Physics at B-factories

Part 3: Search for deviations from the SM predictions, rare decays, D mixing, summary and outlook

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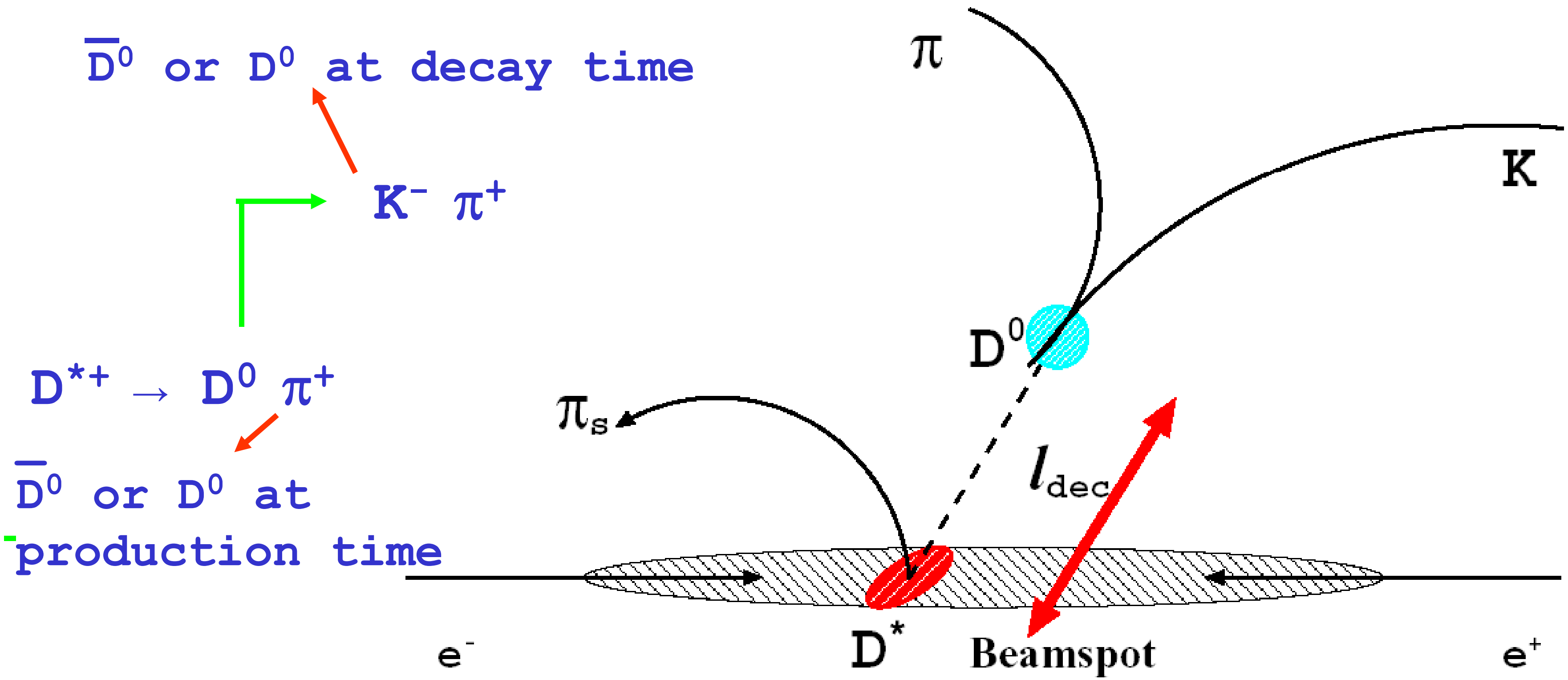
BELLE

Experimental methods in D^0 mixing searches

The method: investigate D decays in the decay sequence:

$D^{*+} \to D^0 \pi^+$, $D^0 \to$ specific final states

Used for tagging the initial flavour and for background reduction



$p_{cms}(D^*) > 2.5$ GeV/c eliminates D meson production from $b \to c$

D^0 mixing in K^+K^-, $\pi^+\pi^-$

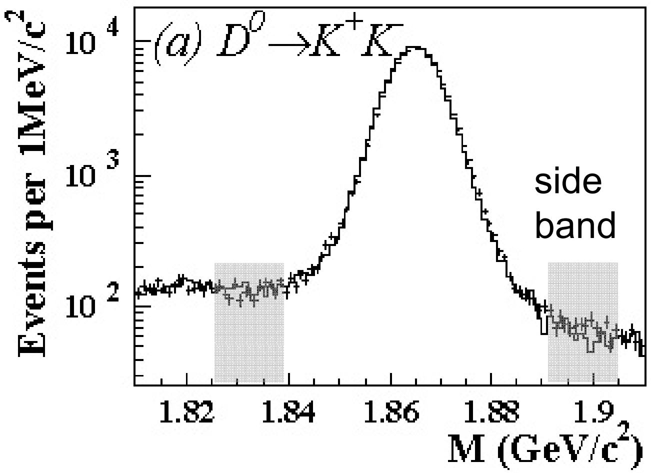
$D^0 \to K^+K^- / \pi^+\pi^-$

CP even final state;
in the limit of no CPV: $CP|D_1\rangle = |D_1\rangle$
$\Rightarrow$ measure $1/\Gamma_1$

$$|D_{1,2}\rangle = p|D^0\rangle \pm q|\overline{D}^0\rangle$$

$$y_{CP} \equiv \frac{\tau(K^-\pi^+)}{\tau(K^-K^+)} - 1 = y\cos\varphi - \frac{1}{2}A_M x \sin\varphi \underset{no\ CPV}{=} y$$

S. Bergman et al., PLB486, 418 (2000)

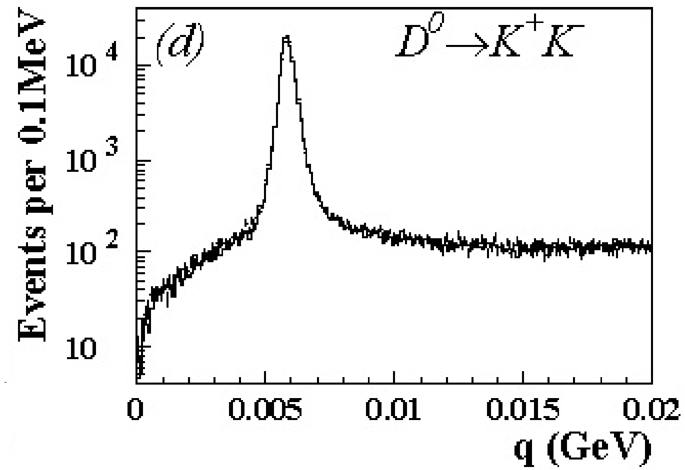


A_M, ϕ: CPV in mixing and interference

Signal: $D^0 \to K^+K^- / \pi^+\pi^-$ from D^*

M, Q, σ_t selection optimized in MC

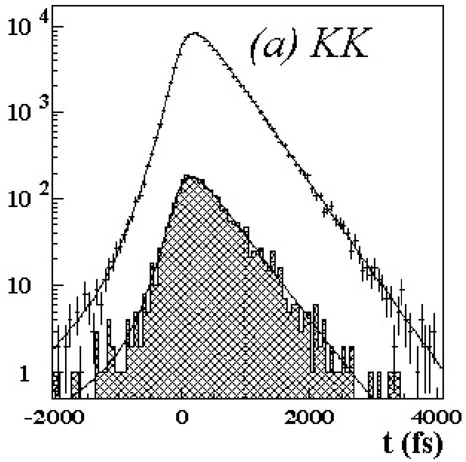
	K^+K^-	$K^-\pi^+$	$\pi^+\pi^-$
N_{sig}	111×10^3	1.22×10^6	49×10^3
purity	98%	99%	92%



PRL 98, 211803 (2007), 540fb^{-1}

D^0 mixing in K^+K^-, $\pi^+\pi^-$

Decay time distributions for KK, ππ, Kπ



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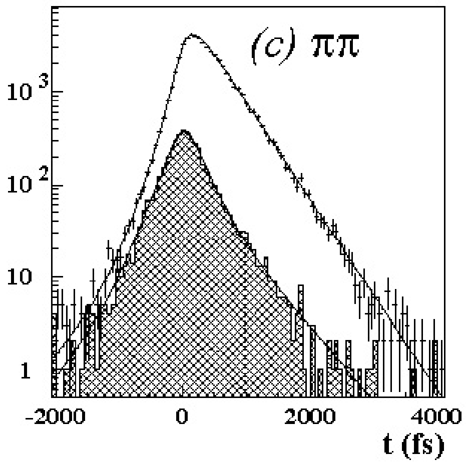
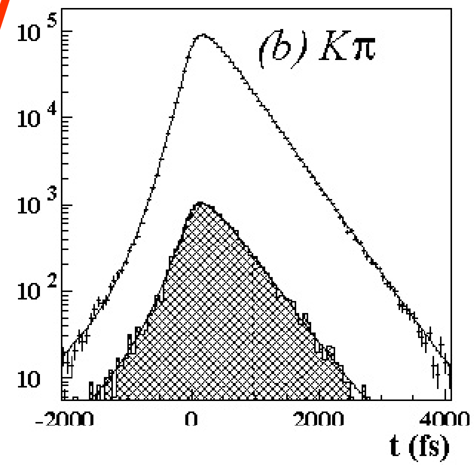
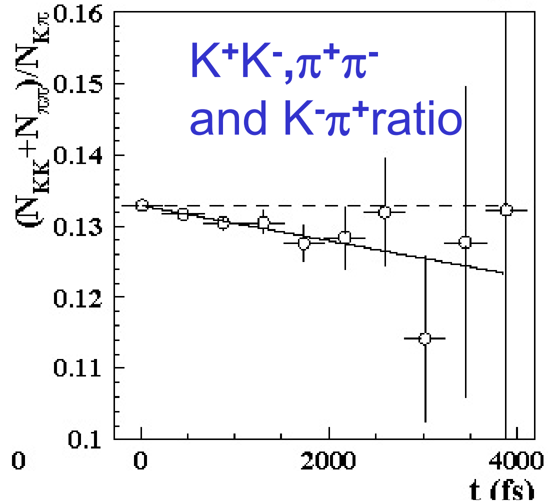




Difference of lifetimes
visually observable
in the ratio of the distributions →



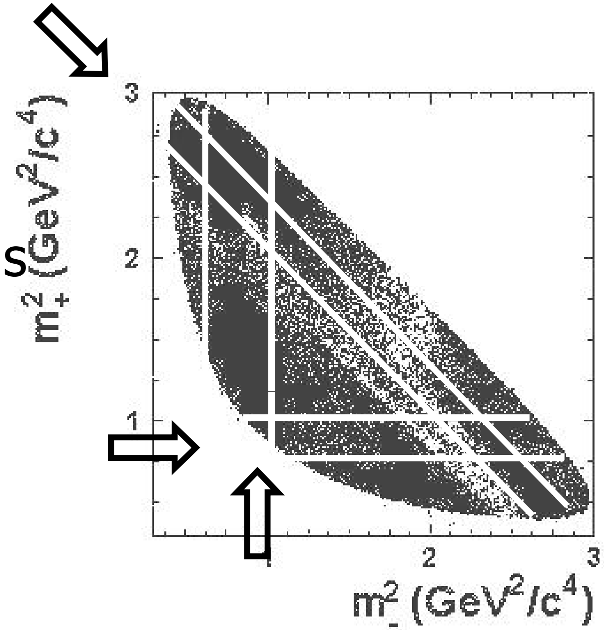
Real fit:

y_{CP} = (1.31 ± 0.32 ± 0.25) %

evidence for D^0 mixing
(regardless of possible CPV)

→ y_{CP} is on the high side of SM expectations

D^0 mixing in $K_S\,\pi^+\pi^-$



time-dependent Dalitz plot analysis

different decays identified through Dalitz plot analysis

CF: $D^0 \rightarrow K^{*-}\pi^+$

DCS: $D^0 \rightarrow K^{*+}\pi^-$

CP: $D^0 \rightarrow \rho^0 K_S$

$m_\pm^2 = m^2(K_S\,\pi^\pm)$: Dalitz variables

time-dependence:

$$\mathcal{M}(m_-^2, m_+^2, t) \equiv \left\langle K_S \pi^+ \pi^- \middle| D^0(t) \right\rangle =$$

$$= \frac{1}{2}\mathcal{A}(m_-^2, m_+^2)\left[e^{-i\lambda_1 t} + e^{-i\lambda_2 t}\right] + \frac{1}{2}\frac{q}{p}\overline{\mathcal{A}}(m_-^2, m_+^2)\left[e^{-i\lambda_1 t} - e^{-i\lambda_2 t}\right]$$

$\langle f \mid D^0 \rangle$ $\qquad$ $\langle f \mid \overline{D}^0 \rangle$

$\lambda_{1,2} = m_{1,2} - i\Gamma_{1,2}/2 = f(x,y)$

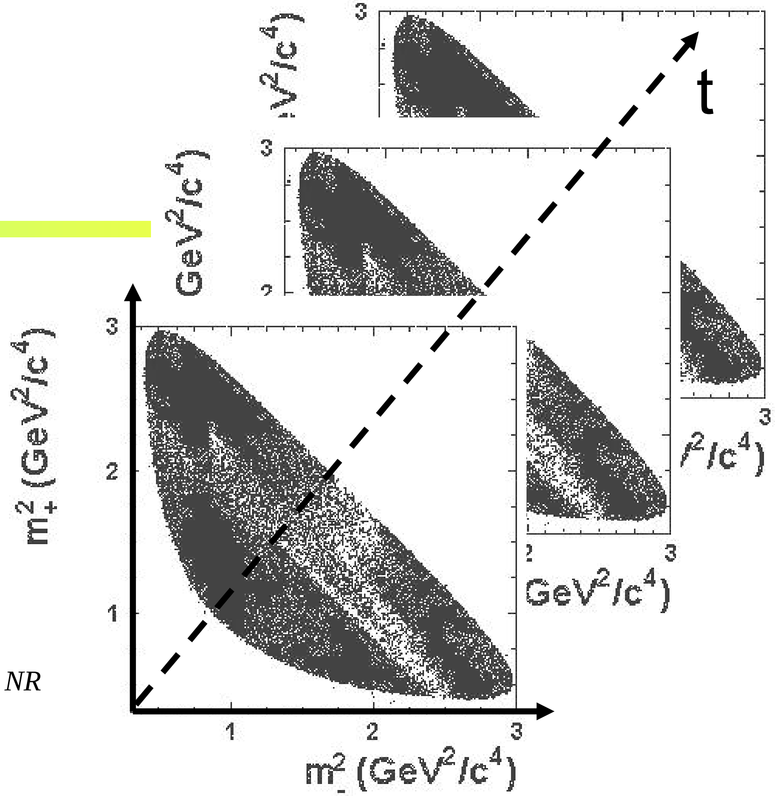
analogous for $\overline{\mathcal{M}} = \langle f \mid \overline{D}^0(t) \rangle$

Rate: terms with $\cos(x\Gamma t)\exp(-\Gamma t)$, $\sin(x\Gamma t)\exp(-\Gamma t)$, $\exp(-(1\pm y)\Gamma t)$ → sensitive to x and y

D^0 mixing in $K_S \pi^+\pi^-$

Signal

N_{sig}= (534.4±0.8)x10^3
P ≈ 95%



Dalitz model

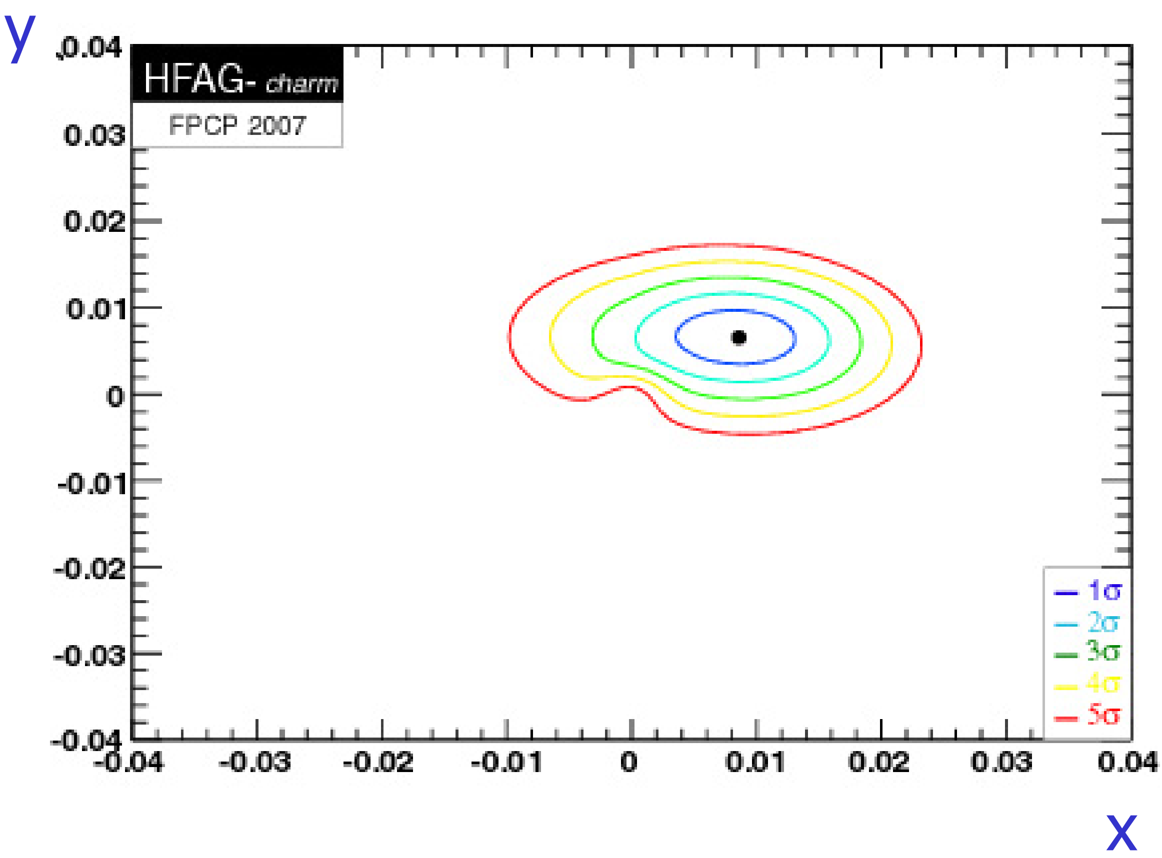
$$\mathcal{A}(m_-^2, m_+^2) = \sum a_r\, e^{i\Phi_r} B(m_-^2, m_+^2) + a_{NR}\, e^{i\Phi_{NR}}$$

18 resonant BW terms + non-resonant contribution

Fit $\mathcal{M}(m_-^2, m_+^2, t)$ to data distribution ⇒ x, y

$x = (0.80 \pm 0.29 \pm ^{0.09}_{0.07} \pm ^{0.10}_{0.14})\%$
$y = (0.33 \pm 0.24 \pm ^{0.08}_{0.12} \pm ^{0.06}_{0.08})\%$

D^0 mixing: all results combined



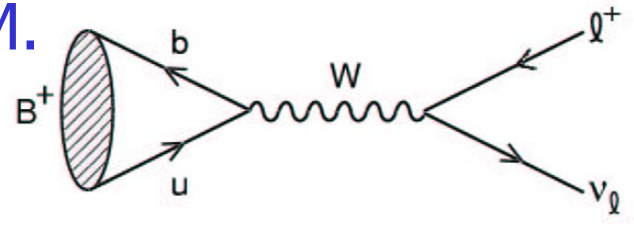
Assuming no CPV

$x = (0.87 \pm {}^{0.30}_{0.34})\ \%$
$y = (0.66 \pm {}^{0.21}_{0.20})\%$
$\delta = 0.33 \pm {}^{0.26}_{0.29}$

(x,y)=(0,0) excluded by >5σ

Purely leptonic decay B→τ ν

- Challenge: B decay with at least two neutrinos
- Proceeds via W annihilation in the SM.



- Branching fraction

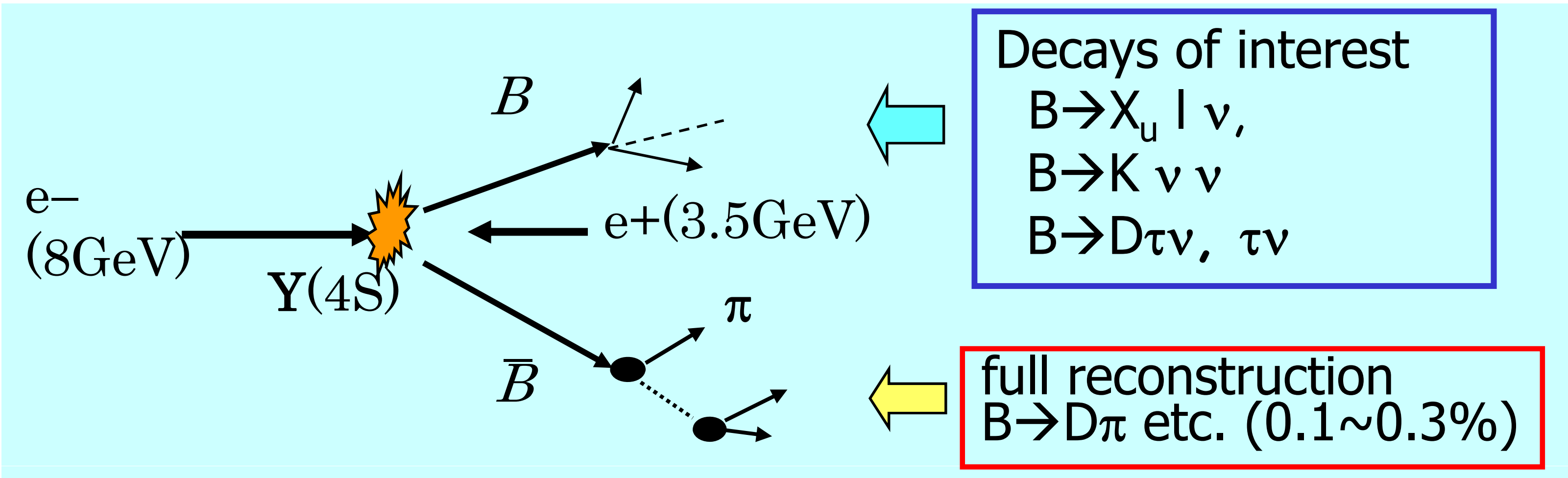
$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

- Provide information of $f_B|V_{ub}|$
  - $|V_{ub}|$ from $B \to X_u\, l\, \nu$ ➡ f_B ⬄ cf) Lattice
  - $Br(B\to\tau\nu)/\Delta m_d$ ➡ $|V_{ub}|\ /\ |V_{td}|$
- Limits on charged Higgs

Full Reconstruction Method

Fully reconstruct one of the B's to

- Tag B flavor/charge
- Determine B momentum
- Exclude decay products of one B from further analysis

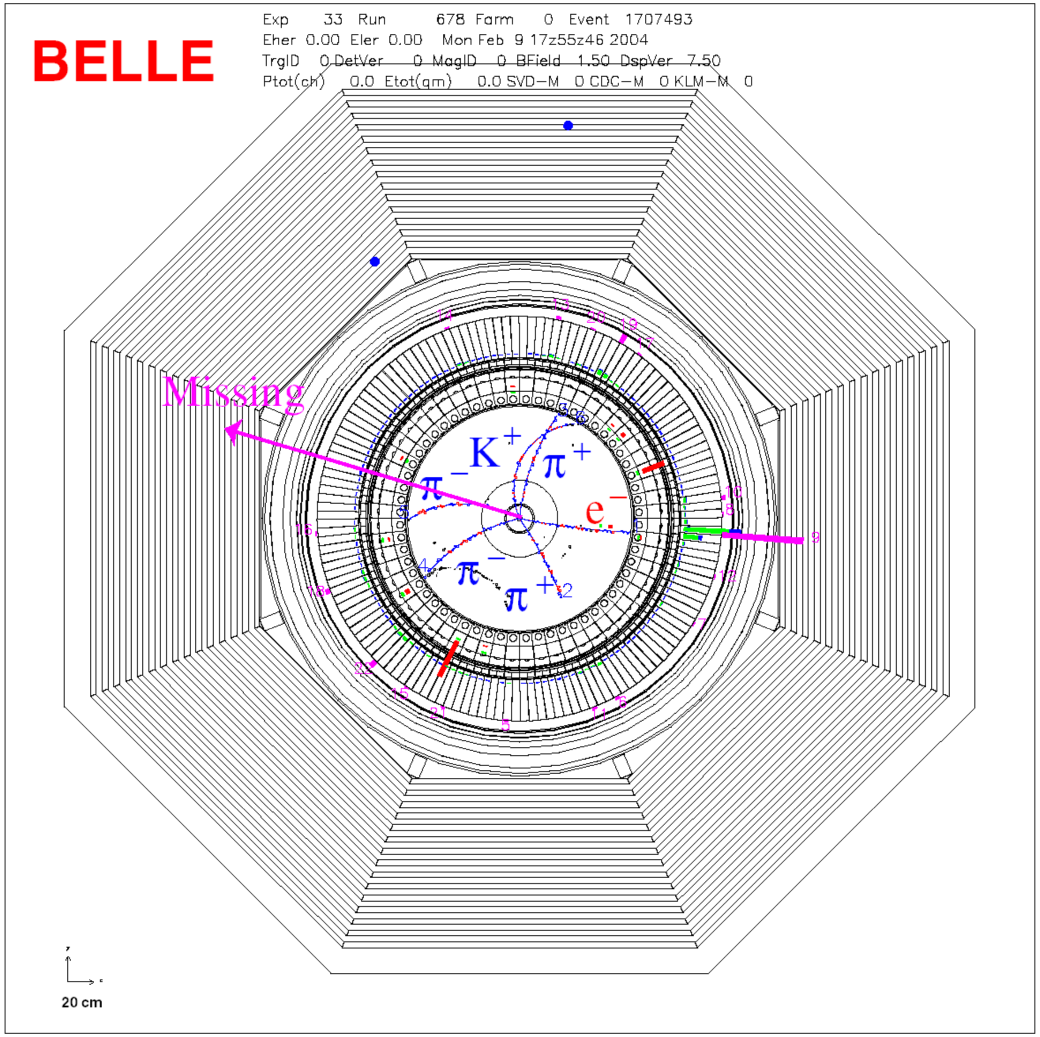


→ Offline B meson beam!

Powerful tool for B decays with neutrinos

Event candidate $B^- \rightarrow \tau^- \nu_\tau$

$$B^+ \rightarrow D^0\pi^+$$
$$(\rightarrow K\pi^-\pi^+\pi^-)$$
$$B^- \rightarrow \tau(\rightarrow e\nu\bar{\nu})\nu$$



B→τ ν

τ decay modes

$$\tau^- \to \mu^- \nu\bar{\nu}, e^- \nu\bar{\nu}$$

$$\tau^- \to \pi^- \nu, \pi^- \pi^0 \nu, \pi^- \pi^+ \pi^- \nu$$

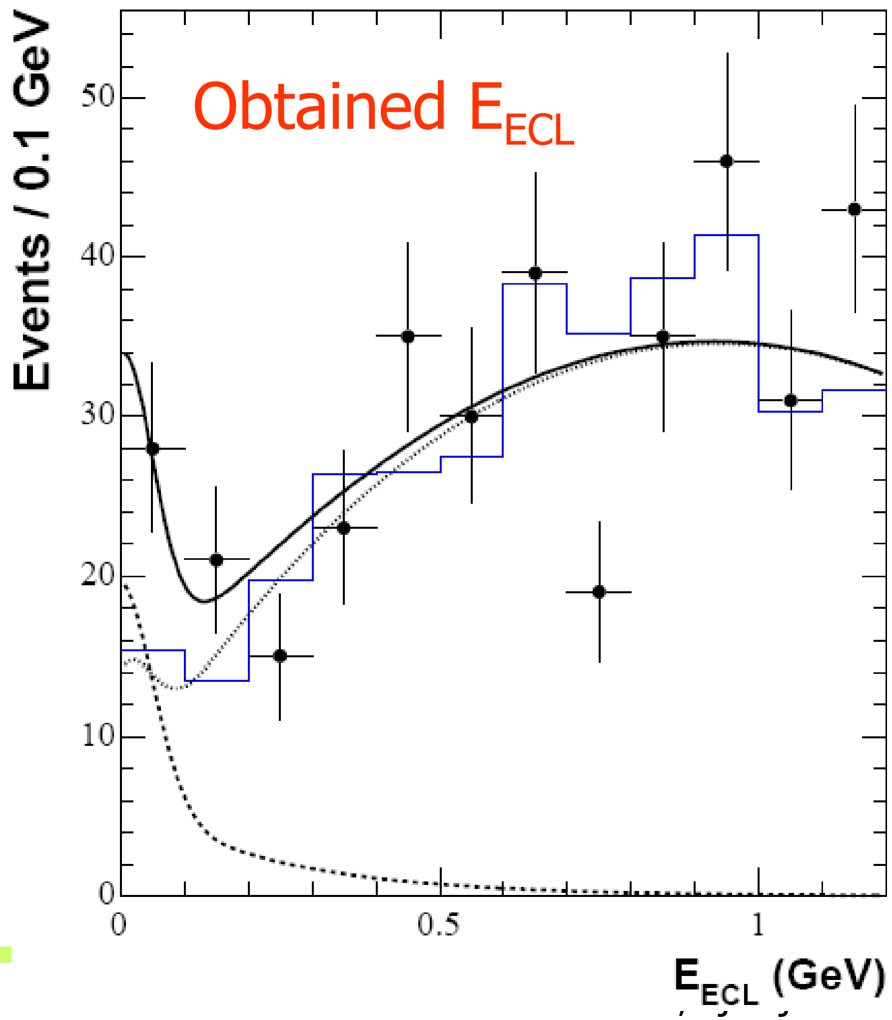
- Cover 81% of τ decays
- Efficiency 15.8%

Event selection

- Main discriminant: extra neutral ECL energy

Fit to $E_{residual}$ → $17.2^{+5.3}_{-4.7}$ signal events.

→3.5**σ** significance including systematics



$B \to \tau \nu_\tau$

$$\mathrm{BF}(B^+ \to \tau^+ \nu_\tau) = (1.79^{+0.56+0.46}_{-0.49-0.51}) \times 10^{-4}$$

$$\Gamma^{SM}(B^+ \to \ell^+ \nu) = \frac{G_F^2}{8\pi} |V_{ub}|^2 f_B^2 m_B m_\ell^2 \left(1 - \frac{m_\ell^2}{m_B^2}\right)$$

→ Product of B meson decay constant f_B and CKM matrix element $|V_{ub}|$

$$f_B \times V_{ub} = \left(10.1^{+1.6+1.3}_{-1.4-1.4}\right) \times 10^{-4}\, GeV$$

Using $|V_{ub}| = (4.39 \pm 0.33)\times 10^{-3}$ from HFAG

$$f_B = 229^{+36+34}_{-31-37}\, MeV$$

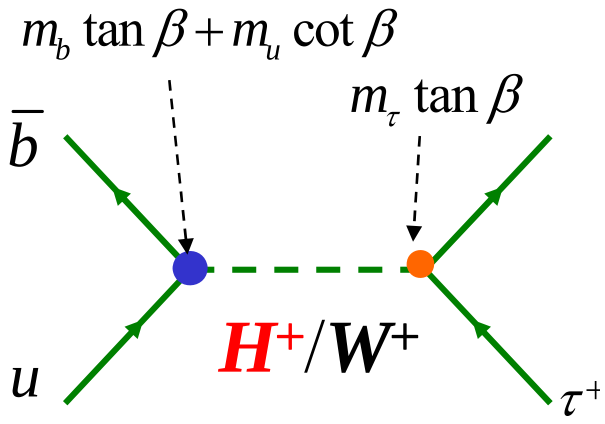
15%   15% = 13%(exp.) + 8%(V_{ub})

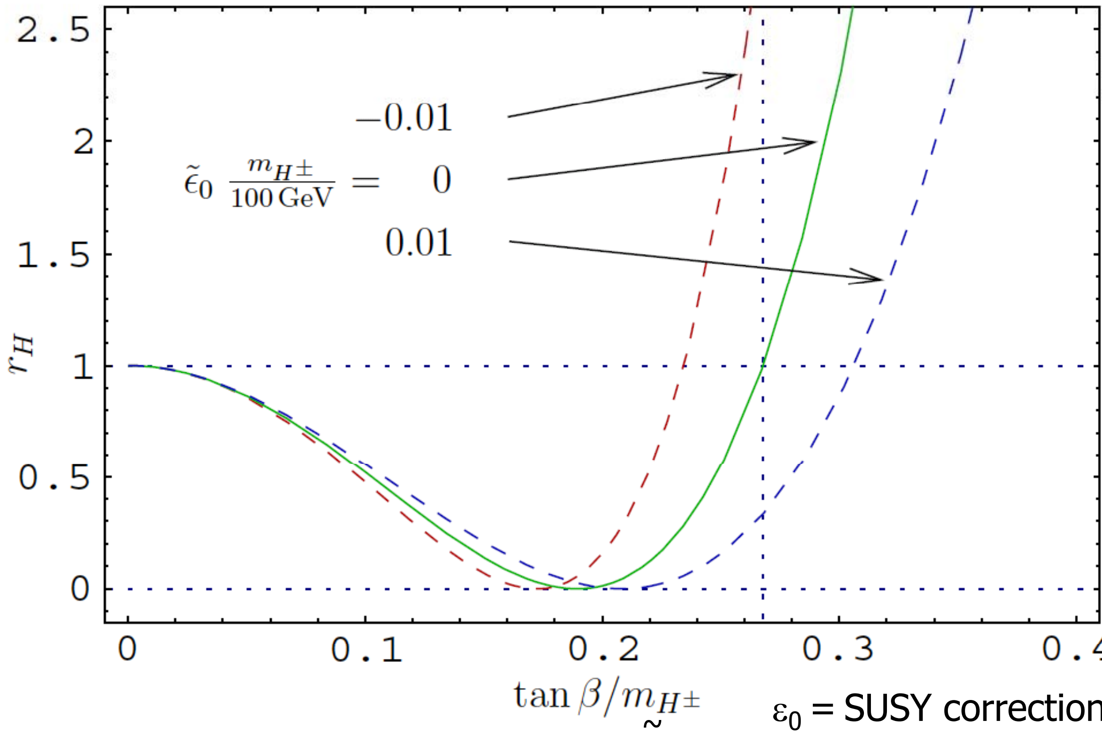
First measurement of f_B!

f_B = (216 ± 22) MeV from unquenched lattice calculation

[HPQCD, Phys. Rev. Lett. 95, 212001 (2005)]

Charged Higgs contribution to $B \to \tau \nu$





ε_0 = SUSY corrections to b Yukawa coupling

$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\rm SM} \times r_H,$$

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

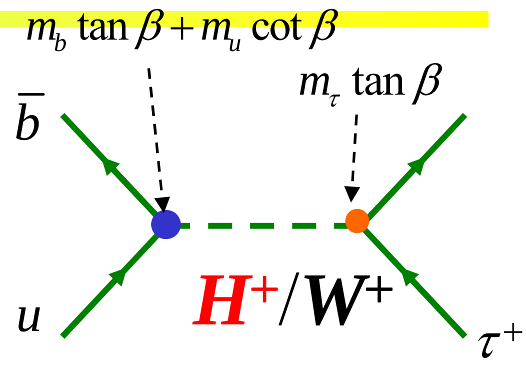
The interference is destructive in 2HDM (type II). $B > B_{SM}$ implies that H^+ contribution dominates

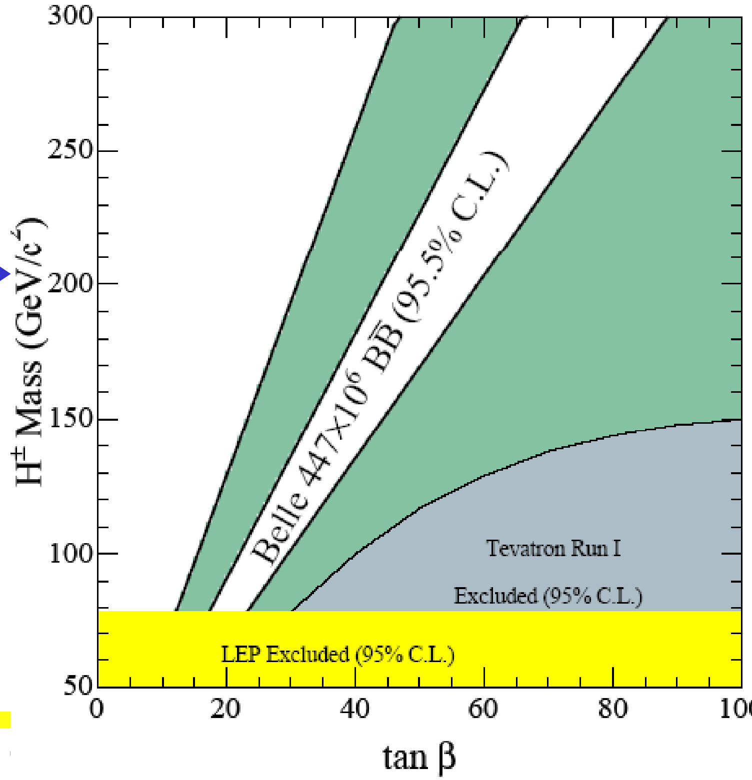
Phys. Rev. D **48**, 2342 (1993)

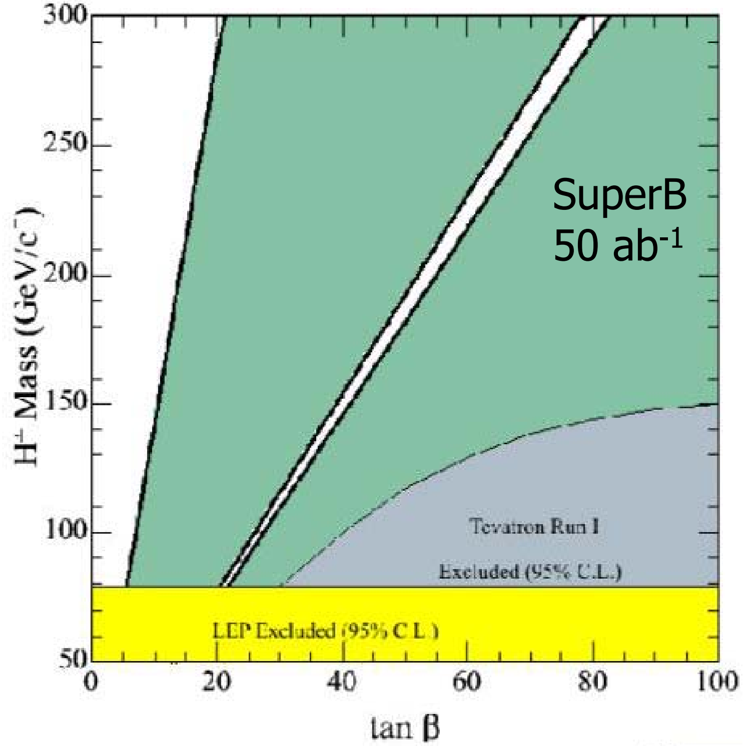
Charged Higgs limits from $B^- \to \tau^- \nu_\tau$

If the theoretical prediction is taken for $\mathbf{f_B}$
→ limit on charged Higgs mass vs. tanβ

$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

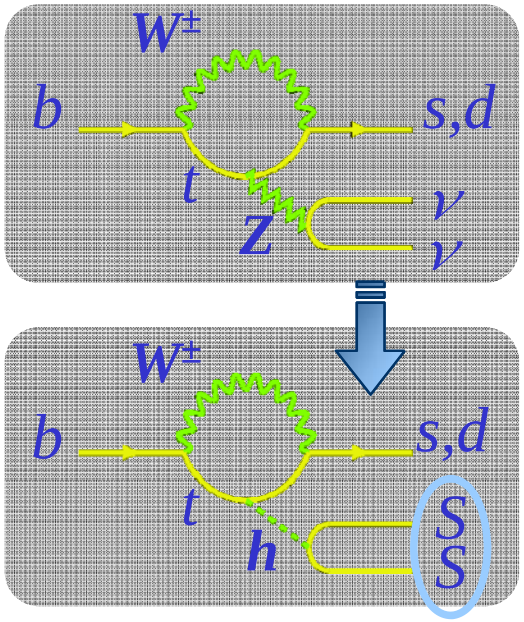


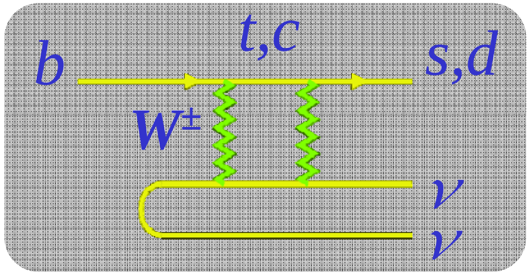




$B \to K^{(*)} \nu\nu$

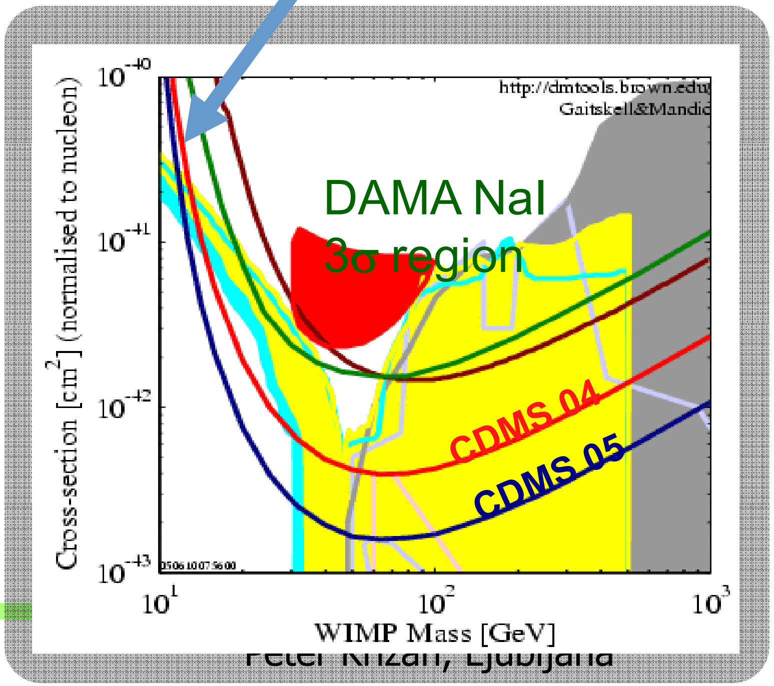
- Proceed through electroweak penguin + box diagram.
- Sensitive to New Physics in the loop diagram.
- Theoretically clean: no long distance contributions.
- May be sensitive to light dark matter (C. Bird, PRL 93, 201803 (2004))



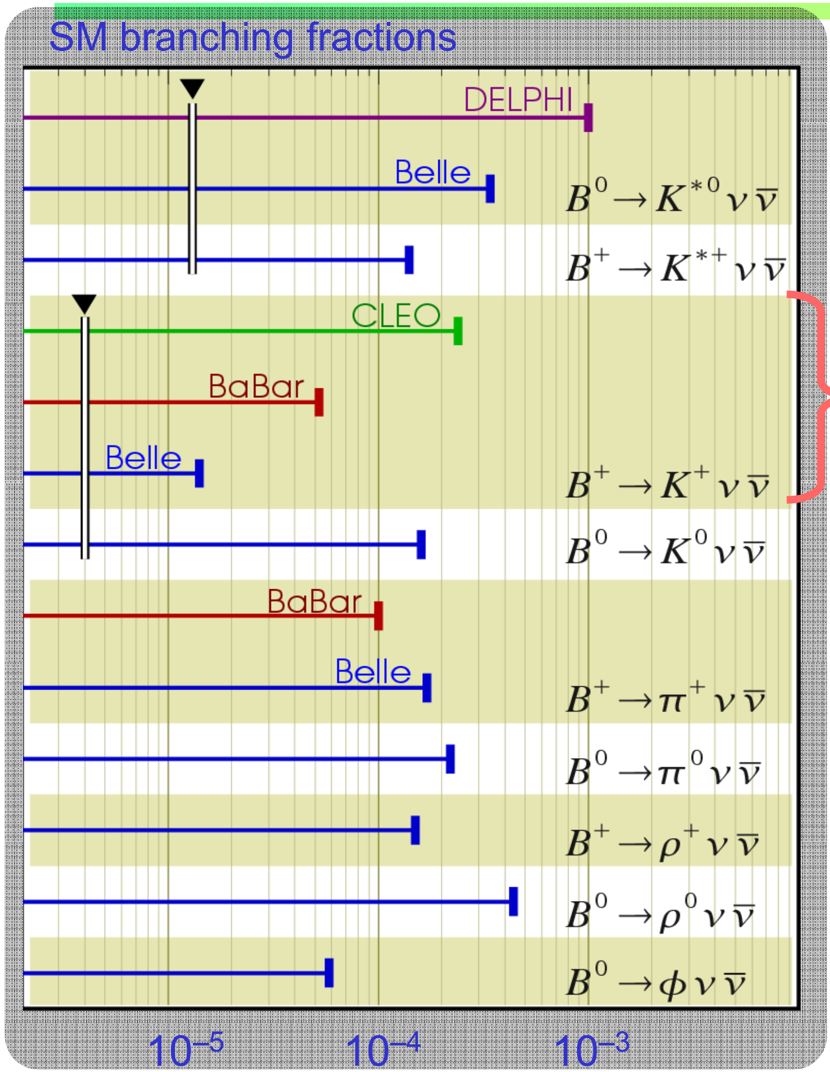


$b \to s$ + Missing E may be enhanced by this extra diagram.

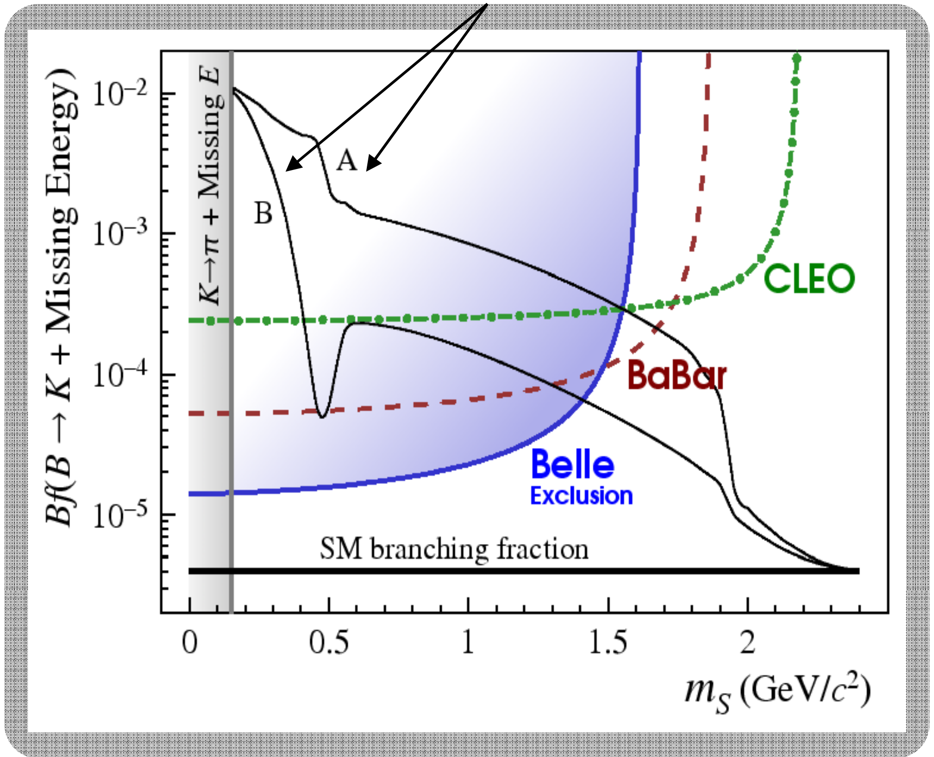
No sensitivity to light dark matter (M<10 GeV) in direct searches



$B \to K^{(*)}\nu\nu$: present limits



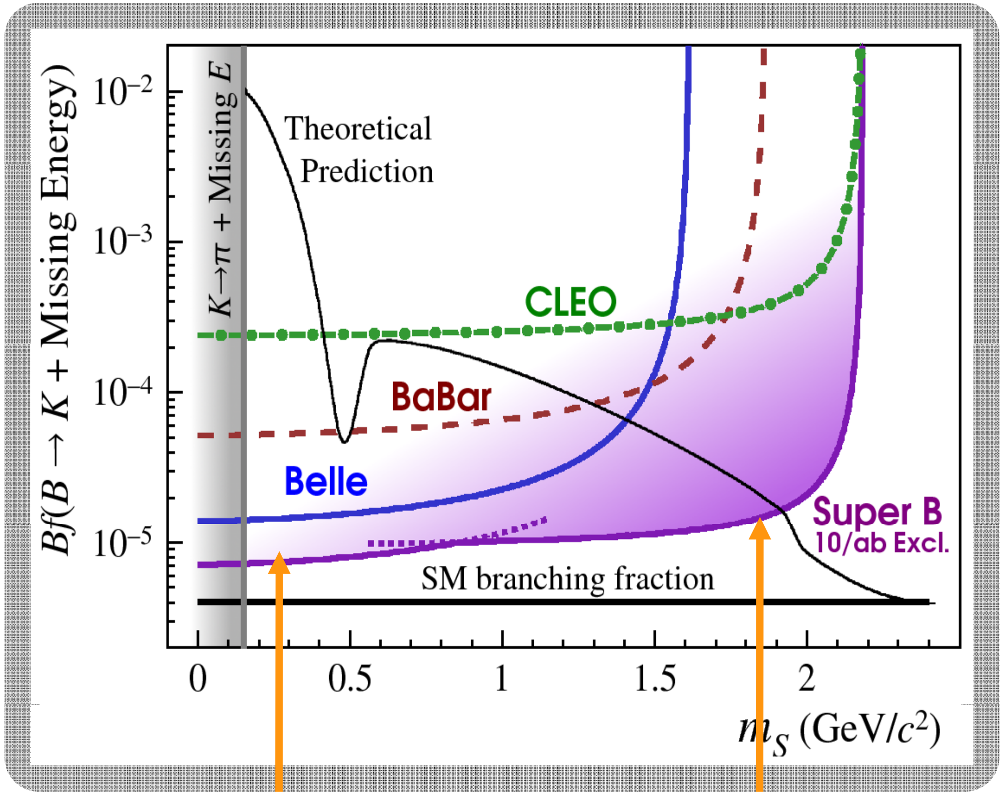
- Limit on light dark matter based on the $K^+\nu\nu$ limits (using theory predictions, C. Bird, PRL 93, 201803 (2004)



- Limit depends on P*(K) momentum cut

$B \to K^{(*)} \nu\nu$: prospects for 10/ab

- Assuming no changes in the analysis & detector:

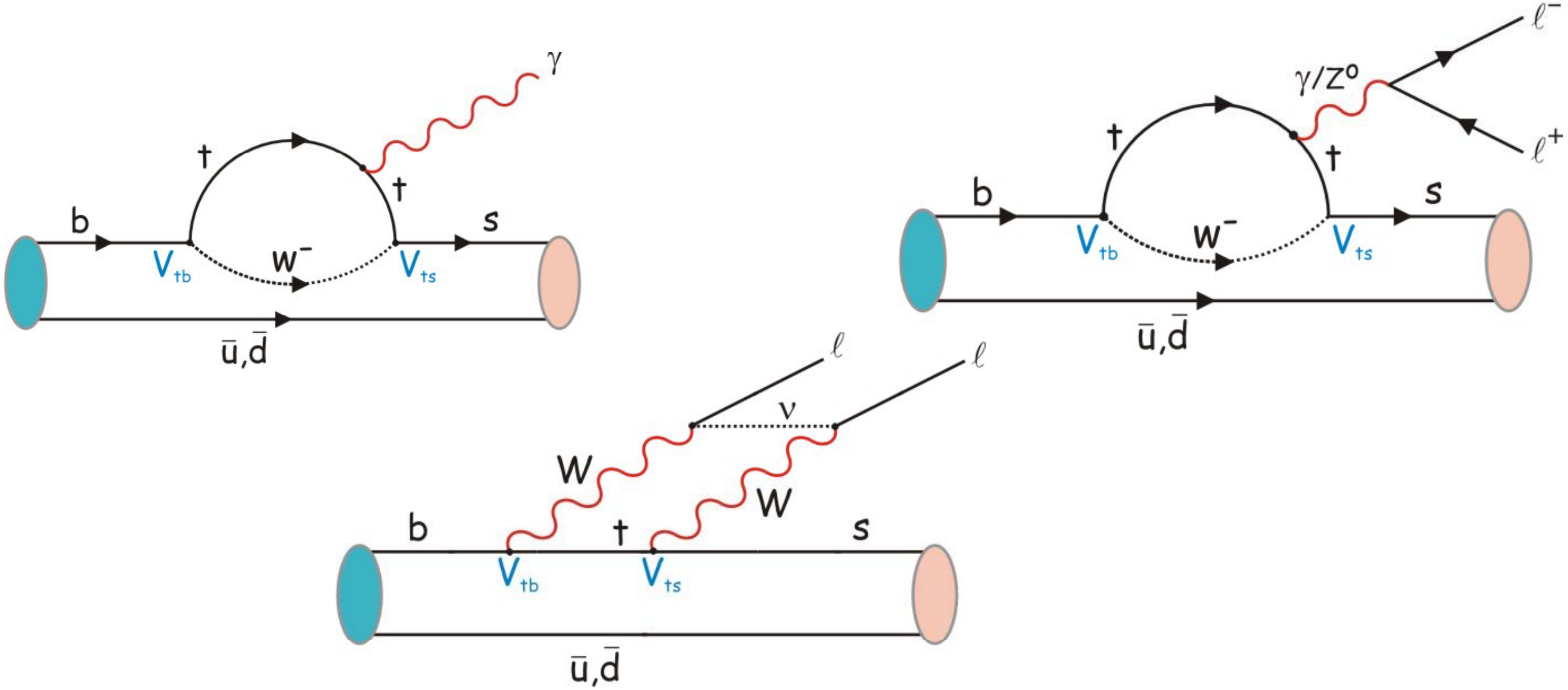


with the same $P^*(K)$ threshold (1.6 GeV)

with a lower $P^*(K)$ threshold (0.7 GeV)

Why FCNC decays?

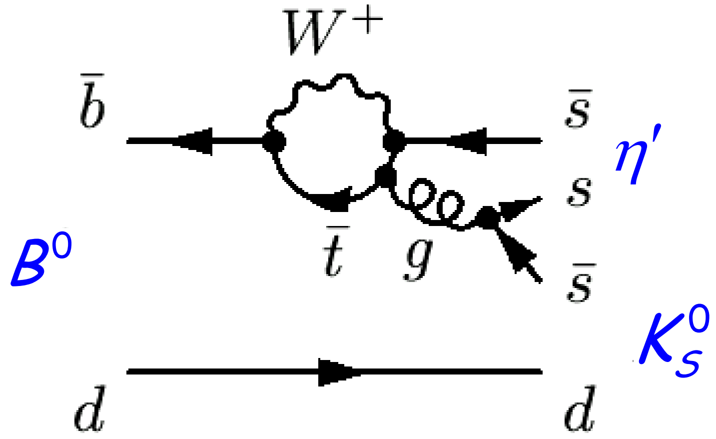
Flavour changing neutral current (FCNC) processes (like b→s, b→d) are fobidden at the tree level in the Standard Model. Proceed only at low rate via higher-order loop diagrams. Ideal place to search for new physics.



How can New Physics contribute to b→s?

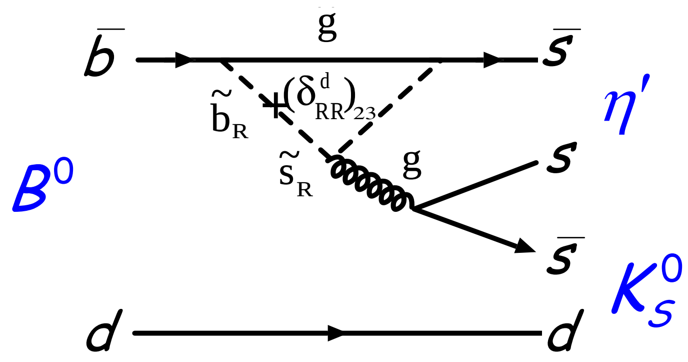
For example in the process:

$B^0 \rightarrow \eta' K^0$



Ordinary penguin diagram with a t quark in the loop

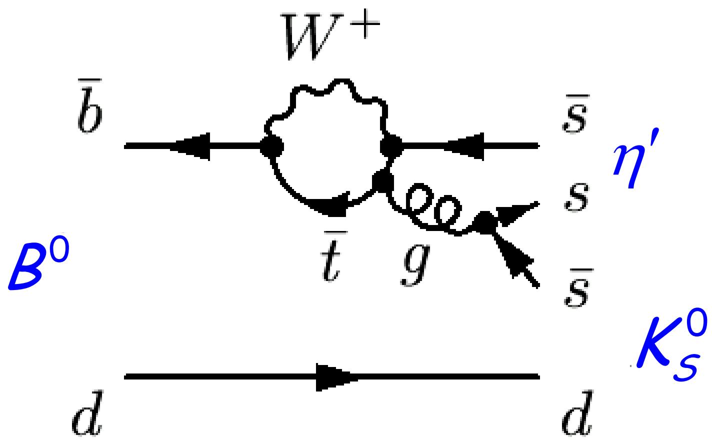
Diagram with supersymmetric particles



Searching for new physics phases in CP violation measurements in b→s decays

Prediction in SM:

$B^0 \to \eta' K^0$



$$a_f = -\mathrm{Im}(\lambda_f)\sin(\Delta m t)$$

$$\mathrm{Im}(\lambda_f) = \xi_f \sin 2\phi_1$$

The same value as in the decay $B^0 \to J/\psi\, K_S$!

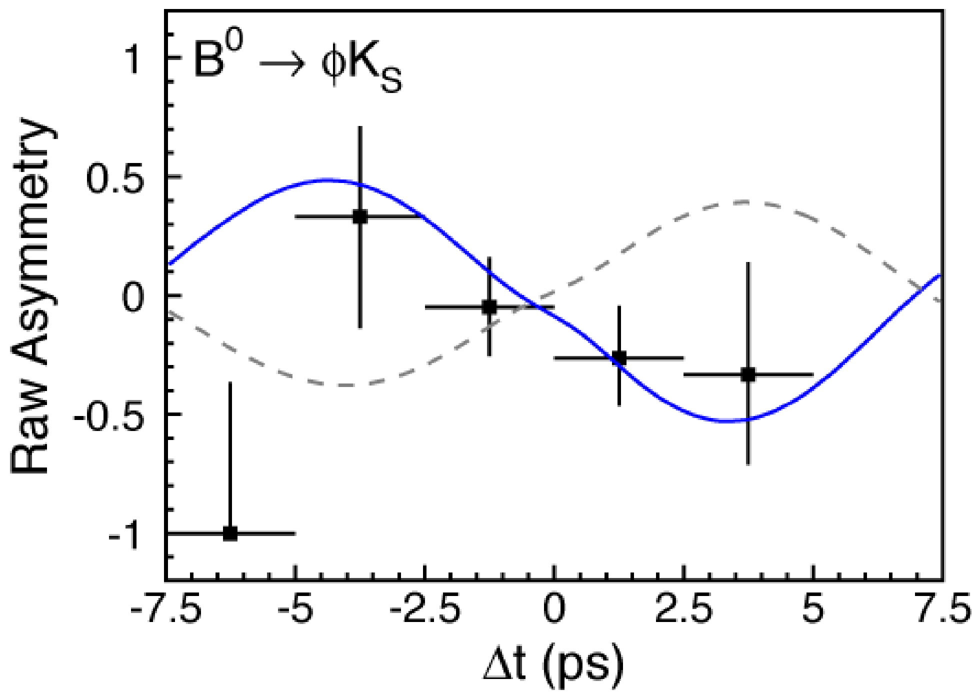
This is only true if there are no other particles in the loop! In general the parameter can assume a different value $\sin 2\phi_1^{\mathrm{eff}}$

Result of 2003 (140/fb): surprise!

Measurement: points with error bars.

Standard Model predictions: dotted

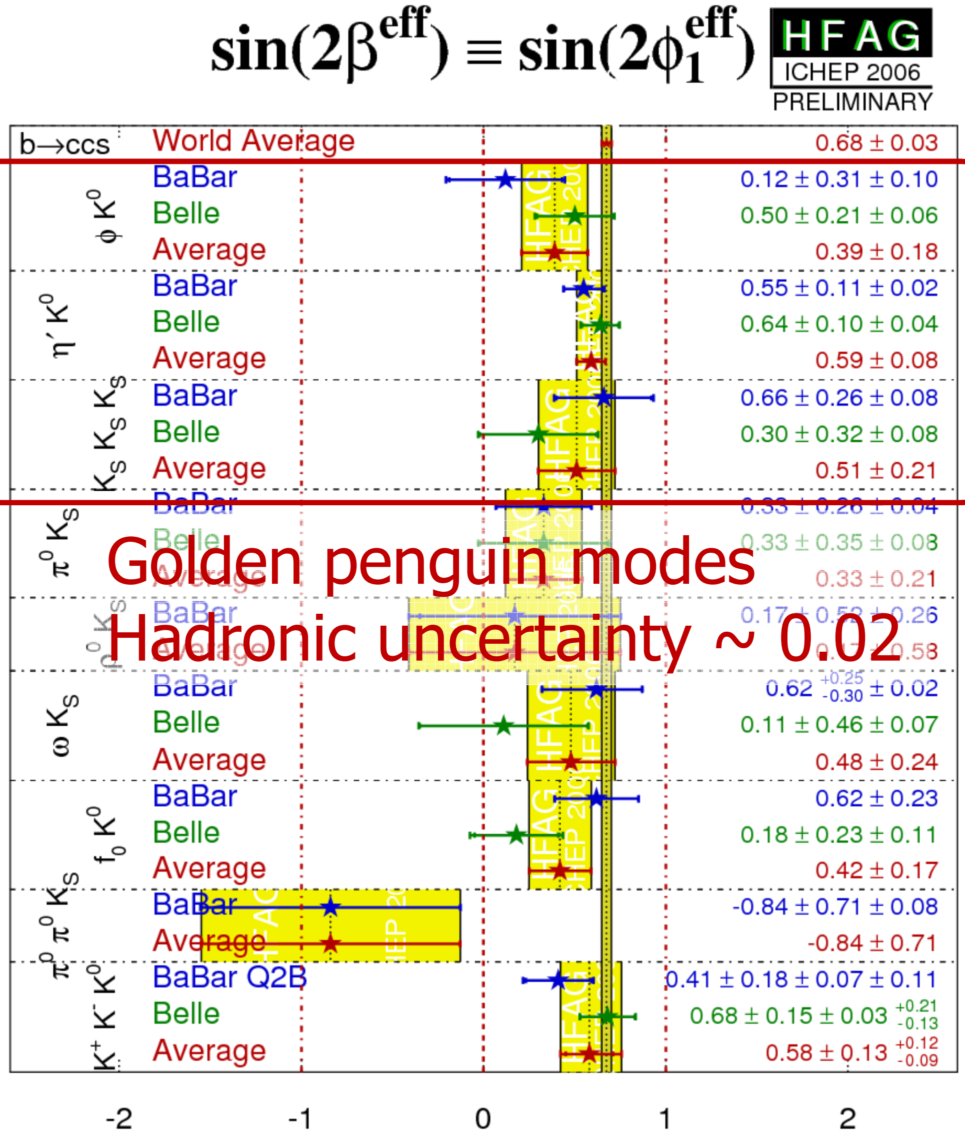
Result of the unbinned likelihood fit: blue curve



Measure: $S=-0.96\pm0.50$, expect $S= \sin2\phi_1=+0.731 \pm 0.056$

not conclusive → needed more data

Search for NP: $b \to s\bar{q}$



Golden penguin modes

Hadronic uncertainty ~ 0.02

ICHEP08

BaBar
Belle
Naïve average

ϕK^0:
0.26±0.25±0.04
0.67± $^{0.25}_{0.27}$ ±0.07
0.45±0.18

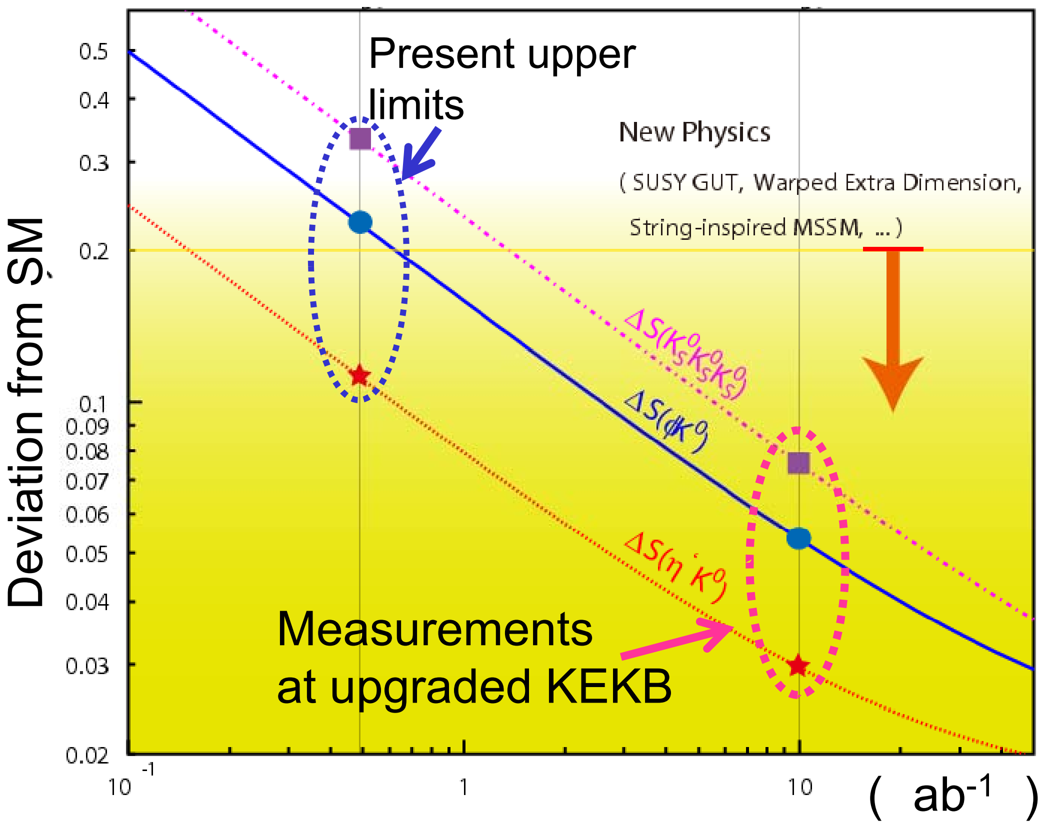
$\eta' K^0$:
0.57±0.08±0.02
0.64±0.10±0.04
0.60±0.07

$K_S K_S K_S$:
0.71±0.24±0.04
0.30±0.32±0.08
0.57±0.20

Need much more data to clarify the issue

Searches for new sources of quark mixing and CP violation

CP asymmetries of penguin dominated B decays



Reach of present B factories

Reach of upgraded KEKB

Deviation from SM

New source of CP violation

Relevant to baryogenesis?

A difference in the direct violation of CP symmetry in B^+ and B^0 decays

CP asymmetry

$$\mathcal{A}_f = \frac{N(\overline{B} \to \bar{f}) - N(B \to f)}{N(\overline{B} \to \bar{f}) + N(B \to f)}$$

Difference between B^+ and B^0 decays

In SM expect $\mathcal{A}_{K^\pm\pi^\mp} \approx \mathcal{A}_{K^\pm\pi^0}$

Measure:

$$\mathcal{A}_{K^\pm\pi^\mp} = -0.094 \pm 0.018 \pm 0.008$$

$$\mathcal{A}_{K^\pm\pi^0} = +0.07 \pm 0.03 \pm 0.01$$

$$\Delta\mathcal{A} = +0.164 \pm 0.037$$

A problem for a SM explanation
(in particular when combined with other measurements)
A hint for new sources of CP violation?

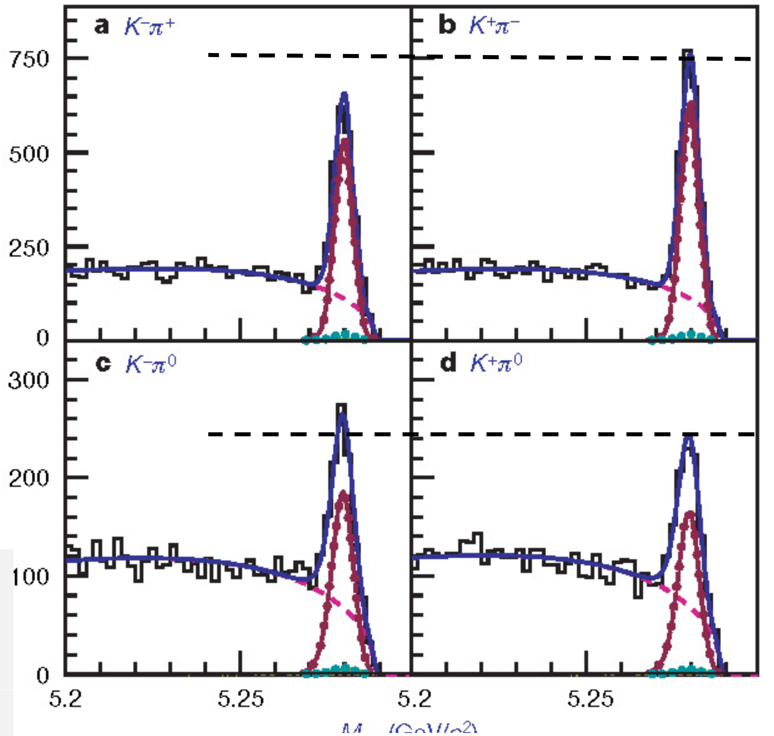

nature International weekly journal of science

nature Vol 452|20 March 2008|doi:10.1038/nature06827

LETTERS

Difference in direct charge-parity violation between charged and neutral *B* meson decays

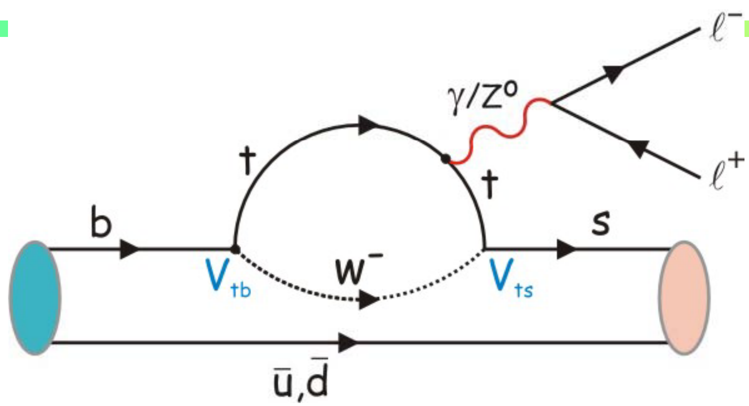
The Belle Collaboration*

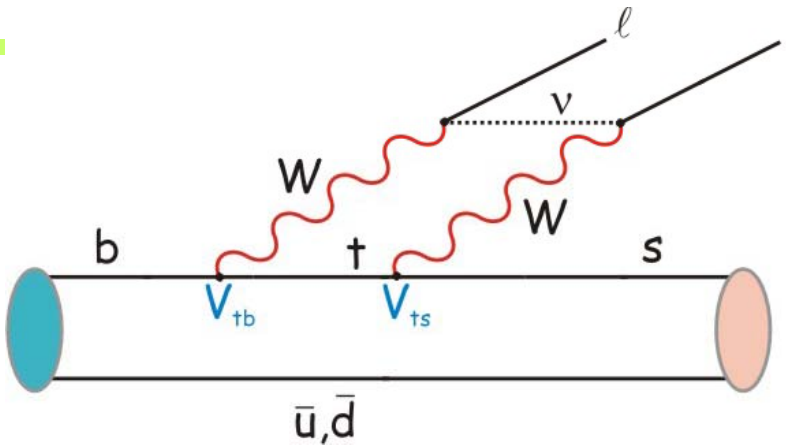


~1 in 10^5 B mesons decays in this decay mode

Belle, Nature 452, 332 (2008)

Another FCNC decay: $B \to K^* l^+ l^-$





$b \to s\, l^+ l^-$ was first measured in $B \to K\, l^+ l^-$ by Belle (2001).

Important for further searches for the physics beyond SM

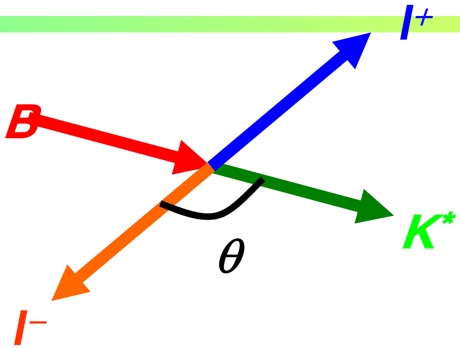
Particularly sensitive: backward-forward asymmetry in $K^* l^+ l$

$$A_{FB} \propto \Re\left[C_{10}^{*} \left(s C_9^{eff}(s) + r(s) C_7 \right) \right]$$

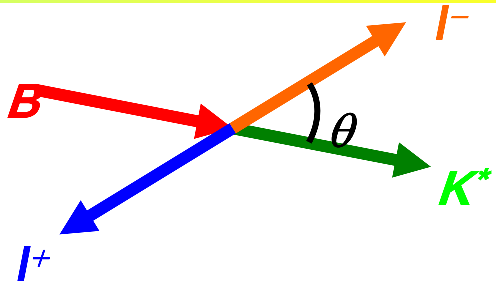
C_i : Wilson coefficients, abs. value of C_7 from $b \to s\gamma$

s=lepton pair mass squared

Backward-forward asymmetry in $K^* l^+ l$

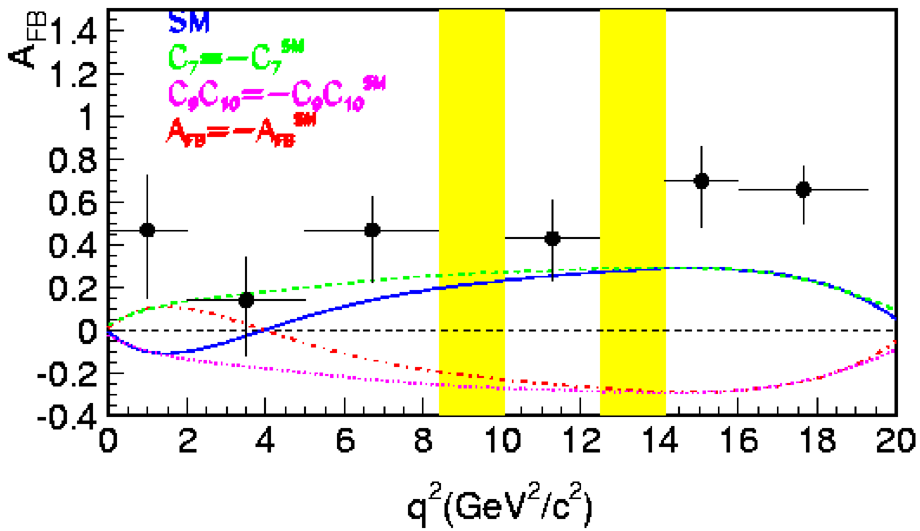


Backward event



Forward event

[γ^* and Z^* contributions in $B \to K^* l\, l$ interfere and give rise to forward-backward asymmetries c.f. $e^+e^- \to \mu^+ \mu^-$]

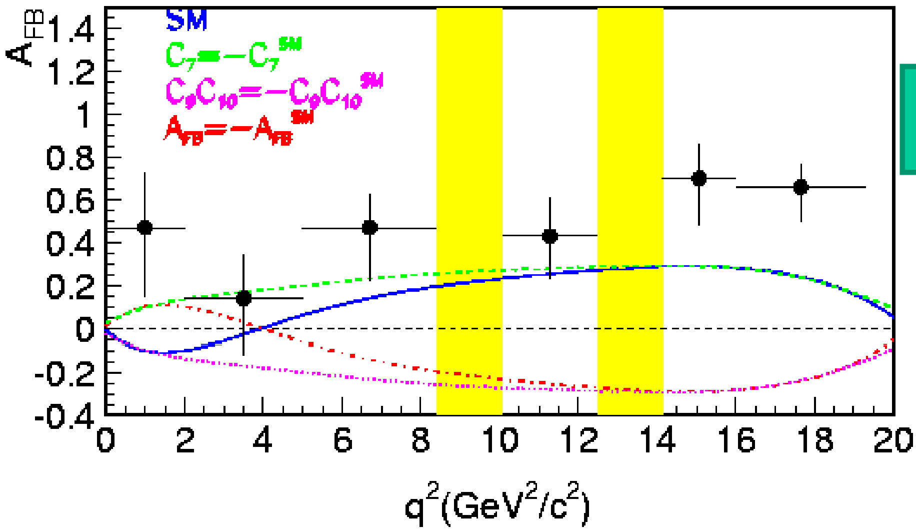


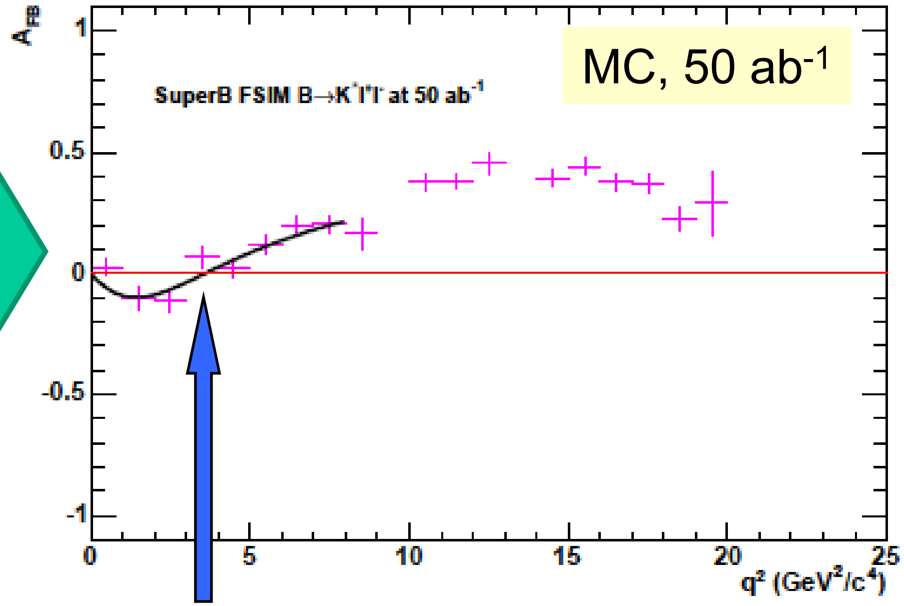
657 M BB

$$A_{FB} \propto \Re\left[C_{10}^{*} \left(s C_9^{eff}(s) + r(s) C_7 \right) \right]$$

$A_{FB}(B \rightarrow K^* l^+ l^-)[q^2]$ at a Super B Factory

657 M BB



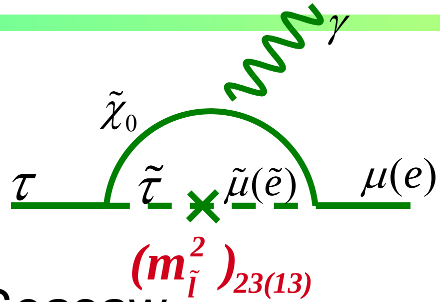


- Zero-crossing q^2 for A_{FB} will be determined with a 5% error with $50ab^{-1}$.

Strong competition from LHCb and ATLAS/CMS

LFV and New Physics

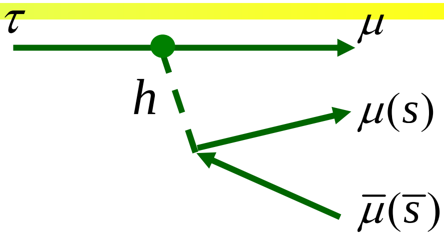
$\tau \rightarrow l\gamma$



- SUSY + Seasaw
- Large LFV $Br(\tau \rightarrow \mu\gamma) = O(10^{-7\sim 9})$

$$Br(\tau \rightarrow \mu\gamma) \cong 10^{-6} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}} \right) \left(\frac{1\,TeV}{m_{SUSY}} \right)^4 \tan^2\beta$$

$\tau \rightarrow 3l, l\eta$



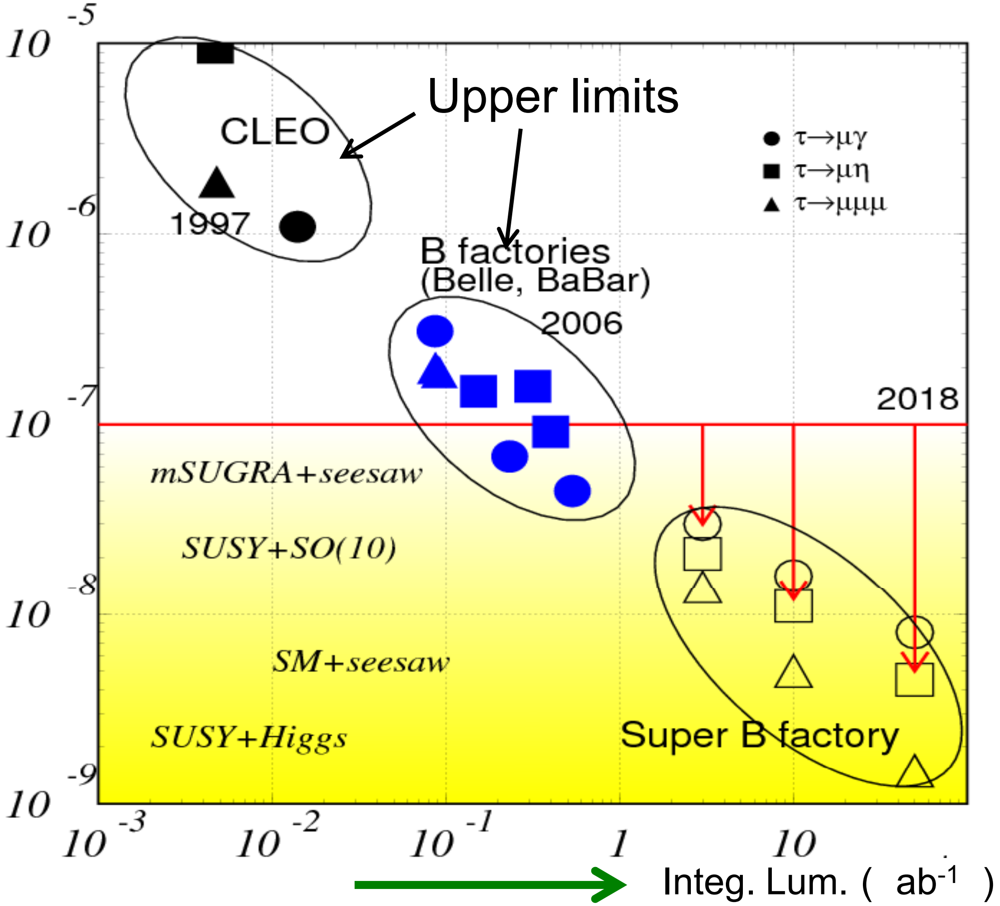
- Neutral Higgs mediated decay.
- Important when MSUSY >> EW scale.

$$Br(\tau \rightarrow 3\mu) = 4 \times 10^{-7} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}} \right) \left(\frac{\tan\beta}{60} \right)^6 \left(\frac{100\,GeV}{m_A} \right)^4$$

model	$Br(\tau \rightarrow \mu\gamma)$	$Br(\tau \rightarrow lll)$
mSUGRA+seesaw	10^{-7}	10^{-9}
SUSY+SO(10)	10^{-8}	10^{-10}
SM+seesaw	10^{-9}	10^{-10}
Non-Universal Z'	10^{-9}	10^{-8}
SUSY+Higgs	10^{-10}	10^{-7}

Precision measurements of τ decays

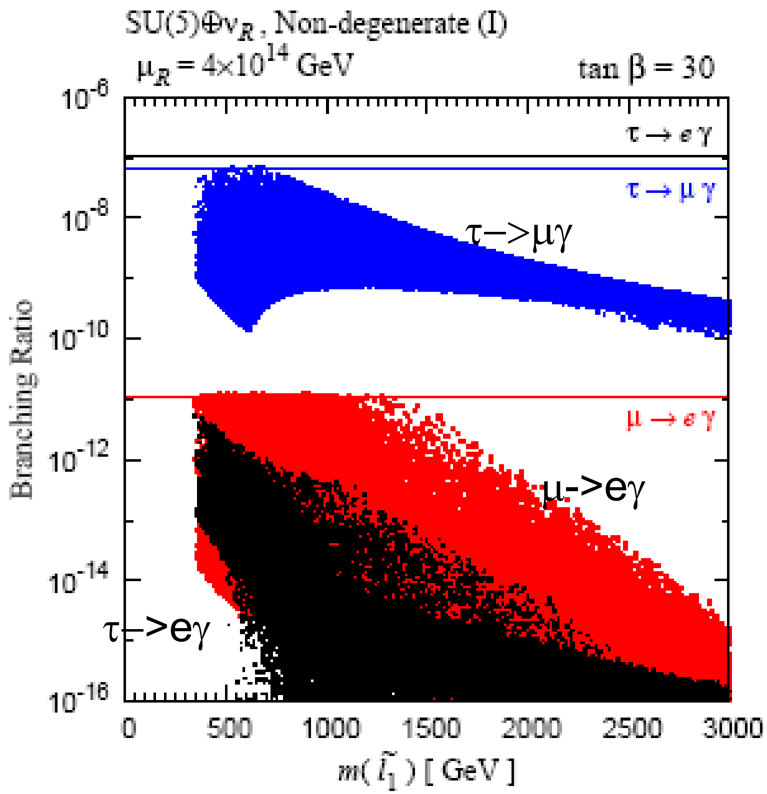
LF violating τ decay?



Reach of B factories

Upgraded KEKB

Theoretical predictions compared to present experimental limits



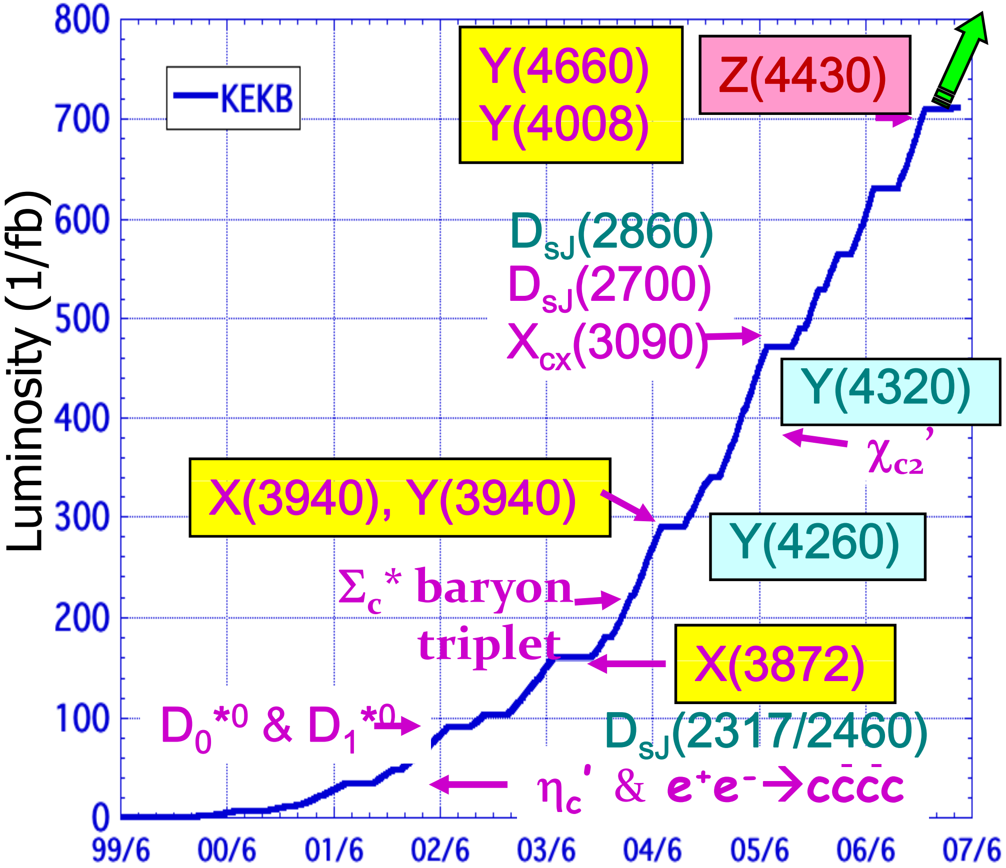
T.Goto et al., 2007

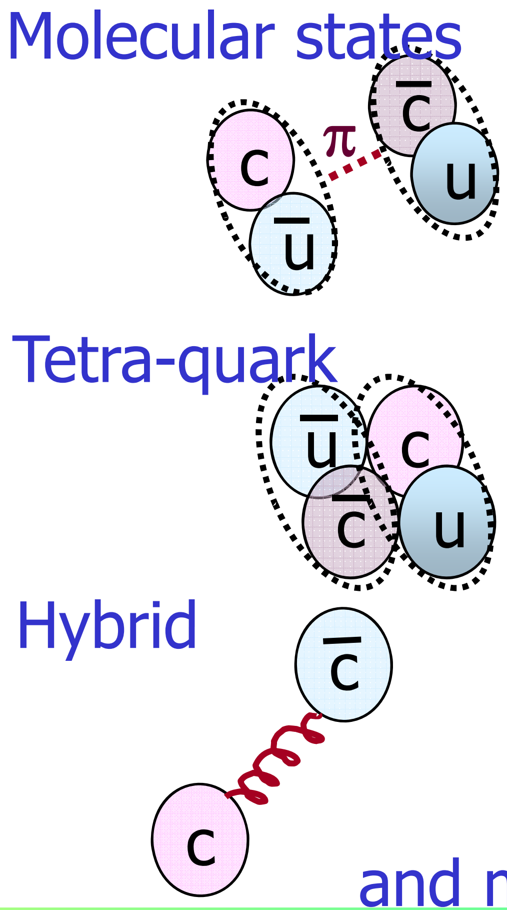
B factories: a success story

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decay modes (e.g., $B \rightarrow \tau\nu$, $D\tau\nu$) by fully reconstructing the other B meson
- Observation of D mixing
- CP violation in $b \rightarrow s$ transitions: probe for new sources if CPV
- Forward-backward asymmetry (A_{FB}) in $b \rightarrow sl^+l^-$ has become a powerfull tool to search for physics beyond SM.
- Observation of new hadrons

New hadrons at B-factories

Discoveries of many new hadrons at B-factories have shed light on new class of hadrons beyond the ordinary mesons.





and more…

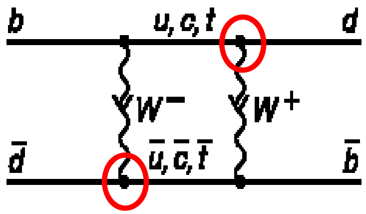
Physics at a Super B Factory

- There is a good chance to see new phenomena:
  - **CPV in B decays from the new physics (non KM)**
  - **Lepton flavor violations in τ decays.**
- They will help to diagnose (if found) or constraint (if not found) new physics models.
- Even in the worst case scenario (such as MFV), $B \rightarrow \tau\nu$, $D\tau\nu$ can probe the charged Higgs in large $\tan\beta$ region.
- **Physics motivation is independent of LHC.**
  - If LHC finds NP, precision flavour physics is compulsory.
  - If LHC finds no NP, high statistics B/τ decays would be an unique way to search for the TeV scale physics.

Super B Factory Motivation 2

- A lesson from history: the top quark

<u>Physics of top quark</u>
First estimate of mass: BB mixing → ARGUS
Direct production, Mass, width etc. → CDF/D0
Off-diagonal couplings, phase → BaBar/Belle

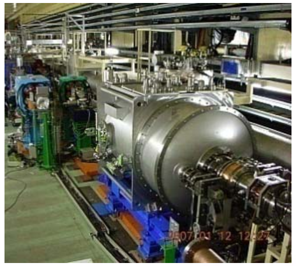


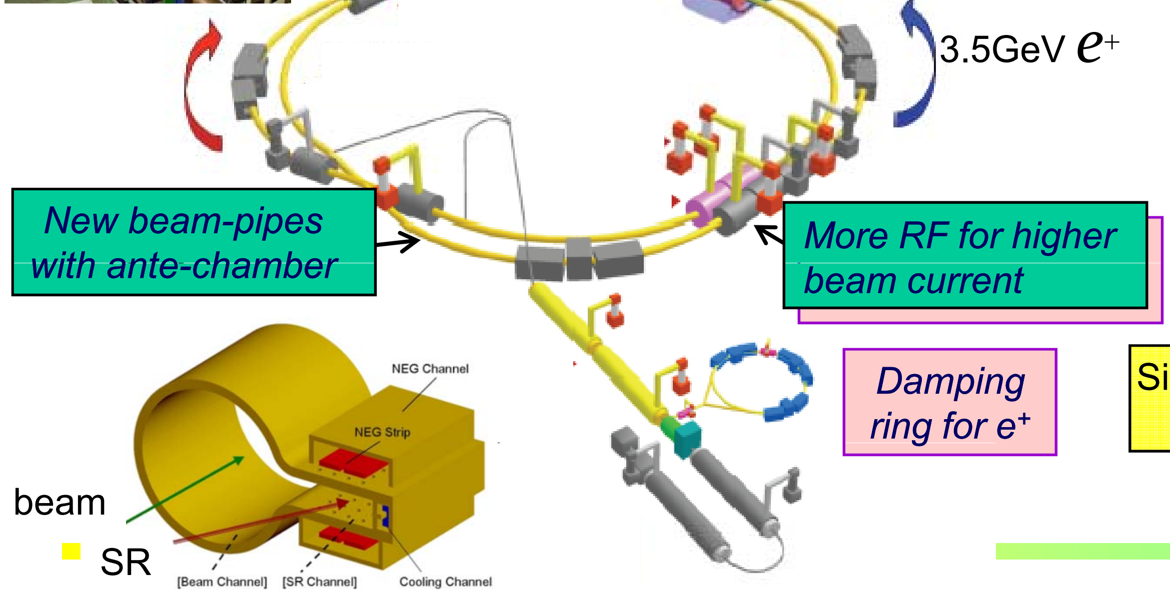
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

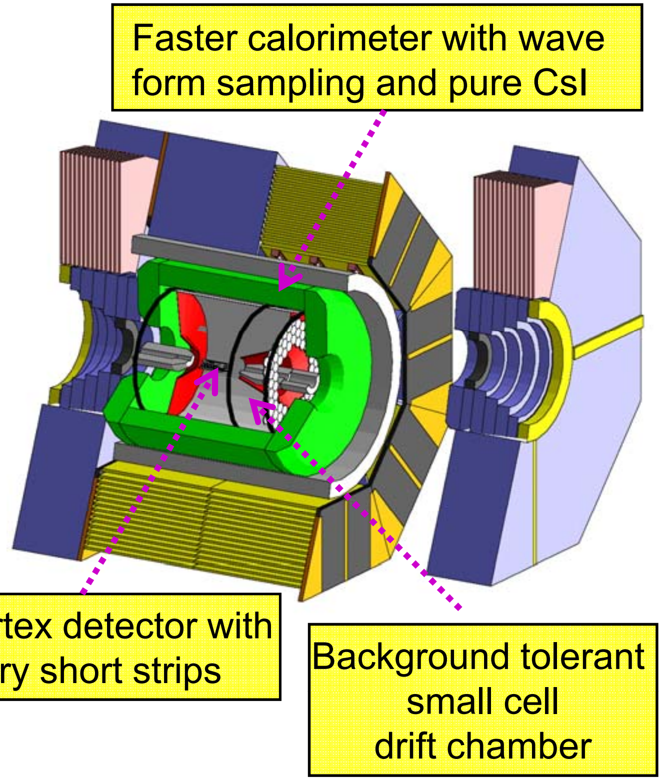
- There are many more topics: CPV in charm, new hadrons, …

KEKB Upgrade Plan : Super-B Factory at KEK

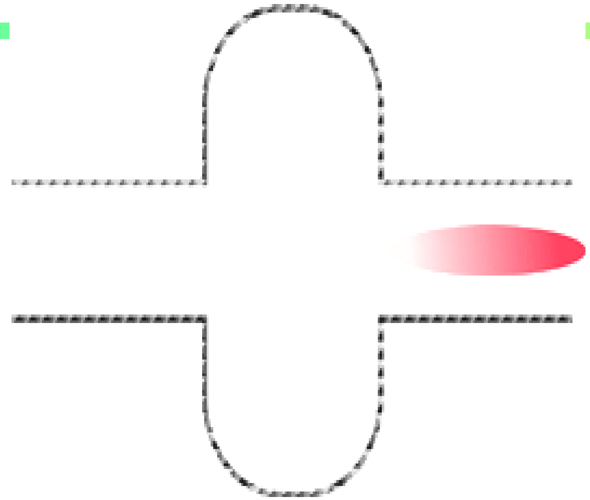
- *Asymmetric energy e^+e^- collider at $E_{CM}=m(\Upsilon(4S))$ to be realized by upgrading the existing KEKB collider.*
- *Initial target:* *10×higher luminosity* $\cong 2\times10^{35}$/cm²/sec **after 3 year shutdown**
  $\rightarrow 2\times10^{9}$ $B\bar{B}$ *and* $\tau^+\tau^-$ *per yr.*
- *Final goal:* $L=8\times10^{35}$/cm²/sec *and* $\int L\,dt$ = 50 ab^{-1}

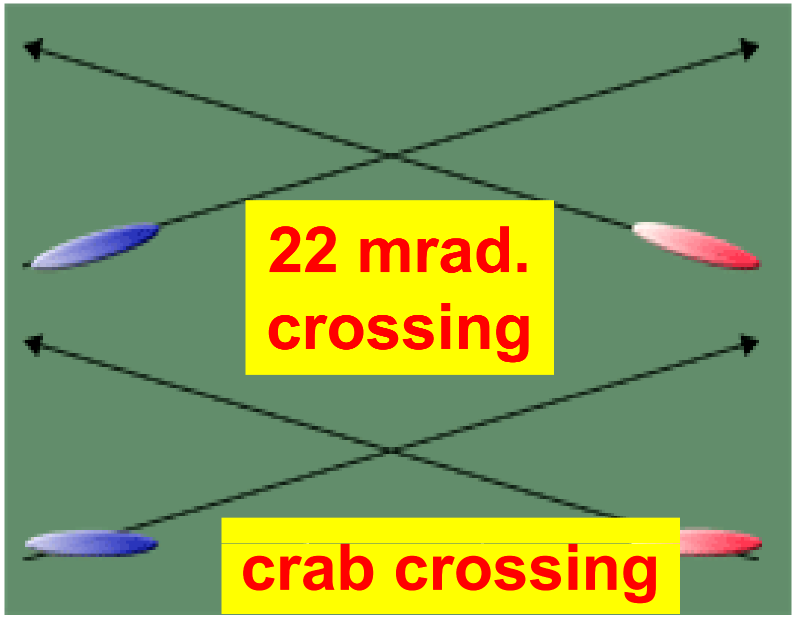






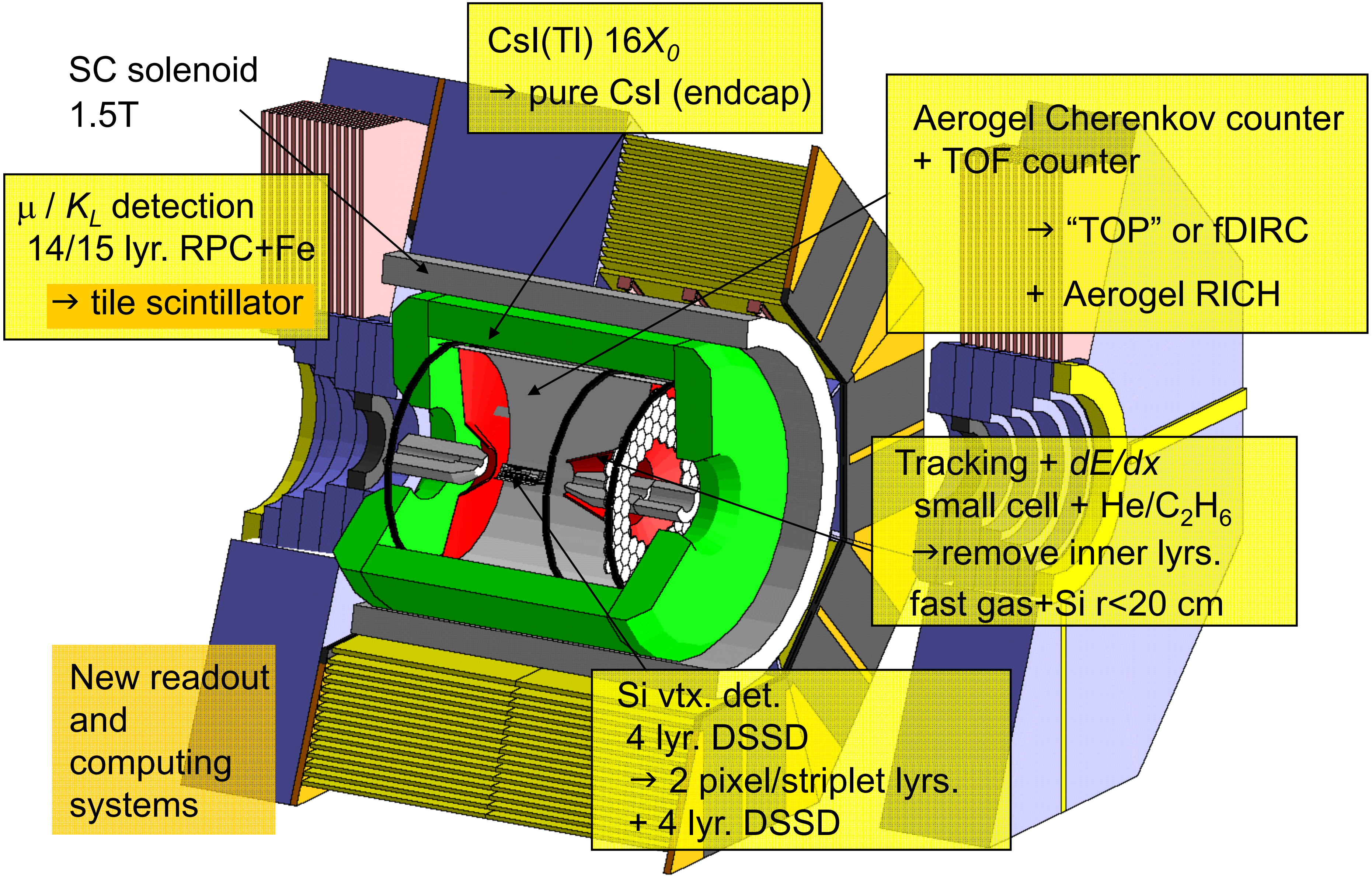
Crab cavity commissioning





Installed in the KEKB tunnel
(February 2007)

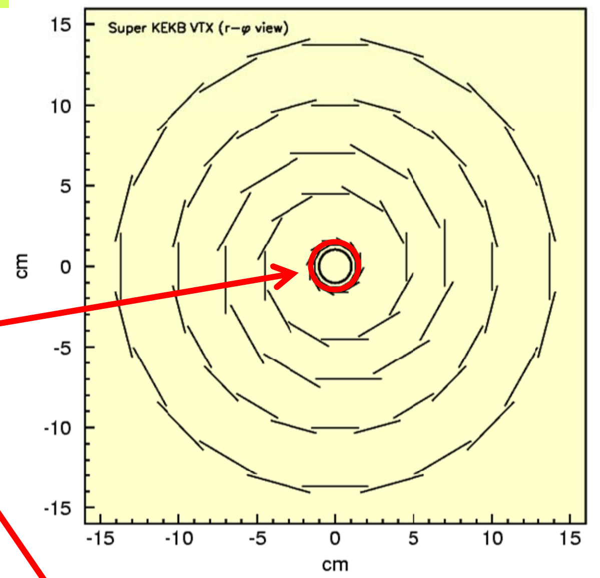
Belle Upgrade for Super-B



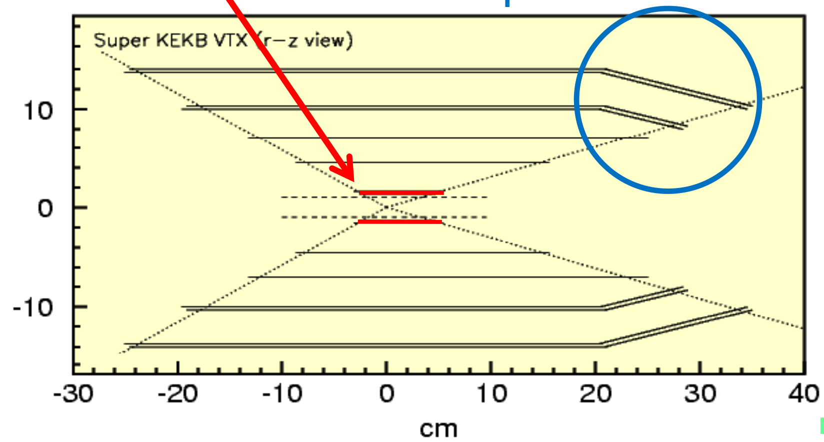
SVD Upgrade

- Readout chip: VA1TA→ APV25
  - Reduction of occupancy coming from beam background.
  - Pipeline readout to reduce dead time.
- Sensors of the innermost layer:

  Normal double sided Si detector (DSSD) → Pixel sensors
- Configuration: 4 layers →6 layers (outer radius = 8cm→14cm)
  - More robust tracking
  - Higher Ks vertex reconstruction efficiency
- Inner radius: 1.5cm → 1.0cm
  - Better vertex resolution. Not on day 1.

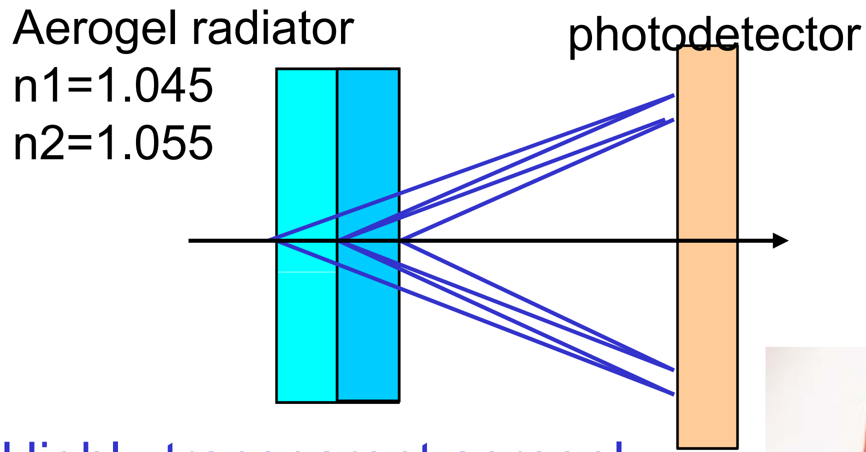


Slant layer to keep the acceptance



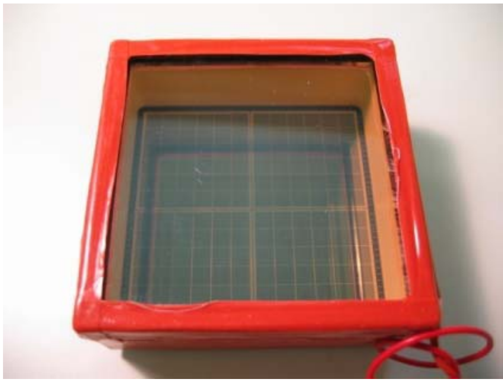
Aerogel RICH

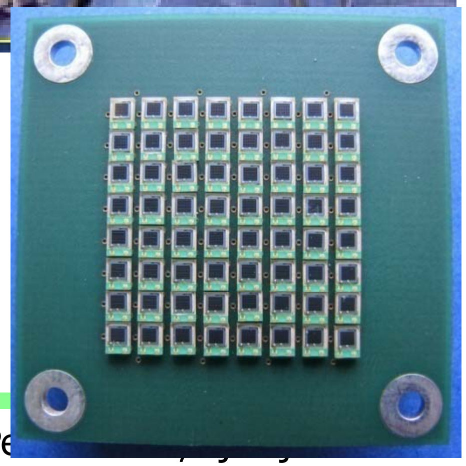
- Proximity focusing RICH with multilayer aerogel radiator with different indices.



Multi-pixel photodetector to measure single photon positions in B=1.5T
→ HAPD/MCP-PMT/G-APD

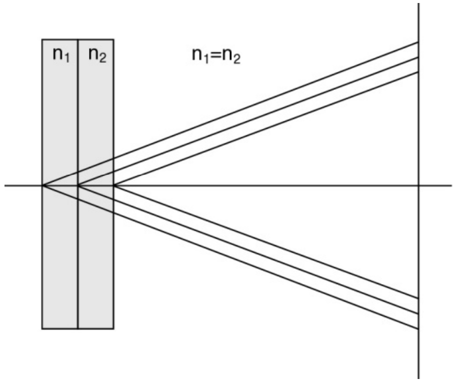
Highly transparent aerogel :
Λ_t > 40mm (λ=400nm)

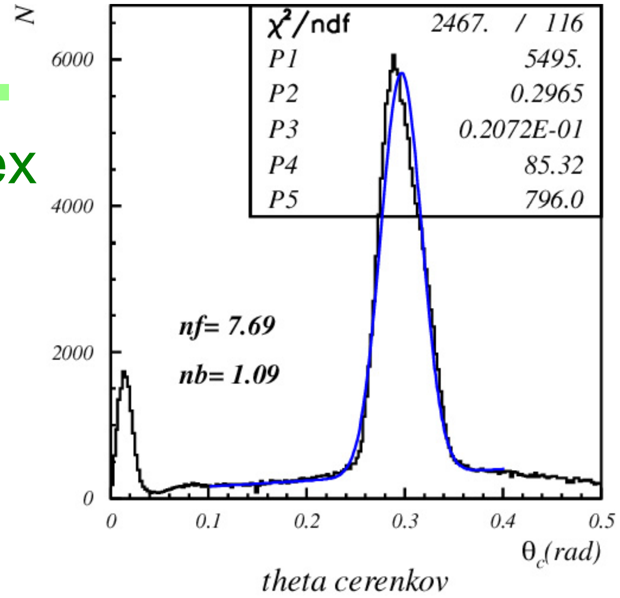


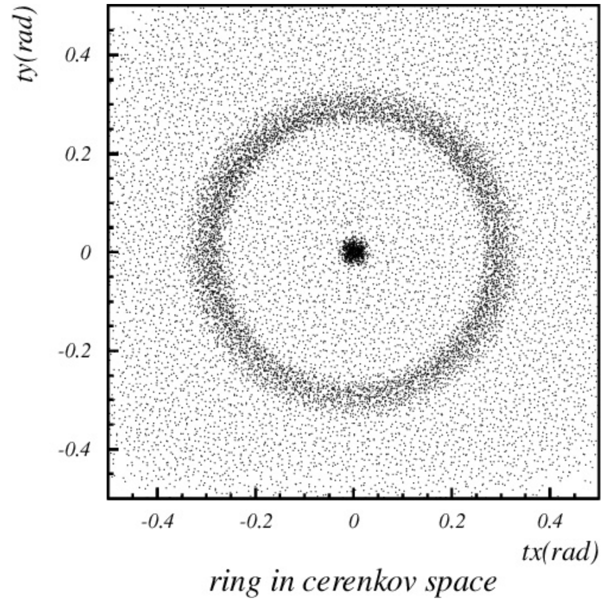


Aerogel RICH – test results

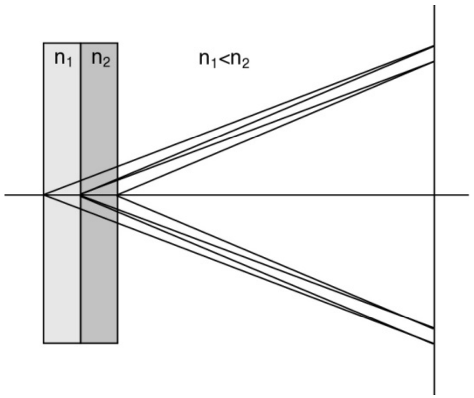
4cm aerogel single index

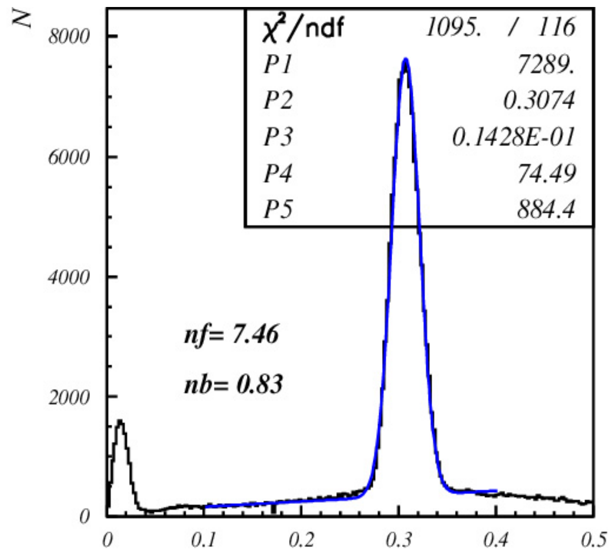


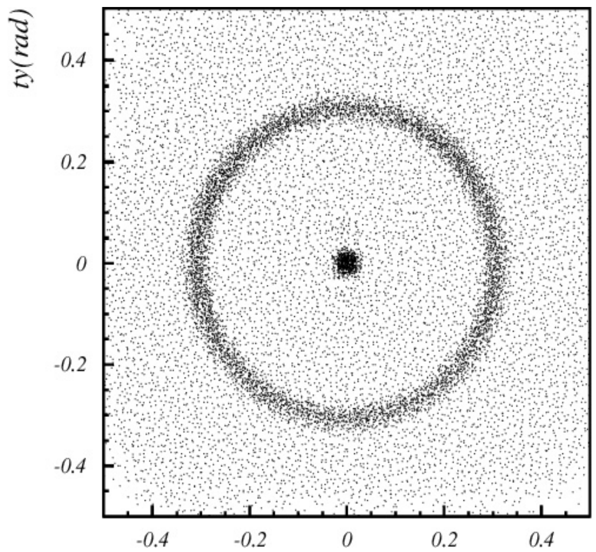




2+2cm aerogel







→NIM A548 (2005) 383

SiPMs for Aerogel RICH

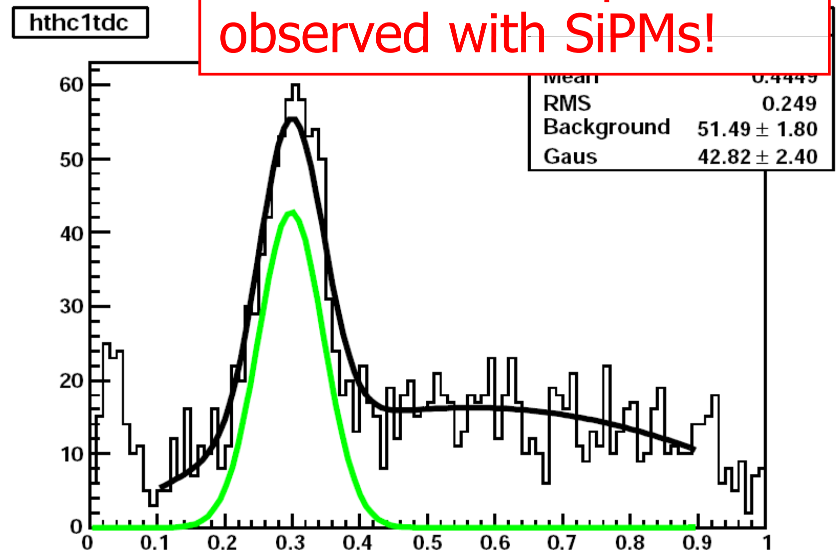
Main challenge: R+D of a photon detector for operation in high magnetic fields (1.5T). Candidates:

•MCP PMT: excellent timing, could be also used as a TOF counter

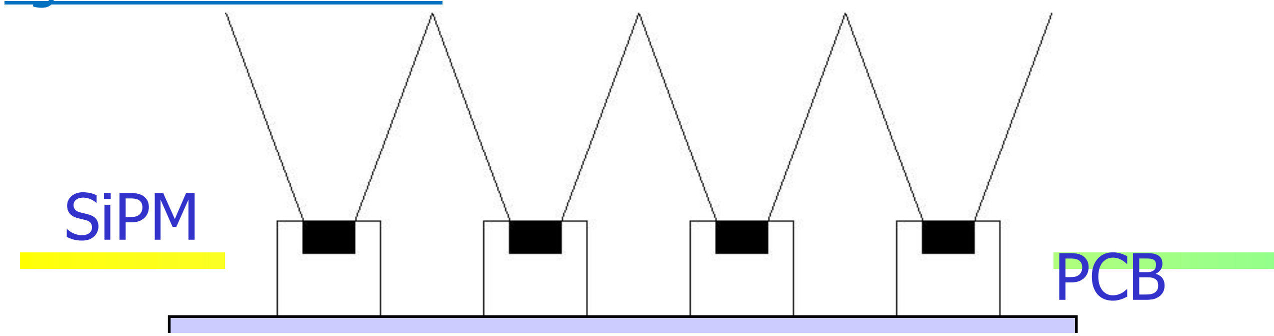
•HAPD: development with HPK

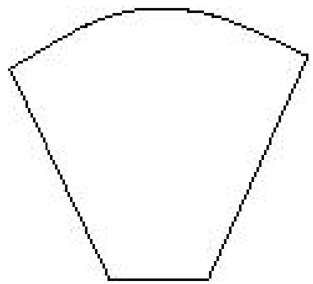
•SiPMs: easy to handle, but never before used for single photon detection (high dark count rate with single photon pulse height) → use a narrow time window and light concentrators

First Cherenkov photons observed with SiPMs!



→NIM A594 (2008) 13

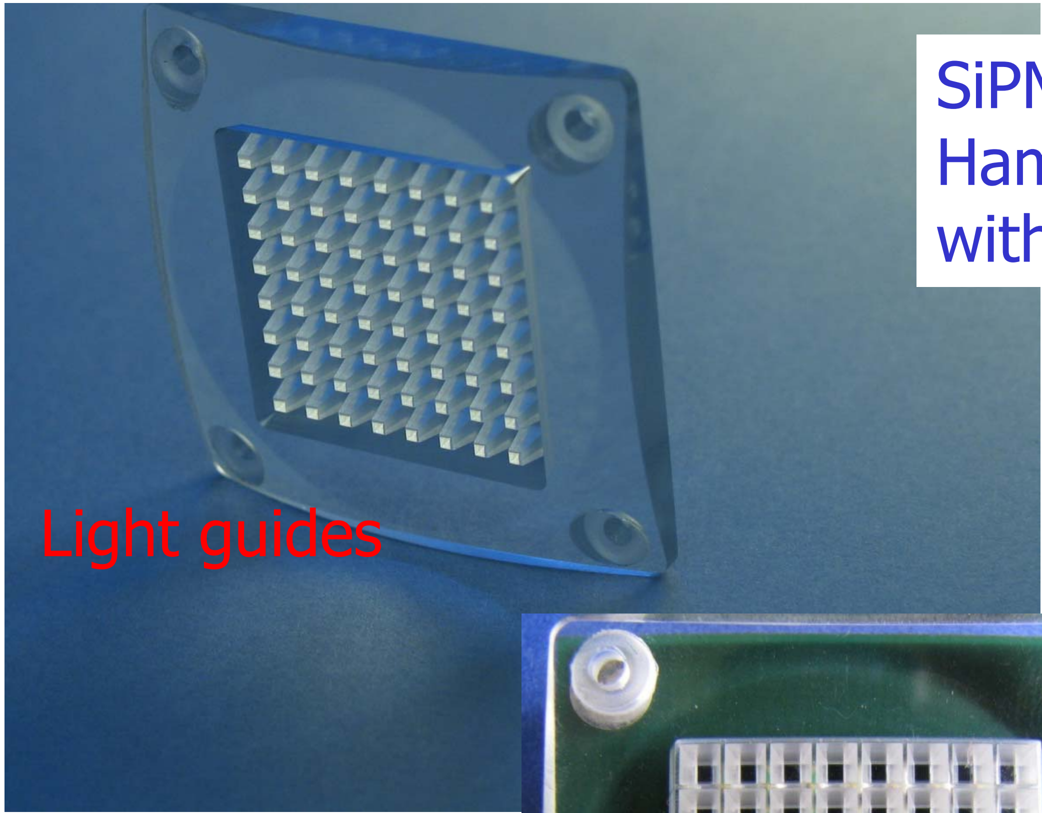


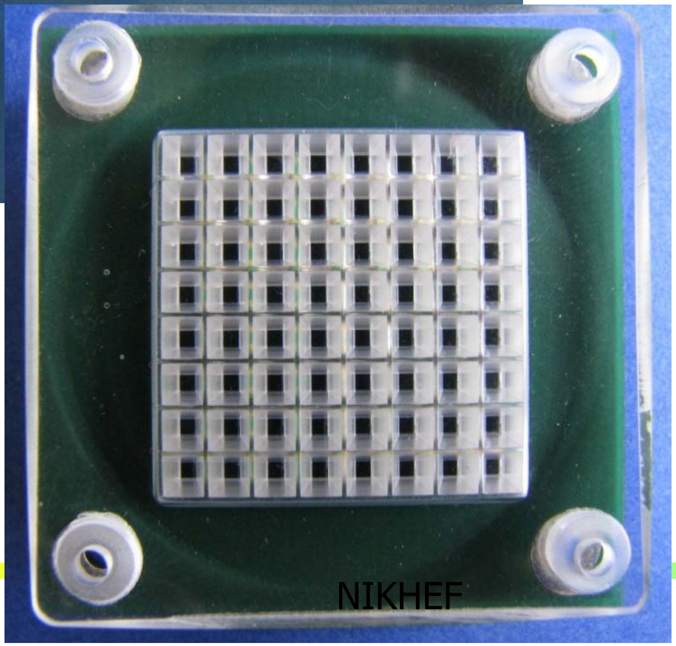


or combine a lens and mirror walls

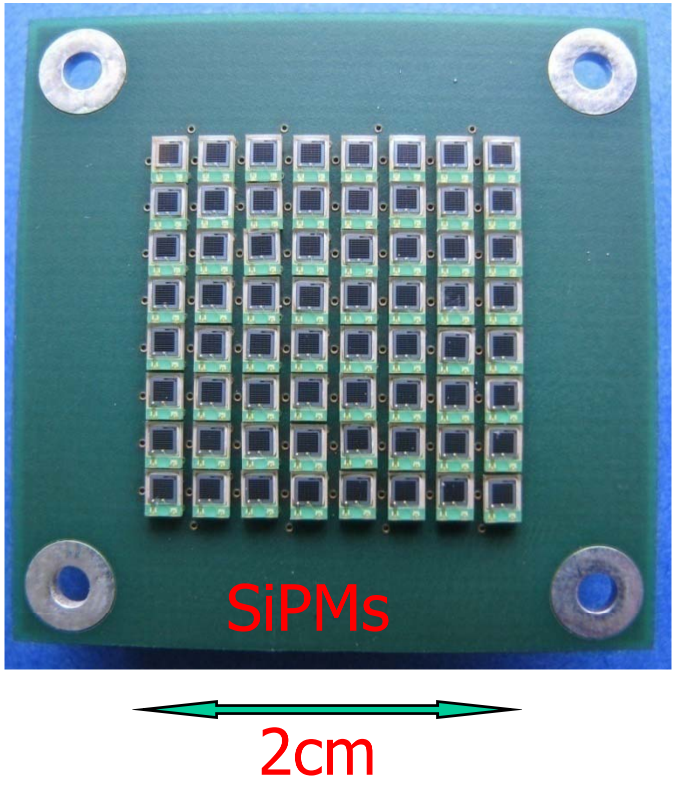
Detector module for beam tests at KEK

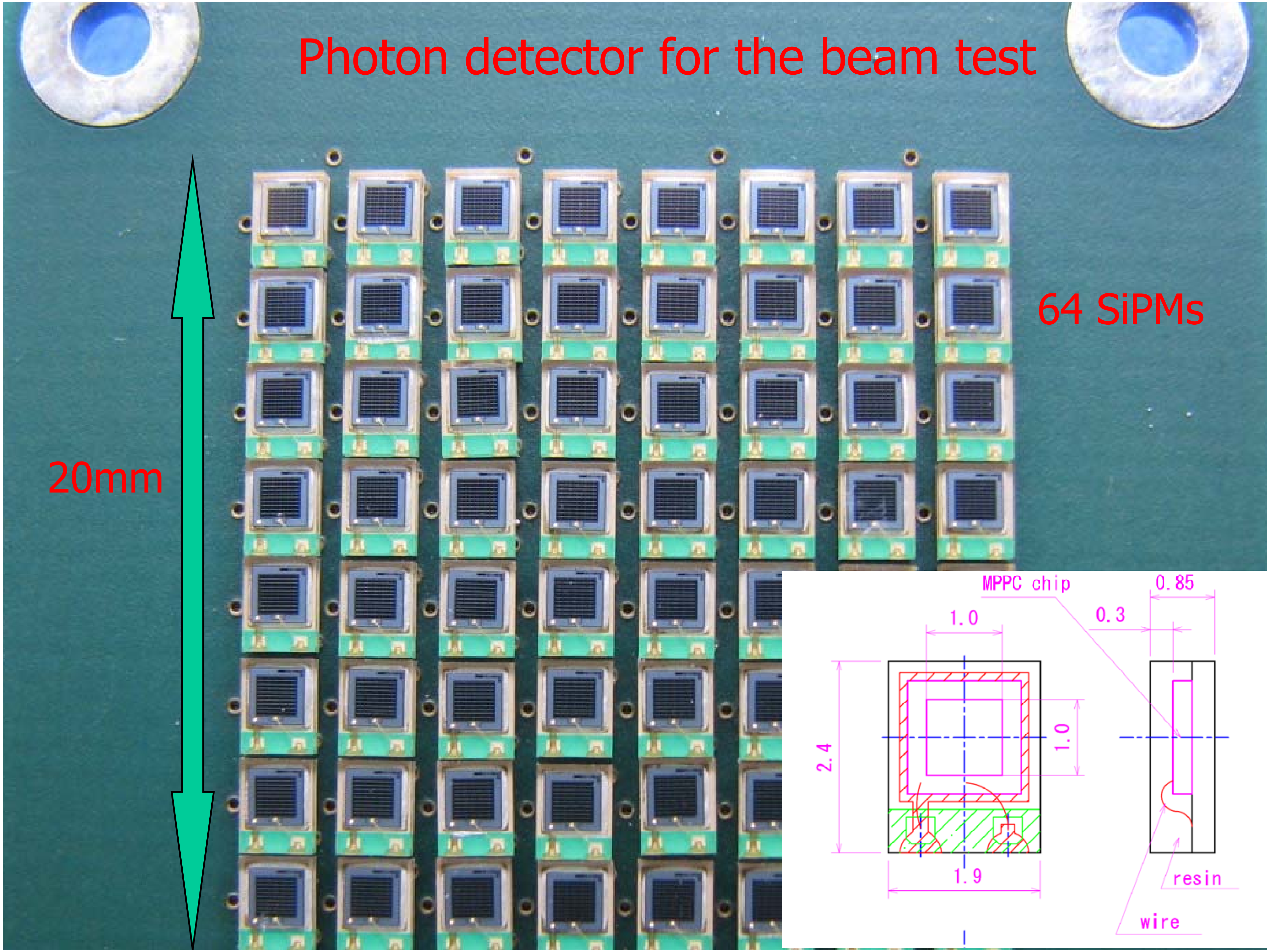
SiPMs: array of 8x8 SMD mount Hamamatsu S10362-11-100P with 0.3mm protective layer



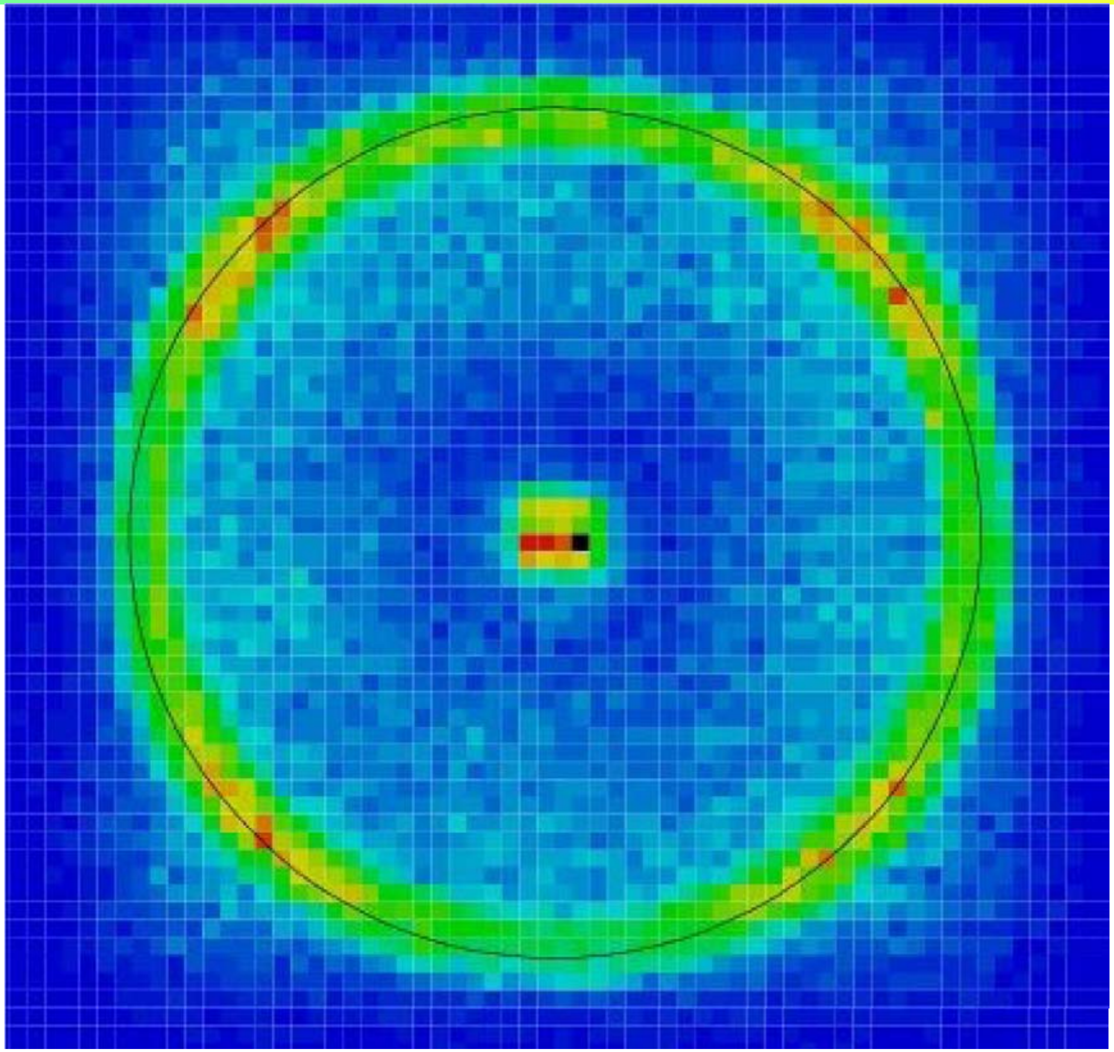


SiPMs + light guides




Photon detector for the beam test
64 SiPMs
20mm
MPPC chip
0.85
0.3
1.0
1.0
2.4
1.9
resin
wire

Cherenkov ring with SiPMs



Summary

- B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of the performance.
- Major upgrade in 2009-12 → Super B factory, L x10 → x40
- Essentially a new project, all components have to be replaced, plans exist (LoI and baseline design), nothing is frozen...
- Expect a new, exciting era of discoveries, complementary to LHC

More: http://www-f9.ijs.si/~krizan/sola/bad-liebenzell/bad-liebenzell.html

Back-up slides

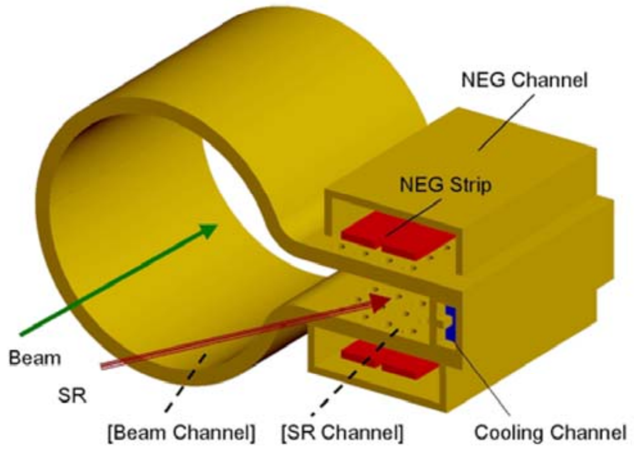
Luminosity gain and upgrade items (preliminary)

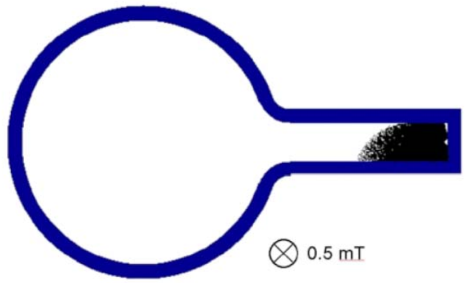
3 years shutdown

Item	Gain	Purpose
beam pipe	x 1.5	high current, short bunch, electron cloud
IR($\beta^*_{x/y}$=20cm/3 mm)	x 1.5	small beam size at IP
low emittance(12 nm) & $\nu_x \rightarrow 0.5$	x 1.3	mitigate nonlinear effects with beam-beam
crab crossing	x 2	mitigate nonlinear effects with beam-beam
RF/infrastructure	x 3	high current
DR/e^+ source	x 1.5	low β^* injection, improve e^+ injection
charge switch	x ?	electron cloud, lower e^+ current

Super-KEKB (cont'd)

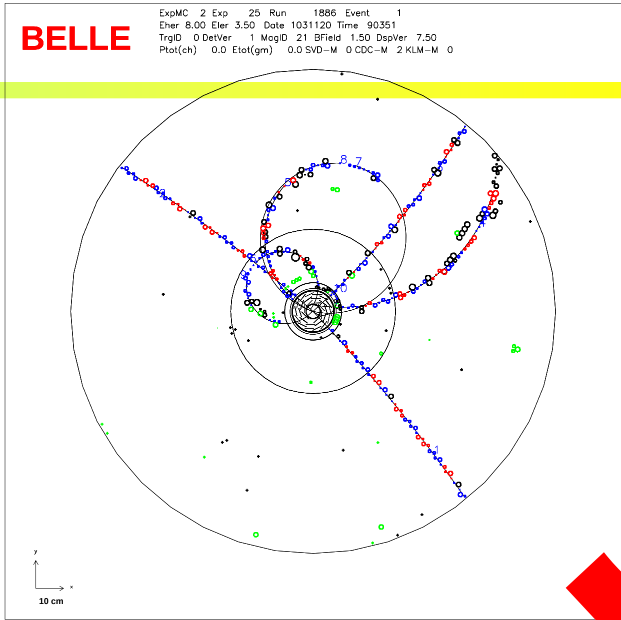
- Ante-chamber /solenoid for reduction of electron clouds





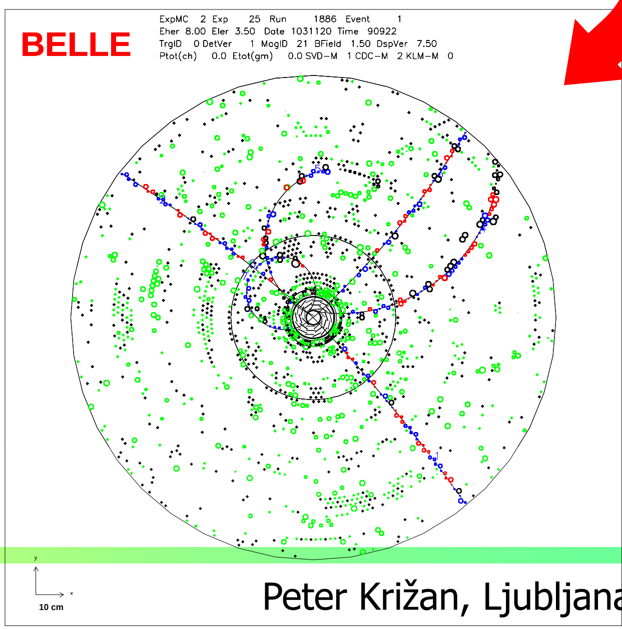
Ante-chamber
with solenoid field

Requirements for the Super B detector



Critical issues at L= 4 x 10^{35}/cm^2/sec

- **Higher background ($\times$20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate ($\times$10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low *p* μ identification $\leftarrow$ s$\mu\mu$ recon. eff.
  - hermeticity $\leftarrow$ ν "reconstruction"



Possible solution:

- Replace inner layers of the vertex detector with a silicon striplet or pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter by pure CsI.
- Faster readout electronics and computing system.

Model-indep. check of NP

- A_{cp} (Kπ) sum rule

M. Gronau, PLB 627, 82 (2005);

D. Atwood & A. Soni, Phys. Rev. D 58, 036005(1998).

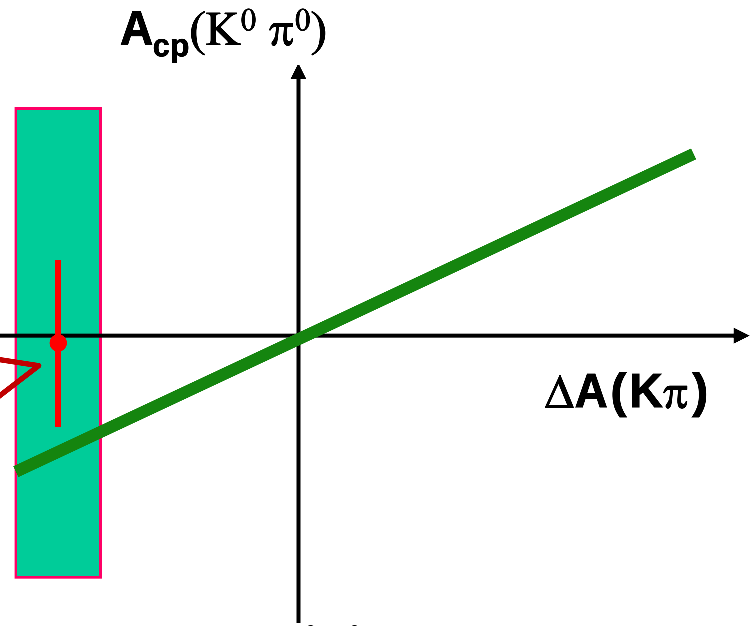
$$\mathcal{A}_{CP}(K^+\pi^-) + \mathcal{A}_{CP}(K^0\pi^+)\frac{\mathcal{B}(K^0\pi^+)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} = \mathcal{A}_{CP}(K^+\pi^0)\frac{2\mathcal{B}(K^+\pi^0)}{\mathcal{B}(K^+\pi^-)}\frac{\tau_0}{\tau_+} + \mathcal{A}_{CP}(K^0\pi^0)\frac{2\mathcal{B}(K^0\pi^0)}{\mathcal{B}(K^+\pi^-)}$$

$B^0 \to K^0 \pi^0$ New

A = –0.13 ± 0.13 ± 0.03

A = +0.14 ± 0.13 ± 0.06

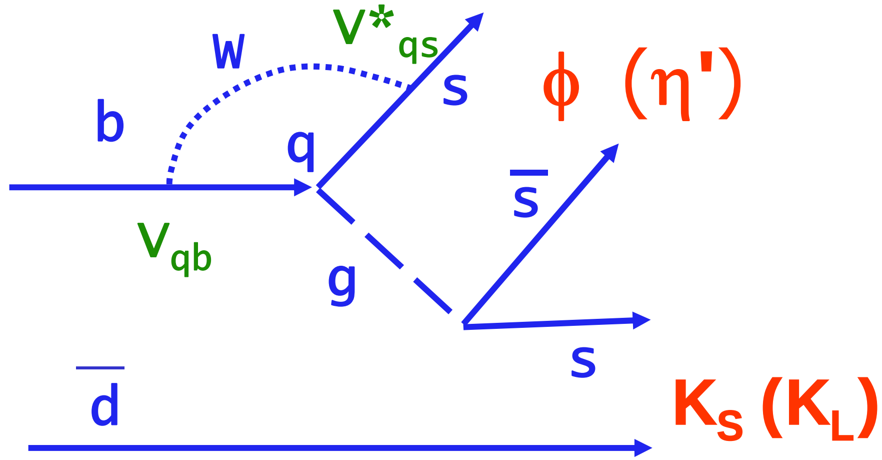
HFAG AVG: –0.01 ± 0.10



Sum rule predicts $A_{cp}(K^0\pi^0)$ = -0.151±0.043

b→sss decays

Pure penguin diagrams



$$A(s\bar{s}s) = V_{cb}V_{cs}^{*}(P_s^c - P_s^t) + V_{ub}V_{us}^{*}(P_s^u - P_s^t).$$

$V_{cb}V_{cs}^* = A\lambda^2$ $\quad$ $V_{ub}V_{us}^* = A\lambda^4(\rho - i\eta)$

First term dominates →

λ same as for $J/\psi K_S$

$$\lambda_{\phi K_S} = \eta_{\phi K_S}\left(\frac{V_{tb}^{*}V_{td}}{V_{tb}V_{td}^{*}}\right)\left(\frac{V_{cd}^{*}V_{cb}}{V_{cd}V_{cb}^{*}}\right)$$

$$\mathrm{Im}(\lambda_{\phi K_S}) = \sin 2\phi_1 = \sin 2\beta$$