Data Acquisition for the ILC

ECFA Study
Physics and Detectors for a Linear Collider

Worldwide Study of the Physics and Detectors for Future Linear e⁺e⁻ Colliders

G. Eckerlin
DESY

LCD Group meeting, SLAC, Jan 27th 2005

Outline

Conditions

Software Trigger Concept

Front End Readout Examples

Central DAQ issues

Some Questions

Credits

Work done and reported by mant people

in the Linear Collider Physics and Detector Workshops

4th ECFA/DESY Workshop	*Amsterdam/Netherlands*	*Apr. 2003*
Cornell Linear Collider Workshop	*Ithaka/USA*	*Jul. 2003*
1st ECFA Study Workshop	*Montpellier/France*	*Nov. 2003*
Asian Linear Collider Workshop	*Mumbai/India*	*Dec. 2003*
ALCPG 2004 Winter Workshop	*SLAC/USA*	*Jan. 2004*
International Linear Collider Workshop	*Paris/France*	*Apr. 2004*
2nd ECFA Study Workshop	*Durham/UK*	*Sep. 2004*
Asian Linear Collider Workshop	*Taipei/Taiwan*	*Nov. 2004*

ILC Physics Processes

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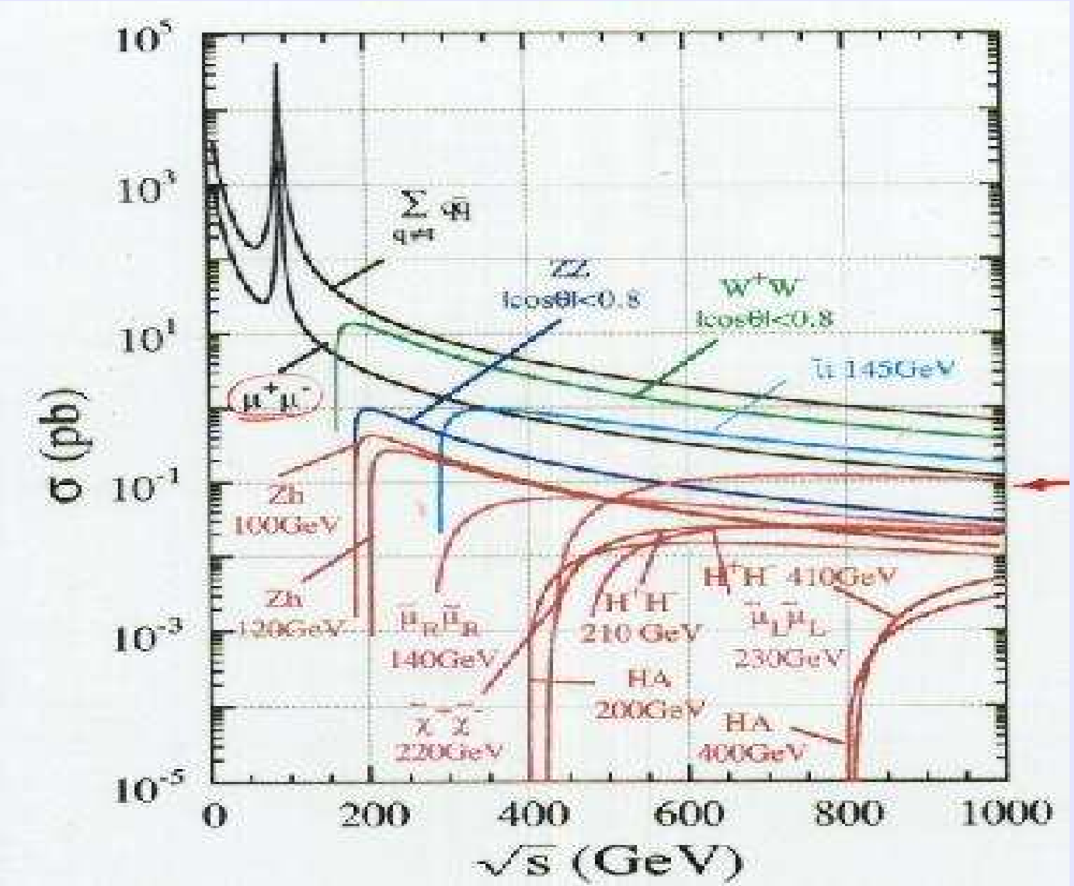

Physics Rates @500GeV (M. Thompson):

$e^+ e^- \to qq$	330/hr
$e^+ e^- \to W^+W^-$	930/hr
$e^+ e^- \to tt$	70/hr
$e^+ e^- \to HX$	17/hr

Backgrounds :

$e^+ e^- \to \gamma\gamma \to X$ 1000/sec (200/train)

VTX : 600hits/BX (due to e^+e^- pairs)

TPC : 6tracks/BX

→ high precision studies of low cross section physics on a huge 'background'

→ be ready for the 'unexpected'

The ILC Time Structure

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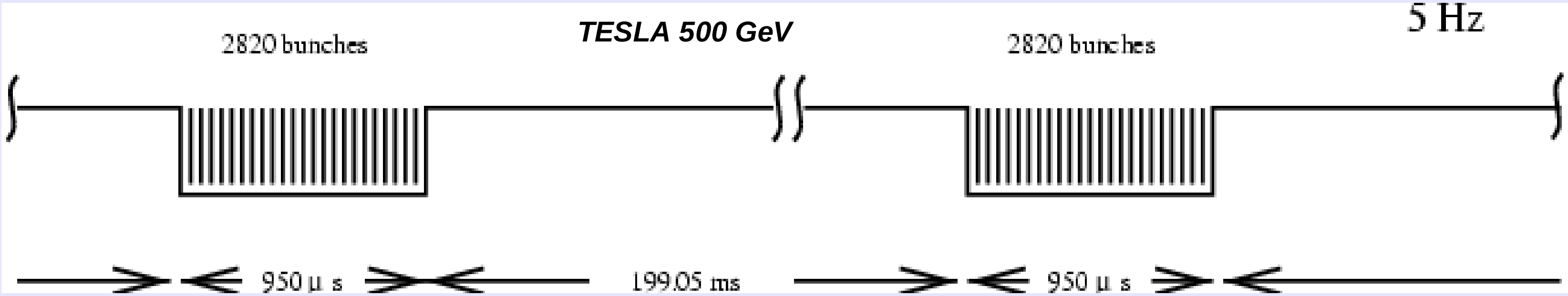

The ILC is a pulsed machine (from TESLA TDR 500/800GeV)

train repetition rate	5	(4)	Hz
bunches per train	2820	(4886)	
bunch separation	337	(176)	ns
train length	950	(860)	µs
train separation	199	(249)	ms

-> long time between trains (relatively short between bunches)

The Software Trigger Concept

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Take advantage of the long time between trains

1ms active pipeline (collect data of complete train)

No trigger interrupt

Sparsification / cluster finding at front end

Read complete detector data between trains (~ 200ms)

Event selection by software based on complete train and detector information

-> Highly efficient and very flexible event selection

Data Acquisition Conceptual Design

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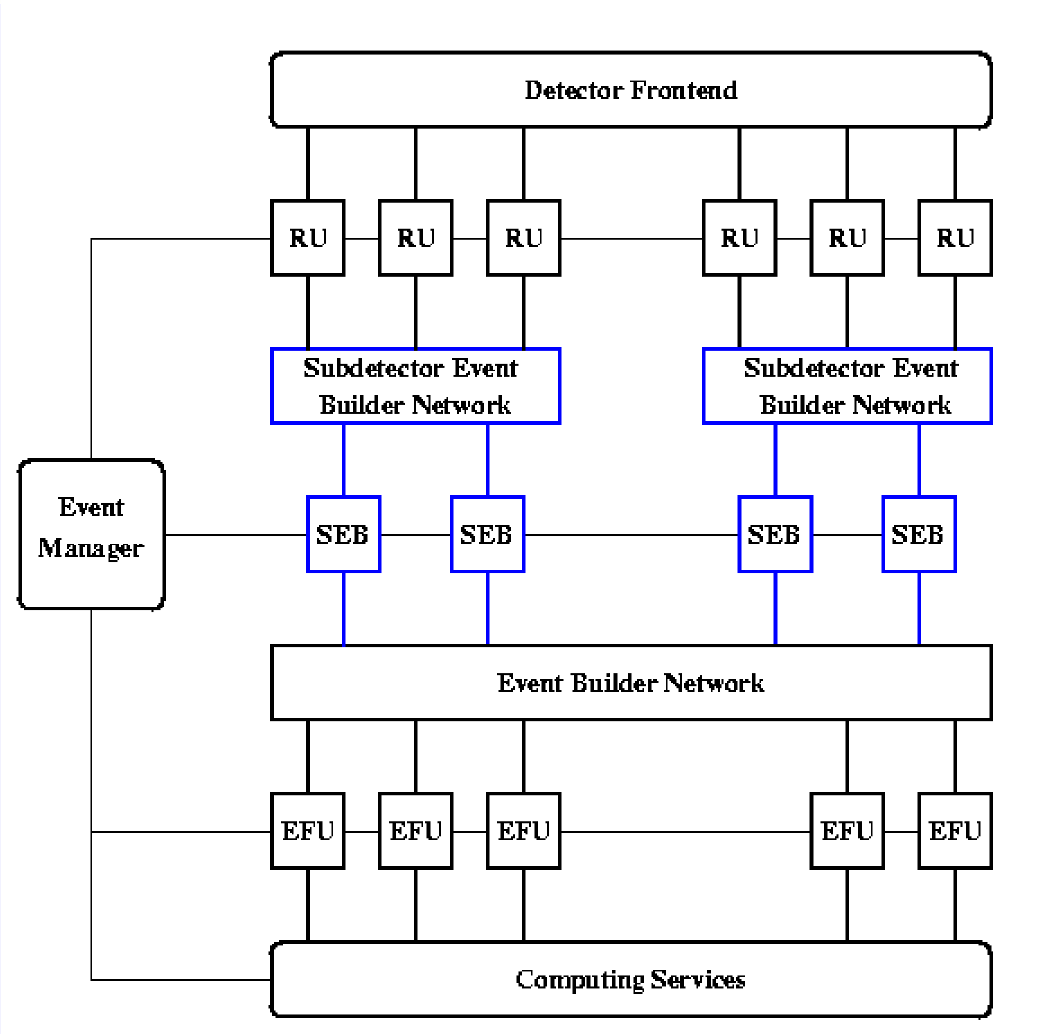

up to 1 ms active pipeline (full train),
no trigger interrupt,
sparcification/cluster finding at FE
standardized readout units (RU)

readout between trains (200ms)

optional subdetector event building

event building network and farm
complete train into a single PC !!

software event selection using
full information of a complete train
define 'bunches of interest'
move data only once into PC
and relevant data to storage

Overview Data Volume *(from Tesla TDR)*

(some numbers outdated but conclusion still holds)

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component	**channels [10E03]**	**Datavolume per train [MByte]**
VXD	799000	8
FTD	40000	2
SIT	300	1
TPC	1200	110
ECAL	32000	90
HCAL	200	3
MUON	75	1
LAT	40	1
LCAL	20	1
Total	**~870000**	**~220**

→ ~ 1 GByte / sec (currently PCs reach 80MB/sec with GbitE !)

CMS DAQ System

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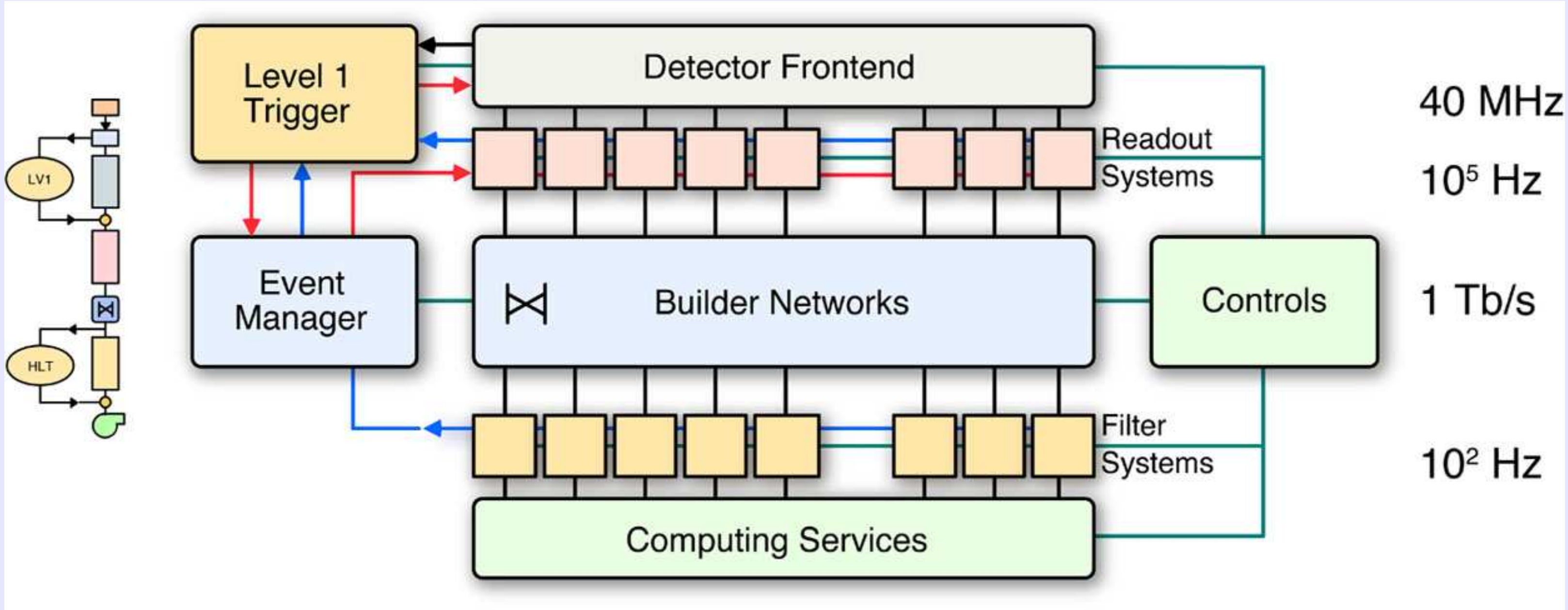

L1 input 40MHz -> L1 output 100kHz *(ILC bx rate : 12kHz)*

up to 500GBit/sec over switched network *(ILC : ~10Gbit/sec)*

⇒ CMS HLT is a good 'prototype' of the ILC software trigger

Comparing DAQ systems

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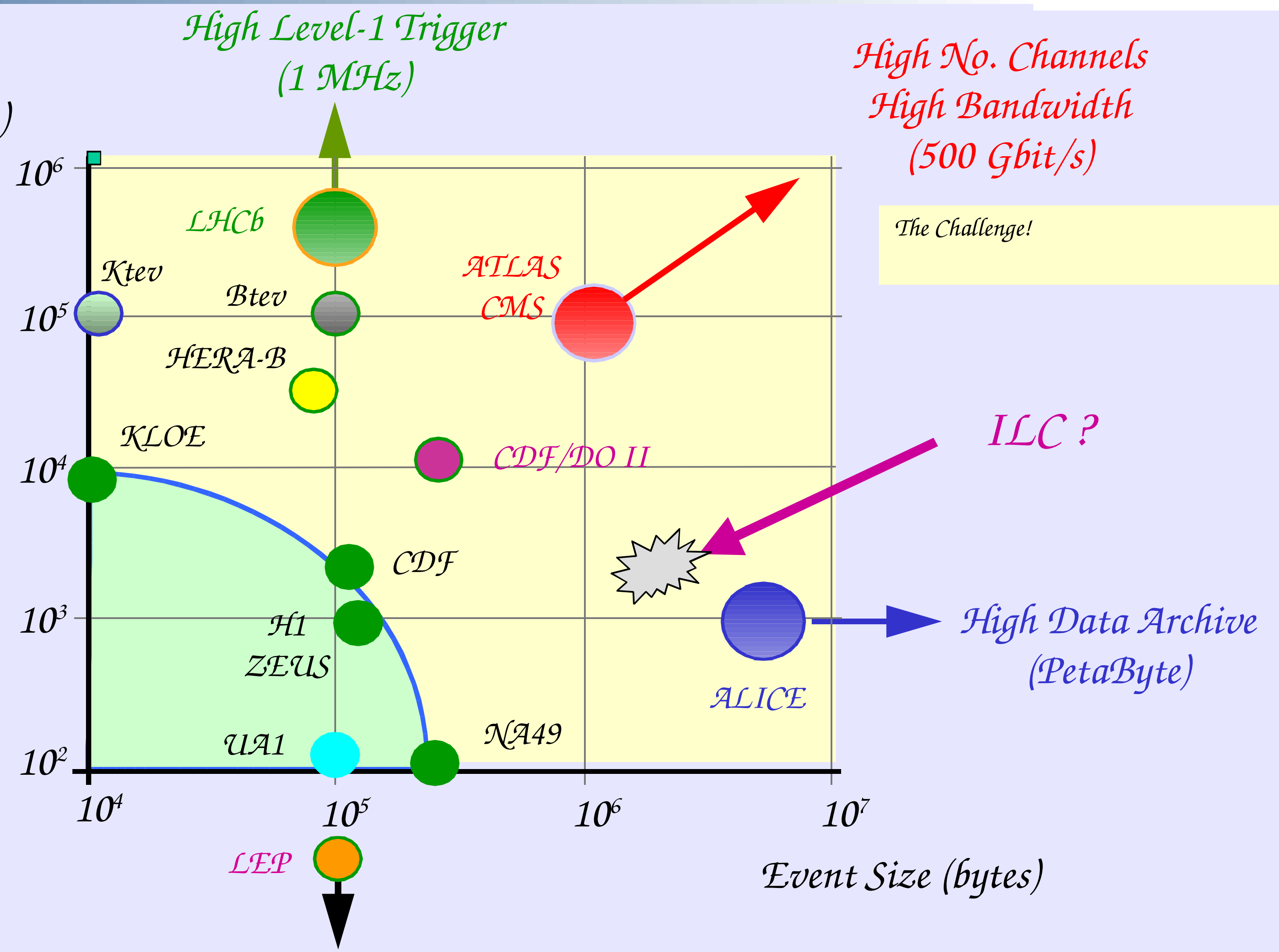
Patrick LeDu, LCWS 2004

Fast Networking Moves Data from a local environment to a Global One

Cheap Commodity Processors allow for powerful algorithms with large rejection

Cheap DRAM allows for large buffering, and latency

L1 Rate (Hz)



Some Front End Readout Examples

Vertex Detector

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- 5 layer pixel detector, Layer 1 as close as possible to beampipe

  high granularity, hugh number of channels (~1Giga pixels)

- Main concern : occupancy due to backgrounds (e+e- pairs)

  Layer 1: 350hits/bx, Layer 2 : 200hits/bx (K. Buesser, Jan.05)

- To keep occupancy low need readout during train

  online sparcification, local buffering

- Data volume per bunch train : ~ 20 Mbytes

Vertex Detector (example CCD)

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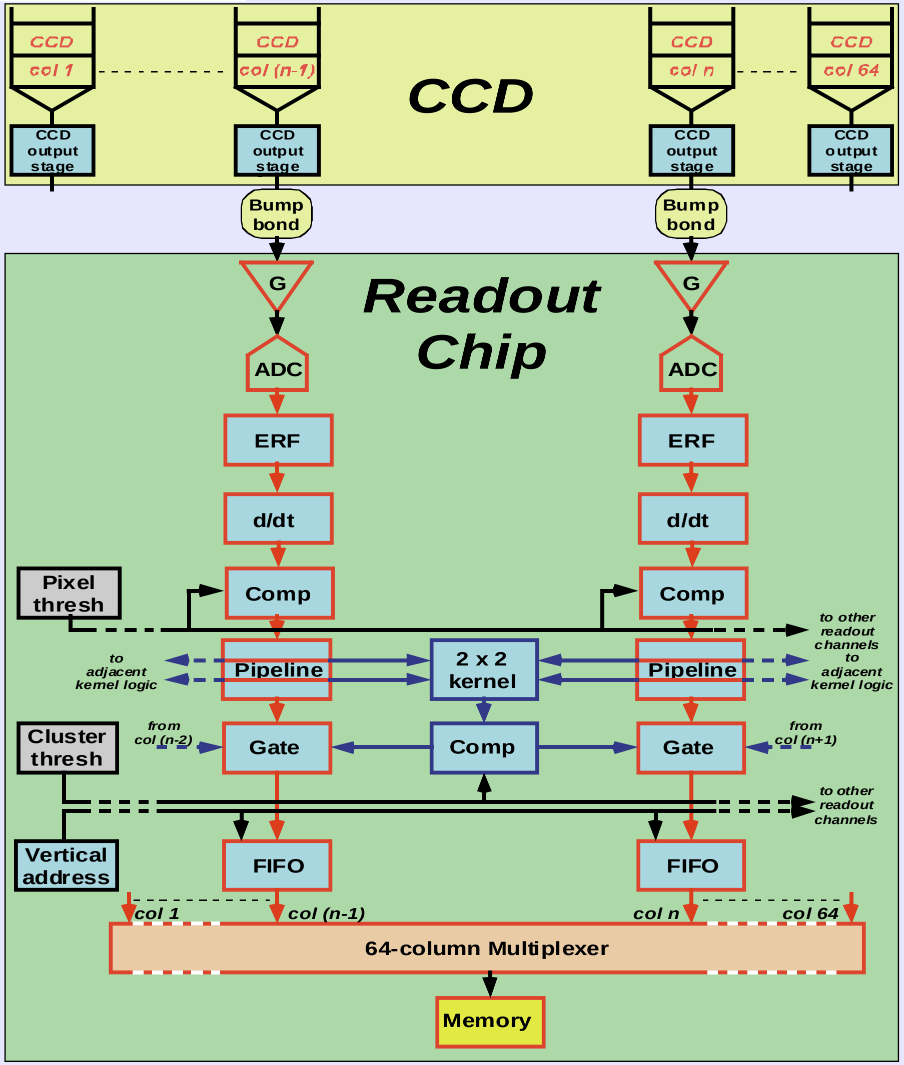
Joel Goldstein, LCWS 2004



- 5 layer CCD
- 800 million channels
- column parallel readout
- readout ASIC bump bonded
  - Amplifier
  - 5-bit FADCs
  - Filter
  - Sparsification logic
  - local memory
- 2 optical links 1Gbit/s
- in total 20 Mbytes / train

TPC Main Tracker

Readout channels : 1.2 x 10^{6} (for digital TPC : up to 10^{10})

200 samples/track, ~ 10^{10} 3D readout voxels (20MHz sampling)

Occupancy ~ 0.1- 0.3 %

Main concern : reduce ion feedback without gating during train

Gasamplification with GEMs or Micromegas

Front end electronics from LHC (Alice) as an example:

- preamp, FADC, zero suppression, digital buffer
- power consumption (40mW/channel) ?

Integrates over 160 bx (total drift time ~50µs)

Data volume per train : ~ 100 – 300 Mbytes

TPC DAQ at LHC

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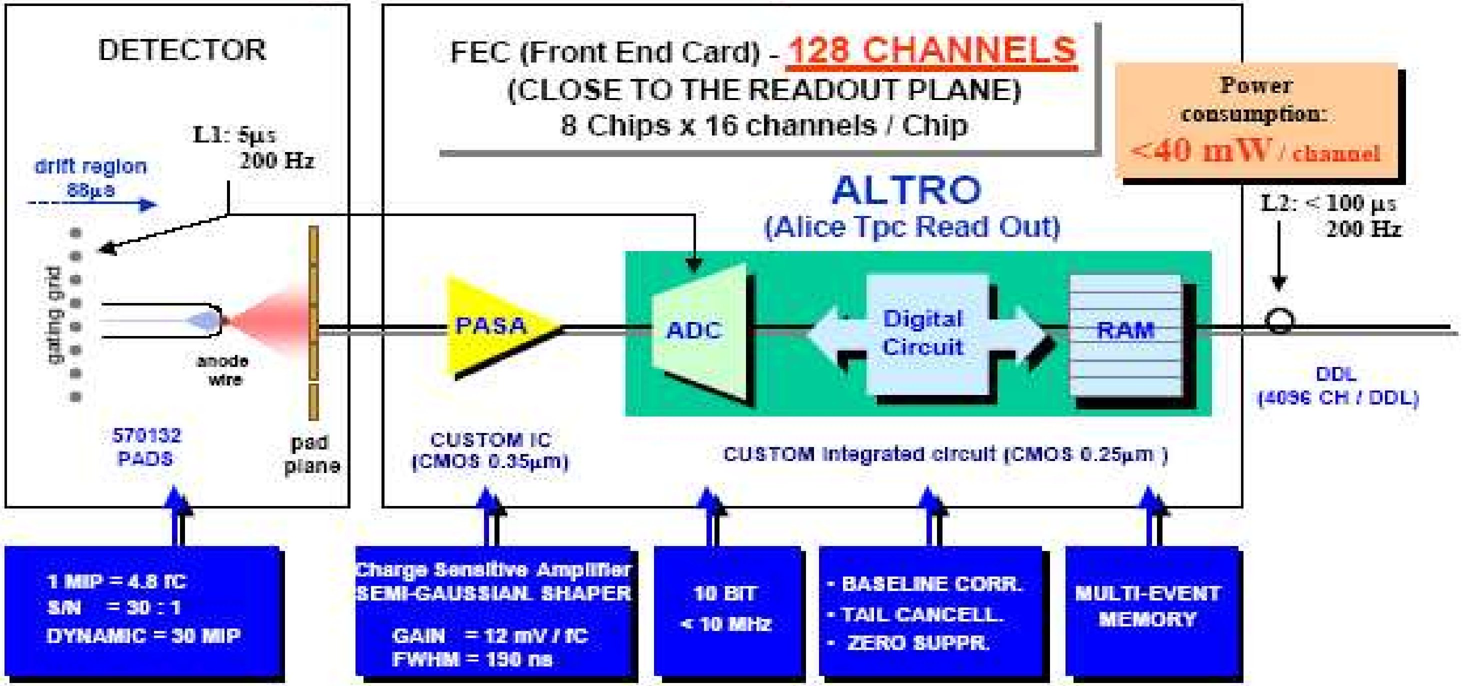
The ALICE TPC Front End Electronics

Source: L.Musa (for the Alice Collaboration)

Ron Settles

Conrnell 2003



A single readout channel is comprised of:

- a charge sensitive amplifier / shaper
- a 10-bit low power ADC
- a digital circuit for the tail cancellation, zero suppression, etc...
- a multi-event buffer (up to 8 event data streams)

Silicon Envelope

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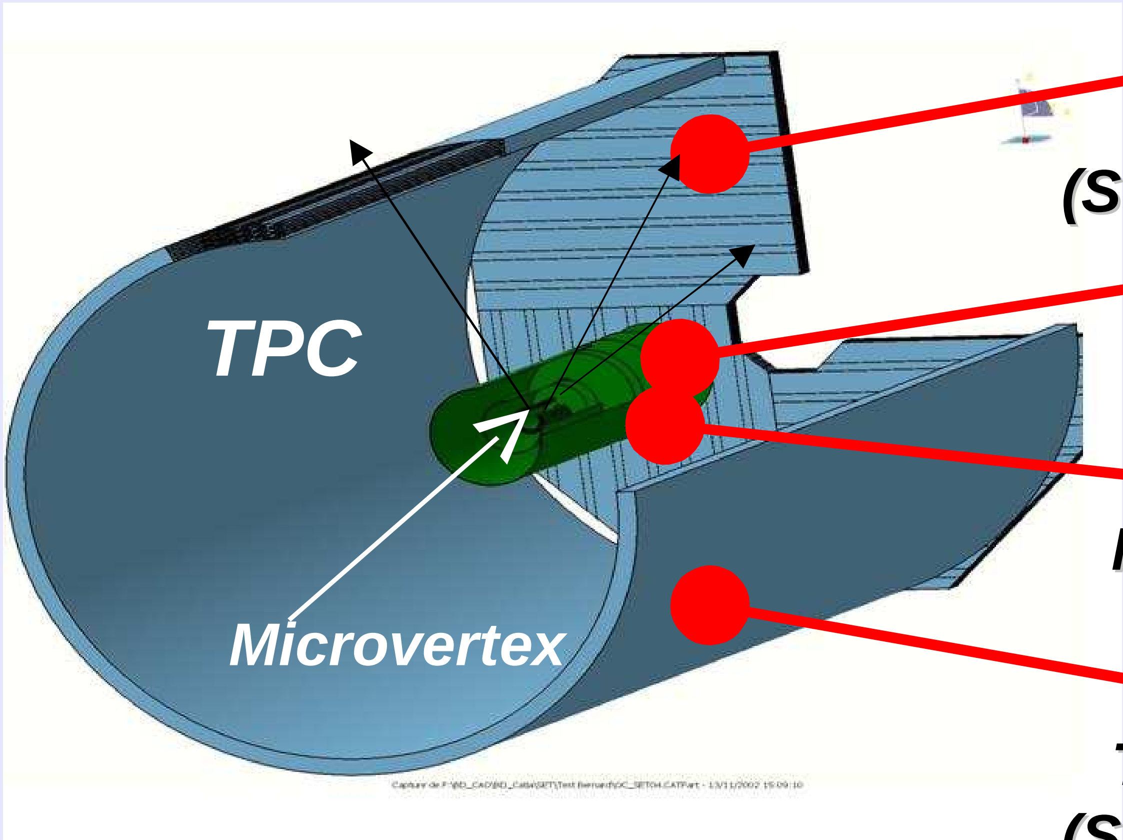
The Silicon Envelope concept =
ensemble of Si-trackers surrounding the TPC (LC-DET-2003-013)



The Si-FCH:
TPC to calorimetry
(SVX,FTD,(TPC),SiFCH)

The FTD:
Microvertex to SiFCH

The SIT:
Microvertex to TPC

The SET:
TPC to calorimetry
(SVX, SIT, (TPC), SET

Silicon Envelope

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(J.F. Genat, H. Lebbolo, Ph. Bailly, T.H. Pham) presented by A. Savoy-Navarro

Few million channels, occupancy from 1 % to <10 %

Main concern :

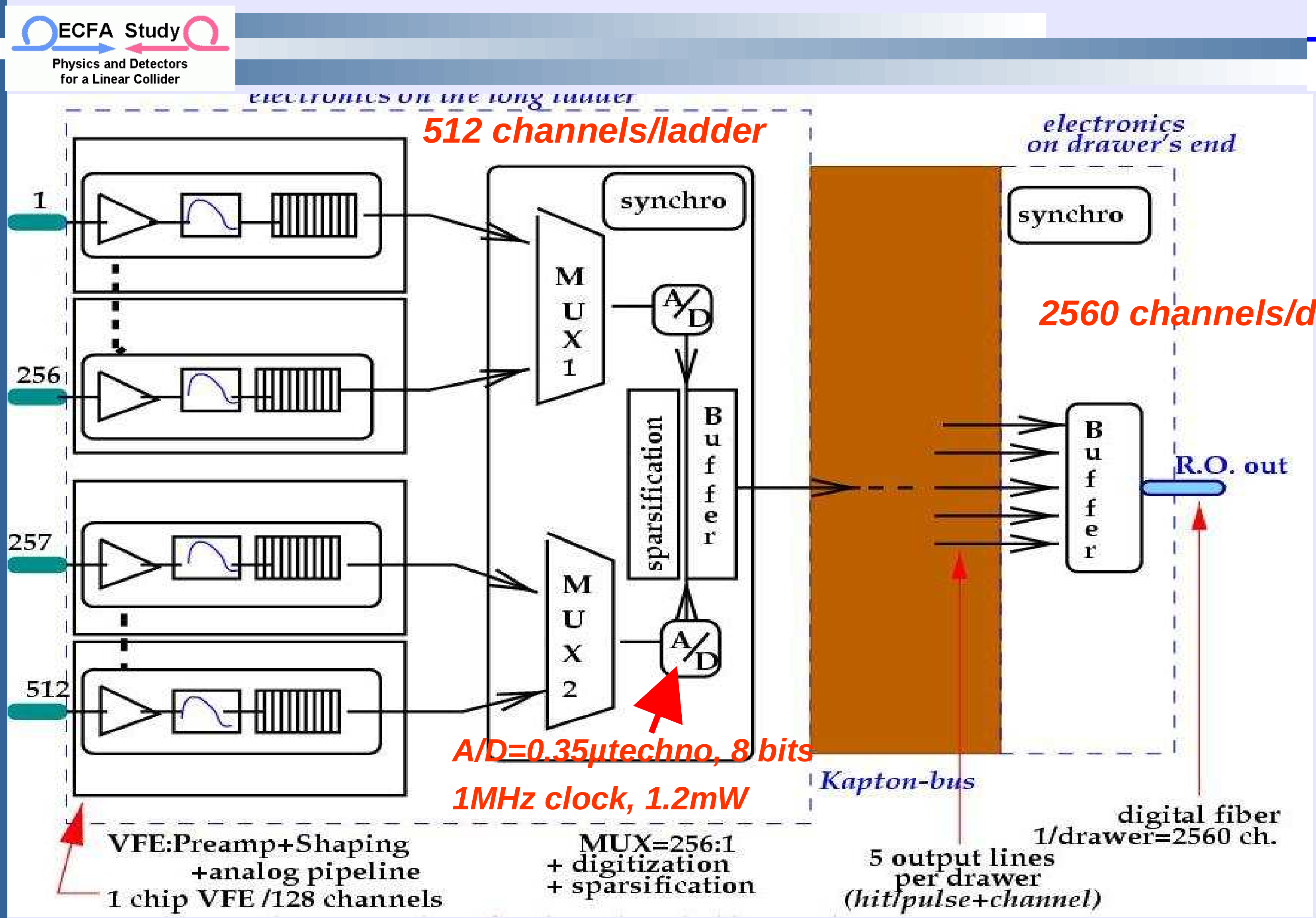
- noise
- power consuption (without power cycling would be ~ 800 W)

Front end readout includes

- analog pipeline, multiplexing 256:1, 10Bit ADC, digital buffers

Data volume per train : ~ few MByte

Silicon Envelope Front End Electronics



Aurore Savoy-Navarro

Amsterdam 2003

Silicon Main Tracker & SiW ECAL

Main concern :

occupancy in forward disks for Si Tracker
power consumption (<40mW/wafer)

Readout 1K (2K) channels per ASIC on a wafer

zero suppession, analog storage, digitization between trains

Data volume per train

ECAL ~ 4MByte,   Si Tracker ?

(see talk from Marty Breidenbach on 16 Dec. 04)

Accelerator Data Acquisition

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NLC Data Collection

Marty Breidenbach

Conrnell 2003

- There are ~11K accelerator sections and 1K BPM's.
- Data per bunch (Not train, debatable if needed)
- BPM X,Y,I – 2 bytes each + 10 bytes stuff = 16 bytes
- Acc Section - 2 positions + FE + RE + phase @ 2 bytes + 20 bytes stuff = 30 bytes
- 200 bunches/train * 120 trains/sec = ~20000 bunch/sec
- Data Rate = 20000*(11K*30+1K*16)=7 Gbytes/sec
- Should not be worse than 10 for the whole machine!!
- Begins to look like a distributed detector data acquisition problem. Some data compression will be needed.
- Rapid access and analysis of this data may be a fun problem.

close to CMS !!

Summary
Front End Readout

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Power consumption (high granularity -> large channel count)

- power cycling assumed otherwise many kW per system
- alternatives ?

Near beam detectors may have occupancy at the limit

- readout of sensors during train (some with local storage)
- sensitive to background variations ? (radial segmentation!)

Complex front end electronics

- zero suppression, analog storage, ADC, digital buffering
- all designs assume to send digital data to the off detector DAQ
- highly multiplexed systems to reduce number of cables
- what about failures, redundancy, alternative designs ?

The Central DAQ Parts...

Detector and DAQ Control
(to do list 1)

Monitor detector hardware

automatic recovery, alarms, automatic configuration ?

Distribute control signal to front end

central clock, first bunch, run start/stop, reset, initialize, etc

Partitioning

allow for readout of detector part and local DAQ runs

parallel streams to storage (ECAL cosmics, TPC pulser, etc)

Download detector constants & calibration data

Calibration (to do list 2)

Good online calibration needed for good event selection

have to develop strategy

Monitor detector performance online

avoid degradation of data quality and selection efficiency

Alignement data, detector linking

check stability, recalibration, special runs needed ?

Event Selection (to do list 3)

Develop filter algorithms

Define data to be stored (Bunch of Interest)

1 TPC picture = 160bx!

Select monitoring data for detector and machine experts

Maybe store everything

Data compression for 'uninteresting data' ?

some Questions

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Are cosmic data needed for calibration or

Can we catch particles with long lifetimes (captured in ECAL)

(power cycling reduces efficiency by 1/100)

Fast feedback signals to machine (influencing detector FE ?)

Identify relevant data from machine DAQ for physics analysis

New technologies, ideas (NOW is the time for developments !!)

Power and cooling

(How much current draws a power cycle of the full system ?)

and even more Questions....

Detector control and monitoring with GDN ?

(have remote monitoring and control in mind during design!)

Is GRID an issue for the DAQ ?

Where will the LCIO data formating be done ?

At least the event filter software will use it (or similar)....

Did we miss an important point ?

Background, Noise, Redundancy, ...

Conclusion Central DAQ I

Concept of software trigger seems feasible

Have to develop detailed concept

Some questions need answers soon, others can wait

Need to proof concept rather soon

$\rightarrow$ DAQ demonstrator

Conclusion Central DAQ II

The DAQ demonstrator needs :

- 'Complete' beam background simulation (or Datasets)
- Physics simulation (or Datasets)
- Detector simulation for the different design studies
- Software for event filter, monitoring, control
- A bit of hardware (PC farm and a switch)

and people to work on

- 'Front end' to 'Central DAQ' interface (conceptual)
- Central DAQ Software architecture (Calibration, Filters, etc)
- Detector control and monitoring (including GDN)
- Offline data model (what do we want to store and how?)

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If you are interested please join !

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Thank You !