# HPS ECal & Trigger

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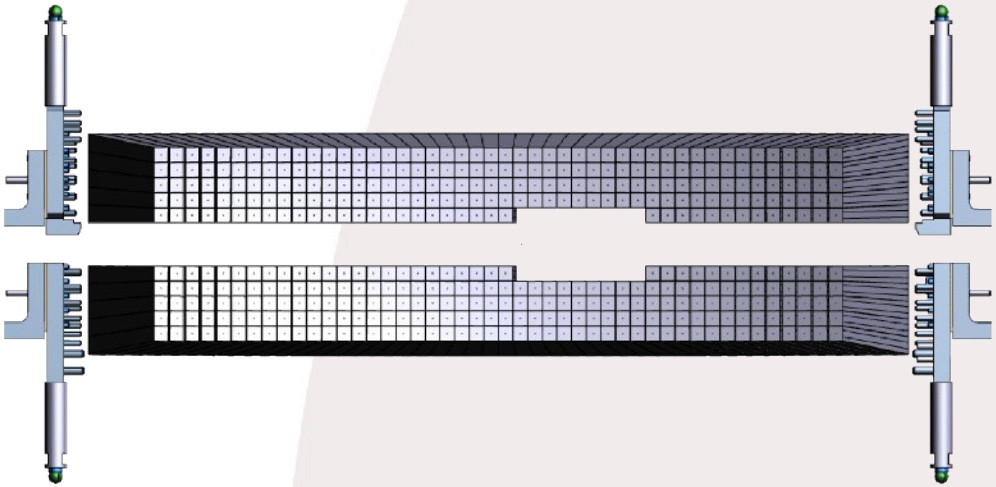
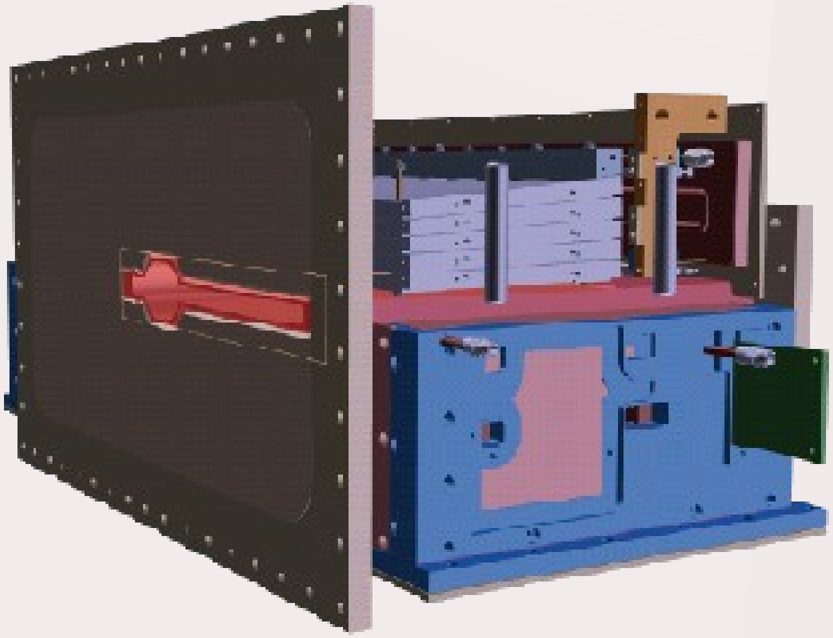
# The ECal

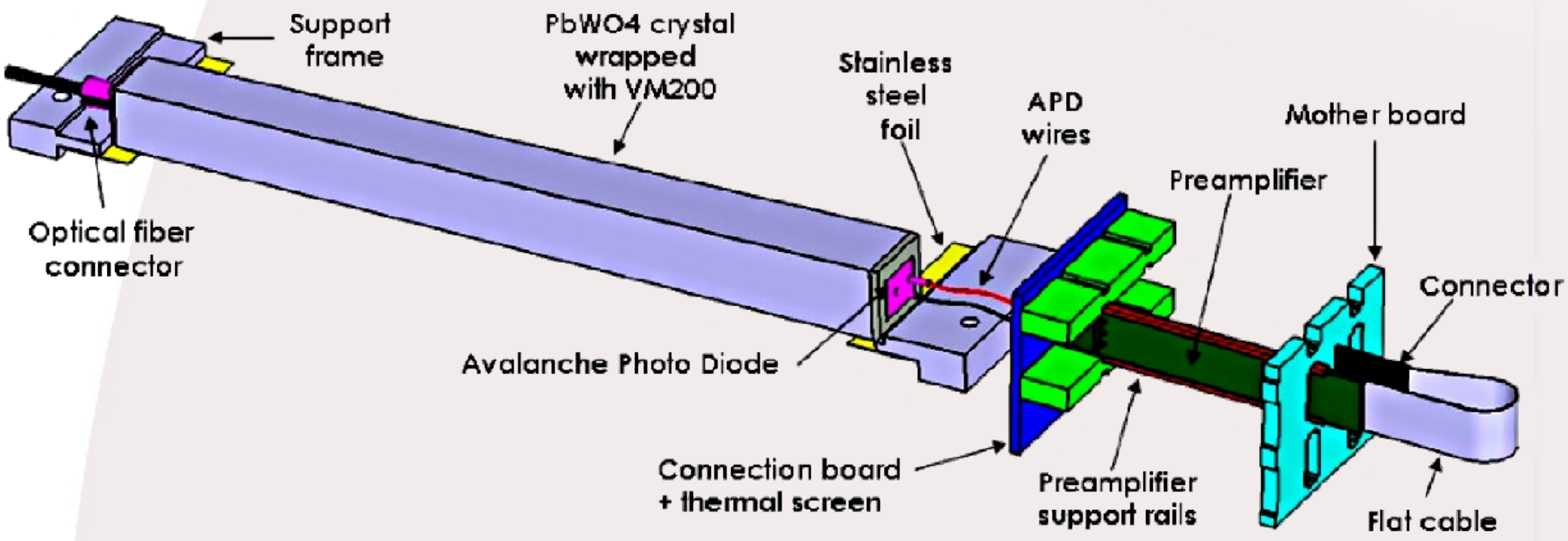




## The calorimeter and its vacuum box

- 442 Crystals of $PbWO_4$
- Used for electron/positron identification
- Provide signal for the trigger

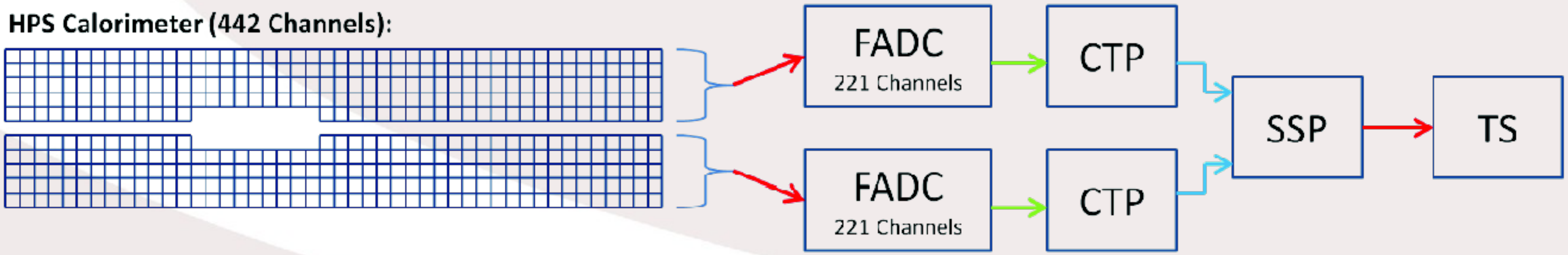
# The Detection Chain




- **Detection Chain**
  - Light produced in the crystal
  - Processed by Avalanche Photo-Diode (APD)
  - Amplified with preamplifier
  - Signal sent to FADC
    - Trigger path
    - Readout path

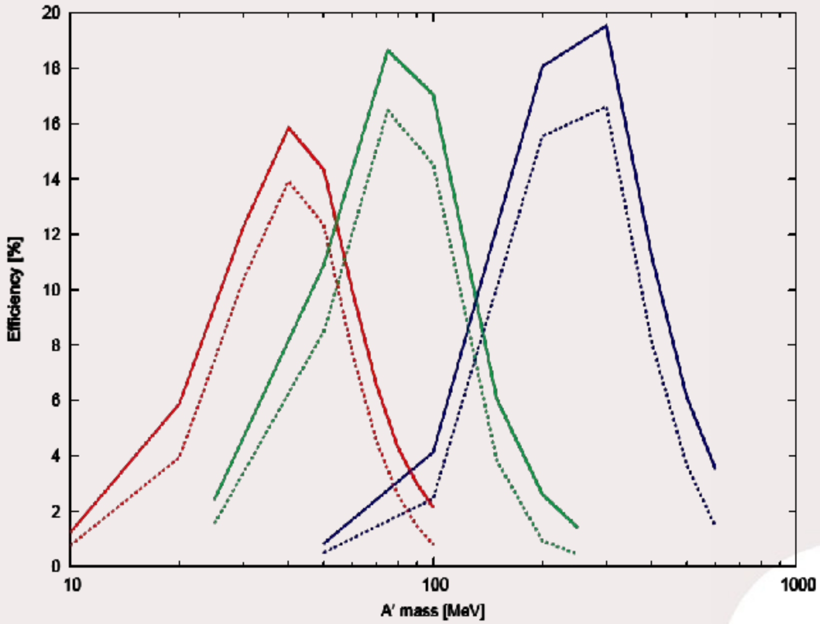
# The Trigger

- **Trigger system**
  - Timing directly provided by FADCs
  - One Crate Trigger Processor (CTP) per side
    - Form clusters every 4 ns
    - Time coincidence in a given cluster (8 ns)
    - Send cluster information to SSP
  - Sub-System Processor (SSP)
    - Time coincidence between clusters (4 ns)
    - Topological selection



# Trigger Algorithm

- **Cluster finding**
  - Look at energy deposit for all 3x3 configurations of crystal
  - Look for maximum configuration if several neighboring clusters pass the threshold
- **Topological Selection**
  - High energy sum
  - Time coincidence
  - Reduced energy difference
  - Coplanarity
  - Energy slope



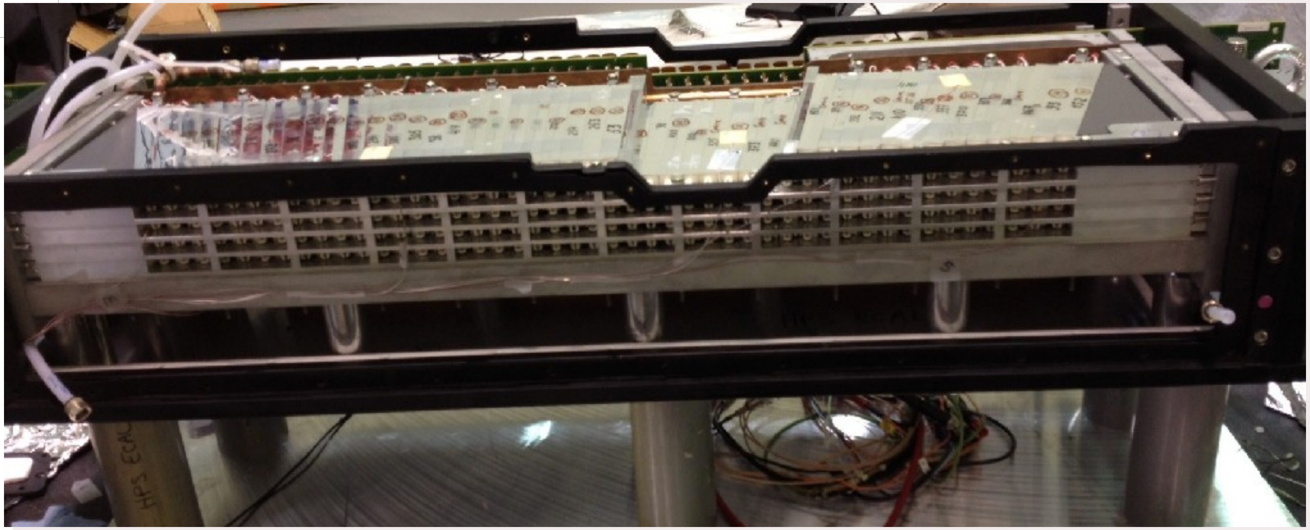
# Trigger Rates

- **Maximum rate for electronics 43 kHz**
- **Monte-Carlo Simulation**
  - Reproduce bunches of electrons
  - We simulated 50 millions bunches per energy
  - Simulation also helped determine trigger cuts

| Sample | Rate (kHz) |
|---|---|
| 1.1 GeV beam background | $15.7 \pm 0.4$ |
| 1.1 GeV beam background+tridents | $18.3 \pm 0.4$ |
| 2.2 GeV beam background | $11.2 \pm 0.3$ |
| 2.2 GeV beam background+tridents | $15.8 \pm 0.4$ |
| 6.6 GeV beam background | $10.2 \pm 0.3$ |
| 6.6 GeV beam background+tridents | $12.6 \pm 0.4$ |
| 6.6 GeV beam background+tridents+pions (FLUKA) | $13.4 \pm 0.4$ |
| 6.6 GeV beam background+tridents+pions (G4) | $13.5 \pm 0.4$ |

TABLE XVIII: Trigger rates using various background samples, with statistical uncertainties.

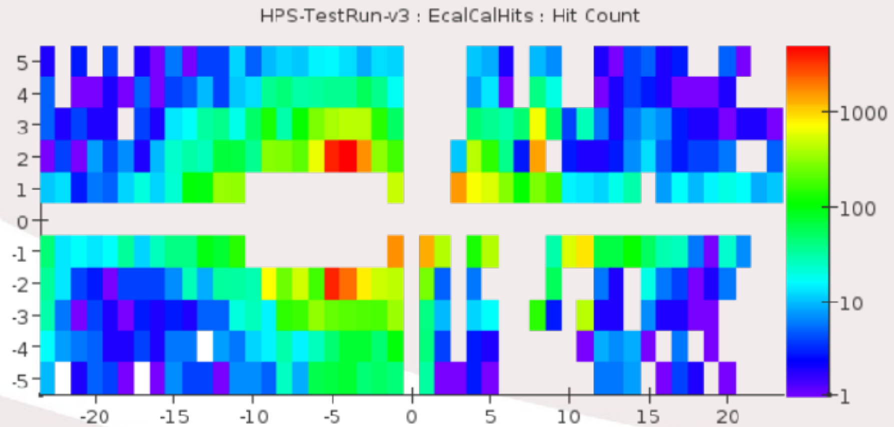
# The Test Run ECal



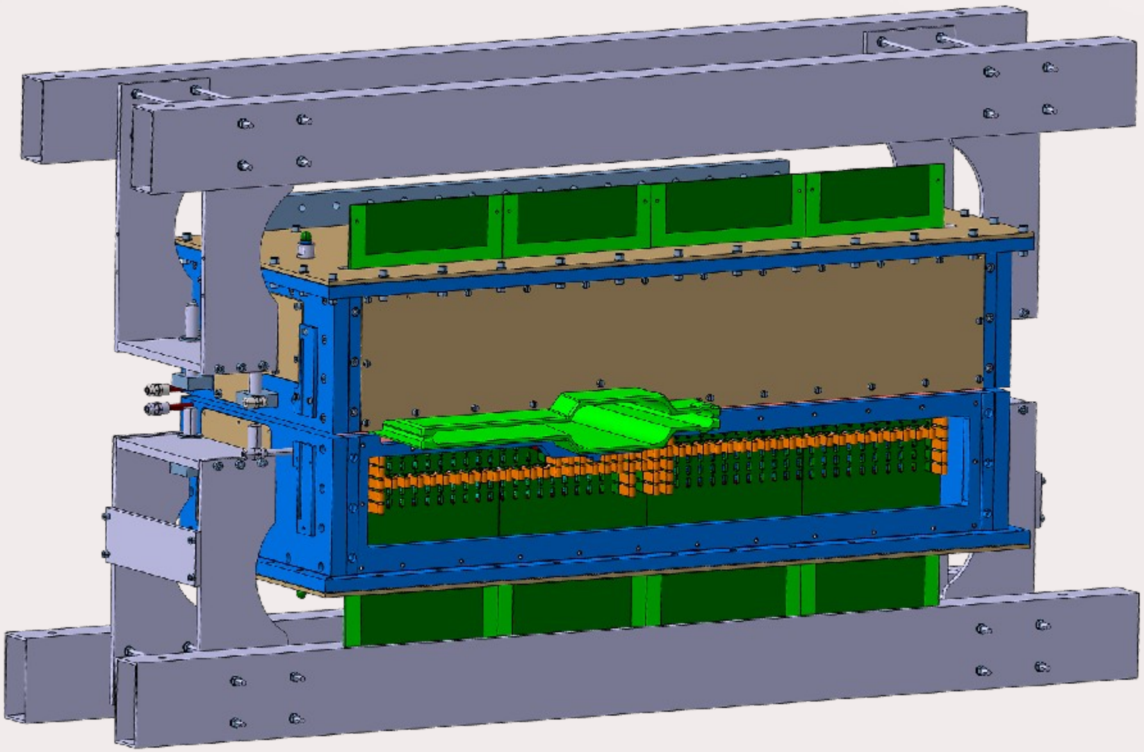
- **Mostly the final detector**
  - Same crystal pattern
  - Same cooling system
  - Same mechanical structure
- **Few differences with final ECal**
  - Several repairs and upgrade in electronics
  - More precise Mechanical mounting system
- **One big addition**
  - Light monitoring system

# Test Run Issues

- **Mostly linked to electronics**
  - Two mother boards not working properly
  - HV shortage & HV group issues
  - One FADC not working properly
  - LV control only in the hall
- **Leads to several dead channels**
  - 39 disabled or disconnected
- **Trigger worked as intended**
  - Some problem of gain variations
- **Some difficulties for precise positioning of the ECal**
- **All these can be easily solved**



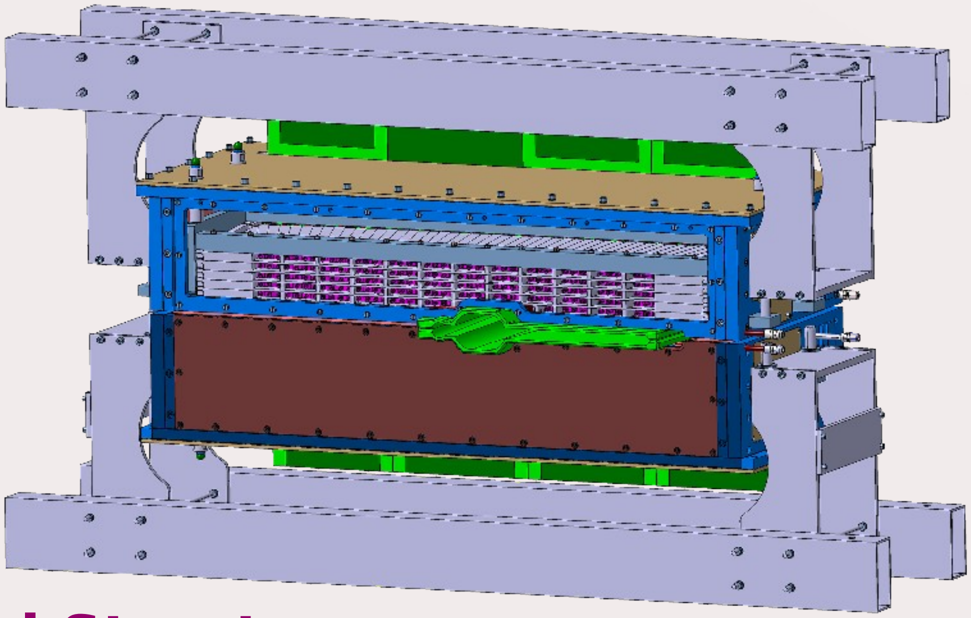
# Mother Board



- **Exit through the top/bottom instead of sides**
  - Possible because of the reduction of the ECal size compared to first plans
  - Reduce the constraints to get the signal out of the box
    - From 16 to 11 levels in the board

(Electronic design from F. Pratolongo / Mechanic design from E. Rindel)

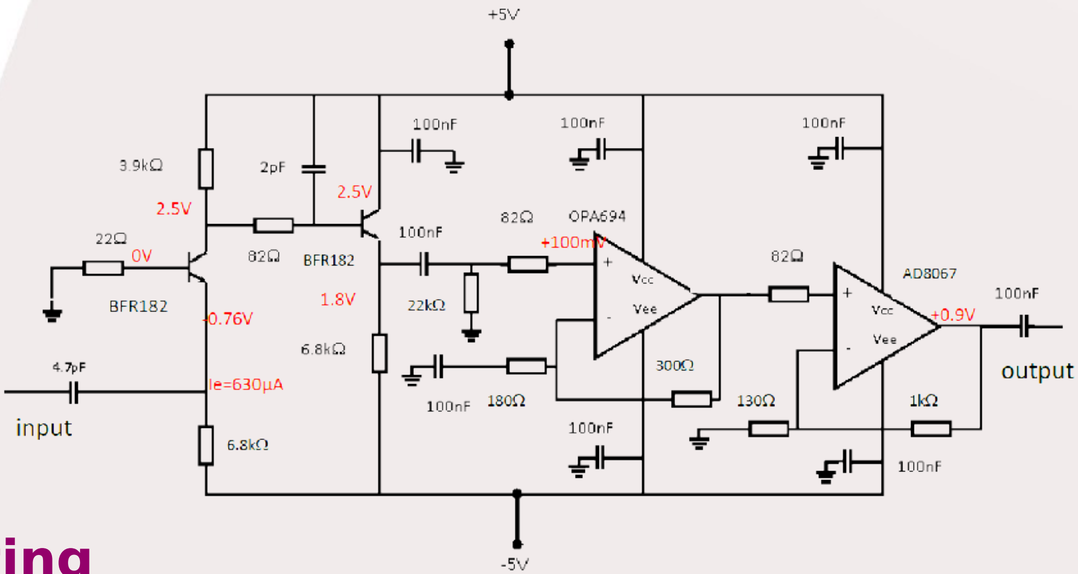
# Mechanics



- **Mechanical Structure**
  - Mostly as developed for the test run
  - Including cooling system and thermal isolation
  - Adaptation for
    - new mother boards
    - light monitoring system
  - Addition of more precise mounting system

(Design from P.  Rosier & E. Rindel)

# Pre-amplificators

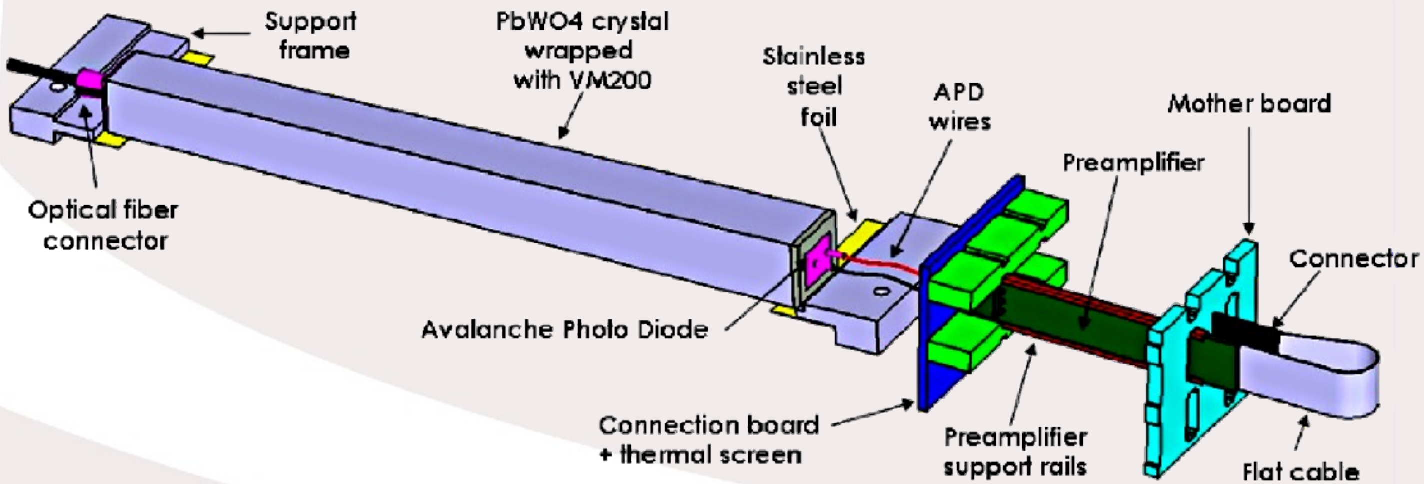



- **New setting**
  - Find the good balance of three parameters
    - gain – speed – noise
  - Adapt to new environment without splitters
- **Need to renew the stock of spares**
- **Tests during the Summer in IPNO**
  - What is the best balance while keeping linearity on the full band width?
- **Production in IPNO end of 2013, early 2014**

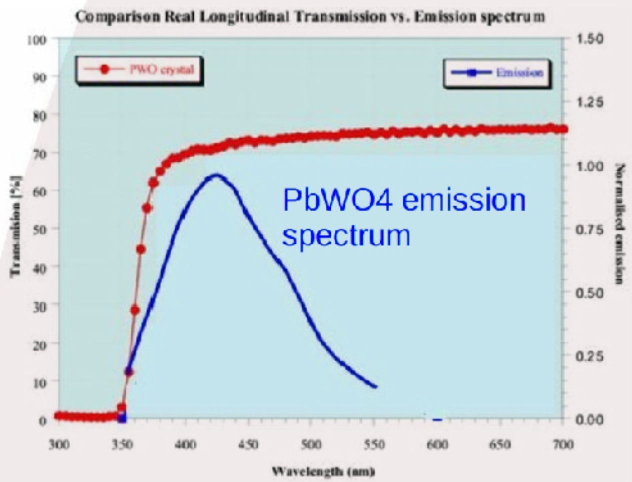
(Tests and new design by E. Rauly / Production by the IPNO electronic workshop)

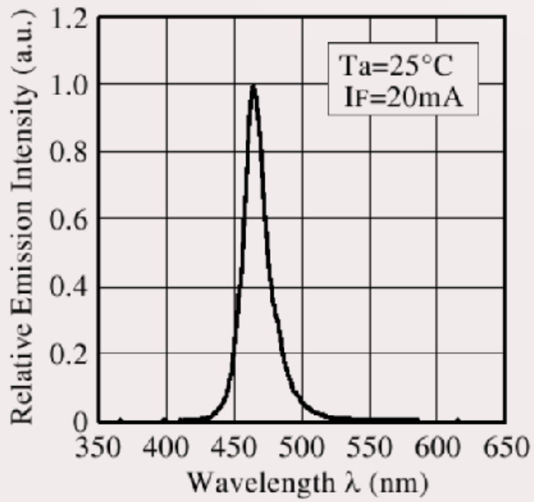
# Light Monitoring System

- **Used to follow radiation damages and electronics status**
- **Design based on tests in INFN**
  - Place one LED in front of each crystal
  - Including electronics to control the system
- **Use of individual LEDs placed directly in front of each crystals**
  - Cheap system compared to optic fibers used for the previous IC calorimeter since each LED costs only ~ 1$



# Light Monitoring System



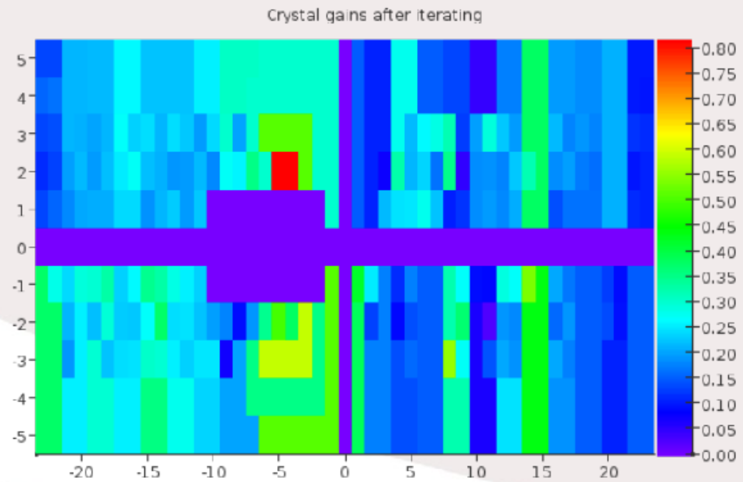

- **Some results are already available**
  - LED was selected to match the PbWO4 emission spectrum
  - LED need to be individually tested
    - factor 2 rejection
  - Very high stability
    - ~2% for a given channel over 100h
    - ~0.1% from one channel to another
- **Other tests are ongoing or planned**
  - How to fix the LEDs to the crystals?
  - Should we use bi-color LEDs?
  - Test radiation damages to the LEDs

(A. Celentano & G. Mini' are testing and developing the system in INFN & a postdoc will also be hired on this project in IPNO)

# Monitoring and Calibration

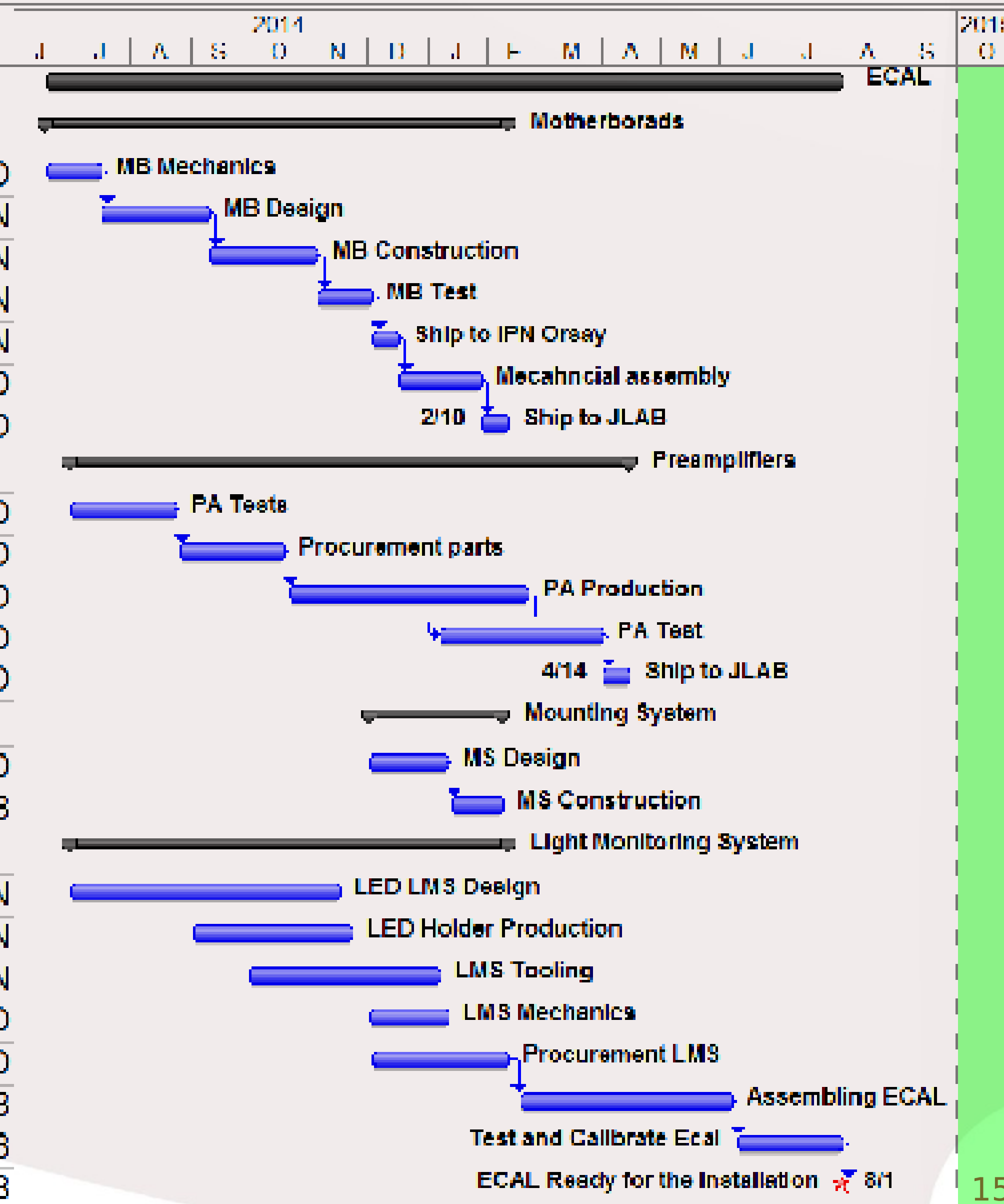
- **Online monitoring to insure data quality**
  - Characterization of crystals/APD before making the HV groups
  - LED light monitoring system
  - Dedicated cosmic runs (self triggered)

- **Offline calibration**
  - Track based calibration (used in test run)
  - Pi0 mass reconstruction



# Schedule

| WBS | Task Name | Where |
|---|---|---|
| 1.4 | **ECAL** | |
| 1.4.9 | **Motherborads** | |
| 1.4.9.1 | MB Mechanics | IPNO |
| 1.4.9.2 | MB Design | INFN |
| 1.4.9.3 | MB Construction | INFN |
| 1.4.9.4 | MB Test | INFN |
| 1.4.9.5 | Ship to IPN Orsay | INFN |
| 1.4.9.6 | Mecahncial assembly | IPNO |
| 1.4.9.7 | Ship to JLAB | IPNO |
| 1.4.10 | **Preamplifiers** | |
| 1.4.10.1 | PA Tests | IPNO |
| 1.4.10.2 | Procurement parts | IPNO |
| 1.4.10.4 | PA Production | IPNO |
| 1.4.10.5 | PA Test | IPNO |
| 1.4.10.6 | Ship to JLAB | IPNO |
| 1.4.11 | **Mounting System** | |
| 1.4.11.1 | MS Design | IPNO |
| 1.4.11.2 | MS Construction | JLAB |
| 1.4.12 | **Light Monitoring System** | |
| 1.4.12.1 | LED LMS Design | INFN |
| 1.4.12.3 | LED Holder Production | INFN |
| 1.4.12.4 | LMS Tooling | INFN |
| 1.4.12.5 | LMS Mechanics | IPNO |
| 1.4.12.2 | Procurement LMS | IPNO |
| 1.4.5 | Assembling ECAL | JLAB |
| 1.4.6 | Test and Calibrate Ecal | JLAB |
| 1.4.8 | **ECAL Ready for the Installation** | JLAB |



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# Budget

| | Tasks | | | | Costs (€) | | | |
|---|---|---|---|---|---|---|---|---|
| | Title | Start | End | Lab | Labor | Travel | Material | Total |
| Mother Boards (MB) | Mechanics for MBs | 01/06/13 | 01/07/13 | IPNO | 4 000 | | | 4 000 |
| | MB Design | 01/07/13 | 01/09/13 | INFN | 6 000 | | | 6 000 |
| | MB Construction | 01/09/13 | 01/11/13 | INFN | 4 000 | 1 000 | 10 000 | 15 000 |
| | MB Test | 01/11/13 | 01/12/13 | INFN | 6 000 | 8 000 | 3 000 | 17 000 |
| | Ship to IPN Orsay | 01/12/13 | 15/12/13 | INFN | | | 2 000 | 2 000 |
| | Mechanics Assembly | 01/01/14 | 01/02/14 | IPNO | 12 000 | | 2 000 | 14 000 |
| | Ship to JLab | 01/02/14 | 15/02/14 | IPNO | 1 000 | | | 1 000 |
| | | | | | | | | **59 000** |
| Preamplifiers | PA tests | 01/07/13 | 01/09/13 | IPNO | 6 000 | | 1 000 | 7 000 |
| | PA Production | 01/11/13 | 01/03/14 | IPNO | 9 000 | | 12 000 | 21 000 |
| | PA Tests | 01/01/14 | 01/04/14 | IPNO | 4 000 | | | 4 000 |
| | Ship to JLab | 01/04/14 | 15/04/14 | IPNO | 1 000 | | | 1 000 |
| | | | | | | | | **33 000** |
| MS | Mounting System Design | 01/12/13 | 01/01/14 | IPNO | 4 000 | | | 4 000 |
| | MS construction | 01/01/14 | 01/02/14 | IPNO | 1 000 | 2 000 | 2 000 | 5 000 |
| | | | | | | | | **9 000** |
| LMS | LED LMS Design | 01/07/13 | 01/12/13 | INFN | 6 000 | 3 000 | | 9 000 |
| | LED holder production | 01/09/13 | 01/12/13 | INFN | 4 000 | | 5 000 | 9 000 |
| | LMS prototyping | 01/10/13 | 01/01/14 | INFN | 1 000 | 3 000 | 5 000 | 9 000 |
| | LMS mechanic | 01/12/13 | 01/01/14 | IPNO | 4 000 | | 2 000 | 6 000 |
| | Procurements LMS | 01/12/13 | 01/02/14 | IPNO | | | 15 000 | 15 000 |
| | | | | | | | | **48 000** |
| ECal | Crystal characterization | 01/12/13 | 01/02/14 | INFN | 10 000 | 10 000 | 8 000 | 28 000 |
| | Assemble ECal | 01/02/14 | 01/06/14 | IPNO | 12 000 | 16 000 | | 28 000 |
| | Test and calibrate ECal | 01/06/14 | 01/08/14 | IPNO | 6 000 | 8 000 | | 14 000 |
| | ECal installation | 01/08/14 | 01/09/14 | IPNO | | 4 000 | | 4 000 |
| | | | | | | | | **74 000** |
| | TOTAL | 01/06/13 | 01/09/14 | INFN | 37 000 | 25 000 | 33 000 | **95 000** |
| | TOTAL | 01/06/13 | 01/09/14 | IPNO | 64 000 | 30 000 | 34 000 | **128 000** |
| | **TOTAL** | **01/06/13** | **01/09/14** | **IPNO + INFN** | **101 000** | **55 000** | **67 000** | **223 000** |

Does not include physicist/postdoc salaries

## Emphasis here on European contribution

- INFN committed to
  - MB Design and construction
  - LMS Design
  - Crystal characterization tooling & manpower
- IPNO committed to
  - All mechanic design and most construction
  - Preamplifier design and production
  - LMS construction
  - Manpower for ECal assembly

**Total 223 k€ (290 k$)**

**+ contingency 65k€**

# Conclusions

- **ECal is already in good shape**
  - Core elements are ready
    - Crystals, mechanics and DAQ electronics
- **Many improvements are planned**
  - Various replacements/improvements in electronics
  - Small adjustments in mechanics
  - Addition of a light monitoring system
  - Most work will be carried on by the European partners
- **Test run showed that trigger works as expected**
  - No major change here but will take advantage of ECal upgrades

# ANR Grant

- **ANR young researcher grant**
  - 256,880€ (~330k$)
  - Dedicated to HPS
- **Budget**
  - 95k€ two years of post doc
  - 55k€ of travels
  - 100k€ of equipment
    - Thanks to Italians, significant savings (65k€)
  - 10k of overhead
- **Labor**
  - Labor is provided by the lab without charge to the project

# APD plans

- **Orsay have ~65k€ extra money on ANR grant dedicated to HPS (already secured) and has an application pending for 350k€ more**

- **INFN will also apply for local funding (~250k€)**

- **If one of the grant application is successful it will lead to**
  - Reduction of preamplifiers gains (reducing noise and/or timing)
  - Allow better calibration with cosmic muons
  - But will make the schedule tight for replacement
    - Travel money is included in INFN grant to have technicians come to JLab to help for the replacement