Performance of the Monitoring Light Source for the CMS Lead Tungstate Crystal Calorimeter

L. Zhang, D. Bailleux, A. Bornheim, K. Zhu, R.-Y. Zhu

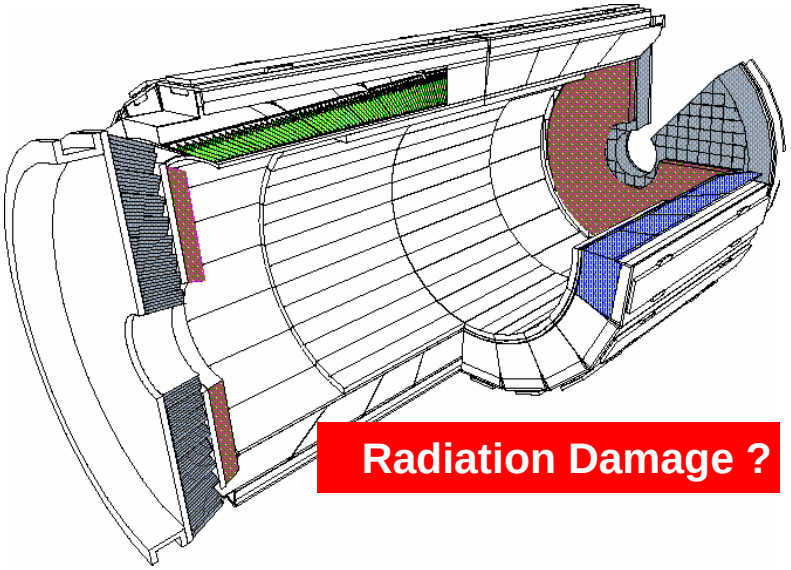
California Institute of Technology

Introduction

- A high resolution PWO crystal calorimeter is under construction by the CMS collaboration for LHC. The mass produced PWO crystals are radiation hard to high integrated dosage, but still suffer from a dose rate dependent damage as shown in induced absorption.
- Measuring variations of crystal transmittance and providing corrections of crystal light output, a light monitoring system plays a crucial role in maintaining PWO calorimeter energy resolution.
- A laser based light source and high level distribution system was designed and constructed at Caltech, and was installed and commissioned at CERN in the last three years.
- Performance and stability of this system in beam test is reported.

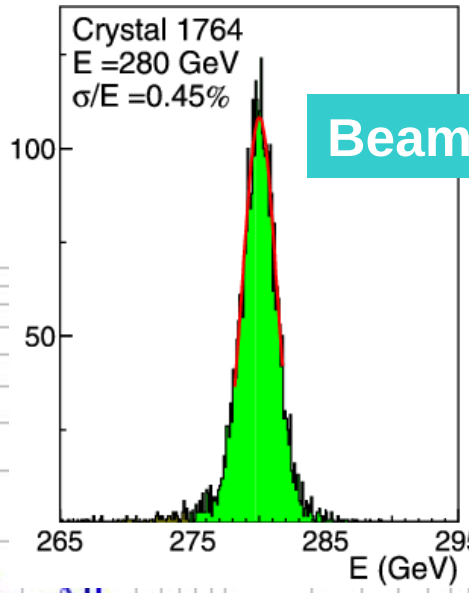
Expected PWO ECAL Resolution

See also talk N6-1, W. Funk



Radiation Damage ?

Beam Test



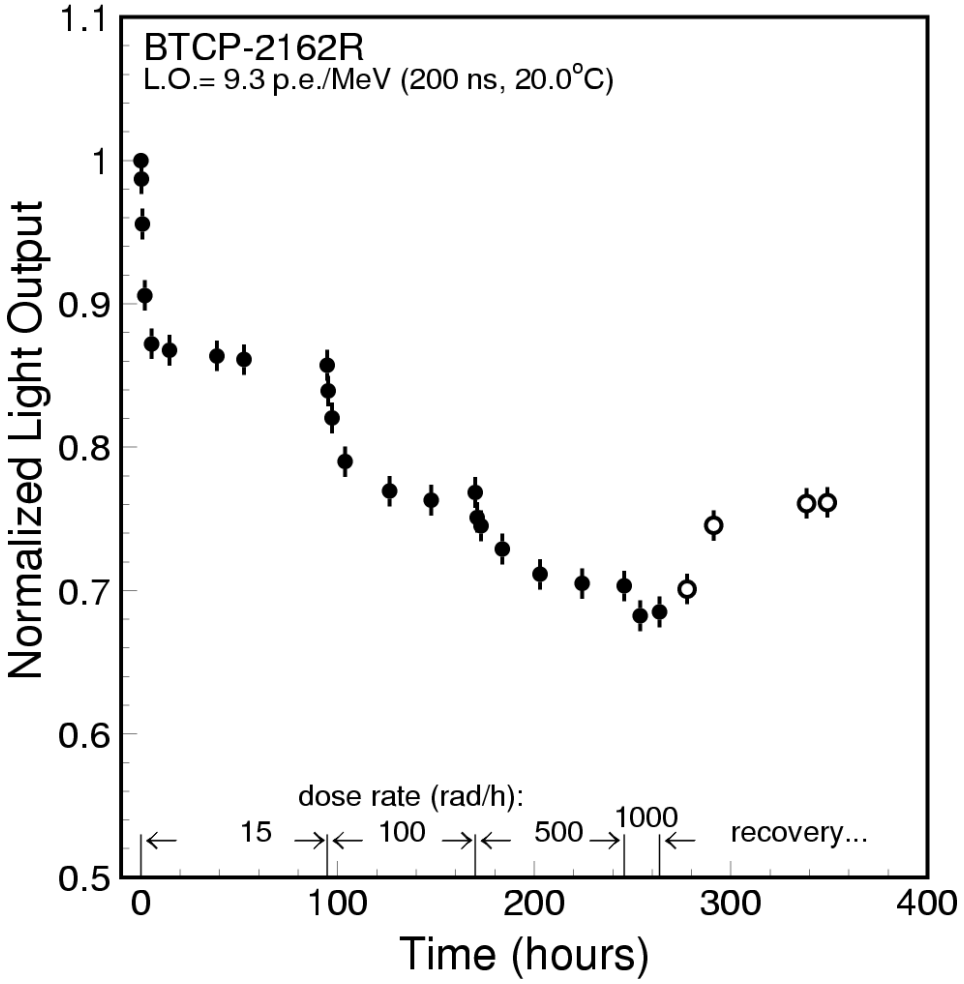
Designed Resolution

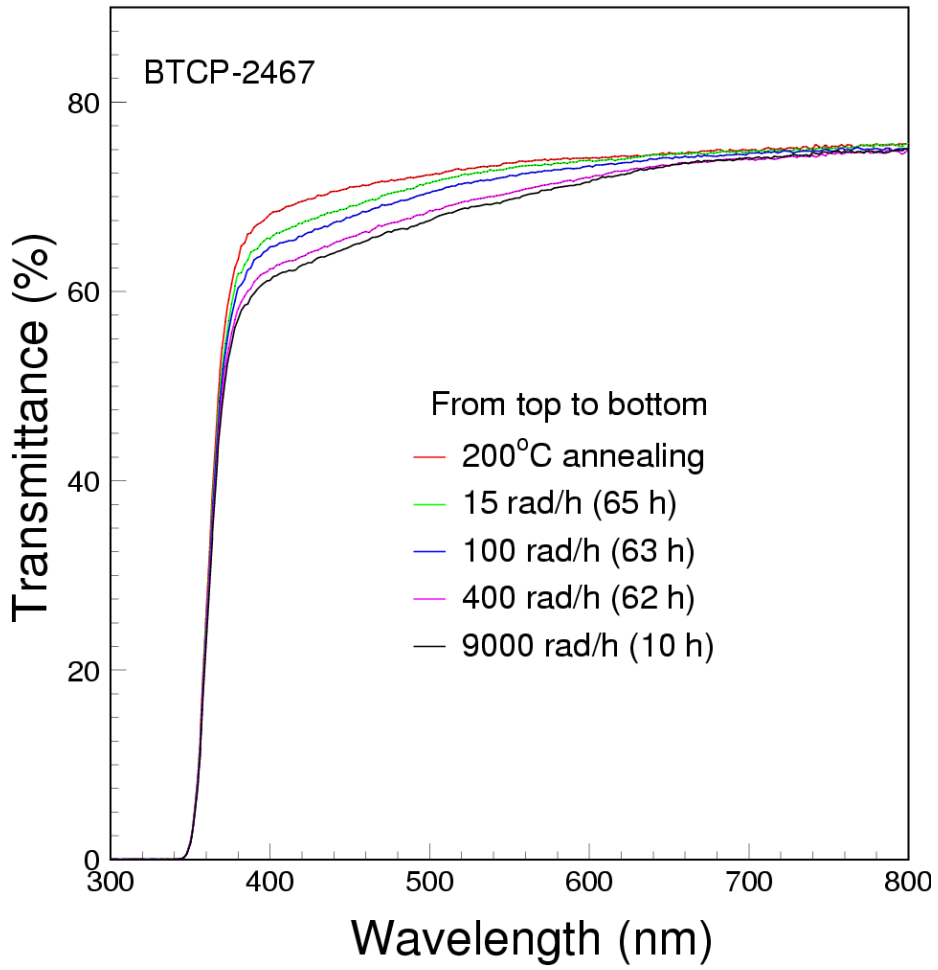
Crystal Calorimetry at very High Energies

PWO Radiation Damage

Damage and recovery: color center formation

Dose rate dependent: cc creation and annihilation

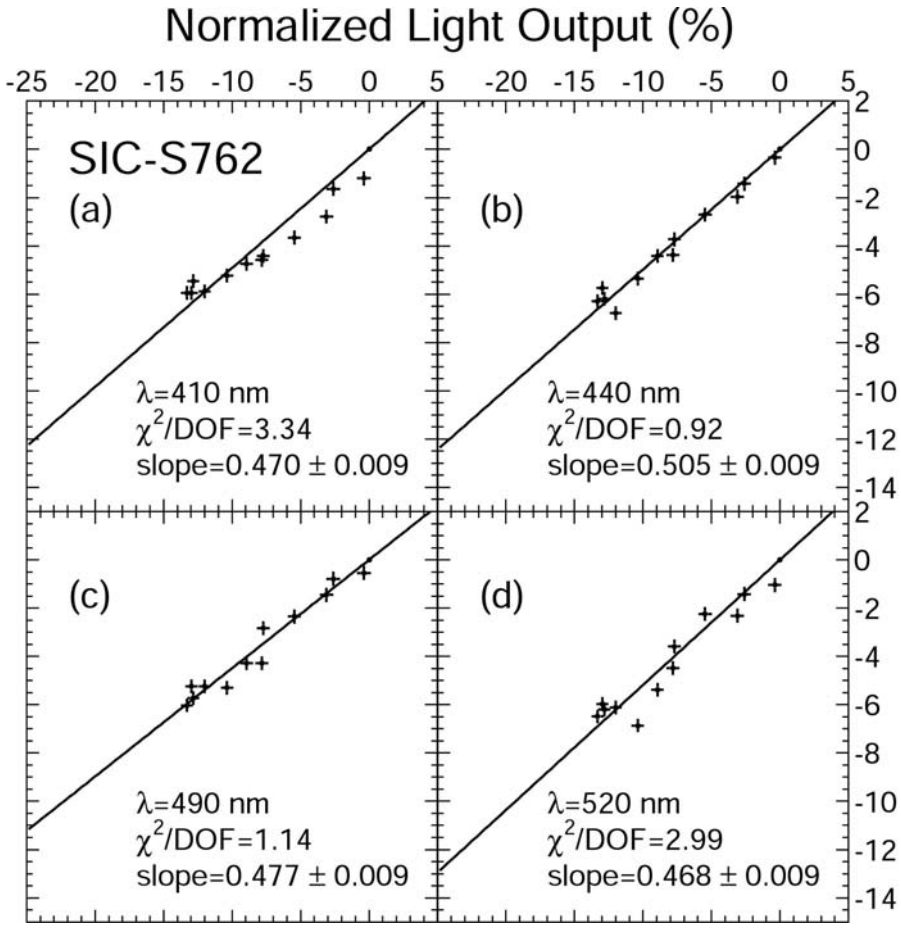




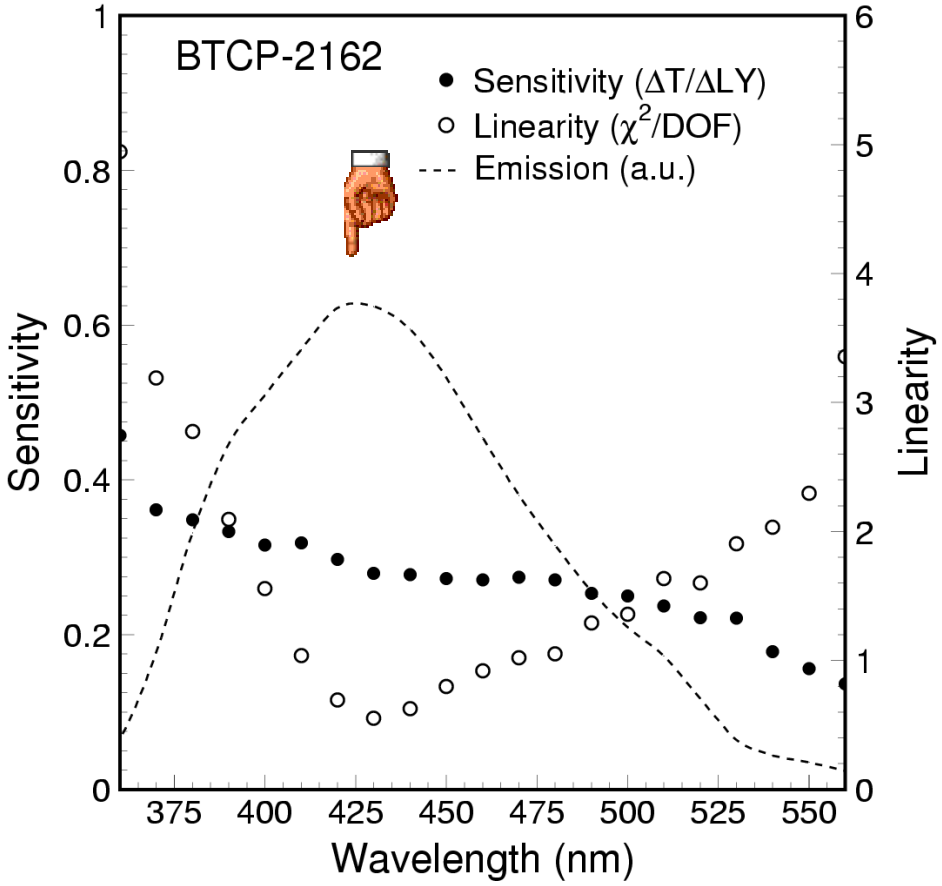
Monitoring Wavelength Determination

IEEE Tran. Nucl. Sci. **V 48 (2001) 372**

Δ(T) versus Δ(LY)



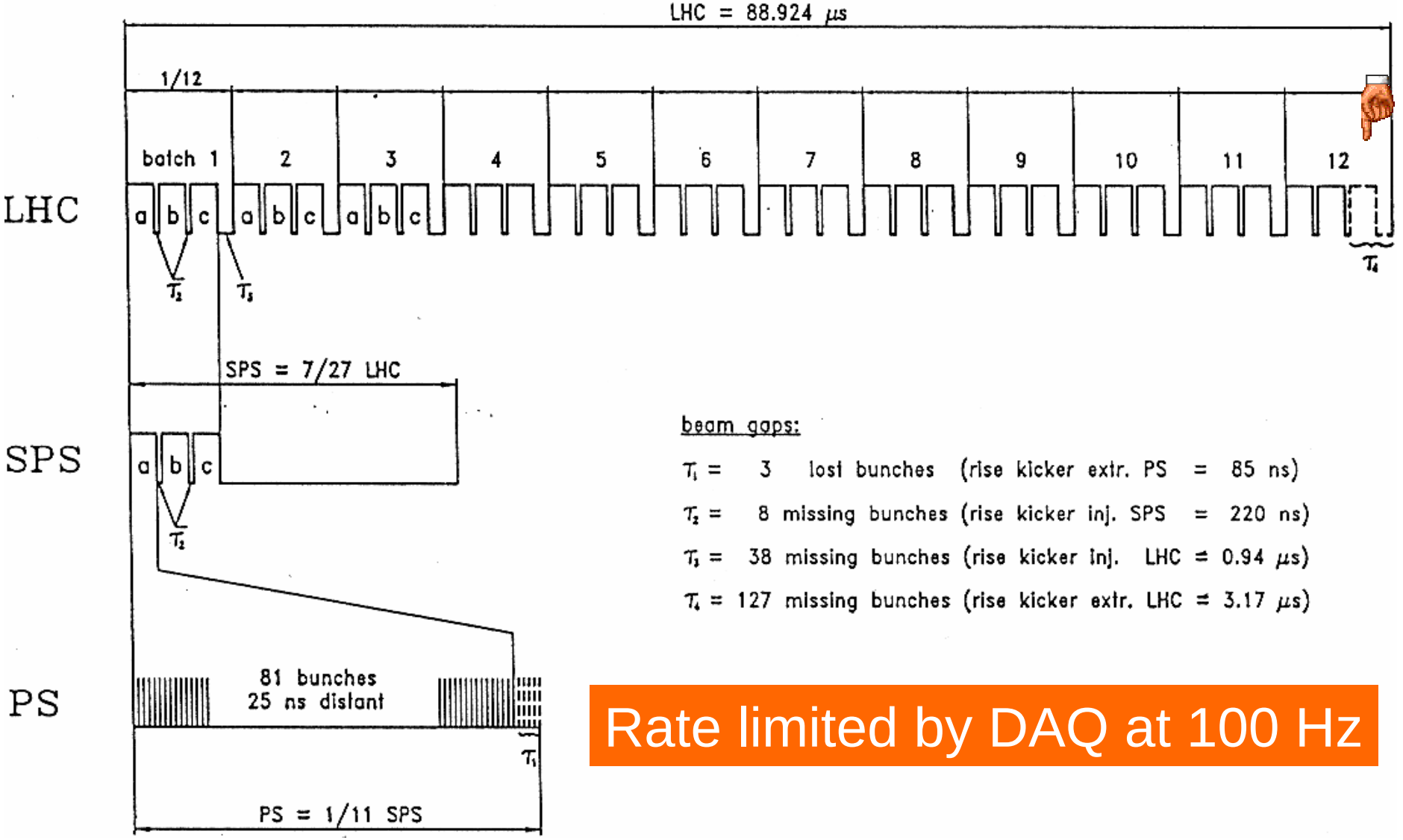
Sensitivity and Linearity



→ 440 nm is chosen for the best linearity

Continuous Monitoring *in situ*

Using 1% beam gaps in theLHC beam structure



beam gaps:

τ_1 = 3 lost bunches (rise kicker extr. PS = 85 ns)

τ_2 = 8 missing bunches (rise kicker inj. SPS = 220 ns)

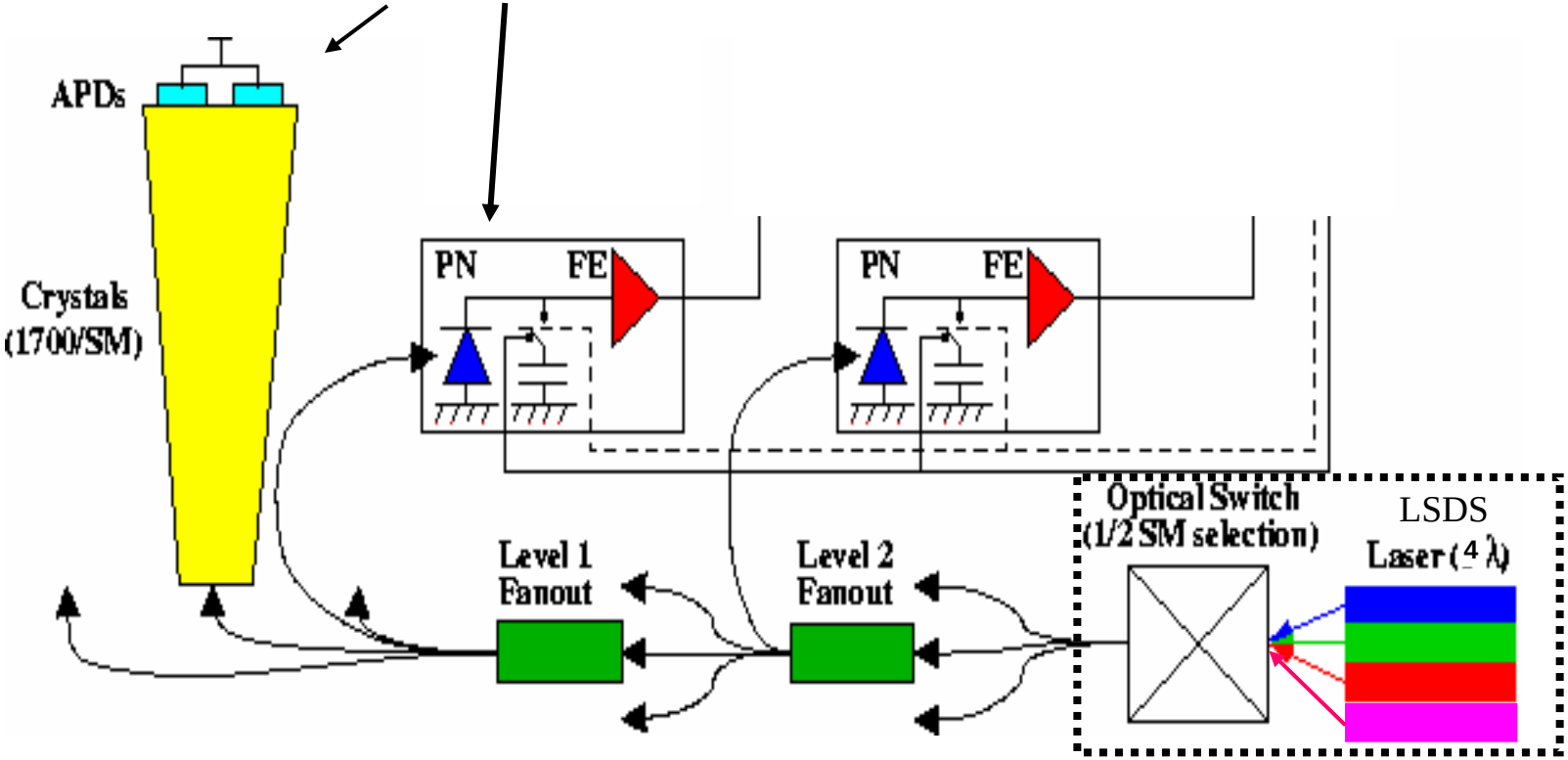
τ_3 = 38 missing bunches (rise kicker inj. LHC = 0.94 μs)

τ_4 = 127 missing bunches (rise kicker extr. LHC = 3.17 μs)

Rate limited by DAQ at 100 Hz

ECAL Light Monitoring System

APD/PD monitors the PWO crystals.



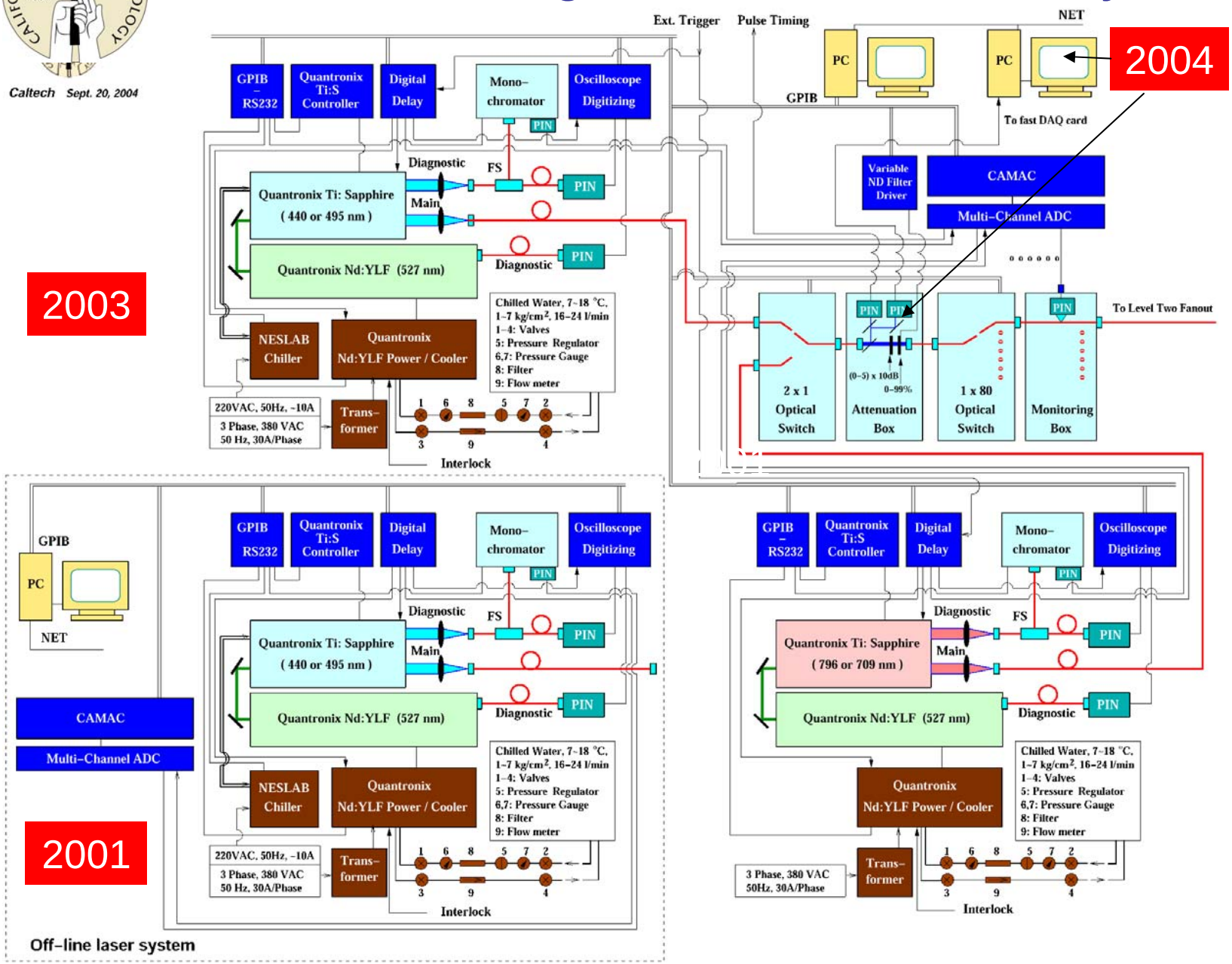
The ECAL light monitoring system consists of laser source, optical switch based high-level distribution system and two level fanout system.

Laser Source Requirements

- Pulse width: FWHM <40ns to match PWO readout.
- Pulse jitter: <4ns/<2ns for long/short term.
- Pulse energy: 0.4 mJ/pulse to provide more than 100 GeV equivalent energy deposition in each crystal.
- Pulse energy instability: <10%.
- Pulse rate: 100Hz, the maximum rate allowed by DAQ.

Lasers and High-level Distribution System

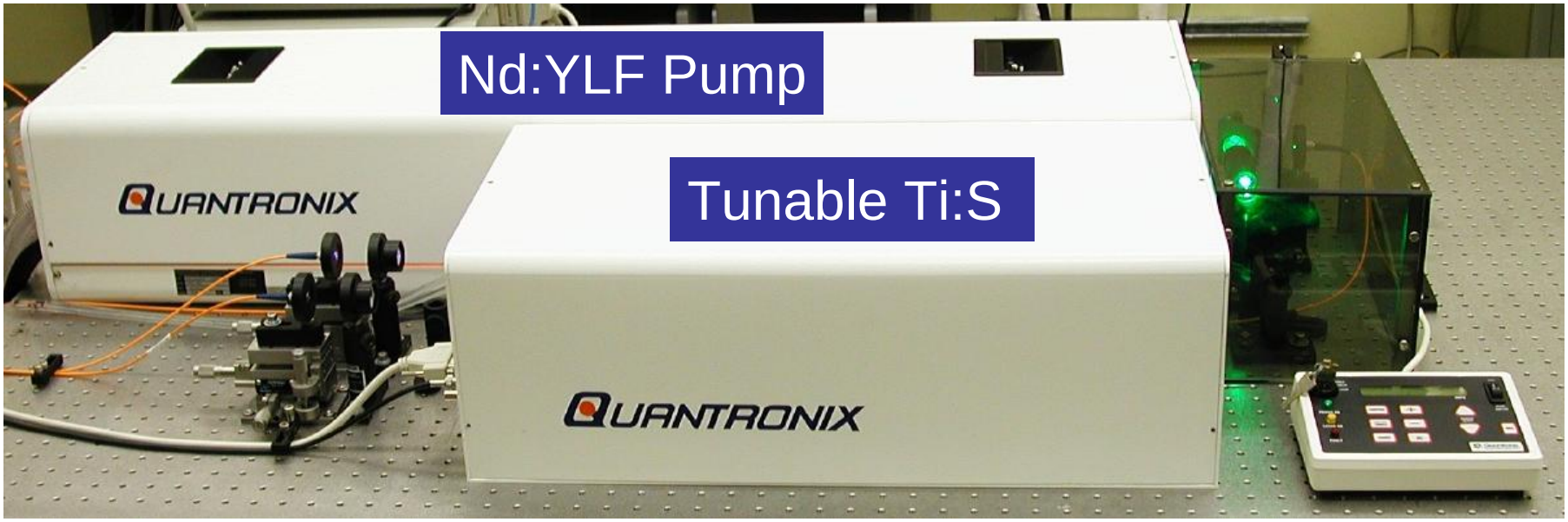
Caltech Sept. 20, 2004

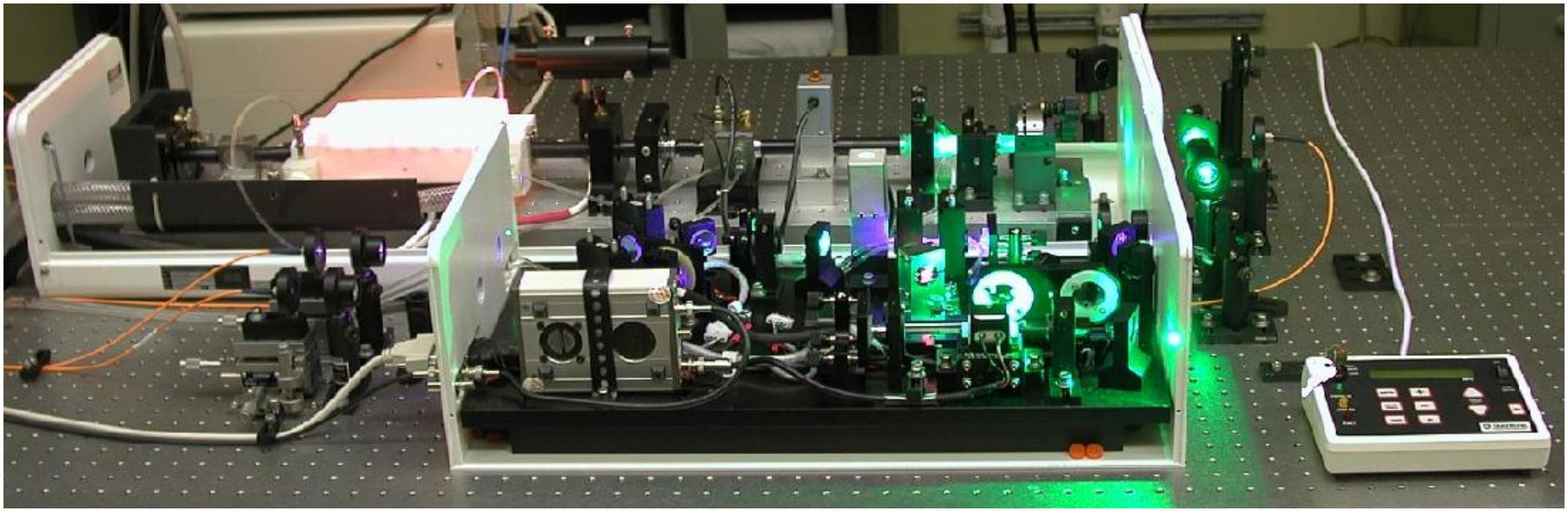


The 1st laser system was Installed in 2001, and used in 2002 beam test.

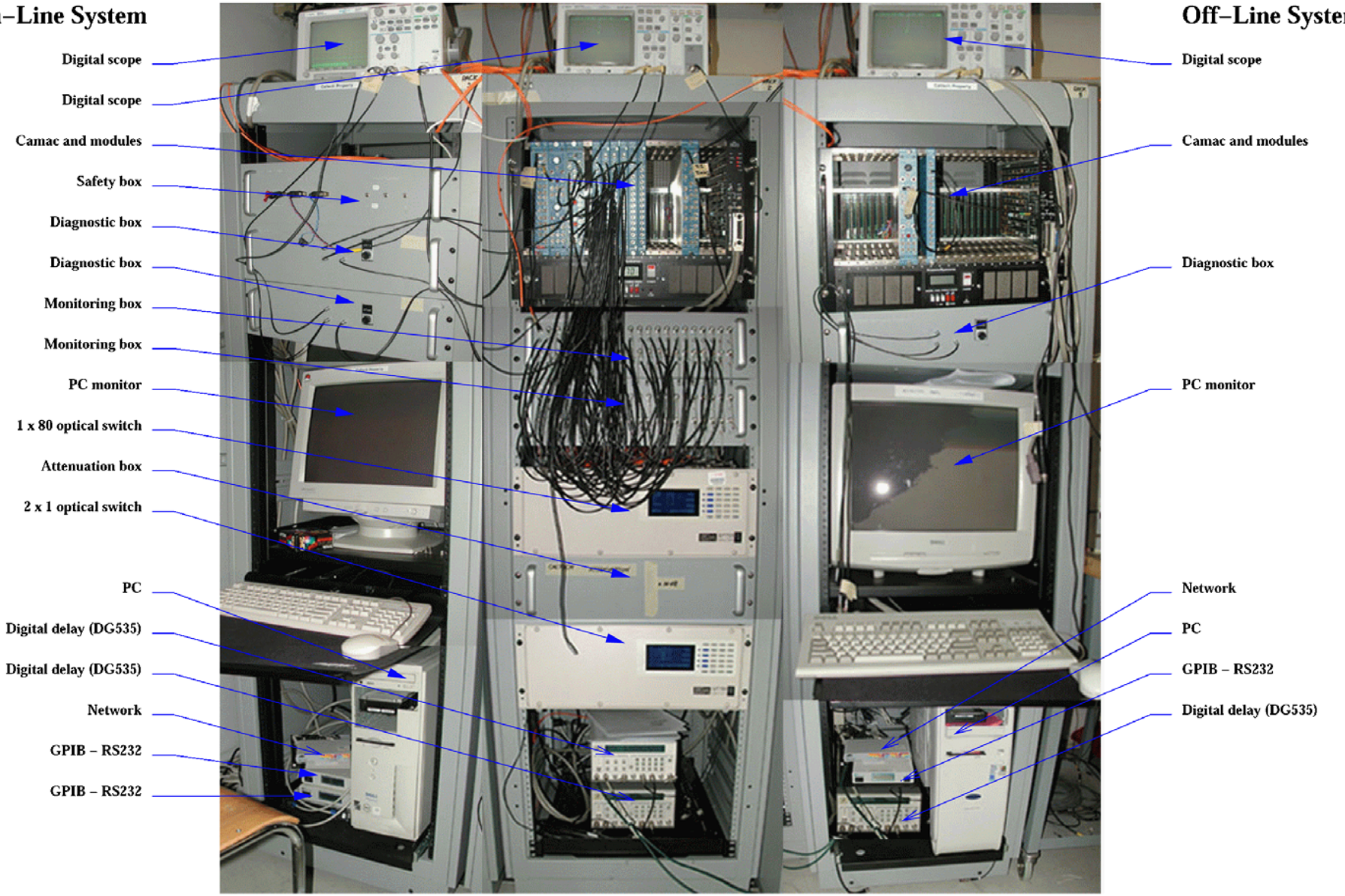
The 2nd and 3rd laser systems installed at CERN in August, 2003.

Ti:Sapphire Laser with Two Wavelengths



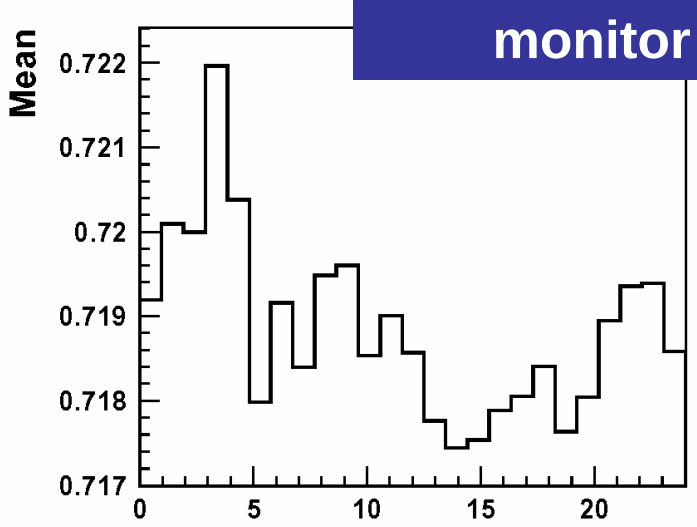


Laser Monitors, DAQ and Distribution System



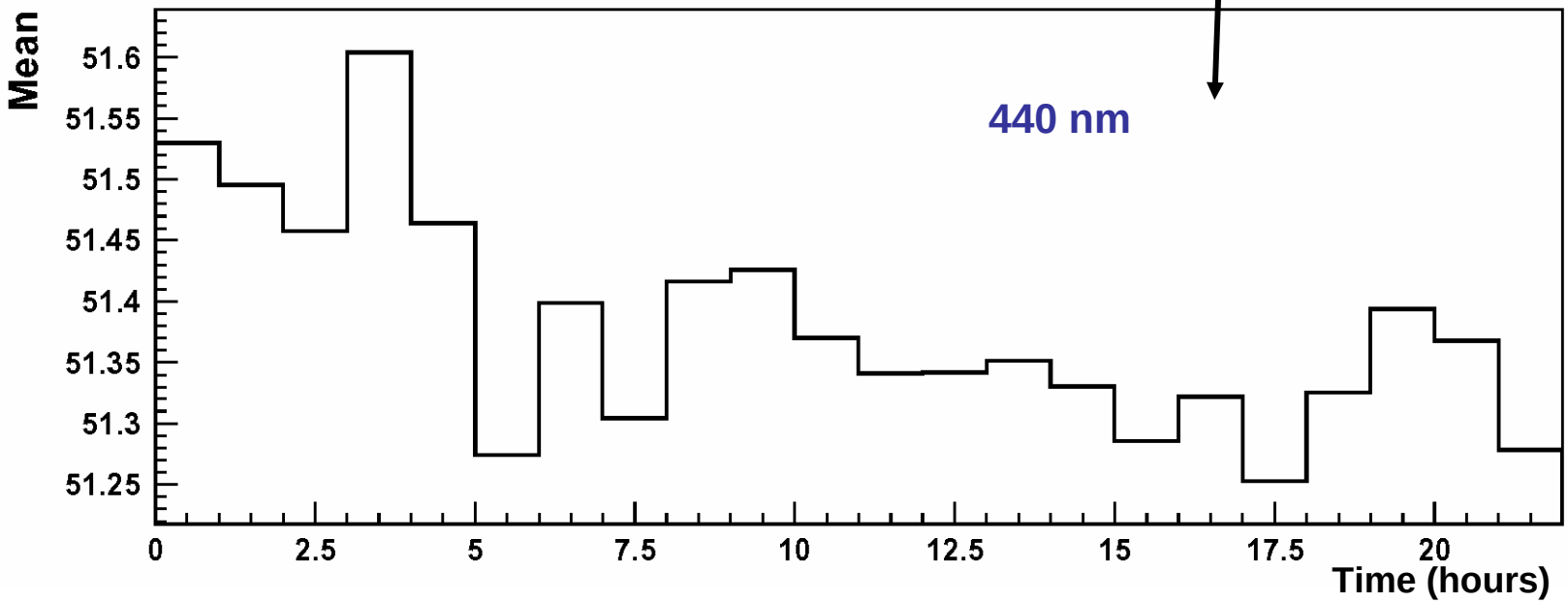
Lasers Ready for 2004 Test Beam

DSO based slow monitor



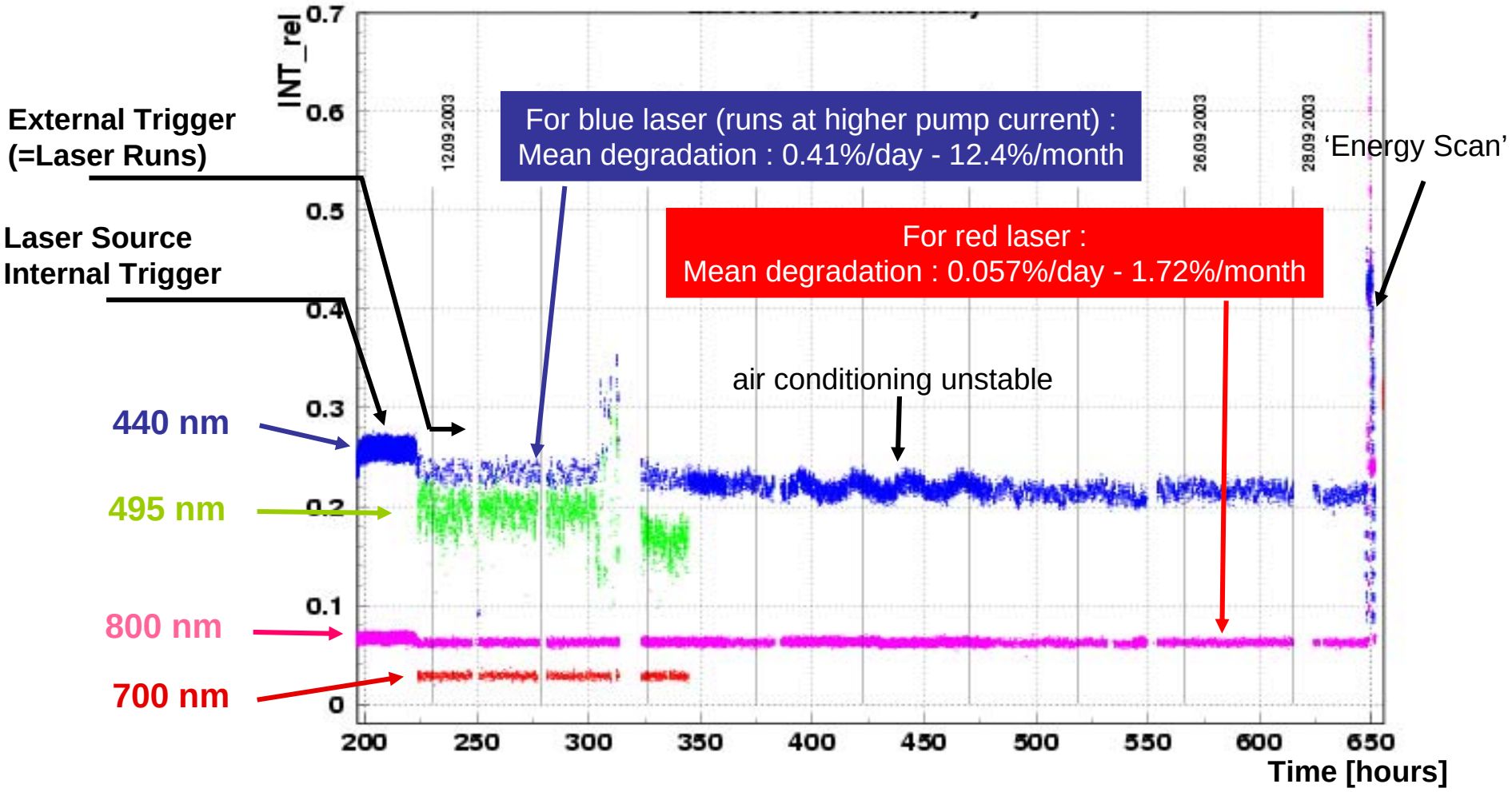
An Acqiris DP210 card of 2 GS/s was installed in 2004 to provide pulse energy and FWHM information for each laser pulse.

Pulse Energy History



Laser Performance in 2003 Beam Test

Typical ‘stable’ operation during 2003 beam test at CERN :



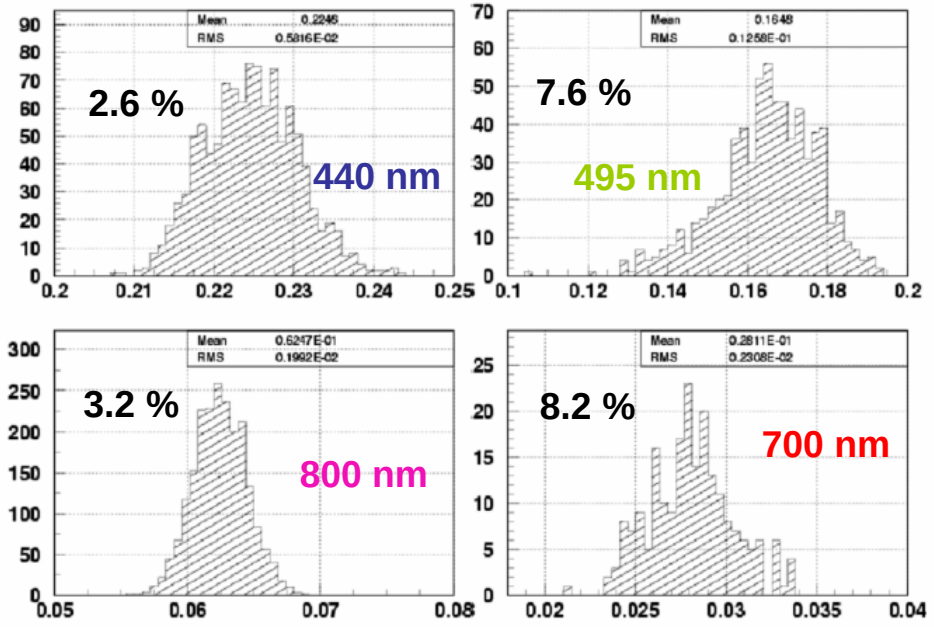
⇒ **In total more than 1200 hours of operation in 2003 beam test**

Pulse Energy Stability

Stability over 25 h

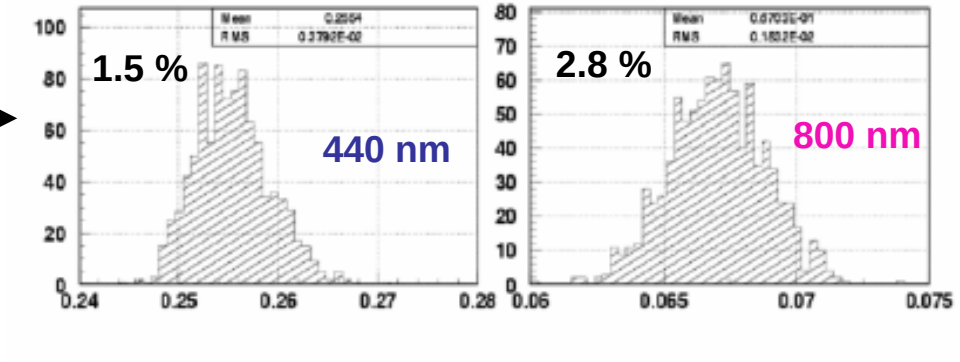
Very good performance exceeds requirements !

t_{ref} : 330 - 355 h



Typical 'Laser Run' in test beam mode takes 10 - 30 minutes.

t_{ref} : 200 - 200.5 h



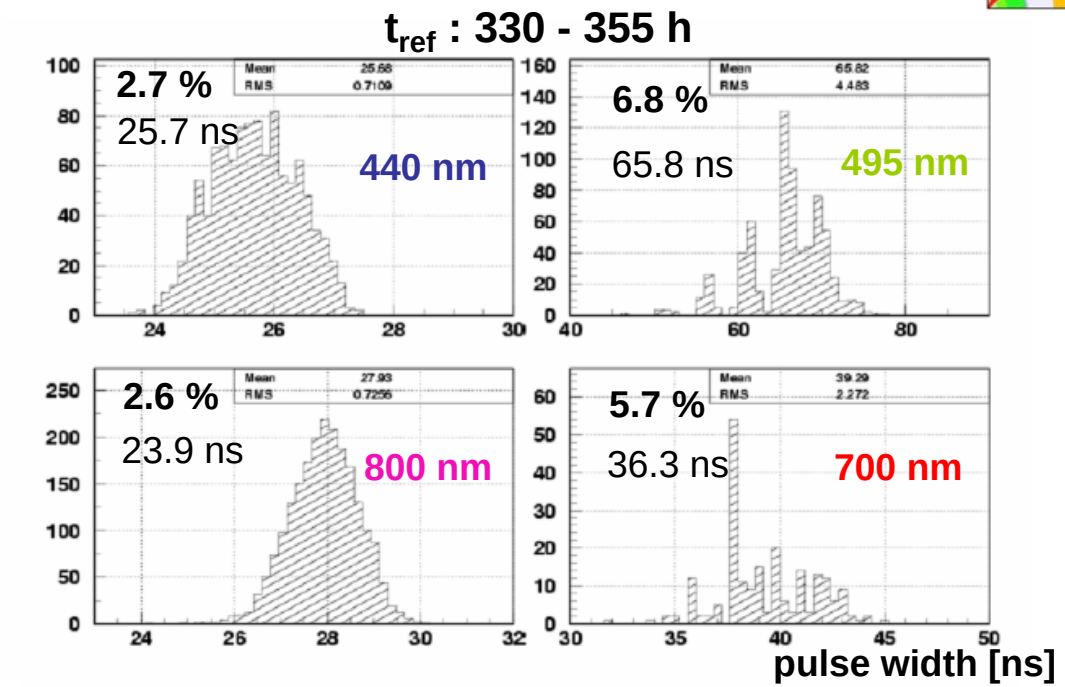
Pulse Width and Timing Jitter Stability

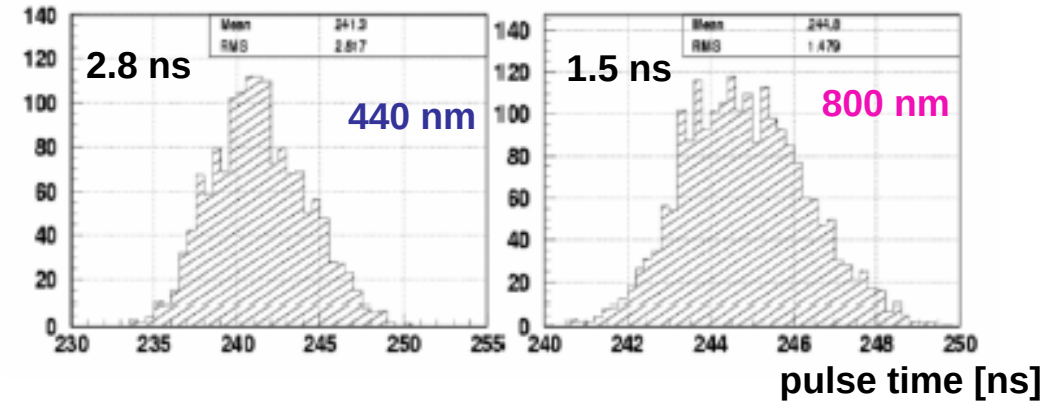
Stability over 25 h

⇒Very good performance.

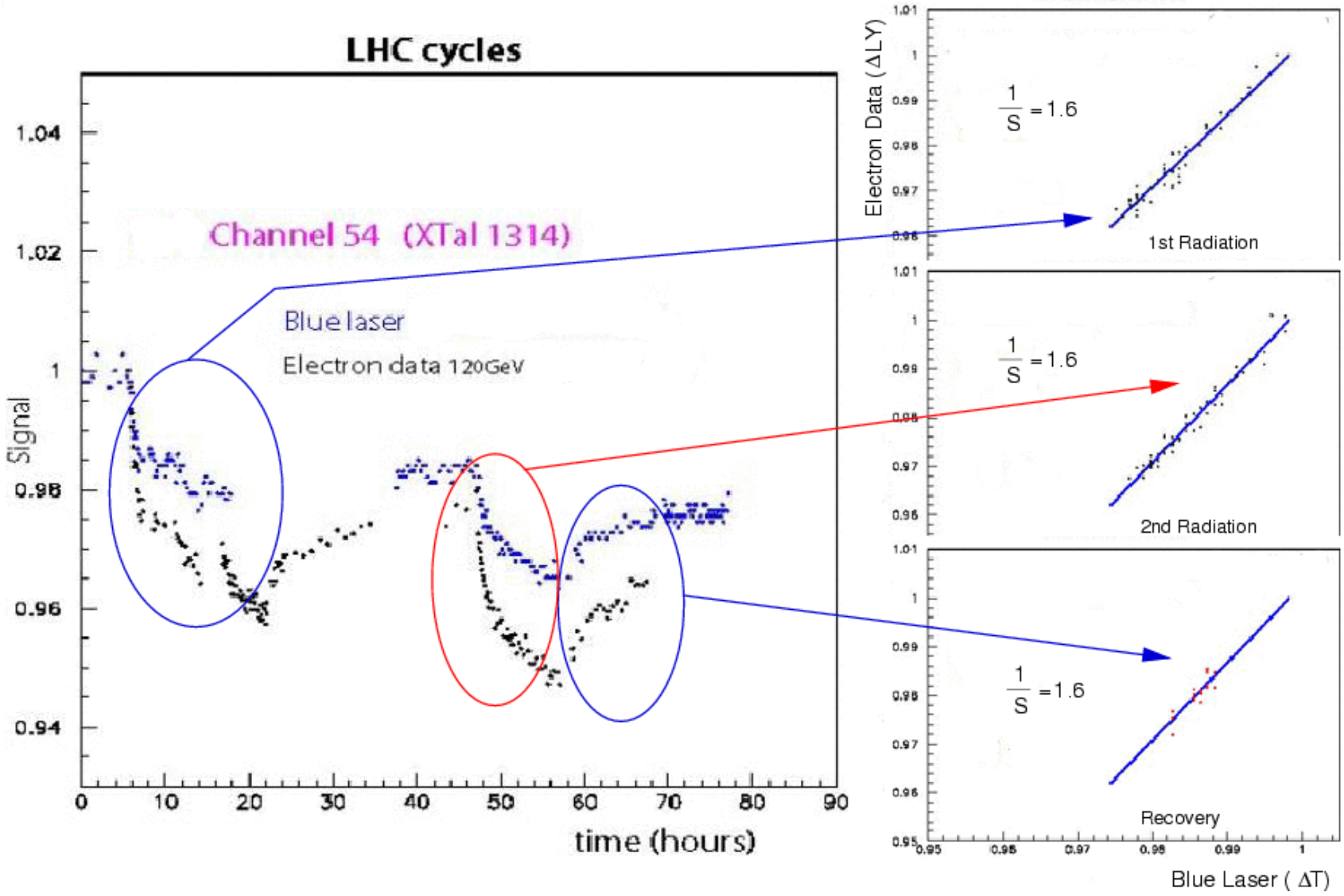
⇒ In general 440nm/800nm better than 495nm/700nm.

⇒Pulse timing jitter is anti-correlated to the pulse energy variations !





Laser Monitoring Application



Tracking damage and recovery with laser light

Summary

- A laser based monitoring light source for CMS PWO crystal calorimeter was designed and constructed at Caltech, and installed and commissioned at CERN.
- An Acqiris DP210 card of 2 GS/s was added in 2004 to provide pulse energy and FWHM information for each pulse.
- The system performance at 440 and 800 nm reached or exceeded the original design specifications.
- Detailed studies are underway to understand the ultimate performance of the CMS ECAL monitoring and systematic effects.

PWO Resolution With Light Monitoring

Nucl. Instr. Meth. **A 412** (1998) 223

Before/after beam irradiation: 10% variation in light output