I. TOP counter and its readout system

**Belle II Time-Of-Propagation (TOP) counter**
- novel PID device to cover the barrel region of the Belle II detector
- measure timing of Cherenkov photons to reconstruct ring image
- fully operational since installation in May 2016
- talk by U. Tamponi at 10:05-10:30 Monday

**TOP readout overview**
- challenging requirements: **excellent time resolution (<100 ps for each photon)**
  + high speed readout (30 kHz trigger rate)
- Application Specific Integrated Circuits (ASICs) for fast waveform sampling and digitization
- online data processing by Field Programmable Gate Array (FPGA) and on-chip processors
- each Subdetector Readout Module (SRM)
  - 4 ASIC carrier boards
  - + 1 Standard Control for ReadOut and Data (Scrod) board

**III. operation history**
- readout performance is determined by firmware/software of SoCs, which has been developed step-by-step.

**Full waveform readout (2016)**
- digitize all the samples for all the channels and readout full waveform
  - robust, no bias
  - very slow (<10 Hz)
  - large data size
  - short buffer
- used for stand-alone calibration runs and cosmic ray data taking
- timing performance: 30 ps electronics resolution

**Interim-Feature-Extraction (2017)**
- readout only timing and pulse height
  - short waveform only for channels with hits
  - reasonably fast (< 500 Hz)
  - deep enough buffer
  - single hit per channel
  - not fully pipe-lined
- combined data taking with other Belle II subsystems

**Production version (2018)**
- close to design performance
  - fast readout (~20 kHz)
  - multi-hit capability
  - no dead time
- large calibration samples
  - used in collision data taking in phase 2 operation
  - stable operation with ≤1 kHz trigger rate

II. specification of readout system

**ASIC : Ice Ray Sampler Version. X (IRSX)**
- developed by U. Hawaii group
- fast waveform sampling with switched capacitor array
- deep analog buffer
to cope with Belle II L1 trigger rate (5 μs)
- selective readout to minimize digitized samples
- Wilkinson ADC for digitization

**online data processing with Zyng SoCs**
- Z-7030 for each carrier board
- and Z-7045 for SCROD board
- asic control and communication with backend data acquisition system by programmable logic
- online-waveform analysis (feature extraction) in processing system

**IV. rooms for improvements**

**template fitting in feature extraction**
- planning to implement waveform fitting in feature extraction
- expect improvement of timing resolution for low-amplitude photon hits

**optimization of ADC parameters**
- slope of $V_{\text{amp}}$ can be optimized to reduce a range of output values
- can help operation with high trigger rate

**V. summary and prospects**

- Frontend electronics for Belle II TOP counter, where a lot of challenging requirements must be satisfied, was developed and is now fully operational.
- To achieve designed readout performance, much effort of firmware (FW) development has been made since detector installation.
- With the current version of FW, TOP readout system has been working successfully in phase2 collision data taking: 1 kHz stable operation and we also confirmed that it can work at 20 kHz trigger rate.
- Thanks to readout improvement, large calibration samples became available, which helped to understand detector and demonstrate initial PID performance with phase2 collision data.
- Further works to improve the performance are on-going.