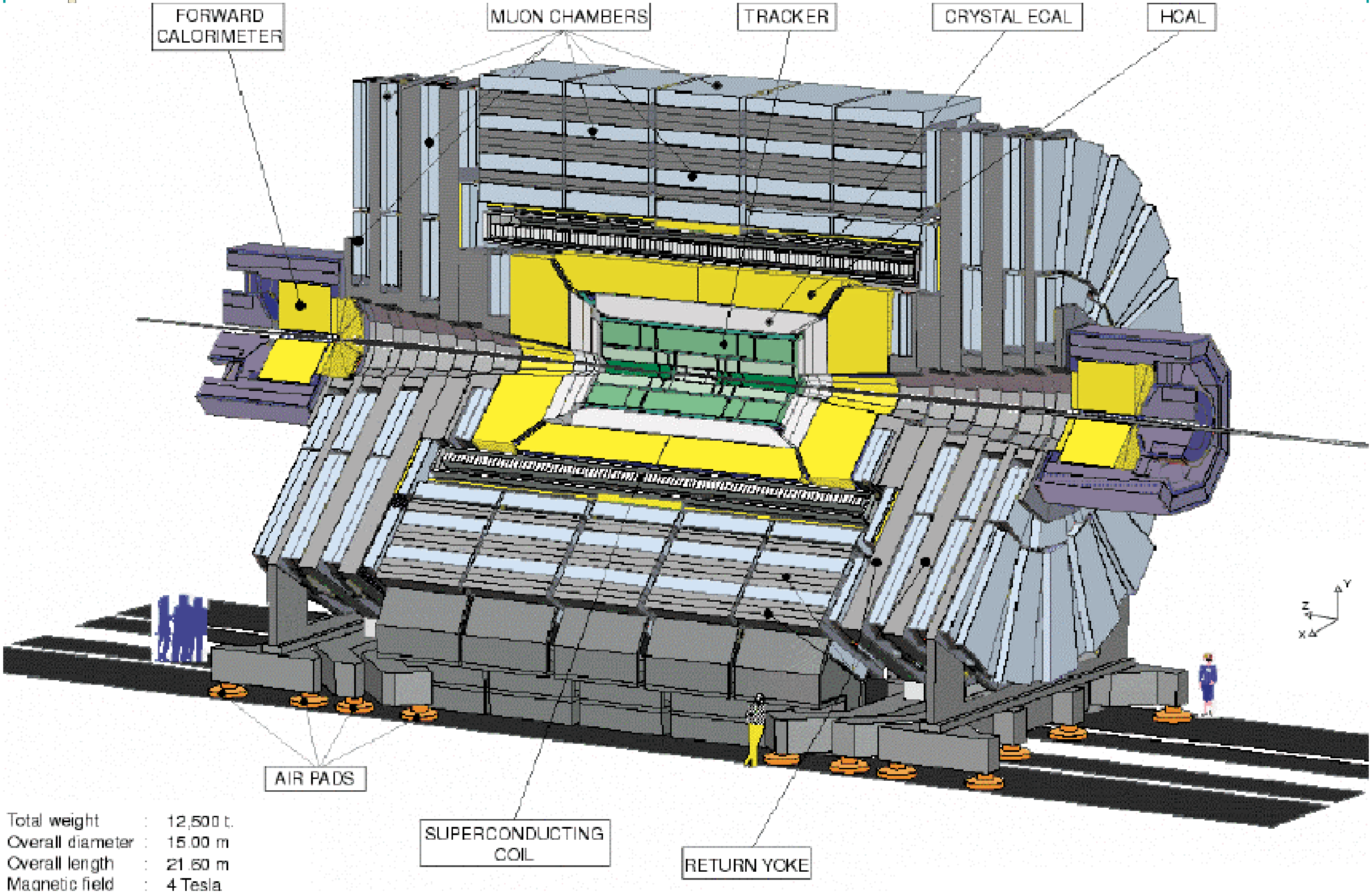
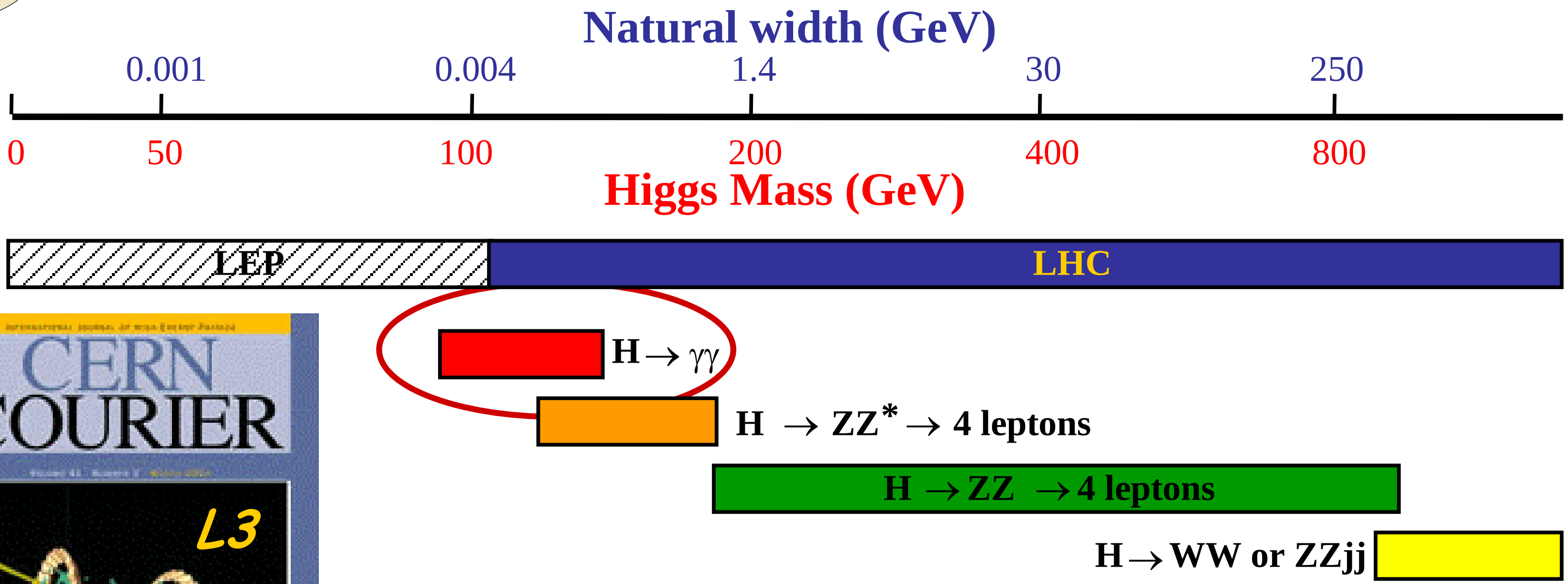
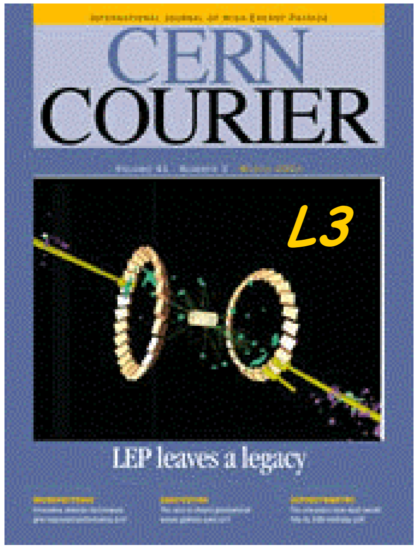
Precision CMS PWO Crystal ECAL

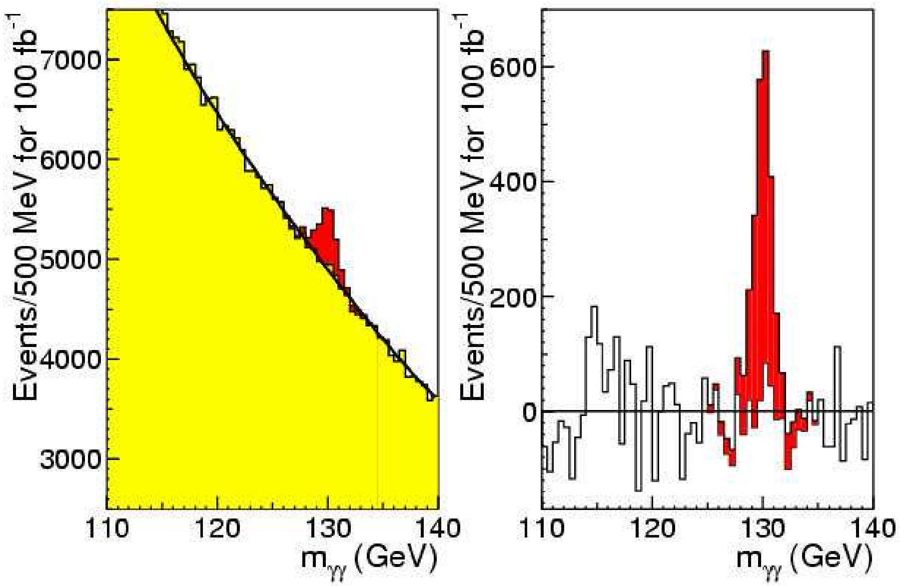


Higgs Hunt at Low Mass



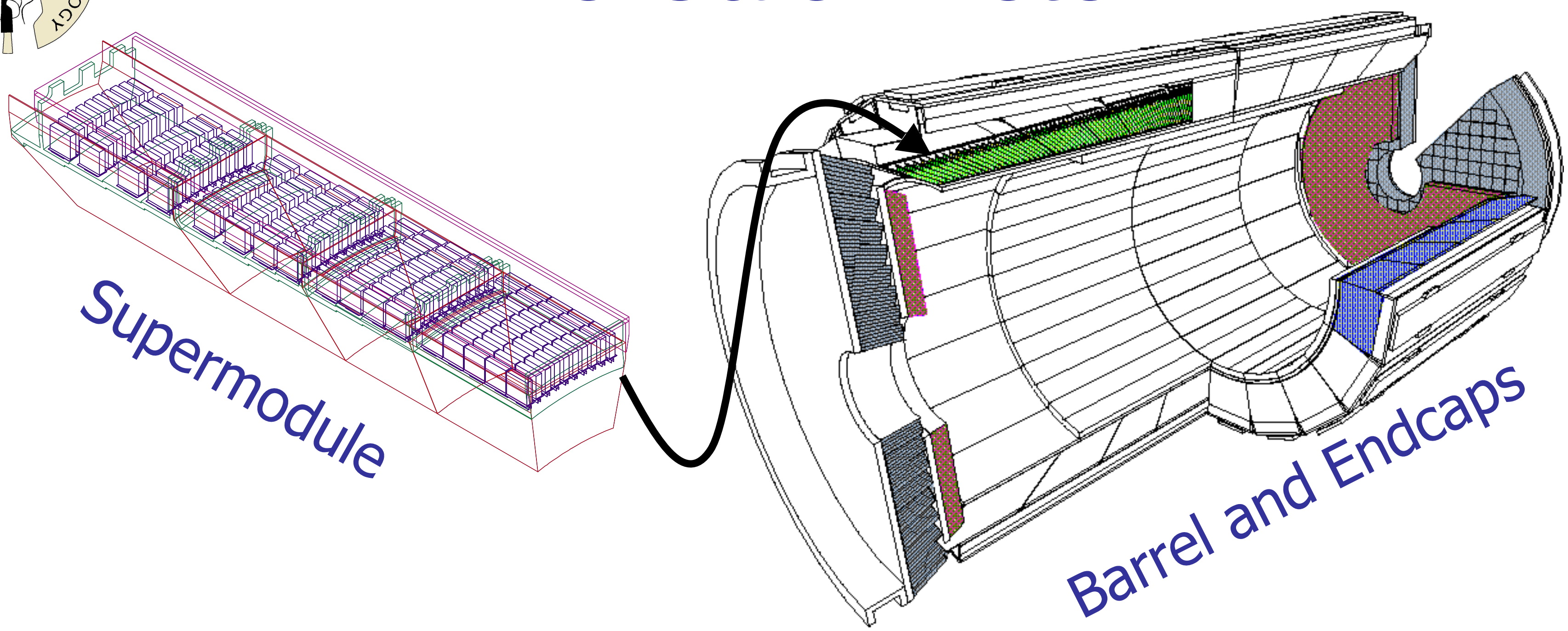


LEP observed an excess of events around 115 GeV



H →γγ signal in CMS ECAL @ design resolution

The Calorimeter



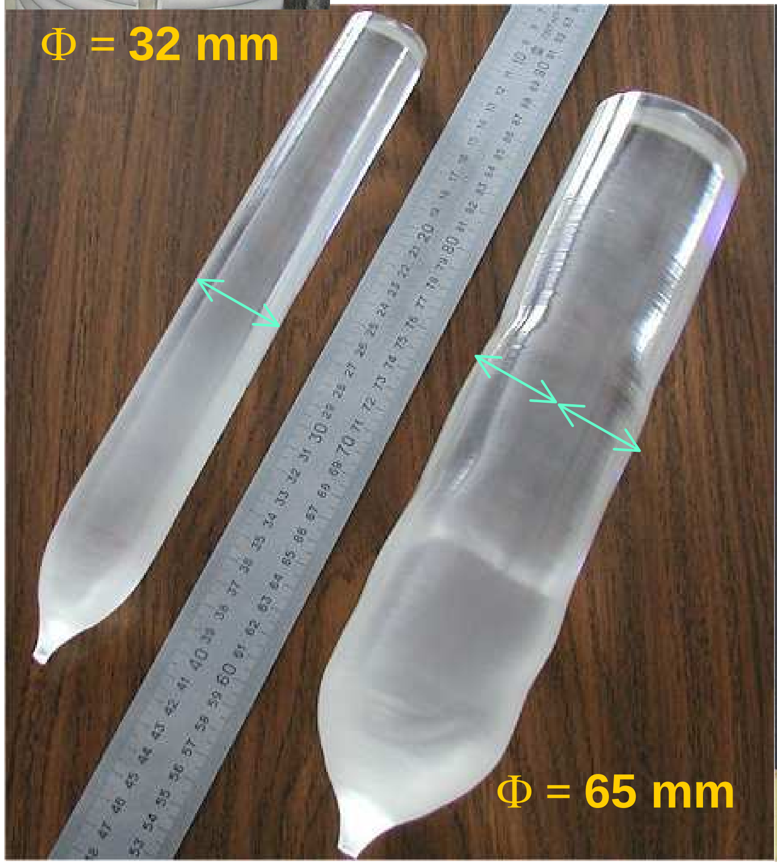
- 36 SMs (1.7k ch) in barrel, 4 Dees (3.5k ch) in endcaps.
- 62k crystal in barrel, 14k crystal in two endcaps. (N5-6)
- 2 APD's/crystal @barrel, 1 VPT/crystal @endcaps.(N32-2)
- 1 monitoring fiber/crystal for *in situ* monitoring.
- Electronics: 0.25 μm ASIC, ESR in October, 2003.(N36-11)

PWO Crystals Growth

32 to 65 mm at BTCP by Czochralski

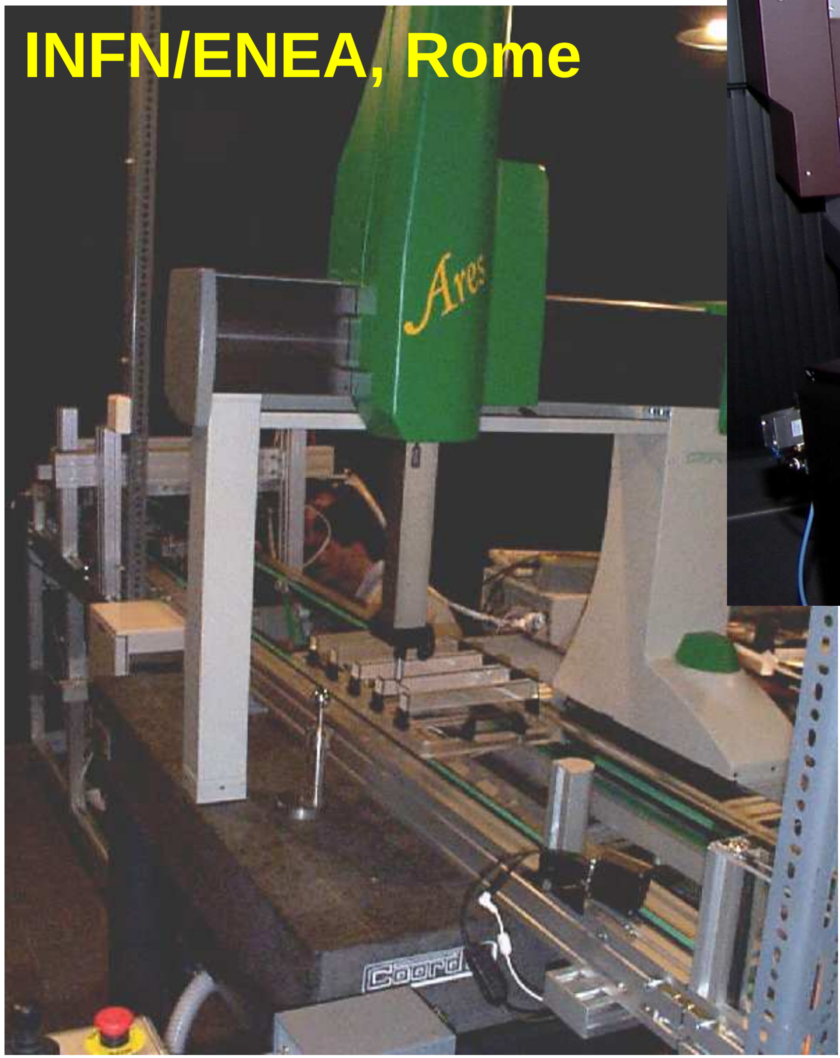
Mass Production for CMS: 2 in one

20k delivered; Complete: Q4, 2005



PWO Crystal Quality Control

2 Regional Centers



Automatic control of:

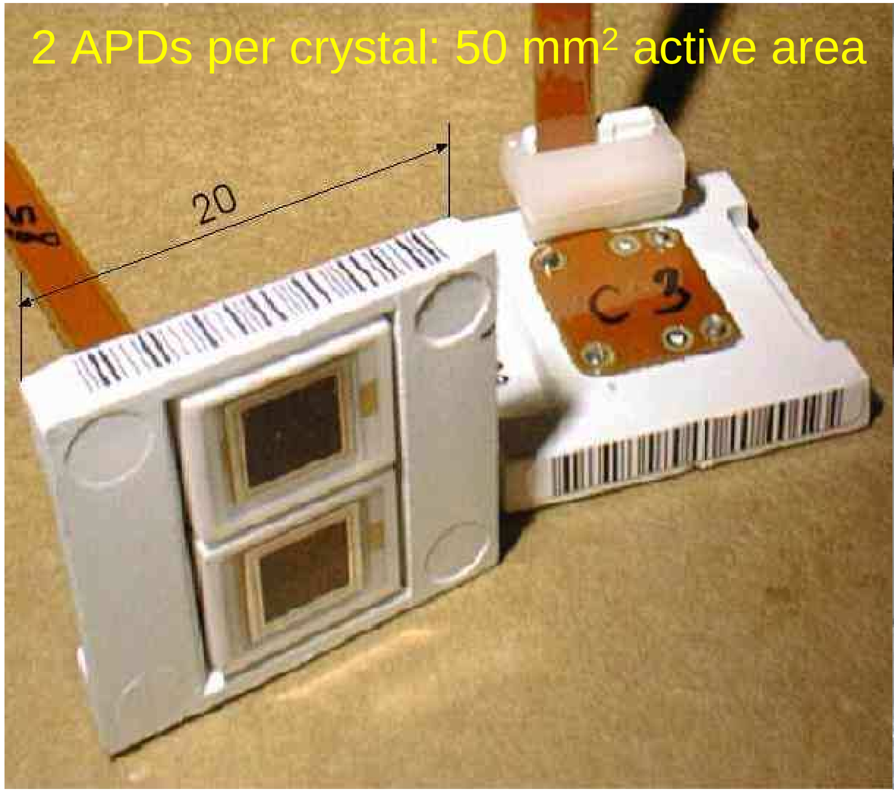
- Dimensions
- Transmission
- Light yield and uniformity

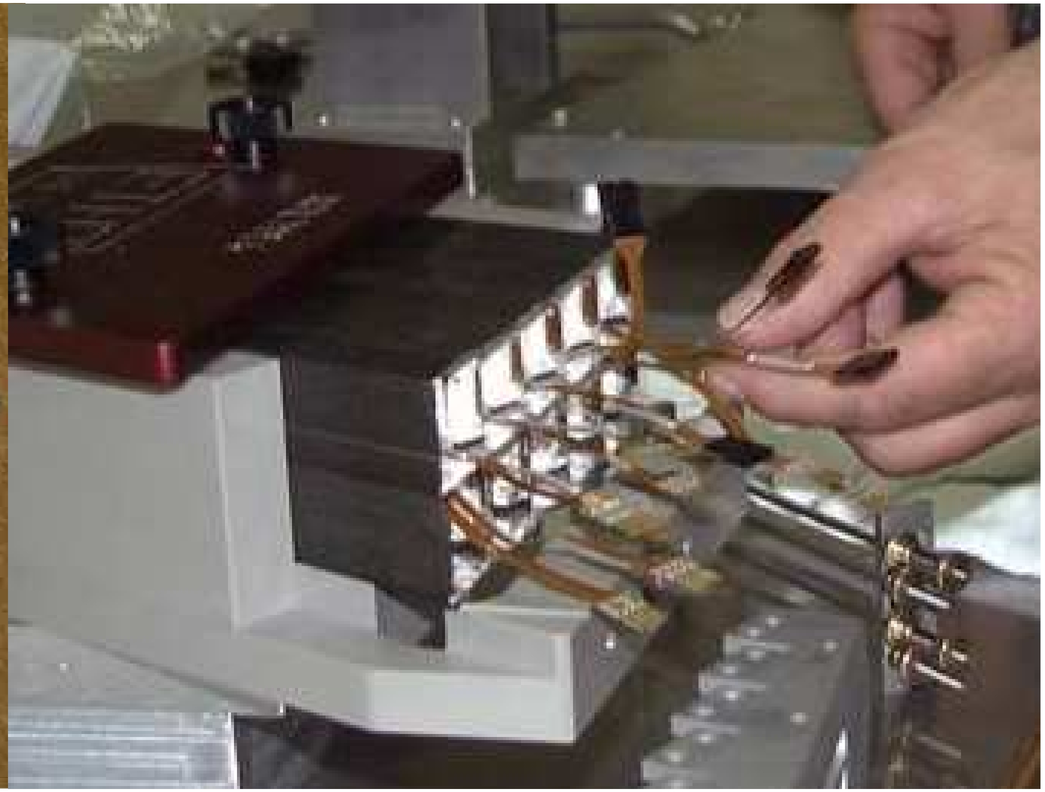
Avalanche Photo Diode (APD)

Delivery will be complete by the end of 2003

QC: ^{60}Co to 5 kGy in 2 h; 80^{o}C aging one month

All test and screening to be complete in April, 2004

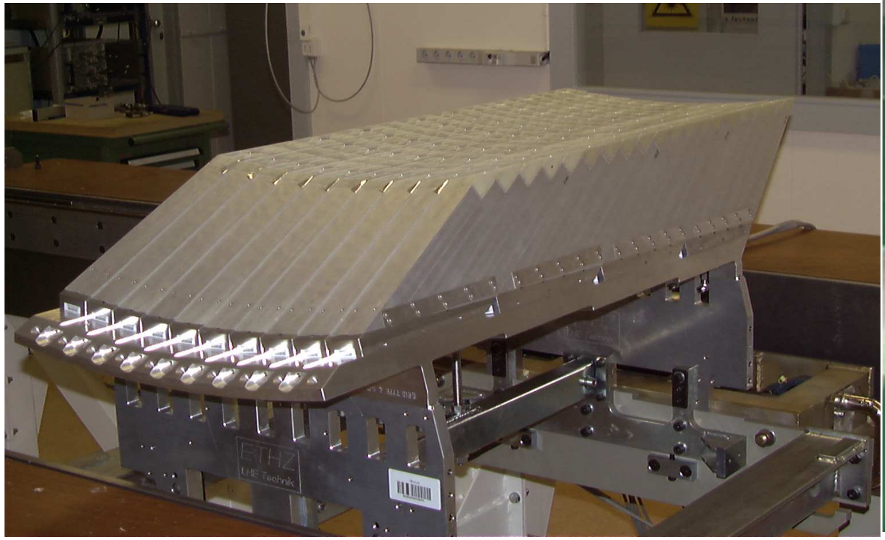




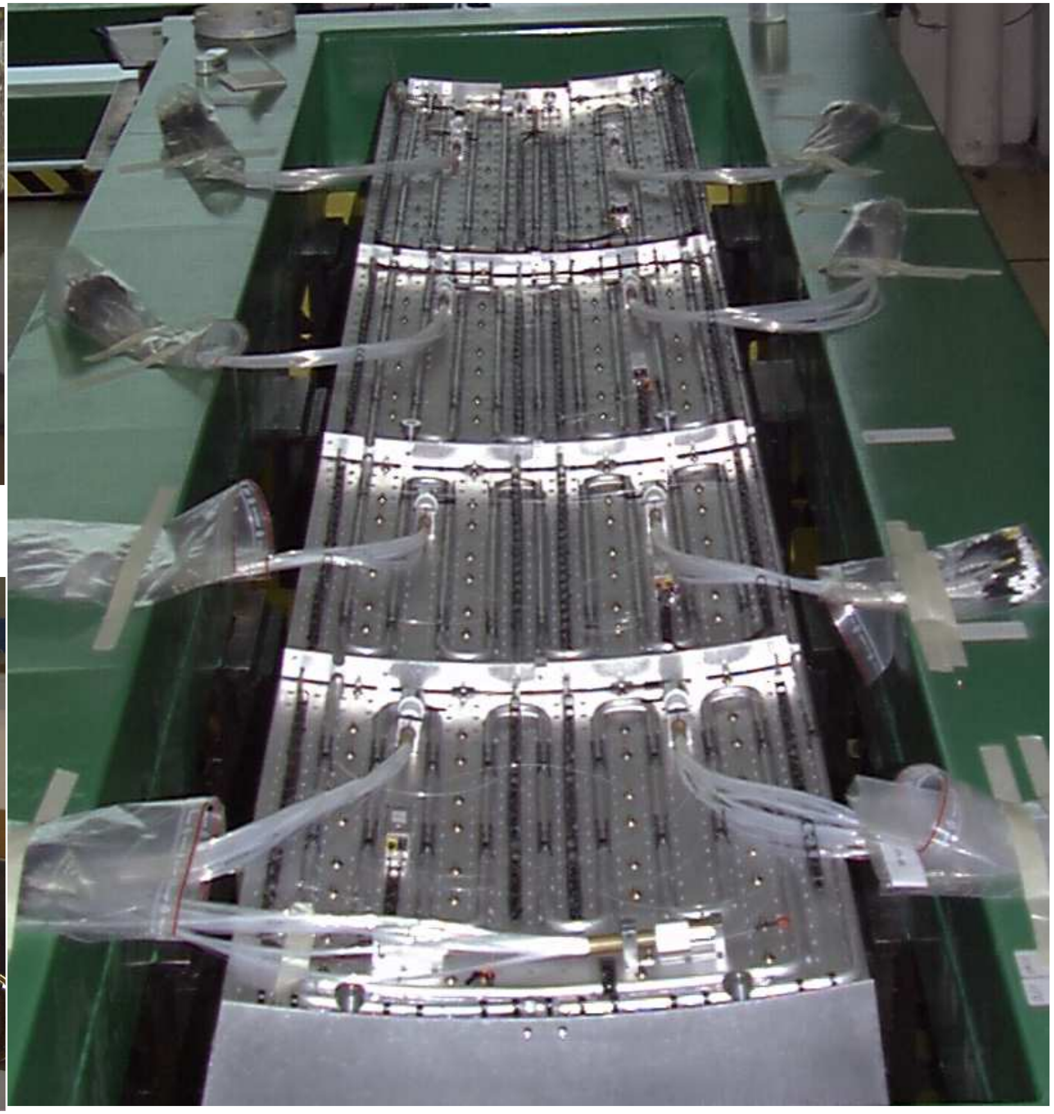
ECAL Module Assembly

Submodule: 10 crystals

Module: 4(5)00 crystals



Supermodule:1,700 crystals

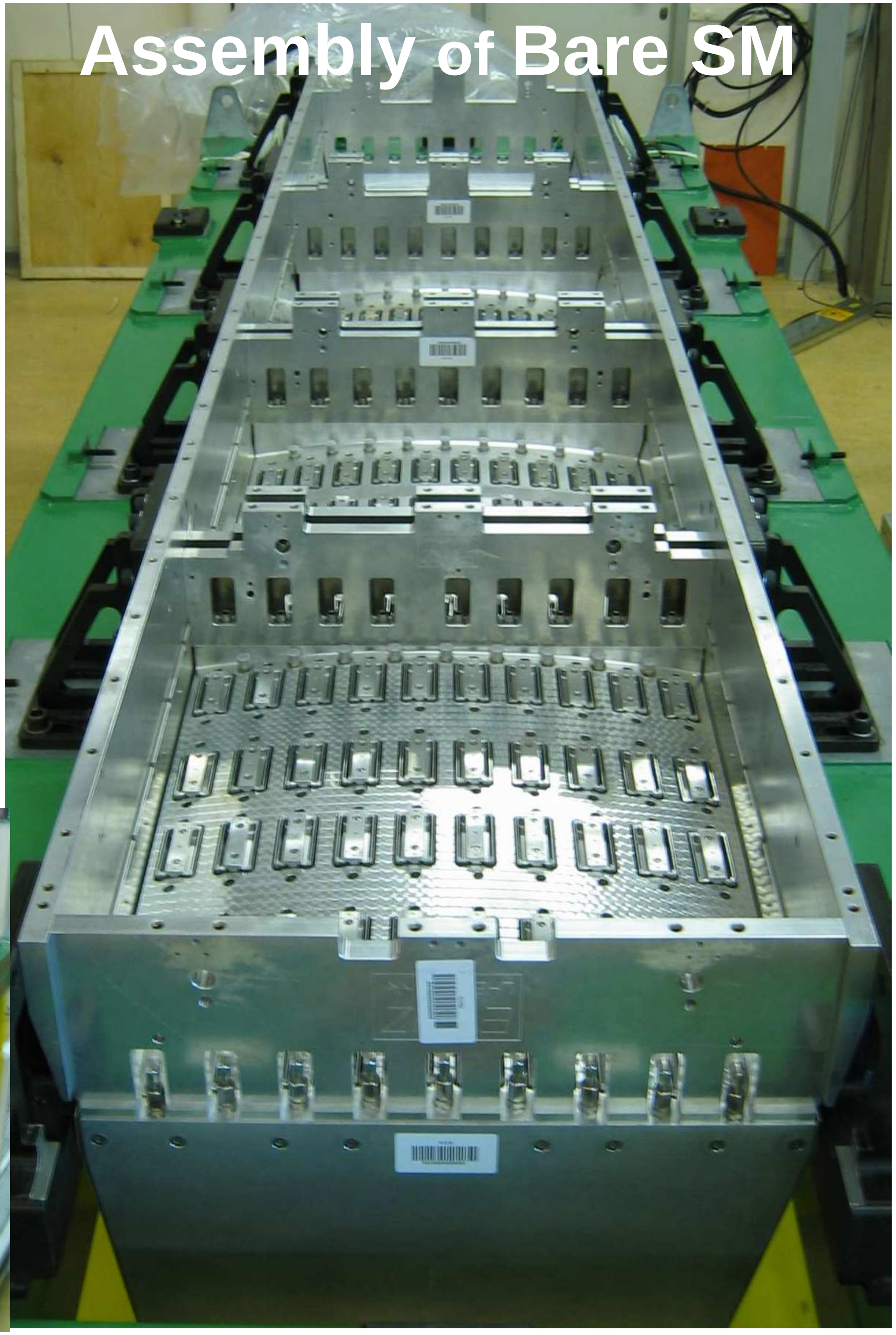


SM Construction

Modules assembled in Rome and CERN centers

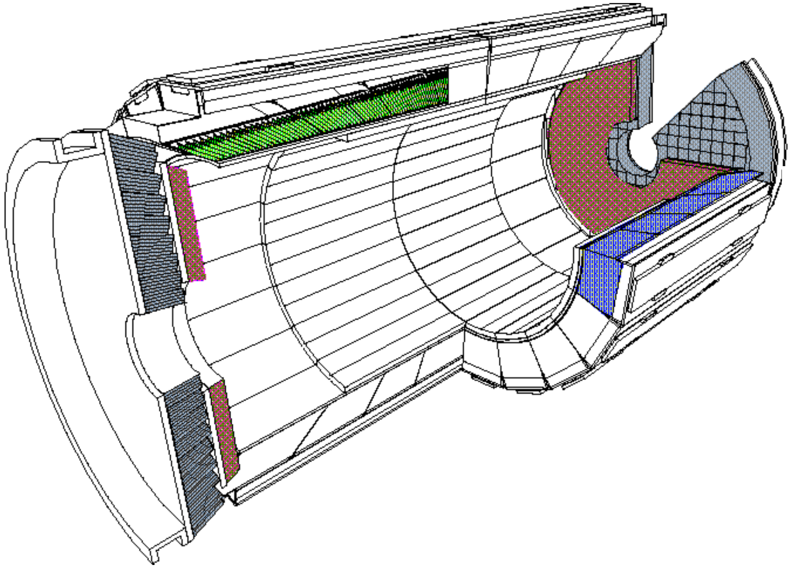
29 modules completed

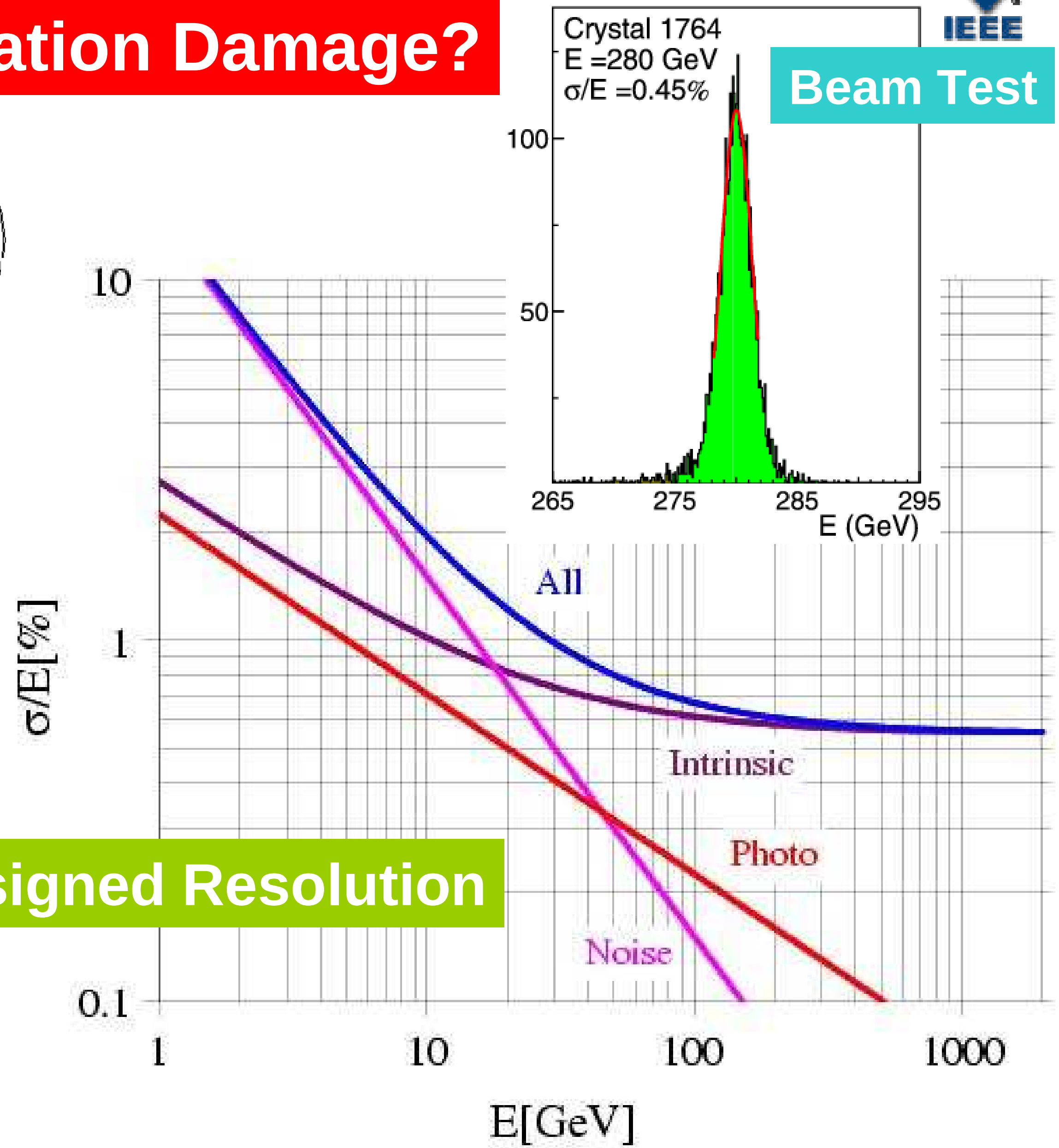
40 modules (10 SM) will be completed in 2003



Expected PWO ECAL Resolution

Radiation Damage?





Beam Test

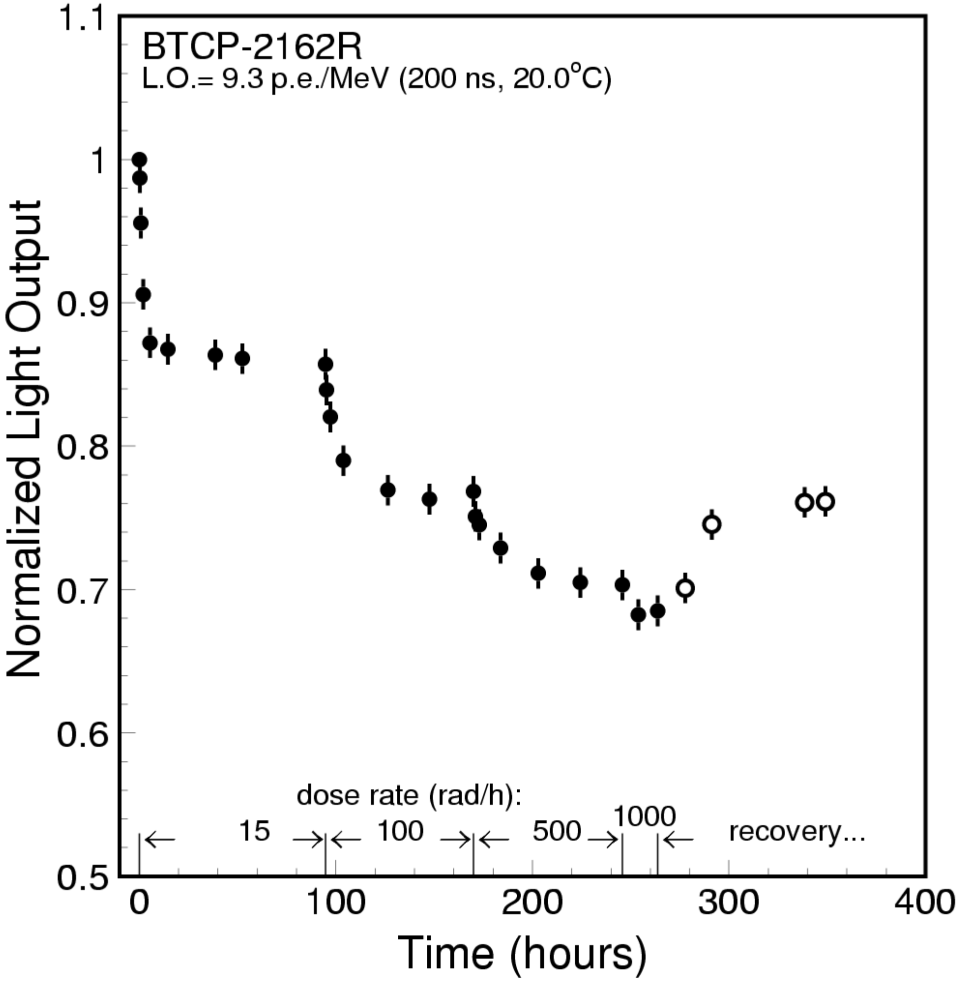
Designed Resolution

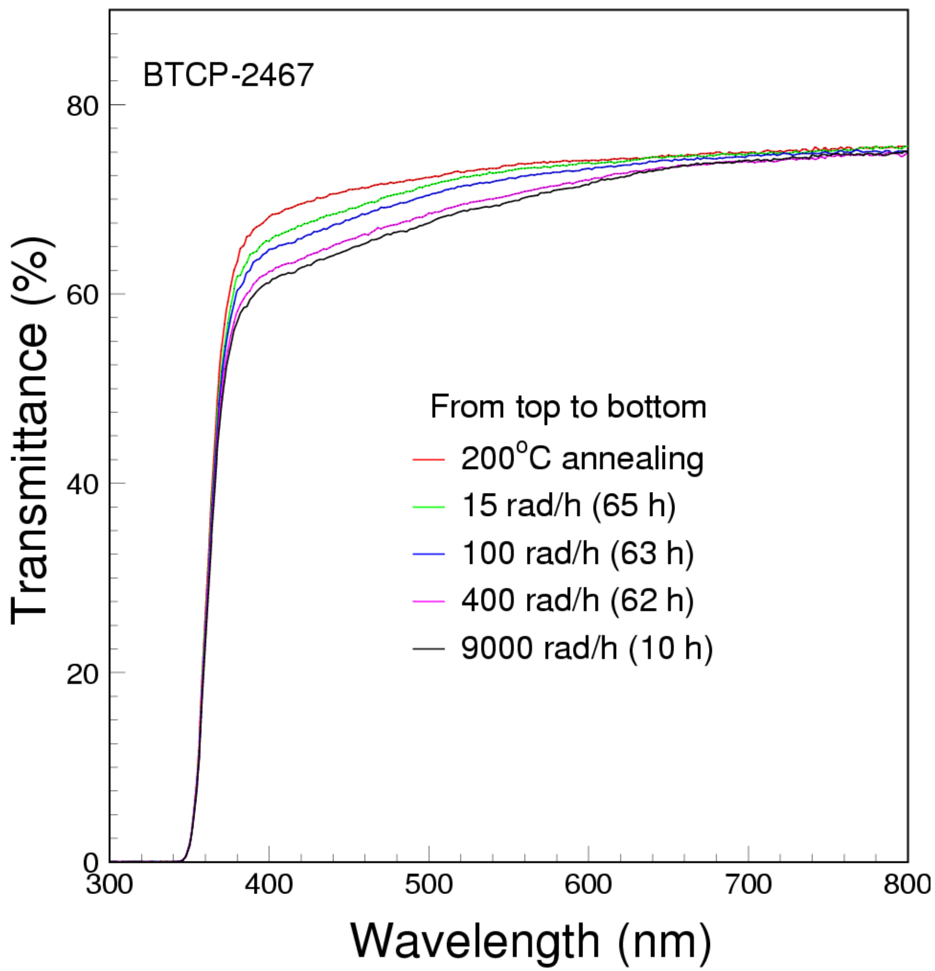
Crystal Calorimetry at High Energies

PWO Radiation Damage (I)

Damage and recovery: color center formation

Dose rate dependent: cc creation and annihilation

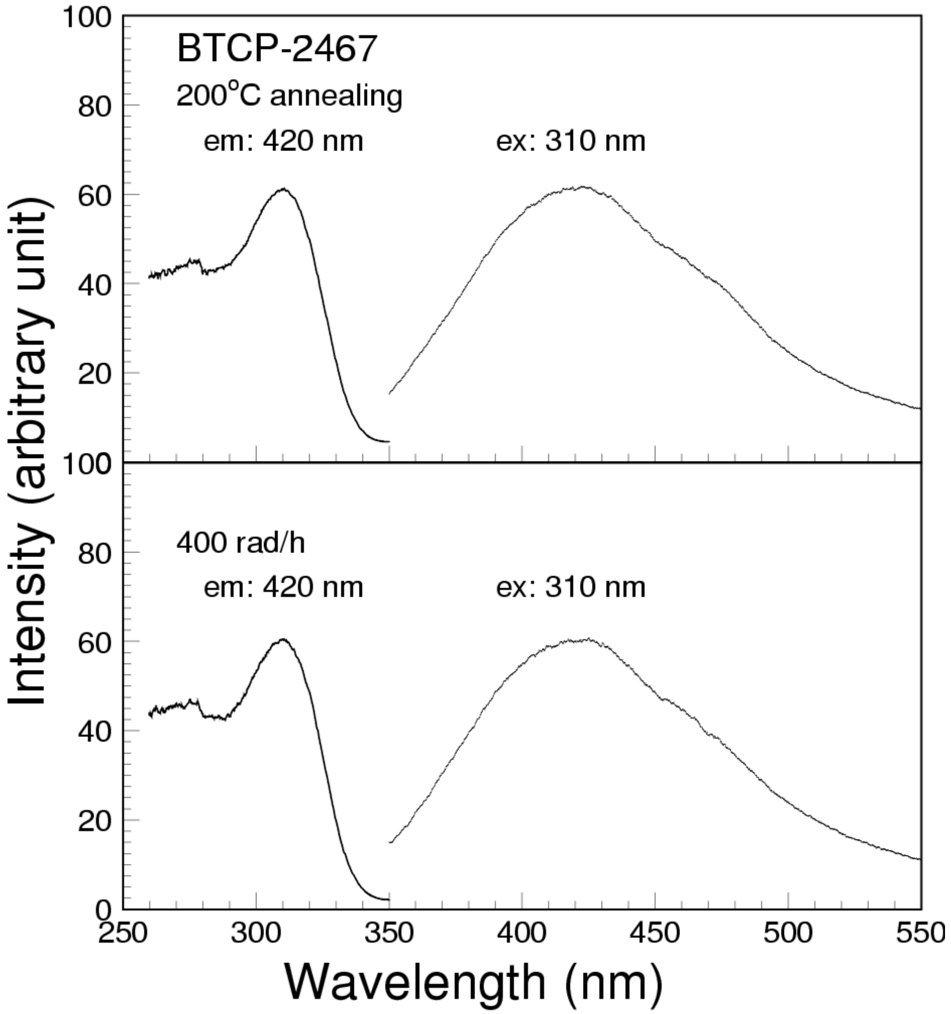


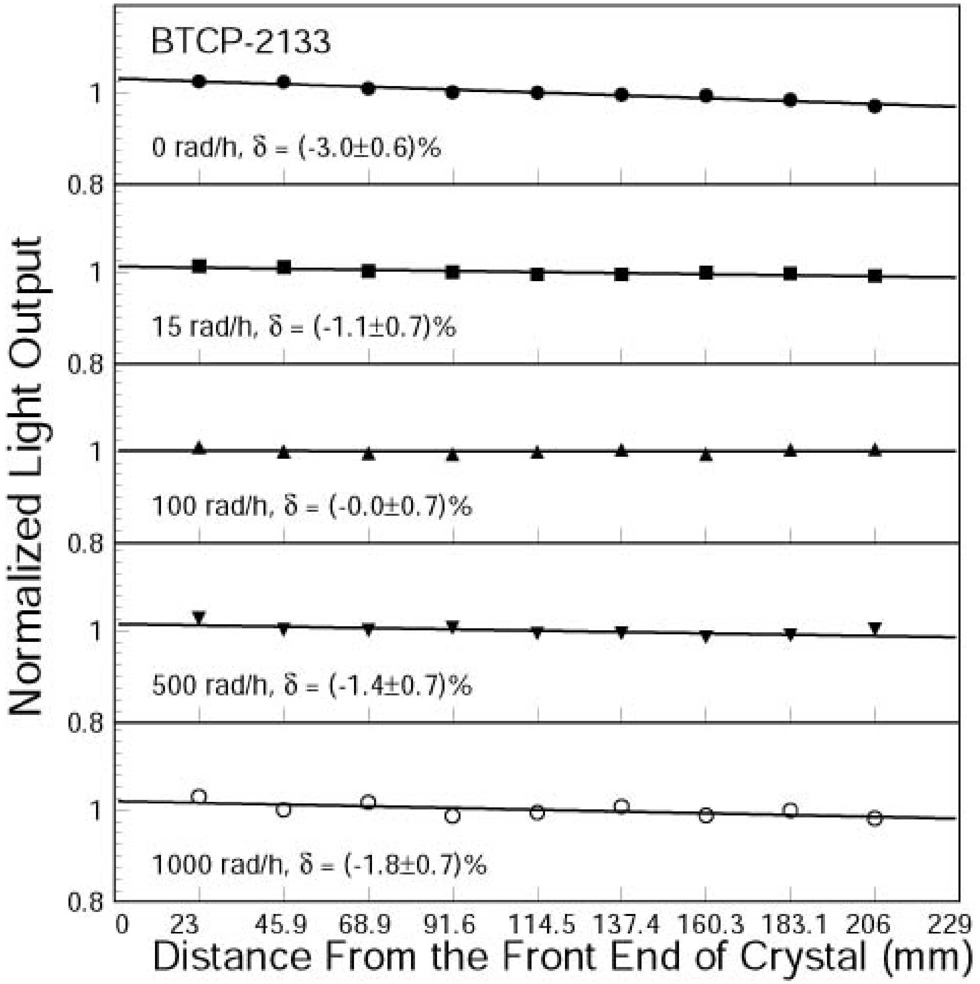


PWO Radiation Damage (II)

No damage in scintillation mechanism

No damage in resolution if light attenuation length > 1 m



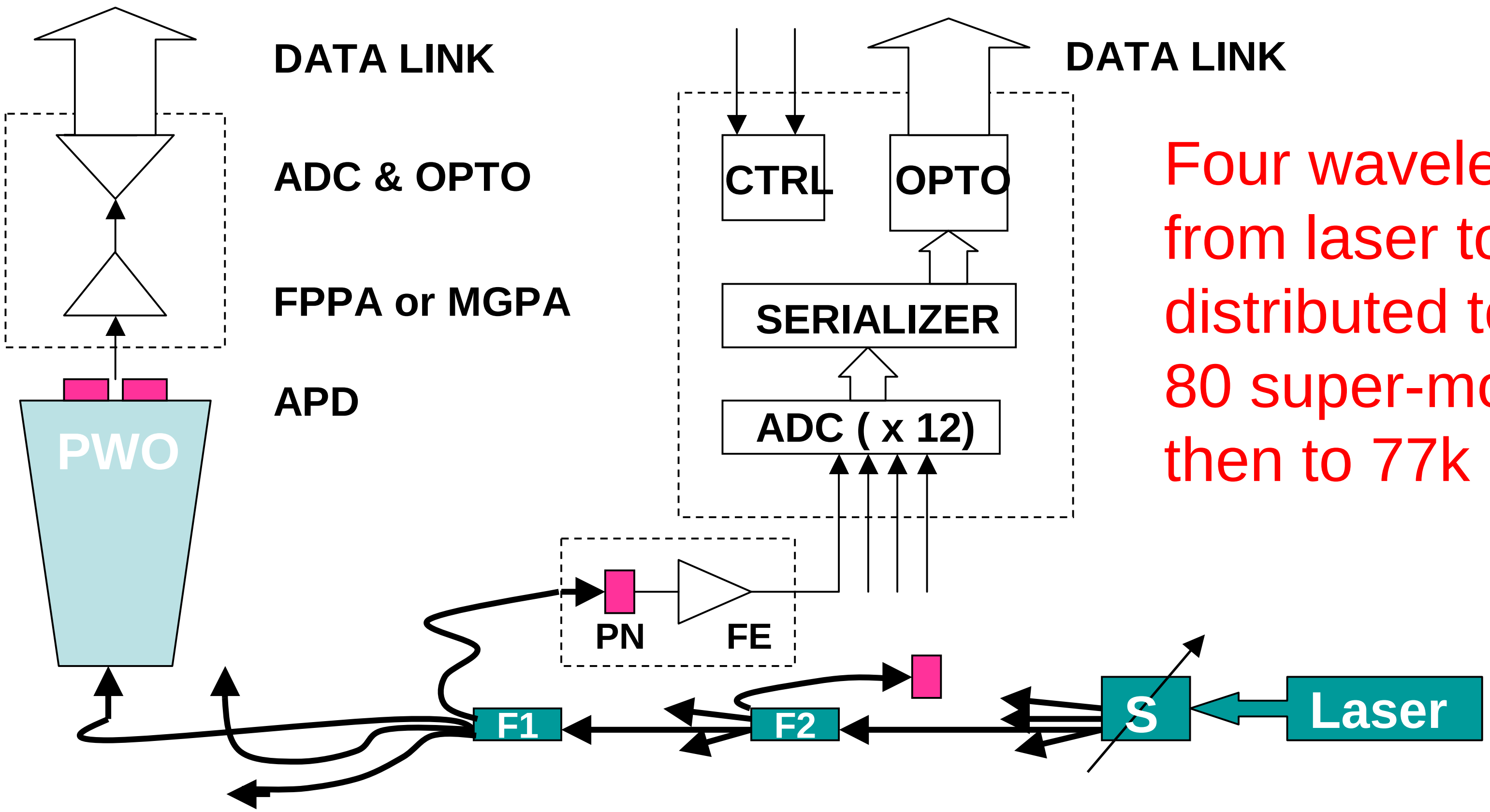


Light Monitoring System

Initial calibration on test beam (as much crystals as possible)

Physics calibration *In situ:* e^+e^- pair (resonance) and e (E/p)

Monitoring crystal evolution by light injection system



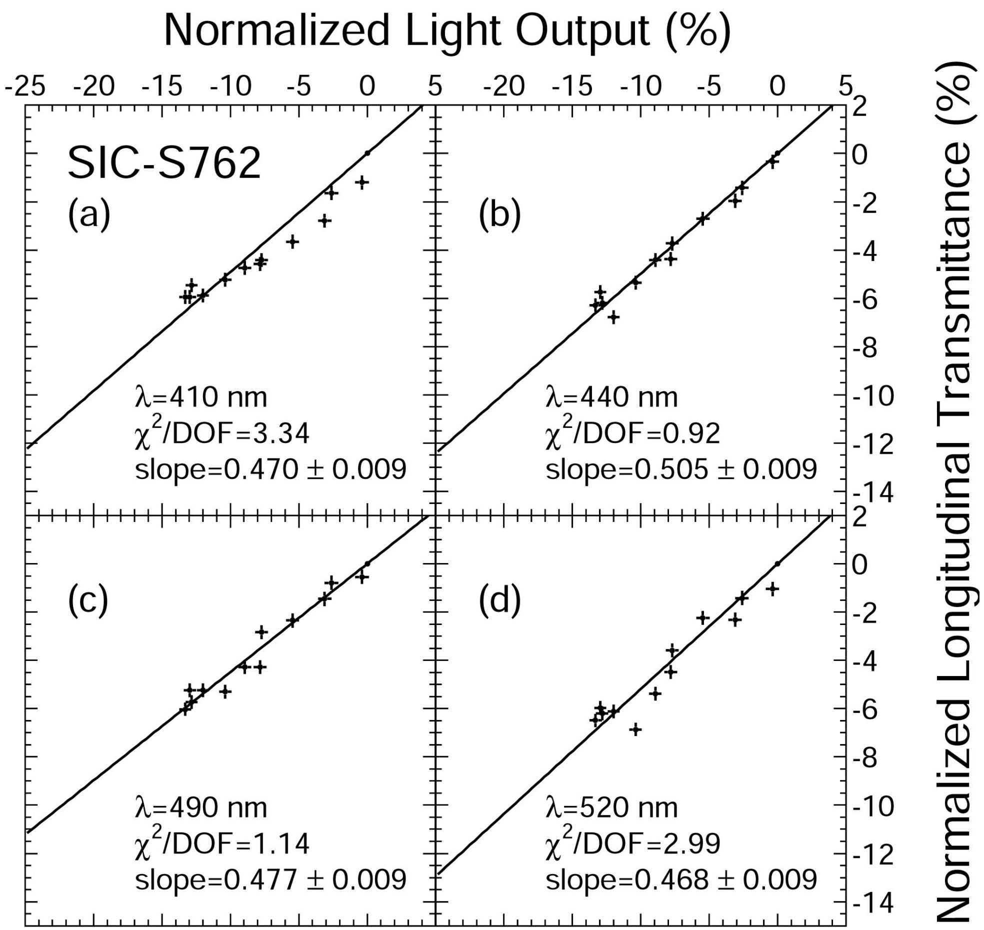
Four wavelengths from laser to be distributed to 80 super-modules, then to 77k PWO.

440 nm
495 nm
709 nm
796 nm

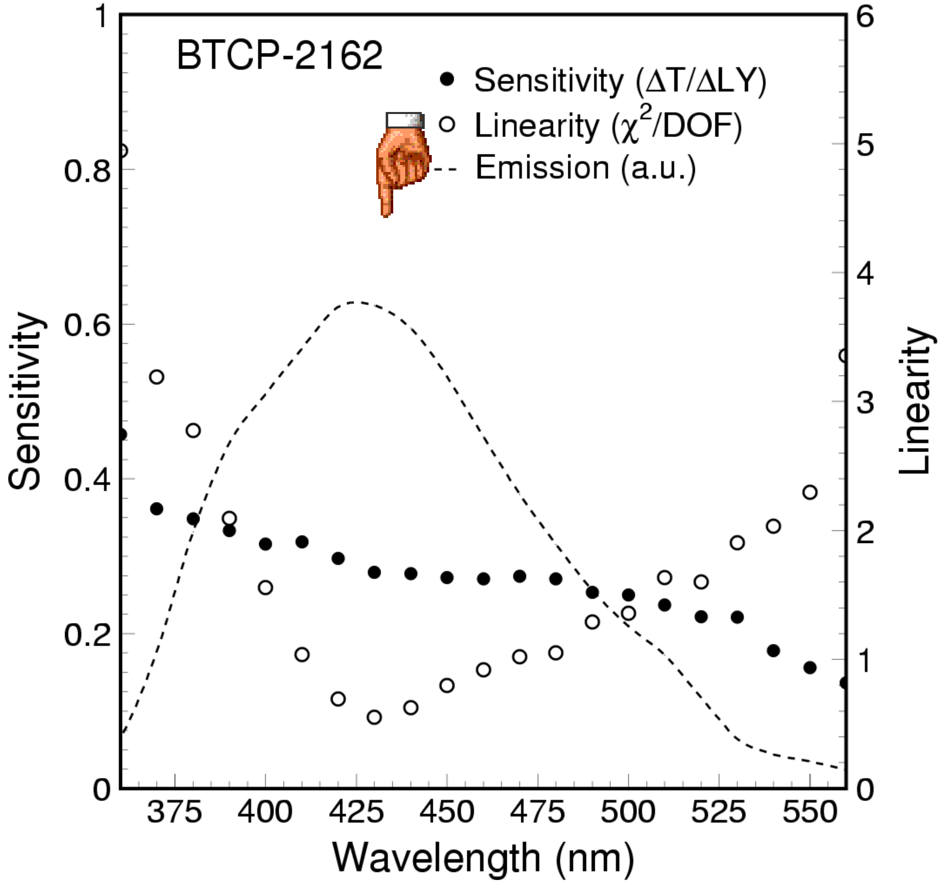
Monitoring Wavelength Determination

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

Δ(T) versus Δ(LY)

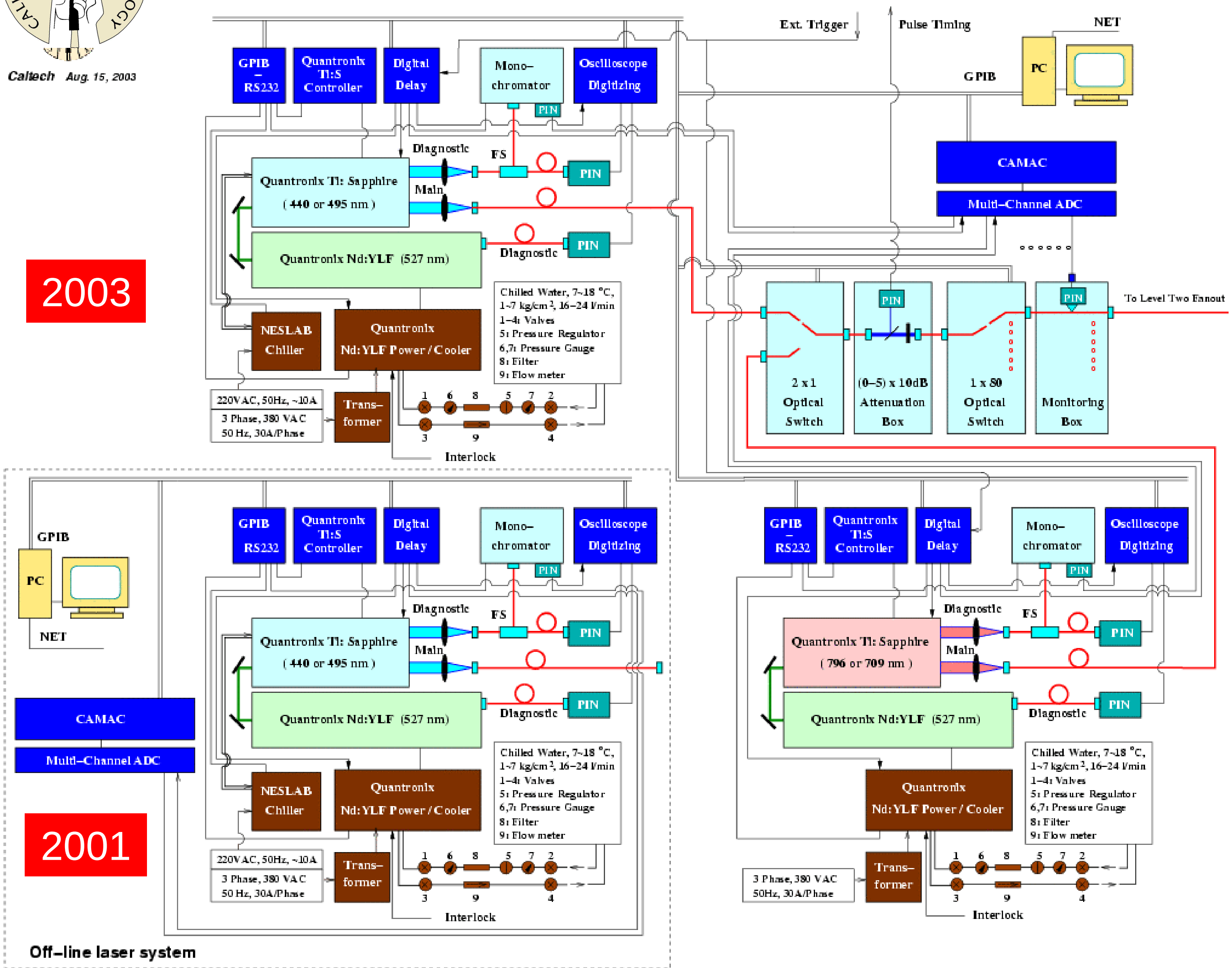


Sensitivity and Linearity



→ 440 nm is chosen for the best linearity

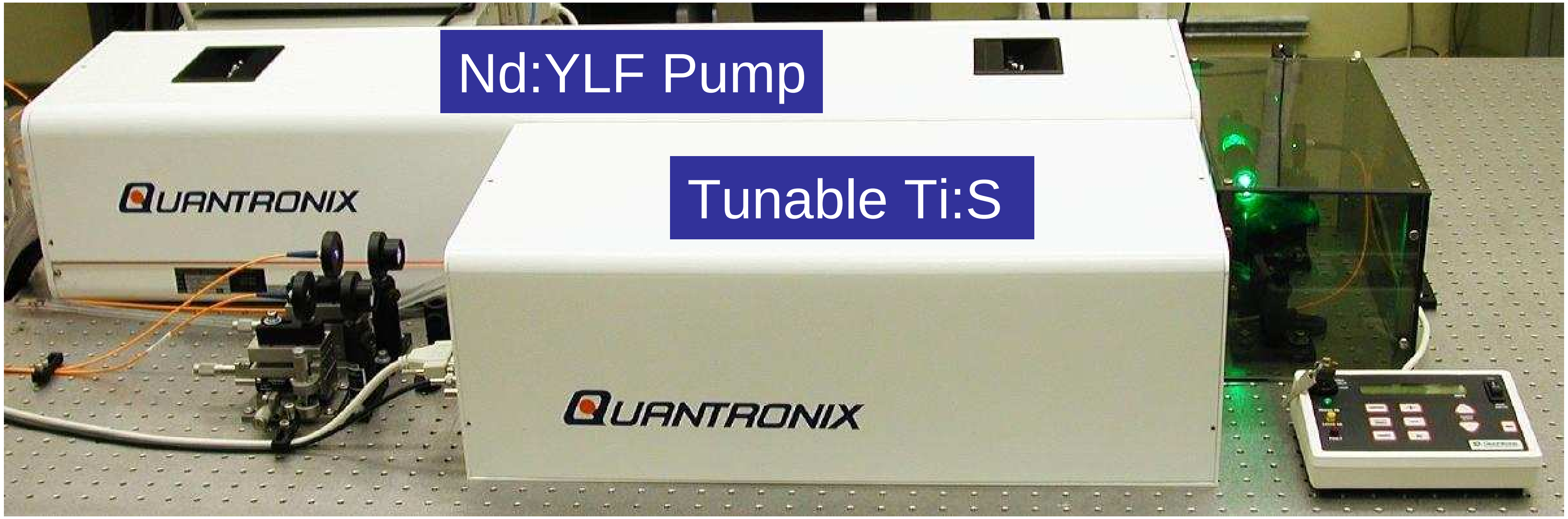
Lasers at CERN for PWO Monitoring

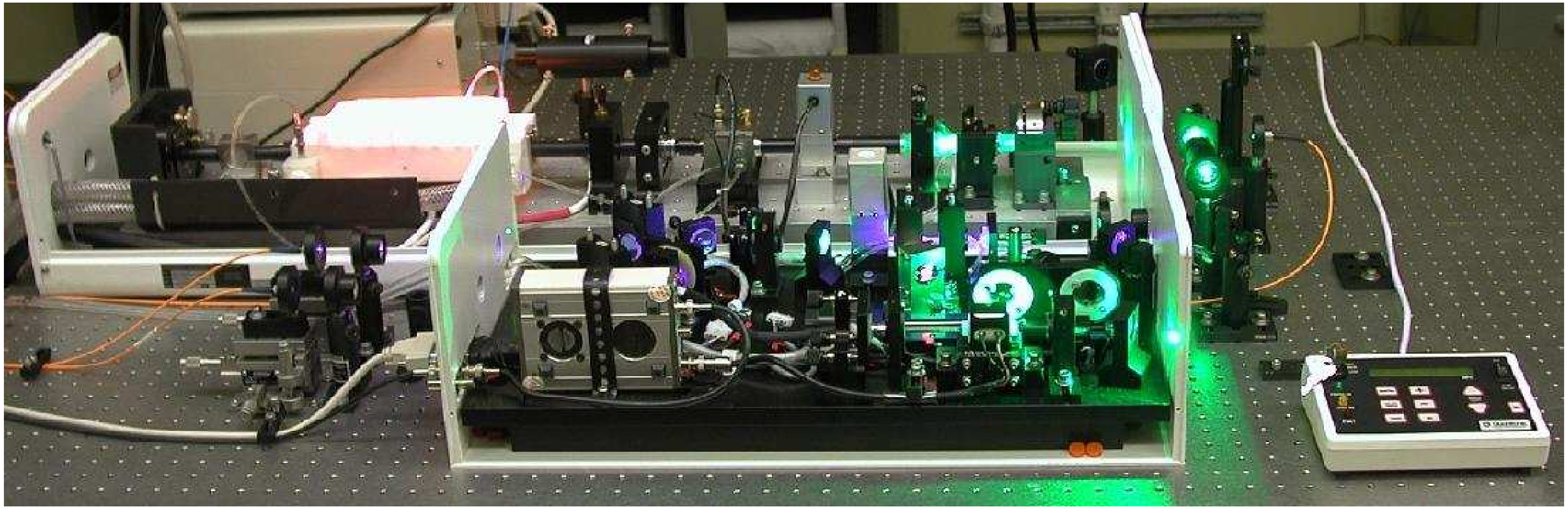


The 1st laser system was Installed in 2001, and used in 2002 beam test.

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

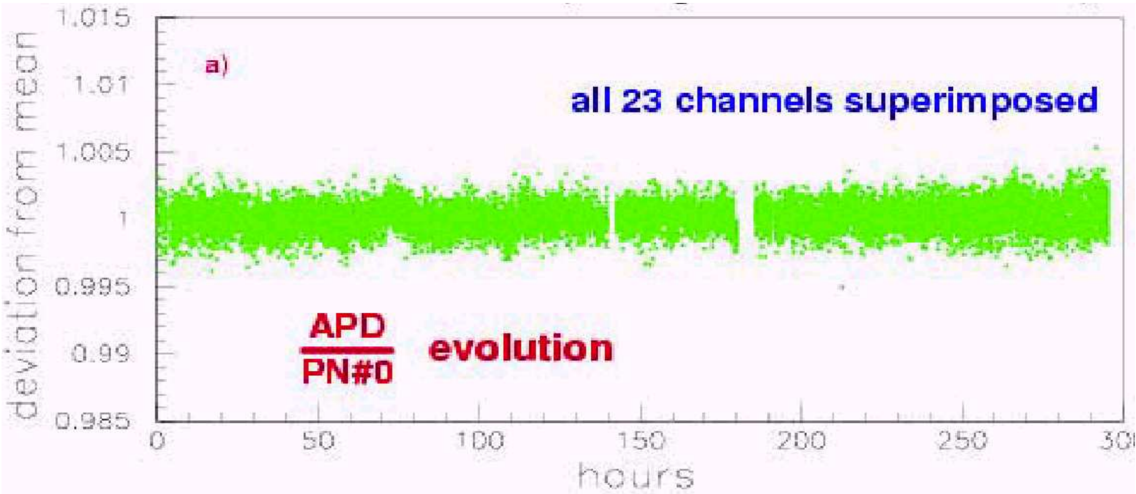
Ti:Sapphire Laser with Two Wavelengths

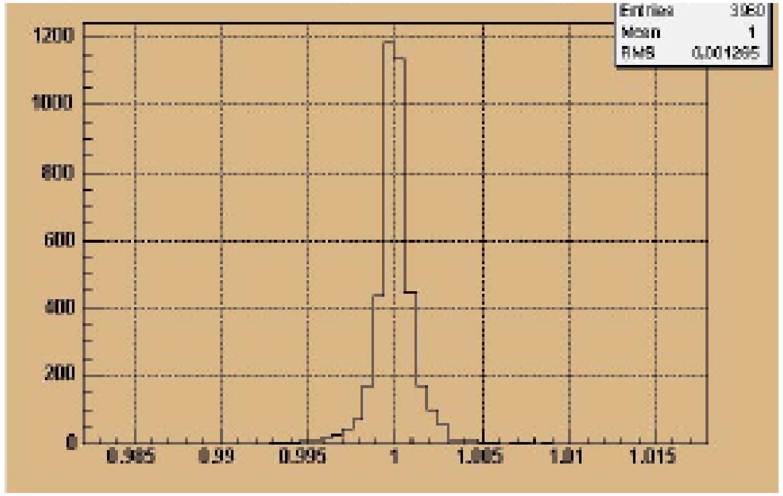


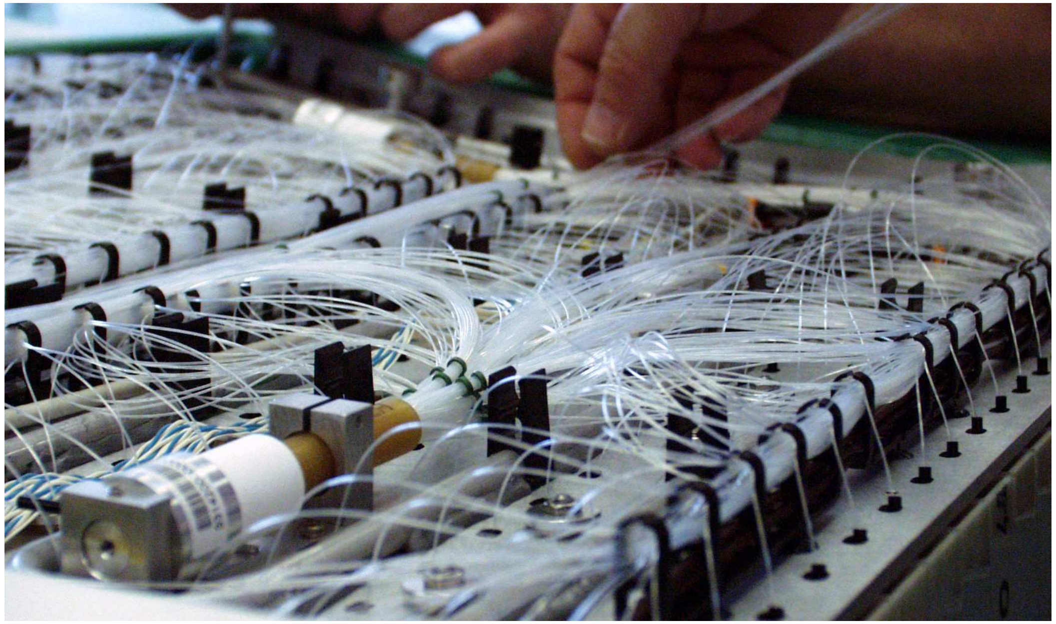


Low Level Light Distribution

Long Term Stability: 0.1%





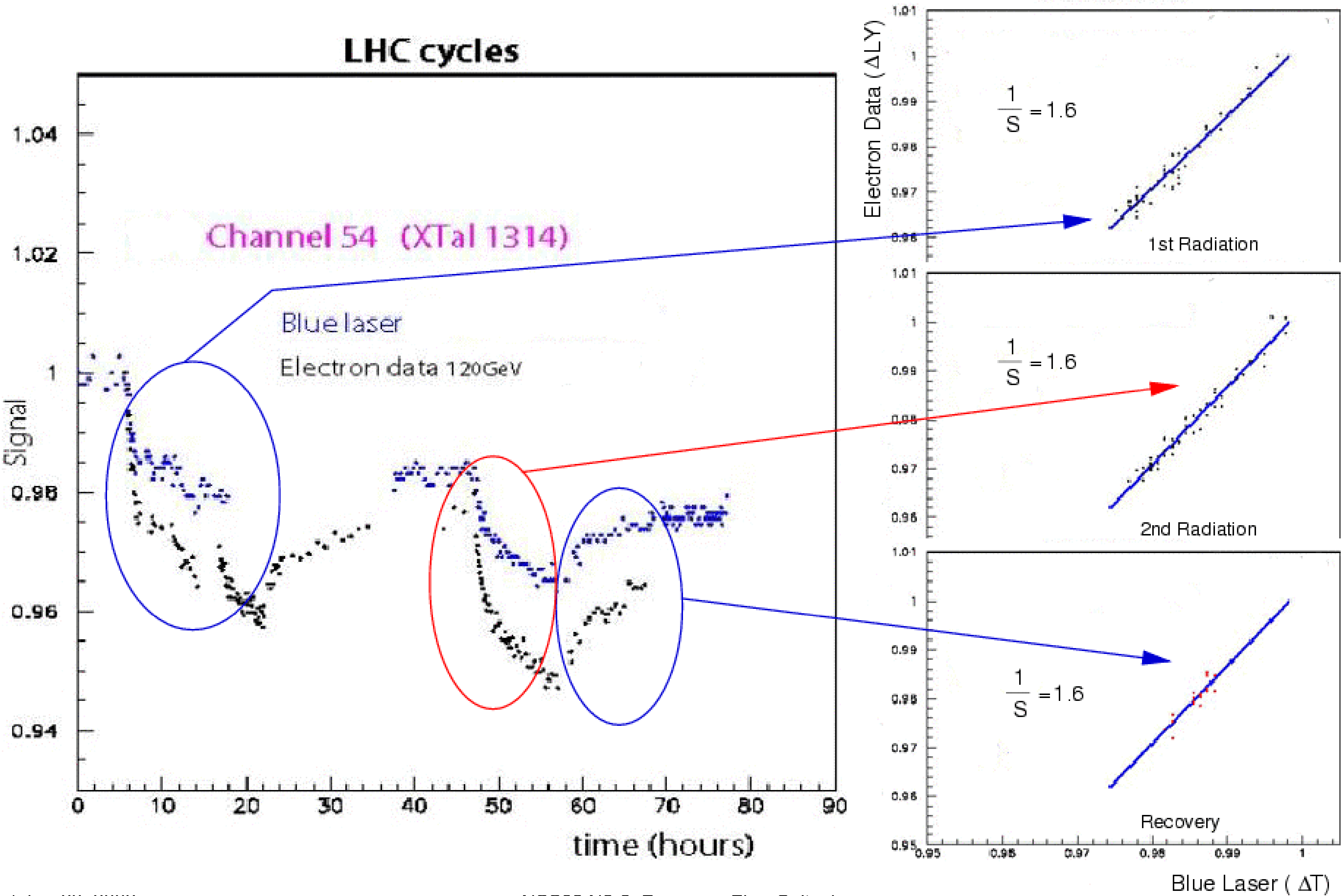


Monitoring

Low Level Fiber

Distribution

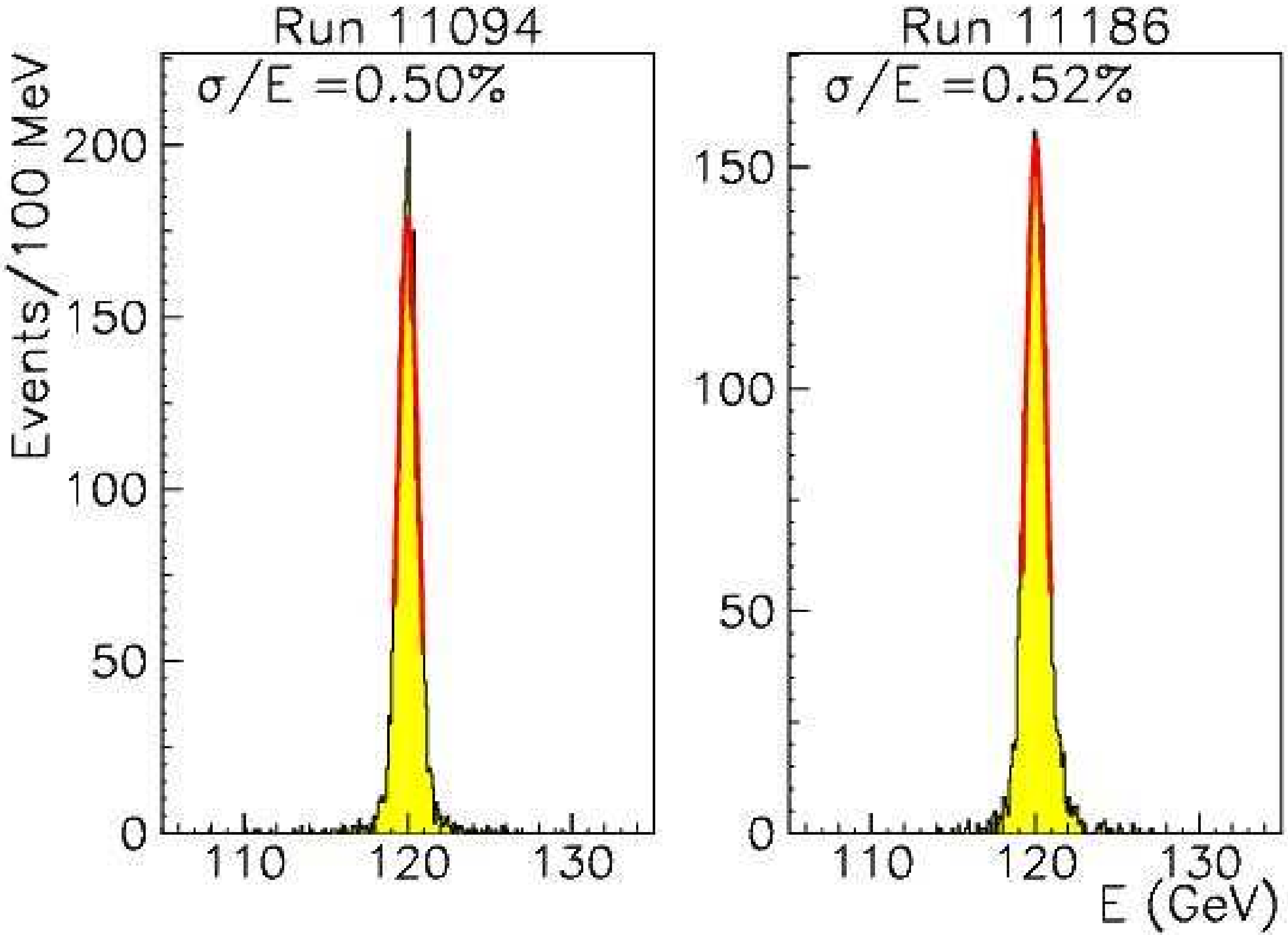
Experiences in 2002 Beam Test



PWO Resolution With Light Monitoring

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

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



Summary

- In the last seven years, CMS has taken a challanging project to build a precision PWO crystal calorimeter at LHC.
- After extensive R&D high quality PWO crystals and APDs are in mass production and detector construction is well under way.
- Radiation damage in PWO crystals is well understood. Variations of PWO crystal light output are monitored by a light monitoring system *in situ*.
- Important development has been achieved for precision crystal calorimetry in radiation environment. Looking forward to precision e/γ physics at LHC.