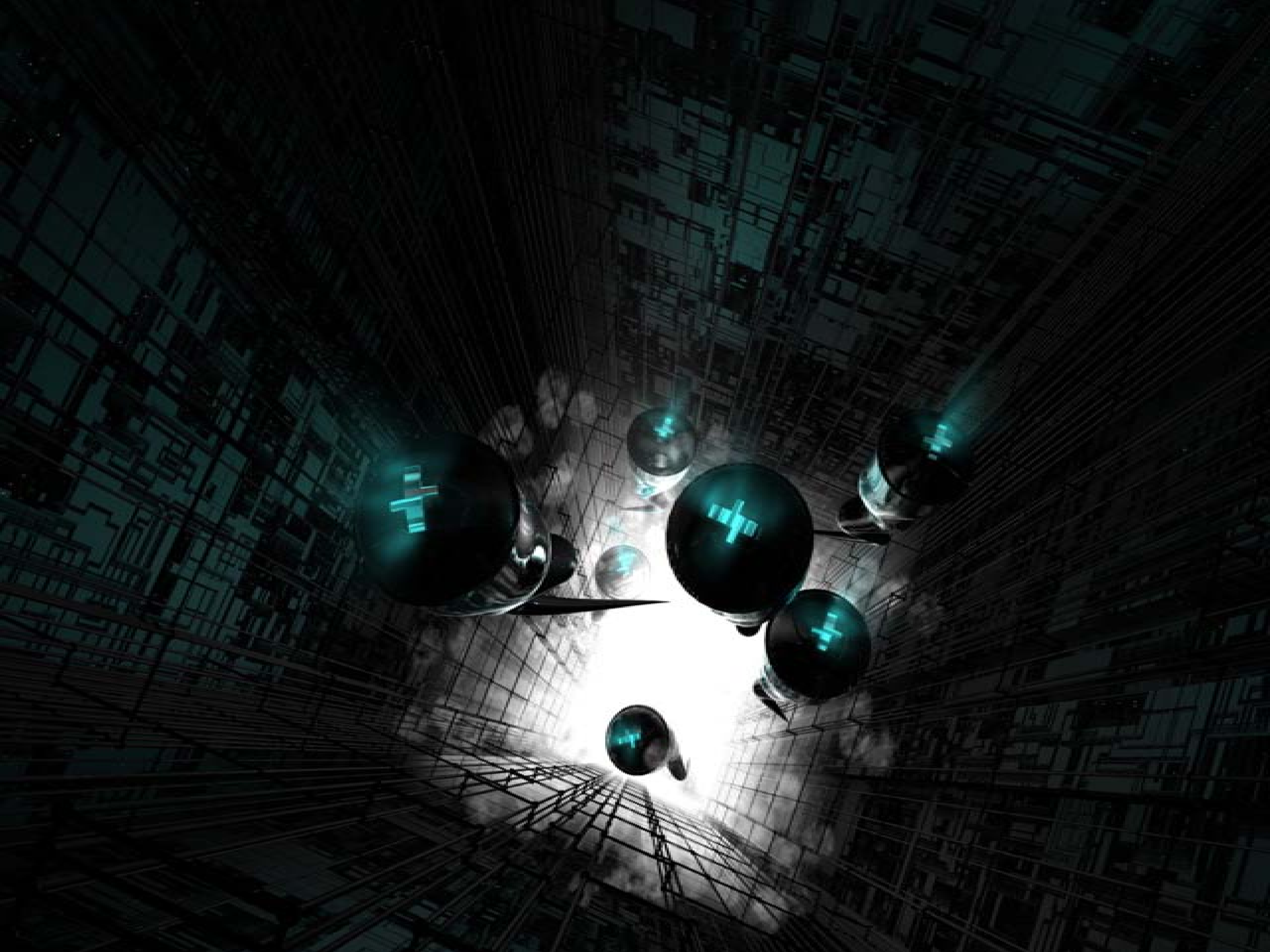

European Organization for Nuclear Research

CINVESTAV – Merida Campus

LCU Meeting

# *Study of the Heat Load in the LHC*

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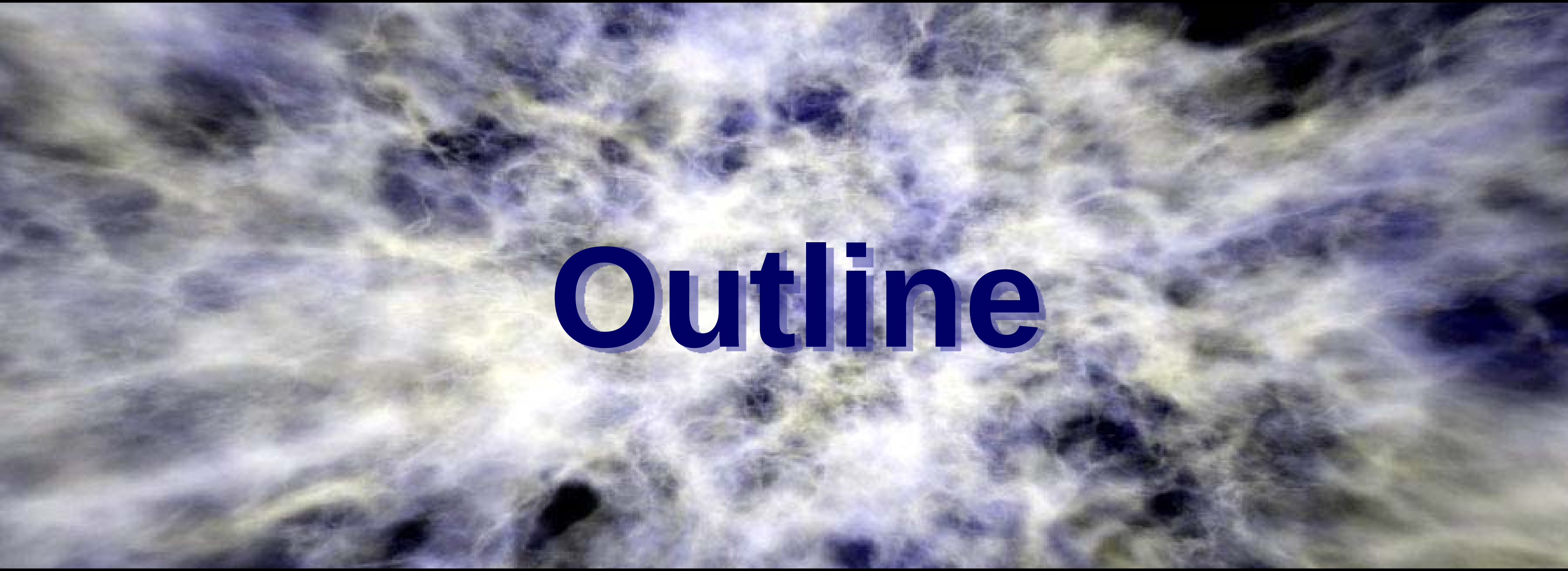
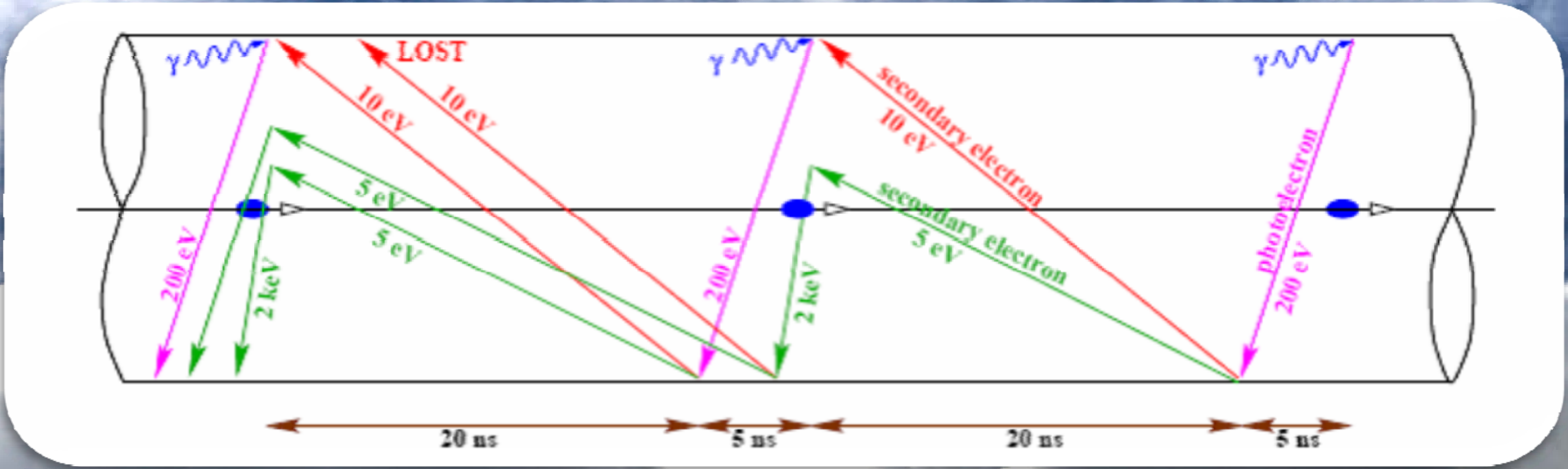
# Outline



# Introduction

# Electron Cloud Build-up

The synchrotron radiation in the LHC creates a continuous flow of photo-electrons. These electrons are accelerated by the electric field of the bunch and hit the vacuum chamber where they create secondary electrons.




Photoemission, residual gas ionization and secondary emission give rise to a quasi-stationary electron cloud inside the beam pipe !!!

# Electron cloud effects:

Due to e- induced gas desorption from the walls of the beam screen the vacuum pressure is increased by several orders of magnitude.

The electrons near the center of the vacuum chamber are attracted by the electric field of the beam and accumulate ("pinch") inside the proton beam during a bunch passage. They can cause beam instabilities, emittance growth, even beam loss, and poor lifetime.

The energetic electrons heat the surfaces that they impact. Only a limited cooling capacity is available for the additional heat load due to the electron cloud.

# Simulation code:

# ECloud

# ECloud simulates the build up of the electron cloud.

- The ECLOUD simulation includes the electric field of the beam, arbitrary magnetic fields, the electron space charge field, and image charges.

- As input numbers, the code requires various beam parameters, surface properties: secondary emission yield (SEY), the vacuum chamber geometry and the type of magnetic field.

# Methodology

# We made 4 sets of simulations:

| Set A “LPA Satellite Scenario” | |
|---|---|
| **SEY** | **Bunch spacing** |
| 1.1 - 1.7 | 50 ns |
| **Nb:** $1 \times 10^{11} – 5 \times 10^{11}$ | |
| **Bunch Profile: Flat** | |

| Set B “LPA Nominal” | |
|---|---|
| **SEY** | **Bunch spacing** |
| 1.1 - 1.7 | 50 ns |
| **Nb:** $1 \times 10^{11} – 5 \times 10^{11}$ | |
| **Bunch Profile: Flat** | |

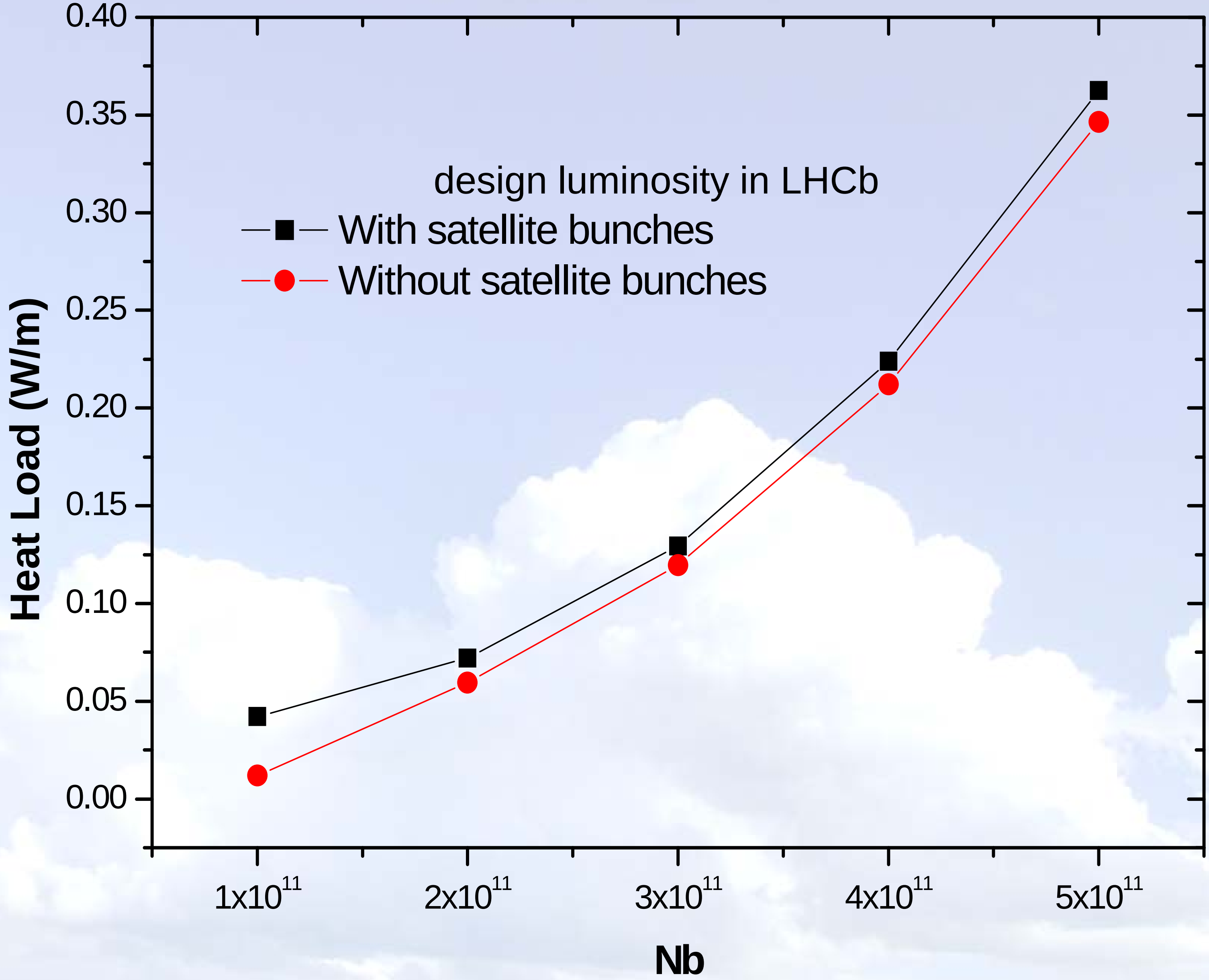
| Set C “Scan Buch Spacing” | |
|---|---|
| **SEY** | **Bunch spacing** |
| 1.1 - 1.7 | 5ns - 50 ns |
| **Nb:** $6 \times 10^{10} – 2.3 \times 10^{11}$ | |
| **Bunch Profile: Flat** | |

| Set D “Scan Buch Spacing” | |
|---|---|
| **SEY** | **Bunch spacing** |
| 1.1 - 1.7 | 5ns - 50 ns |
| **Nb:** $6 \times 10^{10} – 2.3 \times 10^{11}$ | |
| **Bunch Profile: Gaussian** | |

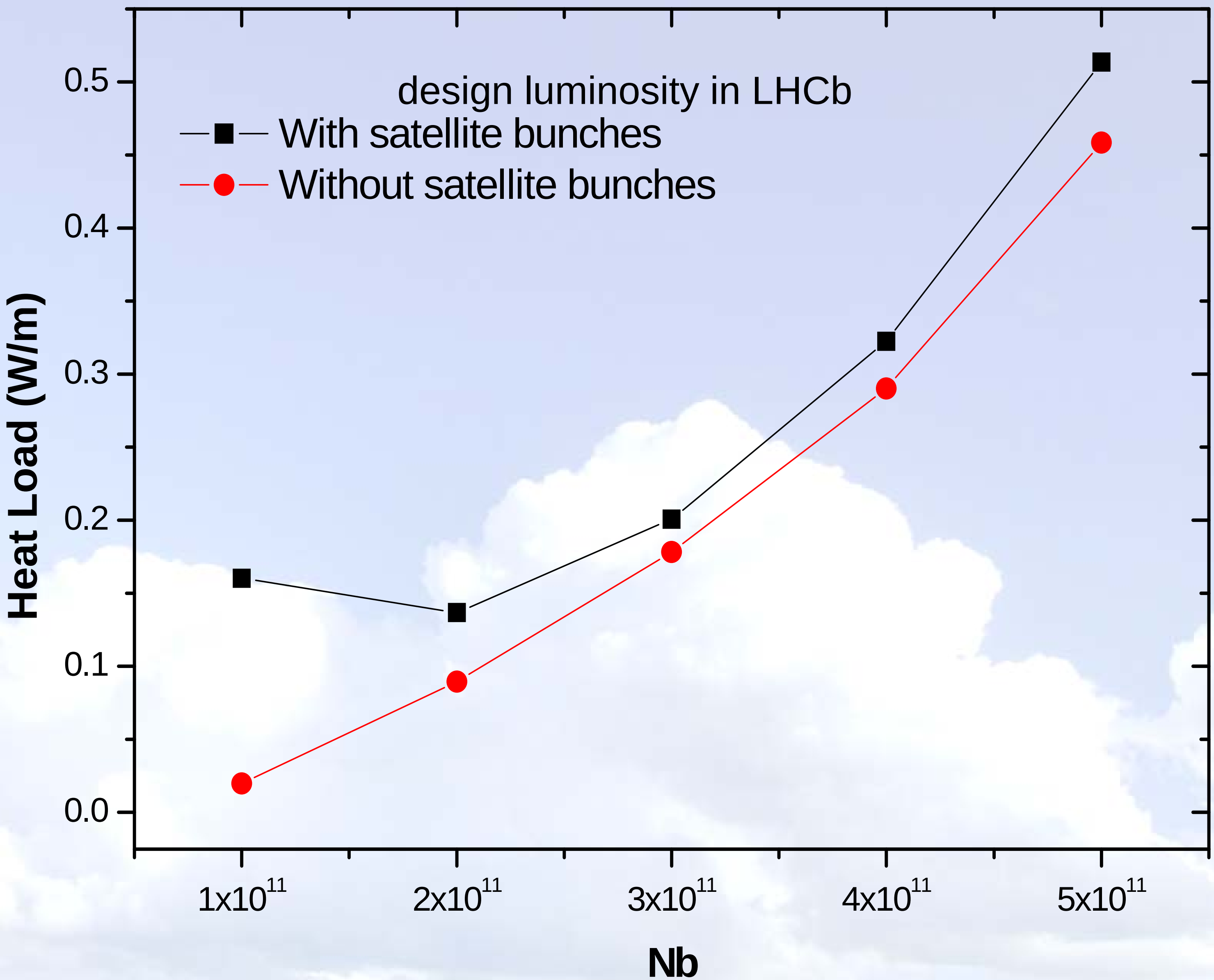
# Results

# I. Satellite Scenario Results

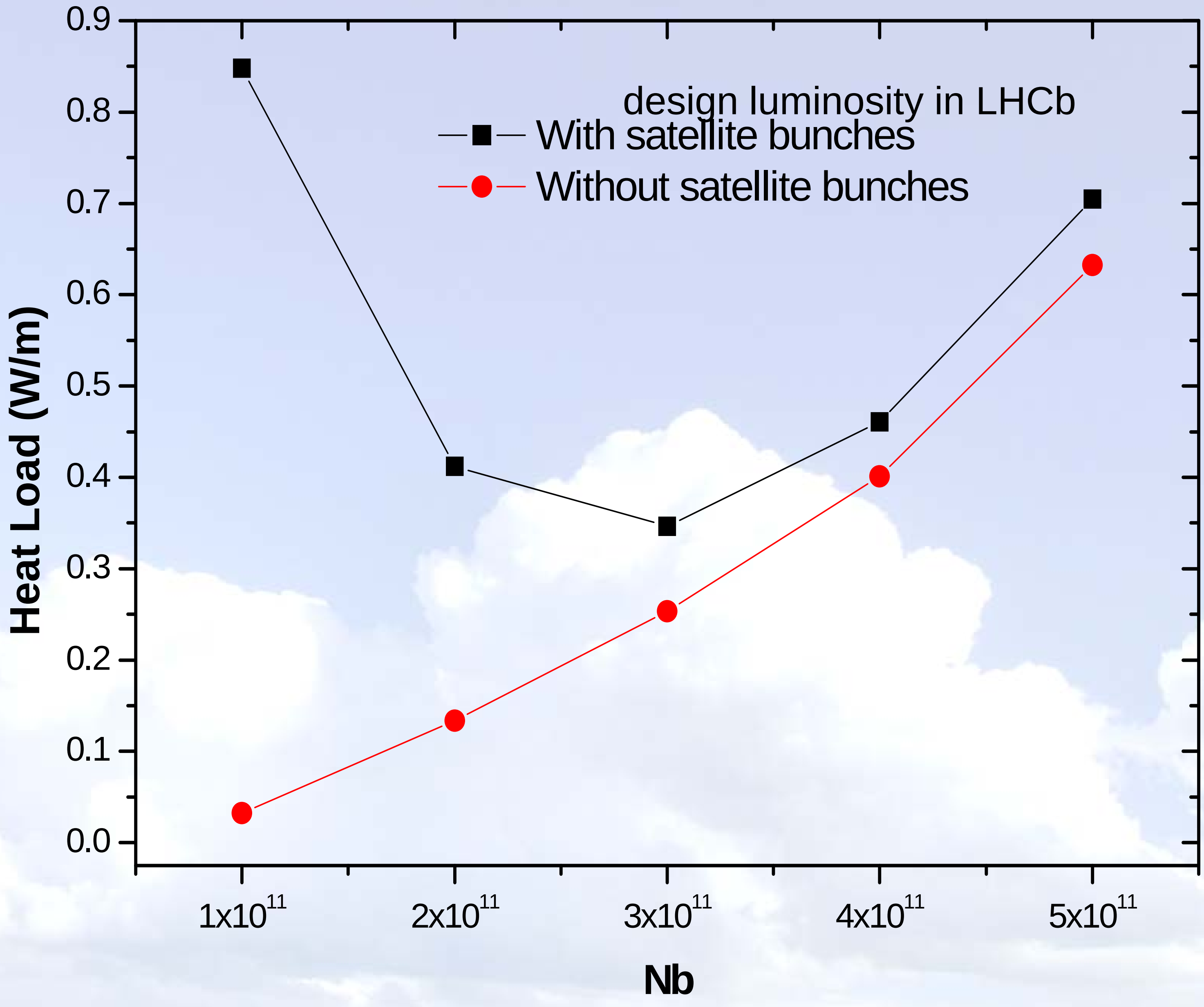
## Average Heat Load - 1st Batch - SEY = 1.1



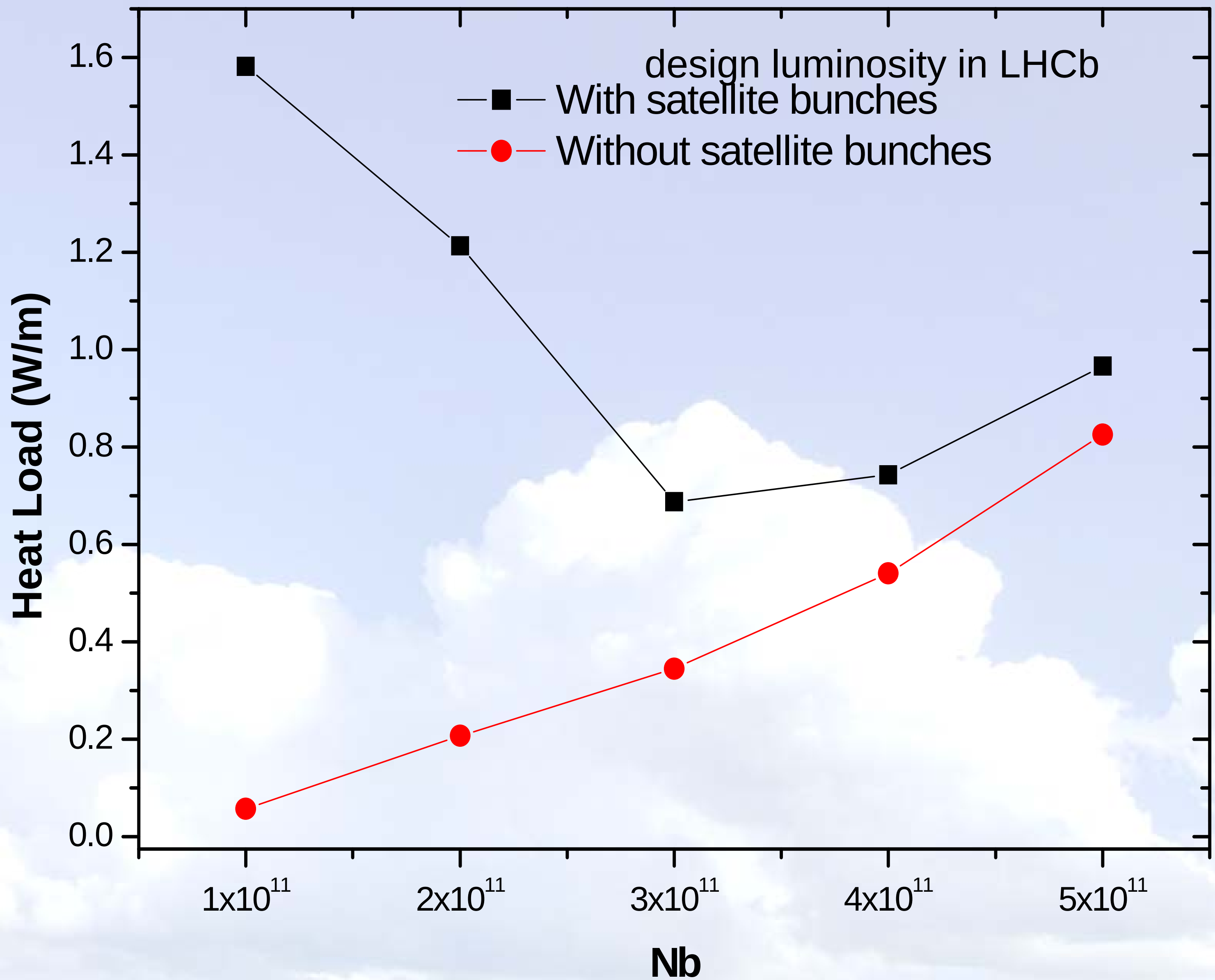
# Average Heat Load - 1st Batch - SEY = 1.3



# Average Heat Load - 1st Batch - SEY = 1.5

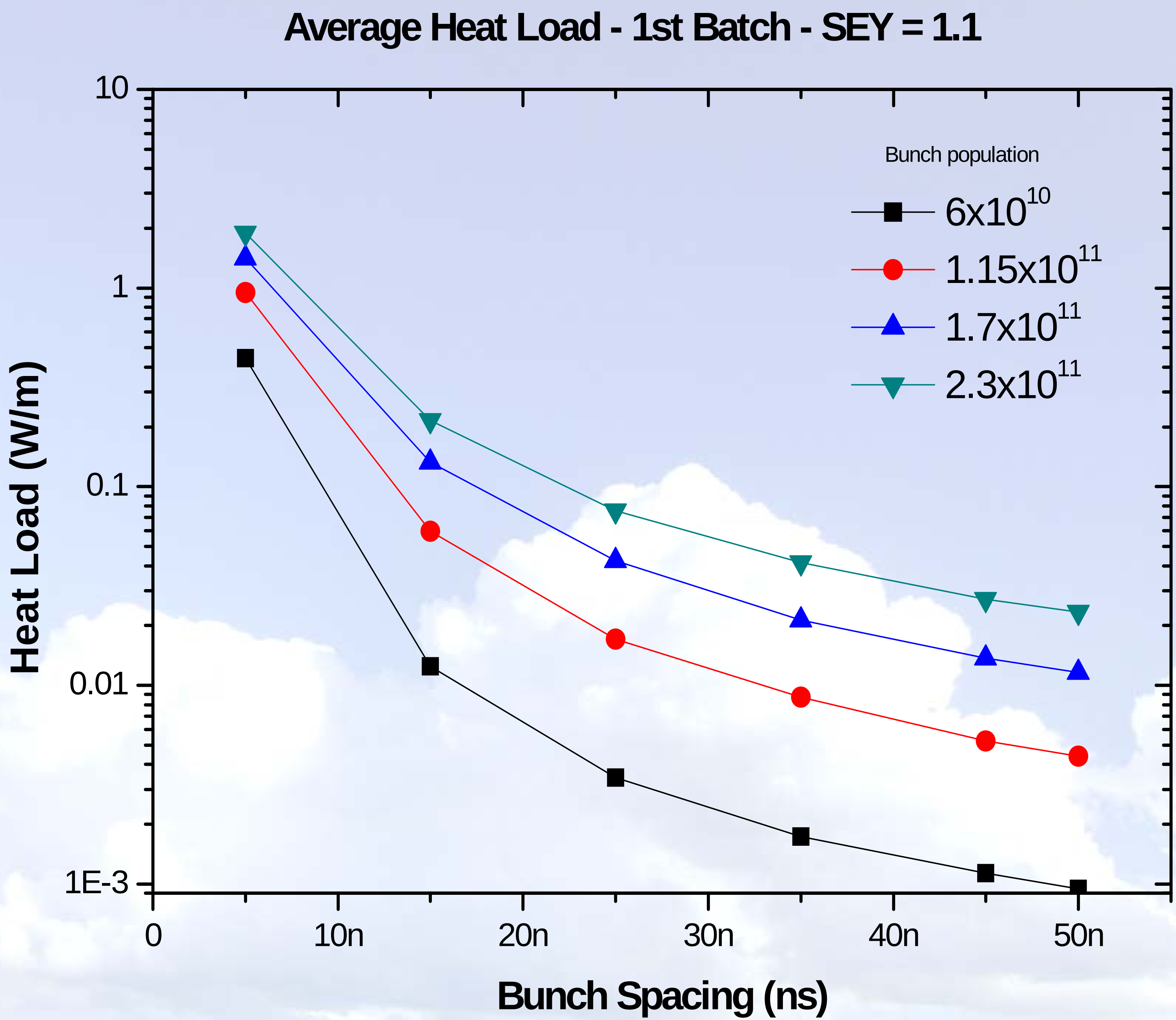


# Average Heat Load - 1st Batch - SEY = 1.7



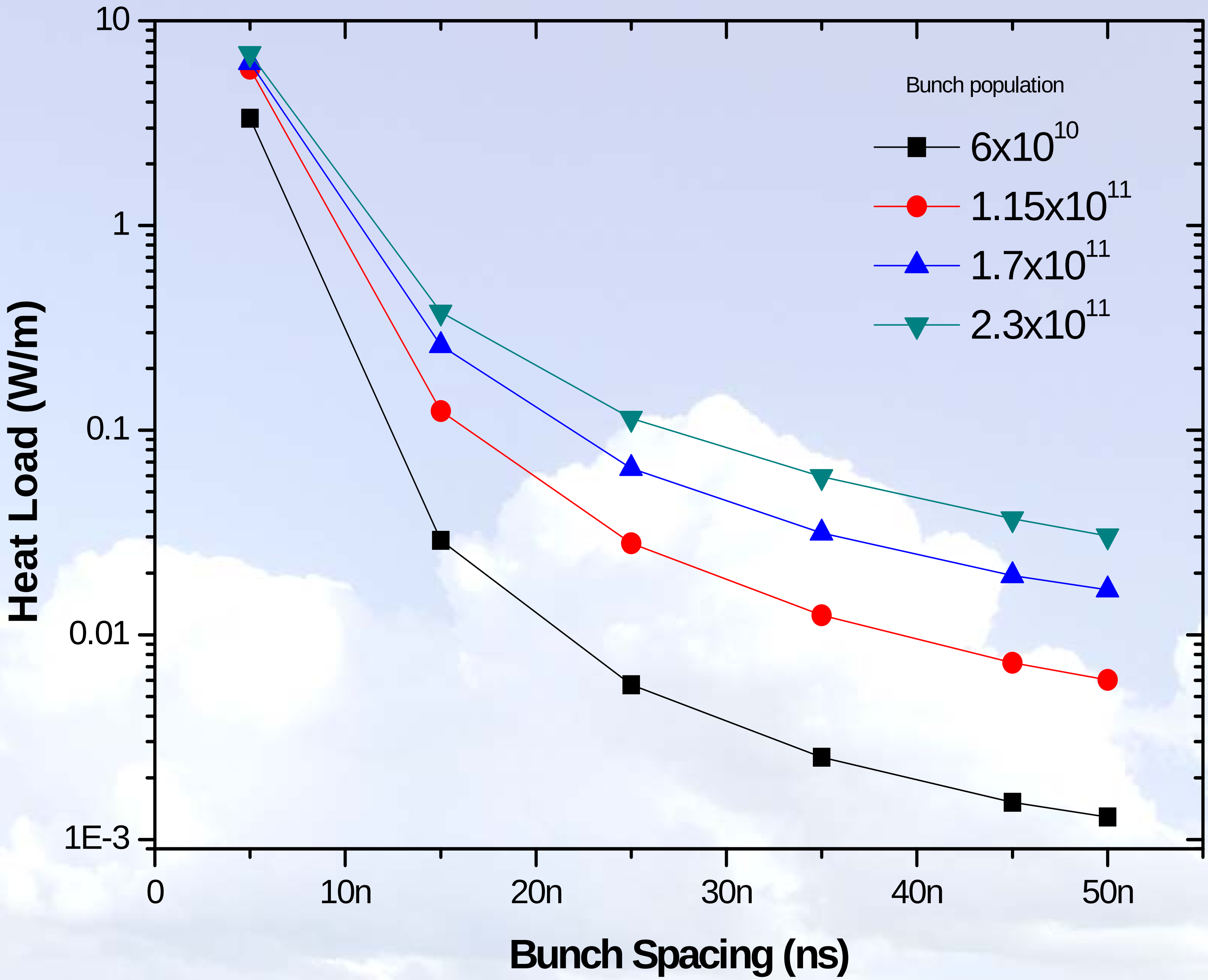
# II. Scan of Bunch Spacing

## - Flat Bunch Profile -

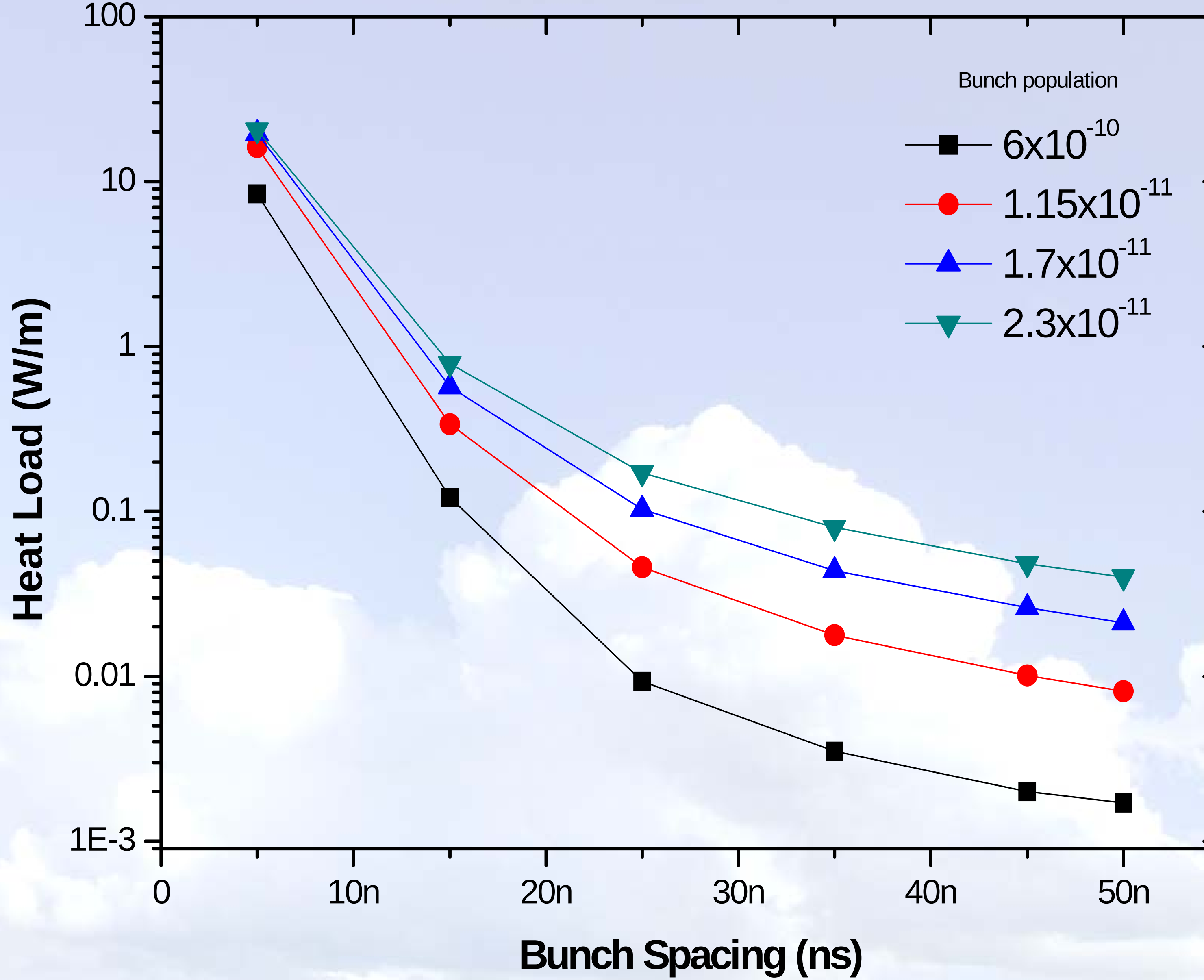


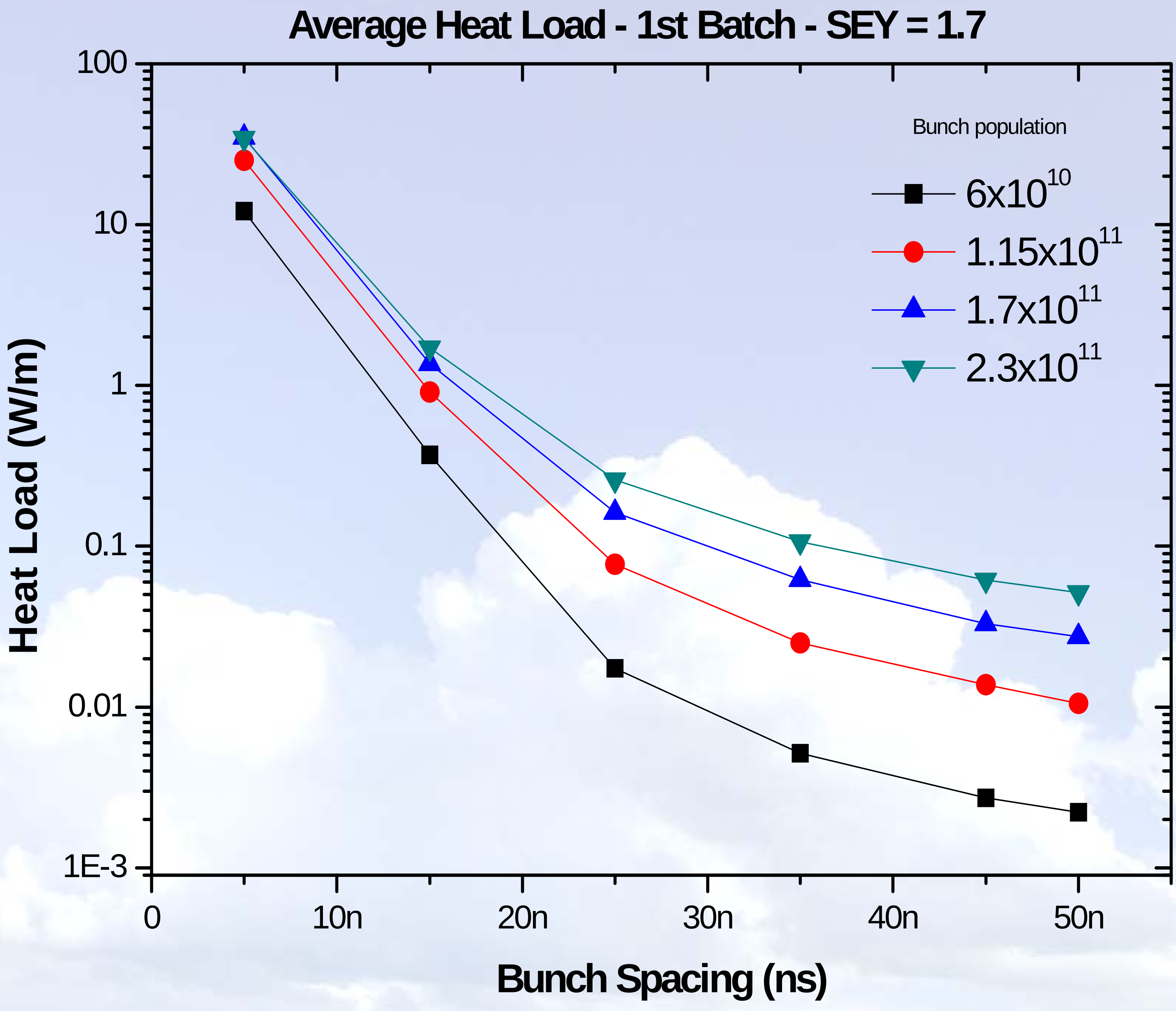
Average Heat Load - 1st Batch - SEY = 1.1
Heat Load (W/m)
Bunch Spacing (ns)
10
1
0.1
0.01
1E-3
0
10n
20n
30n
40n
50n
Bunch population
6x10^10
1.15x10^11
1.7x10^11
2.3x10^11

# Average Heat Load - 1st Batch -SEY =1.3



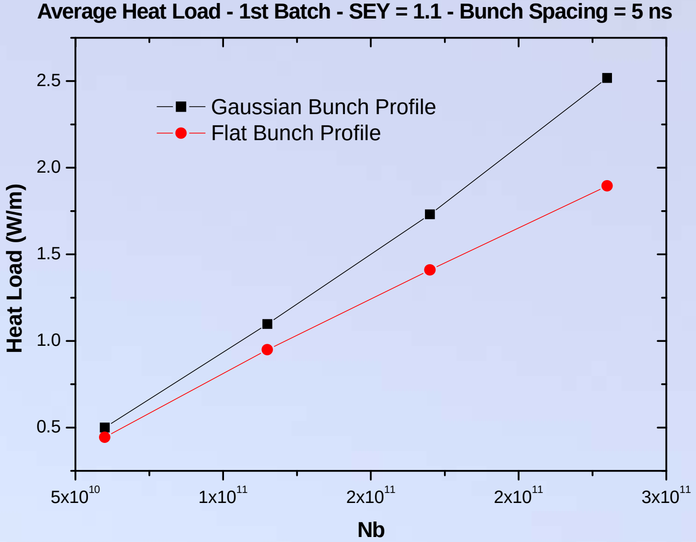
# Average Heat Load - 1st Batch - SEY = 1.5

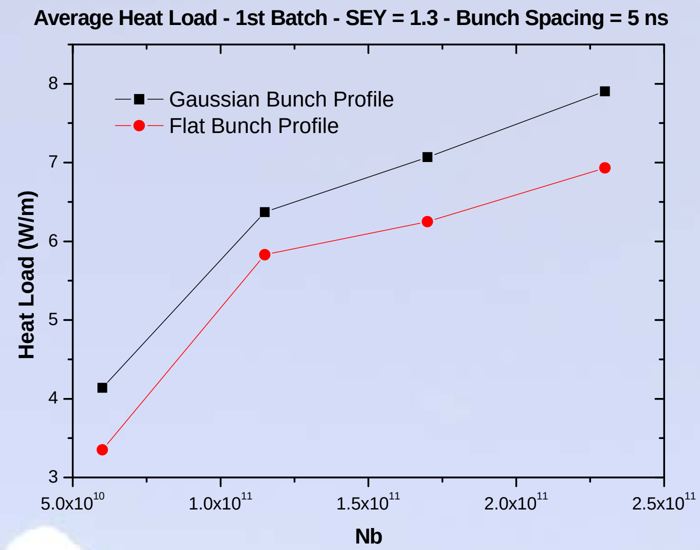


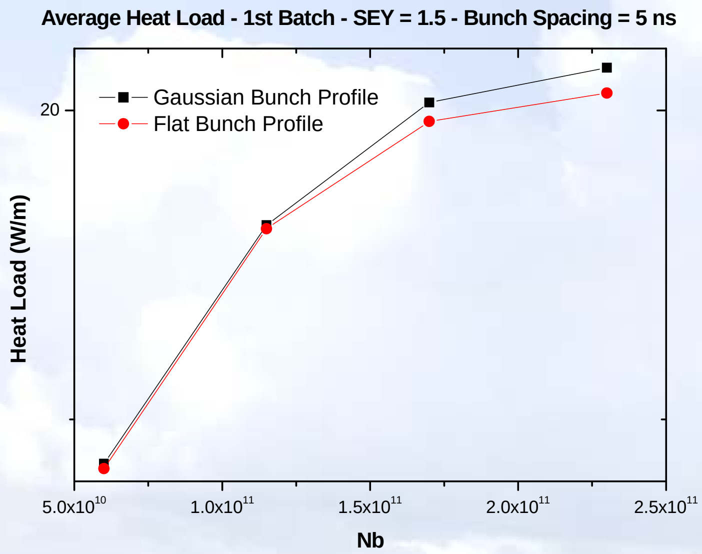

Average Heat Load - 1st Batch - SEY = 1.7
Heat Load (W/m)
100
10
1
0.1
0.01
1E-3
0
10n
20n
30n
40n
50n
Bunch Spacing (ns)
Bunch population
6x10^10
1.15x10^11
1.7x10^11
2.3x10^11

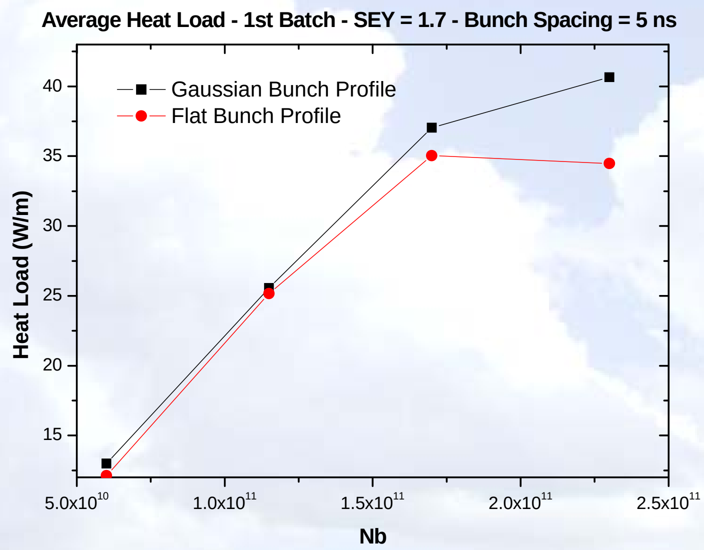
# III. Scan of Bunch Spacing
# - Gaussian Bunch Profile –

(Partial Results)


Average Heat Load - 1st Batch - SEY = 1.1 - Bunch Spacing = 5 ns
Gaussian Bunch Profile
Flat Bunch Profile
Heat Load (W/m)
0.5
1.0
1.5
2.0
2.5
5x10^10
1x10^11
2x10^11
2x10^11
3x10^11
Nb


Average Heat Load - 1st Batch - SEY = 1.3 - Bunch Spacing = 5 ns
Gaussian Bunch Profile
Flat Bunch Profile
Heat Load (W/m)
3
4
5
6
7
8
5.0x10^10
1.0x10^11
1.5x10^11
2.0x10^11
2.5x10^11
Nb


Average Heat Load - 1st Batch - SEY = 1.5 - Bunch Spacing = 5 ns
Gaussian Bunch Profile
Flat Bunch Profile
Heat Load (W/m)
20
5.0x10^10
1.0x10^11
1.5x10^11
2.0x10^11
2.5x10^11
Nb


Average Heat Load - 1st Batch - SEY = 1.7 - Bunch Spacing = 5 ns
Gaussian Bunch Profile
Flat Bunch Profile
Heat Load (W/m)
15
20
25
30
35
40
5.0x10^10
1.0x10^11
1.5x10^11
2.0x10^11
2.5x10^11
Nb


Conclusions

# Conclusions:

- Heat load for 1st & 2nd batch almost the same.
- Satellite Scenario:

  for SEY = 1.1 Heat load with satellites and without satellite almost the same.

  for SEY > 1.1 The satellite scenario has a slightly higher heat load than the nominal one,

  for satellites there is a minimum in the heat load.
- Scan Bunch Spacing – Flat Bunch Profile: For any SEY, bunch spacing of 50 ns has the lowest heat load.
- Scan Bunch Spacing – Gaussian Bunch Profile:

  Gaussian bunch profile seems to have a higher heat load than a longer flat bunch profile.

# Future work

- Compare heat load of the scan of bunch spacing for Gaussian bunches with $\sigma_z$=7.55 cm and longer flat bunches with $l_b$= 41 cm.
- Simulate PS and SPS experiments (later).
- Study the increase of the Pressure in SPS due to electron cloud.
- Compare real LHC data with simulation (maybe the next year!?).

# References


❖ O. Brüning, “Simulations for the Beam-Induced Electron Cloud in the LHC bean screen with Magnetic Field and Image Charges,” LHC Project Report 158 (1997).

❖ N. Diaczenko *et al*., “Killing the electron cloud effect in the LHC arcs” Proceedings of the 2005 IEEE Particle Accelerator Conference (PAC 05). 16-20 May 2005

❖ G. Rumolo and F. Zimmermann, “Practical User Guide for ECloud” (2003).

❖F. Zimmermann and E. Benedetto, “Electron-Cloud Effects in the LHC”, ICFA Newsletter No. 32 , May/June 2004.

❖F. Zimmermann, “A Simulation Study of Electron-Cloud Instability and Beam-Induced Multipacting in the LHC”, LHC Project Report 95 (1997).

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