IP-BSM   Status and Plan

13th ATF2 Project Meeting

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KEK, Tsukuba, Japan

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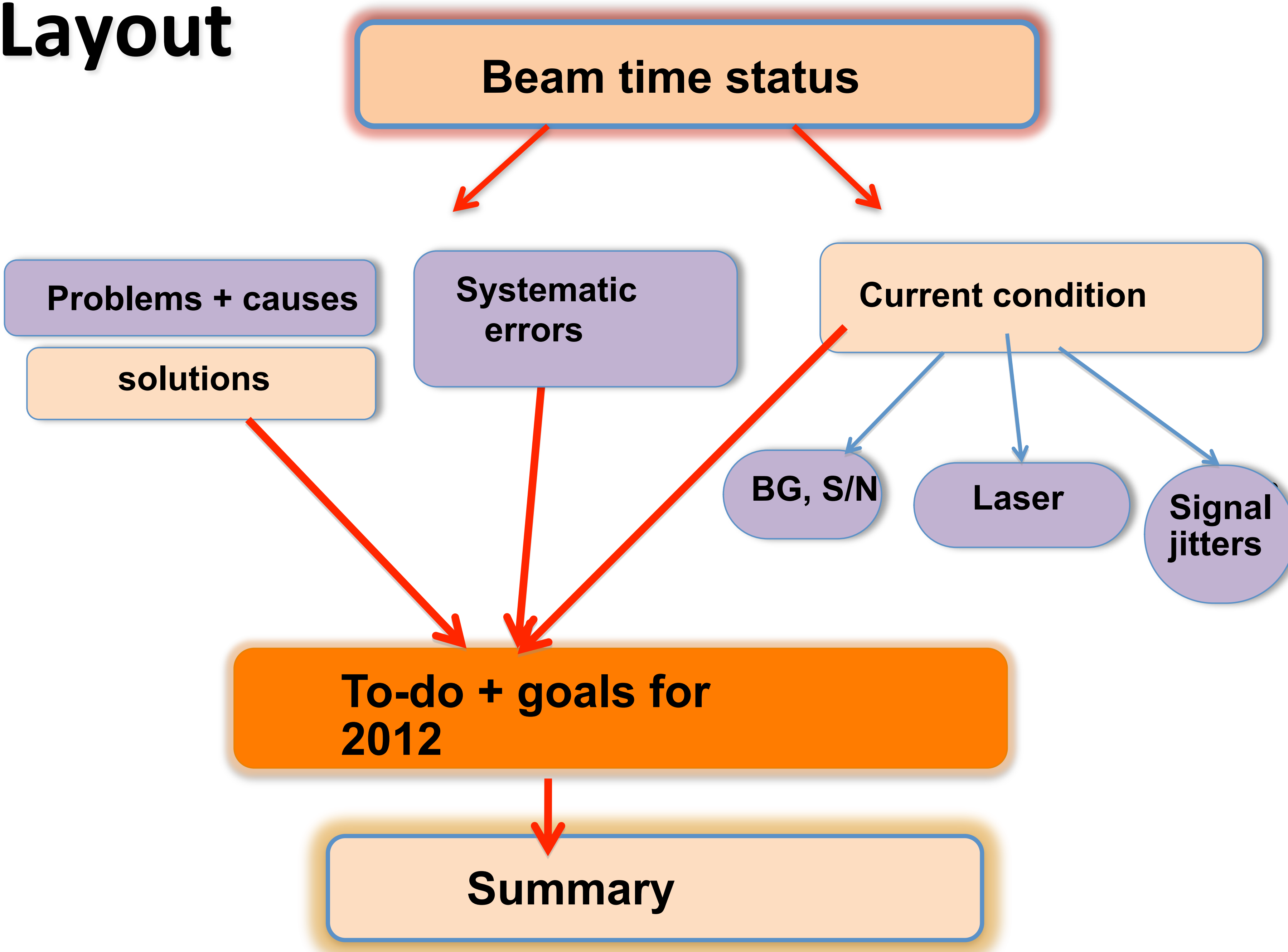
Layout



Beam time status
Problems + causes
solutions
Systematic errors
Current condition
BG, S/N
Laser
Signal jitters
To-do + goals for 2012
Summary

overview

Before beam time (autumn 2011 ~)……..

- Confirmed function for various part of system
- Laser : tuning, inspection, systematic monitoring
- Optimized reducer setting
- Realigned laser transport line
- Improved path alignment method ➔ fast, precise, reproducible *important for mode switching*

Nov 2011 ~ Beam time

◆ 1st week**: commissioned laser wire mode**

Well focused σ_{laser} for both 2 deg and 30 deg modes

◆ **Commissioned interference mode for 2-8 deg mode**

- Measured σy* at variety of modes { 2, 5 , 6, 8 deg }
- Optimized M-detection method, new software for automated, more effective LW/ fringe scans
- **Dec 16, 2011: Stable consecutive measurements at 5 deg mode**

Status:

σ_y^* = 1058 nm **M_{meas} = 0.55** (5.04 deg)

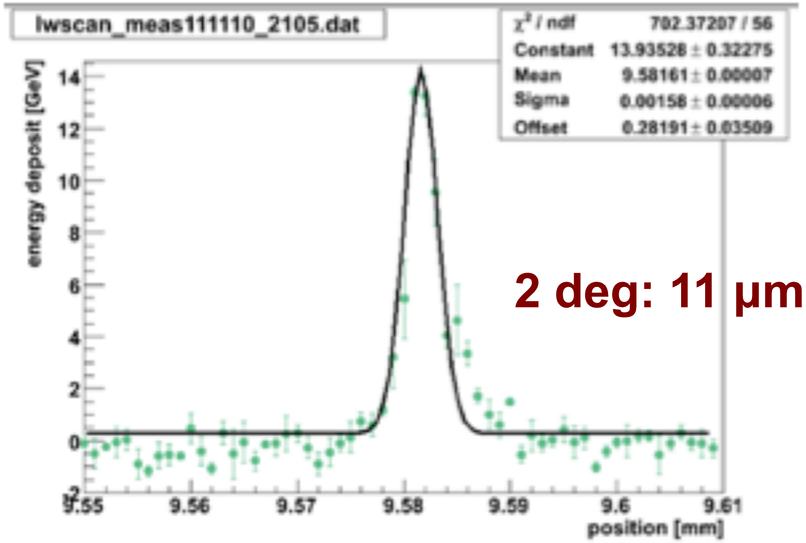
(2.5 x β_x^*, 5 x β_y^*= 0.1 mm)

- eventually σy* not small enough for 30 deg mode

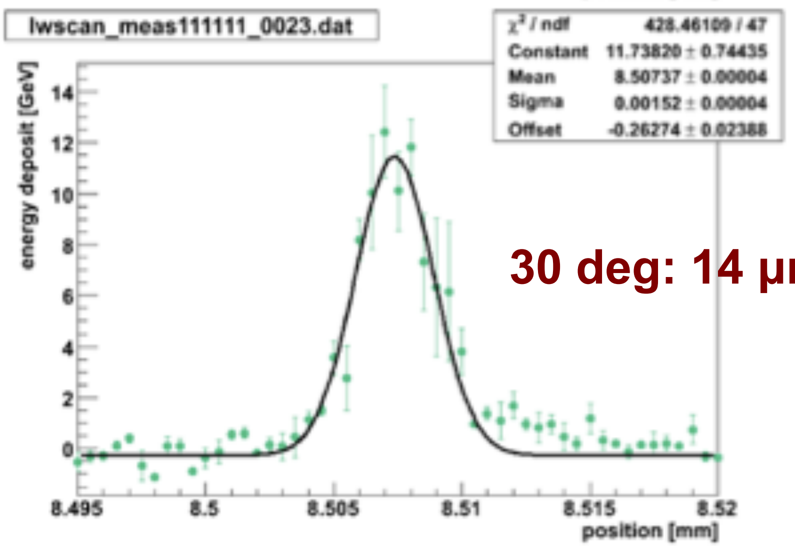
Laser wire mode

Focused σ_{laser} to design size

1st time since May 2010 !!



2 deg: 11 μm



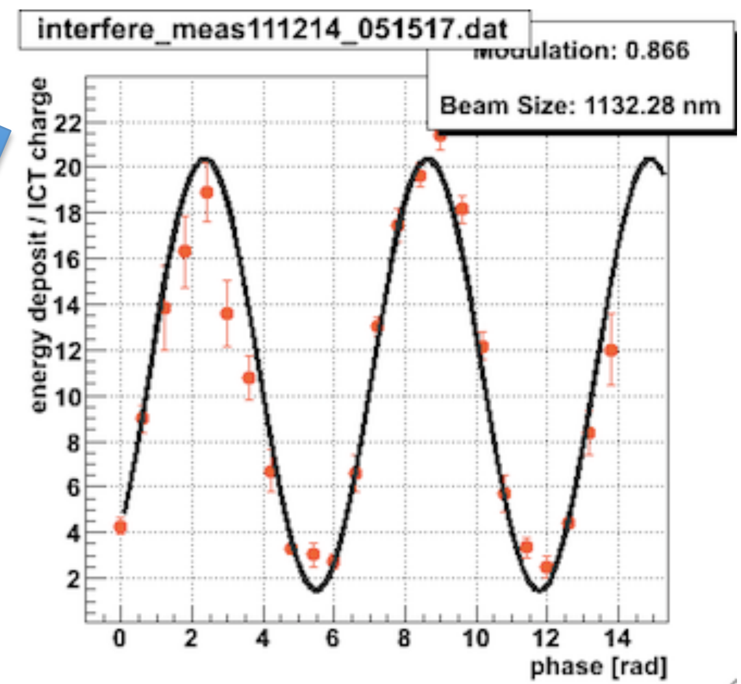
30 deg: 14 μm

Interference mode

first detection:
(10 x β_y* optics)

σ_y* ~ 2.8 μm M_{meas} ~ 0.42
(2.29 deg, Dec 13, 2011)

measured a series of σ_y* at 2 deg
after tuning down to **1 μm**



8 deg → 6 deg → 3.5 deg
in search of region of good resolution

Beam size status

Minimum σ_y^* for current run:

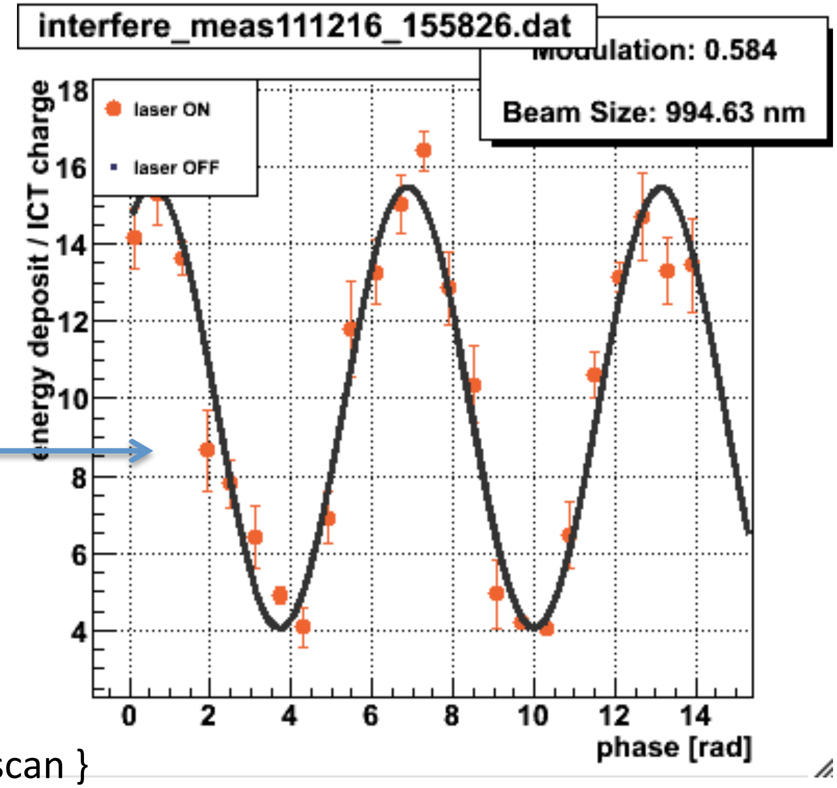
σ_y^*= 1058 ± 60 nm

M_{meas} = 0.55

From 7 stable consecutive scans

5.04 deg, Dec 16, 2011

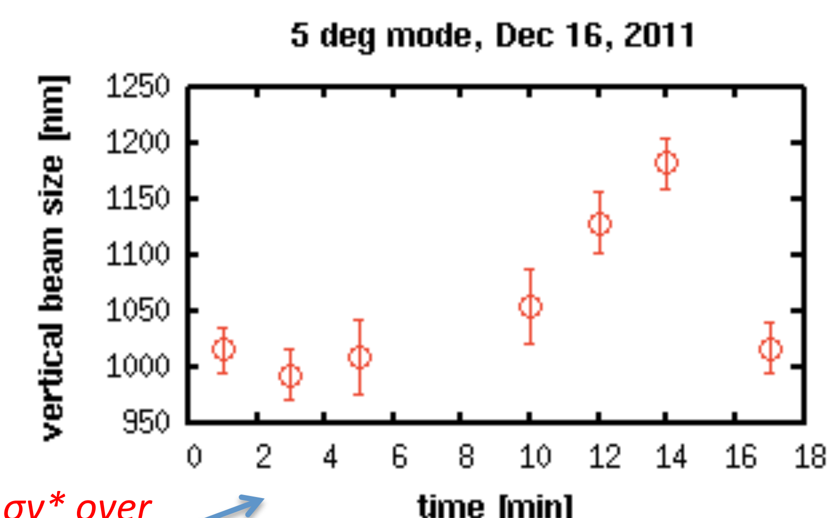
(2.5 x β_x^*, 5 x β_y^*= 0.1 mm)



- **Beam size resolution ~ 2.3%**
- **Signal jitter ~ 21%** : *acceptable*

Took < 30 min for M-detection { screen → LW → z-scan }

- Comparatively precise fitting
- Stable conditions
  - Laser position
  - timing, intensity
  - beam intensity



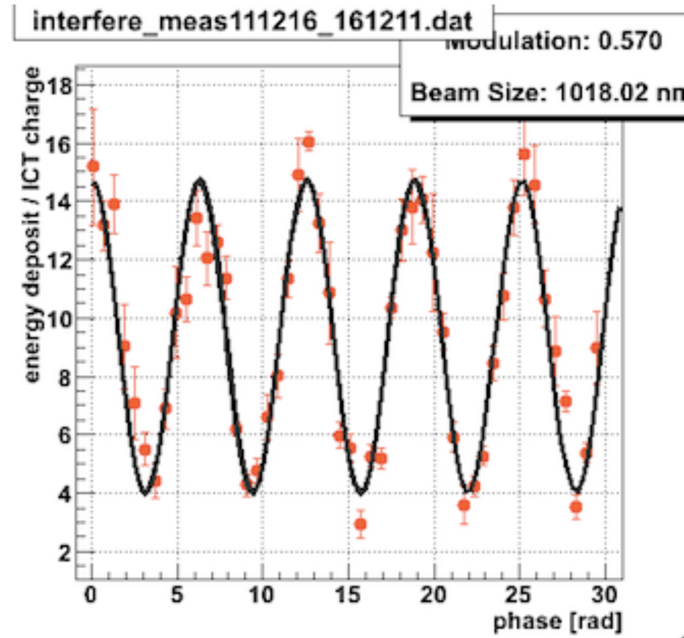
- No significant bias effects observed
- Cross-checked with alternative methods for deriving M

Change in σy over continuous measurement*

Signal jitter Status

For final measurements at 5 deg

Signal jitter ~ 21% (30 avg data)



Sig. jitter ~ 10 – 25 % in general

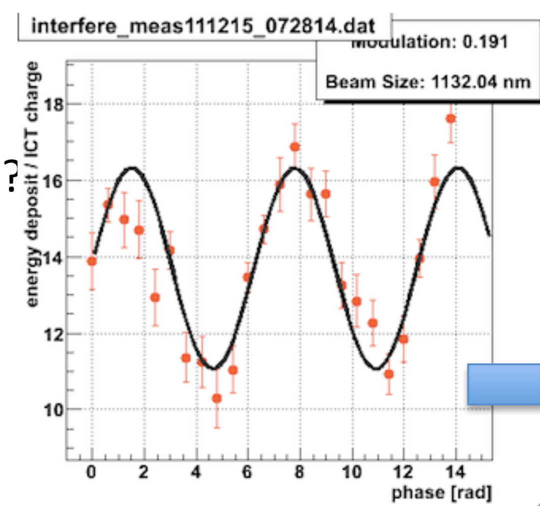
Not as heavy as previous run,

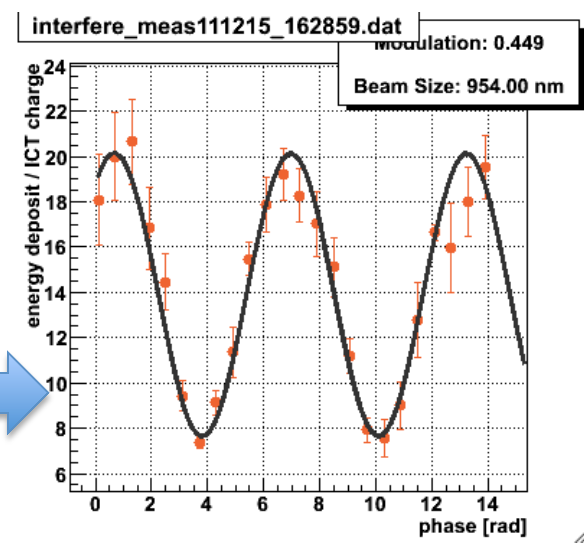
not major issue for M detection (c.f. > 30% in Dec 2010)

However ***occasionally worse***

Why??

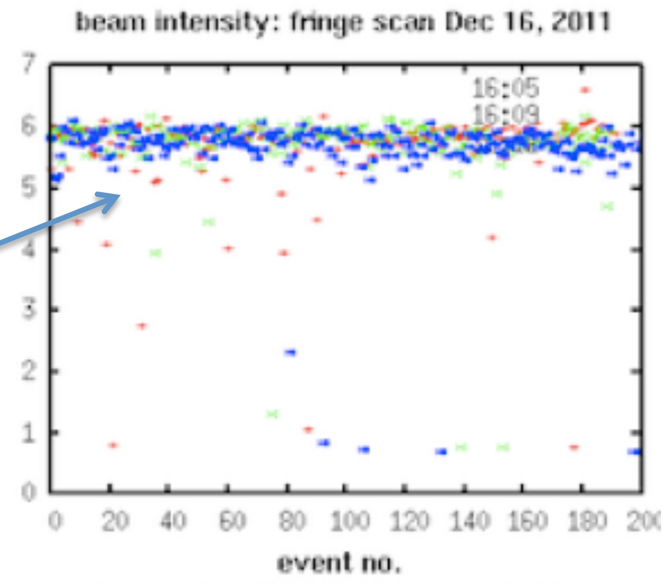
- Laser path hit edge of prism/lens ?
- Laser drift
- Intensity fluctuation





Ex: 30% jitter (7.8 deg) ➔ Lighter after switching to 6 deg

Beam time conditions



Positive :

- initial periods: low BG levels , S/N favorable .
- High and stable beam intensity
- stable laser timing and intensity

Negative:

- Later on, high emittance → large divergence and BG
- Low signal energy
- laser position jitters / drifts
- bad laser profile

		avg E_{BG} [GeV]	BG fluc.	S/N
laser wire mode	startup week	17	29%	4.5
	2nd week	8.2	20%	3 - 4
interference mode	2 deg, 1st detection	55	16%	0.5
	8 deg	24	17%	1
	3.5 deg	45	17%	0.5 - 1
	5 deg	45	18%	1

S/N ~ 1 for interference mode

Beam time conditions

Vertical emittance >~ 50 pm , large divergence (multi-knobs, xy coupling , rotated beam .....)
Cause gamma rays to hit collimators → signal energy loss

High BG , low S/N (~ 1) after switch back to smaller β*y

low S/N makes M detection more challenging

But not a major problem this time

(c.f. Last run: S/N < 0.5, a major cause of signal jitters and M detection failure)

,

Comparing typical beam time conditions

	May, 2010	Dec, 2010	Dec, 2011
Avg BG	~ 20 GeV	~ 115 GeV	**~ 45 GeV**
S/N	5 – 10 (Max ~ 30)	~ 0.5	**1 ~ 3.5**
Sig. jitter	10 %	25 - 30 %	**15-25%**
Avg Sig. Energy	130 – 250 GeV	50 GeV	**~ 80 GeV**
Laser spot size	15 – 20 μm	25 – 35 μm	**10 – 15 μm**
ICT [10^9 e-/bunch]	4.5 – 5	3	**5 – 7**

better

Current status : laser system

region	status
1 relative timing	**Stability ~ 500 ps ; ~ 1.5% on stat.errors** Timing module setting optimized
2. intensity	**Stability ~ 1% ~ 1 % on stat. errors** ***improved !!*** after tuning laser cavity and timing scans
3. temperature	Generally meet standards , constantly monitored
4. Oscillation	Flash lamp, seeder checked, Stable build-up timing
5. profile	Peculiar non-Gaussian form, chipped, dark spots
6. Laser position jitter	affect sig. jitters ***Not as significantly as before (?)*** But need direct PSD caliberation first
7 Laser position drift	Need to realign often Related to temperature (?)

Modulation Detection Issues

could not reconstruct M for 3.5 deg ➔ 7.5 deg mode

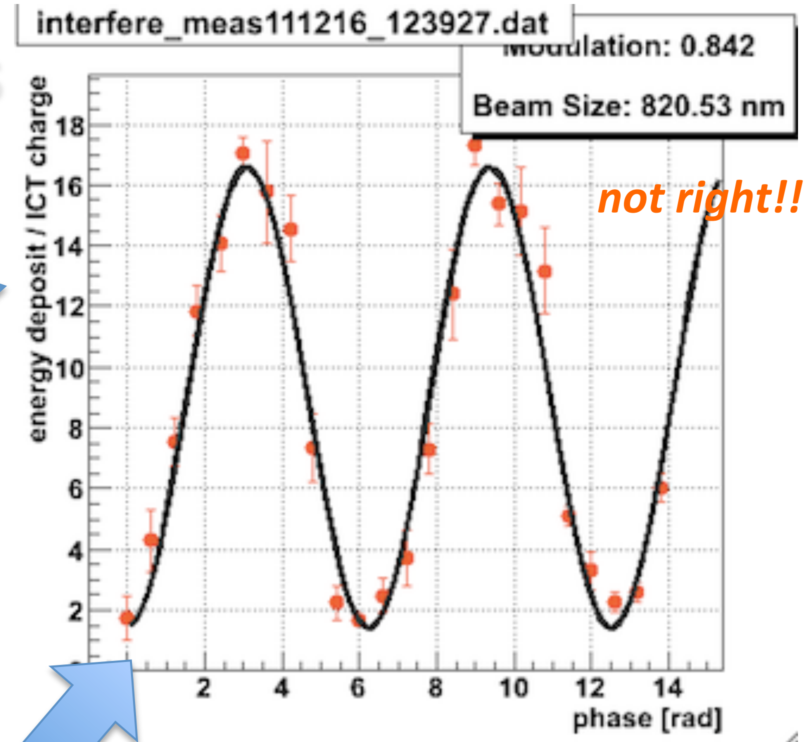
Fitted result: M = 0.85 ***over-evaluated!!***

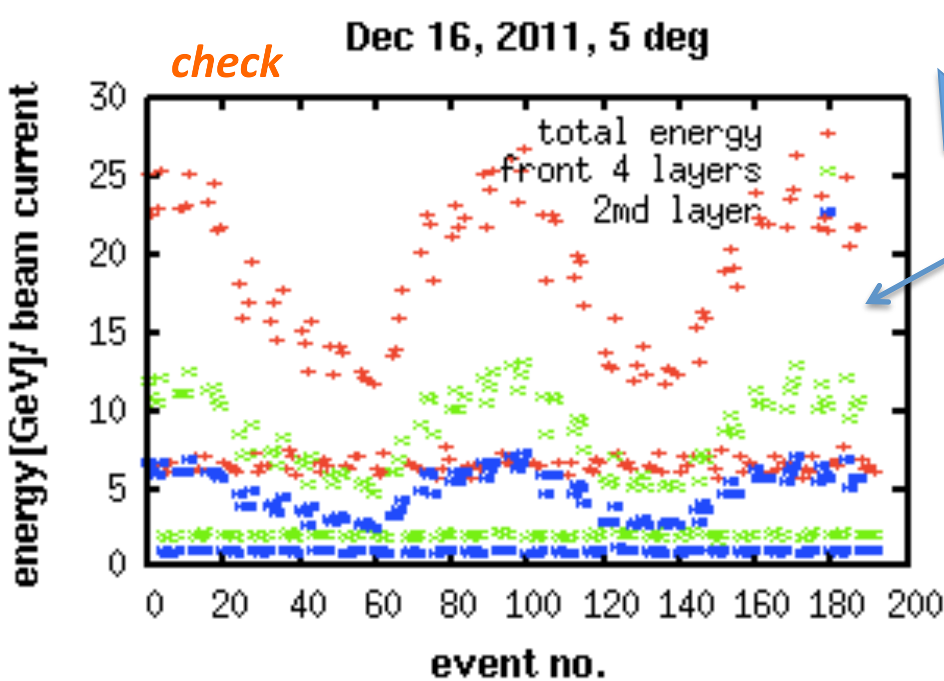
lack of precision in

shot-by-shot method for signal-BG separation

more reliable methods needed

for determining M during beam tuning





To check the fitted results

Calculated M using

alternative ON/OFF method

Inconsistencies between

ON/OFF result M ~ 0.75

and the fitted result M ~ 0.85

Alternative method for M : ON/OFF method

Laser "ON" events : laser colliding with the beam (←→ total energy deposit)
Laser "OFF" events: laser timing is moved away (←→ BG)
determine BG without relying on fitting

Sig = ON − OF F
Subtract BG (OFF) from the peak and valley of ON → **Max** and **Min** of signal

M = (Max−Min) / (Max + Min)

3 types
Compare to "Mfit"

1. all 5 detector layers: **Mtot**
2. front 4 layers: **M4**
3. 2nd layer: **M2nd**

Problem: 3.5 deg

12/16: 3.5 deg	M_{fit}	σ_{fit}	M_{tot}	M_4	M_{2nd}
12:39	0.842± 0.023	820.53± 65.43	0.70	0.76	0.73

final 5 deg : quite consistent

12/16: 5.04 deg	M_{fit}	σ_{fit}	M_{tot}	M_4	M_{2nd}
15:55	0.571± 0.013	1016.25± 21.08	0.54	0.52	0.57
15:58	0.584± 0.014	994.63± 22.57	0.52	0.63	0.51
16:00	0.575± 0.021	1010.12± 33.1143	0.55	0.57	0.62
16:05	0.546± 0.020	1055.5± 32.03	0.62	0.58	0.54
16:07	0.500± 0.016	1129.75± 26.37	0.58	0.58	0.55
16:09	0.469± 0.013	1182.02± 22.0	0.49	0.44	0.43
16:12 (30 avg)	0.570± 0.014	1018.02± 22.37	0.62	0.54	0.57

Low Compton Energy

seem to be **loss in Compton signal energy deposit,**
LW peak Esig, lower than previous runs and simulation

Theoretically N ~ ≃ 1.4 × 10^4 , **98 GeV expected**
However ,in reality **LW peak energy generally below 25 GeV**
sometimes suddenly decreased to half in the middle of beam time

<u>Possible causes:</u>

- signal gamma rays hitting one side of the collimator blocks
- lead blocks of the fixed 20φ collimator need major realignment
- Beam trajectory not properly aligned to BPM centers + large beam divergence

<u>solutions</u>

- Rearranged collimator blocks
- polaroids + collimator scans to confirm gamma rays passed
- After some beam angle tuning, Esig increased slightly, but still too low

<u>Proposals:</u>

- Realign collimator, reconsider collimator aperture
- Cross-checking using different detector layers
- Angular scan of the e- beam angle to directly confirm the effect of small angular jitters on beam centering to the Shintake Monitor detector.

Inconsistent LW results between upper and lower path

<u>Problems with upper path LW scans:</u>

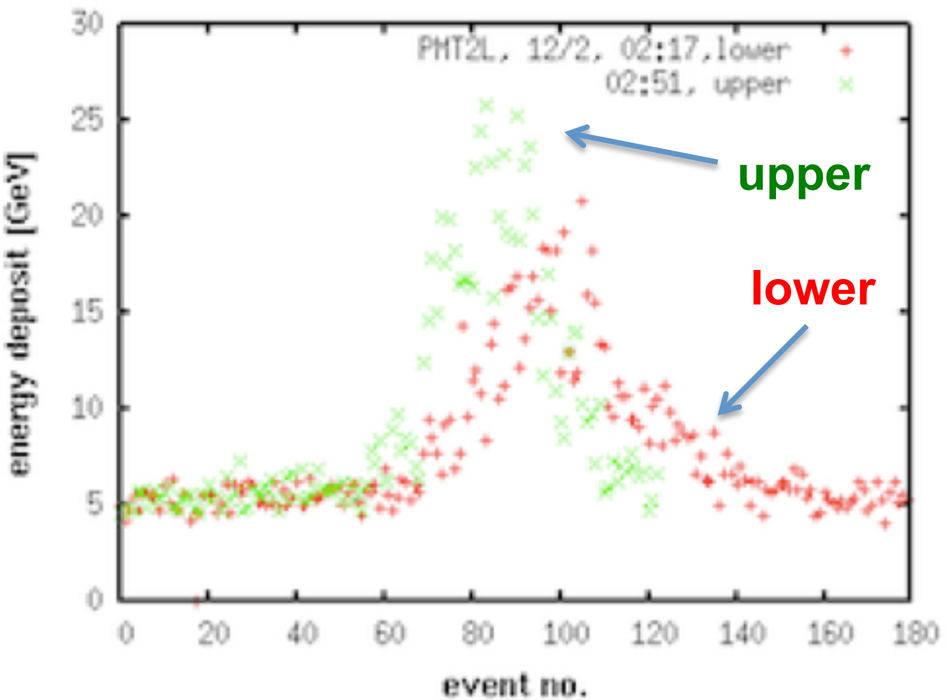
- **More signal fluctuations**
  (realtime on status monitors)
- **σlaser is more focused**
- **worse peak precision and pointing stab**

Why??

- upper path laser beam
  is hitting the edge of the prism (??)

- enters the final lens too offset from center

(signal jitters were largest at 8 deg mode,
when laser beams pass closest to the edge of prisms)



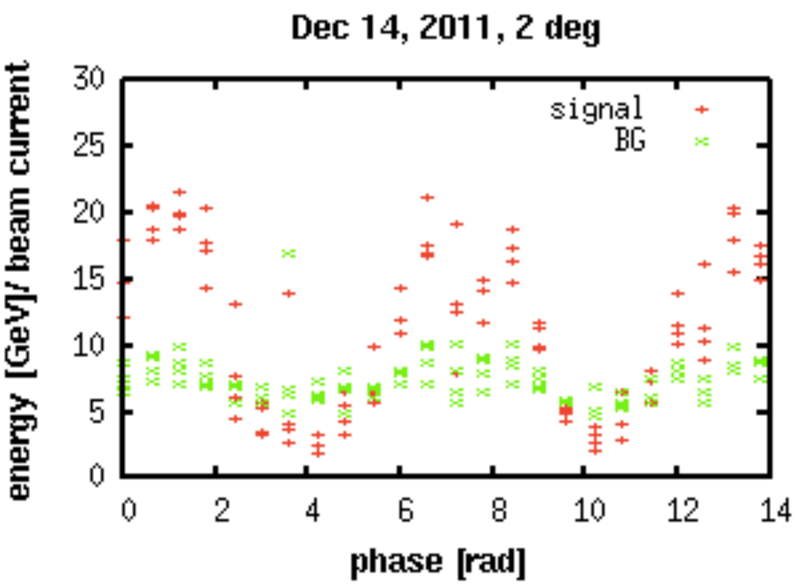
Bias effect from BG modulation

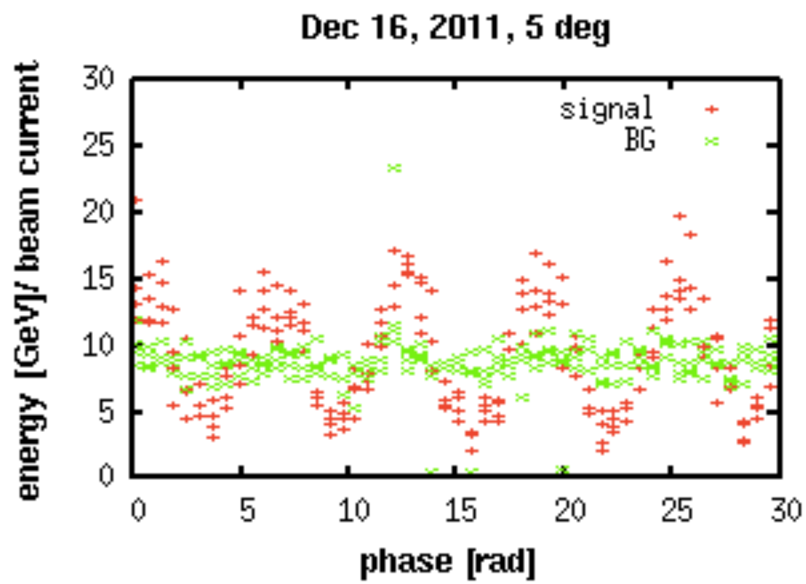
riding on top of signal in the same phase → cause σy* to be measured larger than actual.

Possible Causes:

- **Fluctuation over time of reference shower**
- shot-by-shot fitting not weighted correctly (PMT output , non-linearity , bug in program ???)

especially bad for initial 2 deg mode • not so bad for final 5 deg mode





2011	deg	BG. mod.	Sig. mod	avg BG (/ ICT)	S/N
12/13	2	light, < 0.05	~ 0.45	12 GeV	~ 0.5
12/14	2	significant, ~ 0.18	~ 0.85	7.3 GeV	~ 1.5
12/16	3.5	significant, ~ 0.17	~ 0.85	8.5 GeV	~ 1
	5.04	light, < 0.05	~ 0.6	8.8 GeV	

It happened in previous runs also !!

Examples:

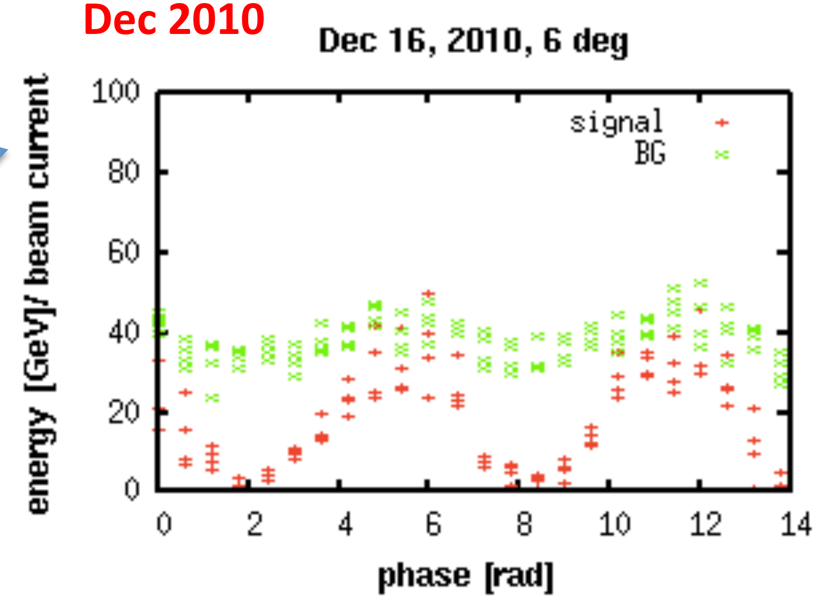
◆ 12/16-17, 2010 *quite bad*

scans that measured the smallest σy∗ (6 deg)

Trying to commission 30 deg mode. (8 deg)

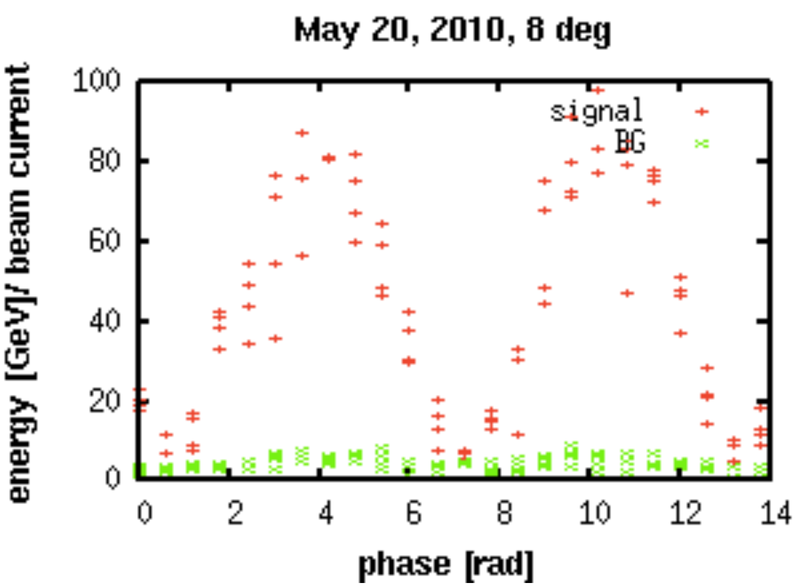
σy∗ may have been over-evaluated

Dec 2010



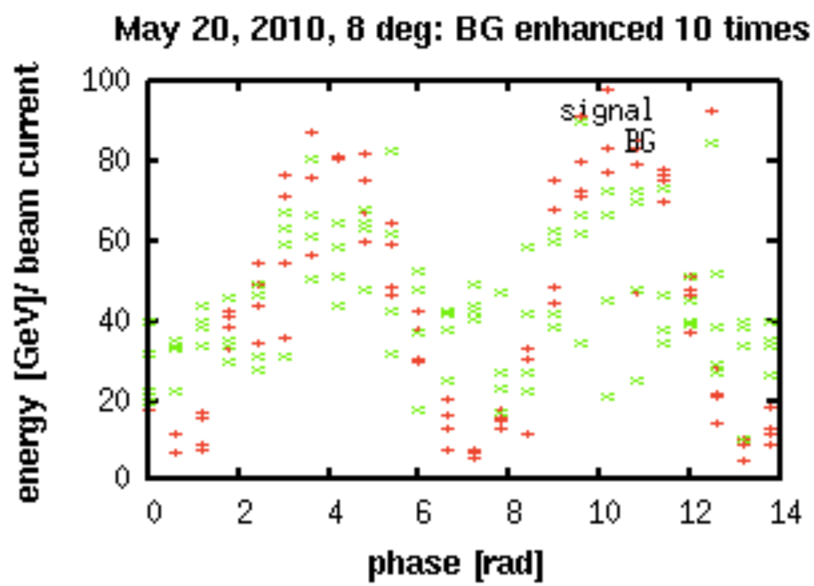
◆ May 2010, 8 deg σy ~ 300 nm

BG modulation here is enhanced by 10 times



May

2010



Systematic errors for current measurements:

Bias on M from " BG modulation effect"

mode	2 deg	3.5 deg	5 deg
syst, error on M	3 - 5 %	~ 15%	~ 5%

Other systematic errors able to be evaluated for now

		1 μm at 2 - 8 deg
laser power + polarization	$C_{pow-pol}$	~ 98%
relative pos. jitter	$C_{rel-pos}$	88.5 % - 99.2%
laser position alignment	z: $C_{z,align}$	$>$ 99.5%
	t: $C_{t,align}$	~ 100%
laser profile imbalance	z: $C_{z,pro}$	$>$ 99%
	t: $C_{t,pro}$	[99.8% , 99.9%]
Fringe tilt	z: $C_{z,tilt}$	$>$ 99.2%
	t: $C_{t,tilt}$	$>$ 98.6%

Systematic errors for current measurements: Fringe Tilt

[1] current scenario: measuring σ_y^* ~ 1 μm at 2 – 8 deg mode
Assume **σx = 20 μm, δφ = 20 mrad**
C(tilt) ~ 98.6% (transv) , 99.2% (long.)
~ 7% beam size error

[2] switching to 30 deg (σ_y^* ~ 300 nm)

- If σx = 20 μm, δφ = 20 mrad : **C ~ 80%** , 67% error
- If σx = 10 μm, δφ = 20 mrad **: C ~ 95%** , 20% error
- If σx = 10 μm, δφ = 10 mrad **: C ~ 98.5%** , 5% error

For 174 deg, after feedback by PSDs expect C ~ 99.7% for σx ~ 2,2 μm

To suppress bias due to fringe tilt

- **Align laser paths more precisely → δφ < 10 mrad**
- **Need smaller σx** *large σx ~ 20 μm makes it hard !!*

Requirements for beam time conditions

Parameters	Requirement / goals
BG energy	**suppress fluctuation**
S/N	**3 – 4 (> 1 at least)**
Sig. Energy	**Should meet expectation 40- 50 GeV in laser wire peak**
Sig. jitter	< 20 % better to be around 10%
Laser spot size	10 – 15 μm ***now OK***
Laser pointing stability	< 1 μm @ IP (< 50 μm @ other PSDs on optical tables)
ICT [10^9 e-/bunch]	6 – 7 x 10^9 / bunch , fluc < few% ***now OK***

Goal and Plans   2012 ~
smooth switching to 30 deg, 174 deg mode

IPBSM system
Our responsibility!!

Resolve precision problems

Correct for bias factors

beam tuning

Favorable beam conditions
Control εy and divergence

smaller σy* (and σx*)

Maintain stable system

Effective and reliable hardware/ software

achieve focusing down to 37 nm

More details coming up in next presentation

Summary

❖ **IPBSM : commissioned for 1st time after earthquake**
- **laser wire mode,**
- **interference mode (2-8 deg)**

❖ **stably measured σy* ~ 1 μm**

Various hardware/ software upgrades since summer
Improvements in laser focusing, signal jitters, timing/intensity stability

Towards achieving goals in 2012:

- **resolve precision problems and bias factors**

- **Improve reliability and effectiveness of IPBSM as beam tuning device**

- BACKUP

2010		**BG, mod.**	Sig. mod	avg BG (/ ICT)	S/N
5/20 8 deg	10:34	~ **0.15**	0.87	4.3 GeV	~ 15
	10:35	~ **0.3**	0.85	4.8 GeV	
	10:38	~ **0.2**	0.86	4.6 GeV	
12/16	6 deg	~ **0.2**	~ 0.9	~ 40 GeV	~ 0.5
12/17	8 deg	~ **0.2**	~ 0.5	~ 40 GeV	

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.

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

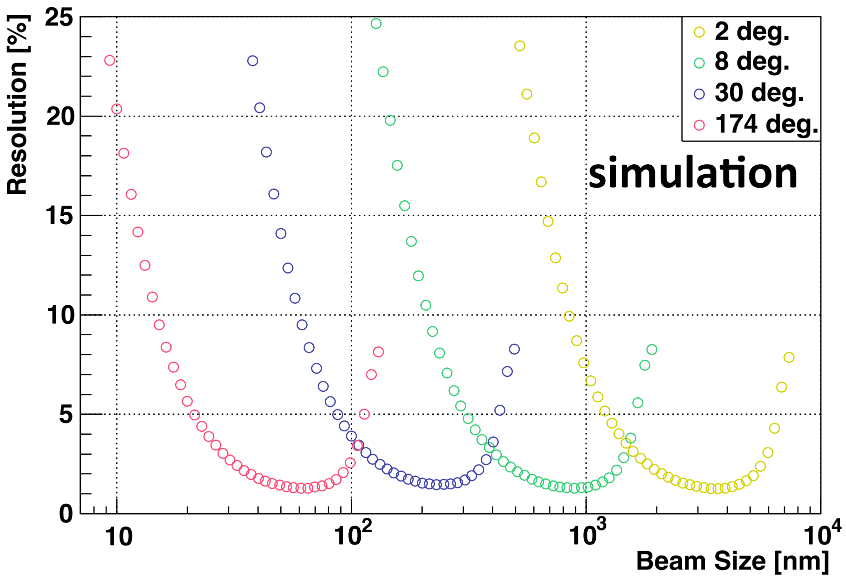
Resolution < 10% expected for σy 25 nm ～6 μm

However…….

- **degraded for low S/N**

~ 15% in Dec, 2010

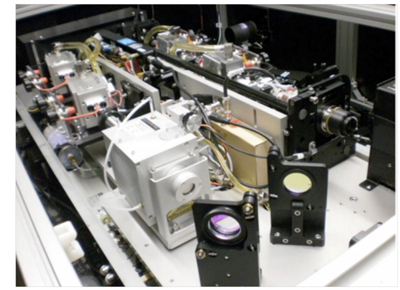
Resolution for each mode



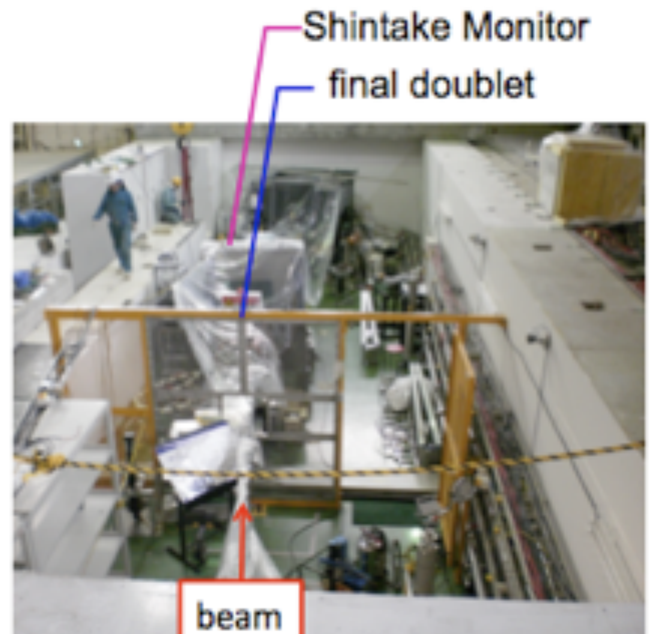
Post Earthquake Recovery and Confirmation

Confirmation of system

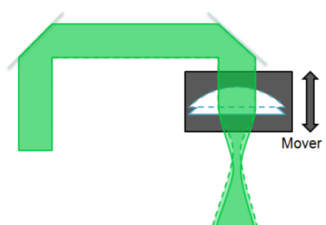
- Inspected each component according to a checklist (see next slide)
- Point is to restore system back to where we left off in the last beam run
- Check for damage (every component!!) , confirm proper function



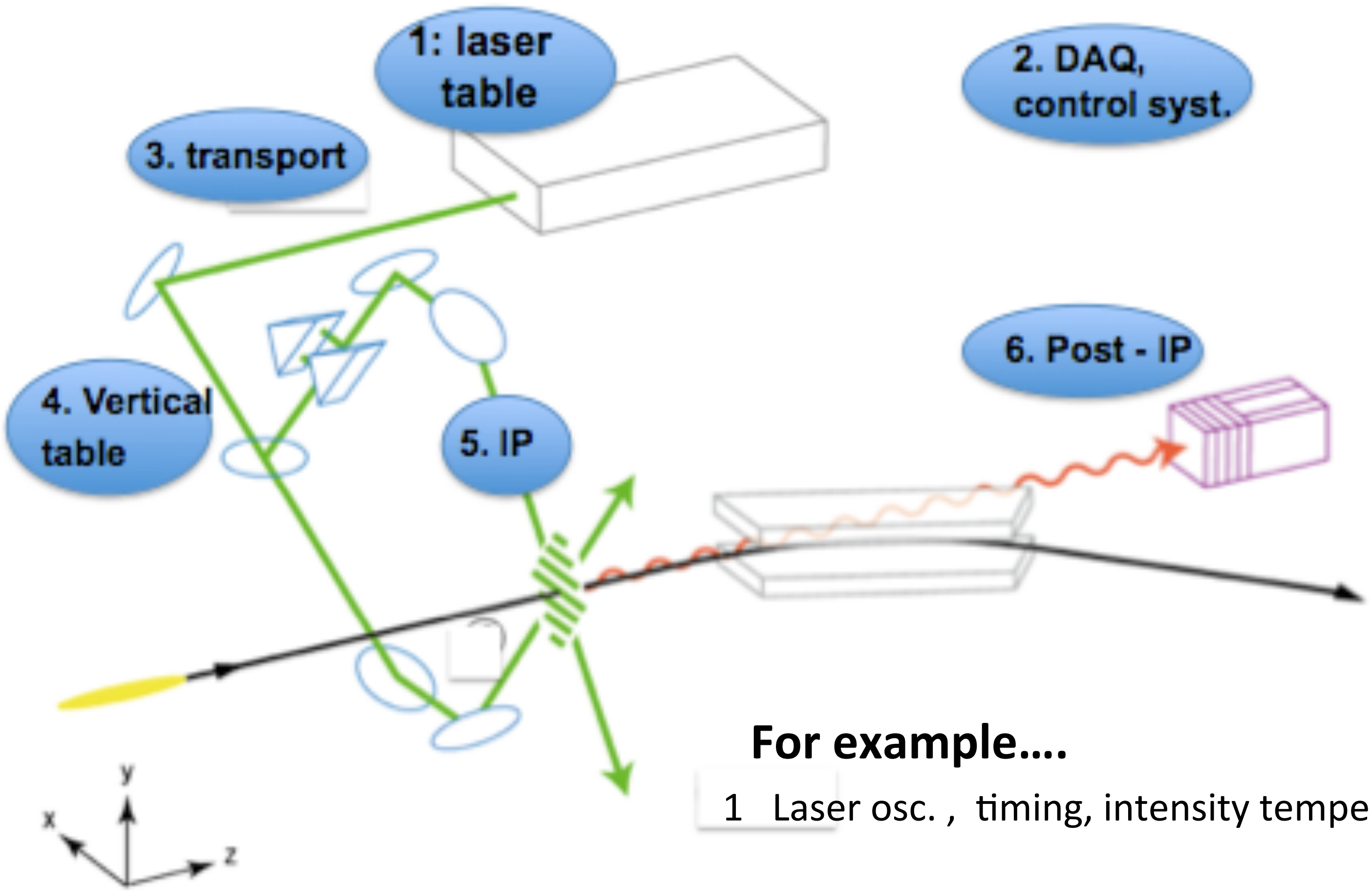
- reconstruct laser path for each mode



- 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 Timing, power Temp dependence	
2. DAQ, control system	DAQ modules (ADC, VME,...) Controller stages Thorlab actuators EPICS, data logger	status read out from ATF-menu
3. transport	Laser profile interlock attenuator	
4. vertical table	Optical components path for each mode PSD , PD signals	PSD caliberation
5. IP	IP mover, screen monitor	PSD caliberation Viewport safety test
Post-IP	Detector *comprehensively!!* BG monitor	Collimator scan

Will finish these up soon before beam run begins

Beam size status

Run of May, 2010

"10 x β_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 β_y*= 0.1 mm

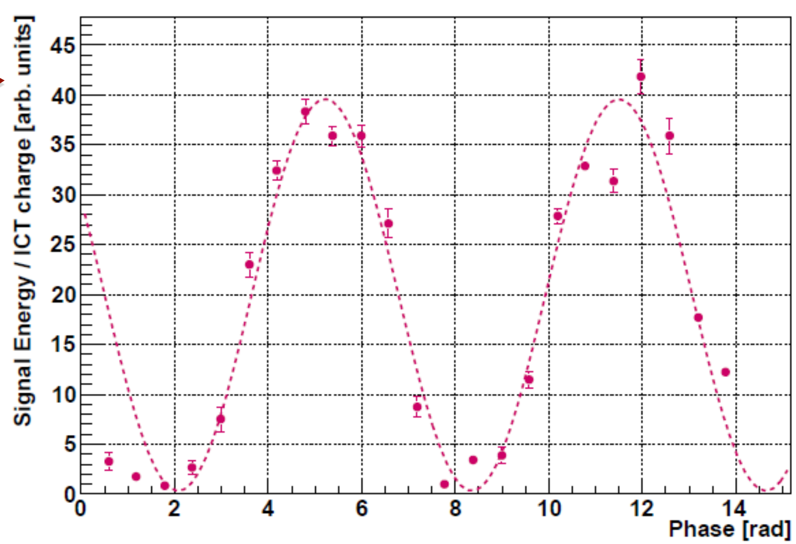
High BG : ~ 40 – 130 GeV

Low S/N : ~ 0.5

Minimum beam size:

σ_y*= 280 ± 90 nm
M_{meas} = 0.918 ~ 0.984

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

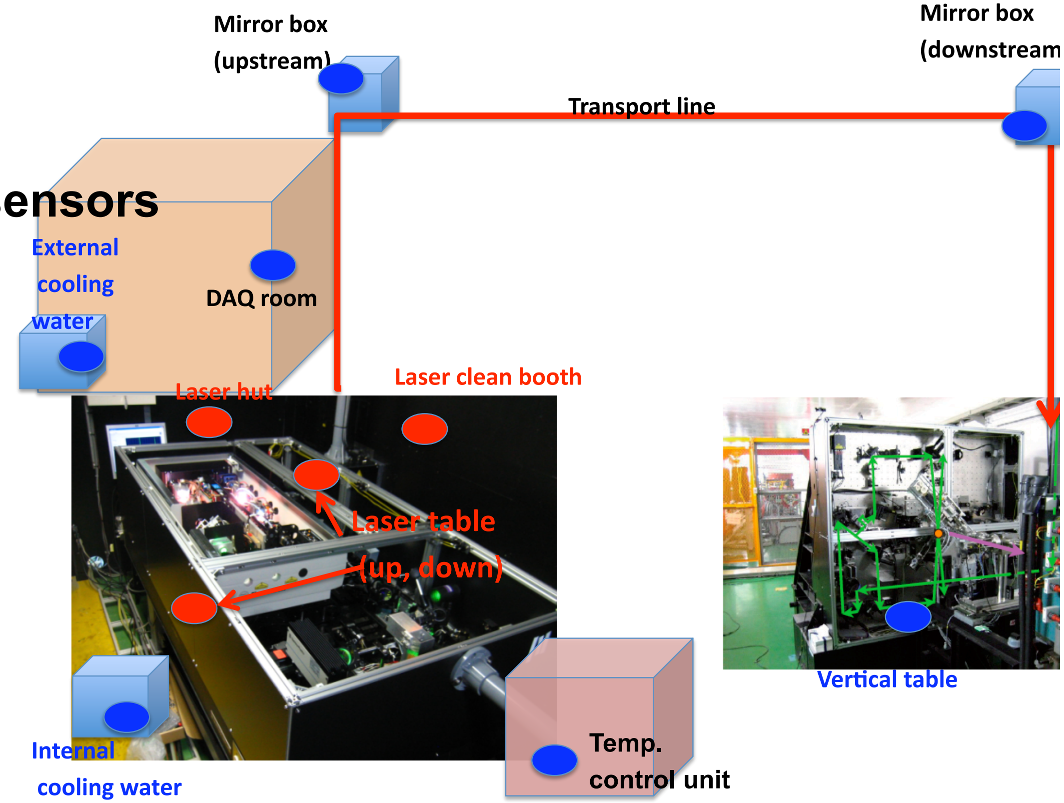


Laser temperature dependence

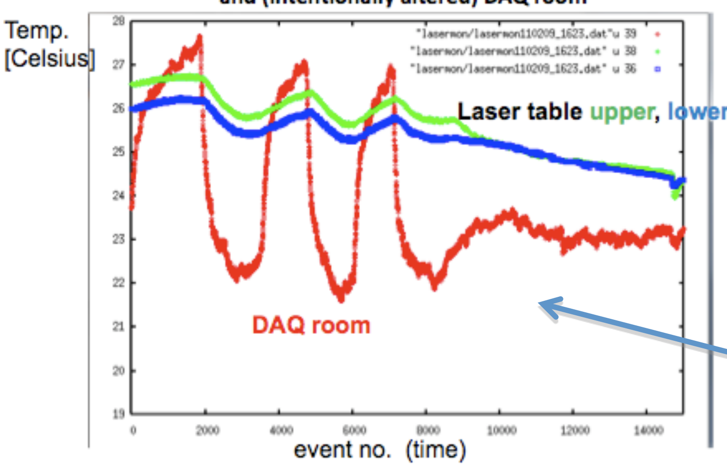
Laser + cooling water sensitive to heat effects!!

moved laser power source

temperature sensors



Temperature correlation between laser table and (intentionally altered) DAQ room



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!!