Test of Notch Collimator - December 2005 & Prospects for SABER

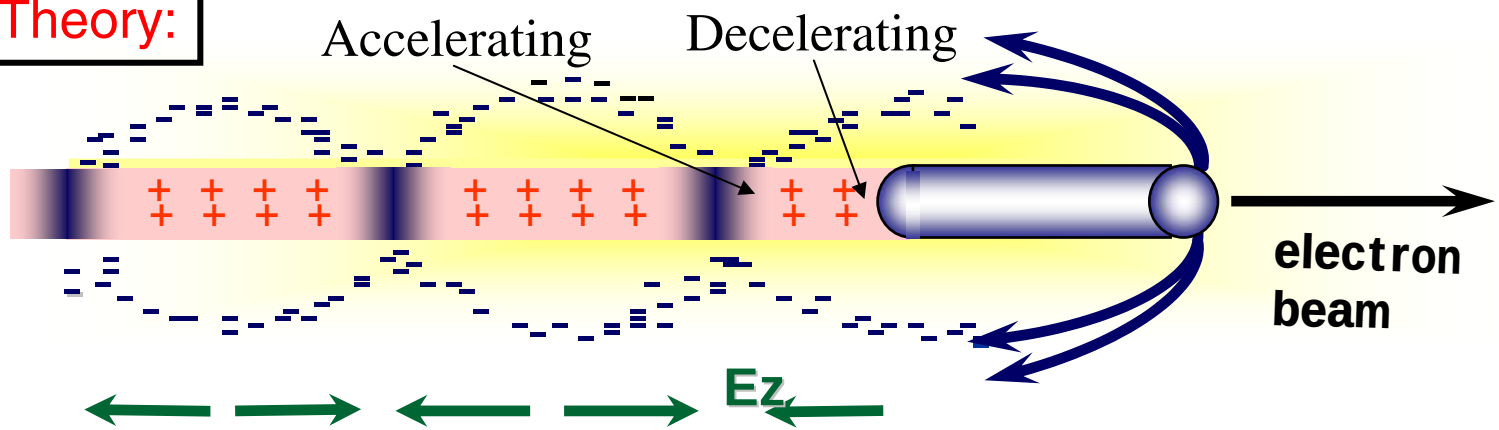
- Why we would like two closely-spaced bunches
- How we are trying to make them with a notch collimator
- What we've seen so far
- What are the prospects for SABER

PWFA:
Plasma Wakefield Acceleration

❑ Looking at issues associated with applying the large focusing (MT/m) and accelerating (GeV/m) gradients in plasmas to high energy physics and colliders

❑ Built on E-157 & E-162 which observed a wide range of phenomena with both electron and positron drive beams: focusing, acceleration/de-acceleration, X-ray emission, refraction, tests for hose instability…

Linear PWFA Theory:



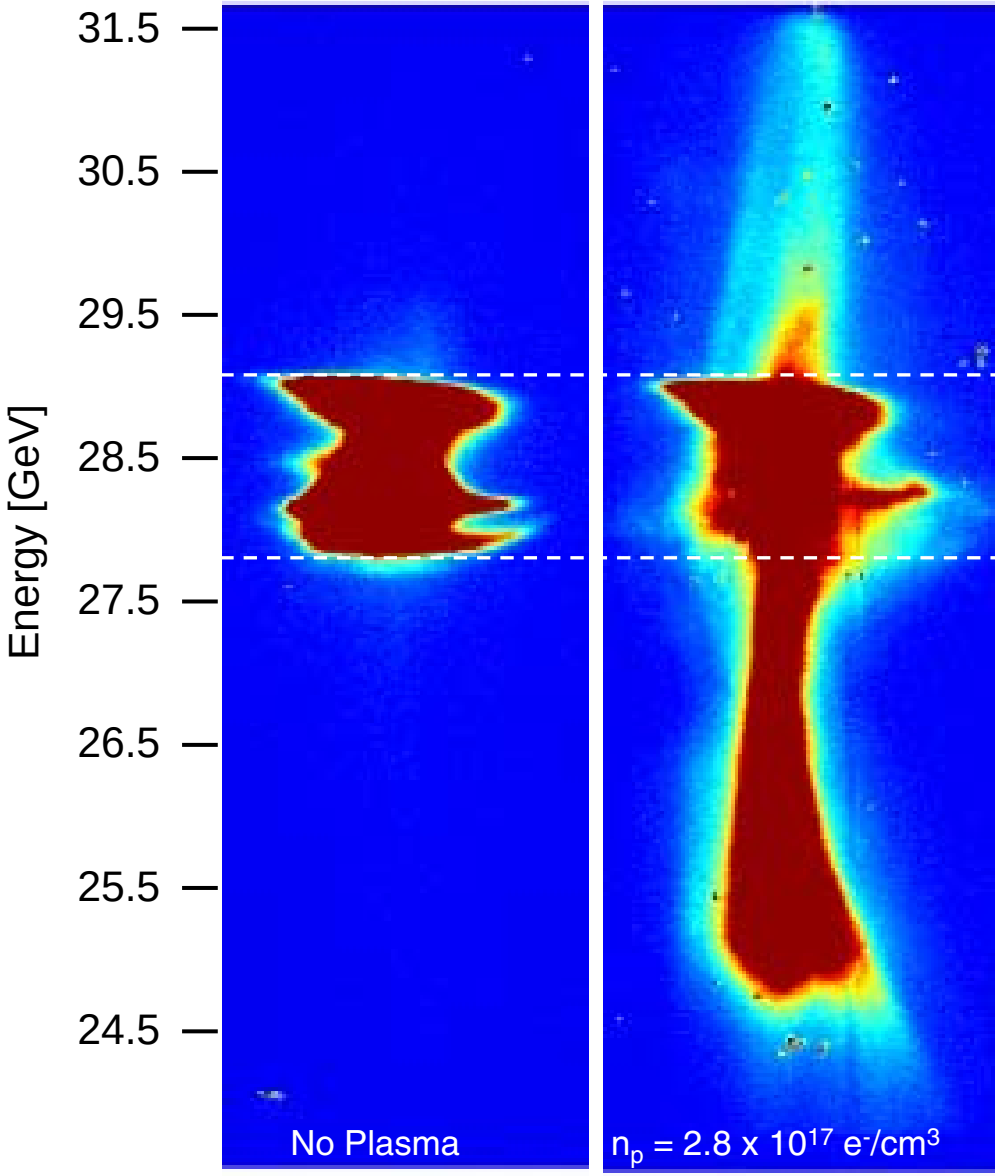
- $E_{z,linear} \quad \frac{N}{2} \quad$ ⬇ Short bunch!
  z
- For $k_{p \quad r} \quad 1$ and $k_{p \quad z} \quad \sqrt{2}$ or $n_p \quad \frac{1}{2}$
  z

E_z: accelerating field
N: # e$^-$/bunch
σ_z: gaussian bunch length
k_p: plasma wave number
n_p: plasma density
n_b: beam density

❑ A single bunch from the linac drives a large amplitude plasma wave which focus and accelerates particles

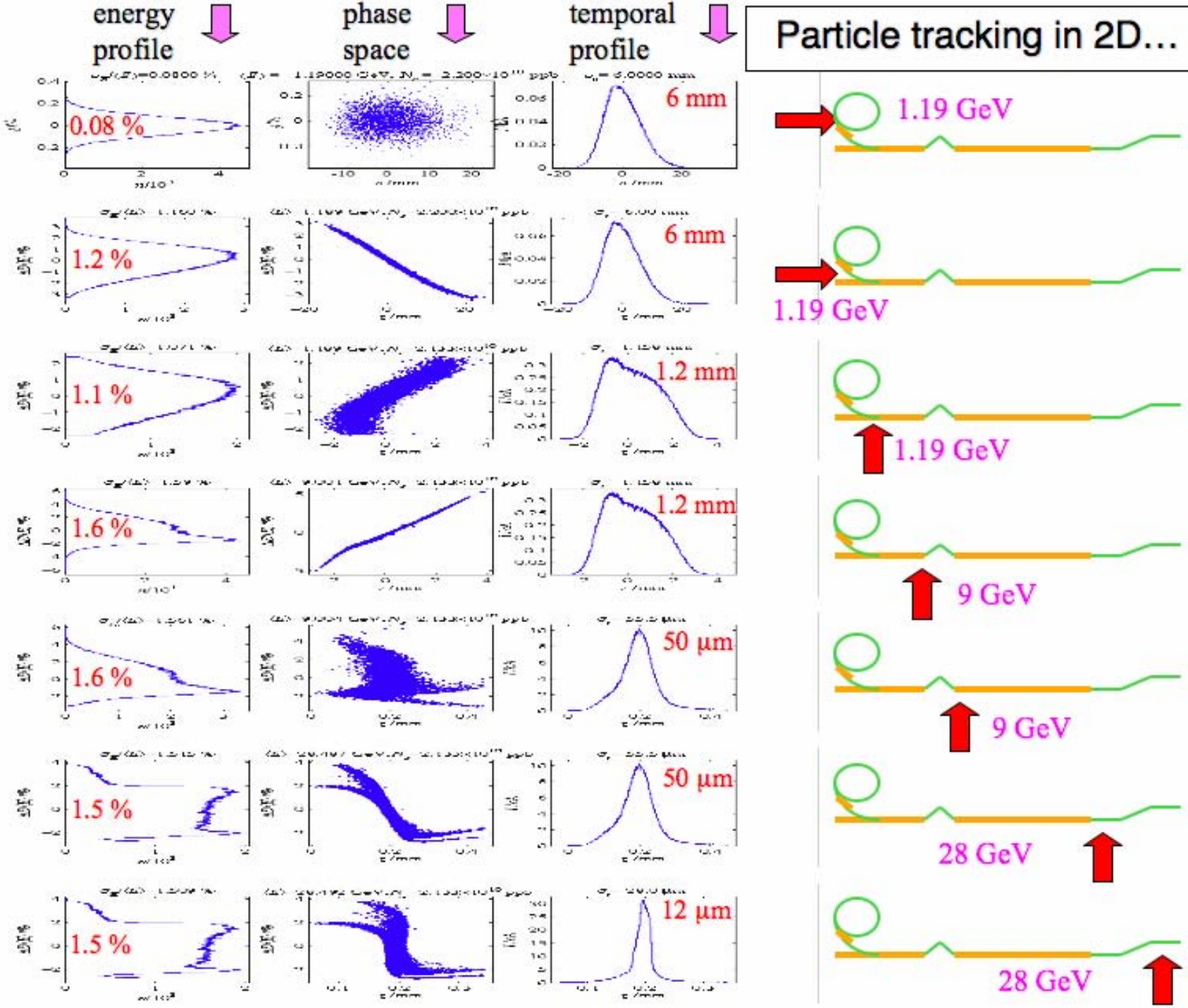
❑ For a single bunch the plasma works as an energy transformer and transfers energy from the head to the tail

Accelerating Gradient > 27 GeV/m! (Sustained Over 10cm)



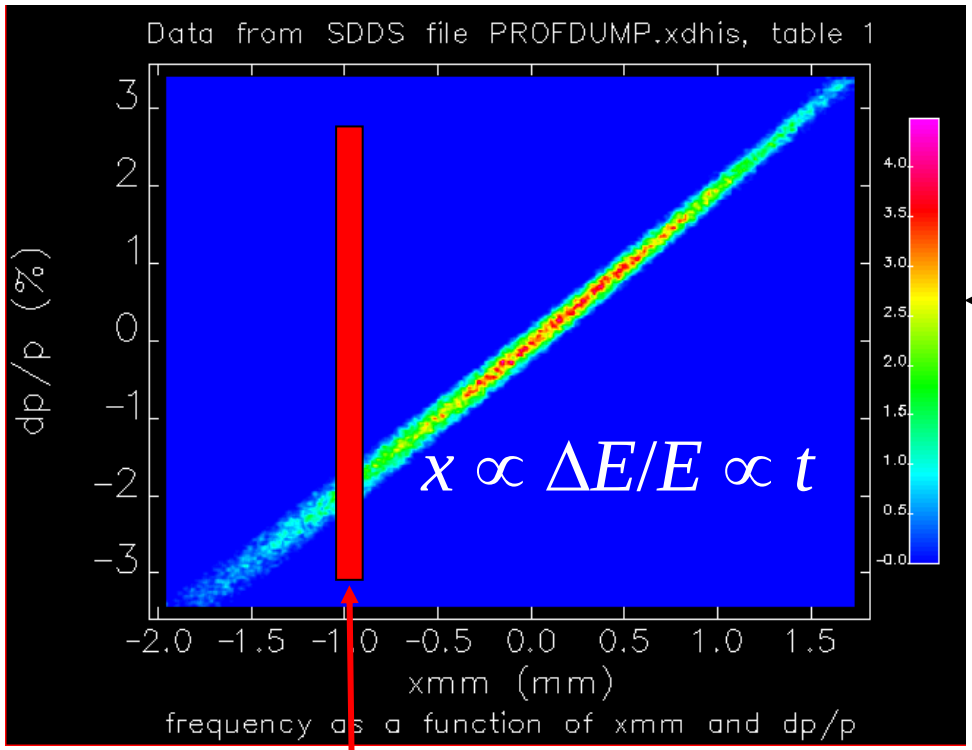
- Large energy spread after the plasma is an artifact of doing single bunch experiments
- Electrons have gained > 2.7 GeV over maximum incoming energy in 10cm
- Confirmation of predicted dramatic increase in gradient with move to short bunches
- First time a PWFA has gained more than 1 GeV
- Two orders of magnitude larger than previous beam-driven results
- Future experiments will accelerate a second "witness" bunch

M.J. Hogan et al. Phys. Rev. Lett. ***95****, 054802 (2005)*


energy profile
phase space
temporal profile
Particle tracking in 2D…
0.08 %
6 mm
1.2 %
6 mm
1.19 GeV
1.1 %
1.2 mm
1.19 GeV
1.6 %
1.2 mm
9 GeV
1.6 %
50 µm
9 GeV
1.5 %
50 µm
28 GeV
1.5 %
12 µm
28 GeV

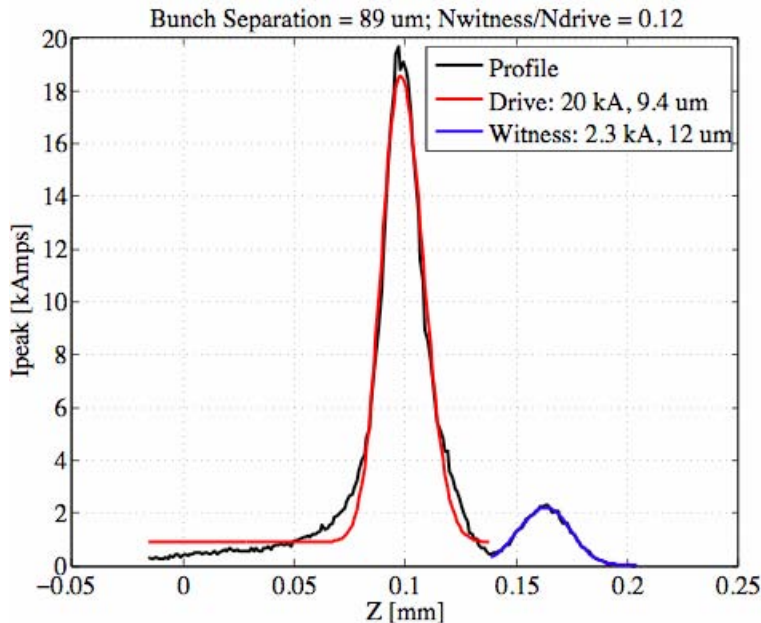
Test of Notch Collimator - December 2005

Exploit *Position-Time* Correlation on e^- bunch in FFTB Dog Leg to create separate drive and witness bunch



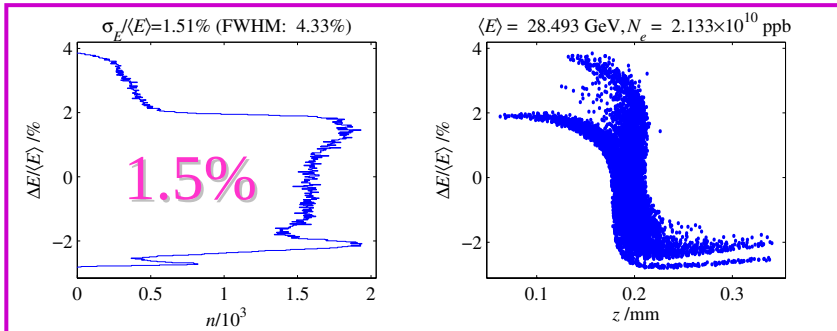
Access to *time* coordinate along bunch

1. Insert tantalum blade as notch collimator
2. Do not compress fully to preserve two bunches separated in time



Short Bunch Generation In The SLAC Linac

Add 12-meter chicane compressor in linac at 1/3-point (9 GeV)

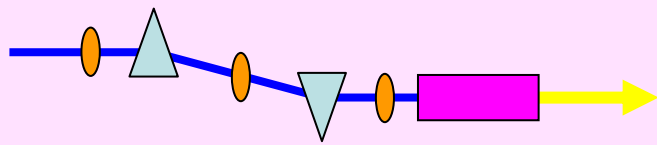


30 kA

80 fsec FWHM

28 GeV

Existing bends compress to **<100 fsec**



- Bunch length/current profile is the convolution of an incoming energy spectrum and the magnetic compression
- Dial FFTB R_{56} & linac phase, then measure incoming energy spectrum.

What about doing the notch collimator in the FFTB?

- Use location of current burnt profile monitor = 1.6m US of ST62
- This is also 2.5m US of existing Momentum slit
  - ⇨These two make me think shielding OK (under berm)

Pros:

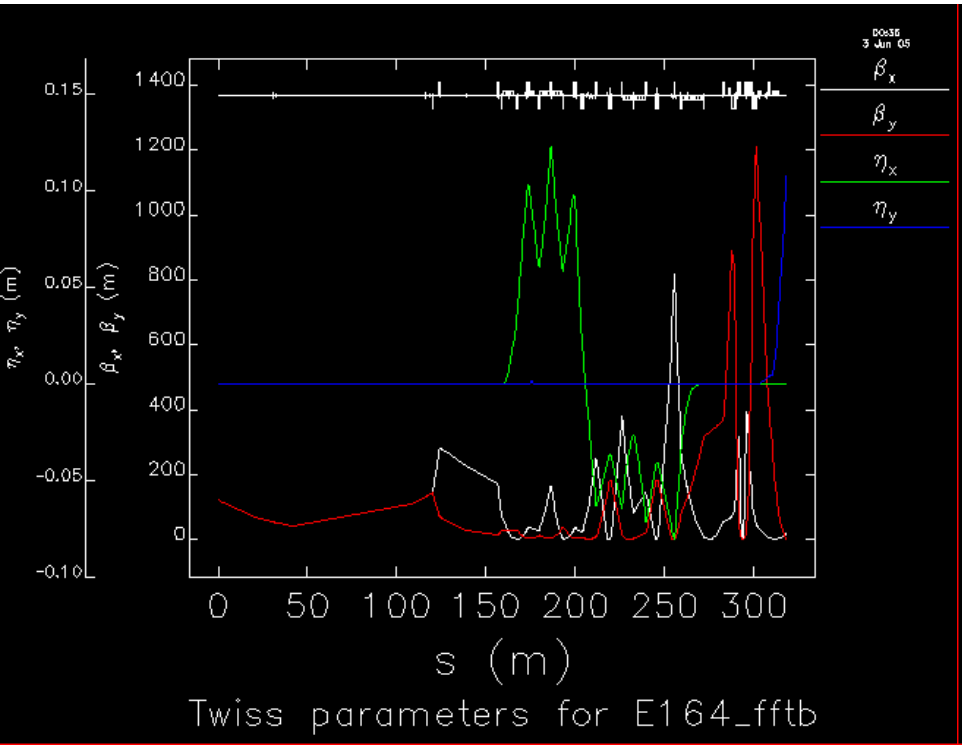
1. It's in the FFTB NOT the linac!!! *"Access?! for what?!…"*
2. Seem to need to notch less of the beam s.t. can still get high peak currents
3. Existing x-ray stripe will show resulting Energy profile

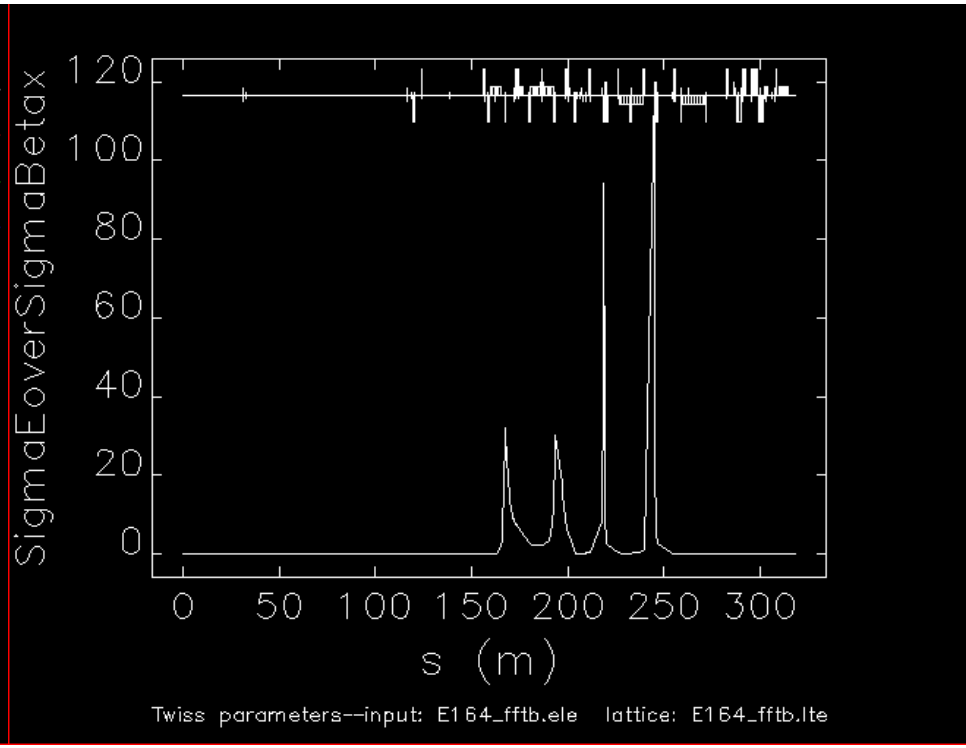
Cons:

1. 28.5GeV instead of 9GeV
2. Smaller dispersion so smaller feature size in collimator silhouette, but thicker due to higher energy

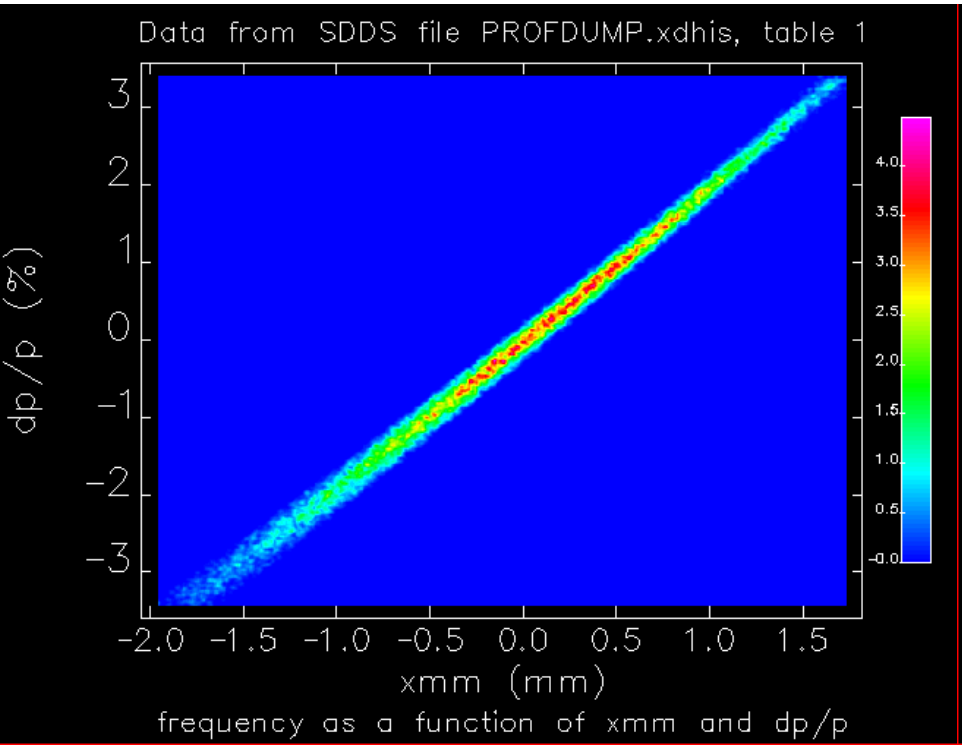
Profile monitor = 168.82m

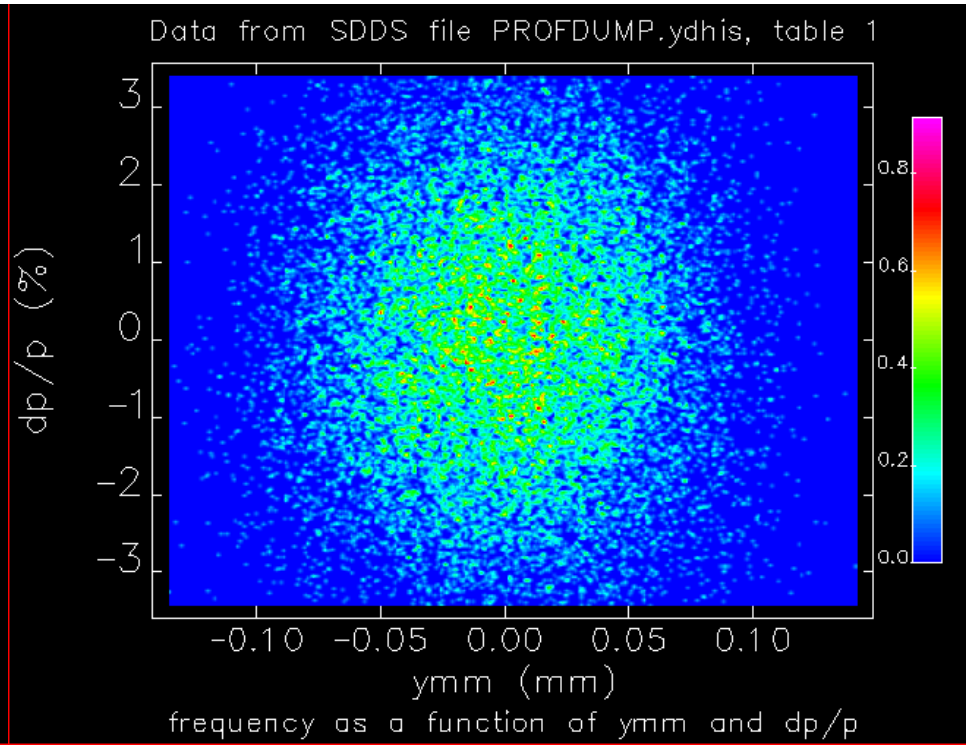
ST-62 = 170.42m



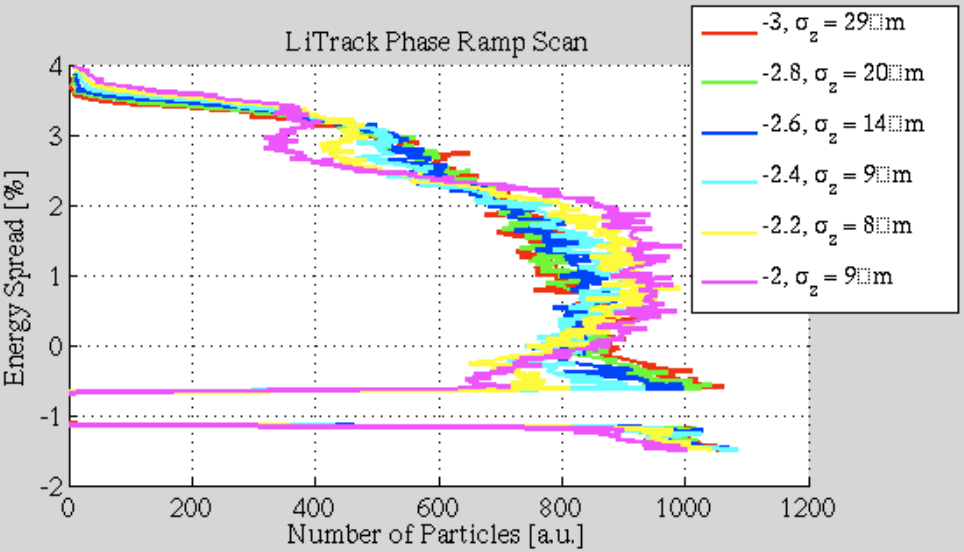


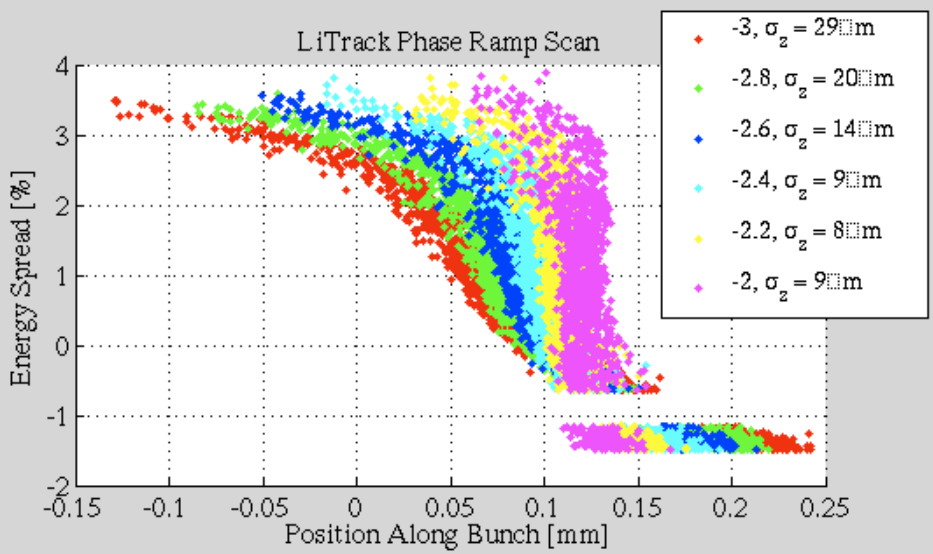
Pretty good correlation if assume 1.5% r.m.s. E-spread:





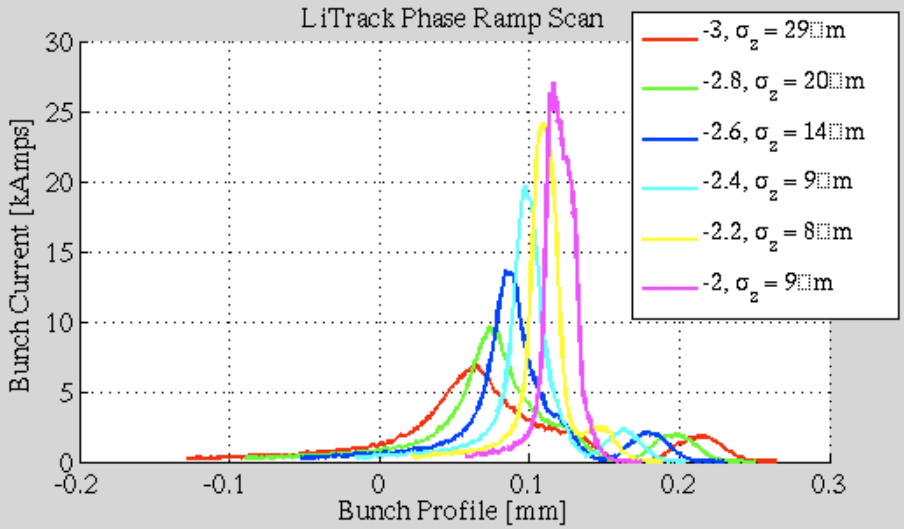
For accelerator parameters ~ from last run except NDR exit offset:



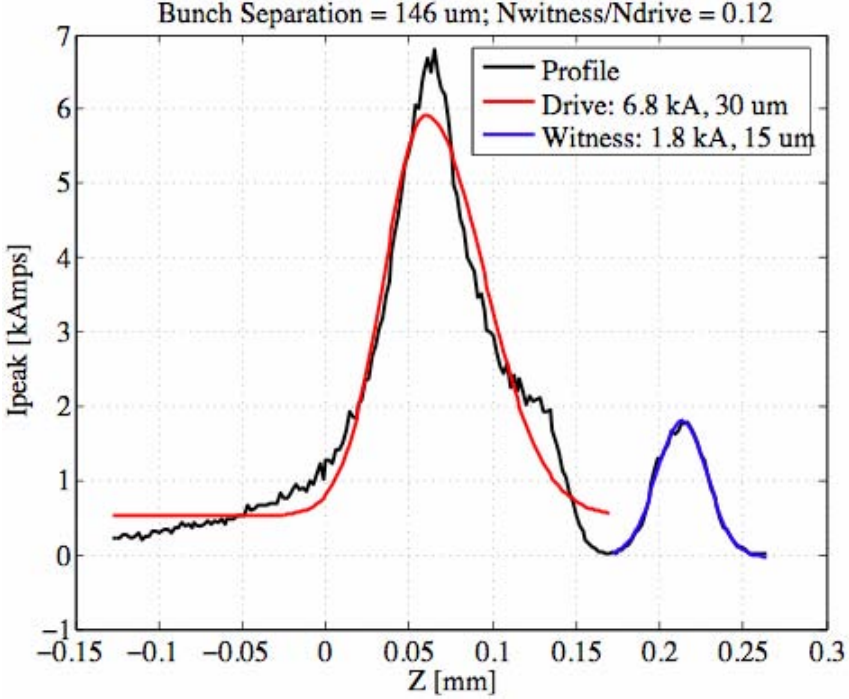


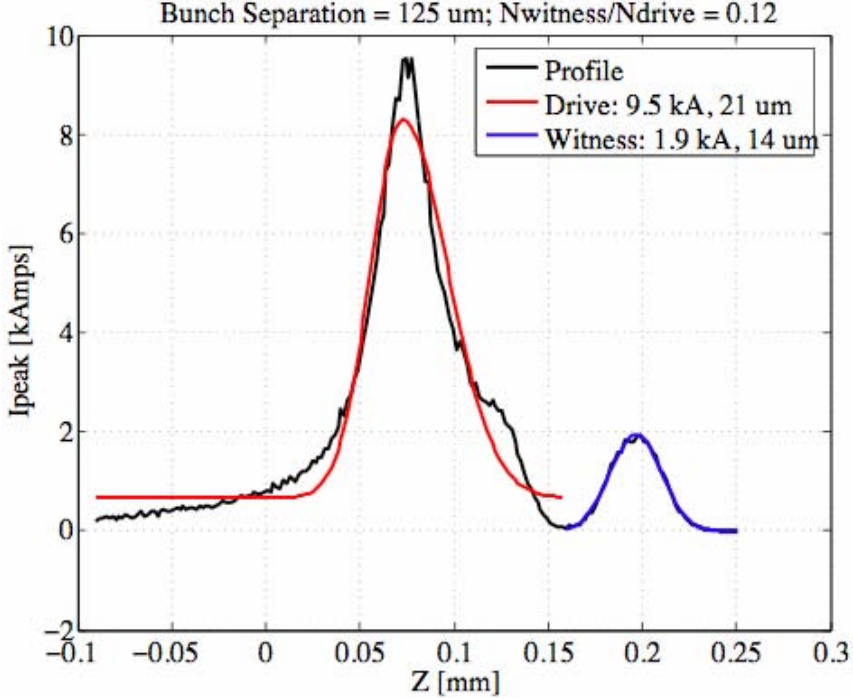
Charge in NDR : 2.05E+10
Compressor : 0.043
Li02-06 Phase : -19.5
RTL R56 : 0.588
FFTB R56 : 0.002
NR into NRTL Timing Jitter : 0
RTL High E Acceptance : 0.025
RTL Low E Acceptance : -0.025
Chicane Notch Collimator Center : -0.009
Chicane Notch Collimator Width : 0.005

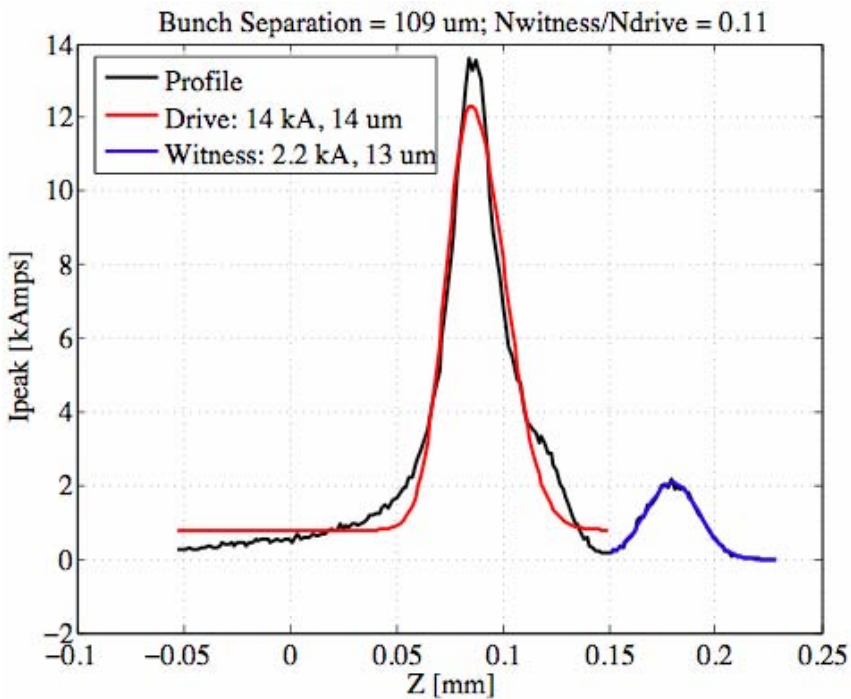
Additional collimation from -1.5% to 4%

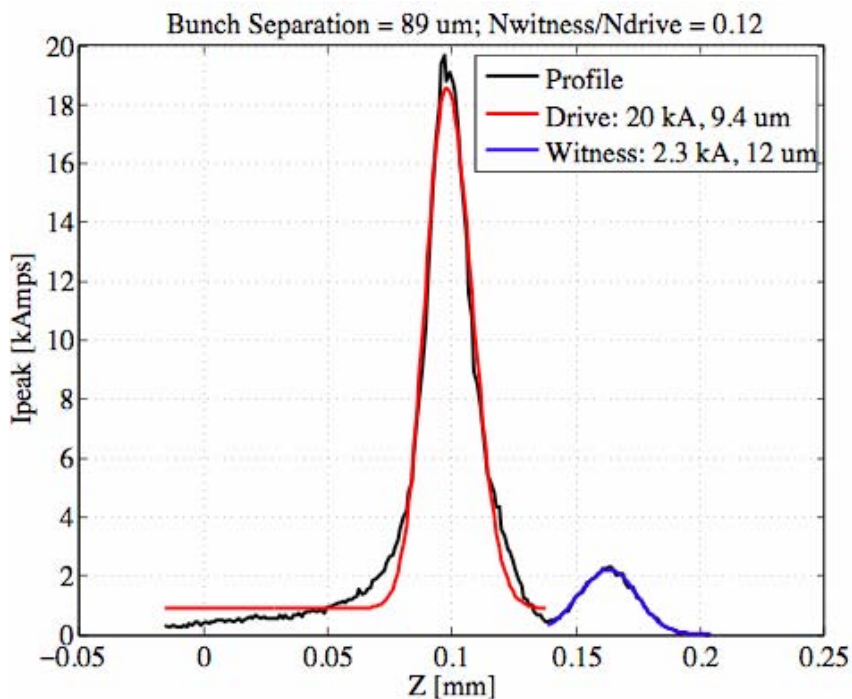


"Wow" image from last run was 10kAmps, 27µm


Bunch Separation = 146 um; Nwitness/Ndrive = 0.12
Profile
Drive: 6.8 kA, 30 um
Witness: 1.8 kA, 15 um
Ipeak [kAmps]
Z [mm]


Bunch Separation = 125 um; Nwitness/Ndrive = 0.12
Profile
Drive: 9.5 kA, 21 um
Witness: 1.9 kA, 14 um
Ipeak [kAmps]
Z [mm]


Bunch Separation = 109 um; Nwitness/Ndrive = 0.11
Profile
Drive: 14 kA, 14 um
Witness: 2.2 kA, 13 um
Ipeak [kAmps]
Z [mm]


Bunch Separation = 89 um; Nwitness/Ndrive = 0.12
Profile
Drive: 20 kA, 9.4 um
Witness: 2.3 kA, 12 um
Ipeak [kAmps]
Z [mm]

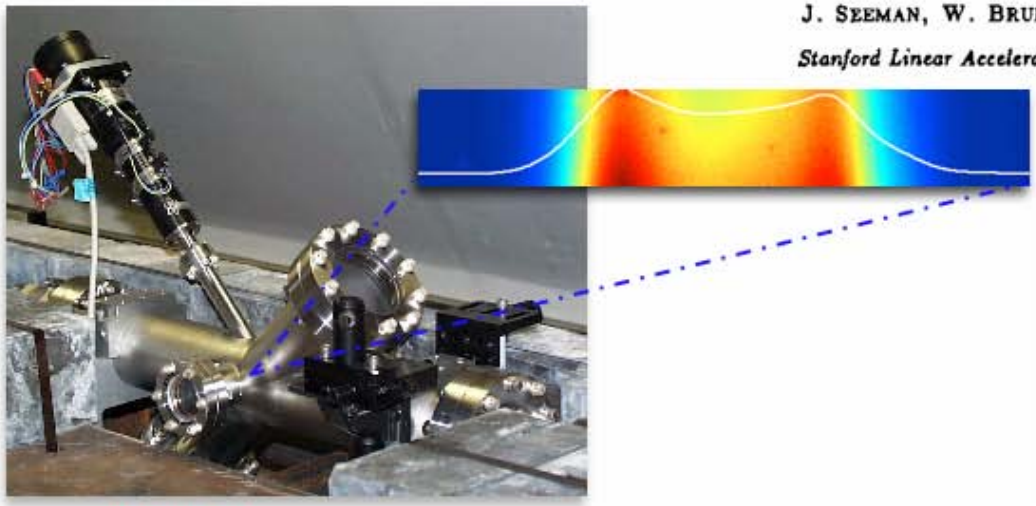
Non-Invasive Energy Spectrometer Upstream of Plasma

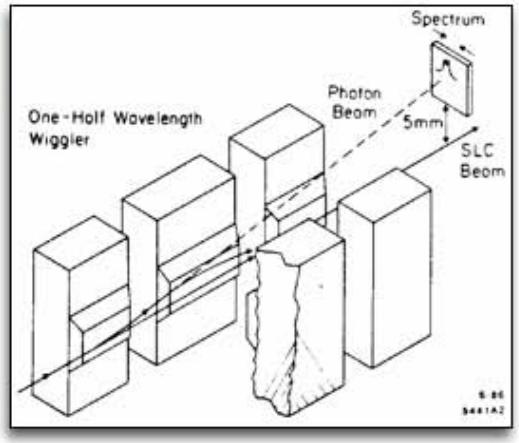
SLC ENERGY SPECTRUM MONITOR USING SYNCHROTRON RADIATION*

J. SEEMAN, W. BRUNK, R. EARLY, M. ROSS, E. TILLMANN and D. WALZ

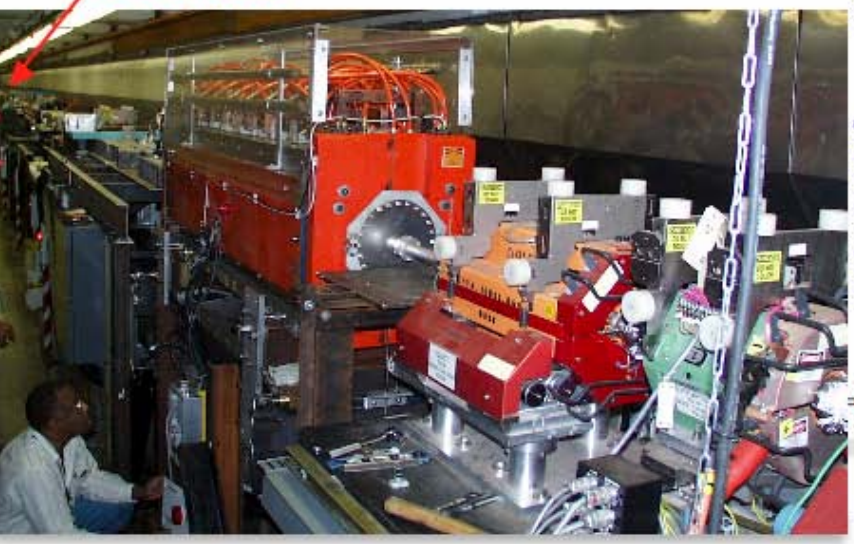
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

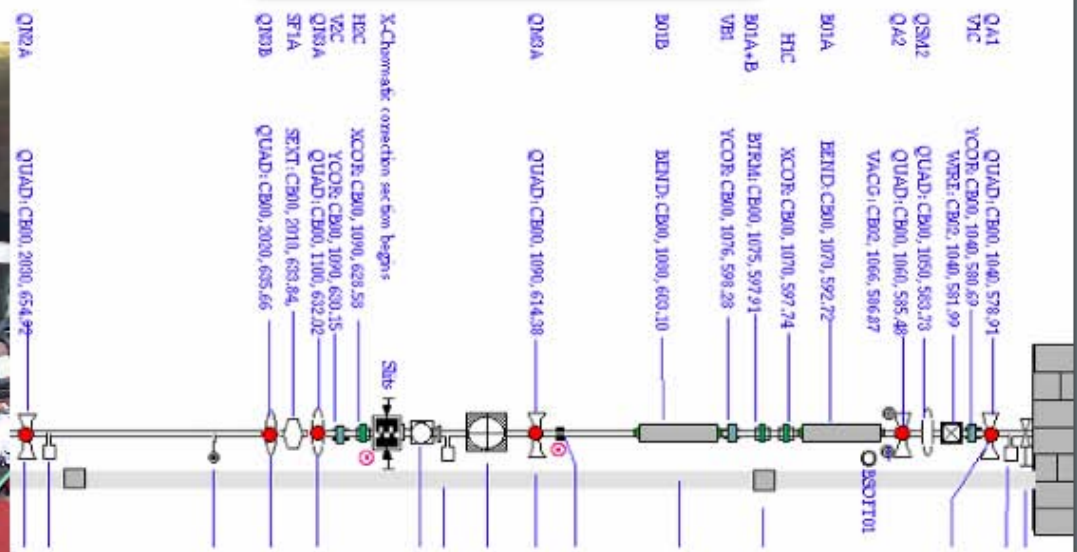
SLAC – PUB – 3945
April 1986





Plasma





Test of Notch Collimator - December 2005

Ta Blade
100-300μm Wide
1.6cm Long (4 X_0)

Energy Spectrum Before Plasma:

Energy Spectrum After Plasma:

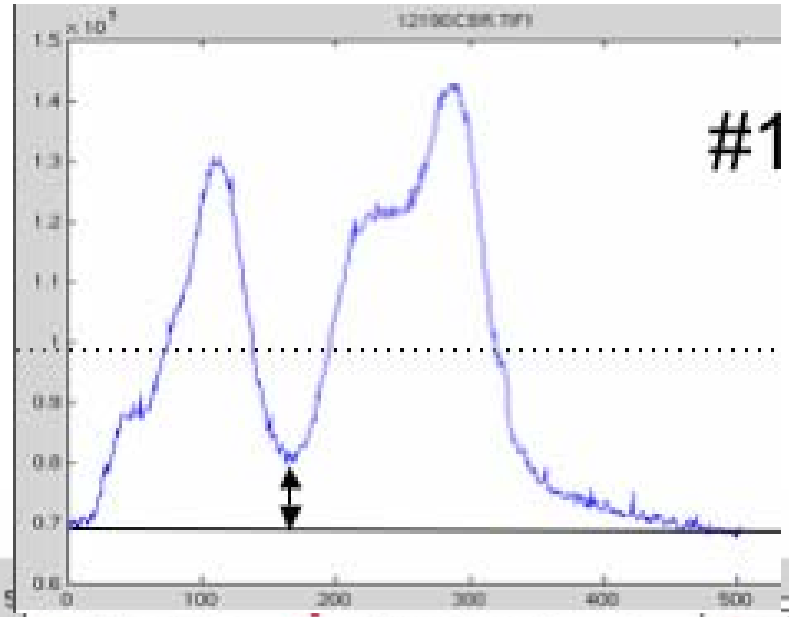
QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

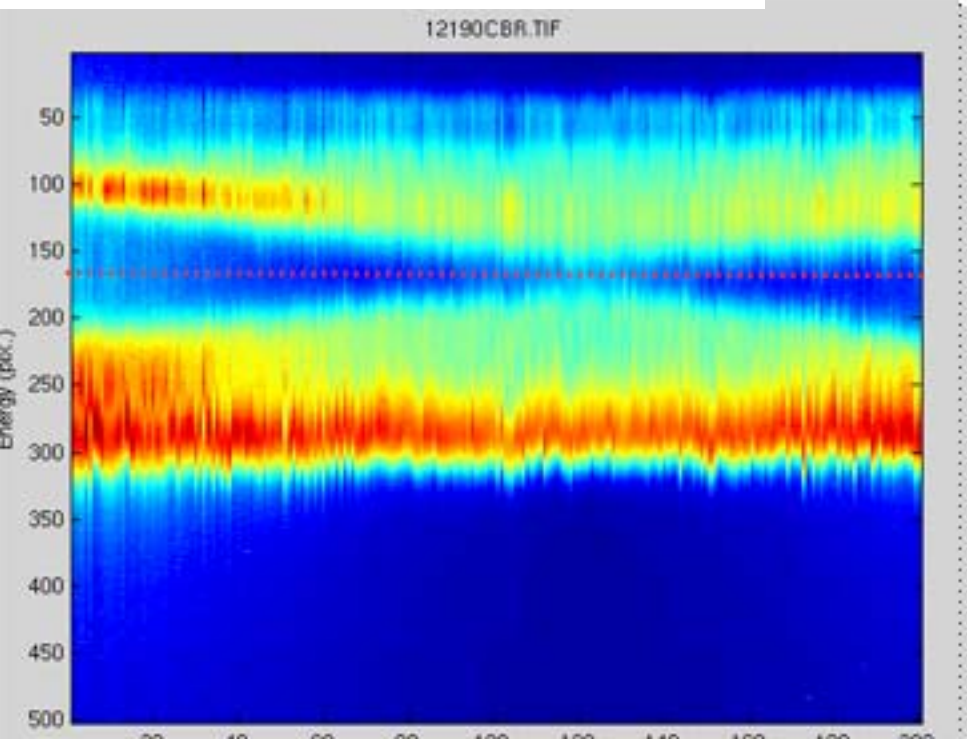
Shot # (Time) →

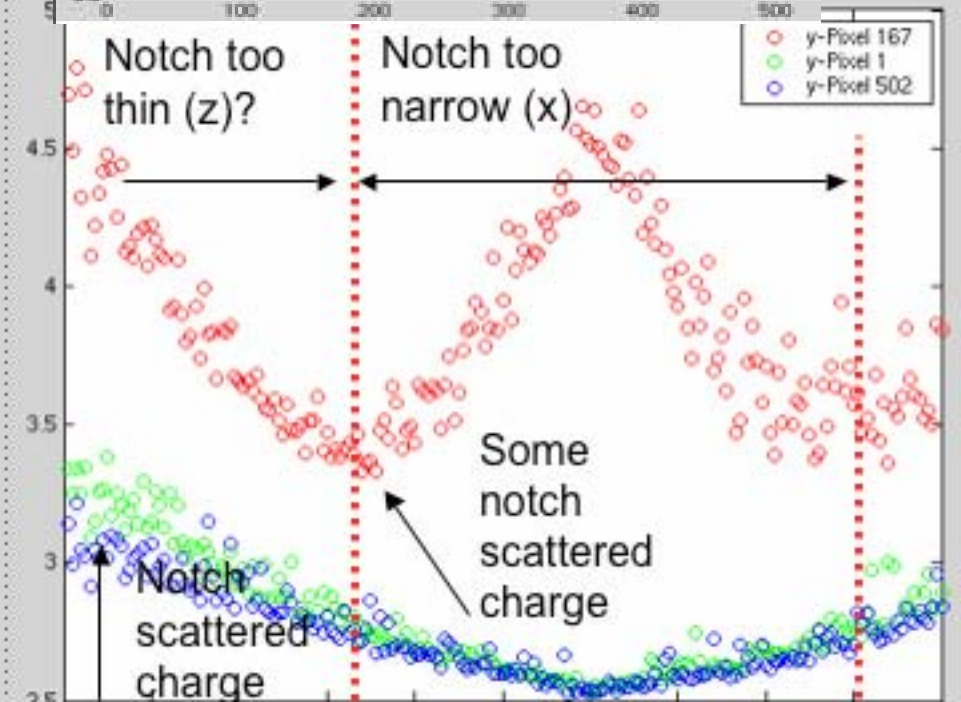
- Acceleration correlates with collimator location (Energy)
- No signature of temporally narrow witness bunch - yet!
- Other interesting phenomena also correlate (see next slide)
- Collimated spectra more complicated than anticipated

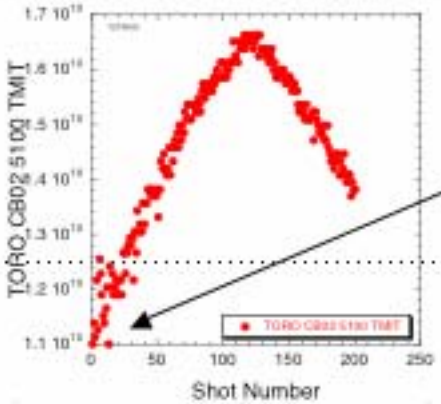
Recent Experiments - December 2005

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.







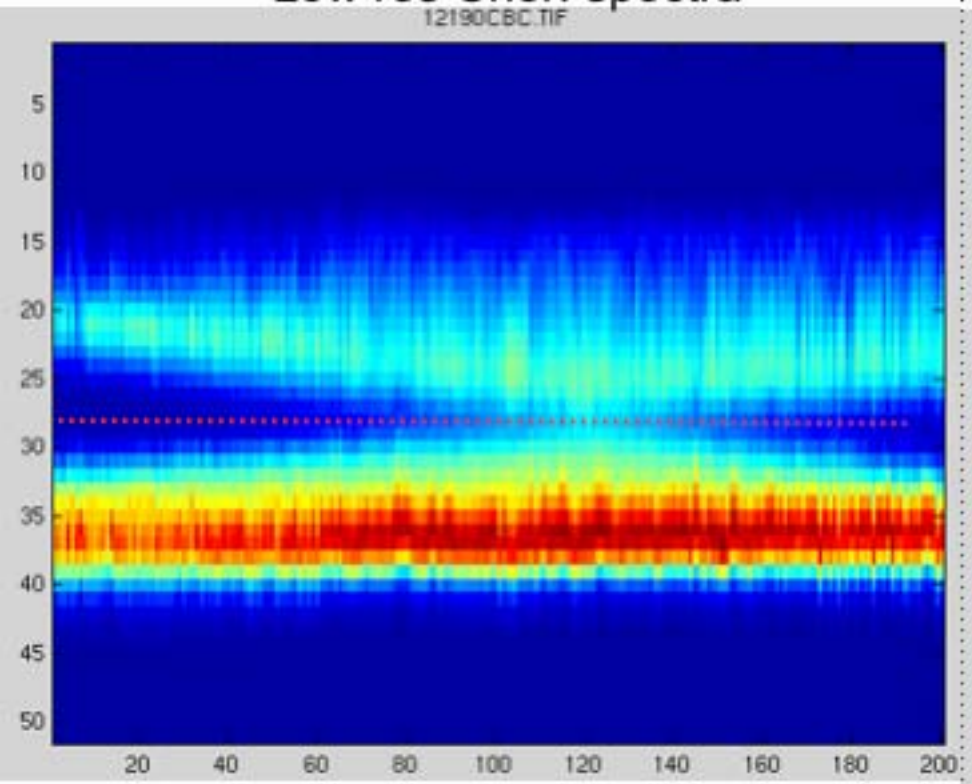


Lots of charge lost to reach a clear hole in the distribution!

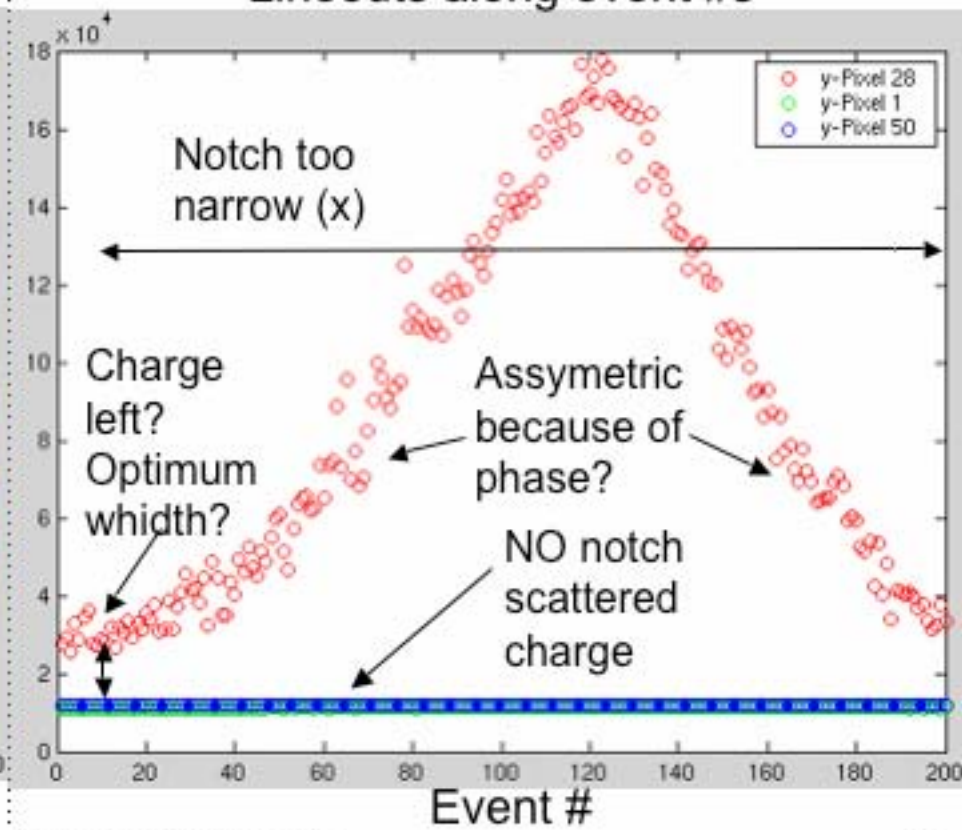
(1.1-1.2 out of 1.7-1.8)

C: Low res. C: By the C location, there is no sign of significant notch scattered charge left. There is an optimum width (x), maybe? Not quite the widest?

Low res Cher. spectra



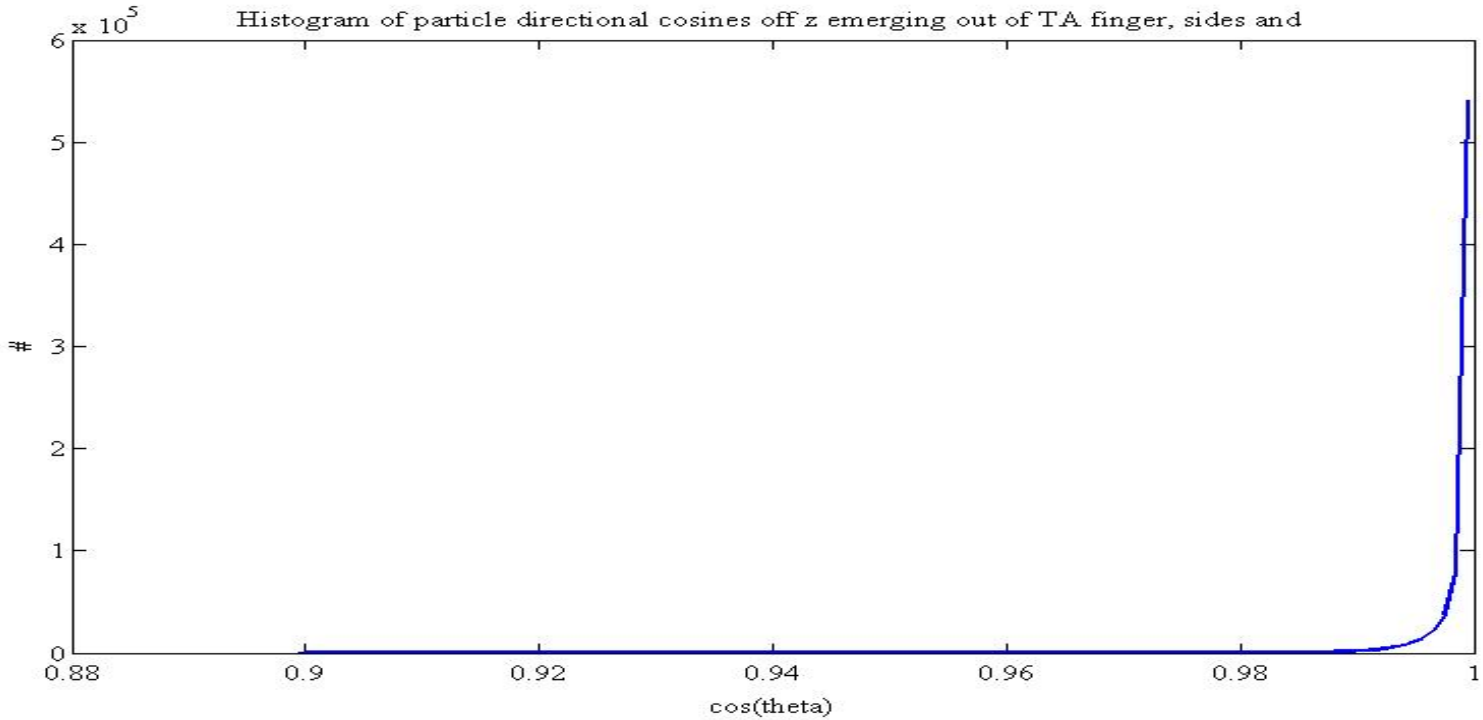
Lineouts along event #s



Egs Simulation

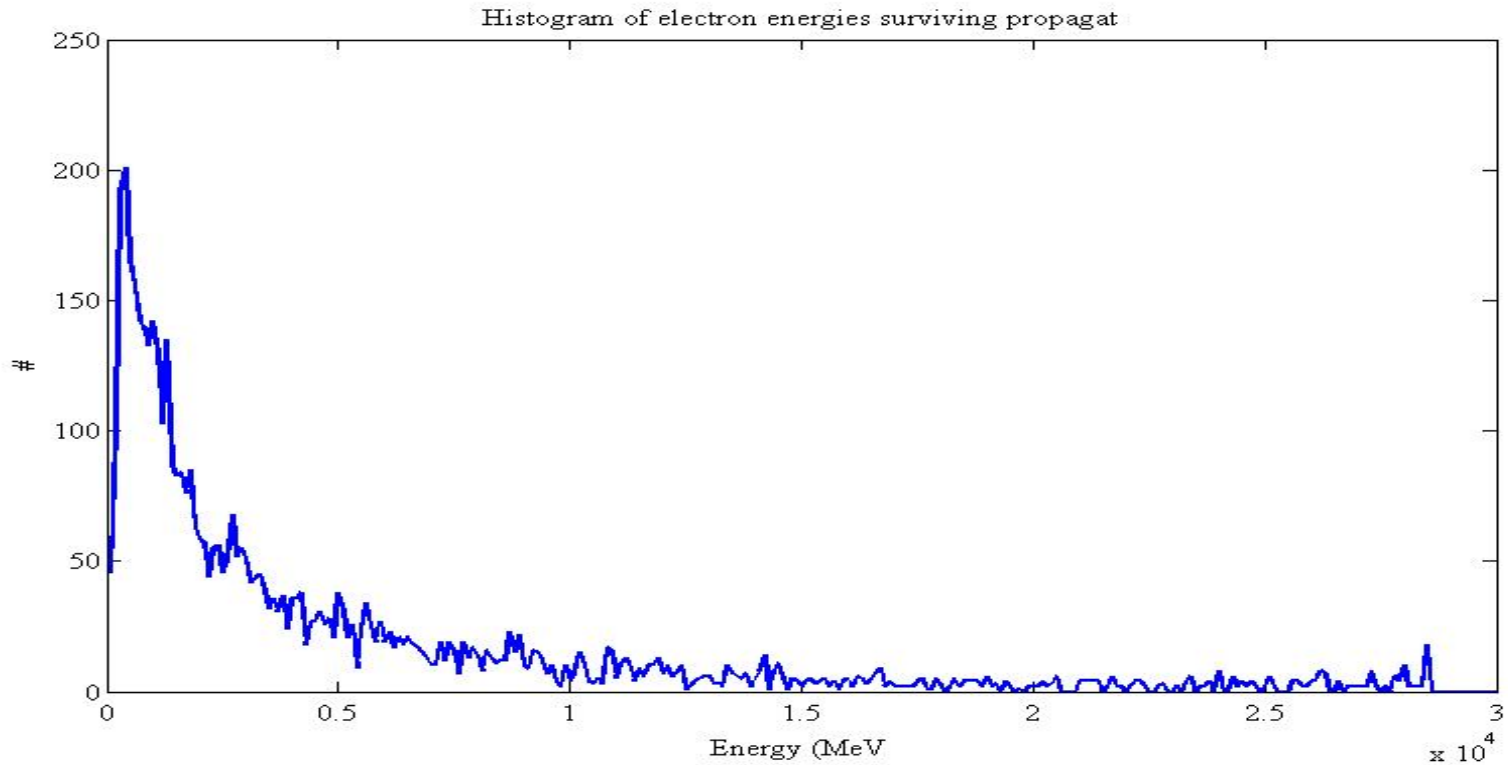
- Geometry:
  - Finger of TA, 1.6cm by 500 microns surrounded by vacuum, centred in beam pipe
  - Then 5.92m of empty vacuum down beam pipe to X-Ray Chicane
- Input conditions:
  - 10000 incident electrons in z-dir at 28.5GeV
  - Perfect emittance
- Output:
  - Particles were propagated down to chicane magnets, statistics compiled on results

Shower Results



- Most particles still have large forward momentum component

Example: Electron Energy Distribution

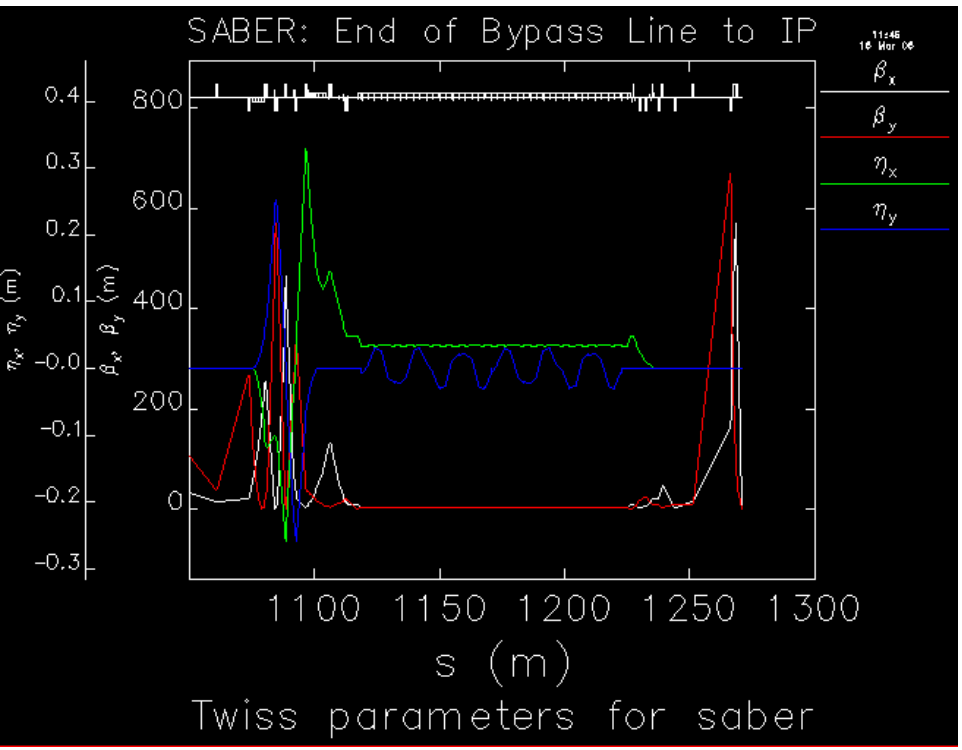


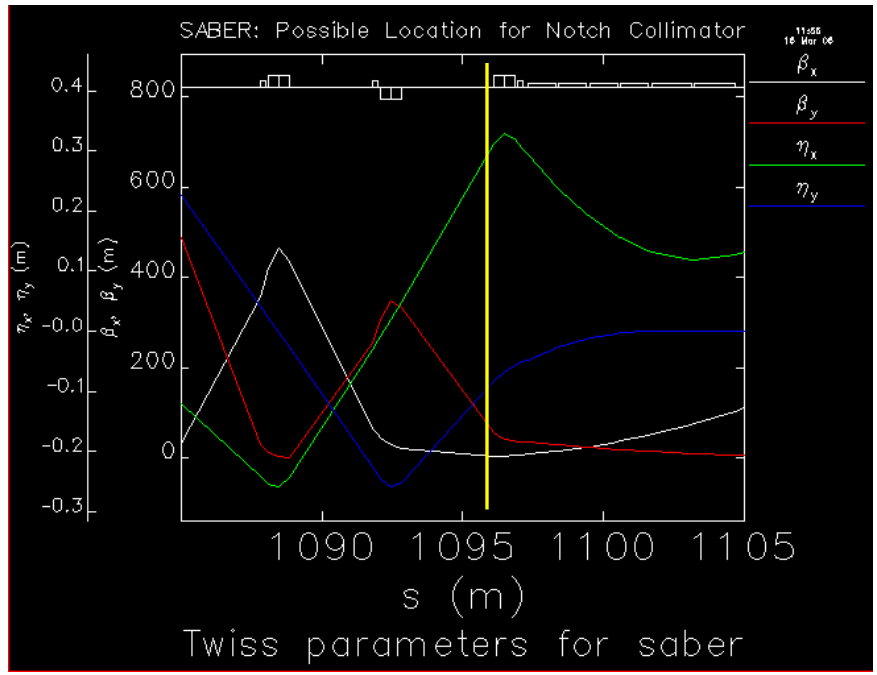
- 5031 electrons survive vacuum propagation, roughly 50% of incident
- Energies from MeV's up to 28.5 GeV
- Expect these to radiate in the chicane and add extra background to X-Ray energy spectrum

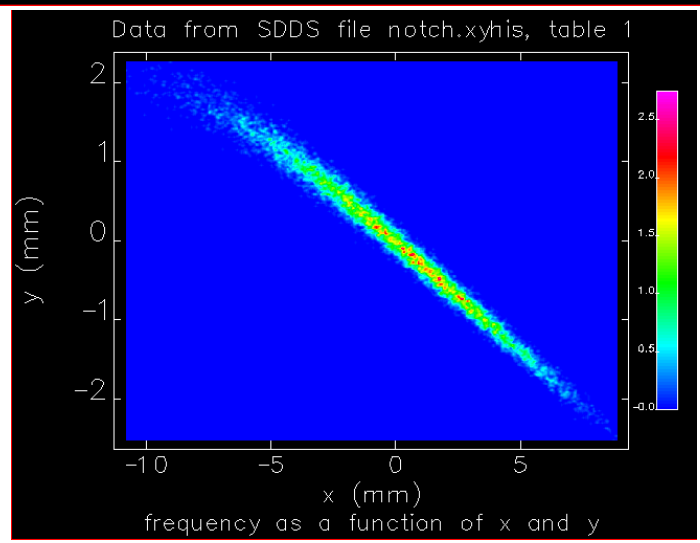
To Do

- We would like to understand what our diagnostic is saying, and eventually be able to match a beam profile
- Next Steps:
  - Add in real beamline components (two quads, one sext)
  - Propagate particles through magnet, simulate radiation by Monte Carlo methods
  - Fold in acceptance and response of X-Ray crystal
  - Use real beam parameters
    - real emittance, real number of incident electrons (should be ~1e9)

Possible Location for Notch Collimator & X-ray Stripe SABER







Prospects for SABER – Summary

- Test in FFTB has not been thoroughly explored
- Will hopefully have more complete data after next run
  - No direct measurement of two bunches
  - E-spectra coupled with PWFA
  - CTR & EO will be brought to bear if things look interesting
- Much more work to be done offline: ELEGANT, EGS5…
- Identified suitable location(s) in SABER beamline