# Nonlinearly Shaped Pulses at LCLS-II

Nicole Neveu, Joseph Duris, Randy Lemons, Yuantao Ding, Agostino Marinelli, Charles Durfee[2], Sergio Carbajo[3]

SLAC National Accelerator Laboratory
[2]Colorado School of Mines
[3] Also at UCLA

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SLAC NATIONAL ACCELERATOR LABORATORY

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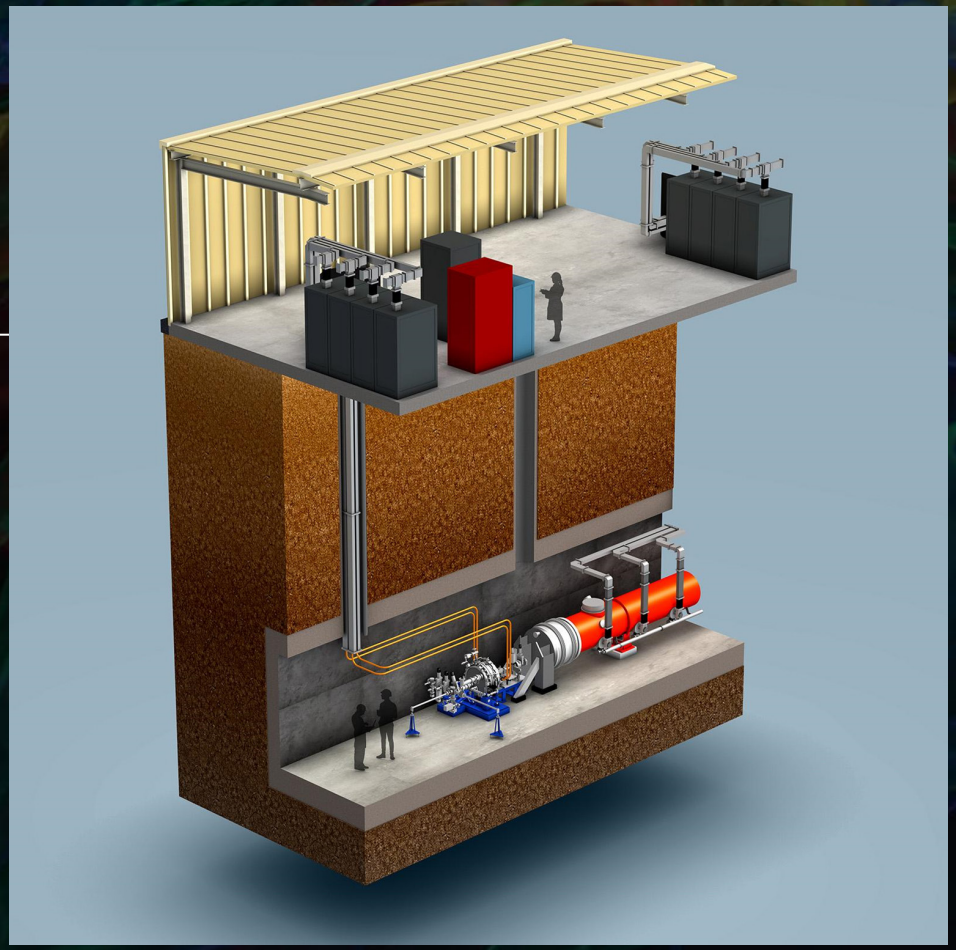
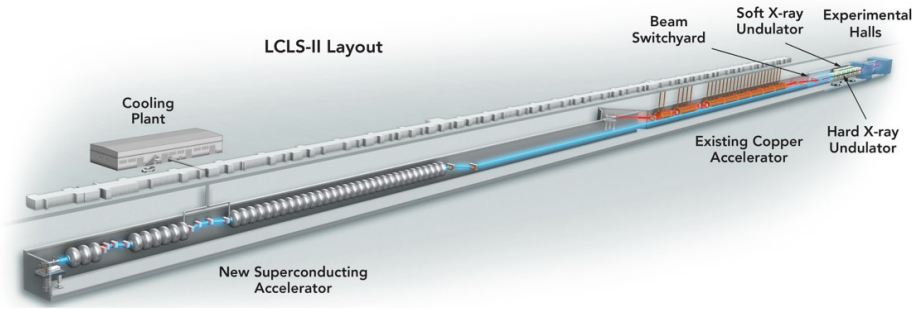
# Overview

- Motivation
- Proposed laser shaping technique
- Beam dynamics studies and optimization (in simulation)



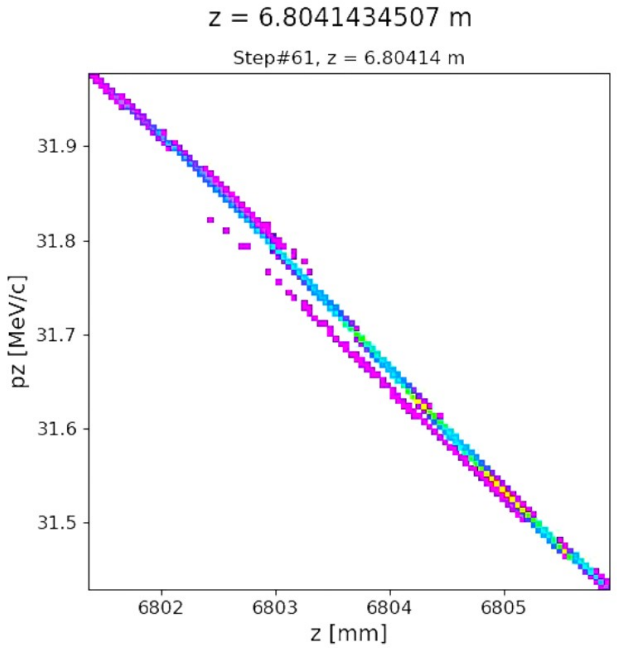
# Motivation



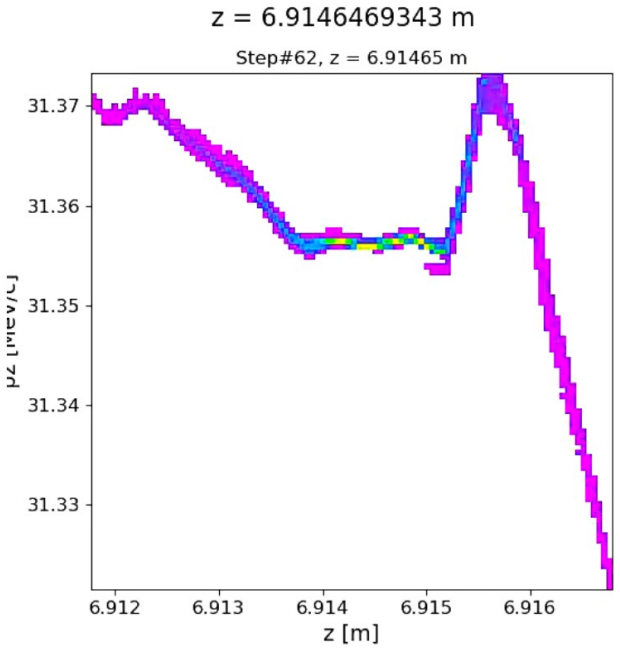

## LCLS–II is currently being commissioned!

However the search for better xrays is ongoing.
One way to accomplish this is better electron beams (smaller emittance, higher energy, lower energy spread, etc)

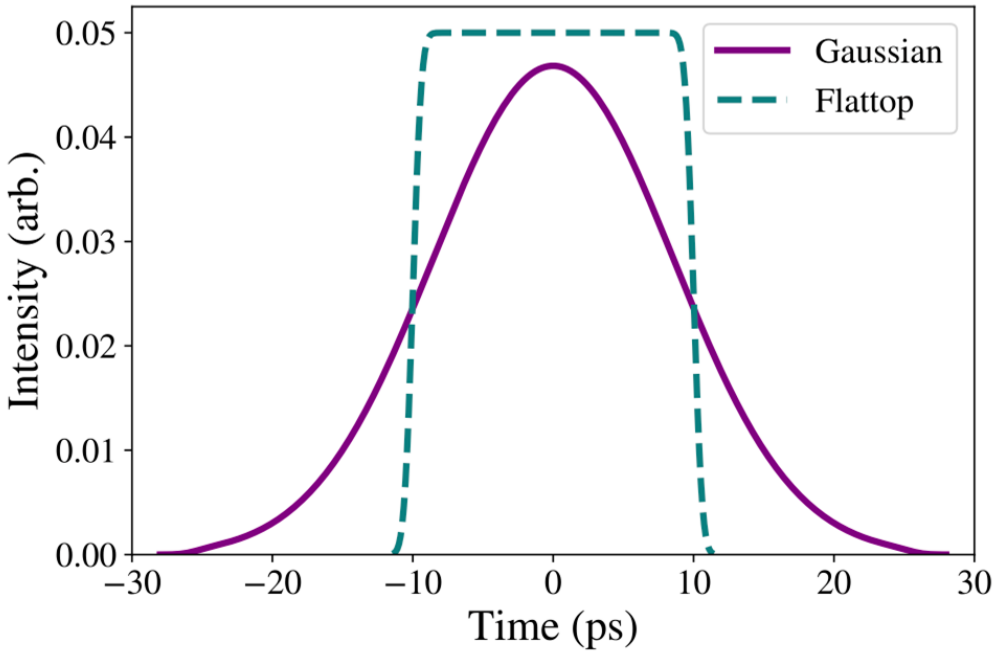
**Gaussian longitudinal phase space:**




**Shaped laser longitudinal phase space:**

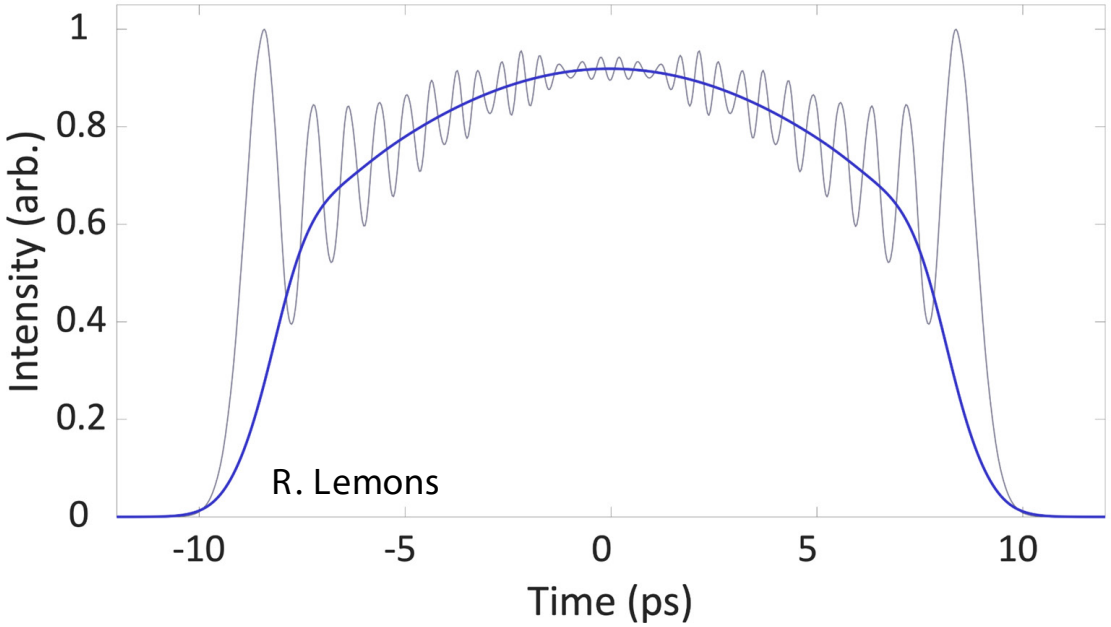


# UV laser pulses at LCLS




## Typical design and working baseline

- LCLS-II is currently running with a Gaussian laser
- FWHM of 20 ps
  - FWHM = full width half maximum




## Proposed shaping: DCNS

- Dispersion controlled non-linear shaping
- Closer to ideal flattop
- Can achieve 20ps FWHM at 1 MHz rep-rate



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# Dispersion controlled non-linear shaping (DCNS)

## Currently being implemented experimentally at LCLS-II

- Second order dispersion (SOD) is used to control pulse duration
- Third order dispersion (TOD) is used to adjust sharpness of rise and fall time

$$\varphi(\omega) = \varphi_0 + \varphi_1(\omega-\omega_0) + \underbrace{\frac{\varphi_2}{2!}(\omega-\omega_0)^2}_{\text{SOD}} + \underbrace{\frac{\varphi_3}{3!}(\omega-\omega_0)^3}_{\text{TOD}} + \frac{\varphi_4}{4!}(\omega-\omega_0)^4 + \cdots,$$

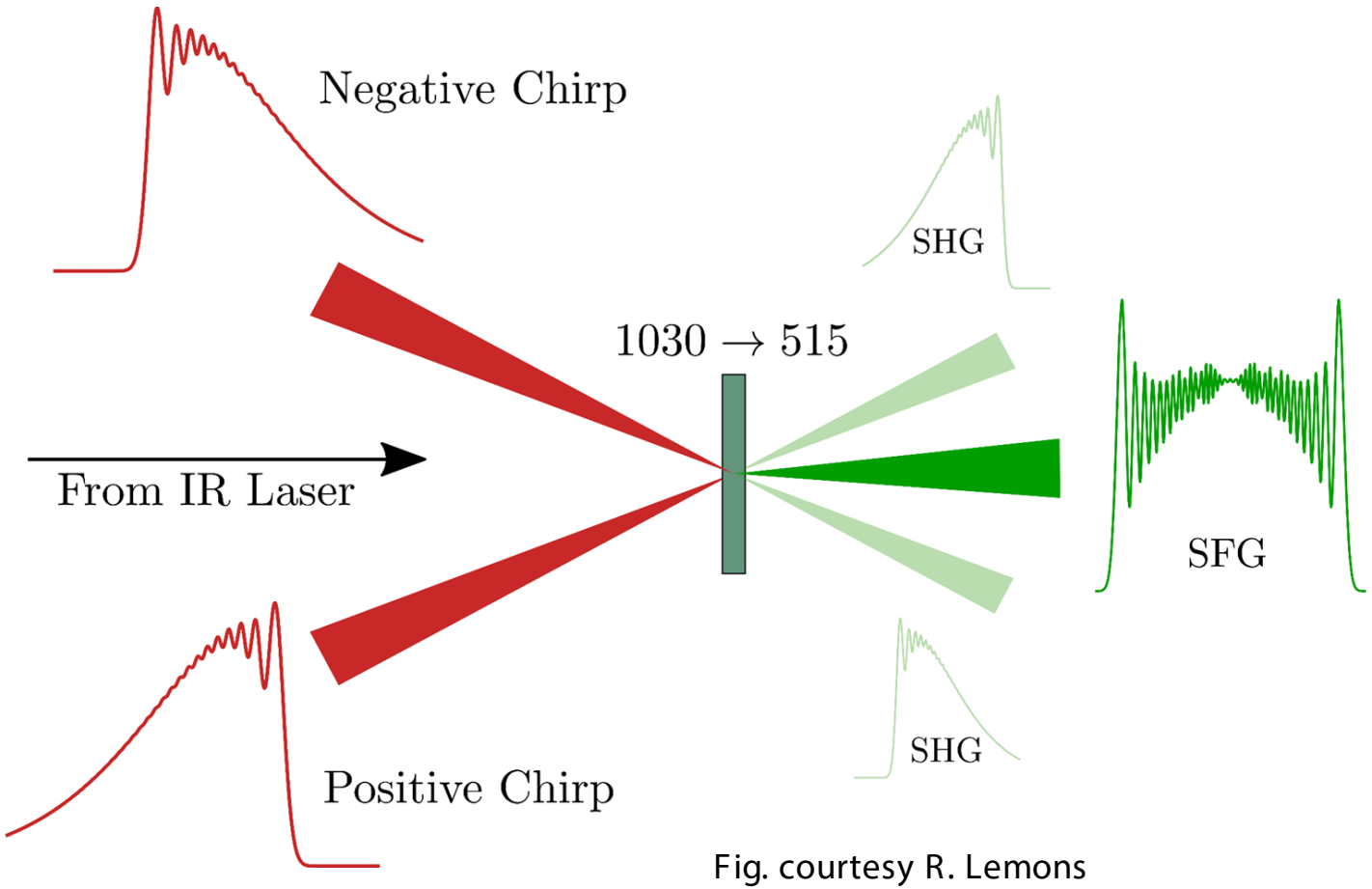
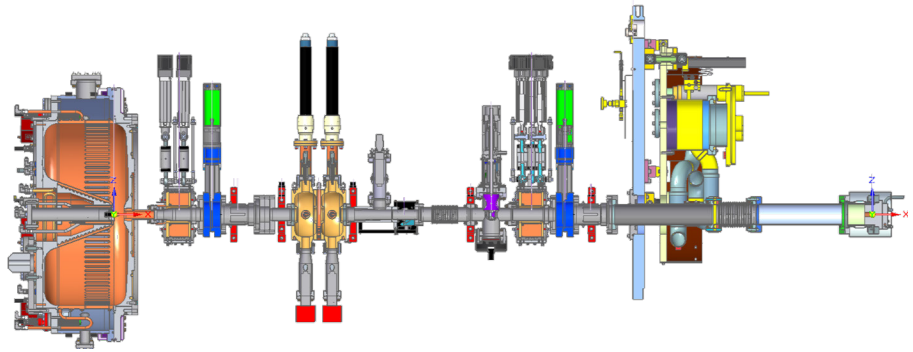



Fig. courtesy R. Lemons

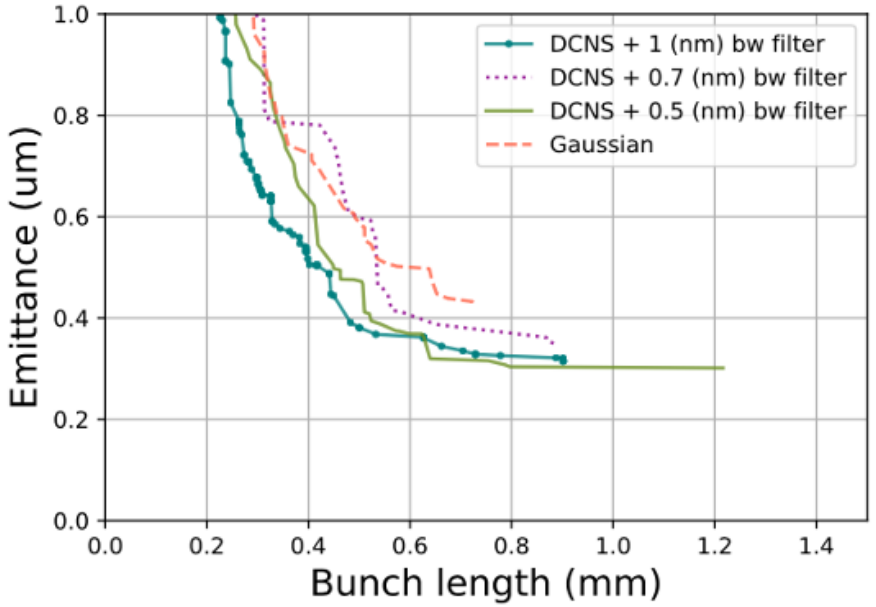
# Photoinjector optimization

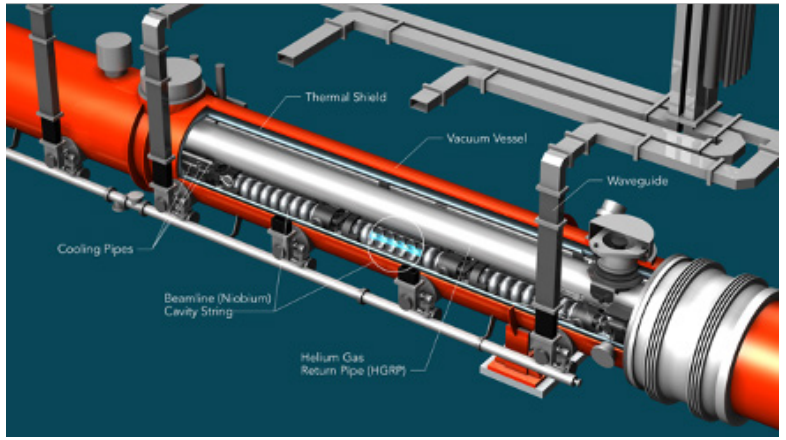
## DCNS achieves lower emittances in simulation

- Simulated photoemission with DCNS shaped laser pulses
- Propagated beam in simulation with space charge through the first cryomodule
- Used NSGA-II to optimize emittance and bunch length at the exit of the cryomodule
  - The beam is ~100 MeV by this location
- DCNS results were compared to a Gaussian baseline
- Used simulation code OPAL:
  - https://gitlab.psi.ch/OPAL/src/-/wikis/home

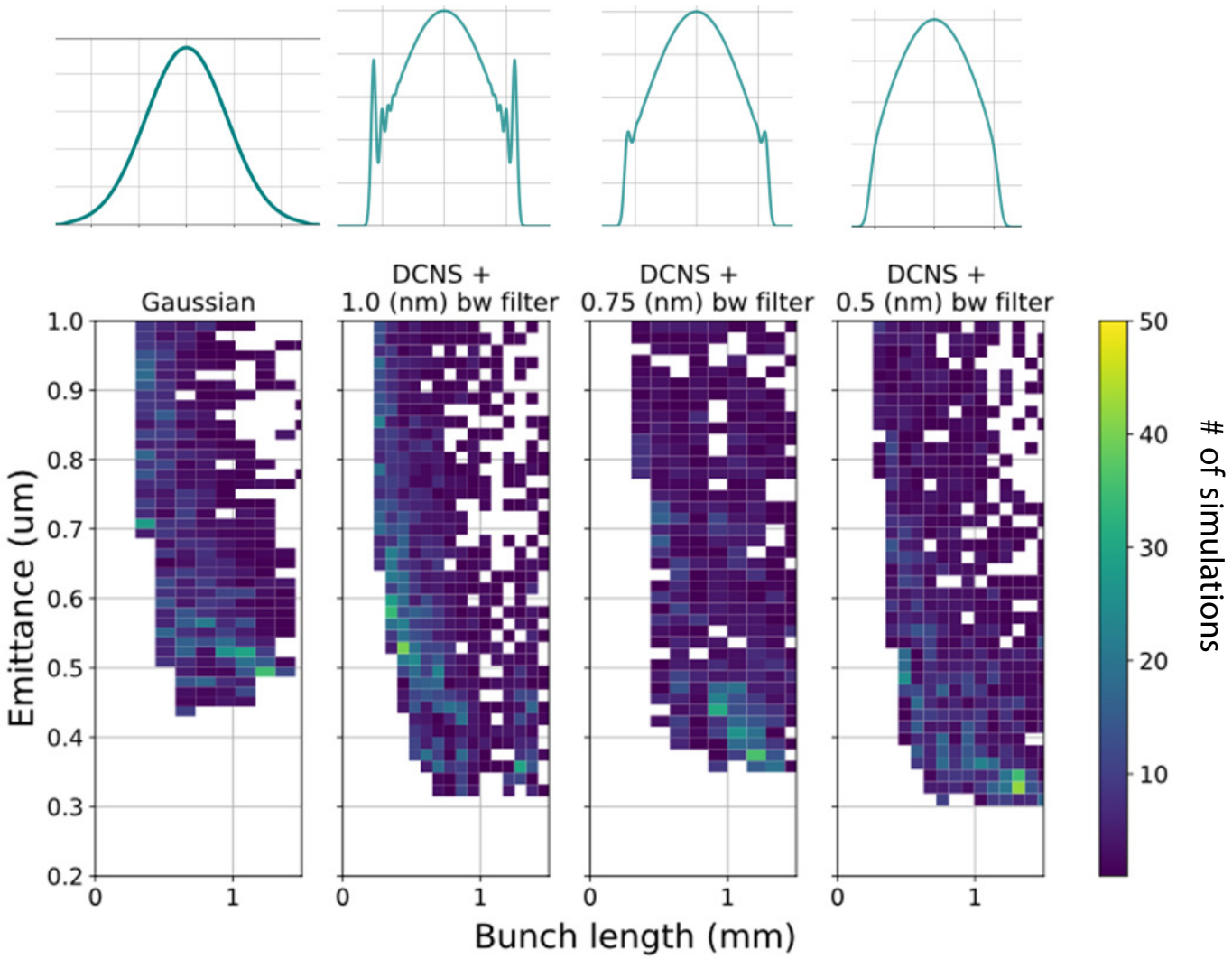


## Gun and first cryomodule results:



# Photoinjector optimization

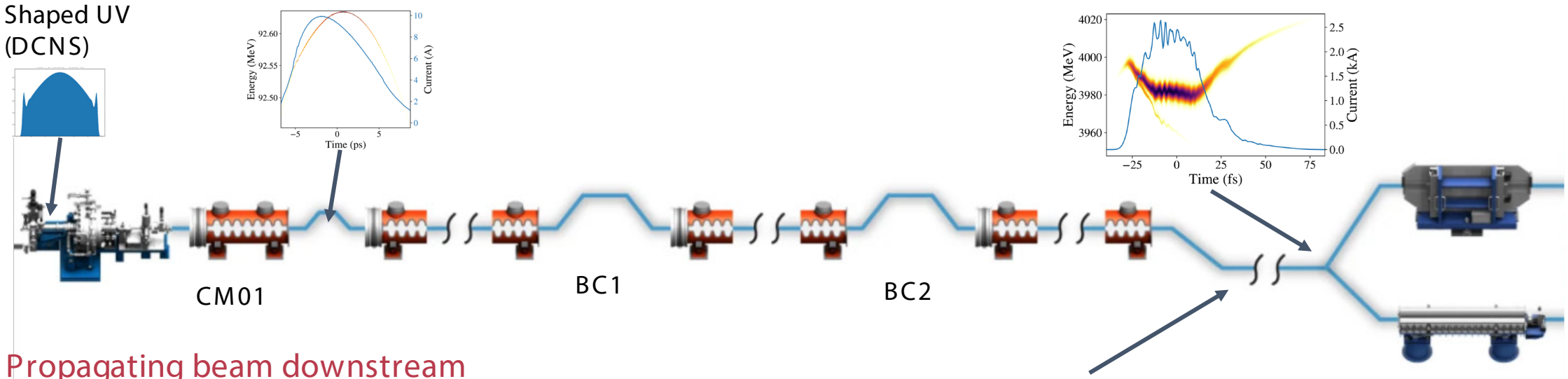



## Potential for increased beam brightness…

- Several UV filter cases were simulated
  - A band pass filter was applied to the DCNS pulses in simulation
- The amount of 'ripples' left in the UV pulse impacted the lowest emittance values
  - Filters can be used as an additional optimization knob
- All filter values achieved lower emittance values than the Gaussian pulses

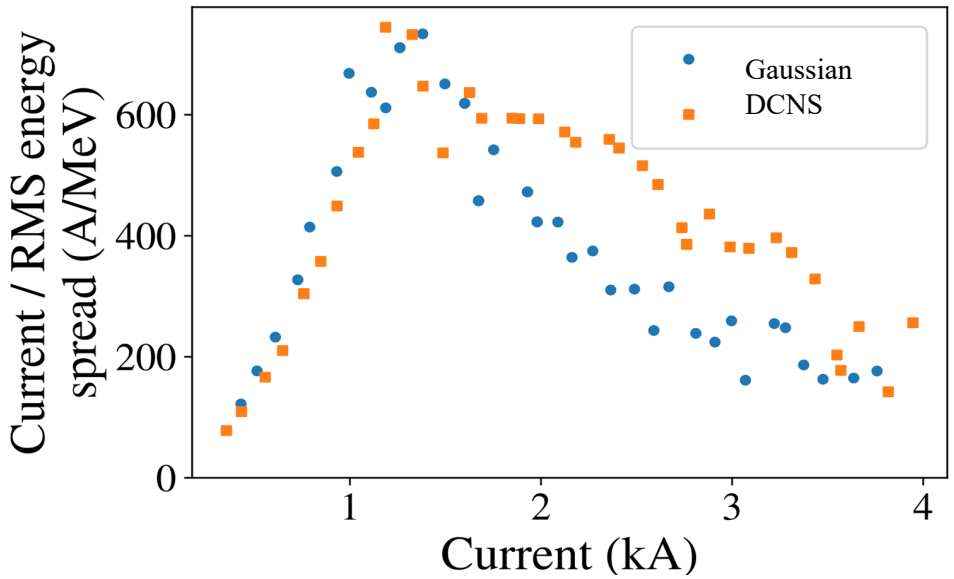
https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.25.013401

# Linac optimization



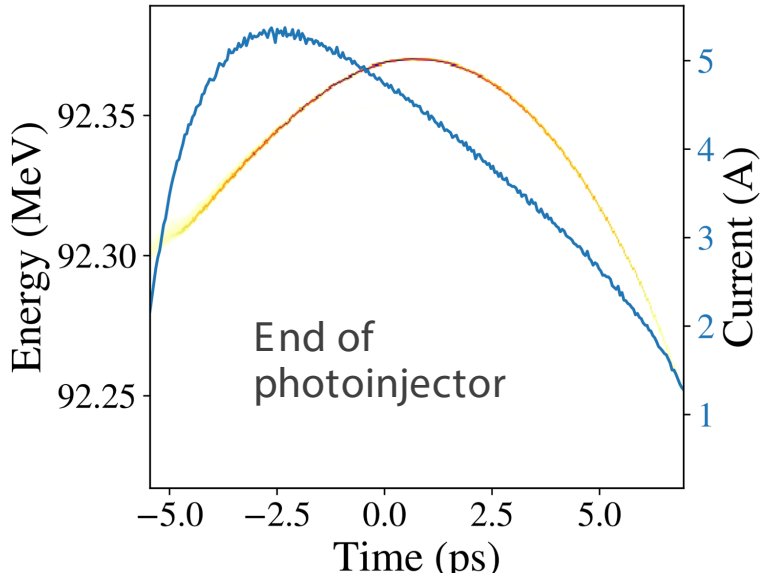

## Propagating beam downstream

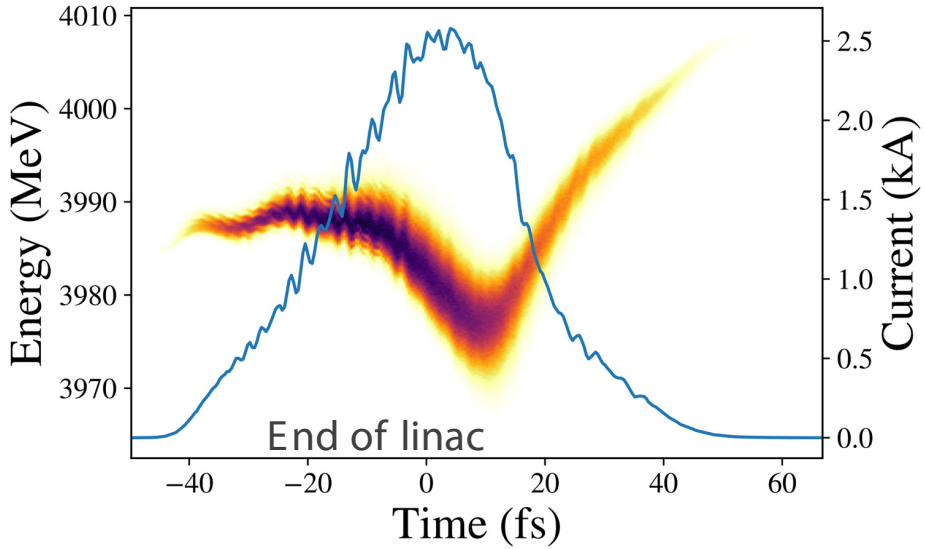
- Using both a Gaussian and shaped UV (DCNS) beam starting at the end of the injector
  - CM01 = Cryomodule 1
  - BC = Bunch compressor
- NSGA-II was used to optimize the current and energy spread at the end of the linac
  - Sliding window was used to measure longitudinal brightness for 70% charge



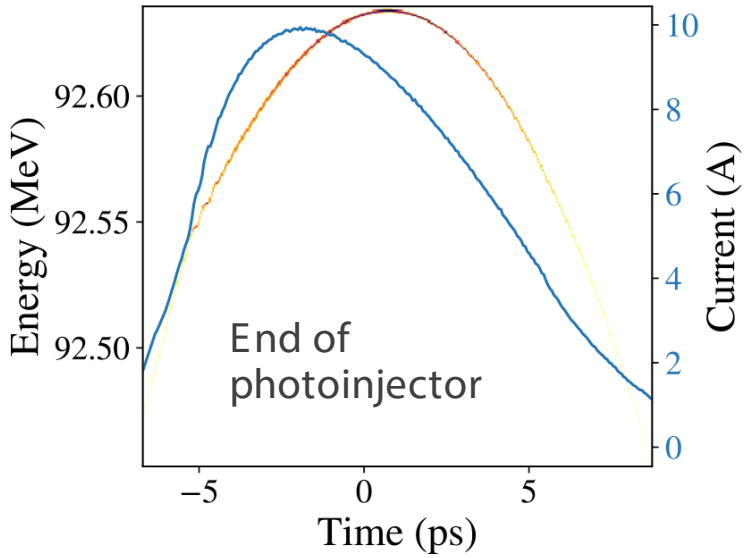
# Linac optimization

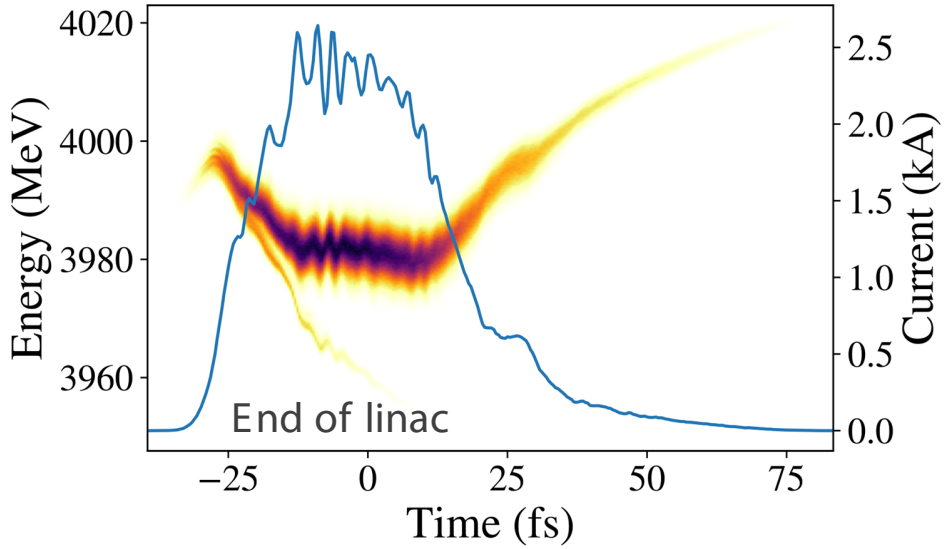
## Gaussian




## DCNS (Shaped UV)



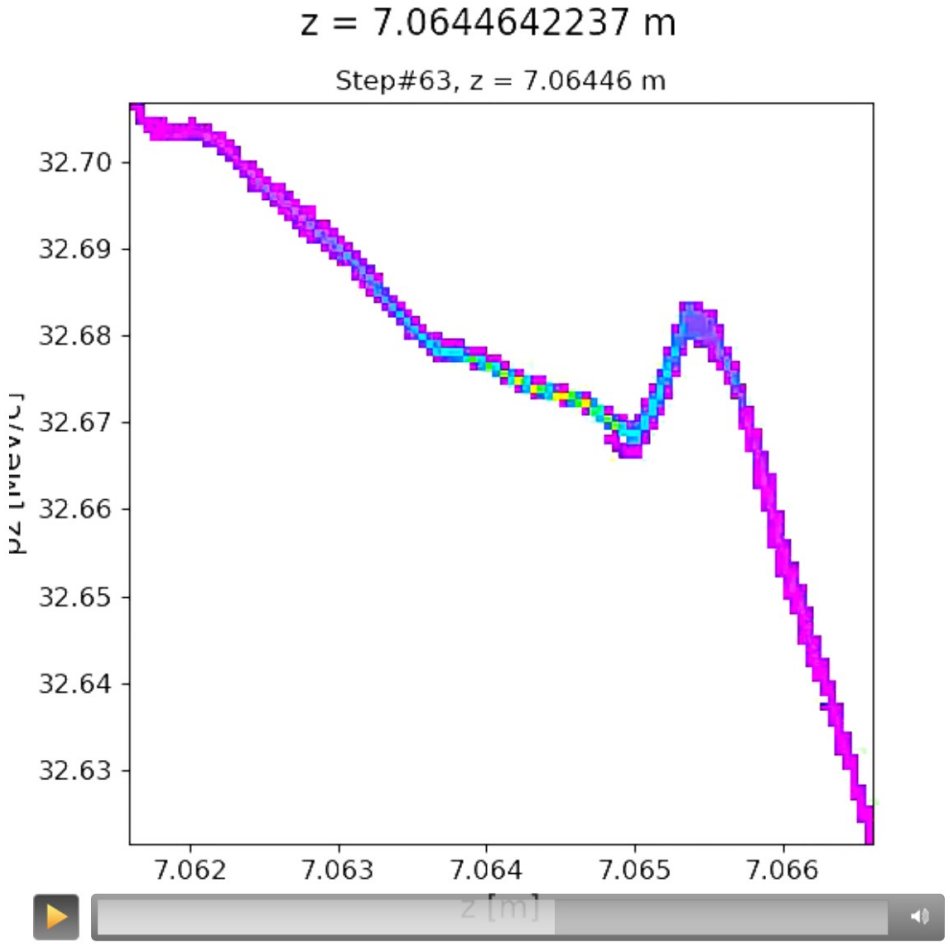
# Conclusion:
# Shaped UV pulses may provide better FEL performance

## Simulation results to date:

- DCNS (shaped UV) pulses may reduce emittance at the end of the LCLS-II photoinjector
- Linac optimization also show promise for higher current beams with lower energy spread
- All results were compared to baseline Gaussian simulations

## Future work:

- Simulate xray emission to determine quality of DCNS after propagation through the linac
- Use experimentally generated UV pulses in simulation to determine if they perform as well as theoretical pulses
    - Laser group is currently installing hardware and taking preliminary measurements



# Thank you!

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