LIPSS results and status

O.K. Baker

For the LIPSS Collaboration

20-June-08

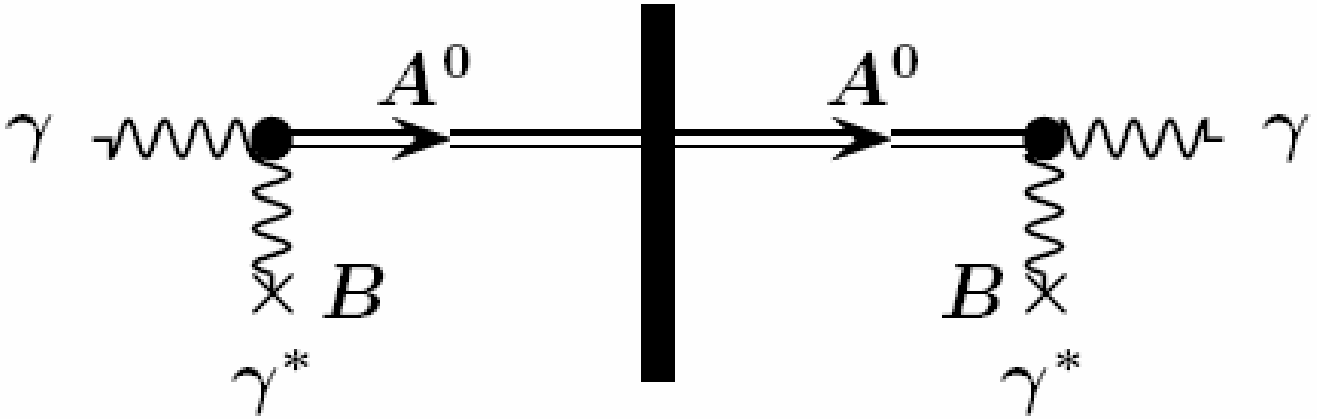
Fourth Patras Workshop

LIPSS at Jefferson Lab

- experimental (data) runs in Feb-March, 2007
  - submitted results for publication: see arXiv:0806.2631

- spent past year . . .
  - characterizing backgrounds better
  - analyzing data with improved methods
  - upgrading FEL optics and LIPSS experiment

photon regeneration
'light shining through a wall'
www.desy.de/~ringwald
Phys. Rev. D47 3707 (1993)



γ-A^0 (or A^0-γ) conversion probability

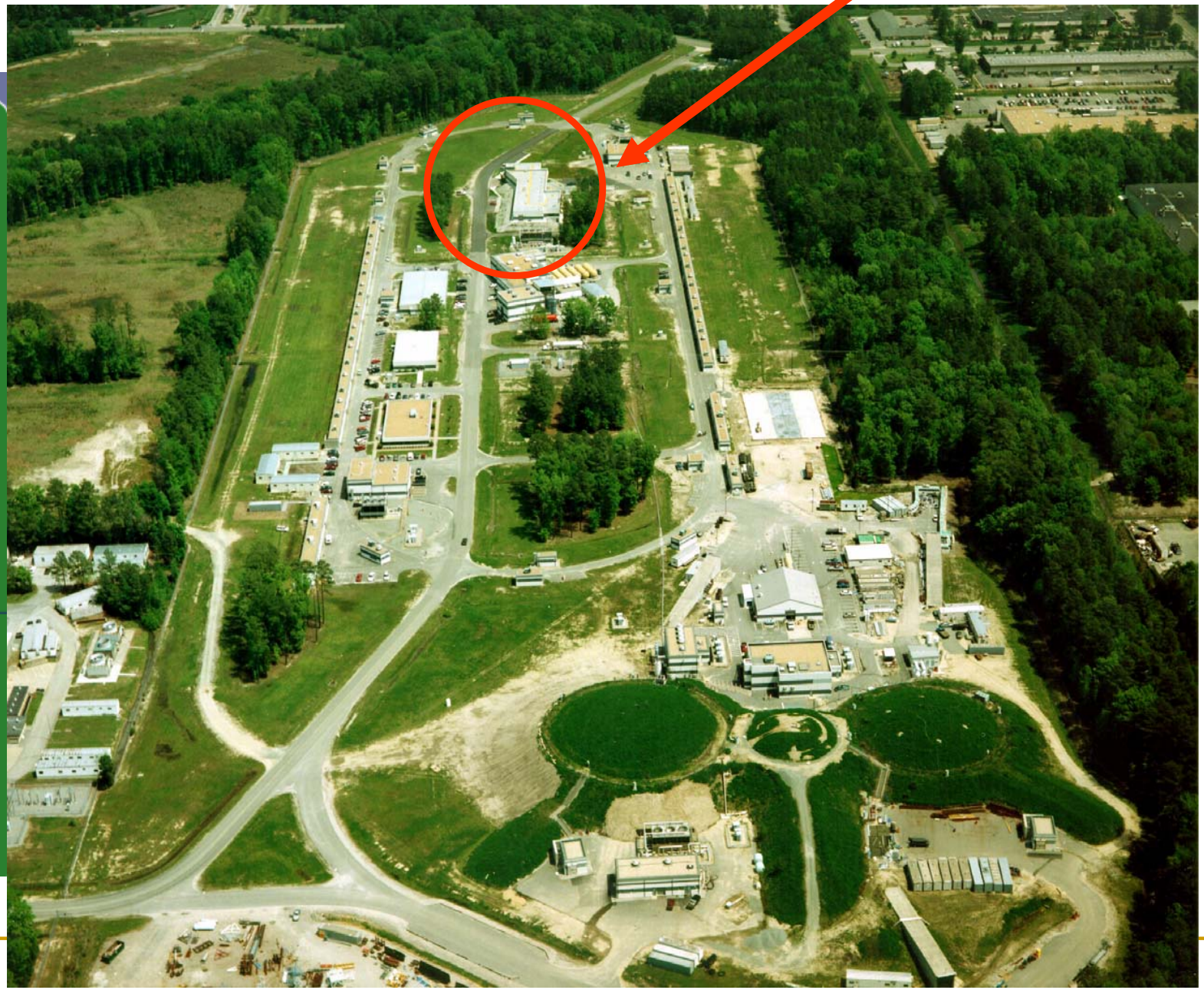
$$P_{\gamma\to\varphi} = \frac{1}{4}(gBL)^2 \left\{ \frac{\sin\left(\frac{m_\varphi{}^2 L}{4\omega}\right)}{\frac{m_\varphi{}^2 L}{4\omega}} \right\}^2$$

$m_\phi^2 < 4\omega/L$

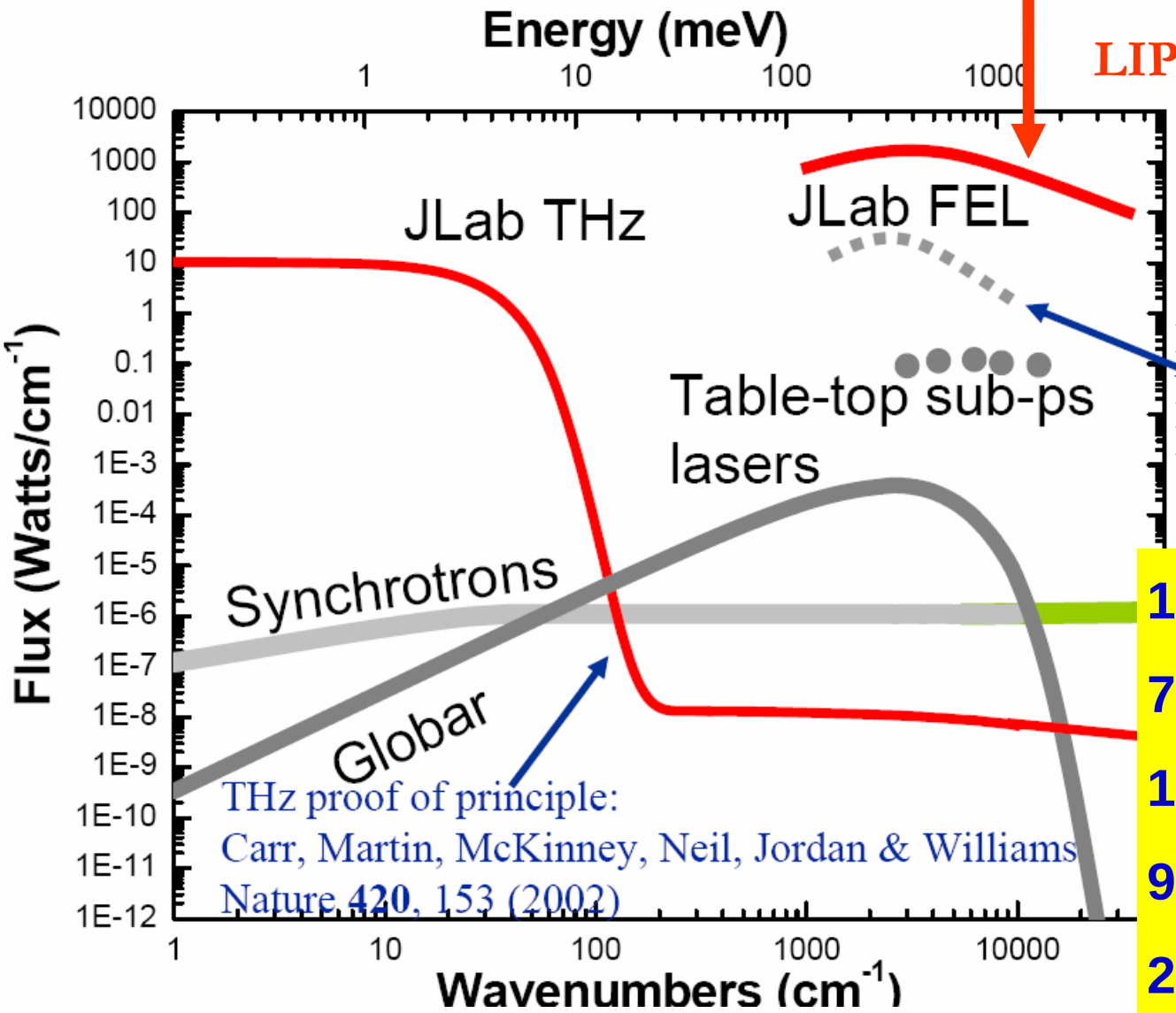
- couple polarized laser light with magnetic field
- Sikivie (1983); Ansel'm (1985); Van Bibber et al (1987)

Jefferson Lab and the Free Electron Laser

Jefferson Lab and the Free Electron Laser



JLAB FEL spectroscopic range



LIPSS IR run at 935 nm

FEL proof of principle:
Neil et al. Phys. Rev.Letts **84**, 662 (2000)

150 fs wide pulses

75 MHz rep rate

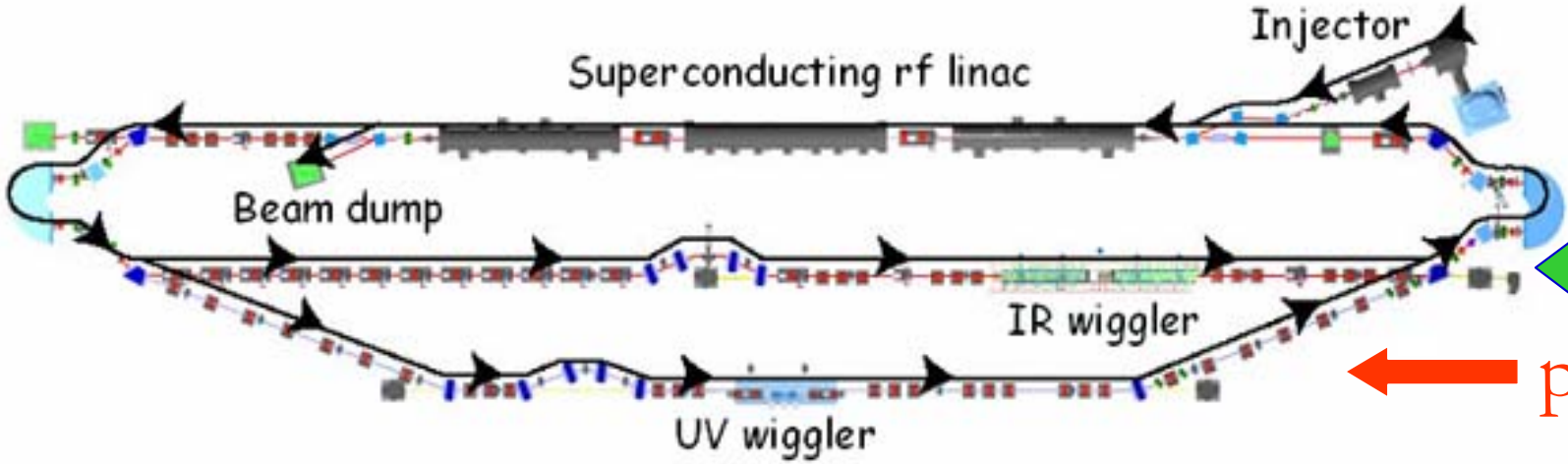
100 % df

935. +/- 005 nm

200 watts avg power

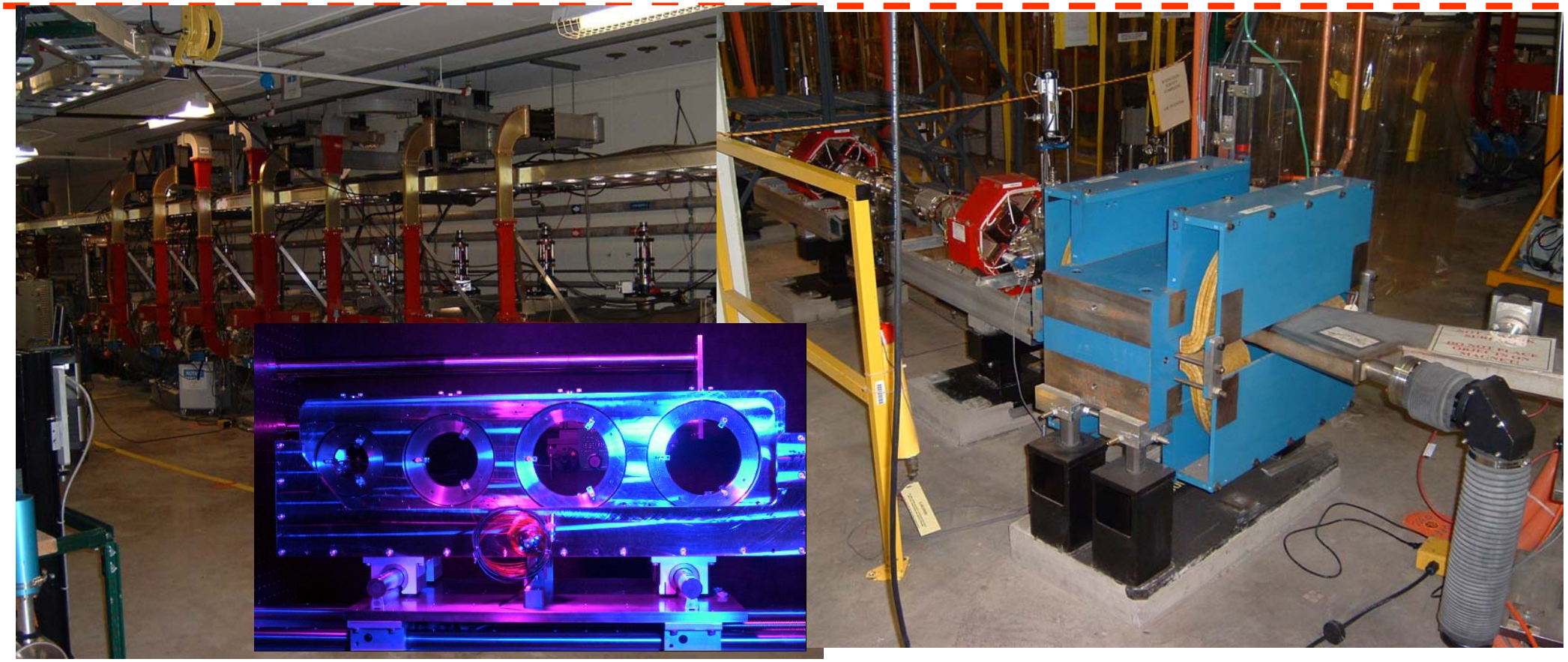
>99% linearly polarized

JLAB FEL: regeneration experiment

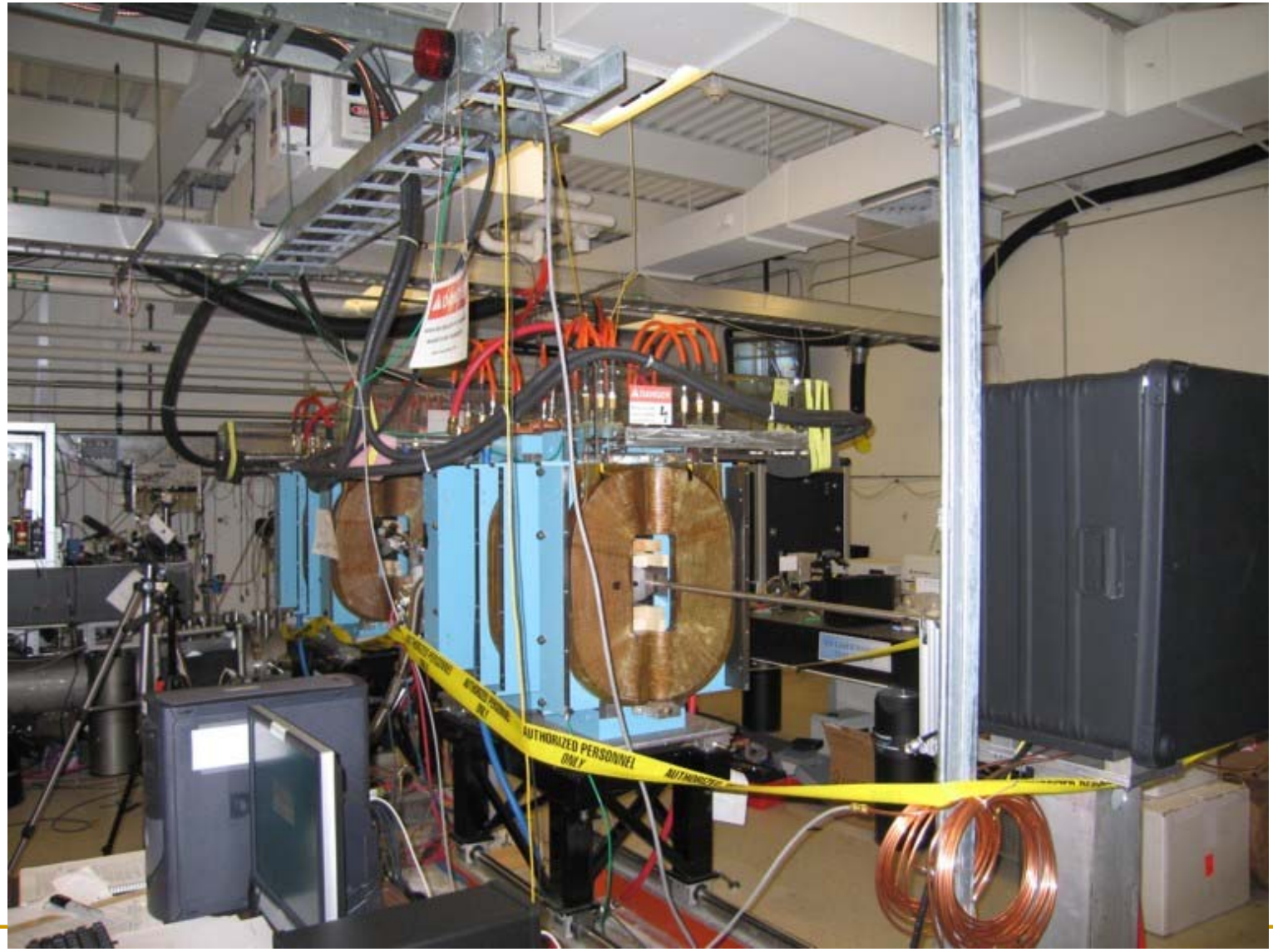


current

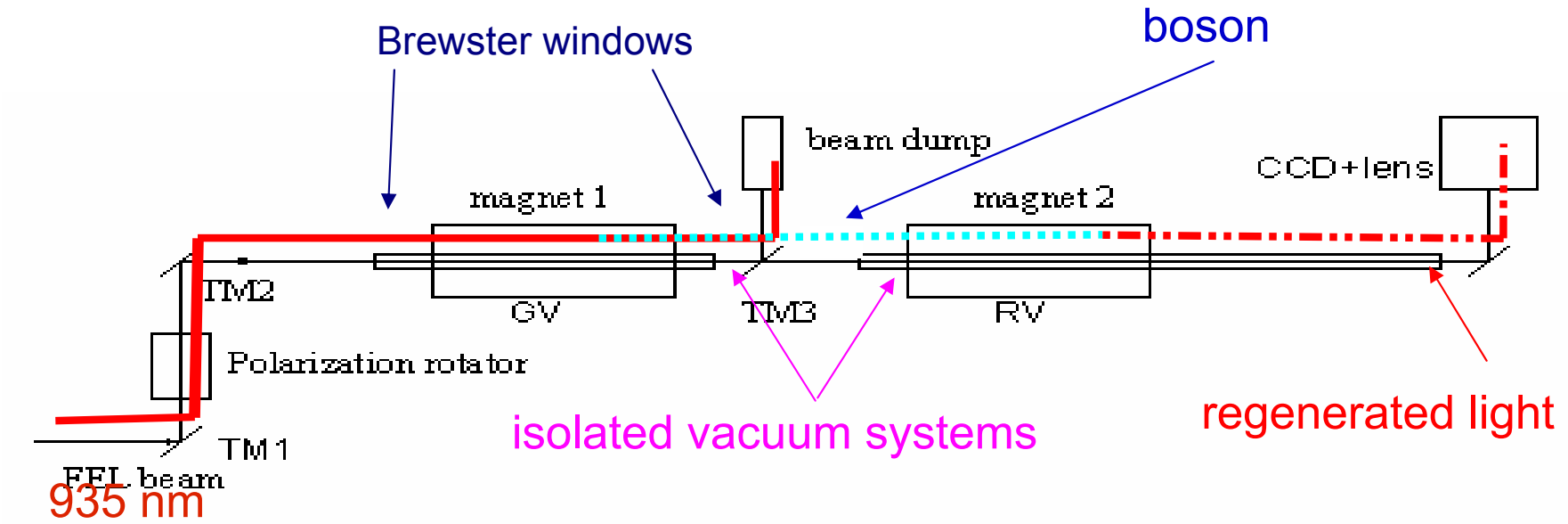
planned; 2009

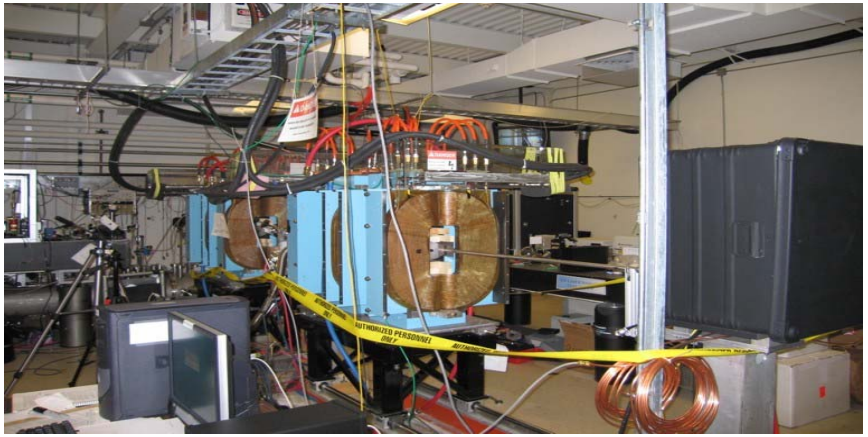


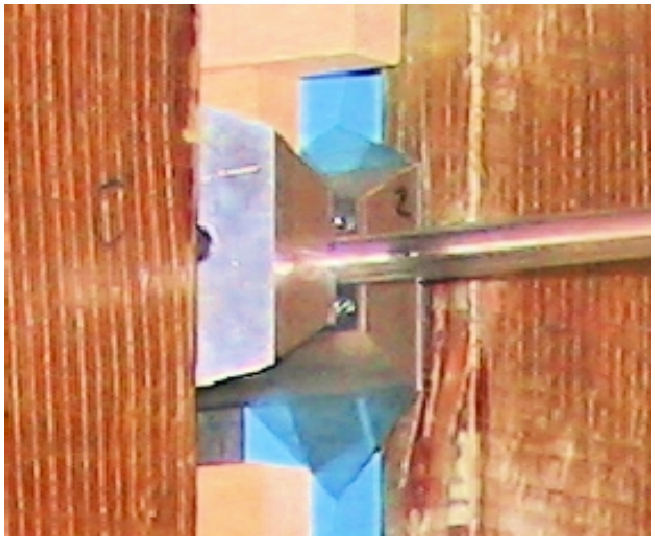
LIPSS at Jefferson Lab

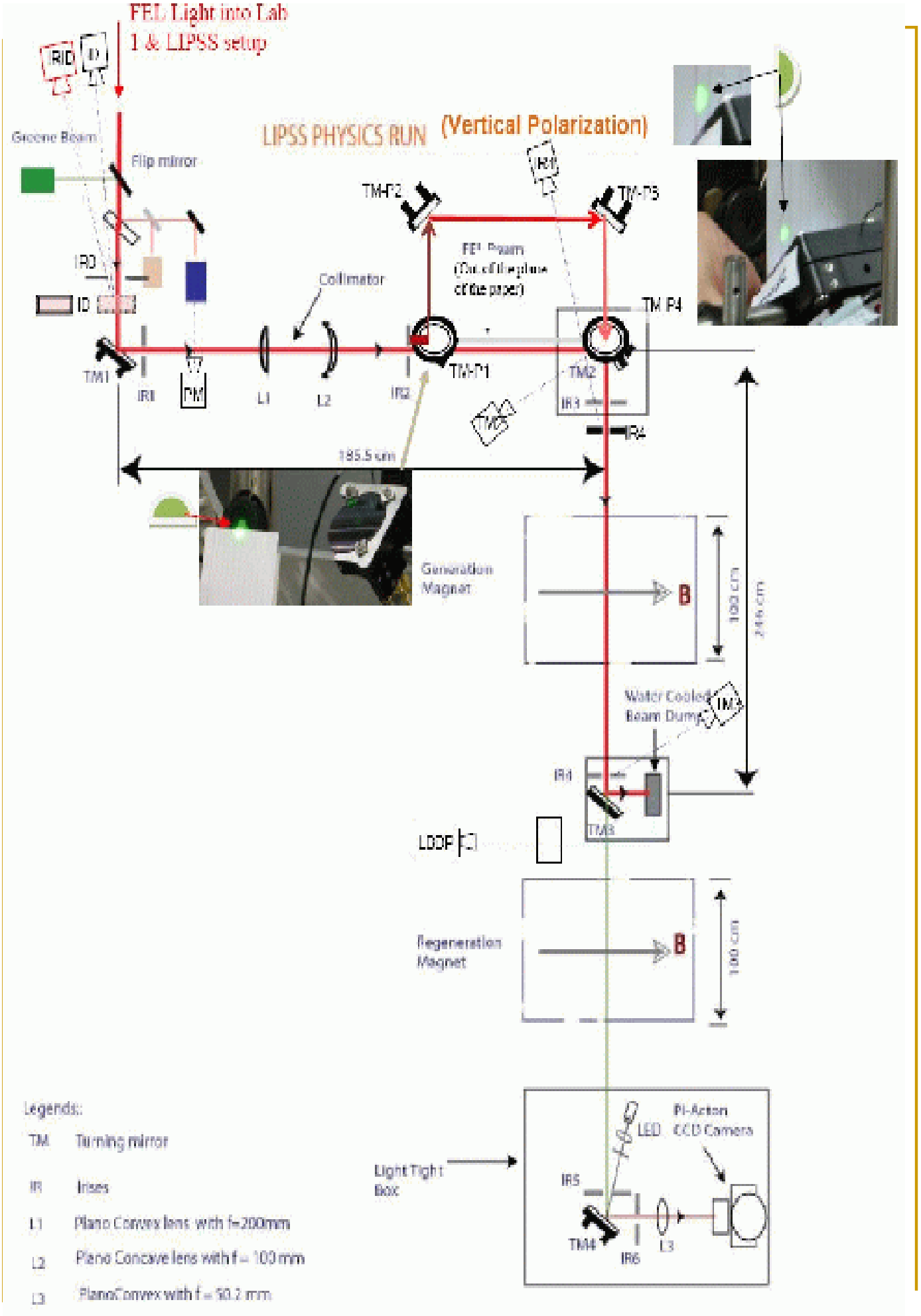


LIPSS – experiment schematic.

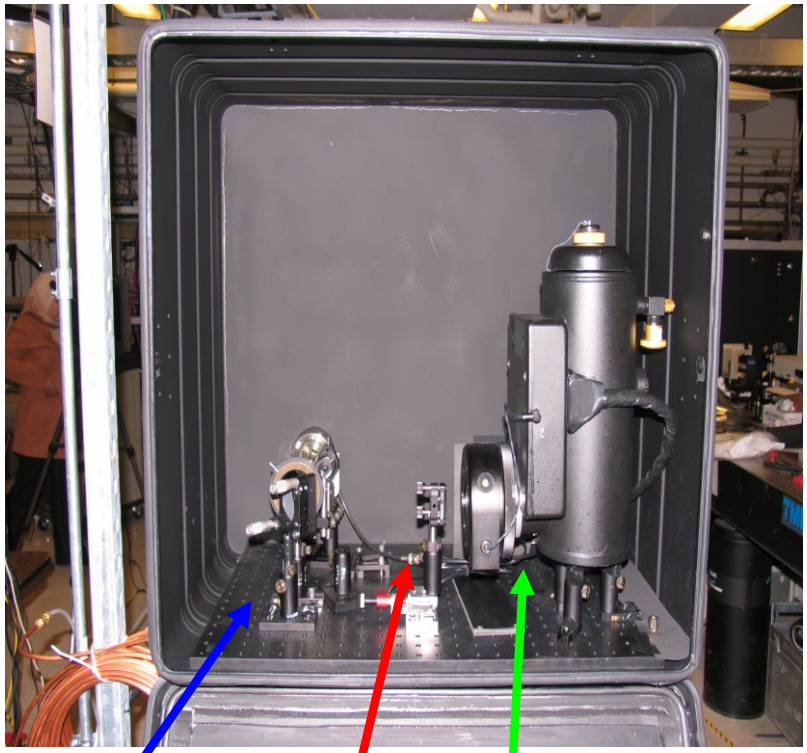






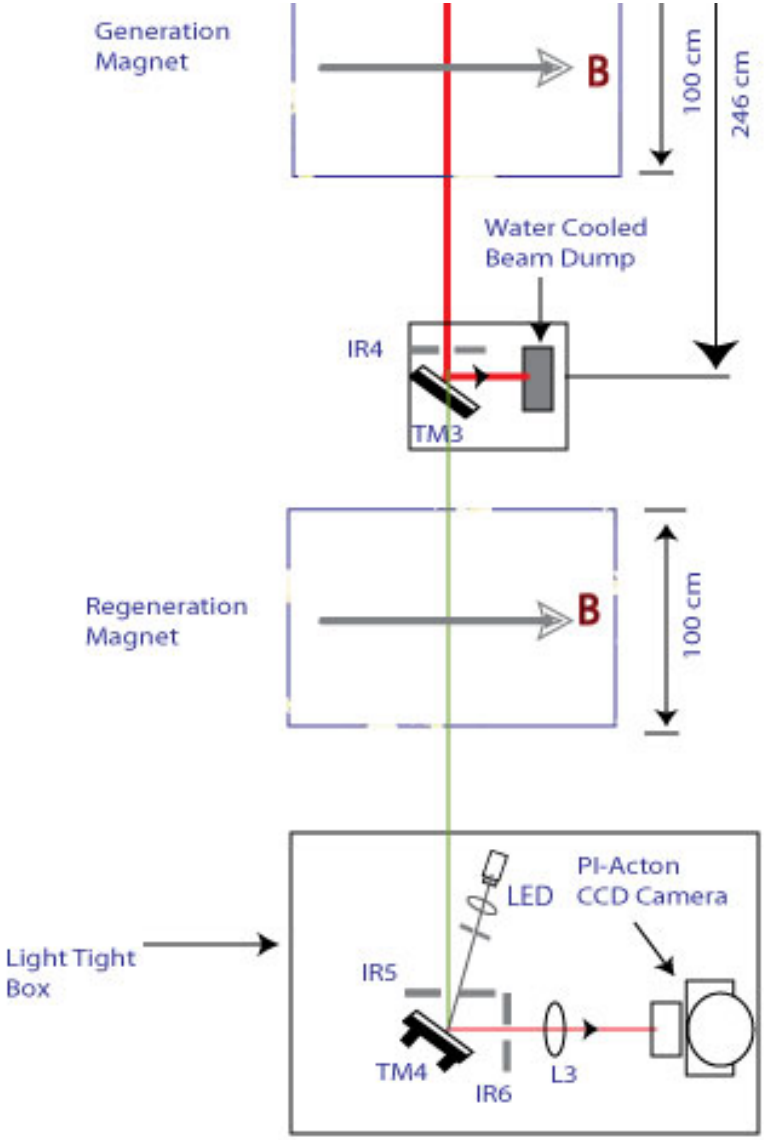

FEL Light into Lab
1 & LIPSS setup
LIPSS PHYSICS RUN (Vertical Polarization)
Green Beam
Flip mirror
IR2
ID
Collimator
TM1
IR1
PM
L1
L2
IR2
TM-P1
TM-P2
TM-P3
TM P4
TM2
IR3
IR4
TM5
185.5 cm
Generation Magnet
B
100 cm
246 cm
Water Cooled Beam Dump
IM3
IR4
TM3
LDDP
Regeneration Magnet
B
100 cm
Light Tight Box
LED
PI-Acton CCD Camera
IR5
TM4
L3
IR6
Legends:
TM Turning mirror
IR Irises
L1 Plano Convex lens with f=200mm
L2 Plano Concave lens with f = -100 mm
L3 PlanoConvex with f = 50.2 mm

LIPSS detector chamber

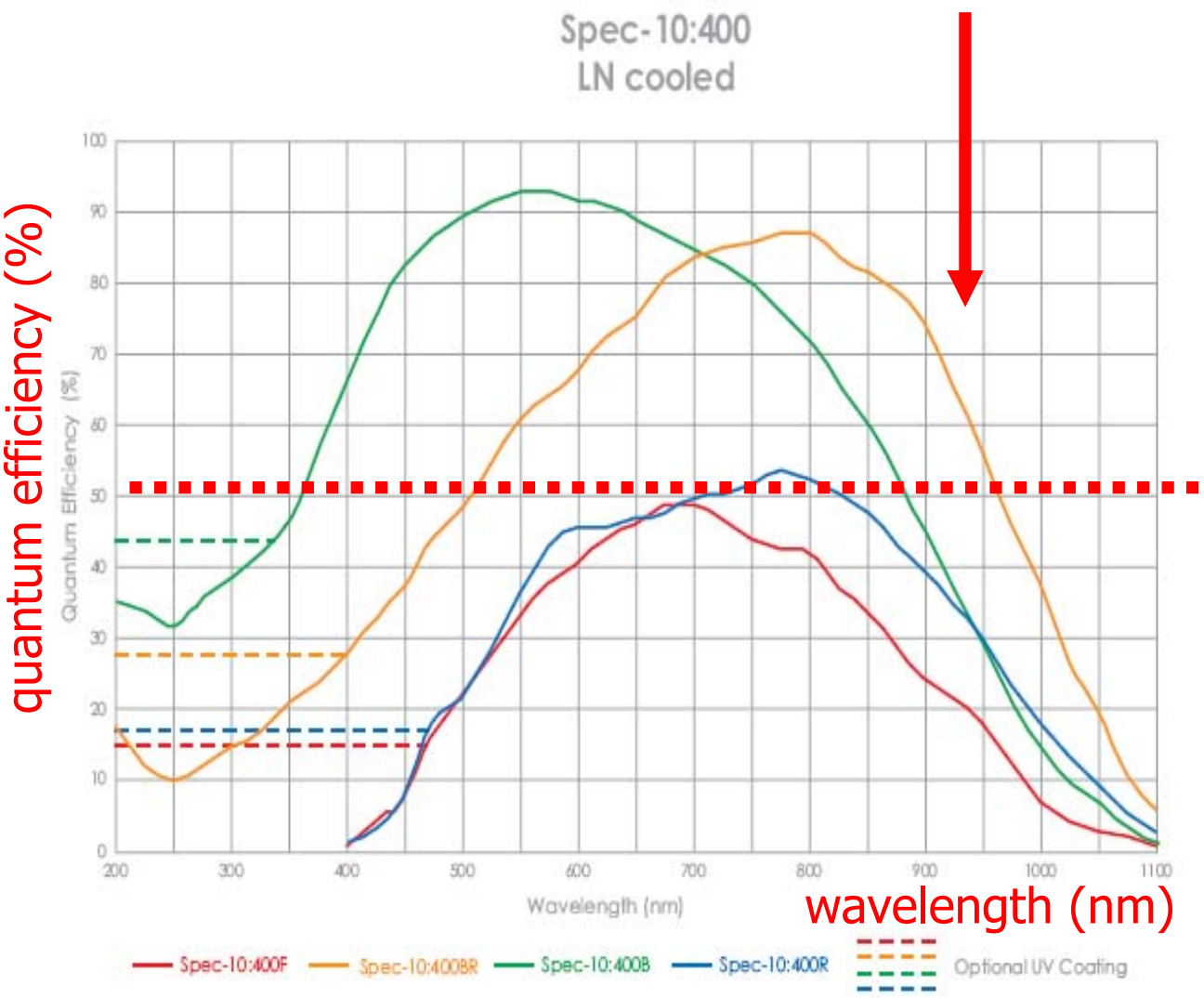


mirror lens

Spec10:400BR-LN camera



Princeton Instruments ACTON 10:400BR-LN



q.e. high at 935 nm

50%

LN2 cooled: <1 e/pix/hour dark noise !!!
used 100 kHZ readout rate

CCD array: characterization

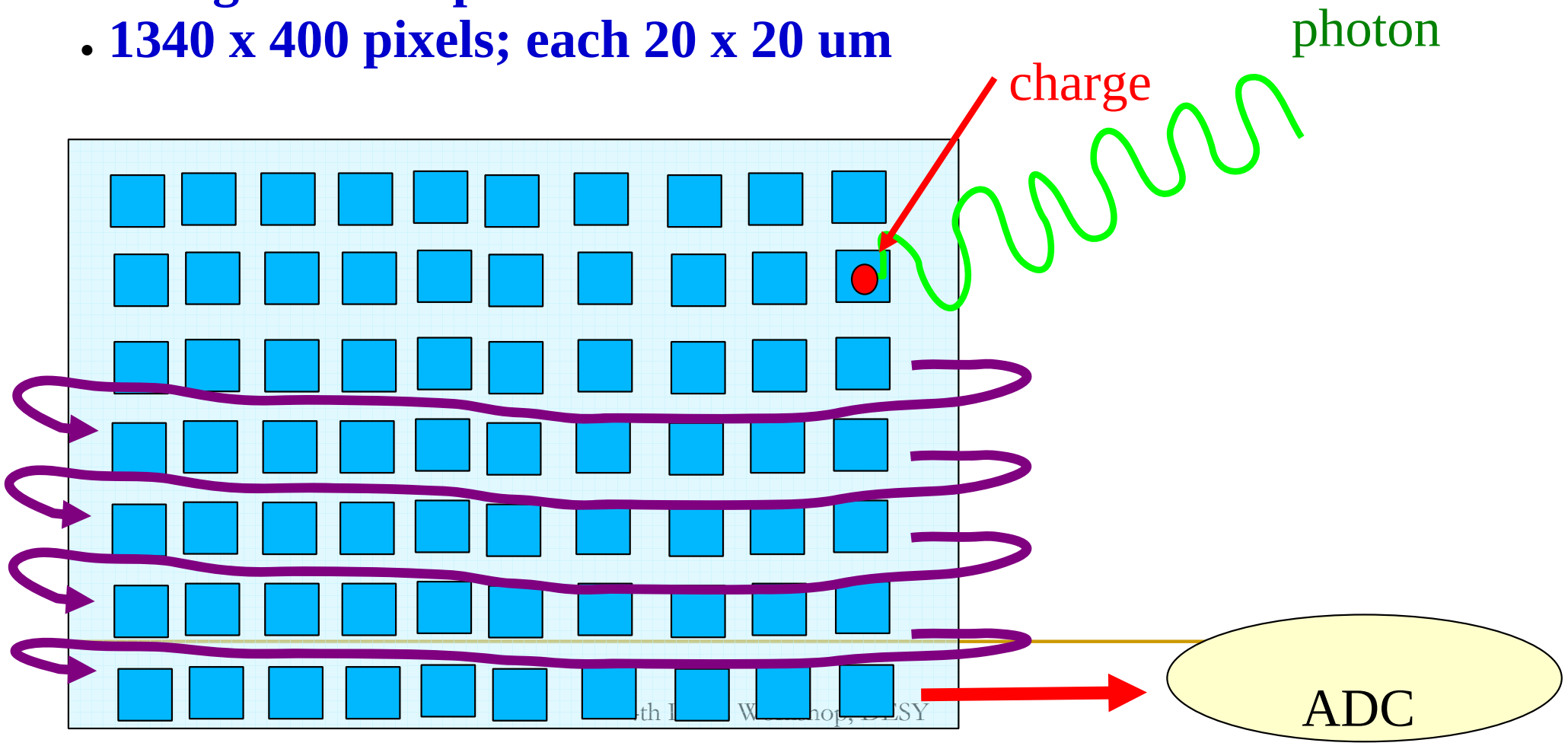
- used calibrated photon source to characterize LIPSS camera (efficiency, uniformity, . . .)
- spent past year further characterizing backgrounds and noise
  - **pixel size:** **20μ x 20μ**
  - **array size** **1340 x 400**
  - **gain:** **1.0 ADU/e**
  - **well depth:** **~250 ke**
  - **dynamic range** **16 bits**

backgrounds

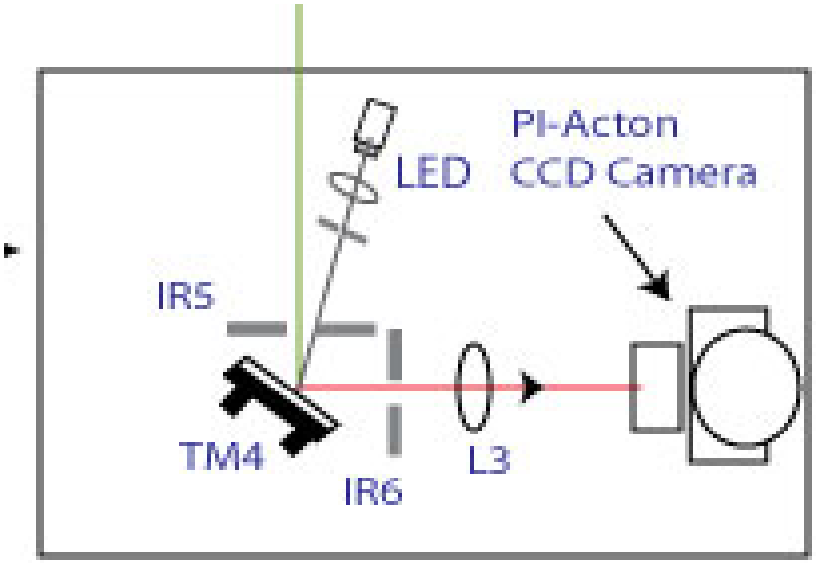
- thermal noise
  - < 1 count/hour/pixel at -120^{o}C
- read noise
  - 2.7 counts per read (every 2 hours)
- stray light
  - < 1 count/hour/pixel
- cosmic rays in vacuuum pipe gas
  - negligible (~10^{-6} Torr vacuum)
- cosmic rays striking CCD array
  - easy to identify and discard
- radiation from FEL
  - negligible
- . . .

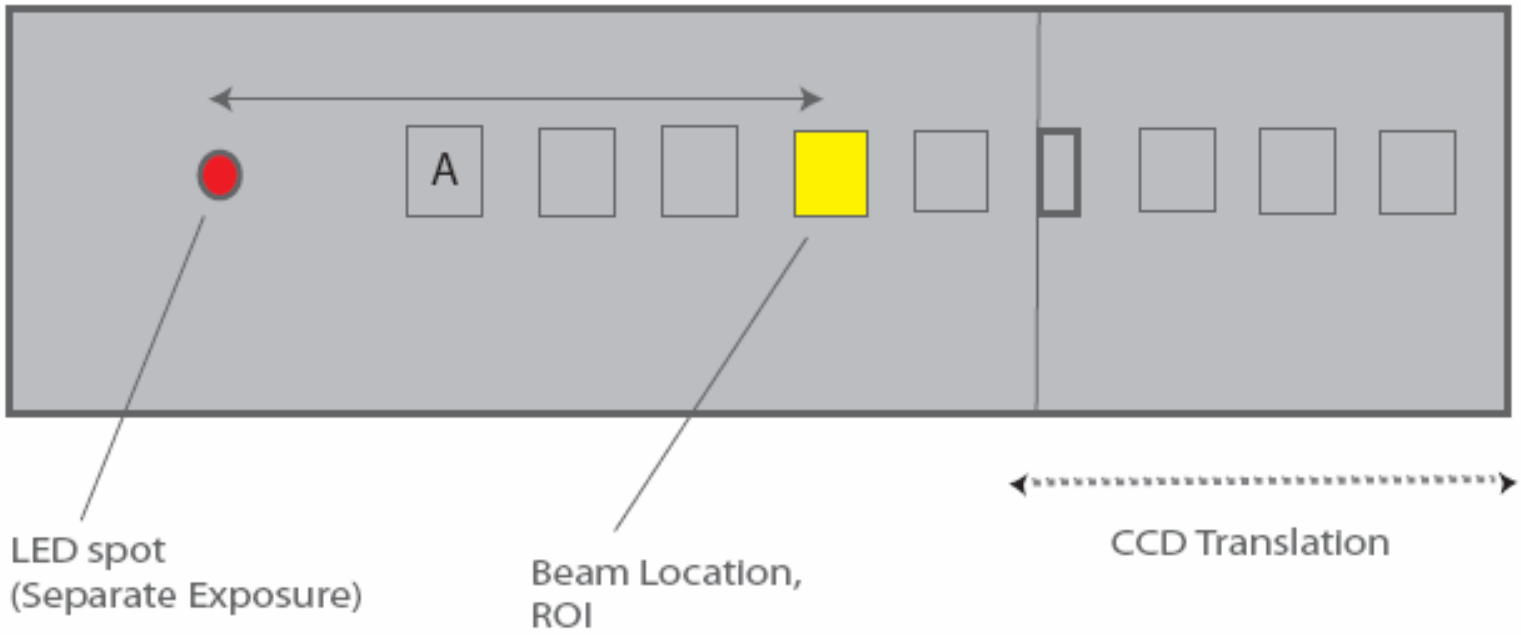
Piacton 400BR-LN CCD camera

- **good position resolution**
- **no time resolution**
- **low dark current (cooled with LN_2)**
- **cosmic rays and background radiation induced events**
- **charge in each pixel converted to an ADU count**
- **1340 x 400 pixels; each 20 x 20 um**



data taking . . .

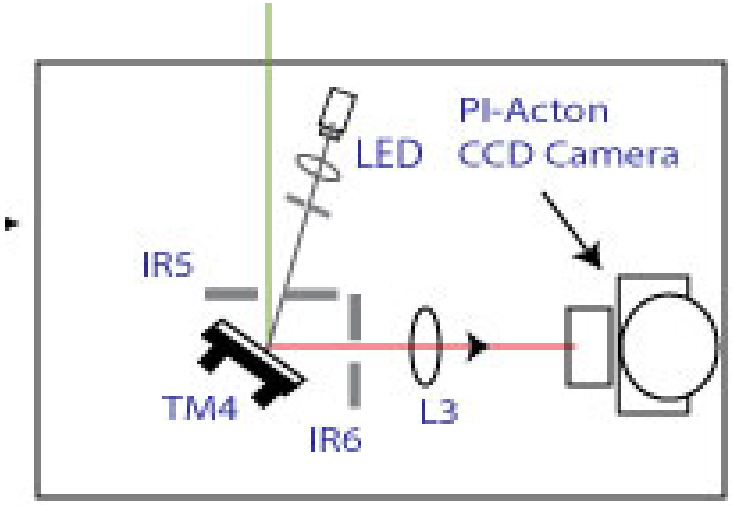

PI-Acton
CCD Camera
LED
IR5
TM4
IR6
L3

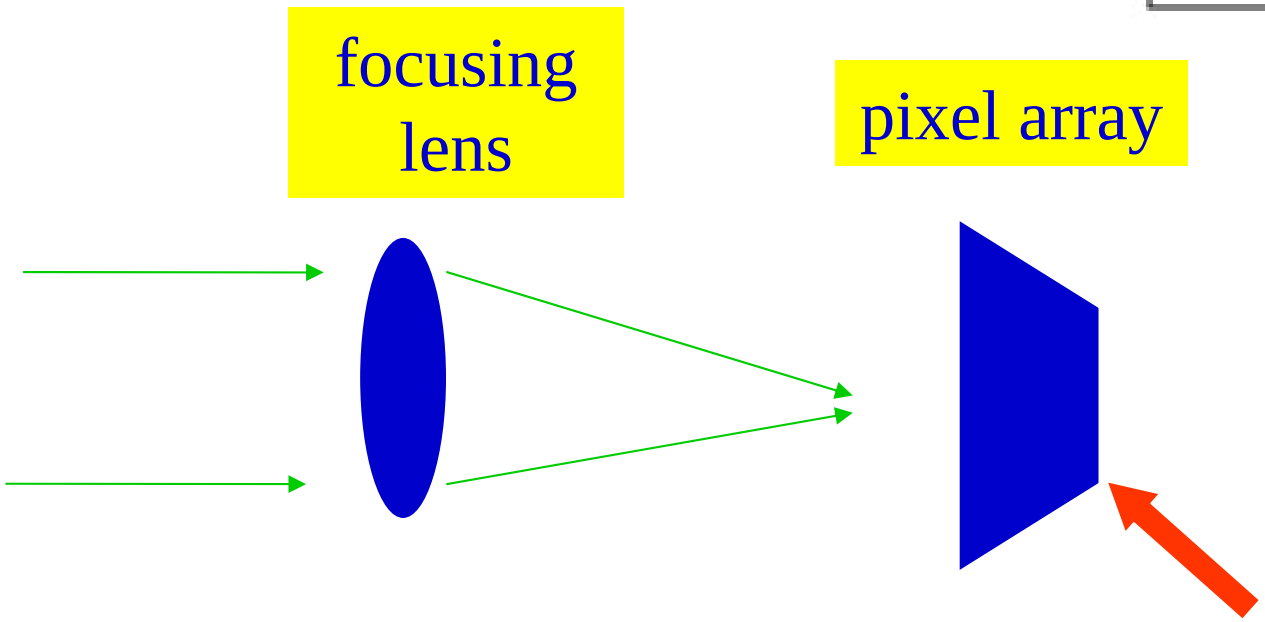

A
LED spot
(Separate Exposure)
Beam Location,
ROI
CCD Translation

increase S/N: focussing light

tested with FEL in alignment mode

tested with HeNe laser

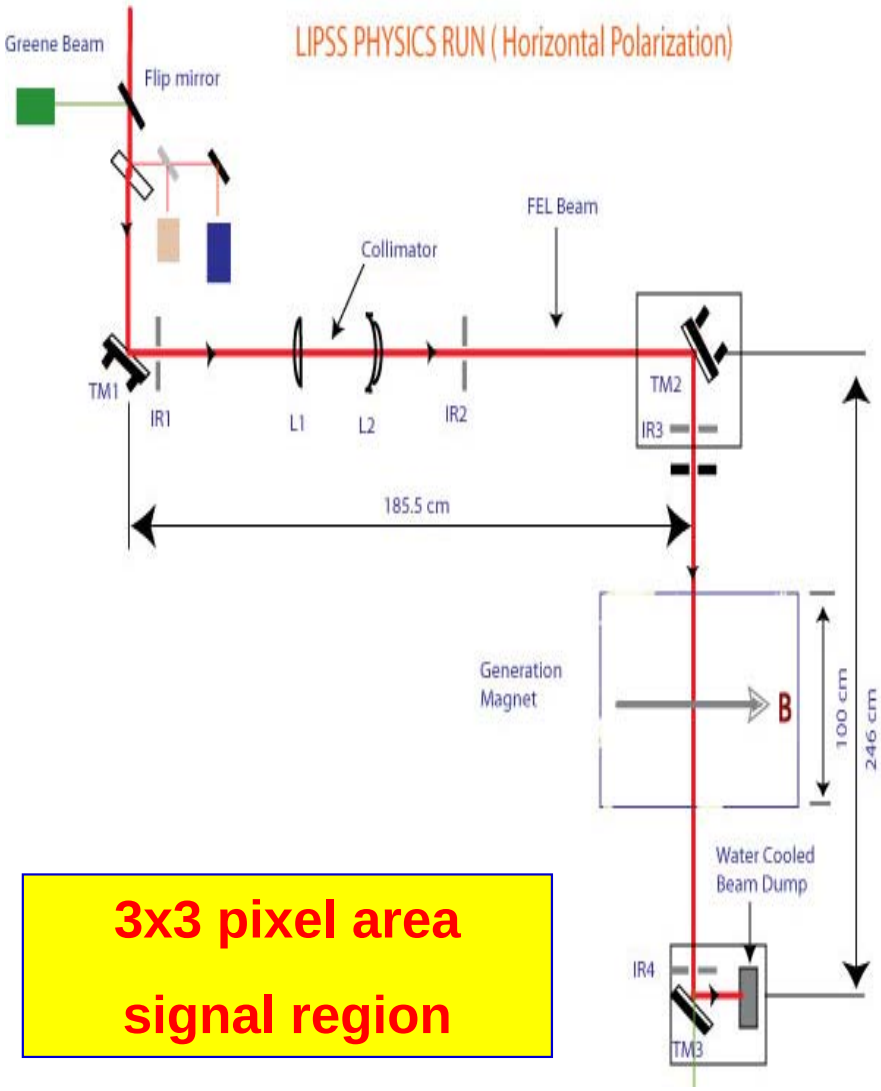




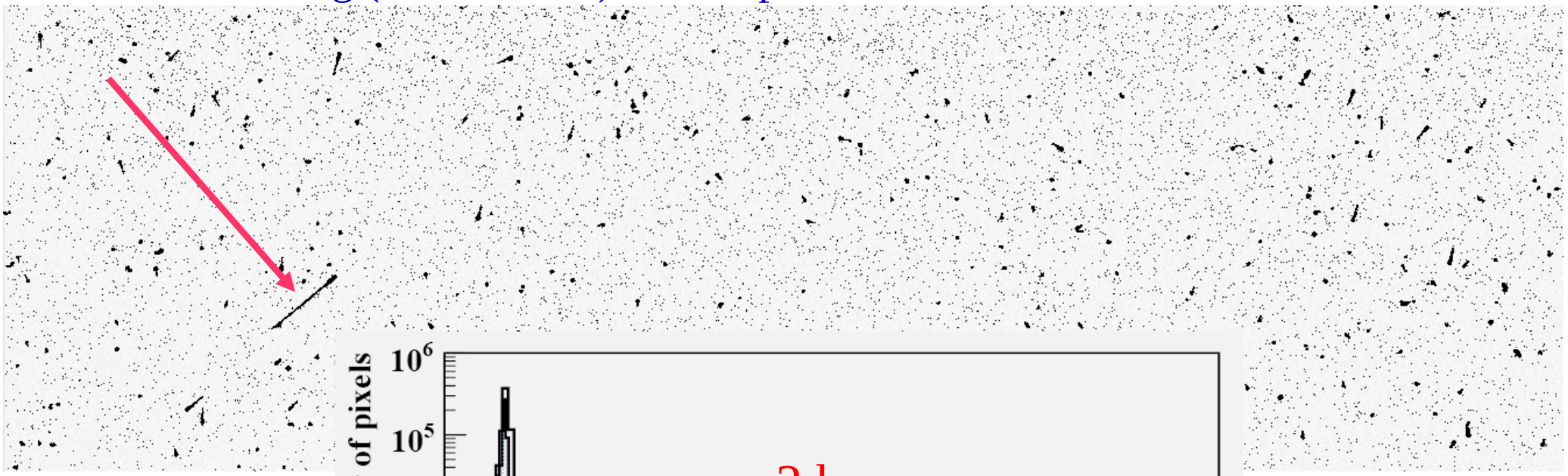
focussed to < 10 µm spot size on pixel

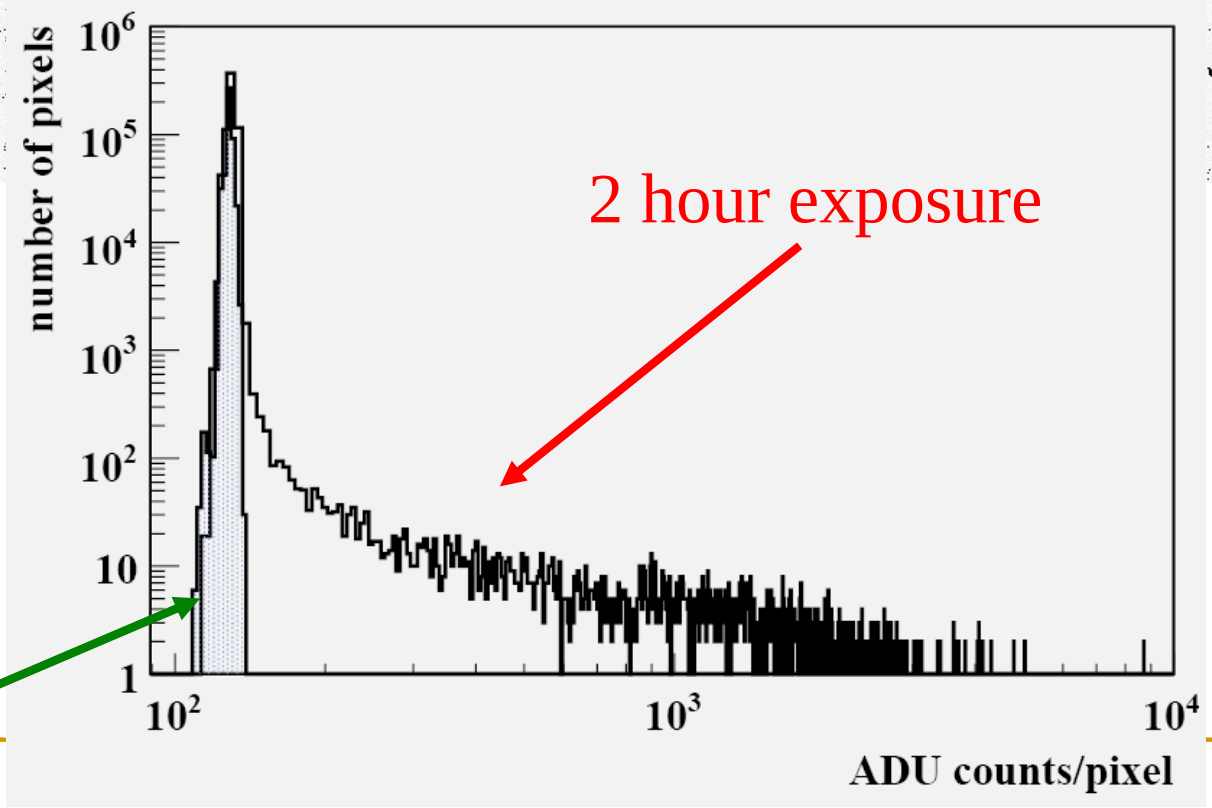
pointing error

- light rays parallel to axis are focussed onto single pixel (spot size < 10 μm)
- light rays not parallel to beam line axis can be focused onto different pixel (spherical aberration)
- controlled by keeping laser fixed at TMs
- studied this behavior during past year (with FEL and HeNe)



typical time exposure; the dark spots are due to backgrounds
(cosmic rays, stray light, thermal, . . .)
long (several hour) hour exposure #1354 from 3/2/07:



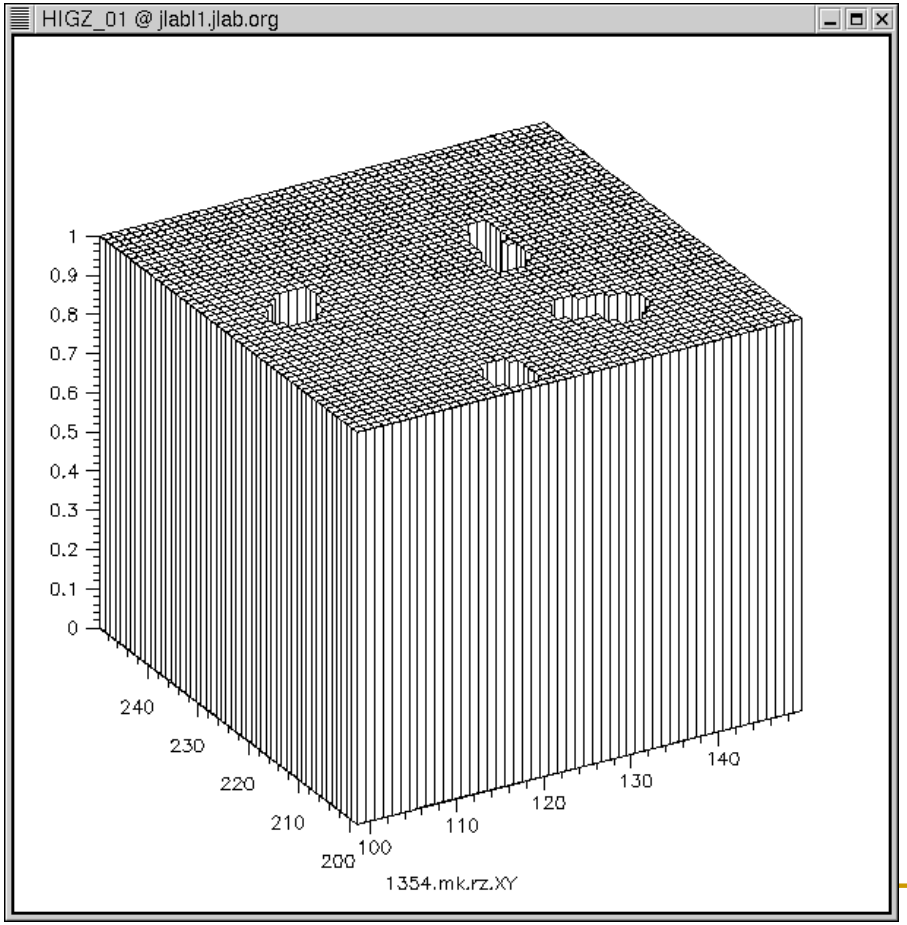


0 sec.
bias run

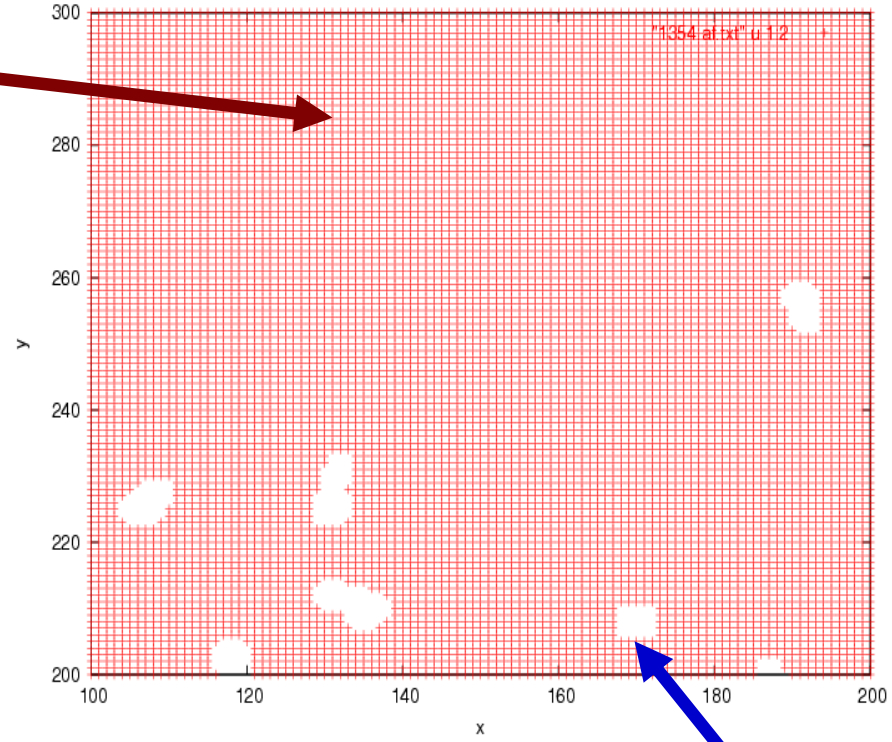
to remove these “anomalies”, a logical mask is created...

estimate σ based on 5-95% cut;
then cut on 10 x σ

also mark off 1 pixel neighborhood



1

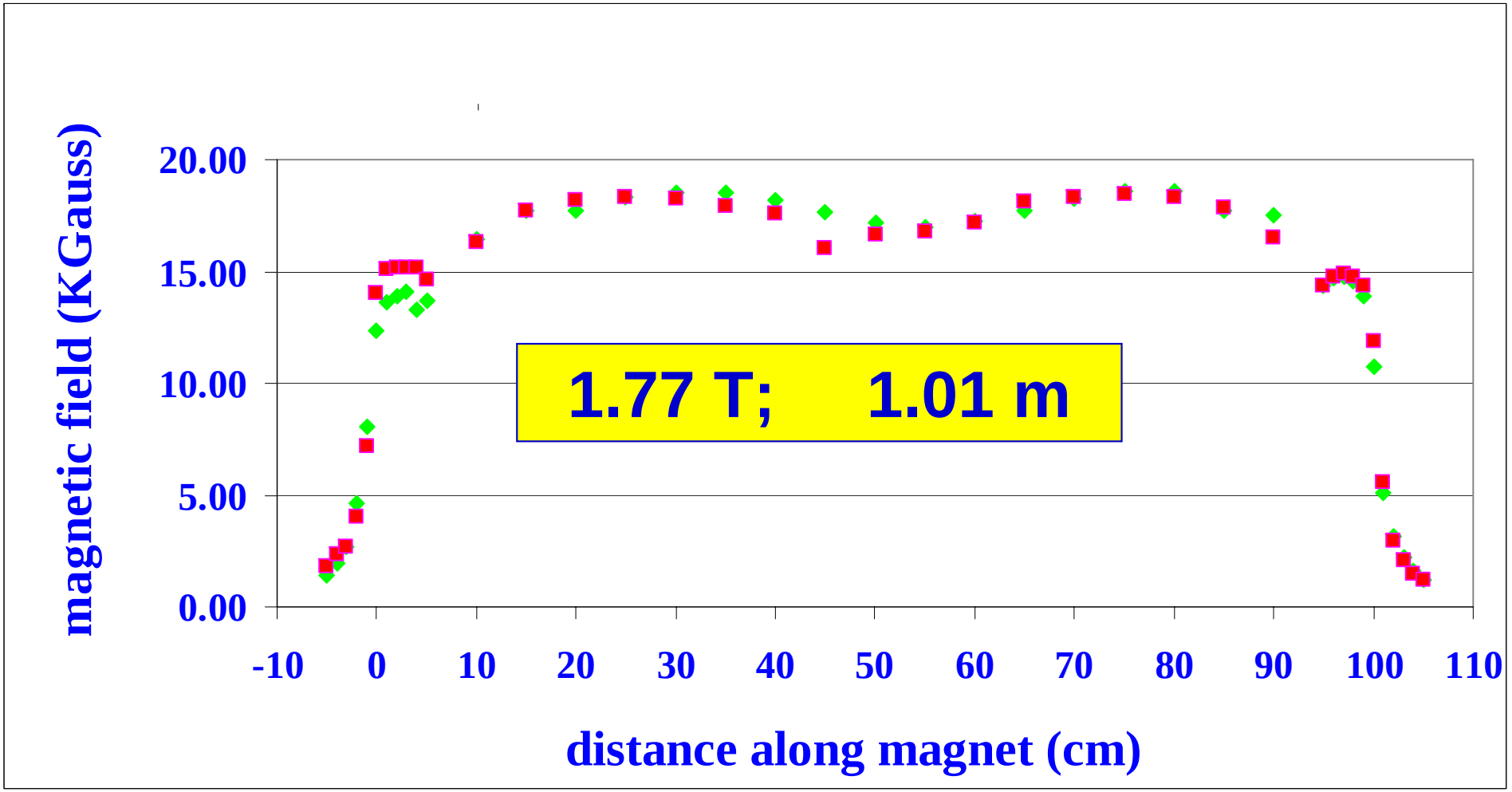


0

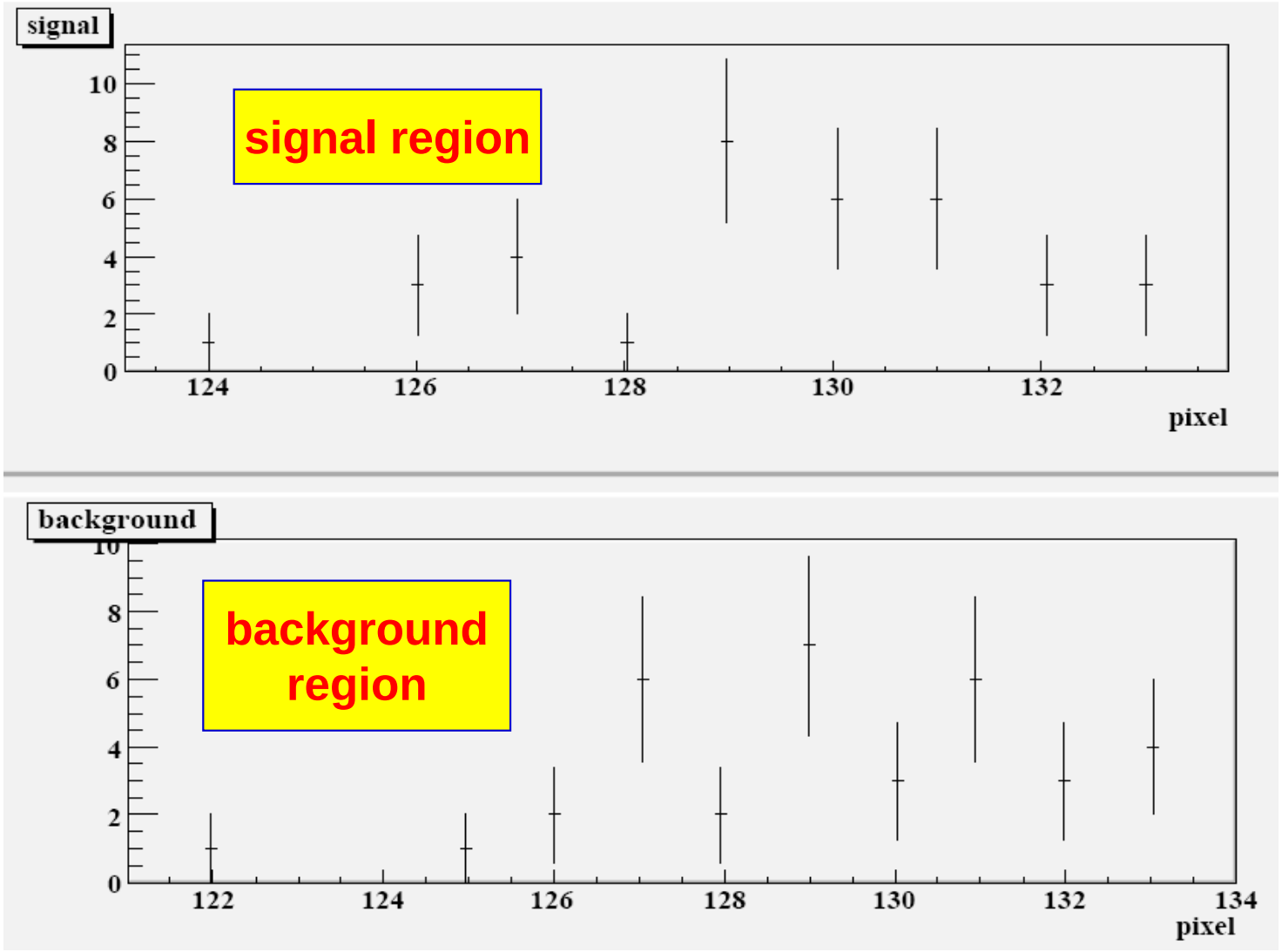
data preparation

- discarded all runs with CR hit within 100 pixels of signal region in any direction
- before each series of runs:
  - shutter open and closed
  - FEL lasing and not lasing
  - magnetic field on and off
  - room lights on and off
  - temp dependence of noise in camera
  - . . .

magnetic field strength and length



data analysis . . .



Spring '07 data

- 17 hours of data taking (over a period of one week).
- laser light polarized perpendicular to magnetic field direction (scalar coupling).
- backgrounds well characterized over the past two years.
  - **large number of background pixels (several million)**
- laser light focussing and pointing error well characterized over the past two years.
  - **focused to 3x3 pixel signal area**

parameters for initial LIPSS run (2007)

- B-field: 1.77 T
- magnet length: 1.01 m
- IR FEL power 0.18 kW
- IR FEL wavelength 935 nm (1.33 eV)
- quantum efficiency 0.45
- linear polarization 100%
- acceptance 100%
- experimental efficiency ~ 90%

results

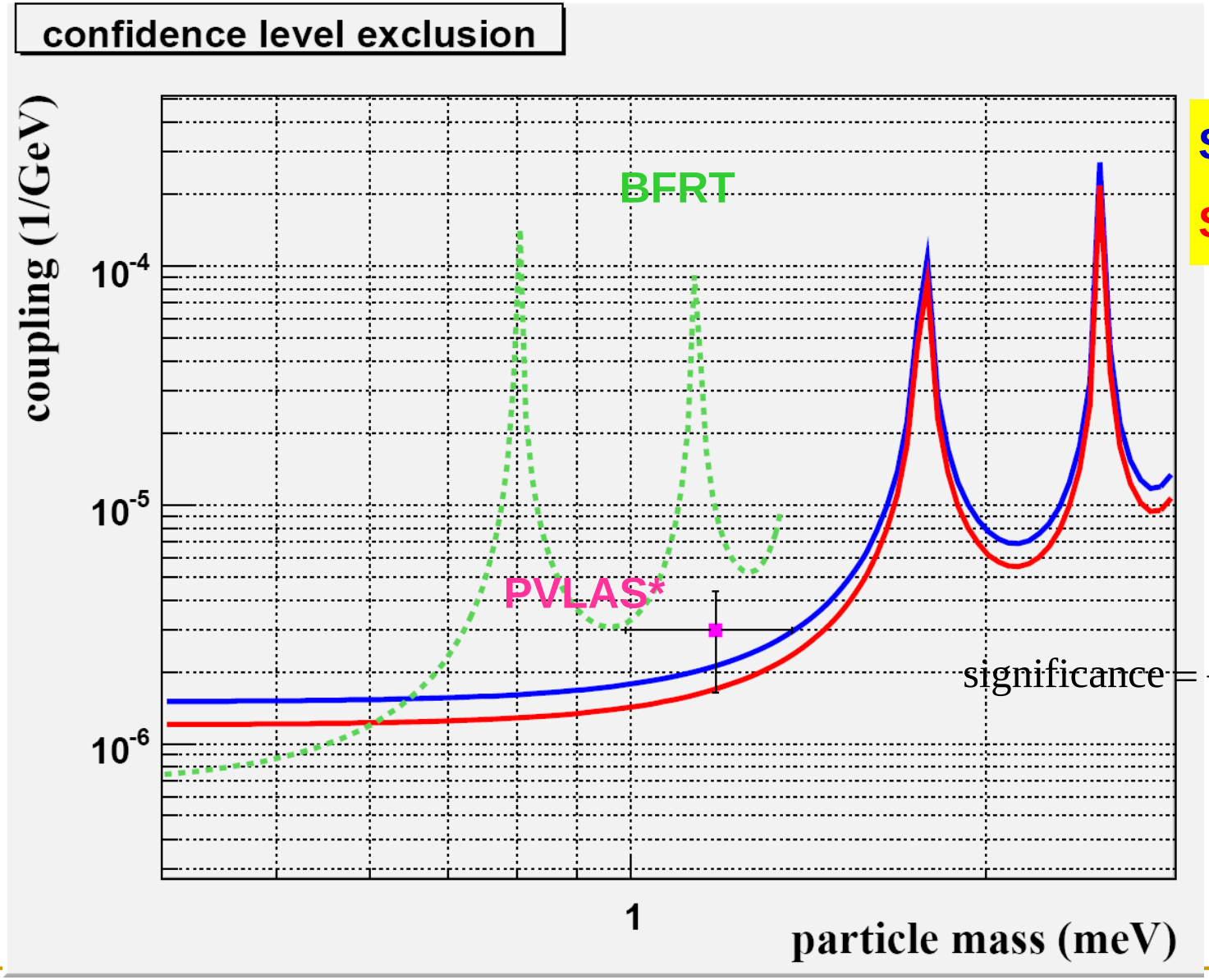
$$Y = n\, P_1\, P_2\, \varepsilon\, (\Delta\Omega/\Omega)$$ yield (#/s)

- n = photon flux (#/s)
- P_1 (P_2) = production (regeneration) probability
- ε = detection efficiency
- $\Delta\Omega/\Omega$ = solid angle

$$S \equiv \frac{R_s \times t}{\sqrt{R_b \times t}} \qquad S \geq 5$$

significance greater than or equal to five for discovery

significance of LIPSS result



$$\text{significance} = \frac{\text{signal}}{\sqrt{\text{background}}}$$

* now disclaimed

LIPSS at Jefferson Lab

- no evidence for scalar coupling at this level
- will resume running at Jefferson Lab in Fall 08
  - upgraded FEL
  - upgraded LIPSS equipment
  - will run in pseudoscalar mode
- developing a new experiment using microwave cavities (see P. Slocum's talk this conference)
  - 34 GHz source
  - resonant cavities

LIPSS collaboration

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Hampton University

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Jefferson Lab

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acknowledgements

- **FEL Division:** F. Dylla, G. Neil, G. Williams, R. Walker, D. Douglas, S. Benson, K. Jordan, C. Hernandez-Garcia, J. Gubeli
- **Hampton Univ:** M.C. Long, K. McFarlane

funding

- **Office of Naval Research**
- **Yale University**