1st FCC-ee mini-workshop
on detector requirements

Triggers @ LEP

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Foreword

- The **LEP trigger strategy** and **hardware** was **developed in the eighties**.
- Trigger **upgrades** where **never under discussion**
  - rates at LEP2 where much lower
- **LEP trigger** systems **worked like a dream** over the **12 years of LEP data taking** in spite of very few experts dedicated to them

LEP and its experiments

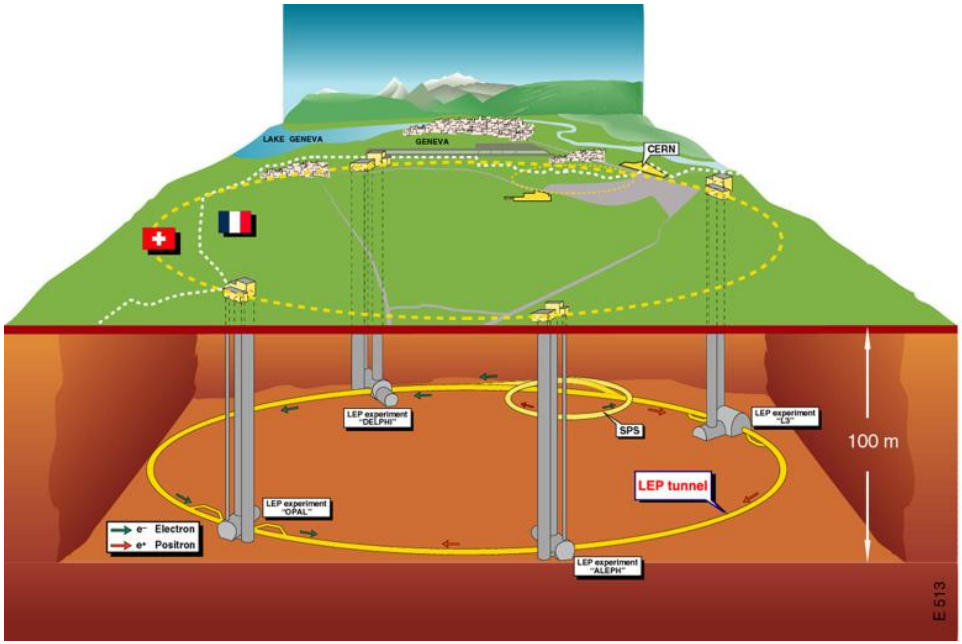
- LEP1 record luminosity
  2.3×10^{31} $cm^{-2}s^{-1}$

→Z rate at peak < 1 Hz

- LEP2 record luminosity
  10^{32} $cm^{-2}s^{-1}$

→WW rate ≈ 2 mHz

- Most data delivered with
  4 bunches (bx 44 kHz)

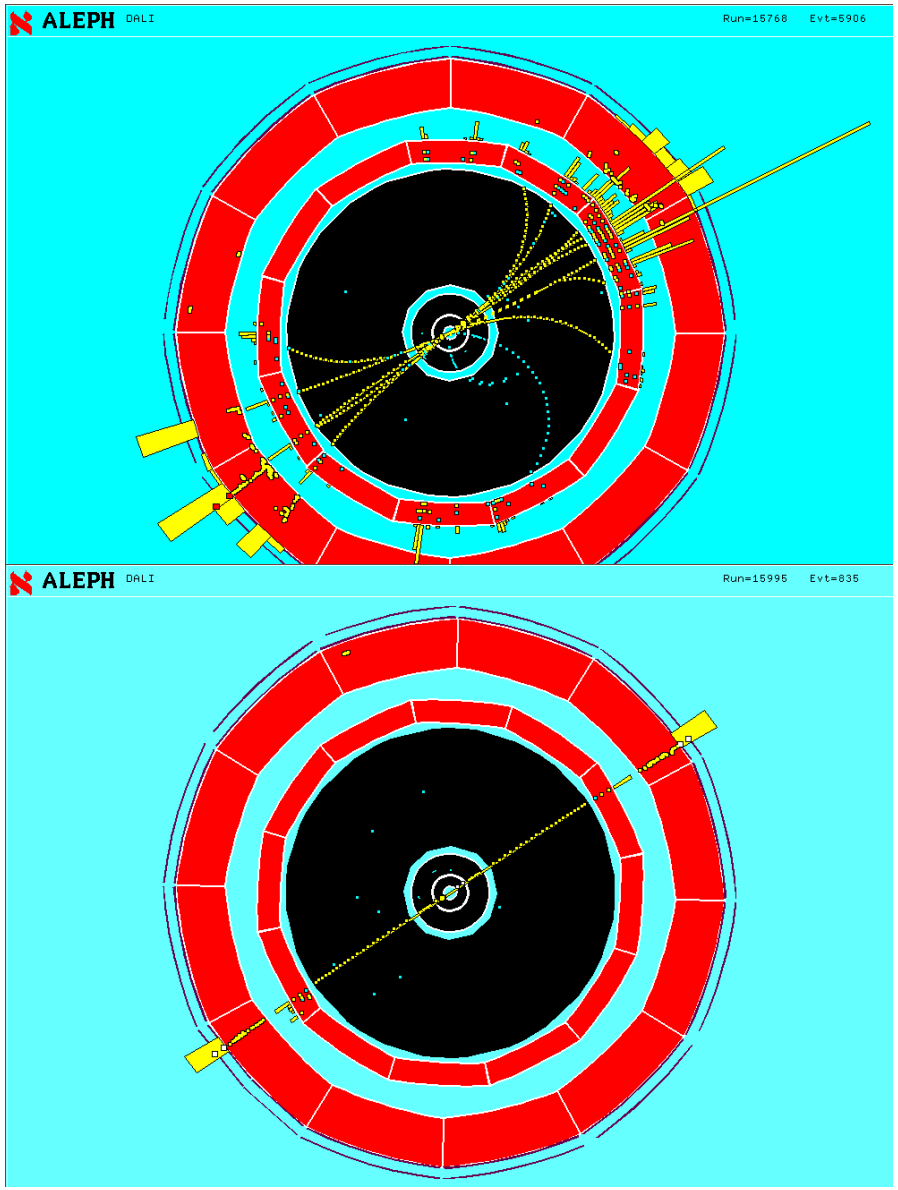


LEP Trigger Strategy

- In the eighties, experiments were prepared having in mind the **high backgrounds of PETRA**, however **LEP turned out to be a fantastically background-free machine**.
- The driving concept was:
  - accept all annihilation events
  - accept two-photon events only if you can (well, in some experiment $\gamma\gamma$ have been considered background until LEP2 ...)

Example from ALEPH (1)

- All systems, except TPC, delivered signals suitable for L1 trigger purpose (i.e much faster than 11 μs)
- L1 criterion was to require the presence of at least one single particle candidate, charged or neutral, from one or more system



Example from ALEPH: strategy (2)

- Level 1: require OR of
  - energy deposit in ECAL [***energy trigger***]
  - coincidence between ITC (track) and ECAL (energy) or HCAL (hits) [***track trigger***]
  - plus luminosity trigger,
  - plus many backup triggers
- Level 2 : *track* validation from TPC (after 50 μs)
- Level 3 : software trigger (microVAX processors) predecessor of modern HLT ...

Example from ALEPH: reality (3)

- Level 1: a powerful (for the eighties) FASTBUS system prepared to provide 500 Hz, mostly due to reject beam-gas interactions, to Level 2
- Level 2 : LEP was so clean that L2 received at most 10 Hz ... so it was not needed ... nevertheless worked for 12 years !!
- Level 3 : used to reject some obvious noise (maximum 30% of L1 triggers) and later on for event tagging, at LEP2 had a role for $\gamma\gamma$ physics

Example from ALEPH: reality (4)

- The **trigger rate at the Z was typically 5 Hz**, luminosity triggers accounted for 2-3 Hz, Z events 0.5 Hz and $\gamma\gamma$ 0.5 Hz
- **Efficiency for hadronic Z decays 99.999 %** with an **uncertainty of 0.001%** determined by comparing independent triggers
- **Inefficiency for leptonic channels (e,μ,τ)** in fiducial region **< 3 x 10^{-5}**
  - as a backup even ECAL was used to trigger muons with a threshold of 200 MeV (!!)

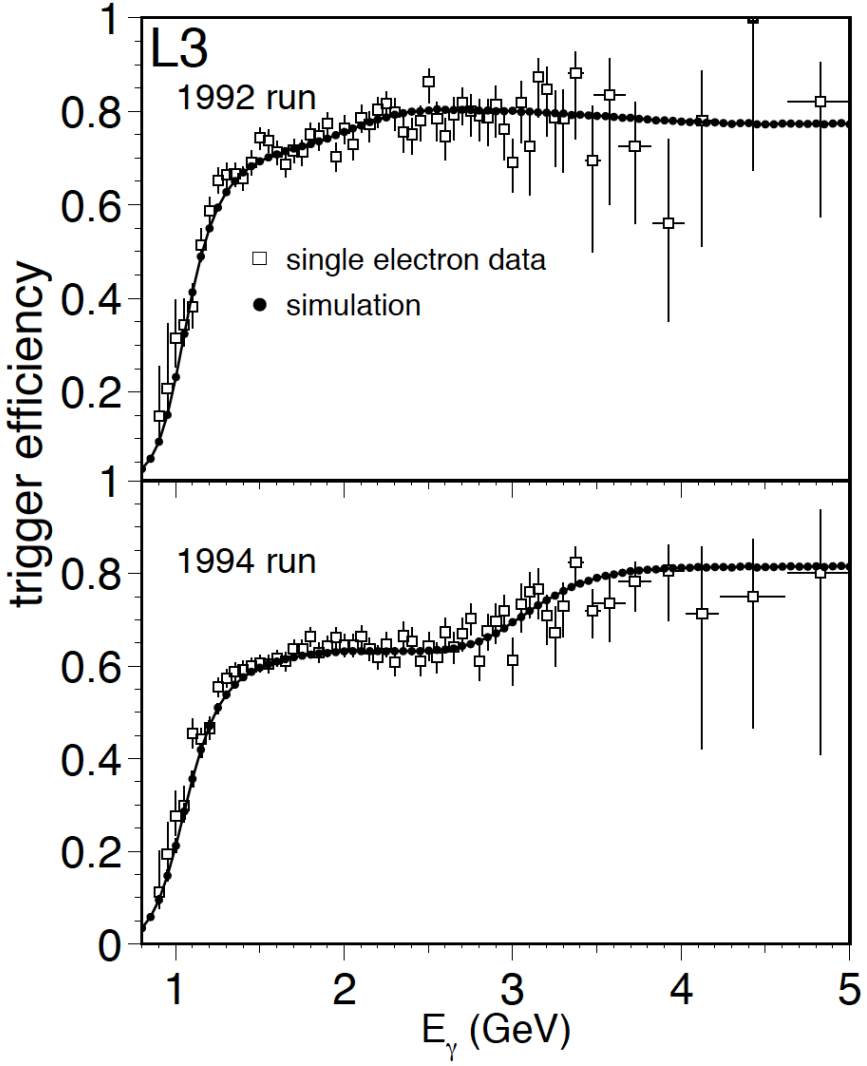
Example from DELPHI

- DELPHI had 4 Trigger levels
- The efficiency for electron and muons was consistent with 1 at the 10^{-4} level
- The efficiency for hadronic Z decays was 1 over nearly the full solid angle

Trigger	Rate (Hz)	Detection			
		e	μ	γ	$c^{\pm}$
Luminosity					
SAT/STIC Bhabha	0.8	•			
Single arm	0.4	•			
Delayed Bhabha	$\ll$0.1	•			
Barrel region					
TPC	0.8	•	•		•
OD*HPC	0.2	•		•	
OD*TOF	0.4	•	•	•	•
HPC*TOF	0.3	•		•	
HPC $\geq$2 clusters	0.1	•		•	
ID*(MUB+HAB)	0.5		•		•
HPC (single-γ)	0.3	•		•	
Intermediate region					
ID*(HAF+MUF)	0.1		•		•
HPC*(HAF+FEMC)	0.1	•		•	
Forward/Backward region					
TPC*FCA/B	0.2	•	•		•
MUF*FCA/B	0.1		•		
TPC*MUF	0.1		•		
FEMC*FCA/B	0.2	•			
FCA/B*HAF	0.4		•		•
HOF back-to-back	0.3		•		
FEMC $\geq$2 clusters	0.2	•		•	
FEMC (High Threshold)	0.5	•		•	
Calibration and special triggers					
NIM	0.04	random trigger			
TPC*(SAT/STIC)	0.1	two-photon trigger			
TOF*HAB (High Threshold)	0.2	search trigger			
HOF*MUPARAL	0.1	halo-μ trigger			

A special case: single photon trigger

- Had to rely on single neutral trigger from electromagnetic calorimeters
- Here example from L3 BGO with threshold $E_\gamma > 1$ GeV
- Efficiency studied with radiative Bhabha events ($ee \rightarrow ee\gamma$)
- These triggers were used also for non-pointing γ (searches for GMSB)



Anything to learn for FCC-ee ?

- LEP precision measurements were not affected by trigger systematic uncertainties because of the **large redundancy of the trigger system** and a very quiet accelerator
  - **preparing for the worst conditions open the possibility to employ redundancy to avoid bias lower systematic uncertainties**
- A **flexible HLT** can always be re-used for other purposes (example from ALEPH Level 3)