LIU Beam Studies Review

SPS Session

28-Aug-2012
Q20 instability improvement

• TMCI
  – threshold expected at $3.5 \times 10^{11}$ for low vert chroma
  – Up to $4 \times 10^{11}$ no TMCI observed
  – Gives margin to reach HL LHC intensities

• Space charge:
  – For Q26 with chroma 0.25 can go up in single bunch intensity but struggling with losses due to TMCI
  – Similar brightness, but better losses for Q20
  – Slightly smaller tune spread for Q20 due to larger dispersion
  – With Q20 can also go up in intensity with lower chroma

• Ecloud
  – Not limited at present, but more margin for Q20 (simulation)
  – Could help for 25 ns beam

• Longitudinal
  – Threshold decreases with energy, controlled blowup
  – Need less blow up for Q20
  – Could also get in trouble at injection with more intensity from PS
Q20 to LHC and studies left

• Bunch length at extraction
  – need more voltage
  – For given emittance longer bunches – capture in LHC
  – Gvie bunch length, smaller long em – IBS in LHC

• Longitudinal beam quality at flattop
  – For Q20 slightly unstable without blow up

• Need to study 25 ns beam for Q20 this year

• Short bunches at LHC
  – Bunch length growth for short bunches 1.45 ns
  – Longer bunches in LHC 1.7, no capture losses, less bunch len growth

• Final steps to make Q20 operational
  – Probe cycle, extraction settings verification, transverse blow up, tails, SPS LLRF

• Studies left for 2012
  – Tails and transverse emittance for 50 ns
  – 25 ns with Q20 optics
  – Single bunch high int for SC and TMCI
  – Ions with Q20, IBS and SC
Q20 discussion

- Dampers: this degree of freedom should be taken into account and properly designed instabilities can be suppressed, does not appear in all machines! Proper parameter place to be chosen, chroma! - High bandwidth FB is addressed in SPS
- Optimisation for IBS growth, in LHC we can do batch by batch blowup and decouple the machines; from MD it seems we don’t need batch by batch blowup for these intensities
- Same long emitt as for Q26, we would try to work with same bunch length – was motivated by capture losses which were not seen in MD, could optimise bunch length, more difficult if we need the same long emittance
- From LHC the limit is capture voltage, should not go to limit of 8 MV; bunches come always with smaller dp/p but same bunch length so we don’t need more voltage
- For MD no setting in LHC had to be changed apart from transfer line settings
- IBS: what is smaller in emittance at LHC collision has faster lumi decay at present operation – no big deal now
Ecloud lessons from 2012 studies

- 25 ns beam, nominal intensity
  - No emittance growth with 4 batches as seen in 2000, (with low chroma settings)
  - In 2000 pos tuen shift (ecload), 2012 negative (impedance?)
  - High chroma needed in 2000 for stability, no degradation in 2012 even with low chroma
  - Only other observable is pressure rise, smaller by $10^4$ than 2002

- 25 ns, ultimate intensity
  - For higher int ecloud can reach non conditioned areas – pressure rise, tried with radial steering, seems to confirm, more tests
  - Conditioning observed with a few hours on these intensities
  - By moving the beam 1 cm clearly see effect even with 50 ns beam on pressure rise by factor 10 – expected by simulations

- Coating:
  - MBA less critical than MBB (risetime, flux, central density) with 25ns
Ecloud lessons from 2012 studies

• Bunch intensity dependence
  – MBA less critical
  – Ecload in central region not increasing with intensity (consistent with model)

• Dynamic pressure rise
  – Why do we observe a dynamic rise on coated chambers?
  – Comes only from stainless steel part of machine

• How to learn more about ecloud?
  – Data logging
  – Microwave transmission technique: send EM wave through pipe and detect phase modulation by ecloud, further increased bandwidth, quantitative estimations of e densities and finally online monitoring, shielded pick up with remote data acquistion to get ecloud decay time
Ecloud studies left and after LS1

• Still to be done this year
  – 25 ns ultimate int
  – Incoherent effects, coast at 26 GeV for some minutes
  – Scrubbing in machine and lab
    • Copper
    • Stainless steel
    • Analyse dark layer on chambers
  – Repeat solenoid experiment
  – Scrubbing localisation

• In LS1:
  – Crucial to preserve vacuum
  – After LS1 scrubbing run with long 40 s cycle
  – Two fully coated cells to be installed, remove aC coated drift with STSt
  – After LS1 profit of high brightness RF schemes in PS
Ecloud discussion

• Decision about coating or scrubbing, asymptotic value of SEY, still correct? - in lab still like this, but the vacuum situation is different in machine and lab, chemical reaction different, startup after LS1 crucial

• Vac quality during LS1 very important, need to know how much time needed for scrubbing, presently consider 2 weeks?

• aC coating or not depends on (Bren’s summary):
  – does aC work as a mitigation? Present answer is yes.
  – is present SPS performance with well-scrubbed machine acceptable for today's and tomorrow's beams? Less obvious, but present performance with 50 ns excellent and nominal 25 ns promising - can we extrapolate easily to HL-LHC regime?
  – can we quickly scrub SPS back to 'acceptable' situation after a long shutdown? This remains to be demonstrated - do we need reference measurements end 2012 to compare with 2014 startup?

• Possible minimum of eclound with bunch intensity, when losing eclound in centre your are losing nonlinearity, so could be misleading that it is beneficial - see clearly also in LHC that we are dependent on central density

• What do you expect for LHC 25 ns beam – emittance growth
Longitudinal instability studies in 2012

- **LHC beam quality in Q26:**
  - Unstable bunches at flat bottom for $N > 1.5 \times 10^{11}$
  - Batch 4 spends no time at flat bottom $\rightarrow$ unstable at the end of ramp or flat top
  - Enhanced instabilities due to increased spread of incoming bunches
  - **Solutions:**
    - Take out the dips in the 200 MHz RF voltage program (done)
    - Introduce more time at flat bottom after the 4th injection (longer FB)
    - Increase emittance blow-up in the PS (3x4.5 kV) $\rightarrow$ more stable in PS $\rightarrow$
      - less spread of bunch parameters at injection in the SPS
  - **Cost:** more losses - about 1%
  - **Q20 (still better with longer FB)**

- Longitudinal impedance identification using long injected bunches (~25 ns) with
  - RF off:
    - Measurements as in the past (1997, 2001, 2007...) of the beam spectrum
      - show a high mode amplitude at 1.4 GHz $\rightarrow$ low Q impedance to be identified
Longitudinal instability studies in 2012

- Longitudinal instability thresholds measured at flat bottom and flat top in single RF:
  - Single bunch ($\varepsilon_L$~0.28 – 0.32 eVs):
    - Flat bottom: Loss of Landau damping due to injection V mismatch – stable
    - with low (matched) capture voltage > 1.4x10^11
    - Flat top: $N_{th}$~1x10^{11} p
  - Single 50 ns LHC batch:
    - Flat bottom: 1.5x10^{11} < $N_{th}$ < 1.8x10^{11} p/b → similar to single bunch
    - Flat top: $N_{th}$< 0.4x10^{11} → stronger effect of beam loading at 800 MHz RF (?)

- 50 ns LHC beam Q20
  - $N_p$~(1.5 - 1.6)x10^{11} p/b on flat top
  - Stable beam on FB
  - Acceptable beam parameters at extraction (bunch length) – injected to LHC
  - Scaling of bunch length/stability between Q20 and Q26 as expected
  - More possibilities with upgraded 200 MHz RF (LS2)
Longitudinal instability plans for 2012/13

MDs:
- High intensity 50&25 ns beam in Q20 → operational. And Q26? (losses increased in the first test)

- Study (thresholds) of single and multi-bunch instability at injection for Q26 and during ramp for Q20 and Q26 in a single and double RF systems

- Reference impedance measurements from quadrupole frequency shift at injection and stable phase shift (? – more difficult)

Simulations:
- Identify the impedance from comparison with measurements done with long (RF off) and short (RF on) bunches

- Reproduce the measured thresholds for single bunches (PL on/off)
Long. instability: Questions to be answered

- **Requirements for the 800 MHz system:**
  - 2\textsuperscript{nd} cavity operational (idle at the moment) – more voltage and better control
  - FB and FF for phase and voltage control under strong beam loading for the two cavities (work in progress)
  - Phase calibration (now based on bunch shape/stability)

- **What else do we need to know to estimate performance after LIU:**
  - Impedance source of longitudinal instabilities $\rightarrow$ measurements of HOMs in the 200 MHz and 800 MHz TW RF systems in labs (spares, not fully equipped) and in situ (tunnel) during LS1 (F. Caspers, E. Montesinos + new fellow/PhD student)
  - 1.4 GHz
  - Complete impedance model
Long. Instability Discussion

• Instability seen in single RF, single batch - should be seen for single bunch as well which is not the case
• The more un-uniform the beam from the PS, the more unstable the beam in the SPS at FT because blow-up becomes more difficult
• In MD found that voltage dips are also important and allow for blow-up due to mismatch
• Also parameter in LLRF found to become more independent from PS beam quality
High bandwidth damper - MD studies in 2012

• Synchronized excitation signal to the bunch.
• Established method by which time aligning can be performed quickly and reproducibly, using variable delay line.
• Excited the beam with band-filtered random noise.
• Excited beam to instability, different modes.
High bandwidth damper - 2012 MD slots

**With LARP:**

- *LARP meeting in Frascati 14-16 November 2012*
- **1st slot:** Beginning of October or before above November LARP meeting: *fine timing, excitation of bunch in a train*
- **2nd slot:** As late as possible, weeks 47 and 48 after LARP meeting: *tests of new hardware for “demonstrator” to close FB loop*

**Further:**

- One dedicated MD with bunch trains at 25 ns
- MDs to check the developed hardware orbit compensation (Urs Wehrle)
- **Note:** any MDs next year (26 GeV) would be extremely useful (consolidated Hardware) for extended demonstrator tests and prototype specification.
Addressing the specific questions...

- Which studies will still require significant MD time before LS1?
  - List of topics given above
- Is any study presently limited by instrumentation or diagnostics? Any improvement possible before LS1?
  - Limited by speed of HW development and availability, rather than intrinsic SPS instrumentation
- Is any study strongly relying on the installation and test of new hardware before LS1?
  - Yes – the single bunch ‘demonstrator’ studies require the HW for the feedback processing channel to be available...tight for end 2012
- How can we optimize the use of the remaining available MD time? Do we need to request for more?
  - The timing of the MD is most critical – as late as possible
- Which are the main motivations why we could benefit from the extension of the MD run into 2013?
  - Would be very useful indeed, as HW will arrive very late in the year. Increase time for measurement, reduce risk of missing deadline, ...
Damper discussion

- MD time really dedicated?
  - means 25 ns cycle but no coast SPS, 12 b would be fine
  - No HI beam next year, which are the CNGS and TOF like beams
  - Two issues, RP and 80 Mhz in PS
  - Probably not highest intensity needed for this MD

- Behaviour of damper for higher number of bunches could be different, should be tested as high as possible
  - Not possible this year
  - Impo effort in parallel going on in simulations

- In what optics
  - Q20 - so what to dump?
  - Can go to higher intensities
  - Should keep Q26

- Still don’t know if PS damper effective at high energy, since beam is not unstable
  - Have to understand if damper from today is enough or more bandwidth needed
  - Mode 0 damping at 0.2 chroma
  - Going to try at high energy but was designed for inj oscillations