Studies on Controlled RF Noise for the LHC

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Outline

Motivation

- Controlled emittance blow-up
- Bunch shaping via RF noise

Simulation methods

- Modelling the LHC controlled emittance blow-up

Studies at flat bottom

Studies during the ramp

- Preliminary

Conclusions & outlook

MOTIVATION:

FROM CONTROLLED EMITTANCE BLOW-UP TO BUNCH SHAPING…

Controlled longitudinal emittance blow-up

LHC beam stability requires

$\varepsilon_{long} \propto \sqrt{E}$

Blow-up by a factor 4—5

Band-limited noise

Band-width $(0.86 - 1.1)\ f_{s0}$

Noise spectrum follows the change in f_{s0}, targeting always the bunch core

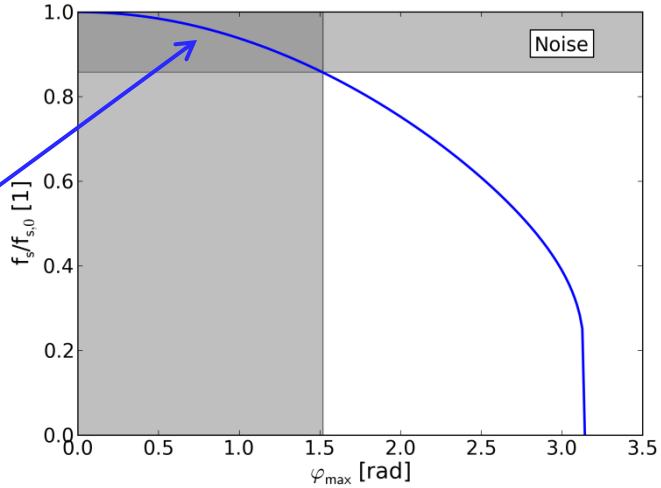
Noise injection

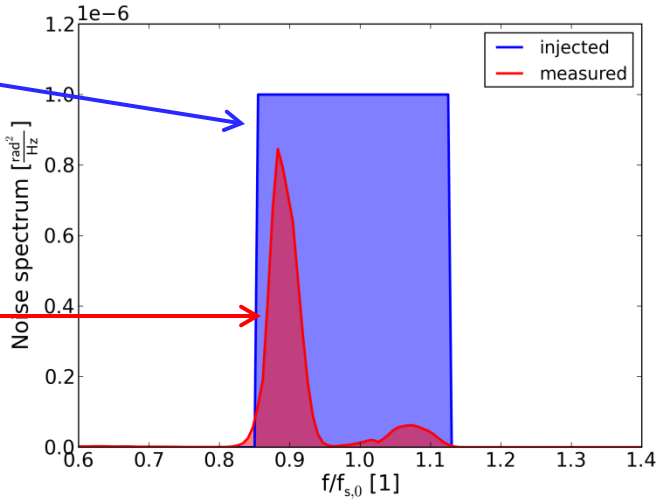
Through phase loop

→ Modifies the spectrum

Alternative: through cavity controller

→ Bifurcation of bunch lengths





Bunch shaping via RF noise

Bunches with flat core

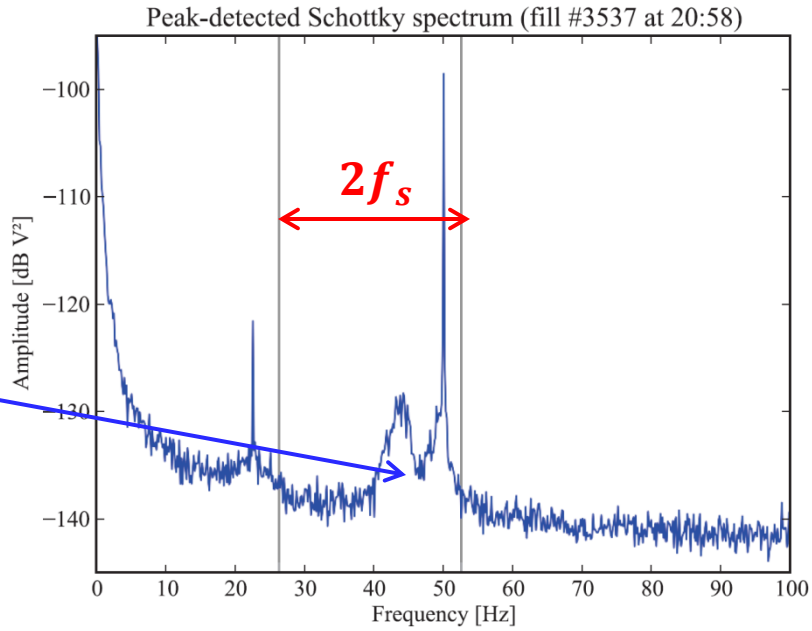
Desirable to reduce machine component heating at $f < 1.2\ GHz$

Reduce peak luminosity pile-up

Bunches at flat top

Schottky spectra show 'hole' in the longitudinal phase-space

- Can have a negative impact on stability and machine heating
- Could be related to the present emittance blow-up scheme



MODELLING THE LHC CONTROLLED
LONGITUDINAL EMITTANCE BLOW-UP:

IMPLEMENTATION IN BLOND

Noise implementation in BLonD

BLonD CERN Beam Longitudinal Dynamics code

Phase noise $\varphi_N{}^{rms} = \sqrt{\int S_\varphi(f)df} = 0.2° \; or \; 2°$

Injected through phase loop (PL) or cavity controller (CC)

Single or multiple seeds for random number generator

Phase loop Calculates phase difference $\Delta\varphi_{PL} = \varphi_{COM} - \varphi_S$

Applies correction $\omega_{RF}{}^{(n+1)} = h\,\omega_{S0}{}^{(n+1)} - g\Delta\varphi_{PL}$

We use a gain of $1/(5 \text{ turns})$

Feedback Scales the noise amplitude to meet target bunch length

Scaling factor: $x^{(n+1)} = ax^{(n)} + k(\tau_{targ} - \tau_{meas})$,

$x^{(0)} = 1, x^{(n)} \in [0,1] \; \forall \, n, a = 0.8, k = 1.5 \times 10^9 \; s^{-1}$

Target bunch length: 1.2 ns, $\tau_{meas} \equiv 4/2.355\tau_{FWHM}$*

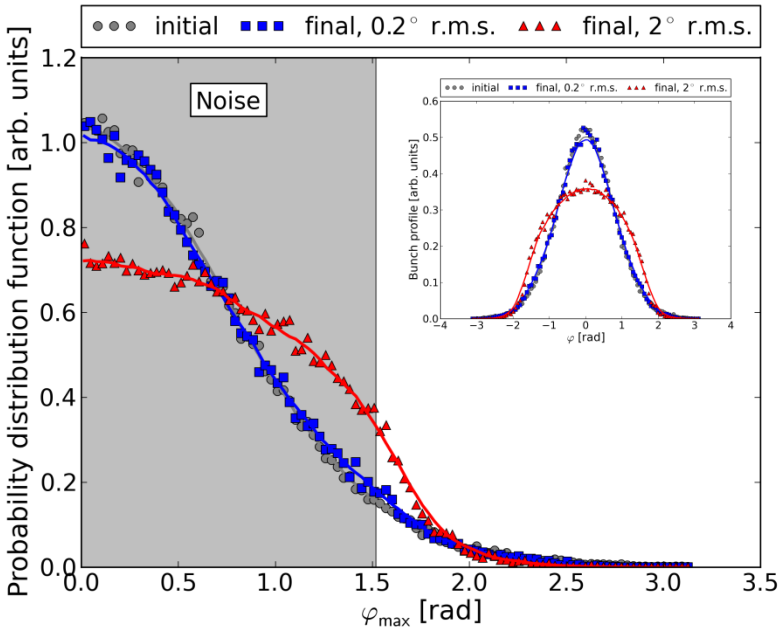
* $\tau_{FWHM} = 2\sqrt{2ln2}\sigma \approx 2.355\sigma$

DIFFUSION AT CONSTANT ENERGY:

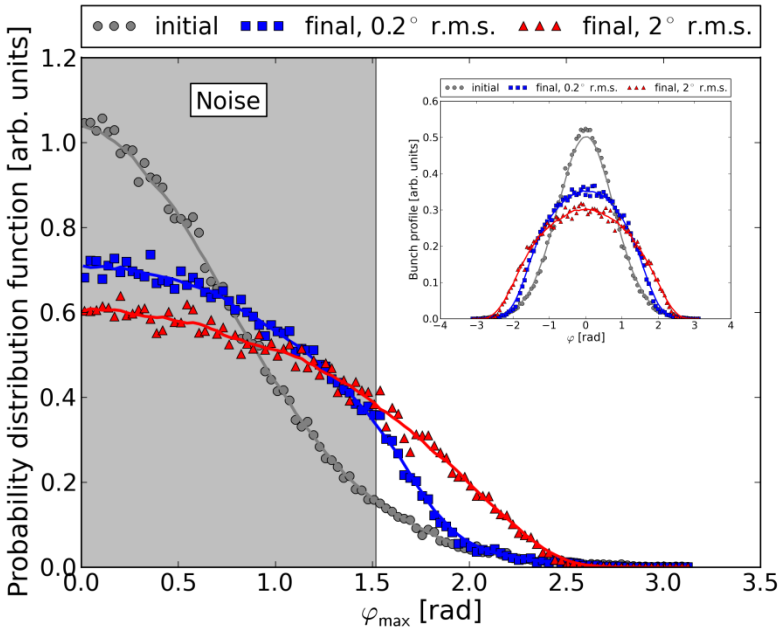
SIMULATIONS AT FLAT BOTTOM

Studies of diffusion at flat bottom energy (1)

Injection through PL



Injection through CC



Noise efficiency strongly reduced when injected through the PL

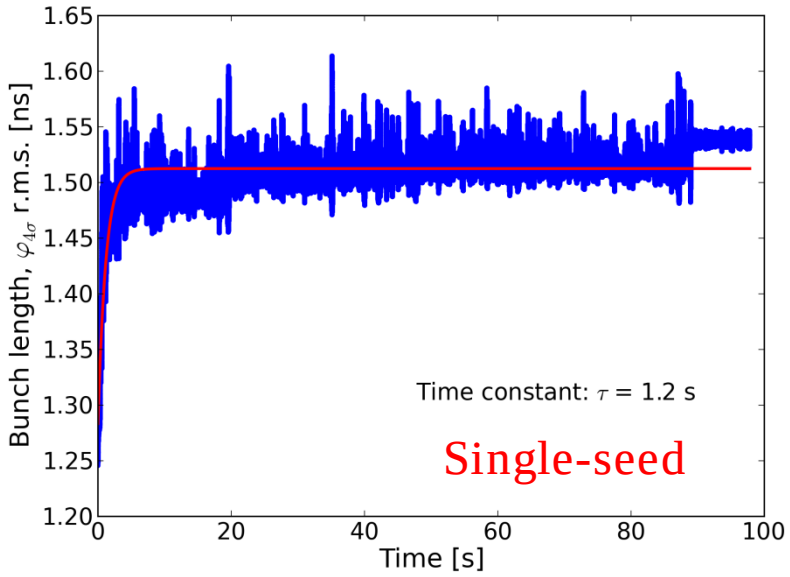
Factor 10 in $\varphi_N(t)$ (factor 100 in $S_\varphi(f)$) needed to compensate

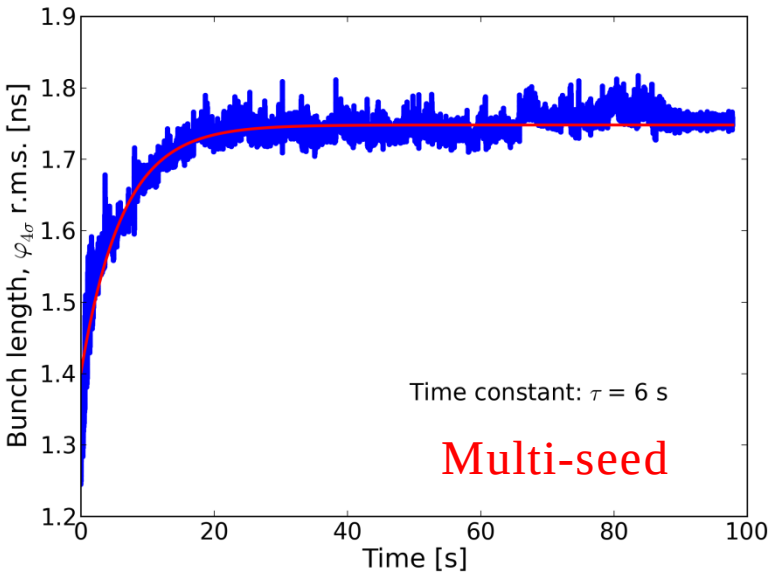
Studies of diffusion at flat bottom energy (2)

Noise realisation (seeding) affects blow-up efficiency

Single-seed Saturates at lower level (creates islands in phase space)

Multi-seed Longer final bunch length, longer time constant



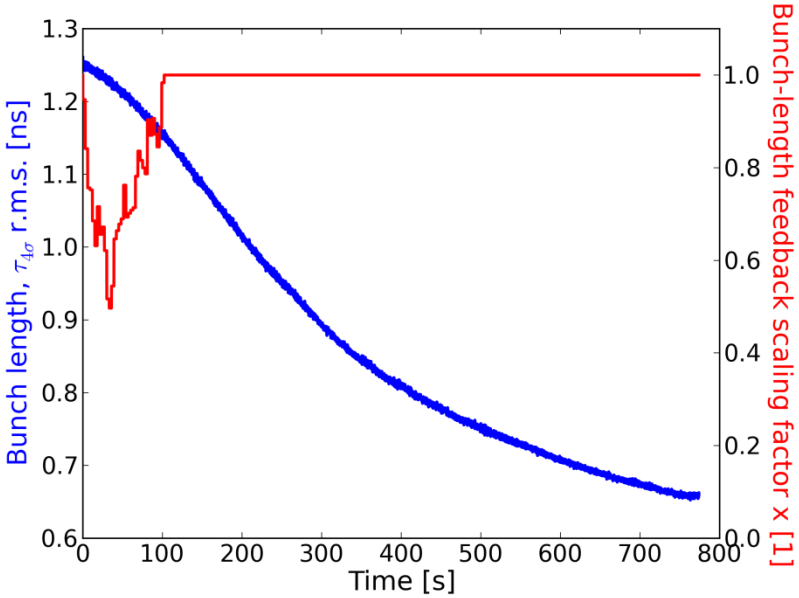


THE LHC BLOW-UP FULLY MODELLED:

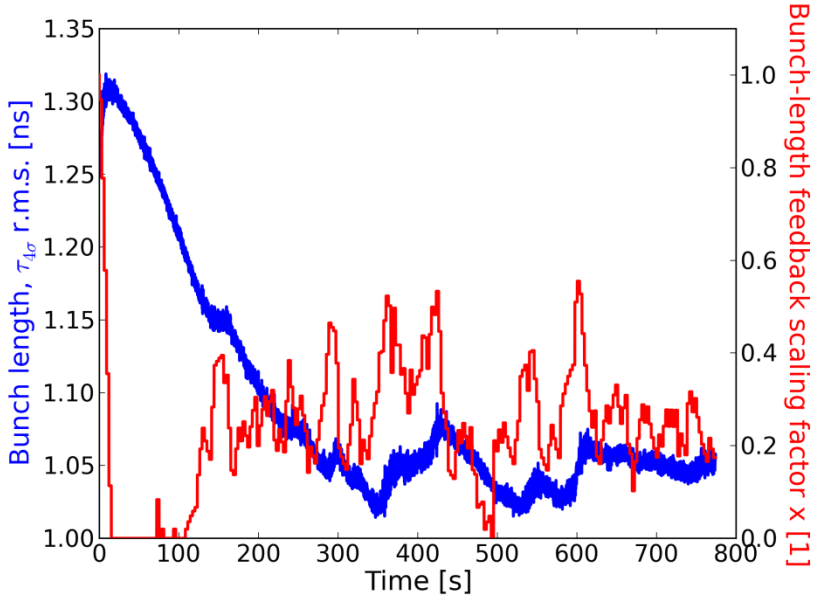
SIMULATIONS DURING THE RAMP
8,700,000 TURNS – 11 MINUTES

Diffusion during the ramp (1)

Injection through PL, 0.2° r.m.s.



Injection through CC, 0.2° r.m.s.

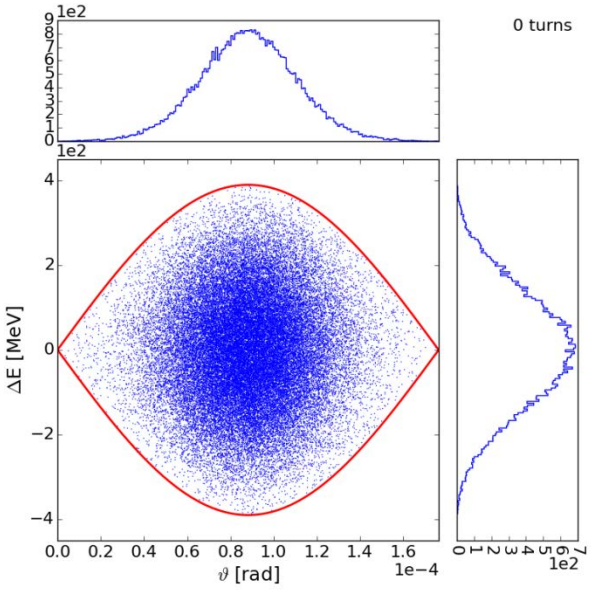


Same amount of noise → insufficient blow-up in PL

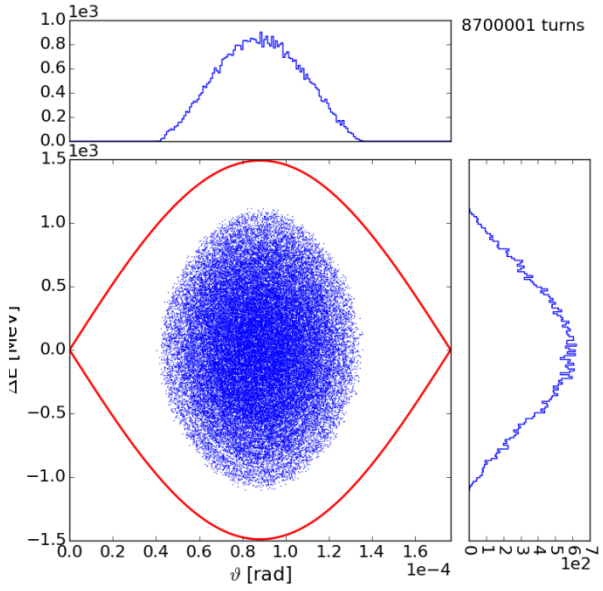
With the feedback, τ_{targ} can be met throughout the cycle

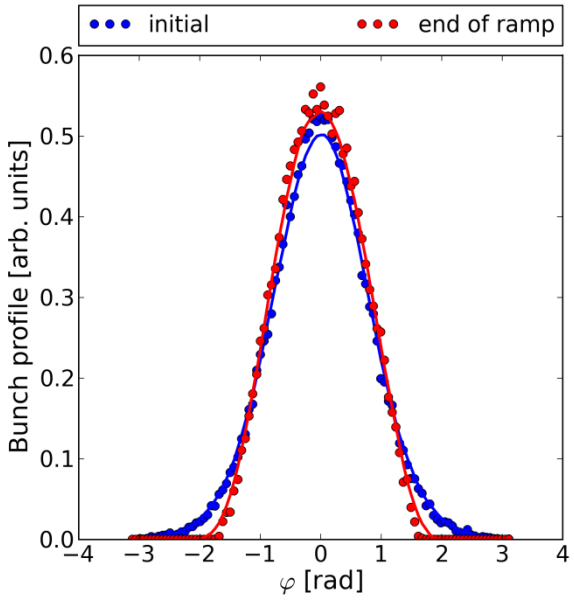
Diffusion during the ramp (2)
Noise injected through CC

Initial (flat bottom)



Final (flat top)





After blow-up, the bunch has a rounder core and very low tail population

- Low tail population is consistent with earlier observations
- Due to controlled emittance increase while bucket area increases

SUMMARY:

CONCLUSIONS & OUTLOOK

Conclusions & outlook

Extending BLonD

Developed new tool to simulate controlled noise injection

Investigating

Several injection schemes, noise realisations & amplitudes

LHC ramp with controlled blow-up

Bunch with round core and low tail population

Underway

Detailed simulation studies to optimise the blow-up

Opportunity to test: LHC re-commissioning early 2015

THANK YOU!