ESRF | The European Synchrotron

Momentum Compaction Measurement using Synchrotron Radiation

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Nicola Carmignani, Andrea Franchi

DEELS 2018, 19/04/2018

Momentum Compaction

The momentum compaction factor is defined as the derivative of normalized path length difference to normalized momentum:

$$\alpha = \frac{\Delta L/L}{\Delta p/p}$$

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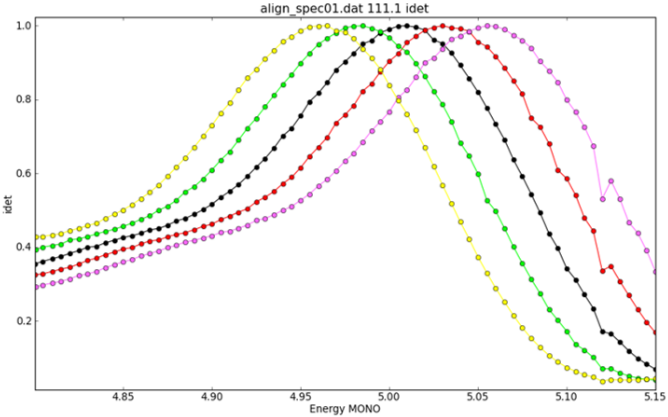
Measure

$$\frac{\Delta L}{L} = -\frac{\Delta f_{RF}}{f_{RF}} \text{ and } \frac{\Delta p}{p} \sim \frac{\Delta E}{E}$$

$$\frac{\Delta f_{RF}}{f_{RF}} = -\alpha \frac{\Delta E}{E}$$

Using Beamlines

Changing the energy of the electron beam, the peak of the undulator radiation moves by a given quantity*



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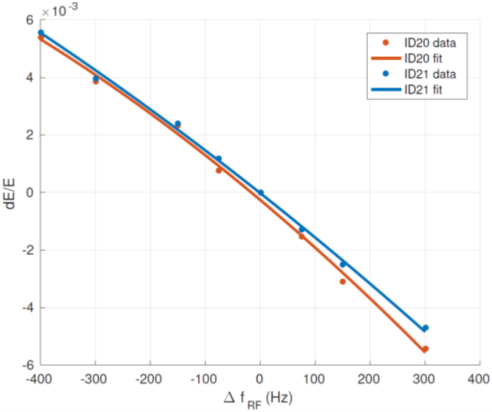

Scan RF ±400Hz

$\alpha_{ORM} = 1.827 \pm 0.004)e-4$

$\alpha_{M,ID20} = (1.8 \pm 0.1)e-4$

$\alpha_{M,ID21} = (1.9 \pm 0.1)e-4$

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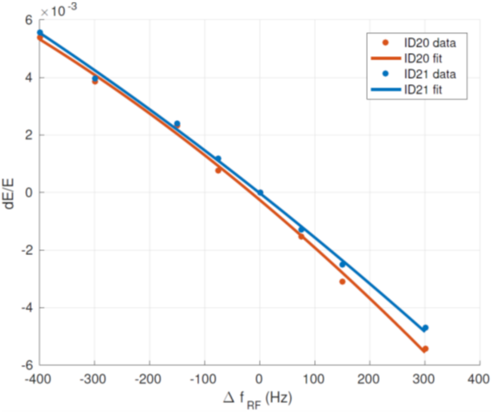

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Difficult to organize, time consuming, not everyone has a beamline!

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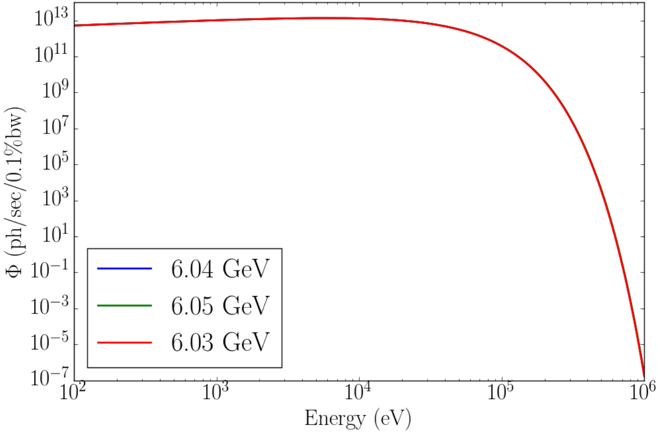
Beam Energy and Synchrotron Radiation Flux

$$\Phi \propto E^2$$



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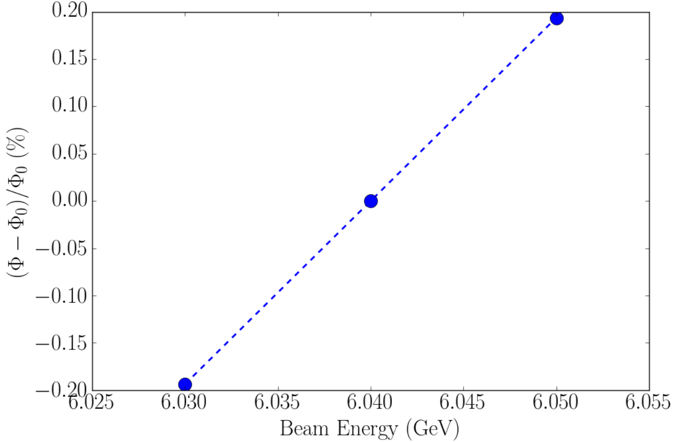


Synchrotron Radiation Flux Measurement

CTWM01 Proceedings of DIPAC 2005, Lyon, France

DETECTION OF HARD X-RAYS IN AIR FOR PRECISE MONITORING OF VERTICAL POSITION & EMITTANCE IN THE ESRF DIPOLES

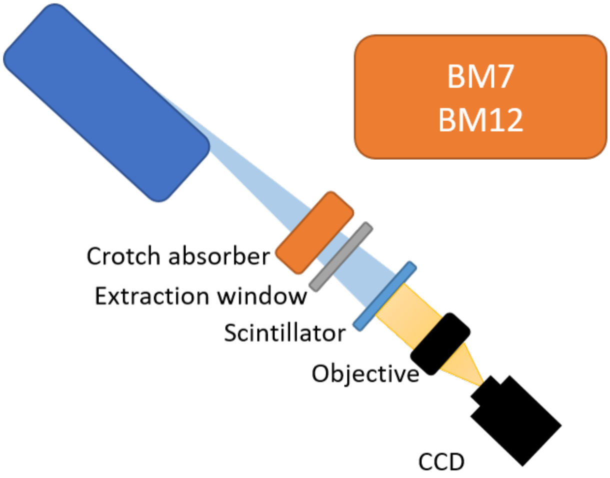
B.K. Scheidt, ESRF, Grenoble, France

MOCYB1 Proceedings of IBIC2014, Monterey, CA, USA

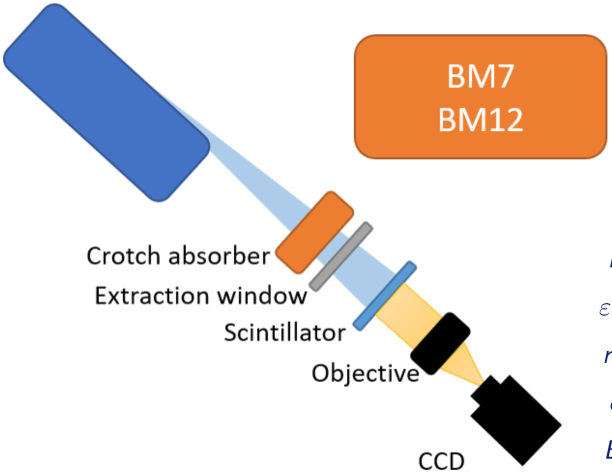
NON-DESTRUCTIVE VERTICAL HALO MONITOR ON THE ESRF'S 6GeV ELECTRON BEAM

B.K. Scheidt, ESRF, Grenoble, France

Synchrotron Radiation Flux Measurement



Synchrotron Radiation Flux Measurement



Scintillator

$$\Downarrow$$

$$P_T = \int_0^\infty \Phi \mathrm{d}E$$

$$P_T = \frac{8}{3}\pi\varepsilon_0 r_0^2 c^3 \frac{E^2 B^2}{(mc^2)^2}$$

P_T : Total power

ε_0: Vacuum permittivity

r_0: Classical electron radius

c: Speed of light

E: Beam energy

B: Magnetic field

m: Mass of the electron

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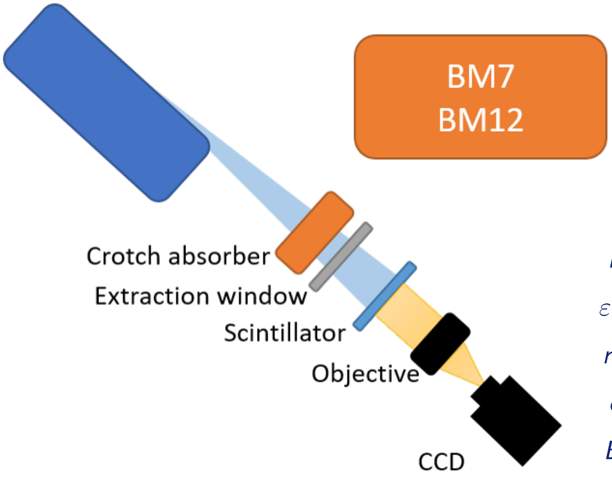

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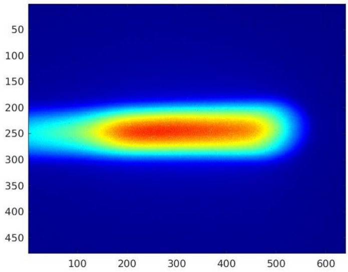
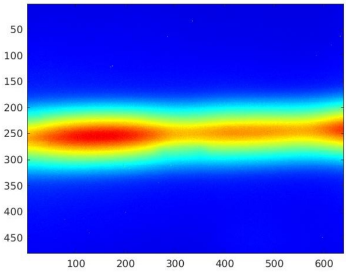
From now on we will address our observable as an intensity (I_M) even we know it it actually a power

Synchrotron Radiation Flux Images

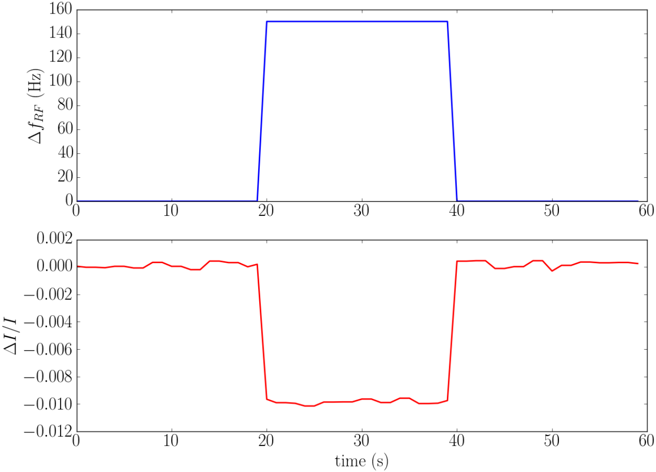
BM7



BM12



Energy Variation Measurement



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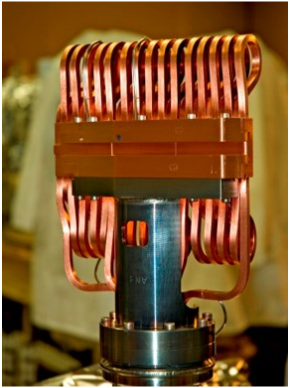

We are able to measure a variation in intensity but the x-rays path has to be taken into account

Energy Variation Simulation

$$\frac{\Delta E}{E} = T(E)\left(\frac{\Delta I}{I}\right) = \frac{\Delta I_{M,S}}{I_{M,S}}$$

- I: Intensity produced by the beam
- $T(E)$: Calculated using XOP
- $I_{M,S}$: Simulated measured intensity after the optical path

Energy Variation Simulation

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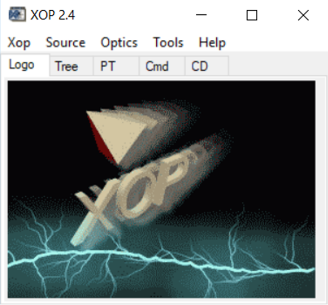


$T(E)$ calculated using XOP

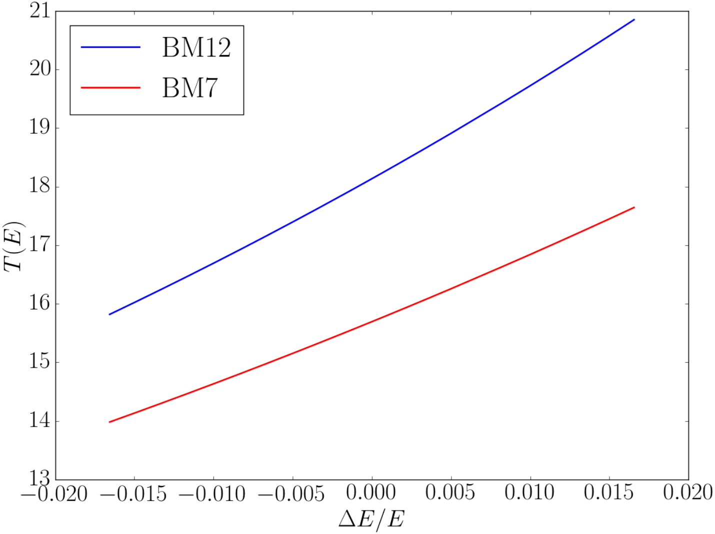
Simulation:

- X-ray spectrum (at different E)
- Crotch absorber transmission
- Extraction window transmission
- Scintillator absorption

Python script:

- Take into account scintillator linear response
- Integrate over the spectrum
- Calculate the $T(E)$ conversion coefficient

Intensity to Energy Conversion Coefficient



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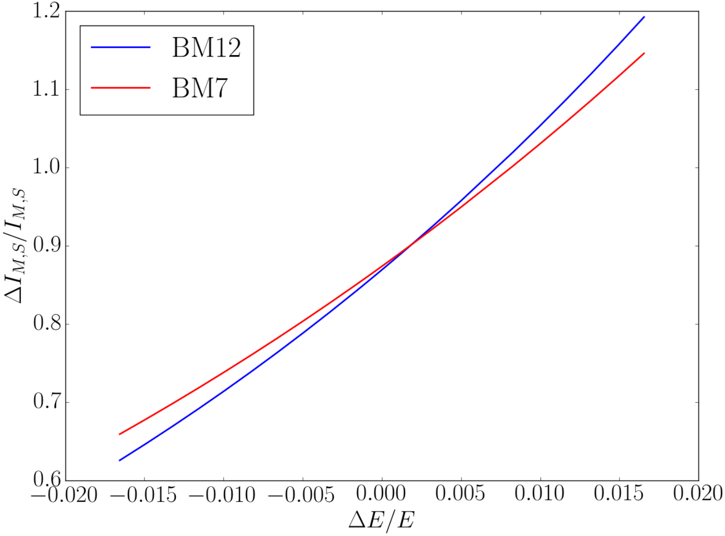
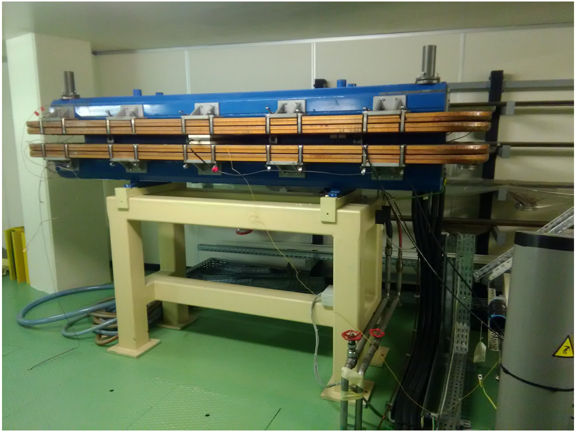


Calibration by Changing B (and E)

Verification of the goodness of the optical path simulations by scanning B and E ($I_M \propto B^2E^2$)



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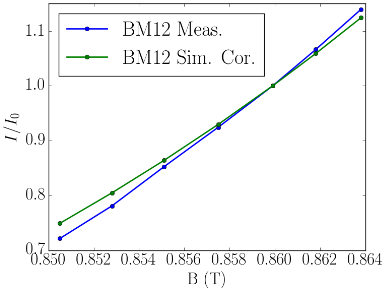
$$B\rho = \frac{p}{e}$$
$$B \propto E$$

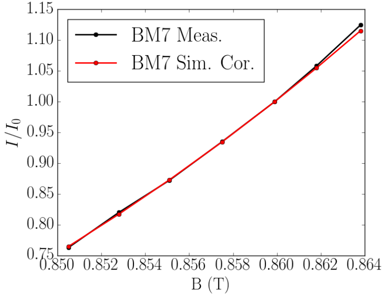
It is possible to "exactly" simulate the calibration, using XOP, and eventually correct the amount of material

Calibration – Measurements

Cu(40 mm)+Fe(3 mm)+
+Prelude(1.6 mm)



Cu(28 mm)+Al(3 mm)+
+$CdWO_4$(6 mm)



Calibration – Measurements

Cu(40 mm)+Fe(3 mm)+
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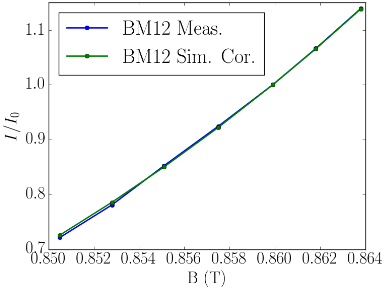

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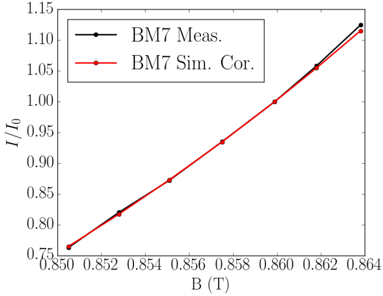
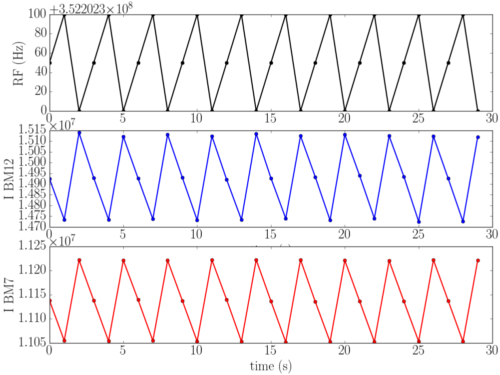


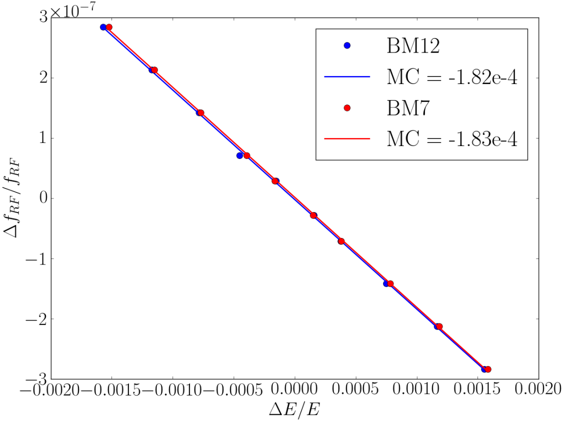
Momentum Compaction Measurement

Vary the RF frequency (-100 Hz to 100 Hz) to change the beam energy and measure the synchrotron radiation intensity variation



Results

Model	MC (10^{-4})
Ideal	1.7795
ORM	1.827±0.004
BM12	1.82±0.03
BM7	1.83±0.02



Beautiful but...

- CCD linearity is important (BM12 measurements are ROI dependent)
- CCDs age quite soon
- Repetitivity is an issue ($\alpha \pm 0.5 \times 10^{-5}$)
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Do you wanna try?