Initial Design of the MaRIE 1.0 X-FEL Linac

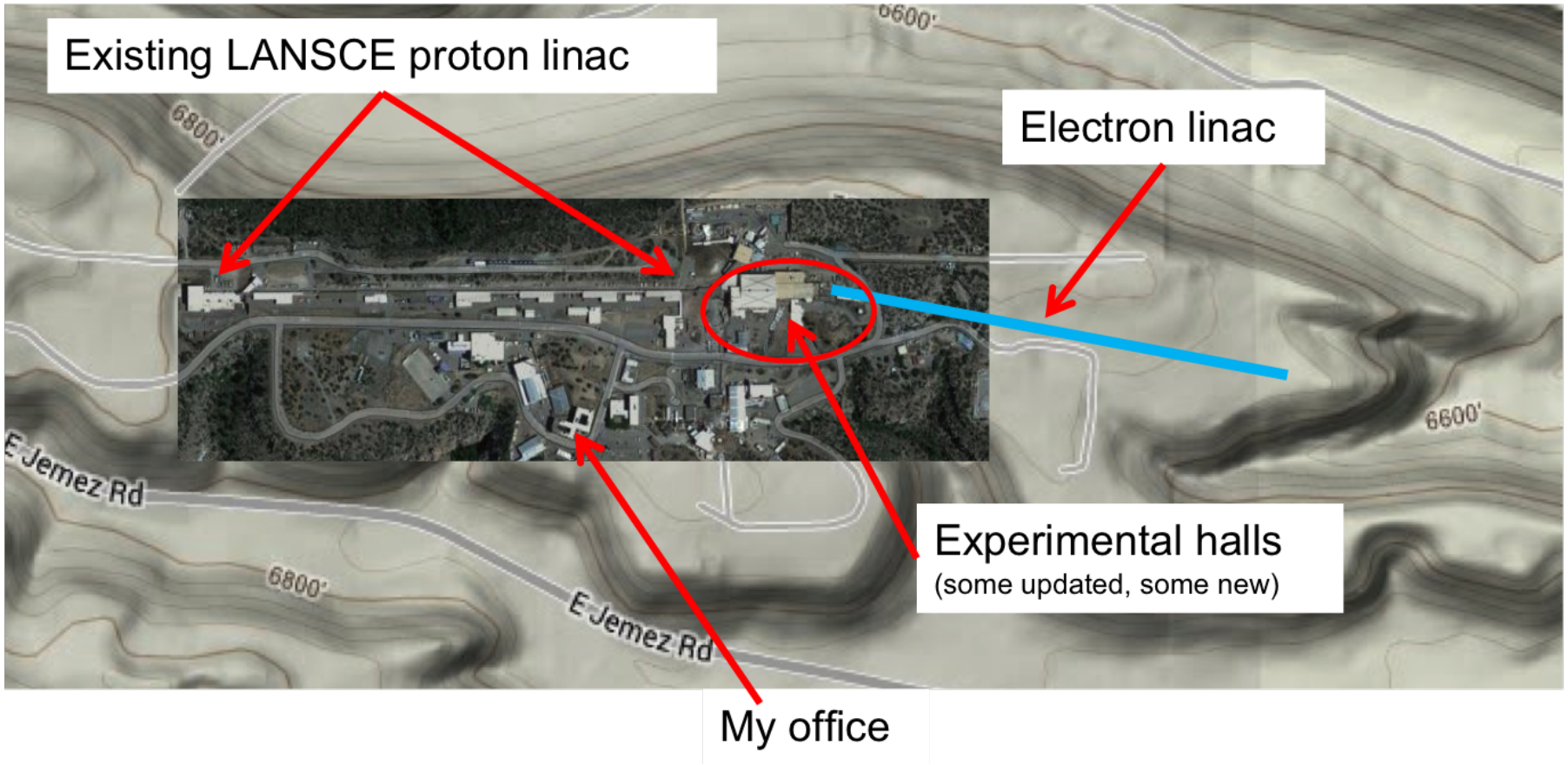
Leanne Duffy, John Lewellen, Bruce Carlsten, Quinn Marksteiner,
Steve Russell, Nikolai Yampolsky

Los Alamos National Laboratory

Overview

- MaRIE X-FEL baseline requirements
- Design challenges
- Linac design to date
- Future work

MaRIE: Matter-Radiation Interactions in Extremes



MaRIE 1.0 X-FEL design goals (challenges)

- Photon energy: 42 keV
- Photons per pulse: $\geq 10^{10}$
- High rep-rates: 30 pulses separated by a minimum of 300 ps up to a maximum of 1 μs
- Pulse length: $<$5 ps
- Bandwidth: 10^{-4}
- Total operational pulse width for one train of 30 pulses: 10 μs

Linac layout

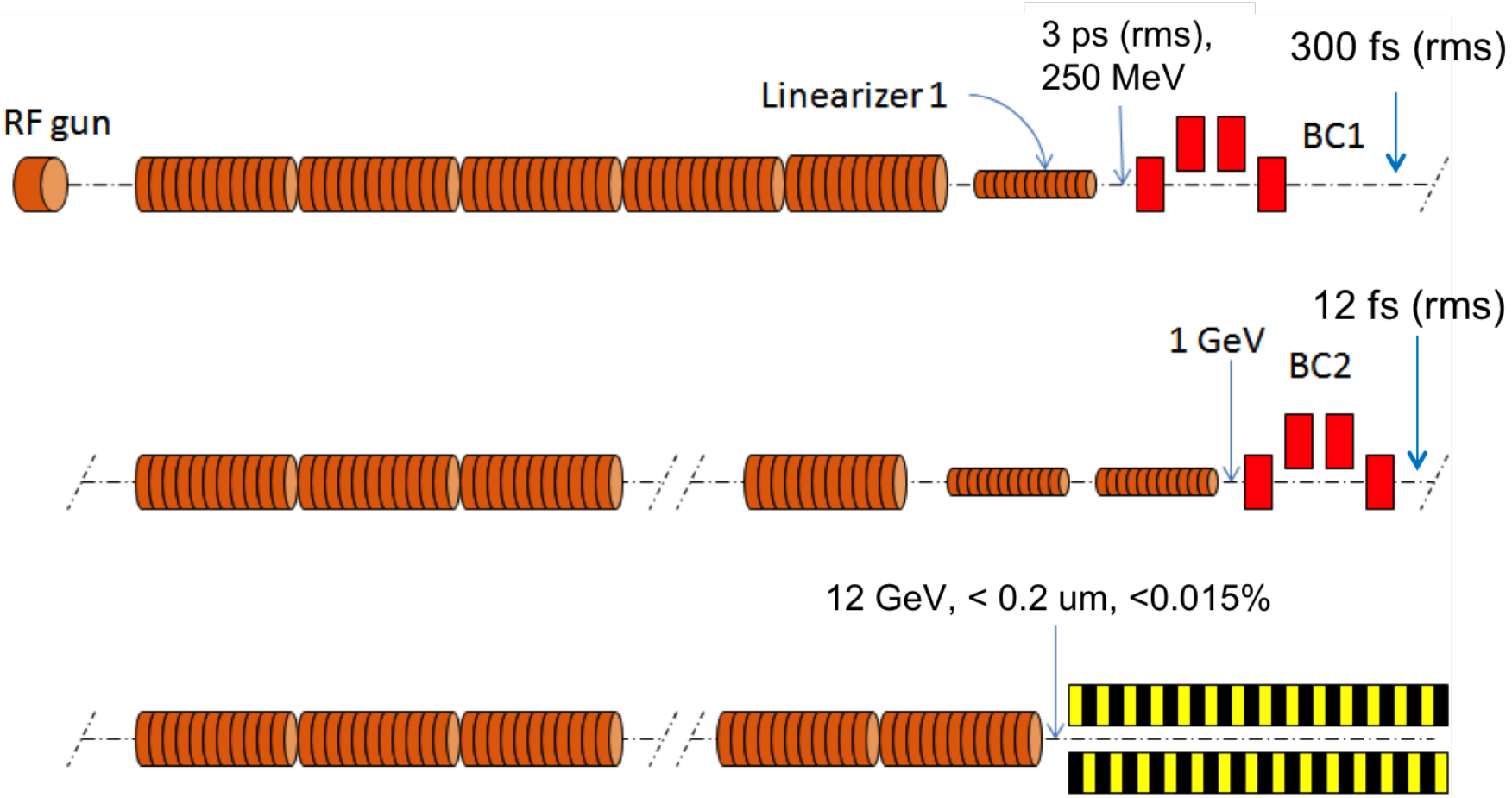
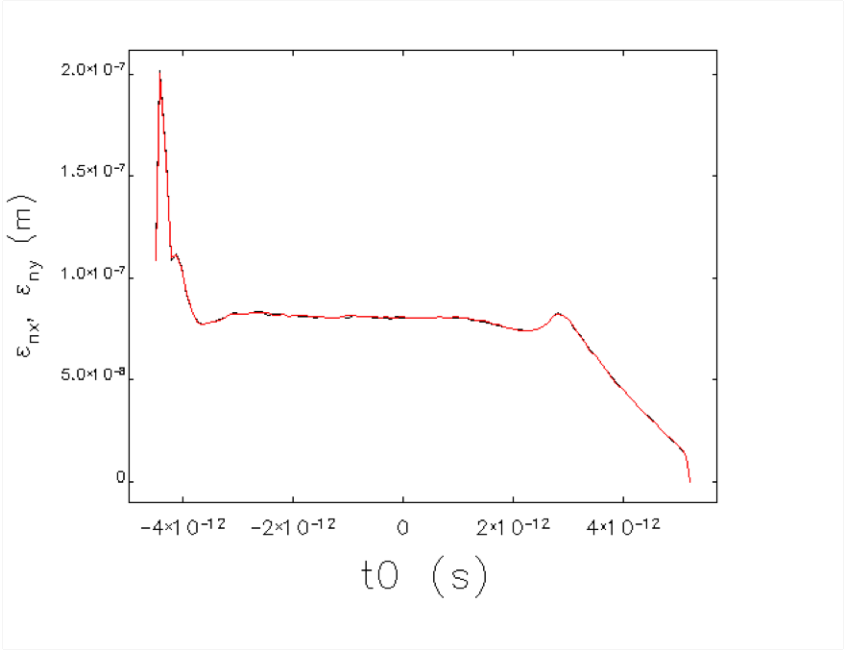
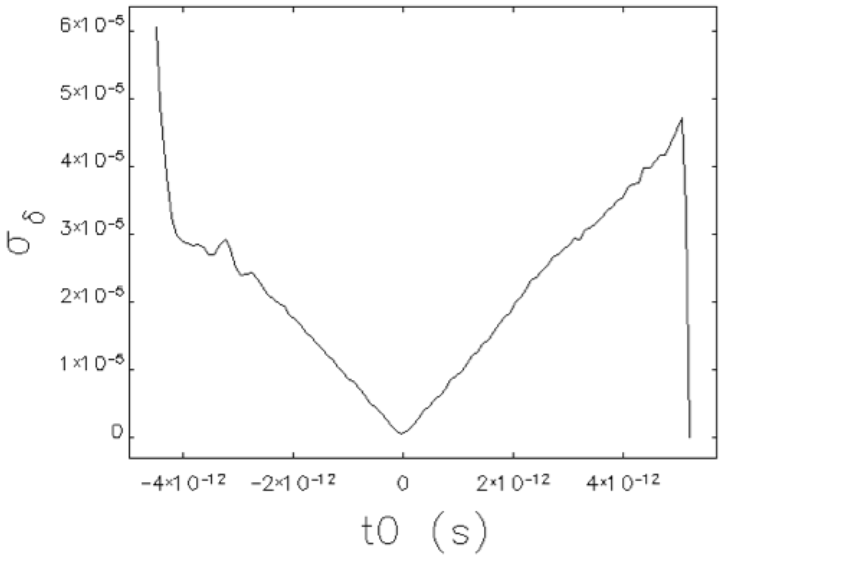


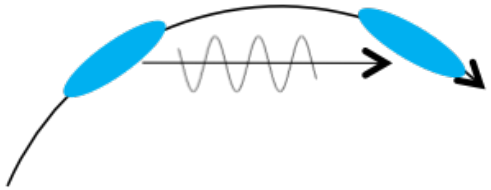
Photo-Injector

- Design by S. Russell (LANL)
- S-band modification of PITZ gun
- Low slice emittance and energy spread at 250 GeV



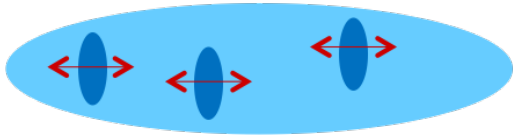


Linac design - charge dependent effects



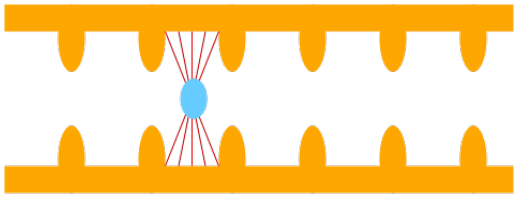
Coherent synchrotron radiation

- Beam in bend interacts with self, changes energy
- "looks like" time-dependent dispersion error



Longitudinal space charge

- Local energy modulation due to local charge density modulation
- More noticeable in "cold" beams

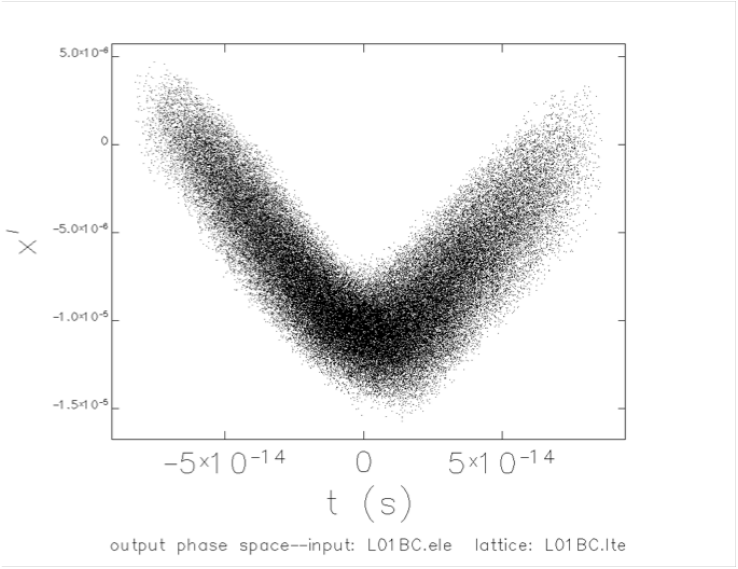


Linac wakefields

- Tail of bunch"droop" in energy
- Transverse kicks if bunch is off-center

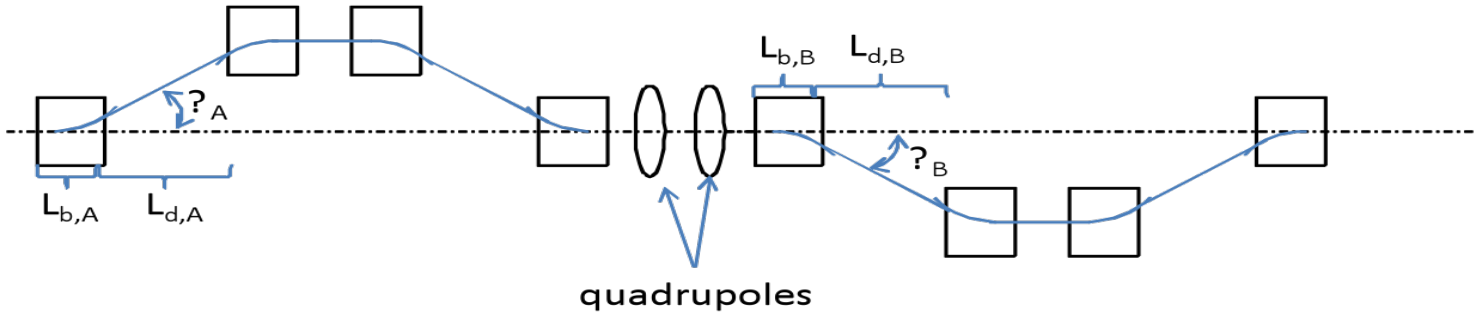
CSR mitigation

CSR generates a "chevron" in t-x' space after a chicane:



Strategies:

- Lower R_{56}: smaller bends, longer drifts
- Undercompress
- Adjust focusing
- Use wakes to help remove residual energy spread
- Use a double reversed chicane to help reduce the "chevron":



LSC mitigation

Problem:

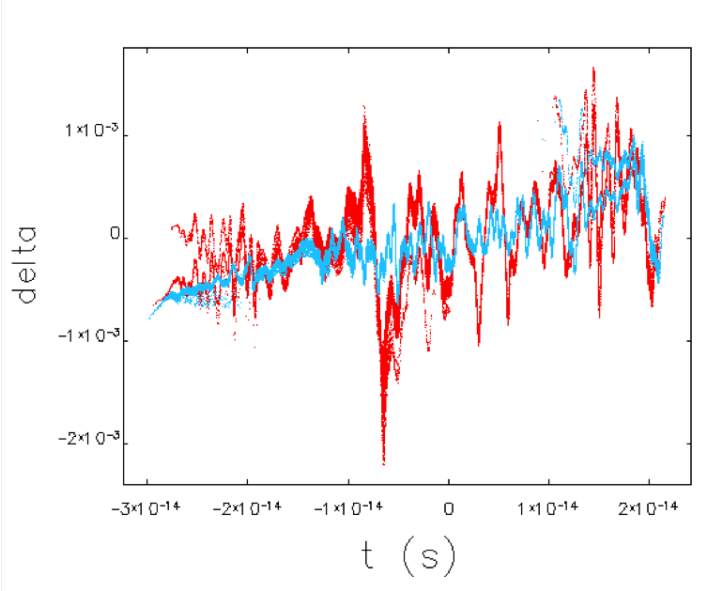
- Causes energy modulation that becomes density modulation in bunch compressors
- Density modulation enhances CSR
- Can't use laser heater - energy spread too great, reversible needs accurate phase control

Strategy:

- Increase dispersion to prevent significant energy modulation
- Chang, Mitchell and Venturini (LBNL) initially proposed
- Yampolsky (LANL) suggested using dispersion-uncorrected dogleg to achieve
- Lewellen shortened last leg of BC1 to implement for MaRIE X-FEL

Simulation shows mitigation works

Longitudinal phase space at 12 GeV:



Without dispersion

With dispersion

- Addition of dispersion shows less energy modulation along the bunch
- Double chicane bunch compressors prevent development of bunch "chevron"
- Linac design with Genesis simulations show we meet MaRIE 1.0 X-FEL requirements

Future refinements

Future work aims to:

- Reduce overall momentum chirp
- Return the beam to the centerline
- Address the residual dispersion
- Retune the linac after the RF structure downselect (currently assuming SLAC-type 3 m structures)
- Address sensitivity
- Consider novel schemes for overall improvement

Thanks to..

- Our LANL colleagues: Petr Anisimov, Ron Barber, Pat Colestock, Henry Freund, Frank Krawczyk, Larry Rybarcyk, Rich Sheffield
- Collaboration with SLAC on structure and klystron design choices
- Discussions with colleagues at LBNL
- Michael Borland and Bob Soliday at Argonne

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