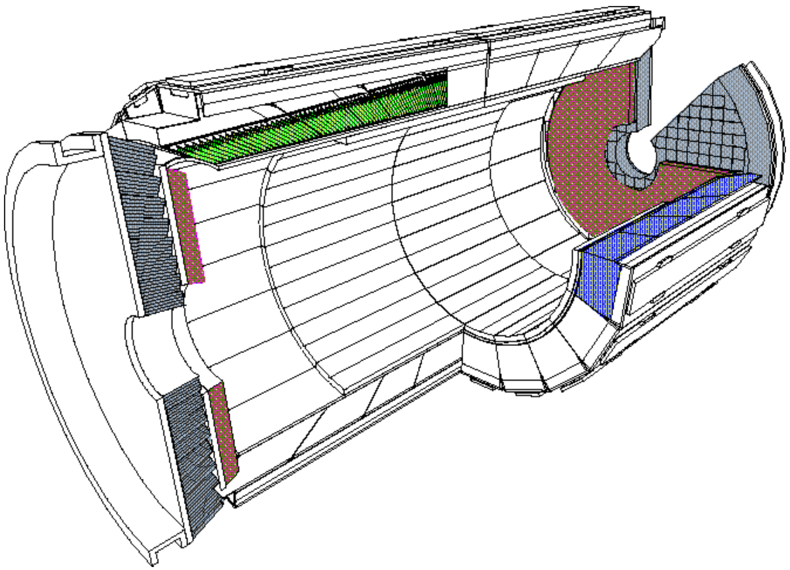
Monitoring Lasers and their Upgrade

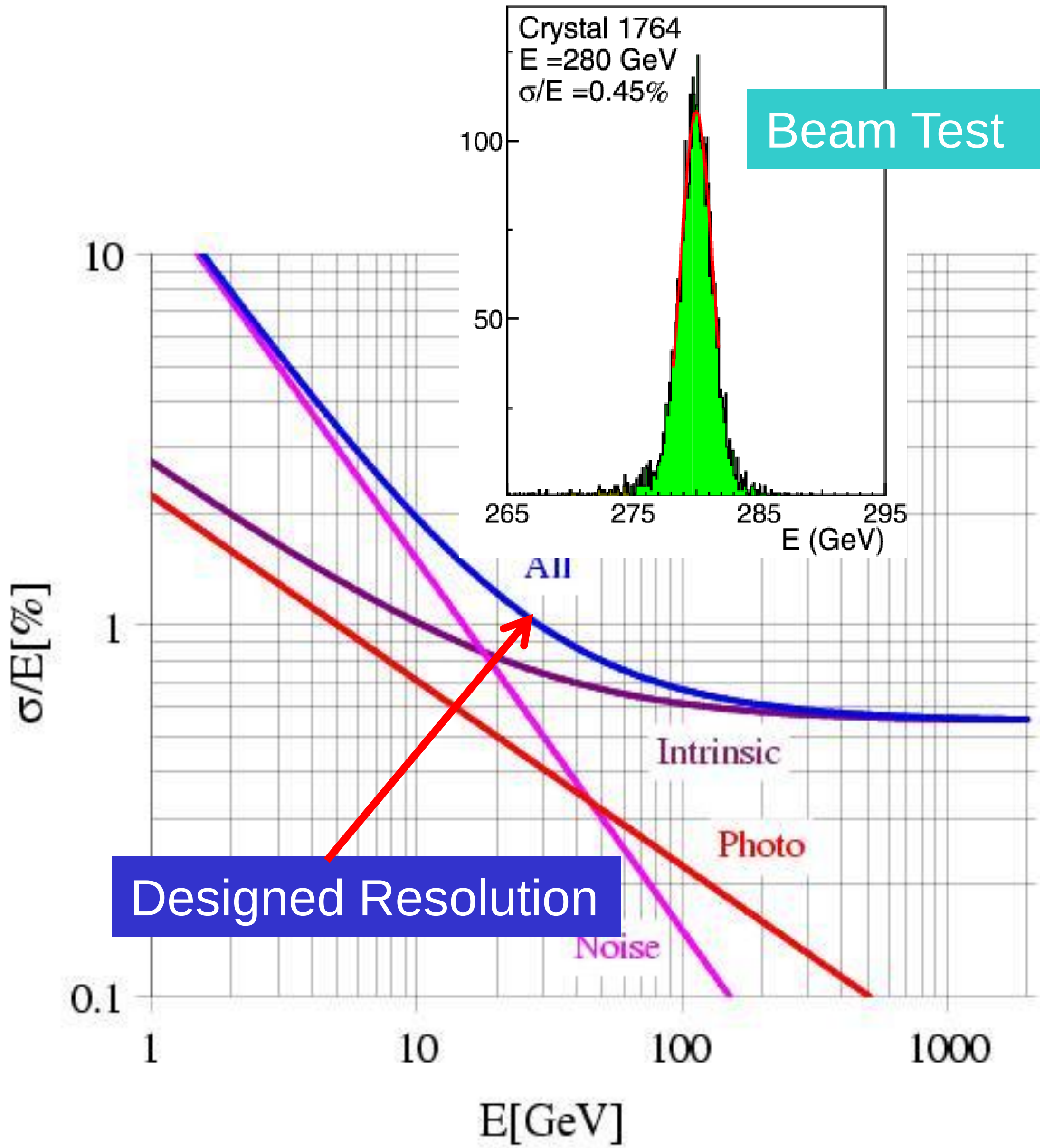
Ren-yuan Zhu

Caltech

September 27, 2010

CMS $PbWO_4$ ECAL Resolution

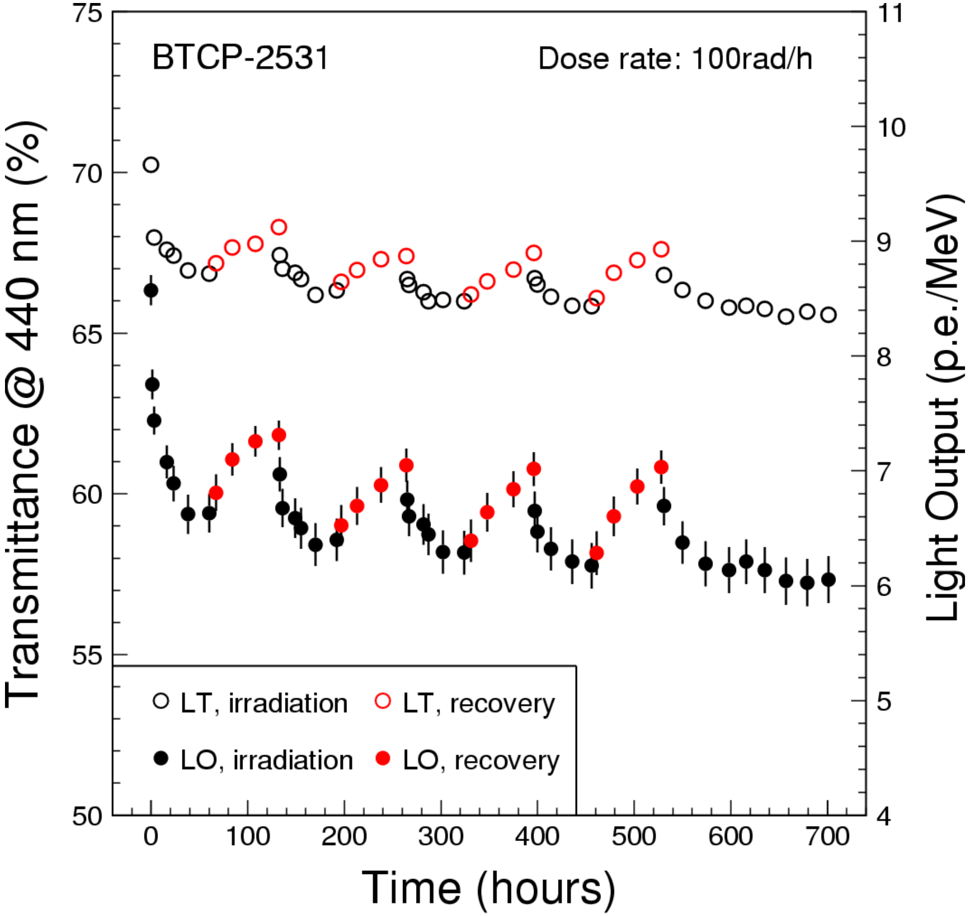


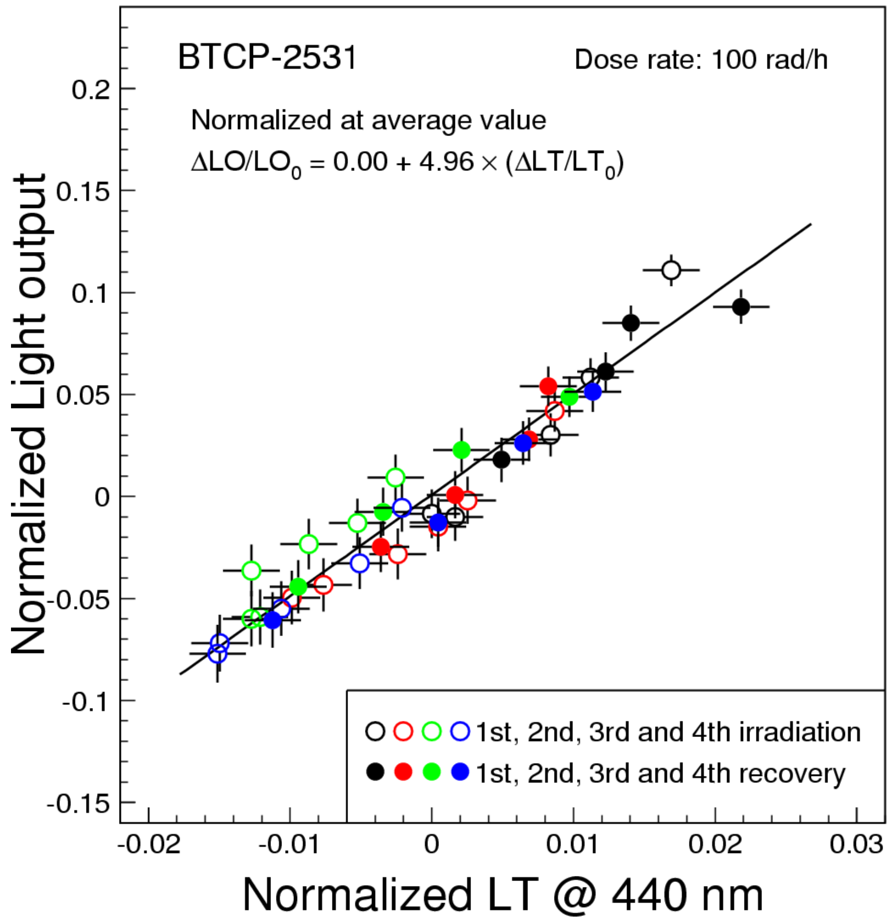


- 75,848 $PbWO_4$ crystals
- To maintain 0.5% constant term in energy resolution, the monitoring precision is required to be 0.2%.

δLO/LO versus δLT/LT @ 100 rad/h

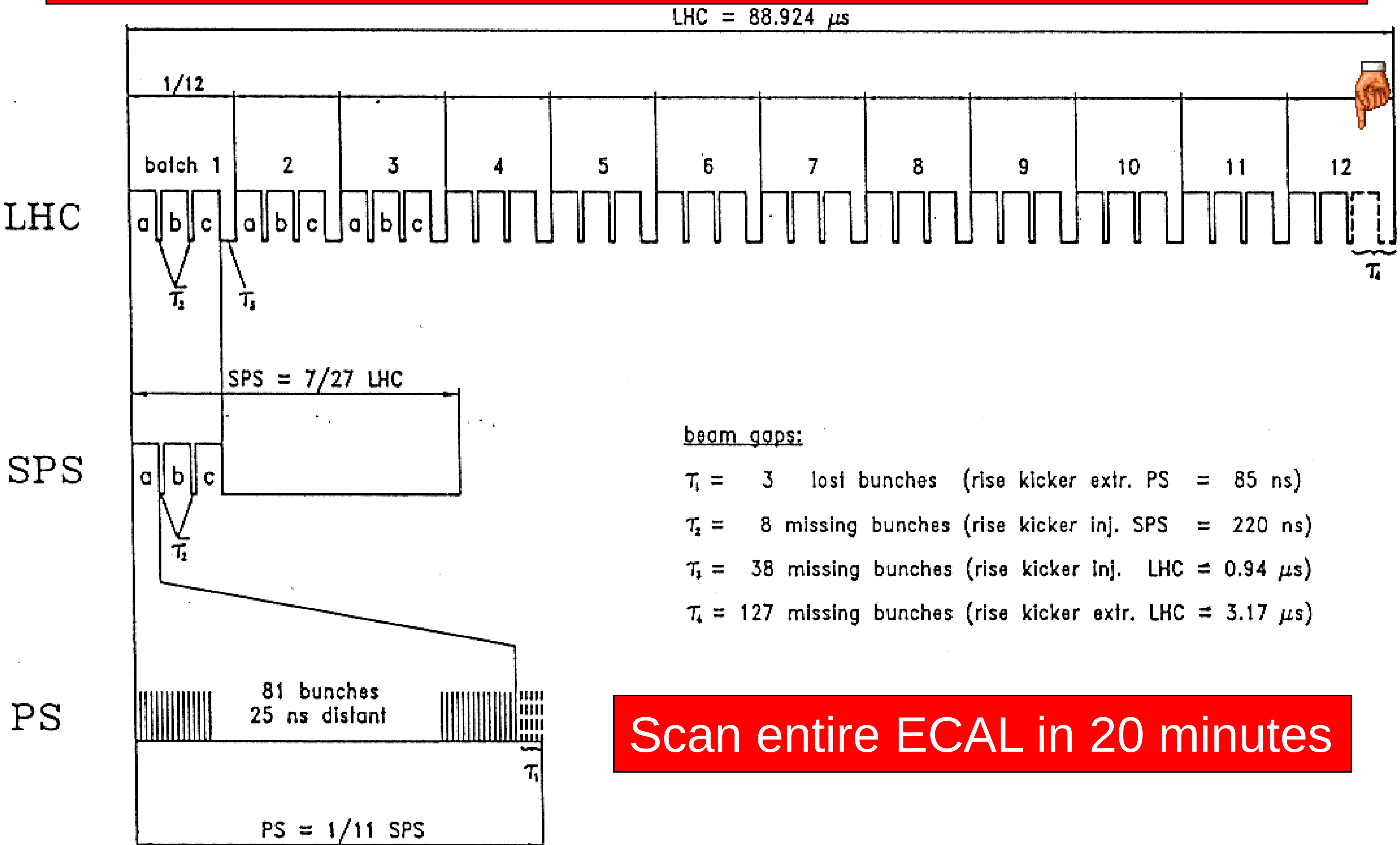
Strong correlation observed between variations of the light output and the longitudinal transmittance for full size $PbWO_4$ crystals in multi cycles of irradiation and recovery





Continuous Monitoring *in situ*

Using 1% beam gaps (100 Hz) in the LHC beam structure

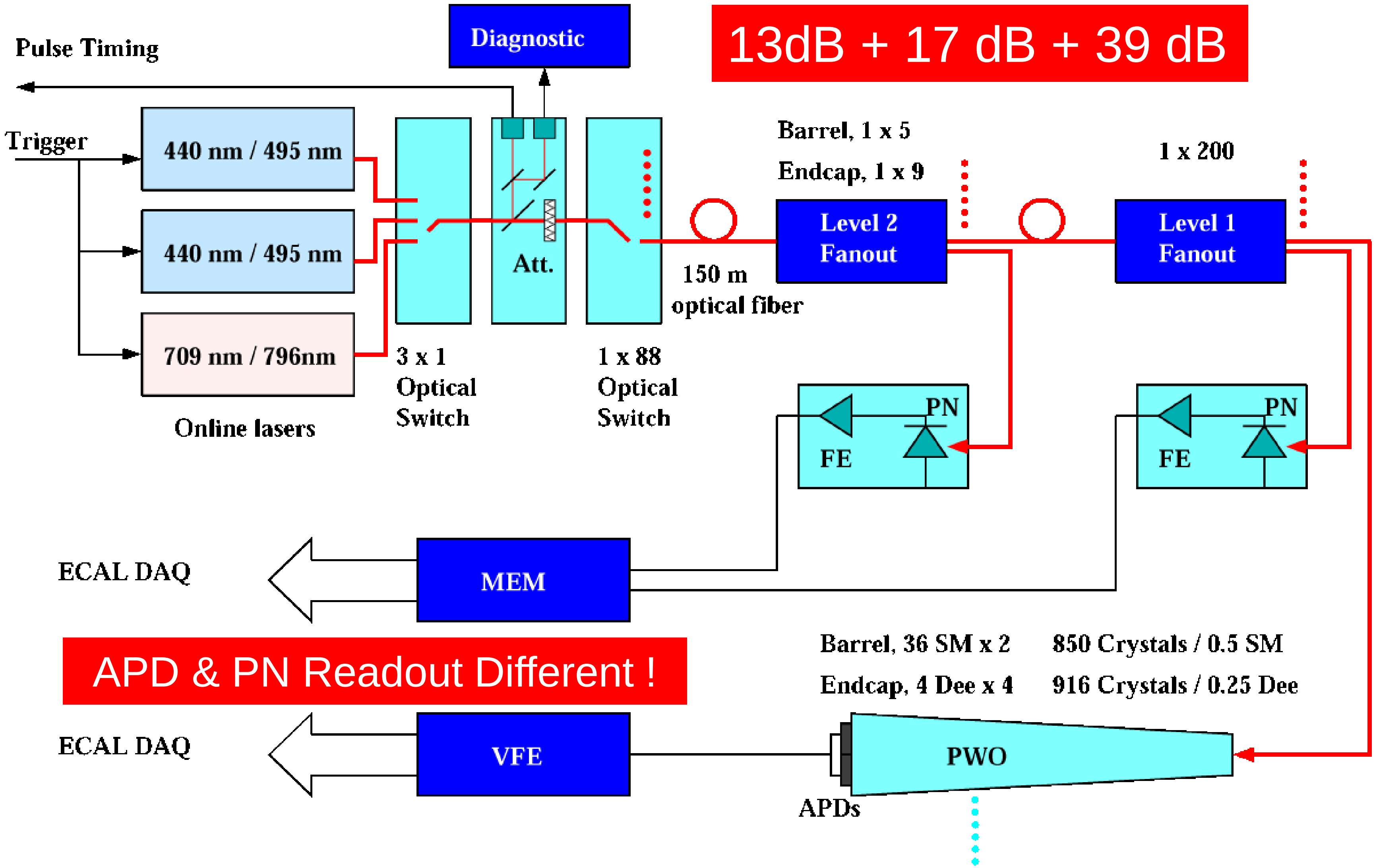


Scan entire ECAL in 20 minutes

Laser Light Monitoring System

Two lasers to guarantee 100% availability of 440 nm

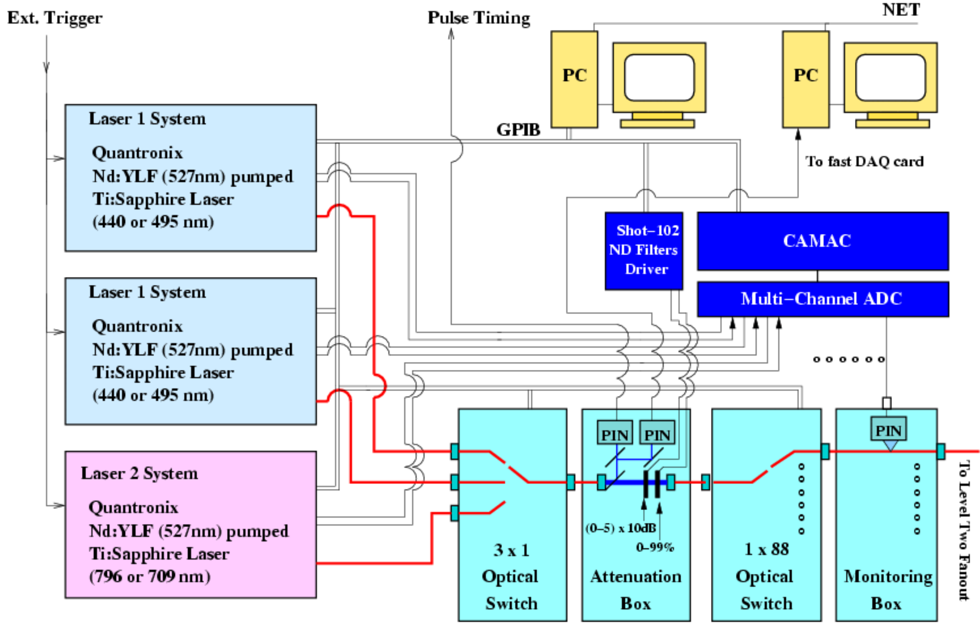
13dB + 17 dB + 39 dB

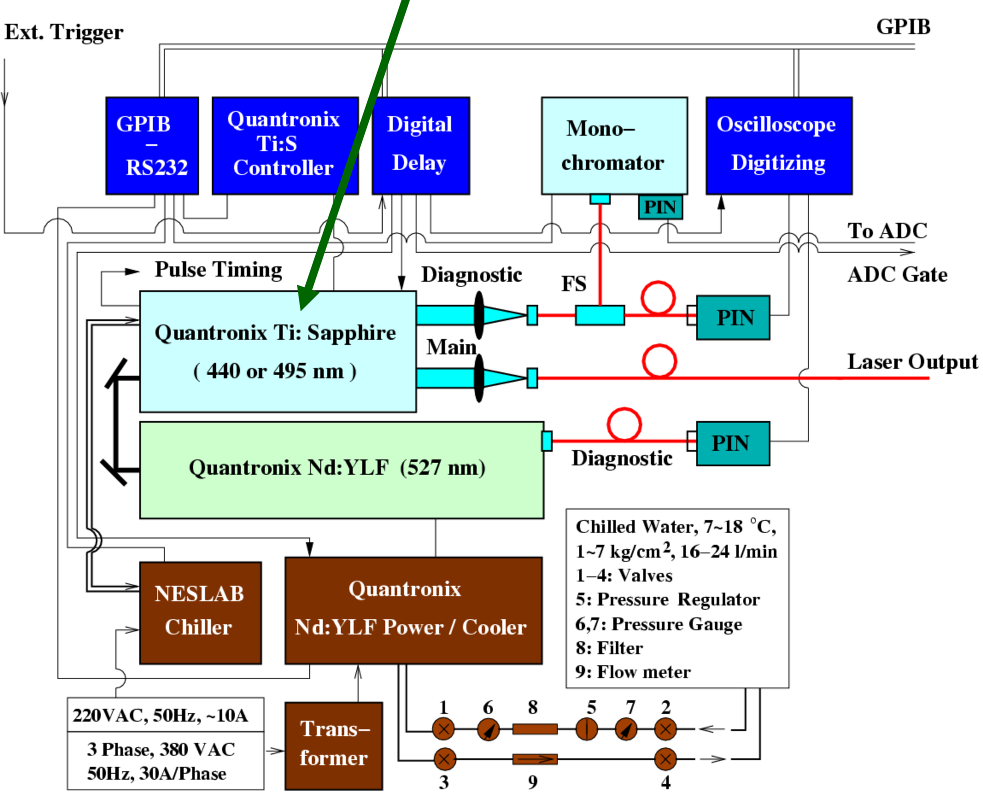


APD & PN Readout Different !

Laser System Commission at CERN

Each laser system contains an Nd:YLF pump laser and a tunable Ti:Sapphire laser with dual wavelengths





1[st] laser at H4: 8/2001
2[nd] & 3[rd] at H4: 8/2003
Software feedback: 5/2006
Two lasers at P5: 3/2007
All at P5: 3/2008

Laser Specifications in TDR

→ Pulse FWHM: < 40 ns to match ECAL readout

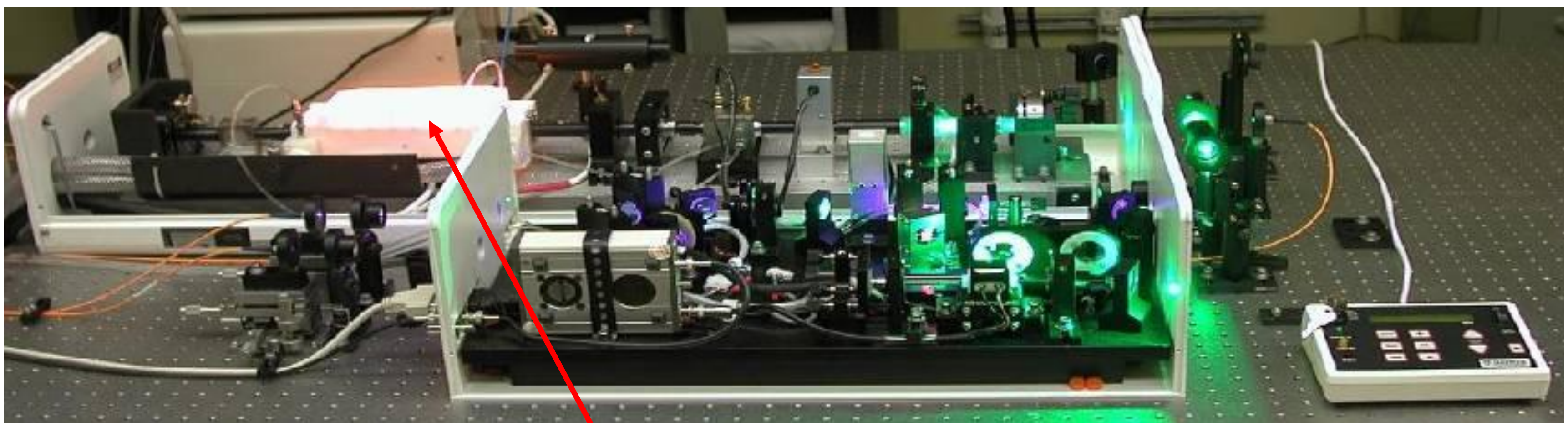
→ Pulse jitter: < 3 ns for synchronization with LHC

→ Pulse rate: ~100 Hz, scan of full ECAL in 20min

→ Pulse intensity instability: < 10%

→ Pulse energy: 1 mJ/pulse at 440 nm, equivalent to 1.3 TeV in dynamic range

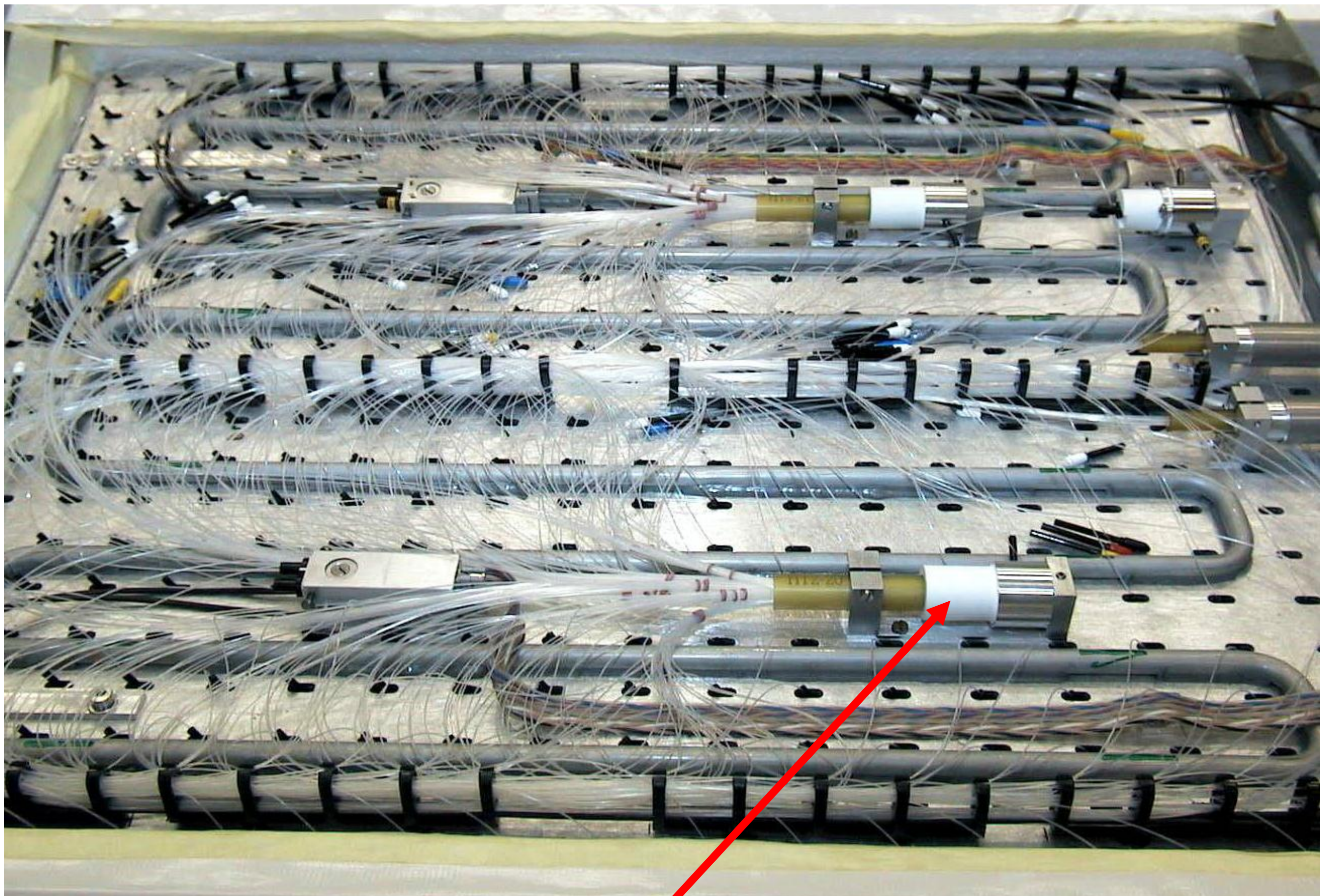
DC Kr Pumped Nd:YLF & Ti:S Lasers



DC Kr lamp ages in time, so reduces laser pulse intensity, increases laser pulse width and timing.

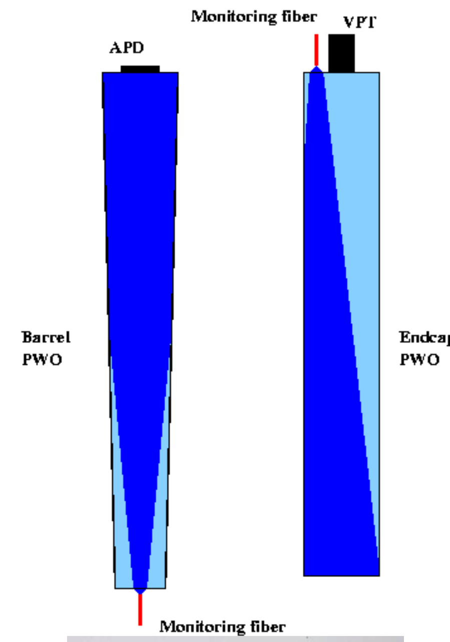
Laser Light Distribution System

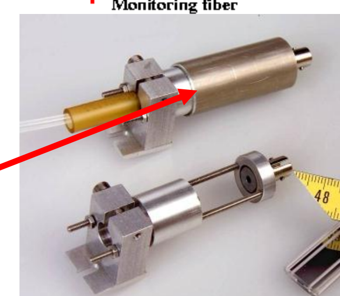
An optical fiber based two-level light distribution system designed and constructed by the Saclay group



Fibers at front for barrel crystal

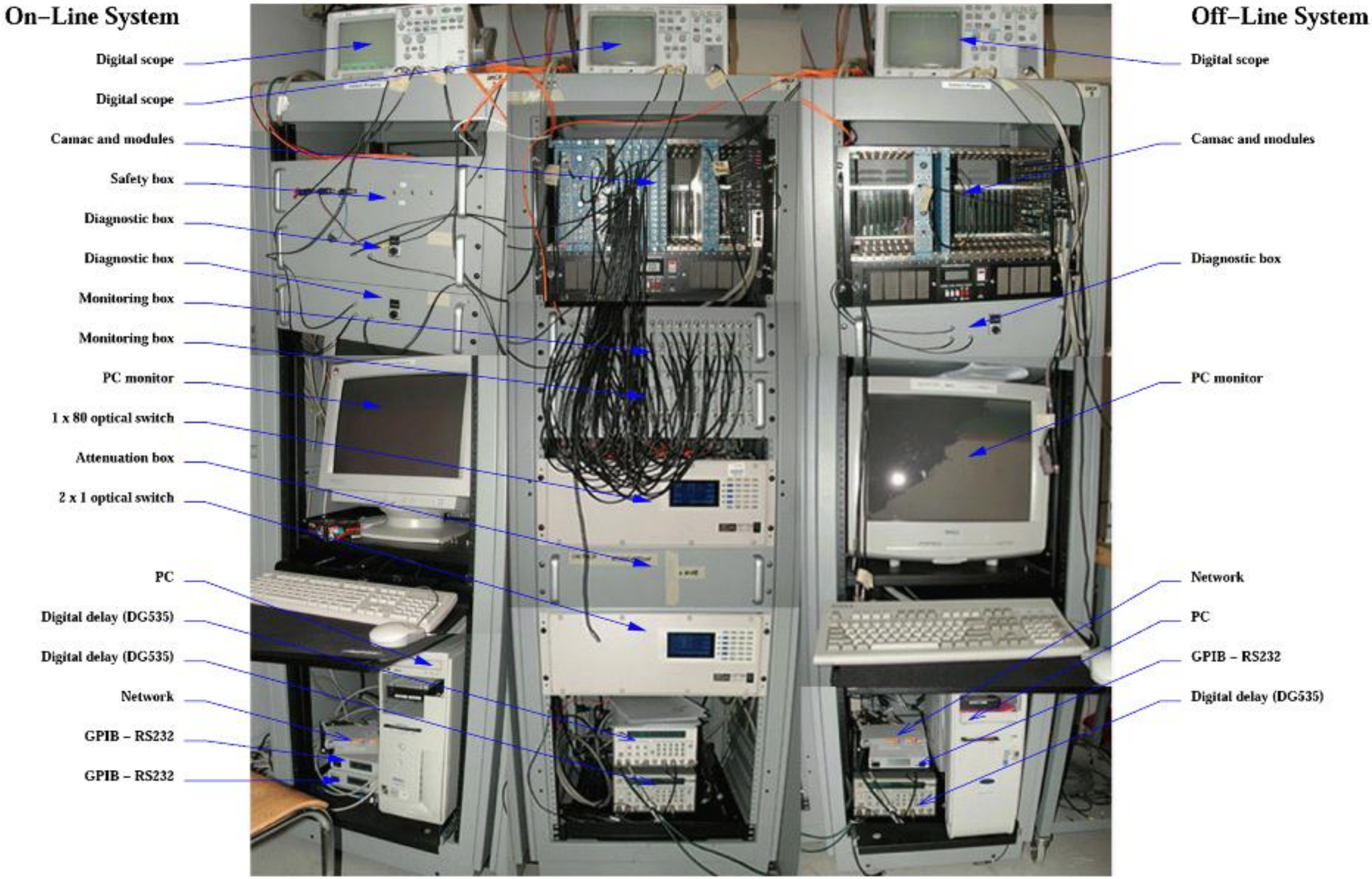
Fibers at back for endcap crystal





Integrating sphere based level-1 distribution for good uniformity

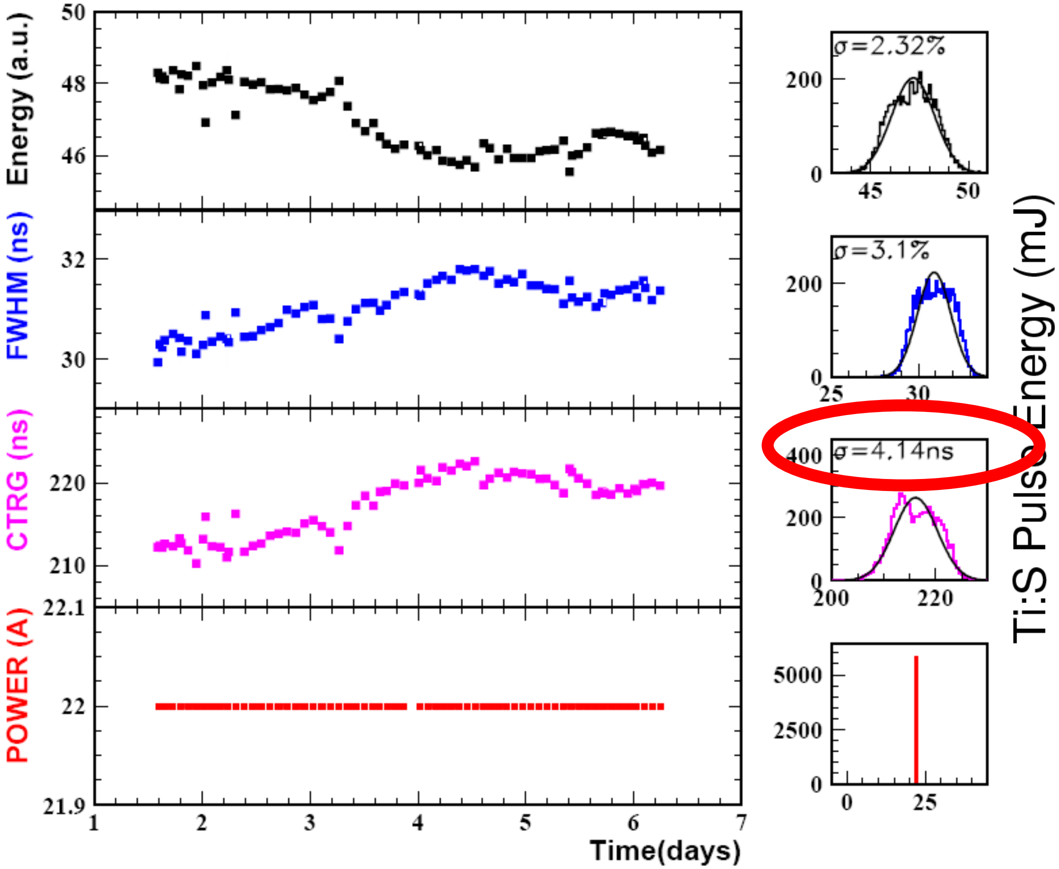
Laser DAQ and Distribution System

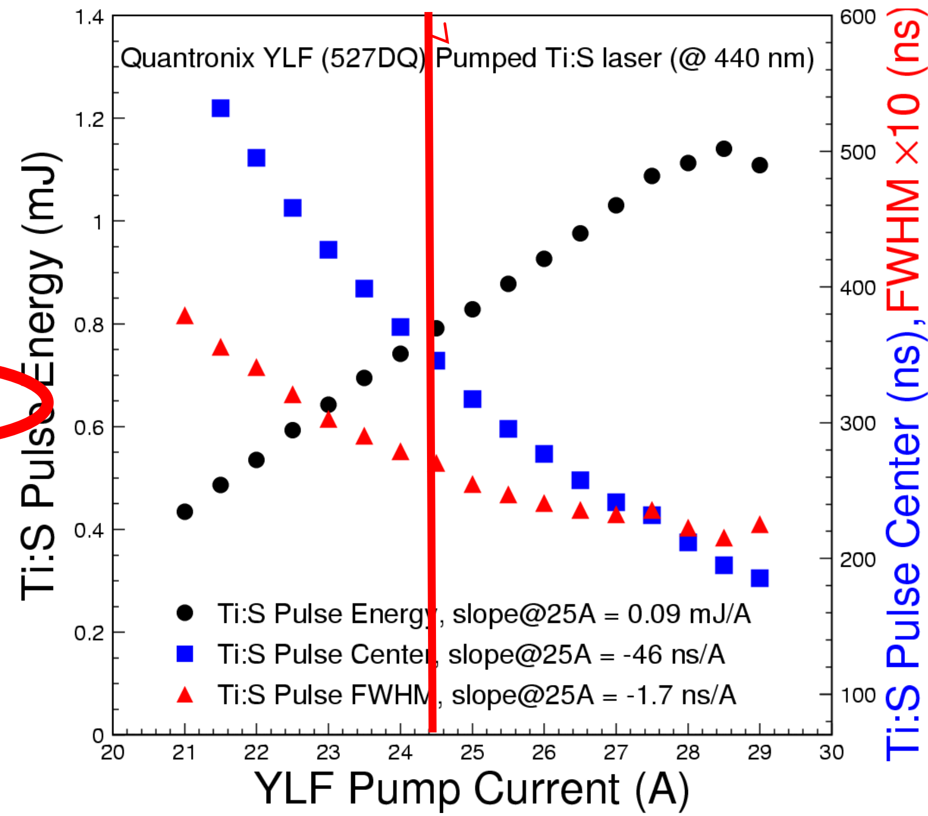


Software Feedback to Maintain Timing

<u>Performance published in IEEE Trans. Nucl. Sci. vol. 52 pp. 1123-1130 (2005):</u> 25 h stability of pulse energy & width: 3% and a long term degradation of laser pulse timing.

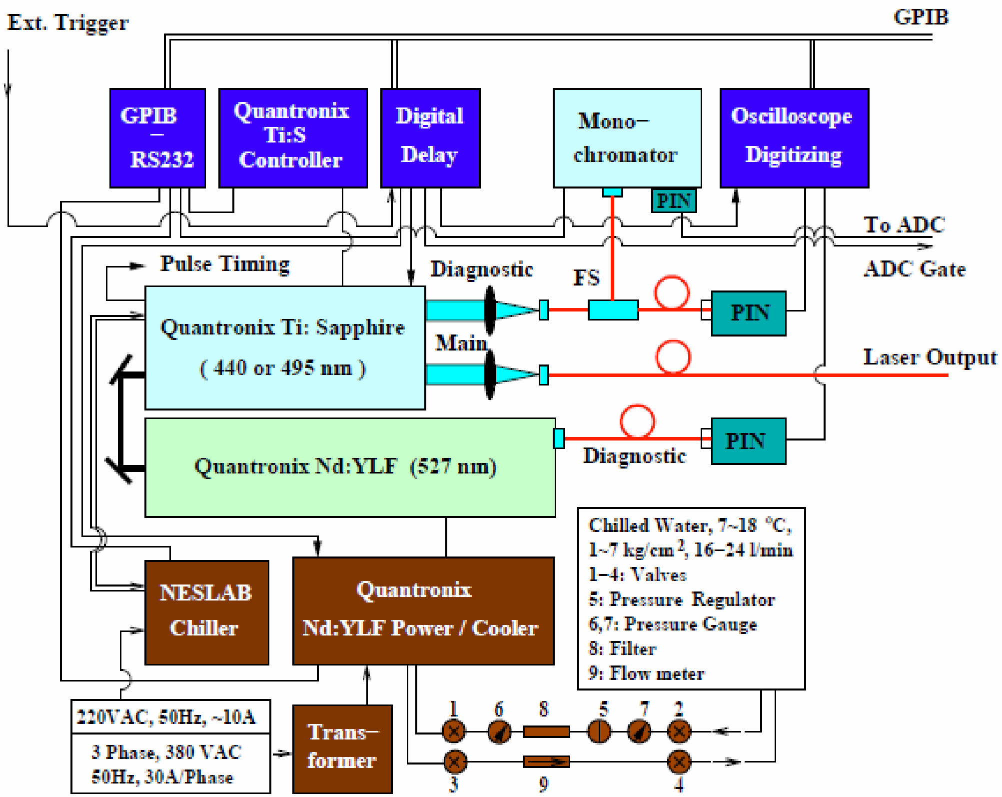
- Laser pulse intensity, width and timing are correlated to the YLF pumping current.
- Better pulse stability could be achieved by trimming the YLF laser pumping current.

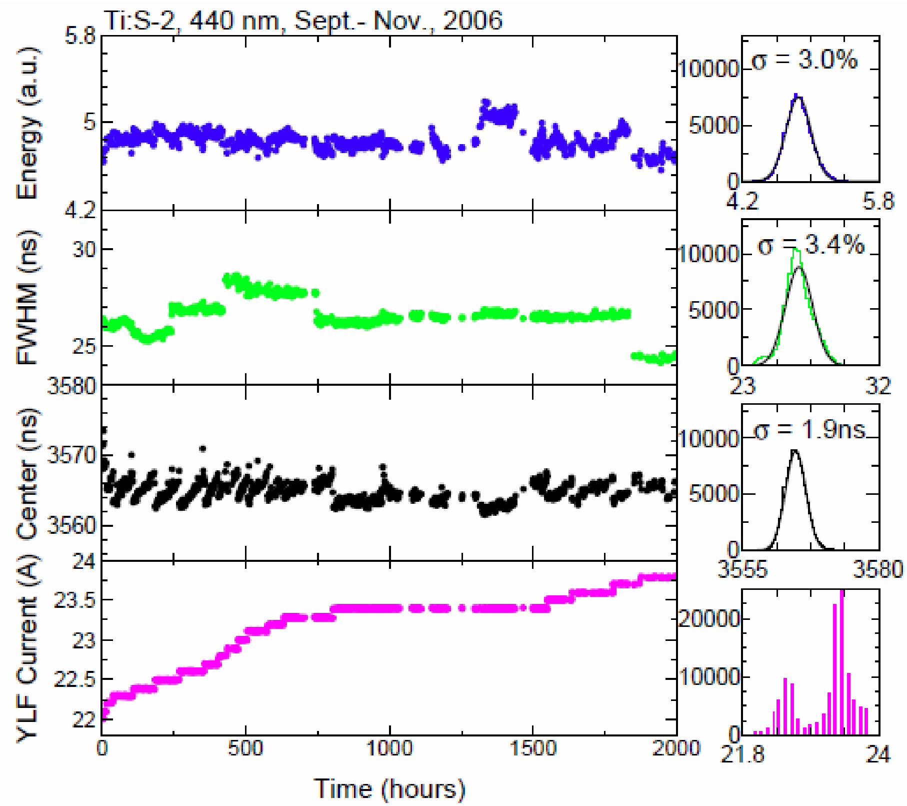




Software Feedback Improves Stability

With a software feedback and an inserted delay the laser pulses show the same intensity and width with about 3% instability and 3 ns jitter.



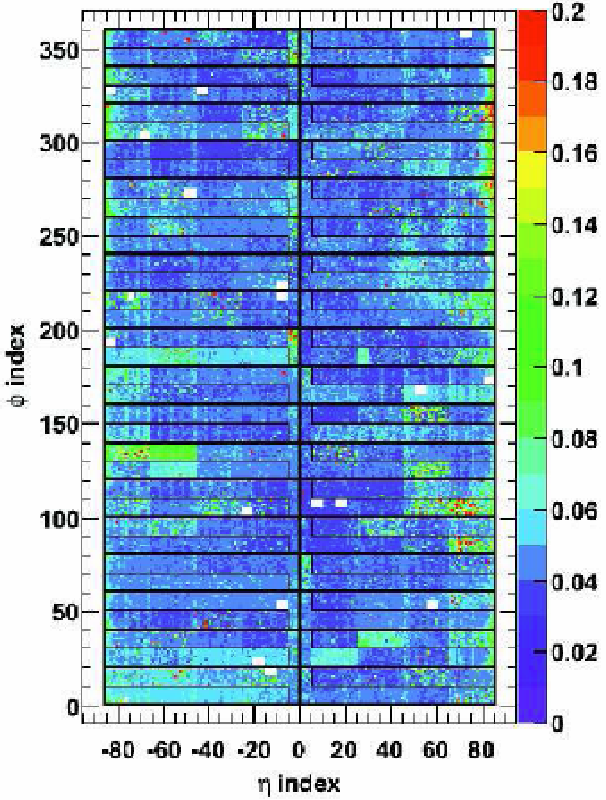


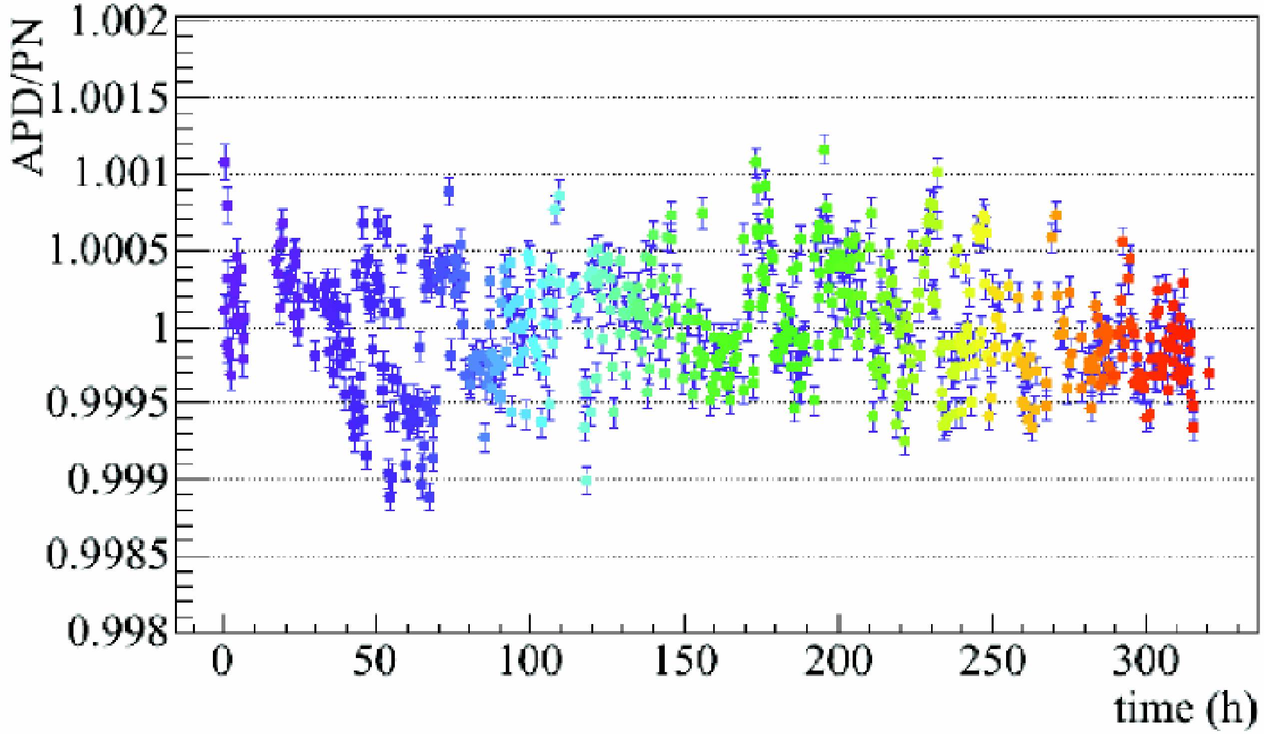
The system operates 24/7, providing 100% availability of the blue (440 nm) as well as the IR (800 nm) as the 2nd wavelength for the barrel.

ECAL Monitoring Stability

Julie Malcies, talk in CMS Weekly General Meeting, Nov 17, 2010

The blue laser data, taken between runs 132226 and 132914 for about 350 h in 2010, shows a mean stability of 0.05% for the barrel, and 0.06% for endcaps.





Four Existing Issues

1. No spares Dicon optical switches: 5 x 1 and 1 x 100. The system will not function when they break.

2. Quantronix discontinued DC Kr lamp pumped Nd:YLF laser in 2005. All parts are discontinued since 2009. Consumable, e.g. pumping lamp housings etc., are no longer available.

3. Quantronix Ti:S lasers are custom made for CMS. They are more stable than the Nd:YLF pump lasers with about 10% failing rate, but no spare parts (LBO etc.) available.

4. ECAL has not reached its designed resolution. APD/PN steps are yet to be understood. Laser maintenance and intervention seem causing steps.

Laser Upgrade

These issues were raised to the ECAL management in 2008 with a formal request submitted in March, 2009, and presented in 2010 December ECAL General Meeting.

- New optical switches
- New solid state pump laser for Ti:Sapphire laser to replace Kr-lamp
- New orange laser for the EE to replace the LED system
- Spares for IR/orange lasers in EB and EE

Laser Committee Members: Brad Cox, Marc Dejardin, Roger Russack, Wolfram Zeuner, Ren-Yuan Zhu

Task – review modifications/upgrades of the laser system

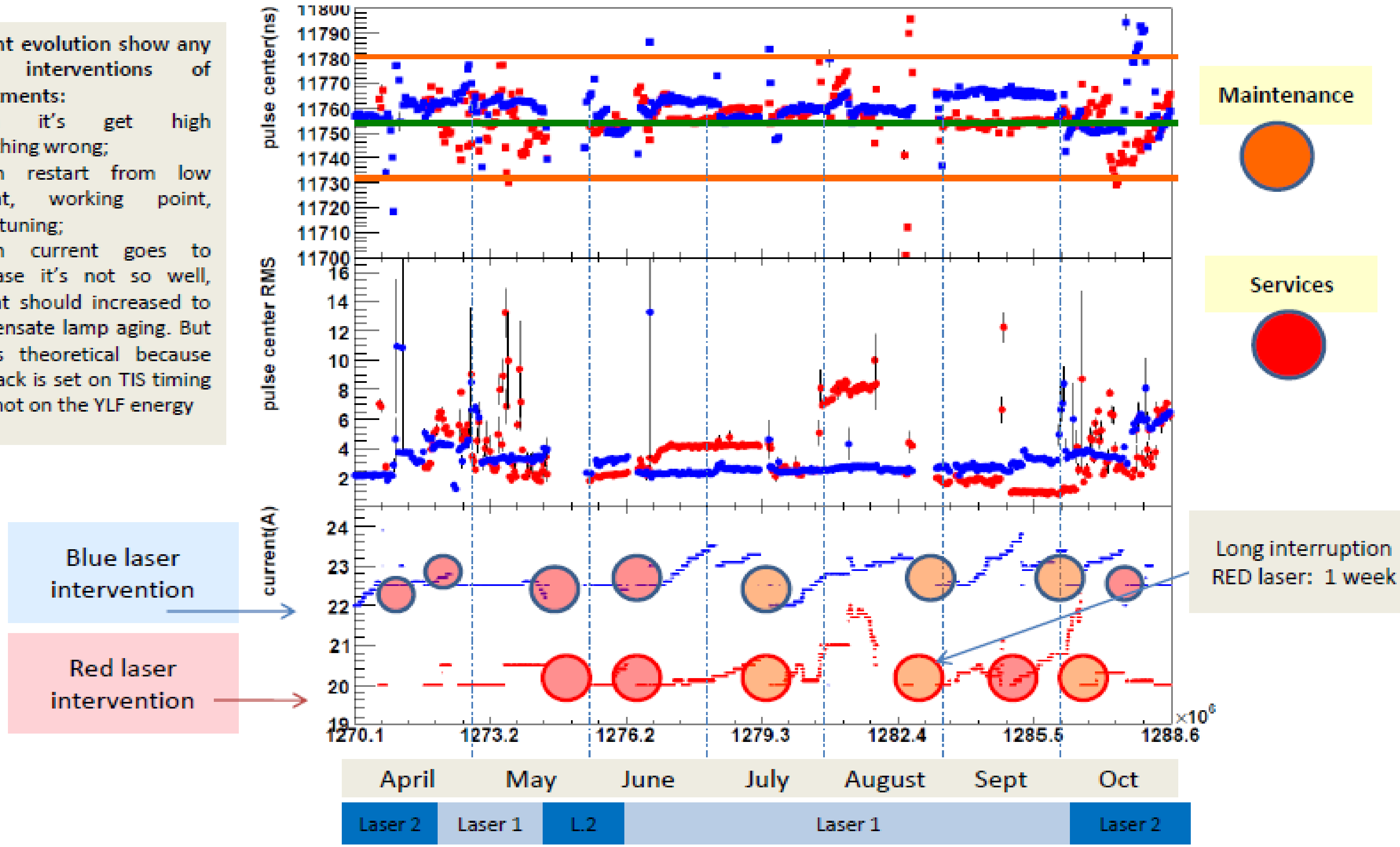
Benefits, risks, integration, time schedule, costs

-→ Recommendations

2010 Laser Run Experience

David Bailleux, Summary of Laser Runs

Current evolution show any laser interventions of adjustments:
-when it's get high something wrong;
- when restart from low current, working point, mean tuning;
- when current goes to decrease it's not so well, current should increased to compensate lamp aging. But this is theoretical because feedback is set on TIS timing now, not on the YLF energy



With laser diode pump the lamp aging effect may be eliminated

APD/PN Steps in 2010

Secs in 2010	Secs since 1/1/1970	Date	Comment from D.Bailleux	Other elogs
5.50E+06	1.27E+09	3/5/10	Lasers restarted on 3rd March	Magnet ramped to 3.8T
6.36E+06	1.27E+09	3/15/10		EB/EE power cycled
7.30E+06	1.27E+09	3/26/10	Intervention on blue laser	
		4/11/10	blue laser became unstable; some tuning done	
		4/13/10	lasers swapped	
		4/14/10		Magnet ramped to 0T
9.05E+06	1.27E+09	4/15/10		Magnet ramped to 3.8T
		4/19/10	Tuning of blue laser	
		4/26/10		Magnet ramped to 0T
		4/27/10	Tuning of blue laser	
1.08E+07	1.27E+09	4/30/10	Tuning of blue on 27th April; started use on 30th April	Magnet ramped to 3.8T
		4/5/10	Quick tuning of blue laser	
1.07E+07	1.27E+09	5/5/10		
1.09E+07	1.27E+09	5/6/10		
1.11E+07	1.27E+09	5/9/10	Red laser problems ??	
		5/11/10	"Huge fluctuations" in run 135248; delay adjusted	
1.21E+07	1.27E+09	5/21/10	Water leak blue laser; lamp & tube broken; swapped lasers	
		5/28/10		Magnet ramped to 0T
		5/31/10	Laser maintenance	
		6/2/10		Magnet ramped to 3.8T
1.34E+07	1.28E+09	6/4/10	After magnet ramping	
1.40E+07	1.28E+09	6/11/10	Was low power for blue laser...	
		6/14/10	blue lasers swapped	
1.60E+07	1.28E+09	7/5/10		Laser became unstable....
1.72E+07	1.28E+09	7/18/10	laser maintenance	Magnet ramped to 0T
1.79E+07	1.28E+09	7/27/10		Magnet ramped to 3.8T
1.86E+07	1.28E+09	8/3/10		Magnet ramped to 0T and back to 3.8T
		8/16/10		Magnet ramped to 0T and back to 3.8T
2.00E+07	1.28E+09	8/20/10		First runs after magnet ramp
2.04E+07	1.28E+09	8/24/10	Red laser problems ??	Switch was stuck on blue laser etc.
		8/30/10	Maintenance of blue laser; flow tube cracked; misalignment	Magnet ramped to 0T
2.11E+07	1.28E+09	9/2/10	Gain 200 run - laser intensities were changed and reverted	Magnet ramped to 3.8T
2.14E+07	1.28E+09	9/5/10	Blue laser maintenance/tuning	
		9/23/10	Swapped blue lasers twice!	
2.39E+07	1.29E+09	10/4/10	Blue laser maintenance/tuning	
		10/19/10		Magnet ramped to 0T
2.56E+07	1.29E+09	10/23/10		Magnet ramped to 3.8T
2.59E+07	1.29E+09	10/27/10		Magnet ramped to 2T and back to 3.8T
2.64E+07	1.29E+09	11/2/10	Increased blue laser power	Magnet ramped to 2T and back to 3.8T
2.71E+07	1.29E+09	11/10/10	Swapped blue lasers	
		11/17/10		Magnet ramped to 2T and back to 3.8T
2.78E+07	1.29E+09	11/18/10	Swapped blue lasers	
2.80E+07	1.29E+09	11/20/10		Blue laser delay adjusted (was off by 25ns)

LAMP or flow tube BROKEN BLUE LASER

- 14 April
- 21 May
- 14 June
- 31 august

Others are usual maintenance

Among 26 steps: 10 B on/off, 9 Laser interventions, 4 ECAL power on/off

Possible Origin of APD/PN Steps

B field on/off: May affect both lasers and MEM readout. Mu material shielding implemented for existing lasers seems not 100% effective. Move lasers out of B field would eliminate the uncertainty caused by laser, but with a cost consequence.

Laser maintenance and swap: Pre-pulse may be caused by leakage of the pumping pulse at 527 nm. Green blocking filters were installed for both lasers. The one on laser 2 was found broken and fixed in June, 2011. It is interesting to see if steps are persist after June service when filters were fixed and only Laser 1 is on-line. This effect should be eliminated by using new DPSS laser with long MTBF (see slide 24) .

ECAL on/off: Nothing can be done unless changing readout electronics.

Laser pulse shape, e.g. FWHM. It would be an issue if existing corrections are poorly done. It is interesting to derive a new set of corrections to see how much progress can be made .

Maintenance/Services in 2011

Dates	Lasers	services	maintenances
8 Feb	Laser3	Lamp flow tube broken	
9 Feb	Laser3	TiS : new HV pulser	
1 March	Laser1		lamp
2 March	Laser3 Laser2	Lamp broken Leak YLF	
3 May	Laser2	Lamp flow tube broken	
5 May	Laser3		lamp
Mid May	Laser3	Valve – cooling issue YLF	
1 June	Laser2-Laser3	Logic unit – power supply start trouble on laser2	
7 June	Laser1	New HV + new Q-switch	lamp
20 June	Laser3	Lamp flow tube broken	
4-6 July	Laser3	Transformer 207V New crystal	lamp
19 July	Laser1		lamp
22 July	Laser1-2	Neslab issue	
30 August	Laser1 Laser3		lamp

Laser 2 Ti:S services from Mid-May not included. No lamp braking related to B field

Laser Committee Recommendations

W. Zeuner, 6/28/11, ECAL Meeting

- The system must be kept running in today's configuration until LS1
  (this might be as long as until spring 2013 !)
  Therefore enough spares must be procured now

- A second large optical switch must be procured a.s.a.p.

- In view of the long term operation, it is not sufficient to replace only the pumping laser of the blue laser system.
- The entire blue laser system must be replaced.
  It can be expected that the new system will show
  much less jumps in the APD/PN ratio
  A market survey should be performed before purchasing
  One laser should be procured in FY12 to perform tests of long term stability
  The general parameters (wavelength, pulse length, shape and stability, jitter….
  can be used from the current system
  The energy of the current laser is an advantage, but not absolutely mandatory
  depending on the chosen technology it might come as by product of the
  required stability.
- There is no need for yet another frequency laser (green)

Revised Specifications

→ **Pulse FWHM: < 30 ns to match ECAL readout**

→ Pulse jitter: < 3 ns for synchronization with LHC

→ **Pulse rate: 0-100 Hz, scan of full ECAL in 20min**

→ **Pulse intensity instability: < 3%**

→ Pulse energy: 1 mJ/pulse at 440 nm, equivalent to 1.3 TeV in dynamic range

→ **Pulse delay from external trigger: < 90 µs, for monitoring trigger to stay in one LHC beam cycle**

The laser will be integrated into the existing monitoring system, so a compact system is highly desired. The laser will be run in the 24/7 mode, the MTBR (mean time between repairs) is required to be better than 3 months.

Issues Under Discussion

The stability of laser pulse intensity: may be relaxed to 10% according to Marc. Since all DPSS lasers satisfy 3% anyway, so not relaxed at this point.

The laser pulse width: Less than 1 ns is possible, but need mode-lock technology which is expansive and has large jitter. Below 10 ns is also possible using Ti:S technology, but requires lasers diode be pulsed powered (instead of DC), which causes a long trigger delay (250 μs) and poor pulse intensity stability. At this point < 25 ns is achievable with DPSS + Nd:YLF + Ti:S technology.

One might consider to measure width more precisely for corrections, e.g. using 2 Ghz sampling instead of 1 Ghz, if it is not systematic limited.

12 Manufactures Contacted

1. Photonics Industries International, Inc, 390 Central Ave., Bohemia, NY 11716
2. Continuum Sub. of GSI Group, 3150 Central Expy., Santa Clara, CA 95051
3. Quantronix, 41 Research Way, East Setauket, New York 11733
4. CrystaLaser LC, 4750 Longley Lane, Reno, NV 89502
5. Spectra-Physics Lasers, A Newport Corp. Brand, 3635 Peterson Way, Santa Clara, CA 95054
6. New Focus, A Newport Corp. Brand, 3635 Peterson Way, Santa Clara, CA 95054
7. JDSU, 430 N McCarthy Blvd., Milpitas, CA 95035
8. Coherent Inc., 5100 Patrick Henry Dr., Santa Clara, CA 95054
9. Teem Photonics USA, Sub. of Teem Photonics SA, 3594 Nyland Way, Ste. TP1, Lafayette, CO 80026
10. IPG Photonics Corporation, 50 Old Webster Rd., Oxford, MA 01540
11. Laserglow Technologies, 216-5 Adrian Ave., Toronto, ON M6N 5G4, Canada
12. Quantel USA, 601 Haggerty Lane, PO Box 8100, Bozeman, MT 59715-2001

440 nm Options: 1 & 0.5 mJ

Photonics Industries International, Inc.

Quotation Number: Q10-1202AI2 — **Quotation**
Date: 12/1/10
Valid Until: 1/10/10
Payment: 25/50/25 (Pending credit approval)
Freight: F.O.B. Bohemia, NY
Delivery: 12-16 Weeks ARO – (exact delivery schedule at time of order acceptance)

To:	California Institute of Technology 1200 E California Blvd, Pasadena CA 91125	**From:**	Photonics Industries 390 Central Avenue Bohemia, NY 11716
Tel:		**Tel:**	631-218-2240
Fax:		**Fax:**	631-218-2275
Attn:	Liyuan Zhang	**Attn:**	Andrew Iadevaia

Description	Unit Price	Qty	Total
TU-L Ti: Sapphire Laser Wavelength 440nm Pulse Energy @ 100Hz 1mJ Pulse Width @ 100Hz <25 ns Beam Mode TEM_{00} Pulse Jitter <3ns rms Divergence <2mRad Pulse to Pulse Instability 3%rms Pulse delay from external trigger < 5 µs Pulse Repetition Rate 0 to 100Hz	$190,000.00	1	$190,000.00
DM-527-30 Pump Laser System for above TU-L Ti: Sapphire Laser Q-switched DPSS Nd: YLF			
DM Power Supply Unit Available in 110VAC or 220VAC formats, 50-60Hz, single phase power. Standard RS232 control interface, Q-switch internal input via RS232 and external input by TTL via BNC. Dimensions: 483mm (19.0") m x 476mm (18.75") D x 178mm (5.25") H.	INCLUDED	1	INCLUDED
Standard DM Cooling Unit 110VAC or 220VAC units available, 50-60Hz, single phase power. Dimensions: 320.5mm (12.62") W x 606mm (23.87") L x 511mm (20.12") H.	INCLUDED	1	INCLUDED
System Software DM Control software provides basic system operating controls in a convenient graphical user interface configuration.	INCLUDED	1	INCLUDED
Warranty Standard Photonics Industries one-year parts and labor warranty.	INCLUDED	1	INCLUDED

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Quotation Number: Q10-1201AI2 — **Quotation**
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Attn:	Liyuan Zhang	**Attn:**	Andrew Iadevaia

Description	Unit Price	Qty	Total
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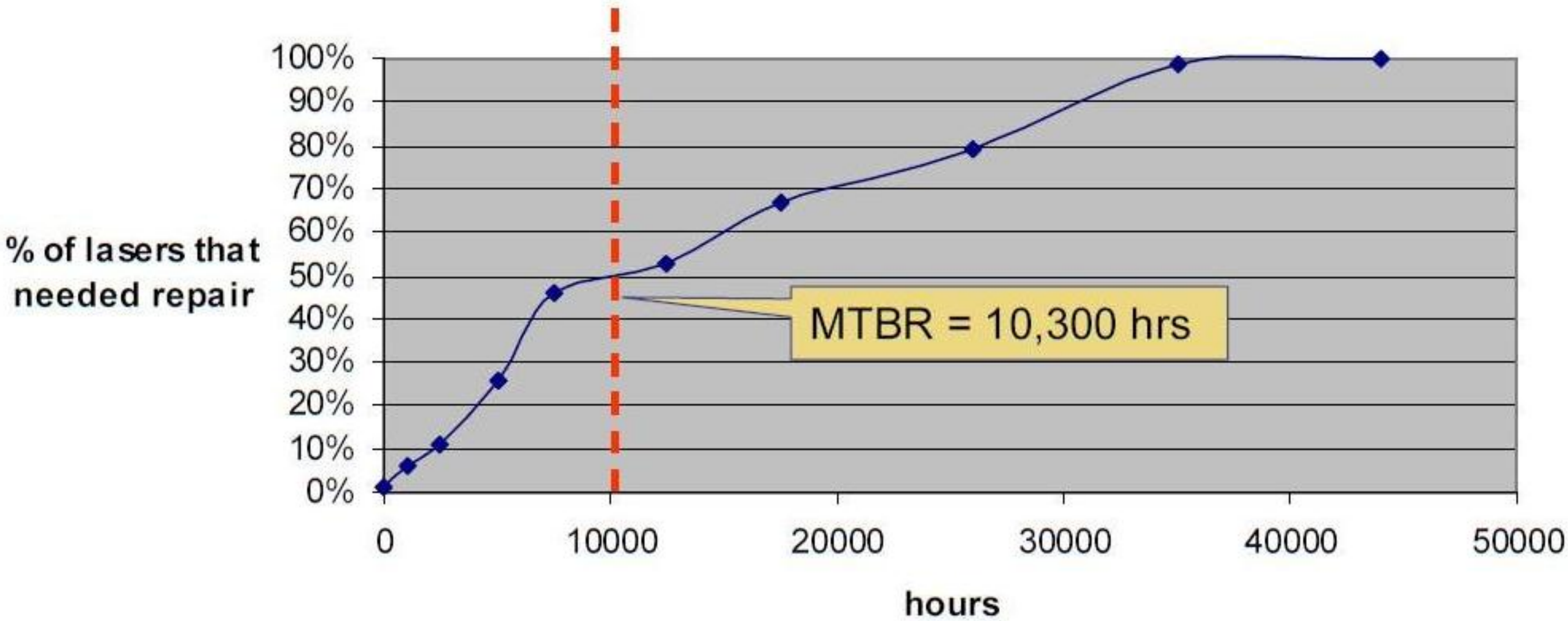
DM-527-30 Pump Laser System for above TU-L Ti:Sapphire Laser Q-switched DPSS Nd: YLF			
DM Power Supply Unit Available in 110VAC or 220VAC formats, 50-60Hz, single phase power. Standard RS232 control interface, Q-switch internal input via RS232 and external input by TTL via BNC. Dimensions: 483mm (19.0") m x 476mm (18.75") D x 178mm (5.25") H.	INCLUDED	1	INCLUDED
Standard DM Cooling Unit 110VAC or 220VAC units available, 50-60Hz, single phase power. Dimensions: 320.5mm (12.62") W x 606mm (23.87") L x 511mm (20.12") H.	INCLUDED	1	INCLUDED
System Software DM Control software provides basic system operating controls in a convenient graphical user interface configuration.	INCLUDED	1	INCLUDED
Warranty Standard Photonics Industries one-year parts and labor warranty.	INCLUDED	1	INCLUDED

DPSS Reliability



Unlike lamp pumped lasers, this laser does not need extensive maintenance service.

User References

Photonics Industries claims that most of its diode pumped lasers are used in military and private industry.

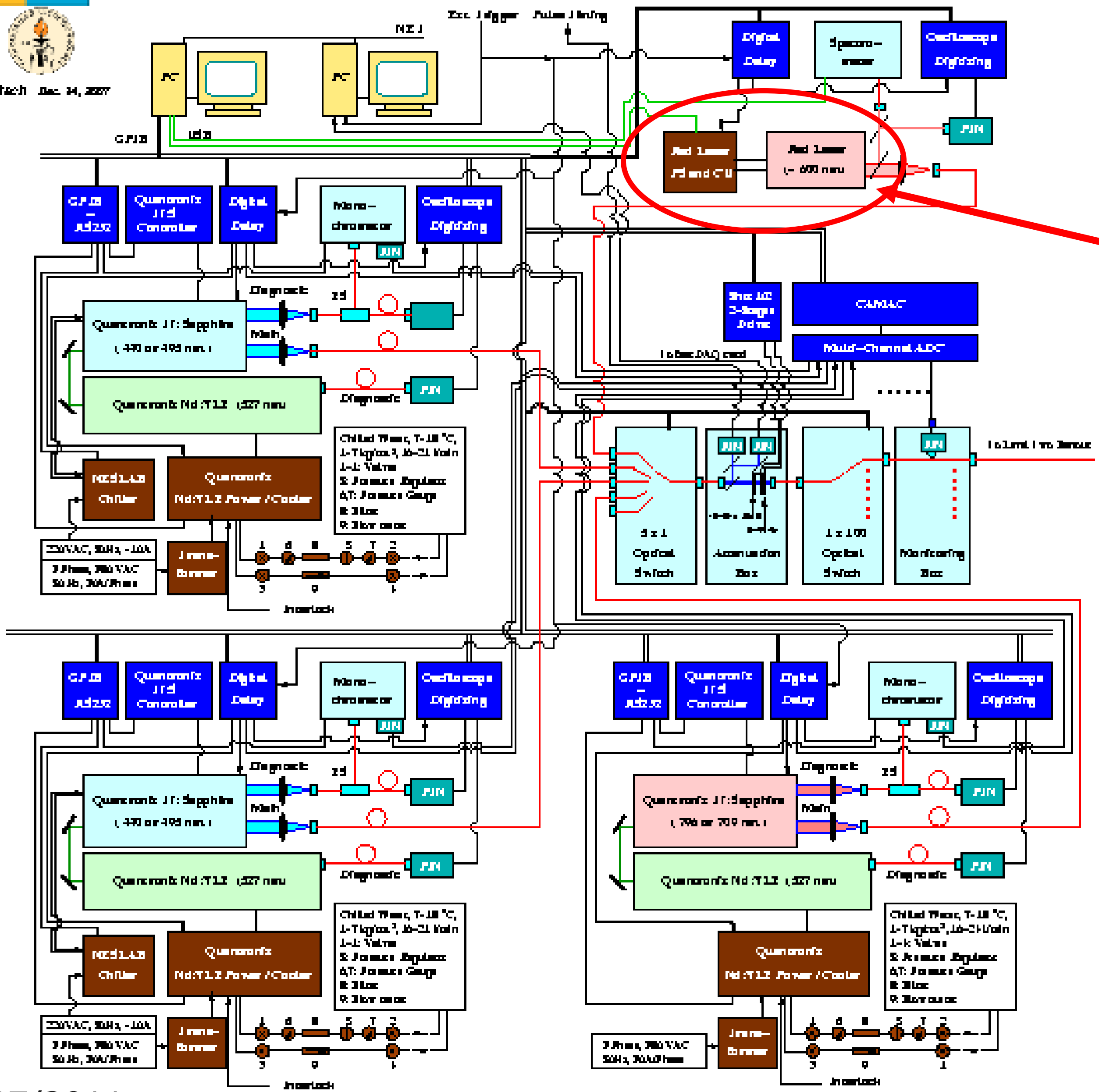
Oakridge National Lab

Dr. Yuan LIU commented on a diode pumped Nd:YLF pumped Ti:Sapphire laser system of Photonics Industries procured about one and half year ago. The laser system is run at 10 KHz in 24/7 mode for several weeks each run. While the Ti:Sapphire laser has no problem, the Nd:YLF had a problem caused by condensed water and it was fixed by Photonics Industries. She recommended Photonics Industries.

University of Washington (Prof. Thomas SPIRO group)

Dr. Balakrishnan commented on their Nd:YLF pumped OPO system of Photonics Industries purchased about 5 yrs ago. They are basically satisfied with the laser. The laser is run at 1 KHz, but NOT in 24/7 mode. The original diode module is still in good shape with accumulated time of over 3,500 hrs. There were some small issues like power dropping, chiller not working properly etc. The service is not as good as expected. While hoping Photonics will improve its service, they recommended the Photonics Industries.

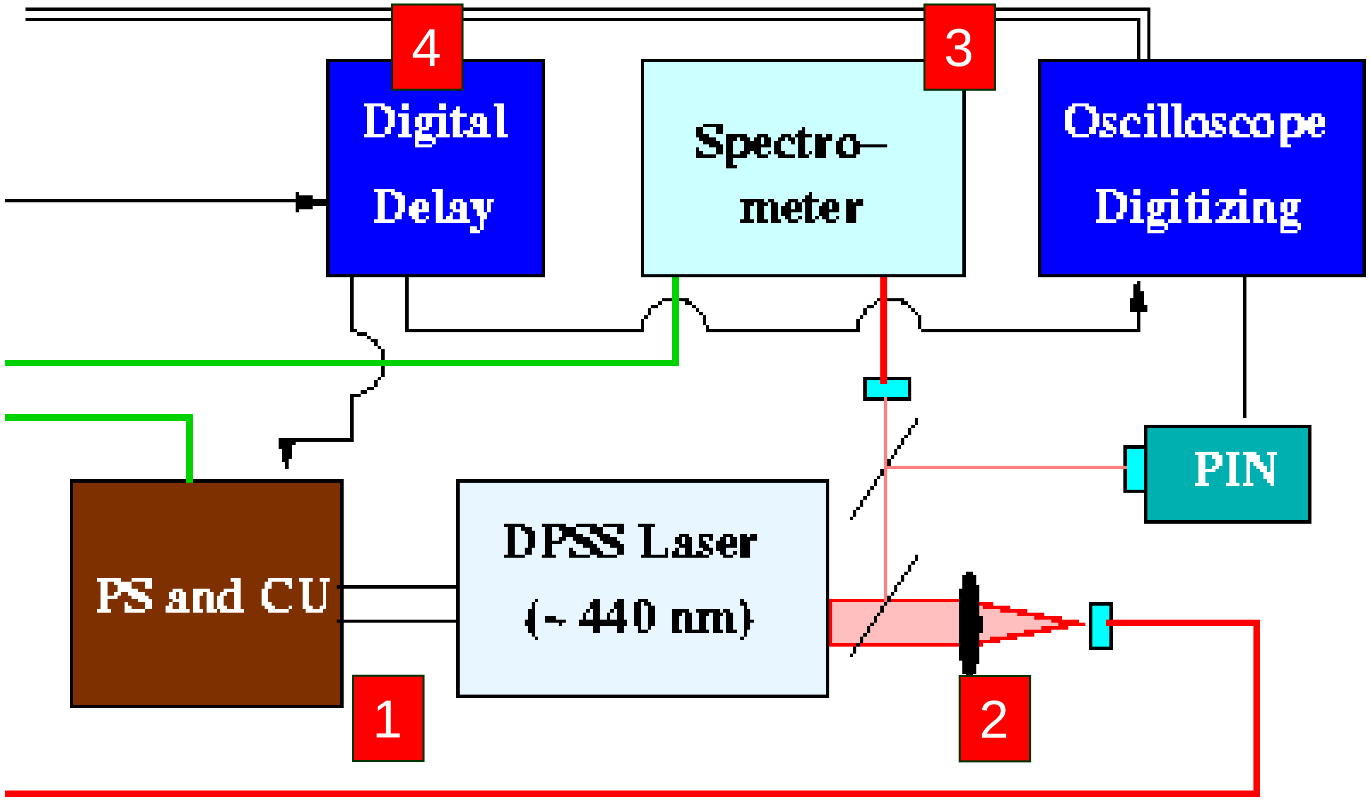
Adding a New Blue Laser



With the existing 5 x 1 switch a new blue laser at 440 nm may be added into the existing system.

Laser Hardware Needed

1) Laser & Power Supply and Cooler Unit;
2) Optics for fiber coupling;
3) Diagnostics: DSO and Spectrometer;
4) Trigger Electronics: Digital Delay.



Summary: Proposed Actions

Laser system plays a crucial role in providing a precision PWO calorimeter *in situ*. The existing laser system performs as designed. The system, however, needs upgrade to continue function with improved performance.

1. Procure two Dicon switches: 5 x 1 and 1 x 100.

2. Procure a DM-527-30 Q-switched DPSS Nd:YLF laser pumped 1 mJ TU-L Ti:Sapphire laser at 440 nm from Photonics Industries, Inc.

3. These procurements went through CMS MB and FM in August. The time needed from issuing a PO to laser commission at P5 is expected to be 28 weeks with schedule contingency. Aiming at catching 2012 runs.