Controlled Density Perturbations Studies on Longitudinally Uniform Beams in the Advanced Superconducting Test Accelerator (ASTA)

University of Maryland

Institute for Research in Electronics and Applied Physics

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IREAP

Outline

- **Collaborative support**
- **Controlled perturbation studies on uniform e-beams (UMD)**
  - Space-Charge waves
  - Soliton wave trains
- **Using BBO Crystals to optically create various longitudinal distributions with perturbations**
- **ASTA Experiments**

Collaborative Support

Recently Announced **Kiersten Ruisard** won the NSF Graduate Research Fellowship Award

To work on IOTA related physics using UMER

Student at Last ASTA Users Meeting.

NSF supports UMD-Fermilab collaboration at IOTA

In Fermilab Today

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- Director's Corner
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Mishra, U.S. Technical Coordinator, Discovery Science Collaboration; Fermilab Director Nigel Lockyer. Not pictured: India Consul Debashish Banerjee, Chicago. *Photo: Reidar Hahn*

In the News

URA funds University of Maryland's ASTA proposal

From *ASTA Newsletter*, April 2014

A research proposal to investigate controlled density perturbations on a high-brightness electron beam at the ASTA has been selected for funding by University Research Association (URA). The proposed work by the University of Maryland scientist Dr. Brian Beaudoin in collaboration with Dr. Jayakar 'Charles' Thangaraj of Fermilab will involve experimentally investigating how density modulations introduced at the beginning of the accelerator evolve in a linear accelerator.

Read more (see page 3)

In the News

The DZero authorship committee keeps track of all members of the collaboration, ensuring that everyone does their fair share of service work before they are rewarded with a place on the author list for new publications. Service work covers a wide range of essential activities, including building or maintaining parts of the detector, designing and implementing essential software tools, and reviewing and editing the papers themselves.

Announcements

Today's New Announcements

English country dancing - May 4

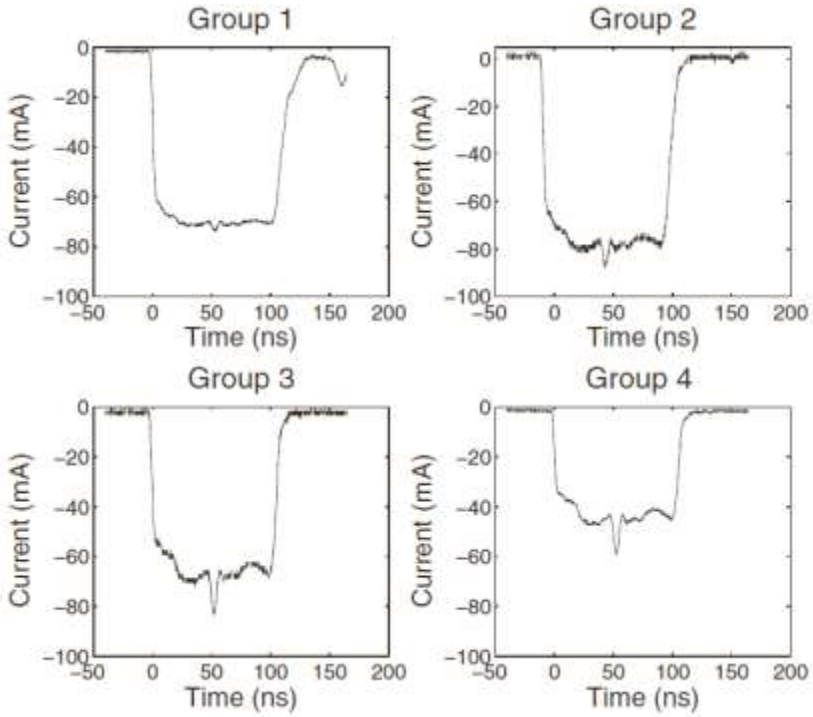
Universities Research Association, Inc.

URA supports UMD-Fermilab collaboration at ASTA

Controlled Perturbation Studies on Uniform Electron Beams

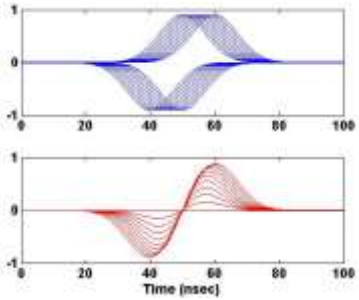
Perturbations to Beams

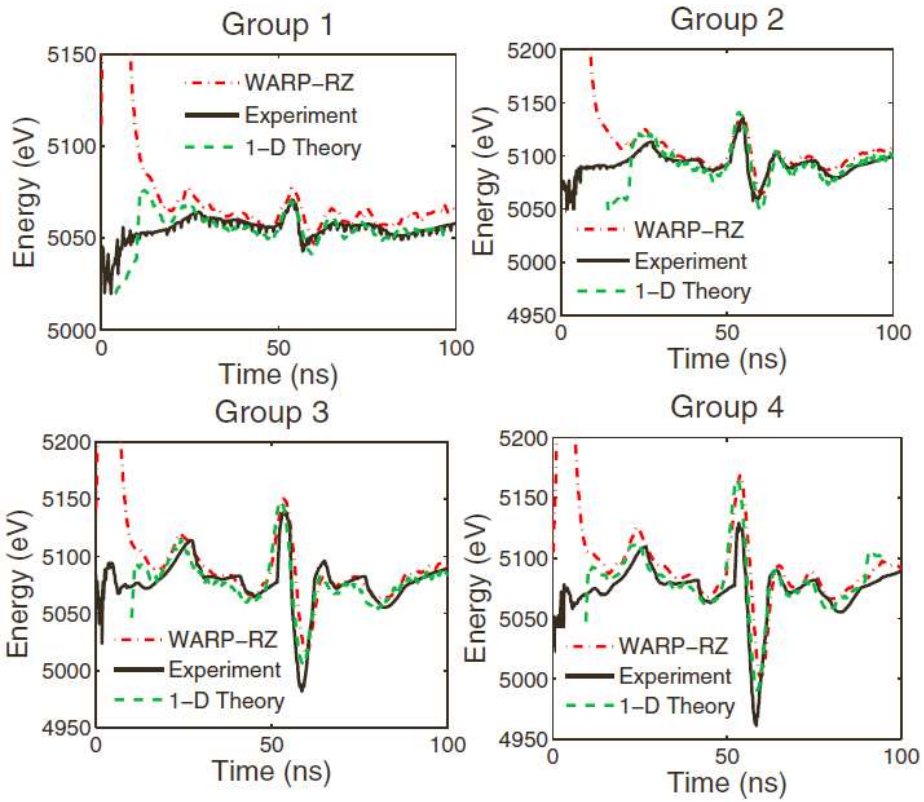
Four Different Perturbation Cases



Good agreement between Experiments, 1D code and full PIC code (WARP)

Density/Velocity Wave Separation





-K. Tian, Y. Zou, Y. Cui, I. Haber, R.A. Kishek, M. Reiser, and P.G. O'Shea, Physical Review Special Topics - Accelerators & Beams, **9**, 014201 (2006).

Propagation of Space-Charge Waves

Perturbations are placed onto rectangular (Flat-top) beams

$$c_s = \left(\frac{qg\lambda_o}{4\pi\varepsilon_0 \gamma_0^5 m} \right)^{1/2}$$

$$\lambda_1(z,t) = \mp \frac{\lambda_o}{2}\left[\delta \frac{v_o}{C_s} \mp (\eta - \delta)\right] p\left(t - \frac{z}{v_o \mp C_s}\right)$$

$$v_1(z,t) = \frac{v_o}{2}\left[\delta \mp (\eta - \delta)\frac{C_s}{v_o}\right] p\left(t - \frac{z}{v_o \mp C_s}\right)$$

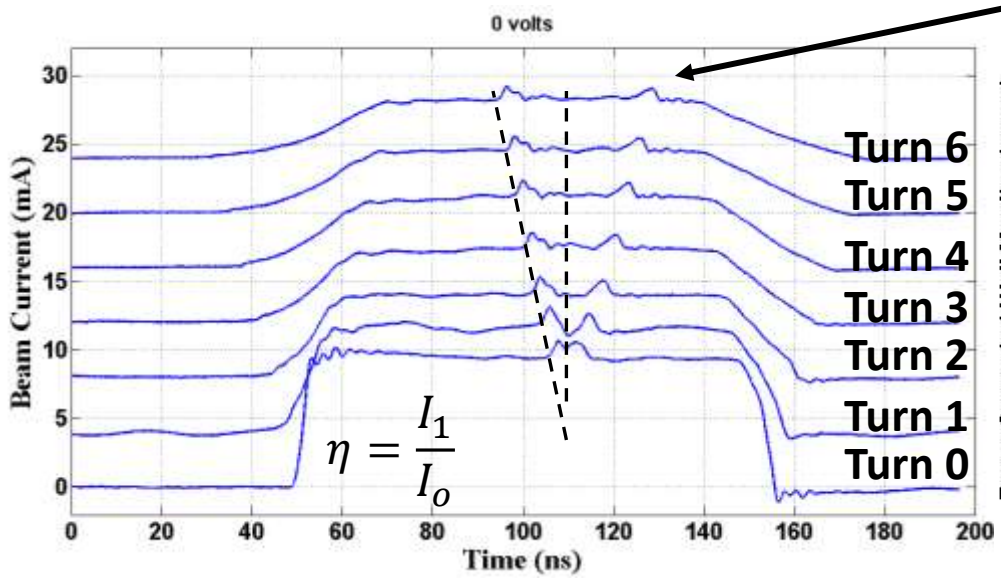
$$I_1(z,t) = \mp \frac{I_o}{2}\left[\delta \frac{v_o}{C_s} \mp \eta + (\eta - \delta)\frac{C_s}{v_o}\right] p\left(t - \frac{z}{v_o \mp C_s}\right)$$

Perturbation

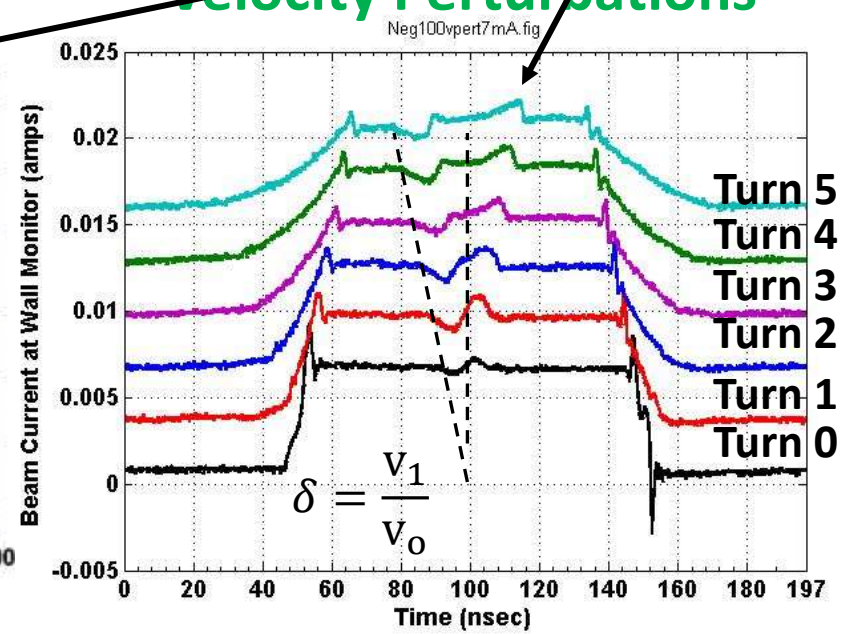
Beam

Wave steepening with sufficient perturbation amplitude

Density Perturbations



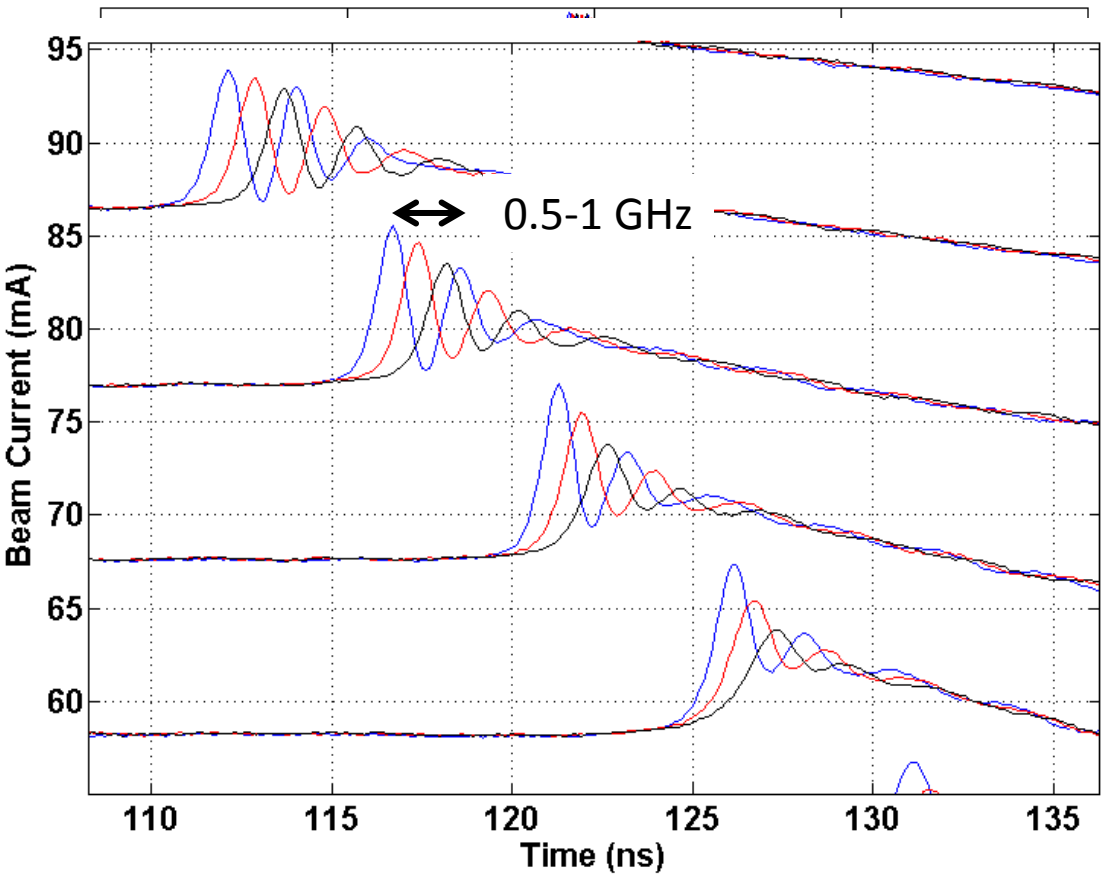
Velocity Perturbations



-Jayakar C.T. Thangaraj, Brian Beaudoin, Donald Feldman, Rami Kishek, Santiago Bernal, David Sutter, Martin Reiser, and Patrick O'Shea, Proceedings of 13th Workshop on Advanced Accelerator Concepts (AAC), Santa Cruz, CA, July/Aug, 2008, (New York: AIP Press **1086**, 2009), p. 732.
-B.L. Beaudoin, S. Bernal, I. Haber, R.A. Kishek, P.G. O'Shea, M. Reiser, J.C.T. Thangaraj, K. Tian, M. Walter, and C. Wu, *PAC*, 2322 (2007).

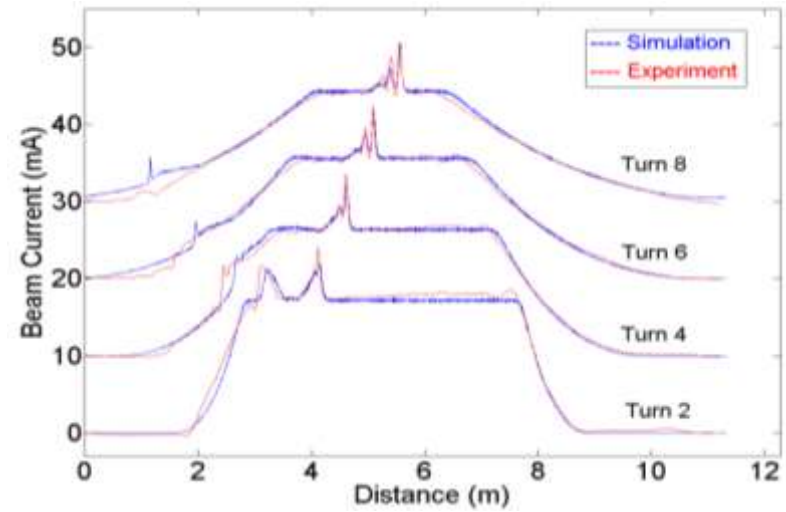
Solitary Wave Trains (PRL,2013)

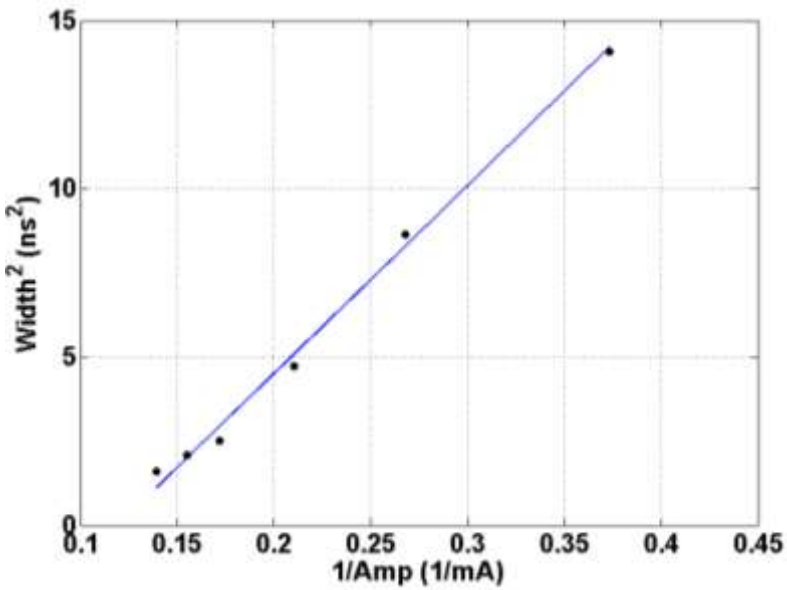
Positive velocity perturbation



Blue curve – 369 v
Red curve – 322 v
Black curve – 277 v

(WARP and Experimental Comparison)

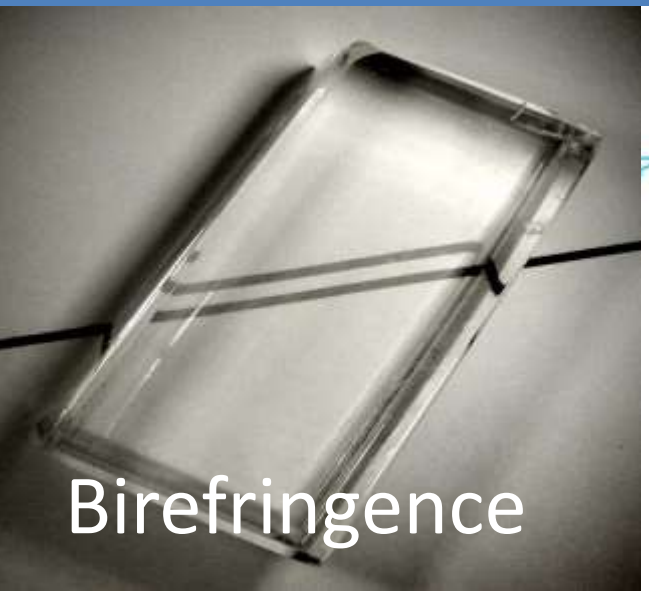


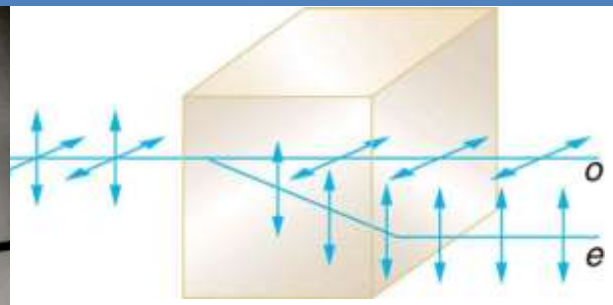


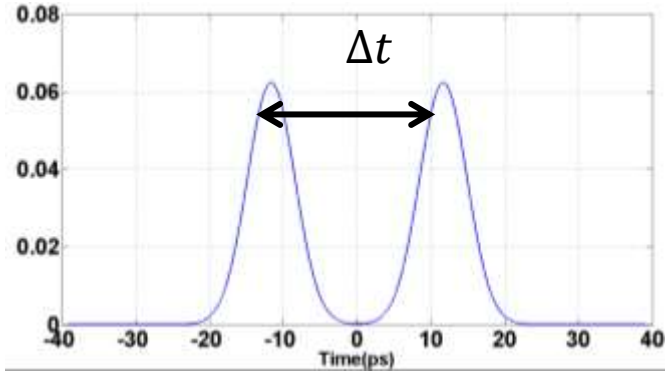
-Y.C. Mo, R.A. Kishek, D. Feldman, I. Haber, B. Beaudoin, P.G. O'Shea, and J.C.T. Thangaraj, *"Experimental Observations of Soliton Wave Trains in Electron Beams,"* Physical Review Letters **110**, 084802 (2013).

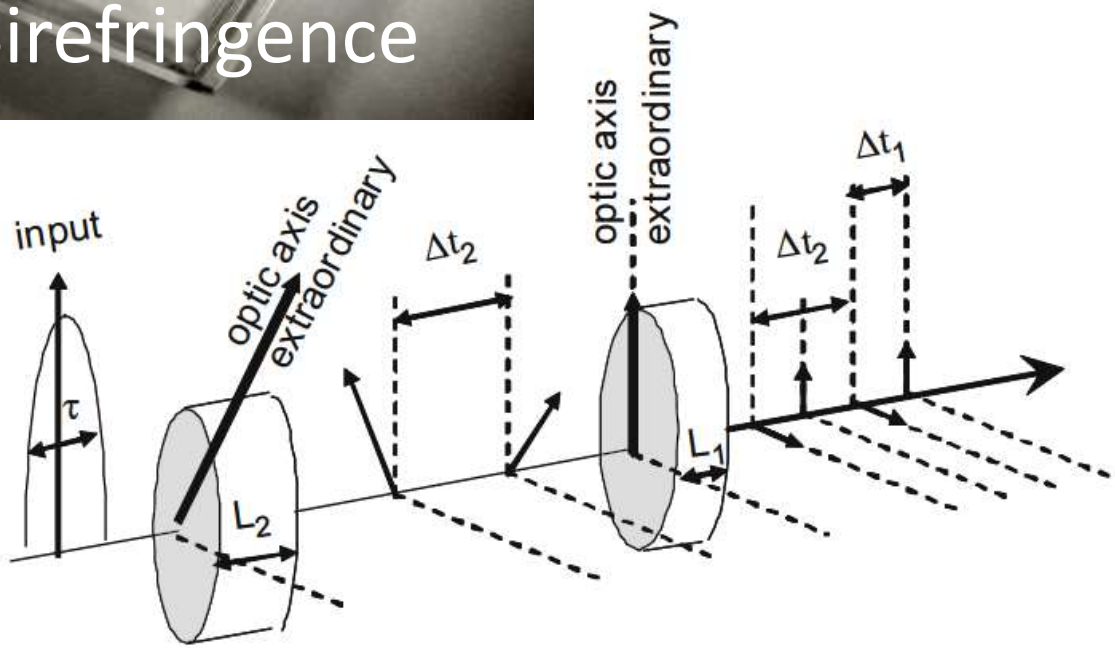
Longitudinally Shaping of the Beam using ASTA Laser

Temporally Shaping the Laser Beam using Birefringent Crystals









Time separation

$$\Delta t = L\left(\frac{1}{v_{ge}} - \frac{1}{v_{go}}\right)$$

Group velocities of the two pulses

$$v_{ge} = c/n_{ge}$$

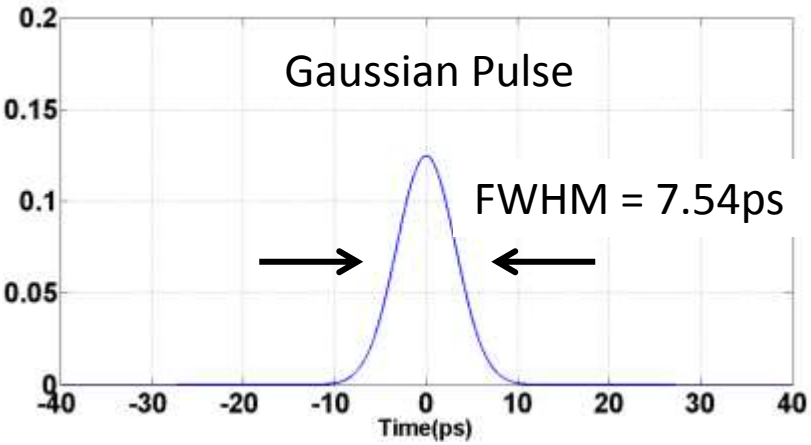
$$v_{go} = c/n_{go}$$

-J.G. Power, C. Jing, I. Jovanovic, "High Frequency Bunch Train Generation from an RF Photoinjector at the AWA", Proceedings of the 2009 Particle Accelerator Conference, Vancouver, 2009 (IEEE, New York, 2009).
-http://cnx.org/

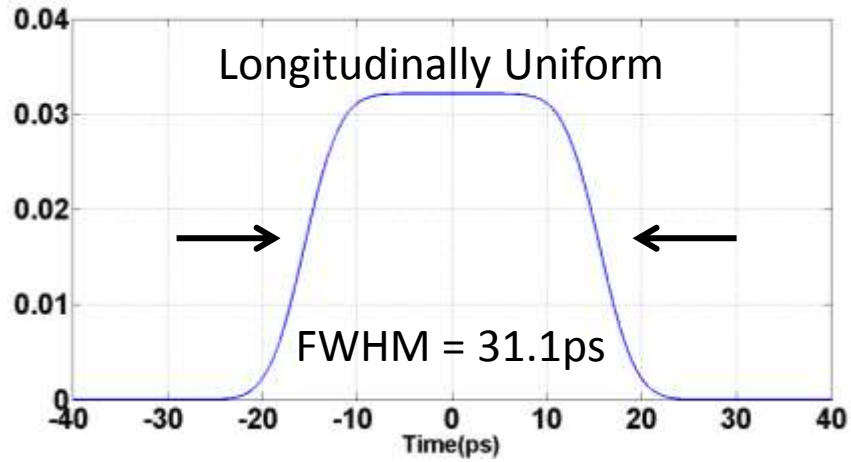
Various Temporal Pulse Shapes

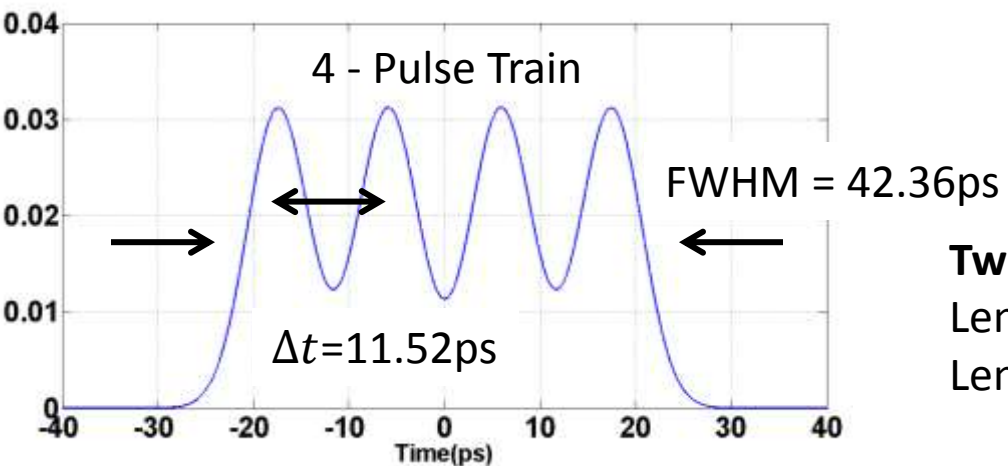
Analytical Calculations

Nominal laser pulse



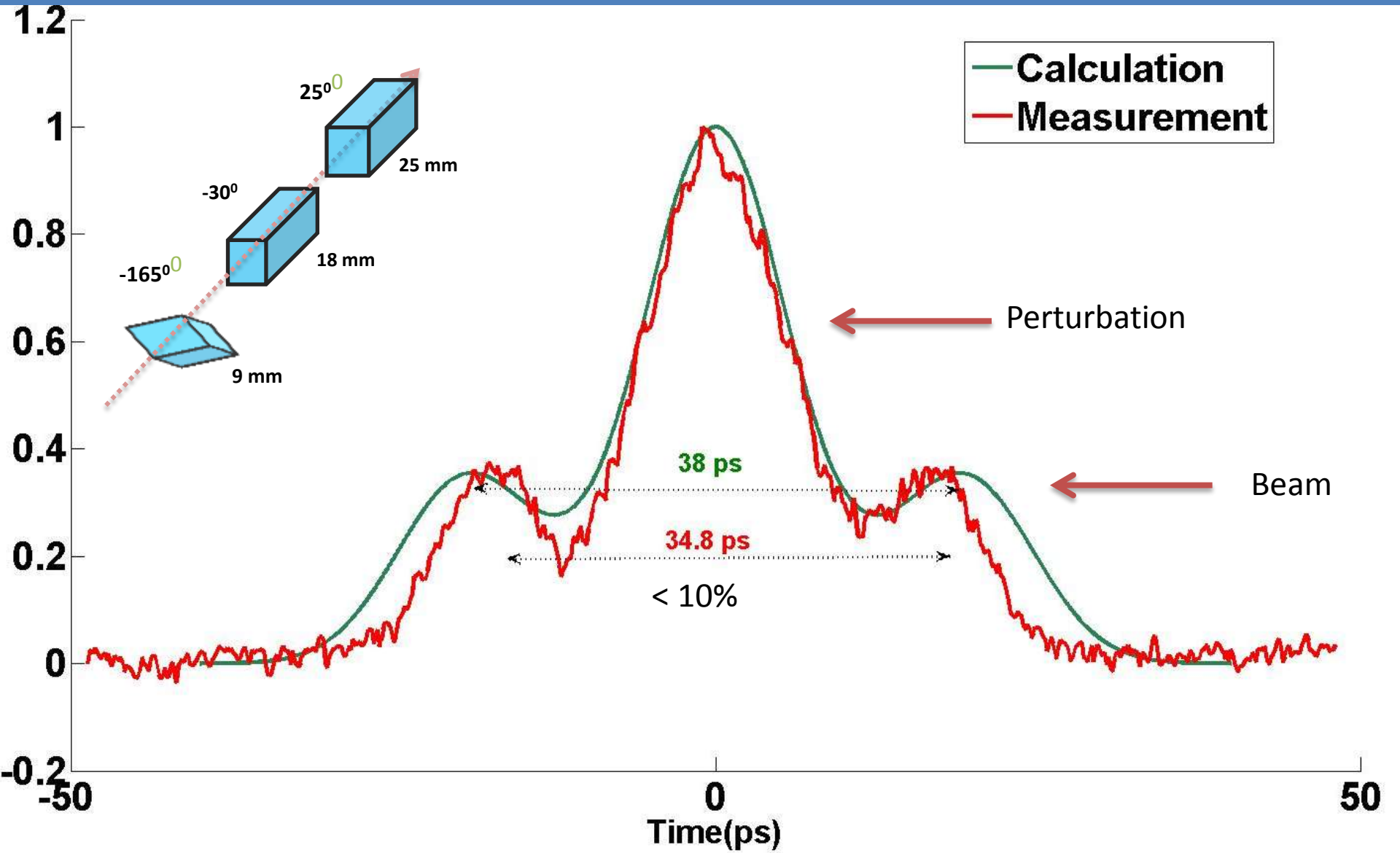
Three Crystals
Length 1 = 18.0mm, 45°
Length 2 = 9.0mm, 45°
Length 3 = 4.5mm, 45°



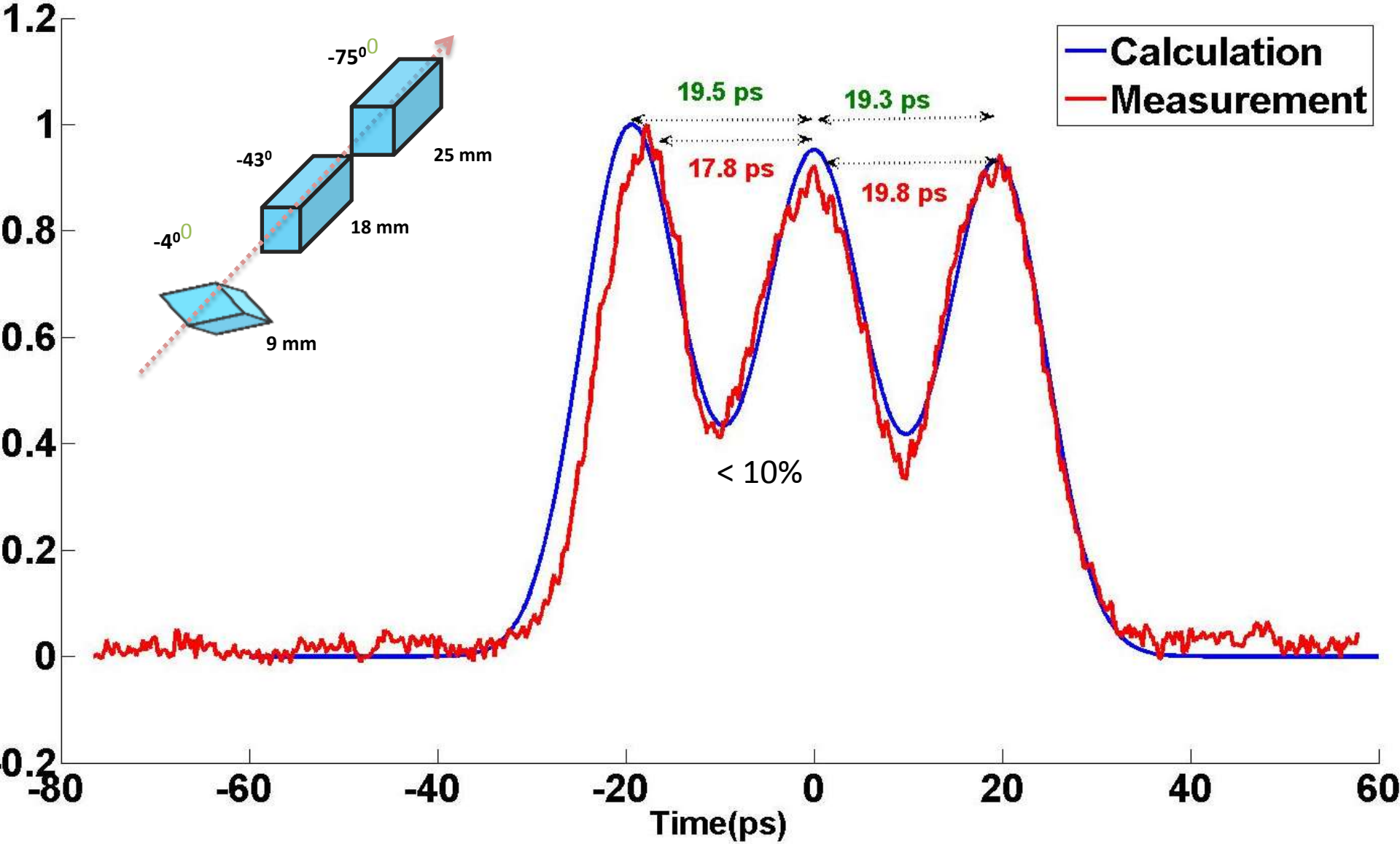


Two Crystals
Length 1 = 27.0mm, 45°
Length 2 = 13.3mm, 45°

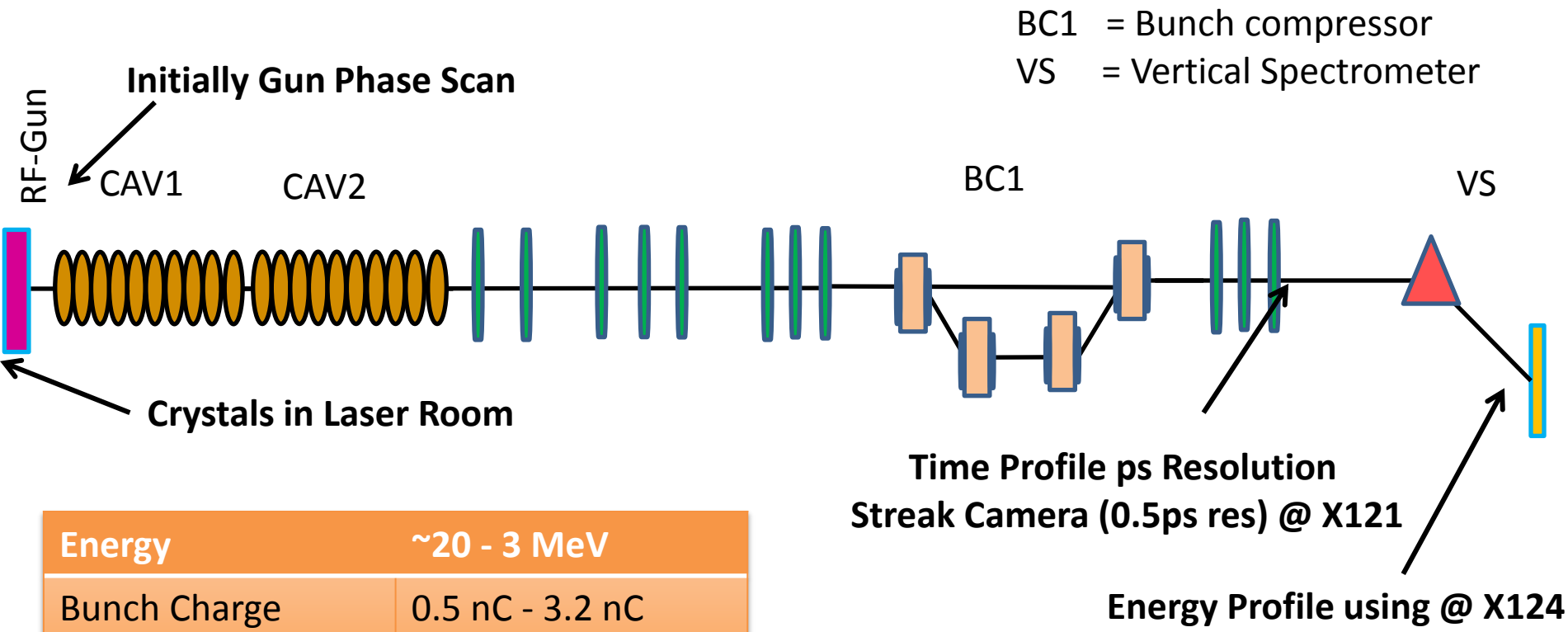
Longitudinal HOTSPOT (Density perturbation)



Multiple Longitudinal Perturbation's



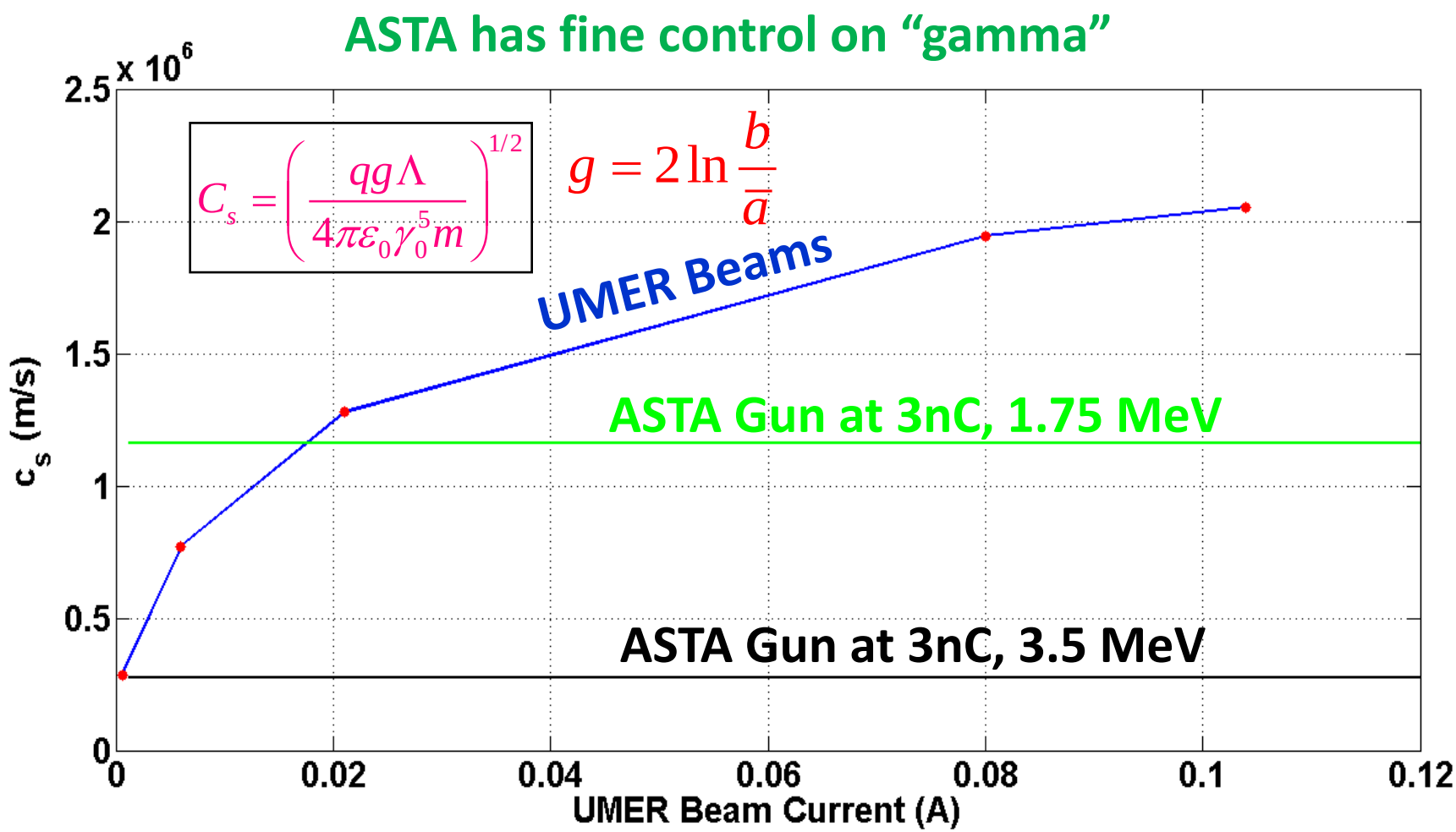
ASTA Low Energy Beamline



Energy	~20 - 3 MeV
Bunch Charge	0.5 nC - 3.2 nC

- Running e-beams created using BBO crystals at charge levels where longitudinal space-charge is moderate
- Measure the effects of space-charge by observing the energy profile as a function of time and perturbation splitting

Space Charge Waves with Acceleration



q: Charge; g: geometric factor; I: beam current; m:mass of e-; Λ: line charge density
b: pipe radius; a: average beam radius; γ_0 Lorentz factor

Plan

- **Phase 1:** Install a reproducible 3 crystal optic setup. Look for a closed loop controller to be procured through ASTA. Experimental setup and gun phase scan. Define what are the lower limitations on beam energy transport.

- **Phase 2:** In parallel do simulations using ASTRA or WARP, and perform measurements using streak camera.

- **Phase 3:** Second set of experiments including energy profile.

Thank you to:

Jinhao Ruan [Lasers and crystals]

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Alex Lumpkin [Streak Camera]

Jamie Santucci [Optics]

Philippe Piot and Vladimir Shiltsev [URA support]

Elvin Harms/Daniel Broemmelsiek [Operations]

Rami Kishek [General guidance]