Zeus Operations and Plans

D. Reeder, W. Smith (ZeusTrigger Convenor/Zeus Editorial Panel)
Professors (former AmZeus Chairs)

A. Savin (Shift Leader/Calorimeter Trigger Coordinator/Former Run Coordinator)
Assistant Scientist at DESY
D. Kcira (Run Coordinator)
Postdoc at DESY

J. Lackey (Designer of Zeus Calorimeter Trigger)
Senior Physics Dept. Engineer -- Task T
M. Jaworski (Design/construction Zeus Calorimeter Trigger)
Physics Dept. Engineer

A. Everett, S. Lammers, Liang Li, P. Ryan, M. Sumstine
Graduate Students resident at DESY (now or by Fall '02)
E. Brownson, D. Clayton, T. Danielson
Summer '02 Graduate Students at DESY

HERA I: machine performance

Superb Luminosity
- Reach design in 5 years
- Peak $\mathcal{L}$: 1.9 x 10^{31}
  - Design: 1.5 x 10^{31}

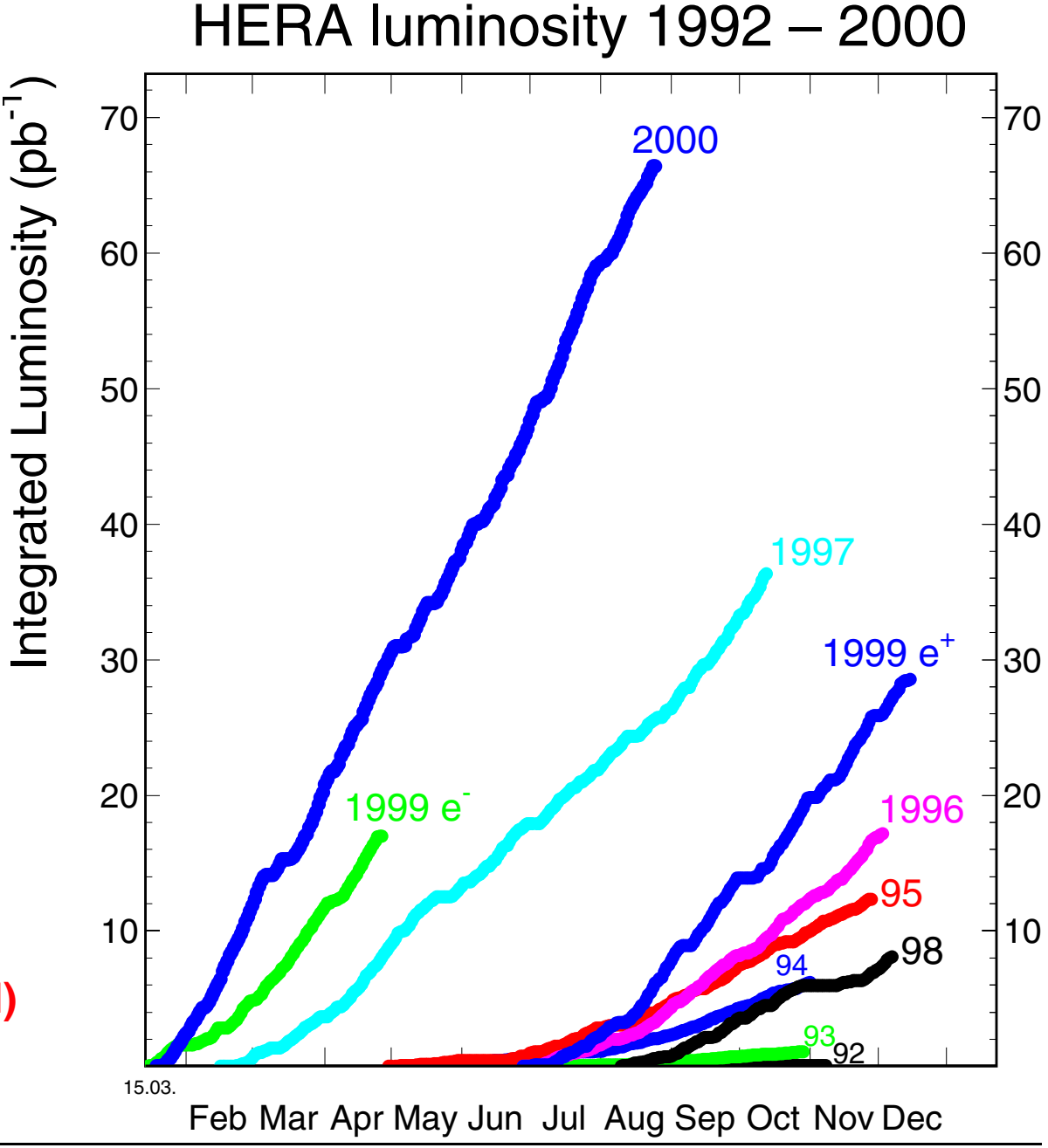
Superb Reliability
- 18 days maint. in 2000

Superb Energy
- p: 820 GeV -> 920 GeV
  - from 1998 on

Electron Running:
- 17pb^{-1} (24M events)

Positron Running
- 115 pb^{-1} (164M events)

Polarization (use for HERA-II)
- 65% peak (typ.: 50-60%)



Next: HERA II

Increase luminosity by a factor of 4-5 - believe it!

- Special magnets into detectors
- Major changes to machine lattice near experiments
- 70 new magnets installed

Electron/Positron Polarization to 70%

- Spin rotators installed at H1 and Zeus

Major upgrades to Zeus

- New microvertex detector - tag charm
- New forward straw-tube tracker (ANL electronics)
- New higher precision Luminosity Monitor, beampipe, etc.

Commissioning Now

- Luminosity with Positrons this year
- Switch to electrons - equal HERA-I positron sample in 2003

Integrated Luminosity of 1 fb^{-1} by end of 2006

- Distributed amongst electrons, positrons, polarizations

HERA I and HERA II Parameters

Parameter	up to 2000		after the upgrade	
	HERA-e	HERA-p	HERA-e	HERA-p
E(GeV)	27.5	920	27.5	920
I(mA)	50	100	58	140
$N_{ppb}(10^{10})$	3.5	7.3	4.0	10.3
n_{tot}/n_{col}	189/174	180/174	189/174	180/174
$\beta_x^\star/\beta_y^\star$(m)	0.90/0.60	7.0/0.5	0.63/0.26	2.45/0.18
ϵ_x(nm)	41	$\frac{5000}{\beta\gamma}$	20	$\frac{5000}{\beta\gamma}$
ϵ_y/ϵ_x	10%	1	17%	1
$\sigma_x/\sigma_y(\mu$m)	192/50	189/50	112/30	112/30
σ_z(mm)	11.2	191	10.3	191
$2\Delta\nu_x$	0.024	0.0026	0.068	0.0031
$2\Delta\nu_y$	0.061	0.0007	0.103	0.0009
$\mathcal{L}(\mathrm{cm}^{-2}\mathrm{s}^{-1})$	$16.9\cdot10^{30}$		$75.7\cdot10^{30}$	
$\mathcal{L}_s(\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{mA}^{-2})$	$0.66\cdot10^{30}$		$1.82\cdot10^{30}$	

Note: HERA design luminosity was 15 x 10^{30}

HERA II Status

Letter from A. Wagner to J. O'Fallon (26 July 2002): Machine Performance

- Specific design luminosity within 20% of design value
- Proof that upgrade was successful in terms of machine optics

Machine Startup

- Unforeseeable technical failures
- Very difficult beam operation due to very tight tolerances

DESY Actions (partial list)

- Communication btw technical & operational groups to act rapidly on & to eliminate technical problems
- Increase of scientific staff working on HERA at the expense of other activities e.g., TESLA

ZEUS & HERA II Physics

Machine & Detector:

- Data samples as large as 1 fb^{-1} by end of 2006
- Longitudinal polarization for electrons & positrons
- Vertexing for identifying c and b quarks with high efficiency

Physics Goals:

- Structure functions F_2,F_L, xF_3 between $10 < Q^2 < 40{,}000\ GeV^2$
- Combine w/Measurement of Jet Production, NNLO $\rightarrow \Delta\alpha_s = 0.0015$
- Measure Charm and Bottom Structure Functions
- Follow the rise of the gluon (into saturation?)
- Test for quark & gluon substructure down to 4×10^{-17} cm.
- Search for right (left)-handed electron (positron) charged current cross sections

Tevatron $\rightarrow$LHC: "cold glue" $\rightarrow$"hot glue"

hi x $\rightarrow$ lo x

Wisconsin Construction Contributions to ZEUS

Trigger System for Full Calorimeter

- Over 1000 electronics cards plus crates & cable infrastructure
- Located on Calorimeter & in Electronics House
- Revolutionary system (see next slides)

Iron Yoke Flux Return

- Design
- Supervision of Construction & Installation
- Fabrication of Energizing Coils

Barrel Calorimeter Infrastucture:

- Cable Harnesses & Bulkheads
- Cooling System
- Monitoring System

Barrel Calorimeter Phototubes

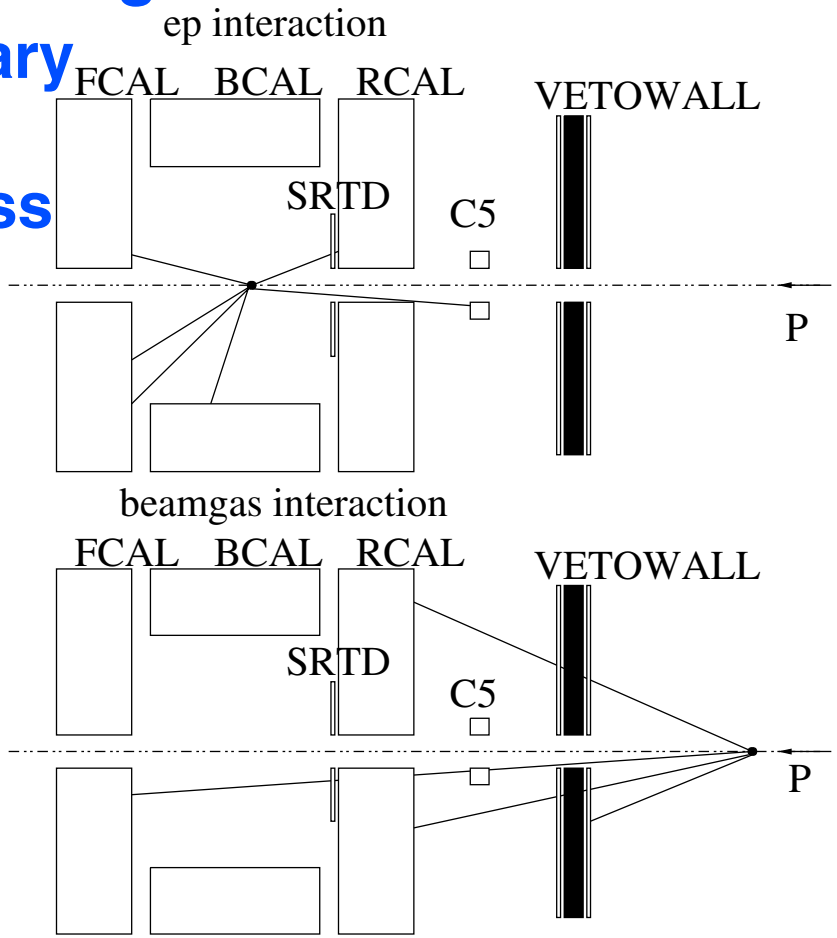
- Purchase & Testing

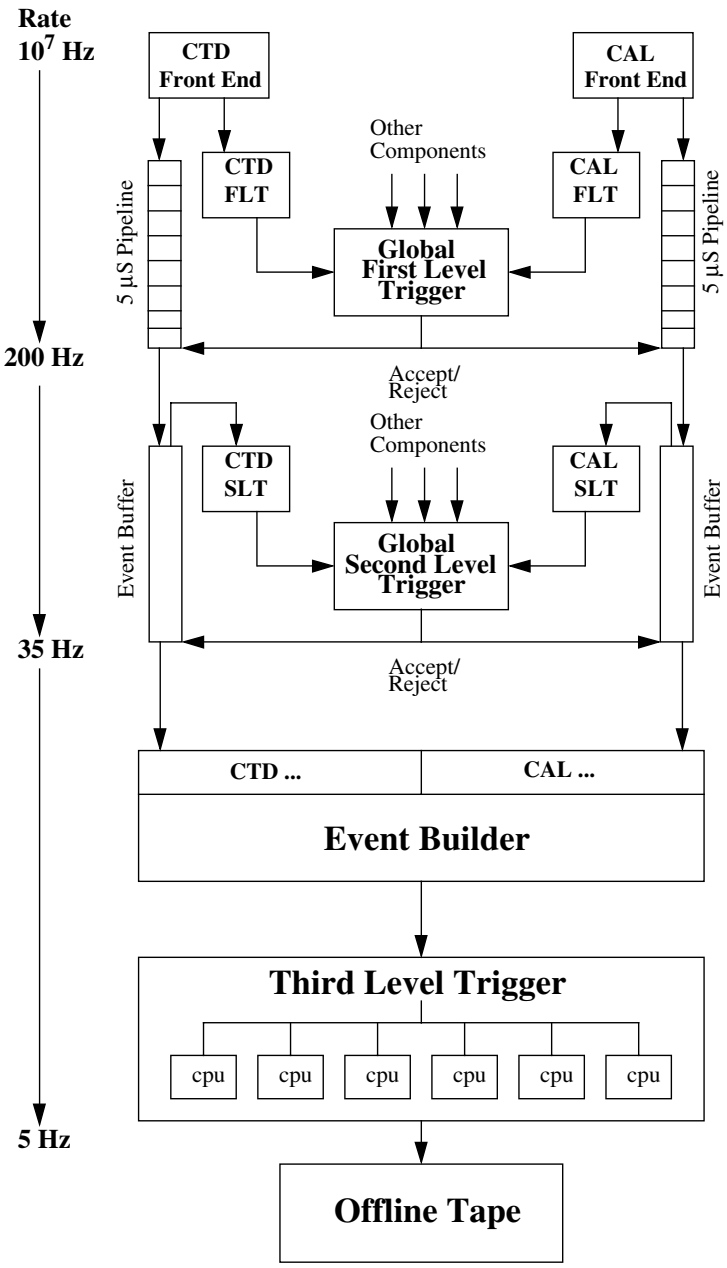
Polarimeter System

ZEUS Trigger - HERA II

Design & Leadership by Wisconsin from beginning

- Challenge: interaction every 96 ns
- Beam-gas background > 100 kHz
- Revolutionary 3-level deadtimeless design





Wisconsin Calorimeter First Level Trigger for ZEUS: Challenges

Input requirements

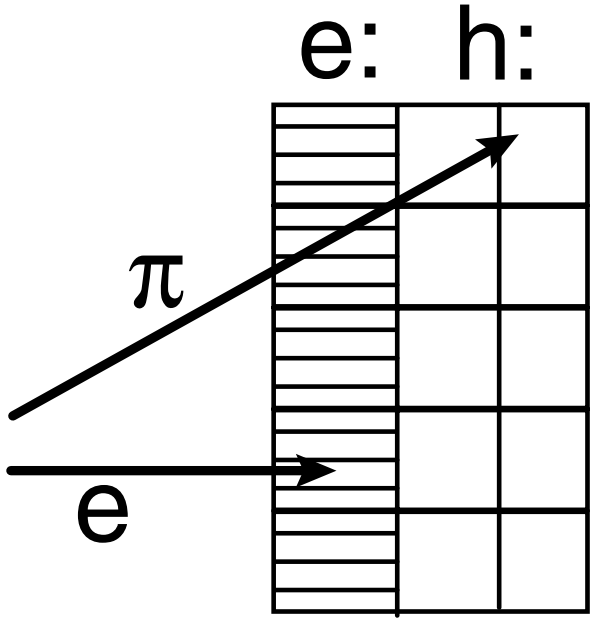
- Beam crossing every 96 nsec
- Background rate <100 kHz
- Max Level 1 Rate < 0.5 kHz

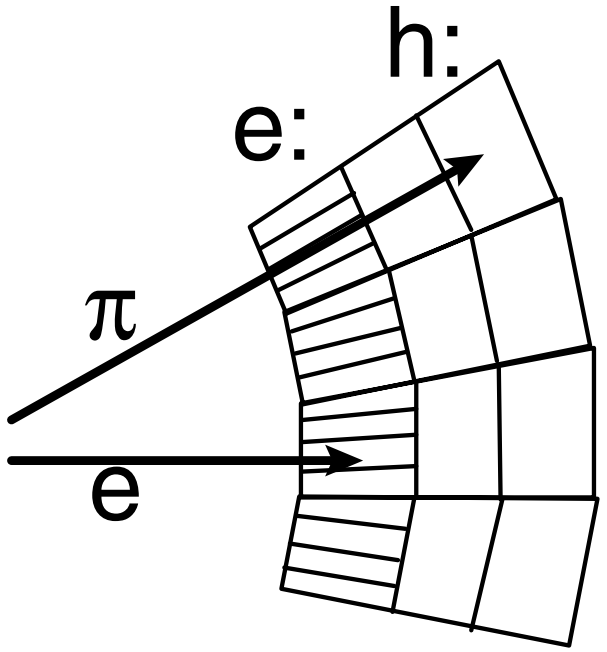
Processing requirements

- 5 μsec trigger decision time
- Data from 13K Phototubes
- Dynamic range of 4096:1

Trigger Functions at Level-1

- Unique to Zeus trigger until LHC
- Identify e, μ.
- Sum energy, missing & total E_t
- Use of pattern logic to compensate for non-projective geometry:





Calorimeter First Level Trigger Mission Critical for ZEUS

Unique - Invaluable

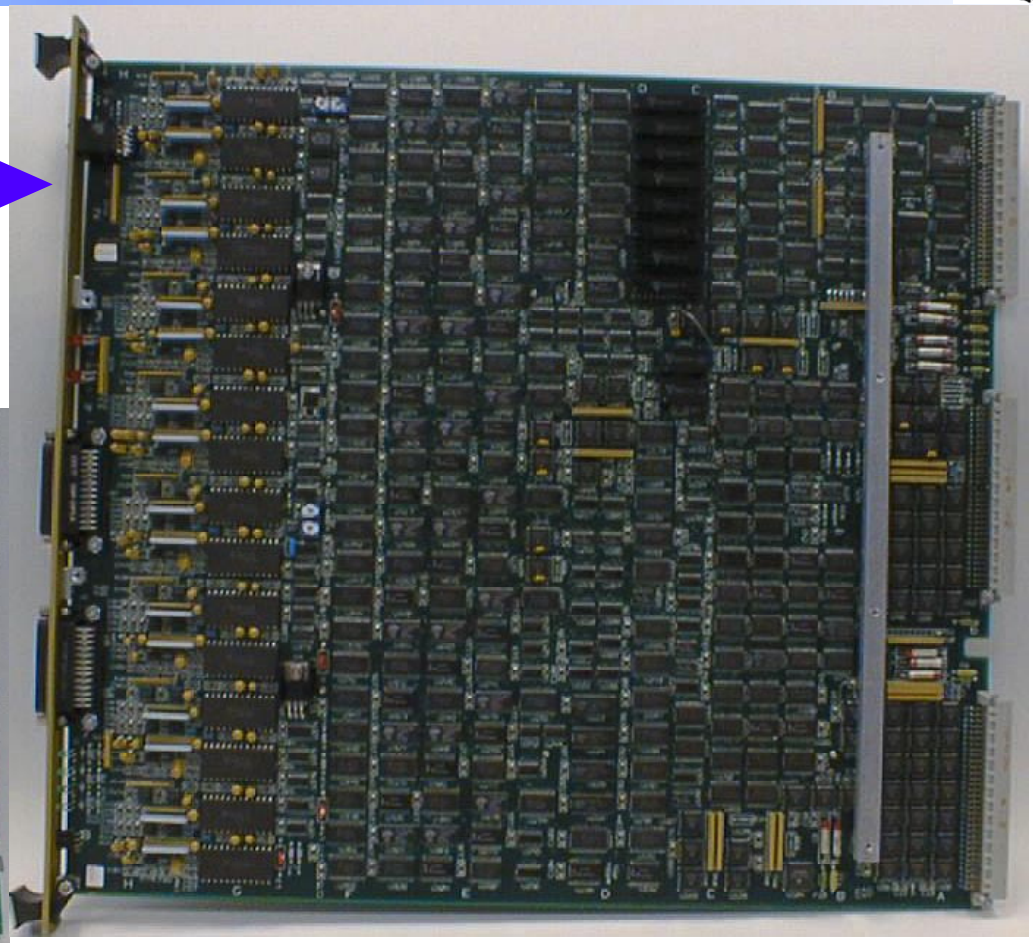
- Zeus can function without most components but not without the trigger.
- Cal FLT is performing detailed pattern logic usually found offline or in highest level triggers at other colliders
- Nevertheless, efficiency and performance is excellent

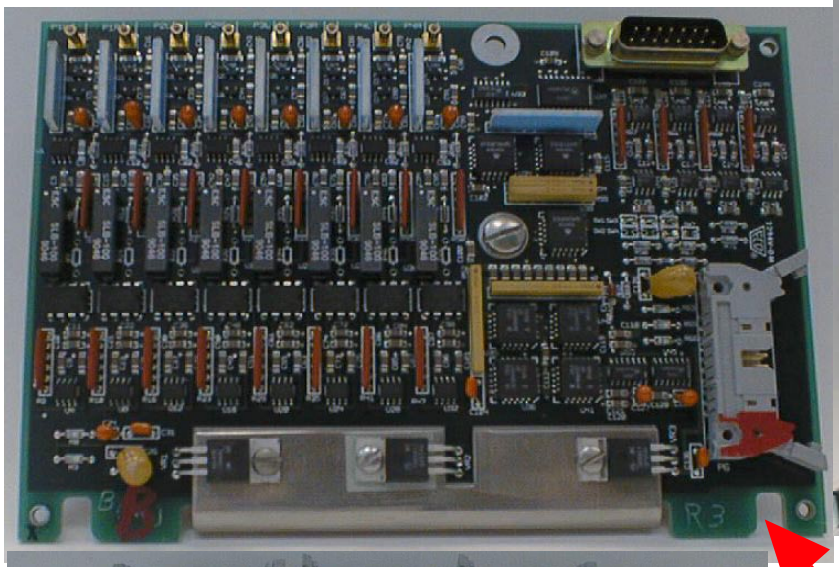
Must be closely monitored

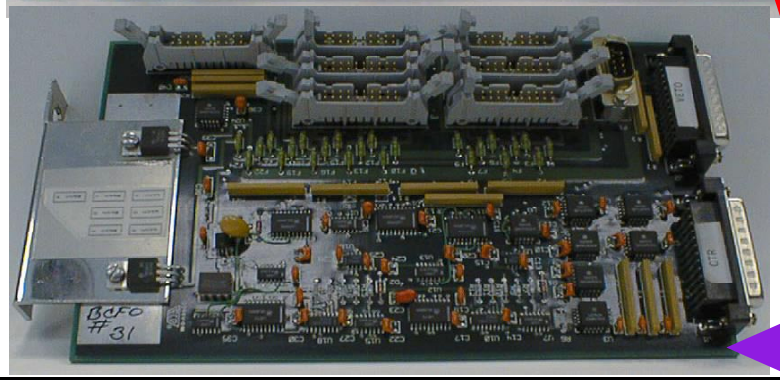
- Zeus is making precision measurements using a complex first level trigger whose efficiency must be precisely known run by run
- We have the tools and proven performance, but this takes vigilant effort and an active, well staffed group at DESY.

CAL FLT Front End/Process

270 Trigger Encoder Cards digitize w/12-bit range, test for E v. H, μ, Quiet & sum energies. Output 80 MHz to Adders







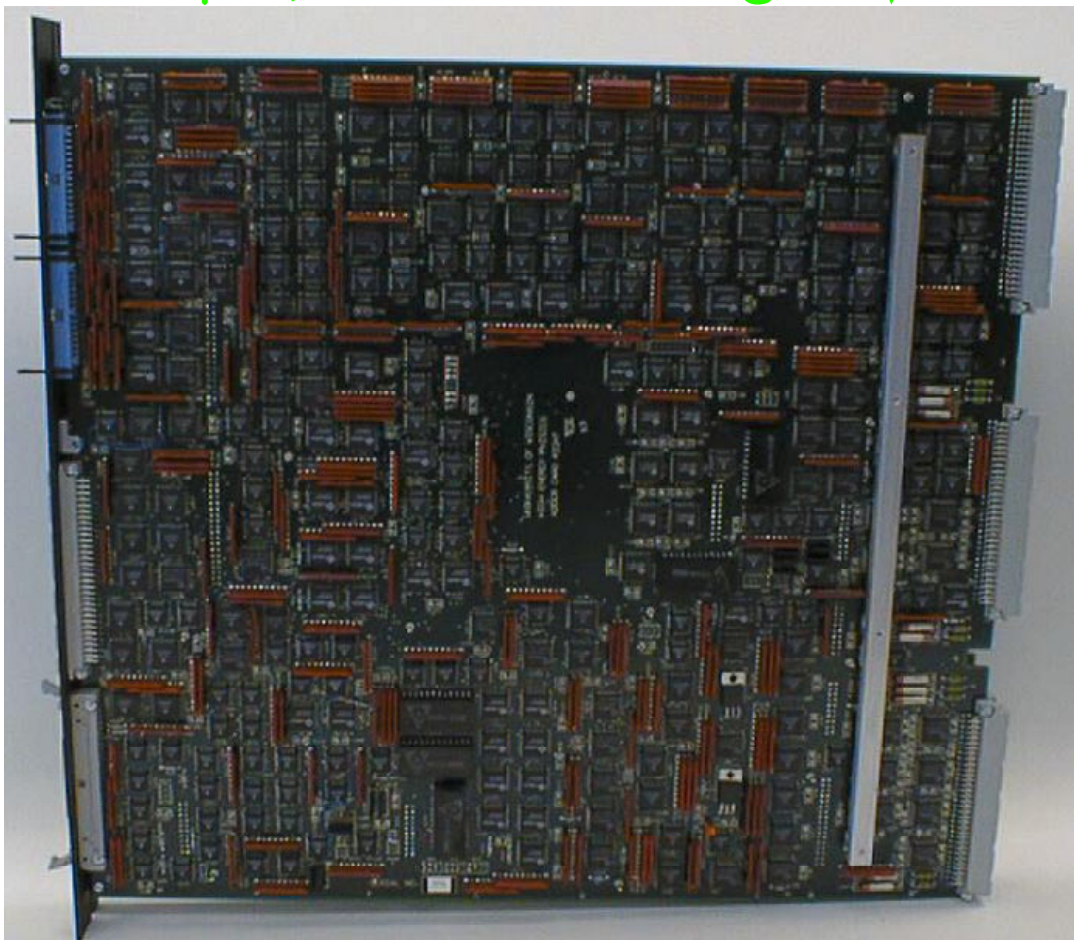
720 Trigger Sum Cards combine analog signals & transmit every 96 ns to TEC's in Electronics House

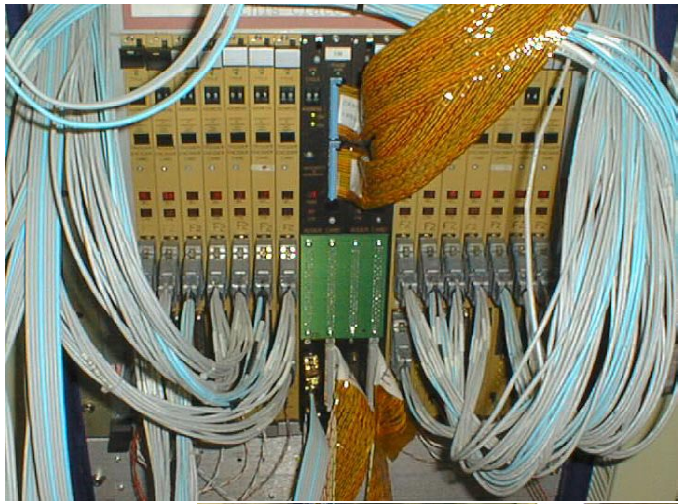
140 Fanout Cards control TSC's

CAL FLT Pattern Logic

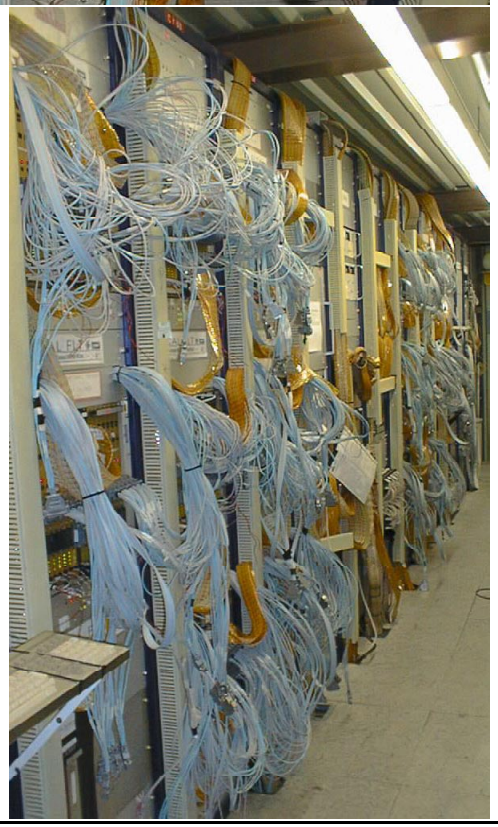
2 double-board Adder Cards/crate receive & process data from 14 TEC's at 80 MHz

Adder Cards find Isolated e's & μ's, and sum energies

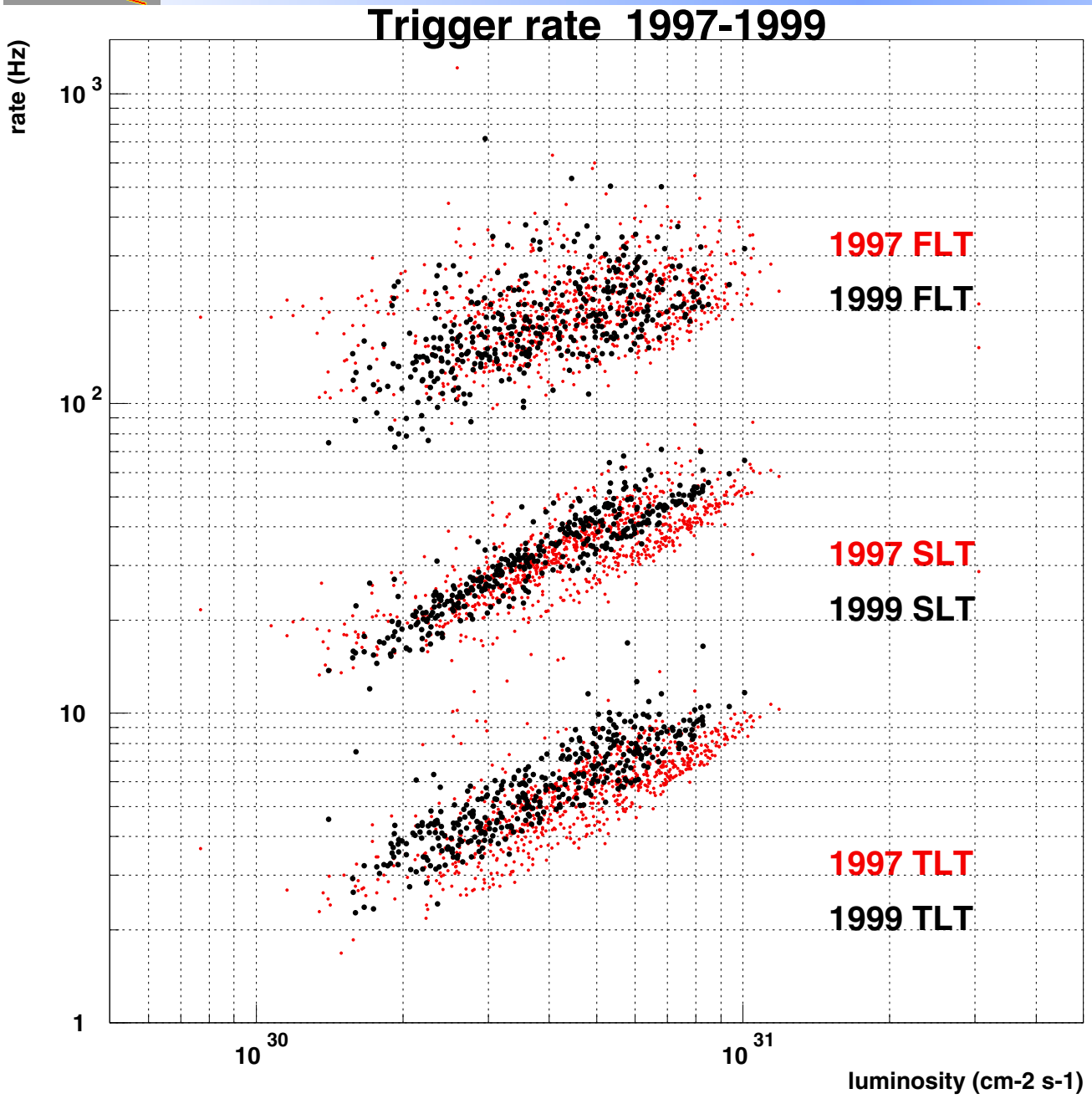




16 crates send results to Global Cal Trigger



ZEUS Trigger keeps pace with HERA



e^+p (820 GeV) ('97) vs. e^-p (920 GeV) ('99)

- consistent performance with changing beam energy, luminosity, backgrounds

Performance continued through 2000.

CAL FLT & Zeus Physics

Deep Inelastic Scattering -- F_2, g(x)

- Isolated electron in the RCAL
- BCAL & RCAL EMC energy

Deep Inelastic Scattering -- Diffractive

- Isolated electron in the RCAL
- Regional energy vetoed by energy around FCAL beampipe
- BCAL & RCAL EMC energy

Hard Photoproduction & Exotics

- Total Energy, E_t, EMC energy
- BCAL & RCAL EMC energy

Soft Photoproduction

- Low Energy activity trigger

CAL FLT & Unique Physics

Physics Zeus can do only because of CAL FLT:

- **Low energy activity trigger:**
  - Deep Inelastic ρ, ϕ
  - Photoproduction of elastic ρ, ϕ, J/Ψ
- **FCAL/BCAL Low, variable threshold Isolated Electron trigger**
  - Exotic Physics (and other studies)

Trigger Evolution

Respond to changing beam conditions by changing trigger

Study new trigger configurations

- **Test runs, Monte Carlo studies, data studies**

Trigger Physics Analysis

- **Understand detailed impact of trigger on physics**

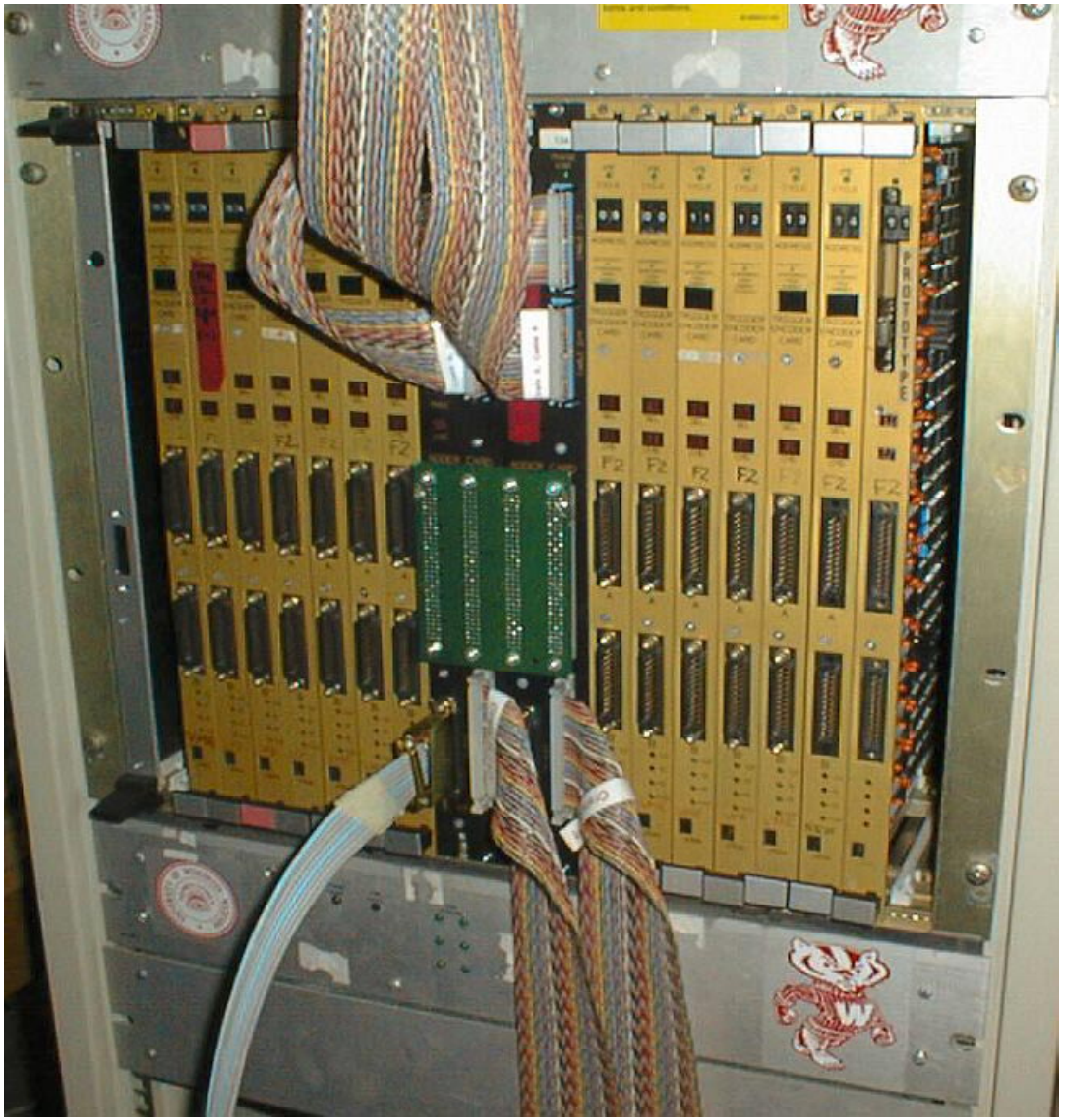
Preparation for HERA II

- **Commissioning HERA II now**
- **Luminosity startup underway**
- **Switching to electrons in 2003 after stable running with positrons in 2002**
- **Changing conditions over 2002/2003 will require considerable work by the trigger group**

Jade Hall Test Facility

Complete test crate & interface to global cal. trigger for full-scale check of counting house (rucksack) electronics

Calorimeter module electronics test with full module infrastructure



Trigger Operations

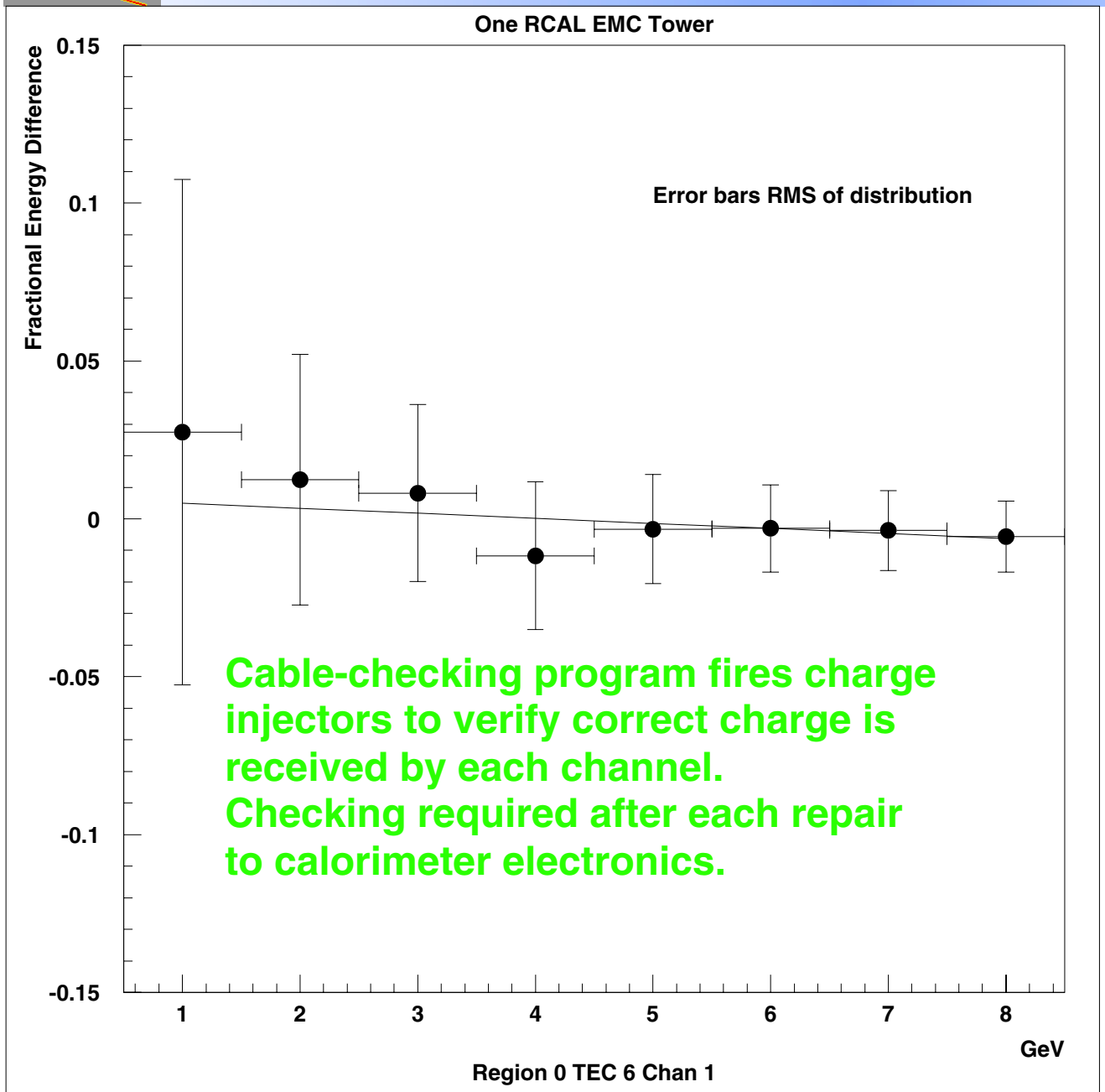
Detector & Electronics House

- **Write, test & maintain electronics test programs**
- **Maintain & update bad channel list**
  - < 1% channels w/any trigger problem (none dead)
- **Diagnose & repair electronics**
  - Experimental downtime due to CAL FLT < 1%
- **Daily checking programs**
- **Maintain & operate Jade Hall Test Facility**
- **24 hour/day support during running**

Software Operations

- **Run Control maintenance**
- **Trigger data validation**
  - Online & Offline analysis of rates & efficiencies
- **Monte Carlo & data trigger simulation maint.**

Trigger Calibration/Maint.

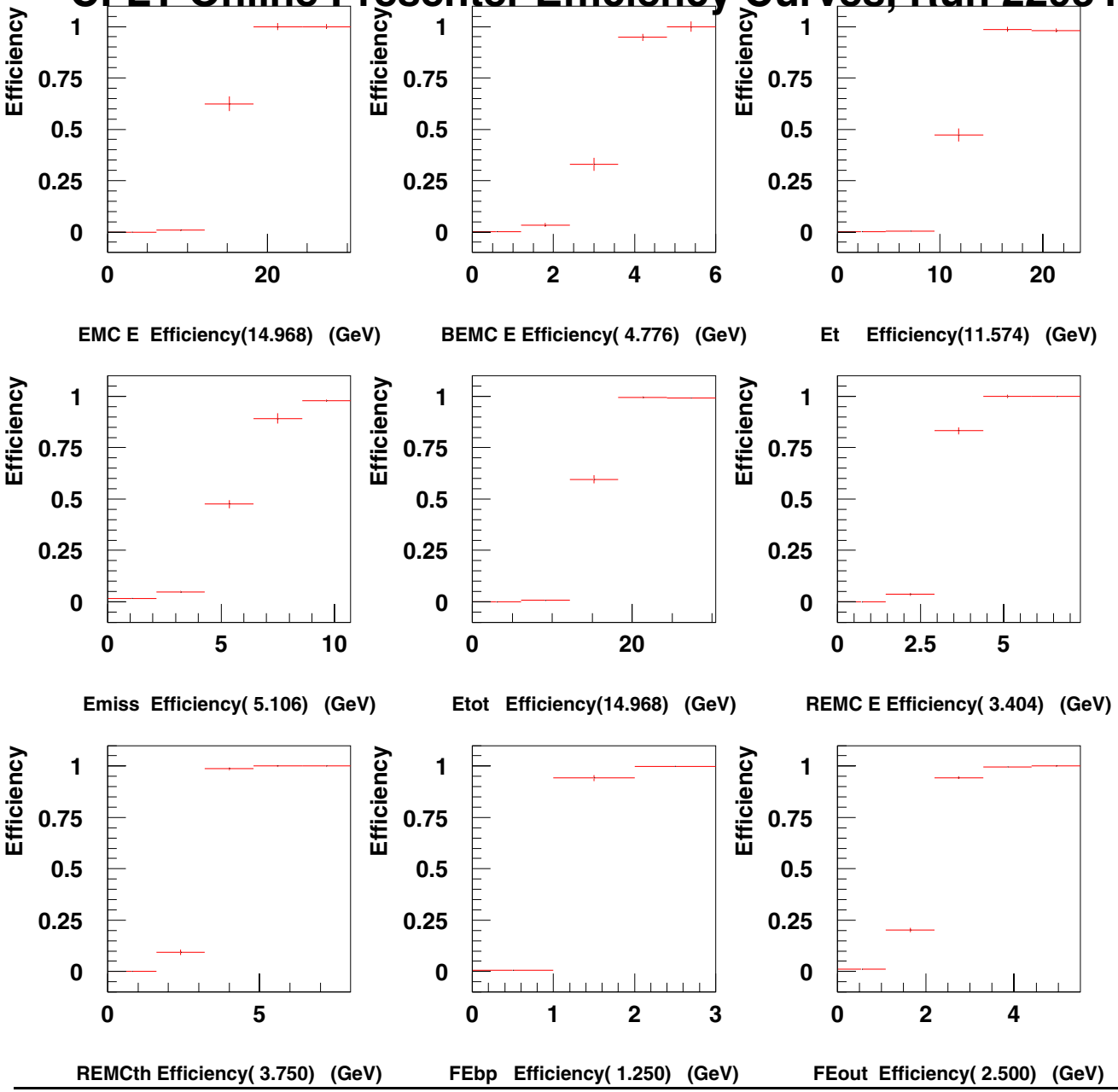


Frequent calibration is performed with charge injectors to set the time & energy.

- Calibration of a single RCAL EM tower trigger vs. full resolution readout data

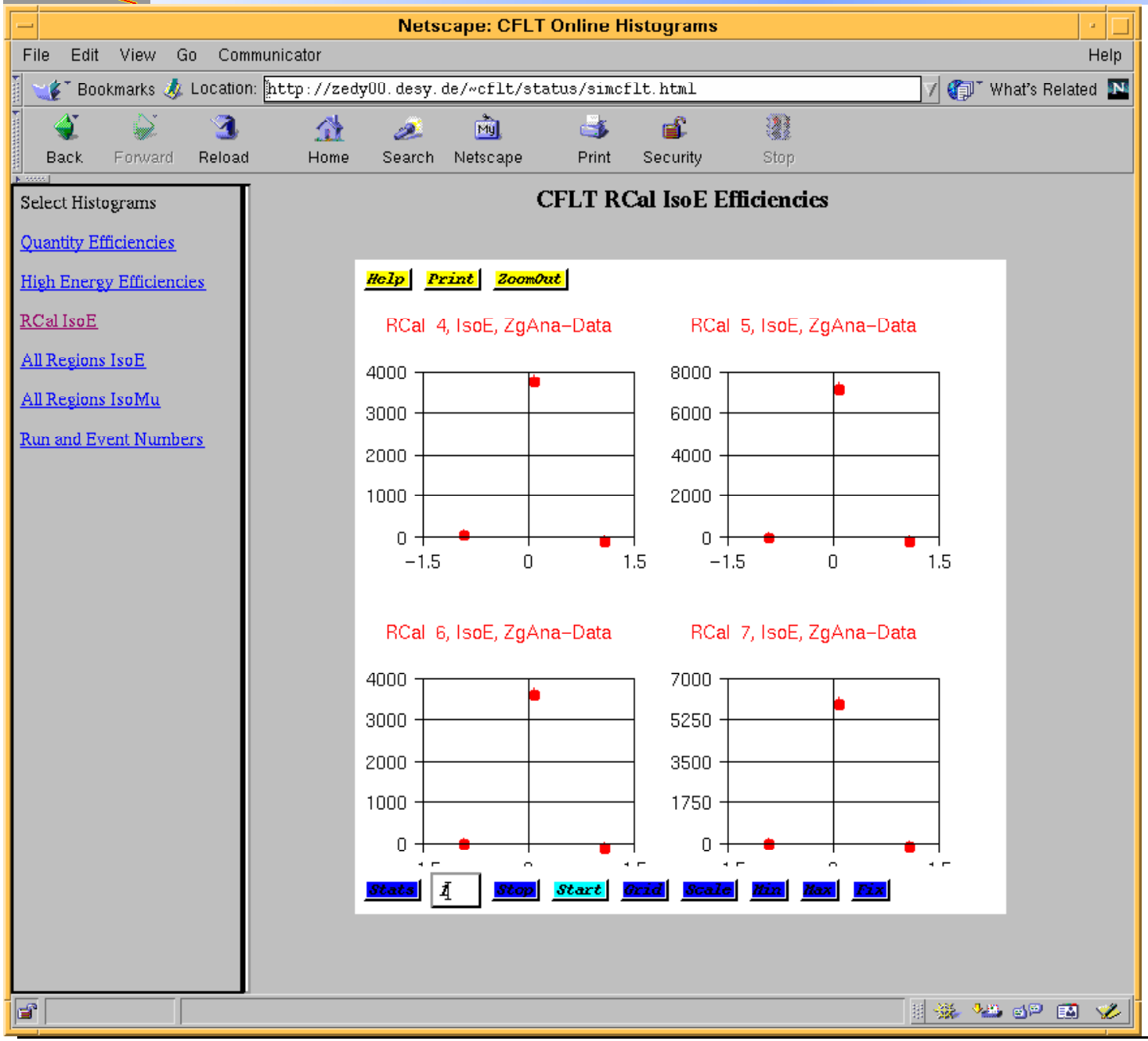
Online Diagnostic Simulation

CFLT Online Presenter Efficiency Curves, Run 22934



Trigger bits vs.simulation of trigger using reconstructed data as input. Each trigger efficiency curve is monitored & checked online.

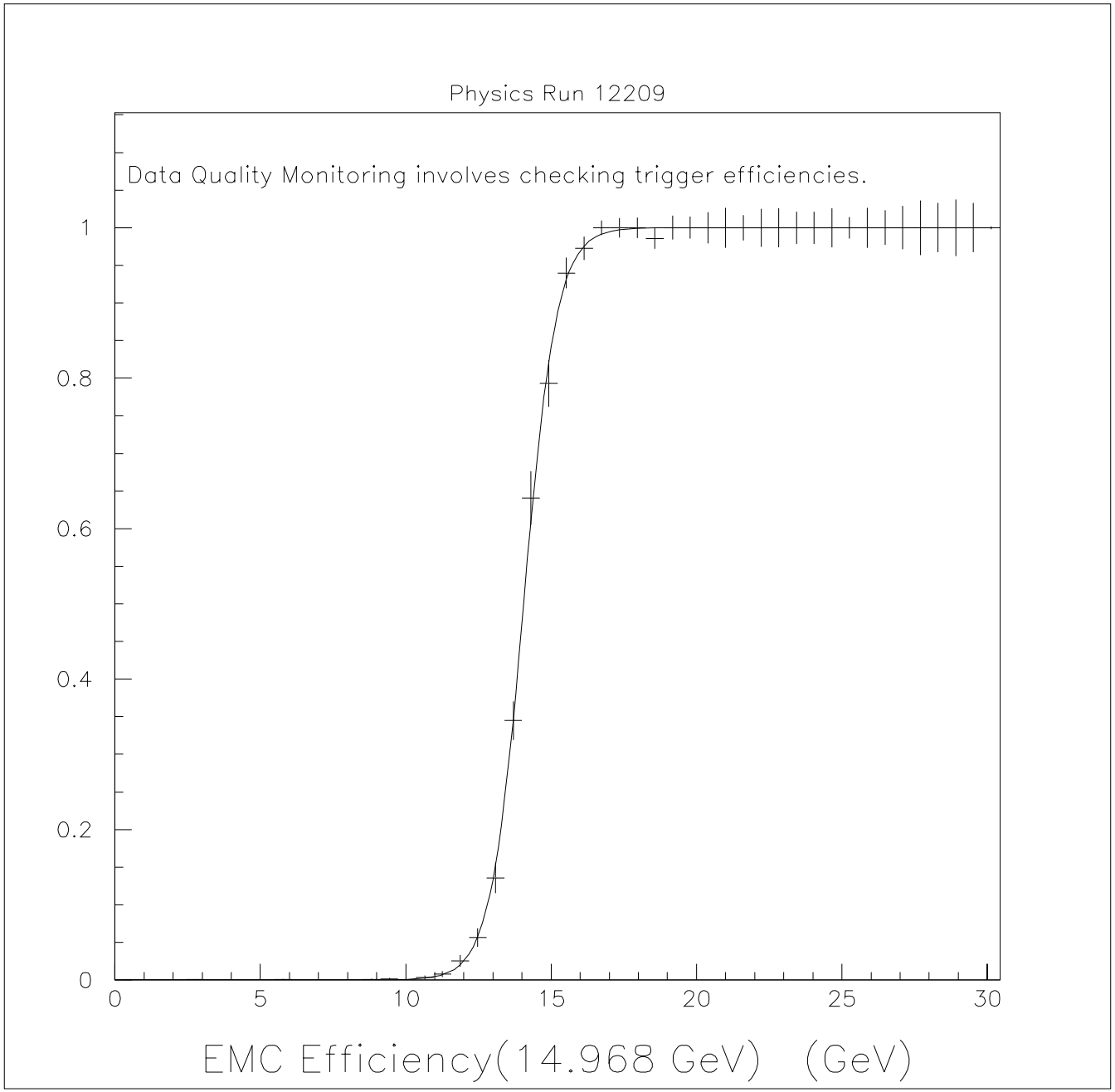
Real-Time study of Elec. Trig.



Example of sophisticated online display

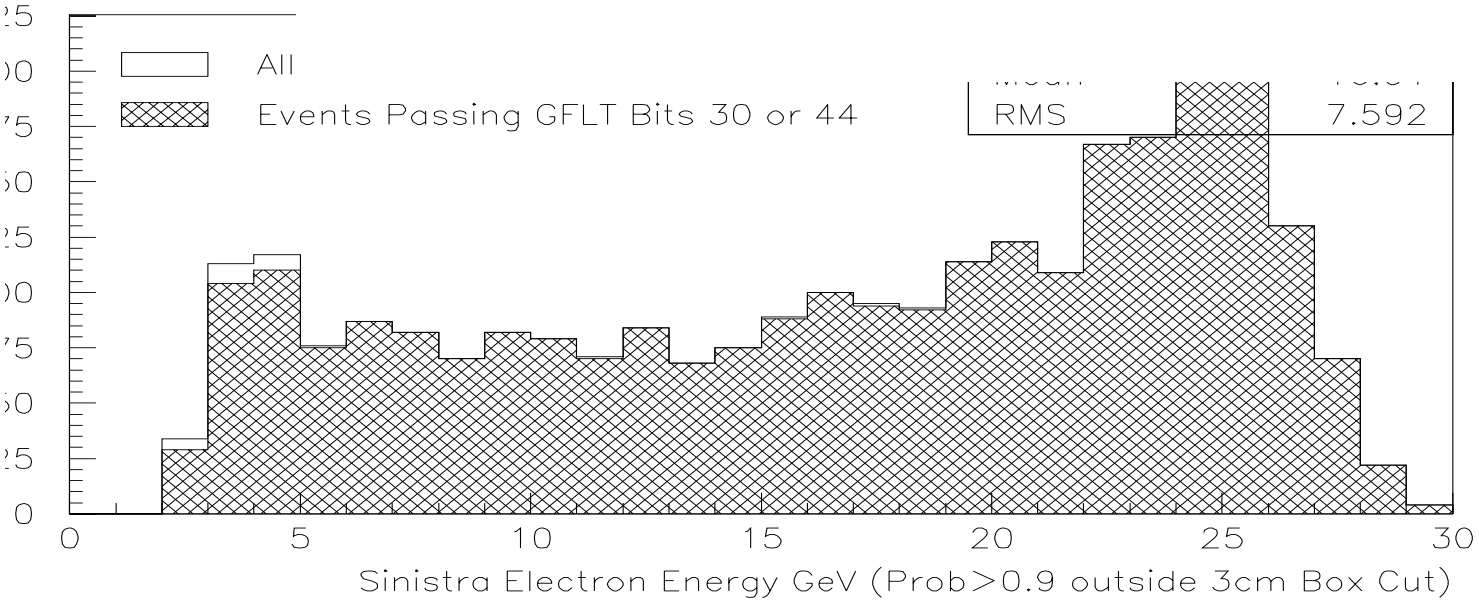
Difference between simulated & data isolated electron trigger bits set for events depositing energy in an RCAL quadrant

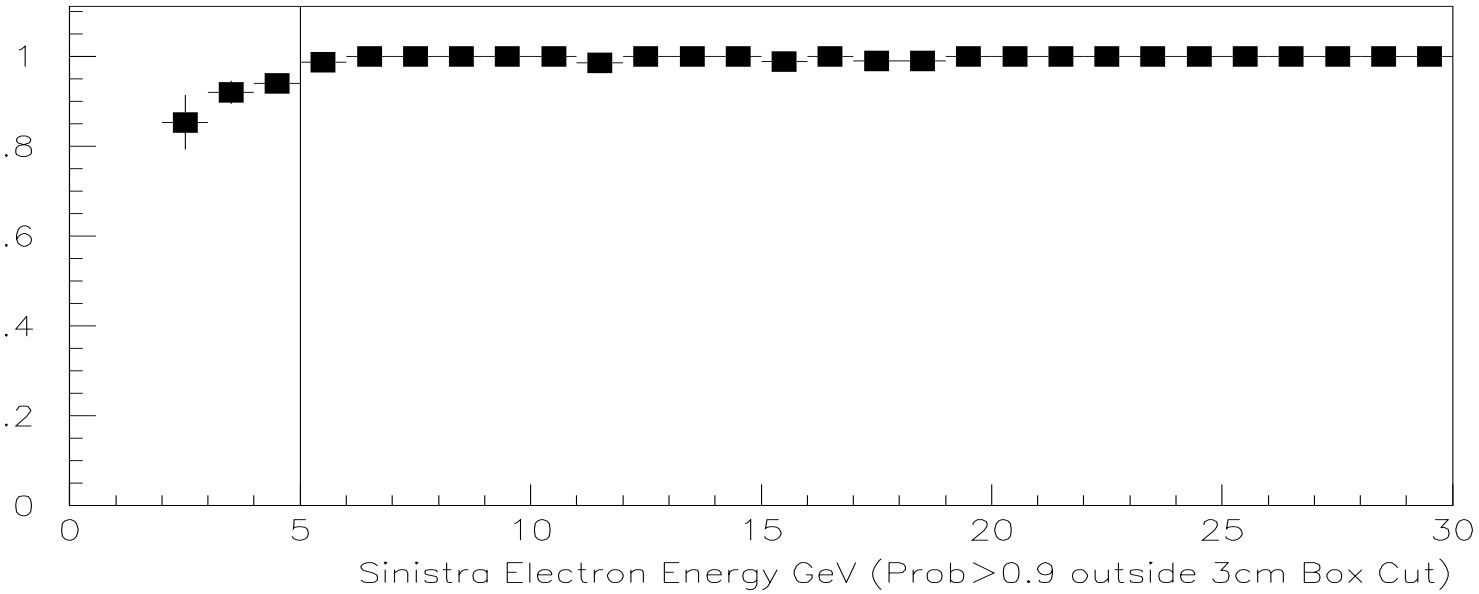
Offline Data Quality Monitoring



Each trigger in every data run is analyzed offline to check efficiency and rise of threshold curve.

Offline Electron Trigger Monitor

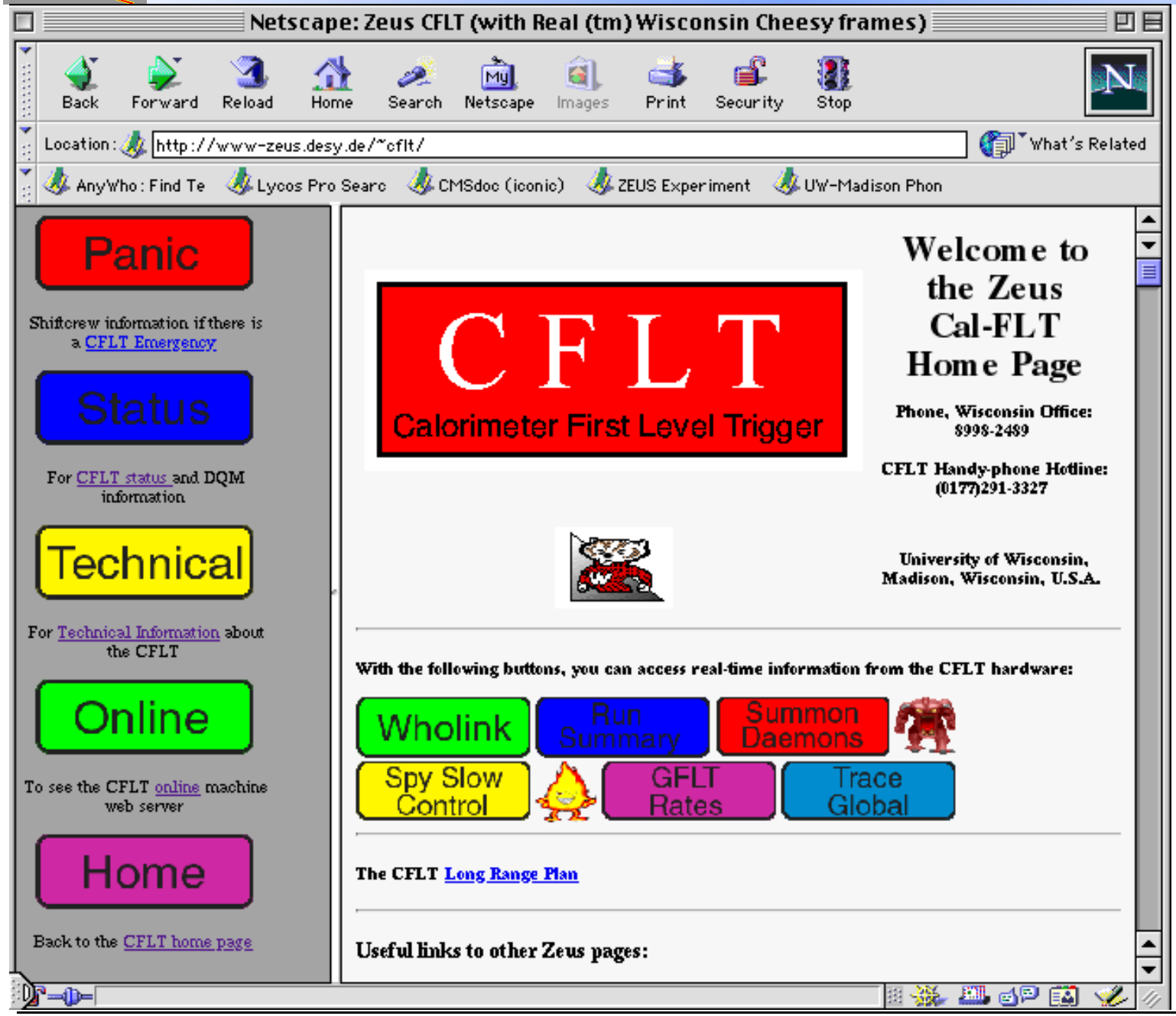




Efficiency vs. electron energy.

- **Efficiency rises from 2.5 to 5 GeV due to energy sharing between towers.**

Web-based Information Server



Up-to-date performance information

Run by run online & offline analysis

Up-to-date status

Full system documentation

Operation of diagnostics

Supervisory Personnel at DESY

Ph.D. Physicists resident at DESY

- **Assistant Scientist - A. Savin**
  - Calorimeter Trigger Coordinator
    - **Provides technical coordination**
    - **Works with other detector leaders**
  - Physics Analysis
    - **Works with students on thesis analysis**
    - **Does own analysis**
  - Local Group Leader
- **Postdoc - D. Kcira**
  - Calorimeter Trigger
    - **Responsible for daily operations**
    - **Works with students on trigger duties**
  - Physics Analysis
    - **Works with students on thesis analysis**
    - **Does own analysis**

Technical Personnel

Loss of funding for Technician: Cathy Farrow

- Operates, repairs, maintains test facility
- Repairs boards/infrastructure under physicist guidance
- Hope that AmZeus/DESY can rehire Cathy with full calorimeter responsibility and that she can spend some time on CAL FLT

Expert Engineer: Matt Jaworski

- ~ 4 trips/year for 2-3 weeks to make difficult repairs
  - Frequency increasing due to electronics aging and to make up for Cathy Farrow's absence.

Designer - available for consultation

- Joe Lackey (on Task T - CMS)

Students at DESY (August '02)

- **Beginning (2)**
  - Learning
  - Cal.Trigger shifts
    - **on call 24x7**
- **Intermediate (2)**
  - Resp.for Cal Trig shifts
  - Begin physics analysis
- **Senior (2)**
  - Released for Thesis analysis
  - Consultation, assistance, shifts
- **Supervision**
  - Local Scientists - A. Savin & D. Kcira
  - Visits by Wisconsin Faculty D. Reeder & W. Smith
  - Weekly (often more) videos between Wisconsin & DESY

Thesis Students:

(+ A. Everett not shown)

Summer Students:

Future Plans for Trigger

No Hardware Upgrade Needed for HERA II

- Detailed studies show trigger for luminosity upgrade can be reprogrammed to for physics at high luminosity

Studies, analysis, software development needed

- Collaborate with physics groups on lumi upgrade trigger
  - Integrate with Fast Clear driven by Cal Trigger data
- Develop and model the new trigger configurations
- Verify the models with data tests
- Along with activities/responsibilities previously discussed

Conclusions on trigger:

- Lots of physics provided by the Cal Trigger
- Lots of work to do
- Lots of physics to come...

Conclusions: UW ZEUS Operations

Leading group on ZEUS in detector & analysis (see next talk)

- Doing great physics (5 major Int'l conference talks in 2002/1)

Wisconsin group Continuity & strength vital for ZEUS

- ZEUS cannot operate without CAL FLT
- Provider of majority of US Zeus students

Exploit huge investment by DESY in HERA II

- 70 new magnets, spin rotators, upgraded detector
- Exciting new physics program amidst shrinking HEP spigots
- Contribute to the US HEP international role
  - A model for future international collaborations (i.e. TESLA)

Graduating top students

- Experience in sophisticated hardware & software
- Physics analysis in close collaboration with theorists
- 11 Wisconsin ZEUS students received Ph.D.s thus far
  - D0 (3), CDF, ATLAS, CLEO, Intel, US defense think tank,...