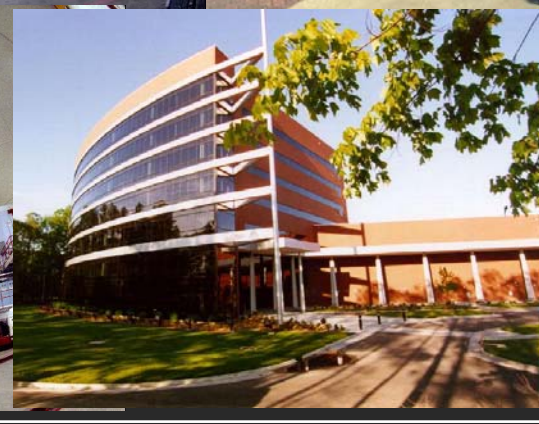
Operational Experience with Synchrotron Light Interferometers for CEBAF Experimental Beam Lines

Pavel Chevtsov

Operational Experience with Synchrotron Light Interferometers for CEBAF Experimental Beam Lines

PCaPAC-2006

CEBAF Center

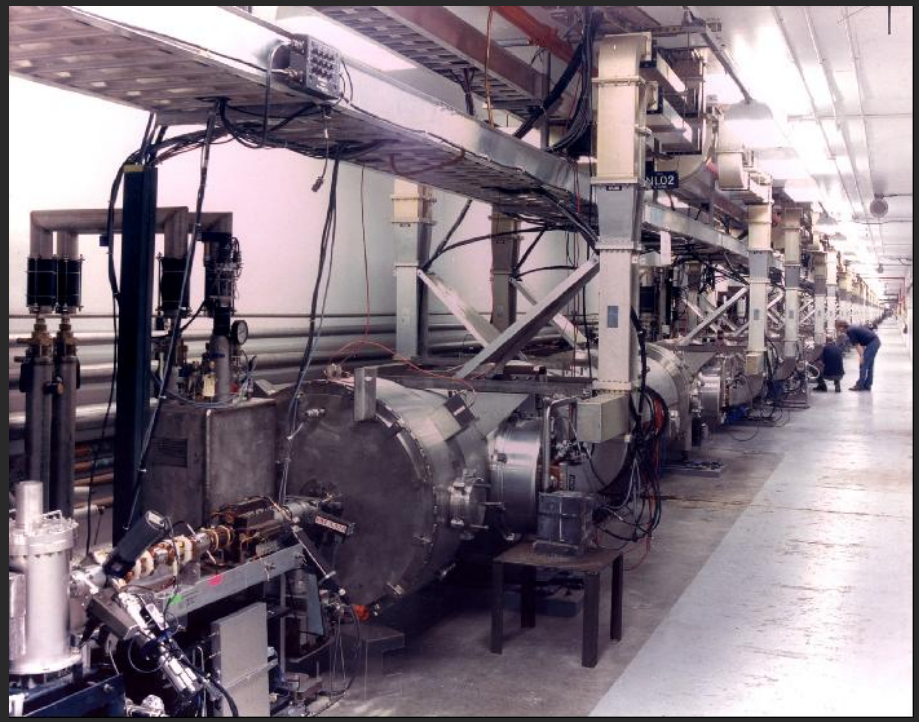


Jefferson Lab

PCaPAC-2006

CEBAF
accelerator

Experimental end stations (Halls)

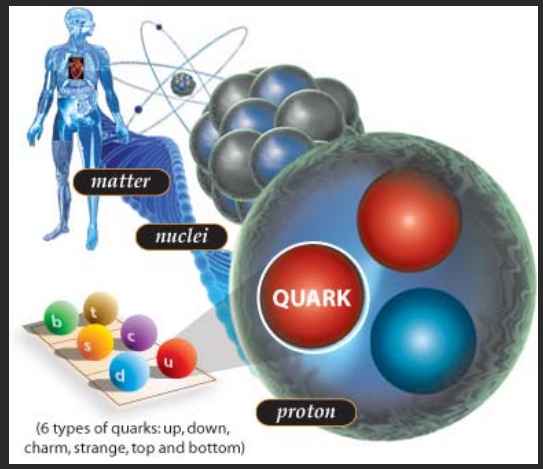


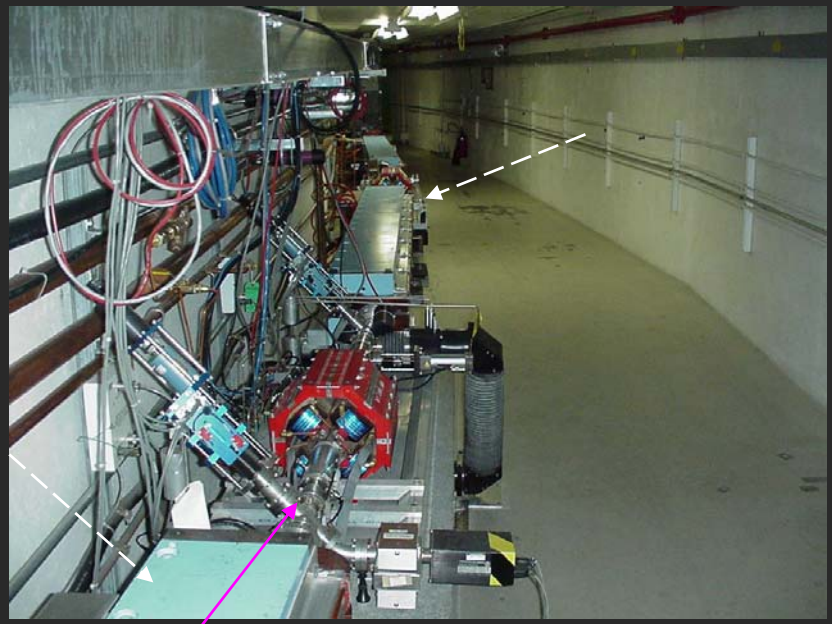
Relative beam energy spread

$\delta E/E \sim 2 \cdot 10^{-5}$

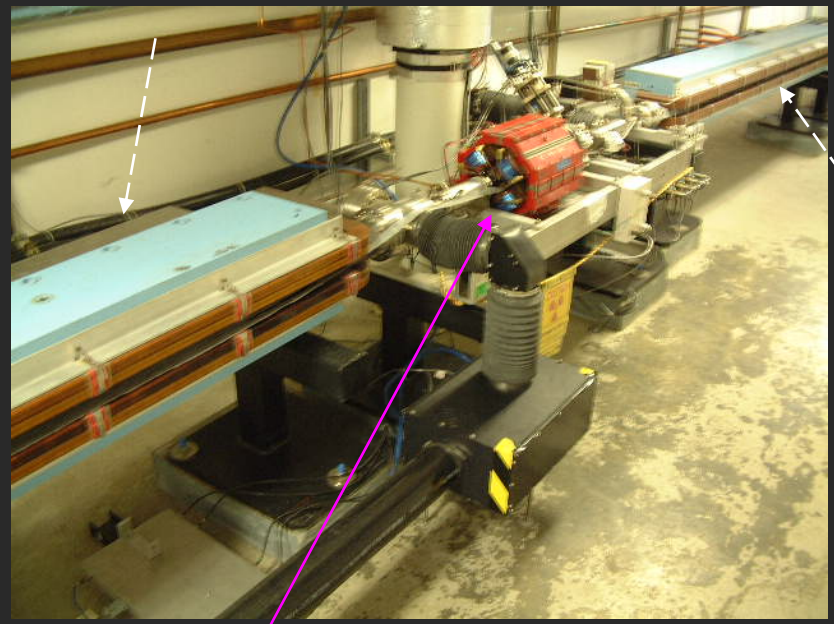
5 GeV electron beams → $\delta E \approx 100$ KeV

$E_{\text{rest electron}} \approx 510$ KeV


matter
nuclei
QUARK
proton
b
t
s
c
d
u
(6 types of quarks: up, down, charm, strange, top and bottom)

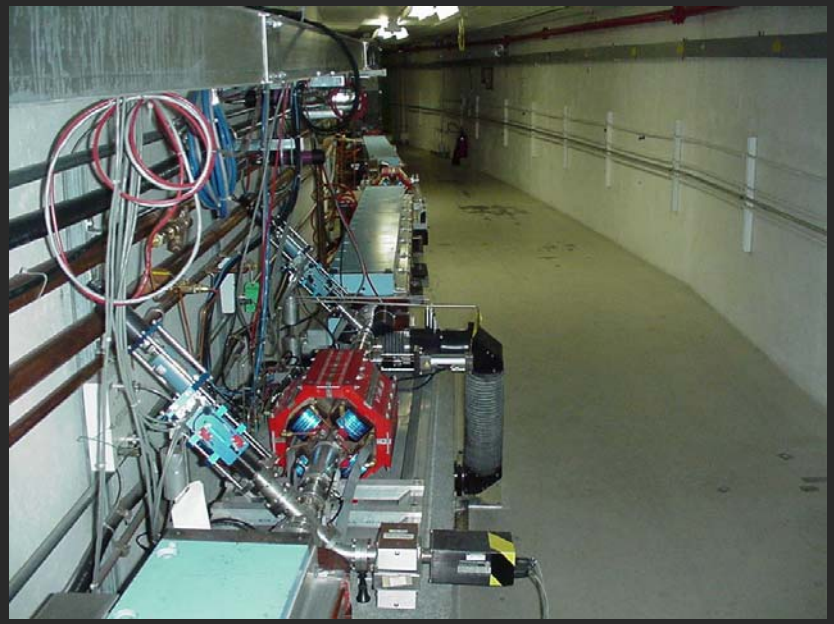


3C12 (hall C beam line)



1C12 (hall A beam line)

$\sigma_{beam} \sim 80\ \mu m$



3C12 (hall C beam line)

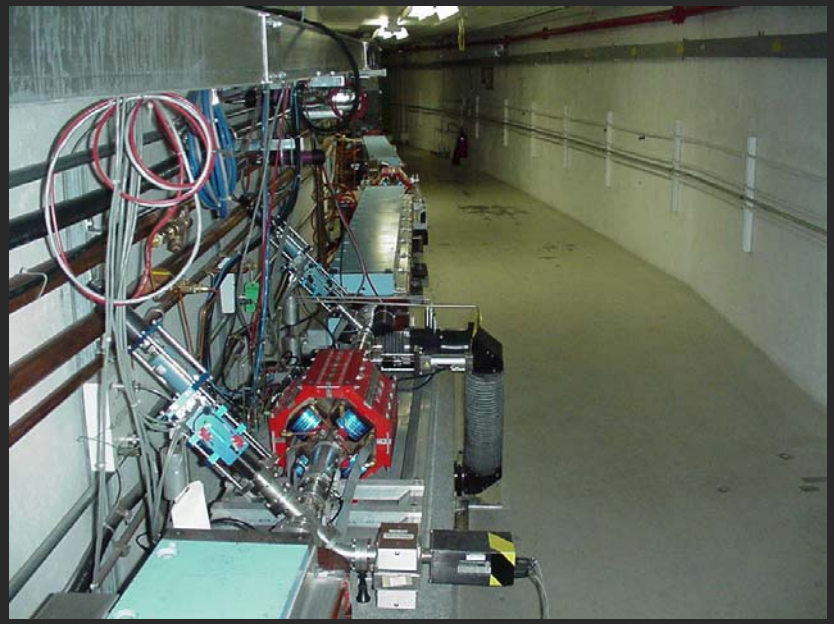
1C12 (hall A beam line)

$$\sigma^2_{beam} = \sigma^2_{\beta} + \sigma^2_{\delta}$$

$$\sigma^2_{\beta} << \sigma^2_{\delta}$$

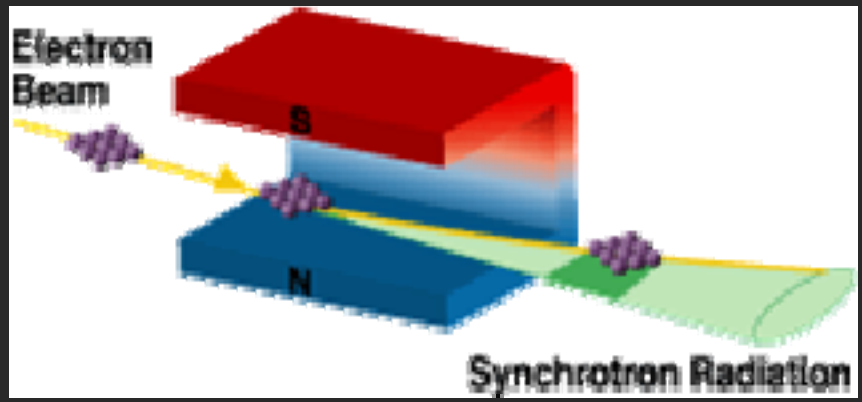
$$\rightarrow$$

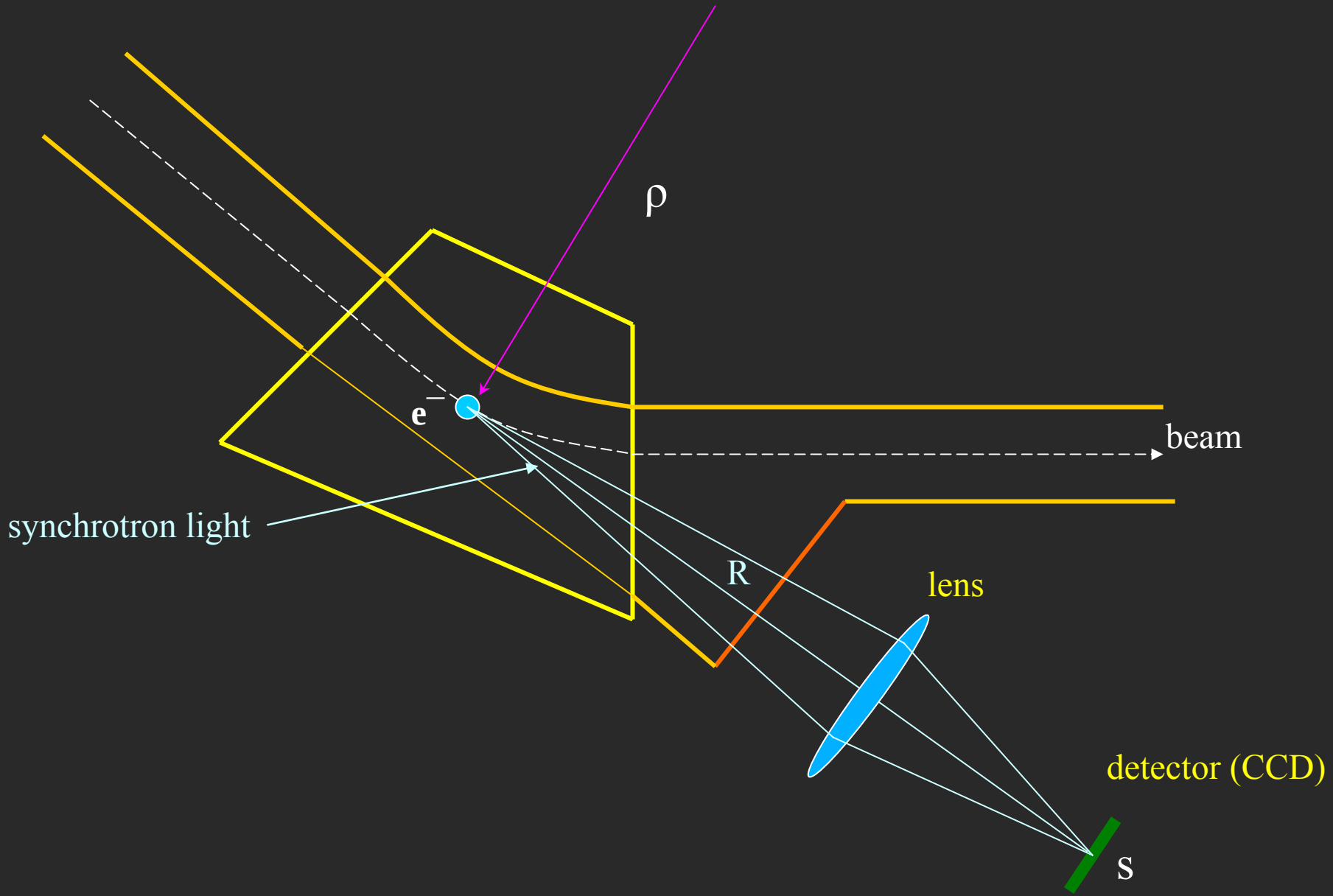
$$\sigma_{beam} = \sigma_{\delta} = (\delta E/E)\, d$$

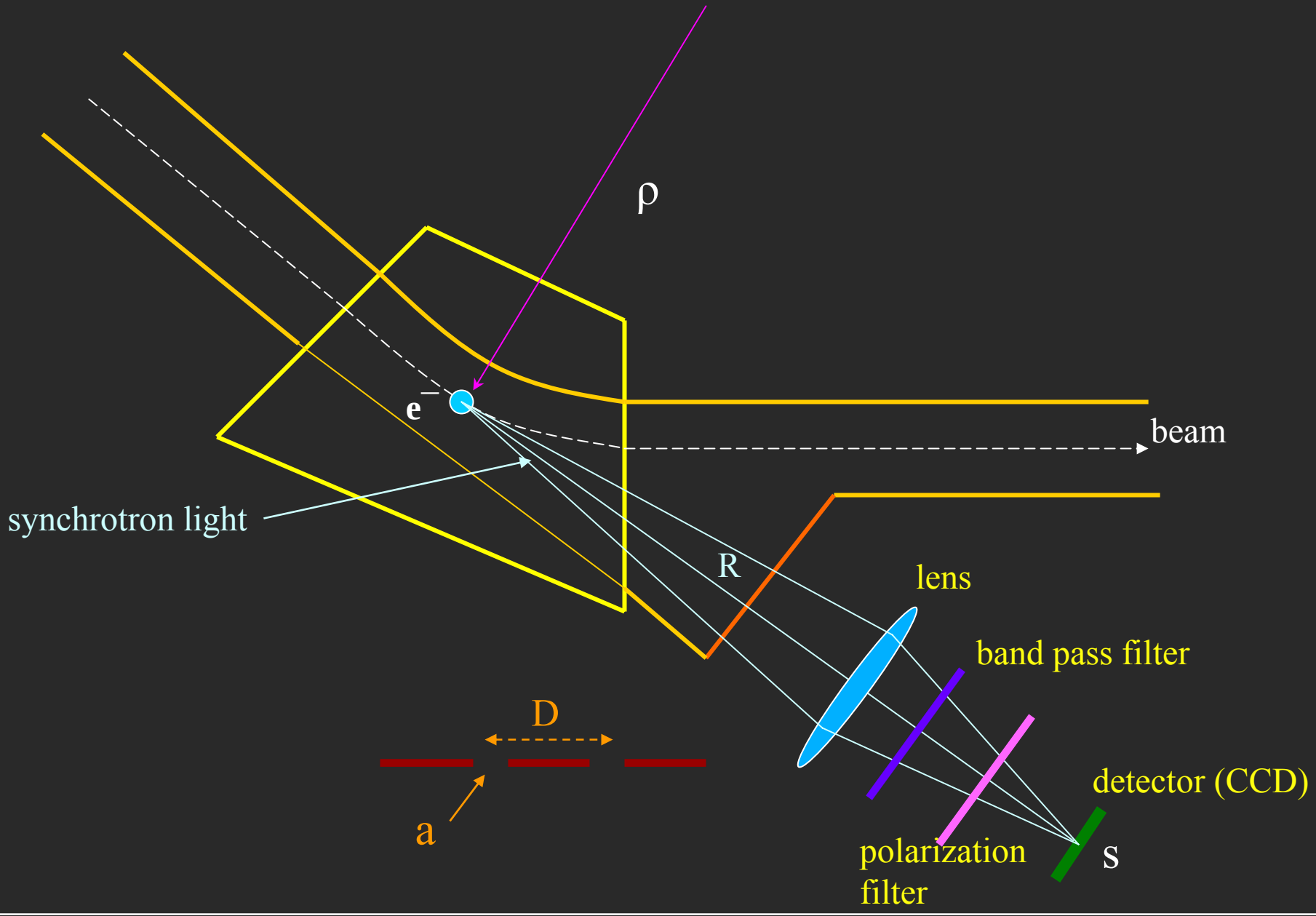


3C12 (hall C beam line)

1C12 (hall A beam line)

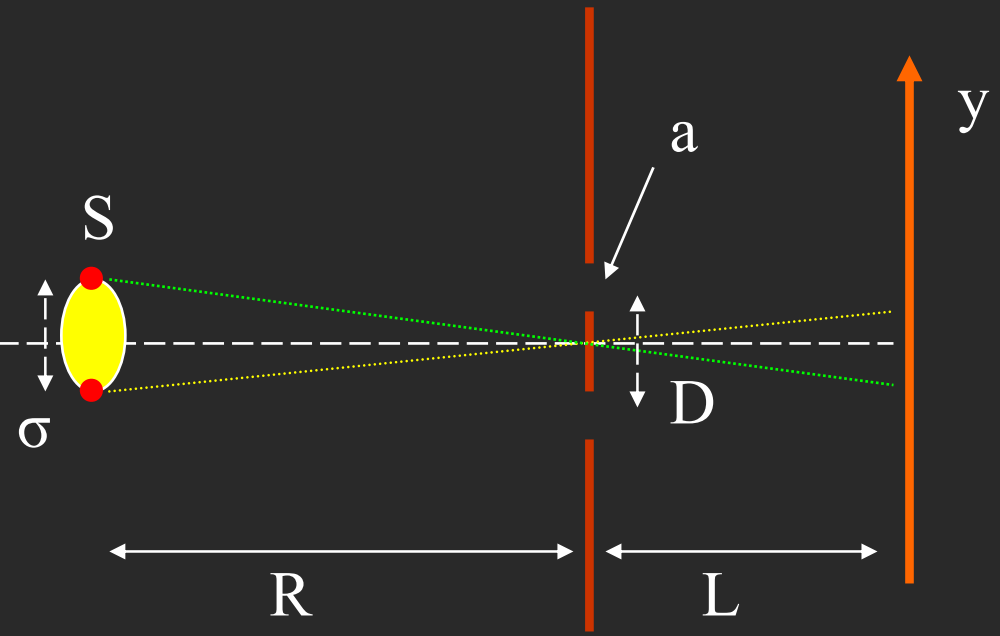


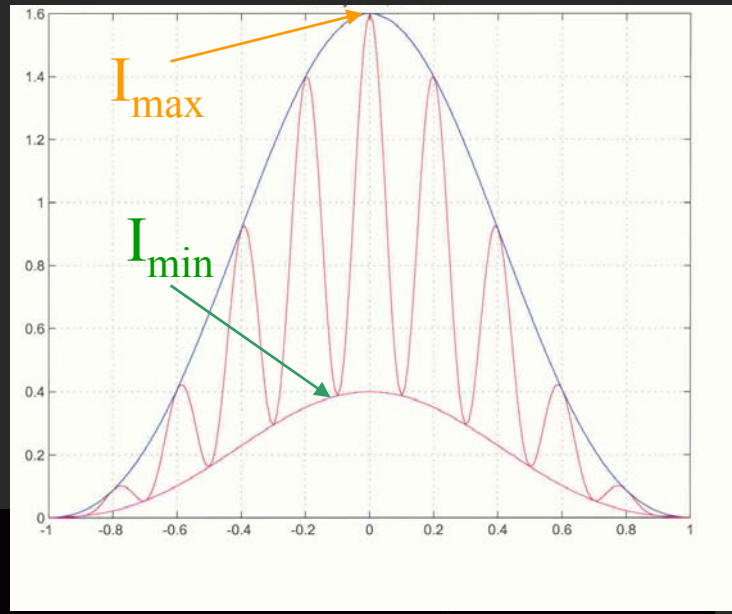

ρ
e
beam
synchrotron light
R
lens
detector (CCD)
s

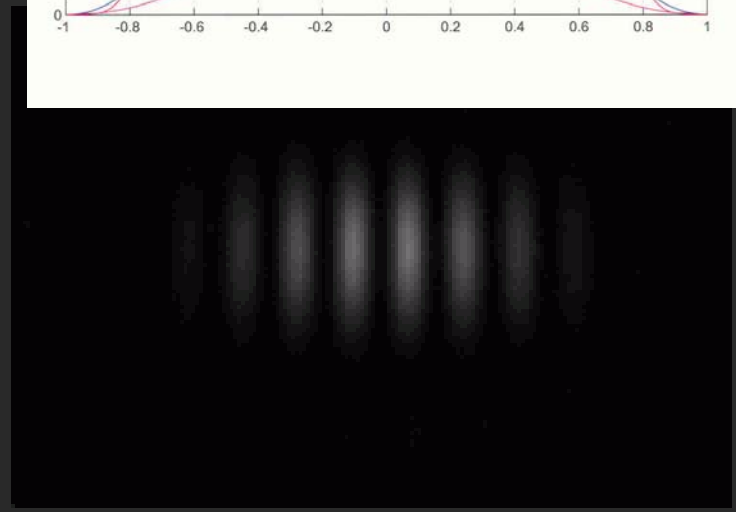

ρ
e
beam
synchrotron light
R
lens
band pass filter
D
a
detector (CCD)
polarization
filter
s

SLI

principal SLI dipole

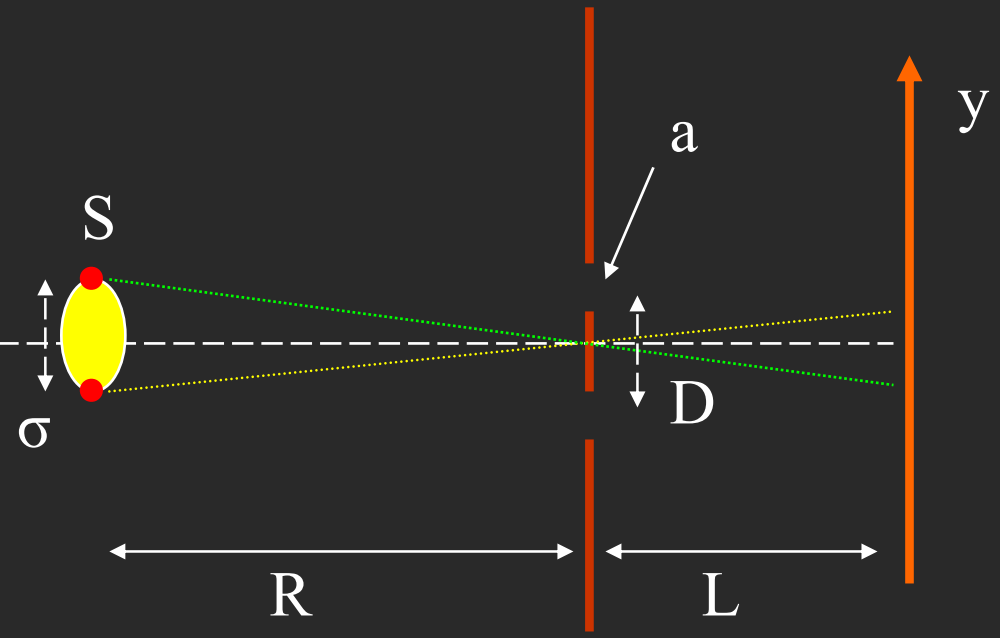


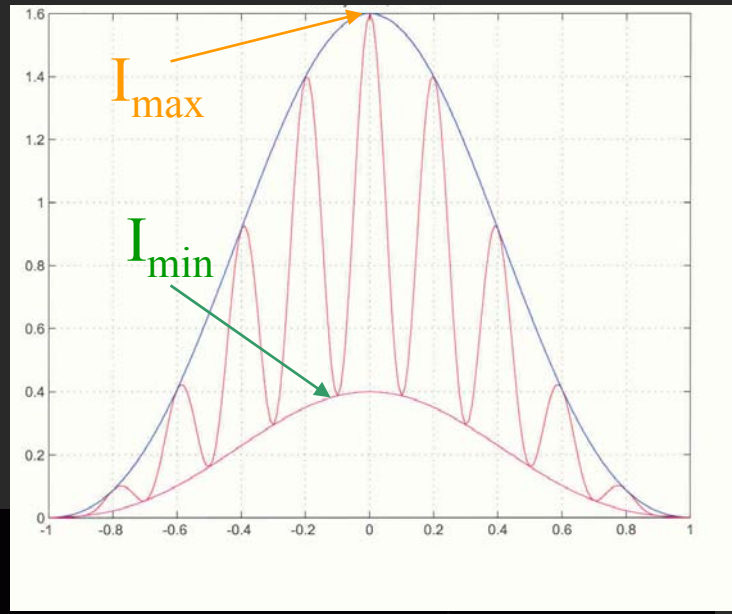


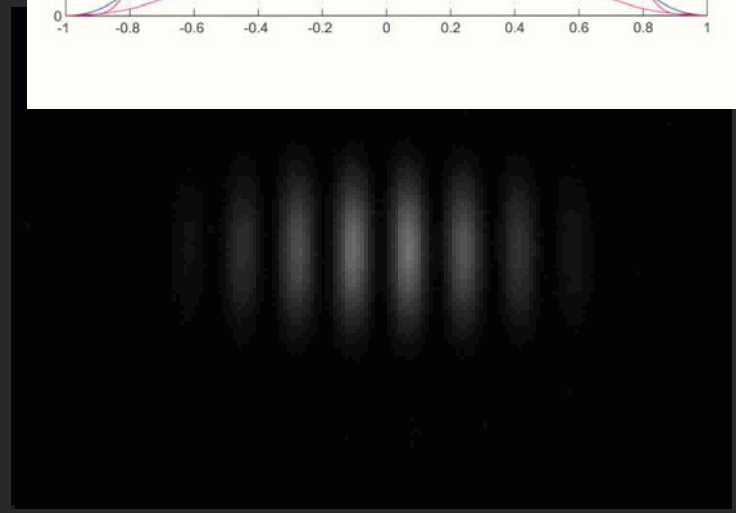


$$I(y) = I_0 \left[\frac{\sin(\alpha a y)}{\alpha a y}\right]^2 [\,1 + V\cos(\beta D y)\,]$$

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



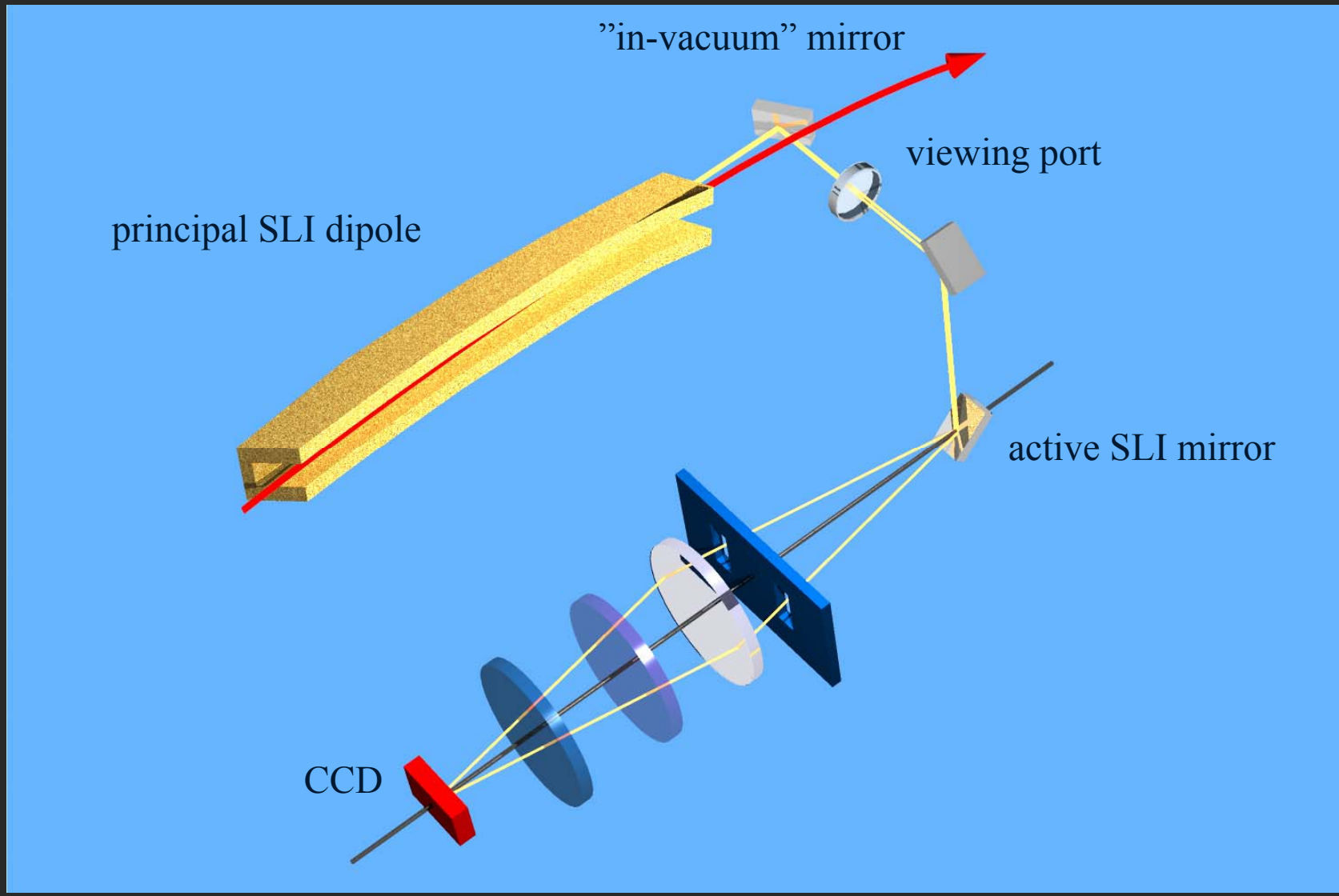


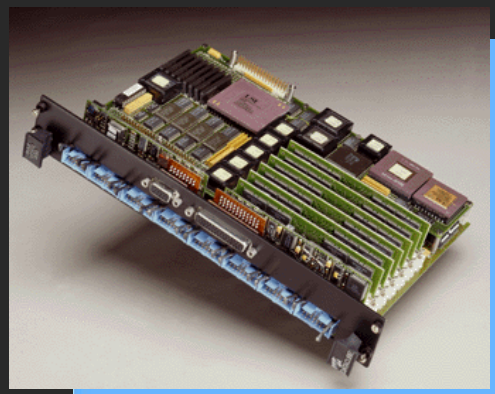


$$\sigma_{source} = \frac{\lambda R}{\pi D}\sqrt{0.5 \ln(1/V)}$$

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$


CAUTION

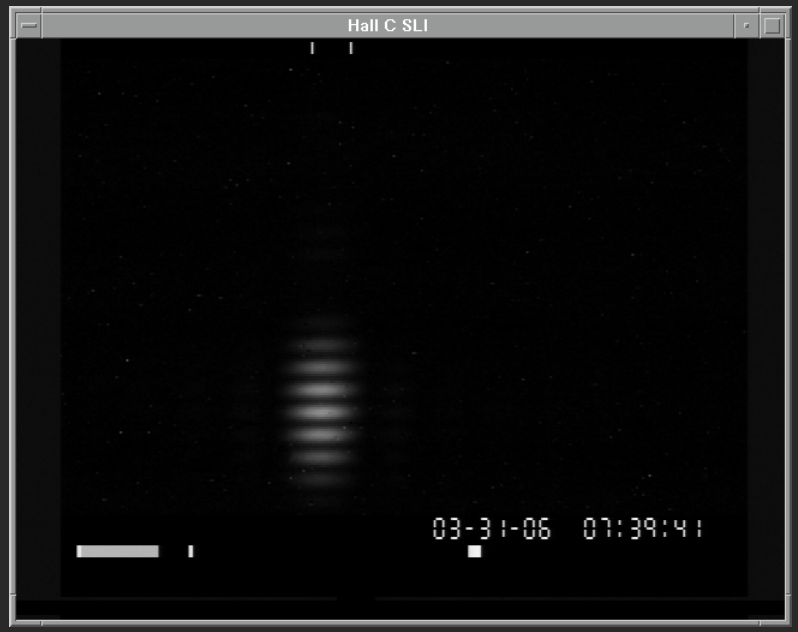

”in-vacuum” mirror
viewing port
principal SLI dipole
active SLI mirror
CCD

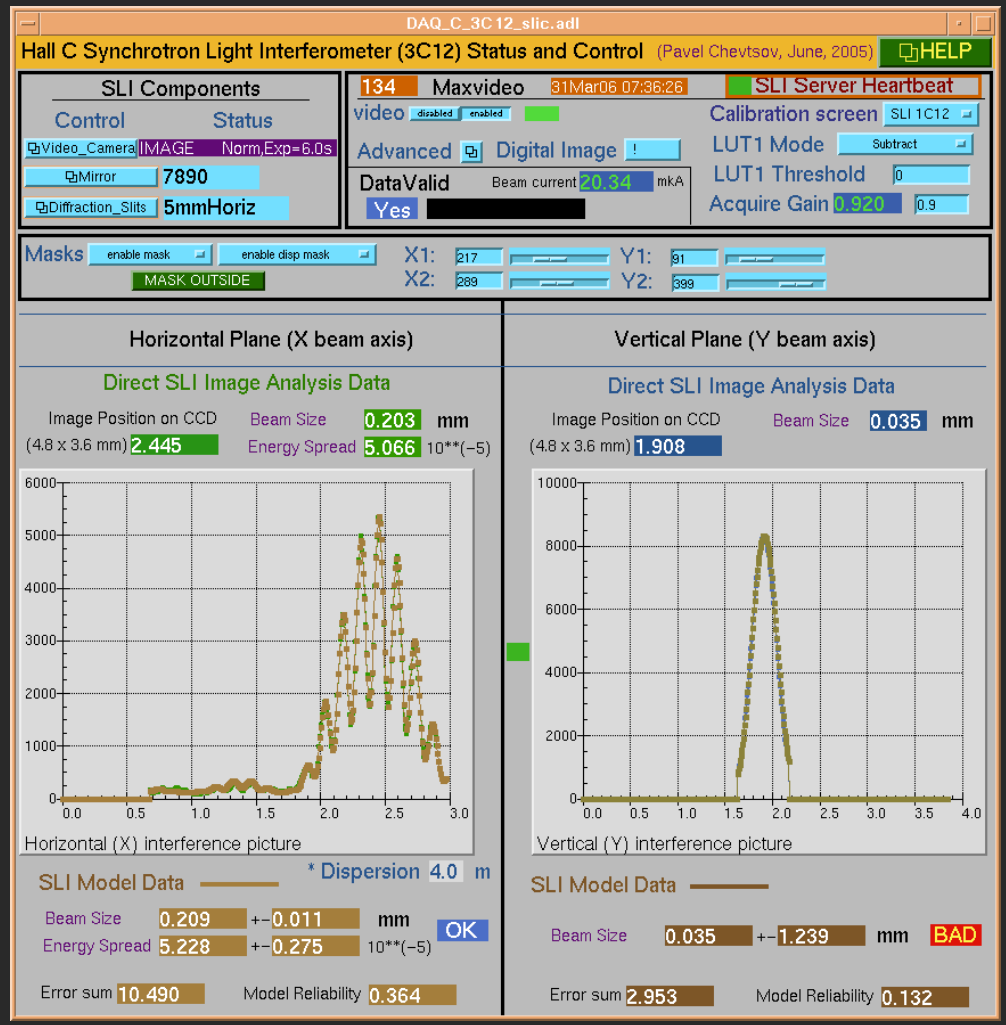


ENCODER MIKE CONTROLLER 18011
ORIEL
ORIEL Model 18011 Encoder Mike Controller

SBIG
STV
Acquire
Control
Guide
Process
Setup
Interrupt

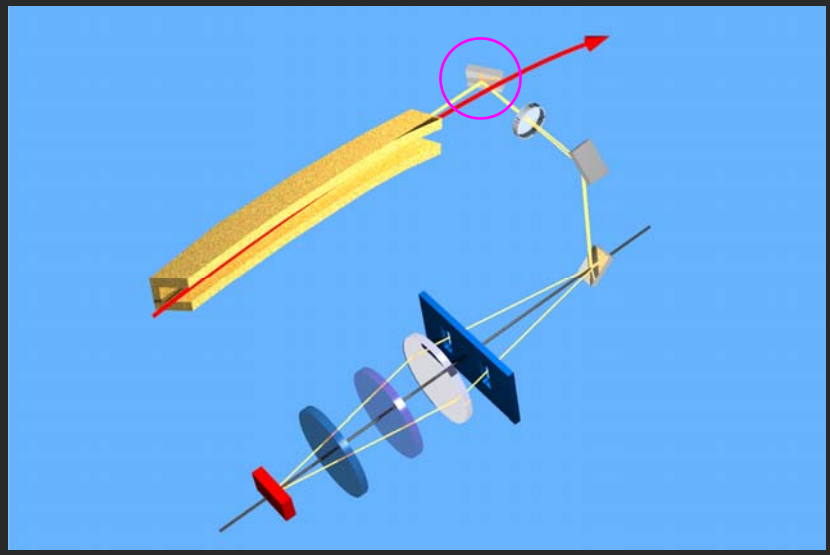
MicroMini™ Controller
National Aperture, Inc.

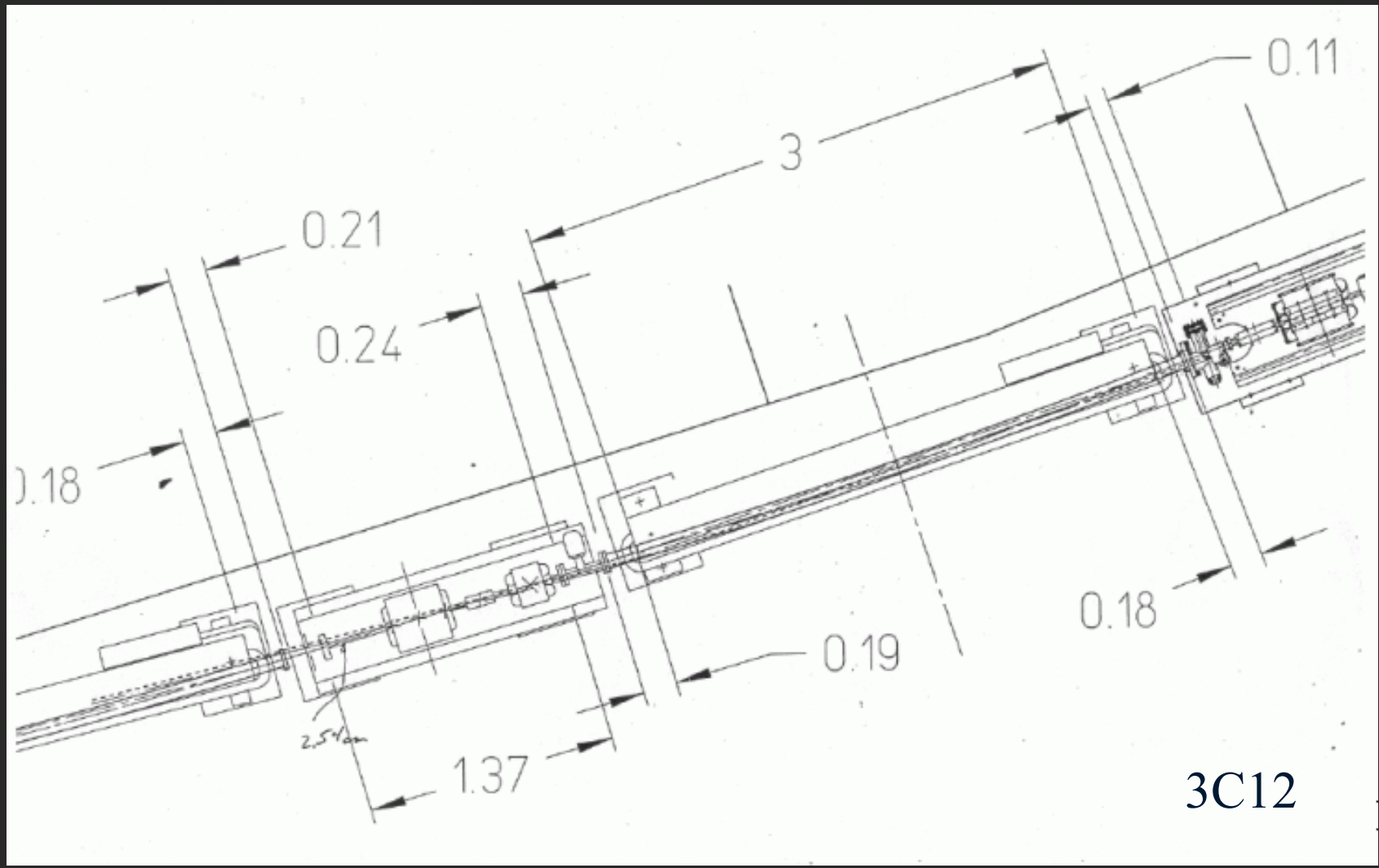

Hall C SLI
03-31-06 07:39:41

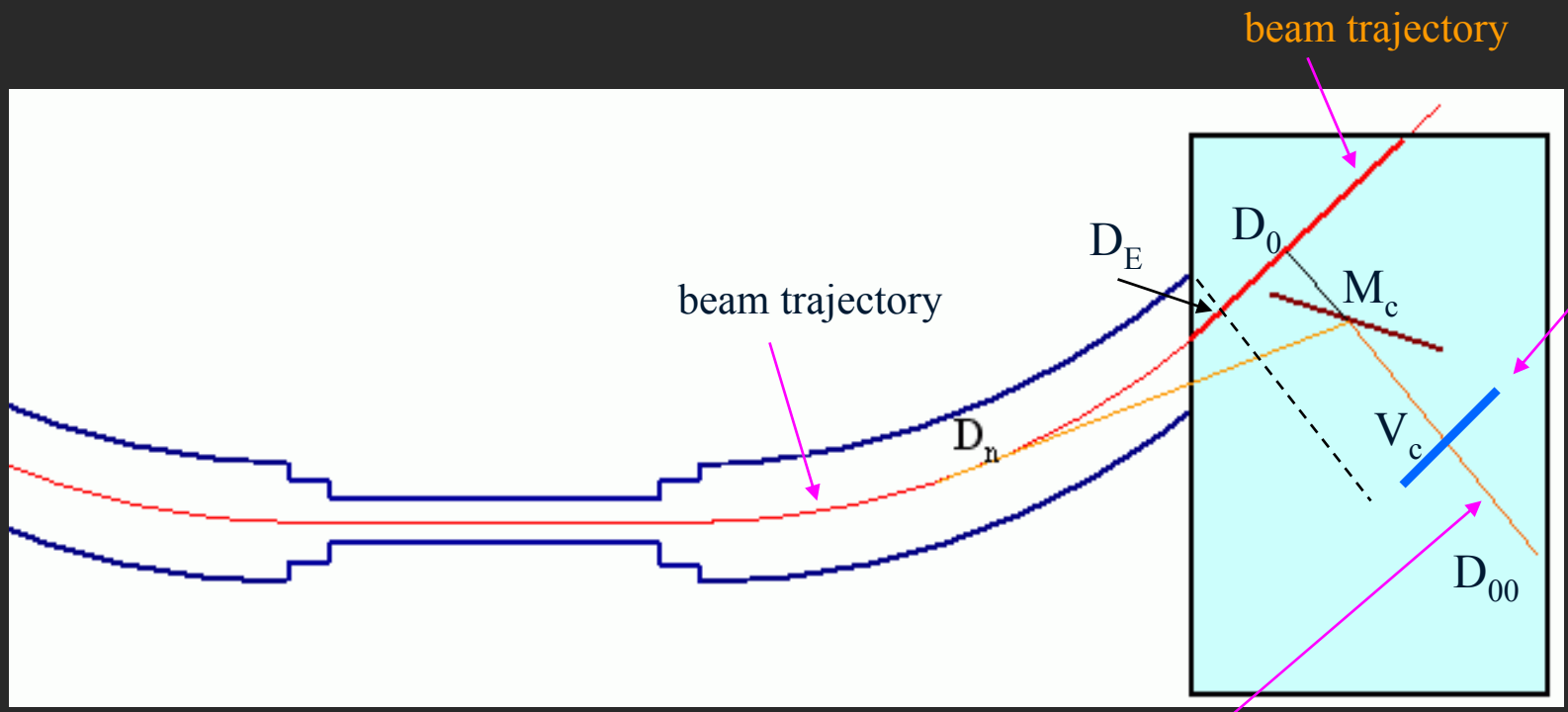

DAQ_C_3C12_slic.adl
Hall C Synchrotron Light Interferometer (3C12) Status and Control (Pavel Chevtsov, June, 2005)
HELP
SLI Components
Control
Status
Video_Camera
IMAGE
Norm,Exp=6.0s
Mirror
7890
Diffraction_Slits
5mmHoriz
134
Maxvideo
31Mar06 07:36:26
SLI Server Heartbeat
video
disabled
enabled
Calibration screen
SLI 1C12
Advanced
Digital Image
LUT1 Mode
Subtract
DataValid
Beam current
20.34
mkA
LUT1 Threshold
Yes
Acquire Gain
0.920
0.9
Masks
enable mask
enable disp mask
MASK OUTSIDE
X1:
217
Y1:
91
X2:
289
Y2:
399
Horizontal Plane (X beam axis)
Direct SLI Image Analysis Data
Image Position on CCD
(4.8 x 3.6 mm)
2.445
Beam Size
0.203
mm
Energy Spread
5.066
10**(-5)
Horizontal (X) interference picture
* Dispersion
4.0
m
SLI Model Data
Beam Size
0.209
+-
0.011
mm
Energy Spread
5.228
+-
0.275
10**(-5)
OK
Error sum
10.490
Model Reliability
0.364
Vertical Plane (Y beam axis)
Direct SLI Image Analysis Data
Image Position on CCD
(4.8 x 3.6 mm)
1.908
Beam Size
0.035
mm
Vertical (Y) interference picture
SLI Model Data
Beam Size
0.035
+-
1.239
mm
BAD
Error sum
2.953
Model Reliability
0.132

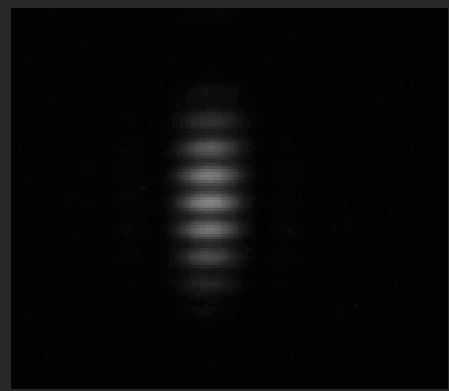
Work on the SLI Systems

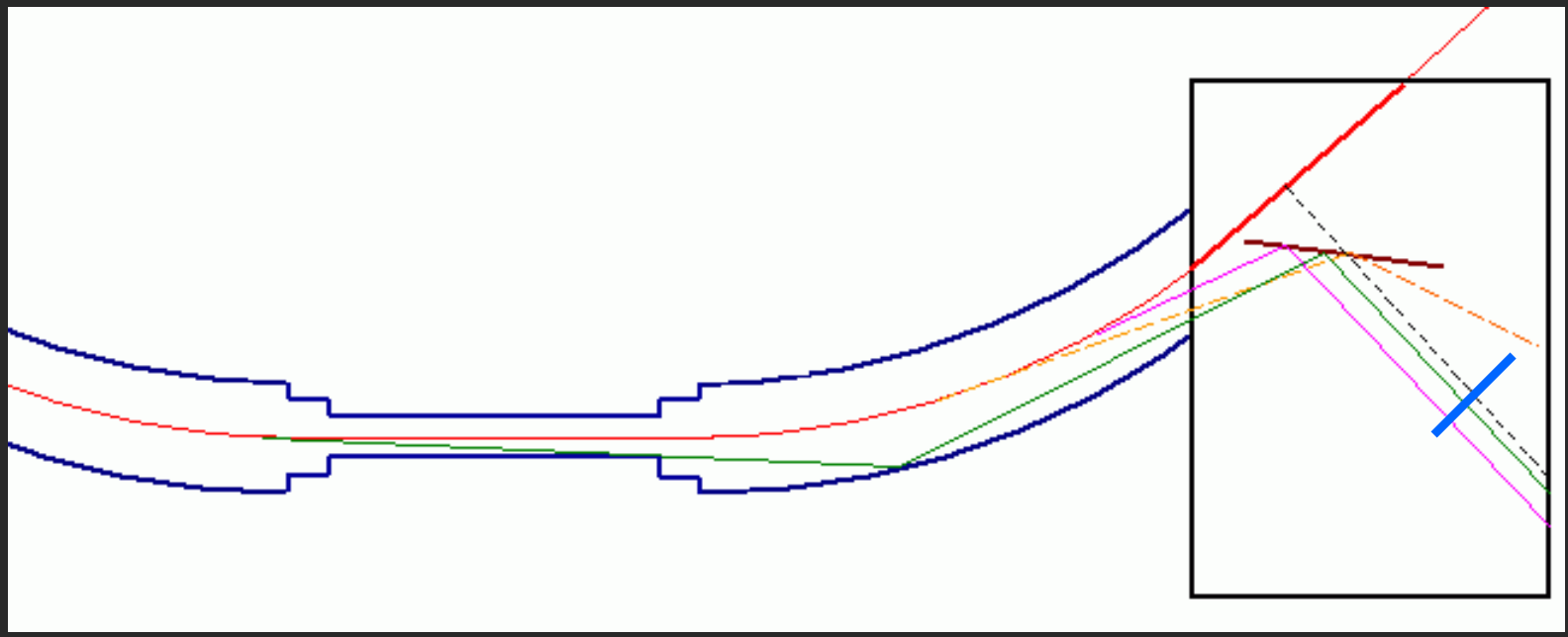
“in-vacuum” mirror

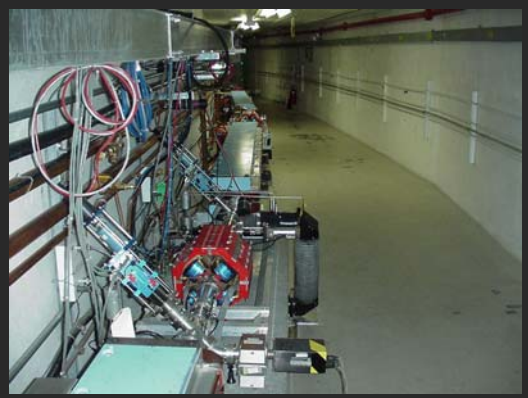


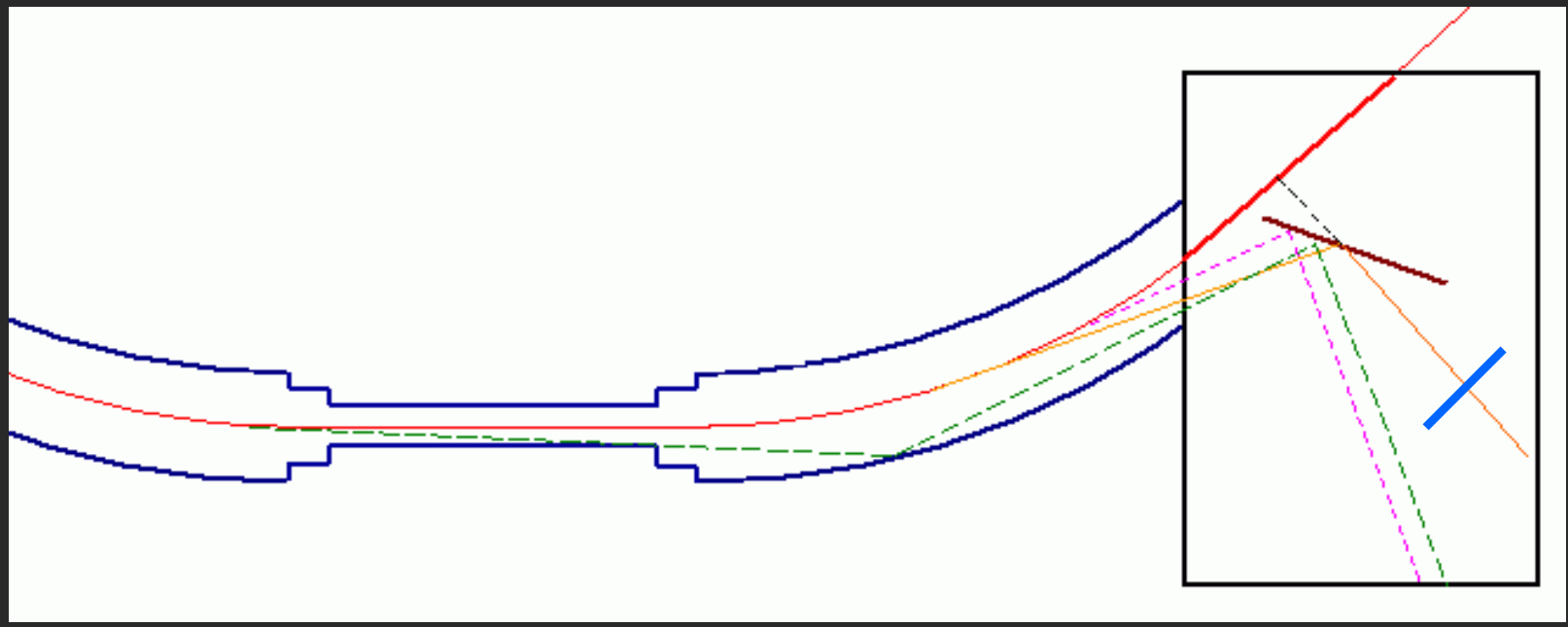

0.11
3
0.21
0.24
0.18
0.19
0.18
1.37
3C12

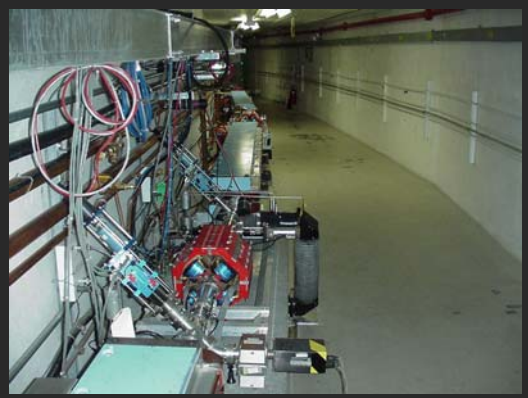

beam trajectory
beam trajectory
D_E
D_0
M_c
D_n
V_c
D_{00}
viewing port
SLI reference line

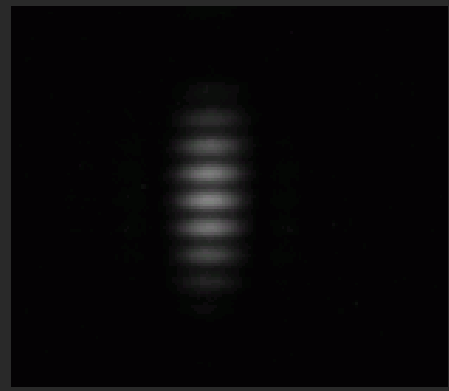


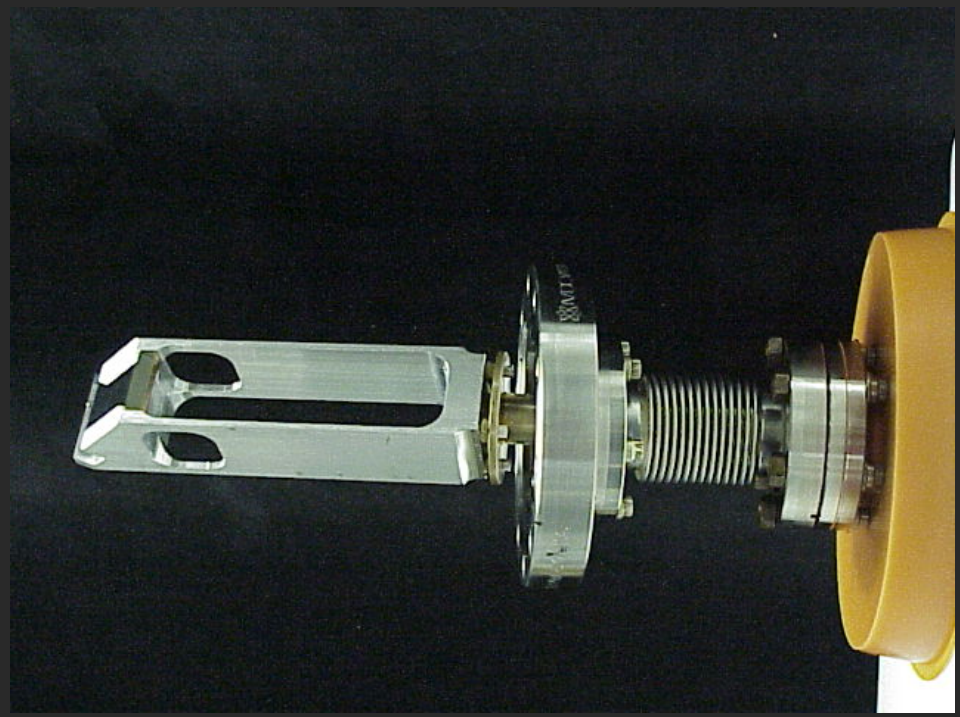




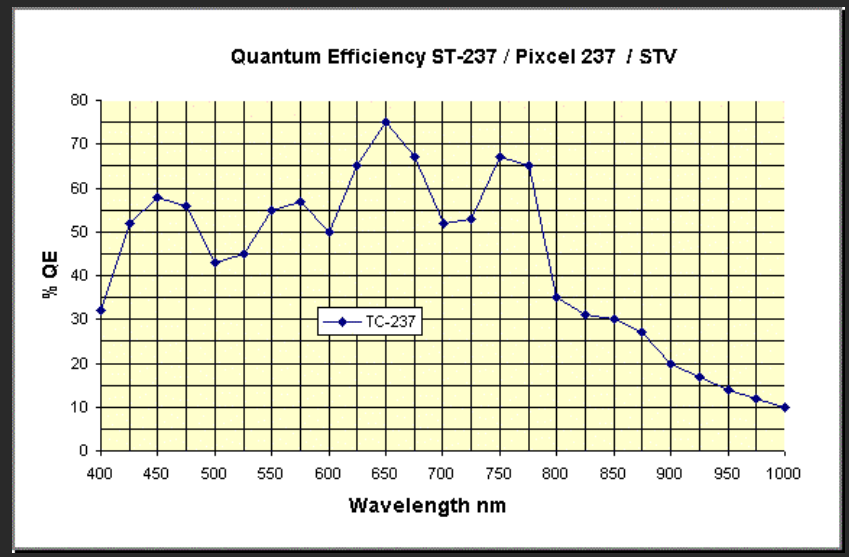






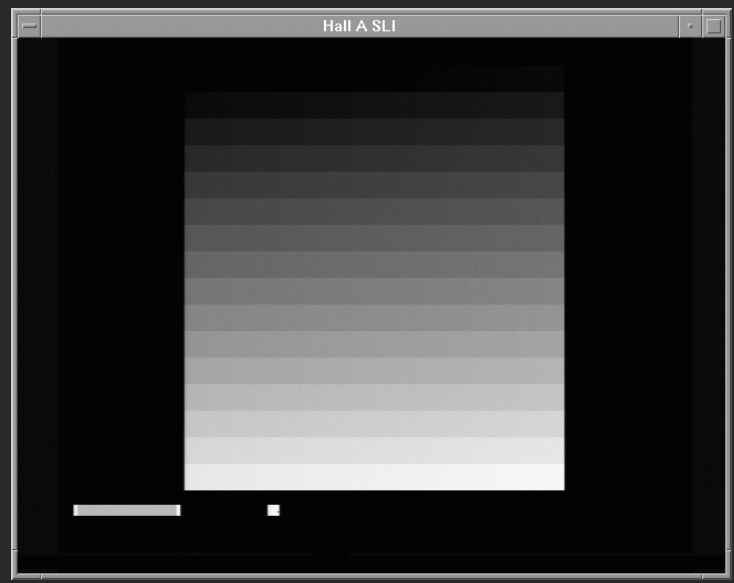


Video Camera



Exposure time:

0.001 sec – 10 min



E ~ 6 GeV, I ~ 100 μA

E ~ 6 GeV, I ~ 100 mA

E ~ 2.4 GeV, I ~ 100 mA

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SLI Control Software

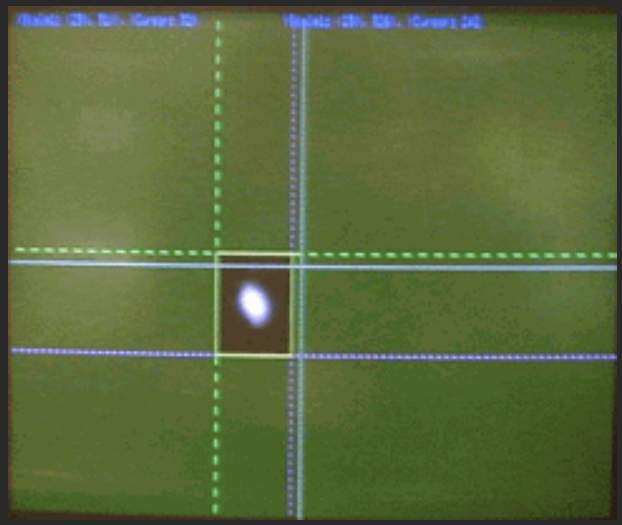
Mirror Control Module

Video Camera Control Module

Diffraction Slits Control Module

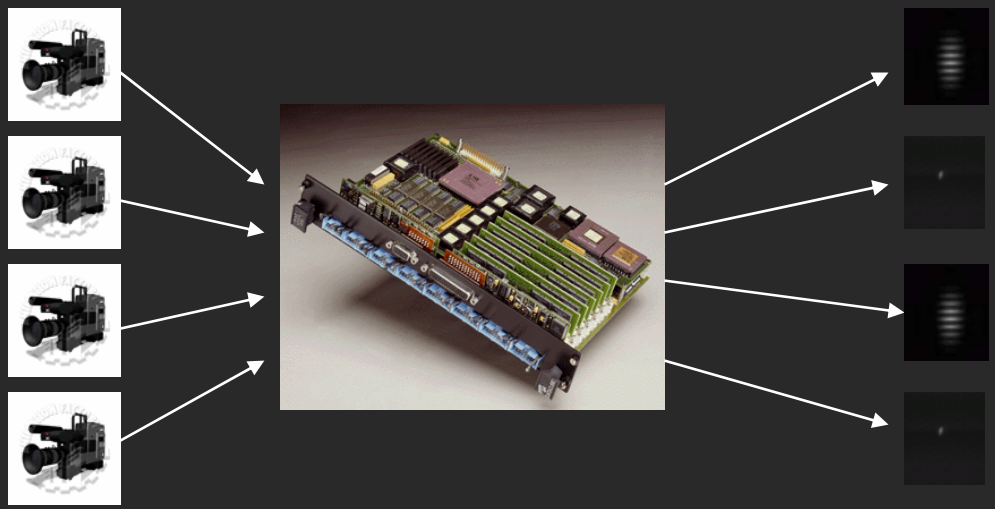
Common Serial Driver/Device Library

SLI Data Processing Software



Beam Size and Energy Spread Estimates

Multiplexed Maxvideo Software



Calculations (GSL, SLI Data Reliability Model)

SLI server

Beam Energy, Beam Current, etc.

Beam Size and Energy Spread Estimates (MV)

$$I(x) = I_0 \left[\frac{\sin(a(x-x_0))}{a(x-x_0)} \right]^2 [\, 1 + V \cos(b(x-x_0)+\varphi) \,] + I_n$$

$$\sigma_{beam} = \frac{\lambda R}{\pi D} \sqrt{0.5 \ln(1/V)}$$

Jefferson Lab

PCaPAC-2006

Conclusions

- The implementation of the SLI systems for the experimental beam lines is one of the most important beam diagnostics projects at Jefferson Lab.

- We have gained a very valuable experience in the SLI installation and support of all its components in operational conditions.

- The systems not only routinely monitor the transverse sizes and energy spread of electron beams in a wide range of beam intensities but also can help identify beam trajectory (energy) problems in the accelerator.

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E N D