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

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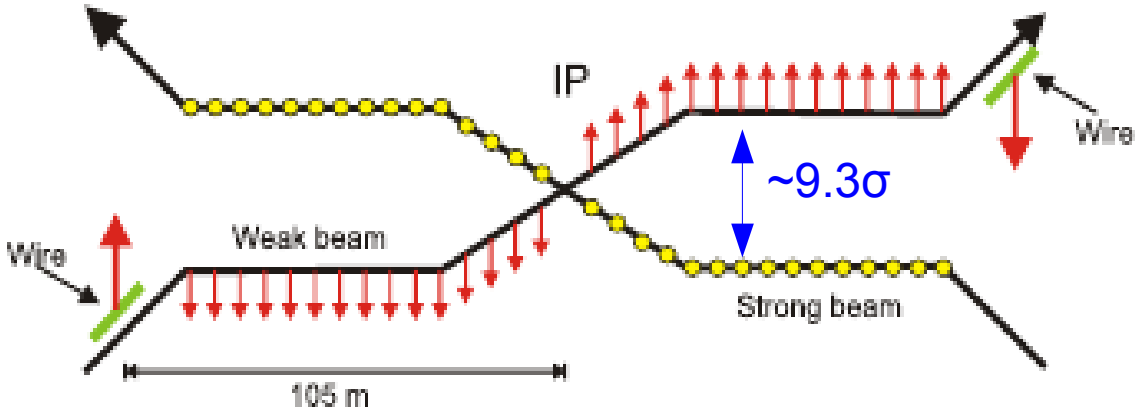
Motivation for Installing a BBC Prototype in the LHC I/II - Passed several Milestones

- 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

LHC Beam-Beam Compensators Specification I/III

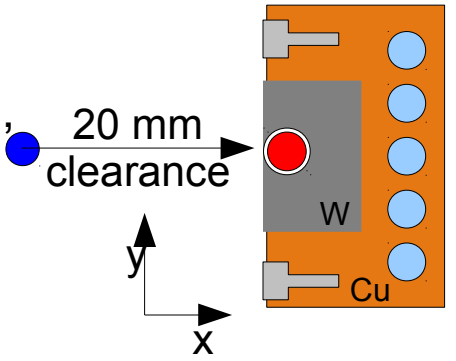
- Reservations around IR1&IR5, LHC-BBC-EC-0001:
  - Min. LRBB → BBC phase advance: $\Delta\mu \approx 2.6°$ (→ 3.1°)
  - Symmetric beta-function: $\beta_{x/y} \approx 1000$ m (for $\beta^* = 0.55$ m)

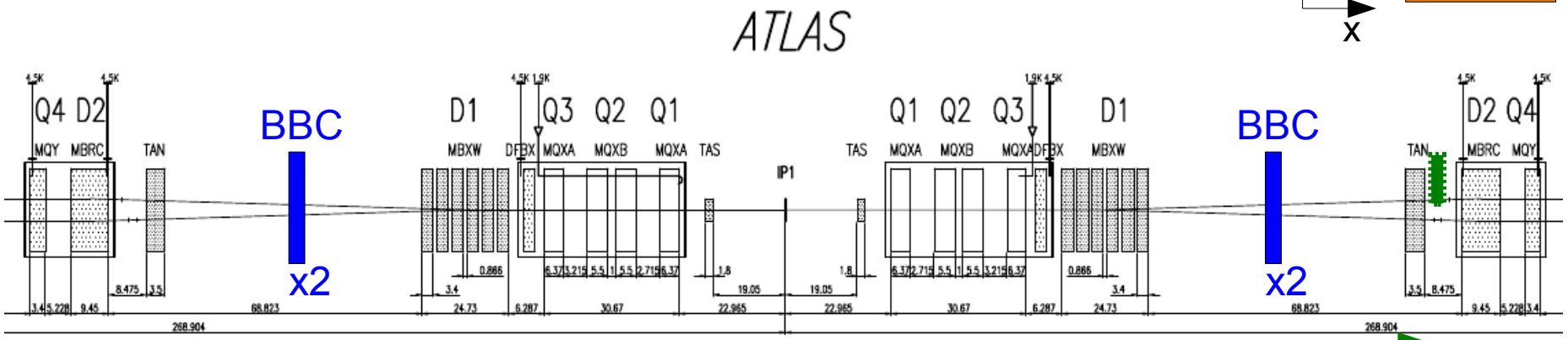
→ Prototype with nominal parameters not feasible during LS-1 (MPP, Cleaning,..).

- 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:
     BBC.B1-H augmenting TCL.xR1.B1 & BBC.B1-V aug. TCT(P).xL5.B1
  3. Wire parameters:
     - Solid wire radius of ~ 1mm → 1kW power dissipation
     - sub-σ level of hor./ver. position control
     - Nominal scheme: $I = I_{peak} \cdot \sqrt{2\pi} \cdot \sigma_s \cdot n_{parasitic} = 72 \ldots 350$ Am (max.)
     - Pulsed wire to accommodate differences for PACMAN bunches
       → not practical at this stage → stick to DC compensation only

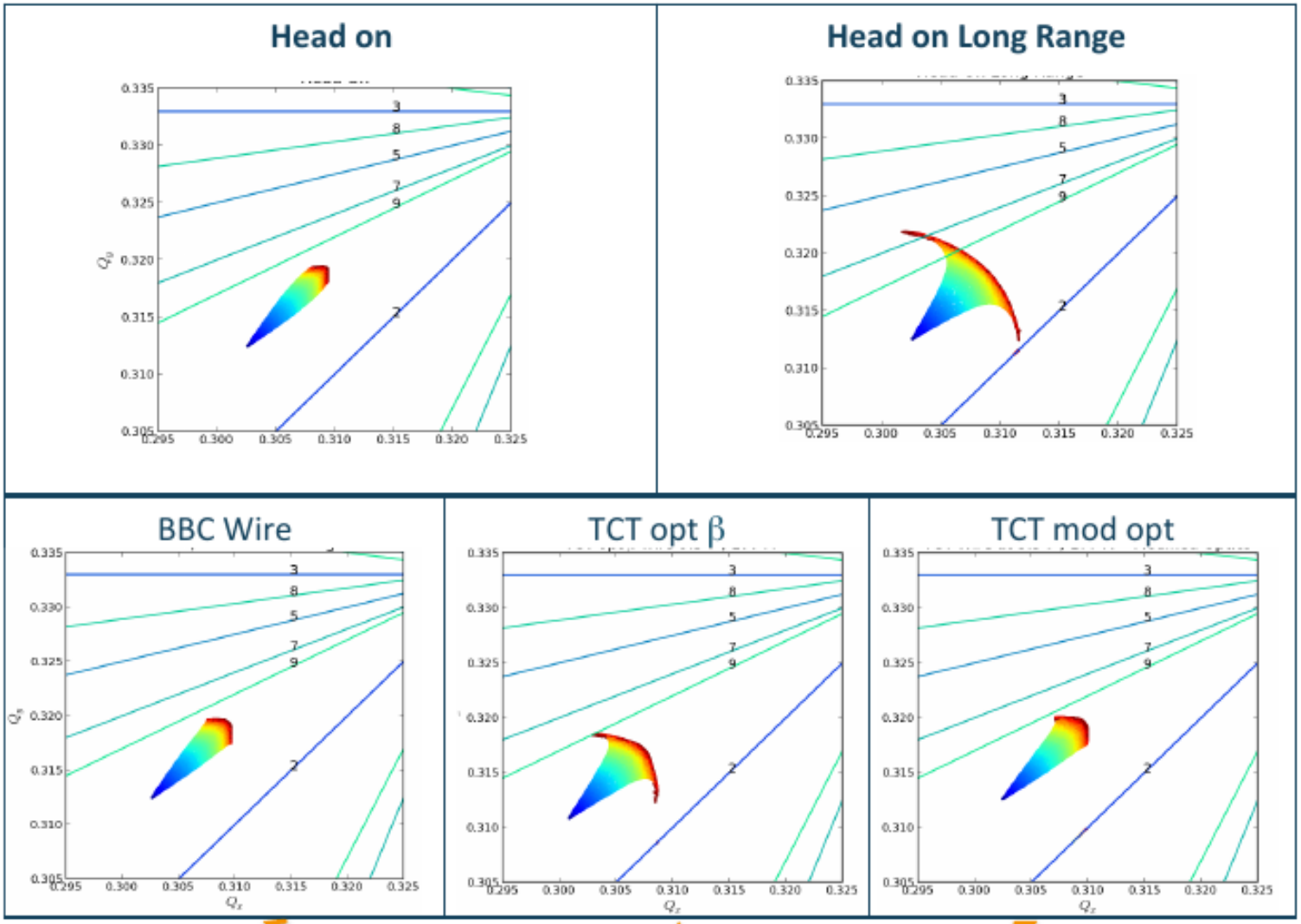
Proposed Prototype Layout after LS-1

- 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.





Long-Range Beam-Beam Compensator Prototype I/II
What can be demonstrated after LS-1

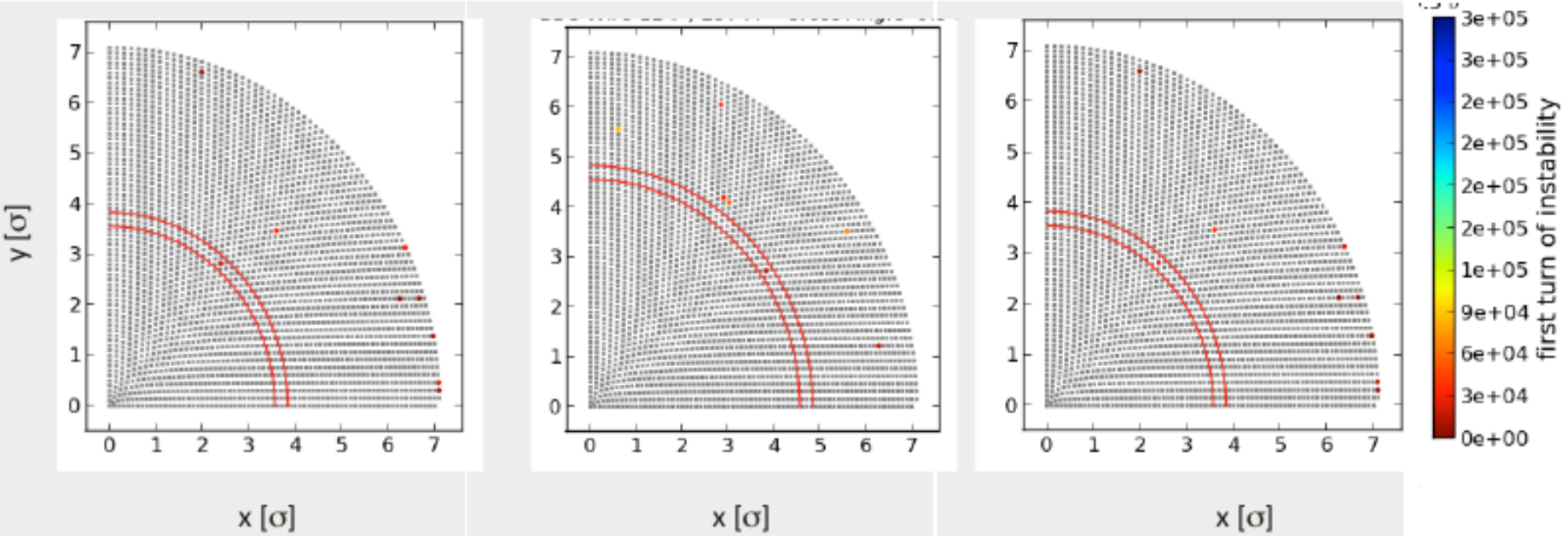


Wire at 9.5 σ – 177 A

Analysis: T.Rijoff & F. Zimmermann

Long-Range Beam-Beam Compensator Prototype II/II
What can be demonstrated after LS-1

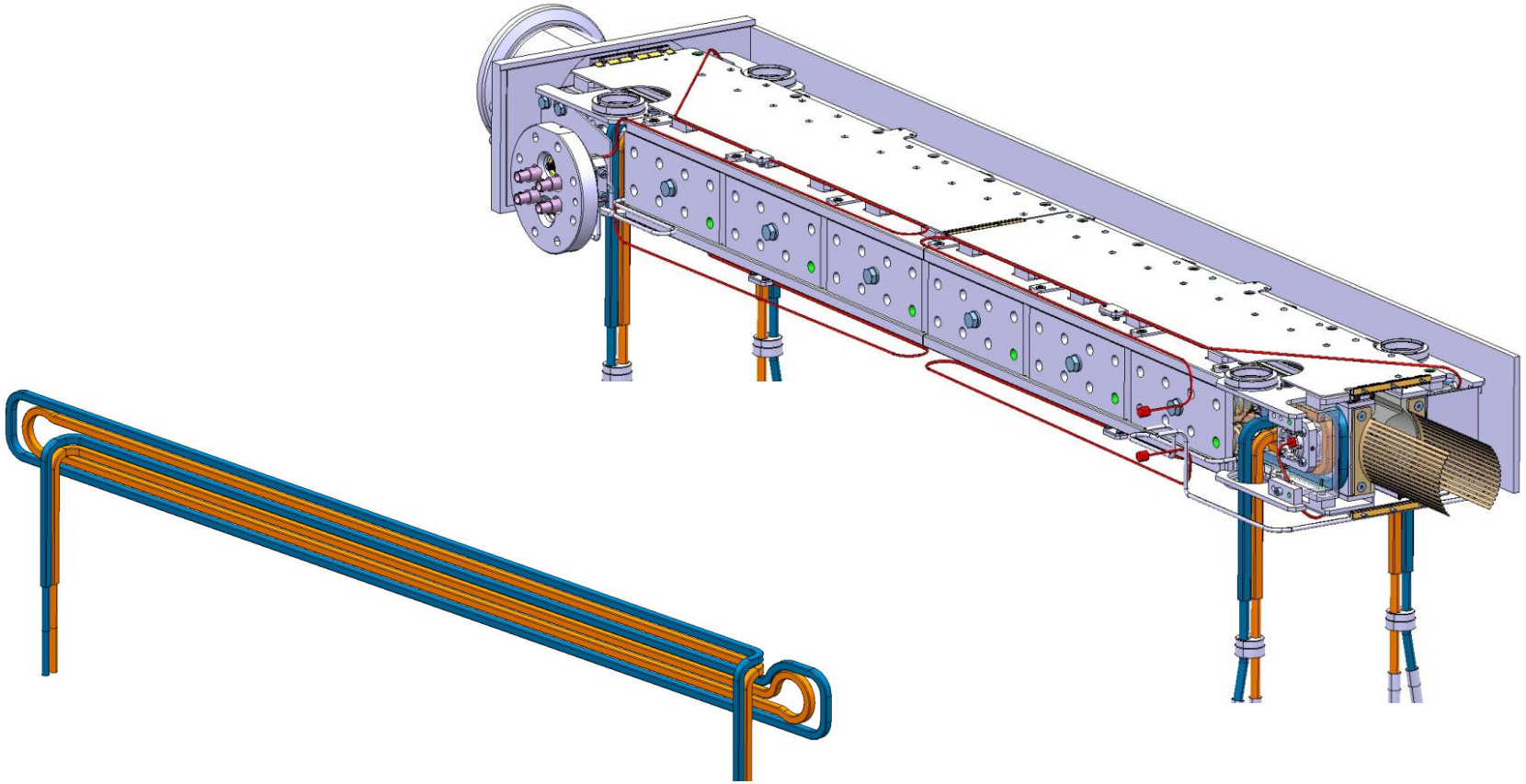
Cross Angle 12 σ	Cross Angle 9.5 σ	
HOLR	BBC 237 A 11σ	TCT opt β 237 A 11σ



12 σ without wire ⟷ 9.5 σ with the wire

Analysis: T.Rijoff & F. Zimmermann

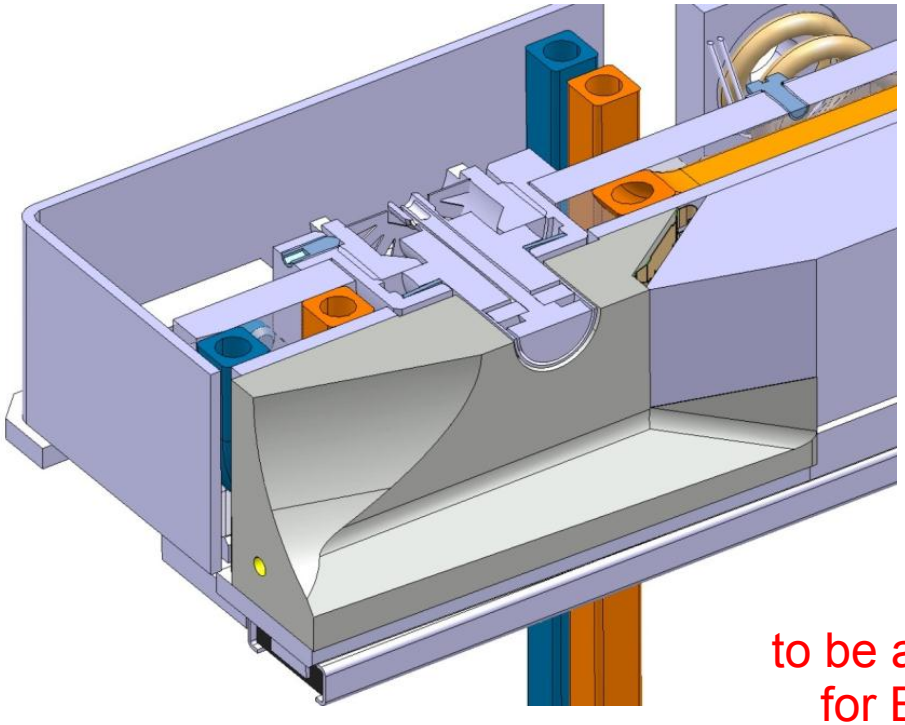
TCTP and Wire-in-Jaw Design I/II



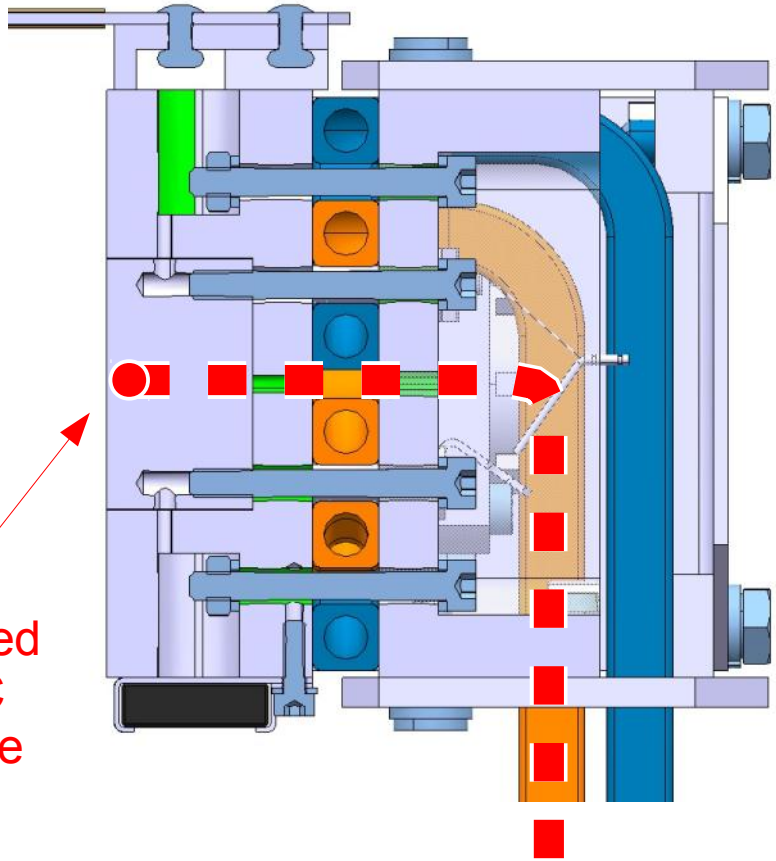
- Can re-use nearly 100% of existing TCTP design.
- Remaining challenge: finding space for the wire current feed-through amongst the cooling circuits and BPM button feed-throughs.

Courtesy Luca Gentini, EN-MME

TCTP and Wire-in-Jaw Design II/II



TCTP cross-section

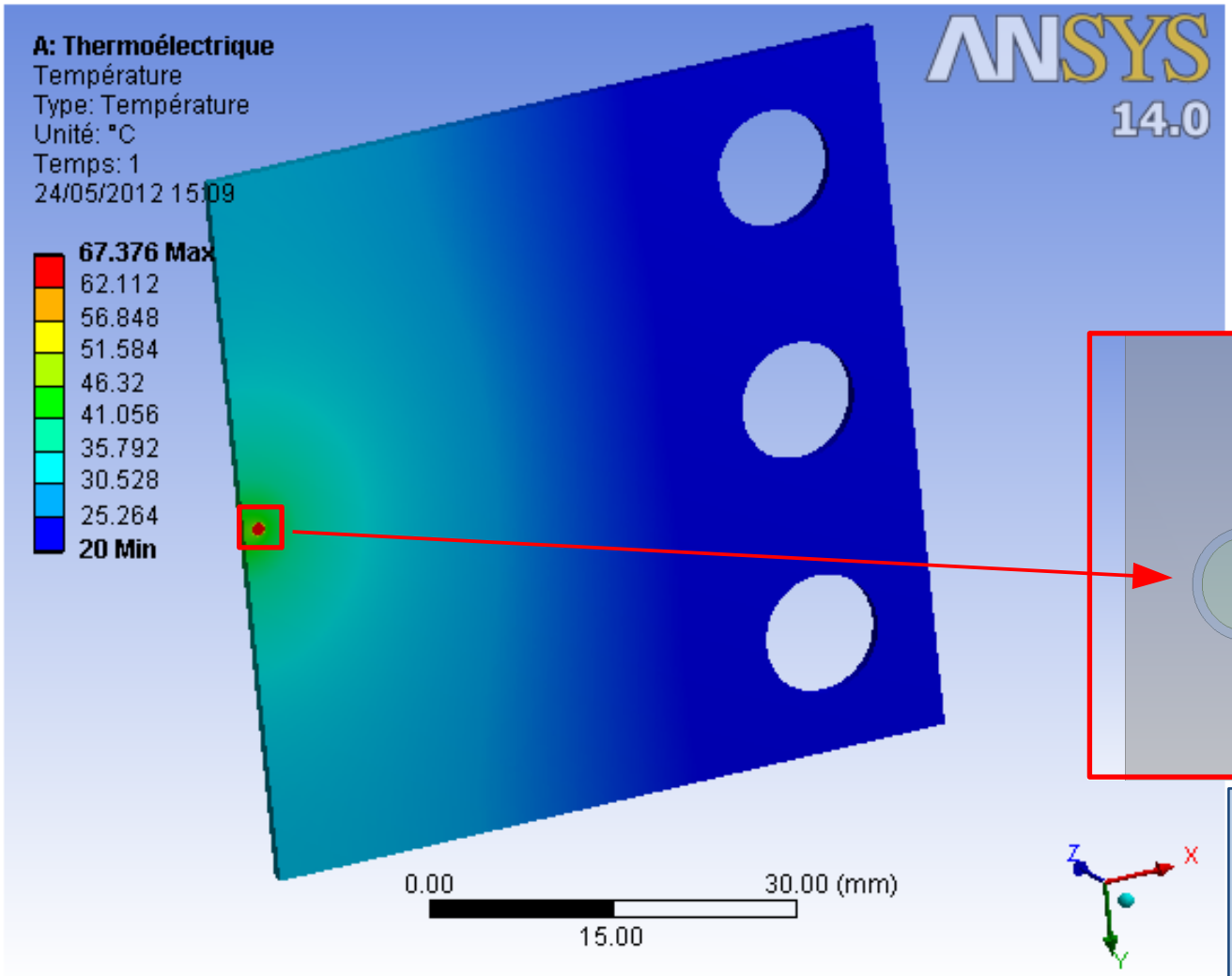


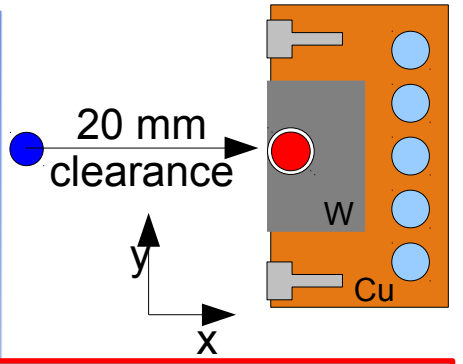
to be added for BBC Prototype

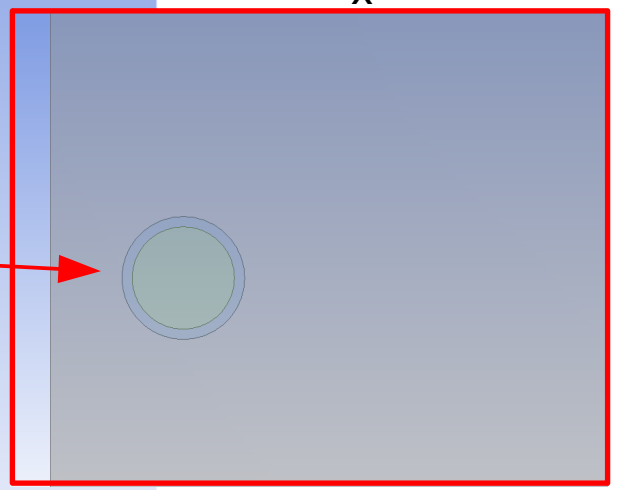
- Gretchen Frage: do we wait until the lab prototype tests are conclusive or do we start with the design/production right away in March?

Courtesy Luca Gentini, EN-MME

Preliminary Ansys Results (Axel Ravni, BI-ML) I/II



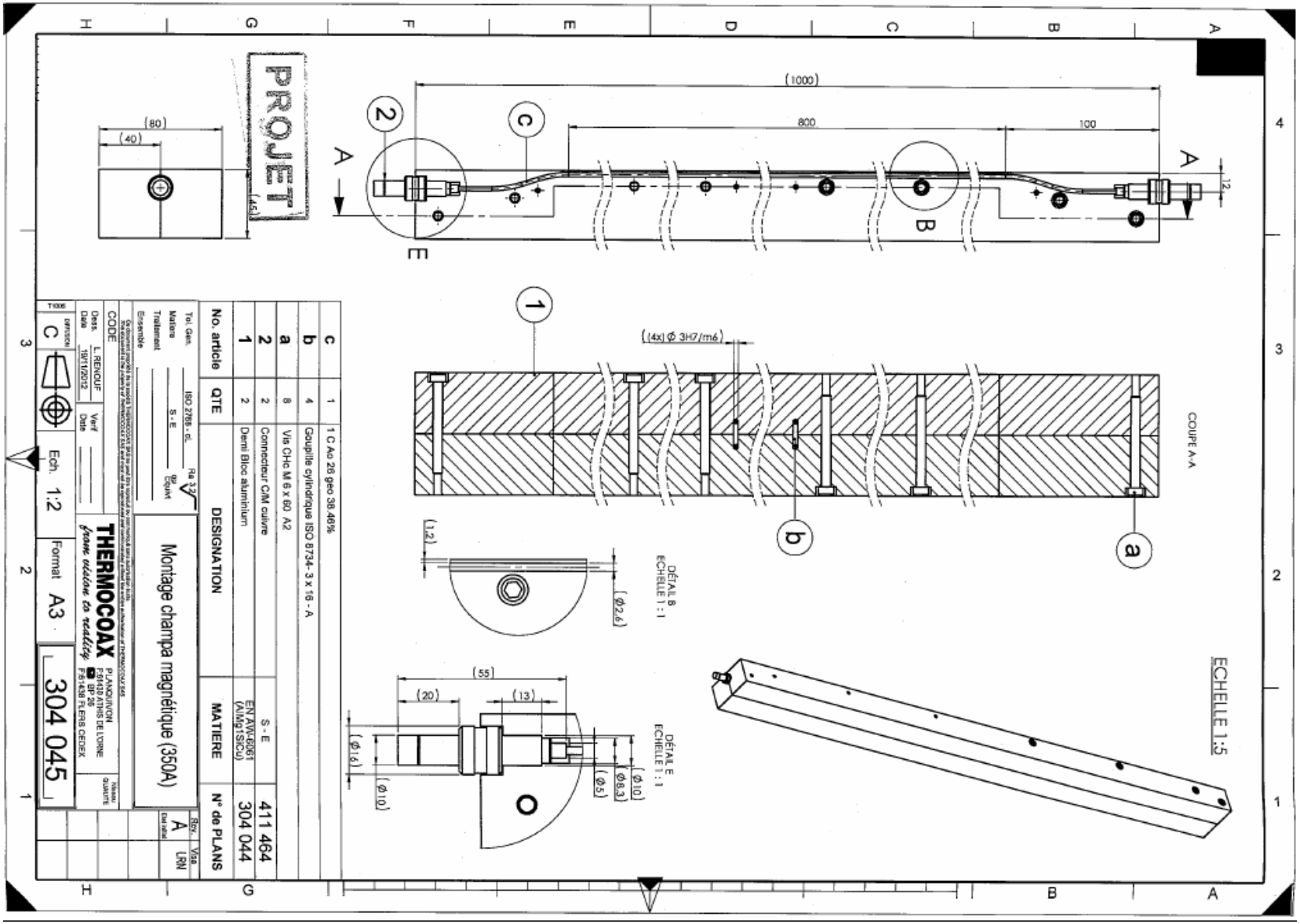




350 A through
Cu wire Ø=1mm
0.1mm Ceramic Insul.
Tungsten block
Cooling@20°C

Finite-Element and analytic estimates agree for given (perfect) conditions
to be further studied → more specific model and lab-prototype test in progress.

Proof-of-Concept: Wire-in-Jaw Embedding & Cooling using commercially available THERMOCOAX solution (A. Ravni)



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

Summary and Status

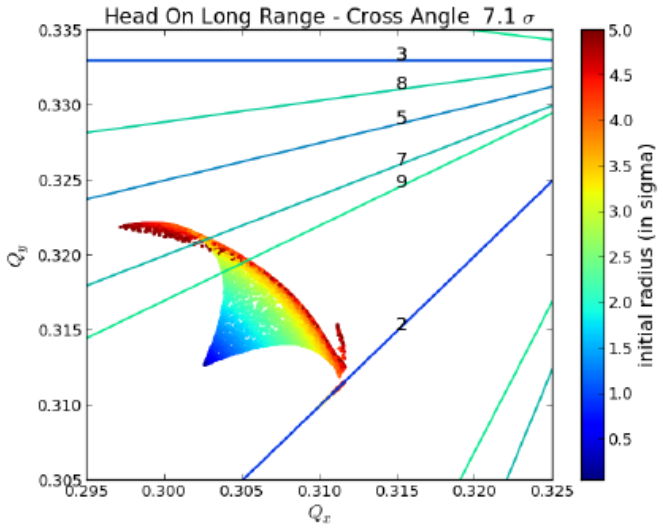
- Necessary technical infrastructure planned to be installed during LS-1 (powering, girders, water, cables, etc.) → ECR and integration in progress

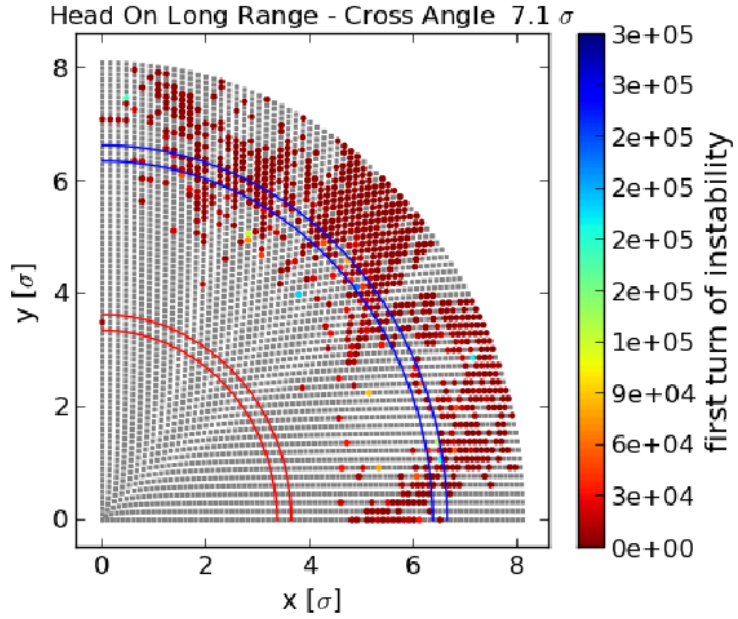
Next Steps:

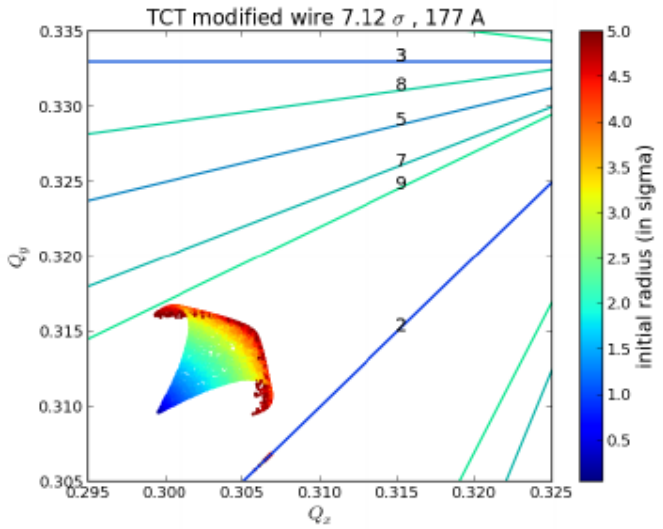
1. Mechanical feasibility, material and vacuum compatibility tests
   - mechanical and electrical constraints, vacuum compatibility
     → lab mock-up test to validate design (Axel Ravni, BI-ML) → March'13
     → In || wire-in-jaw integration into existing TCTP (HLTC A: A. Bertarelli)
2. Impact of wire-in-jaw 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.)

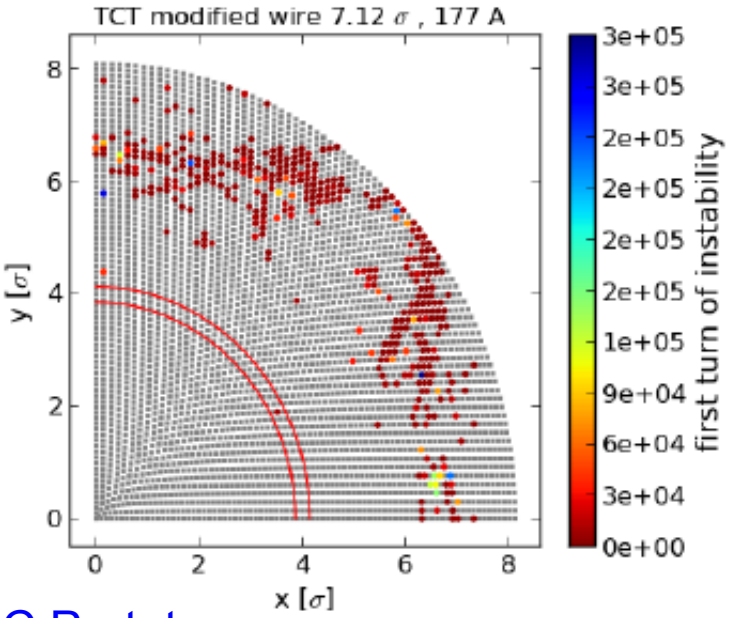
Reserve slides

LHC-BBC Prototype – Proof-of-Concept after LS-1 I/II









BBC Prototype

Analysis: T.Rijoff & F. Zimmermann

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

Transverse position [σ]	Current A	Unstables Particles [%]	Minimum Radius [σ]
HoLr		0	3.2
12	177	0	4.6
14	177	0	4.4
14	237	0	4.0

present LHC

Table 4.14: Summary of the stability test for TCT opt β, using nominal LHC optics and making the tests for differents transverse positions and current values, crossing angle 12 σ.

Transverse position [σ]	Current A	Unstables Particles [%]	Minimum Radius [σ]
HoLr		22	3.5
7.1	177	11	4.0
8.25	177	20	3.5
8.25	237	16	3.8

proof-of-concept

Table 4.16: Summary of the stability test for TCT opt β, using nominal LHC optics and making the tests for differents transverse positions and current values, crossing angle 7.1 σ.

Analysis: T.Rijoff & F. Zimmermann

Physical Space IR5
Requires Horizontal BBC