Beam-Beam Compensator Prototype Parameters and possible Integration into the LHC Collimators

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for and with input from:
Motivation for Installing a BBC Prototype in the LHC I/II - Passed several Milestones

- Initial proposal based on J.-P. Koutchouk's note: CERN-SL-2001-048-BI

Since, SPS wire-wire and RHIC beam-wire experiments demonstrated that:

1. “detrimental wire effect on life-time can be compensated by another wire”
2. Benchmark of numerical tool chain → indication of what to expect at LHC

Further tests require a true long-range beam-beam limited machine...
→ proof-of-principle requires BBC prototype into machine before HL-LHC
Reservations around IR1&IR5, LHC-BBC-EC-0001:
- Min. LRBB → BBC phase advance: $\Delta \mu \approx 2.6^\circ \rightarrow 3.1^\circ$
- Symmetric beta-function: $\beta_{x/y} \approx 1000$ m (for $\beta^* = 0.55$ m)

→ Prototype with nominal parameters not feasible during LS-1 (MPP, Cleaning,..).

Compromises in favour of an early proof-of-concept tests to guide and to gain lead-time for nominal system at HL-LHC:

1. Operation close to MP envelope:
   a) need to embed wire in collimator jaw-type structure – preferred
   b) Operate within shadow of TCTs → ineffective w.r.t. beam-physics

2. Limit nominally 8 BBC units to two:

3. Wire parameters:
   • Solid wire radius of ~ 1mm → 1kW power dissipation
   • sub-σ level of hor./ver. position control
   • Nominal scheme: $I = I_{\text{peak}} \cdot \sqrt{2\pi} \cdot \sigma_s \cdot n_{\text{parasitic}} = 72 \ldots 350$ Am (max.)
   • Pulsed wire to accommodate differences for PACMAN bunches
     → not practical at this stage → stick to DC compensation only
Choice of replacing TCTP/TCL...
- minimises the MP risk w.r.t. asynchronous beam dumps,
- reuses existing collimation infrastructure, and
- allows testing with nominal (/ATS) optics after LS-1.

**Nominal Prototype**

**CMS**

**ATLAS**

**Proposed Prototype Layout after LS-1**

- ~105 m
- 20 mm clearance
Long-Range Beam-Beam Compensator Prototype I/II
What can be demonstrated after LS-1

Analysis: T.Rijoff & F. Zimmermann
Long-Range Beam-Beam Compensator Prototype II/II
What can be demonstrated after LS-1

<table>
<thead>
<tr>
<th>Cross Angle 12 $\sigma$</th>
<th>Cross Angle 9.5 $\sigma$</th>
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<tbody>
<tr>
<td><strong>HOLR</strong></td>
<td><strong>BBC</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TCT opt $\beta$</strong></td>
</tr>
<tr>
<td></td>
<td>237 A 11$\sigma$</td>
</tr>
<tr>
<td></td>
<td>237 A 11$\sigma$</td>
</tr>
</tbody>
</table>

12 $\sigma$ without wire  ➡️  9.5 $\sigma$ with the wire

Analysis: T.Rijoff & F. Zimmermann
- Can re-use nearly 100% of existing TCTP design.
- Remaining challenge: finding space for the wire current feed-through amongst the cooling circuits and BPM button feed-throughs.
- Gretchen Frage: do we wait until the lab prototype tests are conclusive or do we start with the design/production right away in March?
Finite-Element and analytic estimates agree for given (perfect) conditions to be further studied → more specific model and lab-prototype test in progress.

Prototype to be tested in March → then in || integration into W-jaw of TCTP&TCL
Summary and Status

Necessary technical infrastructure planned to be installed during LS-1 (powering, girders, water, cables, etc.) → ECR and integration in progress

Next Steps:
1. Mechanical feasibility, material and vacuum compatibility tests
   - mechanical and electrical constraints, vacuum compatibility
     → lab mock-up test to validate design (Axel Ravni, BI-ML) → March'13
     → In || wire-in-jaw integration into existing TCTP (HLTC A: A. Bertarelli)
2. Impact of wire-in-jaw on machine impedance
   → BBC is similar/the same as the TCTP from an RF point of view
   - don't expect surprises but needs official confirmation (A: E. Metral et al.)
3. Beam cleaning performance simulations (FLUKA)
   - to confirm: similar (physics debris) cleaning performance as TCTP
   - don't expect surprises but needs official confirmation
4. Wire-in-jaw robustness simulations (HiRadMat tests?)
   - to confirm: TCTP-BBC is as robust, or fails similarly as TCTP
5. Medium term action items that are not scheduled yet:
   - BBC prototype construction, pre-installation prototyping and HW integration tests (Lab-cycling, etc.)
Reserve slides
LHC-BBC Prototype – Proof-of-Concept after LS-1 I/II

Analysis: T. Rijoff & F. Zimmermann
LHC-BBC Prototype – Proof-of-Concept after LS-1 II/II

- Crossing angle with average separation of 12 (nom. LHC) → 7.1σ (LR-limited)

<table>
<thead>
<tr>
<th>Transverse position [σ]</th>
<th>Current A</th>
<th>Unstables Particles [%]</th>
<th>Minimum Radius [σ]</th>
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<tbody>
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**Table 4.14:** Summary of the stability test for TCT opt β, using nominal LHC optics and making the tests for different transverse positions and current values, crossing angle 12 σ.

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<tr>
<th>Transverse position [σ]</th>
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<th>Unstables Particles [%]</th>
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**Table 4.16:** Summary of the stability test for TCT opt β, using nominal LHC optics and making the tests for different transverse positions and current values, crossing angle 7.1 σ.

Analysis: T.Rijoff & F. Zimmermann
Physical Space IR5
Requires Horizontal BBC

reserved location IP → 105 m

Excluded by LR beam-beam simulations (thesis T. Rijoff)

Between Q4 and Q5

TCT and roman pots