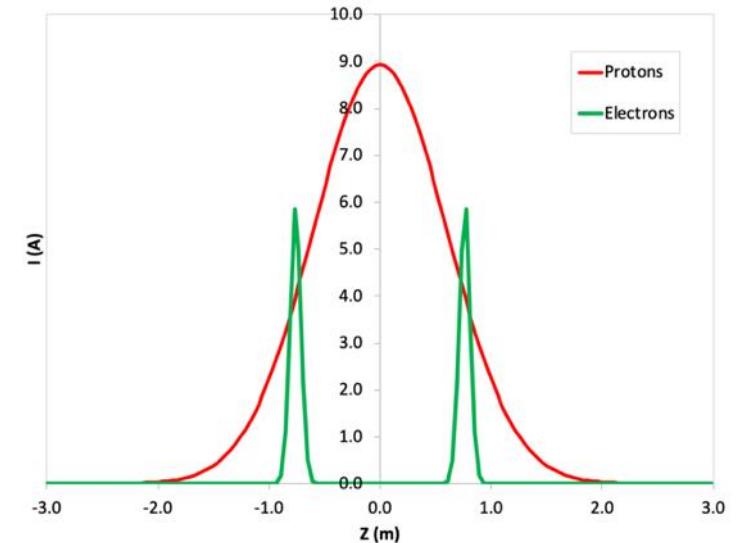


# APEX: recombination studies

D. Kayran, A. Fedotov, P. Inacker, K. Mernick, S. Seletskiy, He Zhao, others

This experiment is important to learn how to optimize the cooling of high-intensity high-energy ions (or protons) by finding the proper balance between cooling/heating/lifetime. It is critical for determining the realistic baseline parameters of high-energy coolers such as those proposed for the EIC. For example, a similar schema of using two electron bunches located at  $\pm$  rms length of the proton bunch is proposed to the precooling of the protons at energy 25 GeV for EIC. It also may help us to improve low-energy RHIC operation with LEReC.



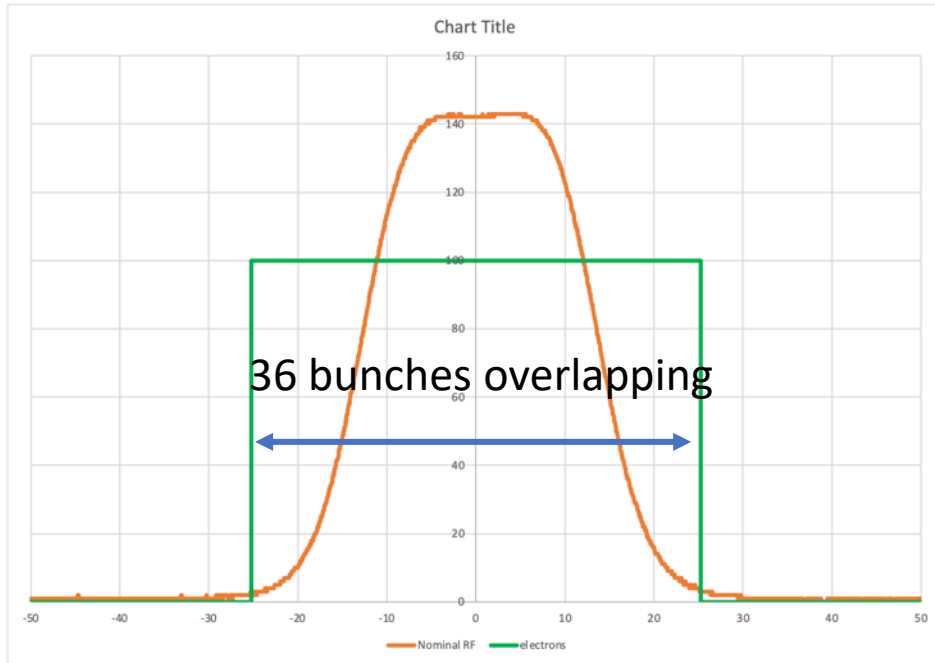
Time structure of two electron bunches synchronized with a single proton bunch

\*A. Fedotov., Low energy cooling for Electron Ion Collider  
BNL-220686-2020-TECH EIC-HDR-TN-012

<https://technotes.bnl.gov/PDF?publicationId=220686>

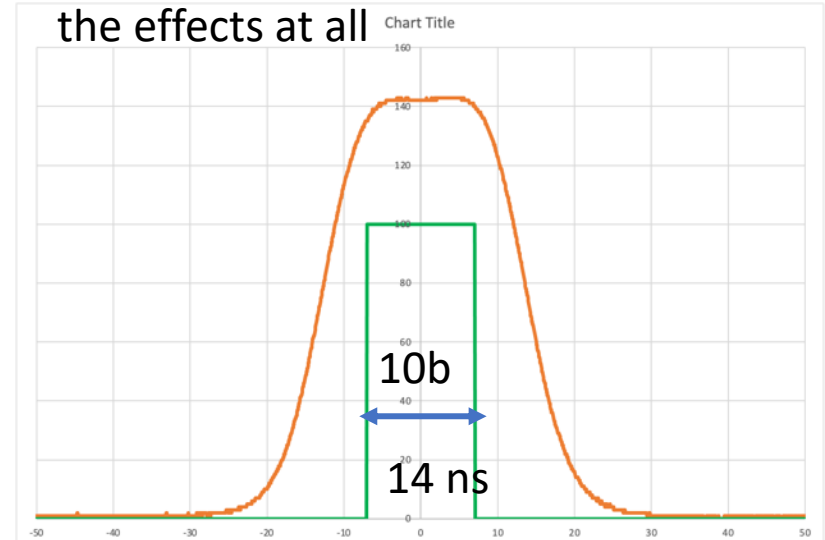
# Comparison cooling, heating, lifetime for the same bunch charge sitting in the center and at the wings of the ion bunch

Running now 1 long macro bunch

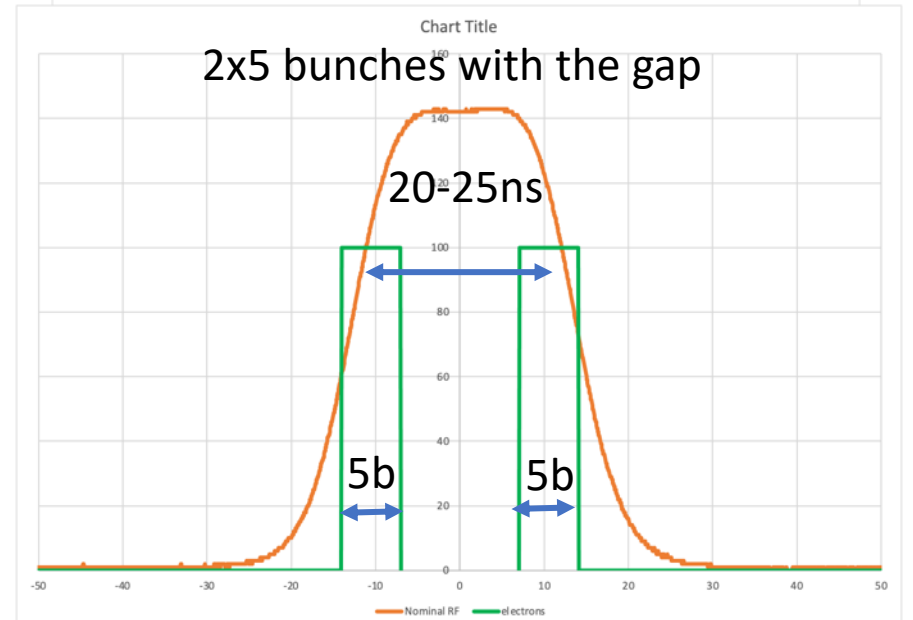


Proposal for APEX

Short macro bunch ~10 bunches in the center  
We might need more charge per bunch to see the effects at all



2x5 bunches with the gap



# Notes from the laser meeting (March 12, 2021):

Based on discussion with Patrick

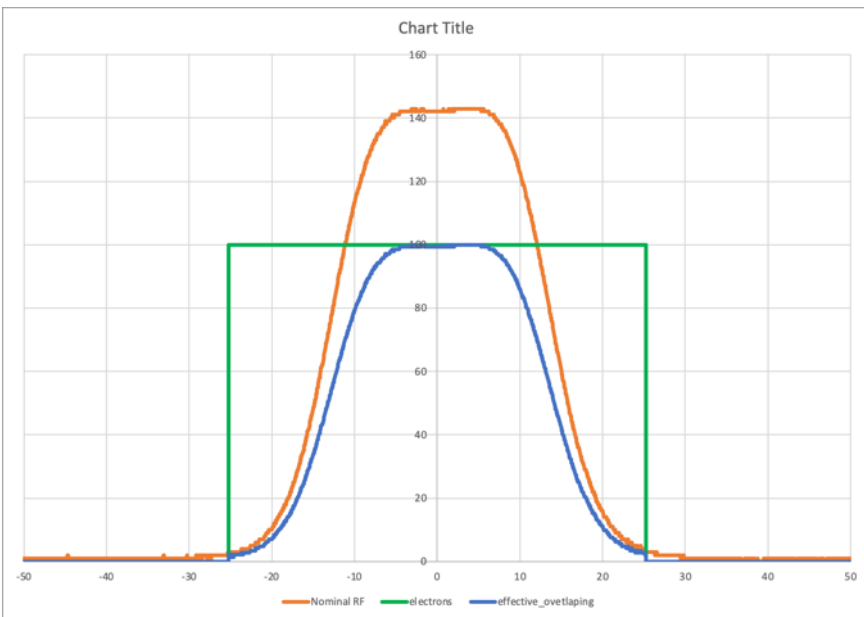
- Some distortion is observed of 2ps bunches starting from 15b per MB

We don't know if and how such distortion effects on 30ps final laser pulse or on e-bunch

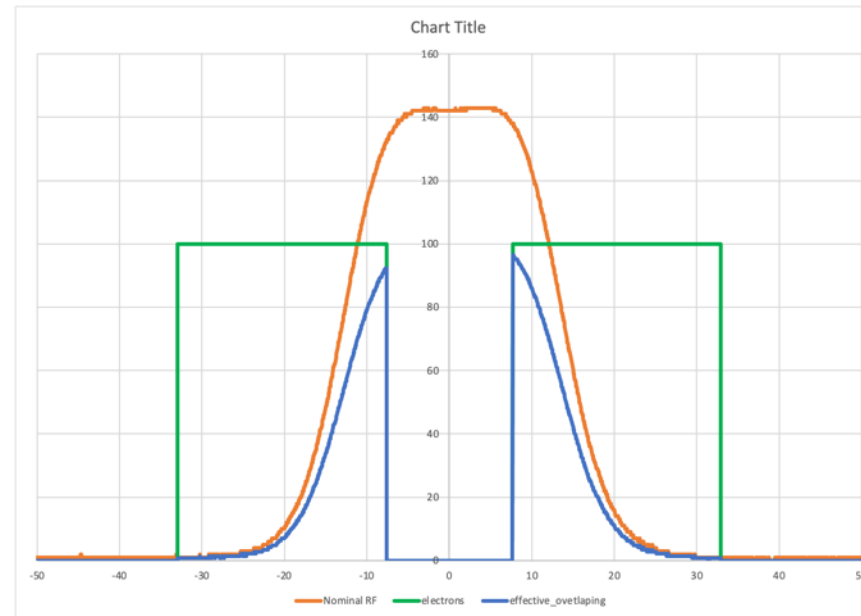
- Need 1-2 hours to study 10b or shorter MB setup
- Kevin prefers to use chunks of 10b. Need to check if shorter MB is possible
- The easier setup we can use 10-10-10 and 20 bunches in the center.

# Update: March ,25 2021:

- We tested 18-11-18 configuration and it's all setup for operation
- The overlapped bunch charge used for interaction is not great. It's only about half in comparison with single MB of 36b
  - It means that for fair comparison we should run twice high current for 18-11-18 (20mA, Qb=60pC) configuration than 36b configuration (10 mA, Qb=30pC)
  - If we can see LEReC linear effects on lifetime (on/off energy ) and heating/cooling at 10mA we should be able to see similar effect on 20 mA
  - For LEReC intensity non-linear effects we should see significant differences if we increase bunch charge by 2 in 18-11-18 configuration.



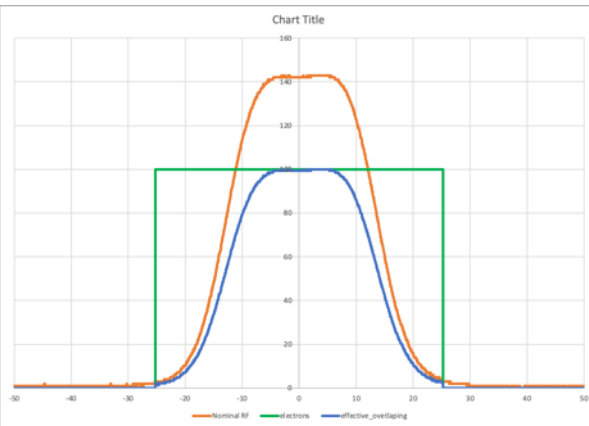
36 bunches, interaction efficiency ~56%



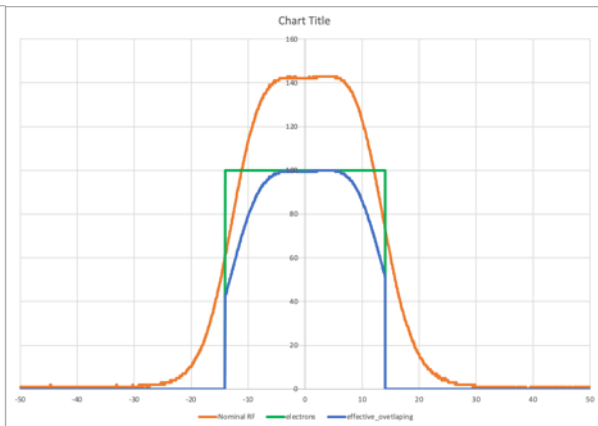
18b-11g-18b, interaction efficiency ~26%

# Update: March ,25 2021 (continue):

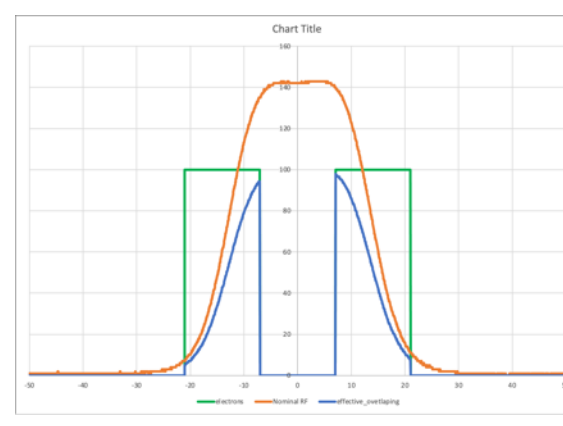
- Kevin confirmed that with current pulse selection system the shortest MB or gap length could be 9b (=12.6nsc)
  - If shorter (5b) MB is desirable It requires significant development time (may be after RHIC run at this energy)
- Then we can compare 36b vs 20b with the about the same bunch charge  $30\text{pC} \cdot 36 \cdot 56\% = 35\text{pC} \cdot 20 \cdot 88\%$
- Or 10b-10g-10b (49% efficiency) vs 10b (~100% efficiency)
  - In order to run 10b in the center we can shift 10-10-10 configuration by 10b then the second MB of 10b will not interact with RHIC bunches
  - Could be done through LLRF laser-timing pet page.



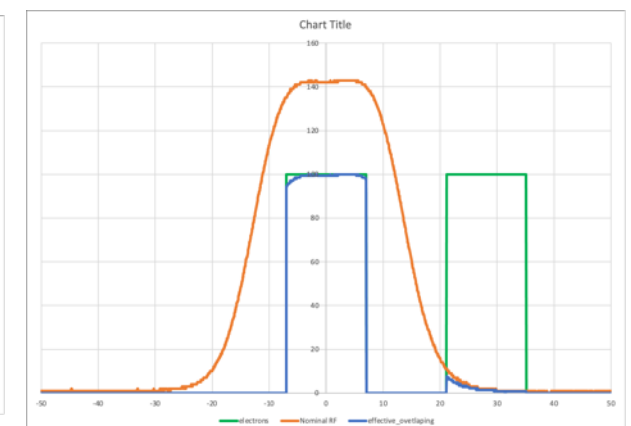
36 bunches, interaction efficiency ~56%



20 bunches, interaction efficiency ~88%



10b-10g-10b, interaction efficiency ~49%



10b-10g-10b (shifted by 10), interaction efficiency ~50%

Results of the new test with better energy matched (Apr 1, 2021).

- Turn off energy feedback
- Use low RHIC intensity
- Optimize energy in nominal 36b configuration
- Run two intensities: 10mA and 8 mA
- Switch to the hollow bunch configuration 18-11-18
- Run two intensities: 16mA and 20mA
- Run with nominal RHIC intensity 18-11-18 (20mA) and 36b (10mA).
  - Cooling is comparable
  - Lifetime was better with nominal configuration of 36b

# Plans for APEX

- In pulsed mode check MB energy distribution (energy spread) of all configurations: 36b, 18b-11g-18b, new 20b and 10b-10g-10b.
- At low intensity conduct cooling/heating/lifetime measurements for 20b, 10b-10g-10b and 10b-10g-10b shifted
- Using regular parabolic ion bucket with close to nominal RHIC operation intensity, optimize CS solenoids to reduce overfocusing of e-bunches setting at the rms size of the ion.
  - Compare results for : centered position vs 10ns shifted position cooling efficiency