

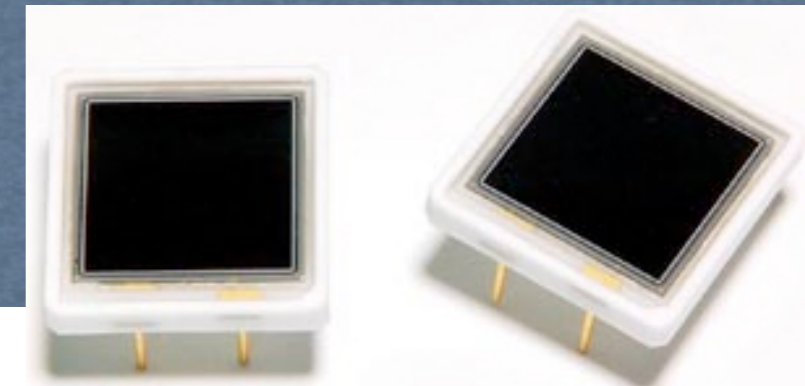
October 17th 2013

New APD installation

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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 mm²

Active area	5x5mm ²
Operating voltage(V _r)	~380V
Capacitance	70pF
Serial resistance	3Ω
Dark Current	<10nA
Quantum Efficiency	~72%@420nm
1/M ^M ×dM/dV(M=50)	3.3%
1/M×dM/dT(M=50)	-2.3%
Excess Noise Factor (M=50)	2
Distance to breakdown (V _b -V _r)	(30-40)V
Effective thickness	~5μm
Gain range	Up tp 1000

^MM is a gain value, T-temperature

Hamamatsu LAAPD (S8148-1010) 10x10 mm²

Type No.	Spectral response range λ (nm)	Peak ^{*3} sensitivity wavelength λ _p (nm)	Photo sensitivity S M=1 λ=420 nm (A/W)	Quantum efficiency QE M=1 λ=420 nm (%)	Breakdown voltage V _{BR} I _D =100 μA		Temperature coefficient of V _{BR} (V/°C)	Dark ^{*3} current I _D		Cut-off frequency f _c (MHz)	Terminal ^{*3} capacitance C _t (pF)	Excess ^{*3} Noise index λ=420 nm	Gain M λ=420 nm
					Typ. (V)	Max. (V)		Typ. (nA)	Max. (nA)				
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				
S8664-10K								0.3	3				
S8664-20K								0.6	6				
S8664-30K								1	15				
S8664-50K								3	35				
S8664-55								5	50				
S8664-1010								10	100				

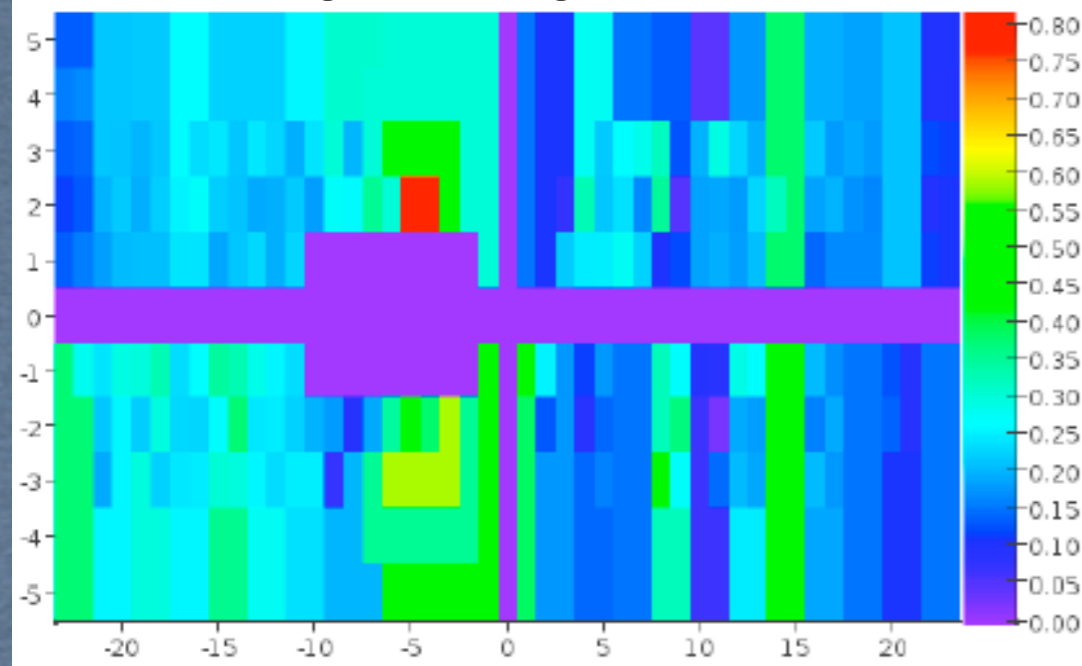
Advantages

- * 10% Gain-matched
- * 4 times more light
- * Lower electronic noise (when coupled to new IPN-Orsay preamps)



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

ECal APD gain during Test run

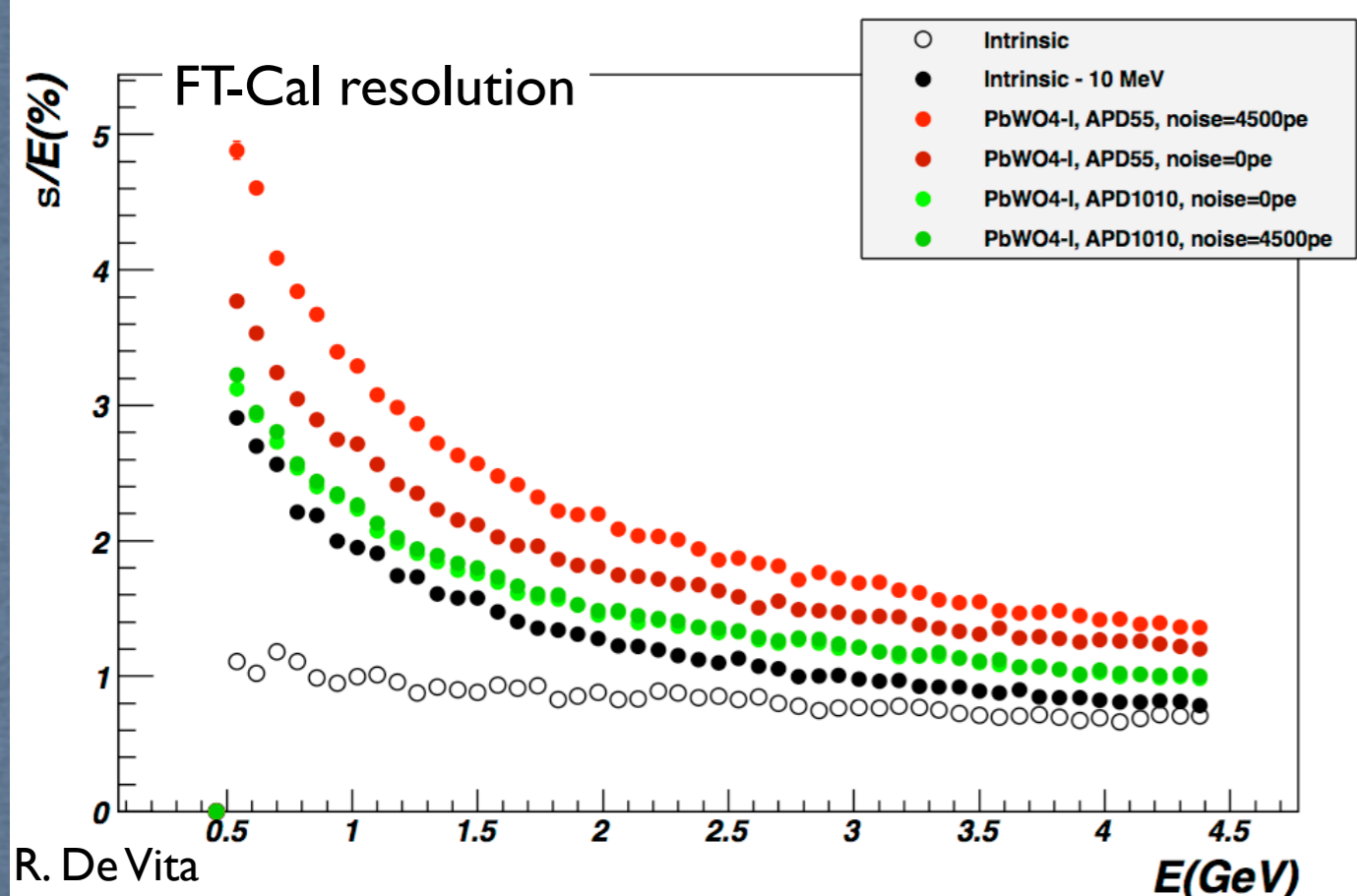


Gain-matching

- * New APDs will be provided gain-matched at 10% level
- * Best running condition selecting the $G \sim 150$
- * 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
- * Lower electronic noise when coupled to new IPN-Orsay preamps



- * Better A'mass resolution

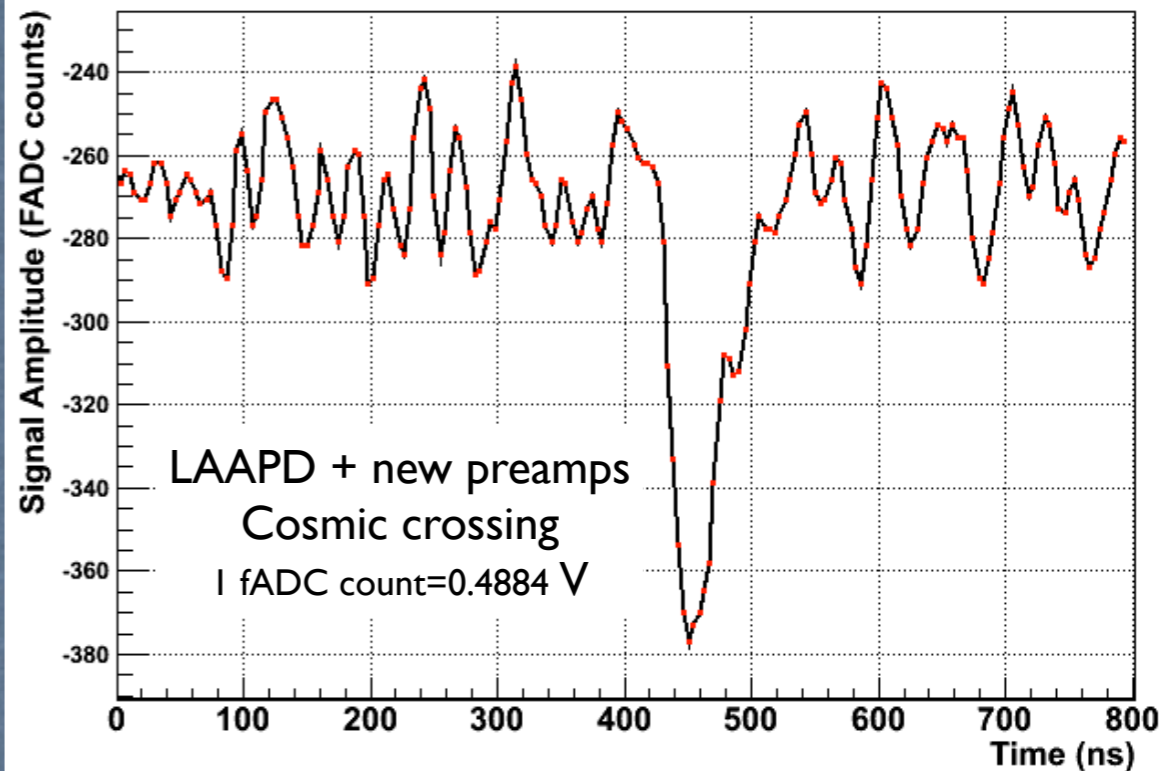
Cosmic ray calibration

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

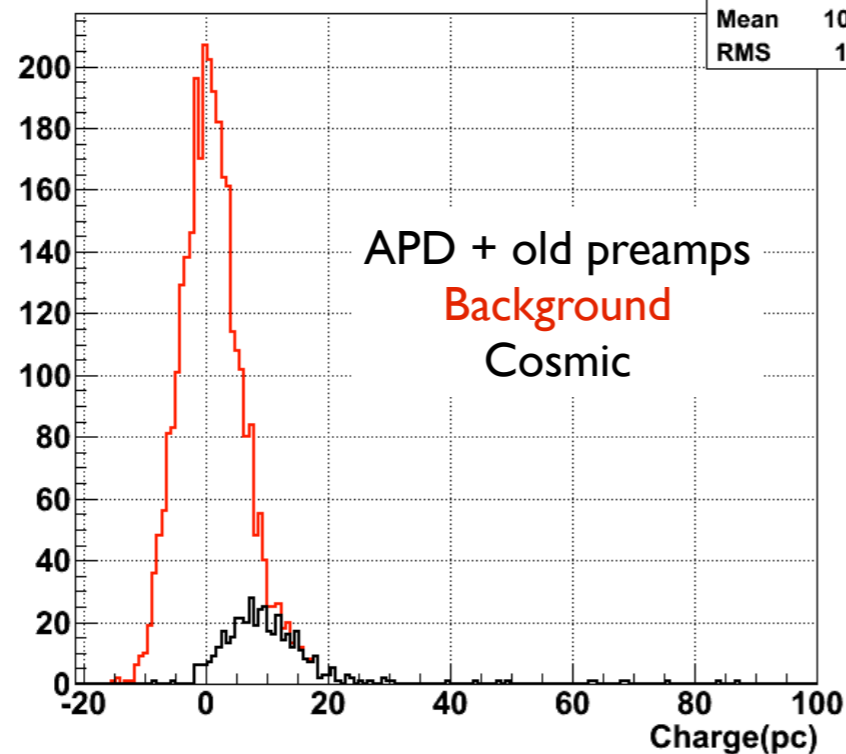


- Old APD G=200
- LAAPD G=150
- T=18 °C

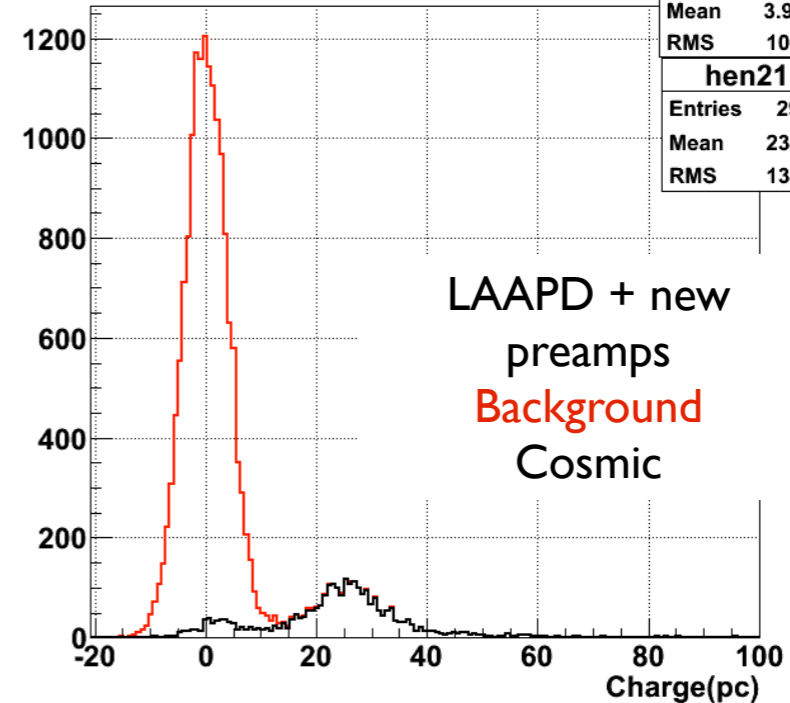
FADC signal

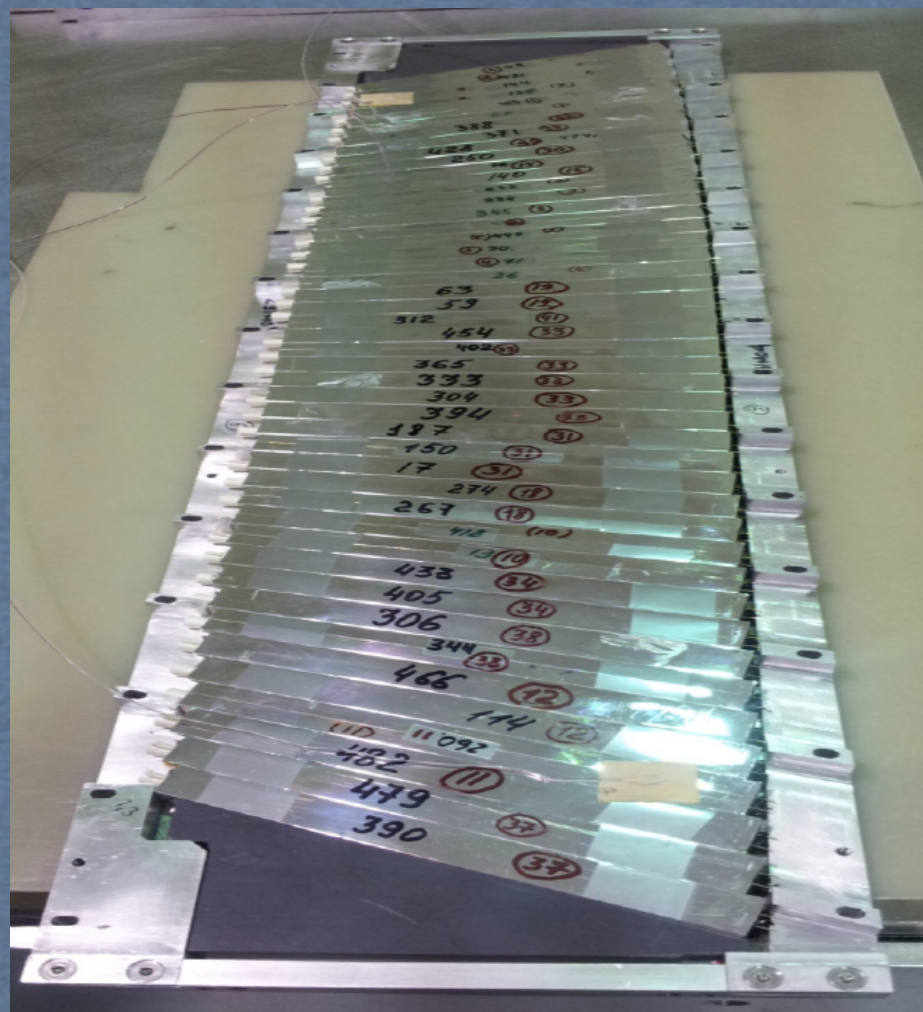


Charge

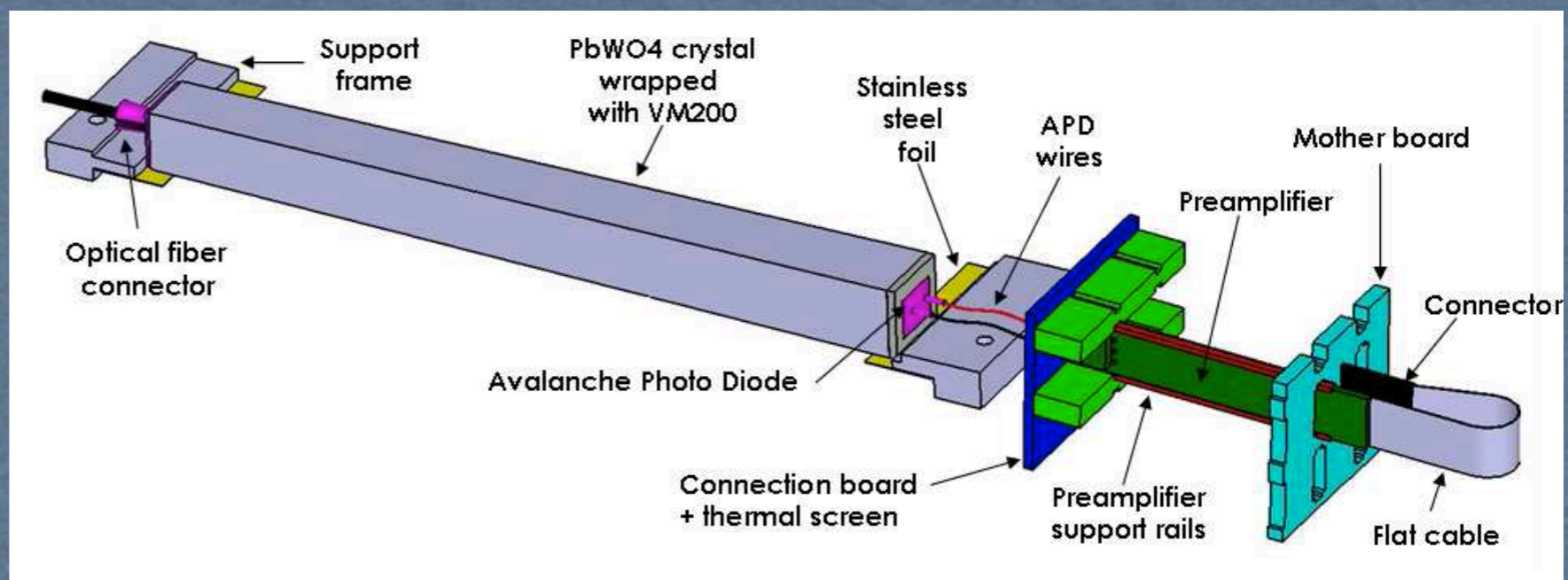


Charge





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 disassemble
- 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
- * ~500 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 205°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 (from more than 500 pcs)
- * The two orders will be considered and processed together from Hamamatsu-Japan

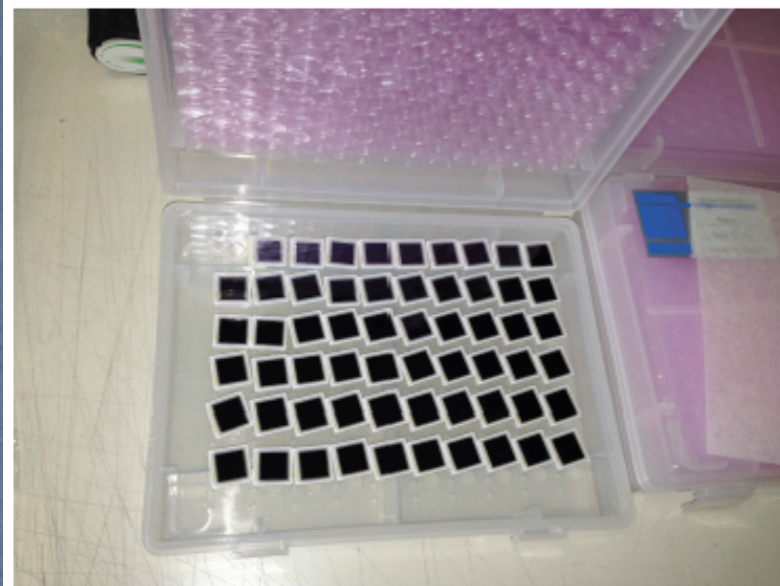
* Expected time for LAAPD procurement:

Deadlines & Milestones:

- 2 months for paperworks
- + 100-120 days for delivery
- + 3 weeks contingency
- = ~7 months

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

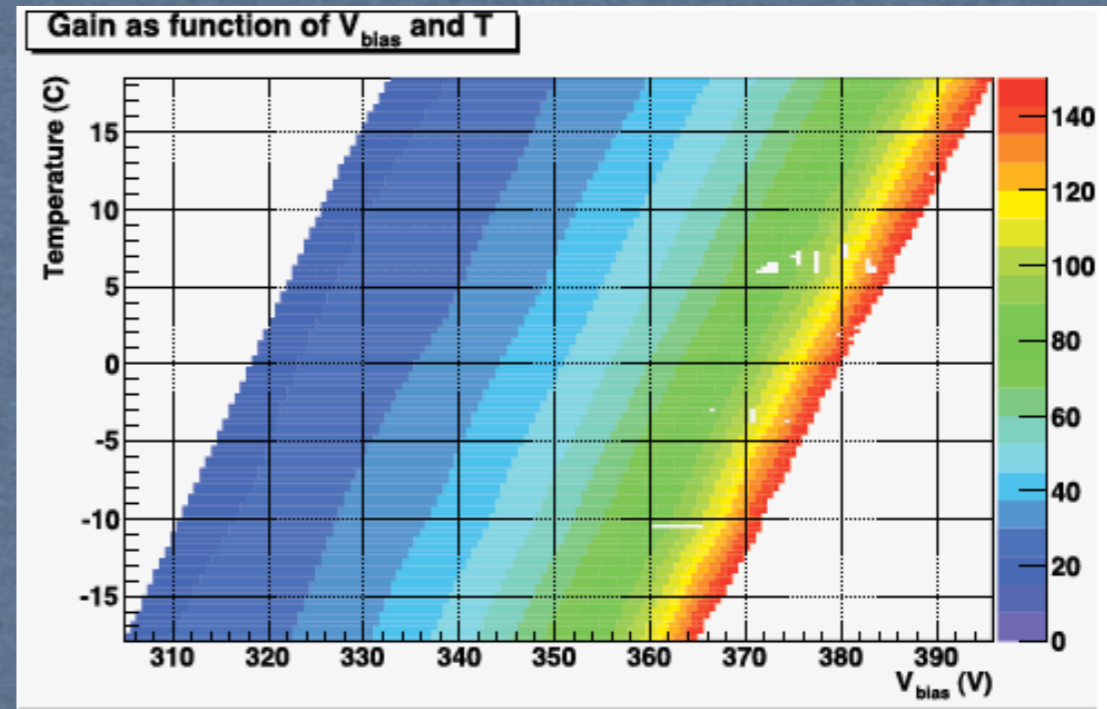
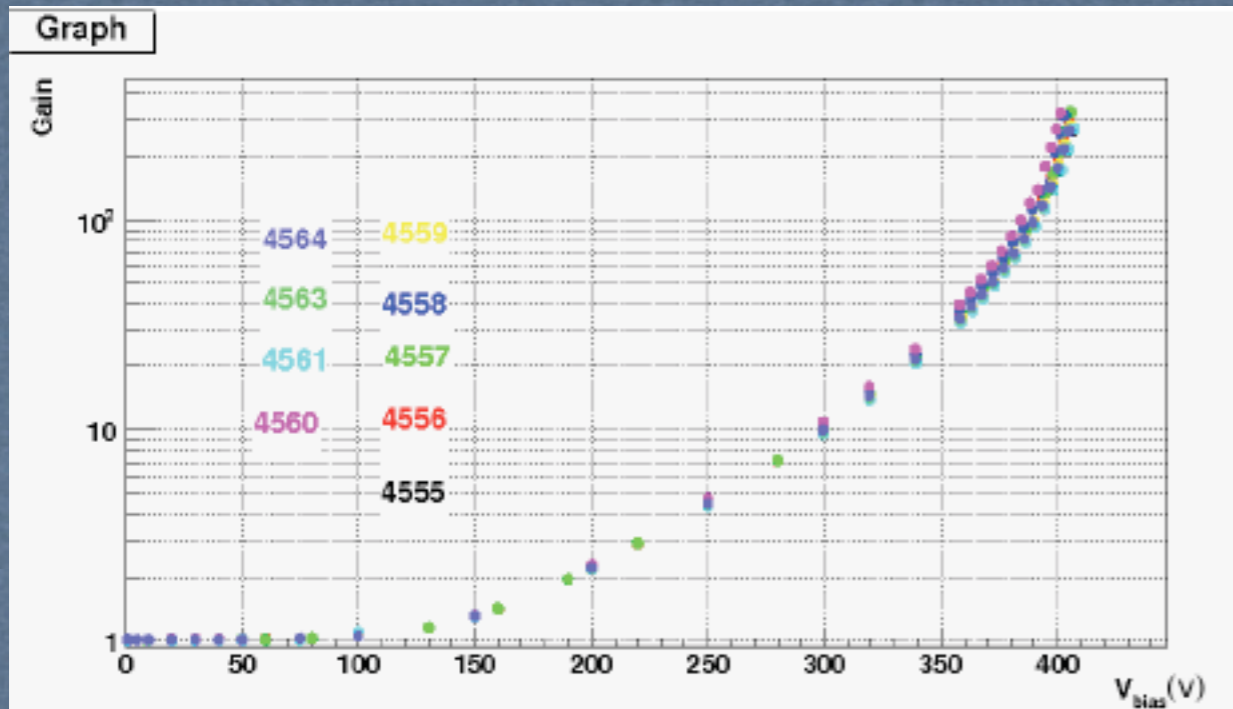
LAAPD benchmarking (I)



- * Once at JLAB the LAAPD need to be benchmarked
- * APD comes with V_{BD} , $V_{Nominal}$, for $G=150$ ($T=20^{\circ}\text{C}$) certified by the vendor
- * Characterization at 3 values of T ($T=15^{\circ}\text{C}$, $T=18^{\circ}\text{C}$, $T=23^{\circ}\text{C}$) 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)
- $I/G \times dG/dV$ 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 measuring I
- * The system only requires a new 110V/60Hz powered chiller, working in the range $T=10^{\circ}\text{C} - 30^{\circ}\text{C}$
- * 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 ECAI parts on the lab desk
 - remove preamplifiers (to be sent to Orsay for upgrade)
- * Technicians from Orsay expected for 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

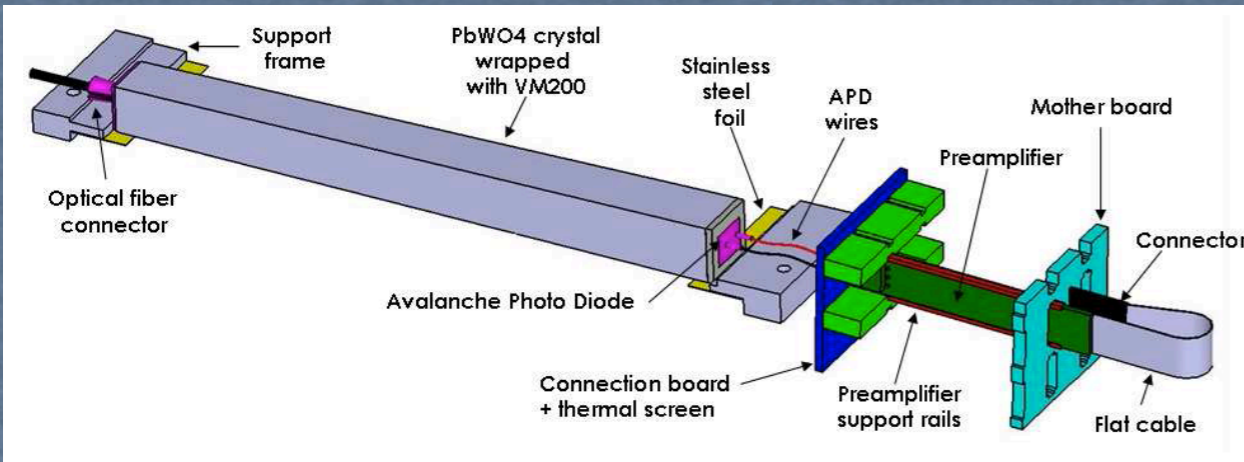
* Expected time for crystal preparation:

- 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

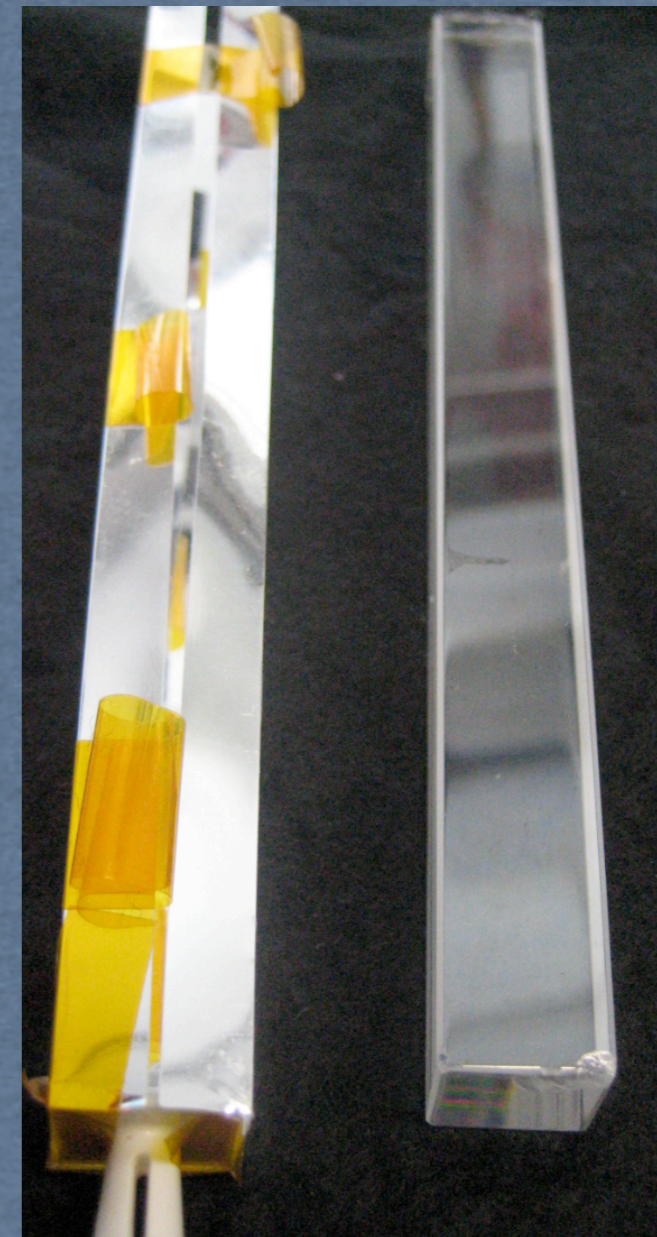
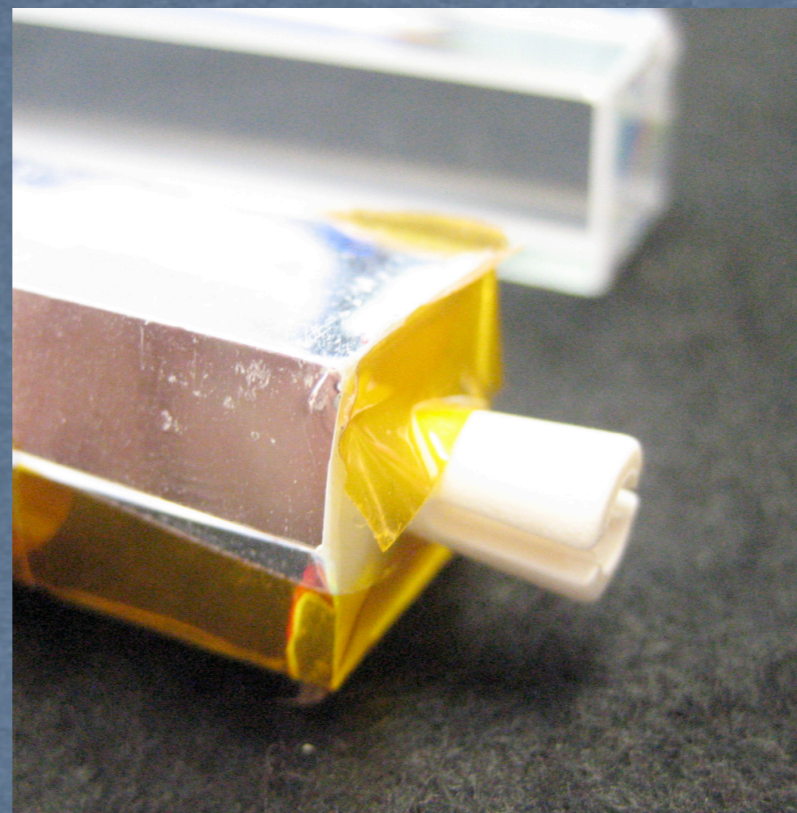
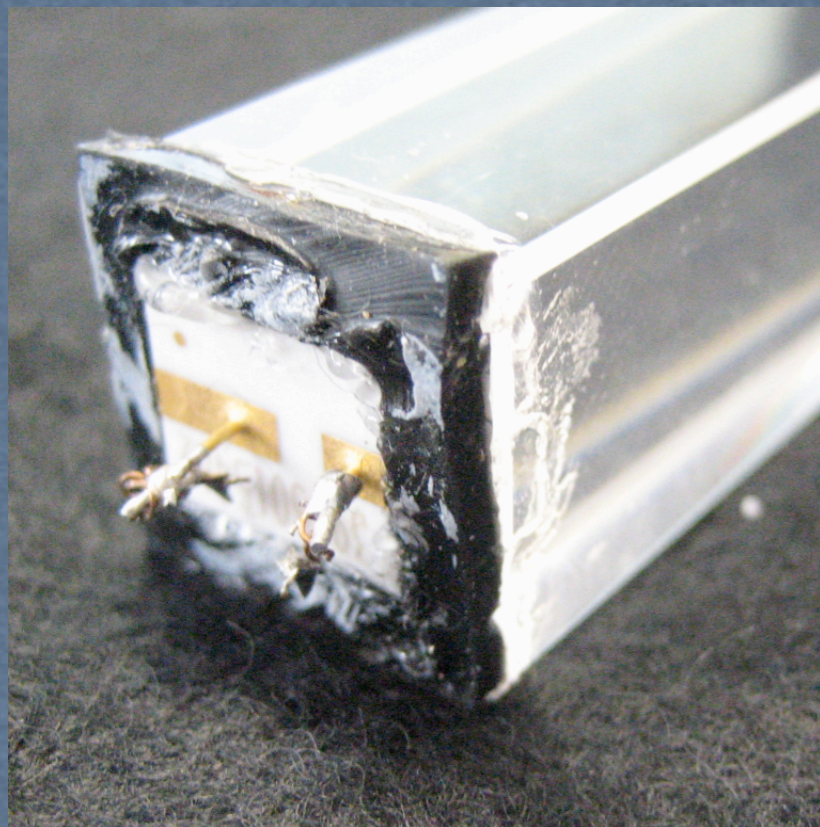
Kept

- VM2000 wrapping

Kept

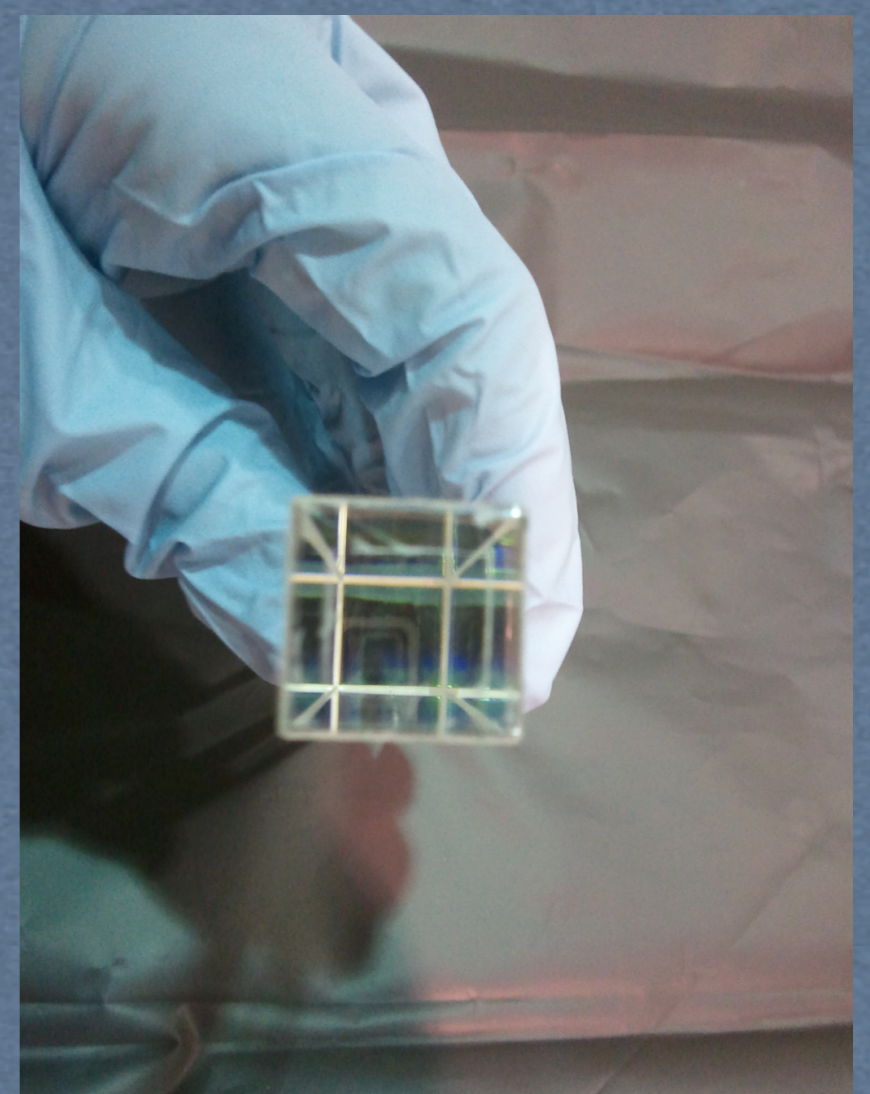
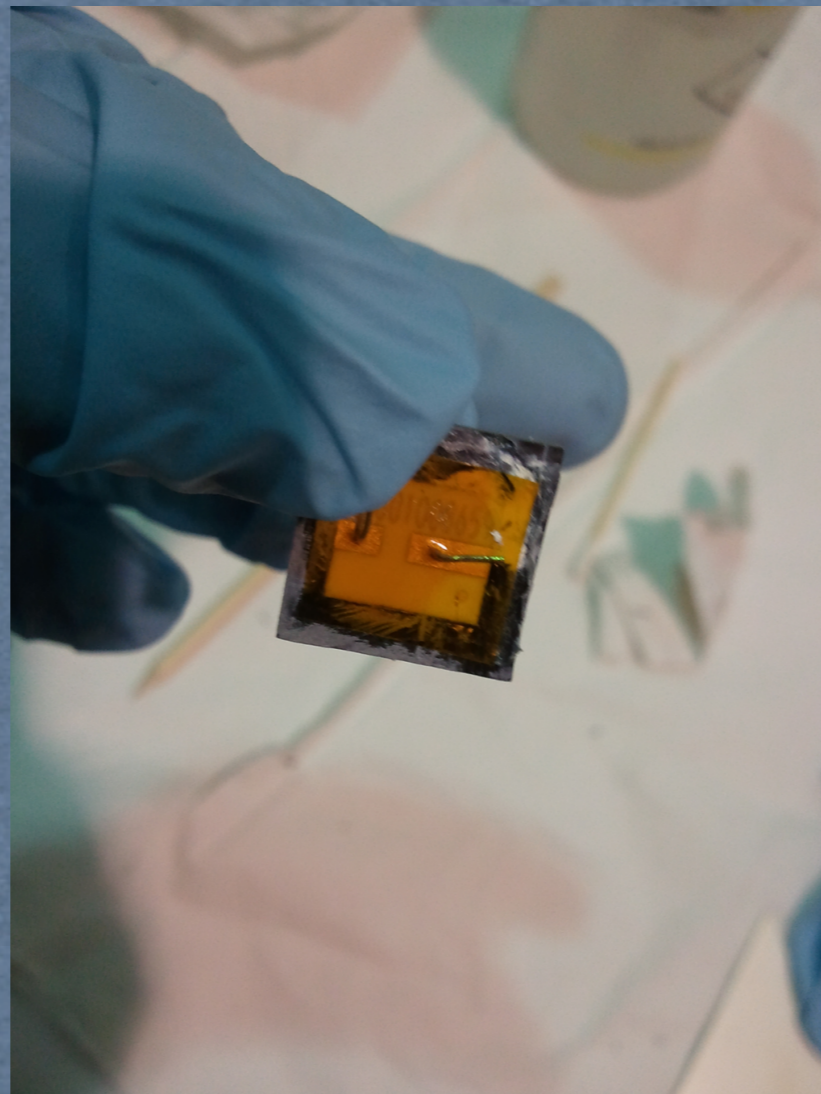
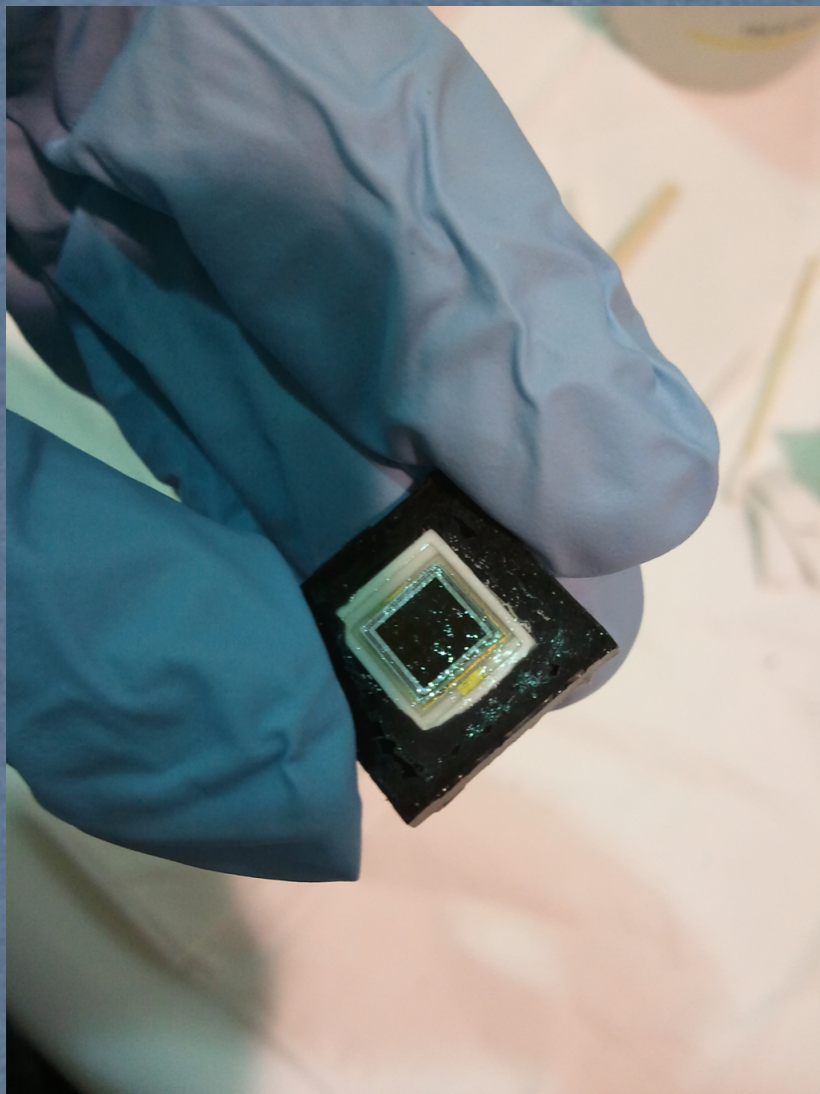
- APD

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 acetone
 - crystals ready for the LAAPD gluing



Crystal preparation

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 - 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

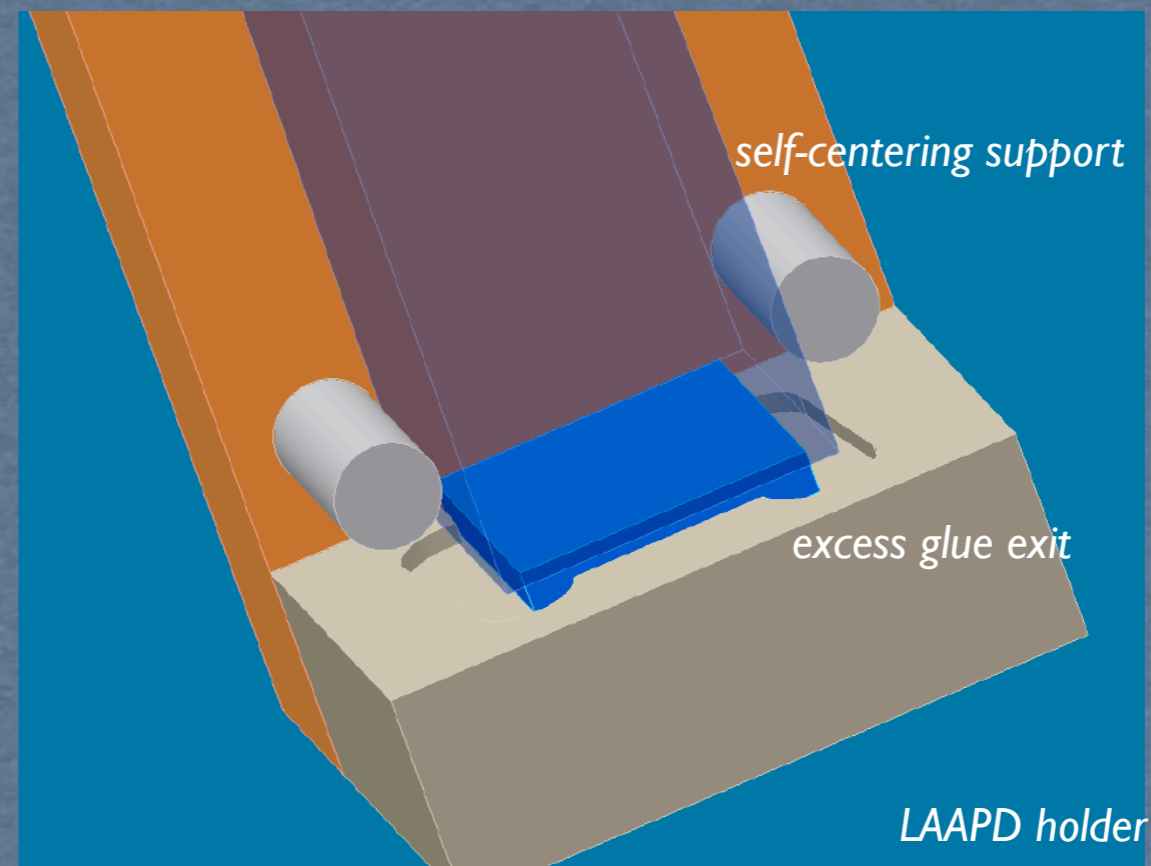
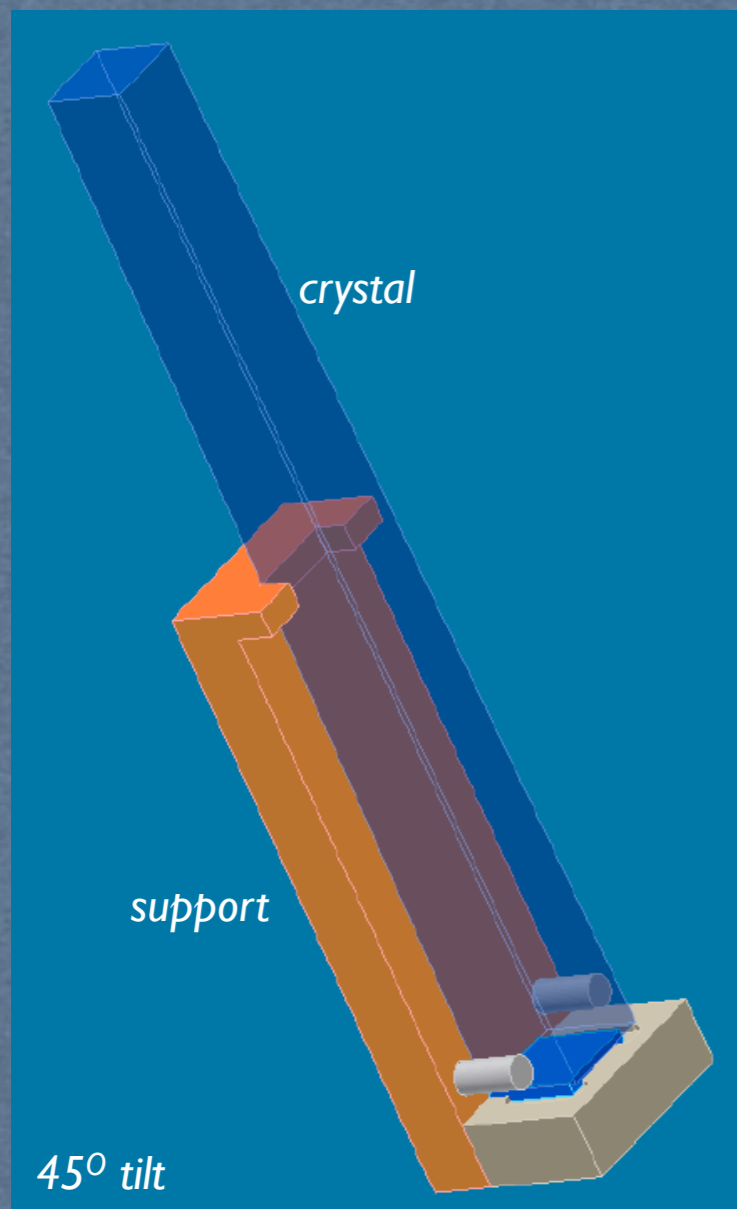
- * Expected time for crystal preparation:
 - 4 cal weeks
 - +1 contingency
 - +1 for possible problems
 - = 6 cal weeks

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-glu: 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



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- * 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

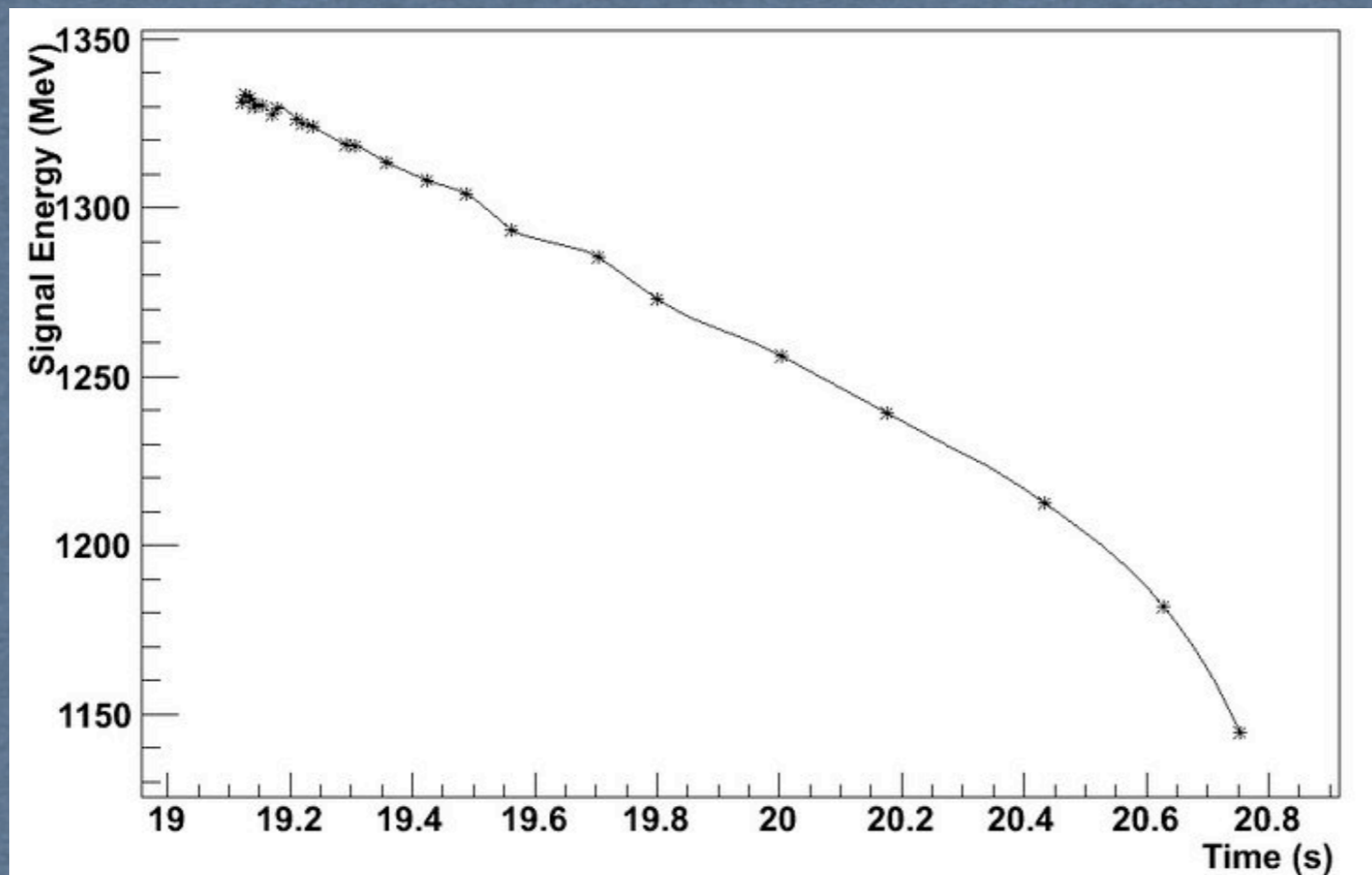
Deadlines & Milestones:

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

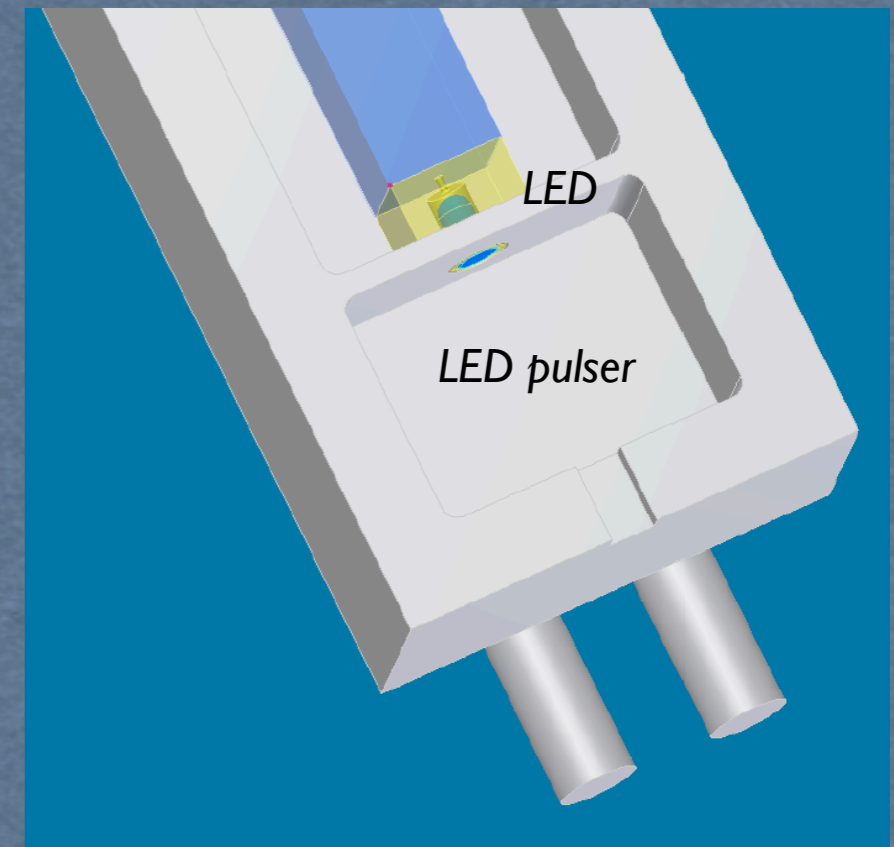
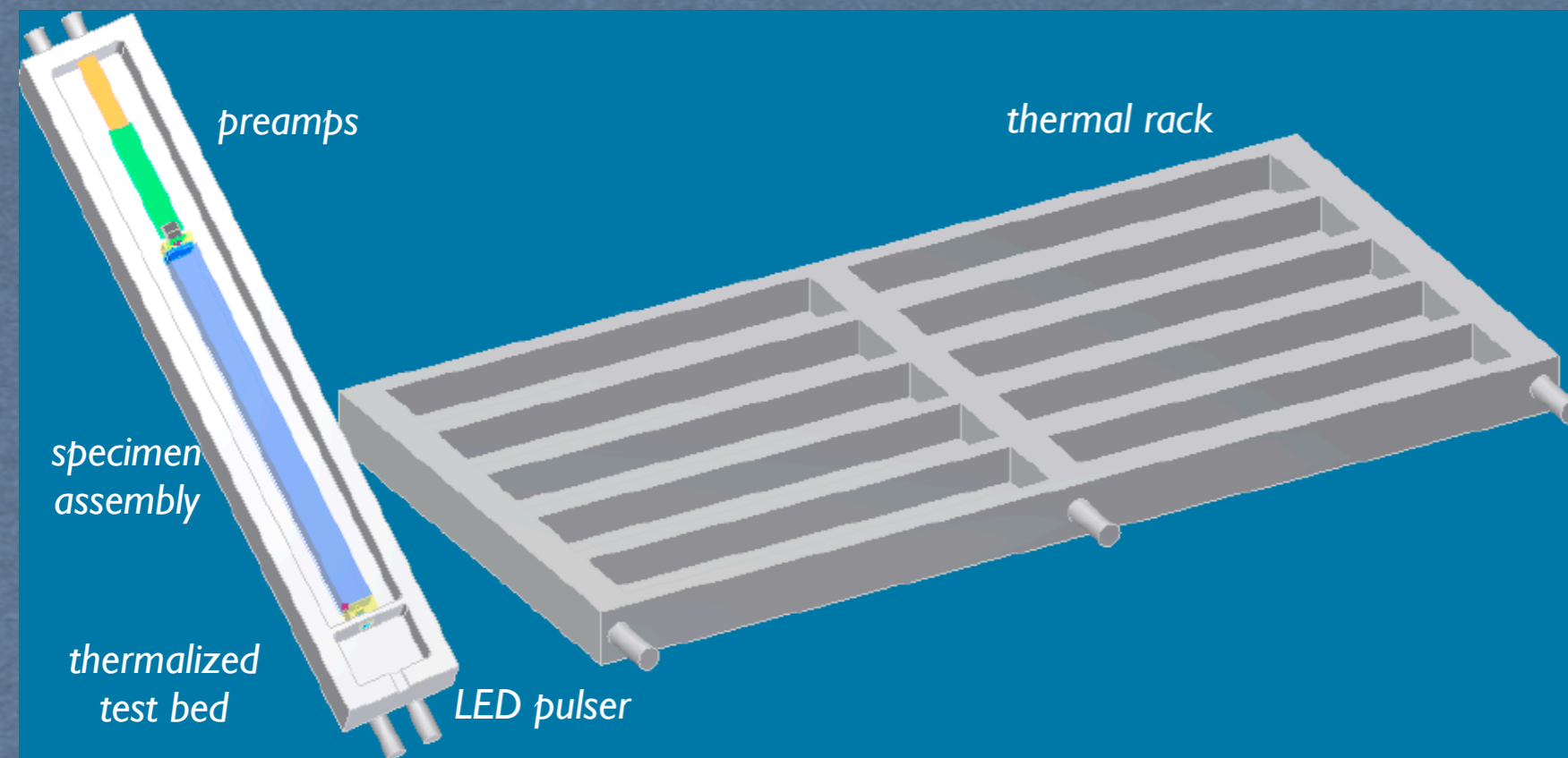
- * After gluing the new crystal+LAAPD assembly needs to be tested with a know light source to check the light transmission
- * The procedure requires to:
 - place the assembly in a thermalized box to keep T constant ($18\pm 2^\circ\text{C}$) for the night (12h)
 - same chiller used to benchmark LAAPDs
 - 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

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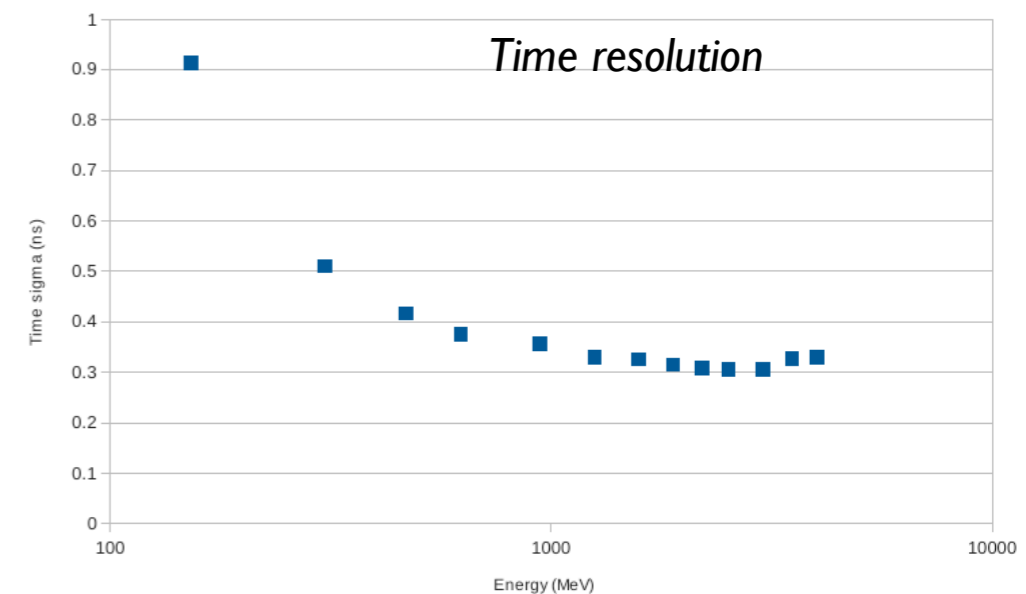
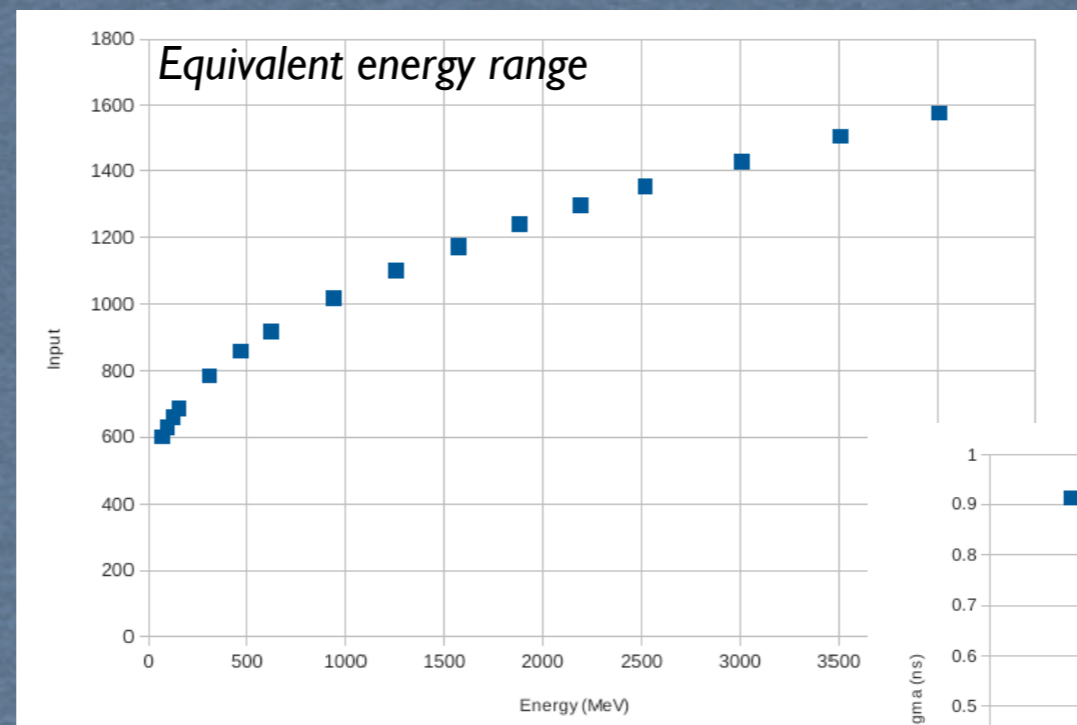


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- * The procedure requires to:
 - place the assembly in a thermalized box to keep T constant ($18\pm 2^\circ\text{C}$) for the night (12h)
 - use the LED testing facility to check light transmission (1 KHz, 100ns, 500mV light pulse)
 - record the mean 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 $\sim 1\%$
- 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 ($18\pm 2^{\circ}\text{C}$) 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
 - = 6 real 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 for 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

		we eks	Oct Nov Dec	Jan	Feb	Mar	April	May	Jun	Jul	Aug	
LAAPD procurement	paperwork	8	■	■								
	production and delivery	24		■	■	■	■	■	■	■	■	
APD benchmarking	FT-Cal benchmark facility refurbishing	2	■	■	■	■						
	US-compliant chiller interfacing	4			■	■	■					
	LAAPD benchmarking	5						■	■	■	■	
Ecal disassemble	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										■

Milestones

LAAPD money secured	October 1st
Ecal disassembling start	October 15th
LAAPD order placed	December 1st
Crystal cleaning procedures defined	December 1st
Ecal disassembly done and ungluing start	December 15th
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

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 disassemble	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

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
Ecal disassembly	1xTC	5.5	10.5	GE
	EE, TC	51.5	10.5	GE
	2xTC	40		JLab
Crystal cleaning (450 pcs)	1xEE	5		JLab
	1xEE	5.5	10.5	GE
	EE, TC	31.5	31.5	CT
Crystal gluing (450 pcs)	2xTC	15		JLab
	2xTC	11	21	CT
	1xEE	5.5	10.5	CT
	EE, TC	31.5	31.5	CA, CT
Crystal assembly test (450 pcs)	2xTC	15		JLab
	2xTC	11	21	CA
	1xEE	5.5	10.5	CT
	EE, TC	47	42	CA, CT, GE
	2xTC	25		JLab
Ecal assembly	1xTC	5.5	10.5	CA
	1xTC	5.5	10.5	CT
	1xEE	5.5	10.5	CT
	1xEE	5.5	10.5	GE
Ecal final tests	EE, TC	25		JLab
	2xTC	20		JLab
	1xEE	5		JLab
Ecal final tests	1xEE	5.5	10.5	CT
	1xEE	5.5	10.5	GE
	1xEE	5.5	10.5	GE
	1xEE	5.5	10.5	CA
	EE, TC	46.5	31.5	CT, GE
	2xTC	20		JLab
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	

Resources

* All funds were allocated and secured fro FY2013/14

LAAPD Hamatsu 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