TH002

IWAA2006(Sep. 25-29, 2006)

Evaluation of error propagation in profilometry using stitching

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Target

Establishing straightness measurement method for profile having long measurement distance (>km) with high accuracy (sub-mm) suitable for initial alignment of accelerator structure in International Linear Collider project.

Contents

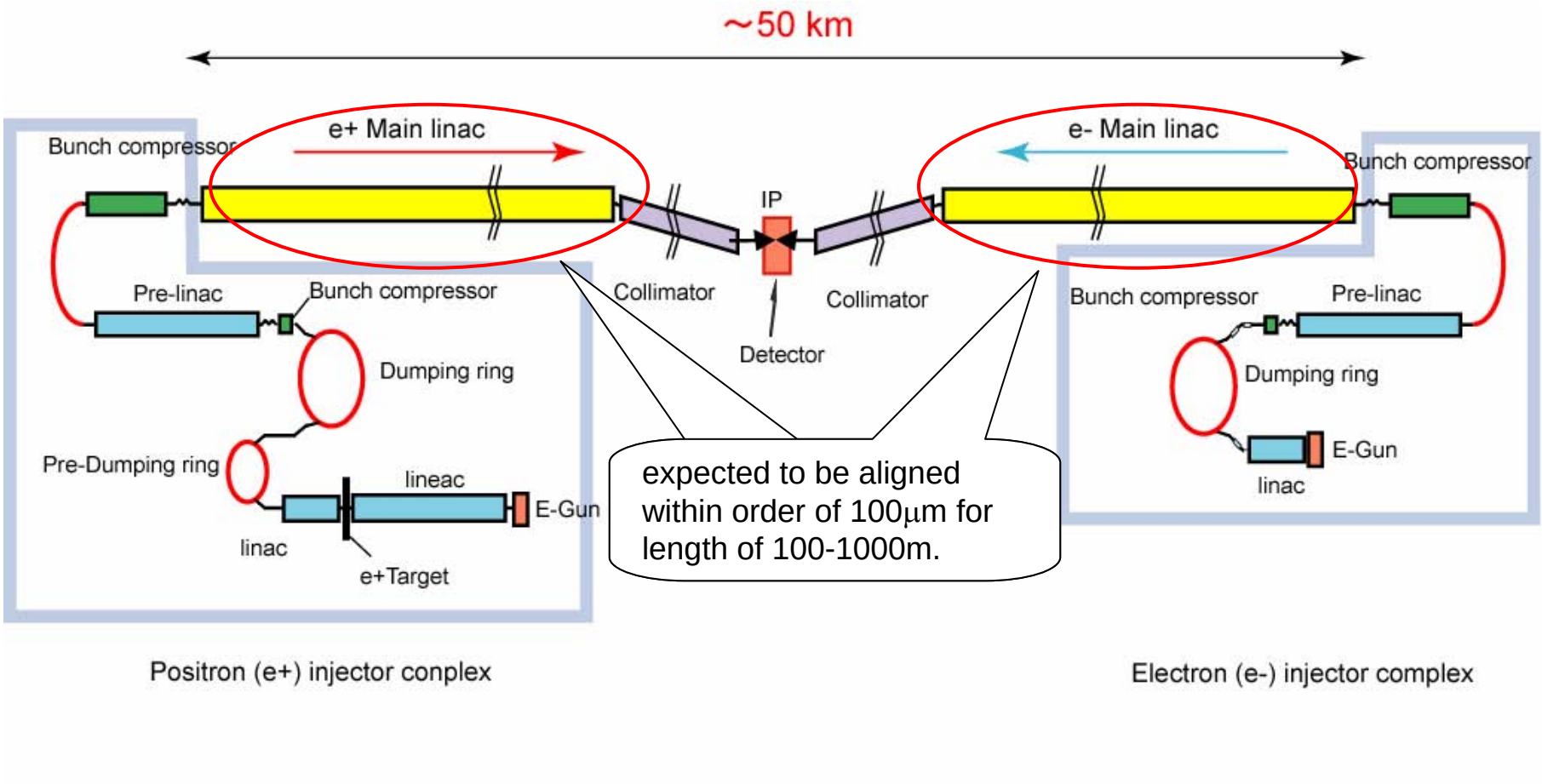
Evaluation of error estimation in case using stitching, through comparison with experimental value.

Overview

1. Straightness measurement for linear collider
2. Analytical error estimation in case using stitching
3. Evaluation of error estimation using experimental value

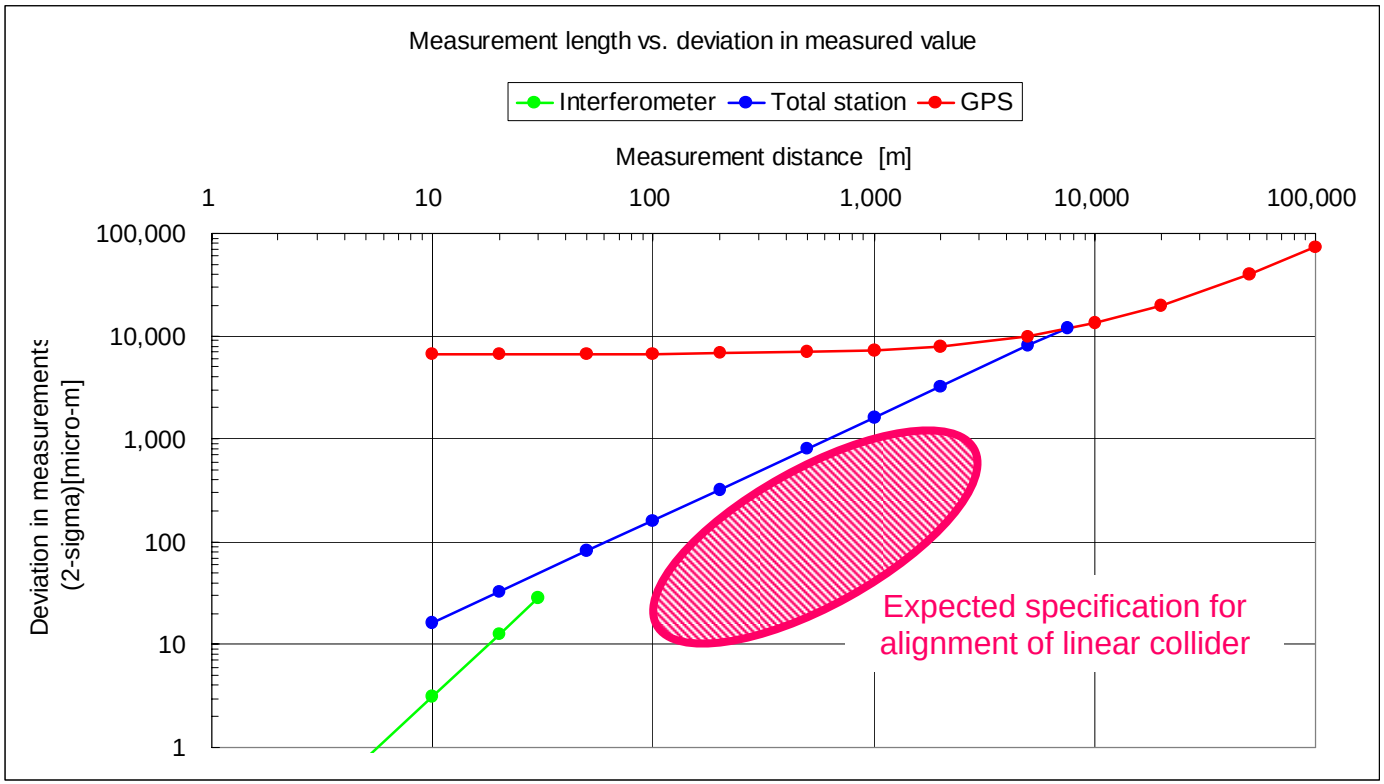
ILC project

International project aiming to construct TeV-class of high energy accelerator (International Linear Collider, http://www.linearcollider.org/cms/)



Accuracy of conventional profilometries

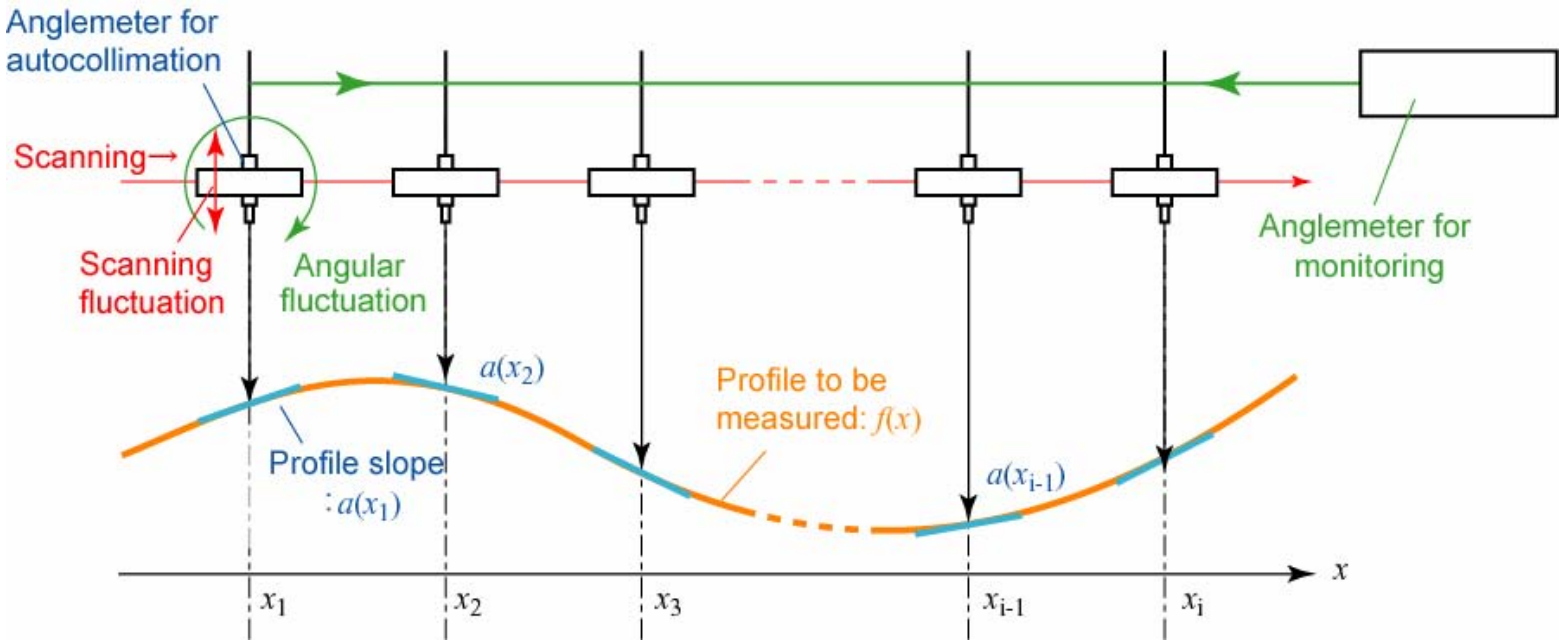
It's difficult to obtain measurement accuracy of 10-100μm
for measurement length of 100-1000m.



Tilt-corrected autocollimation (AC)

Promising for highly precision profilometry with long measurement distance

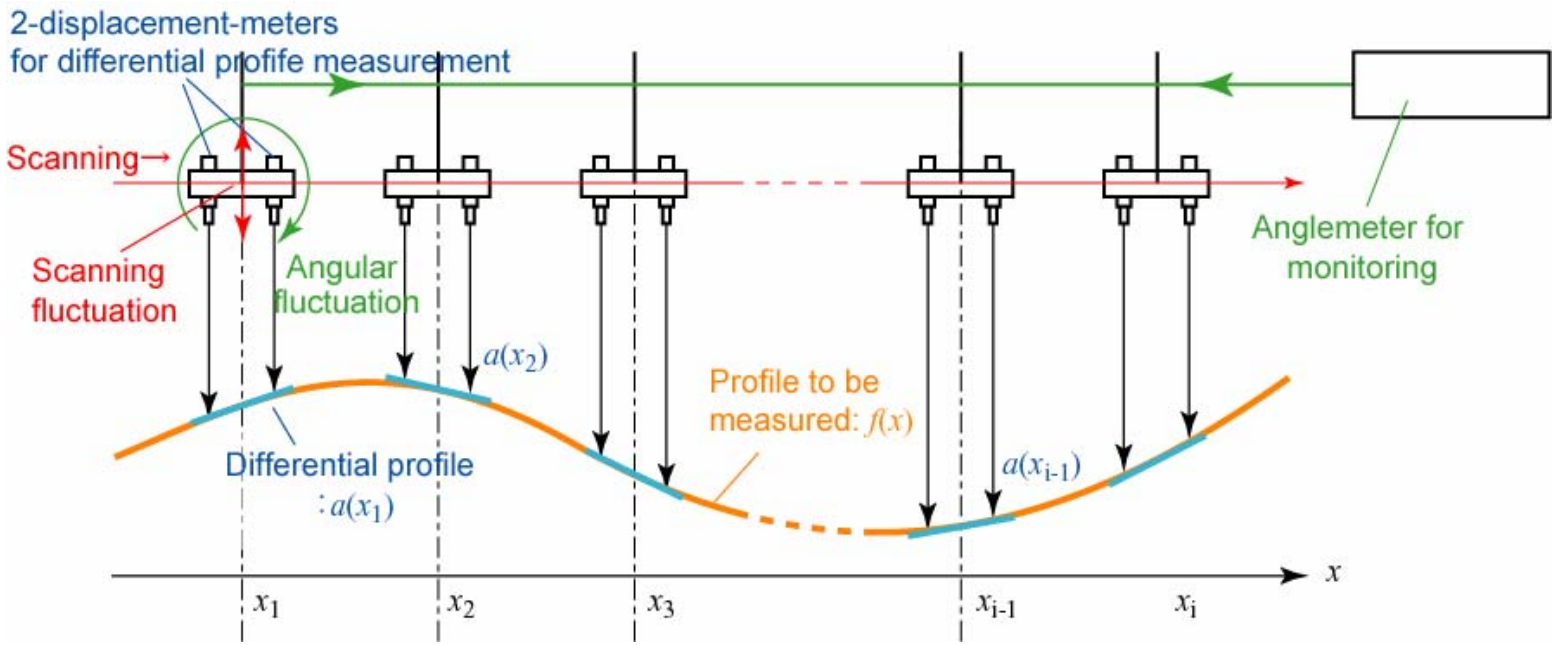
Cancel scanning fluctuation by autocollimation (=measure profile slope),
Correct angular fluctuation (=pitching motion) of the anglemeter for autocollimation by another anglemeter for monitoring.



Tilt-corrected 2 point method

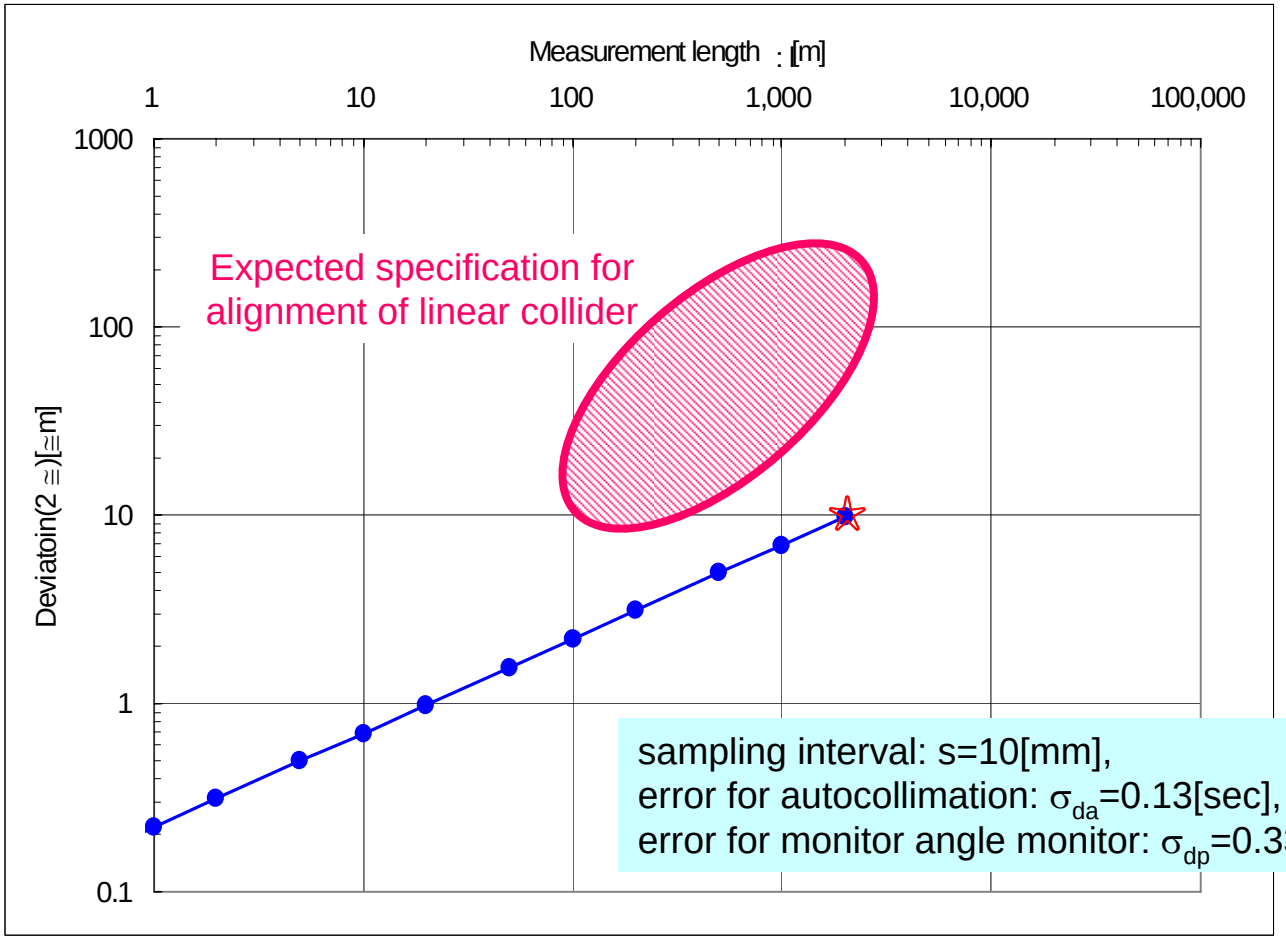
Also promising for highly precision profilometry with long measurement distance

Cancel scanning fluctuation by 2 point method (=measure differential profile),
Correct angular fluctuation (=pitching motion) of the displacementmeters for 2 point method by anglemeter for monitoring.



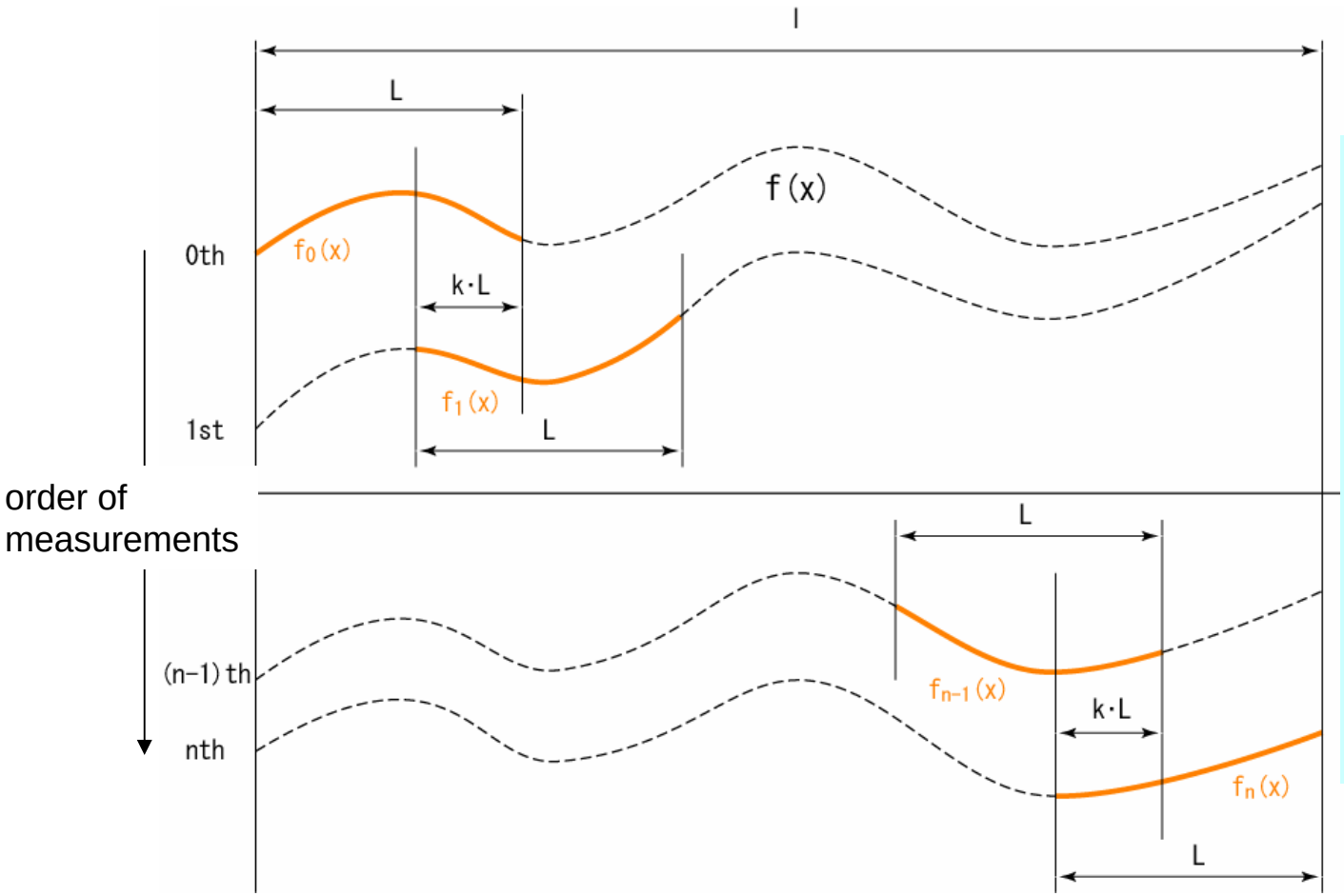
Measurement length limit of corrected AC

Measurement length is limited by measurement length of the angle monitor☆.



Measurement length extension by stitching

Obtain longer measurement length of profile by connecting several profile partly overlapping with each other.



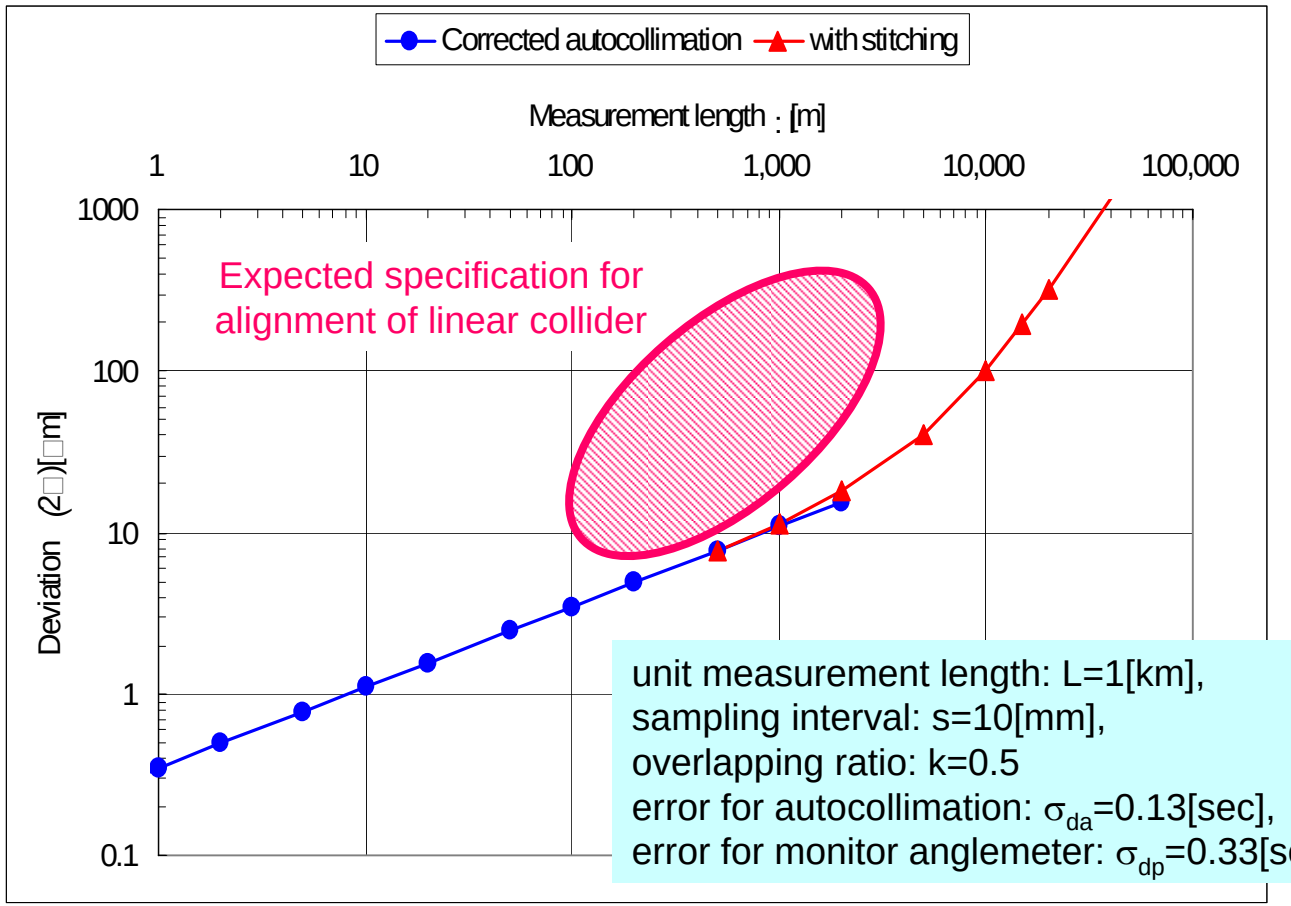
f(x): profile,
$f_i(x)$: unit profile,
L: unit measurement length,
l: Total measurement length,
n: number of stitching,
k: overlapping ratio

*Relationship between measurement length and number of stitching

$L = n \cdot L - (n-1) \cdot k \cdot L$

Accuracy of corrected AC with stitching

Specifications expected for alignment of the Linear Collider can be obtained



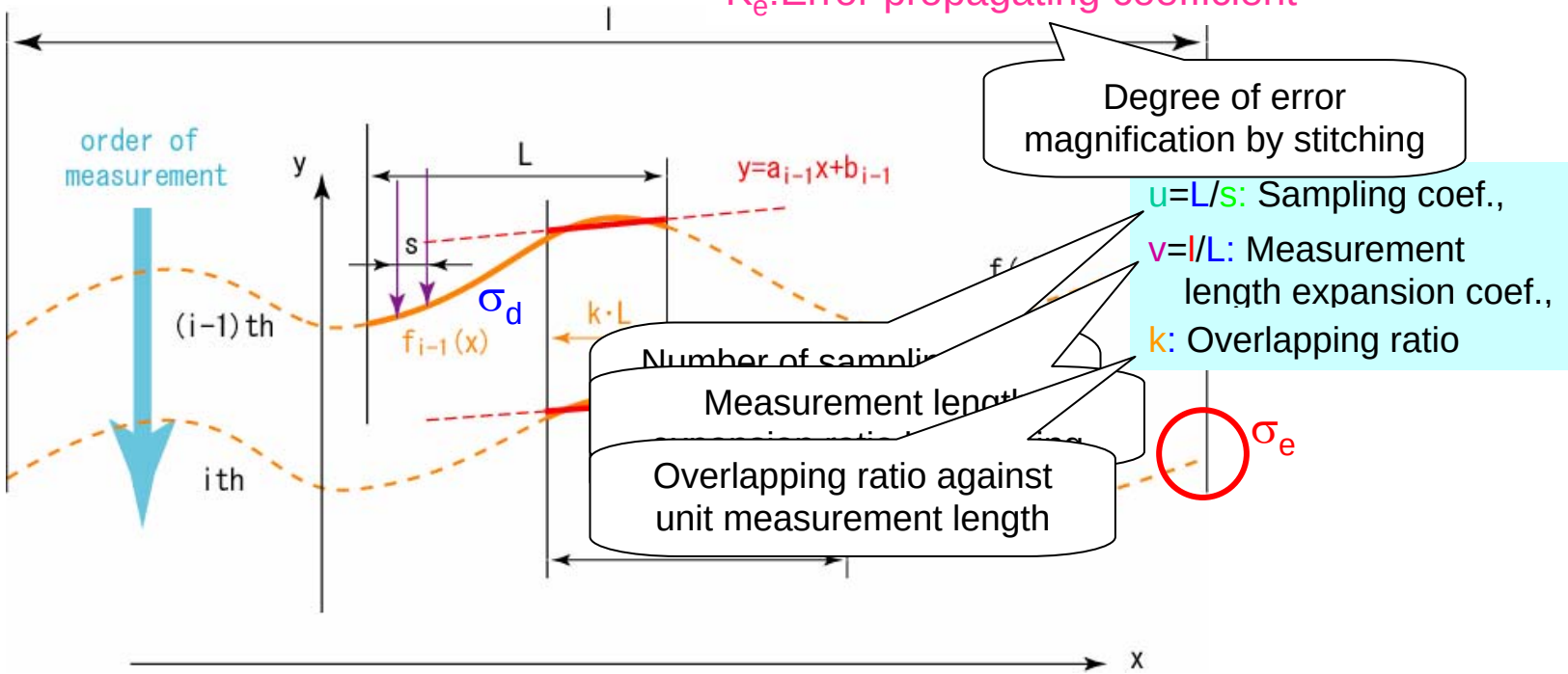
Error propagation through stitching σ_e

-Analyzed value considering error propagating low

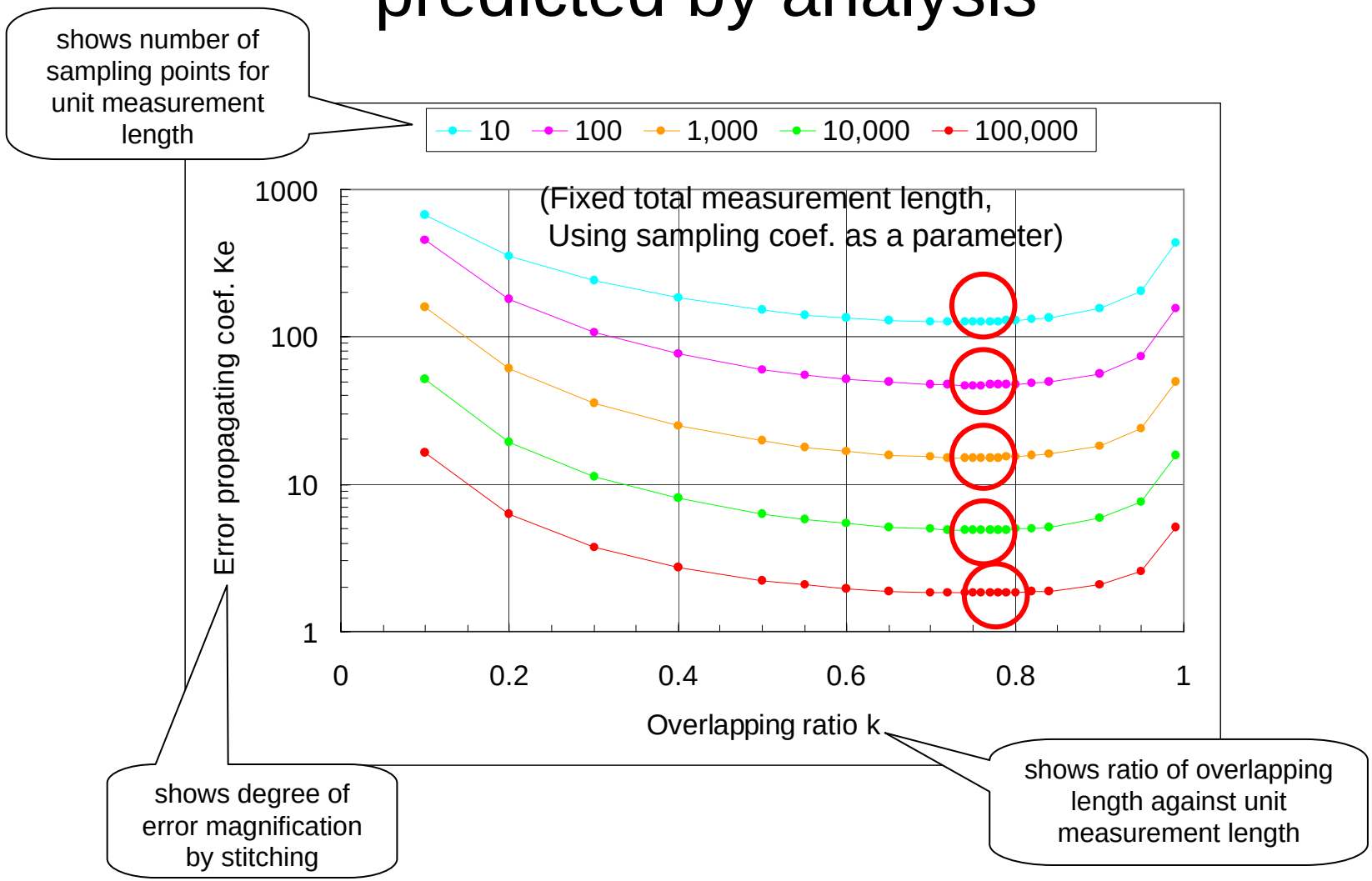
- Error in each measurement ×Error propagating coefficient K_e
- $\sigma_d K_e$ can be expressed by 3 of dimensionless parameters (u, v, k)

$$\sigma_e = \sqrt{1 + \frac{4\cdot(v-k)}{(1-k)\cdot(1+u\cdot k)\cdot(2+u\cdot k)}\cdot\left(\sqrt{\frac{6u\cdot v^2}{k}} + \sqrt{2u\cdot k+1}\right)^2}\cdot\sigma_d$$

K_e:Error propagating coefficient



Existence of optimum k for minimizing K_e predicted by analysis



Effects of measurement parameters

$$\sigma_e = \sqrt{1 + \frac{4 \cdot (v - k)}{(1 - k) \cdot (1 + u \cdot k) \cdot (2 + u \cdot k)} \cdot \left(\sqrt{\frac{6u \cdot v^2}{k}} + \sqrt{2u \cdot k + 1} \right)^2} \cdot \sigma_d$$

K_e:Error propagating coefficient

u=L/s: Sampling coef.,

v=l/L: Measurement length expansion coef.,

k: Overlapping ratio

Dimensionless Coefficients

Independent of size

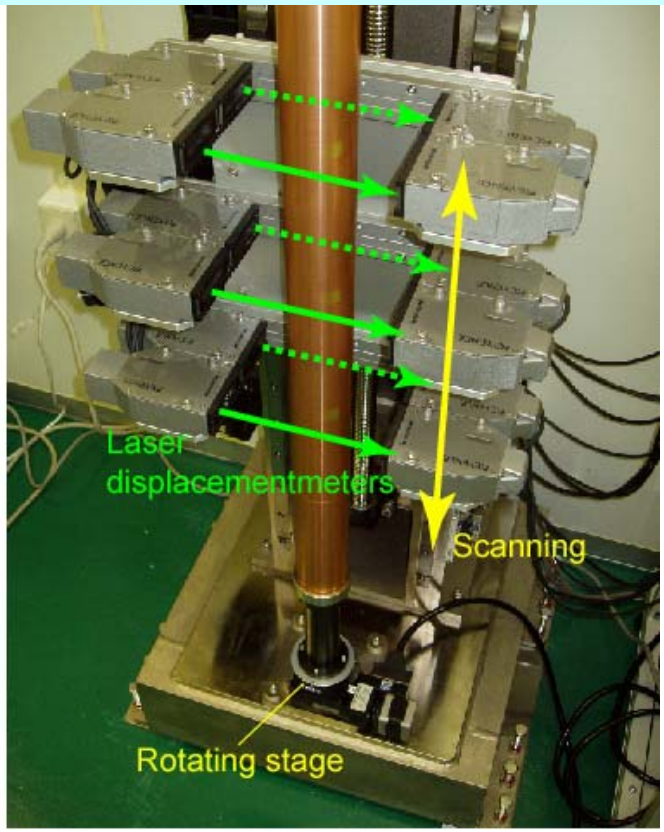
Apply to any scale of stitching

Evaluated by using smaller experimental set

Straightness measurement system for single accelerator structure

Set in thermostatic chamber (20±1℃),
Measured sample: Dummy structure (=Turned Cu rod with 1.5m-length and 60mm-diameter,
Measurement time: 50min for 2 profiles by inversion method,
Sampling interval: s=4mm

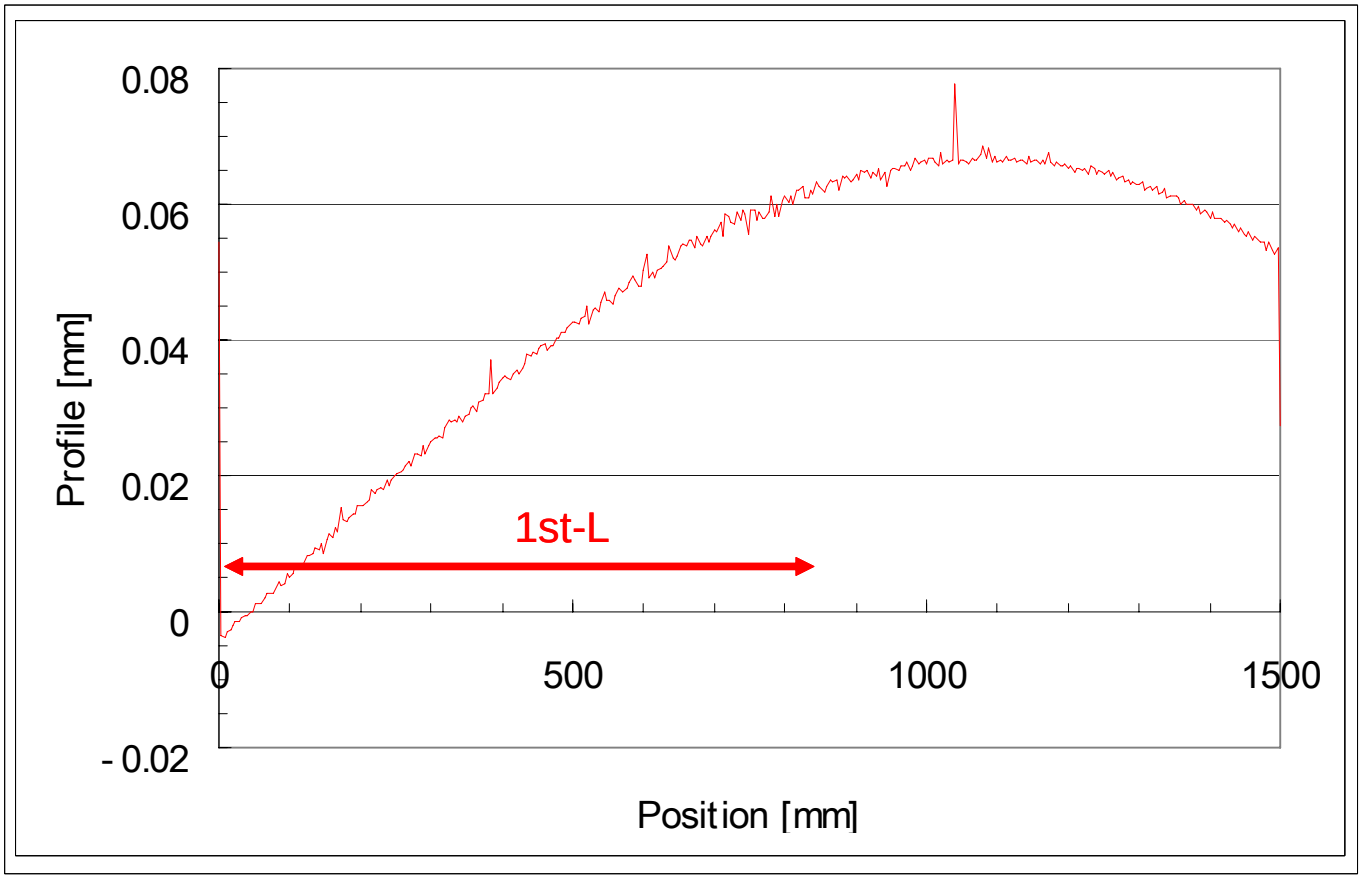
Overview (2.5m height)



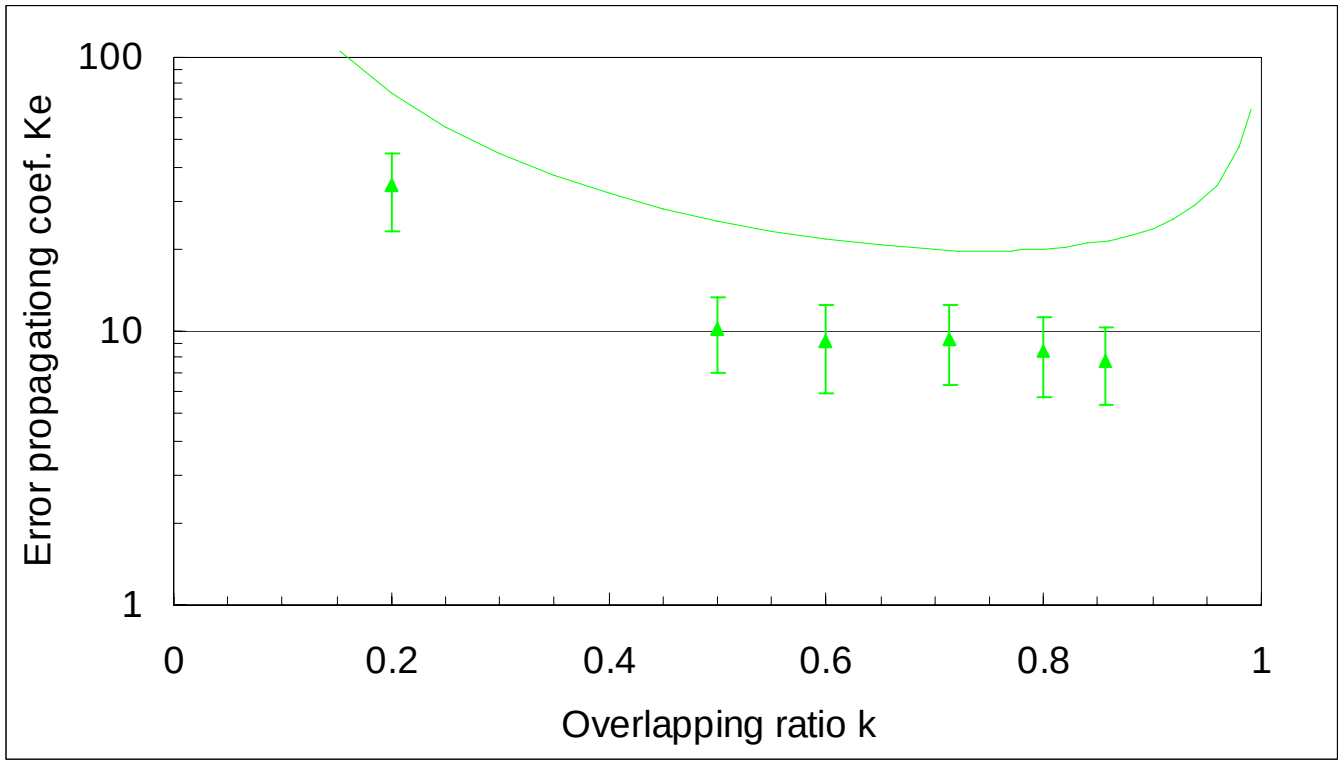
Laser displacementmeters

Virtual stitching

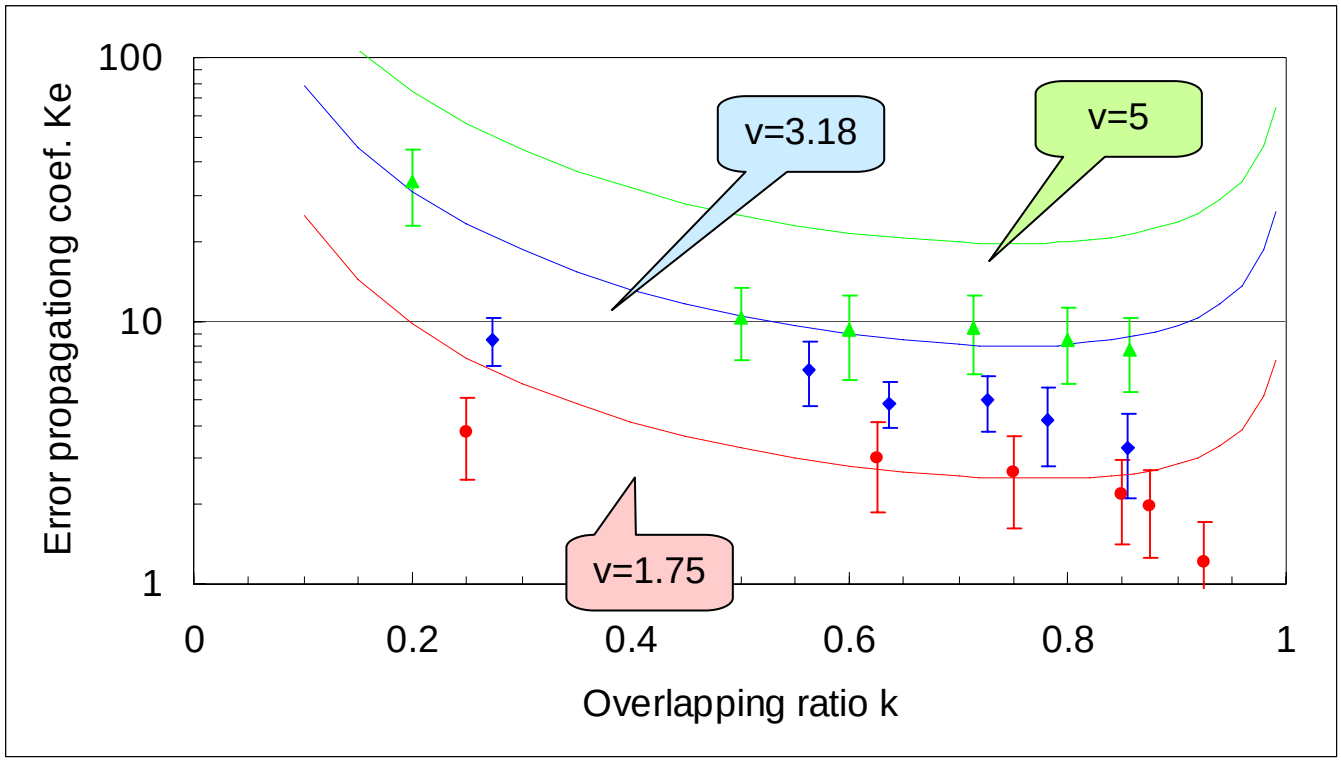
Virtual measurement unit profiles, (having unit measurement length L and overlapping ratio k), to be stitched are cut from several measured profiles.



Comparison between analytical predictions and experiments



Comparison between analytical predictions and experiments



- Existence of the optimum “k”s had not yet clearly shown by experiments
- Experimental values tend to be smaller than predicted values.

Summary

1. Estimated error considering error propagation rule was compared to virtually stitched experimental value.

2. Existence of the optimum “k”s had not yet clearly shown by experiments.

3. Predicted errors tend to be smaller than experimental ones.

Plan

1. Comparison in more various measurement conditions

2. Evaluation by using real stitching data

3. Reconsideration of analysis model (if need) and more accurate error estimation
4. Confirm tilt-corrected autocollimation/2 point method