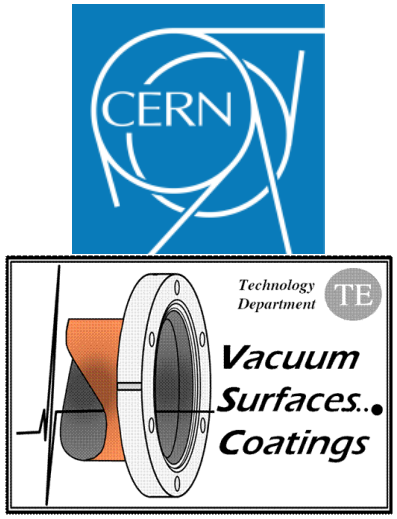


Electron Cloud and 25 ns : Vacuum and Synchrotron Radiation

V. Baglin

CERN TE-VSC, Geneva

1. Vacuum system design
2. Electron cloud at 25 ns
3. Synchrotron radiation
4. Conclusions

LHC Vacuum System Design

LHC design report CERN-2004-003 : ARCS and Stand Alone Magnets

- Overall budget :

  100 h beam life time is required *i.e.* 2 10^{15} H_2/m^3 and ~ 50 mW/m dissipated in cold mass for a loss of 6 10^4 protons/m/s at 3.5 TeV/beam.

  Pressure ~ 2 10^{-9} mbar N_2 equivalent.

  Today (fill 1852, 1092 b) : vacuum life time > 15 000 h *i.e.* P < 10^{-11} mbar N_2 equivalent [LMC 97]

- Local budget :

  Vacuum level below quench limit *i.e.* a local proton loss rate of ~ 2 10^7 p/m/s at 3.5 TeV dissipating ~ 9 W/m in the cold mass.

  Pressure ~ 5 10^{-7} mbar N_2 equivalent.

  → Interlock level should stay in the 10^{-7} mbar range

LHC project report 674, 783 : Long Straight Sections

- After vacuum conditioning

- Estimated performances in LSS1,2,5 and 8 :

  Average gas density ~10^{13} H_2/m^3.

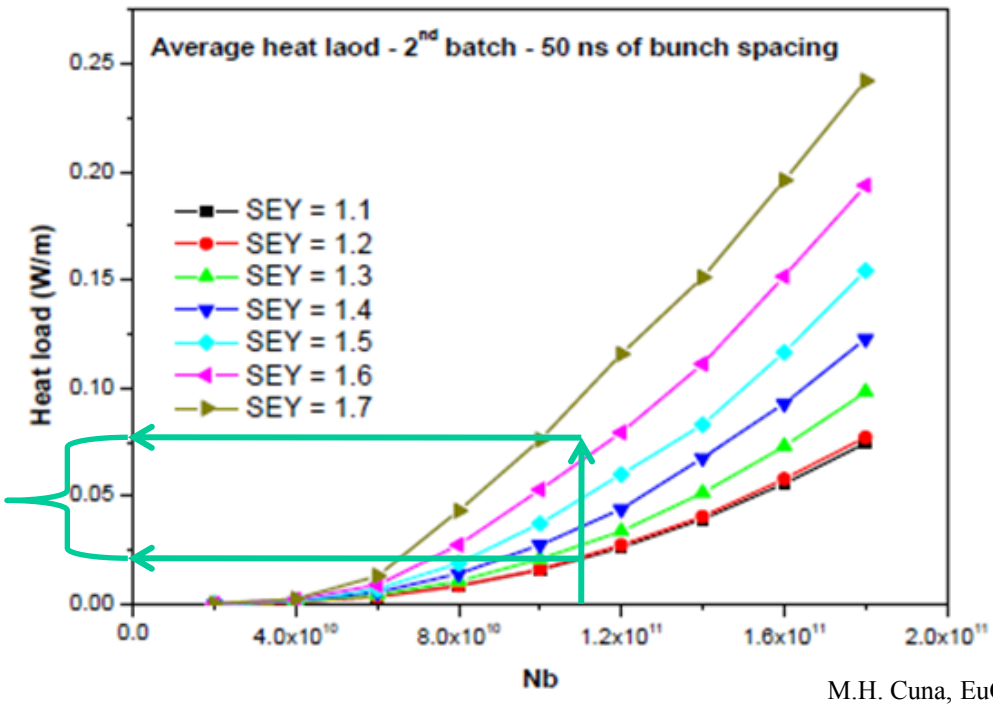
  Pressure ~ 5 10^{-11} mbar N_2 equivalent.

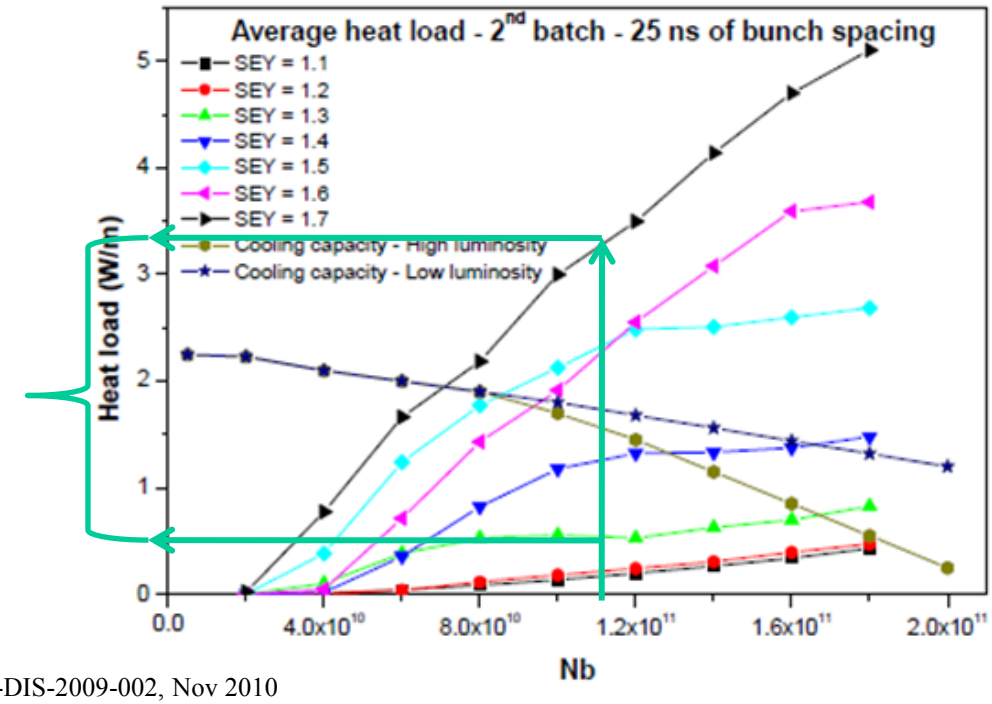
- Estimated performances in ATLAS and CMS :

  Average gas density ~ 3 10^{11} H_2/m^3.

  Pressure ~ 10^{-12} mbar N_2 equivalent.

What is expected at 25 ns ?





M.H. Cuna, EuCARD-DIS-2009-002, Nov 2010

- Heat load in the arcs !!!
- 50 ns : a few tens of mW/m
- 25 ns : some hundreds of mW/m

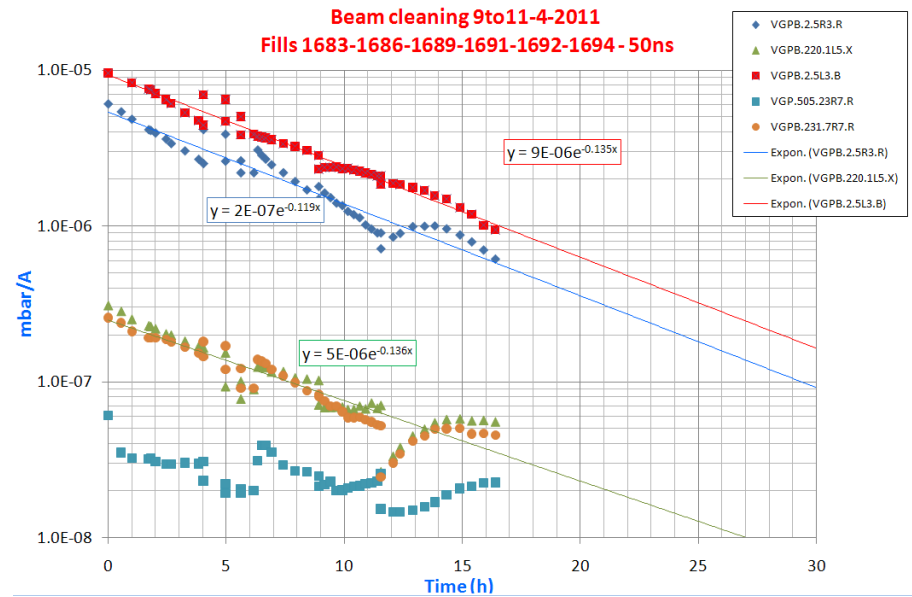
- Pressures increase !!!

$$P = \frac{Q + \eta_{Electrons}\,\dot{\Gamma}_{Electrons}}{S}$$

- Function of beam conditioning and effective pumping speed

Beam Conditioning at 50 ns

- Scrubbing run at 450 GeV,
- We reached 1020 b in both beams
- We gained one order of magnitude in 15 h
- We kept constant cleaning during the period



E-cloud activity in cold arcs

- Heat load increased up to 80 mW/m with 588 b
- Disappeared with beam conditioning
- Run 6 with 804 b :
  equivalent heat load of 60 mW/m with 1380 b
- Sensitivity ~ 20 mW/m
- From Cuna's simulations :

$$1.2 < \delta < 1.6$$

Run	Beam intensity	# bunches	E-cloud peak
	[10^{13}p]	[-]	[mW/m per aperture]
1	3.3	300	25
2	4.7	408	10
3	4.4-3.5	372-300	35
4	5.0-4.1	408-336	No visible
5	7.3	588	80
6	9.3	804	35
7	9.0	804	No visible
8	12.5	1020	No visible

L. Tavian, LBOC, 12/4/2011

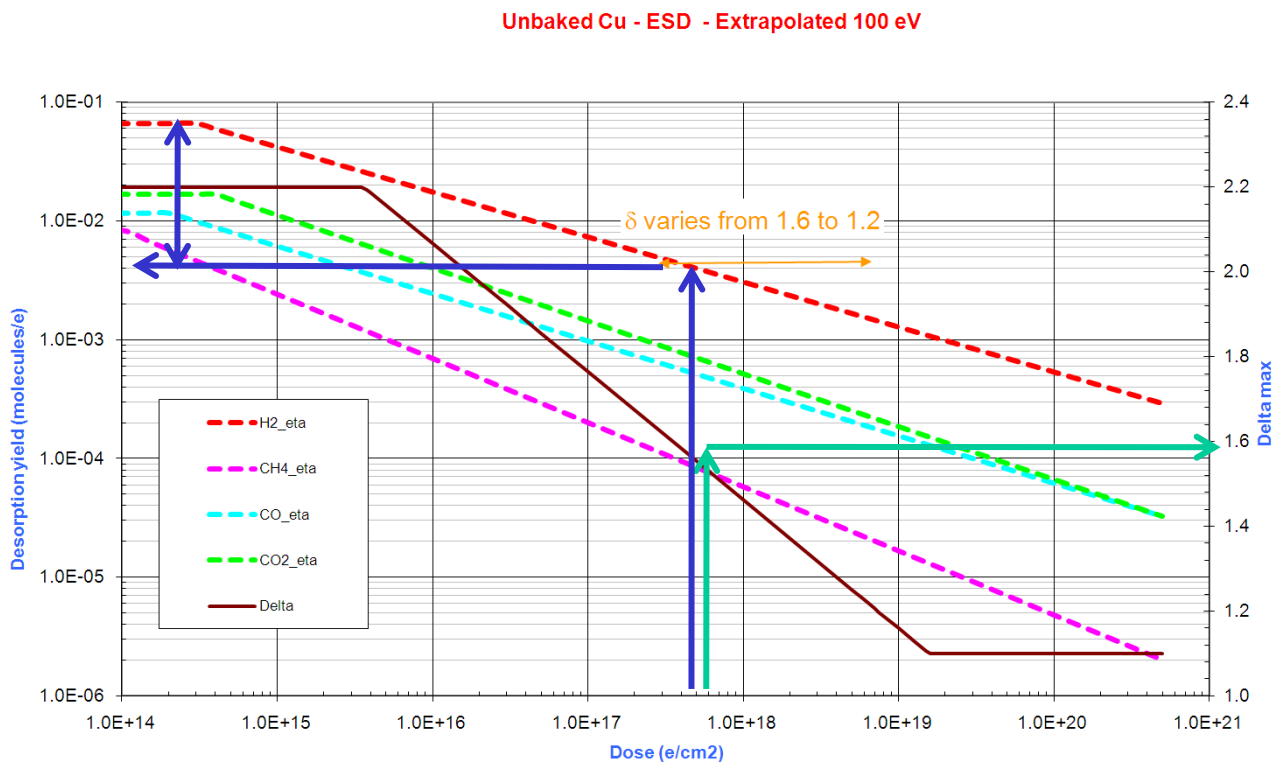
Comparison of previous achievements with rough estimations ?

- Assuming 20 mW/m (10^{15} e/m/s or 2 10^{16} e/cm^2/h) during 15 h
- We have accumulated ~ 5 10^{17} e/cm^2 during the scrubbing week

→ Good agreement of observations with simple estimations

→ We have to increase the electron flux by one order of magnitude to scrub faster (target 10^{18} e/cm^2 range)
Significant heat load should be expected in the arcs

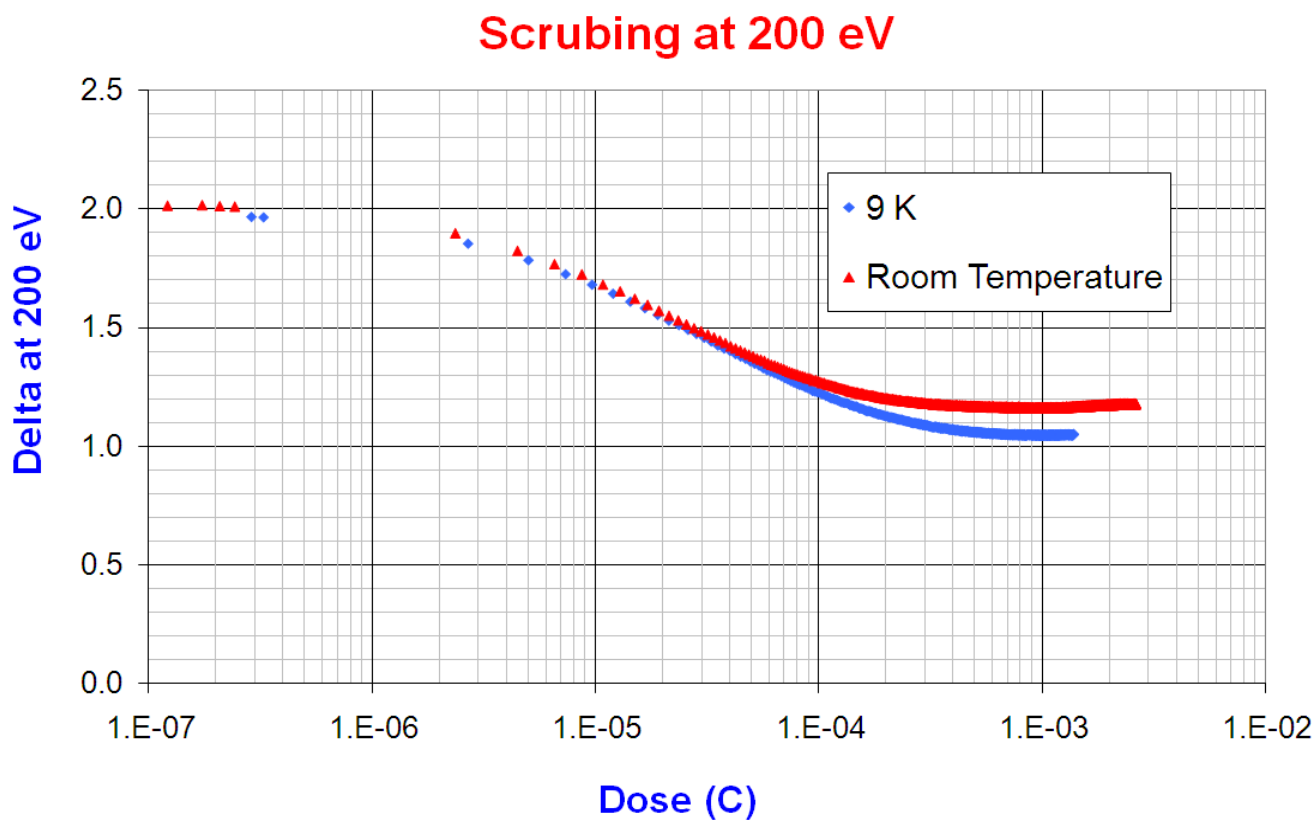
One order of magnitude in pressure



δ ~ 1.6

Reminder: Cryogenic areas

- Unbaked by design
- Beam screen's hole provide pumping speed
- Primary and recycling desorption yields : $\eta'_{monolayer} >> \eta$
- Beam screen's surface coverage should stay below a monolayer : minimize the accumulation of gas on the BS
- Scrubbing rate at cryogenic temperature of a **bare surface** is similar to RT



$$P_{cryo} = \frac{\eta_{Electrons} \dot{\Gamma}_{Electrons,}}{c}$$

Vacuum expectations at 25 ns

- Assuming operation with 10 time more electron flux, the pressure increase will be at least ten times more
- Highest pressures during fill 1901 (28th of June with1308 b per beam) are ~ 5 10^{-8} mbar
- So, the number of accumulated bunch will still be limited by interlock levels : 4 10^{-7} to 2 10^{-6} mbar

- Last MD of 29th of June with 25 ns :
  228 bunches accumulated with 24 b per batch
  no pressure increase larger than 5 10^{-10} mbar / batch was observed in single beam pipe
  Pressure increase of ~ 2 10^{-9} mbar / batch was observed in experimental beam pipe
- Fill 1901 : A pressure increase of 5 10^{-9} mbar / 144b is observed

→ A pressure increase of at least 10^{-8} mbar / 144b should be expected with 25 ns

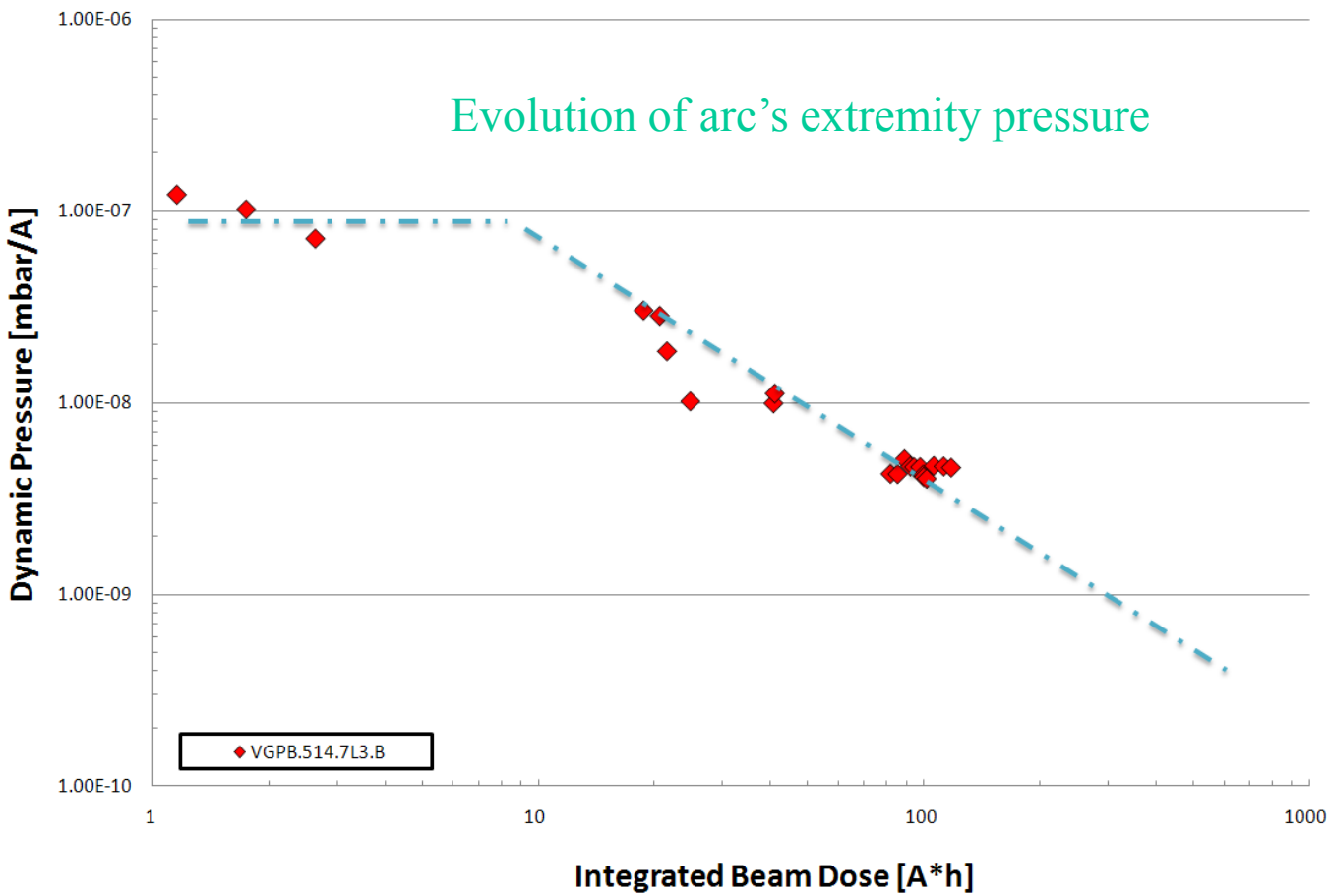
Interlock levels will need to be temporarily raised in the 10^{-6} mbar range to allow accumulation of batches

What is expected with Synchrotron Radiation ?

- More photon flux : from 2.5 10^{16} ph/m/s today to 5 10^{16} ph/m/s with nominal current (2804 bunches)
- But same critical energy (5.5 eV)

$$\dot{\Gamma} \propto \frac{E}{\rho} I \propto B\, I$$

- Pressure increase : twice the one of today *i.e.* 2 x 1.5 10^{-9} mbar
- Still conditioning but it is a log scale !



Conclusions

- Estimation of the current vacuum conditioning state of the machine seems to be in good agreement with observations

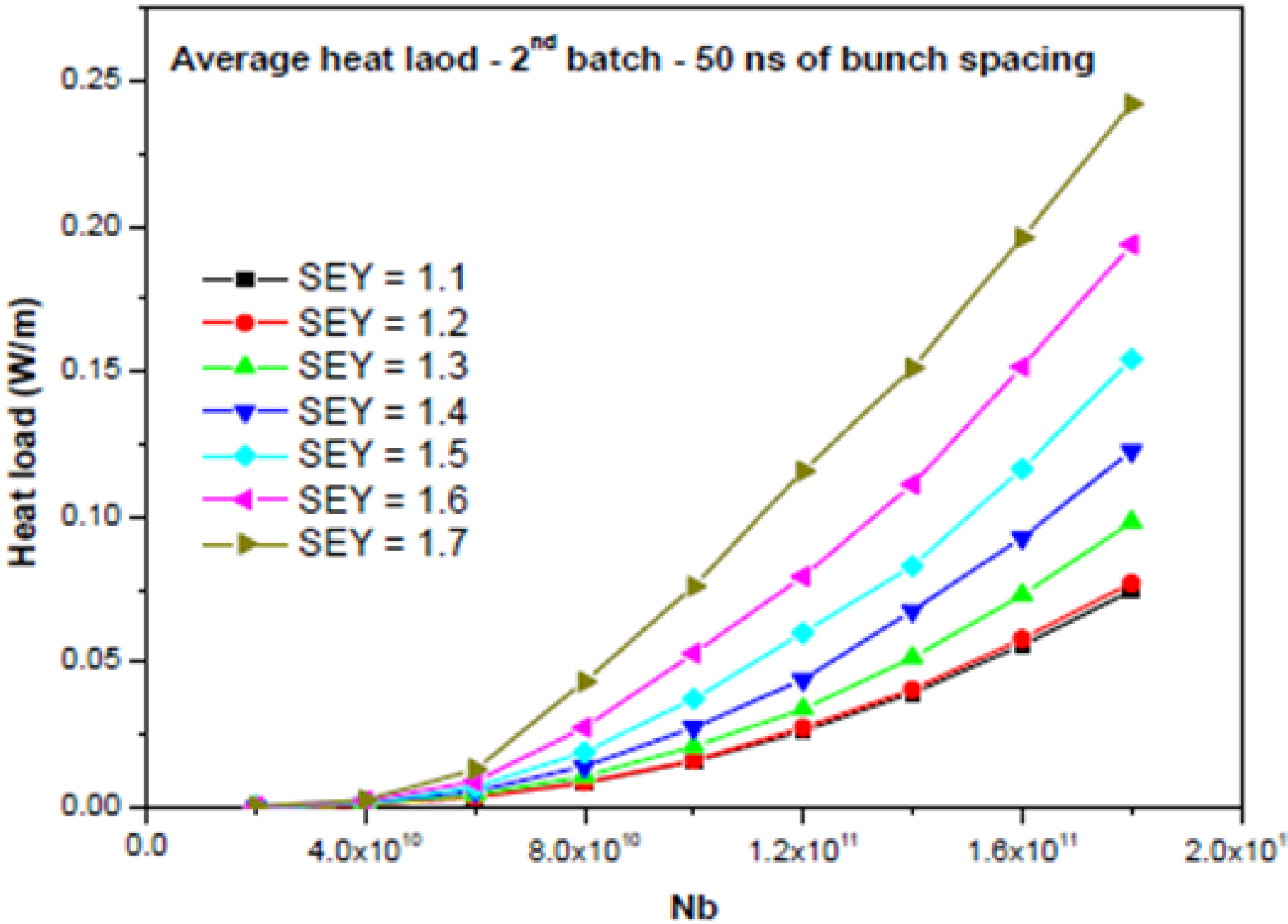
- Operation with 25 ns will lead to pressure increases of at least 10^{-8} mbar / 144b

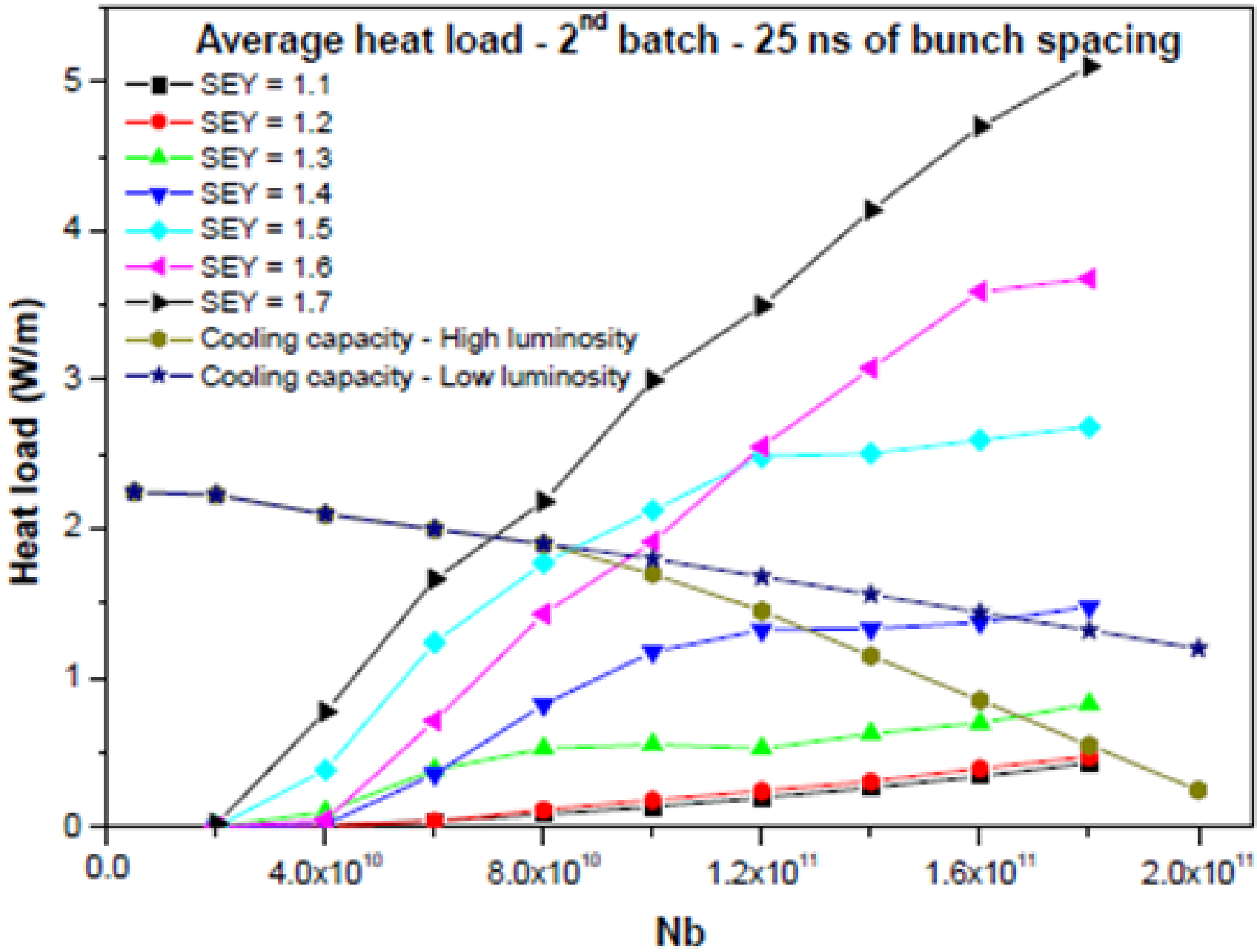
- Increase of interlock levels will be required during scrubbing

- At nominal intensity, once multipacting will be reduced thanks to scrubbing, pressure increase due to synchrotron radiation will be less than 5 10^{-9} mbar

- Future MD's with 25 ns bunch spacing with more bunches per batch to accumulate more than few hundred bunches will be of great importance to further estimate the behaviour of the beam vacuum system

Thank you for your attention !!!


Average heat laod - 2nd batch - 50 ns of bunch spacing
Heat load (W/m)
0.25
0.20
0.15
0.10
0.05
0.00
SEY = 1.1
SEY = 1.2
SEY = 1.3
SEY = 1.4
SEY = 1.5
SEY = 1.6
SEY = 1.7
0.0
4.0x10^10
8.0x10^10
1.2x10^11
1.6x10^11
2.0x10^11
Nb


Average heat load - 2nd batch - 25 ns of bunch spacing
SEY = 1.1
SEY = 1.2
SEY = 1.3
SEY = 1.4
SEY = 1.5
SEY = 1.6
SEY = 1.7
Cooling capacity - High luminosity
Cooling capacity - Low luminosity
Heat load (W/m)
0
1
2
3
4
5
0.0
4.0x10^10
8.0x10^10
1.2x10^11
1.6x10^11
2.0x10^11
Nb