Results and Prospects on Lepton Flavor Violation at Belle/Belle II

K. Hayasaka (KMI, Nagoya Univ.)
for Belle/Belle II collaborations
Introduction

- Lepton flavor violation (LFV) in charged leptons
  ⇒ negligibly small probability in the Standard Model (SM)
    even including neutrino oscillations:
    \[ \mathcal{B}(\tau \rightarrow \mu \gamma) < \mathcal{O}(10^{-40}), \]
    \[ \mathcal{B}(\tau \rightarrow \mu \mu \mu) < \mathcal{O}(10^{-14}) \]
    (X. Pham, EPJC8 513(1999))

Observation of LFV is a clear signature of New Physics (NP)

- Many extensions of the SM predict LFV decays.
  - These branching fractions could be enhanced as high as current experimental sensitivity (~10^{-8}).

- Tau lepton = The heaviest charged lepton
  - Expected strong coupling to NP \[ \tau \text{ LFV search} \]
  - Many possible LFV decay modes = ideal probe to NP
Predicted BF in various models

- Various models predict BF for $\tau \rightarrow \mu \gamma$ and $\tau \rightarrow \mu \mu \mu$.

<table>
<thead>
<tr>
<th>Model</th>
<th>Reference</th>
<th>$\tau \rightarrow \mu \gamma$</th>
<th>$\tau \rightarrow \mu \mu \mu$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM+ $\nu$ mixing</td>
<td>EPJ C8(1999)513</td>
<td>$10^{-40}$</td>
<td>$10^{-14}$</td>
</tr>
<tr>
<td>SM + heavy Maj $\nu_R$</td>
<td>PRD 66(2002)034008</td>
<td>$10^{-9}$</td>
<td>$10^{-10}$</td>
</tr>
<tr>
<td>Non-universal $Z'$</td>
<td>PLB 547(2002)252</td>
<td>$10^{-9}$</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td>SUSY SO(10)</td>
<td>PRD 68(2003)033012</td>
<td>$10^{-8}$</td>
<td>$10^{-10}$</td>
</tr>
<tr>
<td>mSUGRA+seesaw</td>
<td>PRD 66(2002)115013</td>
<td>$10^{-7}$</td>
<td>$10^{-9}$</td>
</tr>
<tr>
<td>SUSY Higgs</td>
<td>PLB 566(2003)217</td>
<td>$10^{-10}$</td>
<td>$10^{-7}$</td>
</tr>
</tbody>
</table>

These numbers correspond to the most optimistic case.

Our sensitivity ($\sim 10^{-8}$) reaches a possible region to find $\tau$ LFV!
predicted BF in various models

Ratios of LFV decay BFs make us to distinguish between NP models.

<table>
<thead>
<tr>
<th></th>
<th>SUSY+GUT (SUSY+Seesaw)</th>
<th>Higgs mediated</th>
<th>Little Higgs</th>
<th>non-universal Z’ boson</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\left( \frac{\tau \to \mu \mu \mu}{\tau \to \mu \gamma} \right)$</td>
<td>~2 $\times$ 10^{-3}</td>
<td>0.06$\sim$0.1</td>
<td>0.4$\sim$2.3</td>
<td>~16</td>
</tr>
<tr>
<td>$\left( \frac{\tau \to \mu e e}{\tau \to \mu \gamma} \right)$</td>
<td>~1 $\times$ 10^{-2}</td>
<td>~1 $\times$ 10^{-2}</td>
<td>0.3$\sim$1.6</td>
<td>~16</td>
</tr>
<tr>
<td>$\text{Br}(\tau \to \mu \gamma)$ @Max</td>
<td>&lt;10^{-7}</td>
<td>&lt;10^{-10}</td>
<td>&lt;10^{-10}</td>
<td>&lt;10^{-9}</td>
</tr>
</tbody>
</table>

(M.Blanke, et al., JHEP 0705, 013(2007), C.Yue, et al.,PLB547, 252 (2002))

Favorite modes $\tau \to \mu \gamma$  $\tau \to \mu \mu \mu$

Thus, it is important to search for various kinds of $\tau$ LFV.

$\to$ We have performed 48 analyses for $\tau$ LFV with the Belle data sample.
Results on LFV at Belle
KEKB/Belle

B-factory: E at CM = Y(4S)
$e^+(3.5\ \text{GeV})\ e^-(8\ \text{GeV})$
$\sigma(\tau\tau)\sim 0.9\text{nb}$, $\sigma(bb)\sim 1.1\text{nb}$

A B-factory is also a $\tau$-factory!
Peak luminosity: $2.1\times 10^{34}\ \text{cm}^{-2}\text{s}^{-1}$
World highest luminosity!

total: > 1$\text{ab}^{-1}$

- Y (4S): 711$\text{fb}^{-1}$
- Y (5S): 121$\text{fb}^{-1}$
- Y (3S): 3.0$\text{fb}^{-1}$
- Y (2S): 24$\text{fb}^{-1}$
- Y (1S): 5.7$\text{fb}^{-1}$

0 off-resonance:
87$\text{fb}^{-1}$

Belle Detector:
Good track reconstruction and particle identifications

- Lepton efficiency: 90% 
- Fake rate: O(0.1) % for e 
- O(1)% for $\mu$

~9x10^8 $\tau\tau$ at Belle
Analysis procedure

- $e^+e^- \rightarrow \tau^+\tau^-$  
  - Br~85%
  - 1 prong + missing (tag side)
  - $\mu\mu\mu$ (signal side)

Signal extraction: $m_{\mu\mu\mu} - \Delta E$ plane

- $m_{\mu\mu\mu} = \sqrt{(E_{\mu\mu\mu}^2 - p_{\mu\mu\mu}^2)}$

- $\Delta E = E_{CM}^{\mu\mu\mu} - E_{beam}^{CM}$

Blind analysis $\Rightarrow$ Blind signal region

Estimate number of BG in the signal region using sideband data and MC

Aug/02/2011
Nufact 2011
LFV $\tau$ decays; Signal and Background

**Signal**
- Signal side:
  - $\mu^-$, $\mu^+$, $\tau^-$, $\tau^+$, $e^-$, $e^+$
  - Neutrinos in both sides
  - Missing energy in signal side

**Tag Side**
- $\bar{\nu}_\tau$
  - Neutrino(s) in tag side
  - Particle ID
  - Mass of mesons

**2 photon process**
- $f =$ leptons, quarks
- $e^-$, $\gamma$, $f$, $\bar{f}$, $e^+$

**Radiative Bhabha process**
- $e^+$, $e^-$, $e^-$
- Many tracks

Aug/02/2011
Nufact 2011
Analysis strategy

- **Rare decay searches**
  - Need to understand background and reduce it as much as possible

- $\tau \rightarrow \ell\ell\ell$
- $\tau \rightarrow \ell K_s, \Lambda h$
- $\tau \rightarrow \ell V^0 (\rightarrow hh')$
- $\tau \rightarrow \ell P^0 (\rightarrow \gamma\gamma)$
- $\tau \rightarrow \ell hh'$
- $\tau \rightarrow \ell\gamma$
  - $\ell = e, \mu$
  - $h = \pi, K$

  - Analyze the modes from simple selection to hard for background reduction

  - Provide feedback to next analysis of similar final state
Search for $\tau \to 3\text{leptons}$

- Data: 782fb$^{-1}$
- No events are found in the signal region.
- **Almost BG free**
  - Expected # of BG: 0.01-0.21
  - Because of good lepton ID
- $\text{Br} < (1.5-2.7) \times 10^{-8}$ at 90%CL.
  - Most sensitive results

<table>
<thead>
<tr>
<th>Mode</th>
<th>$\varepsilon$ (%)</th>
<th>$N_{BG}^{\text{EXP}}$</th>
<th>$\sigma_{\text{syst}}$ (%)</th>
<th>UL ($\times 10^{-8}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^-e^+e^-$</td>
<td>6.0</td>
<td>0.21 ± 0.15</td>
<td>9.8</td>
<td>2.7</td>
</tr>
<tr>
<td>$\mu^-\mu^+\mu^-$</td>
<td>7.6</td>
<td>0.13 ± 0.06</td>
<td>7.4</td>
<td>2.1</td>
</tr>
<tr>
<td>$e^-\mu^+\mu^-$</td>
<td>6.1</td>
<td>0.10 ± 0.04</td>
<td>9.5</td>
<td>2.7</td>
</tr>
<tr>
<td>$\mu^-e^+e^-$</td>
<td>9.3</td>
<td>0.04 ± 0.04</td>
<td>7.8</td>
<td>1.8</td>
</tr>
<tr>
<td>$\mu^-e^+\mu^-$</td>
<td>10.1</td>
<td>0.02 ± 0.02</td>
<td>7.6</td>
<td>1.7</td>
</tr>
<tr>
<td>$e^-\mu^+e^-$</td>
<td>11.5</td>
<td>0.01 ± 0.01</td>
<td>7.7</td>
<td>1.5</td>
</tr>
</tbody>
</table>

Search for $\tau \rightarrow \Lambda h/\bar{\Lambda}h$

Search with 904fb$^{-1}$ data sample
- Select three hadrons
- **Require $\Lambda$ vertex**

4 modes are searched for. ($h=\pi$ and $K$)
- $\tau^+ \rightarrow \bar{\Lambda}h^-$: (B-L) conserving decay
- $\tau^+ \rightarrow \Lambda h^-$: (B-L) violating decay

**Signal**

- $e^- \tau^- \Lambda e^+$
- $\pi^- p \pi^- p$

**Generic $\tau\tau$ BG**

- $\pi^- \pi^+ p\pi^-$
- $\pi^- \pi^+ q\bar{q}$BG

**Misid as $\Lambda$**

- $e^- \tau^+ \tau^+ \pi^- \pi^- \gamma\gamma$
- $p \pi^0 \pi^0 \gamma\gamma$

Aug/02/2011

Updated this summer

Nufact 2011
**BG rejection for \( \tau \rightarrow \Lambda h/\bar{\Lambda}h \)**

To reduce \( \tau \tau \) BG including \( K_S^0 \)

\[ \Rightarrow \text{reconstruct } K_S^0 \text{ and reject events that are likely to be } K_S^0 \]

85% of eff. is kept while
75% of \( K_S^0 \) BG events is rejected.

To reduce \( q\bar{q} \) BG including \( \Lambda \)

\[ \Rightarrow \text{reject events with a proton in tag side} \]
(due to BN conservation, the events including a \( \Lambda \) tend to have baryon on tag side.)

A third of \( q\bar{q} \) BG events are rejected while a loss of eff. Is negligibly small.
Results for $\tau \rightarrow \Lambda h/\bar{\Lambda}h$

In the signal region:
no candidate events are found
$\Rightarrow$ no significant excess

* Expected # of BG: (0.21-0.42)

<table>
<thead>
<tr>
<th>Mode</th>
<th>$\varepsilon$ (%)</th>
<th>$N_{BG}$</th>
<th>$\sigma_{syst}$ (%)</th>
<th>$N_{obs}$</th>
<th>$s_{90}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau^- \rightarrow \Lambda \pi^-$</td>
<td>4.80</td>
<td>0.21 ± 0.15</td>
<td>8.2</td>
<td>0</td>
<td>2.3</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \Lambda \pi^-$</td>
<td>4.39</td>
<td>0.31 ± 0.18</td>
<td>8.2</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \bar{\Lambda} K^-$</td>
<td>4.11</td>
<td>0.31 ± 0.14</td>
<td>8.6</td>
<td>0</td>
<td>2.2</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \Lambda K^-$</td>
<td>3.16</td>
<td>0.42 ± 0.19</td>
<td>8.6</td>
<td>0</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Set upper limits@90%CL:
$\text{Br}(\tau^- \rightarrow \Lambda \pi^-)<2.8 \times 10^{-8}$ (B-L) cons.
$\text{Br}(\tau^- \rightarrow \bar{\Lambda} K^-)<3.1 \times 10^{-8}$
$\text{Br}(\tau^- \rightarrow \Lambda \pi^-)<3.0 \times 10^{-8}$ (B-L) viol.
$\text{Br}(\tau^- \rightarrow \Lambda K^-)<4.2 \times 10^{-8}$

$\rightarrow$ most sensitive results
Search for $\ell V^0 (=\rho^0, K^{*0}, \omega, \phi)$

- Search with 854 fb$^{-1}$ data sample
  - Select one lepton and two hadrons
  - Require di-hadron invariant mass to be consistent with a vector meson mass
    - The requirement helps BG-rejection.

- Possible background
  - For $\ell=\mu$, hadronic tau decay and qq with miss $\mu$-ID
  - For $\ell=e$, 2photon processes could be large BG.
  - It turns out that not only 2photon processes but also ee+X process become large background. → Reduced using missing-momentum direction.

2photon BG
Result for $\ell V^0(=\rho^0,K^{*0},\omega,\phi)$

After event selection
• 1 event $\mu\phi$, $\mu K^{*0}$, $\mu K^{*0}$
• 0 events others in the signal region.
⇒ no significant excess

$\text{Br}(\tau \to \ell V^0) < (1.2-8.4) \times 10^{-8}$ @90%CL
→ most sensitive results

<table>
<thead>
<tr>
<th>$\tau^-$ →</th>
<th>Eff.</th>
<th>$N_{BG}^{exp}$</th>
<th>$N_{obs}$</th>
<th>UL x10^{-8}</th>
<th>$\tau^-$ →</th>
<th>Eff.</th>
<th>$N_{BG}^{exp}$</th>
<th>$N_{obs}$</th>
<th>UL x10^{-8}</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^-\rho^0$</td>
<td>7.6%</td>
<td>0.29±0.15</td>
<td>0</td>
<td>1.8</td>
<td>$e^-K^{*0}$</td>
<td>4.4%</td>
<td>0.39±0.14</td>
<td>0</td>
<td>3.2</td>
</tr>
<tr>
<td>$\mu^-\rho^0$</td>
<td>7.1%</td>
<td>1.48±0.35</td>
<td>0</td>
<td>1.2</td>
<td>$\mu^-K^{*0}$</td>
<td>3.4%</td>
<td>0.53±0.20</td>
<td>1</td>
<td>7.2</td>
</tr>
<tr>
<td>$e^-\phi$</td>
<td>4.2%</td>
<td>0.47±0.19</td>
<td>0</td>
<td>3.1</td>
<td>$e^-\bar{K}^{*0}$</td>
<td>4.4%</td>
<td>0.08±0.08</td>
<td>0</td>
<td>3.4</td>
</tr>
<tr>
<td>$\mu^-\phi$</td>
<td>3.2%</td>
<td>0.06±0.06</td>
<td>1</td>
<td>8.4</td>
<td>$\mu^-\bar{K}^{*0}$</td>
<td>3.6%</td>
<td>0.45±0.17</td>
<td>1</td>
<td>7.0</td>
</tr>
<tr>
<td>$e^-\omega$</td>
<td>2.9%</td>
<td>0.30±0.14</td>
<td>0</td>
<td>4.8</td>
<td>$\mu^-\omega$</td>
<td>2.4%</td>
<td>0.72±0.18</td>
<td>0</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Search for $\ell hh'$

- Update with 854 fb$^{-1}$ data
  - BaBar; $\text{Br}<(7.48)\times10^{-8}$ at 221 fb$^{-1}$
- 14 modes are investigated ($h, h' = \pi^\pm$ and $K^\pm$)
  - $\tau^- \to \ell^+ h^+ h'^-$: 8 modes (lepton flavor violation)
  - $\tau^- \to \ell^+ h^+ h'^-$: 6 modes (lepton number violation)

Signal:
- $e^-$ or $\mu^-$
- $\pi^-$
- $K^+$

Generic $\tau\tau$ BG:
- $\pi^-$
- $\pi^+$

Miss-ID as $\mu^-$

Miss-ID as $K^+$

Missing momentum can help to reject this kind of BGs since signal has $\nu$ only on tag side.

Also, $q\bar{q}$ events can be BG

Updated this summer
Result for $\ell hh'$

In the signal region:
- 1 event: in $\mu^+\pi^-\pi^-$ and $\mu^-\pi^+K^-$
- No events: in other modes

⇒ no significant excess/

Expected # of BG: 0.06-0.72

<table>
<thead>
<tr>
<th>Mode</th>
<th>$\varepsilon$ (%)</th>
<th>$N_{BG}$</th>
<th>$\sigma_{syst}$ (%)</th>
<th>$N_{obs}$</th>
<th>$s_{90}$</th>
<th>$B$ ($10^{-8}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau^- \rightarrow \mu^-\pi^+\pi^-$</td>
<td>5.83</td>
<td>0.63 ± 0.23</td>
<td>5.3</td>
<td>0</td>
<td>1.87</td>
<td>2.1</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^+\pi^-\pi^-$</td>
<td>6.55</td>
<td>0.33 ± 0.16</td>
<td>5.3</td>
<td>1</td>
<td>4.02</td>
<td>3.9</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^-\pi^+\pi^-$</td>
<td>5.45</td>
<td>0.55 ± 0.23</td>
<td>5.4</td>
<td>0</td>
<td>1.94</td>
<td>2.3</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^+\pi^-\pi^-$</td>
<td>6.56</td>
<td>0.37 ± 0.18</td>
<td>5.4</td>
<td>0</td>
<td>2.10</td>
<td>2.0</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^-K^+K^-$</td>
<td>2.85</td>
<td>0.51 ± 0.18</td>
<td>5.9</td>
<td>0</td>
<td>1.97</td>
<td>4.4</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^+K^-K^-$</td>
<td>2.98</td>
<td>0.25 ± 0.13</td>
<td>5.9</td>
<td>0</td>
<td>2.21</td>
<td>4.7</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^-K^+K^-$</td>
<td>4.29</td>
<td>0.17 ± 0.10</td>
<td>6.0</td>
<td>0</td>
<td>2.28</td>
<td>3.4</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^+K^-K^-$</td>
<td>4.64</td>
<td>0.06 ± 0.06</td>
<td>6.0</td>
<td>0</td>
<td>2.38</td>
<td>3.3</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^-\pi^+K^-$</td>
<td>2.72</td>
<td>0.72 ± 0.27</td>
<td>5.6</td>
<td>1</td>
<td>3.65</td>
<td>8.6</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^-\pi^+K^-$</td>
<td>3.97</td>
<td>0.18 ± 0.13</td>
<td>5.7</td>
<td>0</td>
<td>2.27</td>
<td>3.7</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^-K^+\pi^-$</td>
<td>2.62</td>
<td>0.64 ± 0.23</td>
<td>5.6</td>
<td>0</td>
<td>1.86</td>
<td>4.5</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^-K^+\pi^-$</td>
<td>4.07</td>
<td>0.55 ± 0.31</td>
<td>5.7</td>
<td>0</td>
<td>1.97</td>
<td>3.1</td>
</tr>
<tr>
<td>$\tau^- \rightarrow \mu^+K^-\pi^-$</td>
<td>2.55</td>
<td>0.56 ± 0.21</td>
<td>5.6</td>
<td>0</td>
<td>1.93</td>
<td>4.8</td>
</tr>
<tr>
<td>$\tau^- \rightarrow e^+K^-\pi^-$</td>
<td>4.00</td>
<td>0.46 ± 0.21</td>
<td>5.7</td>
<td>0</td>
<td>2.02</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Set upper limits at 90%CL:
\[ \text{Br}(\tau \rightarrow \ell hh') < (2.0-8.6) \times 10^{-8} \]

⇒ most sensitive results (preliminary)
Upper limits for $\tau$ LFV searched for at Belle.

Reach upper limits around $10^{-8}$ ~100x more sensitive than CLEO

Update using full data samples will be finalized soon!

Aug/02/2011

Nufact 2011
Prospects on LFV at Belle II
SuperKEKB/Belle II

KEKB       superKEKB
Vertical $\beta$ function: 5.9 mm $\rightarrow$ 0.27/0.30 mm ($\times$20)
Beam current:        1.7/1.4 A $\rightarrow$ 3.6/2.6 A ($\times$2)

$\rightarrow$ $L = 2 \times 10^{34} \text{cm}^{-2}\text{s}^{-1} \rightarrow 8 \times 10^{35} \text{cm}^{-2}\text{s}^{-1}$ ($\times$40)

SVD: 4 DSSD lyr $\rightarrow$ 2 DEPFET lyr + 4 DSSD lyr
CDC: small cell, long lever arm
ACC+TOF $\rightarrow$ TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC $\rightarrow$ Scintillator + SiPM (end-caps)
Expected luminosity on SuperKEB

We are here

Goals of Belle II/SuperKEKB

We will reach 50 ab\(^{-1}\) in 2020-2021

- Integrated luminosity (ab\(^{-1}\))
- Peak luminosity (cm\(^{-2}\)s\(^{-1}\))

Year


Commissioning starts in late 2014.

5 ab\(^{-1}\) in 2016

9 months/year

20 days/month

5 ab\(^{-1}\) in 2016

20 days/month

We are here

Year


9 months/year

20 days/month

We will reach 50 ab\(^{-1}\) in 2020-2021
Future prospect on tau LFV

- Belle-II will collect 
  \(~10^{10}\) tau leptons. (=50ab\(^{-1}\))

- Sensitivity depends on BG level.
  - Recent improvement of the analysis
    (BG understanding, more optimized selection)
    \(\rightarrow\) Improve achievable sensitivity

- \(\mathcal{B}(\tau \rightarrow \mu \gamma) \sim \mathcal{O}(10^{-9})\) and
  \(\mathcal{B}(\tau \rightarrow \mu \mu \mu) \sim \mathcal{O}(10^{-10})\) at 50ab\(^{-1}\)
  - Improvement of BG reduction is important.
    - Beam BG
    - Signal resolution
Summary

- Belle completed operation with a 1ab\(^{-1}\) data sample, which contains \(\sim 10^9\) tau-pairs. This is the world’s largest \(\tau\) data sample.

- By adding more data and studying the dominant BGs and optimizing the analyses to suppress these BGs, we have significantly improved \(\tau\) LFV upper limits.
  - Almost all upper limits on BF for \(\tau\) LFV are analyzed with Belle’s full data sample and reach O\((10^{-8})\).

- Upgrade of KEKB and Belle is in progress and Belle II will start machine operation in the second half of 2014. Finally, a 50ab\(^{-1}\) data sample will be collected. (~2020)

- A sensitivity of \(\tau\) LFV search will reach O\((10^{-9} - 10^{-10})\).
  - Optimization for BG reduction is important for future experiment
SuperKEKB

Vertical β function:
5.9 mm (KEKB)
→ 0.27/0.30 mm (superKEKB) (x20)

Beam current:
1.7/1.4 A (KEKB)
→ 3.6/2.6 A (superKEKB) (x2)

⇒ \[ L = 2 \times 10^{34} \text{cm}^{-2}\text{s}^{-1} \] (KEKB)
→ \[ 8 \times 10^{35} \text{cm}^{-2}\text{s}^{-1} \] (superKEKB) (x40)

to obtain 40x higher luminosity!
Based on Belle detector

But…

- Higher background \( (\times 10-20) \)
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM

- Higher event rate \( (\times 10) \)
  - higher rate trigger, DAQ and computing

SVD: 4 DSSD lyr → 2 DEPFET lyr + 4 DSSD lyr
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)