PWO Crystal ECAL Status

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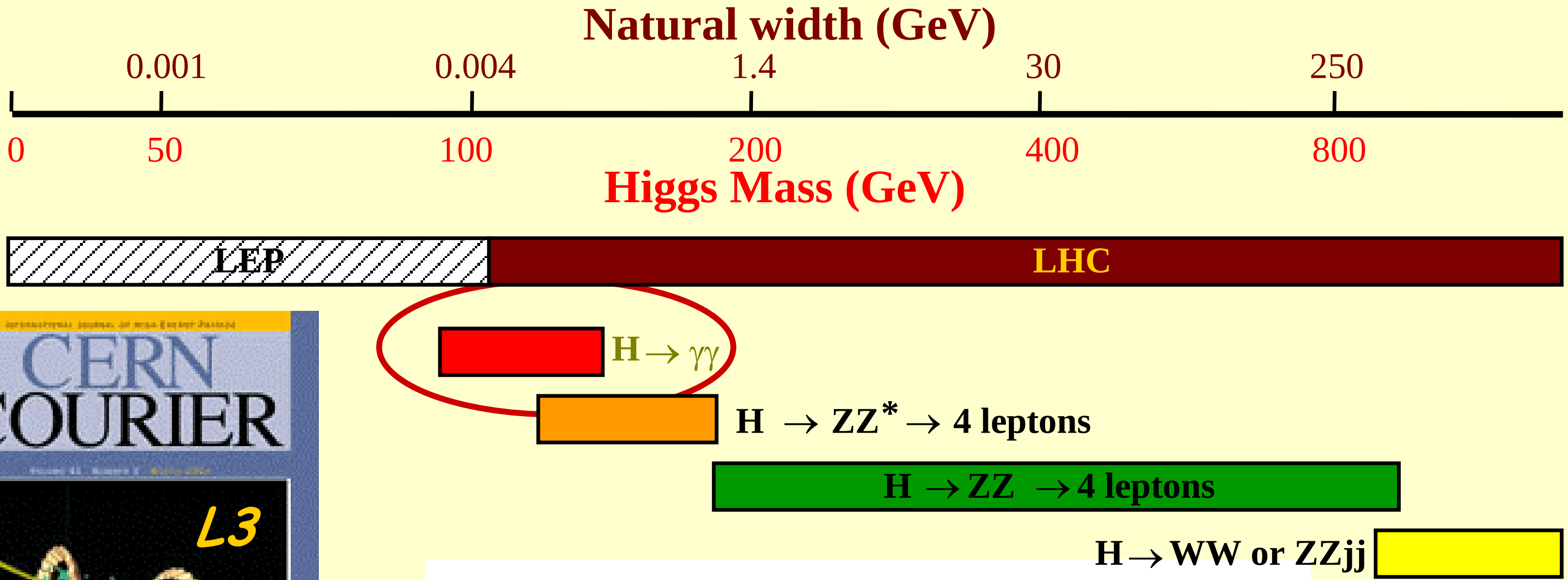
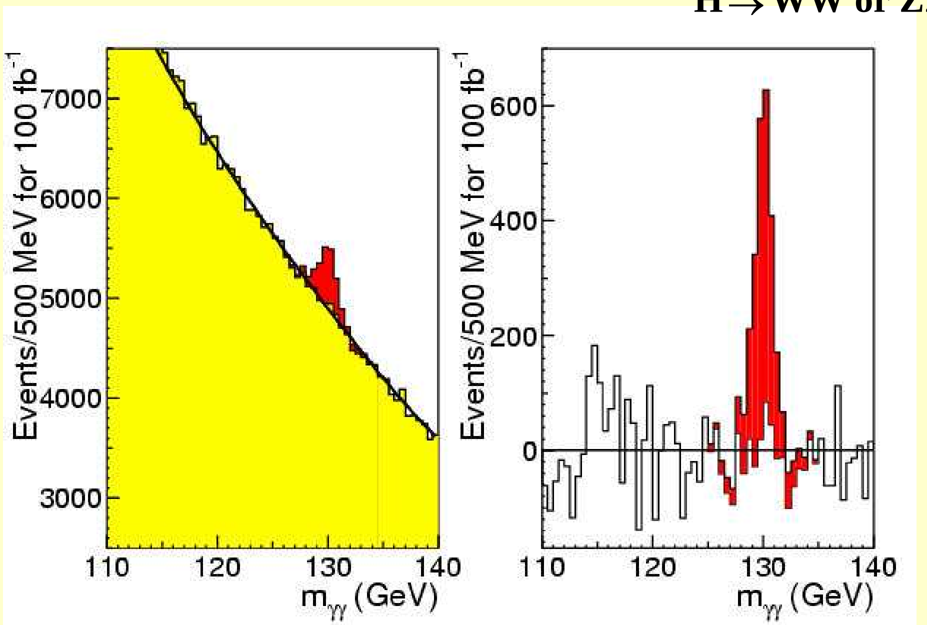
May 11th 2002

Higgs Hunt at Low Mass

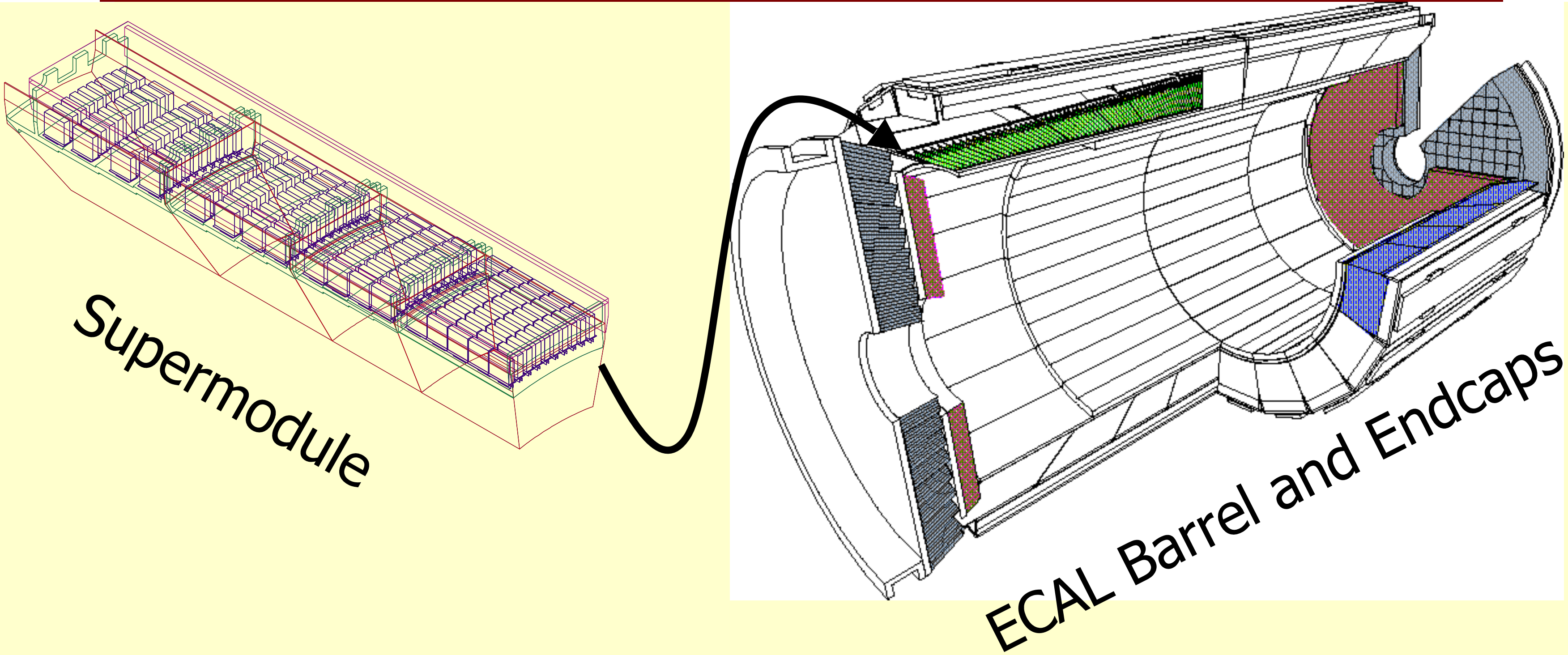


LEP observed an excess of events around 115 GeV



H → γγ signal in CMS ECAL @ design resolution

The Calorimeter

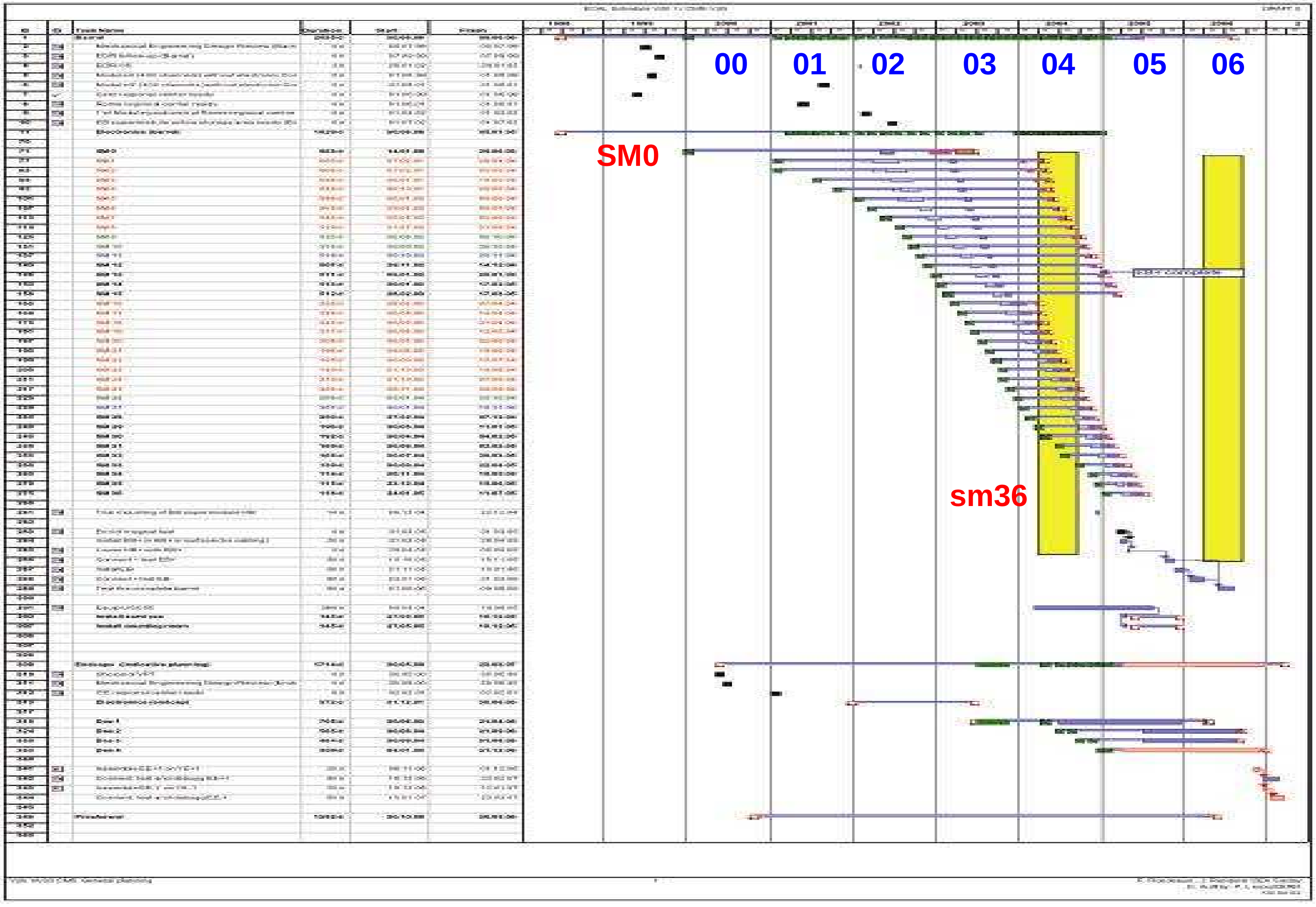


- 36 supermodules in barrel, 4 Dees in endcaps.
  1,700 crystals/supermodule, 4,000 crystals/Dee
- 61,200 crystal/barrel, 16,000 crystal/end caps
- 2 APD's/crystal in barrel, 1 VPT/crystal in endcaps
- High resolution electronics of 95 db dynamics, light to light readout.
- 1 monitoring fiber/crystal for in situ monitoring.

Status: Electronics is Critical

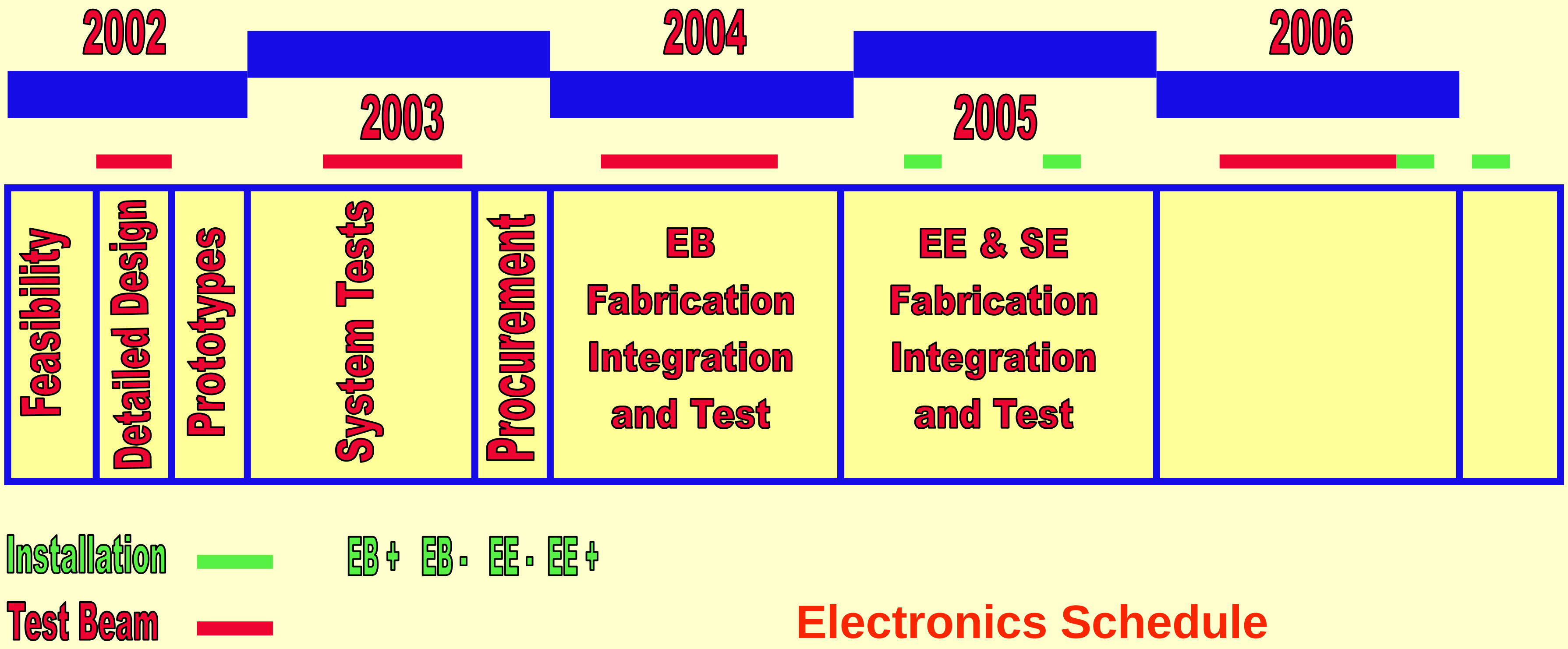
- Crystals:
  - All 61,200 barrel crystals contracted to BTCP, Russia, where 2 crystals grown in one ingot. 8,700 received
  - 1,000/month in 2002 and 1,800/month in 2003
  - Endcap contract pending because of financial uncertainty
- Photo detector:
  - Hamamatsu APD finalized. 25,000 received
  - Ultra fine mesh vacuum phototriode (VPT) for endcaps: G > 8 & QE ~ 20% at 4T, radiation hard
- Electronics:
  - Estimated cost escalated from 31 to 54 MCHF: **redesign**
  - FPPA2000 has high noise (4 X) and wrong pulse shape FPPA2001 prototype expected in February, 2003
- Calibration & Monitoring:
  - On schedule: 1st laser at CERN

ECAL V20.1/CMS V33 Schedule



ECAL Planning

Goal: Apr 07 - ECAL complete and commissioned
Advance the detailed test (also system test) of 1st SM to mid-2003 (final analog electronics + emulated FPGA digital part)
EB electronics mounted in 2004/2005 – calibrate at least 9 SMs in 2004
EE and SE mounted in 2005/2006, calibrate 1 Dee in 2006



Electronics Schedule

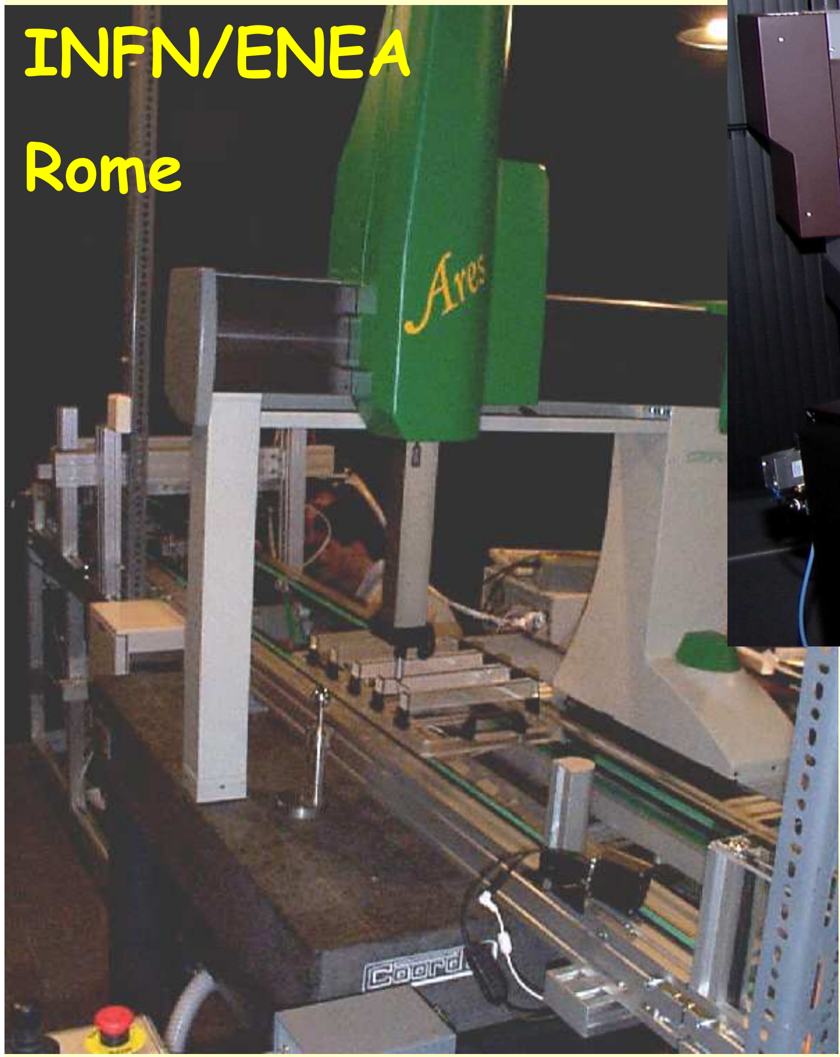
PWO Crystals Growth

32 to 65 cm diameter

at BTCP with Czochralski

PWO Crystal Quality Control

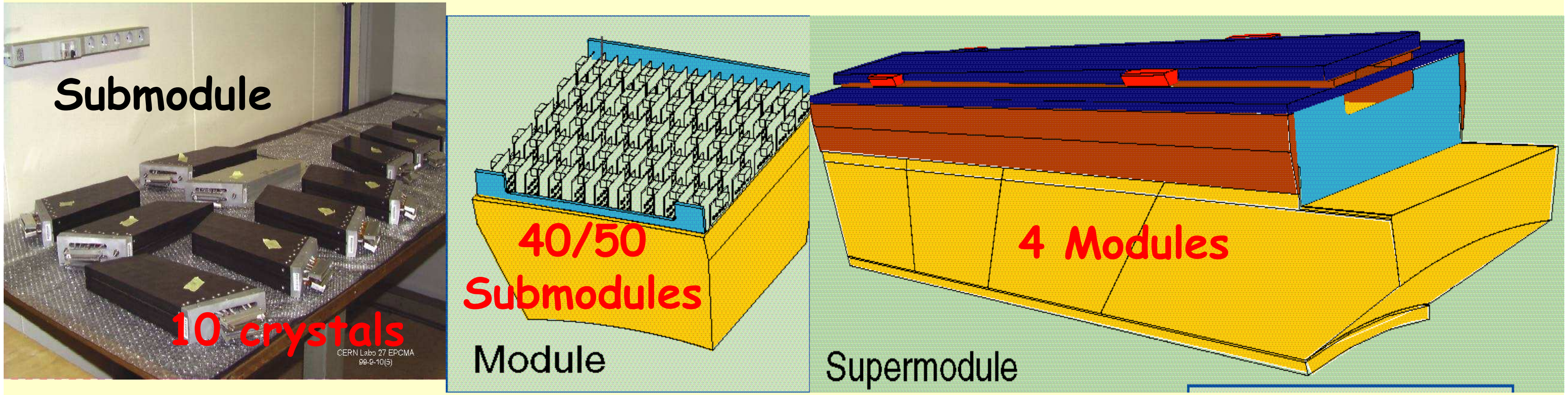
2 Regional Centers

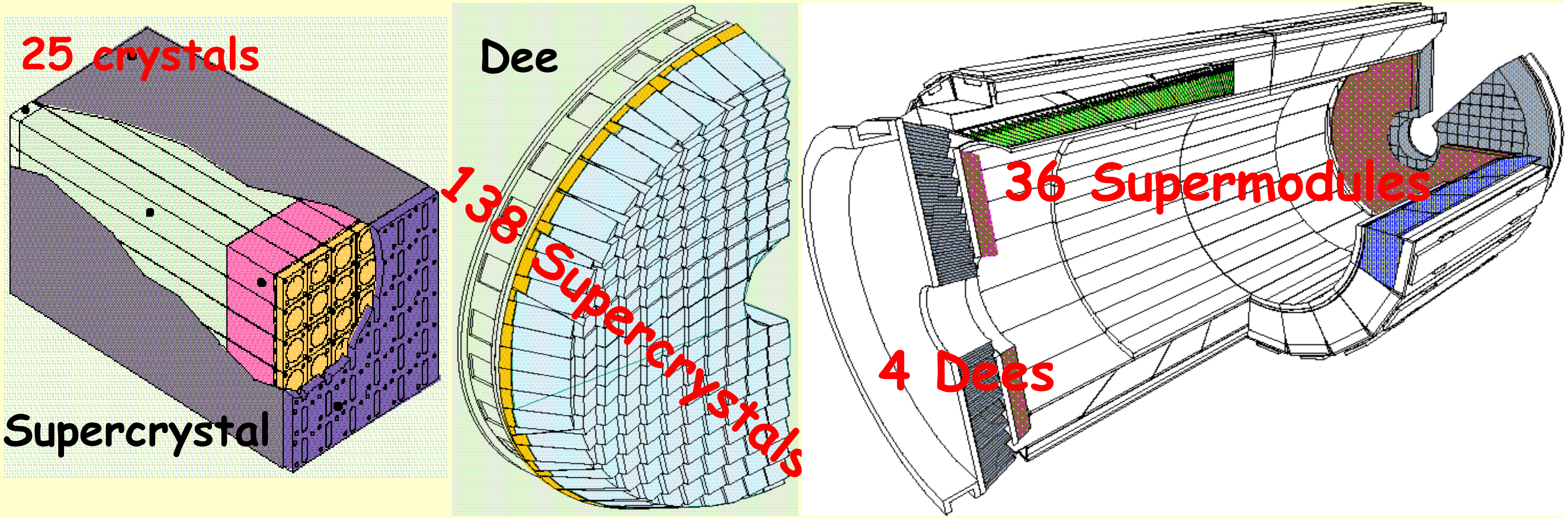


Automatic control of:

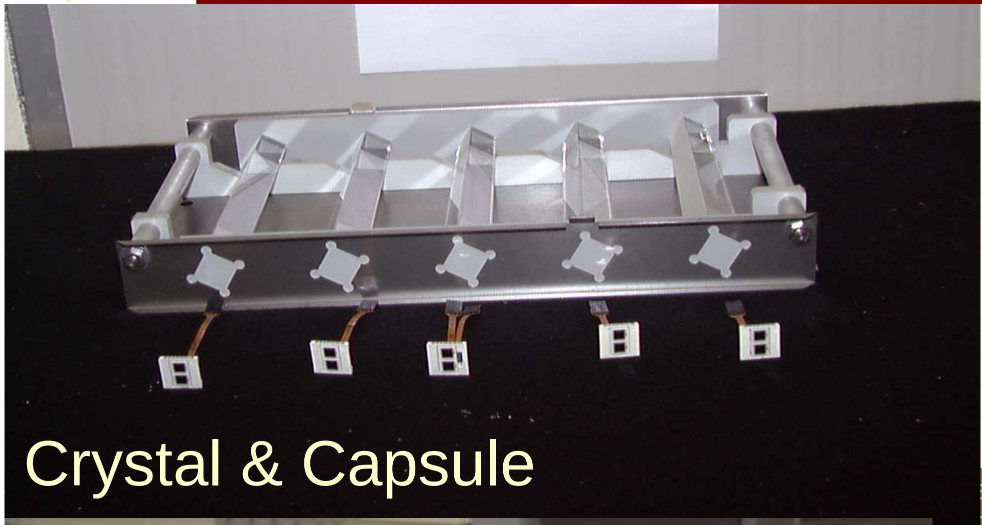
- Dimensions
- Transmission
- Light yield and uniformity

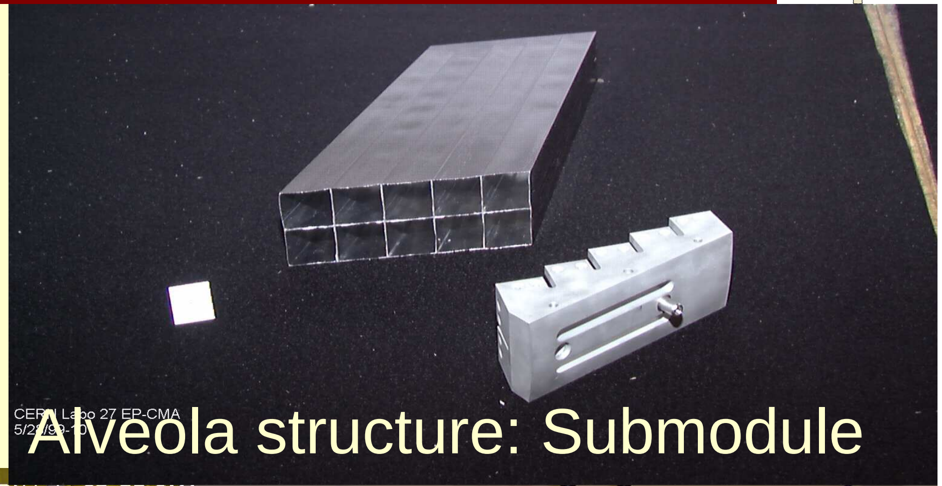
Overall ECAL Assembly

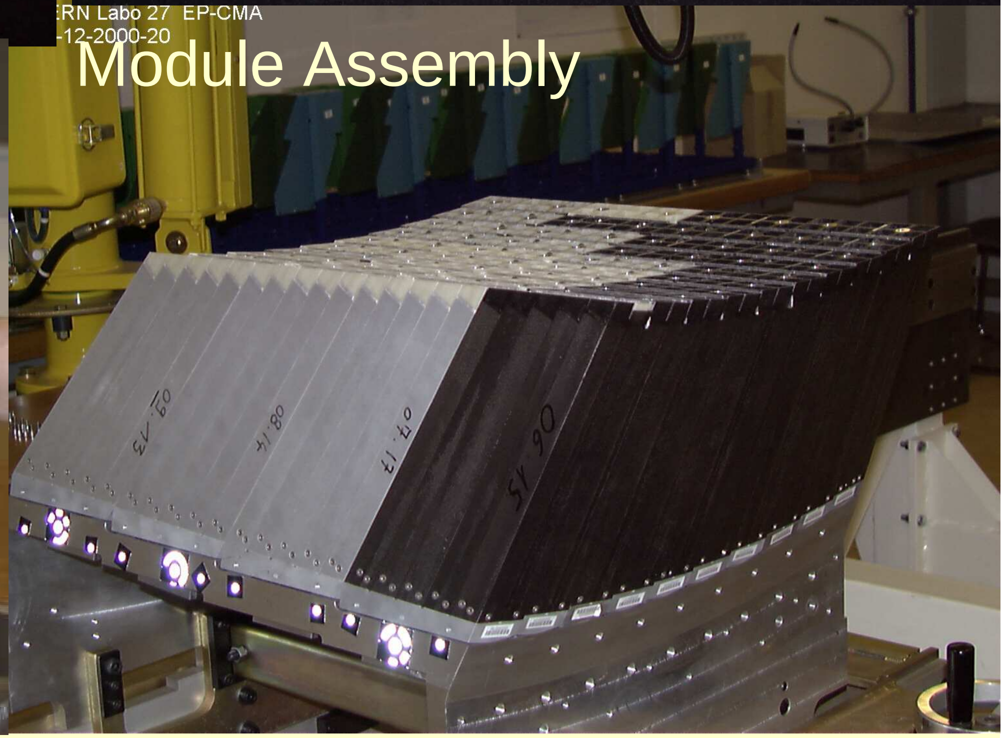




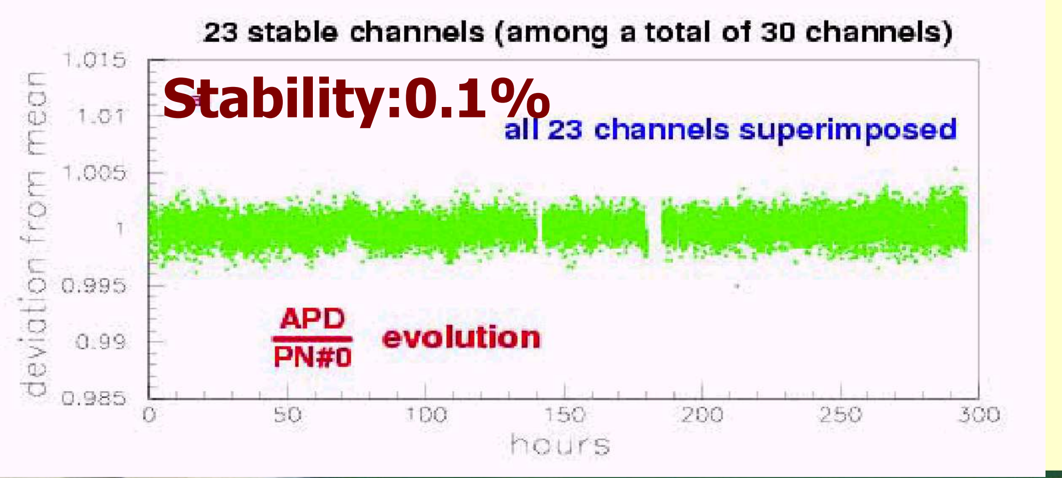
Barrel Construction

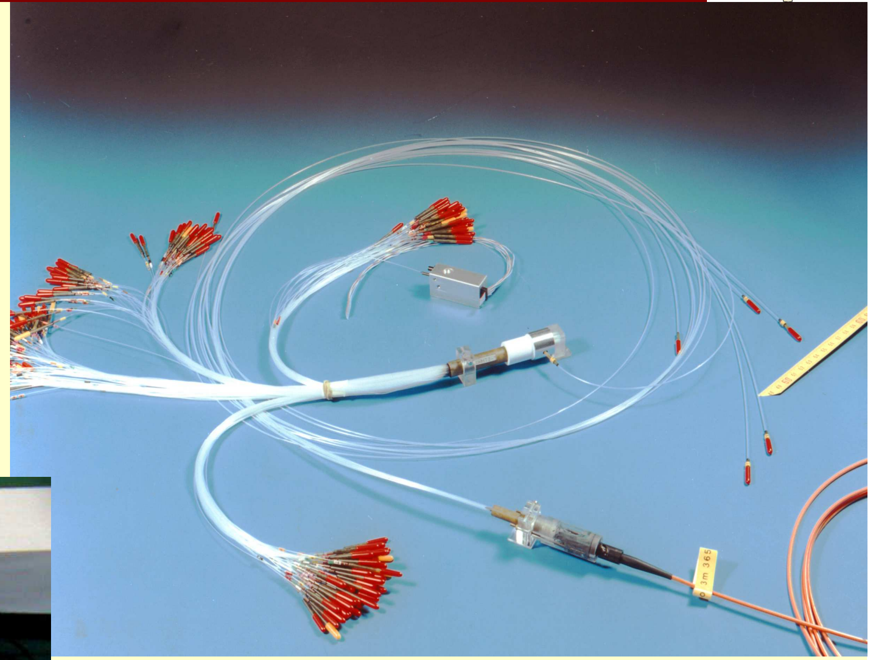


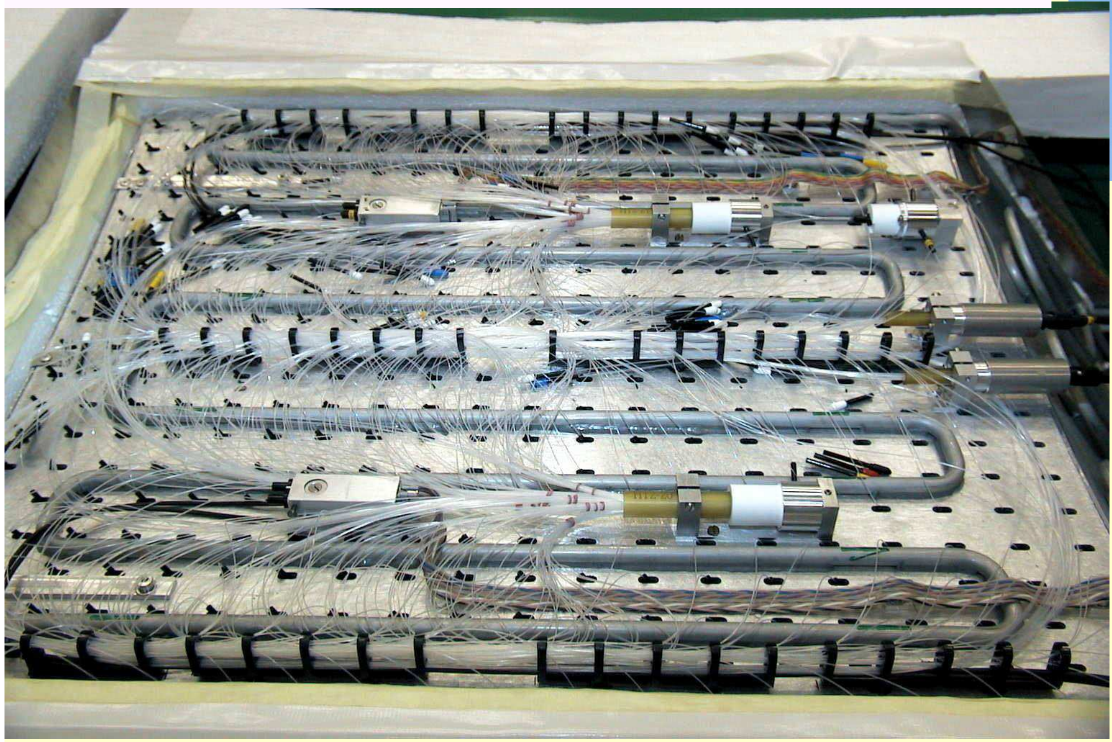




Monitoring Assembly





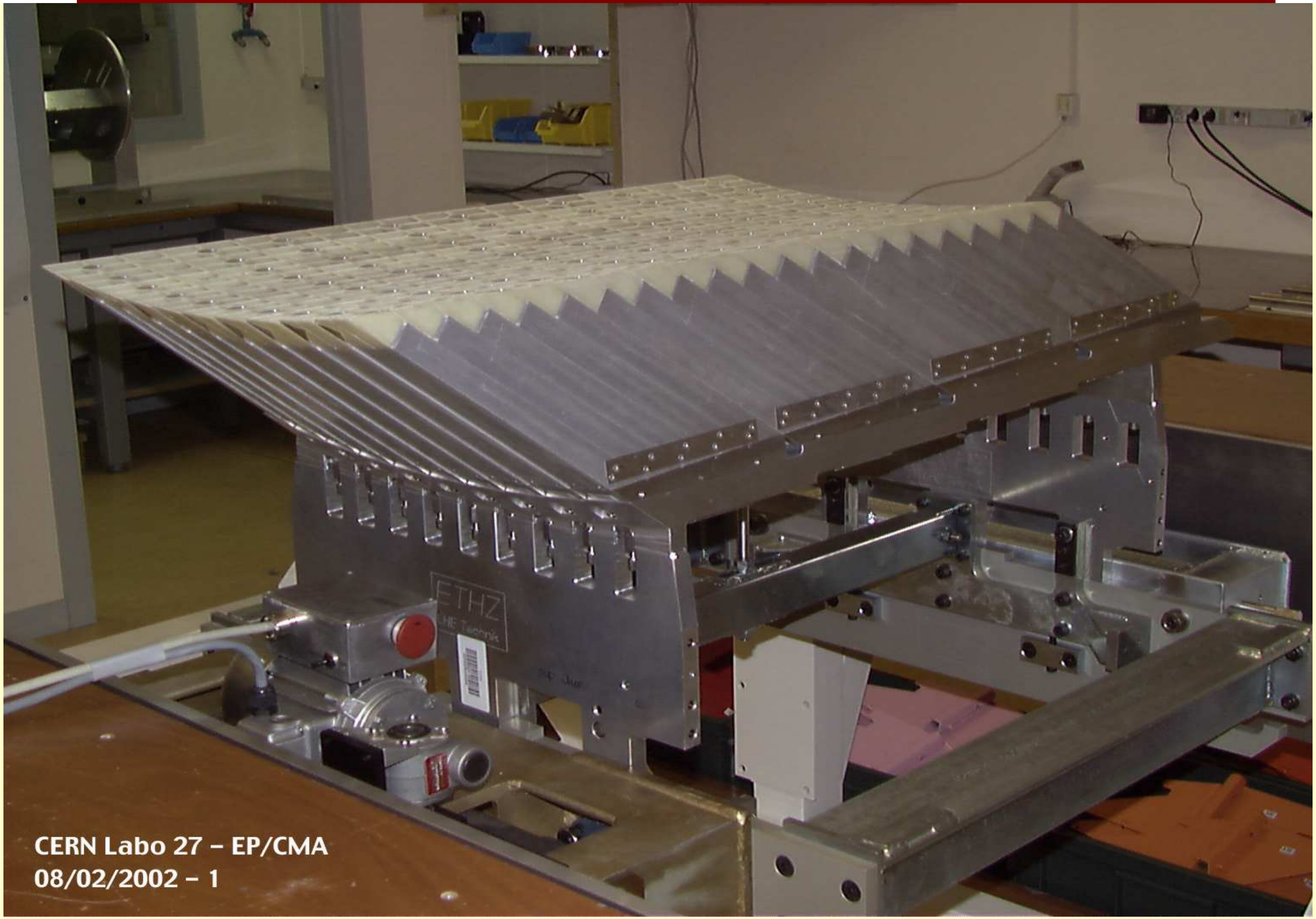


Monitoring

Low Level Fiber

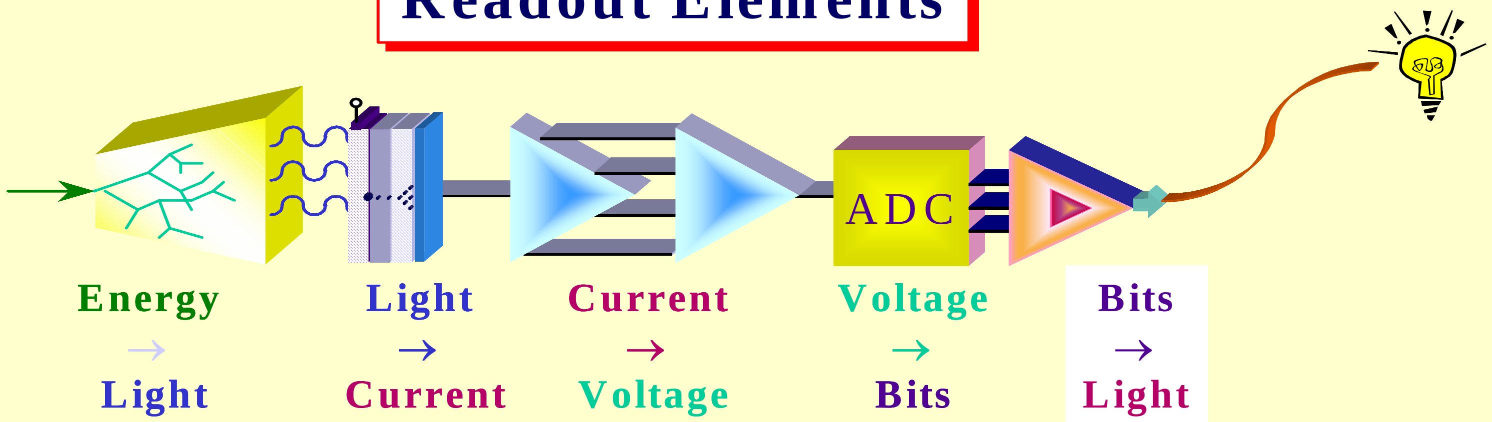
Distribution

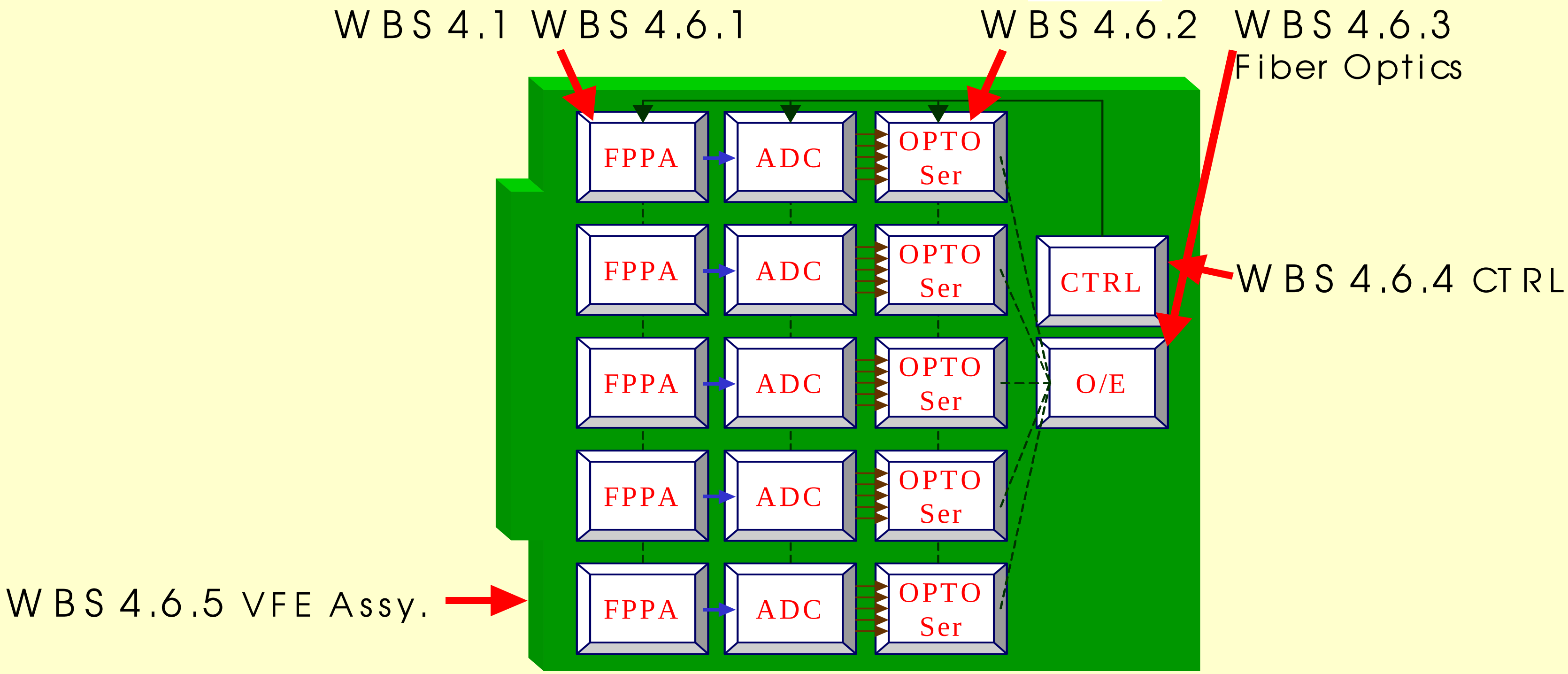
Supermodule: M4 of SM 1



The Baseline Readout in May ‘01

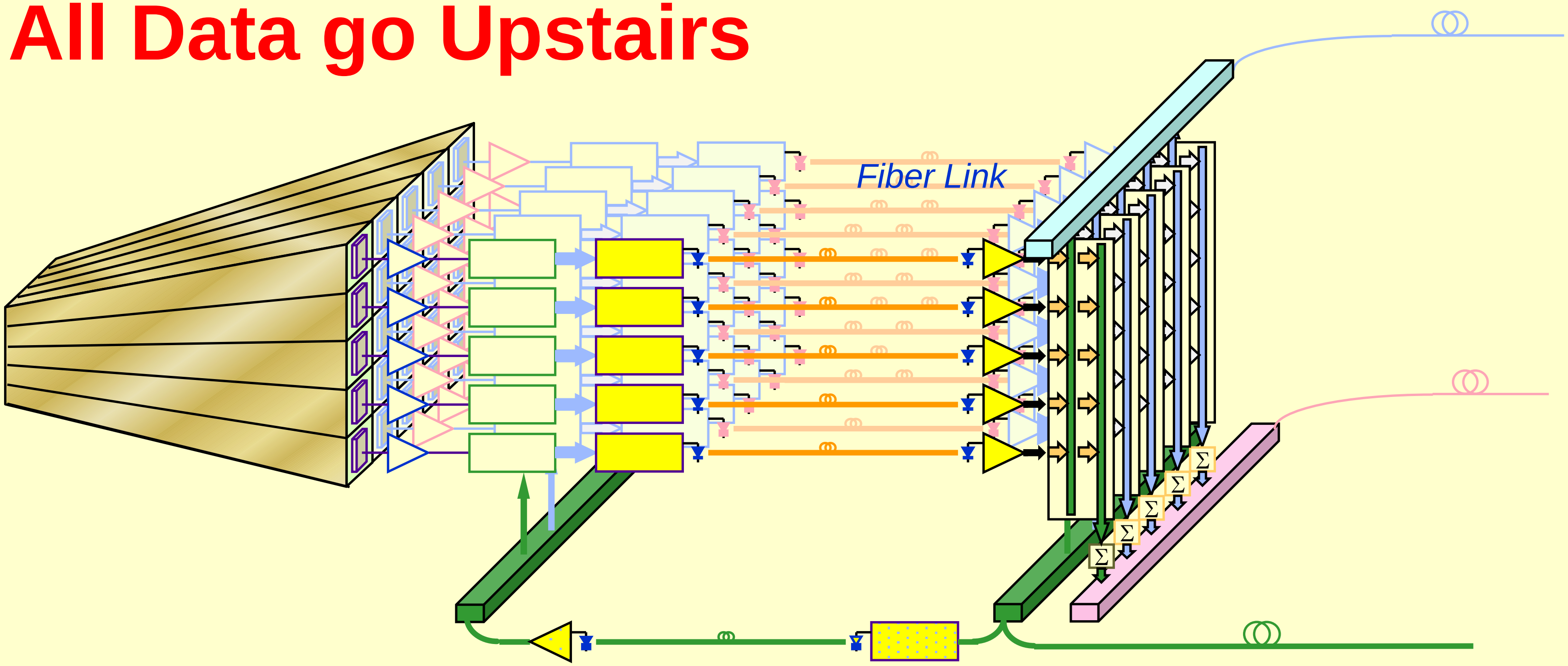
Readout Elements





ECAL Electronics: Old Design

All Data go Upstairs



~90,000 0.8 GHz fiber links

Flexible architecture: All data processing upstairs

Justification: No rad hard electronics in an inaccessible location.

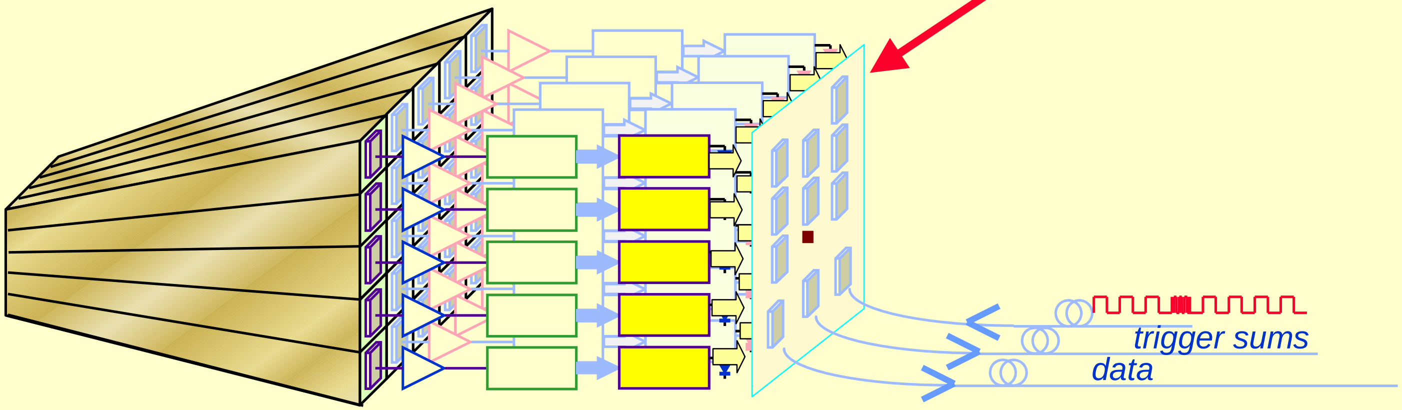
Problems in the Old Design

- Fiber-Optic link:
  - 90,000 links (76,000 signal + 15,500 control) at $150 each.
- Upper level readout:
  - 800 Rose-100 boards in counting room for trigger primitive generation and readout.
- Low voltage power supply:
  - 1,400 LV supplies -- 200 kW dissipated in the control room.

ECAL Electronics: New Design

Move Trigger Processing into detector

Add FENIX Board



Number of fiber links ~ 12,000

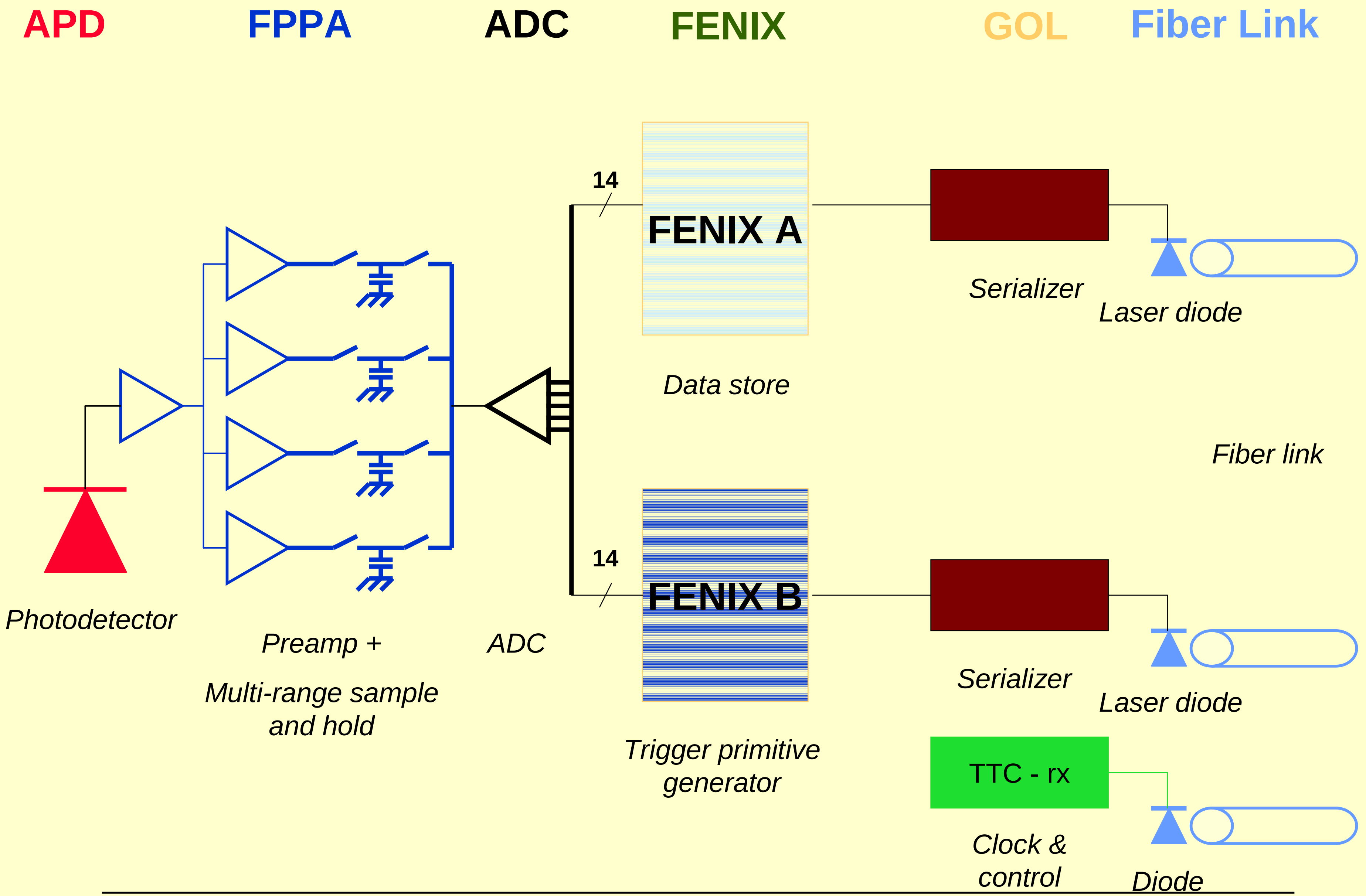
Cost: 20 MCHF less than old design

Function: equivalent to the original design in 1998.

Reduces number of receiver boards to ~ 60.

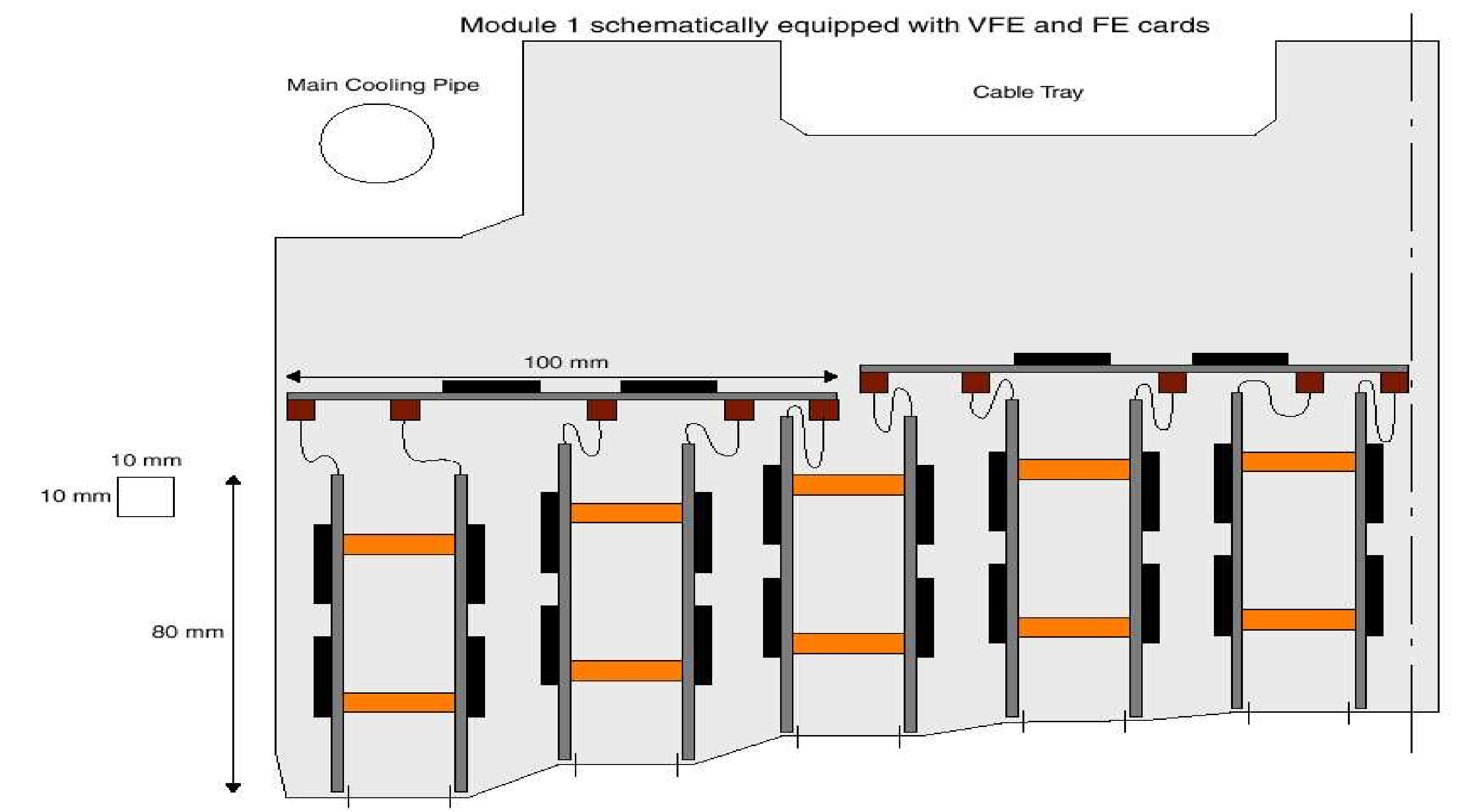
Less flexible and increased risk if channel failure.

ECAL Electronics: New Architecture



ECAL Electronics: New Layout

Details of the system integration are still being worked out.



Power budget is less and the amount of material between the ECAL and HCAL is reduced. Still need to work out full design details.

Status of the Design Change

- The old system cost at least 20 MCHF more than the 112 MCHF cap on ECAL.
- The new lower-cost design was encouraged by ECAL IB and CMS MB in March 2002.
- The new design is still being defined by CMS ‘international’. It will be baselined in June, 2002, after a `feasibility’ study.
- US role is the same wherever possible.
- Some changes to the the US contributions to the project are still under discussion.

Concerns: Global and Local

- Global:
  - Cost of the new design still exceeds available funds.
  - The number of people working on ECAL is less than required.
- US:
  - Peter Denes (electronics coordinator) left Princeton to lead the electronics group at LBL.
  - Princeton has not acted to replace him: lack of base support form the DOE.
  - There have been repeated failures in our ASIC designs.

US Responsibilities (Old)

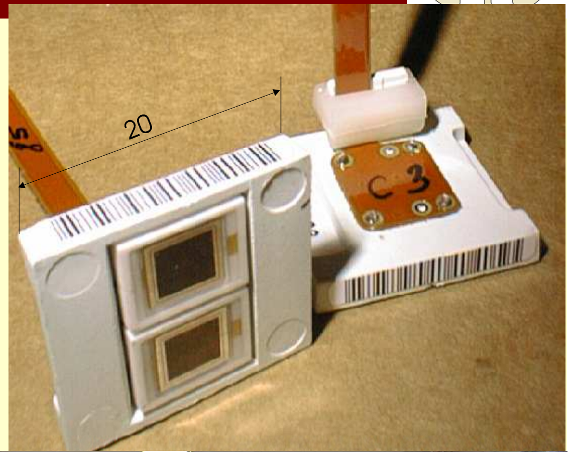
- APD: Northeastern & Minnesota with PSI
  - 30% procurement & 50% calibration
- Barrel Electronics: LBL (Princeton) with Lyon, CERN, ETHZ
  - FPPA, Bit-Serializer, Optical interconnect, ADC & Control chip.
- Monitoring Light Source: Caltech
  - Laser light source and high level distribution for the monitoring and calibration of the calorimeter.

US Responsibilities (New)

- APD: Northeastern and Minnesota with PSI
  - 30% procurement & 50% calibration
- Monitor Light Source: Caltech
  - Laser light source and high level distribution for the monitoring and calibration of the calorimeter.
- Electronics*:
  - FPPA: LBL with Lyon
  - ADC: Minnesota with ETHZ
  - Fiber Links: Minnesota with CERN
  - TTC – rx (Timing & Trigger Control Receiver): Fermilab
  - Low Voltage (Plan to use the same 400V – 400 Hz system for HCAL and FMU): Fermilab (?) with ETHZ

* This distribution of effort is still under discussion

Status of Avalanche Photodiode

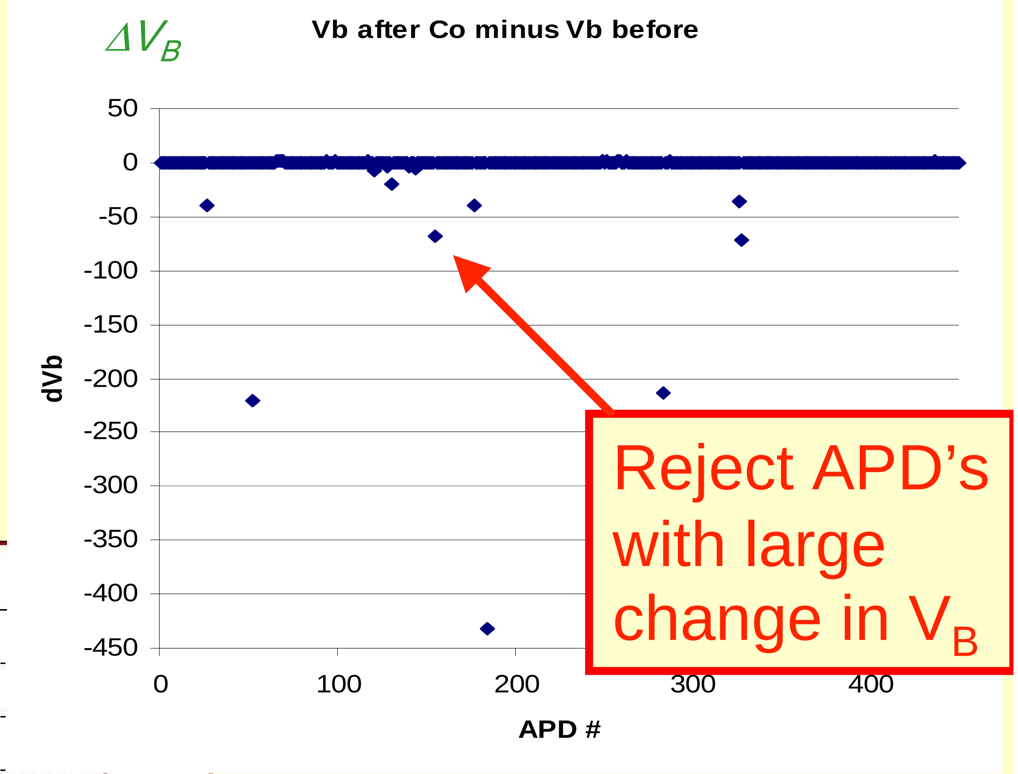


- Similar to PIN diode with × 50 avalanche gain
  - Require failure rate < 1:1000 over detector lifetime.
- Extensive QC for all APD's:
  - Irradiated with ^{60}Co to 500 kRad.
  - Burn in for a month at 85^0C
  - Measure noise, dark current, gain and breakdown.
- Some APD's measured in detail.
  - QE, excess noise factor, detailed gain.
- Some irradiated with 2×10^{13} n/cm^2

25,000 APD's delivered, 6,000 sent to construction, processing at 350/day

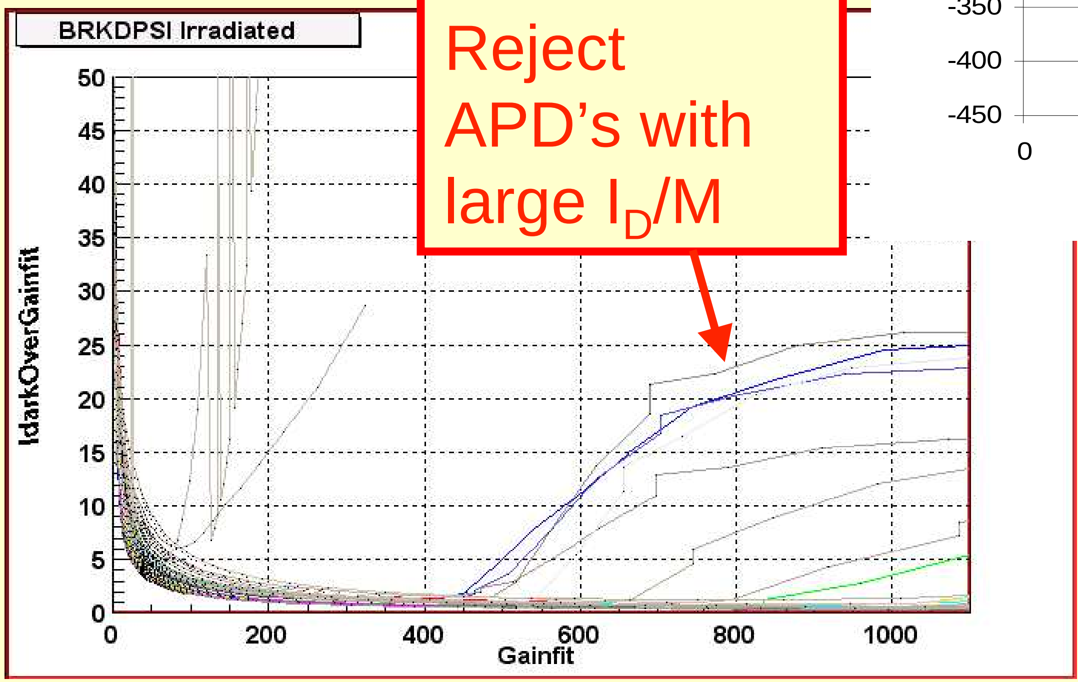
APD Quality Control

APD's which change during irradiation or bake-out are rejected.



Reject APD's with large change in V_B

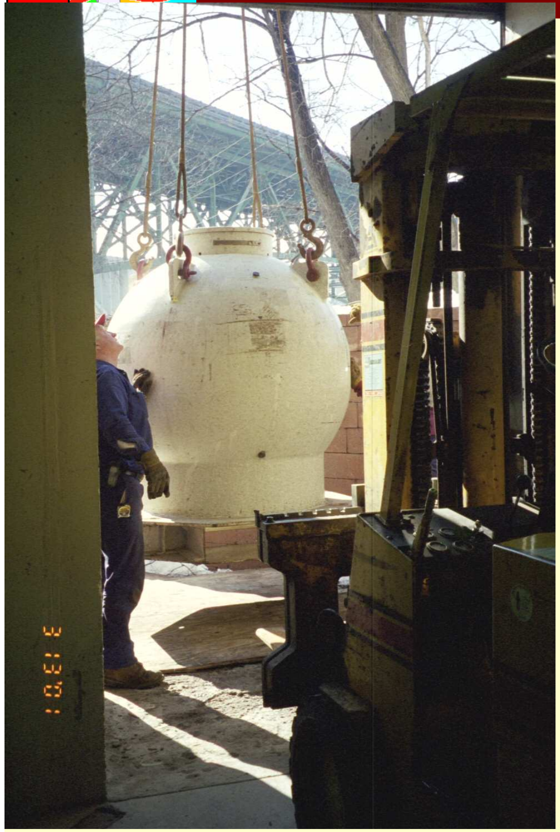
I_D/M

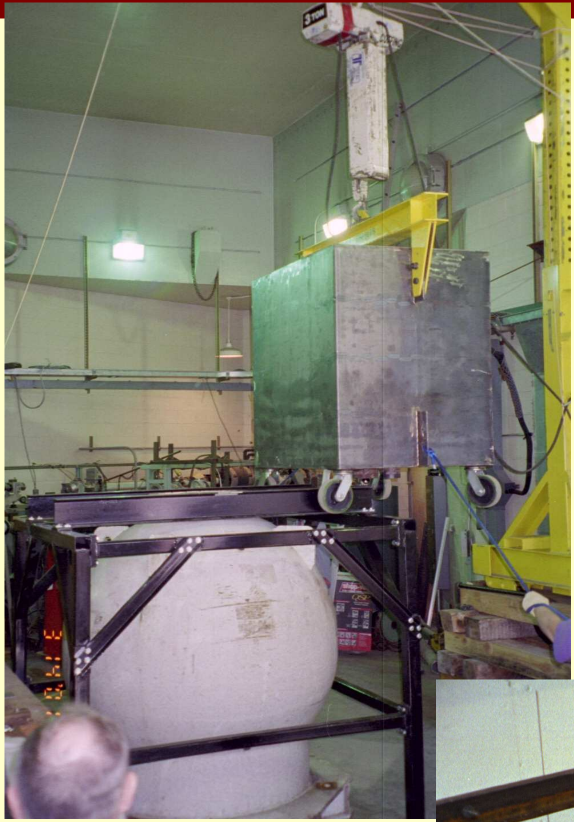


Reject APD's with large I_D/M

All APD's must pass the Gamma-ray irradiation tests.

Neutron Testing of APD's





Minnesota neutron test facility with a large ^{252}Cf source

For APD's, FPPA's and ADC's

Additional a large ^{137}Cs is available for gamma irradiations

Status of Monitoring Light Source

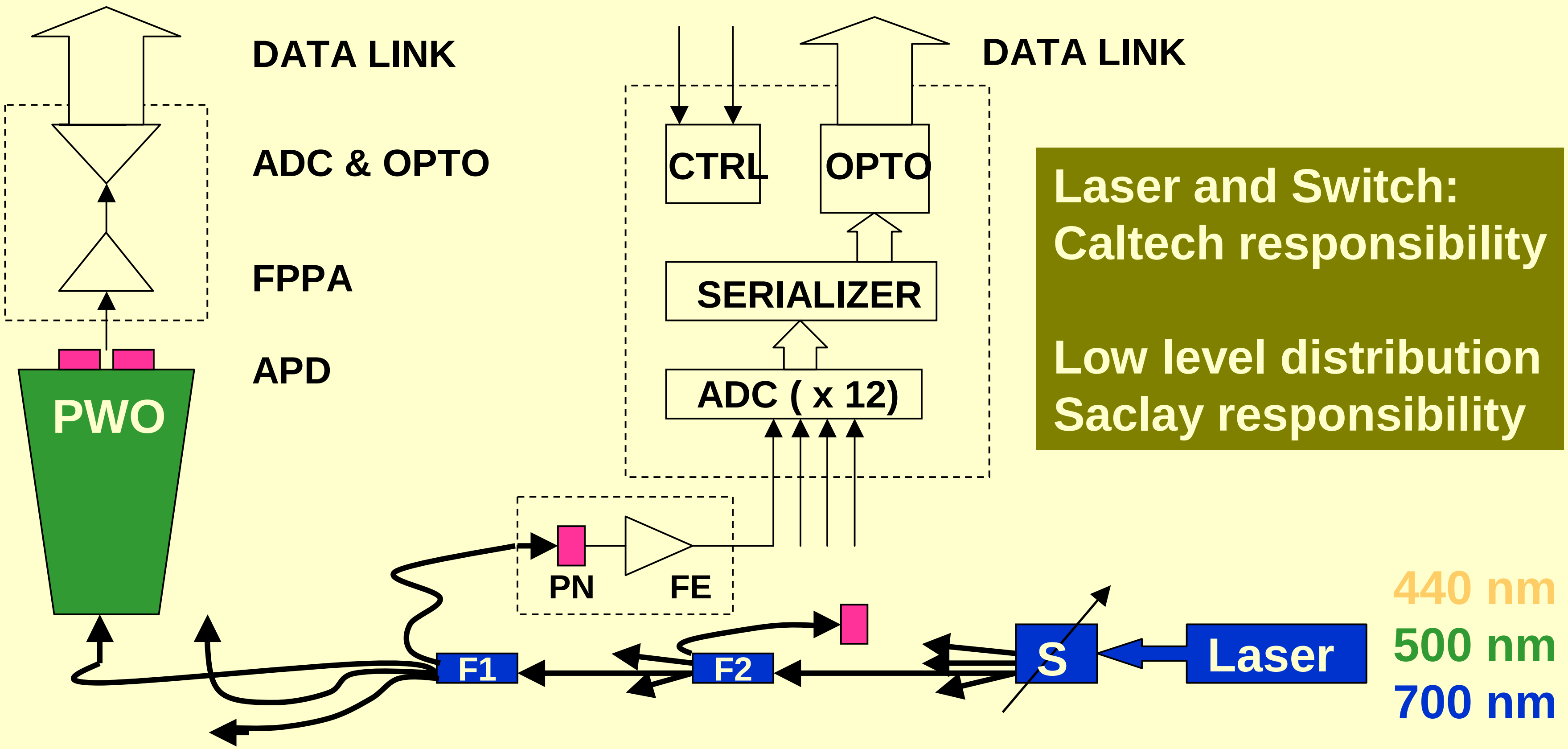
- Completed monitoring test bench, determined monitoring wavelength at 440 nm.
- Laser light source construction is on schedule and cost. 1st laser system was installed & commissioned at CERN in August, 2002.
- A laser at long wavelength (red) is under consideration to be added to the system. Recent ECAL TCG on April 16 decided to choose the Quantronix red laser.

CMS ECAL Monitoring System

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

In situ calibration with physics ($W \rightarrow e^{+}n$, $Z \rightarrow e^{+}e^{-}$): using E/p allows an inter-calibration of 0.5% in 35 days at low luminosity.

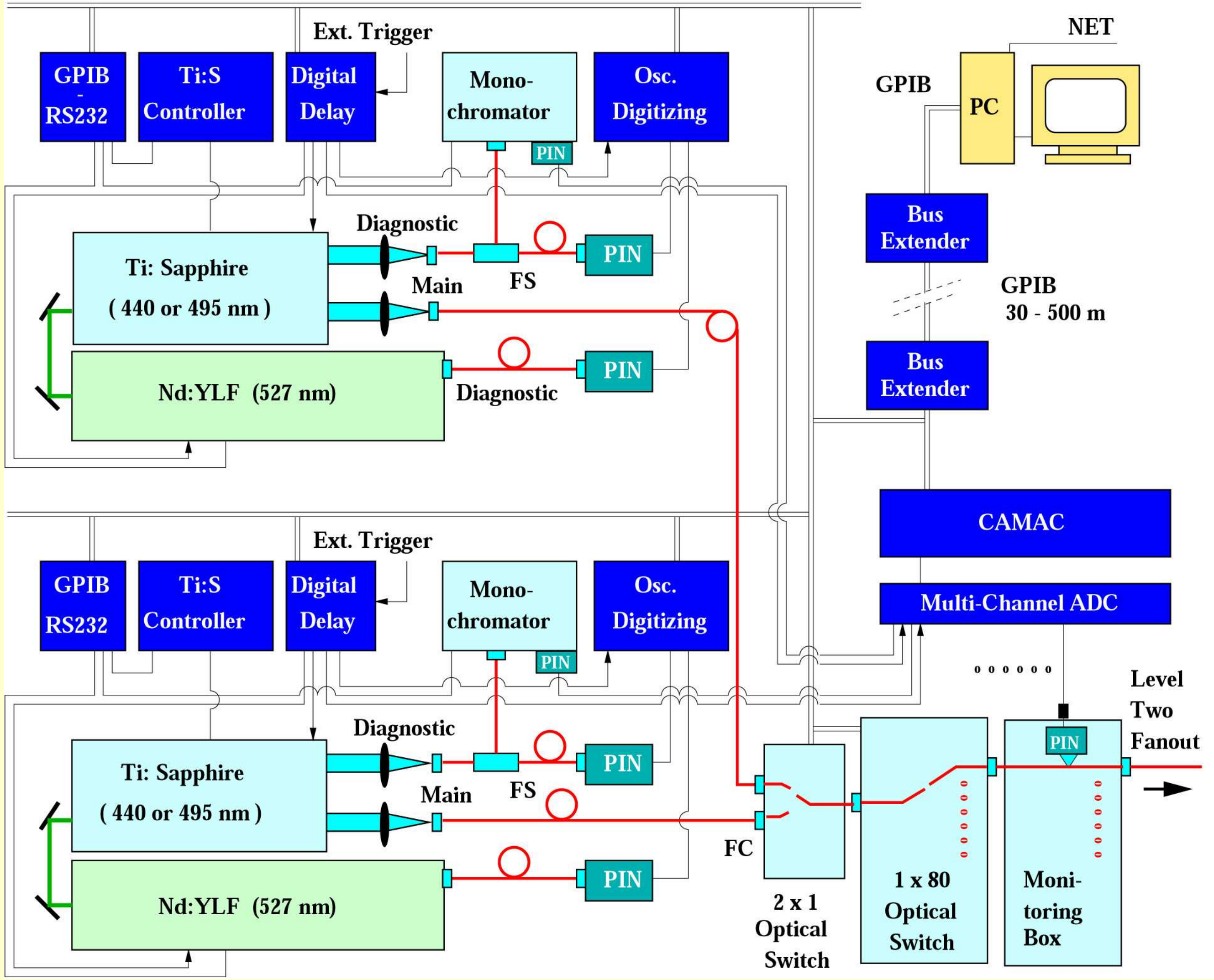
Monitoring evolution of crystal response by light injection system



Laser and Switch: Caltech responsibility

Low level distribution Saclay responsibility

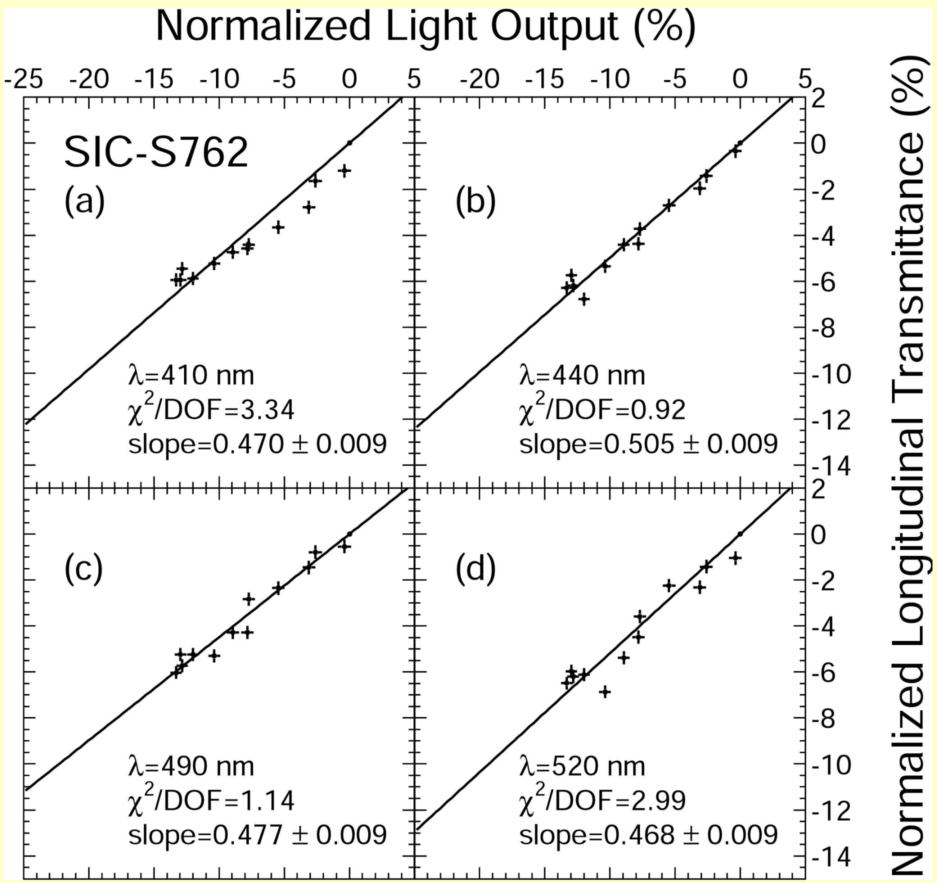
Design of Monitoring Light Source



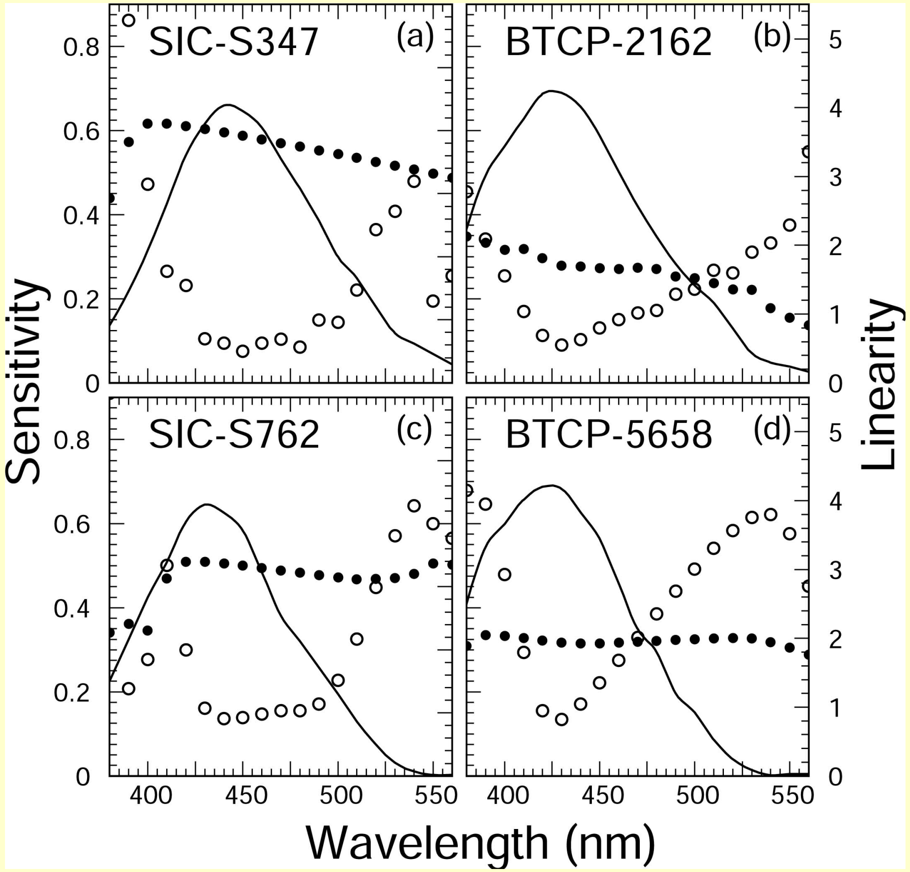
- Two laser systems each tunable at 440 & 500 nm and with own diagnostics on wavelength, jitter and intensity.
- An optical switch directs monitoring laser pulses to 80 super-modules.
- A computer control records the history and performance of lasers and switch.

Monitoring Wavelength Determination

d(T) versus d(LY)



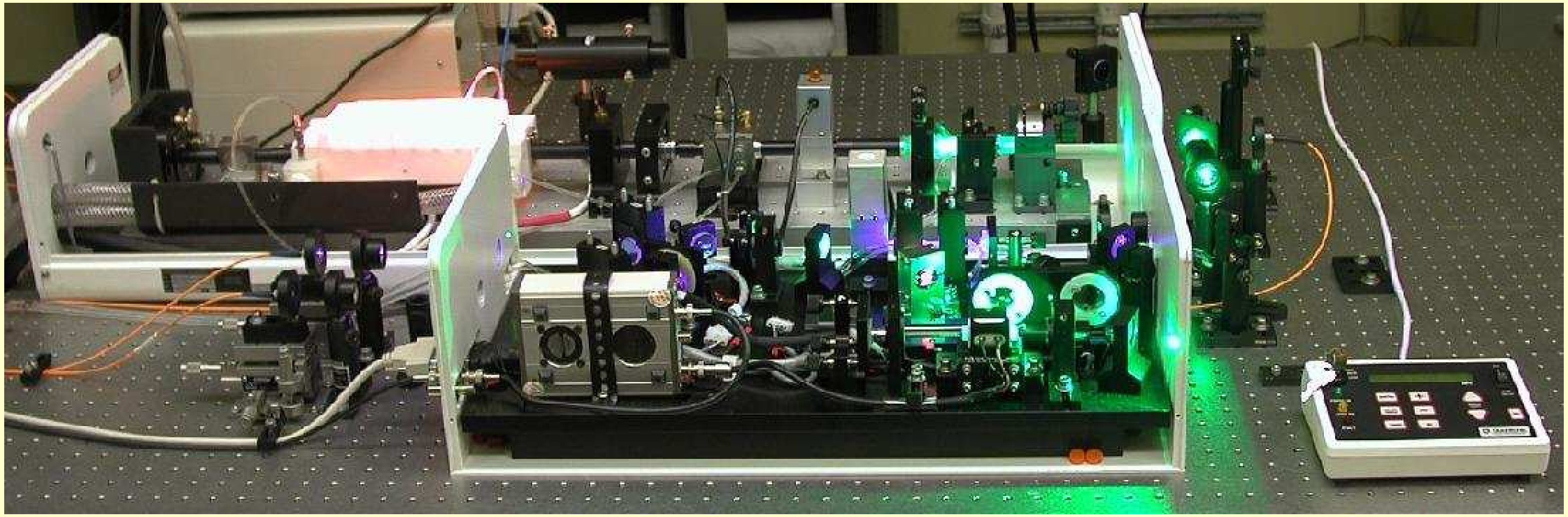
Sensitivity and Linearity



440 nm is chosen for the best linearity

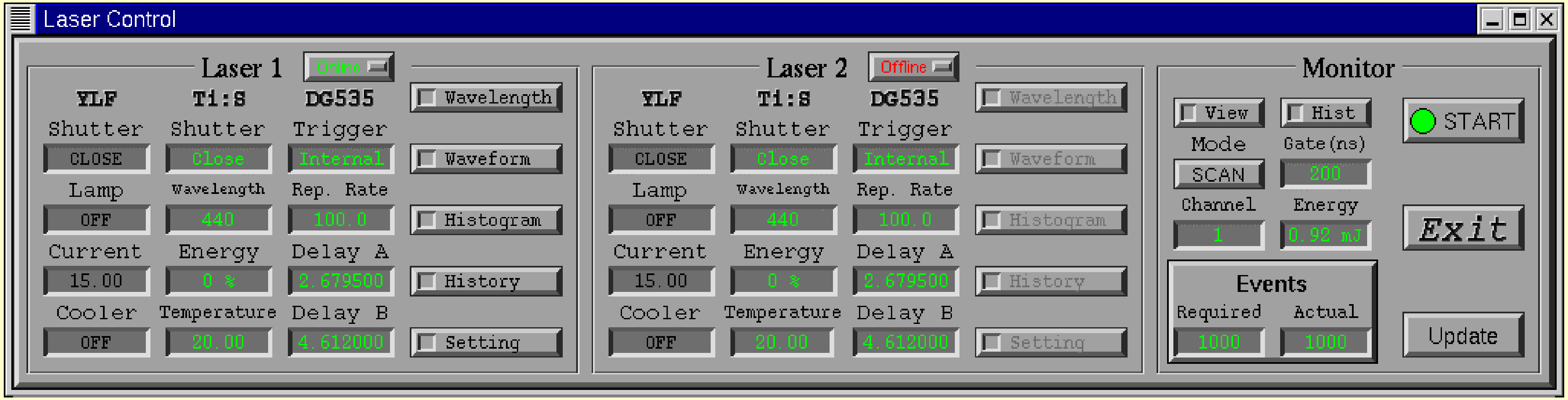
Laser System at Caltech

YLF AND Ti:Sapphire Lasers

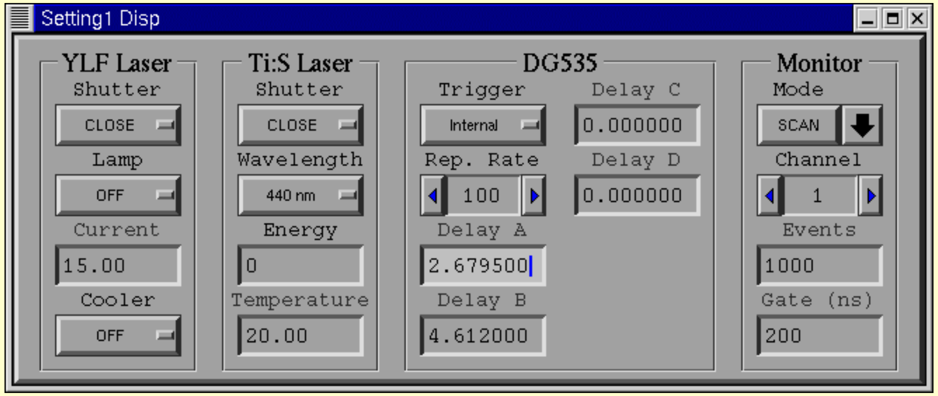


Laser System Control

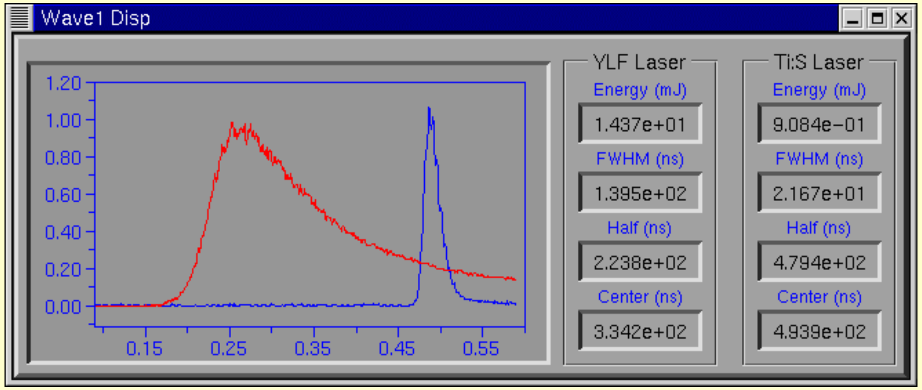
Control: Two Lasers and Monitoring Run Mode



Laser Settings



Laser Waveform Display



Chilled Water Installed on 8/21/2001

Outside Laser Room

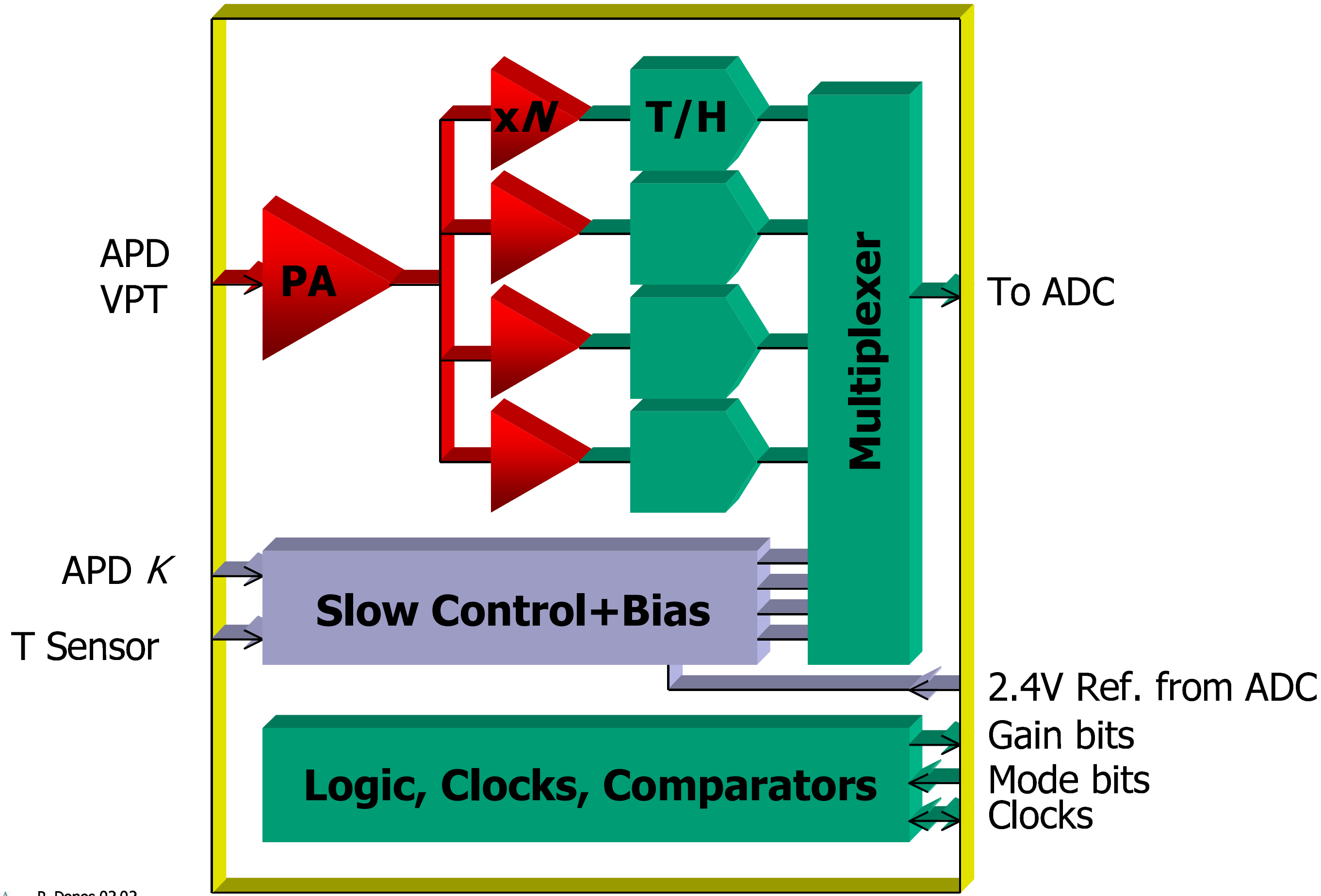
Inside Laser Room

Note: blackened filter caused by dirty chilled water. Solution: add a heat exchanger.

Laser Reached 1.1 mJ/pulse on 8/24

FPPA

FPPA2000 Blocks



P. Denes 02.02
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FPPA-Intro1

FPPA History

- ‘96 Separate PA+FPU circuits; discrete gains non-rad-hard AMS 0.8μ BiCMOS (X3)
- ‘97 Improved versions in rad-hard DMILL 0.8μ BiCMOS, “Light-to-Light” readout at H4
- ‘98 Integrate PA+FPU: problems with DMILL $\rightarrow$ UHF1x
- ‘99 FPPA ‘98 (UHF1x) at H4
- ‘00/01 FPPA2000: 1st full-wafer run, 1st chip with complete final functionality, but with **problems**
- Revision needed $\rightarrow$ FPPA2001

FPPA2000 problems

FPPA2000 did not meet specifications

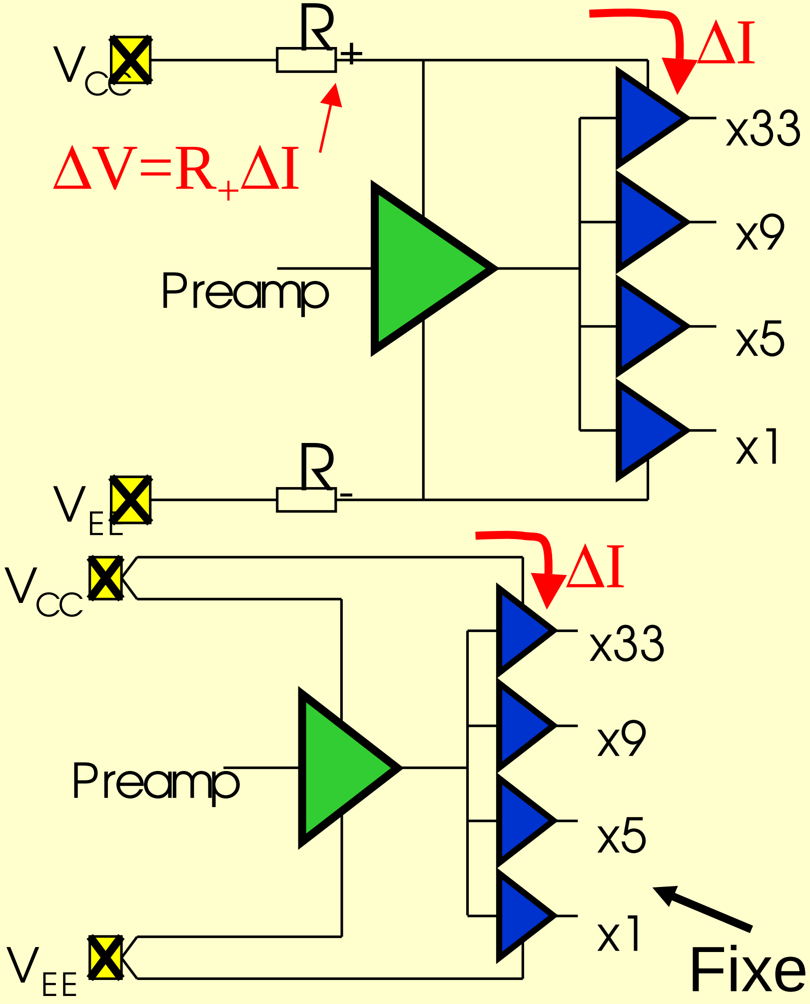
1. Unexpected high noise (FPPA '98 noise OK)
2. Non-linearity & pulse-shape distortion
3. Gain errors
4. Marginal timing of output pulse in some cases (with respect to sampling clock)

1) through 3) explained by on-chip parasitic resistance not in the Intersil simulation, which was proved with EB surgery and improved simulation. All appears to be understood.

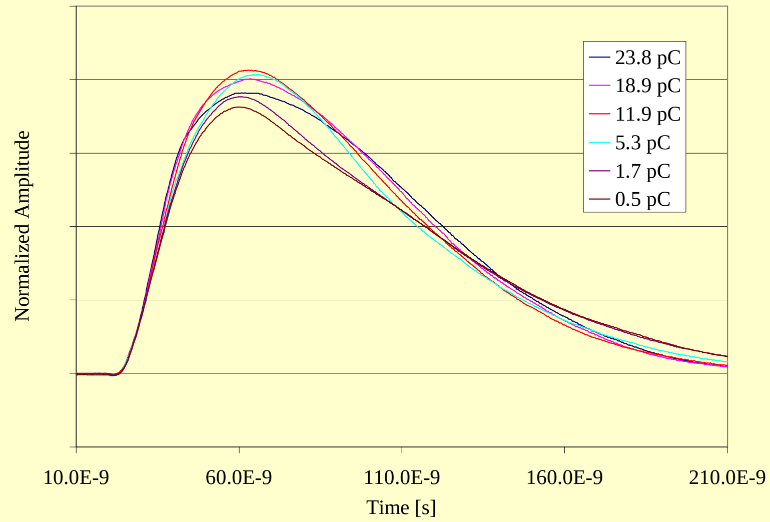
4) Requires a redesign of the output driver. This was Lyon responsibility, now in hands of LBL.

Pulse shape distortion

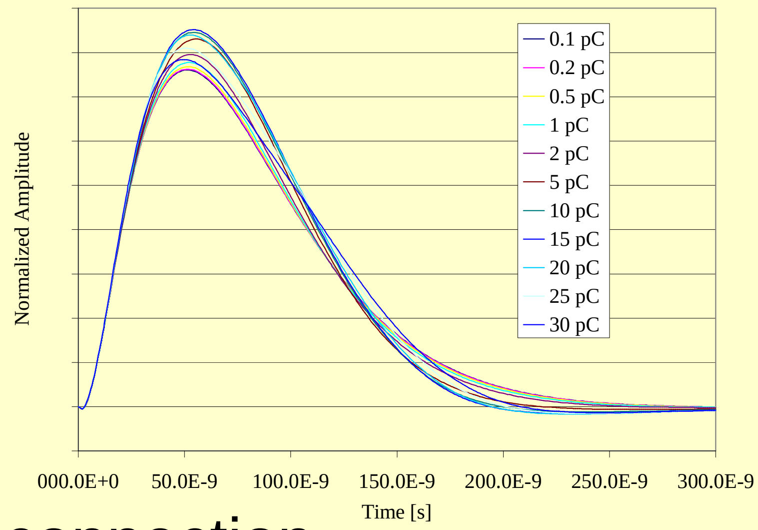
Parasitic resistance in power traces



Measured



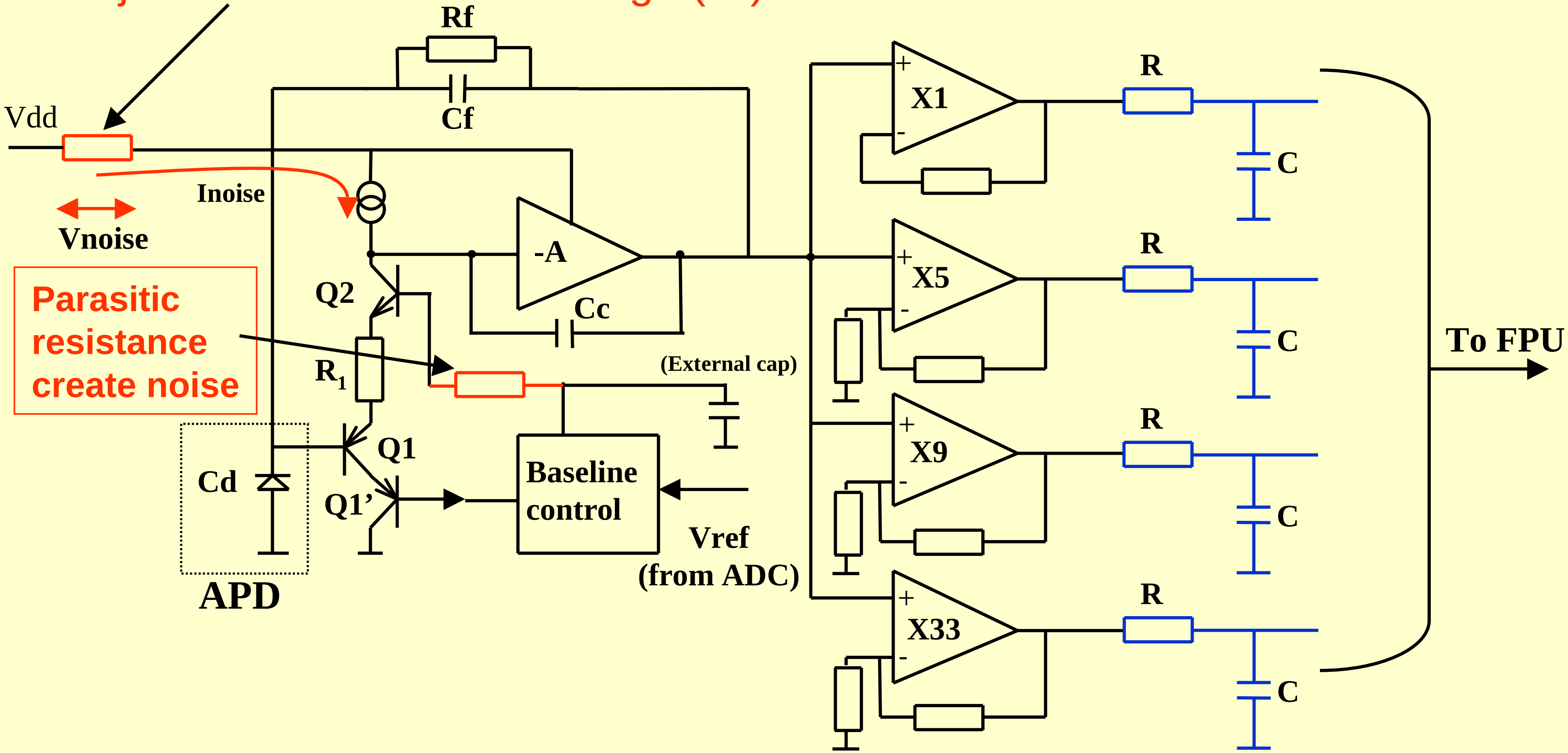
Simulated with parasitic resistance



Fixed by star connection

17 ke Noise

Current noise of the first stage converted into a voltage in series with vdd due to the supply bus parasitic resistance. This voltage noise is injected in the class A/B stage (-A).



Their combination increases the output preamp noise

FPPA Plan

- Second FPPA review late May
- If all OK then
  - Submission late June for full wafer run
  - Wafers back early October (13 weeks)
  - Test small quantity at LBL in ceramic package
  - Package 2000 in plastic package and test at Lyon
    Help from US group needed for this.
- If all OK then (Feb, 03)
  - Proceed to production.

ECAL V20.1/CMS V33 schedule allows for one more iteration: 31,000, 31,000 & 16,000 are needed by Apr/04, Oct/04 & Apr/05 for EB+, EB- & EE, respectively

FPPA Testing

- Current plan:
  - Setup automated package tester at LBL
  - Package all components
  - Test at LBL
  - Expected yield is 50% need 80,000 tested parts
  - Cost ~$500k
- Other options:
  - Do the testing at Fermilab
  - Do it in Europe at Lyon or SDM
  - Industry in the US

Decision will be made in summer based on cost and feasibility

ECAL Major Milestones

- M0 (400 channels) in beam: July, 02. Monitoring laser and APD ready
- SM0 test beam: April 1 – Jun 29, 03
- ADC production starts: Sep, 02
- FPPA production starts: Oct, 03
- FENIX FPGA prototypes ready: Jan, 03
- FENIX ASIC ready: Aug, 03
- SM1 test beam: Apr 22 – 28, 04
- SM2 and SM3 production starts: Jan, 04
- 4 SM/month after…
- EB/EE ready in UX : Jul, 05/Sep, 06
- CMS closed ready: Apr, 07

Summary

- PWO crystal ECAL promises precision photon and electron physics at LHC.
- The overall ECAL V20.1/CMS V33 schedule is extremely tight, and does not allow calibration of all supermodules before installation.
- US takes significant responsibility in ECAL construction. Monitoring light source and APD are on schedule.
- The electronics is going though a major redesign so that it can be built within available resources. The new design will be baselined in June, 02. There are changes of US responsibilities.
- Urgent issue: Electronics, especially FPPA.