LHC Beam-Beam Compensator Prototype

– Update –

Ralph J. Steinhagen

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

- Initial proposal based on to 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: \( \Delta \mu \approx 2.6^\circ \) (→ 3.1°)
- Symmetric beta-function: \( \beta_{x/y} \approx 1000 \text{ m} \) (for \( \beta^* = 0.55 \text{ m} \))

→ 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-\( \sigma \) level of hor./ver. position control
   - Nominal scheme: \( I = I_{\text{peak}} \cdot \sqrt{2\pi} \cdot \sigma_s \cdot n_{\text{parasitic}} = 72 \ldots 350 \text{ Am (max.)} \)
   - Pulsed wire to accommodate differences for PACMAN bunches → not practical at this stage → stick to DC compensation only
Proposed Prototype Layout after LS-1

- 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.

**ATLAS**

**Nominal Prototype**

**CMS**

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.

~105 m
Example: SPS Prototype Design

- Design functionally tested w.r.t. BPM response, integration etc.

- Main required modifications: wire-in-jaw, larger buttons → cable/water routing

Ch. Boccard et al. DIPAC’11, CERN-BE-2011-023 BI
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
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?
Summary and Status

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

- 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
  → After/in || wire-in-jaw prototype mods of existing TCTP design (A. Bertarelli)?

- Impact on machine impedance (E. Metral et al.)
  → BBC is similar/the same as the TCTP from an RF point of view

- Beam cleaning and robustness simulations (FLUKA) – not started yet, tbd.

- Medium term action items that are not scheduled yet:
  - Add. R&D and beam instrumentation
  - BBC prototype construction
  - Pre-installation prototyping and HW integration tests (Lab-cycling)
Reserve slides
LHC-BBC Prototype – Proof-of-Concept after LS-1 I/II
Crossing angle with average separation of 12 (nom. LHC) → 7.1σ (LR-limited)

<table>
<thead>
<tr>
<th>Transverse position</th>
<th>Current A</th>
<th>Unstables Particles [%]</th>
<th>Minimum Radius [σ]</th>
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<tbody>
<tr>
<td>HoLr</td>
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<td>14</td>
<td>237</td>
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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.

<table>
<thead>
<tr>
<th>Transverse position</th>
<th>Current A</th>
<th>Unstables Particles [%]</th>
<th>Minimum Radius [σ]</th>
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<tr>
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<td>7.1</td>
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<td>8.25</td>
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<tr>
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<td>237</td>
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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.
### LHC Long-Range Beam-Beam Compensator Planning

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
<th>FTE</th>
<th>Costs [kCHF]</th>
<th>Time [y]</th>
<th>Comments/Resources</th>
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<tbody>
<tr>
<td>1</td>
<td>Re-design and re-validation of TCT wire-in-jaw design</td>
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<td>Feasibility, material and vacuum compatibility tests</td>
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<td>EN-MME, BE-BI-ML (yellow)</td>
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<td>Evaluation of pick-up response and impact on machine impedance Impact on beam cleaning and robustness studies (FLUKA)</td>
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<td>EN-STI, 1 + 2 prototypes, tbc. (O. Aberle)</td>
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#### Total:

- Costs for 2013: 7.1 kCHF
- Costs for 2014/2015: 2.6 kCHF
- No contingency/delays included (e.g. SPS prototype)

**Primary Item:**
- Conditional activity, can only proceed if primary item is achieved.
- Parallel activity.

### Preliminary BBC Project Planning – DRAFT

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<td>Pre-inst. and HW Integration Tests</td>
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**Note:**
- Q3, Q4, Q1, Q2, Q3, Q4 indicate quarters of the year.
- LST: Preliminary Cost Estimates and Planning - DRAFT.
Physical Space IR5
Requires Horizontal BBC

reserved location IP → 105 m

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

TCT and roman pots

Between Q4 and Q5