Brainstorming Session on Beam Parameters for the High Luminosity LHC

Low γ_t vs. nominal optics in the SPS

Potential limitations and possible alternatives

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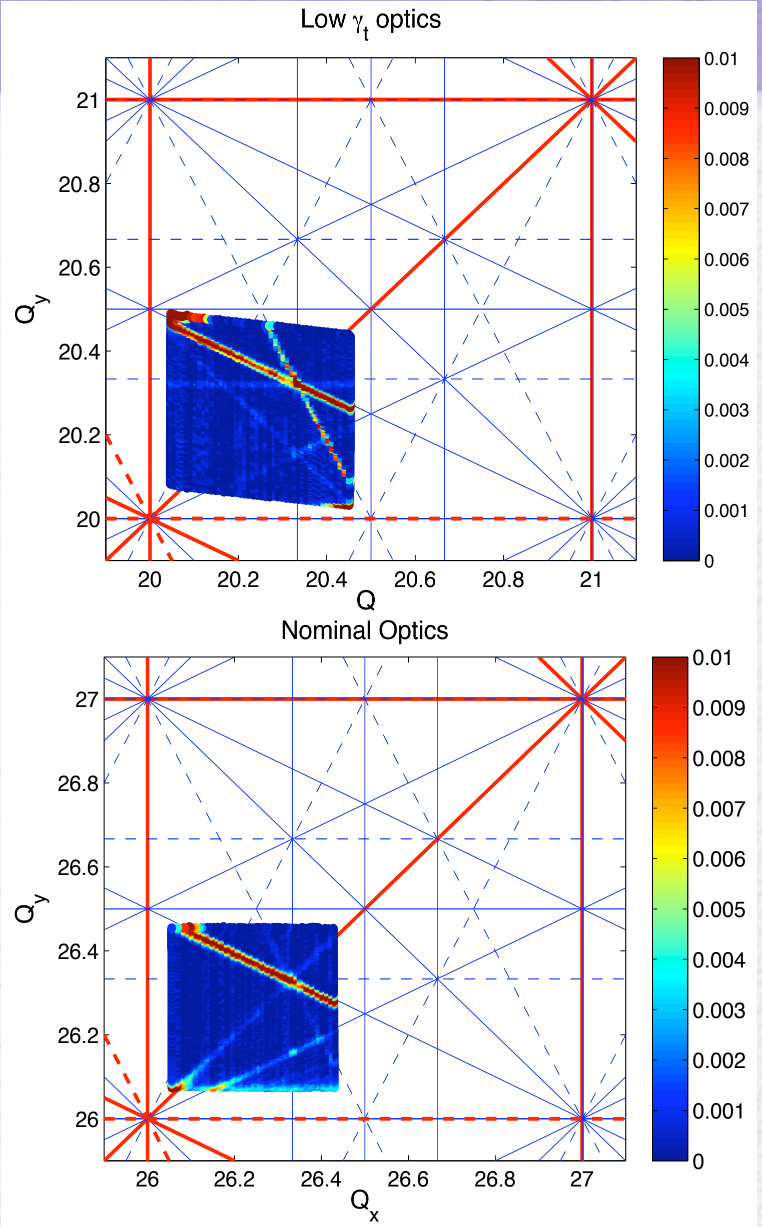
Optics

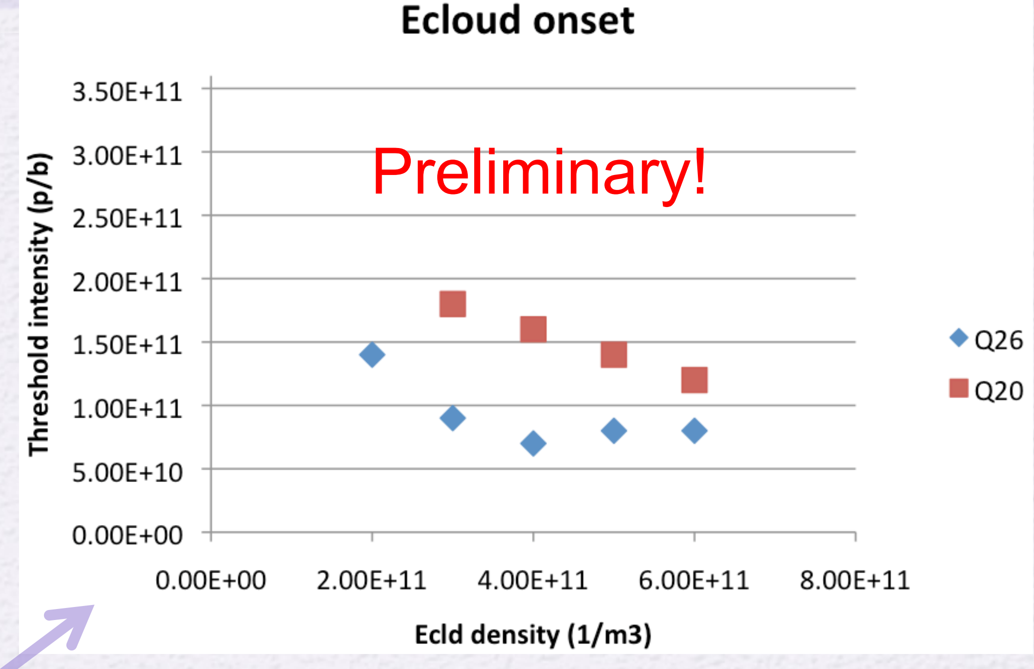
- Horizontal aperture reduced in Q20 (larger dispersion) but no problem for LHC beams
- No clear measured difference for different injection optics (extraction to be confirmed)
- Same resonance diagram for systematic resonances but different phase advance may induce/cancel different resonances
  - Indication of stronger integer resonance for Q26 from both simulations and measurements
  - Repeat measurements with non-linear chromaticity for building non-linear model in both optics
- Cycling of magnets in different optics for fixed target beams can be handled with careful cycle re-programing

Optics	Q20 (low γt)	Q26 (nominal)
Working point	(20.13, 20.18)	(26.13, 26.18)
Max. Dispersion	8 m	4.5 m
Max. β-functions	105 m	105 m
Min. β-functions	30 m	20 m
γt	18	22.8
η @ 26 GeV/c	1.8E-3	0.63E-3
η @ 450 GeV/c	3.1E-3	1.9E-3
Phase advance/cell	3*2π/16	4*2π/16



Instabilities

- Instability thresholds are scaled with slippage factor (or synchrotron tune), thus clear benefit for running at low transition energy
  - TMCI threshold ("zero" chromaticity) 1.6e11p for nominal vs >3.5e11p for Q20 for $\xi_y<0.05$ (observed 4h ago with Rfvoltage=3.7MV)
  - Electron cloud instability
    - Preliminary simulations for injection energy suggest higher threshold for Q20



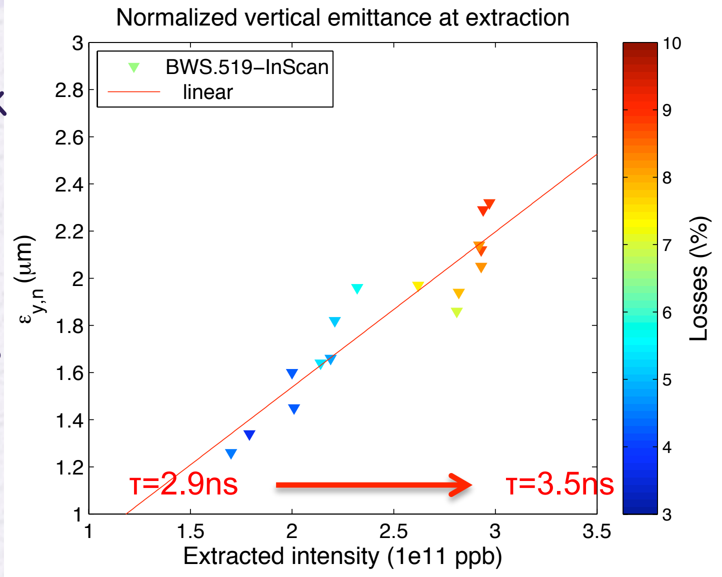
- Longitudinal instabilities $N_{th} \propto \eta \epsilon_l^2 \tau$
  - Loss of Landau damping $N_{th} \propto \eta \epsilon_l^2 / \tau$
  - Coupled bunch

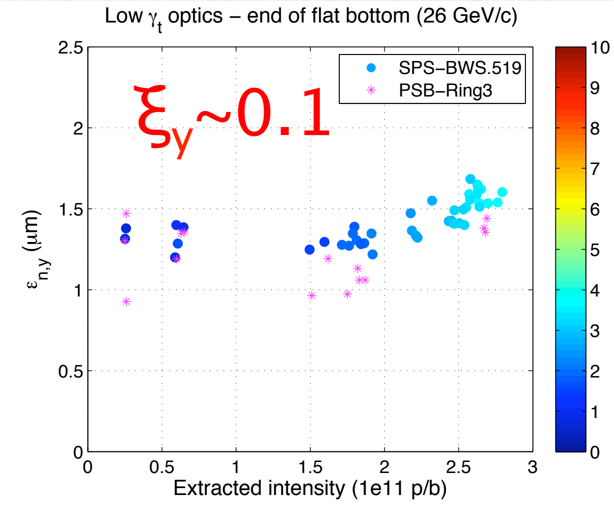
To be checked in MDs

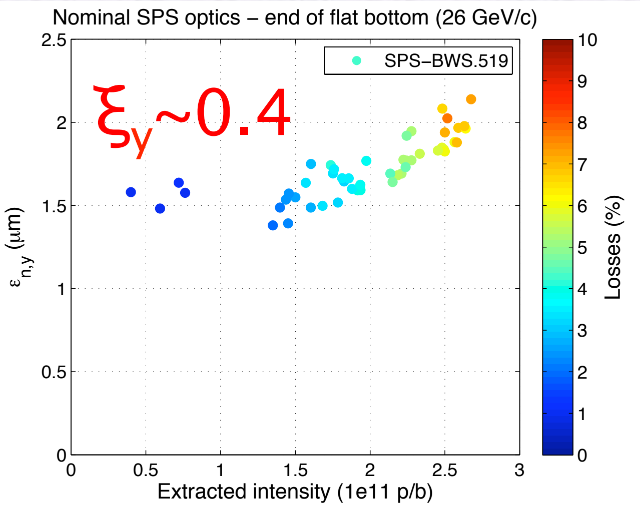
N_{th} ... Instability threshold
ϵ_l ... longitudinal emittance
τ ... bunch length
η ... slippage factor

Emittance vs. intensity vs. losses

- Injection ("short" flat bottom)
  - For Q20, emittance blow-up (>1.5e11 p/b) with peak values of 25% at 3e11 p/b
  - For Q26, slightly larger blow up and increased losses (all along flat bottom)
    - Larger chromaticity (much larger sextupole strengths + integer stop-band)
    - ξ_y of at least 0.4 needed in Q26 for stabilizing beam up to 2.8e11 (avoid losses within 10ms at injection)
  - Working point optimization for both optics

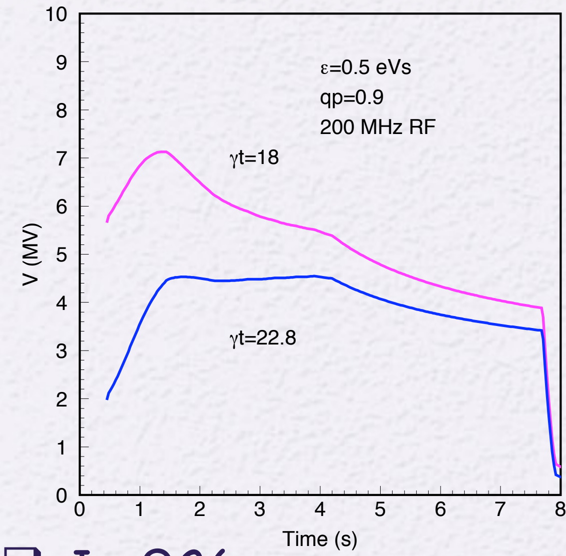


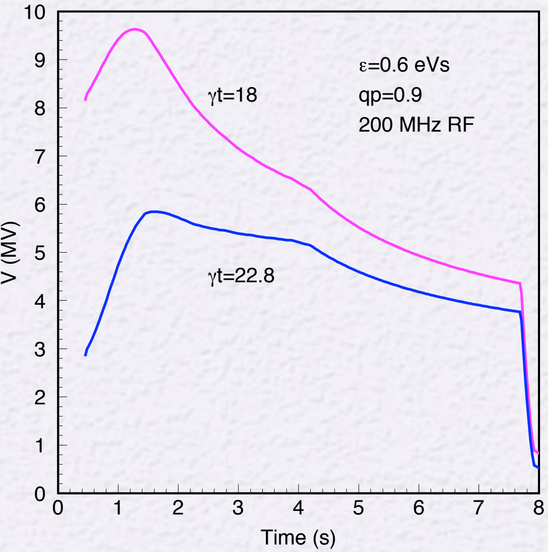




- Extraction (long flat bottom + slow ramp)
  - For Q20, emittance of 2.4μm for 3e11 p/b with <10% losses
    - Mostly injection and capture
    - 20% of bunch length increase
  - For Q26?

Longitudinal emittance





RF-voltage scaled with slippage factor

RF-voltage programs for the 200 MHz cavities and a constant filling factor in momentum (0.9) for different emittances

E. Shaposhnikova

- In Q26
  - Longitudinal emittance blow-up (injection and middle of the ramp) needed for beam stability
  - Maximum RF-voltage (7.5 MV) used now for extraction to LHC (bunch shortening)
  - SPS RF upgrade
- In Q20
  - Emittance blow-up may not be needed
  - For same stability, maximum available voltage @ extraction and given bunch length, longitudinal emittance smaller compared to nominal optics
    - Beam stability issues due to small longitudinal emittance in LHC
    - 200MHz system in the LHC?
    - 400MHz system in the SPS (space, impedance?)

To be checked in MDs

Alternative optics

- Working point with intermediate integer tune e.g. 22
  - Transition energy of 20, i.e. slippage factor increase of 1.9 @ injection and 1.3 @ extraction
  - Non-zero dispersion in straight sections (max of 2m)
    - Problem with injection/extraction?
  - Resonances?
- Manipulate transition at extraction
  - Quadrupole magnet strengths?
  - Additional power convertors
  - Optics distortion?