The Liquid Argon Jet Trigger of the H1 Experiment at HERA

50 JAHRE MPI für Physik in München
50 Years of MPI for Physics in Munich

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What is the Jet Trigger?

A calorimeter trigger implementing a real-time cluster algorithm in 800 ns

Why?

To trigger on low energy electrons and jets

How does it work?

- Finding local energy maxima
- Summing immediate neighbors
- Sorting jets in decreasing energy
- Applying topological conditions

Achievement

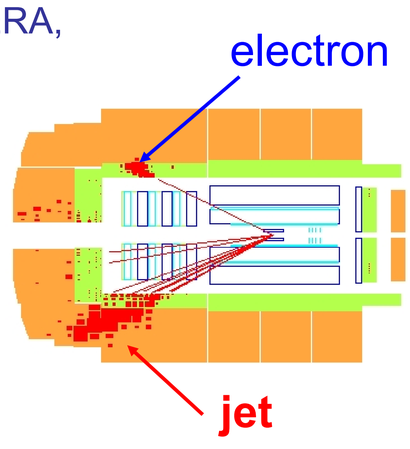
World's 1st measurement of the Longitudinal Structure Function of the Proton FL

Where? When?

In the H1 detector at HERA, DESY, Hamburg, in 2006 - 2007

10 million events/s in the H1 detector

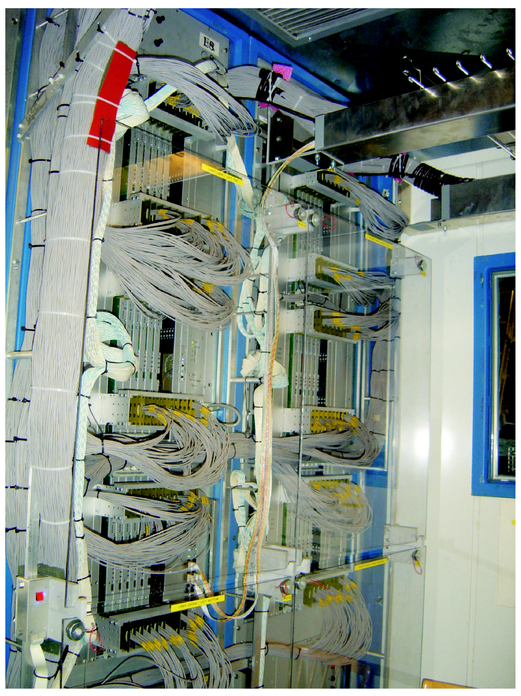
10 events/s can be saved



Jet Trigger Hardware

Signal Preparation

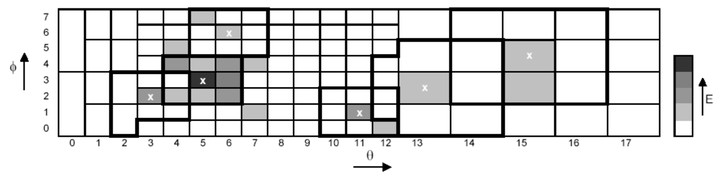
- Transforming energy into transverse energy
- Summing electromagnetic and hadronic energy
- Digitizing then summing: less coherent noise

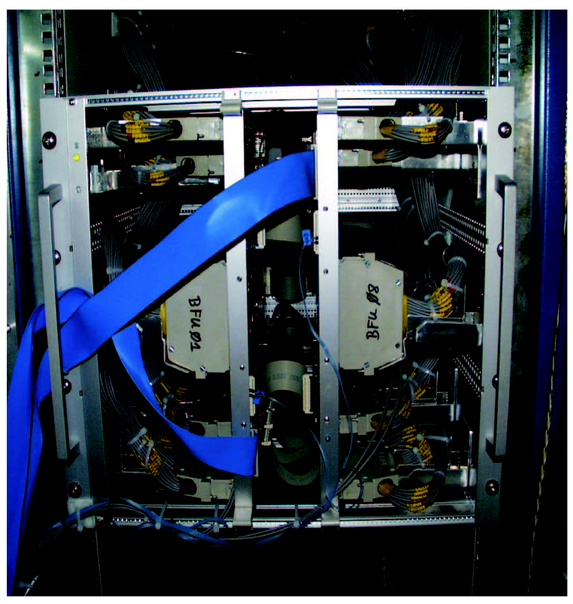


ACS - ADC Calculation Storage Unit:
- 56 motherboads, 440 daughterboards
- 8 bit FADCs
- 496 Altera FPGAs x 30k gates
- Input 1200 analog signals, output 440 towers
- Input rate 12 GB/s, output rate 4.4 GB/s
- Latency 300 ns + 100 ns transmission

Parallel Cluster Algorithm

- Finding local energy maxima: in parallel each tower checks if it has more energy than its neighbors
- Summing immediate neighbors

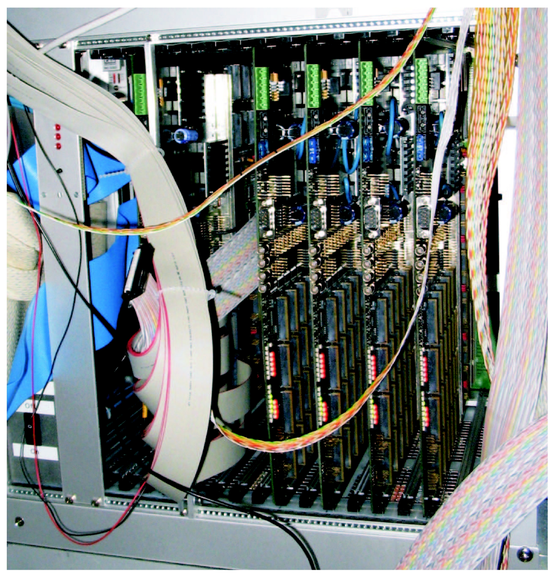




BFU – Bump Finder Unit:
- 2 boards
- 32 Altera FPGAs x 500k gates
- Input 440 towers, output 116 jets
- Output rate 1.2 GB/s
- Latency 100 ns

Energy Sorting,Topological Conditions

- Sorting 16 jets in decreasing energy
  First jets are physics, last jets are noise
- Applying topological conditions on individual energy and location



PSU, SSU – Primary and Secondary Sorting Units:
- PSU sitting on BFU boards, SSU 1 board
- 5 FPGAs (4 Altera x 300k gates, 1 Xilinx x 2M gates)
- Input 116 jets, output 6 jets per quadrant, then 16 sorted jets
- Output rate 360 MB/s
- Latency 2 x 100 ns

TEG - Trigger Element Generator Unit:
- 4 boards
- 5 Xilinx FPGAs x 2 M gates
- Output rate 20 MB/s
- Latency 100 ns

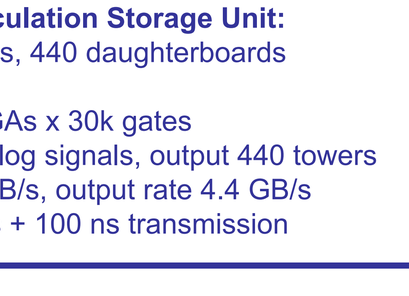
Physics Highlights with the Jet Trigger

Single Forward Jets

- Charged Current measurement limited to central jets
- Challenge: trigger on low angle jets

Efficiency to trigger on jets vs jet angle:

High efficiency at low jet angle with the Jet Trigger

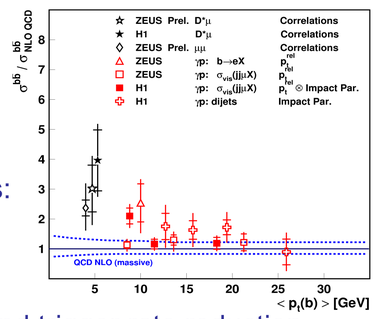


Low efficiency at low jet angle with previous triggers

Single forward jet trigger:
- 1 jet with Et > 8 GeV and angle < 30 deg
- Rate 1 Hz
- Efficiency up to 100% at low angles
- 50 pb^{-1} collected luminosity

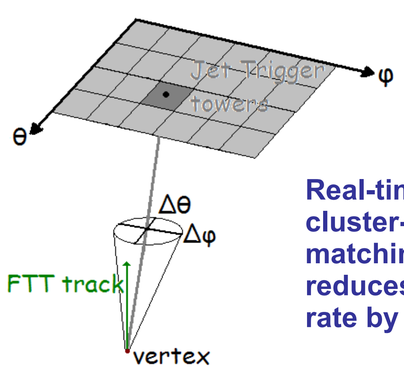
Beauty at Production Threshold

Beauty production is poorly measured at low momentum



- Semi-leptonic b decays: need a low energy electron trigger
- Challenges: electron identification and trigger rate reduction

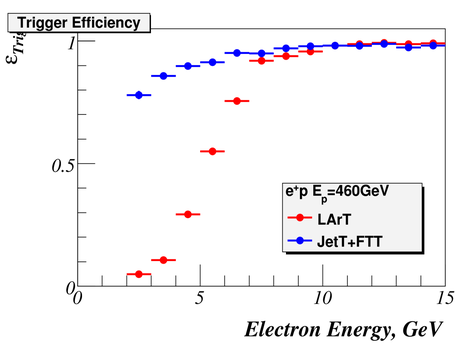
Real-time cluster-track matching in 100 μs:
- Rate reduction via geometrical cluster-track matching
- Electron ID via energy matching Et/Pt
- Rate reduction /100:
- Rate before matching 100 Hz
- Rate after matching 1 Hz
- Electron ID threshold Pt > 1.2 GeV
- 100 pb^{-1} collected luminosity



Real-time cluster-track matching reduces trigger rate by 100

World's First Measurement of the Longitudinal Structure Function of the Proton FL

- Cross sections at HERA proportional to F2 – FL
- FL proportional to gluon density
- Need low energy electrons to access FL
- Challenge: trigger on low energy electrons < 6 GeV



Efficiency to trigger on electrons vs electron energy:
- **Jet Trigger efficient at 2 GeV**
- **previous triggers efficient at 6 GeV**

Low energy electron trigger:
- 1 cluster + 1 electron track
- Rate 5 Hz
- Efficiency
  80% at 2 GeV
  > 90% at 5 GeV
- 20 pb^{-1} collected

QCD describes the FL measurement