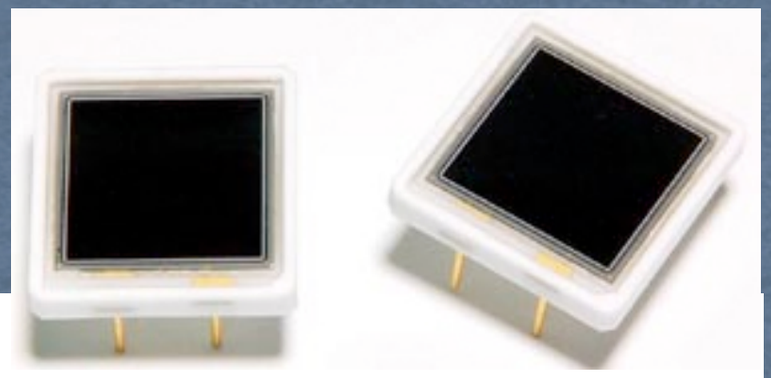
*October 17th 2013*

# New APD installation

*M.Battaglieri*
*INFN-GE, Italy*

# APD replacement

We want to replace the ECal S8148 0.5x0.5 cm2 (CMS-like) with new Hamamatsu Large Area APD S8664-1010 1.0x1.0 cm2



Hamamatsu APD (S8148) 5x5 $mm^2$

| | |
|---|---|
| Active area | 5x5$mm^2$ |
| Operating voltage(Vr) | ~380V |
| Capacitance | 70pF |
| Serial resistance | 3Ω |
| Dark Current | <10nA |
| Quantum Efficiency | ~72%@420nm |
| 1/M[a)]×dM/dV(M=50) | 3.3% |
| 1/M×dM/dT(M=50) | -2.3% |
| Excess Noise Factor (M=50) | 2 |
| Distance to breakdown (Vb-Vr) | (30-40)V |
| Effective thickness | ~5μm |
| Gain range | Up tp 1000 |

[a)]M is a gain value, T-temperature

Hamamatsu LAAPD (S8148-1010) 10x10 $mm^2$

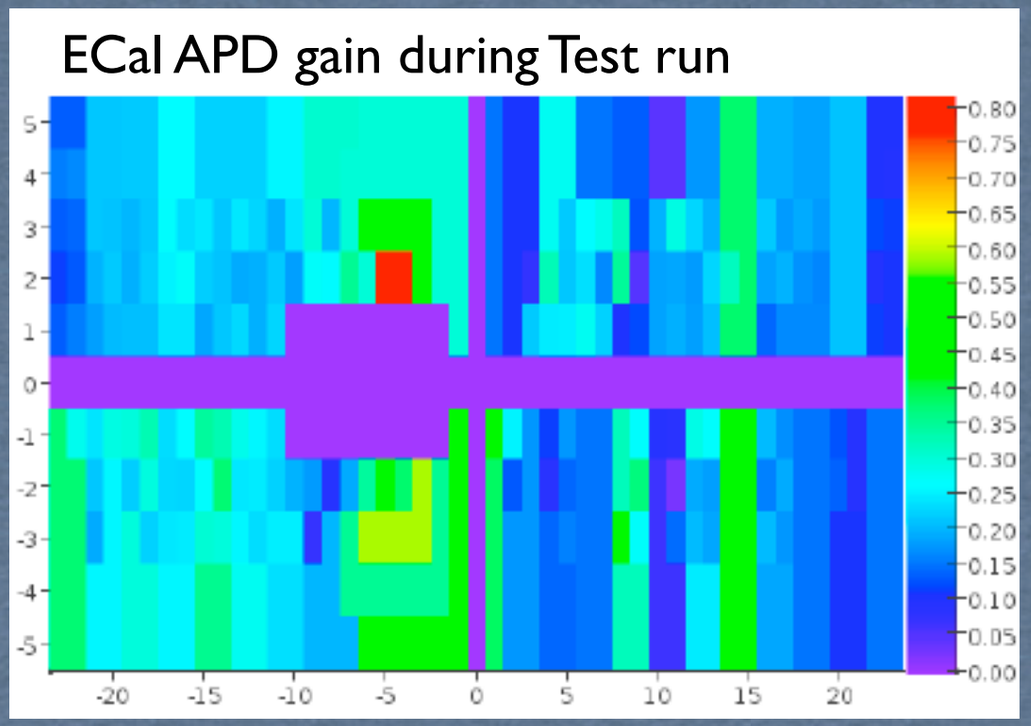
| Type No. | Spectral response range λ (nm) | Peak *3 sensitivity wavelength λp (nm) | Photo sensitivity S M=1 λ=420 nm (A/W) | Quantum efficiency QE M=1 λ=420 nm (%) | Breakdown voltage VBR ID=100 μA Typ. (V) | Breakdown voltage VBR ID=100 μA Max. (V) | Temperature coefficient of VBR (V/°C) | Dark *3 current ID Typ. (nA) | Dark *3 current ID Max. (nA) | Cut-off frequency fc (MHz) | Terminal *3 capacitance Ct (pF) | Excess *3 Noise index λ=420 nm | Gain M λ=420 nm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S8664-02K | 320 to 1000 | 600 | 0.24 | 70 | 400 | 500 | 0.78 | 0.1 | 1 | 700 | 0.8 | 0.2 | 50 |
| S8664-05K | | | | | | | | 0.2 | 1.5 | 680 | 1.6 | | |
| S8664-10K | | | | | | | | 0.3 | 3 | 530 | 4 | | |
| S8664-20K | | | | | | | | 0.6 | 6 | 280 | 11 | | |
| S8664-30K | | | | | | | | 1 | 15 | 140 | 22 | | |
| S8664-50K | | | | | | | | 3 | 35 | 60 | 55 | | |
| S8664-55 | | | | | | | | 5 | 50 | 40 | 80 | | |
| S8664-1010 | | | | | | | | 10 | 100 | 11 | 270 | | |

# Advantages

- ✳ 10% Gain-matched
- ✳ 4 times more light
- ✳ better S/N

(when coupled to new IPN-Orsay preamps)

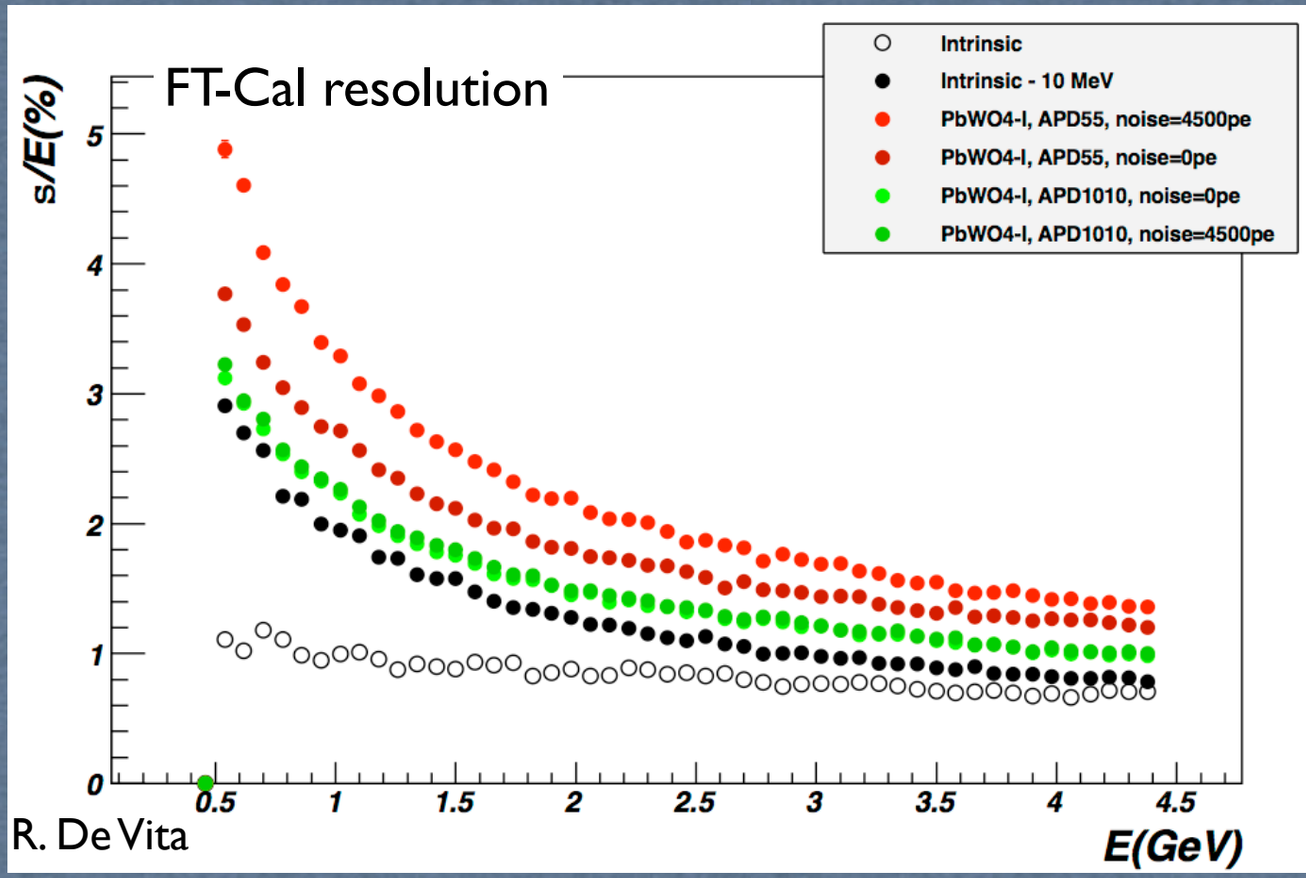
- ✳ Uniformity of trigger thresholds
- ✳ Lower threshold values (highest rate)
- ✳ Better A'mass resolution
- ✳ Cosmic ray calibration




## Gain-matching

- ✳ New APDs will be provided gain-matched at 10% level
- ✳ Best running condition selecting the G~150
- ✳ APD + crystal assembly will be tested for max uniformity

- ✳ Uniformity of trigger thresholds
- ✳ Lower threshold values (highest rate)




## Energy resolution

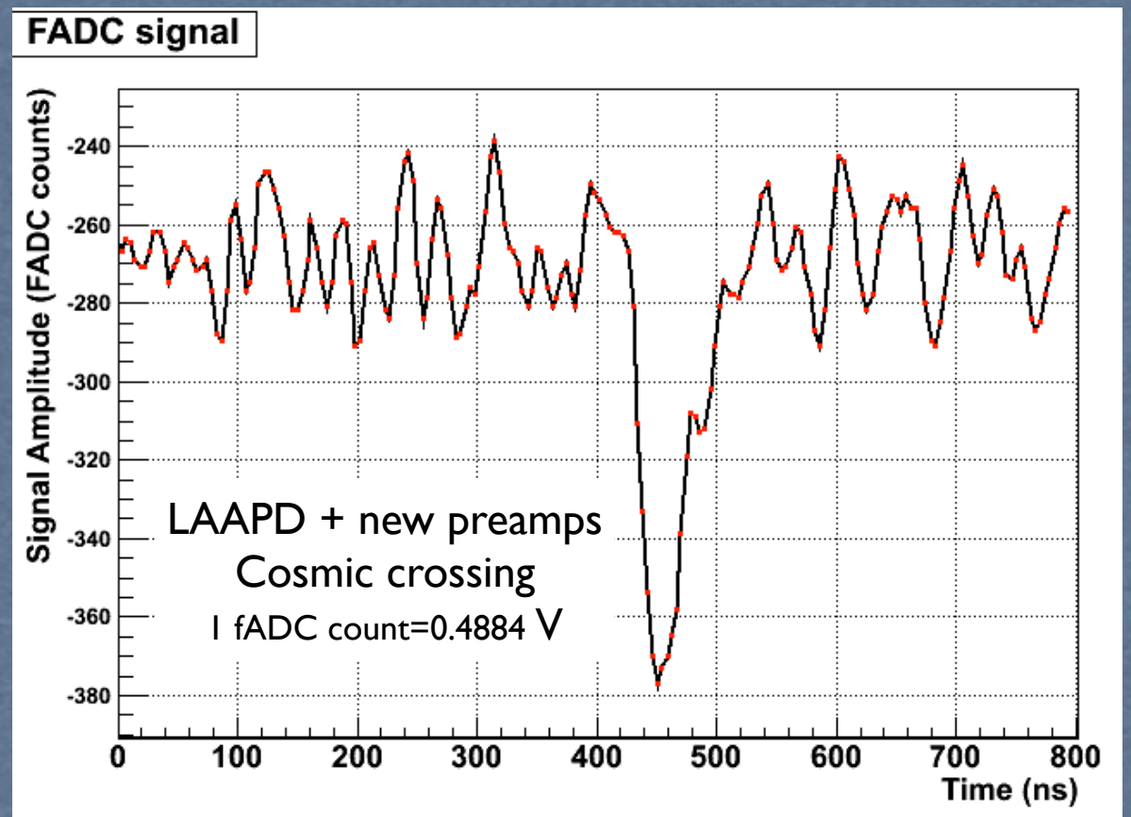
- ✳ 4x area provides 4 times more light
- ✳ Better S/N ratio when coupled to new IPN-Orsay preamps

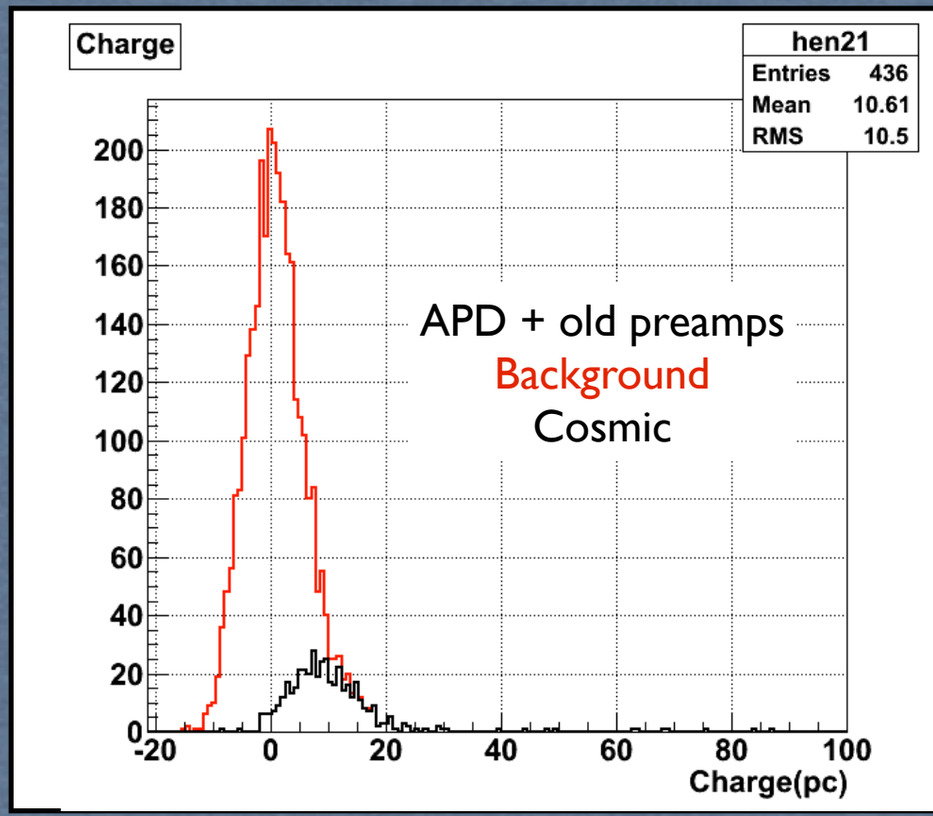
- ✳ Better A'mass resolution

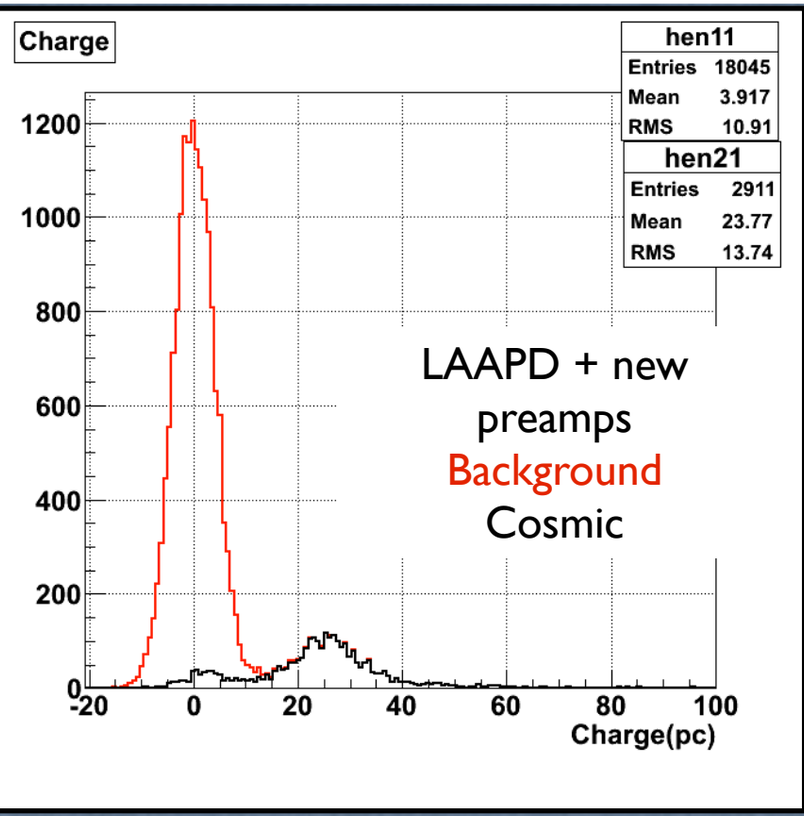
## Cosmic ray calibration

- ✳ LAAPD allows calibration with cosmic muons
- ✳ Tests performed in Genova show the difference
- ✳ New sensors requires new FE electronics

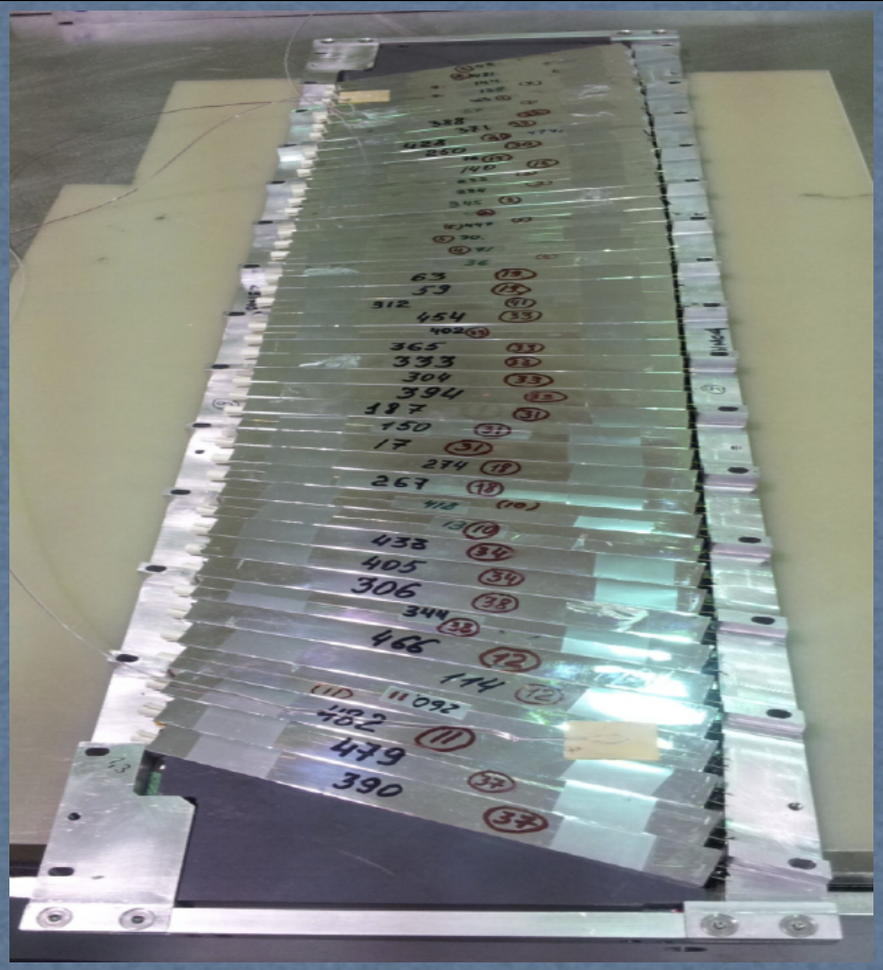
- Old APD G=200
- LAAPD G=150
- T=18 °C



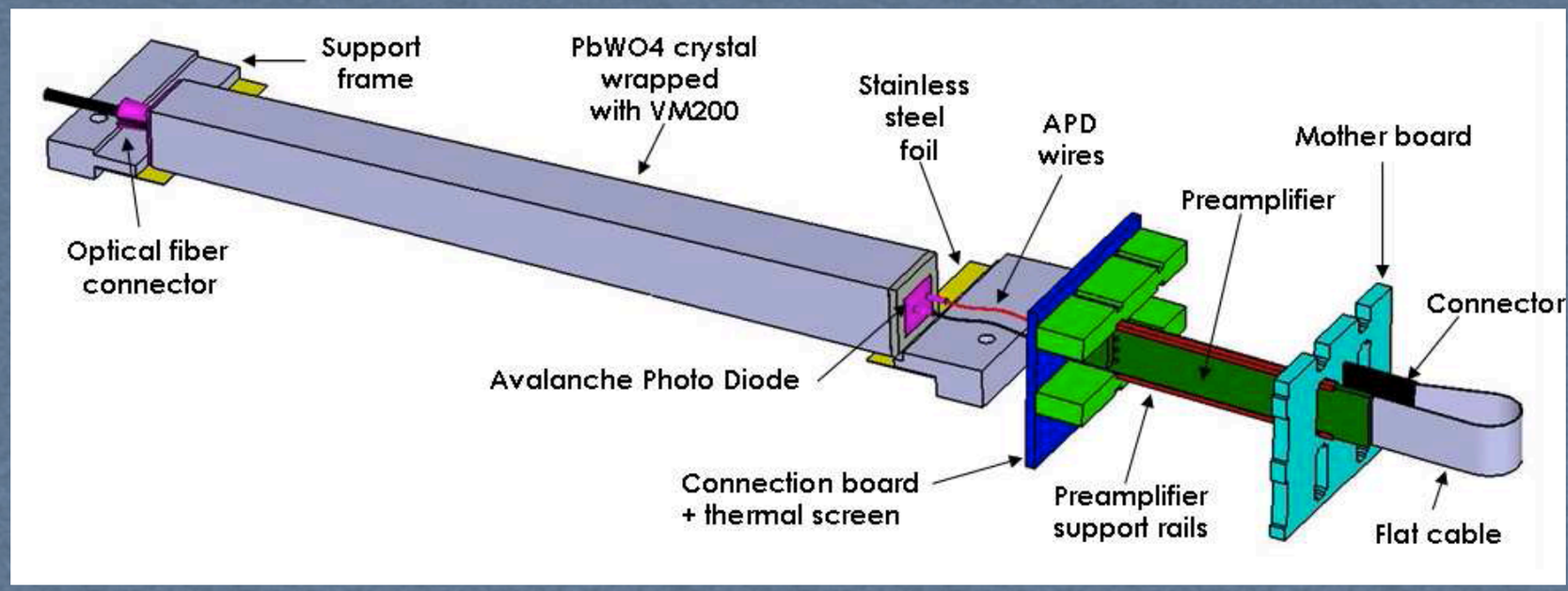




A.Celentano



# Mechanical constraints




- LAAPDs match the back size of the PbWO crystals
- No interference with the Al support grid
- Clearance for new APDs checked with IPN-Orsay (pin position)

# APD replacement phases

- Procurement
- APD Benchmarking
- ECal dissemble
- Crystal preparation: ungluing old APD
- Gluing LAAPD
- Test [Crystal + APD + LED-nose + wrapping] assembly
- ECal reassemble

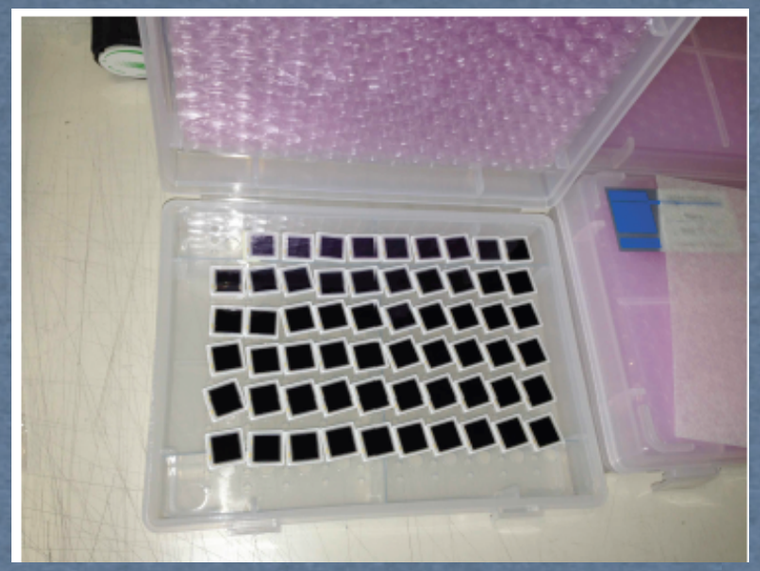
# LAAPD procurement

- Vendor (Hamamatsu) and model (S8664-1010) identified and contacted
- 528 pcs grouped by 12 (10 + 1 spare + 1 potentially rejected per 10 slot of each HV channel)
- Each group with a fixed $V_{Nominal}$ to provide the same gain (G=150 at 25°C)
- The order will be divided into two parts:
  - 216 pcs to be ordered by INFN from Hamamatsu-Italy
  - 312 pcs to be ordered by IPN-Orsay from Hamamatsu-France
- The price per APD has been quoted 400 euro (for more than 500 pcs)
- The two orders will be considered and processed together from Hamamatsu-Japan

- Expected time for LAAPD procurement:
  3 months for paperworks
  + 100-120 days for delivery
  + 2-4 weeks contingency
  = ~7 months

Deadlines & Milestones:
- October 1st INFN/IPN money secured
- October 10th: bid paperworks started
- Mid December 2013: order placed
- Apr 23rd: LAAPD at JLab

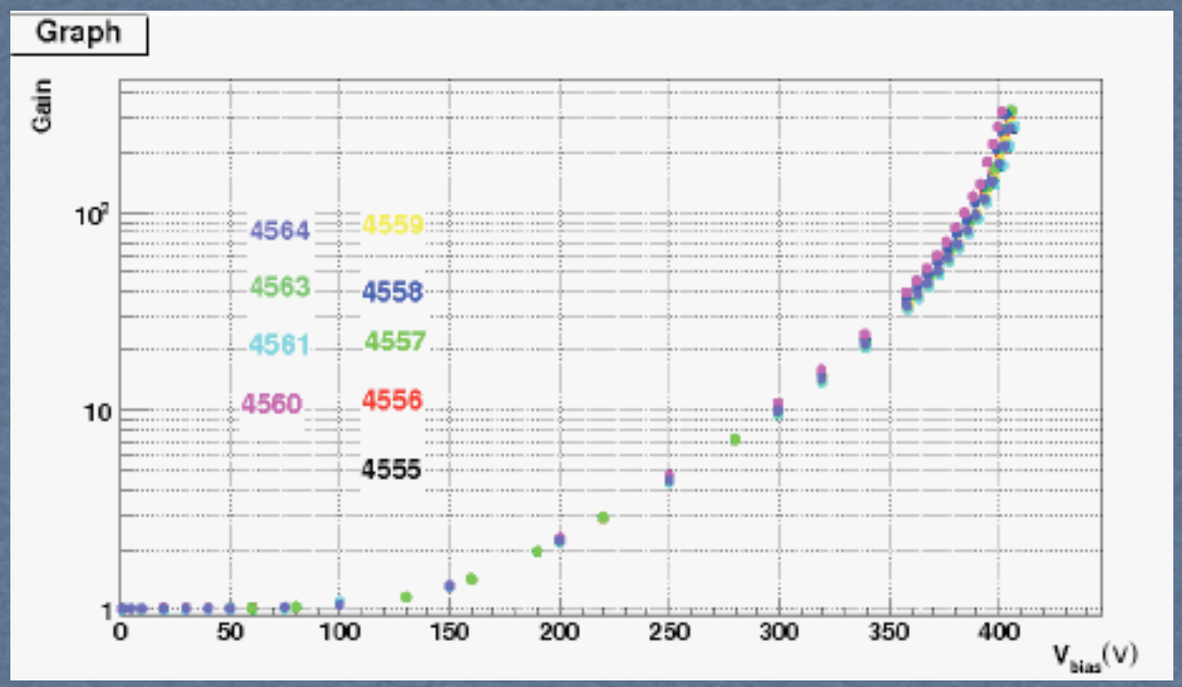
# LAAPD benchmarking (I)

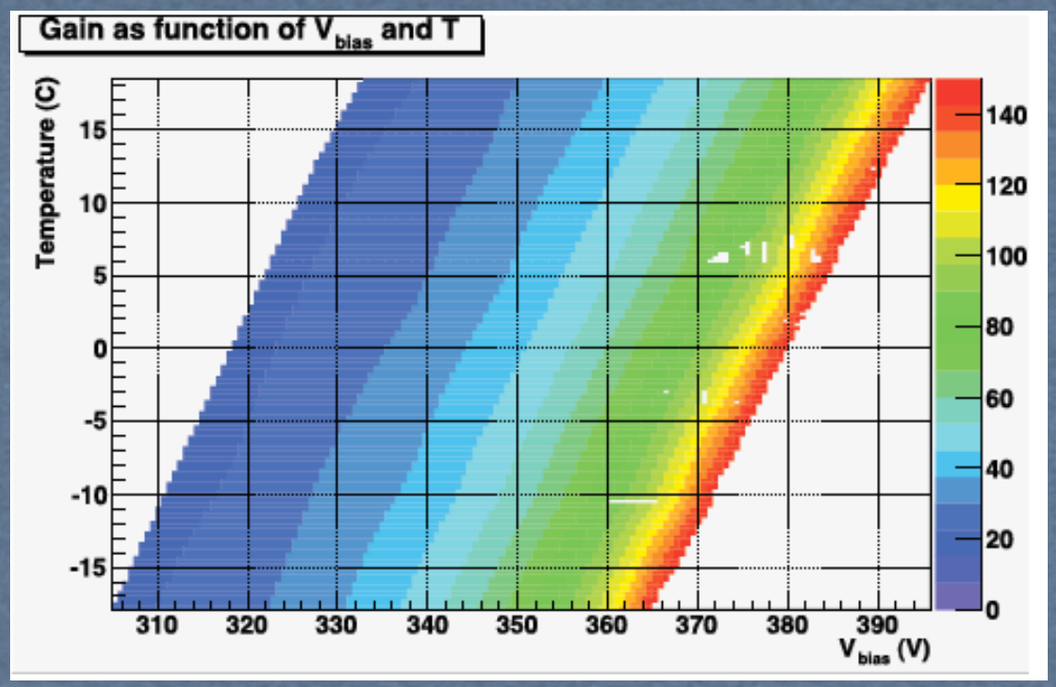


✳Once at JLAB the LAAPD need to be benchmarked
✳ APD comes with $V_{BD}$, $V_{Nominal}$, for G=150 (T=25°C) certified by the vendor
✳ Characterization at 3 values of T (T=15°C, T=18°C, T=23°C) close to the working point; other T's obtained by interpolation

$$G(V,T) = \frac{I_{on}(V,T) - I_{off}(V,T)}{I_{on}(G=1) - I_{off}(G=1)}$$

- Dark current vs $V_{Bias}$
- Dark current vs G (expected linear)
- 1/G x dG/dV vs G
- G(V,T)



# LAAPD benchmarking (II)

✳ Largely reuse of the measurement facility used to characterize the 380 FT-Cal LAAPDs
✳ Automatic bias V-scan in a T-controlled environment
✳ The system only requires a new 110V/60Hz powered chiller, working in the range T=10°C - 30°C
✳ 24 sensors-at-time, 2 batches per 24h = 48 working/day and 11 working day in total
✳ Real week: 4 working day + 1 day to analyze data for a total of 3 cal weeks

✳ Expected time for LAAPD benchmarking:
3 cal weeks
+1 contingency
+1 for a possible 2nd measurement of the 30% of the whole lot
= 5 cal weeks

Deadlines & Milestones:
- Feb 1st: FT-Cal benchmarking facility at JLab
- February: interface with the new chiller
- March 1st: testing facility operational
- Apr 23rd: APD at JLab
- Jun 1st: all LAAPD characterized

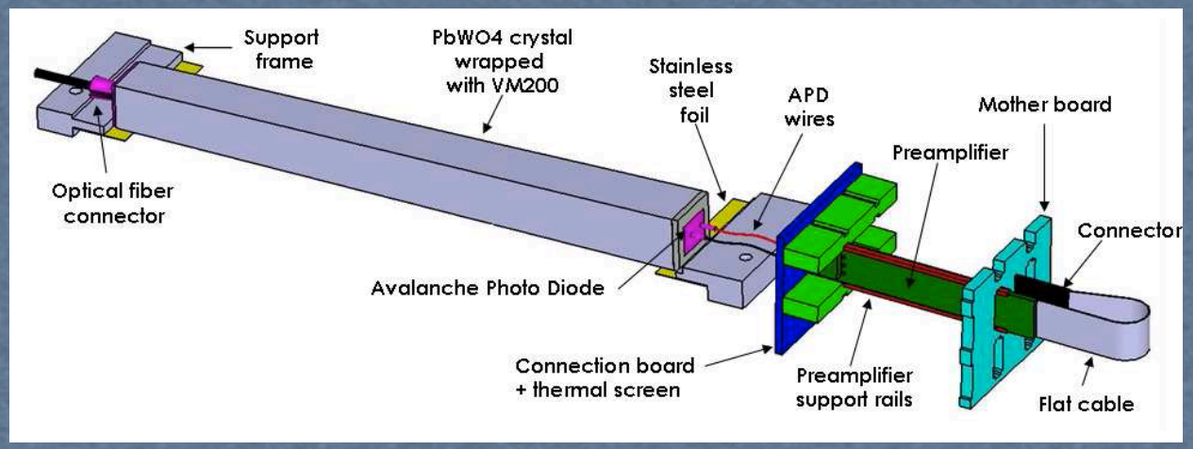
# ECal dissemble

- ECal dissemble procedure just started
  - two ECAl parts on the lab desk
  - remove preamplifiers (to be sent to Orsay for upgrade)
- Team from Orsay in mid November
- 1 week to remove frame
- Few days to have all crystals ready for further processing (APD ungluing, re-gluing …)
- Vessel + frame ready to be sent to Orsay for modification before the end of the year

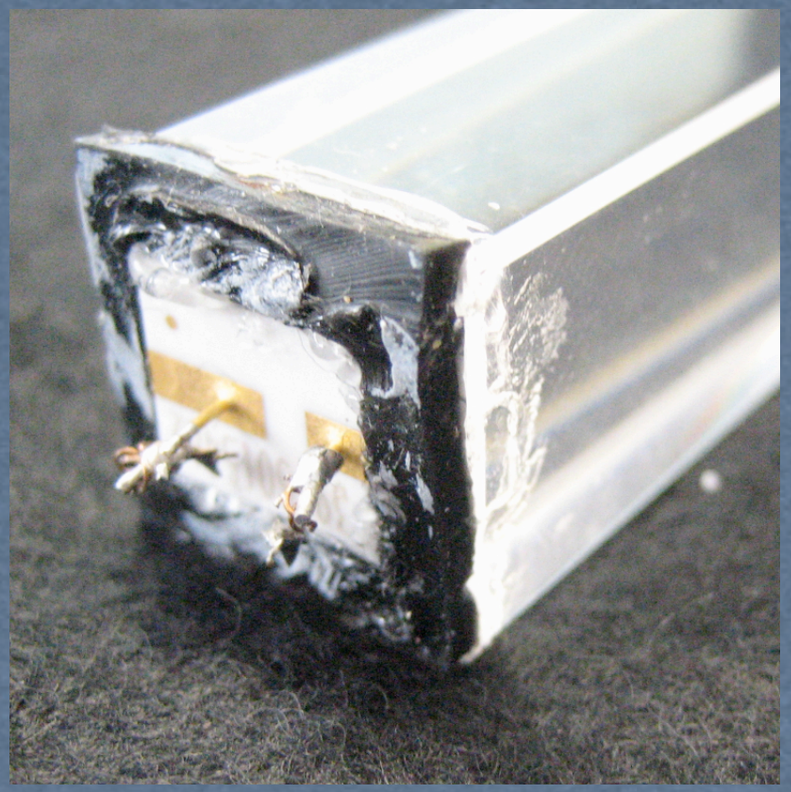
- Expected time for crystal preparation:
  - 4 cal weeks
  - +2 contingency
  - +2 pause to wait for frnch
  - = 8 cal weeks

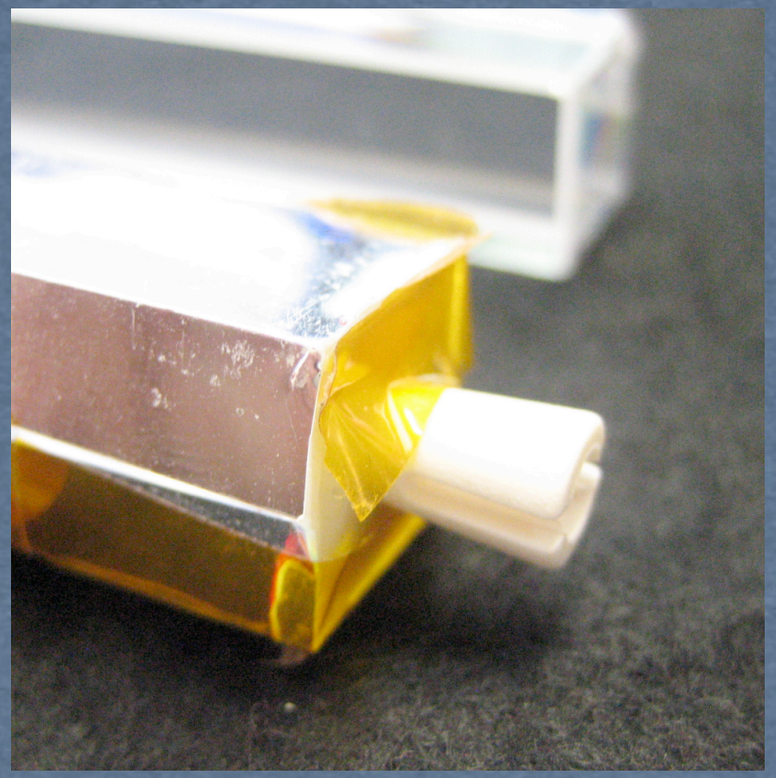
Deadlines & Milestones:
- now - Nov 1st: preamps ready to be sent to Orsay
- Dec 1st: all crystals ready for further processing
- Dec 15th: Vessel + frame sent to Orsay

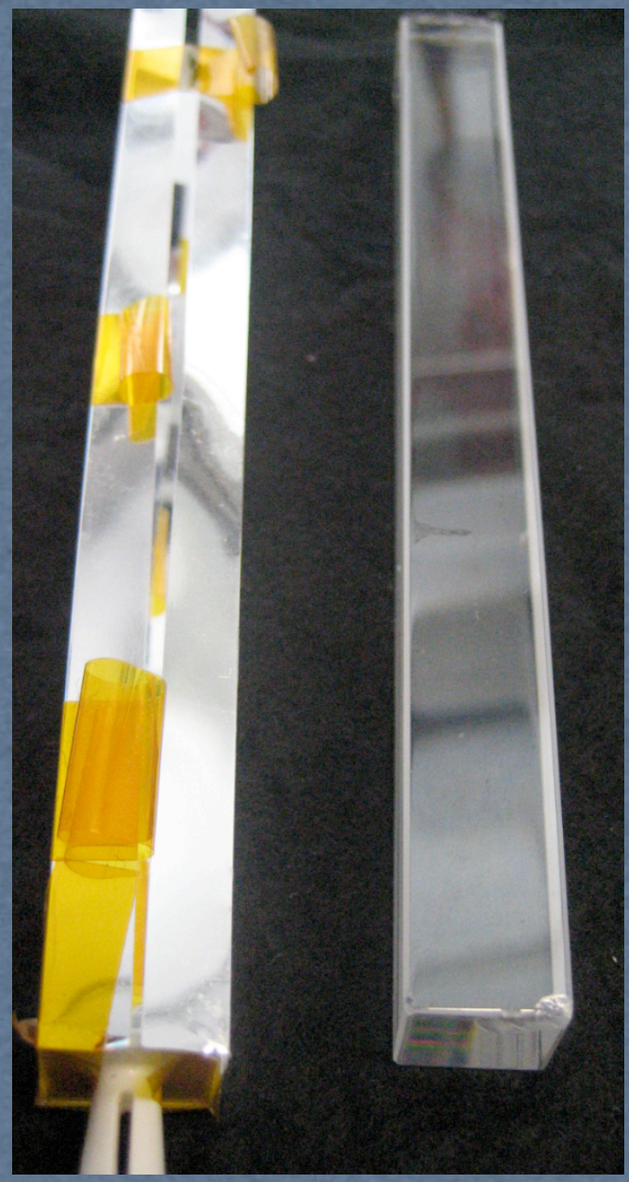
# Crystal preparation




- Crystals assembly includes 4 parts:
  - plastic-nose **To be replaced**
  - crystal **Kept**
  - VM2000 wrapping **Kept**
  - APD **To be replaced**

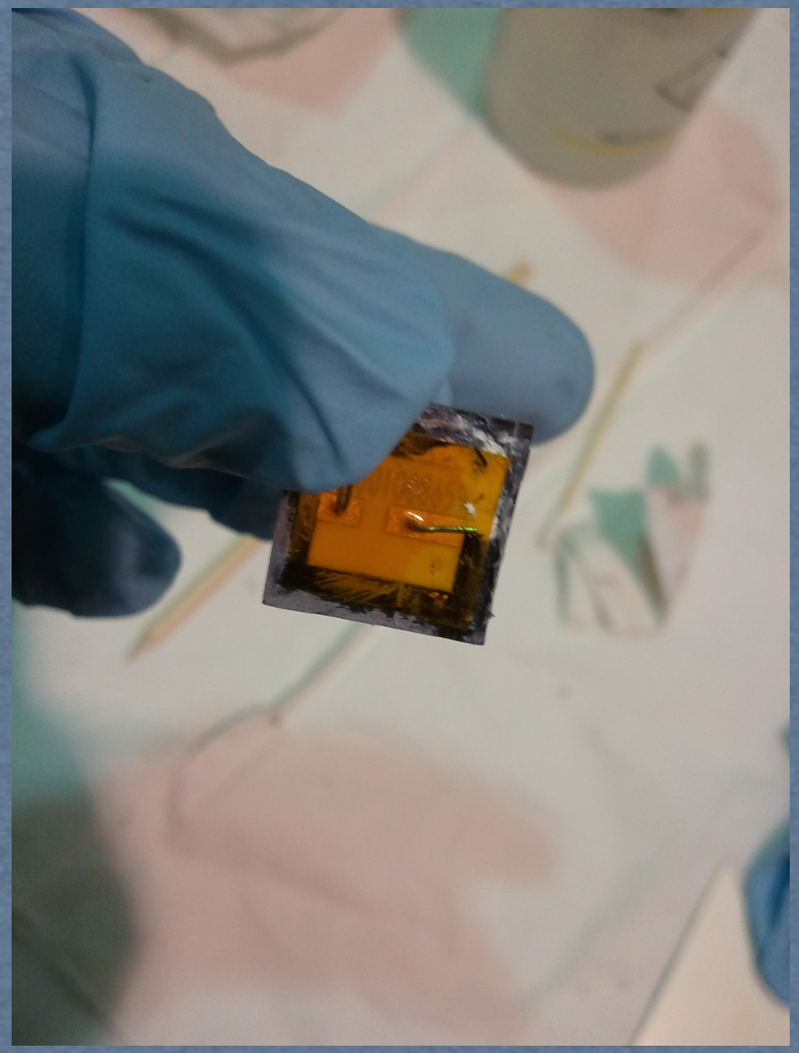


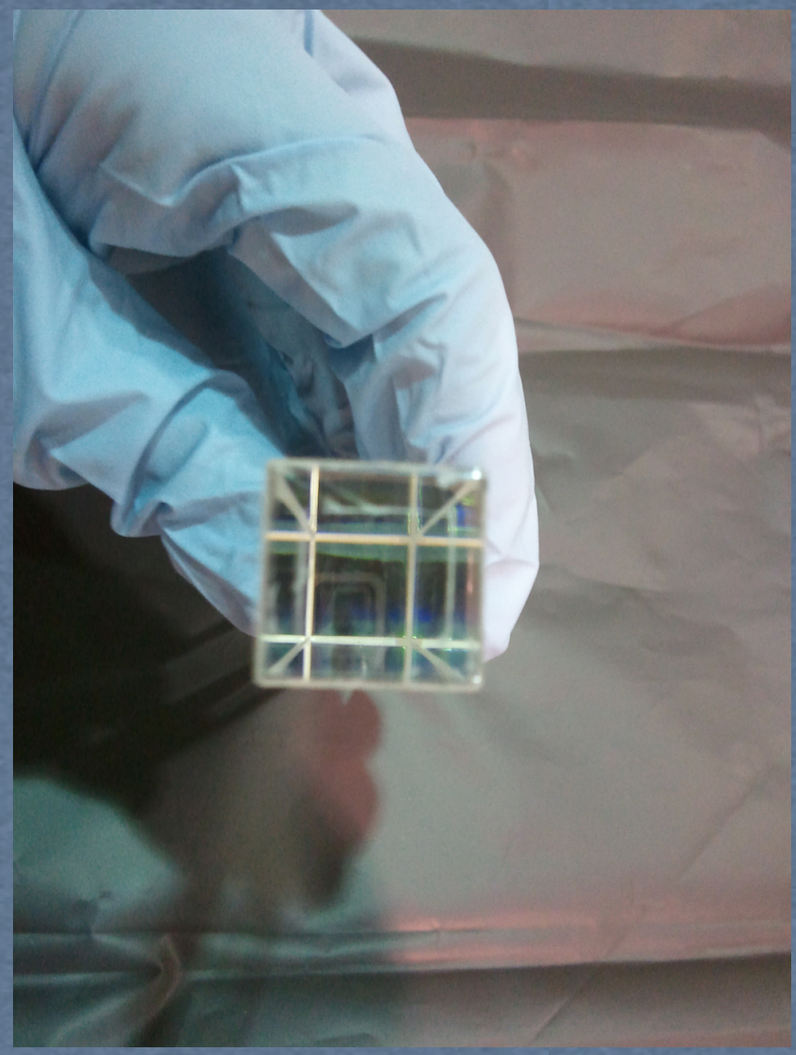




# Crystal preparation

- To glue the new LAAPD the assembly needs to be taken apart
  - carefully open the VM2000 wrapping for reuse
  - disconnect the plastic nose (to be replaced with the LED-nose)
  - unglue the old APD using thermal procedure (use an oven at T=85 for 1h)
  - clean the crystal surface with isopropanol
  - crystals ready for the LAAPD gluing





# Crystal preparation

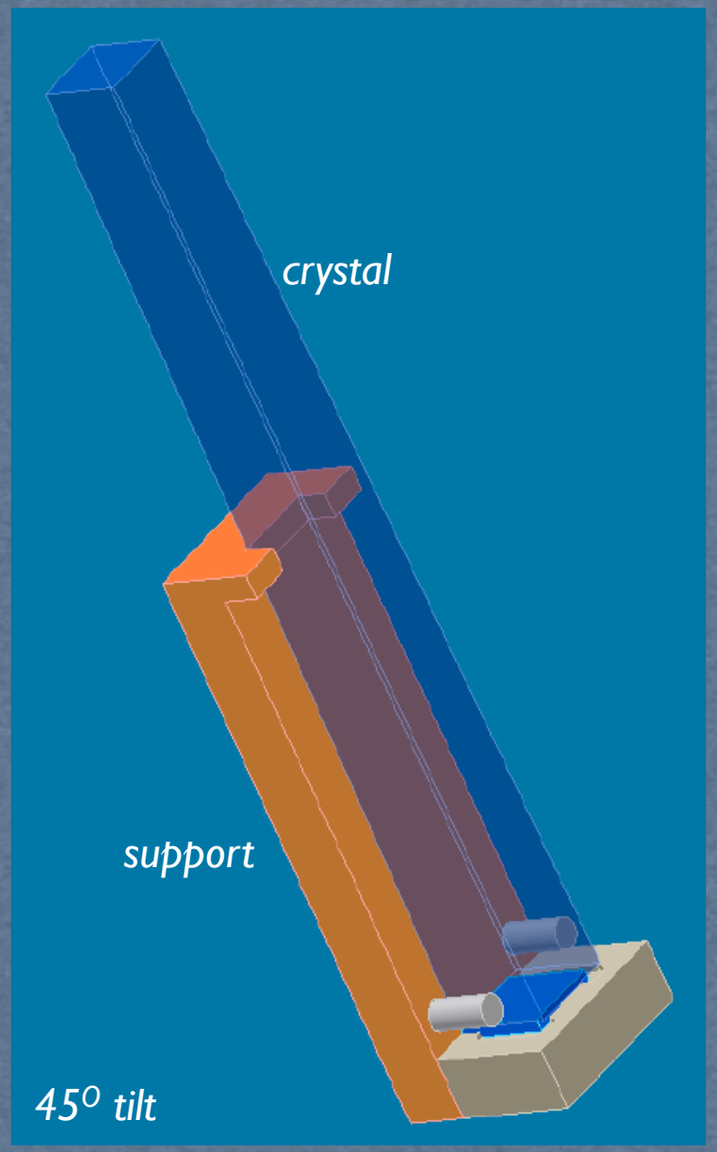
- To glue the new LAAPD the assembly needs to be taken apart
  - carefully open the VM2000 wrapping for reuse
  - disconnect the plastic nose (to be replaced with the LED-nose)
  - unglue the old APD using thermal procedure (use an oven at T=85 for 1h)
  - clean the crystal surface with acetone
  - crystals ready for the LAAPD gluing
- Two batteries of 20+20 crystals can be prepared per day by two TC
- For the preparation of the whole set (440 crystals) 11 working days (3~4 cal weeks) expected
- The procedure needs to be optimized to:
  - reduce the risk of damaging the wrapping
  - maximize efficiency
- A procedure that not require un-wrapping is also under study

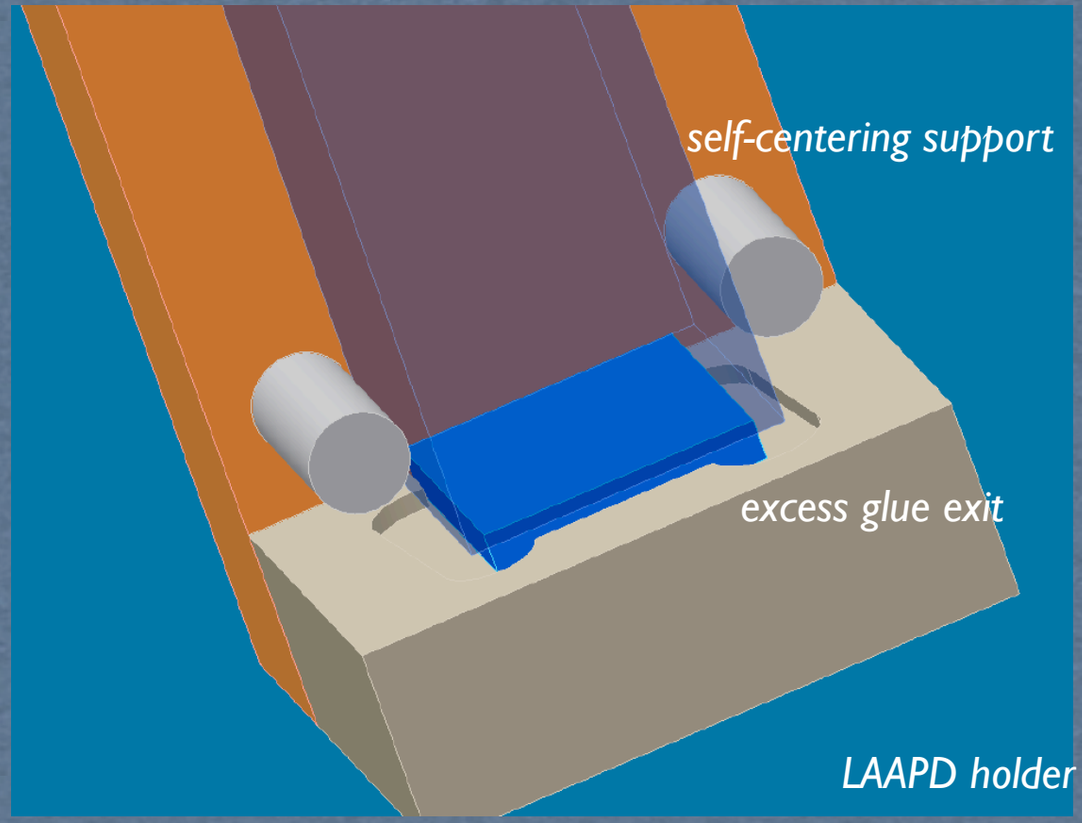
- Expected time for crystal preparation:
  4 cal weeks
  +1 contingency
  +1 for possible problems
  = 6 cal weeks

Deadlines & Milestones:
- now - Dec 1st: ungluing procedure optimization
- Dec 1st: procedure established
- Dec 15th: beginning of the crystal preparation
- February 15th: all crystal cleaned and ready for LAAPDs

# Gluing the new LAAPD

- The new LAAPD will be glued to the back side of the bare crystal replacing the old APD
- Silicone-glue: Dow Corning 3145 RTV-Clear
- The procedure requires to:
  - place the crystal in a self-centering special holder where the LAAPD sits
  - the weight of the crystal is used to provide an adequate and reproducible pressure



# Gluing the new LAAPD

- The new LAAPD will be glued to the back side of the bare crystal replacing the old APD
- Silicone-glue: Dow Corning 3145 RTV-Clear
- The procedure requires to:
  - place the crystal in a self-centering special holder where the LAAPD sits
  - the weight of the crystal is used to provide an adequate and reproducible pressure
  - gluing
  - visual inspection from the crystal front-side to recognize presence of air bubble/dust
  - wait for 12h to harden the glue
  - the morning after the crystal can be handle and the glueing tested using a dedicated facility
- If necessary to repeat, the LAAPD can be easily detached by using alcohol
- Two batteries of 24 + 24 crystals can be glued per day by two TC
- For the gluing of the whole set (440 crystals) 10 working days (2 real weeks) are expected
- The procedure needs to be optimized

- Expected time for LAAPD gluing:
  - 2 cal weeks
  - +1 contingency
  - +1 for possible problems
  - = 4 cal weeks

Deadlines & Milestones:

- now - Dec 1st: gluing procedure optimization
- Jan 1st: procedure established
- Jan 1st - March 15th: tools preparation
- March 15th: gluing tools ready at JLab
- May 15th: beginning of the gluing procedure
- Jun 15th: all LAAPD glued

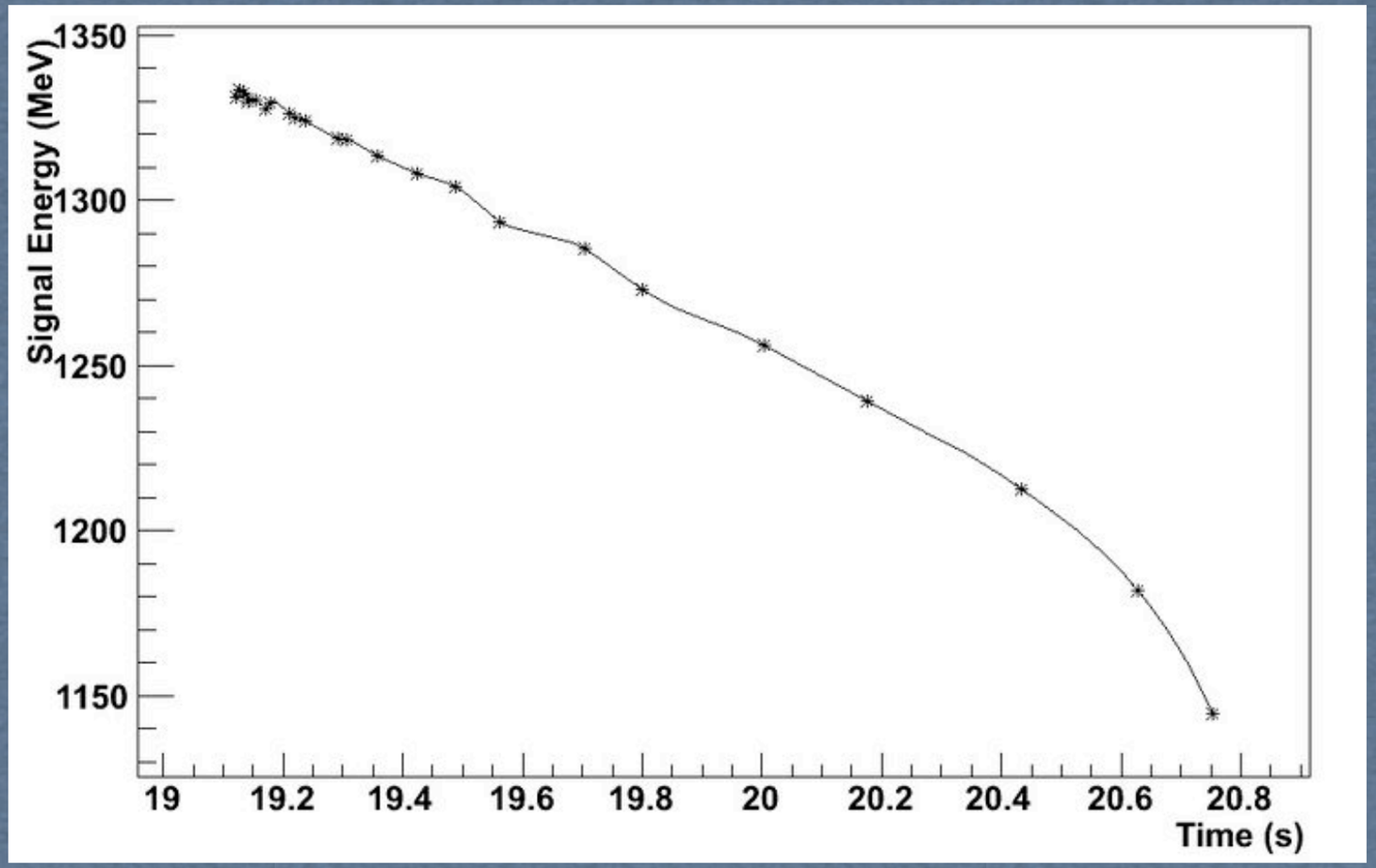
# Testing the new assembly

✳ After gluing the new crystal+LAAPD assembly needs to be tested with a know light source to check the light transmission

✳ The procedure requires to:

- place the assembly in a thermalized box to keep T constant (18±2°C) for the night (12h)
- same chiller used to benchmark LAAPDs
- assembly and LED at constant T

*Variation of the equivalent energy (light seen by crystal+LAAPD) as a function of the LED T*

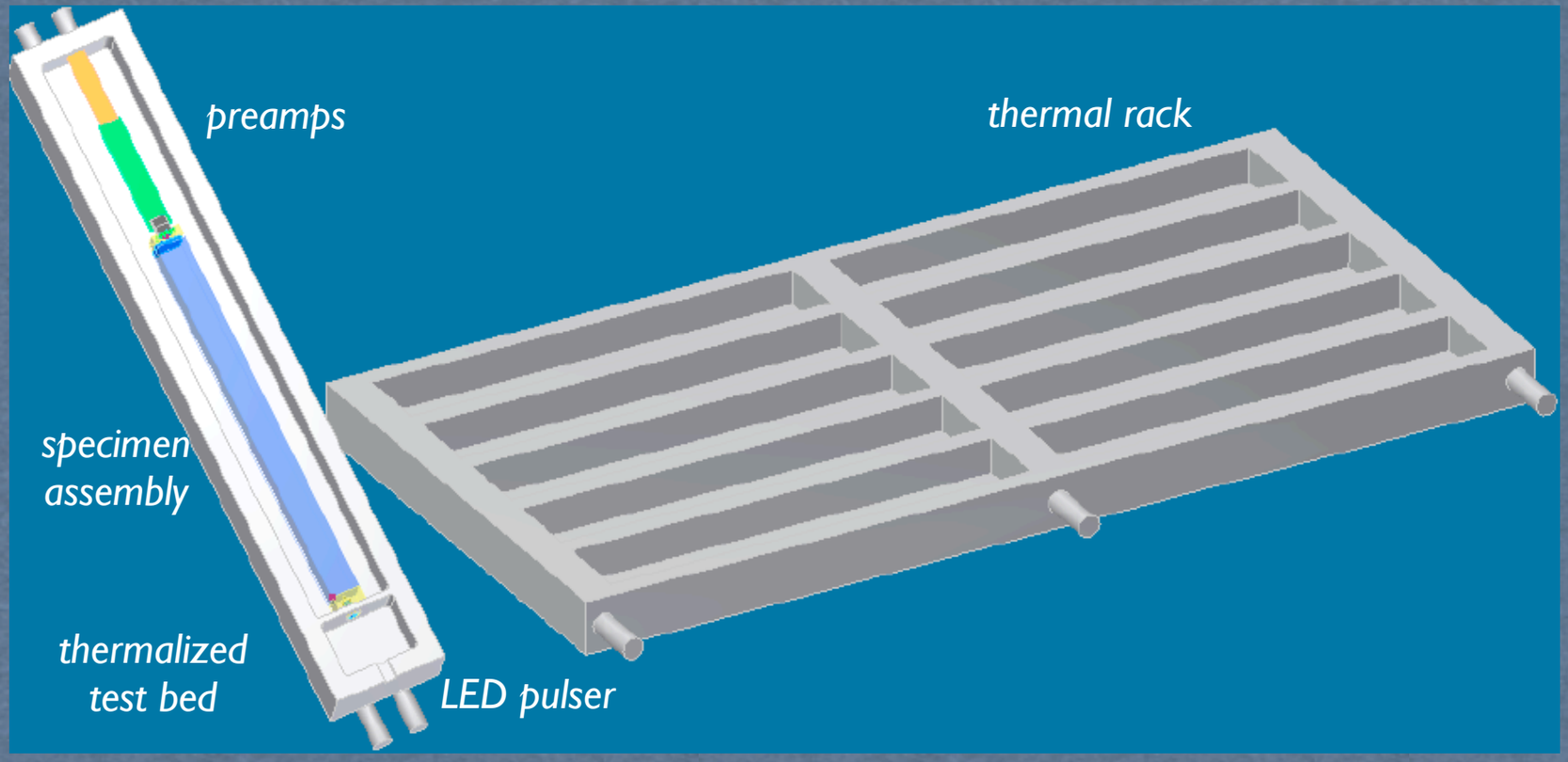


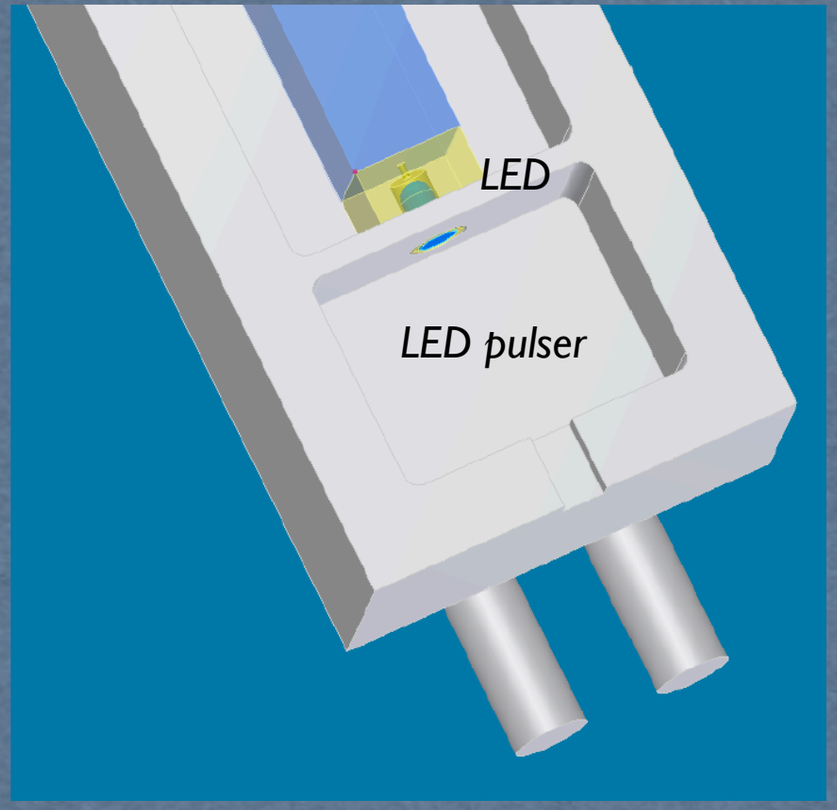
# Testing the new assembly

✳ After gluing the new crystal+LAAPD assembly needs to be tested with a know light source to check the light transmission

✳ The procedure requires to:

- place the assembly in a thermalized box to keep T constant (18±2°C) for the night (12h)
- same chiller used to benchmark LAAPDs
- assembly and LED at constant T



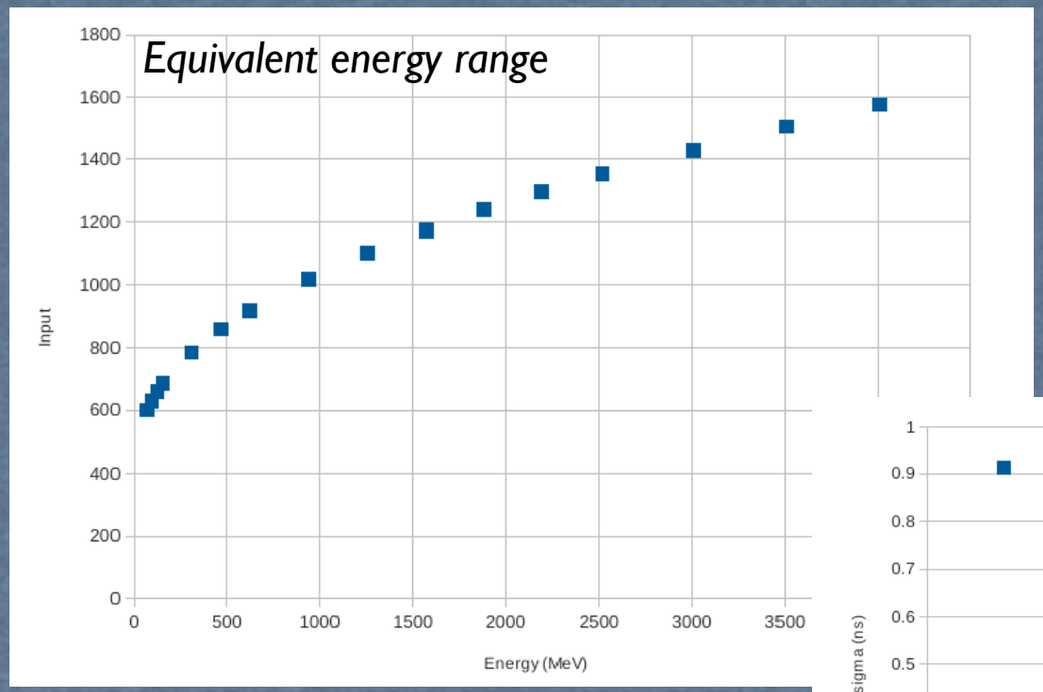
# Testing the new assembly

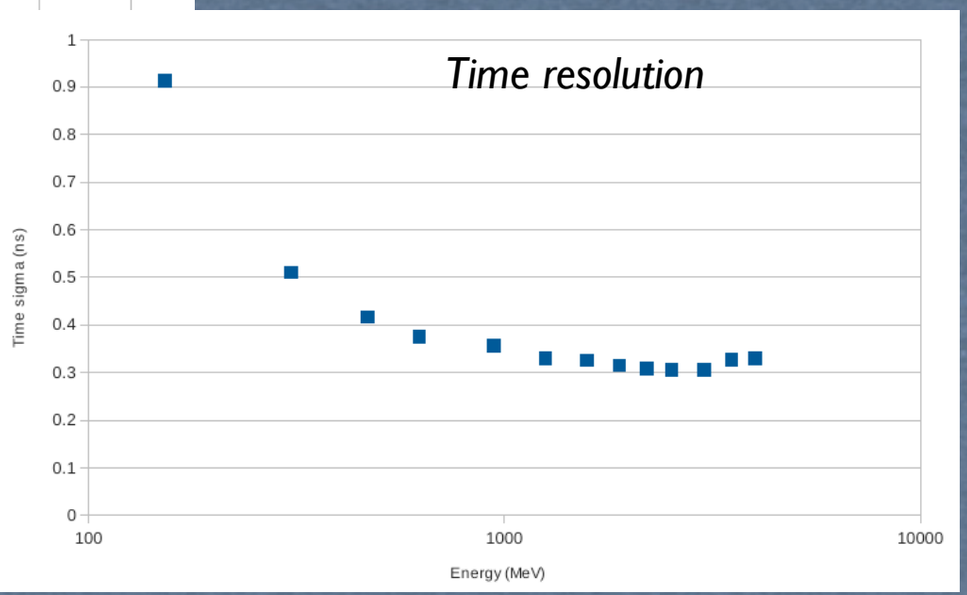
✳ After gluing the new crystal+LAAPD assembly needs to be tested with a know light source to check the light transmission

✳ The procedure requires to:

- place the assembly in a thermalized box to keep T constant (18±2°C) for the night (12h)
- use the LED testing facility to check light transmission (1 KHz, 100ns, 500mV light pulse)
- record the mean value of the amplitude/charge by an oscilloscope (5mn per crystal)






- *RED/BLUE single LED driver*
- *wired controlled*
- *same performance (energy range and time resolution) as LMS driver*
- *abs stability ~1%*
- *4 drivers already available*

# Testing the new assembly

✳ After gluing the new crystal+LAAPD assembly needs to be tested with a know light source to check the light transmission

✳ The procedure requires to:

- place the assembly in a thermalized box to keep T constant (18±2°C) for the night (12h)
- use the LED testing facility to check light transmission (1 KHz, 100ns, 500mV light pulse)
- record the mean value of the amplitude/charge by an oscilloscope (5mn per crystal)
- overall 15mn are expected to fully characterize an assembly

✳ Assembly out of specs will be unglued and re-glued again

✳ Four batteries of 12x2 + 12x2 crystals can be tested per day by two TC

✳ For the gluing of the whole set (440 crystals) 10 working days (2 real weeks) are expected

✳The procedure needs to be optimized

✳ Expected time for LAAPD gluing:

2 cal weeks
+1 contingency
+1 for repeating tests on rejected assembly
= 4 cal weeks

Deadlines & Milestones:

- now - Jan 1st: testing procedure optimization
- Jan 1st: procedure established, specs defined
- Jan 1st - March 15th LED testing facility preparation
- March 15th: LED testing facility ready at JLab
- June 7th: beginning of the testing procedure
- July 7th: all assemblies tested

# ECal reassemble

- The full crystal assembly requires:
  - crystal+LAAPD
  - LED-nose with LED and wires
  - wrapping VM2000

  Expected time: 2 weeks (+1 contingency)
- Mechanical structure reassemble: vessel, supports, crystal assemblies, preamps, LMS

  Expected time: 3 weeks (+1 contingency)
- Final test after reassemble by using the LMS

  Expected time: 2 weeks (+1 contingency)

- Expected time for ECal reassemble:

  2+1 weeks for final assembly
  + 3+1 weeks for reassemble
  + 2+1 weeks fro testing
  = 10 cal weeks

Deadlines & Milestones:
- Jun 15th: full crystal assembly begin
- July 7th: ECal reassembly begin
- August 7th: ECal assembled and ready for testing
- September 1st: Ecal ready for installation

# ECal APD replacement time schedule

| | | weeks | Oct Nov Dec | Jan | Feb | Mar | April | May | Jun | Jul | Aug |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LAAPD procurement | paperwork | 8 | | | | | | | | | |
| | production and delivery | 20 | | | | | | | | | |
| APD benchmarking | FT-Cal benchmark facility refurbishing | 2 | | | | | | | | | |
| | US-compliant chiller interfacing | 4 | | | | | | | | | |
| | LAAPD benchmarking | 5 | | | | | | | | | |
| Ecal dissemble | preamps | | | | | | | | | | |
| | frames | | | | | | | | | | |
| | crystals | | | | | | | | | | |
| Crystal preparation | Procedure optimization | 8 | | | | | | | | | |
| | Tooling | 8 | | | | | | | | | |
| | Ungluing | 4 | | | | | | | | | |
| Gluing | Procedure optimization | 12 | | | | | | | | | |
| | Tooling | 8 | | | | | | | | | |
| | Gluing | 4 | | | | | | | | | |
| Assembly test | Procedure optimization | 12 | | | | | | | | | |
| | Tooling | 8 | | | | | | | | | |
| | Assembly tests | 5 | | | | | | | | | |
| ECal reassemble | Full crystal assembly | 4 | | | | | | | | | |
| | ECal mounting | 5 | | | | | | | | | |
| | Full ECal test with GMS | 4 | | | | | | | | | |

# Resources

✳ All funds were allocated and secured fro FY2013/14

| | | | |
|---|---|---|---|
| LAAPD Hamamatsu S8664-1010 | | | |
| | 216 | INFN | €90k |
| | 300 | IPN-Orsay | €125k |
| LED holders | 450 | INFN | €10k |
| LED drivers for crystal tests | 4+1 | INFN | €10k |
| Tools for crystal assembly | 2 | INFN | €10k |
| Tooling for LAAPD benchmarking | 1 | INFN | €5k |
| Shipping | | INFN | €5k |
| Consumables | | INFN | €5k |
| TOT | | | €260k |
| TOT (VAT+Cont) | | | €275k |

*Funds only includes equipment

**No contingency and VAT on Hamamatsu purchase requisition

✳ Travel money were also allocated to cover this proposal 60k (+ 20k for shifts)

# Backup & Details

# Tasks and manpower

| | | Allocated weeks | INFN resources FTE-days | Orsay/JLab resources FTE-days | Work site |
|---|---|---|---|---|---|
| APD benchmarking | FT-Cal benchmark facility refurbishing | 2 | 1x5 EE + 1x5 TC | | GE/RM2 - Italy |
| | US-compliant chiller interfacing | 4 | 1x8 EE + 1x3 TC | 1x3 EE + 1x3 TC | JLab |
| | LAAPD benchmarking | 5 | 1x5 EE + 1x6 TC | 1x20 TC | JLab |
| Ecal dissemble | two halves apart | 4 | | 1x15 TC | JLab |
| | preamps | 2 | | 1x5 EE | JLab |
| | crystals | 2 | | 2x15 TC | JLab |
| Crystal preparation | Procedure optimization | 8 | 1x5 EM + 1x5 TC | | GE/CT/CA - Italy |
| | Tooling | 8 | 3x3TC | | GE/CT/CA - Italy |
| | Ungluing | 4 | 1x5 EE + 1x5 TC | 2x15 TC | JLab |
| Gluing | Procedure optimization | 12 | 1x5 ME + 1x5 TC | | GE/CT/CA - Italy |
| | Tooling | 8 | 1x5 ME + 4x5 TC | | GE/CT/CA - Italy |
| | Gluing | 4 | 1x5 EE + 3x5 TC | 2x15 TC | JLab |
| Assembly test | Procedure optimization | 12 | 1x8 EE + 1x7 TC | | GE/CT/CA - Italy |
| | Tooling | 8 | 1x8 ME + 3x5 TC | | GE/CT/CA - Italy |
| | Assembly tests | 5 | 2x5 EE + 3x5 TC | 4x15 TC | JLab |
| ECal reassemble | Full crystal assembly | 4 | 2x5 TC | 2x10 TC | JLab |
| | ECal mounting | 5 | 2x5 TC | 1x5 EE + 2x15 TC | JLab |
| | Full ECal test with GMS | 4 | 3x5 EE | 1x10 EE + 2x10 TC | JLab |

# Milestones

| | |
|---|---|
| LAAPD money secured | October 1st |
| ECal disassembling start | October 15th |
| LAAPD order placed | Mid December |
| Crystal cleaning procedures defined | December 1st |
| Ecal disassembly done and ungluing start | December15th |
| Crystal  assembly procedures defined | January 1st |
| Assembly test procedure defined | January 1st |
| All crystal ready for new APD | February 15th |
| All crystals unglued | March 1st |
| Benchmarking facility ready at JLab | March 1st |
| Gluing tools ready at JLAB | March 15th |
| Assembly test facility ready at JLAB | March 15th |
| LAAPD delivered at JLAB and benchmarking start | April 23rd |
| All LAAPD benchmarked | Jun 1st |
| LAAPD gluing start | May 15th |
| Assembly test start | Jun 7th |
| All LAAPD glued and full crystal assembly start | Jun 15th |
| All assemblies tested and ECal reassemble start | Jul 7th |
| Ecal assembly completed | August 7th |
| Ecal fully tested and ready for installation in the Hall | September 1st |

# Manpower

| Activity | Workers | FTE (total) | Travel days | INFN Units |
|---|---|---|---|---|
| **Motherboards design** | **EE** | **30** | | **GE** |
| **Motherboards tests** | **EE, TC** | **35** | **15** | **GE,TO** |
| | EE | 15 | | GE |
| | ME | 5 | | GE |
| | TC | 5 | 5 | TO |
| | TC | 10 | 10 | TO |
| **LED LMS design/prototyping** | **EE, TC** | **35** | **5** | **GE, TO** |
| | EE | 30 | | GE |
| | TC | 5 | 5 | TO |
| **LED holders design** | **ME** | **10** | | **GE** |
| **LED holders production** | **TC** | **20** | | **CT** |
| **LAAPD benchmarking tooling** | **EE, TC** | **11** | **10** | **GE,RM2,CT** |
| | EE | 5 | | GE |
| | EE | 3 | 5 | RM2 |
| | TC | 3 | 5 | CT |
| **Crystal cleaning tools and proc. optimiz.** | **TC** | **11** | **10** | **GE,CT,CA** |
| | TC | 5 | | GE |
| | TC | 3 | 5 | CA |
| | TC | 3 | 5 | CT |
| **Crystal gluing tools and proc. optimiz.** | **TC** | **26** | **10** | **GE,CT,CA** |
| | ME | 5 | | GE |
| | TC | 10 | | CA |
| | TC | 5 | | GE |
| | TC | 3 | 5 | CA |
| | TC | 3 | 5 | CT |
| **Crystal assembly test tooling and proc. opt.** | **EE, TC** | **49** | **15** | **GE,CT,CA** |
| | ME/EE | 25 | | GE |
| | TC | 10 | | CT |
| | TC | 5 | | GE |
| | TC | 3 | 5 | CA |
| | TC | 3 | 5 | CT |
| | EE | 3 | 5 | CT |
| Total | | 140 | | GE |
| Total | | 15 | 25 | CT |
| Total | | 20 | 20 | TO |
| Total | | 9 | 15 | CA |
| Total | | 3 | 5 | RM2 |
| **Total** | | **187** | **65** | |

| Activity | Workers | FTE (total) | Travel days | INFN Units |
|---|---|---|---|---|
| **LAAPD benchmarking (500pcs)** | **EE, TC** | **31** | **21** | **RM2,GE** |
| | 1xTC | 20 | | JLab |
| | 1xEE | 5.5 | 10.5 | RM2 |
| | 1xTC | 5.5 | 10.5 | GE |
| **ECal disassembly** | **EE, TC** | **51.5** | **10.5** | **GE** |
| | 2xTC | 40 | | JLab |
| | 1xEE | 5 | | JLab |
| | 1xEE | 5.5 | 10.5 | GE |
| **Crystal cleaning (450 pcs)** | **EE, TC** | **31.5** | **31.5** | **CT** |
| | 2xTC | 15 | | JLab |
| | 2xTC | 11 | 21 | CT |
| | 1x EE | 5.5 | 10.5 | CT |
| **Crystal gluing (450 pcs)** | **EE, TC** | **31.5** | **31.5** | **CA,CT** |
| | 2xTC | 15 | | JLab |
| | 2xTC | 11 | 21 | CA |
| | 1xEE | 5.5 | 10.5 | CT |
| **Crystal assembly test (450 pcs)** | **EE, TC** | **47** | **42** | **CA,CT,GE** |
| | 2xTC | 25 | | JLab |
| | 1xTC | 5.5 | 10.5 | CA |
| | 1xTC | 5.5 | 10.5 | CT |
| | 1xEE | 5.5 | 10.5 | CT |
| | 1x EE | 5.5 | 10.5 | GE |
| **ECal assembly** | **EE, TC** | **25** | | |
| | 2xTC | 20 | | JLab |
| | 1xEE | 5 | | JLab |
| **ECal final tests** | **EE, TC** | **46.5** | **31.5** | **CT,GE** |
| | 2xTC | 20 | | JLab |
| | 1xEE | 10 | | JLab |
| | 1xEE | 5.5 | 10.5 | CT |
| | 1xEE | 5.5 | 10.5 | GE |
| | 1xEE | 5.5 | 10.5 | CA |
| Total | | 175 | | JLab |
| Total | | 38.5 | 73.5 | CT |
| Total | | 22 | 42 | CA |
| Total | | 22 | 42 | GE |
| Total | | 5.5 | 10.5 | RM2 |
| **Total** | | **263** | **168** | |

DRAFT
In Italy
at JLab