The HEPHY Belle group

Christoph Schwanda

HEPHY Scientific Advisory Board Meeting

Oct. 1, 2008
The Belle experiment

• Belle is a **collider experiment** located at KEK, the Japanese national lab for particle physics in Tsukuba, 50 km from Tokyo

• Belle sits on the **KEKB asymmetric energy e⁺e⁻ collider**, which has been operating since 1999

• It probes the flavor sector of the Standard Model, mainly through measuring **CP violation in B meson decays**
KEKB and Belle @ KEK

- 8 GeV $e^-$ on 3.5 GeV $e^+$

- Center of mass energy: Y(4S) (10.58 GeV)
- Peak luminosity: $1.712 \times 10^{34}$ cm$^{-2}$s$^{-1}$
  (design was $10^{34}$ cm$^{-2}$s$^{-1}$)
Belle will have \( \sim 1/ab \) (~1 billion BB events) by the end of data taking in March 2010.
μ/\KL\ detection
14/15 lyr. RPC+Fe

Si vtx. det.
3(4) lyr. DSSD

SC solenoid
1.5T

CsI(Tl)
16X_0

TOF counter

3.5 GeV e^+

Aerogel Cherenkov cnt.
n=1.015~1.030

Central Drift Chamber
small cell +He/C_2H_5

8 GeV e^−
The Belle collaboration

Aomori U.  
BINP  
Chiba U.  
Chonnam Nat’l U.  
U. of Cincinnati  
Ewha Womans U.  
Frankfurt U.  
Gyeongsang Nat’l U.  
U. of Hawaii  
Hiroshima Tech.  
IHEP, Beijing  
IHEP, Moscow  

HEPHY Vienna  
ITEP  
Kanagawa U.  
KEK  
Korea U.  
Krakow Inst. of Nucl. Phys.  
Kyoto U.  
Kyungpook Nat’l U.  
EPF Lausanne  
Jozef Stefan Inst./ U. of Ljubljana / U. of Maribor  
U. of Melbourne  

Nagoya U.  
Nara Women’s U.  
National Central U.  
National Taiwan U.  
National United U.  
Nihon Dental College  
Niigata U.  
Osaka U.  
Osaka City U.  
Panjab U.  
Peking U.  
U. of Pittsburgh  
Princeton U.  
Riken  
Saga U.  
USTC  

13 countries, 55 institutes, ~400 collaborators

plus Karlsruhe U., MPI Munich, Chennai and Wayne U. (joined in summer 2008)
The Cabibbo-Kobayashi-Maskawa mechanism

- Charged current interaction in the Standard Model

\[ -\mathcal{L}_{W^\pm} = \frac{g}{\sqrt{2}} u_{Li} \gamma^\mu (V_{CKM})_{ij} d_{Lj} W_\mu^+ + \text{h.c.} \]

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

- \( V_{CKM} \) is the unitary 3x3 matrix of coupling constants of weak transitions
- It also contains the KM phase, responsible for all CP violating phenomena observed so far!

[Kobayashi, Maskawa, Prog. Theor. Phys. 49, 652 (1973)]
The unitarity triangle

\[ \sum_i V_{ij} V_{ik}^* = \delta_{jk} \Rightarrow V_{ud} V_{ub}^* + V_{cd} V_{cb}^* + V_{td} V_{tb}^* = 0 \]

\[ \eta \]

\[ \left| \begin{array}{cc} V_{ud} & V_{ub}^* \\ V_{cd} & V_{cb}^* \end{array} \right| \]

\[ \alpha = \phi_2 \]

\[ \beta = \phi_1 \]

\[ \gamma = \phi_3 \]

\[ (0,0) \rightarrow X_{l}\nu \]

\[ B \rightarrow \pi\pi, \rho\pi \]

\[ B \rightarrow D^{(*)}K^{(*)} \text{ Dalitz} \]

\[ \alpha \equiv \varphi_2 \equiv \arg \left( -\frac{V_{td} V_{tb}^*}{V_{ud} V_{ub}^*} \right) \]

\[ \beta \equiv \varphi_1 \equiv \arg \left( -\frac{V_{cd} V_{cb}^*}{V_{td} V_{tb}^*} \right) \]

\[ \gamma \equiv \varphi_3 \equiv \arg \left( -\frac{V_{ud} V_{ub}^*}{V_{cd} V_{cb}^*} \right) \]

\[ (1,0) \rightarrow \rho \]

Oct. 1, 2008

Christoph Schwanda
List of Members

• Wolfgang Dungel, Ph.D. student
• Markus Friedl, electronics
• Christian Irmler, electronics
• Franz Mandl, physics analysis
• Winfried Mitaroff, physics analysis
• Manfred Pernicka, electronics
• *Christoph Schwanda, physics analysis
• Laurenz Widhalm, physics analysis
Belle physics output

• As of today, there are **275 Belle papers** published mainly in Phys.Rev.Lett. and Phys.Rev.D; one paper published in Nature
• 5 Belle papers have a **Vienna first author**
• Number of Belle presentations by Vienna members at **international conferences/workshops**

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Our main fields of interest

• Semileptonic B decays ($|V_{ub}|$, $|V_{cb}|$)
  – First observation $B^+ \rightarrow \omega l^+\nu$ [PRL93, 131803]
  – $|V_{cb}|$ inclusive [PRD75, 032005], [PRD78, 032016]
  – $B^0 \rightarrow D^*-l^+\nu$ ($|V_{cb}|$ exclusive and form factors)
    [ICHEP08 prel.]

• I’m also convenor of the semileptonic decay group in Belle and co-chair of HFAG semileptonic

\begin{align*}
|V_{cb}| \quad \text{and} \quad m_b
\end{align*}
• Charm decays

- $D^0 \rightarrow K^- (\pi^-) l^+ \nu$ [PRL97, 061804]
- $D_s^+ \rightarrow \mu^+ \nu$ [PRL100, 241801]
KEKB/Belle upgrade

- Asymmetric energy $e^+e^-$ collider at $E_{CM}=m(\Upsilon(4S))$ to be realized by upgrading the existing KEKB collider.
- Super-high luminosity $\approx 8\times10^{35}/cm^2/sec \rightarrow 1\times10^{10}$ BB per yr.
  $\rightarrow 9\times10^9\tau^+\tau^-$ per yr.

Higher beam current, more RF, smaller $\beta_y^*$ and crab crossing
$\rightarrow L = 4\times10^{35}/cm^2/sec$

http://belle.kek.jp/superb/loi
KEK Roadmap

- **J-PARC**
  - construction
  - experiment + upgrade

- **KEKB**
  - experiment
  - upgrade
  - experiment

- **PF/PF-AR**
  - experiment + upgrade

- **LHC**
  - construction
  - experiment + upgrade

- **R&Ds for Advanced Accelerator and Detector Technology**
  - Detector R&D
  - ERL
  - C-ERL R&D
    - construction
    - test experiment
  - PF-ERL
    - R&D
  - construction
  - experiment
  - ILC
    - R&D
    - construction
    - Host and Site: Yet to be decided

Very Preliminary

A. Suzuki (KEK DG)
Jan-4, 2008
Belle upgrade at Vienna

• The Vienna institute has expressed its **interest in the Belle upgrade**

• I’m a member of the Super-Belle Steering Committee (SBSC)

• We intend to make a significant contribution to the **upgrade of the Silicon Vertex Detector** (module design/production, readout)
Belle Silicon Vertex Detector

- Present: SVD2 (installed 2003)
  - 4 layers, total of 246 double-sided silicon detectors (DSSDs)
  - Readout electronics (FADCs) built by the Vienna group
  - Extremely low material budget but slow readout (~800ns peaking time)
SVD upgrade

- New readout chip: DSSD layers will be readout by APV25 chips (50 ns shaping time)
- Challenge: maintain good S/N, minimize material
Vienna Origami Concept

- Extension of chip-on-sensor to double-sided readout
- All chips aligned on one side → single cooling pipe
Summary

• Belle and KEKB are running successfully since 1999
  – The Vienna group has made significant contributions to both analysis and detector hardware

• The end of Belle data taking is forseen for March 2010; the upgraded experiment will resume in April 2013
  – The Vienna group is heavily involved in the upgrade effort of the Silicon Vertex Detector