Beam preparation for vdM scans in the injectors

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PSB, PS & SPS operations crews

LHC lumi days 2019

Outline

- Introduction
- Van der Meer beam production at the end of Run 1
- Van der Meer beam production during Run 2
- Outlook for Run 3
- Summary and Conclusions

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Introduction

- **For the van der Meer scans in 2012 the LHC requested to produce single bunches with the following characteristics:**

Single bunch beam parameters requested by LHC	
Intensity	$0.7\text{-}0.9 \times 10^{11}$ p/b
Transverse emittance (norm.)	≥ 2.5 µm
Transverse distribution	**Gaussian**

- **A special beam production scheme was developed**
  - Beam characteristics mainly defined by PSB (unlike previous production schemes with transverse blow-up between PS and SPS with screens)
  - Successfully deployed for the van der Meer scans in 2012
  - Production scheme documented in CERN-ACC-NOTE-2013-0008 MD
- **This scheme was further optimized during Run 2**

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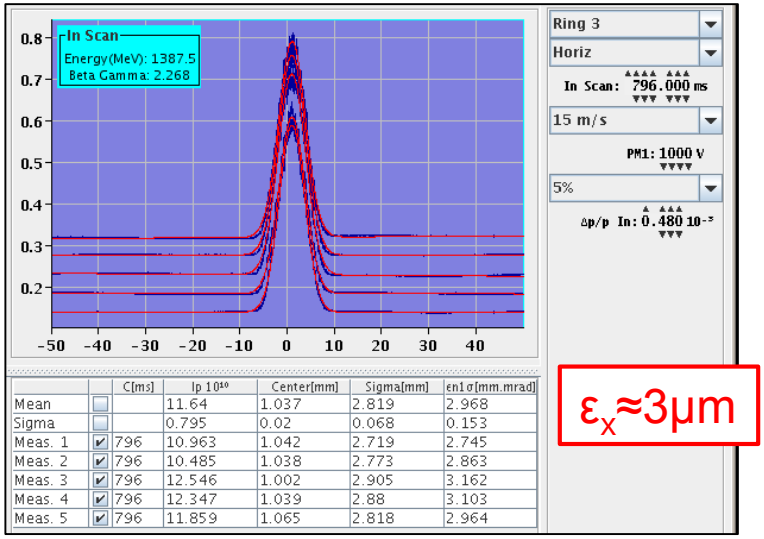
Beam preparation in PSB – end of Run 1

- **Injection of 2.5 turns and loss of 92% of intensity through slow capture**
  - Multiple turns generate the required large transverse emittance
- **Vertical shavers to adjust intensity → tails less populated than Gaussian**

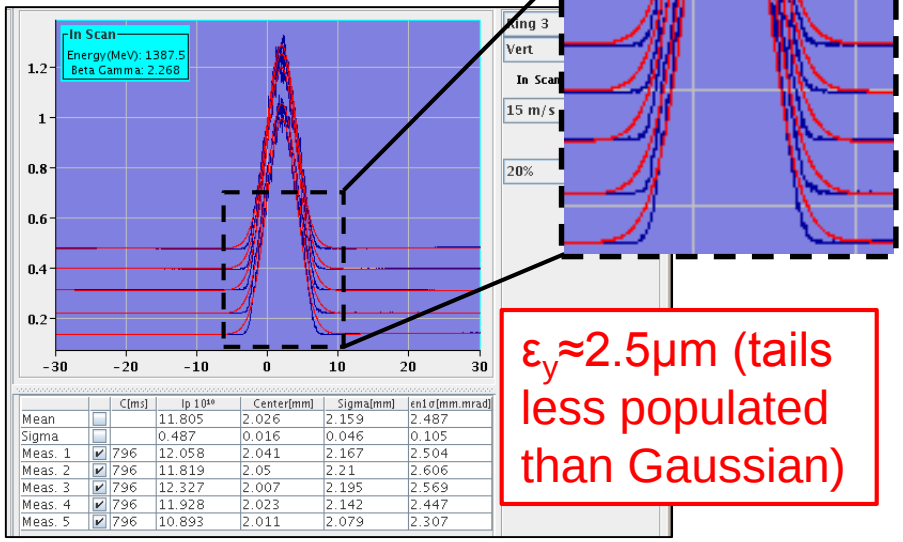
Horizontal



		C[ms]	Ip 10¹⁰	Center[mm]	Sigma[mm]	en1σ[mm.mrad]
Mean	☐		11.64	1.037	2.819	2.968
Sigma	☐		0.795	0.02	0.068	0.153
Meas. 1	☑	796	10.963	1.042	2.719	2.745
Meas. 2	☑	796	10.485	1.038	2.773	2.863
Meas. 3	☑	796	12.546	1.002	2.905	3.162
Meas. 4	☑	796	12.347	1.039	2.88	3.103
Meas. 5	☑	796	11.859	1.065	2.818	2.964

$\varepsilon_x \approx 3\mu m$

Vertical

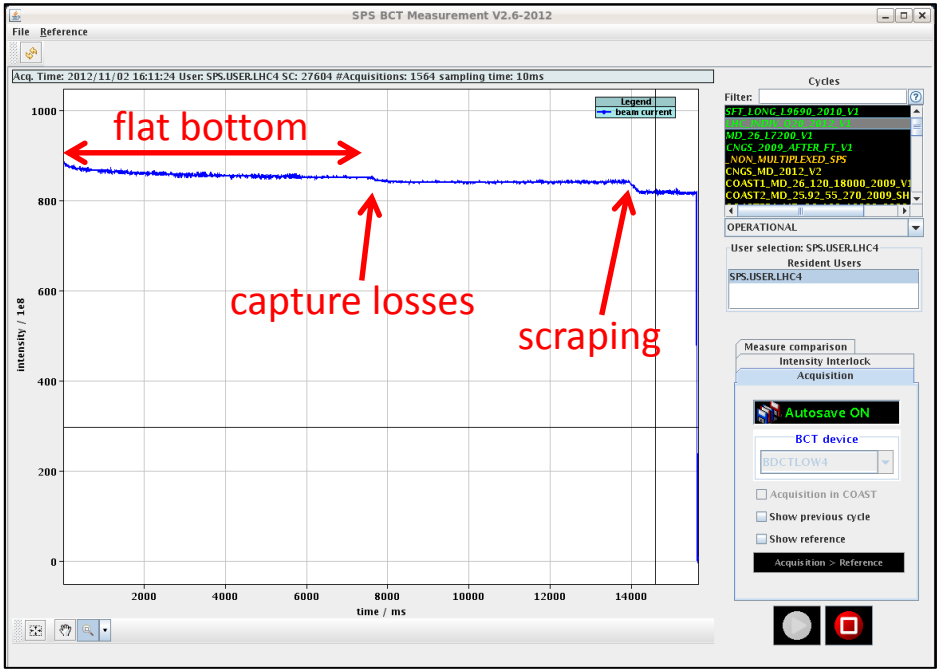


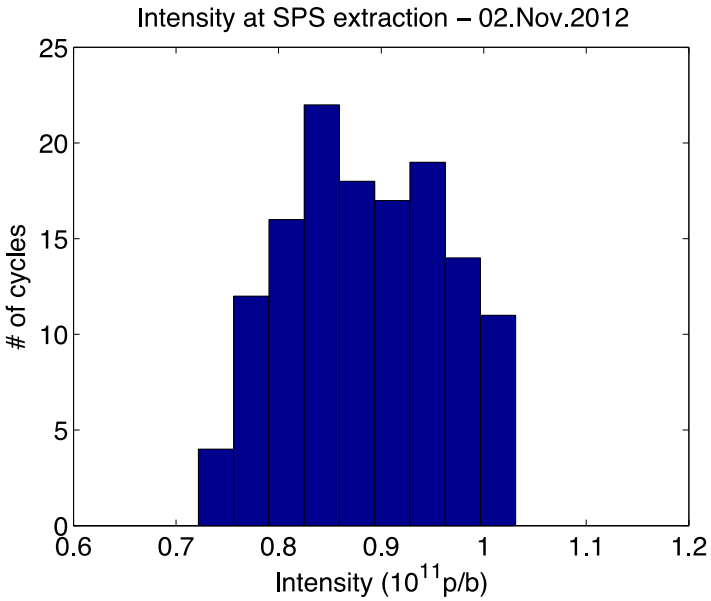
		C[ms]	Ip 10¹⁰	Center[mm]	Sigma[mm]	en1σ[mm.mrad]
Mean	☐		11.805	2.026	2.159	2.487
Sigma	☐		0.487	0.016	0.046	0.105
Meas. 1	☑	796	12.058	2.041	2.167	2.504
Meas. 2	☑	796	11.819	2.05	2.21	2.606
Meas. 3	☑	796	12.327	2.007	2.195	2.569
Meas. 4	☑	796	11.928	2.023	2.142	2.447
Meas. 5	☑	796	10.893	2.011	2.079	2.307

$\varepsilon_y \approx 2.5\mu m$ (tails less populated than Gaussian)

Beam preparation in SPS – end of Run 1

- INDIV cycle (flat bottom of 7.2 s allowing for 4 injections)
- Final adjustments with scrapers → intensity around 0.9(±0.1)x10^{11} p/b





Beam preparation in SPS – end of Run 1

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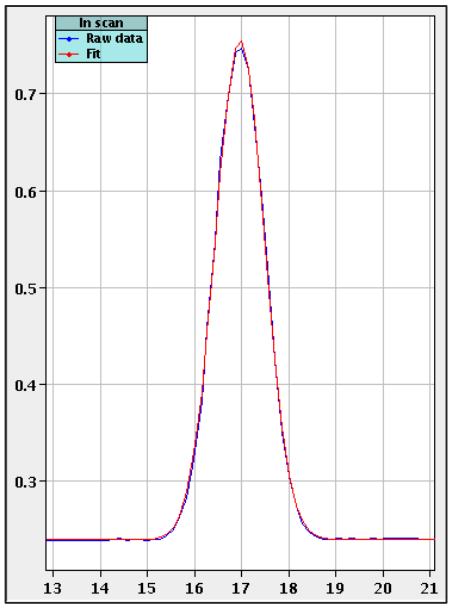
- Resulting profiles at SPS extraction very close to Gaussian

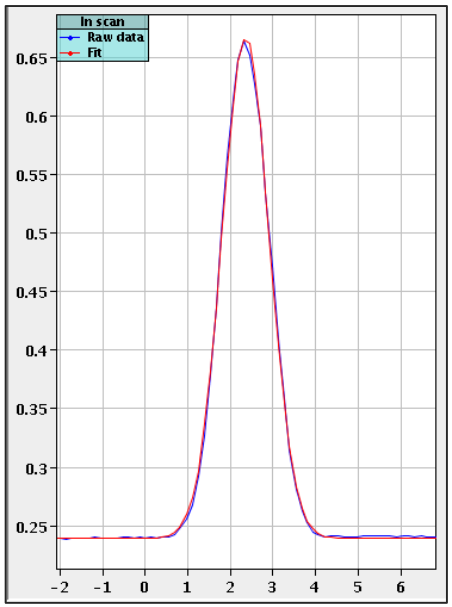
Horizontal



position (mm)

from wire scanner application in 2012 (a single bunch)

Vertical



position (mm)

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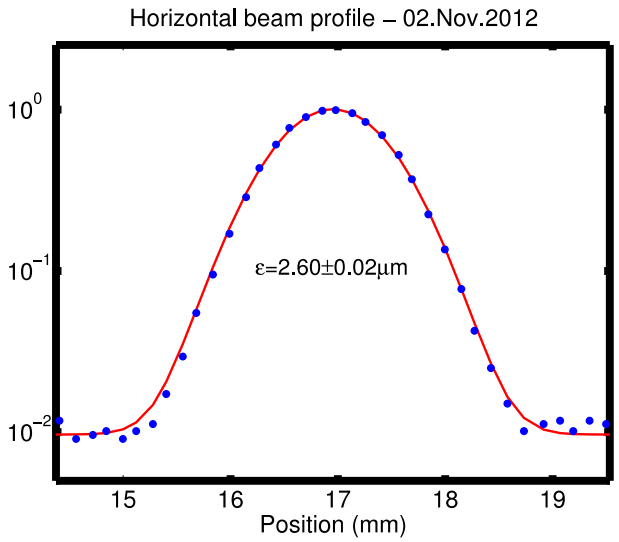
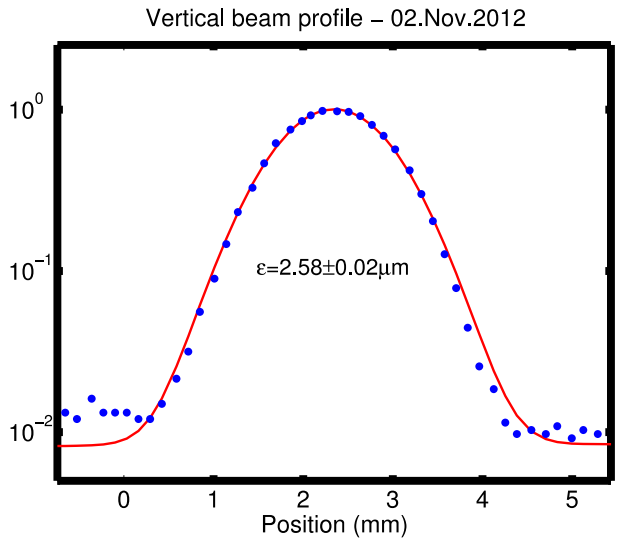


same data in log-scale



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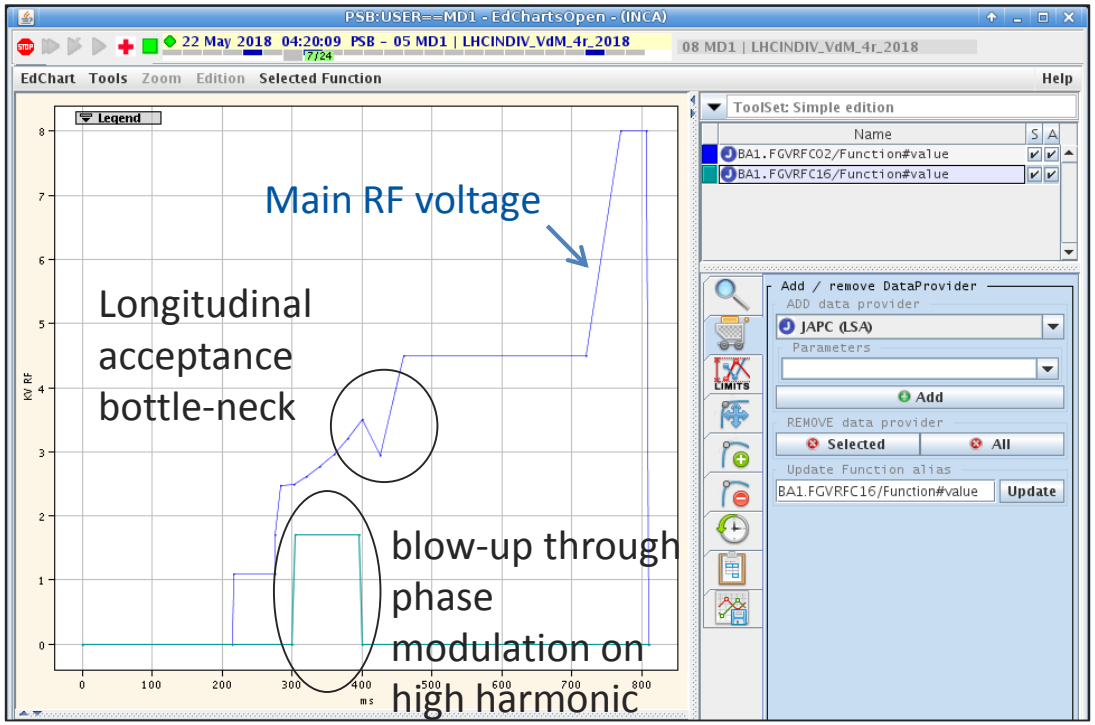
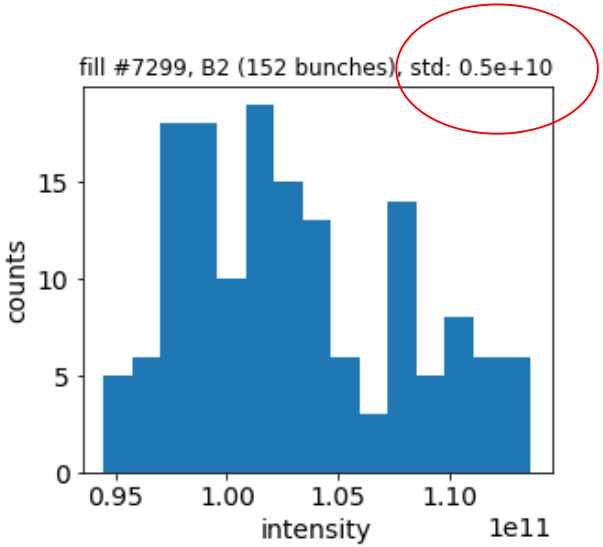
Beam preparation in PSB – in Run 2

- **Intensity adjusted through controlled longitudinal blow-up before reaching longitudinal acceptance bottle-neck**
  - Better reproducibility of beam intensity





Beam preparation in PSB – in Run 2

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- **Transverse emittance adjusted through working point control**
  - Controlled blow-up close to integer tunes

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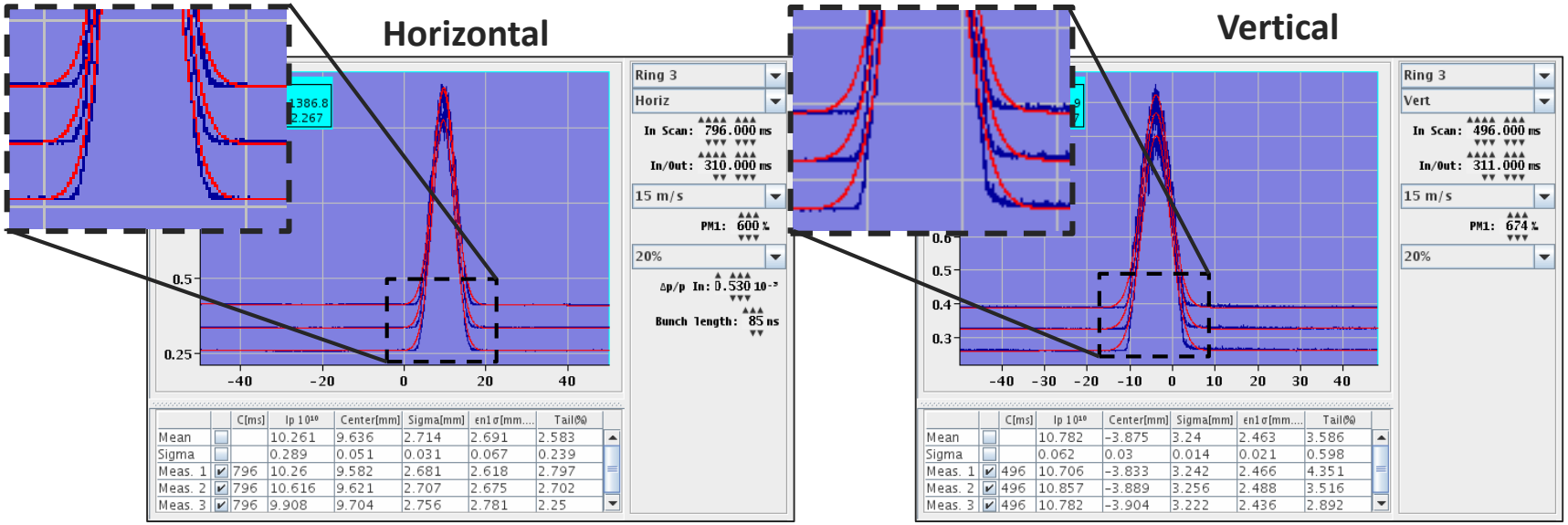

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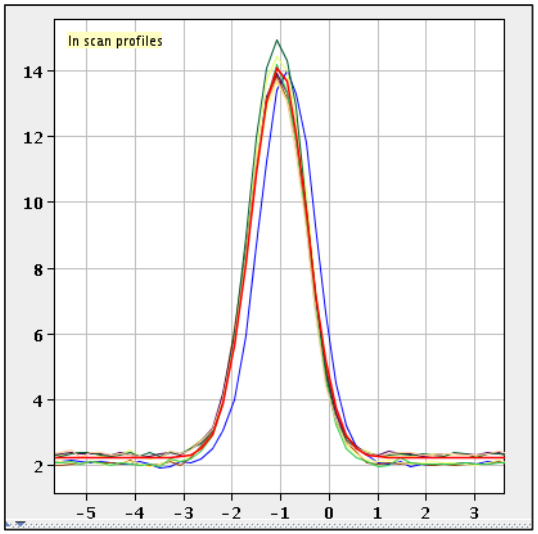
- **Transverse shavers are used to reduce tail population in both planes**
- **Beam on all 4 PSB rings (as requested by LHC)**
  - Optimization to achieve similar beam characteristics for all bunches but some residual differences are unavoidable
  - Faster filling of LHC

Beam preparation in SPS – in Run 2

- **Up to 8 bunches per SPS cycle**
  - 2 injections of 4 bunches with 525 ns bunch spacing and 525 ns batch spacing
- **Bunch-by-bunch wire scanner measurements became operational**
  - BE-BI improved the signal chain to reduce signal distortion (was affecting the old "turn-acquisition" mode) and reduce noise
  - Still only few samples to resolve the beam profile …

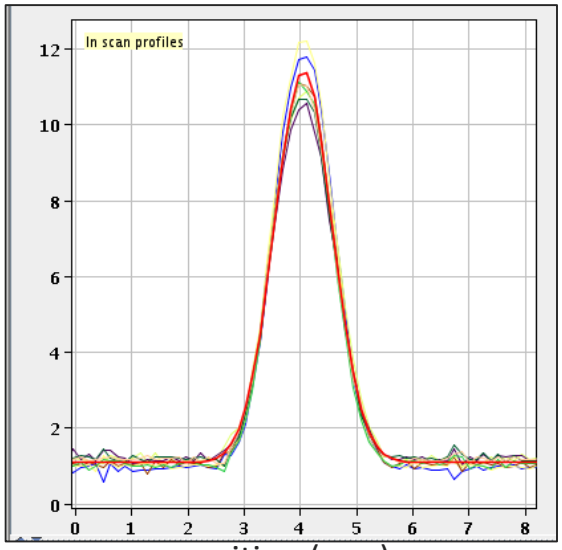
Horizontal



position (mm)

from wire scanner application in 2018 (8 bunches)

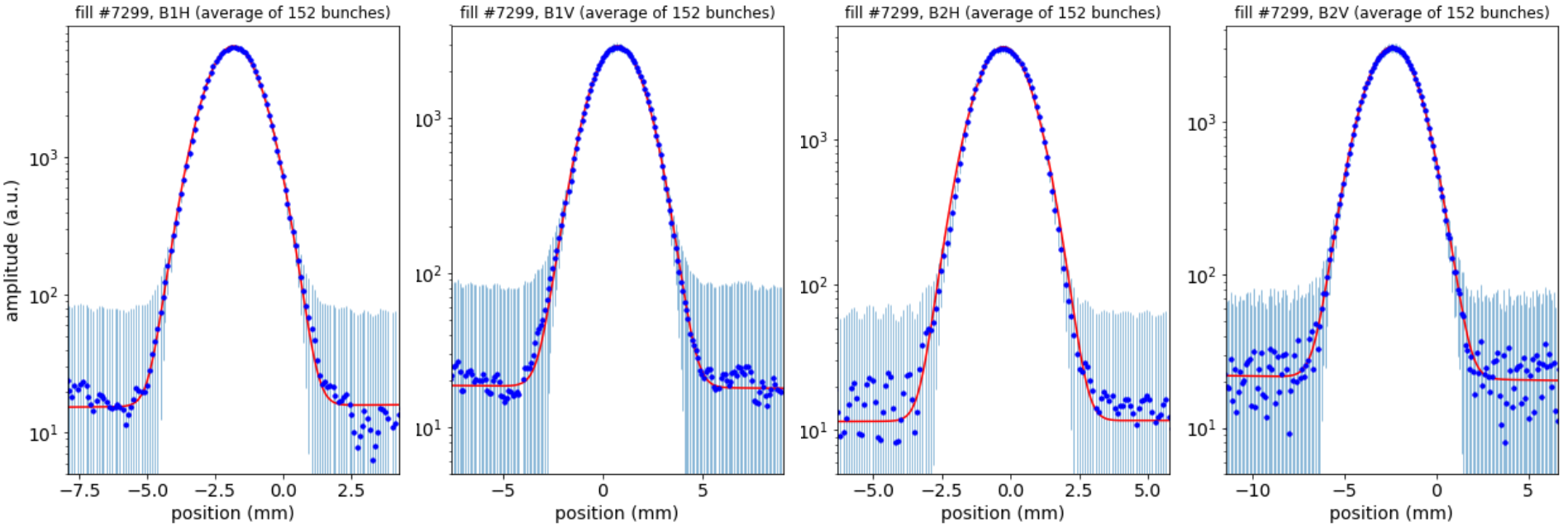
Vertical



position (mm)

Typical profiles measured at LHC injection – in Run 2

- **Wire scanner measurements in LHC much cleaner than in SPS**
  - Profile obtained from average of all bunches (error bars indicate std. deviation)
  - Profiles close to Gaussian at injection



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Outlook for Run 3

- **PSB**
  - New injection scheme with H^-
  - Linac4 provides much smaller emittance
  - Higher injection energy
  - Transverse painting through injection offset
  - Bunched beam injection

  } *production schemes for single bunch LHC beams (with large emittance) remain to be established*

  - Transverse blow-up through excitation with damper might become available (could be used to adjust transverse emittances)

- **PSB-to-PS transfer at 2 GeV**
  - New transfer line optics with matched dispersion (possibly less halo formation)

- **New beam instrumentation**
  - Upgraded wire scanners in all injectors (should allow for better measurements at SPS extraction with higher sampling due to variable rotation speed and higher accuracy of position readout)

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Summary & Conclusions

- **Since the end of Run 1 injectors provide close to Gaussian single bunches**
  - Under-populated tails in PSB to accommodate for halo formation along the chain
- **Improved beam production scheme during Run 2**
  - Better intensity reproducibility through longitudinal blow-up
  - Emittance control through working point in PSB
  - Bunches in all 4 PSB rings
- **Beam production scheme in PSB for Run 3 to be established**
  - Additional knobs should become available, but the production of single bunches with large transverse emittance will be more challenging and need to be studied
- **LHC wire scanners provide best profile measurements so far**
  - Will profit from LIU upgrades of wire scanners in injectors

Thank you for your attention