ILC Main Linac Simulation with Survey/Alignment model, update 200805

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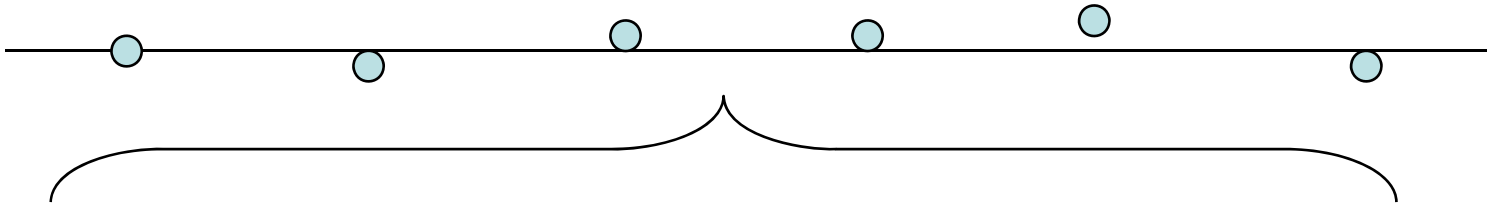
Recent Progress

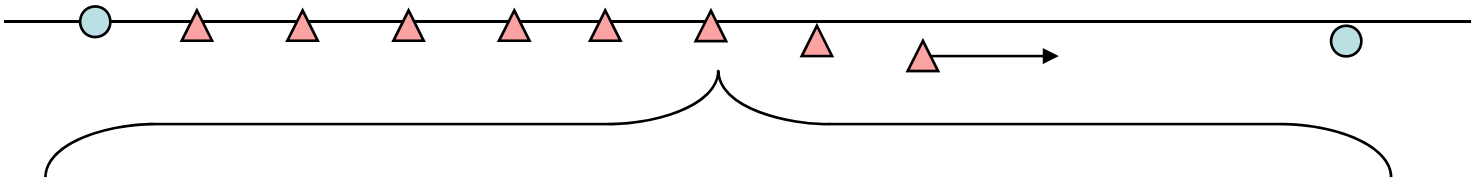
- Bug in the simulation code SLEPT was fixed
  - Setting of initial vertical angle was not correct for reduced energy beam in DFS (Not fatal. Only affected results with very small emittance growth.)
- New survey-alignment model was included
  - Survey (long range) + Random alignment (local)
  - Primary references (every 2.5 km) are used for "parabola correction" of accumulated error → see later slides
- Look at sensitivity to each error
- Simulation with suggested error set by LiCAS group

Alignment procedure

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

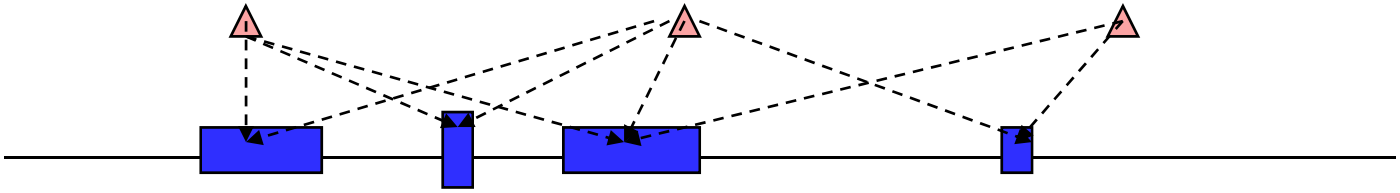


Survey from one primary reference to the next.
Every about 5~50 m, mark reference point



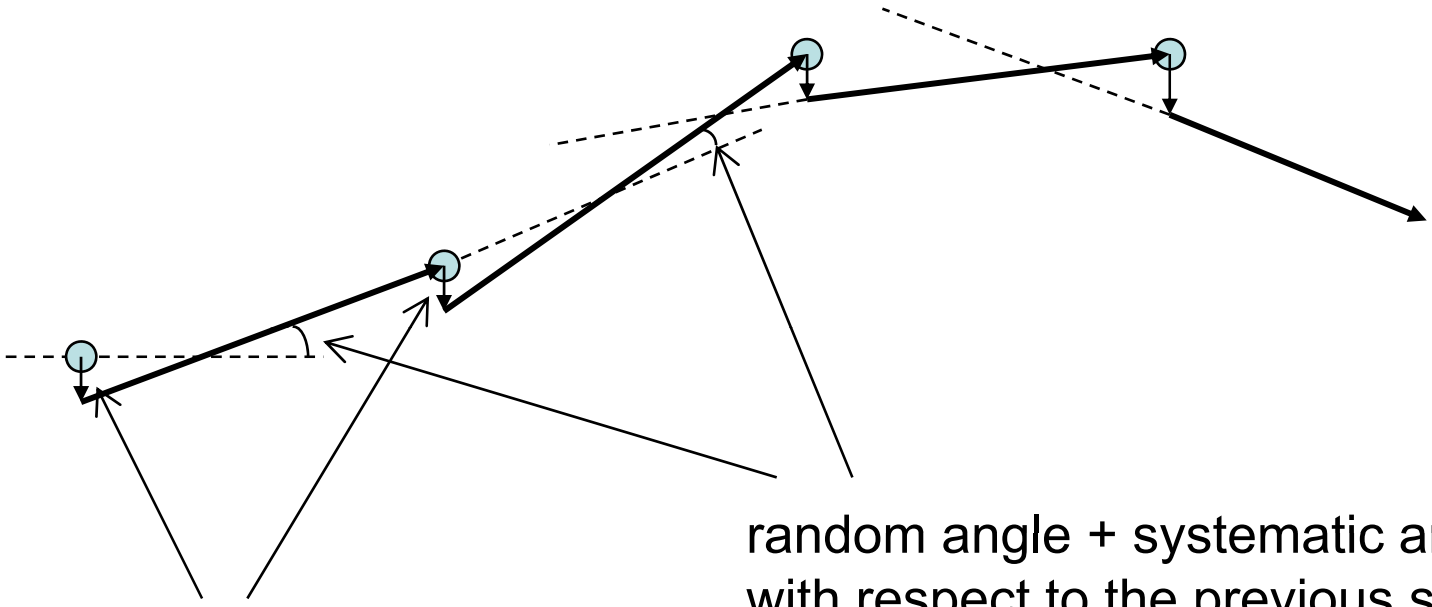
Applied to tracking simulation

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



Not yet applied to simulation

Step by step survey:
Random Walk + systematic angle error



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

random offset

Parameters:

l_{step} : length of one step

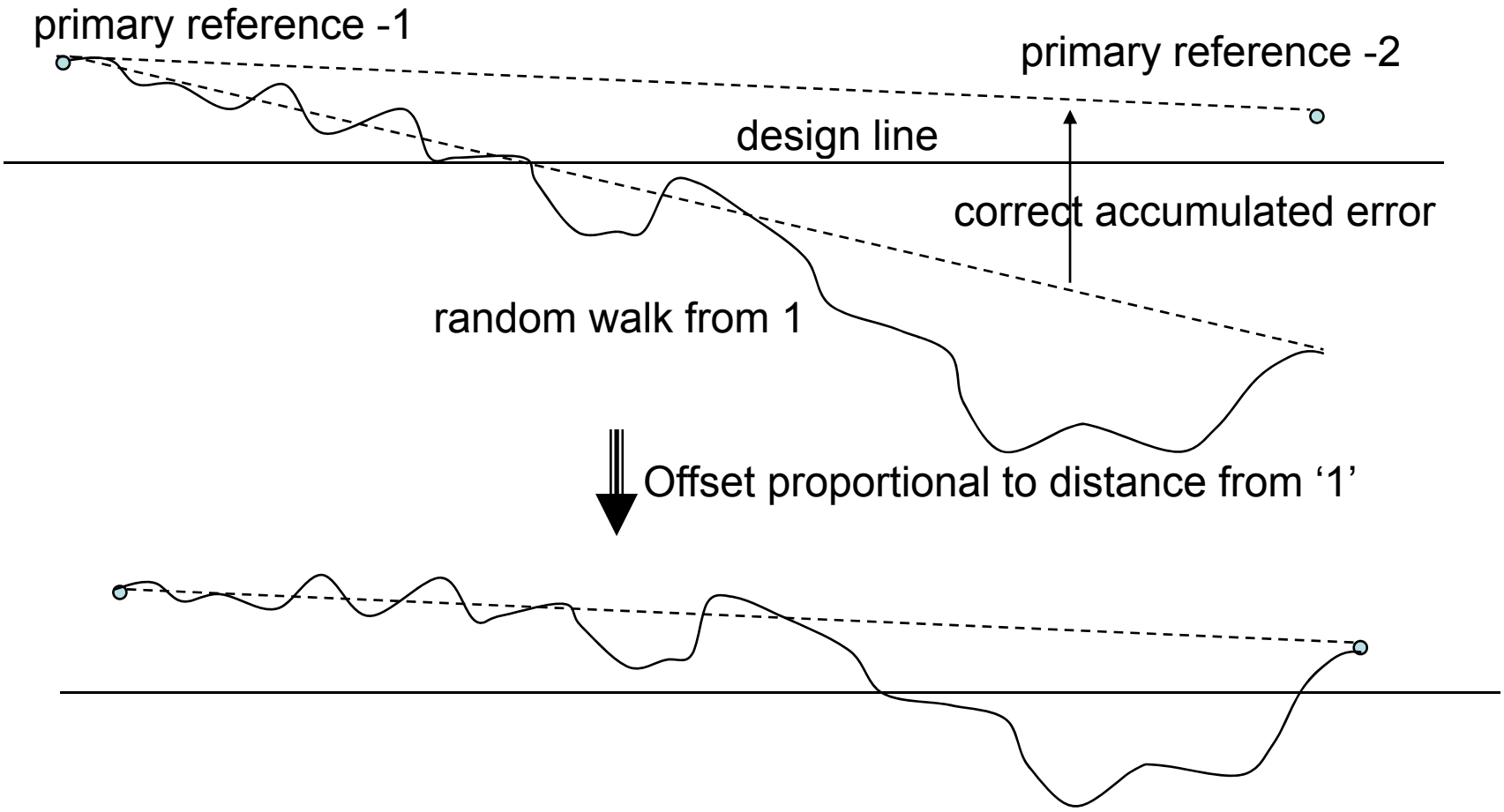
a_y : random offset/step

a_θ : random angle error/step

θ_O : systematic angle error

Systematic offset error was treated as “initial angle” error. See later slides.

Correction of accumulated error in Random Walk using primary reference



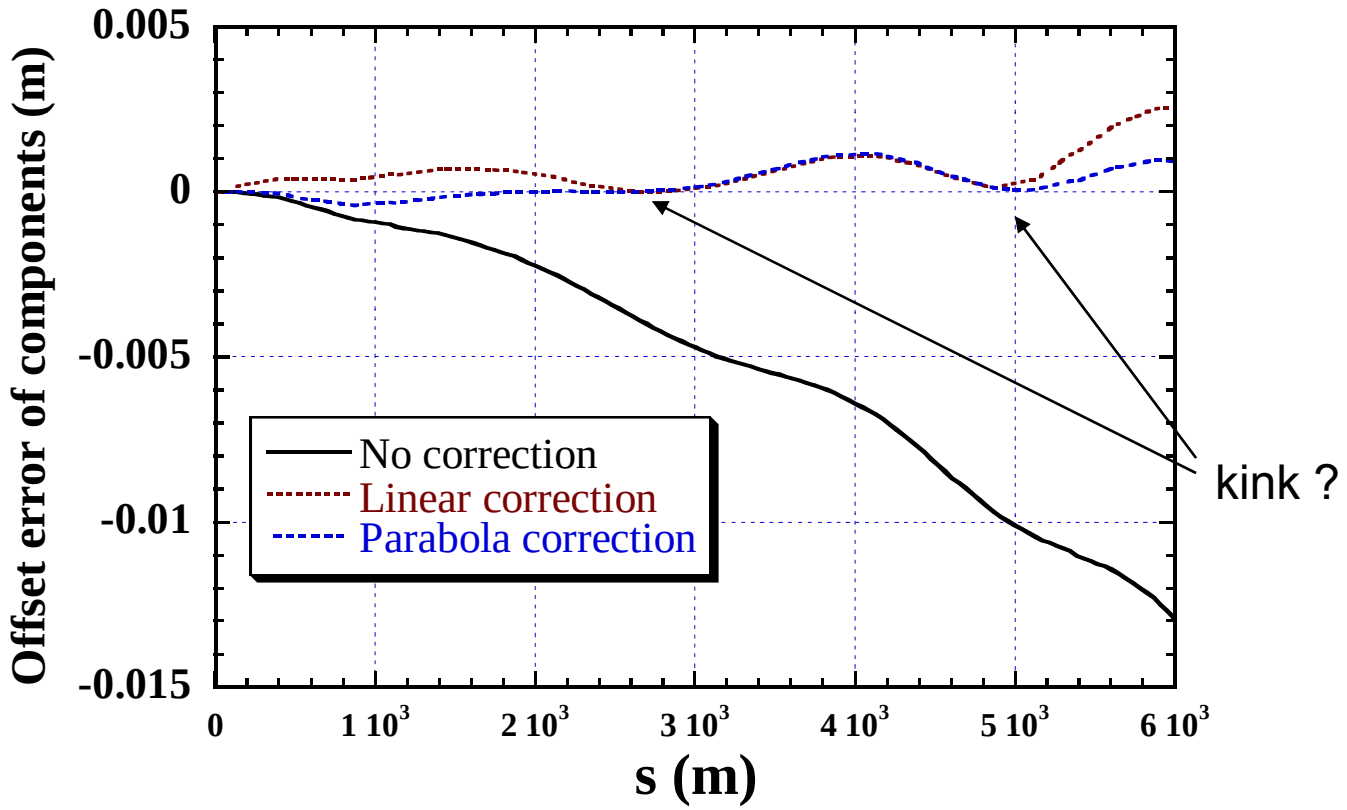
This simple linear correction makes kinks at primary references and is not a good choice. We chose parabola correction here. (Correction is proportional to square of distance.)

Correction of accumulated survey line error using primary references

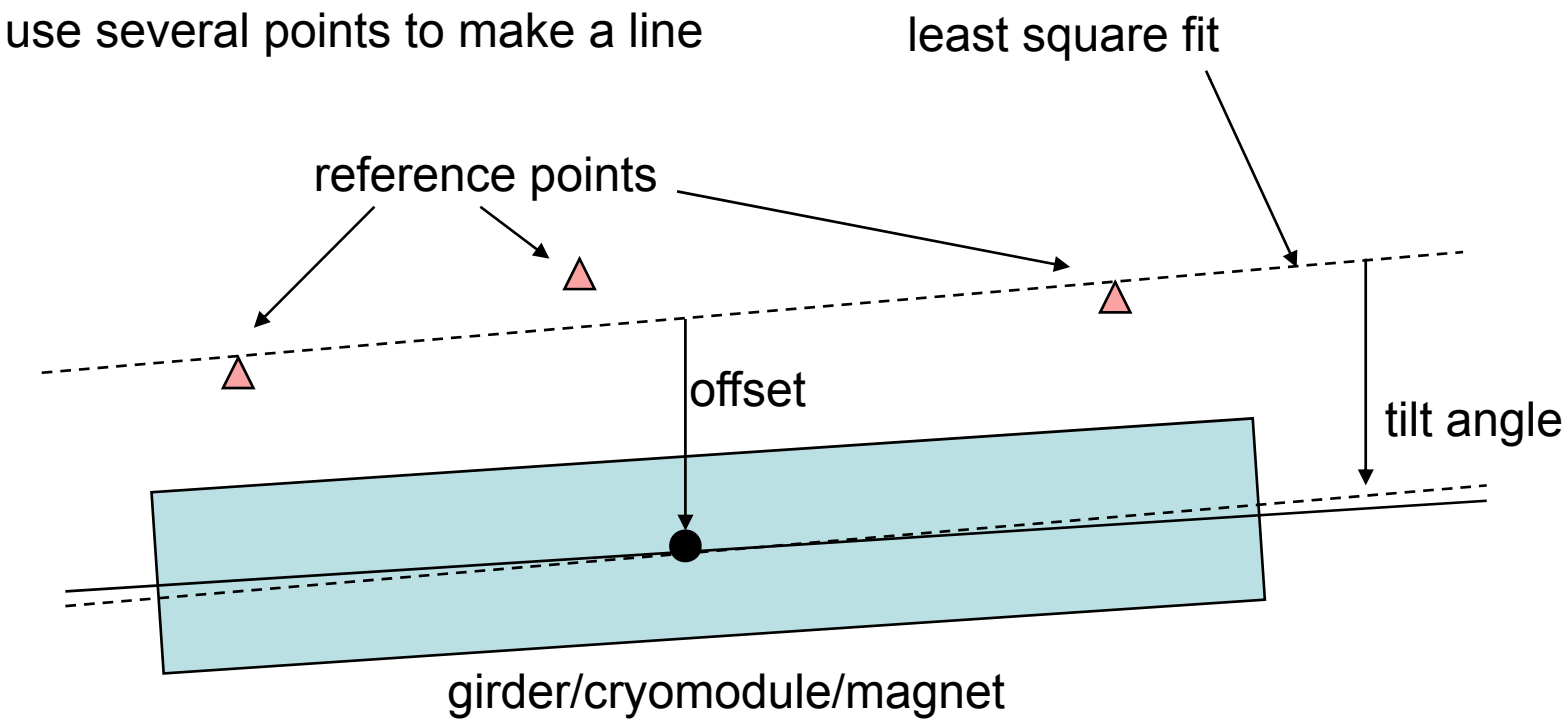
- Linear correction
  - Correction proportional to distance from the start point.
  - Causes kinks at primary reference.
- Parabola correction: We have chosen this
  - Correction proportional to square of distance from the start point.
  - No kinks.
- Other methods (?)

Example: Comparison of correction of accumulated error

Spacing of primary references: 2500 m, Error of primary reference: 0
Step length of survey (random walk): 50 m
Offset error /step, $a_y = 0$, Angle error/step, $a_\theta = 1\ \mu rad$



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



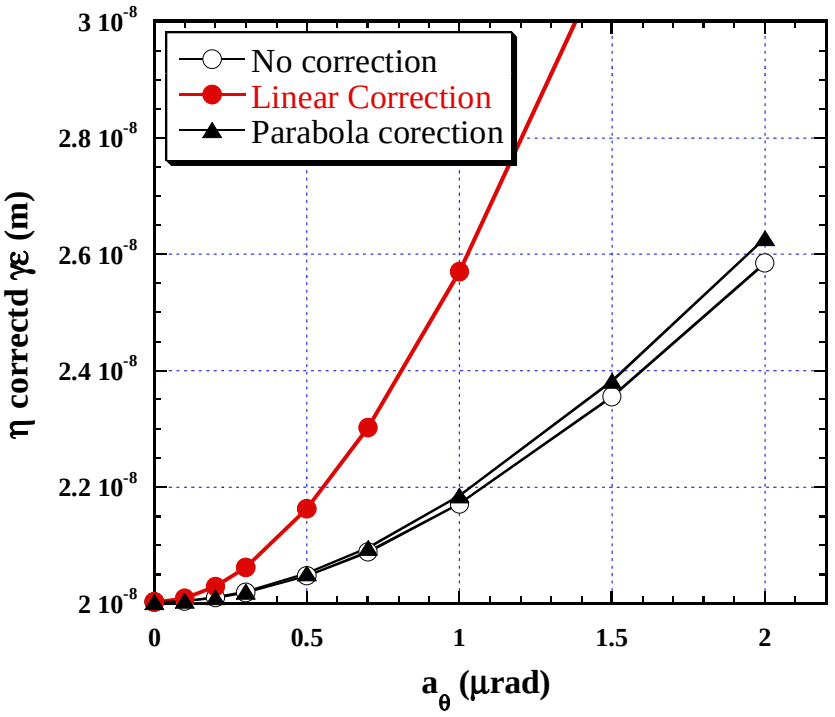
Sensitivity to each error parameter of survey line

- Step length of random walk is chosen as 50 m
- Set one error for each simulation run
  - Random angle/step, a_θ
  - Random offset/step, a_y
  - Error of primary references (every 2.5 km)
  - Systematic angle error θ_0 (error of vertical curvature)
  - Error of initial angle
- DFS (Dispersion Free Steering) is performed
- Looked at final "linear η corrected" emittance

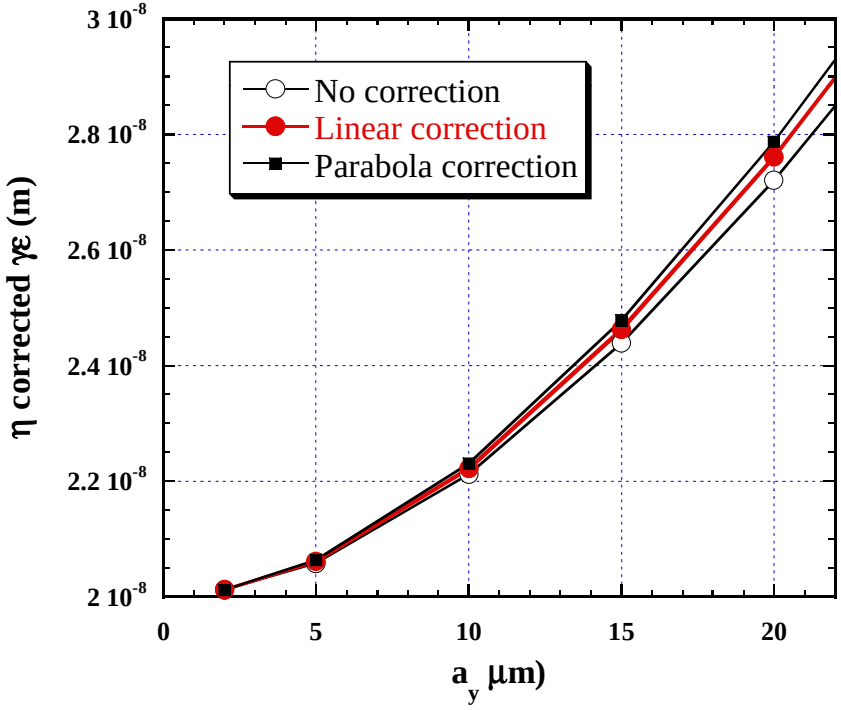
Sensitivity to Random Angle and Random Offset / step after DFS

Average of 40 random seeds

Angle, no other error

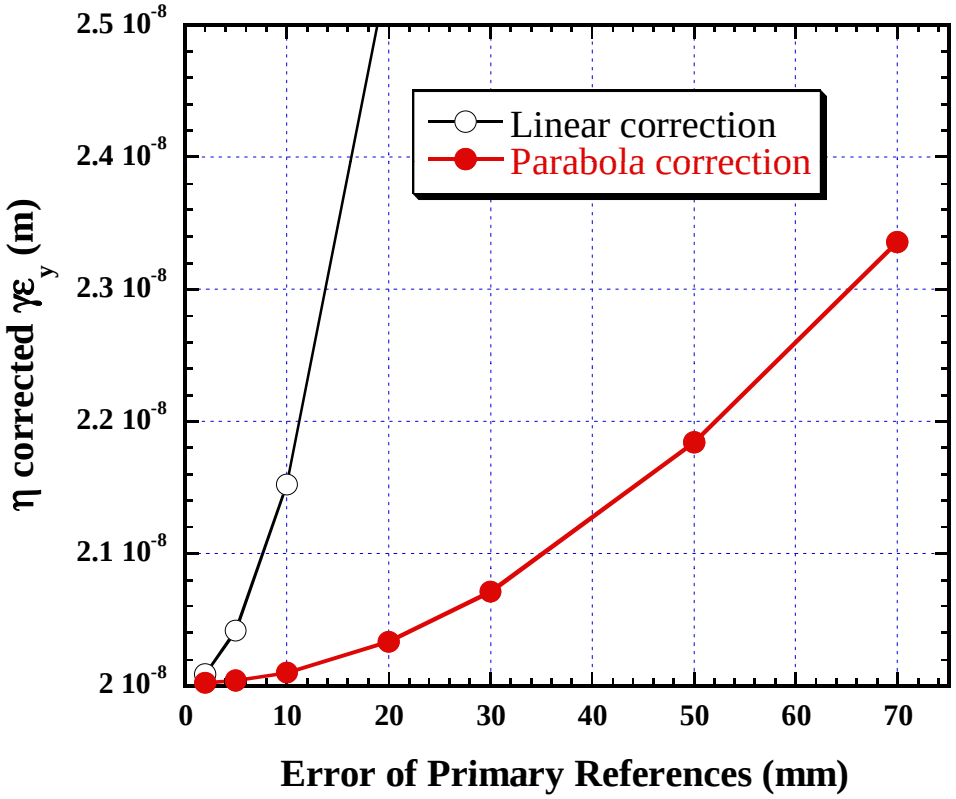


Offset, no other error



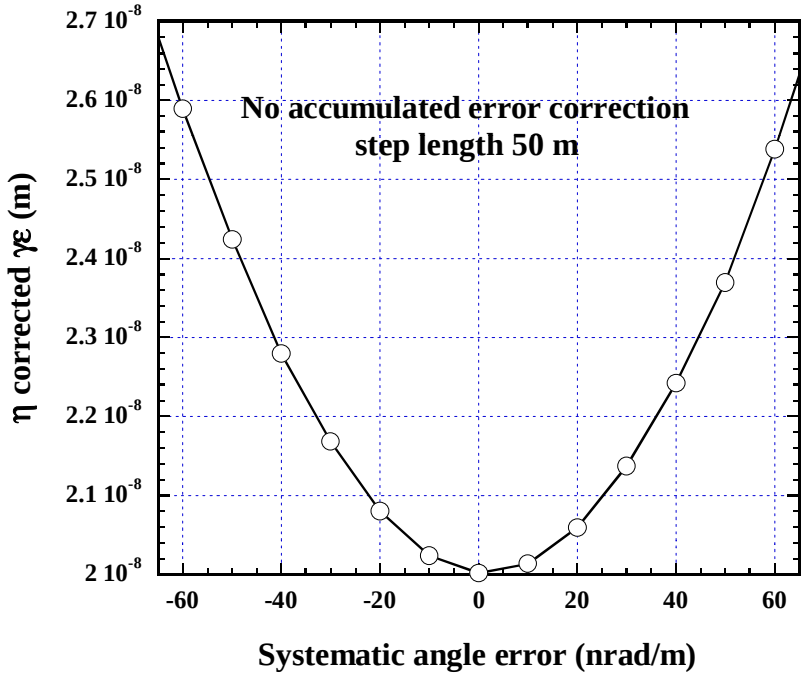
Sensitivity to Offset error of Primary References after DFS

Average of 40 random seeds



Systematic angle error

There should be no effect in case of Parabola correction.
Results in the case of No correction are shown for reference.
(Linear correction has huge sensitivity and not shown here)



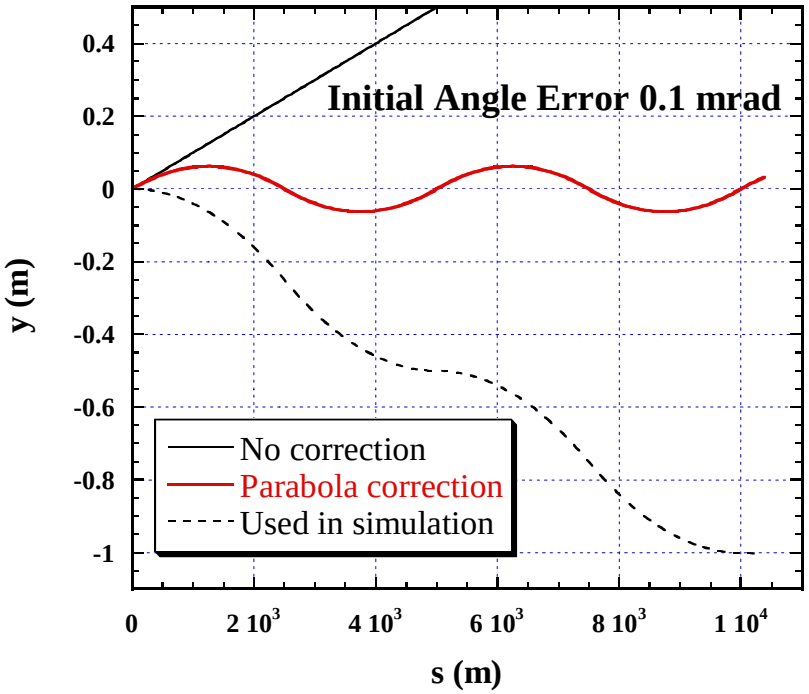
$$y = \frac{(\text{angle error / length})}{2} s^2$$

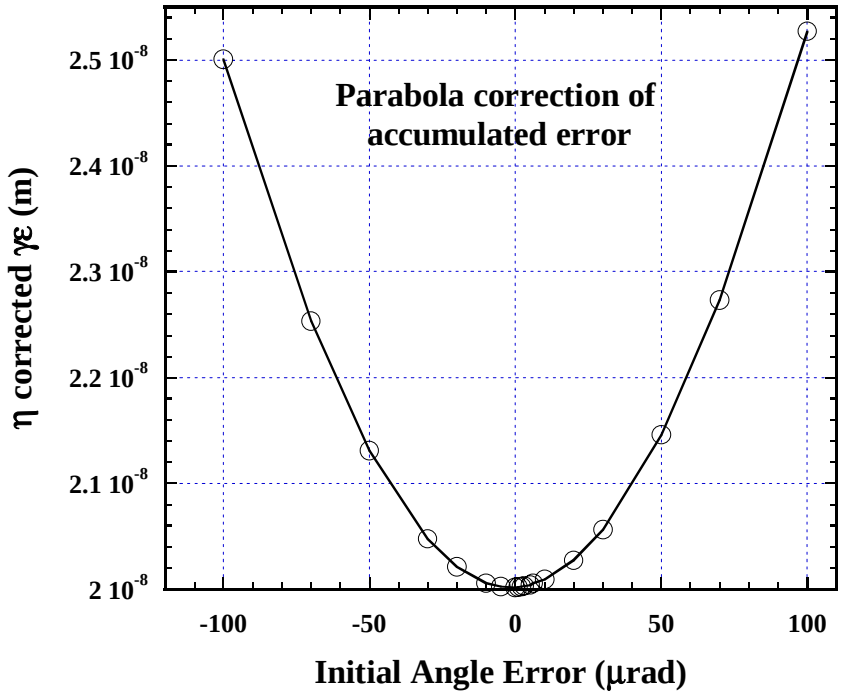
10 nrad/m causes 0.5 m offset at 10 km

Initial angle error

No effect in cases of Linear correction and No correction.
Only results of Parabola correction are shown.

Initial angle error is equivalent to systematic offset error.
To adjust orbit-alignment angle, offset of Primary References were also set in simulations (assuming we can correct injection angle).





“Tolerances” in the case of Parabola correction (looks the best among three cases),

Error 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

Include all survey-misalignment errors

- Survey parameters suggested by LiCAS Group (or Armin Reinchold)
  - Step Length: 25 m, Random angle: 60 nrad/step,
  - Random offset: 5 mm/step, Systematic angle: 250 nrad/step,
  - Primary reference: 10 mm
- Set “standard” local misalignment w.r.t. the survey line.

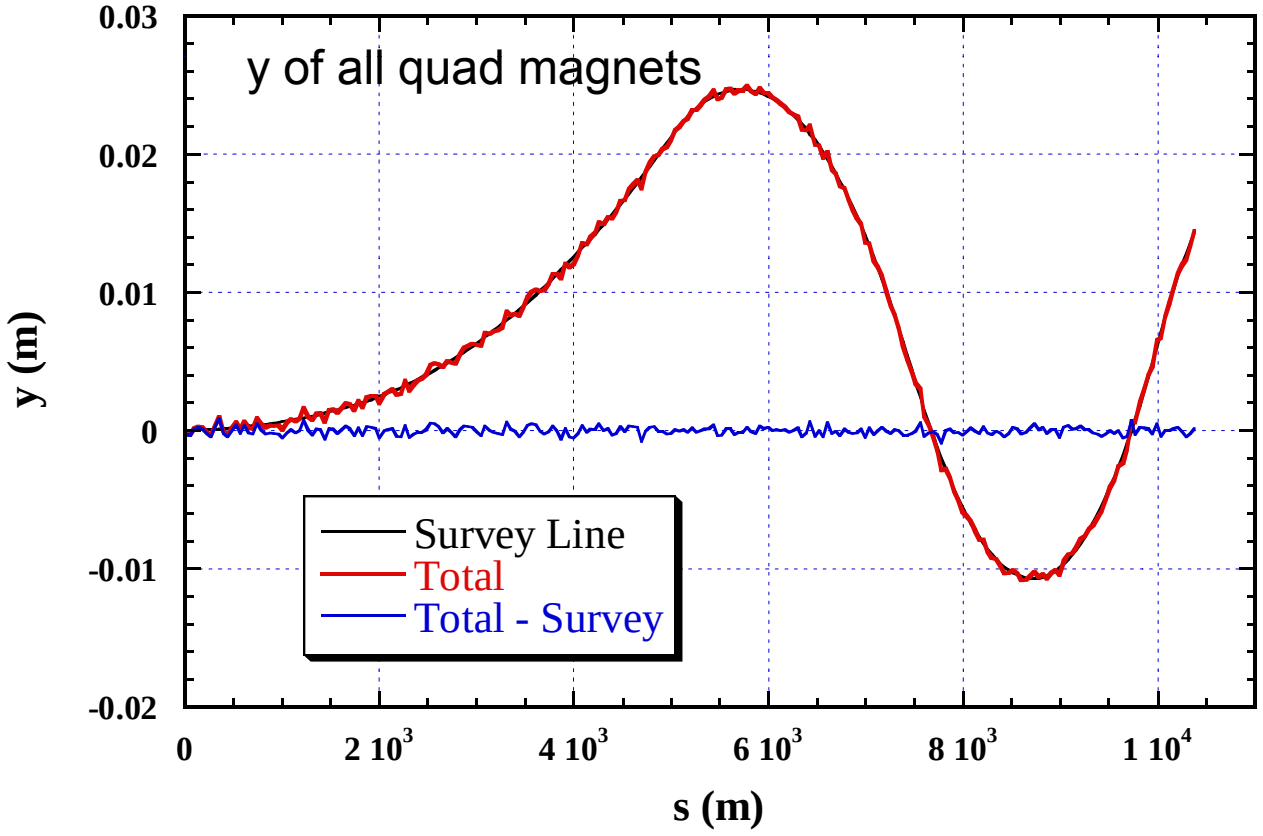
Error	Cold Sections	With Respect To...
Quad Offset	300 μm	Cryomodule
Quad roll	300 μrad	Gravity
RF Cavity Offset	300 μm	Cryomodule
RF Cavity Pitch	200 μrad	Cryomodule
BPM Offset (initial)	300 μm	Cryomodule
Cryomoduloe Offset	200 μ m	Survey Line
Cryomodule Pitch	20 μrad	Survey Line

Example of misalignment in ML

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

(Suggested by LiCAS Group)

+ “Standard” local misalignment



ML simulation with misalignment

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

	$\langle\Delta\gamma\varepsilon\rangle$ (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

Suggested set of survey line errors by LiCAS group (?) is good enough.

SUMMARY

- Main Linac simulations were performed including a survey-alignment model
- Tolerances are estimated in the case the random walk step length 50 m.
  - They should depend on step length. Will be studied .
- Simulation with the error set suggested by LiCAS group was performed.
  - No significant emittance growth due to the survey errors.
- The validity of the model and the parameters should be checked.