Dispersion Matched Steering and Alignment Model in Main Linac

EUROTeV meeting 26/08/08

Freddy Poirier

Simulation of Dispersion Matched Steering (DMS)

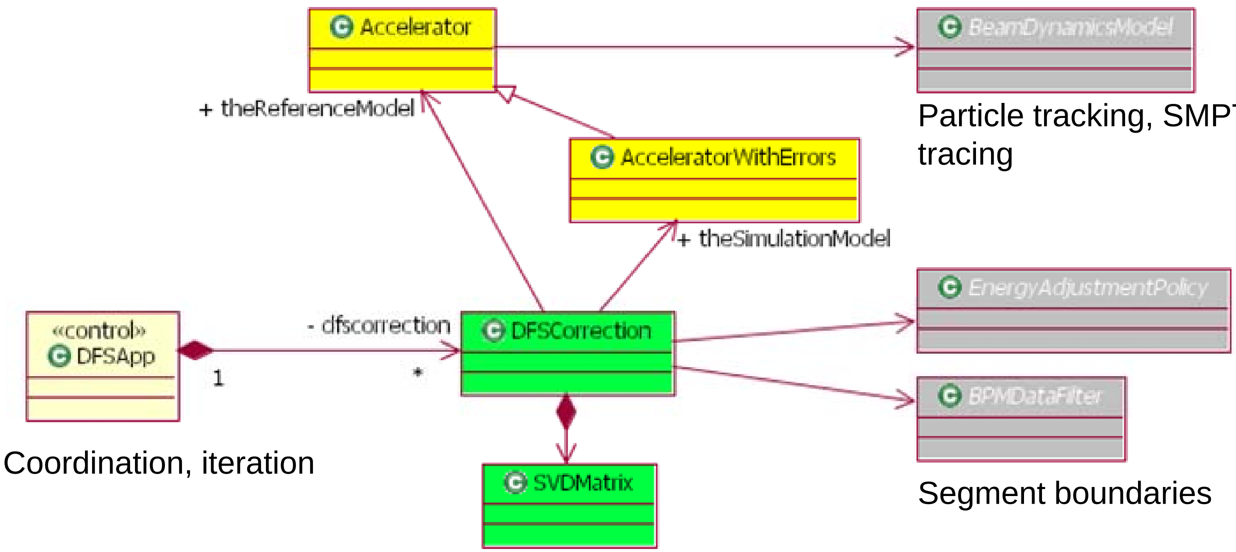
- Present Simulations are using Merlin (a C++ based library for particle tracking)
- The Merlin based ILCDFS package
  - Is performing the tracking throught the curved main linac (positron side)
  - It has implementation of the Beam Based Alignment: Dispersion Matched Steering correction#
- Dispersion Matched Steering (DMS)
  - DMS attempts to locally correct dispersion which arises from magnets and other accelerators components alignment errors.
  - Steerers (here correctors) are set to minimize dispersion and thus preserve the emittance along the Main Linac (ML)
  - This technique uses:
    - A nominal beam (15 GeV at beg. of ML to 250 GeV at exit)
    - One (or more) test-beam with off-energy beam (different energy from nominal)

#Due to non-zero design dispersion (curved linac) which must be match, the more general algorithm applied is here DMS rather than DFS (Free)

Freddy poirier

ILCDFS package

C++ class diagram



Particle tracking, SMPT, Ray tracing

Coordination, iteration

Segment boundaries

`DFSApp` is the core class coordinating other classes (errors, beam dynamics model, energy strategy,…)

An ILC main linac simulation package based on MERLIN EUROTeV Report 2006-076

The package has been used for various work:

- Benchmark[(1)] with other codes (i.e. placet).
- Ground Motion errors studies [(3)]
- Global Correction [(2)]
- Component tolerances, coupling corrections, …
- It includes a class to read offsets from a survey line simulation

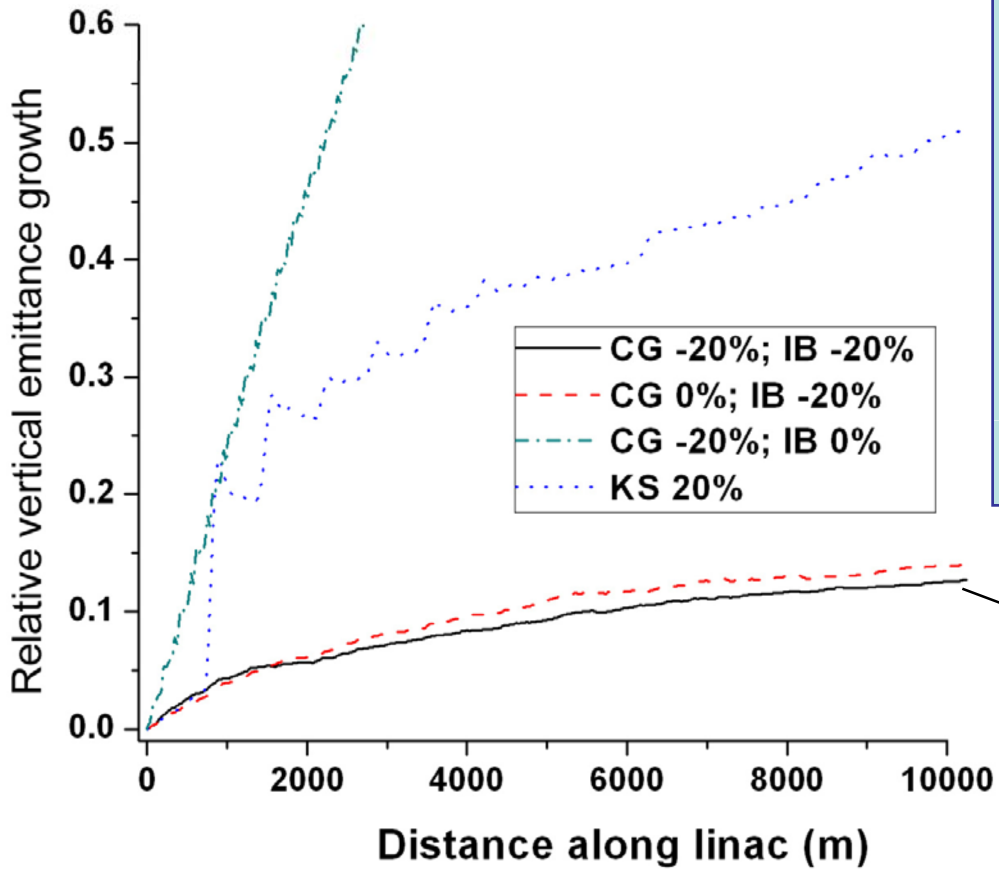
(1) *Study of an ILC Main Linac that follows the Earth Curvature* EUROTeV Report 2006-50

(2) *Evaluation of Component tolerances for the ILC main linac assuming global corrections*, EUROTeV Report 2007-20

(3) *Simulation Studies of Correlated misalignments in the ILC main linac and influence of ground motion*, EUROTeV Report 2008-17

DMS - energy strategy study

Study of energy adjustment strategy for off-energy beam along linac with the Merlin based code ILCDFS



Mean over 100 random machine (uncorrelated static errors)

1) IB: Initial energy is the most effective single adjustment. ($\gamma\varepsilon_{yc}$=22.8 nm)

2) CG: Constant gradient only least effective (59.3 nm)$^{(*)}$

3) Combination of IB and CG helps to obtain better results (22.5 nm)

4) KS: Klystron Shunting (30.2 nm). Steps probably an artefact of simu. due to steering effect. Decrease with energy

This Energy Adjustment Strategy is used in the next study on the alignment.

*CG do not effectively correct dispersion at the beginning as relative uncorrelated energy spread is highest.

See: *Energy Adjustment Strategy for DFS at the ILC using the MERLIN Package ILCDFS* – EUROTeV report 2006-106

Purpose of Alignment Simulation

(courtesy of A. Reichold – Oxford Uni.)

- Solve two long standing problems:
  - LET simulation studies have to date used models of alignment that were not fully comparable to any potential survey and alignment process that may once be used in the ILC

  ➔ we may have missed some problems that alignments may cause for LET

  - The parameters describing these models could not be translated into requirements for survey processes

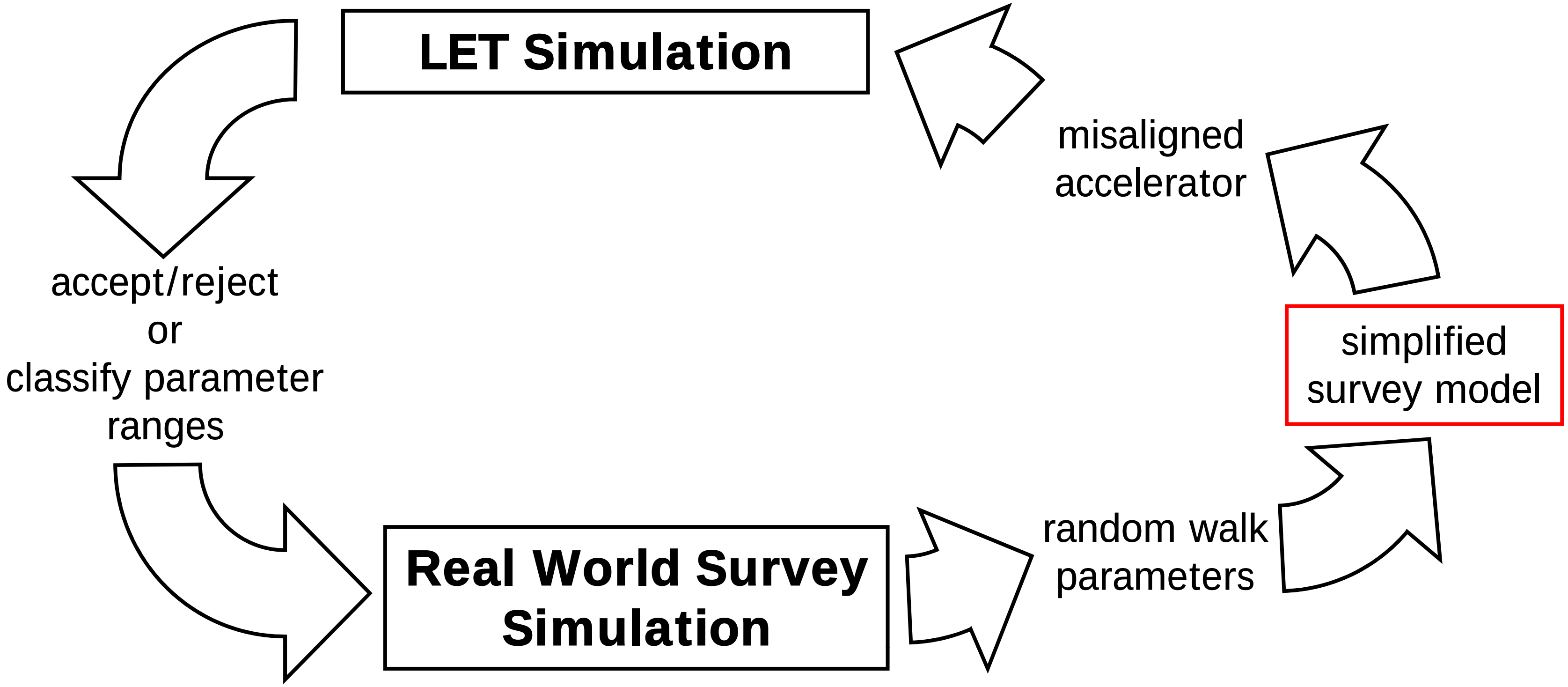
  ➔ we have not determined which survey and alignment processes do or don't satisfy the ILC-LET requirements

<u>We don't have a real world alignment model for ILC!</u>

Purpose

(courtesy of A. Reichold – Oxford Uni.)

- Bootstrap a real optimisation loop between LET simulations and the development of new survey and alignment techniques



Real Survey & Alignment Processes

- Survey and alignment for the ILC will consist of many techniques using many different measurements
- We don’t know the entire chain yet
  - we know candidates for the linear tunnel reference survey (i.e. LiCAS)
  - we know candidates for the site wide reference network O(km) ➔ differential GPS

Survey Model

- A simplified alignment model has been proposed
  - For the tunnel reference survey based on a pseudo-random walk
  - Using the wide reference network (primary points) to correct the reference survey.

- Components of the linac are then positioned according to the adjusted offsets of the survey line

The present model

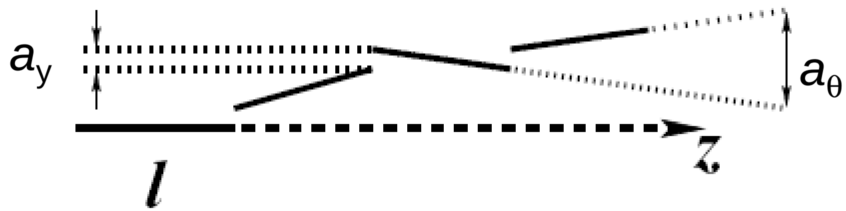
- Random walk (y) parameterized as:

$$\theta_{j,n+1} = \theta_{j,n} + a_\theta + \Delta\theta_{syst}$$

$$y_{0,j,n+1} = y_{0,j,n} + a_y + l_{step}\,\theta_{j,n} + \Delta y_{syst}$$

$$y_{0,j,0} = y_{p,j}$$

$$0 \le n \le N_{rfpt}$$



a_θ and a_y are random Gaussian errors (angle and offset)

θ_{syst} and y_{syst} are the systematic errors

- Errors (stat. and sys.):

$$\sigma_{y,n,stat.} = \sqrt{l_{step}^2 a_\theta^2 \frac{n(n+1)(2n+1)}{6} + a_y^2 \frac{n(n+1)}{2}}$$

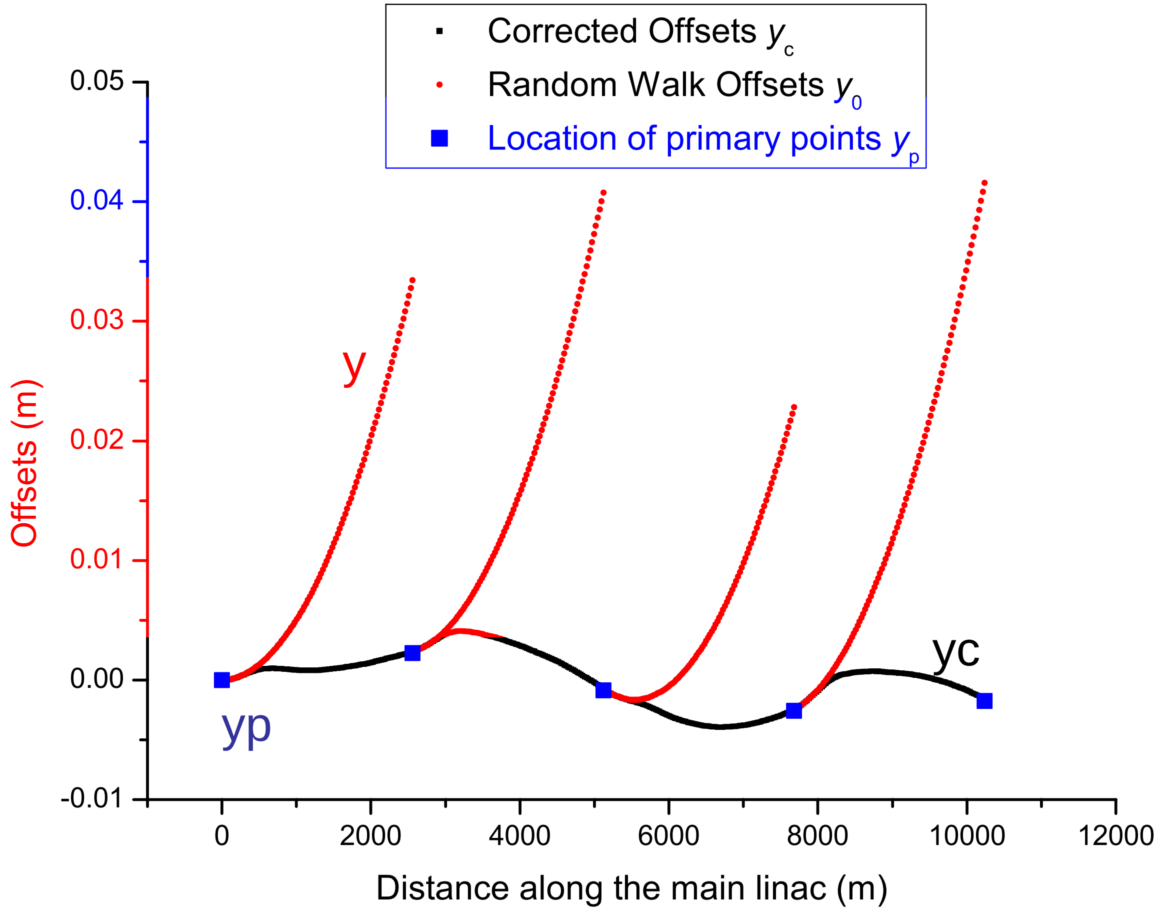
$$\sigma_{y,n,syst.} = l_{step}\Delta\theta_{systematic}\, n\frac{(n+1)}{2} + n\Delta y_{systematic}$$

- Correction (yc): Error weighted average fit (parabolic)

$$y_{j,n} = y_{0,j,n} + \left(y_{0,j,N} - \frac{y_{P,j+1}/\sigma^2_{y-primary} + y_{0,j,N}/\sigma^2_{y-0,j,n}}{\sigma^2_{y-primary} + \sigma^2_{y-0,j,n}} \right)\left(s_j(0,n)/s_j(0,N)\right)^2$$

A Simulated example of Survey

- Yp= offsets of primary points (wide reference network)
  - 2.5 km apart (shaft?)
- Y=offset of the reference survey
  - Random walk
- Yc=corrected offset of the survey line
  - parabola correction (weighted solution)



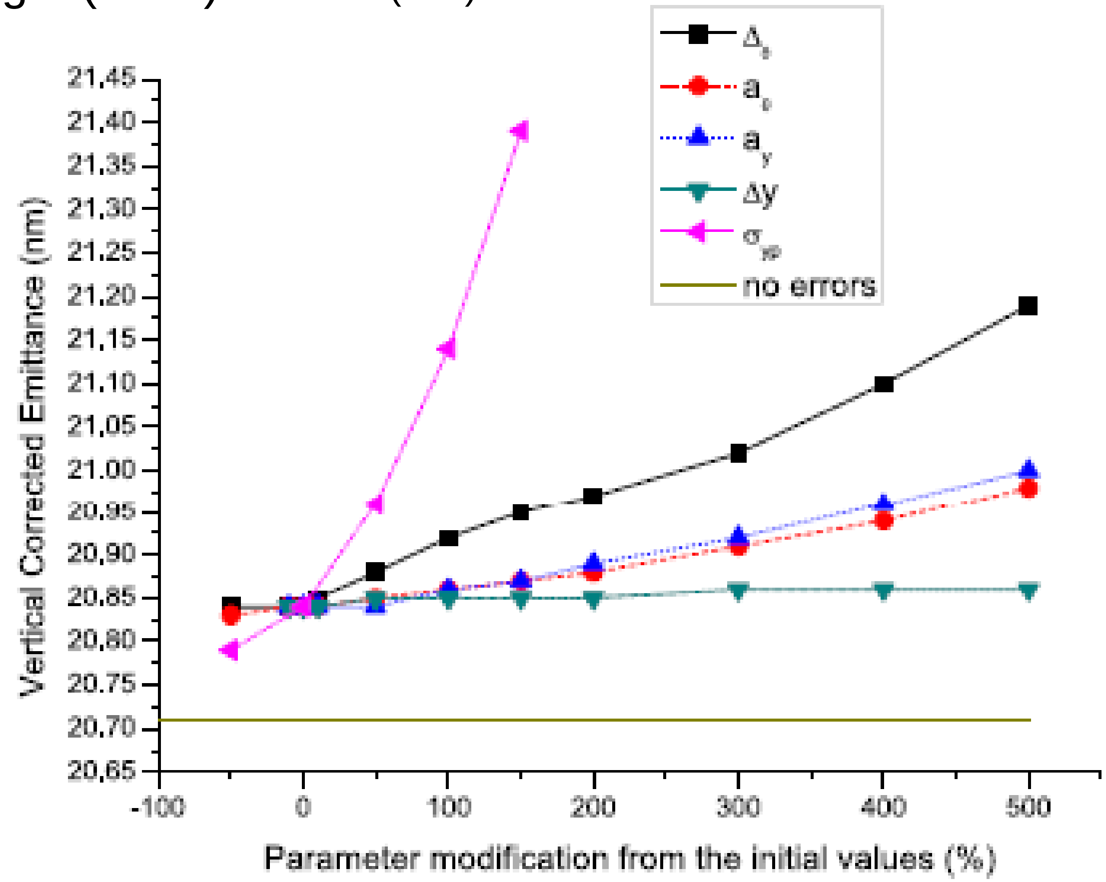
Yp(first)=0 (fixed)

The starting angle of the offset at the beginning of a primary section is the same as the last one from a previous section

Done with scilab: a mathematical tool

DMS & Alignment Simulation

Weight (DMS)= fixed! (=40)



Initial parameters

(thought to be achievable with survey technique such as LICAS):

a_y=	$5\ 10^{6}$	m
a_θ=	$55.4\ 10^{-9}$	rad
Δ_θ=	$260\ 10^{-9}$	rad
Δy=	$5.3\ 10^{-6}$	m
σ_{yp}=	$2.0\ 10^{-3}$	m

(error on primary points)

The sensitivity of the emittance at the end of the linac to the parameters of the model is rather low except for the primary points error (*).

Injection emittance = 20 nm, mean over 100 random generated machine

The model here only uses the correction as given in the version 0.7 of the misalignment paper.

Emittance (or ε_{yc}) here is the vertical emittance with the energy correlation numerically removed

* Though still lower than independent error on components.

Conclusion

- Emittance growth with standard uncorrelated errors = ~2.4 nm
- Emittance growth (alignment model + std errors)=~2.4 nm

• Impact on the emittance growth of the alignment model with (initial) parameters thought to be achievable with survey techniques:

- Negligible

Note

- Traditionally (2007 ILC-GDE meeting) the alignment errors used are 200 μm/ 600m of linac length.
- With the initial parameters used here, the errors obtained from the monte-carlo alignment model are of ~100 μm/ 600m (This includes the correction scheme)

Outlook

- A first loop has been done here to use a simplified model characteristic of an alignment process.

- This study is part of an on-going discussion between beam dynamics group and ILC metrology group.

I would like to thank E. Elsen, K.Kubo, A. Reichold for discussions