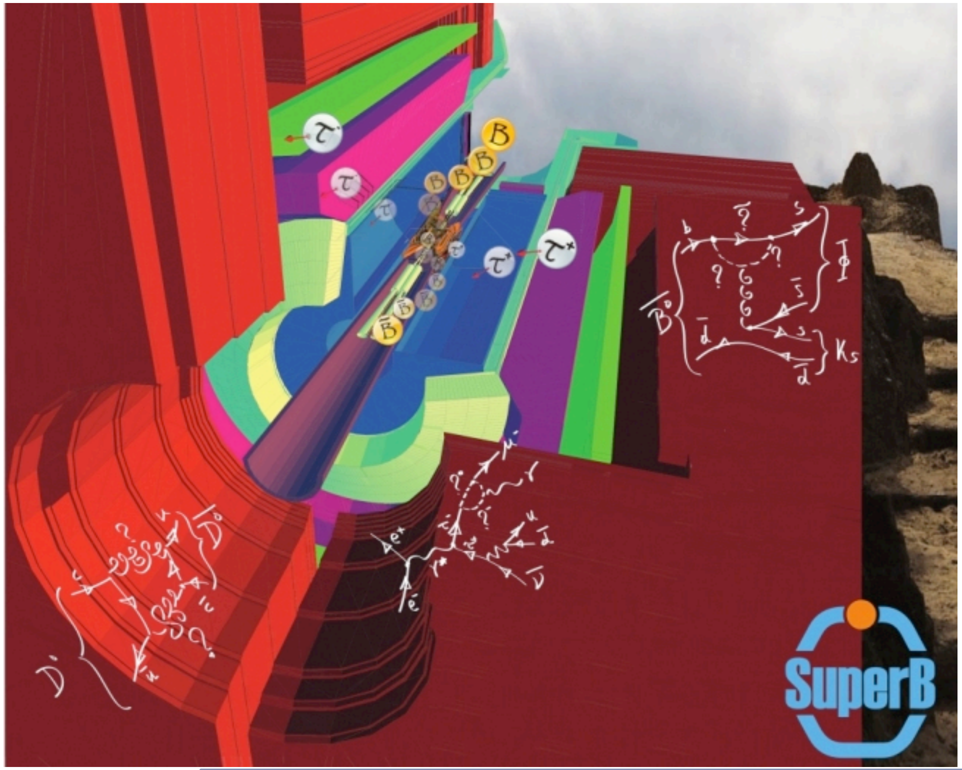

The SuperB Project

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Universite Paris VI et VII, 9th February 2012

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Queen Mary
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Overview

- Introduction
  - The Super Flavour Factories
  - The problem
- Λ_{NP}: the energy scale
- Other NP sensitive flavour observables
- Interplay between measurements
- The facility
- Summary

Introduction

- Current flavour physics landscape is defined by BaBar, Belle and the Tevatron.
  - We learned that CKM is correct at leading order.
  - Placed indirect constraints on NP that will last well into the LHC era. (e.g. H^+ searches).
- SuperB will start taking data in 2017.
  - LHCb will have re-defined some areas of flavour physics on that timescale [and take data through to 2017 shutdown].
  - LHC may (or may not) have found new particles.
    - Existing mass scale exclusions are model dependent.
  - In both scenarios results from SuperB can be used to constrain flavour dynamics at high energy.

MSSM: > 100 parameters

Minimal Flavour Violation: 13 parameters

(+ 6 violating CP)

SU(5) unification: 7 parameters

What we call SUSY depends on how far you want to go in the battle against the curse of dimensionality.

e.g. Only 100 samples per parameter: you need 100^N samples per model.

100^{124} would cover MSSM without ν_R

- The fewer parameters in the model the better!
- The fewer samples the quicker!
- The more constraints the better!

Is this numerical approximation realistic (i.e. good enough)?

The problem

- Many NP models
  - One may be a good description of nature.
  - Almost nothing to go on but the SM and a few hints.

The solution...

Observable/mode	charged Higgs high $\tan\beta$	MFV NP low $\tan\beta$	non-MFV NP 2-3 sector	NP in Z penguins	Right-handed currents	LHT	SUSY AC	RVV2	AKM	δLL	FBMSSM	GUT-CMM
$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★	★★★
$\tau \to \ell\ell\ell$						★★★						?
$B \to \tau\nu, \mu\nu$	★★★(CKM)											
$B \to K^{(*)+}\nu\overline{\nu}$			★	★★★			★	★	★	★	★	?
S in $B \to K_S^0\pi^0\gamma$			★★		★★★							
S in other penguin modes			★★★(CKM)		★★★		★★★	★★	★	★★★	★★★	?
$A_{CP}(B \to X_s\gamma)$			★★★		★★		★	★	★	★★★	★★★	?
$BR(B \to X_s\gamma)$		★	★★		★							★★
$BR(B \to X_s\ell\ell)$			★★	★	★							?
$B \to K^{(*)}\ell\ell$ (FB Asym)							★	★	★	★★★	★★★	?
a_{sl}^s			★★★			★★★						★★★
Charm mixing							★★★	★	★	★	★	
CPV in Charm	★★									★★★		

- It is not obvious which model is correct (if any)
  - Have to look at patterns of deviation from the SM to elucidate the underlying theory.
  - Just like the journey from Cabibbo's 2x2 mixing matrix through to the CKM matrix of today...

Λ_{NP}: the energy scale

- SuperB doesn't operate at high energy
  - So .... what's the point of having it?
  - Model dependent indirect probes for NP reach higher scales than can be attained at the LHC.
  - Model dependent direct searches for NP at the LHC have found nothing so far.

Scenario 1:

LHC finds NP incompatible with flavour data → something to fix in the theory.

Scenario 2:

LHC finds NP compatible with flavour data → can use flavour data to start constraining couplings.

Scenario 3:

LHC finds nothing → probe high energy indirectly and bound possible effects.
e.g. B mixing and the top: everyone knew the top was light until ARGUS found B mixing to be large.

Λ_{NP}: the energy scale

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  - So .... what's the point of having it?
  - Model dependent indirect probes for NP reach higher scales than can be attained at the LHC.
  - Model dependent direct searches for NP at the LHC have found nothing so far.

• Also the problem of decoding NP is not as simple as the days of the top quark searches.

We know something is missing but we don't know what we are looking for.

• Many viable models of NP: SUSY or some simple variant (mSUGRA/ CMSSM/...), extra dimensions, 4th generation, Little Higgs, etc. etc. etc. some are coupled to SM Higgs vs. no Higgs.

Each model guides a search, but only one model can be right (and it's not necessarily one of these).

Λ_{NP}: the energy scale

- Example: Consider MSSM as an illustration of SUSY
  - Simple, and being constrained by the LHC but general enough to illustrate the issue:

e.g. MSSM: 124 (160 with ν_R) couplings, most are flavour related.

Δ's are related to NP mass scale.

LHCb, SuperB

LHC, ILC - HE frontier

$$M^2_{\tilde d} \approx \begin{pmatrix} m^2_{\tilde d_L} & m_d(A_d - \mu \tan\beta) & (\Delta^d_{12})_{LL} & (\Delta^d_{12})_{LR} & (\Delta^d_{13})_{LL} & (\Delta^d_{13})_{LR} \\ & m^2_{\tilde d_R} & (\Delta^d_{12})_{RL} & (\Delta^d_{12})_{RR} & (\Delta^d_{13})_{RL} & (\Delta^d_{13})_{RR} \\ & & m^2_{\tilde s_L} & m_s(A_s - \mu \tan\beta) & (\Delta^d_{23})_{LL} & (\Delta^d_{23})_{LR} \\ & & & m^2_{\tilde s_R} & (\Delta^d_{23})_{RL} & (\Delta^d_{23})_{RR} \\ & & & & m^2_{\tilde b_L} & m_b(A_b - \mu \tan\beta) \\ & & & & & m^2_{\tilde b_R} \end{pmatrix}$$

and similarly for $M^2_{\tilde u}$

  - In many NP scenarios the energy frontier experiments will probe the diagonal elements of mixing matrices.
  - Flavour experiments are required to probe off-diagonal ones.

Λ_{NP}: the energy scale

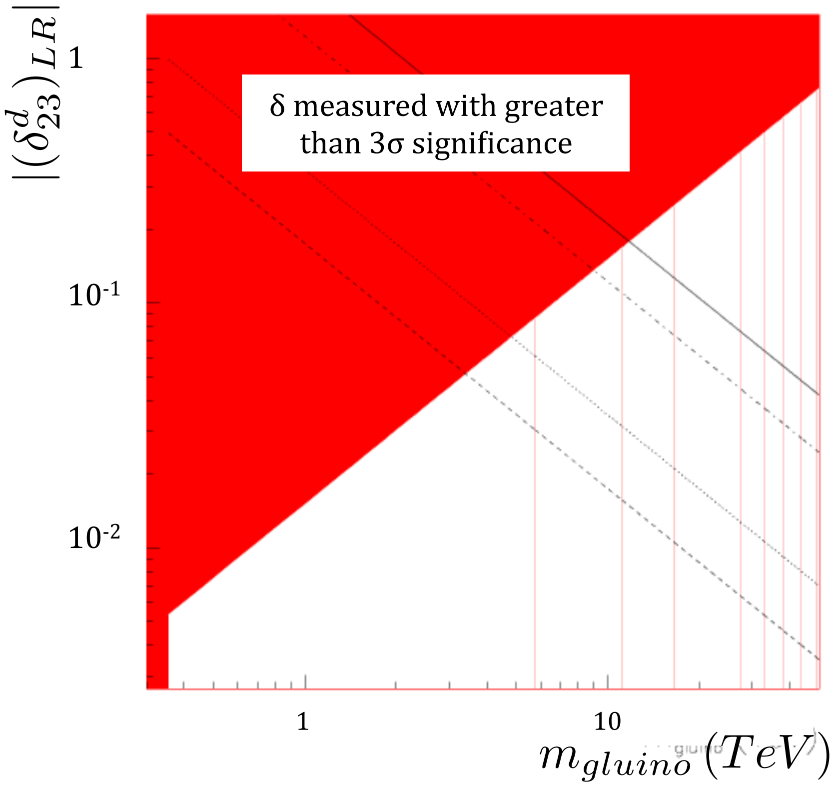
- e.g. MSSM with generic squark mass matrices.
- Use Mass insertion approximation with $m_{\tilde{q}} \sim m_{\tilde{g}}$ to constrain couplings:

$$(\delta^q_{ij})_{AB} = \frac{(\Delta_{ij})^q_{AB}}{m^2_{\tilde{q}}}$$

- Can constrain the δ^d_{ij}'s using

$$\mathcal{B}(B \to X_s\gamma)$$
$$\mathcal{B}(B \to X_s\ell^+\ell^-)$$
$$\mathcal{A}_{CP}(B \to X_s\gamma)$$

Existing LHC constraints on the gluino mass, mean couplings are non-zero, so we can provide an upper bound on Λ_{NP}.



e.g. see Hall et al., Nucl. Phys. B **267** 415-432 (1986)
Ciuchini et al., hep-ph/0212397

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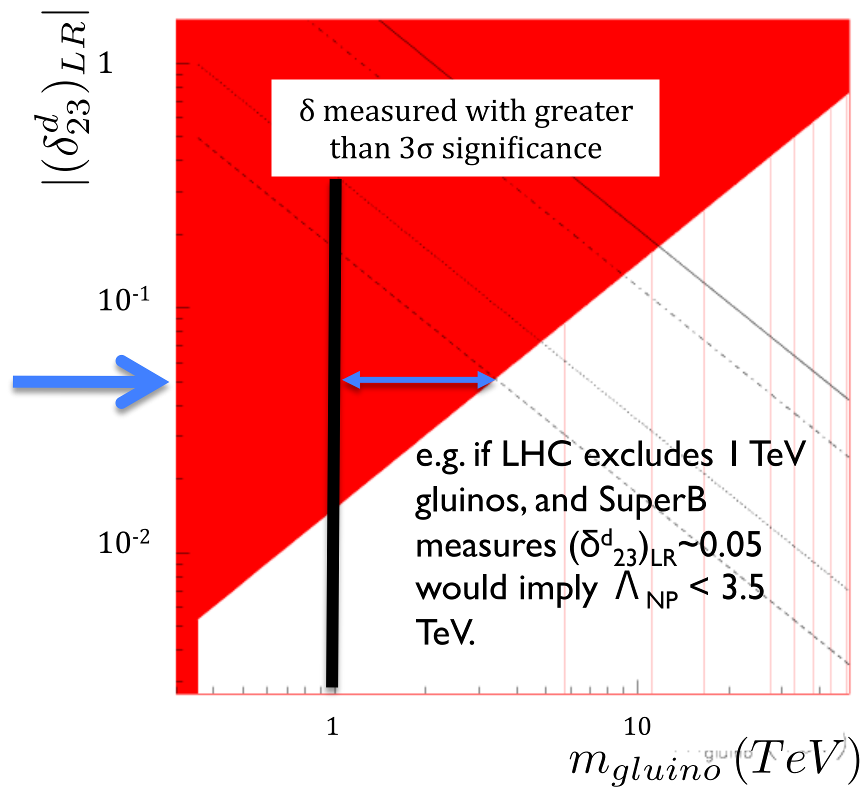

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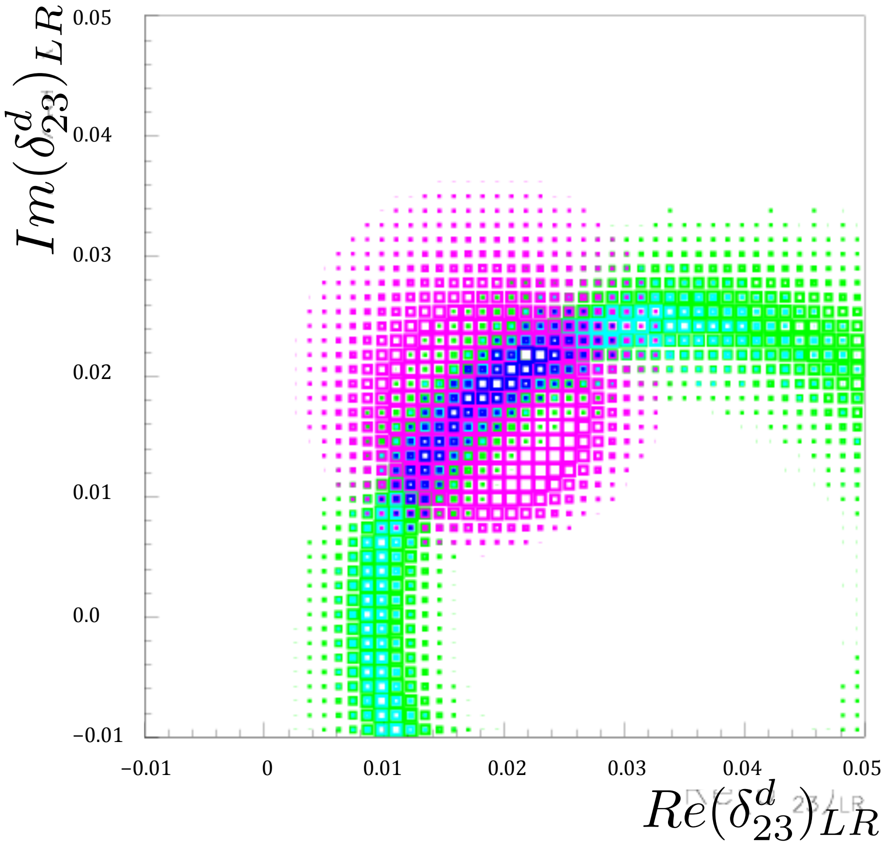

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Other NP sensitive flavour observables

- LFV: τ decays
- B Physics
- D Physics
- Precision $\sin^2\theta_W$

See the following preprints for a more comprehensive overview:

arXiv:1109.5028 [Impact of SuperB]

arXiv:1008.1541 [SuperB Physics progress report]

arXiv:1002.5012 [Belle II Physics Programme]

Lepton Flavour Violation (LFV)

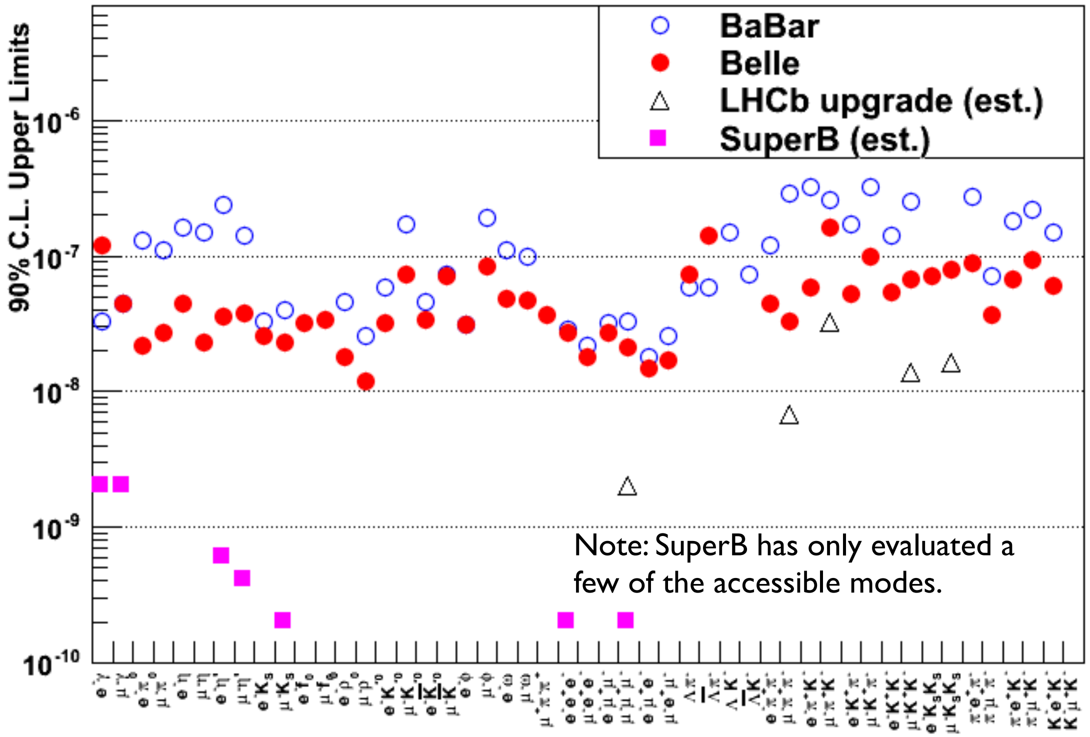
- ν mixing leads to a low level of charged LFV ($B \sim 10^{-54}$).
  - Enhancements to observable levels are possible with new physics scenarios.
  - Searching for transitions from 3rd generation to 2nd and 1st, i.e.

$$\tau \longrightarrow \mu \text{ and } \tau \longrightarrow e$$

➢Two orders of magnitude improvement at SuperB over current limits.

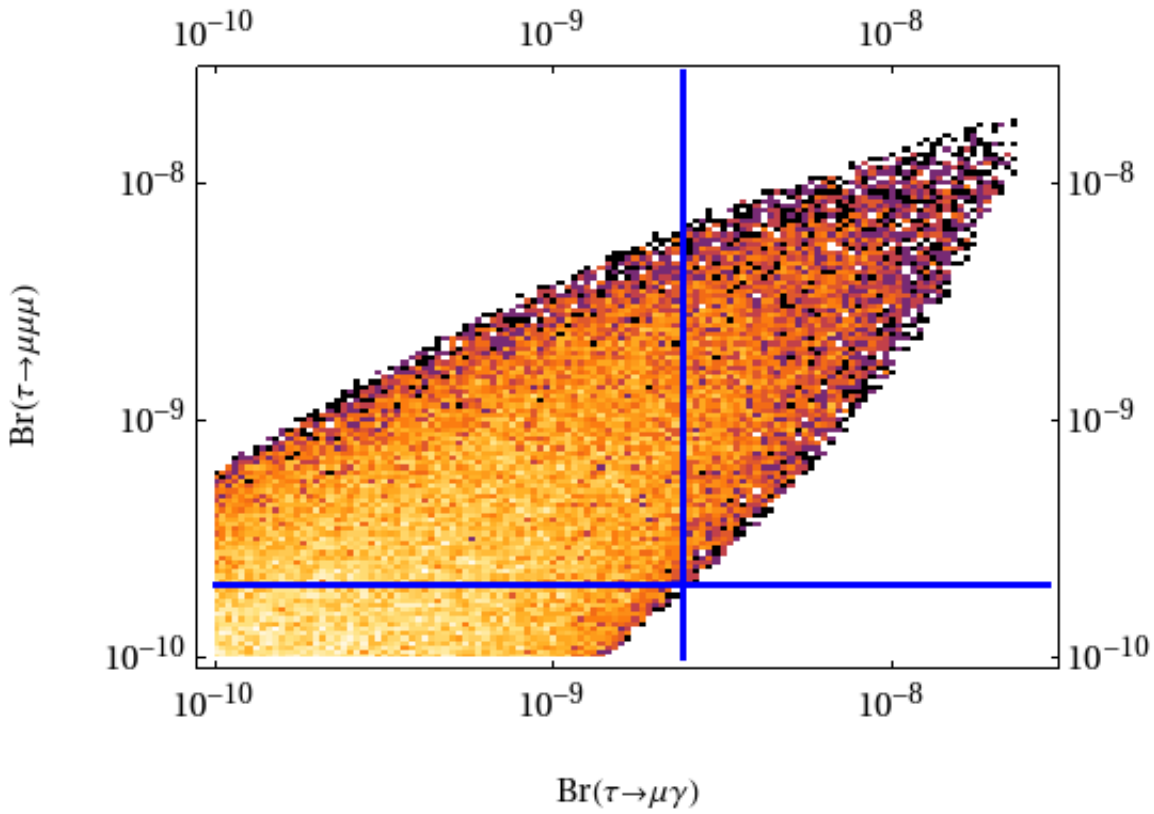
➢Hadron machines are not competitive with e^+e^- machines for this.

- N.B. e^- beam polarisation helps suppress background.



The golden LFV modes: $\tau \longrightarrow \mu\gamma, 3\mu$

- Symmetry breaking scale assumed: 500GeV.



NP scale assumed: 500GeV.

Current experimental limits are at the edges of the model parameter space

SuperB will be able to significantly constrain these models, and either find both channels, or constrain a large part of parameter space.

c/o M. Blanke

M. Blanke et al. arXiv:0906.5454

Specific example: $\tau \to \mu\gamma$

- Only cleanly accessible in e^+e^- (golden modes: μγ, 3 lepton).

Model dependent NP constraint.

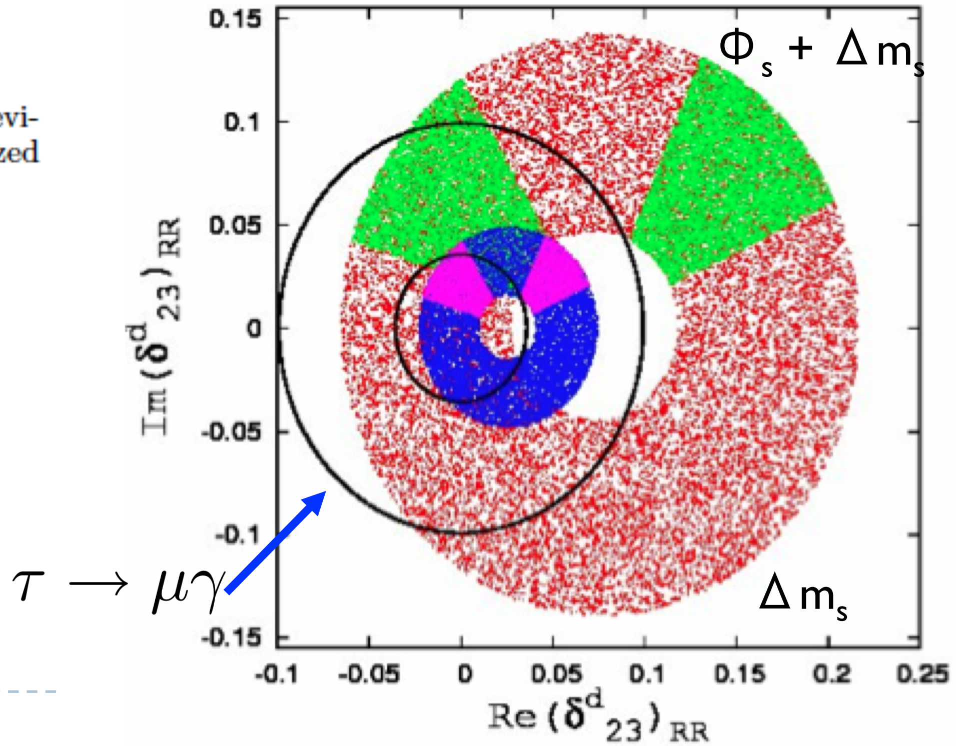
Correlated with other flavour observables: MEG, LHCb etc.

TABLE III: Expected 90% CL upper limits and 3σ evidence reach on LFV decays with 75 ab^{-1} with a polarized electron beam.

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

$m_{\tilde{q}} = 300\, GeV$ BLUE
$m_{\tilde{q}} = 500\, GeV$ RED

Not updated to latest results from LHCb

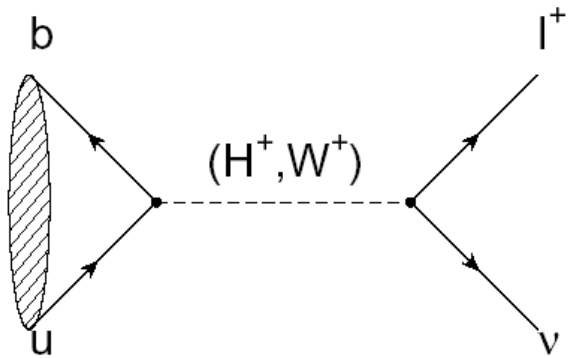


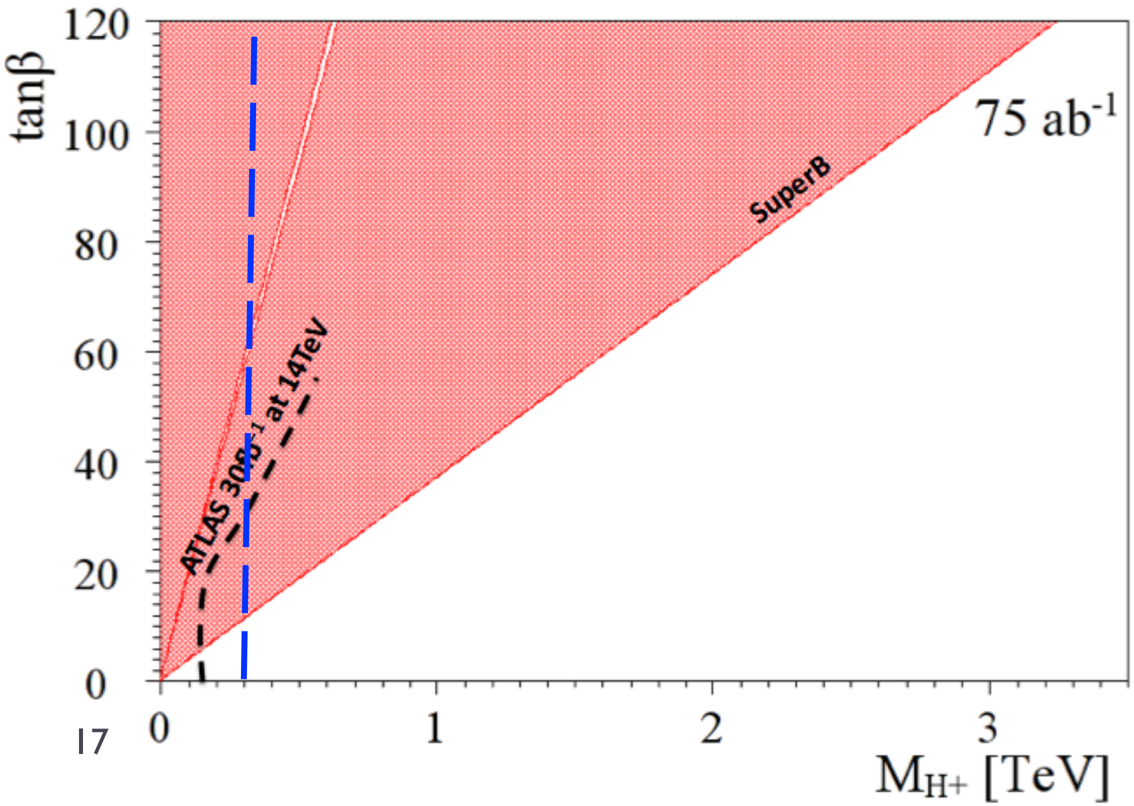
Parry and Zhang Nucl.Phys.B802:63-76,2008

$B_{u,d}$ physics: Rare Decays

- Example: $B^{\pm} \to \ell^{\pm}\nu$
  - Rate modified by presence of H^+

$$r_H = \frac{\mathcal{B}_{SM+NP}}{\mathcal{B}_{SM}}$$





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

Currently the inclusive b to sγ channel excludes $m_{H+} < 295$ GeV/c^2.

The current combined limit places a stronger constraint than direct searches from the LHC for the next few years.

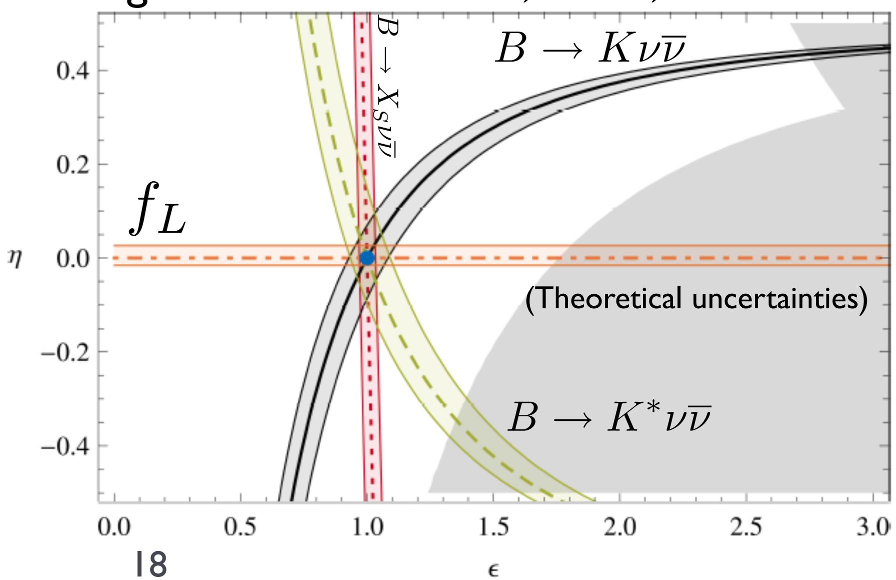
$B_{u,d}$ physics: Rare Decays

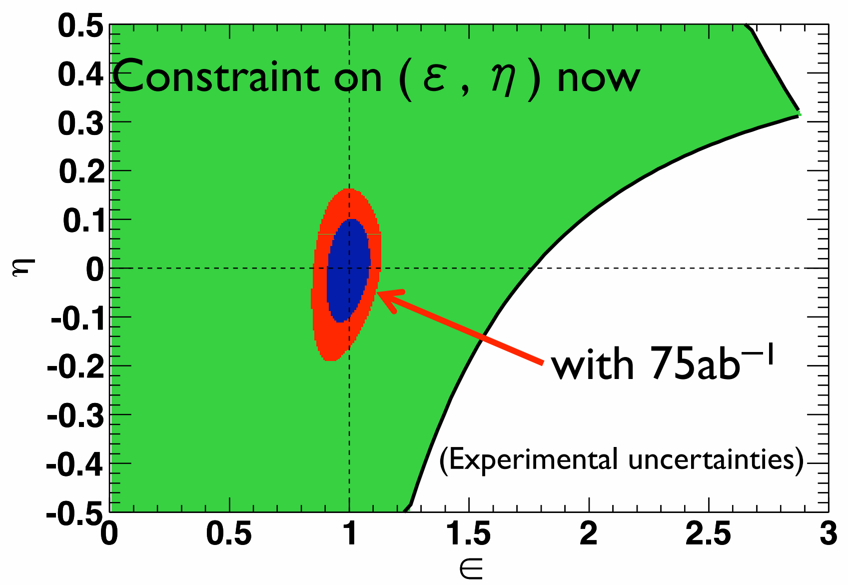
- Example: $B \to K^{(*)} \nu \overline{\nu}$
  - Need $75 ab^{-1}$ to observe pseudoscalar and vector modes.
  - With more than $75 ab^{-1}$ we could measure polarisation.

$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\rm SM}|}, \qquad \eta = \frac{-{\rm Re}\,(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2}$$

Sensitive to models with Z', RH currents and light scalar particles.

e.g. see Altmannshofer, Buras, & Straub





$b \rightarrow s l^+ l^-$

- SFFs can measure inclusive and exclusive modes:
  - Crosscheck results to understand source of NP.
  - Important as theory uncertainties differ.
  - e.g. expect: 10-15,000 K*μμ and 10-15,000 K*ee events at SuperB.

- SFFs can study all lepton flavours:
  - Equal amounts of μ and e final states can be measured.
    - Need both of these to measure all NP sensitive observables.
    - LHCb will accumulate slight more events in the μμ mode.
    - Expect ~20 times the statistics than LHCb for ee mode.
    - S/B~ 0.3, c.f. S/B~1.0 for LHCb.
  - Can also search for $K^{(*)}\tau^+\tau^-$ decay.
  - ... and constrain Majorana ν's using like sign final states.
    - Also of interest for D_s decays to $K^{(*)}ll$ final states near charm threshold.

b→ sl^+l^-

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  - ... and constrain Majorana ν's using like sign final states.
    - Also of interest for D_s decays to $K^{(*)}ll$ final states near charm threshold.

Together the data from SFFs and LHCb can be used to test all NP parameters related to these decays.

TDCPV in B decays (i.e. CKM angles β & α)

- There are many redundant measurements of the CKM angles that are potential probes of NP.

Mode	Current Precision			Predicted Precision ($75\,ab^{-1}$)			Discovery Potential	
	Stat.	Syst.	ΔS^f (Th.)	Stat.	Syst.	ΔS^f (Th.)	3σ	5σ
$J/\psi K^0_S$	0.022	0.010	0 ± 0.01	0.002	0.005	0 ± 0.001	0.02	0.03
$\eta' K^0_S$	0.08	0.02	0.015 ± 0.015	0.006	0.005	0.015 ± 0.015	0.05	0.08
$\phi K^0_S \pi^0$	0.28	0.01	–	0.020	0.010	–	–	–
$f_0 K^0_S$	0.18	0.04	0 ± 0.02	0.012	0.003	0 ± 0.02	0.07	0.12
$K^0_S K^0_S K^0_S$	0.19	0.03	0.02 ± 0.01	0.015	0.020	0.02 ± 0.01	0.08	0.14
ϕK^0_S	0.26	0.03	0.03 ± 0.02	0.020	0.005	0.03 ± 0.02	0.09	0.14
$\pi^0 K^0_S$	0.20	0.03	0.09 ± 0.07	0.015	0.015	0.09 ± 0.07	0.21	0.34
ωK^0_S	0.28	0.02	0.1 ± 0.1	0.020	0.005	0.1 ± 0.1	0.31	0.51
$K^+K^-K^0_S$	0.08	0.03	0.05 ± 0.05	0.006	0.005	0.05 ± 0.05	0.15	0.26
$\pi^0\pi^0 K^0_S$	0.71	0.08	–	0.038	0.045	–	–	–
ρK^0_S	0.28	0.07	-0.13 ± 0.16	0.020	0.017	-0.13 ± 0.16	0.41	0.69
$J/\psi \pi^0$	0.21	0.04	–	0.016	0.005	–	–	–
$D^{*+}D^{*-}$	0.16	0.03	–	0.012	0.017	–	–	–
D^+D^-	0.36	0.05	–	0.027	0.008	–	–	–

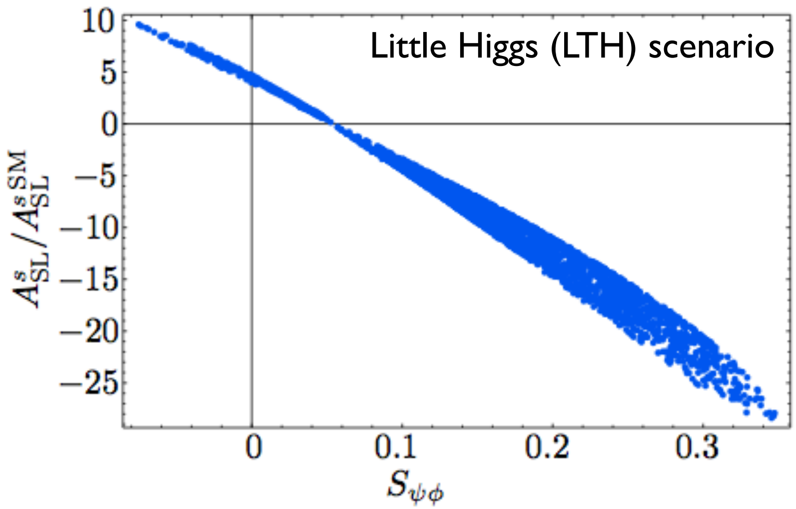
- Can also measure α using all modes: ππ, ρπ, ρρ, $a_1\pi$

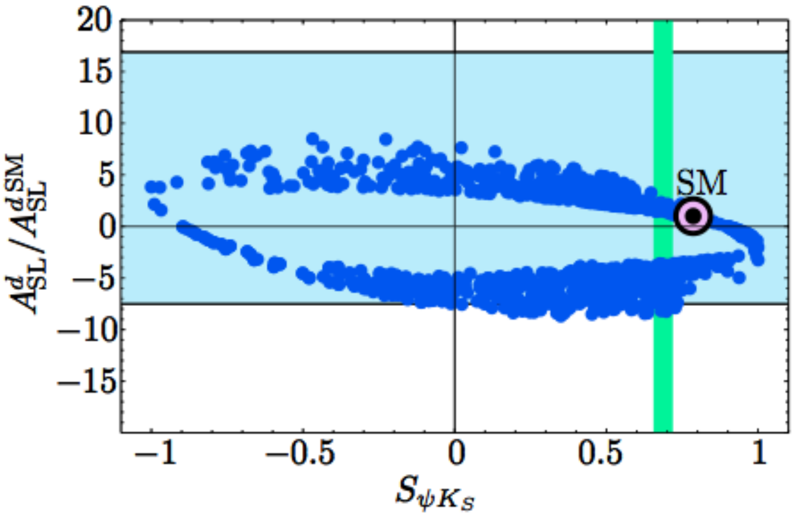
B_s physics

- Can cleanly measure A^s_{SL} using 5S data

$$A^s_{SL} = \frac{\mathcal{B}(B_s \to \overline{B}_s \to X^-\ell^+\nu_\ell) - \mathcal{B}(\overline{B}_s \to B_s \to X^-\ell^+\nu_\ell)}{\mathcal{B}(B_s \to \overline{B}_s \to X^-\ell^+\nu_\ell) + \mathcal{B}(\overline{B}_s \to B_s \to X^-\ell^+\nu_\ell)} = \frac{1 - |q/p|^4}{1 - |q/p|^4}$$

$$\sigma(A^s_{SL}) \sim 0.004 \text{ with a few } ab^{-1}$$





- SuperB can also study rare decays with many neutral particles, such as $B_s \to \gamma\gamma$, which can be enhanced by SUSY.

D Physics

- The programme includes
  - Mixing [This talk]
  - CP Violation [This talk]
  - Quantum Correlation based measurements
  - Rare decays

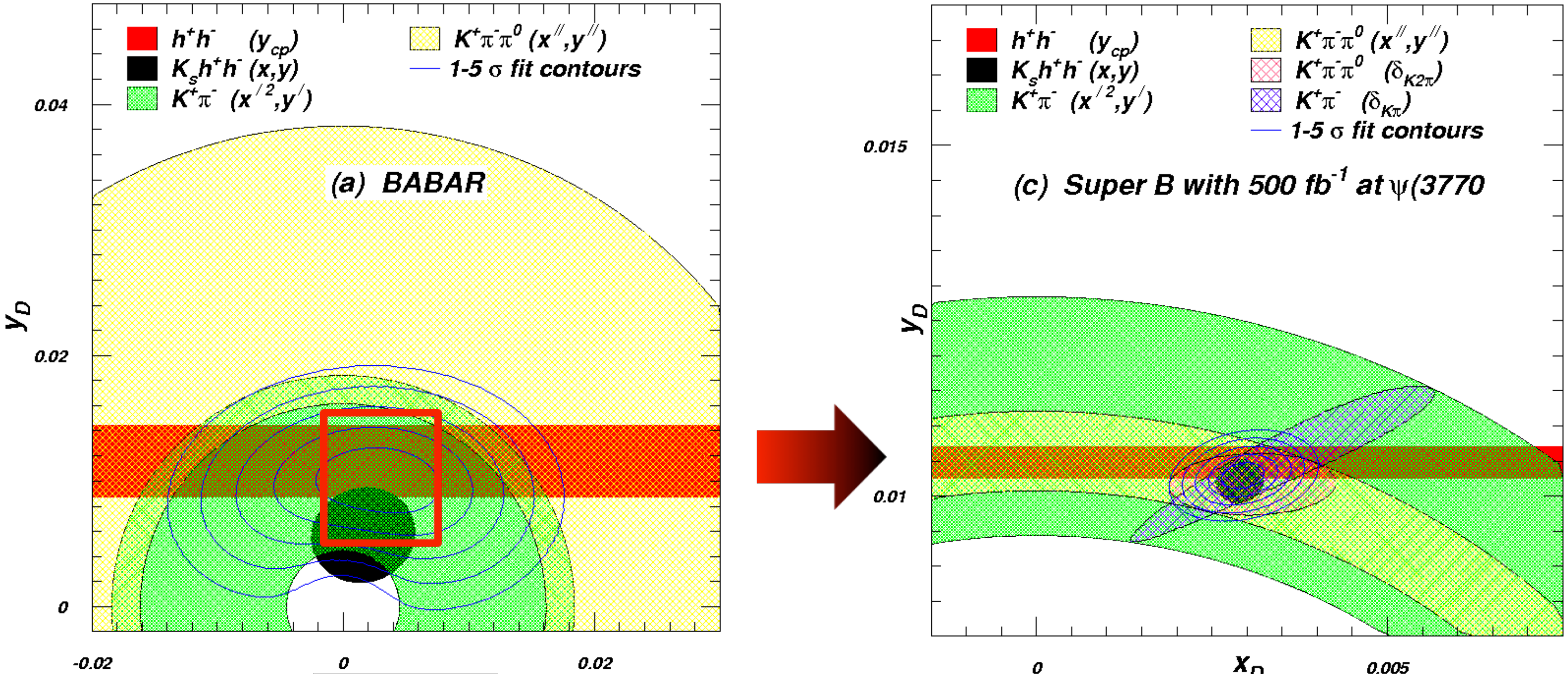
There were a number of talks on charm physics at the threshold workshop in October. Only a few highlights are shown here: see:

http://indico.ihep.ac.cn/conferenceTimeTable.py?confId=2171#all.detailed

for more detailed discussion on this interesting area of the physics programme [AB, Giorgi, Meadows, Neri, Rama, Sokoloff].

Charm Mixing

- Collect data at threshold and at the 4S.
  - Benefit charm mixing and CPV measurements.



- Also useful for measuring the Unitarity triangle angle γ (strong phase in D→Kππ Dalitz plot).

Charm Mixing

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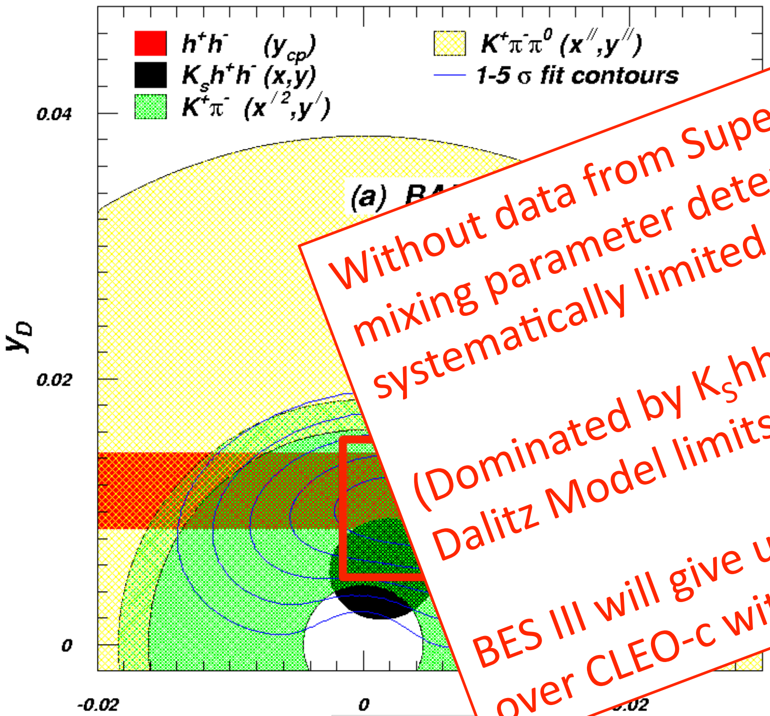
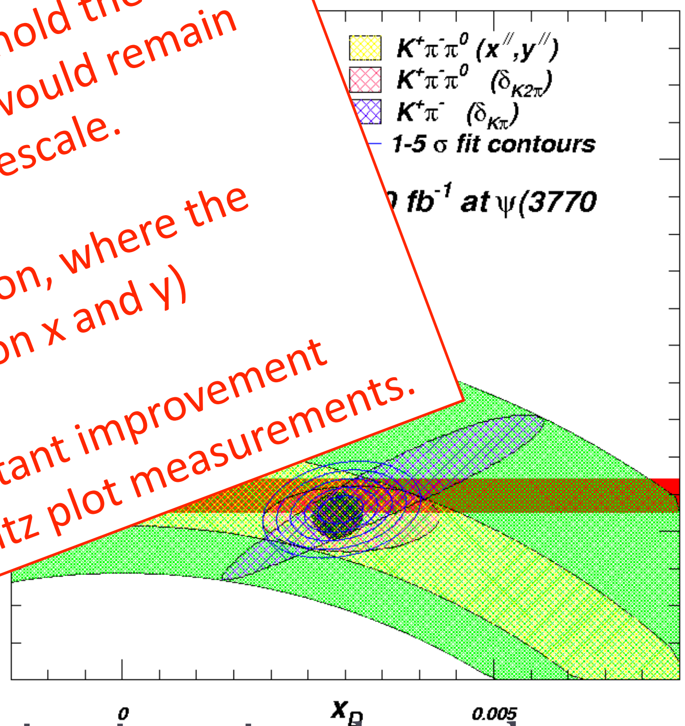




Without data from SuperB at threshold the mixing parameter determination would remain systematically limited on this timescale.

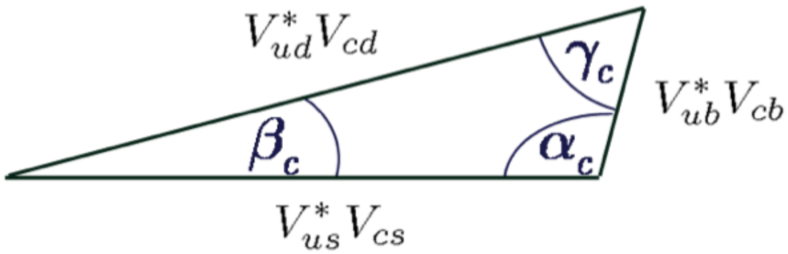
(Dominated by $K_S hh$ contribution, where the Dalitz Model limits precision on x and y)

BES III will give us an important improvement over CLEO-c with $K_S hh$ Dalitz plot measurements.

  - Also useful for measuring the Unitarity triangle angle γ (strong phase in D→Kππ Dalitz plot).

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

- The charm cu triangle has one unique element: β_c



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

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

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

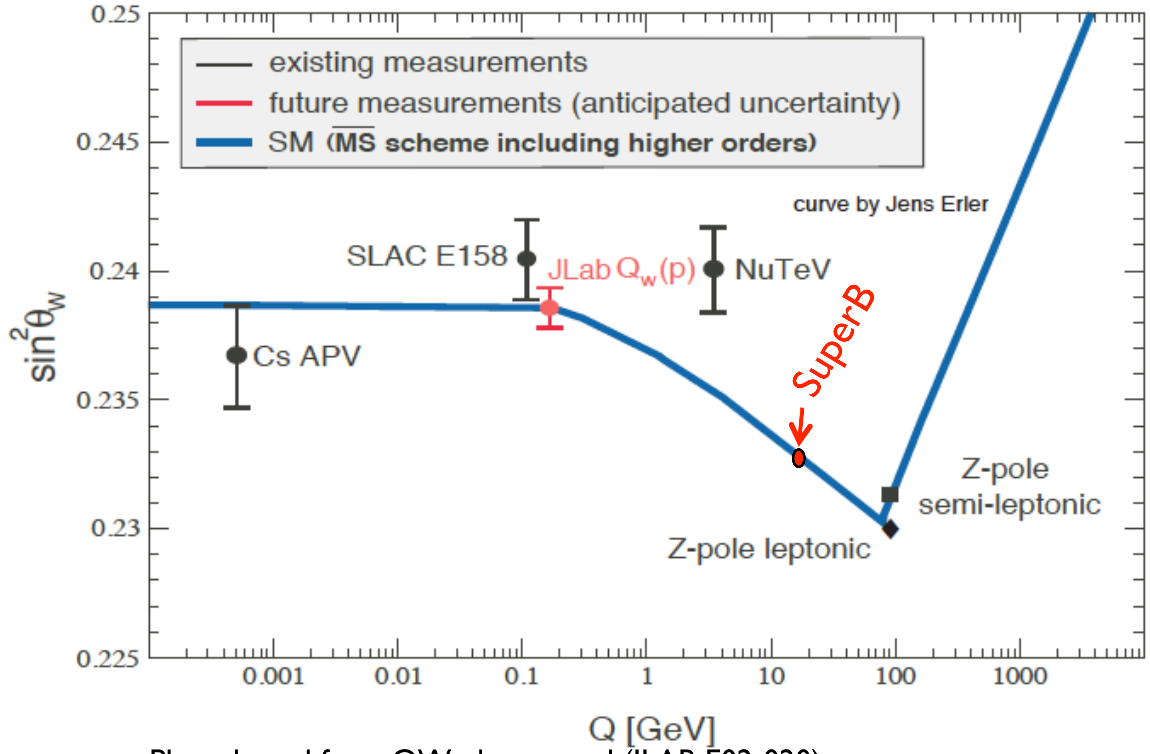
- Precision measurement of mixing phase in many channels (<2°)
- Constrain $\beta_{c,\text{eff}}$ using a $D \to \pi\pi$ Isospin analysis
  - Search for NP and constrain $\beta_{c,\text{eff}} \sim 1°$.
  - Can only fully explore in an e^+e^- environment.
  - Data from the charm threshold region completes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

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

Precision EW Physics

Precision Electroweak

- $\sin^2\theta_W$ can be measured with polarised e^- beam:
  - $\sqrt{s}=\Upsilon(4S)$ is theoretically clean, c.f. b-fragmentation at Z pole.



Plot adapted from QWeak proposal (JLAB E02-020)

Measure LR asymmetry in

$$e^+e^- \rightarrow b\bar{b}$$
$$e^+e^- \rightarrow c\bar{c}$$
$$e^+e^- \rightarrow \tau^+\tau^-$$
$$e^+e^- \rightarrow \mu^+\mu^-$$

at the Υ(4S) to same precision as LEP/SLC at the Z-pole.

Complements measurements planned/underway at lower energies (QWeak/MESA).

This table concentrates on observables that SFFs can measure, with a few of the prime examples from hadron experiments to highlight that there are many things that need to be measured well.

Golden Measurements: General

	Red	Yellow	Blue	Green
Experiment:	No Result	Moderately precise	Precise	Very precise
Theory:		Moderately clean	Clean, needs Lattice	Clean

Observable/mode Luminosity	Current $\sim 1\,\mathrm{ab}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade $50\,\mathrm{fb}^{-1}$	Theory	
τ Decays						
$\tau \to \mu\gamma$	Yellow	Yellow	Green	Yellow	Green	Benefit from polarised e⁻ beam
$\tau \to e\gamma$	Yellow	Yellow	Green	Yellow	Green	
$B_{u,d}$ Decays						
$B \to \tau\nu, \mu\nu$	Yellow	Red	Blue	Red	Blue	very precise with improved detector
$B \to K^{(*)+}\nu\overline{\nu}$	Red	Red	Green	Red	Green	Statistically limited: Angular analysis with >75ab-1
S in $B \to K^0_S\pi^0\gamma$	Yellow	Red	Green	Red	Yellow	Right handed currents
S (other penguin modes)	Yellow	Yellow	Green	Blue	Yellow	SuperB measures many more modes
A_{CP} ($B \to X_s\gamma$)	Blue	Yellow	Green	Yellow	Green	systematic error is main challenge
BR($B \to X_s\gamma$)	Blue	Yellow	Green	Yellow	Yellow	control systematic error with data
BR($B \to X_s ll$)	Yellow	Red	Green	Red	Green	
BR($B \to K^{(*)} ll$)	Yellow	Blue	Green	Green	Yellow	SuperB measures e mode well, LHCb does μ
B_s Decays						
$B_s \to \mu\mu$	Red	Blue	Red	Green	Green	
β_S from $B_s \to J/\psi\,\phi$	Red	Blue	Red	Green	Green	
$B_s \to \gamma\gamma$	Red	Red	Blue	Red	Green	
a_{sl}	Red	Blue	Green	Green	Green	
D Decays						
Mixing parameters	Yellow	Blue	Green	Green	Green	
CP Violation	Red	Blue	Green	Green	Green	Clean NP search
Precision Electroweak						
$\sin^2\theta_W$ at $\Upsilon(4S)$	Red	Red	Green	Red	Green	Theoretically clean
$\sin^2\theta_W$ at Z-Pole	Green	Blue	Red	Green	Yellow	b fragmentation limits interpretation

This table concentrates on observables that SFFs can measure, with a few of the prime examples from hadron experiments to highlight that there are many things that need to be measured well.

Golden Measurements: CKM

- Comparison of relative benefits of SuperB ($75ab^{-1}$) vs. existing measurements and LHCb ($5fb^{-1}$) and the LHCb upgrade ($50fb^{-1}$).

Observable/mode Luminosity	Current $\sim 1\,\mathrm{fb}^{-1}$	LHCb (2017) $5\,\mathrm{fb}^{-1}$	Super$B$ (2022) $75\,\mathrm{ab}^{-1}$	LHCb upgrade $50\,\mathrm{fb}^{-1}$	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 $\rho\pi$

β theory error B_d
β theory error B_s

Need an e^+e^- environment to do a precision measurement using semi-leptonic B decays.

Experiment:	No Result	Moderately precise	Precise	Very precise
Theory:		Moderately clean	Clean, needs Lattice	Clean

Observable/mode	Current now	LHCb (2017) 5 fb^{-1}	Super$B$ (2021) 75 ab^{-1}	Belle II (2021) 50 ab^{-1}	LHCb upgrade (10 years of running) 50 fb^{-1}	theory now
			τ Decays			
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
			$B_{u,d}$ Decays			
BR($B \to \tau\nu$) ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
BR($B \to \mu\nu$) ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
BR($B \to K^{*+}\nu\bar{\nu}$) ($\times 10^{-6}$)	< 80		1.1	2.0		6.8 ± 1.1
BR($B \to K^{+}\nu\bar{\nu}$) ($\times 10^{-6}$)	< 160		0.7	1.6		3.6 ± 0.5
BR($B \to X_s\gamma$) ($\times 10^{-4}$)	3.55 ± 0.26		0.11	0.13	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	0.02		$\sim 10^{-6}$
$B \to K^*\mu^+\mu^-$ (events)	250[c]	8000	10-15k[d]	7-10k	100,000	-
BR($B \to K^*\mu^+\mu^-$) ($\times 10^{-6}$)	1.15 ± 0.16		0.06	0.07		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	400	10-15k	7-10k	5,000	-
BR($B \to K^*e^+e^-$) ($\times 10^{-6}$)	1.09 ± 0.17		0.05	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 ± 0.14[e]	[f]	0.040	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	280		8,600	7,000		-
BR($B \to X_s\ell^+\ell^-$) ($\times 10^{-6}$)[g]	3.66 ± 0.77[h]		0.08	0.10		1.59 ± 0.11
S in $B \to K^0_S\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
			B^0_s Decays			
BR($B^0_s \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A^s_{SL} ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
			D Decays			
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.02%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\lvert q/p \rvert$	$(0.91 \pm 0.17)\%$	8.5%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
$\arg\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	4.4	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
			Other processes Decays			
$\sin^2\theta_W$ at $\sqrt{s} = 10.58\,\mathrm{GeV}/c^2$			0.0002	[l]		clean

Observable/mode	Current now	LHCb (2017) 5 fb^{-1}	Super$B$ (2021) 75 ab^{-1}	Belle II (2021) 50 ab^{-1}	LHCb upgrade (10 years of running) 50 fb^{-1}	theory now
			τ Decays			
$\tau \to \mu\gamma$ ($\times 10^{-9}$)	< 44		< 2.4	< 5.0		
$\tau \to e\gamma$ ($\times 10^{-9}$)	< 33		< 3.0	< 3.7 (est.)		
$\tau \to \ell\ell\ell$ ($\times 10^{-10}$)	$< 150 - 270$	< 244 [a]	$< 2.3 - 8.2$	< 10	< 24 [b]	
			$B_{u,d}$ Decays			
BR($B \to \tau\nu$) ($\times 10^{-4}$)	1.64 ± 0.34		0.05	0.04		1.1 ± 0.2
BR($B \to \mu\nu$) ($\times 10^{-6}$)	< 1.0		0.02	0.03		0.47 ± 0.08
BR($B \to K^{*+}\nu\overline{\nu}$) ($\times 10^{-6}$)	< 80		1.1	2.0		6.8 ± 1.1
BR($B \to K^{+}\nu\overline{\nu}$) ($\times 10^{-6}$)	< 160		0.7	1.6		3.6 ± 0.5
BR($B \to X_s\gamma$) ($\times 10^{-4}$)	3.55 ± 0.26		0.11	[illegible]	0.23	3.15 ± 0.23
$A_{CP}(B \to X_{(s+d)}\gamma)$	0.060 ± 0.060		0.02	[illegible]		$\sim 10^{-6}$
$B \to K^*\mu^+\mu^-$ (events)	250[c]	8000	[illegible]	[illegible]	100,000	-
BR($B \to K^*\mu^+\mu^-$) ($\times 10^{-6}$)	1.15 ± 0.16	[illegible]	[illegible]	[illegible]		1.19 ± 0.39
$B \to K^*e^+e^-$ (events)	165	[illegible]	[illegible]	[illegible]-10k	5,000	-
BR($B \to K^*e^+e^-$) ($\times 10^{-6}$)	$1.09 \pm$ [illegible]	[illegible]	[illegible]	0.07		1.19 ± 0.39
$A_{FB}(B \to K^*\ell^+\ell^-)$	0.27 [illegible]	[illegible]	0.040	0.03		-0.089 ± 0.020
$B \to X_s\ell^+\ell^-$ (events)	28[illegible]	[illegible]	8,600	7,000		-
BR($B \to X_s\ell^+\ell^-$) ($\times 10^{-6}$)[g]	3.66 ± 0[illegible]		0.08	0.10		1.59 ± 0.11
S in $B \to K^0_S\pi^0\gamma$	-0.15 ± 0.20		0.03	0.03		-0.1 to 0.1
S in $B \to \eta' K^0$	0.59 ± 0.07		0.01	0.02		± 0.015
S in $B \to \phi K^0$	0.56 ± 0.17	0.15	0.02	0.03	0.03	± 0.02
			B^0_s Decays			
BR($B^0_s \to \gamma\gamma$) ($\times 10^{-6}$)	< 8.7		0.3	$0.2 - 0.3$		0.4 - 1.0
A^s_{SL} ($\times 10^{-3}$)	-7.87 ± 1.96 [i]	[j]	4.	5. (est.)		0.02 ± 0.01
			D Decays			
x	$(0.63 \pm 0.20\%$	0.06%	0.02%	0.04%	0.02%	$\sim 10^{-2}$ [k]
y	$(0.75 \pm 0.12)\%$	0.03%	0.01%	0.03%	0.01%	$\sim 10^{-2}$ (see above).
y_{CP}	$(1.11 \pm 0.22)\%$	0.02%	0.03%	0.05%	0.01%	$\sim 10^{-2}$ (see above).
$\|q/p\|$	$(0.91 \pm 0.17)\%$	8.5%	2.7%	3.0%	3%	$\sim 10^{-3}$ (see above).
arg$\{q/p\}$ ($^\circ$)	-10.2 ± 9.2	4.4	1.4	1.4	2.0	$\sim 10^{-3}$ (see above).
			Other processes Decays			
$\sin^2\theta_W$ at $\sqrt{s} = 10.58$ GeV/c^2			0.0002	[l]		clean

+ A number of charm decay analogues under investigation

Observable/mode	Current now	LHCb (2017)	Super$B$ (2021)	Belle II (2021)	LHCb upgrade (10 years of running)	theory now
		$5\,\text{fb}^{-1}$	$75\,\text{ab}^{-1}$	$50\,\text{ab}^{-1}$	$50\,\text{fb}^{-1}$	
α from $u\bar{u}d$	6.1°	$5^{\circ\,a}$	1°	1°	[b]	$1-2^\circ$
β from $c\bar{c}s$ (S)	0.8° (0.020)	0.5° (0.008)	0.1° (0.002)	0.3° (0.007)	0.2° (0.003)	clean
S from $B_d \to J/\psi\pi^0$	0.21		0.014	0.021 (est.)		clean
S from $B_s \to J/\psi K^0_S$		?			?	clean
γ from $B \to DK$	11°	$\sim 4^\circ$	1°	1.5°	0.9°	clean
$\lvert V_{cb}\rvert$ (inclusive) %	1.7		0.5%	0.6 (est.)		dominant
$\lvert V_{cb}\rvert$ (exclusive) %	2.2		1.0%	1.2 (est.)		dominant
$\lvert V_{ub}\rvert$ (inclusive) %	4.4		2.0%	3.0		dominant
$\lvert V_{ub}\rvert$ (exclusive) %	7.0		3.0%	5.0		dominant

Decoding New Physics

Observable/mode	charged Higgs high $\tan\beta$	MFV NP low $\tan\beta$	non-MFV NP 2-3 sector	NP in Z penguins	Right-handed currents	LHT	SUSY					
							AC	RVV2	AKM	δLL	FBMSSM	GUT-CMM
$\tau \to \mu\gamma$							★★★	★★★	★	★★★	★★★	★★★
$\tau \to \ell\ell\ell$						★★★						?
$B \to \tau\nu, \mu\nu$	★★★(CKM)											
$B \to K^{(*)+}\nu\bar{\nu}$			★	★★★			★	★	★	★	★	?
S in $B \to K_S^0\pi^0\gamma$			★★		★★★							
S in other penguin modes			★★★(CKM)		★★★		★★★	★★	★	★★★	★★★	?
$A_{CP}(B \to X_s\gamma)$			★★★		★★		★	★	★	★★★	★★★	?
$BR(B \to X_s\gamma)$		★	★★		★							★★
$BR(B \to X_s\ell\ell)$			★★	★	★							?
$B \to K^{(*)}\ell\ell$ (FB Asym)							★	★	★	★★★	★★★	?
a_{sl}^s			★★★			★★★						★★★
Charm mixing							★★★	★	★	★	★	
CPV in Charm	★★									★★★		

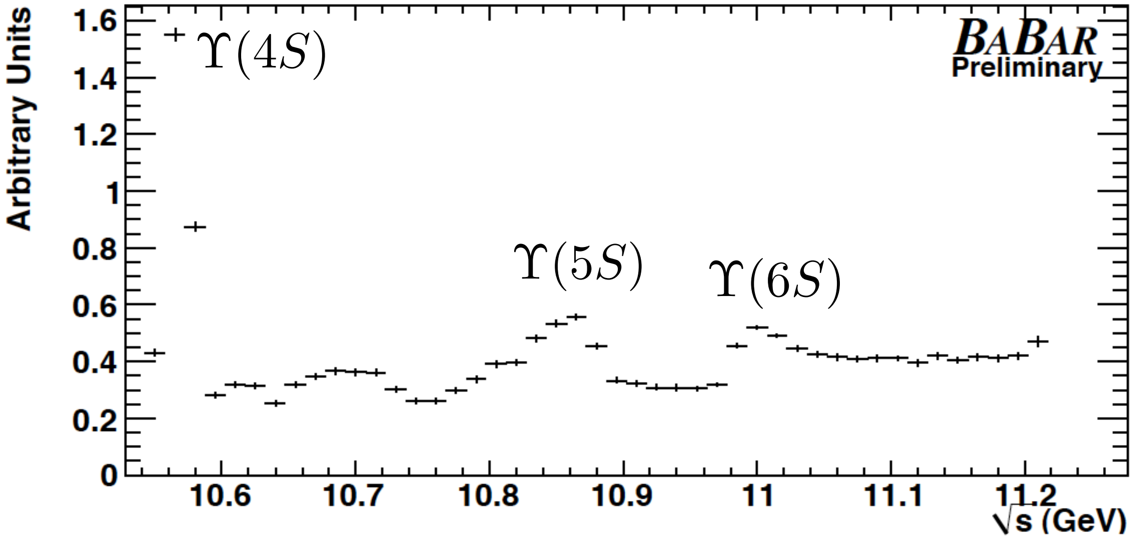
- This matrix is partially complete, but illustrates the point:
  - Decoding NP is not as simple as setting the mass scale for the top was...

The facility

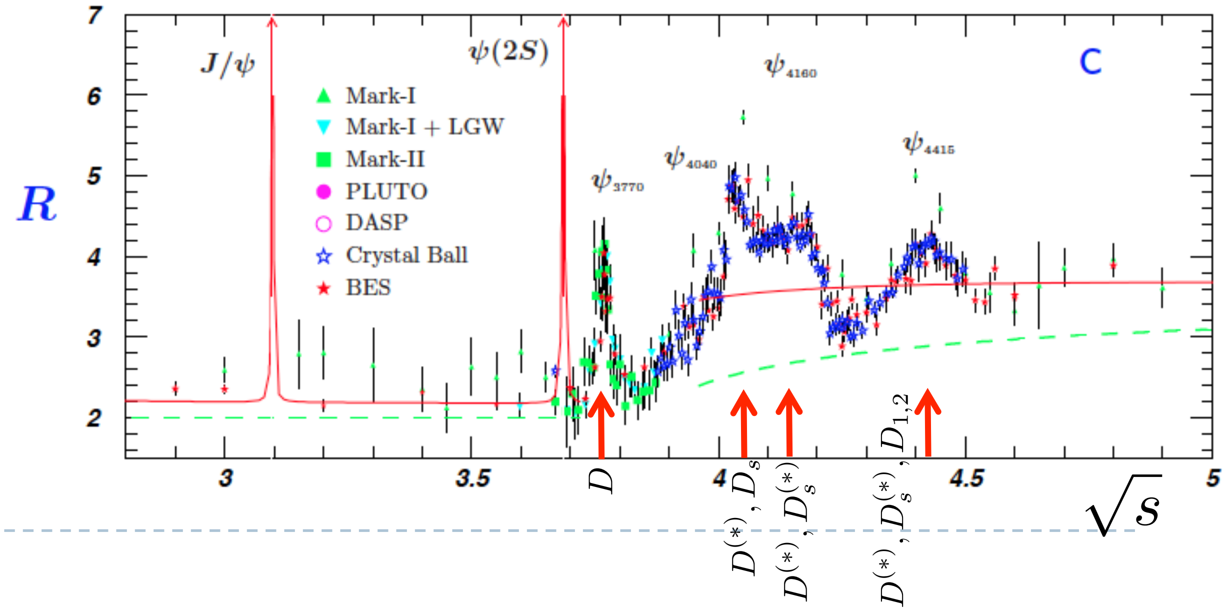
- Physics dictates:
  - $75ab^{-1}$ at the $\Upsilon(4S)$
  - $1ab^{-1}$ at the $\psi(3770)$
  - + running at nearby resonances (e.g. $\sim 1ab^{-1}$ at the $\Upsilon(5S)$ and some running above this)

Data samples available at SuperB

- $\Upsilon(4S)$ region:
  - $75ab^{-1}$ at the 4S.
  - Also run above / below the 4S.
  - ~75 x10^9 B, D and τ pairs.



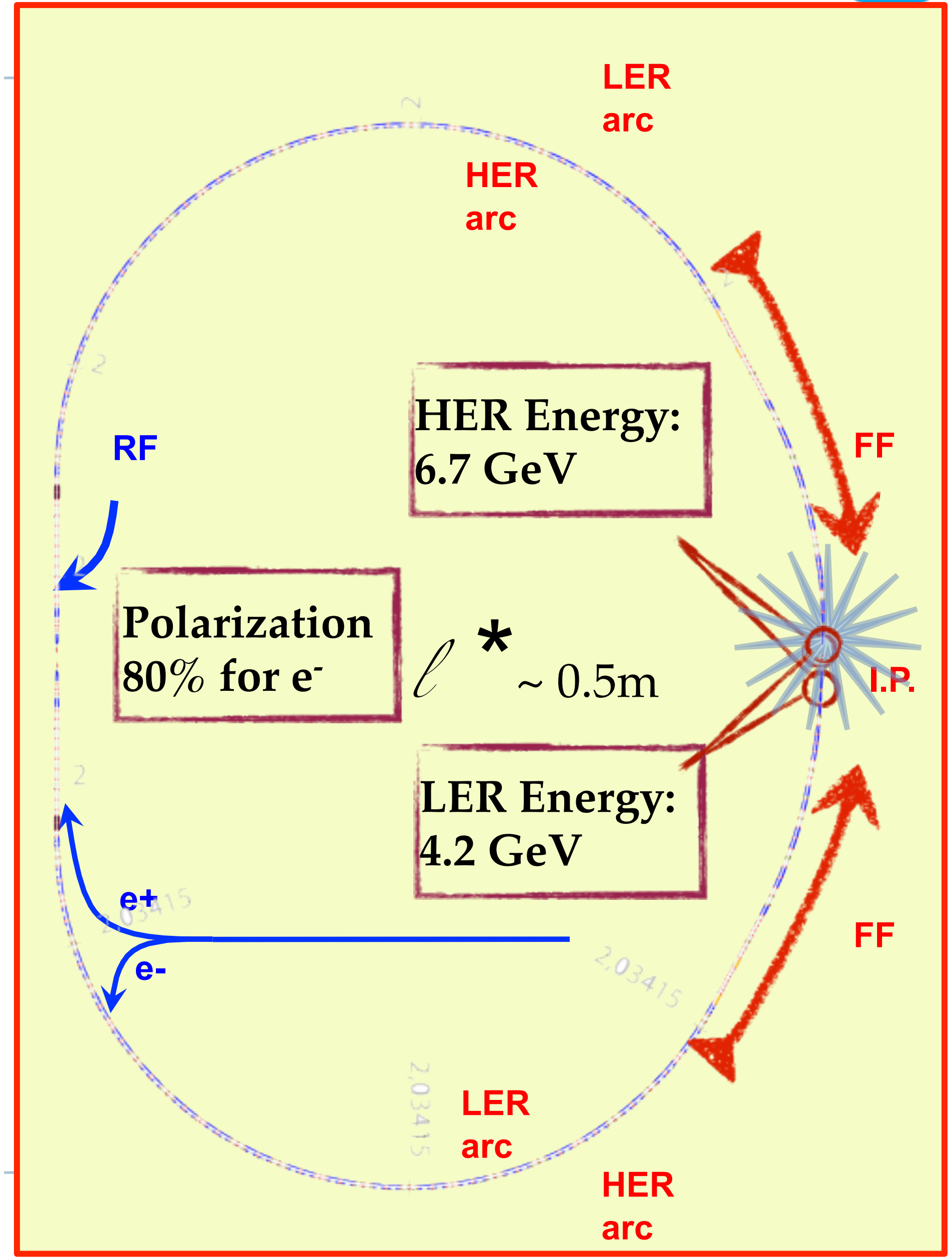
- $\psi(3770)$ region:
  - $500fb^{-1}$ at threshold.
  - Also run at nearby resonances.
  - ~2 x 10^9 D pairs at threshold in a few months of running.



Accelerator

Accelerator Scheme

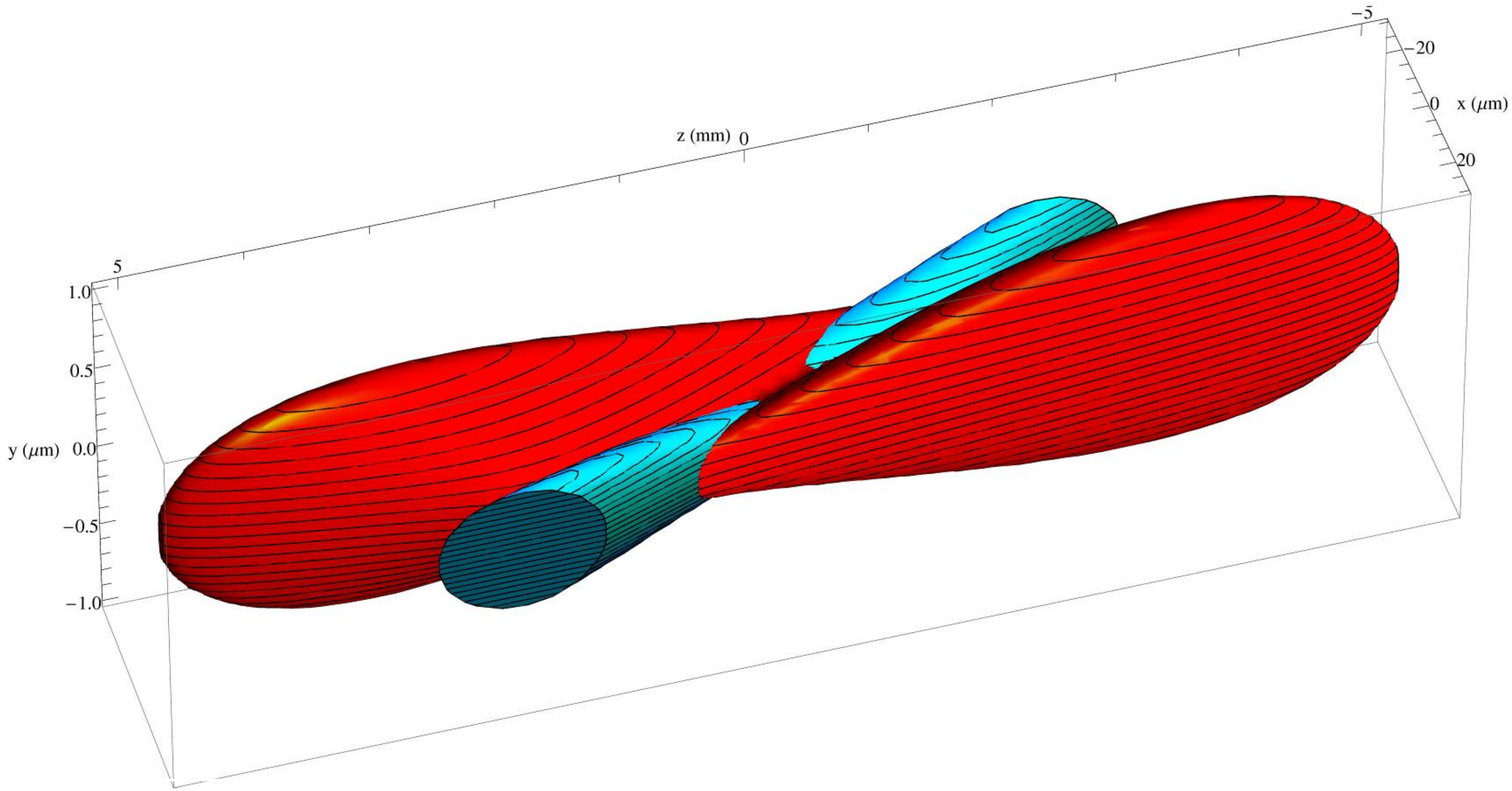
- General strategy:
  - Very small emittance (ILC-DR)
  - Small β* at IP
  - Large Piwinski angle
  - Crab waist technique
  - Currents similar to present accelerators
- Advantages
  - Small collision area
  - No parasitic crossing
  - No synchro-betatron resonances
  - Moderate backgrounds
- Re-use,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



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

Crab-waist scheme

Crab sextupoles OFF: Waist line is orthogonal to the axis of other beam



Crab sextupoles ON: Waist aligned with path of other beam

- **particles at higher ß do not see full field of other beam**
- **no excessive beam-beam parameter due to hourglass effect**

Parameter Table

		Base Line		Low Emittance		High Current		τ/charm	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY (10^{36})	cm^{-2} s^{-1}	1		1		1		1	
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	60		60		60		60	
Piwinski angle	rad	20.80	16.91	29.42	23.91	13.12	10.67	8.00	6.50
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
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (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	
Buckets distance	ns	4.20		4.20		2.10		2.10	
Ion gap	%	2		2		2		2	
RF frequency	MHz	476		476		476		476	
Harmonic number		1998		1998		1998		1998	
Number of bunches		465		465		931		931	
N. Particle/bunch (10^{10})		5.08	6.56	3.92	5.06	4.15	5.36	1.83	2.37
Tune shift x		0.0026	0.0040	0.0020	0.0031	0.0053	0.0081	0.0063	0.0096
Tune shift y		0.1067	0.1069	0.0980	0.0981	0.0752	0.0755	0.1000	0.1001
Long. 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	0.166
σ_E (full current)	δE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	δE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	16.38		12.37		28.83		2.81	

Tau/charm threshold running at 10^{35}

Baseline + other 2 options:
- **Lower y-emittance**
- **Higher currents (twice bunches)**

Baseline:
- **Higher emittance due to IBS**
- **Asymmetric beam currents**

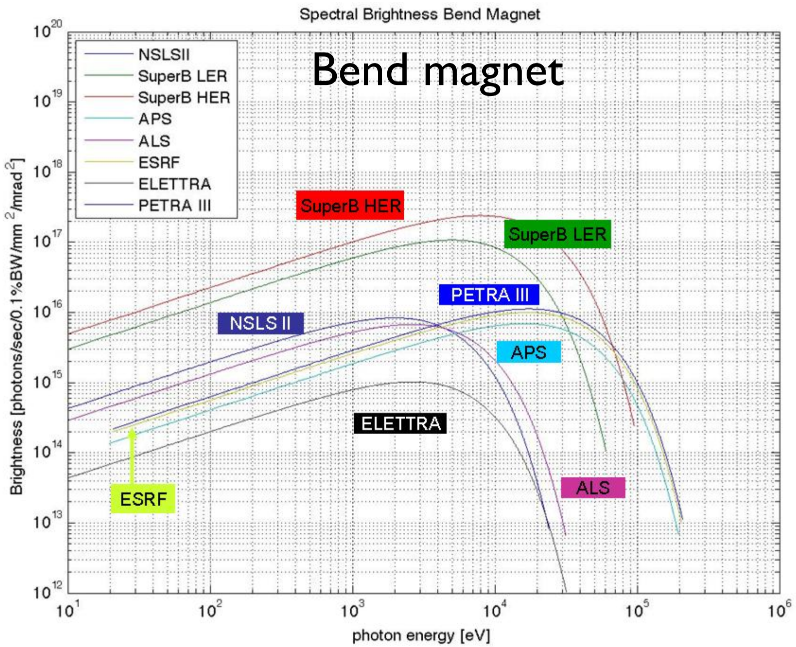
RF power includes SR and HOM

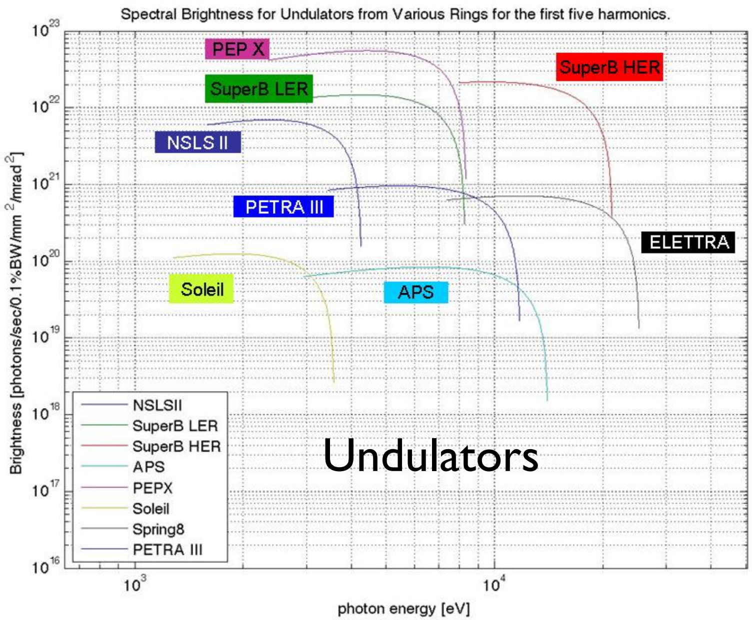
Synchroton Light properties and uses

- Synchrotron light properties from dipoles are competitive
- Assumed undulators characteristics as NSLS-II
- Light properties from undulators still better than most LS, slightly worst than PEP-X (last generation project)

Italian Institute for Technology interests:

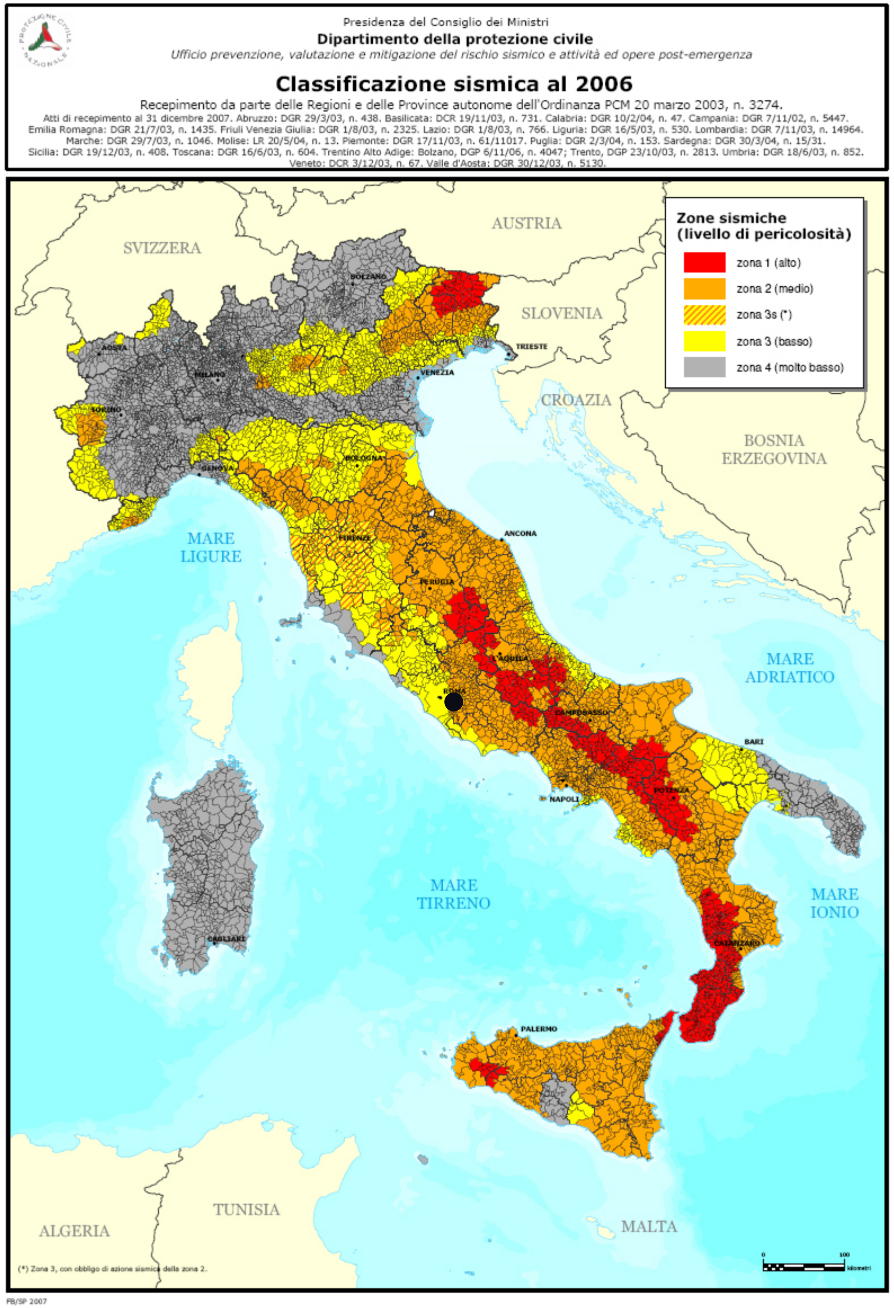
- lithography for 3D scaffolding for bio-engineering
- laser ablation on biomaterials
- femtochemistry studies
- photon induced growth for material science
- innovative interface diffraction techniques
- imaging in biomedicine
- X ray microscopy





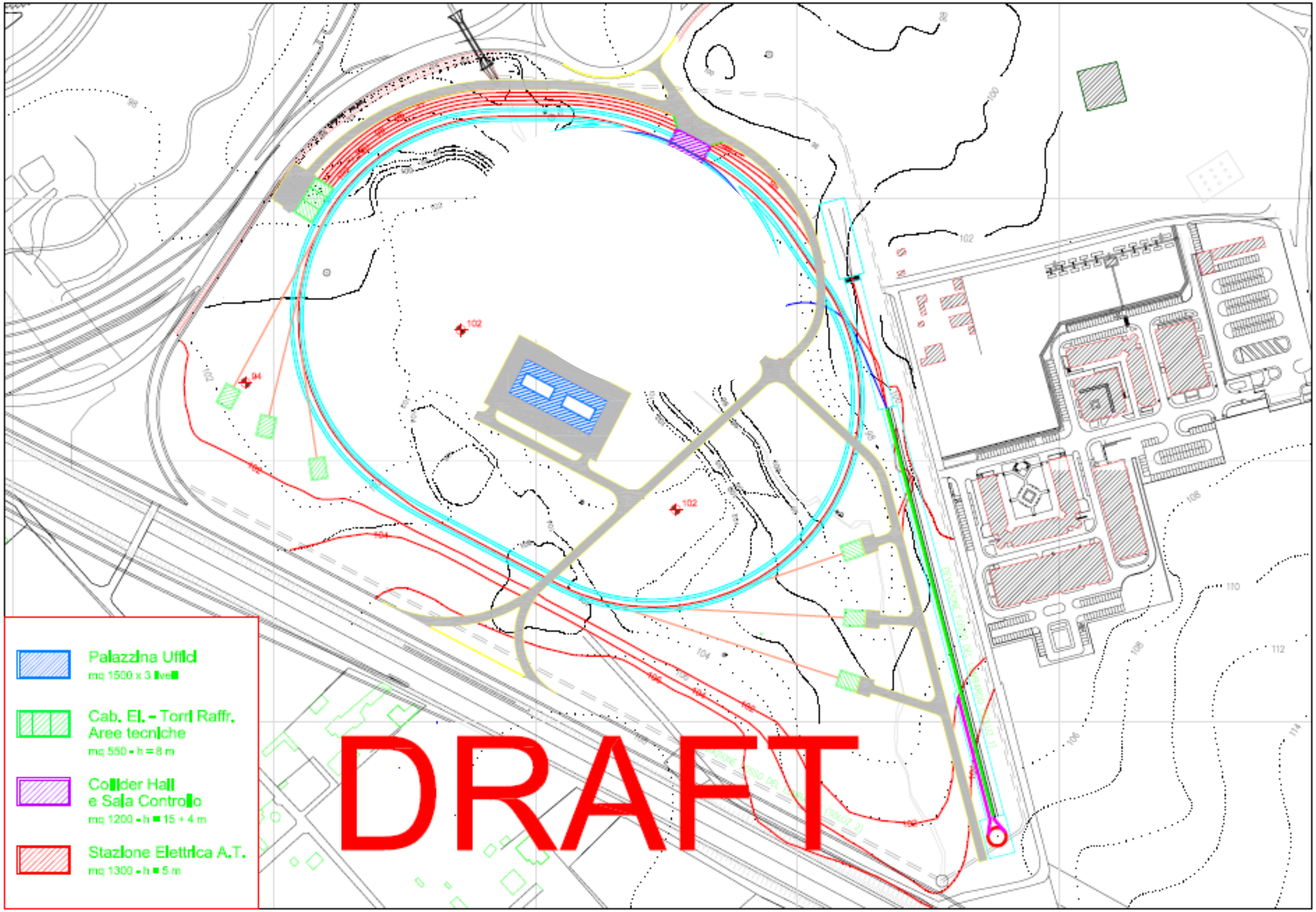
Site Location

- Several locations have been examined
  - Seismic properties, water, infrastructures, etc.
- Decision in May 2011 for the Tor Vergata Campus in Rome.
- Full support of Tor Vergata University for the project




Tor Vergata Site
About 4.5 Km
LNF
A1 dir
Via di Passolombardo
SP77b
SS215
© 2011 Tele Atlas
Image © 2011 DigitalGlobe
© 2011 Europa Technologies

Possible layout @ Tor Vergata

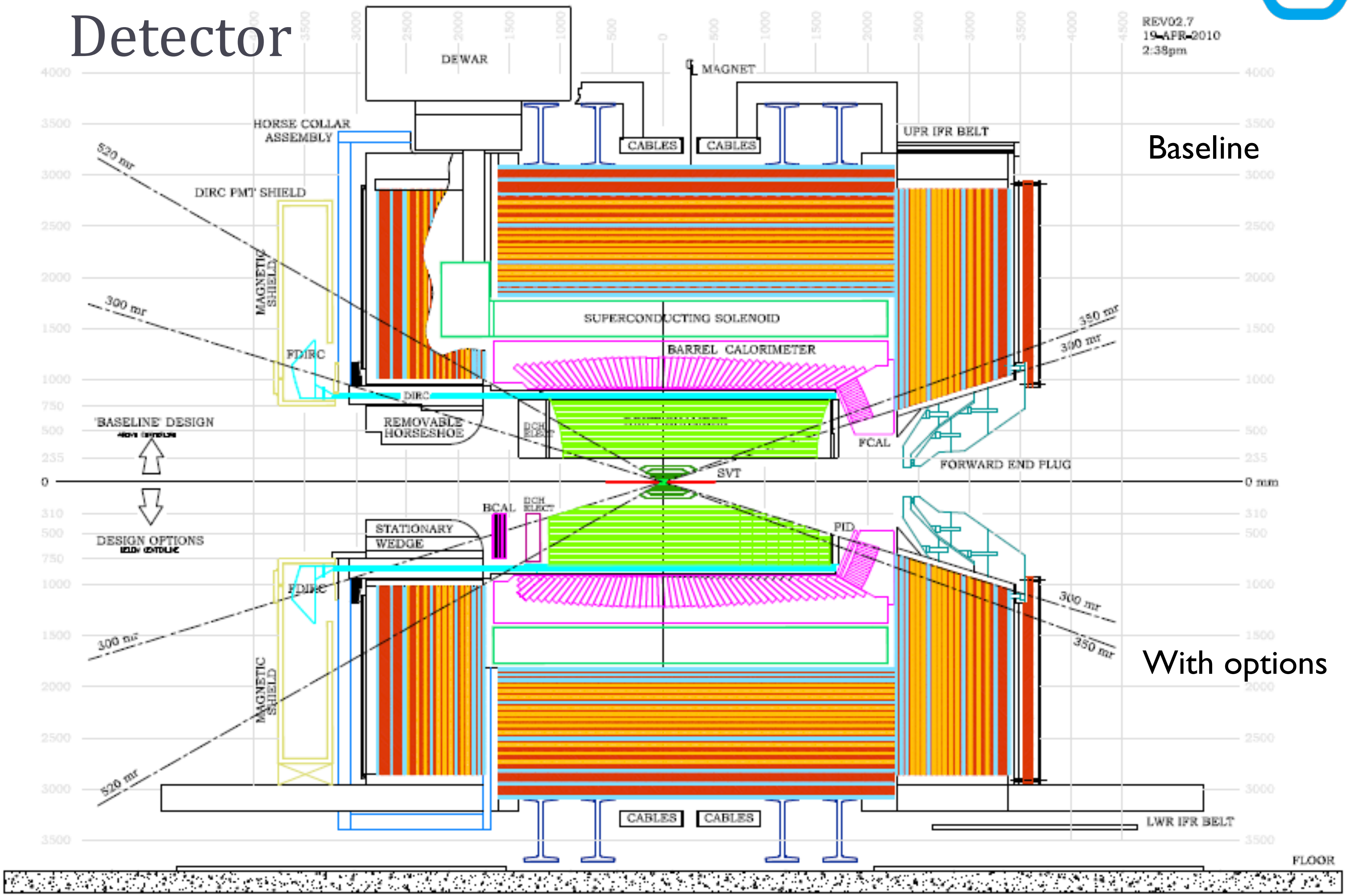


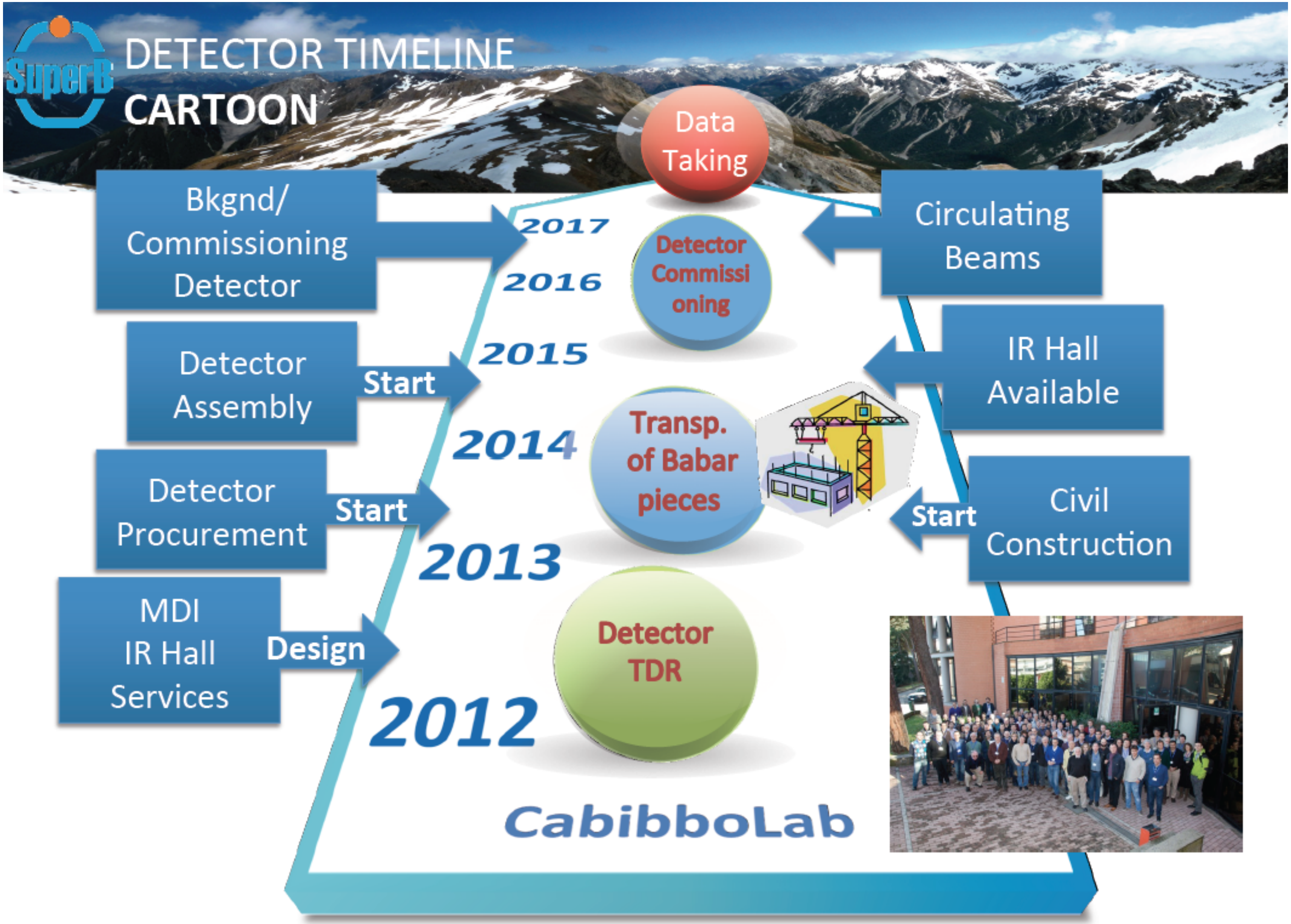
Detector

Detector starts from Babar

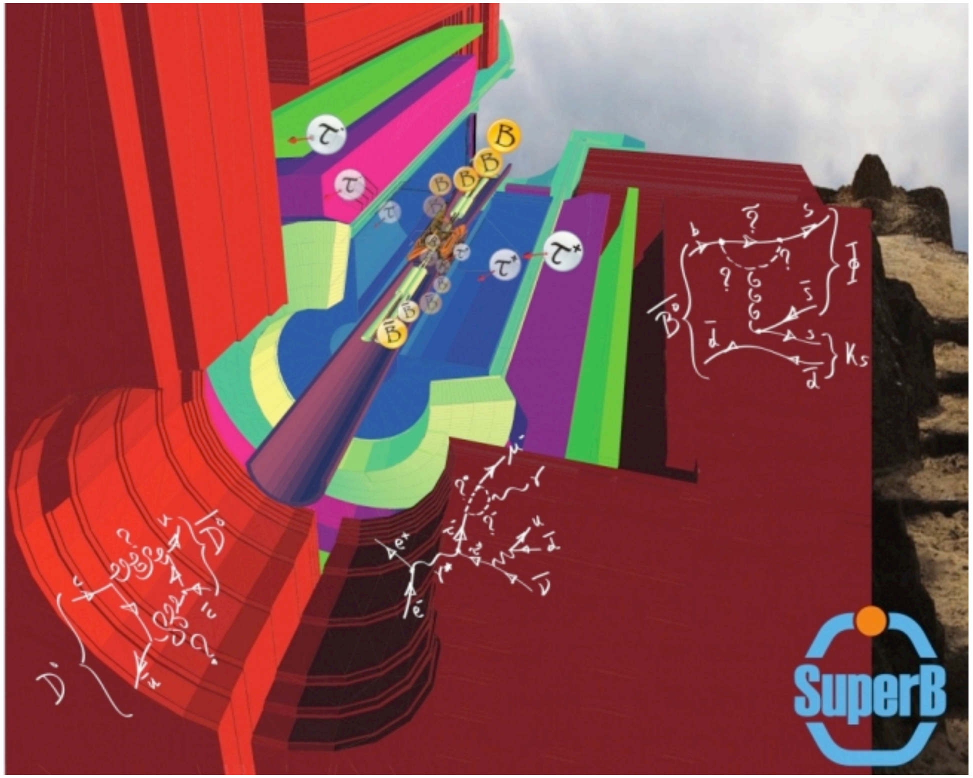
Some parts from BaBar will be reused to make the SuperB detector.

Detector




DETECTOR TIMELINE
CARTOON
SuperB
Data Taking
Bkgnd/ Commissioning Detector
Circulating Beams
2017
2016
Detector Commissi oning
2015
Detector Assembly
Start
IR Hall Available
2014
Transp. of Babar pieces
Detector Procurement
Start
Start
Civil Construction
2013
MDI IR Hall Services
Design
Detector TDR
2012
CabibboLab

Recent public documents



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

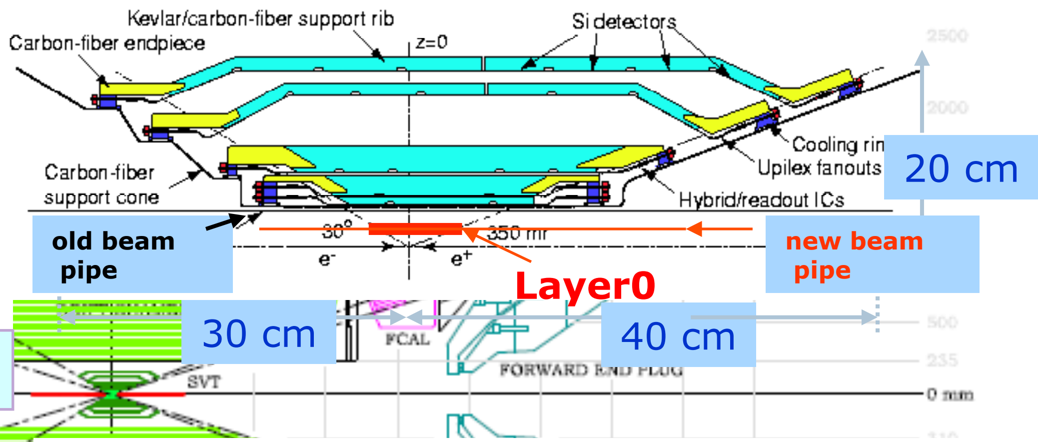
Recent Review:
arXiv:1110.3901

Backup

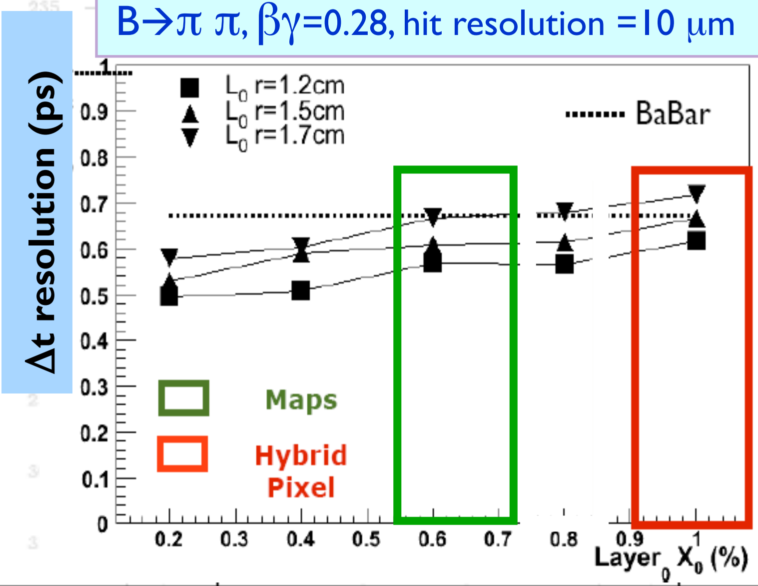
SVT

- SVT provides precise tracking and vertex reconstruction, crucial for time dependent measurements, and perform stand-alone tracking for low p_t particles.

- Based on BaBar SVT: 5 layers silicon strip modules + Layer0 at small radius to improve vertex resolution and compensate the reduced SuperB boost w.r.t PEPII

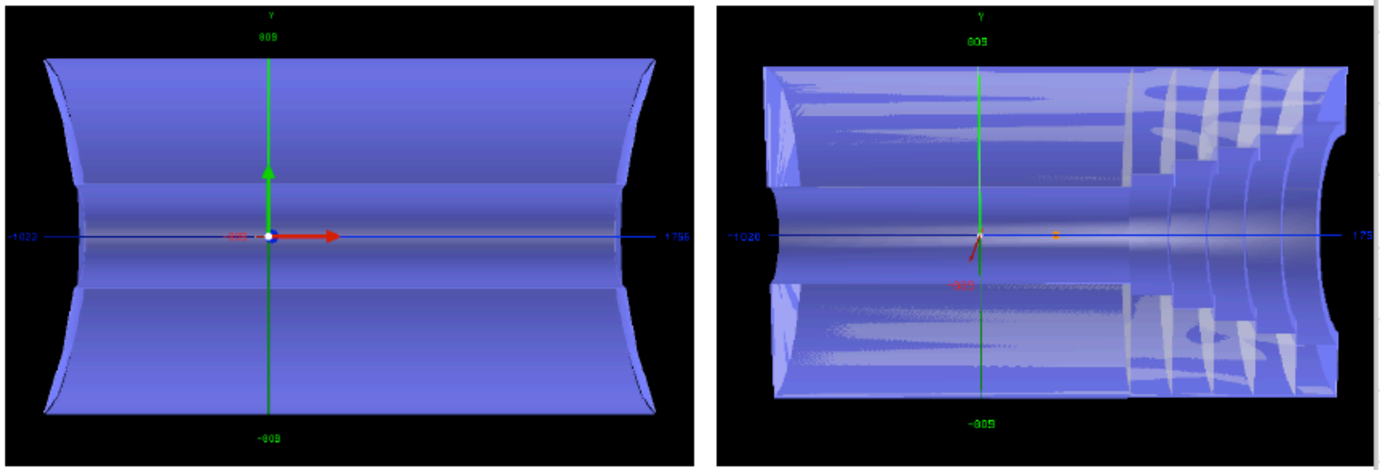


B→π π, βγ=0.28, hit resolution =10 μm



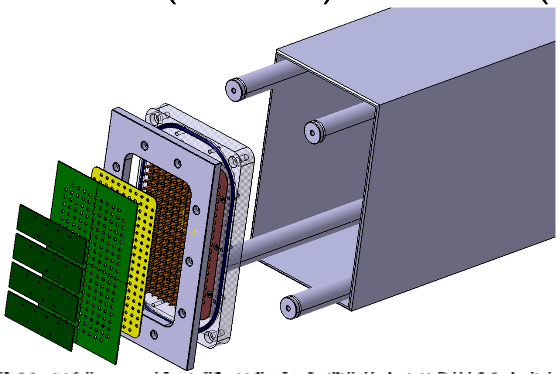
- Physycs performance and back. levels set stringent requirements on Layer0:
  - R~1.5 cm, material budget < 1% X_0,,
  - hit resolution 10-15 um in both coordinates
  - Track rate > 5MHz/cm^2 (with large cluster too!), TID > 3MRad/yr
- Several options under study for Layer0

DCH



(a) Spherical endplates design. (b) Stepped endplates design.

Dimensions dictated by the reuse of the DIRC quartz bars from BaBar (809mm), and SVT (236mm)



26 sense wire / 8 layer prototype being developed to test optimisation of the detector.

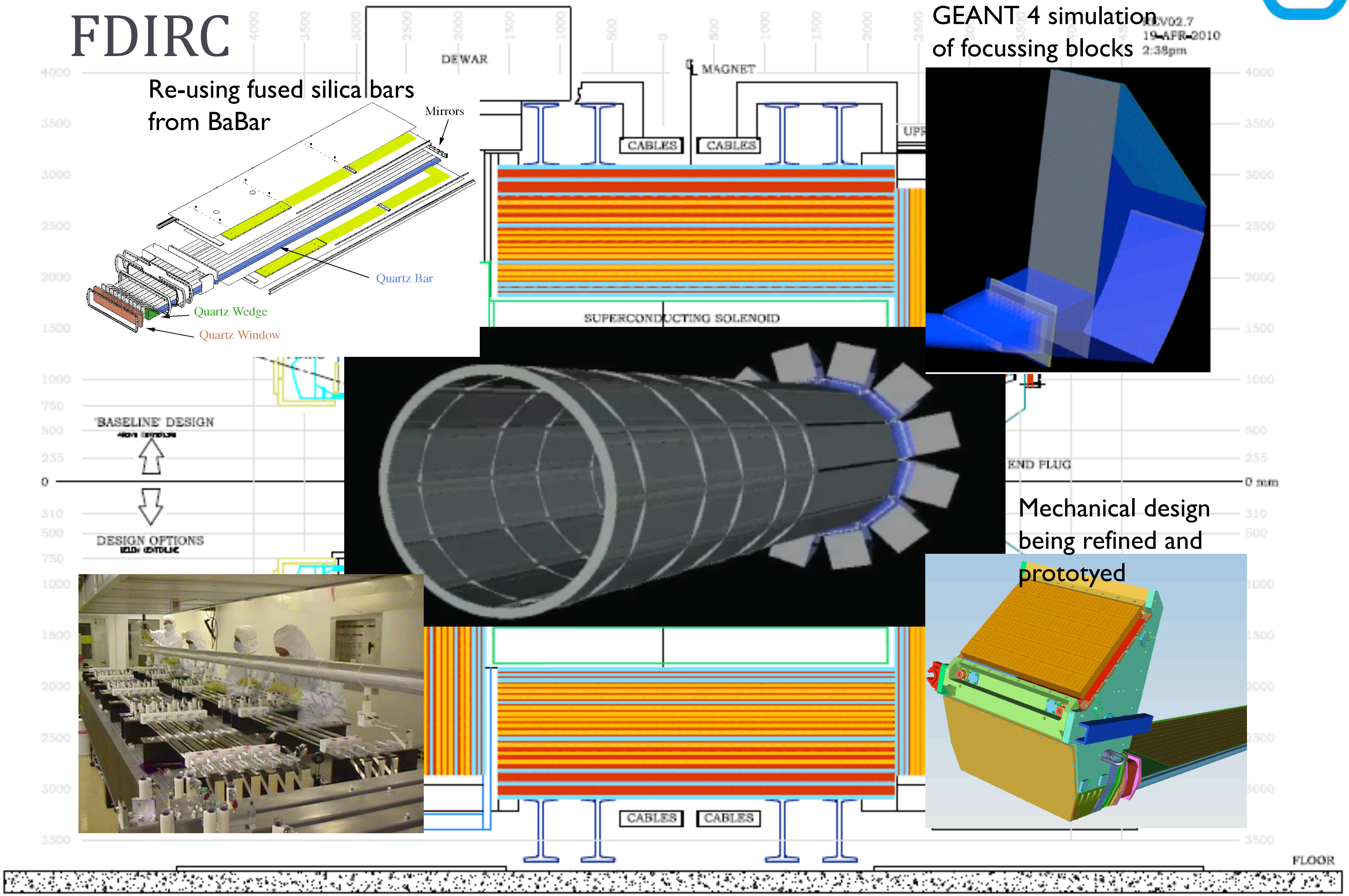
Also looking at use of cluster counting to improve spatial resolution.

FDIRC

Re-using fused silica bars from BaBar

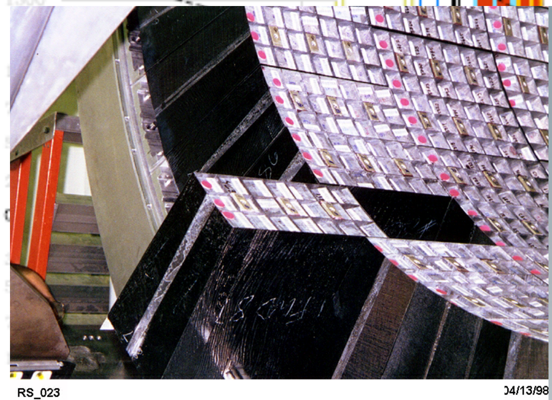
GEANT 4 simulation of focussing blocks

Mechanical design being refined and prototyed

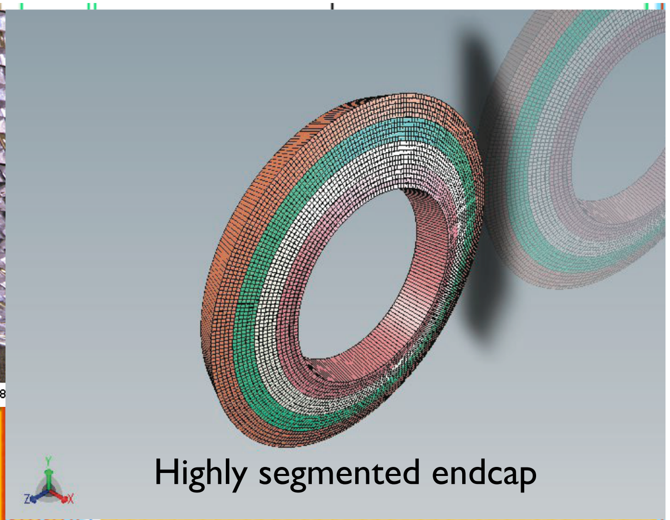


EMC

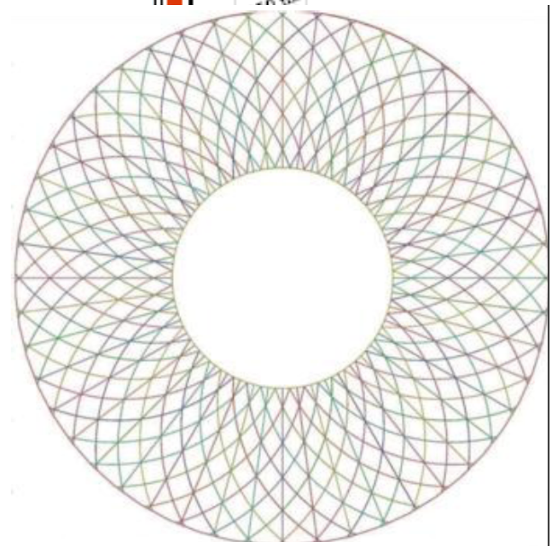
- 4 Layers of 5 crystals.
- 4500 Crystals in total.
- 2.5cm^2 back face (tapers to front)
- PID diodes and APDs under study for signal readout.
- Various crystals under investigation: LYSO is the baseline.



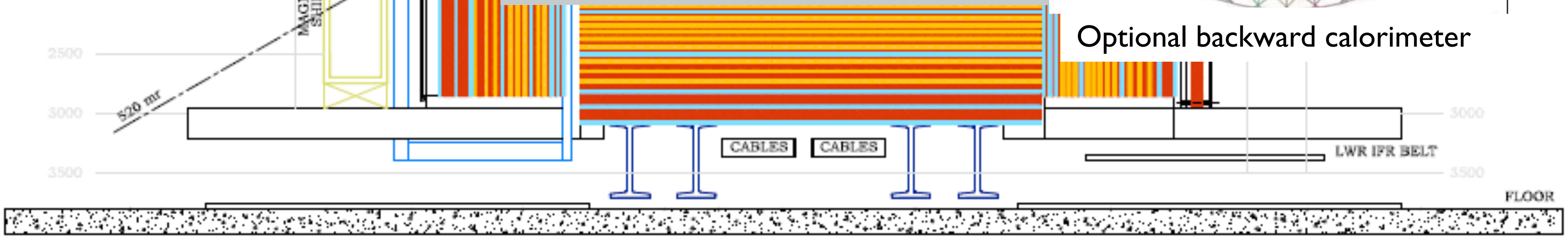
CsI(Tl) Barrel calorimeter from BaBar



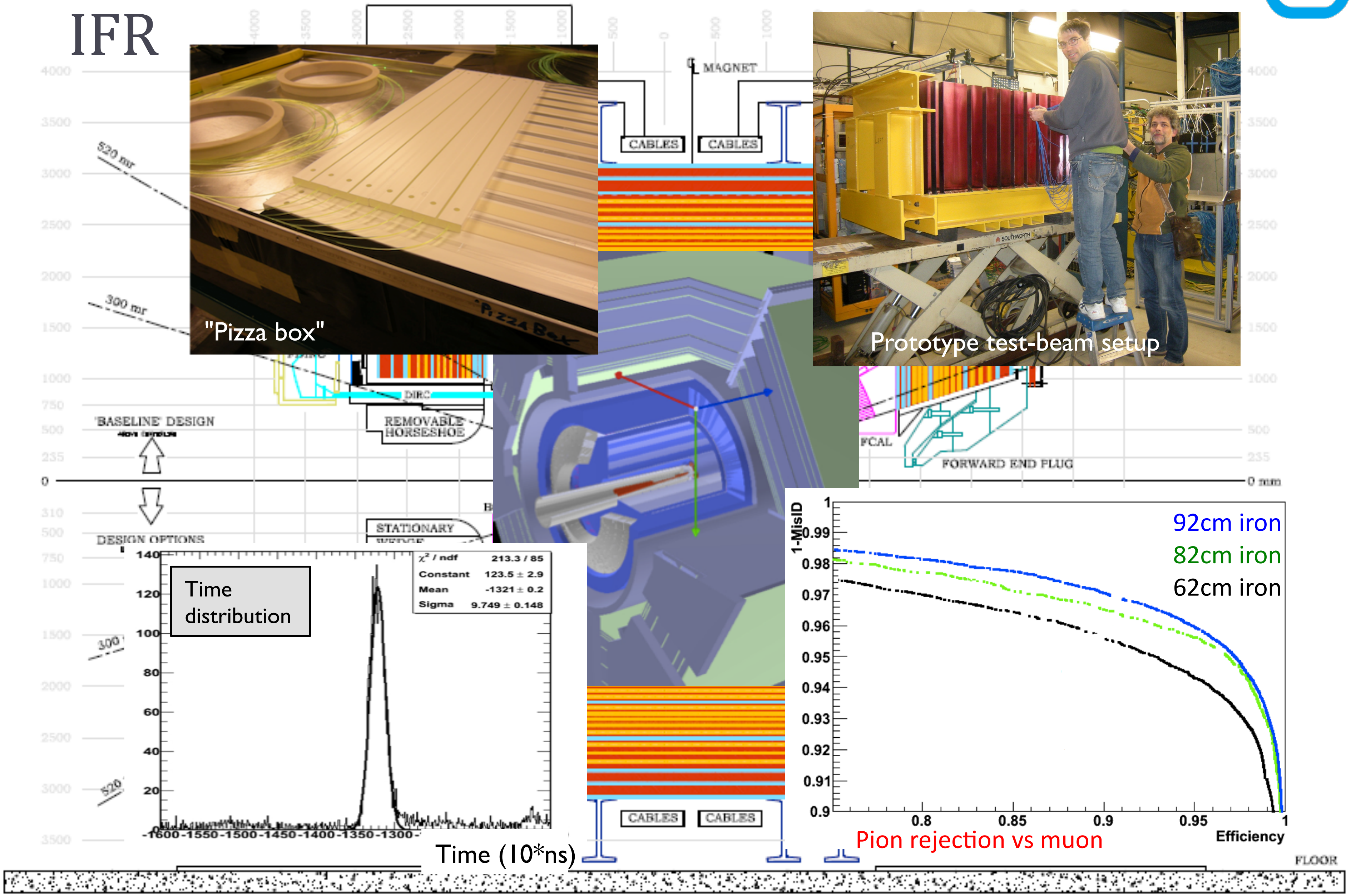
Highly segmented endcap



Optional backward calorimeter



IFR

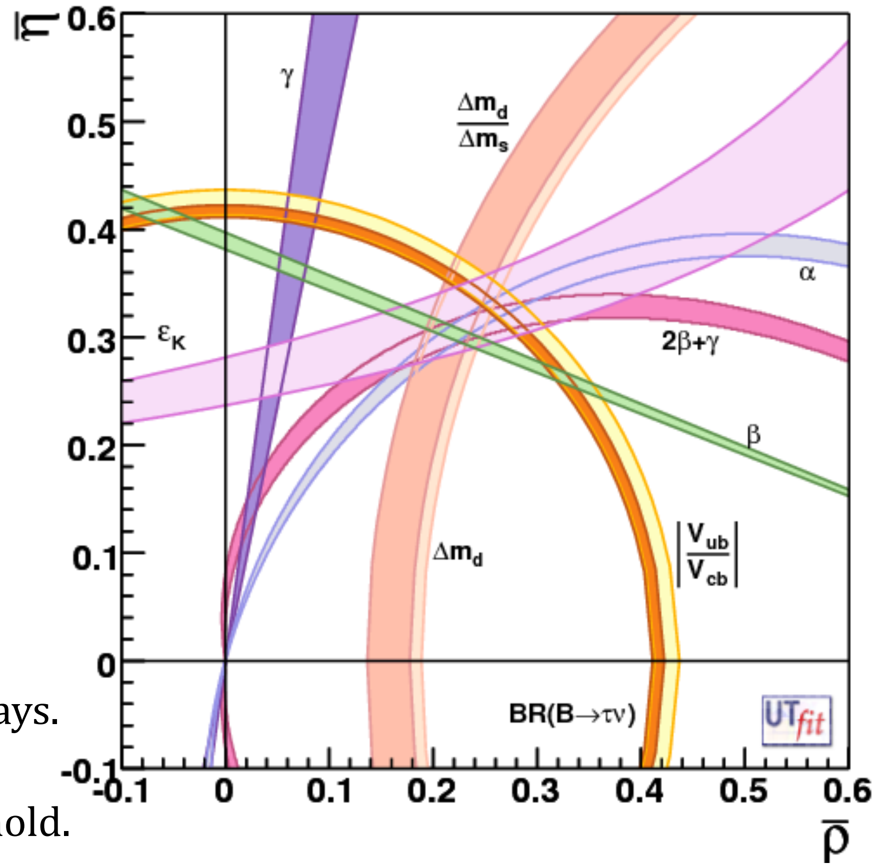


"Pizza box"
Prototype test-beam setup
MAGNET
CABLES
CABLES
DIRC
REMOVABLE HORSESHOE
'BASELINE' DESIGN
DESIGN OPTIONS
STATIONARY
FCAL
FORWARD END PLUG
FLOOR
Time distribution
χ^2 / ndf 213.3 / 85
Constant 123.5 ± 2.9
Mean -1321 ± 0.2
Sigma 9.749 ± 0.148
Time (10*ns)
1-MisID
Efficiency
92cm iron
82cm iron
62cm iron
Pion rejection vs muon

Precision CKM constraints

- Unitarity Triangle Angles
  - $\sigma(\alpha) = 1-2°$
  - $\sigma(\beta) = 0.1°$
  - $\sigma(\gamma) = 1-2°$
- CKM Matrix Elements
  - $|V_{ub}|$
    - Inclusive $\sigma = 2\%$
    - Exclusive $\sigma = 3\%$
  - $|V_{cb}|$
    - Inclusive $\sigma = 1\%$
    - Exclusive $\sigma = 1\%$
  - $|V_{us}|$
    - Can be measured precisely using τ decays.
  - $|V_{cd}|$ and $|V_{cs}|$
    - can be measured at/near charm threshold.

The "dream" scenario with $75ab^{-1}$

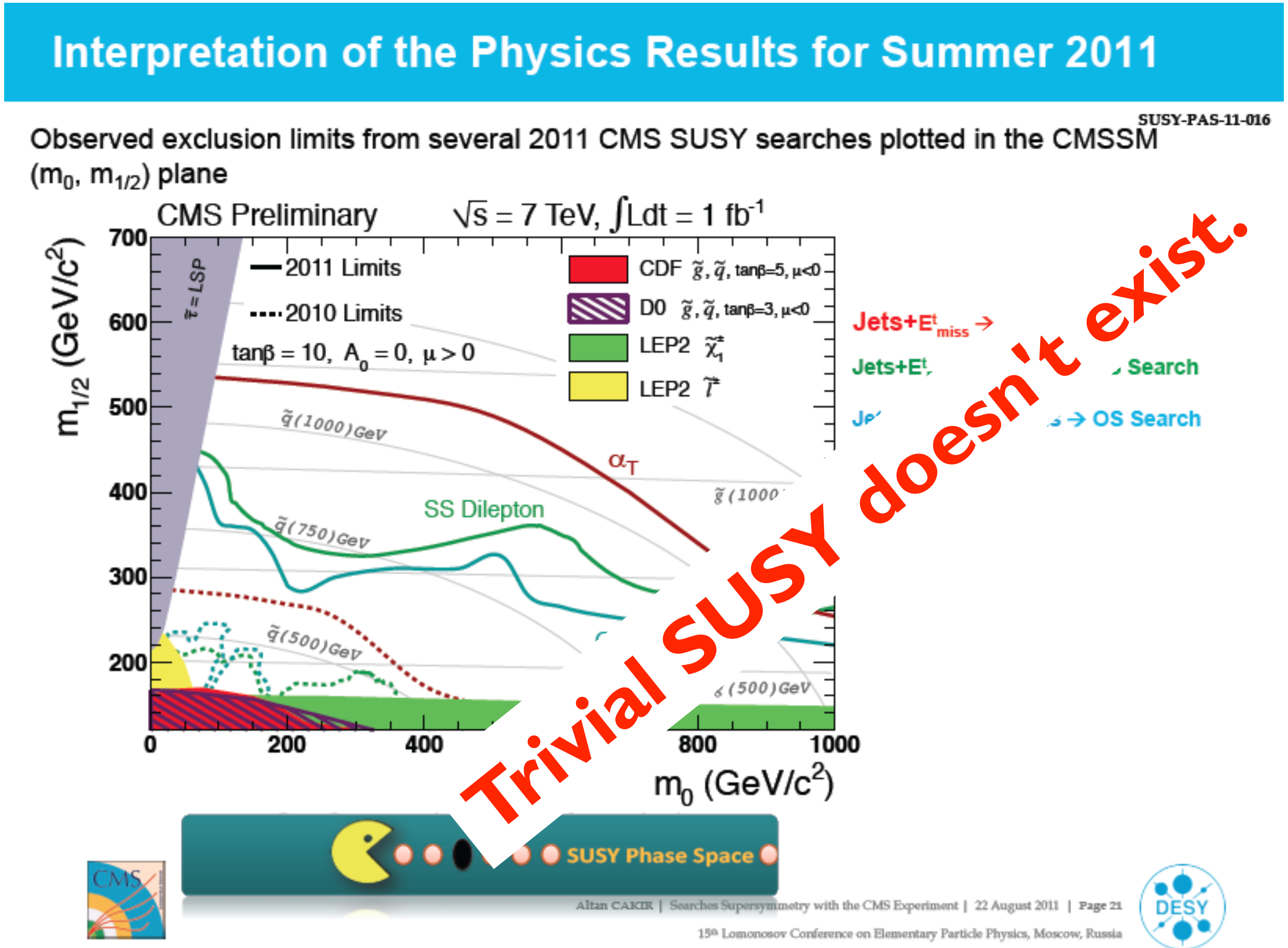


- SuperB Measures the sides and angles of the Unitarity Triangle.

Physics programme in a nutshell

- Versatile flavour physics experiment:
  - Probe new physics observables in wide range of decays.
    - Pattern of deviation from Standard Model can be used to identify structure of new physics.
    - Clean experimental environment means clean signals in many modes.
    - Polarised e^- beam benefit for τ LFV searches **(unique feature)**.
    - Charm threshold running adds many more observables, and improves potential of SuperB **(unique feature)**.
    - Measure angles and sides of the Unitarity triangle.
    - Measure other CKM matrix elements at threshold and using τ data.
- SuperB is working on a TDR for 2012.
- Will be followed by a physics book some time later.
  - Plenty of open areas for newcomers to work on!

LHC Results on SUSY (slide from A. Cakir, Lomonosov XV)



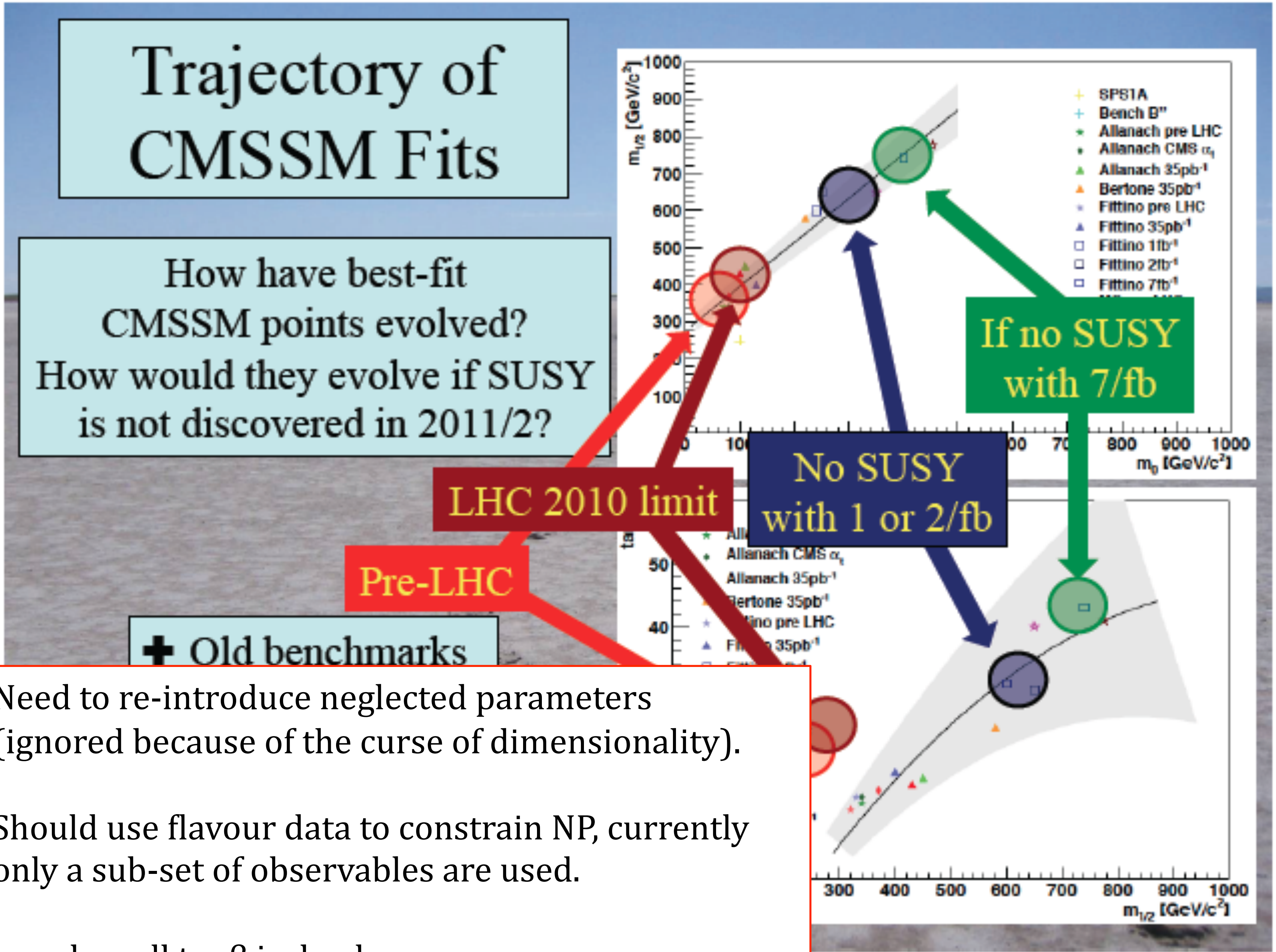
So far no evidence for SUSY.

The SUSY mass scale is now looking likely to be above 1TeV.

This has interesting implications for some of our measurements.

We need to make sure our benchmark processes and assumed scales are still valid as these contours are updated.

J. Ellis



Need to re-introduce neglected parameters (ignored because of the curse of dimensionality).

Should use flavour data to constrain NP, currently only a sub-set of observables are used.

... and small tanβ is dead.