Crab momentum cleaning in LHC

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Thanks to: Ralph Assmann

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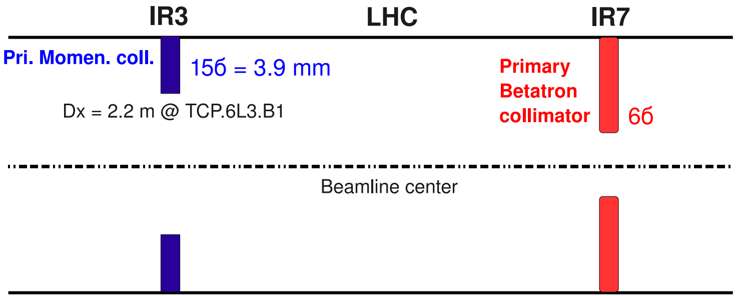
Content

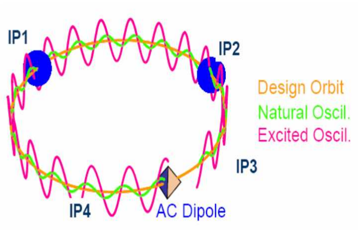
- Stephane's proposal: at top energy, use crab-AC-dip. as a stopper for off-RF-bucket particles –> accept β-beat at IR3 —> good phase between IP1 and IP5 —> PUSH β^* to 0.15 m
- Introduction on LHC momentum cleaning
- Introduction on AC dipole
- Proposal for crab-AC-dipole
- How it works
- Conclusion

LHC momentum cleaning

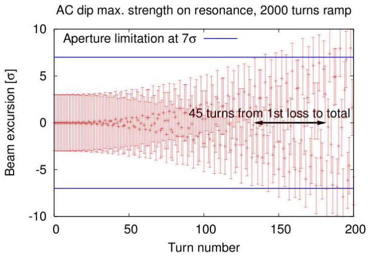


Primary momentum collimator, clean $\delta p >$ -$1.5 - 1.8 \times 10^{-3}$

AC dipole



M. Bai



R. Tomas

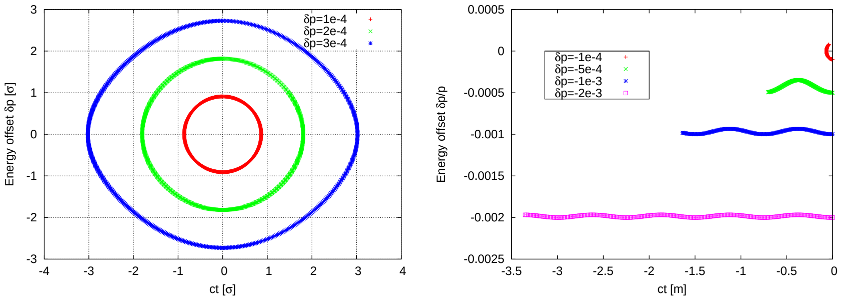
LHC IR3. $Q_{AC} = \frac{\omega_{AC}}{\omega_0}$

1) overcome spin resonance

2) excite coherent oscillations to measure linear & nonlinear beam parameters.

Slow adiabatical ramping –> no emittance growth

Longitudinal motion, LHC 7 TeV (16 MV)



- Left: in-bucket particles, 1000 turns
- Right: off-bucket particles, 200 turns

S. Fartoukh' proposal

Derivation

$\frac{dt}{T_0} = \frac{dC}{C_0} = \eta \cdot \delta p$ and $\Delta p_{x,CC} = \frac{q \cdot V_{CC}}{E_s} \cdot sin(\omega_{CC} \cdot t)$

$\longrightarrow \Delta p_{x,CC} = \frac{qV_{CC}}{E_s} \cdot sin(\frac{\omega_{CC}}{\omega_0} \cdot \eta \cdot \delta p \cdot n)$

Tune of crab-AC-dipole, formula

$Q_{ACC} = \frac{\omega_{CC}}{\omega_0} \cdot \eta \cdot \delta p$

Tune of crab-AC-dipole, LHC

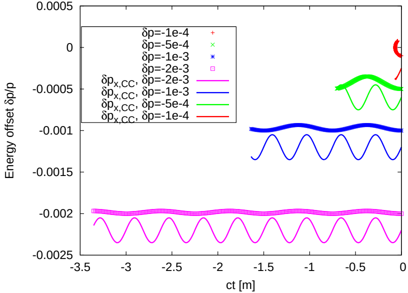
For LHC $\eta_0 = 3.4 \times 10^{-4}$, $\omega_0 = 11KHz$

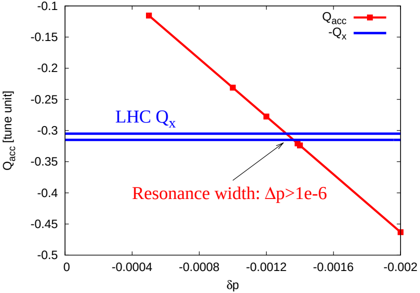
with $\omega_{CC} = 800MHz$, $Q_{ACC} = 0.025$ for $\delta p = 0.001$

with $\omega_{CC} = 8GHz$, $Q_{ACC} = 0.31$ for $\delta p = -0.001386$

—»» $Q_{ACC} = Q_x = 0.31$, coherent oscillations

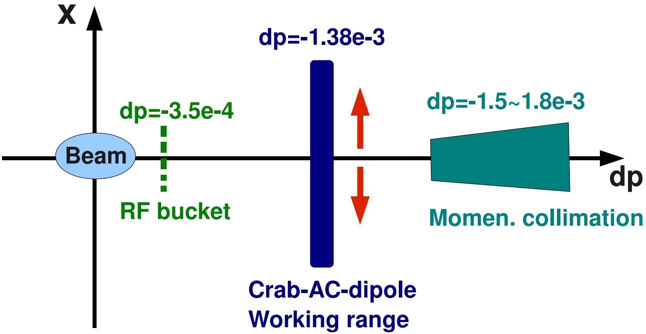
How it works





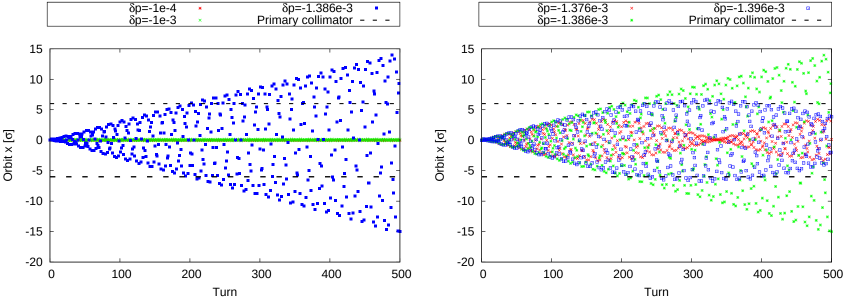
- Left: 800-MHz CC, 6 MV, for different δp in the same 200 turns
- Right: at 7 TeV, energy loss per turn: 10^{-9}, to excite in 1000 turns

Alternative for momentum collimators



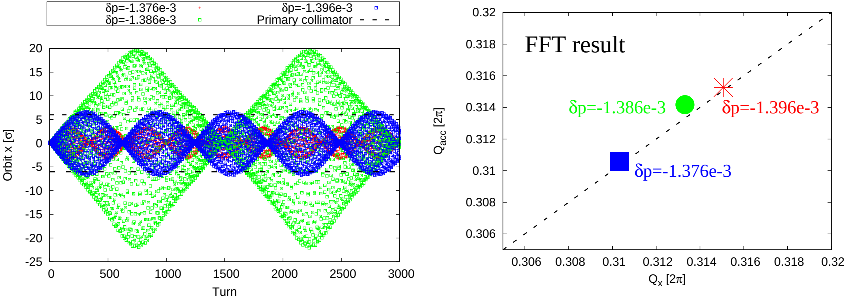
Fast enough, compared with synchrotron radiation loss

Coherent oscillation with 8-GHz CC (1)



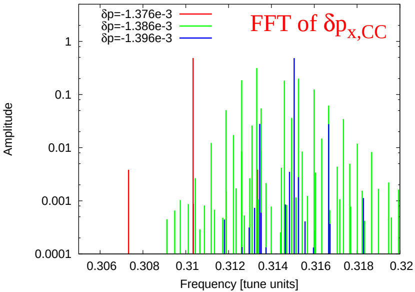
$\delta p = -0.001386$, $Q_{ACC} = Q_x = 0.31$ works with 3×10^{-6}rad, smaller than LHC AC dipole strength

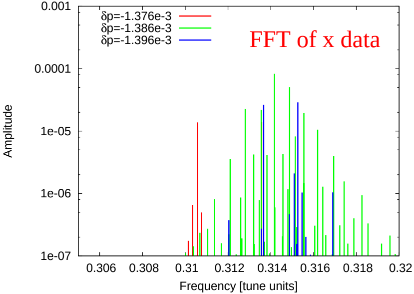
Coherent oscillation with 8-GHz CC (2)



- Decoherence-recoherence, or damping effect?
- Resonance width $\Delta p = 2 \times 10^{-5}$

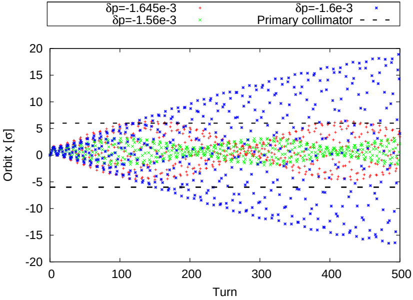
FFT spectrum

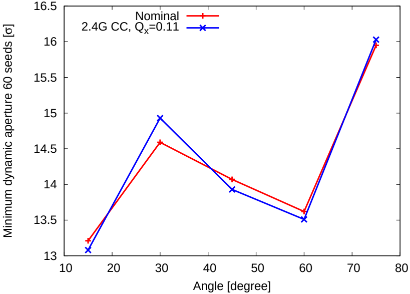




- Left: FFT of turn-by-turn crab-AC-dipole kick
- Right: FFT of turn-by-turn x data

Coherent oscillation with 2.4-GHz CC





- $\delta p = -0.0016,\ Q_{ACC} = Q_x = 0.11$
- Resonance width $\Delta \mathrm{p} = 9 \times 10^{-5}$, voltage 1 MV for 2.4-GHz CC

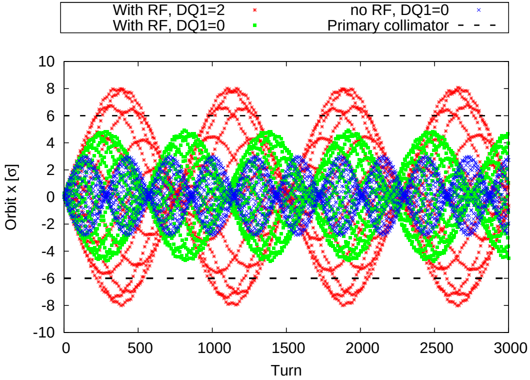
Conclusion

- Crab-AC-dipole works in LHC for 8-GHz & 2.4-GHz
- Clean very early the off-bucket particles which have not yet reached the abort gap (good for background)
- Alternative to the momentum collimation insertion
- pi/2 IR phasing–> $\beta^* = 15\text{cm}$
- For 800-MHz, Q_x–> 0.04 to use linear resonance; or creat the condition for 4th-order resonance

What To do next

- **2.4-GHz possible in LHC?**
- **Crab-cleaning collimation tracking: on-going**
- **Find resonance condition for 800-MHz CC**

Back up



Due to chromaticity and synchrotron motion?