Near Term Plans for the NNT + further Activites in LS1

Based on discussions in F2F and weekly KIT-MPI-TUM meetings

- STT:
  Hardware and software activities next few weeks (still UT3)
  using cosmic rays

  UT4: Integration of 2D/3D preprocessing + neural networks

  Study including full wire information into preprocessing and neural networks

- Development of a Displaced Vertex Trigger (Search for Dark Matter)

Rationale

The driving arguments:

- further improve the z-resolution of the STT due to recently observed new backgrounds close to the IP (from presently about 3 cm to below 2cm)
  [machine background has dramatically increased with increasing luminosity during the last months before the shutdown in June 2020]

- Porting track finding (2D/3D Hough) to UT4 + network operation: provide latency for full exploitation of the CDC information:
  - Use all wires in the track segments
  - Include information of the charge deposition (ADC signals) on the wires
    -> more complex neural algorithms for the STT

  - new algorithms sensitive to events with displaced vertices ("Displaced Vertex Trigger" DVT).

Task list to be completed during the Long Shutdown (LS1)
-> person power in the project needs serious consideration

Near Term Task List for STT

1. New Bit Files to be tested with Cosmic Rays:
   - FW+: Correct a minor error in the preprocessed input quantities in SL0 and SL8 (phi index systematically shifted by small amount)
   - FW++: Include also t0 from ETF (event time finder) to replace the present method of “self timing” (t0 from fastest priority wire in the set of ≤ 9 TS)
   - Main goal: study possible (small) improvements of the z resolution

   We request 3 runs of at least 24 hours
   - present FW to establish a base line data set
   - FW+ :
   - FW++

2. Provide new set of network parameters from training using the ETF t0.
   - Need to study the optimal use of the ETF t0
   - Based on this, perform new network training
   - Provide network parameter set for producing the bit files

   Once the bit files exist, we request at least 48 hours of cosmic running with the new FW.

Task List for STT HW Developments

This is mid-term time scale development (completion ~ first quarter of 2023)

1. Develop FW for the UT4 (160) boards:
    - mandatory for any extension of the present algorithms.
    - First project: port the existing firmware (FW) installed on the UT3 onto the UT4 platform (preprocessing and network algorithms)

    Time scale for realizing the porting of the FW onto the UT4 platform to be discussed

2. Testing and evaluating the newly established FW on the UT4 platform with Cosmics
    - Run without magnetic field (detector open for the installation of the new PXD).
    - Data with both the present UT3 and the new UT4 successively (test may require stay of key developers in Japan during the data taking ?)

Task List for STT HW Developments

This is longer-term time scale development (completion ~ second / third quarter of 2023)

3. Radical change in the hardware chain of the neural track trigger

- Replace the 2D input from the standard 2D track trigger with our own implementation on the UT4 board (sample code from 2D may be used and adapted)
- use standard preprocessing and networks already developed under point 2.
- Important point: new FW should include a cluster algorithm in the 2D Hough plane (this is a necessary exercise for the DVT in the MPI version)

- At the same time (or earlier) the existing 3D preprocessing can be tested (but presently not operational due to missing network algortihms using 3D)

- Test with cosmics using Belle II is required (most likely presence at KEK necessary)

Task List for STT HW Developments

4. Implementation of neural algorithms using 3D preprocessing

- The cluster algorithm from the previous step 3 should be extended to 3D, executing on 9 theta bins in parallel (present optimization).
- Tests to be done with a set of networks trained with the new 3D input.
- The input could be simulated with the wire signals from real data and the training can then be done with this modified input stream.
- Also here a cosmic test would be essential. The time scale most likely towards the second half of 2023. Again, presence of the key developers at KEK would be necessary.

  Question: Do we need new track segments for the optimal use of 3D preprocessing: Lower pt (smaller curvature radius and larger crossing angle in the last CDC superlayer)

  Central question: What is the gain in z resolution? This is most likely more important than increasing the polar angular range.

  What is the time scale for network optimization with 3D preprocessing (realistically not before mid of 2023)

New Idea for the STT z-Resolution

5. For the "ultimate" z-resolution of the STT use the complete wire information from the track segments.

- Presently only the priority wire information is used (1 out of 11 wires in TS)
- Using all 11 wires will require more complex networks (more inputs, possibly more hidden layers).
- Information from CDC ADC counts can be used (thresholds on wire signals with the track segments (TS).

- Required additional latency comes from the integration of the 2D/3D preprocessing (see points 1-4) into the UT4 platform, performing also the neural computation.
- The same "win" in latency will also make possible the implementation and execution of GNNs and other involved network architectures on the UT4 platform for the DVT project
- MPI variant of DVT
  - need new set of TS (optimization ongoing)
  - Algorithms already quite advanced (see Elia's presentation at previous meetings)
  - should be available already during LS1 (test with cosmics)

Summary and Conclusions

- HW/SW program for LS1 period concerning STT clearly defined
- Essential: Full concentration on new UT4 platform step by step
- Main goal is to bring the z resolution below 2 cm (simulation/training needed)
- Time scale to fulfill the new requirements seem OK (1.5 years)
- First DVT (MPI variant) could realistically be brought online for the next running period

Development for LS2 (> 2026 ….) , just for completeness

- New UT5 platform being discussed
- During LS2 CDC frontend will be replaced, providing also the digitized charge depositions on all of the CDC wires (full ADC values, not just thresholds).
- Could be very useful for suppressing background hits for advanced DVTs and further “sharpening” of the STT when design luminosity is being approached.