Hall C SLI Studies and Results - 09-02-2025

Nick Sereno, J. Gubeli, B. Freeman, K. Jordan

J. Benesch, Y. Roblin, M. Tiefenback, D. Turner, S. Shinde, M. Mock, R. Bodenstein

November 11, 2025

Jefferson Lab

U.S. DEPARTMENT OF ENERGY

Main Goal is to Obtain the Beam Energy Spread

CALCULATE THE ENERGY SPREAD BY MEASURING THE HORIZONTAL BEAM SIZE

- BEAM SIZE (σ) HAS TWO CONTRIBUTIONS
  - SIZE DUE TO EMITTANCE – σ_β
    - Emittance – MEASURED FROM qsUtility TOOLSET
    - Beta - MEASURED FROM qsUtility TOOLSET
  - SIZE DUE TO DISPERSION – σ_D
    - Dispersion - MEASURED BY COMPARING AN INTRODUCED ENERGY SHIFT AND THE RESULTING BPM POSITION SHIFT

$$\sigma = \sqrt{\sigma_\beta{}^2 + \sigma_D{}^2}$$

$$\sigma_\beta = \sqrt{Emittance \cdot Beta}$$

$$\sigma_D = Energy\_Spread \cdot Dispersion$$

Two-Slit Interferometer Schematic Diagram

SYNCHROTRON RADIATION INTERFEROMETRY ...   PHYS. REV. ACCEL. BEAMS 25, 080702 (2022)
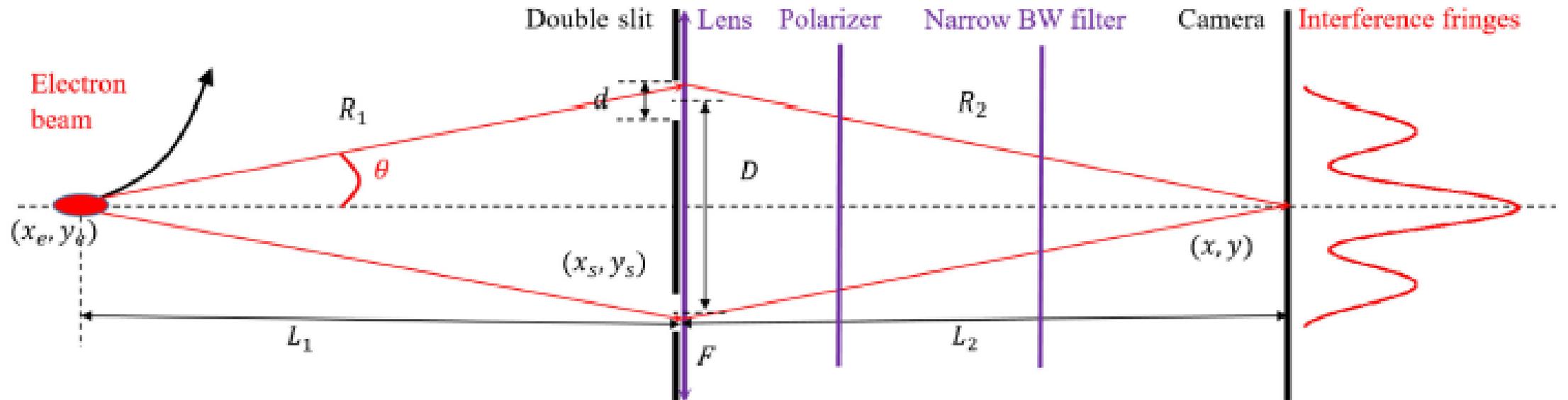
FIG. 2.   Optical layout of an SRI-based electron beam size measurement system. Synchrotron radiation from the electron beam propagates through a double slit and a focusing lens, producing an interference pattern on the image plane of the lens, which is captured by a digital camera. A linear polarizer with its polarizing axis aligned horizontally and a narrow bandpass filter are used to improve the system performance.

Hall C Beamline Two Slit Interferometer Realization

Jefferson Lab

SYNCHROTRON RADIATION INTERFEROMETER (SRI)
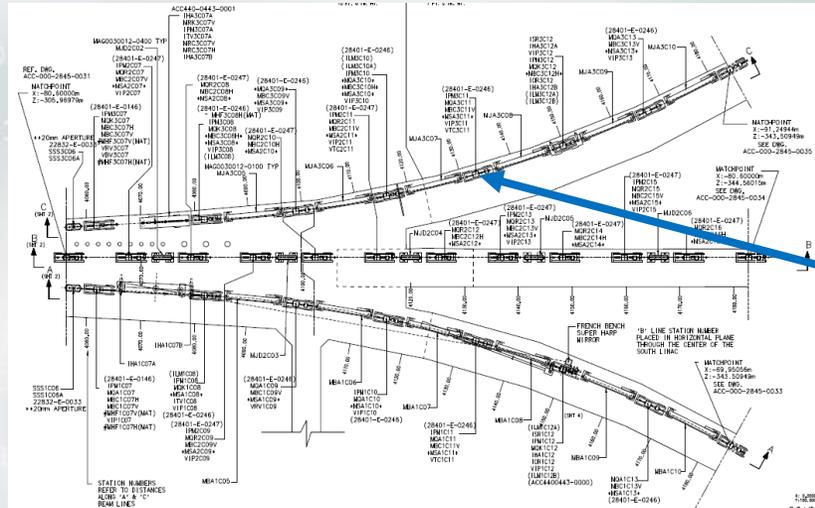
INSERTABLE MIRROR
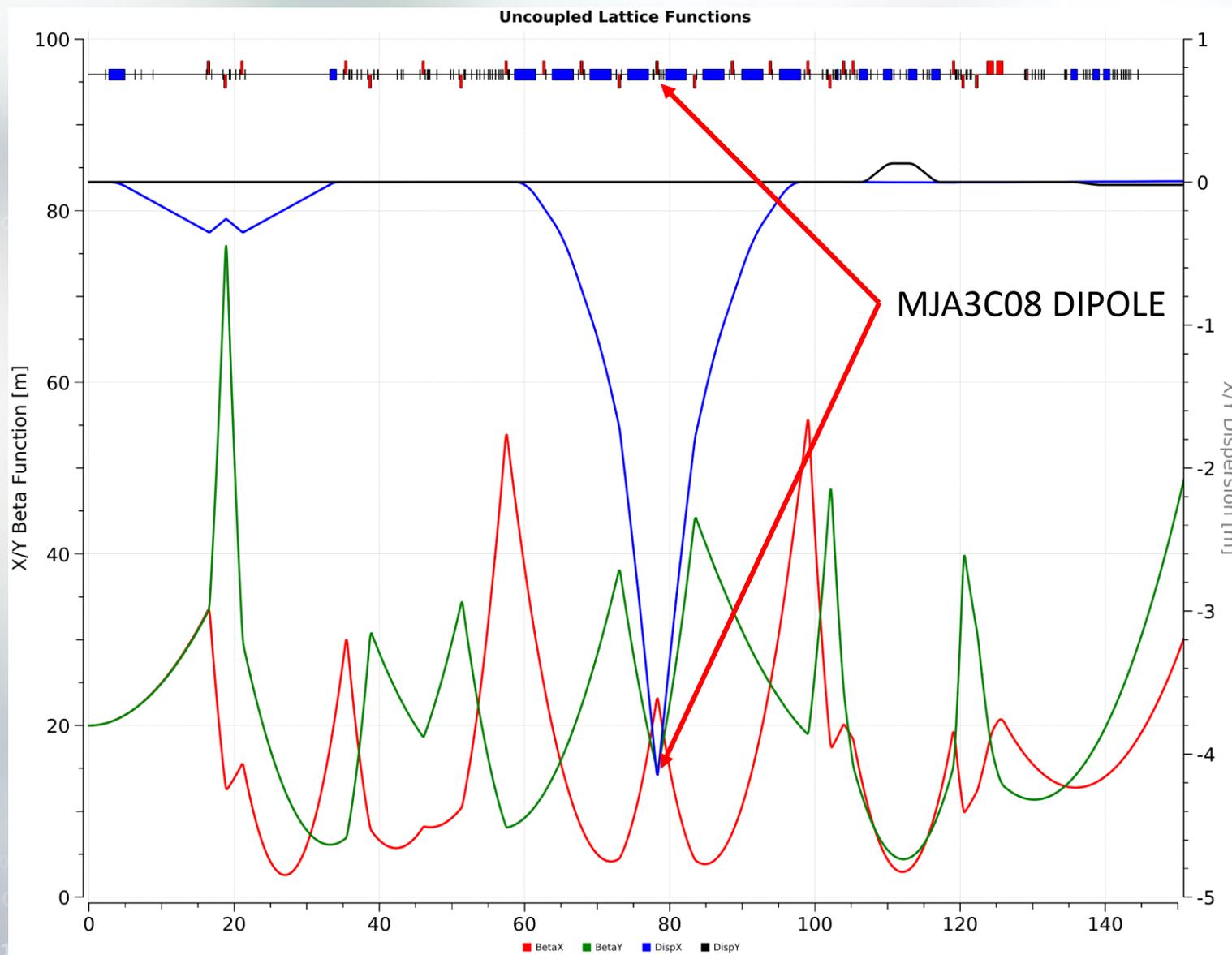(AIR, SOLENOID & TWO LIMIT SWITCHES)

MJA3C08 DIPOLE

3C12 GIRDER

TURNING MIRROR
(TW0 AXIS SERVO)

SLIT STAGE
(AIR, SOLENOID & TWO LIMIT SWITCHES)

GigE CAMERA
(POE & ONE AXIS SERVO)

11/11/2025

Hall C SLI Studies and Results - 09-02-2025
4

4

Hall C Beamline Twiss Parameters

Uncoupled Lattice Functions

MJA3C08 DIPOLE

Hall C SLI Studies and Results - 09-02-2025

5

Studies Chronology Summary

2025-09-04 10:34 COMPLETED by mock (**Matthew Mock**)
Test plan completed 9/2.

2025-09-03 10:39 COMMENT by bfreeman (**Brian Freeman**)
Yesterday, we were given some time to do some 1st pass commissioning activities, here is a short roll up.

Arc 1 SLM Bunch length measurement done : **logbooks.jlab.org/entry/4455333 (bunchlength very long, 0L04 off-crest put on-crest))**

Then the crew spent some time setting up Hall C to first pass. The first pass separator would not initially come up, and then there was a viewer being worked on in Hall A that prevent us from getting into Tune mode for a bit.

We were able to eventually achieve a diffraction pattern after going CW, however the central peak was really bright for some reason, so the software would not achieve a good enough fit of the diffraction. Some images captured here. Note, that this was before the match data was taken and applied:
logbooks.jlab.org/entry/4455366
logbooks.jlab.org/entry/4455375

Match data taken:
logbooks.jlab.org/entry/4455394
logbooks.jlab.org/entry/4455401

Studies Chronology Summary

Then after match:
logbooks.jlab.org/entry/4455458
logbooks.jlab.org/entry/4455460

Calculated the Energy Spread using the Harp trace done after the match:
logbooks.jlab.org/entry/4455496

The SLI team decided to make an access to the BSY, during the MoMod swap to remove one of the slits. This was in hope to be able to simply use the camera calibration factors and a Gaussian fit on the profile to measure the beam size. I was able to make some changes in the software to use this number to calculate energy spread instead of a diffraction fit.

Here is the SLI image with no slit:
logbooks.jlab.org/entry/4455517

and a followup of the archived signals overnight with harp traces:
logbooks.jlab.org/entry/4456074

We all ran out steam, so we did not get to setup the alternate optics. Overall a successful commissioning run.
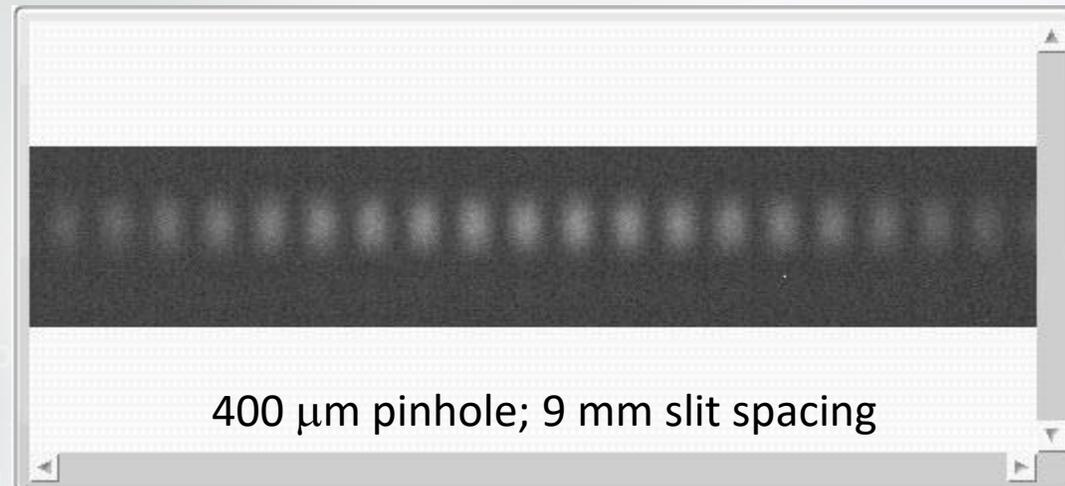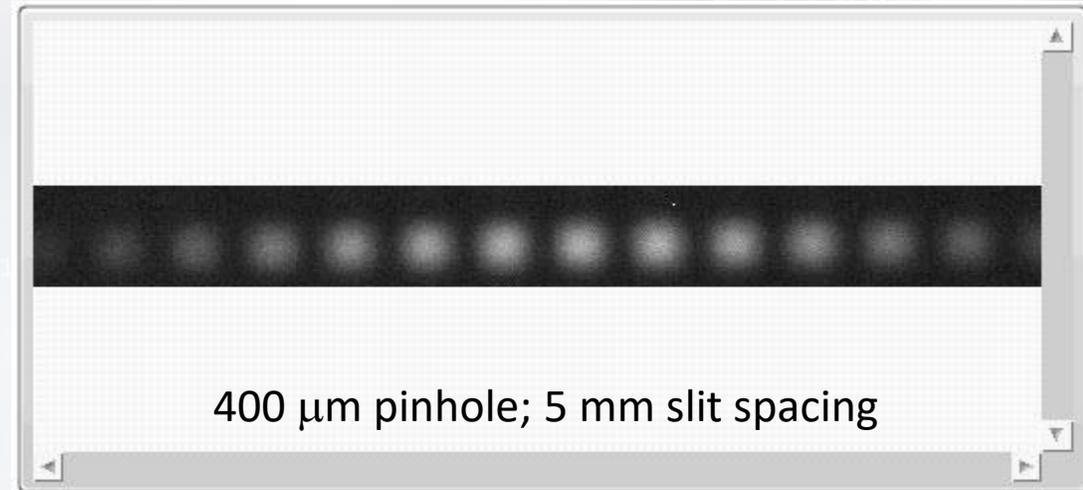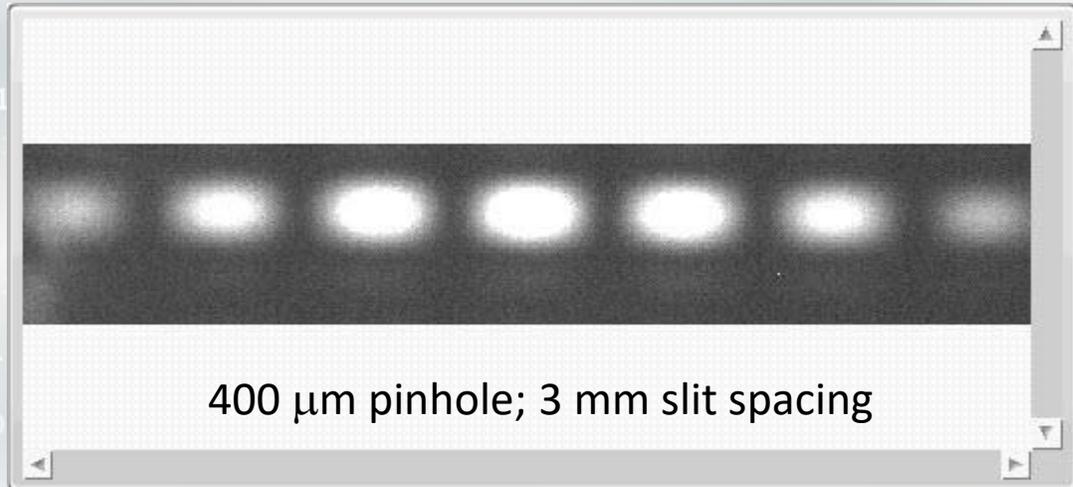2025-08-28 09:44 SCHEDULED by moser

Results Highlights:

- First interference images taken 9/2/2025 ~ 5 uA - 30 uA CW, 1st pass beam ~2.2 GeV

- Very bright central peak causes problems with fitting the image to get beam size

- Central peak may be saturated too (3 mm slit distance 0.125 s integration time)
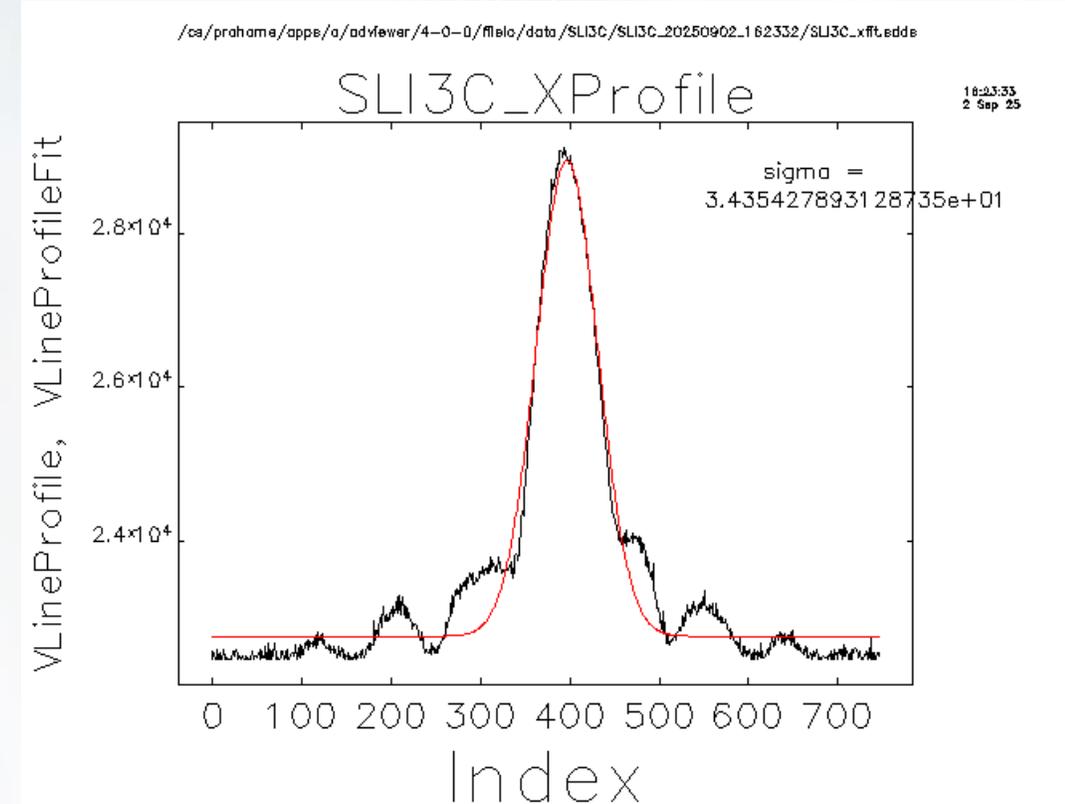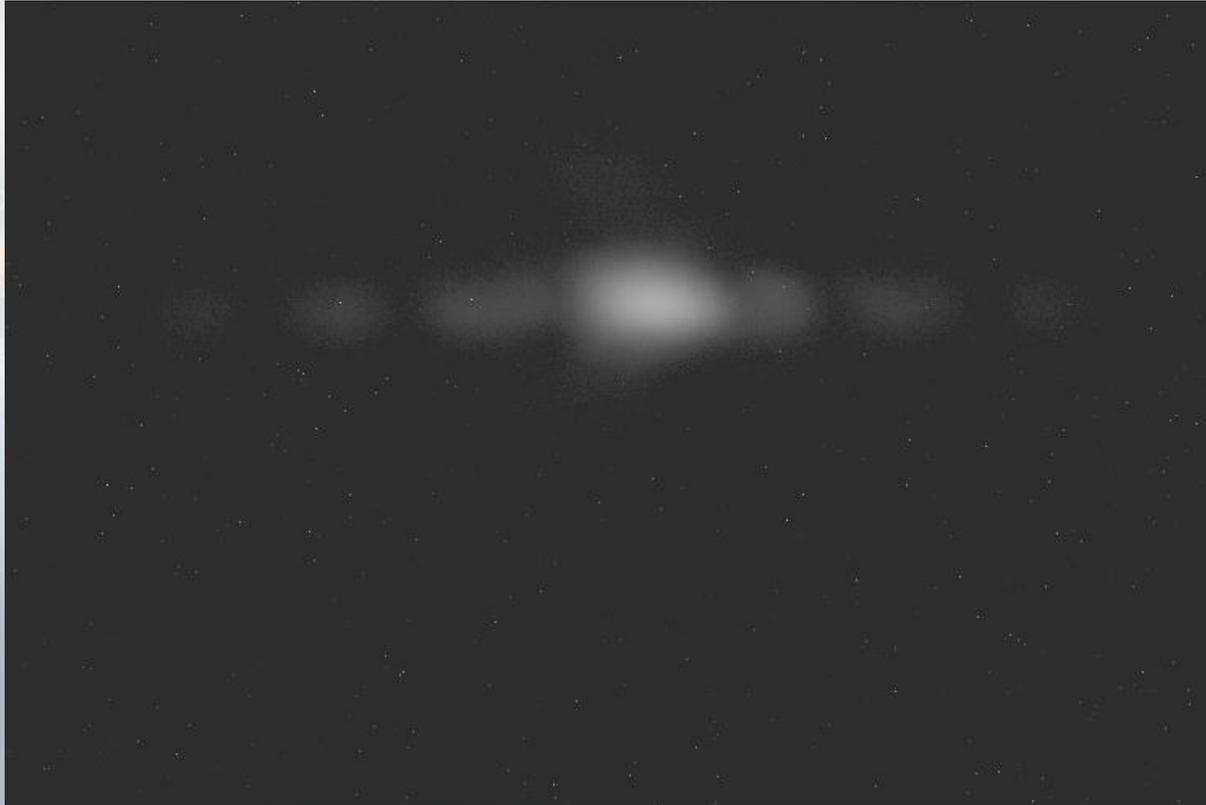
Logbook entry 4455458
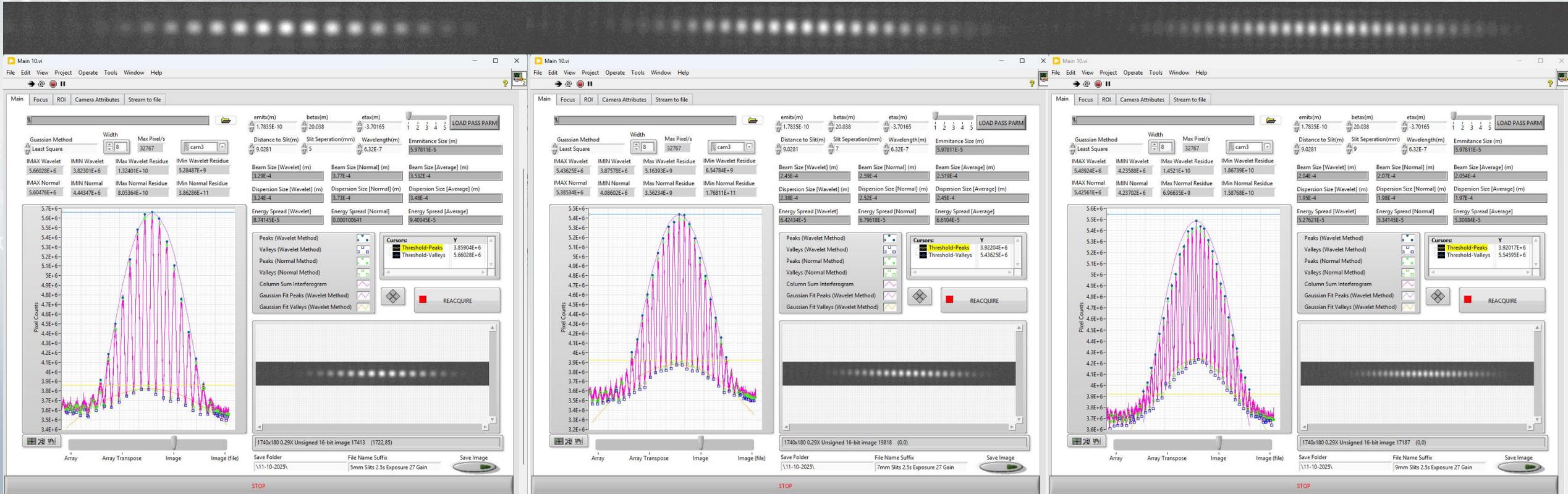
Results Highlights: Bench Testing

- Interference images taken on the bench (J. Gubeli). Much more reasonable results

400 μm pinhole; 3 mm slit spacing

400 μm pinhole; 5 mm slit spacing

400 μm pinhole; 9 mm slit spacing

Results Highlights: Bench Testing

- Interference images taken on the bench (J. Gubeli). Analysis of fringes:

400um PINHOLE - 2.5s EXPOSURE – 27 GAIN – 632nm

5mm SEPARATED SLITS
329um CALC. PINHOLE SIZE

7mm SEPARATED SLITS
245um CALC. PINHOLE SIZE

9mm SEPARATED SLITS
204um CAL PINHOLE SIZE

Results Highlights:

- Took harp scans to measure emittance and twiss functions at IHA3C05

- Removed the slits in the SLI to get essentially a "pinhole" image of the beam (no interference fringes)

- Used camera calibration and a gaussian fit to the profile to get beam size

- From harp horizontal beam size $\sigma_x = 162$ μm

- Using measured emittance and dispersion this is $\delta E/E \sim 3.2 \times 10^{-5}$

- SLI gaussian fit is approximately the same size ~ 200 μm

- Noted drift in beam size overnight corresponding to $\sim \delta E/E \sim 4.5 \times 10^{-5}$ (logbook entry 4456074)
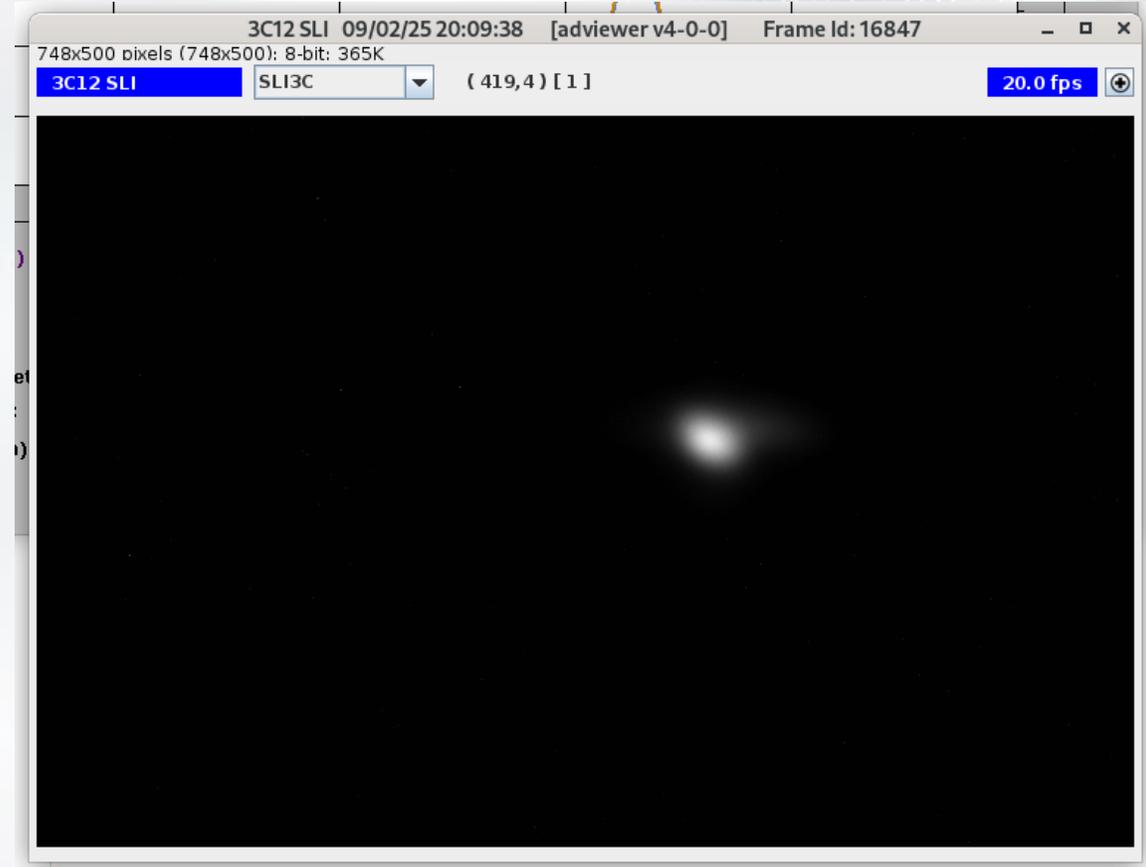
Logbook entry 4455517

Summary

- My opinion is this was a successful shift:

- Obtained first interference fringes from this new device (first in some 25 years or so)

- Demonstrated small acceptable energy spread for Hall C experiments using harp scans and pinhole imaging with the SLI

- One could demonstrate qualitative beam size changes as gang phase was moved (causing higher energy spread due to off crest condition)

- Still need to understand why the interference pattern central peak is so abnormally high (maybe a misalignment of some sort is causing this?)

- Joe Gubeli is performing bench testing to understand the interference patterns (suggestion by M. Tiefenback see extra slide)

- So, hopefully more studies to come in the 2026 run and of course more bench/theoretical analysis

Questions, Comments, Discussion?
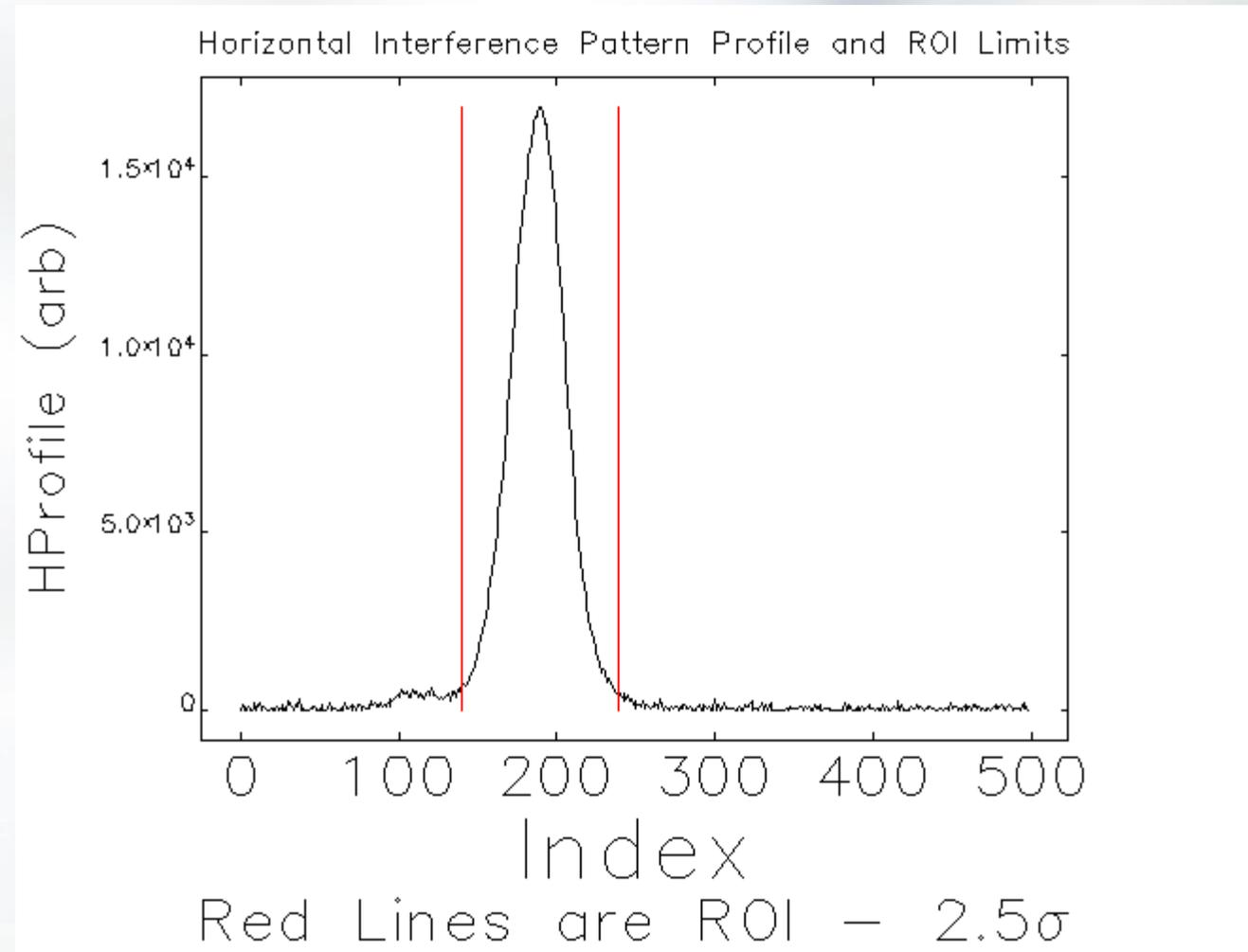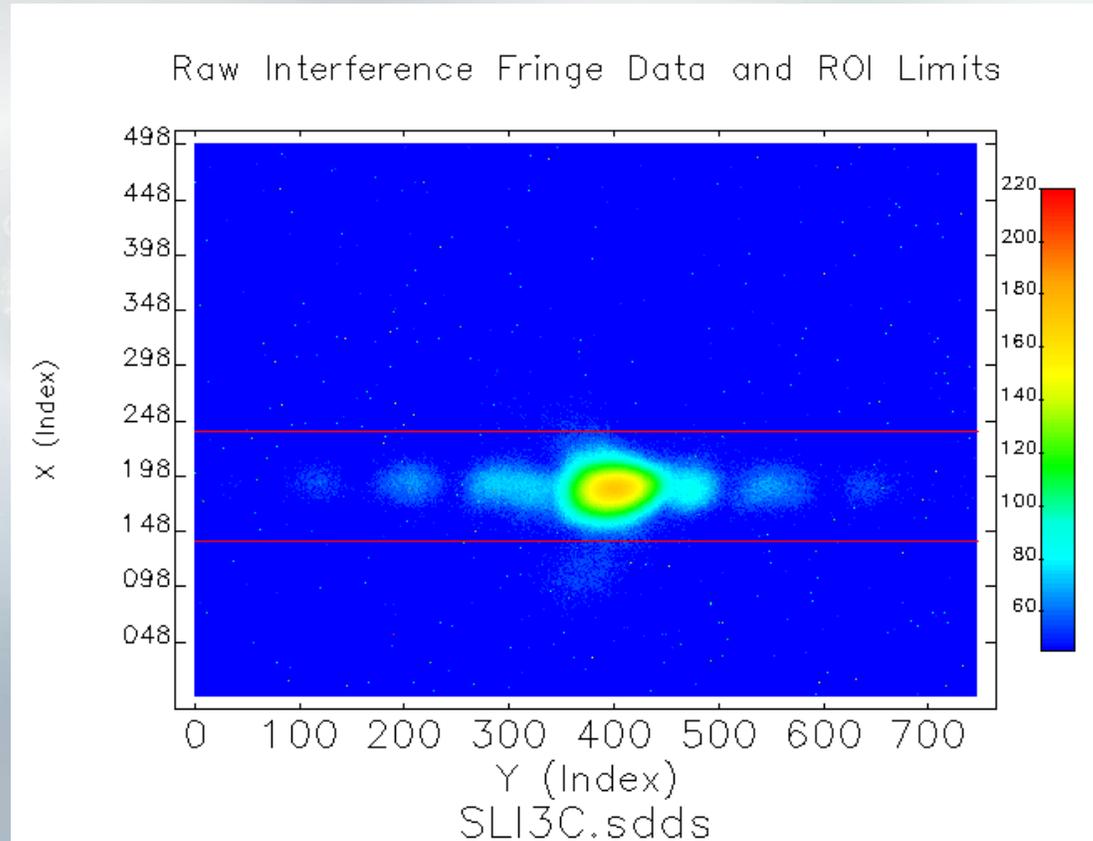
Extra Slides

- Analysis of interference image using sddsgenericfit

Questions, Comments, Discussion?

SLI Interferogram Analysis Using sddsgenericfit

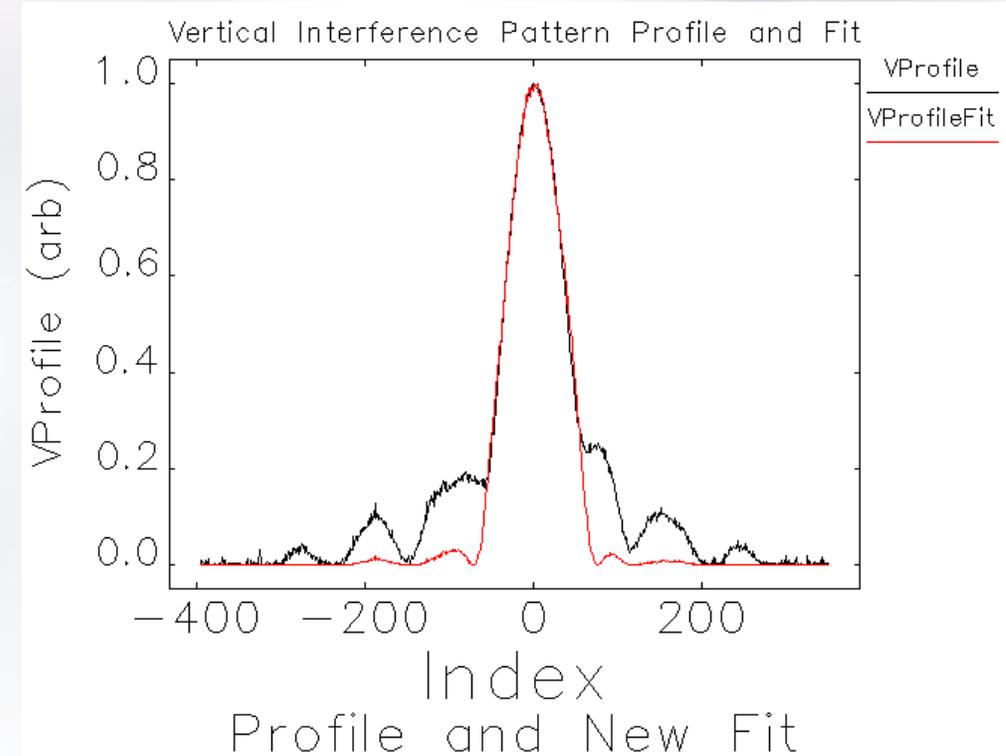- Similar problem, large central peak relative to the fringes

Raw Interference Fringe Data and ROI Limits

SLI3C.sdds

Horizontal Interference Pattern Profile and ROI Limits

Red Lines are ROI − 2.5σ

SLI Interferogram Analysis Using sddsgenericfit

- Fitting two different functional forms does not work well

Profile and Old Fit
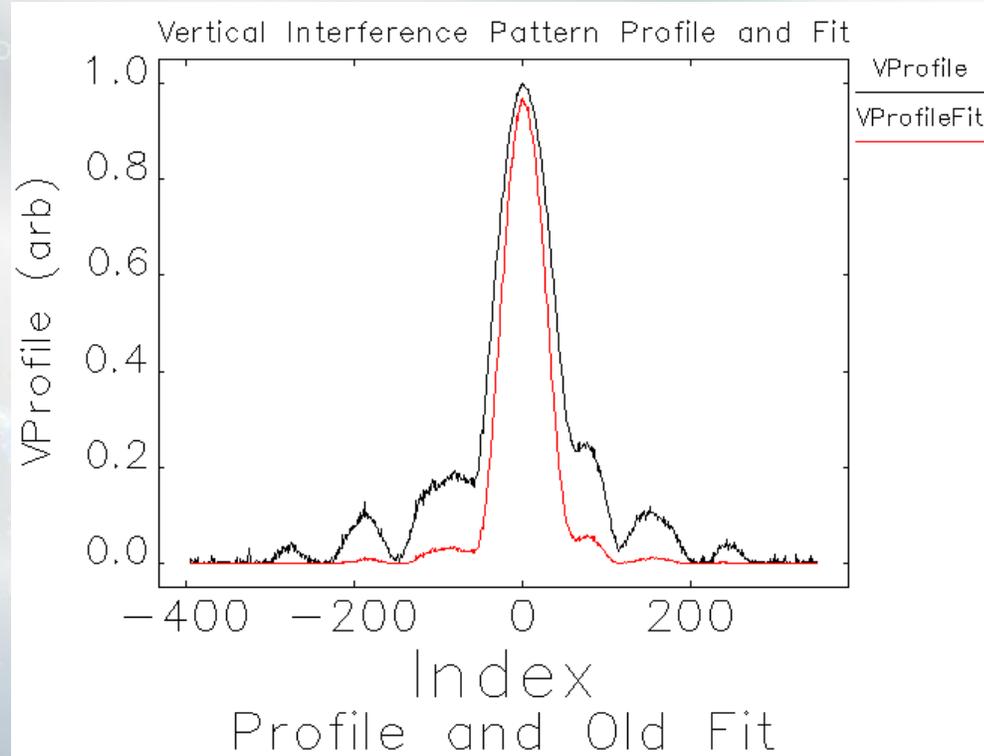
$$I(y) = p_0 + p_1 \text{sinc}^2(p_2 y + p_3)$$
$$\times \left(1 + e^{-p_4}\left\{\cos\left[p_5\left(y + \frac{p_3}{p_2}\right)\right]\right.\right.$$
$$\left.\left. + (p_6 y + p_7)\sin\left[p_5\left(y + \frac{p_3}{p_2}\right)\right]\right\}\right), \quad (17)$$

Profile and New Fit

$$I_1(y) = p_0 + p_1 \text{sinc}^2(c_1 y + p_2)$$
$$\times \left\{1 + e^{-p_3}\cos\left[c_2\left(y + \frac{p_2}{c_1}\right)\right]\right\}, \quad (20)$$