IPBSM Performance Evaluation

17th ATF2 Project Meeting

Feb 12 – 14, 2014
KEK

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IPBSM : essential device for achieving ATF2 's Goal 1 !!

focus **σ_y* to the design 37 nm**

Outline of this talk

Introduction

Recent Beam Time Status

IPBSM Performance Evaluation

Signal Jitters

- **Systematic errors**
- **Phase jitter study**

Summary & Goals

real data analysis & Error study using simulation

Beam Time Status

2012 Laser optics reform (summer)

→ improved laser path reliability

contributed to **first M detection @ 174°mode** (Dec)

Mmeas ∼0.23 (←→ **σ_y ∼ 70 nm**)

Mar 2013

10 consecutive scans @174°

however large phase jitters (?)

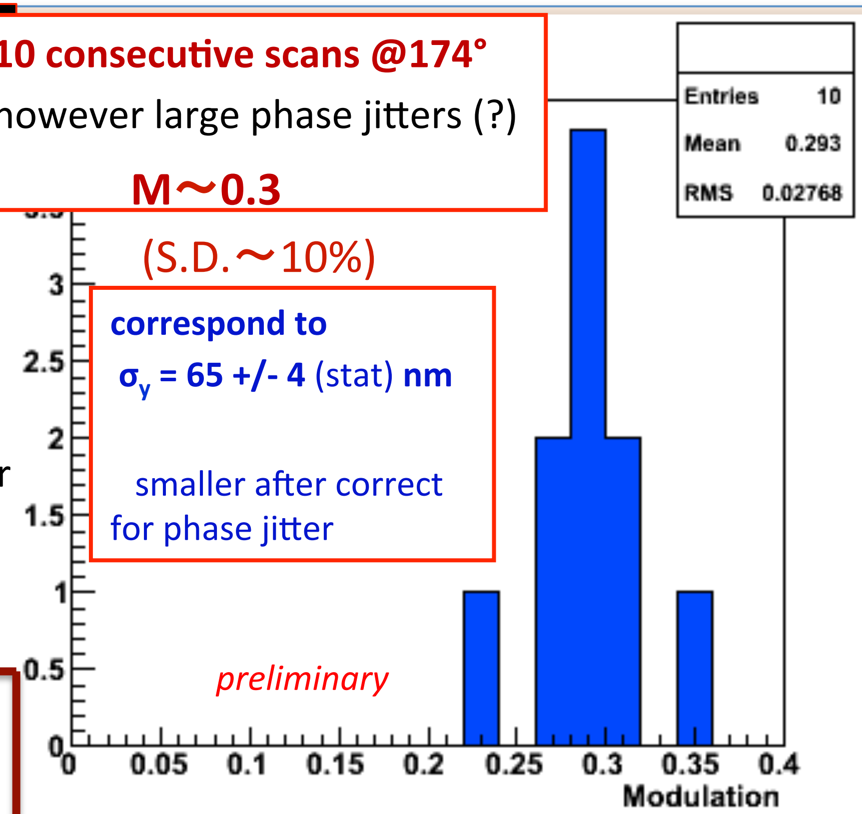
M∼0.3

(S.D.∼10%)

correspond to

σ_y = 65 +/- 4 (stat) **nm**

smaller after correct for phase jitter

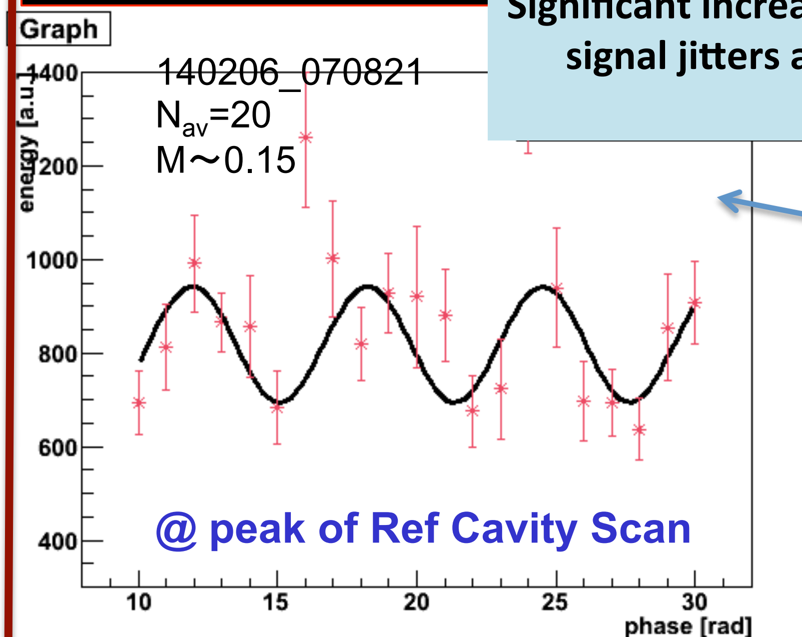


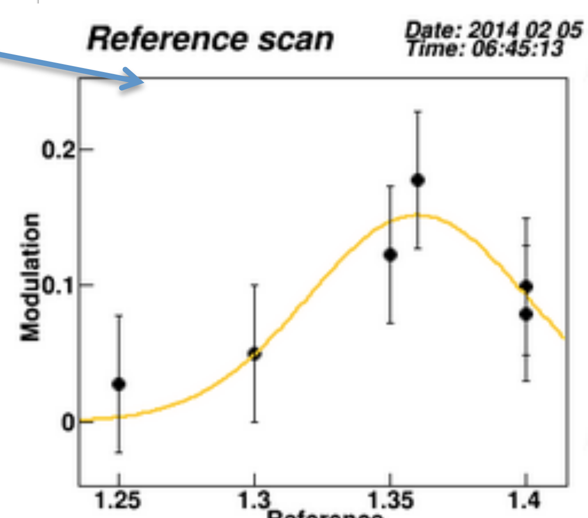
May – Jun 2013 Commissioned Cherenkov detector

relatively **stable performance** during beam tuning and wakefield study

Dec 2013 – Feb 2014

Significant increase in signal jitters and drifts

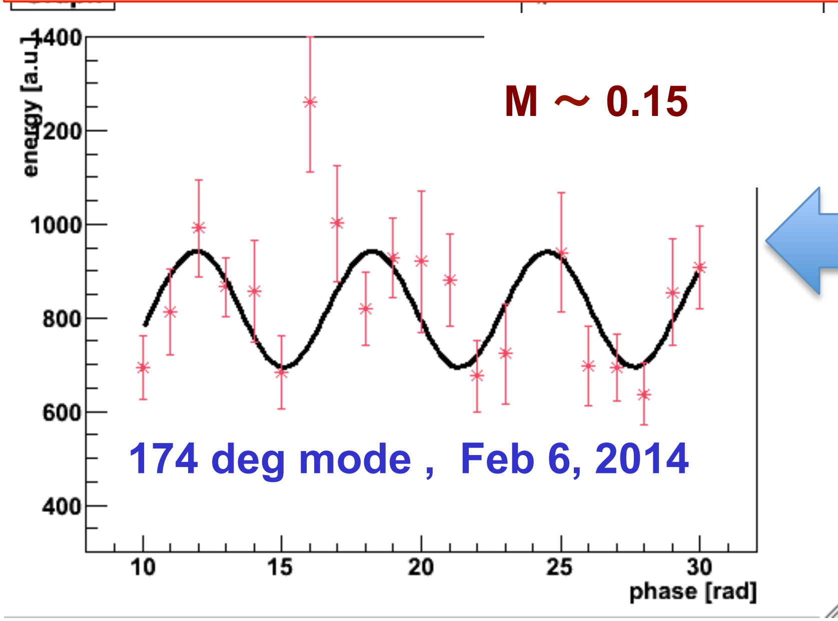




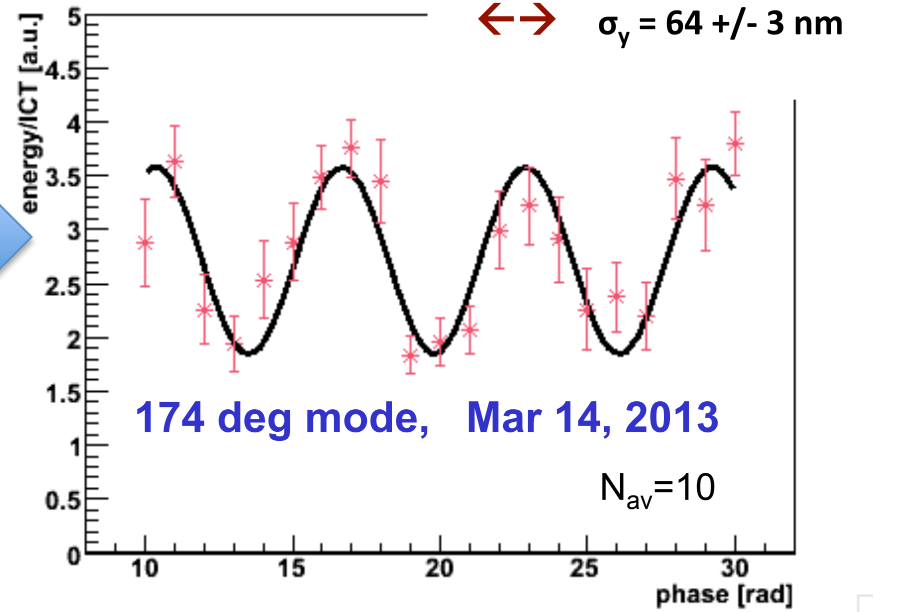
measured M at 174 ° mode

but poor consistency

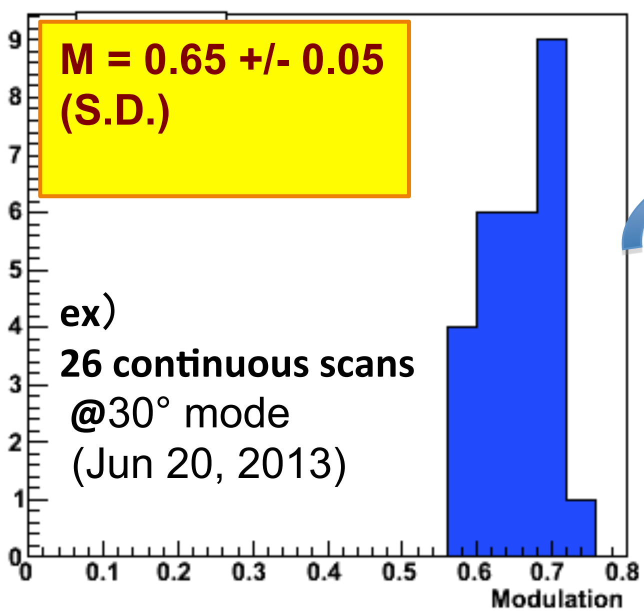
What is reason for increased jitters now?

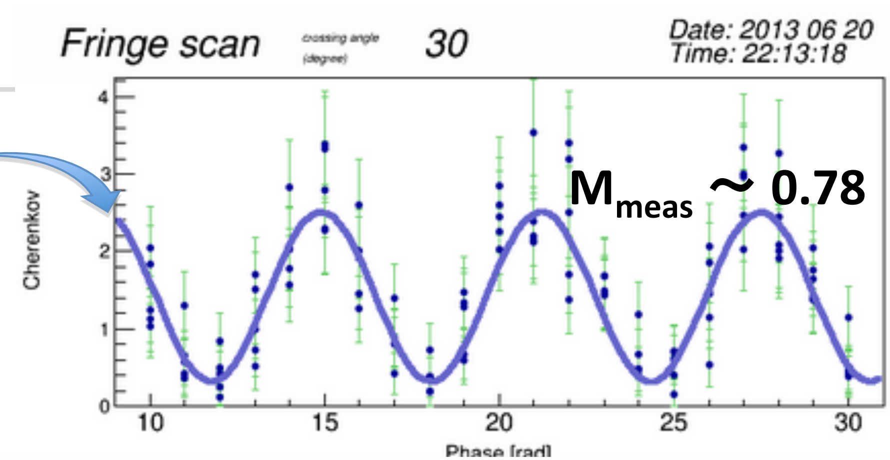


M = 0.32 +/- 0.03 ←→ σ_y = 64 +/- 3 nm



In June 2013, IPBSM demonstrated **measurement stability : 5 ~ 10%**

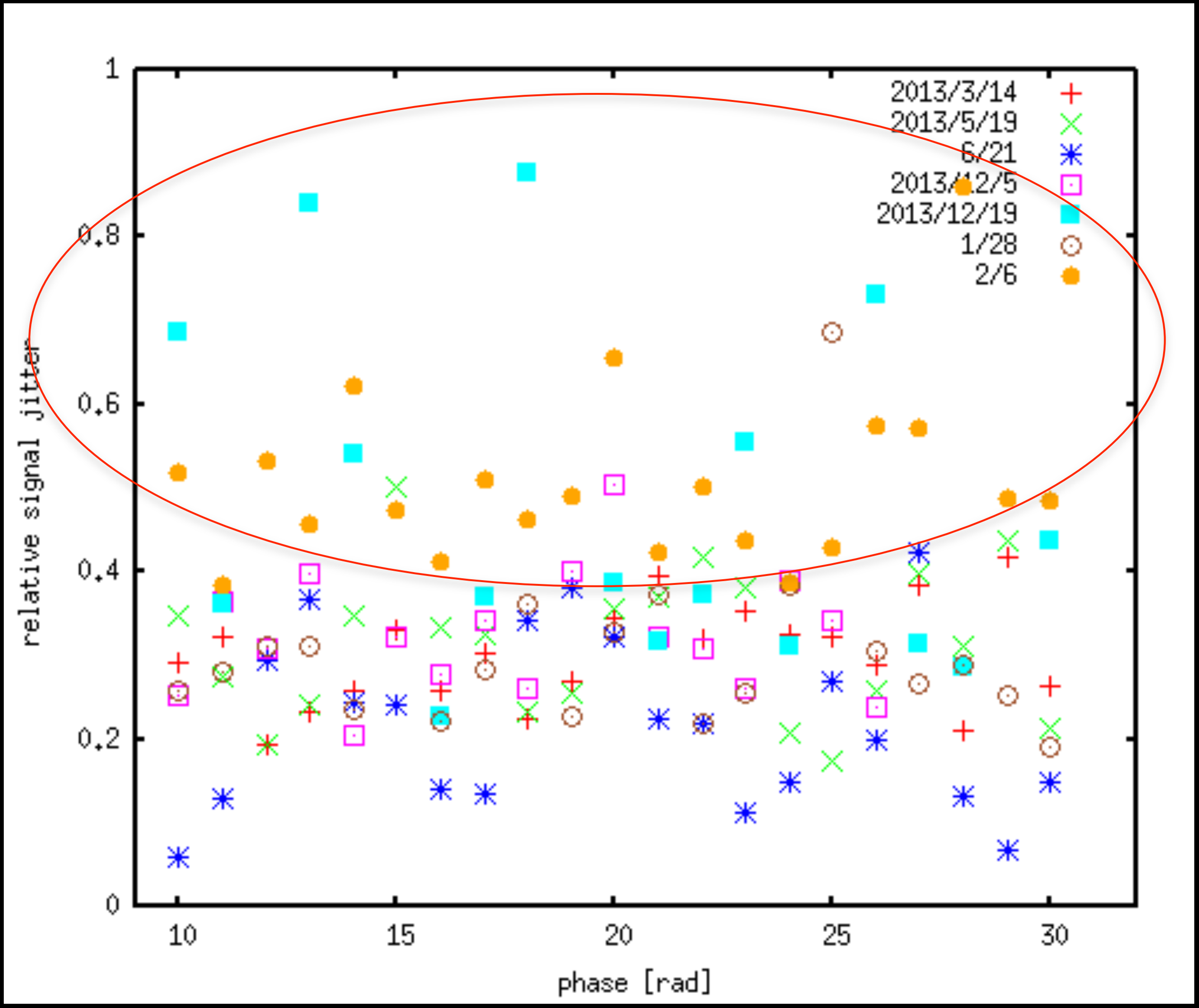




When Cherenkov had just been commissioned

History of signal jitter status in IPBSM fringe scans (Mar 2013 – Feb 2014)

Recent Increase in sig jitters



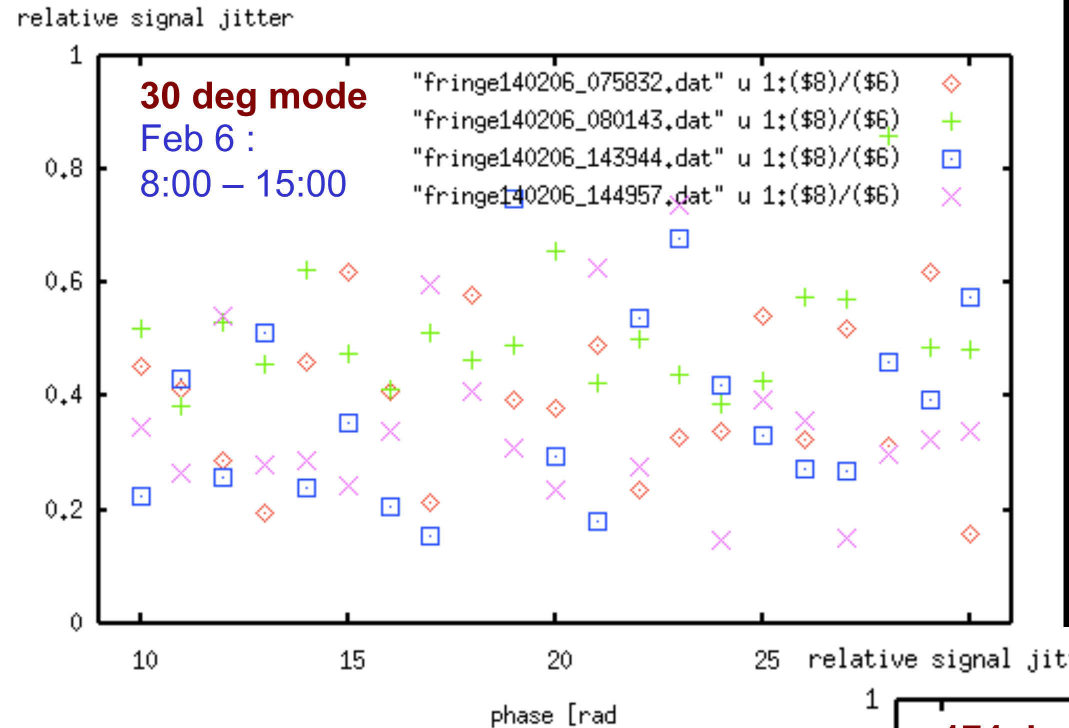
Dec 2013 :

- Collimator (→ optimized by scan)
- Low S/N, BG fluctuation

Jan, Feb 2014 :

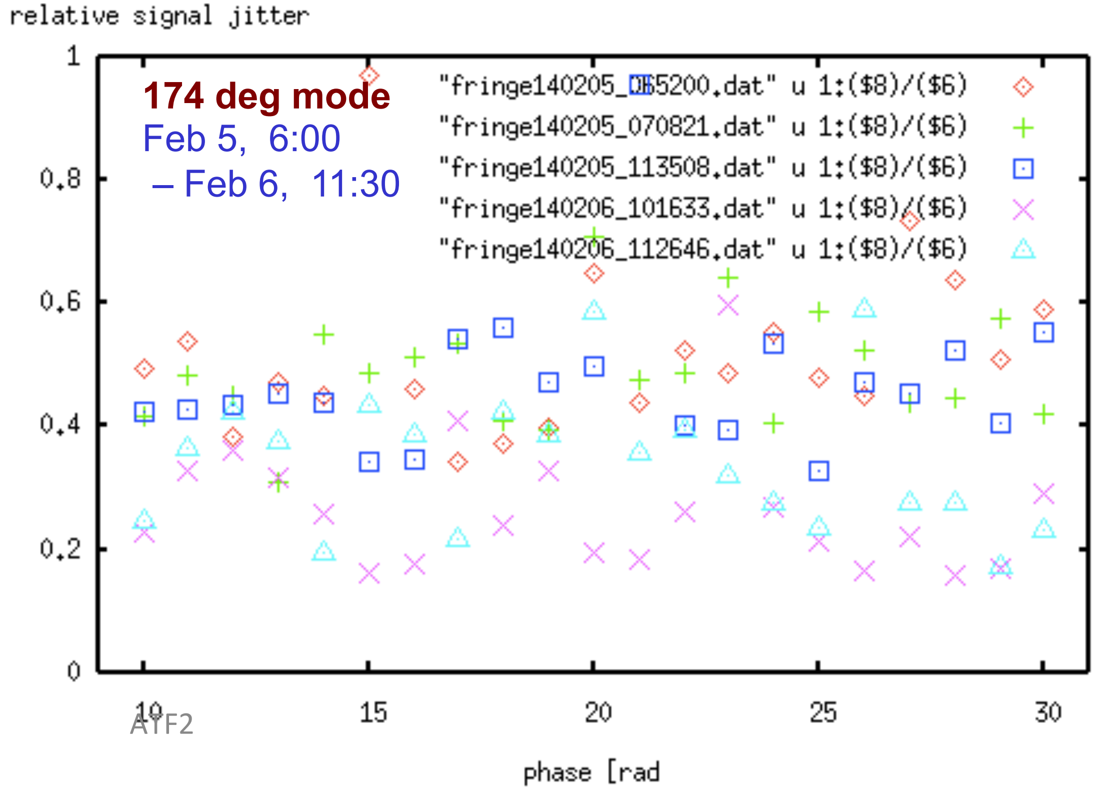
laser related factors

Signal jitter is bad regardless of crossing angle mode

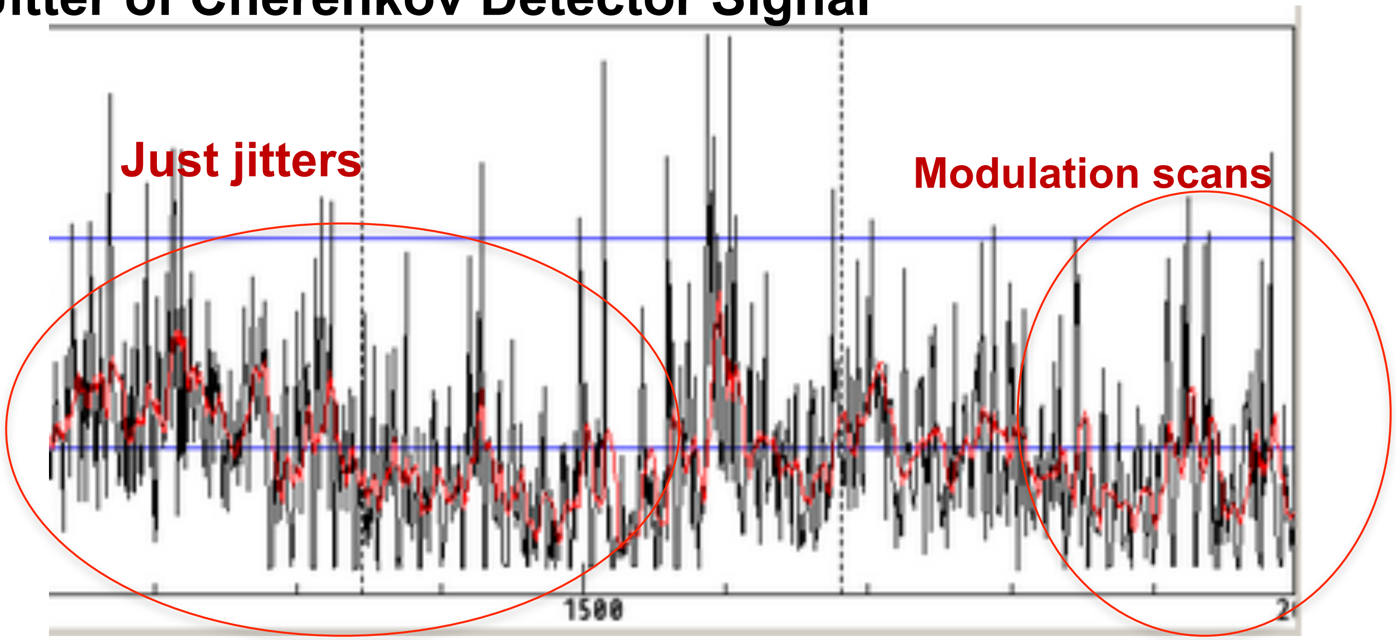


Looking at fringe scans
(Nav=10,20,50)

2/5 – 2/6 , 2014

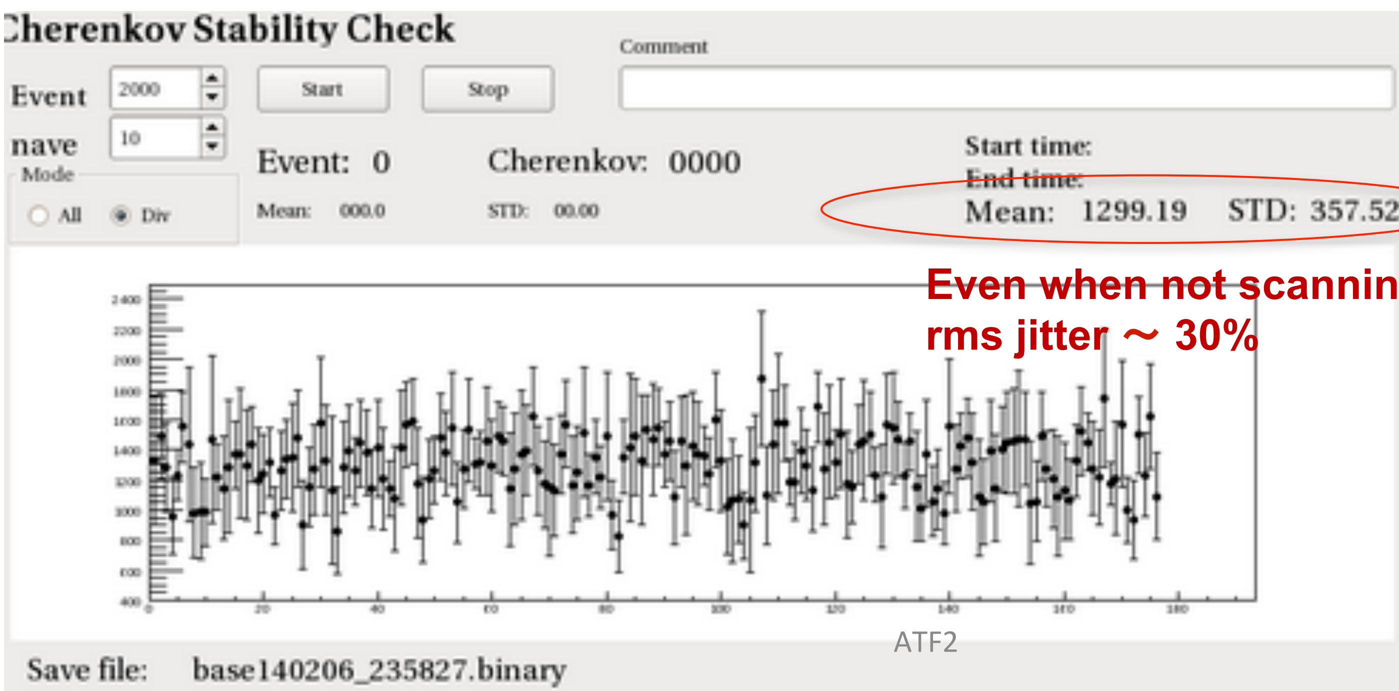


Jitter of Cherenkov Detector Signal



Amplitude and period of jitter is sometimes undistinguishable from fringe scan signal

Both signal jitters and drifts exceed 50% sometimes



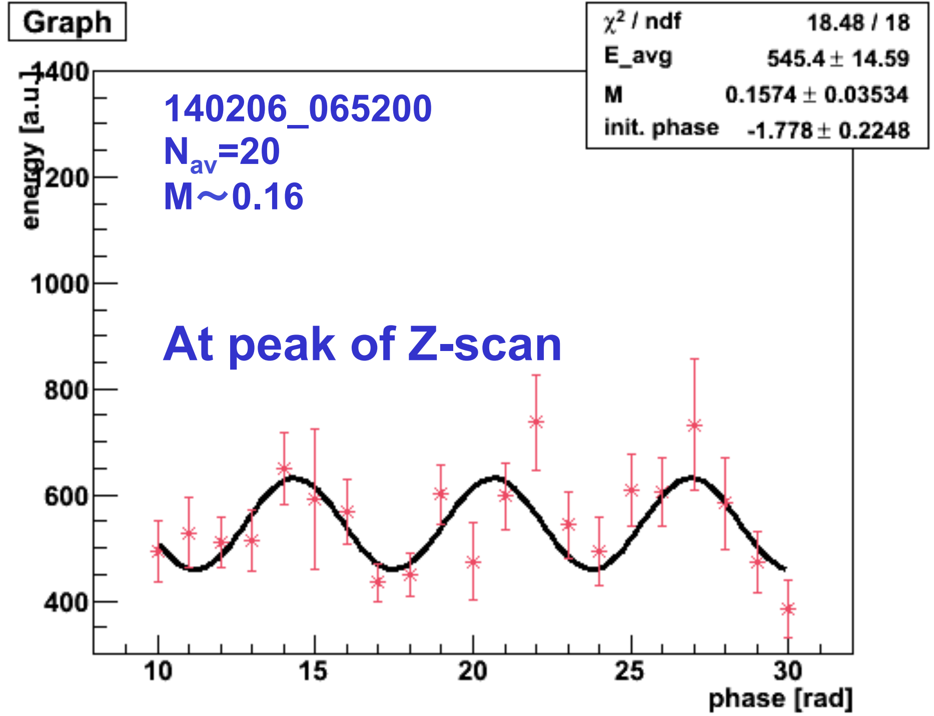
Even when not scanning, rms jitter ~ 30%

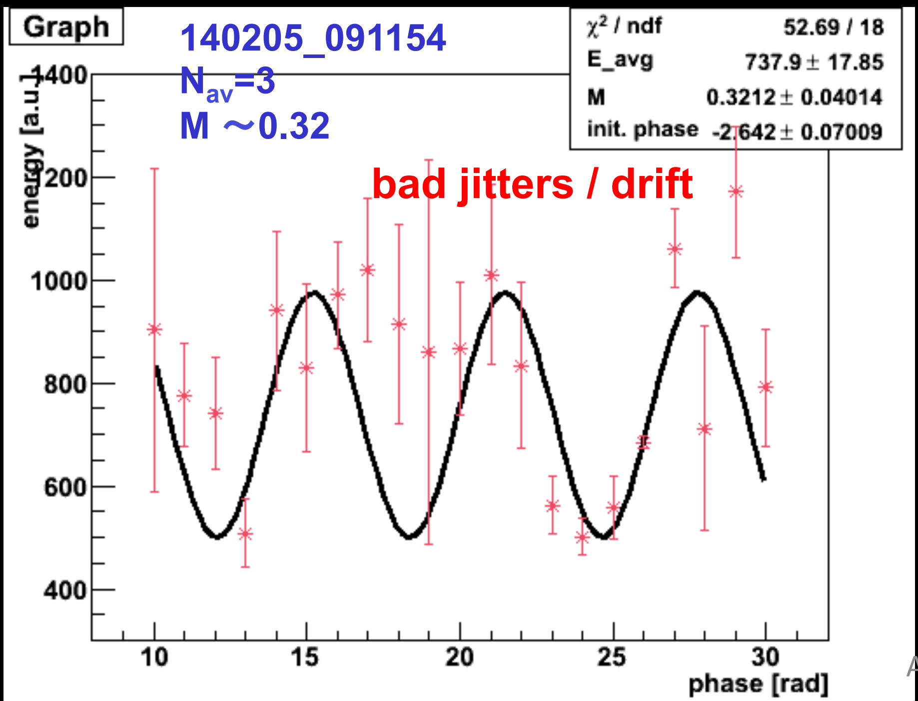
M measured (?) at 174 deg mode in Feb 5-6, 2014

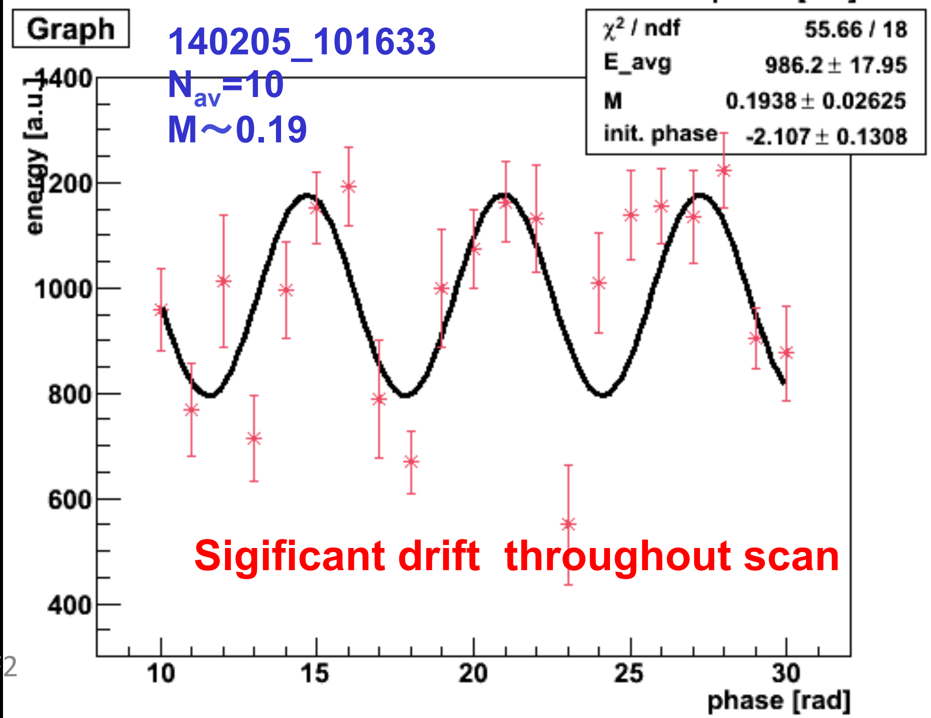
Sometimes seemed to measure M

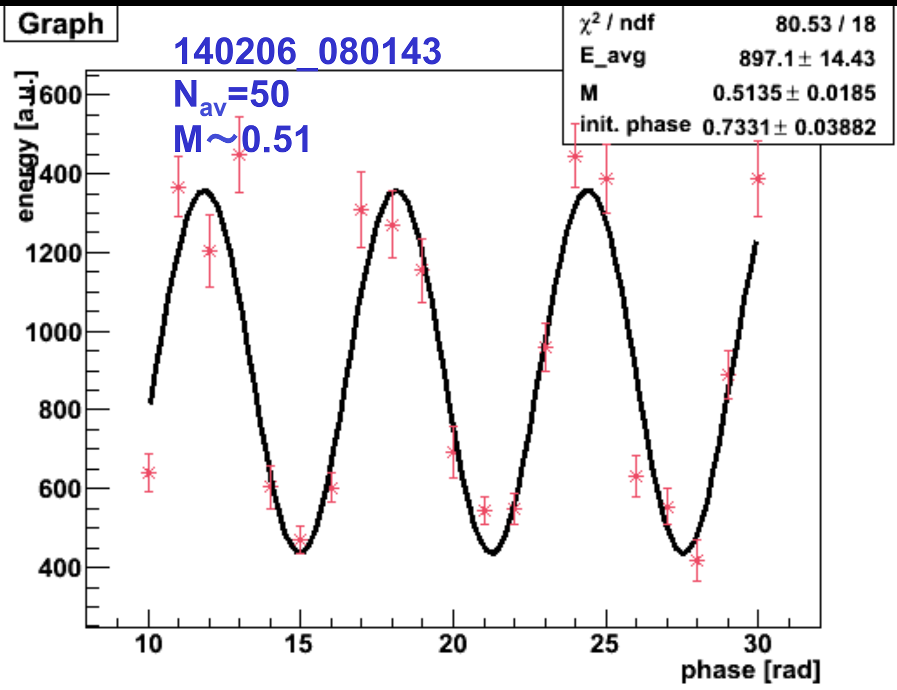
But inconsistency due to bad drift / jitters

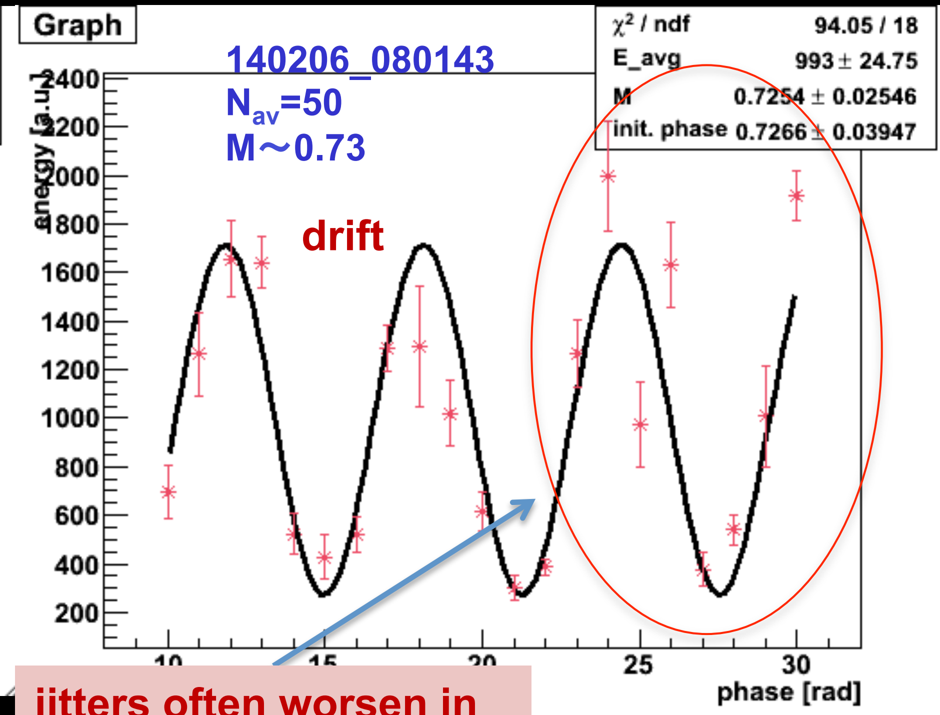
Result differs greatly between data selections
(plot all data, statistic, cut +/- 10% , ect…)



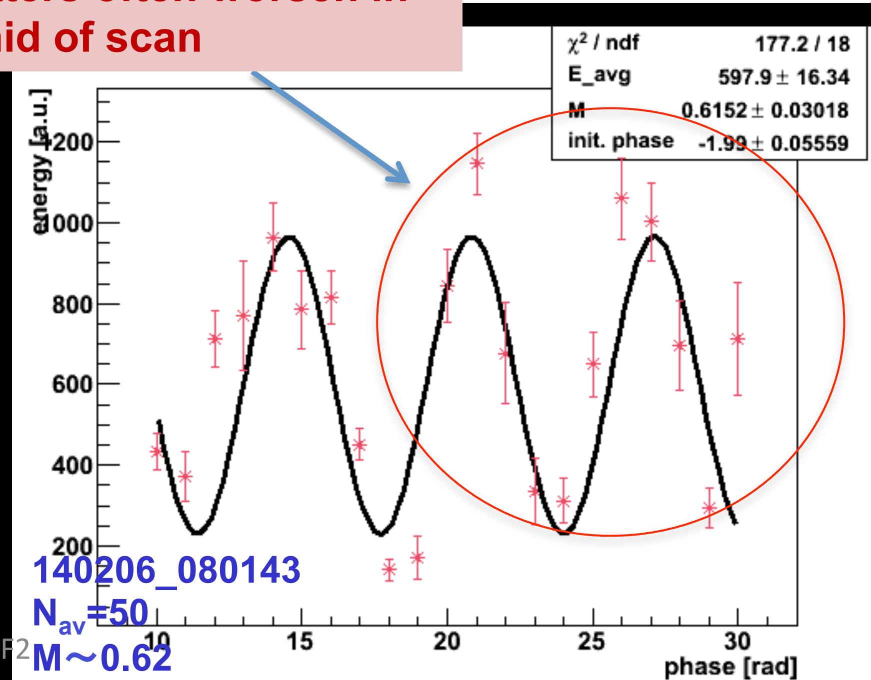








jitters often worsen in mid of scan



Drift and jitters are problems for 30 deg mode also

- effect is smaller since M is larger
- But makes multi-knob tuning hard

Potential Sources of Signal Jitters

	comments
Laser pointing jitters *Change with beam condition*	• observed jitter (CCD) 5-10% of laser profile • investigated H relative position jitter Δx using laserwire scan
Phase jitter Δϕ (V relative position jitter)	for Δϕ = 0.5 rad , M = 0.5 : < ∼10 %@ peak , <∼20%@mid $\sigma_{E,\Delta\phi} = E_{avg} M \sqrt{\frac{1}{2}\left[1-2\cos^2(\phi)\exp(-\Delta\phi^2)+\cos(2\phi)\exp(-2\Delta\phi^2)\right]}$
Laser power jitter	< 10% from PIN-PD on laser hut table
Timing jitter	2 – 3 ns peak to peak, add < few % to signal jitters
Other minor factors	
• BG fluctuation	< few %, not important when S/N is very high
• Compton energy fluctuation	> 5% , not certain *affected by collimator, e- beam intensity, laser power ect….*
• e- beam intensity (ICT) monitor resolution	Few %

Add up → ΔE/Eavg = 20 – 30 %

however in reality there is significant drifts , hard to separate from jitters sometimes

Hardware improvement attempts (by Terunuma-san, Okugi-san, and others)

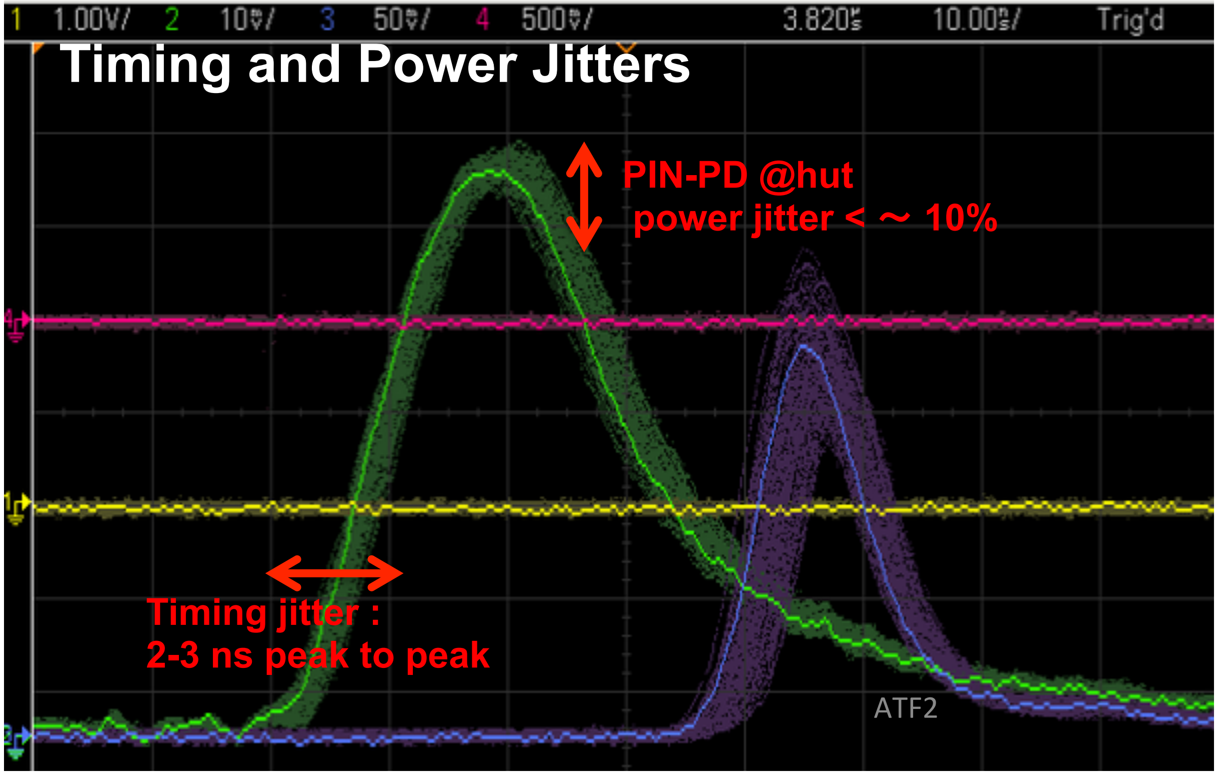
- changed laser Q-SW trigger system → timing stabilized
- Removed cylindrical lens on laser hut table → reduced intensity bias in profile
- Adjusted gate width and variable attenuator of detector read-out module

Laser cooling water system

◆ Tried various external cooling water temp. 18 – 29 deg (default 21 deg)
  effect is unclear → inspection/repair by laser company

◆ Other attempts → no clear improvement

adjust Nitrogen flow , cool power supply source with fan, move sensor away from hot pump
Laser cavity tuning (e.g. rear mirrors) , ect…



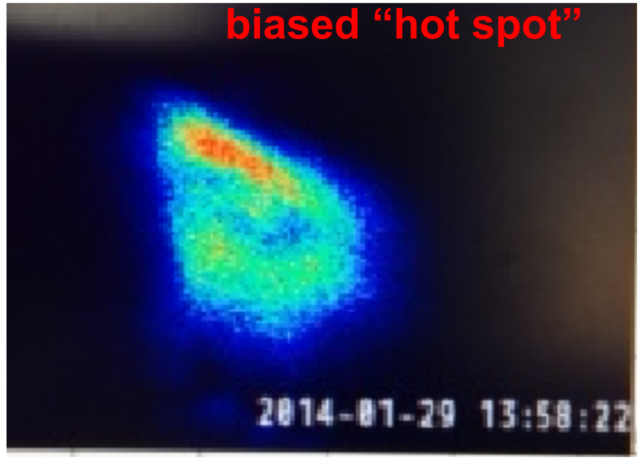
laser tuning , filter exchange by Spectra Physics

→ improved buildup and timing stability

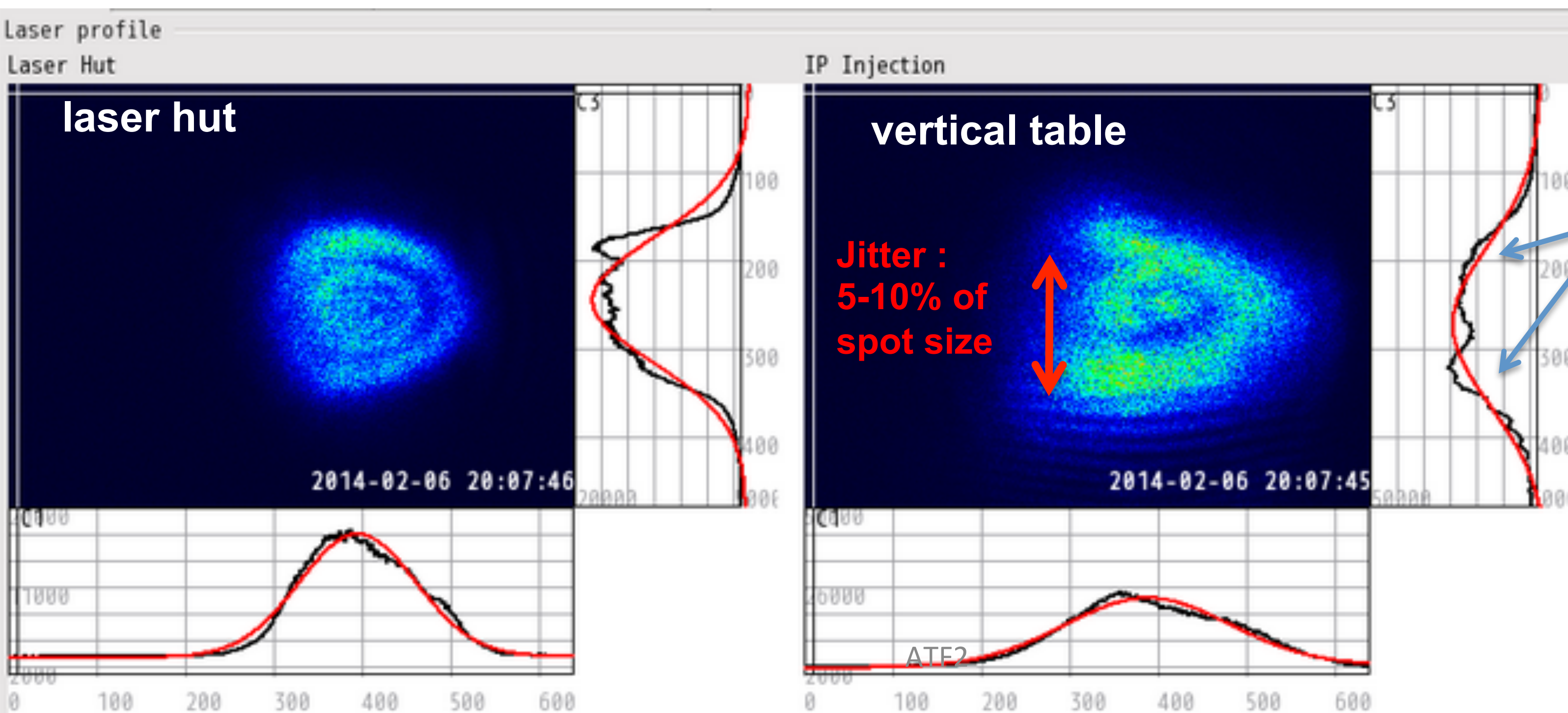
Note: due to sensor size < laser spot size, part of "vertical jitter" may be pointing jitter

Laser Profile

before tuning
(remove cylindrical lens)



after



2 peak structure

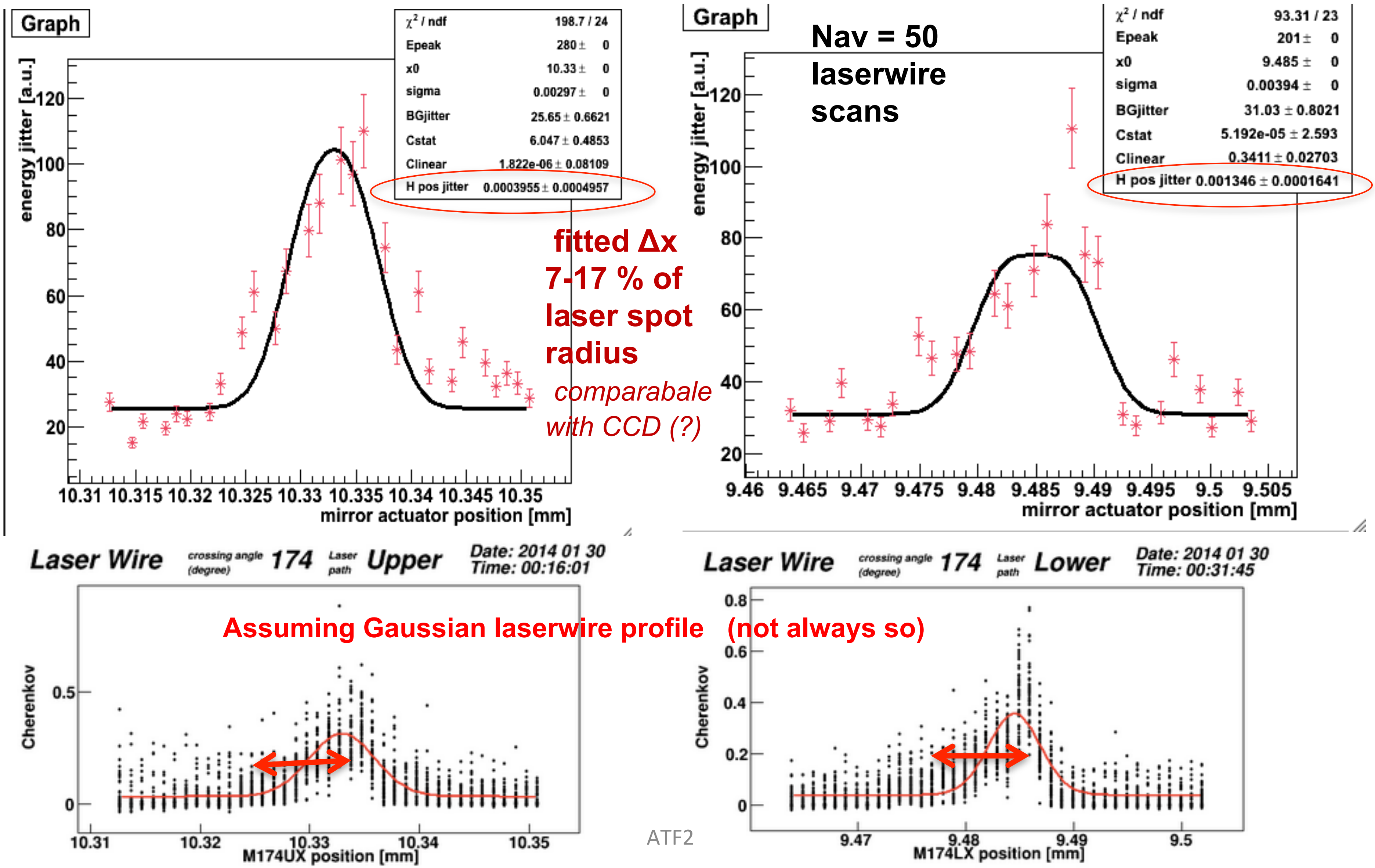
shifting around

May be affecting laserwire profile ?

Laser pointing stability

seen from horizontal relative position jitter ***(Δx)***

	sigma [mm]	Δx [mm]	ΔxIP [mm]	Δx/sigma	ΔE/E_relpos
U	0.0030+/-0.0008	0.0004+/-0.0005	0.0032+/-0.0040	0.133+/-0.171	1.2-8%
L	0.0039+/-0.0013	0.0013+/-0.0002	0.0109+/-0.0013	0.342+/-0.120	6.7-9%



Nav = 50 laserwire scans

fitted Δx 7-17 % of laser spot radius

comparabale with CCD (?)

Assuming Gaussian laserwire profile (not always so)

Error Studies using simulation

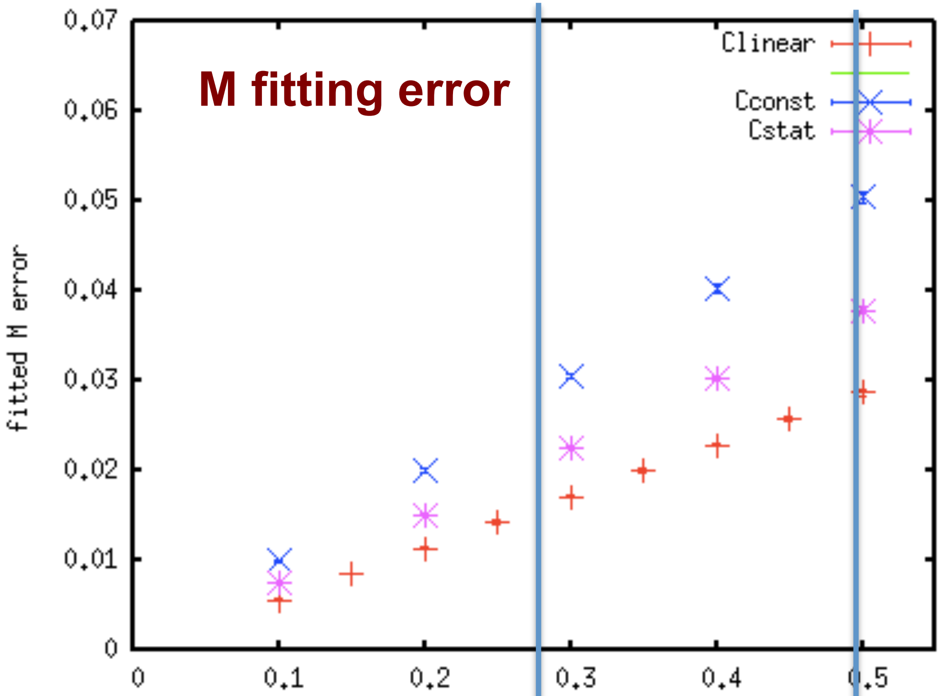
Vertical jitters "C factors"

$$\sigma_V = \sqrt{C_{const}^2 + C_{stat}^2 \cdot \overline{E(\varphi)} + C_{linear}^2 \cdot \overline{\left(E(\varphi)\right)^2}}$$

Input conditions:

100 random seeds
M0 = 0.636, Nav=10, 174 deg mode, $\Delta\varphi = 0$
Change 1 C factor type at a time, Keep others to 0

Effect of vertical jitters on M fitting error

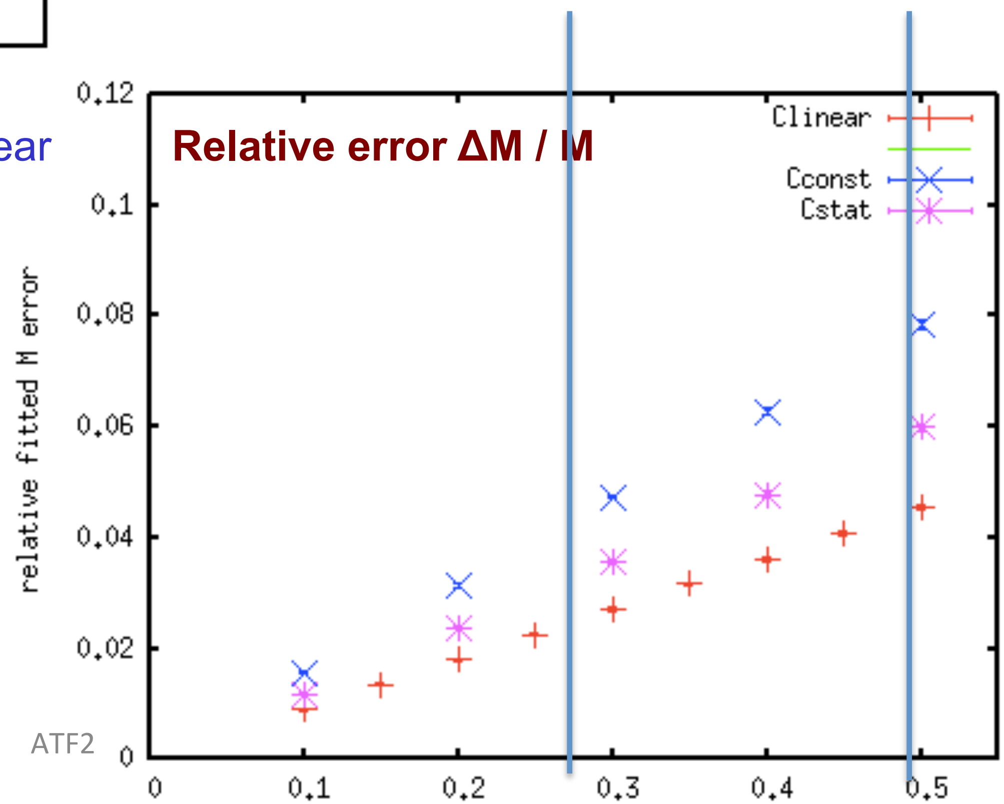


Range of recent Clinear

Cconst has largest effect (?)
but in Jan-Feb, 2014 BG fluctuation is not a problem owing to high S/N

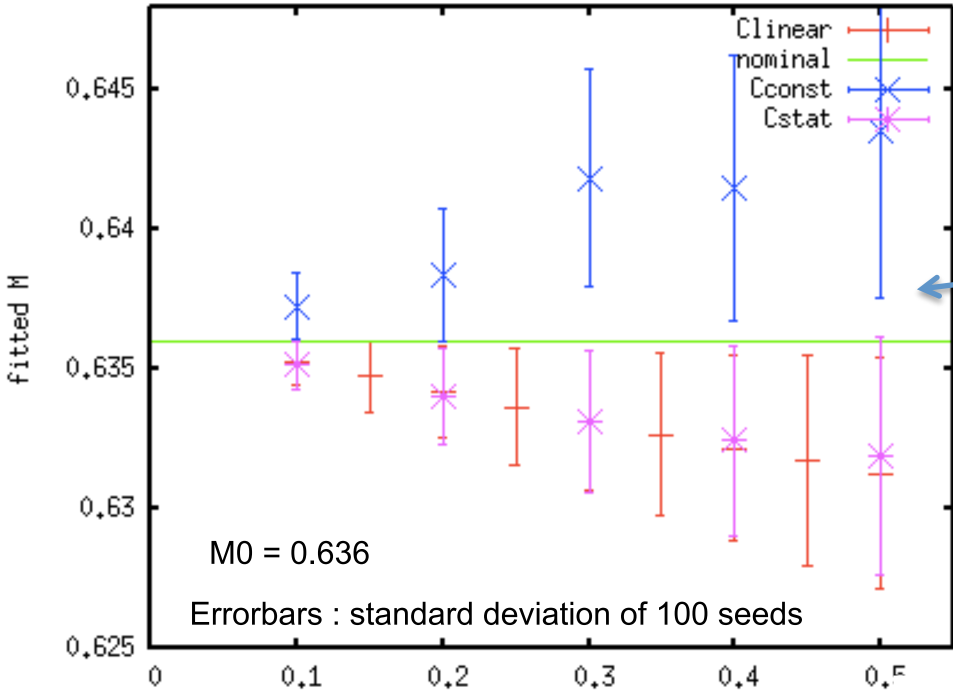
Clinear is the issue at present !!

$$\sigma_V = \sqrt{C_{const}^2 + C_{stat}^2 \cdot \overline{E(\varphi)} + C_{linear}^2 \cdot \overline{\left(E(\varphi)\right)^2}}$$



Input : 100 random seeds
M0 = 0.636, Nav=10, 174 deg mode,
Change 1 C factor type at a time, Keep others to 0

Effect of vertical jitters on fitted M



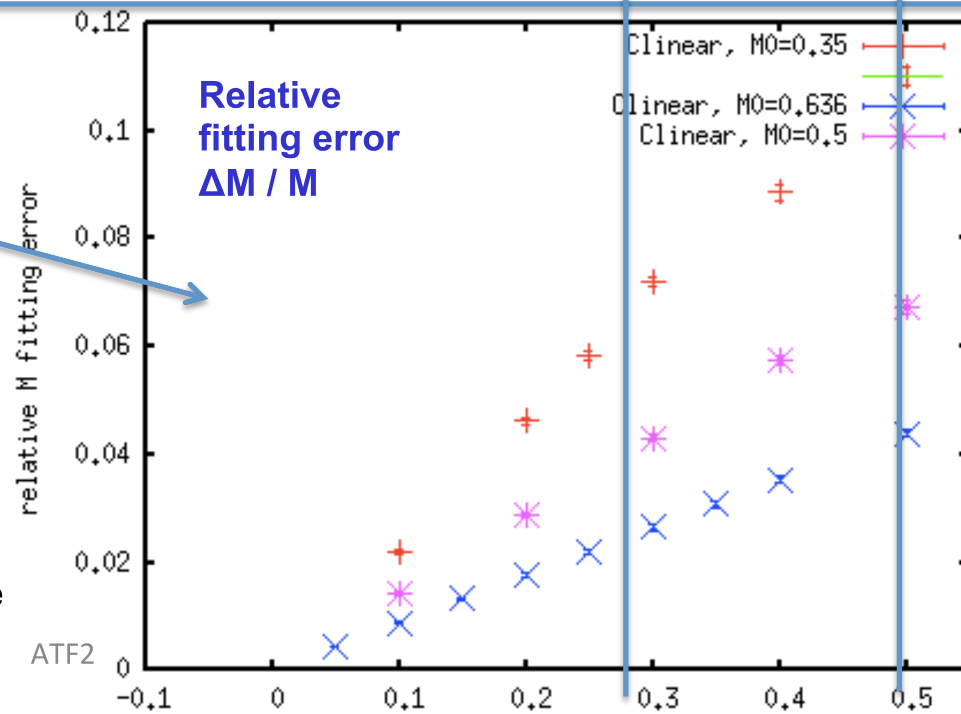
- Over-evaluation for Cconst
- M reduction for Clinear and Cstat

systematic error < few %

Not serious bias (?)

Range of recent Clinear

Clinear cause larger ΔM/M for smaller M_0



Input : 100 random seeds, Nav=10, 174 deg mode
Change 1 C factor type at a time, Keep others to 0

ATF2

Just Focus on Clinear

Keep other factors constant (and realistic ?) in simulation

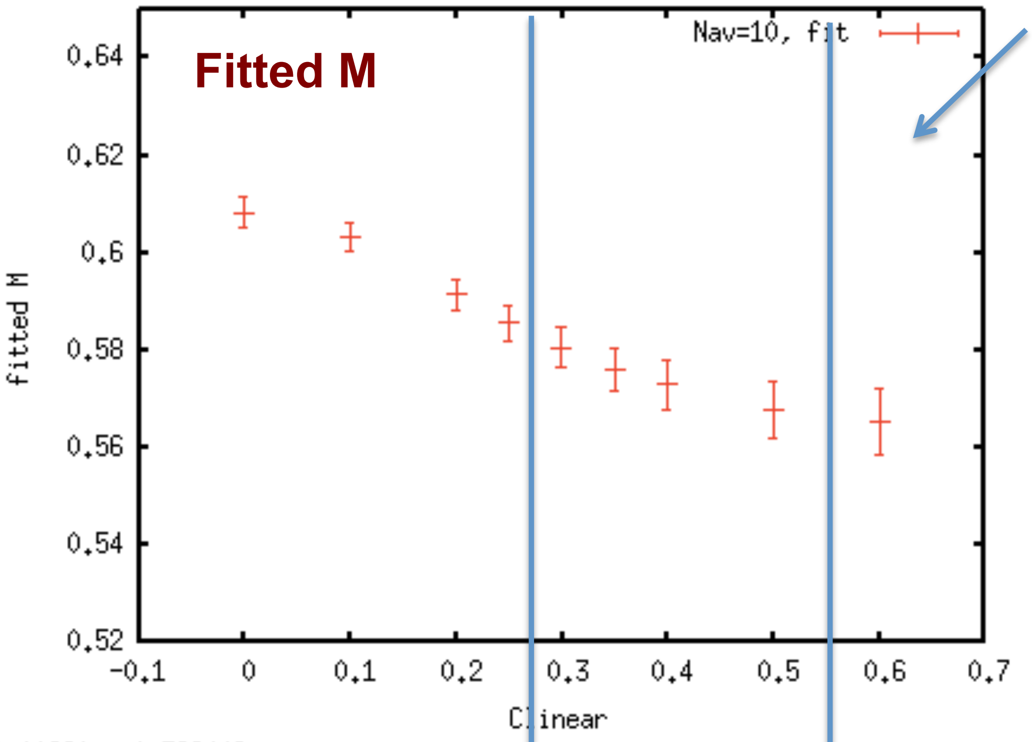
$$\sigma_V = \sqrt{C_{const}^2 + C_{stat}^2 \cdot \overline{E(\varphi)} + C_{linear}^2 \cdot \overline{\left(E(\varphi)\right)^2}}$$

"realsitic" (?) input conditions:

σ_{0y} **= 40 nm**, M_0 = 0.636, 174 deg mode

$\Delta\varphi$ = 470 mrad

Cstat = 0.1 Cconst =0.05



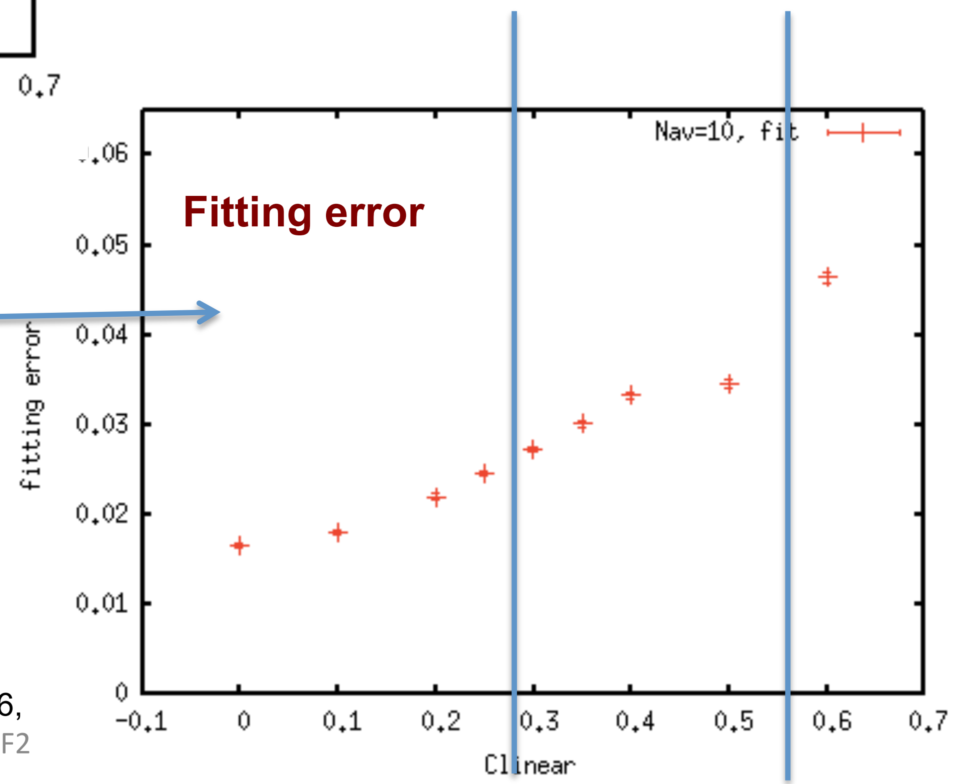
Effect of Clinear on fitted M

3-7 % systematic M reduction ?

Range of recent Clinear

Effect of Clinear on M fitting error

ΔM = 0.025 - 0.035 for recent Clinear range
about consistent with real data
(c.f. ΔM < 0.02 for more stable scans)



Input : 100 random seeds, Nav=10, 174 deg mode, M0 = 0.636,
Cconst = 0.05, Cstat = 0.1, Δφ = 470 mrad

Simulation of sudden change in Compton signal energy

Jitters / jumps/ drift

“realsitic” (?) input conditions:

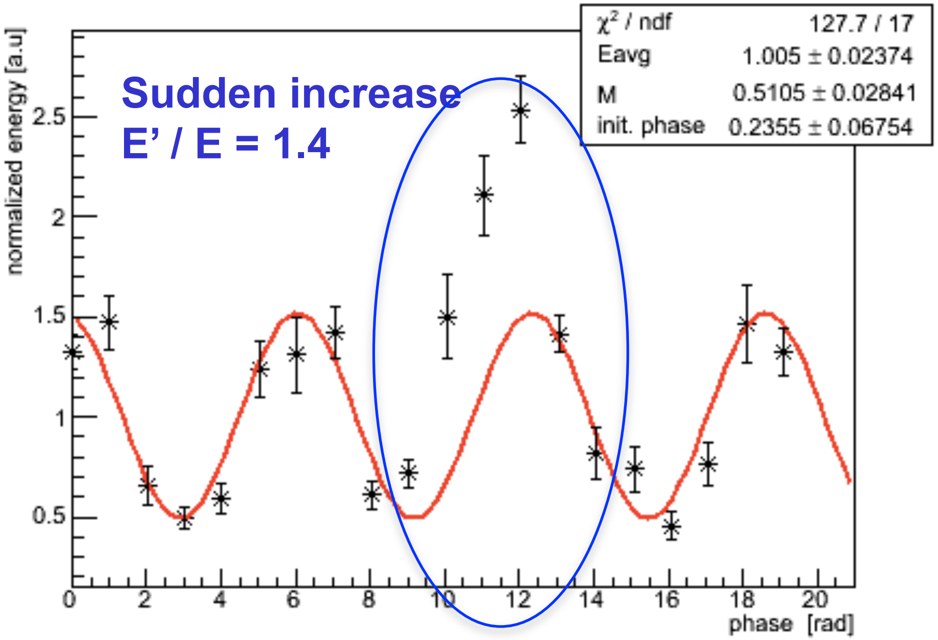
$\boldsymbol{\sigma_{0y}}$ **= 40 nm**, M_0 = 0.636, 174 deg mode

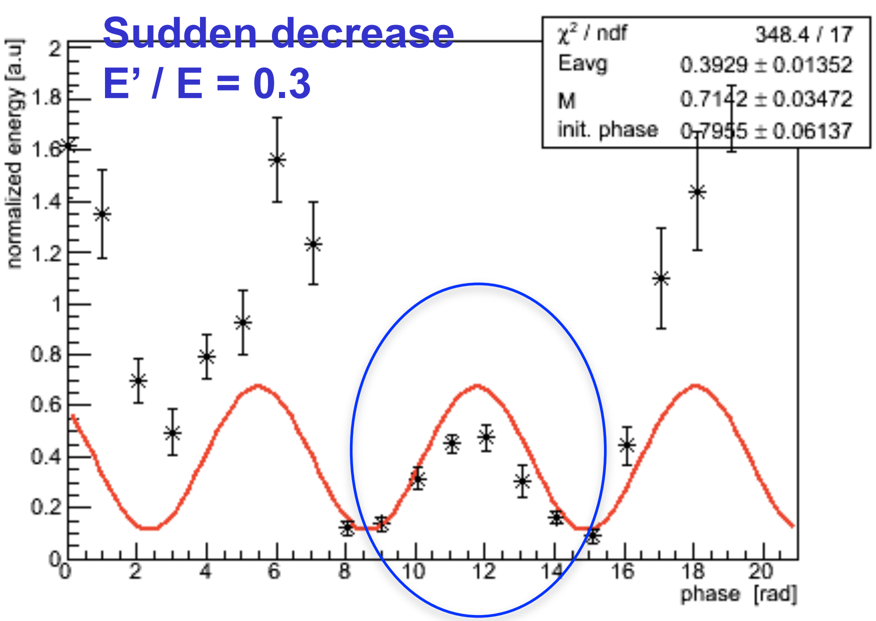
$\Delta\varphi$ = 470 mrad

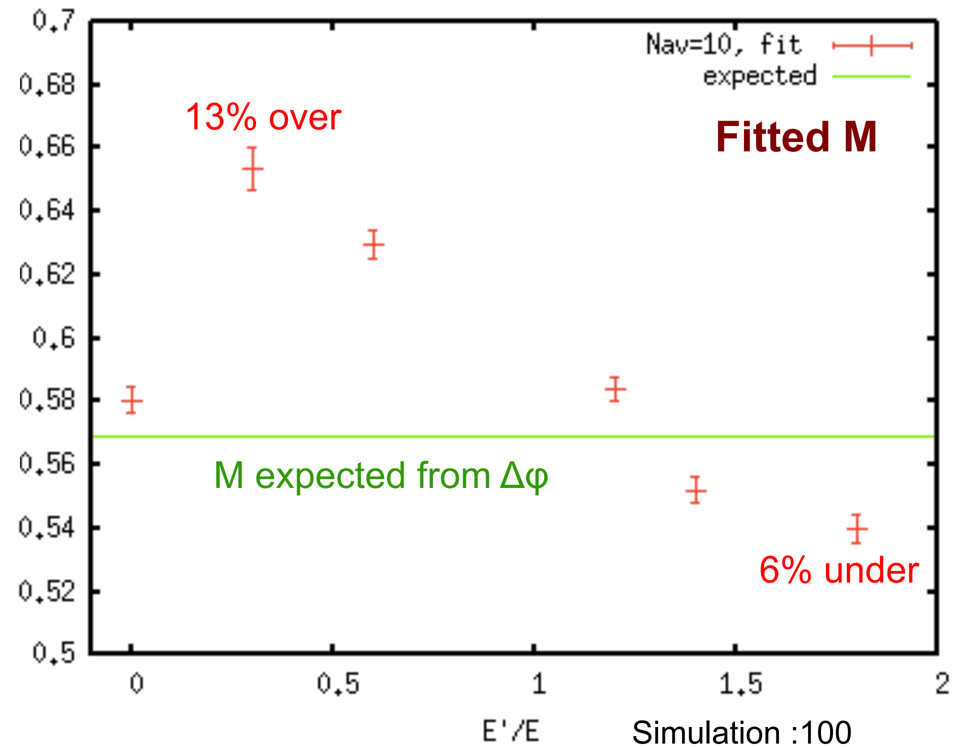
Cstat = 0.1 Cconst =0.05 , Clinear = 0.3

Effect of laser instability on M_meas : Nav=10

Assume Comp. signal intensity suddenly change @ 8 – 15 rad (drift ?)







Simulation :100 random seeds

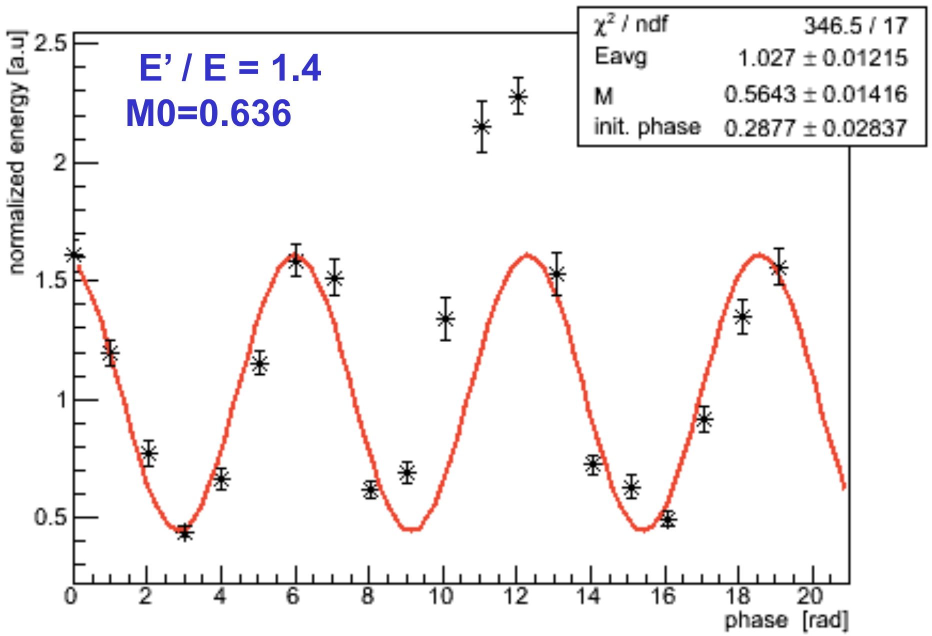
Input : M0 = 0.636, Nav=10, 174 deg mode,
Δφ = 470 mrad, Clinear = 0.3, Cstat = 0.1, Cconst = 0.05

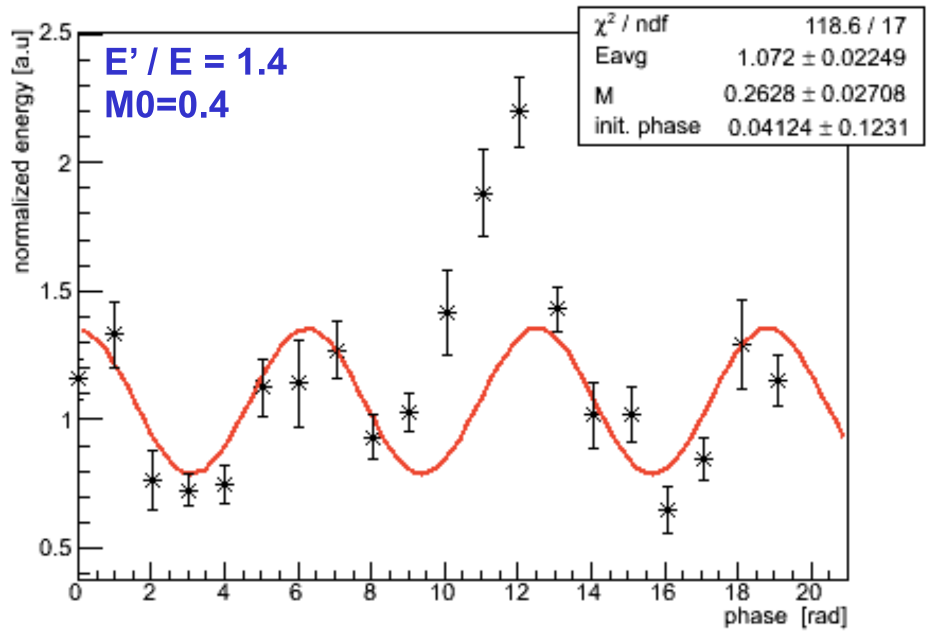
Effect of signal intensity suddenly change (drift ?) E' / E = 1.4 @ 8 – 15 rad

Error is more serious for smaller M0=0.4 than larger M0 = 0.636

ΔM/Mexp =
- 7% for M0 = 0.636
- 11% for M0=0.4

E'/E=1.4	Nav=10	
	Mexp=0.596	**Mexp=0.358**
fitted M	**0.552+/−0.004**	**0.318+/−0.004**
Δ M/Mexp	**0.93**	**0.89**
M fititng err	**0.027**	**0.028**





Input : Nav=10, 174 deg mode,
$\Delta\varphi$ = 470 mrad, Clinear = 0.3, Cstat = 0.1, Cconst = 0.05

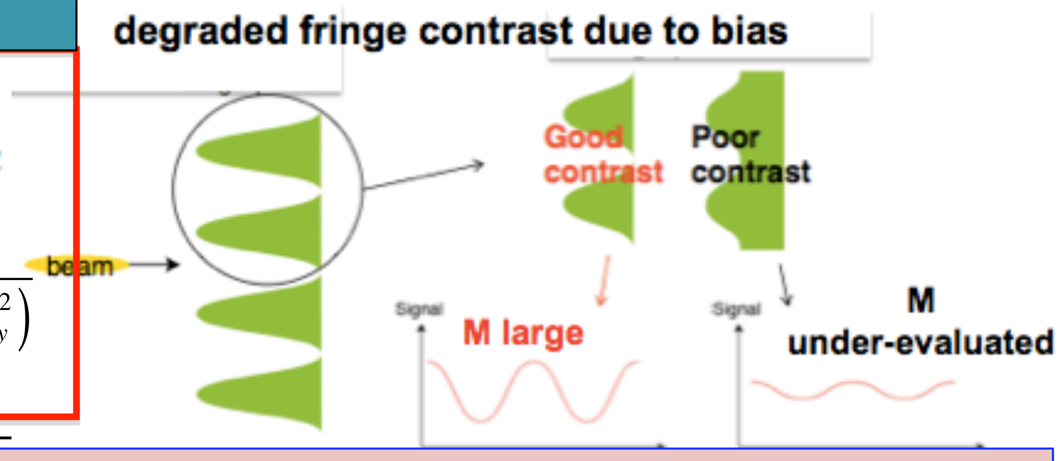
Systematic errors : M reduction Factor

M under-evaluation

$$M_{meas} = C_1 C_2 \ldots\ldots M_{ideal} = \left(\prod_i C_i\right) M_{ideal}$$

σ_y over evalution

$$\sigma_y \rightarrow \sqrt{\sigma_y^2 + \sum_i \left|\ln(C_i)\right| / \left(2k_y^2\right)}$$



Priority is to resolve signal jitters / drifts (→ enable precise evaluation of M reduction factors)

phase jitter (V relative position jitter)	studied using simulation and monitor actual data **Details coming up**
Fringe tilt (z, t)	Optimization by **"tilt scan"** → jitters were too large to try this recently (?)
Laser polarization	polarization measured → optimize by "λ / 2 plate scan "
Misalignment **Laser profile** **Spatial coherence**	profile change shot-by-shot Non-Gaussian profile → sometimes observe 10-20% M reduction
Phase drift	Negligible during typical beam tuning if linear drift < 100 mrad/min maybe partially coupled with laser position drift / jitters → Compton signal intensity drift

Study of IPBSM Phase Jitter

Tested Method using Simulation

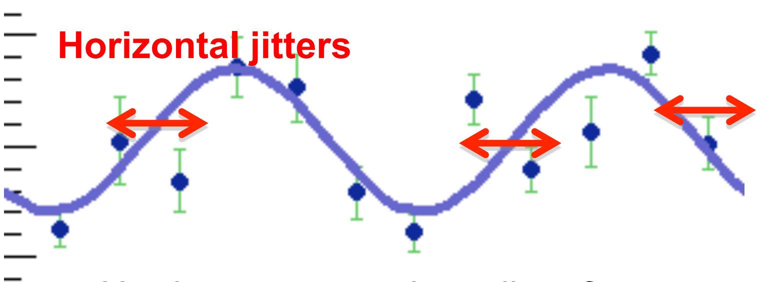
<u>Input conditions:</u>

σ_{0y} = 40 nm, M_0 = 0.636, 174 deg mode

Vary $\Delta\varphi$ = {0.23, 0.47 , 0.70, 0.91, 1.2} rad
<-> Δy = {10 , 20 , 30 , 40 , 50 } nm

About 24% vertical jitter (> ~ typical)
Cstat = 0.07 Cconst =0.05 **Clinear =0.23** ***realistic assumptions??***

Phase jitter Δϕ
(relative position jitter Δy)



- *Hard to separate phase jitter from e-beam jitter and vertical jitters*
- *conditions change over time*

Δφ → M reduction

Small σy especially sensitive !!*

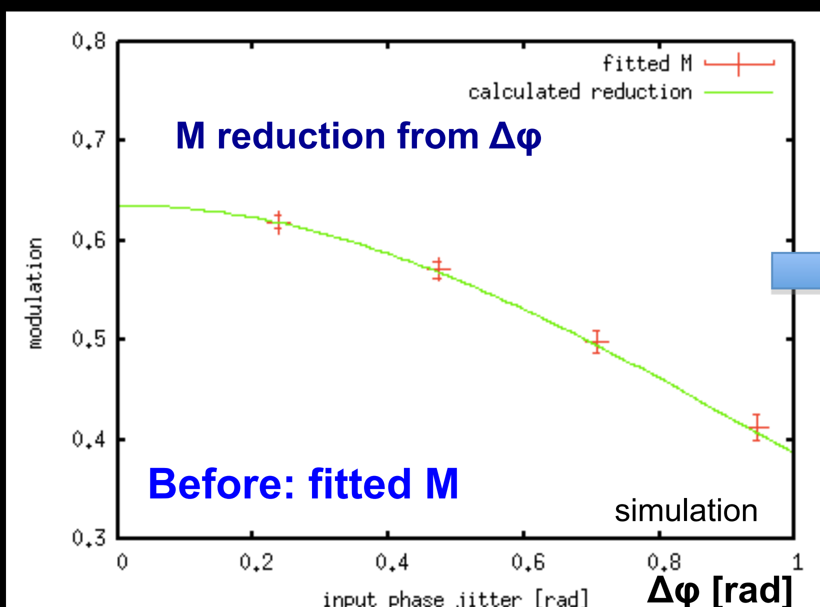
$$y \rightarrow y + \Delta y \qquad \sigma_y^2 \rightarrow \sigma_y^2 + (\Delta y)^2$$

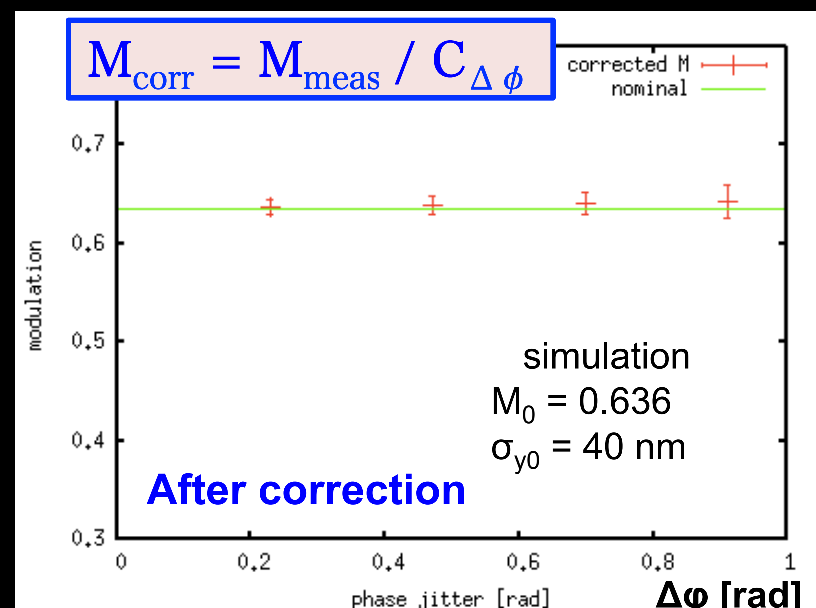
$$\Delta\phi = 2k_y \Delta y \qquad k_y = \frac{2\pi}{\lambda}\sin\left(\frac{\theta}{2}\right)$$

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

(example)
if Δϕ = 400 mrad, $C_{\Delta\phi}$ ~ 90.5 %
σ_{y0} = 40 nm → $\sigma_{y,meas}$ = 44 nm

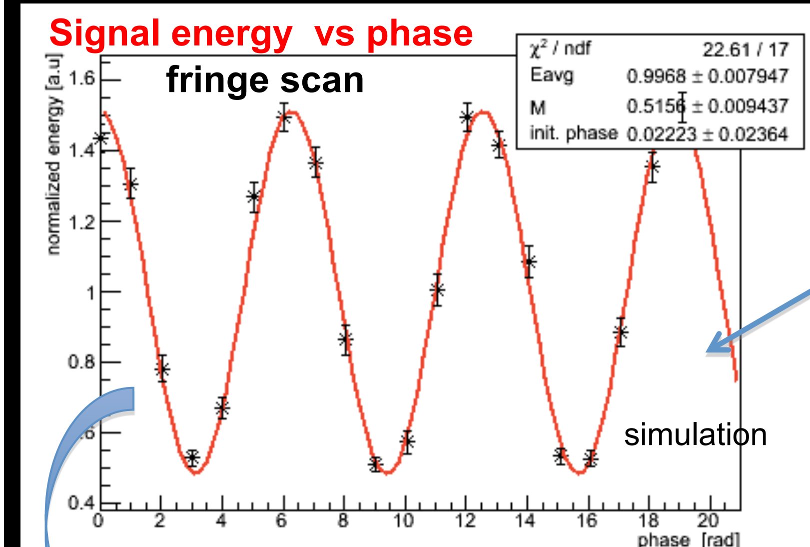
we have developed a method for extracting Δϕ



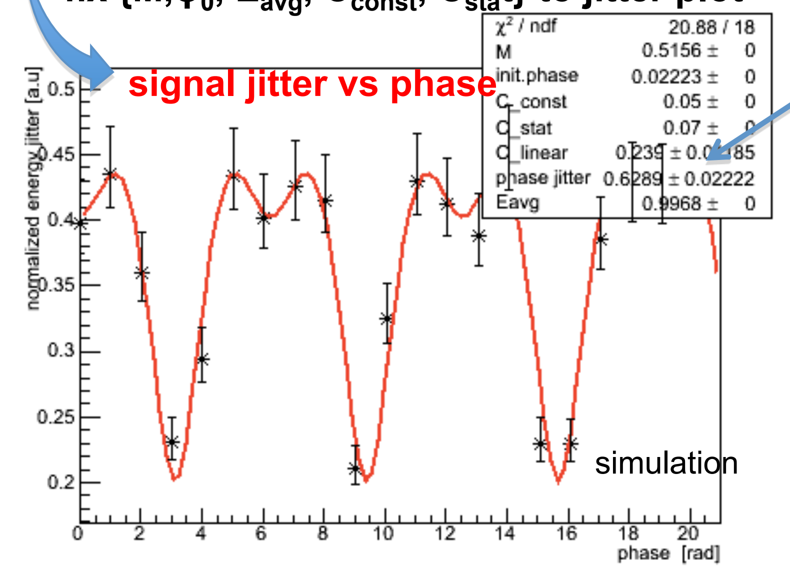


M is corrected almost back to nominal using extracted Δϕ

Reliability test of Δφ extraction using simulation



fix $\{M, \varphi_0, E_{avg}, C_{const}, C_{stat}\}$ to jitter plot



input: σ_{y0} = 40 nm, 174°mode

Δφ = 0.7 mrad , 24.5 % vertical jitter

STEP1: generate signal energy

reflect "realistic condition"

$$E = E_{avg} \cdot \{1 + M \cdot \cos\varphi\} \qquad \varphi \equiv \varphi_{set} + \varphi_0$$

$$\varphi \rightarrow \varphi \pm \Delta\varphi$$

Δφ input

$$E_{avg} \cdot \left\{1 + M \cdot \cos\left(\varphi + \left(Random \rightarrow Gaus(0, \sigma_\varphi)\right)\right)\right\}$$

$$\sigma_{V,input} = \sqrt{C_{const}^2 + \left(C_{stat}\sqrt{E}\right)^2 + \left(C_{linear} \cdot E\right)^2}$$

Input vertical jitters

STEP2: fit jitter plot

→ extract **Δφ , Clinear** (2 free parameters)

Model

$$\Delta E \equiv \sigma_{tot} = \sqrt{\sigma_V^2 + \sigma_p^2}$$

Jitter from Δφ

$$\sigma_p = E_{avg} M \sqrt{\frac{1}{2}\left[1 - 2\cos^2\varphi \exp\left(-\Delta\varphi^2\right) + \cos(2\varphi)\exp\left(-2\Delta\varphi^2\right)\right]}$$

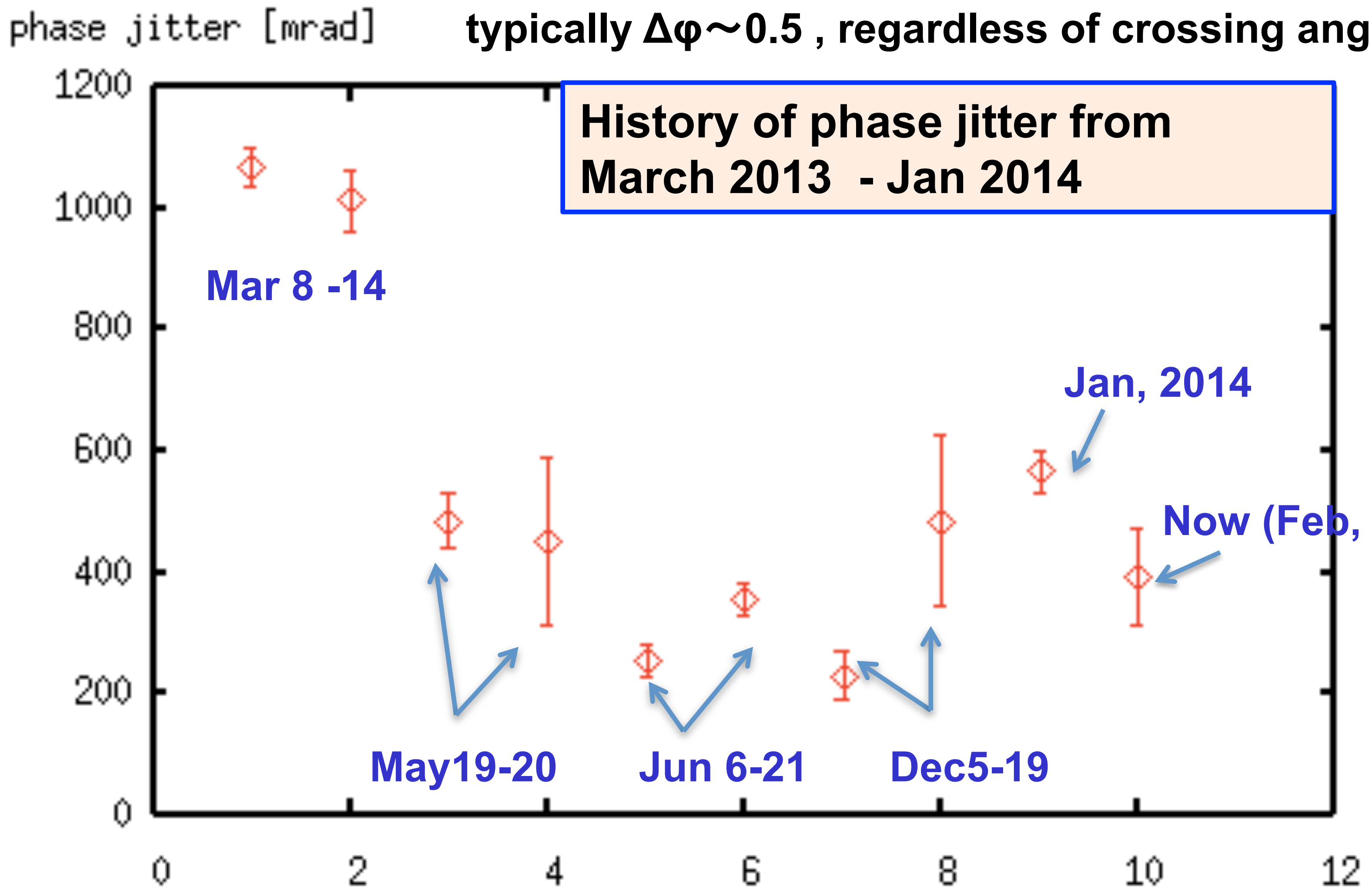
vertical jitter

$$\sigma_V = \sqrt{C_{const}^2 + C_{stat}^2 \cdot \overline{E(\varphi)} + C_{linear}^2 \cdot \overline{\left(E(\varphi)\right)^2}}$$

fixed parameters:

- M, φ_0, E_{avg} : from STEP 1
- Cconst, Cstat: estimated (slight uncertainties are negligible)

typically Δφ～0.5 , regardless of crossing angle mode



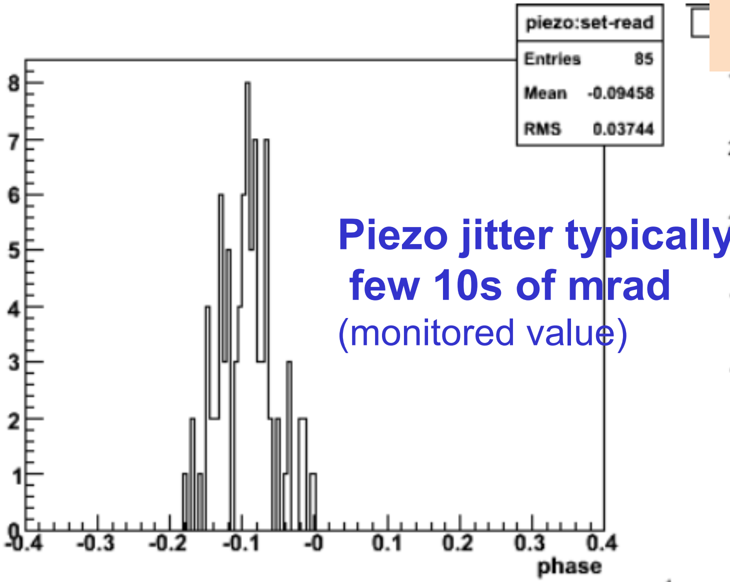
Only big phase jitter in Mar 2013 , reason is still unclear

Δφ ～ 1 rad, ～ 15 nm contribution to beam size ??

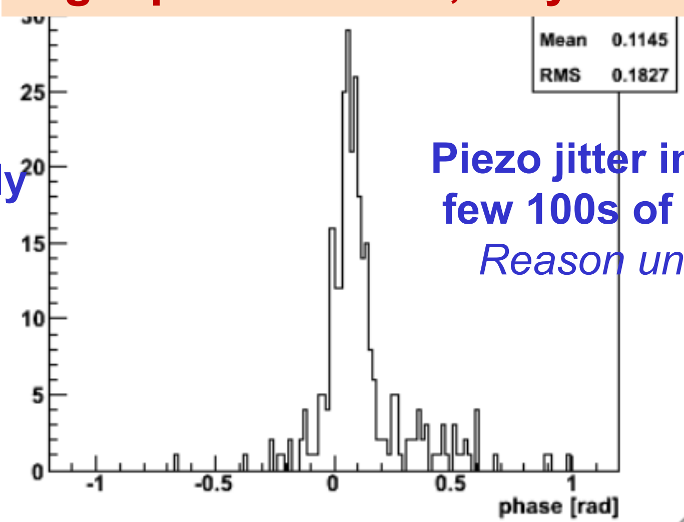
3/8: 1.07 +/- 0.10 (rms) rad 3/14: 1.01 +/- 0.16 (rms) rad

after correction: M_{corr} = 0.50 +/- 0.09 (stat) (←→ σ_y^* = 50 +/- 5 nm)

big Δφ in Mar 2013, maybe due to piezo jitter (?)

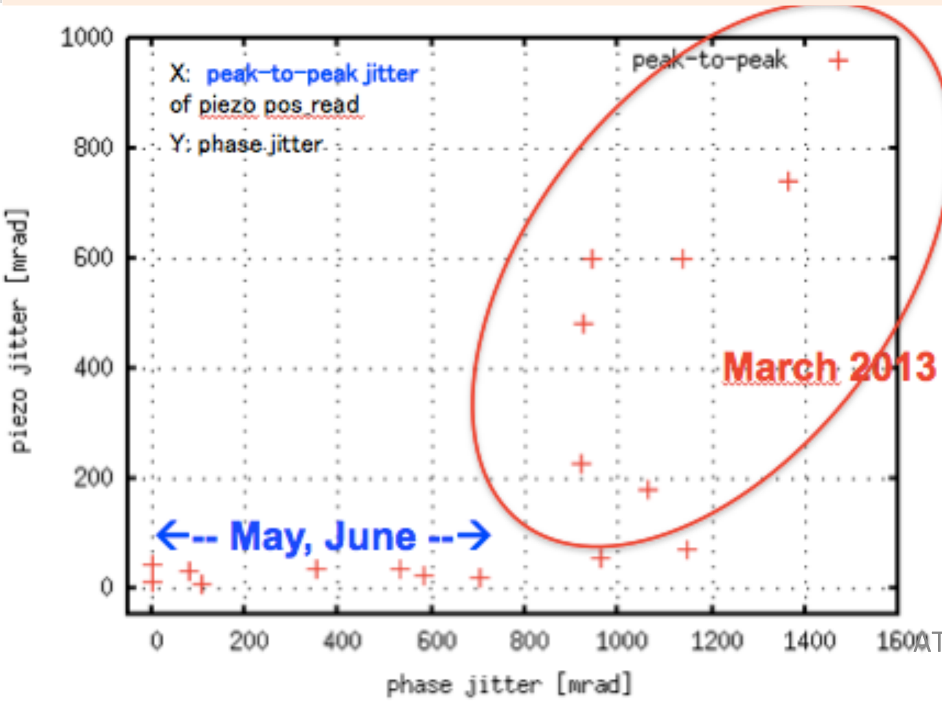


Piezo jitter typically few 10s of mrad (monitored value)



Piezo jitter in Mar 2013 few 100s of mrad
Reason unknown

Mar:	phase jitter ~1 rad	Avg piezo jitter ~ 250 mrad
May, Jun:	phase jitter : 200 – 500 mrad	Avg piezo jitter ~ 25 mrad



can neither claim nor reject correlation (??)

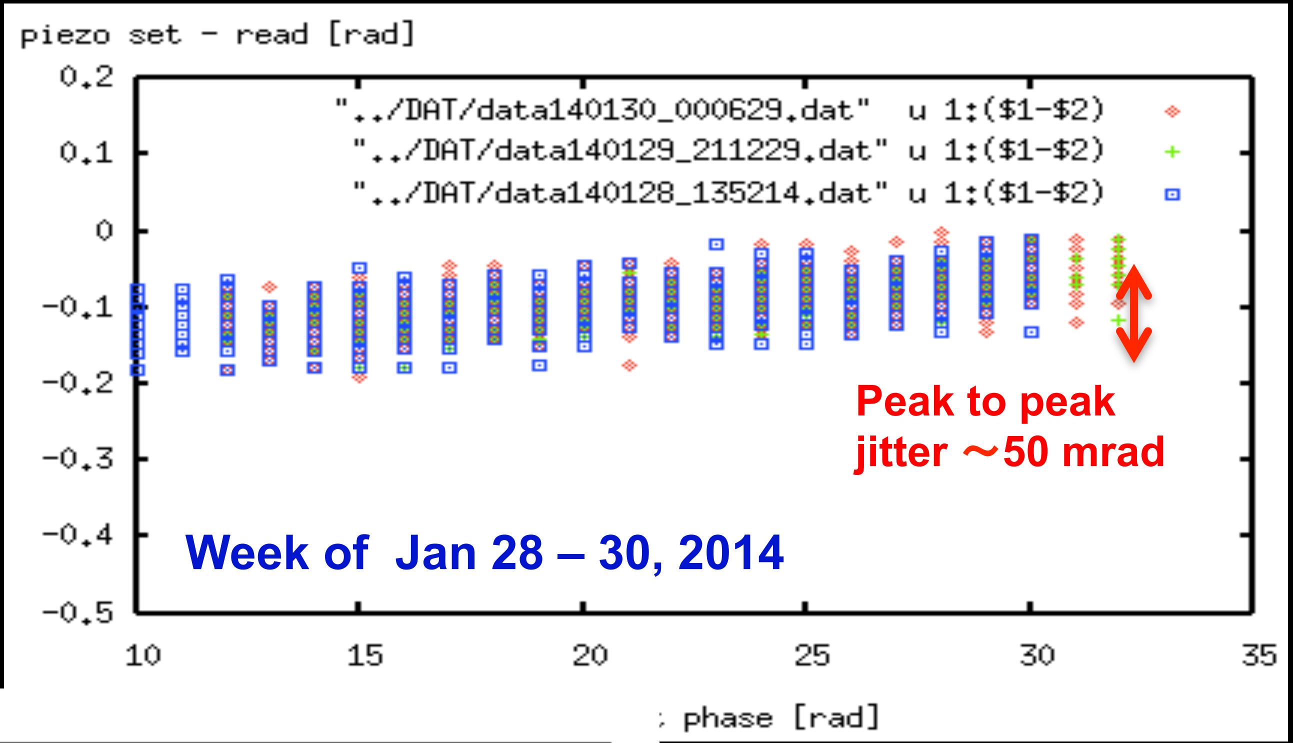
Maybe ADC mal-functioning, noise from nearby devices / cables during beam time , ect….

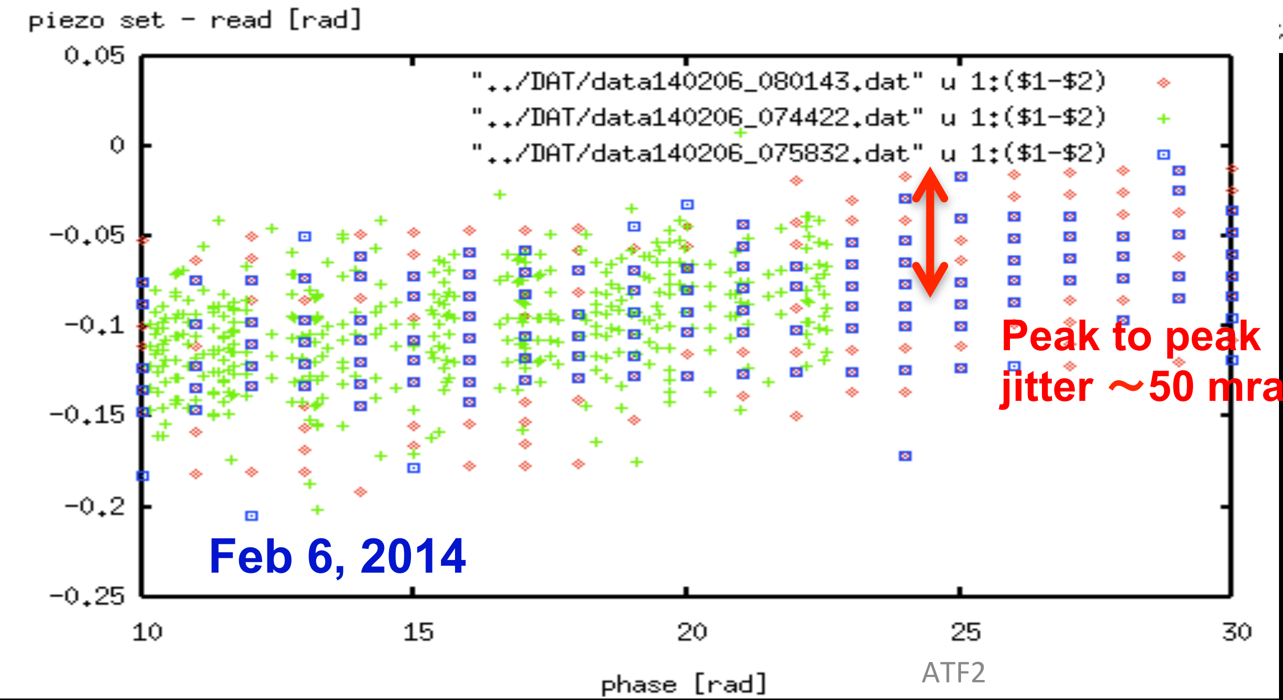
this is all we can investigate for now
(option: cut events with large piezo jumps)

more important to ensure piezo controller and monitor works for current beam run (next page)

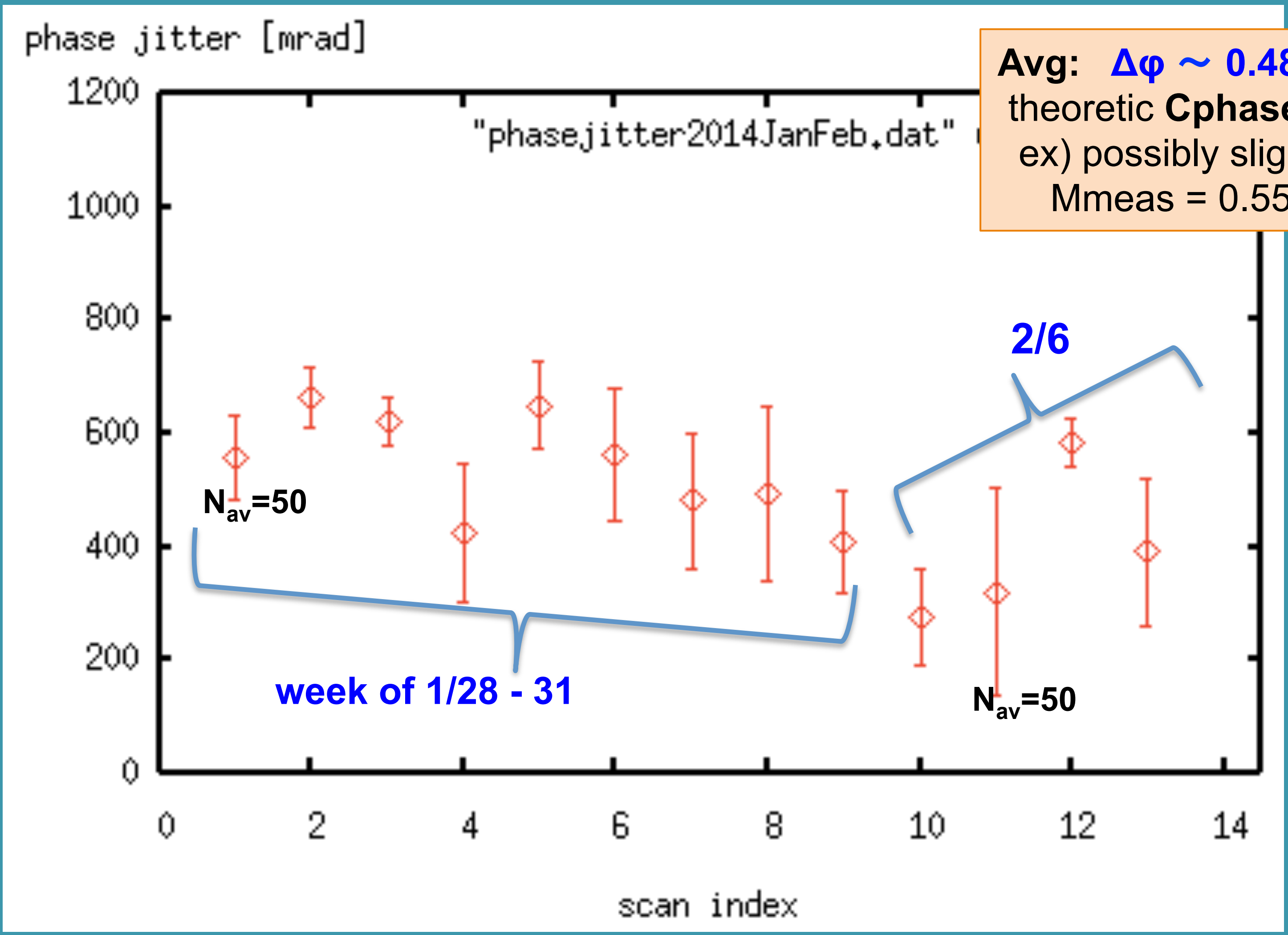
Except for Mar 2013, piezo jitter only a few 10s of mrad

regularly monitored





A look at recent phase jitter status using fringe scan data @ 30 deg mode

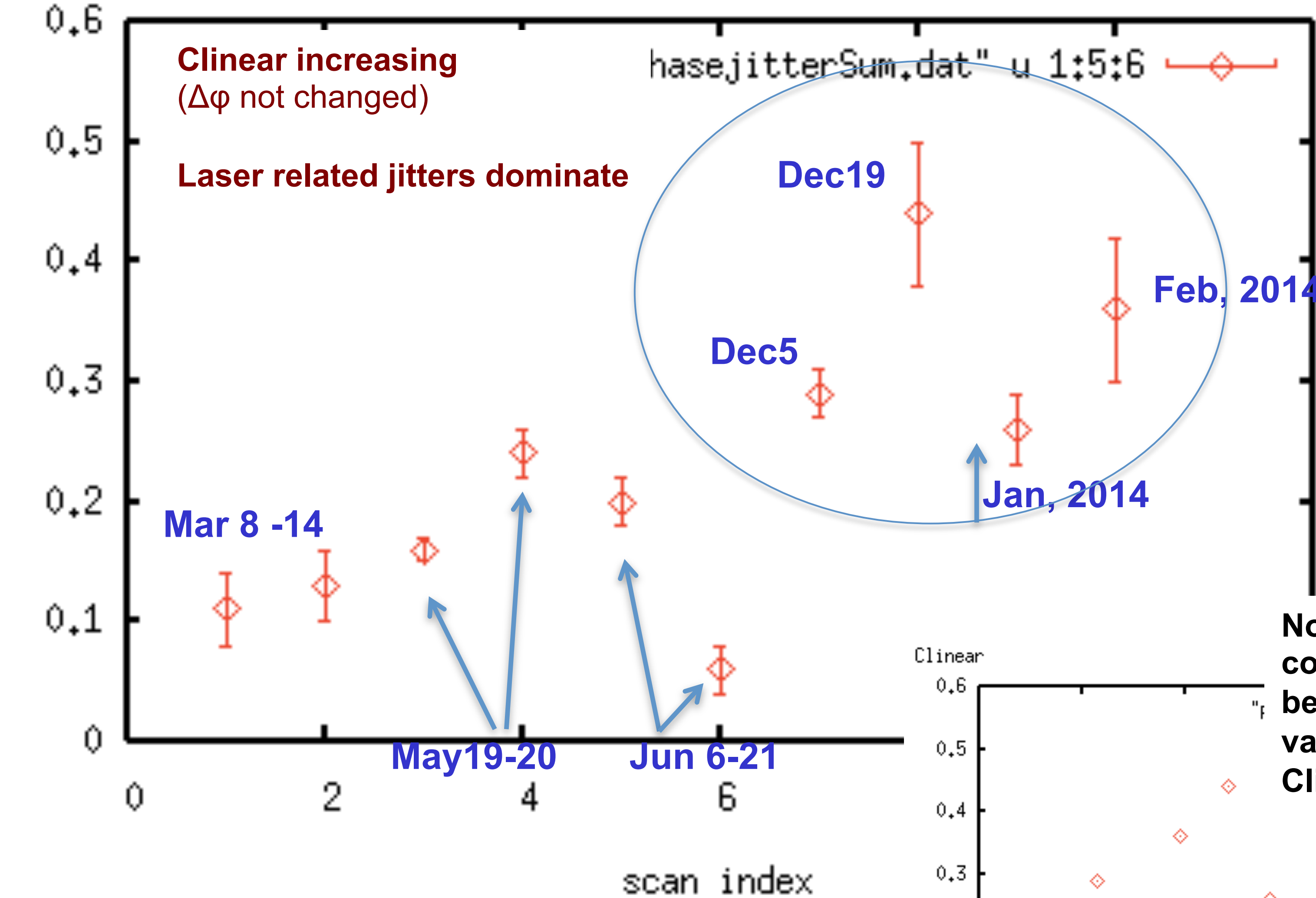


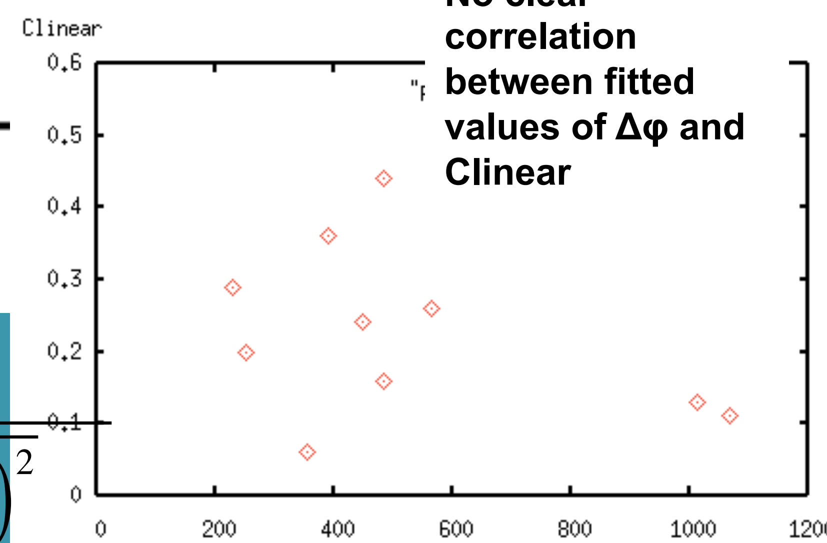
Avg: $\Delta\varphi \sim 0.48$ rad
theoretic **Cphase∼0.89**
ex) possibly slight M reduction
Mmeas = 0.55 → Mcorr = 0.62

N_{av}=10 data were randomly "picked up" i.e. not dedicated to $\Delta\varphi$ study

- Despite different tuning and vertical jitter condition **$\Delta\varphi$ mostly stable & typical**
- not serious problem for current stage of mode switching from 30 deg → 174 deg
- may **limit maximum measured M**

History of Clinear from March 2013 - Jan 2014



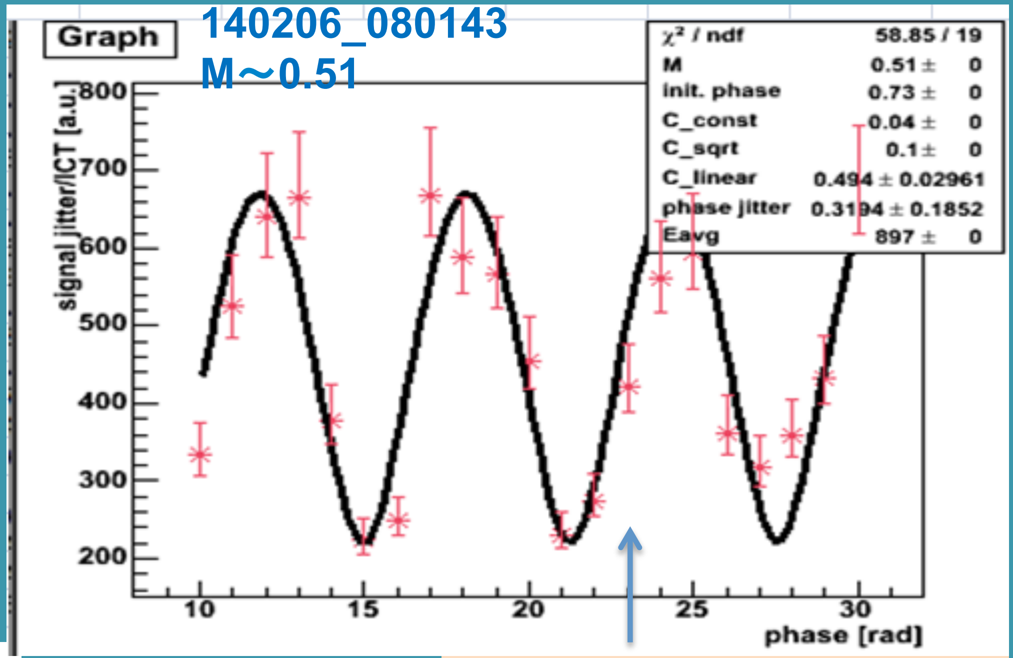


No clear correlation between fitted values of Δφ and Clinear

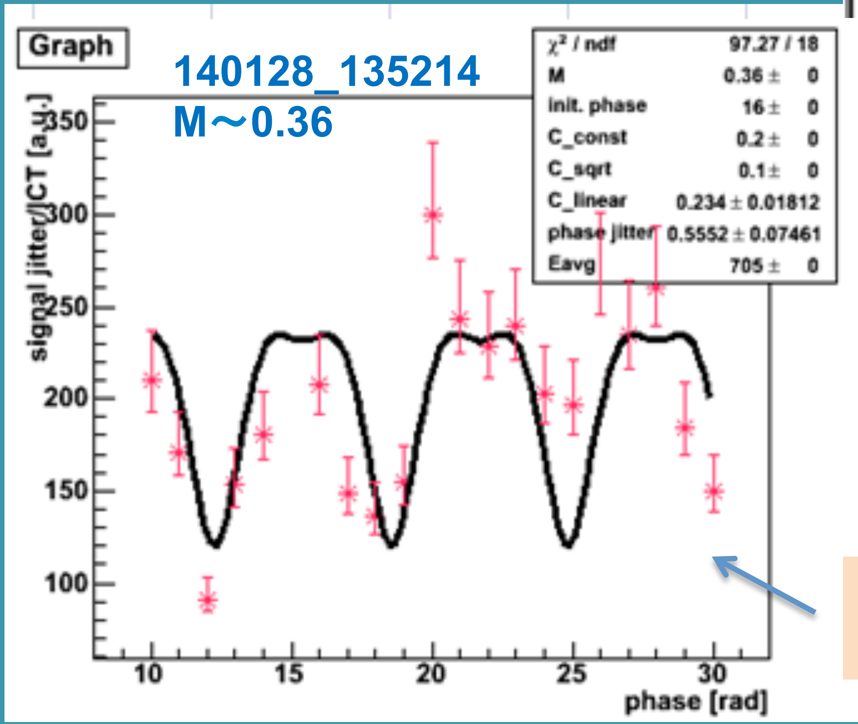
$$\sigma_V = \sqrt{C_{const}^2 + C_{stat}^2 \cdot \overline{E(\varphi)} + C_{linear}^2 \cdot \overline{\left(E(\varphi)\right)}^2}$$

Δφ analysis using Nav=50 scan @ 30 deg mode

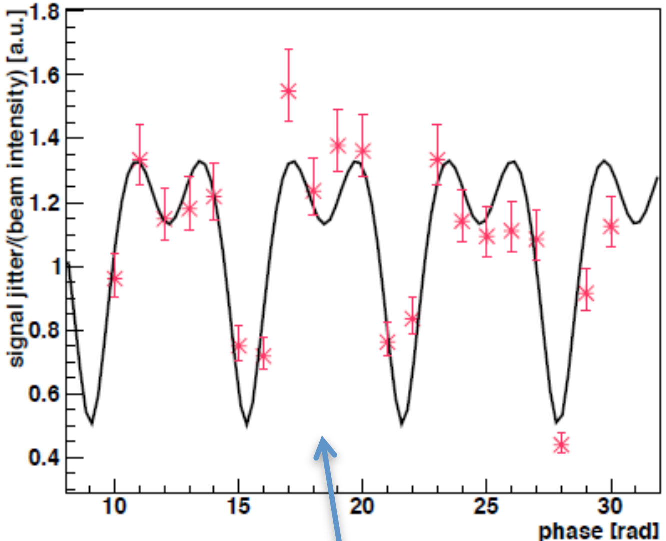
Plots of energy jitter vs phase

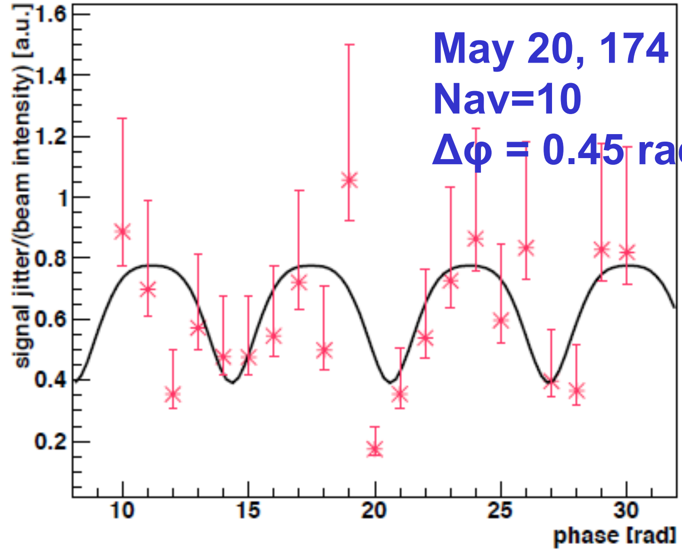


Δφ = 319 +/- 185 mrad
Clinear = 0.49 +/- 0.03



Δφ = 555 +/- 75 mrad
Clinear = 0.23 +/- 0.02



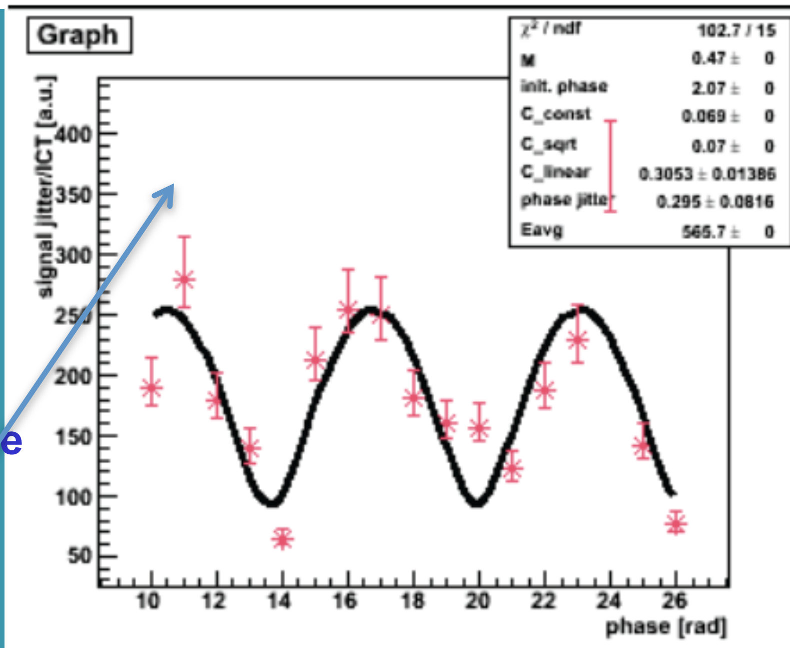


May 20, 174 deg mode
Nav=10
Δφ = 0.45 rad

Fig 10: Analysis of phase jitter (Δφ) using fringe scan data from May 2013: (left) 30°mode, Nav = 99 (130519_233915) Δ ϕ = 0.49 +/- 0.01 rad, Clinear = 0.16+/- 0.01. (right) 174°mode, Nav = 10 (130520_222330) Δ ϕ = 0.45+/-0.14 rad, Clinear = 0.24+/-0.02. For 174° mode here, Δφ contributes 5-10 nm to the measured σy* .

May 19, 30 deg mode
Nav= 99
Δφ = 0.49 rad

Δφ analysis
Plots of energy jitter vs phase



Dec 5, 2-8 deg mode
Nav= 50
Δφ = 0.30 rad

ATF2

Summary

Shintake Monitor (IPBSM) : essential device for achieving ATF's Goal 1

< Status >

- ❖ **～ Jun 2013,** contributed to beam focusing / beam studies with measuring stability **5 -10 %**
- ❖ **Recently (Dec 2013～) : significant increase in signal jitters / drift**
- **hardware improvements are on-going**

< error studies>

- **simulation on effect of vertical jitters :** laser-related jitters (Clinear) can cause $\Delta M/M > 10\%$
- **phase jitter studies : $\Delta\phi$ typically ～ 0.5 rad, not increasing** since May 2013,
  despite vertical laser jitters are getting worse

c.f. analysis of continuous scan @174° in Mar 2013 M = 0.30 +/- 0.04 (stat)

(←→ σ_y^* = 65 +/- 4 nm) **after correction for phase jitter : ～15 nm smaller (??)**

Goals

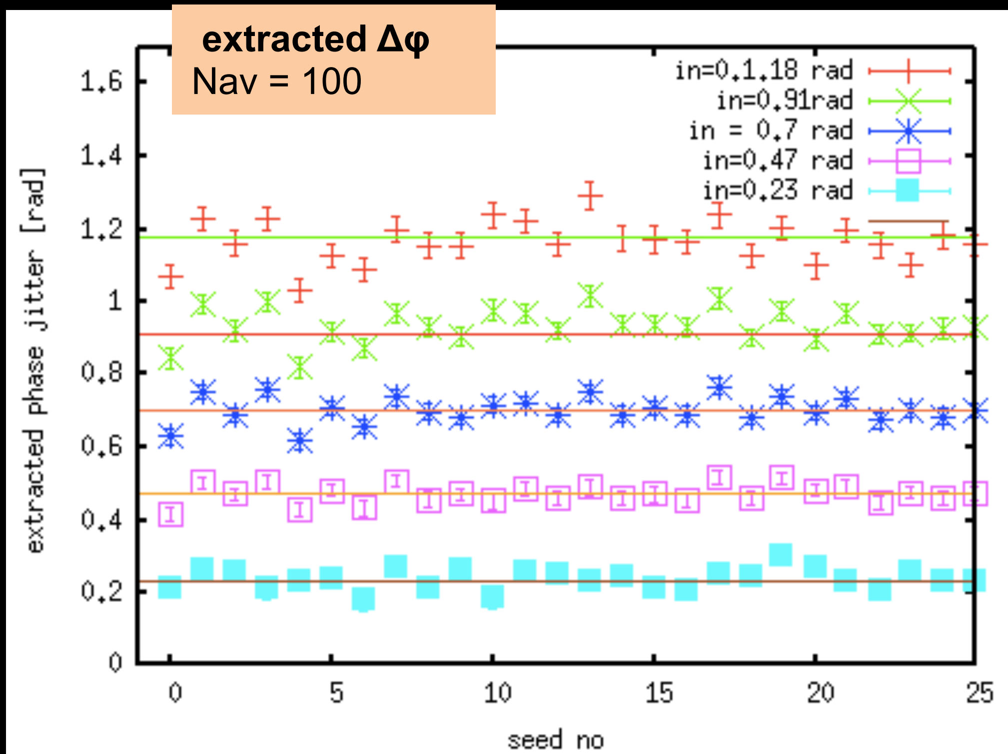
- **improve measurement stability and precision**
- **identify and suppress sources for jitters / drifts**
- **analyze data before/ after to evaluate effect of hardware upgrades**
- **Simulation studies to determine "limit" for instabilities**

these must be achieved before other M reduction factors can be evaluated precisely to correct the measured beamsize

ultimate goal: **measure σ_y^* < 60 as precisely as possible**

→ move towards achieving ATF Goal 1

BACKUP SLIDES

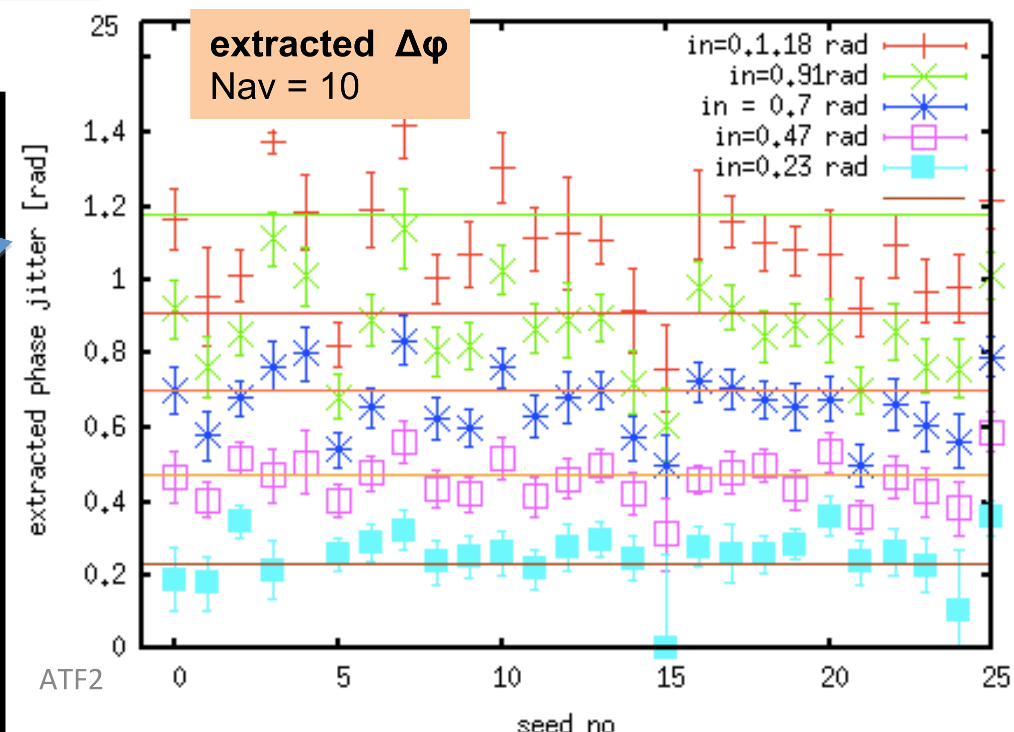


cannot take many scans during beam time
→Need to **observe random distribution**

- X axis: 25 random simulation seeds represent **individual scans**

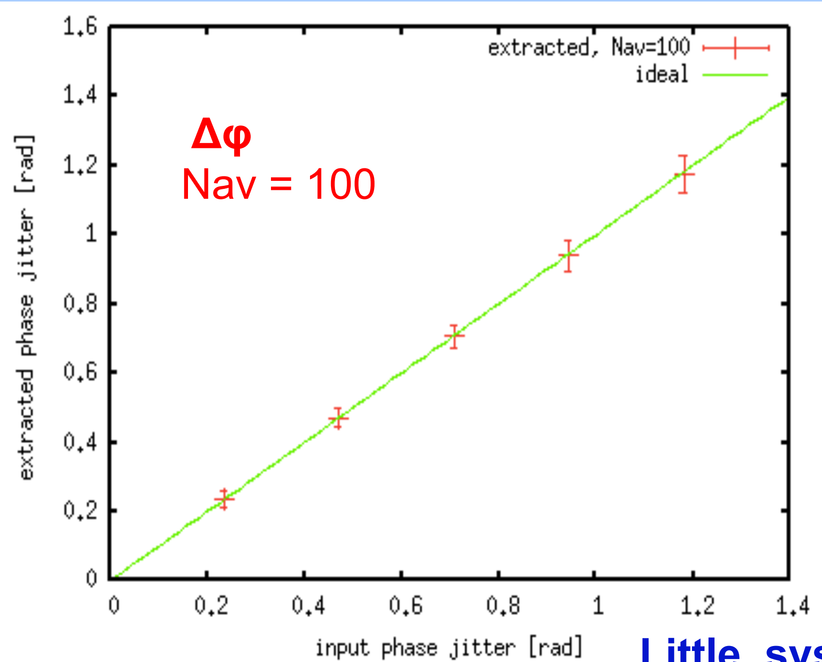
Nav=100 : small deviation from input
(δ<100 mrad even for heavy Δφ)

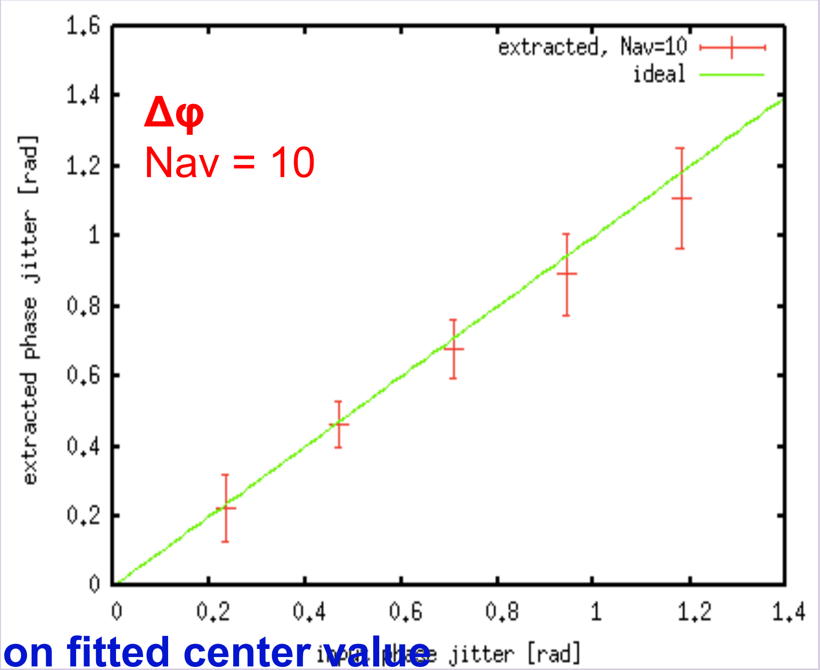
Nav=10 :
large deviations
for heavy Δφ (> 700 mrad)



ATF2

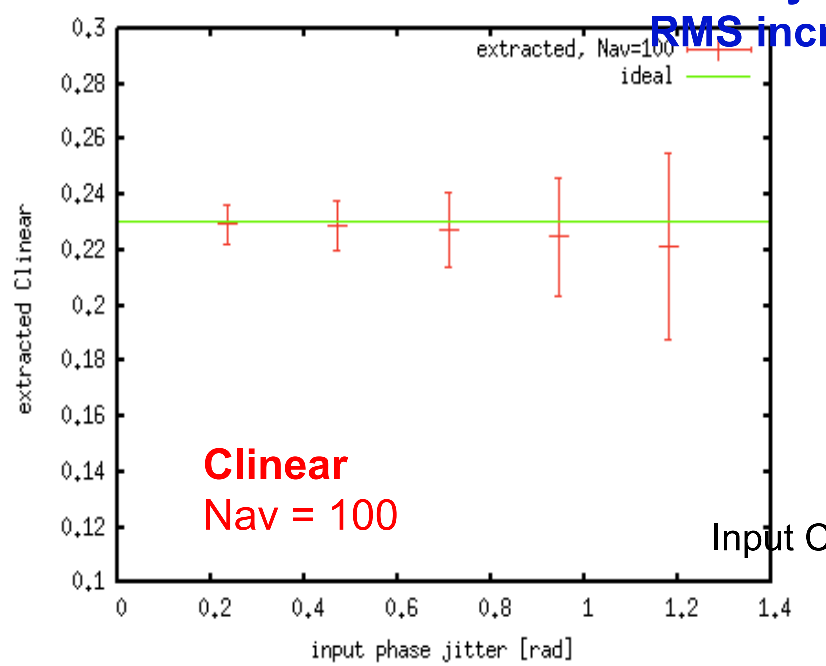
Simulation test： Mean & RMS (S.D.) of 100 random seeds

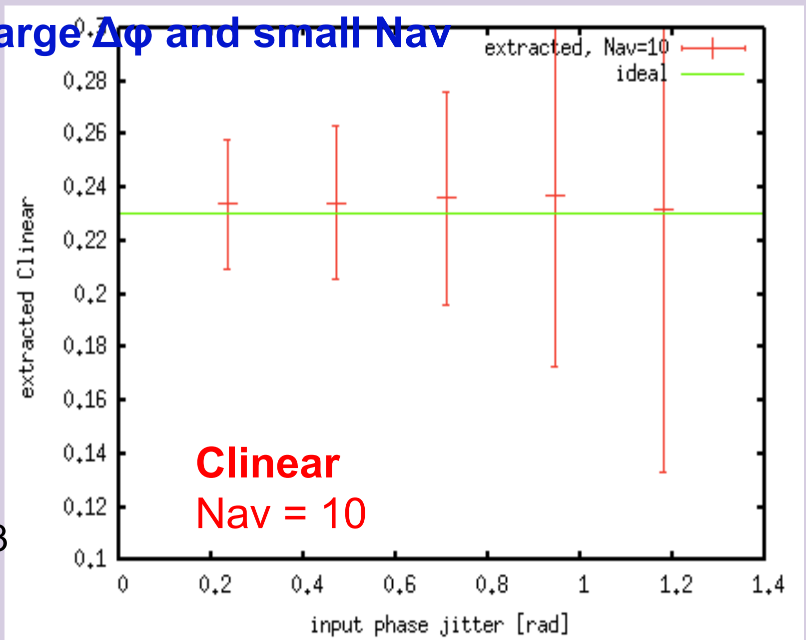




Little systematics on fitted center value

RMS increase for large Δφ and small Nav

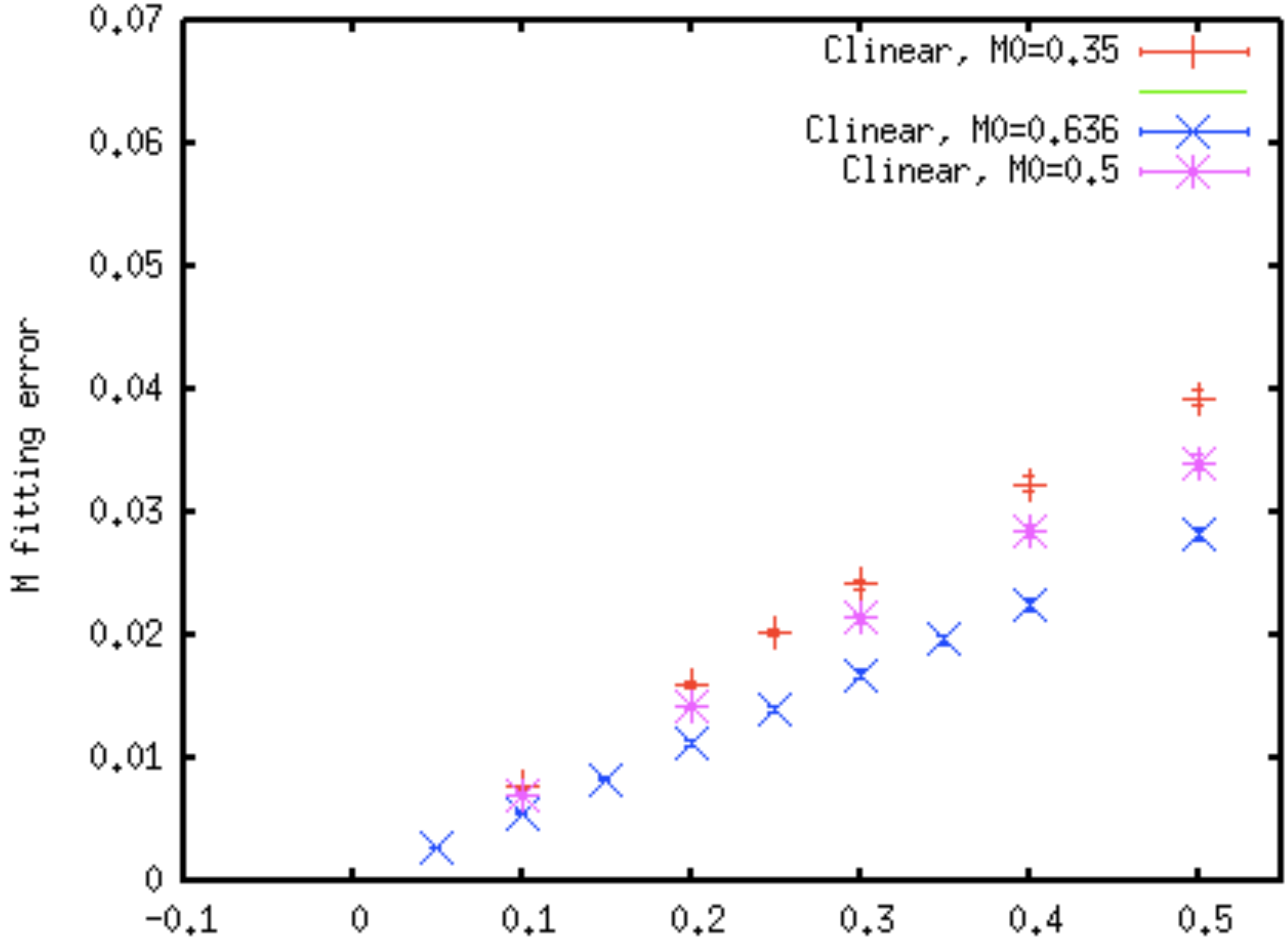




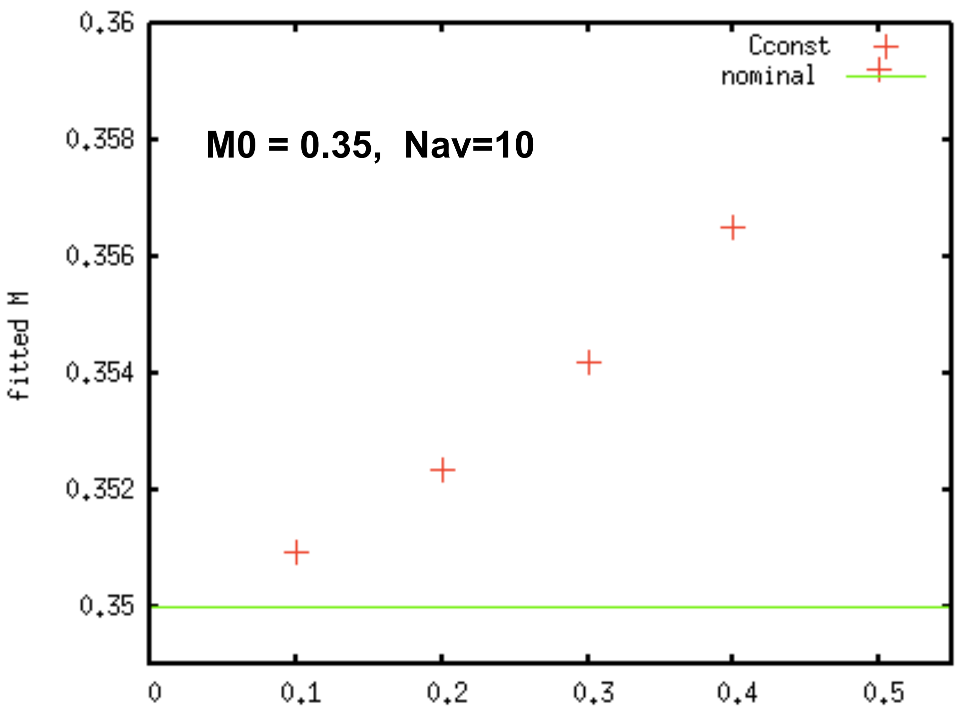
Input Clinear = 0.23

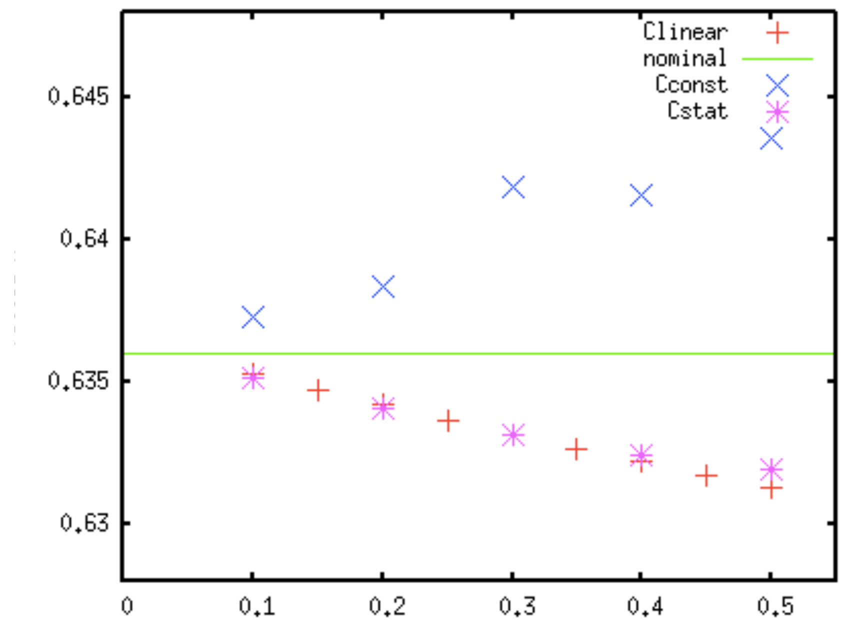
Fitting error has larger effect for smaller M_0

M fitting error



Input :
Nav=10, 174 deg mode,
Change linear ,
Keep others to 0

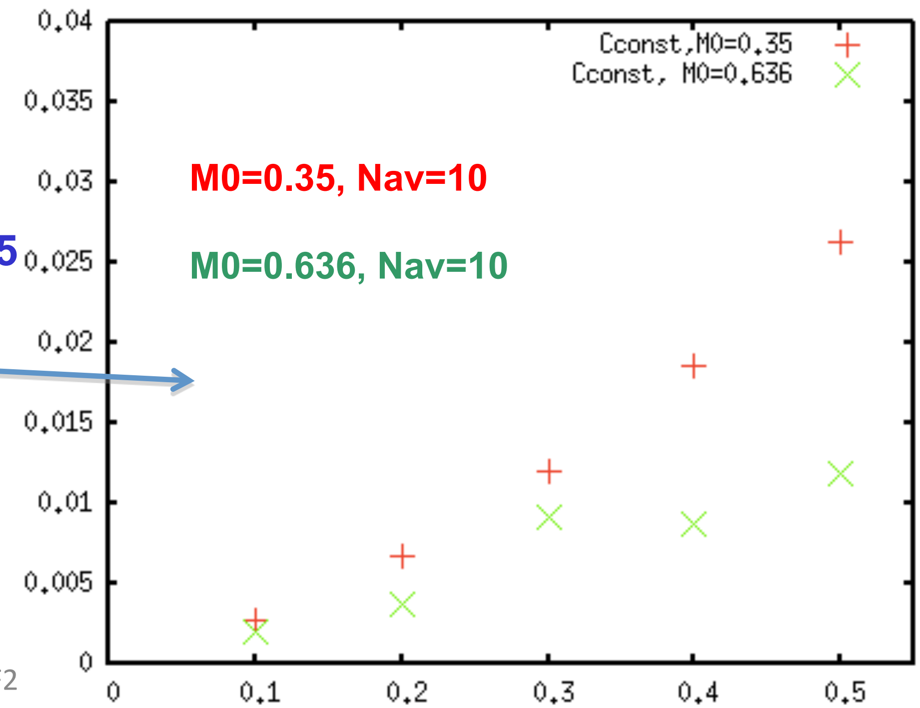




Confirmed over-evaluation effect of Cconst using smaller M0 = 0.35

Compare M0 = 0.636 and M0 = 0.35

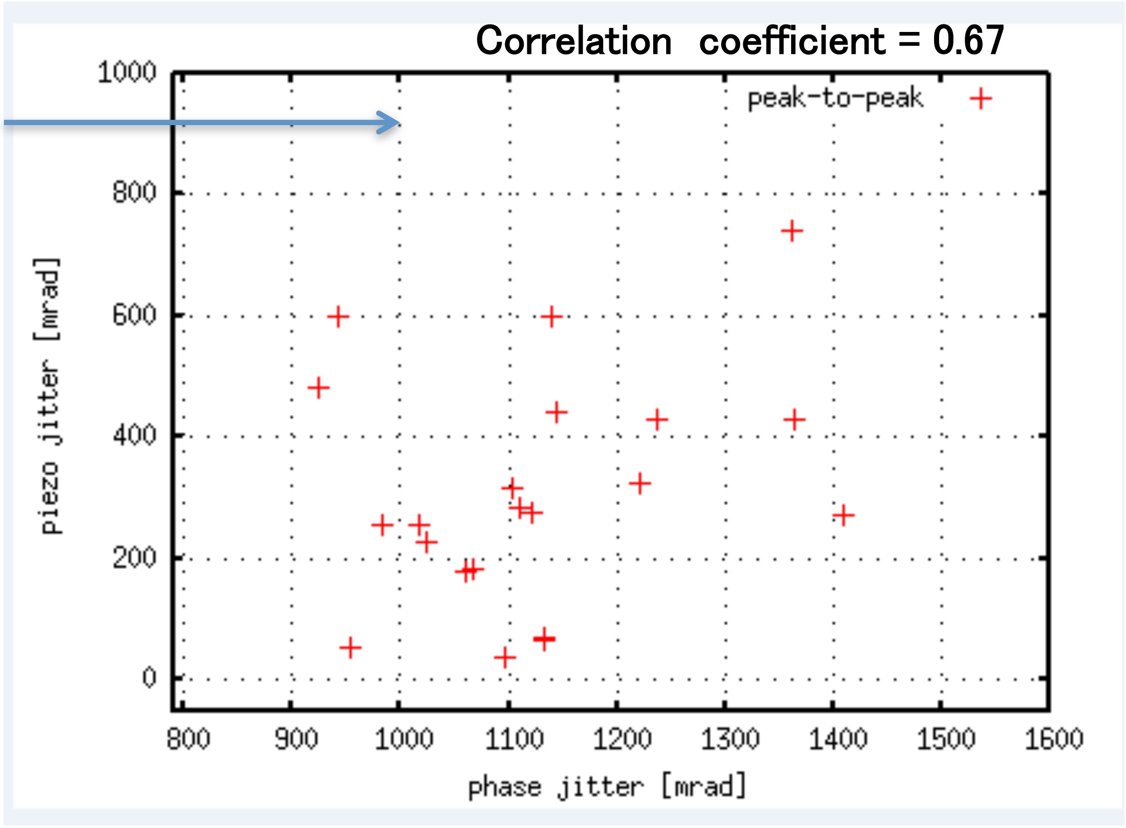
X axis: Cconst
Y axis: (M_fit – M0)/M0

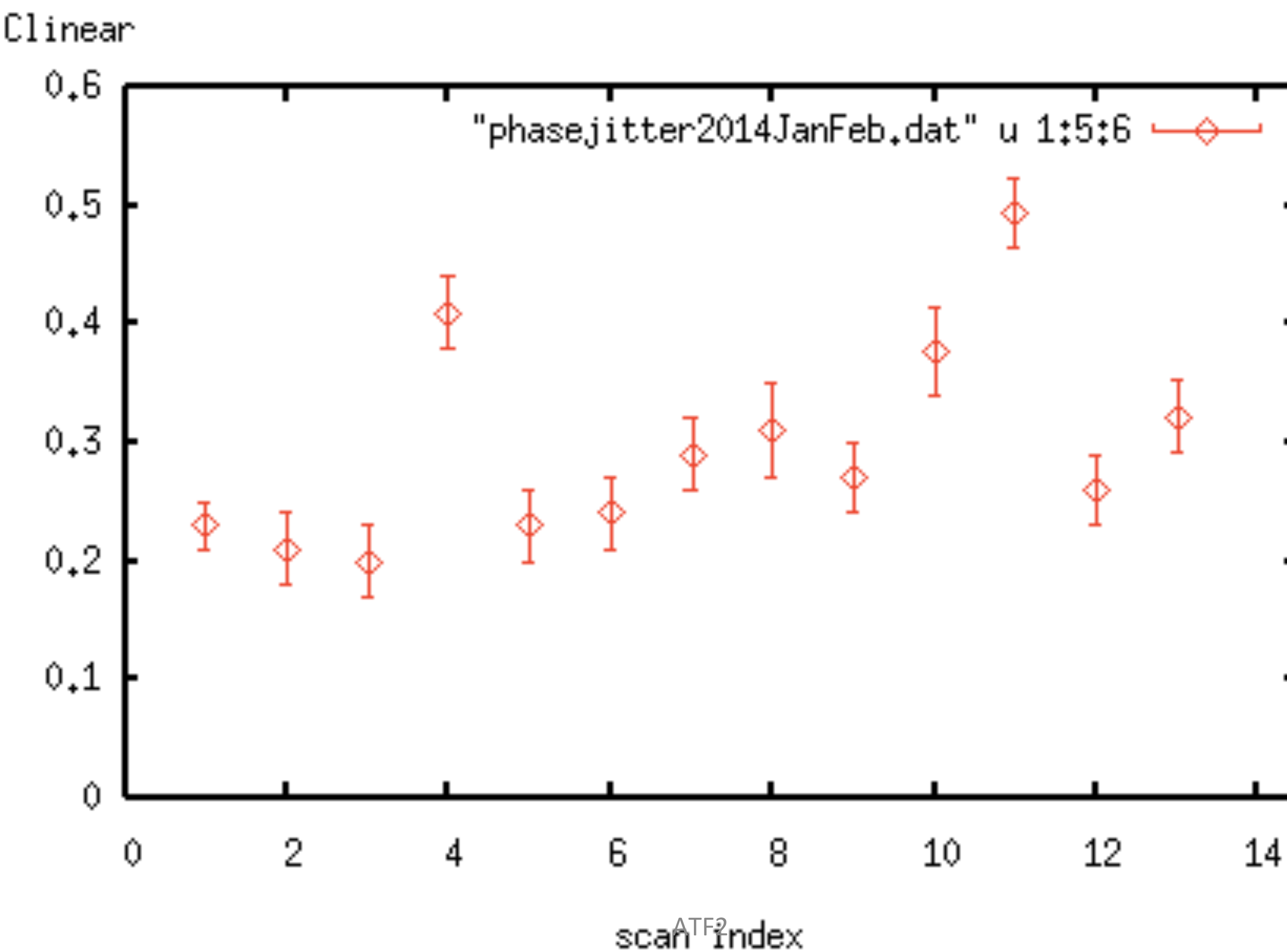


Input :
Nav=10, 174 deg mode,
Change 1 C factor type at a time,
Keep others to 0

Table 2 : Preliminary $\Delta\phi$ analysis results for various periods in spring and winter of 2013.

date (2013)	8-Mar	14-Mar	19-May	20-May	6-Jun	21-Jun	5-Dec	19-Dec
mode [deg]	174	174	30	174	6	30	2.8	4
Nav	10	10	99	10	10	10	50	10
M_meas	0.31+/-0.04	0.30+/-0.04	0.586+/-0.009	0.365+/-0.022	0.807+/-0.018	0.714+/-0.016	0.51+/-0.02	0.54+/-0.04
Δ φ [mrad]	1067+/-31	1013+/-50	485+/-44	449+/-138	253+/-25	356+/-27	229+/-40	485+/-142
Clinear	0.11+/-0.03	0.13+/-0.03	0.16+/-0.01	0.24+/-0.02	0.20+/-0.02	0.06+/-0.02	0.29+/-0.02	0.44+/-0.06





Clinear
0.6
0.5
0.4
0.3
0.2
0.1
0
"phasejitter2014JanFeb.dat" u 1:5:6
0
2
4
6
8
10
12
14
scan index

Proposal by Kubo-san on more accurate fitting function for signal jitters

$$\sigma_E^2 = \sigma_{E,\mathrm{vertical}}^2 + \sigma_{E,\mathrm{phase}}^2$$

Convolution of phase jitter and vertical jitters

$$\sigma_{E,\mathrm{phase}}^2(\varphi_0) = \overline{\left(E(\varphi_0) - \overline{E(\varphi_0)}\right)^2}_{\mathrm{phase}}$$
$$= \frac{1}{2} E_{ave}^2 M^2 \left[1 - 2\cos^2\varphi_0 \exp\left(-\sigma_\varphi^2\right) + \cos(2\varphi_0)\exp\left(-2\sigma_\varphi^2\right)\right]$$

Signal jitter due to phase jitter

Vertical jitters

$$\sigma_{E,\mathrm{vertical}}^2 = C_{\mathrm{const}}^2 + C_{\mathrm{stat}}^2 \overline{E(\varphi_0)} + C_{\mathrm{lin}}^2 \overline{\left(E(\varphi_0)\right)^2} \quad . \qquad (5)$$

$\overline{E(\varphi_0)}$ and $\overline{\left(E(\varphi_0)\right)^2}$ are given by [1] as,

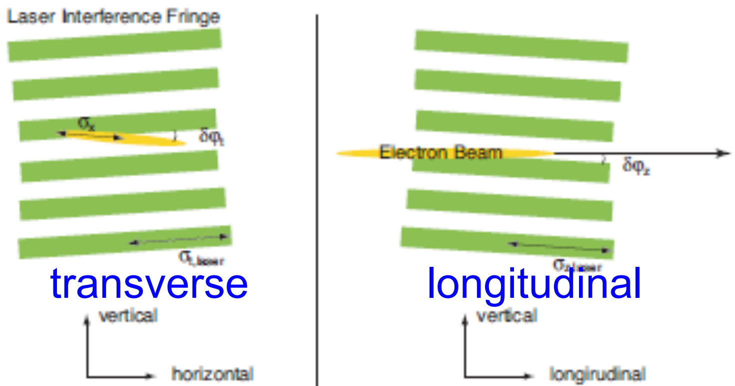
$$\overline{E(\varphi_0)} = E_{ave}\left[1 + M\cos\varphi_0 \exp\left(-\frac{\sigma_\varphi^2}{2}\right)\right] \qquad (6)$$

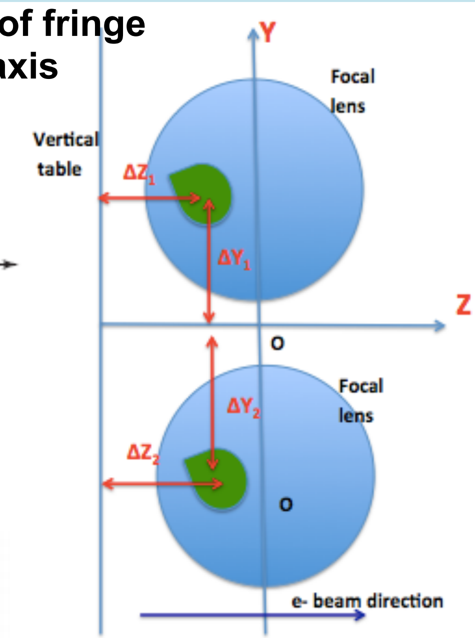
before, I used just
E = Eavg*(1+ M*cos(ϕ+ϕ0))

$$\overline{\left(E(\varphi_0)\right)^2} = E_{ave}^2\left\{1 + 2M\cos\varphi_0 \exp\left(-\frac{\sigma_\varphi^2}{2}\right) + \frac{1}{2}M^2\left[1 + \cos(2\varphi_0)\exp\left(-2\sigma_\varphi^2\right)\right]\right\} \qquad (7)$$

#1 Fringe Tilt

Mis-match of fringe and beam axis





Due to laser path misalignment :

if tilt ∼ 5 mrad

σ_y^* = 40 nm → 65 nm *over*

issues :

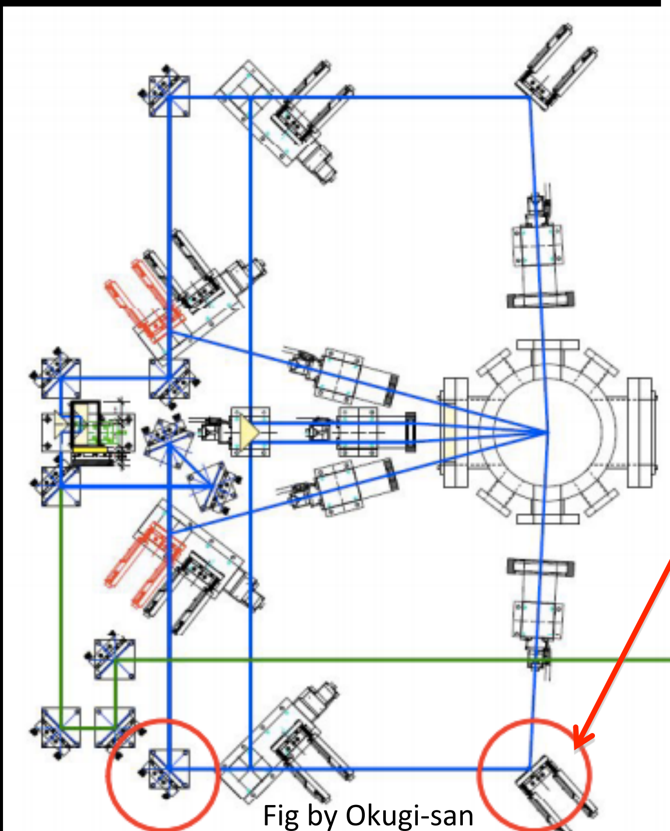
- Precision "by eye" : ∼ few mrad
- Position drift
- Rotated e beam

NEW "tilt scan"

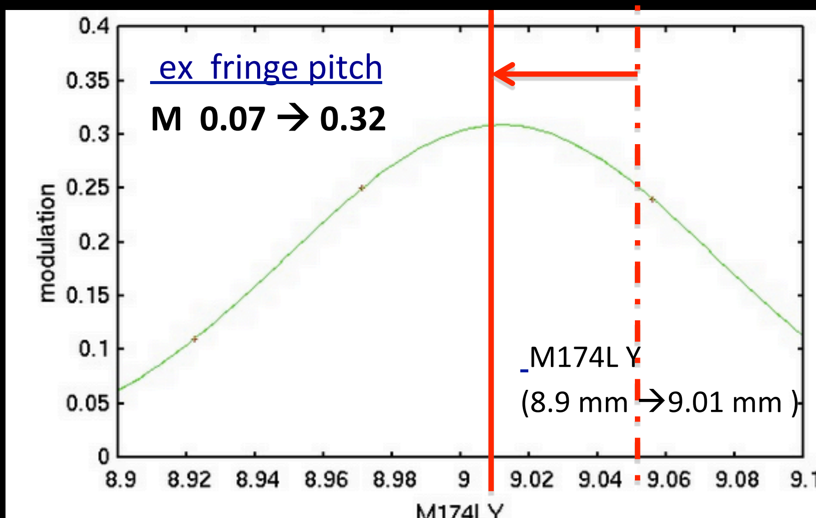
Remote control of mirror actuators

scan tilt to find setting for Max M

Use interaction with beam as reference !!

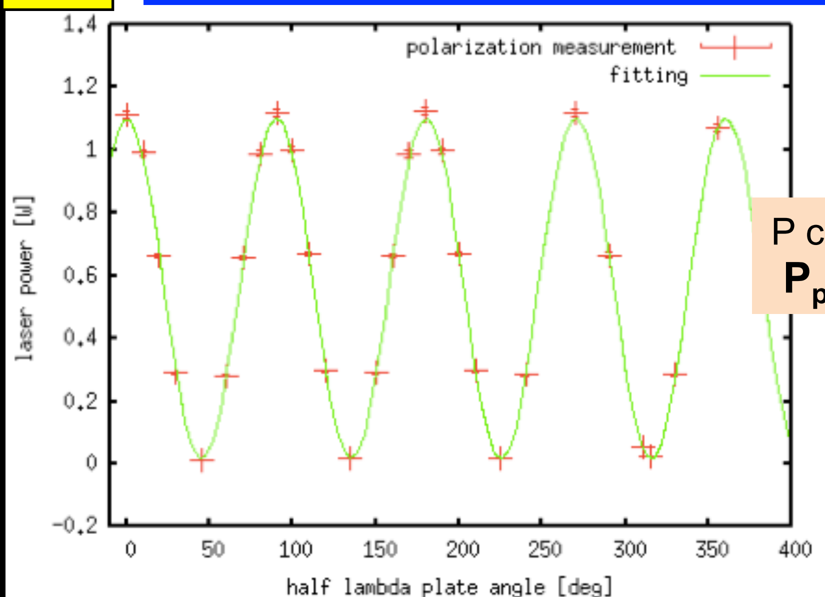


Contributed to improved precision !!

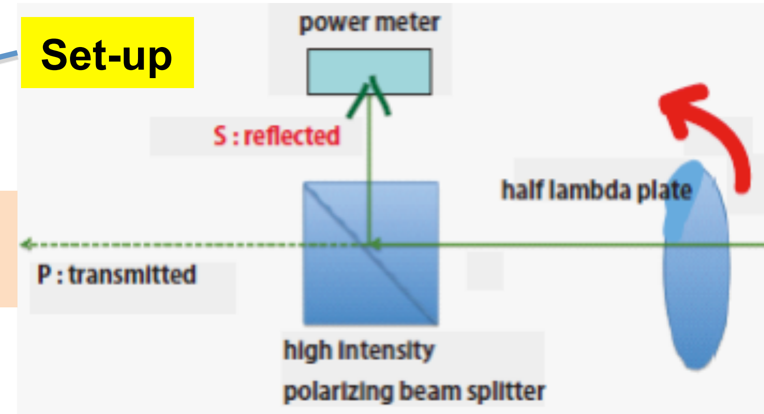


#2 Polarization Measurement

IPBSM optics designed for linear S polarization



Set-up

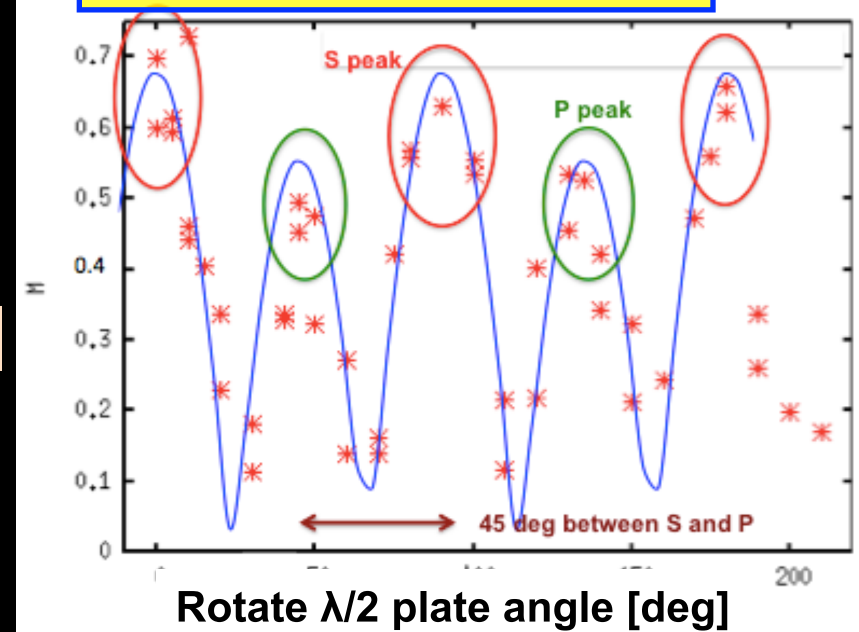


P contamination :
P_p/P_s < 1.5 %

power ratio

almost no M reduction due to polarization

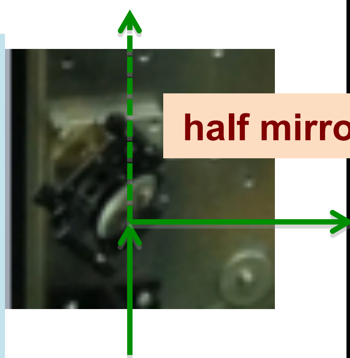
Beamtime : "λ/2 plate scan



confirmed "S peaks" maximize M

Also measured "half mirror" reflective properties

Rs = 50.3 %,
Rp = 20.1 %
→ match catalogue value

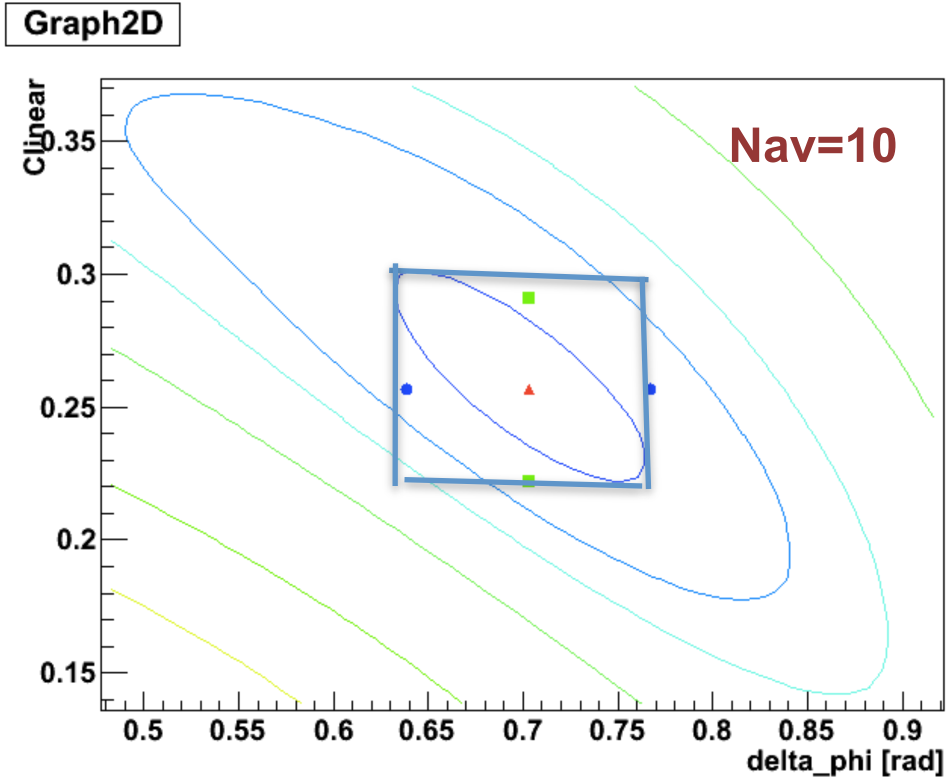


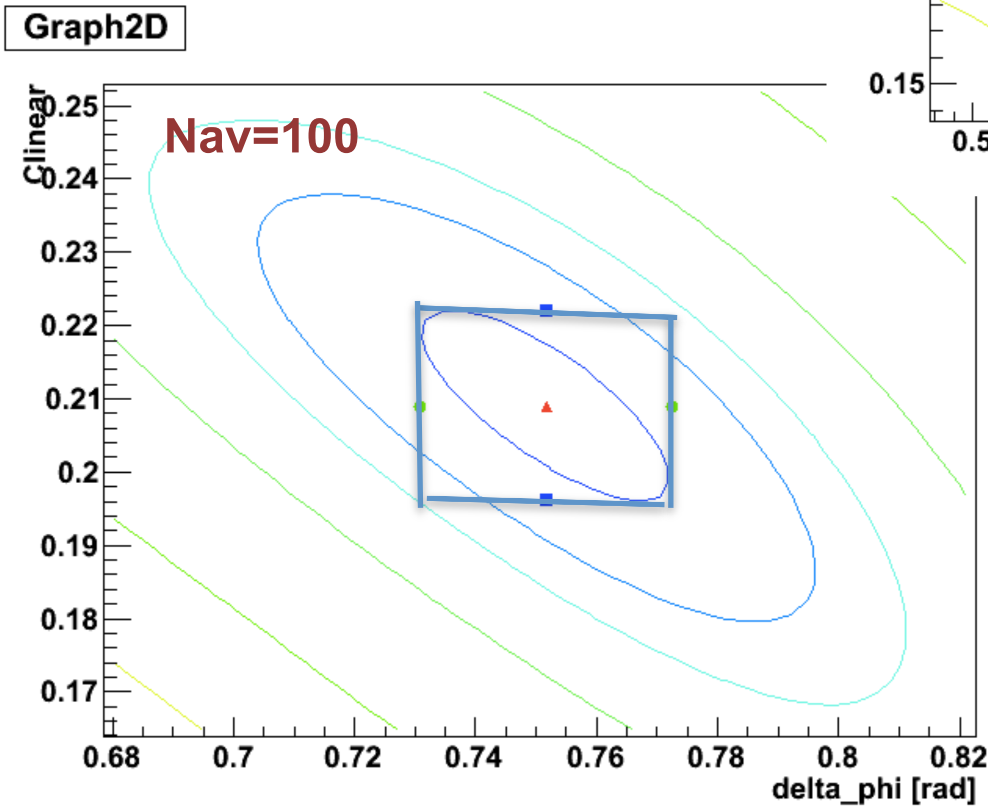
S peaks" also yields best power balance between 2 paths !!

Confirmed chi^2 distr. contour plot seem generally OK

Simulation

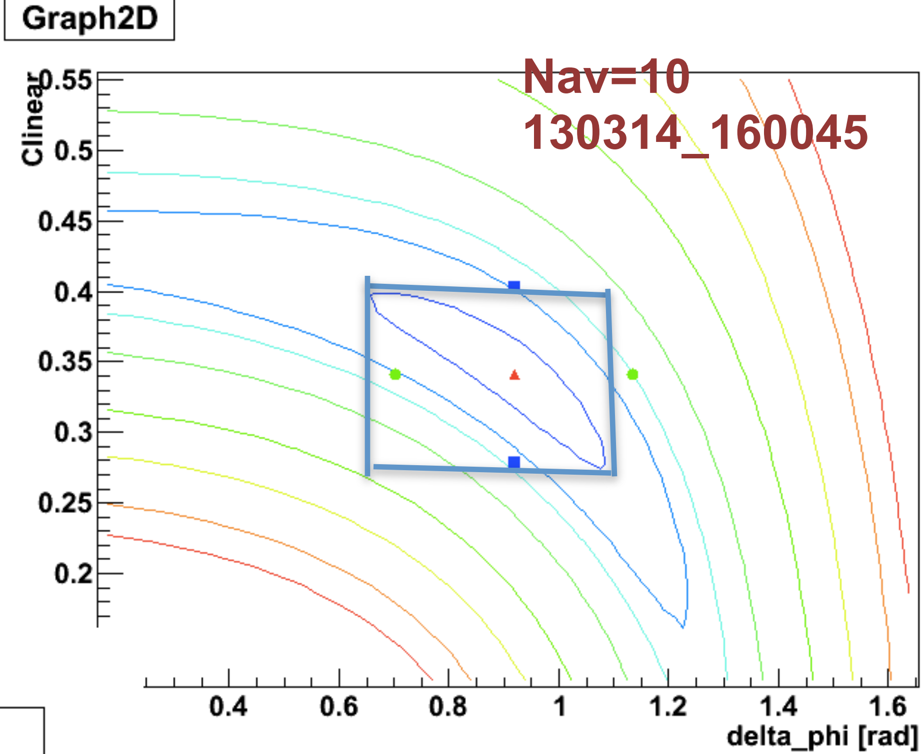
Input: Δφ = 0.7 rad, Clinear=0.23

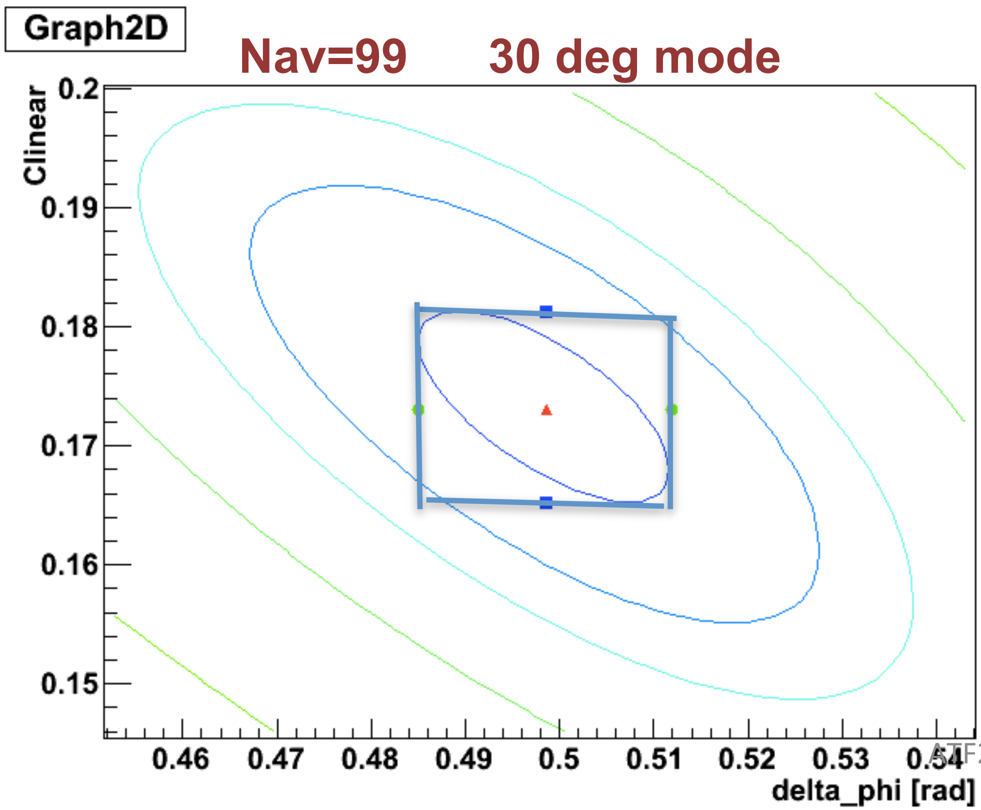


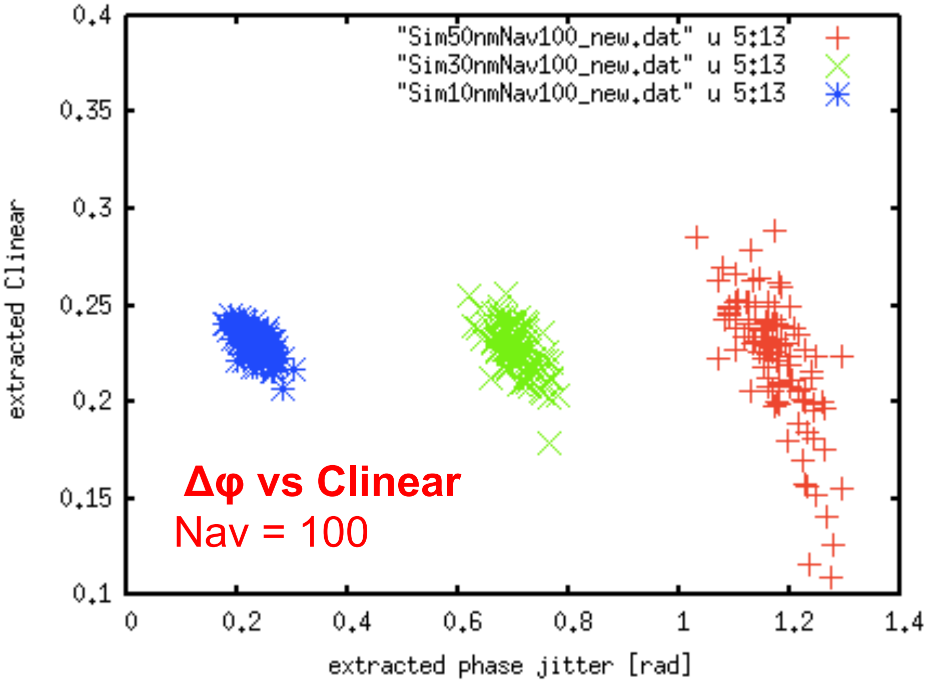


Confirmed chi^2 distr. contour plot seem generally OK

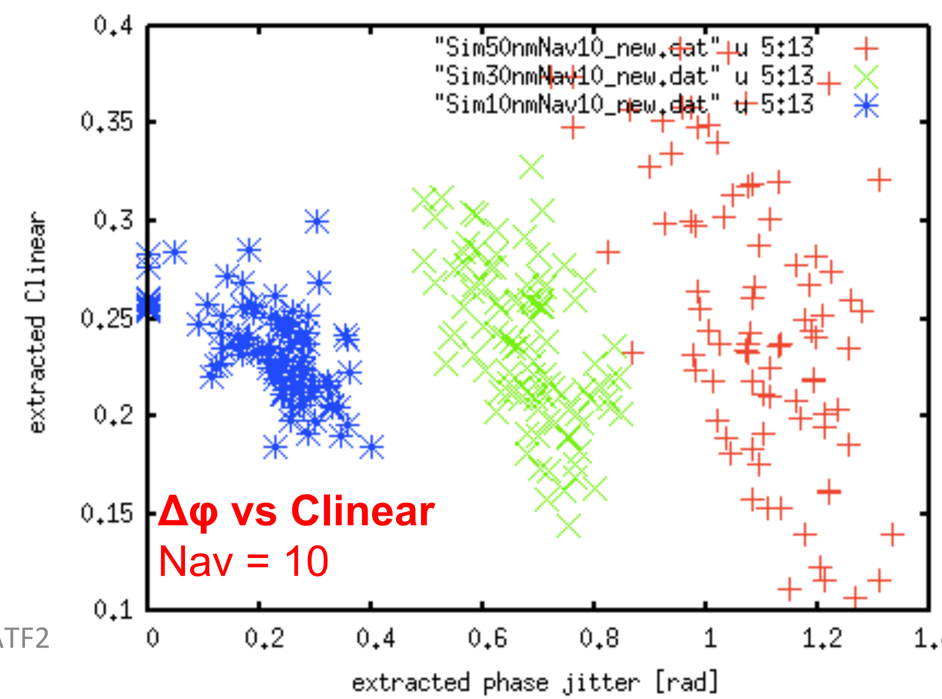
Real data







Correlation between extracted Δφ and Clinear



evaluate laser pointing jitter using Nav=50 laserwire scans

in the form of horizontal relative position jitter between laser and beam

$$E(x) = E_0 \exp\left(-\frac{(x-x_0)^2}{2\sigma^2_{t,laser}} \right)$$

$$\Delta E_{rel}(x) = \frac{dE(x)}{dx}\Delta x = \frac{d}{dx}\left(E_0 \exp\left(-\frac{(x-x_0)^2}{2\sigma^2_{t,laser}} \right) \right)\Delta x$$

$$= E_0 \left(-\frac{x-x_0}{\sigma^2_{t,laser}} e\,\mathrm{xp}\left(-\frac{(x-x_0)^2}{2\sigma^2_{t,laser}} \right) \right)\Delta x$$

$$\Delta E^2_{ON}(x) = \Delta E^2_{sig}(x) + \Delta E^2_{BG}$$

$$\Delta E^2_{sig}(x) = \Delta E^2_{stat}(x) + \Delta E^2_{laser}(x) + \Delta E^2_{rel}(x)$$

$$= \left(C_{stat}\sqrt{E(x)} \right)^2 + \left(C_{laser}E(x) \right)^2 + \left[E_0 \left(-\frac{x-x_0}{\sigma^2_{t,laser}} \exp\left(-\frac{(x-x_0)^2}{2\sigma^2_{t,laser}} \right) \right) \cdot \Delta x \right]^2$$

evaluate laser pointing jitter using Nav=50 laserwire scans

in the form of horizontal relative position jitter between laser and beam

$$\Delta P(\Delta t) = \sqrt{\left\langle P(\Delta t)^2 \right\rangle - \left(\left\langle P(\Delta t)\right\rangle\right)^2}$$

$$= P_0 \sqrt{\sum_{n=0}^{\infty} \frac{(2n-1)!!}{n!}\left(-\frac{\sigma_{\Delta t}^2}{\sigma_t^2}\right)^n - \left\{\sum_{n=0}^{\infty} \frac{(2n-1)!!}{n!}\left(-\frac{\sigma_{\Delta t}^2}{2\sigma_t^2}\right)^n \right\}^2}$$

$$\left\langle P(\Delta t)\right\rangle \approx P_0 \left\{1 - \frac{1}{2}\frac{\sigma_{\Delta t}^2}{\sigma_t^2} + \frac{3}{2}\left(\frac{\sigma_{\Delta t}^2}{\sigma_t^2}\right)^2 - \ldots\ldots \right\}$$

$$\frac{\Delta P(\Delta t)}{P_0} \approx \frac{\sigma_{\Delta t}^2}{\sqrt{2}\cdot\sigma_t^2}\sqrt{1 - 3\frac{\sigma_{\Delta t}^2}{\sigma_t^2} + \ldots\ldots}$$

$$\frac{\Delta E_{pos}(\Delta x)}{E} \approx \frac{(\Delta x)^2}{\sqrt{2}\sigma_{laser}^2}\sqrt{1 - 3\frac{(\Delta x)^2}{\sigma_{laser}^2} + \ldots\ldots}$$

Optics reform of 2012 summer

By IPBSM group@KEK

Proved greatly effective in 2012 winter run

Aim:

- **Suppress systematic error sources**
- **Higher alignment precision & reproducibility**

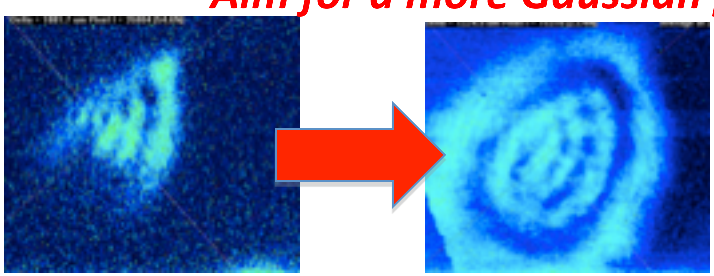
improvements	details
alignment precision ✓match focal point to IP ✓Injection position / angle into lens ✓Re-optimize expander / reducer **consistency , reproducibility** before / after mode switching	• focal point scan for all modes • CW laser + reference lines on new base plates • **new IP target** (screen monitor) • **θ mode switching technique** **{small linear stage + mirror actuators }** now: independent for each mode (before: shared rotating stages)
balanced profiles	suppress difference in path length & focal point

Tuning of main laser

by Spectra Physics

ex: spring 2012 :
Adjust curvature of laser cavity mirrors

Aim for a more Gaussian profile



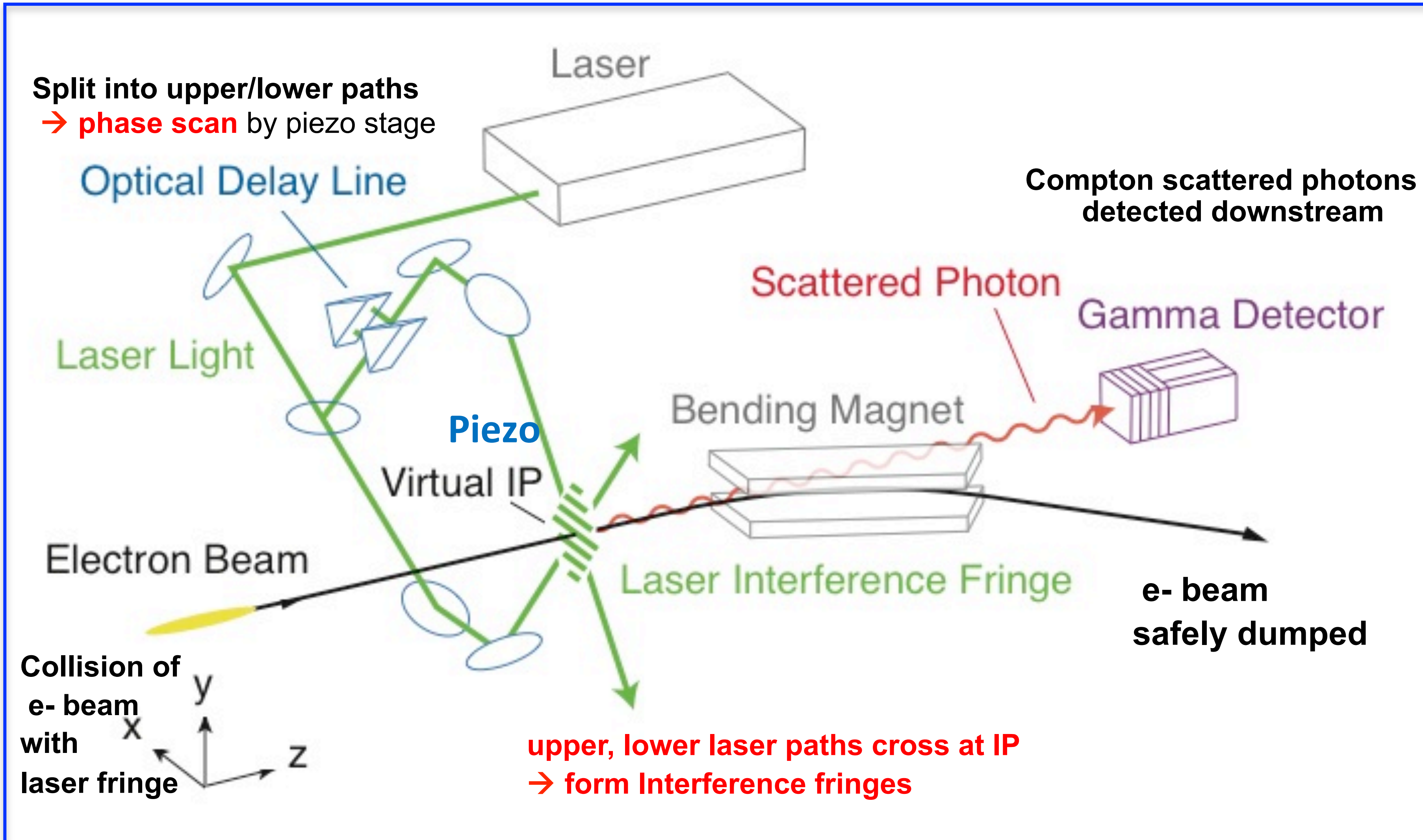
- Reform laser profile and spatial coherence (adjust YAG rod & cavity mirrors)
- Exchange flash lamp
- seeding laser tuning (→ oscillation stability)

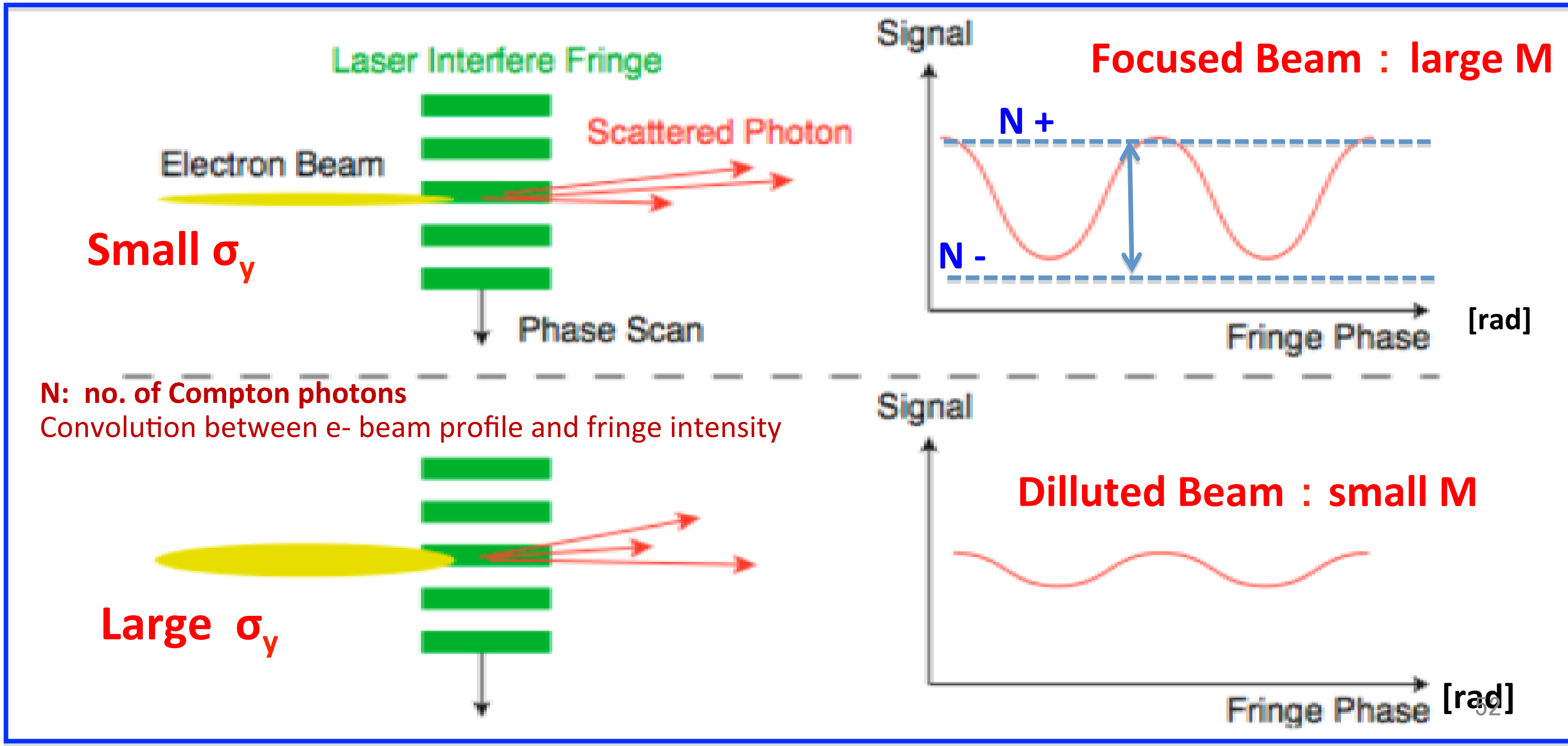
Measurement Scheme

- use **laser interference fringes** as target for e- beam

Only device able to measure σ_y < 100 nm !!

ATF2 beam tuning and achieve Goal 1 → **realization of ILC**





Detector measures
signal **Modulation Depth "M"**

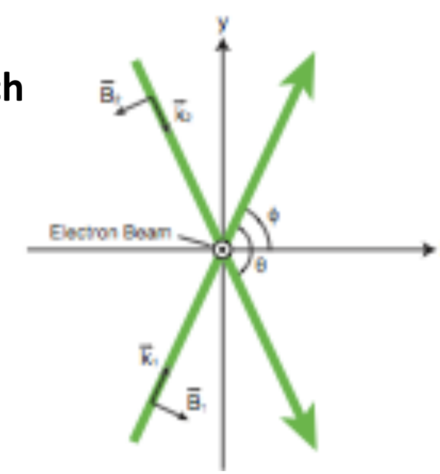
$$\mathbf{M} = \frac{N_+ - N_-}{N_+ + N_-} = \left|\cos(\theta)\exp\left(-2(k_y\sigma_y)^2\right)\right|$$

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

measurable range
determined by **fringe pitch**

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

depend on
crossing angle θ (and λ)



Crossing angle θ	174°	30°	8°	2°
Fringe pitch $d = \frac{\pi}{k_y} = \frac{\lambda}{2\sin(\theta/2)}$	266 nm	1.03 μm	3.81 μm	15.2 μm
Lower limit	20 nm	70 nm	170 nm	700 nm
Upper limit	90 nm	340 nm	1.3 μm	5.2 μm

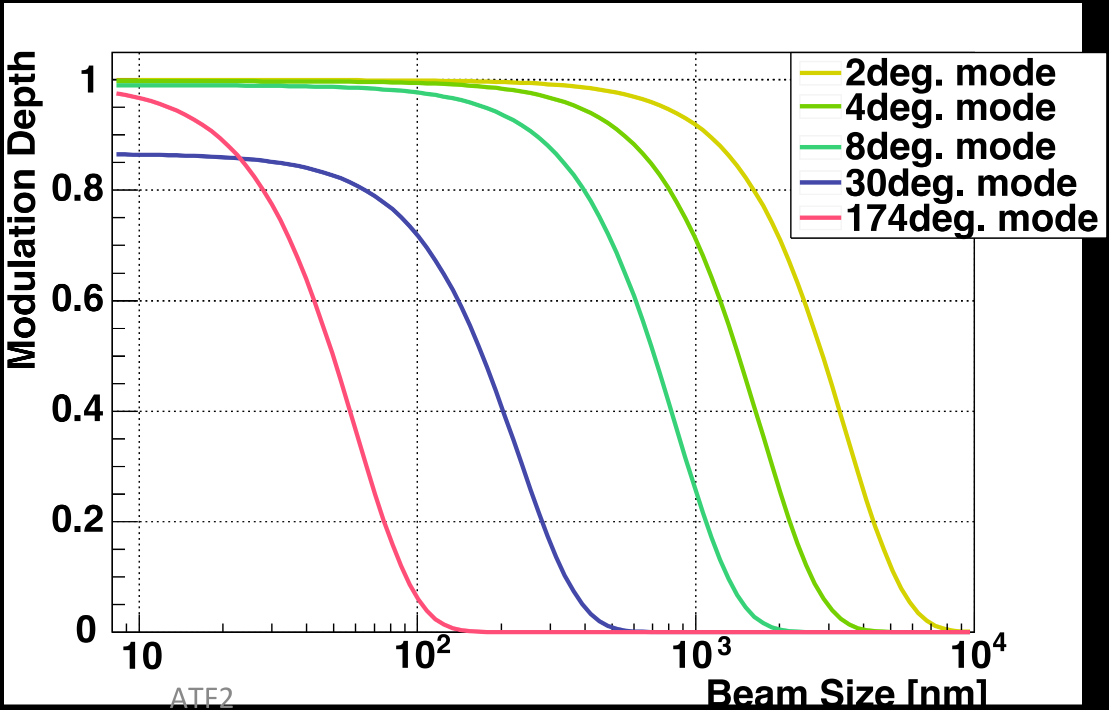
Expected Performance

Measures
σ_y^* = 20 nm ∼few μm
with < **10% resolution**

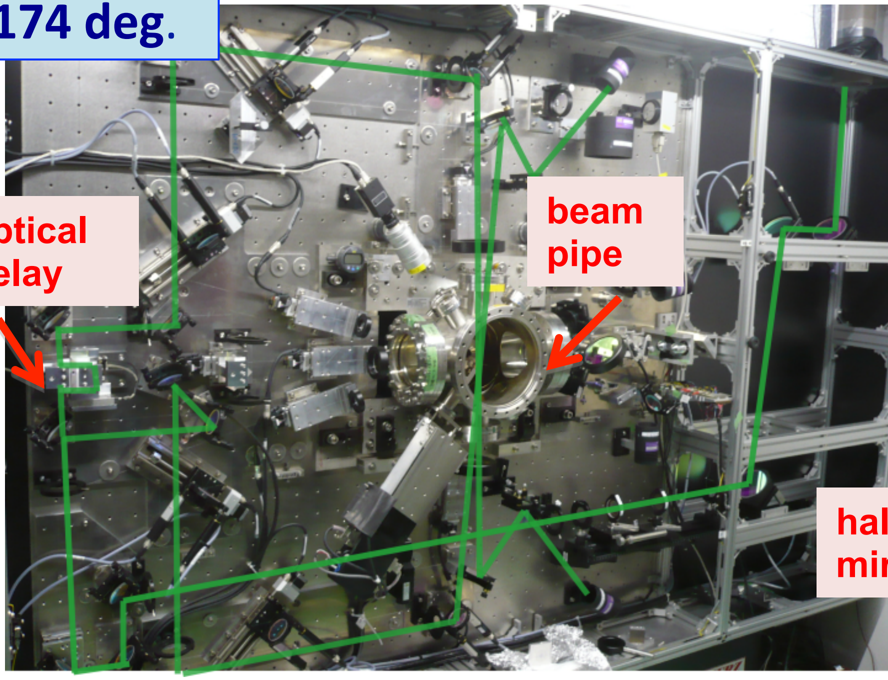
$$\sigma_y = \frac{d}{2\pi}\sqrt{2\ln\left(\frac{|\cos(\theta)|}{M}\right)}$$

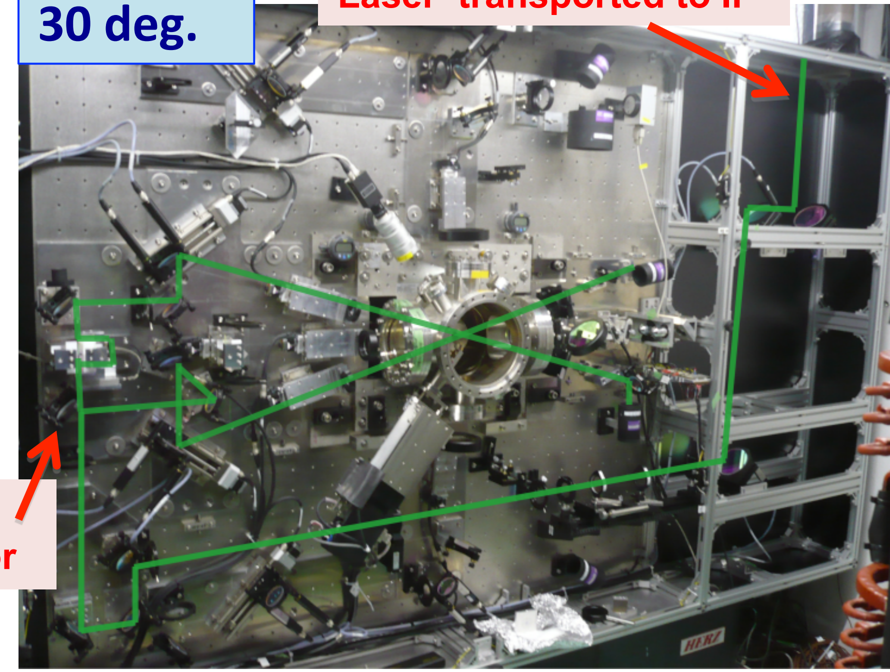
σ_y and M for each θ mode

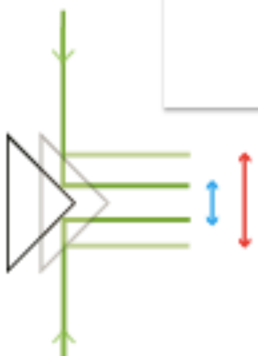
select appropriate mode according to beam focusing

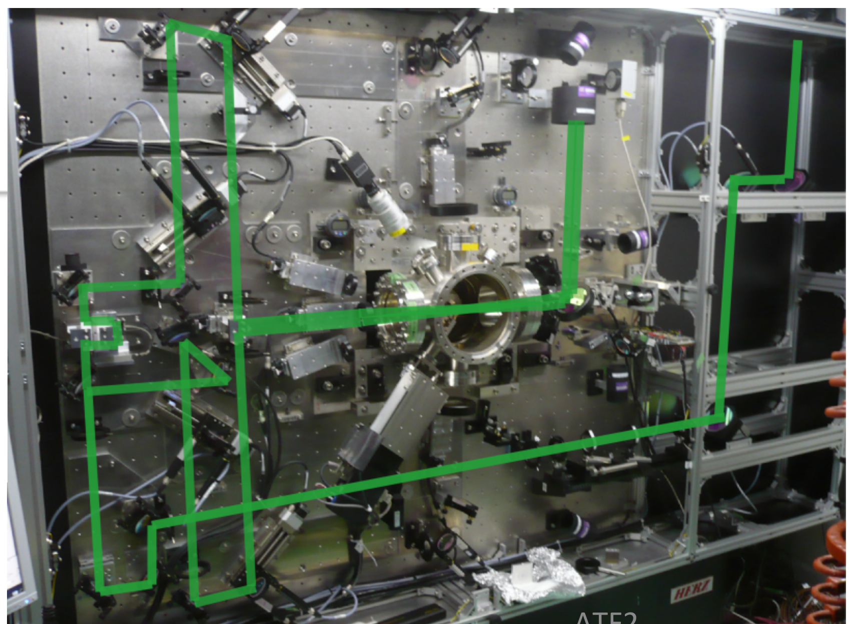


ATF2









Vertical table

1.7 (H) x 1.6 (V) m

- **Interferometer**
- **Phase control (piezo stage)**

path for each θ mode

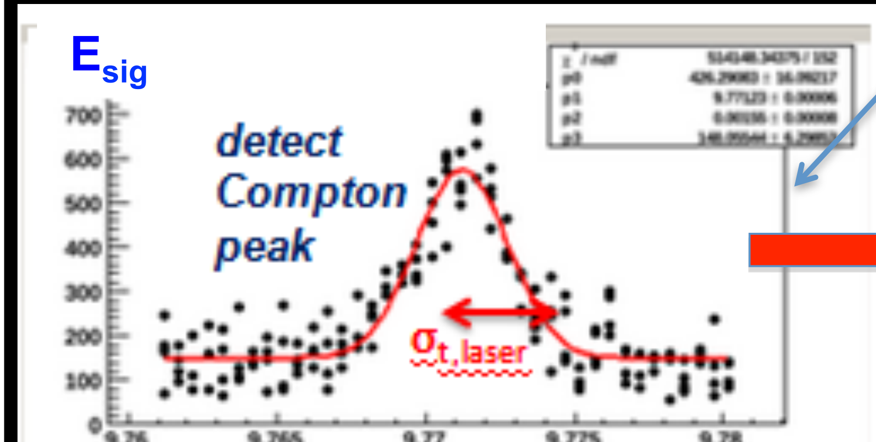
(auto-stages + mirror actuators)

Preaparation of IPBSM for Beam Tuning

★ beforehand …. Align laser paths, timing , ect…..

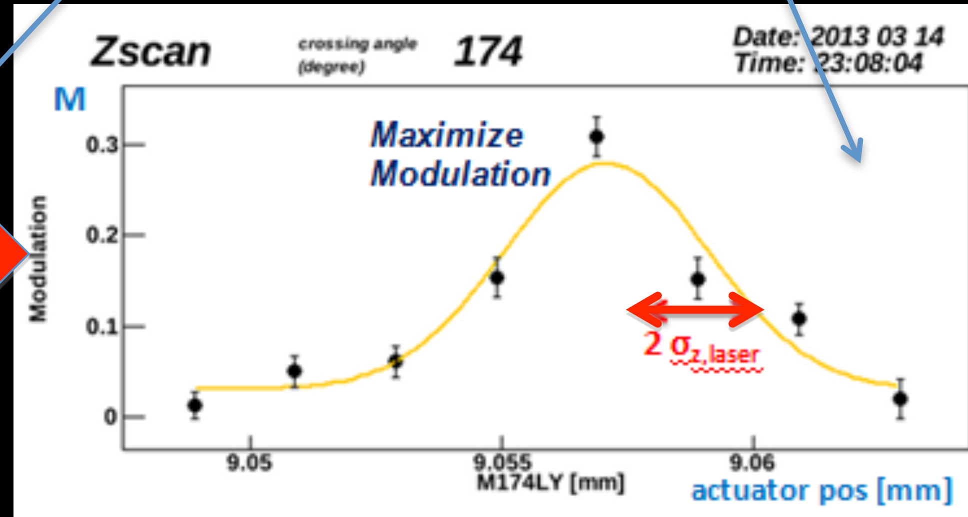
precise position alignment by remote control

transverse : laser wire scan



laser spot size : $\sigma_{t,laser}$ = 10 – 15 μm

Longitudinal : z scan



After all preparations

……….

continuously measure σ_y using fringe scans

→ Feed back to multi-knob tuning