# pros and cons of 75-ns period of operation

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# pros of 75 ns vs. 25 ns operation

- reduced long-range beam-beam effect, scaling as $\propto \sqrt{N_b n_b} \propto \sqrt{L / N_b}$ (constant L) → *slide*
- ~2 times lower initial transverse emittance → much more tolerant to emittance blow-up
- provides an easier intermediate step in the total intensity without reducing enormously the bunch intensity or batch number (it might be difficult to reduce the bunch intensity much below 0.2-0.3×$10^{11}$ p/bunch).
- instrumentation: for precision bunch intensity counts as compared to total beam population

# pros of 75 ns vs 25 ns operation – cont’d

- avoids electron-cloud related problems (pressure rise, poor lifetime, instabilities, heat load) → *slides*
- scrubbing performed at beam-screen region relevant for nominal LHC conditions
- highest possible luminosity if beam current is limited
- with 25-ns bunch spacing $10^{32}$ $cm^{-2}s^{-1}$ luminosity operation might have implications for collimation

# cons of 75 ns vs. 25 ns operation

- larger number of pile-up events: $\propto \sqrt{\mathrm{N_b}} \propto \sqrt{\mathrm{L/n_b}}$
- additional step on the way to nominal LHC
- more charge per bunch might lead to single bunch instabilities
- more emittance growth from IBS $\frac{1}{\tau_{IBS}} \propto \frac{N_b}{\varepsilon_\perp^2}$
- if there is an electron-cloud problem at 25-ns spacing, we will discover it later

illustrating material

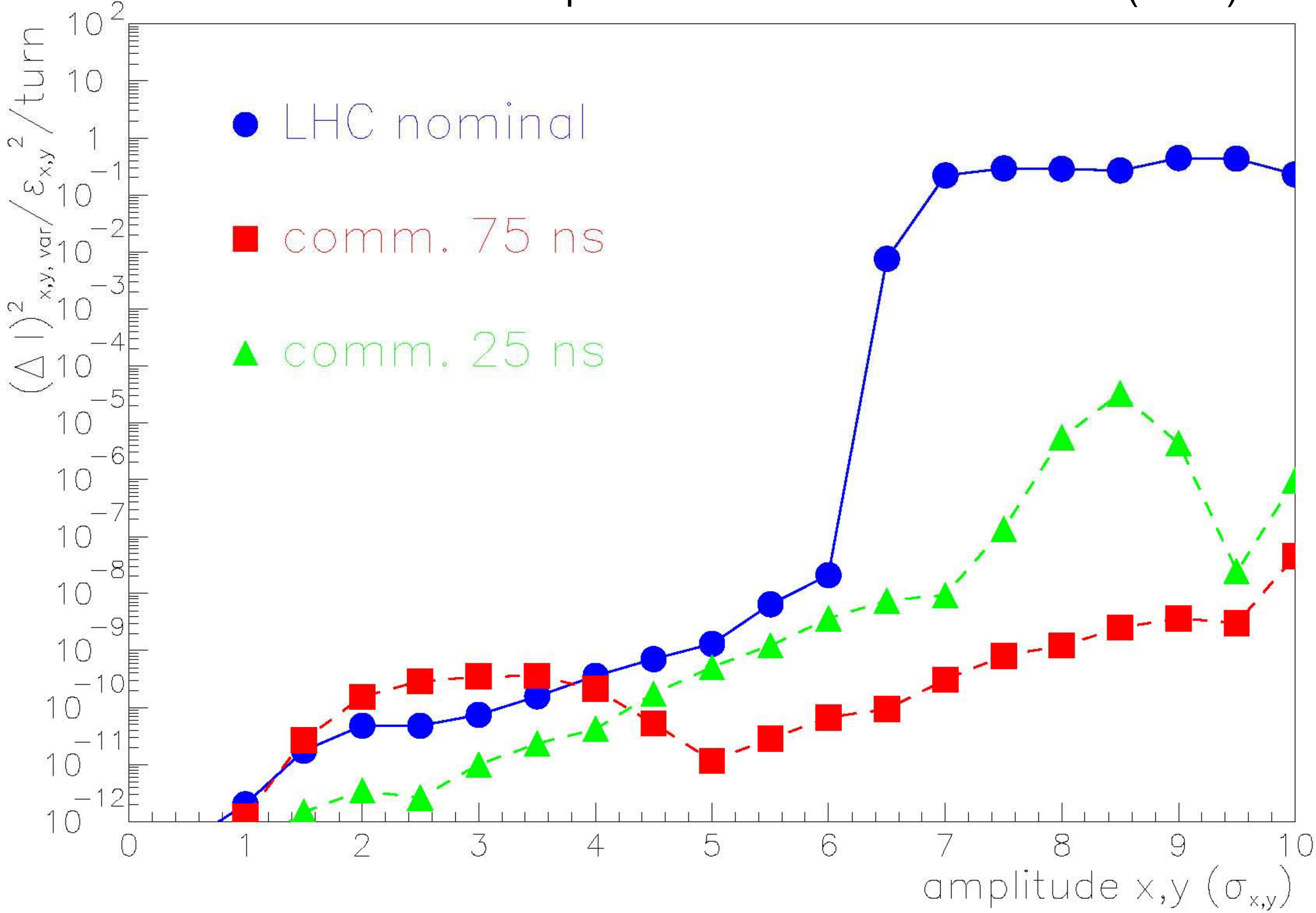
# crossing angle, IBS rise time, event pile up:

Table from Francesco Ruggiero, Chamonix 2003

| parameter | symbol | units | 75 ns spacing | 25 ns spacing | revised nominal |
|---|---|---|---|---|---|
| number of bunches | $n_b$ | | 936 | 2808 | 2808 |
| protons per bunch | $N_b$ | $10^{11}$ | 0.9 | 0.4 | 1.15 |
| average beam current | $I_{av}$ | A | 0.15 | 0.20 | 0.58 |
| normalised transv. emittance | $\varepsilon_n$ | $\mu$m | 3.75 | 3.75 | 3.75 |
| longitudinal emittance | $\varepsilon_L$ | eV s | 2.5 | 2.5 | 2.5 |
| peak RF voltage | $V_{RF}$ | MV | 16 | 16 | 16 |
| r.m.s. bunch length | $\sigma_z$ | cm | 7.55 | 7.55 | 7.55 |
| r.m.s. energy spread | $\sigma_E$ | $10^{-4}$ | 1.13 | 1.13 | 1.13 |
| beta at IP1-IP5 | $\beta^*$ | m | 1.0 | 0.55 | 0.55 |
| full crossing angle | $\theta_c$ | $\mu$rad | 250 | 285 | 285 |
| diffusive aperture | $d_{da}$ | $\sigma$ | 10.0 | 7.5 | 6.2 |
| IBS long. emitt. growth time | $\tau_z^{IBS}$ | h | 80 | 180 | 62 |
| IBS hor. emitt. growth time | $\tau_x^{IBS}$ | h | 135 | 304 | 106 |
| lumi lifetime (only IP1-IP5 coll.) | $\tau_{LN} = \frac{\tau_N}{1.54}$ | h | 56 | 75 | 26 |
| total luminosity lifetime | $\tau_L$ | h | 22 | 26 | 15 |
| peak luminosity at IP1-IP5 | $L$ | $10^{34}$ cm$^{-2}$ s$^{-1}$ | 0.12 | 0.12 | 1.0 |
| events/crossing | | | 7.1 | 2.3 | 19.2 |
| integrated lumi over 200 fills | $L_{int}$ | fb$^{-1}$ | 9.3 | 9.5 | 66.2 |

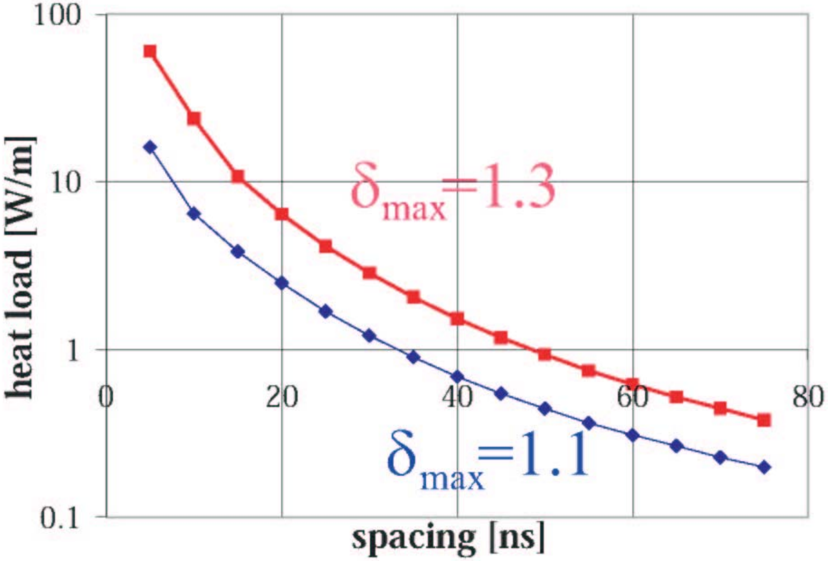
# long-range beam-beam:

diffusion rate vs. amplitude from WSDIFF simulation (2002)

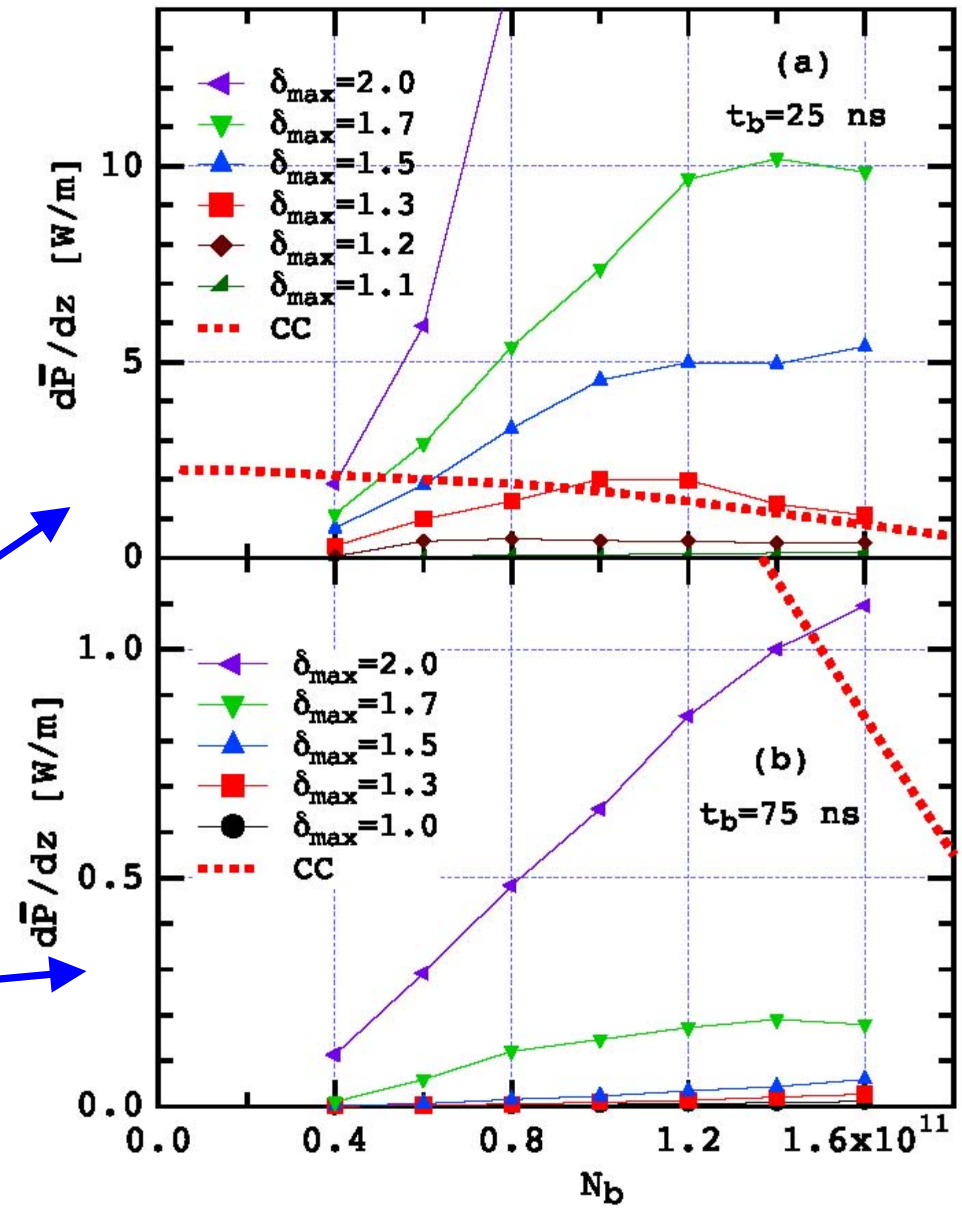


# e- cloud: simulated heat load vs. bunch spacing

2004 simulation




M. Furman & V. Chaplin, 2005




heat load at 25 ns & $N_b$=4x10[10] is >10 times larger than at 75 ns spacing and $N_b$=9x10[10]

# e- cloud: 25-ns & 75-ns spacing in the SPS (Miguel Jimenez)

## Comparison between 25 and 75 ns bunch spacing in dipole field regions (2003 SPS run):

- Smaller pressure rises ⇨ factor 4
- Smaller electron flux to the walls ⇨ factor 20 measured in a dipole field @ 30 K
- ☞ **Multipacting is still present with 75 ns bunch spacing but at a much lower level**

| | **Bunch spacing** | |
|---|---|---|
| | **25 ns** | **75 ns** |
| | **by a factor** | |
| **Pressure increase** | 12 | 3 |
| **Electron cloud activity at 30K** | **Activity in A/m** | |
| In field free conditions | $2.2\times10^{-4}$ | no signal |
| In dipole field conditions | $7.6\times10^{-4}$ | $3.8\times10^{-5}$ |
| **Electron cloud activity (A/m) at RT** | **Activity in A/m** | |
| In field free conditions | $7.0\times10^{-5}$ | no signal |
| In dipole field conditions | $1.1\times10^{-3}$ | no signal |
| | detection limit $10^{-6}$ A/m | |