Collimation requirements for the IR1/5 layout and ongoing WP5 studies

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Acknowledgements: G. Arduini, F. Cerutti, R. De Maria, L. Esposito, L. Lari
Outline

• General scope of IR collimation
• Present and future collimator layouts in IRs (under study)
• Preliminary studies of asynchronous dumps in HL-LHC optics
• Cleaning?
• Conclusions
Collimation system

- Collimation hierarchy has to be respected in order to achieve satisfactory protection and cleaning
  - Protection: avoid damage during abnormal operation or failures
  - Cleaning: removal of unavoidable halo during standard operation

- Aperture that we can protect sets limit for $\beta^*$

- In experimental IRs, we need to worry both about the incoming and the outgoing beam

- Inner triplet (and all IR cold magnets) must operate well below quench limits in case of lifetime drops (issue: load from tertiary halo) and when beams are brought in collision (issue: load from collision debris)
**Present scope of IR collimation**

**Functionalities** for the collimation in the experimental regions:

1. **Protect** the machine from injection errors: TCLIA, TCLIB, TCDD, TDI in IR2 and IR8 *(bold: part of collimation project)*

2. **Clean** the collision debris in high-luminosity experiments: TCL, TCLP collimators in IR1 and IR5

3. **Clean** the triplets from beam halo (and optimize background):
   - TCTH, TCTV collimators in IR1, IR2, IR5, IR8

4. **Protect** the triplets from beam impacts during failures:
   - TCTH, TCTV collimators in IR1, IR2, IR5, IR8

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**IR1 - ATLAS**

Additional DS collimators in the IRs not discussed here!
Key design points:
• Standard TCTs as in present layout: H+V
• Standard TCLs protecting D2
• Similar TCL layout in the matching section: Q5, Q6, Q7...

New features under study:
• Additional TCT-like collimators protecting Q4 (or Q5, see later)?
• Vertical TCL to protect D2
• Need for additional debris protection for crab-cavities (masks?) or Q4
• Not yet studied in detail: integration of BBLR wire in collimators.
Issues to be addressed

• We must foresee appropriate space to ensure adequate protection/cleaning for HL-LHC layouts!

• Intra-beam distance at the present TCT locations between D1 and D2
  
  • Integration issues for present layout – would be nice to improve!
  
  • Major design changes

• Space budget between D2 and Q4

• Do we need additional vertical TCL’s?
Recap. of TCL layouts until LS3

Energy deposition simulations (L. Esposito et al, CWG 2012.07.30): only TCL5 needed, but this is incompatible with forward physics program until HL-LHC.
- TCL4 will be added in LS1
- We might add already TCL6 as well.
- No more changes until LS3 (unless surprises with 7 TeV machine require DS collimators!)

IR1 - ATLAS
Some thoughts for PIC scenario

• Same constraints / design criteria apply for IR collimation
  • Clean/protect smallest aperture (incoming beam)
  • Clean physics debris

• If optics performance limited by the aperture upstream of the triplet, likely additional TCT–like collimators will be required
  • What if the TAN limits the aperture?
  • Can we change also the TAN? -> Additional vertical TCL’s for D2/Q4?

• Detailed aperture studies are required:
  • Minimum margin between MQX and MS aperture for quench and protection?
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Protection

• Sensitive devices (e.g. apertures, TCT) must be protected from damaging losses in case of failures.
  • Studied failure: dump failure, single-module pre-fire (most critical)

• Normally, dump protection collimators (TCSG/TCDQ) intercept kicked beam

• Also in case of imperfections, e.g. orbit farther away from the TCDQ, aperture must be protected. Margins needed in the collimation hierarchy.

• Phase advance from dump kickers to affected equipment very important for likelihood of intercepting beam
### Fractional phase advance from dump kickers

#### B1

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- In HL-LHC v1.0, IR5 TCTs are most exposed in both B1 and B2
Phase space during asynch dump

- Assuming nominal settings, with error on TCTs so that they are at the same opening as the IR6 TCSG ($7\sigma$). Bunch also kicked at $7\sigma$. **Not including aperture (yet)**
Scan over all bunches with 25 ns spacing B4 (single module pre-fire)

- In total, 3.5% of one bunch lost on TCTH5 (=9e9p for 2.2e11 p/bunch). No phase errors assumed so far! Plastic deformations for > 5e9 p [Bertarelli, MPP workshop]. Need more margin?

Situation would improve drastically if the phase advance to TCTs/triplets could be kept further away than ~60 deg from 90 deg and 270 deg. But also a smaller change would help...

Later:
- SixTrack simulations to be done (L. Lari)
- Imperfection studies
Phase advance from MKD IR6 to IR5, B4

- Only about 2 deg phase advance from Q5 to Q1 in HL-LHC v1.0

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Asynch dump phase space for IR6 and IR5, B4

• Question: what is impact of reducing Q4/5 aperture to level of triplet?

• Assuming same aperture in sigma at dump protection and apertures/TCTs in IR5

• MQYL.5R5.B2 now, as suspected, shadowing the TCT and the following apertures.

• Additional collimator in front of Q5 preferable for this case
Example: SixTrack simulations of asynch dump in HL-LHC

- Studies done for optics version SLHC 3.1b (L. Lari et al, IPAC13).
- A few 1e8 particles lost close to Q5 without errors and standard collimator settings.
Outline

• General scope of IR collimation
• Present and future IR layouts with collimators (under study)
• Preliminary studies of asynchronous dumps in HL-LHC optics
• Cleaning
• Future work and conclusions
Cleaning

- Still to be investigated in detail for HL-LHC
- For nominal optics, significant losses seen in triplet if TCTs retracted – TCTs needed to protect the triplet not only for protection
- Simulations to be repeated for HL-LHC with reduced Q4/Q5 aperture and/or open TCTs
Outline

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- Future work and conclusions
Work plans

• For the moment, n1 (w or wo tolerance) best figure of merit
  • But: Difficult to treat off–energy tails and error models in complex tracking/en. dep.
  • We should converge on best way to judge goodness of aperture. Review parameter sets for n1 calculation based on 2010–2012 operational experience
  • We should run simulations before an aperture scenario is approved

• Important to freeze some layout options to perform detailed comparative studies.
  • Ongoing work: loss maps, failure scenarios, energy deposition

• Three proposals:
  • Layout 1: TCT only for triplet + standard TCL’s (used so far!)
  • Layout 2: additional TCTH for Q5
  • Layout 3: TCTH + TCTV for Q5

• Define worst–case scenarios for optics/orbit for loss maps and energy deposition studies.
Conclusions

- **IR collimators should clean/protect** smallest aperture (incoming beam) and clean physics debris (outgoing beam)
- Several layout options for IR collimators are under study
- Phase space shown for asynch dump in HL-LHC
  - Protection of insertions (in this case IR5) from asynchronous dumps can be significantly improved by changing the phase advance
  - If aperture in Q4/Q5 is reduced to the same normalized level as the triplet, likely that we need additional collimator in front of Q5 for protection, possibly also for cleaning. Keep present TCT also for flexibility
- Simulations of collision debris discussed in following talk