

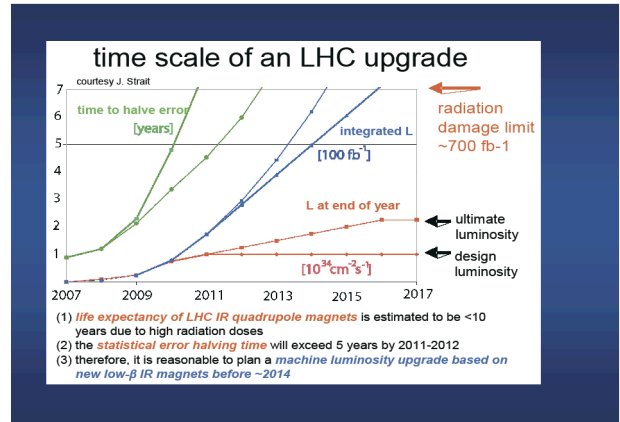
# Informal comments on SLHC machine issues

Andy BUTTERWORTH

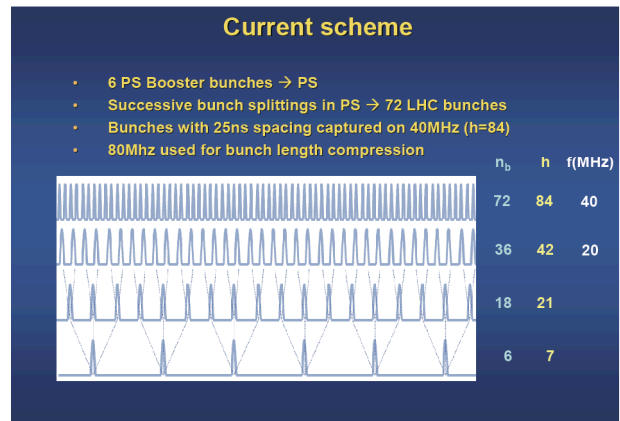
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**Informal comments on LHC upgrade: Impact of reduced bunch spacing**

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- ### Upgrade phases
- Phase 0: Maximum performance without hardware changes
  - Phase 1: Maximum performance with hardware changes in insertions and injector complex
    - IR magnets & layout
    - Crossing angle
    - Protons per bunch  $N_b$  up to ultimate intensity
    - High harmonic RF system 1200MHz → bunch shortening
    - Double number of bunches
  - Phase 2: Maximum performance with major hardware changes (HPS, SC PS etc.)



- ### Current scheme
- SPS 200MHz → 450 GeV
  - Injected into LHC on 400MHz or 200 MHz capture RF (for ultimate intensity beam)

- ### Closer bunches
- All RF manipulations assumed to be done in the PS
  - 12.5 ns spacing: 12.5 ns is not a whole number of 200 MHz RF periods
    - PS: one more splitting to be done, needs more RF voltage at 80 MHz for bunch length
    - SPS: 200 MHz no longer works, so need a new RF system (160 or 240 MHz)
    - LHC: need a new capture RF system in LHC (200 MHz no longer works)
  - 10 ns spacing:
    - no changes in SPS
    - new RF system in PS (95.4 – 100 MHz)
  - 15 ns spacing:
    - no changes in SPS
    - new RF system in PS (63.5 – 66.7 MHz)

## Closer bunches – other issues

- **Beam brilliance ( Brilliance =  $N_b/\epsilon_n$ )**
  - Ultimate intensity requires increase of beam brilliance in the PSB by 1.7 (brilliance =  $N_b/\epsilon_n$ )
  - Reduced bunch spacing requires increase of brilliance in PSB by a similar factor
  - Various schemes to increase brilliance (batch compression in PS, LINAC4 160 MeV → PSB)
- In the SPS more problems with e-cloud (V-emittance blow-up) and coupled bunch instabilities.
- **Beam loading in SPS RF 200 MHz and 800 MHz systems**
  - tests with high power pulsing over ½ ring
  - upgrade of power plant and couplers

## RF upgrades and tentative cost for different LHC bunch spacings

(F. Ruggiero, LHC-LUMI-05 – Session 2: High Intensity Effects)

- 12.5 ns
  - PS: double RF voltage at 80 MHz ~ 2 MSfr
  - SPS: more RF power and new RF cavities at 160 or 240 MHz ~ 75 MSfr  
new Faraday cage and infrastructure ~ ?
  - LHC: new capture cavities at 160 or 240 MHz (2x3 MV) ~ 5 MSfr  
new BPM electronics (MSfr + manpower + time)
  - TOTAL (12.5 ns) > 82 MSfr
- 10 or 15 ns
  - PS: new RF system at 66 or 100 MHz ~ 5 MSfr
  - SPS: double RF power at 200 MHz + new couplers ~ 20 MSfr
  - LHC: no new capture cavities
  - TOTAL (10 or 15 ns) ~ 25 MSfr
- Any bunch spacing shorter than 25 ns requires new electronics for the LHC BPM system, upgraded transverse feedback, collimation, cryogenics, beam dump, ...