Bunch trains and crossing angles at injection

(rumours and facts ...)

reported by W. Herr, (for Friday afternoon crew, etc.)

Objectives:

- **Inject bunch trains in the presence of crossing angles**
- **Bunch spacing 150 ns**
- **It was not a (controlled) beam-beam study**
- **Determine the minimum required crossing angle (to gain aperture) at injection**
- **Might be possible because:**
  - **Number of long range interactions smaller than nominal**
  - **Emittance smaller than nominal**

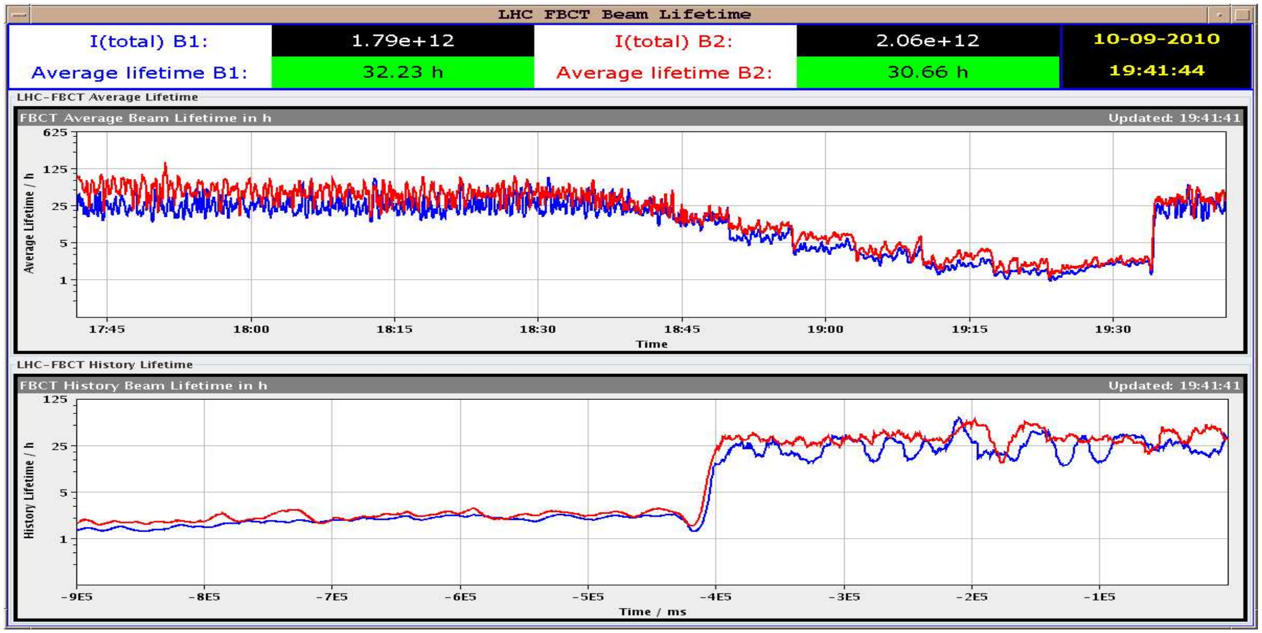
Conditions:

- 4 trains in each beam: (4,) 8, 8, 8 bunches (chosen that some bunches have full number of long range interactions for 150 ns spacing, 12 bunches per train would not give more)
  - → Number of long range interactions between 4 and 20 (not up to 6, as reported Saturday)
- Intensities around 0.9 - $1.0 \cdot 10^{11}$
- Parallel separation in all IPs ($\pm$ 2 mm)
- Start at nominal crossing angles ($\pm$ 170 μrad)

Procedure:

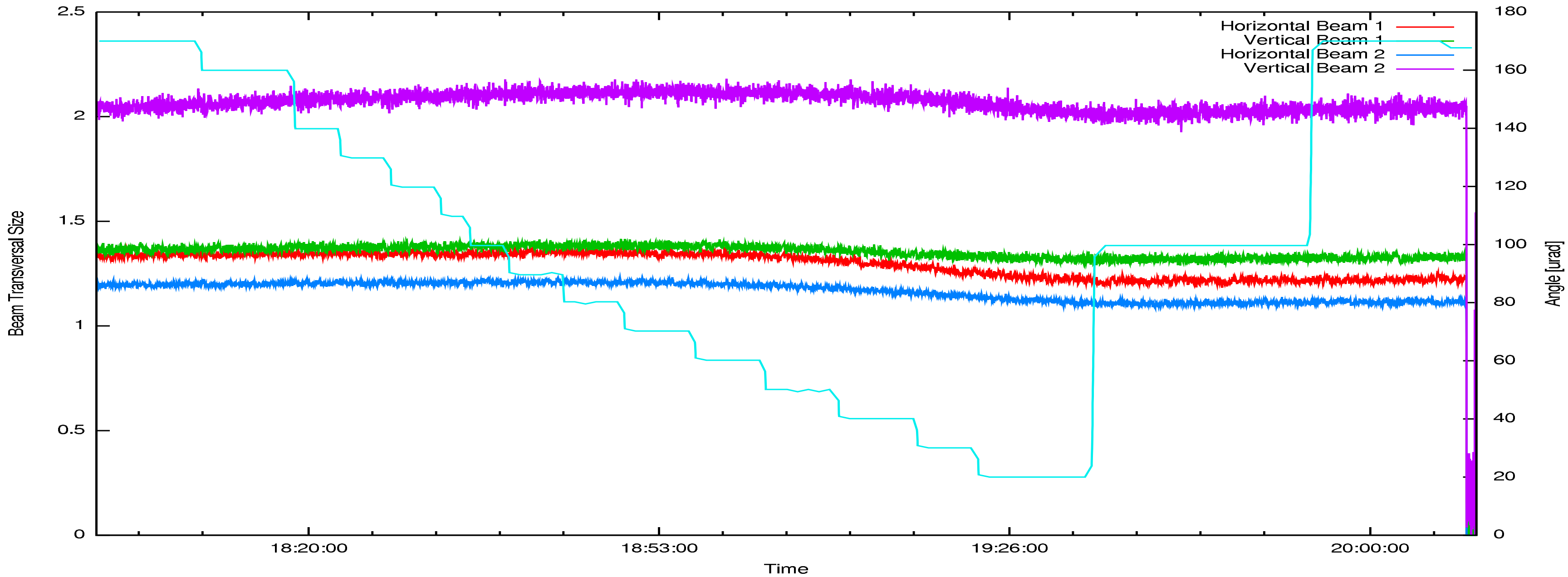
- **Set collimators to allow trimming down the crossing angle**
- **Reduce crossing angles in all IPs simultaneously, observe life time, orbit closure, beam losses etc.**
  - **Parallel separation remains constant (i.e. beam separation never drops below $\approx$ 3 σ for nominal emittance)**
  - **Scan from $\pm$ 170 μrad to $\pm$ 20 μrad (in steps of 20 μrad or 10 μrad)**
  - **No re-optimization of life time between steps**

Life time for different α



- What we saw in the control room .....
- Life time steps corresponds to change of angle

Beam size as function of α



- Recorded beam size as function of time (angle)
- No dramatic dependence, as expected

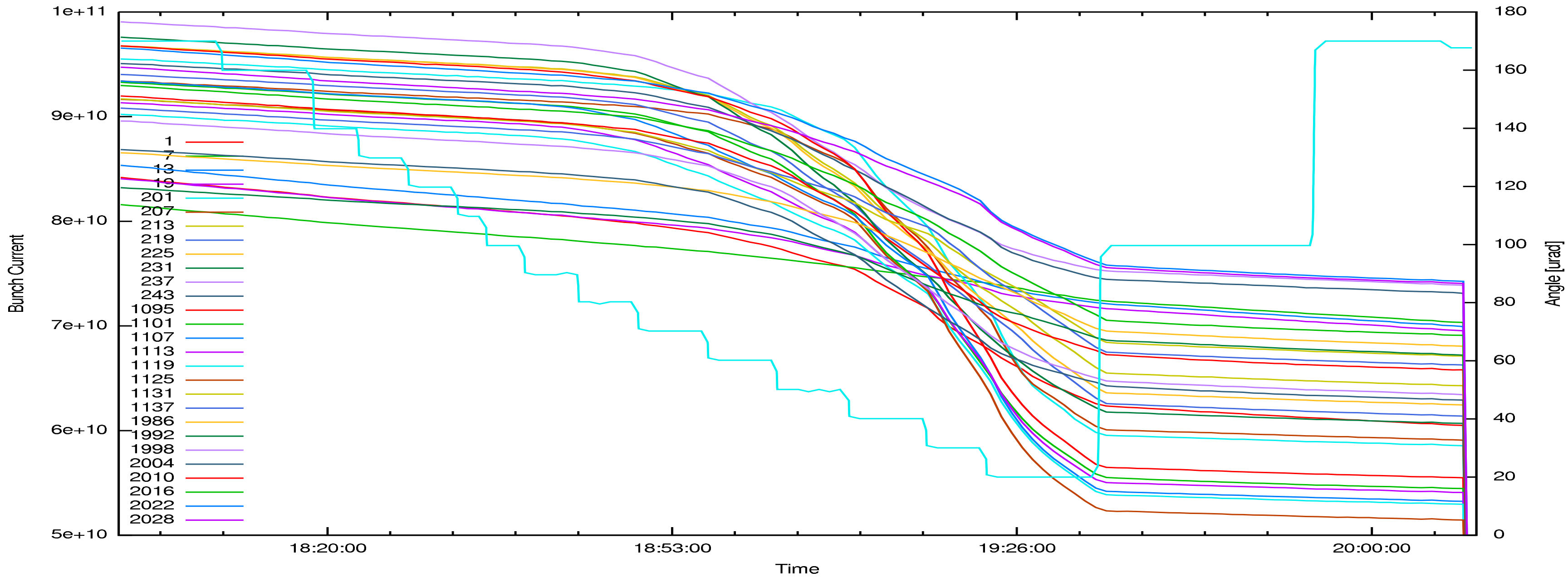
First observations I:

- **Little effect on life time between $\pm$ 170 μrad and $\pm$ 120 μrad**
- **First (very small) effect at $\pm$ 100 μrad**
- **First (significant) effect from $\pm$ 100 μrad to $\pm$ 90 μrad**
- **Final drop to less than 1 hr, (remember even with $\pm$ 20 μrad still minimum $\geq\ 3\ -\ 3.5\ \sigma$ separation)**
- **Returning to $\pm$ 100 μrad restored the beam lifetime ! (hysteresis from crossing angle seems small)**
- **Don't jump to conclusions, because:**

First observations II:

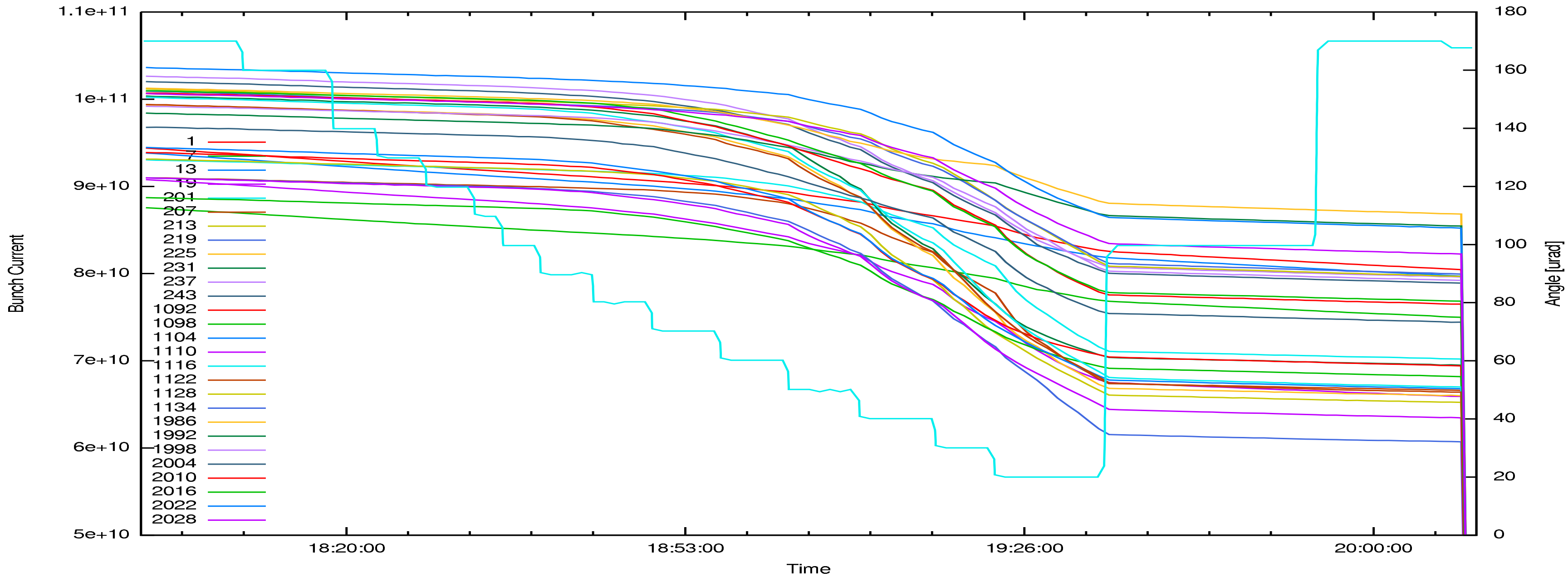
- **Measured emittance (WS) significantly smaller than nominal (lower than 3 μm)**
- **Intensities at end of experiment already lower**
- **Not all bunches see the full collision scheme, this life time is a mixture**
  - → **Analyse bunches separately**

Bunch current as function of α - beam 1



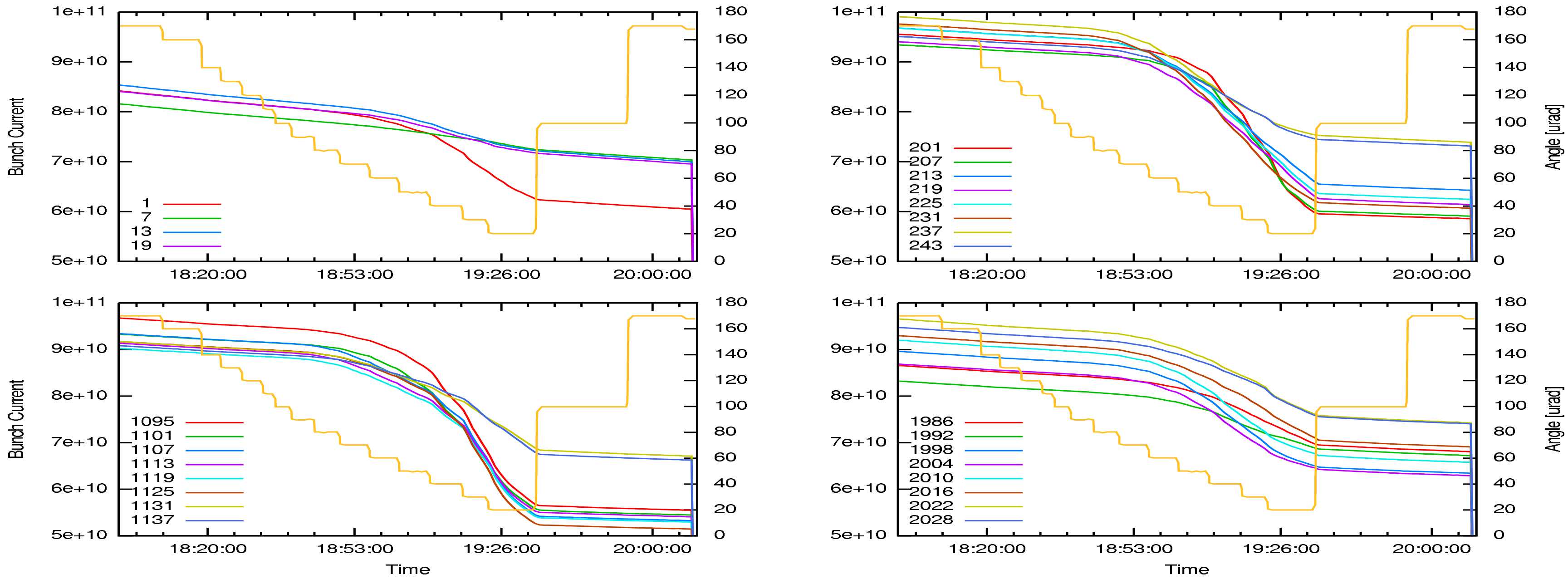
➡ **Lifetime for different crossing angles (beam 1)**

Bunch current as function of α - beam 2



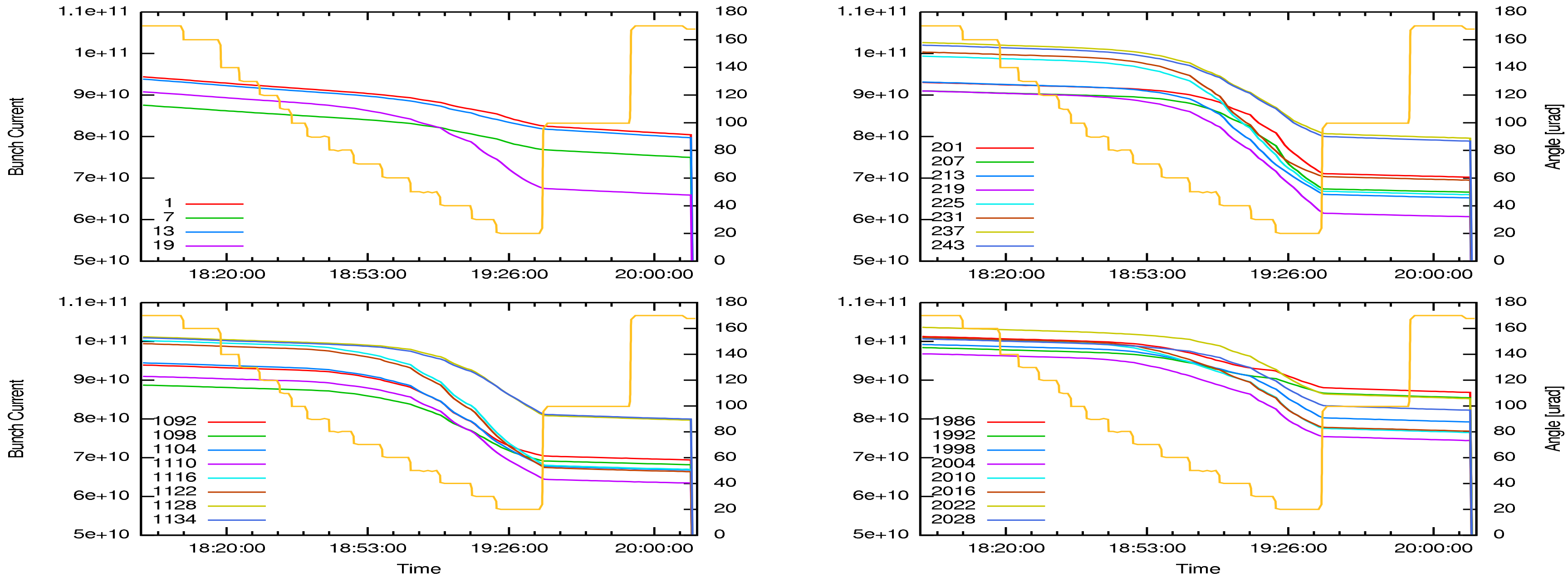
➡ **Lifetime for different crossing angles (beam 2)**

Bunch current as function of α - beam 1



- Separately for the 4 bunch trains
- Lifetime for different crossing angles (separate trains)
- Not all details understood, but clear trends ..

Bunch current as function of α - beam 2



➡ **Separately for the 4 bunch trains**

➡ **Lifetime for different crossing angles (separate trains)**

➡ **Not all details understood, but clear trends ..**

Observations continued ..

- **Bunches behave very differently, depending on collision pattern**
  - **Different number of long range interaction**
  - **Different encounters, i.e. separation**
  - **Different collision symmetry (left/right of IP)**
- **This is what we expected, PACMAN is there ... (maybe stronger than expected)**
- **Qualitatively mostly understood, detailed study required (good quantitative study requires bunch-to-bunch diagnostics and dedicated run time)**

Summary

- **Very clear long range beam-beam effects can be observed**
- **Clear correlation between collisions and beam loss**
- **Smaller separation may be sufficient for 150 ns spacing (although not comfortable) , probably difficult for more bunches**
- **The nominal machine will be (very) interesting ...**