Conceptual Design of the PETRA III Orbit Feedback

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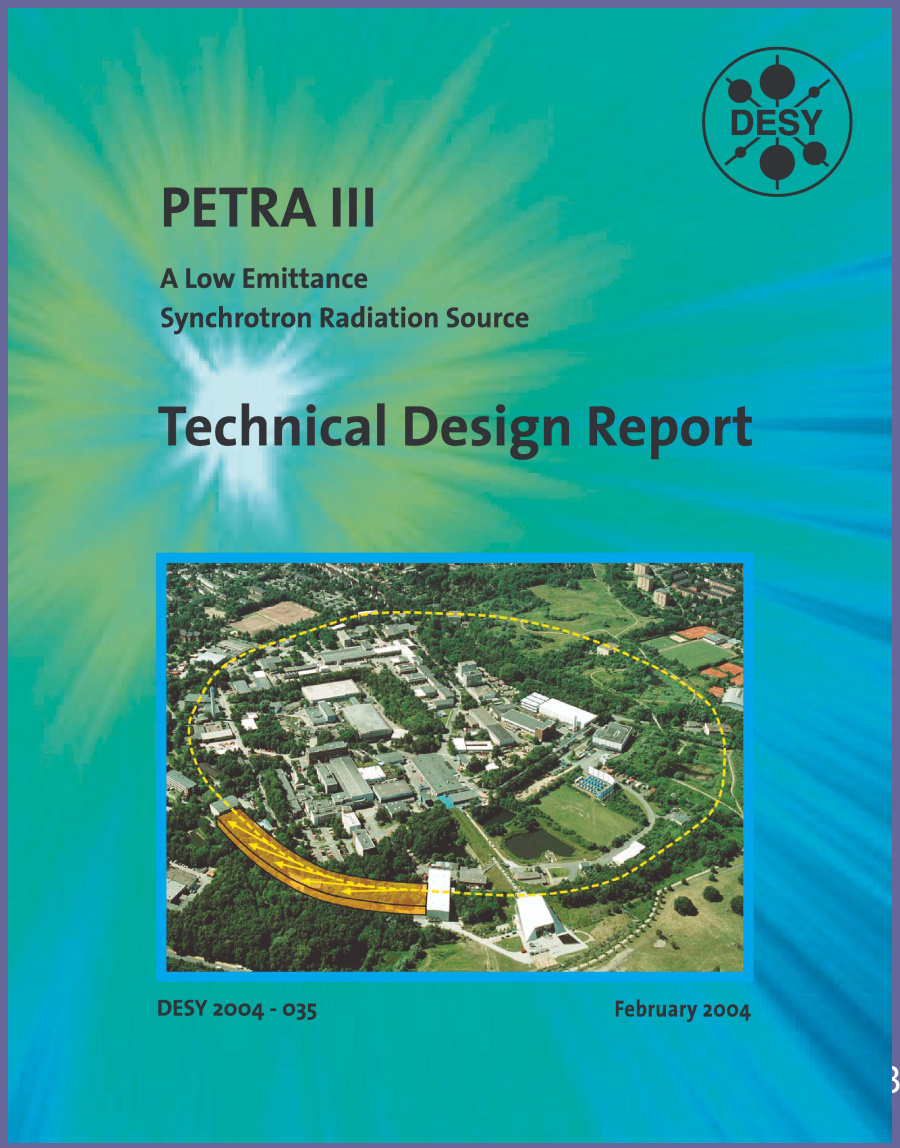
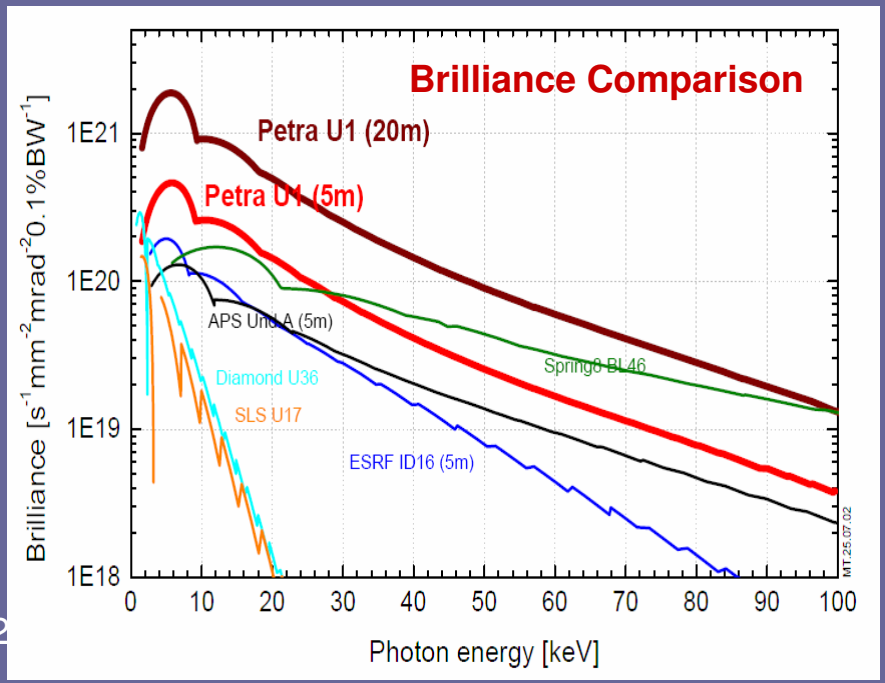
PETRA III

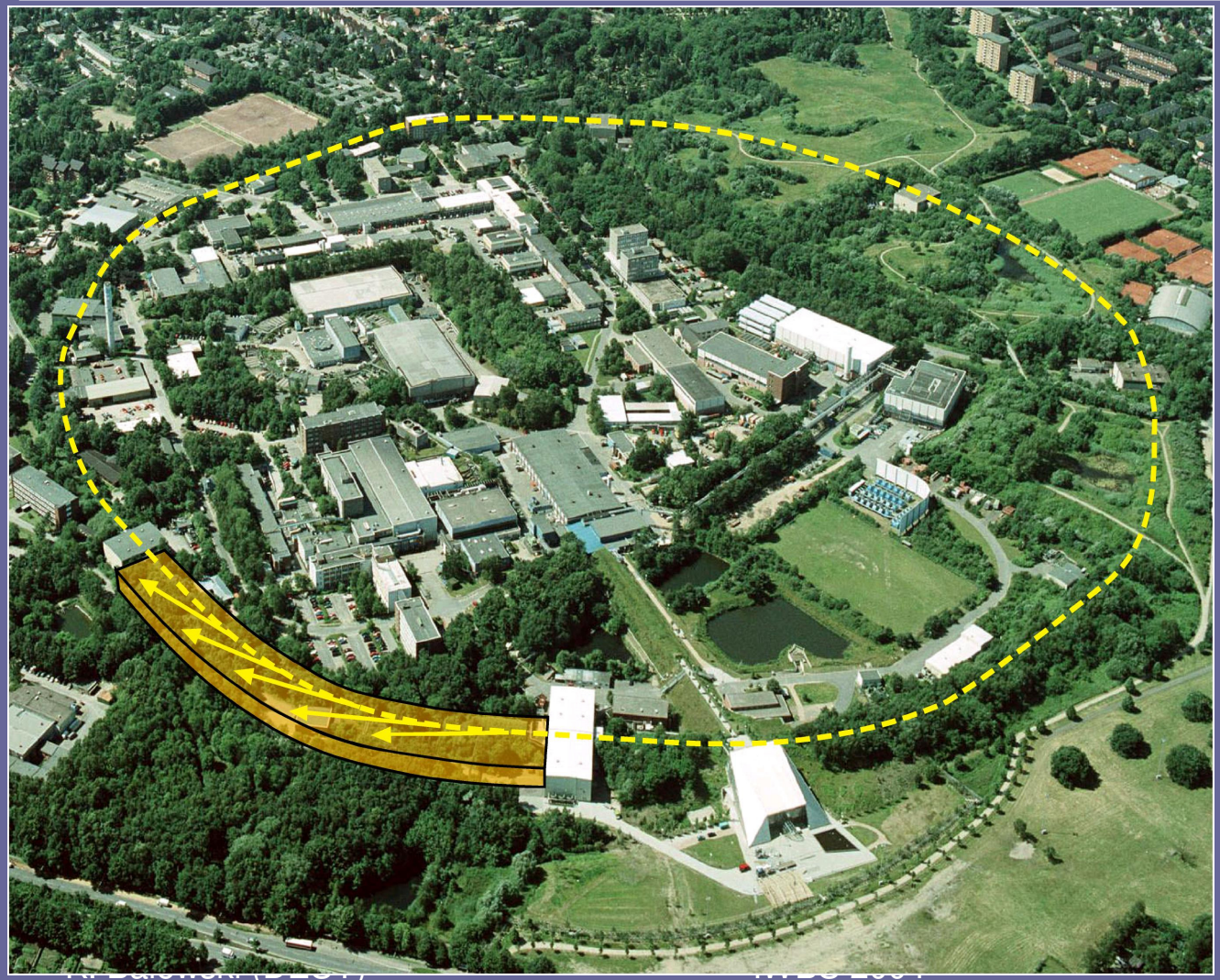


Parameters:

- energy: 6 GeV
- current: 100 mA
- emittance: 1 nmrad
- straight sections: 9
- undulators: 13
- undulator length: 2, 5, 20 m



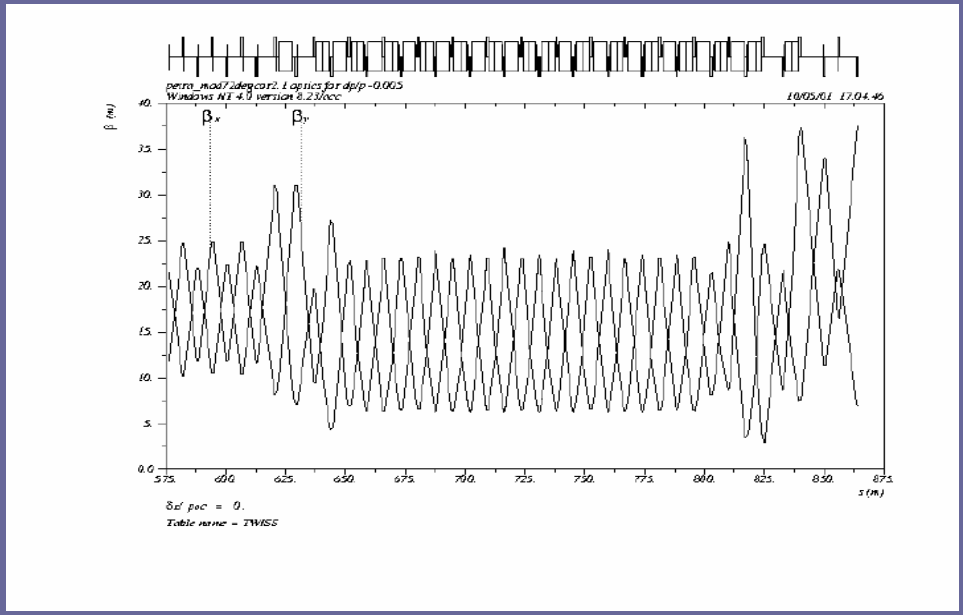
PETRA III
Conversion of PETRA II (2304 m circ.)



Conversion is going to start middle of 2007

Operation with beam should start in 2009

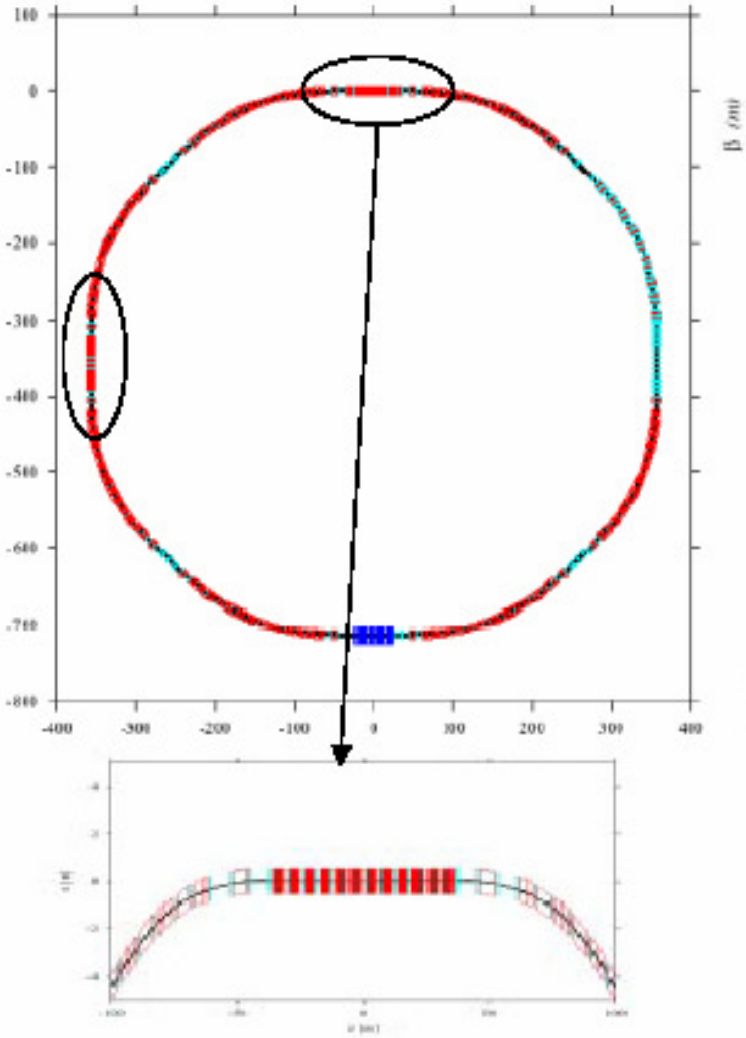
PETRA III
Optics old octant

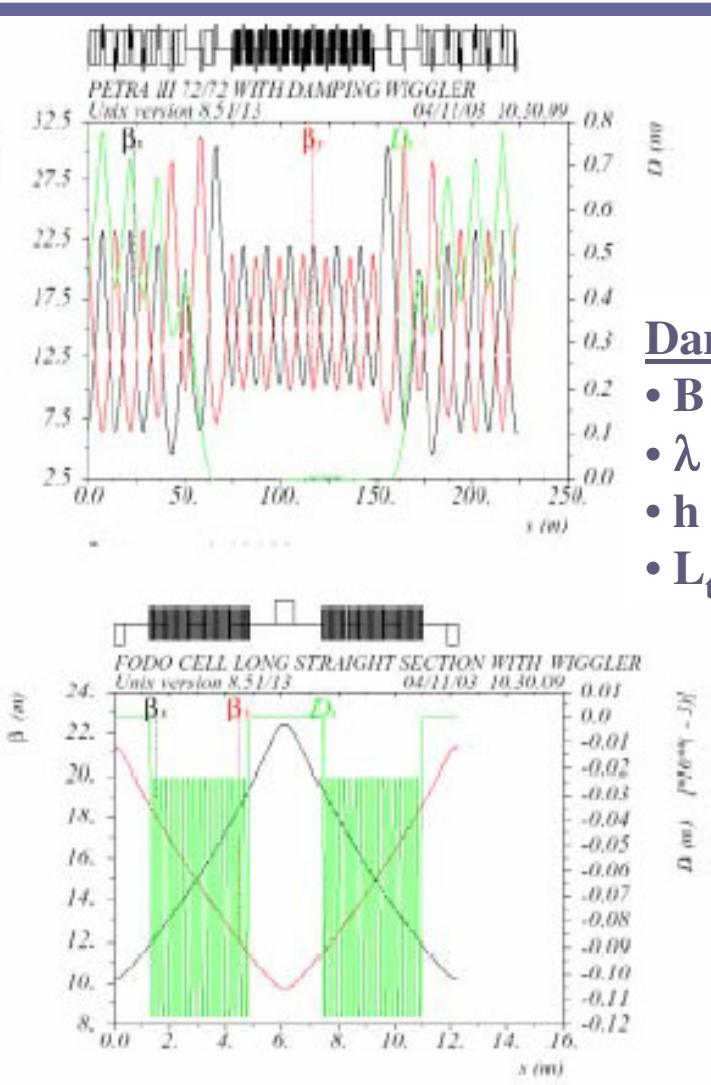


element	Hor. (µm)	Ver. (µm)	Roll (mrad)	Long. (µm)
monitors	200	200		
Quad's old oct.	250	250	0.2	500
Dipoles	250	250	0.2	500
Sext.	250	250	0.2	500

PETRA III
damping wiggler

ε_x: 4 → 1 nmrad

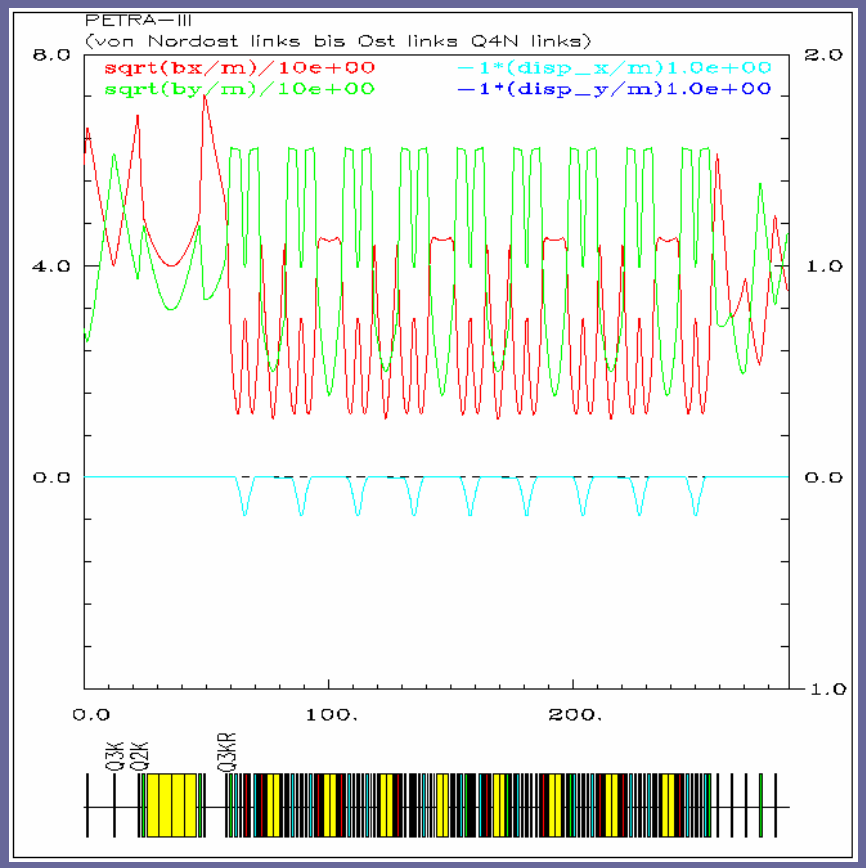




Damping wigglers

- B = 1.5 T
- λ = 0.2 m
- h = 0.025 m
- L_{tot} = 80 m (2x40m)

PETRA III
Optic new octant



element	Hor. (µm)	Ver. (µm)	Roll (mrad)	Long. (µm)
monitors	200	200		
Quad's new oct.	100	100	0.2	500
Dipoles	250	250	0.2	500

Dispersion limits to achieve design emittance

	Hor. (mm)	Ver. (mm)
Wiggler section	18	5
Undulator‘s (ID‘s)	20	3
FODO arc		58
DBA	22	31

Orbit stability goal

ε_x = 1nmrad coupling 1%

	Low β insertion			High β insertion		
	β(m)	σ(μm)	σ'(μrad)	β(m)	σ(μm)	σ'(μrad)
Horizontal	1.2	34.6	28.9	20.0	141	7.1
Vertical	3.9	6.2	1.6	2.4	4.9	2.0

Stab. Requirement 0.1 * σ
→Sub micron orbit stability !!

1. Golden Orbit

Combined orbit and dispersion correction:

$$\begin{pmatrix} \alpha \vec{u} \\ (1-\alpha)\overrightarrow{D_u} \end{pmatrix} + \begin{pmatrix} \alpha R \\ (1-\alpha) S \end{pmatrix} \vec{\theta} = \vec{0}$$

u and D_u measured orbit or dispersion
R and S orbit or dispersion response matrix
α weighting factor

Alternative: separated orbit & dispersion correction with skew quads

Elements for orbit correction

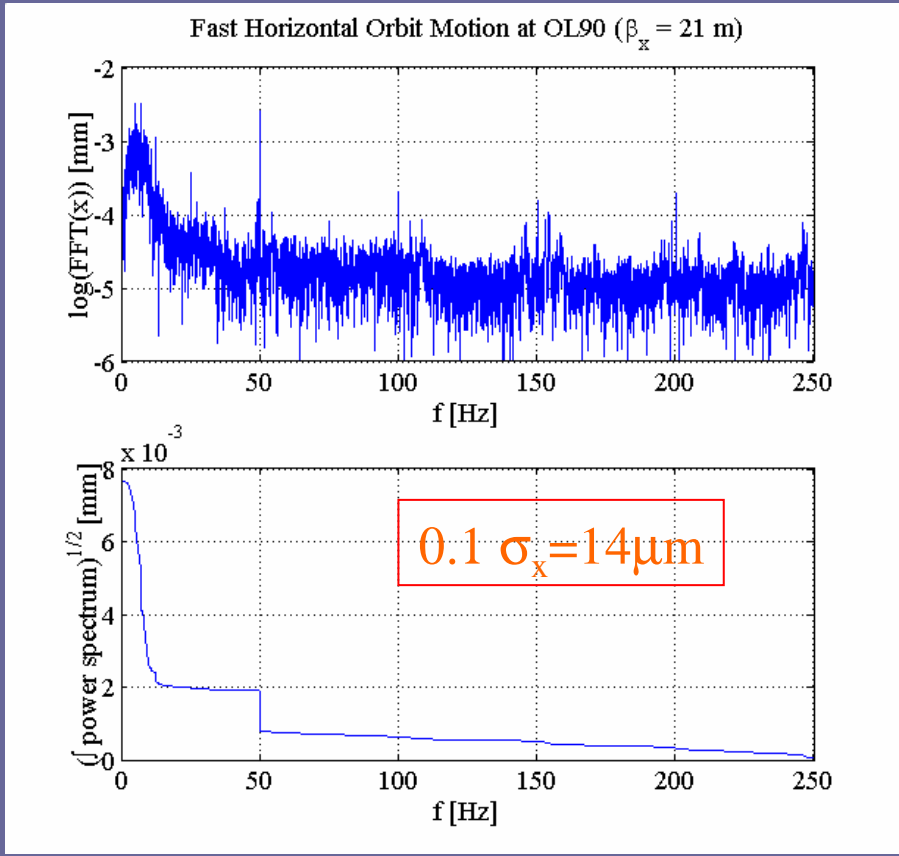
- 206 beam position monitors
- 182 horizontal correctors (resolution ≥ 16 bit)
  - 98 backleg windings on old dipoles
  - 18 backleg windings on new dipoles
  - 66 single correctors
- 189 vertical correctors (resolution ≥ 18 bit)
  - 91 additional windings on sextupoles
  - 98 single correctors

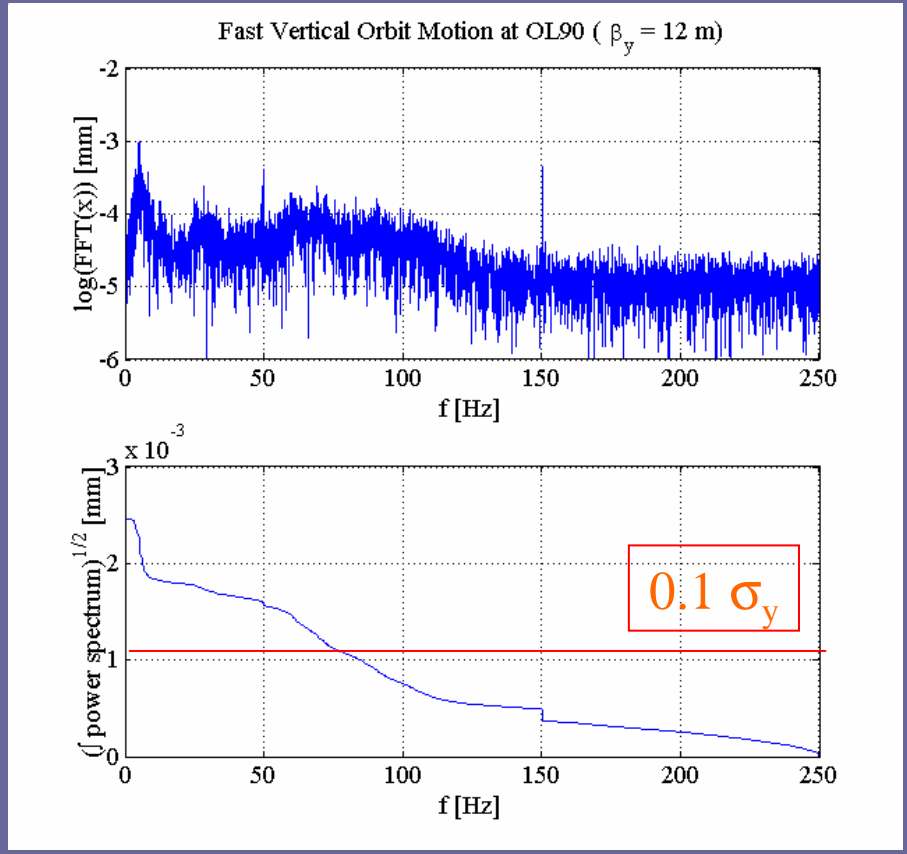
$\Theta_{max} \approx 0.5$ mrad ⇙ $B^*l = 100$ Gm

2. Orbit stabilization

- top -up
- slow feedback: repeated orbit correction every few seconds
  - using all monitors and correctors via SVD algorithm
- fast feedback : BW few tenth of Hz up to 100 Hz

Fast orbit distortions in PETRA II





Fast feedback requirements: BW 100 Hz amplitude reduction faktor ≤ 5

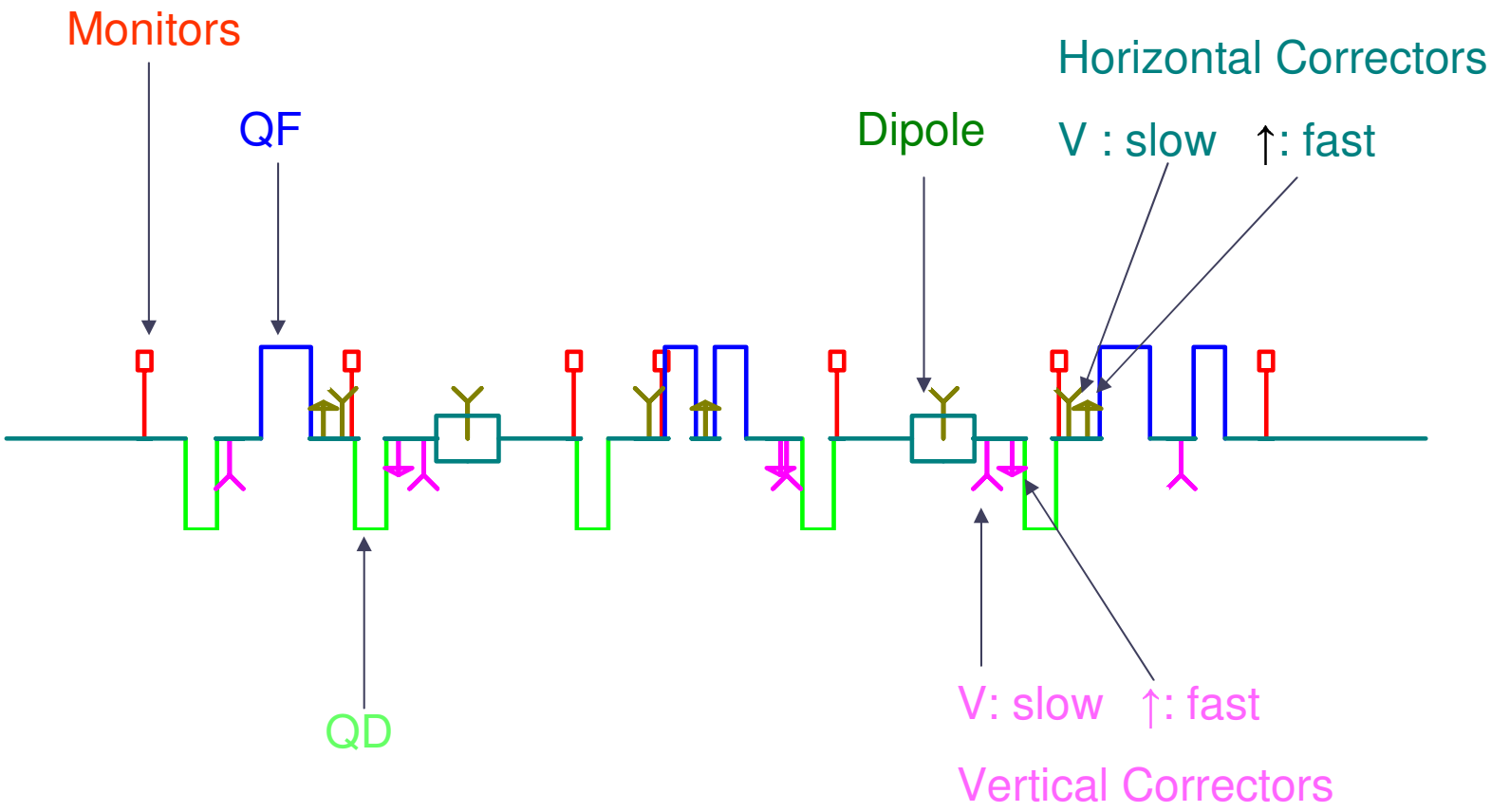
Elements for fast orbit correction

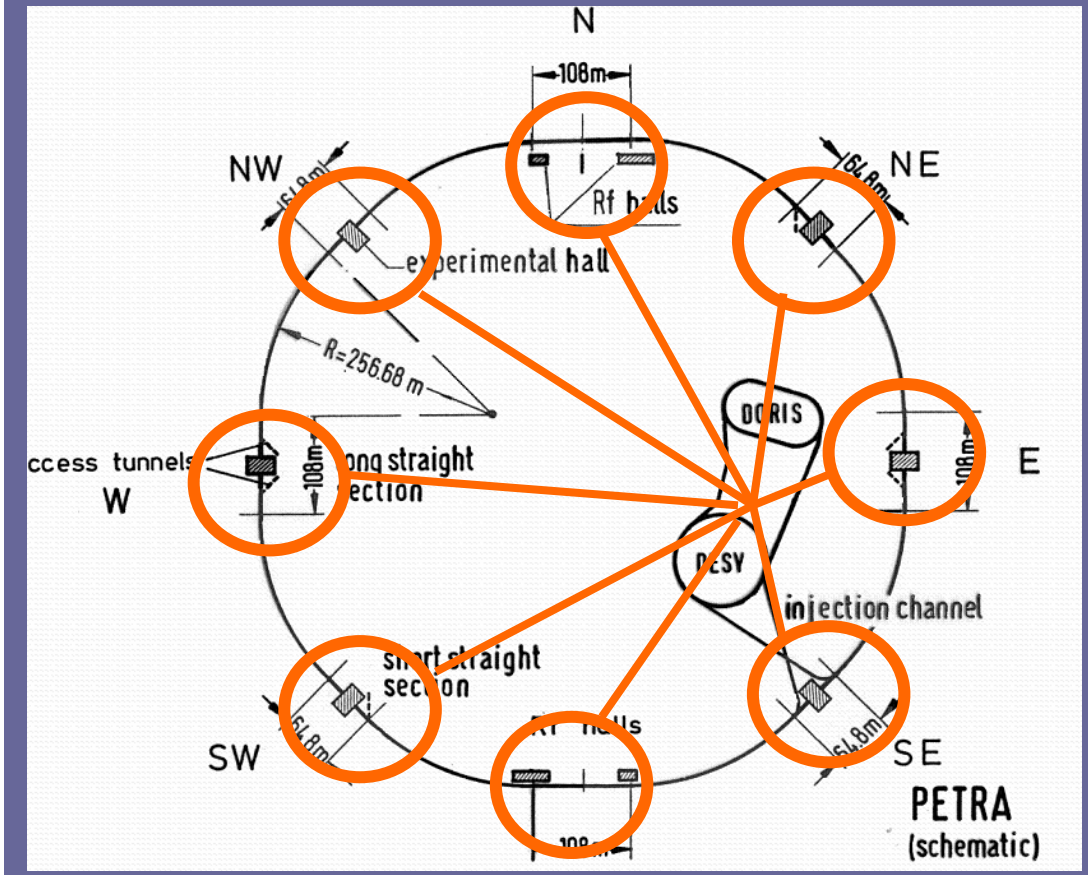
- **41 vertical & horizontal correctors** (air coils: Θmax ≈ 5 µrad ⇔ B*l = 1 Gm)
  - 30 new octant (for orbit stabilisation)
  - 11 old octant (1 per short straight & 1 at the beginning and end of long straight section) to maintain small vertical emittance
- **Photon BPM's (?)**

• monitor (resolution)

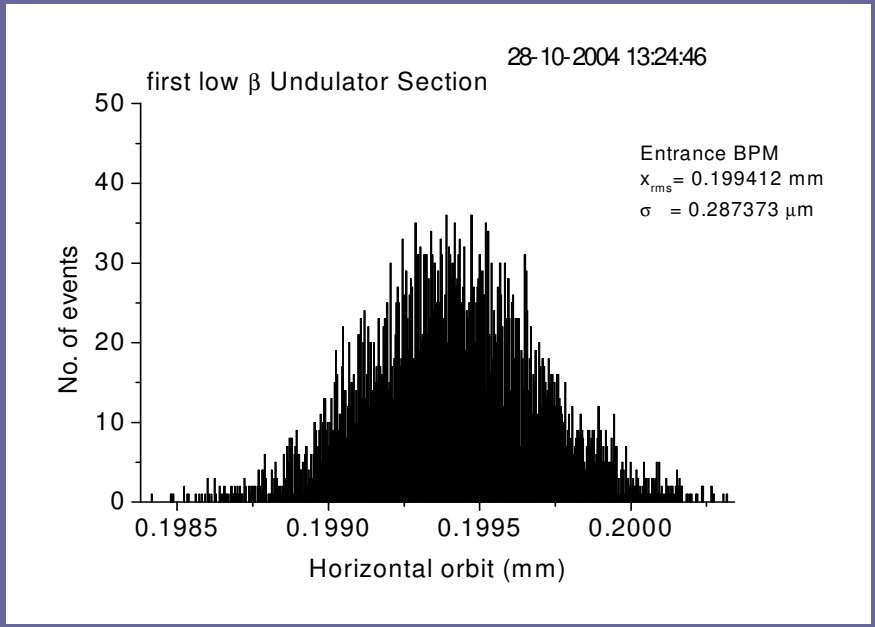
monitors	#	Hor. (µm)	Ver. (µm)
Old octant	148	**10**	**10**
New octant	40	2	0.5
Next to ID	18	2	0.2

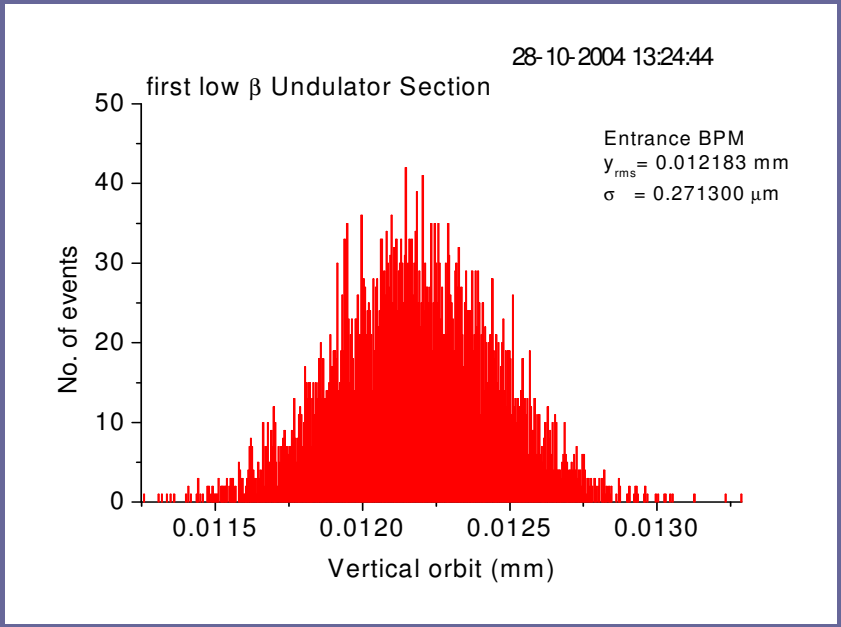
Position of Monitors & Correctors in DBA cell

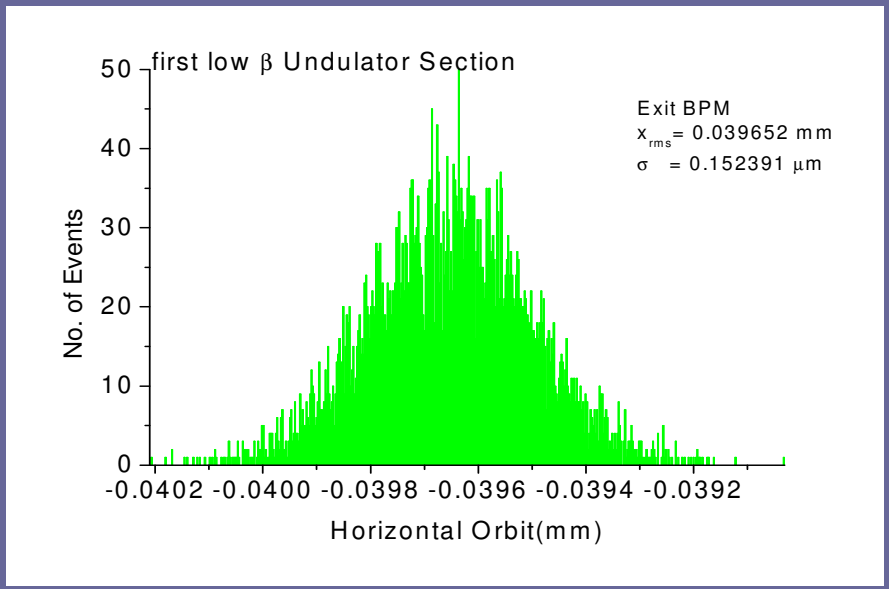


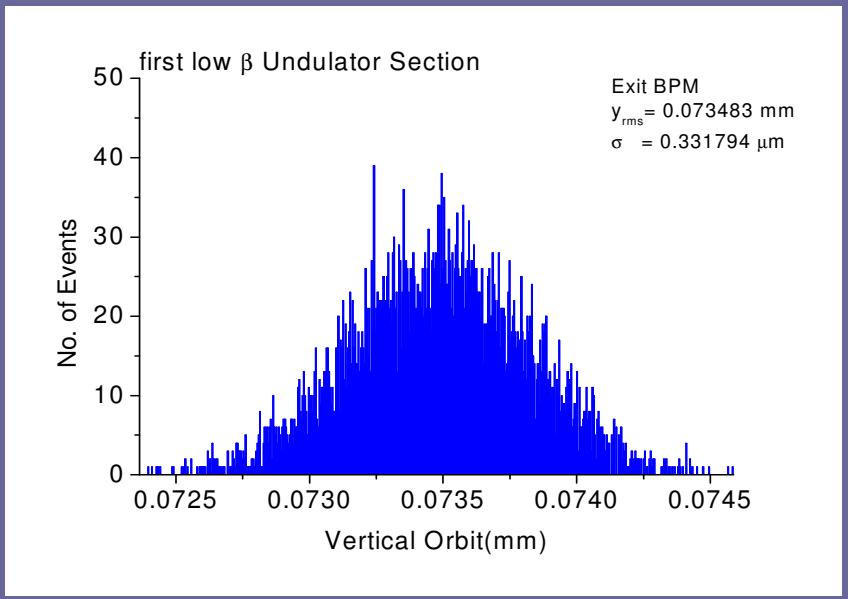


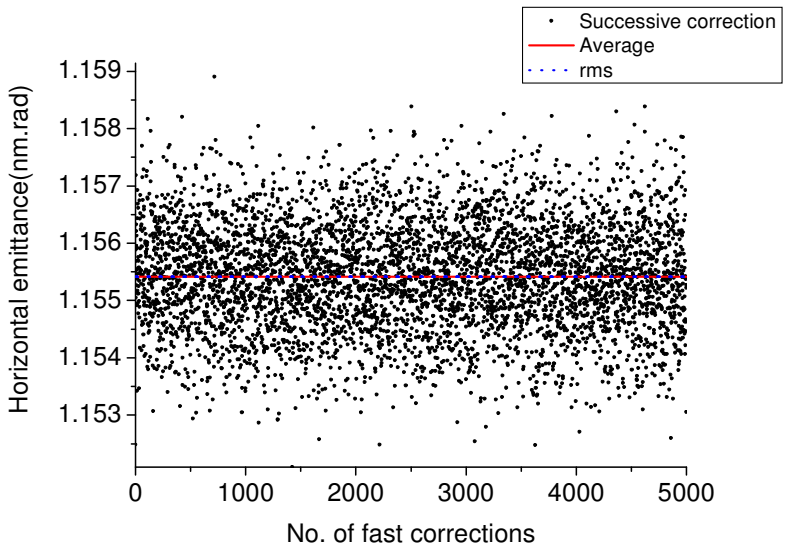
Rate of orbit measurements: ≥4 kHz
Data flow on cables (fiber optics) manageable
Digital controller (SVD & PID) feasible
Power supplies: work in progress
Correctors: air coils similar to ESRF

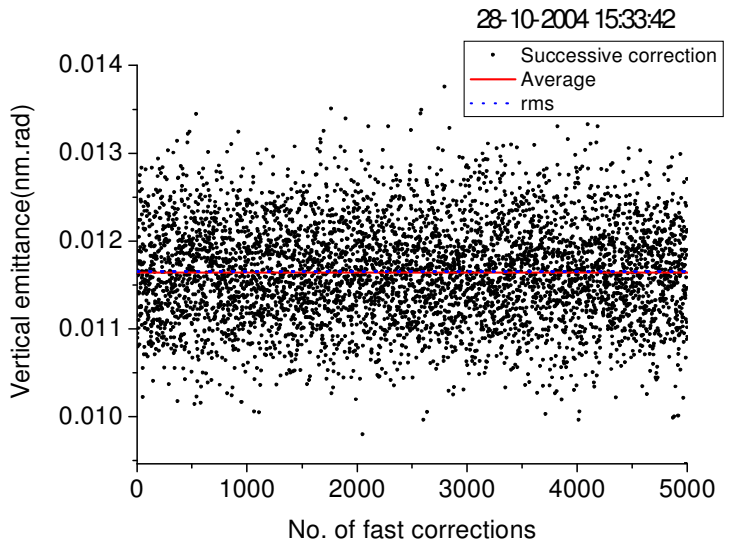

28-10-2004 13:24:46
first low β Undulator Section
Entrance BPM
x_{rms}= 0.199412 mm
σ = 0.287373 μm
No. of events
Horizontal orbit (mm)
0
10
20
30
40
50
0.1985
0.1990
0.1995
0.2000

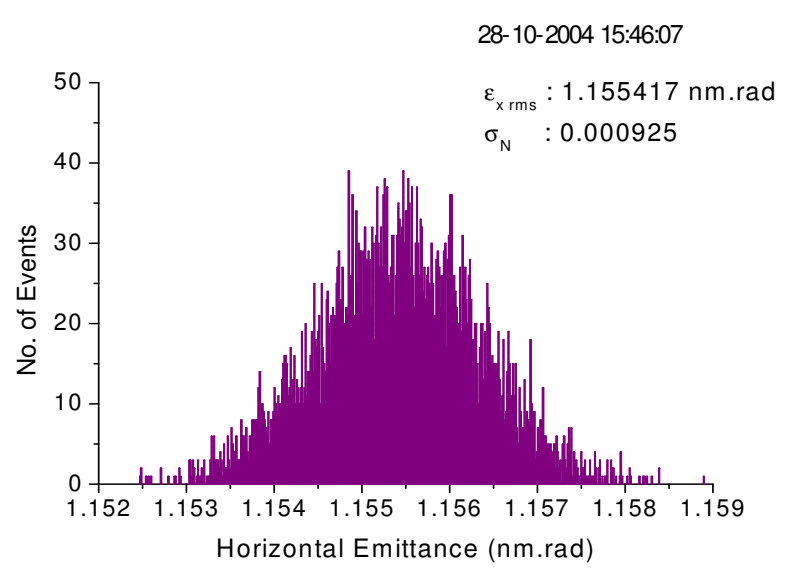

28-10-2004 13:24:44
first low β Undulator Section
Entrance BPM
y_{rms}= 0.012183 mm
σ = 0.271300 μm
No. of events
Vertical orbit (mm)
0
10
20
30
40
50
0.0115
0.0120
0.0125
0.0130

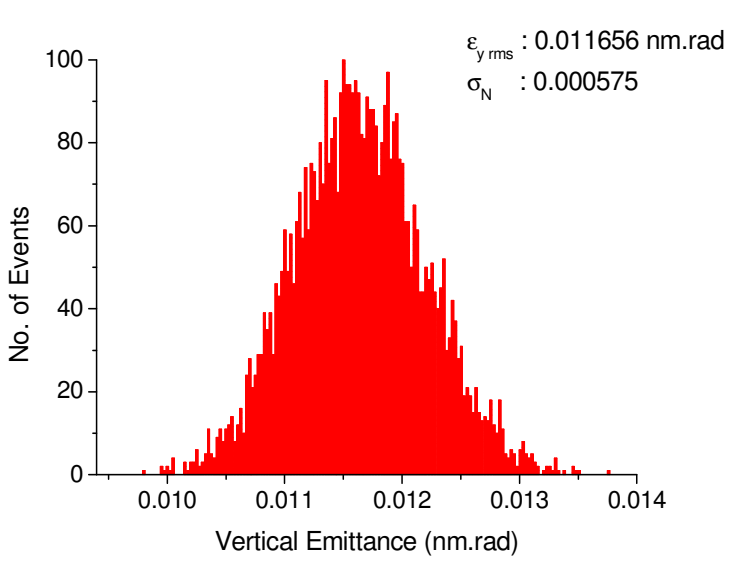

first low β Undulator Section
Exit BPM
x_{rms}= 0.039652 mm
σ = 0.152391 μm
No. of Events
Horizontal Orbit(mm)
0
10
20
30
40
50
-0.0402
-0.0400
-0.0398
-0.0396
-0.0394
-0.0392


first low β Undulator Section
Exit BPM
y_{rms}= 0.073483 mm
σ = 0.331794 μm
No. of Events
Vertical Orbit(mm)
0
10
20
30
40
50
0.0725
0.0730
0.0735
0.0740
0.0745


Successive correction
Average
rms
Horizontal emittance(nm.rad)
1.159
1.158
1.157
1.156
1.155
1.154
1.153
0
1000
2000
3000
4000
5000
No. of fast corrections


28-10-2004 15:33:42
Successive correction
Average
rms
Vertical emittance(nm.rad)
0.014
0.013
0.012
0.011
0.010
0
1000
2000
3000
4000
5000
No. of fast corrections


28-10-2004 15:46:07
$\varepsilon_{x\ rms}$: 1.155417 nm.rad
σ_N : 0.000925
No. of Events
50
40
30
20
10
0
1.152
1.153
1.154
1.155
1.156
1.157
1.158
1.159
Horizontal Emittance (nm.rad)


$\varepsilon_{y\ rms}$: 0.011656 nm.rad
σ_N : 0.000575
No. of Events
100
80
60
40
20
0
0.010
0.011
0.012
0.013
0.014
Vertical Emittance (nm.rad)

Long term stability slow orbit feedback

•Alignment of the machine every half year
• temperature stability (new octant ± 0.1 ℃ old octant ± 1 ℃)
• cooling water temperature ± 0.2 ℃)
• establishing a new golden orbit ≥ 24 h

ATL law: $\Delta x^2 = A \cdot T \cdot L$

A=4*10^{-6} µm²/m/s ; L = 65 m
Δx = 15 µm
⇩ **T = 10 d**

monitors	#	Hor. (µm)	Ver. (µm)
Old octant	148	**20**	**20**
New octant	40	2	0.5
Next to ID	18	2	0.2*

*** Special supports for monitors close to ID's**

Summary

- PETRA III is an unconventional Light Source
- Unconventional measures have to be taken to fulfill the stability requirements
- Nevertheless use can be made of the experience gained at other light sources concerning correction procedures and hardware design