# MDs in the CERN accelerator complex

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for the injector and LHC MD coordination teams

With inputs from so many colleagues!

# Agenda

- Why do we do MDs?
- Organization of MDs
- Outcome of 2024
- Incoming in 2025
- Critical MDs to be done before LS3
- Outlook

# Why do we do MDs?

- **Study new R&D concepts and test new hardware**
  - **Empty bucket channeling** → **improvement** of operational spill quality
  - **Crystal** extraction and shadowing
  - **New equipment** for HL-LHC (Crab cavities, wire compensation, TWOCRYST, BGC, BGV, BSRT, COLDEX
  - New **theories**: 4D resonance structures in SPS
- **Studies to increase performance to reach global goals set by projects**
  - LIU
  - HL-LHC
  - SHIP
- **Better understanding of the machine and its limitations**
  - **Tail** studies throughout the complex → **reduction of losses** in LHC operation
  - Optimization of **LHC RF voltage at injection for ions** → large increase of **lifetime** in operation
  - **Resonance compensation** in PSB → improved **transmission** for ISOLDE in operation
  - TOF **instability studies** in PSB → gained **transmission** and lower emittance by change of working point
- **Solve operational problems and hardware issues**
  - Optimization of **LHC longitudinal blow-up** → gained **margin** in operation
  - North Area **spill quality** issues → large **gain** in operation
  - **50 Hz** component impact on SPS ion beam (and protons?) → large **gain** for LHC operation
- **Improve tunability, reliability and reproducibility of the machines**
  - Automation for **MTE splitting**
  - Automation for **bunch splitting**
  - Automation for 50 Hz components
  - **Hysteresis compensation** automation

→ Decisive impact of MDs on recent operational performance

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# Organization of MDs

- **LHC MDs**
  - **Coordination**: Georges, Gianni and Jan
  - LHC-OP as well as all injector teams
  - rMPP
  - Injector beam request **linkperson** since Fall: Panos

- **Injector MDs**

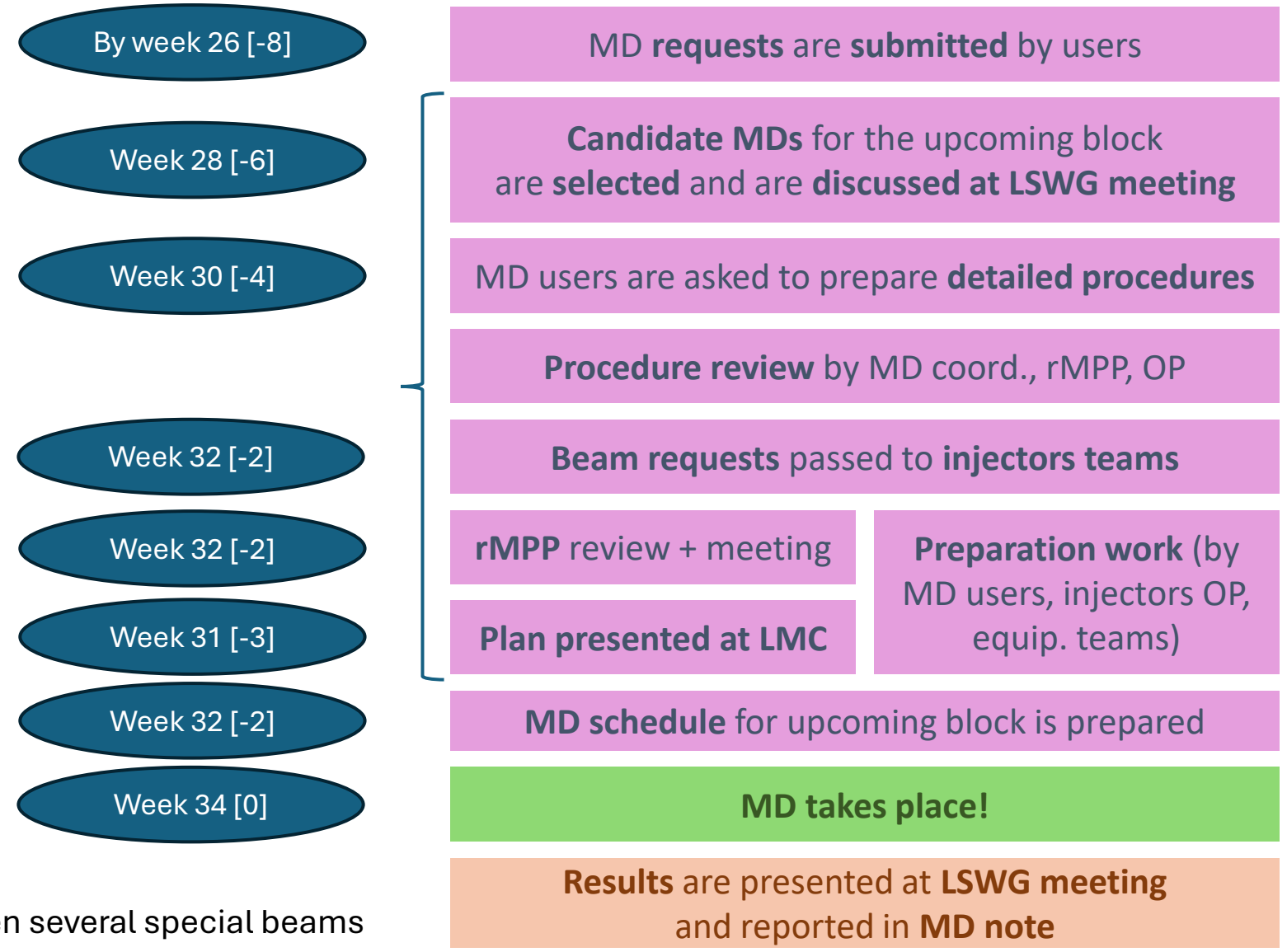
  → coordination of MDs in Linac4, PSB, PS and SPS

  → MDs also going on in Linac3, LEIR, AD/ELENA, but coordination has not been needed

  - **Coordination**: Foteini and Benoit
  - OP **linkpersons**:
    - PSB: Fabrice
    - PS: Gil and Oliver
    - SPS: Chris and Johan

- **ASM support**: Emanuele

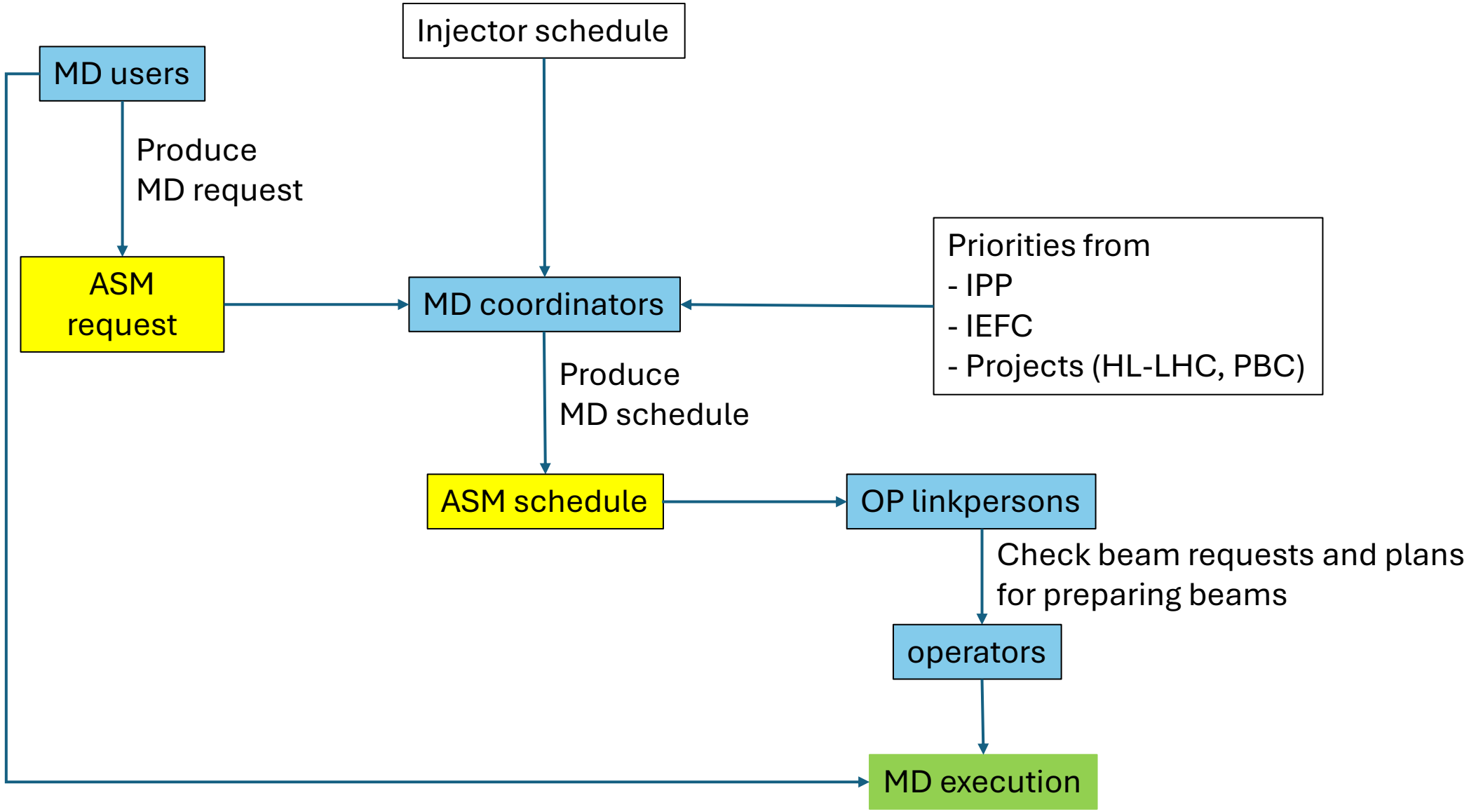
# LHC MD workflow (example of MD3 - 2024)



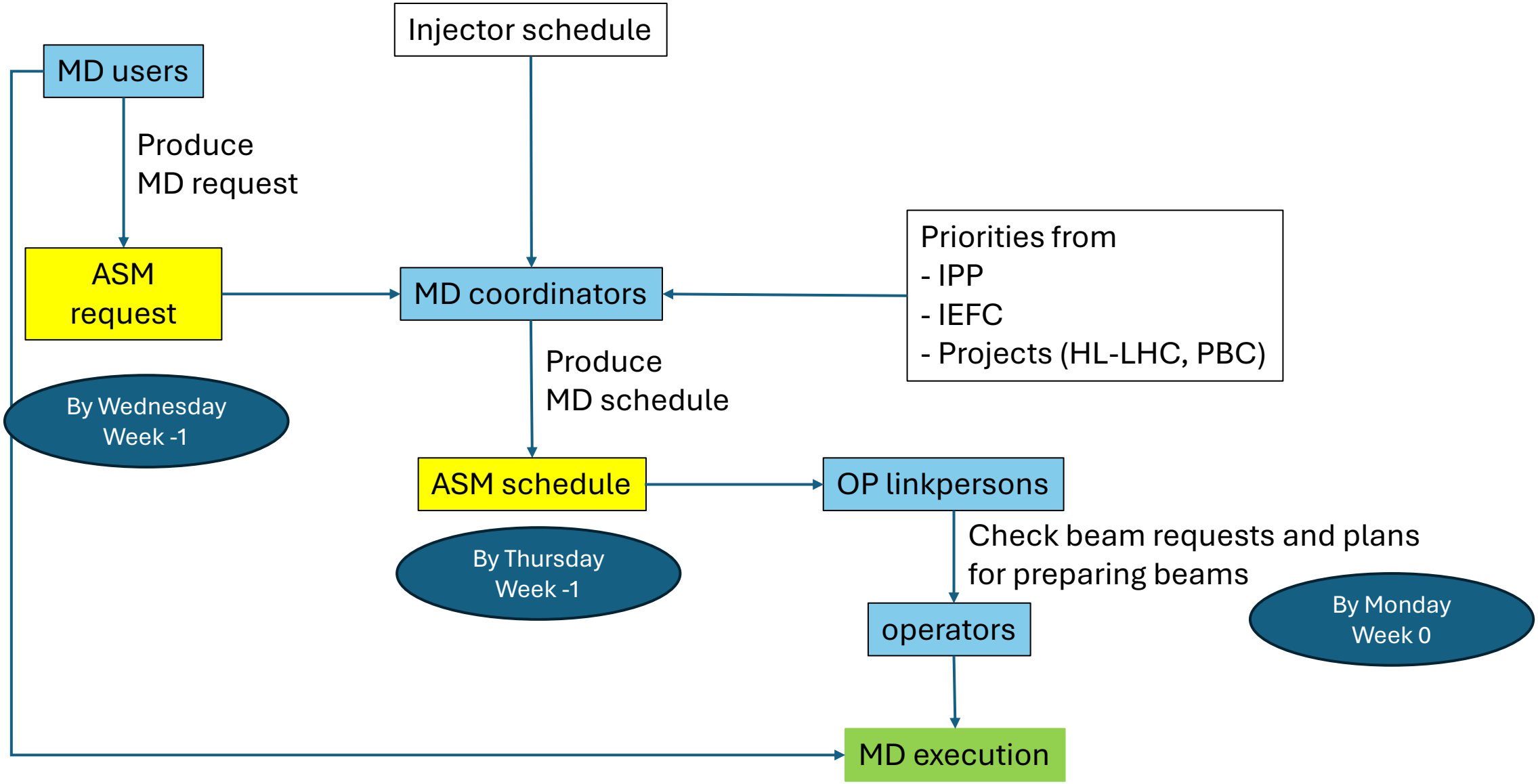

→ Long process taking ~ 8 weeks

→ Beam preparation in the injectors difficult when several special beams are requested in the same LHC MD block → **procedure changed after MD3**

# Injector MD workflow



# Injector MD workflow




→works well, except when beams names in ASM are not correctly filled → to be worked on for next year

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# News this year

- Injector **MD coordination coffees** every Friday
- Tag more clearly **MDs that go beyond operational parameters**
- Short parallel MDs **allowed after 20:00**
- Short parallel MDs **also on Fridays**

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# Main points for MDs in 2024

- LHC
  - High intensity studies **left for the last proton MD blocks** (intensity limitation from SPS RF)
  - **Good availability** except for MD3 and ions
  - Clear **shift in focus** from Run 3 studies to HL-LHC studies

- SPS
  - **Very dynamic schedule** due to issues with North Area magnets → very good collaboration!
  - **Dedicated MDs**: extraction studies, COLDEX, hysteresis compensation (no crab cavities or SHIP)
  - **Long parallel MDs**: LIU beams optimization, constraints due to intensity limitations from SPS RF
  - **Short parallel MDs**: not enough MDs towards the end of the year and ion run

- PS
  - Went smoothly!
  - **No impact from high intensity MDs in 2024**

- PSB
  - Went smoothly!

- Linac4/PSB
  - Smooth transparent switch to **high current** during MDs
  - High current reliability run for the two last weeks of the Run not approved

→ A very good year also for MDs!

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# Issues during injector MDs

## Planning/coordination issues

- Many dedicated MDs need to send beam to North Area
  → Mailing list set up to coordinate and communicate access requests to North Area during dedicated MDs
- User change moved from Wednesday to Monday for SPS ion run
  → If communicated, we could have moved dedicated MDs from Wednesday to Monday to help users.
  → Will be solved next year
- Difficult to tune fixed target performance when two different MD users in the supercycles
  → proposal from MD OP linkperson to simplify if the same MD is included twice in the supercycle
  → very successful, MDs are now much more transparent
- Not enough MD slots towards the end of the year in the SPS (very busy schedule!)

## Availability/beam issues

- Start of **LHC ion** period almost effectively means the end of efficient MDs (and other activities in injectors)
  → 1 dedicated MD slot with LHC ion run **is worth about half** of a dedicated MD slot during LHC proton run
- **SPS sometimes idling during LHC fillings** (e.g. waiting for pilot corrections or issue solving in LHC)
  → more dynamic switching of supercycle would help
- **Limitations to intensity** during Summer (especially SPS RF)
  → High intensity tests pushed when there were very few long parallel MD slots
- Settings not easy to restore from previous MDs
  → useful to schedule one short parallel MD slot before long parallel MD slots as “SPS MD prep”
  → important for MD users to identify in ASM **the correct MD beam name** in all machines

# Issues during LHC MDs

**Setting up of LHC beams in injectors**

- Need tighter coordination for beam preparation across the injectors (before and during MD block)
  → Panos in charge of coordinating this activity since fall 2024
- Need to adapt length of the LHC MD prep and place it better
  → Proposal from LHC MDs: target Thursdays instead of Fridays, and use Fridays as contingency

**Experts are required everywhere all the time during MDs**

- Experts required for most MDs cannot stay all MD long **(collimation** and **ADT)**
- Lack of overlap of beam experts in injectors during Summer before MD3

**LHC MDs used as cooldown before technical stops or VIP visits**

- Constraints on intensity and luminosity
  → Do we have other activities that could be scheduled together with MDs during these cooldown periods?

- LHC MDs during the weekend: accelerator complex in "degraded" mode during 8 consecutive shifts while LHC MDs are the most demanding period
  - Less (no) experts around in LHC and injectors to help on the spot and advise
  - More difficult and longer to reach piquets and best effort than during the week
  - 2 operators in PS complex instead of 3
    → more difficult to set up beams, inefficient in solving issues, easier to make mistakes and waste precious MD time

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# Incoming next year

- **High current** operation of **Linac4**
- High intensity and high energy test for **ISOLDE beams**
- Experience with partial operational tags has improved (to avoid reverting parameters that were changed in the meantime)
- Large number of dedicated MD requests from SHIP and HL-LHC crab cavities in SPS in 2025/26
- Request for large number of short SPS dedicated MDs (3h) for hysteresis compensation
- Plan to set supercycles for the coming 2 weeks during PS/SPS users meeting to gain efficiency

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  - Injectors
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# Critical MDs to be done before LS3: LHC

- Quench test on B1 (to close the story of the 11T dipole)
- Rematched IR3 and IR7 optics, to mitigate losses in DS and confirm global impedance budget
- RF power studies (and longitudinal beam losses) at injection for HL parameters
- Halo monitoring
- Finish validation of HL round/flat optics cycle and optics correction strategies
- Validation of nominal HL beam parameters [we cannot reach more than 1.8e11 p/b with full machine until LS3]

  → Are there remaining intensity limits from RF, electron cloud, beam-beam and heating that we can check before LS3?

**Important checks before LS3:**

- 2.3e11 p/b with full machine at injection for beam induced heating and electron cloud
- 2.3e11 p/b with full machine at start ramp for RF
- 2.3e11 p/b with full machine with 8b4e up to flat top for beam induced heating and electron cloud (ok for TCDS according to STI in JAP 2023)
- 2.3e11 with short bunch trains (12-24 tbc) in collisions to demonstrate beam-beam
- 1.8e11 p/b with full machine with BCMS/standard beam (limit for TCDS)

→ When should we do these checks?

*[Markus Zerlauth and Rogelio Tomas for HL-LHC]*

# Critical MDs to be done before LS3: injectors

- LIU:
  - Complete the push to LIU nominal performance for standard filling scheme
  - Brightness & tail characterisation and optimisation
  - Reliability and reproducibility
  - Operational margin?

*[IEFC#359 talk by Giovanni]*

- SHIP and high intensity fixed target beams
- Automation and reliability (in particular MTE splitting and bunch splitting)
- From HL-LHC: SPS RFD crab cavity

  → validation of performance, counter phasing, detuning, comb-filter

Once **LIU parameter goals are reached**, part of the **long parallel MDs should change focus** and may take a different form

→ shorter but **more frequent checks of LIU beams** on a quasi-daily basis?

→ see next talk of Panos

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# Outlook

- MDs contributed to the operational success of the 2024 LHC Run
- MDs went globally well and issues experienced during 2024 are being addressed in view of 2025

  → Introduction of OP linkpersons for injector and LHC MDs has been a clear success to facilitate communication
- Important MDs in the pipeline for 2025/26 in both injectors and LHC
- Strong impact of intensity limitations in SPS and LHC on 2024 MDs to prepare for HL-LHC

**When is the best time to perform these high intensity tests?**

- New territory → involves known and unknown risks
- Requirement from current users for maximum availability

  → Should be delayed until the end

- But equipment and support groups will need enough time to find a solution in case of issue (and one should not wait until the very end as we could miss the opportunity)

  → Should be done as early as possible

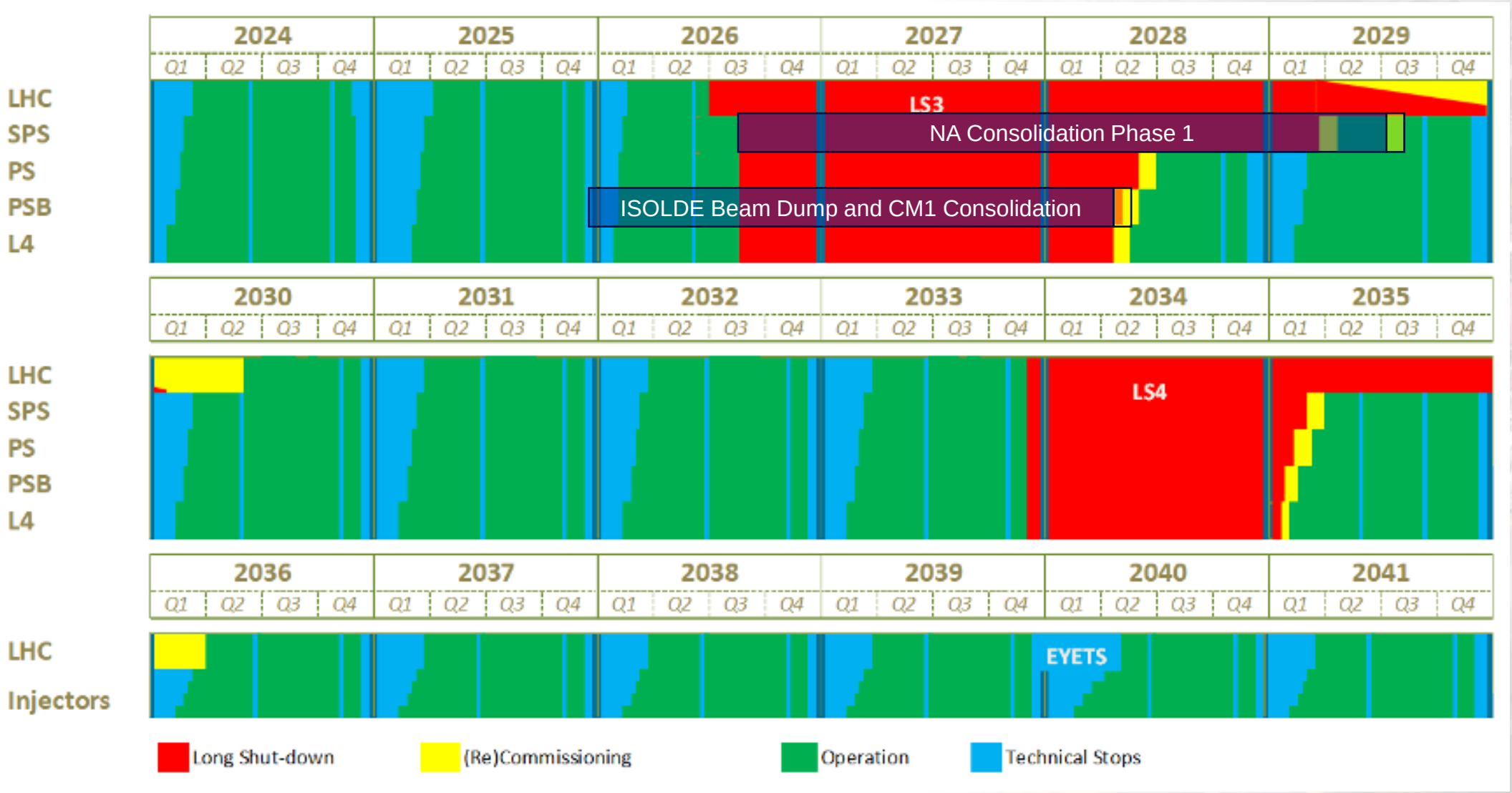
→ high intensity should be tested (1) as soon as possible (2) when it hurts the complex less (for both current **and** future users)

Thank you very much for your attention!

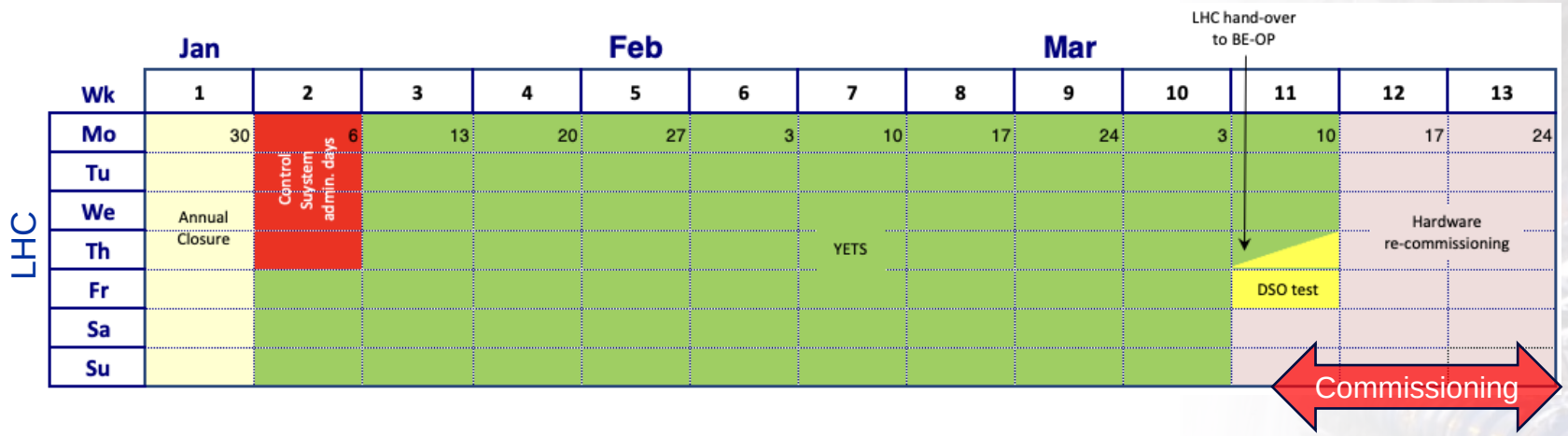
IPP MD days on Feb 3rd to 5th 2025

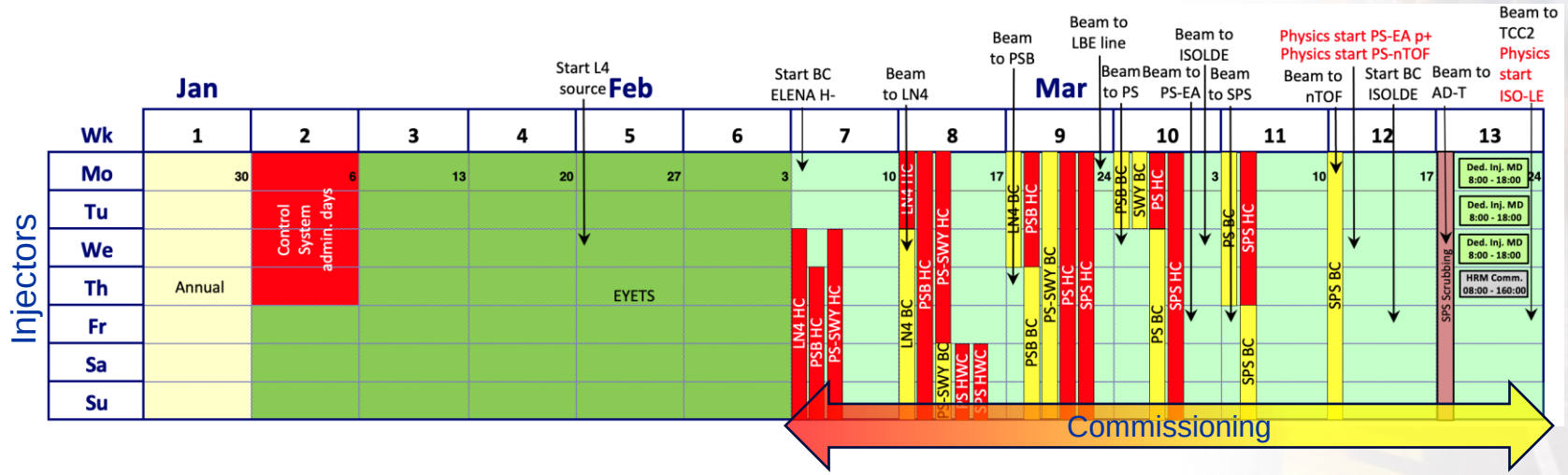
# Appendix

# The Updated Long-term Schedule



# Approved Injectors and LHC Schedules 2025 – Q1



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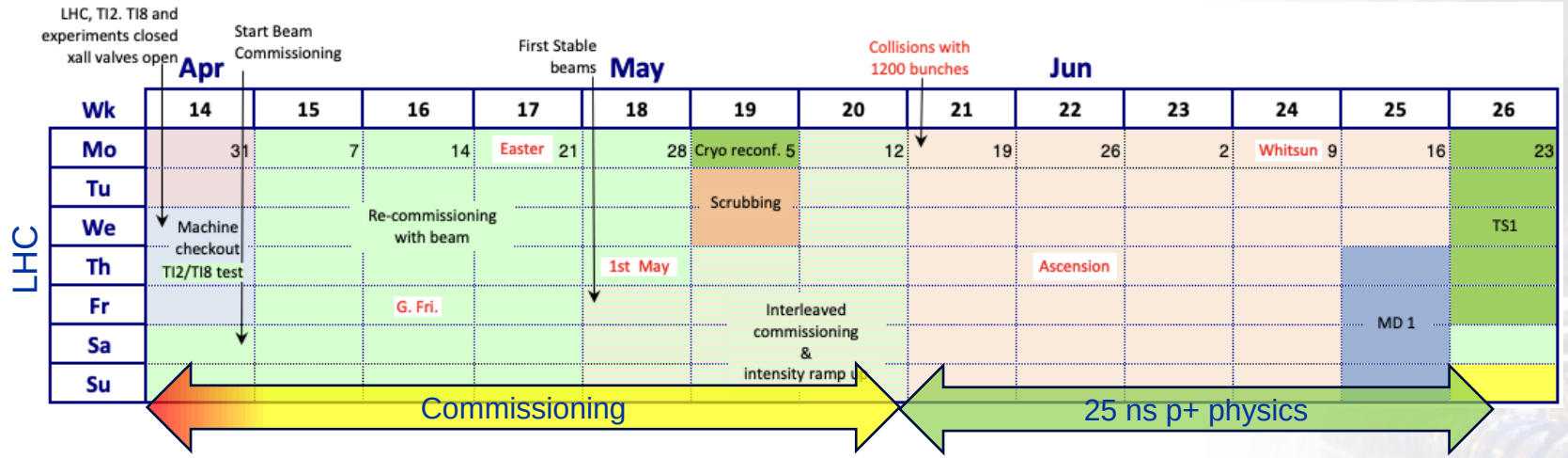


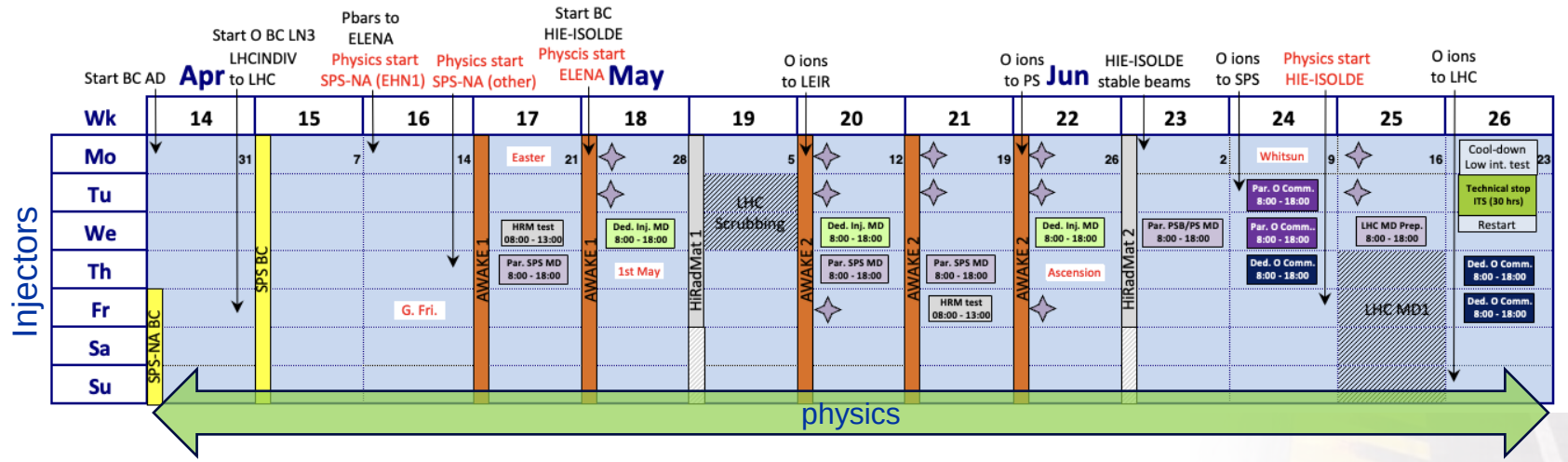

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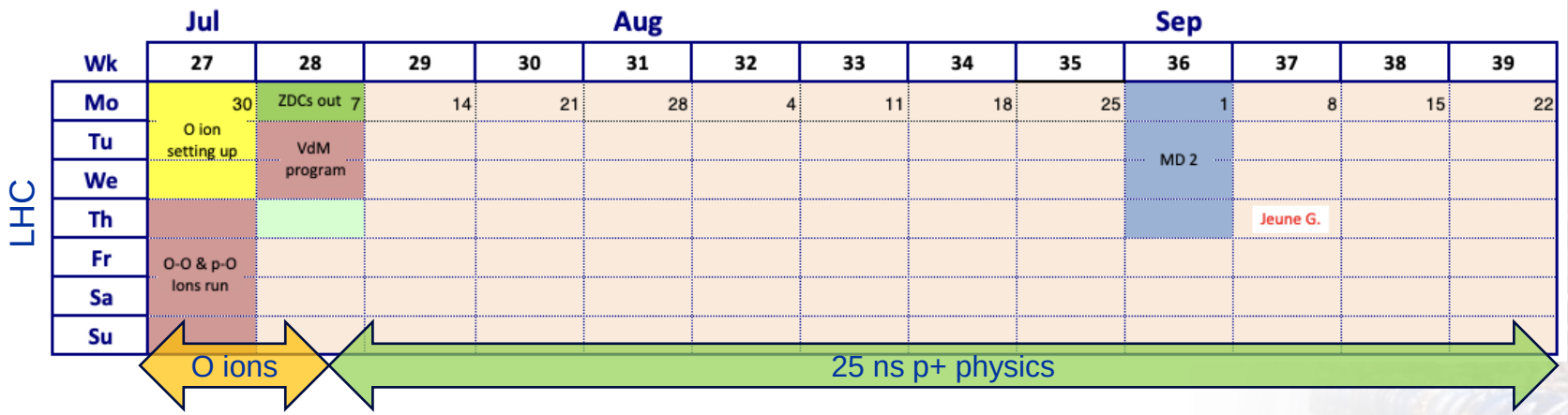
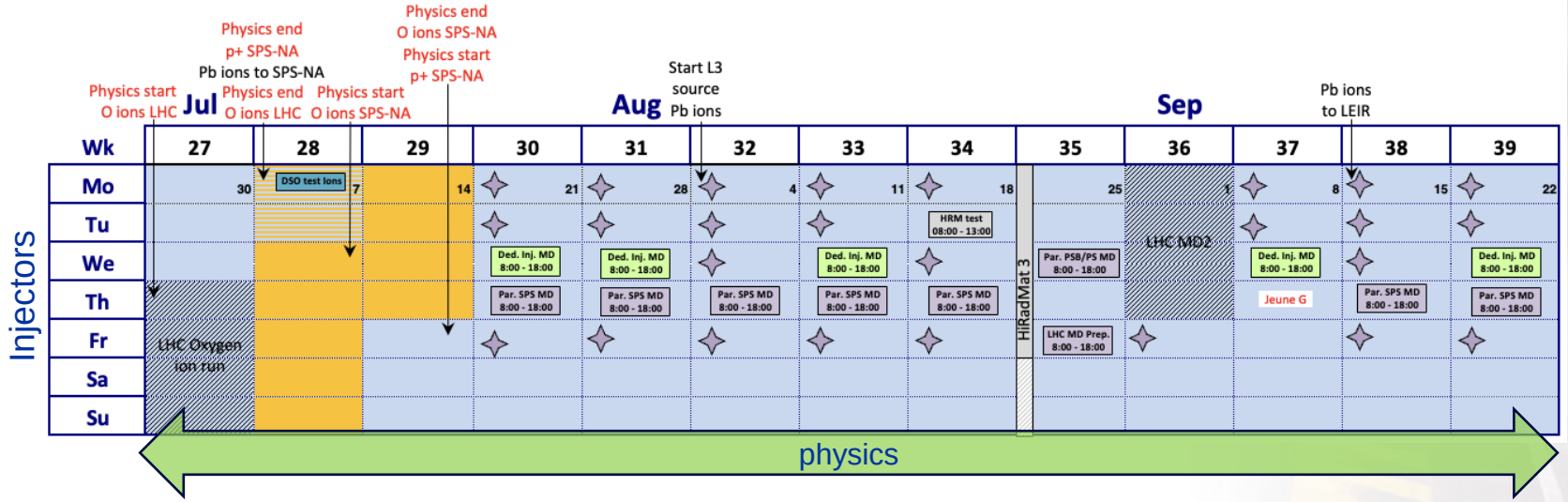
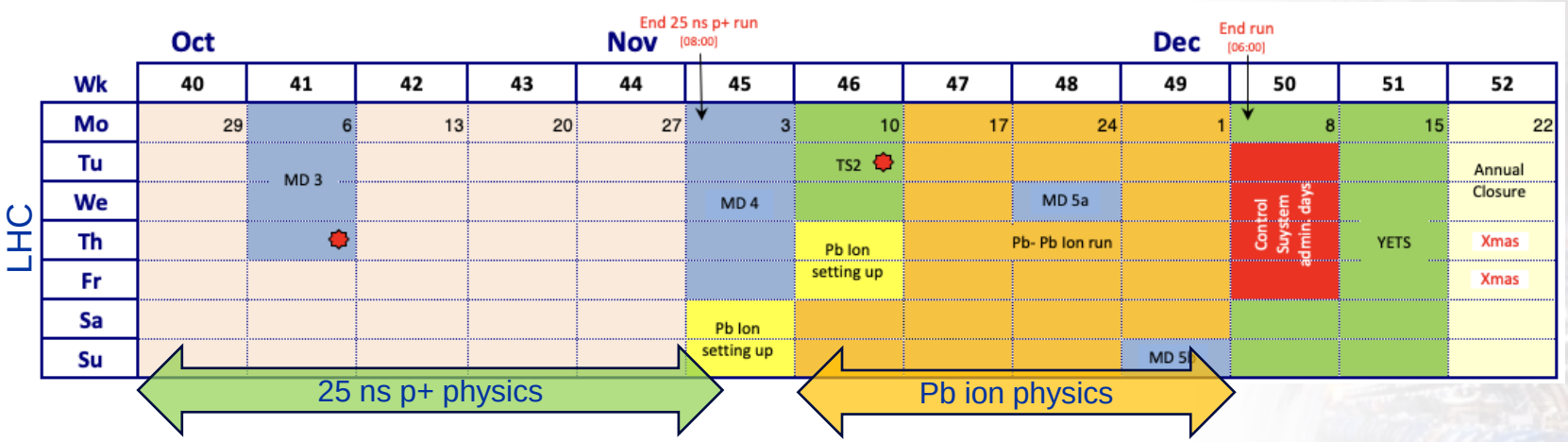
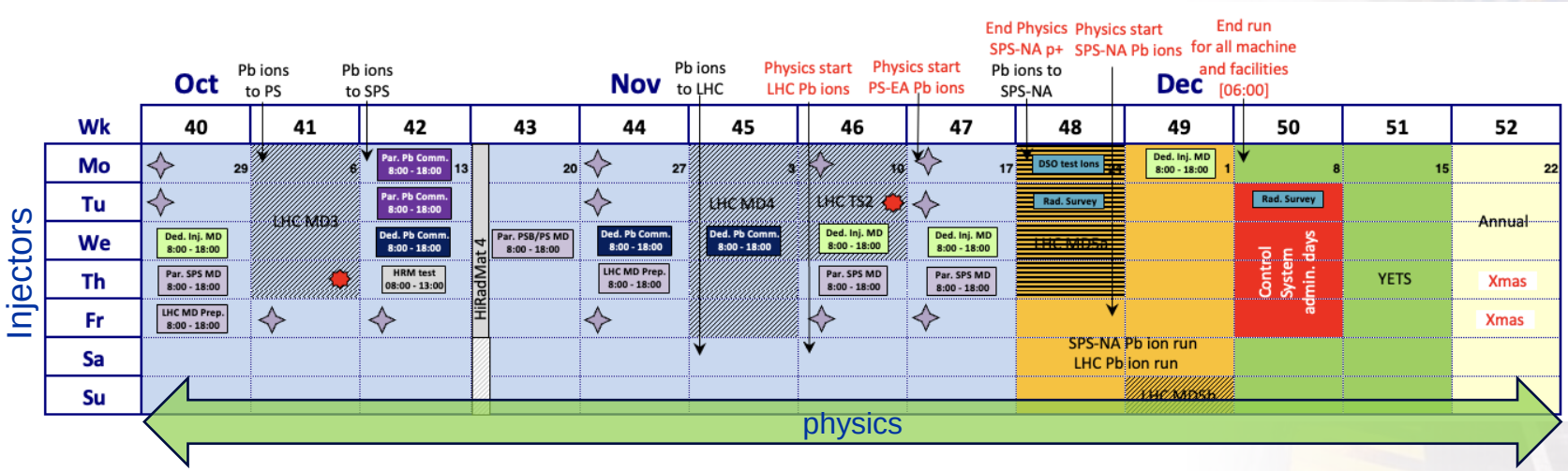


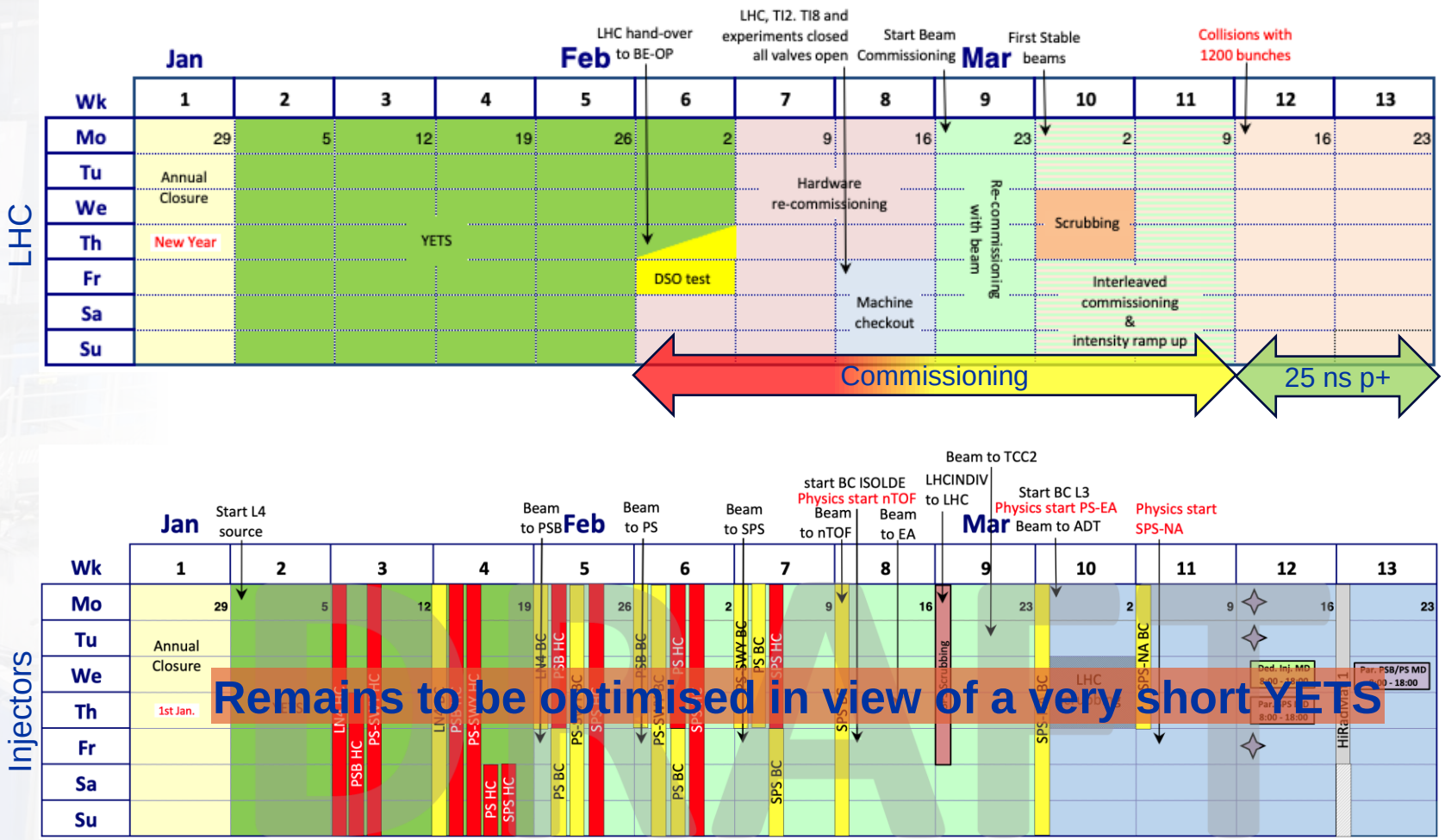



# Approved Injectors and LHC Schedules 2025 – Q4

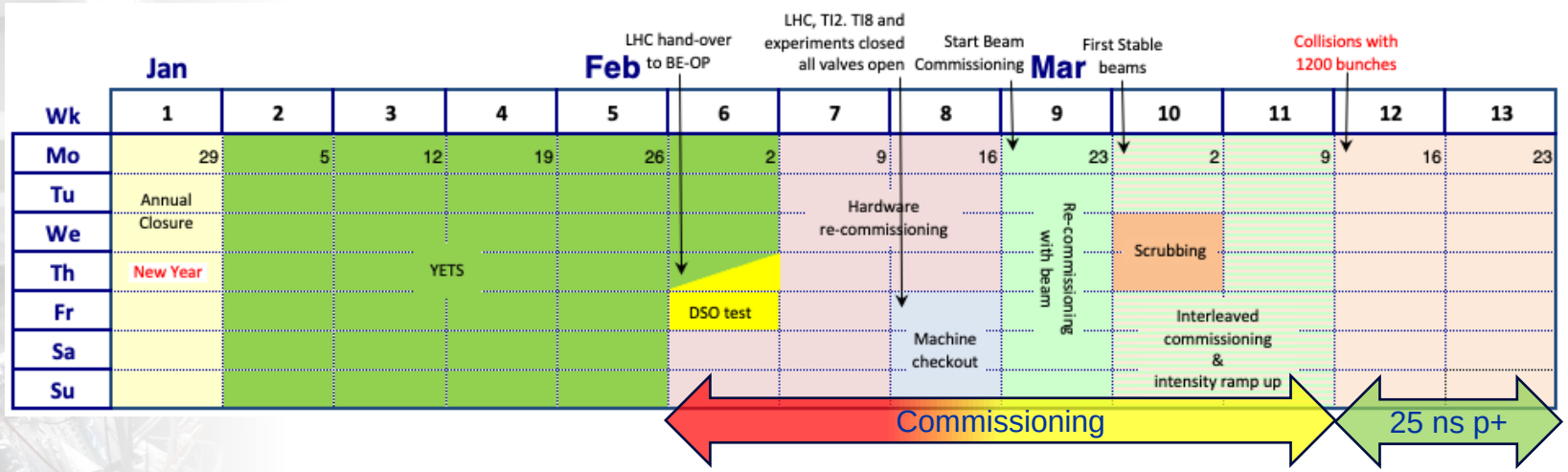


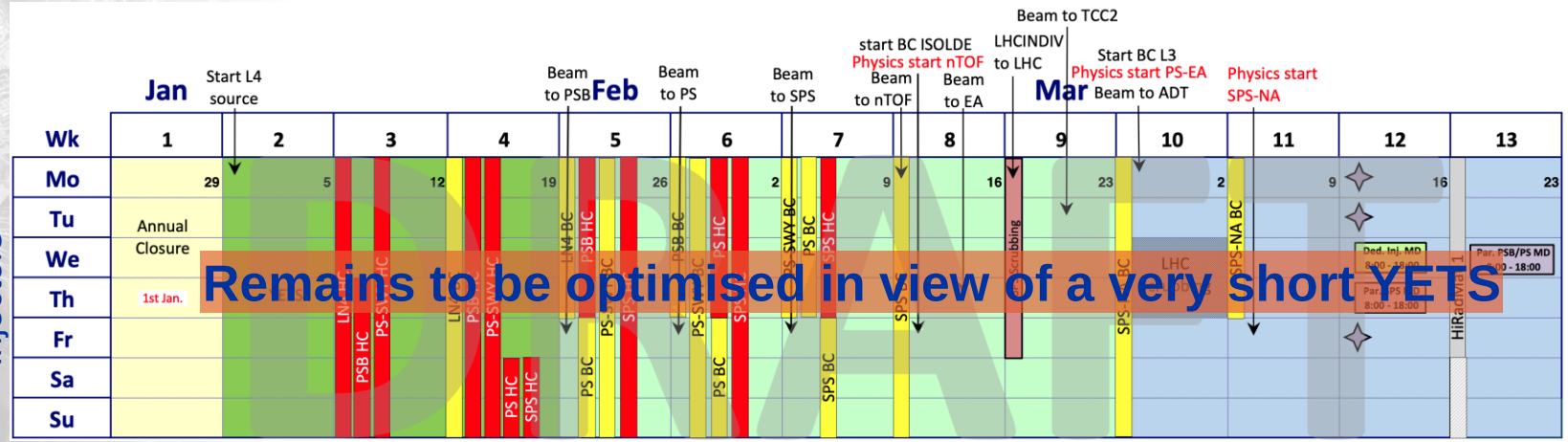



# Draft Injectors and LHC Schedules 2026 – Q1



# Draft Injectors and LHC Schedules 2026 – Q2



# Draft Injectors and LHC Schedules 2026 – Q3