HERMES tracking for OLYMPUS. Part #1. Detector survey.

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Layout of the talk

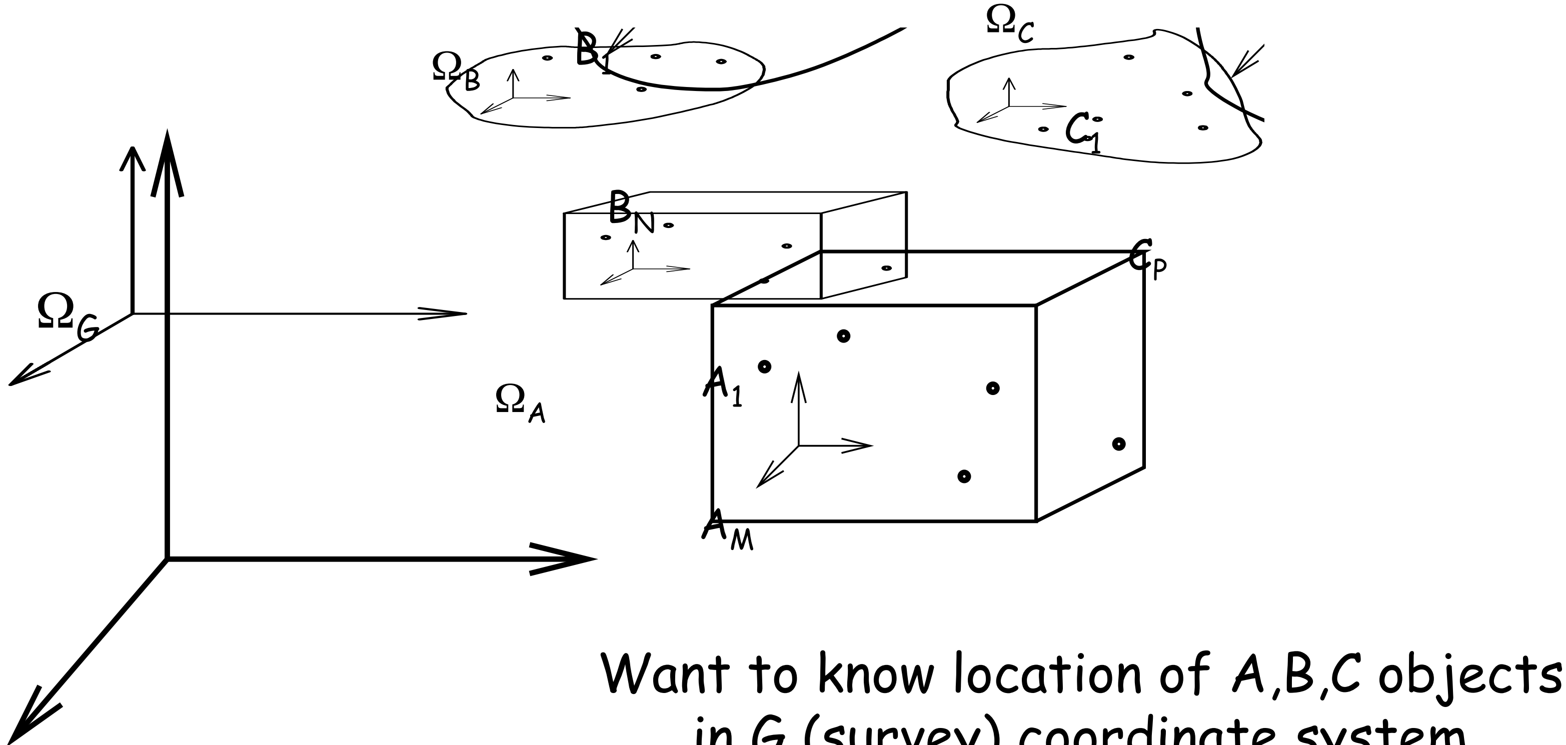
- Goals of alignment procedure
- Formalism of survey data analysis
- Survey procedure at HERMES
- Proposal for OLYMPUS and discussion

Goal: put together the following …

- Direct survey measurements of tracking detector frames in some coordinate system(s)
- Detector frame technical drawings
- Detector plane optical measurements (if exist)
- Tracking information in some way

… in order to obtain 3D locations of registering planes in space

3D object position in space



Want to know location of A,B,C objects
in G (survey) coordinate system

- Ignore temperature expansion effects
- Simple case: one data set, all points are seen

Formalism: notation

$$\vec{A}_0^{\,L} = \{A_1^{\,X} \cdots A_M^{\,Z}\} \in R^{3*M}, \hat{M}_A$$

vector of measured local coordinates of object "A" with the respective covariance matrix

$$\vec{B}_0^{\,L}, \hat{M}_B, \cdots, \vec{C}_0^{\,L}, \hat{M}_C$$

same for objects B and C

$$R_A : \vec{A}^L \rightarrow \vec{A}^G = R_A \vec{A}^L, R_B, R_C$$

linear 6-parameter transformation from local object systems to the global one

$$\vec{V}^G = \{\vec{A}^G, \vec{B}^G, \vec{C}^G\} \hat{M}_V$$

vector of the survey measurements with it's own covariance matrix

Minimization functional

$$\Psi = \Psi_G + \Psi_A + \Psi_B + \Psi_C$$

$$\Psi_G = \left\langle d\vec{V}^G \mid \hat{M}_V^{-1} \mid d\vec{V}^{G^T} \right\rangle \qquad \Psi_A = \left\langle d\vec{A}^L \mid \hat{M}_A^{-1} \mid d\vec{A}^{L^T} \right\rangle$$

$$d\vec{V}^G = \vec{V}^G - (R_A \oplus R_B \oplus R_C) * (\vec{A}^L \oplus \vec{B}^L \oplus \vec{C}^L) \qquad d\vec{A}^L = \vec{A}^L - \vec{A}_0^L$$

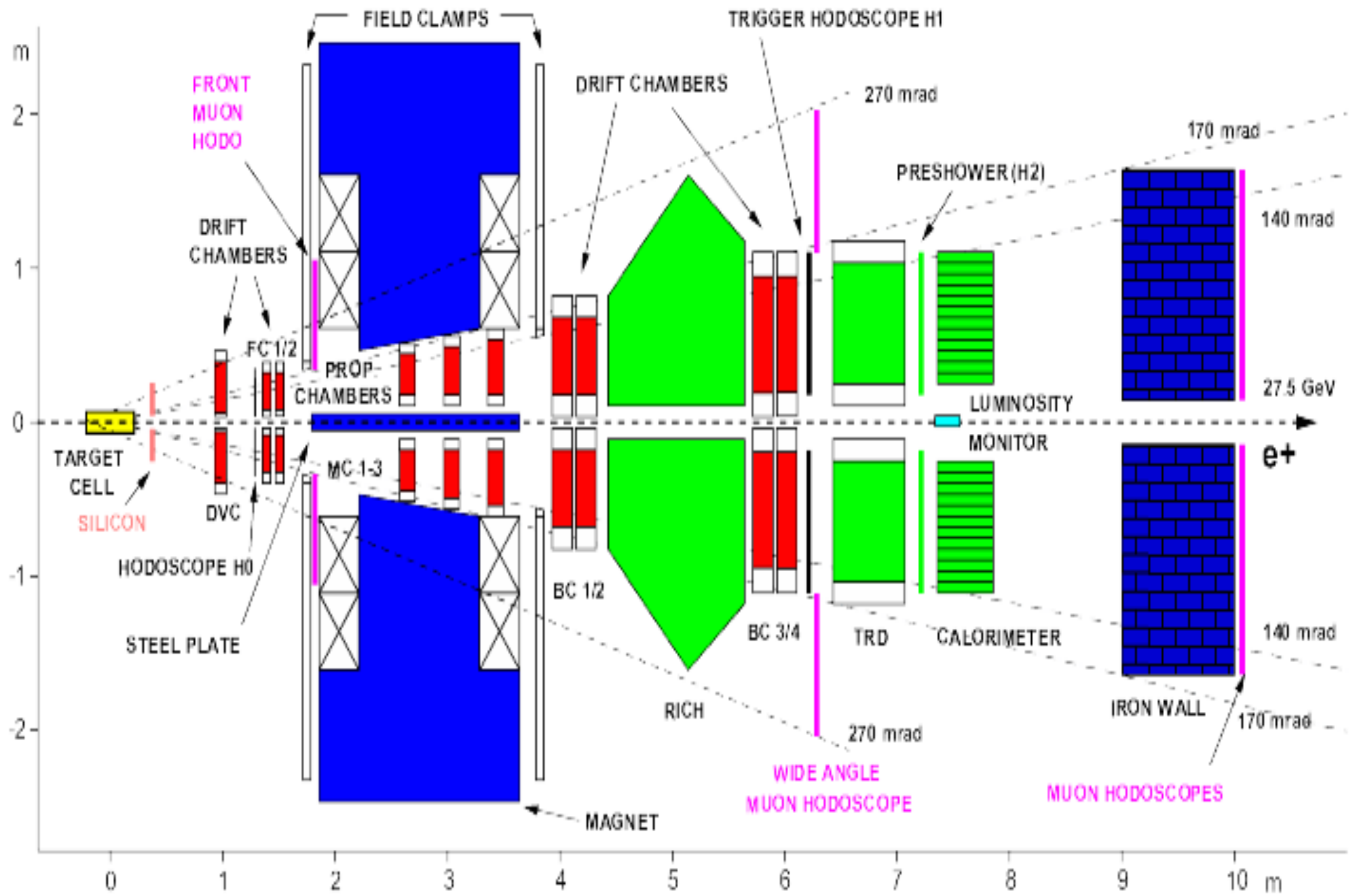
- Free parameters: $\vec{A}^L, \vec{B}^L, \vec{C}^L$ and R_A, R_B, R_C .
- If object B,C location in object A coordinate system is wanted, respective R matrices are presented as $R_B = R_A R_{B \to A}$

→ After minimization retain $\{R_A, R_B, R_C\}$ part and the task is solved

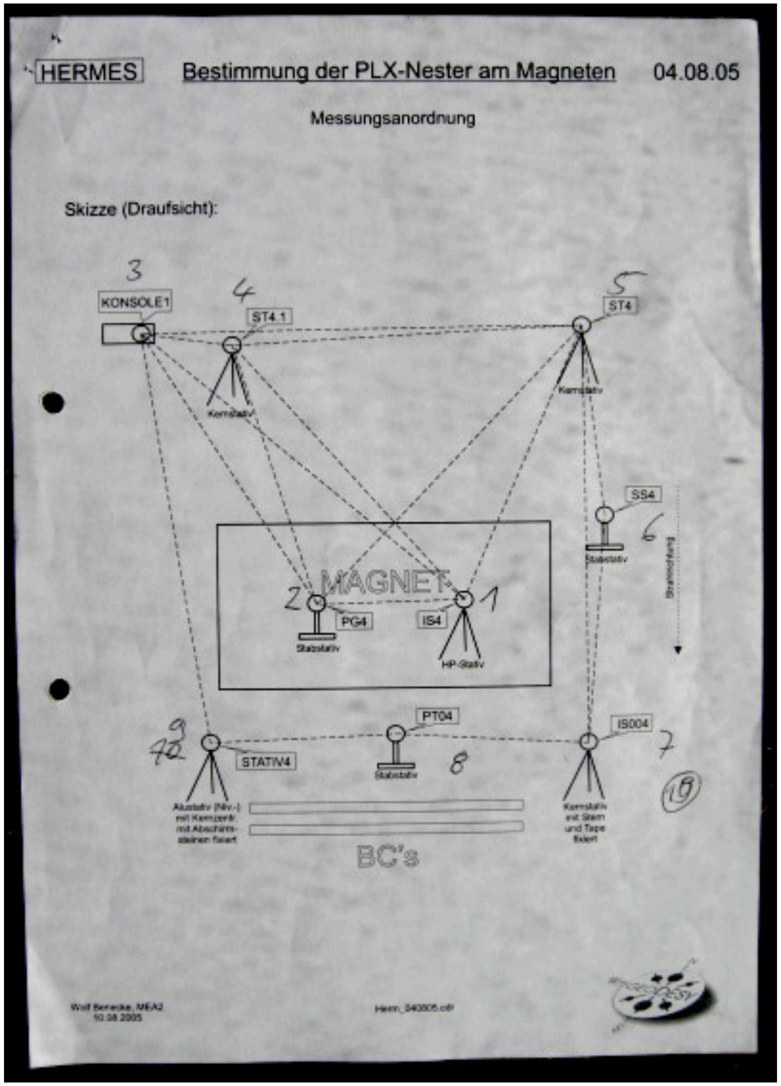
Would be too easy, right?

- All the input to the previous page needs to be obtained from survey data and design drawings
- Not all the points seen during survey
- Temperature expansion may be noticeable
- Several groups of independent measurements may exist (dozens if not hundreds of points, partly crap)
- Covariance matrices of some objects unknown, therefore need to be estimated
- Objects can move with time (say, after maintenance)

HERMES spectrometer



Survey measurements @HERMES



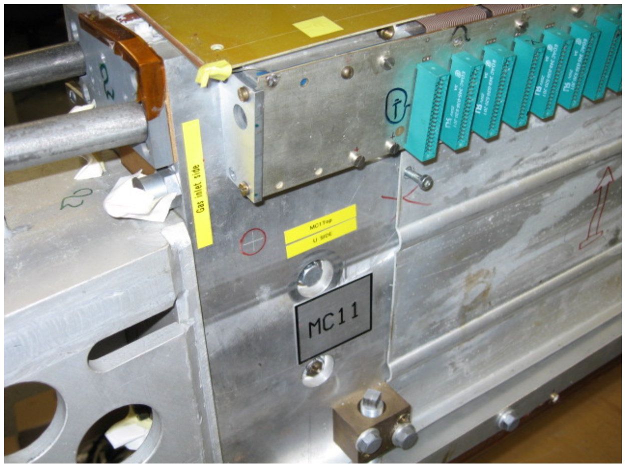
TC002A theodolite

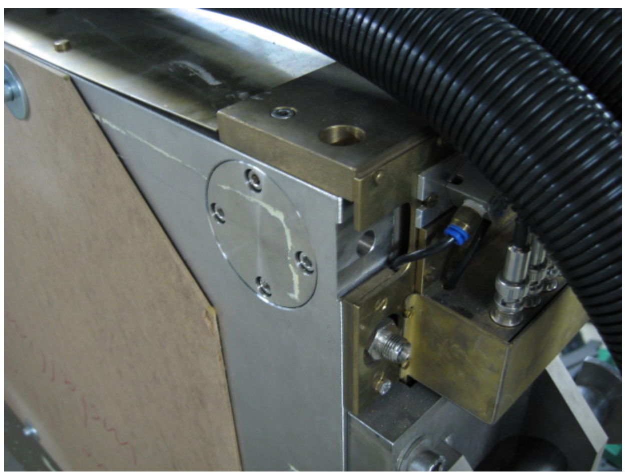
- Intrinsic spatial accuracy ~100 μm
- Intrinsic angular accuracy ~100 μrad
- Gives a grid of points with positional uncertainty well below 100 μm per projection

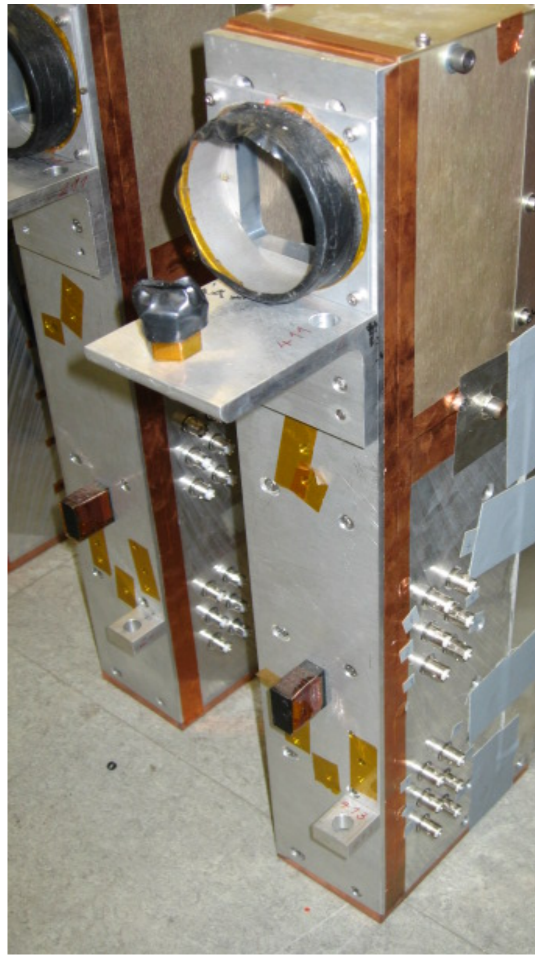
"Standard" optical targets

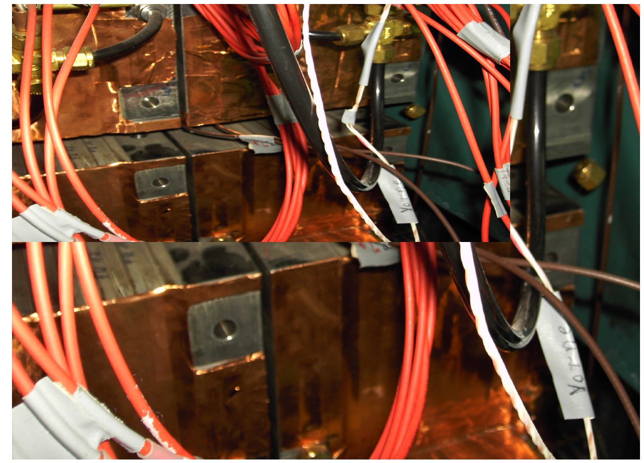
- Taylor-Hobson flat targets in spherical adapters
- Reflectors for distance measurements
- Brass "monuments" (dots - less precise)
- Chamber frame points -> next page

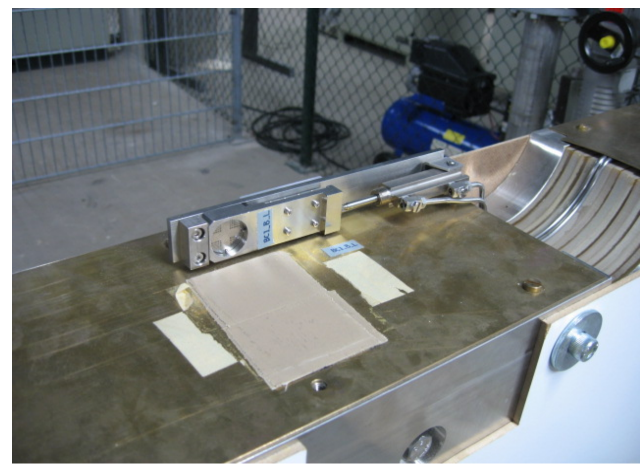
Tracking chamber targets











Dots, crosses, opt.target mounting holes, …, basically everything

Coordinate system choice

Spectrometer magnet yoke!

- Positional accuracy ~100μm
- Dimensions (almost) match the design

NB: beam parameters are determined in this same coordinate system later, based on tracking results

		Measurement	Design
Length in X [mm]		2449.69 (10)	2450.00
Length in Y [mm]		2235.30 (08)	2235.00
Length in Z [mm]		874.83 (05)	875.00
X-slope [mrad]		-7.98 (02)	-
Y-slope [mrad]		-5.90 (03)	-

Software scheme, summary

- Type in and structure the survey database
- Guess on initial point coordinates
- Feed each data set to MINUIT separately
- Check convergence and errors, remove outliers, rerun
- Obtain vector of estimated point coordinates $\vec{V}_G$ and covariance matrix $\hat{M}_V$ for each data set
- Type in the chamber design drawing database
- Merge survey and design data in a unified framework

At the end: 3D locations of all tracking chambers known within 100-150 microns in the coordinate system coupled to the spectrometer magnet yoke

Application to OLYMPUS

- Use exactly the same measurement scheme?
- Objects (confirm survey mark topology!):
  - Toroid magnet coils
  - Drift chamber frames
  - GEM & MWPC frames
  - Scintillator walls
  - Beam line survey marks
  - Moeller/Bhabha monitor
- Coupling to the magnetic field map?
- Beam line extracted from tracking, clear

NB: zero porting overhead for related software!