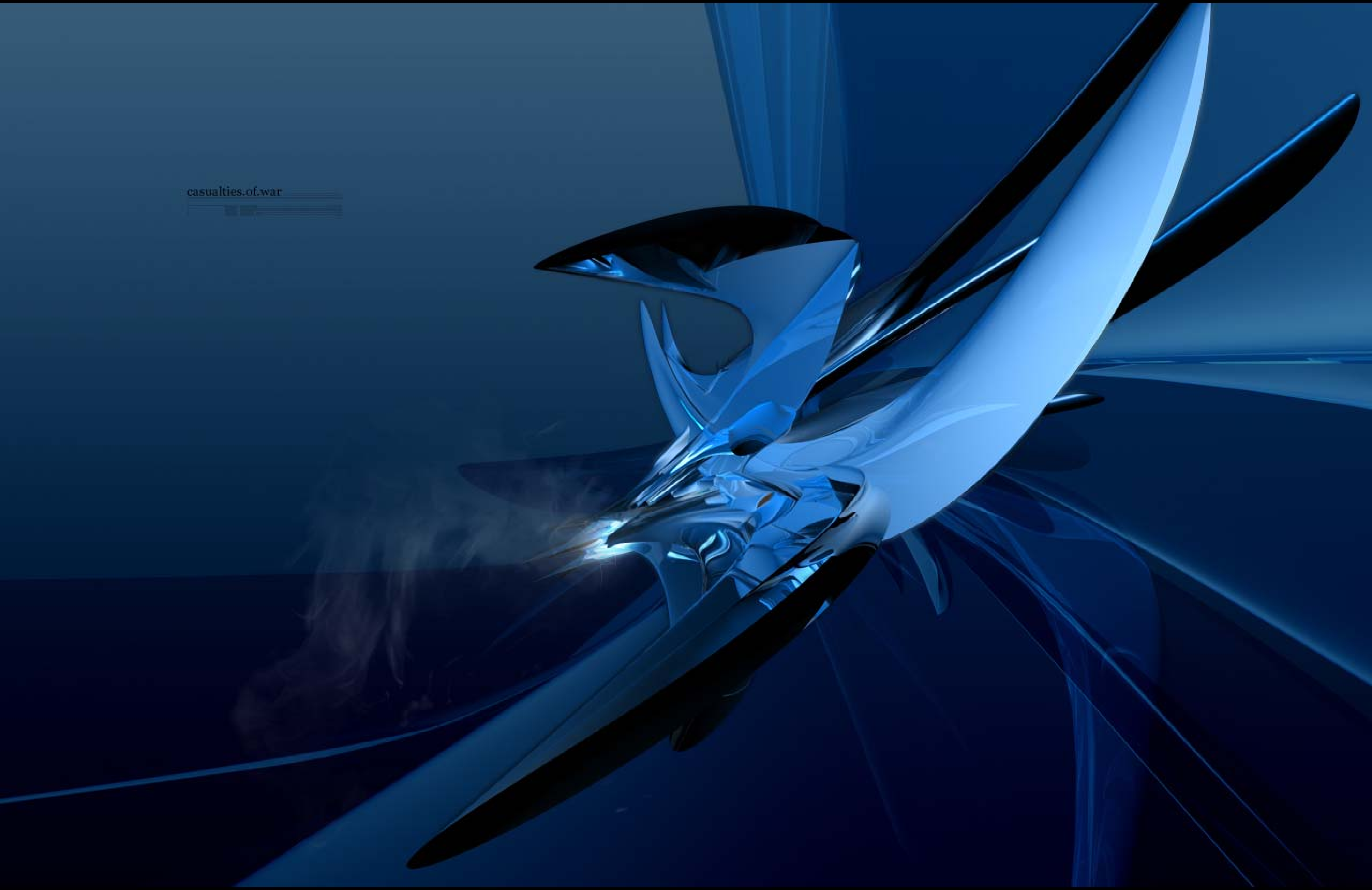
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European Organization for Nuclear Research

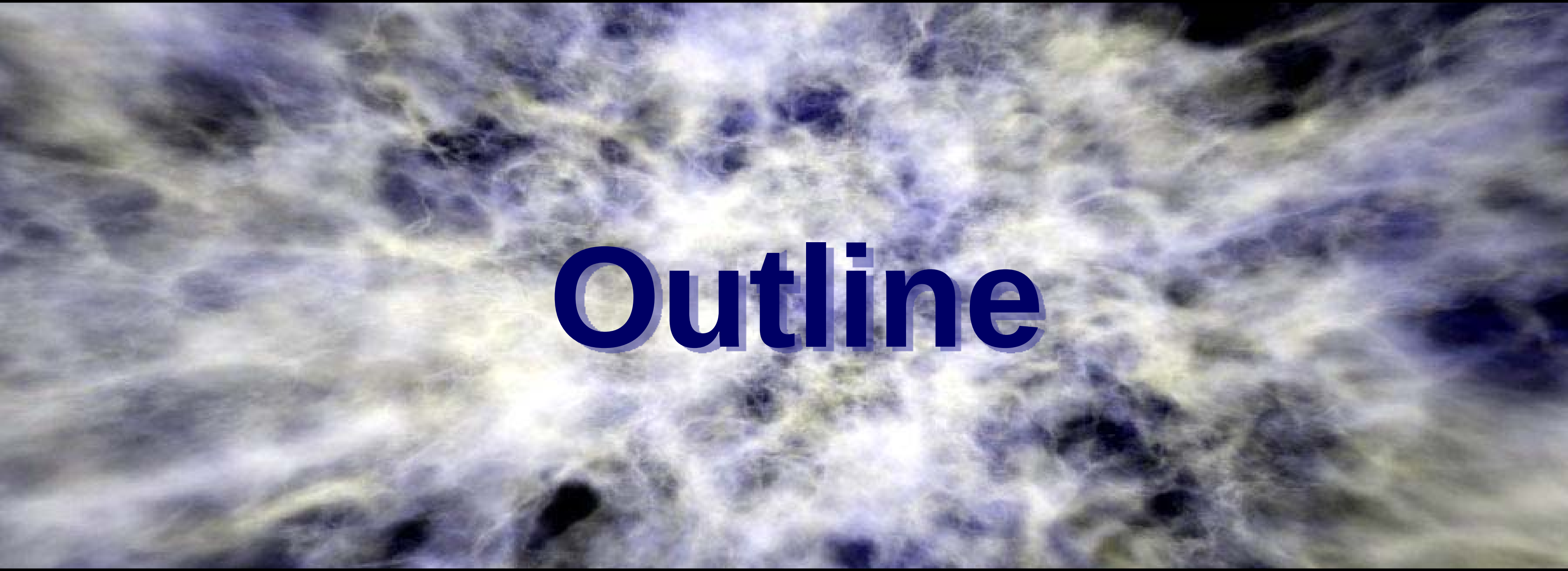
CINVESTAV – Campus Mérida

Electron Cloud Effects in the LHC

Humberto Maury Cuna

Supervisor:

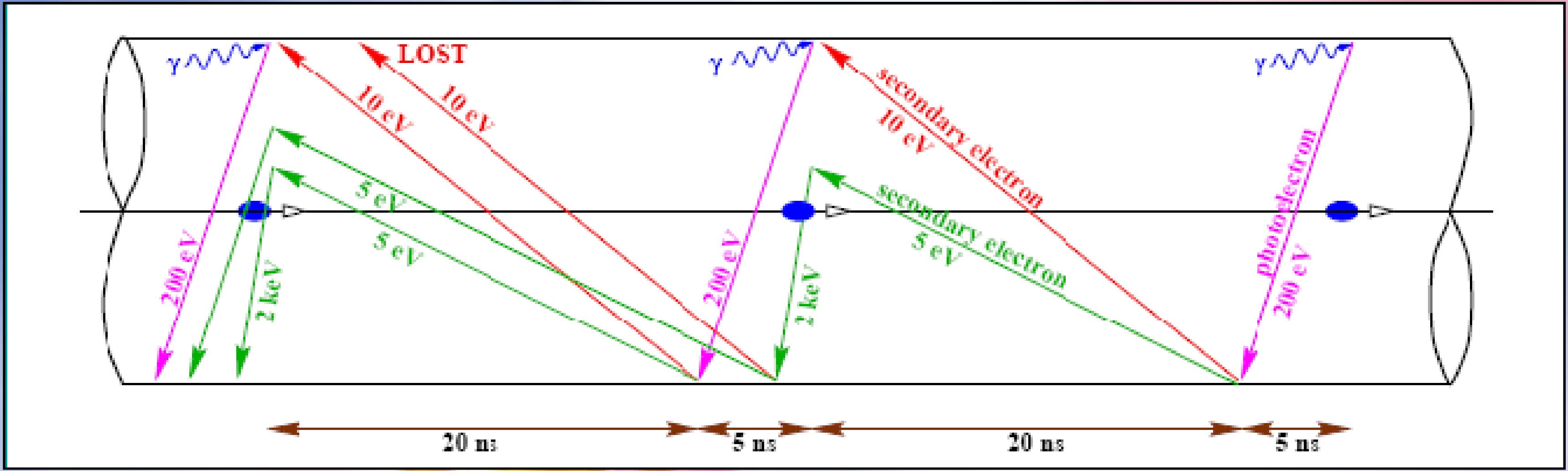
Dr. Frank Zimmermann


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, the vacuum chamber geometry and the type of magnetic field

Methodology

We made 3 sets of simulations:

Set A "nominal"	
Yield	**Bunch spacing**
1.1 - 1.7	25 ns
Nb	
2×10^{10} - 18×10^{10}	

Set B "50-ns alternative"	
Yield	**Bunch spacing**
1.1 - 1.7	50 ns
Nb	
2×10^{10} - 18×10^{10}	

Set C "upgrade"	
Yield	**Bunch spacing**
1.1 - 1.7	50 ns
Nb	
20×10^{10} - 60×10^{10}	

* For drift and dipole magnets the number of "bunch places" was 160 (2 trains) and for quadrupole we considered only 130 (50 bunches in second train).

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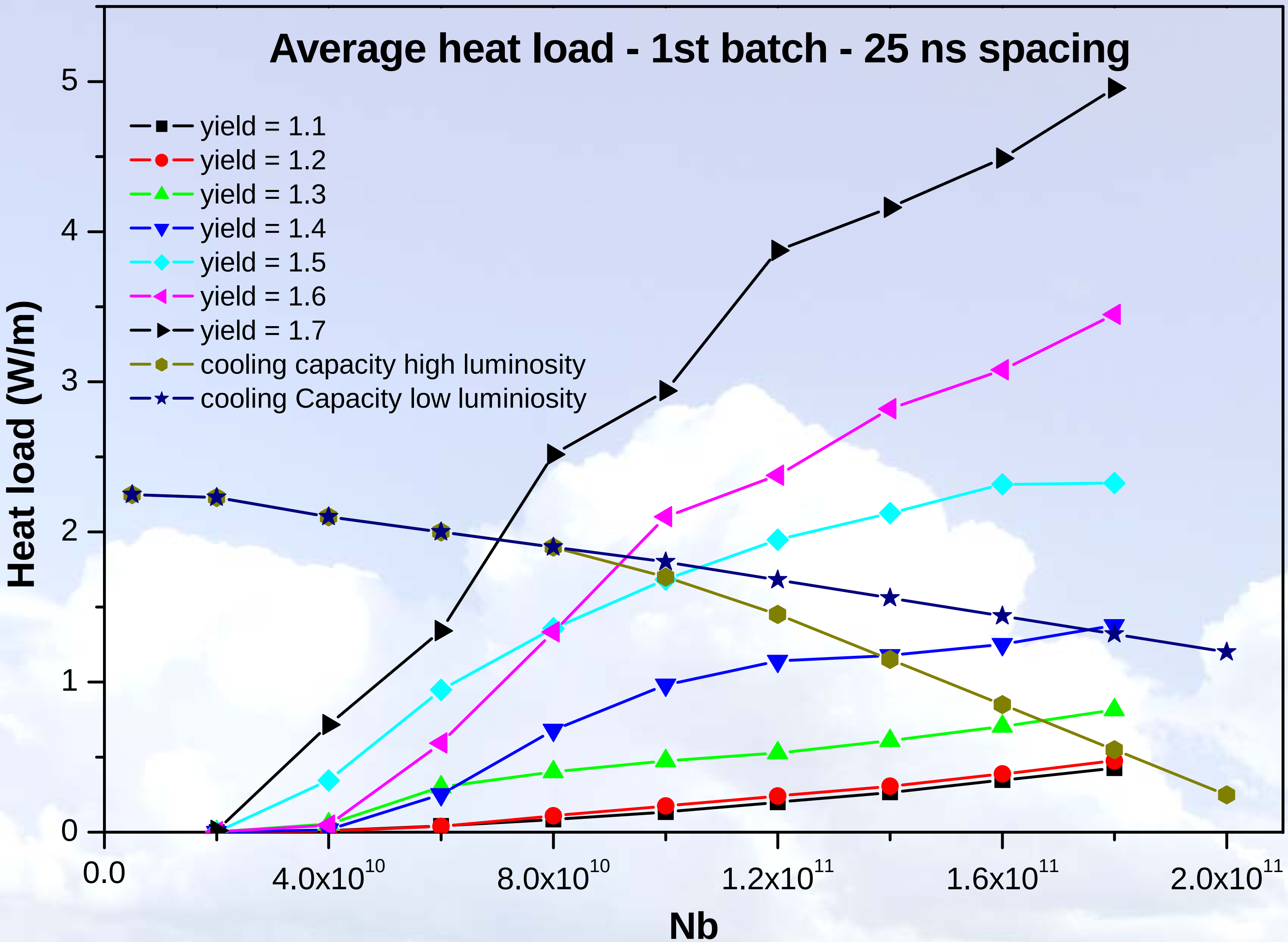
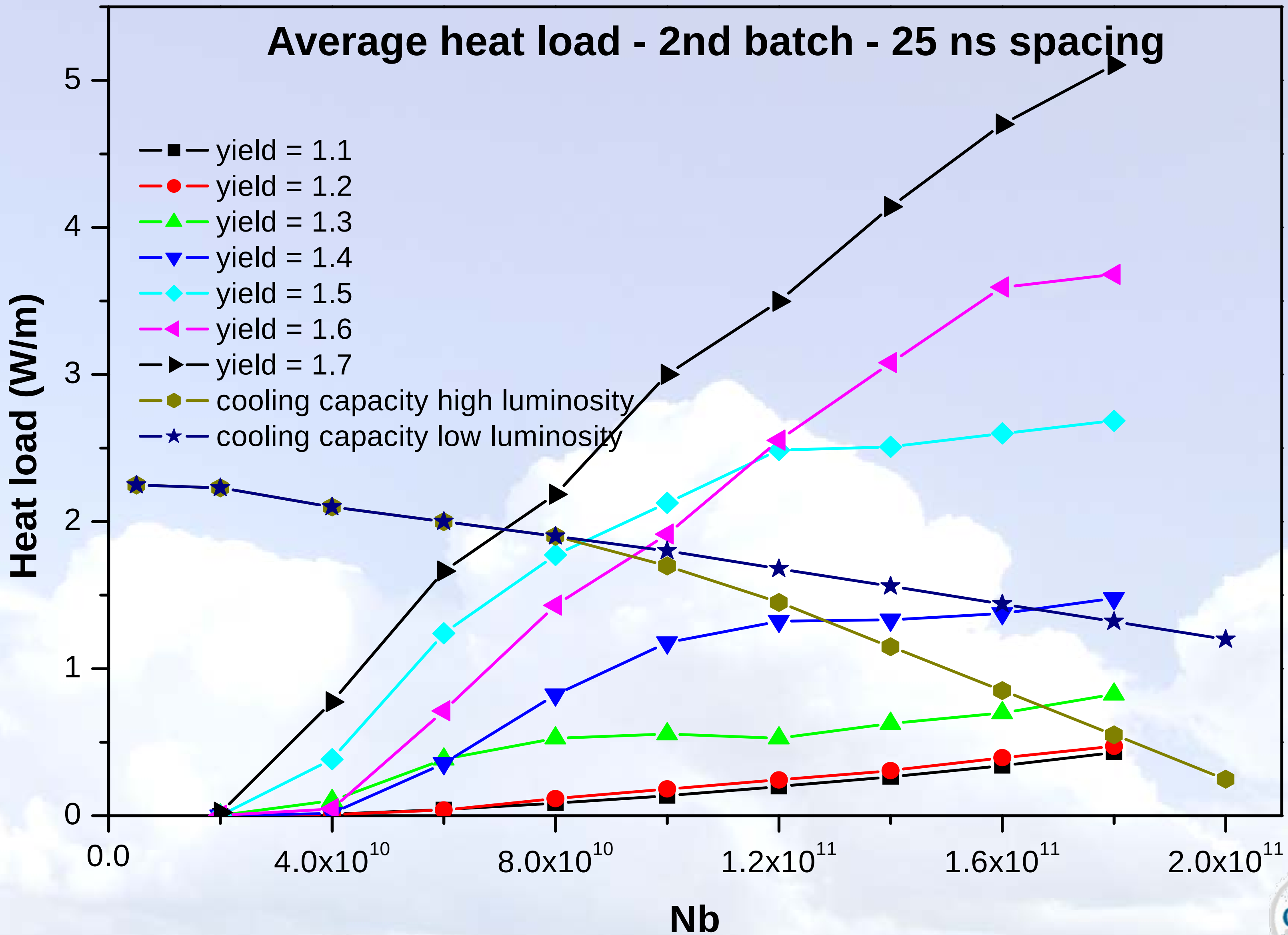
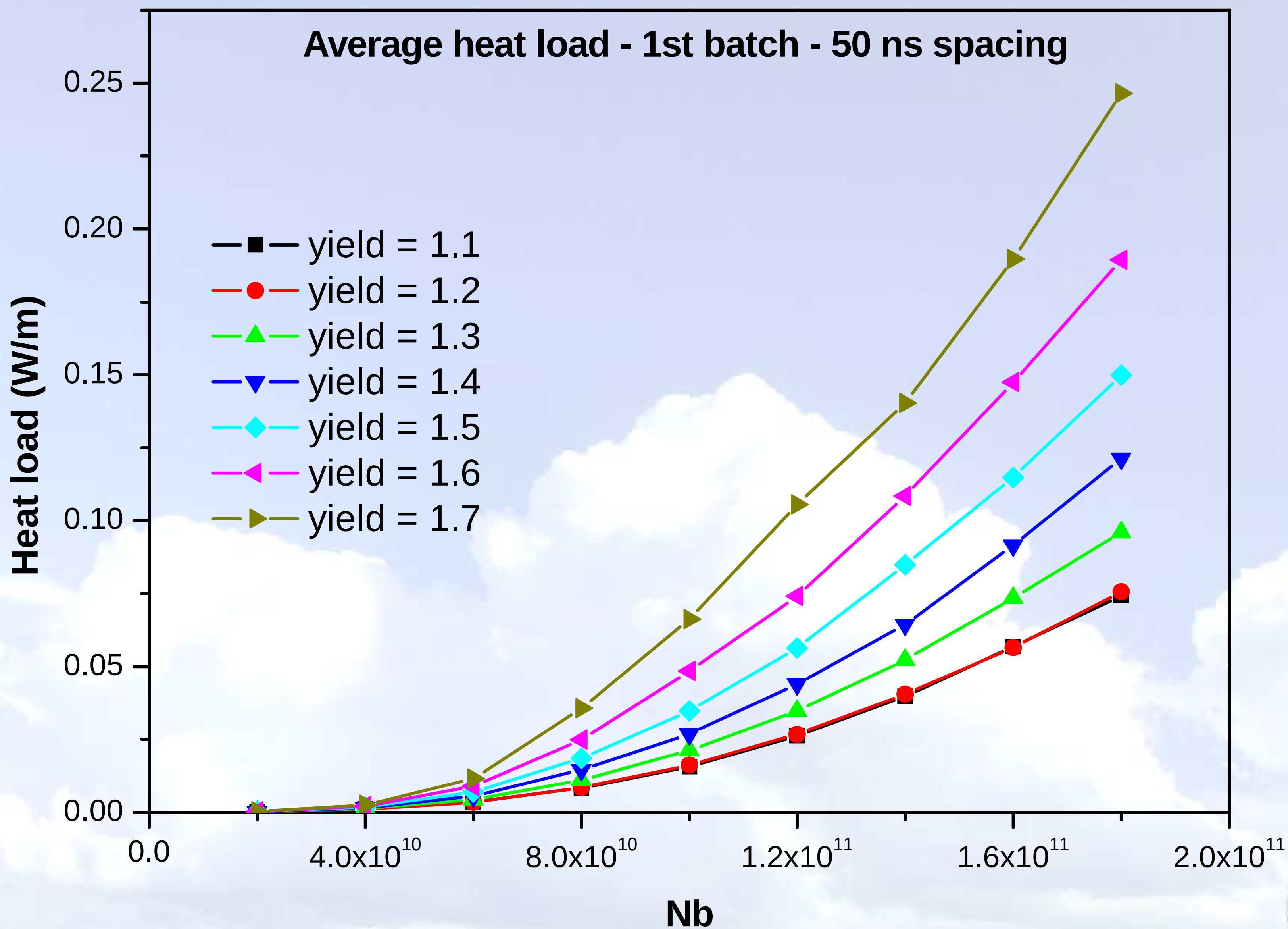
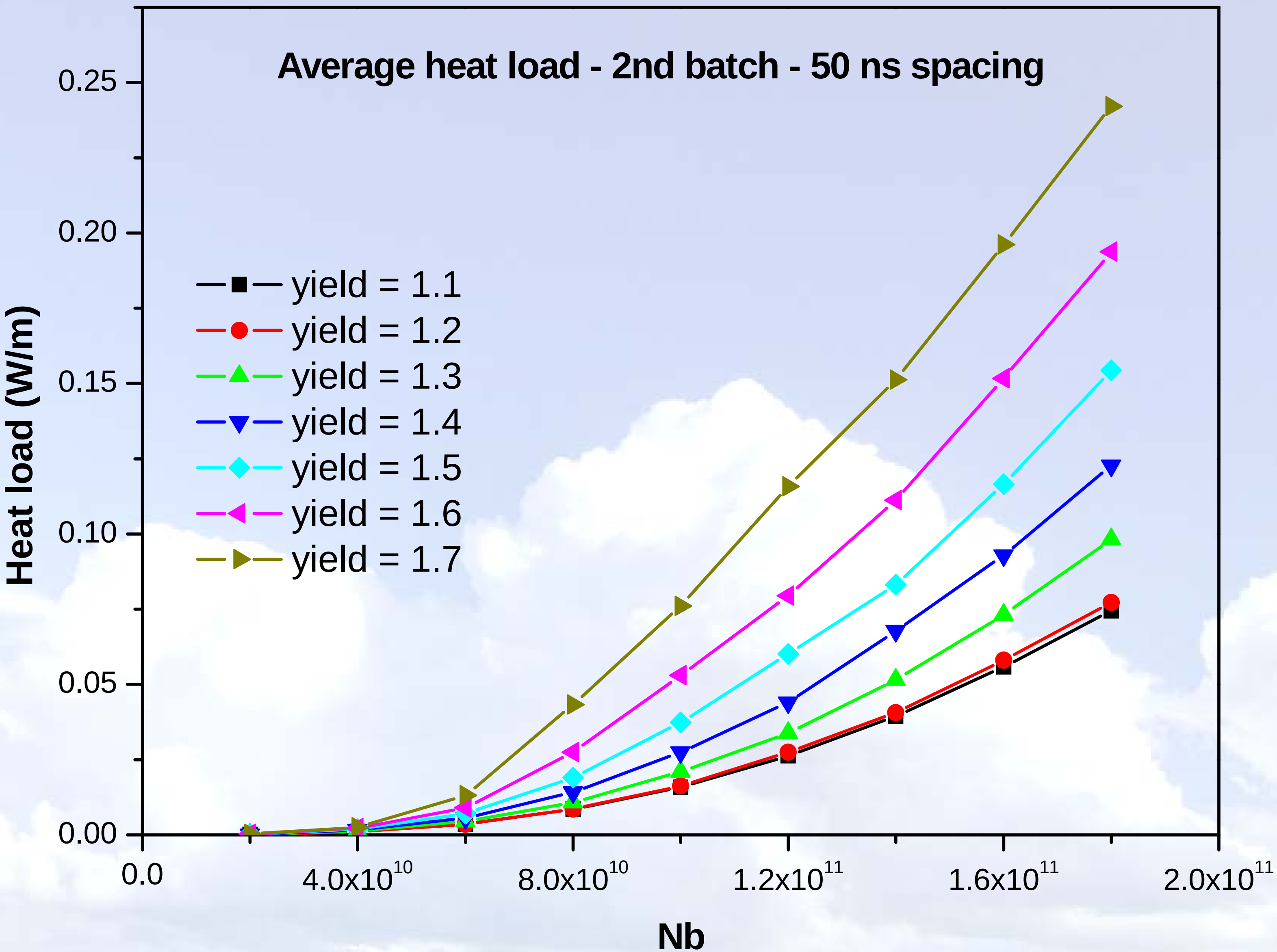
Results


Average heat load - 1st batch - 25 ns spacing
yield = 1.1
yield = 1.2
yield = 1.3
yield = 1.4
yield = 1.5
yield = 1.6
yield = 1.7
cooling capacity high luminosity
cooling Capacity low luminiosity
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

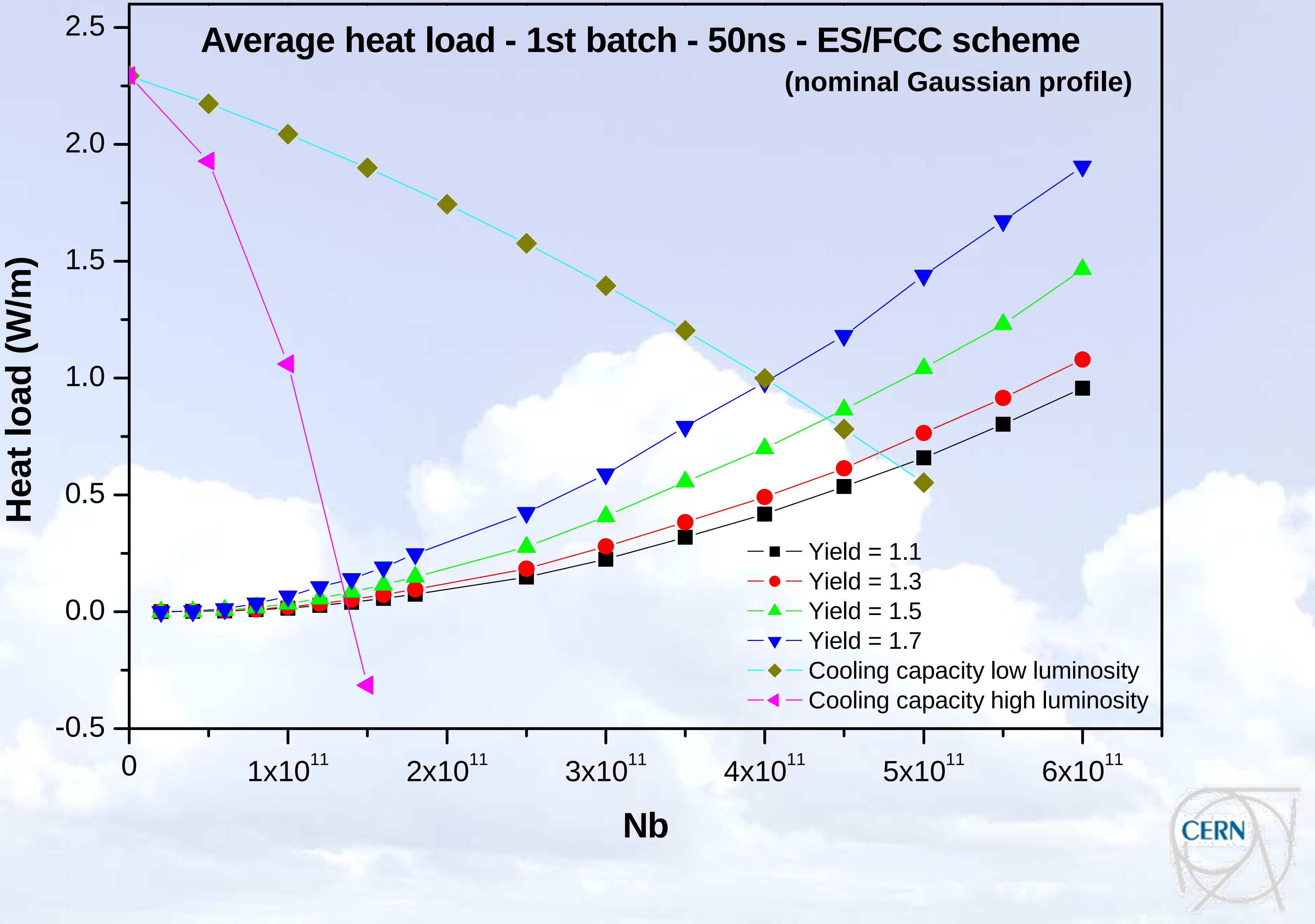

Average heat load - 2nd batch - 25 ns spacing
Heat load (W/m)
Nb
0
1
2
3
4
5
0.0
4.0x10^10
8.0x10^10
1.2x10^11
1.6x10^11
2.0x10^11
yield = 1.1
yield = 1.2
yield = 1.3
yield = 1.4
yield = 1.5
yield = 1.6
yield = 1.7
cooling capacity high luminosity
cooling capacity low luminosity



Average heat load - 1st batch - 50 ns spacing
Heat load (W/m)
0.25
0.20
0.15
0.10
0.05
0.00
yield = 1.1
yield = 1.2
yield = 1.3
yield = 1.4
yield = 1.5
yield = 1.6
yield = 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 - 50 ns spacing
Heat load (W/m)
0.25
0.20
0.15
0.10
0.05
0.00
0.0
4.0x10^10
8.0x10^10
1.2x10^11
1.6x10^11
2.0x10^11
Nb
yield = 1.1
yield = 1.2
yield = 1.3
yield = 1.4
yield = 1.5
yield = 1.6
yield = 1.7



Average heat load - 1st batch - 50ns - ES/FCC scheme
(nominal Gaussian profile)
Heat load (W/m)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
1x10^11
2x10^11
3x10^11
4x10^11
5x10^11
6x10^11
Nb
Yield = 1.1
Yield = 1.3
Yield = 1.5
Yield = 1.7
Cooling capacity low luminosity
Cooling capacity high luminosity
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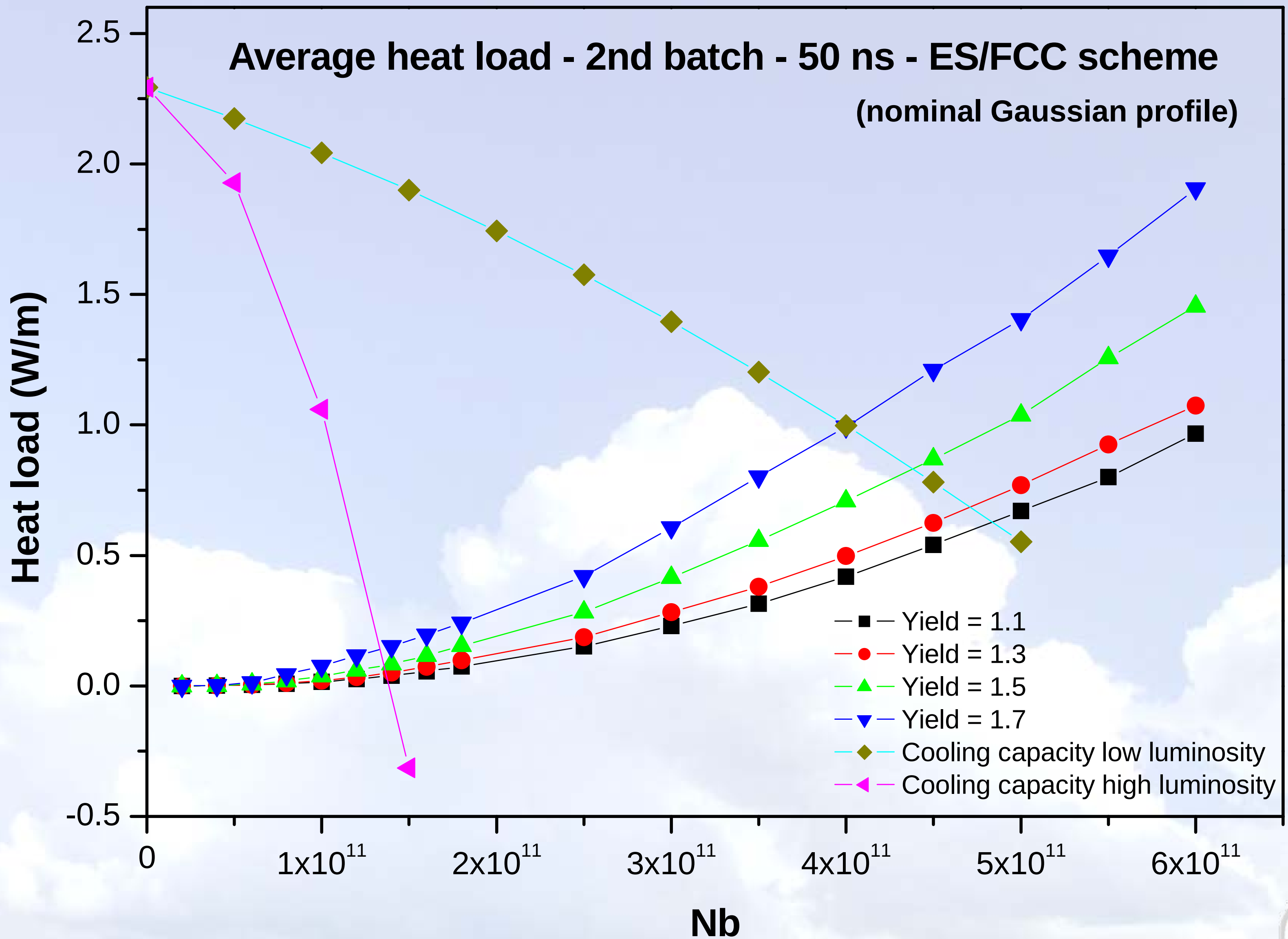
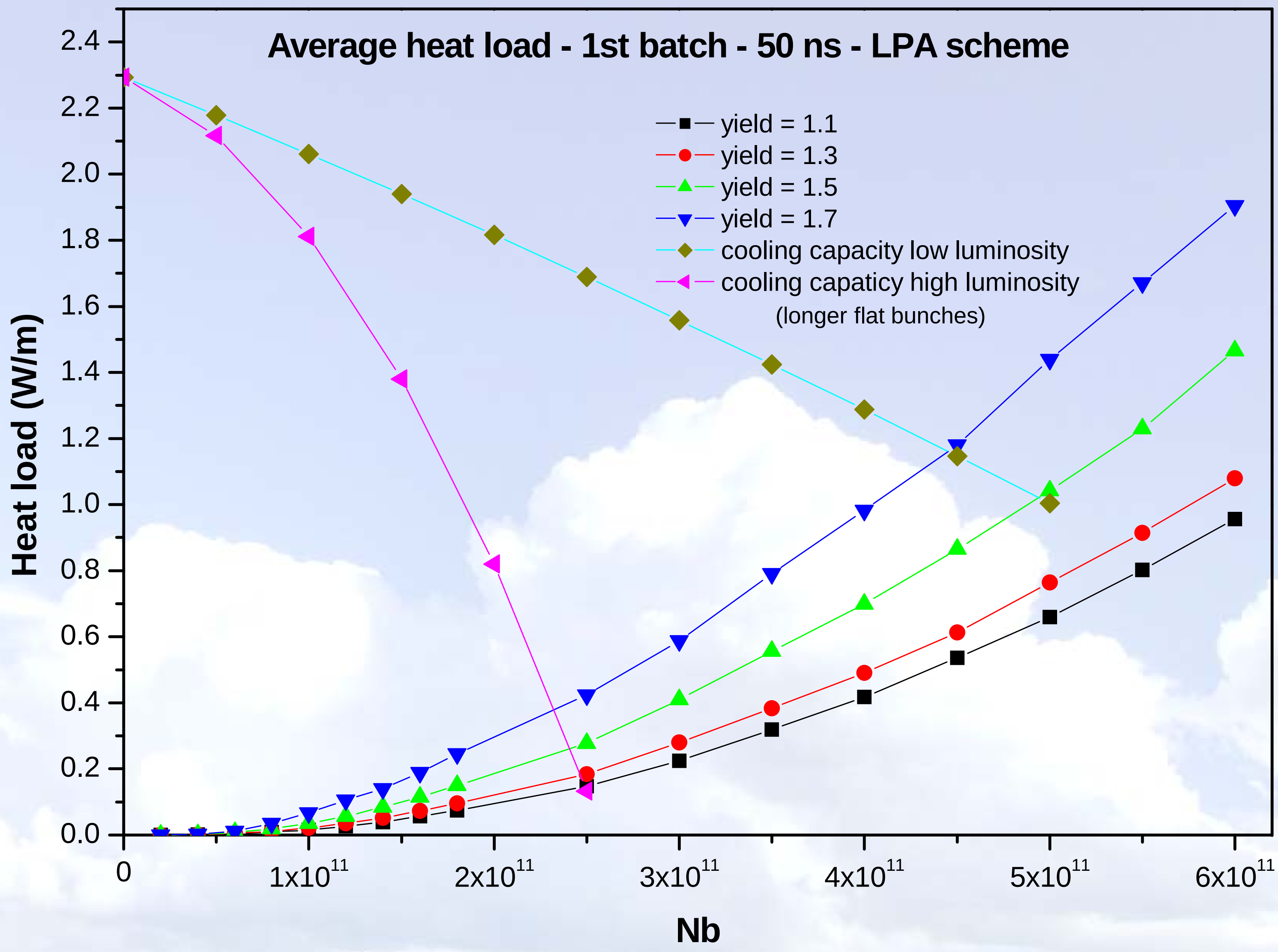


Average heat load - 2nd batch - 50 ns - ES/FCC scheme
(nominal Gaussian profile)
Heat load (W/m)
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
0
1x10^11
2x10^11
3x10^11
4x10^11
5x10^11
6x10^11
Nb
Yield = 1.1
Yield = 1.3
Yield = 1.5
Yield = 1.7
Cooling capacity low luminosity
Cooling capacity high luminosity



Average heat load - 1st batch - 50 ns - LPA scheme
Heat load (W/m)
Nb
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
0
1x10^11
2x10^11
3x10^11
4x10^11
5x10^11
6x10^11
yield = 1.1
yield = 1.3
yield = 1.5
yield = 1.7
cooling capacity low luminosity
cooling capaticy high luminosity
(longer flat bunches)
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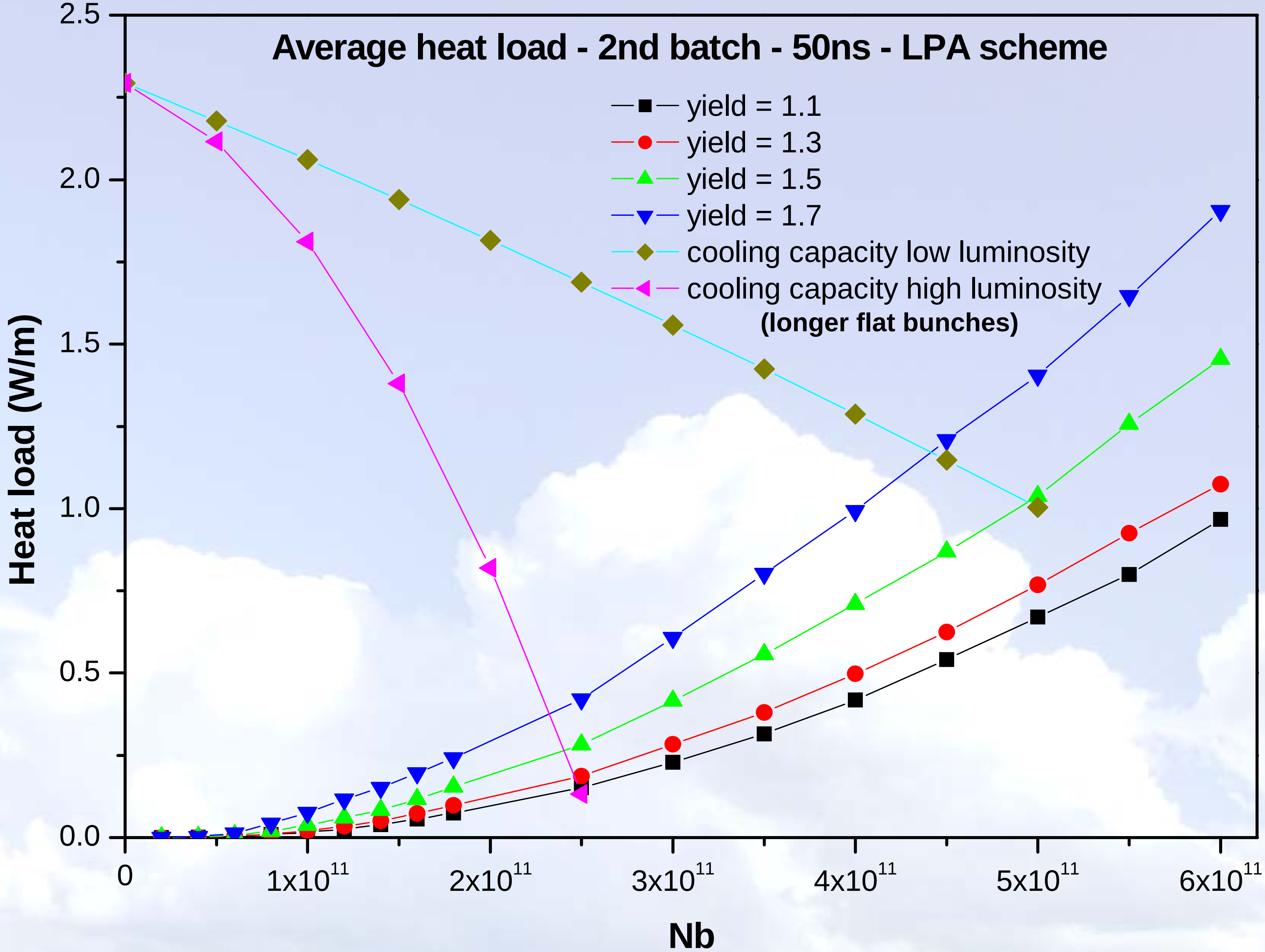
Average heat load - 2nd batch - 50ns - LPA scheme
yield = 1.1
yield = 1.3
yield = 1.5
yield = 1.7
cooling capacity low luminosity
cooling capacity high luminosity
(longer flat bunches)
Heat load (W/m)
Nb
0.0
0.5
1.0
1.5
2.0
2.5
0
1x10^11
2x10^11
3x10^11
4x10^11
5x10^11
6x10^11
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Conclusions

Conclusions:

- heat load for 1st & 2nd batch almost the same
- 25 ns spacing:
  for SEY < 1.3 ultimate parameters,
  for SEY < 1.4 nominal LHC,
  for SEY < 1.5 up to N_b=9x10^{10}
- 50 ns spacing:
  for nominal β^*=0.55 m up to N_b>2x10^{11}
- High-luminosity upgrade requires separate cooling for IRs; then
  ES/FCC (β^*=0.08 m) up to N_b ~ 4.5x10^{11}
  LPA (β^*=0.25 m) up to N_b ~ 5.5x10^{11}

Future work

- Compare heat load for Gaussian bunches with σ_z=7.55 cm and longer flat bunches with l_b=41 cm.

- Simulate PS and SPS experiments (later).

- Compare real LHC data with simulation (next year!?).

References

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