Alignment (Survey) Tolerances in Main Linac from Beam Dynamics Simulations

200811 Kiyoshi Kubo

Modeling of Survey Line
+ Local Alignment

By Armin Reichold and Kiyoshi Kubo

With contribution from

Ryuhei Sugahara, D. Schulte, Catherine LeCocq, Grzegorz Grzelak, Freddy Potier, and more ? ? ?

We made a simplified model of
survey and alignment,
for beam dynamics simulations

- Realistic enough for beam dynamics, but
- As simple as possible.

Not necessarily follow real procedures of
alignment.

But must be accurate from beam dynamics
point of view.

"Standard" Alignment Model

- Mark primary reference point, every L m.
  - Error will be random, independent Gaussian.
  - $L \sim 2000$ corresponds to distance between shafts

- Between them, mark reference point every l m
  - Survey from one primary point to the next one.
  - The process is a random walk (random angle and offset)
  - One step length depends on method of survey

- 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.

- Most components are placed on girders or cryomodules
  - Error will be random, independent Gaussian, w.r.t. girders/cryomodules

Alignment procedure

Every 2.5 km, primary references,
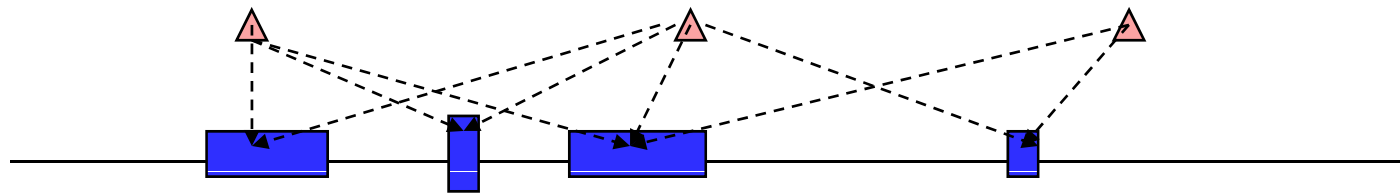? using GPS? Random error.
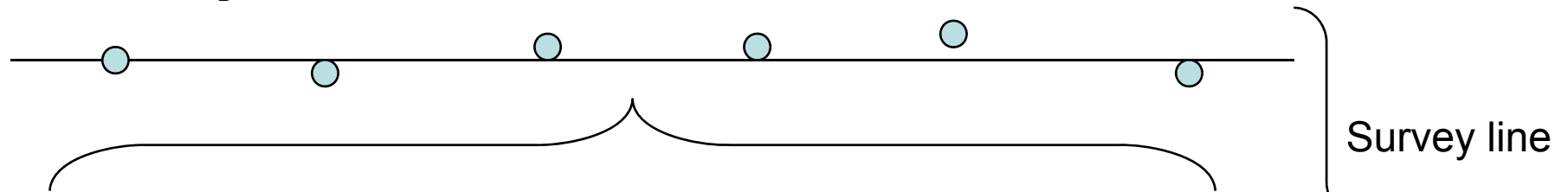
Survey from one primary reference to the next.
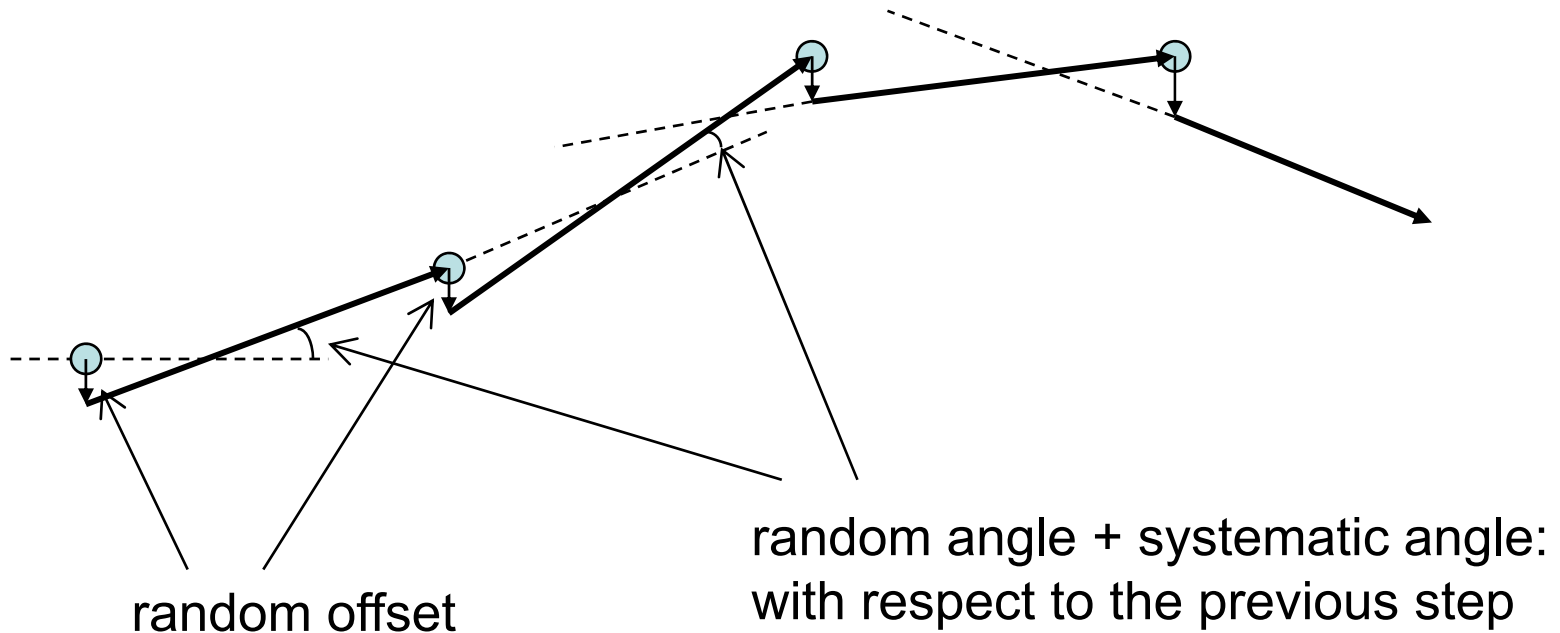Every about 5~50 m, mark reference point

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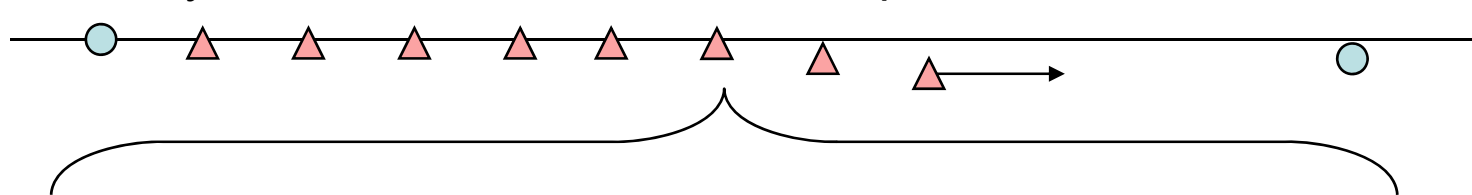
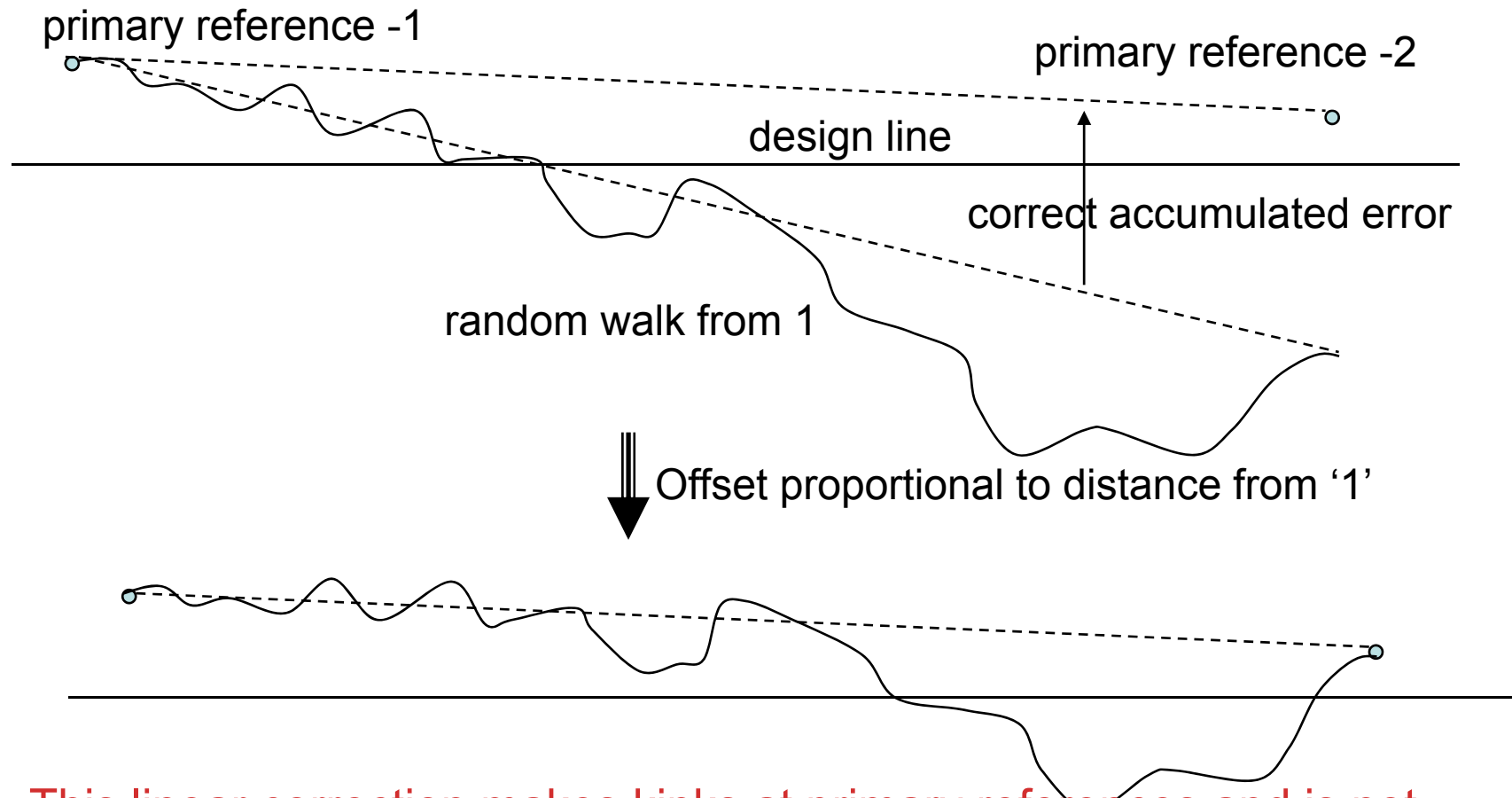Girders, cryomodules, etc. are aligned w.r.t. the reference.

local alignment

Step by step survey:
Random Walk + systematic angle error

random offset

random angle + systematic angle:
with respect to the previous step

Parameters: l_{step} : length of one step

a_y : random offset/step

a_θ : random angle error/step

θ_O : systematic angle error

θ_{init} : initial angle error

Correction of accumulated error in Random Walk using primary reference

primary reference -1

primary reference -2

design line

correct accumulated error

random walk from 1
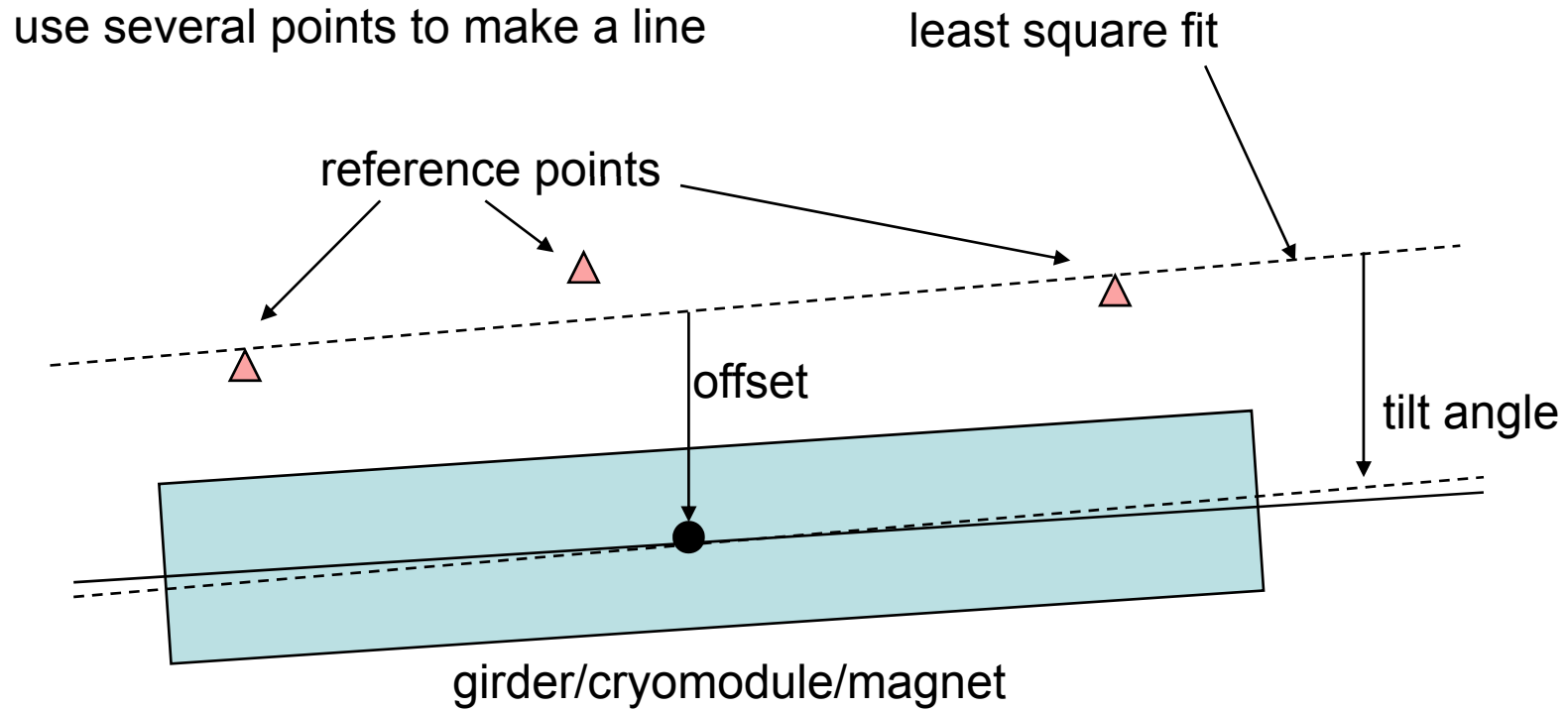
Offset proportional to distance from '1'

This linear correction makes kinks at primary references and is not a good choice.
We use parabolic correction.
There must be better methods?

Survey line to component alignment, Alignment model w.r.t. reference points (example)


use several points to make a line

least square fit

reference points

offset

tilt angle

girder/cryomodule/magnet

"Standard" Local Alignment Error in ML

Error	Cold Sections	With Respect To...
Quad Offset	300 μm	Cryomodule/Survey
Quad roll	300 μrad	Gravity
RF Cavity Offset	300 μm	Cryomodule
RF Cavity Pitch	200 μrad	Cryomodule
BPM Offset (initial)	300 μm	Cryomodule/Survey
Cryomoduloe Offset	200 μm	Survey Line
Cryomodule Pitch	20 μrad	Survey Line

Example of misalignment in ML using suggested error set

Step Length: 25 m, Random angle: 60 nrad/step,
Random offset: 5 μm/step, Systematic angle: 250 nrad/step,
Primary reference: 10 mm
+ "Standard" local misalignment

(Suggested by LiCAS Group)
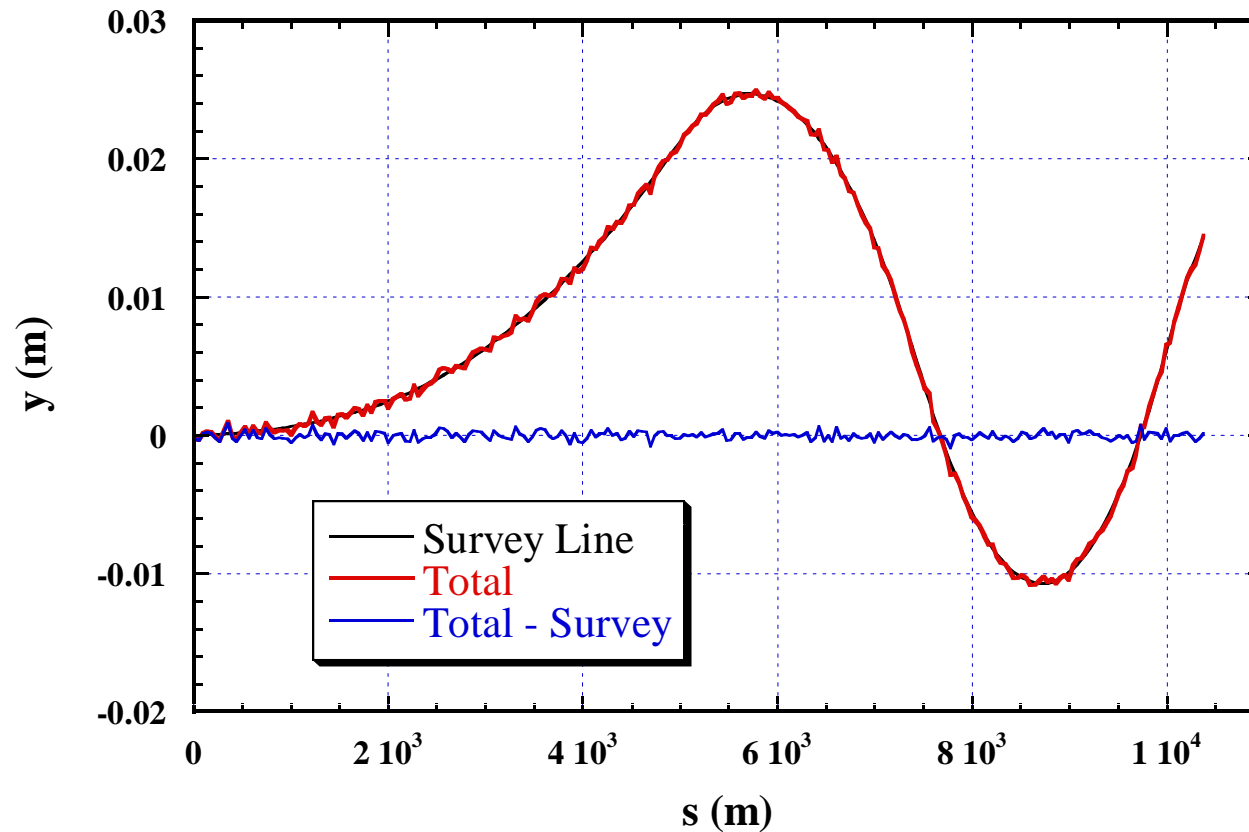
ML simulation with misalignment

Parameters of survey: Suggested by LiCAS Group
Local alignment; "standard"
DFS correction

Mean of emittance and standard deviation from 40 random seeds.
(initial emittance is 2E-8 m)

Misalignment	$<\Delta\gamma\varepsilon$ (m)	STD
Survey	0.053E-8	0.052E-8
Local misalignment	0.670E-8	0.581E-8
Survey + local	0.673E-8	0.591E-8

Assumed survey line error has only little effect and acceptable.

Sensitivity to each error
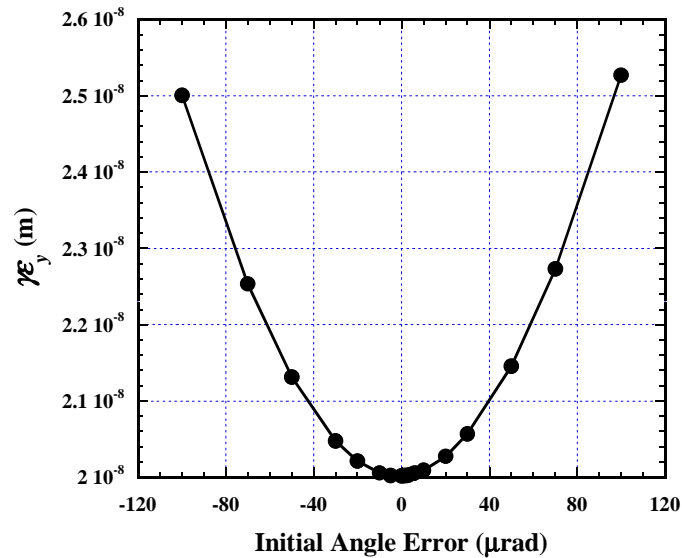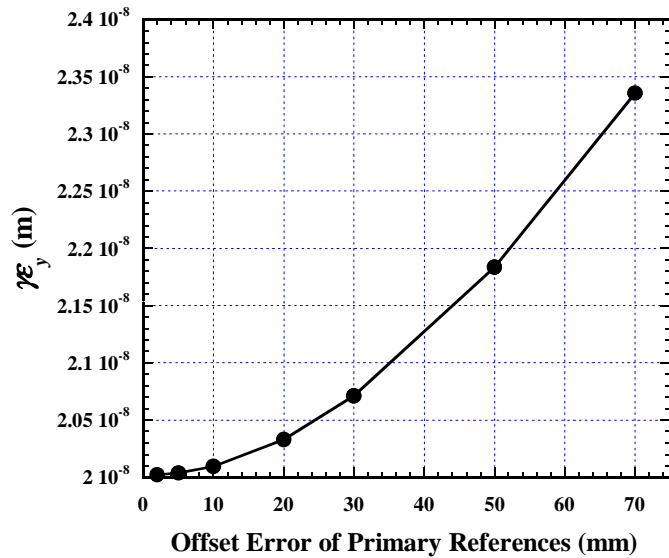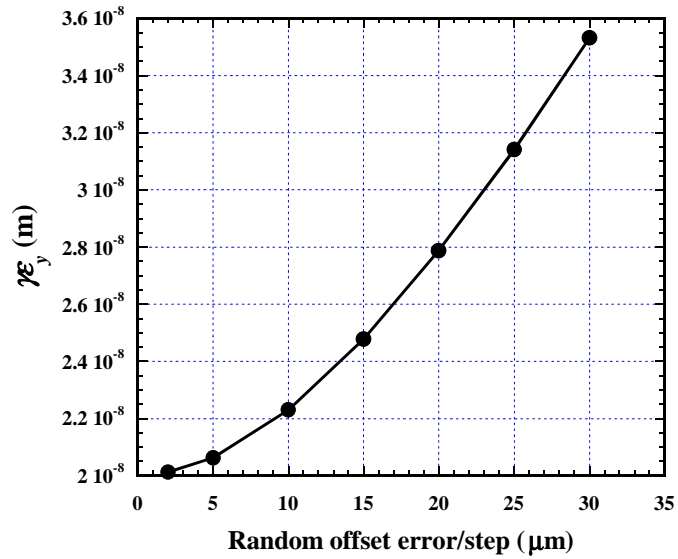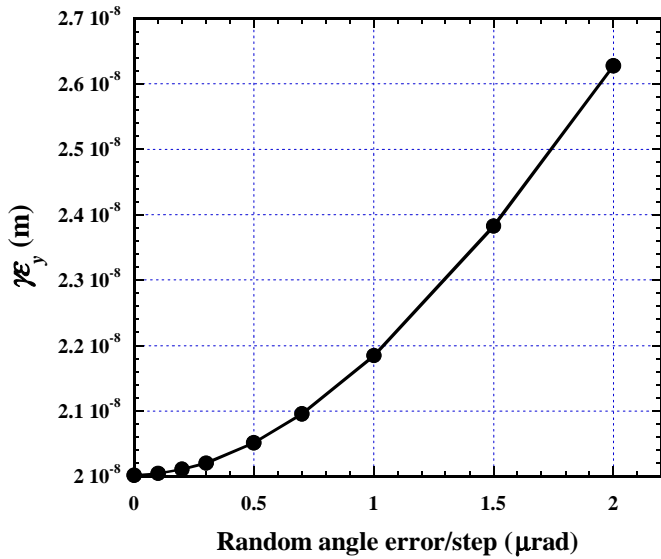
No other errors.   Step length = 50 m

Preliminary "Tolerances", Errors causing 0.2 nm (1% of nominal) average emittance growth

Random walk step length 50m

Error	for1% $\Delta\varepsilon$
Random angle / step	300 nrad
Random offset / step	3 um
Offset of Primary References	15 mm
Initial angle	15 urad

Tolerances look tight ??

Message in May 2008

Dear all,

We are trying to make a realistic mode of survey and alignment of ILC accelerator, which can be used in beam dynamics simulations.

The newest version by Armin Reichold is temporarily put on the web;
http://lcdev.kek.jp/~kkubo/tempdata/AlignmentModel-v07_compressed.doc

I would like to **make "official" document of alignment model in ILC-GDE "Simulations" Group.**

Please give your comments to the model and this document.
Since we should use the model soon, please send your comments by the end of May.
(Our plan is to make it "official" in "Simulations" Group soon, though It does not mean the document cannot be changed after that.)

Please forward this message to anyone who may be interested.

Thank you.
Kiyoshi Kubo

We need help from survey/alignment experts. But,

The problem is:

Nobody in ILC-GDE is really responsible. (?)

It will be difficult to improve the model until alignment group is established in GDE.