WG10: Online Software & Computing

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FCC-ee/TLEP physics workshop (TLEP8)
LPNHE, Paris
29 October 2014

What is New

- Announcements
  - ➢ Emmanuelle Perez (CERN) joins the WG10 coordination

- "Crab-waist" option
  - ➢ Significant increase in luminosity for low-mass $\sqrt{s}$ (Z, W^+W^-)
  - ➢ If you like Z bosons, x10 the fun!

- Software developments
  - ➢ Discussing requirements & prototypes with FCC software team

Mandate

"Work towards hardware & software solutions that will allow TLEP experiments to store interesting physics with high efficiency & redundancy (with minimum uncertainties or biases)"

Considerations:

- Physics
- Computing
- Software

Physics

Physics specs

- LO assumptions
  - ➢ Trigger input = trigger output = DAQ rate = interesting physics. In other words:
    - Signal efficiency ~ 100%
    - Background ~ not a major consideration
  - ➢ Rate of interesting physics (head-on scheme):
    - ~15 kHz (Z events) + 60 kHz (Bhabha)
    - "Crab-waist": Rates in low-mass operating points ($Z, W^{+}W^{-}$) larger by a factor of ~10 to 3.5

(Vast gap in terminology between hadron and lepton collider people….)

Physics specs #2

- Conventional wisdom
  - ➢ Low/minimum-bias triggers with built-in redundancy
    - Calo-based vs muon-based vs tracker-based

- Detector considerations
  - ➢ Choice of tracker, calorimeter, etc

- TLEP case
  - ➢ Huge interaction rates

What others do

- Lepton (and non-lepton) colliders' approach to trigger
  - ILC: "trigger-less DAQ" (very small rates)
  - LEP: calo- and tracker-based online selection
  - LHCb upgrade plans: collect ~everything
  - Remember: LHCb already has
    - higher rate (x10)
    - but also: smaller event sizes (x10)

    compared to ATLAS, CMS

"Good artists copy; Great artists steal"

Computing

Head-on vs Crab-waist options

D. Shatilov: **http://indico.cern.ch/event/313708/contribution/34/material/slides/1.pdf**

Luminosity at Low Energies (Z, W)

Energy	TLEP Z		TLEP W	
Collision scheme	Head-on	Crab Waist	Head-on	Crab Waist
Np $[10^{11}]$	1.8	1.0	0.7	4.0
θ [mrad]	0	30	0	30
σ_z (SR / total) mm]	1.64 / **3.0**	2.77 / **7.63**	1.01 / **1.76**	4.13 / **11.6**
ε_x [nm]	29.2	0.14	3.3	0.44
ε_y [pm]	60.0	1.0	7.0	1.0
ξ_x / ξ_y [nominal]	0.03 / 0.03	0.02 / 0.14	0.06 / 0.06	0.02 / 0.20
L $[10^{34}\ cm^{-2}s^{-1}]$	**17**	**180**	**13**	**45**

Head-on: parameters taken from FCC-ACC-SPS-0004

Crab Waist scheme requires low emittances. This can be achieved by keeping the same lattice as for high energies (i.e. $\varepsilon_x \sim \gamma^2$).

The numbers obtained in simulations are shown in blue.

Conclusions

- ❑ At low energies (Z, W) crab waist scheme can provide much higher luminosity than head-on collision.
- ❑ At high energies (H, tt) both schemes are of equal efficiency.

Rates & Event sizes at TLEP

- Three (or four) parameters here
  - Rate of interesting physics to record
  - Event size
  - Data throughput (ie. Read-out & write-out capacity)

- Relevant parameter: data throughput, not rate!
  - Capacity: data volume per unit time =

    (event size) × (interesting physics rate)

Data throughput: Readout

- ATLAS and CMS
  - Level-1 trigger accept rate: 100 kHz → this drives DAQ requirements for feeding events into HLT (1 MB/evt)
  - Technology: Gigabit Ethernet/Myrinet with 1-2 Gbit/s
  - Nominal DAQ throughput: 100 GByte/sec

- TLEP
  - Heads-on: 15 kHz of Z events, 60 kHz of Bhabha events
  - Crab Waist: 150 kHz of Z events, 600 kHz (?) of Bhabha events
  - For event sizes ≤ "LHC event" sizes:
    - Z events: within factor 2 below today's budget
    - Bhabha events: within factor 8 below today's budget

Data throughput: Output to disk

- ATLAS and CMS
  - ➢ HLT output rate: ~ 1 kHz or 1 GB/s
    - ATLAS & CMS can output much more (with larger T0 disk buffer): factor of 10 (ATLAS; S. George) or 2 (CMS; E. Meschi) (Estimate: not tested and/or commissioned)
  - ➢ Technology: HLT algorithms & Storage Manager (CMS)/SubFarm Output Units (ATLAS): C++
  - ➢ NB: Disk space capacity the actual bottleneck here, ***not*** trigger rate or output to disk

- TLEP
  - ➢ Heads-on: 15 kHz of Z events, 60 kHz of Bhabha events
  - ➢ Crab Waist: 150 kHz of Z events, 600 kHz (?) of Bhabha events
  - ➢ For event sizes ≤ "LHC event" sizes:
    - Z stream: within factor 20 below today's capacity
    - Bhabha stream: within factor 80 below today's capacity

Event size at TLEP

- What is the event size?
  - ➢ Assumption that event size is fraction of LHC event size
    - Factor of 10? Less?
  - ➢ Need to evaluate potential impact of:
    - Synchrotron radiation, beamstralung, beam backgrounds
    - Detector design (granularity, noise/zero-suppression)

- We do not really know
  - ➢ Needs to be evaluated for different detector scenarios, beam profiles

Software

Level-1 or HLT?

- ILC assumes DAQ with "trigger-less" design

- Main question for TLEP
  - ➢ Hardware-based (aka: Level-1) or software-based (aka: C++/HLT) trigger?
  - ➢ Examples of technologies involved:
    - Level-1: FPGAs
    - HLT: GPU or Many-Core

Level-1 or HLT?

- Why not stick to software/C++ and keep things simple?

- Detector choices can have an impact on trigger/DAQ, eg:
  - Tracking: a Time Projection Chamber (TPC) that cannot be read out every 20 ns (not a favorable option with crab-waist rates)
  - Calorimetry: with a fine-granularity & noisy calorimeter one may not be able to apply zero suppression at the trigger

Software technologies

- Begin with GPU or many-core development of physics-object reconstruction algorithms
  - ➢ Exact underlying technology (e.g. GPU vs Many-Core, OpenCL vs nVidia's CUDA, FPGAs' C-like code) is not important to know
  - ➢ Main challenge: develop parallelizable algorithms that can then "easily" get ported to another architecture if needed
    - FCC software and P(lain) O(ld) D(ata): simplicity and parallelism (promised to be) built in
  - ➢ Need software experts that work very closely with detector and reconstruction experts

WG10 prerequisites

- Physics studies: one can start from MC-truth particles, apply some smearing and carry out a feasibility study and/or expected measurement precision

- Experimental environment: need detector hits so we can evaluate event sizes, and put together reconstruction algorithms, study inefficiencies, latencies, biases, etc
    - WG10 prerequisite: simulation of detector hits (collaboration with WG9)

List of WG10 tasks #1

- Implementation of sw tools to allow WG10 studies

  To-do list:

  ➢ Production of SimHits from a GenParticle transversing a detector geometry (Anna Zaborowska et al.)

  ➢ Data formats for storing the SimHits

  ➢ Going from SimHits to "physics object candidates" with various reconstruction algorithms (electrons, muons, jets, etc)

- Required statistics

  ➢ Start with small samples (Fast- or Full-Sim)

  ➢ Eventually move to large samples (Fast-Sim)

  Collaboration with FCC-sw and FCC-hh trigger people

List of WG10 tasks #2

- Define list of specific tasks that can be assigned to (and studied by) individuals and small groups

Examples:

- Algorithmic inefficiencies, impact on asymmetries, etc
- Algorithmic redundancy
- Zero-suppression at trigger compatible with potentially noisy calorimeter?
- Beam background's impact on rates, event size

Collaboration with object reconstruction, beam experts

List of WG tasks #3

- Studies to be carried out for
  - Different detectors designs (sizes, granularity, etc)
  - Accelerator parameters

Summary

- To-do list
  - ➢ Collaborate with FCC sw team to implement tools
  - ➢ Collaborate with Detector team to understand physics requirements and detector layouts
  - ➢ Collaborate with Machine team to understand beam environment
  - ➢ Talk to other "trigger-less" people
  - ➢ Develop proof-of-principle HLT (or L1) algorithms:
    - Goal: "100%" signal efficiency and "0%" bias (redundancy)
    - Evaluate event sizes, data throughput
    - Demonstrate feasibility and/or improvements needed