LIU Beam Studies Review

SPS Session

28-Aug-2012

Q20 instability improvement

- TMCI
  - threshold expected at 3.5e11 for low vert chroma
  - Up to 4e11 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 i n 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 lenght 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 intabilities 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 observalbe is pressure rise, smaller by $10^{e}4$ 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 thes e 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
  - Srubbing 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 ecloud with bunch intensity, when losing ecloud 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 1011
  - Batch 4 spends no time at flat bottom → 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) → more stable in PS →
    - less spread of bunch parameters at injection in the SPS
  - **Cost**: more losses - about 1 %
  - **Q20 (still better with longer FB)**
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- **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 → 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** (ε_L~0.28 – 0.32 eVs):
    - Flat bottom: Loss of Landau damping due to injection V mismatch – stable
    - with low (matched) capture voltage > 1.4x1011
    - Flat top: - N_{th}~$1x10^{11}$ p
  - **Single50 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 (?)
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- **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:**
  - 2nd 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 → 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