# IP-BSM Status and Plan

## 12th ATF2 Project Meeting (LCWS 2011)

Sept. 28, 2011
Granada


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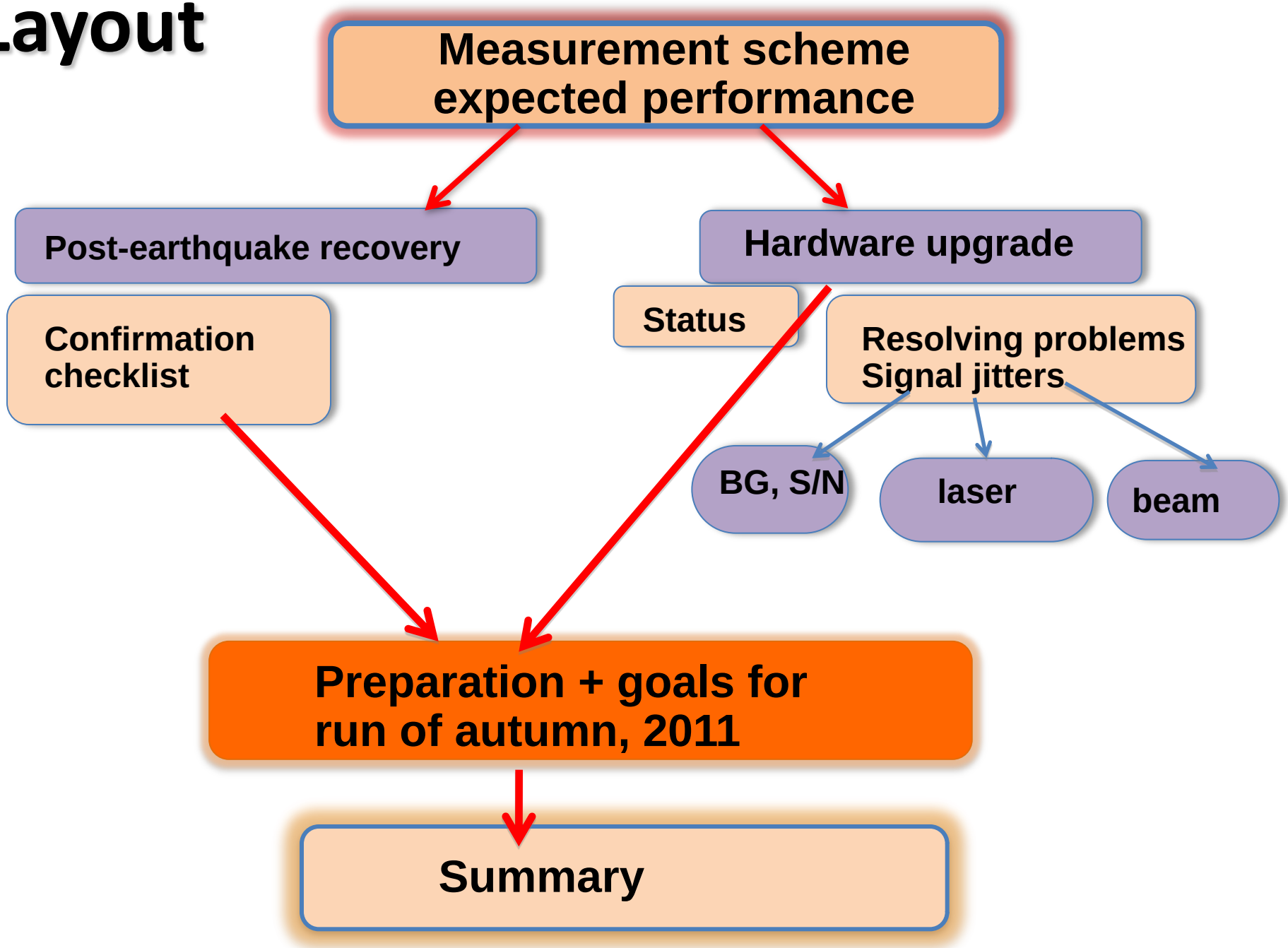
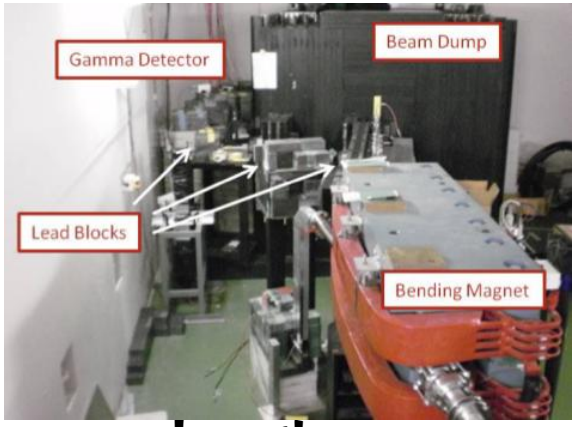
# Layout

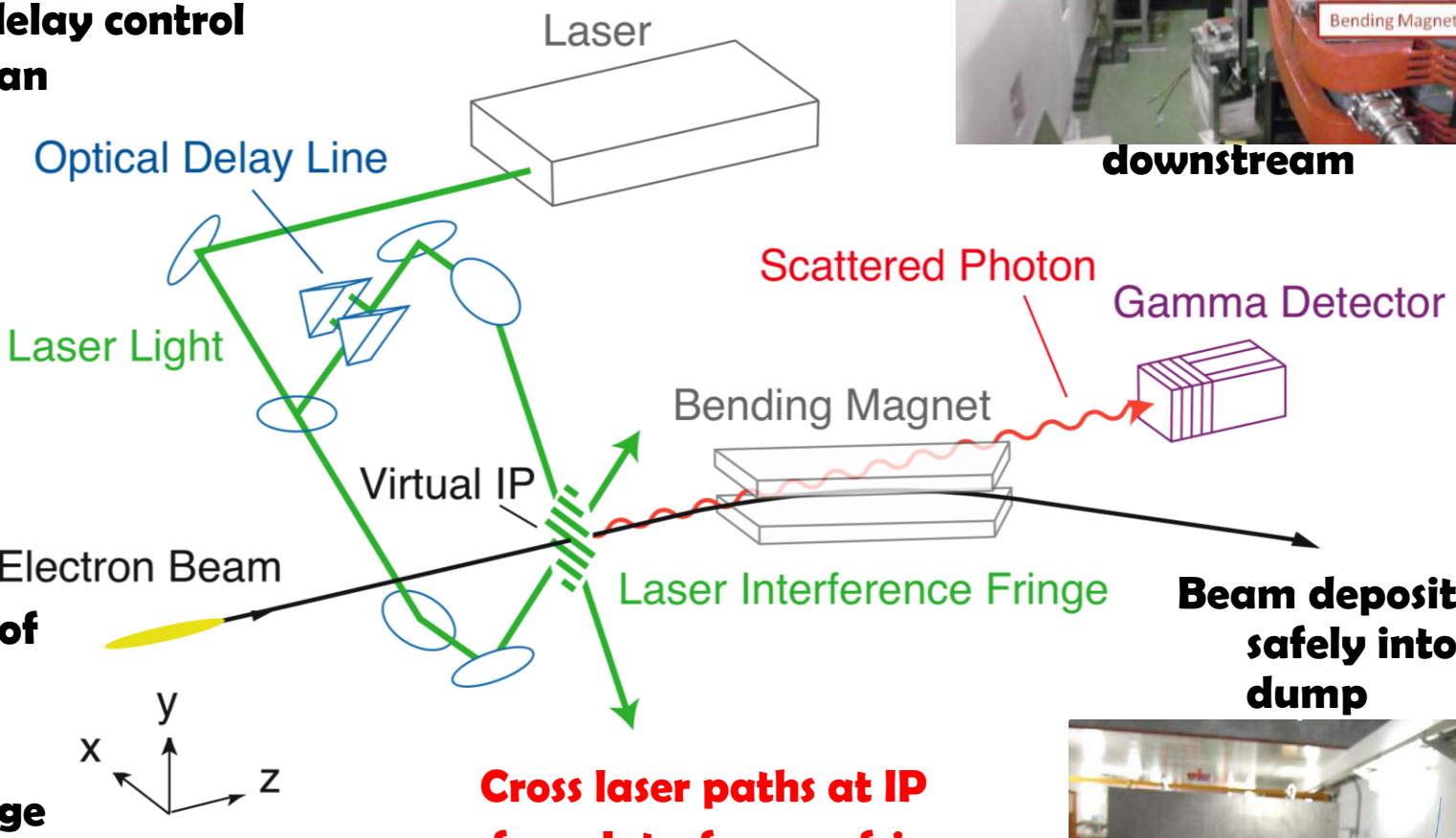

Measurement scheme
expected performance
Post-earthquake recovery
Hardware upgrade
Confirmation
checklist
Status
Resolving problems
Signal jitters
BG, S/N
laser
beam
Preparation + goals for
run of autumn, 2011
Summary

# Measurement Scheme

**Split into upper/lower path**
**Optical delay control**
**phase scan**



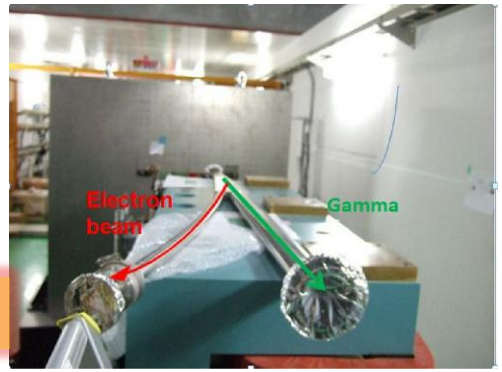

**downstream**




**Collision of e- beam with laser fringe**

**Beam deposited safely into dump**

**Cross laser paths at IP form Interference fringes**




Only currently existing device capable of measuring σy < 100 nm !!

# Expected performance and resolution

$$\sigma_y = \frac{d}{2\pi}\sqrt{2\ln\left(\frac{|\cos(\theta)|}{M}\right)}$$

$$d = \frac{\pi}{k_y} = \frac{\lambda}{2\sin(\theta/2)}$$

| Crossing angle θ | 174° | 30° | 8° | 2° |
|---|---|---|---|---|
| Fringe pitch d | 266 nm | 1.028 μm | 3.81 μm | 15.2 μm |
| Lower limit | 25 nm | 100 nm | 360 nm | 1.4 μm |
| Upper limit | 100 nm | 360 nm | 1.4 μm | 6 μm |

*Assuming ~ 4 % res.*

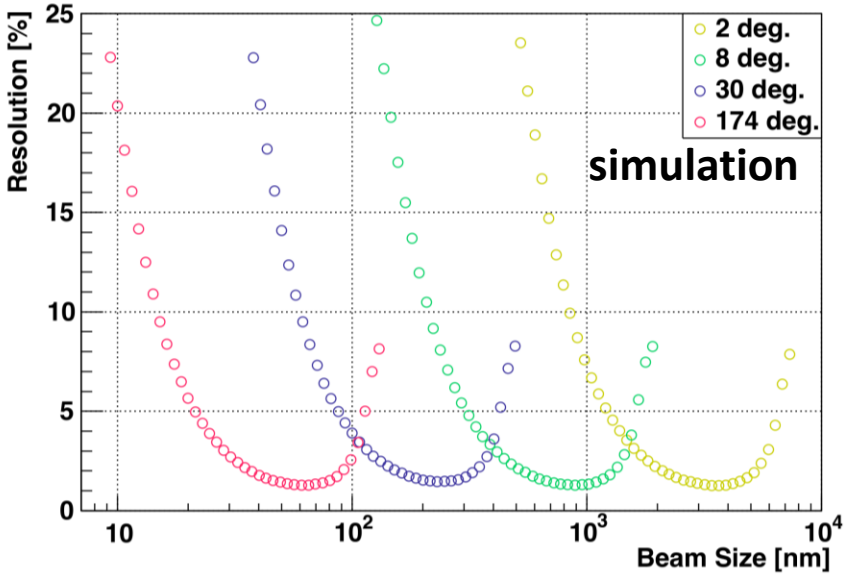
$$37 \pm 1.4\,(\text{stat})^{+0}_{-2}\,(\text{sys})\ \text{[nm]}$$

**Resolution < 10% expected for σy 25 nm ~6 μm**

However…….

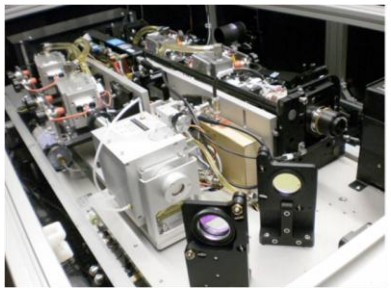
- **degraded for low S/N**
  ~ 15% in Dec, 2010

**Resolution for each mode**



# Post Earthquake Recovery and Confirmation

## Confirmation of system



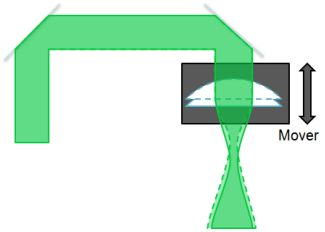
- Inspected each component according to a checklist (see next slide)
- Point is to restore system back to where we left off in the last beam run
- Check for damage (every component!!) , confirm proper function

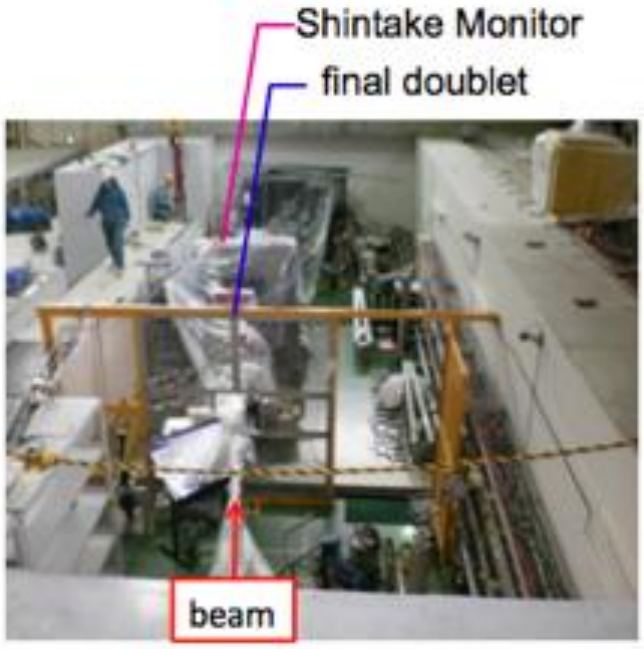
- reconstruct laser path for each mode

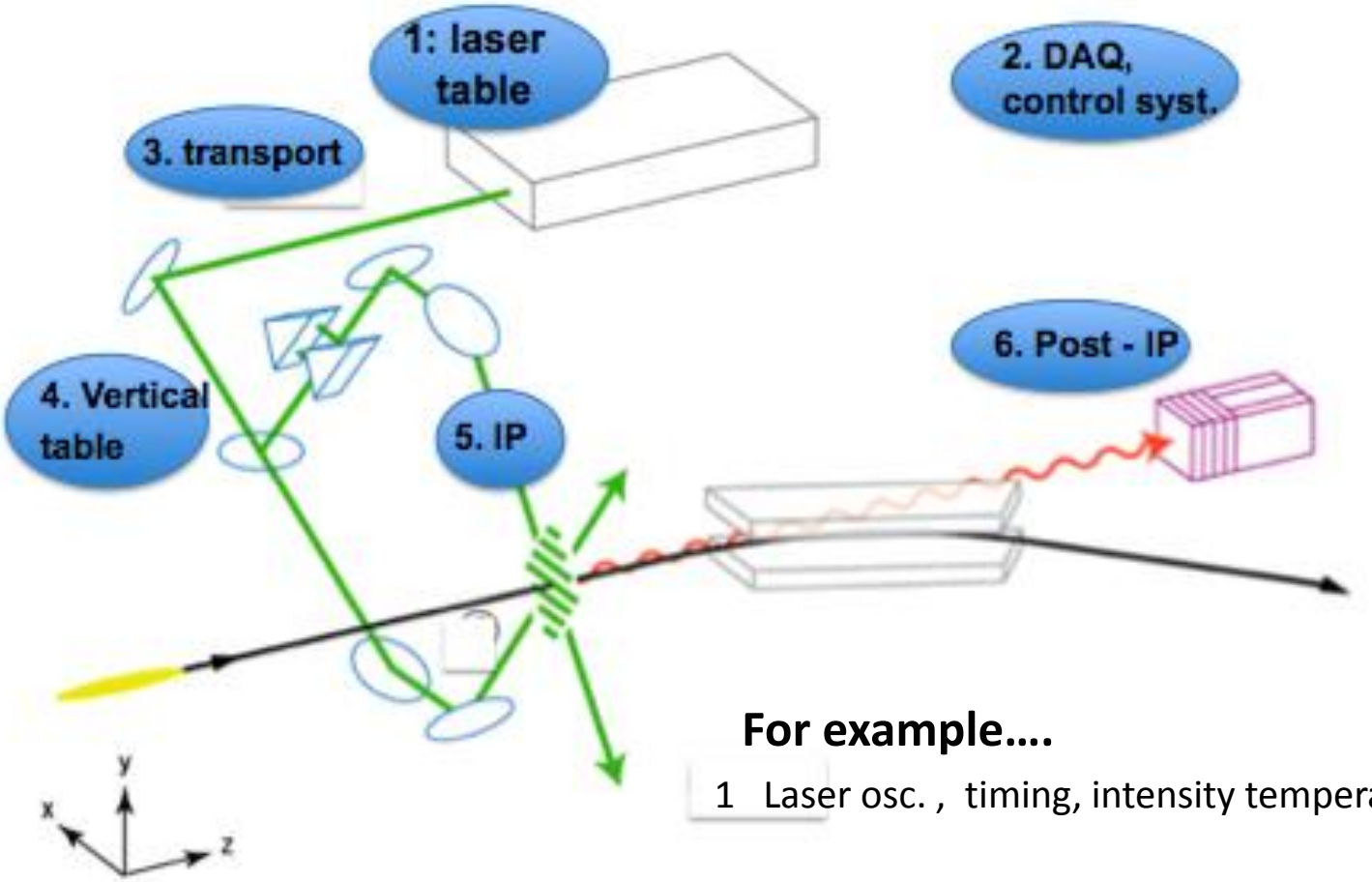
- Confirm with laser wire mode (reducer scan):
  change in size on screen at low power

- Confirm phase scan with phase monitor output

- Additionally focal point scan for 174 deg mode,
  check mover visually






# Checklist

**For example….**

1 Laser osc. , timing, intensity temperature, PSD

2. DAQ modules, ADC, VME, EPICS, controller stages, read out state
3. Interlock, attenuator, profile

4. Optical components, reducer, PSDs, optical paths
5. Screen monitor, IP mover, viewport safety

6. detector, collimator scan, BG monitor

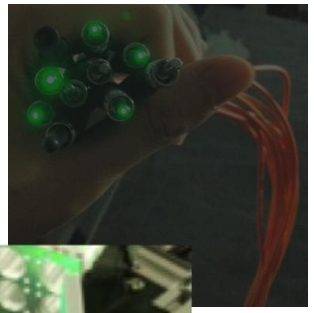
# Current confirmation status

| region | confirmed | still to be resolved |
|---|---|---|
| 1 laser table | Oscillator, flash lamp<br>Timing, power<br>Temp dependence | |
| 2. DAQ,<br>control system | DAQ modules (ADC, VME,...)<br>Controller stages<br>Thorlab actuators<br>EPICS, data logger | status read out from ATF-menu<br><br>***Will finish these up soon before beam run begins*** |
| 3. Transport | Laser profile<br>interlock<br>attenuator | |
| 4. vertical table | Optical components<br>Laser path (2 deg)<br>PSD , PD signals | PSD caliberation<br>Laser path for all modes |
| 5. IP | IP mover, screen monitor | PSD caliberation<br>Viewport safety test |
| Post-IP | Detector ***comprehensively!!***<br>BG monitor | Collimator scan |

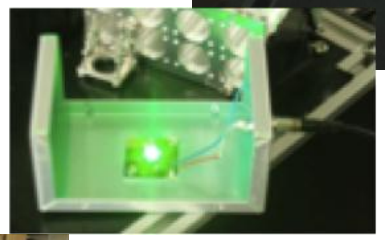
# Checked every gamma detector component !!

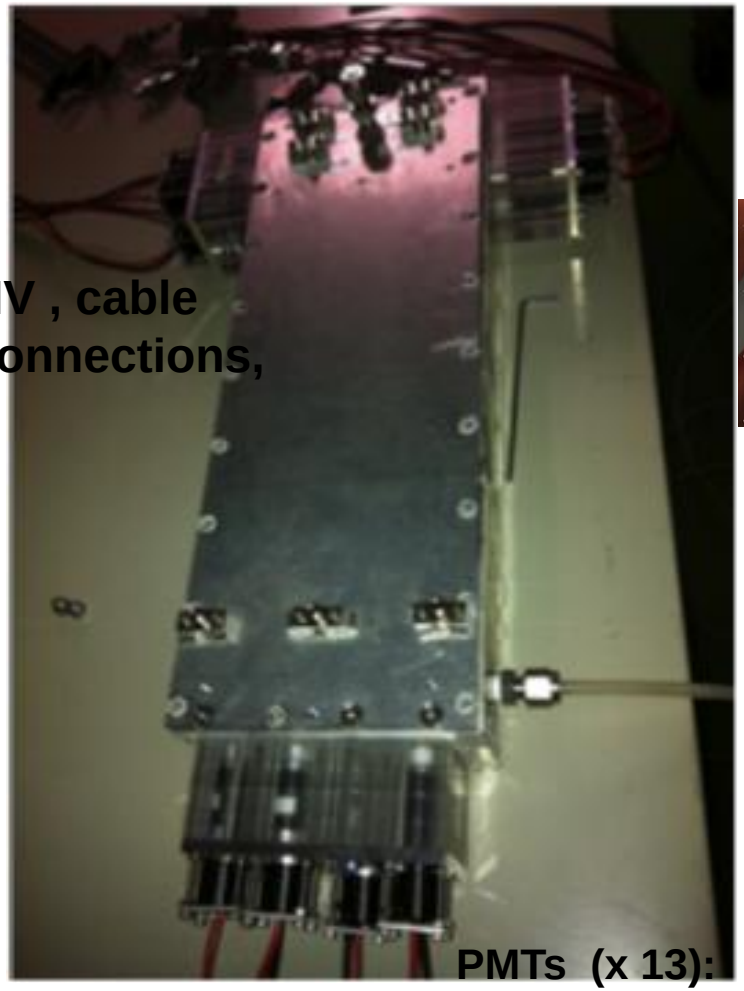
comprehensive check of damage , signal readout, ect…

➔ Reassembled, careful of firm connections



**LED, exchanged ref. fibers**

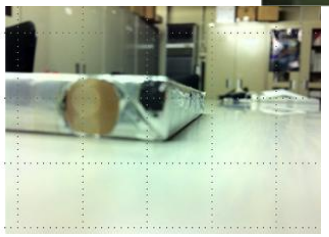




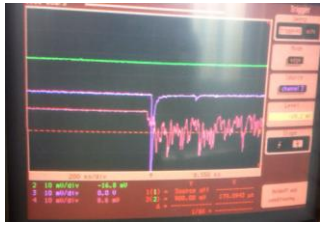
**HV , cable connections,**

**CsI(Tl) x 7 layers: no eliquescency**

**2007** **2011**



**now all confident and in mid of cosmic ray test (detector recaliberation)**



**PMTs (x 13): windows ok Proper gain**

# Hardware Upgrades

For ……..

- smooth commissioning of higher deg modes
- improving beam size resolution

# Beam size status

**Run of May, 2010**

**"10 x $\beta_y$* optics"** low BG, high S/N

$$\sigma^*_y, \min. = 310 \pm 30(stat.)^{-10}_{-70}(syst.) \quad nm \qquad @8\deg$$

**Run of autumn, 2010 – early 2011** **back to nominal optics** $\beta_y$*= 0.1 mm

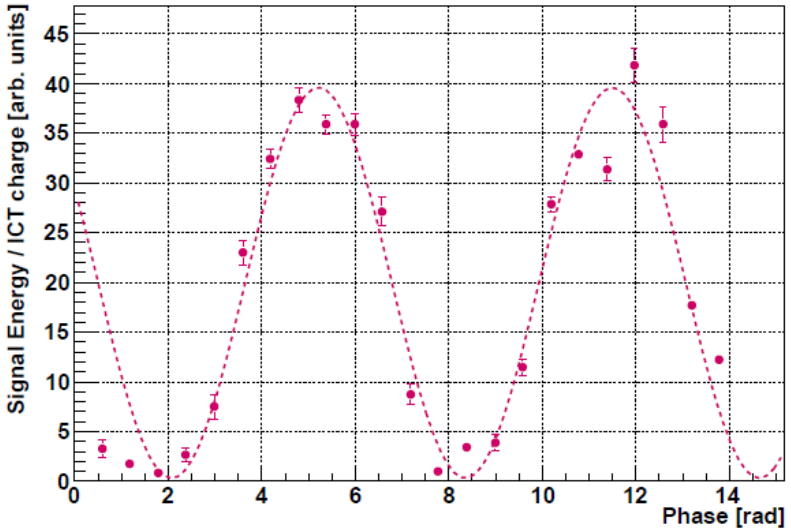
**High BG:**
**~ 40 – 130 GeV**

**Low S/N :~ 0.5**

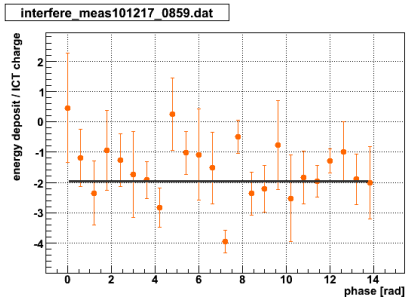
**Minimum beam size:**

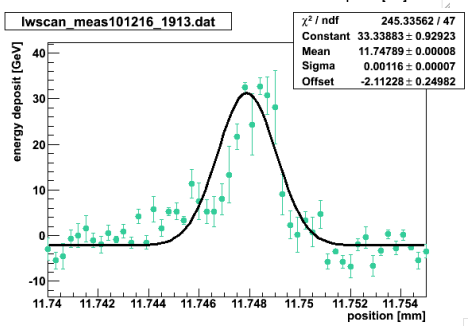
**$\sigma_y$*= 280 ± 90 nm**
**$M_{meas}$ = 0.918 ~ 0.984**

(5.96 deg, 14:31 Dec 16, 2010)



# Laser Problems from last beam run




- **Could not move on to 30 deg mode (**12/16 - 17)

*attempted 30 deg directly from 6 deg, should have gone from 8 deg*

- unstable beam intensity

**Laser problems :**

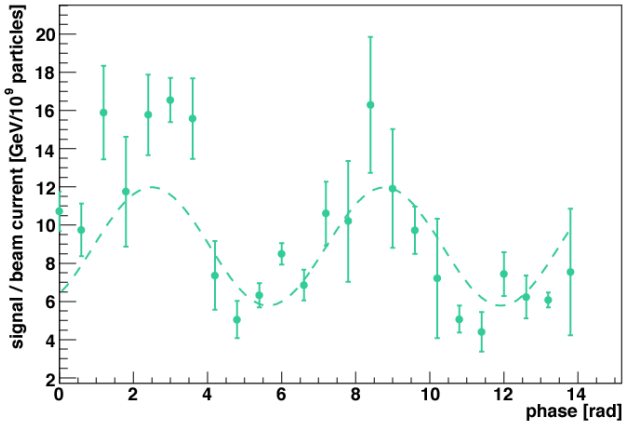
**Unfocused $\sigma_{laser}$ at IP** > 25 μm @ 30 ° ➔ ***low signal, low S/N***

- Laser timing jitters hindered beam-laser collision *resolved !!*

  ➔ Switched to all digital delay control module

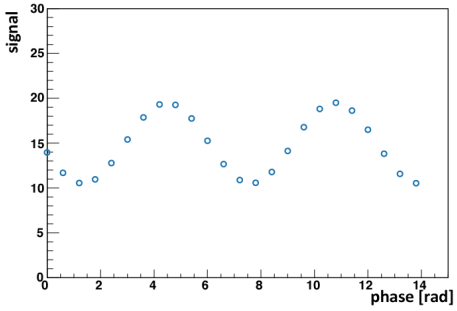
**Signal jitters !!**

ex) **could not reconstruct modulation** when switching to 30 deg mode in Dec due to **large signal jitters > 30%!!!**

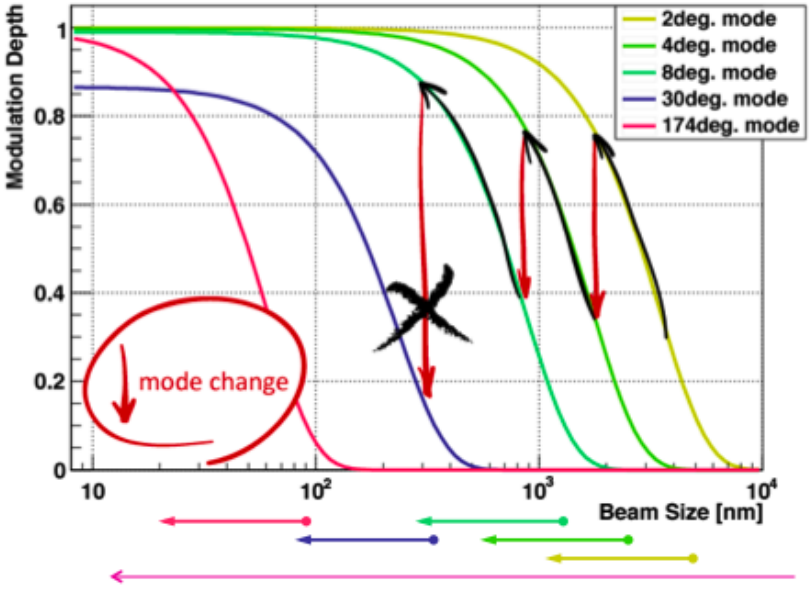



Dec:
M = 0.35
S/N = 0.6
res. degraded to ~ 15%

**c.f. No jitters**



# Major problem !!

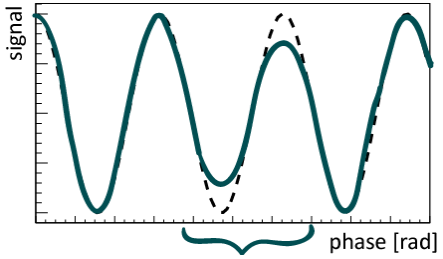



M is lost when:
**signal jitter > ~ M**

**Abrupt modulation drop during mode switching**

## <<Main causes for signal jitters>>

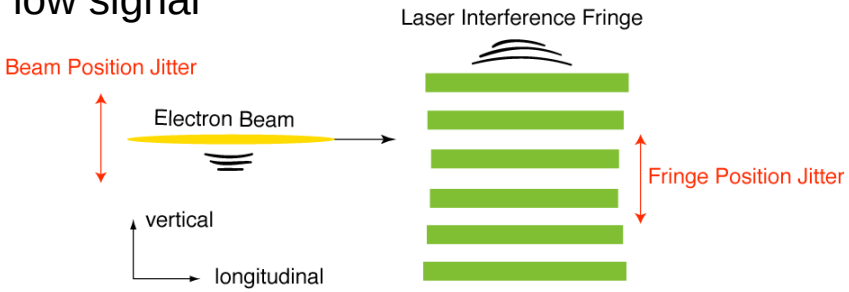
- **High BG, Low S/N**


- **Laser pointing stability**
- **laser profile degradation**, M^2 worsened
  **Unfocused $\sigma_{laser}$ at IP** → laser fringe density, low signal

- **beam size jitter** *(maybe)* （if so, ～ 20%）

- **relative position jitter**
  between beam and laser fringe

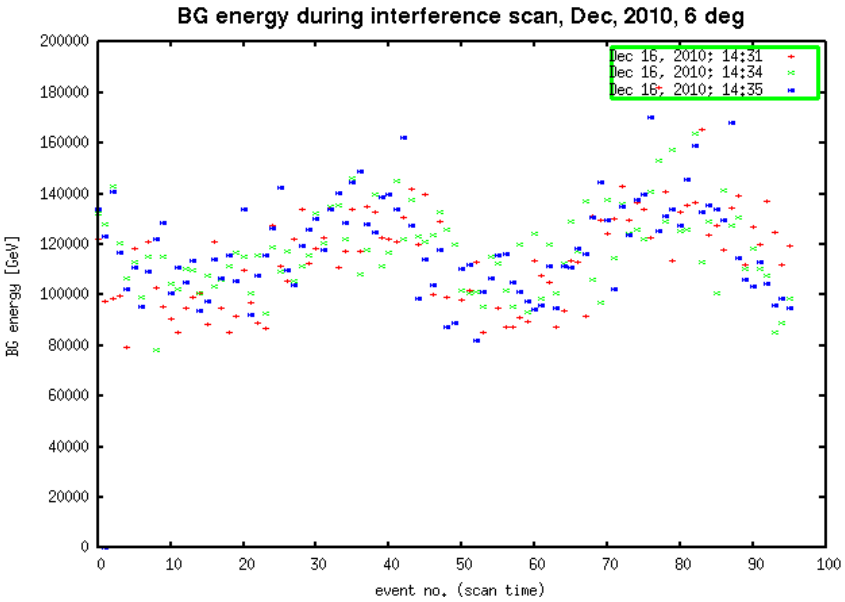


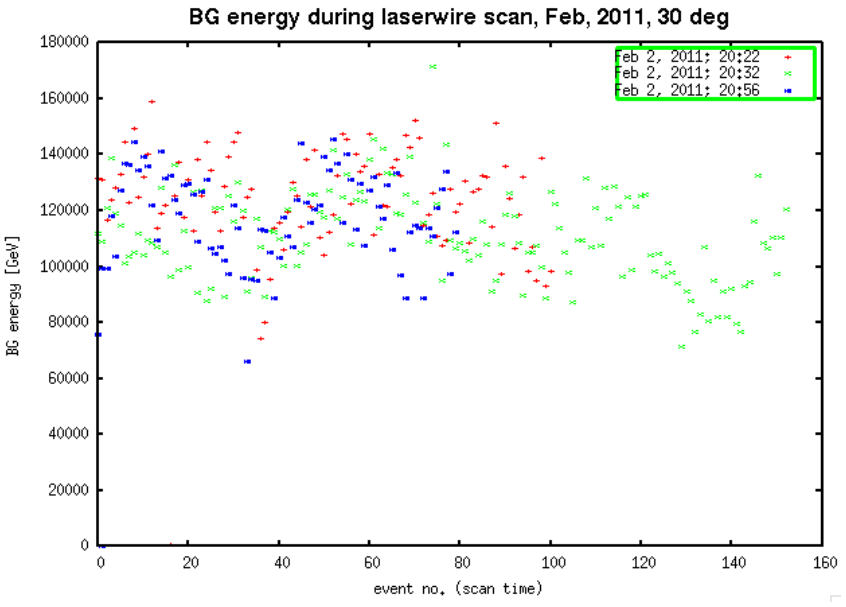
# Comparing typical beam time conditions

| | May, 2010 | Dec, 2010 | Jan-Feb, 2011 |
|---|---|---|---|
| Beam size res. | ~ 7 % | ~ 17 % | |
| Avg BG energy [GeV] | 13 – 20 | ~ 115 GeV | 80 – 130 GeV |
| S/N | 10 - 15 (Max ~ 30) | 0.4 – 0.5 | Min ~ 0.2 |
| Sig. jitter | 8 – 9 % (worst ~ 20% ) | 20 - 30 % | 20 – 60 % |
| Avg Sig. Energy [GeV] | 140 – 250 GeV | 50 GeV | 50 GeV |
| Laser spot size [μm] | 15 – 20 | 6 deg: ~ 20<br>8 deg: 25 – 35 | 35 – 45<br>Min ~ 25 |
| ICT [10^9 e-/bunch] | 4.5 – 5 | 3 | 2 – 5 |

High BG !!

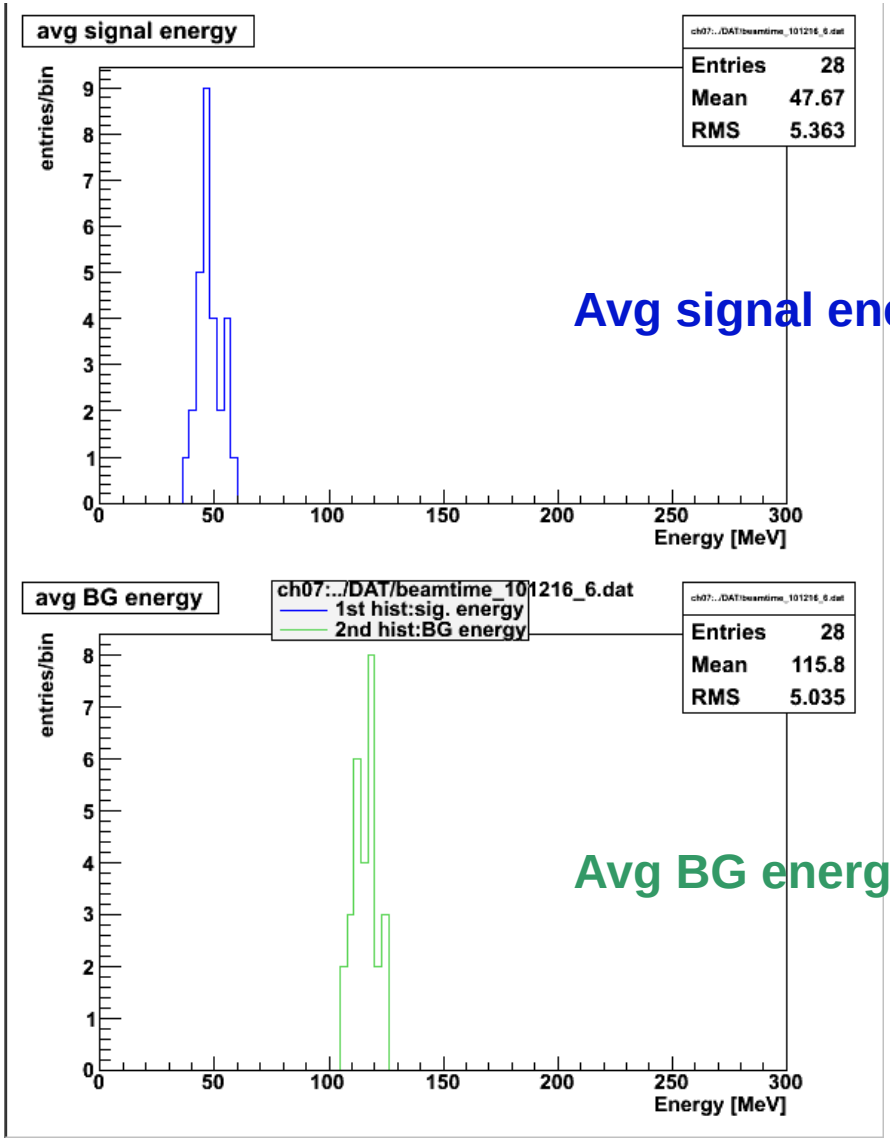
unfocused Laser !!



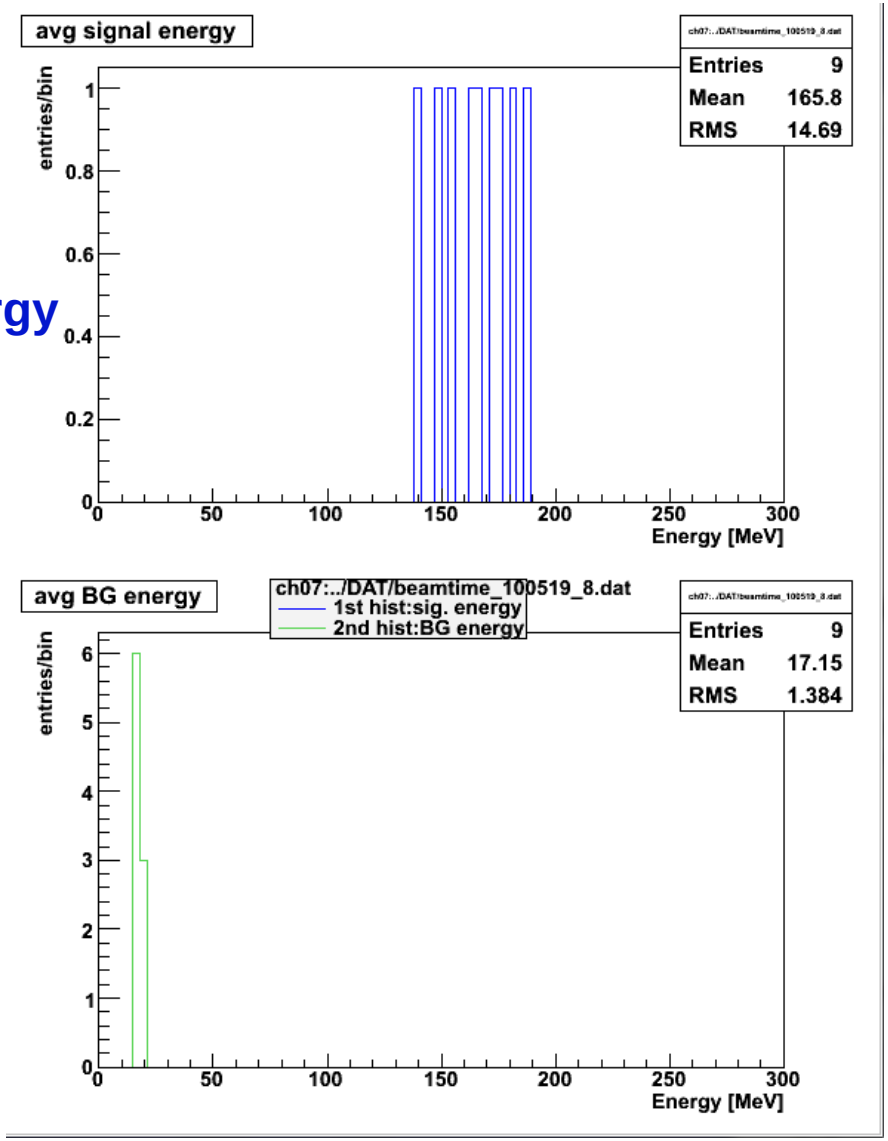



**Dec, 2010**

**May, 2010**




**Avg signal energy**







**Avg BG energy**

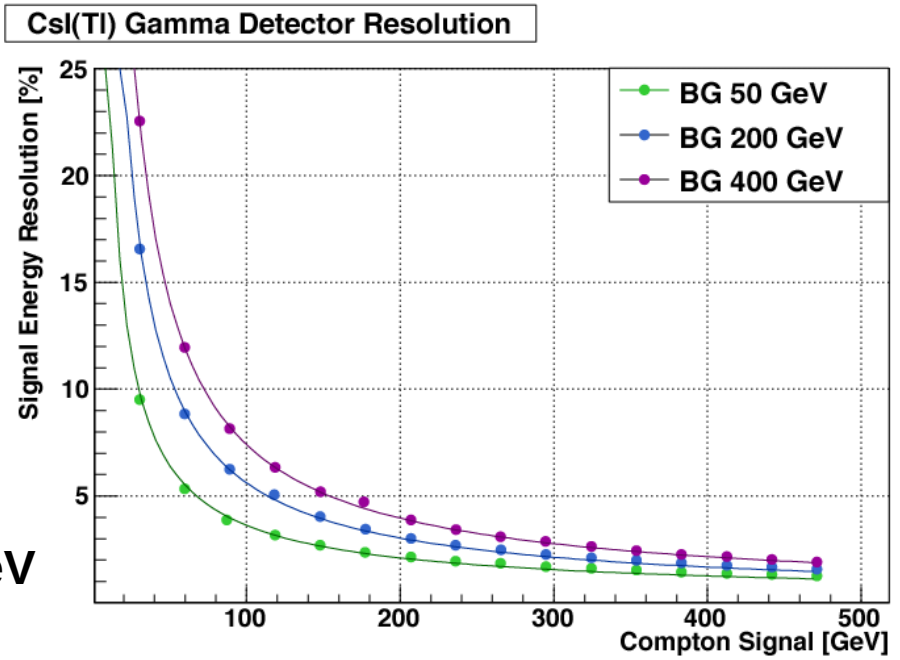
# Requirements for beam time conditions

Simulation under different BG settings

(under ideal signal jitters condition)

*Aim for < 10% resolution*

**Higher BG tolerable if signal > 50 GeV**




| parameters | Requirement / goals |
|---|---|
| **BG energy** | **< 50 GeV** *at least below signal energy* |
| **S/N** | **> 1** |
| **Sig. Energy** | **> 50 GeV** |
| Sig. jitter | < 10% (20% ok if S/N is high) |
| Laser spot size | 10 – 15 µm |
| Laser pointing stability | < 1 µm @ IP ( < 50 µm @ other PSDs on optical tables) |
| ICT [10^9 e-/bunch]<br>ICT fluctuation | Around a typical value : 2.5 – 5<br>< 5% |

$\alpha \rightarrow \alpha + \Delta\alpha$ $y \rightarrow y + \Delta y$ $\sigma_y^2 \rightarrow \sigma_y^2 + (\Delta y)^2$

***Phase jitter*** ***beam pos jitter*** ***beam size***

$$C_{phase} = \exp\left(-\frac{(\Delta\alpha)^2}{2}\right)$$

$$\Leftrightarrow \quad C_{\Delta y} = \exp\left(-2(k_y \Delta y)^2\right)$$

$$k_y = \frac{2\pi}{\lambda}\sin\left(\frac{\theta}{2}\right)$$

$$\Delta y \Leftrightarrow \frac{\Delta\alpha}{2k_y} = \frac{\lambda\Delta\alpha}{4\pi\sin(\theta/2)}$$

| Δα [mrad] | $C_{phase}$ | Δy [nm] @2 ° | Δy [nm] @8 ° | Δy [nm] @30 ° | Δy [nm] @174 ° |
|---|---|---|---|---|---|
| **200** | 0.98 | **485** | **121** | **33** | **8.5** |
| **300** | 0.96 | **728** | **182** | **49** | **13** |
| 400 | 0.92 | 970 | 243 | 65 | 17 |
| 500 | 0.88 | 1212 | 303 | 82 | 21 |

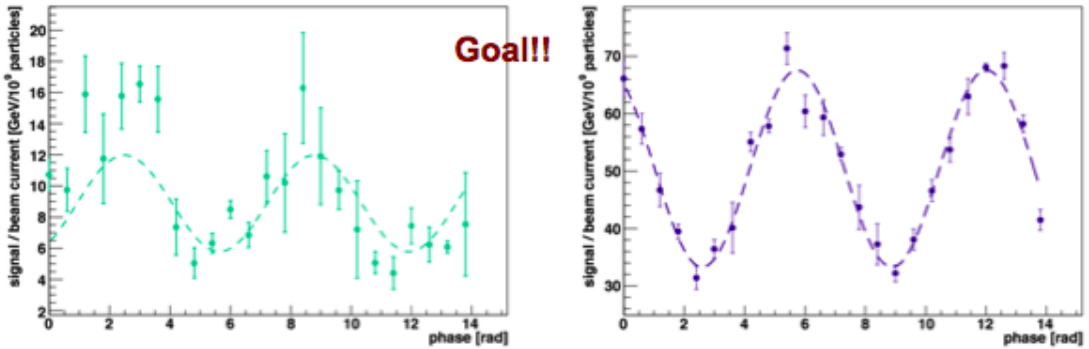
*Correlation between phase jitter and beam pos jitter*

**Typical requirement Δy < 0.3 σy***

| | 2 deg | 8 deg | 30 deg | 174 deg |
|---|---|---|---|---|
| **Beam pos. jitter (Δy ~ 0.3*σy)** | **0.3 x 1 μm = 300 nm** | **0.3 x 500 nm = 150 nm** | **0.3 x 100 nm = 30 nm** | **0.3 x 40 nm =12 nm** |
| IPBPM res. ( < 1/3 *Δy) | < 100 nm | < 50 nm | < 10 nm | < 4 nm |

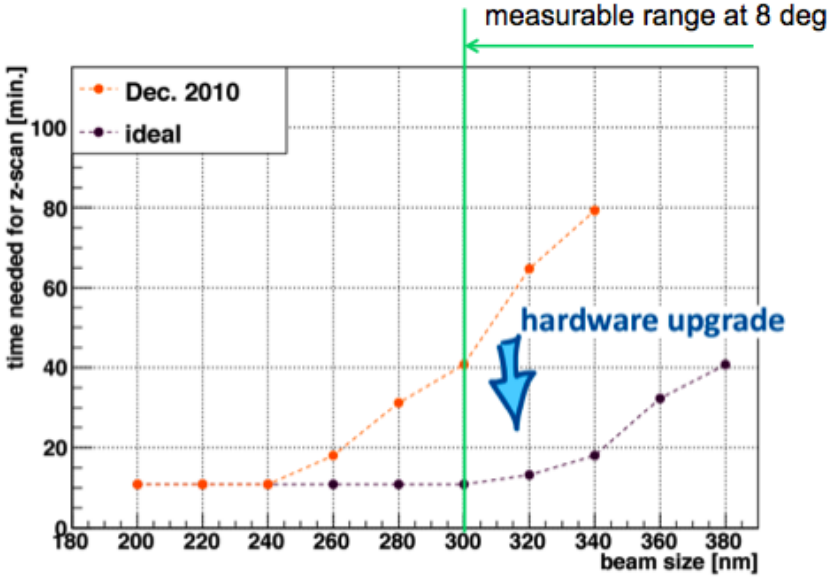
➔ **Phase jitter Δα tolerance : 200 – 300 [mrad]**

# Resolving signal jitters




Then, we can ……
**switch modes quicker and easier**

interference scan under **stable beam and laser conditions**




High BG → intermediate collimator

Beam position → IPBPM + other BPMs

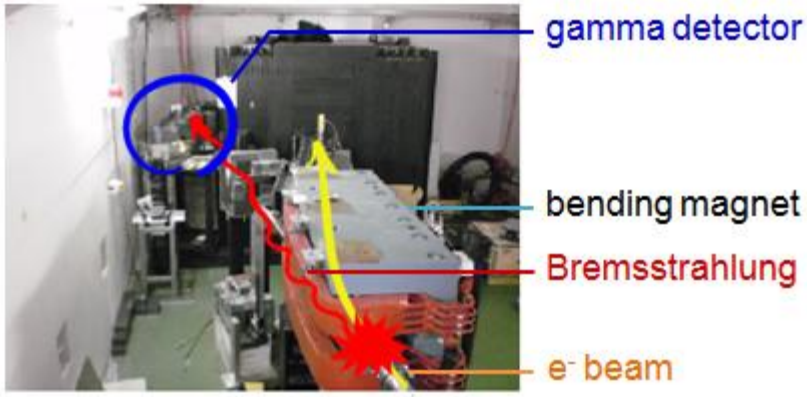
Beam size jitter → new status display

Laser position
→ temperature, vibration stabilization

Laser profile → deep cleaning, IP clean room

**High BG** → **Investigate new BG source ➔ intermediate collimator**

**Extra post–IP BG source**

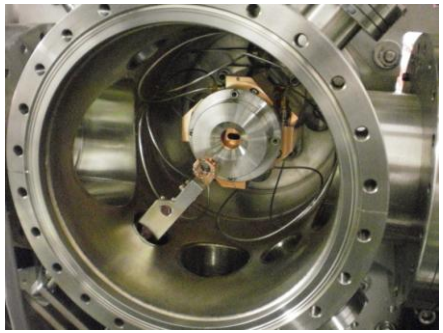



**Beam size jitter** → **New status display**

**Monitor beam profile, magnet current**

**Beam position jitter** → **IPBPM + upstream BPMs**

Requirement for 30° mode, σy ~ 100 nm:
**IPBPM res. < 30 nm**
**Beam position jitter < 50 nm**



New analysis method:
**"atfepics_full"**
Include data of all ATF2 BPMs

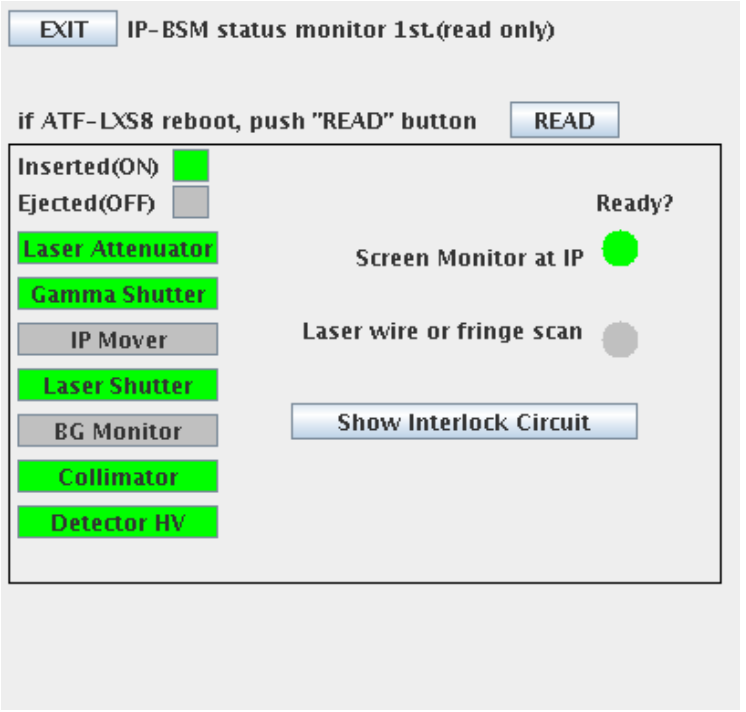
# New status display will also include many other parameters

- IPBSM group may not be present during all beam tuning shifts

  → need status display that anyone can use / understand

- **Green = OK**
- **Red = call a IPBSM member**

**Ex: current status display (I and II)**
cannot provide adequate info




**ex: over 80 parameters in all**

Laser power
Build-Up
Laser piezo
temperature x 14
Nitrogen flow

Attenuator
Gamma Shutter
Laser Shutter
IP Mover
BG Monitor IN/OUT
Collimator
CsI(Tl) HV

ICT-DUMP
CsI(Tl) ADC count
BG Energy
Signal Energy
BG Shower
Signal Shower

Mirror Actuator x 14
Rotation stage x 2
Delay line piezo

IP-BPM → beam position (x, y)
Beam angle (x, y)

Chamber vacuum

Laser Timing
Beam Timing
Laser - Beam Timing

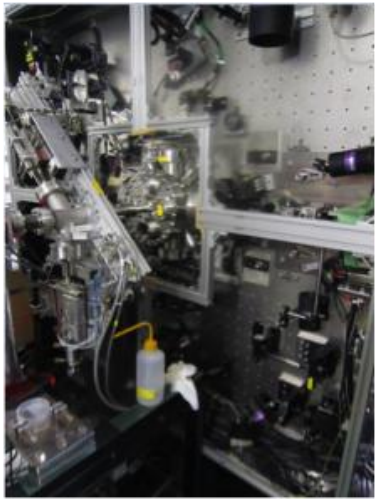
*2 display panels needed (control room, DAQ room)*

## Laser profile

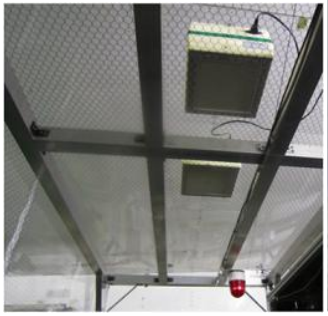
- Deep cleaning of optical components

***Prevention of a series of problems that may have caused unfocused laser***

***→ confirm with laserwire scan***



- Clean room around vertical table with air filter



## Laser position stability

→ **Temperature/ vibration stabilization**

- Installed **temperature sensors around entire laser optics** → data logger
  Systematically monitor / analyze long **laser monitor data** (details coming up)

- **Moved laser power unit** (int. cooling water) to inside of laser hut
  **Temp. control unit +** laser hut insulation reinforcement

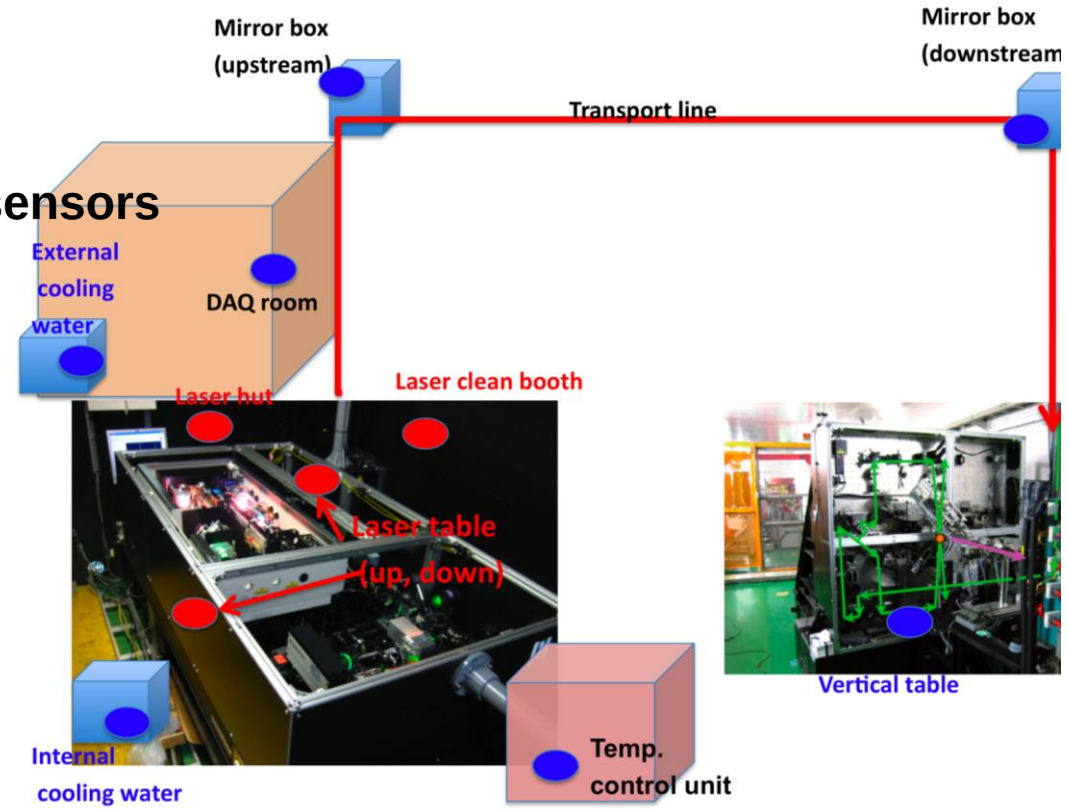
- **insulation and anti-vibration for mirror box in transport line**

Insulation box

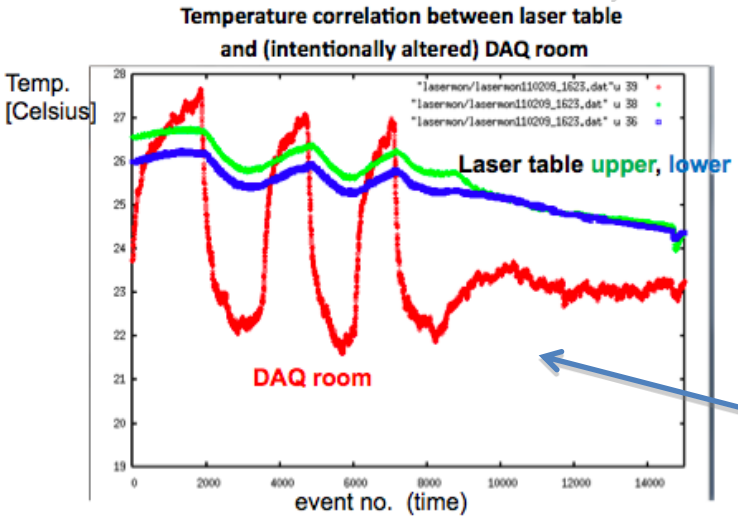
# Laser temperature dependence

**Laser + cooling water sensitive to heat effects!!**

**temperature sensors**




***moved laser power source***

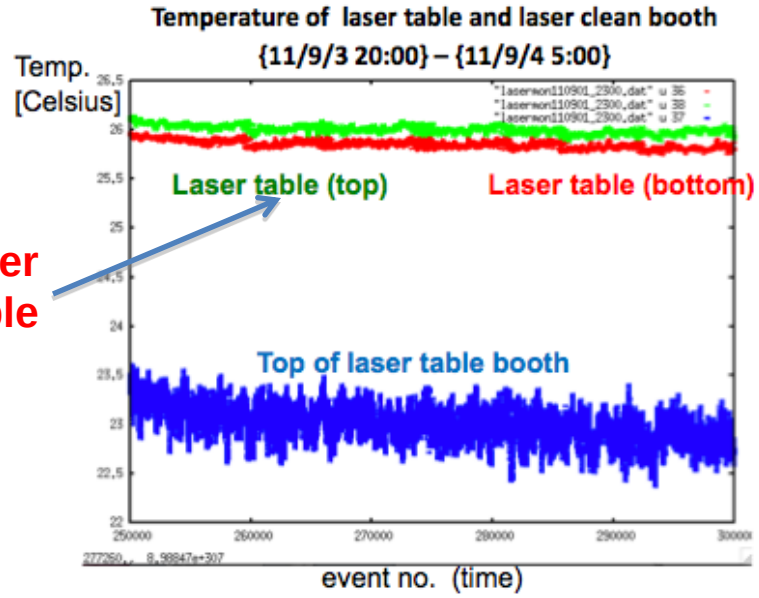


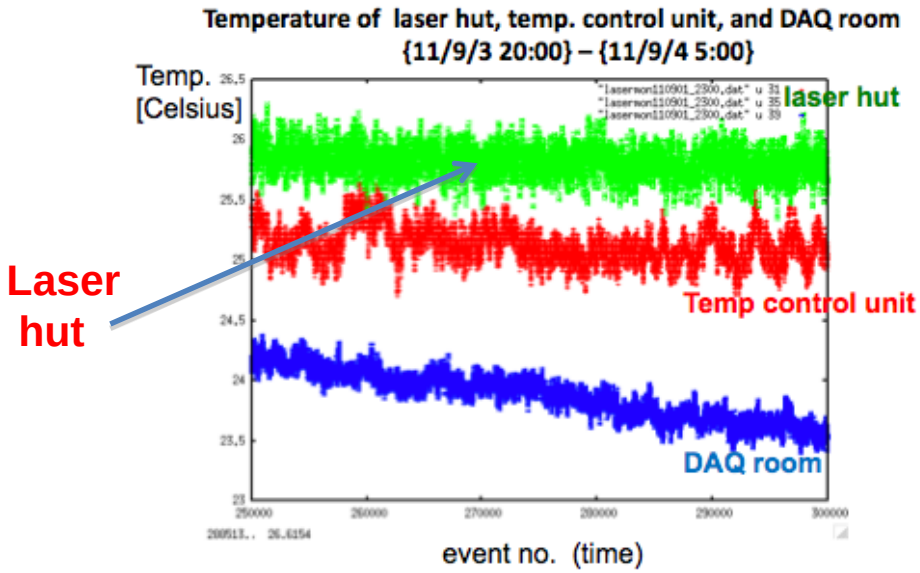

Switched DAQ room AC on /off
to investigate heat exchange
between DAQ room and laser hut
→ Set DAQ room to same temp as
laser hut + insulation added

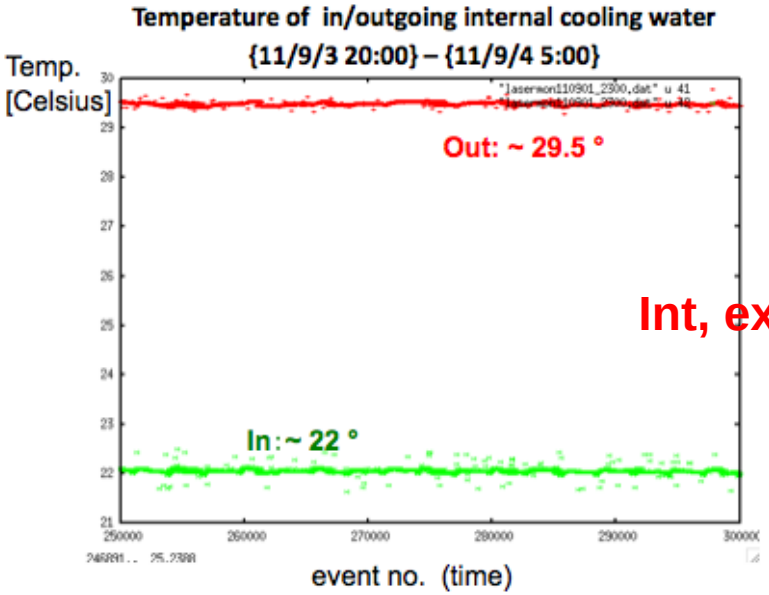
**Now laser temp. very stable!!**

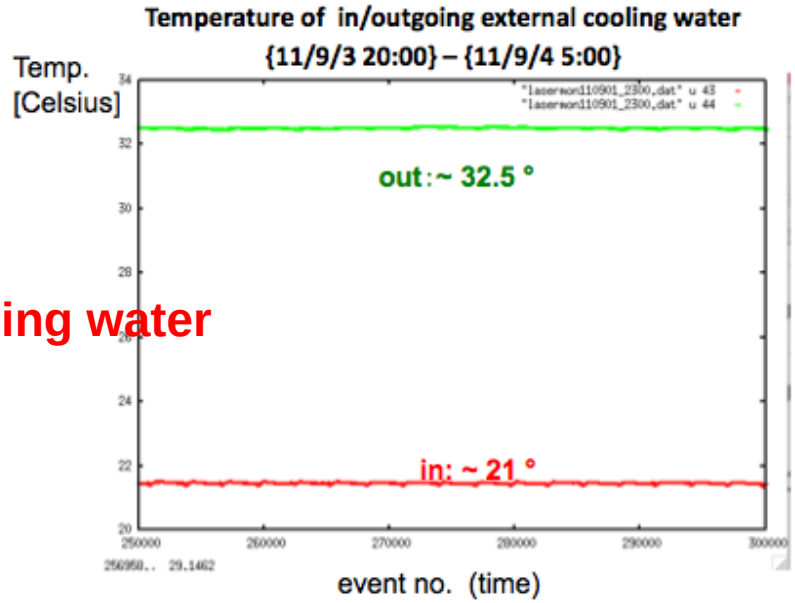
# Example of stabilized temperature #1

*even during a stormy typhoon night !!*




**Int, ext, cooling water**

# Example of stabilized temperature #2

**Current typical values and tolerated fluctuation（ after 8/30 flash lamp exchange）**

**From data over 16 hrs**

| Location | typical values | typical deviation |
|---|---|---|
| temp. control unit | 25 - 26 | 0.7 |
| mirror box (upstream) | 29.5 - 31.5 | 2.0 |
| mirror box (downstream) | 29.8 - 30.5 | 1.0 |
| vertical table | 28.2 | 0.1 |
| air pipe in laser hut | 25.8 | 0.3 |
| laser table (lower) | 25.8 | < 0.1 |
| laser table (upper) | 26 | < 0.1 |
| top of laser clean booth | 23 | 0.5 |
| DAQ room | 23.5 | 0.2 |
| internal cooling water (in) | 29.5 | |
| internal cooling water (out) | 32.5 | |
| external cooling water (in) | 21 | |
| external cooling water (out) | 32.5 | |

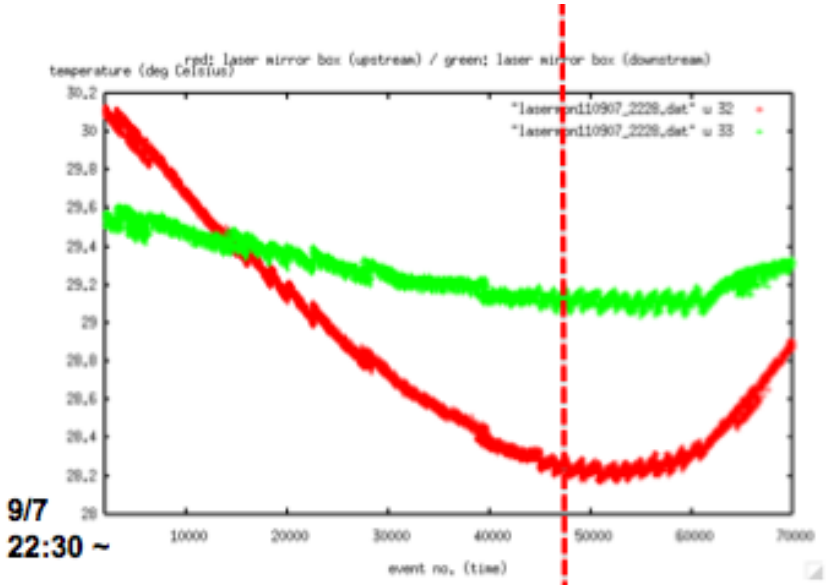
**Very small variation at laser table**

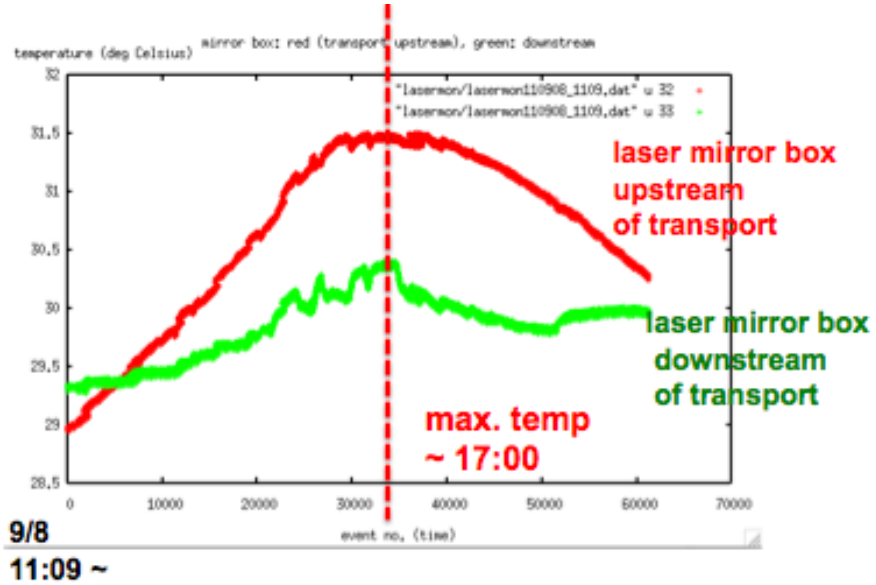
**< 0.1 deg (~ 16 hr)**

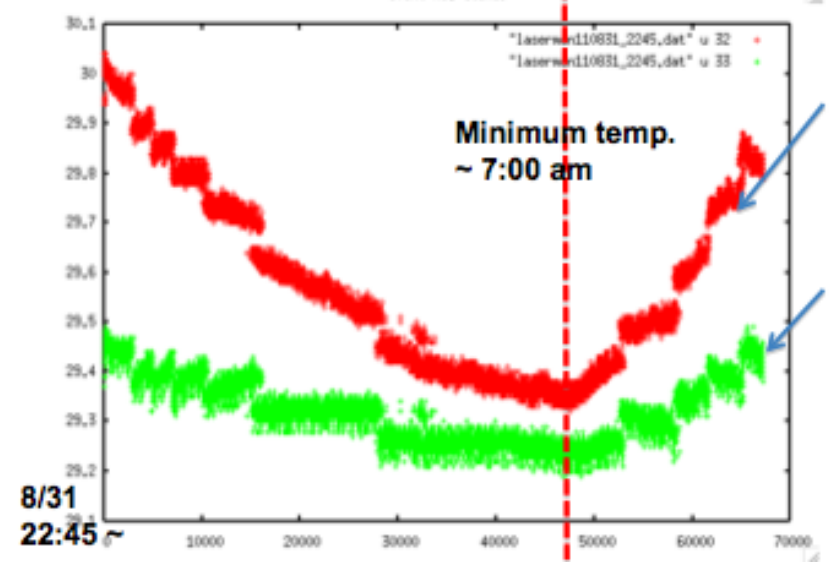
Without external disturbances, **generally very slight fluctuation**

*May be showing effect of temperature stabilization*

# Example of stabilized temperature #3




laser mirror box
upstream
of transport

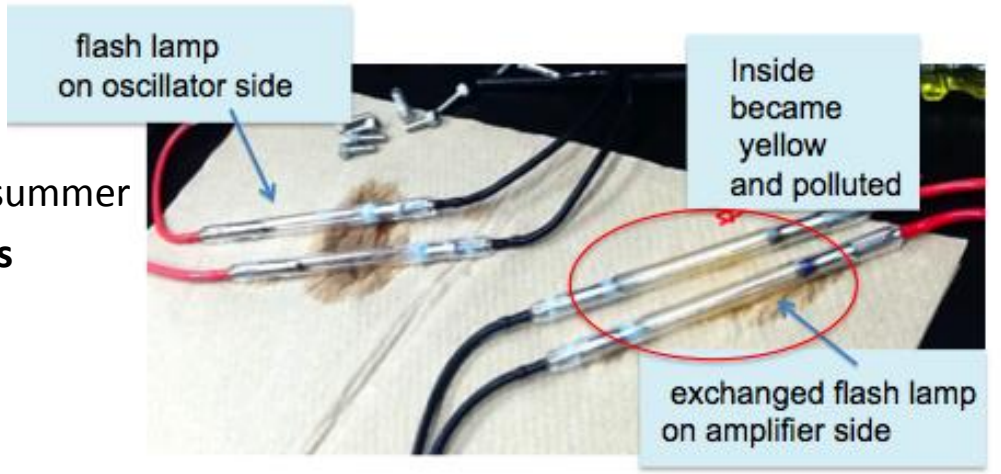
laser mirror box
downstream
of transport

**Temp response pattern**
**for mirror box in transport line**

(over **~ 16 hrs**)

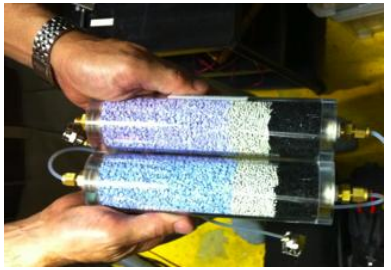
time for lowest and highest
temp generally consistent
day to day

# Laser oscillation and interlock




- Laser occasionally failed to simmer on this summer
- **Exchanged mal-functioned flash lamp parts**
- Filter change + power adjustment

Similar problems during last beam run…..
Uncertain of cause (air bubbles?)
Actually may have also been flash lamp + cooling water



*must be cautious to*

- **Check water level, evaporation speed frequently** during long runs
- not only refill, but **exchange all** (no less than once a month)
- water temperature: store box inside laser hut

**Now we can identify and fix problems immediately during beam time!!**

**view/control with PC** (RS232C connection)

- Comprehend error code
- Convenient for detecting time and cause of interlock stop

# Internal Cooling Water Purity

- We measured internal cooling water purity
- Higher value (Unit : Ω cm) = higher purity

| ATF sample [e5 Ω cm] | | | New cooling water | | | Cooling water in tank | | |
|---|---|---|---|---|---|---|---|---|
| 7.12 | 7.19 | | 7.56 | 7.56 | | **8.78** | **8.67** | |
| 7.01 | 6.98 | 6.96 | 7.55 | 7.55 | 7.53 | **8.65** | **8.65** | **8.56** |
| | | | Similar values in Jan 2011 | | | | | |

- Water already in tank is even purer than new water from box!!!
  → proves **water filter functions well**

# Laser recovery

**after abrupt interlock stop, laser may be unfocused, unstable for a while**
**Investigated recovery time** → *prepare for similar cases during beam run*

Different components show diverse recovery time

*Intentionally stopped laser for ~ 10 minutes*

| parameter | Recovery time |
|---|---|
| Build-up, piezo | ~ 4 s |
| Timing (PIN-PD), intensity | ~ 12 |

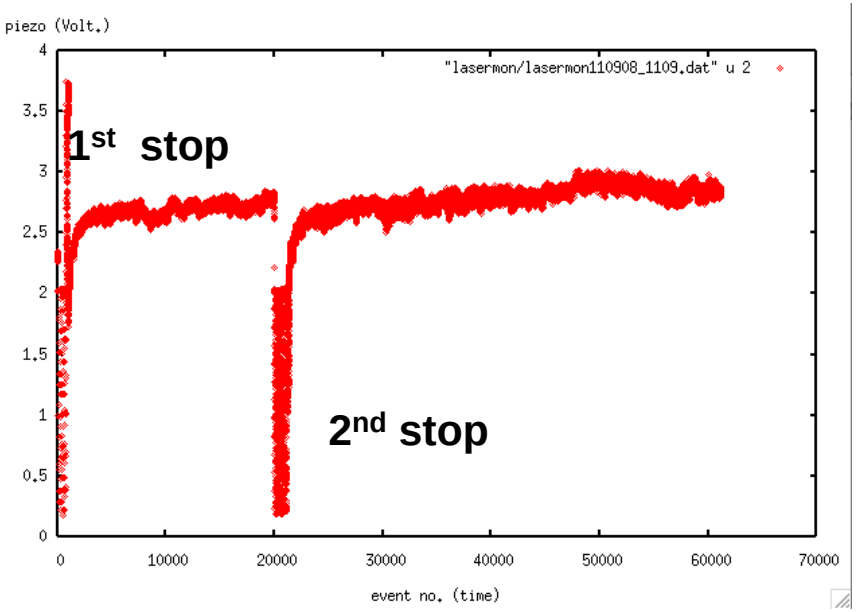
| location | Recovery time |
|---|---|
| Laser hut | ~ 2 min |
| Laser table | ~ 15-25 min |
| Cooling water (internal/external) | ~ 10-20 min |
| Laser mirror box | Very slow to respond<br>Almost no effect for short stops |

**May have effect on operation**

investigated relationship between piezo and build-up timing

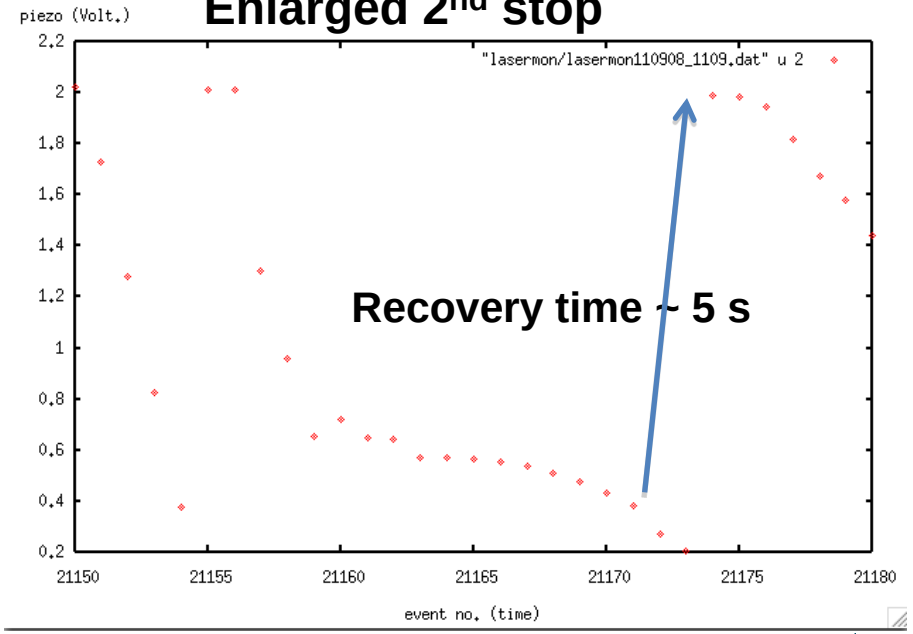
- **without external disturbances: Stable build-up 、piezo、timing, temp. dependence**

# Example of recovery investigation #1

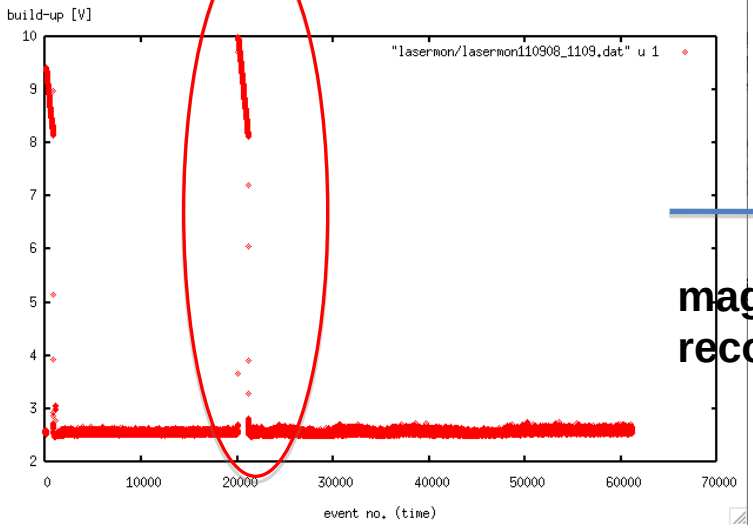



## Piezo in laser cavity

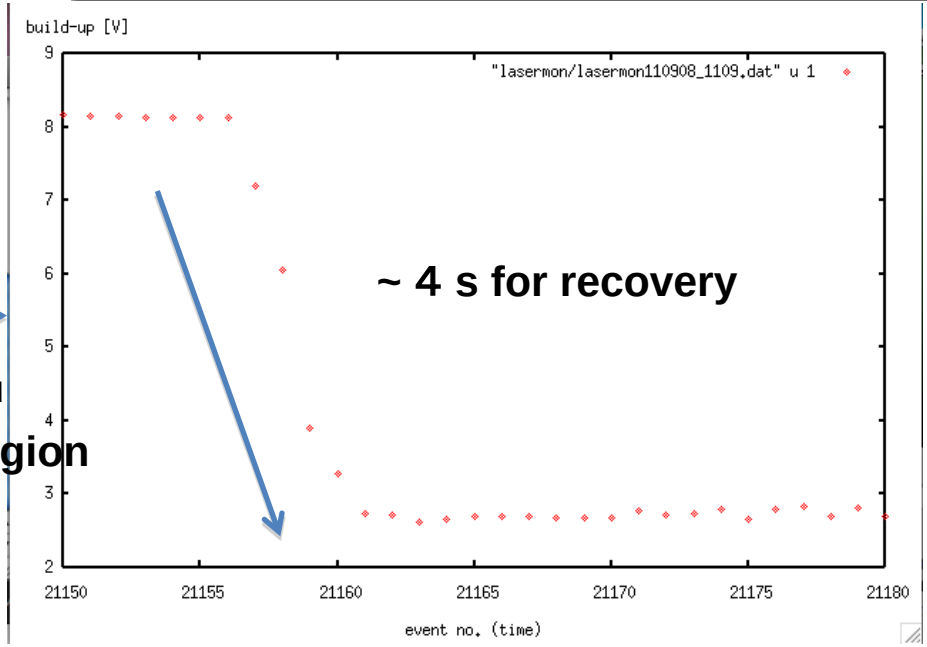
## Enlarged 2nd stop




## Laser build-up time

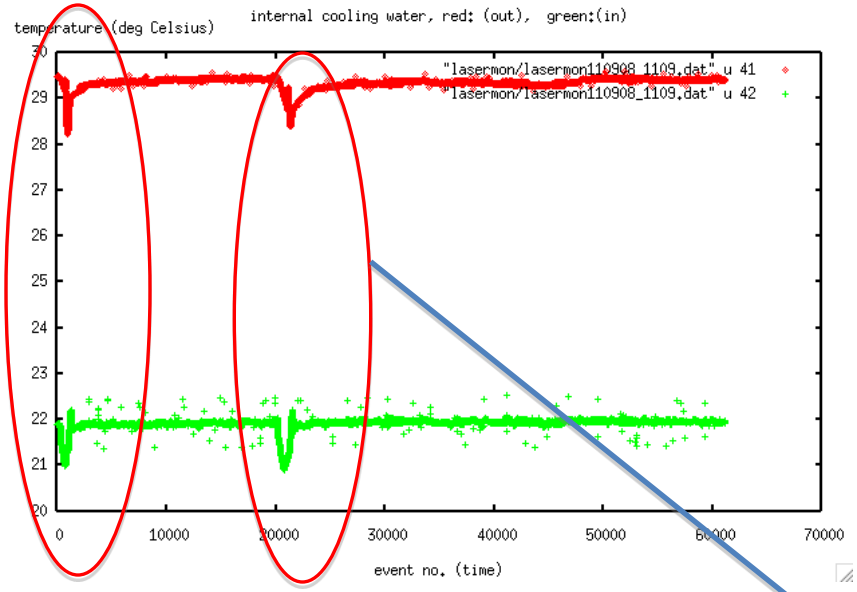



magnify 2nd recovery region



# Example of recovery investigation #2

**1st stop** **2nd stop**




**enlarge 2nd stop**

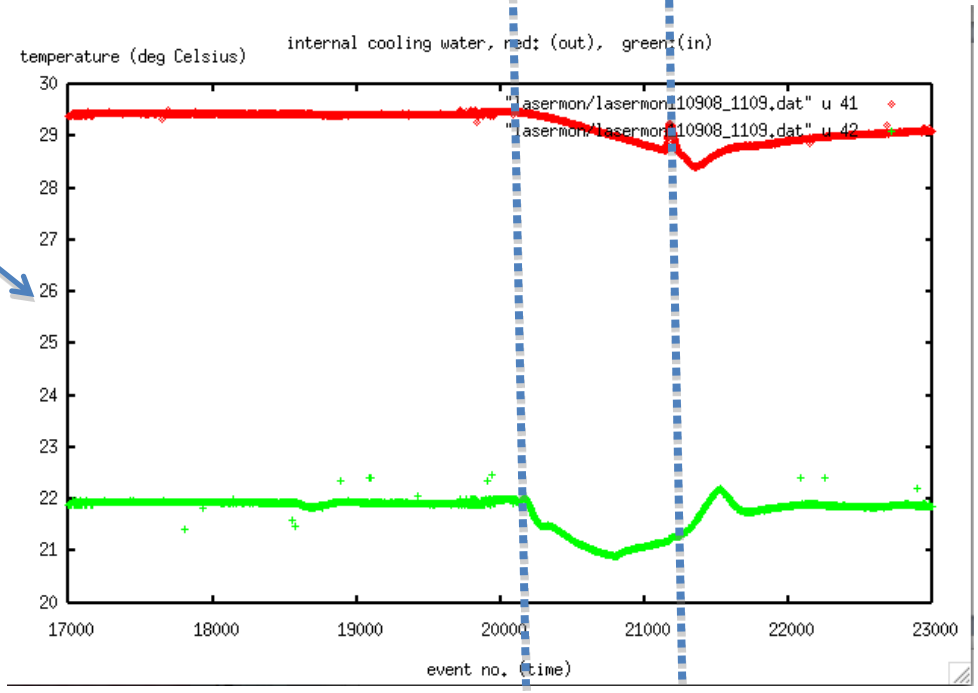
**Internal cooling water**

**out** **in**

**10 ~ 20 min until recovery**

Similar with external cooling water

**stop** **restart**



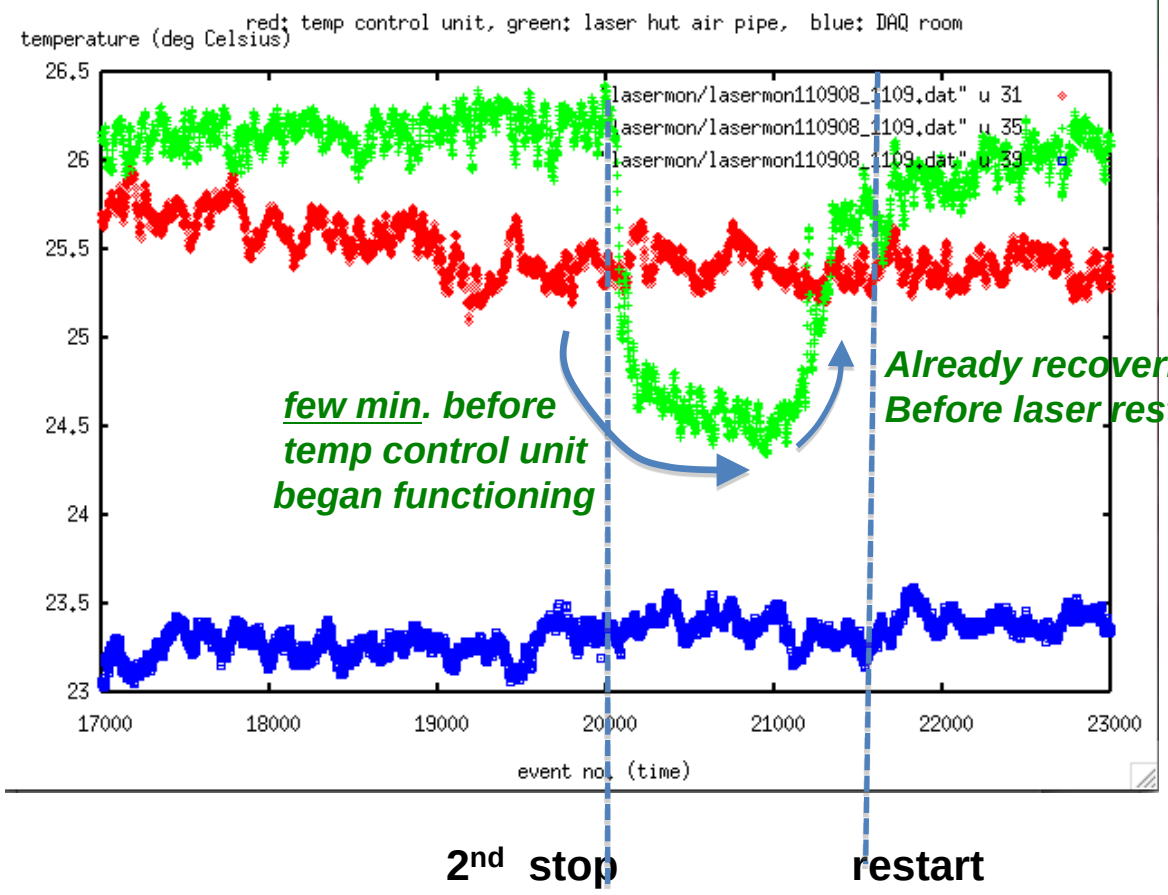
# Example of recovery investigation #3

## Laser hut temperature

Temp.control unit room

Laser hut

DAQ room




Response of laser hut temp. **demonstrates function of temp. control unit** (next to laser hut)

**total recovery time ~ 20 min.**

DAQ room and the temp. control unit room did not show changes due to the intentional laser disturbances.

## Need dedicated beam time for evaluation of beam size resolution

**continuous 10 – 20 times of interference scans**
**under favorable and consistent conditions !!** (stable beam and laser, S/N, ect…)
**repeat for each mode** to check for res. consistency

**about 45 min each mode ( ~ 3 hrs in all)**

**Our responsibility!!**

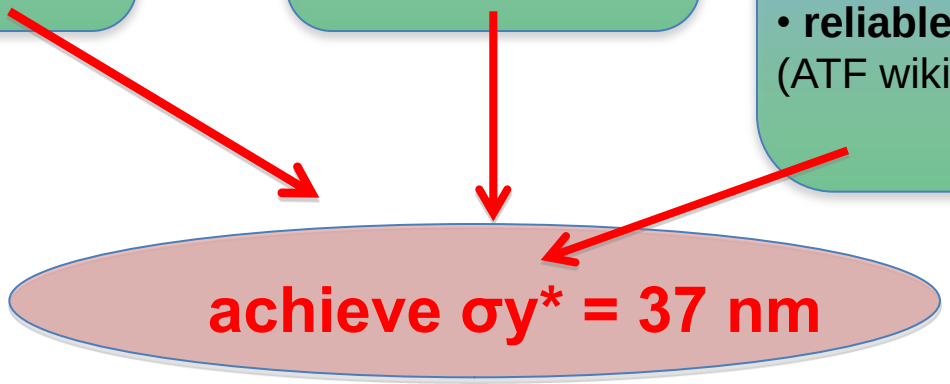
**hardware upgrade to prepare for smooth commissioning of 30 , 174 deg modes**

**Between all ATF2 groups**

**Favorable beam conditions**

**IPBPM !!**

**well planned shifts**
- **effective decision making** during beam tuning **(**esp. during mode switching**)**
- **reliable info sharing** (ATF wiki, internal reports**)**




*important for M. Oroku's D thesis*

# Summary

- **IPBSM "Shintake Monitor" :**
- **Only existing device capable of measuring σy* < 100 nm**

➔ **Indispensible for beam tuning and realizing ATF2 goals**
(+ realizing future linear colliders!!)

- **Recovered from earthquake**
  and in **preparation for upcoming beam run**
- Past problems include **signal jitters** (laser, beam, BG…)

➔ well investigated and planned **hardware upgrades** during summer

# Plans : autumn, 2011 ~

**Complete confirmation and upgrade for all modes**

**Smooth shift to 30 , 174 deg mode**
from 8 deg mode

**Close collaboration**
**with all beam tuning groups**

**achieve focusing down to 37 nm**

- BACKUP

# Example of stabilized temperature #2

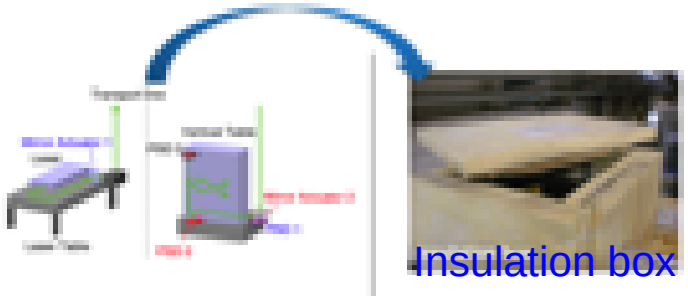
**Current typical values and tolerated fluctuation（ after 8/30 flash lamp exchange）**

| Location | typical values | typical deviation |
|---|---|---|
| temp. control unit | 25 - 26 | 0.7 |
| mirror box (upstream) | 29.5 - 31.5 | 2.0 |
| mirror box (downstream) | 29.8 - 30.5 | 1.0 |
| vertical table | 28.2 | 0.1 |
| air pipe in laser hut | 25.8 | 0.3 |
| laser table (lower) | 25.8 | < 0.1 |
| laser table (upper) | 26 | < 0.1 |
| top of laser clean booth | 23 | 0.5 |
| DAQ room | 23.5 | 0.2 |
| internal cooling water (in) | 29.5 | |
| internal cooling water (out) | 32.5 | |
| external cooling water (in) | 21 | |
| external cooling water (out) | 32.5 | |

Much smaller temperature gap between laser mirror boxes upstream and downstream of transport
→ effect of insulation box

**Typical value in Feb,2011**

| | |
|---|---|
| mirror box (upstream) | 18 |
| mirror box (downstream) | 21 |




*Without external disturbances,*
***generally very slight fluctuation***

# Ray PRO interlock system

**Laser head**

- **Cover**

**Cooling water**

- flow amount
- Temperature

**Cable connection**

**Laser power supply**

- **Cover**

- **Internal cooling water**
  - Amount inside tank
  - Flow amount

- **External cooling water pressure**

- **" accessory plug" :**
  external interlock plug

**Controller (on top of power supply)**

- Connection to interlock

**Possible causes for laser start up failure**

(1) **External cooling water pressure**

(2) **Internal cooling water:**

- too close down to limit
- Insulation deficit (purity)

(3) **Flash lamp degradation**

(4) **HV** system faults

ect.....

# Interlock Checklist

- ✓ Switch on **external cooling water:** **pressure 2.5～4 MPa**
- ✓ **Cover of laser head and laser power supply in place**
- ✓ **External interlock key switched OFF**
- ✓ **Enough internal cooling water** inside tank
  "Low Water" indicator lamp OFF
- ✓ **Lamp energy at START** position (on controller)
- ✓ **Switch ON "ENABLE"**
  ➔ Pump begin revolving ➔ "Interlock fault" indicator lamp go OFF

**CDRH should go off and Simmer ON within 10 – 15 sec**

# DAQ modules and controllers **Checklist**

laser attenuator

SHOT204:  IP mover ,  collimator

D250  rotating stage, prizm stage,  focal point scanner,

gamma shutter

ip-ccnet

TD4

laser shutter

BGモニタ

RPV171V005L

Discriminator

Thorlabs actuator

TDC

GNV150

Data backup

Actuator for each mirror

Able to move from cpmmand line, from atf-menu, EPICS

 atfepics_full

 read out state

AVME500 (phase monitor)

 RPV130

- PSD x 12
- Phase monitor x 2
- Laser power
- Build-Up
- Laser piezo
-
- Attenuator
- Gamma Shutter
- Laser Shutter
- IP Mover
- BG Monitor IN/OUT
- Collimator
- CsI(Tl) HV
-
- Reducer
- TD4
- Prism Stage
- Focal Point Scanner (upstream)
- Focal Point Scanner (downstream)
-
- Cross Angle
- ICT-DUMP
-
- CsI(Tl) ADC count x 12
- BG Energy
- Signal Energy
-
- Laser Timing
- Beam Timing
- Laser - Beam Timing

- Mirror Actuator x 14
- Rotation stage (upstream)
- Rotation stage (downstream)
-
- Delay line piezo
-
- temperature x 14
- Nitrogen flow
-
- IP-BPM → beam position (x, y)
- Beam angle (x, y)
-
- Chamber vacuum
-
- BG Shower
- Signal Shower
-

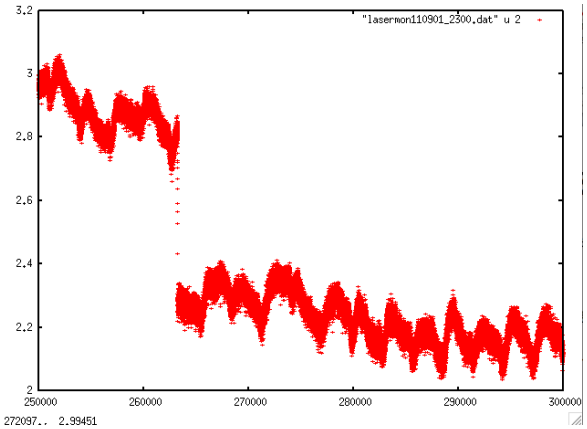
86! parameters to monitor

2 display panels needed (control room, DAQ room)

**Monitor function of piezo- electric elements and build-up, intensity, ect….**

**Ex: abnomal**

**Proper reset**




Proper reset（0V→2V）

correcting heat effects