Support structure for the LHCb Inner Tracker stations

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LPHE / IPEP / SB / EPFL

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✦ Introduction
✦ Design overview
  ● Pillars and C-sandwich plates
  ● Acceptance and Integration in LHCb
  ● Rolling in/out
  ● Electrical switch for “End of travel” → Peter F.
  ● Cables and the all the impedimento
  ● Installation
✦ The prototype and what we have learned
✦ Procurements and Schedule.
Introduction

We are here!

October 11, 2005

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Inner Tracker supports are in the exp. acceptance: ⇒ requirements

- Place LV and HV supplies in bunker,
- Use same frame as Outer Tracker,
- Fit into space left free by OT,
- $z$ envelope: 190, 220 and 190 mm for T1, T2 and T3.
- $z$ clearance: 1 cm!
- Sliding in/out independently of OT.
General design

✦ Two hollow pillars in Carbon fibre 76 mm x 76 mm, thickness : 3.2 mm.
✦ These pillars hold the whole structure.
✦ The structure is hanging on the same global structure as the O.T. and is guided at the bottom.
✦ Rolling + precise guidance on top rails.
✦ Opening of the station in 2 halves for repairs and maintenance.
✦ Beam pipe distance monitoring to be finalized.
✦ Detector boxes, cables, pipes hanged on 9 mm honeycomb-carbon sandwich plates (Carbon skins 0.5 mm).
✦ Cables from detector- to service boxes (10 kg/m) fixed to the structure.
✦ Service boxes (40 kg per half-station) placed at the bottom.

✦ HV and LV power supplies and patch panels placed in bunker.
✦ Connections to the supplies in the bunker done using flexible cable chain.
**Pillars**

- Glass-Carbon fibres (50%-50%)
- Ext. dimensions: 76.2 ± 0.5 mm,
- Wall thickness: 3.2 ± 0.5 mm,
- Weight: 9.64 kg,
- Density: 1.77, (6.3% $X_0$ 2.4% $\lambda$)
- Pillar length: 5922 mm, in 2 pieces assembled at 40% of the length by four C plates (70 x 150 x 3 mm$^3$).

**C-sandwich plates**

- Used to hold the detector boxes and cables
- Dimensions chosen accordingly
- 8 mm thick, (0.92% $X_0$ 0.53% $\lambda$)
- Aramid honeycomb and C fibre skins (0.5 mm).

C-sandwich plates fixed with screws into inserts glued in the pillars or in the other plates. Reinforcements glued onto C-sandwich plates.
Design of the support structure 3

**Vertical acceptance:** 250 mrad

At station 1. 
Beam angle accounted for.

**Horizontal acceptance:** 300 mrad

At station 3. 
Beam angle accounted for.
**Integration of the detector boxes**

The detector boxes are held on the C-sandwich plates with flat angle brackets made of C-fibres. Precision of mounting: better than 1 mm in $y$ and $z$ directions w.r.t. fiducial marks on structure.
**Signal cable**

**TDE SCSI cables**
- 28 cables / detector box (1 / ladder),
- 34 pairs of insulated conductors,
- Double shielded:
  - inner shielding: Al/polyester tape,
  - outer shielding: Tin plated copper braid.
- length:
  - < 3 meters for L, R and B boxes,
  - < 5 meters for U box.
- 8.87% $X_0$, 1.29% $\lambda$.

**SCSI connectors**
- from detector box: (4% $X_0$, 0.85% $\lambda$)
  - VHDCI 68p, 0.8mm pitch, 2 rows.
- to service box: Mini DB 68 poles.

**HV cable**
- 56 conductors in double shield,
- ext $\phi$ 17.2 mm, 6.57% $X_0$, 1.48% $\lambda$.

**Cooling pipes**

Cooling pipe in Nitrile:
- inlet: ext. 15 mm, int. 9 mm,
- outlet: ext. 20 mm, int. 14 mm.

Insulation: Armaflex 19 mm thick.
Résumé of the thickness of each element

For each station:

<table>
<thead>
<tr>
<th>Elements</th>
<th>Main components</th>
<th>[% $X_0$]</th>
<th>[% $\lambda$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector</td>
<td>plastic, steel</td>
<td>4.00</td>
<td>0.85</td>
</tr>
<tr>
<td>Signal cable</td>
<td>copper, plastic</td>
<td>8.87</td>
<td>1.29</td>
</tr>
<tr>
<td>HV cables</td>
<td>copper, plastic</td>
<td>6.21</td>
<td>1.40</td>
</tr>
<tr>
<td>Cooling pipe outlet</td>
<td>$C_6F_{14}$, rubber, plastic</td>
<td>2.67</td>
<td>1.24</td>
</tr>
<tr>
<td>Cooling pipe inlet</td>
<td>$C_6F_{14}$, rubber, plastic</td>
<td>1.79</td>
<td>0.88</td>
</tr>
<tr>
<td>Pillars of structure</td>
<td>Carbon, glass (50% 50%)</td>
<td>6.22</td>
<td>2.84</td>
</tr>
<tr>
<td>Carbon-sandwich plates</td>
<td>Carbon, aramid honeycomb</td>
<td>0.92</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Not mentioned here:
- thickness of the detector boxes (see related EDR),
- elements outside LHCb acceptance.
Rolling the support structure in and out 1

- Use same support and same rolling system as the Outer Tracker.
- Coarse rail for the in/out movements.
- Precise rail for the final positioning (see next slide)
- The whole support structure is hanging on the “Upper Trolley”.
- Near the end position, the final $z$ coordinate is ensured by the precise trolley.
- The structure is guided on the bottom rails (figure below)
The precise guiding rail

- Machining precision: 20 µm
- Mounting precision: < 0.2 mm w.r.t. bridge in z direction.
- Recall coarse rail precision: a few mm in z direction.
The precise trolley

Eccentric

Adjustment

Upper rail can have some play inside

The upper trolley

This trolley follows the coarse rail; it can tip in 3 directions thanks to a spherical plain bearing (roulement à rotule sur billes)
The service boxes and their supplies

Service boxes use
- 2.5 V and this line consumes 32 A,
- 5.0 V and this line consumes 10 A.

Need cables in which voltage drop is not too high.
One line to and one from the service box.
The lines have to be drawn to the supplies located under the bunker.

RMS: radiation monitor system only at T2
Copper braid for grounding not drawn
Cooling pipe is for the service boxes.

Cables in the cable chain
- LV cable diam. 23 mm for 2.5 V.
- LV cable diam. 17 mm for 5.0 V.
- Always one spare cable of each type.
Rolling out the half station. A cable tray is added on the bunker wall.

Plates (gray) added on bunker extension
♦ guide the half station rolling,
♦ guide the cooling pipes and the chain.
Cable chain mechanically supported at bottom.

Cables to the supplies viewed from the bottom.
Fixed point on the left hand side.
End travel security 1

Rely on both mechanics and electric switch (see Peter’s presentation)

Mechanics:

✦ Half station will be slid in manually.
✦ End of travel will be done manually with a knob (see next slide).
✦ There will be stops on top rail and bottom rail.
Third mechanical security
At the end of the sliding in procedure:
✦ Put the locking pin in.
✦ Turn the knob until stop.
✦ The screw and knob support is precisely positioned.
✦ Not possible to do the above operation if yellow part not in place!
# Weight of a station

<table>
<thead>
<tr>
<th>Half Station</th>
<th>Mass [kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Left</strong></td>
<td></td>
</tr>
<tr>
<td>Support (pillars + plates)</td>
<td>19</td>
</tr>
<tr>
<td>Cooling pipes</td>
<td>6.5</td>
</tr>
<tr>
<td>Signal cables</td>
<td>≈ 21</td>
</tr>
<tr>
<td><strong>Right</strong></td>
<td></td>
</tr>
<tr>
<td>Support</td>
<td>19</td>
</tr>
<tr>
<td>Cooling pipes</td>
<td>8.5</td>
</tr>
<tr>
<td>Signal cables</td>
<td>≈ 33</td>
</tr>
<tr>
<td>LV and HV cables</td>
<td>≈ 90</td>
</tr>
<tr>
<td>Service boxes</td>
<td>80</td>
</tr>
<tr>
<td>Detector boxes</td>
<td>13</td>
</tr>
<tr>
<td>Trolleys + rolling system</td>
<td>30</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
</tr>
<tr>
<td>Full Station</td>
<td>≈ 320</td>
</tr>
</tbody>
</table>
Mounting the structure at CERN

Need place 10 x 10 m$^2$ on the floor to mount a full station.

Service boxes not to be mounted at this stage. Mounting at 0° might be easier than at 45° or 90°. The proposed support can be transformed very easily.
Can also mount half stations at CERN Lab I and transport them to LHCb pit.
**Beam tube not being installed**  
(April 2006).

- Can only put the half stations from the left ($x > 0$)  
  Outer Tracker will also slide in from $x > 0$
- Measure and tune $y$ and $z$ position of the structure: theodolite will be placed inside the magnet.  
  Fiducial marks to be put on pillars (see next slide)
- Locate positions of detector boxes w.r.t. these fiducial marks.
- Signal cables already installed.
- Installation of service boxes, cooling pipes, LV, HV cables as far as possible.

**Beam tube being installed**  
(July and August 2006).

- Installation of service boxes, cooling pipes, LV, HV cables.
- Connecting the signal cables to the detector boxes and to the service boxes.
Survey of the stations positions

Adjusting the position of each half station

✦ in $x$ : with the end travel blockers,
✦ in $y$ : with the upper trolley,
✦ in $z$ : with
  ● the position of the precise guiding rail,
  ● the bottom (NIKHEF) rail,
  ● the bottom rolling wheels.

✦ Adjust the verticality of the half stations in “closed position”.
✦ Measure the position of the fiducial points on pillars w.r.t. the experiment’s ref. frame.
✦ Locate position of detector boxes w.r.t. fiducial points in “open position”.

Fiducial marks on the other side of the support!
A prototype at EPFL

Upper rail with the precision rails and the trolleys.
A prototype of a half station has been constructed and is cabled. Can already point to several improvements.

Possible improvements

✦ Carbon-sandwich plates vibrating although positions are reproducible.
✦ Increase the rigidity of the Carbon-sandwich plates by
  ● either increase the width of the "reinforcement wing",
  ● or (non exclusive) the number of these "wings",
  ● or (non exclusive) connect two plates.
✦ Design additional support panels to maintain and guide the cables.
✦ Design a special tool to hold and position the signal cable with its connector onto the printed circuit board.

Some possible improvements of the C-sandwich plates rigidity.
Procurements:

✦ Pillars, Carbon-sandwich plates: Composite Design Echandens. We have a long and positive experience with this company.
✦ Trolleys, rails: machined at EPFL.
✦ Nitrile cooling pipes: Angst + Pfister AG, CH.
✦ ARMAFLEX insulation: ARMACELL, CH.
✦ LV and HV cables: available through CERN stores.
✦ TDE SCSI cables: Trans Data Electronik, Germany. They will deliver the cables with the connectors on both ends. ⇒ Need to know the cable lengths.
✦ Cable chain:
  ● in stainless steel: Elspec, Germany?
  ● in plastic: Flexatec, Germany?
Tentative schedule:

Still to be done:

➢ Need to build a “right side” prototype as the station is asymmetrical and we have less space on right hand side.
➢ This prototype will be ready by January 2006

In the mean time:

➢ The pillars are already ordered and will be delivered this month.
➢ Order the C-sandwich plates this month.
  Delivery expected at the end of the year.
➢ Build and test an electrical “end of travel” monitor (see Peter’s presentation)
➢ Proceed a.s.a.p. to the fabrication of the trolleys and guiding rails.
➢ Proceed a.s.a.p. to the fabrication of the sliding-in devices.
➢ Expect to have these elements made at EPFL in three to four months → end of January or February.
➢ Order a.s.a.p. signal cables, LV, HV cables, pipes, etc …
➢ Unless unexpected delay, we will be able to install the stations support structures in April 2006.
Conclusion

My conclusions

✦ We have gone through the entire prototyping of the support structure.
✦ Production and mounting steps have been defined.
✦ Improvements have been pointed out in order to improve rigidity and cabling easiness.
✦ Wait for green light to proceed and be ready for installation in April 2006.