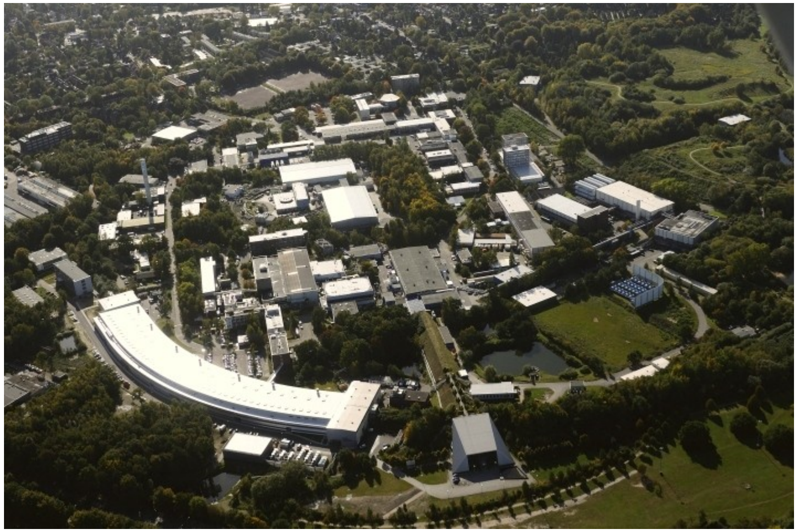
Observations of Electron Cloud Phenomena at PETRA III

Presentation at the ECLOUD 2012 workshop



Rainer Wanzenberg

ECLOUD 2012
June 5-8, 2012

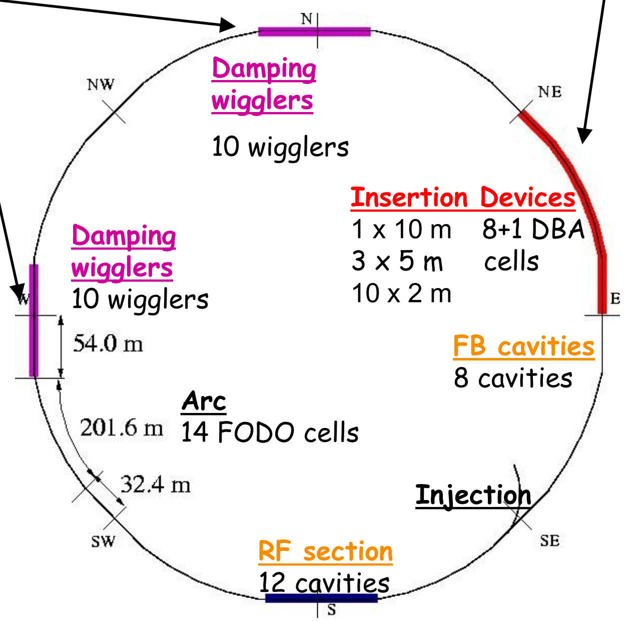
Hotel Hermitage
La Biodola, Isola d'Elba, Italy

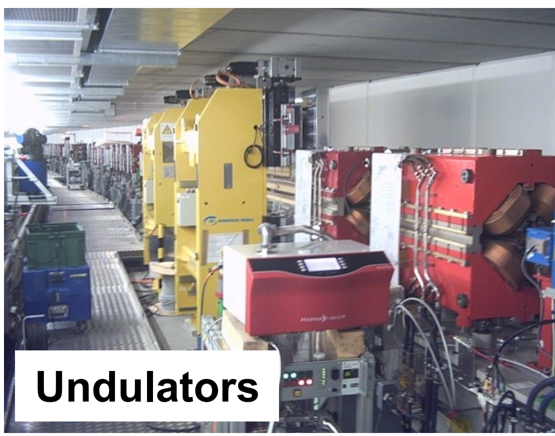
HELMHOLTZ ASSOCIATION

DESY

PETRA III - Overview

“Old Octants”





PETRA III - Parameters

Design Parameter	PETRA III	
Energy / GeV	6	
Circumference /m	2304	
RF Frequency / MHz	500	
RF harmonic number	3840	
RF Voltage / MV	20	
Momentum compaction	$1.22\ 10^{-3}$	
Synchrotron tune	0.049	
Total current / mA	100	
Number of bunches	**960**	**40**
Bunch population / 10^{10}	**0.5**	**12**
Bunch separation / ns	**8**	**192**
Emittance (horz. / vert.) /nm	1 / 0.01	
Bunch length / mm	12	
Damping time H/V/L / ms	16 / 16 / 8	

PETRA III is running with positrons !

Damping wigglers

- **Number 20**
- **$L_{wiggler}$ = 4 m**
- **B = 1.5 T**
- **λ = 0.2 m**

$\Big\}$ **80 m**

$\boxed{\varepsilon_x\text{: } 4.5 \rightarrow 1 \text{ nm rad}}$

User runs in 2011 and 2012

100	100	80
240	**60**	**40**
2.0	**8.9**	**9.6**
32	**128**	**192**

DESY

Instability threshold – coasting beam model

Broad band resonator model + coasting beam model *)

$$Z(\omega) = \frac{cR_S}{\omega} \frac{1}{1 + iQ\left(\frac{\omega_e}{\omega} - \frac{\omega}{\omega_e}\right)} \qquad (10)$$

$$= K \frac{\lambda_e}{\lambda_+} \frac{L}{\sigma_y(\sigma_x + \sigma_y)} \frac{\omega_e}{\omega} \frac{Z_0}{4\pi} \frac{Q}{1 + iQ\left(\frac{\omega_e}{\omega} - \frac{\omega}{\omega_e}\right)},$$

where K is an enhancement factor due to cloud size, pinching etc. [11], and Z_0 is the impedance of vacuum (377Ω). The figure 4 shows $K = 1.5$. In the case of KEKB, the enhancement factor was $K = 2 \sim 4$ for the vertical wake field.

$$U \equiv \frac{\sqrt{3}\lambda_+ r_e \beta \omega_0}{\gamma \omega_e \eta \sigma_\delta} \frac{|Z_\perp(\omega_e)|}{Z_0} = \frac{\sqrt{3}\lambda_+ r_e \beta}{\gamma \nu_s \omega_e \sigma_z / c} \frac{|Z_\perp(\omega_e)|}{Z_0} \quad < 1$$

threshold density:

$$\rho_{e,th} = \frac{2\gamma \nu_s \omega_e \sigma_z / c}{KQ\sqrt{3} r_e \beta L}$$

$$K \sim \omega_e \sigma_z / c.$$

(L = circumference of the ring)

Q ~ 5 < K

$$\omega_{e,y} = \sqrt{\frac{\lambda_+ r_e c^2}{\sigma_y(\sigma_x + \sigma_y)}}$$

λ_+ = beam line density in the e+ bunch

	$K \sim \omega_e \sigma_z / c.$
PETRA III:	**~ 1.4 x 10^{12} m^{-3}**

(PETRA III, 960 bunches, 100 mA)

*) K. Ohmi: Electron Cloud Effect in Damping Rings of Linear Colliders
31st ICFA Advanced Beam Dynamics Workshop on Electron-Cloud Effects "ECLOUD'04"

PETRA III Vacuum chamber

IPAC 2011

Secondary Electron Yield of Al Samples from the Dipole chamber of PETRA III

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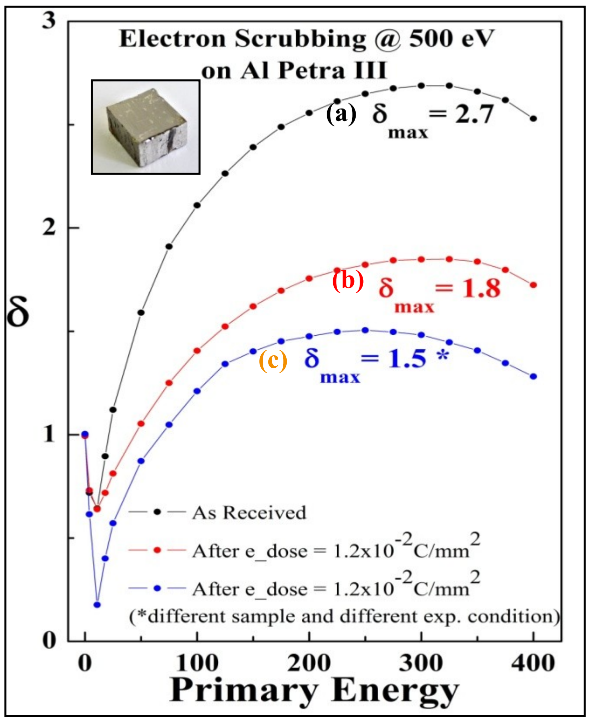
R. Flammini, CNR-IMIP, Monterotondo, Italy
R. Larciprete, CNR-ISC, Rome, Italy
R. W., DESY, Hamburg, Germany



Arc: **Al**, 80 mm x 40 mm

Wiggler: **Al**, 96 mm x 17.9 mm
NEG coated

Undulator: **Al**, 57 mm x 7 mm

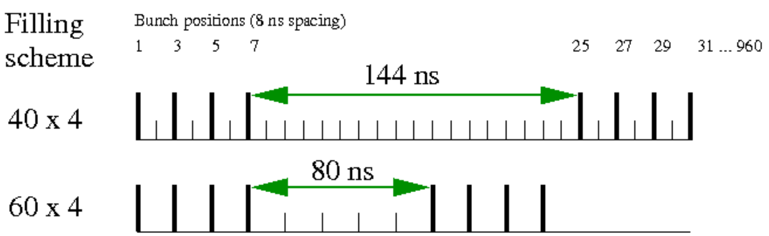
PETRA III – Commissioning and User Runs

2009

- **>** Commissioning:
  - First stored beam (April 13)
  - Operation with **<u>all</u>** (2 x 10) wigglers from Aug 12, 2009

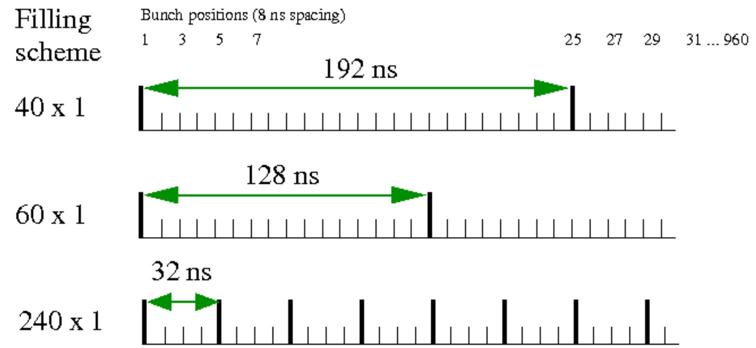
2010

- **>** First user runs (friendly user) (Feb, 2010)
- **>** Ecloud studies May/June 2010
- **>** Aug 2 – Aug 7, 2010
  - Machine studies **<u>without</u> wigglers**
- **>** User runs (Aug 2010)



2011

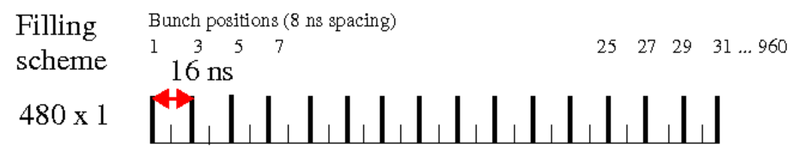
- **>** About 9 month of user runs
  - 3 bunch patterns



- **>** Ecloud Studies Oct, Nov.

2012

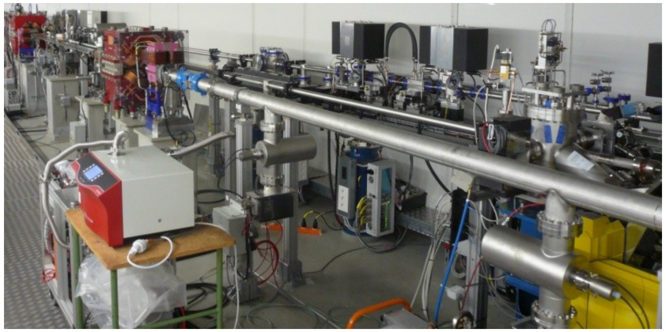
- **>** Scrubbing Run (March)

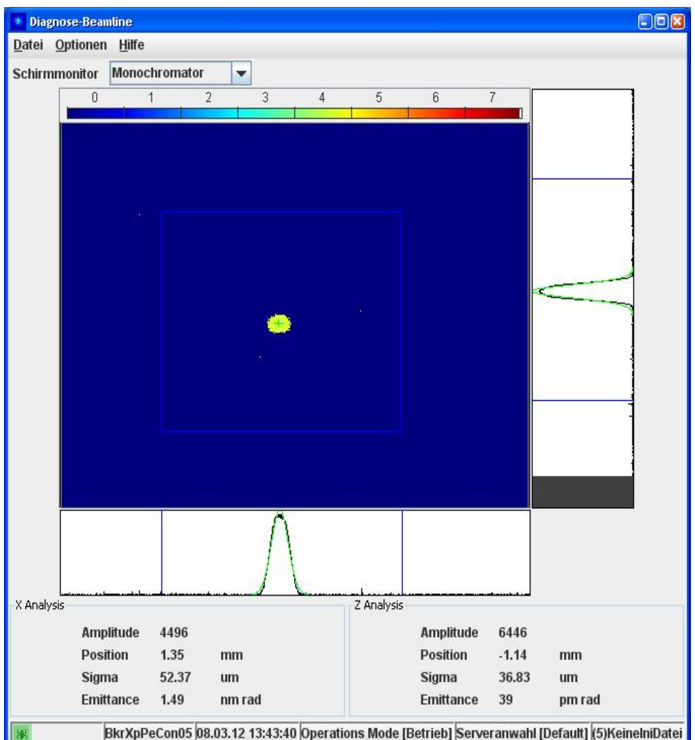


- **>** User runs, bunch pattern as 2011 + recently 320 bunches

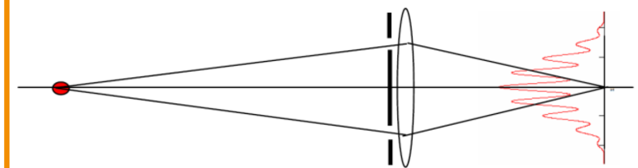
PETRA III Emittance Diagnostics

Diagnostic Beam Line (Exp. Hall)

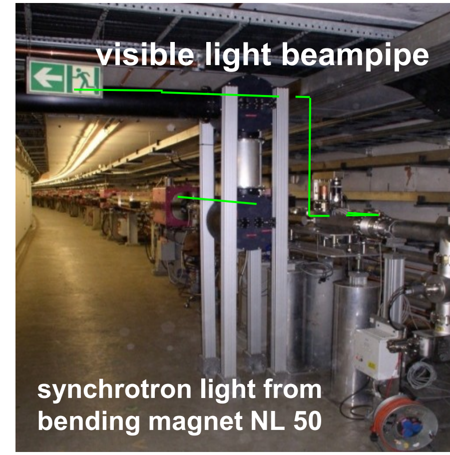


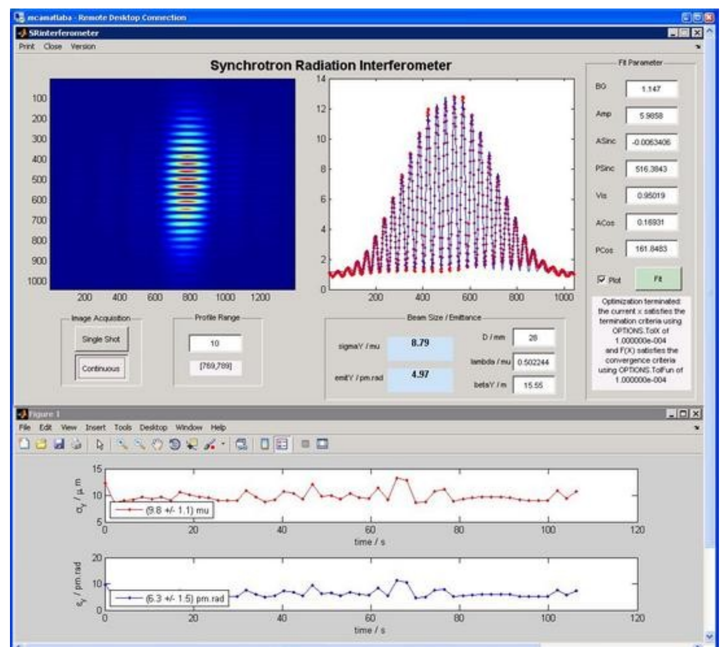


Interferometric beam size measurements (North)



Reference:
PETRA III
G. Kube, DIPAC'07, EPAC'08
ATF - KEK
H.Hanyo et al., Proc. of PAC99 (1999), 2143
T. Naito and T. Mitsuhashi, Phys. Rev. ST Accel. Beams 9 (2006) 122802





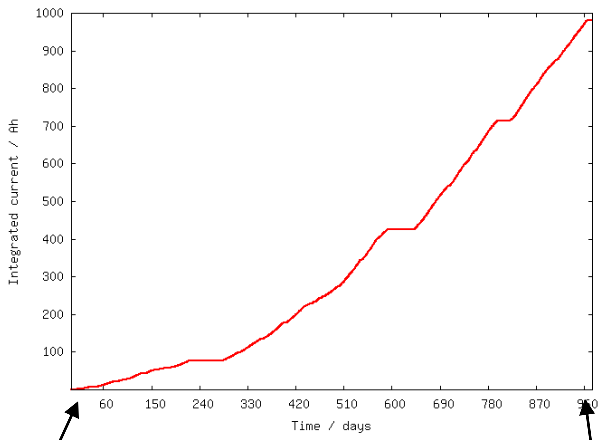
60 x 4 bunches,
100 mA
Vert. Emittance

~ 5 pm rad

(March 8, 2012)

Conditioning

Integrated beam current



May 2009 Jan 2012

Now more than
1000 Ah

Average Vacuum pressure (2012):

5.0×10^{-10} mb (without beam)
1.4×10^{-8} mb (100 mA, 240 bunches)

The vacuum pressure does NOT depend on the filling pattern.

Photons per length and bunch population

$$\frac{dN_\gamma}{ds} = \frac{5}{2\sqrt{3}} \frac{1}{137} \frac{E}{m_0 c^2} \frac{1}{\rho} = 0.0645 \frac{1}{\mathrm{m}}$$

100 mA beam current

Total beam population
4.8×10^{12} positrons

3.1×10^{11} photons per meter

Photoelectron dose: ($Y \sim 0.1$, $C_{ch} = 194$ mm)

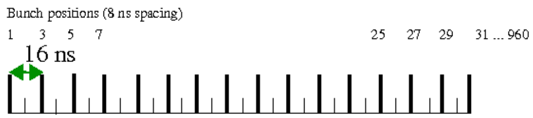
$$d_{ch} = Y \frac{dN_\gamma}{ds} \frac{1}{C_{ch}} \int I \; dt = 3.33 \frac{10^{-7}}{\mathrm{mm}^2} \int I \; dt$$

= 1.2 C/mm^2 (1000 Ah)

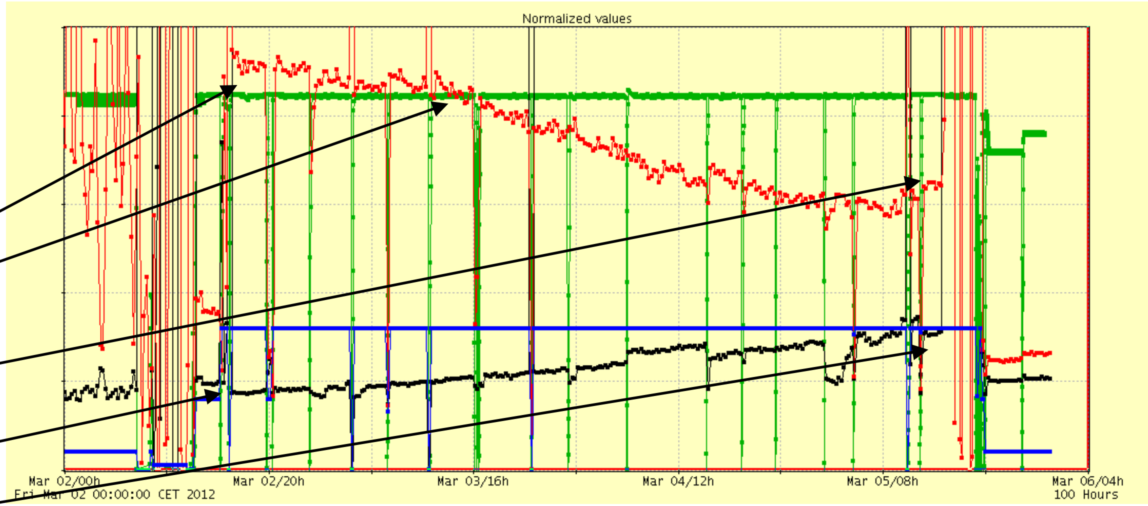
Scrubbing runs (March 2012)

Filling scheme

480 x 1

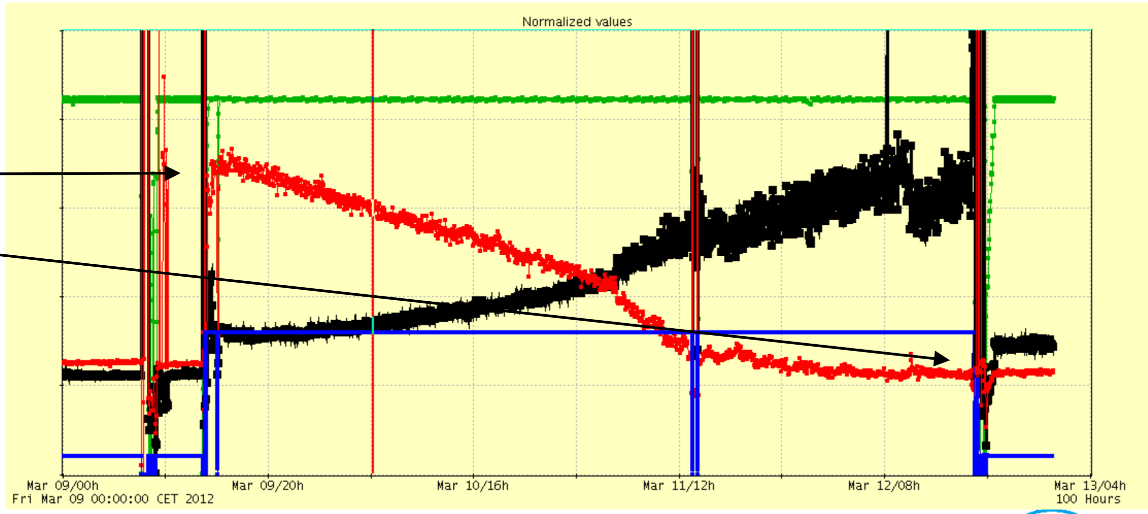


Run 1:
March 3 / 4, 2012
Vert. Emittance
~140 pm rad (for 20 h)
Than dropping to 97 pm rad
Horz. Emittance
Starting at 1.0 nm rad
Increasing to 1.8 nm rad



Green: total current (100 mA) Red: vertical emittance (scale 0 … 150 pm rad)
Blue: Number of bunches (480) Black: horizontal emittance (scale 0 … 6 nm rad)

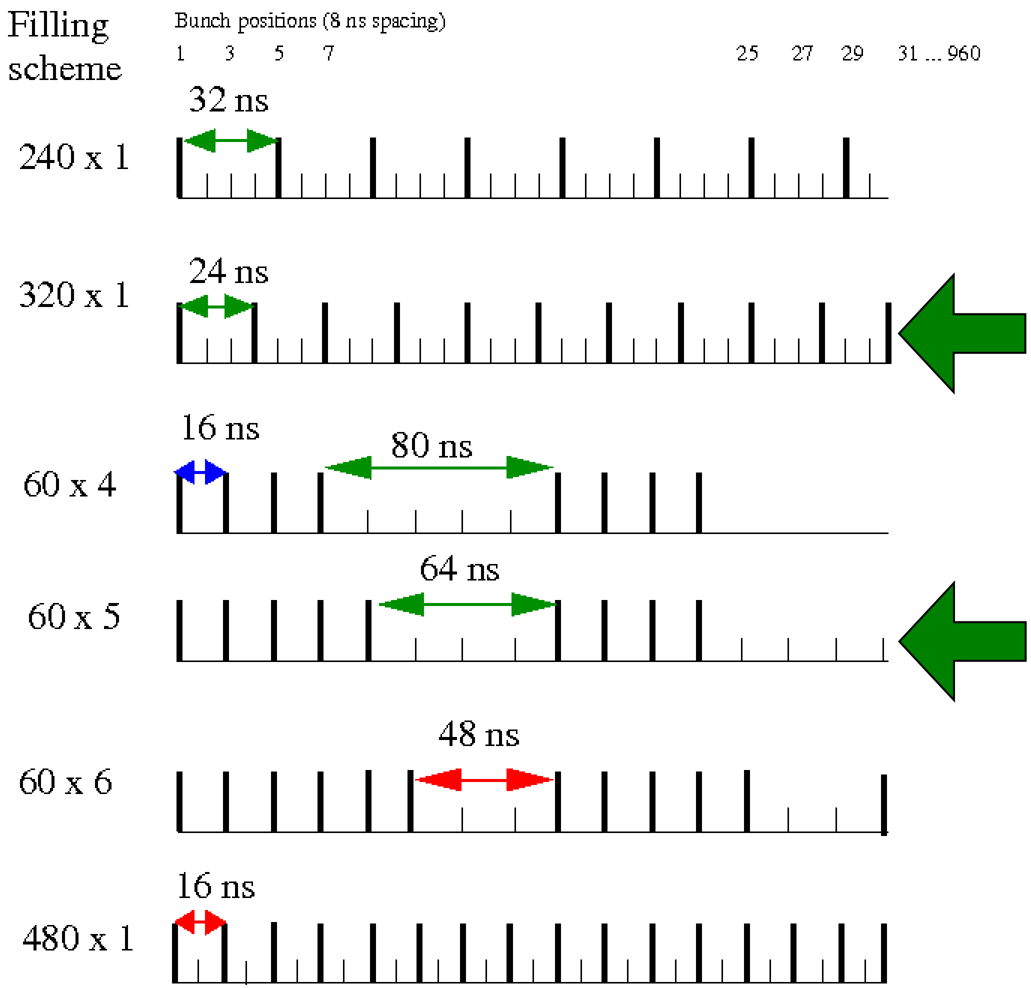
Run 2:
March 10 / 11, 2012
Vert. Emittance
Starting at 104 pm rad
Decreasing to 33 pm
But
Horz. Emittance
increase from 2 nm rad
to 4 nm rad



Time scale: 4 days
~10 Ah, 1.2×10^{-2} C/mm^2

240 bunches

Conditioning + Scrubbing: Benefits



100 mA in 320 bunches
Without any significant
emittance increase !

100 mA in 60 x 5 bunches
Without any significant
emittance increase!

Emittances increase:
60 x 6 bunches

480 bunches (used for scrubbing)

Tune shifts (bunch train) after the scrubbing runs

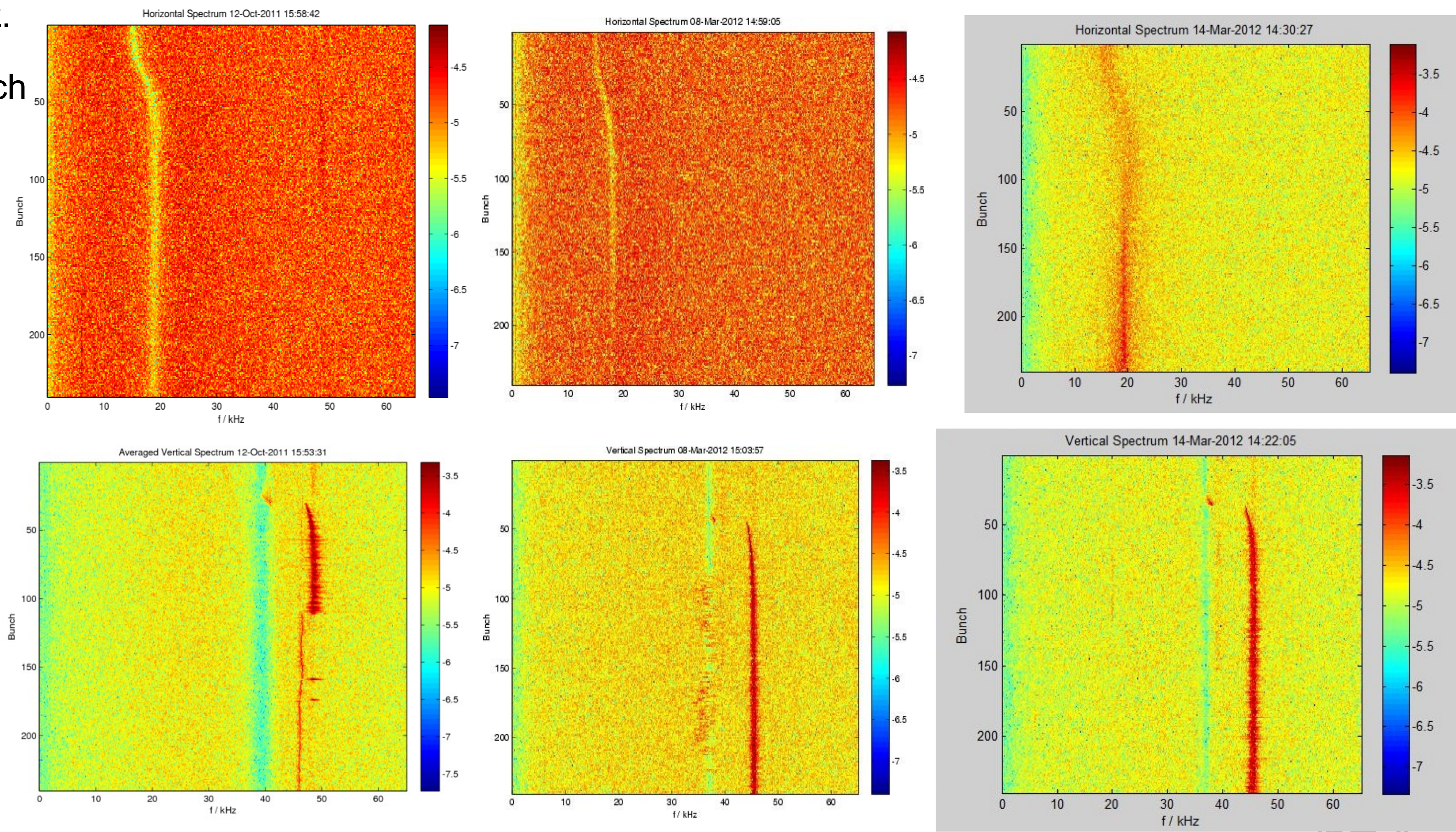
240 bunches (8 ns bunch spacing)

Oct 12, 2011, 36 mA | **Mar 8, 2012, 31 mA** | **Mar 14, 2012, 37 mA**

Horz.

Bunch #

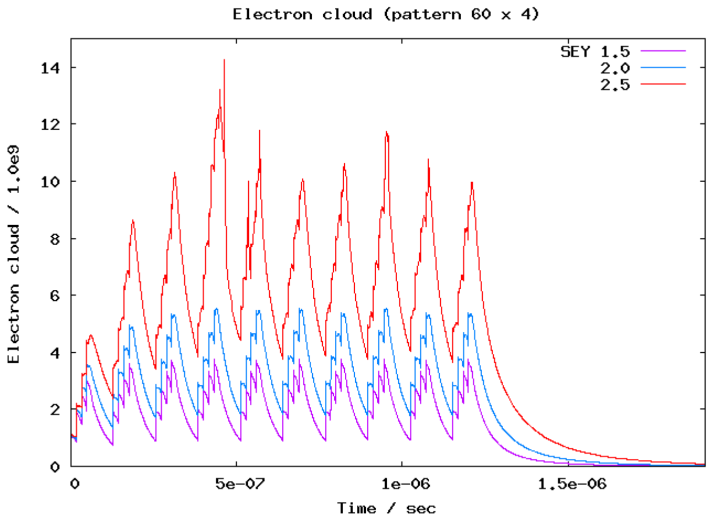
Vert.

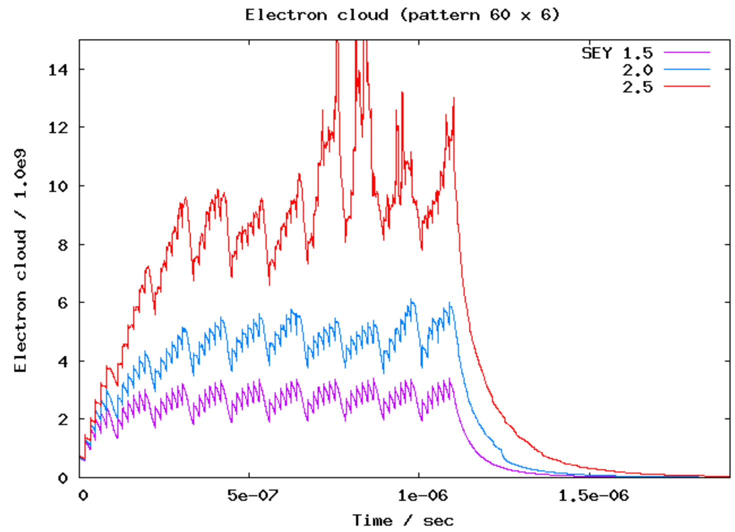


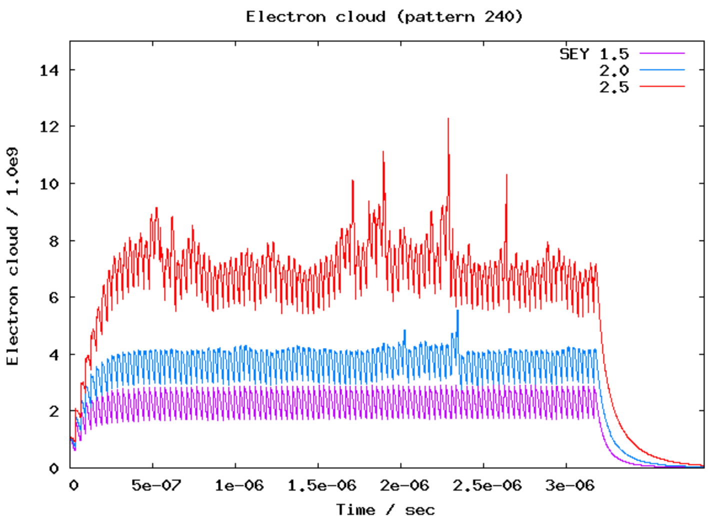
f / kHz

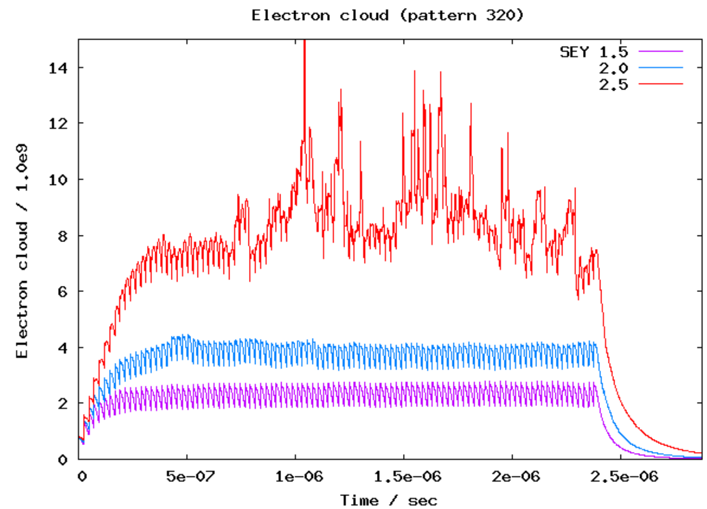
Simulations with ECLOUD 4.0

PETRA III, 100 mA, different filling patterns, SEY: 1.5, 2.0, 2.5



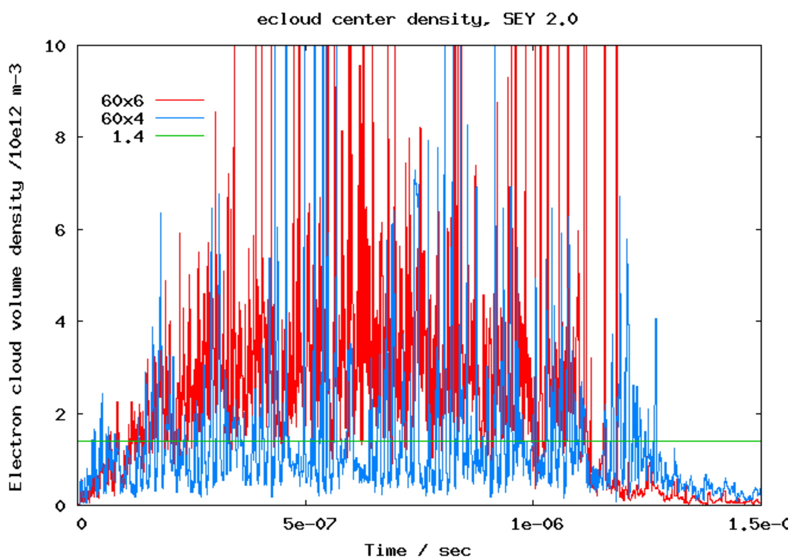






Simulations with ECLOUD 4.0 (cont.)

PETRA III, 100 mA, different filling patterns, center density



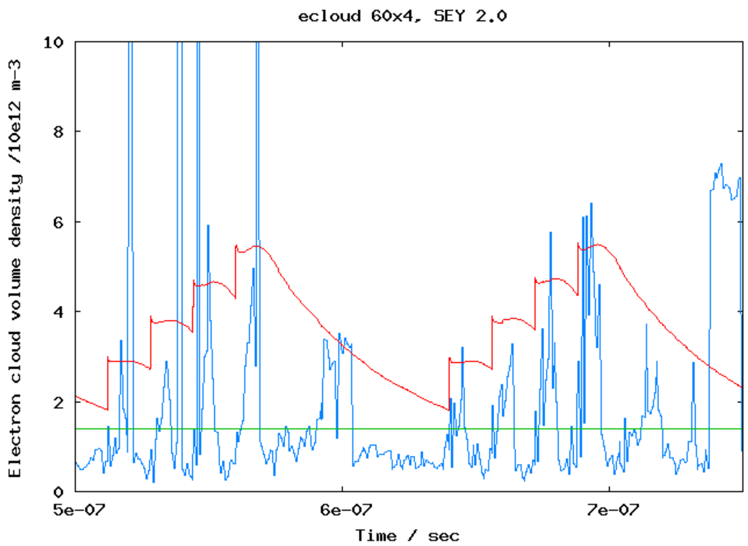
Emittance growth

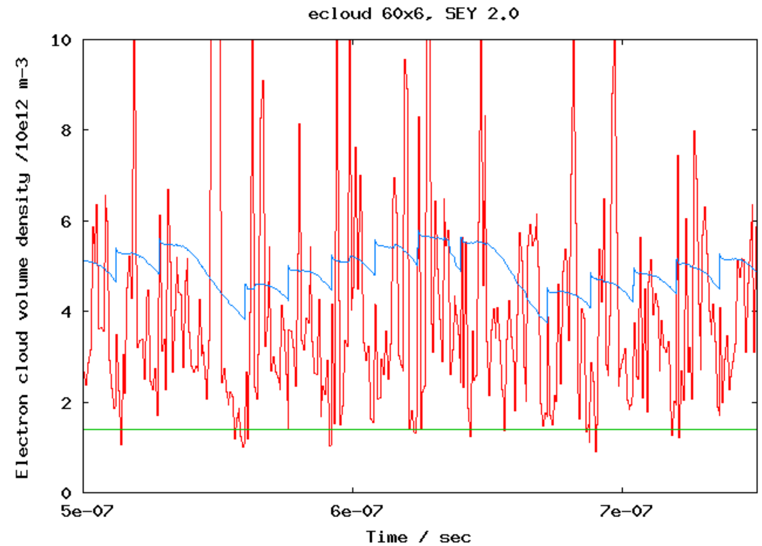
100 mA 60 x 6 not ok

100 mA 60 x 4 ok

(threshold density ~ 1.4e^{12} m^{-3})

Simulation studies indicate an instability for the 60 x 6 pattern if the SEY is about 2.0





Summary

- A vertical emittance growth has been observed for bunch trains with 8 ns and 16 ns bunch to bunch spacing.
- There a “upper-sidebands” in the vert. tune spectra with a clear build-up along a bunch train.
- A clear conditioning effect has been observed. For user runs filling patterns with 40 x 4 and 60 x 4 bunches were used in 2010. In 2011 it was possible to fill 240 bunches with a 32 ns bunch spacing.
- In 2012 two dedicated scrubbing runs have improved the situation. It is possible to use 320 bunches with 24 ns bunch spacing and no significant emittance growth.
- This “proves” that the observed emittance growth is really due to electron clouds.
- The tune shift along a bunch train are not changed after the scrubbing runs.
- Simulations for diffenrent filling patterns indicate that the SEY < 2.0 after conditioning and scrubbing.
- Recently (May 16, 2012) 320 bunches with 24 ns bunch spacing have been used for user runs.

Thank you for your attention !

Acknowledgment:

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