DRAFT

The CMS ECAL Laser Monitoring System

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Astroparticle, Particle, Space Physics, Detectors and Medical Physics Applications

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Introduction

CMS is building a high resolution Crystal Calorimeter (ECAL) to be operated at LHC in a very harsh radiation environment.

⇒ Talk by P. Bloch (Monday)

Calibrating and maintaining the calibration of this device will be very challenging.

Hadronic environment makes physics calibration more challenging.

⇒ Talk by P. Meridiani (talk today)

PWO Crystals change transparency under radiation.

The damage is large (few % - typically ~5 % for CMS ECAL barrel radiation levels) compared to the desired constant term (0.5 %).

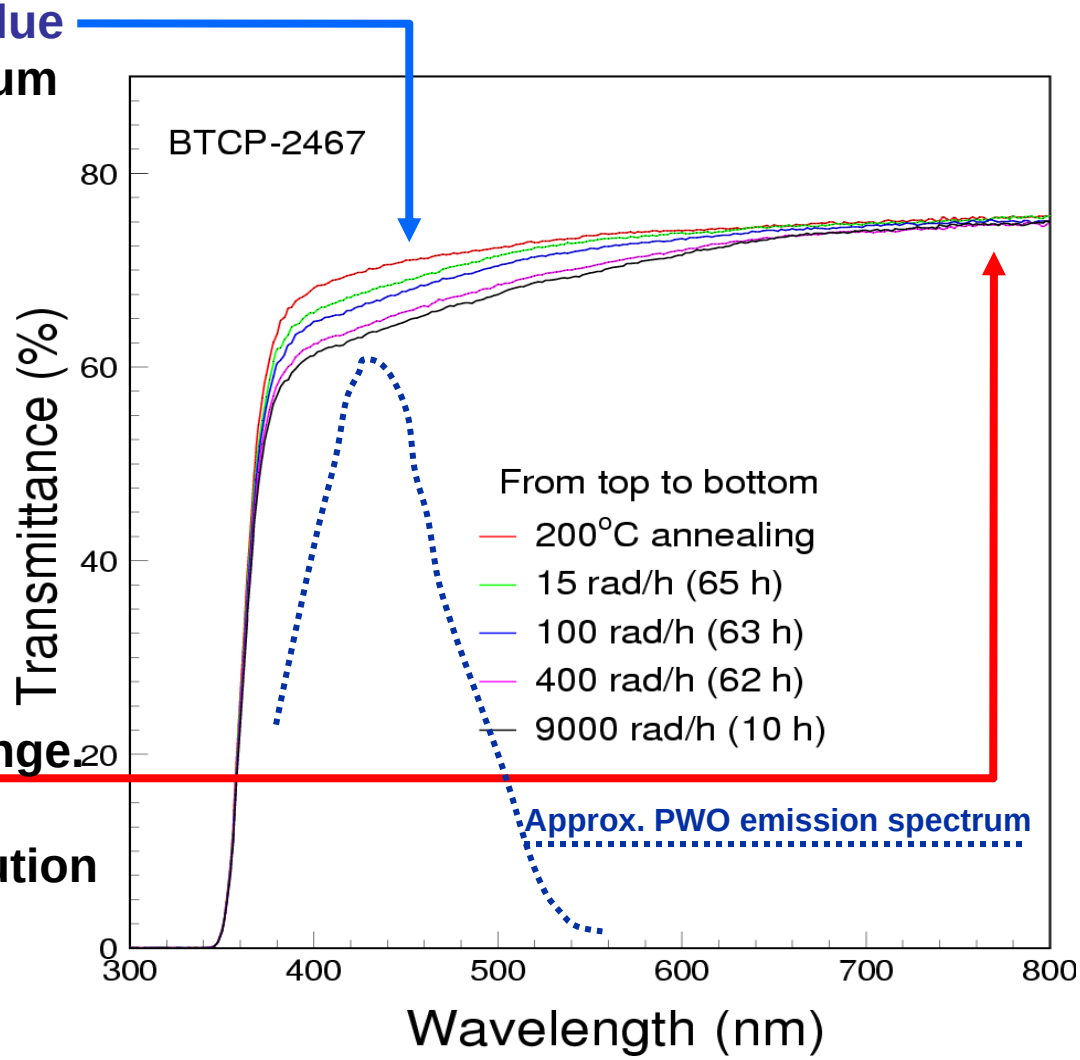
The dynamics of the transparency change is fast (< 1h) compared to the time scale needed for a calibration with physics events(weeks - month).

⇒ Compensate this by monitoring the change with a lase monitoring system

Radiation Effects on PWO Transparency

- Radiation Reduces transmittance in the blue and green, peak of PWO emission spectrum
- Effect is dose rate dependent.
- Monitoring relative loss of PWO transmittance with pulsed laser light.

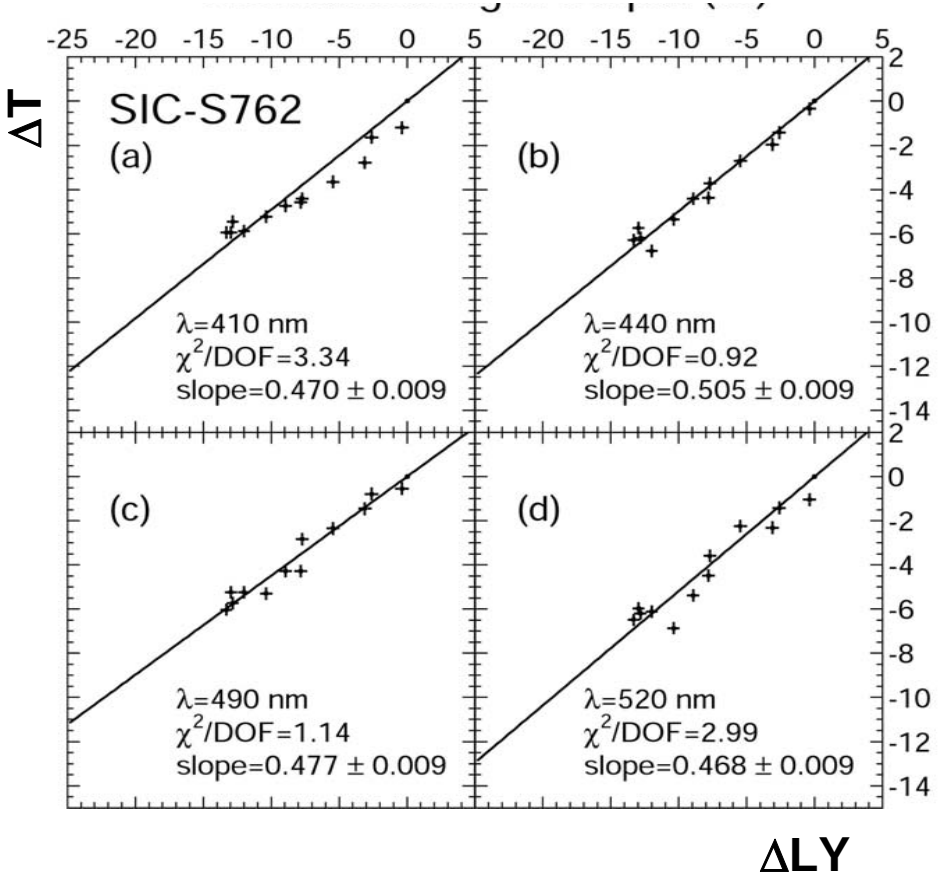
For the expected dose rate at CMS barrel (15 rad/hour), transmittance loss is at a level of ~5%.



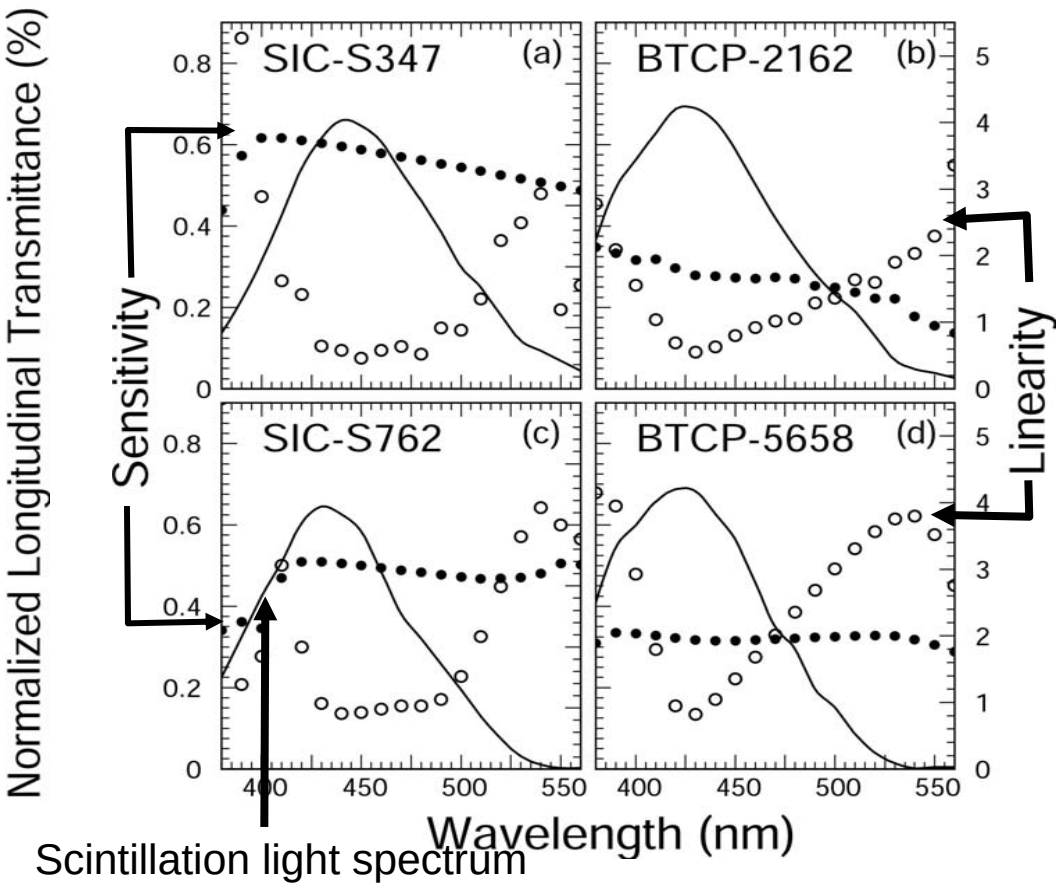
- Almost no effect in the red wavelength range.
- Monitor with red light to separate out possible variations in the light distribution system and the readout chain.

Choosing Optimal Monitoring Wavelength

Δ Transmission vs. Δ Light Yield



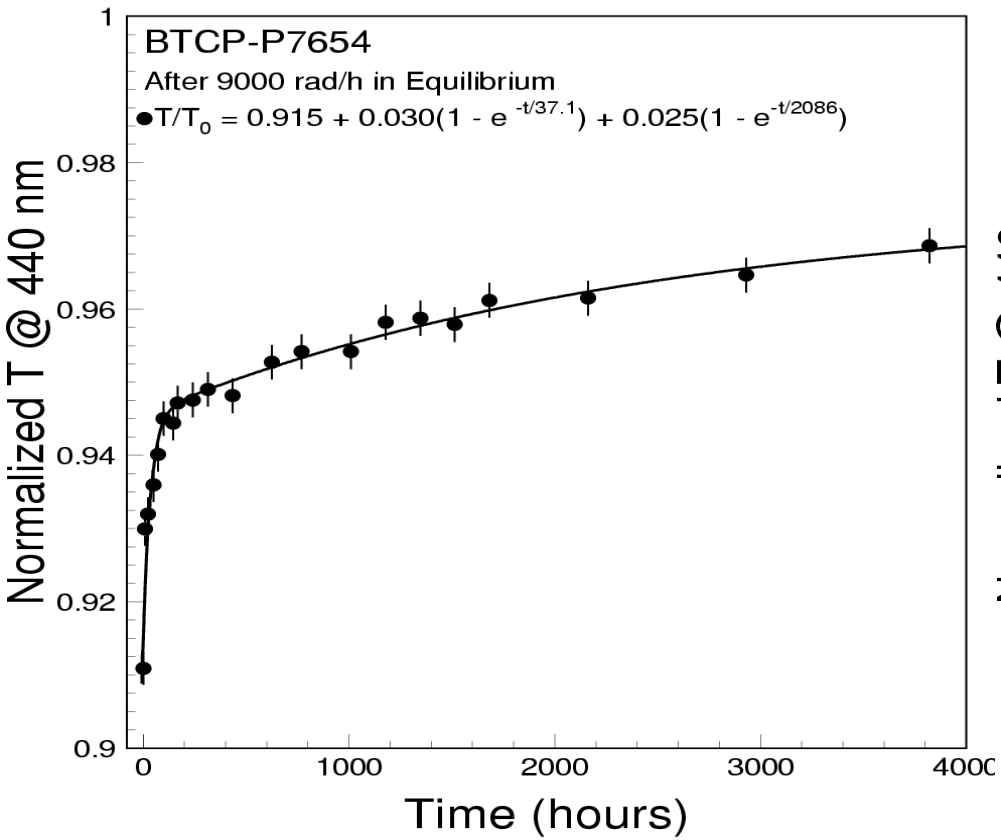
Sensitivity and Linearity vs. Wavelength

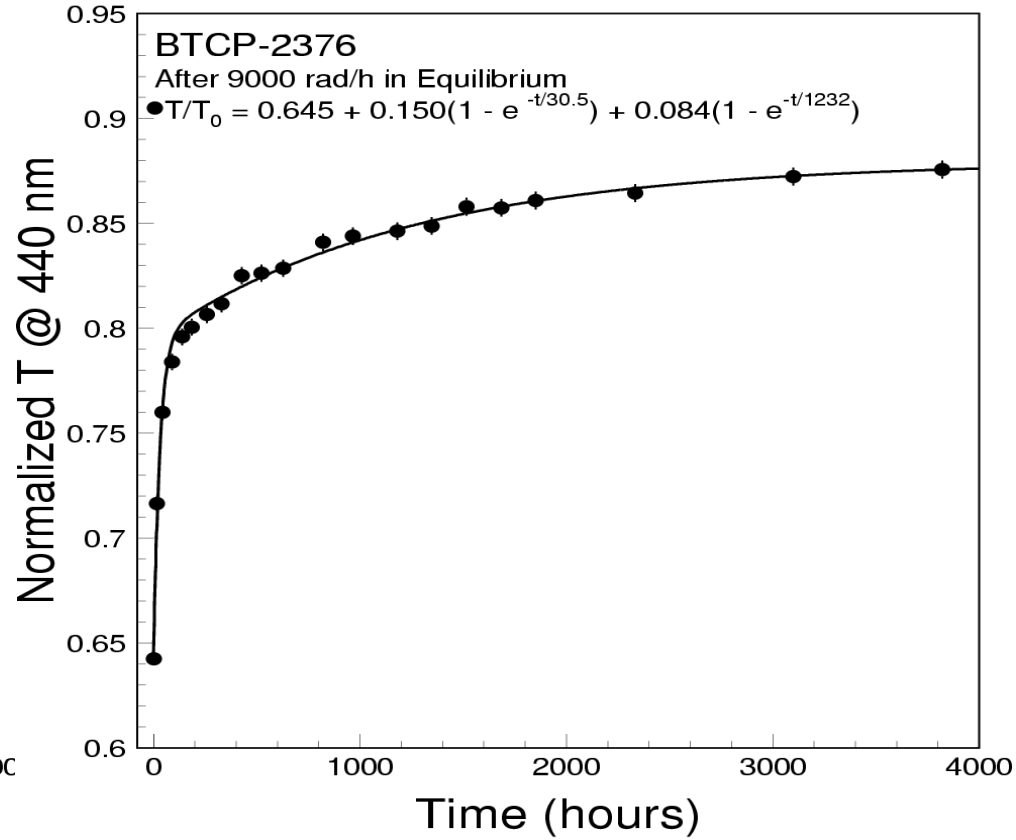


⇒ For best linearity 440 nm is chosen to monitor radiation damage

For red/infrared laser : optical fiber transmittance, APD, electronics cross check

PWO Recovery Kinetics

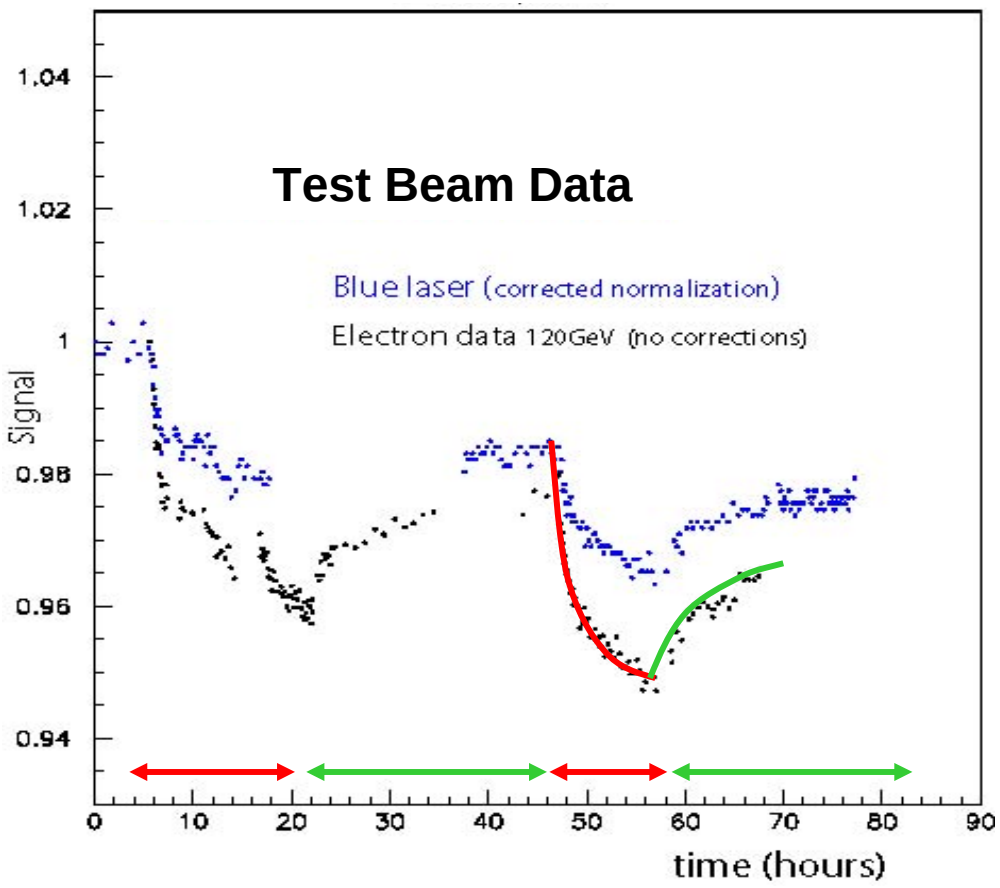


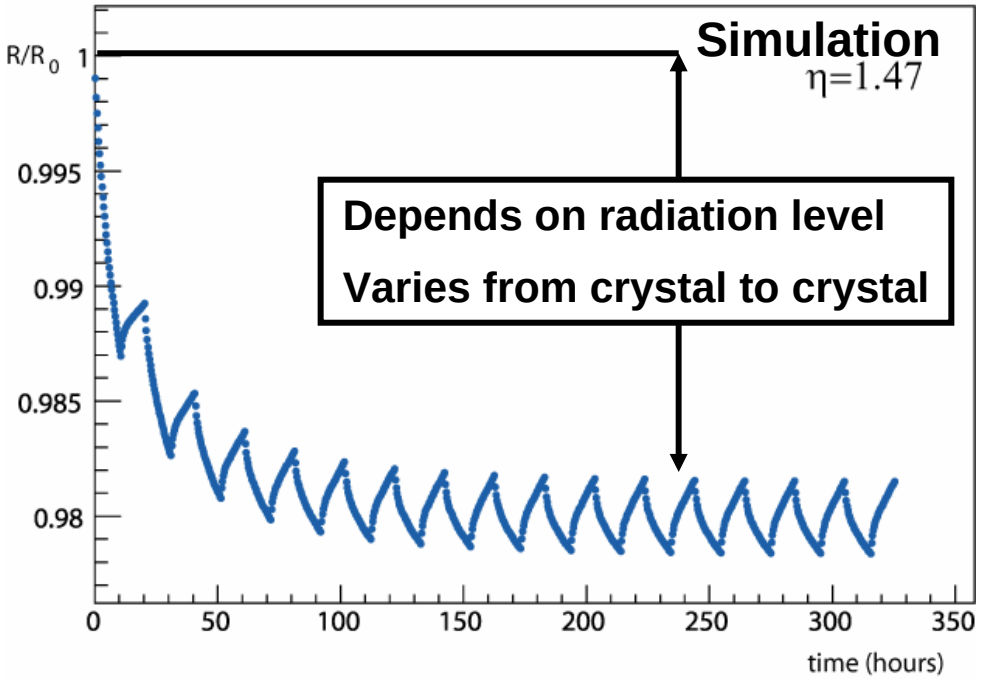


- **PWO recovery can be described with two time constants.**
- **Here, for two BTCP examples : 30h/37 h and ~1,200h/2,000 h**
- **These time constants vary from crystal to crystal.**

⇒ Need to monitor each crystal individually.

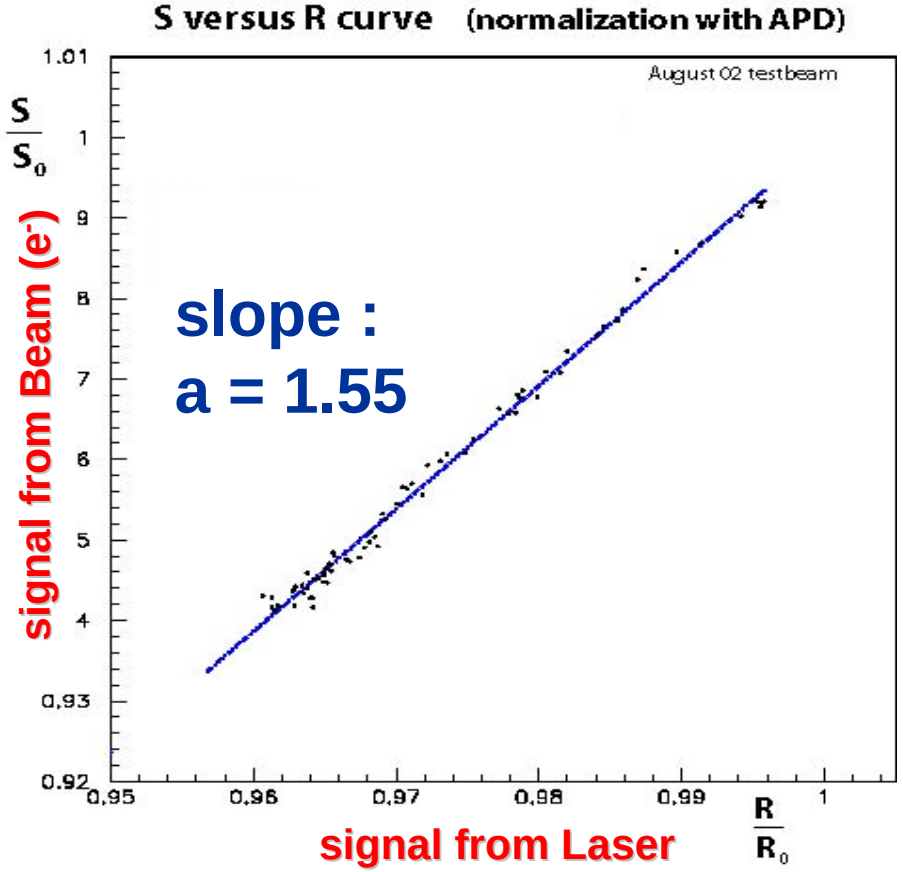
Damage and Recovery in a the 'LHC Cycle'

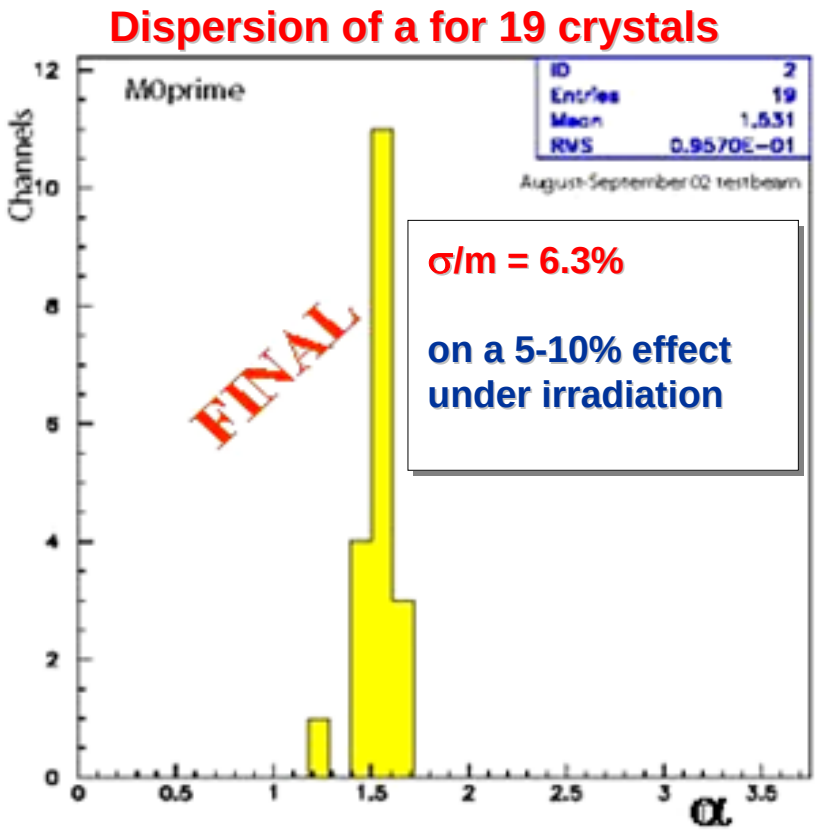




⇒Damage-recovery cycle in sync with the ~12 hour LHC fill cycle

Laser Light Loss – Electron Signal Loss

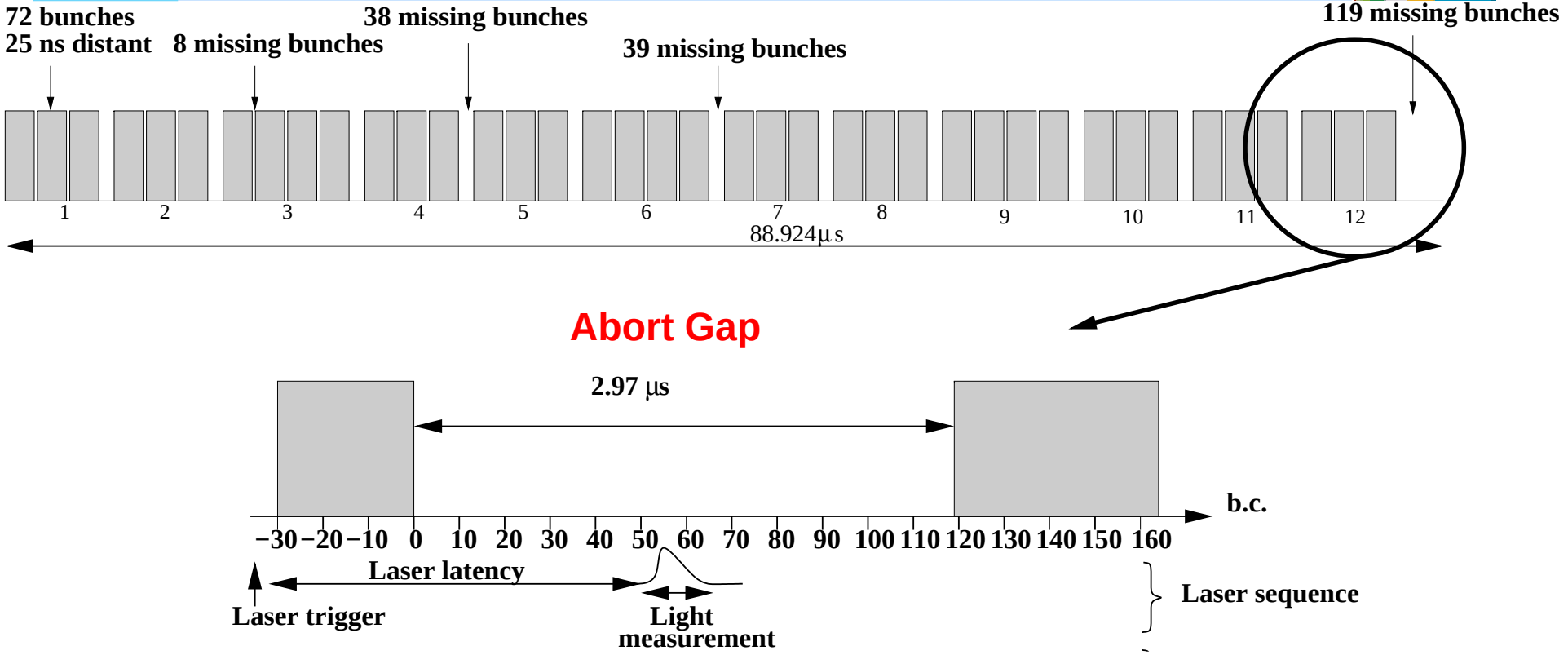




⇒ Use of same a coefficient for all crystals possible !

⇒ Can use same correction parameters for all crystals.

In-Situ Monitoring & LHC Bunch Train



Abort gaps occur at ~10 kHz - Laser pulses at ~100 Hz ⇒ Use ~1% of gaps

⇒ Scan entire ECAL every 20 minutes

Laser Source Requirements

- **Pulse Energy : 1.0/0.6 mJ at 440nm/495nm**
  Enough light to flash several hundred crystals at a time trough a multi level light distribution system.

- **Pulse Energy Stability: ECAL specification < 10 % RMS**
  Small enough to avoid possible non-linearities in the APD/PN ratio.

- **Pulse Width : ECAL specification < 40 ns**
  Match the 25 ns read out cycle of the ECAL electronics.

- **Pulse Jitter : Pulse timing, long/short term, typically <4 ns / < 2 ns**
  Ensure precise timing in LHC 25 ns cycle.

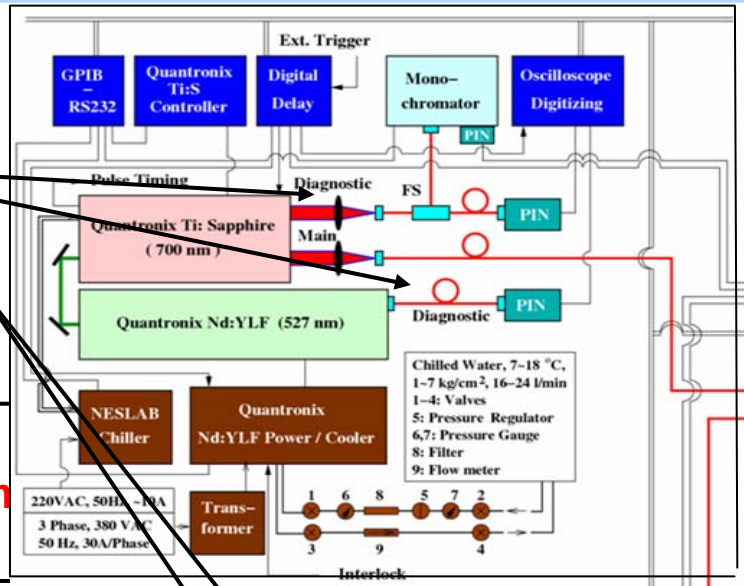
- **Wave Length :**
  440 nm primary wavelength at the PWO emission peak,
  495 nm /800 nm / 700 nm for systematic cross checks.

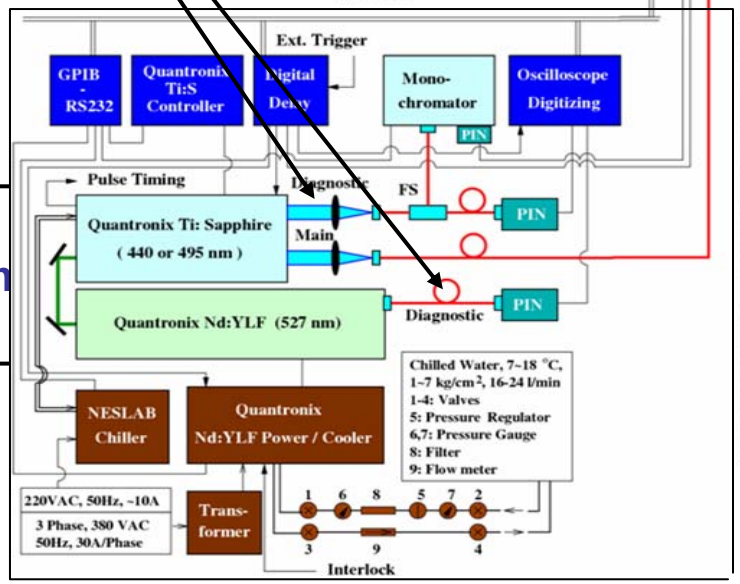
Laser Source Layout for CMS ECAL

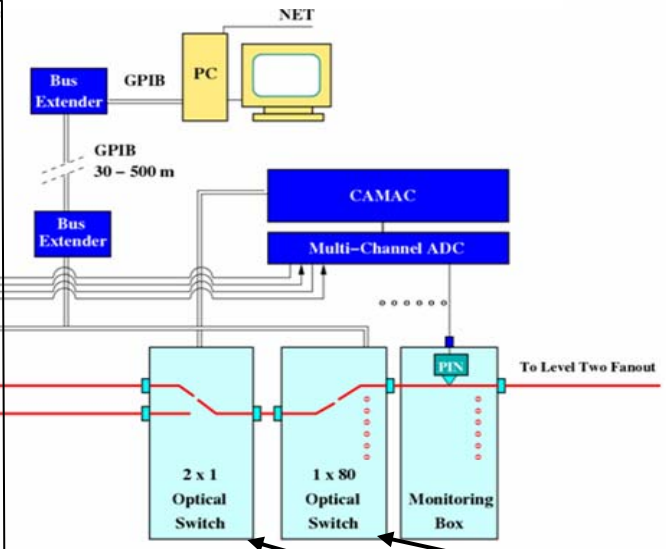
Monitor :
energy, pulse width, timing of pump laser and main laser

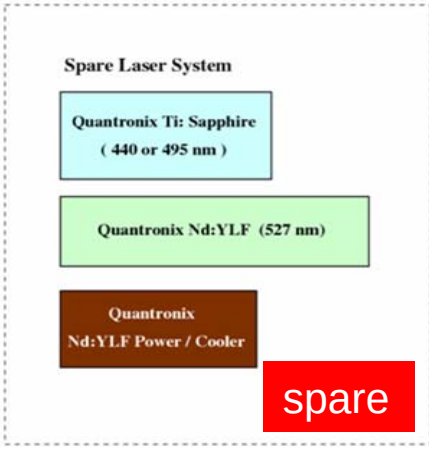
RED Laser:
Provides **700 nm** and **800 nm**

BLUE Laser:
Provides **440 nm** and **495 nm**





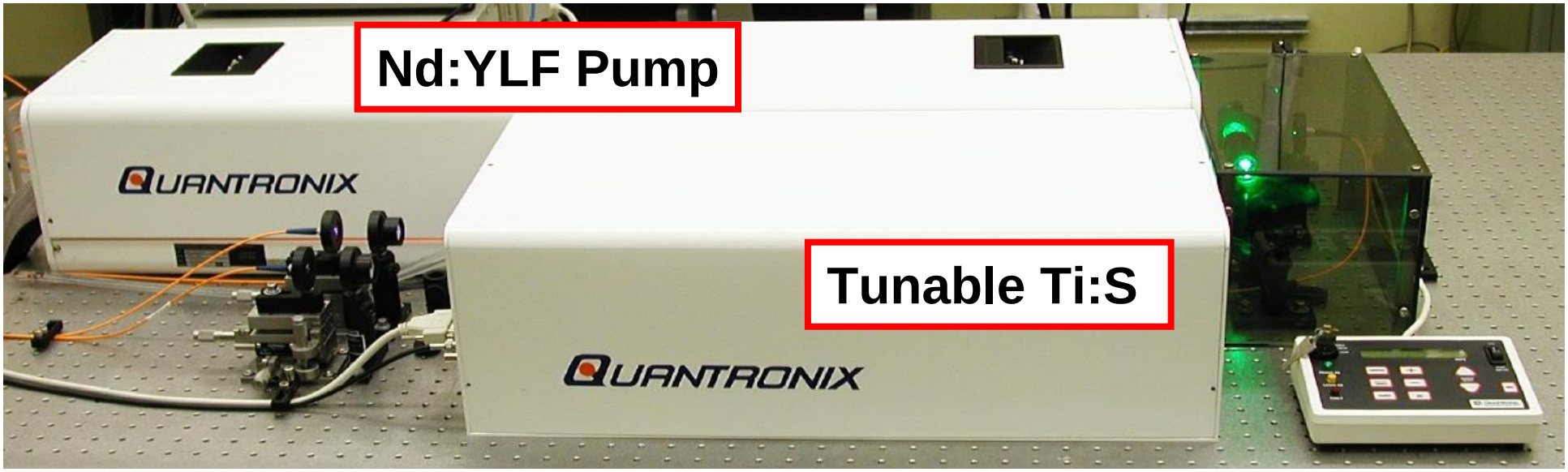


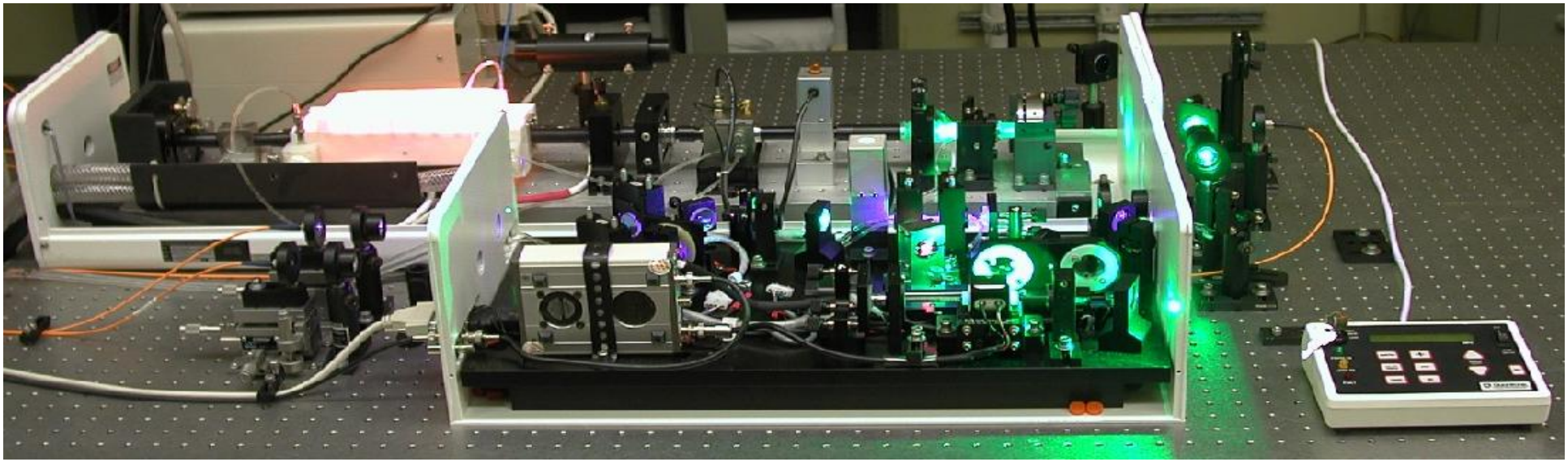


2x1 and 1x80 switch :
2x1 selects red or blue laser,
1x80 switch selects SM

Caltech June 13, 2002

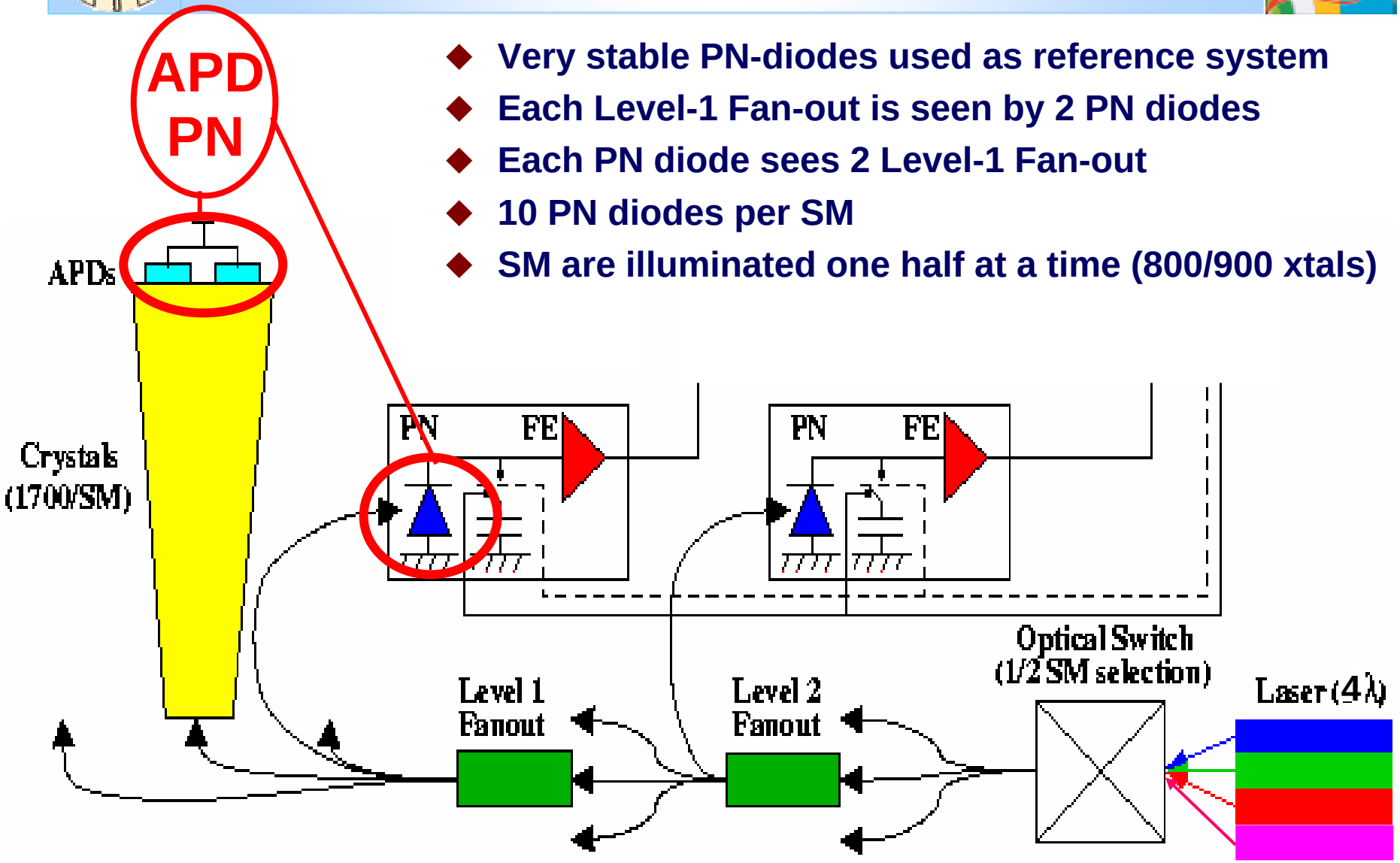
Ti:Sapphire Laser with Two Wavelengths



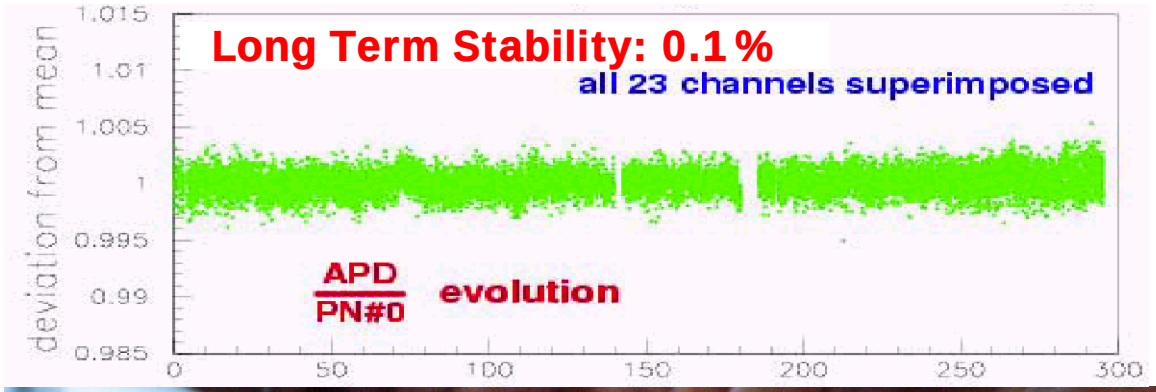


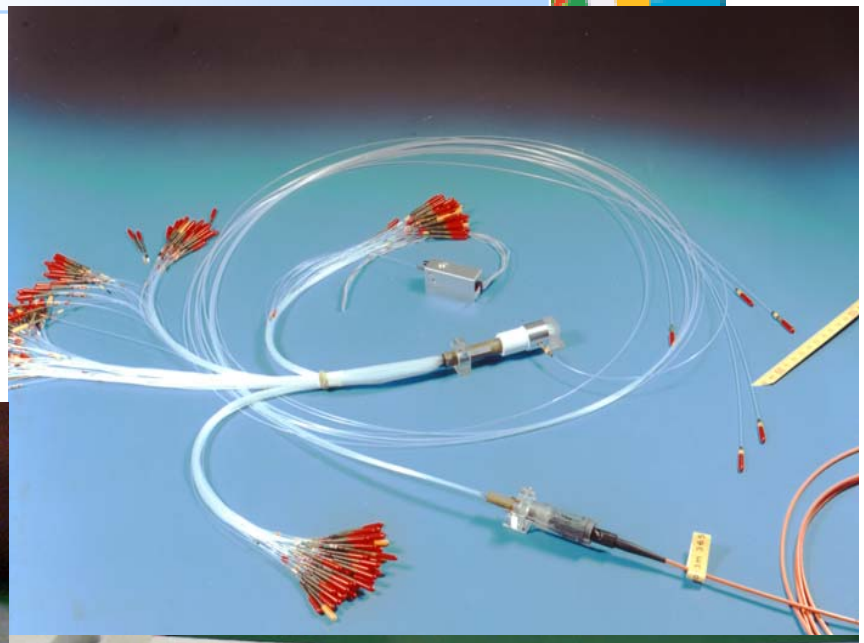
On-Detector Monitoring System

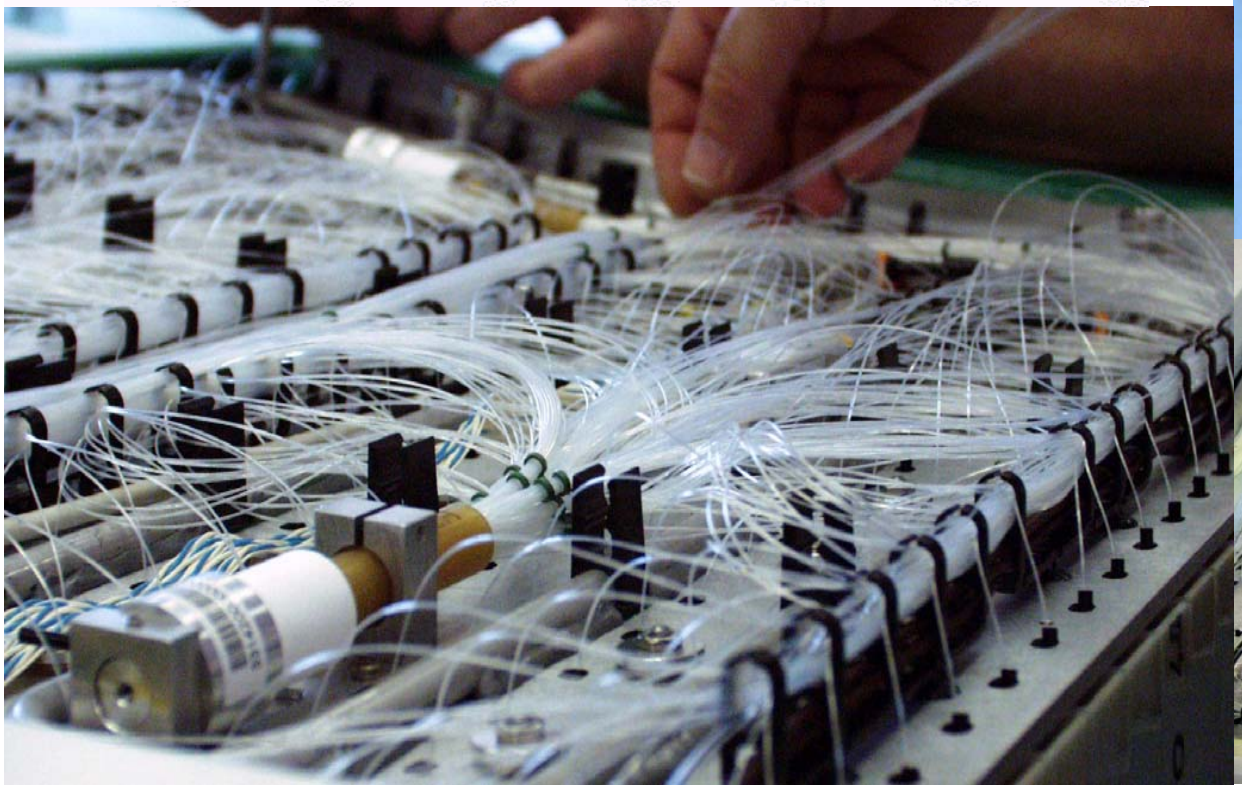
- Very stable PN-diodes used as reference system
- Each Level-1 Fan-out is seen by 2 PN diodes
- Each PN diode sees 2 Level-1 Fan-out
- 10 PN diodes per SM
- SM are illuminated one half at a time (800/900 xtals)

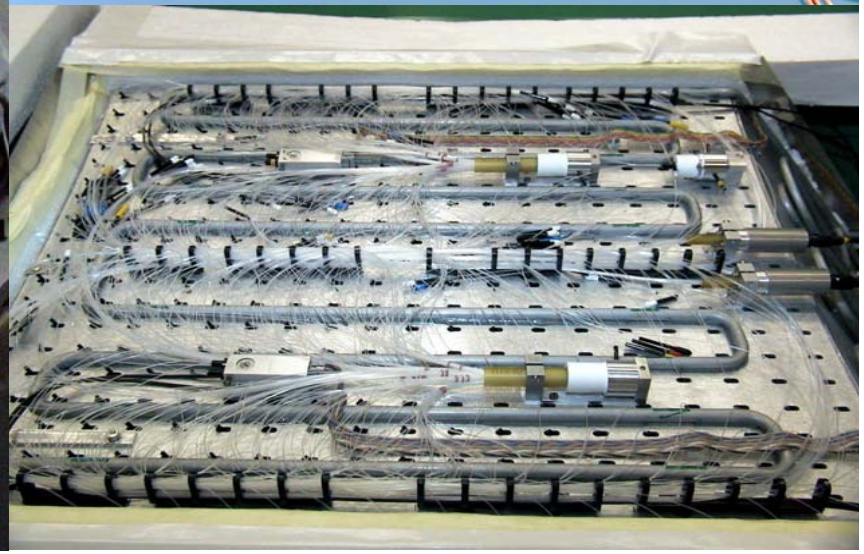


Light Distribution System



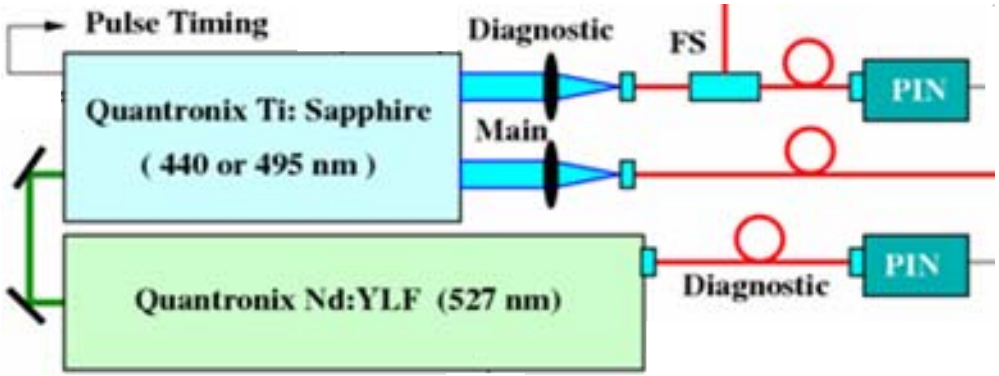


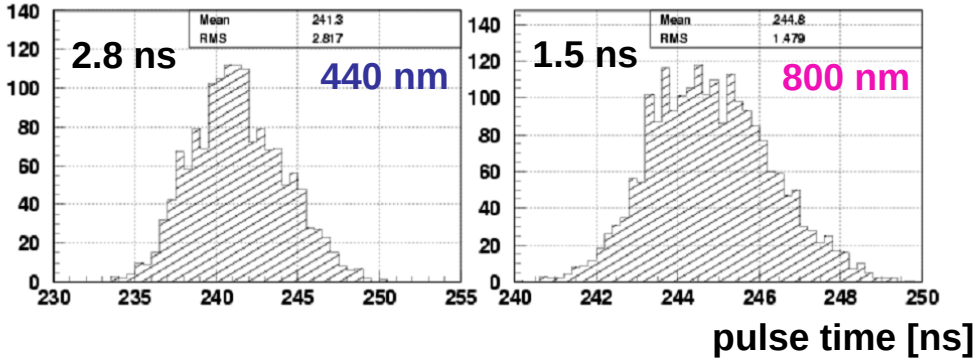


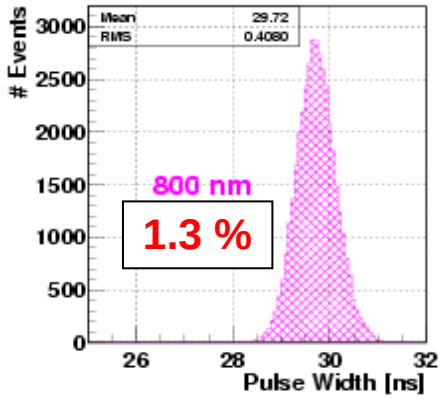


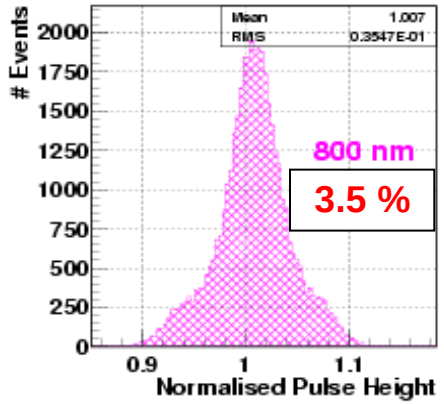
Laser Source Monitoring

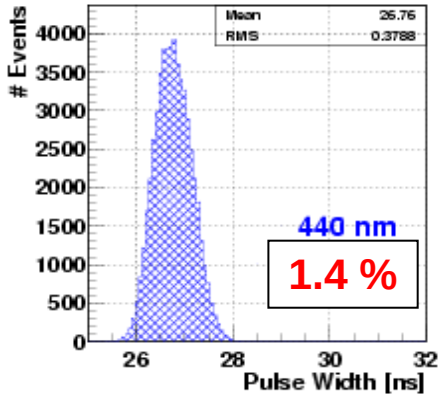
Each laser has a monitor output which allows to adjust and monitor its performance of pulse energy, pulse width and pulse timing.

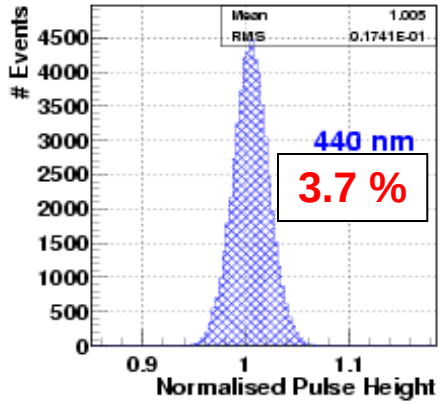








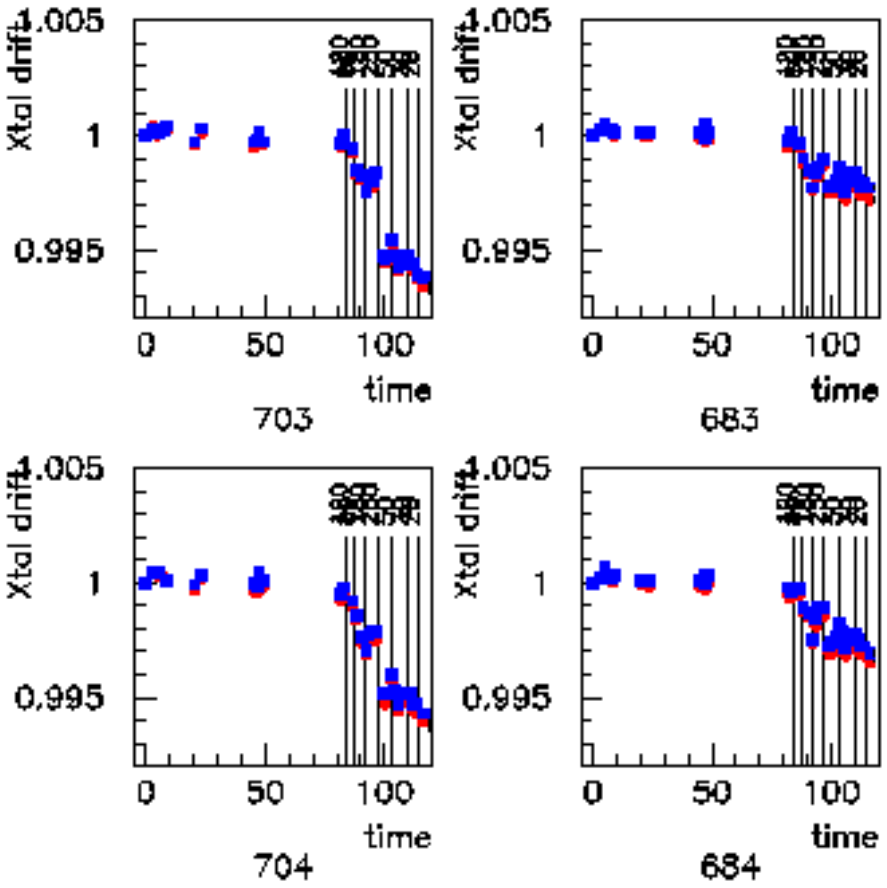


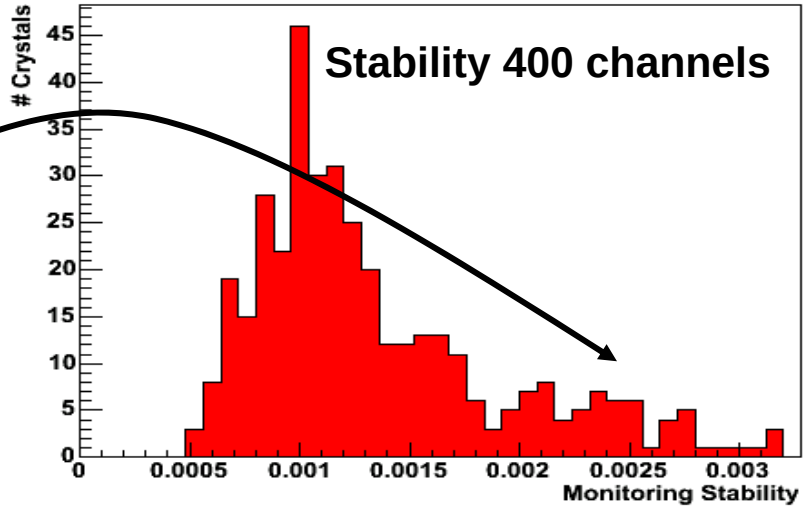


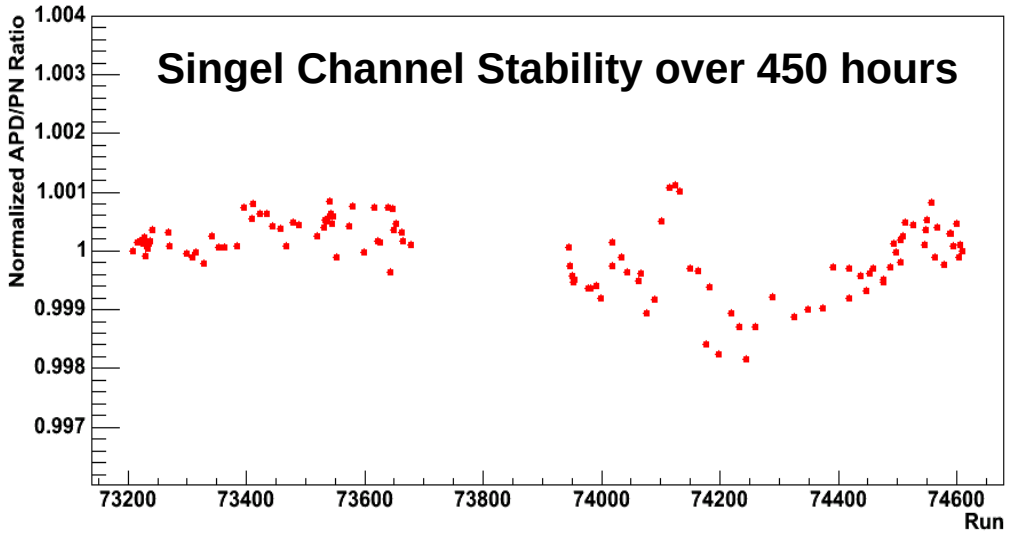
⇒ Stability typically a few percent / few ns.

Monitoring System Performance

Transparency change during calibration



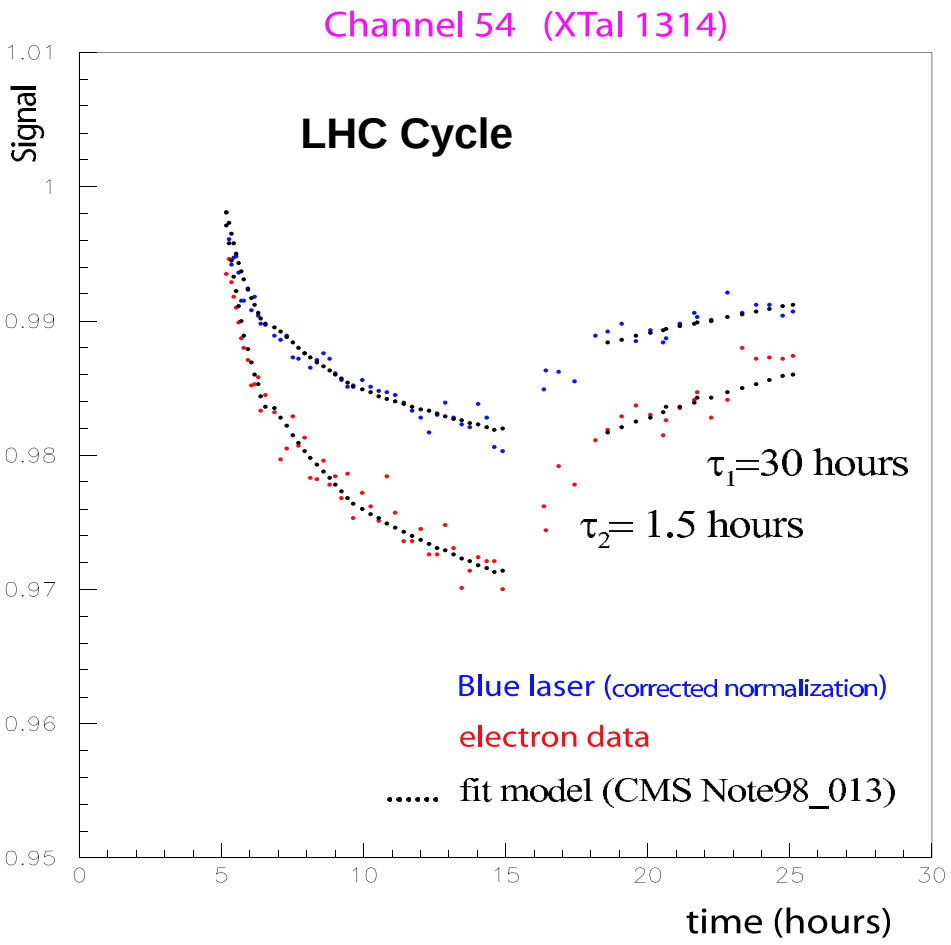




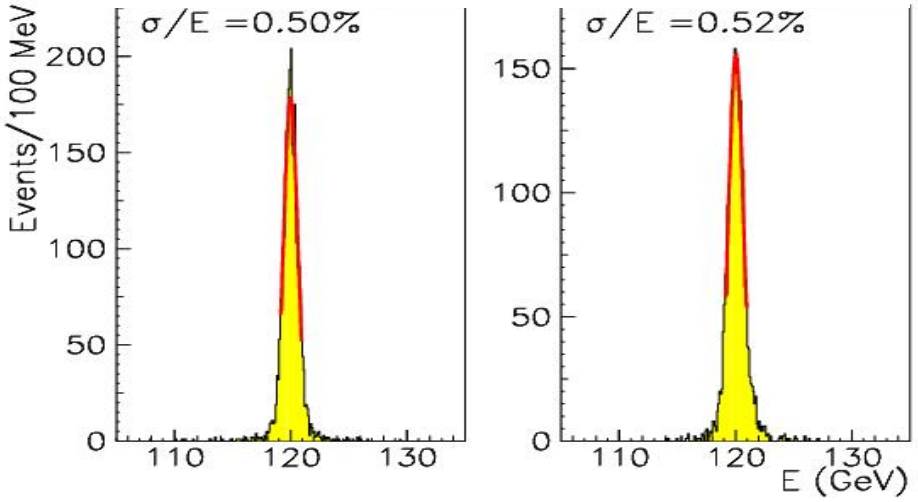
⇒Typically ~0.1 % long term stability in real environment

Laser Monitoring Performance

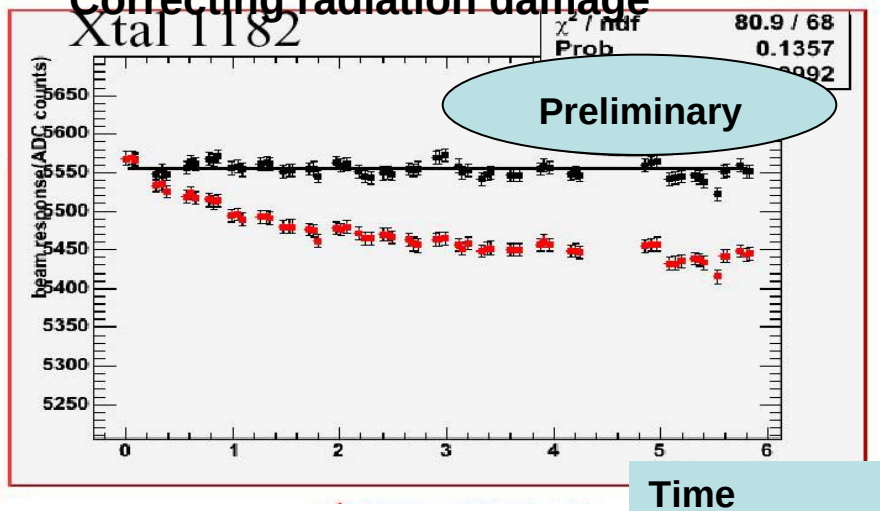
Tracking damage and recovery with laser light



Resolution before and after irradiation



Correcting radiation damage



Summary

- **Final design Laser Monitoring System has been installed and tested over several thousand hours at the test beam.**
- **All performance criterions have been achieved.**
- **Now, installation and comissioning the entire system next challenge. After that, operating the system over 10 years and follow the crystal transparency on the level of 0.1%.**