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Grid Fits for BIL X-Tomography Data

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Both for the Rome/Pavia and the Protvino BIL chamber, the X-tomography group provided a dataset with the wire locations in a plane as extracted from an X-ray scan near one chamber end. Both chambers had 2×3 layers of 32 tubes each i.e. 192 tubes in total. Notably due to obstructions (long beams) not always all wire coordinates could be determined. These are simply skipped in this analysis. Also the BIL/Protvino chamber had 15 tubes of a shorter lenght to accommodate light paths for the projective alignment system. The analysis of these tubes requires a correction for the sag difference between long and short wires *and* the sag of the long tubes themselves since the short tubes were positioned w.r.t. to the long tubes for this particular chamber (not ideal and also not what the layered approach advocates; short tubes require intermediate jigs). Because of this, these 15 tubes were skipped as well in the present analysis.

The analysis proper is straightforward: the wires are supposed to fall on a regular grid and a fit (MINUIT) to this hypothesis yields all the relevant information. We focussed on three fit scenario's (in all cases, three additional irrelevant parameters are used to describe the overall translation (Y, Z) and rotation (α_X) of the measurement plane w.r.t. the grid):

1. Fit parameters ('layer fit', 11 parameters):
   - Z_{pitch} (1 parameter), Z spacing between tubes within a layer,
   - Z_{ofset} (5 parameters), Z shift of each layer w.r.t. first layer,
   - Y_{ofset} (5 parameters), Y shift of each layer w.r.t. to previous layer.
2. Fit parameters ('multilayer fit', 4 parameters):
   - Z_{pitch} (1 parameter), Z spacing between tubes within a layer,
   - Y_{pitch} (1 parameter), Y spacing between tubes within a multilayer,
   - Z_{ofset} (1 parameter), Z shift between the multilayers,
   - Y_{ofset} (1 parameter), Y shift between the multilayers.
3. Fit parameters ('chamber fit', 1 parameter):
   - T_{scale} (1 parameter), overall scale factor.

The 'layer fit' informs you about the mistakes you made in your assembly jigging, the 'multilayer fit' informs you only about the mistake you made in the relative location of the two multilayers and the 'chamber fit' gives you an overall figure of merit i.e. how close you came to the design. We think it is obvious that for the real operation of the ATLAS muon spectrometer, we could easily accommodate a few variables to describe the geometry of a chamber *provided* these variables are available. I.e. instead of using a perfect grid to describe a chamber we could as well add the two parameters which describe the offset between the two multilayers or even the ten (or fourteen for a 2×4 configuration) parameters to describe the offsets between any pair of layers. In both schemes these parameters will be monitored (and measured) during chamber assembly i.e. for the layered approach the Y, Z offsets of all layers w.r.t. to a reference are known using an MPA setup and for the multilayer approach the relative offsets between the two multilayers must be monitored (and measured) using a similar setup.

Coming to the results: in table 1 we list the design geometry of the Rome/Pavia and the Protvino BIL chanbers. These are of course irrelevant for the 'layer fit', slightly relevant for the 'multilayer fit' since the stacking scheme enters (i.e. is layer two shifted by +1/2 or -1/2 a tube w.r.t. layer one) and very relevant for the 'chamber fit' since only an overall scale factor is allowed w.r.t. the design parameters.

Chamber	Z_{pitch}	Y_{pitch}	Spacer height	Stacking
Rome/Pavia	30.010	25.989	180.000	010-010
Protvino	30.100	26.067	180.000	010-010

Table 1: *Nominal design parameters (mm) for the Rome/Pavia and Protvino BIL chambers.*

In tables 2, 3 and 4 we list the fit results for the three fits performed, respectively. In figures 1 and 2 we show the wire displacements from their fitted values for the 'chamber fit' i.e. this figure gives you immediately an idea about what went wrong where.

We have three preliminary conclusions:

- Both schemes perform rather well as long as only a single gluing step is involved i.e. within a layer for the layered approach (about 15 μm r.m.s. in Z and about 25 μm r.m.s. in Y) and within a multilayer for the multilayer approach (about 20 μm r.m.s. in Z and about 25 μm r.m.s. in Y),
- Both schemes have difficulties with the relative offsets of either multilayers or layers. This means that the offset generation mechanism, i.e. the six towers, requires monitoring (foreseen) and possibly improvements.
- Both schemes clearly failed to reproduce the design values within the specifications. However, please realize that these are the first large scale prototypes and that hopefully some simple fine adjustment of the offset generation mechanism could improve the situation drastically.

Parameter	Rome/Pavia BIL	Protvino
Z_{pitch}	30.0075	30.0990
Z^{12}_{ofset}	−15.002	+15.107
Z^{13}_{ofset}	+0.015	+0.063
Z^{14}_{ofset}	+0.062	−0.016
Z^{15}_{ofset}	−14.917	+15.046
Z^{16}_{ofset}	+0.089	+0.009
Y^{12}_{ofset}	25.986	26.127
Y^{23}_{ofset}	25.989	26.089
Y^{34}_{ofset}	179.874	179.994
Y^{45}_{ofset}	25.994	26.103
Y^{56}_{ofset}	25.989	26.081
r.m.s. Z	19.8 μm	16.0 μm
r.m.s. Y	24.3 μm	25.4 μm

Table 2: *'Layer fit' results for Rome/Pavia and Protvino BIL chambers.*

Parameter	Rome/Pavia BIL	Protvino
Z_{pitch}	30.0075	30.0991
Y_{pitch}	25.989	26.101
Z_{ofset}	+0.073	−0.045
Y_{ofset}	179.875	179.990
r.m.s. Z	21.9 μm	27.4 μm
r.m.s. Y	24.2 μm	27.0 μm

Table 3: *'Multilayer fit' results for Rome/Pavia and Protvino BIL chambers.*

Parameter	Rome/Pavia BIL	Protvino
T_{scale}	0.99985	1.0000
r.m.s. Z	42.0 μm	35.9 μm
r.m.s. Y	52.8 μm	47.4 μm

Table 4: *'Chamber fit' results for Rome/Pavia and Protvino BIL chambers.*

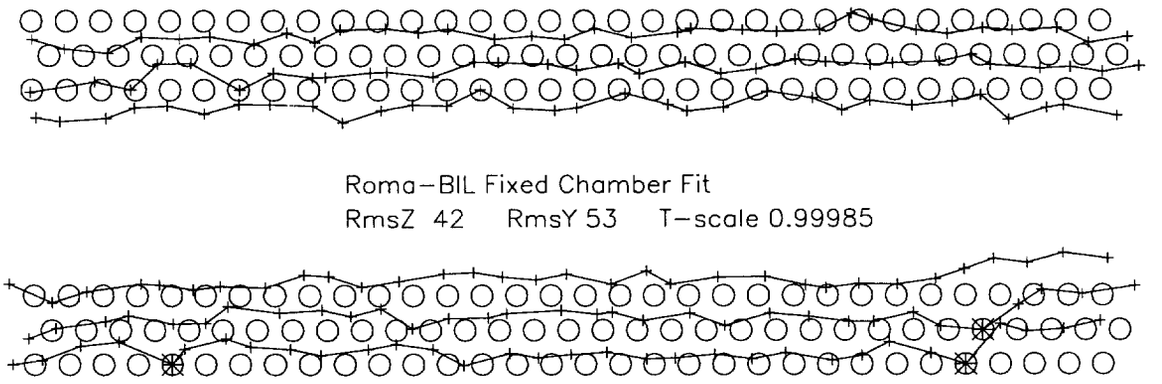

Figure 1: *Wire displacements w.r.t. nominal geometry for the Rome/Pavia BIL chamber. This with the parameters as listed in tables 1 and 4. Tubes skipped for the fit are indicated. The circles (60 μm diameter) represent the expected tube locations and the line connecting the crosses gives the measured tube locations.*

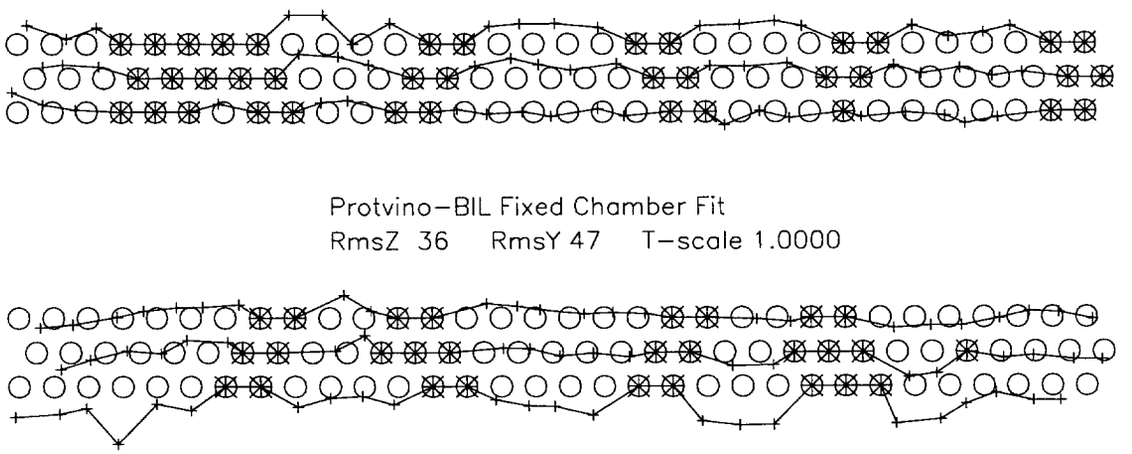

Figure 2: *Wire displacements w.r.t. nominal geometry for the Protvino BIL chamber. This with the parameters as listed in tables 1 and 4. Tubes skipped for the fit are indicated. The circles (60 μm diameter) represent the expected tube locations and the line connecting the crosses gives the measured tube locations.*