Proposal For A (Final) Set of MDT Chamber Deformation Parameters

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Motivation

- **Current situation of parameter sets:**

  several sets of chamber deformation parameters exist and are being used (Claude Guyot model, current AMDB implementation, CA’s ARAMyS implementation)

  all equivalent at first glance, small differences in details – e.g. reference to HV/RO side versus positive/negative axis-direction side, meaning of positive/negative sign, ... 

  non-existing (CA) or incomplete (CG, AMDB) documentation; where documentation exists, only sketches, no formulae

  CG and AMDB sets incomplete: two more parameters required to describe observed endcap chamber deformations

- **Aim of this presentation:**

  deformations will be implemented in several different programs: ARAMyS, ASAP, GeoModel, Muonboy, GEANT – first priority is to make sure all implementations are identical

  propose and fully document a complete parameter set that is optimized for ease of implementation: minimize potential sources of ambiguities, no external quantities (e.g. material constants) and knowledge (e.g. where is HV side?) required
Test Yourself

- **Is this HV or readout side?**
  
  *Easy* to answer when you are standing in front of the chamber; much less easy when you are sitting in your office (which is where deformation parameters are implemented, and where we all will be after the LHC start-up in 2009).

- **Which side of the chamber does the positive \( s \)-axis point to?**
  
  *Trivial* to answer if you know the chamber coordinate system definition (if not, you need to look it up anyway before starting to work on deformation parameters).

- **What is the thermal expansion coefficient of Aluminum?**
  
  \( \alpha_{Al} = 20 \, \mu m/m/K \) ?
  
  \( \alpha_{Al} = 25 \, \mu m/m/K \) ?
  
  \( \alpha_{Al} = 22.3 \, \mu m/m/K \) ???
Conventions

- top view (along $-t$)
- side view (along $-s$)
- side view (along $+z$)

On the next slides:

- three schematic views of a (barrel) MDT chamber
- thick black lines represent (approximately) cross-plates
- local chamber coordinate systems: $szt$ (AMDB-style) or $XYZ$ (TDR-style), will use $szt$ in this talk
- chamber sides are denoted, where necessary, by N/P

Effects of deformations (for positive sign) will be shown in one or more of the views, supplemented by the formulae for implementation to simplify formulae:

map $s \in [-\frac{1}{2} \text{width}, +\frac{1}{2} \text{width}]$ onto $s_{\text{rel}} \in [-1, 1]$ and $z \in [0, +\text{length}]$ onto $z_{\text{rel}} \in [-1, 1]$

(so that $s_{\text{rel}} = \pm 1$ along outer cross plates)
Tube Bow in the Plane: \( b_z \) (1 Parameter)

- \( b_z \):
  - bow of tubes in chamber plane, endpoints unchanged
  - maximum elongation along tube (at middle cross plate) equals \( b_z \), positive for bow towards negative \( z \)
  - unit: mm
  - typical: \( \mathcal{O}(10 \, \mu m) \)
  - formula:
    \[
    \phi = b_z \cdot (s_{rel}^2 - 1)
    \]
  - transformation:
    \[
    s \rightarrow s \\
    t \rightarrow t \\
    z \rightarrow z + \phi
    \]
Tube Bow out of Plane: \(bp, bn\) (2 Parameters)

- \(bp, bn\):
  - Bow of tubes out of chamber plane, endpoints unchanged
  - Maximum elongation along tube (at middle cross plate) equals \(bp\) at P-side long-beam, and \(bn\) at N-side long-beam, positive for bow towards negative \(t\)
  - Unit: \(\text{mm}\)
  - Typical: \(\mathcal{O}(100 \, \mu\text{m})\)

Formula:
\[
\phi = \frac{1}{2}(bp + bn) \cdot (s_{\text{rel}}^2 - 1) + \frac{1}{2}(bp - bn) \cdot (s_{\text{rel}}^2 - 1) \cdot z_{\text{rel}}
\]

Transformation:
\[
\begin{align*}
  s &\rightarrow s \\
  t &\rightarrow t + \phi \\
  z &\rightarrow z
\end{align*}
\]

New parameter (\(bp = bn\) before)
Cross Plate Sag out of Plane: \( sp, sn \) (2 Parameters)

- **sp, sn:**
  - sag of cross plates out of chamber plane, tubes remain straight
  - maximum elongation along cross plate (at center) equals \( sp \) at P-side cross-plate, and \( sn \) at N-side cross-plate, positive for sag towards negative \( t \)

  **unit:** mm

  **typical:** \( \mathcal{O}(10 \, \mu m) \)

  **formula:**
  \[
  \phi = \frac{1}{2}(sp + sn) \cdot (z_{rel}^2 - 1) + \frac{1}{2}(sp - sn) \cdot (z_{rel}^2 - 1) \cdot s_{rel}
  \]

  **transformation:**
  
  \[
  \begin{align*}
  s & \rightarrow s \\
  t & \rightarrow t + \phi \\
  z & \rightarrow z
  \end{align*}
  \]
Twist: \( tw \) (1 Parameter)

- \( tw \):
  - out-of-plane rotation of both outer cross-plates in opposite directions, tubes remain straight
  - maximum out-of-plane shift (at corners) equals \( tw \), positive for shift of corner at \( s_{\text{rel}} = 1, z_{\text{rel}} = 1 \) towards negative \( t \)
  - unit: mm
  - typical: \( O(100 \mu \text{m}) \)
  - formula:
    \[
    \phi = -tw \cdot s_{\text{rel}} \cdot z_{\text{rel}}
    \]
  - transformation:
    \[
    s \rightarrow s \\
    t \rightarrow t + \phi \\
    z \rightarrow z
    \]
Parallelogram: $pg$ (1 Parameter)

- $pg$:
  - in-plane rotation of both outer cross-plates in same direction, tubes remain straight, endpoints for all practical purposes unchanged
  - maximum in-plane shift (at corners) equals $pg$, positive for shift of corner at $s_{\text{rel}} = 1, z_{\text{rel}} = 1$ towards negative $s$
  - unit: mm

- Typical: $O(1 \mu m)$ (at tubes), $O(100 \mu m)$ (at cross plates)

- Formula:
  $$ \phi = -pg \cdot z_{\text{rel}} $$
  new parameter

- Transformation:
  $$ s \rightarrow s + \phi $$
  $$ t \rightarrow t $$
  $$ z \rightarrow z $$
  endcap chamber implementation more complicated
Trapezoid: \( tr \) (1 Parameter)

- **\( tr \):**
  - In-plane rotation of both outer cross-plates in opposite directions, tubes remain straight, endpoints for all practical purposes unchanged.
  - Maximum in-plane shift (at corners) equals \( tr \), positive for shift of corner at \( s_{rel} = 1, z_{rel} = 1 \) towards negative \( s \).
  - Unit: mm

  **Typical:** \( \mathcal{O}(10 \, \mu m) \) (at tubes), \( \mathcal{O}(100 \, \mu m) \) (at cross plates)

**Formula:**
\[
\phi = -tr \cdot s_{rel} \cdot z_{rel}
\]

**Transformation:**
- \( s \rightarrow s + \phi \)
- \( t \rightarrow t \)
- \( z \rightarrow z \)

Trapezoidal effect partially due to mechanical deformation (decoupled by flexos), partially due to temperature differences of tubes (not decoupled).
Global Expansion: eg (1 Parameter)

- eg:
  - uniform expansion of chamber, around origin, tubes remain straight
  - relative change in chamber size equals eg, positive for increase in size

**unit**: 1 (unitless)  
**typical**: $\mathcal{O}(100 \text{ ppm})$

**formula**:
$$\phi = eg$$

**transformation**:
$$s \rightarrow s \cdot (1 + \phi)$$
$$t \rightarrow t \cdot (1 + \phi)$$
$$z \rightarrow z \cdot (1 + \phi)$$

Note that the red arrow does not indicate a length in this drawing.

Global expansion is mostly due to temperature, but change in tube pitch could enter here, too.
Local Expansion: ep, en (2 Parameters)

- **ep, en:**
  - local differences in expansion of chamber, around center
  - difference from outer to middle cross plates in relative change in chamber size equals ep at P-side cross-plate, and en at N-side cross-plate, positive for increase in size

- **unit:** 1 (unitless)

- **typical:** $\mathcal{O}(10 \text{ ppm})$

- **formula:**
  \[
  \phi = \frac{1}{2}(ep + en) \cdot s_{rel}^2 + \frac{1}{2}(ep - en) \cdot s_{rel}
  \]

- **transformation:**
  \[
  s \rightarrow s \cdot (1 + \phi)
  
  t \rightarrow t \cdot (1 + \phi) - \frac{1}{2}\phi \cdot \text{height}
  
  z \rightarrow z \cdot (1 + \phi) - \frac{1}{2}\phi \cdot \text{length}
  \]

*note that the red arrows do not indicate lengths in this drawing*
Summary and Proposal

**Summary:**

using the previous slides, it is **trivial** to write a stand-alone FORTRAN/C/C++ function implementing MDT deformations.

input to the function are the **chamber dimensions** (width, length, height) and the **11 deformation parameters**; it returns the coordinates \((s', z', t')\) after deformation of a point \((s, z, t)\)

**Proposal:**

propose to adopt the presented parameters as “the” final set; this talk could serve (at least temporarily) as documentation

AMDB experts please define **new format of B-lines**

if any **mistakes** are found on the previous slides, a corrected version will be uploaded to the agenda page; these slides are also at [http://cern.ch/amelung/talk-atlas-muon-sep07.pdf](http://cern.ch/amelung/talk-atlas-muon-sep07.pdf)

if anyone has well-founded **objections** to this set, and would like to propose a different set, he/she should **follow the same scheme of documentation**, i.e. to provide a sketch, a description in words, the sign definition, the formulae for implementation.
Modifications and clarifications:

Changed the “typical” order of magnitude of sp,sn from $1 \mu m$ to $10 \mu m$. During the presentation it was pointed out that this effect could be caused by temperature differences across the cross plates, not only by mechanical deformations (which are expected to be tiny).

The coordinate system $szt$ is the local chamber reference frame as defined in the AMDB documentation. In the original version of these slides, $SZT$ had been used for better readability, which turned out to be confusing, however, because $SZT$ in AMDB denotes the global ATLAS reference frame after rotation around the beam line.

Beware that “length” (chamber size in $z$) and “height” (size in $t$) as used in these slides and in the TDR are elsewhere referred to as “height” (size in $z$) and “thickness” (size in $t$).

Example of the proposed format of B-lines:

* TypJffJzzJob bzb bpn sp sn tw pg tr eg ep en
B EIL 1 -1 0 -0.002 0.022 0.022 0.000 0.000 -0.064 -0.051 -0.000 0.031 0.031 -0.031

(all parameters in mm except for eg,ep,en having unit permille, i.e. the printed value is 1000 times the actual value)