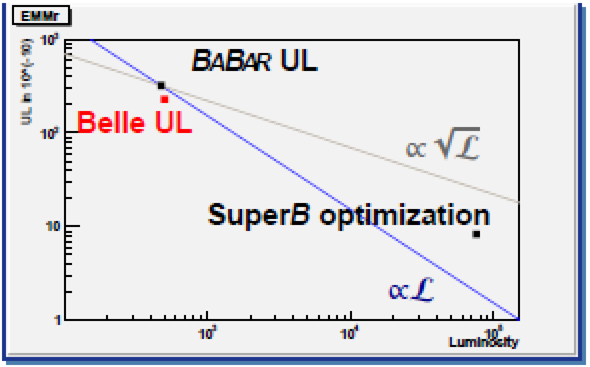
Super*B* tau physics specific activities

- extrapolations from published analyses results
- exp. limitations on J.Bernabeu et al. tau EDM and $g-2$ sensitivity estimates with polarized beams
- re-optimization of *BABAR* 3 leptons analysis [mainly B.Oberhof (Pisa)]
- study of events with $\tau \to \mu\gamma$ against $\tau \to \pi\nu$ with beam polarization [mainly A.Cervelli (Pisa)]
- independent work on $\tau \to 3\ell$ by C.Weiland, S.Coquereau [w. A.Bevan (QMUL)]

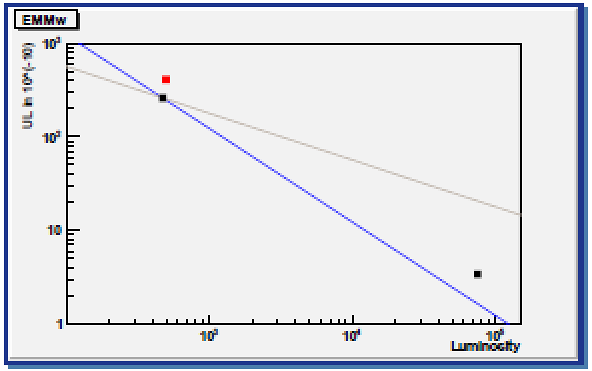
$\tau \to 3\ell$ UL extrapolations: $\propto \mathcal{L}$ vs. $\propto \sqrt{\mathcal{L}}$ vs. re-optimization



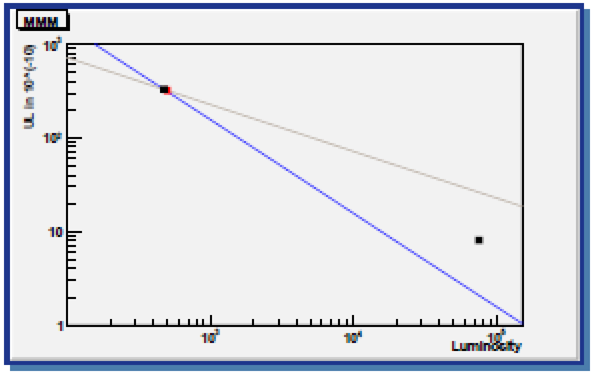
$\tau \to eee$



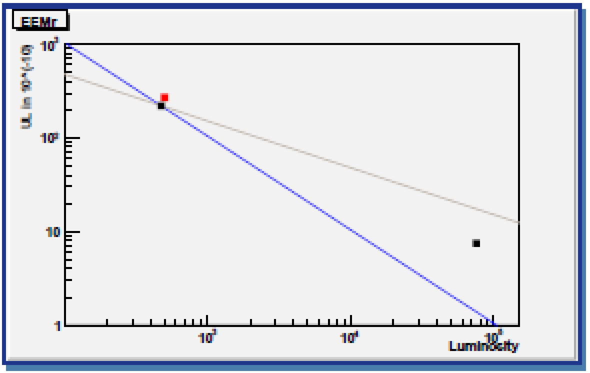
$\tau \to e\mu{+}\mu{-}$



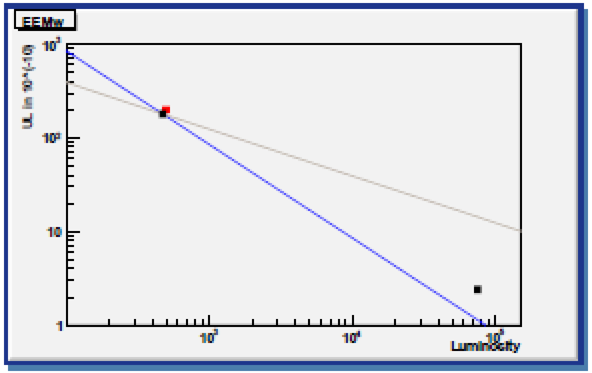
$\tau{-} \to e{+}\mu{-}\mu{-}$



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



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



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

Expected 90% CL upper limits for $\tau \rightarrow 3\ell$ at Super*B*@75 ab^{-1} (preliminary)

Channel	Efficiency (%)	exp.bkg	90% CL UL (10^{-10})
$e^+e^-e^+$	5.2 ± 0.5	1.7 ± 0.6	5.1
$e^+e^-\mu^+$	2.3 ± 0.2	0.16 ± 0.05	7.5
$e^+e^+\mu^-$	8.6 ± 0.9	0.3 ± 0.1	2.4
$\mu^+\mu^-e^+$	4.2 ± 0.4	3.8 ± 1.3	8.3
$\mu^+\mu^+e^-$	6.5 ± 0.6	0.8 ± 0.3	3.4
$\mu^+\mu^-\mu^+$	4.1 ± 0.4	3.3 ± 1.0	8.1

- to be compared with $2 \cdot 10^{-10}$ in the Valencia report first estimate

Super*B* sensitivity on tau *g*–2

- SUSY is a viable explaination for existing th.-exp. discrepancy $\boxed{\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} \approx (3 \pm 1) \times 10^{-9}}$
- SUSY contribution is larger for tau $\boxed{\Delta a_\tau / \Delta a_\mu = m_\tau^2 / m_\mu^2 \approx 300}$

	Snowmass points predictions						Super*B*
	1 a	1 b	2	3	4	5	exp. resolution
$\Delta a_\mu \times 10^{-9}$	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	2.4–1.0

Experimental measurement of tau *g* – 2 at Super*B*

- tau $g{-}2$ can be measured from spin-angle differential cross-section $e^+e^- \to \tau^+\tau^-$
  (**0707.2496 [hep-ph] (J.Bernabeu et al.)**
- the amplitude for the $f\bar{f}\gamma$ vertex is:

$$\langle f(p_-)\bar{f}(p_+)|\, J^\mu(0)\,|0\rangle = e\,\bar{u}(p_-)\left[\gamma^\mu\, \boldsymbol{F_1} + \frac{1}{2m_f}(i\,\boldsymbol{F_2} + \boldsymbol{F_3}\gamma_5)\sigma^{\mu\nu}q_\nu + \left(q^2\gamma^\mu - q^\mu\ \not{q}\right)\gamma_5 \boldsymbol{F_A}\right] v(p_+)$$

$\boldsymbol{F_1(q)} \to$ vector current, $\boldsymbol{F_A(q)} \to$ anapole moment, $\boxed{\boldsymbol{F_2(q)} \to (g{-}2)}$, $\boldsymbol{F_3(q)} \to$ EDM

$\boxed{F_2(0) = \mathrm{Re}\,\{F_2(0)\} = a_f = (g{-}2)_f/2}$ $\boxed{d_f = \dfrac{e}{2m_f}F_3(0)}$

- **Re $\boldsymbol{F_2(q)}$** can be fitted from shape of polar angle differential cross section

$$\frac{\mathrm{d}\sigma(e^+e^- \to \tau^+\tau^-)}{\mathrm{d}\cos\theta_{\tau^-}} = \frac{\pi\,\alpha^2}{2s}\beta\,\left[(2-\beta^2\sin^2\theta_{\tau^-})\,|F_1(s)|^2 + 4\ \mathbf{Re}\ \boldsymbol{F_2(s)}\right]$$

- using 100% polarized e^- beam, analyzing tau polarization with tau decay charged prongs angles one can construct asymmetries that are directly proportional to **Re $\boldsymbol{F_2(q)}$**
- assuming perfect detector for Super*B* at 75 ab^{-1}: $\boxed{\Delta a_\tau = 0.75\cdot 10^{-6}}$

Experimental measurement of tau $g-2$ at Super*B*

improved estimate of Δa_τ

- MC study on simulated events with **KK generator** and **Tauola**
  (simulate complete spin correlation density matrix of the initial and final state)
- Super*B* at 75 fb^{-1}, $\boxed{80\% \pm 1\%\ e^-\ \text{beam polarization}}$
- estimate real conditions effects
  - 80% geometrical acceptance in polar angle
  - (uneven) track reconstruction efficiency 97.5% ± 0.1%
- use all tau decay channels (paper only uses $\tau \to \pi\nu, \rho\nu$)
- combine two proposed measurement methods for Re F_2
- prelim. MC studies for tau EDM show $\boxed{\text{detector systematics} \approx 10\% \text{ of stat. error}}$
  measurements exploiting tau polarization less affected by detector systematics
- $\boxed{\Delta a_\tau = [1.0 - 2.4]\cdot 10^{-6}}$ (uncertainty depends on how well we can exploit all tau decay modes)

Experimental measurement of tau EDM

- tau EDM can be measured from spin-angle differential cross-section $e^+e^- \to \tau^+\tau^-$ **(arXiv:0707.1658 [hep-ph])**
- polarized beams improve Super*B* sensitivity
- assuming perfect detector, 100% polarized electron beam: $\Delta\left(\mathrm{Re}\{d_\tau^\gamma\}\right) = 7.2{\cdot}10^{-20}\,e\,\mathrm{cm}$

- estimate real conditions effects
  - 80% geometrical acceptance in polar angle
  - (uneven) track reconstruction efficiency 97.5% ± 0.1%
- Super*B* sensitivity estimated at $\approx 10{\cdot}10^{-20}\,e\,\mathrm{cm}$

- extrapolate result on tau EDM by Belle from $29.5\,\mathrm{fb}^{-1}$ to $75\,\mathrm{ab}^{-1}$
- Super*B* sensitivity estimated at $\approx [17-34]{\cdot}10^{-20}\,e\,\mathrm{cm}$ not systematically limited

Super*B* can much reduce tau EDM exp. uncertainty although "natural" SUSY NP effects too small

T/CP-odd observables in tau decay

Theory expectations

- clean SM predictions
  - *CP* asymmetry rate of $\tau^{\pm} \to K^{\pm}\pi^{0}\nu$ estimated order of $\sim 10^{-12}$
  - $\tau^{\pm} \to K_S\pi^{\pm}\nu$ rate asymmetry 3.3×10^{-3} with 2% relative precision
- most NP cannot generate observable *CP*-violating effects in τ decays
- effects with R-parity viol. SUSY or non-SUSY multi-Higgs up to the current UL from CLEO ($\sim 10^{-3}$)

Super*B* sensitivity

- experimental upper limit on charge-dependent angular rate asymmetry for $\tau \to K_S\pi^{\pm}\nu$ [CLEO Collaboration, Phys. Rev. Lett. 88, 111803 (2002), hep-ex/0111095, ($13.3\,\text{fb}^{-1}$]
- extrapolating to Super*B* at $75\,\text{fb}^{-1}$ ➔ exp. sensitivity improves by a factor ≈ 75 resolution on optimal observable from $1.8 \cdot 10^{-3}$ to $\sim 2.4 \cdot 10^{-5}$
  - channel can rely on calibration provided by $\tau \to \pi\pi\pi\nu$ on the K_S sidebands
  - further improvements may be possible with beam polarization (not yet studied)

Update on $\tau \rightarrow \mu\gamma$ sensitivity

- extrapolate from final *BABAR* result **expected upper limit**
  - *BABAR* bkg estimates, 2σ box cut & count
  - assume improved Super*B* tracking reduces $\Delta m - \Delta E$ box to 65% of *BABAR* size
  - assume photon efficiency improves by 20%
    (no significant gain possible on loose muon PID used in this analysis)

sensitivity without using beam polarization

```
Valencia limits                         SuperB limits
  tau -> mu gamma                         tau -> mu gamma
    efficiency          = 7.40%             efficiency          = 7.32%
    expected background = 200               expected background = 335
    upper limit 90% CL  = 1.84e-09          upper limit 90% CL  = 2.39e-09
    3sigma evidence     = 4.16e-09          3sigma evidence     = 5.44e-09
```

Update on $\tau \rightarrow \mu\gamma$ sensitivity with beam polarization

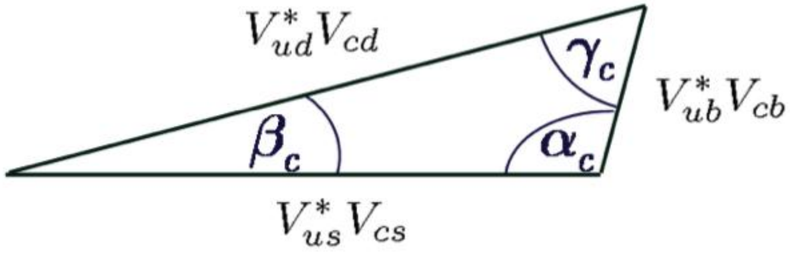
- using A.Cervelli May 2011 (Elba) presentation on $\tau \rightarrow \mu\gamma$ vs. $\tau \rightarrow \pi(\rho)\nu$ simulated with FastSim
- **using most natural SUSY LFV $\tau \rightarrow \mu\gamma$ production mode**
- assuming cuts have same effect on all tau hadronic decays in tag side
- assuming we use only hadronic decays on tag side

  (actually, with some degradation leptonic decays can be used as well)

```
SuperB, hadronic tags, 2D Fastsim helicity cuts    SuperB limits with 1D helicity cut on MC truth
  tau -> mu gamma                                    tau -> mu gamma
    efficiency          = 1.60%                        efficiency          = 5.12%
    expected background = 27                           expected background = 167
    upper limit 90% CL  = 3.35e-09                     upper limit 90% CL  = 2.44e-09
    3sigma evidence     = 7.09e-09                     3sigma evidence     = 5.50e-09
```

The quest for the final angle of the CKM matrix: β_c

- The charm cu triangle has one unique element: β_c



$$\begin{aligned}\alpha_c &= \arg\left[-V_{ub}^* V_{cb} / V_{us}^* V_{cs}\right].\\ \beta_c &= \arg\left[-V_{ud}^* V_{cd} / V_{us}^* V_{cs}\right],\\ \gamma_c &= \arg\left[-V_{ub}^* V_{cb} / V_{ud}^* V_{cd}\right],\end{aligned}$$

$$\begin{aligned}\alpha_c &= (111.5 \pm 4.2)^\circ\\ \beta_c &= (0.0350 \pm 0.0001)^\circ\\ \gamma_c &= (68.4 \pm 0.1)^\circ\end{aligned}$$

$$V_{ud}^* V_{cd} + V_{us}^* V_{cs} + V_{ub}^* V_{cb} = 0$$

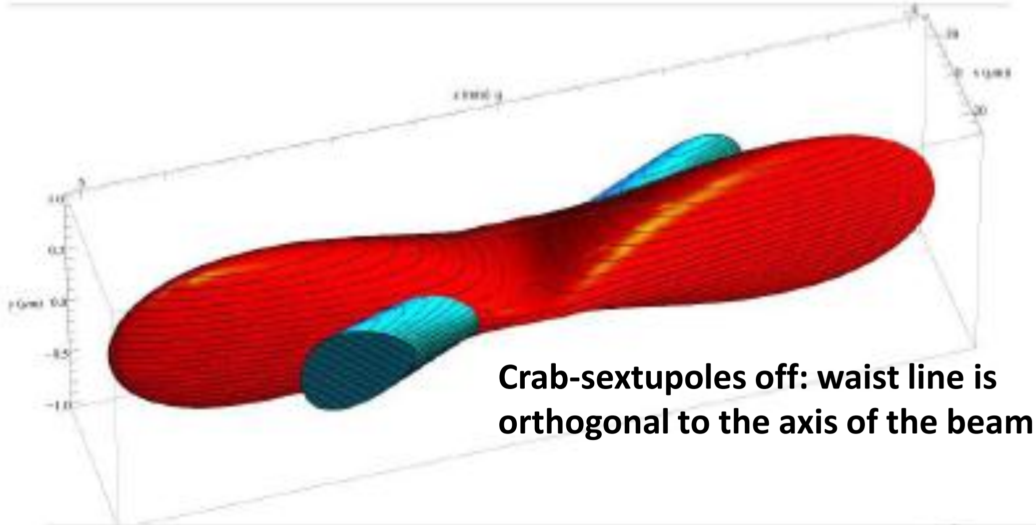
- Precision measurement of mixing phase in many channels (<2°)
- Constrain $\beta_{c,\mathrm{eff}}$ using a $D \to \pi\pi$ Isospin analysis
  - Search for NP and constrain $\beta_{c,\mathrm{eff}} \sim 1^\circ$.
  - Can only fully explore in an e^+e^- environment.
  - Data from the charm threshold region completes the set of 5 $|V_{ij}|$ to measure: needs SuperB to perform an indirect test of the triangle.

Bevan, Inguglia, Meadows, PRD **84** 114009 (2011)

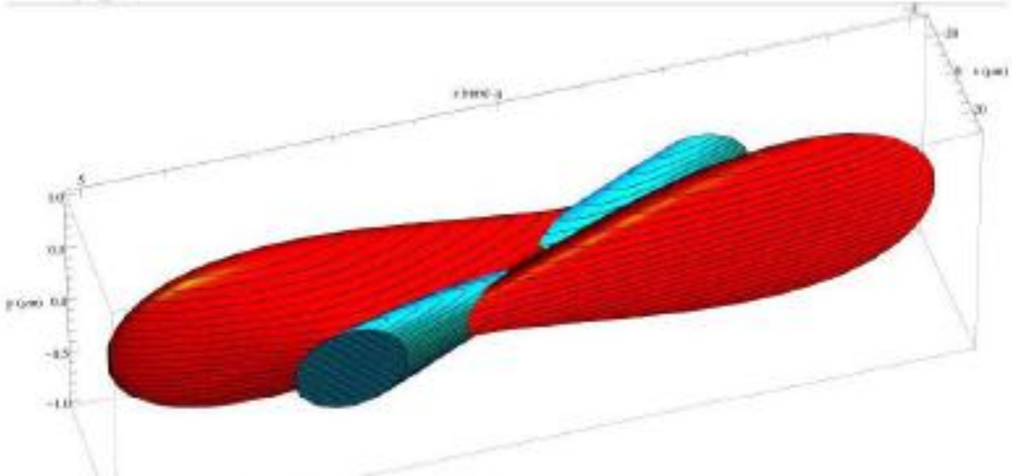
A SuperB Innovation: The Crab Waist Final Focus

Raimondi, Shatilov, Zobov
http://arxiv.org/abs/physics/0702033

- Make the final focus so that only a small fraction of one bunch collides with the other bunch
  - Large crossing angle
  - Long bunch length
  - No parasitic crossings
- Due to the large crossing angle the effective bunch length (the colliding part) is now very short so we can lower β_y* by a factor of 50
- The beams must have very low emittance, like present day light sources
  - The x size at the IP now sets the effective bunch length
  - In addition, by crabbing the magnetic waist of the colliding beams we greatly reduce the tune plane resonances enabling greater tune shifts and better tune plane flexibility



Crab-sextupoles off: waist line is orthogonal to the axis of the beam



Crab-sextupoles on: waist moves parallel to the axis of other beam: maximum particle density in the overlap between bunches

Luminosity Profile: SuperB vs. Super-Belle

- SuperB design and max instantaneous luminosity will exceed Belle-II
  - SuperB: >10^{36}
  - Belle-II: ~0.8$10^{36}$
- Both machines expect turn- on about 2016-2017
- By 2022-2023:
  - SuperB: 75 ab^{-1}
  - Belle-II: 50 ab^{-1}
- Belle-II uses up-date of current KEK machine, polarized beam, charm threshold running are not possible