ILD studies on Rates & Backgrounds

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Forewords

Quick overview of the efforts

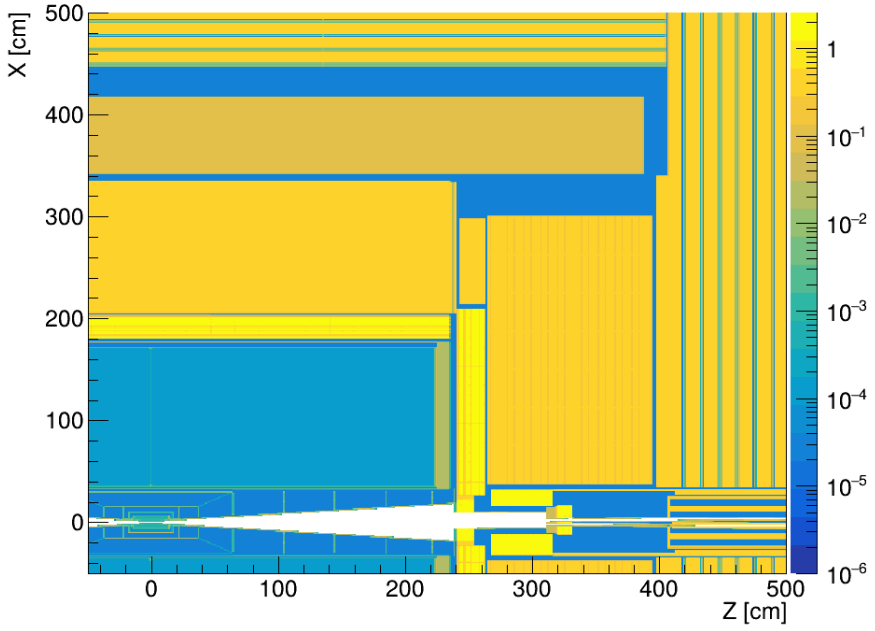
- ***Everything is preliminary***
- Many slide stolen
  - from D. Jeans' (KEK) presentation at the ILD meeting close to the LCWS25 meeting of 24/10/2025: https://agenda.linearcollider.org/event/10836/
    - Meeting dedicated to the adaptation of ILD to the FCC-ee
  - From V. Schwan, B. Keyworth, J. List (DESY) on VTX
  - But all fairly recent work

Area bing looked at:

- VTX
- TPC
- LumiCal
- Calorimeters

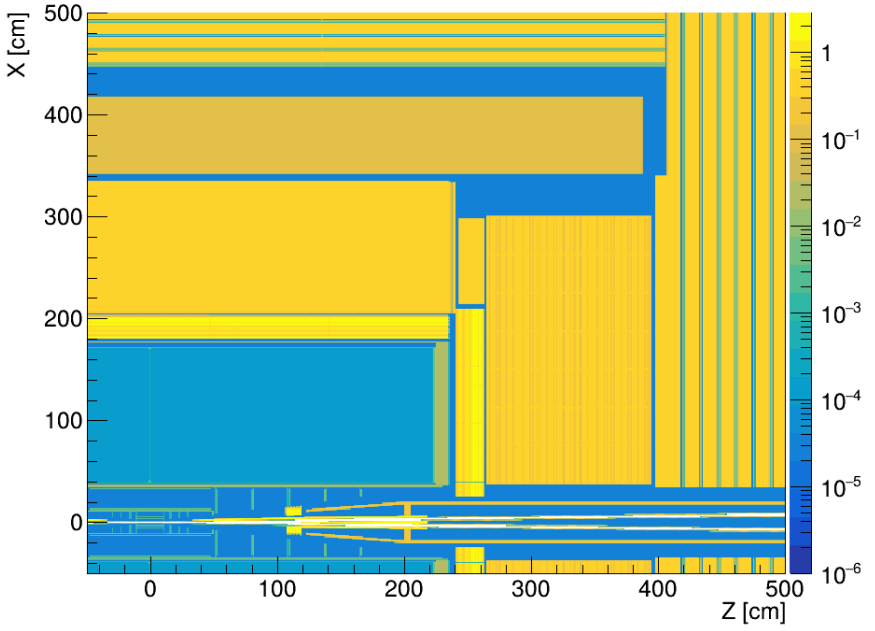
DD4Hep models for the FCC-

D. Jeans and V. Schwan



ILD_l5_v02

- Dual Sim of calorimeters
  - (SiW + ScintW) ⊗ (Scint HCAL + RPC HCAL)



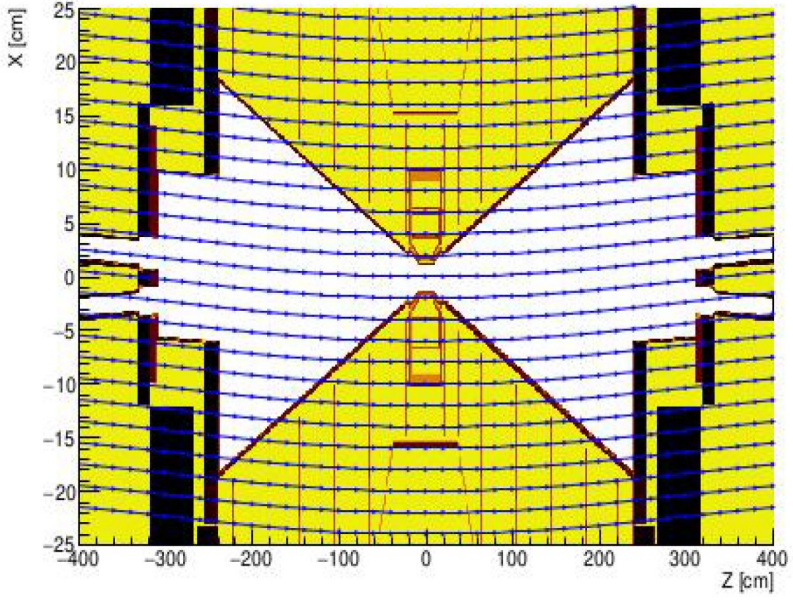
common MDI:

- MDI_o1_v00 vertex, inner tracker adapted from CLD_o1_v07
- Remainder of ILD untouched

Magnetic fields

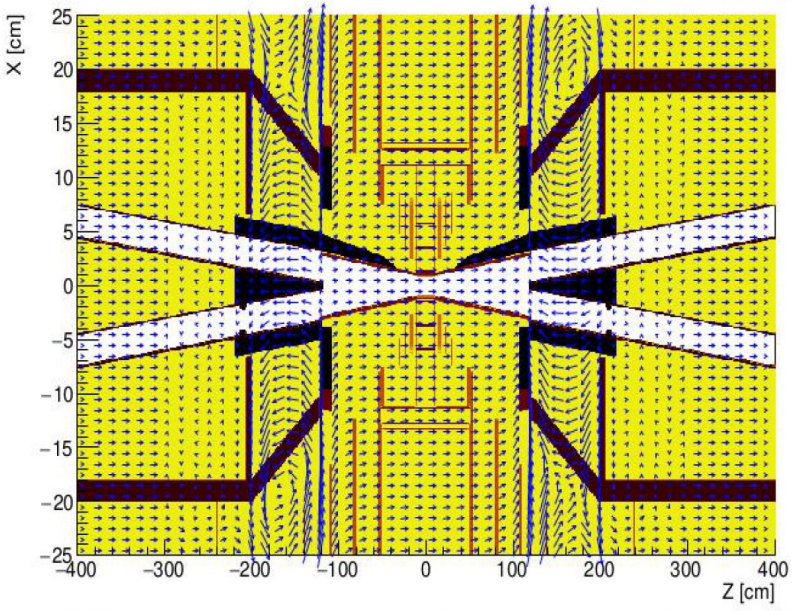
D. Jeans

field lines



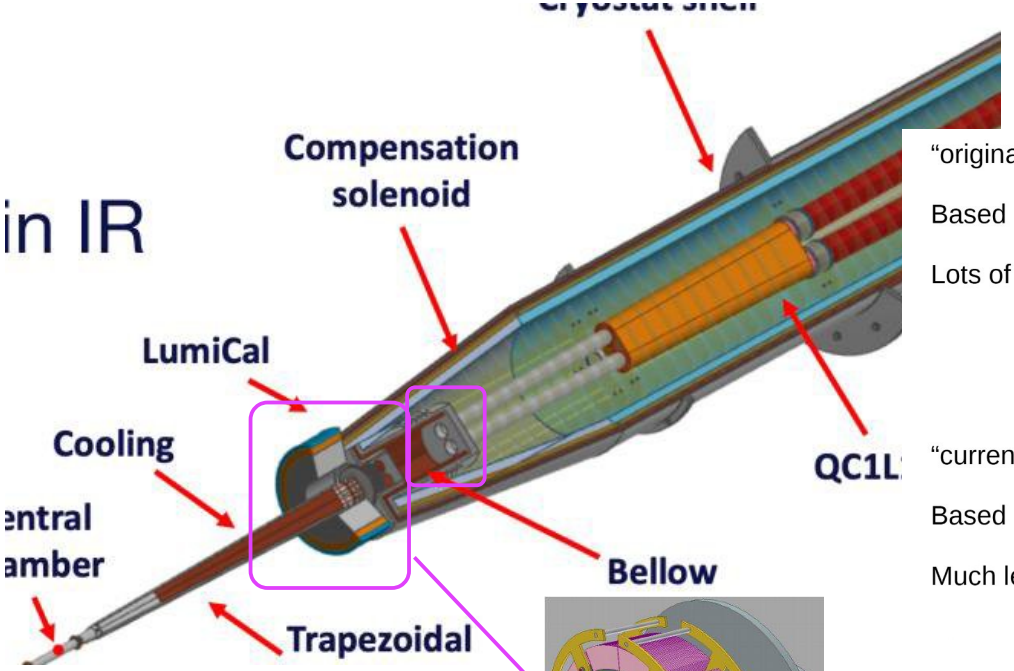
ILC with anti-DID

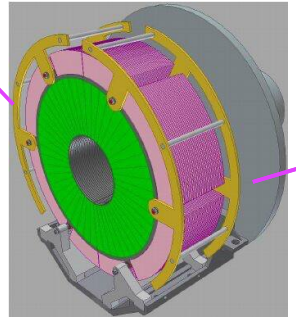
field magnitude & orientation



FCCee: screening and compensating coils

MDI at the FCC-ee



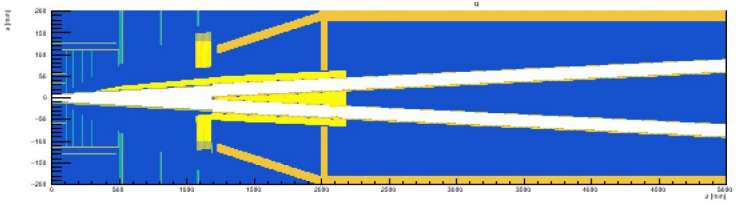


Design being optimised

"original" FCCee-MDI design

Based on simple shapes

Lots of shielding

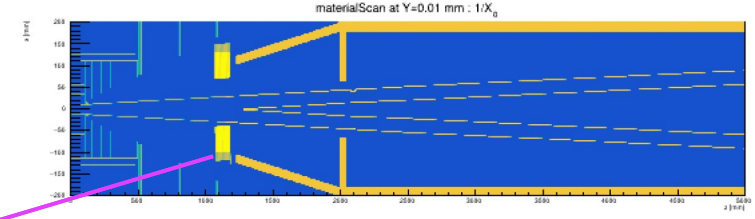


IP LumiCal 2m 4m

"current" MDI design

Based on CAD model

Much less shielding



Beam induced in the LumiCal

Based on 100 BX simulation using GuineaPig :

- ILC-250 (from ILD/Mikael Berggren)
- FCCee-91, FCCee-240 (from FCCee/Andrea Ciarma)

Using DD4HEP ILD detector models

- ILD@ILC:
  - Uniform 3.5 T (V02)
  - Uniform 2T (v02_2T)
  - Field map with and without anti DID (v03 and v05)
- ILD@FCCee:
  - Uniform 2T (v11beta)
  - Detailed magnetic field (v11gamma)

Mean number of hit pads can be used for TDAQ estimate.
Continous readout with 0-suppr.

Number of hit pads (mean value) in LumiCal

ILC				FCC			
v02	V02_2T	V03	V05 antiDID	V11 beta @Z Uniform 2T	V11 beta @ZH Uniform 2T	V11 gamma @Z Field map 2T	V11 gamma @ZH Field map 2T
986	19310	1017	589	71	271	85	355

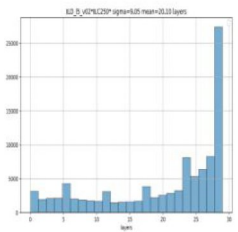
Important effect of magnetic field reduction

Important effect of anti DID

30% increase with additional B field

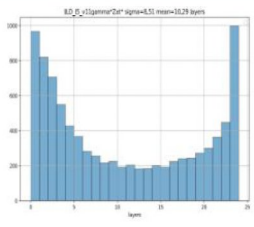
45% increase

v02



Lumical layer

V11 gamma @Z



Lumical layer

Y. Benhammou

Y. Benhammou

VTX: Synchrotron radiations

On-going work by V. Schwan, B. Keyworth, J. List (DESY and MDI groups) → All very prelim.

Synchrotron radiation sims:

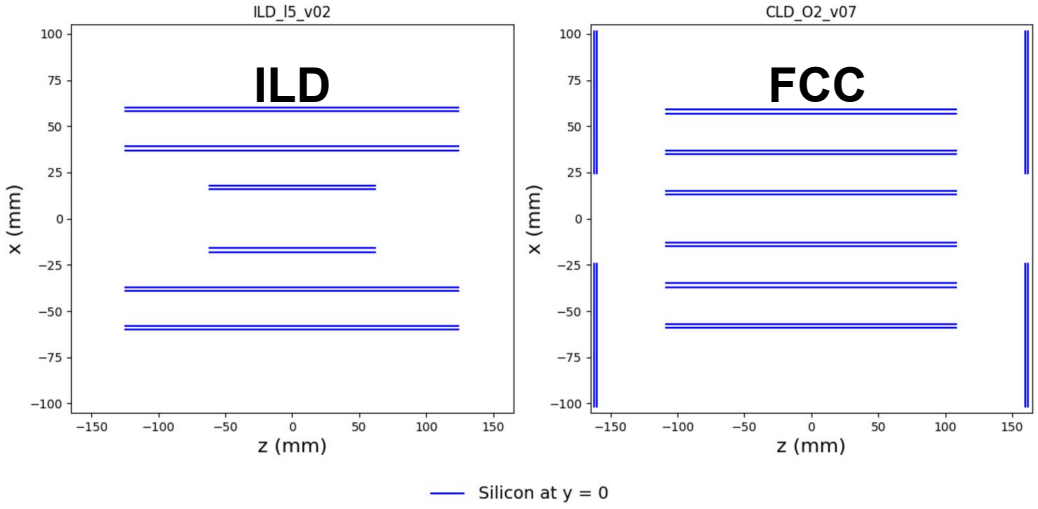
- Preliminary SR samples are available - pending full validation
- Beam core and halo separately simulated for 172.5 GeV beam energy (ttbar)
  - Core simulated with 10 µrad width parameter (very conservative)
  - Only a fraction of the particles in a bunch simulated → Results upscaled!

MDI:

- Two major versions, neither fully accepted by FCC's MDI group
  - V0: native DD4HEP → easy to understand & adjust; unfeasible beampipe shape, considered outdated
  - V1: CAD-import → difficult to adjust; sophisticated beampipe shape; some issues (e.g. misplaced SR mask); currently no shielding

VXD geometry:

- FCC's VXD slighly closer to the beam pipe
- FCC's inner layer extends farther in *z*
  - Might explain some difference - tbc

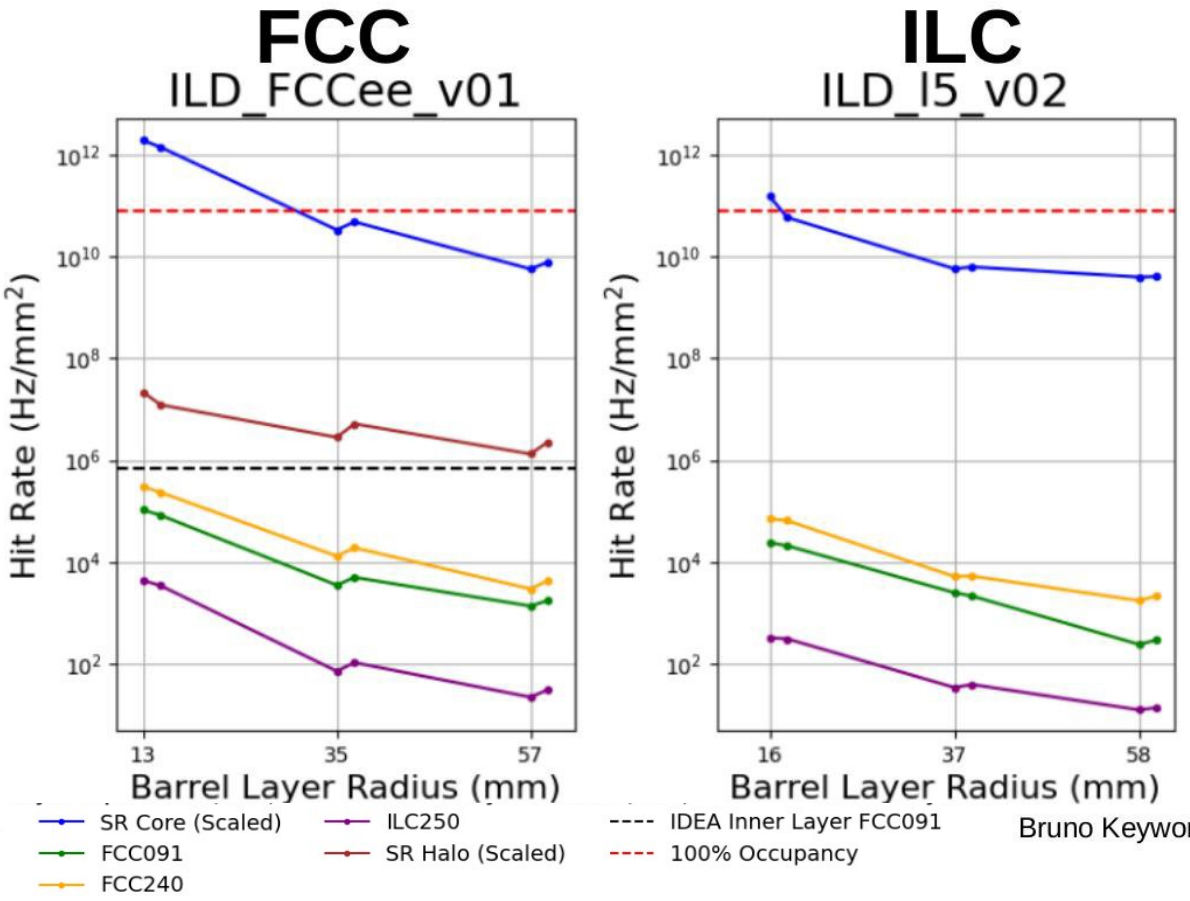


Preliminary Results of Vertex Occupancy: FCC-ee vs ILC

- Very preliminary results, to be taken with many grains of salt
- Occupancy goal: small, single-digit value
  - Otherwise, e.g., track reconstruction degraded

Takeaways:

- SR constitutes a non-neglibile background and requires more detailed study
- Meticulous study of optimal SR mask placement and shielding necessary
- Study of VXD geometry to be considered



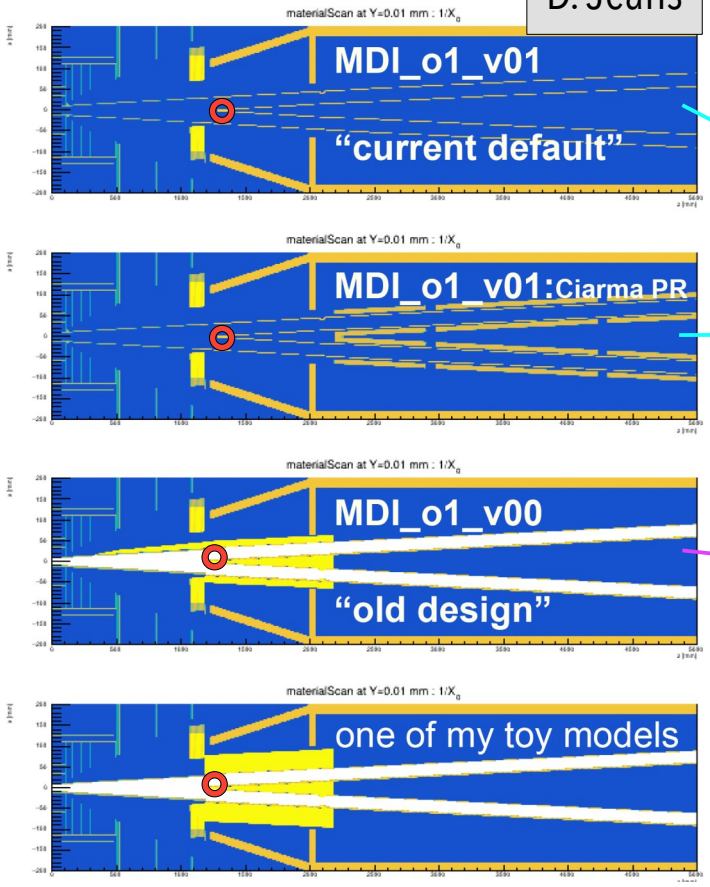
Bruno Keyworth

Hit rates per layer

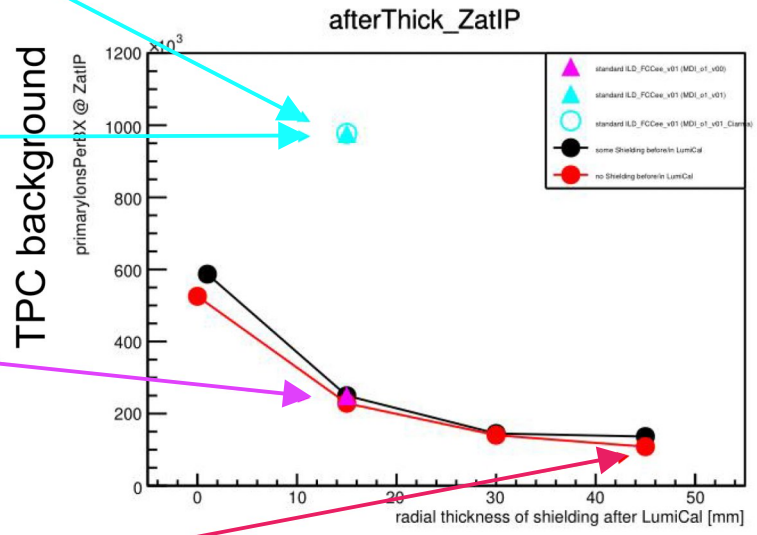
- Reconstructed hit rates from BS and SR
- Only vertex detector layers

TPC backgrounds at FCC-ee@91

D. Jeans



TPC backgrounds:
dependence on MDI modeling



shielding after LumiCal seems useful against beamstrahlung

Primary ions per BX → Rates :
- **⊗ Drift**
- **⊗ spread on readout pads**
- **× bits…**

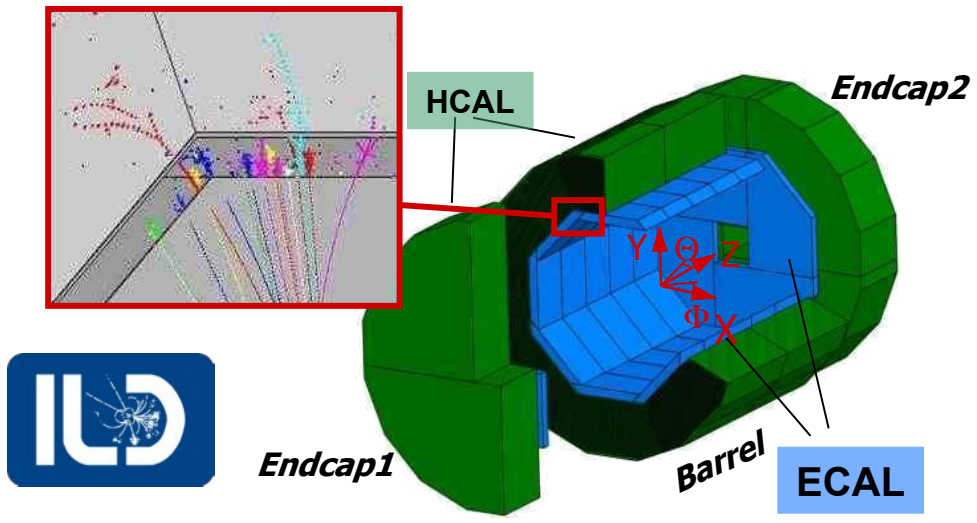
Occupancy highly R dependant

Backscattering from the " scrotch" : factor of 10 effects

CaloFlux for HG calorimeters: ILD as an example

ILD high granularity calorimeters

- Designed for ILC,
  - Power pulsing, low occupancy
- Marginally adapted for CLIC and CLD
  - Physics : number of layers
- Partially Adapted for CEPC
  - Lower granularity, …
- Needs strong adaptation for EW physics and continuous operation
  - Rates, Heat, Electronics



ECAL: 30 layers
- SiW-ECAL": Si cells $0.5 \times 0.5\,cm^2$
- ScECAL: Scint strips $0.5 \times 5.0\,cm^2$

10–100M channels

HCAL: 48 layers
- AHCAL: scint. cells $3 \times 3\,cm^2$
- SDHCAL: RPC cells $1 \times 1\,cm^2$

10–70M channels

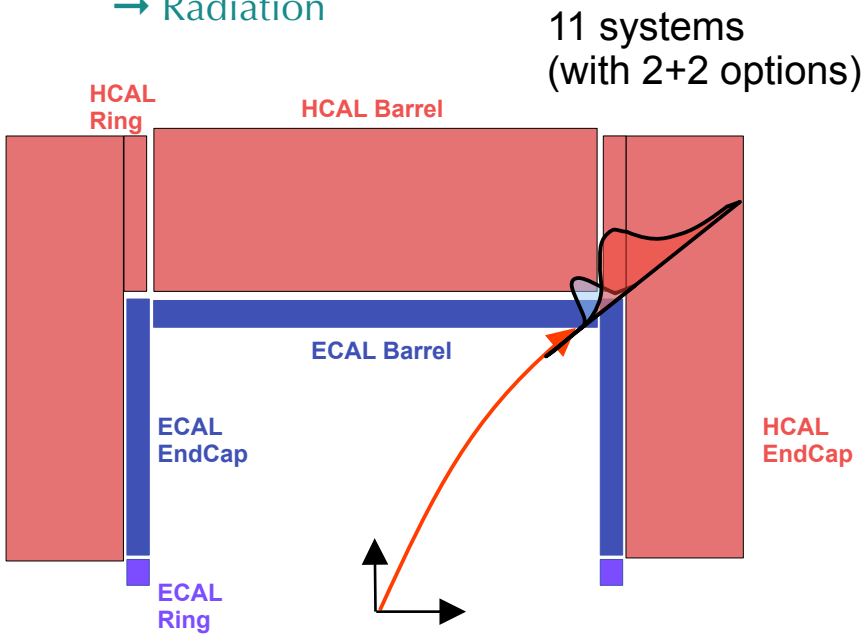
Calorimeter Fluxes from Full Simulations

Quantities useful for Self-Triggering & Low Occupacy Front-End electronics & Design

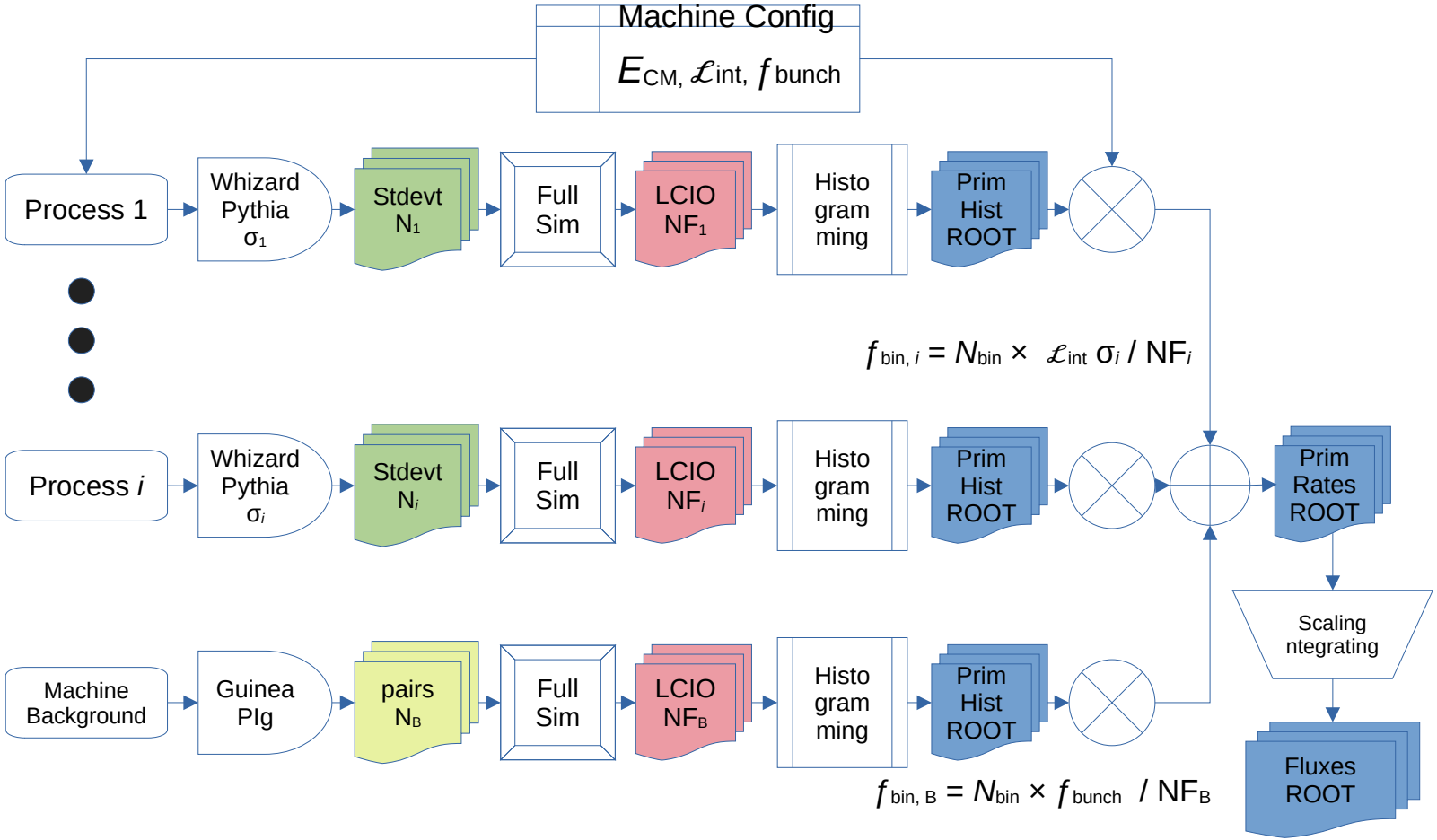
- Number of hits/s per ASICs
  - → Power (Energy per conversion)
  - → Memory size
- Distribution of Energy & Time
  - → Dynamic ranges
  - → Power per conversion (if Wilkinson ADCs)
  - → Frequency of Double hits
- Data output
  - → Data Flux per readout partition (DAQ)
    - → DAQ scheme (Calo trigger to other parts ?)

Other quantities

- Deposited energies
  - → Radiation



Processes to Fluxes



Generated data: ILD_l5_v02 (+ cross-angle 30mrad, B=3.5T), bgd files → ILD_l5_v11gamma

Table 1: $91.2\,GeV$
($N = 10000$, $L_{ins} = 1.4 \times 10^{-3} fb^{-1} s^{-1}$)

Channels	σ $(10^5 fb)$	$(\frac{\sigma \times L_{int}}{N})$ (s^{-1})
$ee \to qq$	344	4.82
$ee \to ll$	34.6	0.484
$ee \to ee$ $(M_{ee} < 30GeV)$	1.01	0.0141
$ee \to ee$ $(M_{ee} > 30GeV)$	57.8	0.809

Table 2: $162.5\,GeV$
($N = 10000$, $L_{ins} = 2.14 \times 10^{-4} fb^{-1} s^{-1}$)

Channels	σ $(10^5 fb)$	$(\frac{\sigma \times L_{int}}{N})$ (s^{-1})
$ee \to qq$	1.55	3.32×10^{-3}
$ee \to ll$	0.241	5.16×10^{-4}
$ee \to WW$	0.0504	1.08×10^{-4}
$ee \to ee$ $(M_{ee} < 30GeV)$	0.240	5.14×10^{-4}
$ee \to ee$ $(M_{ee} > 30GeV)$	12.9	2.76×10^{-2}

Table 3: $240\,GeV$
($N = 10000$, $L_{\rm ins} = 6.9 \times 10^{-5}\,{\rm fb}^{-1}\,{\rm s}^{-1}$)

Channels	σ $(10^5\,{\rm fb})$	$(\frac{\sigma \times L_{\rm int}}{N})$ $({\rm s}^{-1})$
$ee \to qq$	0.550	3.80×10^{-4}
$ee \to ll$	0.100	6.88×10^{-5}
$ee \to WW$	0.167	1.15×10^{-4}
$ee \to ZH$	0.00204	1.41×10^{-6}
$ee \to ee$ $(M_{ee} < 30GeV)$	0.120	8.29×10^{-5}
$ee \to ee$ $(M_{ee} > 30GeV)$	5.92	4.09×10^{-3}

Table 4: $365\,GeV$
($N = 10000$, $L_{ins} = 1.2 \times 10^{-5} fb^{-1} s^{-1}$)

Channels	σ $(10^5 fb)$	$(\frac{\sigma \times L_{int}}{N})$ (s^{-1})
$ee \to qq$	0.228	2.74×10^{-5}
$ee \to ll$	0.0430	5.16×10^{-6}
$ee \to WW$	0.111	1.33×10^{-5}
$ee \to ZH$	0.00123	1.47×10^{-7}
$ee \to tt$	0.00372	4.46×10^{-7}
$ee \to ee$ $(M_{ee} < 30GeV)$	0.0499	5.99×10^{-2}
$ee \to ee$ $(M_{ee} > 30GeV)$	2.57	3.08×10^{-4}

Machine background sources :

Source	#particles per bunch	< E > (GeV)
Disrupted primary beam	2×10^{10}	244
Bremstrahlung photons	2.5×10^{10}	244
e^+e^- pairs from beam-beam interactions	75k	2.5
Radiative Bhabhas	320k	195
$\gamma\gamma \to$ hadrons/muons	0.5 events/1.3 events	–

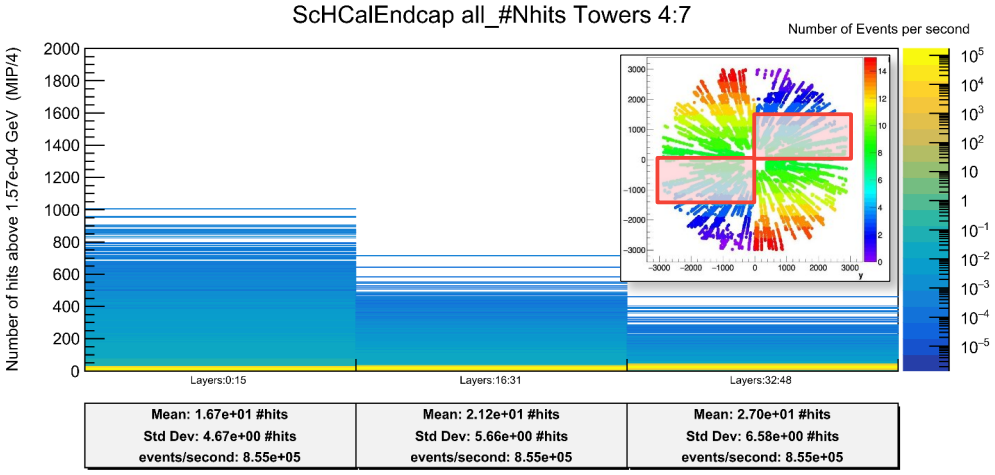
T. Behnke, et al.
The International Linear Collider Technical Design Report - Volume 4: Detectors,
arXiv:1306.6329 [Physics]. (2013)

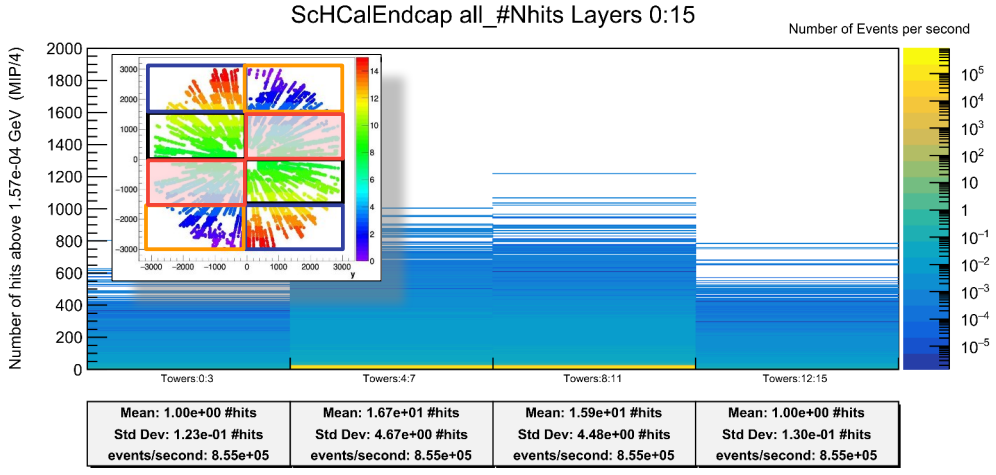
Incoherent pair production :
100 BX at FCC-ee 91.2 GeV and 240 GeV

Produced by Andrea Ciarma,

Simulated (special setup) in ILD's by D. Jeans

Results: Scintillator AHCAL Endcap





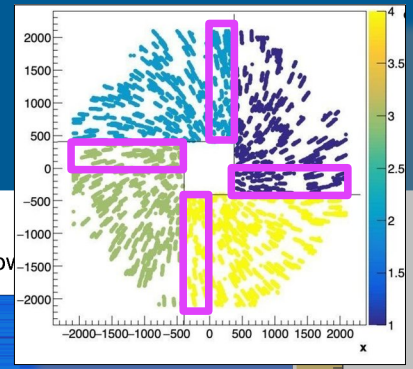
Average	14E+6 hits/s	18E+6 hits/s	23E+6 hits/s	855E+3 hits/s	1E+6 hits/s
MaxNhits	1000 Nhits/event	600 Nhits/event	400 Nhits/event	400 Nhits/event	400 Nhits/event
for 6B/hits	86E+6 B/s	109E+6 B/s	139E+6 B/s	5E+6 B/s	9E+6 B/s
Est. Ncells	278 756	278 756	278 756	Not Yet avail,	278 756
Occupancy/BX	1,0E-06	1,3E-06	1,7E-06	Not Yet avail,	1,0E-07
cell size	30				

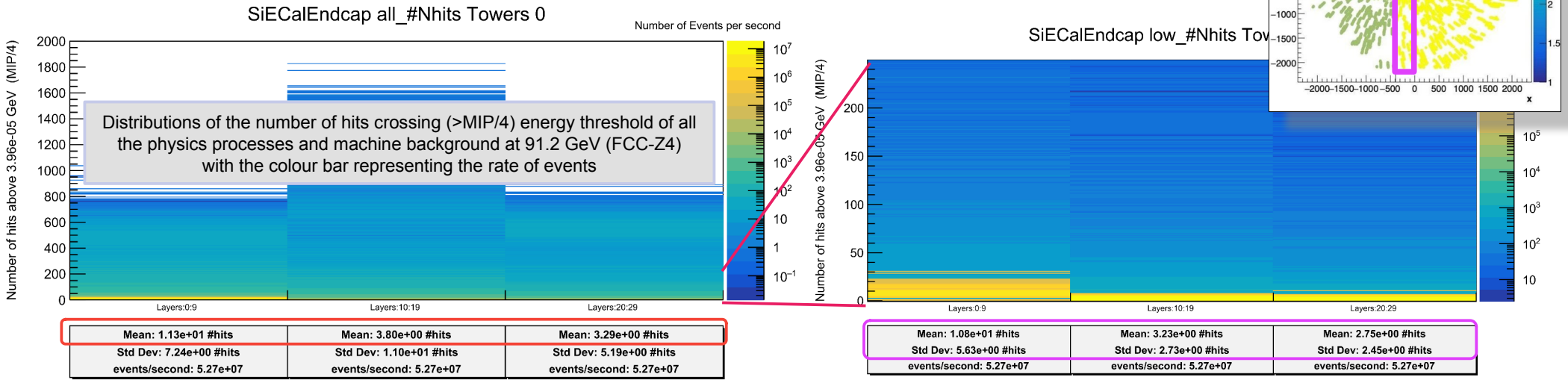
Note 1 : **Very preliminary**
Note 2 : Rates for all tower 4:7 modules → /4 per module, /16 per layer

Distributions of the number of hits crossing (MIP/4) energy threshold of all the physics processes and machine background at **91.2 GeV** (FCC-Z4) with the color bar representing the rate of events

- **Max of the hits rate are in the first 2 thirds of the calorimeter, but in average more in the back (!)**
- **Significant angular dependence.**
- **The central towers have most of the hits due to the closeness to the beam pipe.**

Results: Rates in SiECAL EndCaps, Tower 0 vs depth





T0 all quadrants	**L0:9**	**L10:19**	**L20:29**
Average #hits/s	572E+6 hits/s	176E+6 hits/s	147E+6 hits/s
Max	2000 hits/event	2500 hits/event	1000 hits/event
Data rate	4,00E+9 B/s	1E+9 B/s	1E+9 B/s
Ncells	1.161.775	1.161.775	1.161.775
Occupancy/BX	**9,4E-06**	**2,9E-06**	**2,4E-06**
Length/Width	2496		565
Base power	12E+03	12E+03	12E+03
Conversion power	515E+00	159E+00	132E+00
Total power	**12E+03**	**12E+03**	**12E+03**
% conv.	4,2 %	1,3 %	1,13 %

cell size	5,5
Bytes/hit	7
powa (W/cell)	10E-03
powb (J/hit)	870E-12
Conv & RO E/hit/µJ	0,9
Δt	19E-9

- **Machine background in first layers**
- **High E ee→ee in middle of ECAL (next slide)**
- **Power driven by the continuous part (Pre-Amps)**

Note 1 : (still) **preliminary**
Note 2 : Rates & Power for all T0 modules
→ /8 per quadrant, *10 per layer for 1 slab → 150* W / slab
→ ~50 MB/s = 400 Mb/s / inner slab
Note 2 : Total Endcap data ~ 2×T0 = 12 GB/s

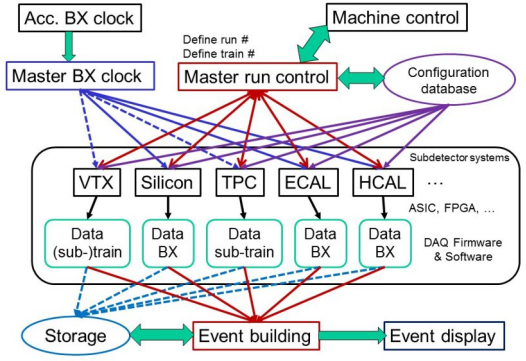
Old numbers… as a X-check: ILD ‘TDR’ and IDR

The International Linear Collider Technical Design Report - Volume 4: Detectors, arXiv:1306.6329 [physics], (2013).

The ILD Collaboration, International Large Detector: Interim Design Report, arXiv:2003.01116 (2020).

DAQ achitechture designed for the ILC:

- 1ms bunch trains of 2625, at 5 Hz, ILC500
- Readout between bunches
- Event Building on a full bunch train by FPGAs (~ bunch tagging) → Farm
- Raw data rate: $\mathcal{O}$(100 MB)/train
  - Dominated by VTX and BeamCal



R&D on Common DAQ basis: EUDAQ2

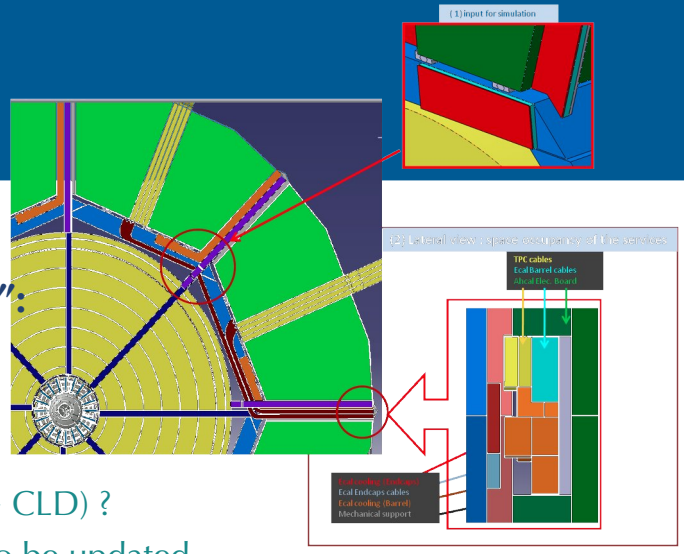
- TLU: Trigger Logic Unit
- DQM4HEP (Monitoring)
- Used for Beam Tests (DRDs, CALICE, LCTPC, …)
  - “easy” interface to all components ⊃ beam telescopes

ILC TDR Detector part: 500 GeV

Table III-5.4. Pair induced backgrounds in the subdetectors for nominal 500 GeV and 1 TeV collision energy beam parameters [380]. The numbers for the ECAL and the HCAL are summed over barrel and endcaps. For the vertex detecor, the double-layer option has been chosen for this simulation. The TPC hits are the digitised hits that would be written to the data acquisition system. The errors represent the RMS of the hit number fluctuations of ≈ 100 bunch crossing (BX) simulations.

Sub-detector	Units	Layer	500 GeV	1000 GeV
VTX-DL	hits/cm^2/BX	1	6.320 ± 1.763	11.774 ± 0.992
		2	4.009 ± 1.176	7.479 ± 0.747
		3	0.250 ± 0.109	0.431 ± 0.128
		4	0.212 ± 0.094	0.360 ± 0.108
		5	0.048 ± 0.031	0.091 ± 0.044
		6	0.041 ± 0.026	0.082 ± 0.042
SIT	hits/cm^2/BX	1	0.0009 ± 0.0013	0.0016 ± 0.0016
		2	0.0002 ± 0.0003	0.0004 ± 0.0005
FTD	hits/cm^2/BX	1	0.072 ± 0.024	0.145 ± 0.024
		2	0.046 ± 0.017	0.102 ± 0.016
		3	0.025 ± 0.009	0.070 ± 0.009
		4	0.016 ± 0.005	0.046 ± 0.007
		5	0.011 ± 0.004	0.034 ± 0.005
		6	0.007 ± 0.004	0.024 ± 0.006
		7	0.006 ± 0.003	0.022 ± 0.006
SET	hits/BX	1	0.196 ± 0.924	0.588 ± 2.406
		2	0.239 ± 1.036	0.670 ± 2.616
TPC	hits/BX	-	216 ± 302	465 ± 356
ECAL	hits/BX	-	444 ± 118	1487 ± 166
HCAL	hits/BX	-	18049 ± 729	54507 ± 923

Anti-conclusions



Status on rates estimations:

- Vertex, Trackers: domainted by BiB
  - No estimation of the physics done, yet (but some in the old LoI, TDR, IDR)
- LumiCal
  - Estimation done (depends on the BIB file)
- Calorimeters
  - Rates highly dependant on the location
    - BIB dominate close to the Beam Pipe (ECAL and HCAL)
    - Rates low everywhere else but
      - 1st layers of the ECAL: Low-*E* photons from scattered

ALL VERY PRELIM.

- But can be soon be integrated

Some answers to "Questions to addessed":

- Simulation status ? 'very complete' with Digitization
  - But for the VTX (⬌ CLD) ?
  - Some item needs to be updated (e.g timing in calos)
  - **TDAQ mat. in sim ?** Yes (cabling etc), but in dd4hep ? to be updated…
- Readout capacities tested ?
  - Yes for all prototype for ILC
    - VTX: new electronics in dev (IPHC)
    - TPC: ??
    - CaloRoc in dev. (1st proto end 25) ~ ℓ Ar
      - Proto in 2029(?)
- Acquisition rates ? 50 MHz (calos)