NEW DEVELOPMENTS IN CLOSE RANGE PHOTOGRAMMETRY APPLIED TO LARGE PHYSIKS DETECTORS

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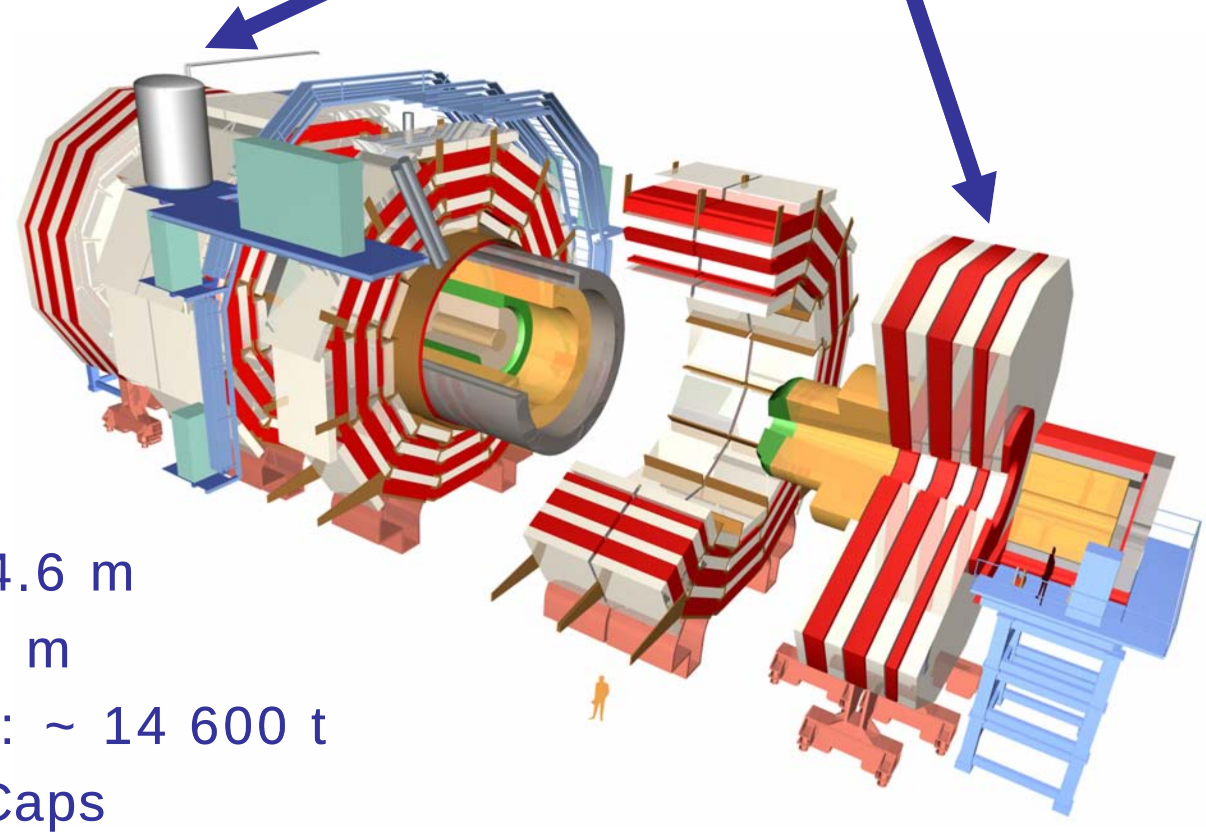
- Photogrammetric system
- Project: CMS Yoke End Cap
- Movement of principle point
- Extended calibration model
- Conclusions

- DCS460 and DCS660 cameras
- AICON software packages DPA-Win and 3D Studio
- Retro-reflective targets
- Carbon fibre scale bars

Yoke End Caps



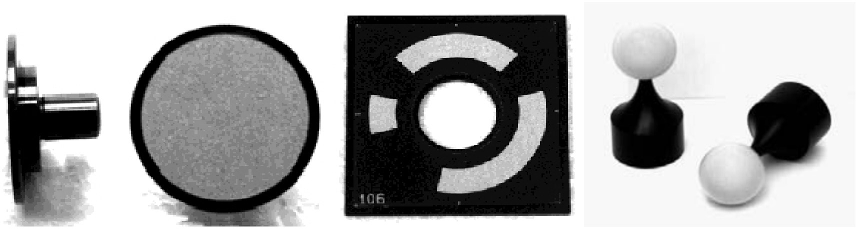
- Diameter: 14.6 m
- Length: 21.6 m
- Total Weight: ~ 14 600 t
- 6 Yoke End Caps

6 Yoke End Caps
➔ 12 photogrammetric validations in Japan after preassembly

♦ Image acquisition: Japan, Evaluation: CERN

♦ Diameter: 14 m
♦ Thickness: 0.6 m or 0.25 m

- 108 Reference holes equipped
- Spherical targets for connection
- 24 Distance observations
  - 12 Carbon fibre scale bars, length 1.4 m
  - 12 Tape measurements, length 5 m - 14 m
- 90 Images
- ~ 3 hours



Problem: Decreasing quality with conventional calibration model

Possible reason: Instability of interior orientation

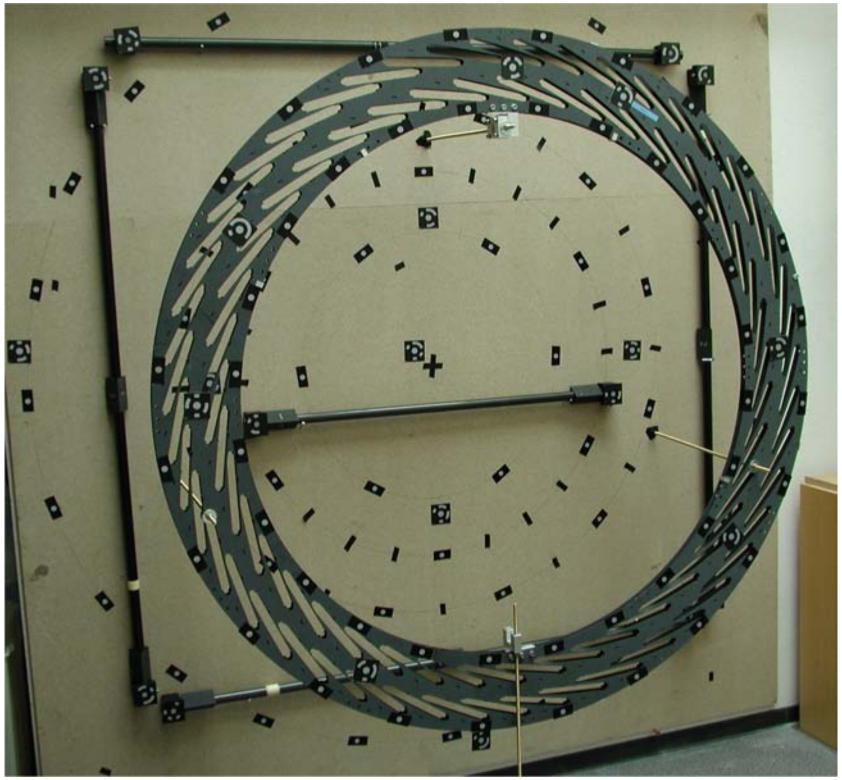
- Mechanical influences by the user
  - Hand-held shots
  - Scaffolding, lifting device
- Effects of gravity
- Heating of the camera

Test: Evaluation of movements of the principle point

- Circular object
- Diameter: 2 m
- Depth: 0.5 m

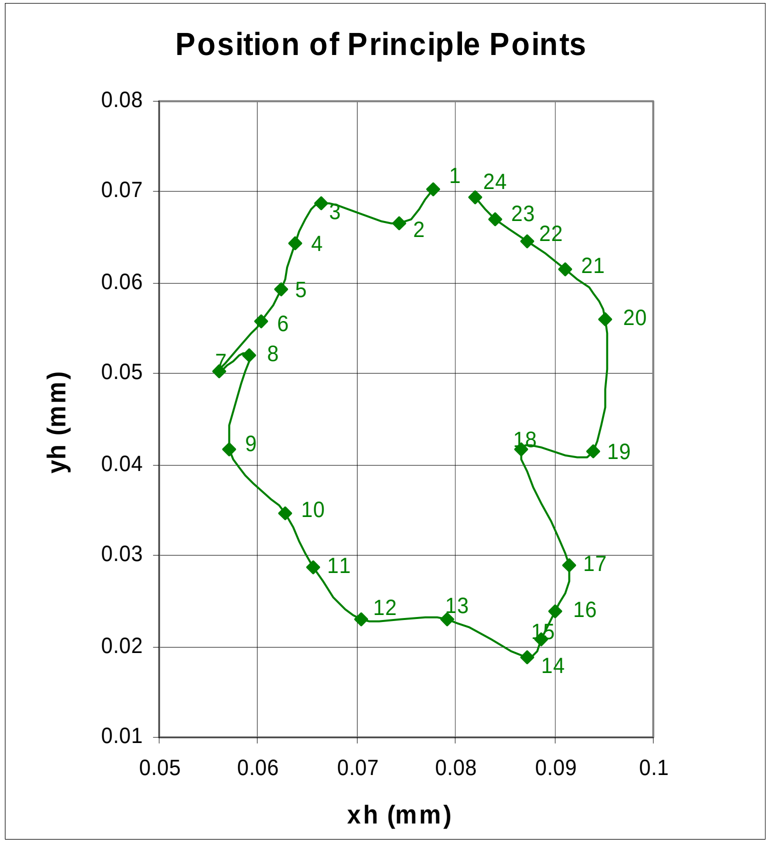
- Camera in front of wheel
- Rotated by 15 degrees around optical axis

➔ 24 Images



♦ Principle point not stable
♦ Movement elliptical
♦ Amplitude
  • 40 µm in x-direction
  • 50 µm in y-direction

➔ Effects of gravity
  • Deformation camera body
  • Movement of CCD sensor



Possible solution: calculate principle distance / principle point for each image

BUT for real objects:

- ♦ Lack of depth
- ♦ Unfavourable distribution of points
- ♦ Insufficient number of points

➔ Weak equation system

➔ Improved mathematical model for camera calibration required

Extended Calibration Model

- Conventional calibration model extended by Institute of Applied Photogrammetry, University of Oldenburg (Germany)

- AICON 3D Systems GmbH, Braunschweig (Germany)
- CERN

Image-variant interior orientation

- Parameters introduced as observed unknowns
- A priori accuracy defined by user
  - ➔No weak equation system
  - ➔Smearing effects caused by correlations minimized

Radial-symmetric distortion A1, A2, A3

Finite elements correction grid

- Correction of
  - Tangential-asymmetric distortion
  - Affinity and shearing
  - Sensor unflatness

- Raster-wise correction grid
- Correction as plane vector for each grid point

- Curvature constraints as pseudo observations
- A priori accuracy defined by user

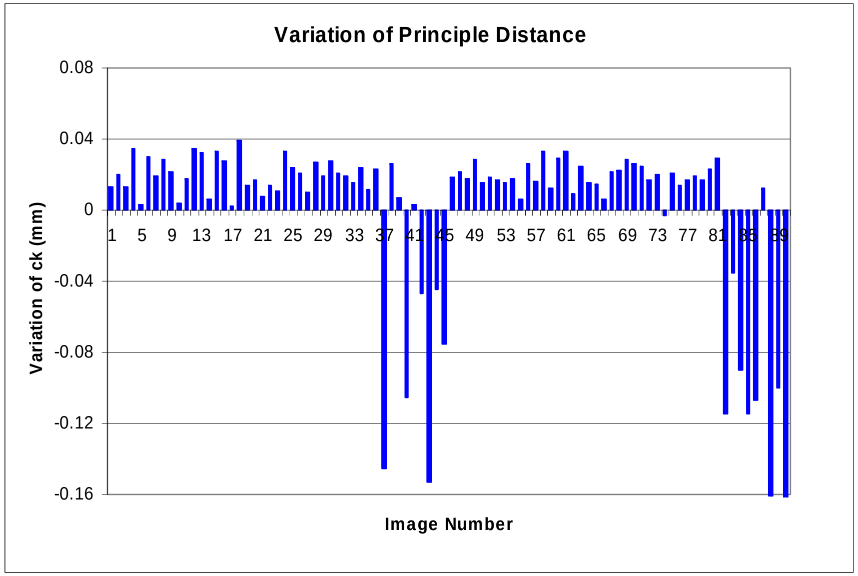
  ➔No weak equation system

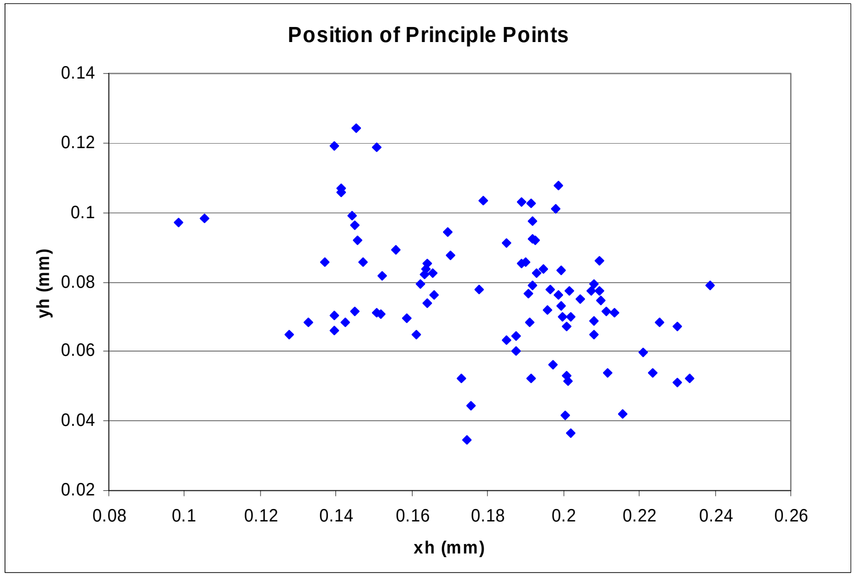
Results - Interior Accuracy

- Enhancement of relative precision ~ 30 %

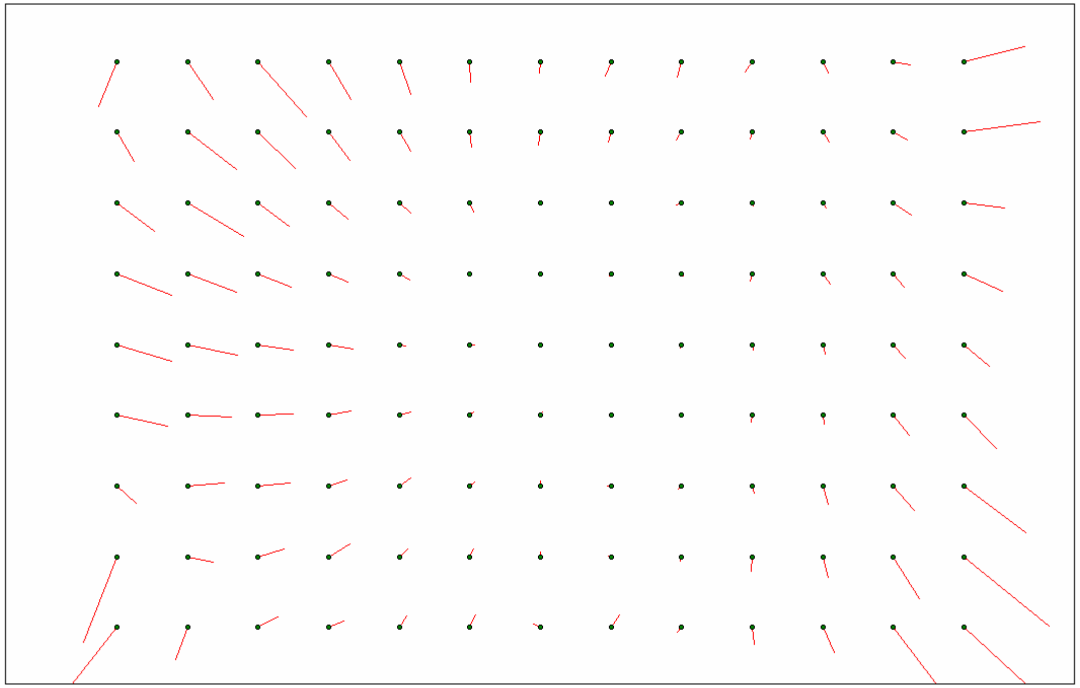
Calibration model	**Conventional**	**Extended**
RMS_{XYZ} (mm)	0.18	0.12
Relative precision by interior accuracy	1 : 80 000	1 : 110 000
Sigma 0 a posteriori	0.8	0.5

- A priori accuracy interior orientation: 15 µm
- Variation of principle distance: 200 µm
- Variation of principle point: 140 µm in x-direction
  90 µm in y-direction

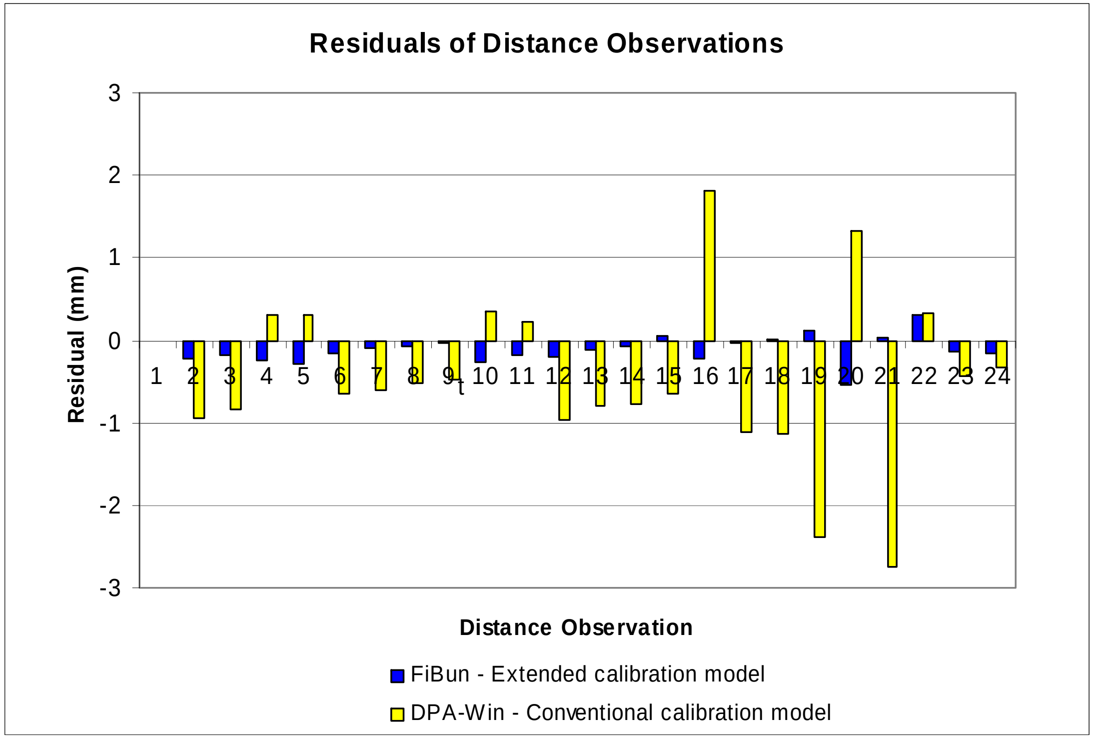




- Raster-width of 2.35mm → 13:9
- A priori accuracy curvature constraints: 1 µm
- Maximum length of correction vector: 8 µm
- Tangential-asymmetric distortion



- 1 Long distance information for scale definition
- Remaining distance observation as external control
  - ➔12 Carbon fibre scale bars (< 0.02 mm, 1 σ)
  - ➔12 Long distance information (0.3 mm, 1 σ)



	DPA-Win	FiBun
Range	4.56 mm	0.85 mm
Stdev	0.99 mm	0.17 mm

Project CMS Yoke End Cap, Japan

Extended calibration model

➔ Interior and exterior accuracy enhanced

➔ Possible careless handling by untrained operator

Evaluation for different projects

Camera careful handled by photogrammetric experts

Extended calibration model

➔No clear conclusion possible

➔Further investigation how results improve significantly

Thank you for your attention!

New Developments in Close Range Photogrammetry applied to Large Physics Detectors

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