e^+e^- machines:

SuperB
Belle upgrade / SuperKEKB
τ-charm factories

Adrian Bevan

Queen Mary
University of London

Community Review of Particle Physics Programme
Birmingham, 13th July 2009

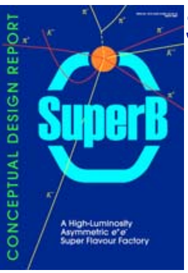
Overview

- Upcoming Projects
- SuperB:
  - Accelerator
  - Site
  - Detector
  - Organization
  - UK Involvement
  - KE
  - Costs
- Summary

Upcoming Projects

- BES-III
  - Started data taking at the J/Psi and psi(2S) resonances.
  - Considering running at charm threshold (20fb^{-1} soon – timescale tbc).
  - Aim for $\mathcal{L} \sim 10^{33}$ cm^{-2}s^{-1}.

No UK Interest



SuperB
  - Working on TDR between now and Feb 2011.
  - Aim to record 75ab^{-1} of data at the Y(4S) in 5 years.
  - Will take data at other Y(NS) resonances and also run at charm threshold.
  - Aim for $\mathcal{L} \sim$ 1-4 $\times 10^{36}$ cm^{-2}s^{-1}: longitudinally polarized electron beam.

SuperKEKB / Belle-II
  - Adiabatic upgrade plans – will start taking data (target = 10ab^{-1}) in a few years, and hope to steadily upgrade the facility to record a total of 50ab^{-1} at the Y(4S).
  - Aim for $\mathcal{L} \sim 0.8 \times 10^{36}$ cm^{-2}s^{-1}.
  - Physics goals similar to SuperB, but no polarization.

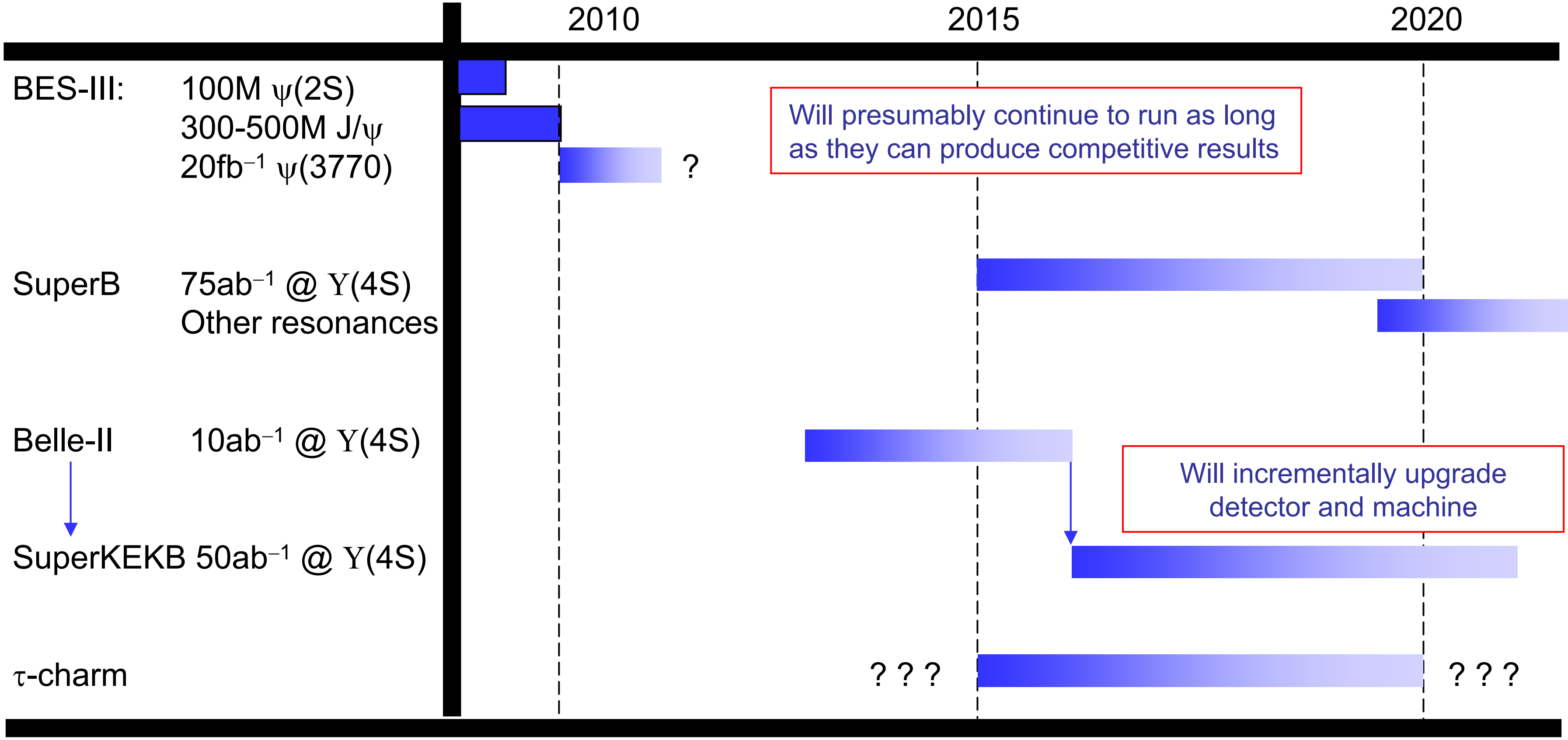
No UK Interest

Novosibirsk τ-charm factory
  - Concepts under development since 1995.
  - Aim for $\mathcal{L} \sim 10^{35}$
  - Physics goals: Charmonia, charm, charm baryons and spectroscopy.
  - Based on the SuperB crabbed waist technology.

No UK Interest

Timescales

I have back up slides on the other projects: from here on in I'll concentrate on SuperB as that has an established UK involvement.

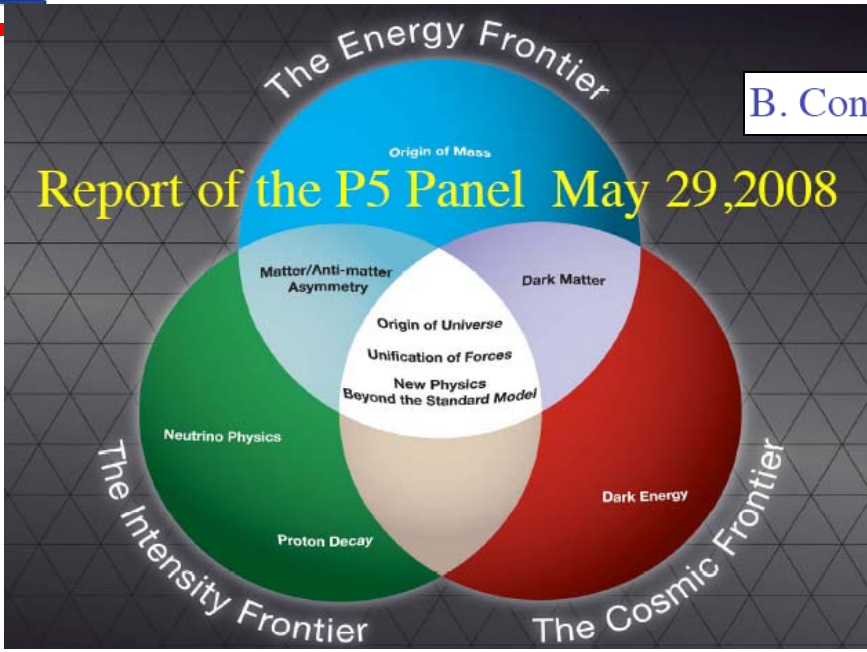


Belle-II / SuperKEKB

Some detector upgrades for $10ab^{-1}$ will have to be replaced as they aren't rad hard enough for SuperKEKB. Occupancy issues lead to quite different constraints for the two phases.

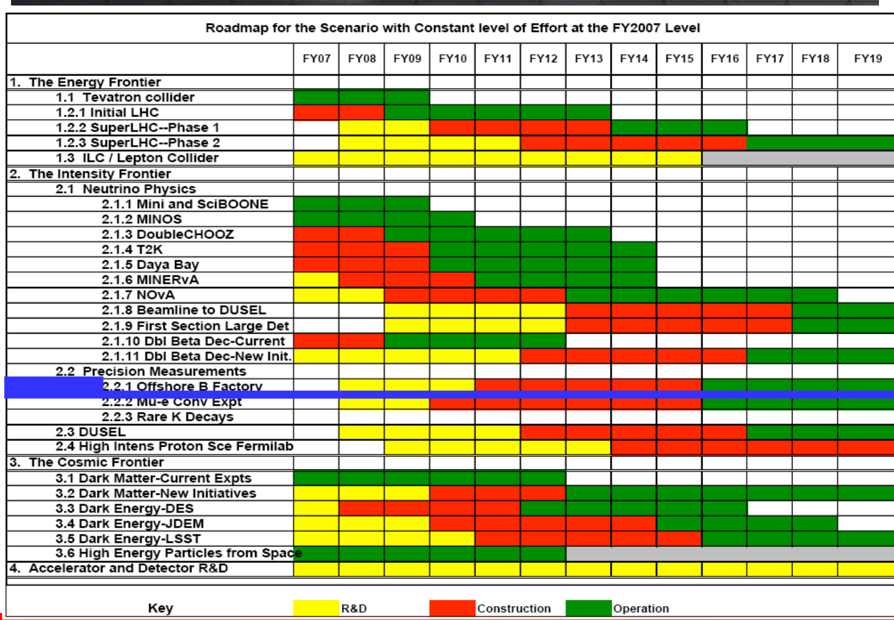
Similarly the meaning of an 'adiabatic' path to an accelerator with nano-beams and $\sim 0.8\times10^{36}$ $cm^{-2}s^{-1}$ is not clearly defined yet.

In the context of the US roadmap ...



B. Constant effort at the FY2007 level(752 FY07 M$ DOE)

- US HEP is funded in the intermediate budget scenario.
- "The intermediate budget scenario would allow in addition to pursuing significant participation in one overseas next-generation B-factory."
- This means US participation in SuperB, as participation in (Super)KEKB is a small activity.

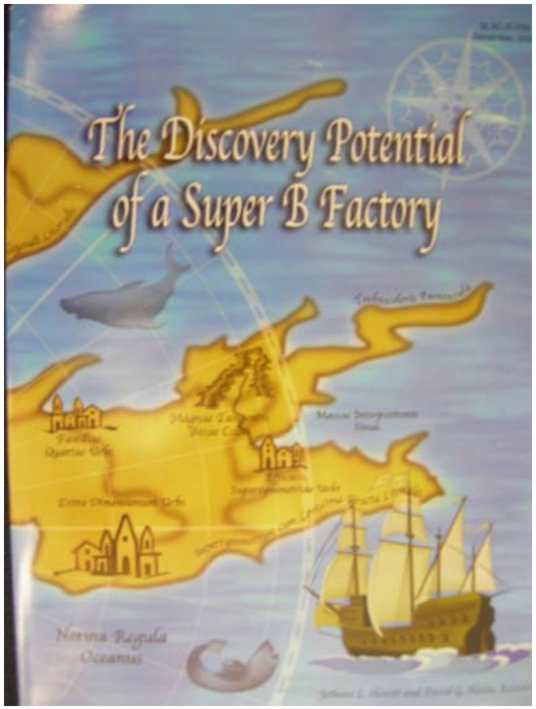


SuperB R&D funding

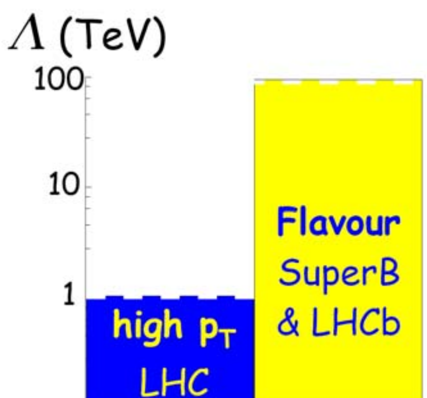
Construction phase (from FY11)

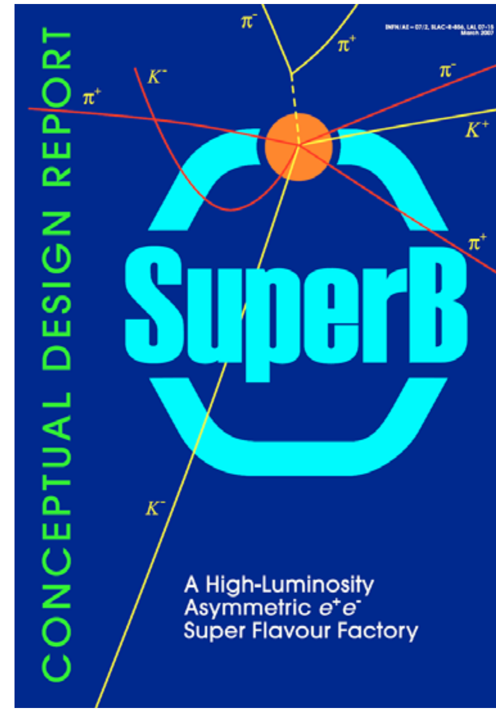
Operation phase (from FY16)

SuperB



2005



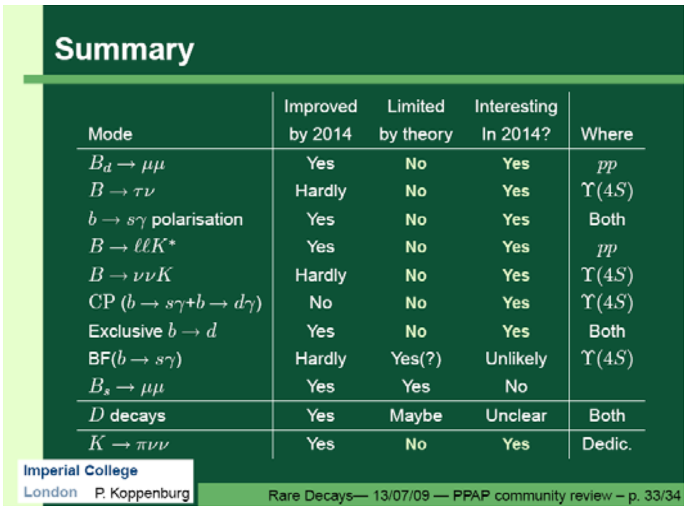


2007

Physics (Flashback to earlier today)

- Jonas:
  - CKM/CPV goals cover potential to constrain SM and search for TeV scale effects via CP violation observables.

- Patrick:



Summary

Mode	Improved by 2014	Limited by theory	Interesting In 2014?	Where
$B_d \to \mu\mu$	Yes	No	Yes	pp
$B \to \tau\nu$	Hardly	No	Yes	$\Upsilon(4S)$
$b \to s\gamma$ polarisation	Yes	No	Yes	Both
$B \to \ell\ell K^*$	Yes	No	Yes	pp
$B \to \nu\nu K$	Hardly	No	Yes	$\Upsilon(4S)$
CP ($b \to s\gamma$+$b \to d\gamma$)	No	No	Yes	$\Upsilon(4S)$
Exclusive $b \to d$	Yes	No	Yes	Both
BF($b \to s\gamma$)	Hardly	Yes(?)	Unlikely	$\Upsilon(4S)$
$B_s \to \mu\mu$	Yes	Yes	No	
D decays	Yes	Maybe	Unclear	Both
$K \to \pi\nu\nu$	Yes	No	Yes	Dedic.

Imperial College London P. Koppenburg

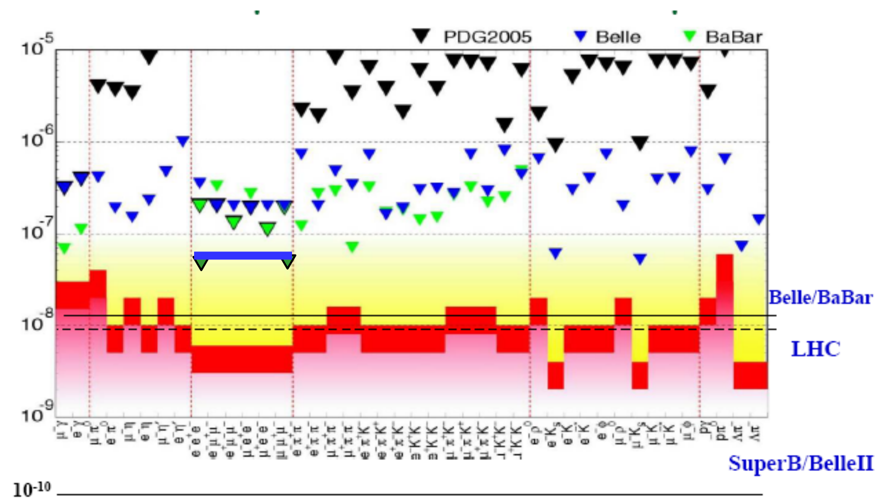
Rare Decays— 13/07/09 — PPAP community review – p. 33/34

The interesting modes beyond 2014 are nearly all accessible to SuperB [except $K \to \pi\nu\bar{\nu}$ and $\mu\mu$].

Many channels will give better constraints on NP than the LHC.

- Fergus:

  SuperB will provide important constraints that have synergy with
  - Other LFV experiments (MEG)
  - neutrino experiments
  - and the energy frontier.



Accelerator

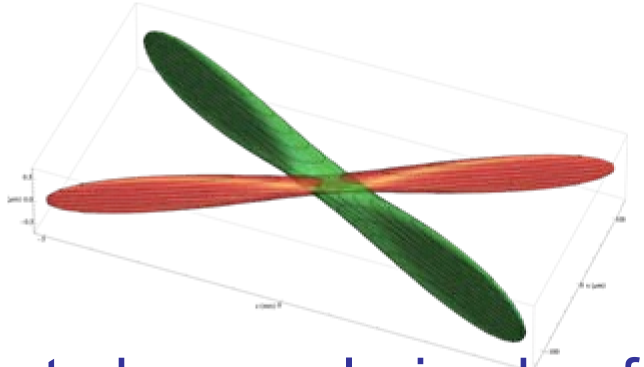
- Use low emittance path to high luminosity.

- Crabbed Waist (P. Raimondi) technique used to increase luminosity by skewing bunches at the IP.

  Compensates for hourglass effect.

  Use sextupoles to skew bunches.

  Technique has been tested at LNF and works!



2 different polarization schemes are being investigated.

All accelerator requirements have been proven to work at a working Accelerator facility.

No show stoppers for the machine!

- Aim to have polarized e^- for part of the physics programme.
  - Longitudinal polarization ~60-80%

Machine Parameters

- Shown by seeman@mini-MAC

LER/HER	Unit	June 2008	Jan. 2009	March 2009	LNF site
E+/E-	GeV	4/7	4/7	4/7	4/7
L	cm^{-2} s^{-1}	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$
I+/I-	Amp	1.85 /1.85	2.00/2.00	2.80/2.80	2.70/2.70
N_{part}	$x10^{10}$	5.55 /5.55	6/6	4.37/4.37	4.53/4.53
N_{bun}		1250	1250	2400	1740
I_{bunch}	mA	1.48	1.6	1.17	1.6
$\theta/2$	mrad	25	30	30	30
β_x^*	mm	35/20	35/20	35/20	35/20
β_y^*	mm	0.22 /0.39	0.21 /0.37	0.21 /0.37	0.21 /0.37
ε_x	nm	2.8/1.6	2.8/1.6	2.8/1.6	2.8/1.6
ε_y	pm	7/4	7/4	7/4	7/4
σ_x	µm	9.9/5.7	9.9/5.7	9.9/5.7	9.9/5.7
σ_y	nm	39/39	38/38	38/38	38/38
σ_z	mm	5/5	5/5	5/5	5/5
ξ_x	X tune shift	0.007/0.002	0.005/0.0017	0.004/0.0013	0.004/0.0013
ξ_y	Y tune shift	0.14 /0.14	0.125/0.126	0.091/0.092	0.094/0.095
RF stations	LER/HER	5/6	5/6	5/8	6/9
RF wall plug power	MW	16.2	18	25.5	30.
Circumference	m	1800	1800	1800	1400

Design approved by MAC

No showstoppers for the machine!

Will have to move slightly off 7 on 4 for polarized beams.

Two equivalent sites are available.

Machine Parameters

- Shown by seeman@mini-MAC

LER/HER	Unit	June 2008	Jan. 2009	March 2009	LNF site
E+/E-					
L					
I+/I-					
N_{part}					
N_{bun}					
I_{bunch}					
θ/2					
β_x^*					
β_y^*					
ε_x					
ε_y	pm	7/4	7/4	7/4	
σ_x	µm	9.9/5.7	9.9/5.7	9.9/5.7	
σ_y	nm	39/39	38/38	38/38	
σ_z	mm	5/5	5/5	5/5	
ξ_x	X tune shift	0.007/0.002	0.005/0.0017	0.004/0.0013	0
ξ_y	Y tune shift	0.14 /0.14	0.125/0.126	0.091/0.092	
RF stations	LER/HER	5/6	5/6	5/8	
RF wall plug power	MW	16.2	18	25.5	
Circumference	m	1800	1800	1800	

Design approved by MAC

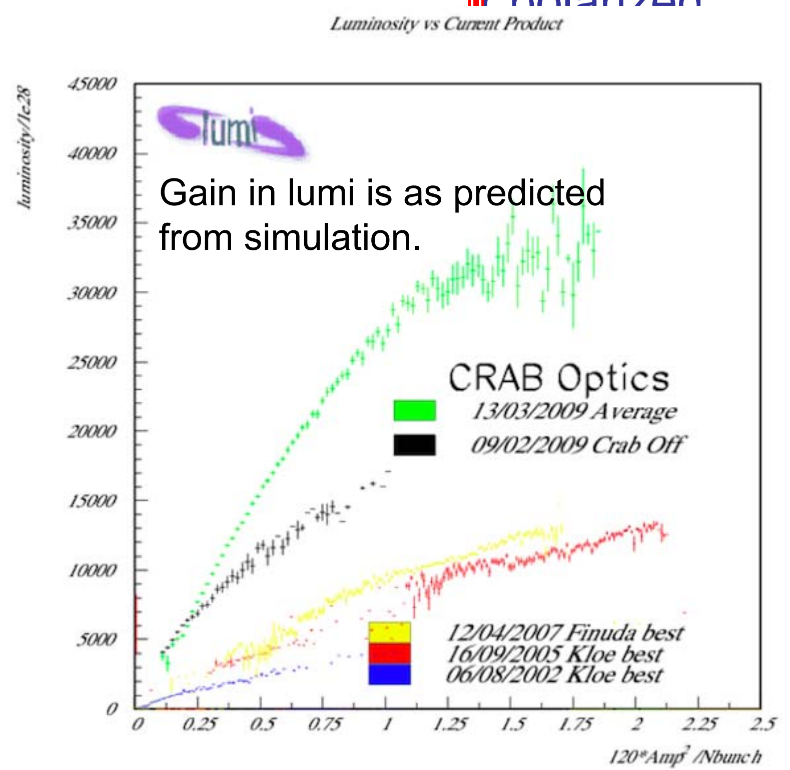
…ppers for the

…move slightly

…r polarized

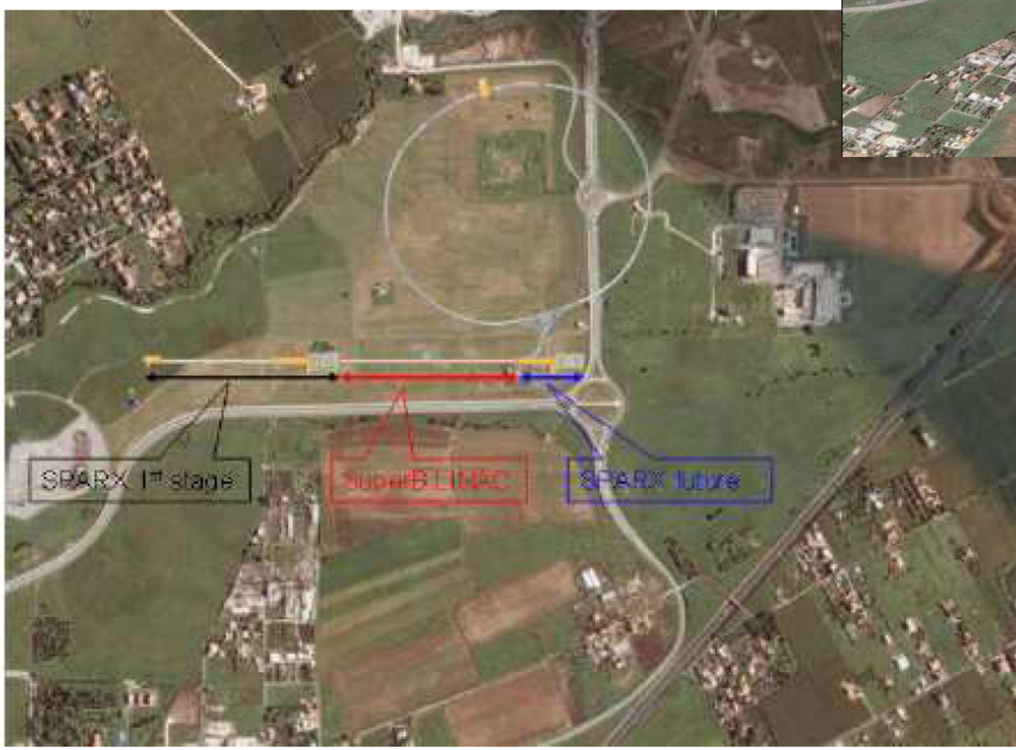
"MAC now feels secure in enthusiastically encouraging the SuperB design team to proceed to the TDR phase, with confidence that the design parameters are achievable"

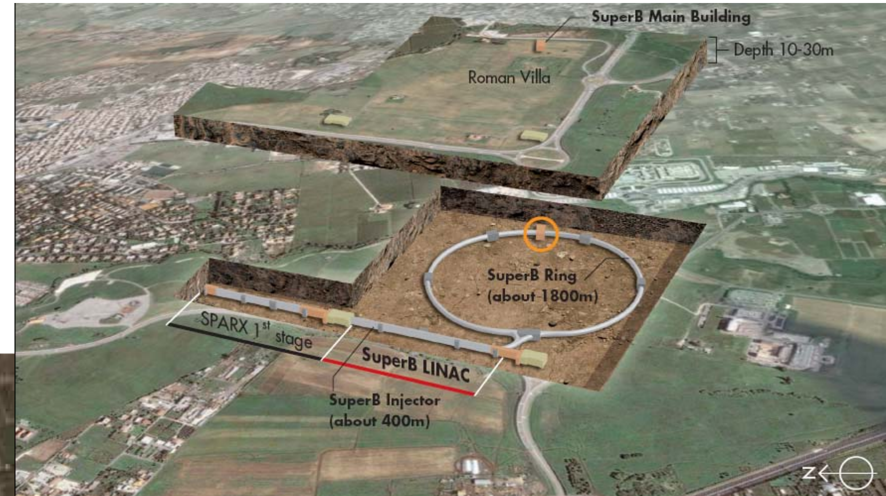
April 2009



Site

SITES : Tor Vergata.......



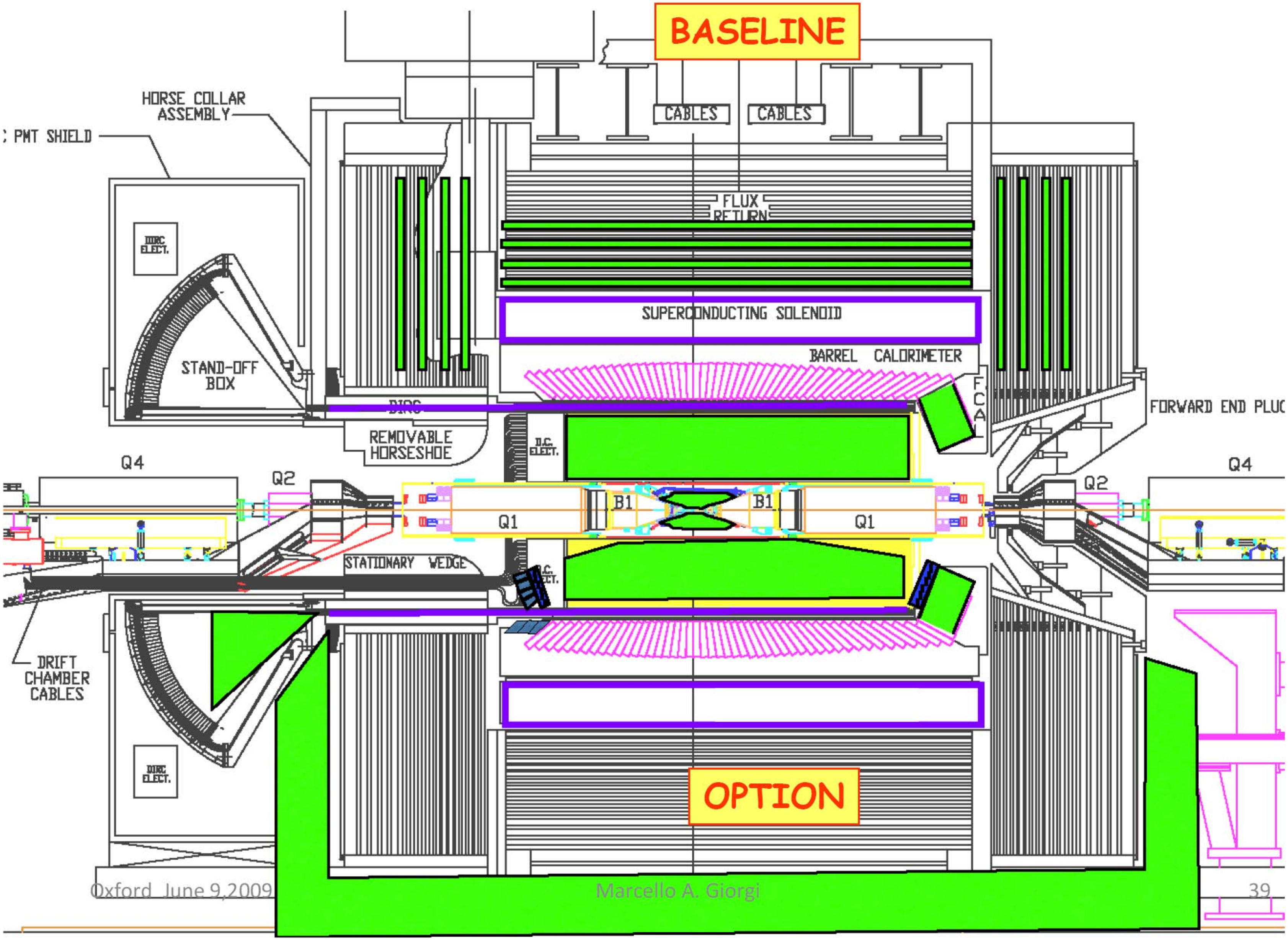


Site

LNF option

- FEL (a separate project) can fit on either site.
- SuperB can fit on either site.
- Part of the ring will be on the AE site on opposite LNF.
- Part of the ring may go under a vineyard [this is not a problem].
- LNF site would have the benefit of existing facilities (and guest house!).

Detector


BASELINE
CABLES
CABLES
HORSE COLLAR ASSEMBLY
PMT SHIELD
FLUX RETURN
DIRC ELECT.
SUPERCONDUCTING SOLENOID
BARREL CALORIMETER
STAND-OFF BOX
DIRC
REMOVABLE HORSESHOE
FORWARD END PLUG
D.C. ELECT.
Q4
Q2
B1
B1
Q1
Q1
Q2
Q4
STATIONARY WEDGE
DRIFT CHAMBER CABLES
DIRC ELECT.
OPTION

Detector

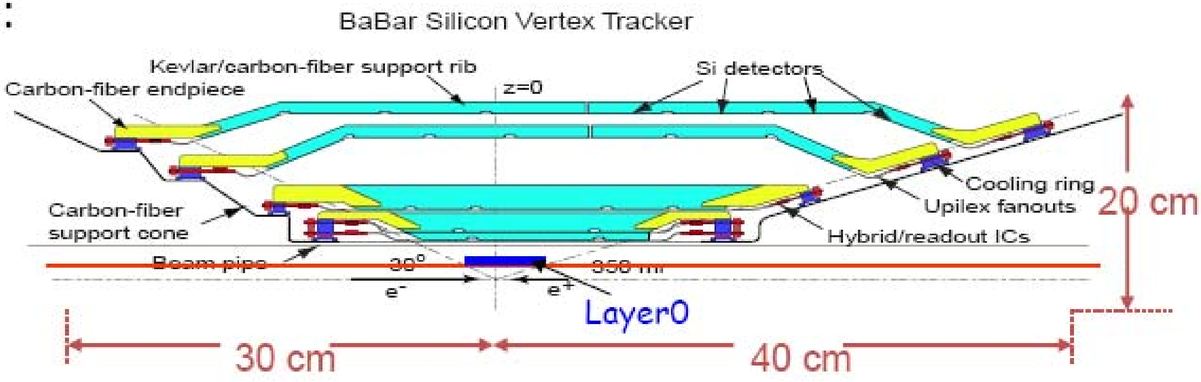
- Will re-use some parts of BaBar to minimize costs: barrel calorimeter, quartz bars of the PID system, Solenoid.
- All other subsystems are open for new design geometry and technology choices.
  - Developed SuperB software (derived in part from BaBar) to help with this task.
  - Aim to run Monte Carlo simulation productions between now and next autumn to test designs and update sensitivity studies.
  - In the context of the SVT: nothing is fixed, and any new level of collaboration is welcome.
    - Current baseline is a simple extension of BaBar:
      - Layer 0 of pixels (or striplets)
      - Surrounded by a BaBar-like silicon strip tracker.

This is adequate for the job at hand, but is not optimal.

Detector issues

Detector Issues:

SVT



- Smaller machine asymmetry

➔ Need a new SVT (very similar to that of the 5 layer BaBar SVT) supplemented by a new layer 0 to measure the first hit as close as possible to the production vertex. Goal is coverage to 300 mrad both forward and backward.

- Beam pipe radius and thickness are crucial to obtain adequate resolution in vertex separation.

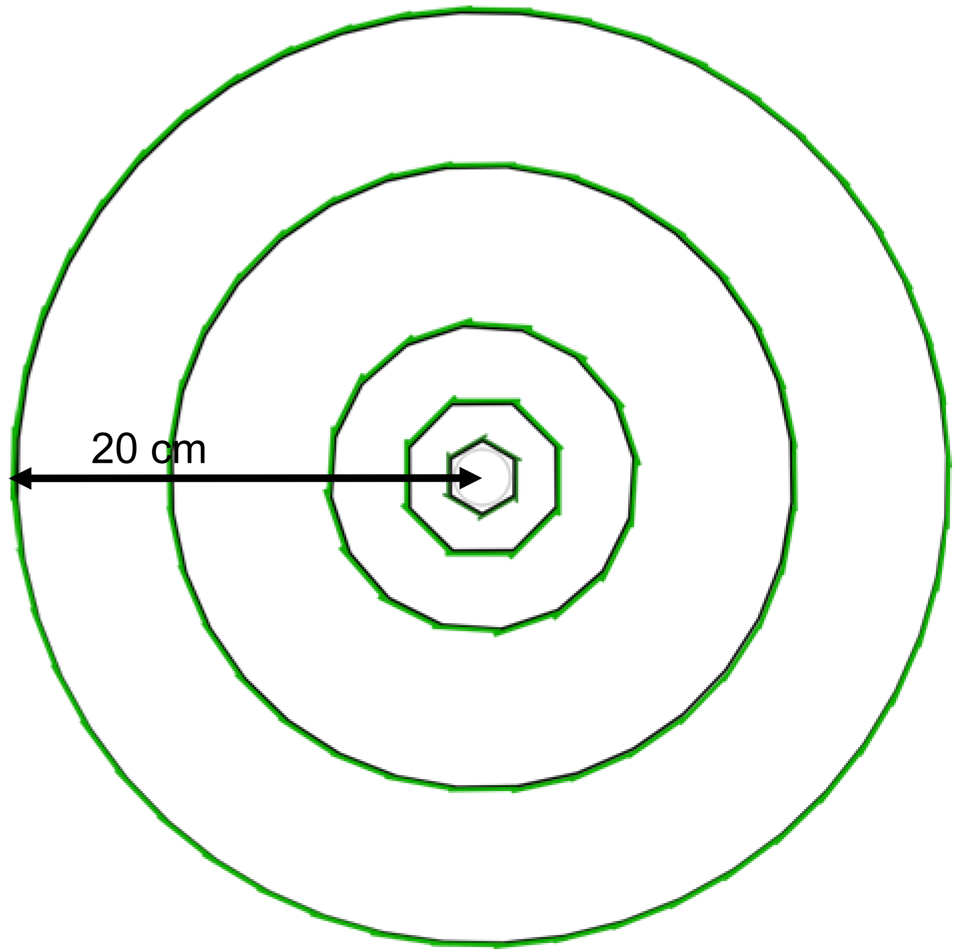
Options:MAPS, Hybrid Pixels, Striplets (the latter is difficult due to the expected Bhabha occupancy)

- Maximum of ~1m^2 of silicon.
- UK MAPS experts are interested in designing and building a pixel detector.
- Requires Detector Geometry optimization work now!

A Vertex-Detector for SuperB

- Using 50 μm pixels.
- Vertex Detector with:
  - 5 single layers.
  - Two types of ladders only.
    - Easy assembly.
- low-mass staves.
  - easy access.
  - minimize cabling.
    - No High voltage needed.
- Geometry will need optimization

M. Stanitzki

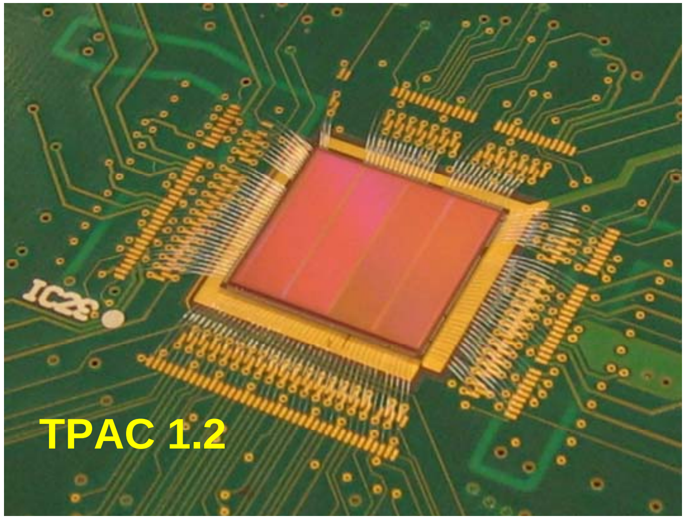


V. Preliminary UK design for a 5-layer pixel detector for SuperB

Potential technologies : INMAPS

M. Stanitzki

- INMAPS process pioneered in the UK
  - allows full CMOS functionality
  - allows time-stamping
  - In-pixel CDS (low-noise)
  - 4T structures
  - High resistivity layer
    - Increased Charge collection speed
    - Increased radiation hardness
- INMAPS used in many chips already
  - TPAC
  - Fortis
  - Elena
- UK has world-leading technology in place
- Building on expertise and developments from SPiDeR and CALICE, LCFI ...



Designed at RAL

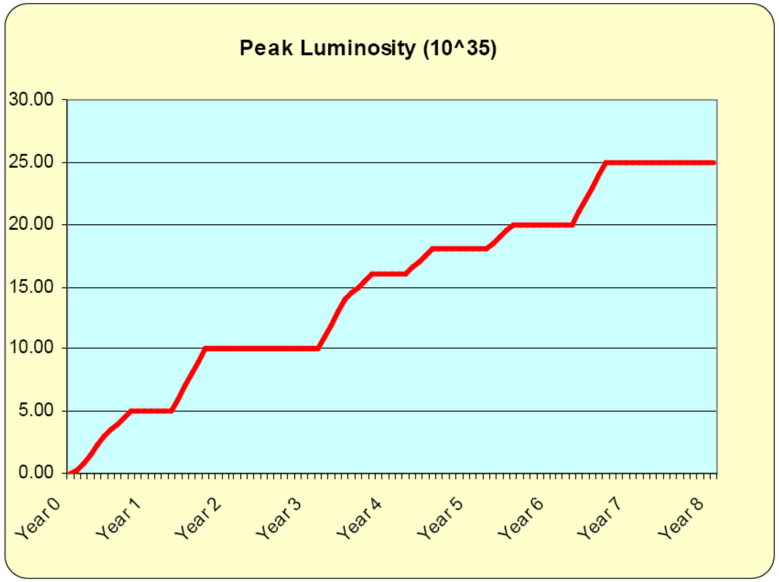
Timescale

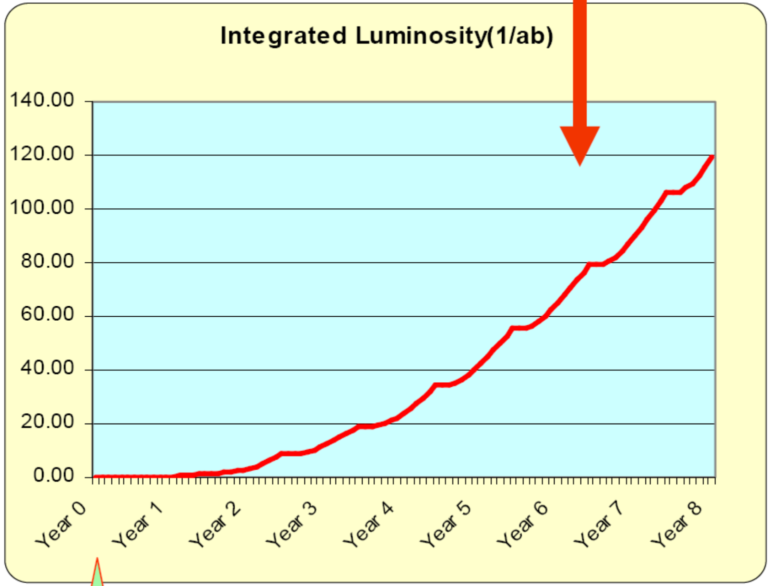
- TDR Phase:
  - Started: Feb '09.
  - End: 2 years later Feb '11.

6 years = 5 years of nominal data taking + start-up

- Produce an interim report at the end of '09 (6 months).

>80ab-1 after 6 years





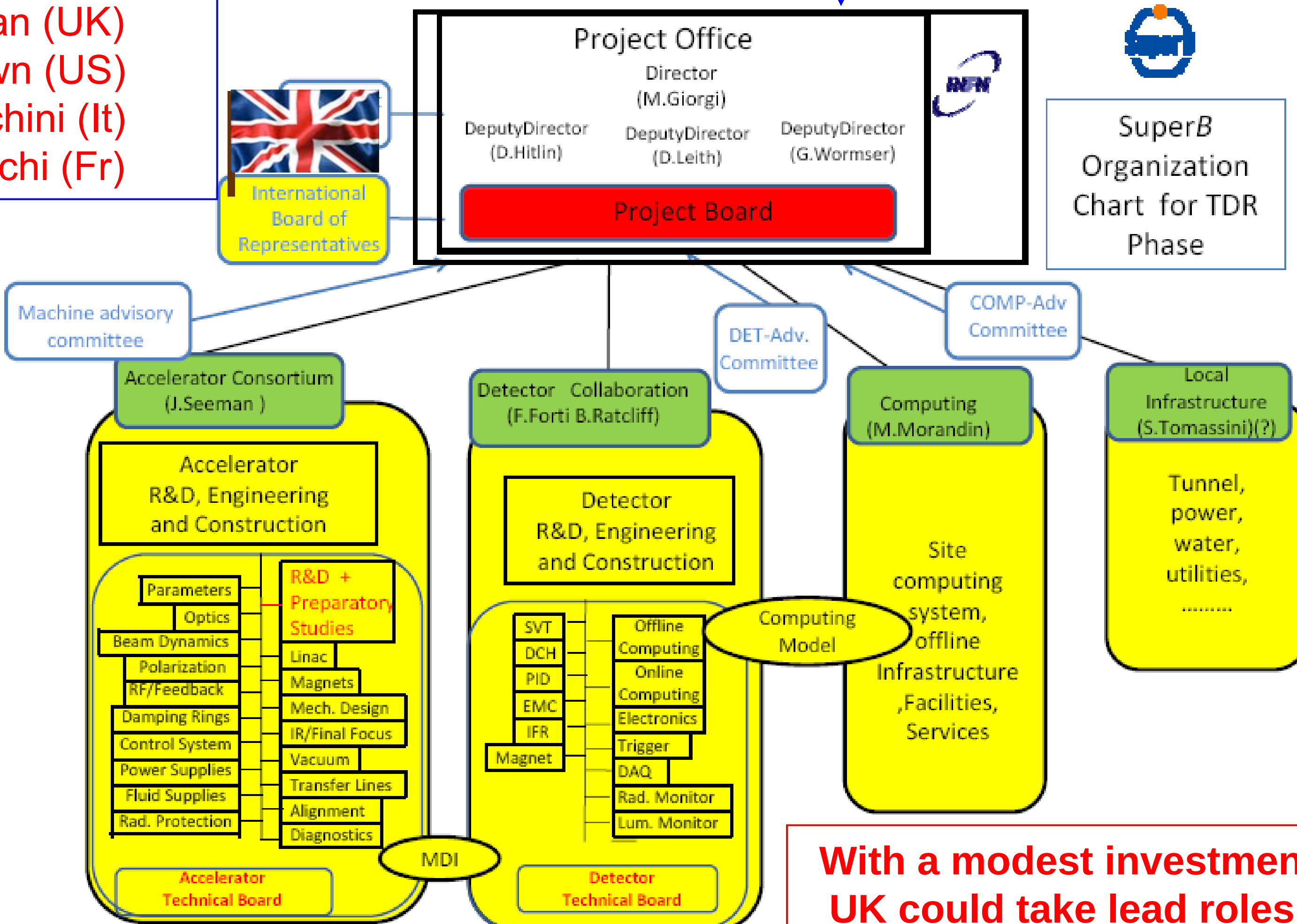
Can add a 2nd IP without affecting the luminosity.

2015

A 2015 depends on funding

Machine/Detector TDR Organization

Physics Co-ordinators:
- A. Bevan (UK)
- D. Brown (US)
- M. Ciuchini (It)
- A. Stocchi (Fr)



With a modest investment now, the UK could take lead roles in silicon detector and machine efforts.

Current UK Involvement

- Cockcroft Institute
  - Gabriele Bassi
  - Kai Hock
  - Andi Wolski [MAC member]

- QMUL
  - Adrian Bevan [Physics co-ordinator]
  - Alex Martin
  - Michael Lazos (graduate student starting Fall '09)
  - Cedric Weiland (summer student)

- RAL
  - Fergus Wilson [International Board/Steering Committee rep., Coordinating physics code for simulation production/On computing model design board]
  - Marcel Stanitzki & Renato Turchetta [both are interested in using MAPS technology SuperB pixel detector]

- Plan to devote computing resources to TDR effort over the coming 18months.

- CI currently have a PRD proposal under review with STFC.

Cost

- Site Development (Tunnel+Surface buildings)
  - 47M€

This number is from a real quote and is ~½ of that given in the CDR.

- Accelerator:
  - 191M€ of new money
    - In addition ~126M€ of in kind contribution from re-use of PEP-II components.
- Detector:
  - 41M€ of new money (not incl FECs)
    - In addition about 47M€ of in kind contribution from re-use of parts of BaBar.
- 5 layer pixel SVT:
  - $8.5M + 56 FTE of effort for R&D and construction.
  - What fraction of this is the UK share?

Using today's exchange rates:
= 6.1MEuro
= £5.2M

KE

- Detector and accelerator activities would be able to support UK industry.

- MAPS project could be used to build a full scale detector.
  - Build a complete MAPS detector!
  - Use world leading UK developed (STFC funded) R&D as base for this!
    - Could also be viewed as a test device for a future LC detector.

- Accelerator issues required for SuperB will/have benefit(ed) the world community:
  - Daϕne has benefited already: KLOE-2.
  - τc factory plan to take on board new technology.
  - CERN have a team working with the SuperB machine group.
  - KEK are looking at ways of improving their machine using SuperB's design.
  - Will benefit any future LC.

Summary

- SuperB is a world class facility to complement the energy frontier experiments.
  - Search for NP in Υ(NS), $B_{d,u}$, D and τ decays.
- International project:
  - Canada, France, Italy, Norway, Russia, Spain, UK, and US participate in collaboration meetings + a number of leading theorists contribute to these meetings.
- UK currently a small, but focussed group.
  - Existing expertise in the UK to develop pixel detector sub-system.
  - Existing expertise can tackle important machine design issues.
- Has leadership roles <u>without</u> funding from STFC (yet).
- Potential to make significant intellectual input to the whole programme!
- Strong KE potential matching the quality of intellectual input.
- The UK should be participating in this project.

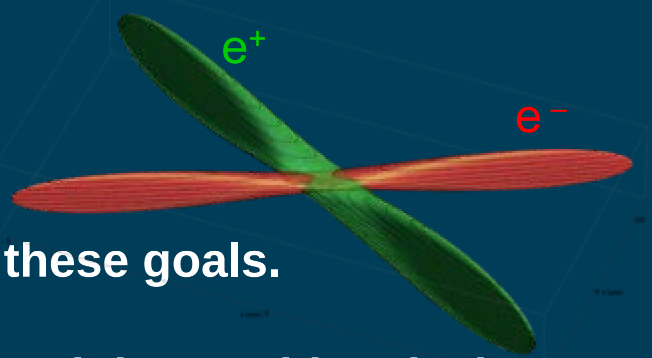
Concentrating on the project with a UK interest

Additional Material

SuperB

SuperB (In a Nutshell)

- Asymmetric energy e^+e^- collider, with roughly 7GeV e^- on 4GeV e^+.
- Low emittance operation (like LC).
- Polarised beams [60-80%].
- Luminosity 10^{36} cm^{-2}s^{-1}
  - 75ab^{-1} data at the Υ(4S).
  - Will collect data at other Υ resonances, and at charm threshold.
  - Start data taking as early as 2015.
- Crab Waist technique developed to achieve these goals.

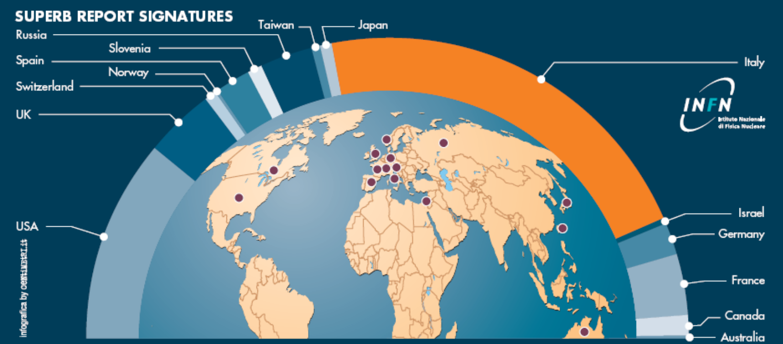


- MAC approved the machine design earlier this year.

http://www.pi.infn.it/SuperB/

Precision B, D and τ decay studies and spectroscopy.

- New Physics in loops.
  - 10 TeV reach at 75ab^{-1}.
  - Rare decays.
  - ΔS CP violation measurements.
- Lepton Flavour & CP Violation in τ decay.
- Light Higgs searches.
- Dark Matter searches.
- Sample of data at the ψ(3770) can utilize quantum correlations in $D^0\bar{D}^0$.

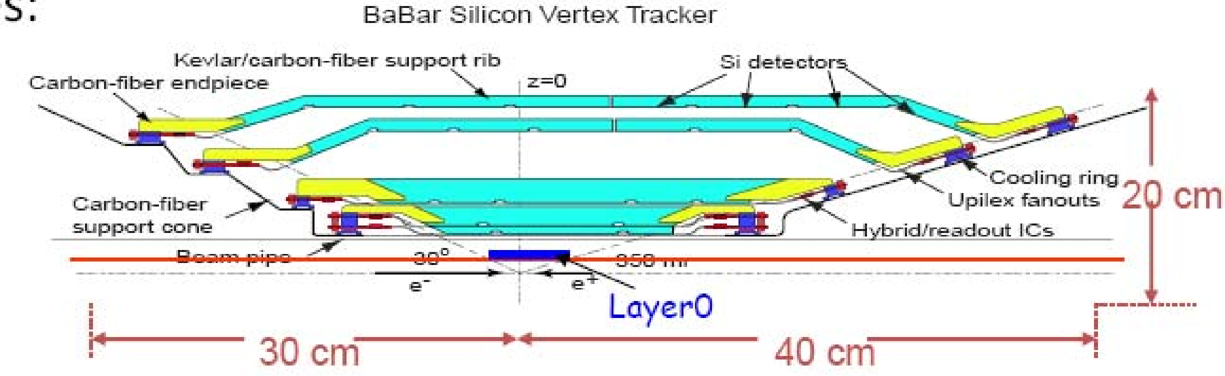


Geographical distribution of CDR signatories.

Detector issues

Detector Issues:

SVT



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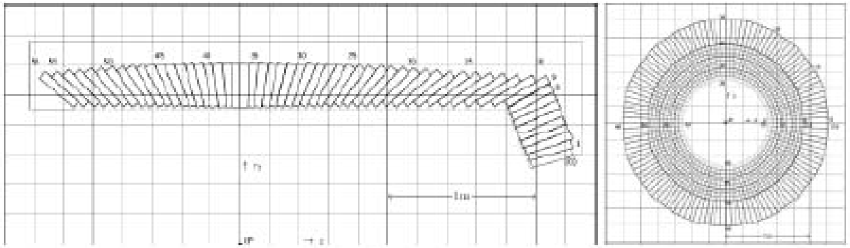
- Beam pipe radius and thickness are crucial to obtain adequate resolution in vertex separation.

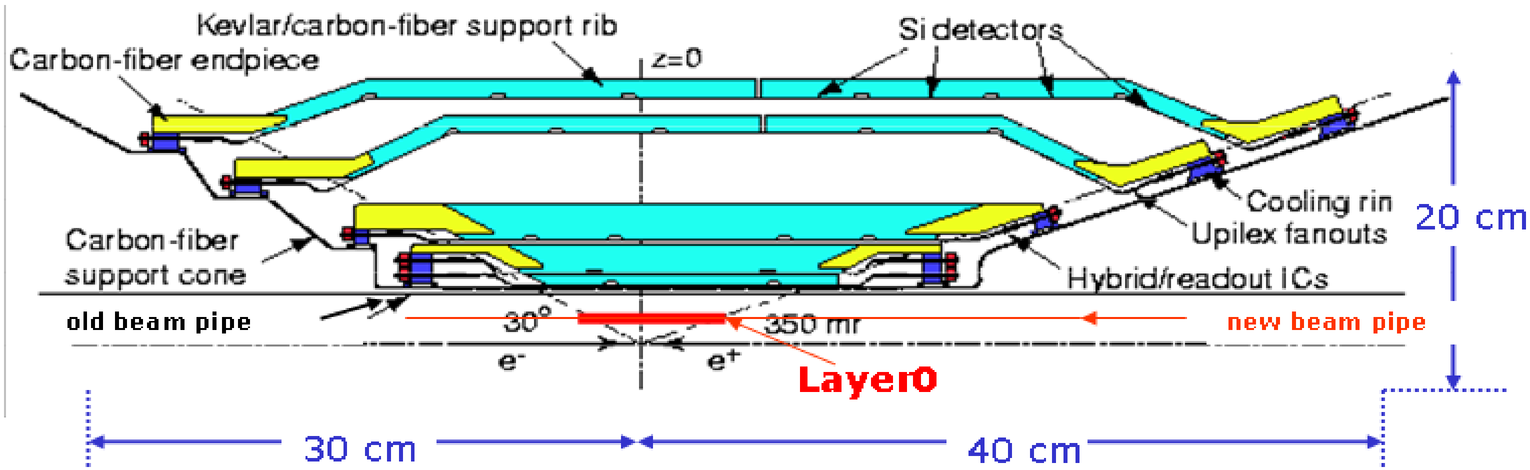
Options:MAPS, Hybrid Pixels, Striplets (the latter is difficult due to the expected Bhabha occupancy)

Forward EMC



- Forward Endcap EMC
  - Inner BaBar Crystals are radiation damaged. Need replacement.
  - At forward angles in SuperB, CsI(Tl) is too slow (occupancy) and radiation soft.
  - Propose LYSO.

SuperB Upgrade baseline



- Basically BaBar layout
- Layer 0 : Pixels (50 µm) or Short strips
- Layer 1-5 Si-Strip

Super B requirements

	SuperB plans	Achievable with MAPS	Comments
Material per Layer (X_0)	1.00%	0.20%	Assuming ILC conditions
Pitch (μm)	50	25-50	
Particle flux /s cm^2	10^6	ok	
Hits per Pixel /s	25	ok	
Total pixel area m^2	1	1	
Total pixels	$4 \cdot 10^8$	ok	
Radiation (Mrad)	10	ok	have test devices in Silicon
Detector Data Volume Gbyte/s	40	yes	requires R&D for DAQ
Power (W/cm^2)	2	0.32	from TPAC architecture

Workpackages

- Sensors
  - MAPS-based staves
- Integration & Services
  - low-mass foams (build on Low-mass experiences)
  - Serial Powering schemes to reduce cabling
  - Is Gas-cooling do-able ?
- DAQ
  - High-speed links

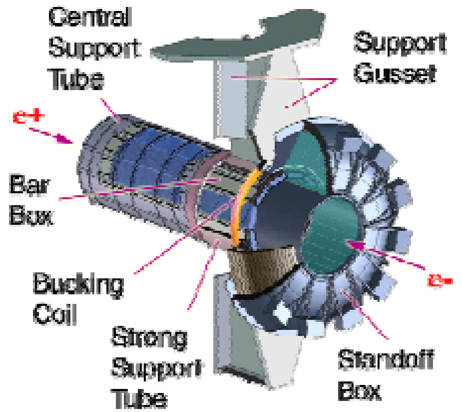
Vertex Detector System Costs

- Following ILC costing models
- Construction + R&D for entire system
- Construction
  - 5 M$ for Material, Services and Contingency
  - 26 Man Years
- R&D
  - 2.5 M$ for Material, Services and Contingency
  - 20 Man Years
- DAQ (Vertex-specific)
  - 1.0 M$ Material, Services and Contingency
  - 10 Man Years
- Total: 8.5 M$ + 56 Man years
- UK share ???

Detector issues

- Baseline is to reuse BaBar DIRC barrel-only design.
  - Excellent performance to 4 GeV/c.
  - Robust operation.
  - Elegant mechanical support.
  - Photon detectors outside field region.
  - Radiation hard fused silica radiators.
  - But…PMTs are slow and aging. Need replacement. Large SOB region senstive to backgrounds so volume reduction is desirable.

PID



- Photon detector replacement
  - Baseline… Use pixelated fast PMTs with a smaller SOB to improve background performance by ~x50-100 with ~ identical PID performance.
  - Several other photon detector options are considered in the CDR.

OPTIONS for the Forward PID

- Modest solid angle but event acceptance for “veto physics” or decays with multiple particles (e.g., B$\rightarrow$ K_sKK) scale much faster than linearly. Physics case needs to be established.

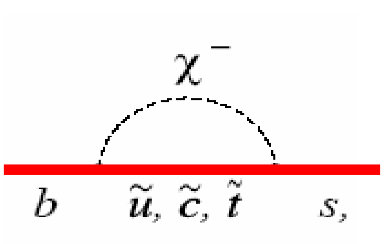
- Not just a PID problem. Overall detector optimization required.
  - Adds material before EMC.
  - Takes space from tracking or EMC.

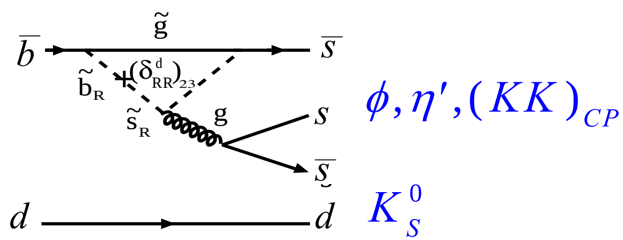
- Aerogel RICH and Very Fast Cherenkov-based TOF seem plausible.

  - Space requirements.
  - Fast tubes have substantial material. SiPMs are noisy and neutron sensitive.
  - R&D underway

Physics

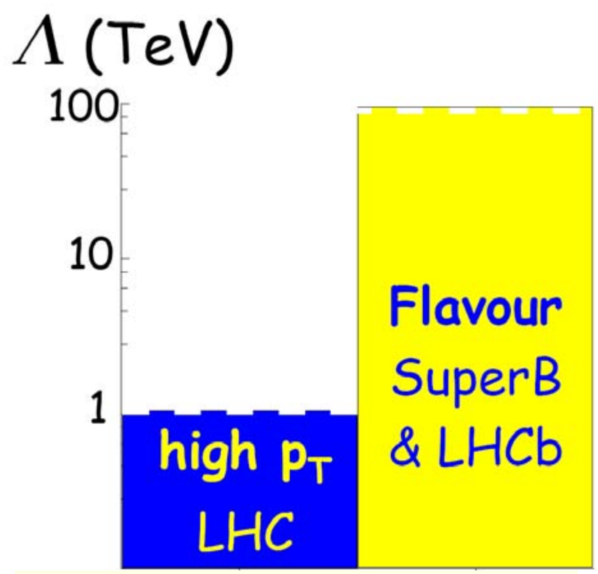
- Goal is to *indirectly* search for new physics using loop/box and forbidden processes.
  - Sensitivity to NP scales ~ $\Lambda > 1$TeV
  - Flavor changing neutral currents and loops can give 100-1000TeV search capability.





$$\mathcal{L}^{NP}_{eff} = \mathcal{L}_{SM} + \sum_k \left(\sum_i c_i^k \, Q_i^{(k+4)}\right)/\Lambda^k$$

- If the new physics is fine tuned
  - c_i are small (~0)
- Otherwise c_i~1 and Λ is *very* large.



Physics

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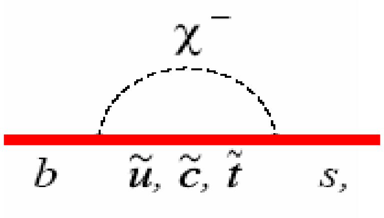
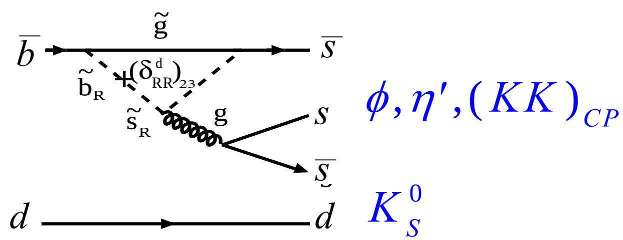




$$\mathcal{L}^{NP}_{eff} = \mathcal{L}_{SM} + \sum_k \left(\sum_i c_i^k\, Q_i^{(k+4)}\right)/\Lambda^k$$

Y. Nir et al.

Mixing	$\Lambda_{NP}^{CPC} \gtrsim$	$\Lambda_{NP}^{CPV} \gtrsim$
$K-\overline{K}$	1000 TeV	20000 TeV
$D-\overline{D}$	1000 TeV	3000 TeV
$B-\overline{B}$	400 TeV	800 TeV
$B_s-\overline{B_s}$	70 TeV	70 TeV

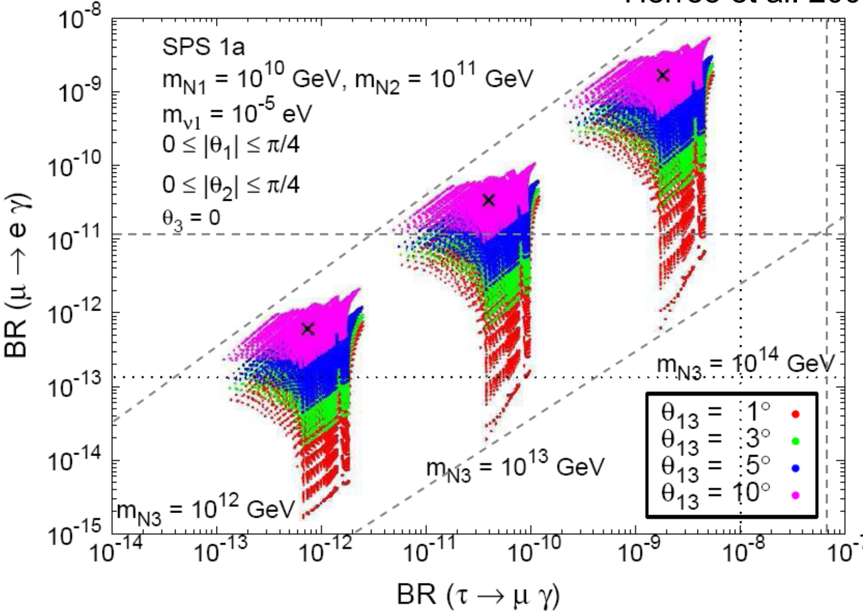
- If the new physics is fine tuned
  - c_i are small (~0)
- Otherwise c_i~1 and Λ is *very* large.

Lepton Flavor Violation in τ decay

- $\tau \rightarrow \mu\gamma$ upper limit can be correlated to θ_{13} (neutrino mixing/CPV, T2K etc.) and also to $\mu \rightarrow e\gamma$.
- Complementary to flavour mixing in quarks.
- Golden modes:
  - $\tau \rightarrow \mu\gamma$ and 3μ.
- e^- beam polarization:
  - Lower background
  - Better sensitivity than competition!
- e+ polarization used later in programme.
- CPV in $\tau \rightarrow K_S \pi \nu$ at the level of $\sim 10^{-5}$.
- Bonus:
  - Can also measure τ g-2 (polarization is crucial).
  - σ(g-2) $\sim 2.4 \times 10^{-6}$ (statistically dominated error).

SUSY seasaw = CMSSM + $3\nu_R$ + $\tilde{\nu}$

Herreo et al. 2006

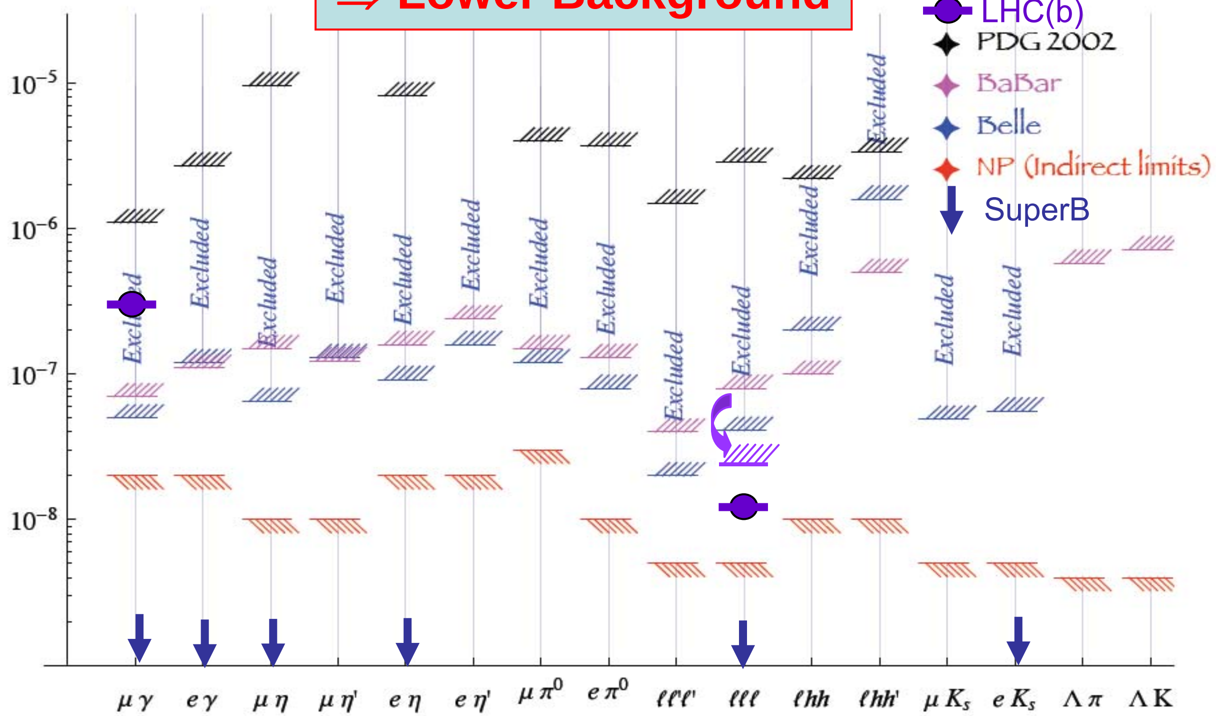


Process	Expected 90%CL upper limited	4σ Discovery Reach
$\mathcal{B}(\tau \to \mu\gamma)$	2×10^{-9}	5×10^{-9}
$\mathcal{B}(\tau \to \mu\mu\mu)$	2×10^{-10}	8.8×10^{-10}

Use $\mu\,\gamma$/3l to distinguish SUSY vs. LHT.

Lepton Flavor Violation in τ decay

e⁻ beam polarization
⇒ Lower Background



SuperB Sensitivity (75ab^{-1})

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

- LHC is ***not*** competitive (Re: both GPDs and LHCb).
- SuperB sensitivity ~10 – 50× better than NP allowed branching fractions.

Rare Decays

- No one smoking gun… rather a ‘***golden matrix***’.

X = Golden Channel o = Observable effect	H^+ high $\tan\beta$	Minimal FV	Non-Minimal FV (1-3)	Non-Minimal FV (2-3)	NP Z-penguins	Right-Handed currents
$\mathrm{BR}(B \to X_s\gamma)$		X		o		o
$A_{CP}(B \to X_s\gamma)$				X		o
$\mathrm{BR}(B \to \tau\nu)$	X-CKM					
$\mathrm{BR}(B \to X_s l^+ l^-)$				o	o	o
$\mathrm{BR}(B \to K\nu\overline{\nu})$				o	X	
$S(K_S\pi^0\gamma)$						X
β (ΔS)			X-CKM			X

- Need to measure all observables in order to select/eliminate new physics scenarios!

Mode	Sensitivity		
	Current	10 ab^{-1}	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%
$\mathcal{B}(B^+ \to \mu^+\nu)$	X	20%	5–6%
$\mathcal{B}(B \to X_s l^+ l^-)$	23%	15%	4–6%
$A_{\mathrm{FB}}(B \to X_s l^+ l^-)_{s_0}$	X	30%	4–6%
$\mathcal{B}(B \to K\nu\overline{\nu})$	X	X	16–20%
$S(K^0_S\pi^0\gamma)$	0.24	0.08	0.02–0.03

- **The golden modes**
  - **will be measured by SuperB.**
  - **`smoking guns’ for their models.**

- **Measurements not yet made are denoted by <u>X</u>.**

- **With 75ab^{-1} we can**
  - **Reach above a TeV with B→ τν**
  - **See B→Kν$\overline{\nu}$**

Rare Decays : SUSY CKM

- Flavour couplings in squark sector (like CKM)

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 $M^2_{\tilde{u}}$

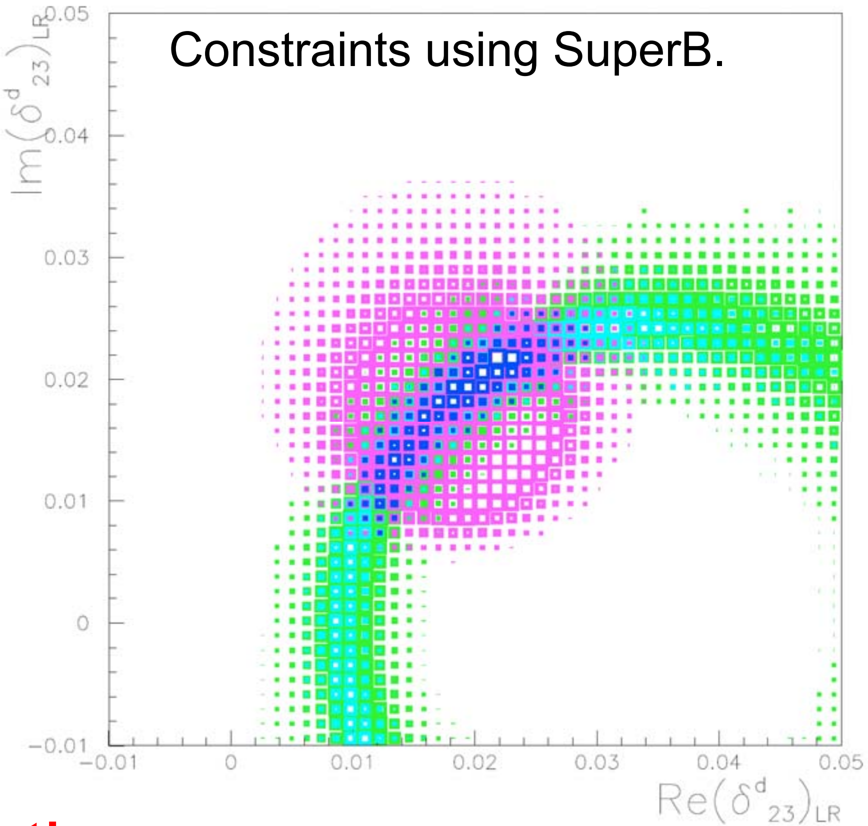
- NP scale: $m_{\tilde{q}}$
- Flavour and CP violation coupling: $(\Delta_{ij}^d)_{AB}/m_{\tilde{q}}^2$
- Why?
  - Non trivial CKM & MSW, so it is natural for squarks to mix!
  - Unnatural to have couplings ~0 and a low mass scale.
- e.g. MSSM: 124 parameters (160 with ν_R).
  - Most are flavour couplings!

Rare Decays : SUSY CKM

- Couplings are $\left(\delta_{ij}^{q}\right)_{AB} = \left(\Delta_{ij}^{q}\right)_{AB} / m_{\tilde{q}}^{2}$
  where $A,B=L,R$, and i,j are squark generations.

- e.g. Constraint on $(\delta_{23}^{d})_{LR}$ using:

- $\mathcal{B}(B \to X_s \gamma)$ [green]
- $\mathcal{B}(B \to X_s l^+l^-)$ [cyan]
- $A_{CP}(B \to X_s \gamma)$ [magenta]
- Combined [blue]



SuperB probes new physics in SUSY larger than 20TeV (and up to 300TeV in some scenarios)

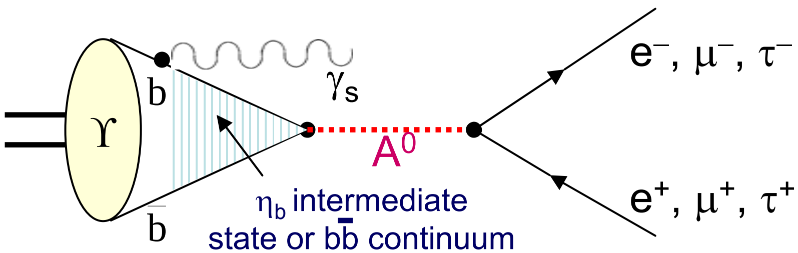
Now: Whole Range allowed.

SuperB: % level measurement!

See (or rule out) a sparticle signal at TeV scale with 75ab^{-1}.

Searching for a Light Higgs & Dark Matter

- Many NP scenarios have a possible light Higgs Boson (e.g. 2HDM).
- Can use $\Upsilon(nS)\to l^+l^-$ to search for this.
  - Contribution from A^0 would break lepton universality



M. A. Sanchis-Lozano, hep-ph/0510374, Int. J. Mod. Phys. A19 (2004) 2183

- Can expect to record at least 300fb^{-1} recorded at the $\Upsilon(3S)$ in SuperB.
- This is $10 \times$ the BaBar data sample at the $\Upsilon(3S)$.

- NMSSM Model with 7 Higgs Bosons

Physical Higgs bosons: (seven)

2 neutral CP-odd Higgs bosons ($A_{1,2}$)
3 neutral CP-even Higgs bosons ($H_{1,2,3}$)
2 charged Higgs bosons ($H^{\pm}$)

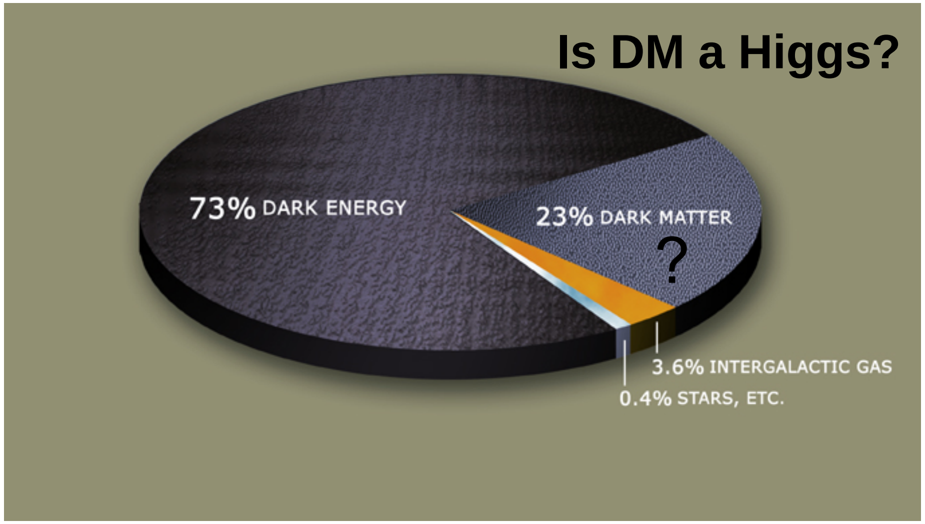
Possible NMSSM Scenario

$A_1 \sim 10$ GeV
$H_1 \sim 100$ GeV (SM-like)
Others ~300 GeV (almost degenerate)

- A_1 could be a light DM candidate.

Gunion, Hooper, McElrath [hep-ph:0509024]
McElrath [hep-ph/0506151], [arXiv:0712.0016]

Searching for Dark Matter

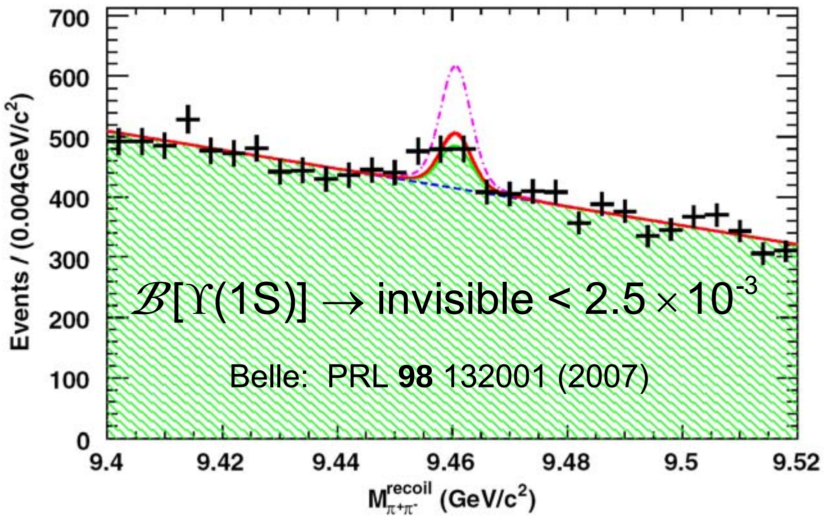


• Possible to search for the effect of DM at the B-factories for most modes:

$$\Upsilon \to invisible \qquad J/\Psi \to invisible$$
$$\eta \to invisible \qquad \Upsilon \to \gamma + invisible$$
$$B^+ \to K^+ + invisible \qquad \Upsilon \to \gamma A_1, A_1 \to \tau^+\tau^-$$
$$K^+ \to \pi^+ + invisible \qquad J/\Psi \to \gamma A_1$$

hep-ph/0506151, hep-ph/0509024, hep-ph/0401195, hep-ph/0601090, hep-ph/0509024, hep-ex/0403036 ...

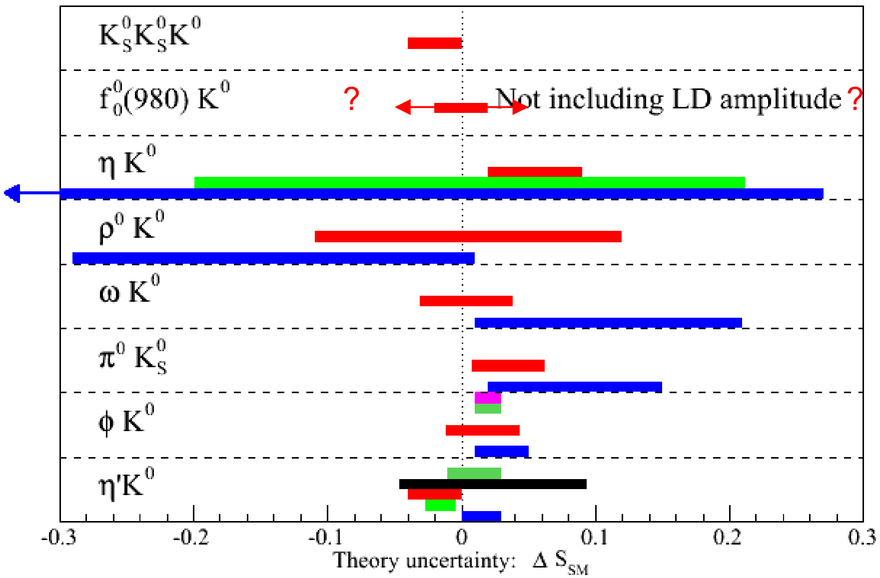
- SM Expectation:
  $\mathcal{B}(\Upsilon(1S) \to \nu\bar{\nu}) = (9.9 \pm 0.5) \times 10^{-6}$
- NP extension:
  $\mathcal{B}(\Upsilon(1S) \to \chi\chi)$ up to 6×10^{-3}
- SuperB should be able to provide a precision constraint on this channel.
- Belle has 7fb-1 at the Υ(1S), SuperB will have hundreds of fb^{-1}.



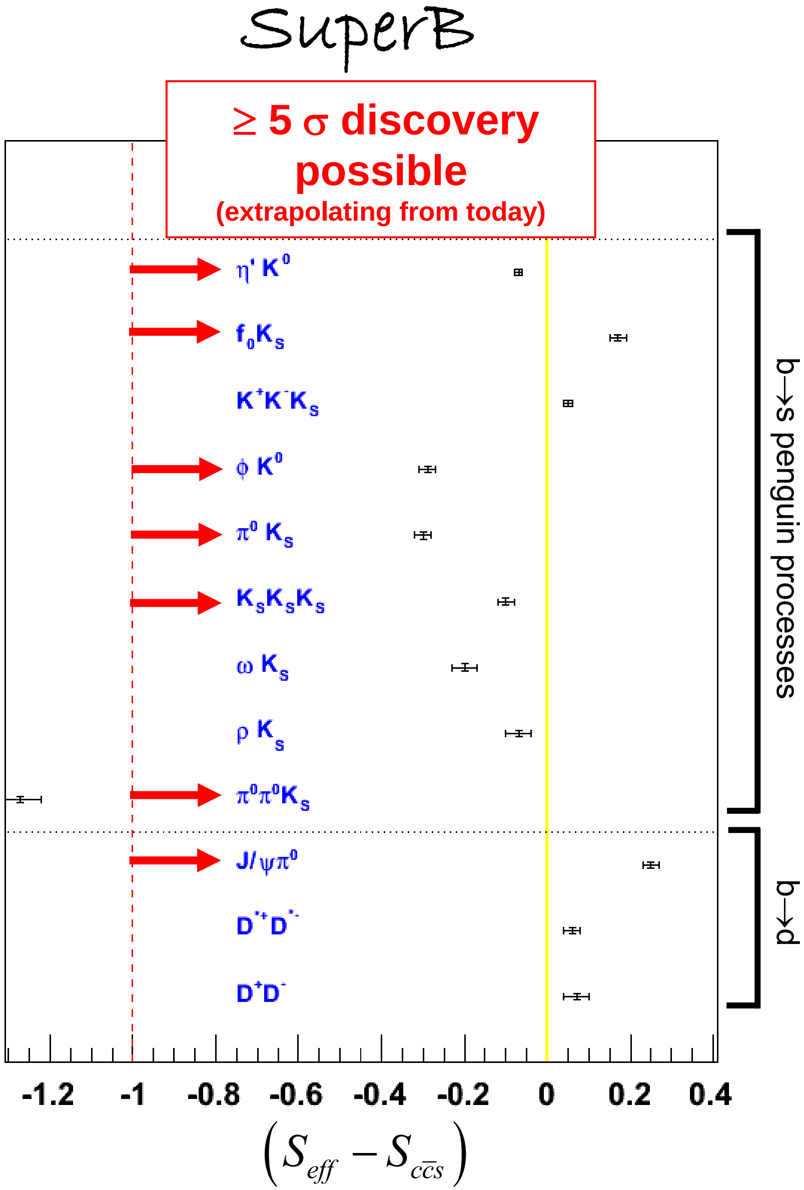
ΔS measurements (CPV)

- β=(21.1±0.9)° from Charmonium decays.
- Look in many different b→s and b→d decays for sin2β deviations from the SM:

$$\Delta S_{\rm NP} = S_{eff} - S_{c\bar{c}s} - \Delta S_{\rm SM}$$



QCDF Beneke, PLB**620**, 143 (2005)
SCET/QCDF, Williamson and Zupan, PRD**74**, 014003 (2006)
QCDF Cheng, Chua and Soni, PRD**72**, 014006 (2005)
SU(3) Gronau, Rosner and Zupan, PRD**74**, 093003 (2006)
QCDF Buchalla, Hiller, Nir, Raz, JHEP 09, 074 (2005)
Li and Mishima PRD74, 094020 (2006)



Standard Model measurements.

B Physics at Υ(4S)

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi\, K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi\, K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\, \pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K^0_s K^0_s K^0_s)$	0.15	0.02 (∗)
$S(K^0_s \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_s)$	0.17	0.03 (∗)
$S(f_0 K^0_s)$	0.12	0.02 (∗)
γ $(B \to DK, D \to CP$ eigenstates$)$	$\sim 15^\circ$	2.5°
γ $(B \to DK, D \to$ suppressed states$)$	$\sim 12^\circ$	2.0°
γ $(B \to DK, D \to$ multibody states$)$	$\sim 9^\circ$	1.5°
γ $(B \to DK,$ combined$)$	$\sim 6^\circ$	1–2°
α $(B \to \pi\pi)$	$\sim 16^\circ$	3°
α $(B \to \rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta + \gamma$ $(D^{(*)\pm}\pi^\mp, D^\pm K^0_s \pi^\mp)$	20°	5°
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B \to \tau\nu)$	20%	4% (†)
$\mathcal{B}(B \to \mu\nu)$	visible	5%
$\mathcal{B}(B \to D\tau\nu)$	10%	2%
$\mathcal{B}(B \to \rho\gamma)$	15%	3% (†)
$\mathcal{B}(B \to \omega\gamma)$	30%	5%
$A_{CP}(B \to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B \to \rho\gamma)$	~ 0.20	0.05
$A_{CP}(b \to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b \to (s+d)\gamma)$	0.03	0.006 (†)
$S(K^0_S \pi^0 \gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B \to K^*\ell\ell)$	7%	1%
$A^{FB}(B \to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B \to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B \to K\nu\bar{\nu})$	visible	20%
$\mathcal{B}(B \to \pi\nu\bar{\nu})$	–	possible

Rare Charm Decays: 1 month at ψ(3770)

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

Charm Mixing

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}	
$D^0 \to K^0_S\pi^+\pi^-$	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		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

See CDR and Valencia report for details of the SM measurements and other possible NP searches.

τ: LFV / CPV / …

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

B Physics at Υ(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^s_{SL}	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s \to \gamma\gamma)$	38%	7%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s \to K^0\bar{K}^0$	24°	11°

- SuperKEKB / Belle-II

SuperKEKB / Belle-II

- Mainly Belle groups involved, with some interest from the German ILC community for detectors (DEPFET).

- No UK involvement.

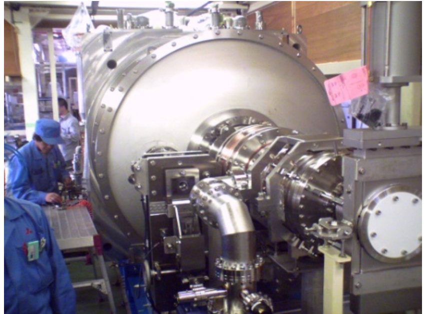
- Aim to integrate $10ab^{-1}$ using minor upgrades to KEKB (this is called Belle-II).
  - c.f. total world data sample of $1.5ab^{-1}$ at the Υ(4S).
    - Only a factor of 2.6 improvement in statistical errors scaling by $\sqrt{N}$.

- Follow up with a second upgrade to reach $50ab^{-1}$ by 2020 (this is called SuperKEKB).

- High current solution for accelerator has been studied by their MAC.
  - Rejected as not viable in the spring. Have started working on a 'nano-beam' solution similar to the Italian SuperB project.
  - Expect to have a nano-beam machine design available by the end of the year.

Ushiroda Hints '09 workshop, March KEK

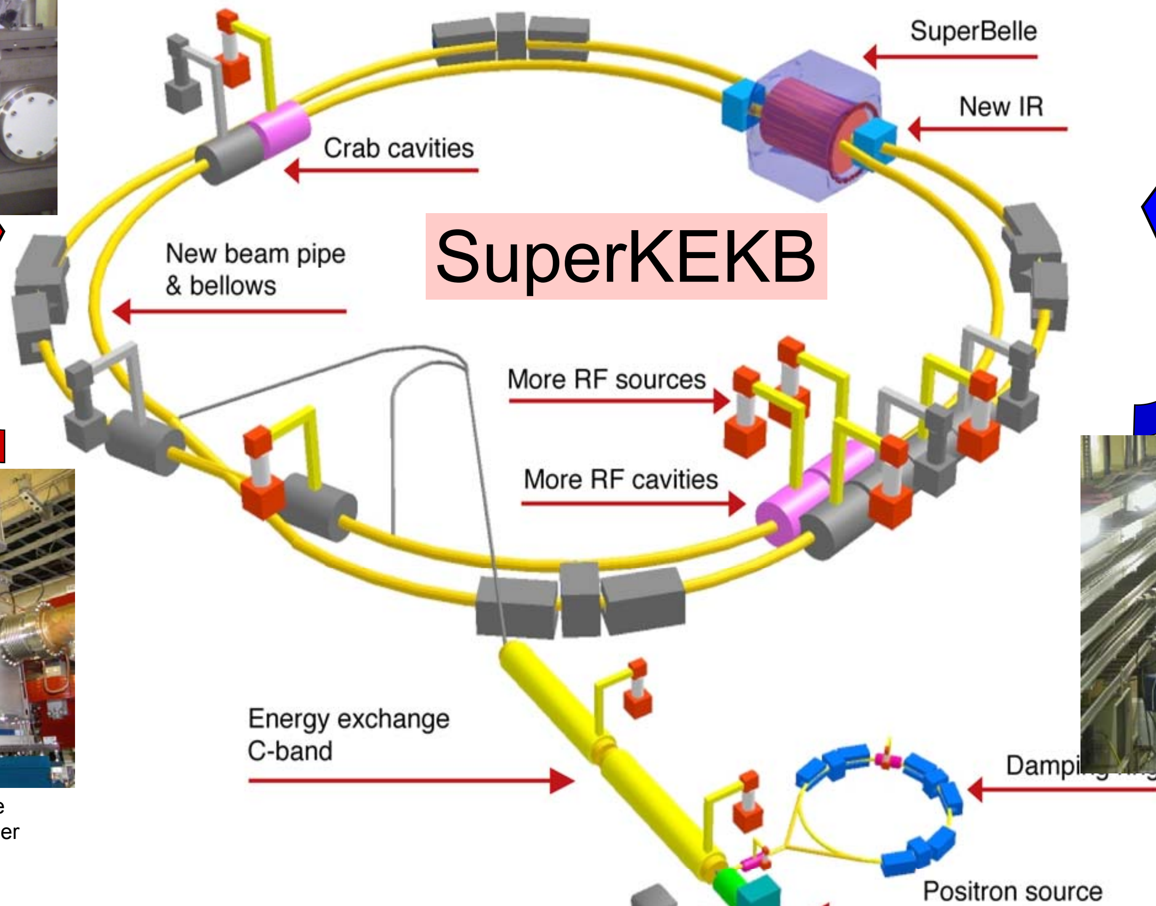
$\beta^*_y = \sigma_z = 3$ mm



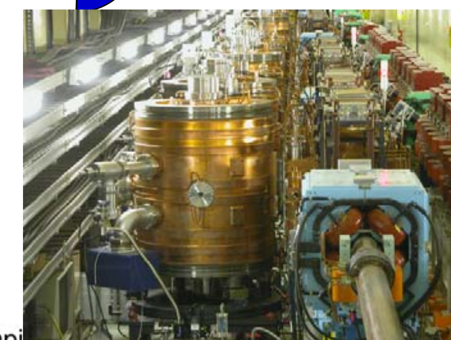
Crab cavities will be installed and tested with beam in 2006.

e^+ 4.1 A

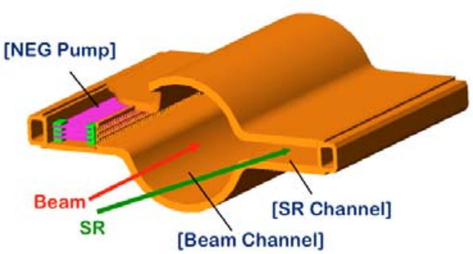
e^- 9.4 A

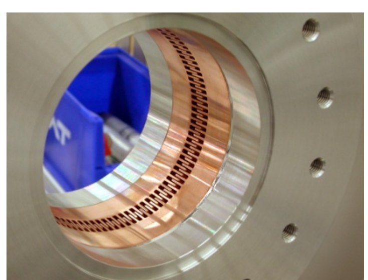


The superconducting cavities will be upgraded to absorb more higher-order mode power up to 50 kW.



The state-of-art ARES copper cavities will be upgraded with higher energy storage ratio to support higher current.





The beam pipes and all vacuum components will be replaced with higher-current-proof design.

$$L = \frac{\gamma_\pm}{2 e r_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

$\mathcal{L} = 8 \times 10^{35}$ $cm^{-2}s^{-1}$.

Integrate $50 ab^{-1}$

Machine parameter sets

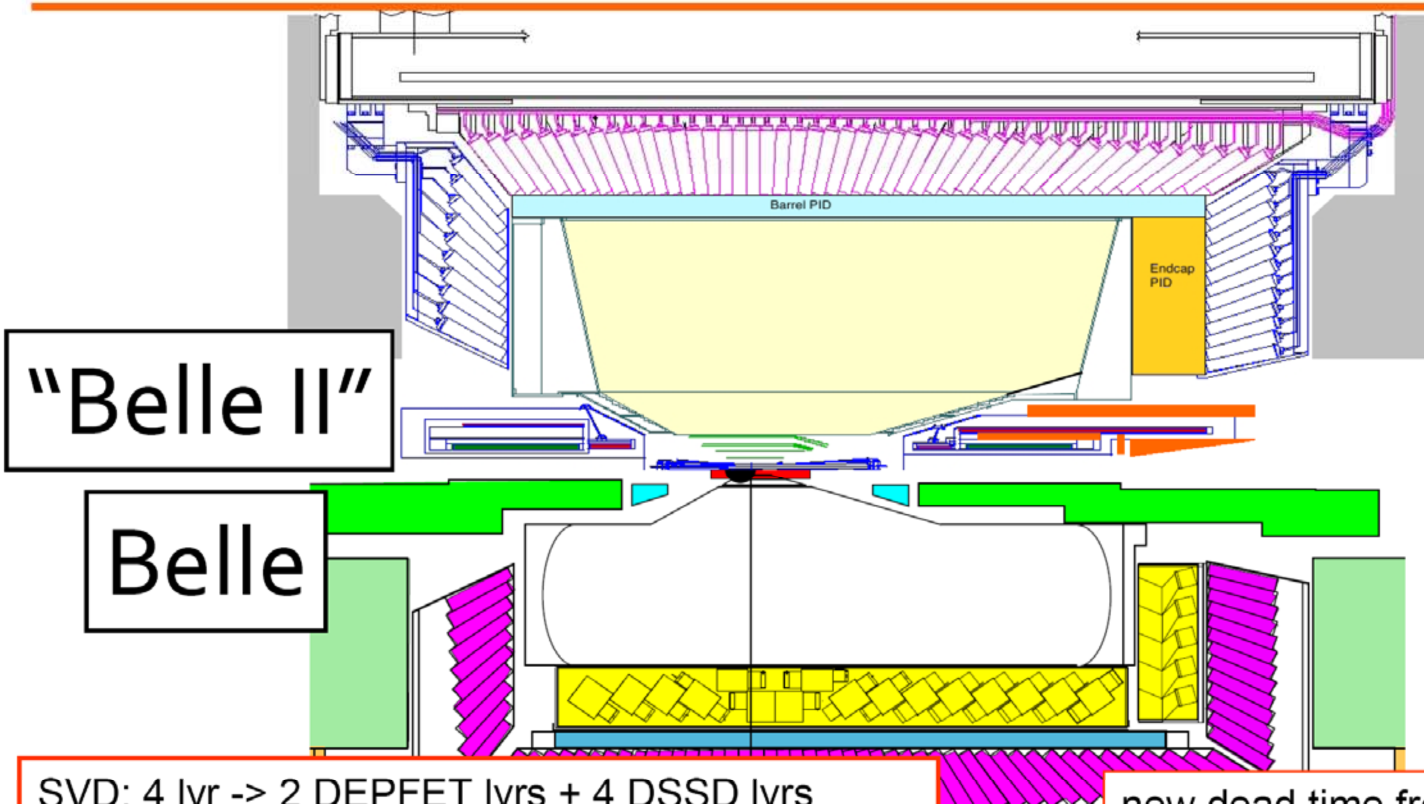
Comparison of Options

	KEKB Design	KEKB Achieved (): with crab	SuperKEKB High-Current Option	SuperKEKB Nano-Beam Option
β_y^* (mm)(LER/HER)	10/10	6.5/5.9 (5.9/5.9)	3/6	0.21/0.37
ε_x (nm)	18/18	18/24	24/18	2.8/1.6
σ_y(μm)	1.9	1.1 (0.84)	0.85/0.73	0.070/0.052
ξ_y	0.052	0.108/0.056 **(0.120/0.089)**	0.3/0.51	0.07/0.07
σ_z (mm)	4	~ 7	5(LER)/3(HER)	6
I_{beam} (A)	2.6/1.1	1.8/1.45 (1.60/1.13)	9.4/4.1	3.70/2.13
$N_{bunches}$	5000	1387 (1585)	5000	2778
Luminosity (10^{34} cm^{-2} s^{-1})	1	1.76 **(1.96)**	53	80

High Current Option includes crab crossing and travelling focus.
Nano-Beam Option does not include crab waist yet

C. Kiesling, CIPANP, San Diego, May 26-31, 2009 13

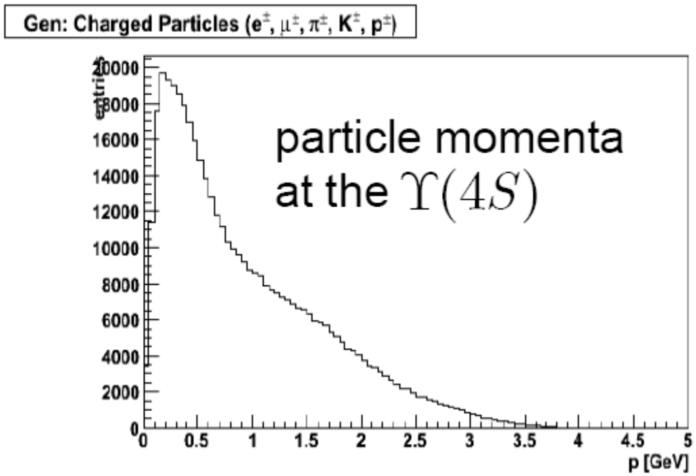
Detector: Baseline Design



SVD: 4 lyr -> 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF -> TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC -> Scintillator +SiPM (end-caps)

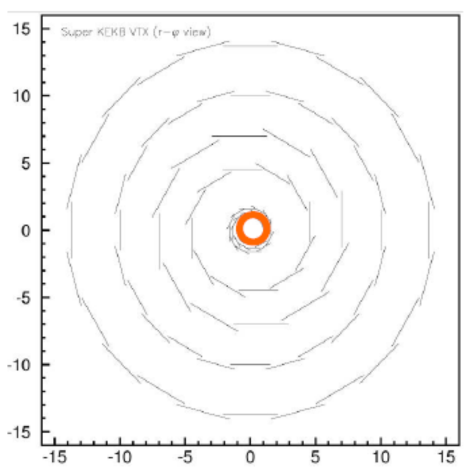
new dead time free readout and high speed computing systems

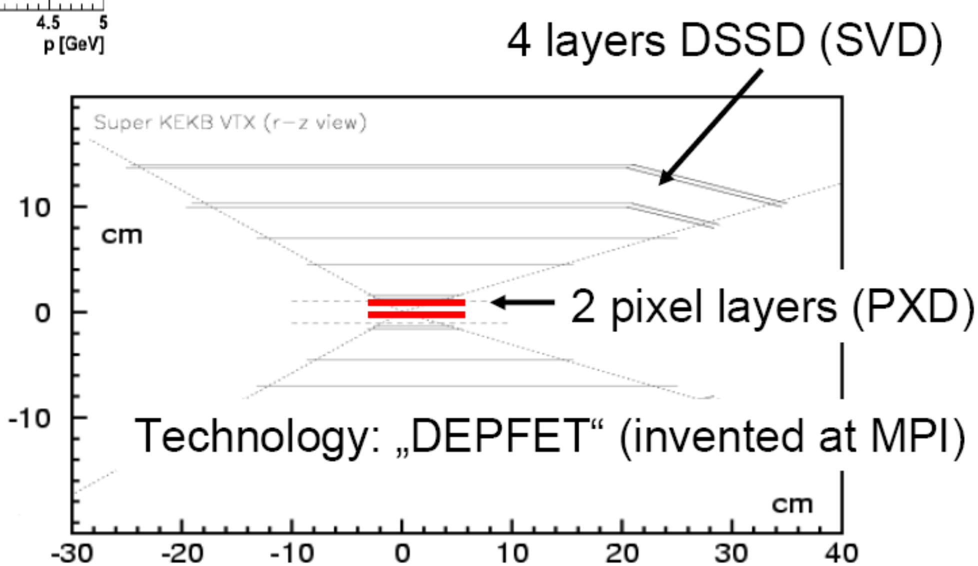
Pixel Detector for Belle II (~2 layers of pixels + Belle SVD)



Both machine options:
large backgrounds = high occupancy

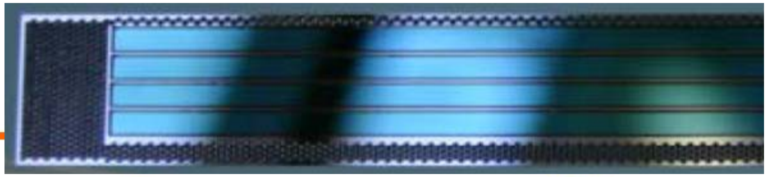
- pixels at the innermost (<2cm) radii
- must be thin, rad. hard, fast readout
- ready for installation in 2013





C. Kiesling, CIPANP, San Diego, May 26-31, 2009 18

DEPFET Principle



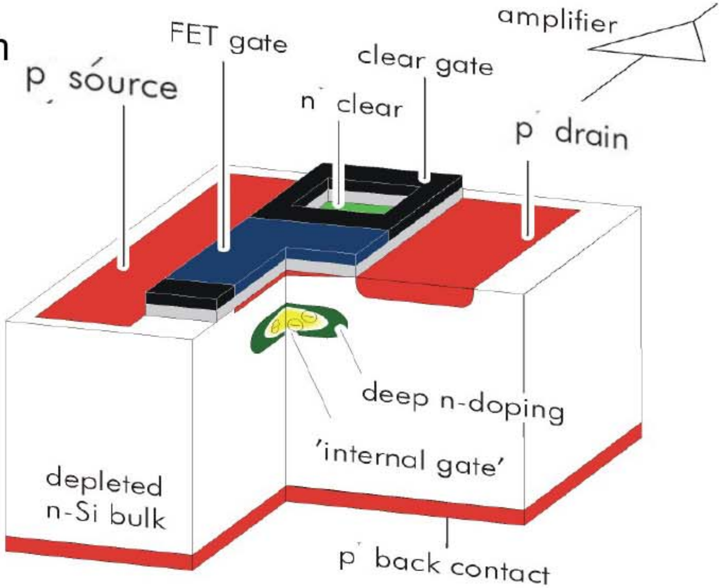
Depleted p-channel FET

p-channel FET on a completely depleted bulk

A deep n-implant creates a potential minimum for electrons under the gate ("internal gate")

Signal electrons accumulate in the internal gate and modulate the transistor current (g_q ~ 400 pA/e^-)

Accumulated charge can be removed by a clear contact ("reset")



Fully depleted:
→ large signal, fast signal collection

Low capacitance, internal amplification → low noise

Transistor on only during readout: low power

Complete clear → no reset noise

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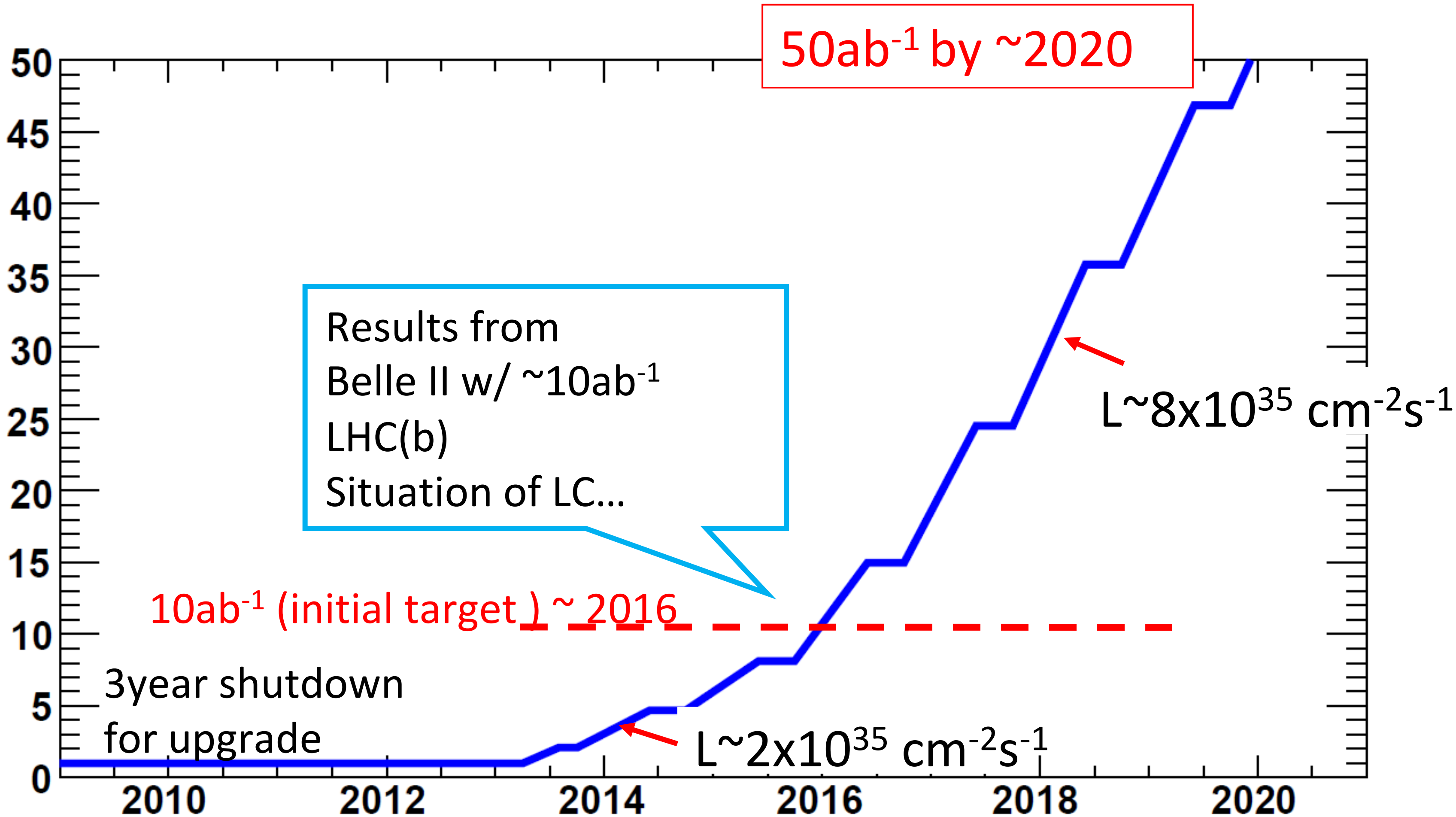
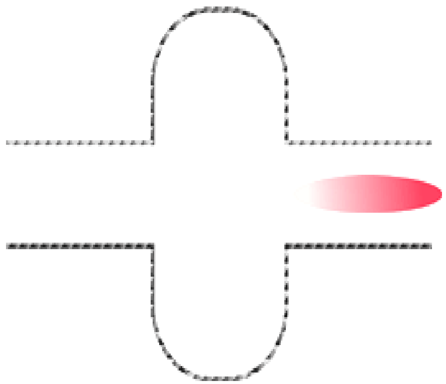
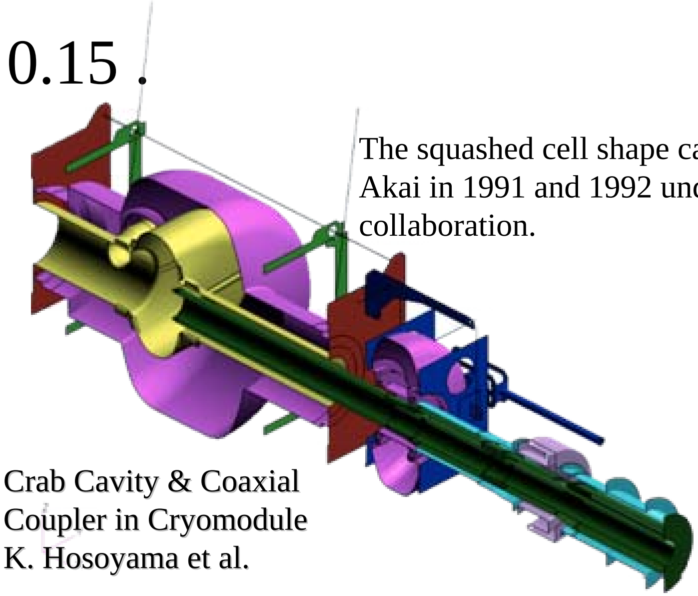

50ab^{-1} by ~2020
Results from
Belle II w/ ~10ab^{-1}
LHC(b)
Situation of LC...
L~8x10^{35} cm^{-2}s^{-1}
10ab^{-1} (initial target) ~ 2016
3year shutdown
for upgrade
L~2x10^{35} cm^{-2}s^{-1}
0
5
10
15
20
25
30
35
40
45
50
2010
2012
2014
2016
2018
2020

Crab Crossing / Cavity

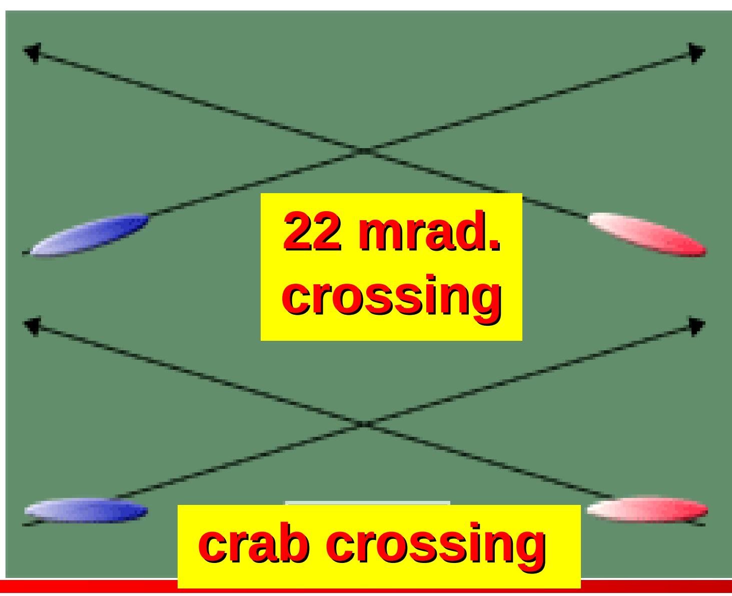
- Boost the beam-beam parameter > 0.15 .

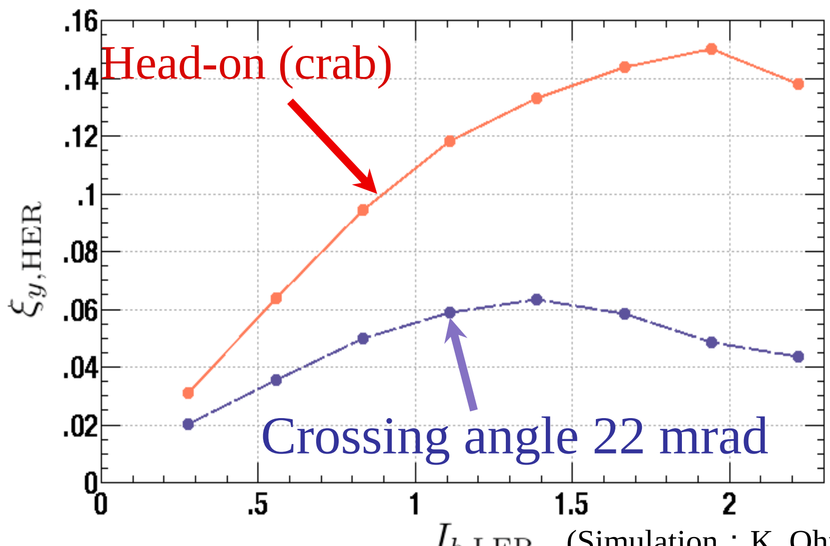




The squashed cell shape cavity studied by K. Akai in 1991 and 1992 under KEK-Cornell collaboration.

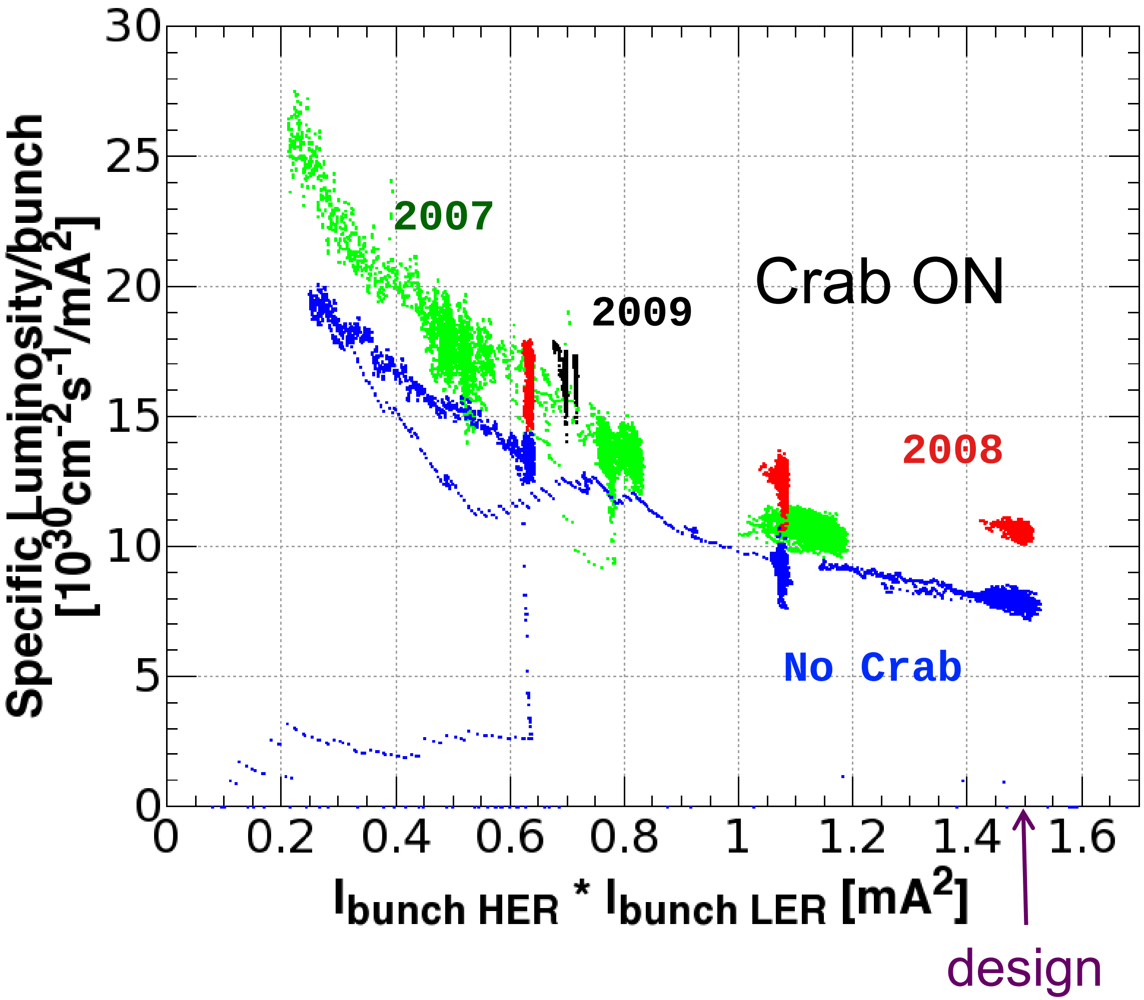
Crab Cavity & Coaxial Coupler in Cryomodule
K. Hosoyama et al.

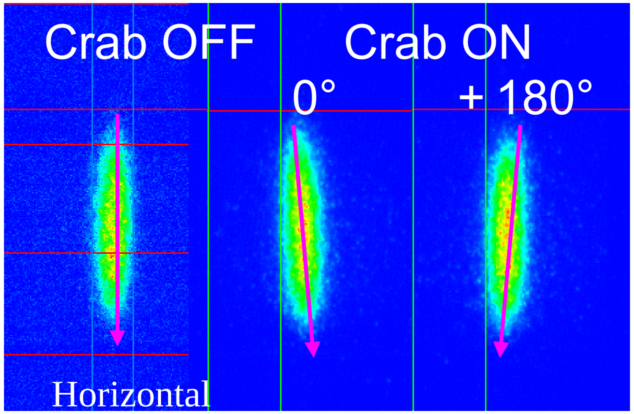




(Simulation：K. Ohmi)

Lum. with Crab Crossing





HER(1.43MV)

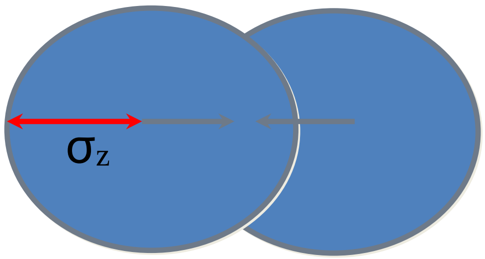
Crabbing: successful !

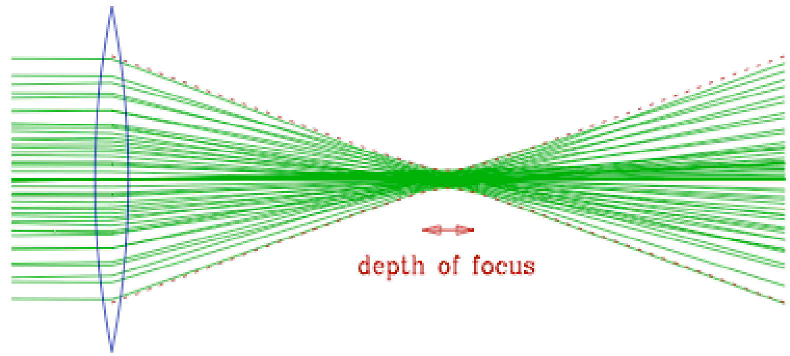
L = 1.96 x10^{34}(6-May)
higher than w/o Crab
(new skew sextupoles)

Specific Lum:
increased ~30%

Still study going on

CSR (Coherent Synchrotron Rad.)





Hourglass condition: $\beta_y^* >\sim \sigma_z$

Beam size changes along Z

Recent simulation study

Short bunch: SR ~coherent

$\rightarrow$ increase energy spread, bunch size

Traveling waist(focus) can recover

β_x^* 40cm $\rightarrow$ 20cm

LER(σ_z)	Lum(10^{35})
3mm	5
5mm	2
5mm	4
5mm	~6

"Realistic" baseline design done: ~5 x 10^{35}

(KEKB, PEP-II exceeded design Lum. x 2~4 !)

54

- Tau Charm Factory

- No UK involvement.

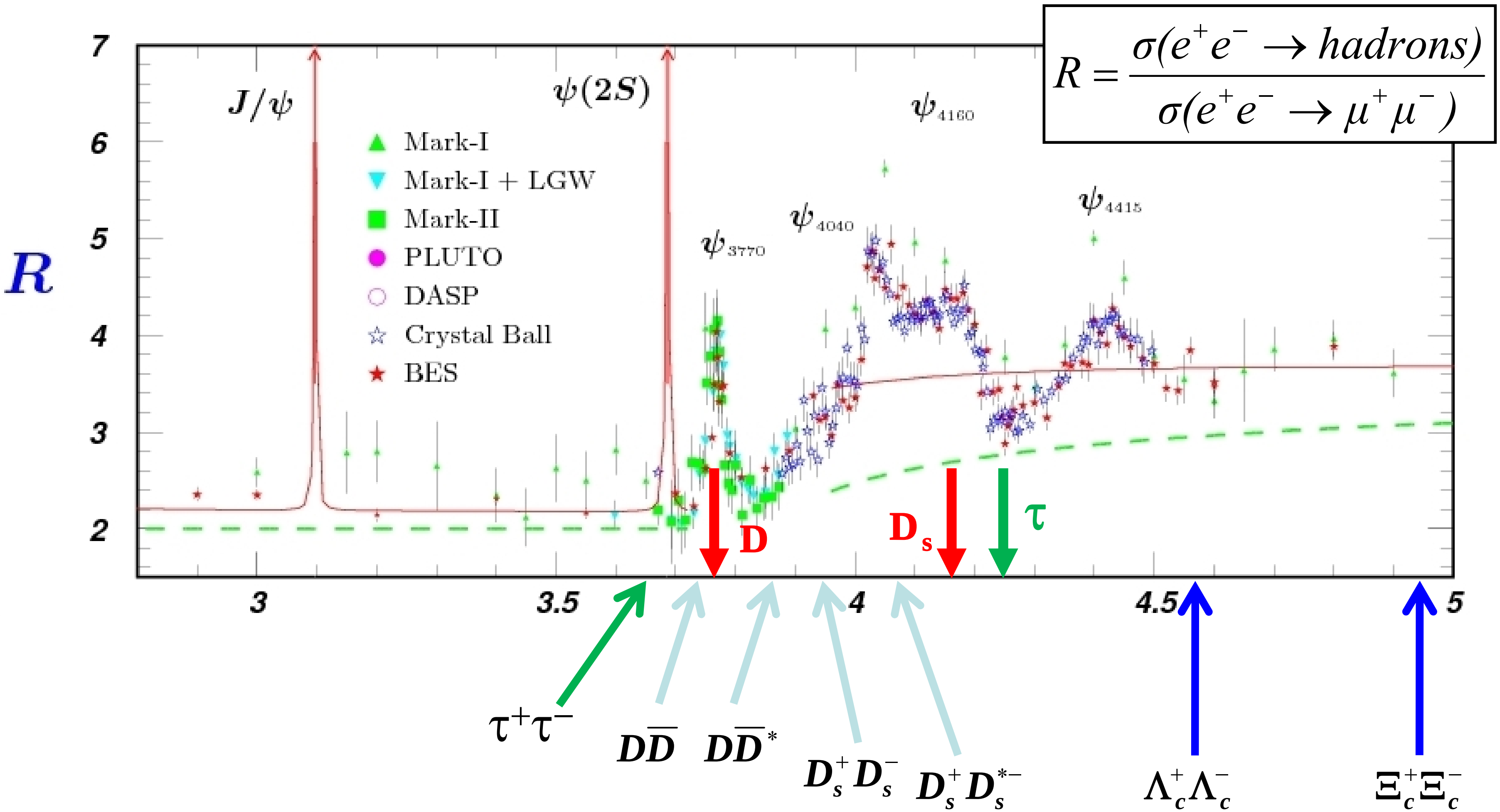
- Slides taken from

  E.Levichev

  Budker Institute of Nuclear Physics, Novosibirsk

  Japan-Italy Collaboration Meeting "Crab Factories" : LNF
  Wednesday 10 December 2008

Tau Charm Factory



Tau Charm Factory

Charmonia
- Spectroscopy, BFs
- Light hadron spectroscopy
- J/ψ rare decays
- …

Tau
- Spectral functions, BFs
- Lorentz structure
- CP violation
- LFV decays
- …

Charm
- Spectroscopy
- (Semi)leptonic decays
- Rare decays
- Mixing
- CP violation
- …

Charm baryons
- BFs
- Semileptonic decays
- …

Requirements: $L > 10^{34}$ cm^{-2} s^{-1}, longitudinal polarization

Tau Charm Factory

- ► Variable energy E_{cm}= 3 – 4.5 GeV (from J/psi to charm baryons)
- ► $L = 1 \div 2 \times 10^{35}\ cm^{-2}s^{-1}$
- ► At least one beam (e^-) should be polarized longitudinally
- ► No energy asymmetry is needed
- ► No beam monochromatization is needed
- ► Energy calibration with medium accuracy (Compton backscattering)

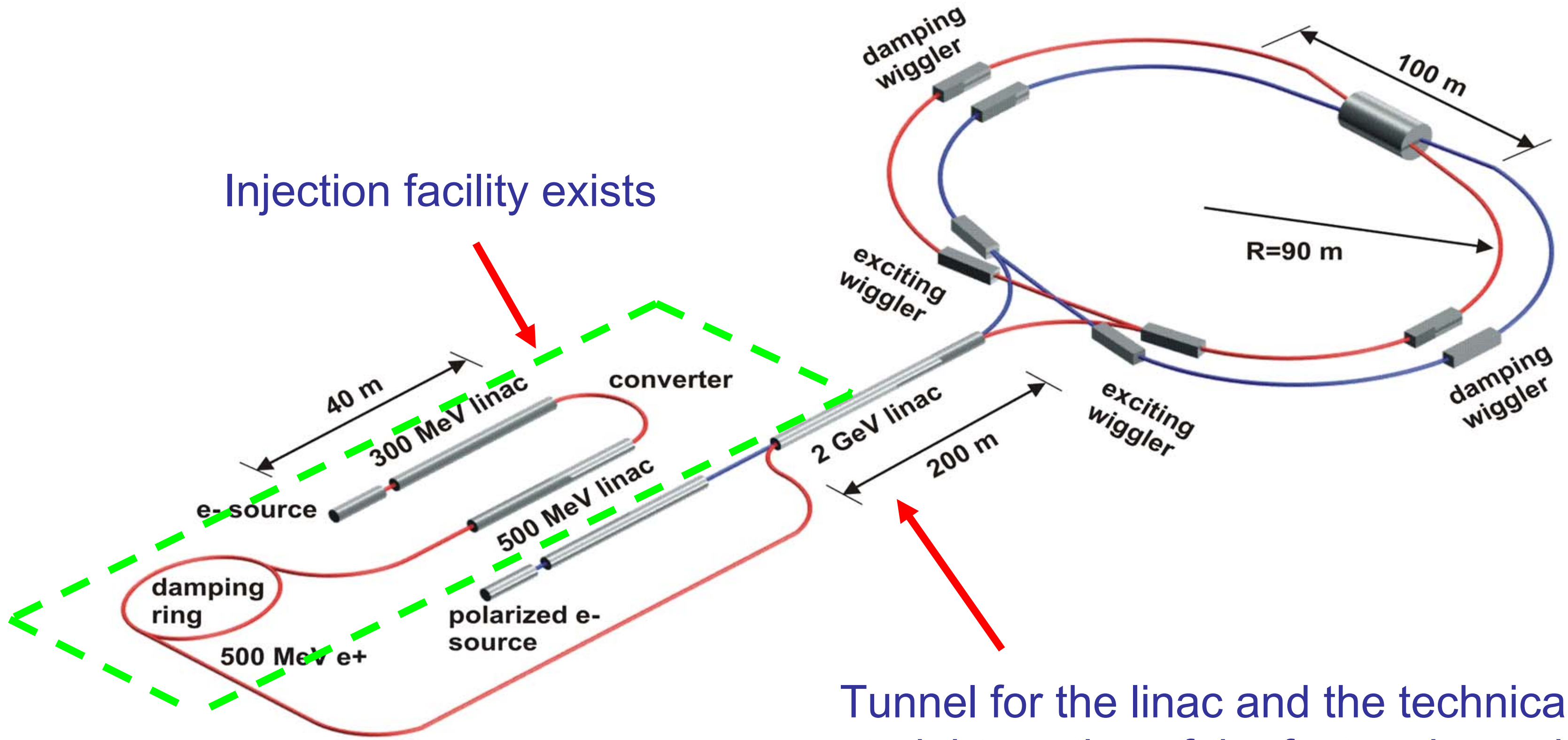
Tau Charm Factory

► Two rings with a single interaction point
► Crab waist collision → extreme importance of the FF design
► Polarized e^- injector and longitudinally polarized electron beam at IP
► Wigglers to keep the same damping and emittance in the whole energy range (optimal luminosity)
► Low emittance arc cell
► A wide adaptation of the existing injection complex, construction facilities (tunnels, halls, etc.) and elements (wigglers, etc.) for cost effectiveness

Both CT project in Novosibirsk and SuperB in Tor-Vergata exploit the Crab waist approach → similar problems and solutions → good background for collaboration

Tau Charm Factory

Injection facility exists



Tunnel for the linac and the technical straight section of the factory is ready

Tau Charm Factory

Energy, GeV	2
Beam current, A	1.36
Number of bunches	295
β_x, mm	20
β_y, mm	0.76
ε_x, nm rad	10
Coupling $\varepsilon_y/\varepsilon_x$, %	1
Beam length σ_z, cm	1
Crossing angle, mrad	34

Tune shift ξ_y	0.13
Particles per bunch	$7 \cdot 10^{10}$
Luminosity, cm^{-2}sec^{-1}	$1 \cdot 10^{35}$
Hour glass $\frac{\sigma_x}{\theta\beta_y}$	1.095
Piwinski angle $\varphi = \frac{\sigma_z\theta}{\sigma_x}$	12.021

- No bend for incoming beam.
- No longitudinal field integral over each final focus lens.
- Longitudinal field is compensated before each final focus lens.
- Interaction region length less than 100 m.
- Place for CRAB sextupole.

- BES-III

BES-III

- No UK involvement.

- Latest iteration of BES at Beijing.
  - US groups joining the effort from CLEO-c
  - Experiment is running at lower resonances at the moment and accruing world class statistics at these.

Expression of Interest

for

Expanded U.S. Participation

in the

Charm Physics Program of BES III

Roy Briere,[1] Dan Cronin-Hennessy,[2] Jim Napolitano,[3]
Ron Poling,[2] Ed Thorndike,[4] and John Yelton[5]

[1]*Carnegie Mellon University*
[2]*University of Minnesota*
[3]*Rensselaer Polytechnic Institute*
[4]*University of Rochester*
[5]*University of Florida*

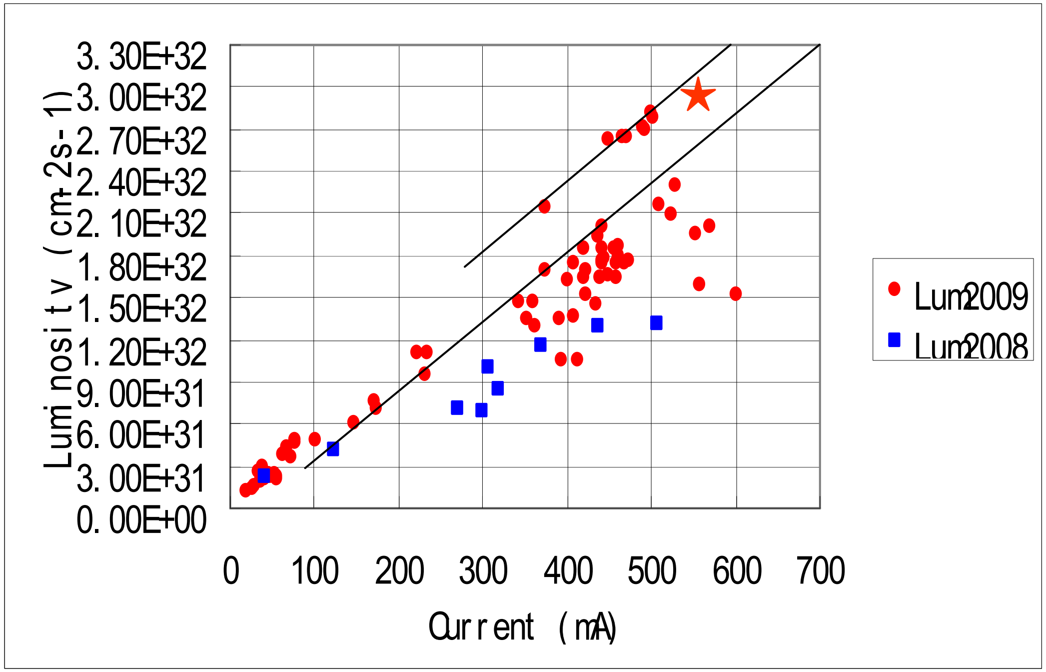
(Dated: September 21, 2007)

Abstract

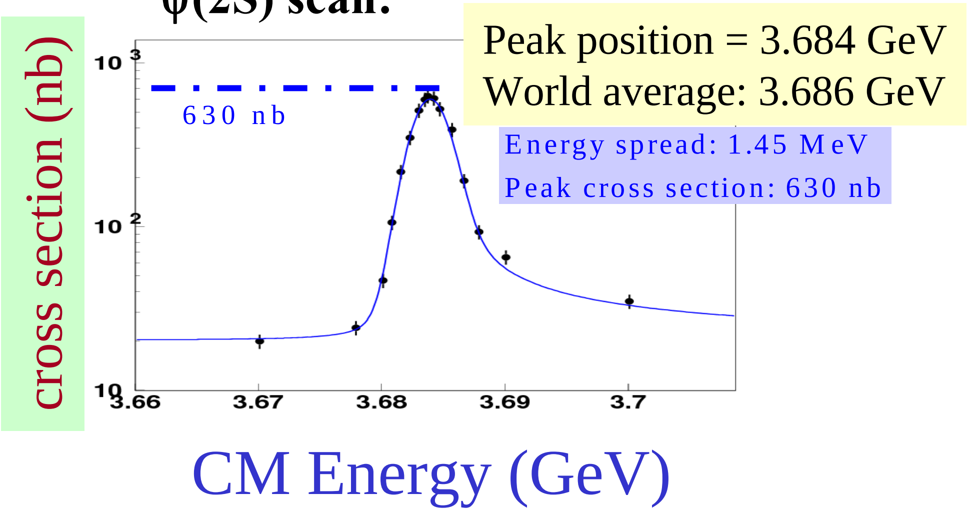
We argue for the physics reach of a program in open charm physics at BES III, and for new opportunities afforded by an expanded US participation. These opportunities are based on the proponents' experience in such physics with the CLEO and CLEO-c experiments at CESR. Specific contributions of this US group are based on a framework of physicists with a long track record of a coherent, mutually beneficial working relationship. Key aspects include Monte Carlo simulations using the Minnesota computing farm; analysis tools developed specifically for D and D_s production near threshold; long experience with reduction of systematic error in such measurements; and physics interests that are largely complementary to those of the current BES III collaboration membership. Future upgrade opportunities are also outlined. We further argue that we can pursue these opportunities by naturally transferring existing resources from CLEO to BES III, insofar as the operating expenses of the individual groups are involved.

BES-III

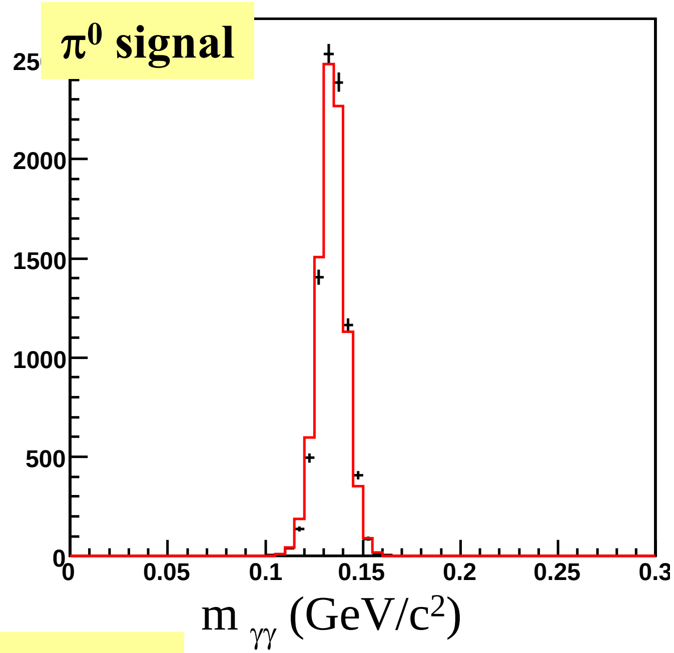
- Accelerator achieved $\mathcal{L}$~3×10^{32}cm^{-1}s^{-2} and is running well.
- Recorded 100M ψ(2S) events.
- J/ψ run started:
  - Aim: 300-500M events

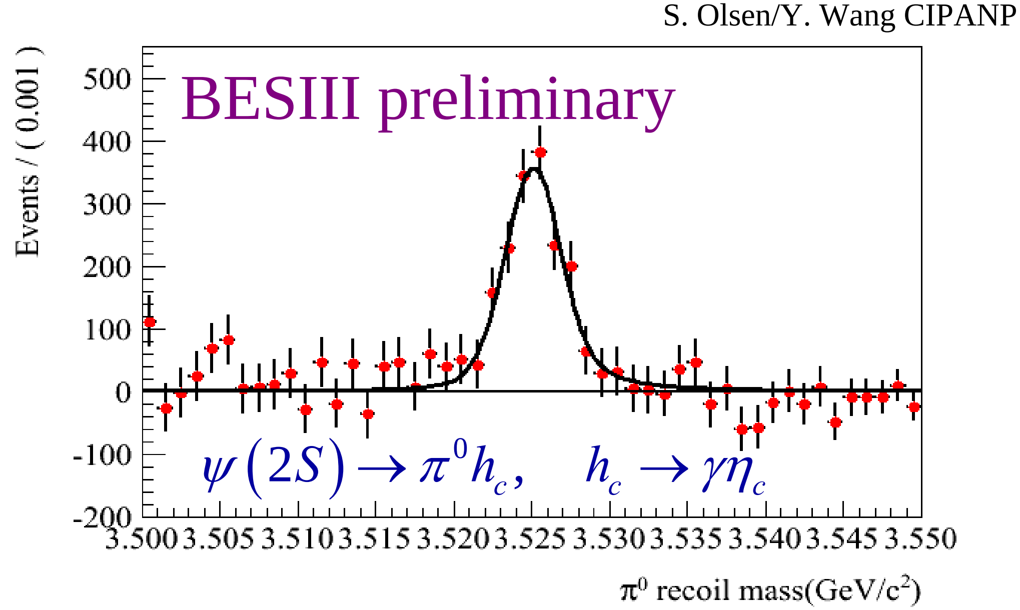


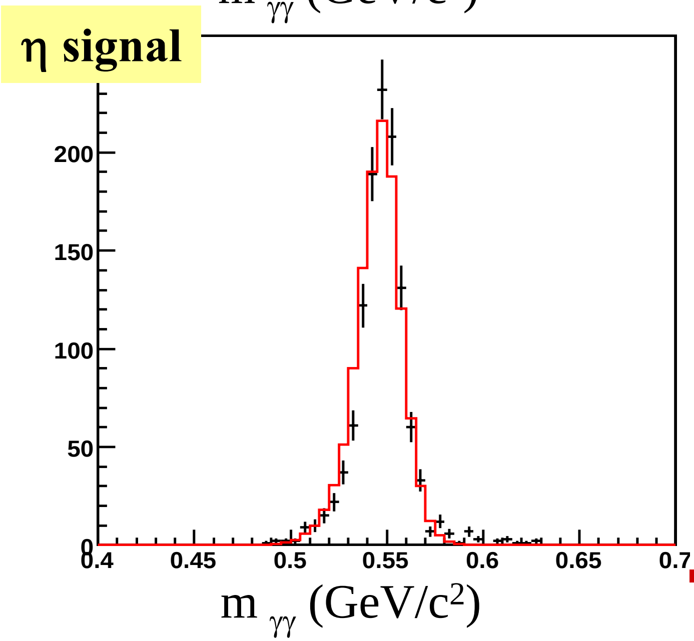
ψ(2S) scan:



BES-III







- Detector working well
  - Mass distributions of π^0, η, Λ, K*, etc. confirm this.
- Physics results starting to appear from 2S data sample.
- Aim to record 20fb^{-1} at $\psi(3770)$, and above $D_s\overline{D}_s$ threshold soon.