Draft of Conceptual Phase 2 Collimation System Design

Phase 2 Specification and Implementation Meeting

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Introduction

- So far 5 meetings for phase 2 specification.
- Goal today: **Discuss where we are and define steps ahead to reach our ambitious goals** (factor 10 minimum improvement)!
- Overall time 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).
  - First report middle of June 08 for LHC Machine Advisory Committee.
- 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 (can be around 5-10% with imperfections) there will be huge pressure (prepare now!).

General Info

- Phase 2 collimation project (White Paper):
  - We are setting up official structure (Project Request Form sent and fully approved).
  - Budget codes requested. Should be there soon, I hope.
  - Manpower request for white paper posts.
  - All slower than hoped for but no fundamental problem…
- FP7 request EURCARD with collimation work package:
  - Overall marks very high (14.5/15.0).
  - Expect that this will fly and make available additional resources (enhancing white paper money).
  - Remember: Advanced collimation resources through FP7(cryogenic collimators, crystal collimation, …).

This I3 selectively addresses some of the most critical S&T topics for advanced accelerators, thus laying the groundwork for decisions to be made on future European and Global accelerators in the next 5 years. The concept is sound and the quality of the objectives is world leading. The activities in the framework of this proposal are a useful, more technical complement to FAIR-PP, SLHC-PP, ILC-PP, Hi-GRAD and EuroNu-DS. The proposal brings together all the leading European laboratories, and will reinforce and expand existing collaborations.

The RTD activities will lead to clear progress beyond the state-of-the-art. These include, for example, prototyping next generation accelerator magnets of ~20T field, of a hybrid Nb3Sn + High-Tc superconductor design, which the Panel considered to be the strongest component of the JRA. It is also gratifying to see a concerted effort within this proposal in normal-conducting RF structures, now that CLIC has been redesigned for X-band, thus allowing the considerable technology investment of the world-wide high energy physics community over the past two decades to be leveraged.

The proposal methodology is well-tailored to its objective to shape and inform intermediate-term decisions on future accelerators; it reflects the priorities of the CERN Council for high energy physics, and the ESFRI roadmap more broadly for the accelerator needs of nuclear science and light sources. The JRAs were thus selectively chosen and given precedence over NA and TA activities; and the ongoing R&D investments of the participating labs are highly leveraged.

The Networking activities were deliberately minimal, in order to focus on RTD work. The NAs were topically appropriate, focusing on neutrino facilities, accelerators and colliders, and RF technologies. Importantly, the NAs also reach out and link with other EU initiatives, and global forums and partners, as the next generation of great accelerator facilities will require a world-wide effort.

The Transnational Access activities were also deliberately minimal, restricted to four facilities of high value to the JRA: the magnet test facility, and a high-power beam facility for materials testing, both at CERN; the DESY Tesla Test Facility; and the muon cooling facility at RAL. The TA component will facilitate access for smaller EU institutes to leading-edge test facilities which are unique in the world.

FP7 Review of EUCARD Proposal Part 1

Responsibility for the management (WP1) resides with CERN, which has long-standing experience in the organisation of large, international collaborations. The partners are the leading EU accelerator labs plus a number of institutes with experience in the relevant fields or who joined recently in the effort. Especially welcome is the participation of industrial firms. The proponents have reached out and involved a large number of non-EU institutions, which will lay the groundwork for a long-term collaborative relationship, when hopefully some of these future facilities enter project construction phase.
The consortium is well above the critical mass. Responsibilities and work are well-distributed over the institutes and the EU.

A near-term technical impact of this work will be to facilitate the luminosity upgrade of LHC. Later, this work will optimally shape and inform decisions to be made within the time-frame of FP7 about future European and Global accelerator infrastructures. In particular, it may provide a critical catalytic effect for starting the ILC, once the LHC provides some insight about the TeV-scale physics landscape. The impact of this work will also be felt in other fields, particularly x-ray FELs, an increasing number of which are under construction or on the drawing boards around the world. More broadly, this I3 would link nearly all labs in EU which perform accelerator R&D. The large labs have already been well-connected, though this bonding has not been as strong as it could be, as possible synergies have been difficult to discern so far. A number of possible synergies have been taken up within this proposal, apparently under the impetus of the ESGARD Committee. The proposal has the merit to first strengthen the bonding in the fields with potential synergies, and second to include also the smaller institutes and to give them facilitated access to a number of leading-edge facilities, which is important (WP5-7). This will improve the structure in the field of accelerator R&D.

The Panel recommends that R&D on high-field magnets (WP8) are given highest priority. There is considerable potential for cost-savings in the superconducting RF work (WP11) which is requesting the lion's share of the EC funding.

There are two non-EU partners in this proposal:
The Russian Research Center "Kurchatov Institute" (RRC KI), which will contribute to studies of materials under thermal shocks; and the Budker Institute of Nuclear Physics (BINP) that will carry out beam dynamics simulations. The Panel agrees that both these institutes are making unique and high -value contributions to this proposal, and thus their participation is well-justified.

This proposal builds upon a successful I3 project under FP6. The present proposal makes a clear case that this collaboration should be continued and even expanded. In view of the need to achieve long-term sustainable integration of the infrastructures and services offered, the participants should urgently set out to develop lasting structures based on mutual interest, which will allow them to increase the efficiency of their own scientific activities as well as the services they offer to the user community. Activities with this aim should figure prominently in the description of work to be agreed during negotiation. The EC funding for the current proposal should clearly focus on a sustainable integration and on reaching a stronger commitment of the public authorities linked with the participating institutes and/or user communities, allowing a growing independence of external EC funding.

➔ So far very good news for EUCARD and collimation in FP7.

FP7 Review of EUCARD Proposal Part 3

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, …).
  - 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.
- However, we should not constraint ourselves to the preparations (number of cables, dimensions of support, collimators to be improved). This can be modified!
- **Phase 2 does not need to respect the same constraints as the phase 1 system.**
- Challenge: **Improve at least by factor 10 beyond phase 1!**

Constraints: Phase 2

- Strict constraints in 2003 for phase 1 system:
  - Availability of wo[illegible] collimation syst[illegible] for beam start-up (2007 originally)
  - Robustness agai[illegible]atastrophic problems)
  - Radiation handling [illegible]rovements)
  - No modifications [illegible]C areas (due to [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.

My view: There might still be initial resistance to change SC machine areas! However, cannot justify intensity limitations!

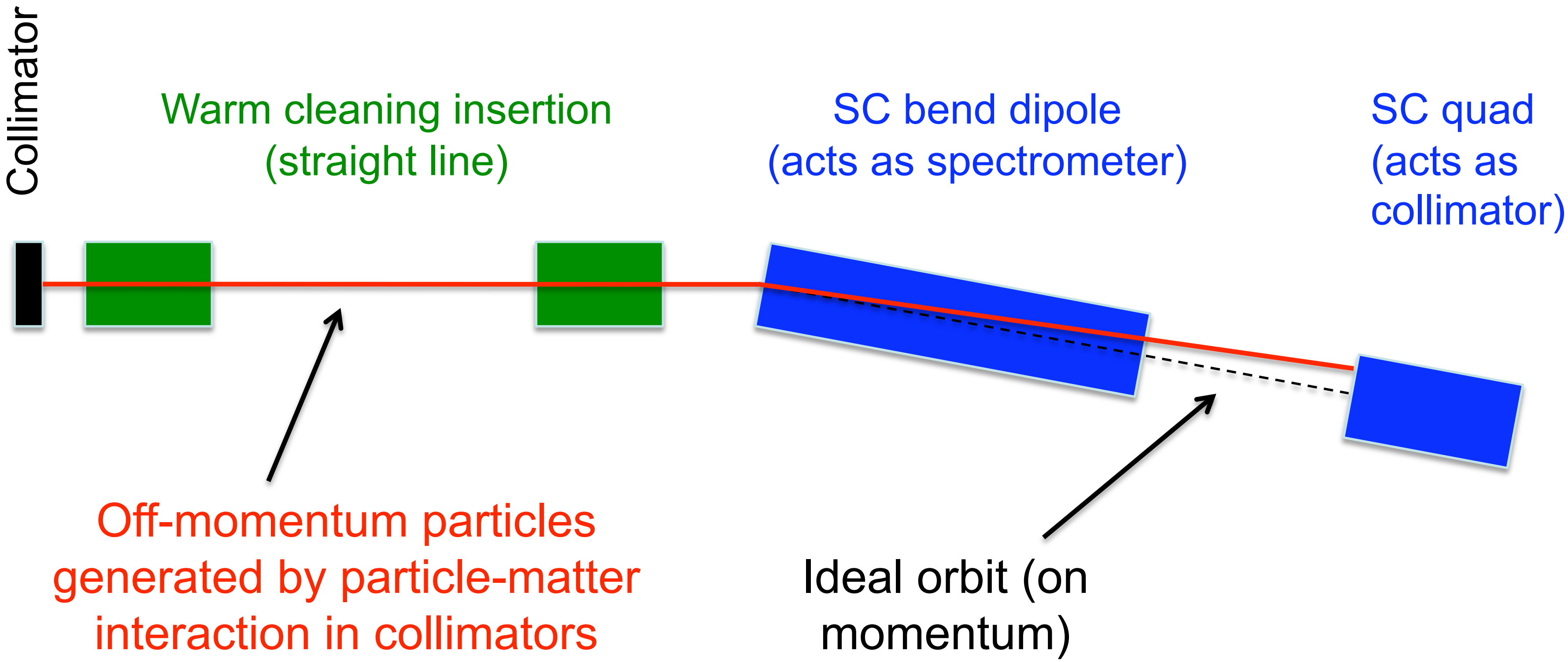
Concept to Realize Improvement on Phase 2 Timescale

- Factor 10 efficiency for protons and ions (see work Thomas/Ralph):
  - Placement of phase 2 collimators (not sufficient, see talk by Chiara Bracco).
  - Placement of cryogenic collimators into SC dispersion suppressor (make use of 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 (see minutes collimator design meeting phase 2).
  - 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 ideas! See talks by Elias Metral.
  - Rely to some extent on beam-based feedback. See talk Wolfgang Hoefle.
  - Open collimators or use less collimators with improved efficiency and increased triplet aperture (phase 1 upgrade), if feedback cannot stabilize beam.

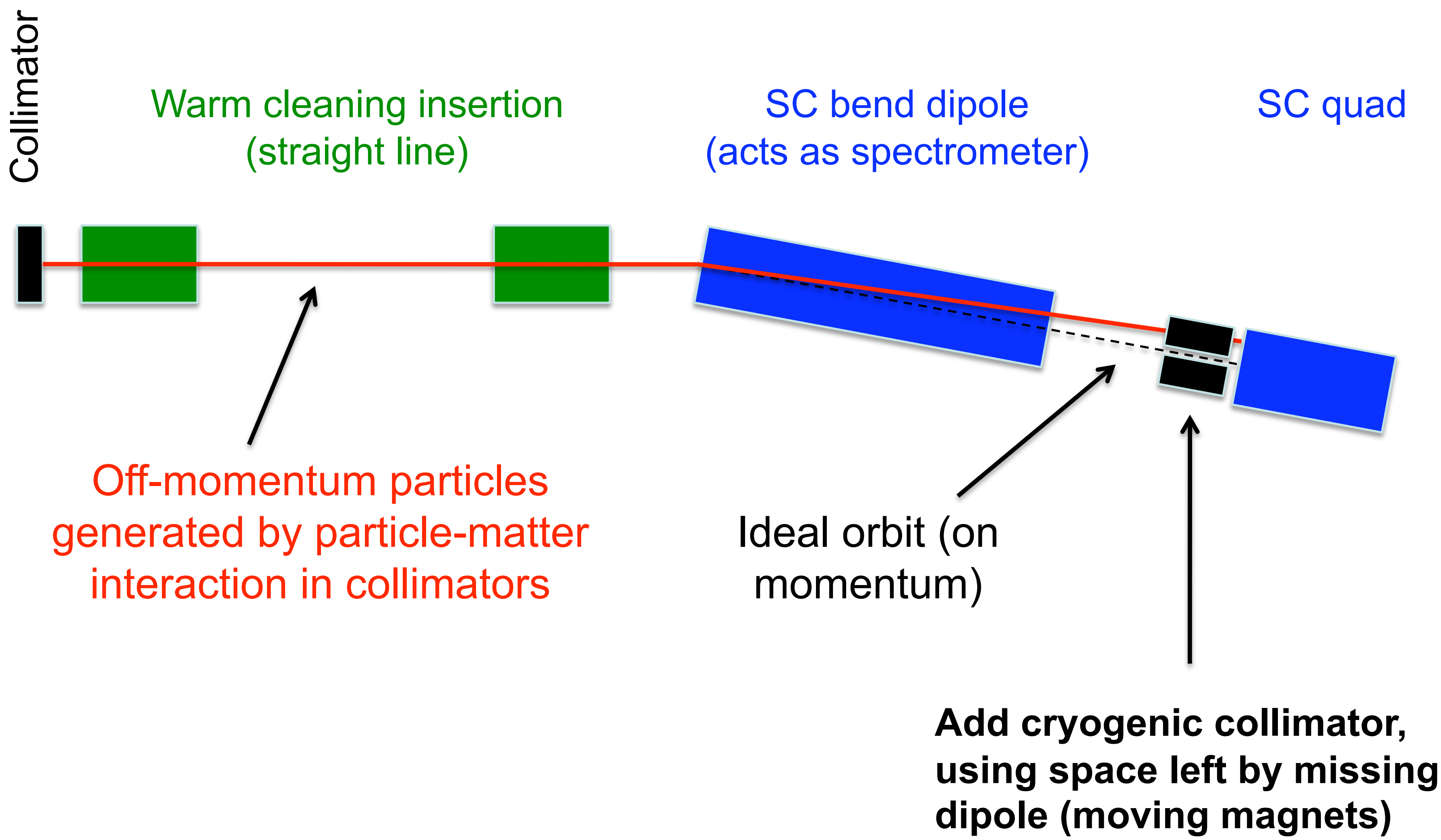
1) Concept for Improving Efficiency

- 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.
- Solution:
  - 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



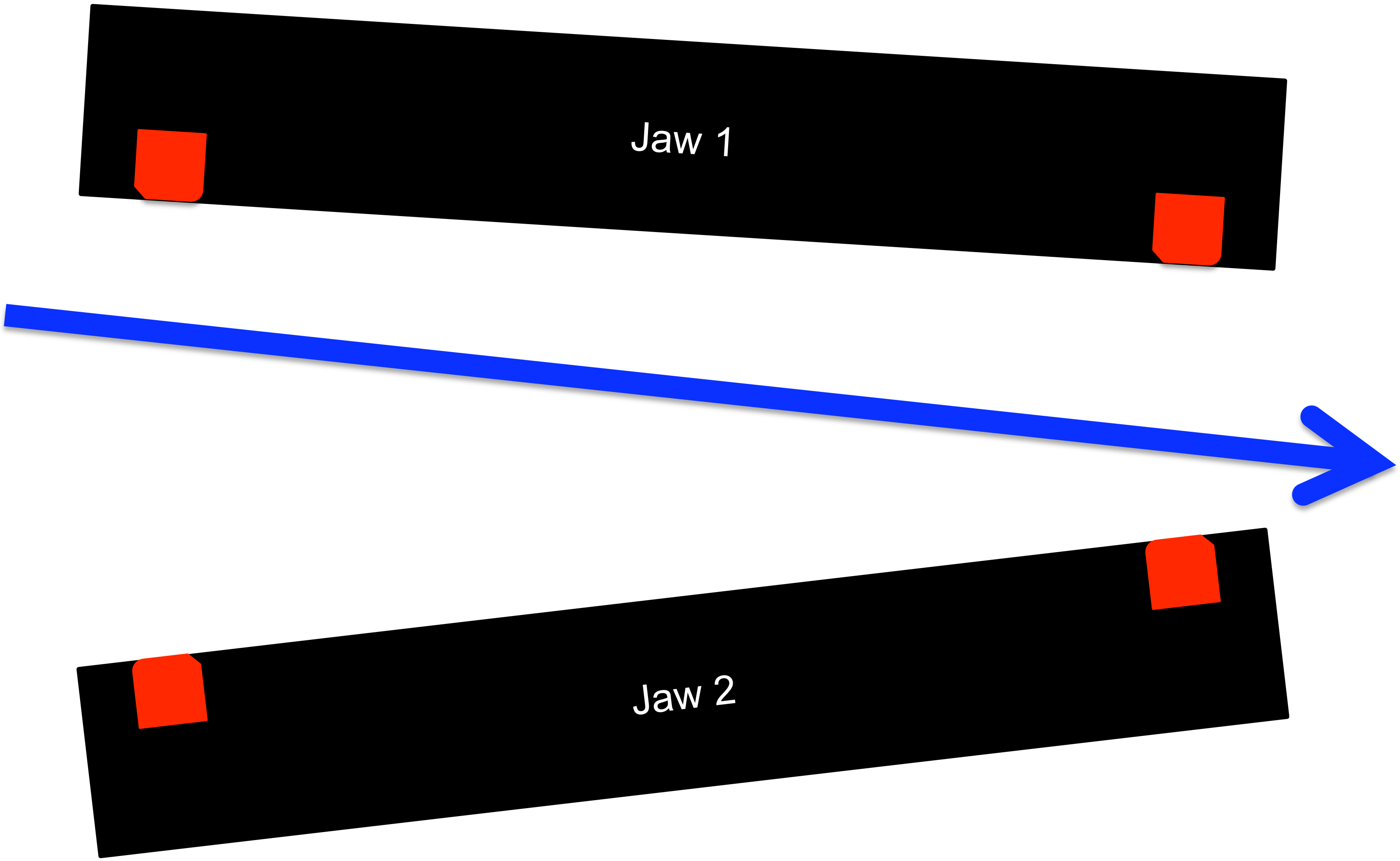
Schematic Solution Efficiency



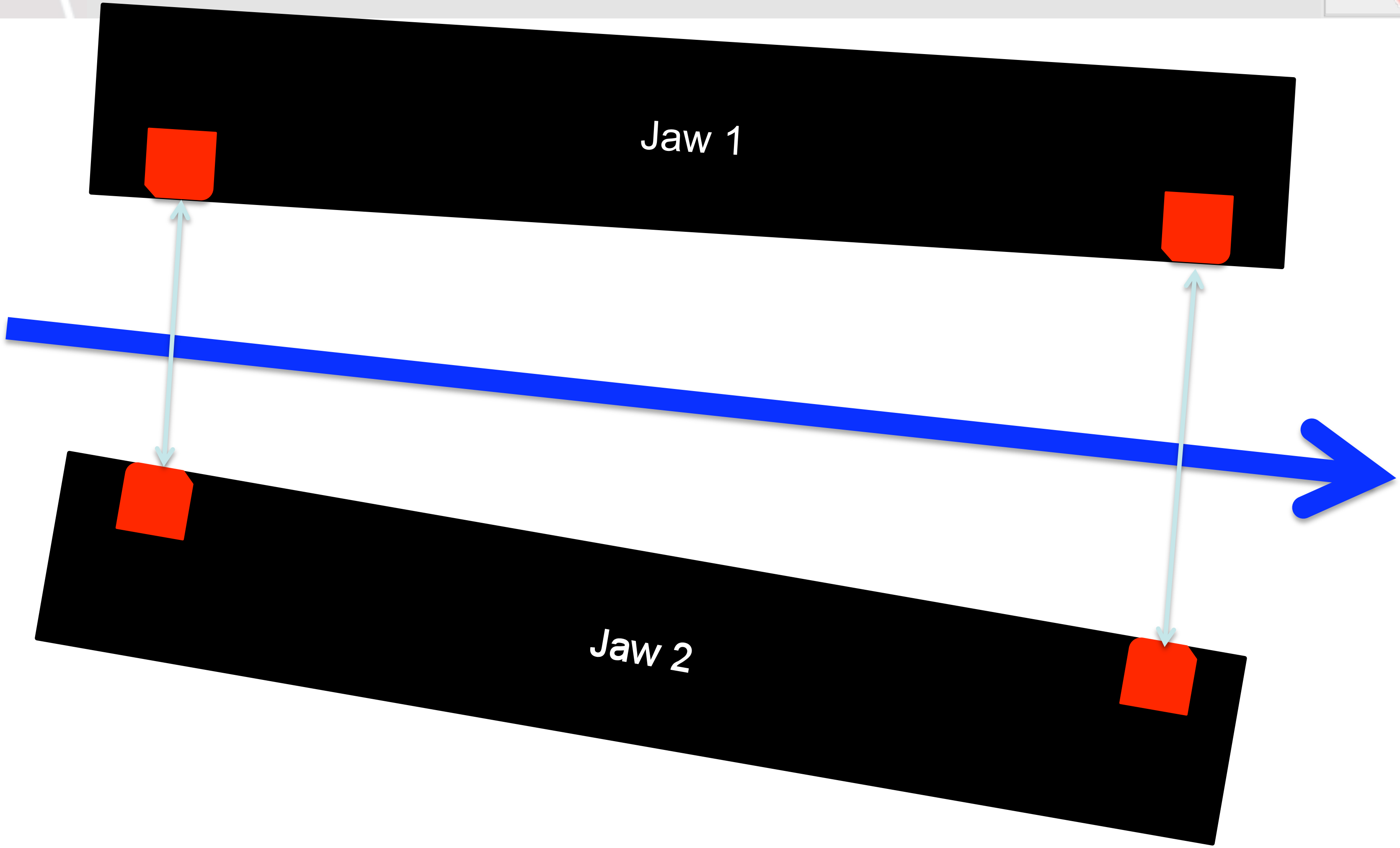
2) Concept for Improving Set-Up

- 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

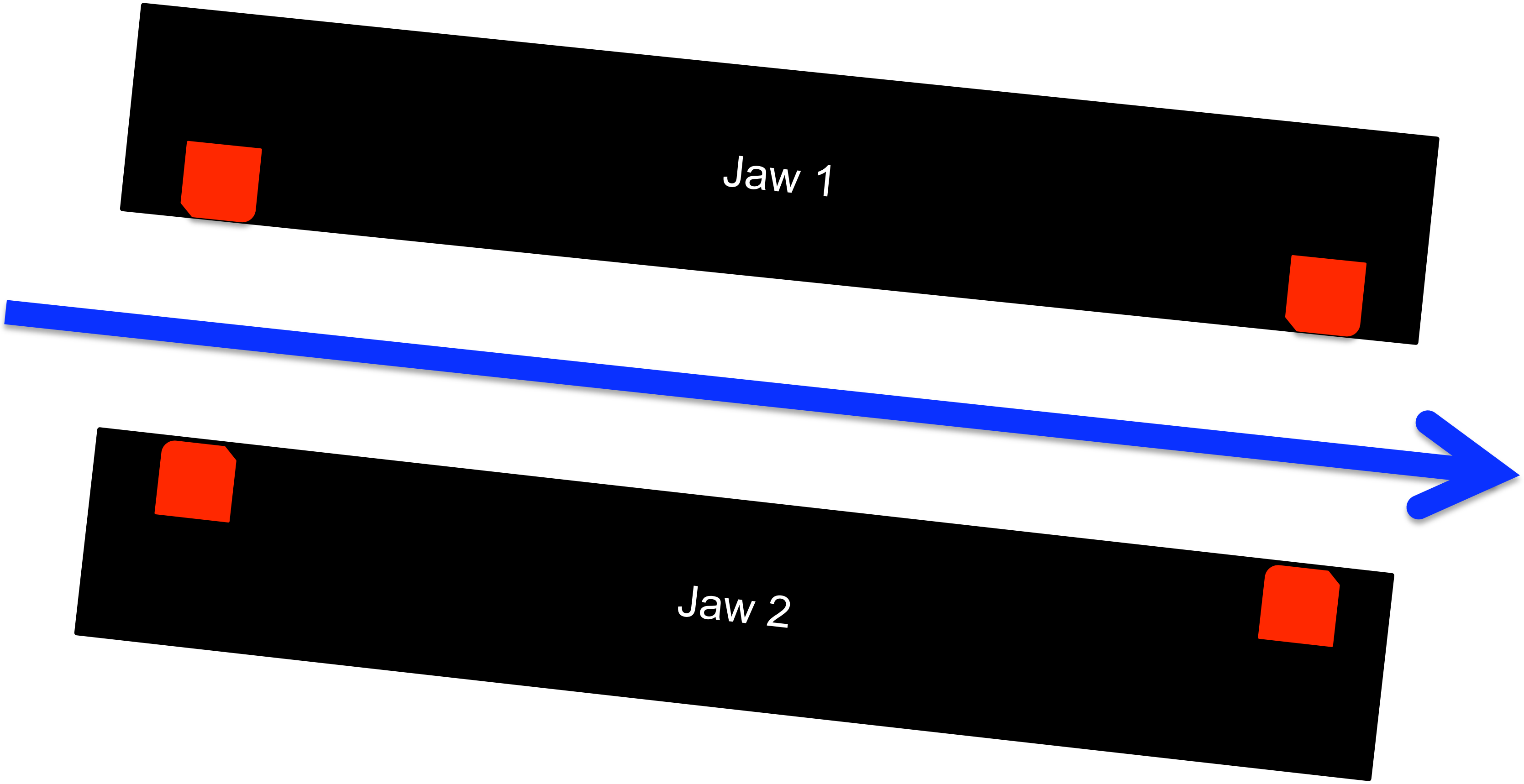


Schematic 2



1) Center jaw ends around beam by zeroing difference signal from pair of pickups. Do in retracted position (no beam loss).

Schematic 3



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

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.

What Does it Mean in Terms of Work

- System simulations (Ralph, Thomas, Markus, Francesco, Stefan):
  - Evaluate concept with cryogenic collimators (proton cleaning, ion cleaning, energy deposition, radiation), identifying best setting (good cleaning, minimal energy deposition, low radiation).
  - Look at hardware constraints.
  - Optimize material for primary collimators.
- Phase 2 secondary collimators (Alessandro, Alessandro, Elias, Fritz, Rhodri et al, Bernd et al, Noel):
  - 1 concept high Z metal at CERN (comb, …) and 1 high Z concept at SLAC.
  - 1 concept low Z material (with coating/foil?) at CERN.
  - Pickups to be included into design (not necessarily all designs).
  - Beam loss measurements to be included into design.
- Cryogenic collimators (Alessandro, Noel, AT???):
  - Look into design, starting from GSI/FAIR design (FP7).

What Does it Mean in Terms of Work II

- Phase 2 primary collimators (Ralph, Thomas):
  – Needs study in accelerator physics side.
- Advanced scrapers for the LHC (???) :
  – Need to be looked into again. Could not find better scraper than phase 1 primary collimators.
  – Directions can include hollow electron beam lens, lasers, rotating targets.
- Phase 2 absorbers (Markus, Francesco, Stefan):
  – Needs study for energy deposition and radiation.

Conclusion

- Within the last months we have gained quite a bit in knowledge: thanks to all for your contributions.
- Based on this understanding we can propose a big step forward (factor 10) for LHC collimation, evolving the existing system with relatively modest modifications (no new dipoles needed).
- Excellent outcome but will put us under pressure to deliver (good chance that people will want these goodies early on).
- Important milestone: **Review of conceptual design with parallel development paths in autumn 2008.**
- At this time define work packages and budget in more detail.
- Before this need:
  - Detailed proposal for CERN materials and paths (work ongoing).
  - Decide how to work in cryogenic side (support from AT required).