COULD THE LASER TRACKER AT401 REPLACE DIGITAL LEVELLING AND “ECARTOMETRY” FOR THE SMOOTHING AND REALIGNMENT OF THE LHC?

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Outlook

- Introduction
- Measuring the sector 78 of LHC using standard and CERN specific instruments
- The AT401
- Studies and simulations
- Measuring with the AT401
- Comparisons
- Benefits
- Conclusions
Introduction

- Sector 78 of the LHC is very unstable
  - Has to be surveyed and re-aligned very often
  - LHC is critical as much in vertical as in Horizontal (it was not the case for the LEP
    - Circular vacuum chamber
    - Fragile interconnections
  - It was foreseen during last Winter Technical Stop to make a survey in V and H
- CERN is always looking for a sensor to measure remotely the LHC components from a survey train
- HEXAGON/LEICA claims that AT401 is a good digital level
- Then it was decided to make a measurement of the same area using the AT401
Direct levelling with DNA03 and additional ones with NA2
Ecartometry with offsets with respect to a stretched wire

Horizontal deviations of the components of sector 78 of the LHC

Wire n+1

Cumulative distance [m]
A new Boson compatible with the HIGGS described in the standard model discovered at CERN by both ATLAS and CMS: announcement of July, 4th 2012

- 125 Gev

Still a lot of characteristics to study
The AT401

- Hybrid between a total station and a laser tracker

- Main parameters
  - Distances up to 160 m
  - Heating time 3h
  - Measurement time < 2s
  - No measurements under 2m

- Accuracy at 2 \( \sigma \) (from manufacturer):
  - +/-10 \( \mu \)m at 80 m
  - Angles: \( \sim 3 \) dmgon
Simulations of measurement sequences

- **Case 1**: one station in front of every quadrupole measuring one half-cell (53 m) on each side
- **Case 2**: one station in front of every two quadrupoles measuring two half-cells (106 m) on each side
- **Case 3**: one station in front of every quadrupole measuring two half-cells (106 m) on each side

<table>
<thead>
<tr>
<th>Case</th>
<th>Radial (mm at 1s)</th>
<th>Longitudinal (mm at 1s)</th>
<th>Vertical (mm at 1s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.43</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>2</td>
<td>0.27</td>
<td>0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>3</td>
<td>0.07</td>
<td>0.02</td>
<td>0.03</td>
</tr>
</tbody>
</table>
The AT401 campaign

- 55 positions of the AT401
- ~50 points per station
- Length: 2500m
- Measurements done with Face I and Face II
- ~7500 observations
- Initialisation of the instrument at 10 m
The AT401 campaign

- Bad closure of round of angles > Differences between FACE I and II

- For H angles

- For V angles

- The origin was probably due to overheating of the AT401
Two calculations were done

- with measurements at a max distance of 53 m
- will all measurements

<table>
<thead>
<tr>
<th>Observations</th>
<th>meas &lt; 53 m</th>
<th>All meas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R.m.s</td>
<td>average</td>
</tr>
<tr>
<td>H angle (dmgon)</td>
<td>0.6</td>
<td>0</td>
</tr>
<tr>
<td>V angle (dmgon)</td>
<td>2.8</td>
<td>1.6</td>
</tr>
<tr>
<td>Distances (mm)</td>
<td>0.11</td>
<td>0.00</td>
</tr>
</tbody>
</table>
- H Measurements with AT401 are closer to the nominal mainly because they are equivalent to a wire of 200m.
- Magnets with important deviations are the same.
V Measurements with AT401
Data post processing with LGC (cont’d)

- Difference between Altitudes AT401 and H direct levelling for each position of the instrument

- A similar test in another area gave almost the same results
Modelisation of the error

\[ y = 0.0002x^2 + 0.0062x - 0.0234 \]

\[ R^2 = 0.9933 \]

\begin{center}
\begin{tabular}{|c|c|c|}
\hline
Observations & meas < 53 m & All meas \\
\hline
R.m.s & average & R.m.s & average \\
\hline
\( V \) angle (dmgon) & 1.7 & -0.6 & 2.6 & -1.2 \\
\hline
\end{tabular}
\end{center}
Data post processing with LGC (cont’d)

☐ after modelisation
The relative position of the magnets is more important for the beam than the absolute one.

The deviations w.r.t a smooth curve, much more significant, were calculated with PLANE (window, threshold).

The idea is to run PLANE with the data of:

- AT401
- Levelling and ecartometry

And to compare the distances to the smooth curve.
In horizontal
- Ecartometry
- AT401: all measurements
- AT401: measurements at a max distance of 53 m

Very gaussian
- 85% of the deviations are with 0.1 mm
- 2 points are further than 0.3 mm
- No major difference between short and long distances measurements
Data post processing with Plane (cont’d)

- In vertical
  - Direct levelling
  - AT401: all measurements (with and without modelisation)
  - AT401: measurements at a max distance of 53 m (with and without modelisation)
- 80% of differences are within 0.1mm
- 2 points are outside the 0.3mm
- No major difference between short and long distance measurements
- Modelisation influences only long distance meas.
Other benefits of AT401

- Longitudinal position
- Radial deformation of dipoles
- Sensor for a train?
  - Stability to be solved
  - Targeting
  - Orientation of target robot

Radial deformation of long dipoles

Longitudinal deviations with respect to theoretical
Conclusions

- AT401 measurements for smoothing the LHC
  - Quicker than standard ones
  - In horizontal
    - better global shape
    - almost as accurate as the ecartometry for relative position
  - In Vertical
    - Pb of vertical angles which are not in the specifications
    - Not possible to use it as a level for a long traverse
    - For relative positioning, almost as accurate as digital levelling
  - I would use it for H measurements but NOT for V ones until the vertical angles problem is solved