Emittance Preservation through the 2012 LHC Cycle

Preliminary Results

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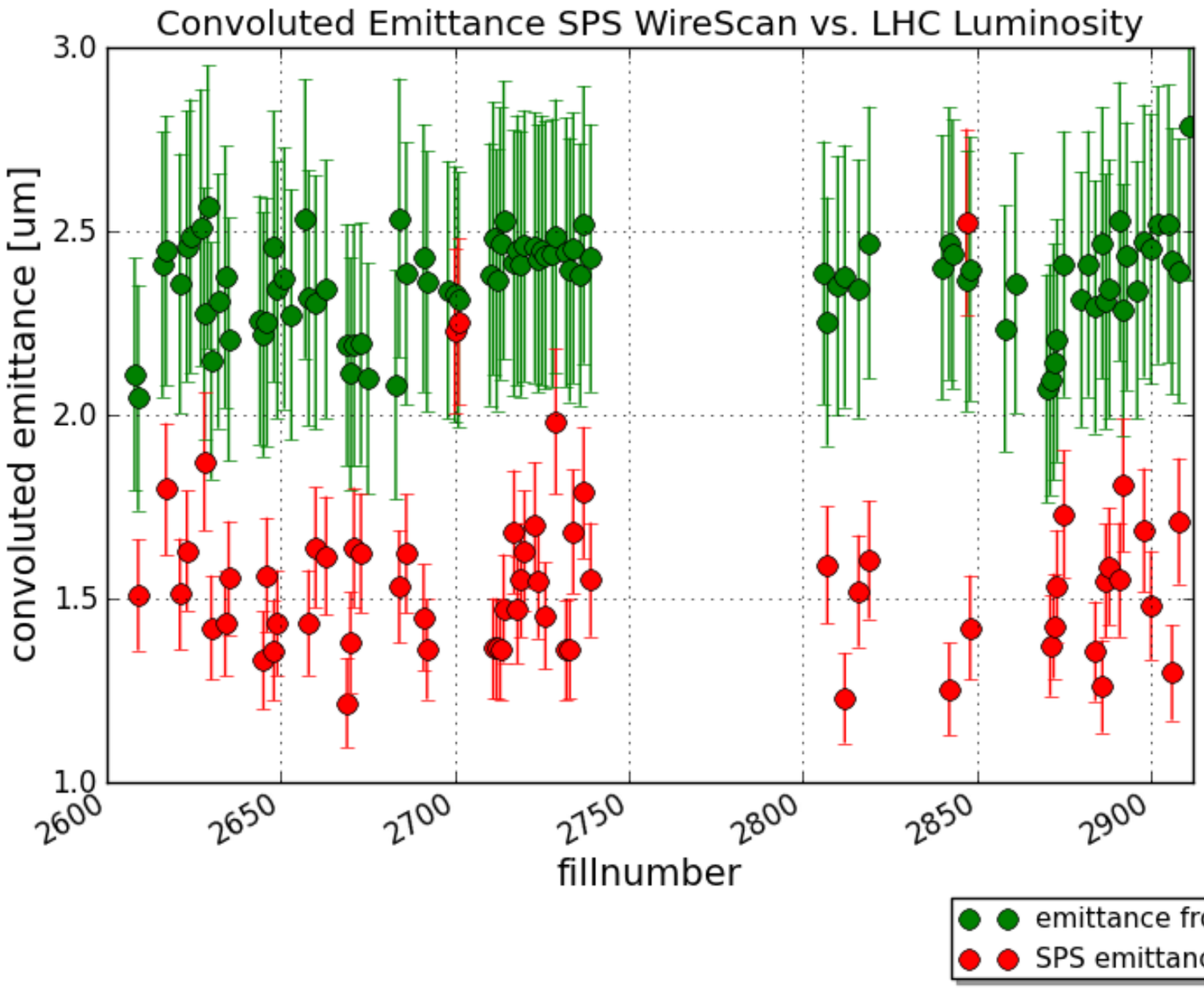
Emittance preservation 2012

- 2012 run: emittance from luminosity and emittance from SPS wire scanners on full 50 ns SPS batch (144 bunches)
- Large errors on emittance from luminosity
- Blow-up evident despite large errors



up to 1 μm

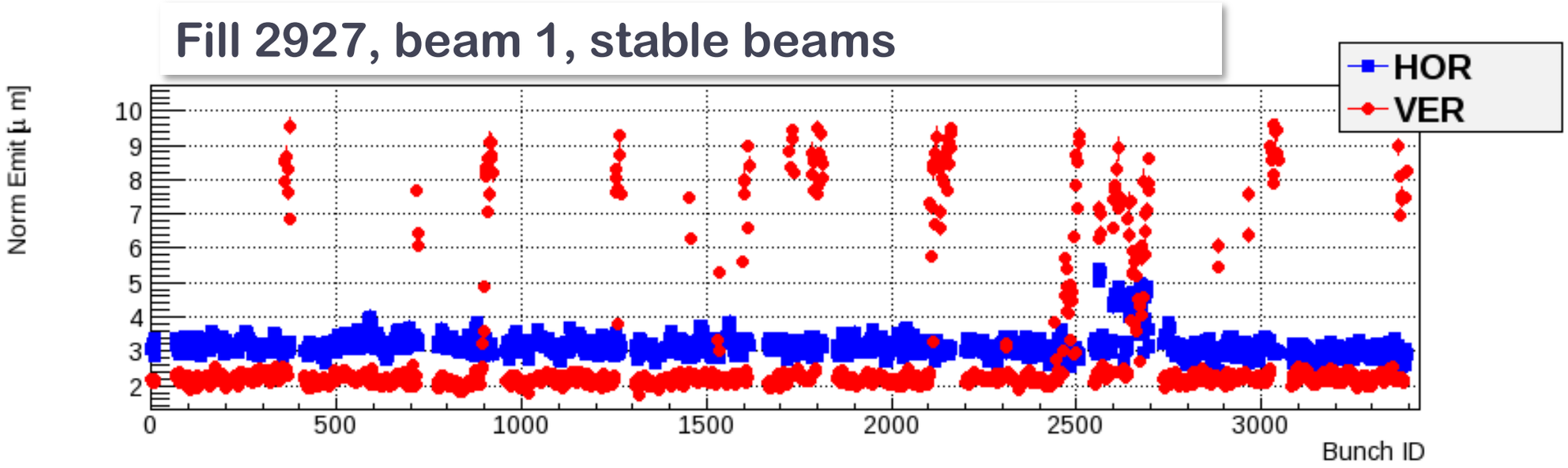
Where does the blow-up occur in the LHC cycle and how much is it really?

Blow-up due to instabilities

Will not talk about this in detail

- Instabilities due to electron cloud
  - With 25 ns

- Instabilities due to impedance and/or beam-beam – blow-up of individual bunches



What remains when these are under control?

2011 Blow-up Investigations

1. No measureable blow-up from injection process
   - Sensitivity: ± 10 %

2. Blow-up during injection plateau → bunch-by-bunch differences, smallest effect on total emittance blow-up
   - Consistent with IBS simulations
   - 0 – 10 %, different for different batches

3. Significant blow-up during the ramp
   - > 20 % for 1.6 μm

4. Blow-up during the squeeze for beam 1, horizontal plane
   - > 20 %

5. Absolute emittance growth through cycle independent of bunch intensity and emittance
   - $\Delta\varepsilon \sim$ 0.5 – 0.6 μm for convoluted, averaged emittance from luminosity

See talks at LHC Performance workshop Chamonix 2012, LHC Operations workshop Evian 2011

Emittance Preservation Measurement

- Main limitation: instrumentation – no system fully adapted to measure physics beams through cycle
- Several different profile measurement systems in the LHC
  - Wire scanners, low intensity only
  - Synchrotron Light Monitors (BSRT): continuous, bunch-by-bunch, not during energy ramp, calibration difficult
  - Beam-Gas Ionization Profile Monitor (BGI): continuous, not commissioned in 2011/2012
  - (Luminosity)
- Lessons learnt 2011:
  - Importance of fast and well-calibrated continuous emittance measurement – emittance evolution needs to be available online: Synchrotron light monitor (BSRT) and Beam-Gas Ionization monitor (BGI)
  - Importance of using measured optics
- Status 2012: BGI not suitable – systematic limitations, BSRT fast server not operational yet

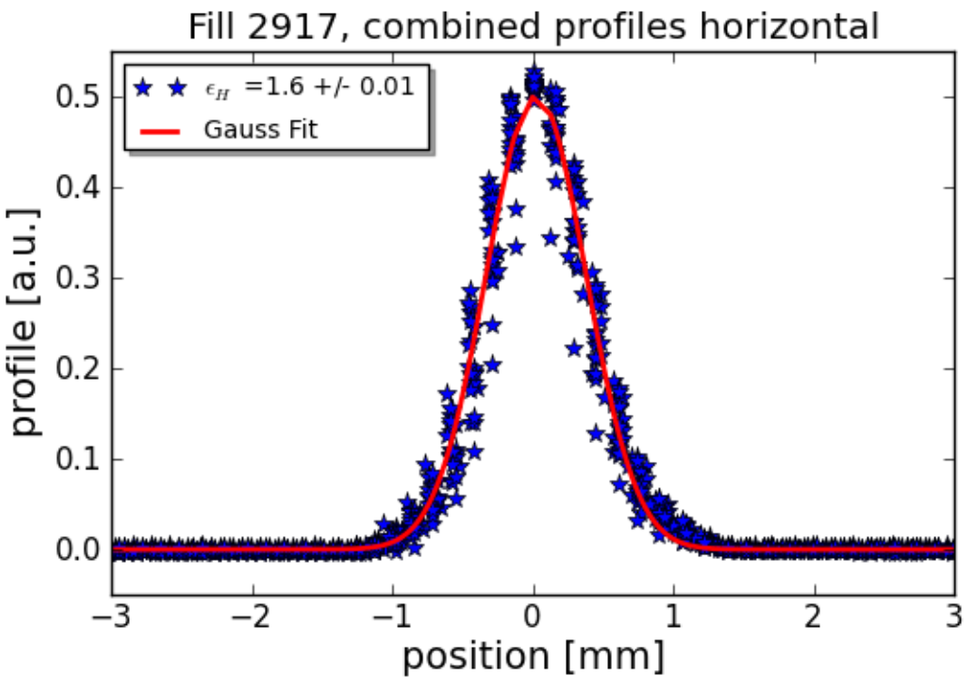
⇨ Only wire scanners to qualify ramp: low intensity

BSRT still too slow for squeeze or injection plateau qualification

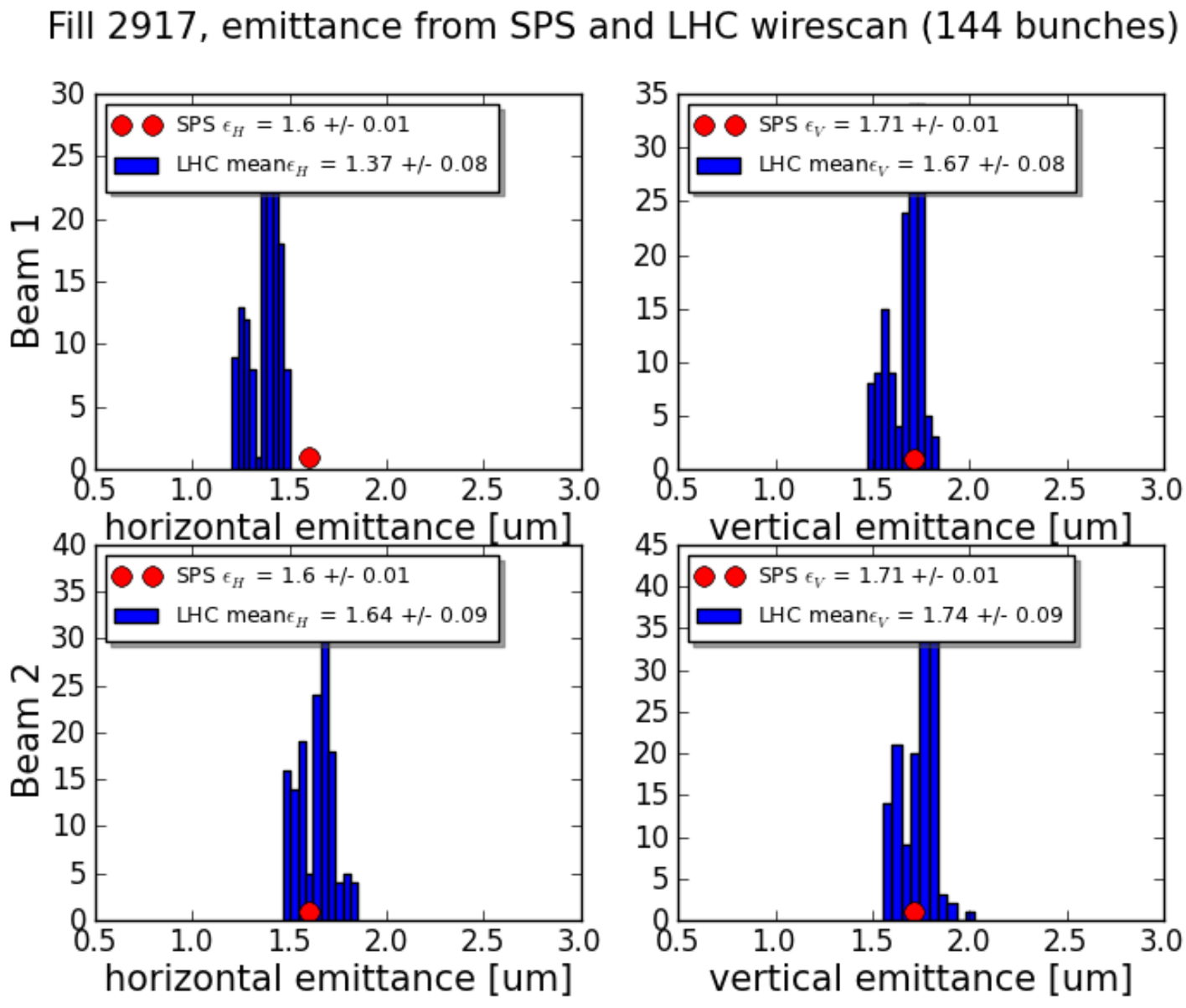
EMITTANCE PRESERVATION THROUGH THE DIFFERENT LHC PHASES

Injection Process: SPS 2 LHC

- No operational matching monitor
- Comparison of wire scans on 144 bunches, using measured betas in LHC



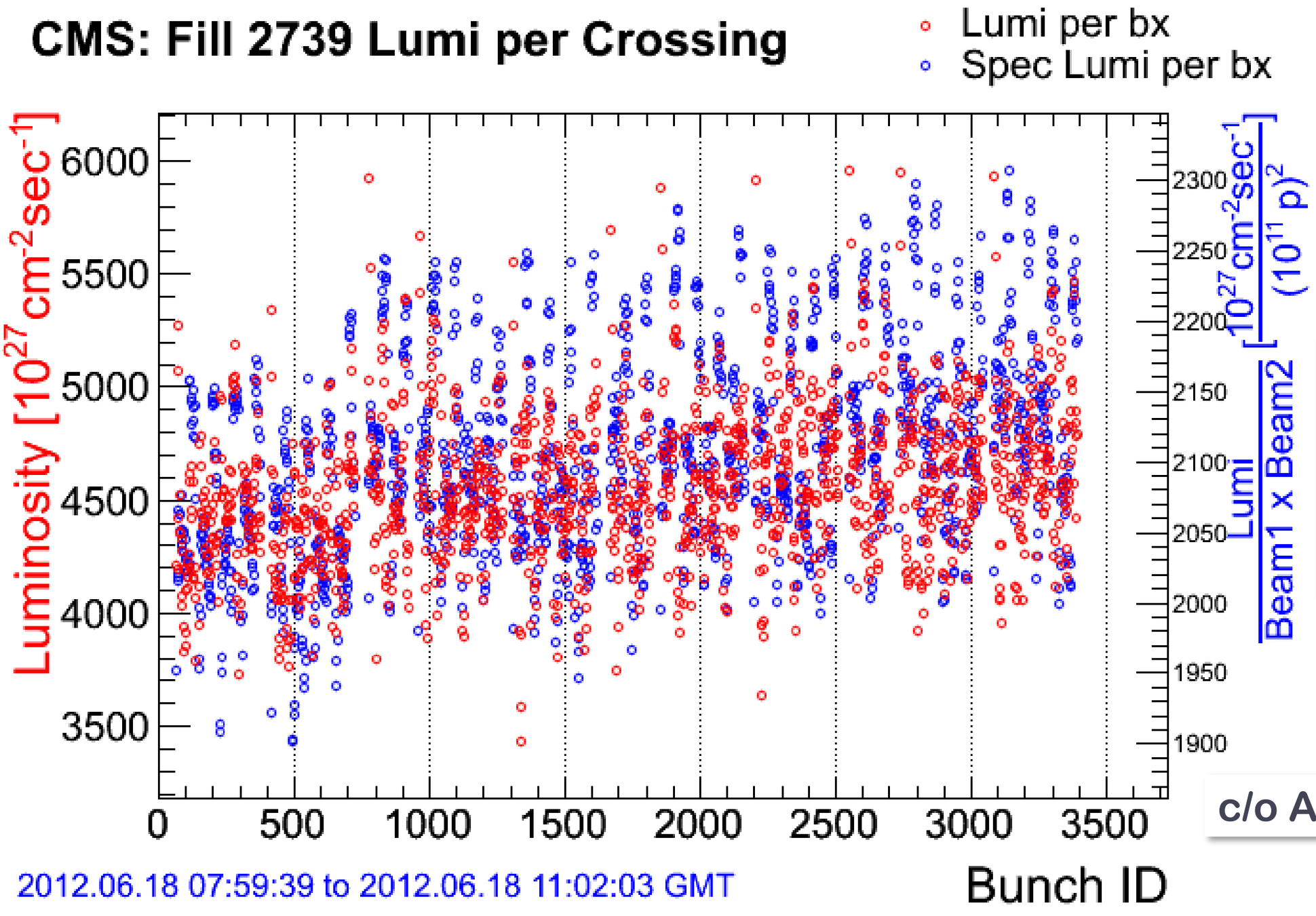
SPS profiles: ~10 profiles combined for accuracy



Within the measurement accuracy (+/- 10 %) the emittances are preserved at LHC injection. ….as in 2011.

Blow-up at injection (1)

- Stay about 30 min at injection plateau for physics filling
- Beams are blowing up slowly at 450 GeV

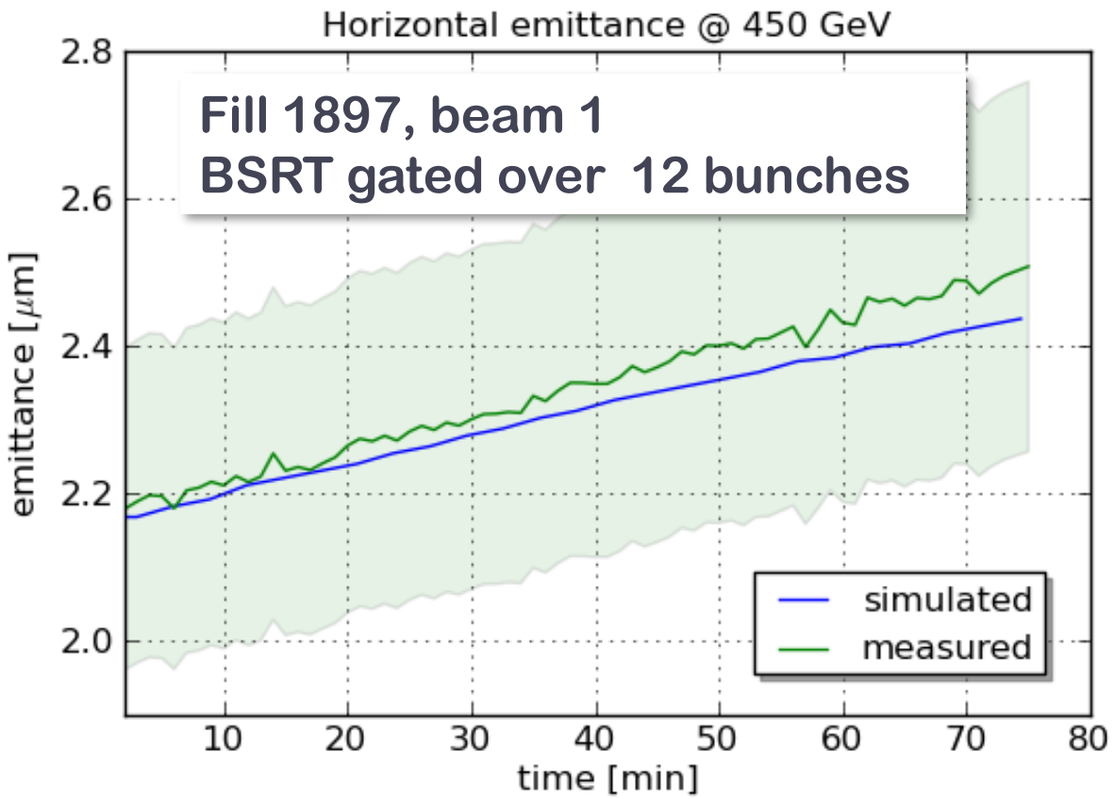


5 – 10 % difference between first and last batches

c/o A. Ryd

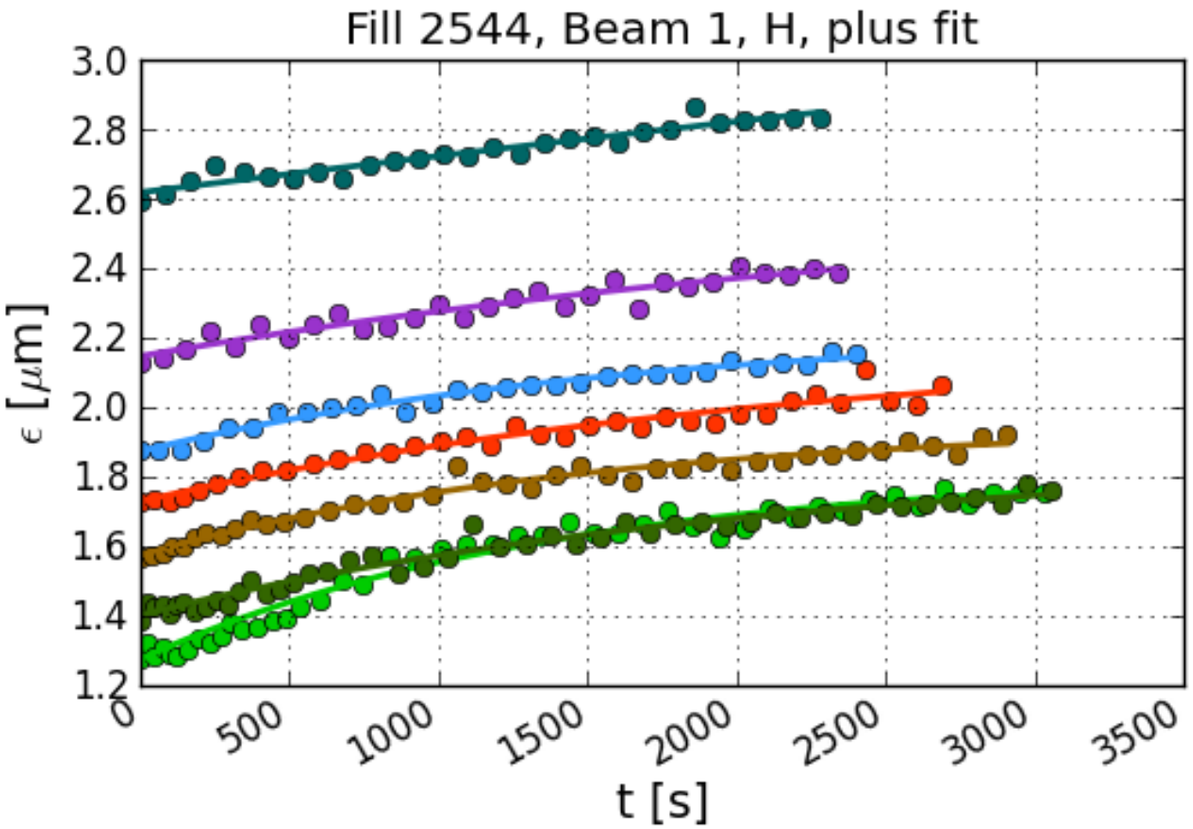
Blow-up at injection (2)

- Results of 2011 – growth mainly in H and consistent with IBS (10% in 20 min)



2011 data plus simulation

c/o T. Mertens



2012 MD data:
Characterize IBS: different trans. emittances, different intensities, different long. emittances

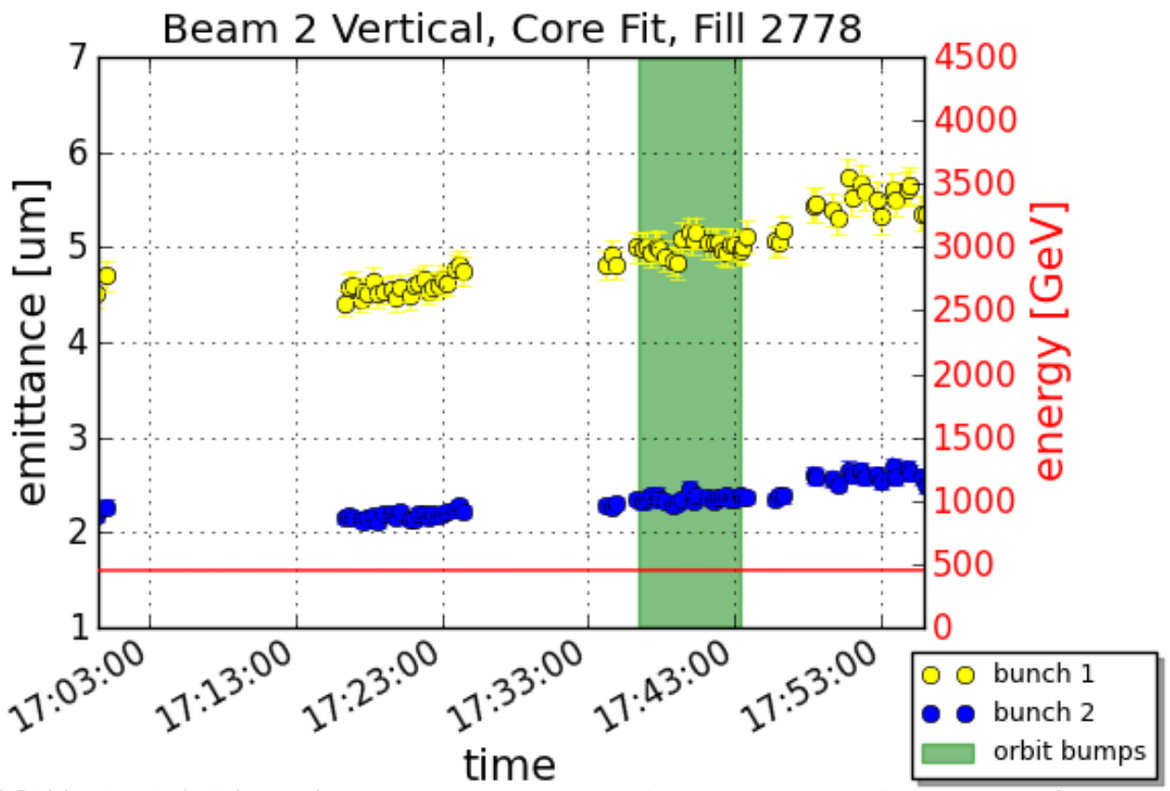
No comparison with simulation yet

Blow-up at injection (3)

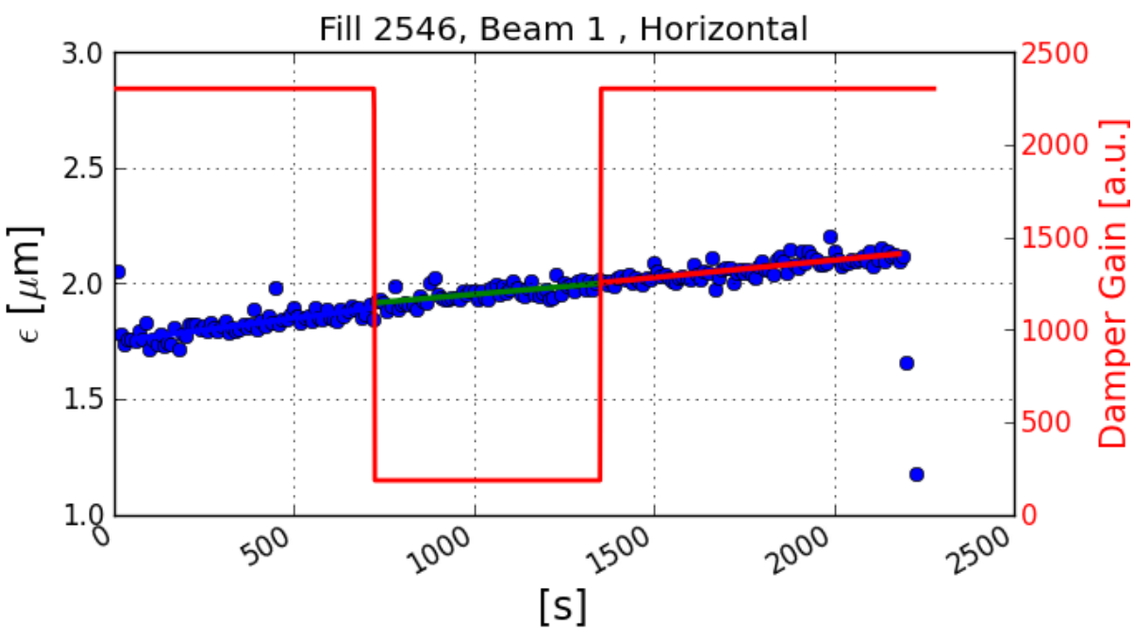
- Are there other sources for blow-up during injection?

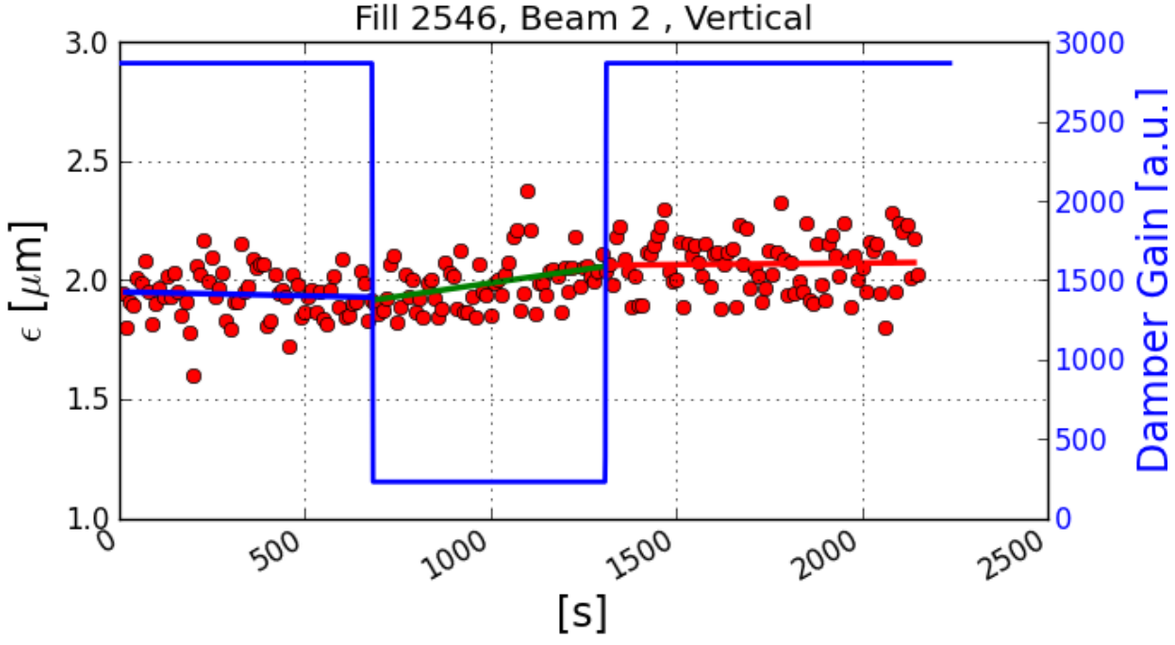
Fill 2778: damper settings not switched to single bunch settings

Blow-up in the vertical plane @ 450 GeV



- Data from MD with single bunches (fill 2546), damper settings optimized

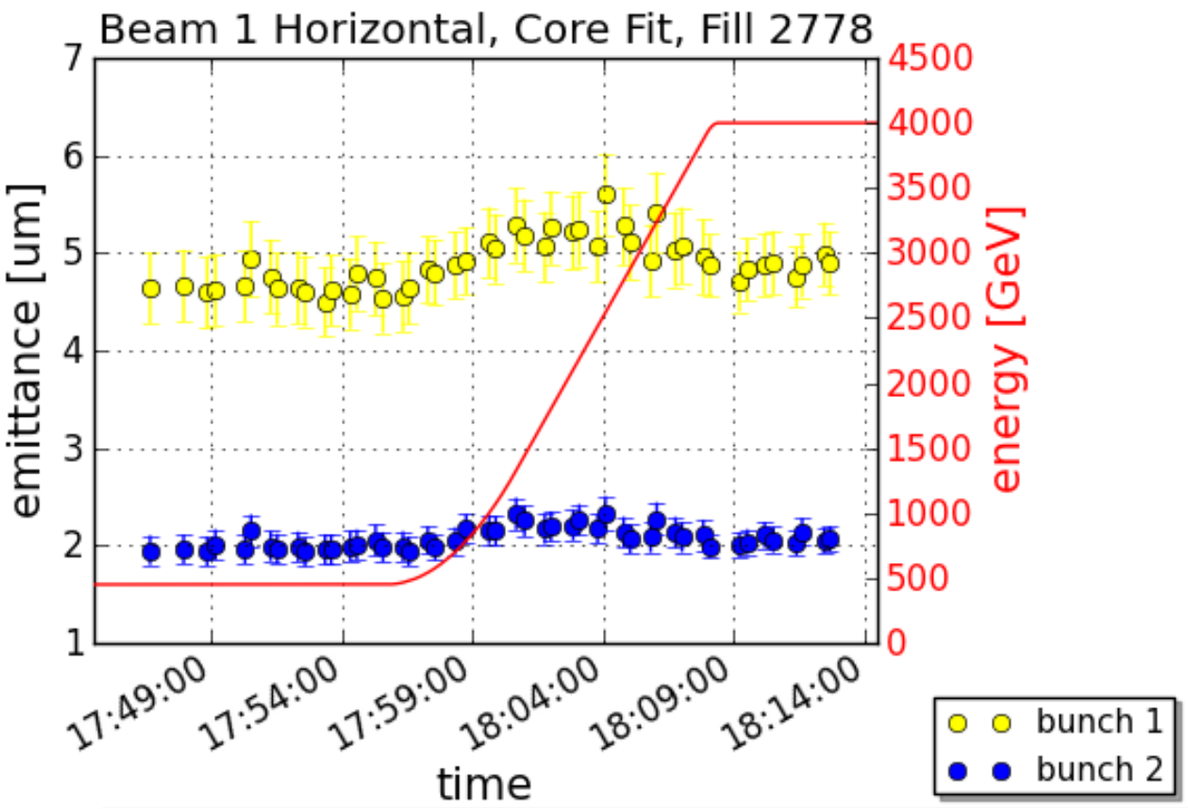


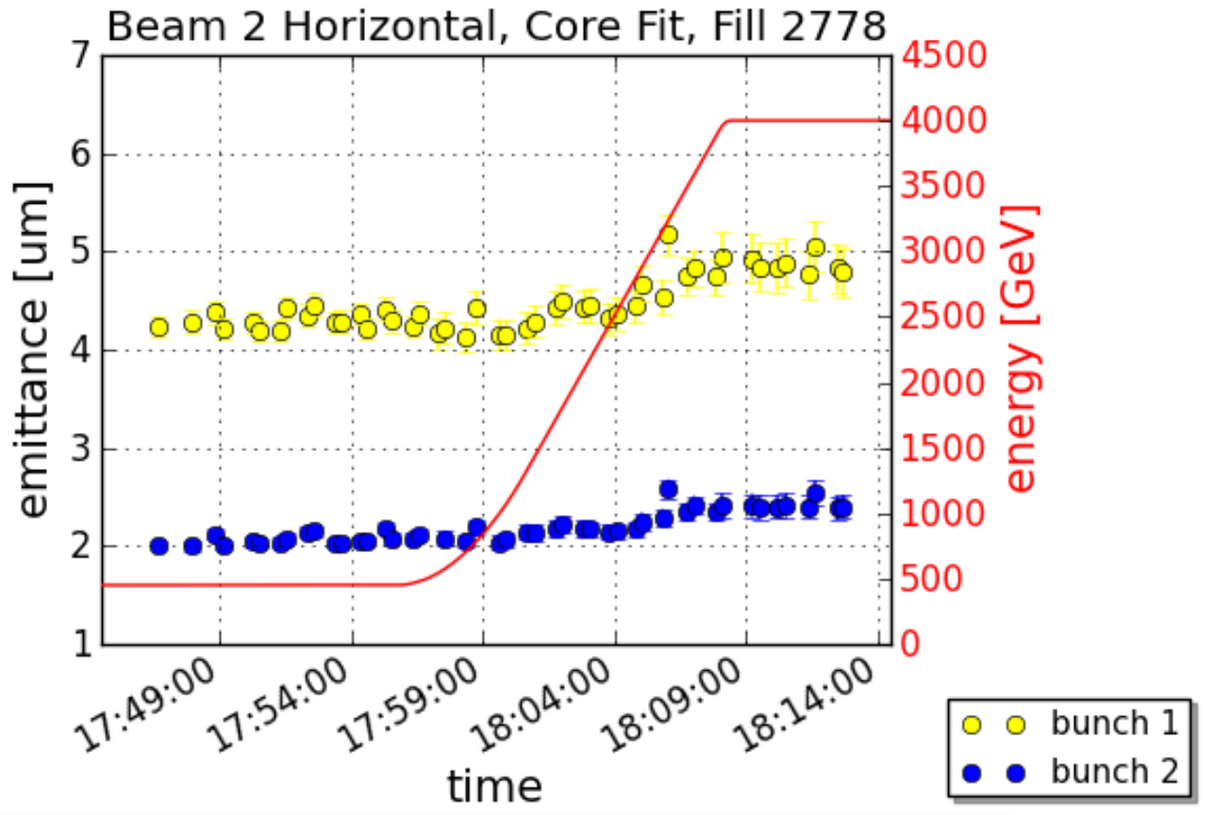


- Small blow-up in V when reducing damper gain during ramp preparation?

The Ramp

- Reasonable measurements were only possible after optics measurement at wire scanners with k-modulation (MD II) – still preliminary results
- Results of MD with single bunches: different initial emittances





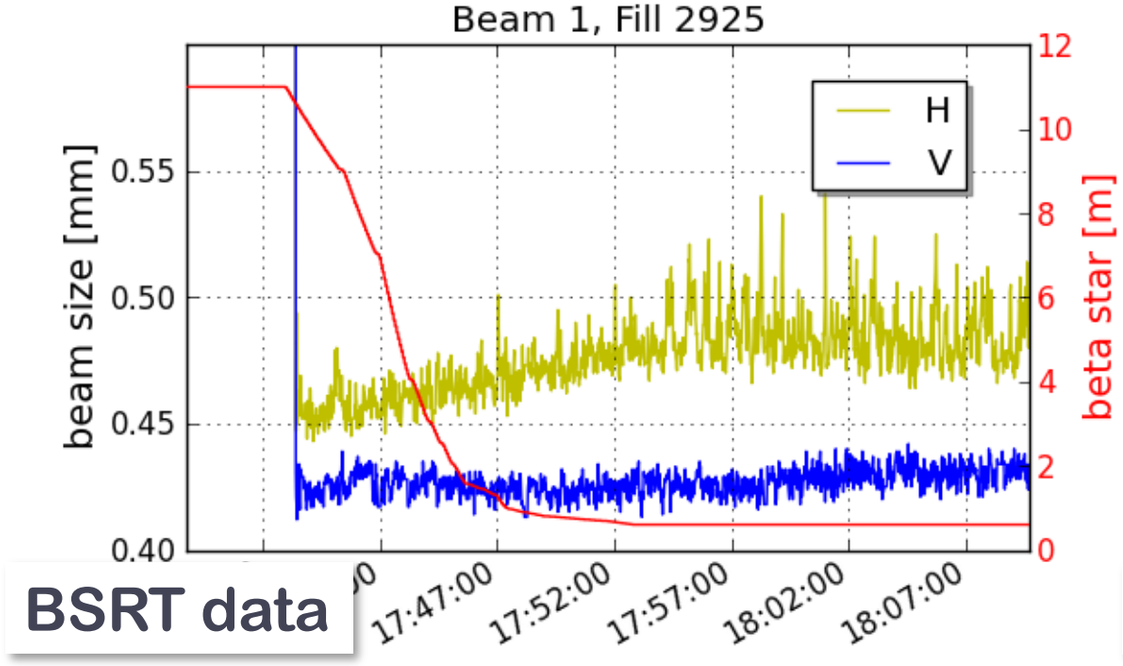
Beam [plane]	Injection [μm]	Flattop [μm]	Growth
Beam 1 [H]	2.05 ± 0.34	2.1 ± 0.15	Possible growth ~ 0.1 μm, errors large
Beam 1 [V]	2.84 ± 0.14	2.72 ± 0.27	No measurable growth
Beam 2 [H]	2.11 ± 0.38	2.52 ± 0.19	**Growth 0.4 – 0.6 μm**
Beam 2 [V]	2.4 ± 0.03	2.42 ± 0.3	No measurable growth

Only beam 2 H significantly growing !

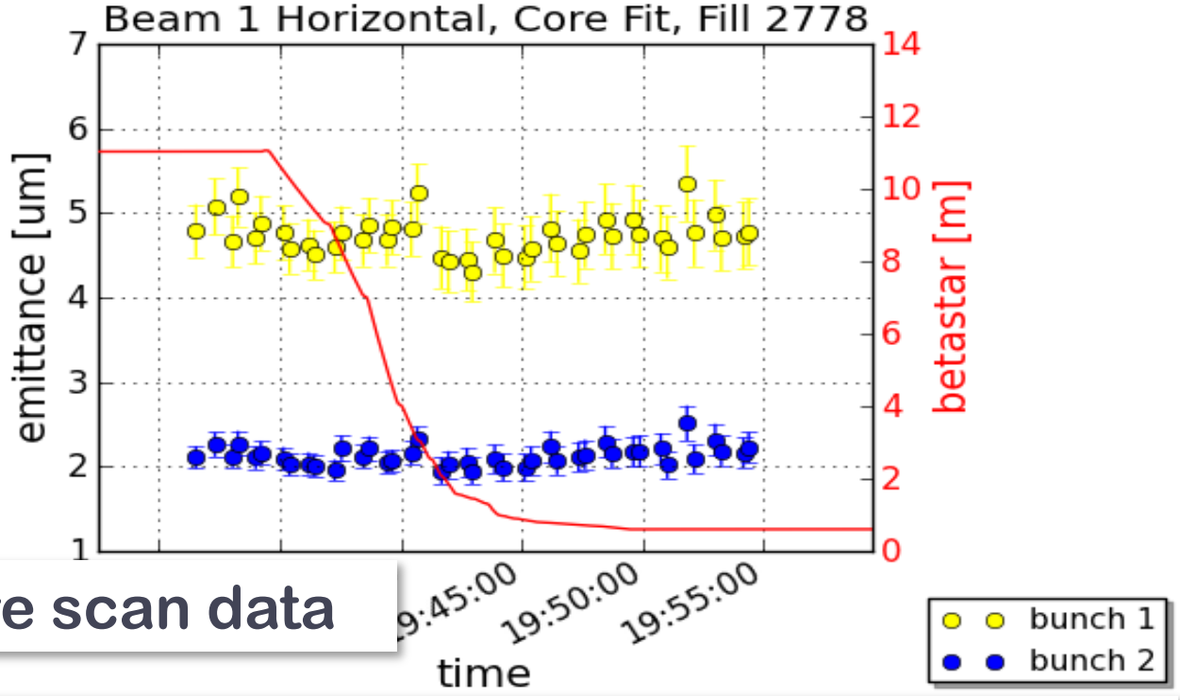
The squeeze

- 2011: indication of blow-up through squeeze for Beam 1 H only
- 2012: no systematic measurements yet
  - Wait for fast BSRT operational

- With few bunches: current BSRT fast enough:
  - Data from test fill with 6 + 6 bunches (50 ns trains) after octupole polarity swap 7/8/2012
  - Beam size blowing up for beam 1 H; beam 1 V and beam 2 H and V stay “constant”



BSRT data



Wire scan data

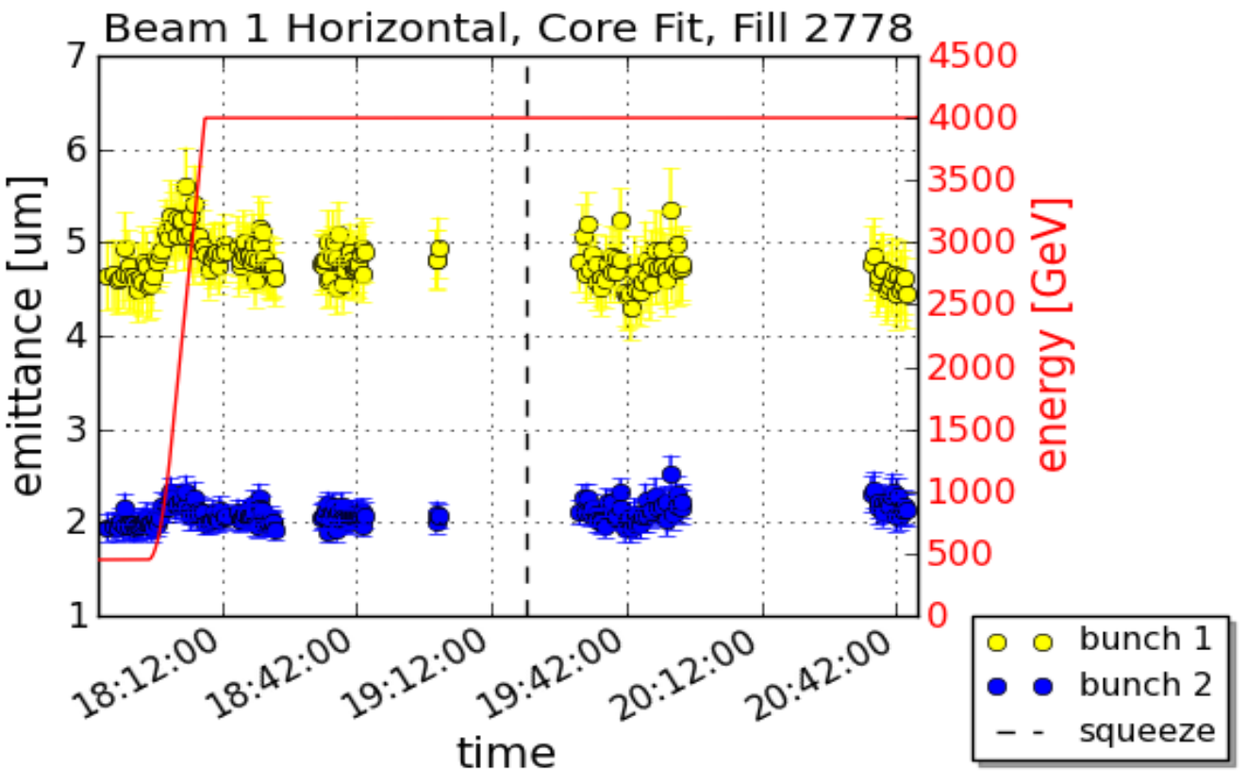
$\Delta\sigma \sim 8\,\% \rightarrow \Delta\varepsilon \sim 15\,\%$

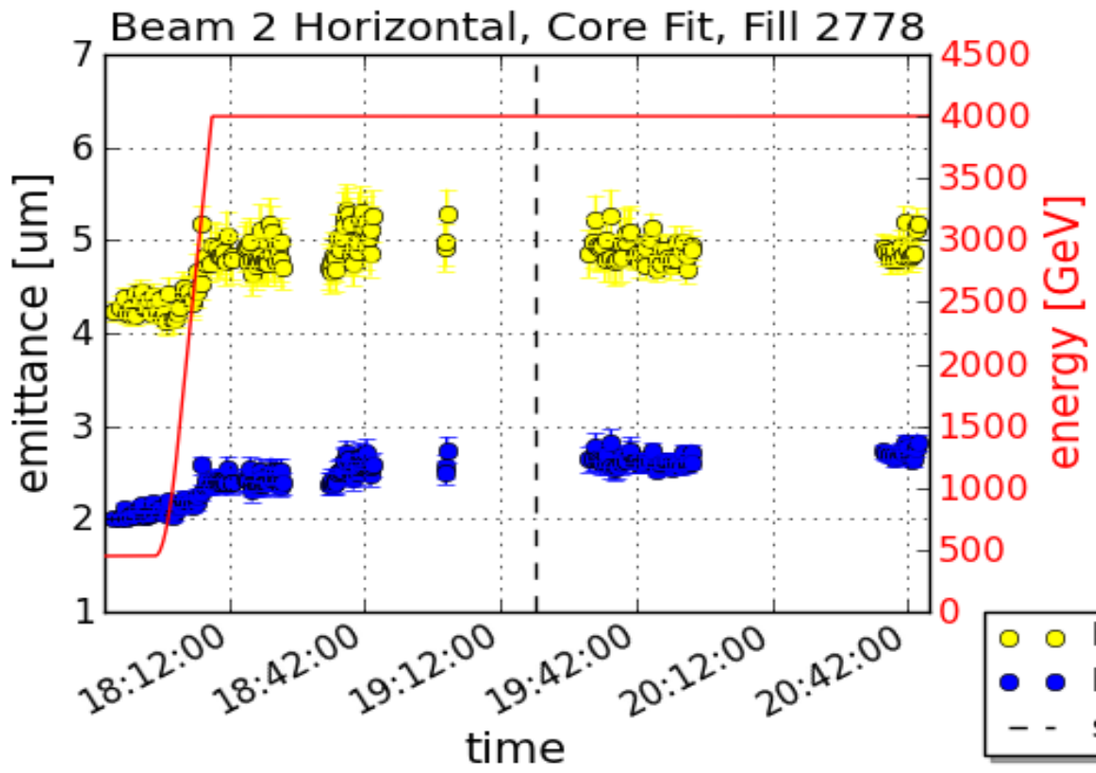
No sign of it during MD with wire scans:
$\Delta\varepsilon \sim 5\,\%$

- Will study it further parasitically on physics fills with new BSRT server

Overall growth through cycle

- Data from single bunch MD: fill 2778
  - Went through full cycle: injection + ramp + squeeze + collide





Beam [plane]	Injection [μm]	Collisions [μm]	Growth
Beam 1 [H]	2.05 ± 0.34	2.25 ± 0.3	Within error the same, < 0.2 μm
Beam 1 [V]	2.84 ± 0.14	2.49 ± 0.5	Within error the same
Beam 2 [H]	2.11 ± 0.38	2.8 ± 0.4	~ 0.7 μm
Beam 2 [V]	2.4 ± 0.03	2.45 ± 0.6	Within error the same

Is there a difference to physics beams?

Conclusion

- The emittances from luminosity compared to the emittances at SPS flattop indicate significant blow-up - as in 2011.

- Measuring blow-up through LHC cycle hampered by
  - Optics knowledge – using now preliminary results from k-modulation around instruments
  - Instrumentation: no adequate instrument for physics beams through full cycle
  - Working with wire scanners and low intensity: results comparable to full machine?
  - new fast server for synchrotron light monitor not operational yet

- Results so far: WORK STILL ONGOING
  - Beams are blowing up at injection plateau: 0 – 10 % depending on moment of injection
    - IBS, other sources still under investigation
  - Beam 2 H is blowing up significantly during the ramp: $\approx$ 0.5 μm
    - Absolute growth independent of intensity and emittance?
  - Is beam 1 blowing up during the squeeze?
- Assuming constant absolute growth of beam 2 H and IBS (5 % on average):
  - 1.7 μm from SPS convoluted ➔ 2 μm convoluted at collision
  - Not enough compared to results from luminosity