
CERN

Measurement of the beam (transverse) emittances

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LHC Lumi Days 2019

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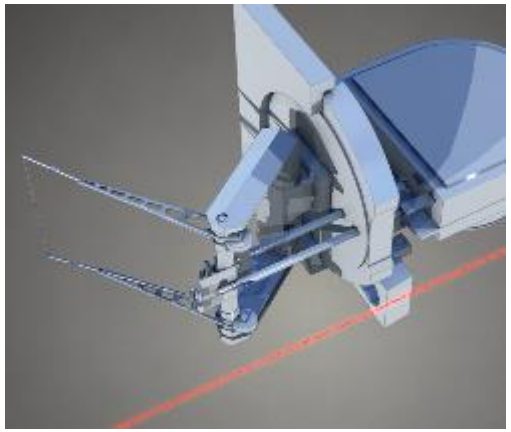
CONTENT



Wire Scanners

Synchrotron Radiation Monitors

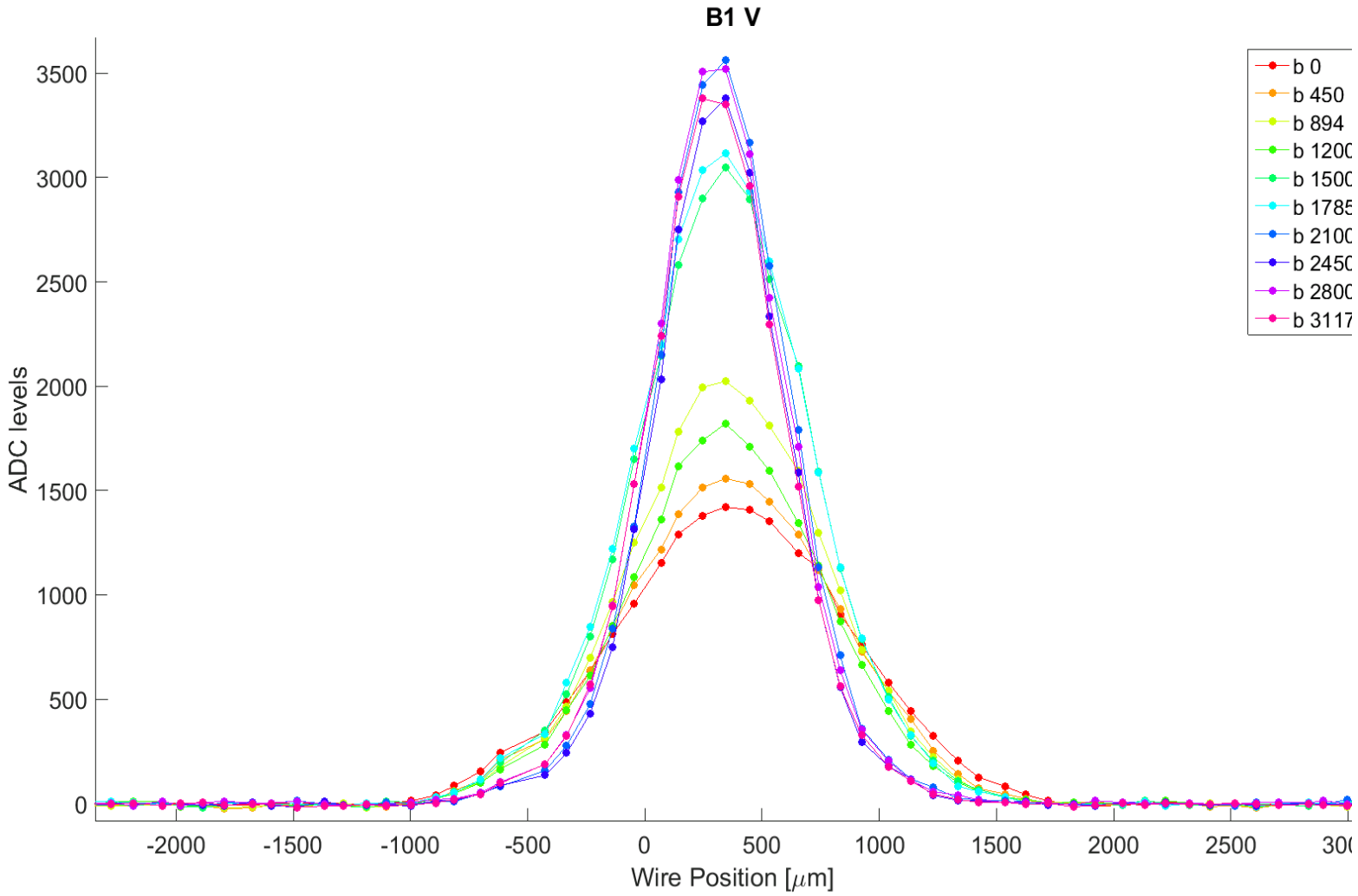
Wire scanners 1

- 4 Scanners per beam, 2H and 2V
- WS is the reference instrument for emittance measurement
- Possible to measure bunch by bunch beam size at any energy
- Use limited by total intensity in the machine
  - Wire damage (all energies)
  - Magnet quench (high energy)

Wire scanners 2

- Principle
  - Scan a 30um diameter carbon wire trough the beam
  - Measure the flux of secondary particles ~10m downstream as function of wire position (scintillator+PMT)
- Error sources
  - Electronic noise on PMT signal + ADC
  - Linearity of PMT and electronics
  - Crosstalk between bunches (cables, BW)
  - Indirect sampling of wire position (fork w.r.t. wire)
  - Absolute scale of potentiometer
  - Electronic noise on potentiometer signal

Example of WS profiles at 6.5 TeV



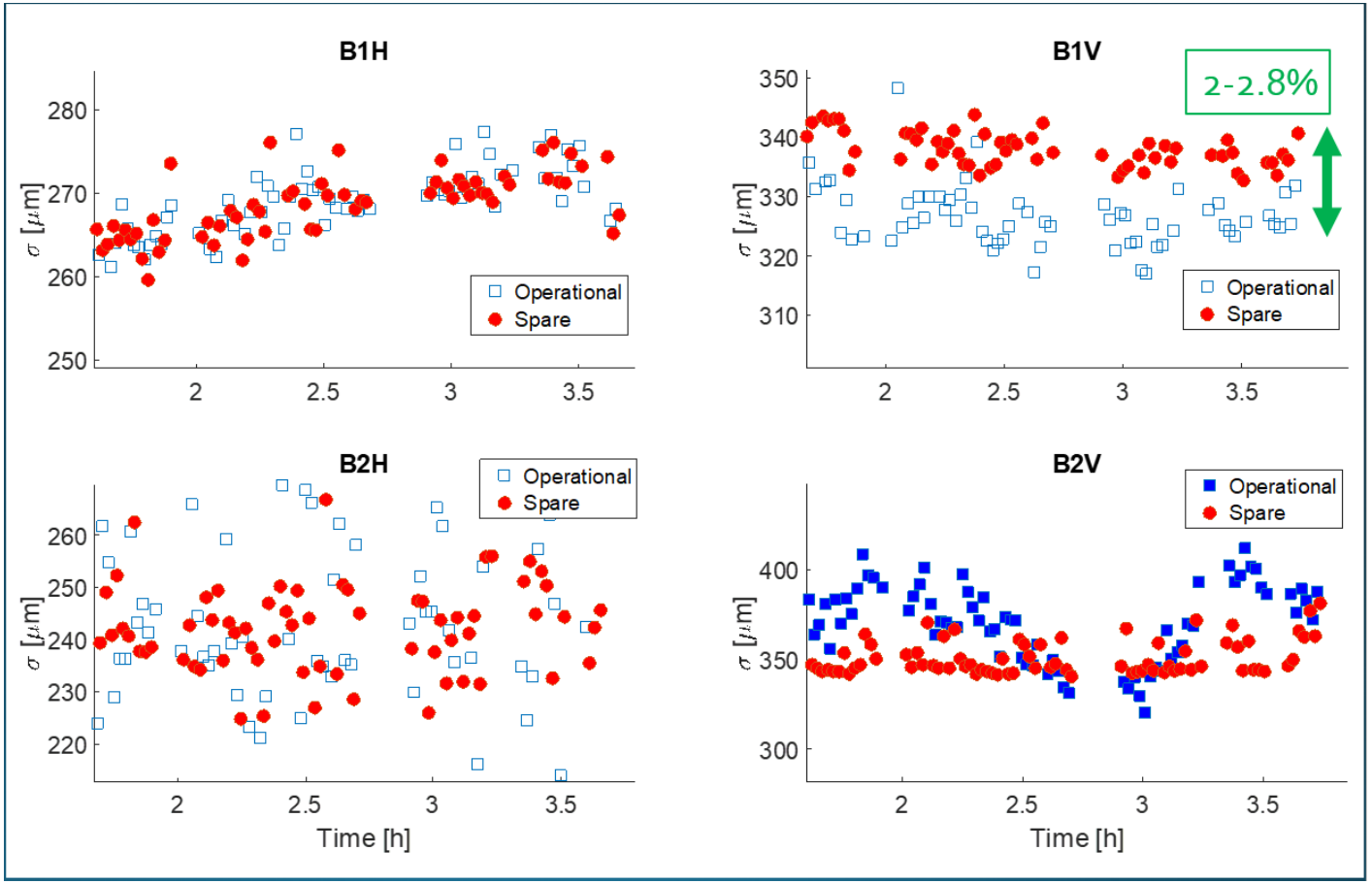
WS accuracy

Compare operational and spare scanners

Max difference 2.8% (B1V)

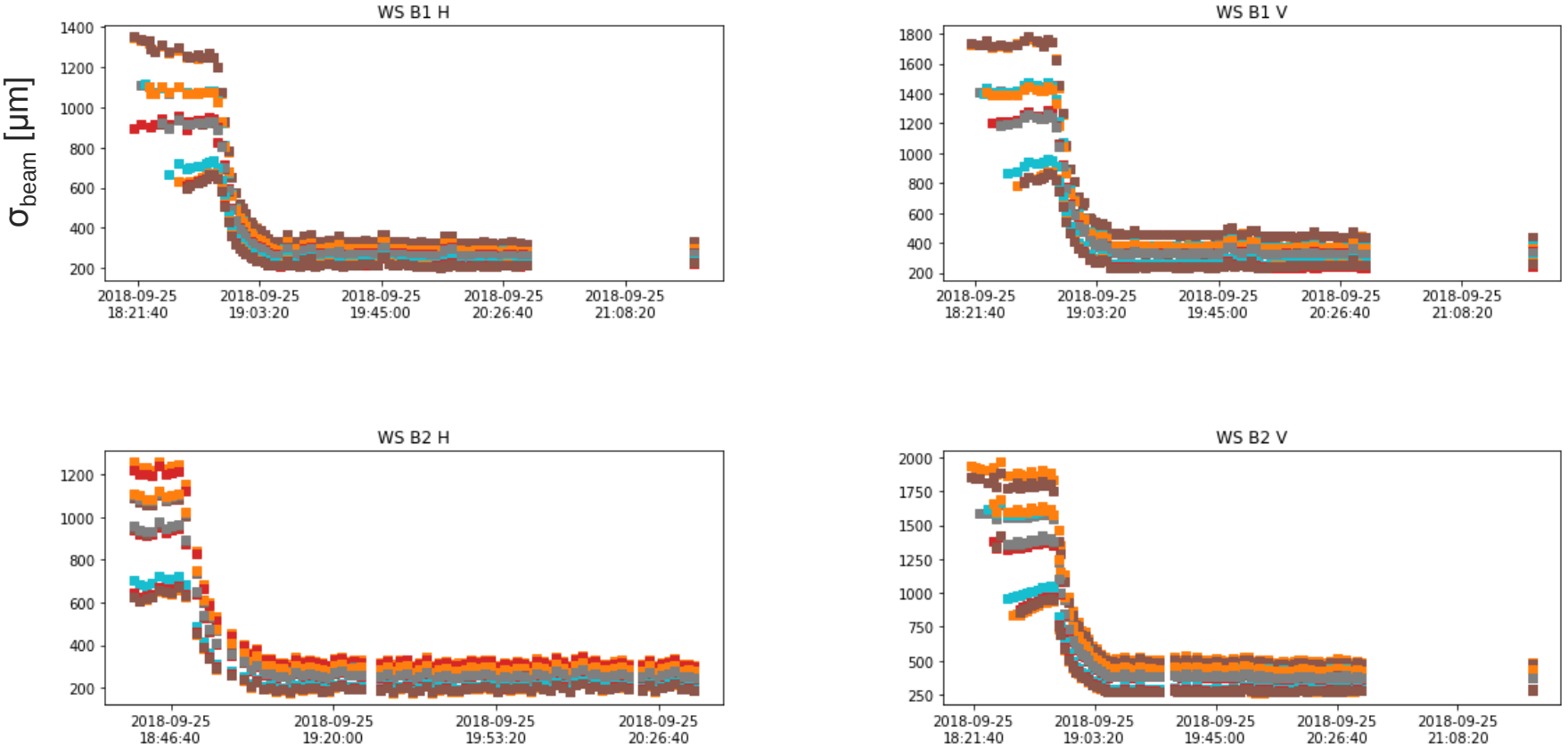
Max spread 4% (B2H)

Potentiometer of 1 WS crosschecked with interferometer, discrepancy <1%



B2 “operational” WS wires found damaged in LS2

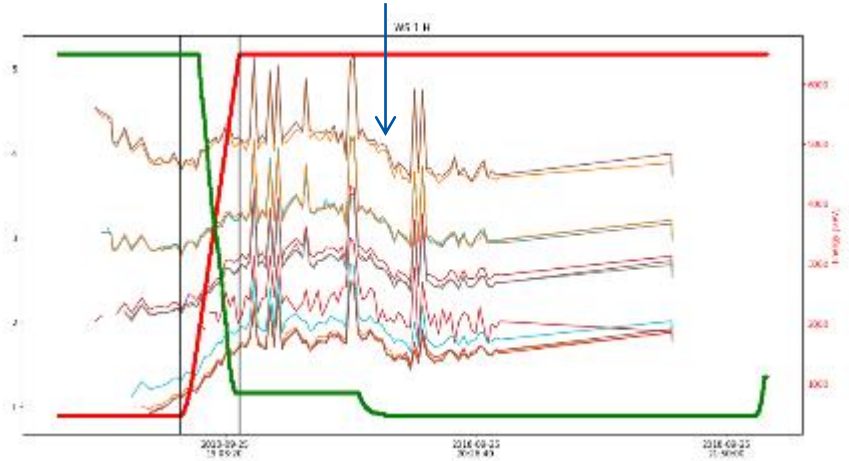
WS size evolution during cycle

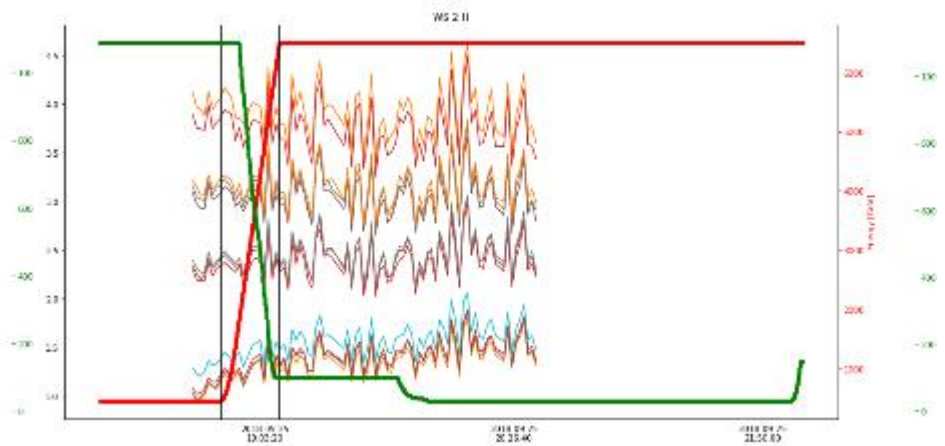


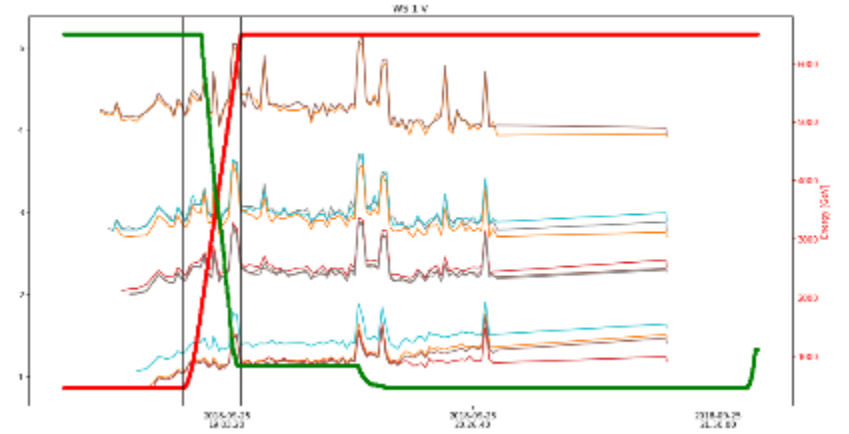
"Steps" behavior not yet understood

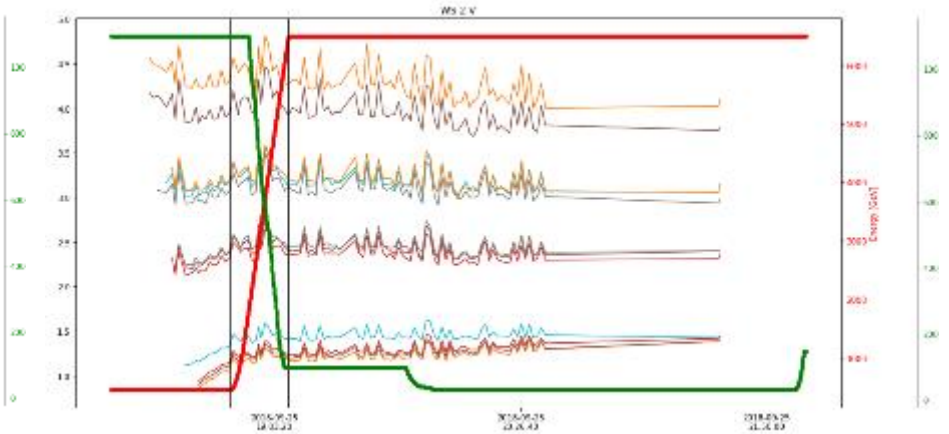
WS emittance evolution during cycle

Changes of beta?



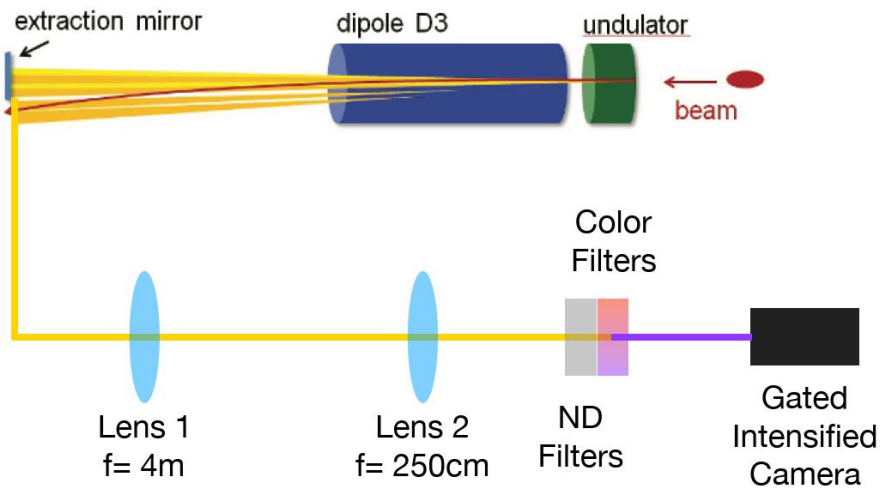




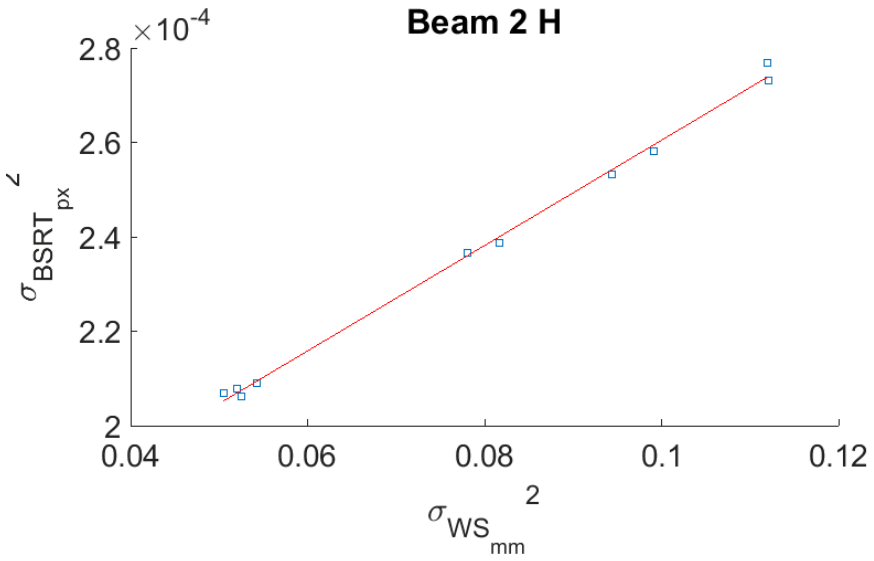


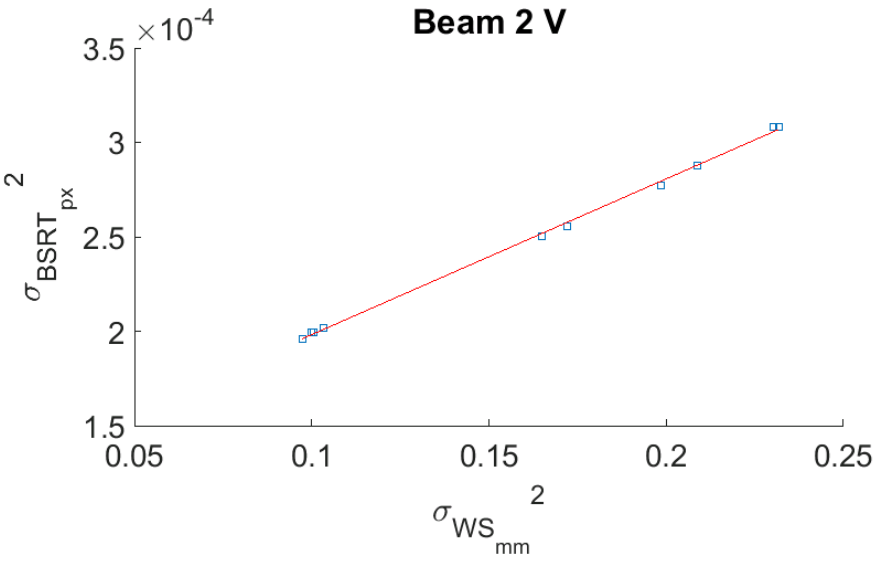
Synchrotron light telescope (BSRT)

- Complex source and optics
- Magnification and line spread function can only be determined by cross calibration with the WS
- LHC optics enters the cross calibration



BSRT calibration





$$\sigma_{BSRT} = \sqrt{\varepsilon \beta_{BSRT}}$$

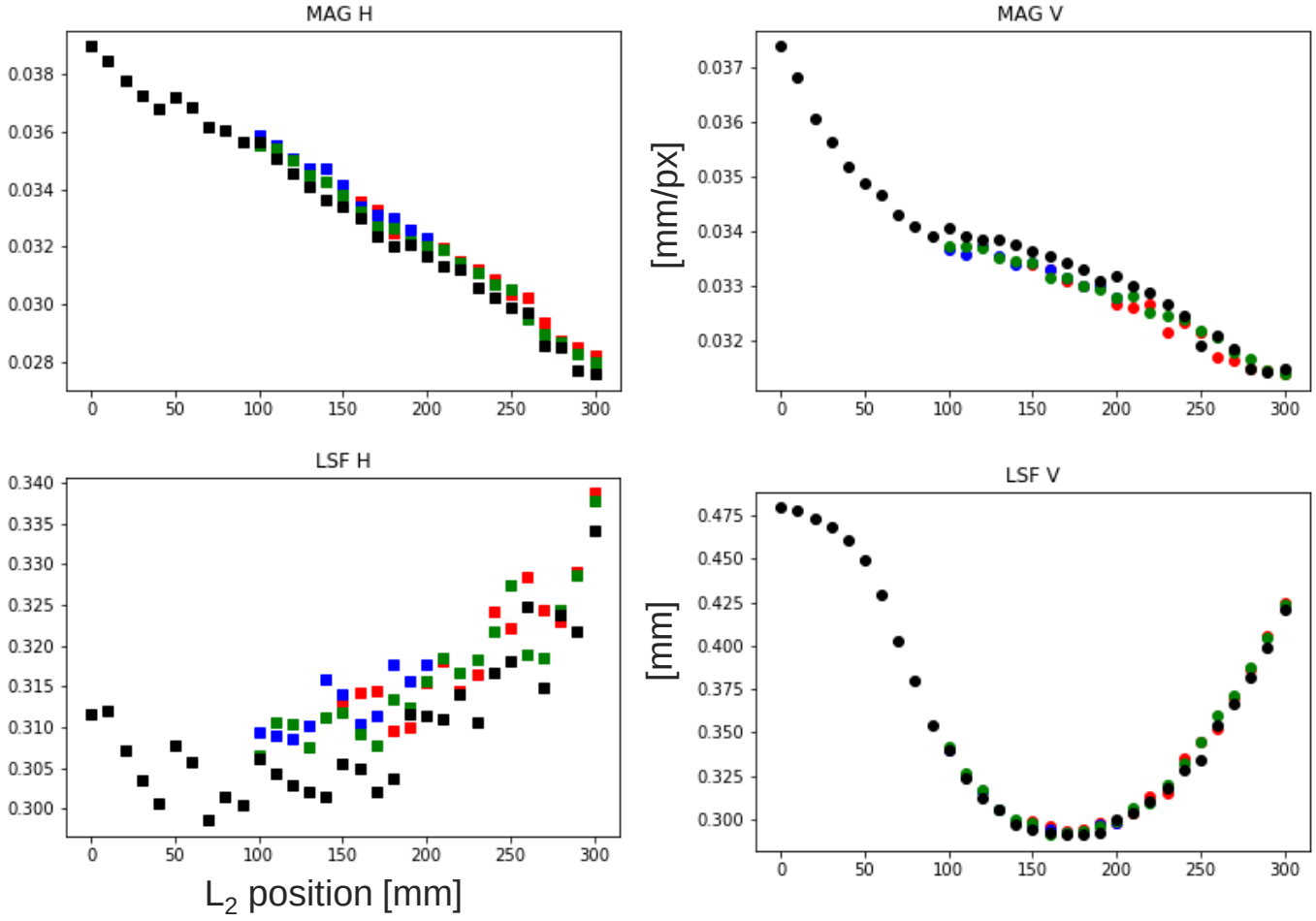
Assuming no dispersion at the WS and BSRT

$$\sigma_{WS} = \sqrt{\varepsilon \beta_{WS}}$$

$$\sigma^2_{BSRT} = s^2 \sigma^2_{BSRT_{pixels}} - LSF^2$$

$$\sigma^2_{BSRT_{pixels}} = \frac{1}{s^2} \frac{\beta_{BSRT}}{\beta_{WS}} \sigma^2_{WS} - \frac{LSF^2}{s^2}$$

L_2 lens scan repeatability



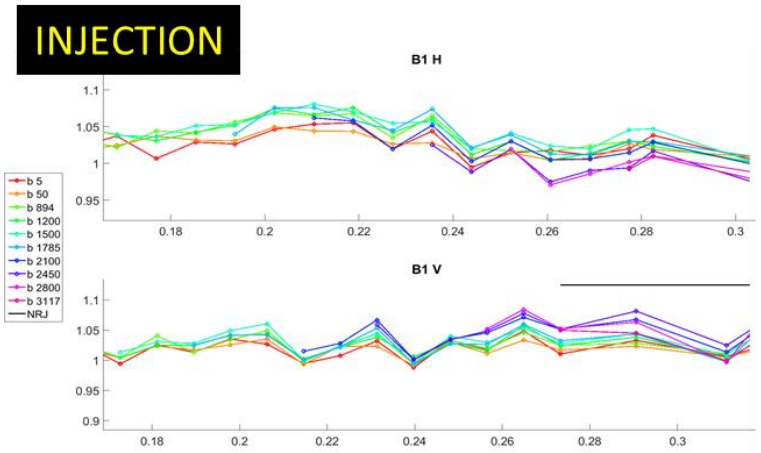
4 lens scans

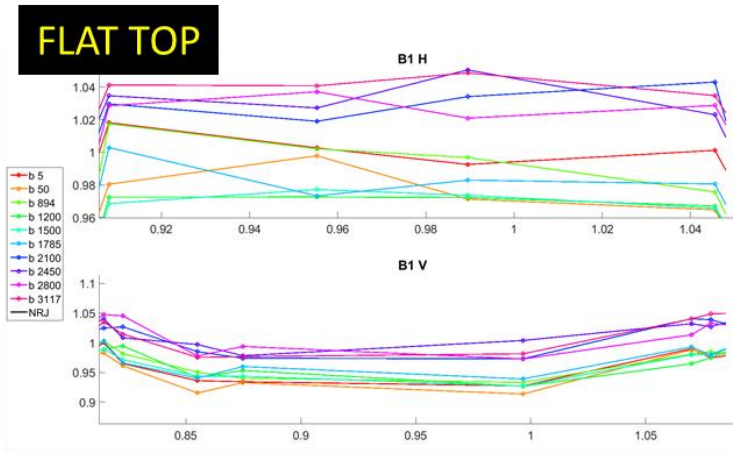
Very close results

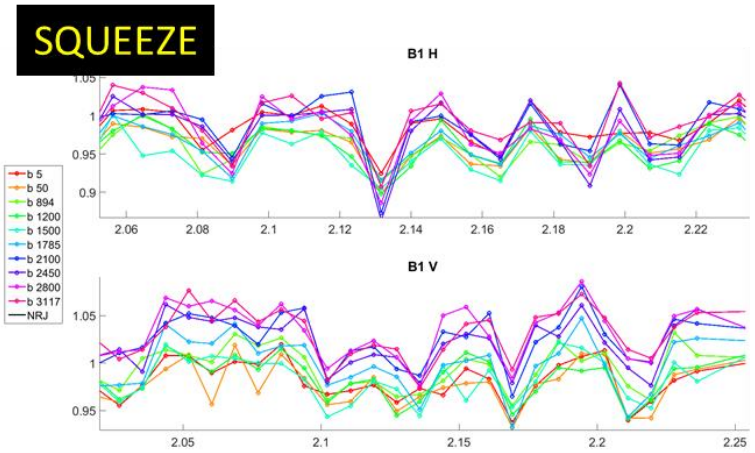
Max difference between any two calibrations <5% above 1.5um

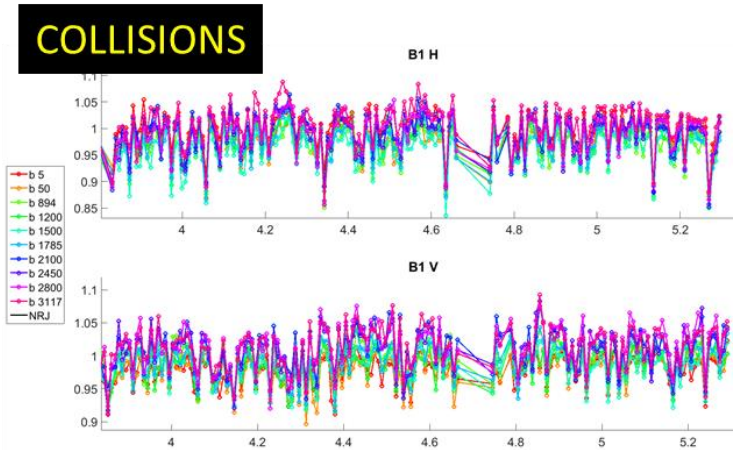
Calibration stability

Ratio of Emittances from WS and BSRT
2 months after calibration



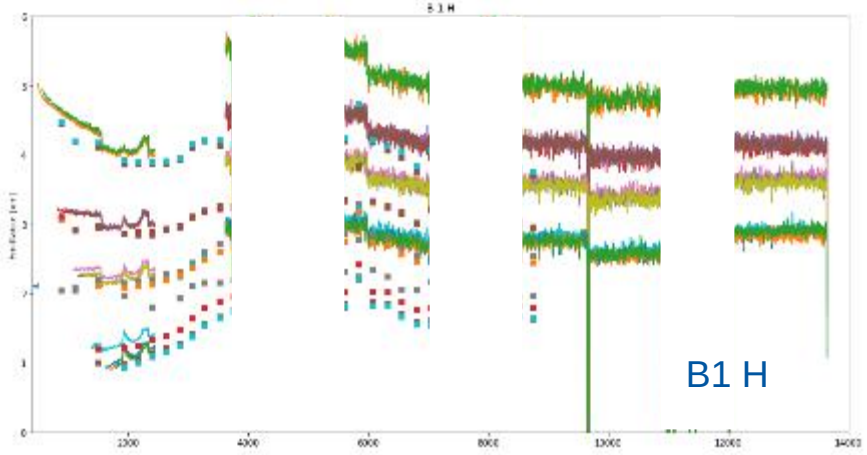


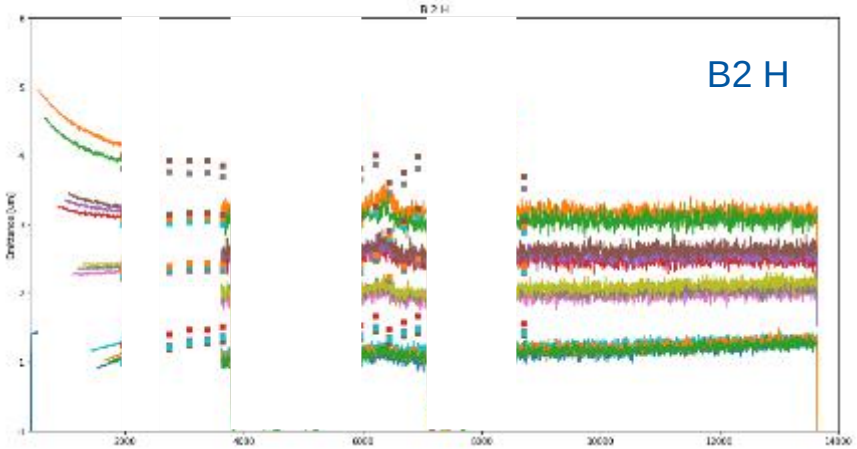


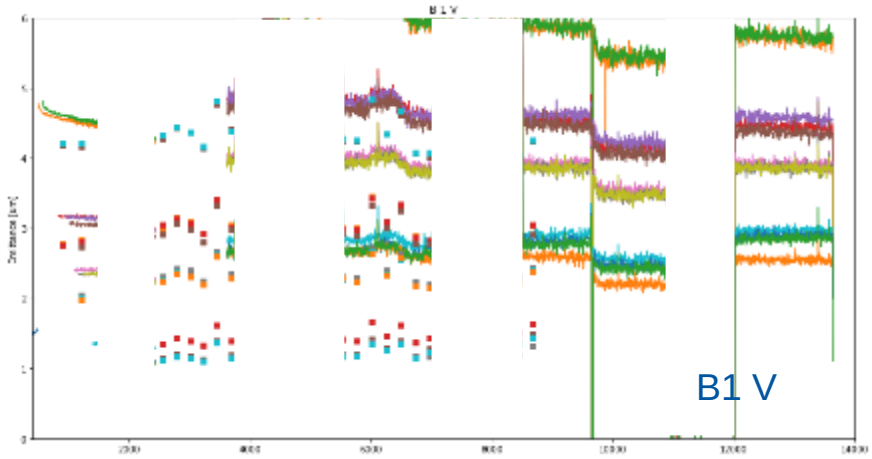


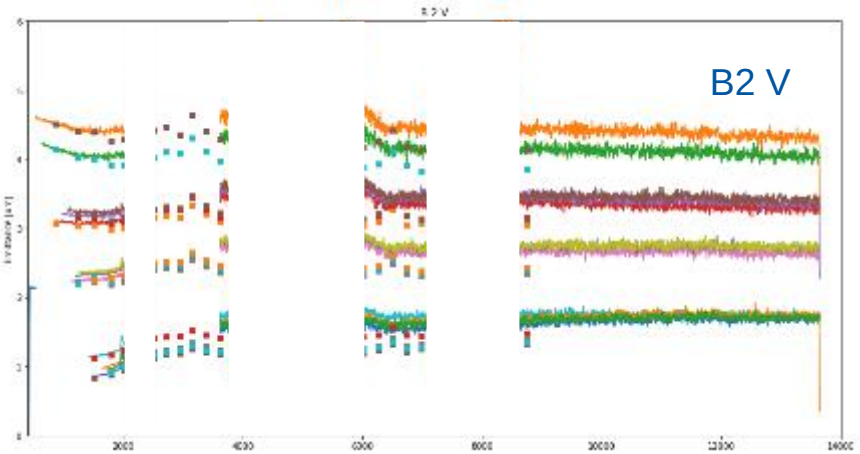
Calibration stability

Emittance from WS and BSRT, 2 months old calibration, B1 damaged optics (UV)





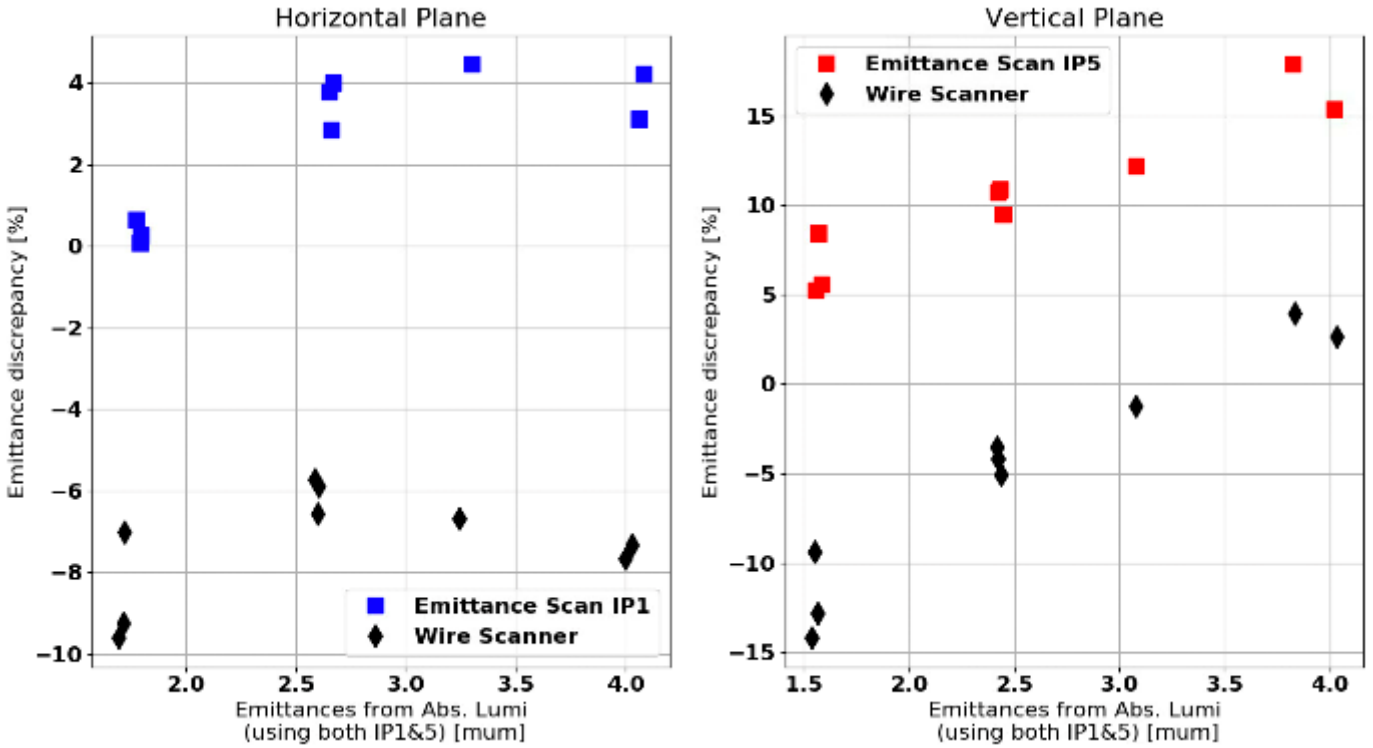




BSRT accuracy

- LSF ~ beam sigma at flat top
- Deconvolution needed
- Resolution of few % (B by B differences)
- Absolute accuracy ? 10-20%
  - Calibration, beta, coupling, etc.
- Very large error during the ramp: beta, LSF, mag. Not usable at the moment
  - May be with a segmented ramp a calibration could be obtained

WS vs emittance scans vs emittance from absolute lumi



Conclusions

- WS provide the reference measurement for the transverse emittance
  - Still some strange behavior to be understood
- BSRT works well for short time evolution and for B by B comparison
  - Need to understand/improve long term stability and possibly differences between calibration fills and physics fills
- Emittance from luminosity not self consistent
  - Need to understand discrepancy between emittance scans and WS