Lead Tungstate Crystal Quality Control for the CMS High-Resolution calorimeter

- ECAL Performance
- Crystal specifications
- Crystal characterisation
- ACCOS machines
- Status and some results

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October 13, 2000

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Introduction:

The CMS electromagnetic calorimeter:

- aims at a **very high resolution** for **e** and γ:

$$\sigma/E \approx a/\sqrt{E} \oplus c \ll 1\%$$

- down to relatively low γ energies:

50 ≈ 70 GeV for **Higgs** search in **intermediate** mass region!

This means that:

⇨ both **stochastic term a** and **constant term c** must be **small!**

Aim: **a** ≤ 3% **c** ≤ 0.5%

@ Stochastic term **a** is usually low for **Homogeneous** media, such as crystals, provided there is enough light collected:

→ For PWO, level of Light output must be carefully checke

@ Constant term **c** is small only in a '**dedicated**' calorimeter, i.e. a calorimeter with all parameters carefully optimised!

In crystals, one of the main contributions to the **c-term** is: the **longitudinal light collection non-uniformity**, due to:

- light attenuation along crystals,
- tapered shape of crystals pointing to the interaction region

→ Uniformity of LY along crystal must be carefully checke

PWO characterisation for ECAL

Several years of R&D on PWO have shown that in orc to **guarantee crystal properties** adequate for a high-resoluti ECAL, one needs to measure:

1. Quantity of Light Collected: Light Yield (**LY**)
2. Non-Uniformity of Light Collection (**NU**)
3. Decay Time (**DT**) to collect most of the light in a short
4. Longitudinal Light Transmission (**LT**):
   - to check optical quality: presence of absorption banı
   - to maximise LY (correlation LT/LY)
   - to understand NU profiles
   - to 'predict' Radiation Hardness (slope of band edge ris
5. Transversal Transmission (**TT**) along crystal:
   - to check homogeneity: absence of large TT gradie
   - to understand NU profiles
6. Radiation Hardness (**RH**):

   to stand LHC high radiation levels with:
   - 'small' LY losses (by transmission decrease)
   - negligible effect on NU of crystals
7. Dimensions (**Dim**):

   To guarantee mounting in individual 'alveoles' witl enough clearance to avoid transmission of constraints!

Geometry

- **L, AF, BF, CF, AR, BR, CR: 0 ← → - 0.1 mm** @
- Planarity <0.02 mm for all faces,
- Angles: ≤ 0.05/d
- Chamfers: 0.3 mm ← → 0.7 mm in diagonal projection
- 5 faces optically polished: Ra ≤ 0.02 μm
- 1 side face (D) polished only to Ra ≈ 0.45 ± 0.05 μm

Optical Transmission

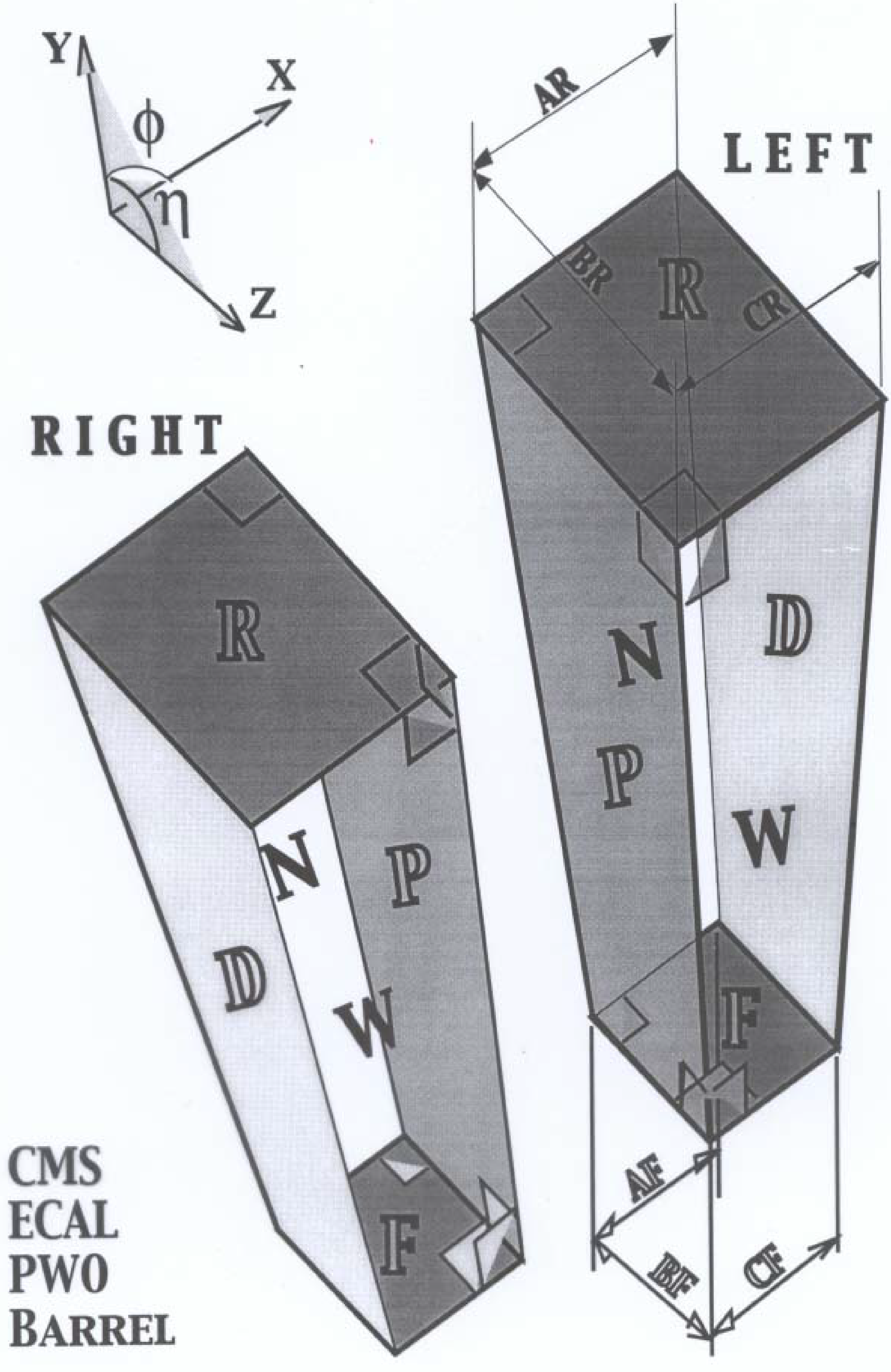
- **Longitudinal:**

  ≥10% at 360 nm @
  ≥ 55% at 420 nm
  ≥ 65% at 620 nm

- **Slope (S)** of the **band edge** of longitudinal transmissio
  fitted between 340 and 370 nm:
  S ≥ 3.0 %/nm

- **Transversal:**

  At a Transmission of 50%, **δλ ≤ 3 nm**
  for 6 measurements every 4 cm,
  starting at 1.5 cm from front face.



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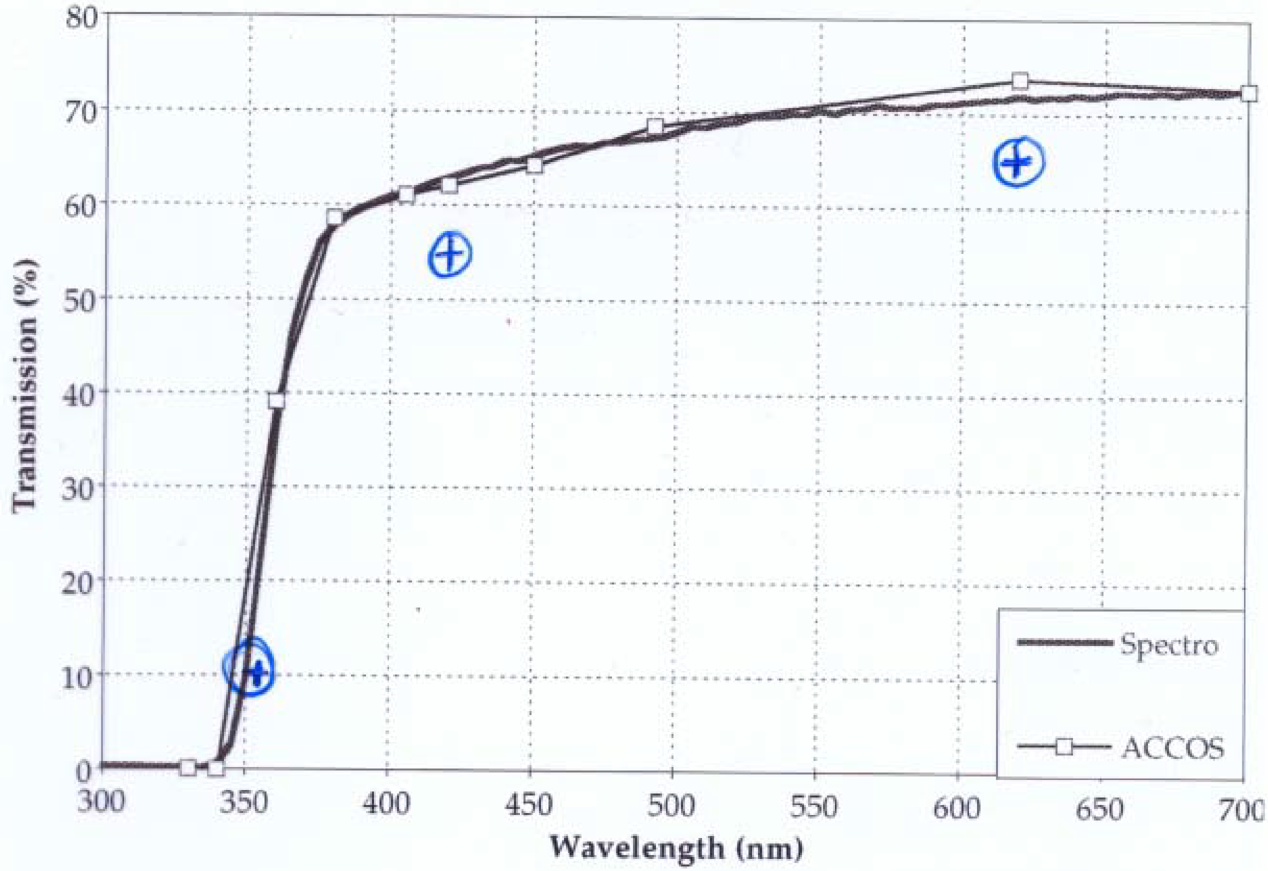
ECAL
PWO
BARREL

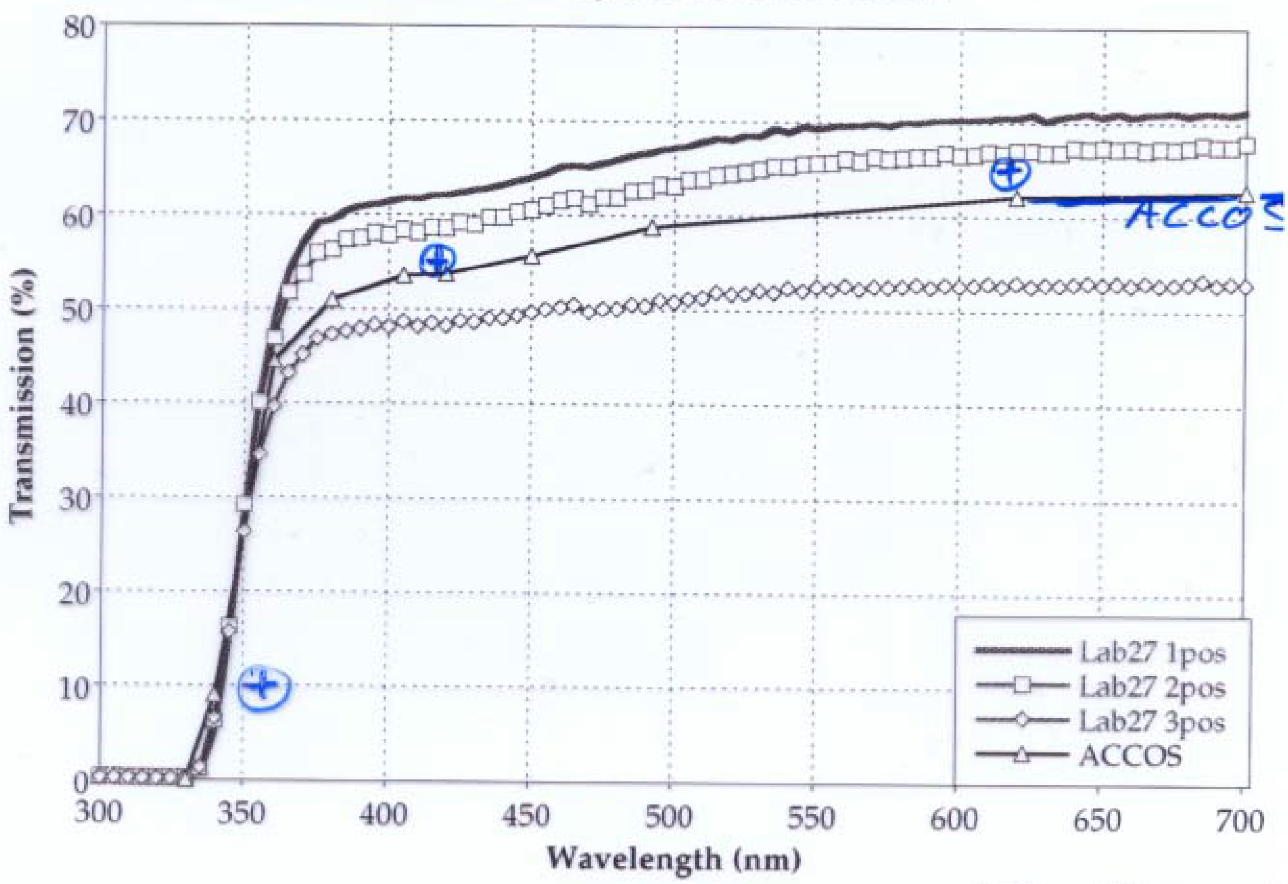
PWO3050



PWO3050_longcomp.QPC

E.Auffray, M.Schneegans, EP-(
04.12.98

PWO2097 crystal with core defect



PWO2097_longcomp.QPC

E.Auffray, M. Schneegans, El
15.09.98

Scintillation light:

- **Light Yield:** **≥ 8 photoelectrons/MeV**
  - measured at 18^0C and in a **100 nsec** gate,
  - with ^{60}Co source **at 8Xo** from PWO front face,
  - with a Phillips XP2262B photomultiplier,
  - covering all rear face, with n=1.5 silicon coupling grea
  - wrapped on 4 sides and end face in 1 layer of Tyvek.

- **Decay Time:** **- LY(100 ns)/LY(1μs) ≥ 90%**
  - Afterglow ≤ 0.5% of peak amplitude
  with a ^{60}Co counting rate of 1MHz

- **Radiation Hardness:**
  - Induced absorption for full crystal saturation:
    $\mu \leq 1.5$ m^{-1} at 420 nm
    for lateral ^{60}Co irradiation, ≥50 krad, ≥ 10 krad/h
  - **Light Yield loss ≤ 6%**
    for front ^{60}Co irradiation, 200 rad, 15 rad/h ⇐ LH
  - No recovery time constant shorter than 1 hour.

* * *

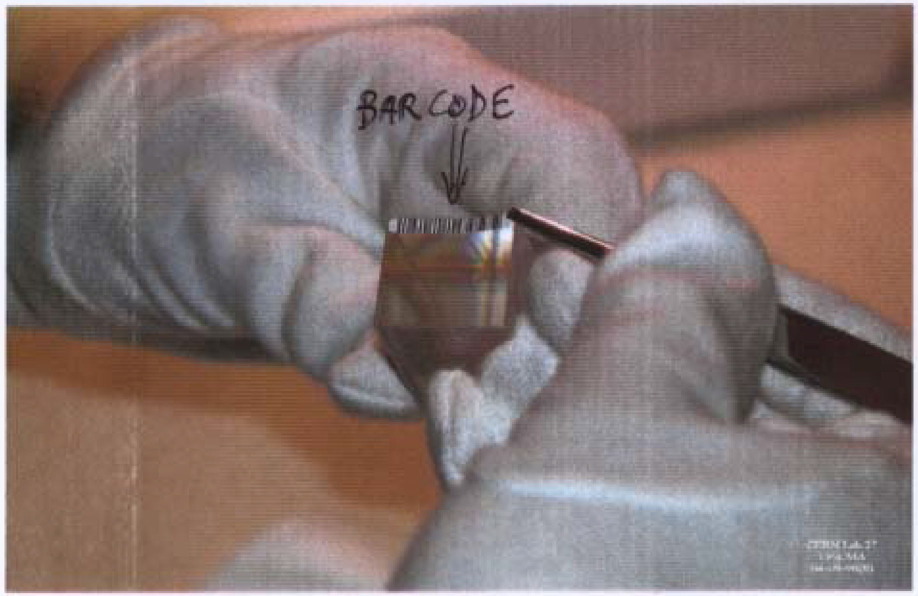
Crystal Quality Control Principles

1. All crystals are identified by a **barcode** label.
2. Each crystal delivered by the producers is first carefully inspected by eye: **Visual Inspection.**
3. Crystals are registered in Database during Visual Inspectio
3. Their main characteristics are then measured on a:

   Automatic Crystal Control System (**ACCoS**)

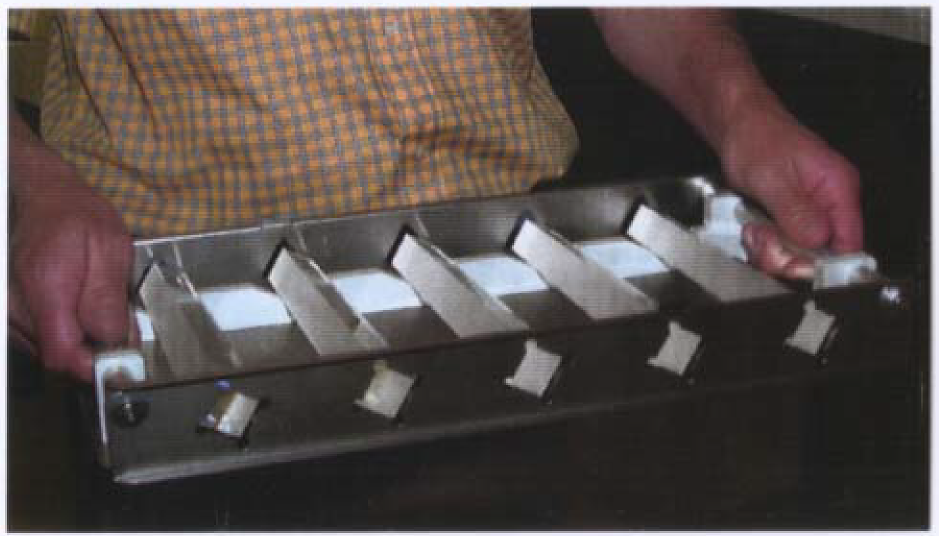
   in one of the two Regional Centers (RC).
4. The **certification** (or rejection) of crystals is the responsab lity of the Regional Centers (RC) after full measurements.
5. All (?) crystals are first measured with similar machines at the production plants in order to:
   - to monitor production quality,
   - to minimise crystal rejection rate.
6. All ACCOS measurements are performed in a fully automatic mode with no manual crystal handling.
7. All data are automatically transferred to a common datab Object Oriented (C.R.I.S.T.A.L.) accessible from all labs.

CRISTAL in fact 'pilots' all the measurements.



Crystal identification

Crystal registration & Visual inspection



Multifunctional box

- STORAGE
- ACCOS LOADING
- CAPSULE GLUING

Producers

V V

Regional Centers

CERN/Geneva **ENEA/Rome**

+ British Universities for End Cap construction

V

Crystal Quality Control

- Visual Inspection
- ACCOS Measurements

V

APD/Capsule Gluing

V

Sub-Module (10 cx) Assembly

V

Module (400-600 cx) Assembly

V

Super-Module (4 Modules) Assembly

V

Calibration in Beam

V

ECAL Global Assembly

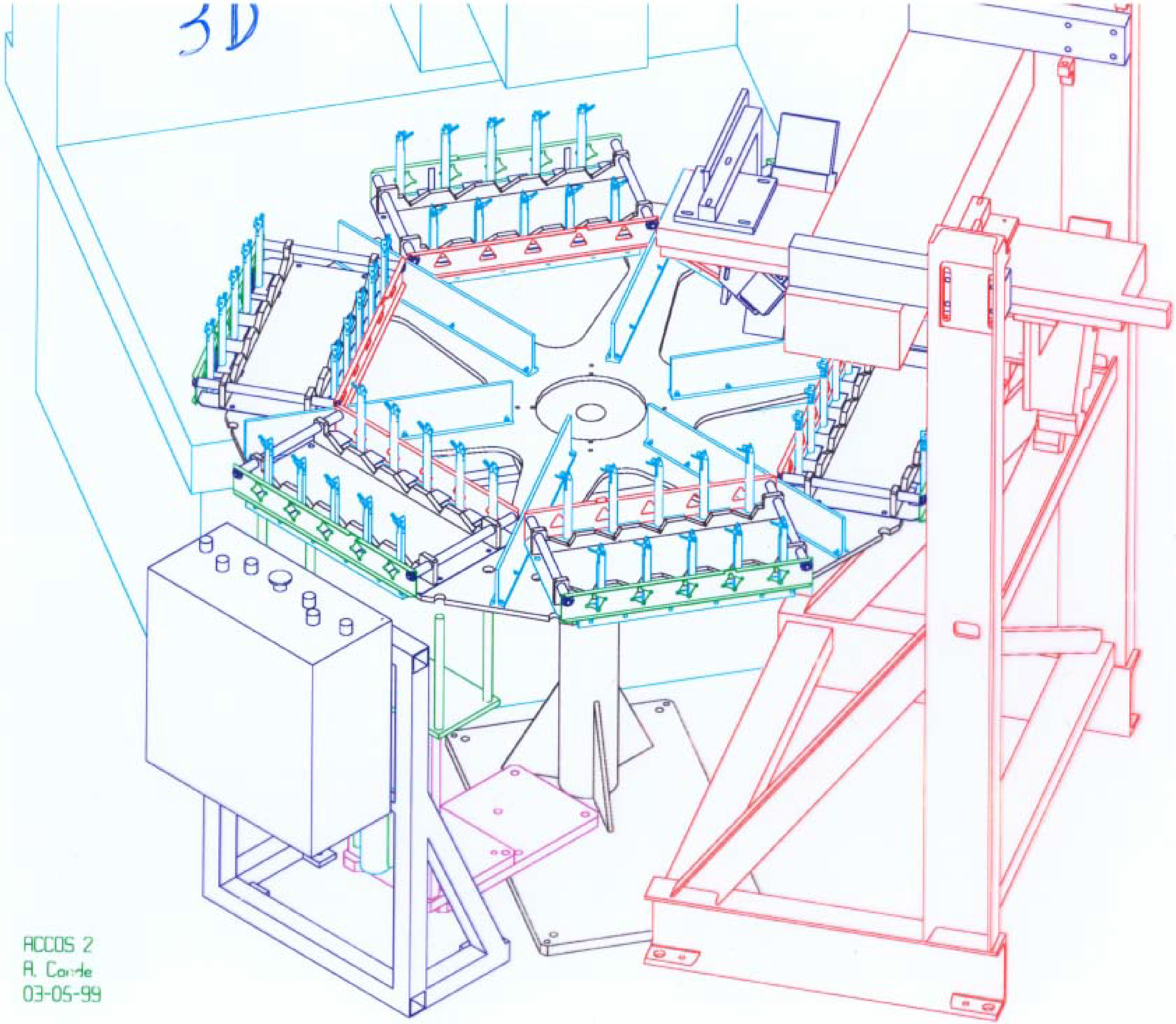
Automatic Crystal Control System (ACCoS)
Main features

1 Concept, 2 systems!

ACCoCE: 2 machines at CERN/B27, 1 in Bogoroditsk/Russ

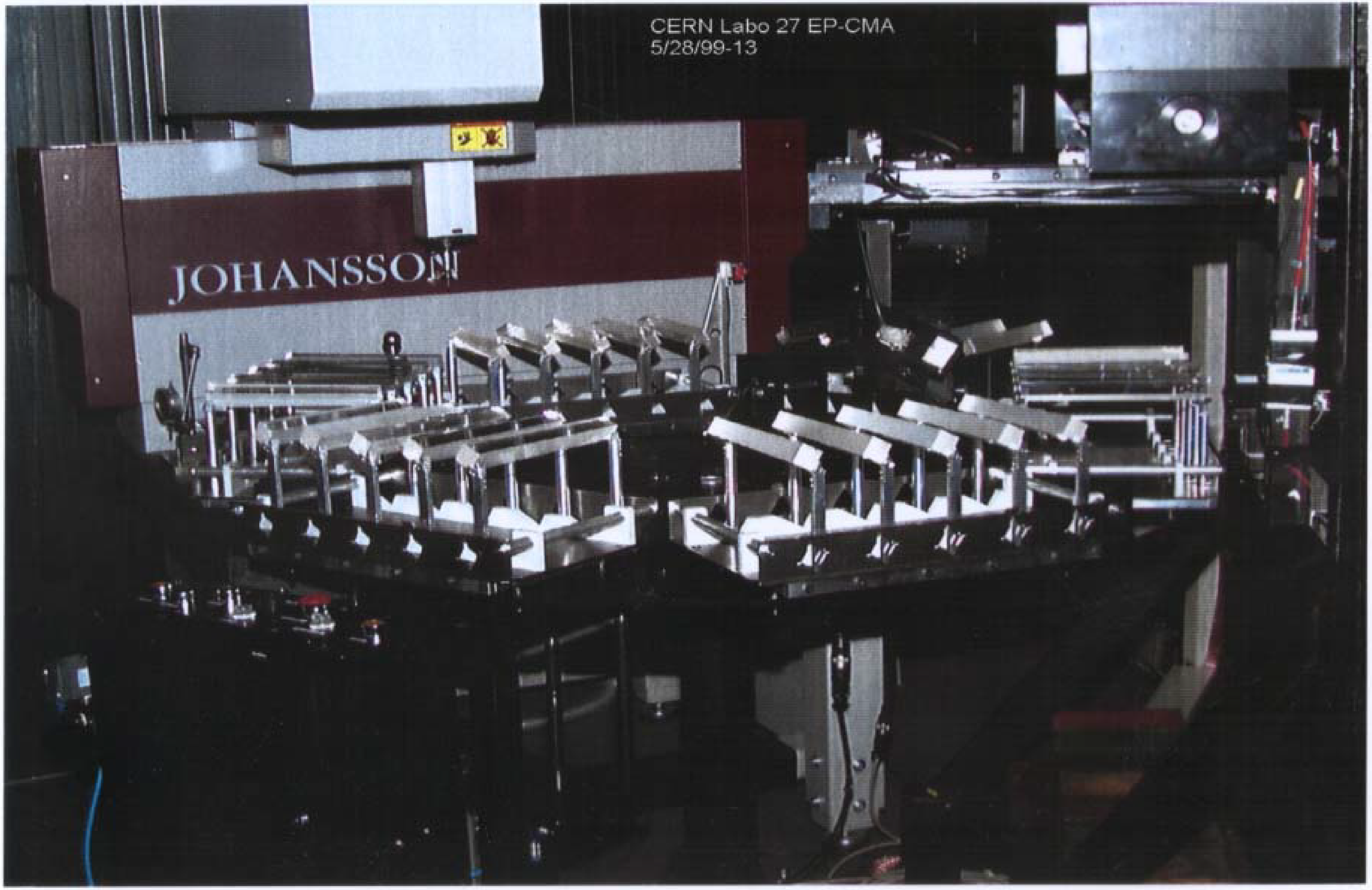
- Concept and construction by a collaboration:
  LAPP/Annecy-INP/Minsk-CERN
- Crystals loaded on **circular** server in boxes of 5 units @
- All crystal's barcode are first read-in on ACCoS server
- Dim measured by conventional 3D machine to ±10 μm,
- LT +TT measured by compact mobile spectrometers (Min with 10 interferential filters (TT in 11 points along crystals),
- DT, LY and NU measured by a Start-Stop method:
  - Start telescope: ^{22}Na source +BaF_2 crystal +PM
  - Stop telecope: PM at ~7mm from crystal large end
  - Decay time spectra in 21 points

  One derives: → Time characteristics
  → Relative LY
  → NU profiles
- No systematic RH measurements by crystal Irradiation,
- RH 'predicted' by band edge slope in LT measurement,
- 30 crystals are measured in 7~9 hours.



ACCOS 2

6 x 5 =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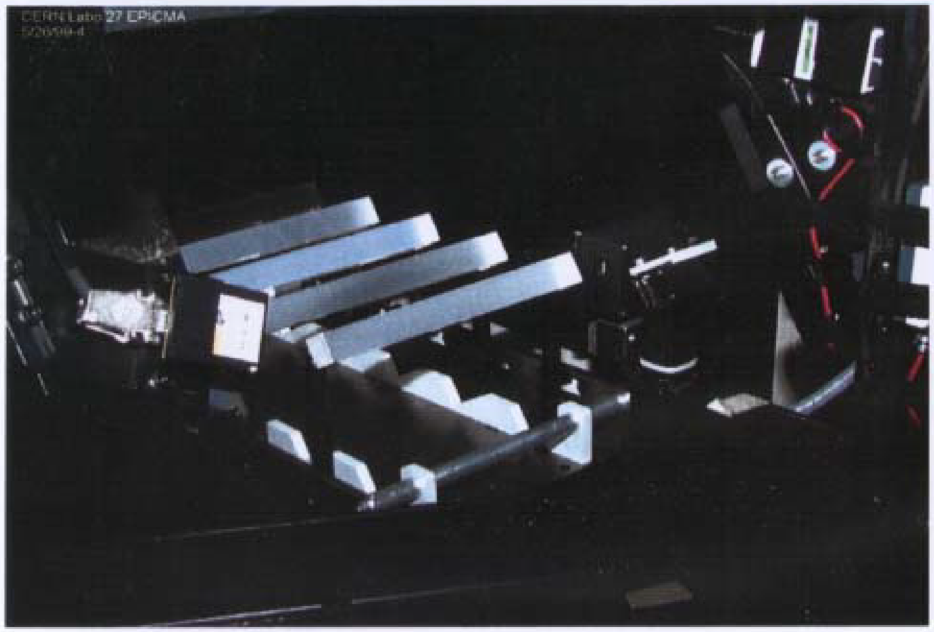
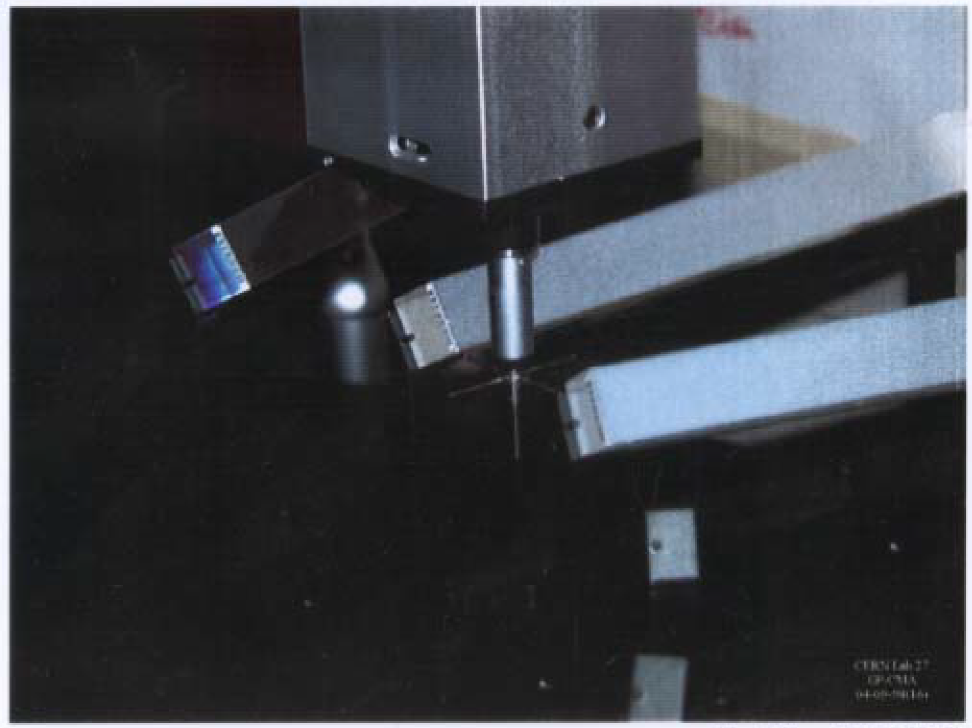
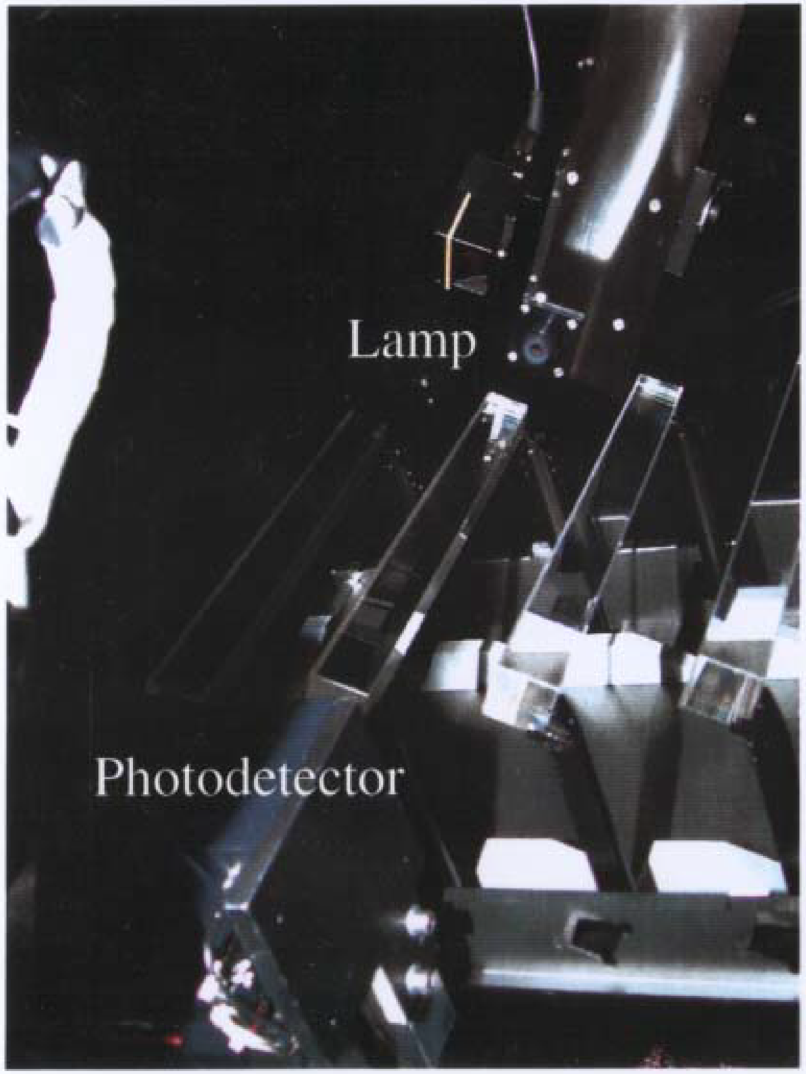


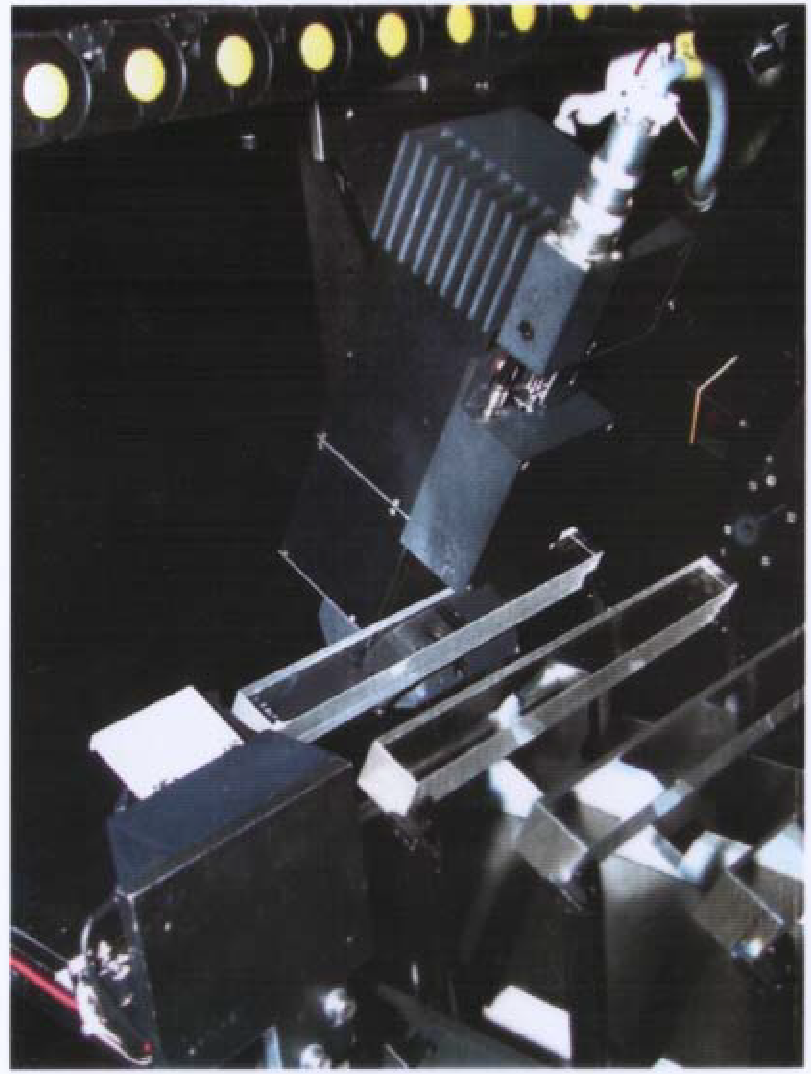
Barcode reading

Dimension measurements

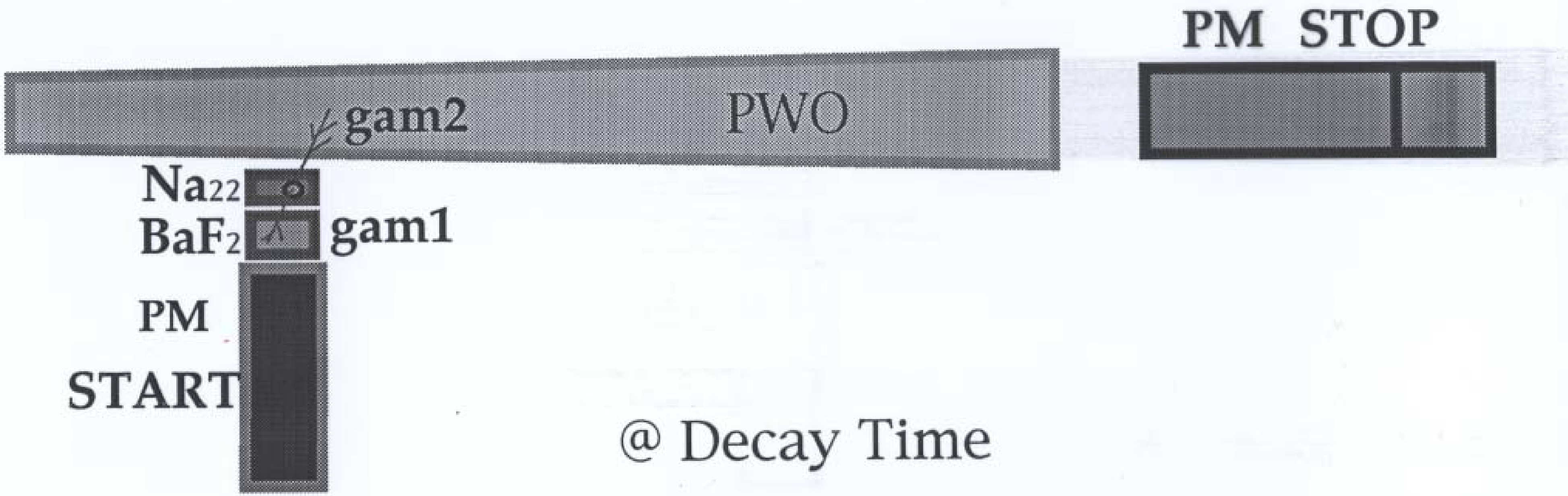




Longitudinal transmission



Transversal transmission
+ kinetic SPECTRA ⇒ LY, NU



@ Decay Time

@ Light Yield

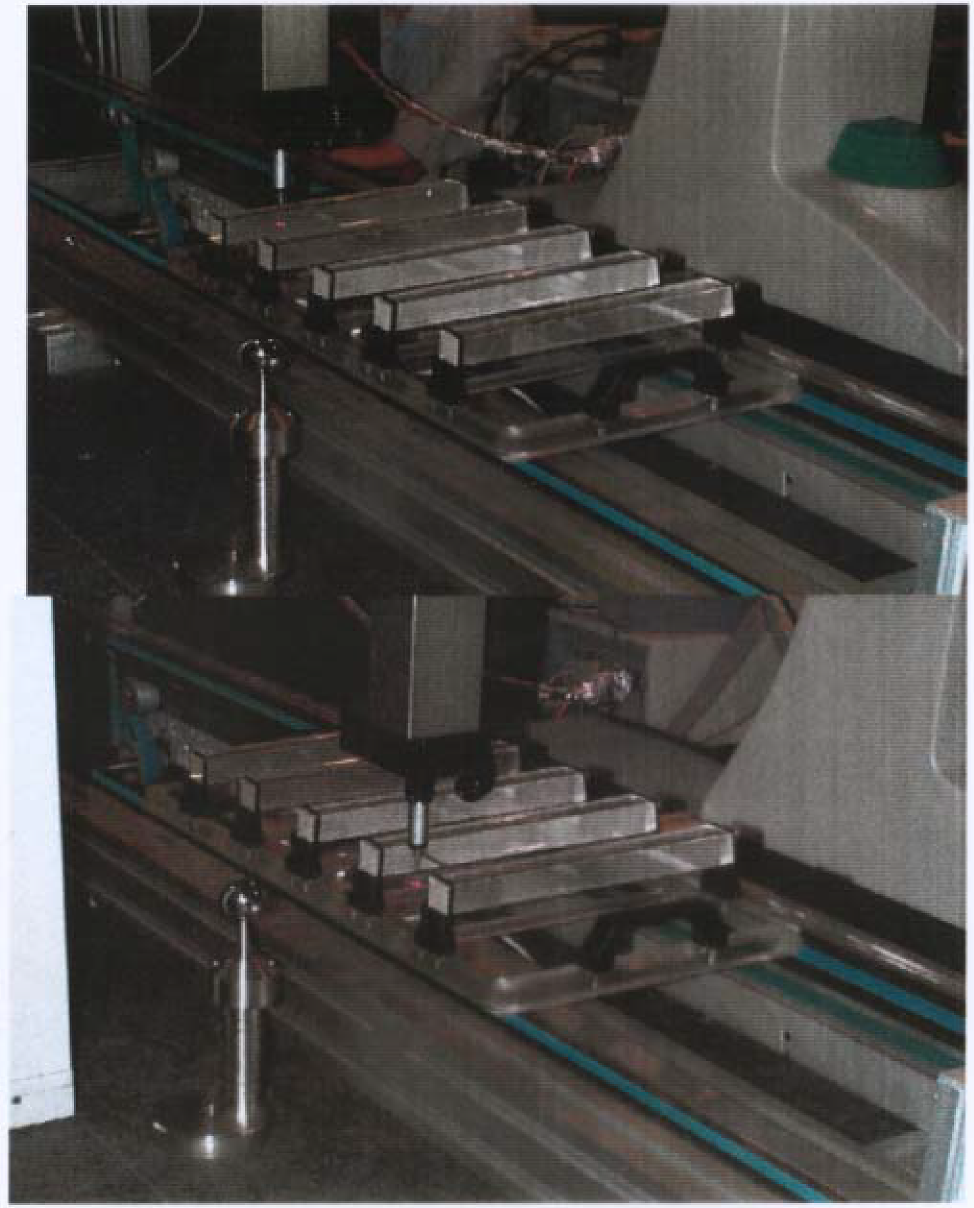
@ Uniformity of light collection

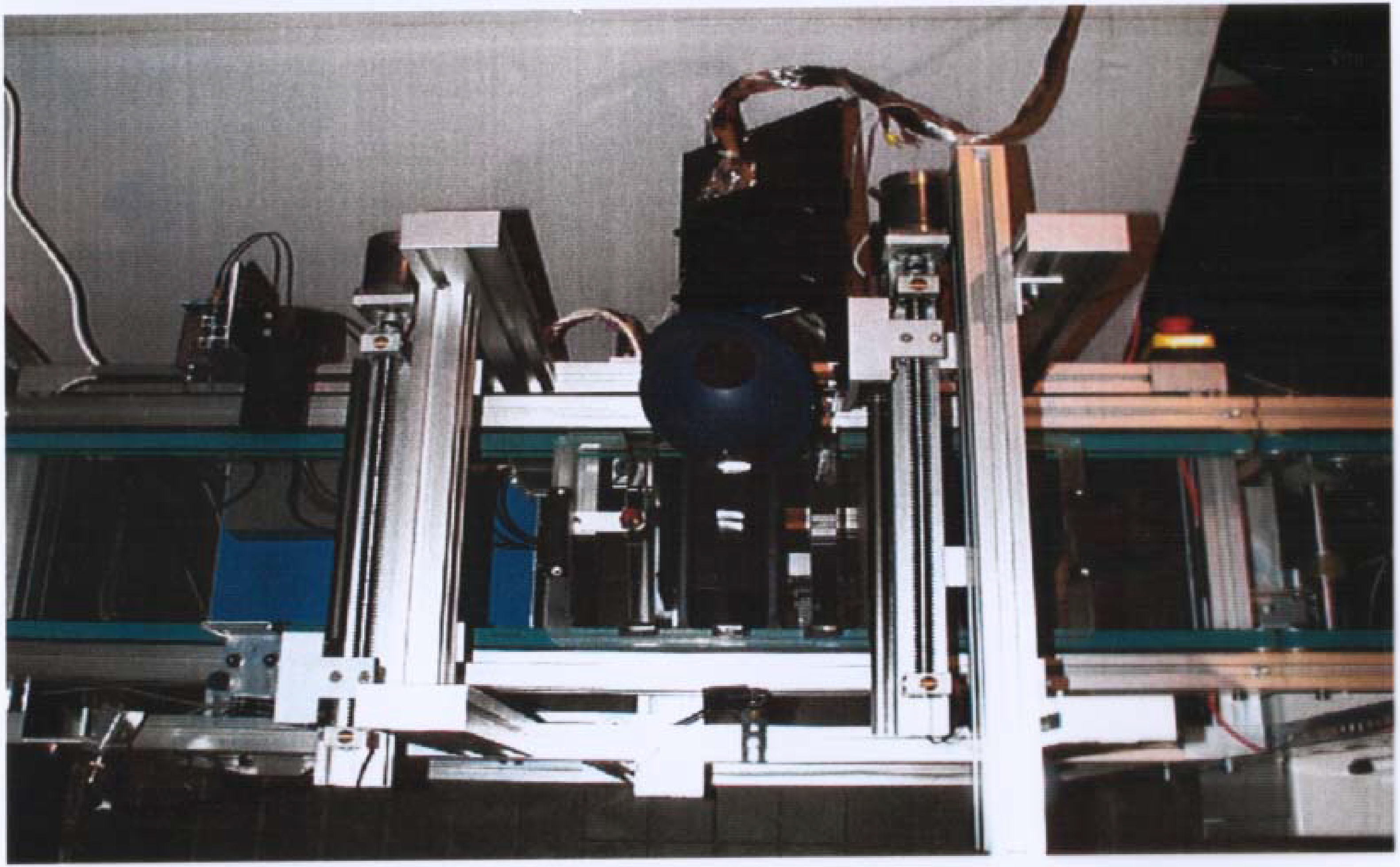
1 concept, 2 Systems…

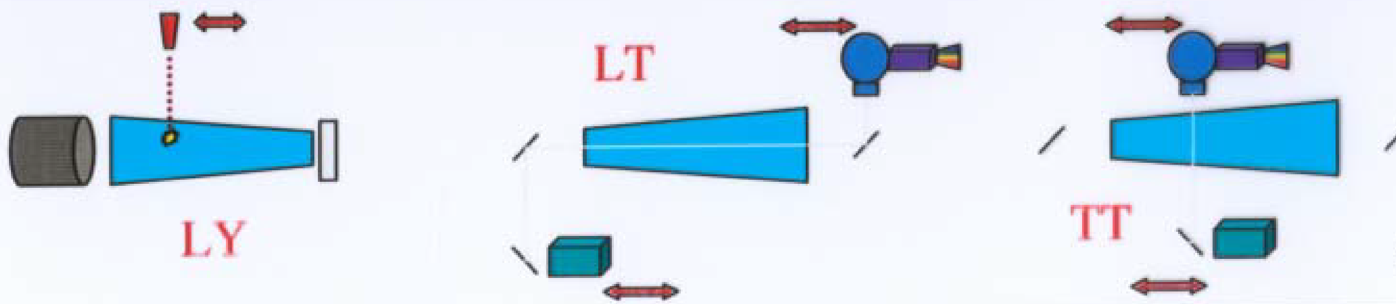
ACCoR: 1 machine at ENEA/Rome, 1 in SIC/Shanghai

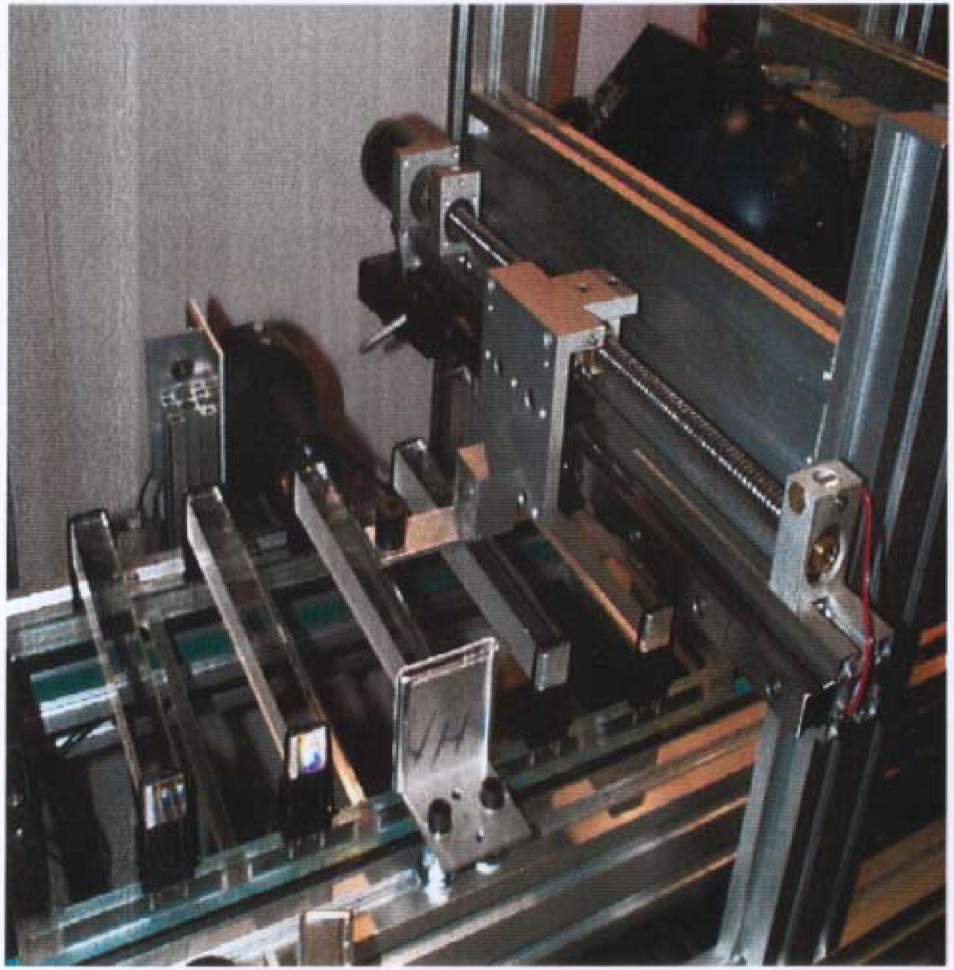
- Conceptual study and construction by the *INFN/ENEA/Rome group*
- Crystals presented on trays of 5 units on **linear** server,
- All crystal's barcode are first read-in on ACCoS server
- Dim measured by conventional 3D machine to ±10 μm, @
- LT and TT measured by one classical spectrometer sliding with mirrors and integration sphere, @
- LY and NU measured by standard Pulse Height method PM near-contact to large crystal end + sliding ^{60}Co source @
- DT checked by ratio: LY(100ns)/LY(1000ns),
- No systematic RH measurements by crystal Irradiation,
- RH 'predicted' by band edge slope in LT measurement,
- 30 crystals are measured in ~7-9 hours.

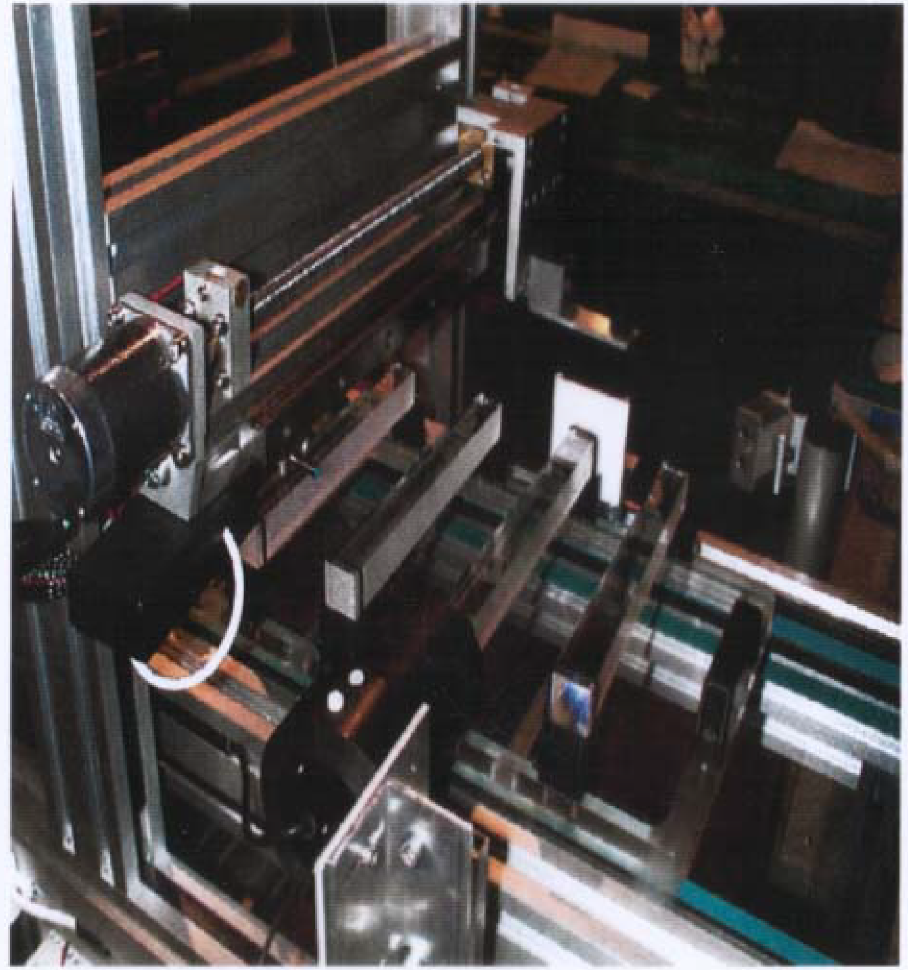

Ares






LY
LT
TT





CMS/ECAL October 2000

ACCOS machines Status

1. **ACCoCE1:** Operational since 1.5 years
   ~5000 crystals of pre-production were received and controlled on this machine.

2. **ACCoCE2:** Operational since last Summer
   Comparisons of results with ACCoCE1 under way.

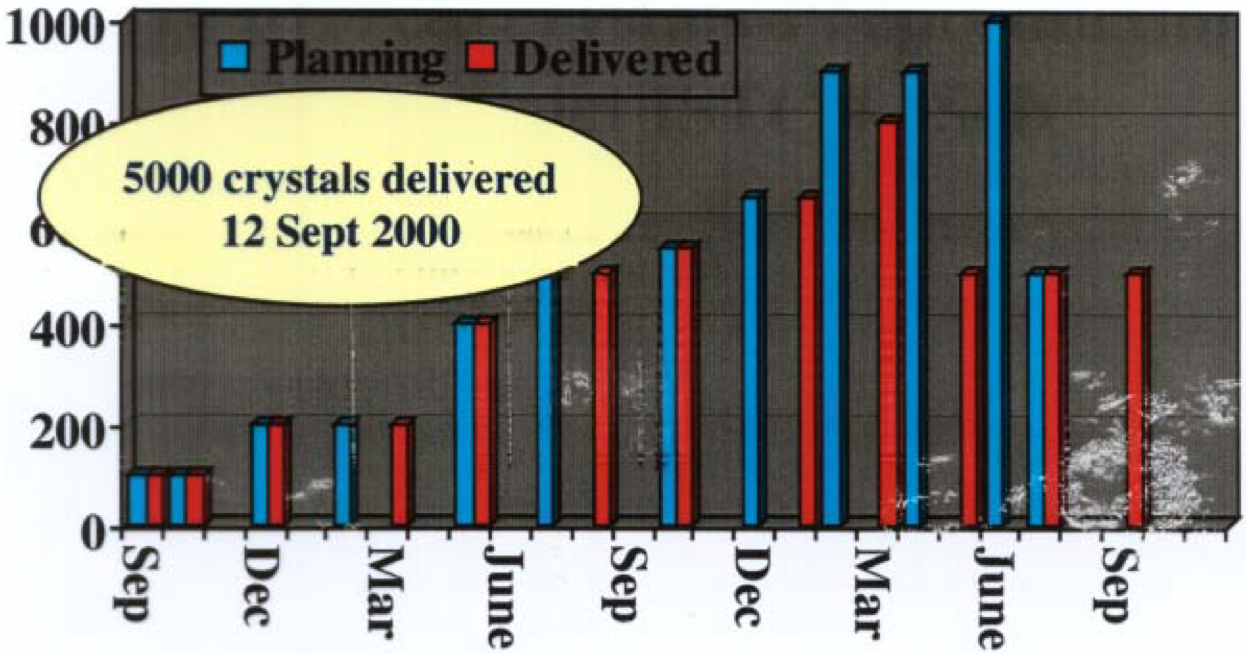
3. **ACCoBog:** ACCoCE machine at BTCP/Bogoroditsk (producer)
   Operational since Fall 1999.
   Some chronic mechanical difficulties.
   Upgraded and revised these days.

4. **ACCoR:** Operational since ~0.5 years
   Comparisons of results with ACCoCE1 under way.

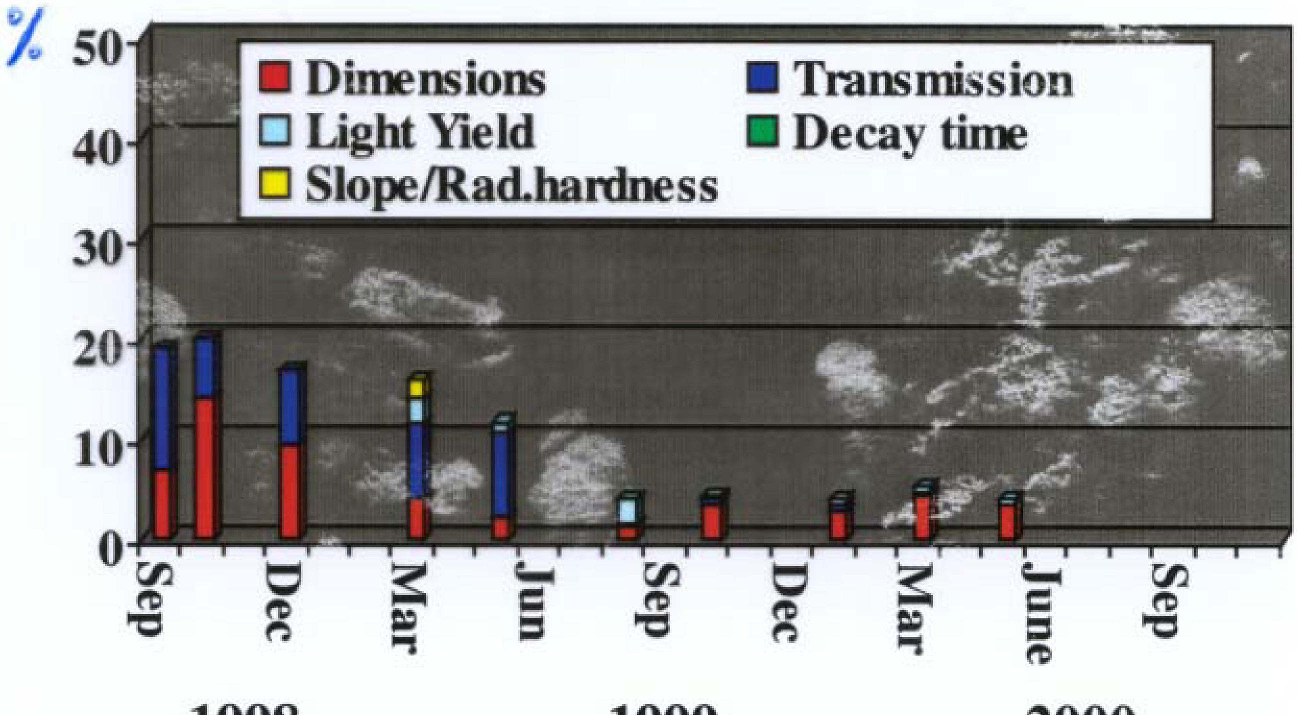
5. **ACCoSIC:** ACCoR machine at SIC/Shanghai (producer)
   In setting-up

Status of crystal delivery from Bogoroditsk (Russia)

Delivered crystals-Preproduction contract ISTC # 354b



Rejected crystals (in%)



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EP/CMA1

Conclusions

- The principle of measuring all main characteristics of each of ~80 000 crystals for CMS/ECAL has proved to be realistic
- The principle of fully automatic measurements and data transfer without crystal handling has proved feasible.
- The principle of measuring twice each crystal (at produce and in RC) is an additional guarantee of mounting in ECA well-known high-performance crystals.
- ACCOS machines, after relatively long start-up and deb ging periods are now performing well and reliably (not all y
- Measurements stability and reproductibility are goo provided performance is monitored continuously with he of Reference crystals.
- ACCOS machine capacities (up to ~100 crystals/day at CERI are well adapted to future peak production rates (up to 15 /month at CERN).
- Crystal rejection rates are continuously decreasing.

CRISTAL System

- Product and process tracking for CMS detectors
- 1 Terabyte collected over 4 years of construction
- Distributed over CERN, UK, Rome, China
- Industrial-strength software to handle complexity
- Flexible model, catering for system evolution
- Based on OO technologies (OODBMS, CORBA)
- Reusable for Tracker, HCAL, Muons
- Technology could be transferred to industry