

# HL-LHC

# Optics MD

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# Motivation for optics studies for HL-LHC

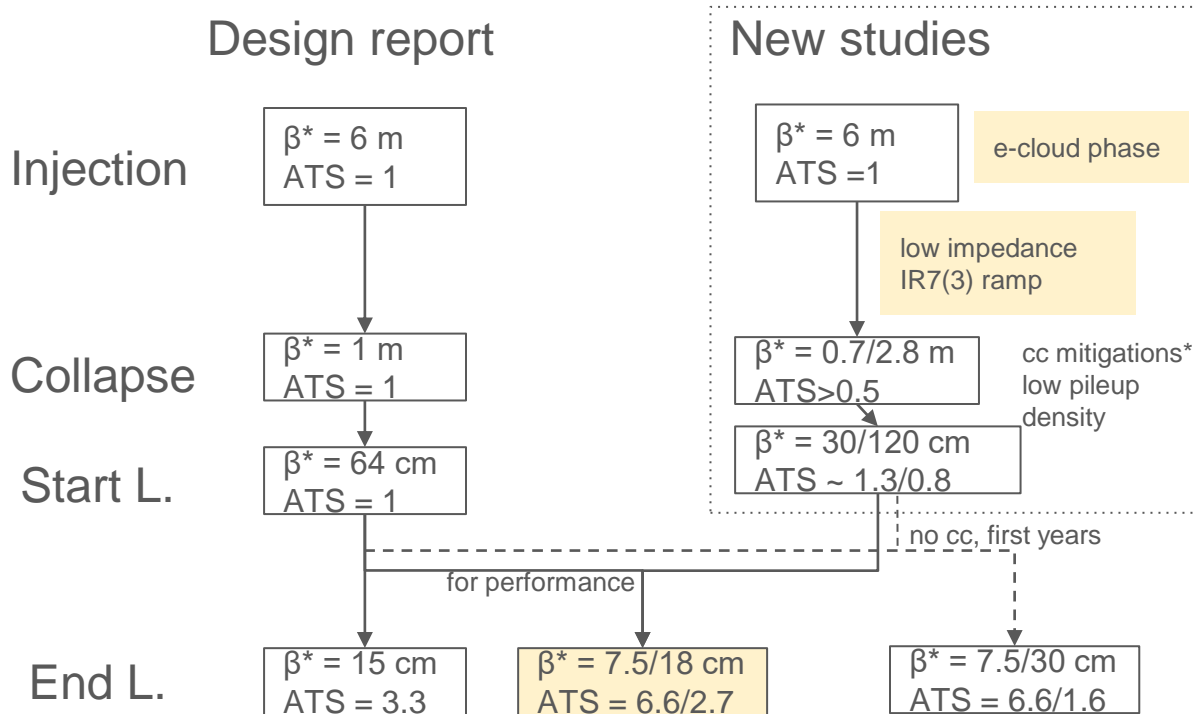
Despite missing HL-LHC triplets, it is still possible to deploy most of the HL-LHC optics in the LHC:

- e.g. IR1/5 presqueezed at  $\beta^* \sim 2.5\text{m}$  to reach  $\beta^* = 35\text{ cm}$  for large ATS factors (6.6 compared to 2 operations in 2023 and 4 in MDs).

While we are very confident on linear optics:

- HL-LHC optics pushes limits on optics correction and aperture at flat top in the arcs.
- We can test the impact of orbit/tune stability (e.g. 10 Hz) for large ATS factor. Compare the impact of PC regulators from 2024 and 2025.
- Alternative optics configurations (such as collapse in flat) to the baseline are being studied to prepare for mitigating potential limitations related to impedance, emittance growth, failure scenarios. Useful to gain experience.
- Synergies with beam-beam and collimation studies.

# Nominal cycle vs new proposals for HL-LHC

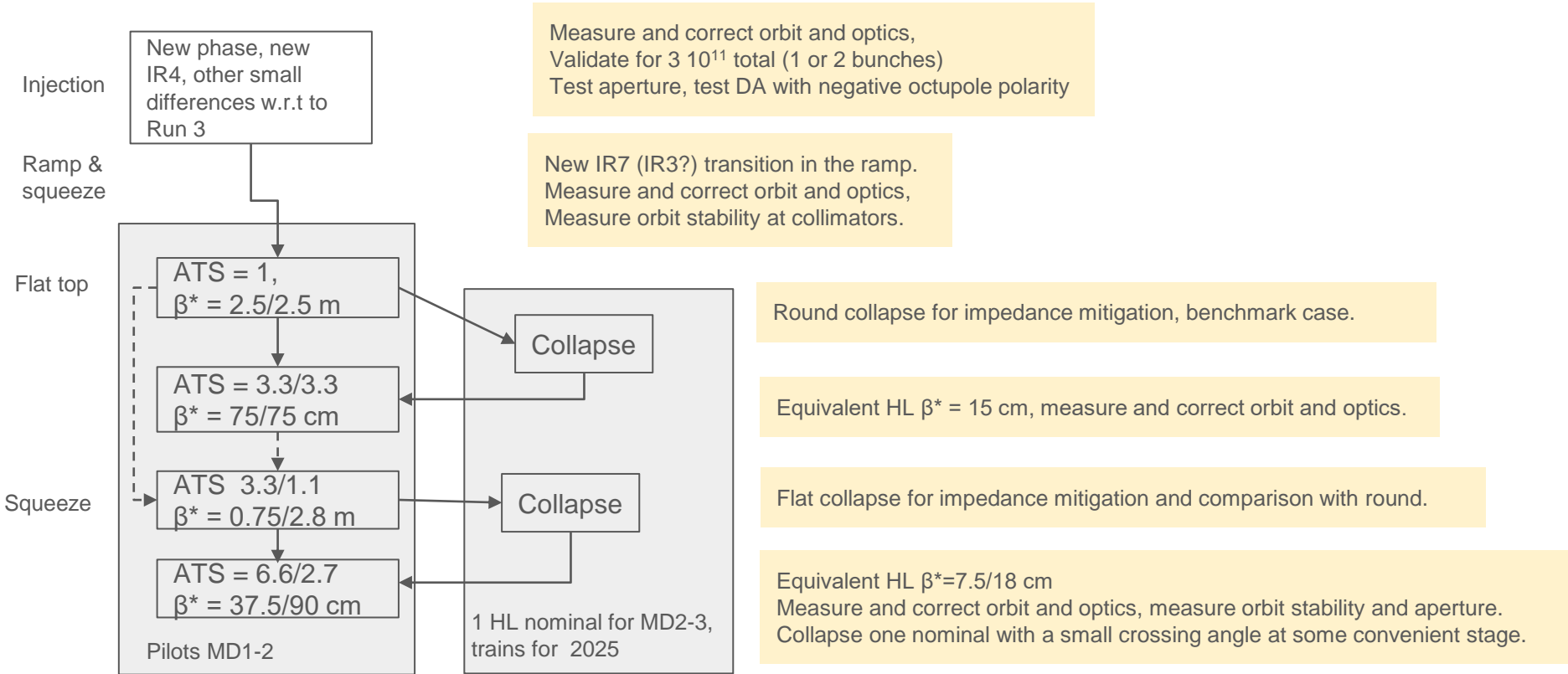


- Several decisions pending for new studies:
1. crossing plane VH better  $\beta^*$  reach (MKD-TCT)
  2. detailed  $\beta^*$ , ATS steps

MD to focus on new studies and extremes cases.

\* cc impedance, emittance growth, fast failure

# HL-LHC Optics, BB, Noise MDs



Crossing planes VH: additional crossing plane rotation (not needed in HL) adds complexity (no TCDQ/SMP control upgrade available).

# Injection MDs

Injection	Time
Improved phase advance without phase knob, new phases overall.	4h: setup orbit, OMC 4h: one or twos corrections
IR4: higher beta at instrumentation, slightly smaller aperture margins	
Test the minimum acceptable aperture at injection: 12.6@2.5um (Note) instead of 13.1@2.5um (Run3)	4h: global aperture checks

In 2024, we focus on pilots and 1-2 nominal large intensity ( $<3.3 \cdot 10^{11}$  total).

Negative octupole polarity will be used.

For 2025 we propose to move to train to study loss maps, cleaning efficiency ( $\sim 16$ h).

This requires +8h for a full MP validated setup.

# Ramp&Squeeze MDs

Ramp&Squeeze	Time
IR7 transition to low impedance optics	12h orbit, OMC,
IR3 transition to low impedance optics?	$\beta^* \sim 2.5\text{m}/1\text{ats}$

In 2024 we focus on pilots and 1-2 nominal large intensity ( $<3.3 \cdot 10^{11}$  total).

Test operational feasibility, orbit stability in collimators.

For 2025 we propose to move to train to study beam-beam effects, loss maps, cleaning efficiency.

This requires +8h for a full MP validated setup.

# Squeeze/Levelling MDs

Flat top	Time
Test arc optics correction up to 6.6 tele-index optics, impact 10 Hz	4h+4h to OMC
Implement a collapse at flat top	4h (BB MD)
Measure arc aperture up to 6.6 tele-index optics	+2h if AC dipole works +4h if not
Study ideal MKD-TCT phased optics at 3.3 and/or 6.6x tele-index, off-momentum beta-beating impact on cleaning efficiency, IR3 settings	2025 synergy with collimation studies
Low-beta in Point 8 for Run 5, $\beta^*=0.5/1.5$ m	synergy with ion run

In 2024 we focus on pilots and 1 nominal. negative octupole polarity will be used.

For 2025 we propose to move to train to study beam-beam effects and collimation test loss maps.

This requires +16h for a full MP validated setup.

In 2025 we consider to add other aspects related to HL-LHC options, future projects, other optimizations.

# Conclusion

MD plan for 2024 and 2025 to answer questions HL-LHC optics challenges for optics, noise, BB and collimation, coming from

- large beta functions and aperture in the arcs,
- more complex ramp&squeeze,
- different collapse process,
- negative polarity through the cycle.

Total for 2024: 48 h

Total for 2025: 48 h

Study	Block	Time	Beam
Injection OMC, Aperture	MD1-2	12h	Pilots/ IND
Ramp with IR7 transition, OMC, orbit and tune stability	MD1-2	12h	
Squeeze, OMC, Aperture	MD3-4	12h	2-3 $10^{11}$
Inj, Ramp, Collapse for BeamBeam studies, Noise	MD3-4	12h	
Inj, Ramp, Coll Alignment and MP Validation, tune stability	2025	16h	1 Train
Inj, Ramp, Squeeze, Loss maps, cleaning	2025	16h	
Inj, Ramp, Squeeze, Loss maps, cleaning	2025	16h	

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