17TH ADVANCED BEAM DYNAMICS WORKSHOP ON
FUTURE LIGHT SOURCES

Operating the ESRF at 4 GeV

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- **Goal**

Achieve as low an emittance as possible, whilst providing a reasonable photon flux at 10 KeV.

Propose to beamline scientists to investigate experiments who may take advantage of such low emittances

Some of the characteristics at 4 GeV

ESRF Parameters	nominal	achieved	*expected*
Energy (GeV)	6.04	**4.00**	*4.00*
Energy spread (%)	0.10	0.07	*0.07*
Energy loss per turn (MeV)	4.90	0.94	*0.94*
H emittance (nm.rad)	3.8	**1.8**	*1.7*
V emittance (pm.rad)	30	**12**	*13*
RF voltage (MV)	12	**4.5**	*2.0*
Intensity max (mA)	200	**100**	*100*
Lifetime at I max (h)	55	**10**	*20*

CONCLUSIONS

by JL Laclare

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MEDIUM-TERM PROGRAMME AND ORGANISATION

We were given a five year R&D programme, with several intermediate milestones, on linac FELs, ending with a full SASE demonstration. Then, and only then, will we be in a position to propose linac FELs as possible 4th generation successors to the present storage rings in 15 to 20 years from now. It is hoped by all that SASE is a success and the research and development programme received strong support.

In parallel, studies will be made on 3rd generation rings when operated well below their nominal energy close to the diffraction limit (ESRF storage ring at 2 GeV) and in a quasi-isochronous mode to determine the limits of circular machines in terms of average brilliance, bunch length and peak brilliance.

Several ambitious projects of storage ring driven FELs are in their commissioning phase. All the synchrotron radiation community is attentive to the results.

Similar to the ICFA panel for beam dynamics, and under the Chairmanship of myself, it has been decided to create a panel of accelerator physicists, experts in synchrotron light sources. This committee will be formed in the coming weeks. It will regularly publish a newsletter and organise specialised workshops including the successors to the 1992 Stanford and 1996 ESRF workshops. A call for candidate laboratories will be launched in due time.

Lifetime at 4 GeV

Even in multibunch mode is essentially dominated by Touschek effect. The Touschek lifetime is proportional to

$$\tau_t \propto \frac{\gamma^2 \cdot \left(\frac{\delta p}{p}\right)^3 \cdot \sigma_x \sigma_z \sigma_s}{I_b}$$

with :

γ	:	beam energy
I_b	:	bunch intensity
σ_x , σ_z , σ_s	:	bunch dimensions
$(\delta p/p)$	:	energy acceptance

⇨ Touschek lifetime scaled down with γ^2 => reduction by a factor 2.25

⇨ The transverse beam sizes (σ_x , σ_z) are also reduced by γ

⇨ **In total, the Touschek lifetime at 4 GeV is reduced by γ^4 i.e. by a <u>factor 5</u> compared to the lifetime at 6 GeV.**

It is important to provide long bunch length σ_s

=> operate with minimum RF voltage.

20 hours expected lifetime for a perfectly corrected machine at 100 mA in uniform filling, with 2 MV RF voltage.

BUT :

Some difficulties to find correct settings with respect to HOMs :

- The threshold currents are much lower
  (scaled down with $\gamma^{3.5}$)

- Landau damping due to fractional filling or active modulation is much weaker.

- Operating at higher RF voltage helps.

- Careful tuning of temperature of RF cavities.

Achieved so far :

100 mA in 2/3rd filling with Vrf=4.5 MV, and lifetime=10 h

Beam position :

⇨ The closed orbit was the same as at 6 GeV, i.e., the beam positions and angles as seen by the Electron BPMs were the same.

⇨ Same stability achieved with global feedback operating.

Photon flux at 4 GeV :

⇨ Energy of fundamental of IDs scaled down by **2.25**

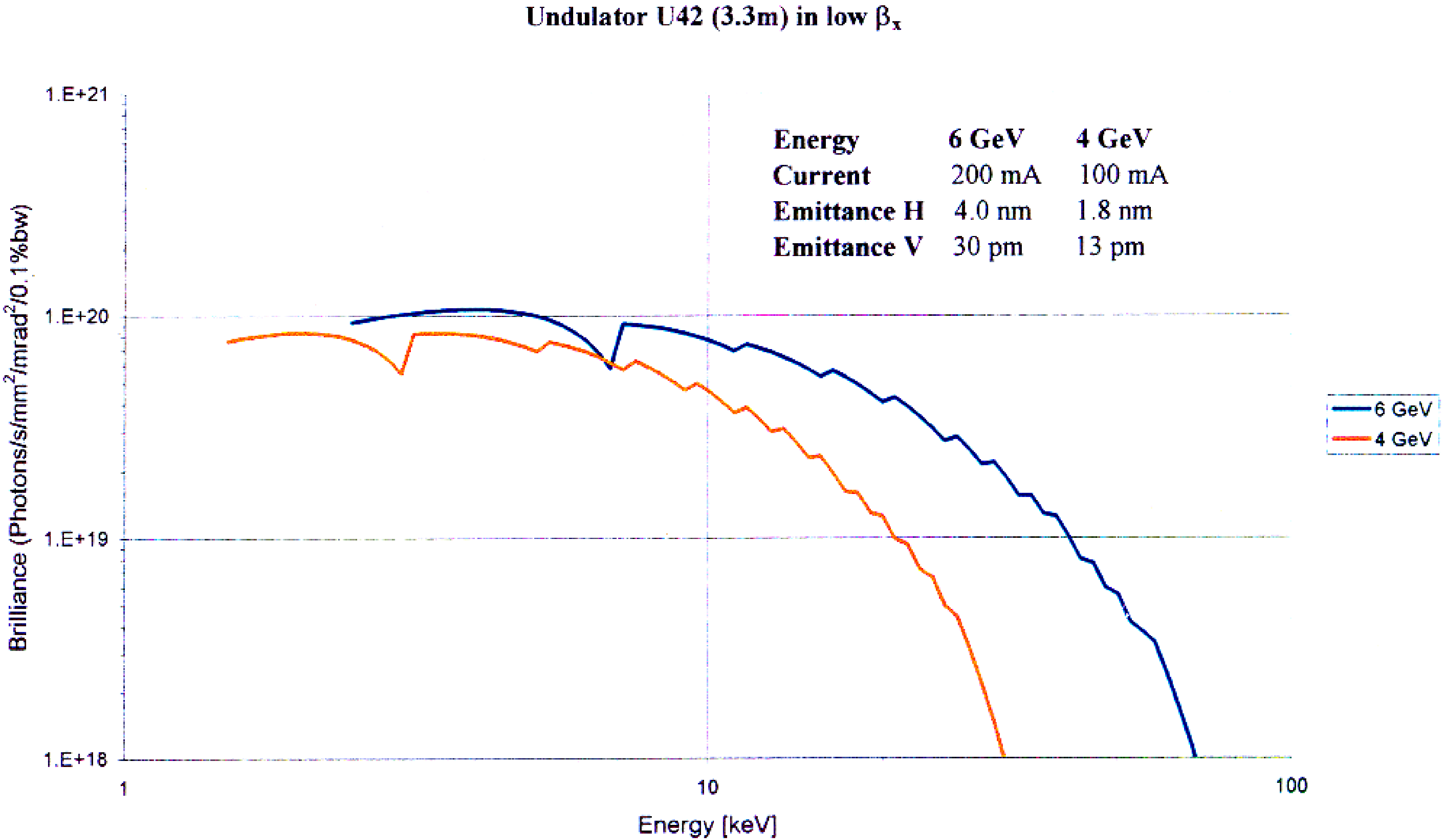
Beamlines operating above 20 KeV have tuned their undulators on high harmonic (up to 21, for 30 KeV)

⇨ good validation of ID spectrum shimming
⇨ but photon flux up to 8 times less (at 30 KeV)

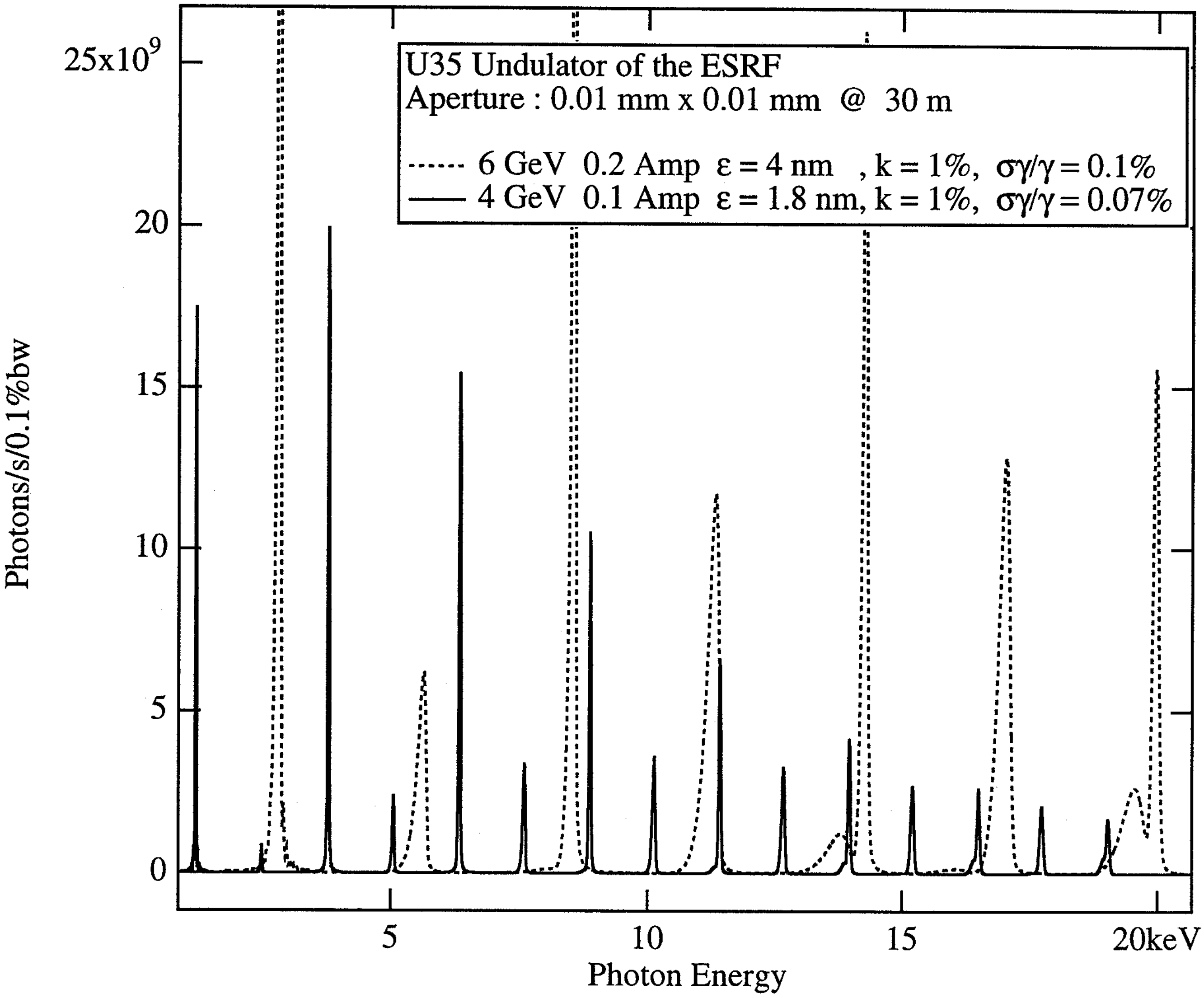
Only beamlines equipped with windowless front-ends could operate at lower energy with similar photon flux.

⇨ Critical energy of bending magnets scaled down by 3.4

4 GeV beam hardly useable for bending magnet beamlines



Undulator U42 (3.3m) in low β_x
Energy 6 GeV 4 GeV
Current 200 mA 100 mA
Emittance H 4.0 nm 1.8 nm
Emittance V 30 pm 13 pm
6 GeV
4 GeV
Brilliance (Photons/s/mm²/mrad²/0.1%bw)
Energy [keV]
1.E+21
1.E+20
1.E+19
1.E+18
1
10
100

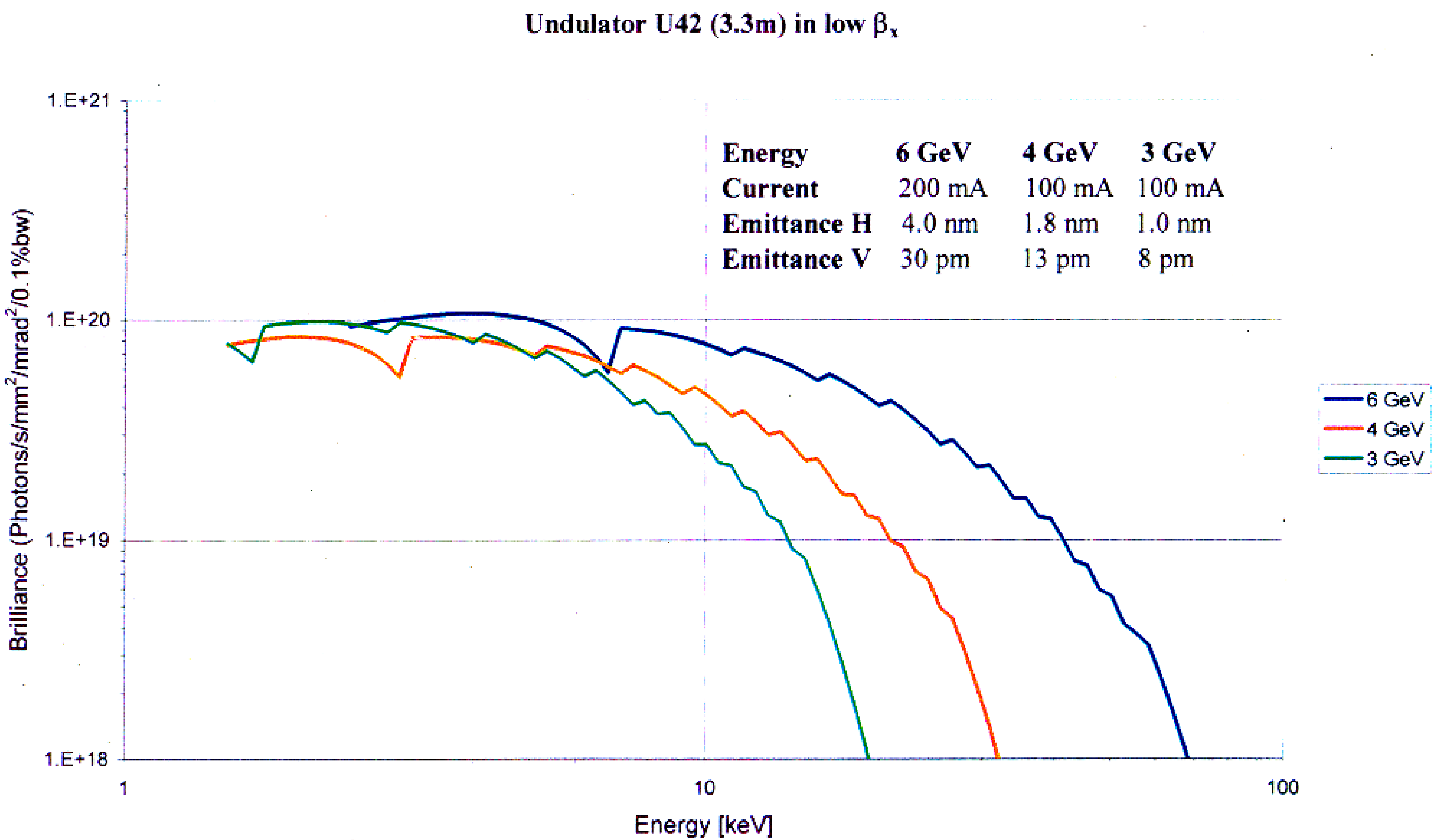

U35 Undulator of the ESRF
Aperture : 0.01 mm x 0.01 mm @ 30 m
6 GeV 0.2 Amp ε = 4 nm , k = 1%, σγ/γ = 0.1%
4 GeV 0.1 Amp ε = 1.8 nm, k = 1%, σγ/γ = 0.07%
25x10^9
20
15
10
5
0
Photons/s/0.1%bw
5
10
15
20keV
Photon Energy

Why 4 GeV ?

To achieve a significant reduction of emittance while providing reasonable photon flux up to 20 KeV.

Why not 3 GeV ?

- The photon flux reduction above 10 KeV would be too large to stay attractive
- It would have been even more difficult to achieve 100 mA due to HOMs limitations
- The lifetime would have been very short (a further factor 3 reduction)



Undulator U42 (3.3m) in low β_x
Energy 6 GeV 4 GeV 3 GeV
Current 200 mA 100 mA 100 mA
Emittance H 4.0 nm 1.8 nm 1.0 nm
Emittance V 30 pm 13 pm 8 pm
6 GeV
4 GeV
3 GeV
1.E+21
1.E+20
1.E+19
1.E+18
Brilliance (Photons/s/mm^2/mrad^2/0.1%bw)
1
10
100
Energy [keV]

Delivery of 4 GeV beam to Beamlines

During 48 hours
From Monday Mar 8 (7 am) till Wednesday Mar 10 (7 am)

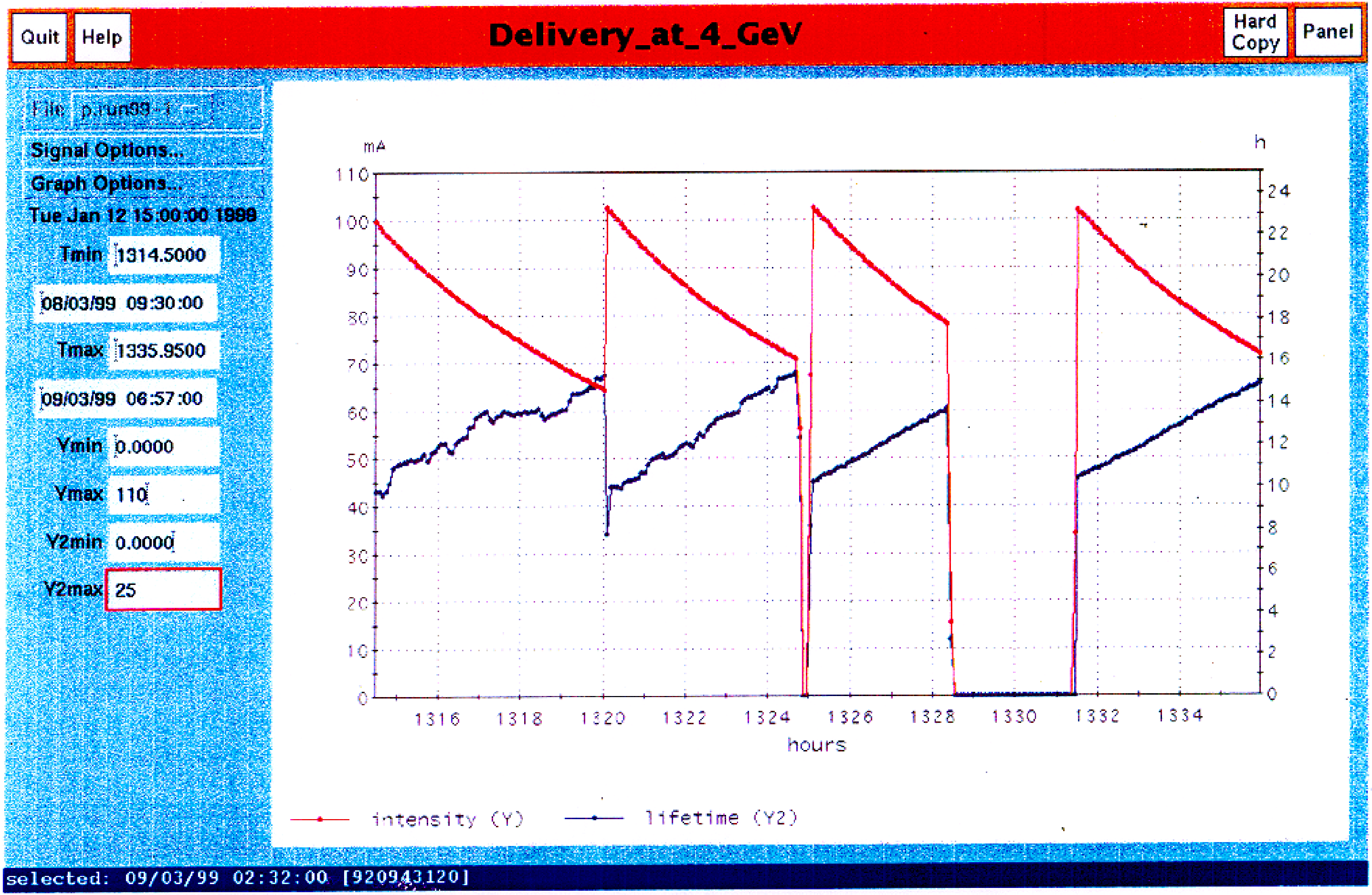
Feedback from beamline responsibles :

Reduced lifetime and flux are not too much favourable.

Would require more time to correctly tune the beamlines and probe beneficial effects of increased coherence.

One beamline could take this occasion to perform experiments at lower energy (450 KeV) with an helical undulator.

A few shifts or days will be rescheduled for an operation at 4 GeV in the second half of 1999.



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09/03/99 06:57:00
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Ymax 110
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Y2max 25
mA
h
hours
intensity (Y)
lifetime (Y2)
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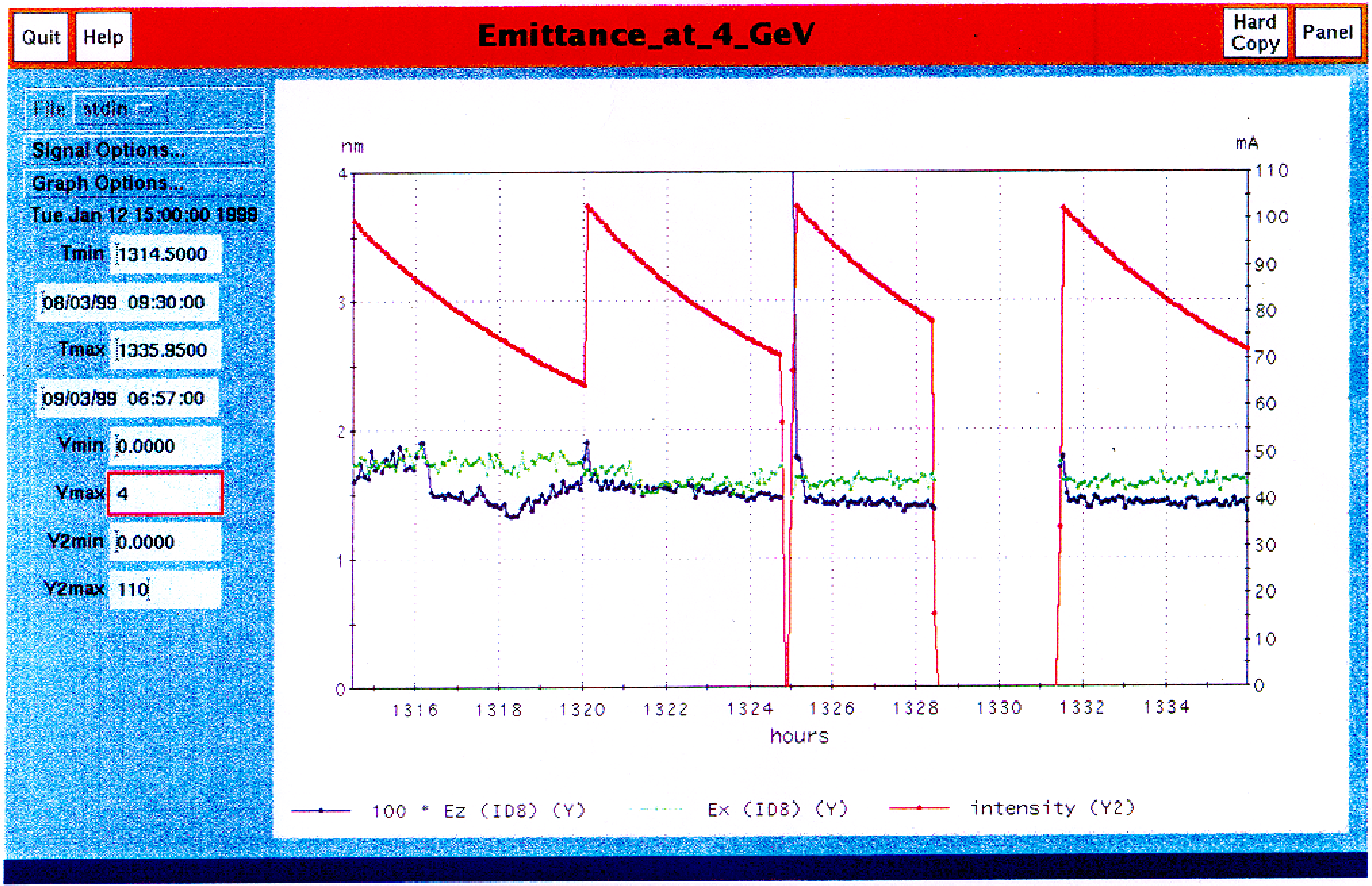
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Emittance_at_4_GeV
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Tmax 1335.9500
09/03/99 06:57:00
Ymin 0.0000
Ymax 4
Y2min 0.0000
Y2max 110
nm
mA
hours
1316 1318 1320 1322 1324 1326 1328 1330 1332 1334
0 1 2 3 4
0 10 20 30 40 50 60 70 80 90 100 110
100 * Ez (ID8) (Y)
Ex (ID8) (Y)
intensity (Y2)