Laser Long Term Performance & Pulse Width Issues

The Laser Workshop

Adi Bornheim
California Institute of Technology

CERN, September 16, 2005

Outline

Part 1 : Laser long term performance 2003 - 2005

Interlude : Convoluting Pulses

Part 2 : APD/PN pulse width dependence.

Laser Long Term Performance

What is long term ?

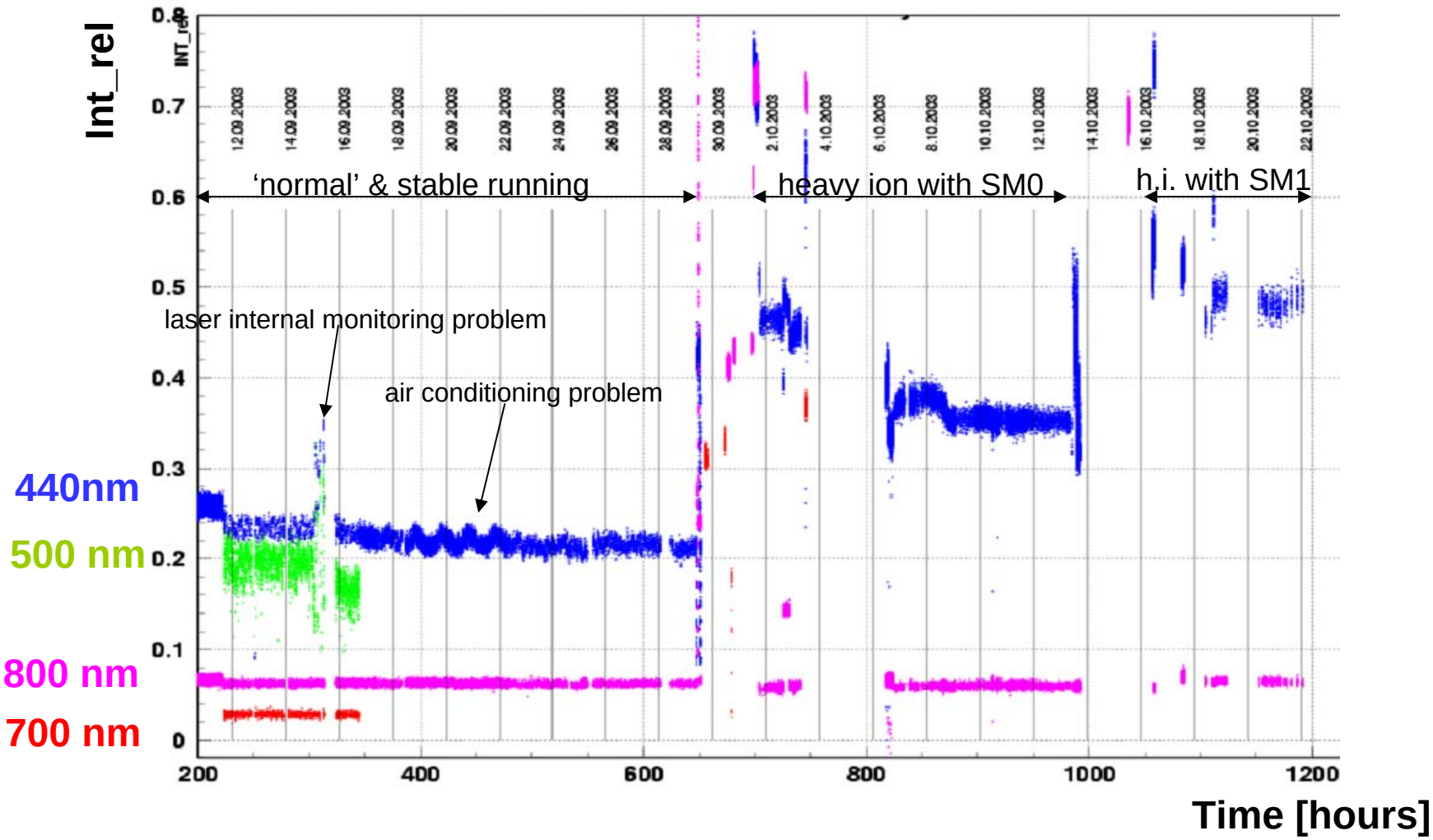
‘Natural scales’ :

LHC cycle : 24 h	1 day
Accelerator ‘maintenance cycle’ : 1 week (SPS), @ LHC ?	7 days
YLF Lamp aging : 500 h to 1000 h	20 – 40 days
‘Various’ other laser parts (eg. flowtube) : 1 year	365 days

Accumulation of luminosity for In-situ calibration :	few months	~60 days
	more are startup	>>60 days

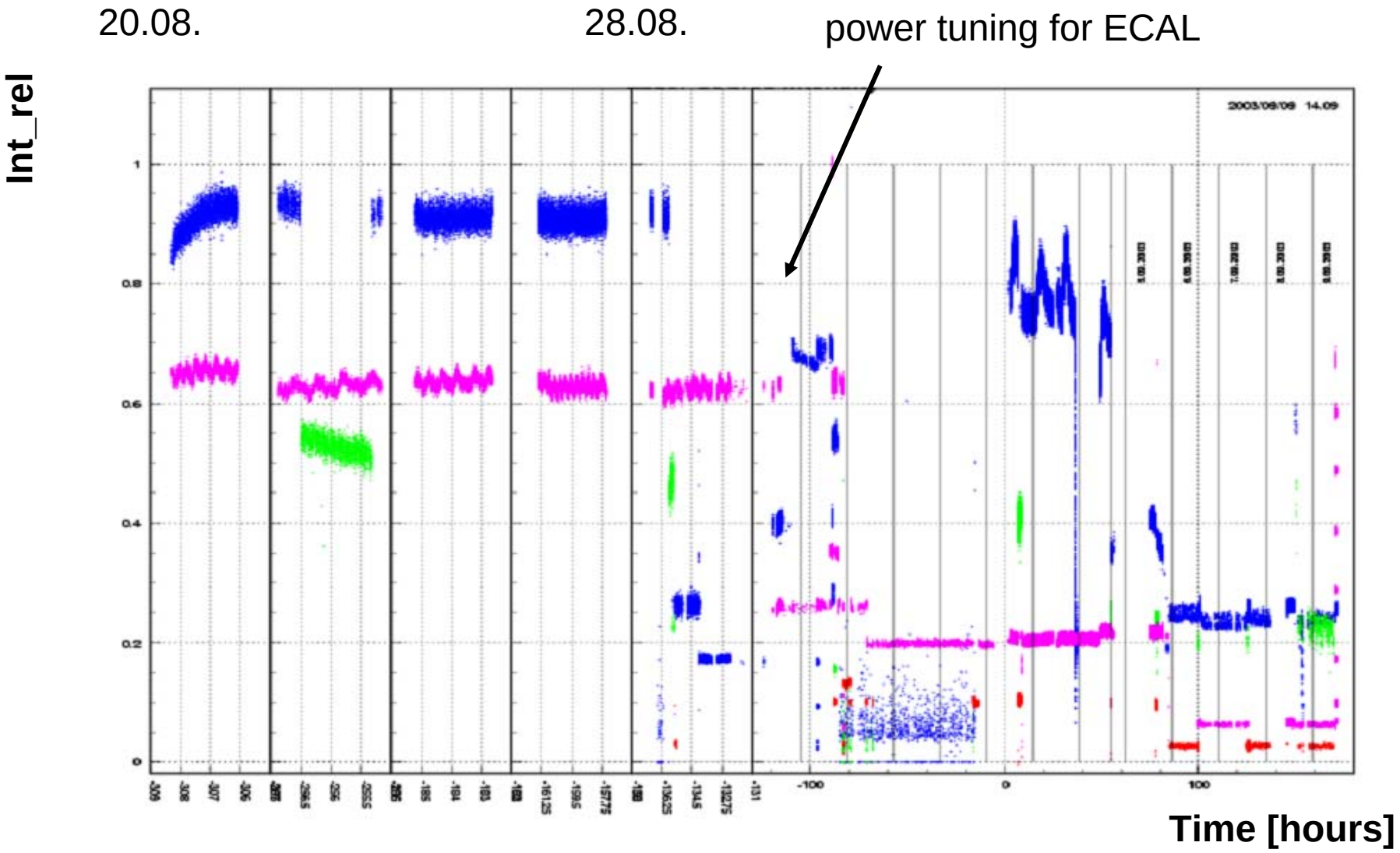
Over which time scale do we have to achieve the stability requirements ?

Laser Operation 2003 – Beam Periods

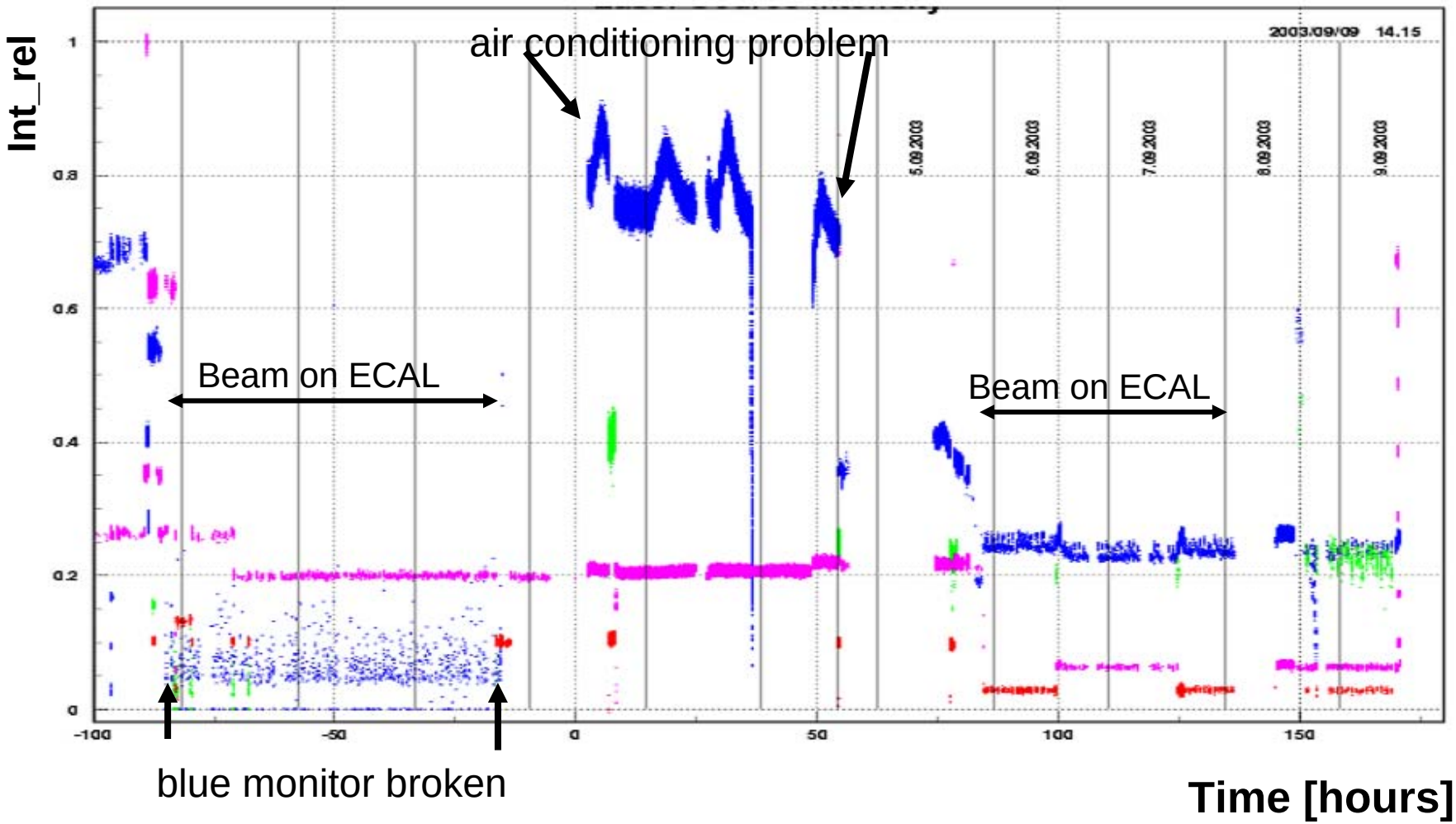


➢ **2003 was the only time we ran the laser on green (and red). The benefit is unclear.**

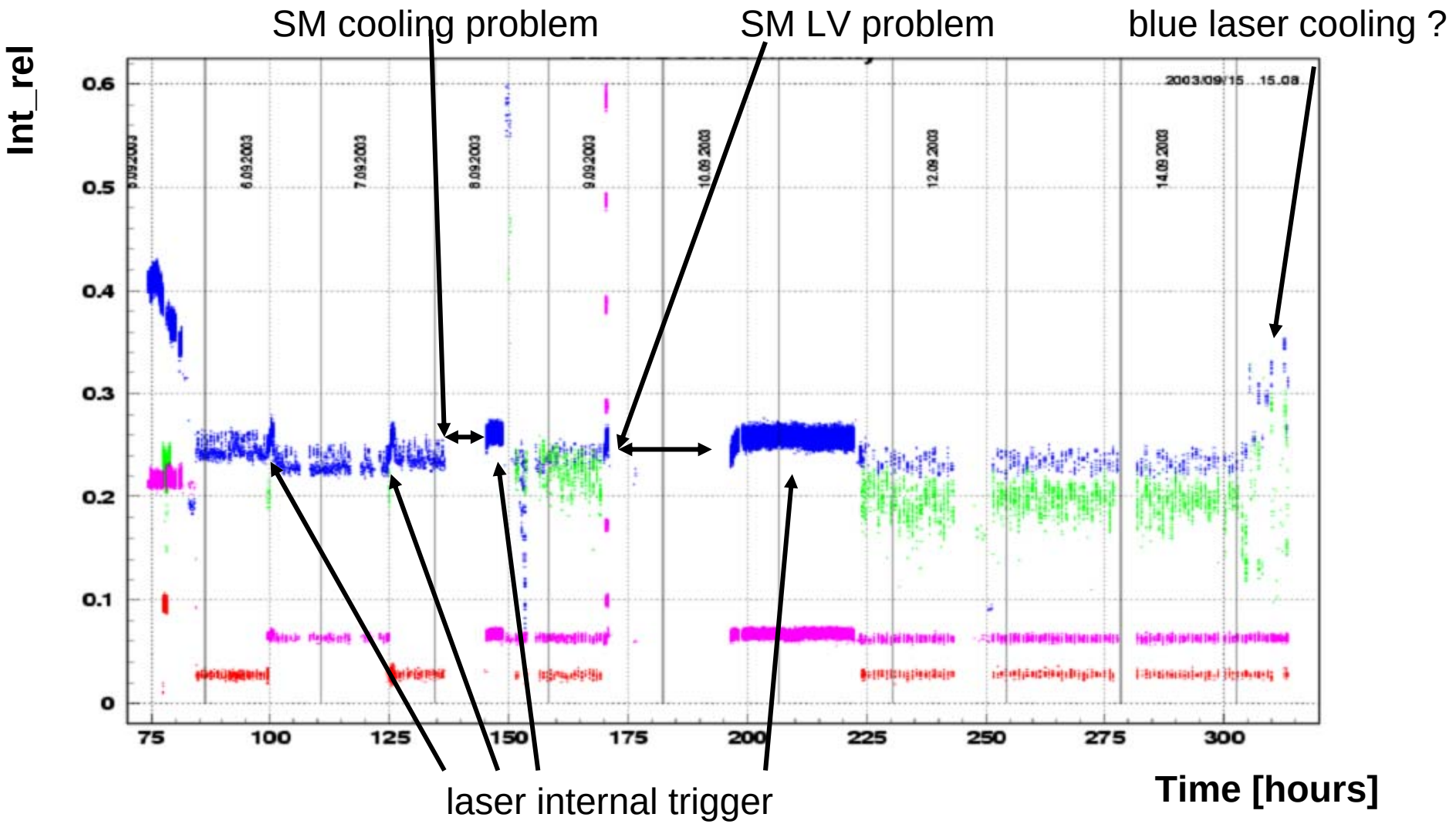
Laser Operation 2003 - Setup Period



Laser Operation 2003 – Beam Periods

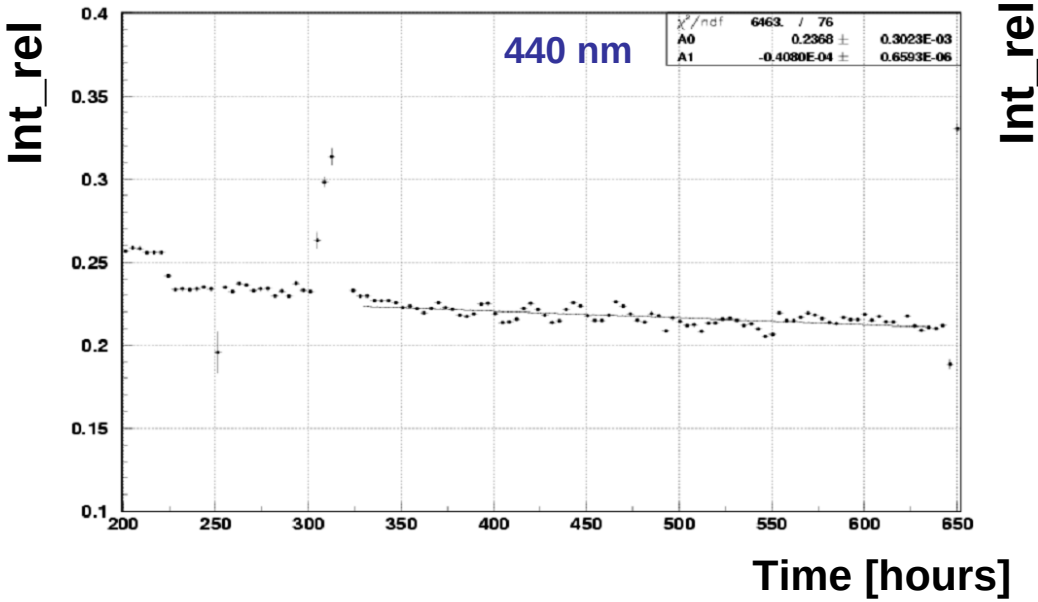


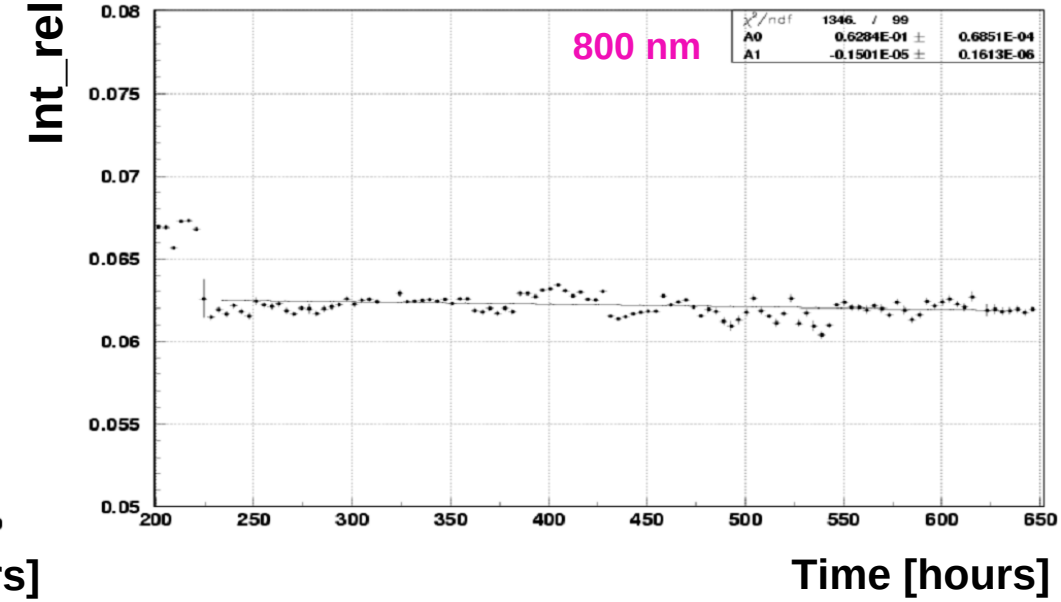
Laser Operation 2003 – Beam Periods



YLF lamp aging - 2003

Pump lamp for pump laser degrades over time
→ Pulse energy degradation for constant pump current.



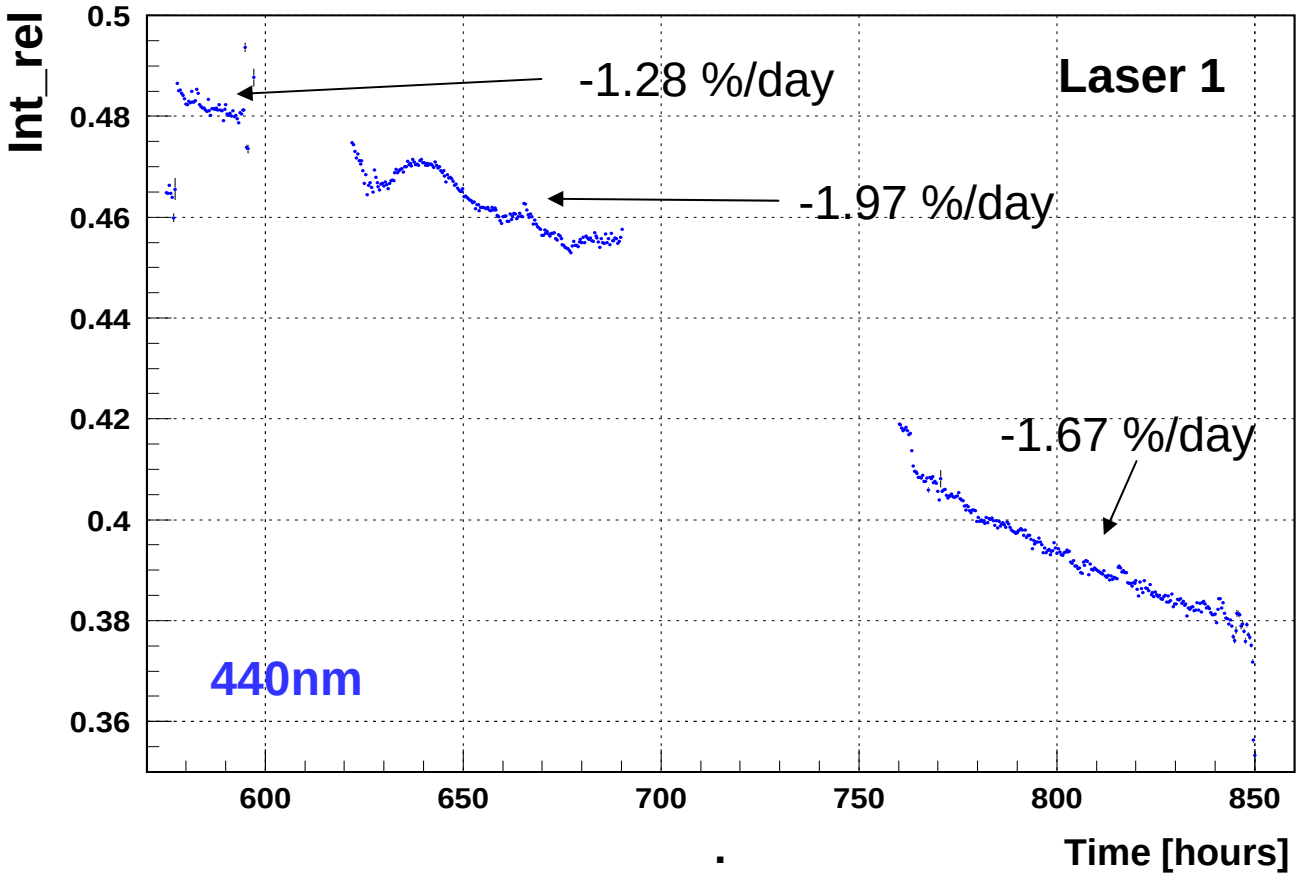


For blue laser (runs at higher pump current, here 25 A) :
Mean degradation : 0.41%/day - 12.4%/month

For red laser (runs at 20 A):
Mean degradation : 0.057%/day - 1.72%/month

This can be compensated by increasing the pump current and replacing the pump lamp.
The pump current adjustment can be automated with a feedback system.
It was decided to not touch the lasers during the period shown above to ensure stable running.

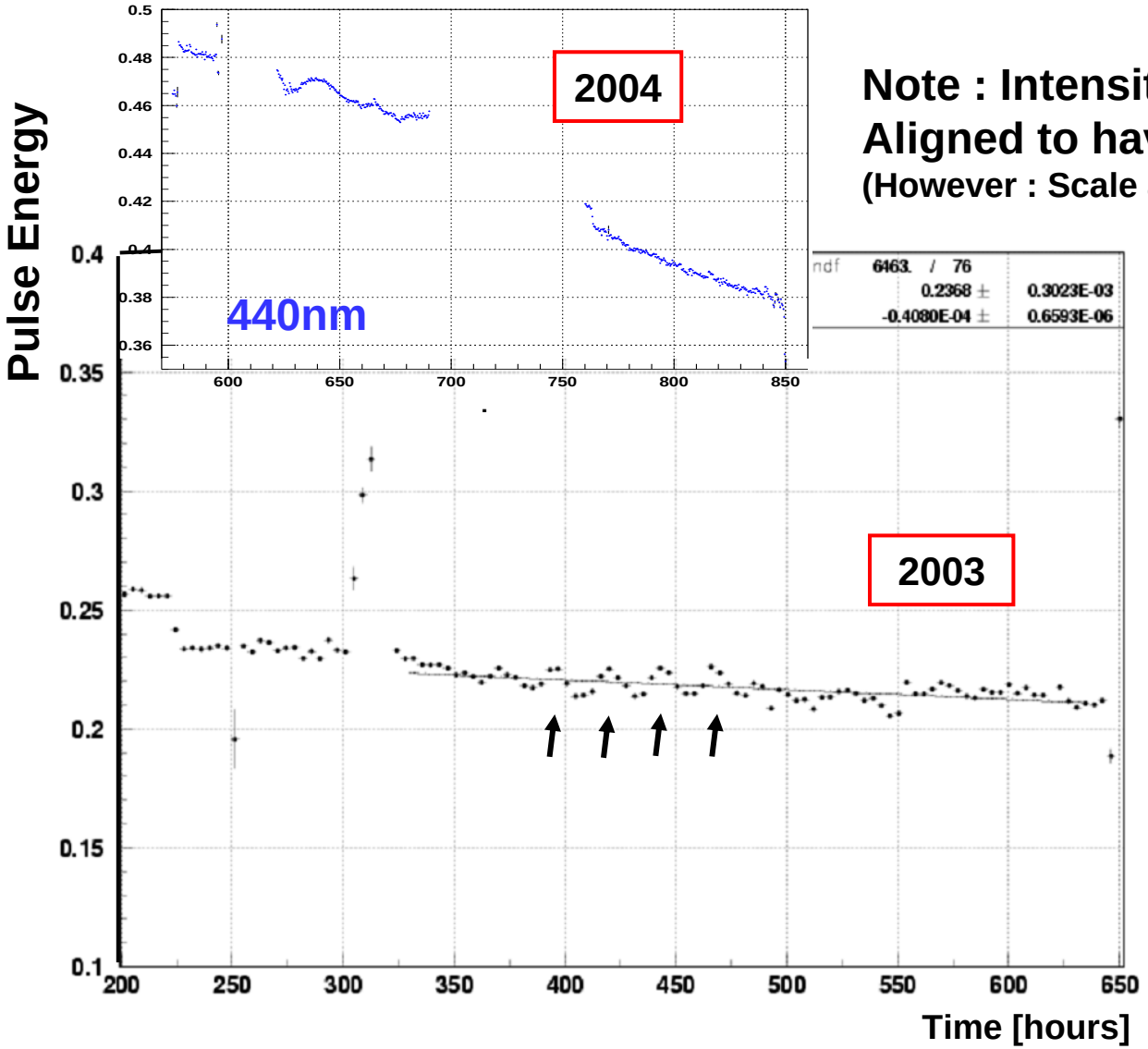
Hardware Trouble – Spring 2004



Was later traced to damaged optical components. Laser 2 had a hardware problem at the same time - which was later traced to a broken flowtube.

➢At the time it was decided not to intervene but to continue data taking !

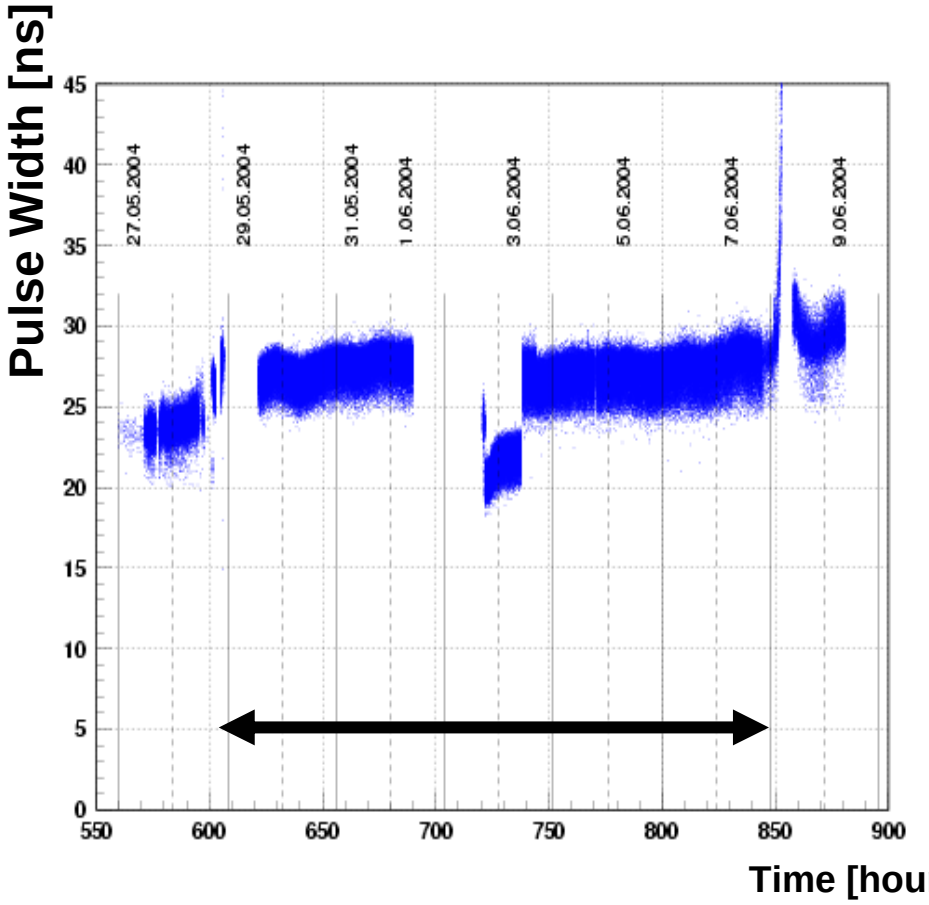
Comparison Degradation 2003 / 2004

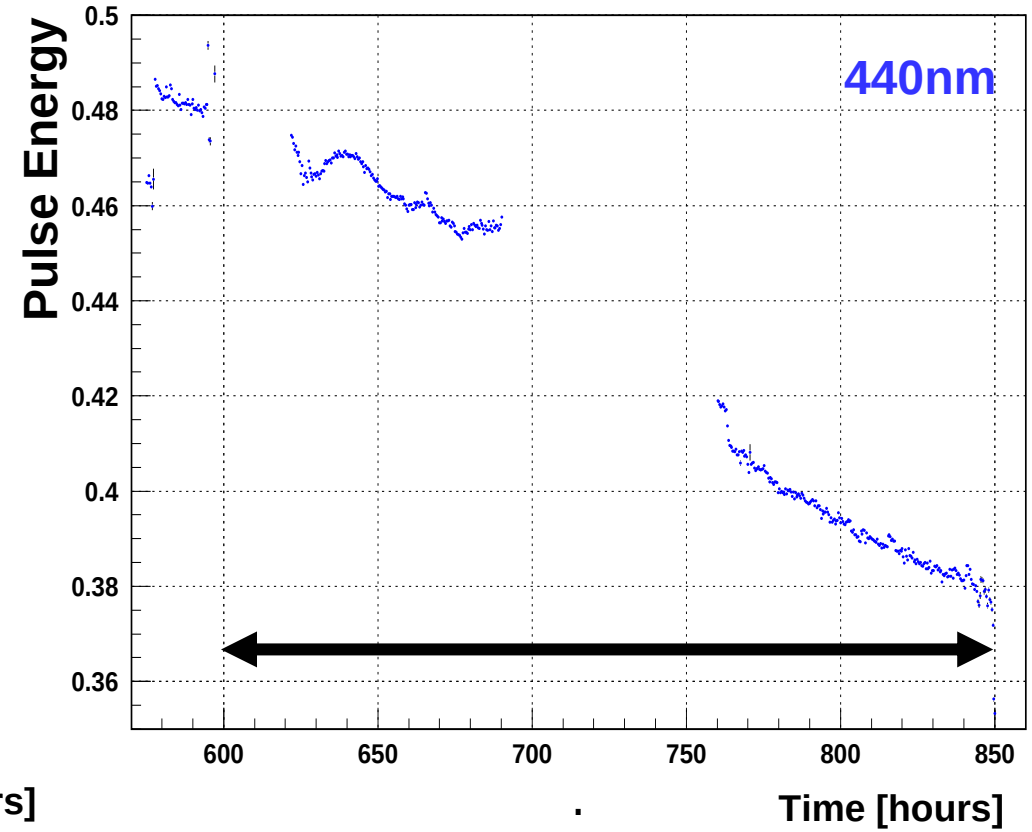


Note : Intensity Scale Arbitrary !!!
Aligned to have common '0'.
(However : Scale agrees with power settings)

2004 : ~ -1.6%/day (w.r.t. 0.5)
2003 : ~ -0.4%/day (w.r.t. 0.28)

Pulse width history - Spring 2004

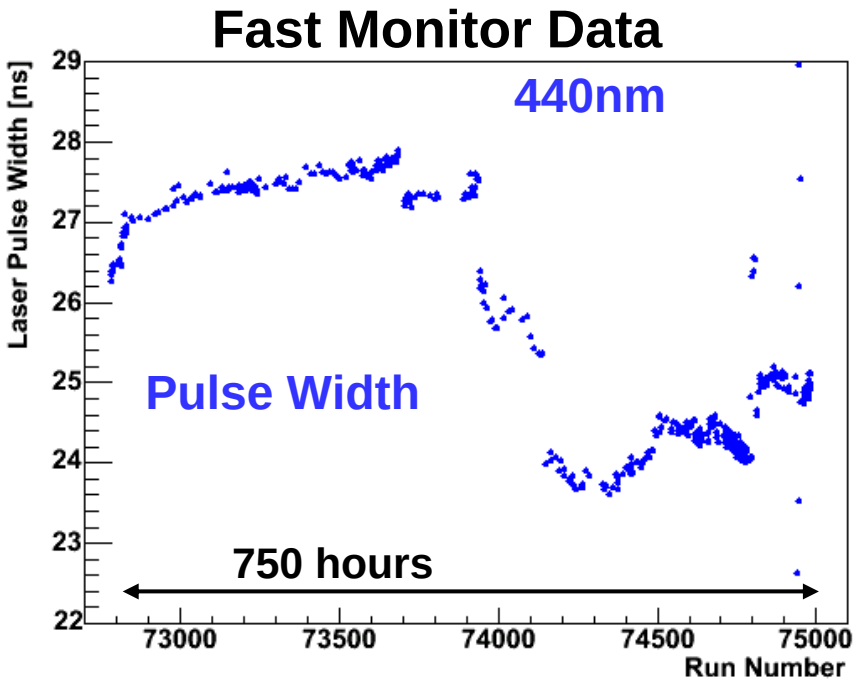




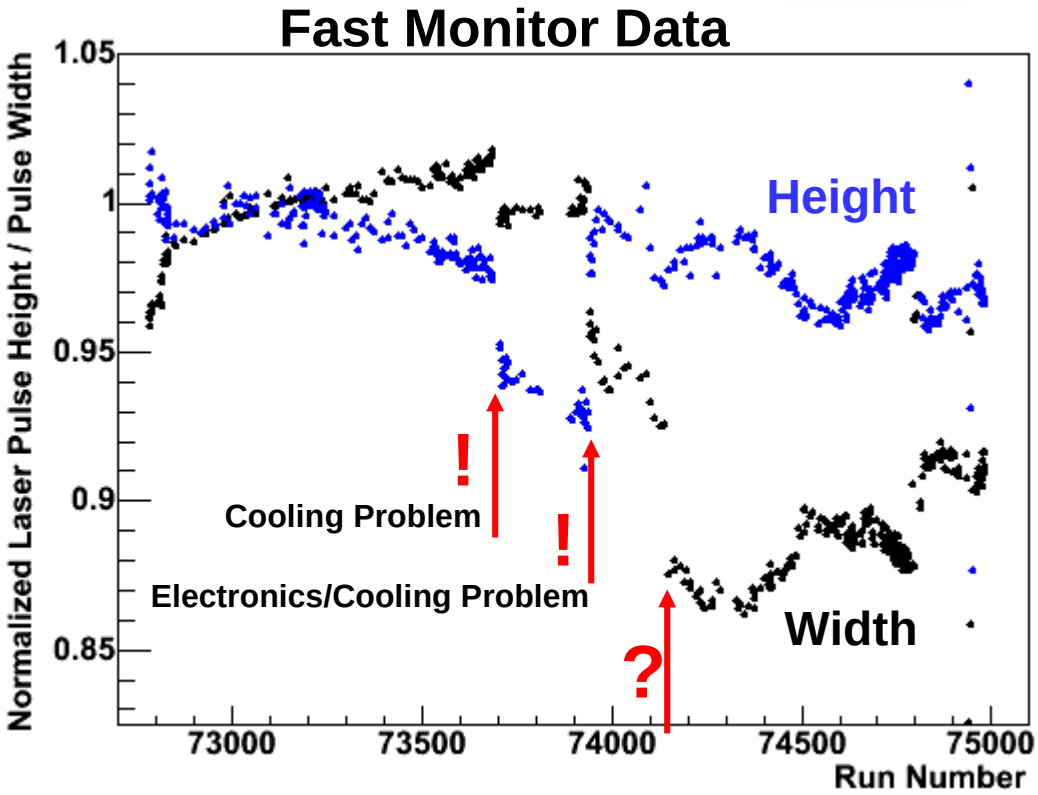
- **Hardware problems can cause non-standard behavior !**

  Pulse width seems to be not affected as much as pulse energy.
  Anti-correlation not as strong as normally.

Laser Operation SM10 – Fall 2004

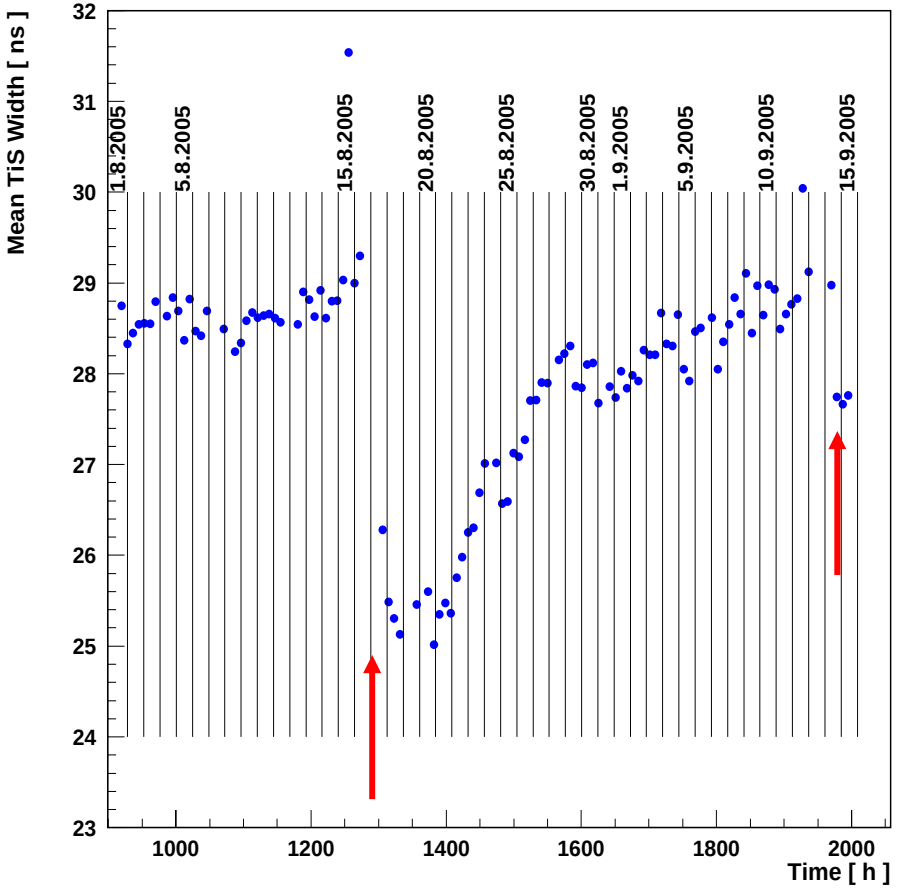


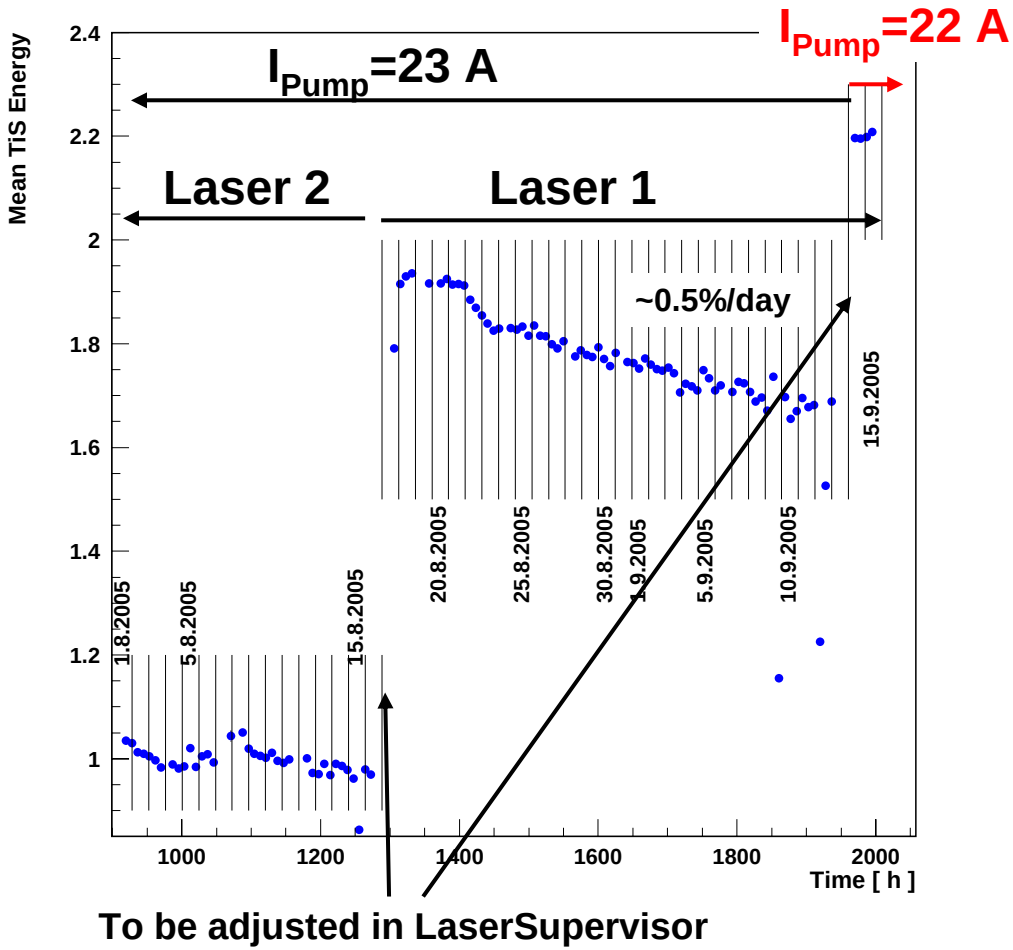
Fast monitor (event by event) averaged over one run.



- Overall performance good.
- Three ‘hick ups’ during 750 hours operation – one of unknown source.
- Two ‘non standard’ – height and width change in the same direction – incidents.

Laser operation (440 nm) 2005

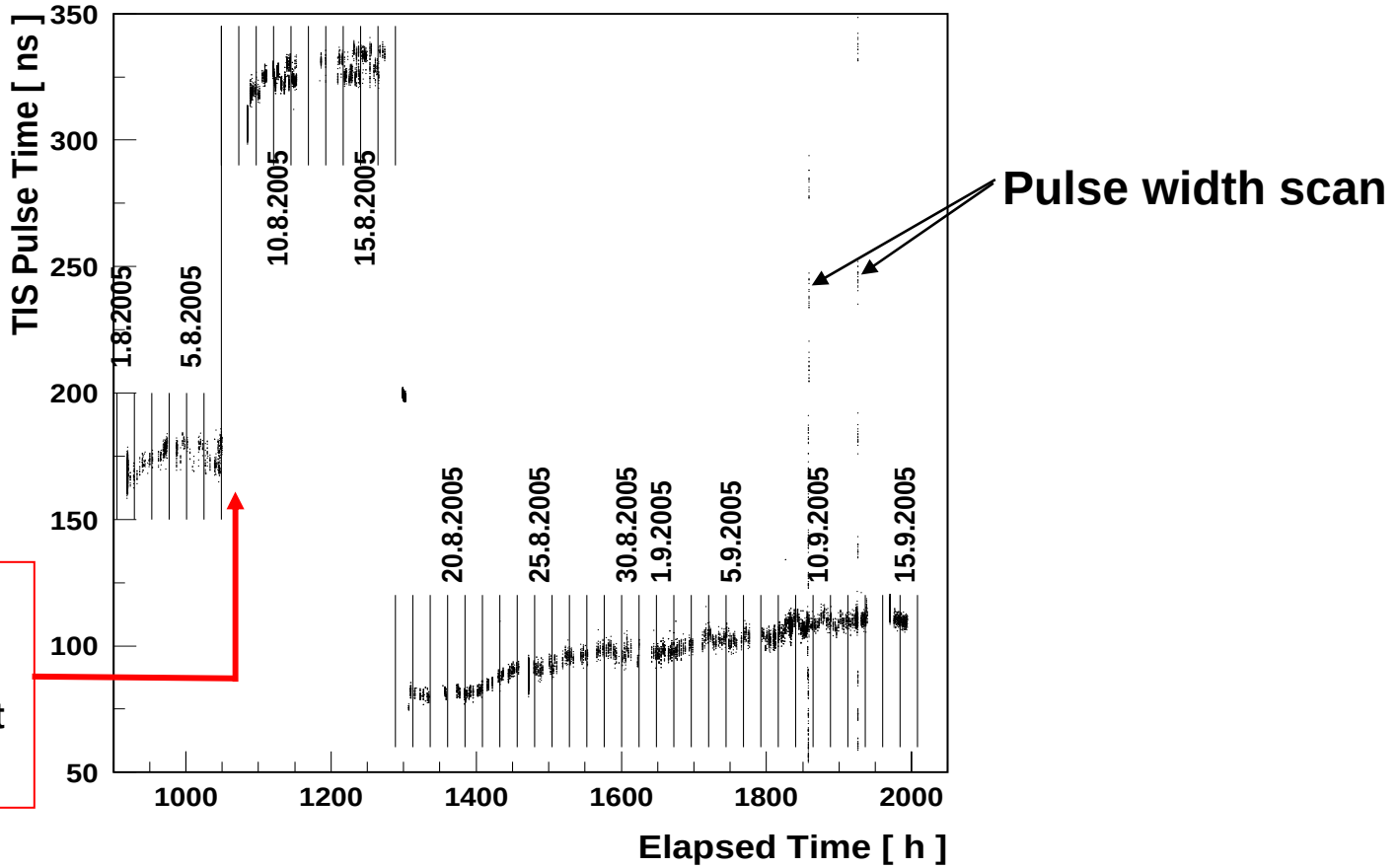




To be adjusted in LaserSupervisor

- Operation so far good.
- Continue to optimize retuning procedure to match pulse width and height.

Pulse Timing Drift - 2005



Compare previous Page :

There can be shifts

in pulse timing independent

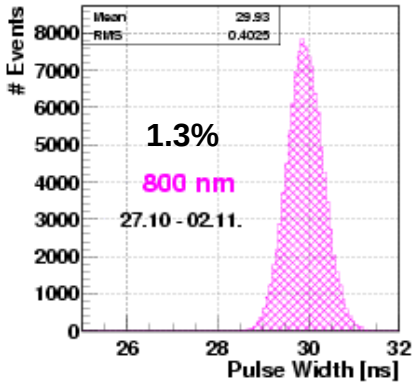
of pulse energy/width

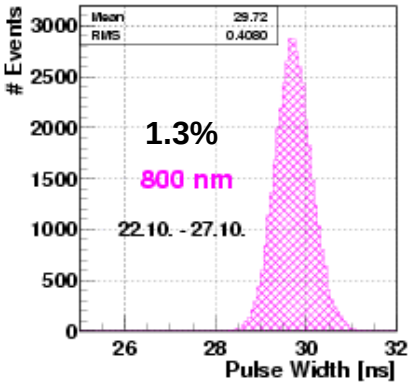
➢ **Pulse Time is anti-correlated to the pulse energy and correlated to the pulse width !**

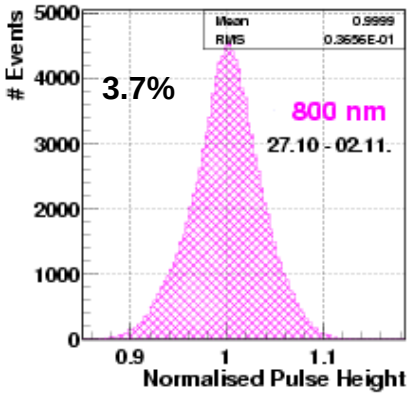
The return signal from the laser DAQ guarantees proper timing of the ECAL readout. The timing of the TiS pulse drifts over several LHC clock cycles on the time scale of weeks.

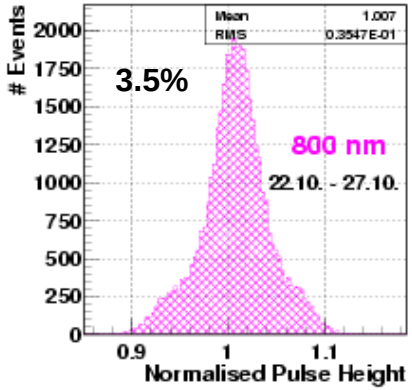
Laser Source Performance

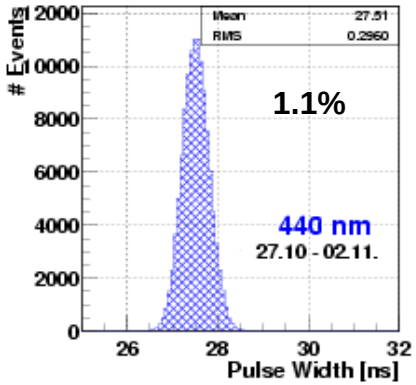
Stability over periods of 5 days :

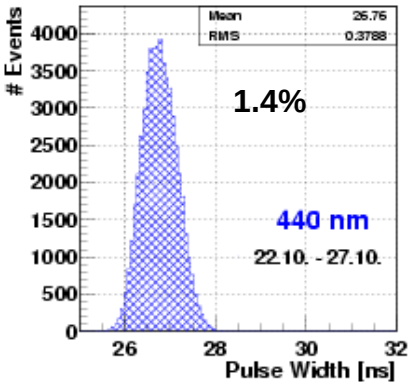


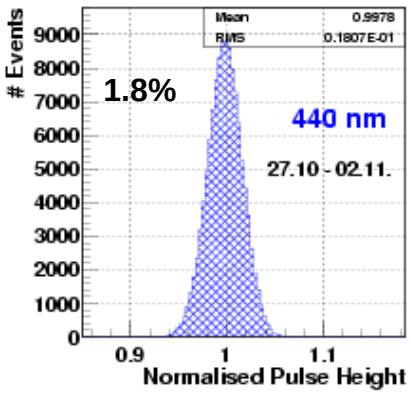


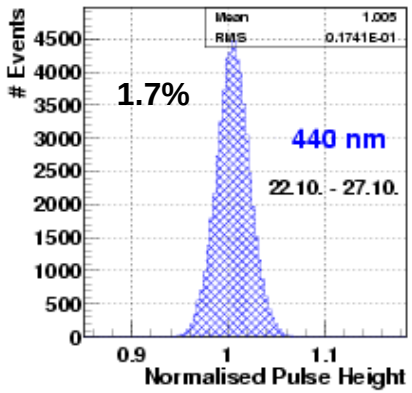










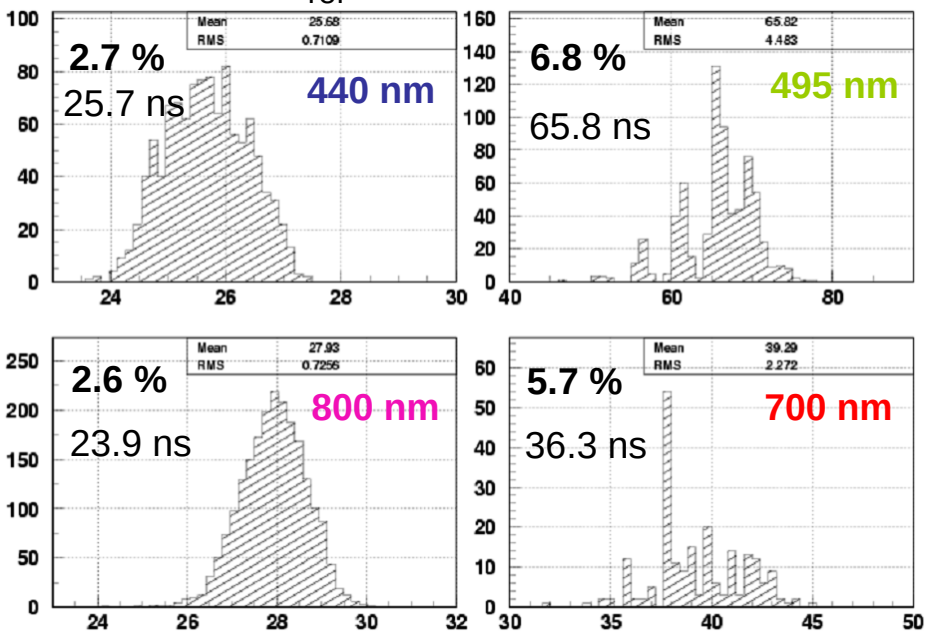


➢**The lasers were tuned to optimize the pulse width stability – seems to work.**

2003 :	440 nm	800 nm
Pulse Height :	2.6% / 25 hours	3.2% / 25 hours
	1.5%/ 30 min	2.8% / 30 min
	0.4%/day (long term)	0.06%/day (long term)
Pulse Width :	2.7% / 25 hours	2.6% /25 hours

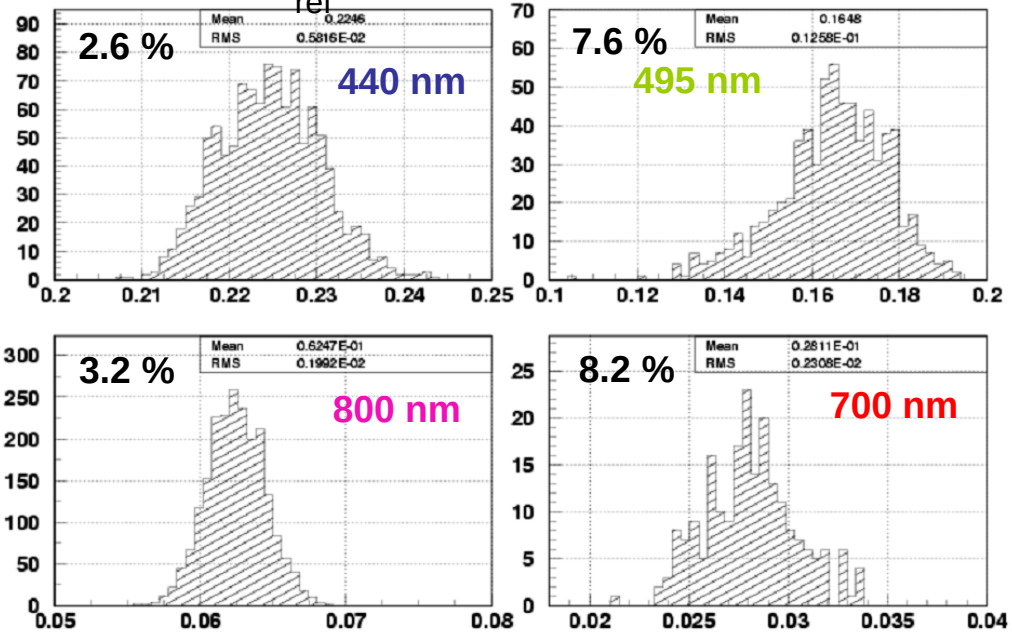
Short Term Stability - 2003

t_{ref} : 330 - 335 h

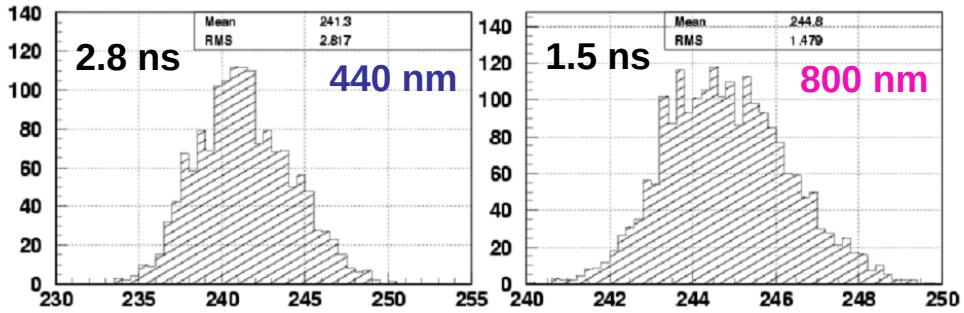


pulse width [ns]

t_{ref} : 330 - 335 h



pulse height



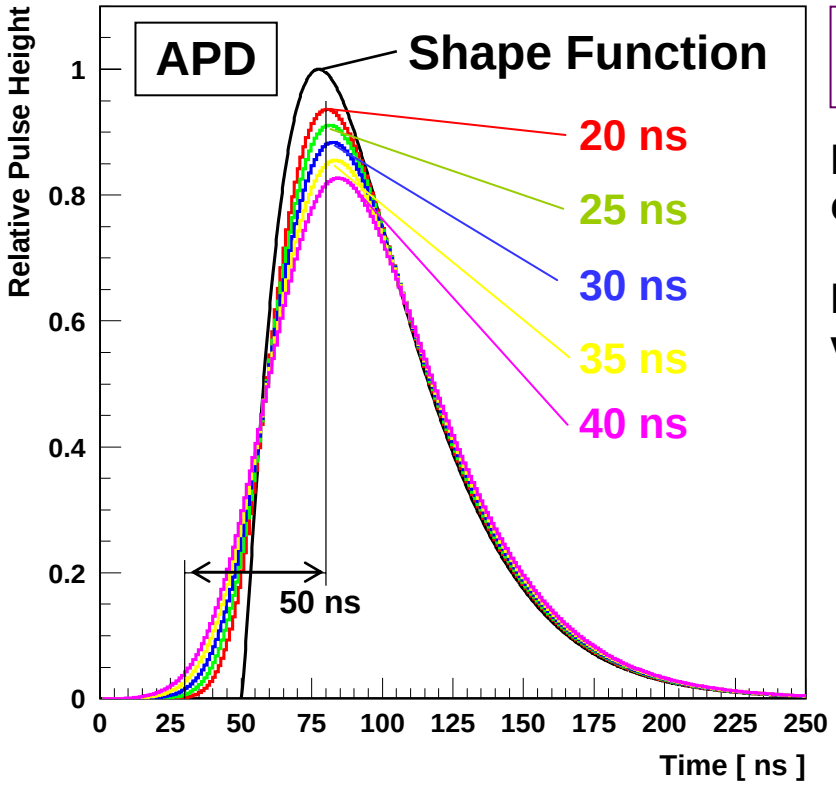
pulse time [ns]

Note : The higher the pump current the better the short term stability.

In 2003 we used a higher pump current than in 2004 & 2005.

Convoluting Pulse Shapes

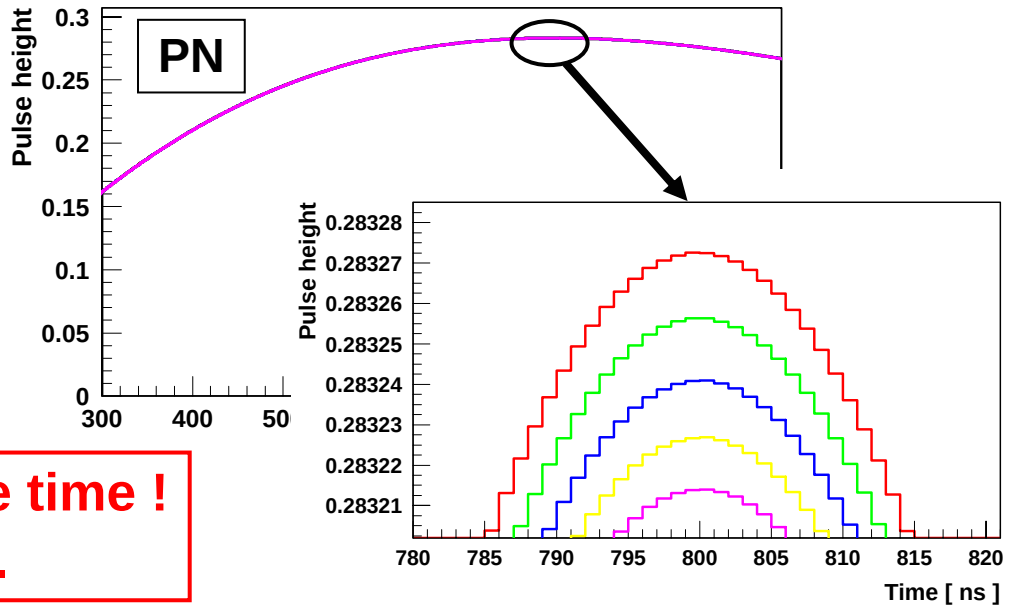
The sampled pulse is a convolution of the electronic shape and the laser pulse shape. We then estimate the energy from the pulse height.



$$f(t) = \left(\frac{t - (T_{\max} - T_{peak})}{T_{peak}}\right)^{\alpha} \exp\left(-\alpha \times \left(\frac{t - T_{\max}}{T_{peak}}\right)\right)$$

Laser shape (Gauss with FWHM 20 ns, .. , 40 ns) convoluted with shape function.

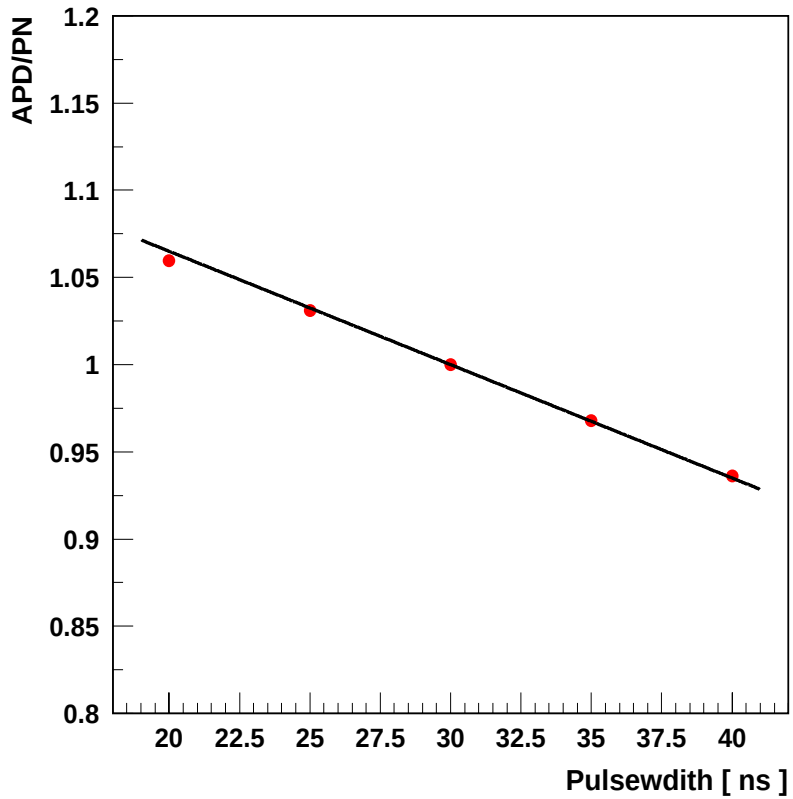
Parameters for shape function adjusted to match values measured as from Renauld's talk 16.03.2005.



Effect strongly depends on the rise time !
Sizable for APD - Negligible for PN.

Pulse Shape Convolution (con't)

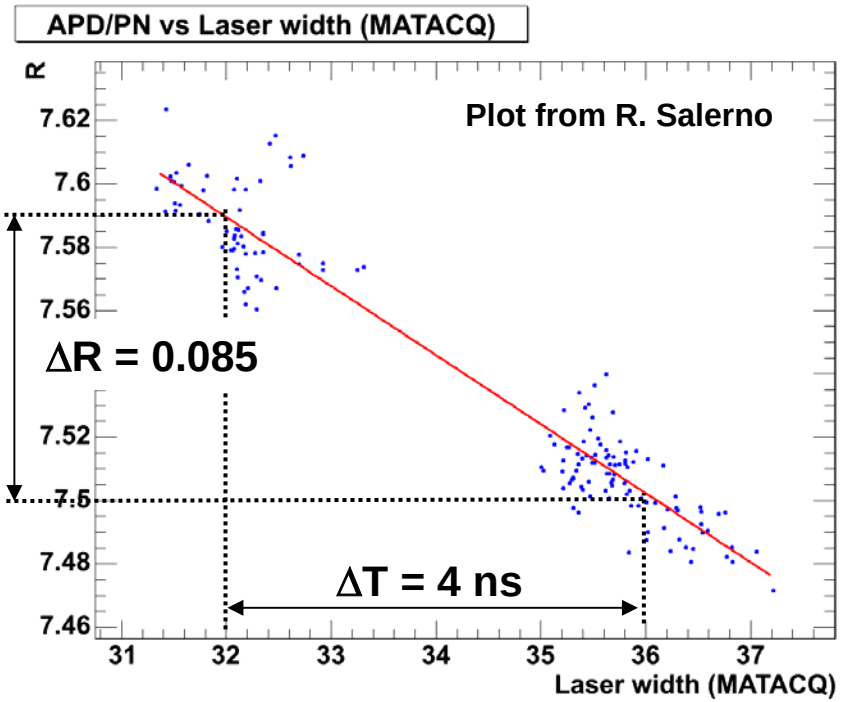
APD/PN Ratio from previous page



Effect (slope) is of the order of 0.006/ns.

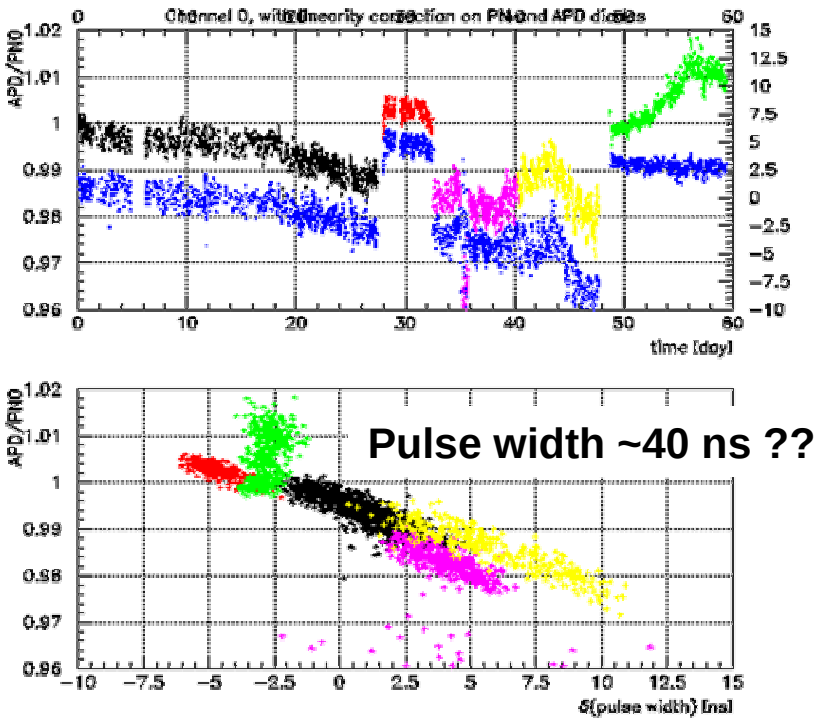
But this number is strongly (within a factor 2) rise time dependent.

Pulse Width Dependence in Data



Normalize R to 1 ⇒ Slope : ~ 0.003/ns

Marc, WACH2002, Paris, 2002 Data



Slope : ~ 0.002/ns

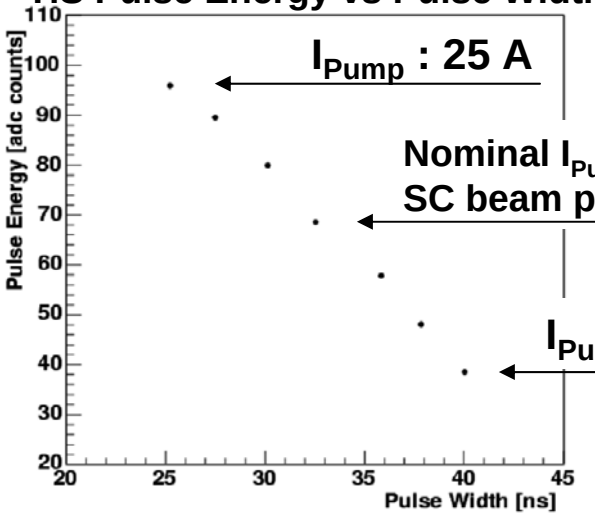
But : Pulse width determination different.

Note : Here very different setups are compared (electronics, width measurement, etc.).

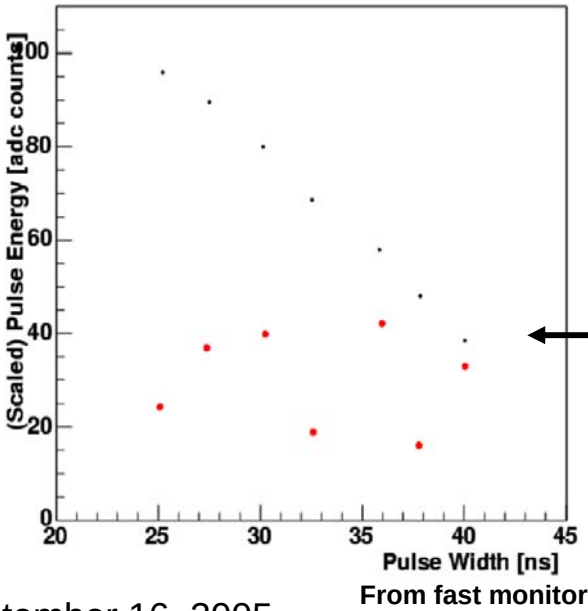
Pulse Width Scan – Spring 2004

Compare : Adi's talk on 06.10.2004

TiS Pulse Energy vs Pulse Width

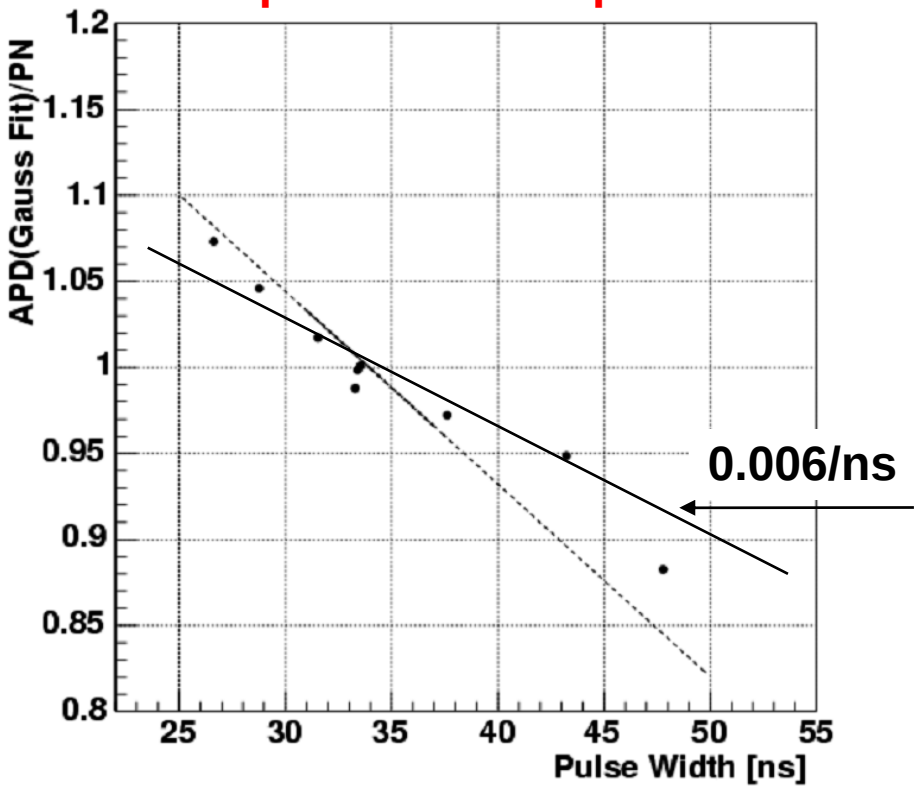


From fast monitor



From fast monitor

APD/PN pulse width dependence

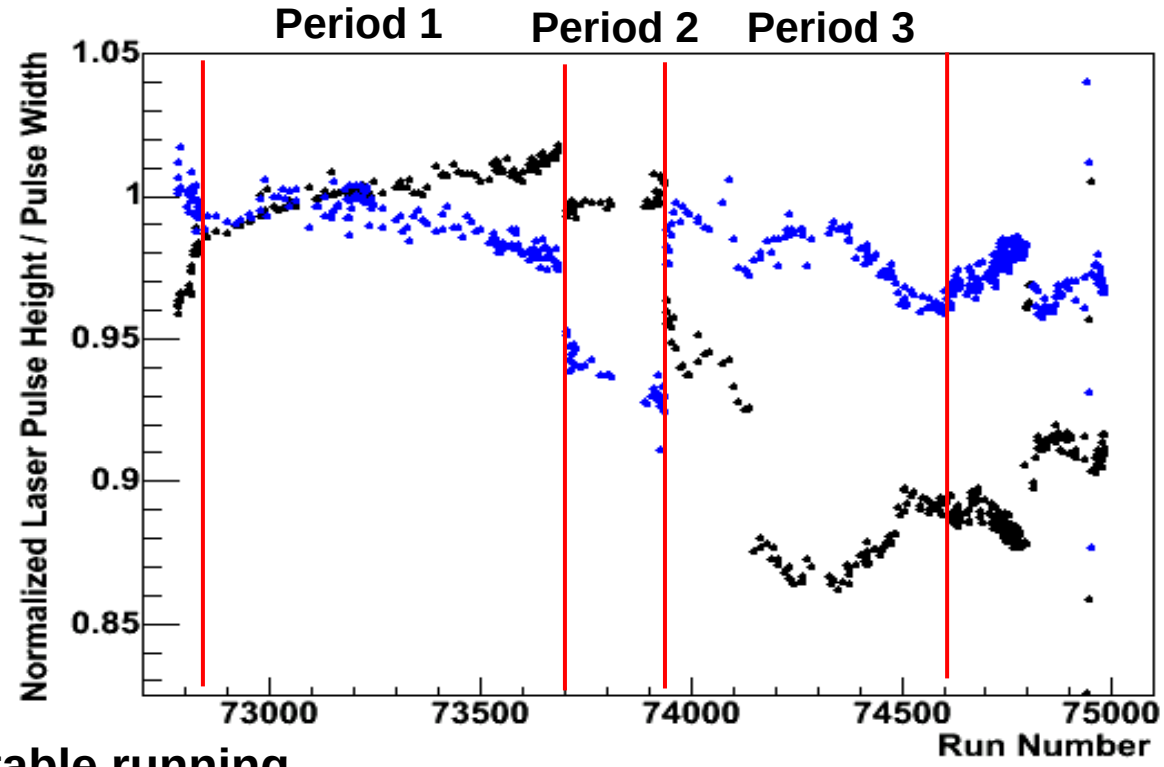


From MATACQ

Attempt to compensate pulse energy change with the intensity regulator 'online' to isolate pulse width effect. Since pulse height non-linearity is much smaller this is not necessary.

Laser Pulse Width Correction - 2004

Please recall Patrice's presentation at test beam meeting on 18.05.2005 :



Period 1 : Stable running

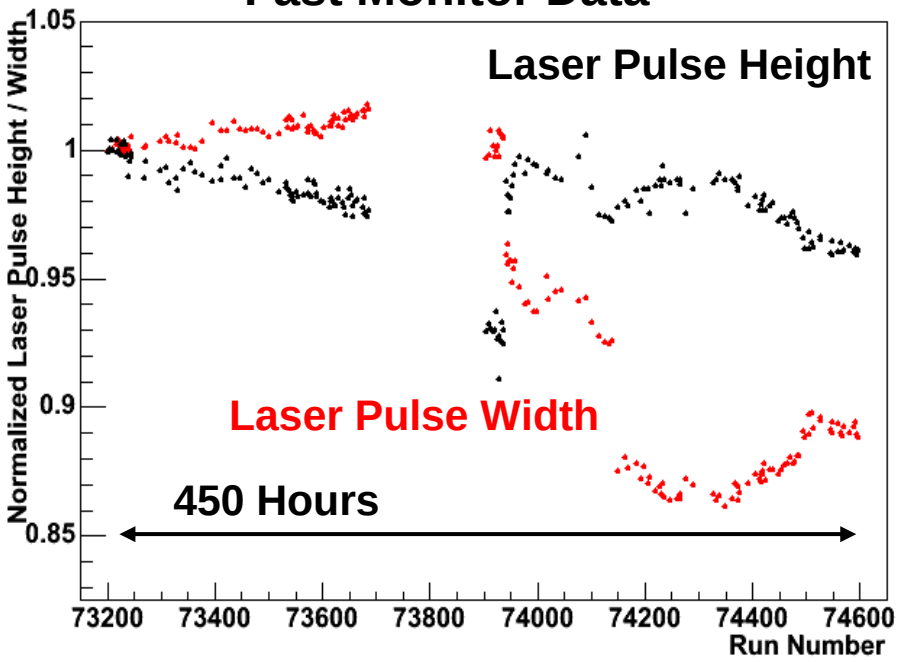
Period 2 : H4 DAQ trouble (timing ?) **Note : The laser problems in this period have nothing to do with the H4 DAQ trouble.**

Period 3 : Running

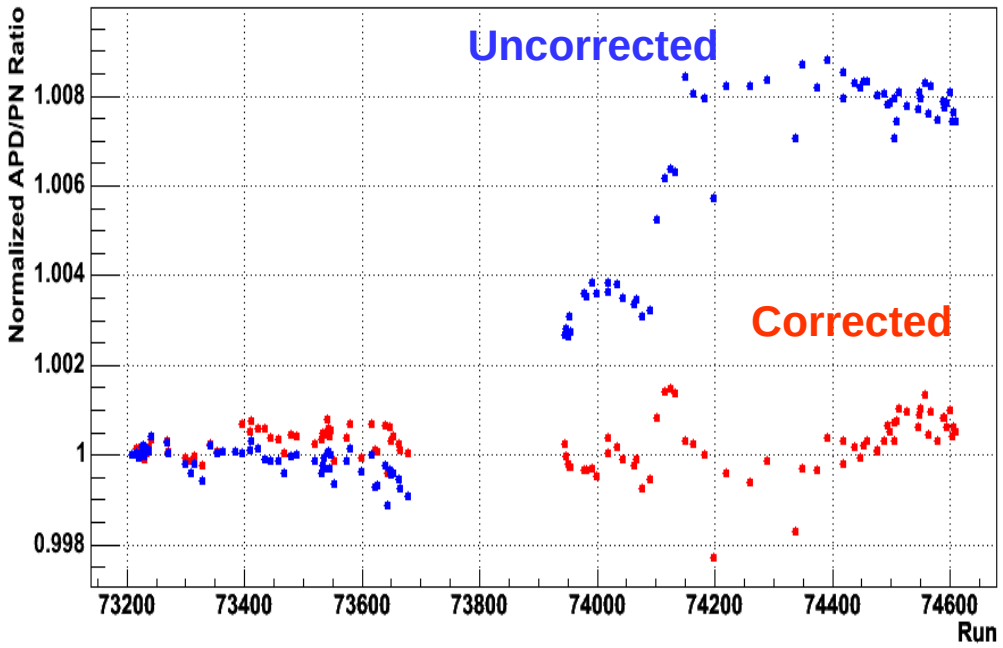
After period 3 : Temperature step, HV scan, laser scans, token ring broken …

Pulse Width Correction on SM10 - 2004

Fast Monitor Data



ECAL APD/PN, Single Channel Monitoring History



Data analysed :

Part of Period 1 (not all the data was re-reprocessed to fix PN data) and Period 3. Period 2 is problematic - and thus not used.

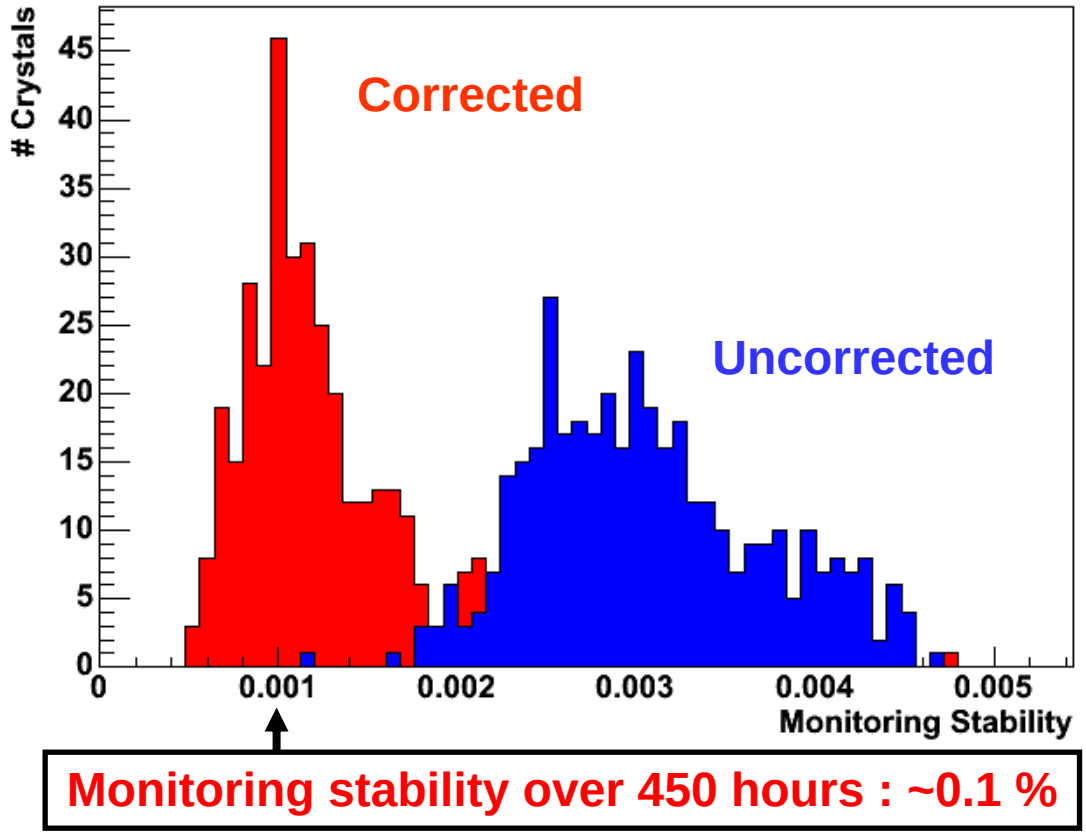
Pulse width correction :

$$APD/PN\_cor = APD/PN + c \cdot PW\_Laser$$

Pulse Width Correction Performance

Judge performance (monitoring stability) by projecting values onto Y-Axis for each channel (actually 400 for the plot shown) and determine the RMS.

Period 1 and Period 3 combined.



Summary & Outlook

- **The long term laser performance and our understanding of its limitations improved over the three years the system is in operation.**
- **Pulse energy and pulse width can be kept stable within the requirements for several weeks.**
- **We continue to improve the operation of the laser to minimize the impact of maintenance operation and hardware failures.**
- **The pulse width dependence of the APD/PN ratio remains a critical issue. It appears that a width stability on the level of <1ns is needed.**

- **Analyse SM5 pulse width scan data as soon as rrf-files are available.**
- **Perform further scans on SM5 and on further SM as they become available. Presumably the effect is not channel-to-channel depedent.**