Update on simulations with large gas densities: stability and effect of solenoid

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Acknowledgements: G. Iadarola, K. Poland, G. Rumolo

WP2 meeting

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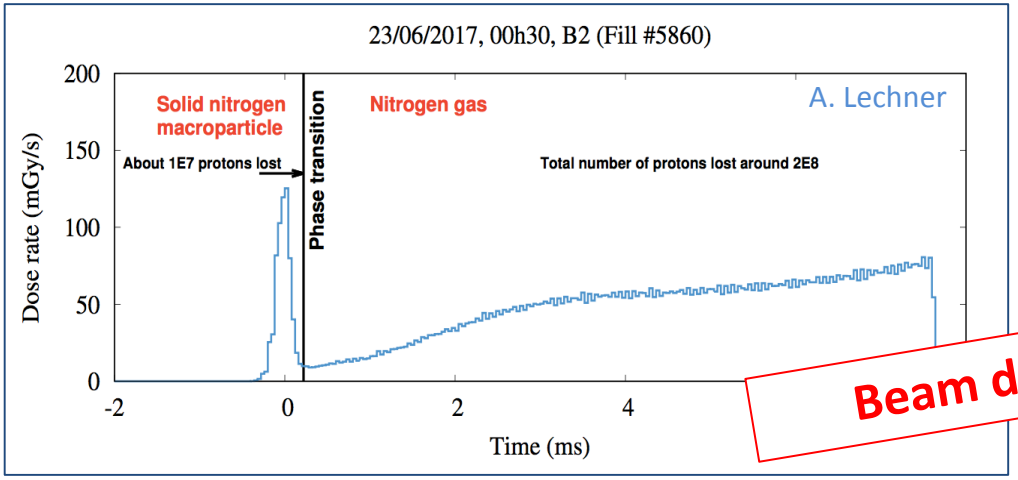
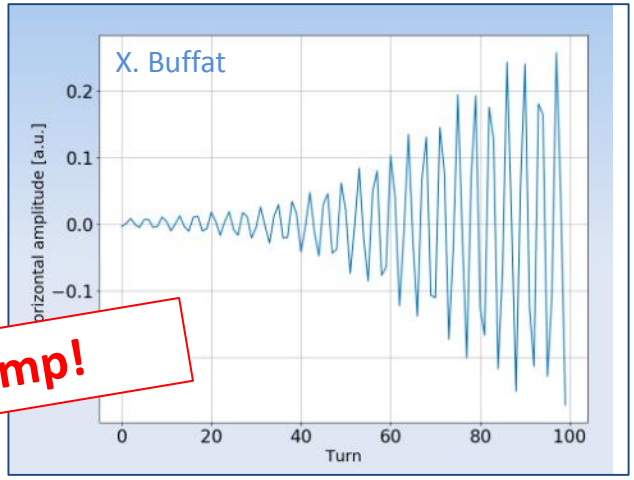
Motivation

In 2017 (and 2018) LHC operation was affected by the ‘16L2’ events:

Suddenly appearing characteristic losses



Fast instabilities



Beam dump!

Caused by the beam-induced phase transition of macro-particles of frozen air (N_2 / O_2)

→ Unprecedentedly high gas densities

→ Beam instabilities due to electrons and/or ions produced through gas ionization

Simulation tools developed to self-consistently model this step of the process

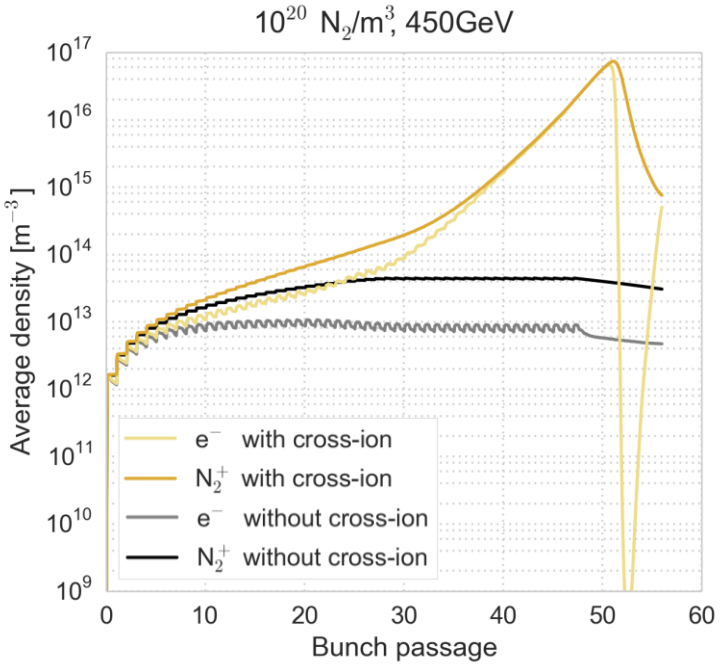
Recap of current status

Multi-species tool simulating electrons and ions together

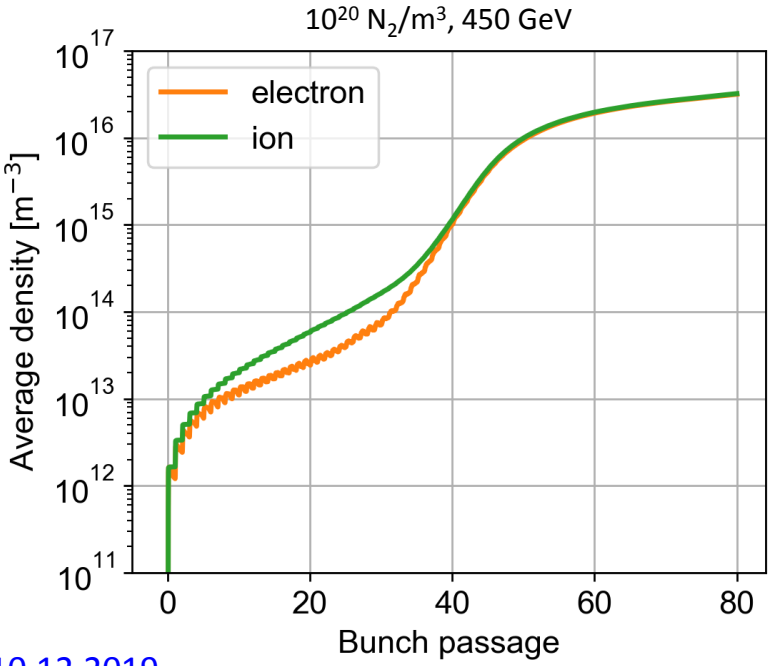
- Cross-species ionization module to include electron-induced gas ionization

Electron and ion densities reach close to values expected to cause instabilities

The densities grow too much for the code to handle → numerical breakdown



After much investigation and optimization: stable simulation up to 70-80 bunch passages for gas density of 10^{20} N_2/m^3



[WP2 meeting 10.12.2019]

Update on stability

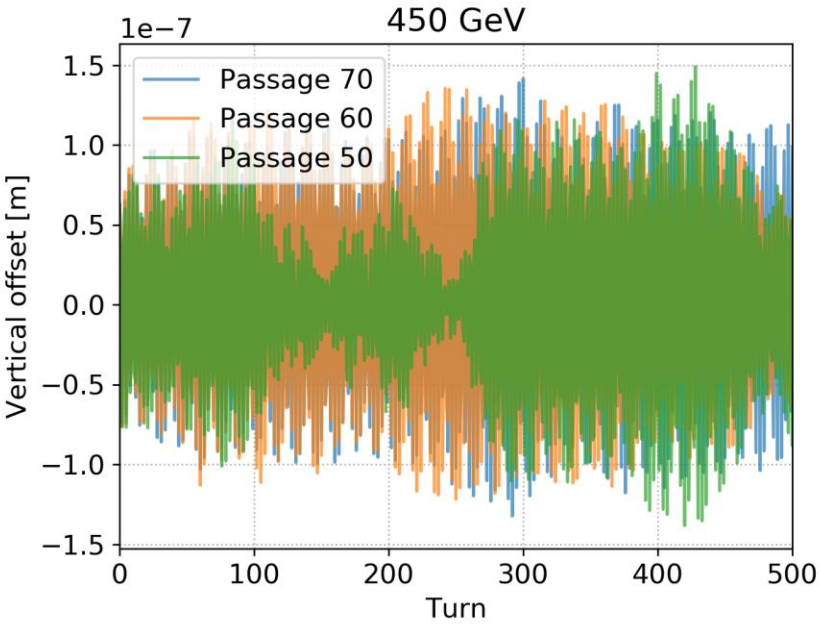
First studies of beam stability with cross-ionization have been performed

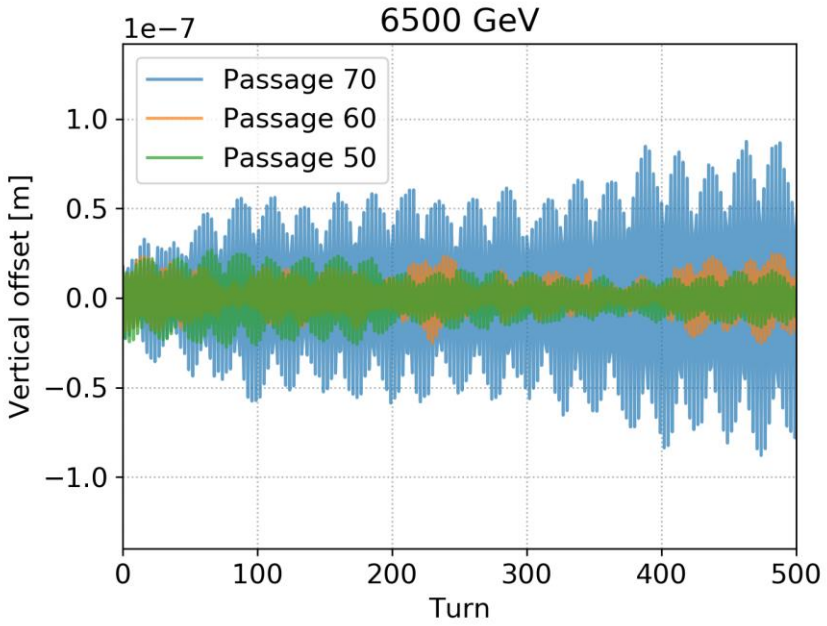
- The simulation have been done in the usual way
  - Electron and ion states saved at a certain point in the build-up simulation
  - The beam interacts with the same saved distributions over multiple turns
  - → Better suited for standard steady state e-cloud than the current transient situation

Update on stability

First studies of beam stability with cross-ionization have been performed

- A developing instability can be seen at collision energy



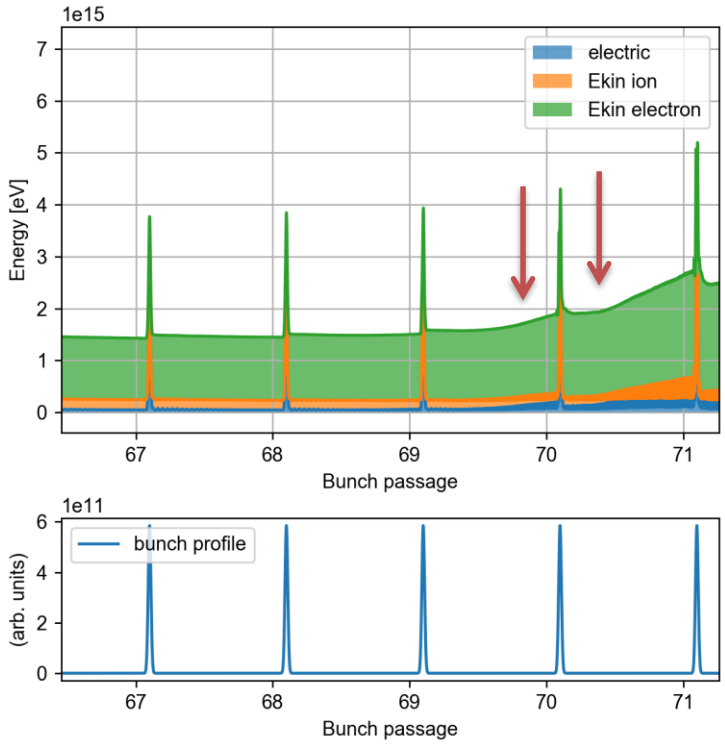


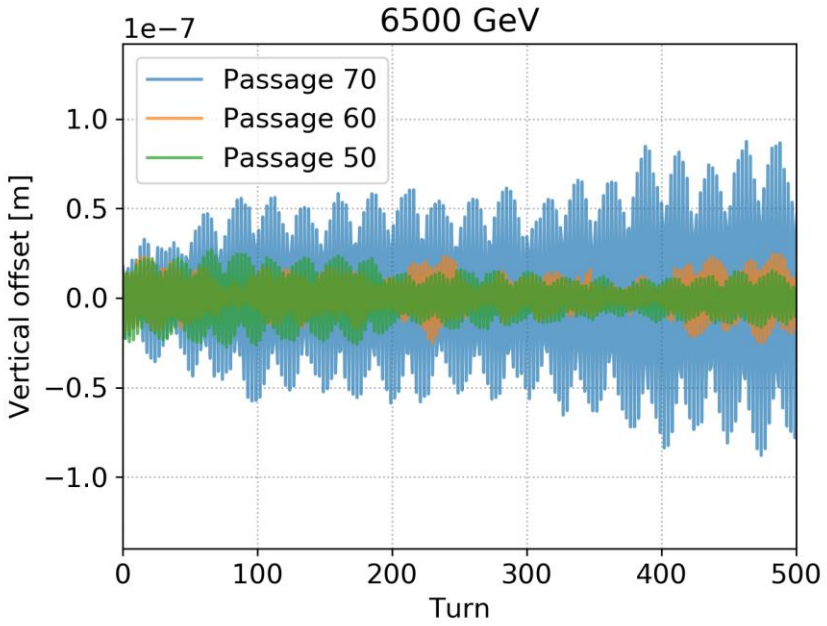
Update on stability

First studies of beam stability with cross-ionization have been performed

- A developing instability can be seen at collision energy, however
  - Extensive convergence studies have been performed only at 450 GeV
  - The state used for the instability studies corresponds exactly to the moment the build-up simulation starts showing unphysical behaviour

Total energy increases in closed system!

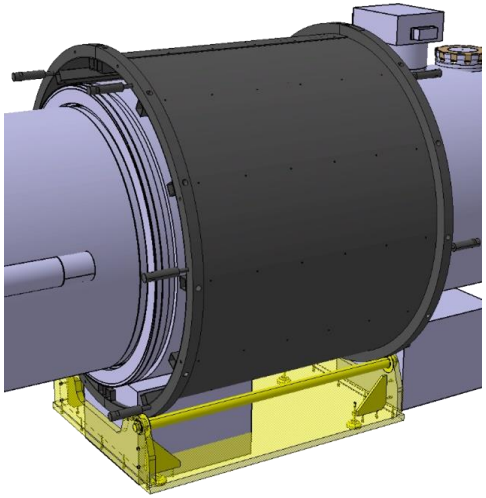




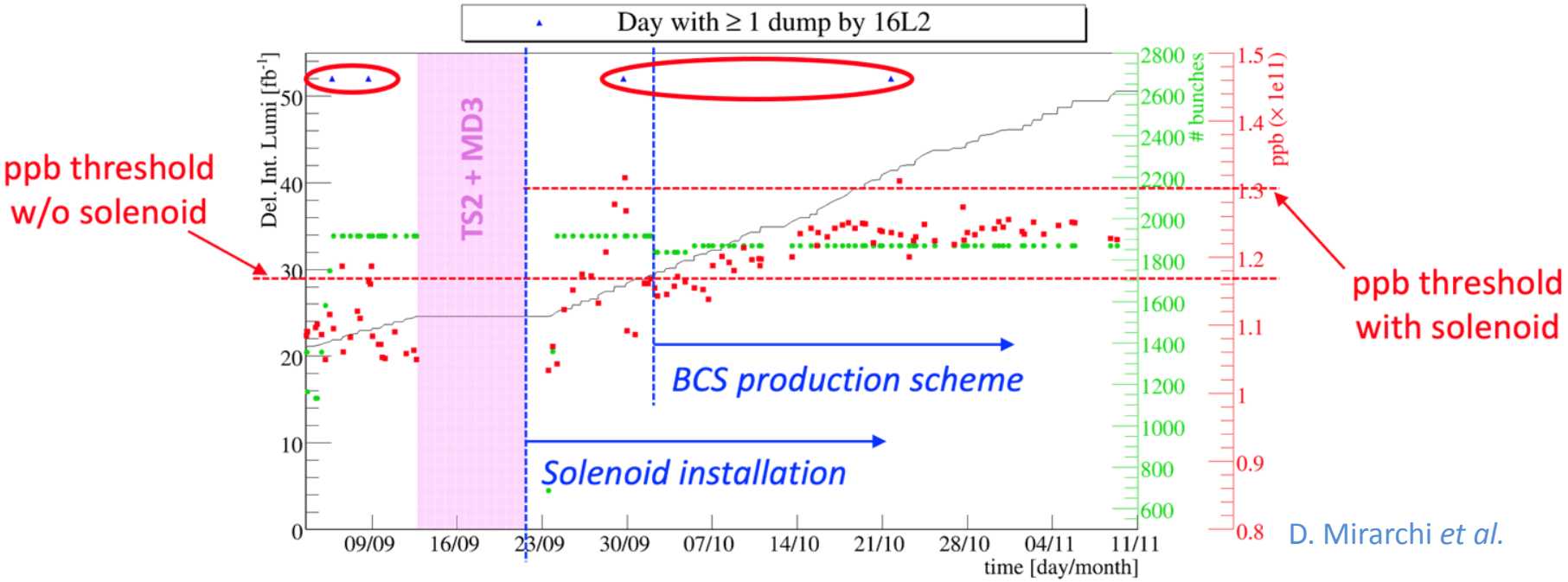
16L2 solenoid

A solenoid was installed around the 16L2 area during 2017

- Maximum solenoid field around 7 mT
- The solenoid had a mitigating effect on the 16L2 events, which allowed for a 10% increase in bunch intensity



G. Arduini, A. Milanese, D. Perini *et al.*

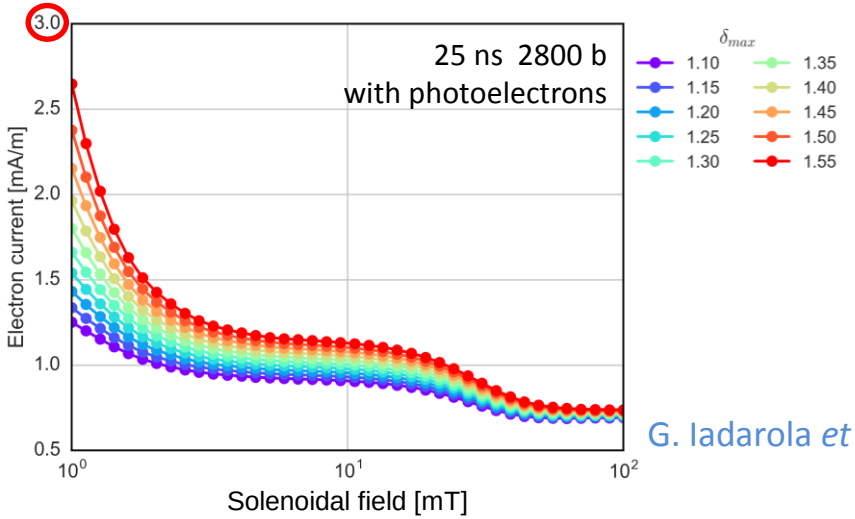


D. Mirarchi *et al.*

16L2 solenoid

The beneficial effect of the solenoid field was likely due to a suppression of the occurrence of 16L2 loss events, since

- Observations indicated that 16L2 loss events were triggered by e-cloud (50 ns tests, 8b+4e operation)
- Simulations showed that a solenoid field of 5-10 mT could significantly reduce e-cloud build-up



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It is also possible that the solenoid field could have had a mitigating effect on the evolution of 16L2 loss spike events (action)

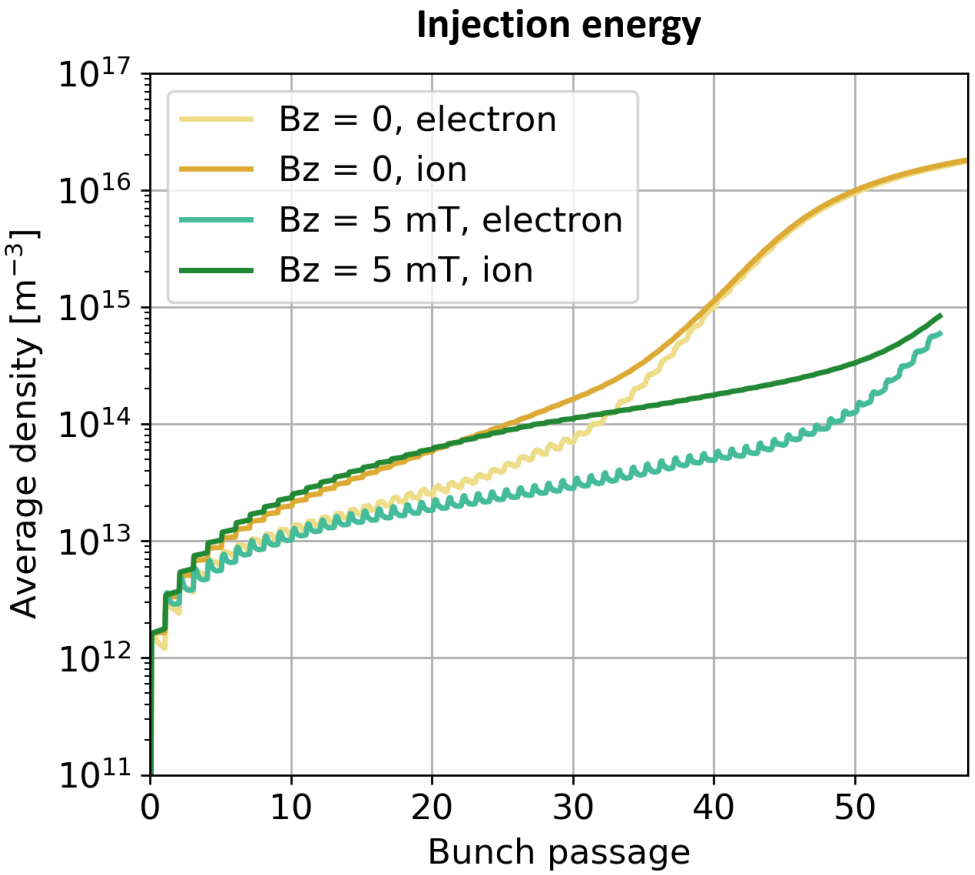
- We have investigated this possibility with multi-species build-up simulations

Simulation case	
Solenoid field	5 mT
N_2 gas density	10^{20} N_2/m^3
Beam energy	450GeV

Effect of solenoid field

In our simulation, the solenoid field has a mild mitigating effect on the multi-species build-up process

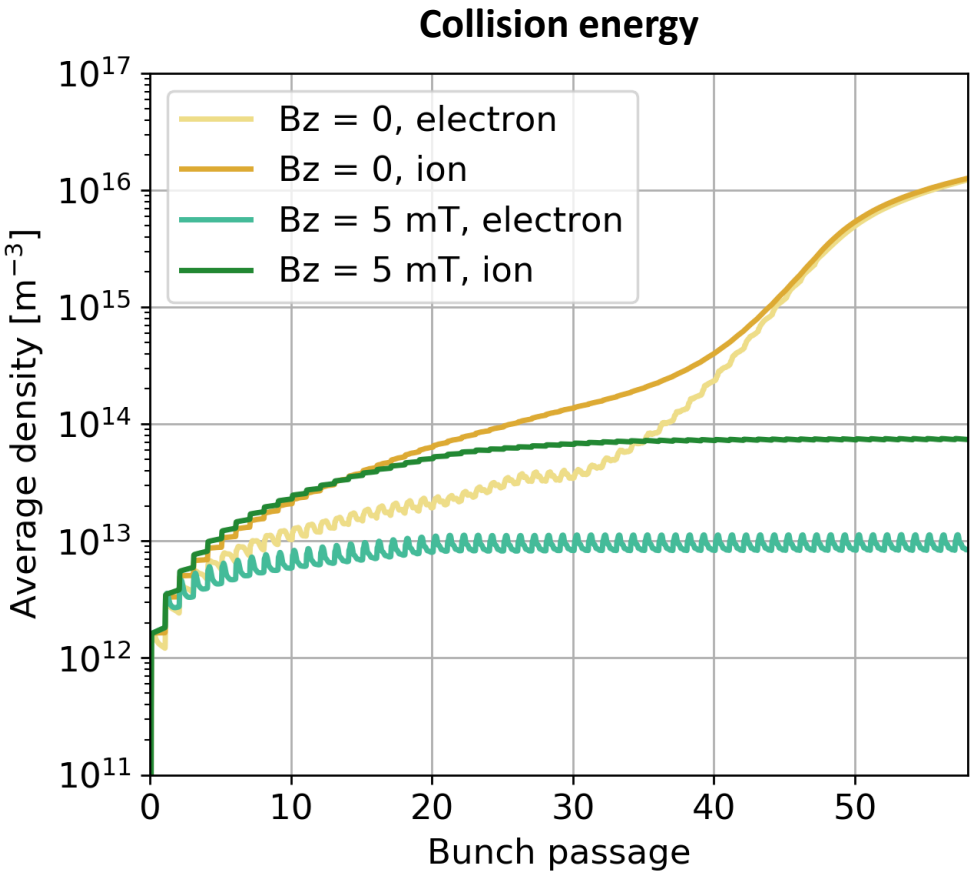
- The build-up is delayed by about 20 bunch passages



Effect of solenoid field

In our simulation, the solenoid field has a mild mitigating effect on the multi-species build-up process

- The run-away behaviour of the build-up is suppressed



!!!
Extensive convergence studies have been performed only at 450 GeV

Conclusions

- The simulations that can currently be done lead to electron and ion densities around the range expected to induce fast instabilities
  - At injection, instabilities have not been reproduced in simulations
  - More studies would be needed for conclusive results at collision energy

- A solenoid field of 5 mT slows down the growth of electron and ion densities
  - At injection the build-up is delayed by around 20 bunch passages
  - At collision energy a stronger suppression is seen, but more studies would be needed for conclusive results