SOLEIL SYNCHROTRON

ACTOP 08

Trieste , October 9-11, 2008

Simultaneous estimation of the surface shape and the instrument error function from a highly redundant set of LTP data

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Outline

- Errors in LTP measurements
- Non linearity of slope measurements revealed by measuring strongly curved surfaces
- A stitching model that takes systematic errors into account
- Conclusions

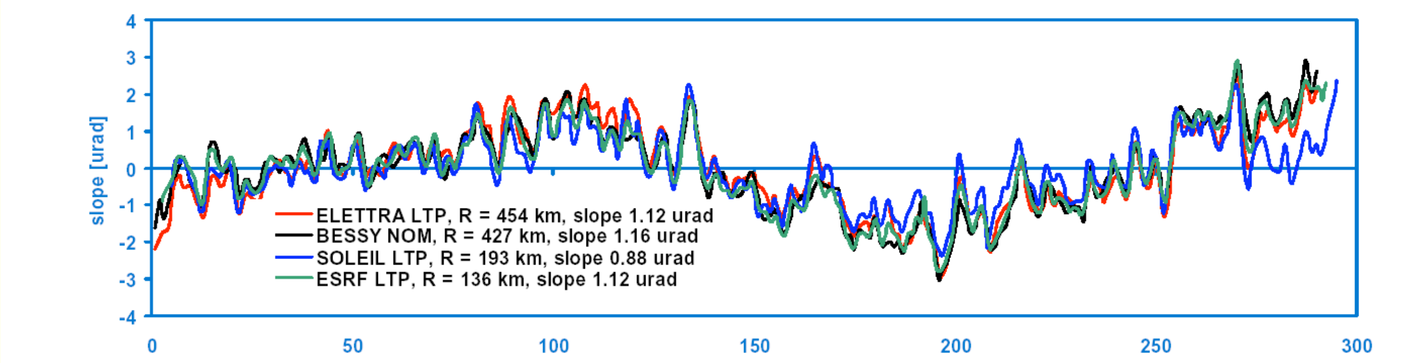
Errors in LTP measurements

- **3 main sources of errors**
  - **Translation stage errors**
    - Effect of the pitch error of the slide reduced to 2nd order by the use of a pentaprism
    - Effect of roll and yaw errors is 2ndorder
    - These errors can be detected by repeated measurement in different directions and at different positions on the LTP bench
    - Easily measured on flat surfaces, usually very small
  - **Stability errors**
    - Vibrations , air turbulence
    - Reduced by the clean room environment (typ ~0.3-0.5 µrad RMS)
    - Precision can be increased by repeated measurements
  - **Optical path errors**
    - Errors due to non identical return path when the beam is scanned along the surface :
      - Residual aberrations of the lens
      - Local defects of the optical elements
    - They can be detected by tilting the surface (for curved surfaces)
    - Generate sytematic errors which increase with surface curvature

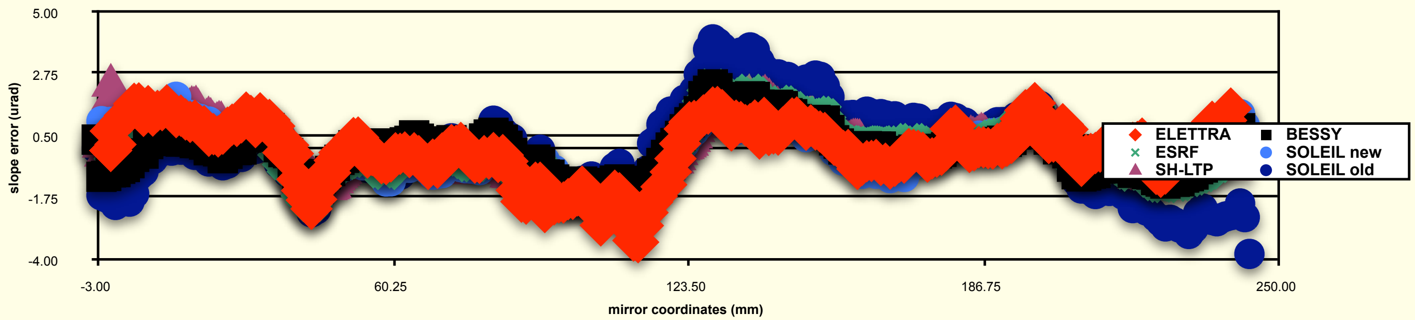
Results from the Cost P7 Round Robin

Better agreement between LTPs on flat surfaces than on curved ones

Plane mirror P1
Residual slope (after best sphere subtraction)



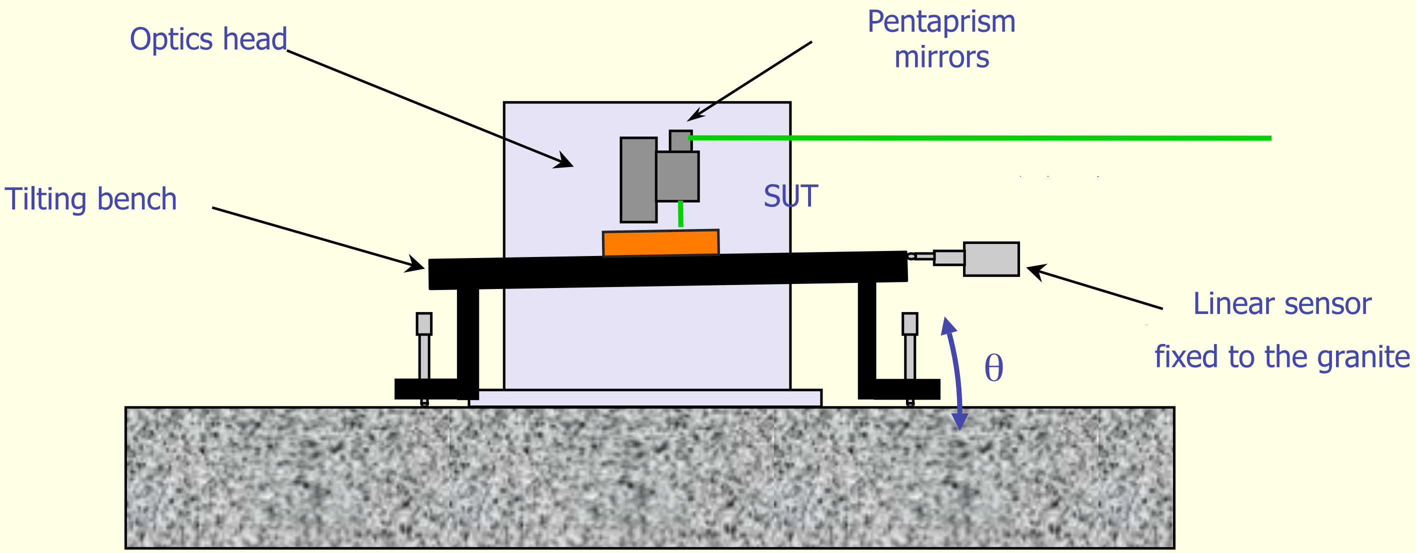
Reference Mirror S1 (R~83 m) Residual slopes (after best sphere subtraction)



Measuring strongly curved surfaces

- **Strongly curved surfaces:**
  - **Surfaces that cannot be measured on a single trace**
    L/R > LTP measuring range (~8mad)
- **Require the use of a stitching procedure:**
  - **Record several traces on limited overlapping X ranges**
  - **The surface is tilted between traces to center the slope range**
  - **Overlapping edges are adjusted to reconstruct the slope profile**
- **How is the result affected by systematic errors ?**
  - **Influence of data recording parameters ?**

Stitching data recording set-up



The small horizontal displacement of the tilt stage is measured and compensated

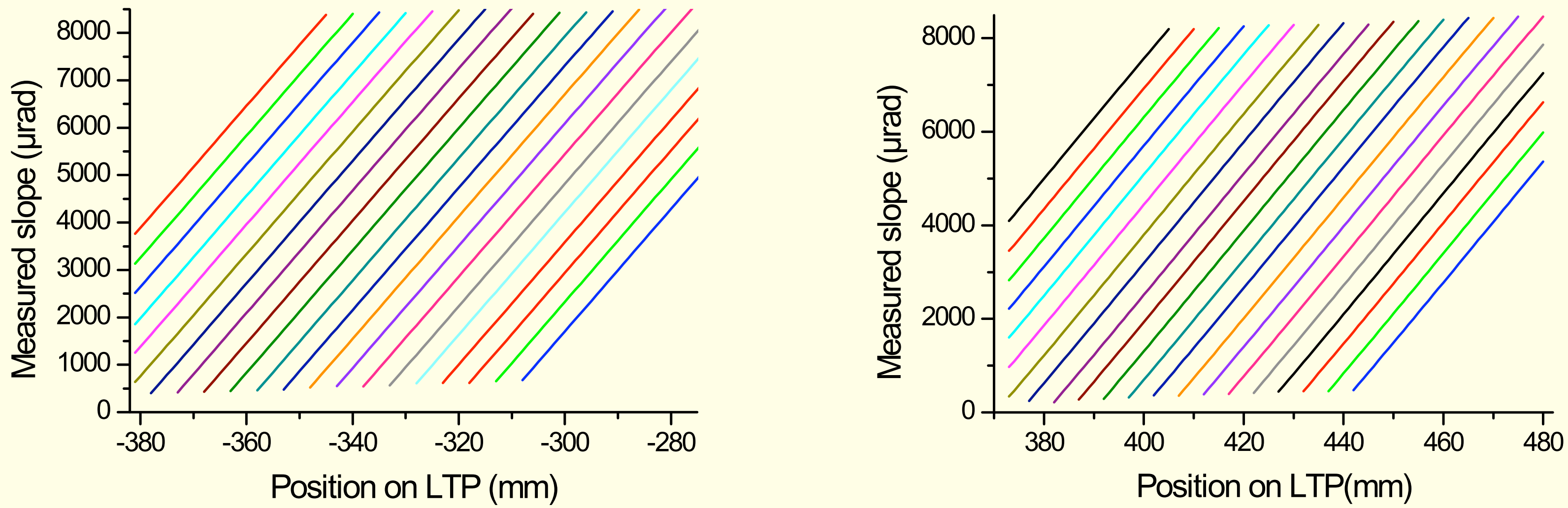
Experiments on M54 mirror

- **Radius of curvature 7.7m**
- **Length 110 mm (90 mm useful)**

  ⇒ **full angular range 14.3 mrad**

2 X 21 traces recorded (each measurement repeated 3 times)

- **at equally spaced tilts**
- **at 2 different positions of the LTP bench**

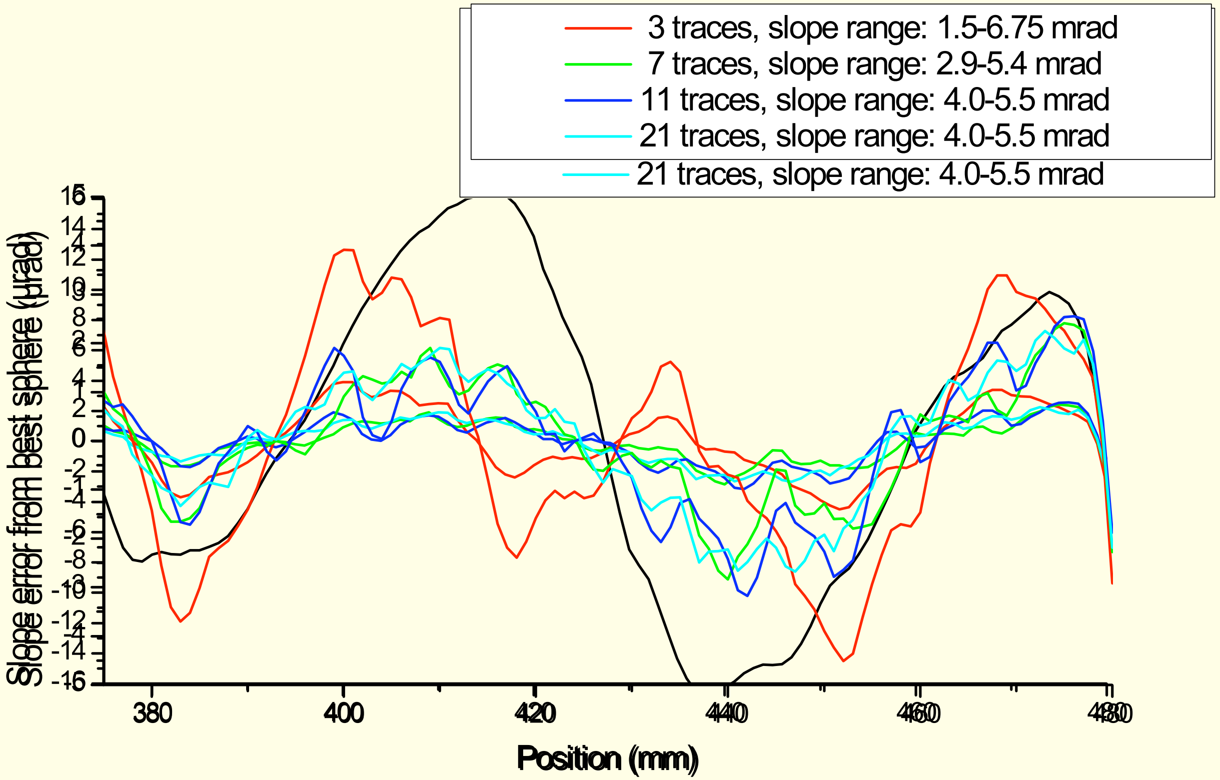


Various reconstruction are made with

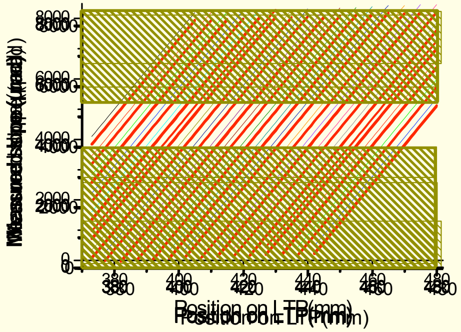
selected traces and selected slope ranges

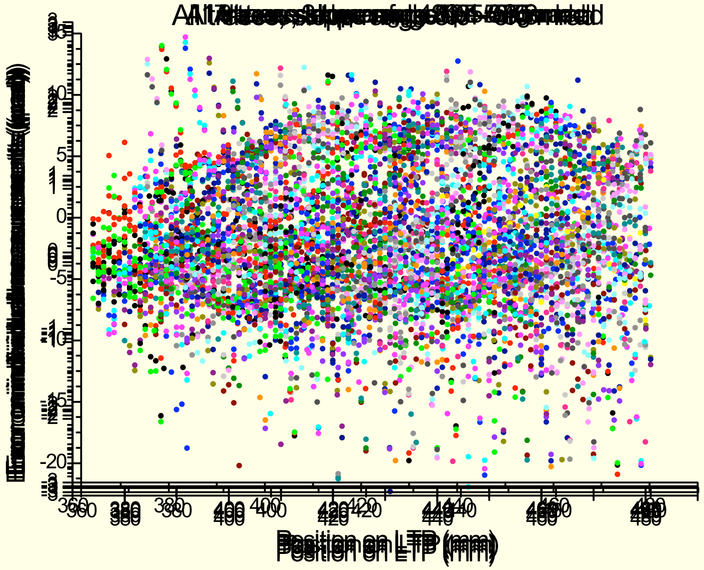
Simple stitching

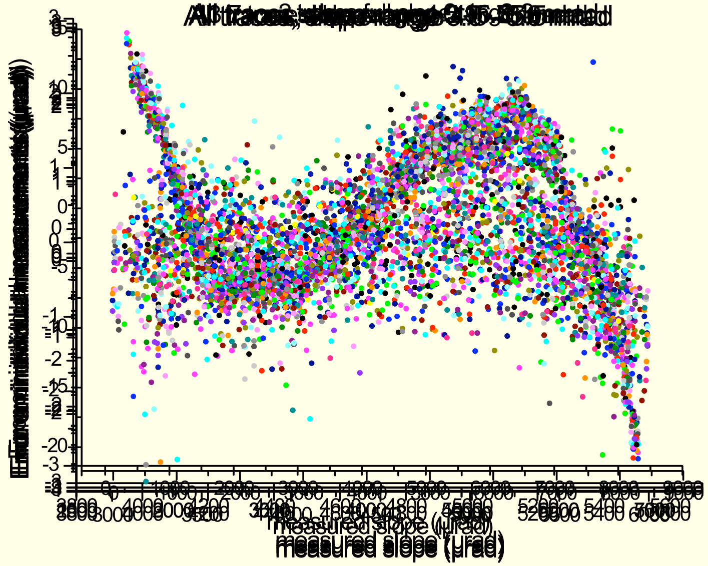
- **Stitching result depend on chosen parameters**
  - **Number of traces**
  - **Slope amplitude and data overlap**



Residual errors



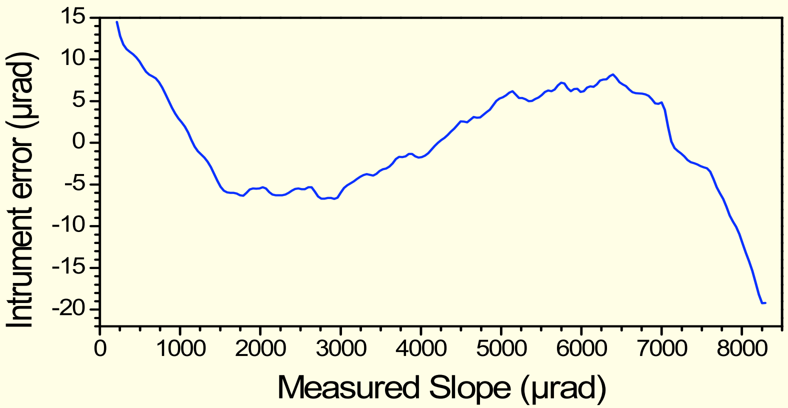




Instrument Error Function

- **Deviation of measured data to the best fit profile is strongly correlated to the measured slope.**

- **The Instrument error function, ie. the departure from linear response, can be estimated by fitting the residual errors**



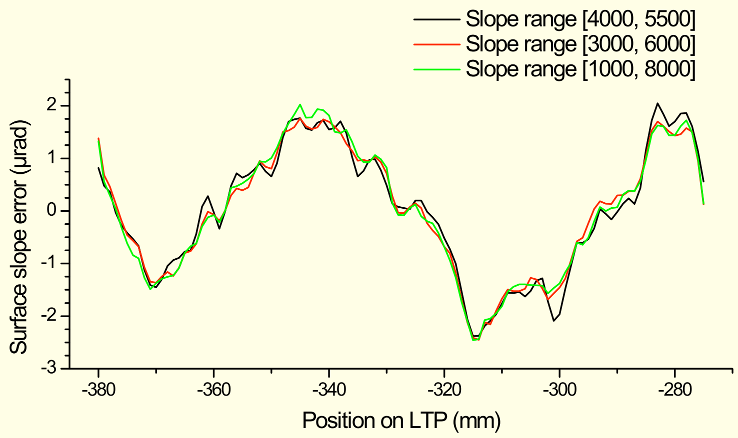
- **A better estimation of the slope of the measured surface and of the instrument error function cans be expected if the instrument error is taken into account**

A Stitching model including the Instrument Error Function

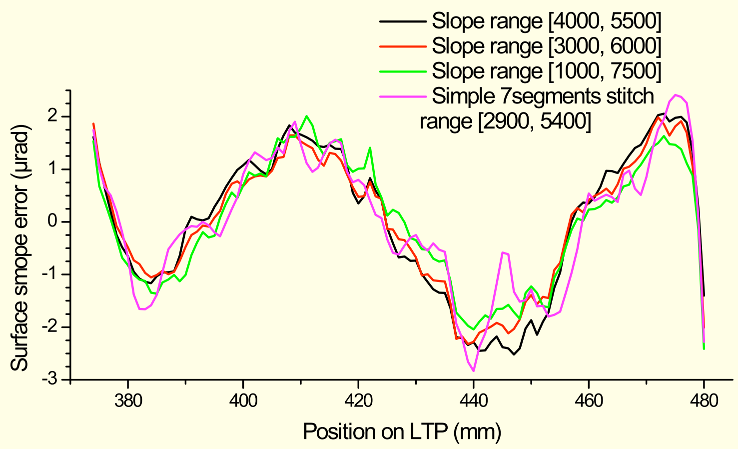
- The Instrument Error Function is continuous and should be defined by an interpolation function
  - Cubic spline interpolation has been used
- Model parameters
  - The surface slopes at equally spaced abscissa points
  - The slope offsets between independent traces (tilt stage)
  - \+ The set cubic spline coefficients defining the IEF
- Surface slopes and IEF are simultaneously obtained by fitting the model to the highly redundant measured data
- The stitching algorithm implemented in C++ under Origin 7.5

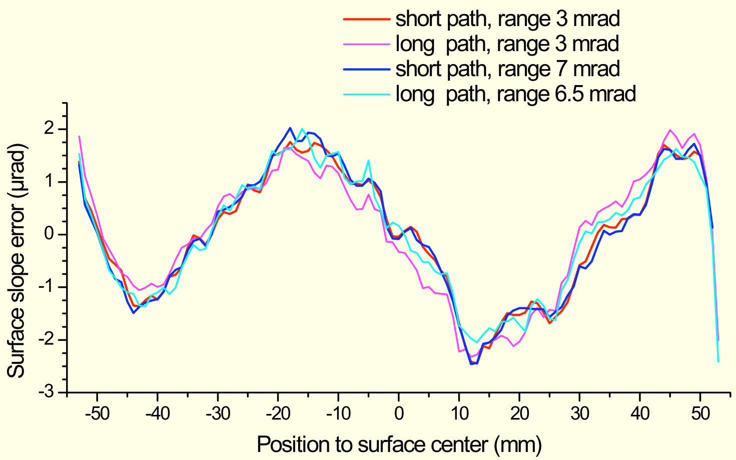
Stitching Results on M54

Short LTP path

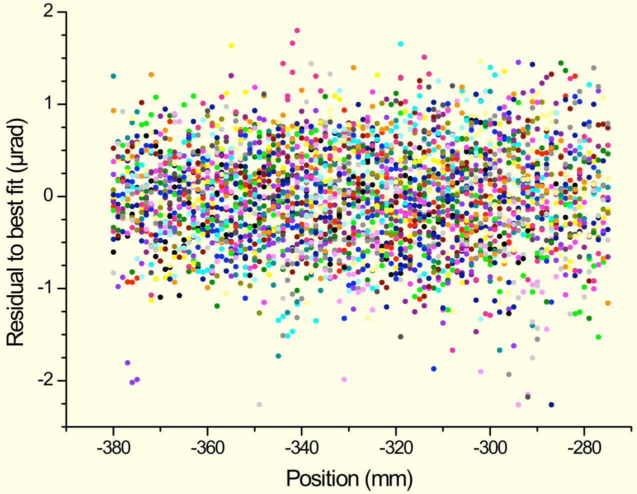


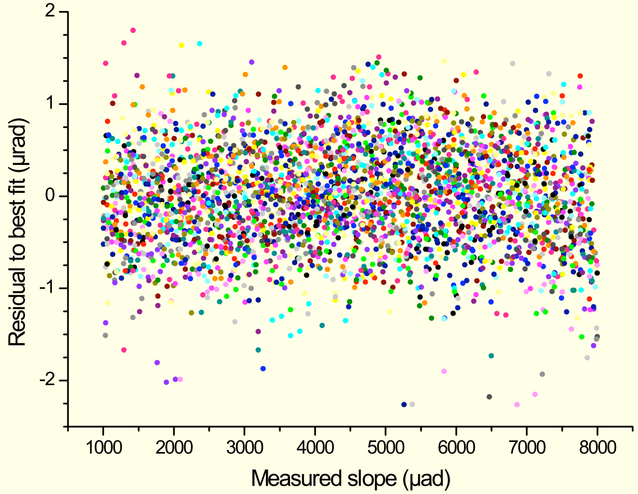
Long LTP path





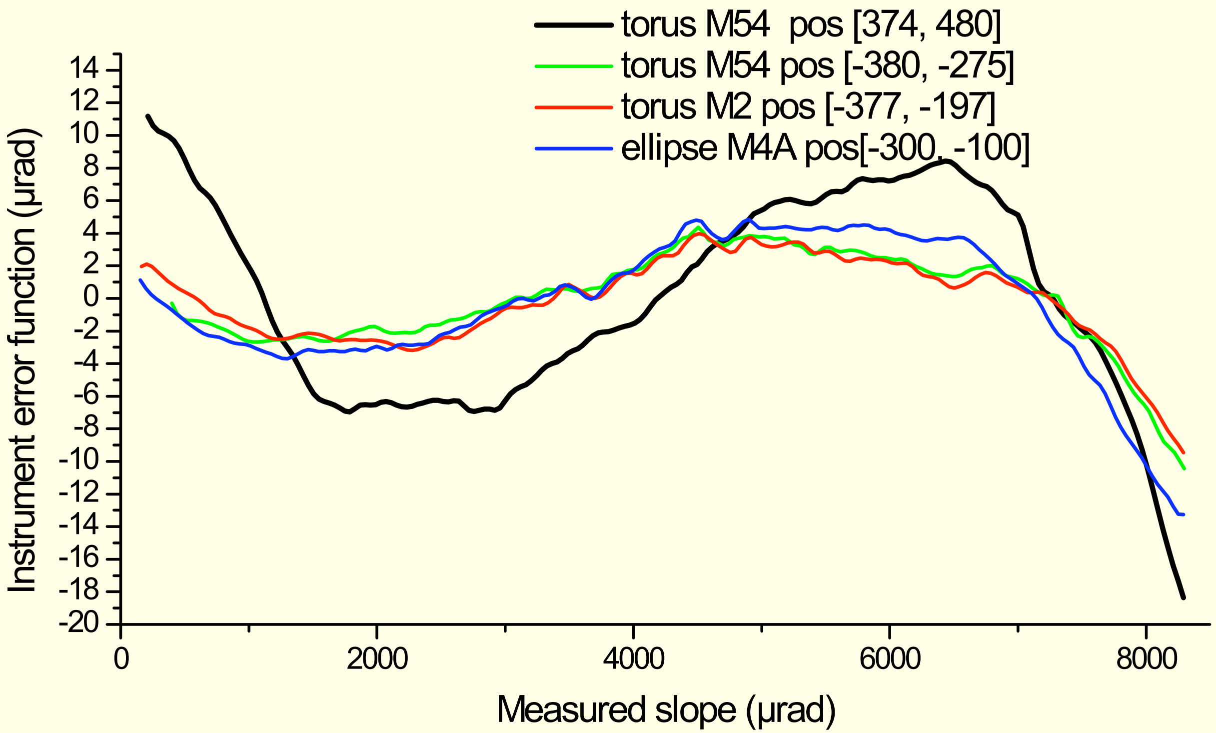
Residuals





Residual errors are 0.5 µrad RMS as unaveraged measurements

Instrument error function



- **The instrument error function depend the position on LTP**
- **Marked influence of the focusing lens (spherical aberration)**
- **Local defects are visible.**

Summary

- A stitching procedure has been develop to take the non-linearity of the LTP response into account.
- It requires a highly redundant set of LTP traces recorded with different surface tilt and covering the full measuring range
- The surface slopes and the instrument error function are obtained simultaneously
- The procedure could be extended to correct slope profiles which do not exceed the LTP measuring range