Collimation hierarchy and tracking for extraction failures

R. Bruce, E. Quaranta, S. Redaelli

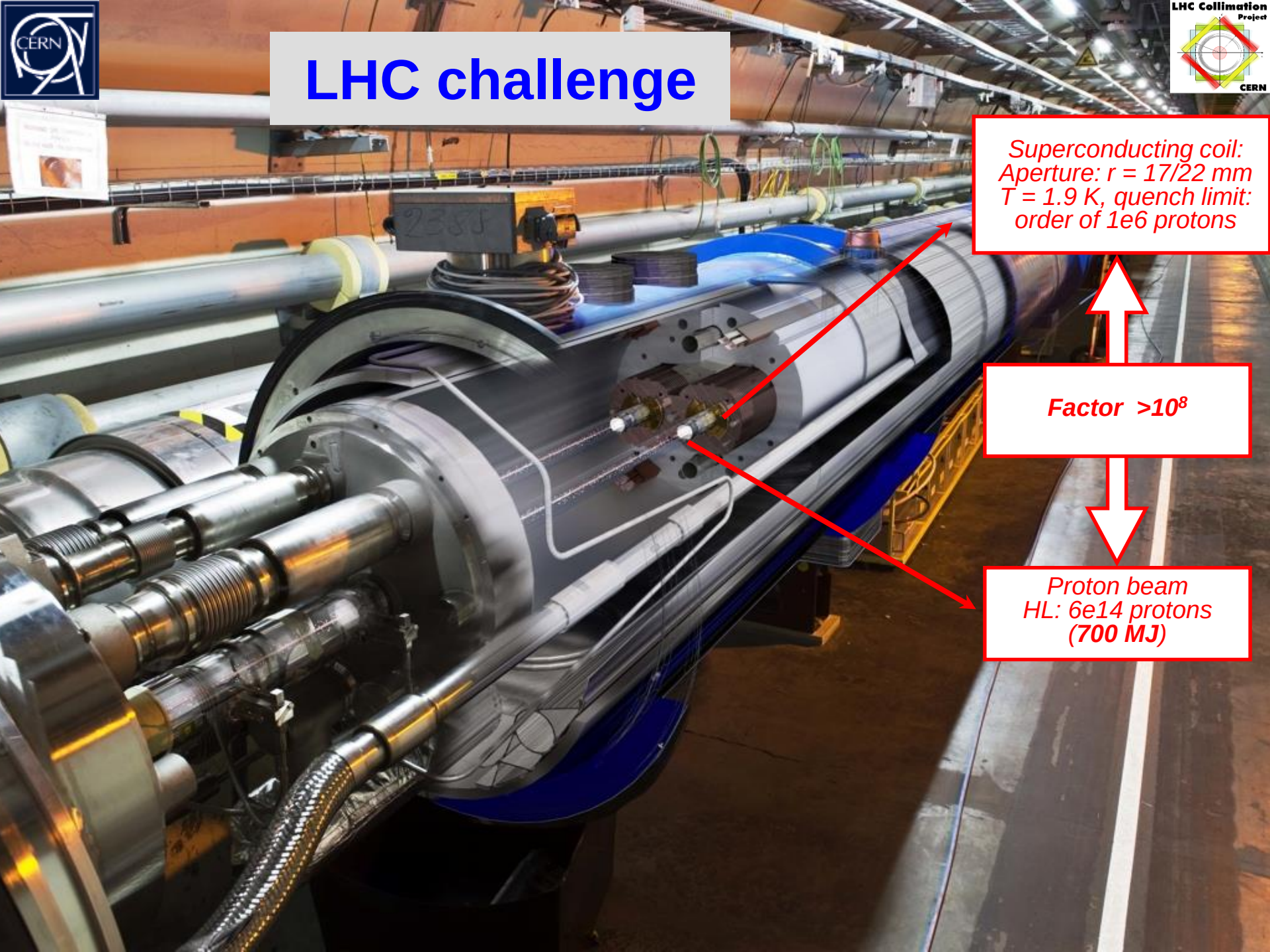
With valueable input from:

A. Bertarelli, C. Bracco, H. Burkhardt, F. Carra, F. Cerutti, S. Fartoukh, M. Fraser, M. Giovannozzi, P. Gradassi, B. Goddard, P. Ortega, E. Skordis, K. Sjobak, J. Uythoven, F. Velotti, J. Wenninger, D. Wollmann

Outline

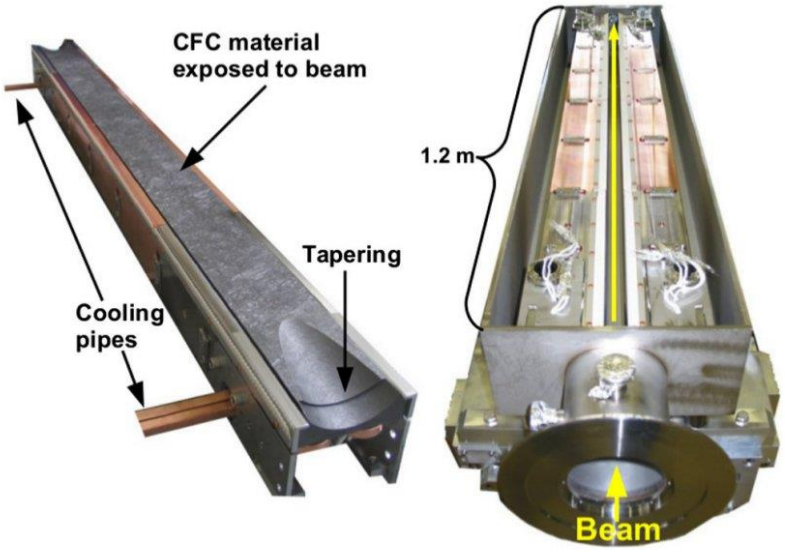
- Collimation system
- Influence of collimation hierarchy on luminosity performance
- Limitations from failures – asynchronous beam dump
- Simulation studies for asynchronous beam dump
- Conclusions

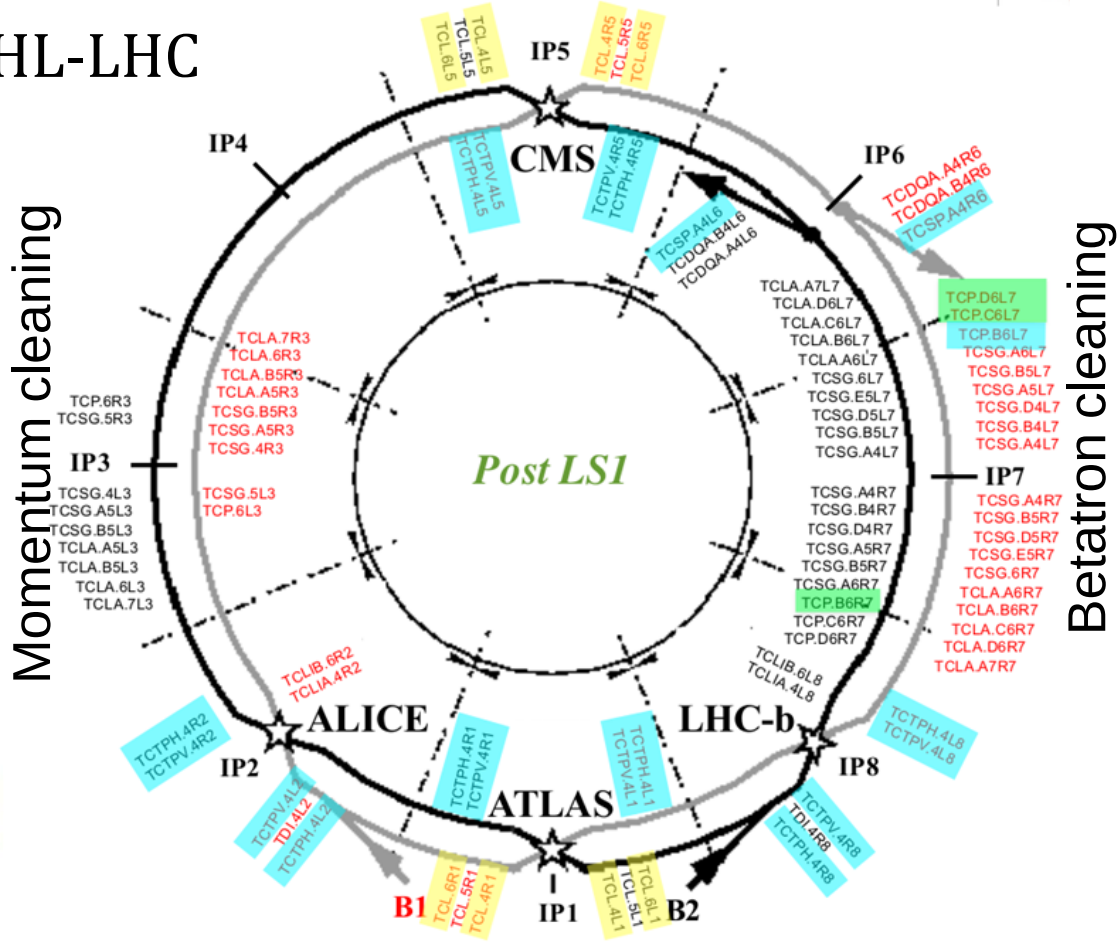
LHC challenge



LHC collimation system

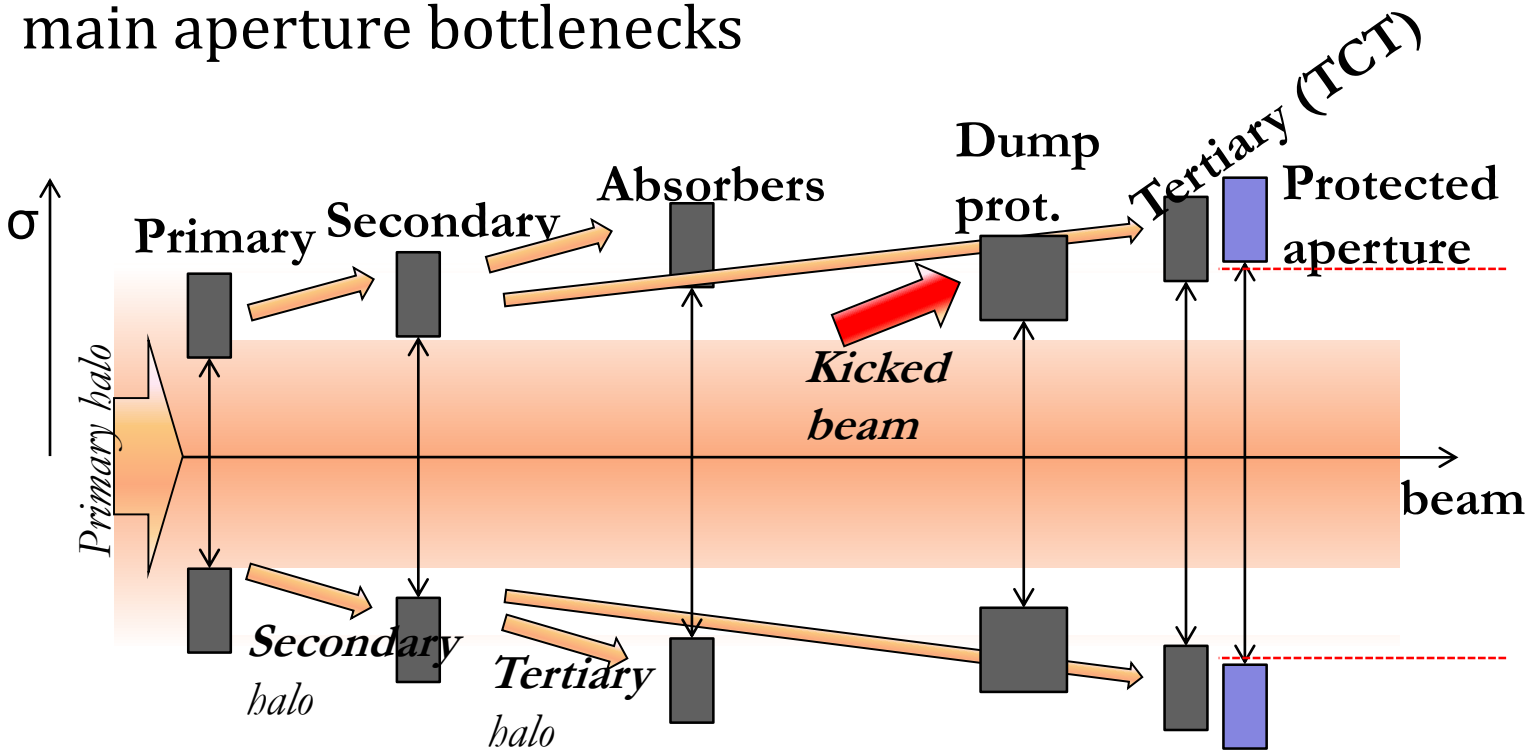
- Need collimation to safely dispose of regular and irregular beam losses
- Present collimation system: > 100 movable devices. Several upgrades foreseen for HL-LHC





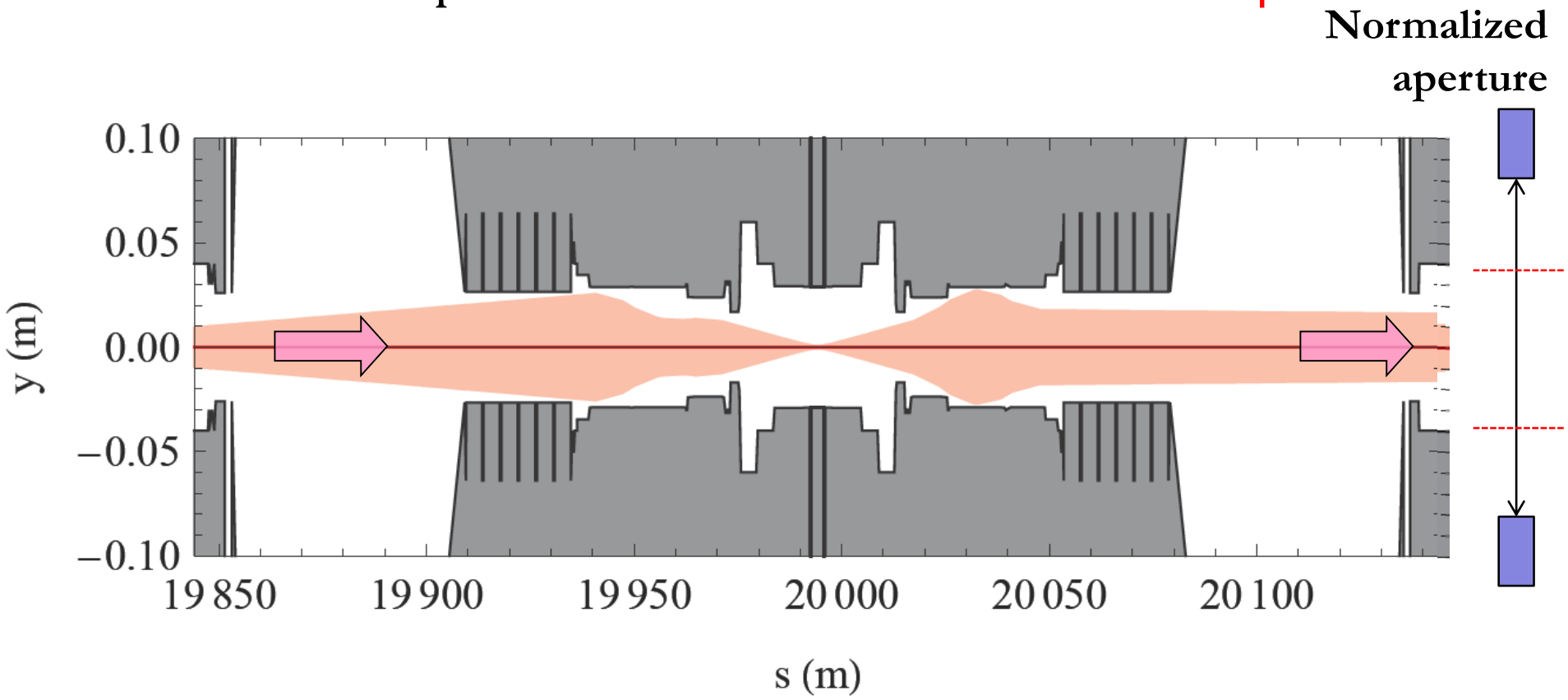
Collimation hierarchy

- Hierarchy needed for optimal performance
- All (normalized) apertures of the machine must be larger than the protected aperture
- With squeezed beams for physics, inner triplets in IR1/5 are main aperture bottlenecks



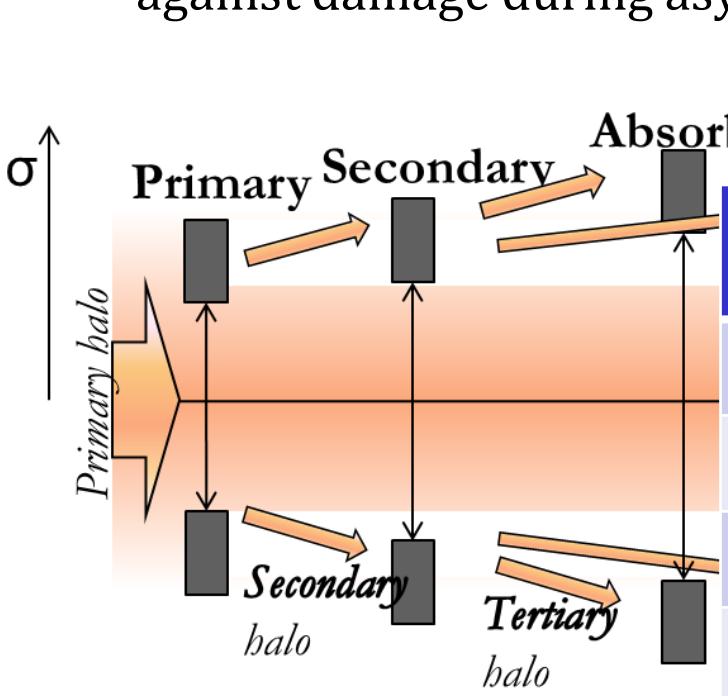
Aperture limit on β*

- Collimation determines minimum protected aperture
- As β* is squeezed for smaller beam size at IP and higher lumi, beam size increases in triplet =>
  Normalized aperture decreases => Limitation on β*



Collimation margins

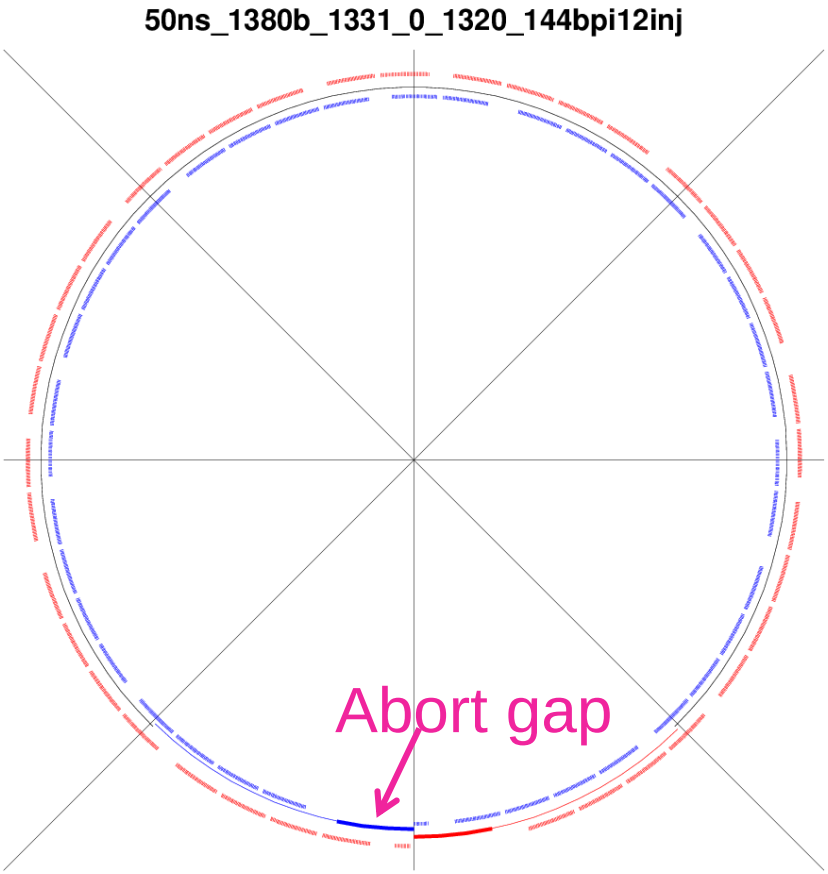
- To gain in β*-reach: Move in collimators, reduce margins => Smaller aperture can be tolerated
- Largest margin between dump protection and to aperture to protect against damage during asynchronous beam dumps



	Setting [σ with ε=3.5μm]	Setting [σ with ε=2.5μm]
Primary	5.7	6.7
Secondary	7.7	9.1
Dump prot.	8.5	10.1
Tertiary IR1/5	10.9	12.9
Protected aperture	12.2	14.4

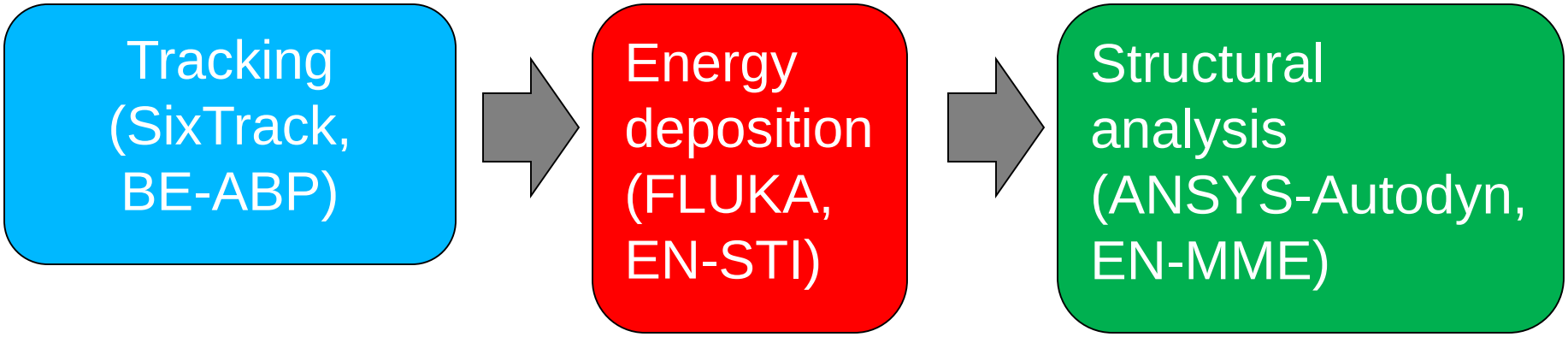
Asynchronous beam dump

- LHC filling scheme has abort gap to allow rise of the extraction kickers
- Possible failure mode: Kickers fire at the wrong moment, when beam is passing
  - 1-3 failures per year could be expected
- Intermediate kicks could send beam directly onto sensitive equipment (TCTs / aperture)
  - Present TCTs are also not robust against high-intensity impacts – could be damaged!
  - Shower propagating to the triplets and experiments
- Dump protection (TCDQ / TCSP) installed to protect against this



Simulation chain

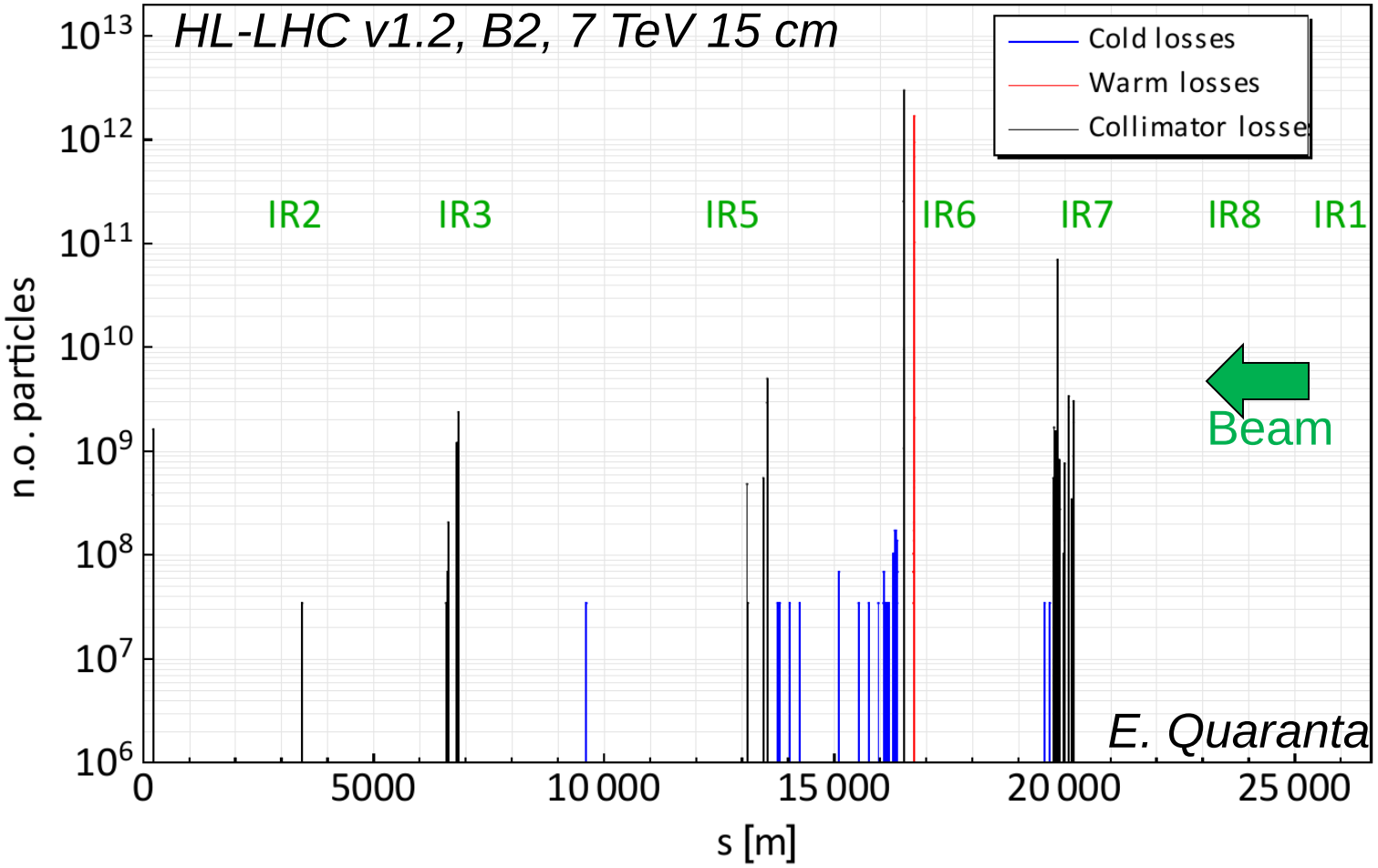
- Simulation chain in place to quantify potential damage to sensitive equipment during asynchronous beam dumps



- Simulation tools benchmarked with various beam tests

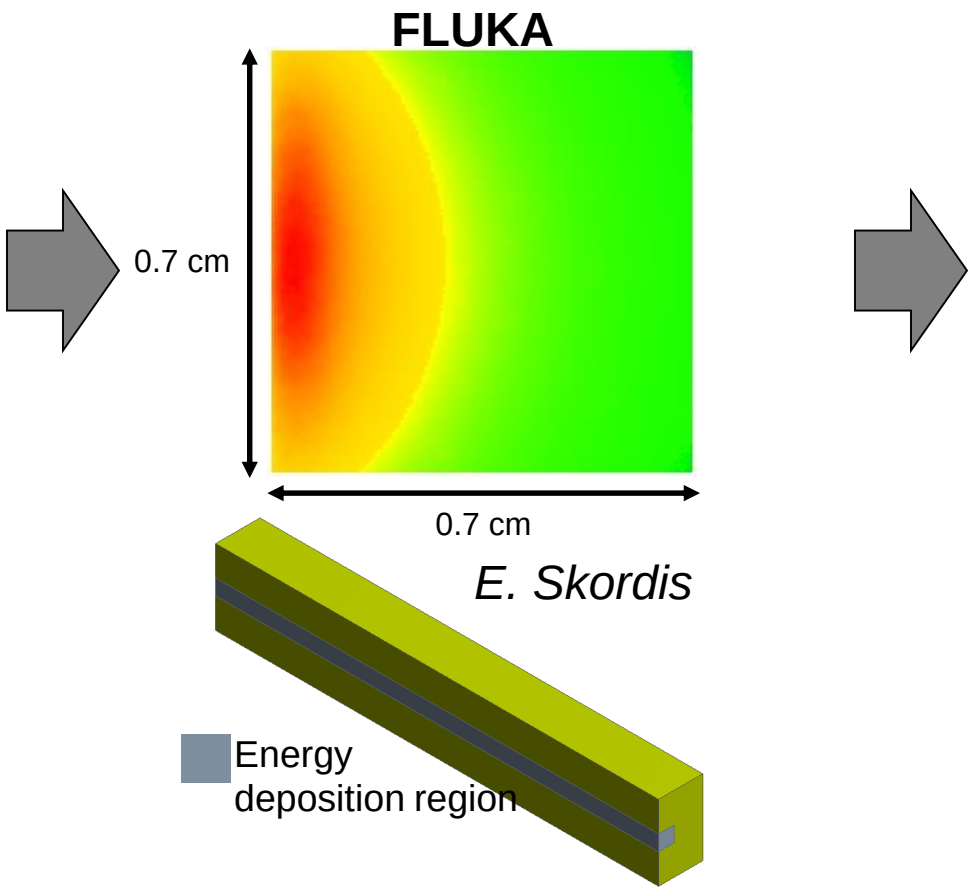
Loss distribution from asynch. beam dump

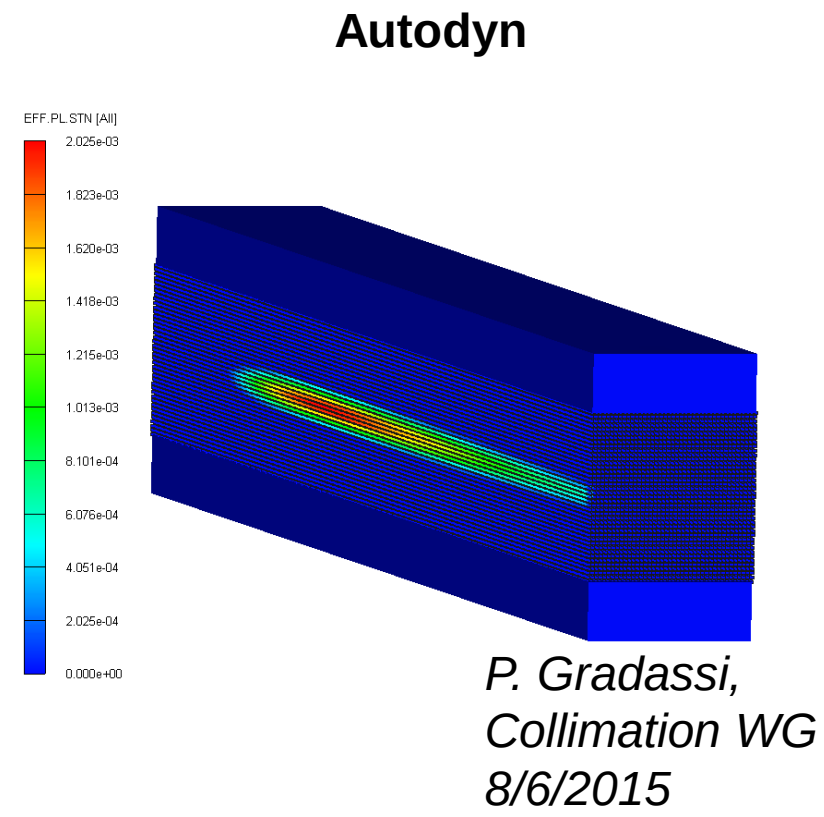
- Output from tracking: losses on aperture and collimators
- Example: assess TCT damage risk



Simulations of damage limit

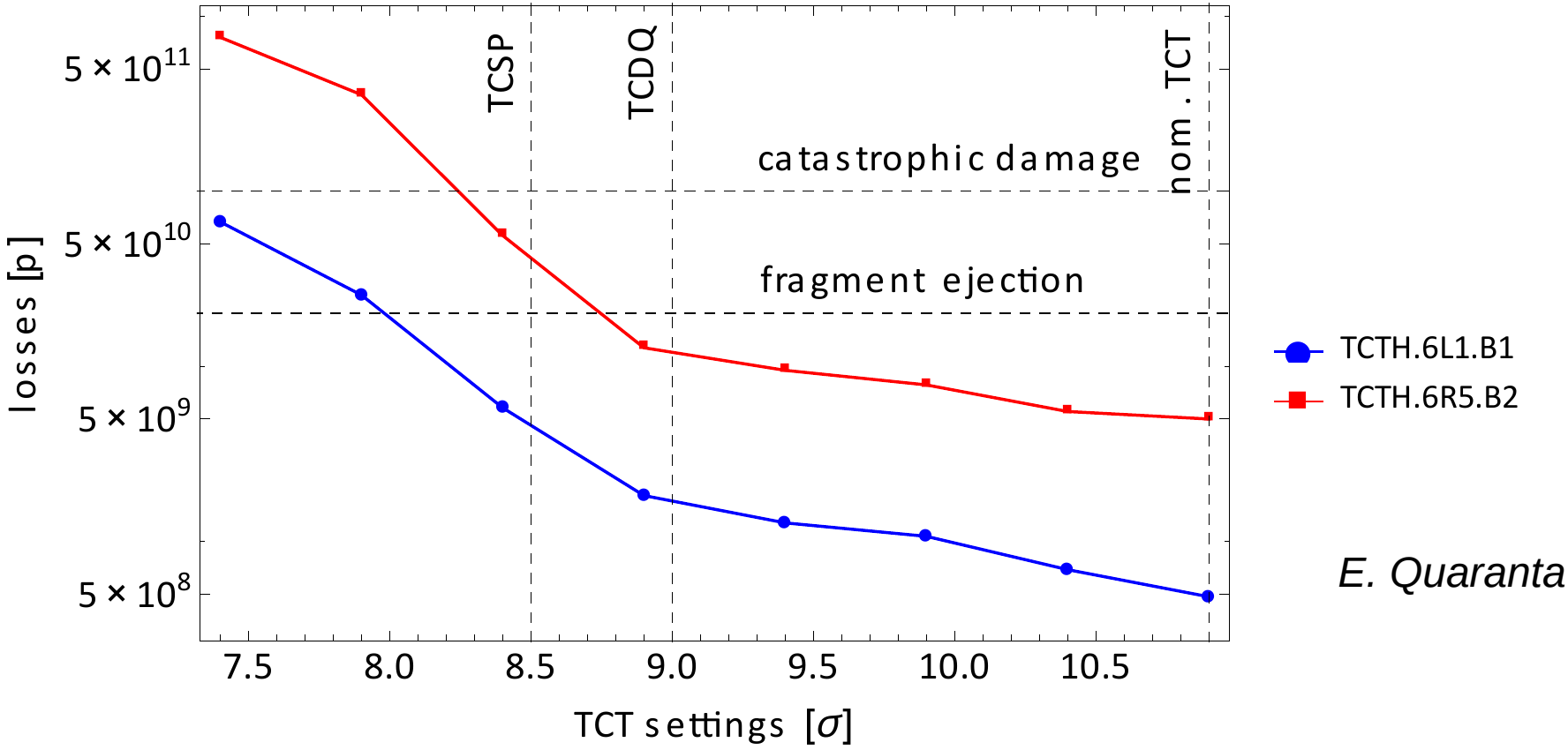
- Output of tracking studies (impacts on TCTs) used as input to energy deposition studies with FLUKA
- Energy deposition profile used as input to Autodyn to assess damage level





Sensitivity of losses to TCT setting

- Using damage level, assess risk for TCT damage – tracking studies with scan over settings
- Assume TCT could go in to 8.9 σ due to imperfections



E. Quaranta

Results and consequences

- Most critical tertiary below damage, but not a large margin.
  - Need to improve situation
- Considered mitigation methods (could also be used to decrease protected aperture)
  - New TCTs made of more robust materials studied for HL-LHC
    - Should study also influence on magnets and experiments
  - Better control of orbit at collimators with BPM => smaller tolerance
  - Change phase advance from dump kickers so it is far from 90^0 and 270^0
  - Consider moving in dump protection and secondary collimators. Drawback: higher impedance
  - Final resort: Open TCTs and step back in β*

Showers to experiments

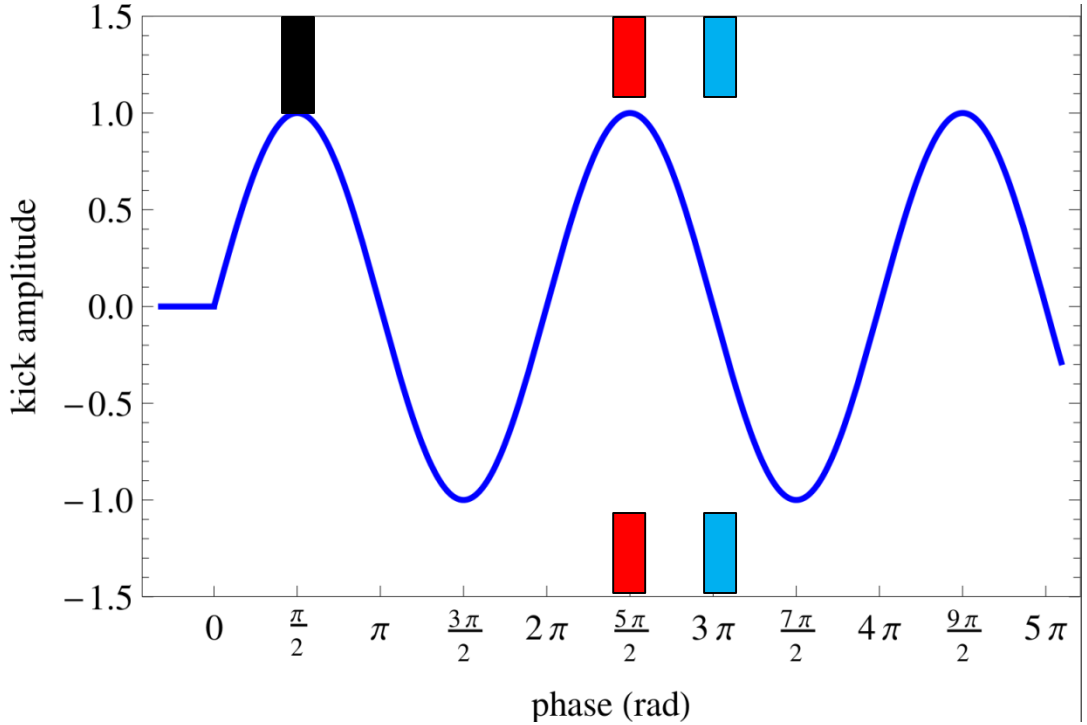
- Shower propagates out of TCT
- Early studies for nominal LHC using MARS (Mohkov and Weiler, Fermilab-Conf-08-147-APC)
- Recent FLUKA studies of triplet energy deposition during asynchronous beam dump for present LHC: P. Ortega, Collimation WG 8/6/2015
  - New simulations planned with FLUKA team for HL-LHC
- Simulation setup can easily be extended to track the shower to the experiments
- Compare simulations for crab-cavity failure (see next talk K. Sjobak)

Summary

- Collimation hierarchy must protect aperture
  - constrains β*
  - Trade-off between performance (closer TCTs) and protection (more open TCTs).
- Main limit during Run I from asynchronous beam dump
- Detailed simulation chain set up to study consequences and quantify performance limits
  - Assess damage risk at TCTs and downstream magnets
  - Can be extended to study shower to experiments in HL-LHC

Thanks for your attention!

Backup

Effects of asynchronous beam dumps

- Bunches kicked to different oscillating orbits, local dump protection at 90 deg from kickers
- What escapes risks to go to the experimental IRs (aperture bottlenecks)
  - Present TCTs are also not robust against high-intensity impacts – could be damaged!
  - Shower propagating to the triplets and experiments