Event rates & online issues

FCC-ee WG10

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Mandate

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

Defining the problem: Rates & event sizes

Physics specs

- LO assumptions
  - ➢ Trigger input = trigger output = DAQ rate = interesting physics. In other words:
    - Signal efficiency ~ 100%
    - Background ~ not a major consideration (TBC)
  - ➢ Rate of interesting physics:
    - Head-on scheme: ~15 kHz (Z events) + 60 kHz (Bhabha)
    - "Crab-waist" scheme: 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….)

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 (high-purity requirements on online selection)
    - Remember: LHCb already has
      - higher rate (x10)
      - but also: smaller event sizes (x10)

      compared to ATLAS, CMS

Relevant parameter: data throughput, not rate!

- Capacity: data volume per unit time =

  (event size) × (interesting physics rate)

Rates, data output to disk

Experiment	Trigger rate (kHz)	Event size (MB)	Throughput to disk (GB/s)	Notes
ATLAS/CMS (2012)	1	1	1	Can do up to 2 GB/s (limited by storage)
ATLAS/CMS (Phase 2)	5	4	20	Pileup: 140
LHCb upgrade	10-20	0.1	1-2	
ILC/TESLA		0.2+5.0		Full train (1 ms) Largest size from bgd
FCC-ee (Z-pole)	150	???	???	Crab-waist

Event size at FCC-ee

- 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
  - ➢ Best guess: start from ILC detector designs

WG10 organisation:
Working Units

Working Units & Synergies

Physics analyses requirements

- Evaluate the precision needed on the determination of trigger efficiencies
  - Absolute trigger efficiencies don't need to be known much better than the luminosity. Some analyses (e.g. asymmetries) may need a precise knowledge of relative (e.g. Forward vs Backward) efficiencies
- Methods for evalua
  - What was d
- Proto-algorithm de
  - ~100% effic

Software tools

- Port to DD4Hep the geometry of ILD or SID

Beam and machine backgrounds

Description: beam-beam, synchrotron radiation, beam-gas, halo muons, etc

- Rates and event sizes to be evaluated with fast/full simulation when tools are in place

Readout and general architecture

- Propose readout specifications: what is read out (e.g. hits, or clusters already made by the electronics), what is the number of bits per channel, amount of zero suppression
  - What assumptions have been made for zero suppression for ILC?

- From brainstorming to concrete projects
- With the help of software: turn into well-defined tasks (to be advertised to individuals and new groups)

- Can we use an approach a la LHCb with the number of channels planned for the FCC-ee detector ?

https://twiki.cern.ch/twiki/bin/viewauth/FCC/FCCeeOnlineSoftware

Beam & Machine backgrounds

Beam and machine backgrounds

Description: beam-beam, synchrotron radiation, beam-gas, halo muons, etc

- Rates and event sizes to be evaluated with fast/full simulation when tools are in place
- Will require an implementation in DD4Hep / Geant of several beam-line elements (e.g. final quadrupoles which can be a source a backscatters for the beamstrahlung background, and which is needed to determine the synchrotron radiation background.
  - Interaction with Acc/MDI

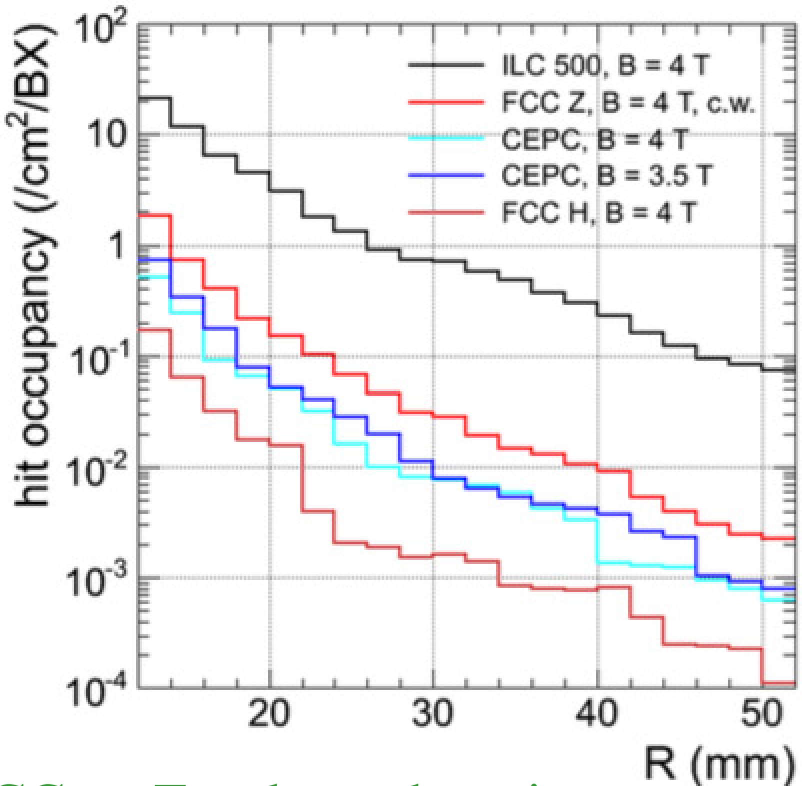
Before DD4Hep/Geant tools are available:

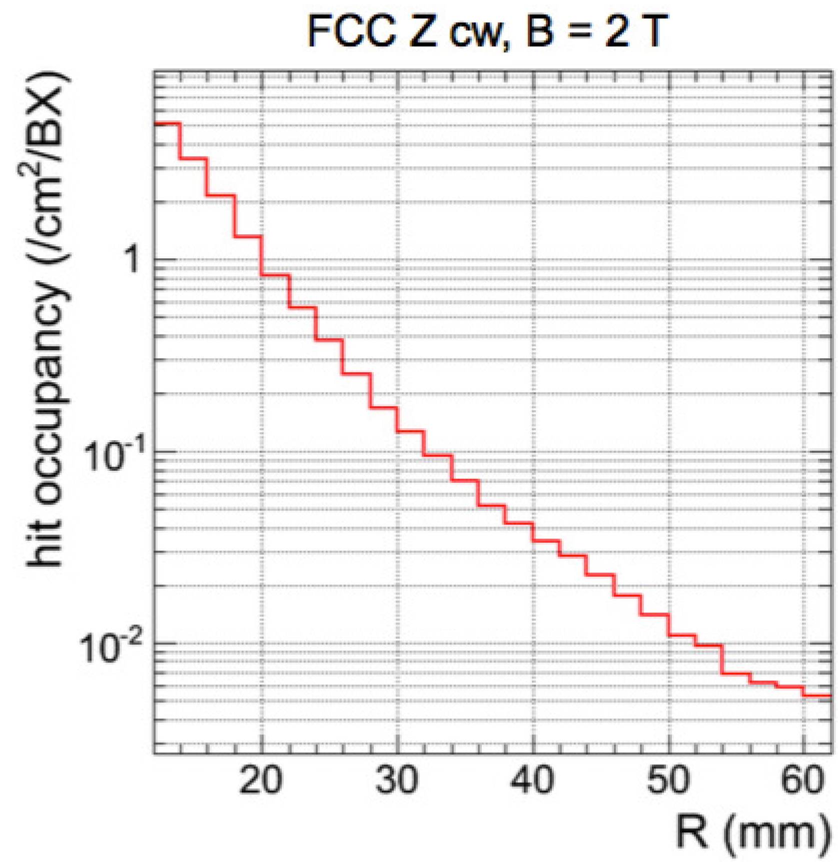
- Determine multiplicities & spectra of pairs created within the detector acceptance using Guinea-Pig
- Attempt to scale projections from corresponding studies done for the ILC (cf ILC TDR and TESLA TDR) and get approximate occupancies / rates / event sizes
- What existing simulation tools could we be using?
- For beam-gas, halo muon backgrounds : review the background induced rates seen at LEP and see what can be scaled to the beam current for the (Giga-Z)

Determination of beamstrahlung pair-production background

- Run Guinea-Pig (e^+e^- beam-beam simulation programme) with FCC-ee parameters (with Z-pole crab-waist scenario)
- Take GP output, pass through ILC software with ILD detector (full simulation)
- Evaluate particle flux through magnetic field and as function of radial distance from beam

Beam & Machine backgrounds





FCC-ee Z-pole, crab-waist:

- 15x less pairs than ILC500
- And with 10x less energy

Pair production appears not to be a (major) issue

The larger the magnetic field, the smaller the pair-production rate

See E. Perez's talk at TLEP9 workshop in Pisa

Event sizes in ILD scheme

< Nhits >	Pair bckgd (c.w.)	Z to μμ	Z to jj	Bhabha	ZH to jjbb at 350 GeV
VTX	90	15	160	7	350
TPC	< 0.06	90	1400	50	3000
Ecal	5	70	1400	20	9000
HcalBarrel	-		2000	5	9000
HcalEndcap	340	90	1000	15	
Muons	-	50	30	6	50
BeamCal				60	
LumiCal				800	
LHCal				75	
Approx size	2 - 4 kB	1.6 kB	30 kB	2.5 kB	110 kB

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- hence, with a TPC, an "offset" of 30 kBytes to add to the raw data corresponding to any triggered event written to disk.
  - a Zmumu event would be 30 kBytes
  - a Bhabha event would be 30 kBytes...

Hadronic pile-up

See E. Perez's talk at TLEP9 workshop in Pisa

Event sizes in ILD scheme

- Pair-production does not seem to be an issue
  - Small contribution to event size (unlike ILC)

- "Guesstimate"of ~100 kB seems to hold (hadronic events)
  - Z-pole & crab-waist scheme: throughput similar to HL-LHC

- "Empty" events (e.g. Bhabha) may not be empty
  - Detectors with large readout times (e.g. TPC) incur pile-up
  - But not a major issue either

- Several background sources still need to be considered
  - Fwd region of FCC-ee detector must be included in Simulation

Beam & Machine backgrounds

Beam and machine ba…

Description: beam-beam, synch…

- Rates and event sizes to…
- Will require an implemen… beamstrahlung backgrou…
  - Interaction with Ac…

Negligible event size in VTX detector (ILD) with Mokka (Full Sim) for pair-production in FCC-ee (few kBytes/evt), dominated by endcap calorimeter.

Before DD4Hep/Geant tools are available:

- Determine multiplicities & spectra of pairs created within the detector acceptance using Guinea-Pig
- Attempt to scale projections from corresponding studies done for the ILC (cf ILC TDR and TESLA TDR) and get approximate occupancies / rates / event sizes
- What existing simulation tools could we be using?
- For beam-gas, halo muon backgrounds : review the background induced rates seen at LEP and see what can be scaled to the beam current for the (Giga-Z) FCC-ee operation
  - How were the LEP backgrounds predicted before starting operation ?
- Additional sources of potential background to be estimated:
  - Back-scattering of beamstrahlung photons and γγ --> hadrons (using Guinea-Pig)
  - Synchrotron radiation
  - beam halo, beam gas
  - background from injection?

Additional source of potential background to be evaluated in collaboration with Experiments-Machine interface group

Software

Software tools

- Port to DD4Hep the geometry of ILD or SID
  - in collaboration with Offline software
- Develop some software that converts the Geant Hits into an event size
  - need ability to mix events, in case the background is not negligible
- Framework development towards enabling parallelisation of HLT algorithms (e.g. GaudiHive, CUDA or such)
  - Parallelisation, vectorization

- Implementation of additional detector geometries (e.g. SID), SimHits and tool for conversion into event sizes
- In collaboration with software group

The Next Steps

- Detector mini-workshop at beginning of May (TBC)
- Potential topics/presentations to include
  - Beamstrahlung photons rates, backscattering from interactions in forward region, dependence on distance of LumiCal from IP
  - Simulation of synchrotron radiation
  - Software-only trigger for LHCb upgrade
  - DD4Hep tutorial? SimHits generation?

Summary

- FCC-ee WG10 is making slow but steady progress
  - From brainstorming, to concrete tasks, to prototypes & proposed solutions
  - First studies on beam backgrounds presented at Pisa
  - Next steps: beef up effort on software tools, define deliverables
  - Discussion to continue at detector mini-workshop

Epilogue

"The trigger for FCC-ee? I don't want a version. I want a vision."

Backup

Physics analyses requirements

Physics analyses requirements

- Evaluate the precision needed on the determination of trigger efficiencies
  - Absolute trigger efficiencies don't need to be known much better than the luminosity. Some analyses (e.g. asymmetries) may need a precise knowledge of relative (e.g. Forward vs Backward) efficiencies
- Methods for evaluating and minimising trigger efficiencies (e.g. tag-n-probe, algorithm redundancy, etc)
  - What was done for LEP?
- Proto-algorithm development
  - ~100% efficiency, redundancy, minimise biases & algorithmic asymmetries
  - A lot will depend on levels of background and if any (real) rejection is needed

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)

Readout & general architecture

Readout and general architecture

- Propose readout specifications: what is read out (e.g. hits, or clusters already made by the electronics), what is the number of bits per channel, amount of zero suppression
  - What assumptions have been made for zero suppression for ILC?
  - Reduction of data beyond zero-suppression: e.g. some clustering could be done on the chips - see ideas in the context of the HL-LHC pixel detectors.
  - Connection to software task #2
  - Interactions with detector group for determining number of bits
- Study the evolution of event size w.r.t. detector granularity and beam conditions
  - For an ILC-like detector the size is ~ 200 kB for a multijet event without any background (TESLA TDR); adding all background sources relevant to the ILC, this increases to several MB's.

- Scenarios: purely software trigger or have a hardware L1 that limits the readout rate and the event building rate ?
  - Summarise pros and cons of both options
    - Purely software trigger: solution chosen by ILC and LHCb, although for different reasons
    - Can that be chosen for TLEP as well ? what are the constraints set by such a scheme in a collider mode environment with BX = 20 ns ?
    - What are the constraints that a purely software trigger would put on the design of the detector ? e.g. readout of the tracker (input from LHCb?) Impact of Time Projection Chamber choice on crab-waist operation at Z-pole?
    - Can we use an approach a la LHCb with the number of channels planned for the FCC-ee detector ?

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