



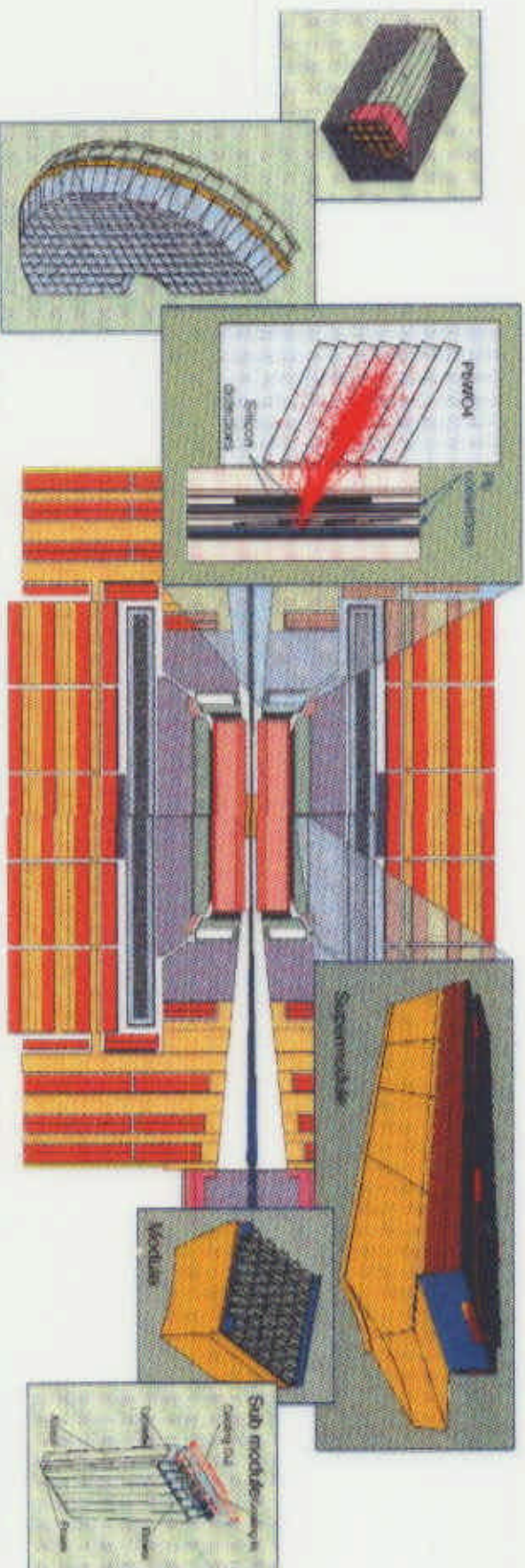
CMS

ELECTROMAGNETIC CALORIMETER

OVERVIEW

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CMS ECAL PERFORMANCE

Benchmark for low luminosity :

Higgs physics : $H \rightarrow \gamma\gamma$ $m_H < 150 \text{ GeV}$

Needs high resolution :

$$\frac{\sigma}{E} = \frac{3\%}{\sqrt{E}} \oplus 0.5\% \oplus \frac{200 \text{ MeV}}{E}$$

AND

- magnetic field of 4 T
- crossing at 40 MHz
- radiations : 0.15-0.3 Gy/h in the barrel, up to 15 Gy in the endcaps

Choice of : lead tungstate crystals (fast, rad hard, density)



- + Avalanche PhotoDiodes (APD) in barrel (B not sensitive, gain)
- + Vacuum PhotoTriodes (VPT) in endcaps (rad hard, gain)



LEAD TUNGSTATE : PbWO_4

ADVANTAGES

- 26 radiation lengths in 23 cm of material (barrel), endcaps : 22 cm
- molière radius of 21.9 mm, density of 8.2 g/cm³

COMPACT CALORIMETER

- 85% of the light in 20 ns, $\lambda \sim 480$ nm
- radiation hardness : saturated loss < 4% for 0.15 Gy/h

BUT

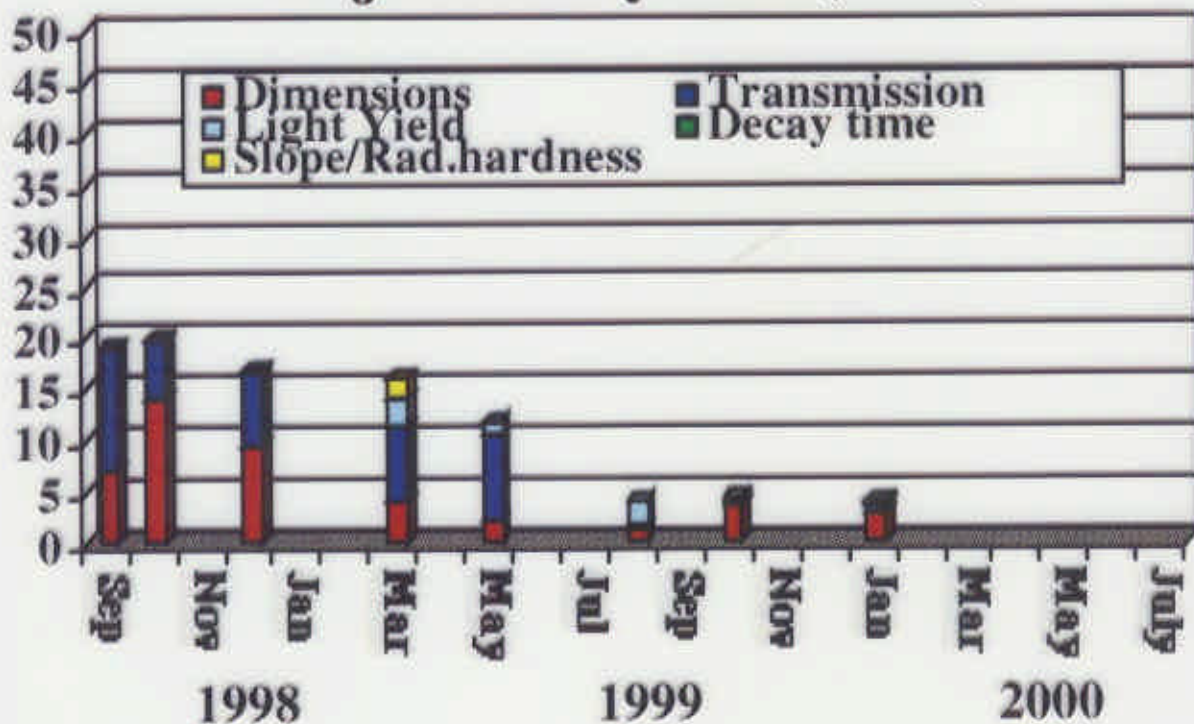
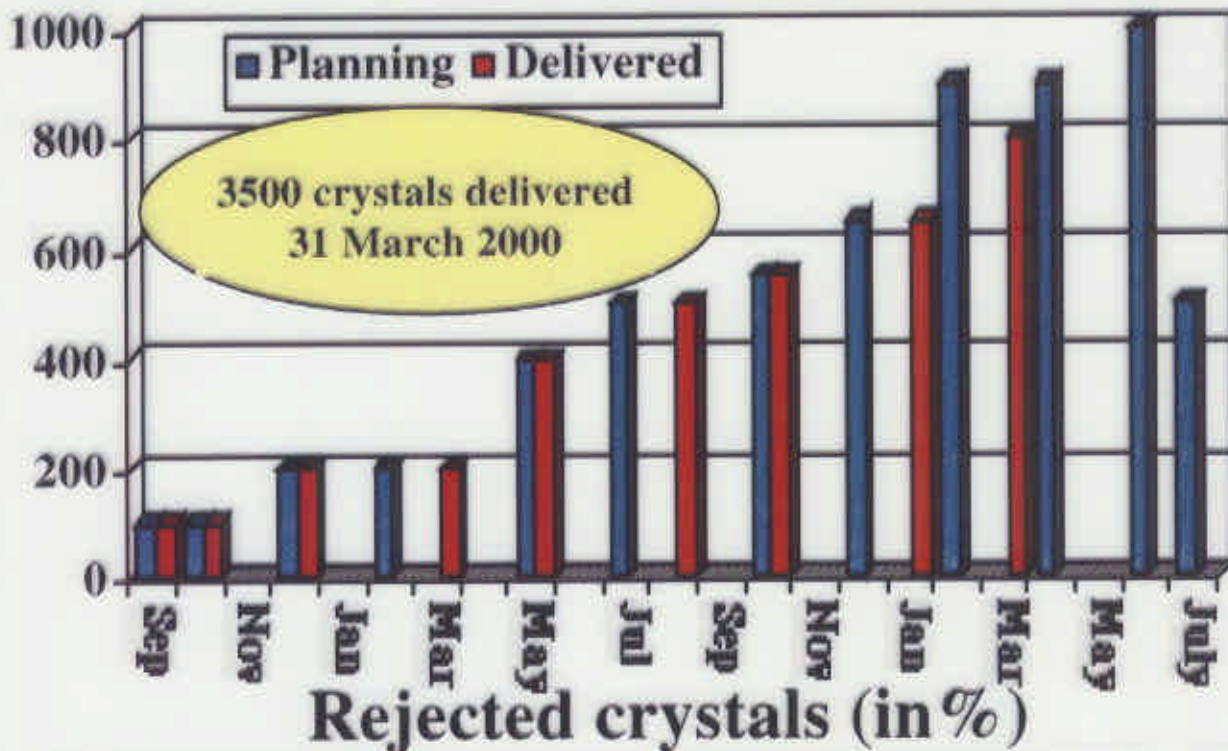
- LOW Light Yield : about 60 photons/MeV for a crystal
- readout with APDs (gain 50) and VPTs (gain 6-8 in 4T)
- low run temperature : 16-18 °C to maximise LY

- Temperature sensitivity of crystals and APDs ($\sim -2\%/^{\circ}\text{C}$) requires a 0.1 °C temperature stabilisation.



Status of crystal delivery from Bogoroditsk (Russia)

Delivered crystals-Preproduction contract ISTC # 354b

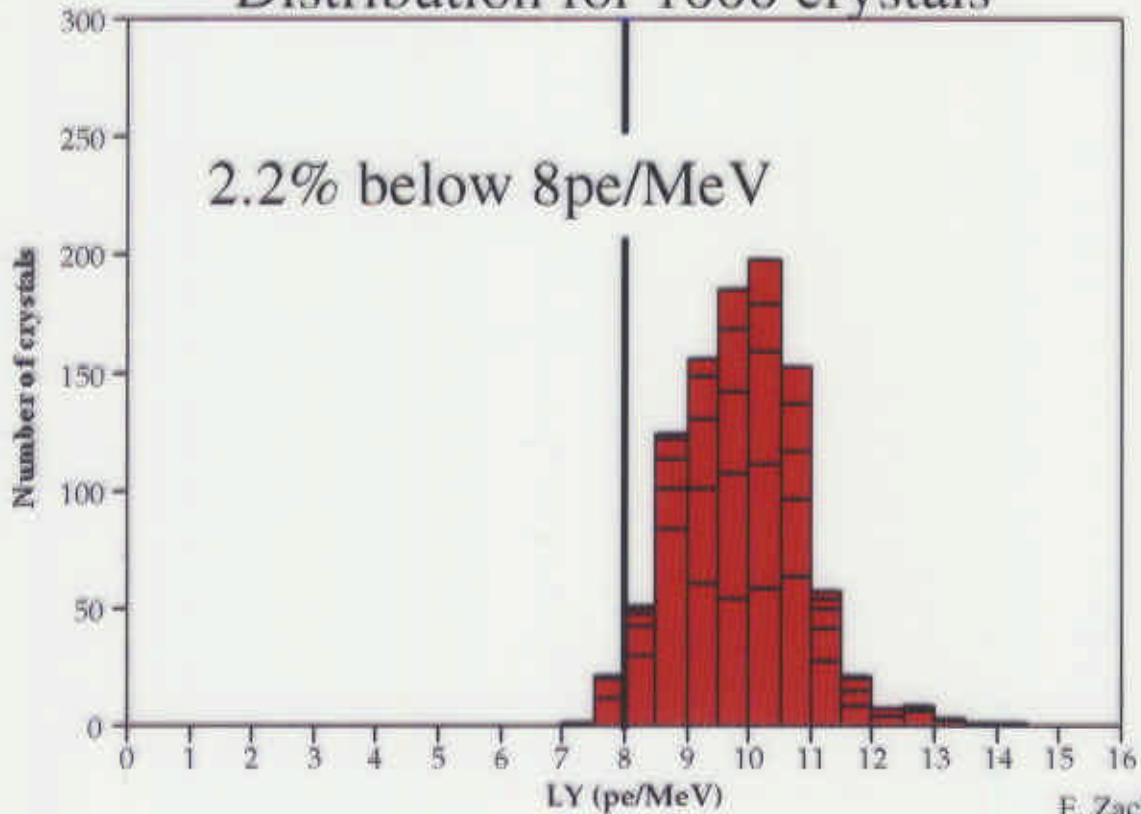


Light Yield

LY at $8X_0$



Distribution for 1000 crystals

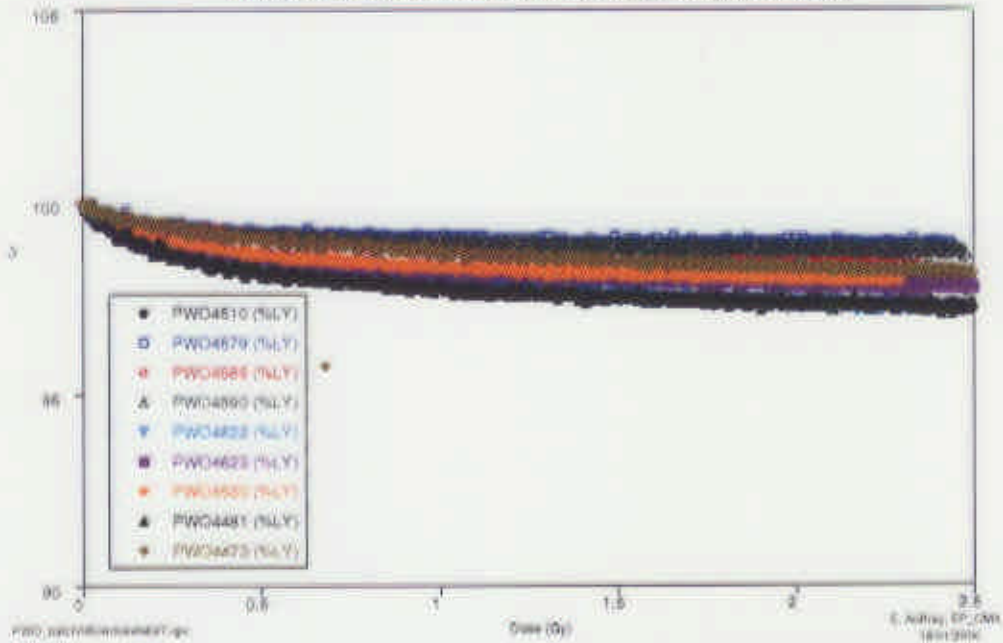




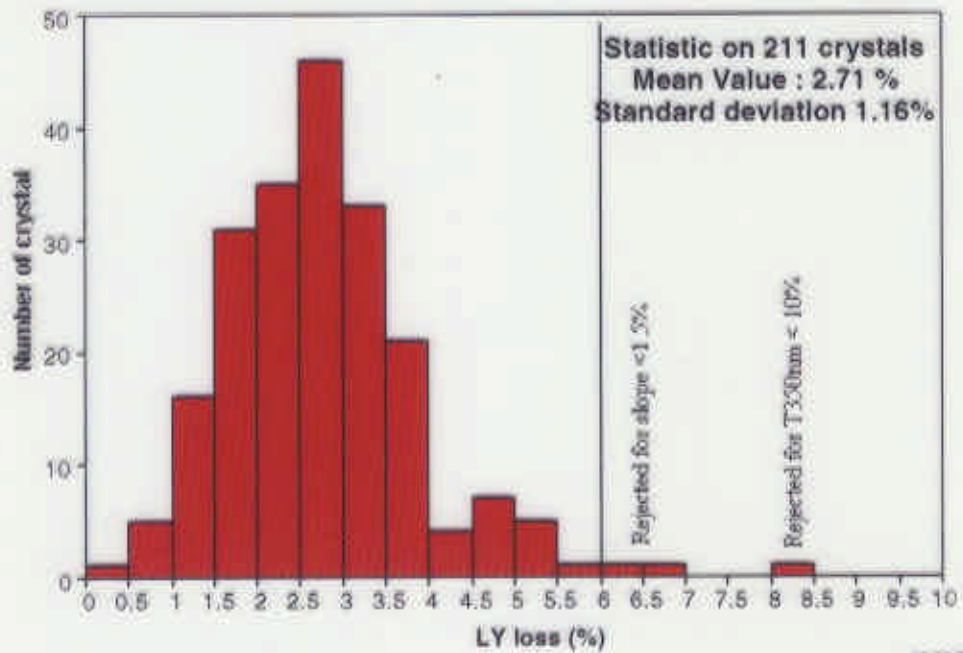
Radiation hardness

Lowdose rate in Lab27

Low dose rate irradiation of some BTCP crystals of Batch06 in lab27



Front irradi., 1.5Gy, 0.15Gy/h



12.04.2005



PHOTO DETECTORS : APDs and VPTs

APDs at present time (**Hamamatsu**):

- no magnetic field sensitivity
- gain 50, with a voltage sensitivity of 3.5%/V
- temperature sensitivity of -2.3%/°C
- quantum efficiency of 80%
- area of 25 mm² → 2 APDs → 50 mm² and 4 pe/MeV
- radiations increase bulk current → electronic noise X 2 after 10 years : keep good resolution.
- Capacitance ~ 80 pF

VPTs (pre-production by RIE St. Petersburg, final choice in 2001):

- more resistant to radiations than APDs, 250 mm²
- drop of gain by a factor 2 in axial 4 T magnetic field

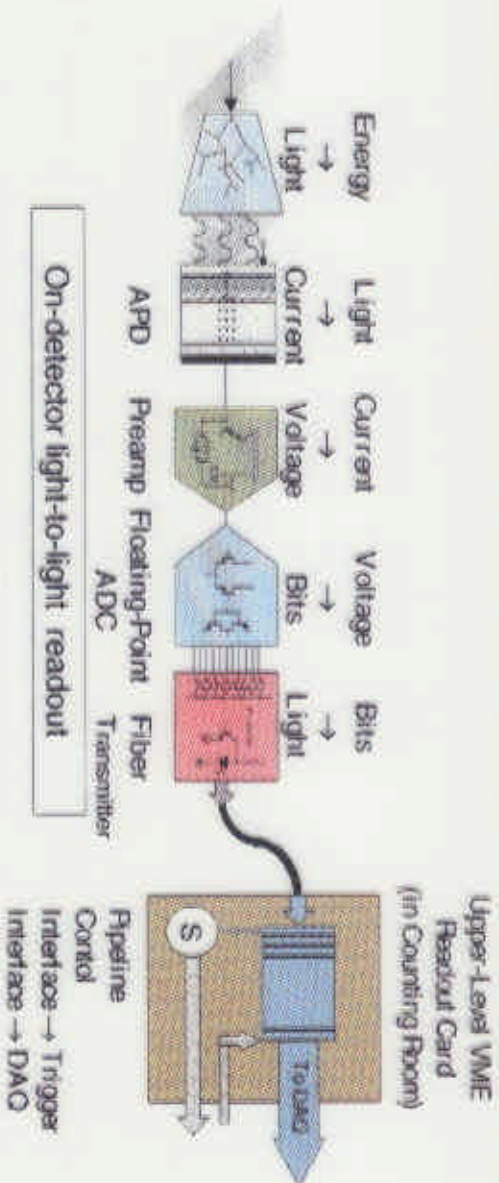
First Production Run

June 2000

3600 APDs



PHOTODETECTORS READOUT : P.A. + Sample ADC + optic link

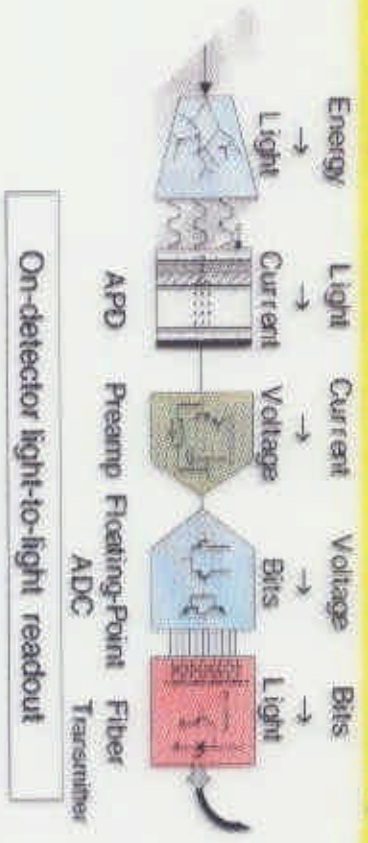


RAD HARD ELECTRONIC (HARRIS, backup solution DMILL) with low power dissipation:

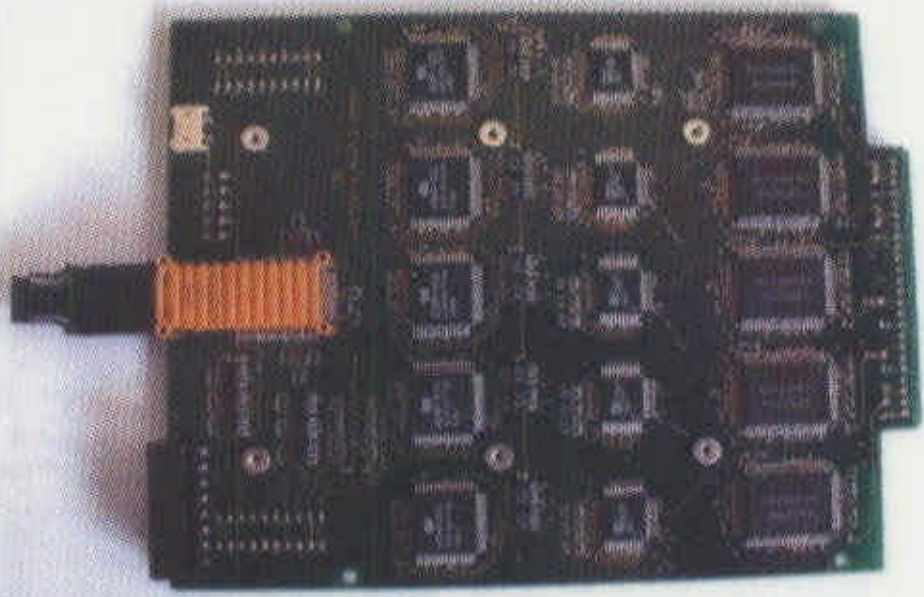
- Transimpedance P.A.
- FPU : Switches of gains (1,5,9,33) to have better resolution
- Sampling ADC : 40 MHz, 4096 channels (A.D. 9042)
- One serialiser per channel (800 Mbit/s) to bring out the SADC samples with digital optic link



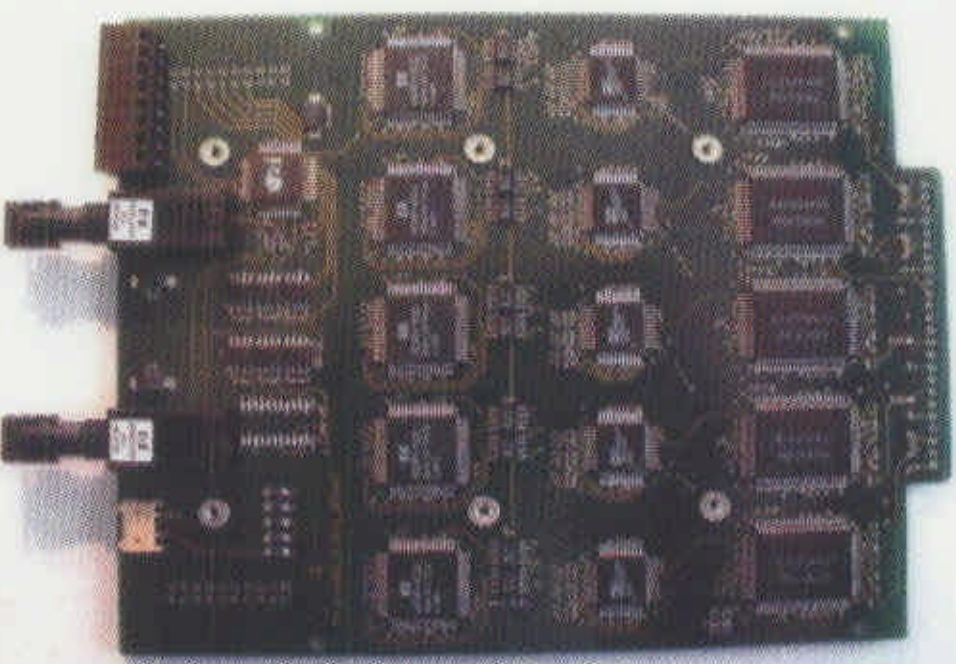
PHOTODETECTORS READOUT : P.A. + Sample ADC + optic link



Master



Slave





ECAL STRUCTURE

BARREL

GRANULARITY OF 360 (ϕ) x 170 (θ) crystals

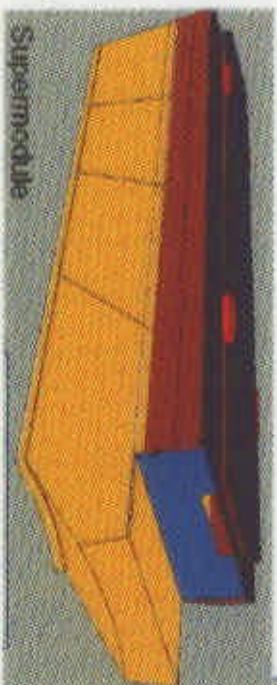
A **submodule** = 2x5 crystals in reflective alveola, + tablet

A **module** = 10x4 (5) submodules = 400 (500) crystals,
+ grid + basket

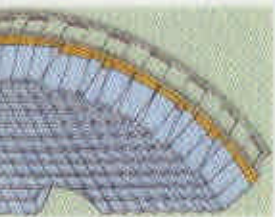


A **supermodule** = 4 modules

36 supermodules = 61200 crystals



ENDCAPS



7810x2 crystals grouped in **supercrystals**
(5x5 alveolar unit, or less)



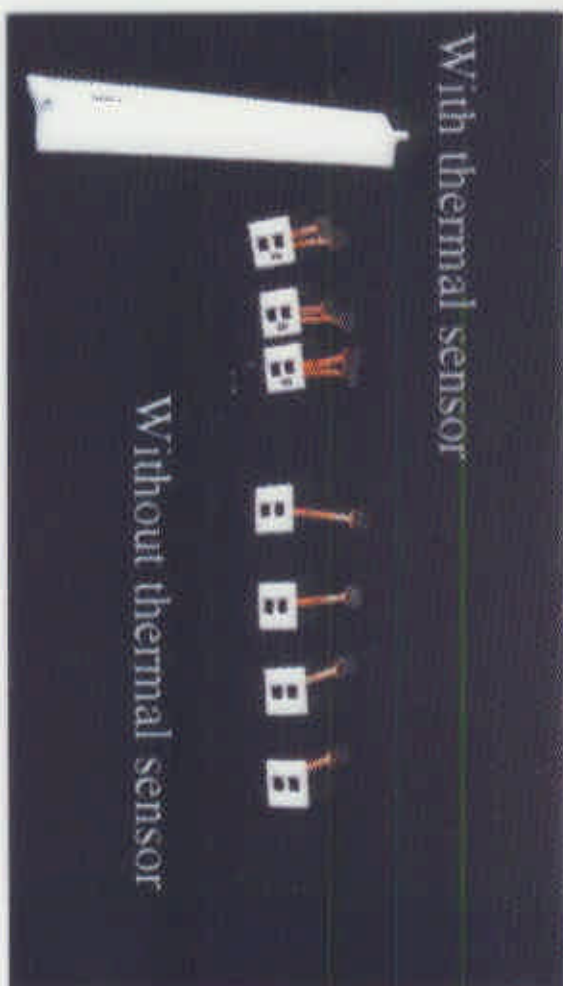
TOTAL : 76820 crystals



Submodule elements



17 types of crystals



7 types of capsules





TEST BEAM

- **Prototype 1999** : 30 pre-production crystals and APDs, QADDC

→ Dedicated to noise studies and energy scan

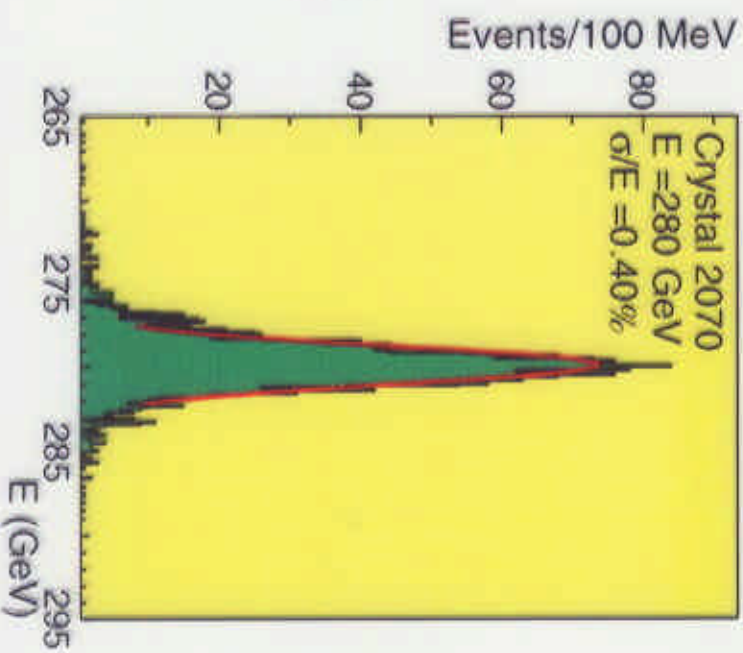
< Noise > = 36.3 MeV or 10.530 e-

< Correlated Noise > = 8 MeV or 2.200 e-

< Light Yield > = 5.6 pe/MeV

< Light Yield > = 5.5 pe/MeV by ACCOS

$$\frac{\sigma}{E} = \frac{2.74\%}{\sqrt{E}} \oplus 0.41\% \oplus \frac{142\text{MeV}}{E}$$

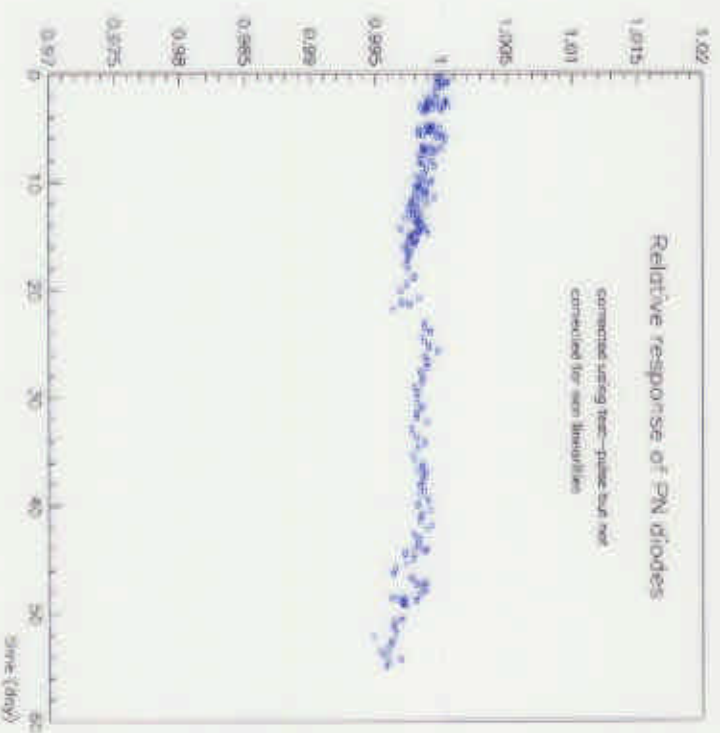
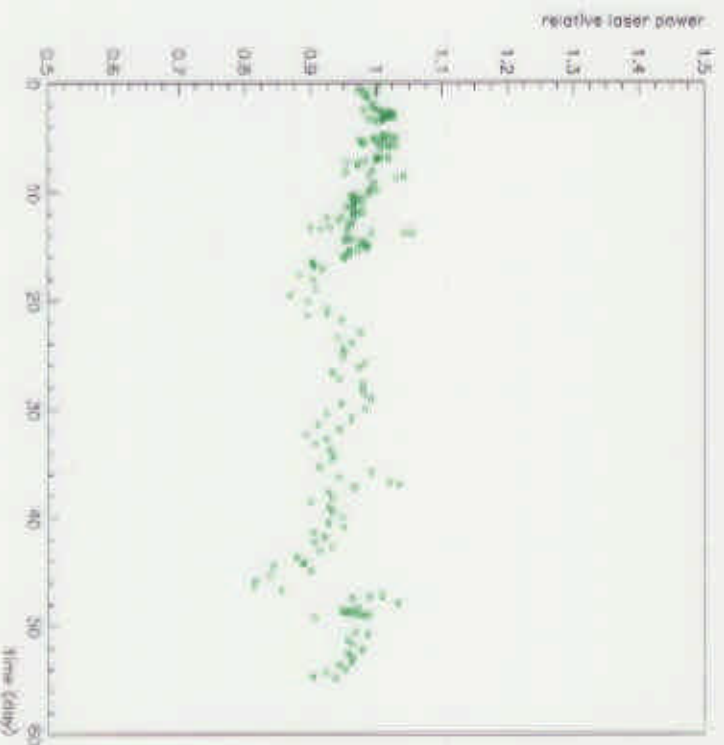




TEST BEAM

- **Prototype 2000** : 30 production crystals with final : capsules - alveola - tablettes - connexion system and 60 production APDs

➡ Dedicated to monitoring and calibration



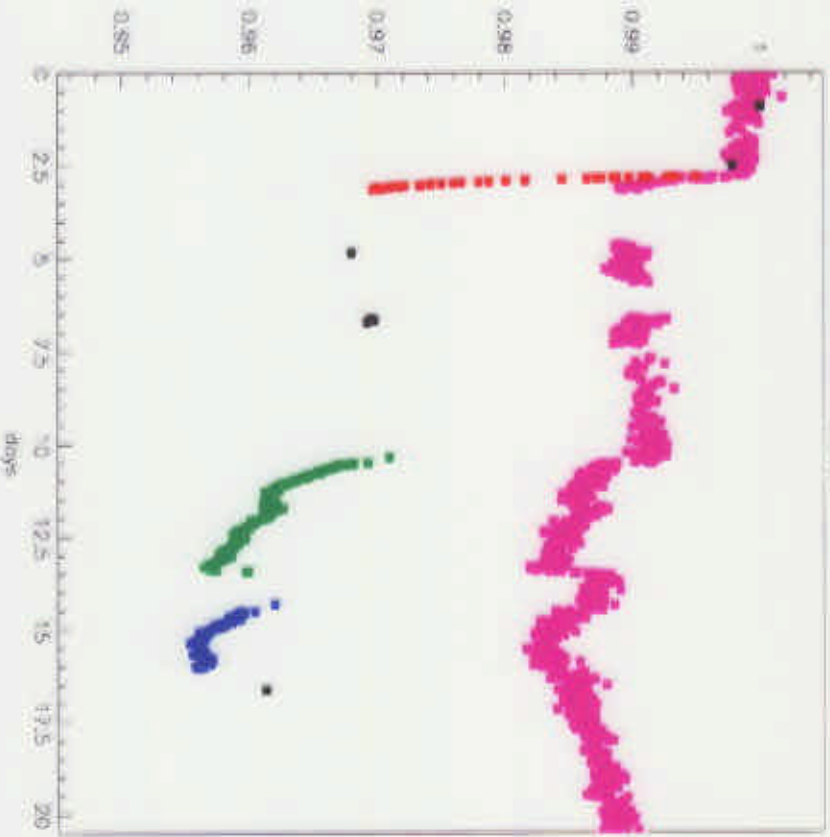
< 0.4 %



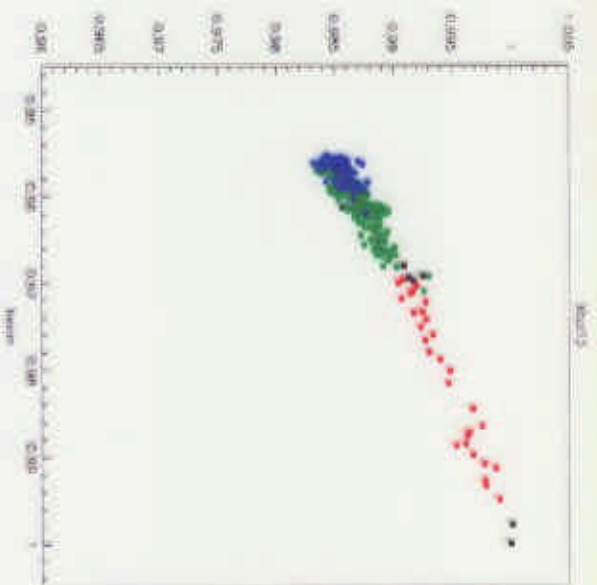
TEST BEAM

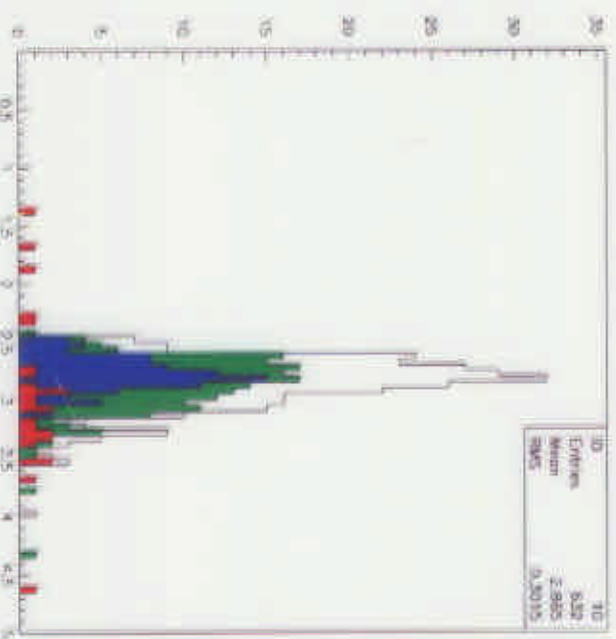
Prototype 2000

Dedicated to monitoring and calibration



laser and beam







Calibration and Monitoring

- **TEST BEAM CALIBRATION OF ALL CRYSTALS (CERN)** in their super-modules, at two energies with electrons before detector installation
- **LIGHT MONITORING TO KNOW CRYSTALS AND READOUT EVOLUTION**
- **CALIBRATION IN SITU WITH PHYSICS**

$$Z \rightarrow e^+ e^-$$

E/p calibration with electrons measured by tracker



Within 35 days at low luminosity

→ Mapping of all crystals

Intercalibration better than 0.3 %



CONCLUSION

- **PRODUCTION OF CRYSTALS HAS STARTED,**
- **APDs CONSTRUCTOR HAS BEEN CHOSEN, PRODUCTION HAS STARTED**
- **RAID HARD ELECTRONIC READOUT WILL BE FULLY TESTED IN 2000, TECHNOLOGY OF V.F.E. IS FIXED**