**Belle II & Vertex detector**

- KEK, Tsukuba, Japan
- $e^+e^-$ asymmetric collider (SuperKEKB)
- Study of CP violation in $B$-meson decay
- Next generation B-factory

- DEPFET pixel (PXD) sensors
- Double-sided strip (SVD) sensors
- Thickness of pixel sensors is 75 $\mu$m.
- Thickness of strip sensors is 300 - 320 $\mu$m.

**Legendre polynomials & VXD alignment parametrization**

Legendre polynomials in one dimension

$$\begin{align*}
L_0(x) &= 1, \\
L_1(x) &= \frac{(3 - 4x^2)}{2}, \\
L_2(x) &= \frac{35x^4 - 80x^2 + 24}{8}.
\end{align*}$$

Legendre polynomials in VXD alignment

If sensor has a uniform illumination at least along one side, the contribution from different orders are independent. Surface orders can be used depending on necessity.

**Type of collected data during Commissioning run**

- Data was collected in two different data taking periods:
  2. Cosmic muon passed through full CDC volume and hit one VXD sensor

**Calibration and alignment of Central Drift Chamber**

- Calibration is based on 4 stages:
  1. $T_D$ correction: Minimization of drift time residual
  2. $XT$ relation: $XT = T_D$ (layer, $L/R$, $\alpha$, $\theta$)
  3. Position resolution: $\sigma = \langle x \rangle$ (layer $L/R$, $\alpha$, $\theta$)

**Alignment of vertex detector powered by Belle II & GBL**

- We are using track based alignment and parameters are estimated using Millepede II
- MP II is based on global linear $\nu^2$ minimization and constraints can be applied/ included.
- Tracks are retifed by General Broken Lines to provide Millepede II input.
- The CDC is used as reference for VXD geometry.
- VXD alignment procedure is able to determine 6 rigid body parameters:
  - 3 shifts ($u$, $v$ and $w$) and 3 rotations ($\alpha$, $\beta$, and $\gamma$) per each VXD sensor
- If necessary, VXD alignment can be extended to more parameters for elimination of surface deformation, Lorentz angle estimation, ...

**VXD alignment strategies**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Number per sensor</th>
<th>Total number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rigid body</td>
<td>6</td>
<td>6 x 18 = 108</td>
</tr>
<tr>
<td>Surface simple</td>
<td>9 + 3</td>
<td>9 x 18 = 162</td>
</tr>
<tr>
<td>Surface complex</td>
<td>6 + 3 + 4</td>
<td>13 x 18 = 234</td>
</tr>
</tbody>
</table>

**Monitoring tools of VXD alignment quality**

- Monitoring is based on:
  1. Track to hit residuals in directions of measurement ($U$, $V$)
  2. Extrapolation to third local coordinate ($W$) of sensor
  3. Time walk effect calibrated as function of
  4. Wire by wire alignment using cosmic muons

**VXD alignment procedure results**

Alignment result for PXD sensor (2.1.2) on left and center figures, SVD sensor (3.1.2) on right picture

**Time dependent VXD alignment validation**

- Figure showing validation results for different strategies and time intervals.