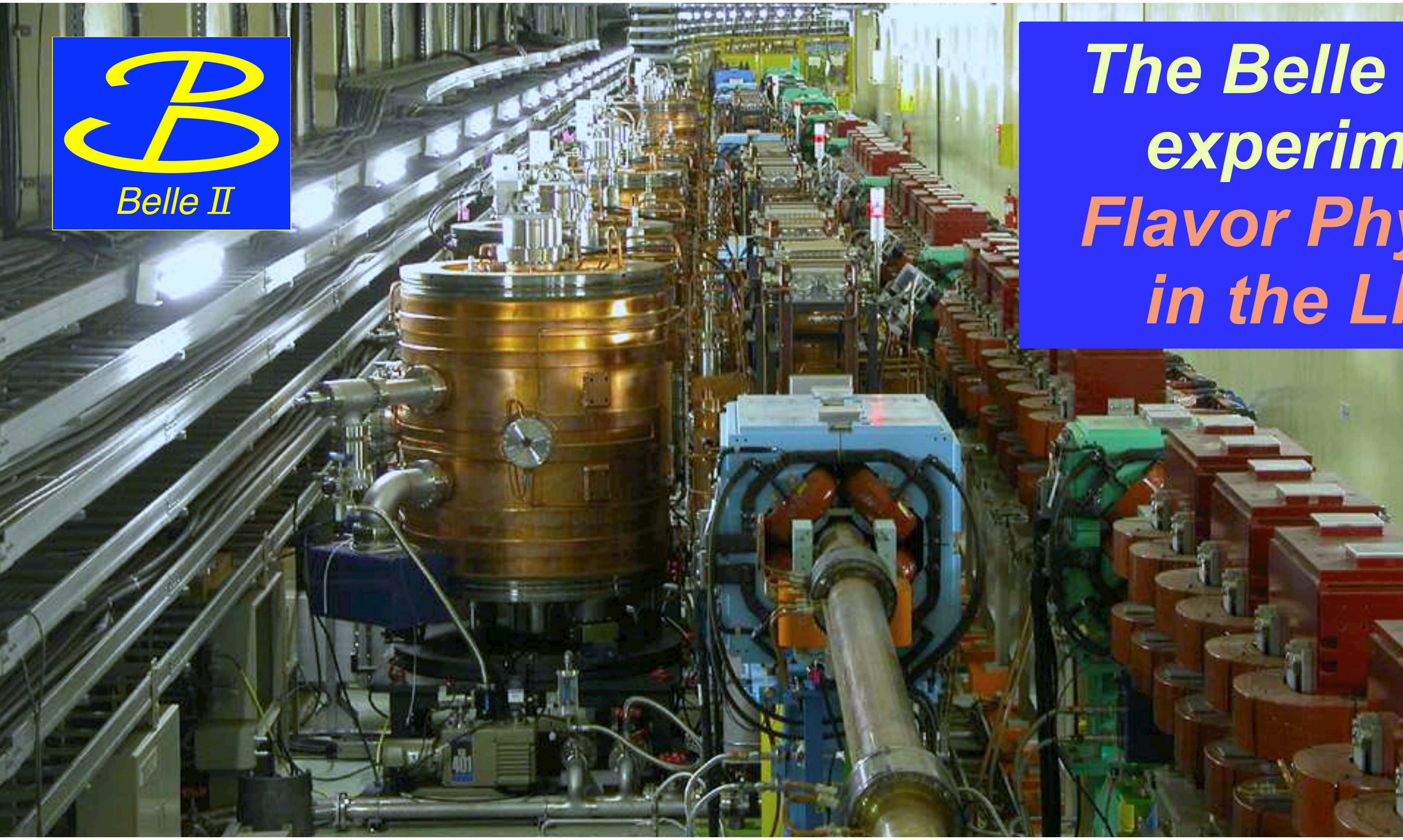


Belle II

The Belle II experiment: Flavor Physics in the LHC Era

Alan Schwartz
University of Cincinnati, USA

LISHEP 2011
4-10 July 2011
Rio de Janeiro

- *physics motivation*
- *the KEKB machine*
- *the Belle II detector*
- *some physics details*
- *schedule, approval, etc.*

Overview I:

Big issues:

- *why $SU(2)_L xU(1)$?*
- *what breaks $SU(2)_L xU(1)$?*
- *what gives particle mass?*
- *what stabilizes the electroweak scale below 1 TeV?*

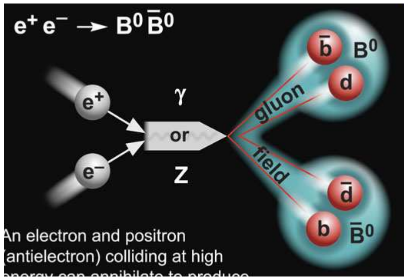
⇒ ***LHC***
(Atlas, CMS)
(i.e., the "energy frontier")

but let's not forget:

- *why 3 generations? (are there more?)*
- *why are the masses so different?*
- *why the pattern of CKM weak couplings?*
- *what causes the phase in the CKM matrix?*
- *why do we live in a matter, rather than antimatter, universe?*

⇒ ***Flavor "factory":***
(CLEO, Belle, BaBar, CDF/D0, BESIII, Belle-II, SuperB, LHCb)
(i.e., a facility where large numbers of heavy quarks (c,b) or leptons (τ) are produced)

Reminder:
solutions to the latter set may help us answer the first set, and vice-versa



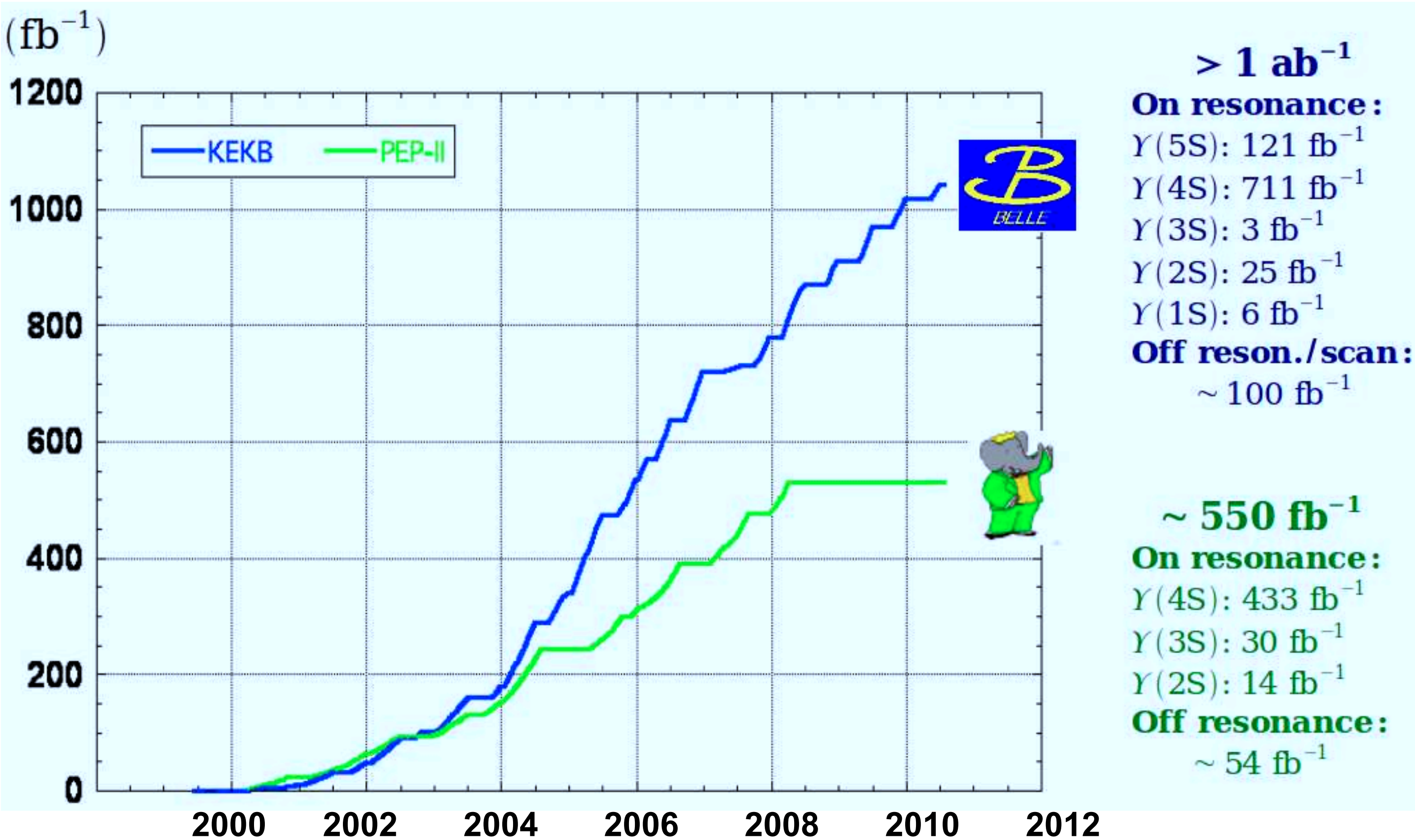
Overview II:

Why a flavor factory is so important:

- *A flavor factory studies processes that occur at 1-loop in the SM but may be O(1) in NP: FCNC, neutral meson mixing, CP violation. These loops probe energy scales that cannot be accessed directly (even at the LHC).*
- *Current experimental bounds NP scale is 10-100 TeV; thus, if the LHC finds NP at O(1) TeV, it must have a nontrivial flavor/phase structure*
- *Even if no new sources of CPV or flavor violation, current SM couplings are sufficient to provide sensitivity to new particles at a super flavor factory*
- *SM CP violation is insufficient to account for baryogenesis of matter-dominated universe; must be other sources of CPV*
- *If supersymmetry is found at the LHC, a crucial question will be: how is it broken. By studying flavor couplings, a flavor factory can address this.*

A (super) flavor factory searches for NP by phases, CP asymmetries, inclusive decay processes, rare leptonic decays, absolute branching fractions. There is a wide range of observables. These are complementary to the LHC Atlas and CMS experiments, which search for NP via direct new particle production at high-p_T.

The Belle+BaBar Era:



Future: Belle-II Goal: *40 x present = 4 x 10^{10} BB pairs* ***...but how to do it?***

How to achieve $L{\sim}10^{36}$? Super-KEKB

$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{y\pm}}{\beta_{y\pm}^*}\left(\frac{R_L}{R_{\xi_y}}\right)$$

- Lorentz factor ($\gamma_\pm$)
- Beam current ($I_\pm$)
- Beam-Beam parameter ($\xi_{y\pm}$)
- Geometrical reduction factors (crossing angle, hourglass effect) (R_L/R_{ξ_y}) ***(0.8-1.0)***
- Vertical beta function at IP ($\beta_{y\pm}^*$)
- Beam aspect ratio at IP (σ_y^*/σ_x^*) ***(0.01-0.02)***

Two options considered:	***I (current)*** *(amps)*	β_y *(mm)*	ξ
High current	***9.4/4.1***	***3/6***	***0.3/0.51***
→ chosen ***Nano-beam*** ***(Raimondi for SuperB)***	***3.6/2.1***	***0.26***	***0.08***
KEKB achieved	***1.8/1.45***	***6.5/5.9***	***0.11/0.06***

The KEKB Machine

Decision: nano-beam option

- *For high current scheme, $\xi \propto \sqrt{(\beta^*/\varepsilon)}$= 0.3 looked hard (KEKB achieved 0.1)*
- *No solution was found for IR design to realize β^*_x=20 cm.*
- *Bunch length could not be reduced to 3mm because of the coherent synchrotron radiation.*
- *Higher operating costs.*

Nano-beams design:

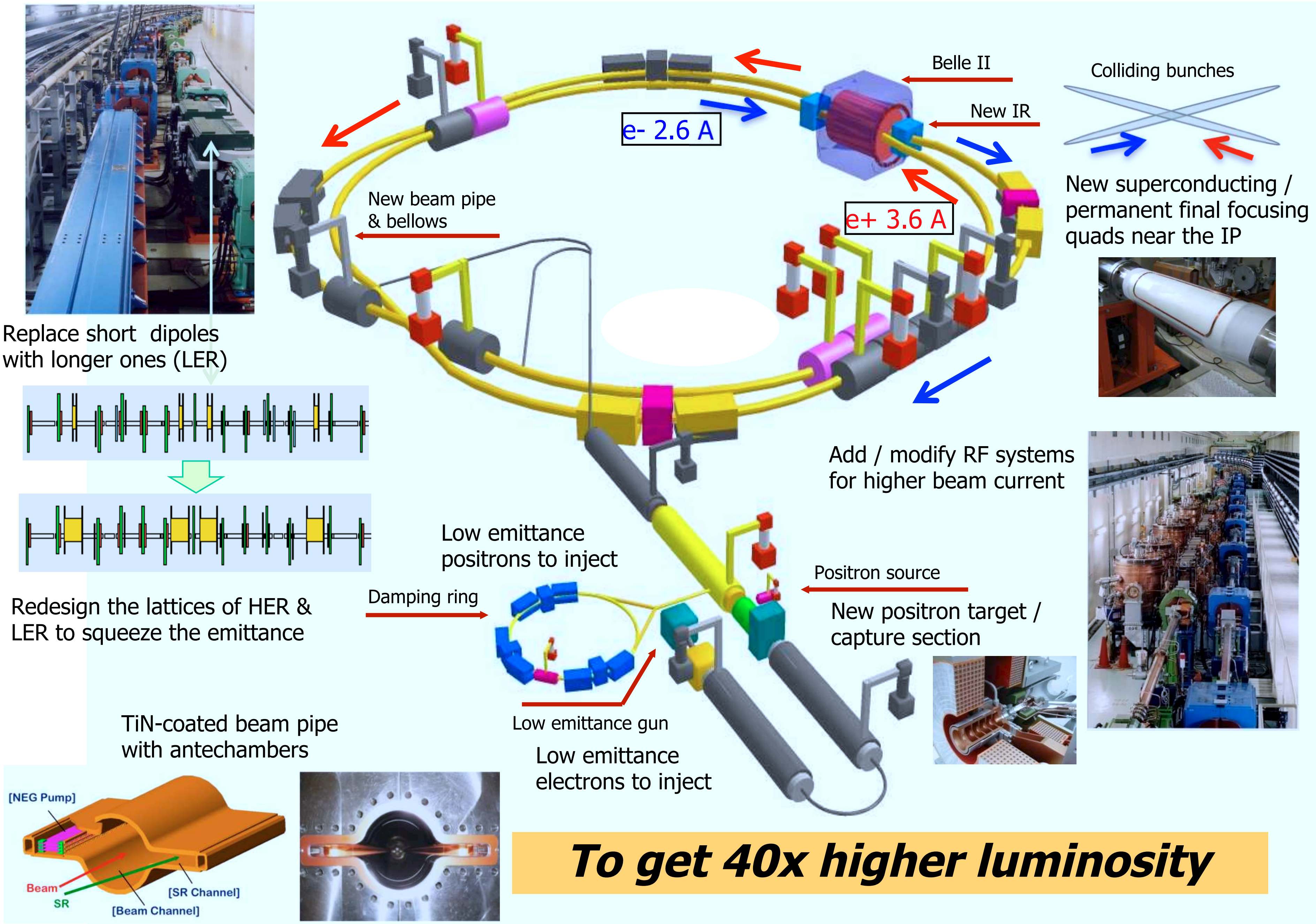
- *Small beta function at IP (x 1/20): horiz: 1200→32/25mm vert.: 5.9→0.27/0.42mm beam size 100μm(H) x 2μm(V) → 10μm(H) x 59nm(V)*
- *Crab waist is considered as an option (but current KEKB machine optics diminishes impact)*
- *For such small β, two final-Q magnets in both L/R sides are needed*
- *To put final-Q magnets closer to IP, increase crossing angle 22→ 83 mrad. (Use crab cavities to recover L)*
- *For acceptable dynamic aperture, reduce energy asymmetry to 7 GeV x 4 GeV*

Super-KEKB Parameters

	KEKB Design	KEKB Achieved : with crab	SuperKEKB High-Current	SuperKEKB Nano-Beam
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	3.5/8.0	4.0/7.0
β_x^* (cm)	100/100	120/120	20/20	3.2/2.5
β_y^* (mm)	10/10	5.9/5.9	3/6	0.27/0.42
ε_x (nm)	18/18	18/24	24/18	3.2/1.7
σ_y(μm)	1.9	0.94	0.85/0.73	0.059
ξ_y	0.052	0.129/0.090	0.3/0.51	0.09/0.09
σ_z (mm)	4	~ 6	5/3	6/5
I_{beam} (A)	2.6/1.1	1.64/1.19	9.4/4.1	3.6/2.6
$N_{bunches}$	5000	1584	5000	2500
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	53	80

Belle II

KEKB → SuperKEKB (nano-beam)



Detector Upgrade:

Challenges:

Higher background (×20), higher event rate (×10)

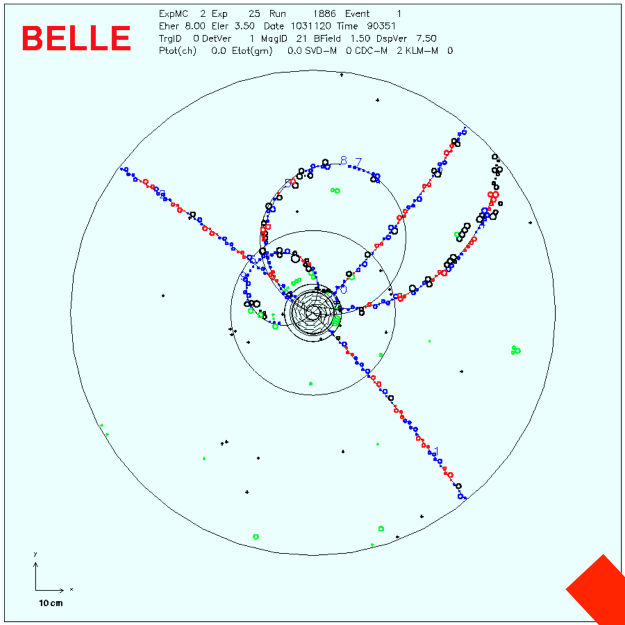
- ***radiation damage and occupancy***
- ***fake hits and pile-up noise in the EM***

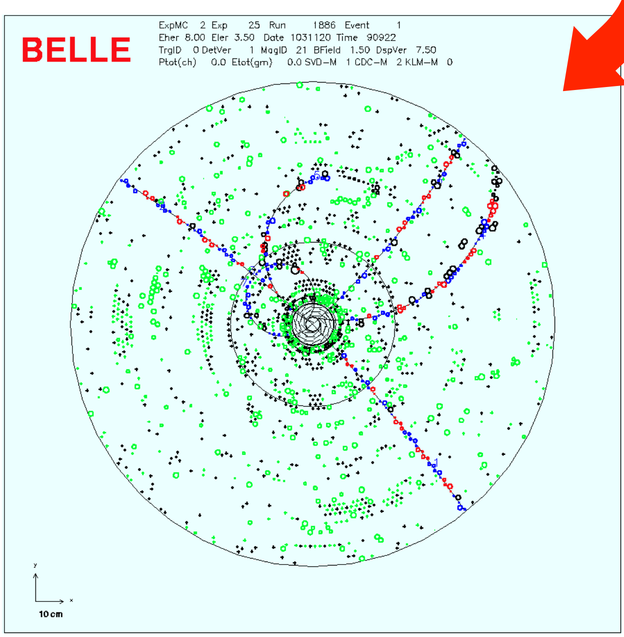
Targeted improvements:

- ***Increase hermiticity***
- ***Increase K_S efficiency***
- ***Improve IP and secondary vertex resolution***
- ***Improve π/K separation***
- ***Improve π^0 efficiency***
- ***Add PID in endcaps***
- ***Add μ ID in endcaps***

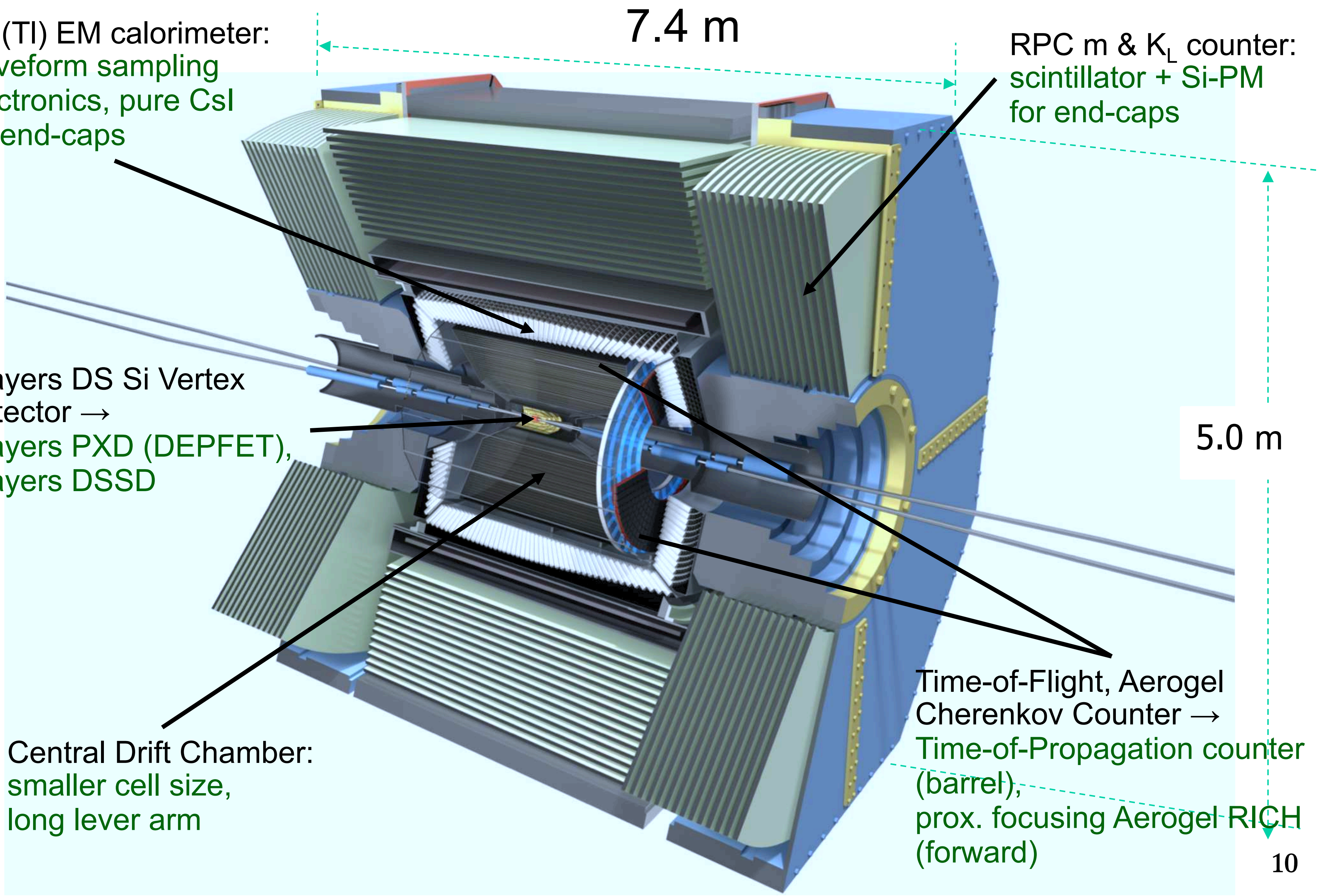
Detector Choices:

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



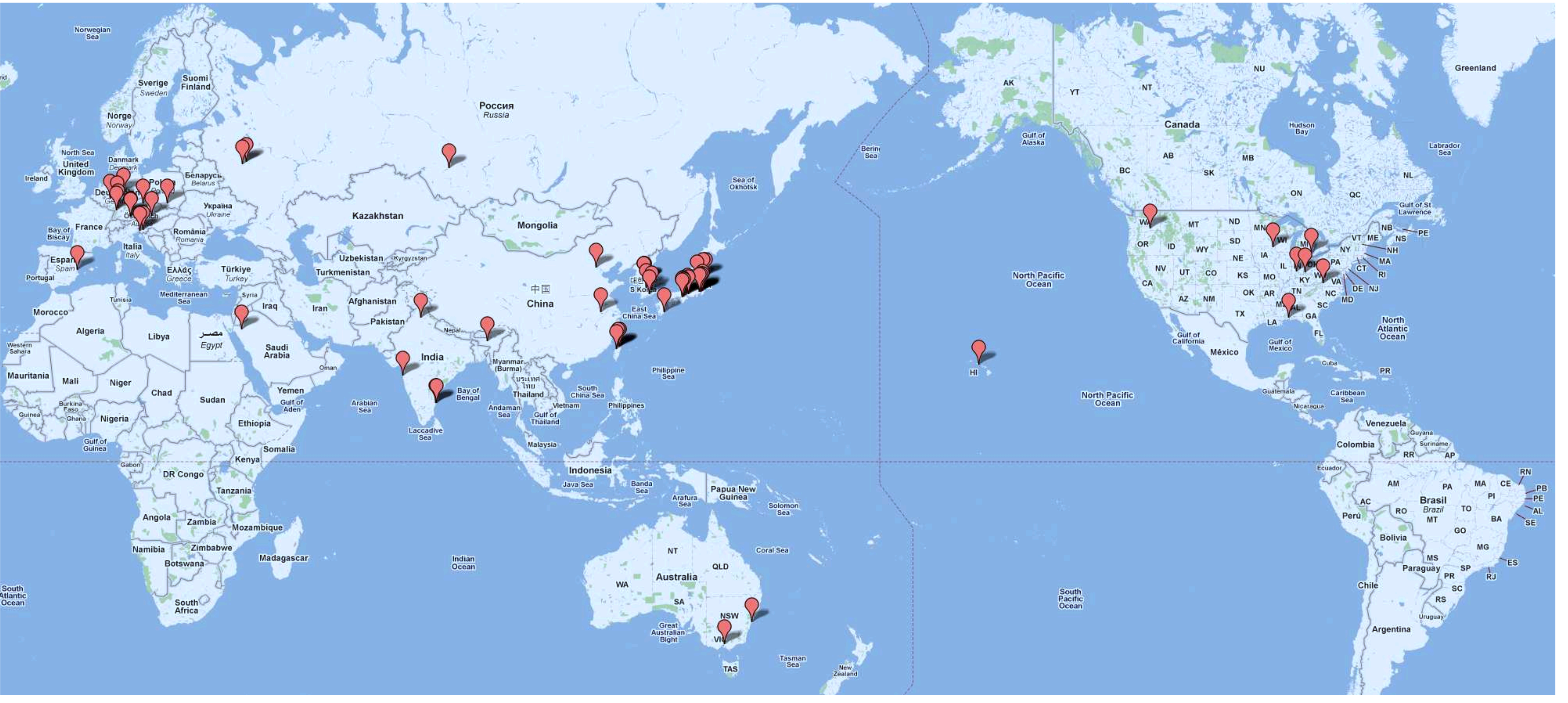


The Belle II Detector:



The Belle II Collaboration

http://belle2.kek.jp



15 countries/regions, 60 institutions

~400 collaborators,
~150 from Europe

The Belle II Collaboration

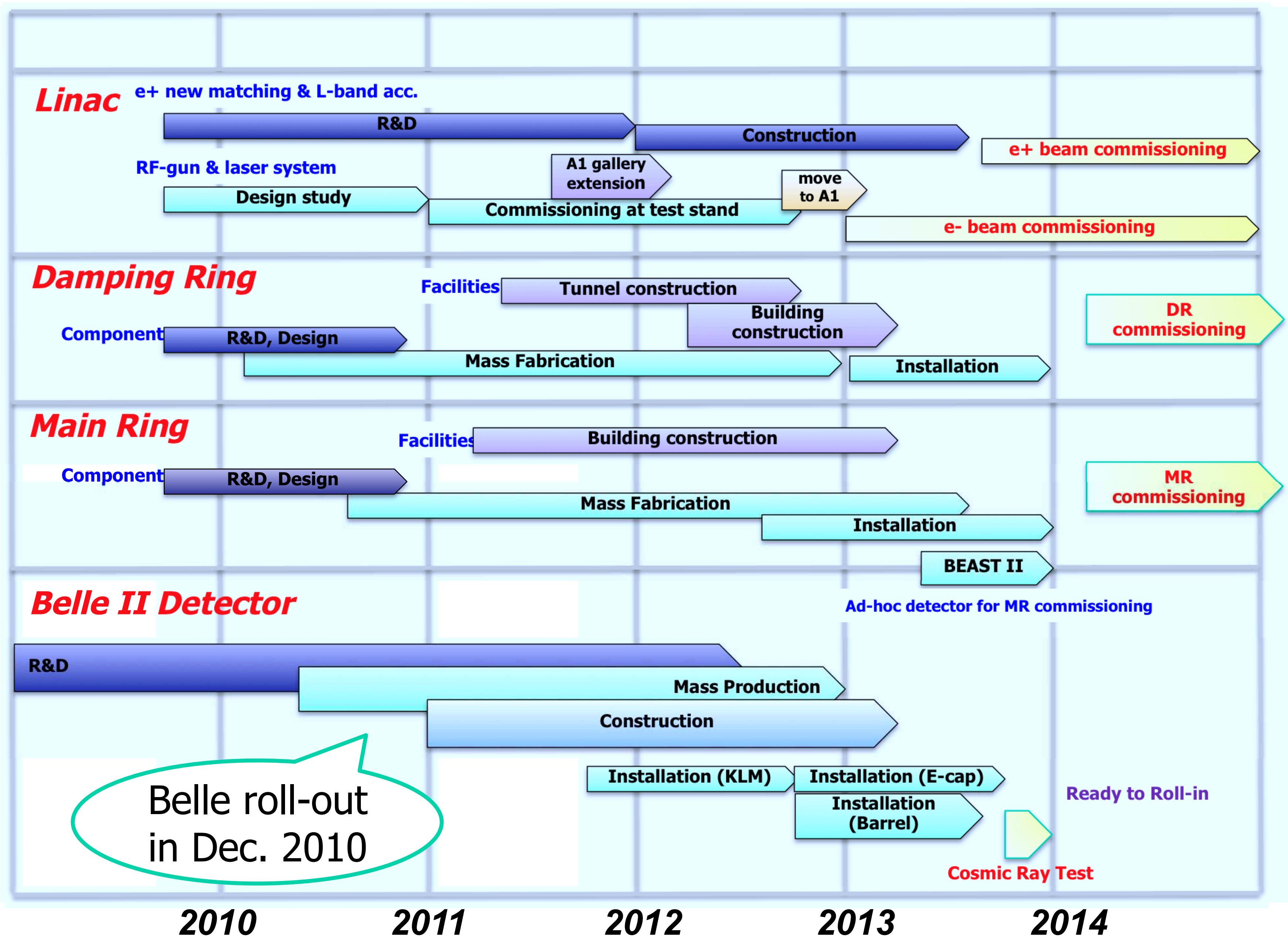
June 2004: LoI for SuperKEKB
January 2008: KEK Roadmap → identified as high priority project at KEK
December 2008: New collaboration (Belle-II) officially formed

November 2009: 4th Open Collaboration Meeting
March 2010: 5th Open Collaboration Meeting
July 2010: 6th Open Collaboration Meeting
November 2010: 7th Open Collaboration Meeting
~~April 2011: 8th Open Collaboration Meeting~~ *canceled*
➡ July 2011: 8th Open Collaboration Meeting
November 2011: 9th Open Collaboration Meeting and SuperKEKB groundbreaking

Separate group/organization from Belle

- Executive Board (Chair: H. Aihara)
- Spokesperson: P. Križan
  Project manager: M. Yamauchi
- Institutional Board (Chair: Eunil Won)
- Physics coordinator: B. Golob
- Technical coordinator: Y. Ushiroda
- Software /computing coordinators: T. Hara / T. Kuhr

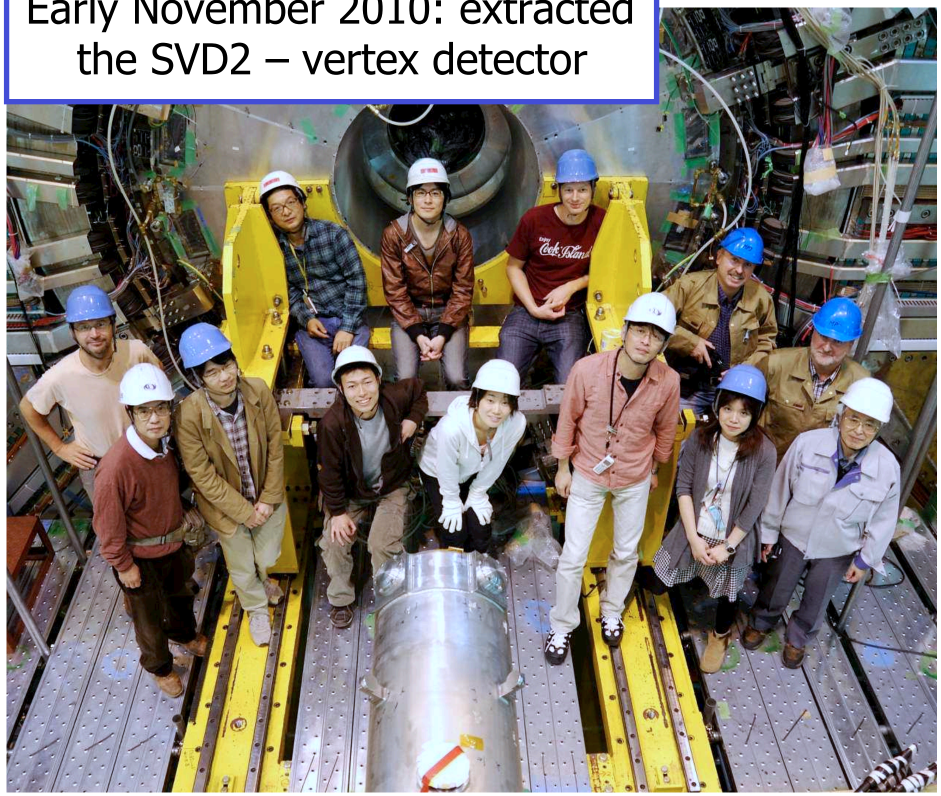
Schedule:

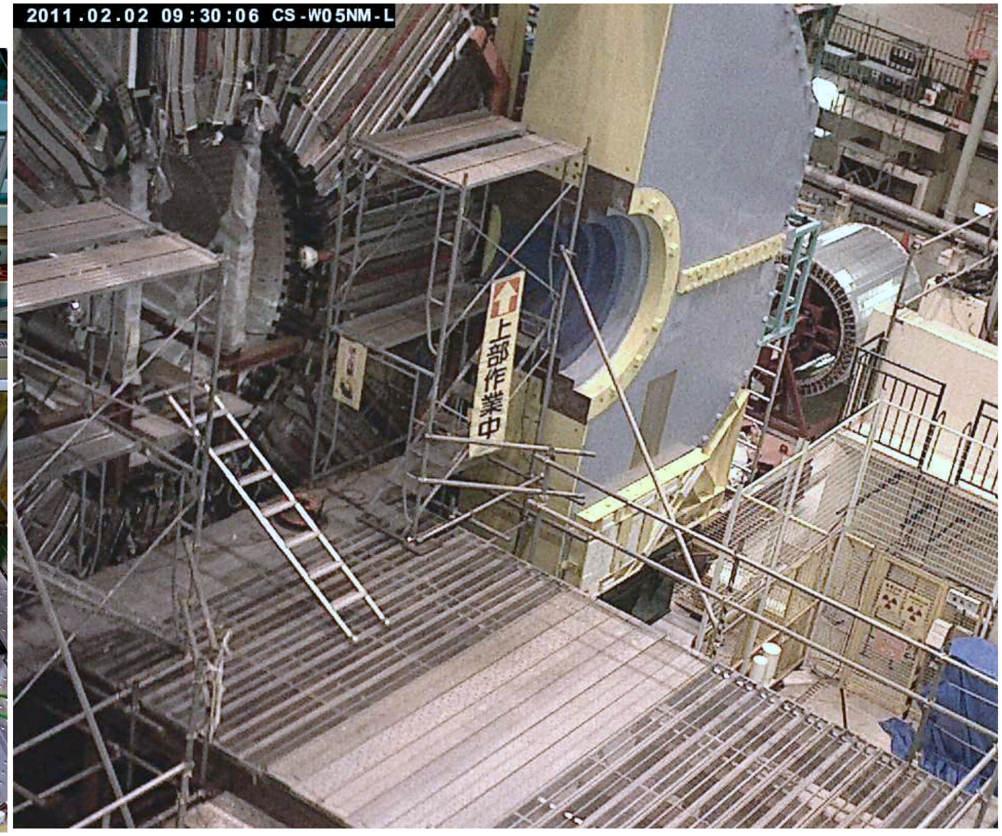


Linac
e+ new matching & L-band acc.
R&D
Construction
e+ beam commissioning
RF-gun & laser system
A1 gallery extension
move to A1
Design study
Commissioning at test stand
e- beam commissioning
Damping Ring
Facilities
Tunnel construction
Building construction
DR commissioning
Component
R&D, Design
Mass Fabrication
Installation
Main Ring
Facilities
Building construction
Component
R&D, Design
MR commissioning
Mass Fabrication
Installation
BEAST II
Ad-hoc detector for MR commissioning
Belle II Detector
R&D
Mass Production
Construction
Installation (KLM)
Installation (E-cap)
Installation (Barrel)
Ready to Roll-in
Cosmic Ray Test
Belle roll-out in Dec. 2010
2010
2011
2012
2013
2014

De-installing Belle, making space for Belle II:

Early November 2010: extracted the SVD2 – vertex detector

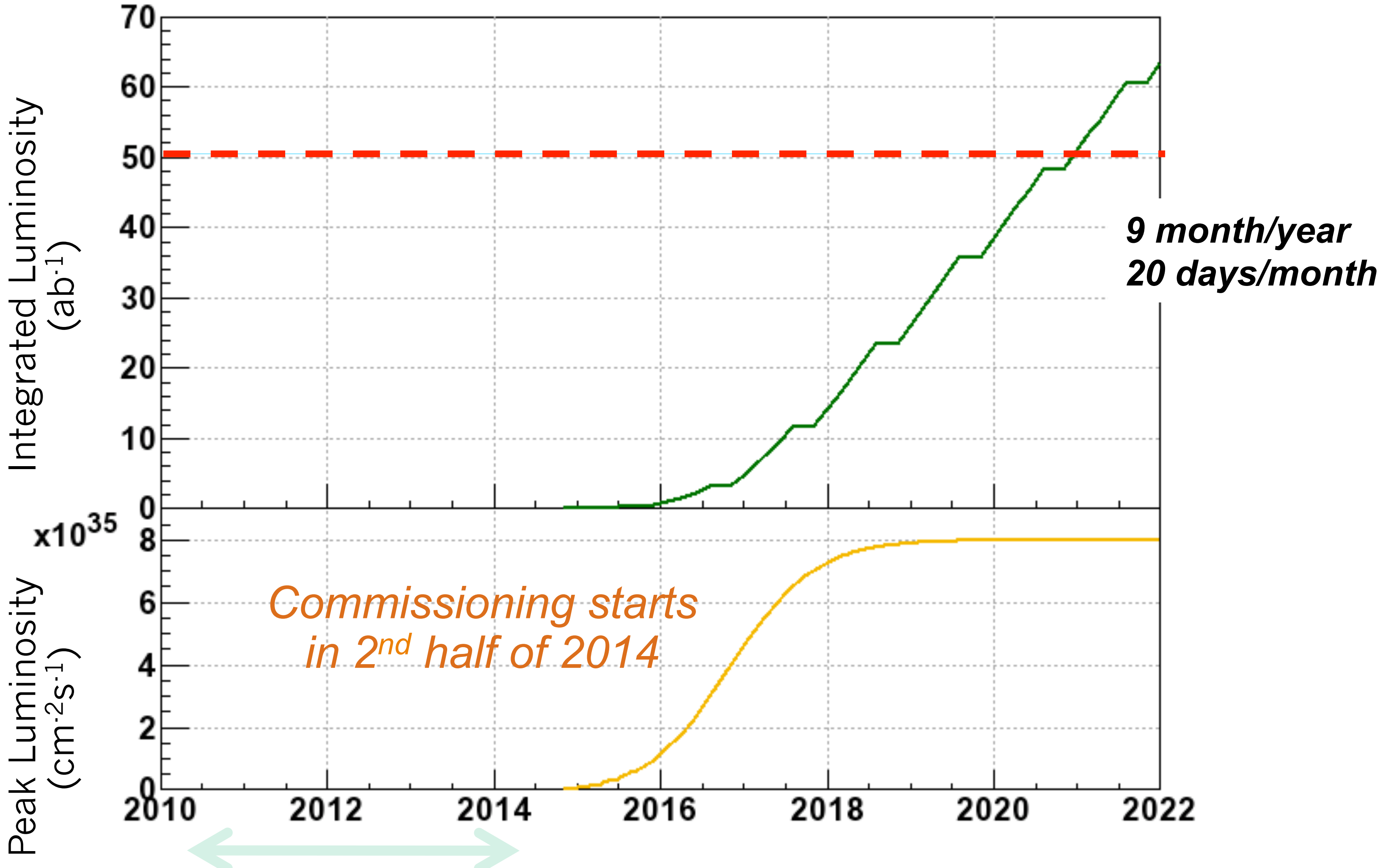




Belle Detector Roll-out: Dec. 9, 2010
End-caps, CDC, B-ACC, TOF extraction: end of Jan. 2011
Ready for new construction to start…

Luminosity prospects:

- *4-year shut-down for upgrade of the accelerator and detector*
- *Start machine operation in 2014*
- *We plan to reach 50 ab^{-1} in 2020-2021*



Belle II approval + funding status:

- The KEKB upgrade was fully approved by the Japanese government in December 2010. The project is in the JFY2011 budget as approved by the Japanese Diet at the end of March 2011

- \$32M were allocated for detector R&D in FY2009; \$6M were allocated for the damping ring in FY2010; and \$110M have been allocated for the machine in FY2011 (Very Advanced Research Support Program)

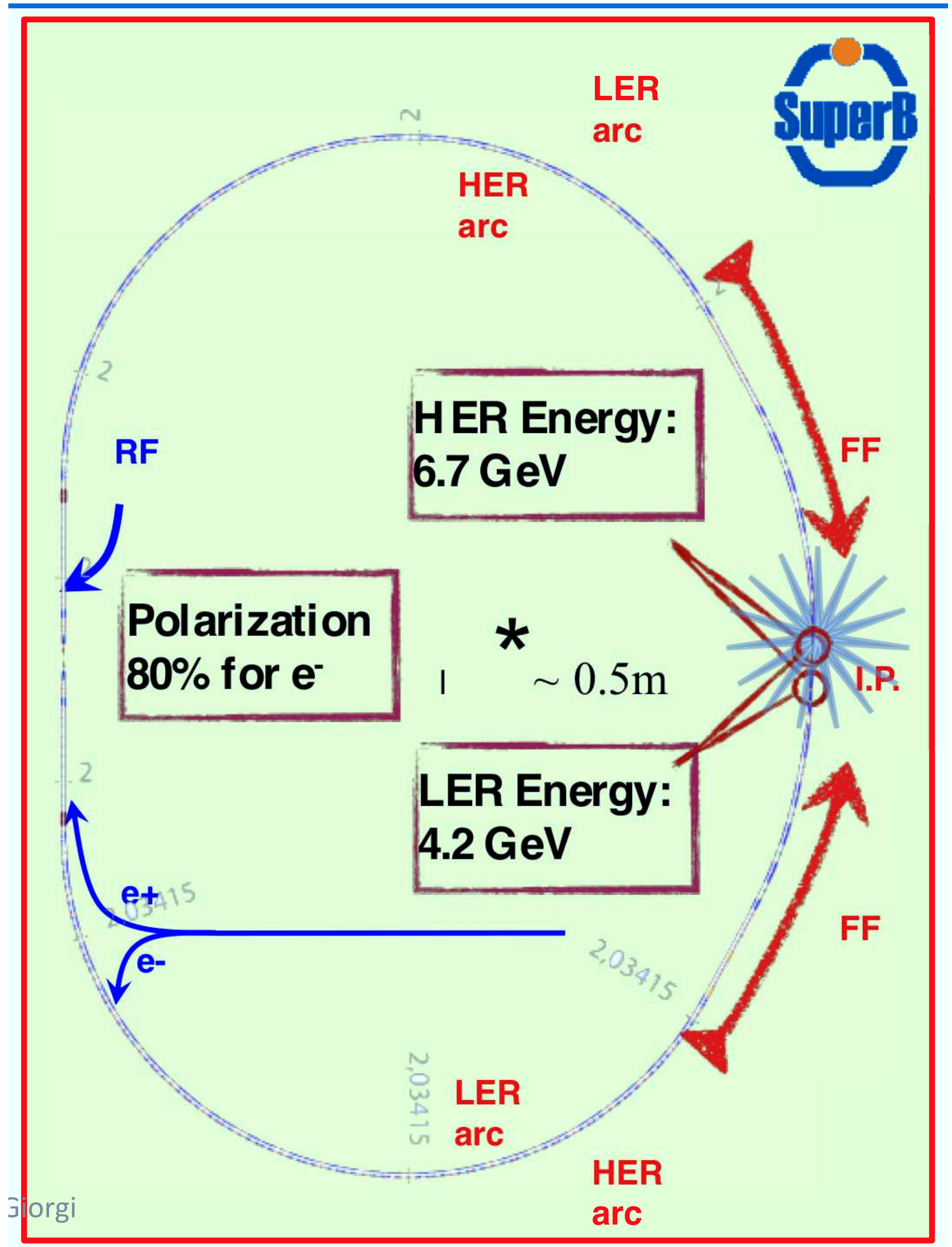
- Super-KEKB and Belle-II are priorities of KEK

- Several non-Japanese funding agencies have already budgeted sizable funds for the upgrade (Germany, Russia, Korea). The US DOE has declared Belle II to be their priority project for e^+e^- physics.

Belle II is not the only future super-B factory...

- **SuperB** was approved by the Italian government in December 2010
- Tor Vergata has been chosen as the site
- First collisions are expected by middle 2016

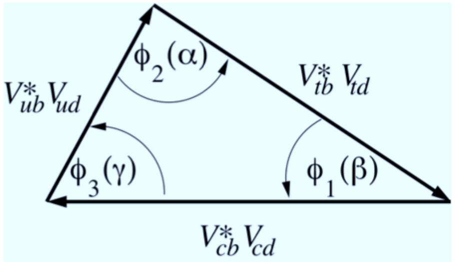
Quantity	Parameter
Peak luminosity	$>10^{36}$
Integrated luminosity	>75 ab^{-1}
Polarization (e^- beam)	80%
Low energy running	10^{35} at charm thresh
e^+/e^- energies	6.7 GeV/4.8 GeV
σ_x (e^+/e^-)	60 μm/66.5 μm
σ_y (e^+/e^-)	2.4 μm/2.6 μm
I (e^+/e^-)	1892 mA/2447 mA



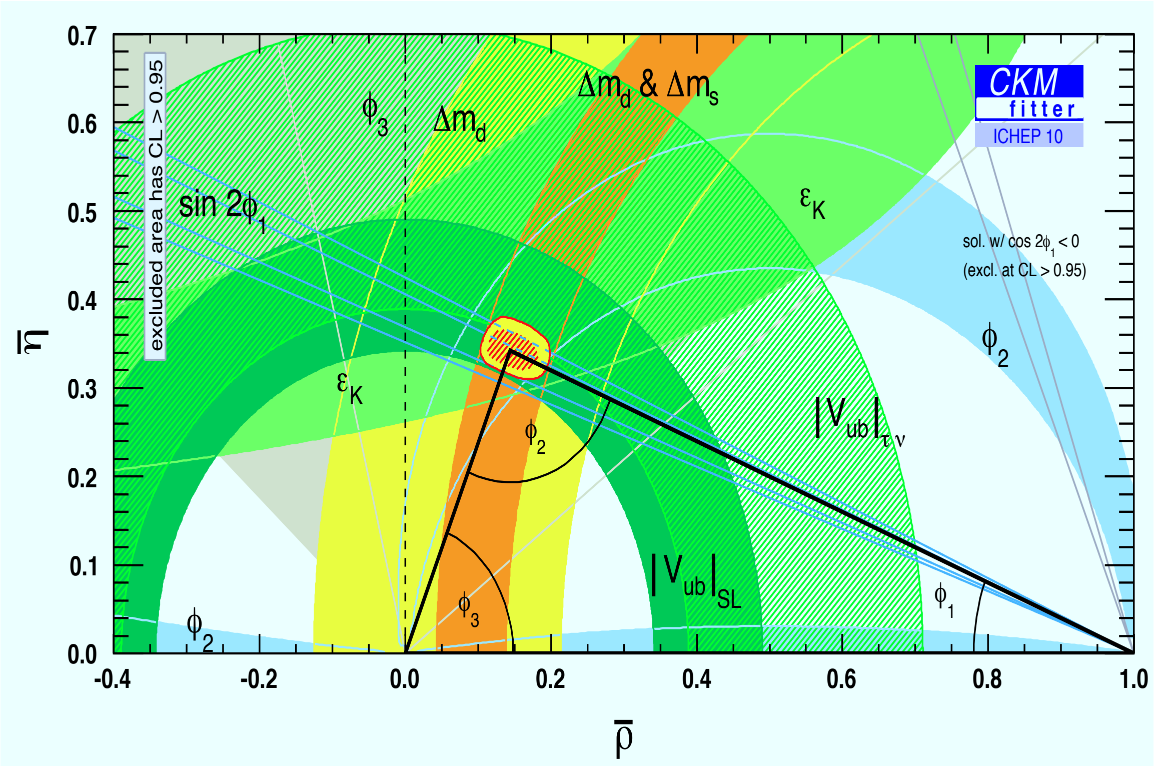
Physics Program

For Belle II details see: arXiv:1002.5012

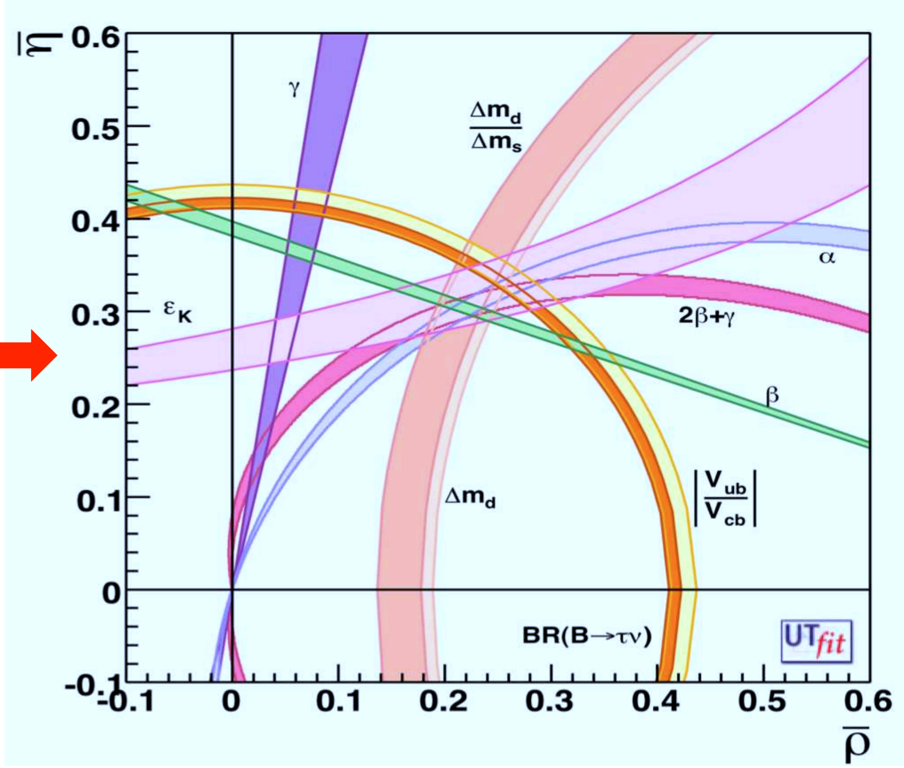
A main physics goal is to substantially reduce the uncertainties on the CKM UT triangle



Today:



Super B factory (75 fb[-1]):



Broad Physics Program:

M. Giorgi, ICHEP 2010:

B Physics @ 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)	$\sim 15°$	2.5°
γ $(B \to DK, D \to$ suppressed states)	$\sim 12°$	2.0°
γ $(B \to DK, D \to$ multibody states)	$\sim 9°$	1.5°
γ $(B \to DK$, combined)	$\sim 6°$	1–2°
α $(B \to \pi\pi)$	$\sim 16°$	3°
α $(B \to \rho\rho)$	$\sim 7°$	1–2° (∗)
α $(B \to \rho\pi)$	$\sim 12°$	2°
α (combined)	$\sim 6°$	1–2° (∗)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^{\mp}, D^{\pm}K^0_s\pi^{\mp})$	20°	5°

Observable	B Factories (2 ab^{-1})	Super$B$ (75 ab^{-1})
$\|V_{cb}\|$ (exclusive)	4% (∗)	1.0% (∗)
$\|V_{cb}\|$ (inclusive)	1% (∗)	0.5% (∗)
$\|V_{ub}\|$ (exclusive)	8% (∗)	3.0% (∗)
$\|V_{ub}\|$ (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

Charm mixing and CPV

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}	
	$\|q/p\|$	3×10^{-2}	
	ϕ	2°	
$\psi(3770) \to D^0\overline{D}^0$	x^2		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

B_s Physics @ 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
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\|V_{td}/V_{ts}\|$	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°

+ τ decays, rare D decays, D_{sJ}, X, Y, Z studies, etc.

Belle II

Competitiveness with LHCb:

Experiment: No Result (red) | Moderate Precision (yellow) | Precise (blue) | Very Precise (green)

Theory: Moderately clean (yellow) | Clean Need lattice (blue) | Clean (green)

SuperB Physics Group

Observable/mode	Current (now)	LHCb (2017)	SuperB (2021)	LHCb upgrade ')	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: Ang. analysis with >75ab^{-1}
S in $B \to K^0_S\pi^0\gamma$	yellow	red	green	red	yellow	Right handed currents
S in 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
$BR(B \to X_s\ell\ell)$	yellow	red	green	red	green	
$BR(B \to K^{(*)}\ell\ell)$	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	red	green	red	green	
D Decays						
mixing parameters	yellow	blue	green	green	green	
CPV	red	blue	green	green	green	Clean NP search
Precision EW						
$\sin^2\theta_W$ 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

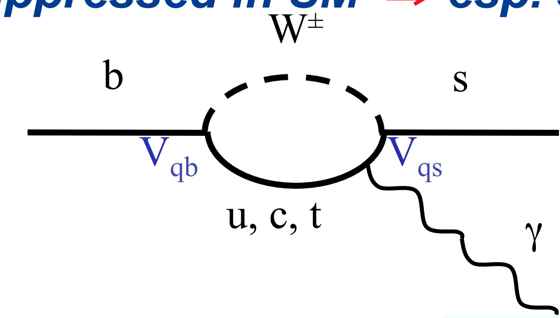
June 27,2011

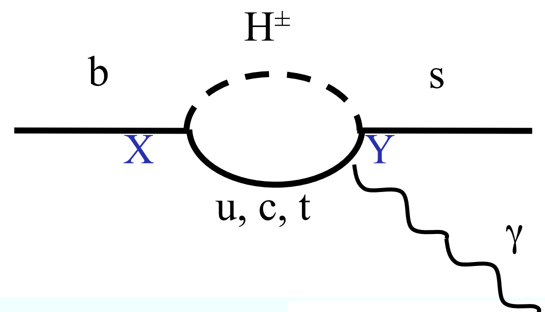
M.A.Giorgi

9

Measuring a charged Higgs: $b \rightarrow s\gamma$

1-loop suppressed in SM $\Rightarrow$ esp. sensitive to NP:





95% C.L. lower limit on $m(H^{\pm})$, all $\tan\beta$

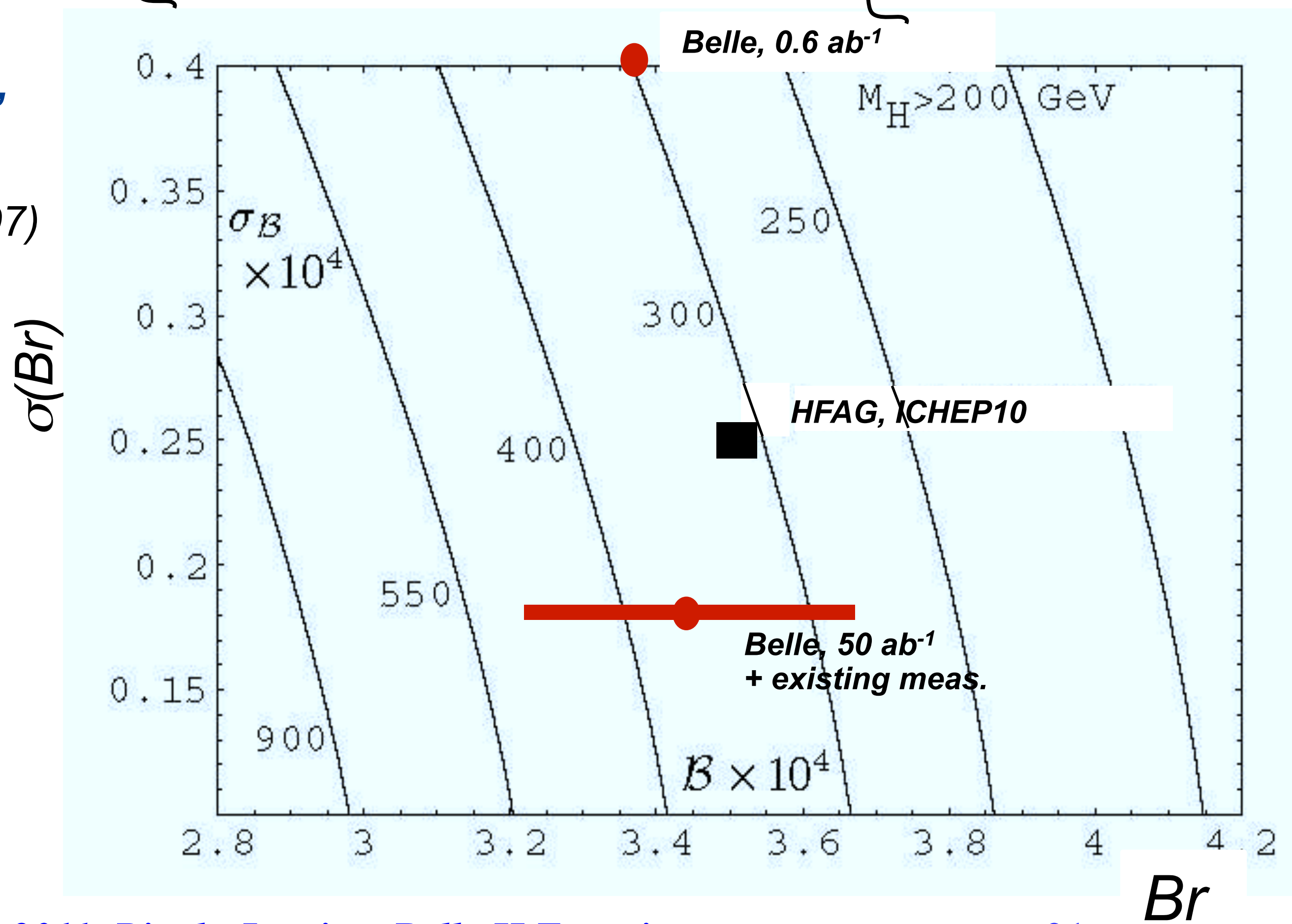
Misiak et al., PRL 98, 022002 (1997)

Current HFAG WA

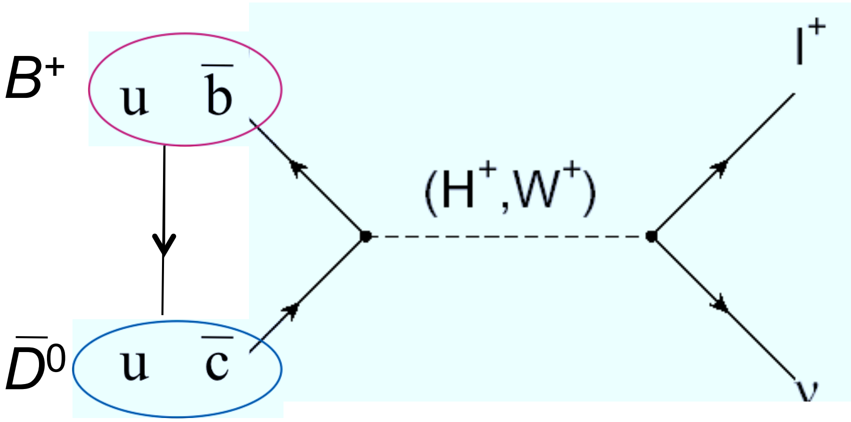
$\mathcal{B}(B \rightarrow X_s\gamma) = (3.55 \pm 0.25) \times 10^{-4} \Rightarrow$

$m_{H+} > 300$ GeV (95% CL) for all $\tan\beta$

(complementary to hadron colliders)

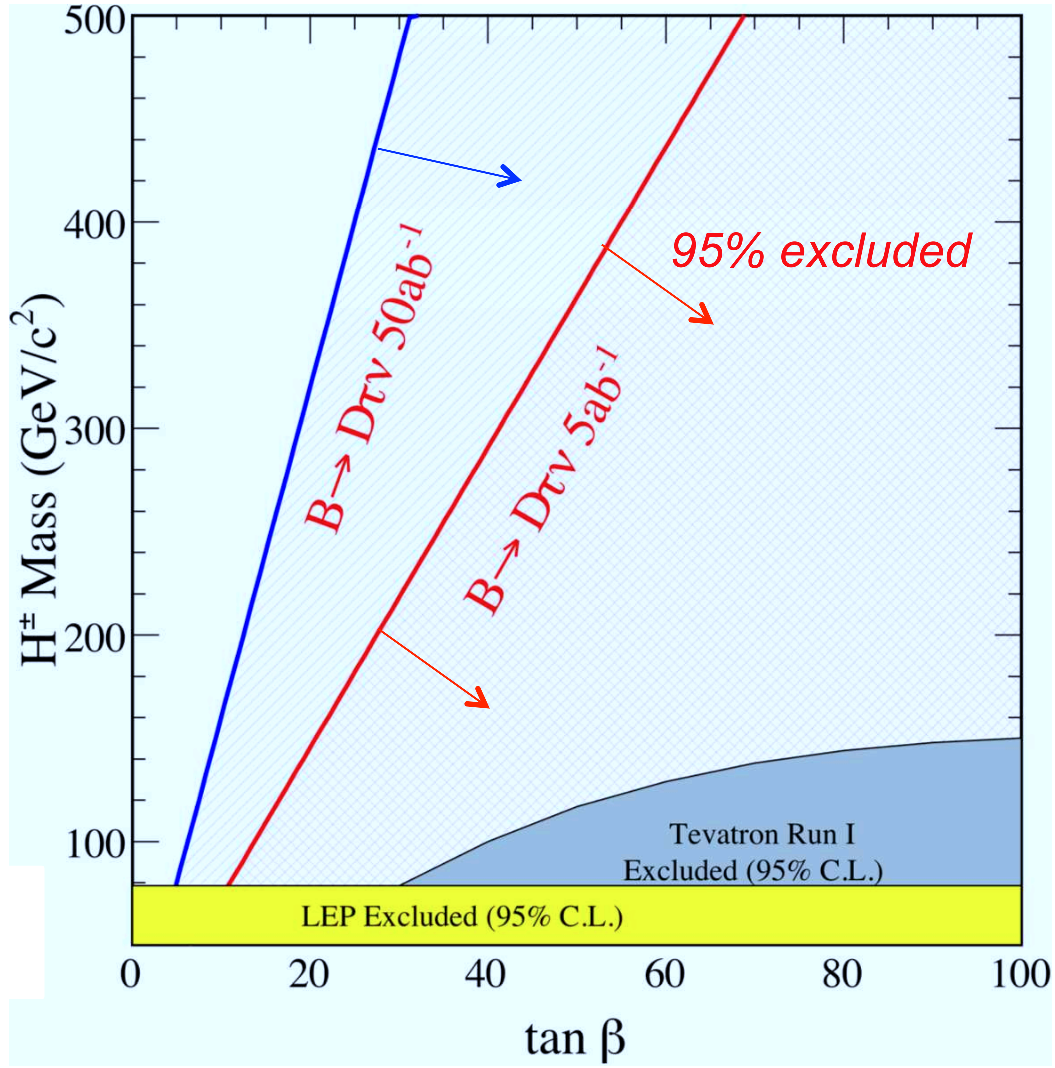


Measuring a charged Higgs: $B \to D\ell^+\nu$



2-Higgs doublet model:

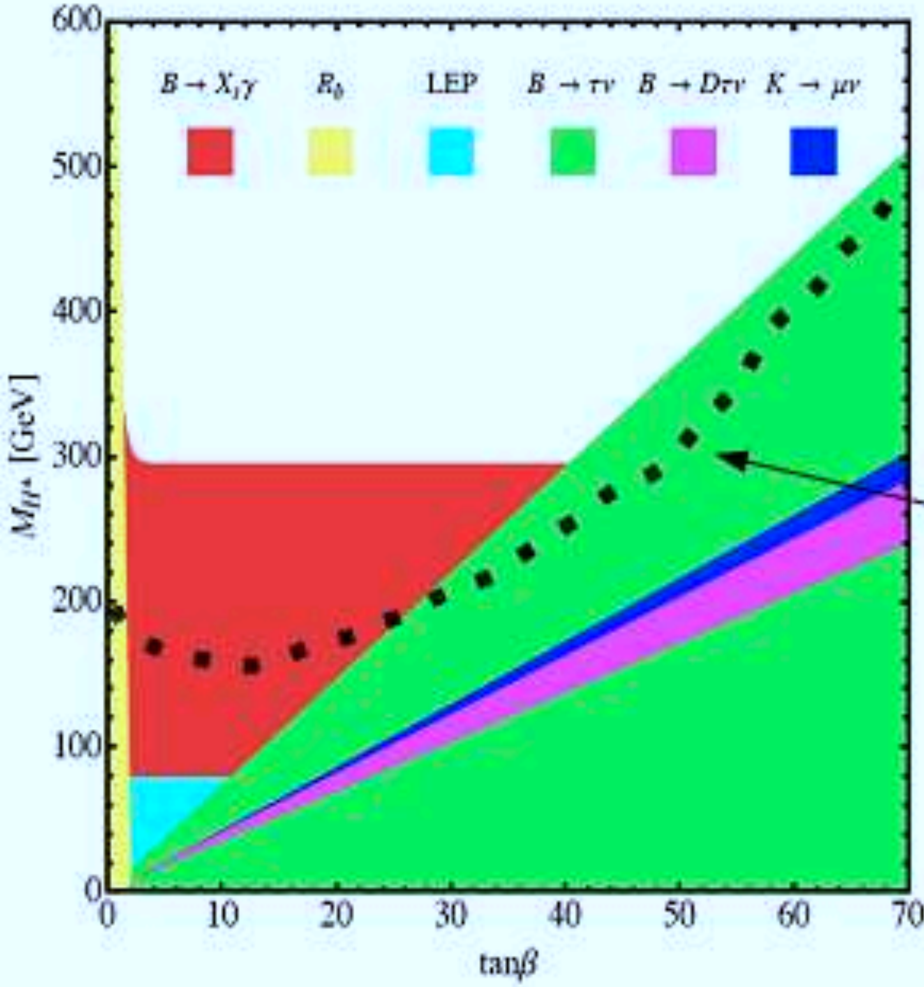
Buchalla et al., EPJC 57, 309 (2008); arXiv:0801.1833



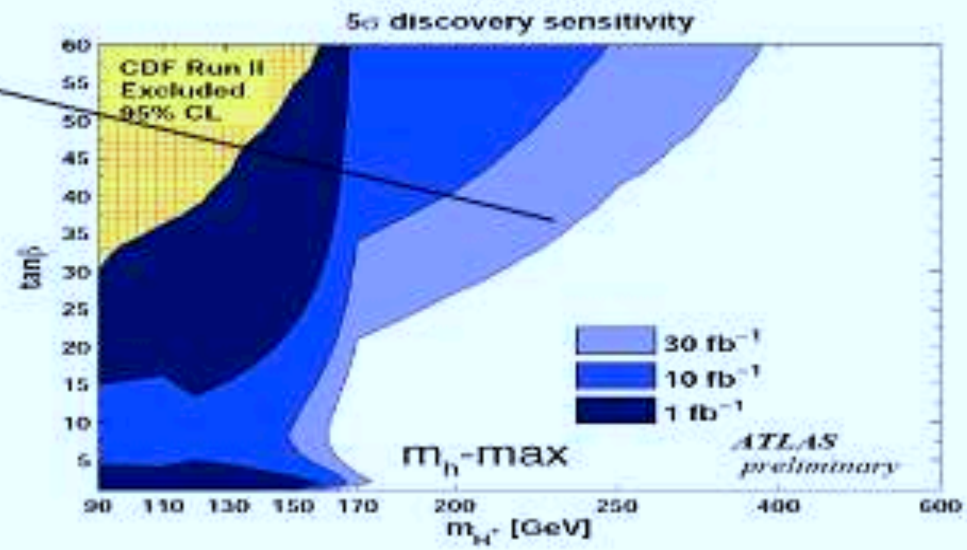
⇒ *Much of LHC H+ mass range covered (can be excluded) for large tanβ*

Measuring a charged Higgs: $B^+ \to \tau^+ \nu$

Haisch, arXiv:0805.2141, Atlas curve added by S. Roberton:



Current flavour constraints are complementary (and competitive) with LHC expected direct search sensitivity for charged Higgs



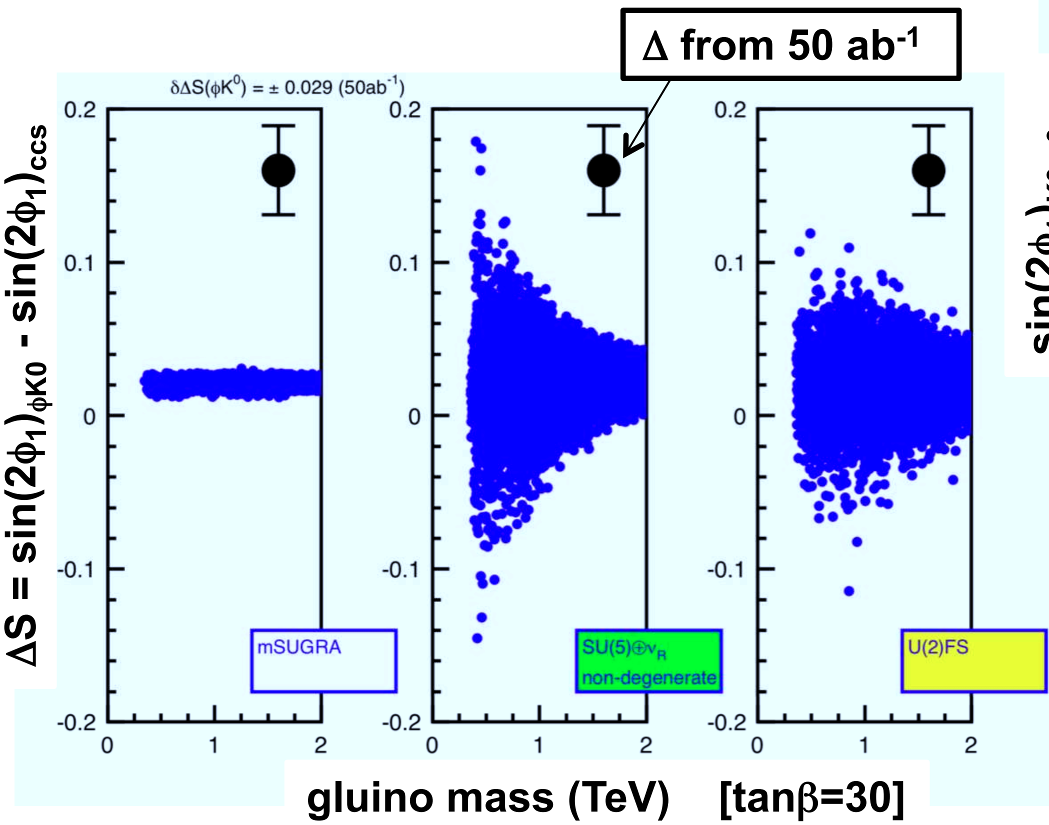
Determining how Supersymmetry is broken

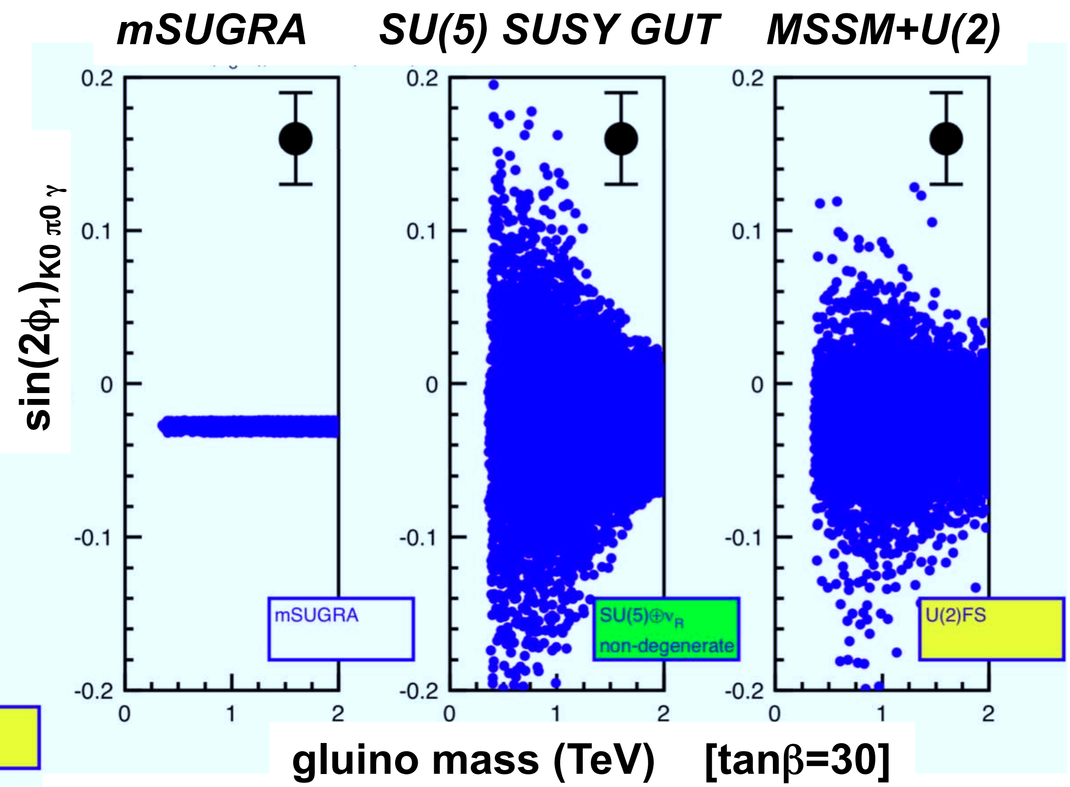
Buchalla et al., EPJC 57, 309 (2008); arXiv:0801.1833

LHC: *measure SUSY mass spectrum (e.g., gluino mass)*

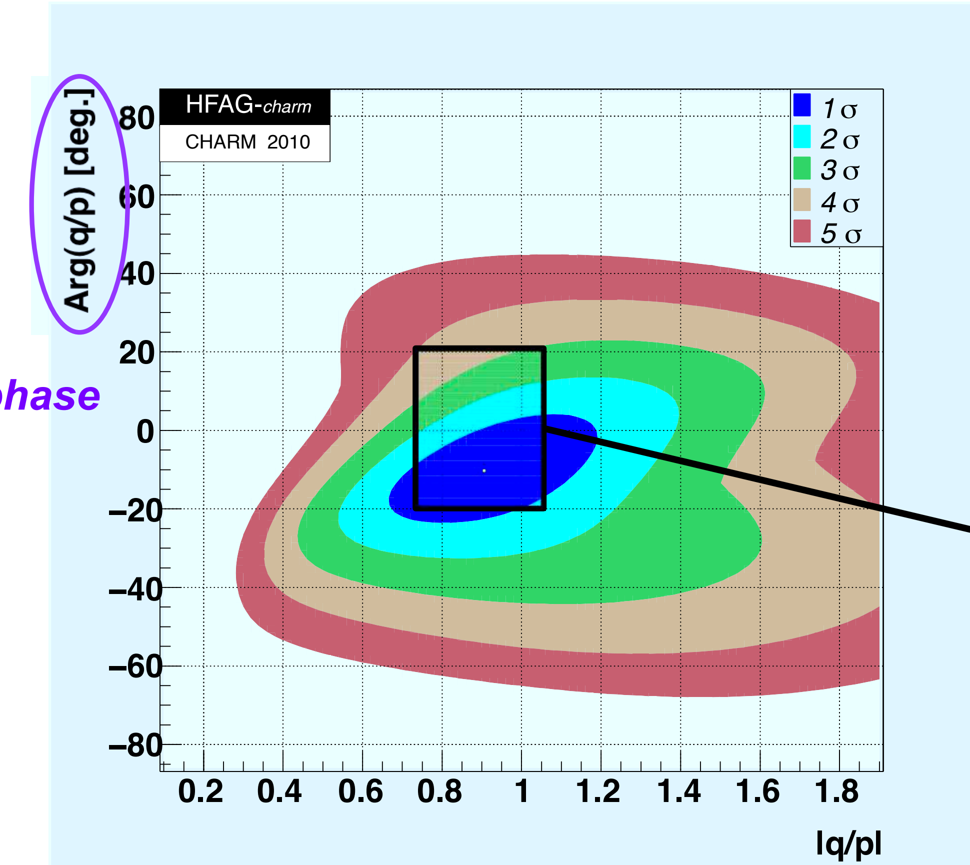
Flavor Factory: *measure observables sensitive to off-diagonal elements in squark mass matrix*

⇒ discriminate among SUSY-breaking mechanisms



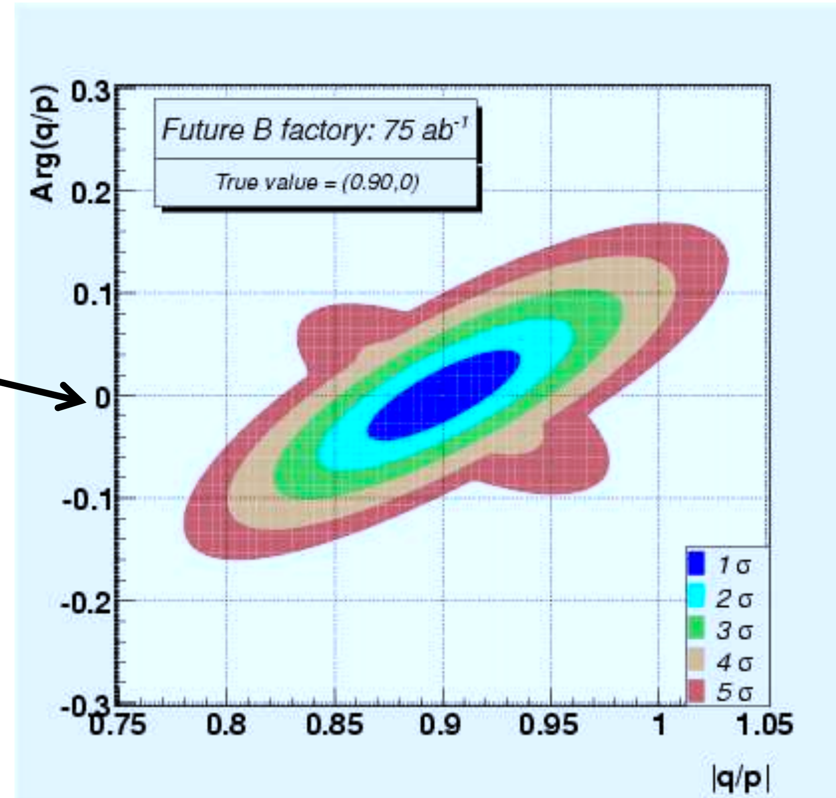


CPV search in the D^0-$\bar{D}^0$ system:



NP phase

75 ab^{-1} :
[improvement in x, y, y' x'^{2}, y_{CP}]



Current measurements of x, y give many constraints on NP models
[see Golowich et al., PRD76, 095009 (2007); 21 models considered, e.g., 2-Higgs doublets, left-right models, little Higgs, extra dimensions, of which 17 give constraints]

Summary

- B factories have proven to be an excellent tool for flavour physics, producing a wealth of physics results, having reliable long-term operation, and having constant improvement of performance.

- Major upgrade at KEK in 2010-14 → Super B factory: L x 40. Essentially a new project, many components and most electronics will be replaced, options to be frozen in the next few months

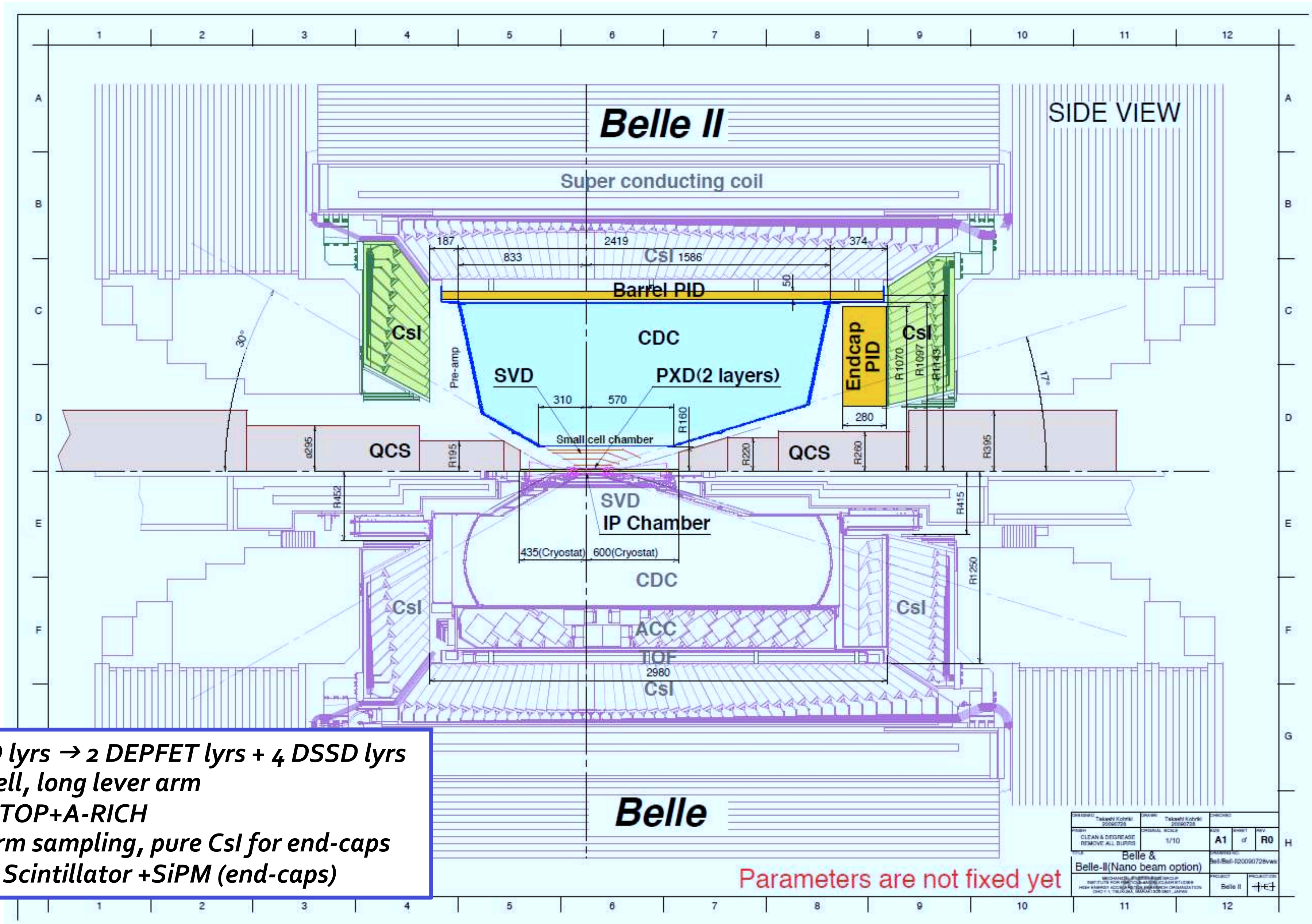
- A Super B Factory should resolve current flavor puzzles of Belle and Babar, e.g., difference in phase ϕ_1 between $b \to s$ loop diagram and $b \to c$ tree diagram; possible enhanced loop diagram in $B \to K\pi$ decays; high rate of $B \to \tau\nu$ (which gives high V_{ub})

- A Super B Factory can identify new CP phases responsible for baryogenesis of our matter universe

- A Super B Factory factory can help discriminate among new physics identified at the LHC, e.g., what breaks SUSY

Extra

Belle II detector compared to Belle:



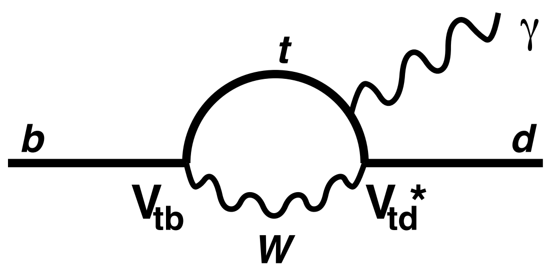
SVD: *4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs*
CDC: *small cell, long lever arm*
ACC+TOF → *TOP+A-RICH*
ECL: *waveform sampling, pure CsI for end-caps*
KLM: RPC → *Scintillator +SiPM (end-caps)*

Belle II Institutes: 400 members, ~2/3 outside Japan

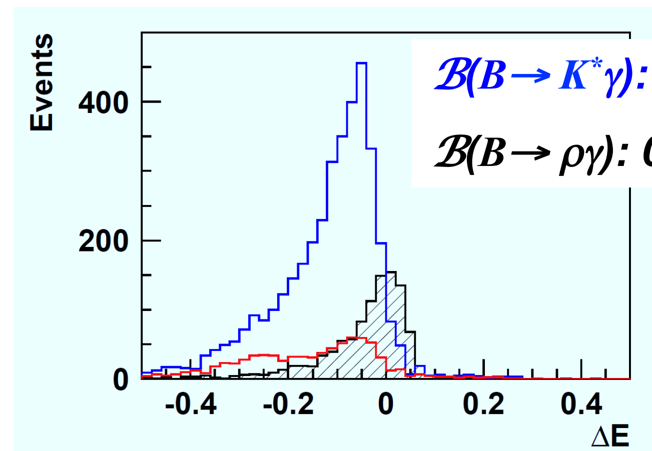
Australia	Univ. of Sydney
	Univ. of Melbourne
Austria	Austrian Academy of Sciences (HEPHY)
China	Institute of High Energy Physics, Chinese Academy of Science
	Univ. of Science and Technology of China
Czech	Charles University in Prague
Germany	Karlsruhe Institute of Technology
	Max-Planck-Institut fur Physik - MPI Munich -
	Univ. of Giessen
	Bonn Univ.
India	Indian Institute of Technology Guwahati
	Indian Institute of Technology Madras
	Institute of Mathematical Sciences (Chennai)
	Panjab Univ.
	Tata Insitute of Fundamental Research
Korea	Gyeongsang National Univ.
	Korea Institute of Science and Technology
	Information
	Korea Univ.
	Kyungpook National Univ.
	Seoul National Univ.
	Yonsei Univ.
Poland	The Henryk Niewodniczanski Institute of Nuclear Physics - Polish Academy of Science
Russia	Budker Institute of Nuclear Physics
	Institute for Theoretical Experimental Physics
Slovenia	Jozef Stefan Institute (Ljubljana)
	Univ. of Nova Gorica
Taiwan	Fu Jen Catholic Univ.
	National Central Univ.
	National United Univ
	National Taiwan Univ.
U.S.A.	Univ. of Cincinnati
	Univ. of Hawaii
	Virginia Polytechnic Institute and State Univ.
	Wayne State Univ.
Japan	Nagoya Univ.
	Nara Women's Univ.
	Niigata Univ.
	Osaka City Univ.
	Toho Univ.
	Tohoku Univ.
	Tokyo Metroporitan Univ.
	Univ. of Tokyo
	KEK

Belle π/K discrimination:

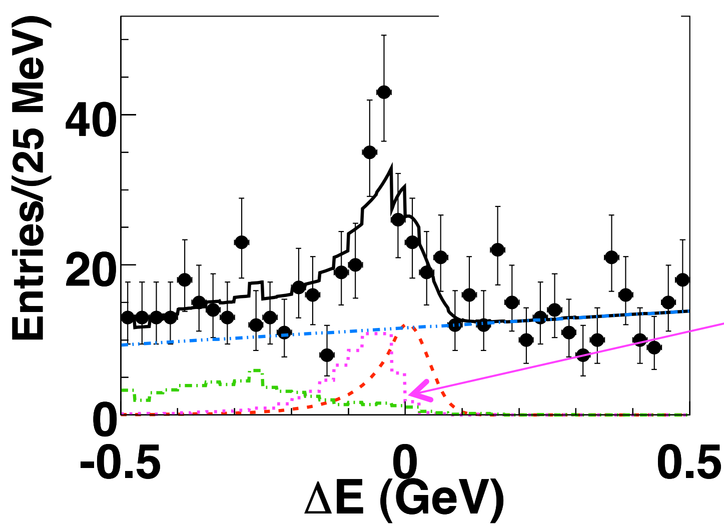
Probes new physics:



But separating from $B \to K^* \gamma$ is tough:

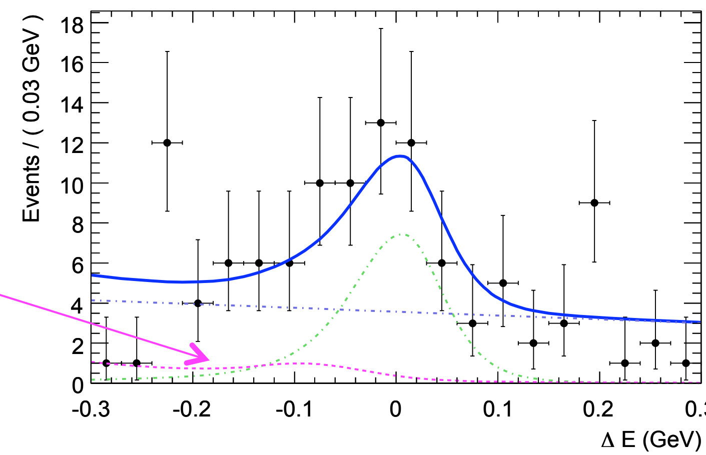


Taniguchi et al., PRL 101, 111801 (2008)
620 fb^{-1}, ***K→ π mis-ID = 8.5%***



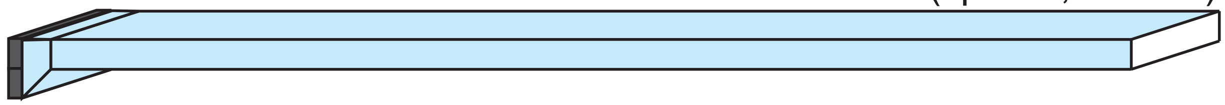
$B \to K^* \gamma$

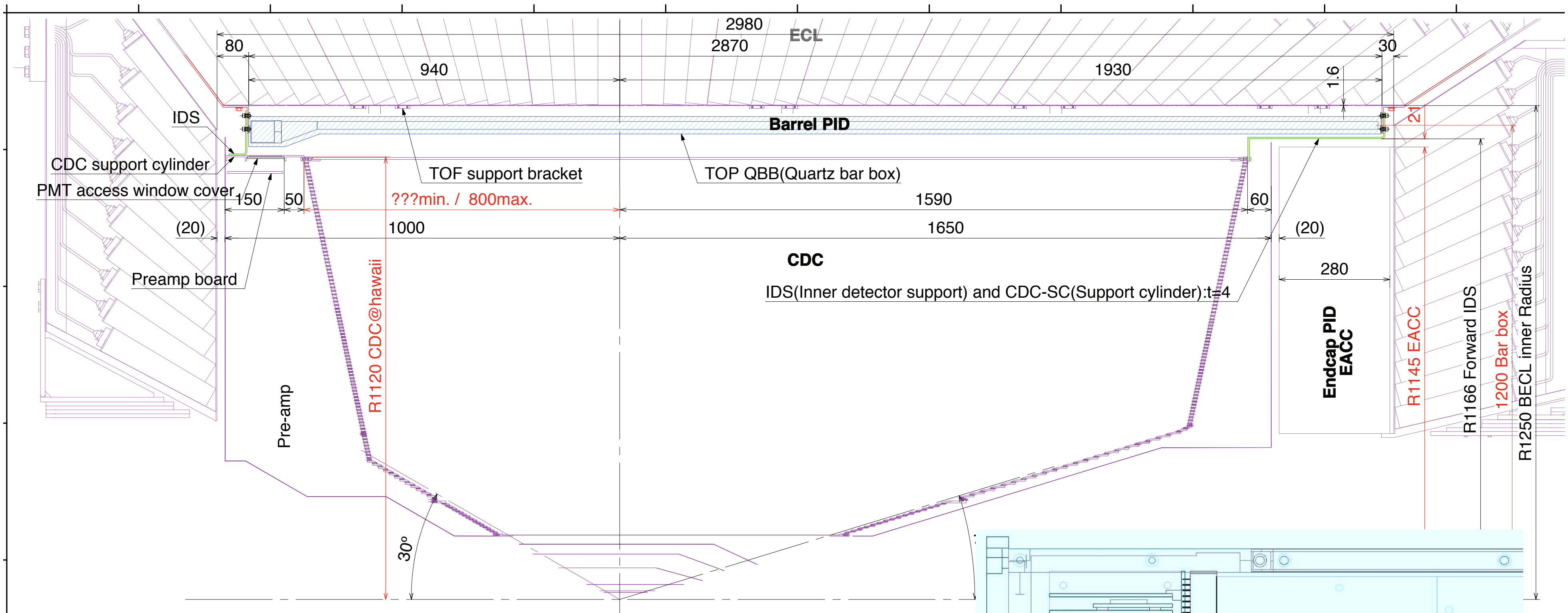
Aubert et al., PRD 78, 112001 (2008)
423 fb^{-1}, ***K→ π mis-ID = 1%***



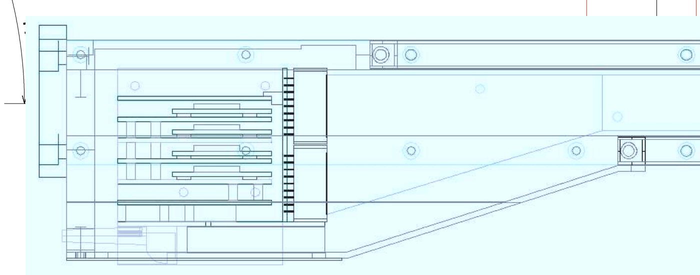
Belle II particle identification (barrel):

Quartz radiator + expansion block + MCP PMT:



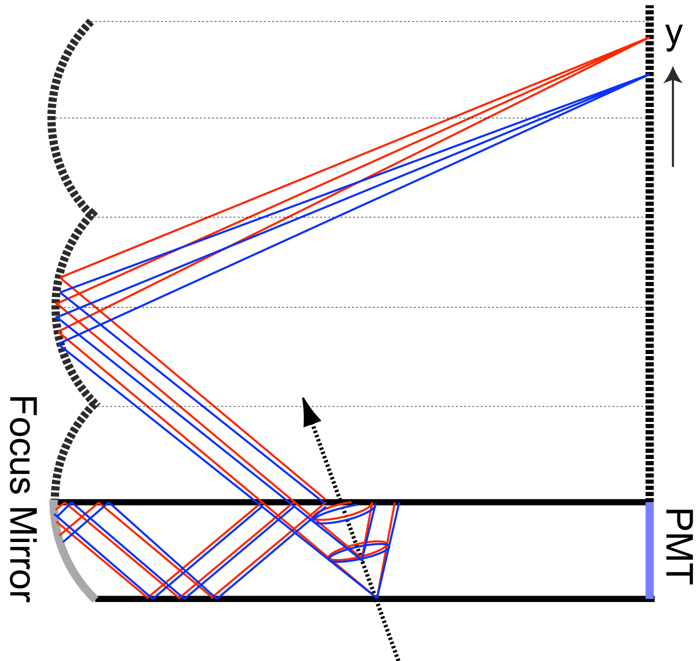


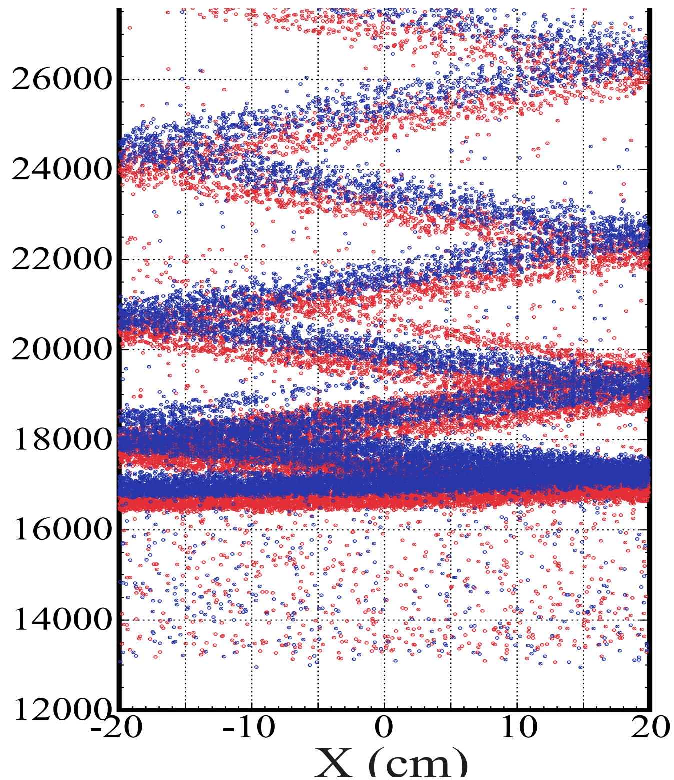
End assembly:

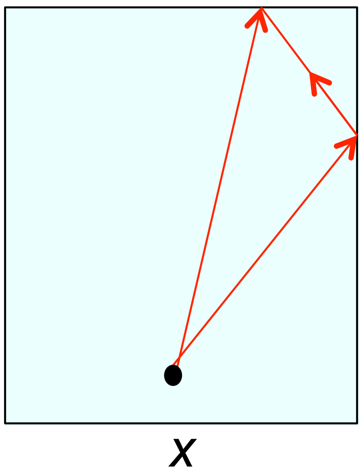


Belle II barrel particle ID: imaging TOP counter

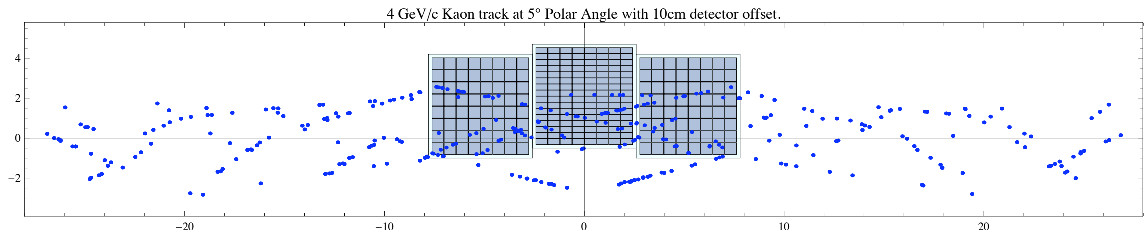
- **from timing:**





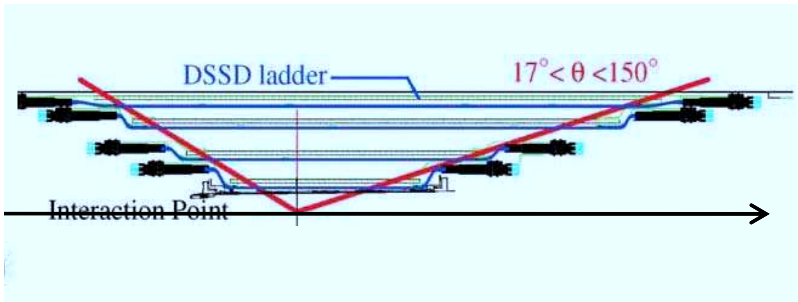


- **exploring additional discrimination from image:**

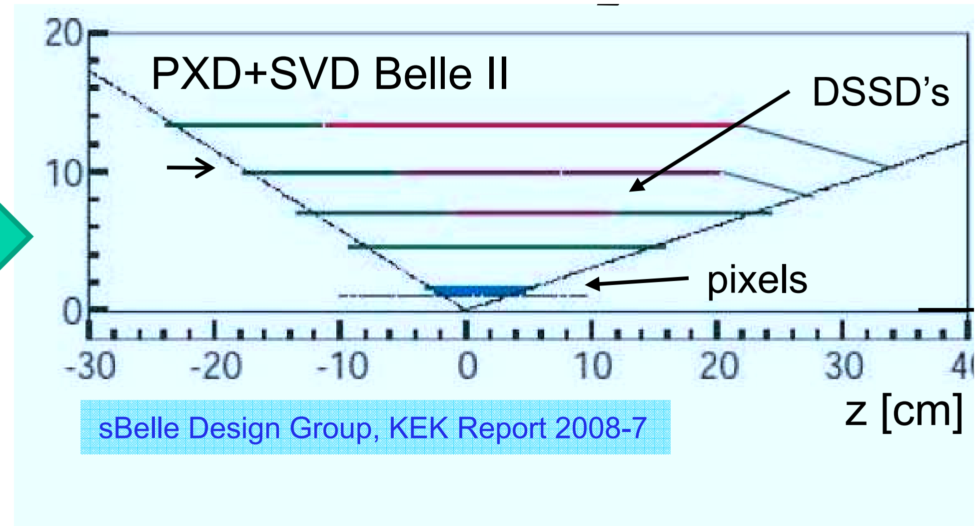


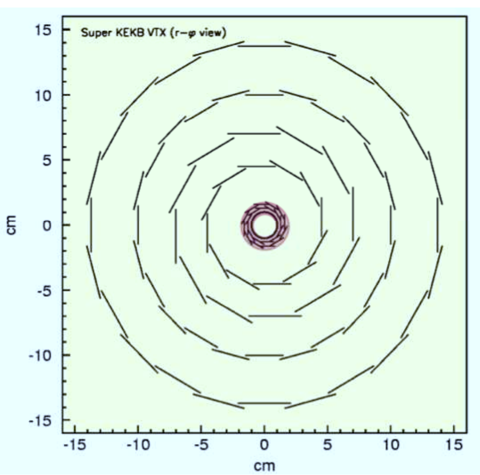
4 GeV K^+

SVD: 4 layers → 6 layers w/pixels



Upgrade





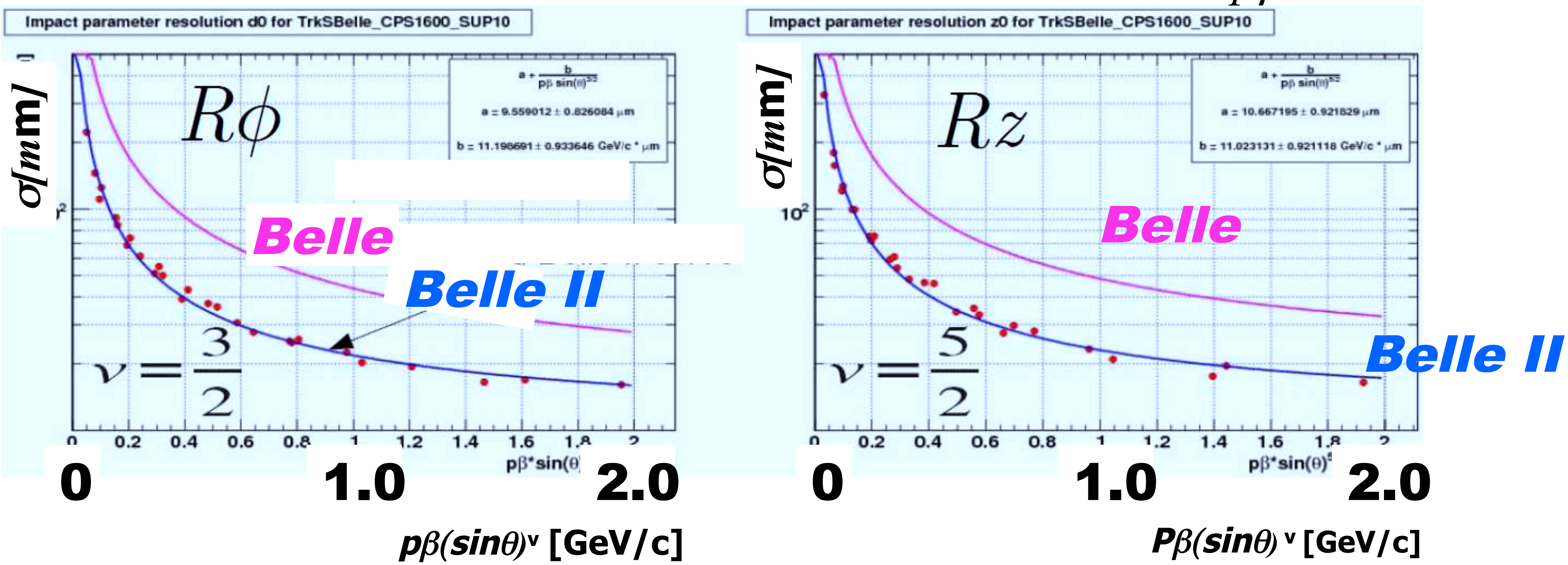
Beam Pipe	**r = 1cm**
DEPFET	
Layer 1	**r = 1.3cm**
Layer 2	**r = 2.2cm**
DSSD	
Layer 3	**r = 3.8cm**
Layer 4	**r = 8.0cm**
Layer 5	**r = 11.5cm**
Layer 6	**r = 14.0cm**

- *Outer radius increases: 8→14 cm*
  ∴ K_S recon. effic. increases ~30%
- *Inner radius decreases 1.5 → 1.3 cm*
  ∴ 25% improv. in vertex resolution
- *Inner 2 layers are DEPFET pixel detectors developed in Germany*
  ∴ greatly reduce occupancy
- *Layers 3-6 readout chip: VA1TA →APV25*
  ∴ reduce occupancies

Expected performance

Significant improvement in IP resolution:

$$\sigma = a + \frac{b}{p\beta \sin^{\nu}\theta}$$



Will greatly help analyses such as $B \to K_S \pi^0 \gamma$
(B decay vertex determined by K_S and IP)

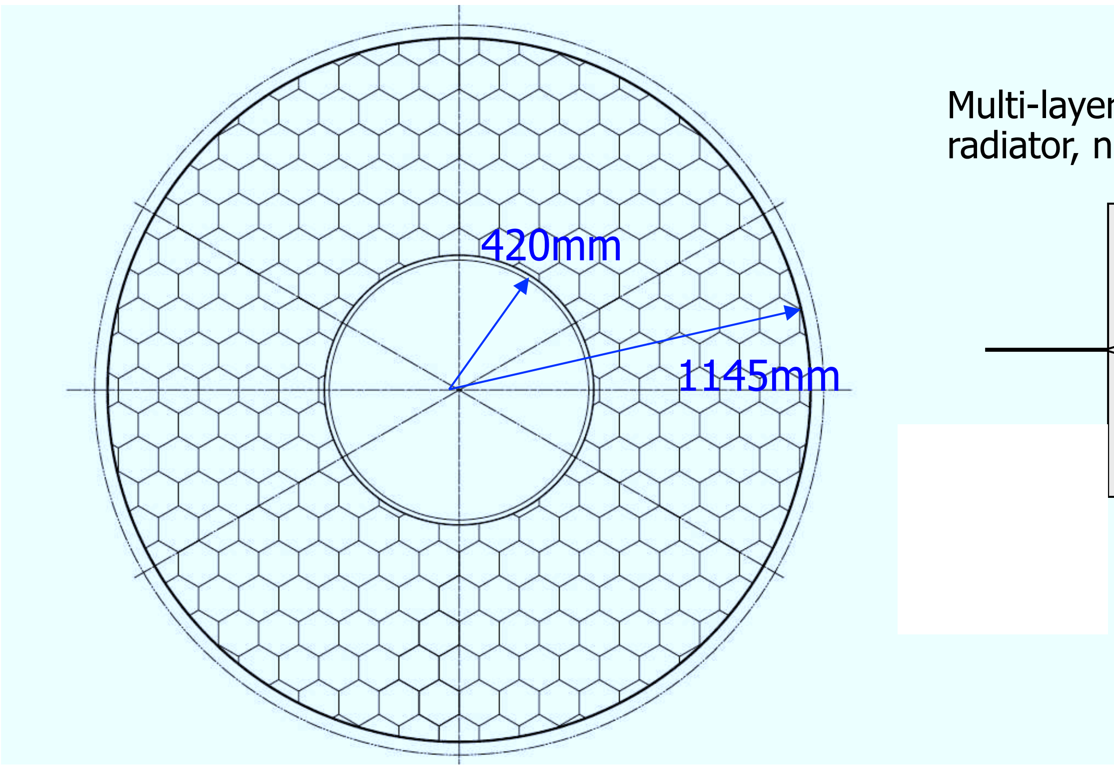
$C_{CP}(K_S\, \pi^0\gamma) = -0.07 \pm 0.12$

$S_{CP}(K_S\, \pi^0\gamma) = -0.15 \pm 0.20 \to$ 0.09 (5 fb^{-1})

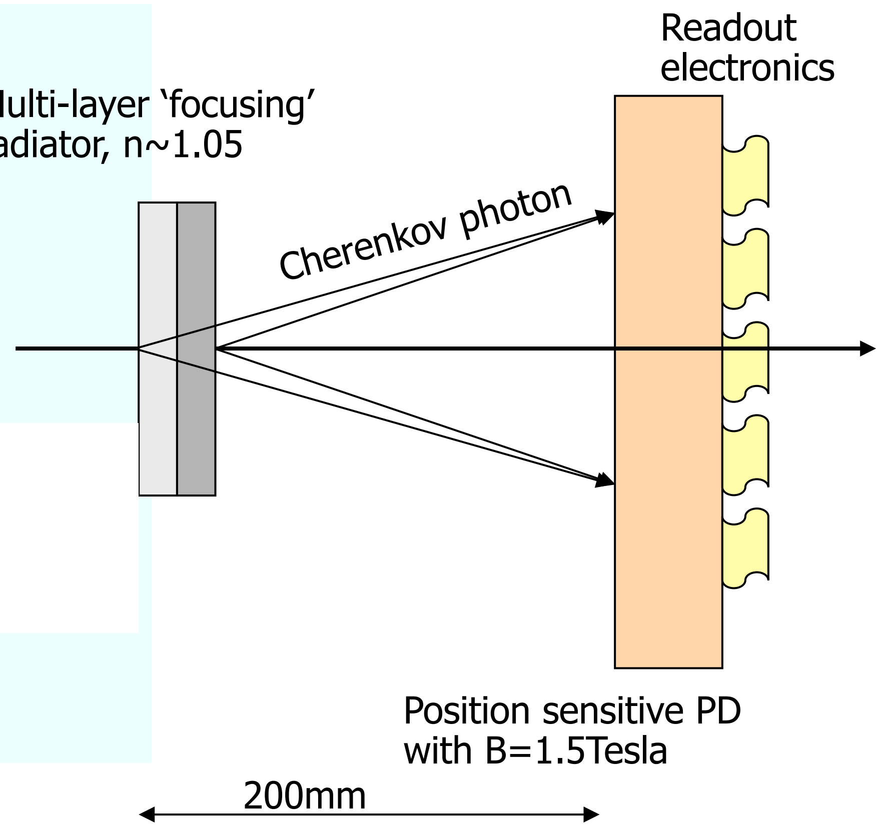
$\to$ 0.03 (50 fb^{-1})

Endcap PID:

Proximity focusing RICH with silica aerogel as Cherenkov radiator in a 'focusing' configuration



x-y view of forward end-cap

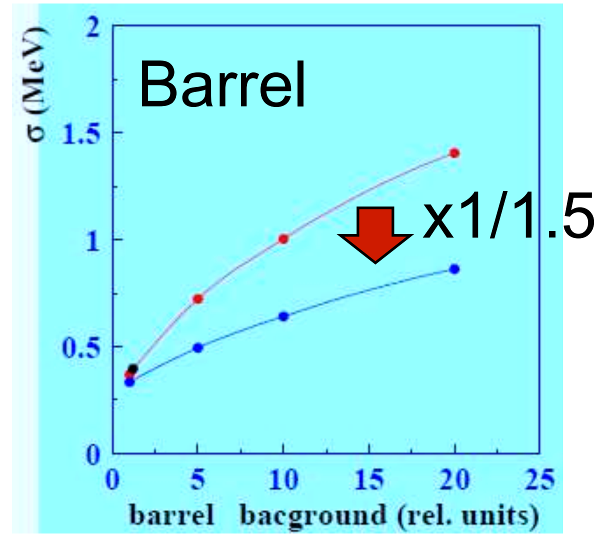


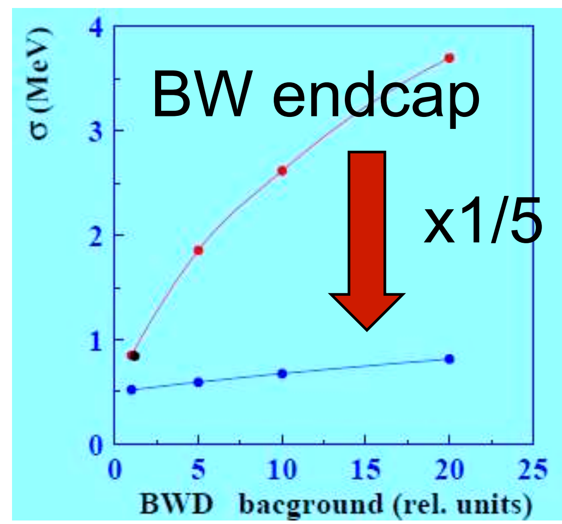
Electromagnetic calorimeter (ECL) upgrade

- *Increase of dark current due to neutron flux*
- *Fake clusters & pile-up noise*

- Barrel:
  0.5ms shaping + 2MHz w.f. sampling.
- Endcap:
  rad. hard crystals with short decay time (e.g. pure CsI) + photopentodes
  30ns shaping + 43MHz w.f. sampling

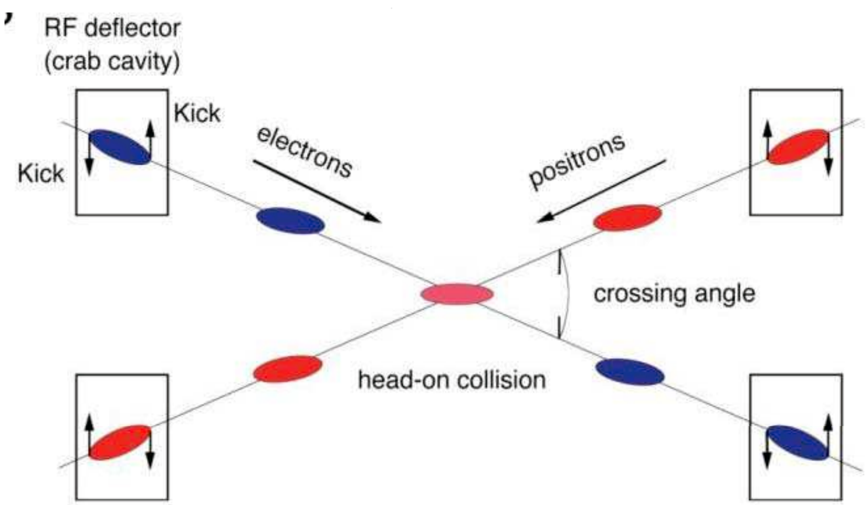
Pure CsI & photopentodes



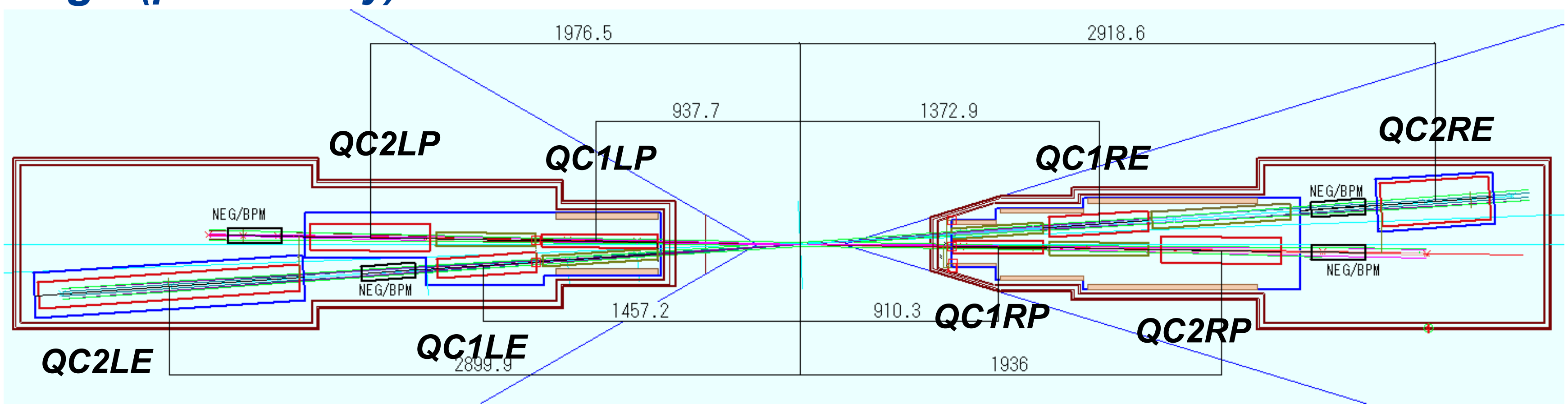


Crab crossing:

Crab crossing (installed Feb. 2007):



IR design (preliminary):

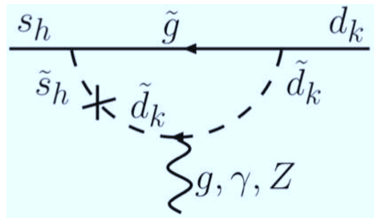


Some Theory:

Buchalla et al., EPJC 57, 309 (2008); arXiv:0801.1833
Browder et al., arXiv:0802.3201

Consider generic $\Delta F = 2$ processes (e.g., B^0-B^0 mixing):

$$H_{\rm eff}^{NP} \;=\; \frac{C^{NP}}{\Lambda_{NP}^2}\,[\bar d_{Lj}\gamma_\mu d_{Li}]^2$$



Compare to SM weak Hamiltonian:

$$H_{\rm eff}^{SM} \;\approx\; \left(\frac{1}{4}\right)\left(\frac{g^2}{4\pi\, M_W}\right)^2 (V_{td}^* V_{tb})^2\,[\bar d_L\gamma_\mu t_L][\bar t_L\gamma_\mu b_L] \;=\; \frac{(\sin^3\theta_c)^2}{4\times(2.5\ {\rm TeV})^2}\,[\bar d_L\gamma_\mu t_L][\bar t_L\gamma_\mu b_L]$$

Since we do not observe $\Delta F = 2$ effects, this implies :

$$\Lambda_{NP} \;>\; \sqrt{C_{NP}\frac{4\times(2.5\ {\rm TeV})^2}{(\sin^3\theta_c)^2}} \;\sim\; 400\ {\rm TeV}$$

The fact that this scale is much larger than the weak scale is the flavor problem

Most pessimistic scenario: "Minimal Flavor Violation"

no new sources of flavor or CP violation, i.e., flavor violation appears only in SM-like Yukawa couplings:

$$H_{\rm eff}^{NP} \;=\; \frac{C^{NP}}{\Lambda_{NP}^2}(V_{td}^* V_{tb})^2\,[\bar d_L\gamma_\mu t_L][\bar t_L\gamma_\mu b_L] \quad\Longrightarrow\quad \Lambda_{NP} \;>\; \sqrt{C_{NP}\times 4\times(2.5\ {\rm TeV})^2} \;\sim\; 5\ {\rm TeV}$$

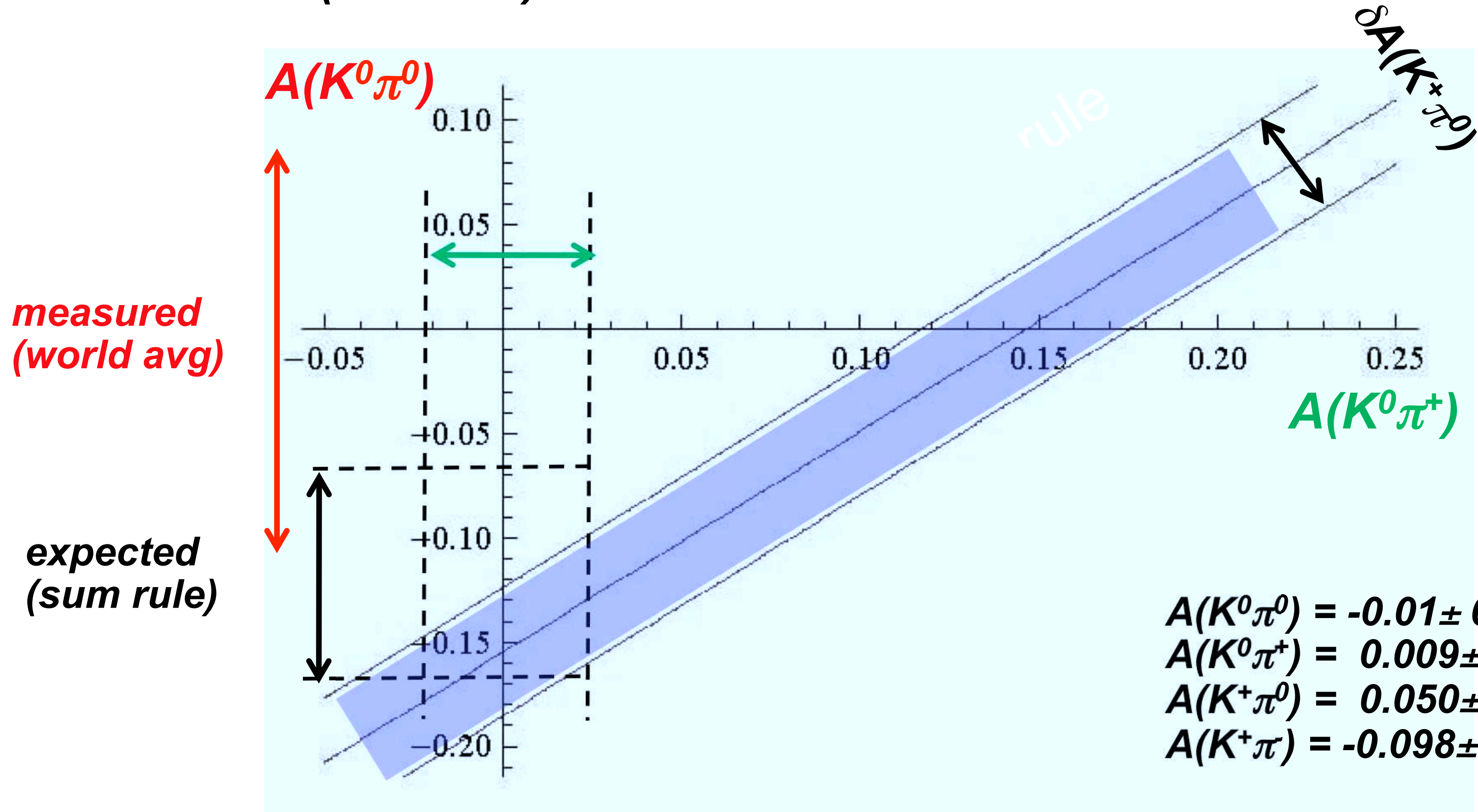
Measuring decay phases, cont'd

``Model independent" sum rule for all four modes:

Gronau, PLB 627, 82 (2005); Atwood & Soni, PRD 58, 036005 (1998):

$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

B factories now (~1.4 fb^{-1}):



$A(K^0\pi^0)$ = -0.01± 0.10
$A(K^0\pi^+)$ = 0.009± 0.025
$A(K^+\pi^0)$ = 0.050± 0.025
$A(K^+\pi^-)$ = -0.098± 0.012

Measuring decay phases, cont'd

$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

B factory at 50 fb^{-1}, with today's central values: