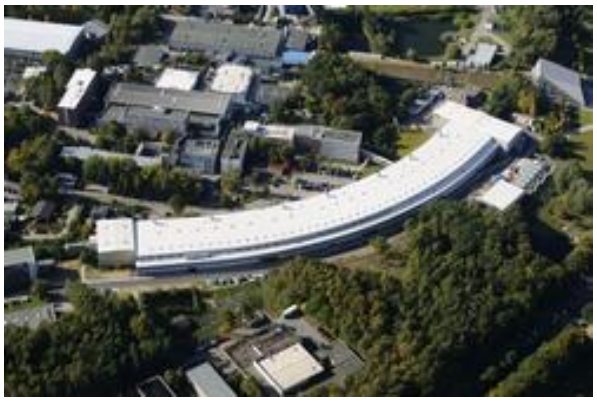
Low Energy/Emittance Studies at PETRA III.

Intar Beam Scattering and Touschek Lifetime



Alexander Kling
MPE - DESY

Dec. 2013, SLAC

HELMHOLTZ ASSOCIATION

DESY

MOTIVATION.

Statement from USR workshop 2012 in Beijing:

Modeling and simulation:

1. Codes for collective effects for USRs are in various stages of completeness (rated 1-5, 5 highly complete): Touschek lifetime (5), IBS (4), impedance (3), ion instability (2), CSR (2), space charge for low-E rings (1)).
2. Codes/formulas should be benchmarked on working machines that can approximate USR parameters by reducing energy, coupling, etc. (e.g. PETRA-III, ESRF, SPring-8).
3. General scaling laws that take into account as much as possible all the effects, including emittance (with collective effects), brightness, spectrum, circumference, magnet strengths, running costs, etc.).

Low Energy Studies.

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  - Focussing and intrinsic octupole scale quadratic with energy
  - Do higher multipoles matter?

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- What emittances can be realized in PETRA III at low energies
- Look for interesting and viable energies

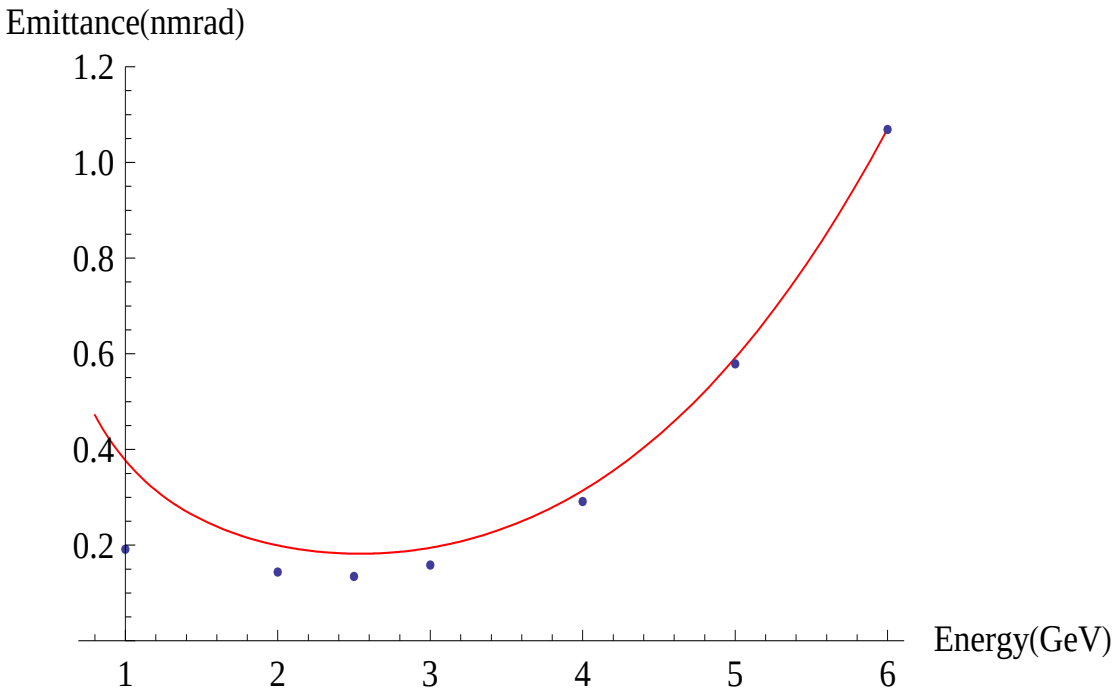

FIGURE : Simple scaling of emittance with energy (red) and emittance calculated from matched optics with madx.

Low Energy Studies.

- Behaviour of wigglers at low energies?
  - Focussing and intrinsic octupole scale quadratic with energy
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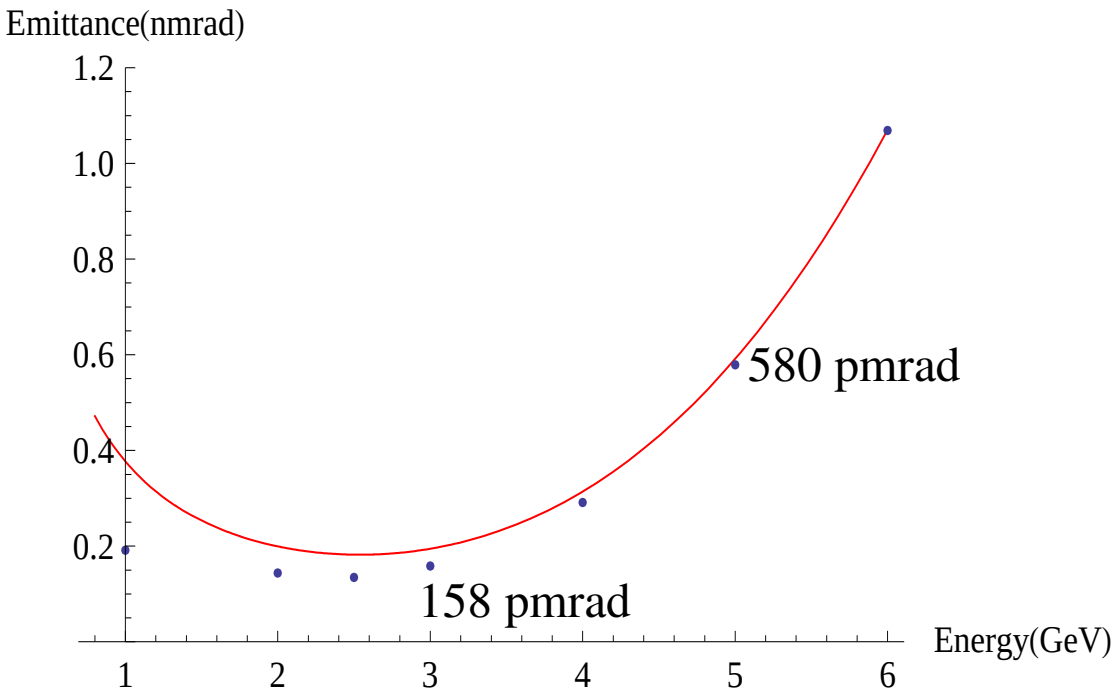
- What emittances can be realized in PETRA III at low energies
- Go for 5GeV and 3GeV



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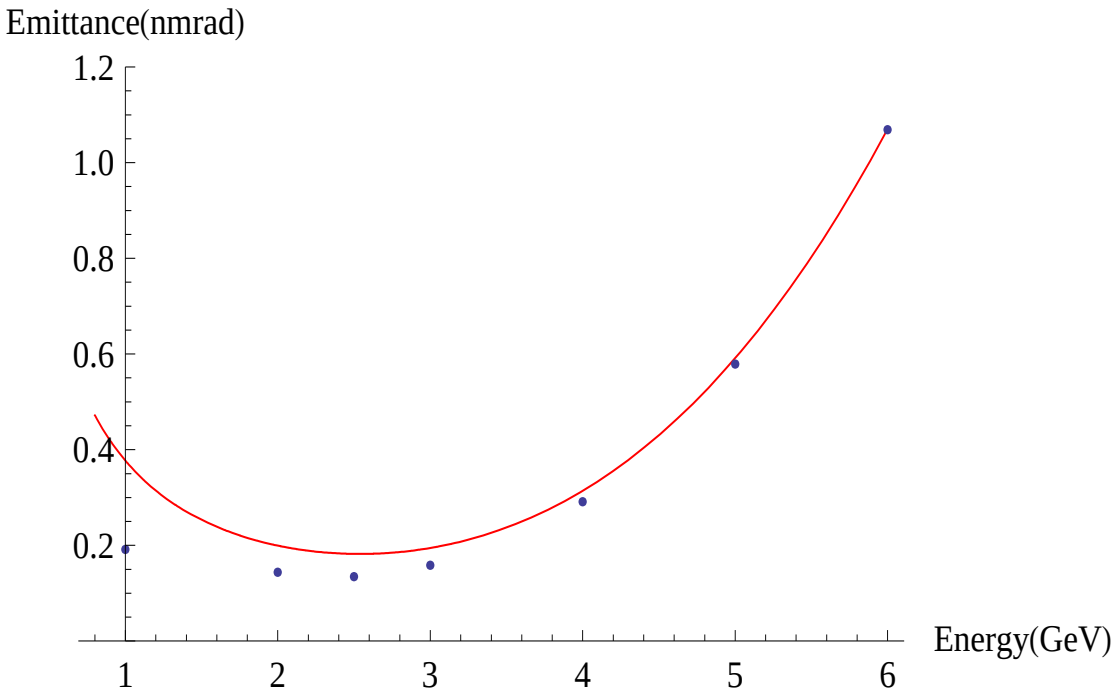

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Physics: IBS, Touschek-Lifetime, ...

Warm up Exercise - 5 GeV.

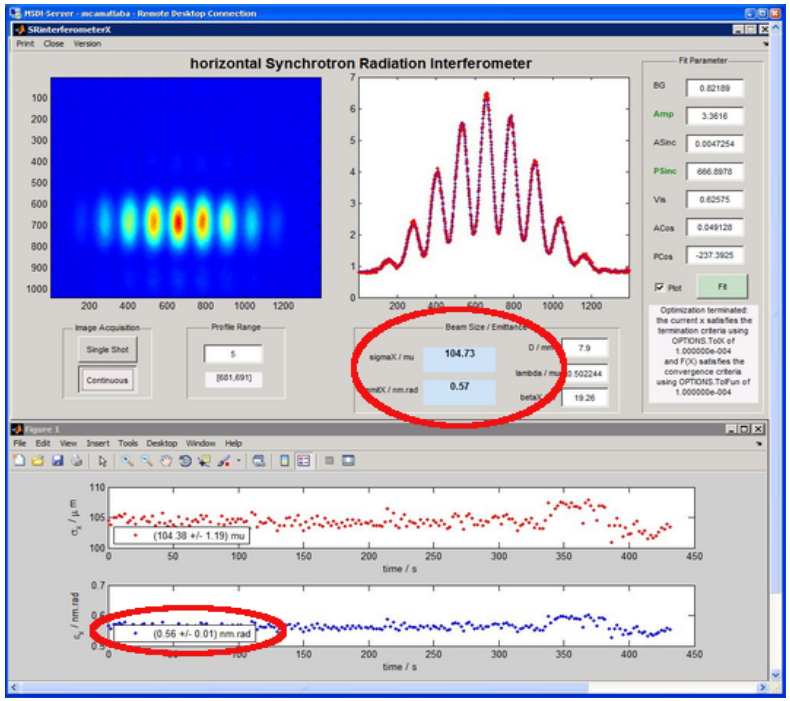


Figure : Interferometric emittance measurement of the horizontal emittance at 5 GeV. $\varepsilon_x = 570$ pm rad.

- Test for machine setup
- Check of hard edge dipole model used for wiggler modeling
- Optic corrected once via orbit response matrix measurement
- Resulting emittance as expected
- No strong IBS observed

PETRA III @ 3 GEV.

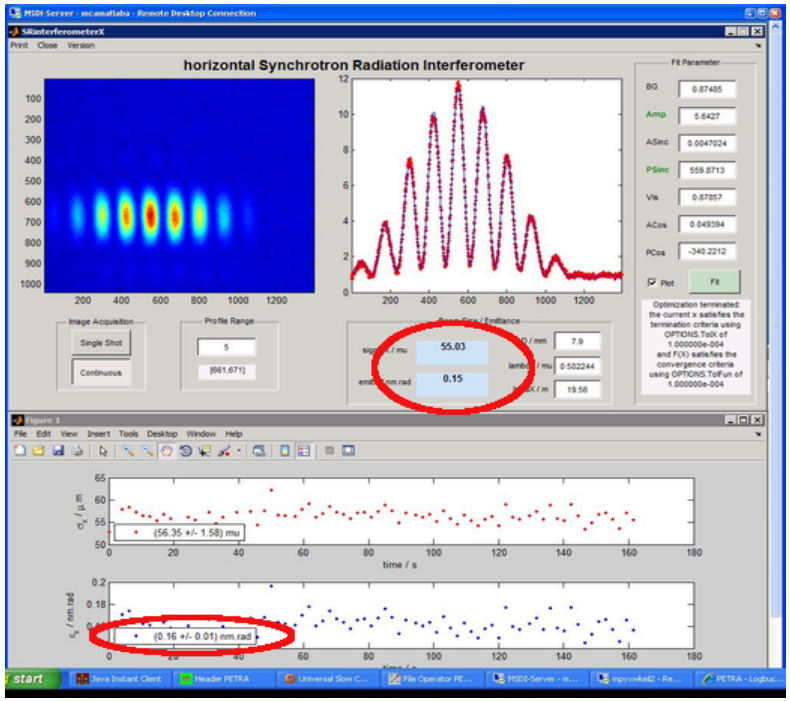
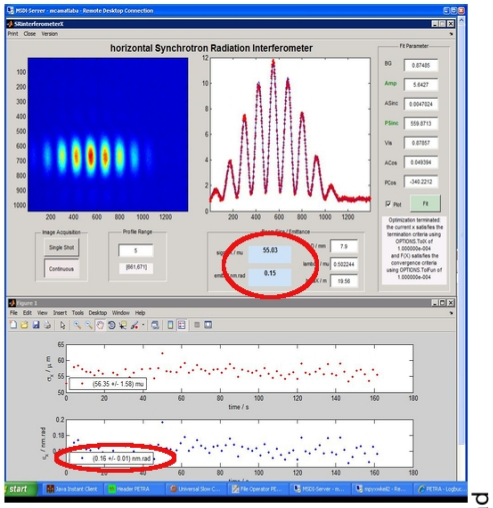


FIGURE : Interferometric emittance measurement of the horizontal emittance at 3 GeV. $\varepsilon_x = 160$ pm rad.

- Machine setup much more tedious
- Hard edge dipole model still o.k.
- Optic corrected twice via orbit response matrix measurement (slow convergence)
- Resulting emittance as expected, but only at very small single bunch intensities!
- Strong IBS observed

PETRA III @ 3 GEV: IBS.



Hor. Emittanz als Funktion des Einzelbunchstroms

IBS:
160 pm -> 350 pm

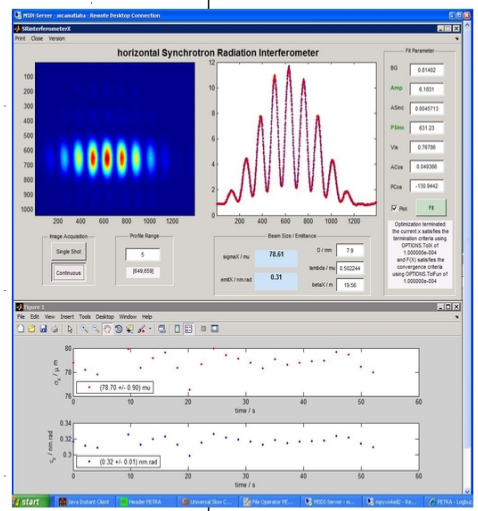
50 mA in 480 Bunches
Np = 5 x 10^9

5 mA in 480 Bunches
Np = 5x10^8

Modeling is work in progress

ε_x / pm*rad

I_b / µA



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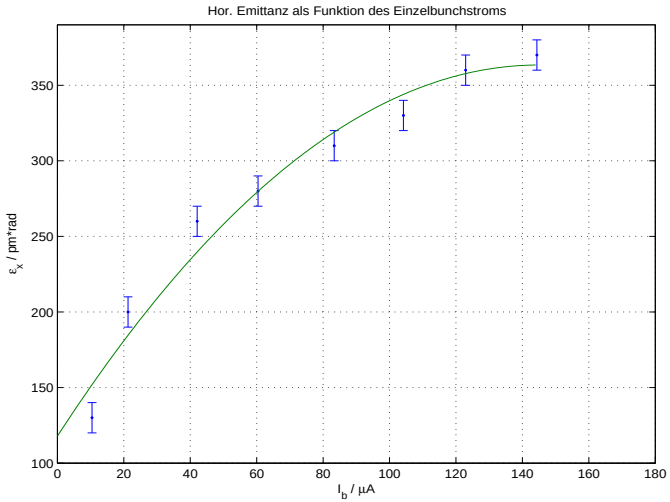
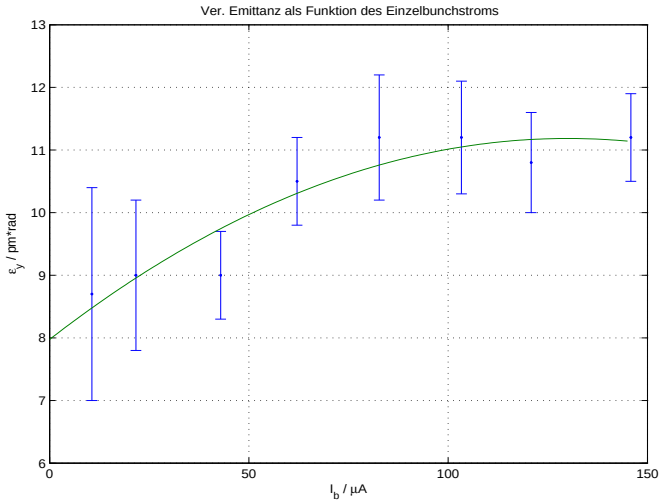


FIGURE : Horizontal emittance at 3 GeV vs. single bunch current.



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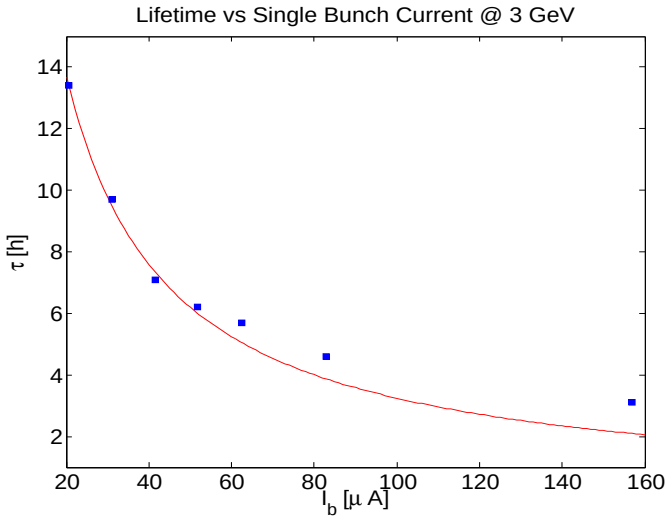

FIGURE : Beam lifetime at 3 GeV vs. single bunch current. The red curve is a fit to the first few data points neglecting the emittance growth with single bunch current.

- Emittance growth in the vertical plane and effect on the bunch length is small
- At the resolution limit of the measurement
- Modeling of lifetime is work in progress
- Simple estimate from a fit to the first data points yields a Touschek lifetime of ∼8 minutes @ 2.5mA (MadX: 6 minutes).

Modeling IBS.

Using MadX to model IBS + solving equations selfconsistently (iteratively)

- Growth rate for the horizontal emittance (BM):

$$\frac{d\varepsilon_x}{dt} = \frac{2}{T_x}\varepsilon_x$$

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$$\frac{d\varepsilon_x}{dt} = \frac{2}{T_x(\varepsilon_x, \dots)}\varepsilon_x$$

MODELING IBS.

Using MadX to model IBS + solving equations selfconsistently (iteratively)

- Horizontal emittance:

$$\frac{d\varepsilon_x}{dt} = -\frac{2}{\tau_x}(\varepsilon_x - \varepsilon_{x0}) + \frac{2}{T_x}\varepsilon_x$$

Modeling IBS.

Using MadX to model IBS + solving equations selfconsistently (iteratively)

- Steady state horizontal emittance:

$$\varepsilon_x = \frac{T_x}{T_x - \tau_x}\varepsilon_{x0}$$

MODELING IBS.

Using MadX to model IBS + solving equations selfconsistently (iteratively)

- Steady state transverse emittances:

$$\varepsilon_x = \frac{T_x}{T_x - \tau_x}\varepsilon_{x0}$$

$$\varepsilon_y = \left((1-r)\frac{T_y}{T_y - \tau_y} + r\frac{T_x}{T_x - \tau_x}\right)\varepsilon_{y0}$$

r controls the vertical emittance growth induced by coupling.

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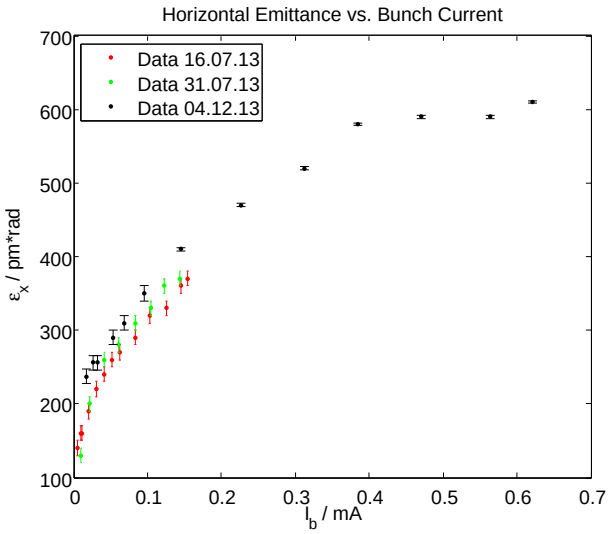
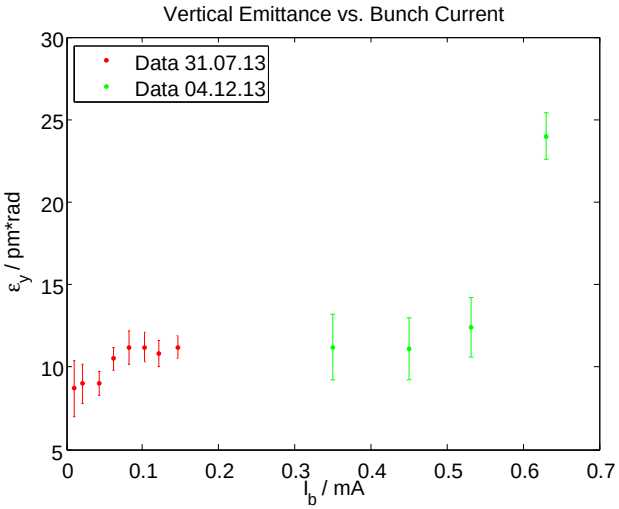
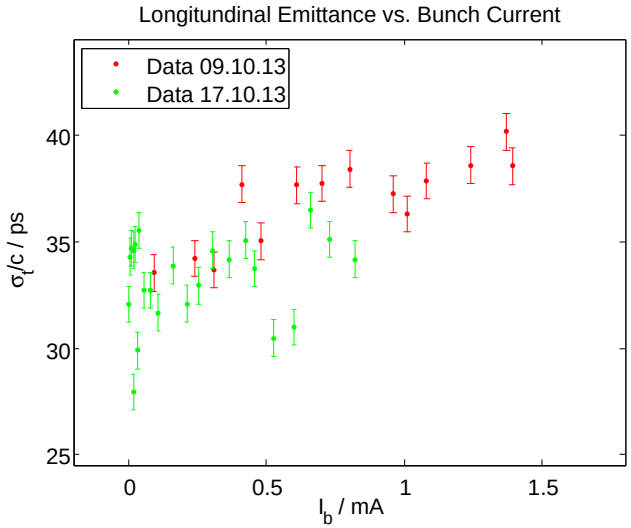
- Coulomb Log:
  - MadX computes ~ 19
  - Tail cut formulas suggest ~ 12

MODELING THE DATA - A FIRST GLANCE.







- Vertical emittance growth small!
- Impedance effect of bunch lenghtening has to be subtracted.
- Coulomb logarithm alowed as free parameter

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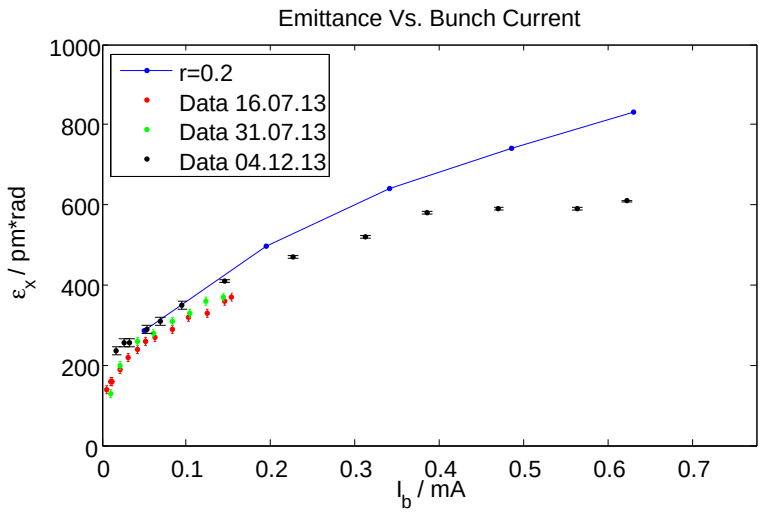
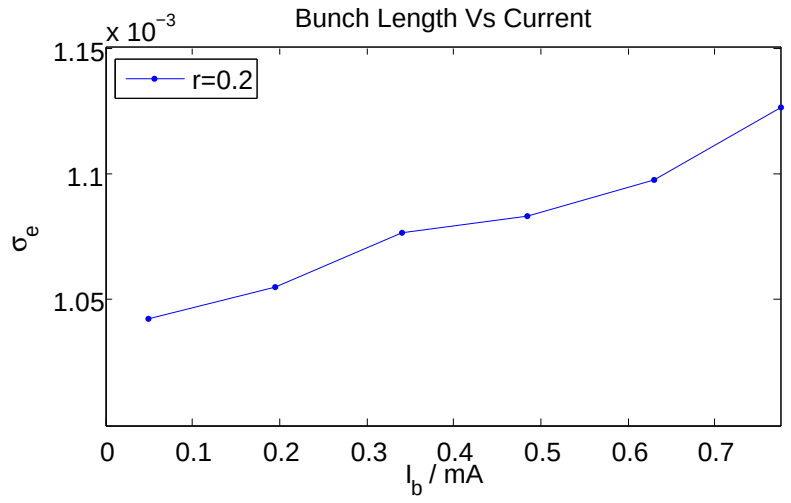
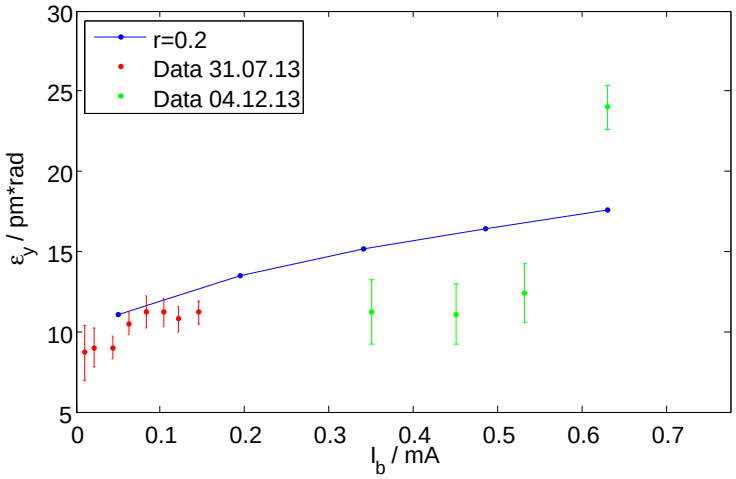
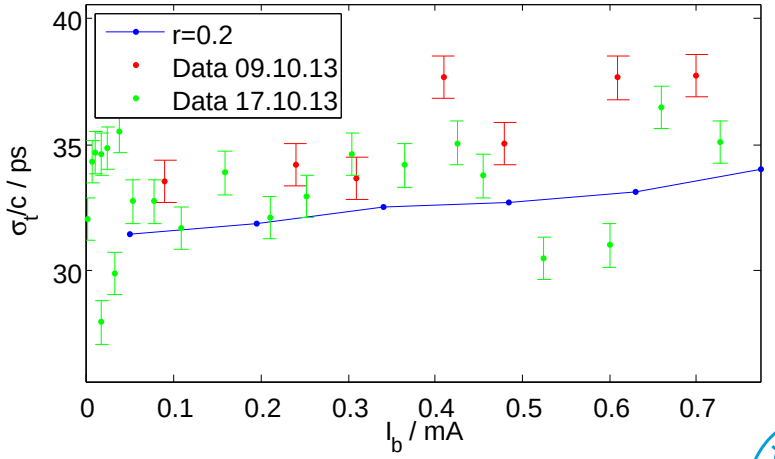




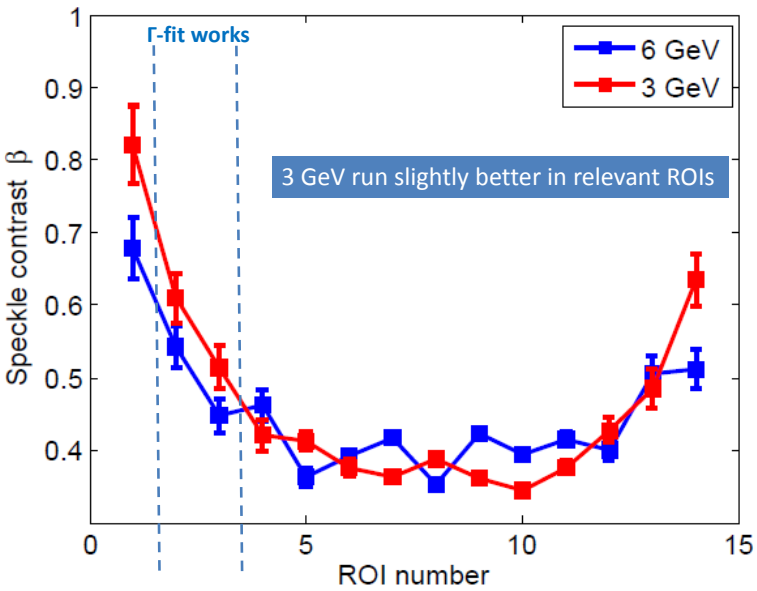




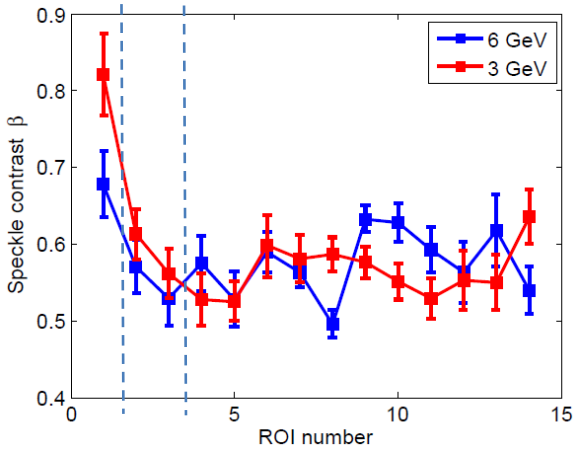
PHOTON BEAM PROPERTIES.

Measured at beamline P04:

6 GeV vs. 3 GeV



Incoherent background correction



Again, 3 GeV has slightly higher speckle contrast within relevant ROIs

PETRA III @ 3 GEV: ROUND BEAM (COUPLED).

Round beam generated via coupling: 90 pmrad measured in both planes

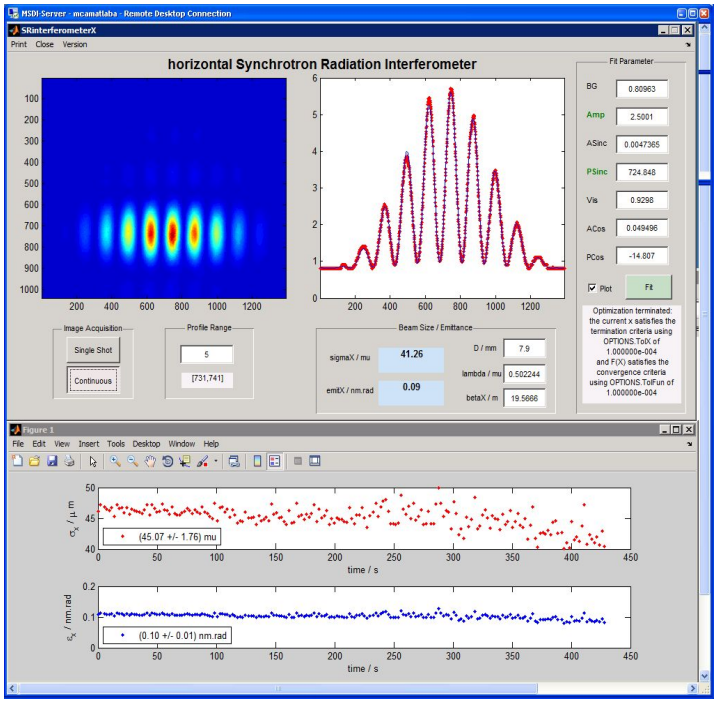
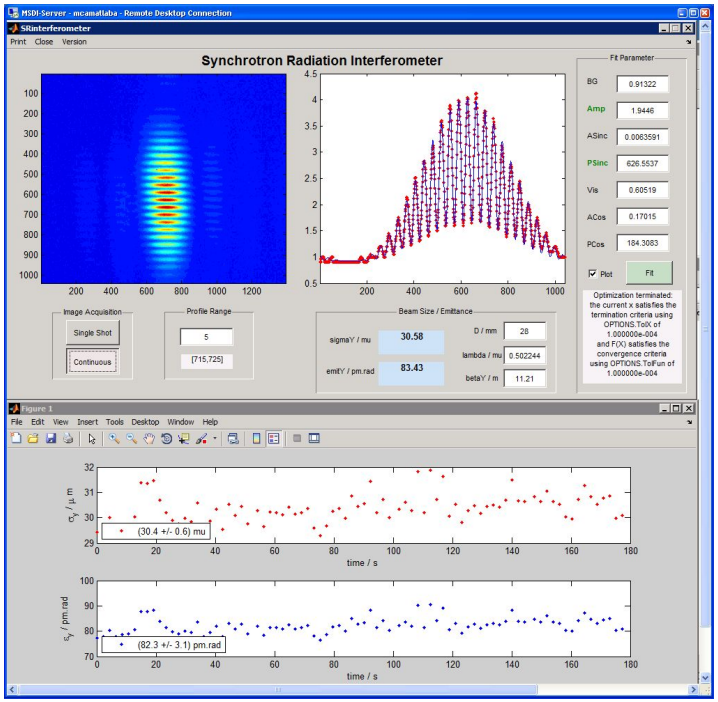


FIGURE : Horizontal emittance at 3 GeV at the coupling resonance.



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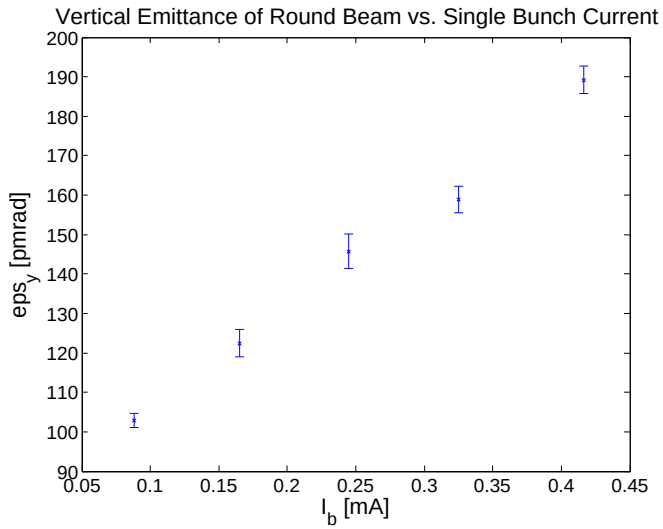
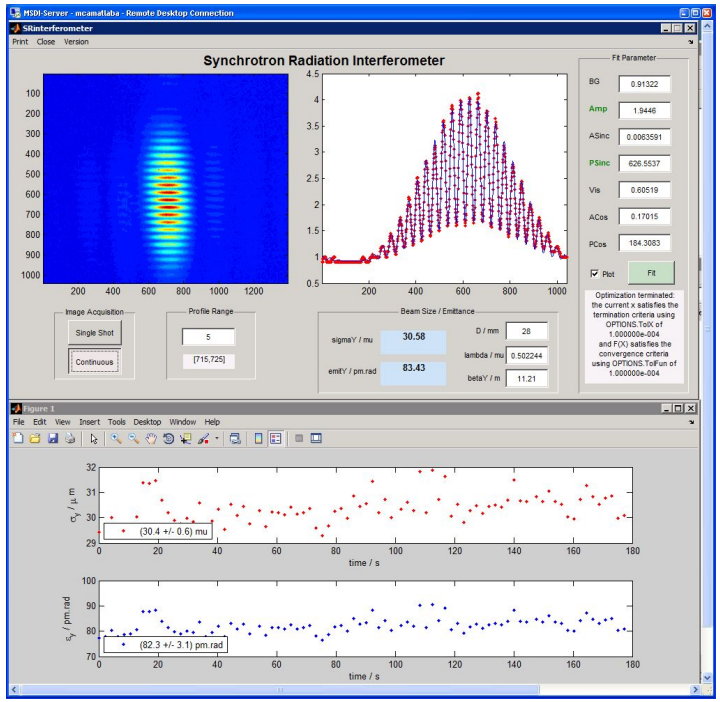


FIGURE : Vertical emittance vs. single bunch current for the round beam.



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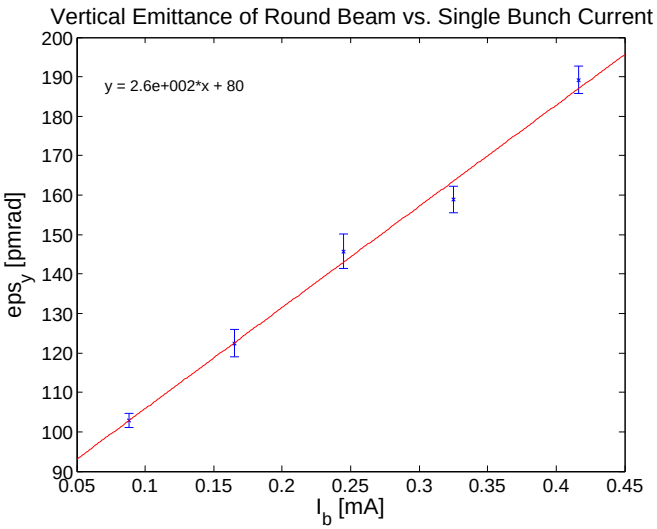

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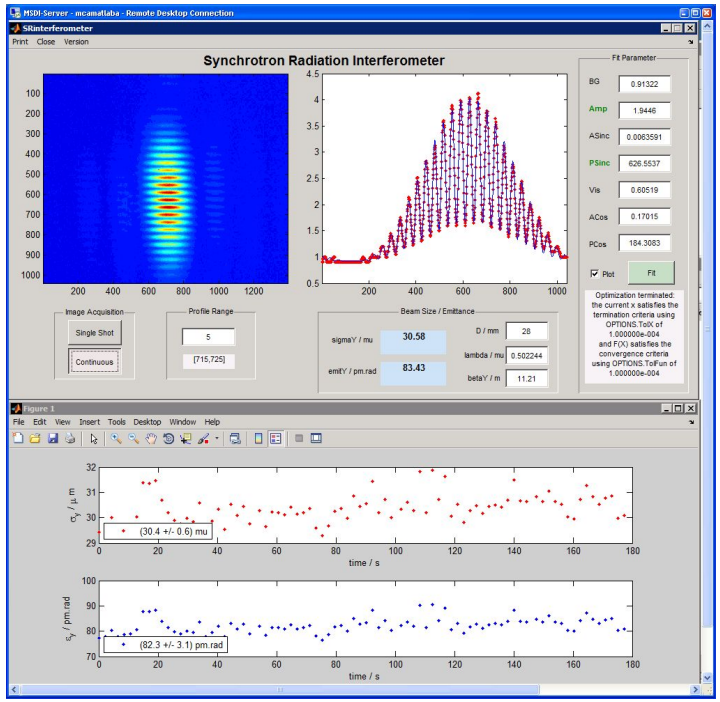

FIGURE : Vertical emittance at 3 GeV at the coupling resonance.

SUMMARY.

- PETRA III operated at 5 GeV and 3 GeV
- Natural emittances in both cases established
- No significant IBS at 5 GeV, but strong IBS at 3 GeV
- Modeling of IBS at 3 GeV still in progress:
  - Coulomb log cut off
  - Ratio of coupling contribution to contribution by dispersion to vertical emittance
- 3 GeV round beam with 90pm rad demonstrated
- Further studies planned, but limited time due to reconstruction starting in February

SUMMARY.

Thank you for your attention!