The Belle II Experiment

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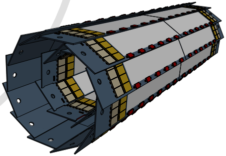
DEPFET
Active Pixel Detector



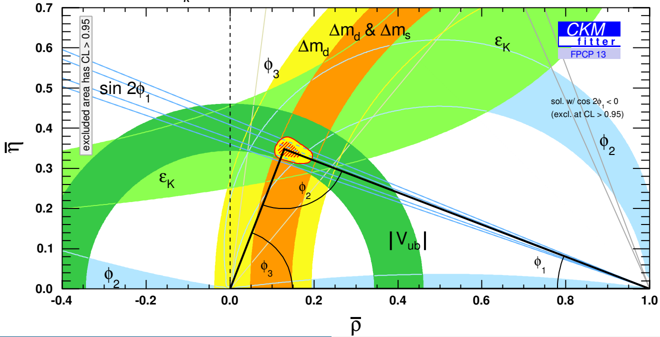
CP Violation (CPV) is established in the Standard Model (SM) in the weak interaction

- Cabibbo-Kobayashi-Maskawa-Matrix: Complex, unitary mixing Matrix between flavor/mass eigenstates

$$\lambda = \sin\theta_C \approx 0.2$$

$$\underbrace{\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}}_{V_{\text{CKM}}} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + \mathcal{O}(\lambda^4)$$

- unitary constraints: $\sum_k V_{ik}V^*_{jk} = 0; \quad \underset{\mathcal{O}(\lambda^3)}{V_{ud}V^*_{ub}} + \underset{\mathcal{O}(\lambda^3)}{V_{cd}V^*_{cb}} + \underset{\mathcal{O}(\lambda^3)}{V_{td}V^*_{tb}} = 0$



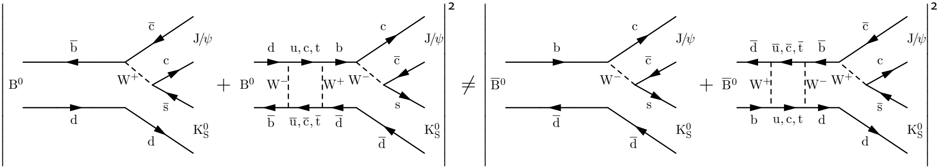
Measurement of CP Violation

Objective: Measure time dependent decay asymmetry of B and $\overline{\mathrm{B}}$ going to the same final state

$$a_{CP}(t) = \frac{\Gamma\left(\overline{\mathrm{B}}^0 \to f_{CP}; t\right) - \Gamma\left(\mathrm{B}^0 \to f_{CP}; t\right)}{\Gamma\left(\overline{\mathrm{B}}^0 \to f_{CP}; t\right) + \Gamma\left(\mathrm{B}^0 \to f_{CP}; t\right)}$$

3 possible contributions

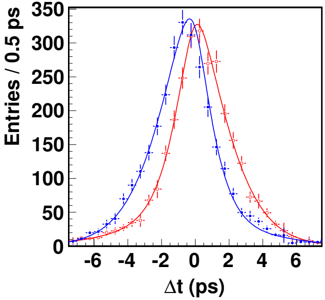
- CP violation in decay (direct)
- CP violation in mixing (indirect)
- CP violation by interference of mixing and decay (mixing induced)



- For B mesons, contributions from indirect CP violation are negligible
- For many decays, loop diagrams contribute to the amplitudes
  ➡ possibility to indirectly detect new physics

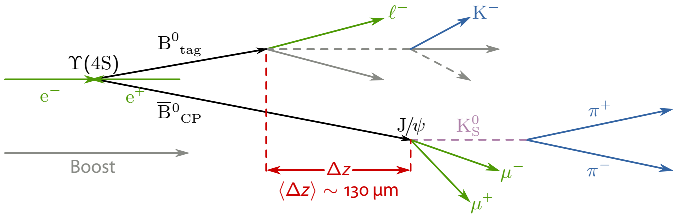
Experimental challenging task:

- lifetime of B mesons is 1.5 ps
- flavour of B meson has to be known

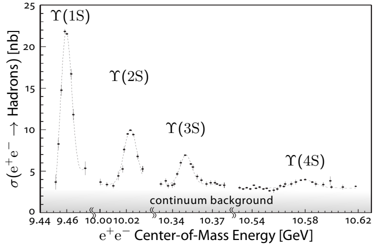


Solution

- $\Upsilon(4S)$: coherent B-meson pair production
- one B to determine flavour (tag side), other B for CP measurement (CP side)
- boost system using asymmetric beam energies $t \to \Delta t = \frac{\Delta z}{\langle \beta\gamma \rangle c}$



Experimental requirements



Best place to produce $B\overline{B}$ in a clean environment is at the $\Upsilon(4S)$:

- lowest energy with free B mesons
- 1/3 of all hadronic events are $B\overline{B}$
- possibility to “turn off” B production by lowering center of mass energy by 50 MeV

Differences to LHC

Energy is factor $\mathcal{O}(1000)$ smaller than for LHC:

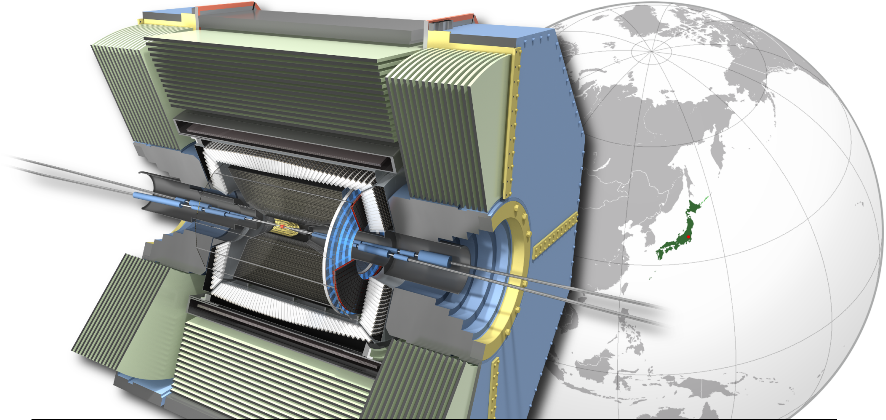
- there are no real “jets”: we see single particles
- mean momentum of charged particles is around 500 MeV

Electron Collider:

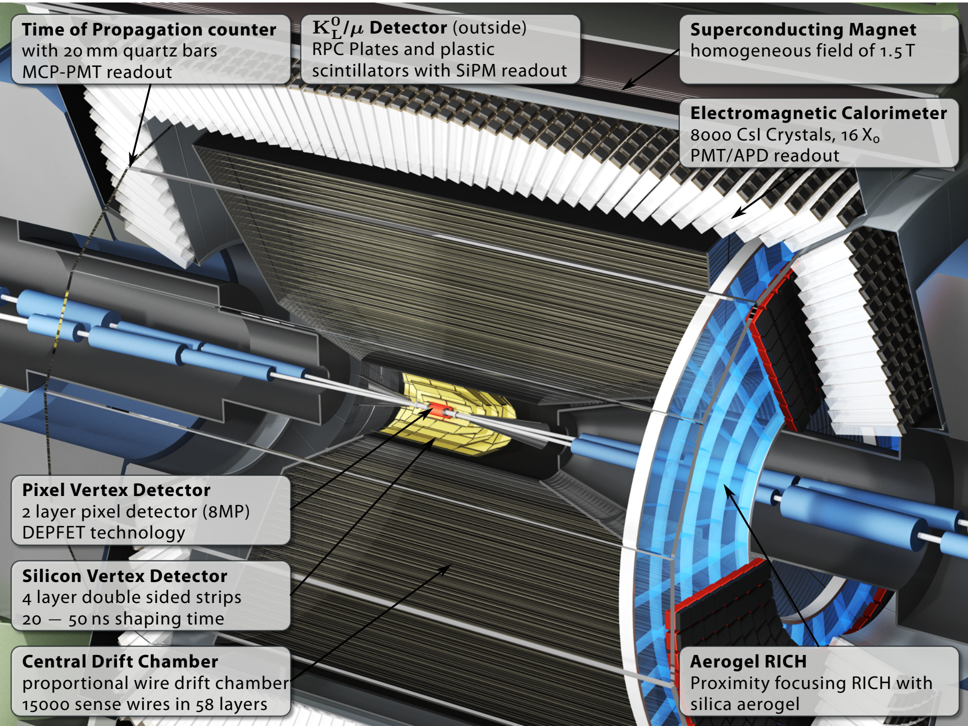
- full knowledge about the center of mass frame
- no underlying events
- but: low cross section (more than factor 100)

Belle/Belle II Experiment

Asymmetric e^+e^- experiment mainly at the $\Upsilon(4S)$ resonance (10.58 GeV)



	KEKB/Belle	SuperKEKB/Belle II
operation	1999 – 2010	2016 – 2024
e^-/e^+ beam energies	8 GeV/3.5 GeV	7 GeV/4 GeV
peak luminosity	$2.11 \times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$	$8 \times 10^{35}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
integrated luminosity	$1023\,\mathrm{fb}^{-1}$ (772 million $B\bar{B}$ pairs)	$50\,\mathrm{ab}^{-1}$



Time of Propagation counter
with 20 mm quartz bars
MCP-PMT readout
K_L^0/μ Detector (outside)
RPC Plates and plastic
scintillators with SiPM readout
Superconducting Magnet
homogeneous field of 1.5 T
Electromagnetic Calorimeter
8000 CsI Crystals, 16 X_0
PMT/APD readout
Pixel Vertex Detector
2 layer pixel detector (8MP)
DEPFET technology
Silicon Vertex Detector
4 layer double sided strips
20 – 50 ns shaping time
Central Drift Chamber
proportional wire drift chamber
15000 sense wires in 58 layers
Aerogel RICH
Proximity focusing RICH with
silica aerogel

Our Contributions

Develop the pixel detector

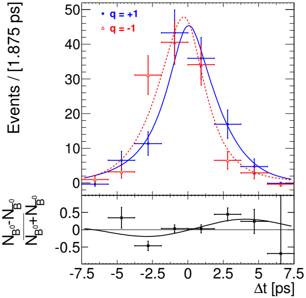
- sensor design, production and testing
- mechanical design, final assembly
- cooling system

Belle II software development

- common Belle II simulation backend
- pixel and strip detector simulation
- vertexing and flavour tagging
- neuronal *z*-vertex trigger

Various Belle physics analyses

- one student, one analysis (or two)
- $\mathrm{B}^0 \rightarrow \pi^+\pi^-, \mathrm{B}^0 \rightarrow \rho^0\rho^0, \mathrm{B}^0 \rightarrow \omega \mathrm{K}^0_\mathrm{S}$



Thank you
for your attention

The ATLAS Detector