17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

Recent Developments in Quasiperiodic Undulator Design

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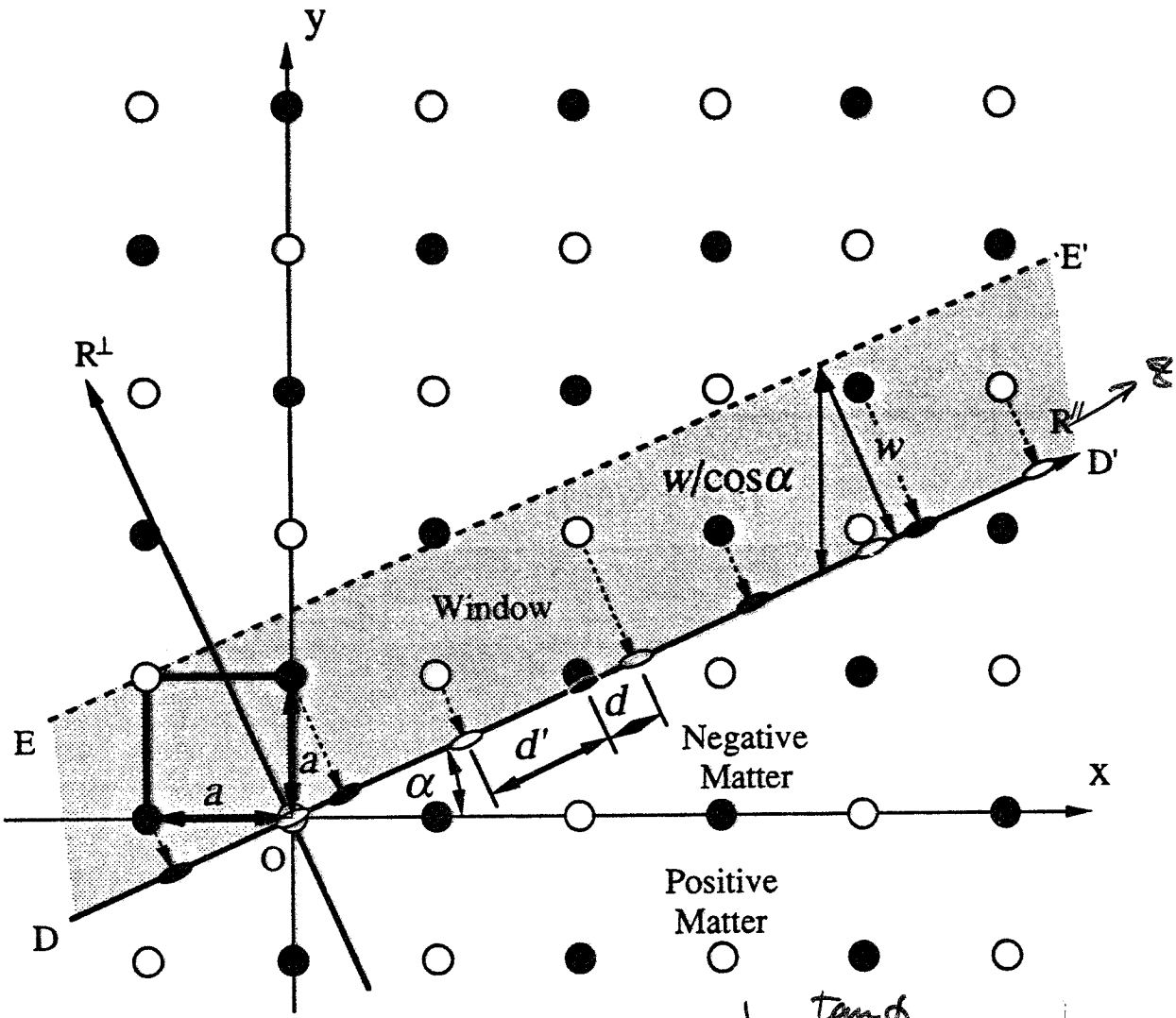
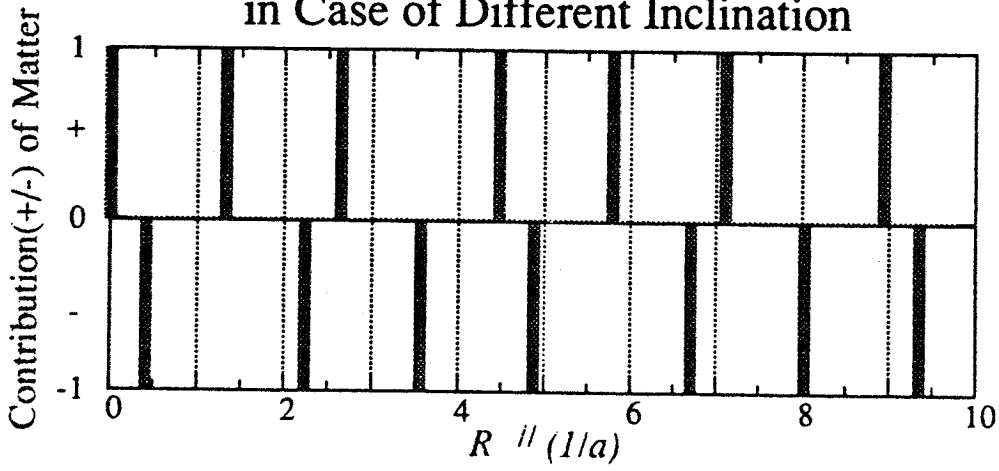
ARGONNE NATIONAL LABORATORY, ARGONNE, IL U.S.A.

Alternative Inclination (tanα=√5)

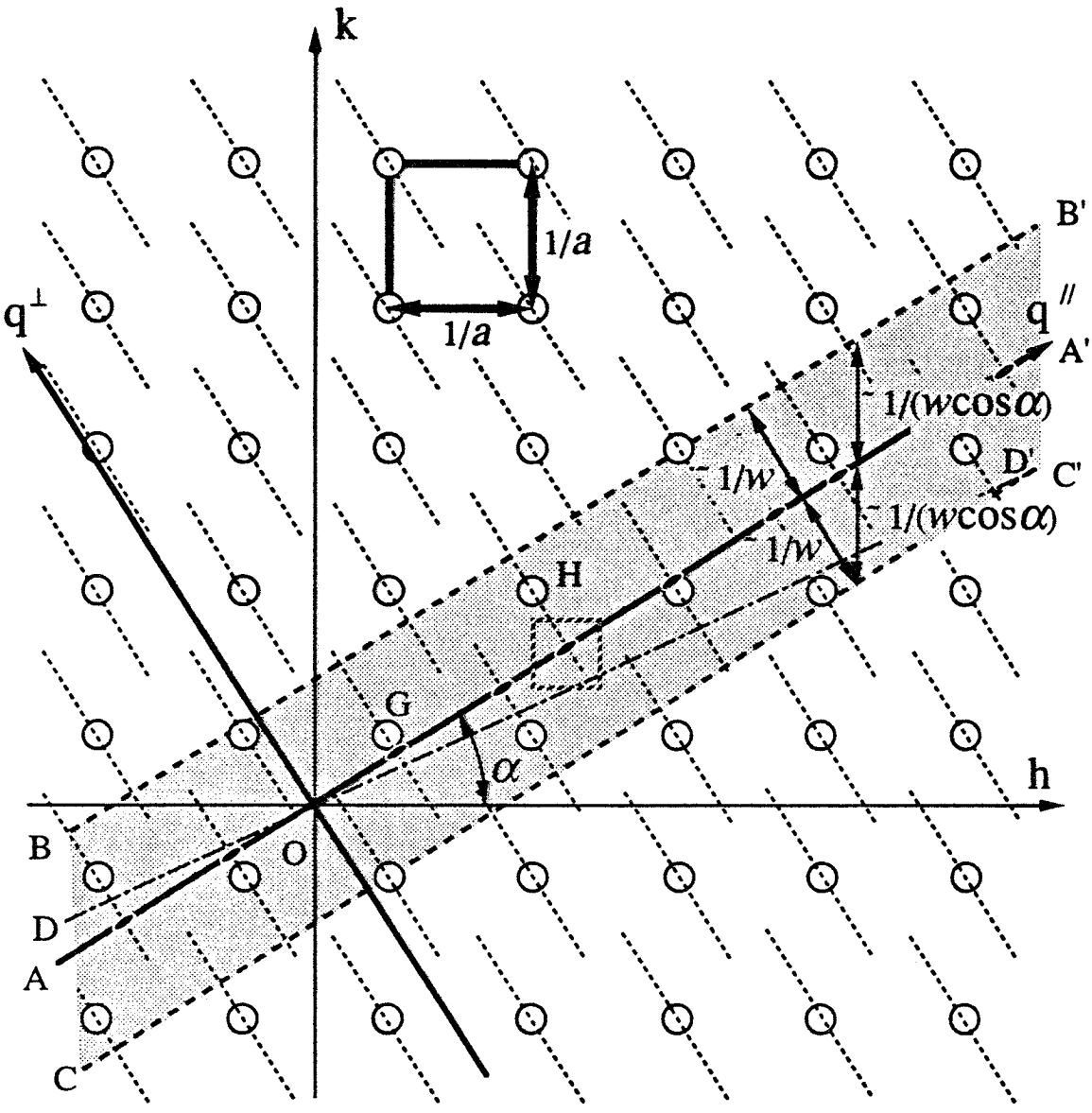


$$Z_m \propto m + (\tan\alpha - 1)\left\lfloor \frac{\tan\alpha}{1+\tan\alpha} m + 1 \right\rfloor$$

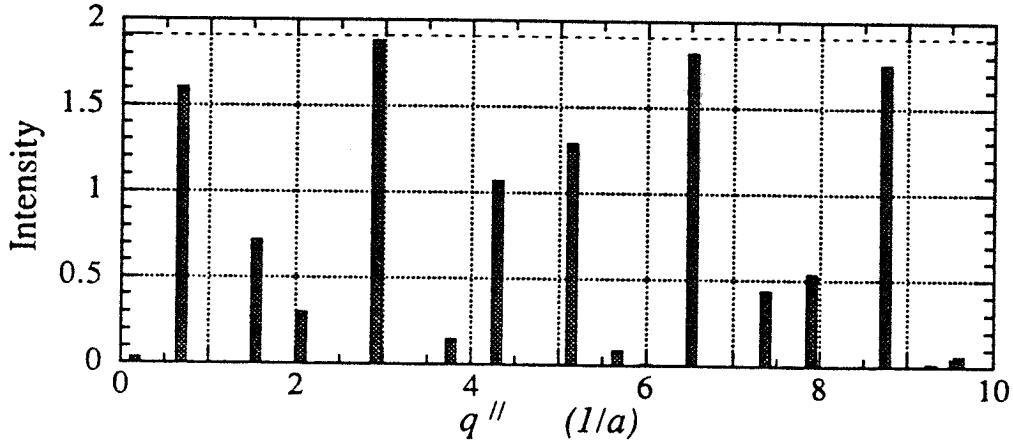
Quasi-Periodic Array of Poles in Case of Different Inclination



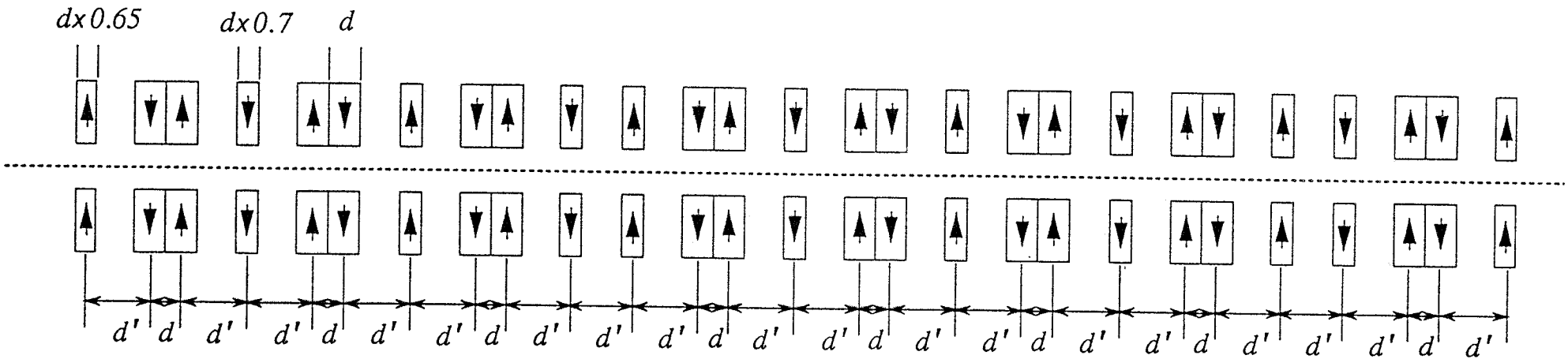
Reflection Peaks from Quasi-Periodic (+/-) Matters



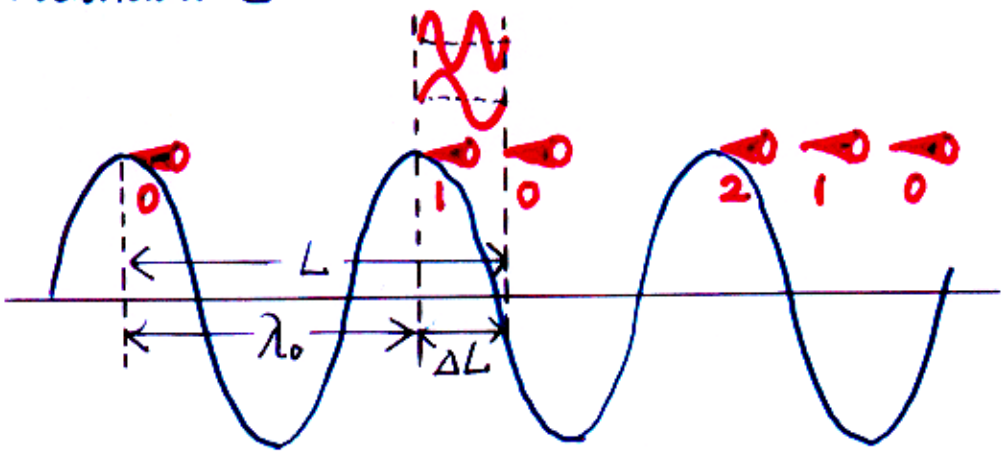
Intensity Distribution on the q(para) Axis



Real Magnetic Array of QPU



Conventional U



$$\Delta L = \frac{1}{\lambda_0^{-1}}\left(\frac{1}{\beta_z} - 1\right) = \frac{\lambda_0}{2\gamma^2}\left(1 + \frac{K^2}{2}\right)$$

phase difference (0, 1)

$$\Delta\phi = k\Delta L = k\frac{\lambda_0}{2\gamma^2}\left(1 + \frac{K^2}{2}\right) = 2\pi\frac{k}{k_1} = 2\pi\frac{\omega}{\omega_1}$$

Then, Total photon intensity propotional

$$\sum_{m=0}^{N-1} \exp\left(2\pi i\, m\frac{\omega}{\omega_1}\right)$$

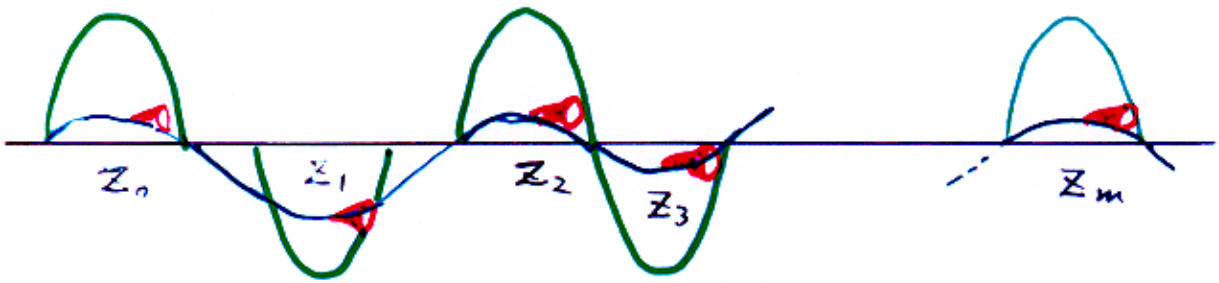
When $\Delta\phi = 2\pi n$ i.e. $\omega = n\omega_1$ (n: integer

Max. photon intensity

⇩

harmonic structure (integer)

QPU



phase factor

$$\sum_{m=0}^{N-1} \exp\left(i\pi \frac{\omega}{\omega_1'} [\hat{z}_m - \eta m] - i\pi m \right)$$

$\hat{z}_m$: lattice position

$$\hat{z}_m = m - (\tan\alpha - 1) + (\tan\alpha - 1)\left[\frac{\tan\alpha}{1+\tan\alpha} m + 1 \right]$$

$$\omega_1' = \frac{2\delta^2 \omega_0}{1+K^2} \tan\alpha$$

$$\frac{\omega}{\omega_1'} = k_{pq} \quad : \text{peak position}$$

$$k_{pq} = \left[2\left(p + q \frac{\tan\alpha}{1+\tan\alpha} \right) - 1 \right] \Big/ \left(\frac{1+\tan^2\alpha}{1+\tan\alpha} - \eta \right)$$

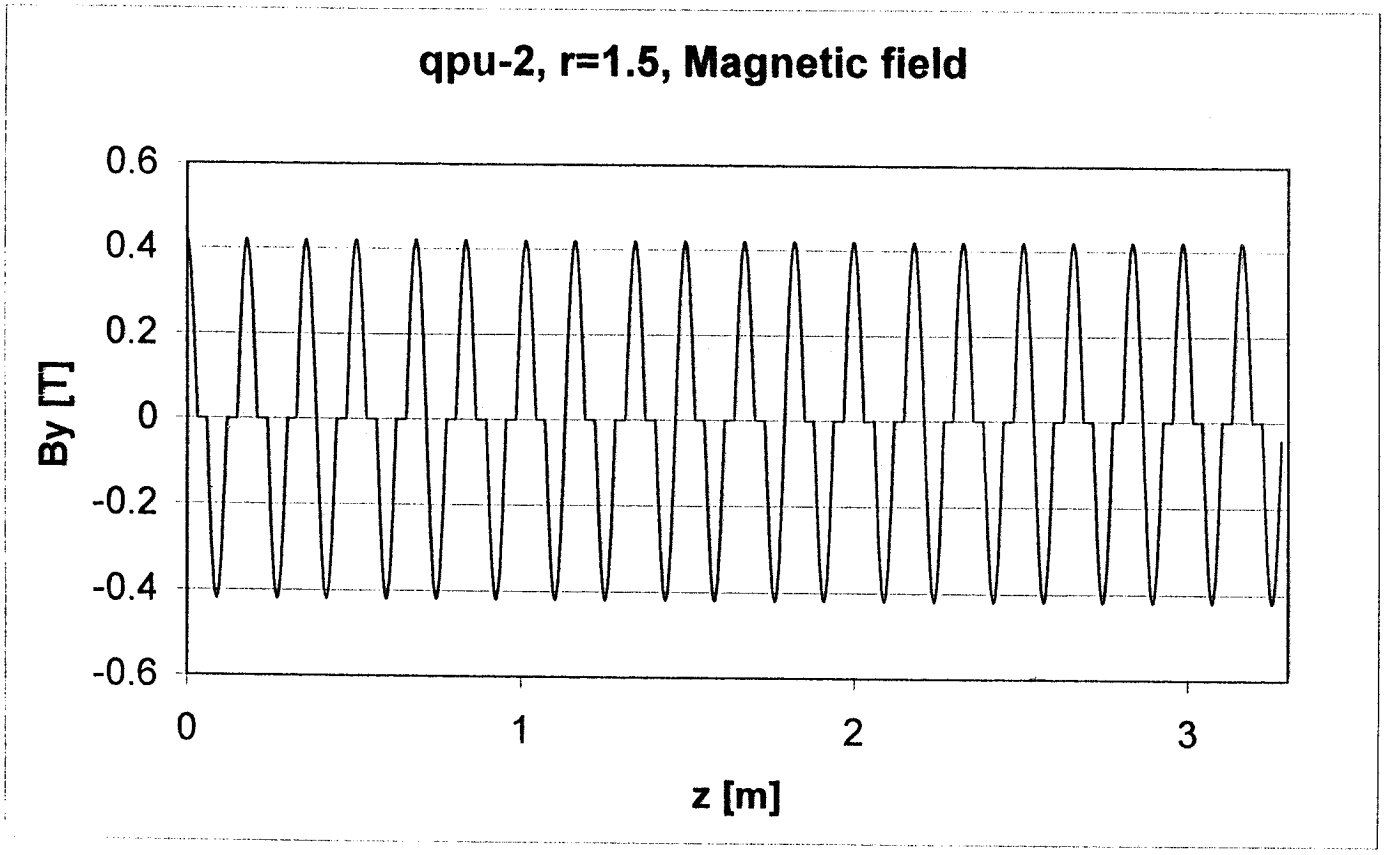
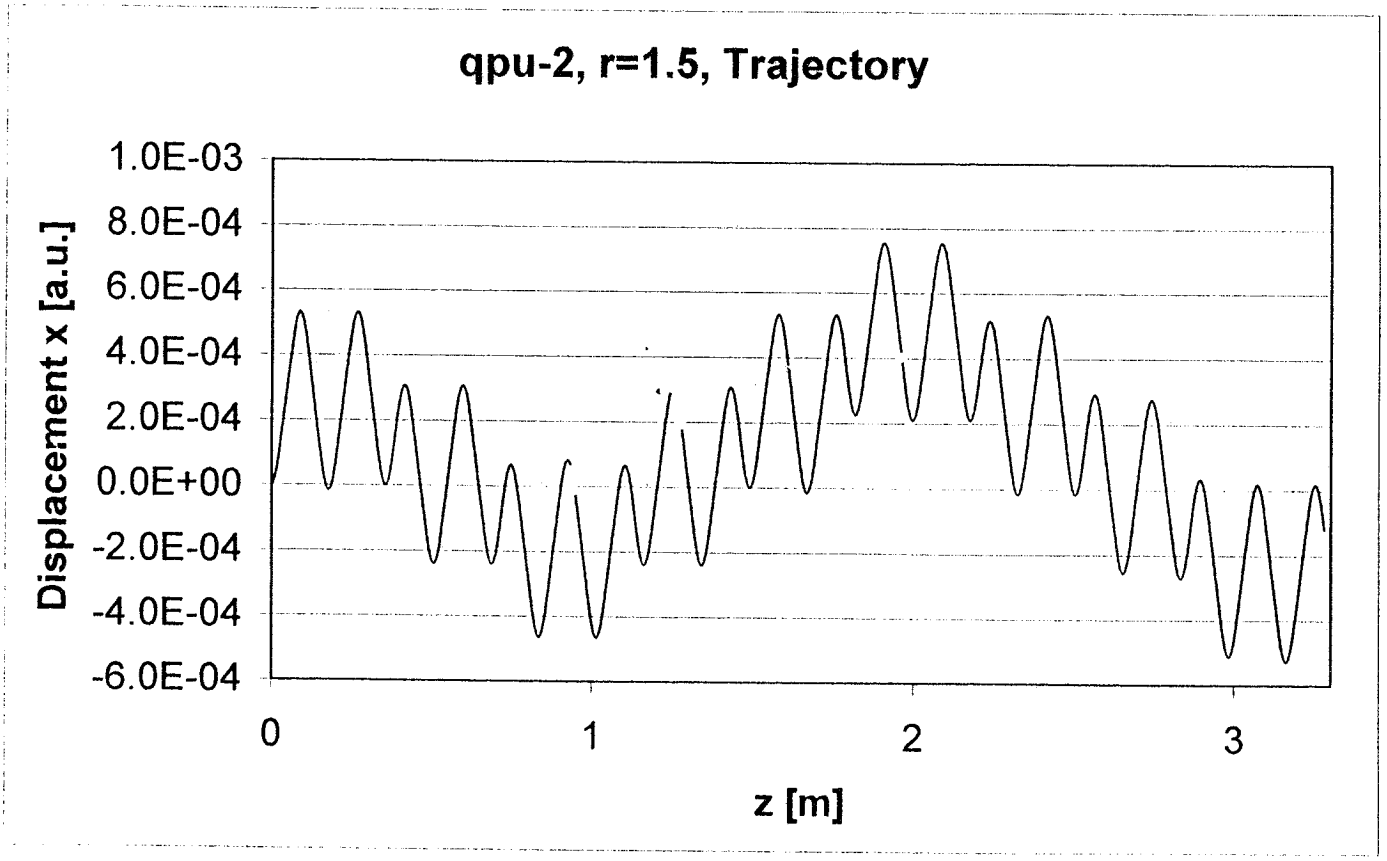

qpu-2, r=1.5, Magnetic field
By [T]
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
1
2
3
z [m]

Fig 2


qpu-2, r=1.5, Trajectory
Displacement x [a.u.]
1.0E-03
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
-2.0E-04
-4.0E-04
-6.0E-04
0
1
2
3
z [m]

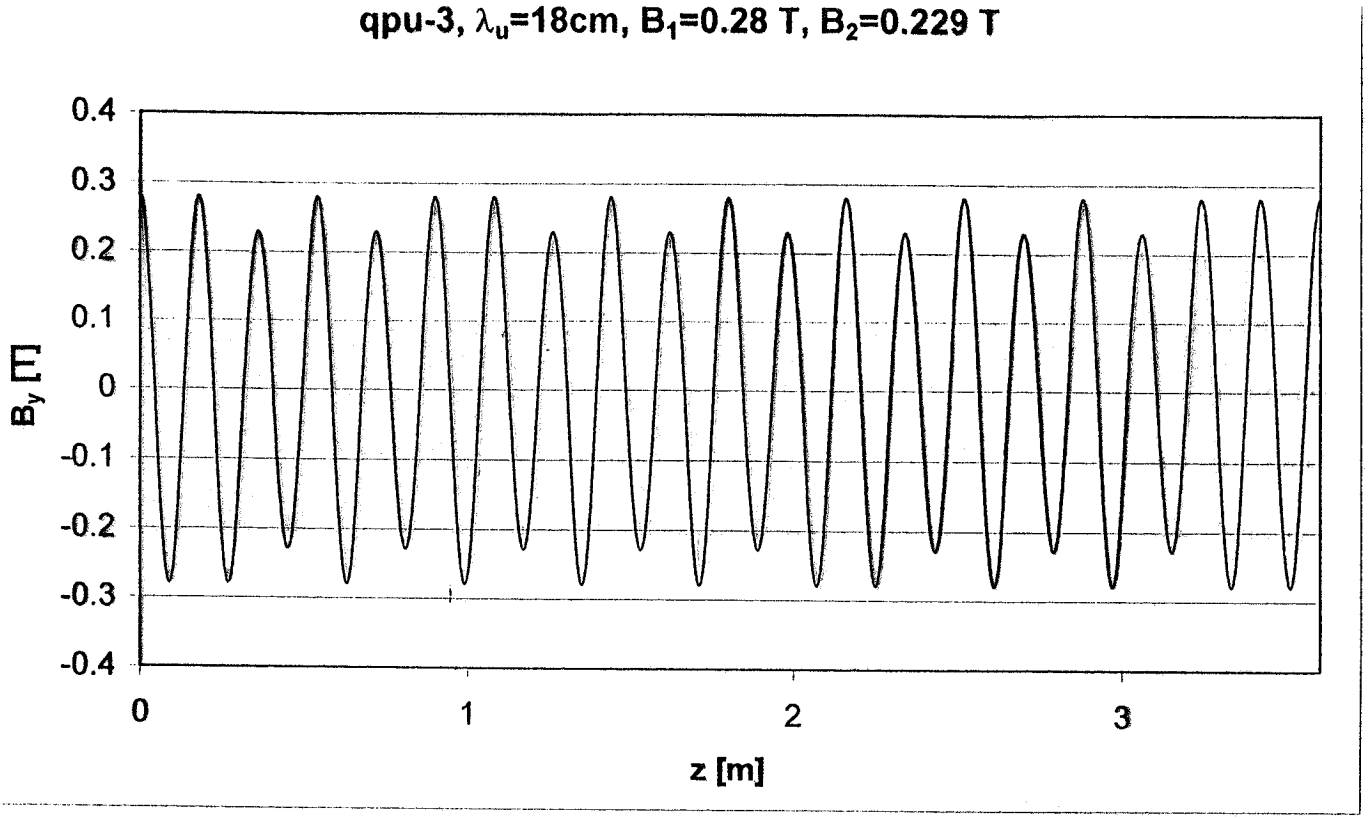
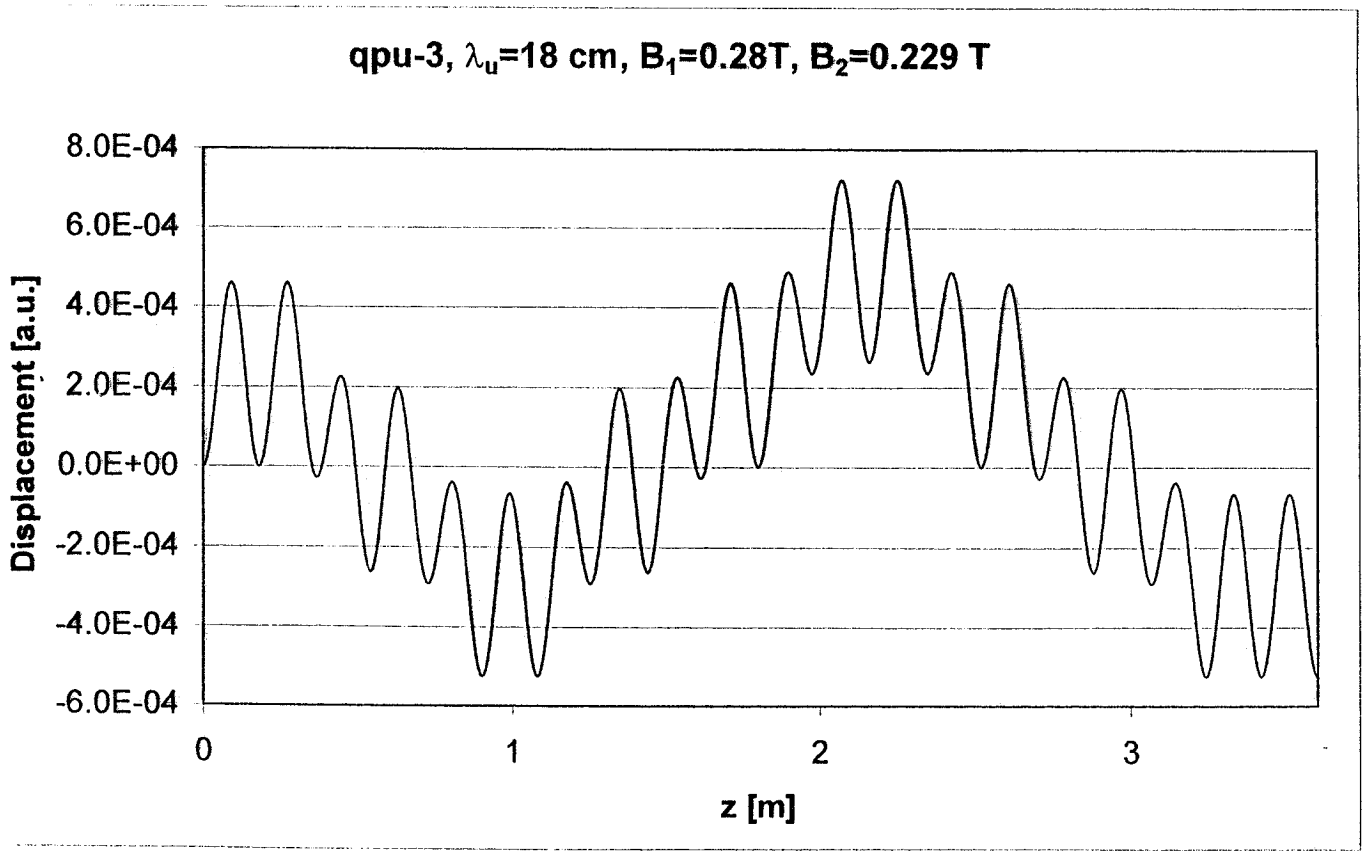
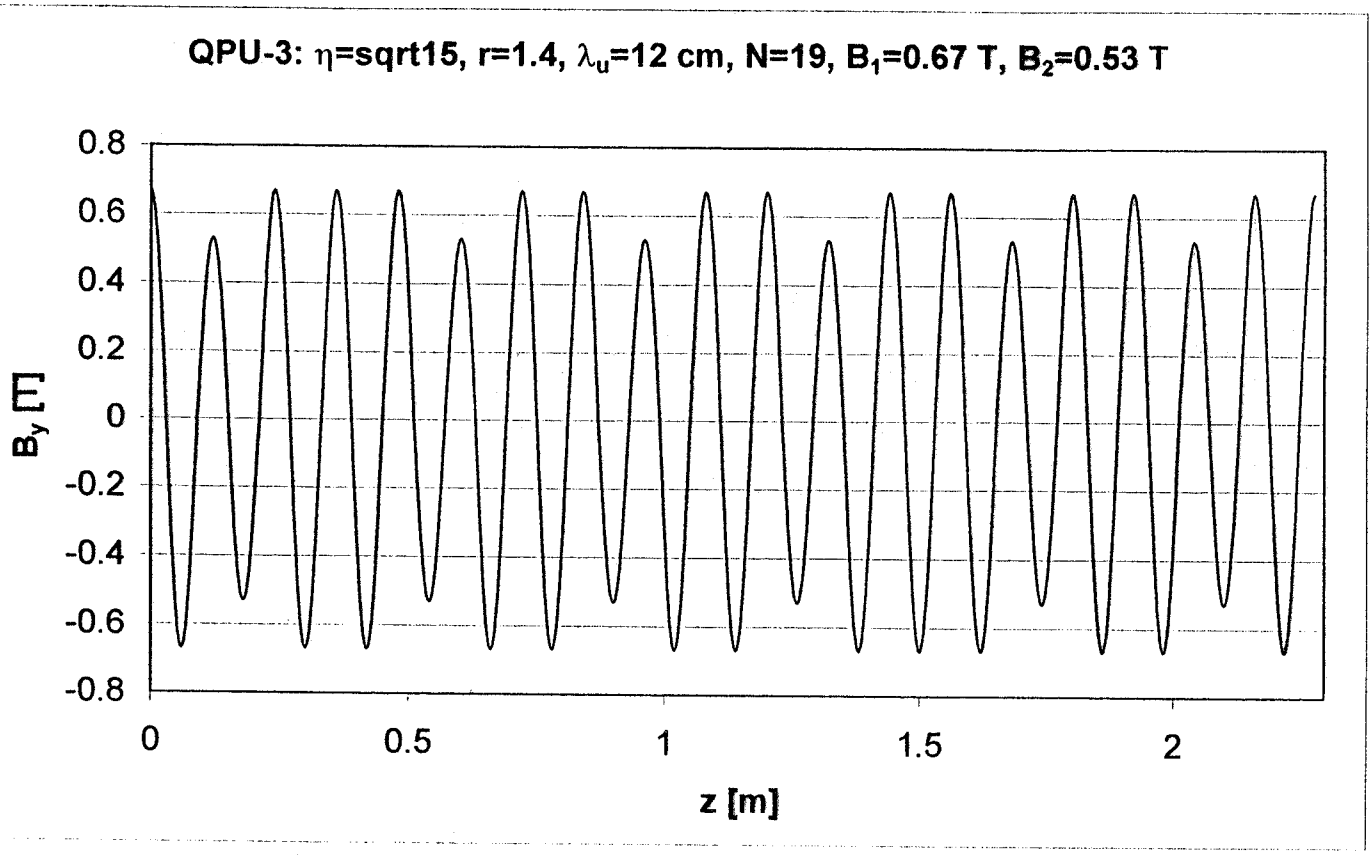
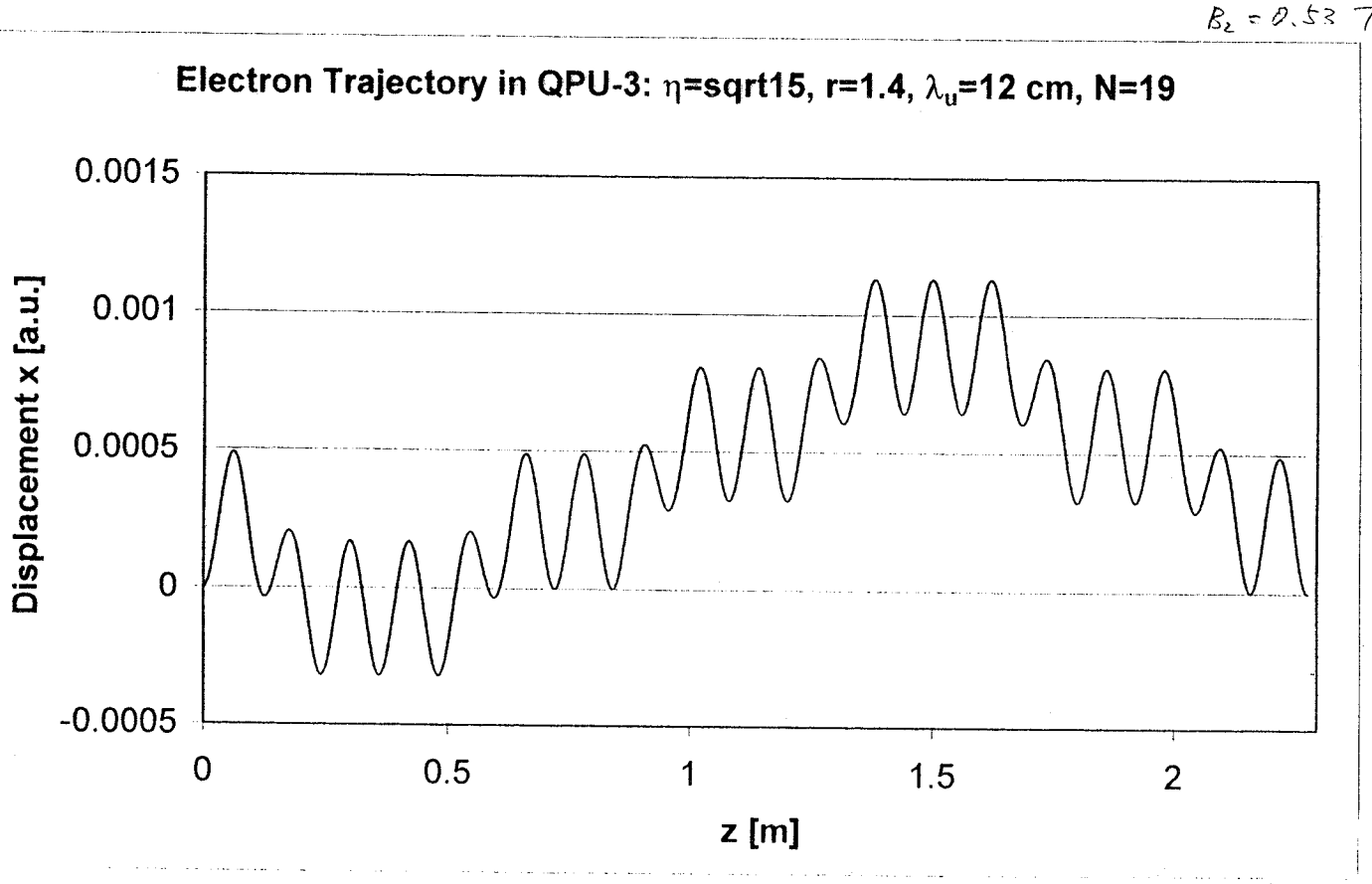

qpu-3, λ_u=18cm, B_1=0.28 T, B_2=0.229 T
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
B_y [T]
0
1
2
3
z [m]

Fig. 9


qpu-3, λ_u=18 cm, B_1=0.28T, B_2=0.229 T
8.0E-04
6.0E-04
4.0E-04
2.0E-04
0.0E+00
-2.0E-04
-4.0E-04
-6.0E-04
Displacement [a.u.]
0
1
2
3
z [m]


QPU-3: η=sqrt15, r=1.4, λu=12 cm, N=19, B1=0.67 T, B2=0.53 T
By [T]
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.5
1
1.5
2
z [m]

$B_2 = 0.53$ T


Electron Trajectory in QPU-3: η=sqrt15, r=1.4, λu=12 cm, N=19
Displacement x [a.u.]
0.0015
0.001
0.0005
0
-0.0005
0
0.5
1
1.5
2
z [m]

In a half period of periodic undulator, the path length difference can be written:

$$\Delta l = \frac{l}{\beta} - \frac{\lambda_u}{2} = \left(1 + \frac{1}{2\gamma^2} + \frac{K^2}{4\gamma^2}\right) l - \frac{\lambda_u}{2}$$

where l is the trajectory length over a half period.

$$= \frac{\lambda_u}{2}\left\{\left(1 + \frac{1}{2\gamma^2} + \frac{K^2}{4\gamma^2}\right)\left(1 + \frac{x_0^2 k^2}{4}\right) - 1\right\}$$

in the original QPU

$$\frac{\Delta l}{\Delta l'} = \frac{d}{d'} = \tan\alpha \equiv \frac{1}{\eta}$$

The same path length differences can be obtained by changing the amplitude.

↑

New QPU scheme.

Position of *m*-th magnet pole:

$$z_m = \hat{z}_m \frac{w}{r \tan\alpha}$$

$$\hat{z}_m = m + (r\tan\alpha - 1)\left\lfloor \frac{\tan\alpha}{r + \tan\alpha} m + 1 \right\rfloor$$

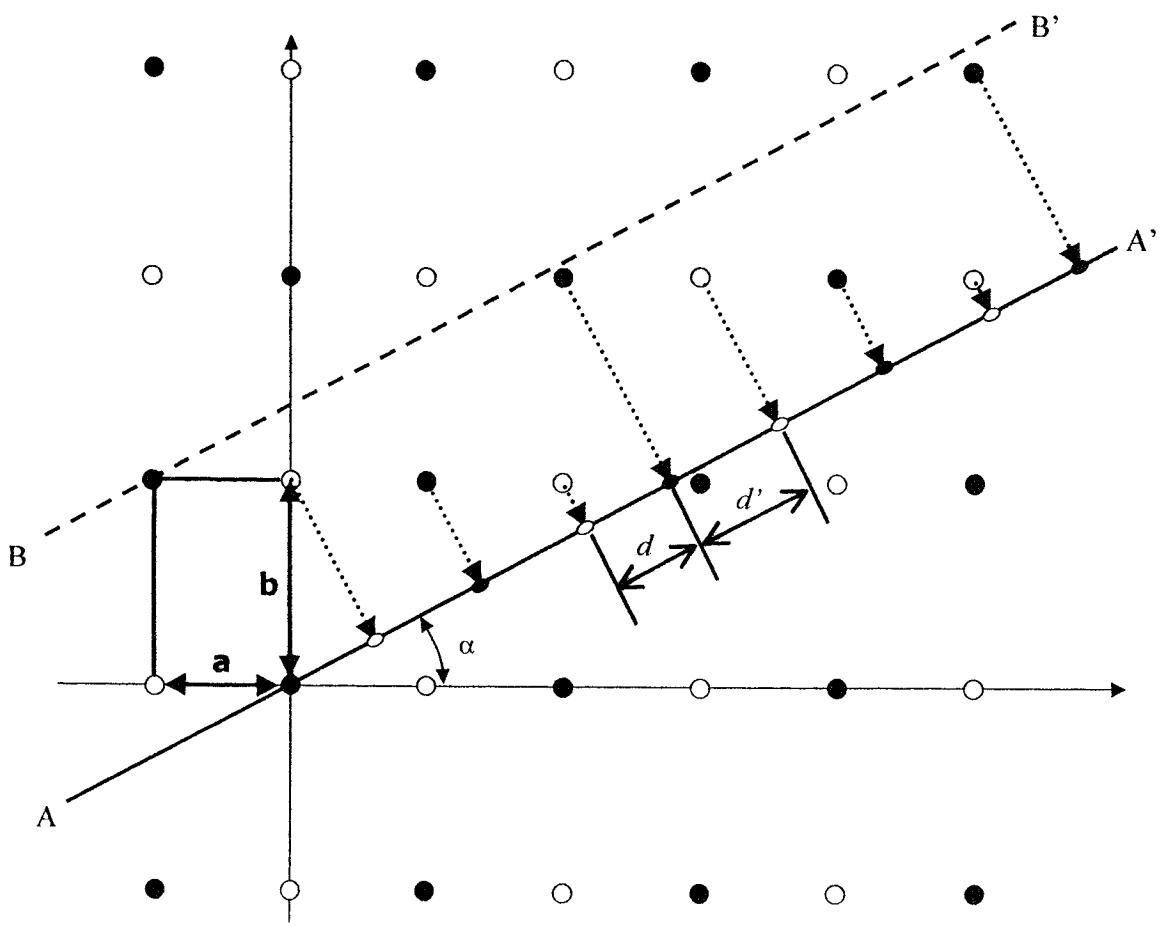
$$r = b/a$$

Where a and b are the lattice constants of rectangular lattice in the two dimensional hyper-space.

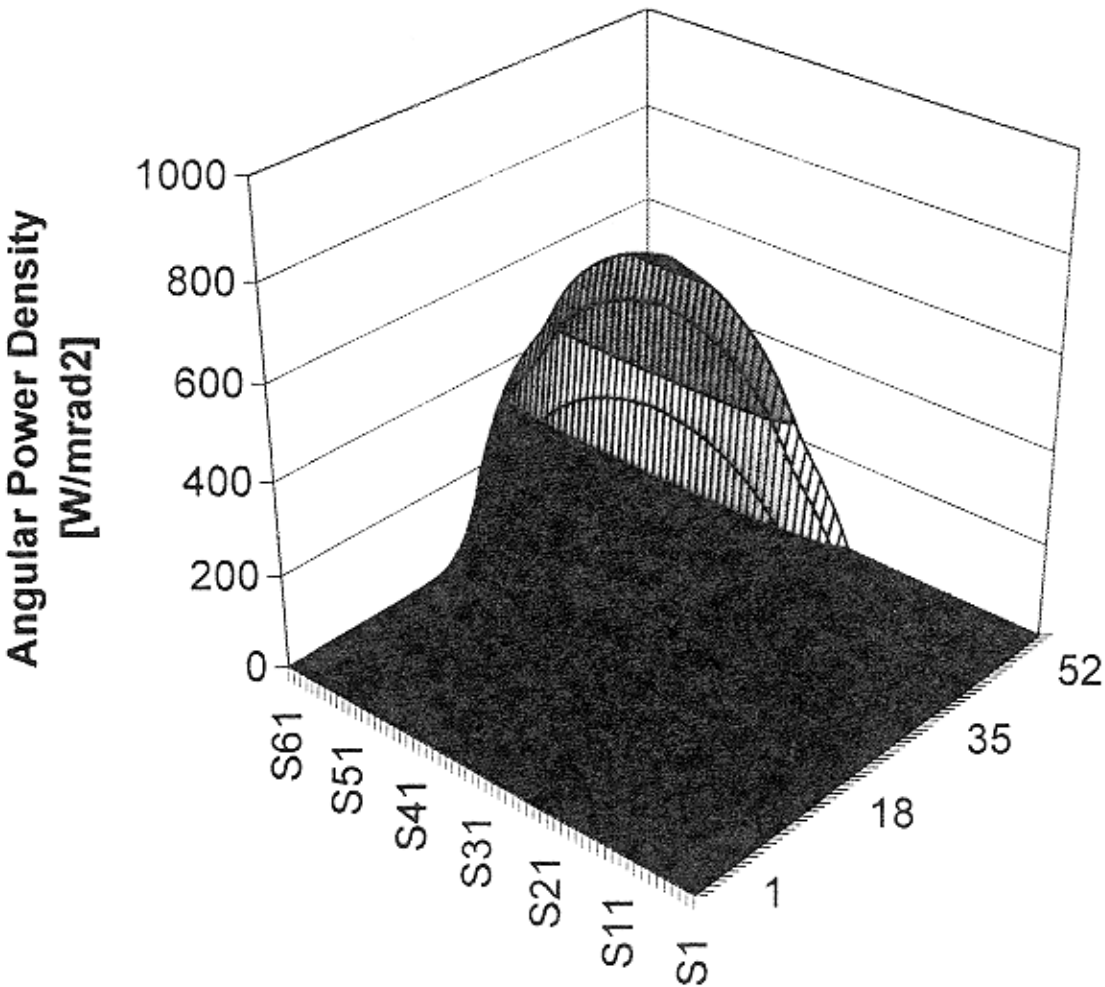
In this consideration, w=6 cm, tanα=1/$\sqrt{5}$, and r=1.5 were used.

$d = 6.0$ cm

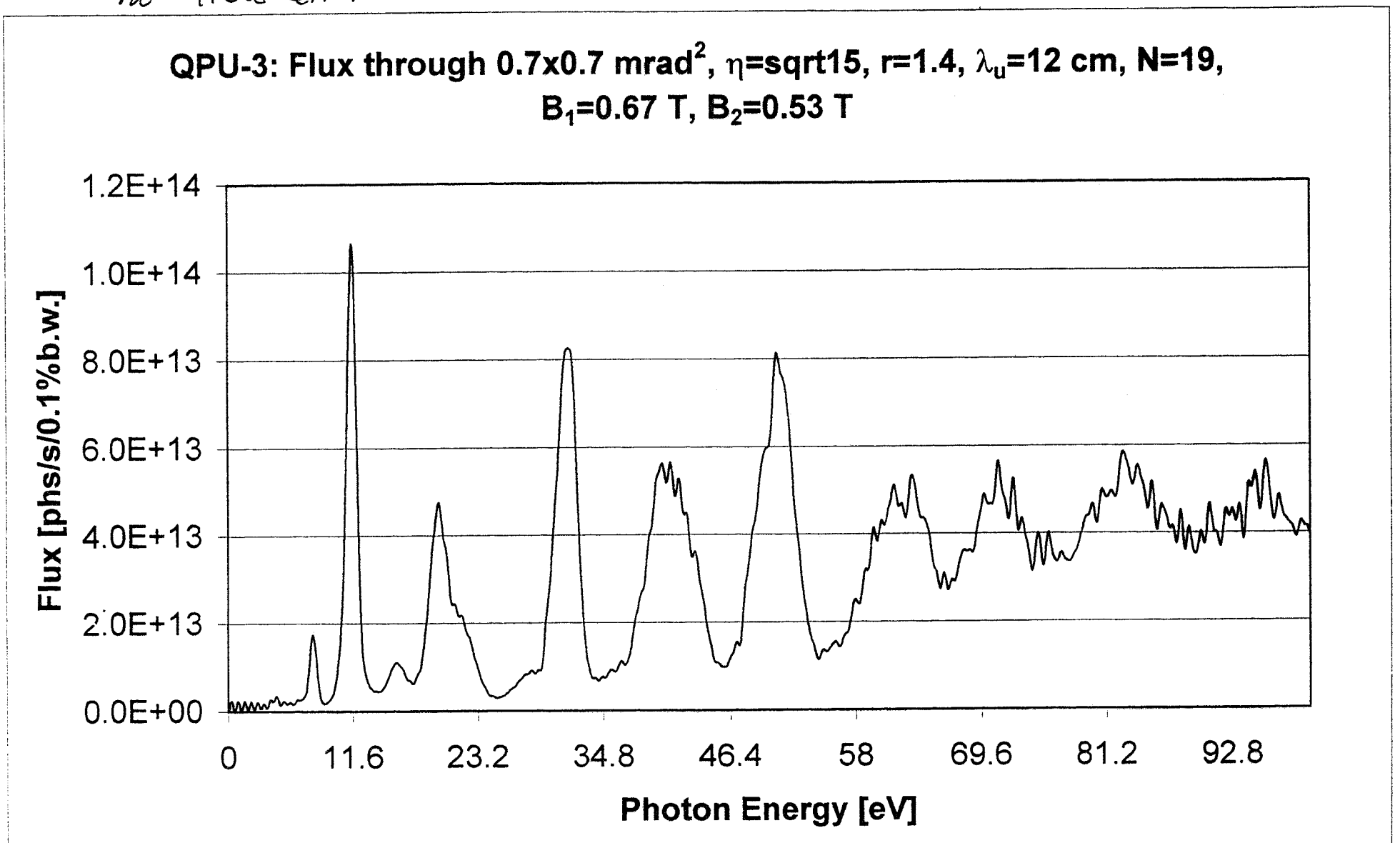
$d' = 8.944$ cm

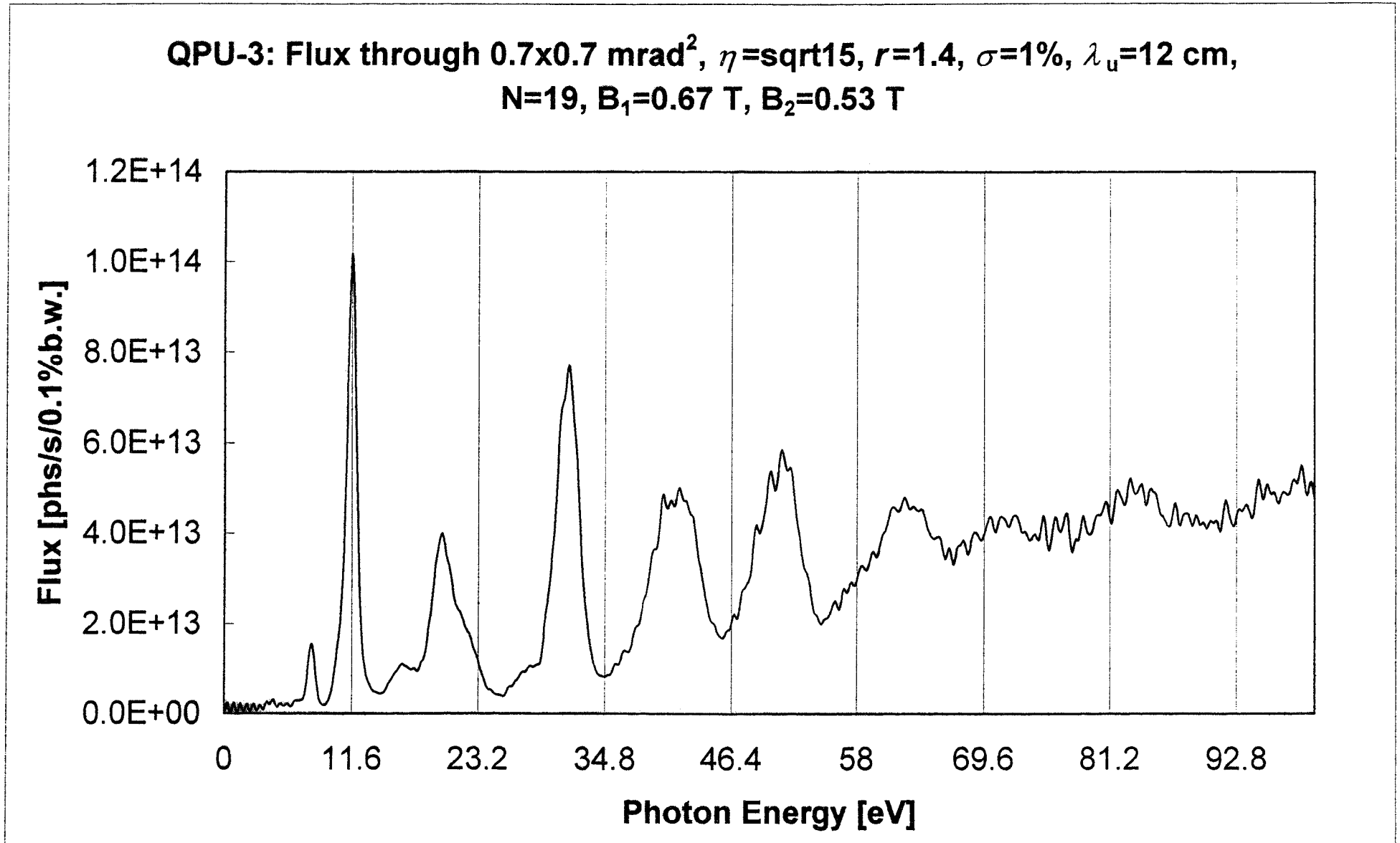


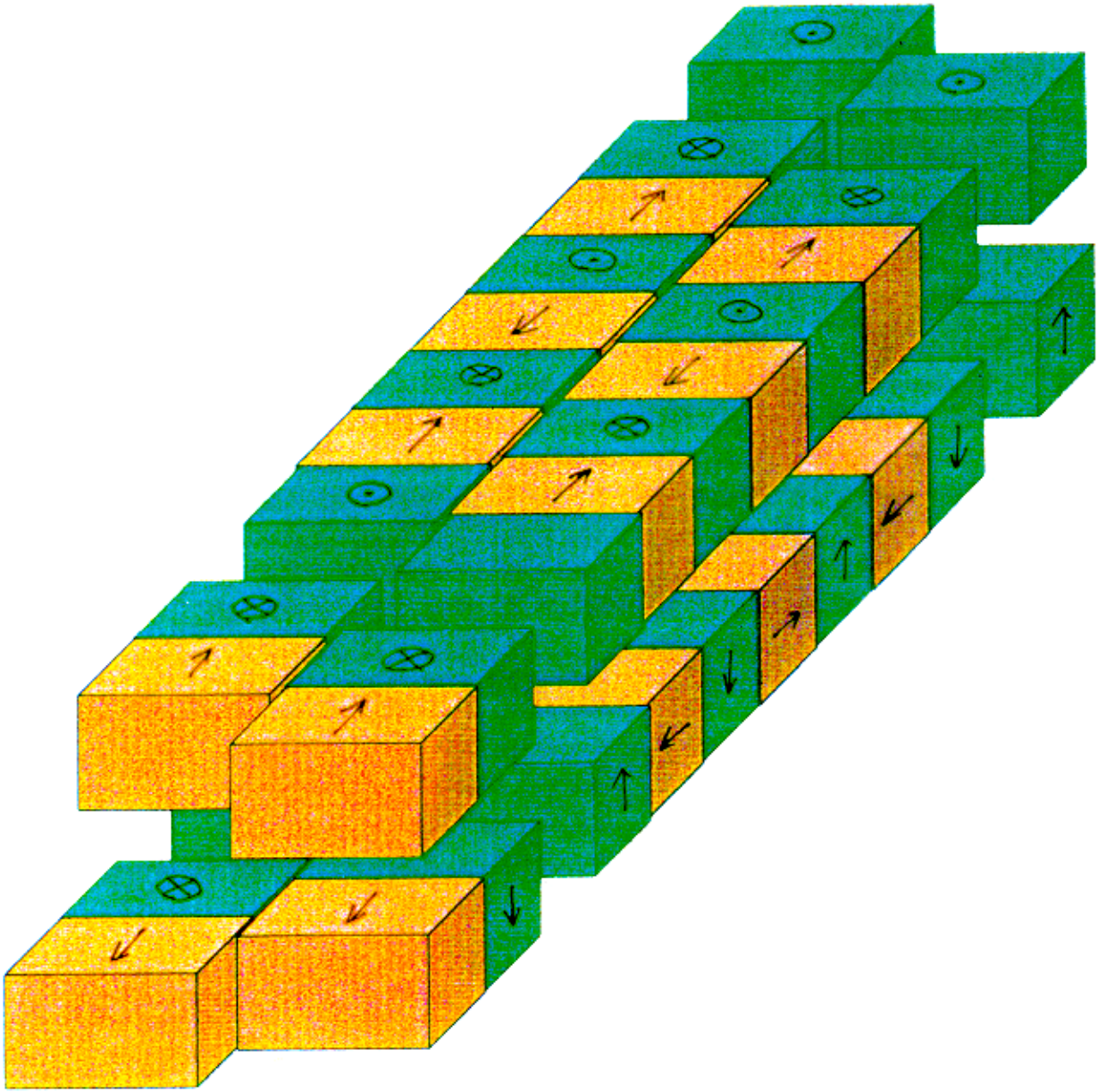
QPU-3: Angular Power Distribition

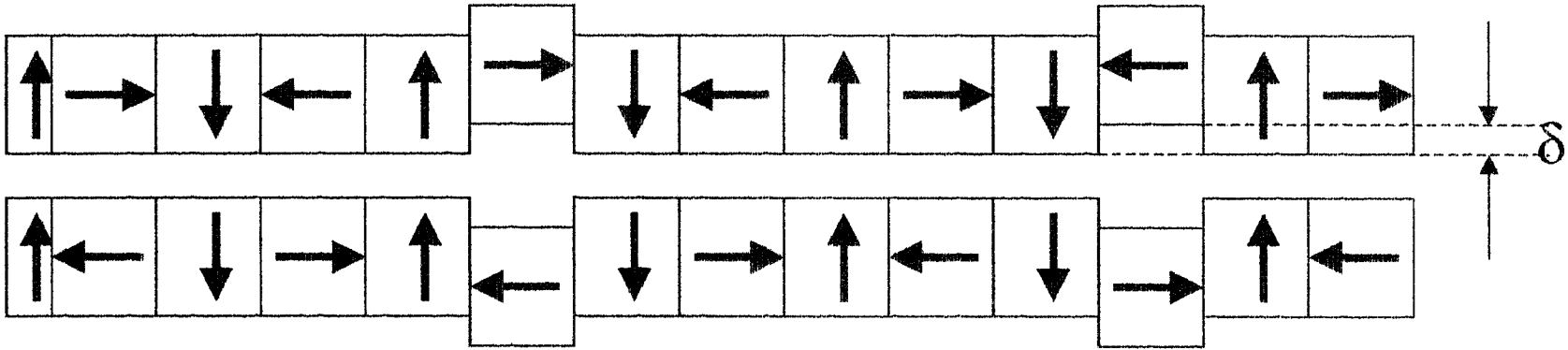


no-field-error

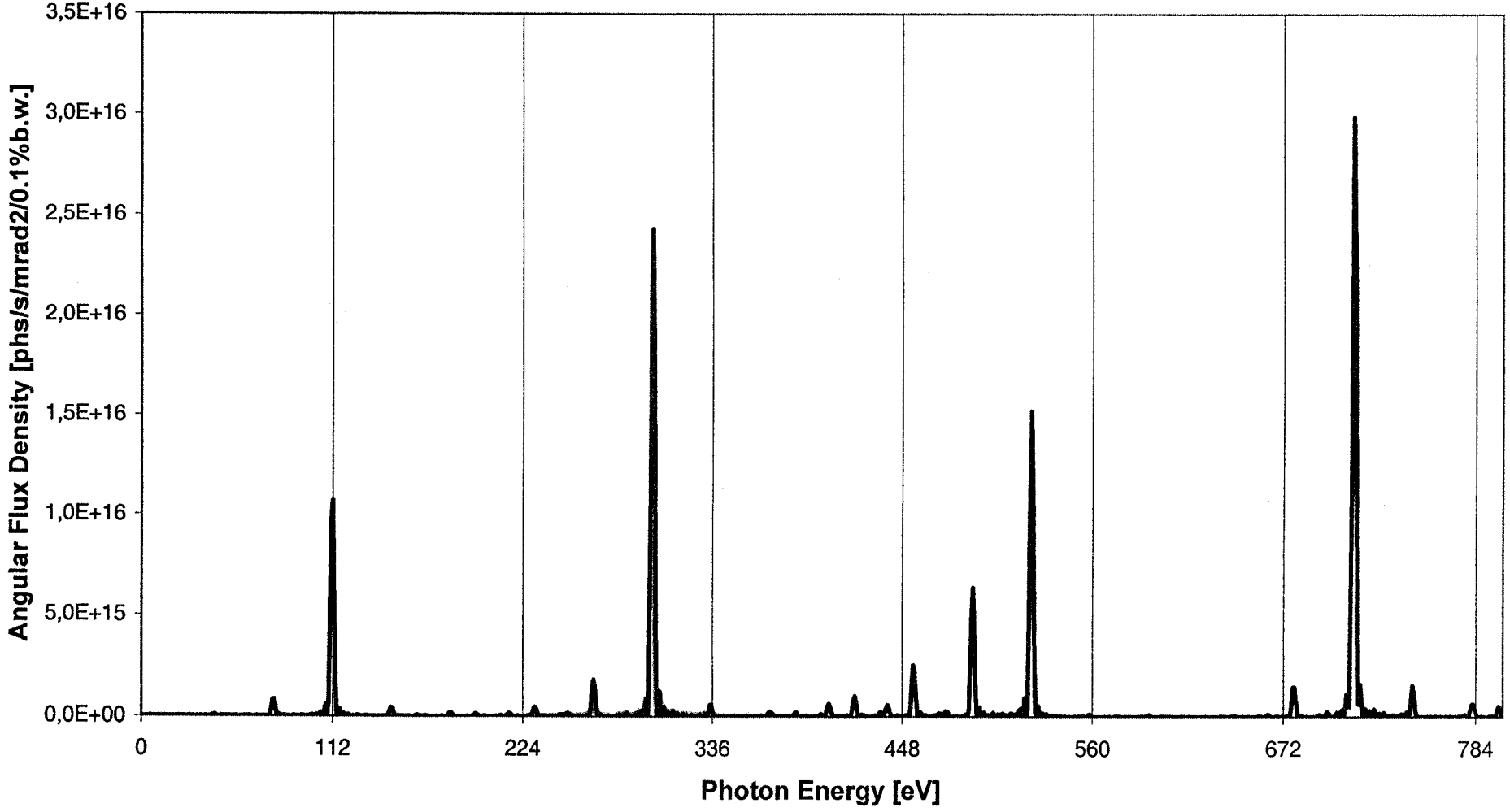



QPU-3: Flux through 0.7x0.7 mrad², η=sqrt15, r=1.4, σ=1%, λu=12 cm,
N=19, B1=0.67 T, B2=0.53 T
1.2E+14
1.0E+14
8.0E+13
6.0E+13
4.0E+13
2.0E+13
0.0E+00
Flux [phs/s/0.1%b.w.]
0
11.6
23.2
34.8
46.4
58
69.6
81.2
92.8
Photon Energy [eV]

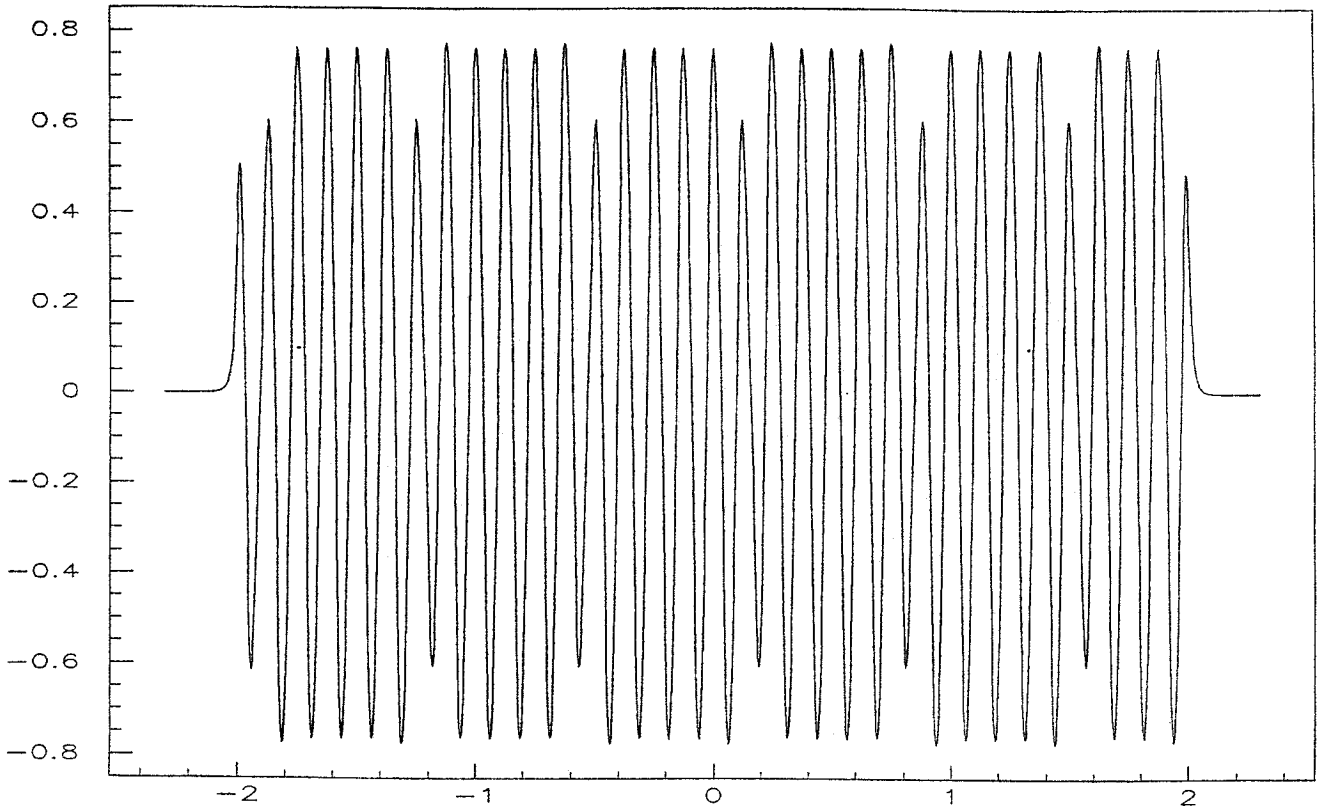



δ

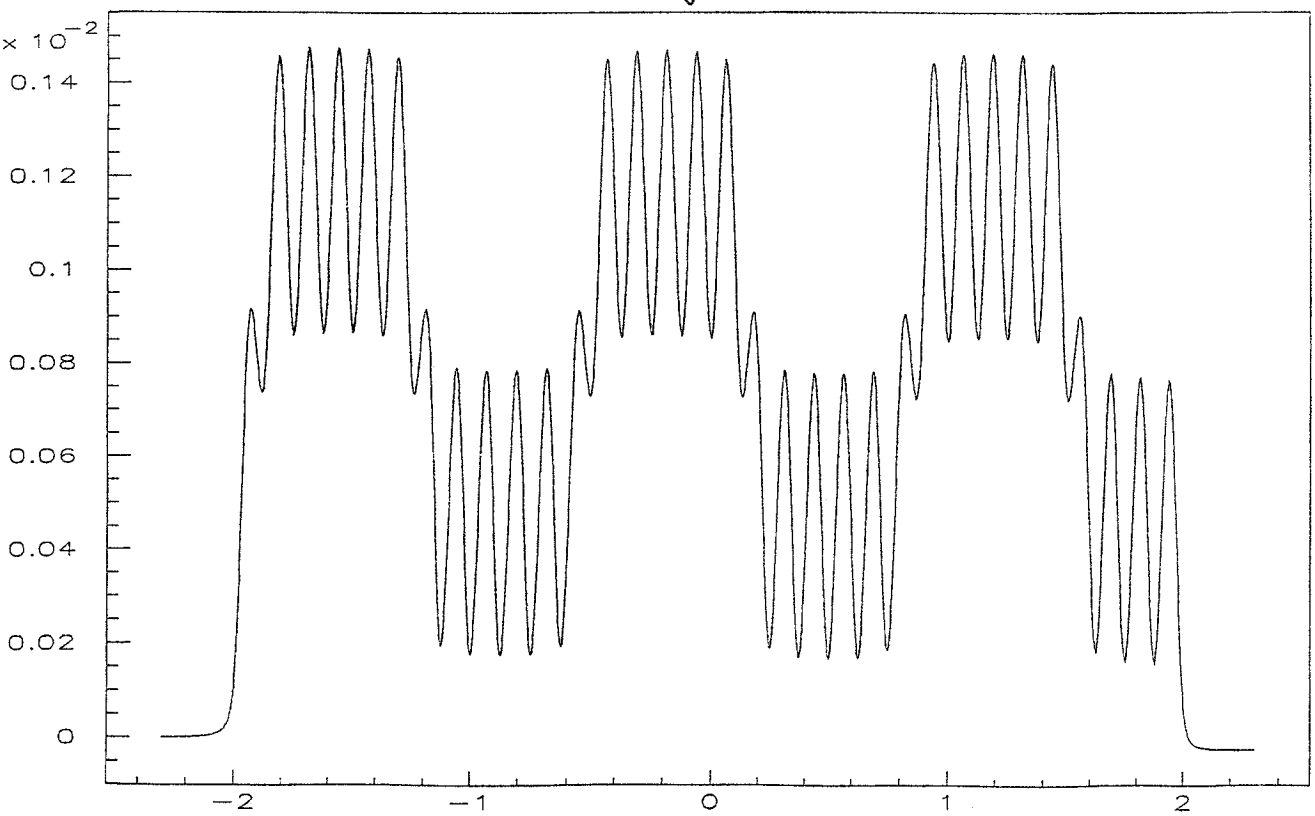
QPU48; L=2 m, B_{max}=0.67 T, r=1.4, tanα=1/sqrt15
Electron Energy: 1.7 GeV, Current: 100 mA



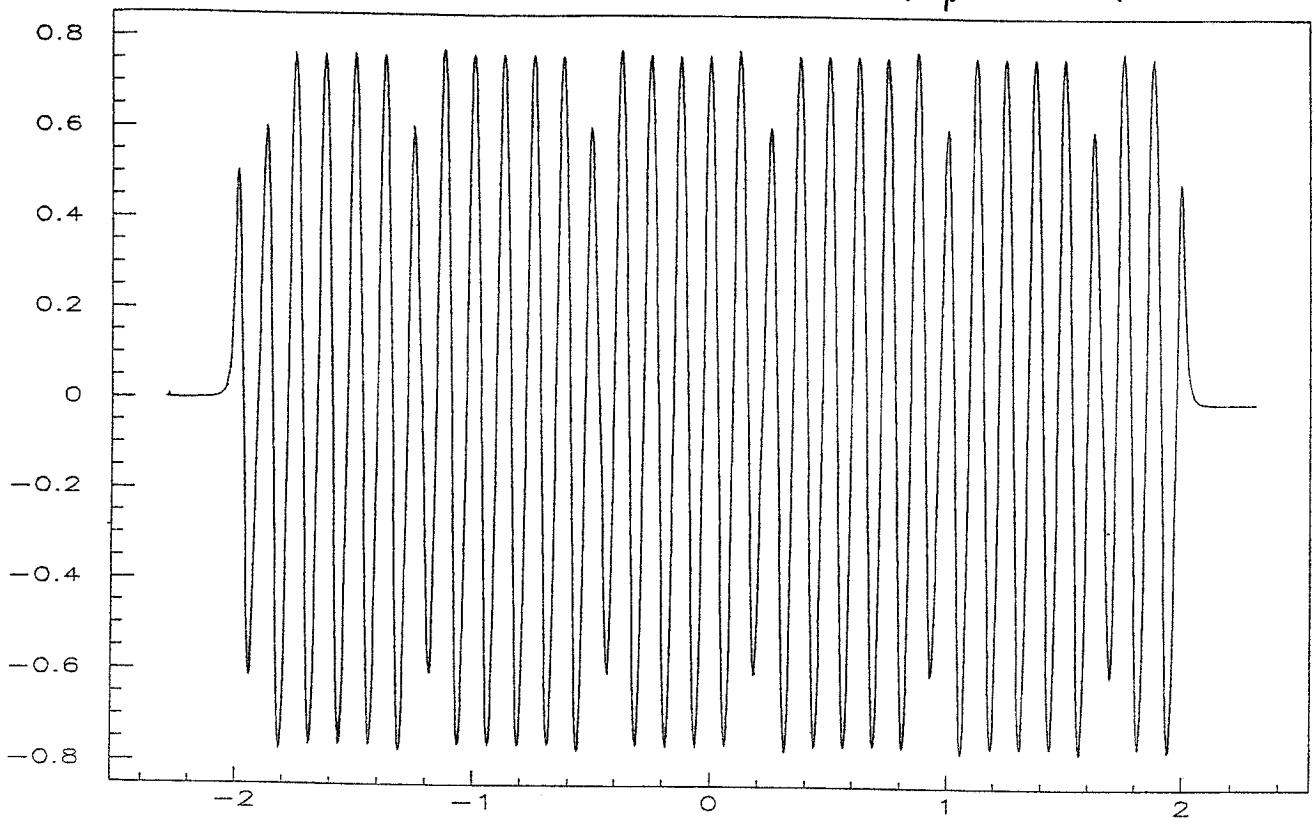
Periodic Undulator



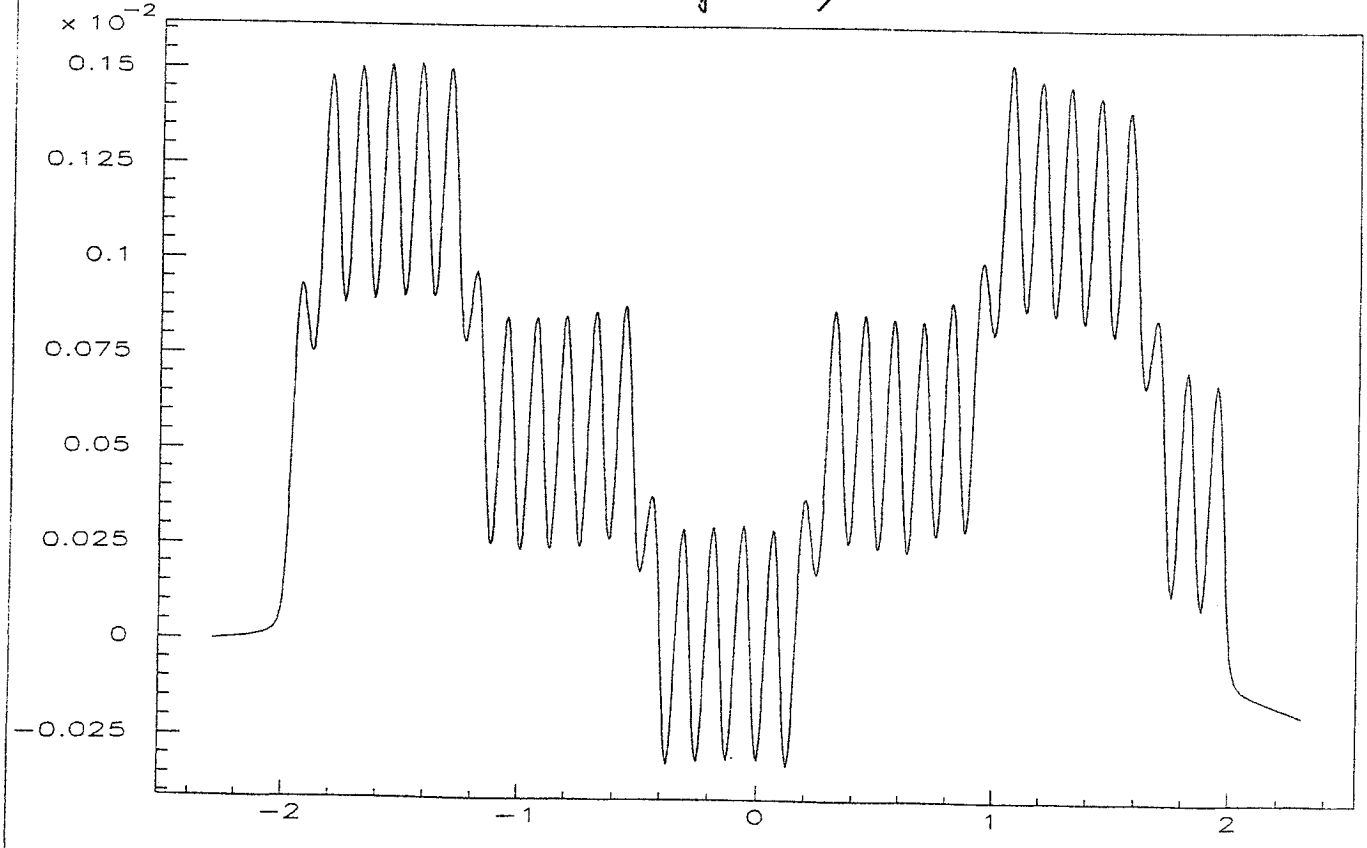
Trajectory

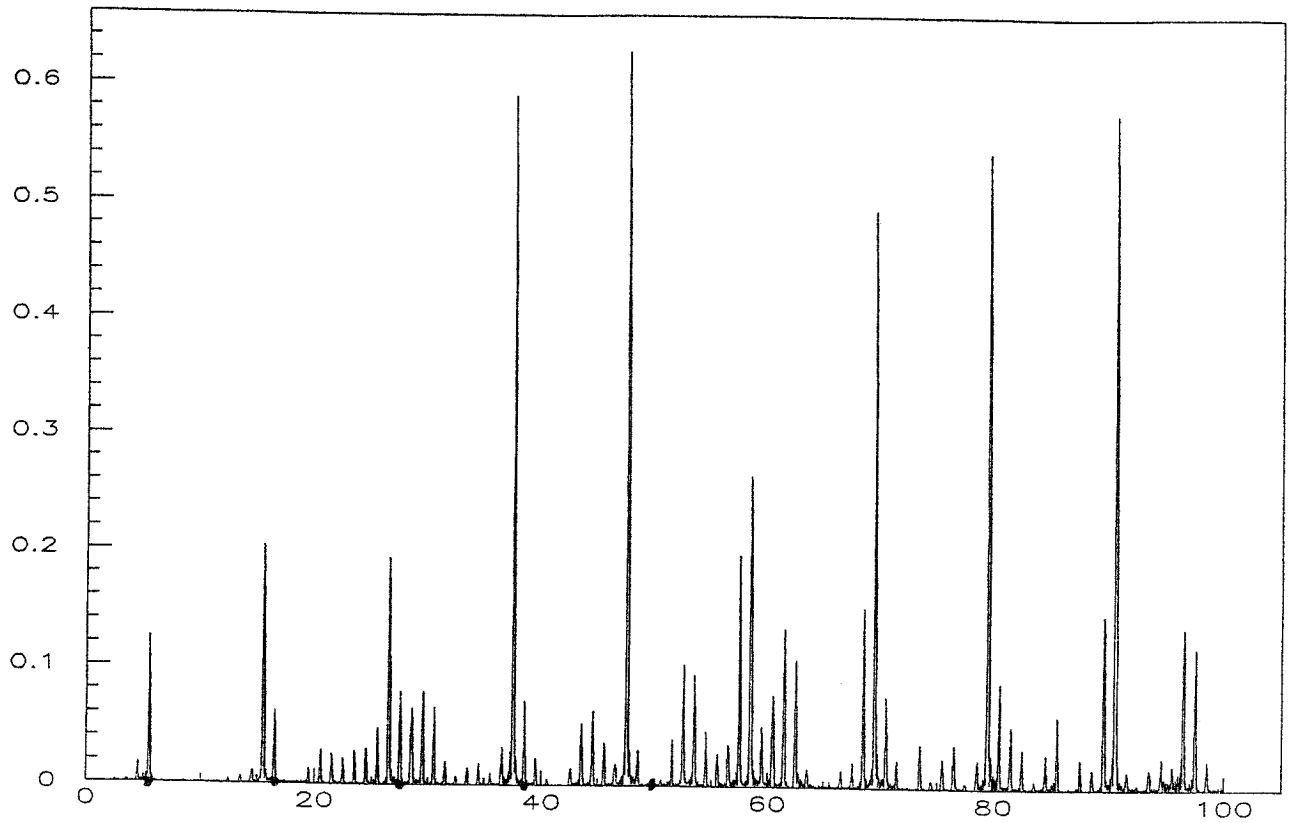


BESSY 125 QPU Gap 30 mm

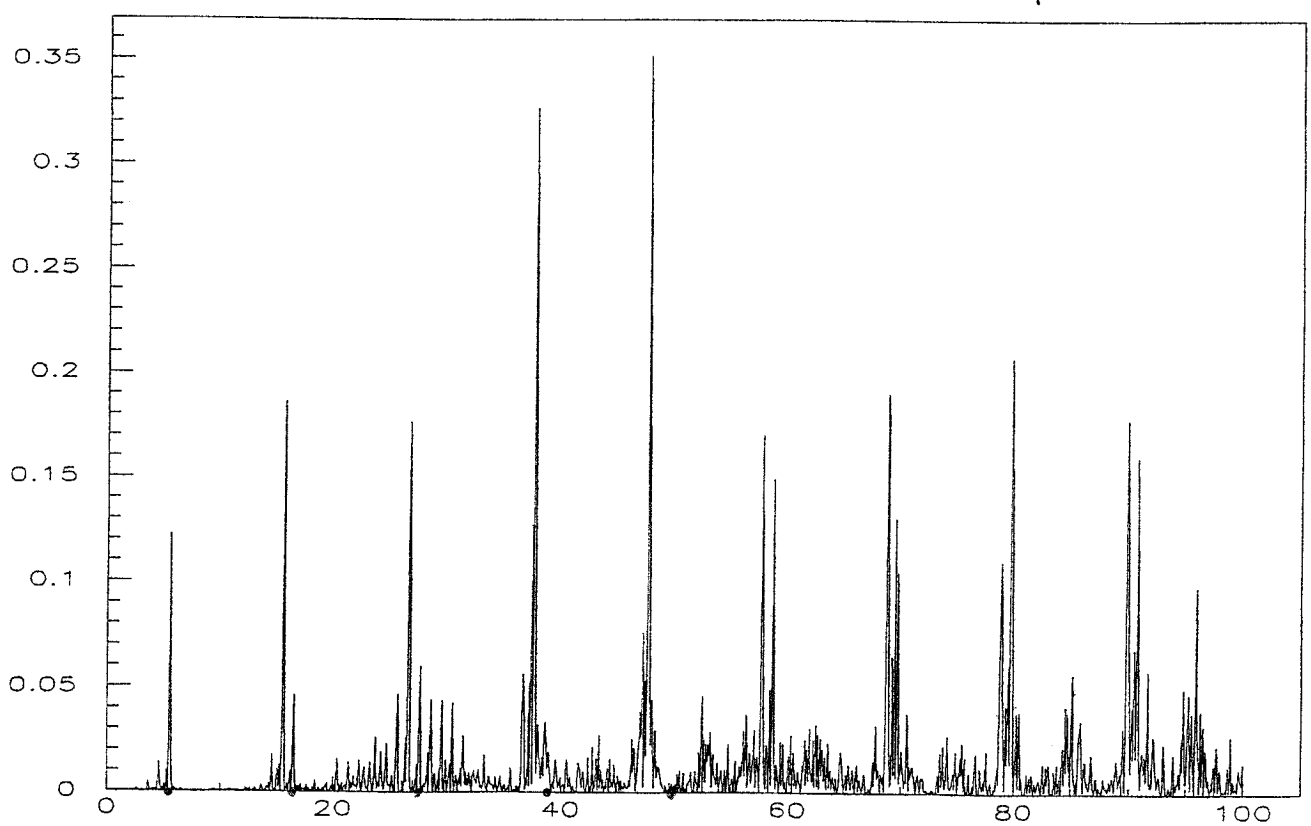


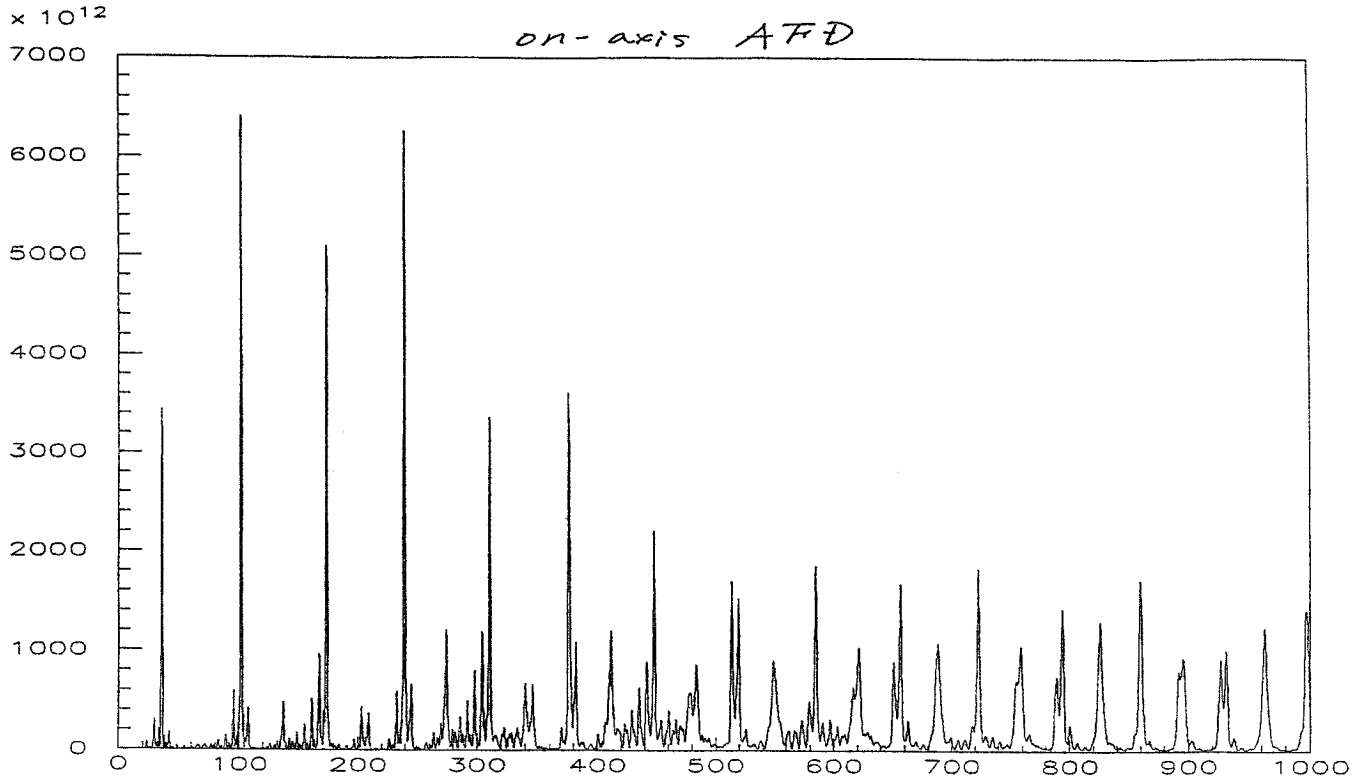
Trajectory





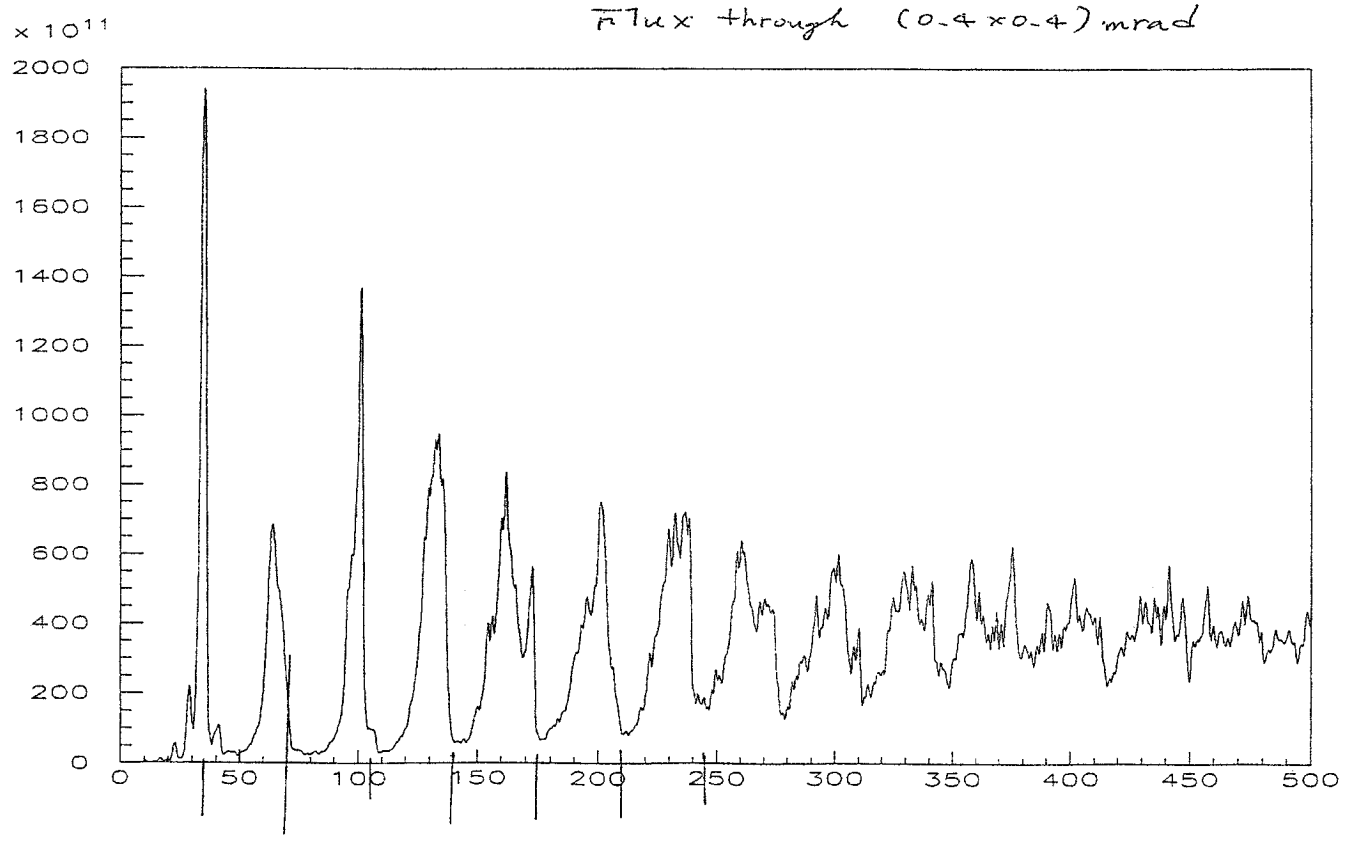
BESSY 125 QPU Gap 30 mm





$r = 1.9$, $\eta = \sqrt{31}$

BESSY 125 QPU 3 m $B_1 = 0.3\,T$ $B_2 = 0.24\,T$



BESSY 125 QPU L=4m Gap ≈ 68 mm

Flux through pinhole (0.2×0.2)[mrad²]