Alignment model - first trial

K.Kubo 20070918
revised 20071018

References

- “archive” of https://lists.desy.de/sympa/info/ilc-metapy
  - Communication with Armin Reihold, using the mailing list ilc-metapy@desy.de
  - Newest draft documentation of the model is attached to one of the e-mail
- LICAS
  - http://www-pnp.physics.ox.ac.uk/~licas/page_talks/IWAA2004/iwaa2004_gg_talk_v1.pdf
  - http://iwaa2004.web.cern.ch/IWAA2004/subsite/PDF/20041007_TS10-3_Grzegorz-Grzelak.pdf
- Private communication with R. Sugahara (KEK)

Alignment (offset and tilt) model

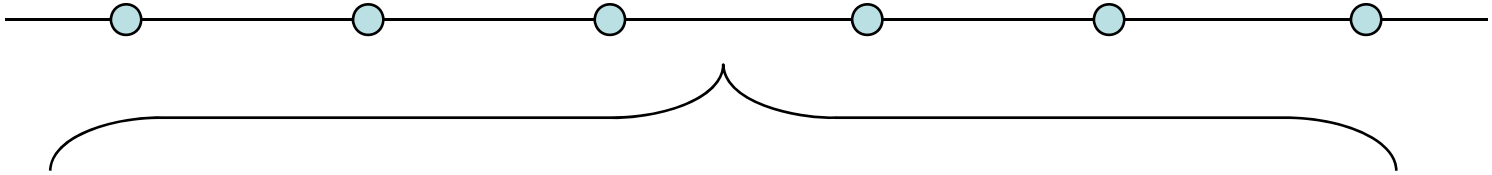
1. Mark primary reference point, every 2.5(?) km.
   - Error will be random, independent Gaussian. ~mm
   - 2.5 km corresponds to distance between shafts

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

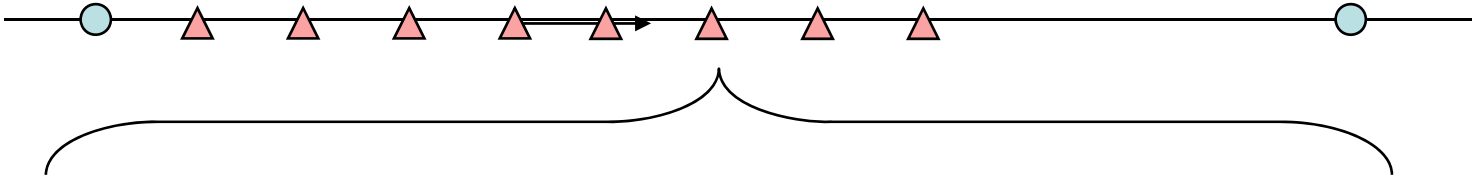
3. Girders, cryomodules and other independent components will be placed w.r.t. the nearest reference.
   - Error will be random, independent Gaussian, w.r.t. survey line.

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

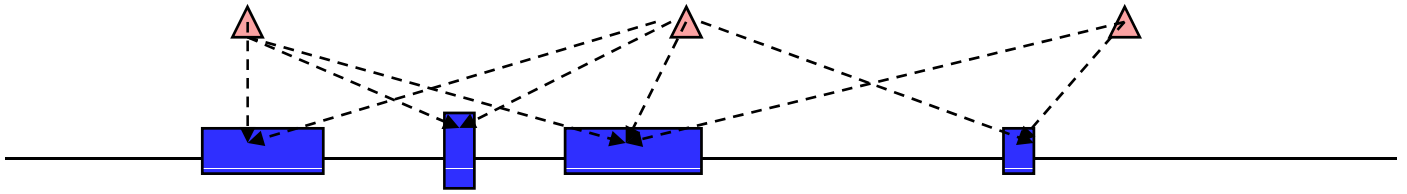
Every about 2.5 km, primary references,
? using GPS? Random error.



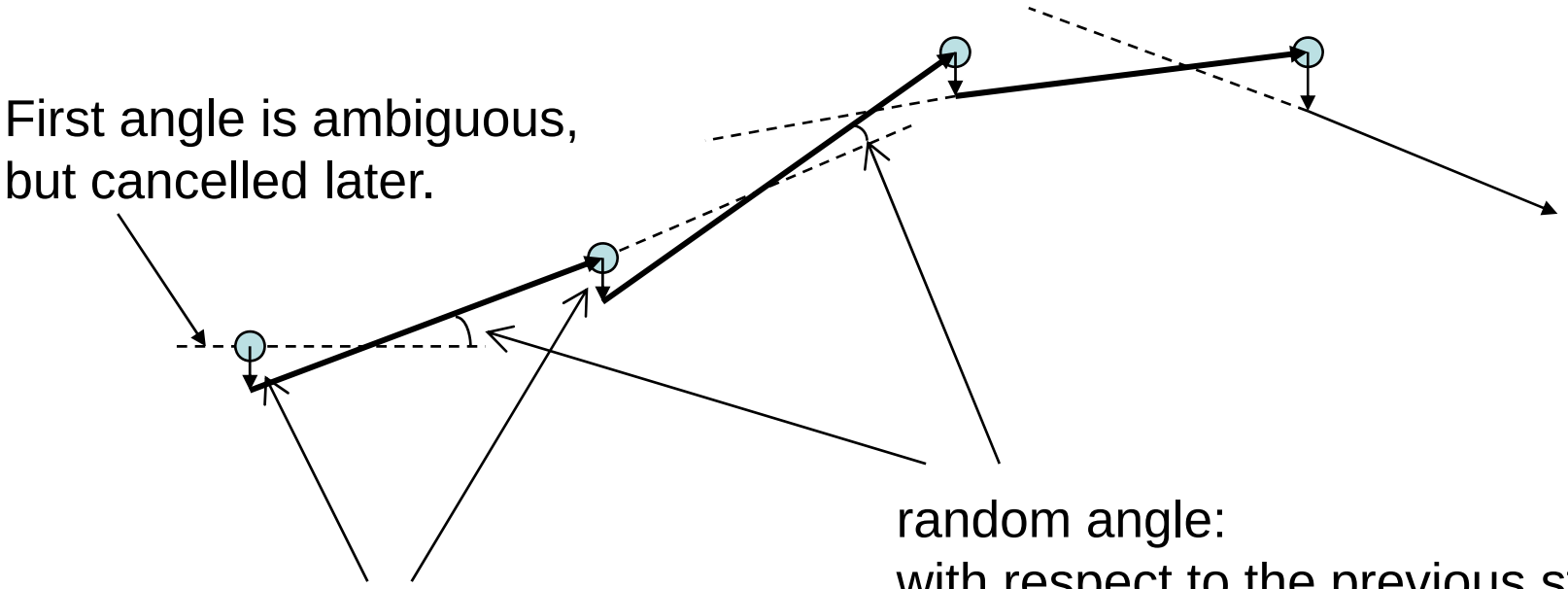
Survey from one primary reference to the next.
Every about 5~50 m, mark reference point



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



Random Walk



From reference of LICAS,

Step length ~ 5 m,

Offset RMS 0.5 μm,

Angle RMS 0.1 μrad

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 angel of the n-th step in the j-th region, the effect of the one step can be expressed as:

$$\theta_{j,n+1} = \theta_{j,n} + G(a_\theta, t_\theta) + \theta_O$$

$$y_{0,j,n+1} = y_{0,j,n} + G(a_y, t_y) + l_{step}\theta_{j,n+1} \qquad (0 \le n \le N-1) \quad (1\text{-}2)$$

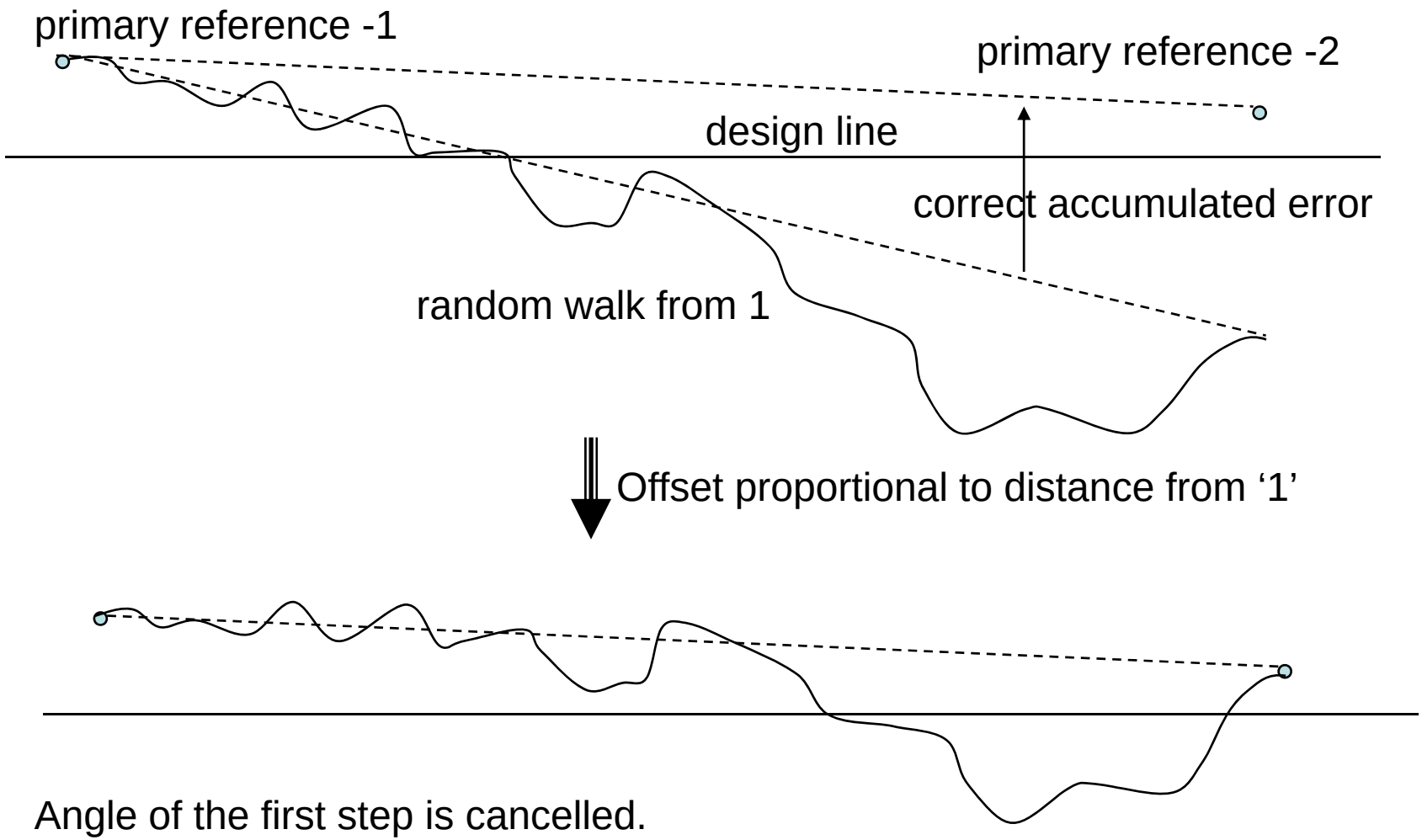
$$y_{0,j,0} = y_{P,j}$$

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.

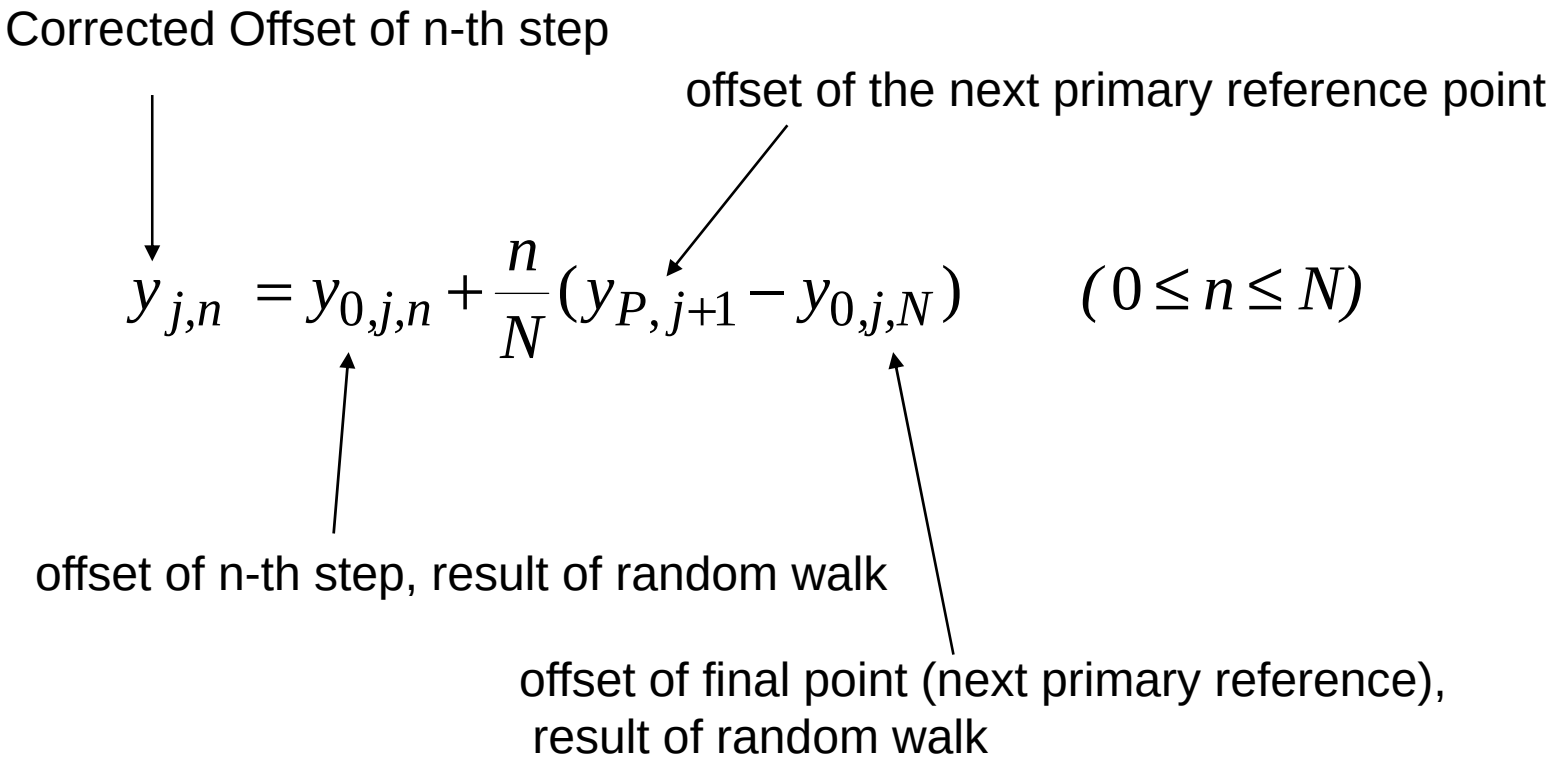
From reference [1], tentative parameters can be $a_y = 0.5\,\mu\text{m}$, $a_\theta = 0.1\,\mu\text{rad}$ and $l_{step} = 4.5\,\text{m}$.

Correction of accumulated error in Random Walk



Angle of the first step is cancelled.

Correction of accumulated error in Random Walk



There is a commnent that this process is not necessary.

$$y_{j,n} = \left(1-\frac{n}{N}\right)y_{P,j} + \frac{n}{N}y_{P,j+1} + \left(1-\frac{n}{N}\right)\sum_{i-1}^{n}\Delta_{y,i} - \frac{n}{N}\sum_{i-n+1}^{N}\Delta_{y,i} + l_{step}\frac{n(N-n)}{2}\theta_O$$
$$+ l_{step}\left(1-\frac{n}{N}\right)\sum_{i=1}^{n}(1-i)\Delta_{\theta,i} - l_{step}\frac{n}{N}\sum_{i=n+1}^{N}(N+1-i)\Delta_{\theta,i} \qquad (1 \le n \le N) \quad , \text{(A-1)}$$

where $\Delta_{y,i}$ is the random number ($G(a_y, t_y)$) for offset at the i –th step and $\Delta_{\theta,i}$ the random number ($G(a_\theta, t_\theta)$) for angle change at the i –th step.

Assuming the all random numbers are independent and without truncations ($t_{pr}, t_y, t_\theta = \infty$) it can be shown after a little manipulations that the variance of the offset at the n -th offset will be as follows.

$$\sigma^2_{y,n} = \frac{(N-n)^2 + n^2}{N^2}a^2_{pr} + \frac{n(N-n)}{N}a^2_y + \left(\frac{n(N-n)}{2}\right)^2 (l_{step}\theta_O)^2$$
$$+ \left\{\left(1-\frac{n}{N}\right)^2 \frac{n(n+1)(2n+1)}{6} + \left(\frac{n}{N}\right)^2 \frac{(N-n)(N-n+1)(2N-2n+1)}{6}\right\}(l_{step}a_\theta)^2 \qquad \text{(A-2)}$$

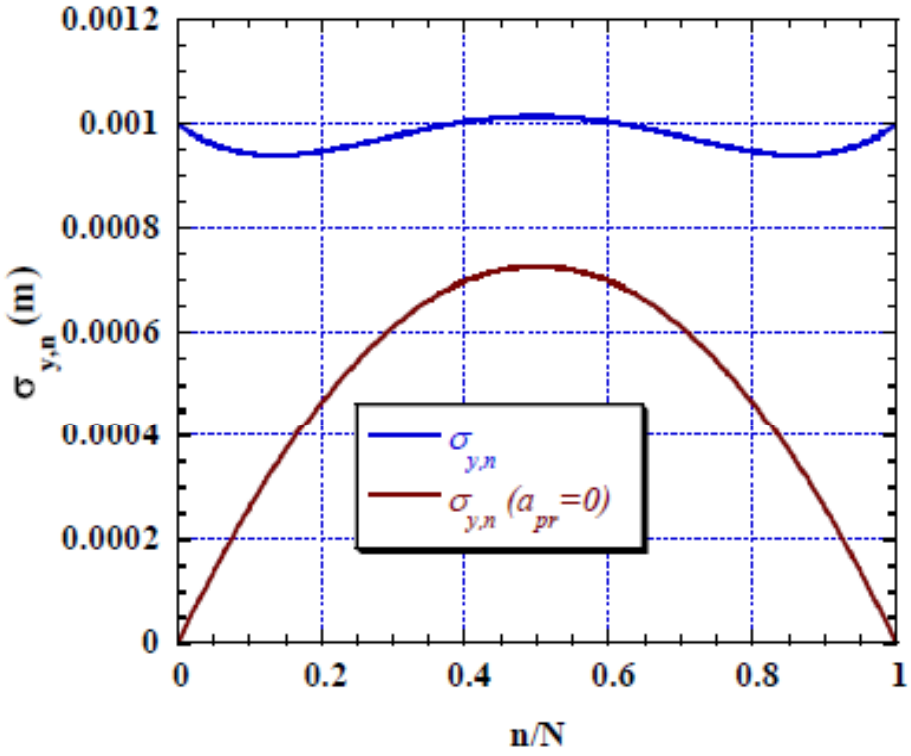
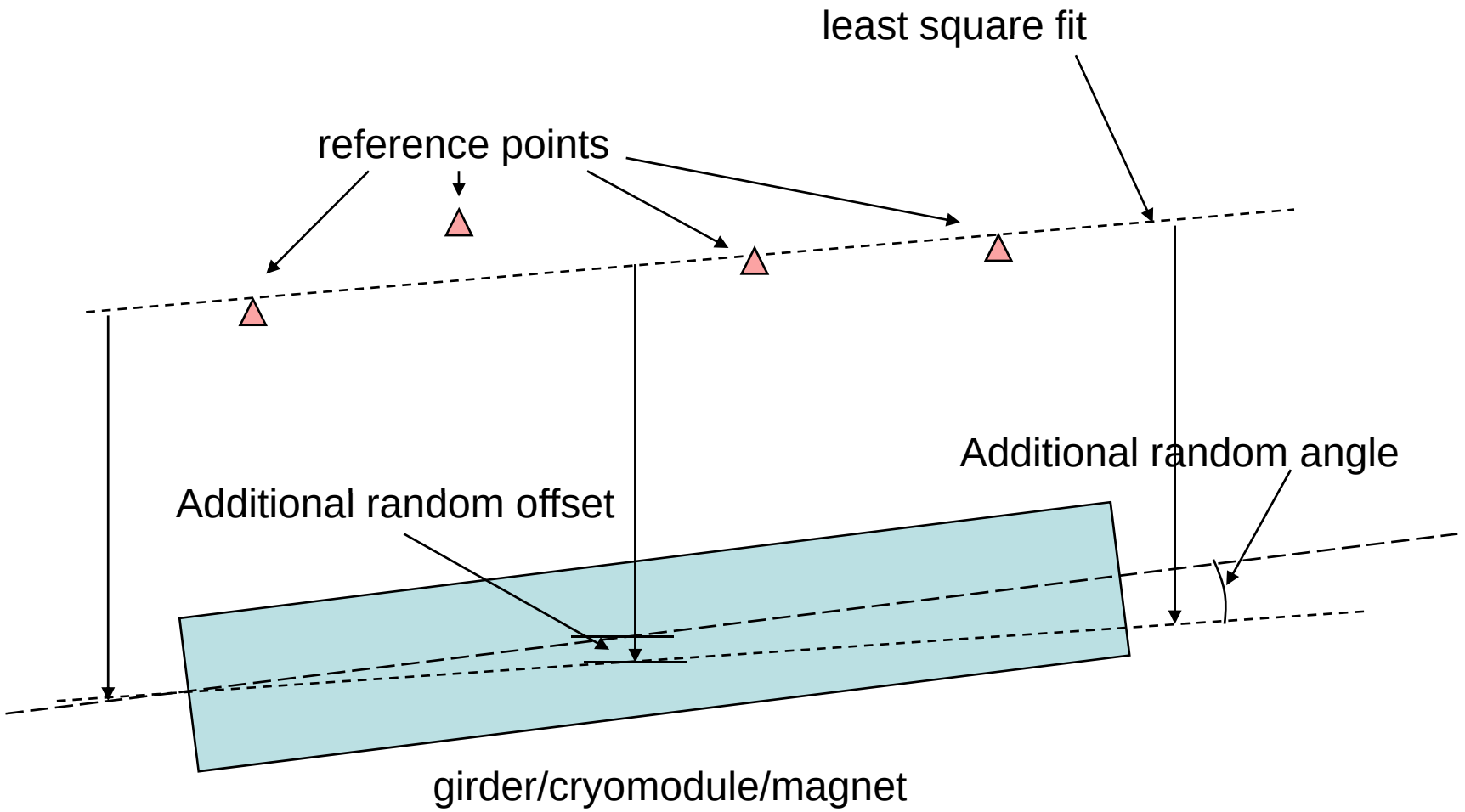


Fig. 3, $\sigma_{y,n}(a_{pr}=1\,\text{mm})$ and $\sigma_{y,n}(a_{pr}=0)$ as function of n/N

$a_y = 0.5\,\mu\text{m}$, $a_\theta = 0.1\,\mu\text{rad}$ and $l_{step} = 4.5\,\text{m}$ $\theta o = 0$, $N=500$

Alignment 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

- Variation of gravity can be ignored?

Summary

- Alignment model is being developed.
  - Draft documentation is sent to ilc-metapy@desy.de, see “archive” of https://lists.desy.de/sympa/info/ilc-metapy
  - Still need to check some
    - Usage of “Primary references” and correction of “accumulated error”
    - Gravity variation is small enough?
  - Still need numbers for most of the parameters