CERN Plan for Phase 2 Collimation

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ABP – LCU meeting

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Reminder: Constraints Phase 1

- Strict constraints in 2003 for phase 1 system:
  - Availability of working collimation system for beam start-up (2007 originally)
  - Robustness against LHC beam (avoid catastrophic problems)
  - Radiation handling (access for later improvements)
  - No modifications to SC areas (due to short time and problems with QRL)
- Compromises accepted:
  - Limited advanced features (e.g. no pick-ups in jaws).
  - Risk due to radiation damage for fiber-reinforced graphite (electical + thermal conductivity changes, dust, swelling, …). Kurchatov data shows factor 4-5 changes with irradiation in various important parameters.
  - Steep increase in machine impedance due to collimators.
  - Excellent cleaning efficiency, however, insufficient for nominal intensity.

The Phase 2 Path

- Due to LHC extrapolation in stored energy and predicted limitations in phase 1 system:
  The LHC collimation system was conceived and approved during its redesign in 2003 always as a staged system.
- Phase 1 collimators will stay in the machine and will be complemented by additional phase 2 collimators.
- Significant resources were invested to prepare the phase 2 system upgrade to the maximum extent.
- **Phase 2 does not need to respect the same constraints as the phase 1 system.**
- The challenge we put to ourselves: **Improve at least by factor 10 beyond phase 1!**

Constraints: Phase 2

- Strict constraints in 2003 for phase 1 system:
  - ~~Availability of wo[illegible]ing collimation syst[illegible] for beam start-up (2007 originally)~~
  - ~~Robustness agai[illegible] [illegible]astrophic problems)~~
  - ~~Radiation handling ([illegible] [illegible]provements)~~
  - ~~No modifications [illegible] areas (due [illegible] [illegible]t time and problems with QRL)~~
- Phase 2 constraints:
  - Gain factor ≥10 in cleaning efficiency.
  - Gain factor ≥10 in impedance.
  - Gain factor ≥10 in set-up time (and accuracy?).
  - Radiation handling.
  - Sufficient robustness, also against radiation damage.

Phase 2 Collimation Project

- Phase 2 collimation project on R&D has been included into the white paper, thanks to strong support by CERN top management :
  - We set up project structure in January. Key persons in place.
  - Budget requested and allocated.
  - Manpower request for white paper post sent.
  - We are gaining momentum. Emphasis now on technical progress…
- FP7 request EUCARD with collimation work package ColMat:
  - Overall marks very high (14.5/15.0). Budget reduced 25% (33% on average).
  - Expect that this will fly and make available significant additional resources (enhancing white paper money).
  - Remember: Advanced collimation resources through FP7 (cryogenic collimators, crystal collimation, …).
- US effort (LARP, SLAC) is ongoing and we are well connected (not reported here). Expect first basic prototype results before EPAC.

General Work Plan

- So far 8 meetings for phase 2 specification (R. Assmann). In parallel collimator design meetings going on in TS/MME (A. Bertarelli)
- Overall work plan:
  - Define general directions until July 08.
  - Prepare conceptual design until October 08.
  - Discuss conceptual design and organize project details in November 08.
  - Testing of hardware in 2009/10 (lab and beam tests).
- Time plan will be affected by start of LHC beam operation (highest priority to make phase 1 collimation system work).
- However, once LHC intensity is limited (see previous slides) time will be short (prepare now!).
- Note: Phase 2 locations in IR3 might initially be used for installing **temporary betatron cleaning** to live with electronics problems in IR7 (*study for combined betatron/momentum cleaning for LHC ongoing ➔ not reported here*).

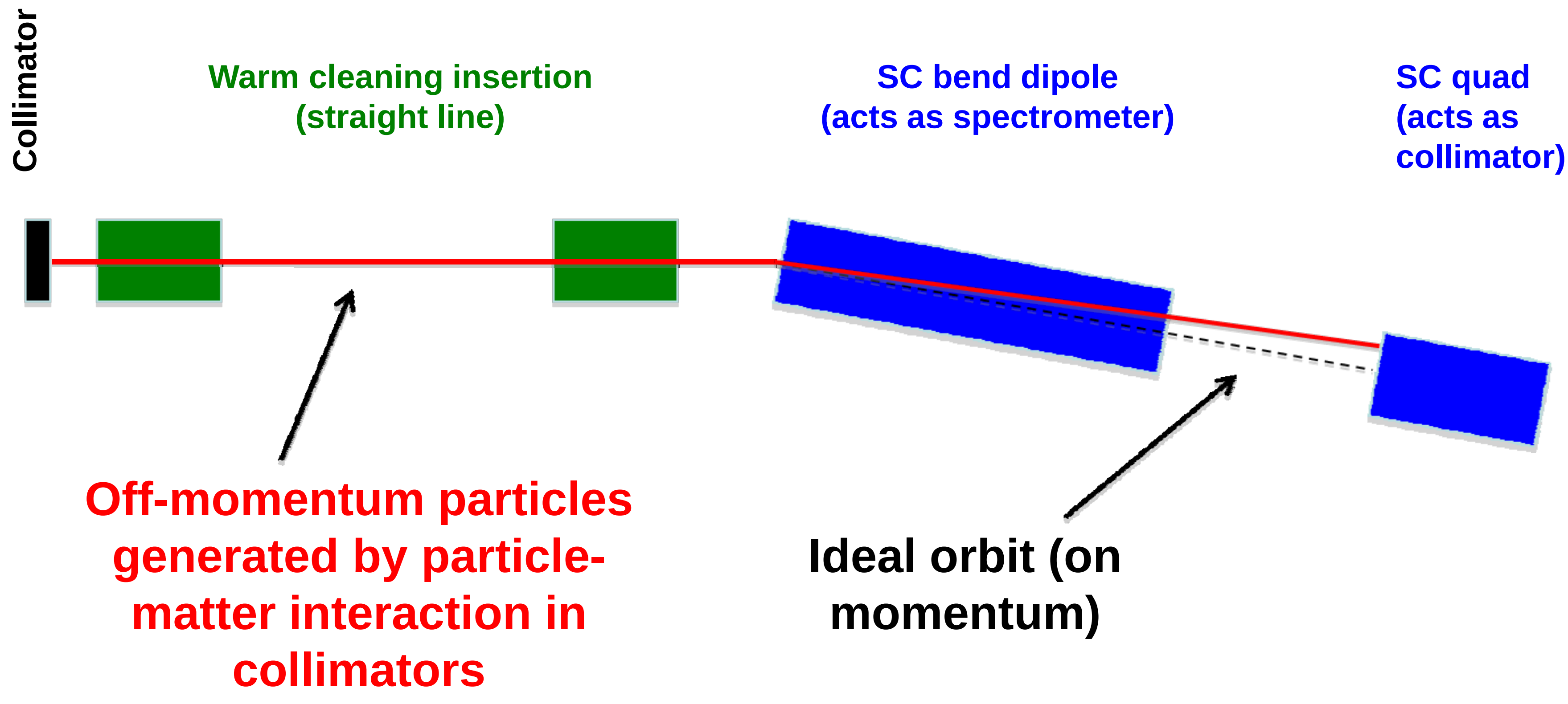
Concept to Realize Improvement on Phase 2 Timescale

- Factor 10 efficiency for protons and ions (idea&scheme R. Assmann/T. Weiler):
  - Place metallic, advanced phase 2 collimators (efficiency study by Chiara Bracco). 2-3 complementary development paths in CERN and US (SLAC rotatable design).
  - Place cryogenic collimators into SC dispersion suppressor (use missing dipole space).
  - Different material for primary collimators (to be evaluated).
- Factor 10 in set-up time (and accuracy?):
  - Integration of pick-ups into collimator jaws for deterministic centering of jaws around circulating beam. Support from BI group (R. Jones et al).
  - Gain accuracy due to possibility to redo for every fill (avoid reproducibility errors fill to fill).
- Factor 10 in impedance:
  - No magic material yet (factor 2 seems possible). Pursue further the various advanced ideas! Work by Elias Metral and Fritz Caspers. Tests ongoing.
  - Rely to some extent on beam-based feedback. Work by Wolfgang Hoefle.
  - Open collimators or use less collimators with improved efficiency (see above) and increased triplet aperture (phase 1 triplet upgrade), if feedback cannot stabilize beam.

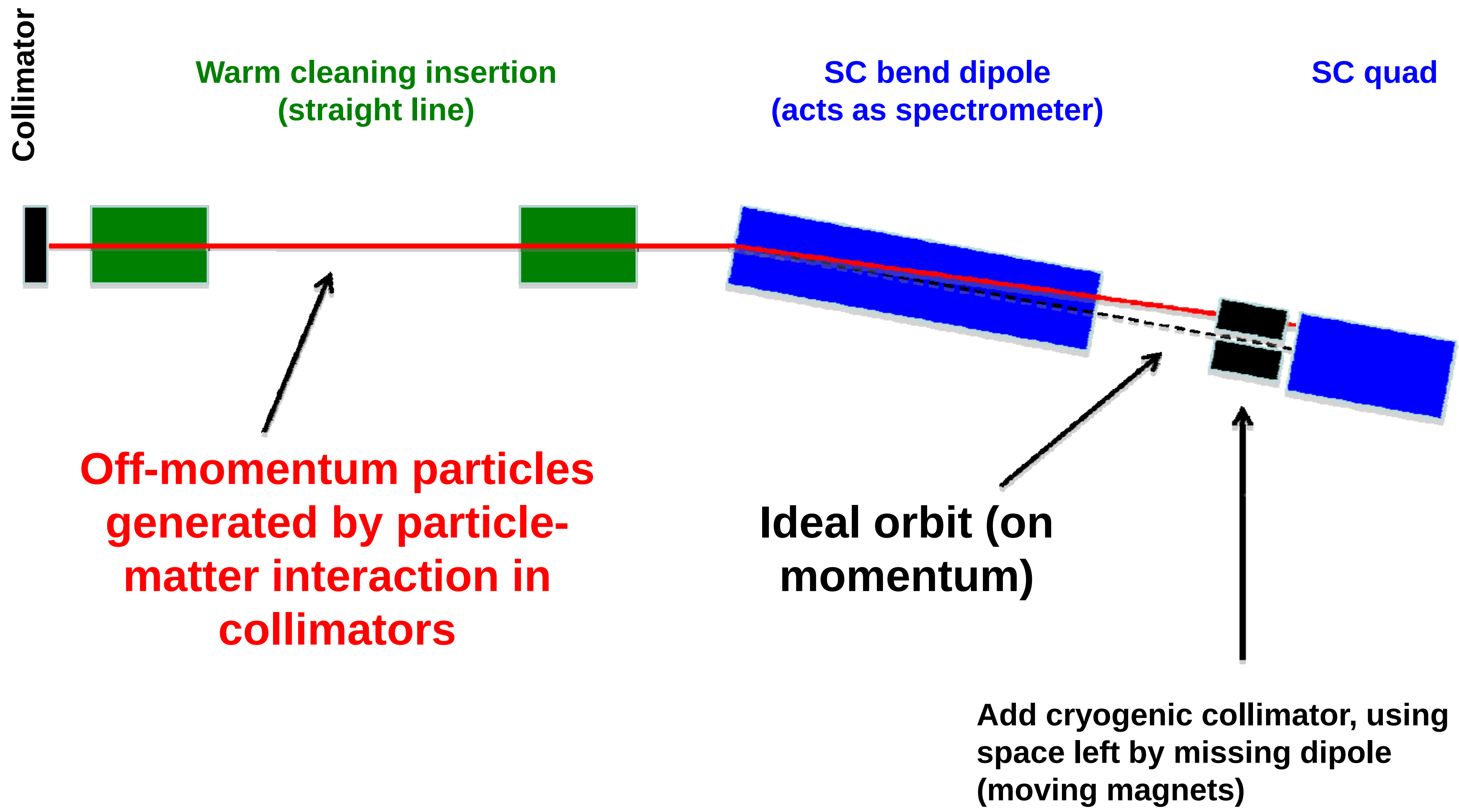
1) Concept for Improving Efficiency

- Fundamental problem:
  - Particle-matter interactions produce off-momentum particles in straight cleaning insertions (both p and ions). These are produced by different basic physical processes that we cannot avoid (single-diffractive scattering, dissociation, fragmentation).
  - No dispersive chicane after collimation insertion: Off-momentum particles get lost in SC magnets after first bend magnets downstream of straight insertion.
- Conceptual solution (no decisions taken – under study):
  - Reduce number of off-momentum particles produced (phase 2 primary and secondary collimators).
  - Install collimators into SC area, just before loss locations to catch off-momentum particles before they get lost in SC magnets.
  - Might be beneficial to install around all IR’s, for sure in IR3 and IR7.
  - Elegant use for space left by missing dipoles!

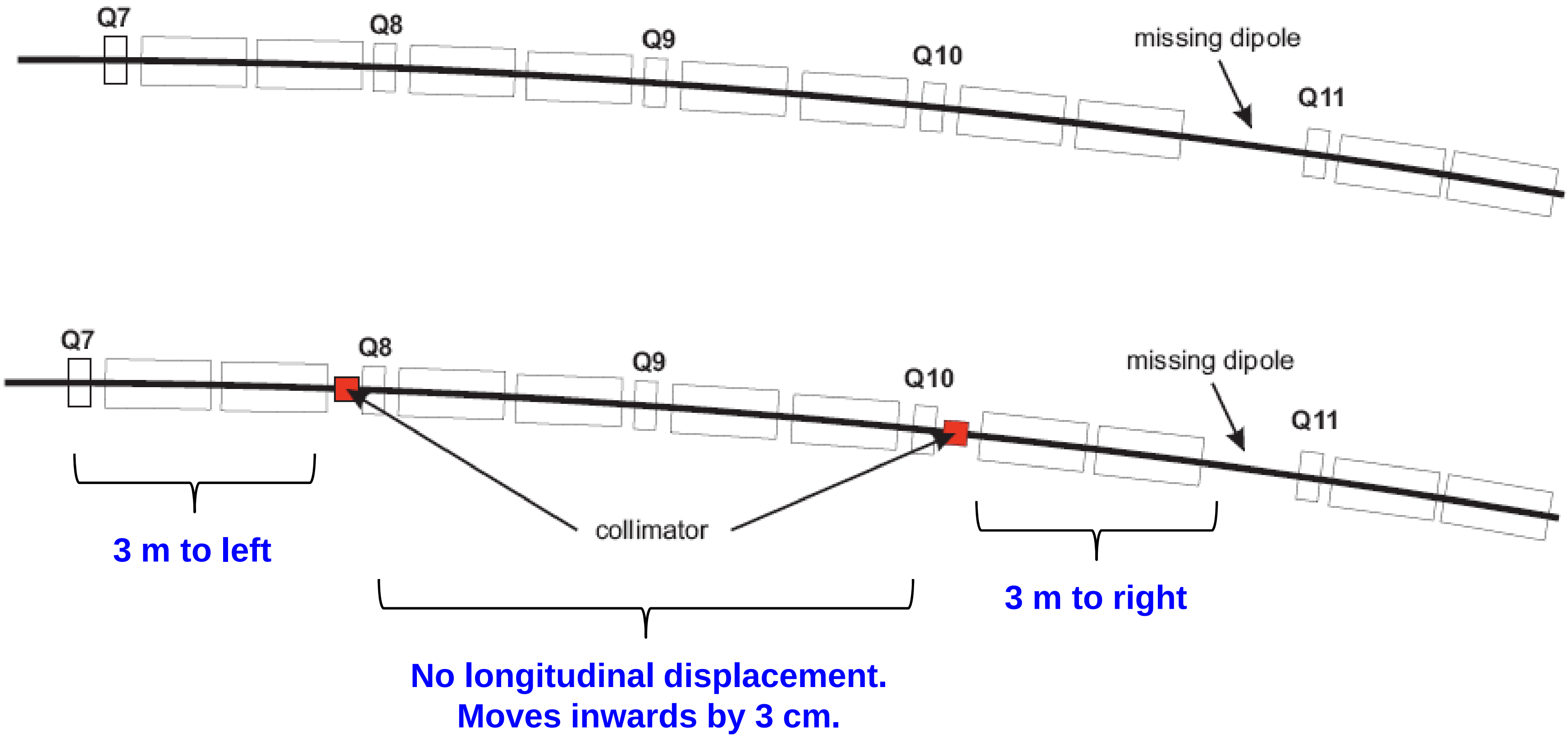
Schematic Solution Efficiency



Schematic Solution Efficiency

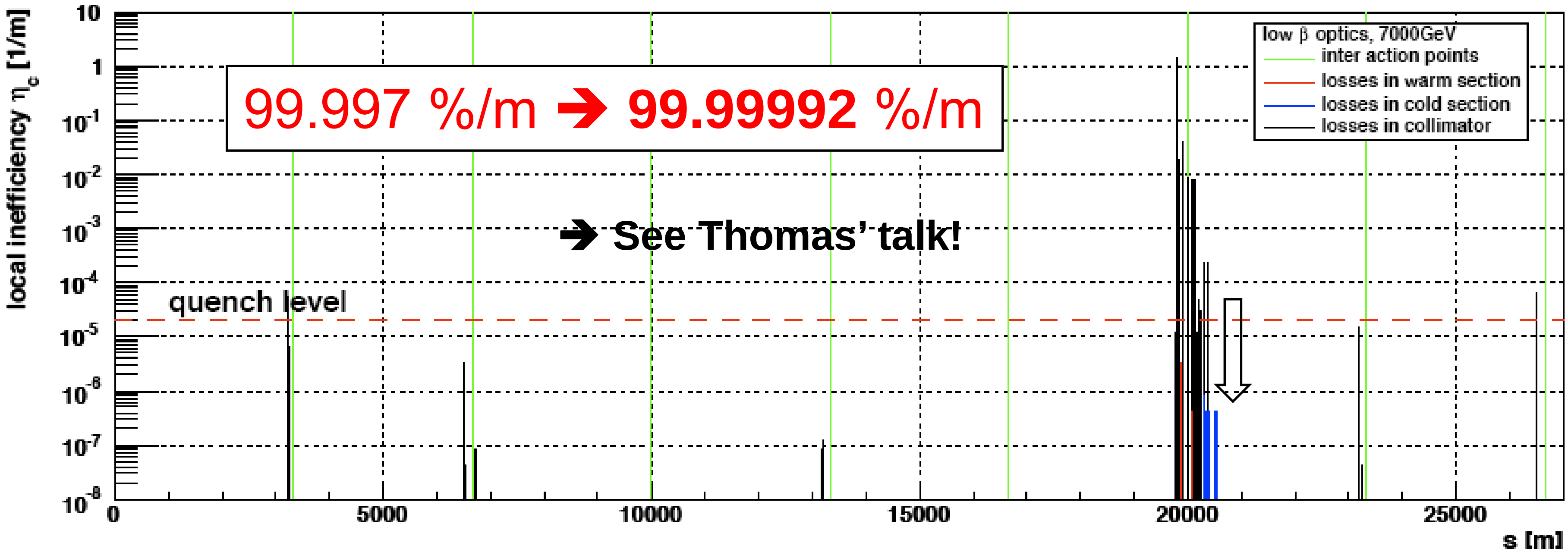


Change in Layout of DS



Layout and optics checked with MADX. No problem for the optics and survey seen. Optics change (move of Q7) small even without optics rematch. More careful work is required. Note, that impact on infrastructure was not checked yet!

Proton Collimation Efficiency with Phase 2 Cu Collimators and Cryogenic Collimators



Inefficiency reduces by factor 30 (good for nominal intensity). Lower losses in the experimental collimators (background). Should also work for ions.

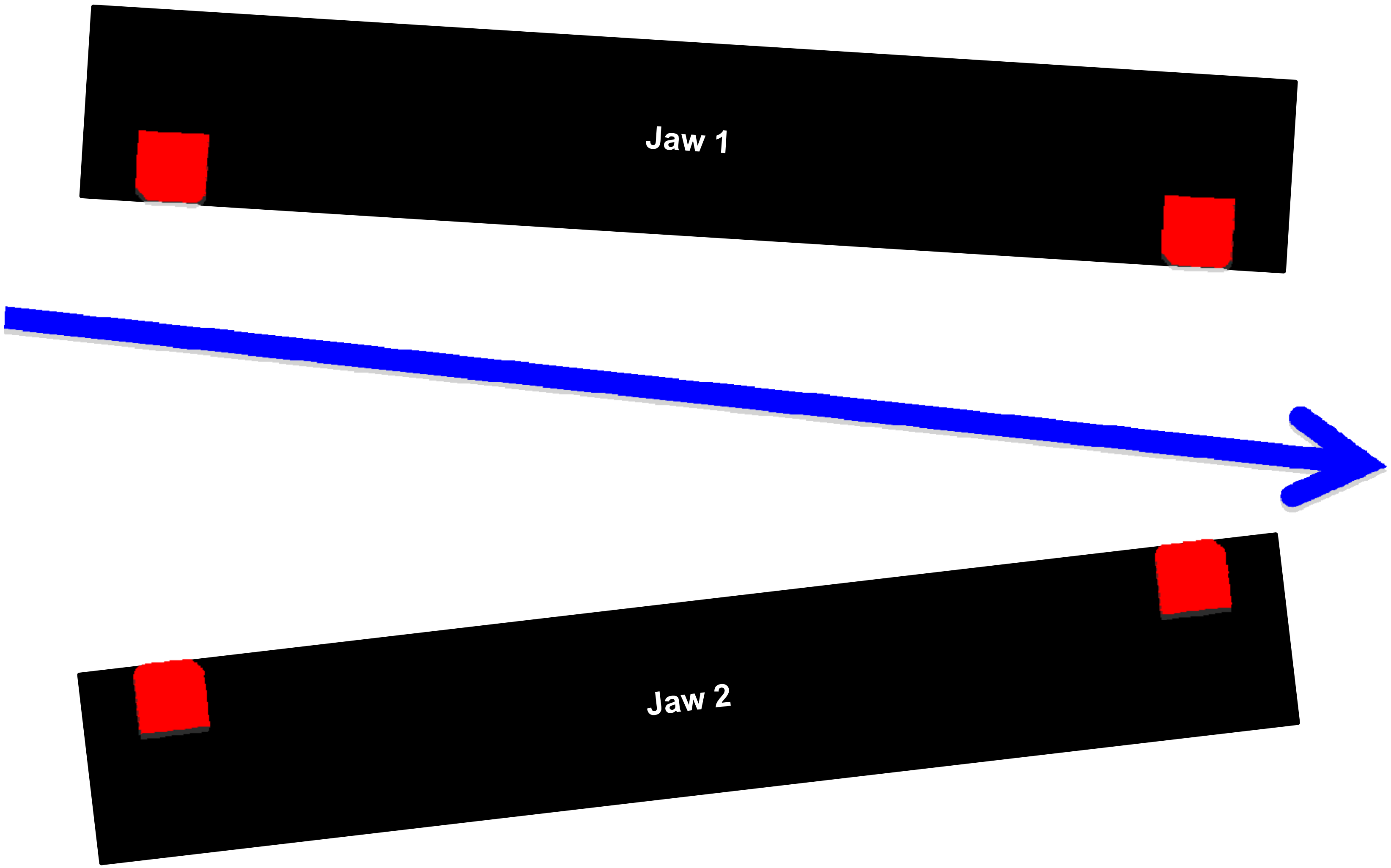
Caution: Further studies must show real feasibility of this proposal (energy deposition, heat load, integration, cryogenics, beam2, …). Just a concept at this point.

Cryogenic collimators will be studied as part of FP7 with GSI in Germany.

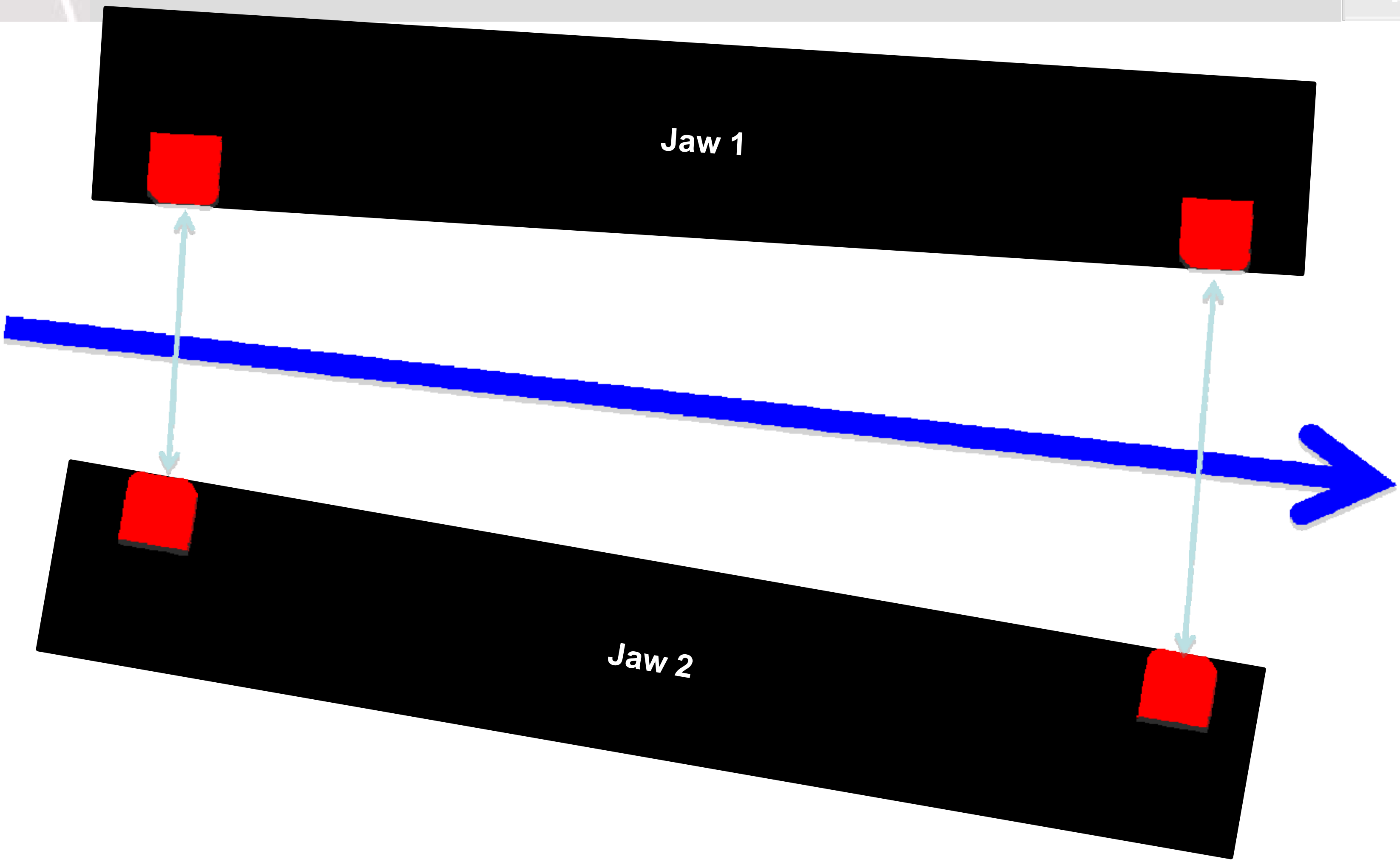
2) Concept for Improving Set-Up

- Standard method relies on centering collimator jaws by creating beam loss (touching primary beam halo with all jaws).
- Procedure is lengthy (48h per ring?) and can only be performed with special low intensity fills for the LHC.
- Big worries about risks, reproducibility, systematic effects and time lost for physics (integrated luminosity).
- Tevatron and RHIC must rely on collimator calibration and optimization performed at the start of each physics run.
- LHC can only do better if **non-invasive methods** are used (no touching of primary beam halo and no losses generated):
  - **integration of pick-ups and loss measurements into jaws.**

Schematic 1

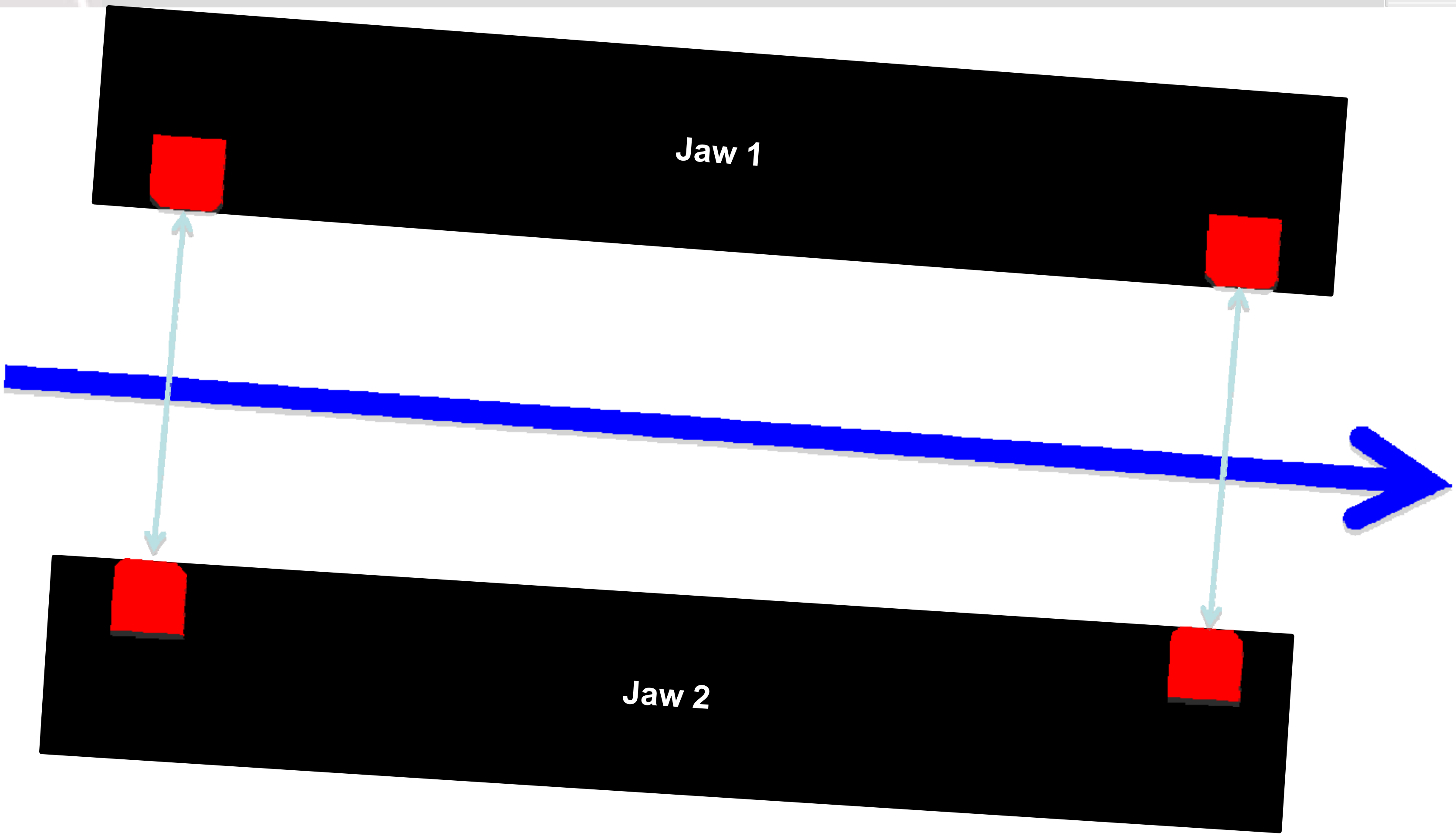


Schematic 2



1) Center jaw ends around beam by zeroing difference signal from pair of pickups (not touching beam halo ➔ no or very low losses.

Schematic 3

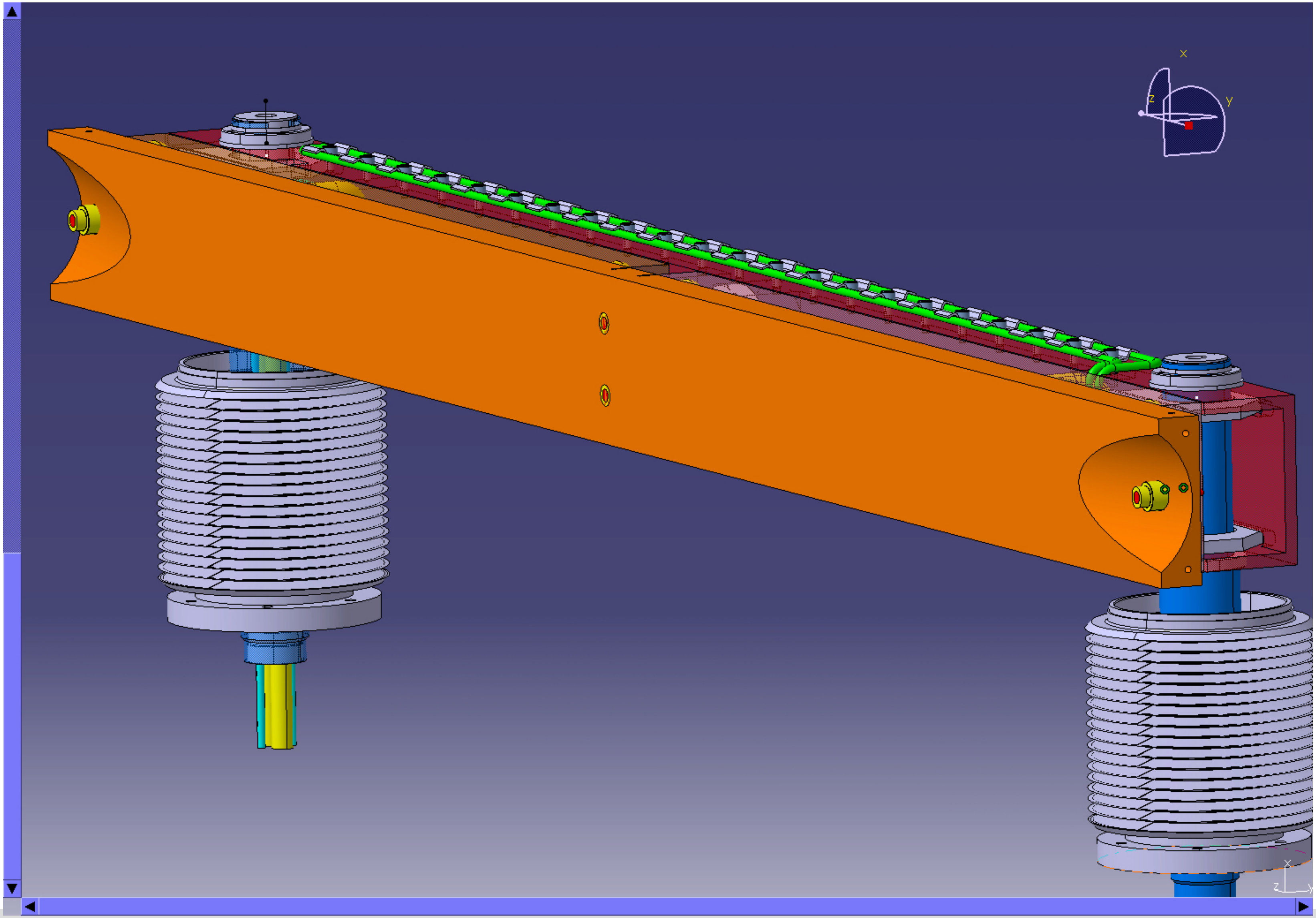


2) Put the same gap at both ends as measured from jaw position (phase 1 feature).

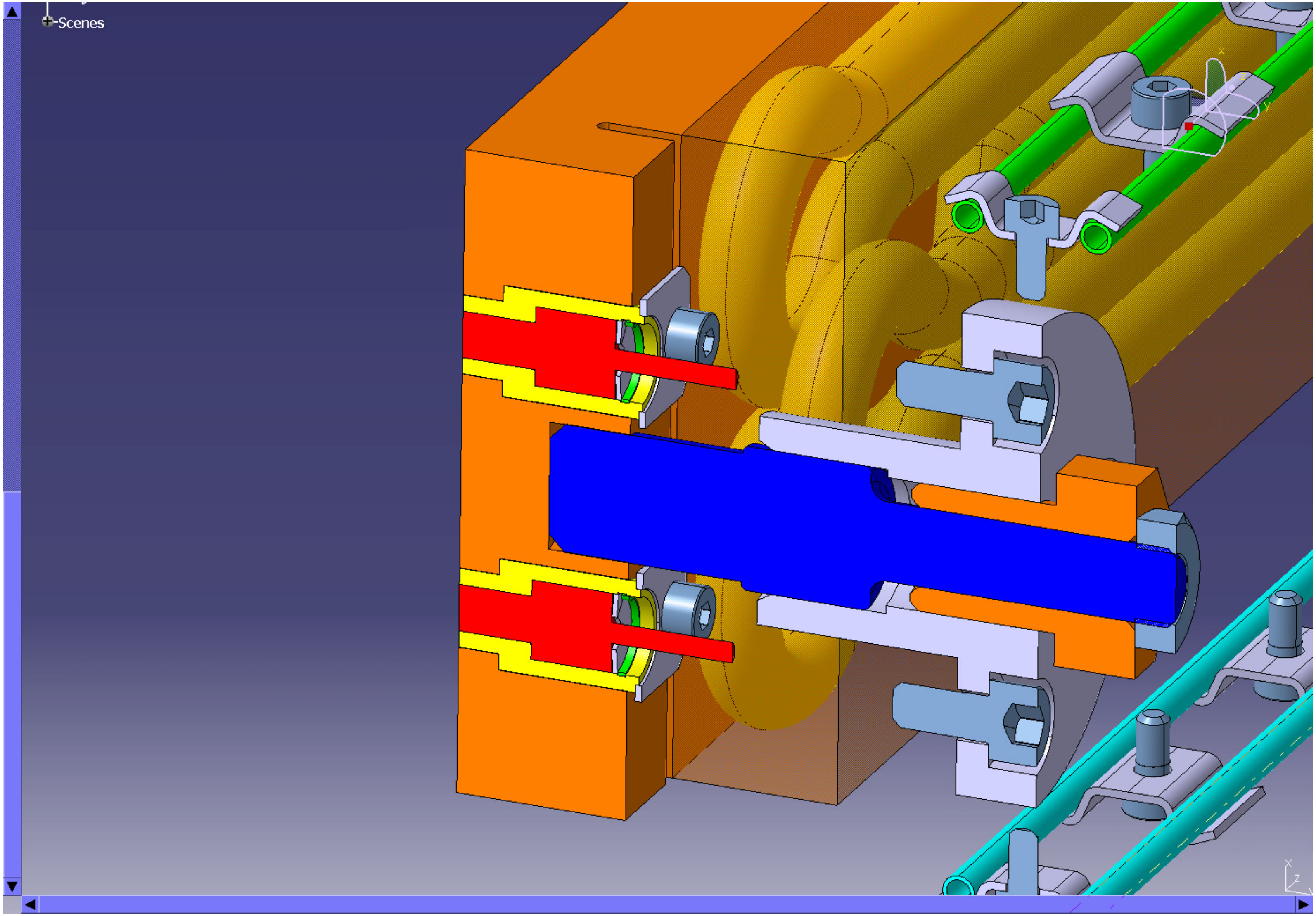
Collimator - BPM Study

- No time for detailed studies and simulations this year. Will start next year.
- In the meanwhile implement “best guess” electrodes into mechanical design.
- Crucial help from BI group (R. Jones et al). Engineering design driven by TS in phase 2 collimation project.
- Ansatz: Implement some reasonable buttons, build a prototype and test with beam how well it works (improve then with second generation design).
- Needed for high intensity: Should not be too difficult to reach much better accuracy than with collimator beam-based alignment method.
- Will still require knowledge of local beta function. Can in principle be evaluated with movable BPM buttons. However, chance to measure with global methods regularly (1000 turn small kicks).

Engineering Design for Prototype



Electrode Design



Improvements Beyond Phase 2

- We should not forget these advanced directions because we might need to have them at some point to advance LHC intensity.
- Time scale is beyond phase 2 collimation (2011/2).
- Several advanced directions have been proposed but are too early for starting engineering design now. They are pursued as longer term improvements:
  - Crystal collimation, waiting for successful results from Tevatron and SPS.
  - Non-linear collimation.
  - Hollow electron beam lens.
  - Laser collimation.
- Partly funded through FP7 proposal.

Conclusion Phase 2

- Within the last months we have gained quite a bit in knowledge: thanks to many colleagues for their support in very busy times.
- Based on this work we can hopefully **propose a big step forward for LHC collimation**, evolving the existing system with relatively modest modifications (no new magnets). Concept being evaluated for:
  - Factor 30 in efficiency (AP OK, check with energy deposition studies).
  - Factor 50 in setup time, some factor in accuracy.
  - Factor 2 in impedance, hope to stabilize with feedback, use increased aperture after phase 1 triplet upgrade, trade-off with efficiency.
  - Higher radiation robustness.
- Feasibility will now be addressed in more detail. The LHC tunnel is very constrained and we might encounter showstoppers.
- Important milestone: Review of conceptual design with parallel development paths in late autumn 2008.