

Alignment model - first trial

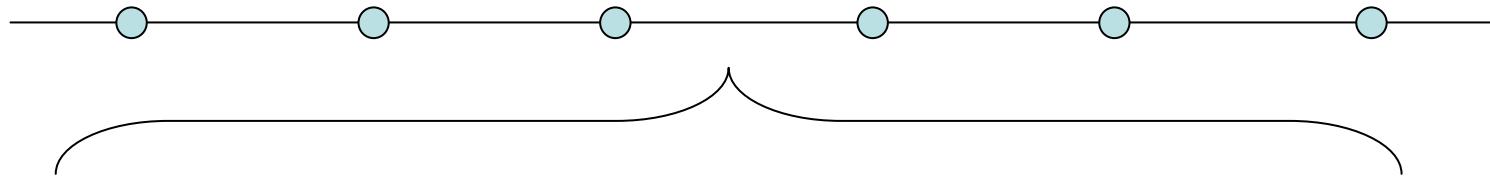
K.Kubo 2007.12.

1. Model of Survey Line
2. Survey line to component alignment
3. Some results of tracking simulations

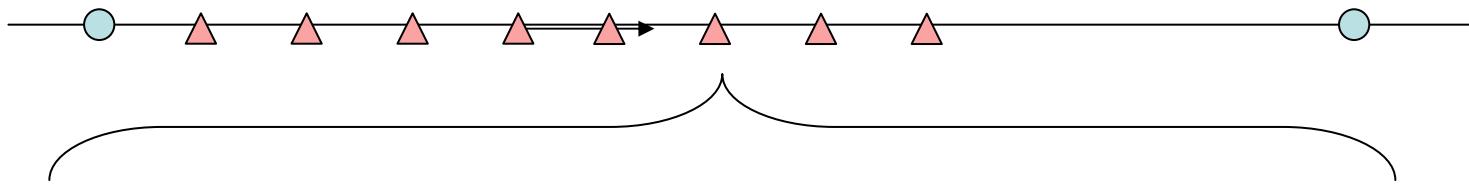
Alignment (offset and tilt) model

1. Mark primary reference point, every 2.5(?) km.
 - Error will be random, independent Gaussian. ~mm
 - 2.5 km corresponds to distance between shafts
2. Between them, mark reference point every ? (5~50) m
 - Survey from one primary point to the next one.
 - Error will be from random walk (random angle and offset)
 - Distance depends on method of survey
3. Girders, cryomodules and other independent components will be placed w.r.t. the nearest reference.
 - Error will be random, independent Gaussian, w.r.t. survey line.
4. Most components are placed on girders or cryomodules
 - Error will be random, independent Gaussian, w.r.t. girders/modules

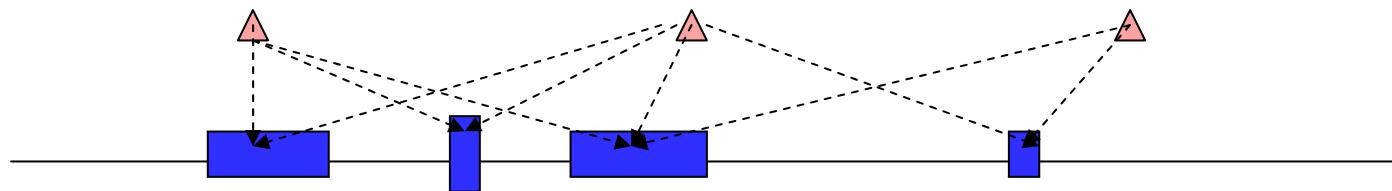
Every about 2.5 km, primary references,
? using GPS? Random error.



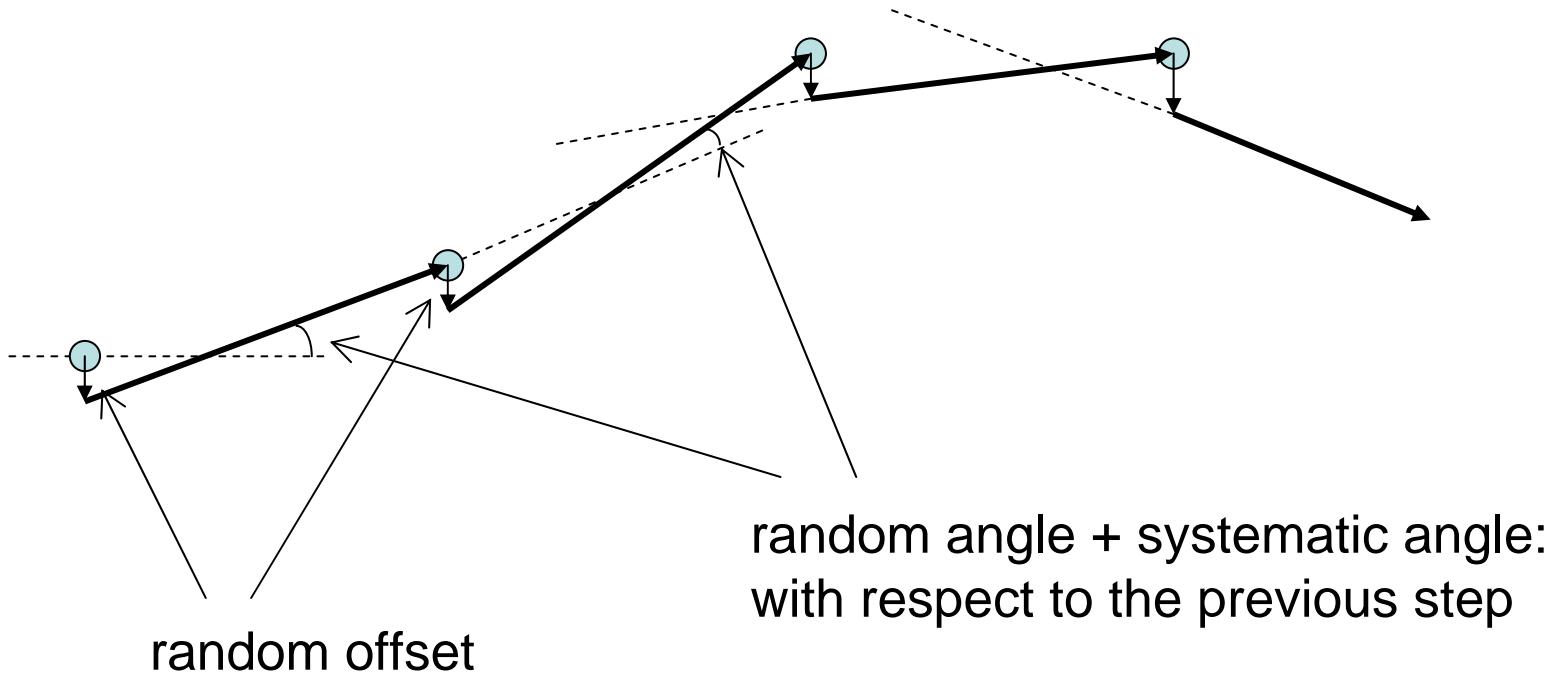
Survey from one primary reference to the next.
Every about 5~50 m, mark reference point



Girders, cryomodules, etc. are aligned w.r.t. the reference.



Random Walk



Parameters:

- l_{step} : length of one step
- a_y : random offset
- a_θ : random angle error
- θ_O : systematic angle error

Random walk

reference point). Let $y_{0,j,n}$ denote the offset at the n -th step in the j -th region and $\theta_{j,n}$ the angle of the n -th step in the j -th region, the effect of the one step can be expressed as:

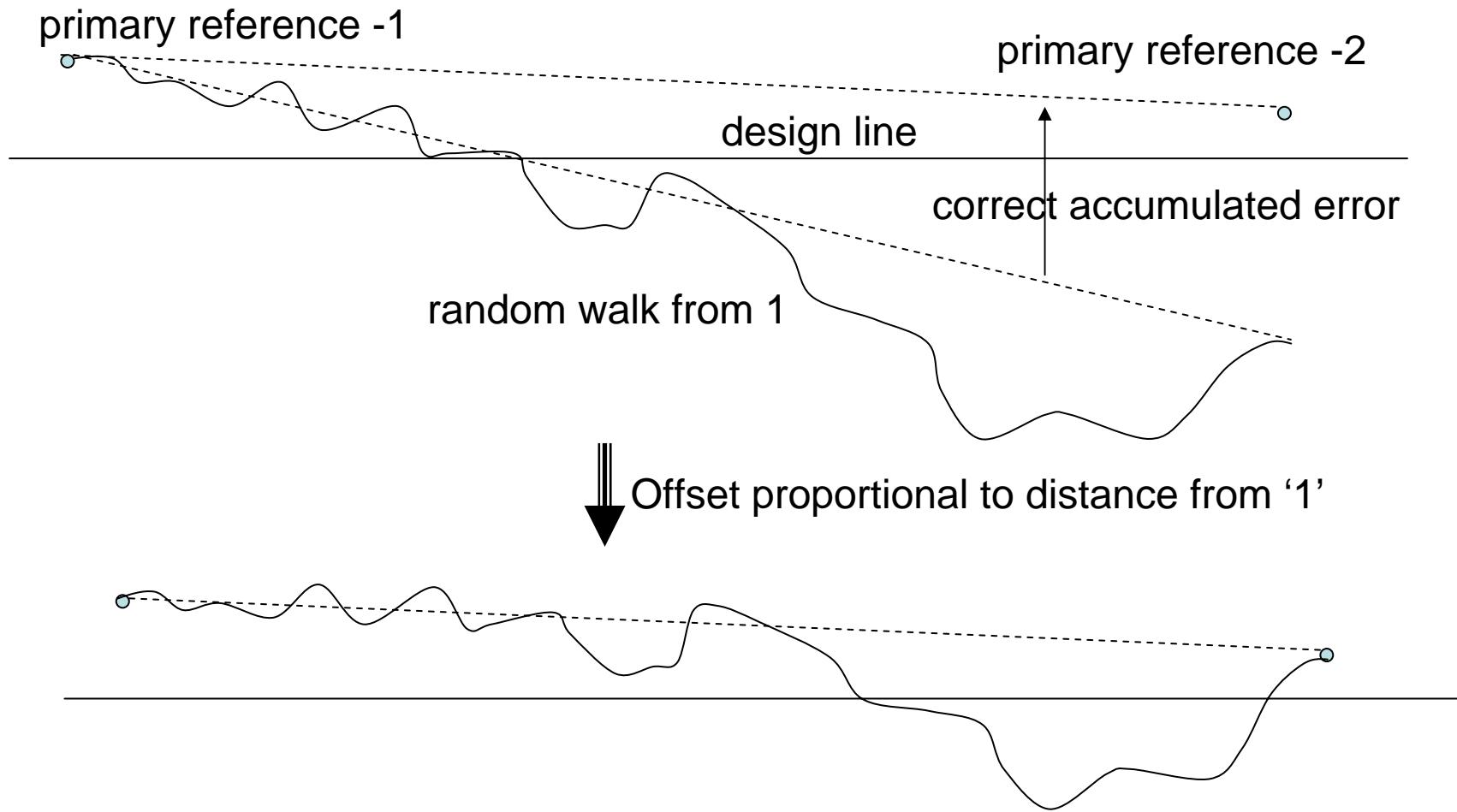
$$\begin{aligned}\theta_{j,n+1} &= \theta_{j,n} + G(a_\theta, t_\theta) + \theta_O \\ y_{0,j,n+1} &= y_{0,j,n} + G(a_y, t_y) + l_{step} \theta_{j,n+1} \quad (0 \leq n \leq N-1) \quad (1-2) \\ y_{0,j,0} &= y_{P,j}\end{aligned}$$

where a_y , t_y , a_θ and t_θ are parameters for the random walk and θ_O represents systematic error. (See reference [1].)

N is the number of steps in the j -th region, $n=0$ corresponds to the j -th primary reference point and $n=N$ corresponds the $j+1$ -th primary reference point. It is natural to make L_r / l_{step} integer.

From reference [1], tentative parameters can be $a_y = 0.5 \mu\text{m}$, $a_\theta = 0.1 \mu\text{rad}$ and $l_{step} = 4.5 \text{ m}$.

Correction of accumulated error in Random Walk

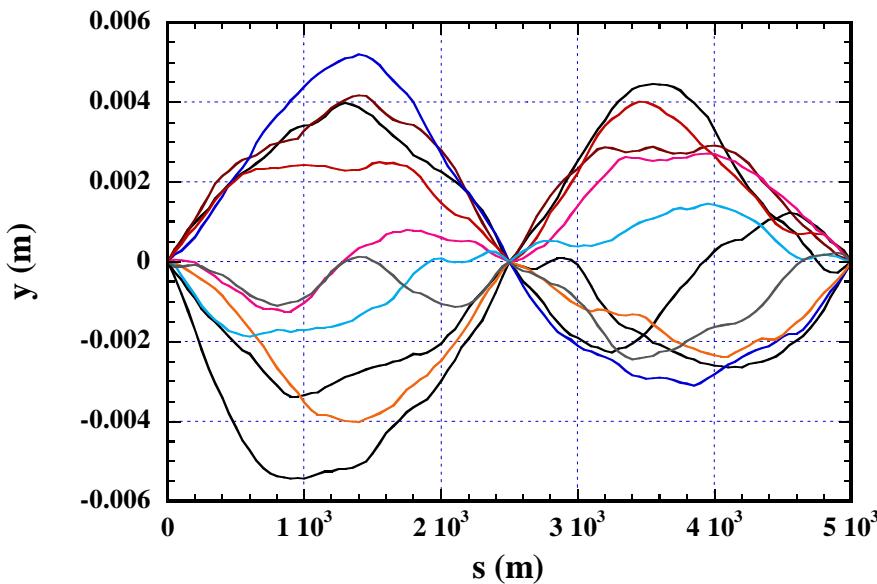


This simple correction makes kinks at primary references and may not be good enough. (see beam simulation results later.)
There must be better methods.

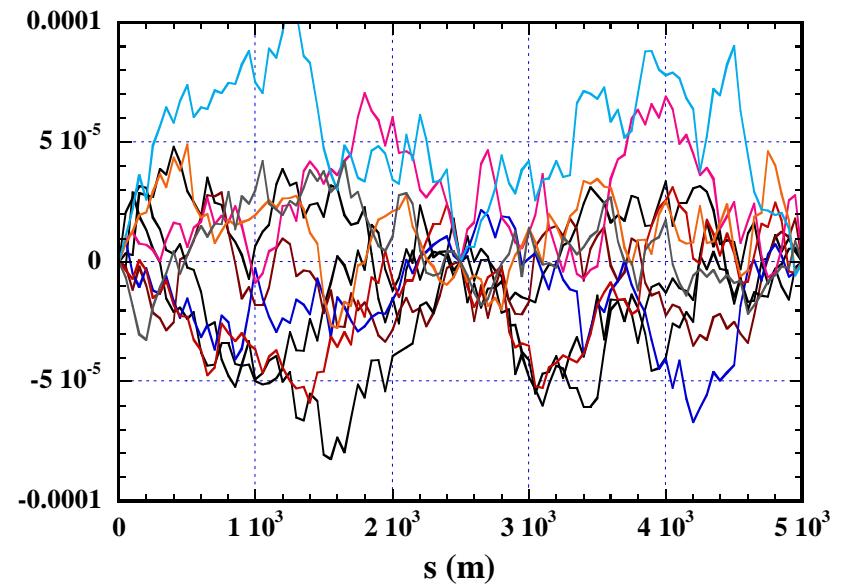
Example of survey line

Spacing of primary references: 2500 m, Error of primary reference: 0
Step length of survey (random walk): 50 m

Offset erro /step, $a_y = 0$
Angle error/step, $a_\theta = 1 \mu\text{rad}$



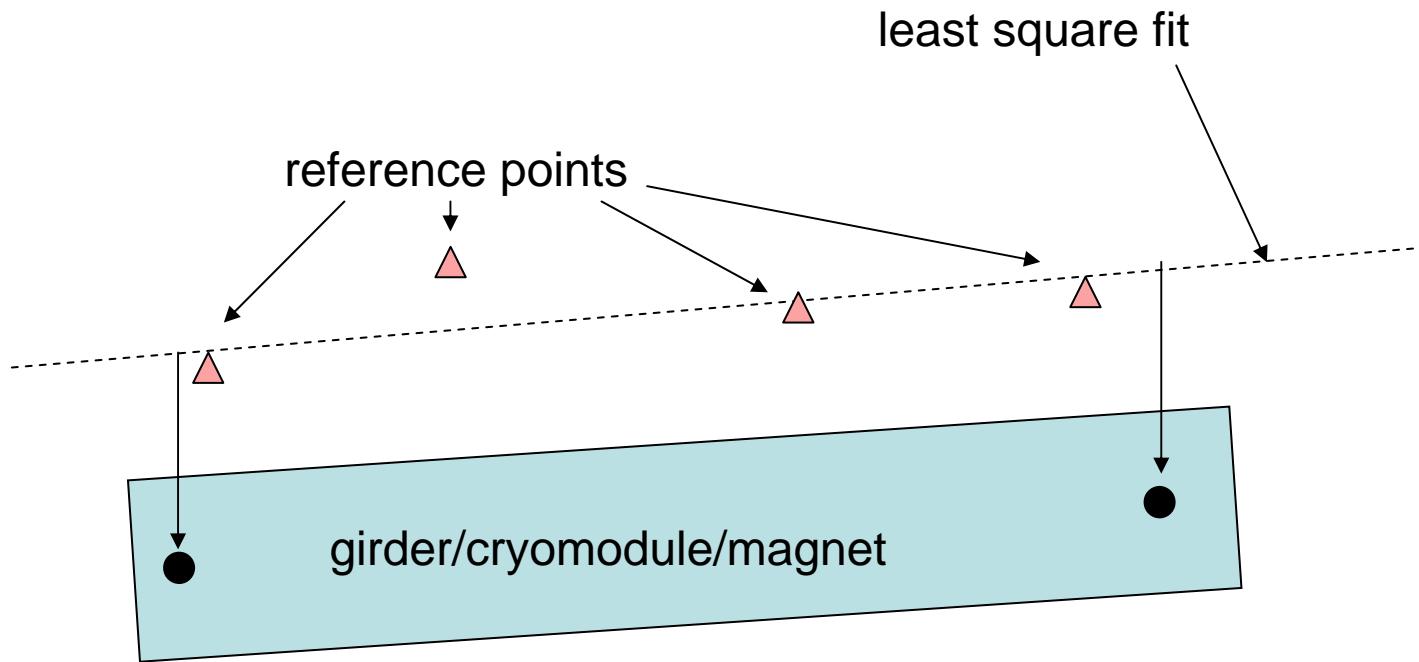
Offset erro /step, $a_y = 10 \mu\text{m}$
Angle error/step, $a_\theta = 0$



RMS deviation at the middle of primary references:

$$\sigma_{y,n}^2 \approx \frac{1}{2} a_{pr}^2 + \frac{1}{4} \frac{L_{pr}}{l_{step}} a_y^2 + \frac{1}{16} (L_{pr} \theta_O)^2 + \frac{1}{48} \frac{L_{pr}}{l_{step}} (L_{pr} a_\theta)^2$$

Alignment model w.r.t. reference points (example)



Rotation error model

- Rotation is adjusted w.r.t. gravity
 - Variation of gravity can be ignored?
- Every warm magnet has independent random error
- Every cryomodule has independent random error
 - Cold magnet and cold BPM has random error w.r.t. cryomodule

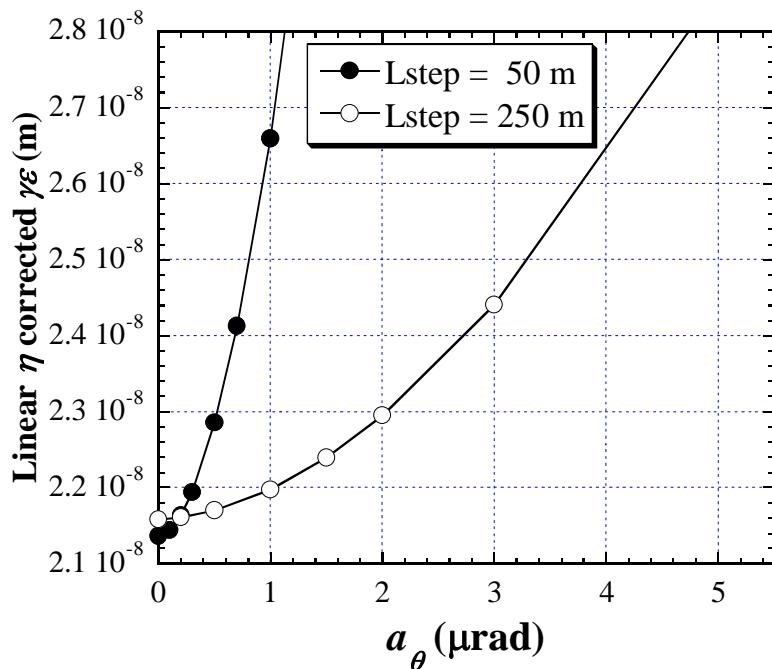
Apply to tracking simulations

First trial: Using simplified model

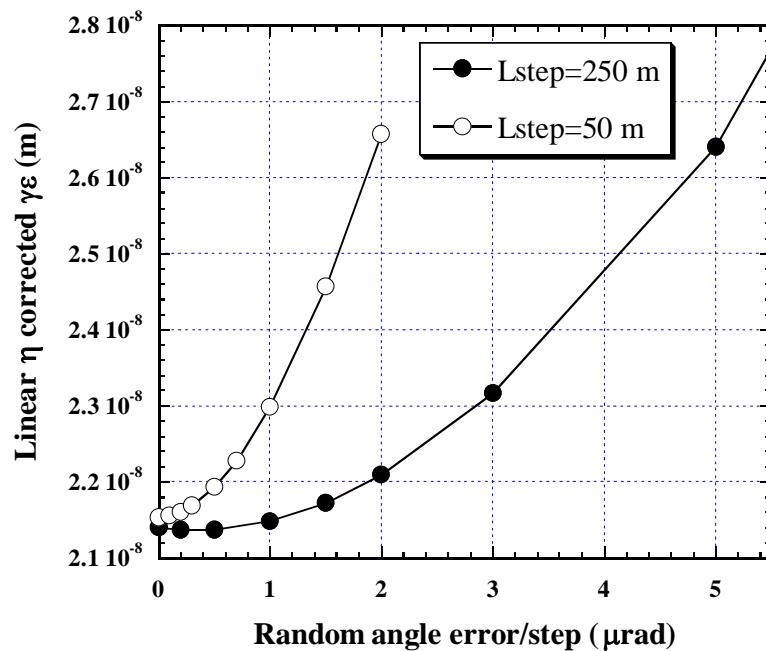
- Every component (quad, cavity or BPM) is aligned perfectly along the survey line
 - For each component, use the three closest reference points to make a reference line (least square fitting)
 - The component is placed along this line.

Angle error of random walk vs. Final emittance after DFS correction

With Correction of accumulated error

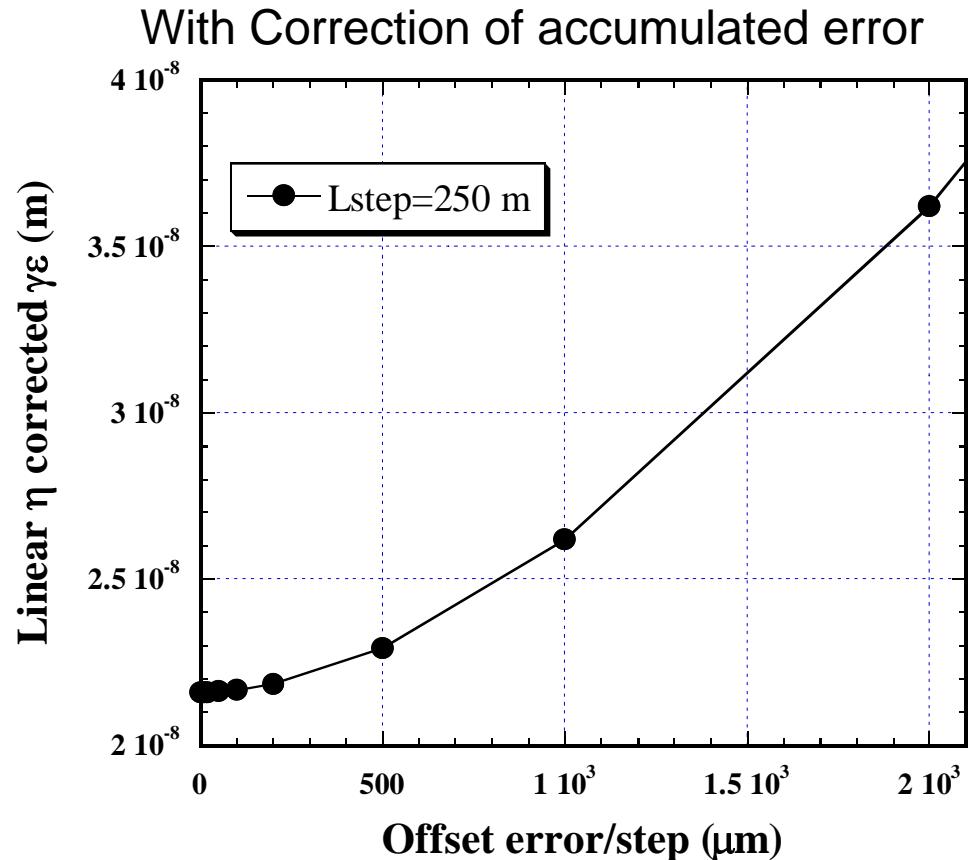


No Correction of accumulated error



No other errors, except BPM resolution 1 μm

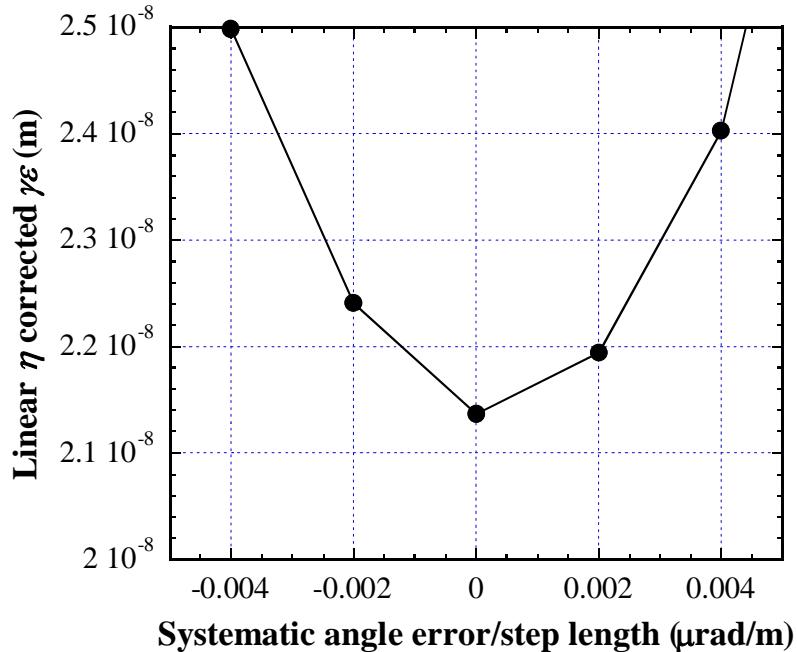
Offset error of random walk vs. Final emittance after DFS correction



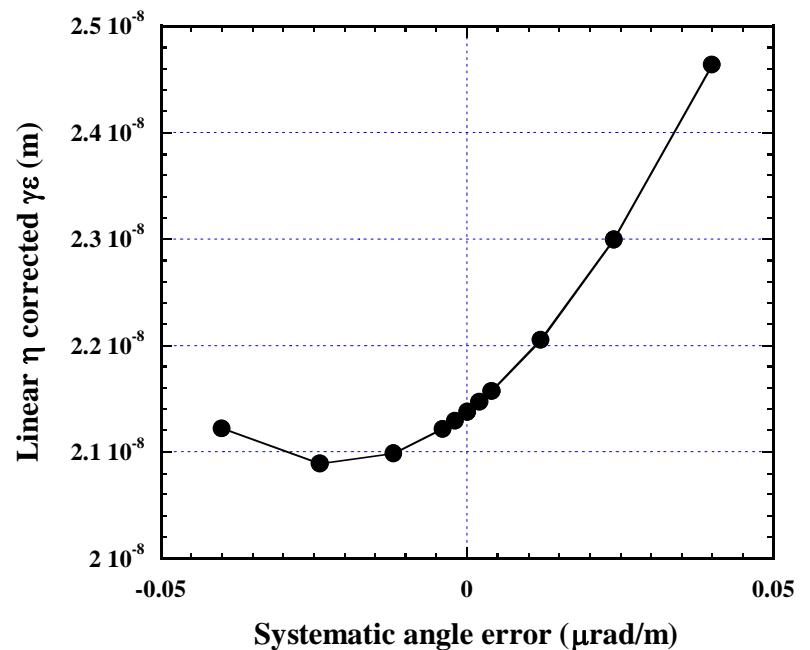
No other errors, except BPM resolution 1 μm

Systematic angle error/step vs. Final emittance after DFS correction

With Correction of accumulated error



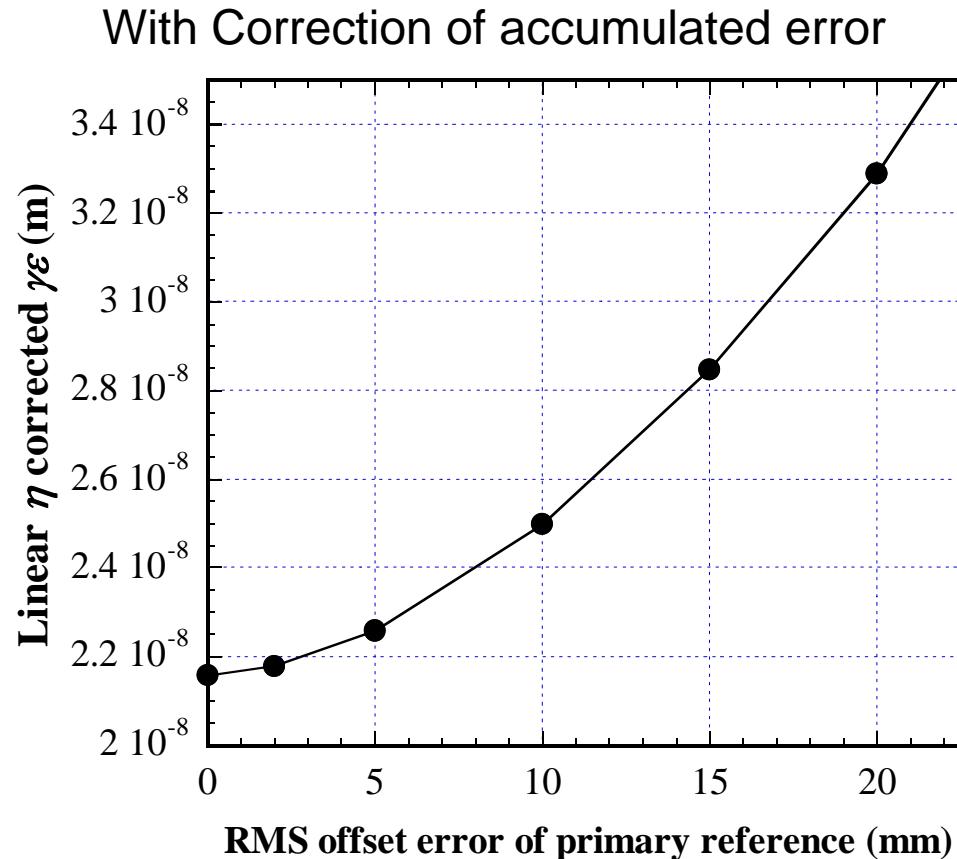
No Correction of accumulated error



(Earth's curvature = $0.16 \mu\text{rad}/\text{m}$)

No other errors, except BPM resolution $1 \mu\text{m}$

Offset error of primary reference (2.5 km spacing) vs. Final emittance after DFS correction



No other errors, except BPM resolution 1 μm

SUMMARY - 1

Model of Survey Line (reference points)

- Setting primary reference
- Random walk between primary reference
 - Present method of correction of accumulated error is not good enough

Survey line to component alignment

- Least square fit using several references
- Plus random, independent errors

Some results of tracking simulations

- Simulated error of survey line
- Assumed perfect “survey line-to-component” alignment
- Perform DFS
- Tolerances look tight ?

Summary-2

Parameters for Survey

	Suggested numbers
Distance between primary reference	2.5 km
RMS offset error of primary reference	~5 mm truncated 3σ (?)
Step length of survey	50 ~ 250 m (5 m for LICAS)

Roughly estimated tolerances		
Step length of survey	50 m	250 m
Random Angle error of one step	0.5 μ rad	2 μ rad
Random Offset error of one step	-	0.3 mm
Systematic angle error (error of vertical curvature)	~10 % of the Earth's curvature	

References

Document of this model:

“DRAFT: Alignment model of ILC LET components – for beam dynamics simulations”

<https://lists.desy.de/sympa/arc/ilc-metapy/2007-10/pdfSdh4G1uubO.pdf>

Communications:

Join mailing list ilc-metapy@desy.de

ref: <https://lists.desy.de/sympa/info/ilc-metapy>

archive of past mails: <https://lists.desy.de/sympa/arc/ilc-metapy>

Reports in LCWS (GDE meeting) at DESY, May-June 2007

Reports in GDE meeting at FNAL, Oct. 2007