Trigger and DAQ for FCC-ee

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Trigger / DAQ for FCC-ee ?

High precision measurements require :

- a very high luminosity - e.g. at the Z peak, could reach about 2 10^{36} $cm^{-2}s^{-1}$
- highly granular detectors
  - e.g. using ILC detectors as an example :
    - VTX : 1000 M channels (CMS phase-1: 80M, LHCb upgrade: 40M)
    - ECAL : 100 M channels (CMS : 100 000)

→ Large data through-put to disk (trigger rate times "event size")

→ Large data volume through the event builder
- L1 trigger rate times the size of a L1-Accepted event
- or crossing rate times the size of a zero-bias event if no hardware trigger
  - but crossing rate can reach 270 MHz at the Z pole (Δt = 4 ns)

→ Requirements on the readout electronics
- Especially if full readout at the crossing rate

Data throughput to disk

Luminosity expected at the Z-peak : could reach 2 10^{36} cm^{-2} s^{-1} (crab-waist scheme)
σ(ee -> had at Z peak) ≈ 30 nb
Hence a rate of O(100 kHz) of physics events to write to disk (+ Bhabha).
Feasible ? Depends on the event size.

	Trigger rate	Event size	Throughput to disk
ATLAS / CMS Phase 2	5 kHz	4 MB (PU = 140)	20 GB / s
LHCb upgrade	20 kHz - ?	100 kB	1 GB / s

Event size at of a multi-jet event in the TESLA detector, from the TESLA TDR (*) :
- Data due to the signal event only ≈ 200 kBytes
- However, adding the background, this increased to 5 MB !

100 kHz x 200 kB = 20 GB / s would be OK
but 100 kHz x 5 MB = 500 GB / s would be a lot !

(*) 15 yrs old… the more recent ILC TDR does not give the event size of a “signal” event, since ~ all the data volume comes from background; and give the volume of a bunch train, which is what is relevant.

Background sources and "event sizes"

• machine-induced background, e.g. synchrotron radiation upstream of the IR
  - hopefully, can be limited or shielded

• Background processes inside the IR, e.g. :

  - Especially pair-production background, γγ to e+e-
    low PT particles, enter (many times) in the vertex detector.
    Or can make showers in material in the fwd region (e.g. Lumi monitor),
    leading to secondaries that can backscatter into the main detector
    - at ILC : most of the data volume is coming from pair-production bckgd
      Largely induced by the large amount of beamstrahlung

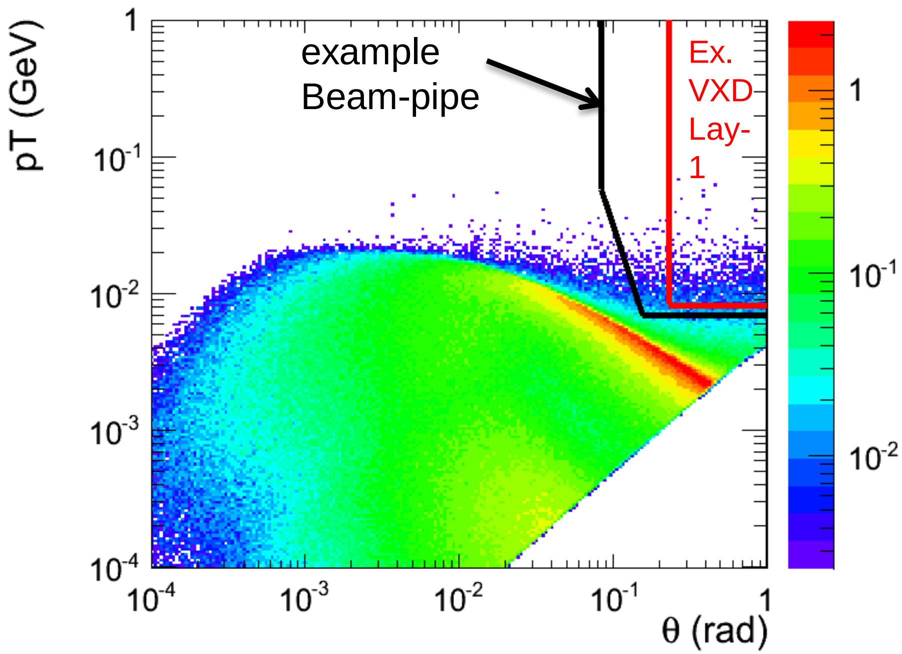
  - similarly, γγ to hadrons

First studies of the pair-production background, for the FCC beam parameters, have been made and were shown at the workshop in Pisa
  - using the Mokka simulation tools (ILC), and the ILD detector and forward region
  - Talk at the Pisa workshop, Feb 2015

Pair-production background (FCC-ee Z, crab-waist parameters)

Beamstrahlung & pair-production for FCC calculated by Guinea-Pig (D. Schulte)

Kinematics of background e+e- pairs



As long as the innermost layer of the VXD detector is away from the hot region, the background in the VXD is small.

Full simulation using the ILD model: O(kB) or lower.

Remains the case if the IR of the ILD model is modified, to bring QD0 down to 2m of the IP (was 4m in ILD). LumiCal (θmin = 70 mrad) and Beamcal consequently moved closer to the IP, hence more backscattering.

[Talk at the detector mini-workshop, June 18, 2015]

But the background depends on the exact configuration of the IR.

Since June / Now / next

- Also took a first look at radiative Bhabha events

- Move from the Mokka framework to ddsim
    - GEANT detector simulation using DD4HEP for the geometry description
    - use the tools developed by the CLICdp group
    - changes (detector, interaction region) are easier to make than with the Mokka tools.

- Start from the CLIC model (CLIC_o2_v04)
    - adapt minimally the detector :
        - pixel detector : first layer can be brought closer to the BP, e.g. at R = 1.5 cm (compared to 3 cm in CLIC)
        - calorimeter : requirements different from those of CLIC – but for the background studies, mostly concerned about the tracker
    - Implement an interaction region following MDI's recommendations
        - esp. shielding and compensating solenoids
        - and the detector(s) in the forward region – luminosity monitor

- Consolidate the event sizes obtained so far : O(100 kB) for a Z -> jj event, and O (2 kB) for a Bhabha or a background event

Trigger architecture : L1 or software only ?

ILC and LHCb upgrade : no L1 hardware trigger
- ILC : because of the bunch structure : can readout everything in the long time (199 ms) between two trains
- LHCb : because they need a very pure selection at the trigger level

LHCb: Talk R. Le Gac at the June workshop

	Zero-bias event size	Rate	FE to Event Builder
ATLAS / CMS Phase 2	4 MB	O(500 kHz)	2 TB/ s
LHCb upgrade	100 kB	40 MHz	4 TB / s
FCC ee (Z c.w.)	2 kB	270 MHz	500 GB / s

Assuming that the size of a zero-bias event is indeed of a few kB, the data volume through the event builder should not be a showstopper for a software-only trigger.

Trigger architecture and systematic uncertainties

Trigger efficiencies should be very high.
But they must be known to a very high level of accuracy.

Best: have independent triggers – see experience from LEP, uncertainties on trigger efficiencies for Z events of O (10^{-5}) : redundancy was the key

Talk of Roberto C, June workshop

For electrons / jets : independent online selections using the calorimeter and the tracking detectors, i.e. :

- if a hardware L1 : L1 Tracking (and calo, and mus) at up to 270 MHz
    - or have a more simple system, at L1, that provides the redundancy

- with a software only trigger :
    - need to readout the whole detector at 270 MHz
    - online reconstruction must be fast in order to cope with the rate

Readout of the whole tracker at 270 MHz ?

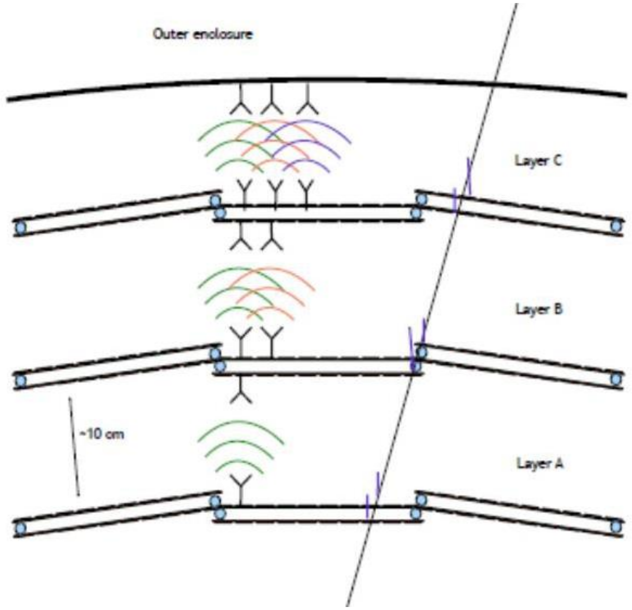
- w.r.t. LHCb at HL-LHC : readout at f x 7, and VXD has x25 more channels
- w.r.t CMS at HL-LHC : readout at f x 500, and 10x more channels
- but the occupancy is much lower at FCC-ee than at HL-LHC

With O(1 kB) of VXD data : 2000 Gb / s
A few hundreds of cables should be enough for the readout.

If amount of data is much larger (by > 10x) : large number of readout links that could make a non-negligible contribution to the material budget.

Wireless readout could then be a possibility ?
See WADAPT consortium, application of wireless techniques for particle-physics detectors.
May also ease the implementation of a L1-tracking.

WADAPT proposal



CERN seminar, C. Dehos and J.L Gonzalez Jimenez, Jan 12, 2016

Online reconstruction / parallelization ?

Software-only trigger, farm of N CPUs : to digest an incoming rate of 270 MHz, each CPU should treat an event within less than N / 270 MHz.
For N = 10000 CPUs, that's 40 μs [HLT in CMS : 150 ms per event]

- most of these events should be "empty". Using just the rate of the "physics" events, 100 kHz, one gets 100 ms - comfortable.

- minimal reconstruction needed even for the "empty" events (e.g. transforming the RAW data into something that can be exploited). Will takes $T \neq 0$

Parallelization may help:

- squeeze many cores into the same processor that can run algorithms in parallel. Useful when the same type of algorithm is run in different detector regions

- LHC-wide effort (driven by LHCb + ATLAS) on building such a "future" (ie. multi-core, parallelisation built-in, etc) framework.
  -> Gaudi-Hive, should be compatible with the FCCSW framework.

Plans

Move forward with the simulation studies :

- Start with the CLIC machinery
  - implement a DD4HEP-compliant version of the IR
  - get experience with DD4HEP and some numbers
- Then migrate and integrate with FCCSW

(Wo)manpower to come through applied CERN fellows (1 with MDI, + 1 ?) and summer/Master's students over the year.

	Z	W	H	t
Δt	3.7 ns	65 ns	430 ns	4.3 μs
f	270 MHz	15 MHz	2 MHz	200 kHz