Bunch Compression and CSR Study in ASTA

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July 24th, 2012

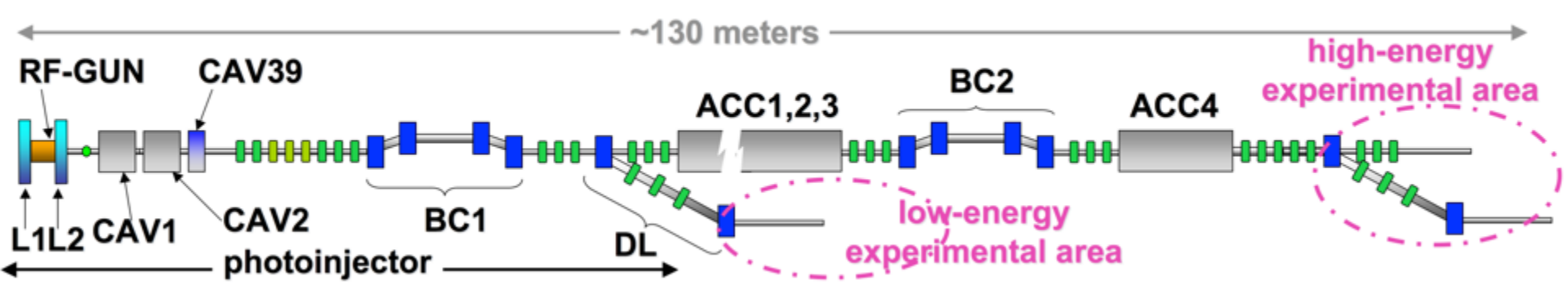
Overview

- ASTA (Advanced Superconducting Test Accelerator)
- Develop SRF technology
- International Linear Collider component design
- Beams with ILC parameters

Goals:

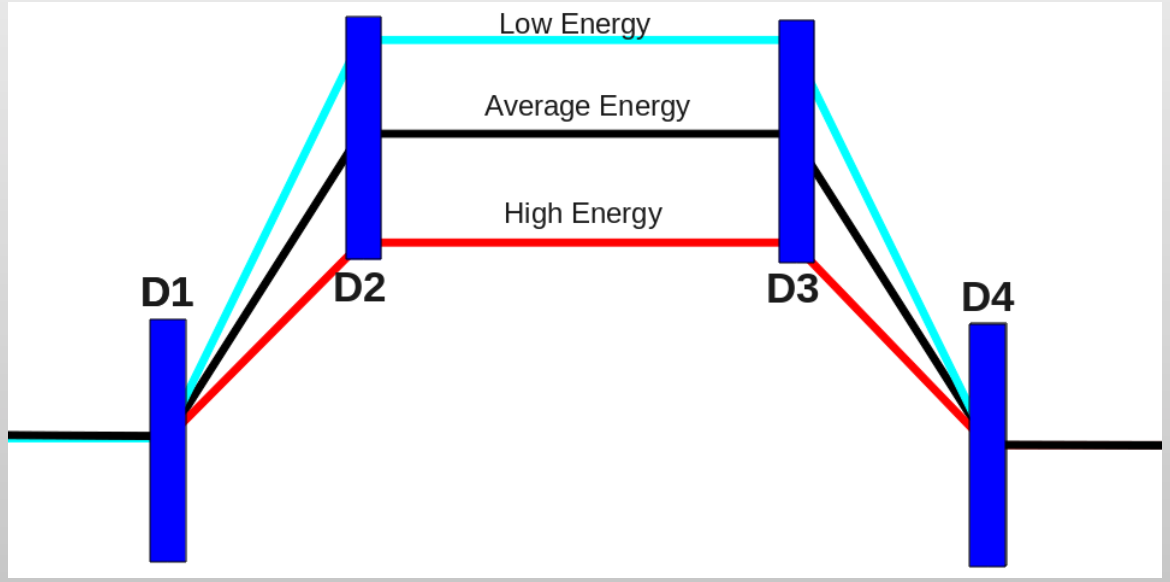
- Optimize two-stage bunch compression
- Minimize emittance distortions due to CSR effects

Beamline



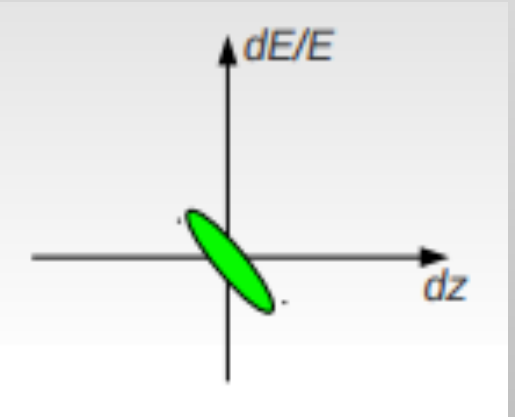
Credit P. Piot, C. Prokop, NIU

- Two stage bunch compression
- Compression from differences in path length

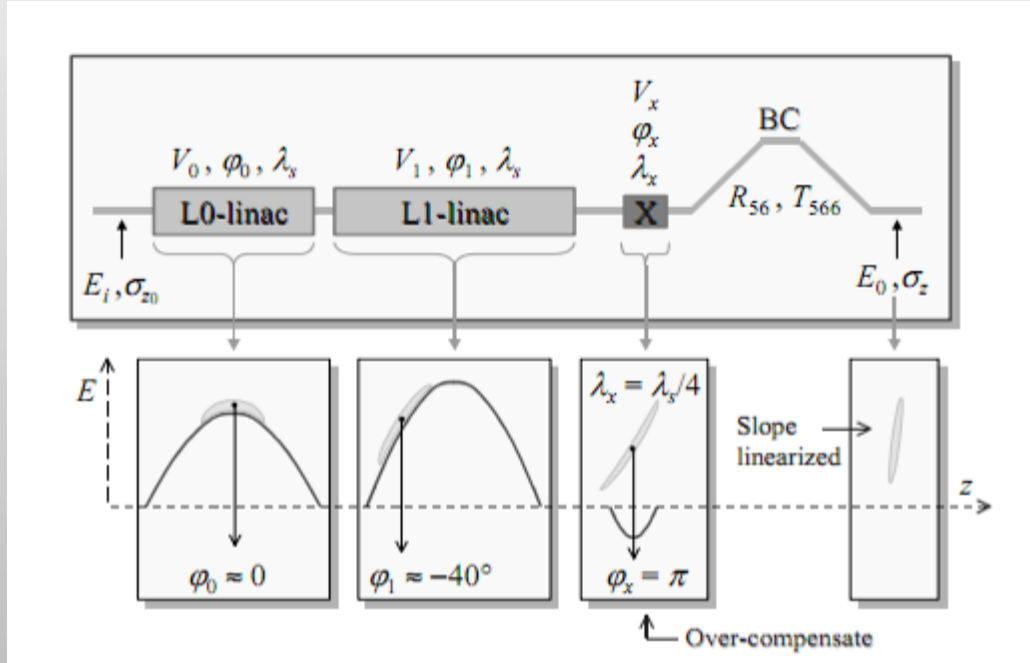


Linearization Procedure

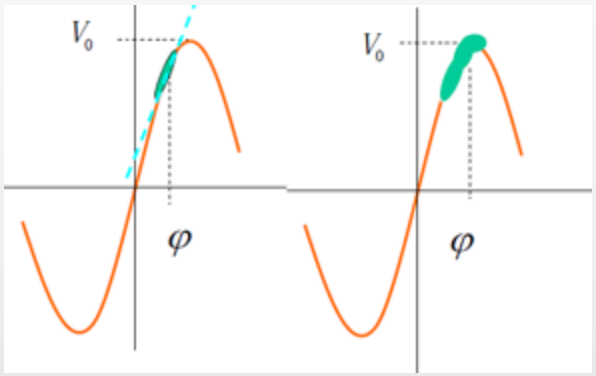
- $\Delta E = eV\cos(\varphi + kz)$
- Optimize phase of CAV2: CAV1 – CAV2 – BC1
- Remove quadratic term of LPS:
  - CAV1 – CAV2 – CAV39 – BC1
  - Voltage optimization: CAV2, CAV2, CAV39 phase on-crest
  - Phase optimization: CAV2 on phase, scan CAV39



Credit E. Kim, KNU



Linearization of phase space

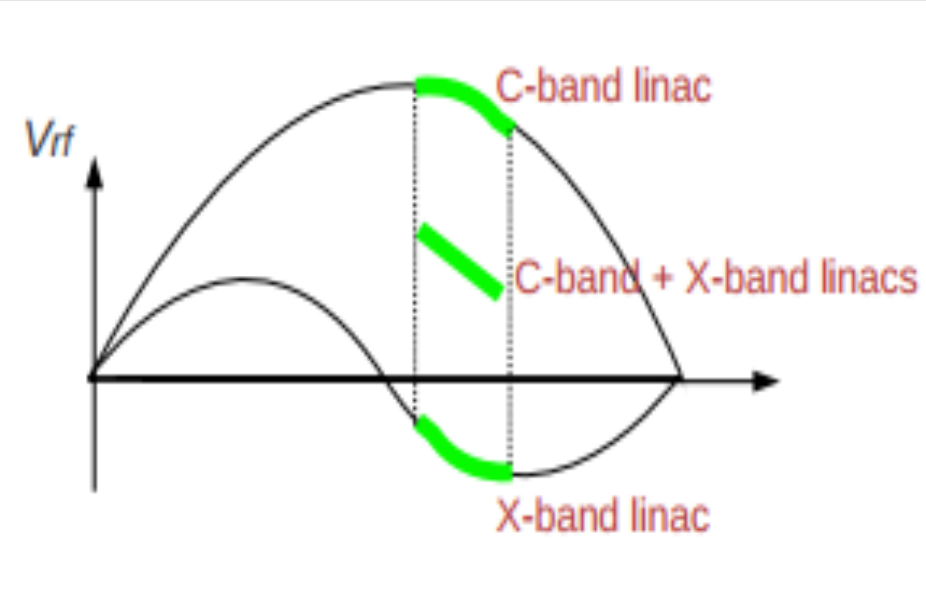


Chirp: $R_{56}\ h_1 = -1$

$$\Delta E = eV\cos(\varphi + kz)$$

$$\Delta E/E_0 = \Delta E_0/E_0 + h_1 z + h_2 z^2 + \ldots\ldots$$

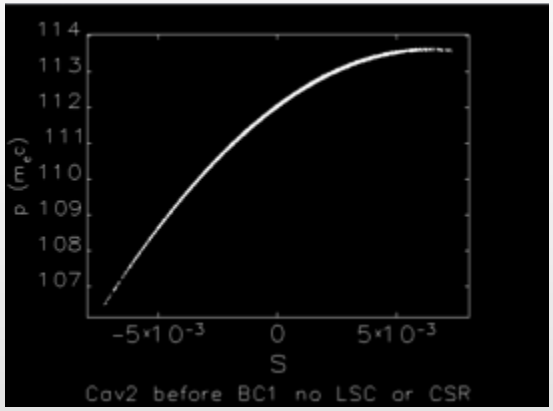
Credit M. Mamtinim, ISU

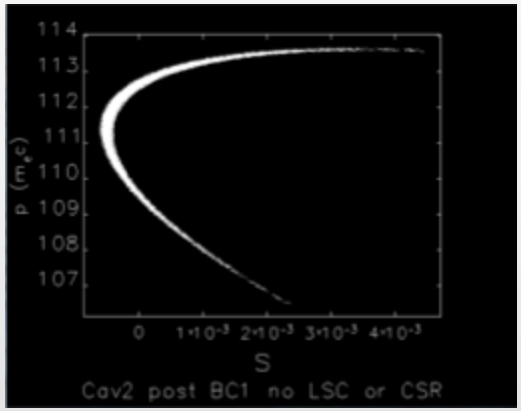


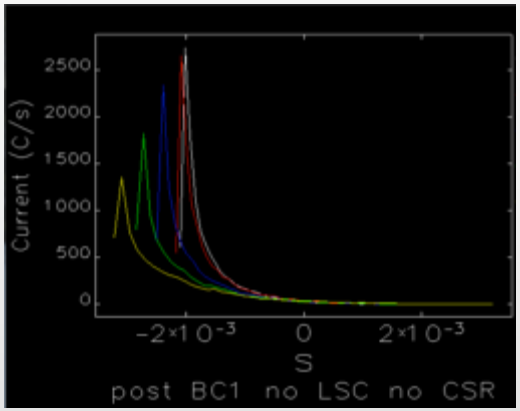
- ELEGANT simulation code
- 6D particle tracking
- Simulation of tracking errors
- Computations of CSR, space charge, wakefields

1D Simulation with ELEGANT

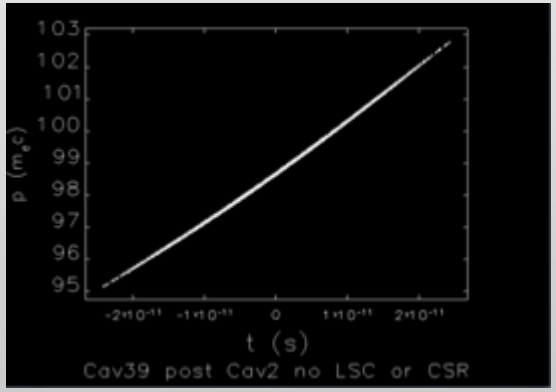
Cav2

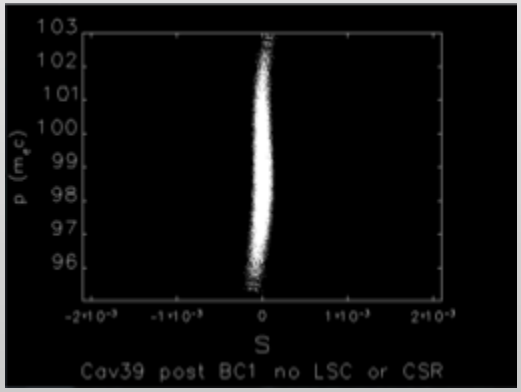


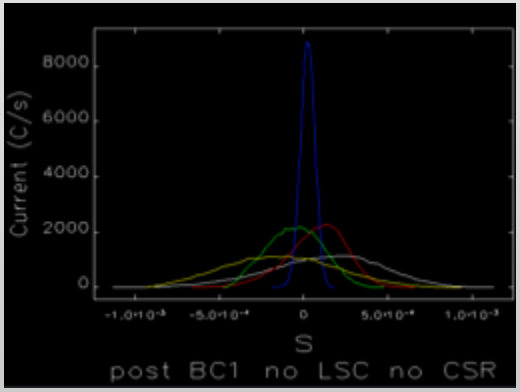




Cav39



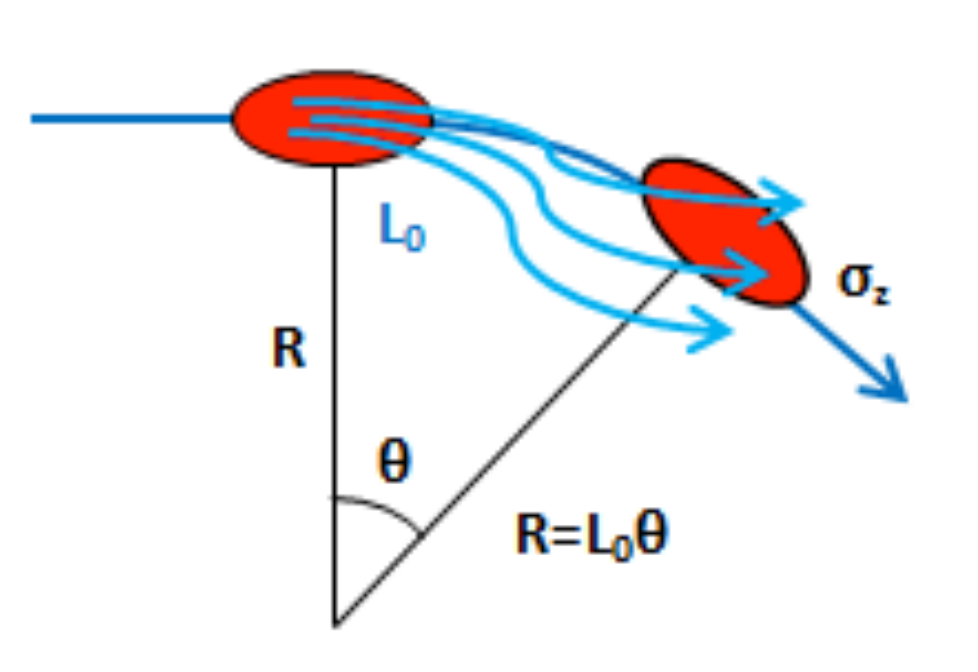




Before BC1 | After BC1 | Profile

CSR Complications

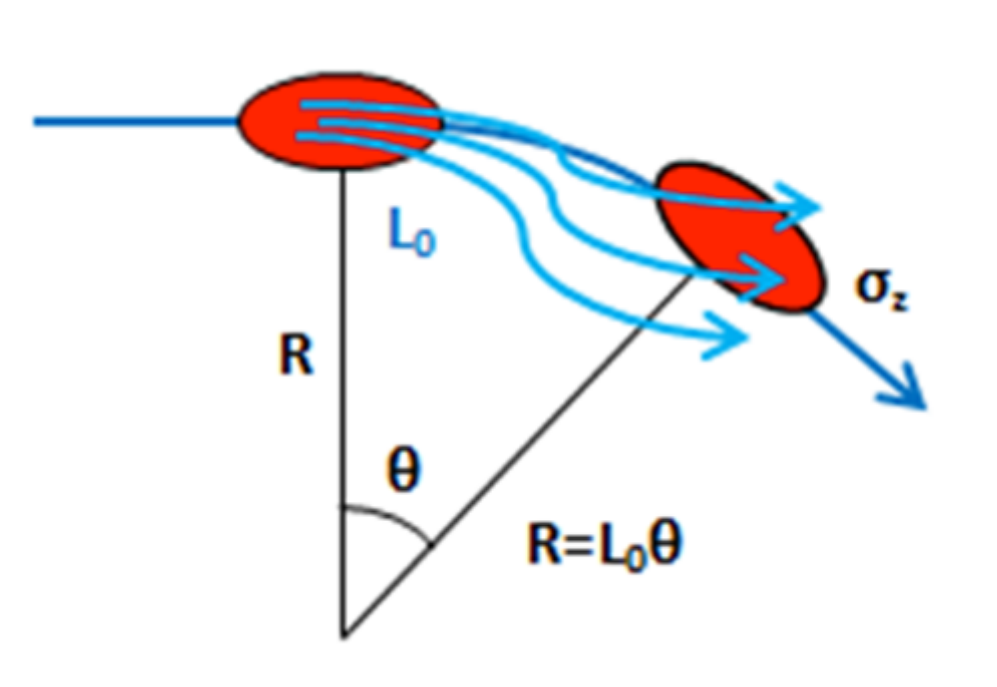
- Charged particles in dipole emit synchrotron radiation in phase
- Coherent Synchrotron Radiation generates energy spread (tail interacts with head)



CSR Complications

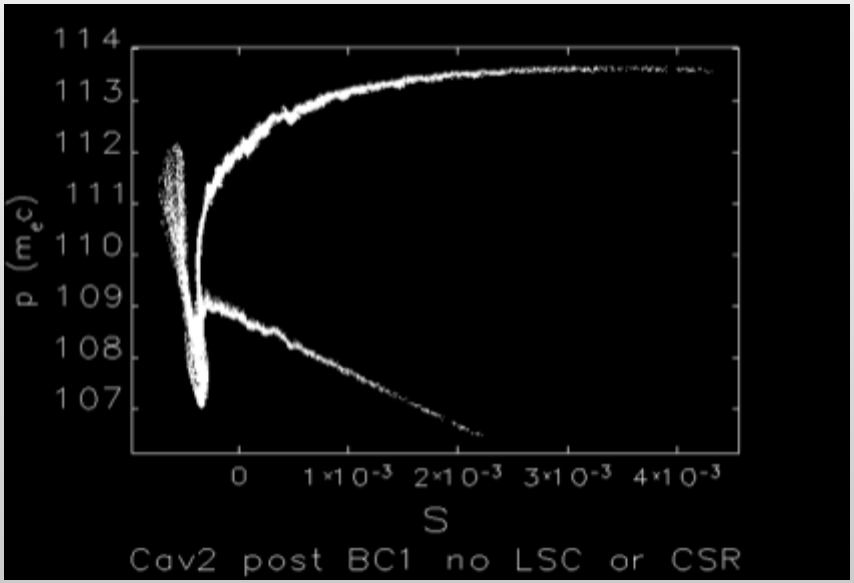
- Charged particles in dipole emit synchrotron radiation in phase
- CSR generates energy spread (tail interacts with head)

- Benefits of two-stage compression
- Reduce bending angle
  - (R_{56})
- Stronger harmonic cavi



Bunch Compressor CSR

- Nonlinearities introduced to LPS
- Readjust optimal CAV2 phase
  - Phase closer to on-crest



Without Cav39

Bunch Compressor CSR

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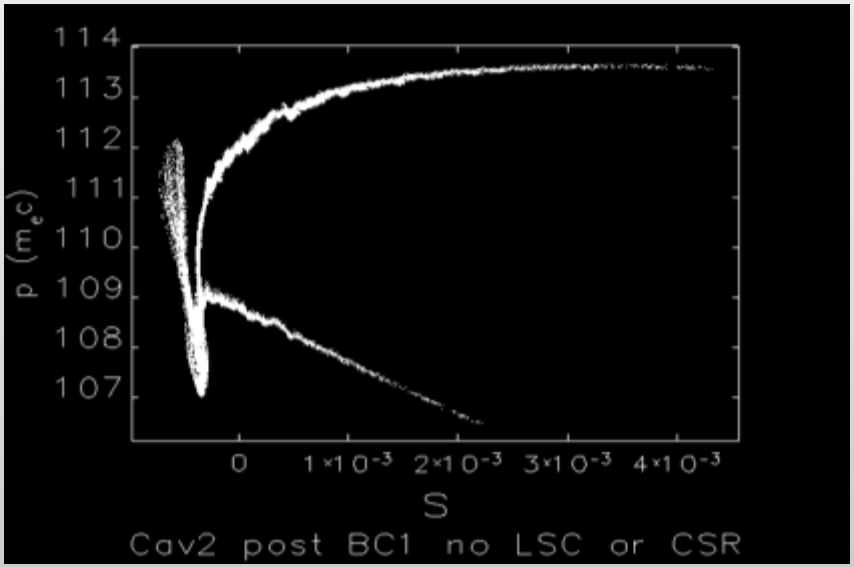
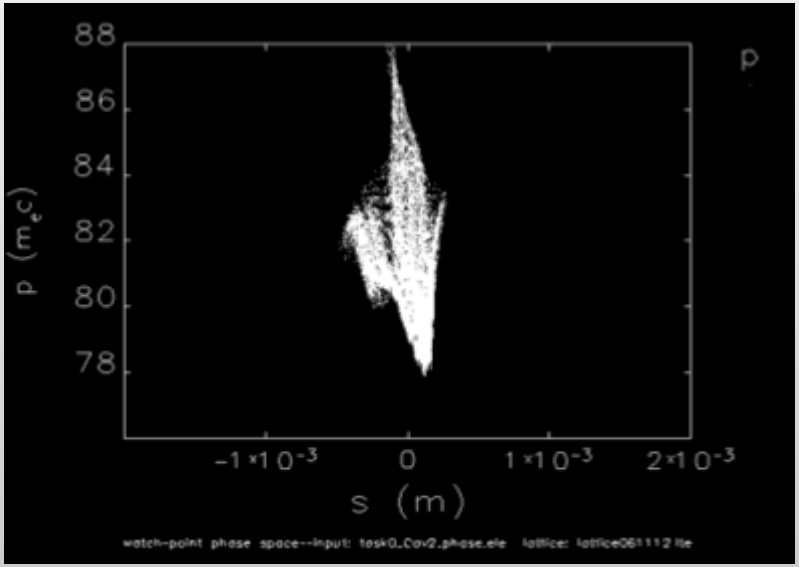


Without Cav39



With Cav39

Conclusion & Next steps

- BC1 compression from 2.4mm to 0.07mm
- CSR increases RMS size to 0.2mm

- Study CSR effects in BC2
- With addition of BC2, optimize:
  - CM1 phase
  - R_{56} of BC2
  - Cav39 phase

Acknowledgements

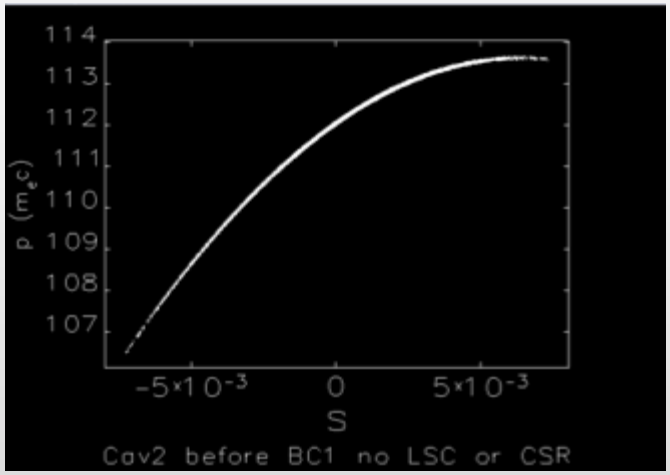
- Tanaji Sen
- Chris Prokop and Philippe Piot
- Eric Prebys and Carol Angarola

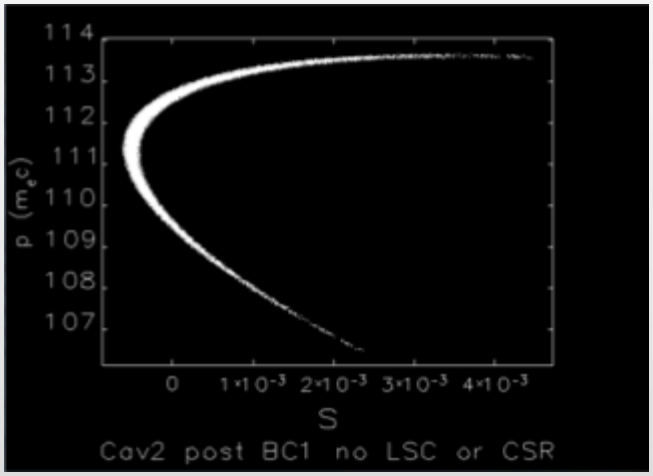
Questions

1D Simulation

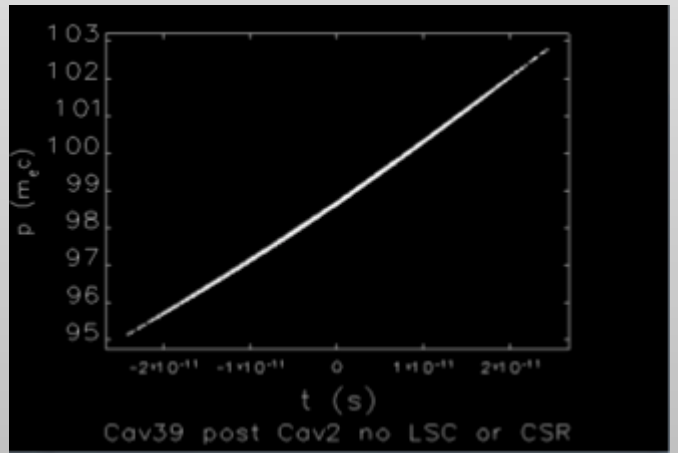
- Longitudinal dynamics with ELEGANT

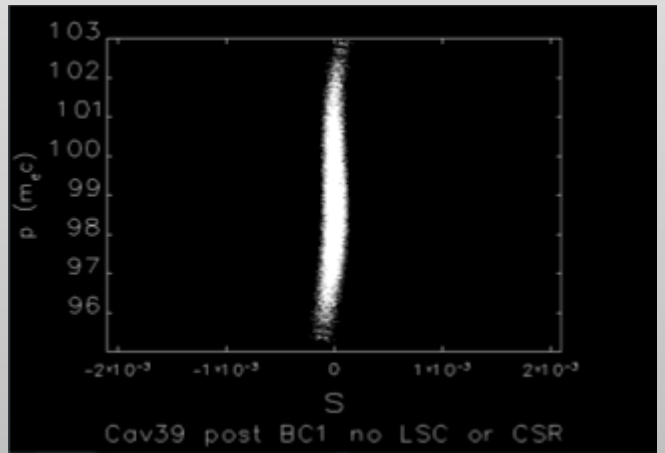
Cav2



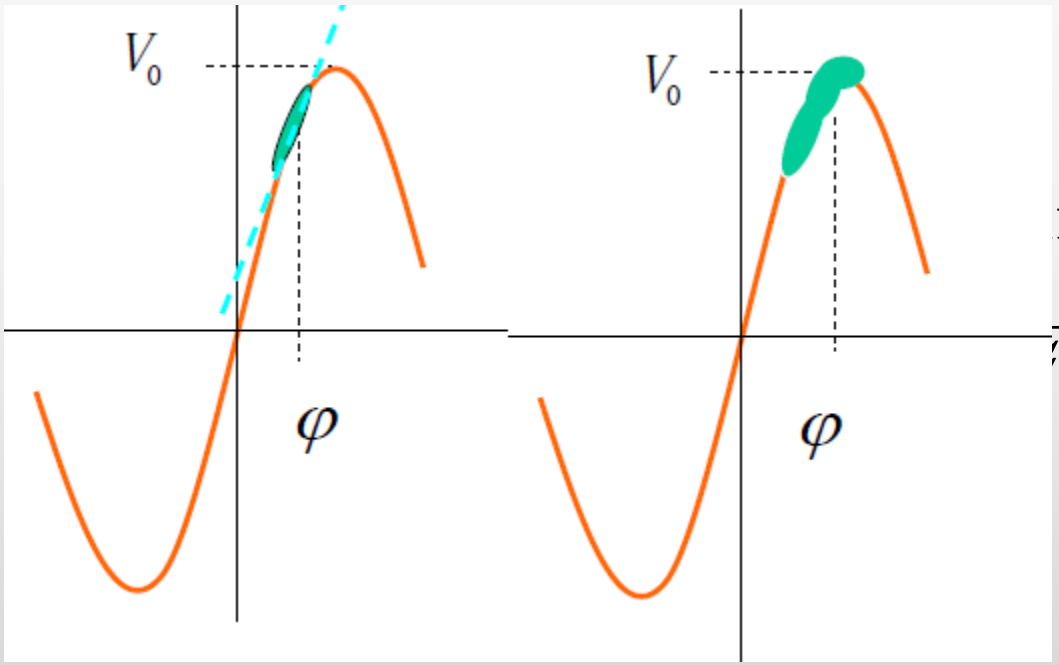


Cav39





Linearization of phase space



irp: $R_{56}\ h=-1$

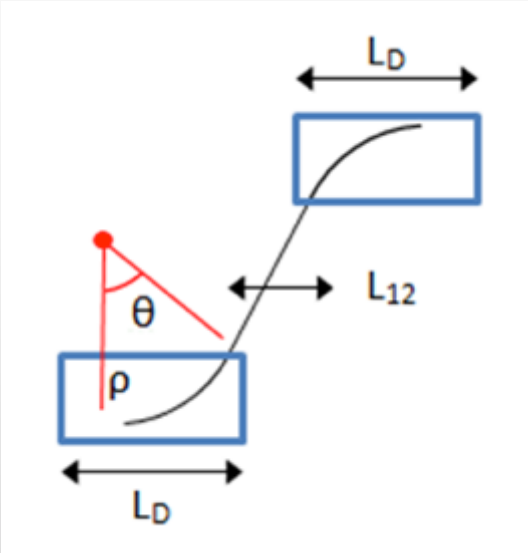
$=eV\cos(\varphi+kz)$

$\Delta E/E_0 = \Delta E_0/E_0 + h_1 z + h_2 z^2$

$h_1 = -eVk\sin\varphi / E_0$

$h_2 = 0 \rightarrow V_{39}\cos\varphi_{39} = -V_2 k_2^2 / k_{39}^2 \cos\varphi_2$

Linearization of phase space



$$S=2\rho\theta+L_{12}/\cos\theta$$

$$\rho=p/eB$$

$$\theta=\sin^{-1} L_B\, eB/p$$

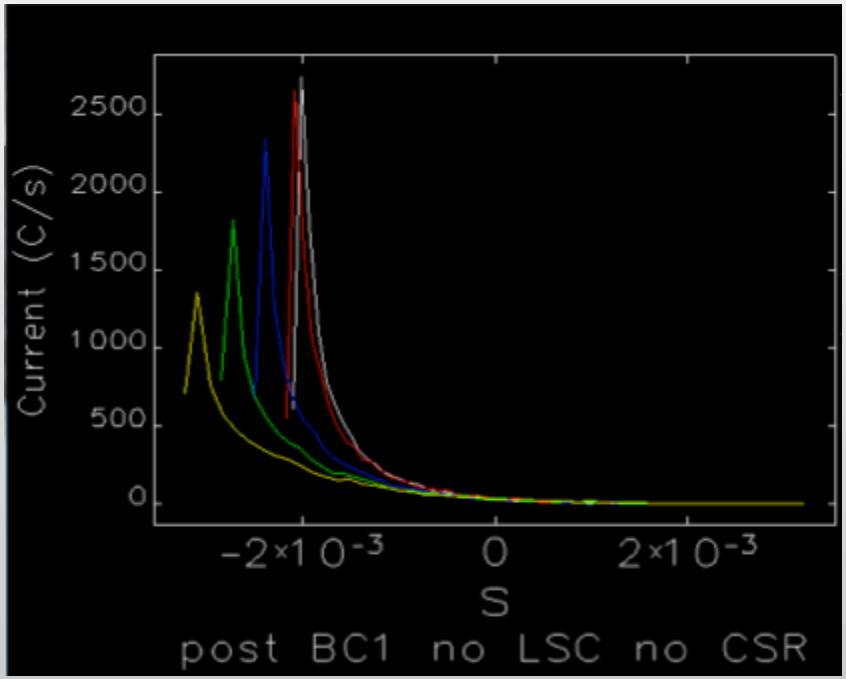
Introduce deviation: $\rho\rightarrow\rho(1+\delta)$

$$S(p)=S(p_0)+\partial y/\partial x\, p\delta+1/2\,\partial^2 S(p)/\partial p^2\,(p\delta)^2+\ldots$$

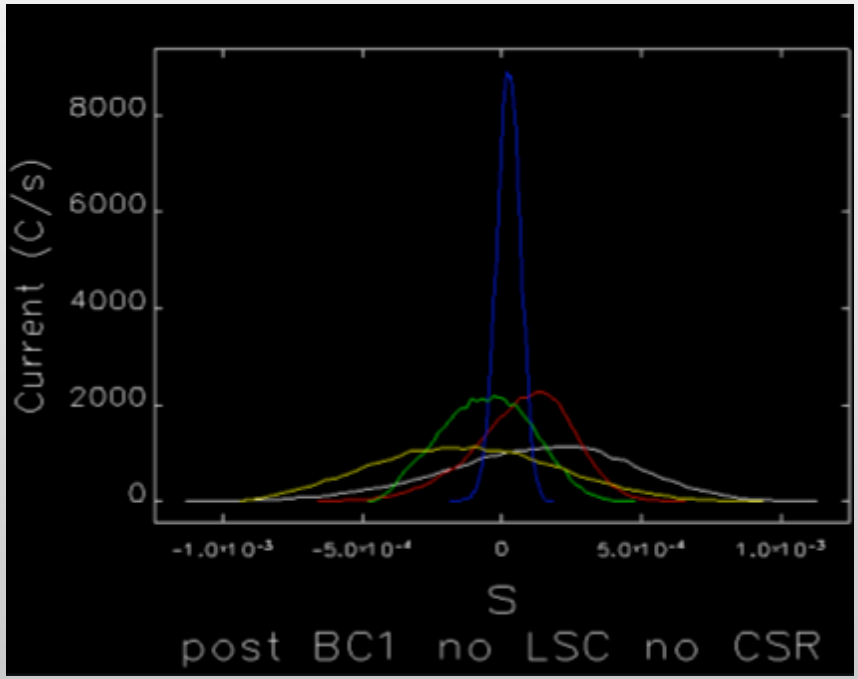
$$=S(p_0)+R_{56}\,\delta+T_{566}\,\delta^2$$

1D Simulation

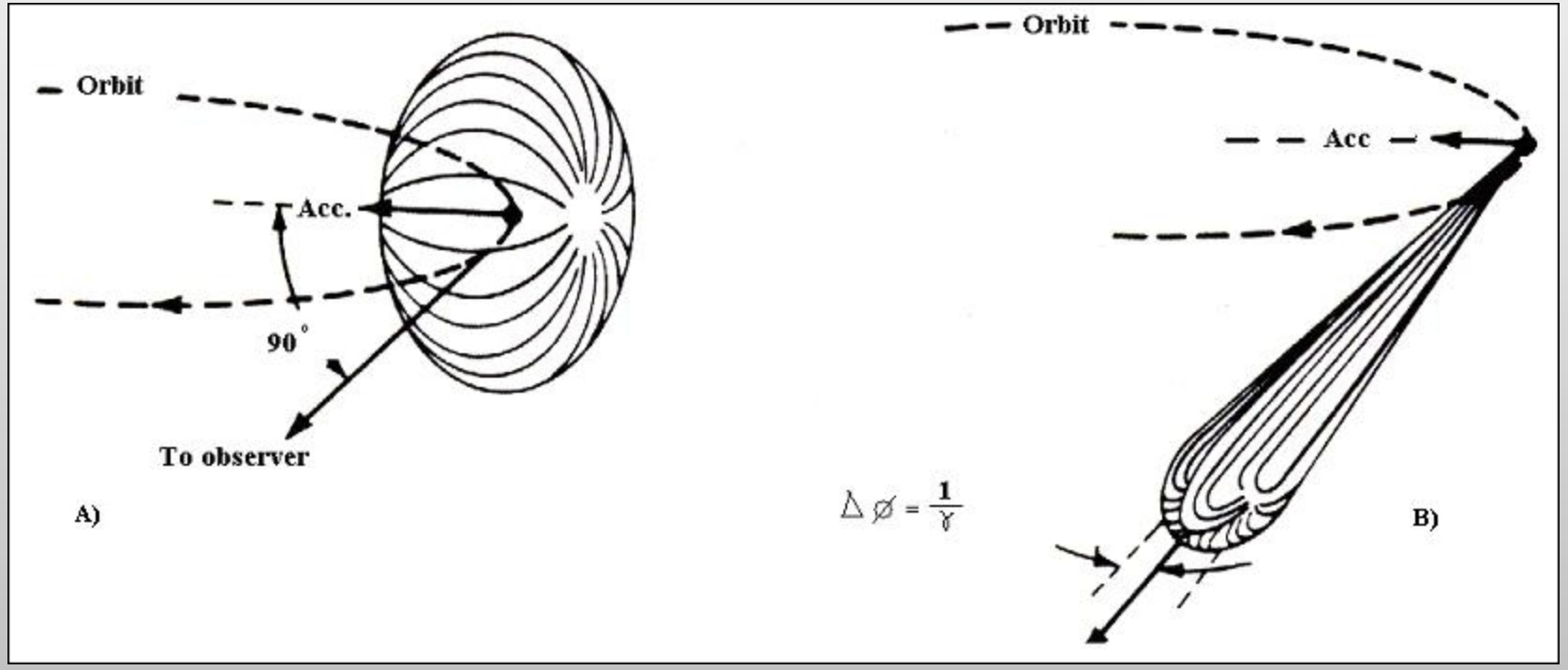
- Longitudinal dynamics with ELEGANT
- More compression equates with higher peak current



Cav2



Cav39

Nonlinear effects on LPS

- Unwanted emittance growth
  - Collective space charge effects (LE)
  - Falls as $1/\gamma^2$
  - Coherent Synchrotron Radiation (HE)