LHC Injectors Upgrade

Performance Reach of LHC Beams in the PSB

H. Bartosik, C. Carli, H. Damerau, A. Findlay, A. Guerrero, S. Hancock, G. Iadarola, V. Kain, M. Kuhn, B. Mikulec, V. Raginel, G. Rumolo, R. Steerenberg

CERN

Outline

① Overview of different LHC beams in the PSB

② Emittance evolution of LHC50/25 and LHC H9 beam along the LHC injector chain

③ Do we need additional MDs before LS1 to prepare post-LS1 era?

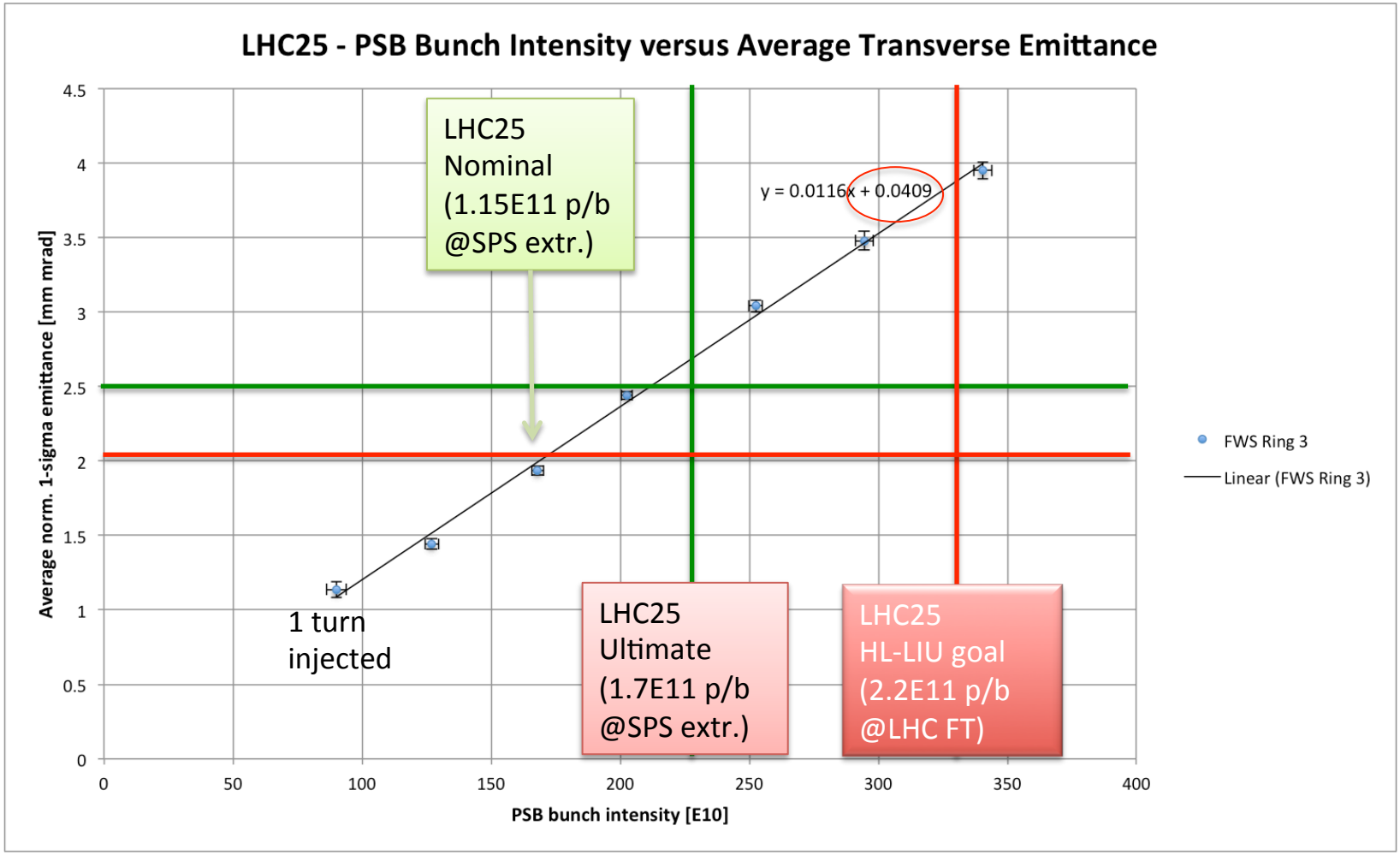
Emittances quoted in the presentation are 1-sigma normalised emittances!

LHC Beams in the PSB – Overview

LHCPROBE	h1, 0.5-2E10 p (R3), 0.2 eVs, long. shaving, $\varepsilon_{h/v}$<1 µm
LHCINDIV	h1, 2-12E10 ppb, 0.3 eVs, long. shaving, $\varepsilon_{h/v}$<2 µm
LHC25 DB	h1, **160E10 ppb**, 1.3 eVs, **$\varepsilon_h+\varepsilon_v$**<5 µm **as low as possible (a.l.a.p.)**
LHC50 DB	h1, **85-120E10 ppb**, 1.2 eVs, **$\varepsilon_{h/v}$ a.l.a.p.** (~1.3 µm @110E10 ppb**)**
LHC50 SB	h2+1, 180E10 p/ring, 0.9 eVs, $\varepsilon_{h/v}$<2.5 µm
LHC75 SB	h2+1, 110E10 p/ring, 0.85 eVs, $\varepsilon_{h/v}$<2.5 µm
LHC100 SB	h2+1, 10E10 p/ring, ~0.9 eVs, $\varepsilon_{h/v}$<0.5 µm
LHC_lowemt_H9	h1, 50E10 ppb, 0.8 eVs, 1 turn, transv. shaving, **$\varepsilon_{h/v}$ a.l.a.p.** (~1 µm**)**
LHC_low_El_H9	h1, **50E10 ppb, 0.7 eVs**, 1.2 turns, transv. shaving, **$\varepsilon_{h/v}$ a.l.a.p.** (~1 µm**)**
LHC200 (ions)*	h2+1, 2.4E10 p/ring, 0.25-0.3 eVs

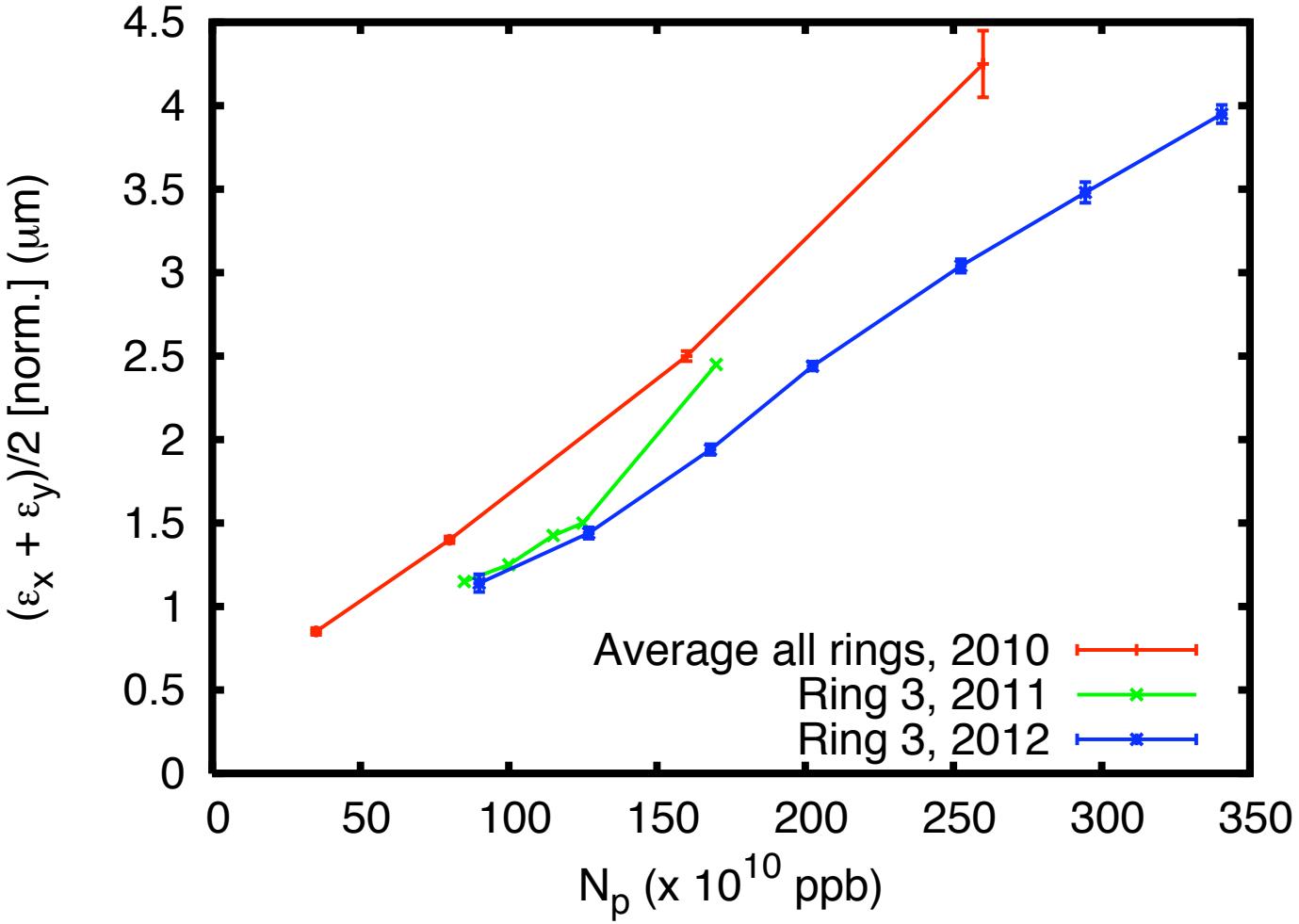
* Under investigation.

PSB FT – Average Emittance versus Intensity (Ring3)



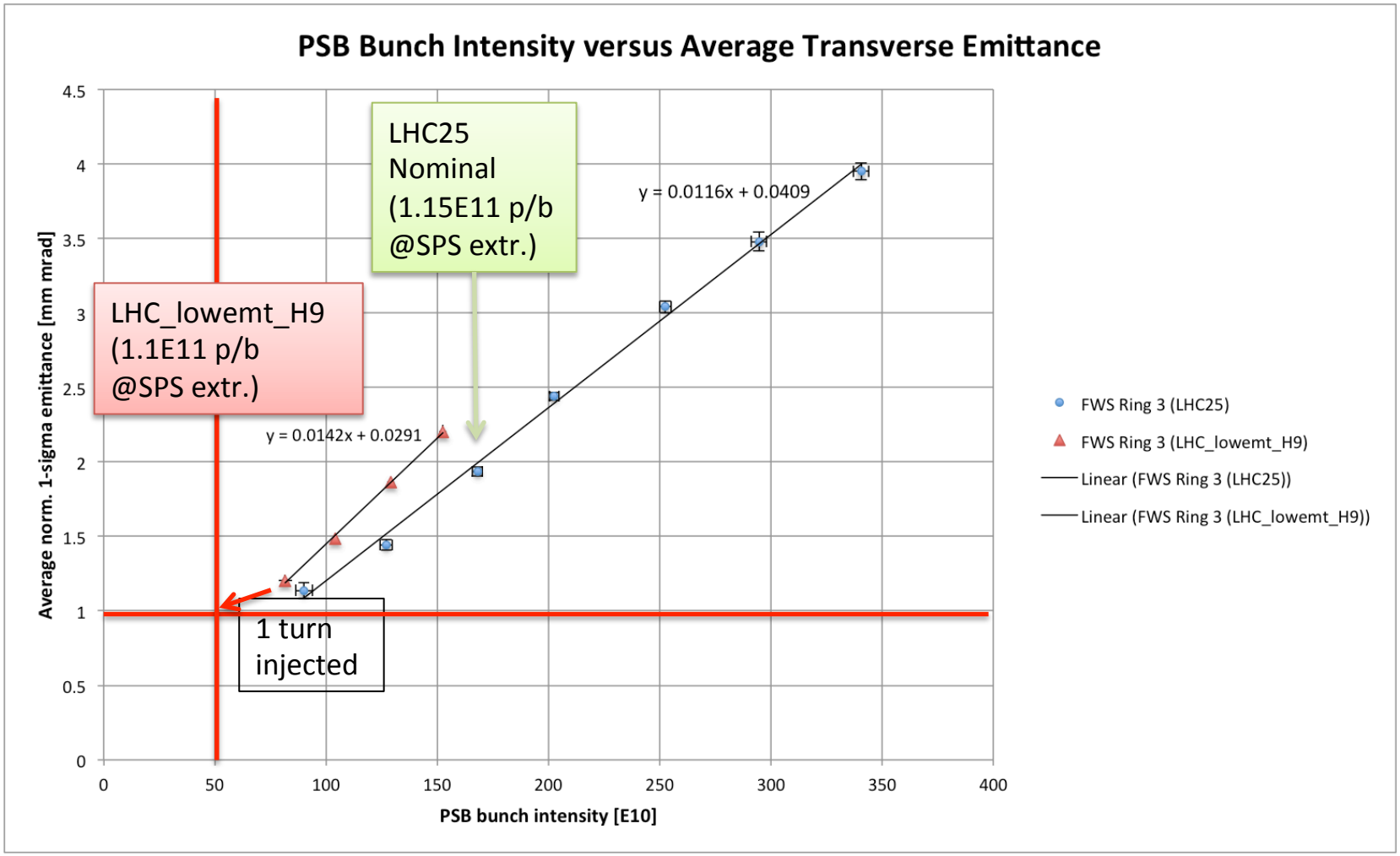
Remark: Constant emittance of ~1.19 eVs and injection parameters+WP tuned for each measurement point.

PSB – Emittance Evolution of LHC50/25



Good beam quality needs constant work and tuning (x4 for PSB)…

PSB FT – Average Emittance versus Intensity (Ring3) for Different Longitudinal Emittance

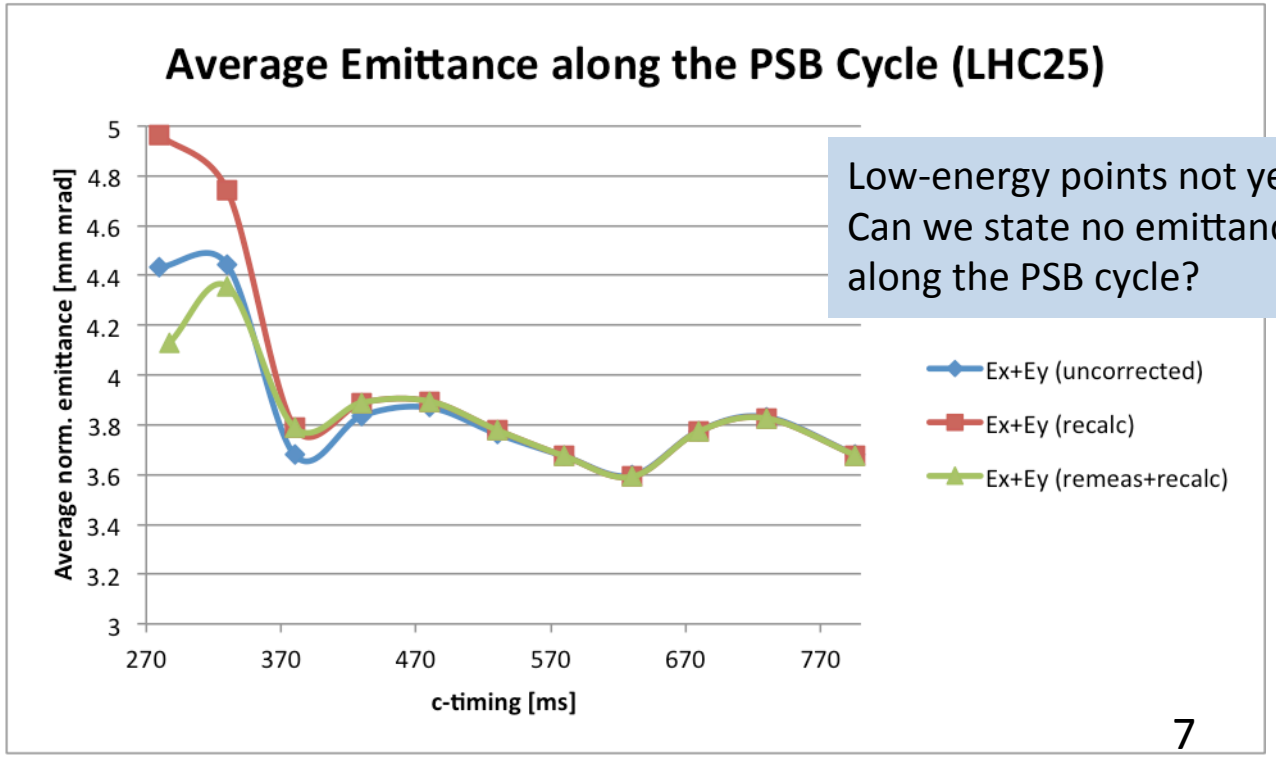


Remark: Constant emittance of **~1.19 eVs for LHC25 beam** and **~0.86 eVs for LHC_lowemt_H9 beam** (transv. shaving disabled).

LHC25 Emittance along PSB Cycle

Very difficult to understand all factors relevant for correct wire scanner measurement:

- Calibration and measurement errors of wire scanners
- Optics (mind: in PSB only optics from MADX model available)
- Measurement error of Δp/p (in particular for dual-harmonic case)
- Saturation effects of wire scanner (should perform saturation curve measurements at low energy)
- Scattering at low energy (in range of 10% emittance growth @ 50 MeV; F. Roncarolo)
- Fit error
- …



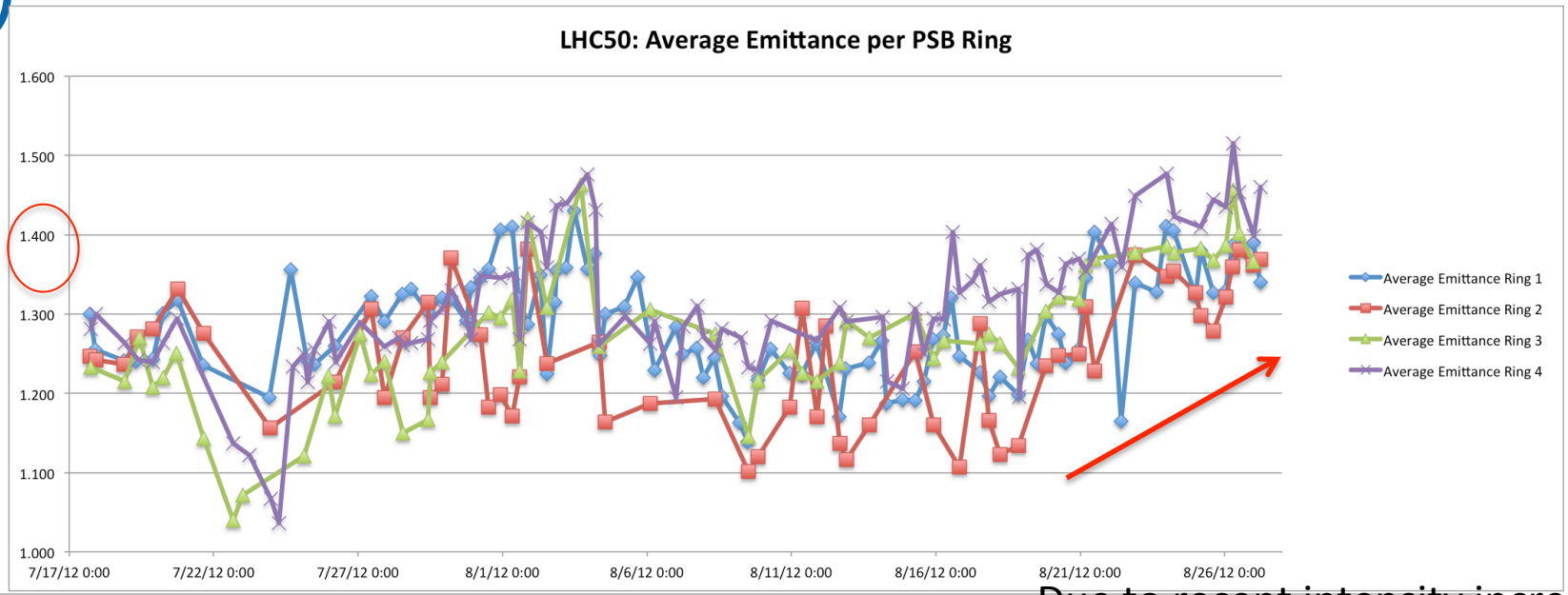
Low-energy points not yet understood. Can we state no emittance blow-up along the PSB cycle?

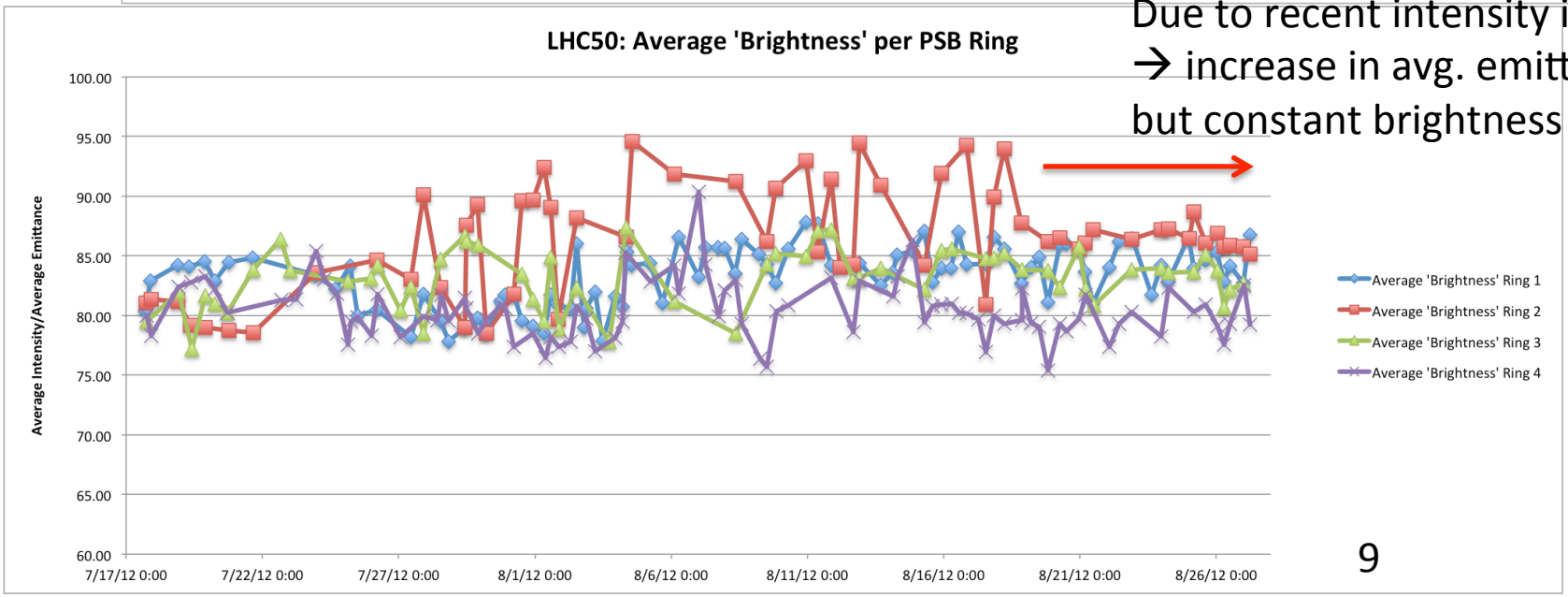
Beam Quality Logging for Injectors

Starting Point: LHC suffered from larger emittance and tails after TS1 and again after TS2

- → Mandate to put LHC Beam Quality WG for the Injectors in place (V. Kain, R. Steerenberg, B. Mikulec)
- → Systematic logging in Timber since July for PSB+PS
- → SPS/LHC and automatic data extraction related to LHC fill # to follow

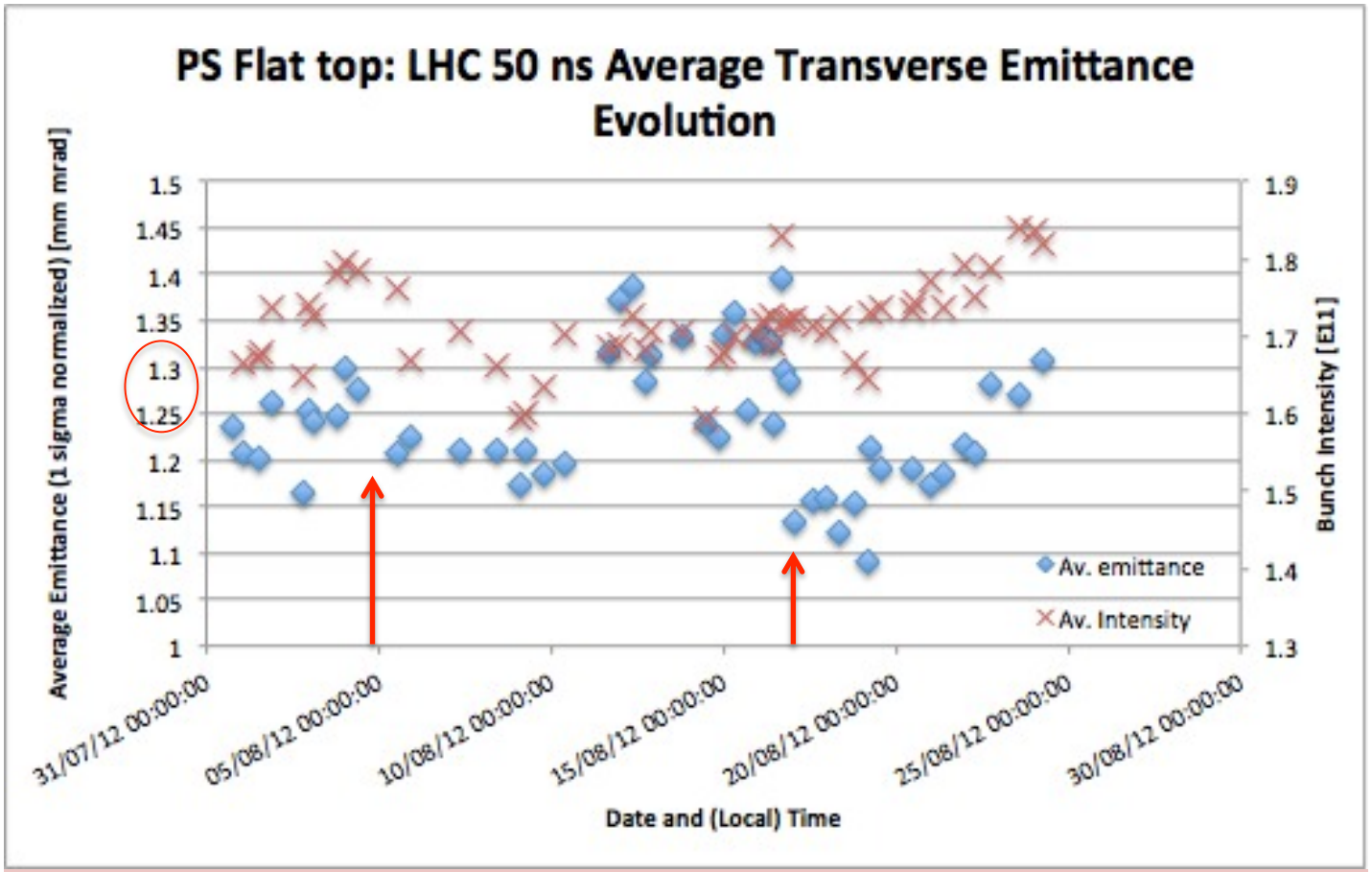
PSB FT – LHC50 Emittance Logging





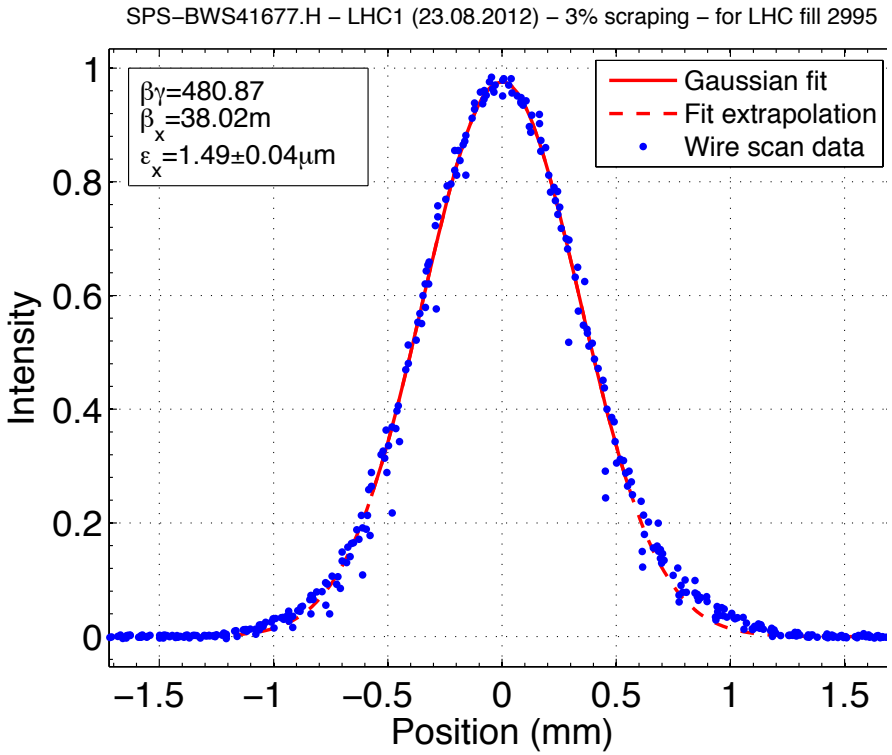
Due to recent intensity increase → increase in avg. emittance, but constant brightness

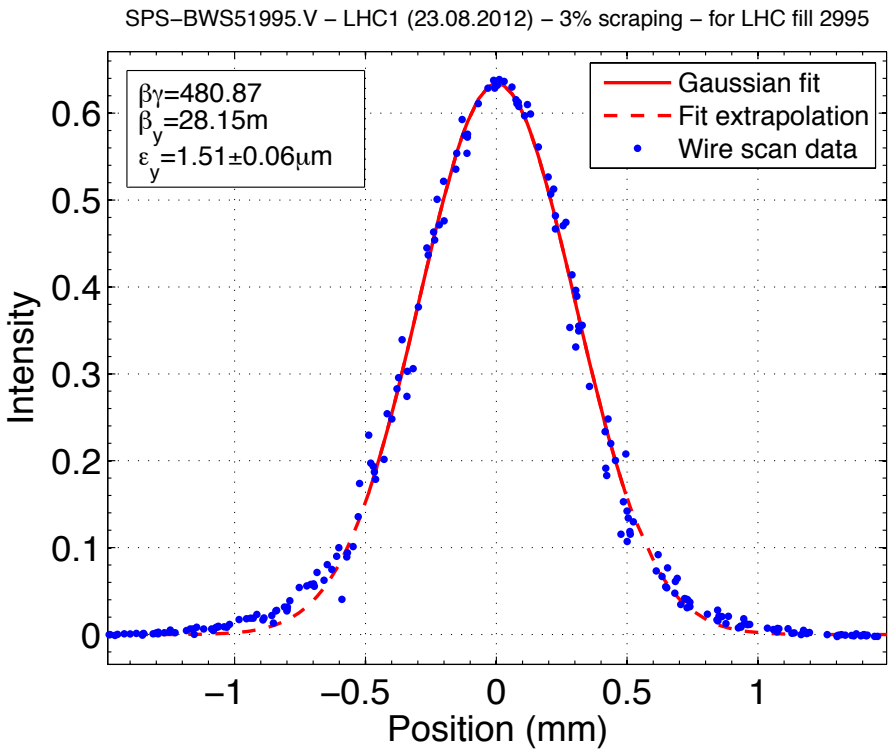
PS FT: LHC50 Emittance Logging



For LHC50 the transv. emittance SEEMS to be conserved between PSB and PS (but difficult to say, as measured emittance at PS FT is smaller than the one at PSB FT).

SPS FT – LHC50 Emittance Measurements





Courtesy of H. Bartosik

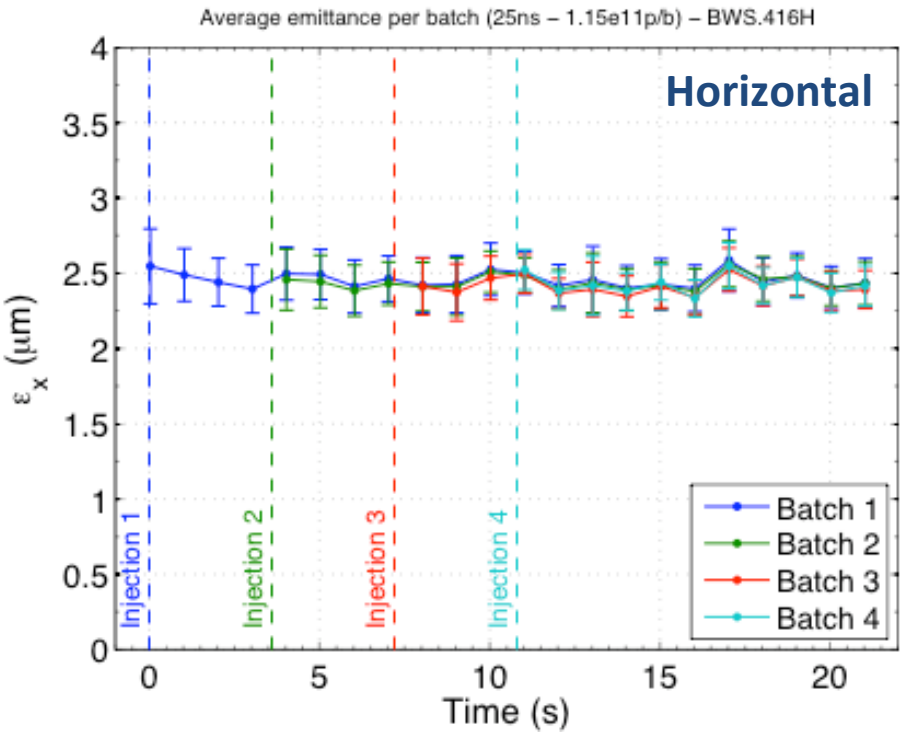
Average emittance of LHC50 beam at SPS FT: ~1.5 μm

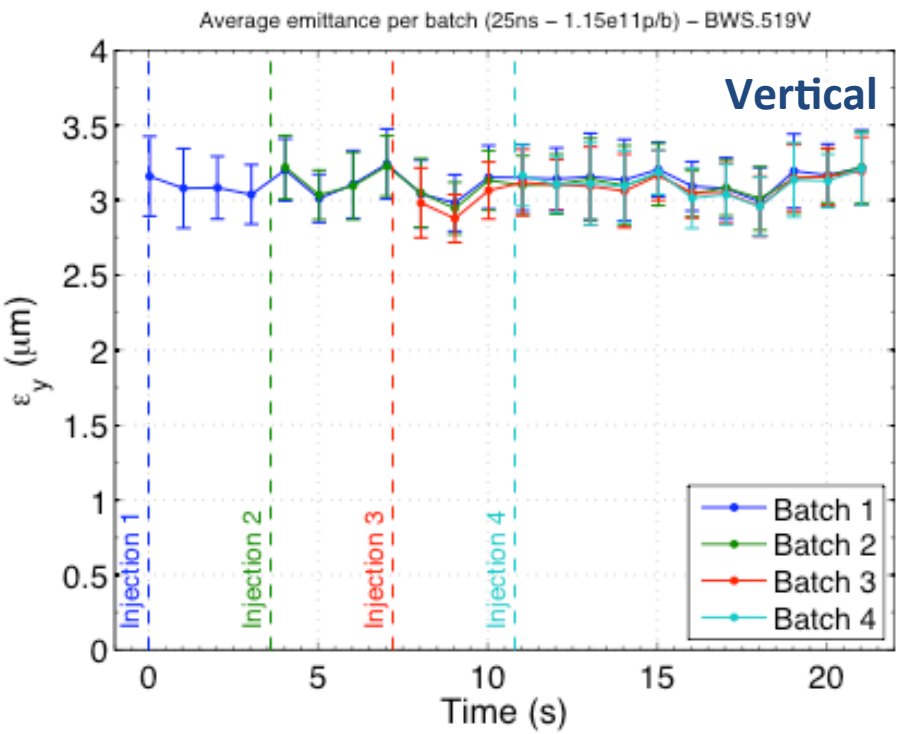
- ~1.6E11, 3% scraping

SPS FB – Emittances of 25ns LHC Beam in 2012

Average emittance with 4 batches of 1.15E11 p/b:

Courtesy of G. Iadarola, H. Bartosik, G. Rumolo





- No measurable emittance growth along 20s flat bottom
  - E-cloud not anymore dominant compared to 2000 measurements (see presentation G. Iadarola) – scrubbing pays off!
- Emittance values within specifications (although absolute values to be taken with caution…)

32-Bunch LHC H9 Beam

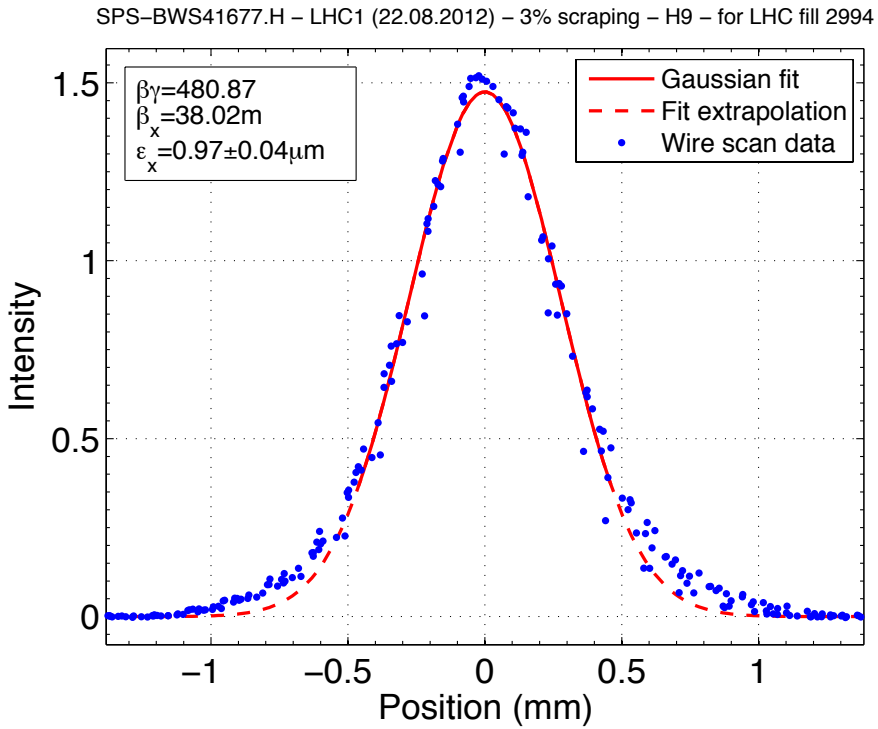
- MD on Wednesday **22nd August**: Beam injected into LHC + collisions.
  - H9 splitting in PS: **h=9 → 10 → 20 → 21** (8 PSB bunches → 32 PS bunches; see presentation H. Damerau).
  - Intensity: **1.1E11 ppb** @ SPS extraction.

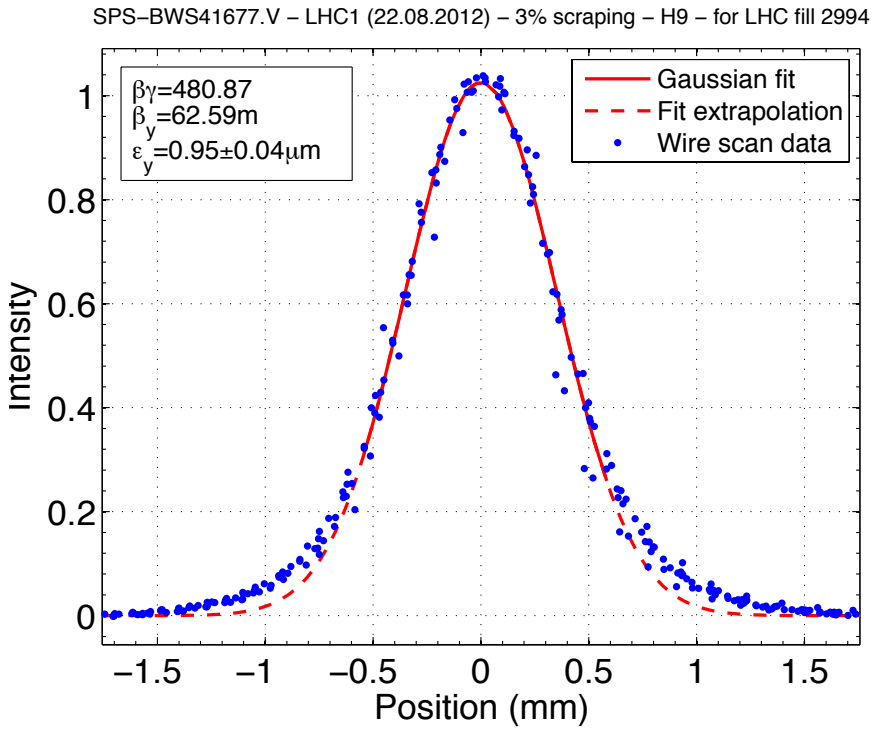
	PSB FT	PS FT	SPS	LHC B1 FB
ε_h* [µm]	0.9-1.1	1	1	~1.1
ε_v* [µm]	0.85-0.9	0.8	0.95	~1.2

LHC B1+B2 FT	Convoluted Emittance [µm]					
Wirescan Core Fit of Combined Profiles			CMS Luminosity			ATLAS Luminosity		
1.388	+/-	0.102	1.751	+/-	0.263	1.686	+/-	0.253

Courtesy of M. Kuhn

32-Bunch LHC H9 Beam in SPS





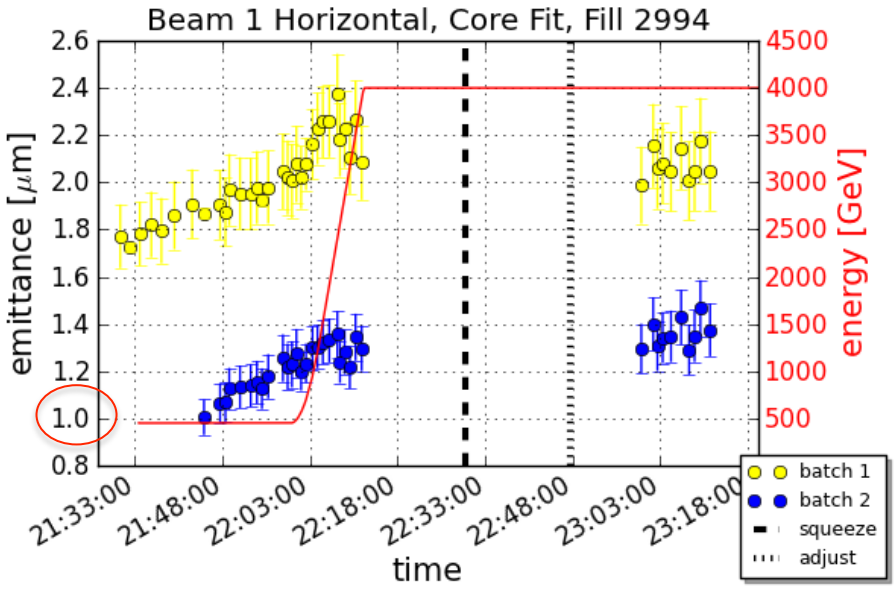
Courtesy of H. Bartosik

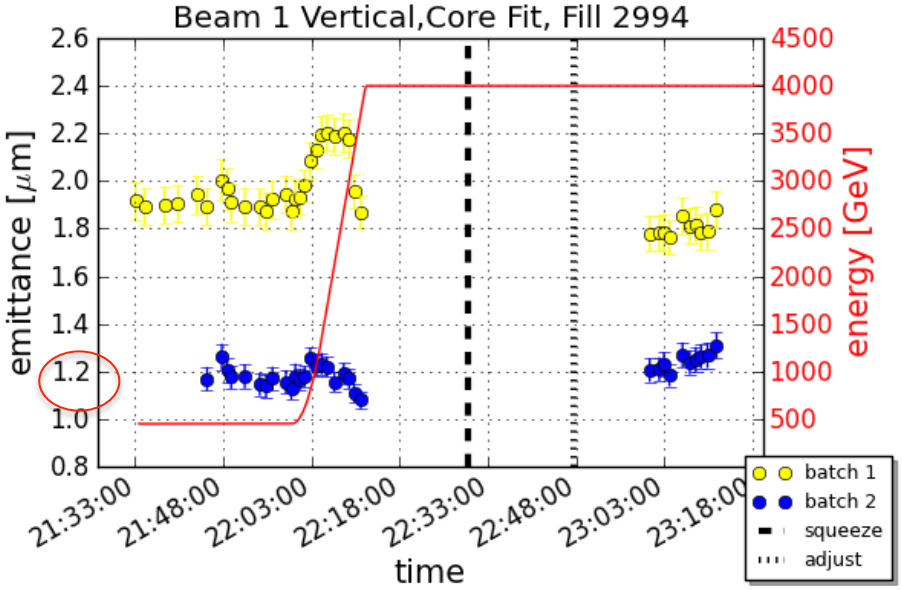
Average emittance of H9 beam at SPS FT: ~1 μm

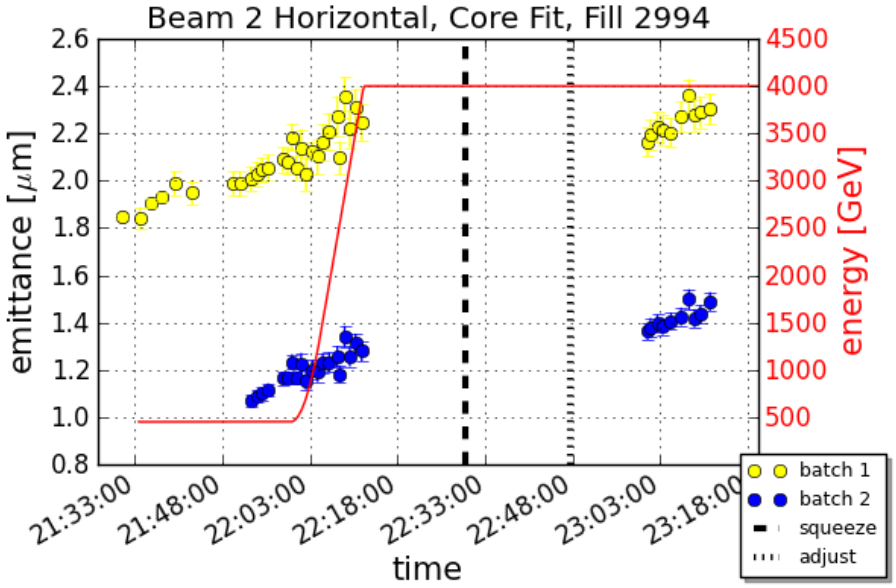
- ~1.1E11, 3% scraping

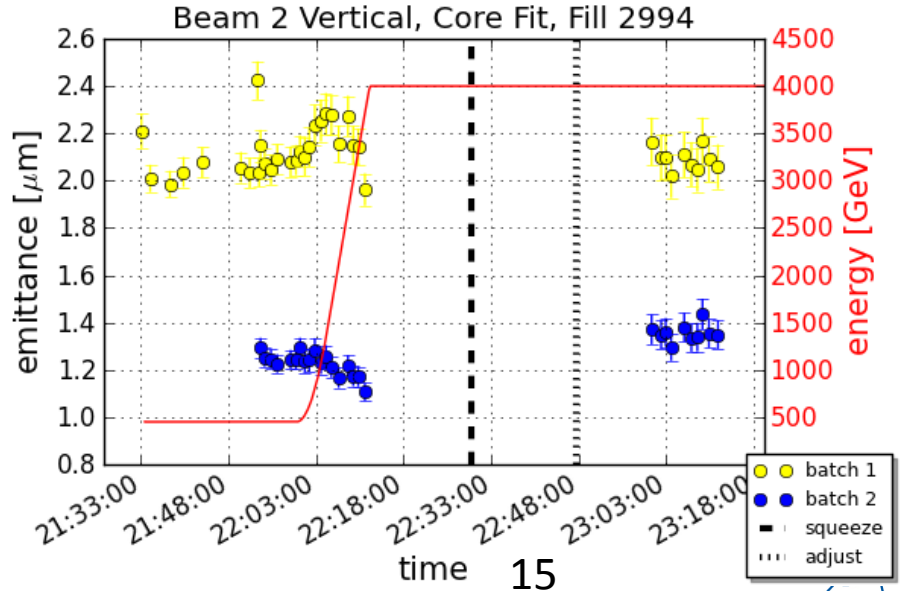
32-Bunch LHC H9 Beam in LHC

Courtesy of M. Kuhn









PSB with Linac4 50 MeV Protons

- Connection possible after DTL commissioning (~end of 2014)
- Note CERN-ATS-Note-2012-047 PERF
- Currently this note is being refined
  - Benchmarking of Linac2 injection with LHC25, CNGS, LHC_lowemit_H9 ongoing (V. Raginel)
  - MD foreseen to inject on slower bump decrease closer to Linac4 case

PSB MDs Outstanding still for this Run?

- Continue MDs on Finemet cavity, digital LL-RF, transverse feedback → presentation A. Findlay
- Parallel MD for PSB with p from Linac4
- Parallel MDs concerning emittance blow-up with direct space charge, transverse resonances and their compensation, …

Conclusions

- PSB working at constant brightness (if steadily optimised); no emittance blow-up along the cycle → not much to gain after LS1
- PSB on track for LHC25 Ultimate, but emittance blow-up along the injector chain needs to stay below ~20%
- Linac4 needed for HL-LIU goals (LHC25+LHC50)
- Absolute transverse emittance measurements in the injector chain not possible due to various error sources, but relative measurements give reliable evolution per machine → effort to improve detailed understanding of wire scanner measurements should continue
- SPS scrubbing run will be essential after LS1 restart
- Studies for new batch-compression schemes should continue after LS1, but challenging for the PSB for standard operation (at the limit concerning longitudinal and transverse emittance as well as intensity stability)