Smith-Purcell radiation as a longitudinal profile beam diagnostic

Nicolas Delerue
with the E-203 & SPESO collaborations

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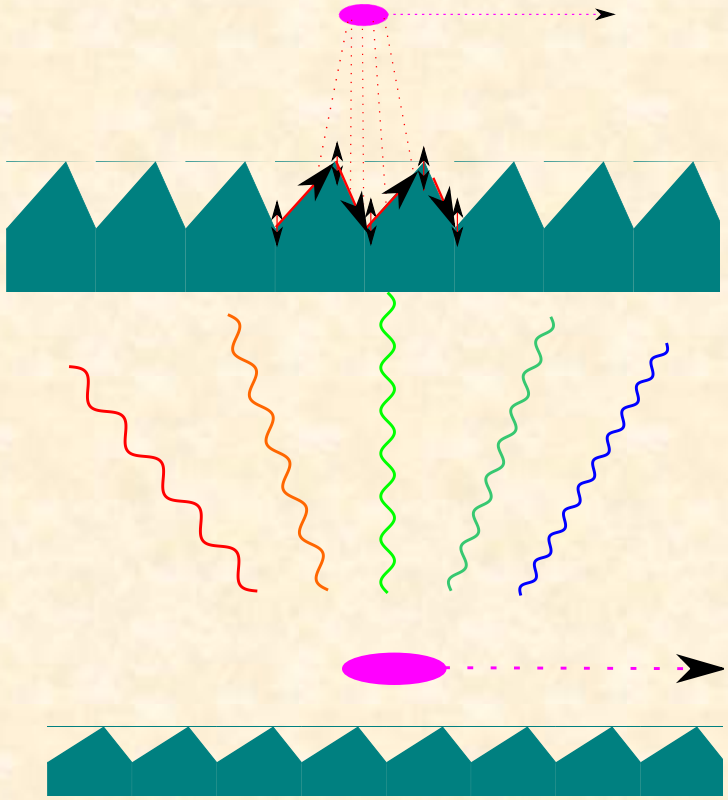
Coherent Smith-Purcell radiation

- An electron beam passing above a grating can induce a surface current on the grating.
- This will lead to the emission of radiation (called Smith-Purcell radiation).
- For bunches shorter than the emission wavelength this emission is coherent.



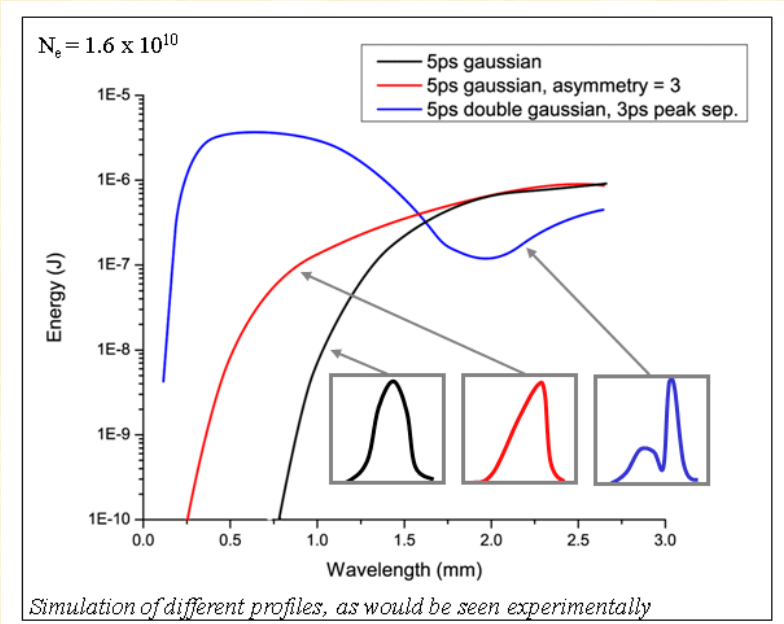
S.J. Smith and E.M. Purcell, Phys. Rev. **92**, pg. 1069, (1953)

Ishiguro and Tako, Optica Acta (GB) 8 1961 25

$$\left(\frac{dI}{d\Omega d\omega}\right)_{N_e}(\Omega,\omega) \approx \left(\frac{dI}{d\Omega d\omega}\right)_{sp}(\Omega,\omega)\cdot\left[N_e + N_e(N_e-1)\,|\,F(\omega)\,|^2\right]$$

Coherent SPR as a longitudinal profile diagnostic

- Coherent SPR encodes the Fourier transform of the longitudinal profile.
- => It can be used as a single shot non destructive diagnostic.
  => allows separate measurement of signal and background.
- Such diagnostic requires a measurement of the CSPR spectrum and then "FT inversion" to recover the spectrum (currently done using the Kramers-Kronig relation).



Simulation of different profiles, as would be seen experimentally

$$\left(\frac{dI}{d\Omega d\omega}\right)_{N_e}(\Omega,\omega) = \left(\frac{dI}{d\Omega d\omega}\right)_{sp}(\Omega,\omega)\cdot[N_e + N_e(N_e+1)\,|\,F(\omega)\,|^2]$$

Phys. Rev. ST Accel. Beams 12, 032803 (2009)

Comparison between CSPR and Transition radiation

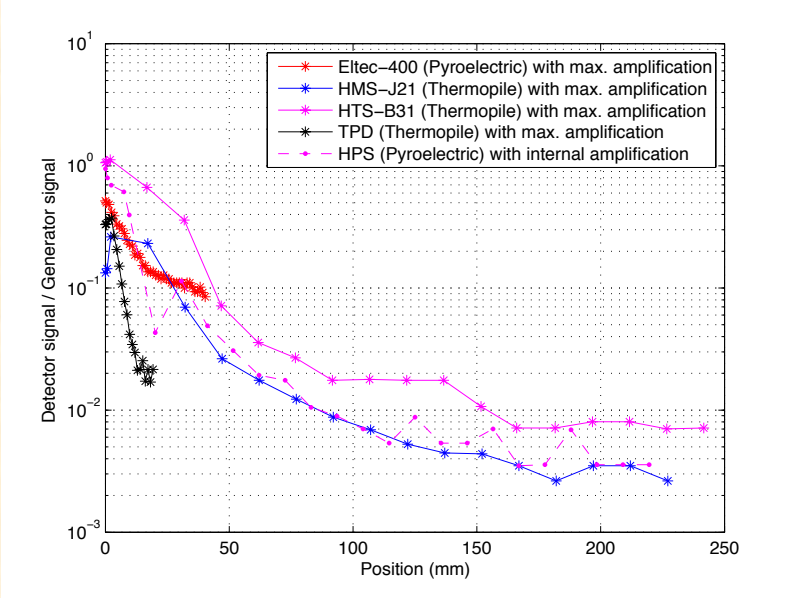
$$\left(\frac{dI}{d\Omega d\omega}\right)_{N_e}(\Omega,\omega)=\left(\frac{dI}{d\Omega d\omega}\right)_{sp}(\Omega,\omega)\cdot[N_e+N_e(N_e+1)\,|\,F(\omega)\,|^2]$$

$$\left(\frac{dI}{d\Omega}\right)_{sp}=2\pi q^2\,\frac{Z}{\ell^2}\,\frac{n^2\beta^3}{(1-\beta\cos\theta)^3}\,R^2\exp\left(-\frac{2x_0}{\lambda_e}\right)$$

- In both case there is a dependence on the square of the bunch charge.
- For CSPR, dependence on the bunch-grating separation (and grating pitch).
- In CSPR the radiation is dispersed spectrally
  => it is possible to separate CSPR from other backgrounds (independent background subtraction).

Wavelength and detectors

- This diagnostic is being developed for classical and novel accelerators.
- For a ps beam the CSPR is in the mm range.
- For 100fs beam the CSPR is in the far IR/THz range.
- We use pyroelectric detectors: good wavelength coverage but low responsivity (could use other detectors where available).

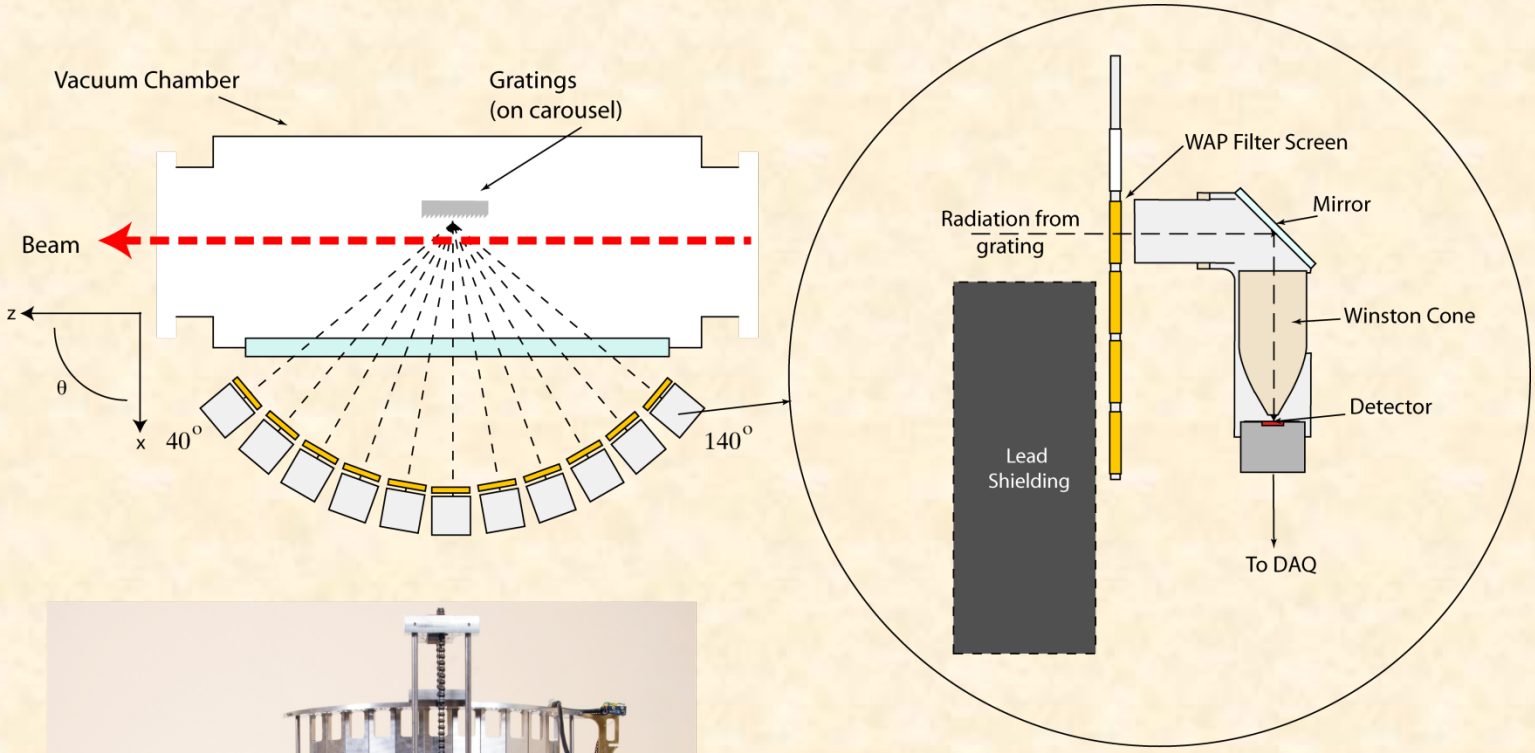


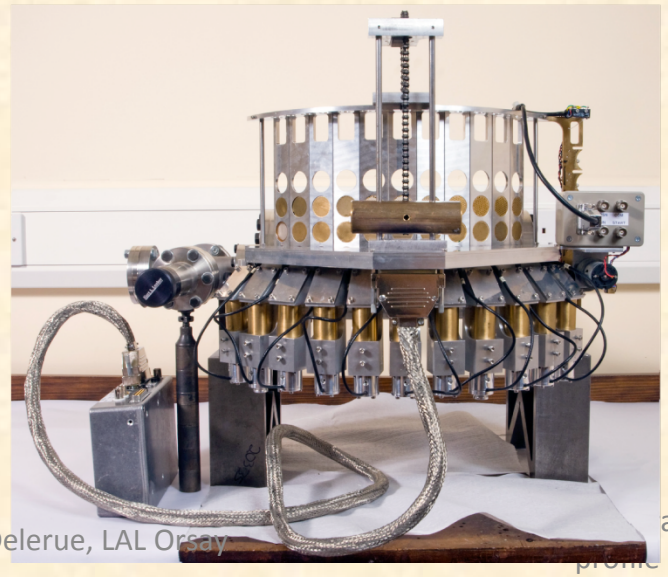
Current R&D toward CSPR as a bunch length diagnostic

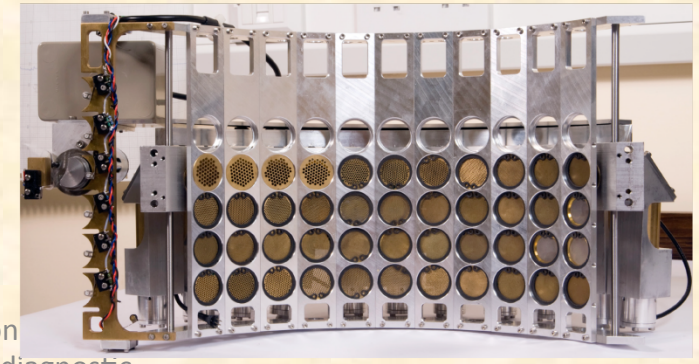
There are 2 collaborations working on using CSPR as a single shot bunch length diagnostics in the fs range:

- E-203 (Oxford, SLAC et al.): Experiment at FACET to demonstrate CSPR as a diagnostic in the fs-range using hardware previously validated during tests at End Station B.
- SPESO (LAL, SOLEIL et al.): Experiment at SOLEIL to map the distribution of CSPR and test various detection strategies.

E-203 Experimental apparatus (schematic)

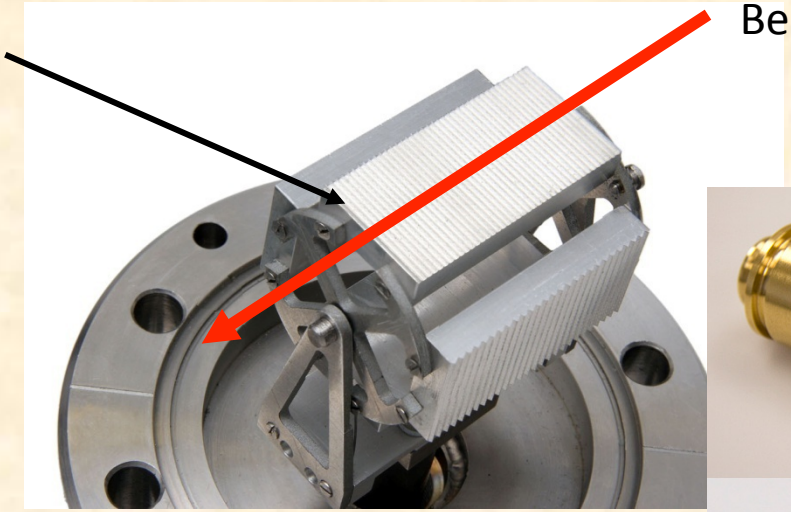




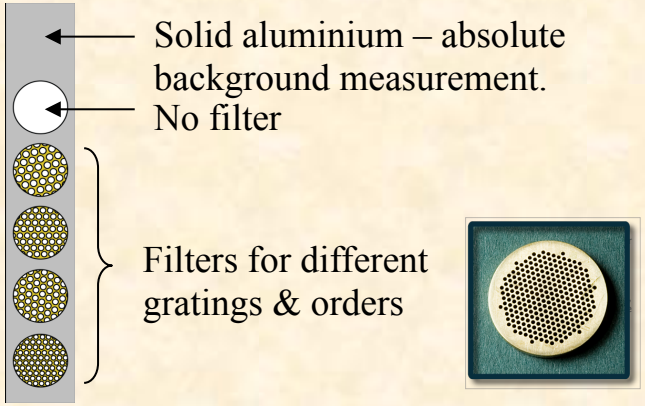


E-203 Experimental apparatus: gratings carousel

3 gratings
1 blank piece of aluminium

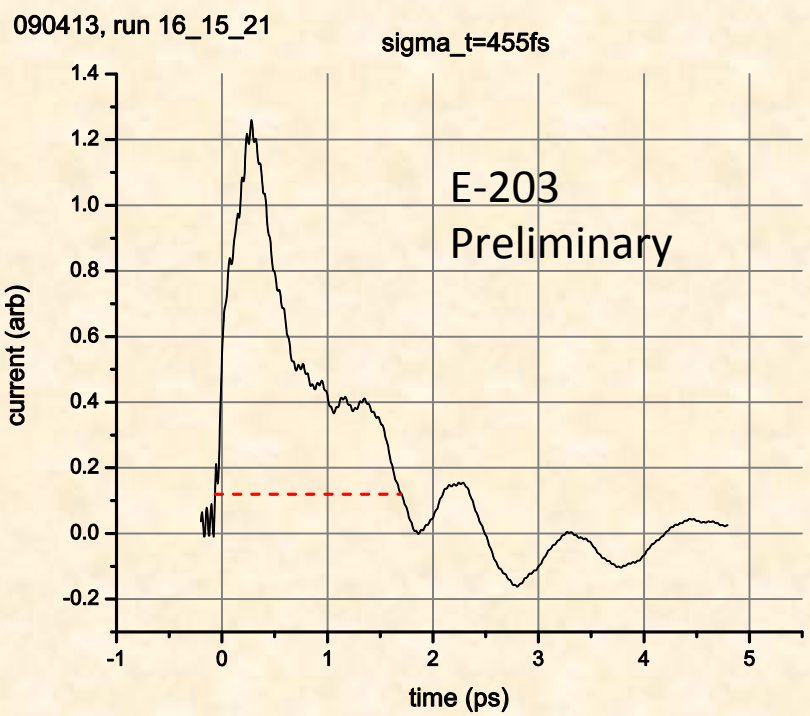


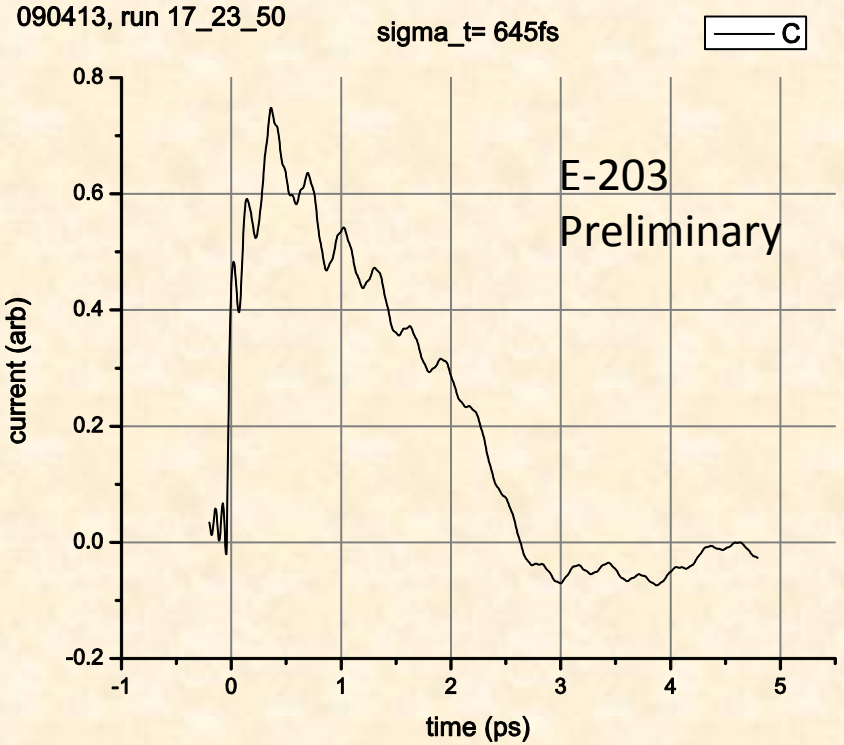
The carousel can rotate and offer three different gratings or one blank to the beam.



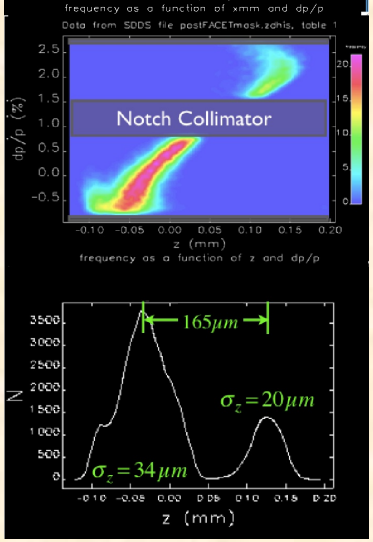
Example of recent results from E-203

At FACET it is possible to change the settings of the compression chicane to compare high compression settings (left) and low compression settings (right) .

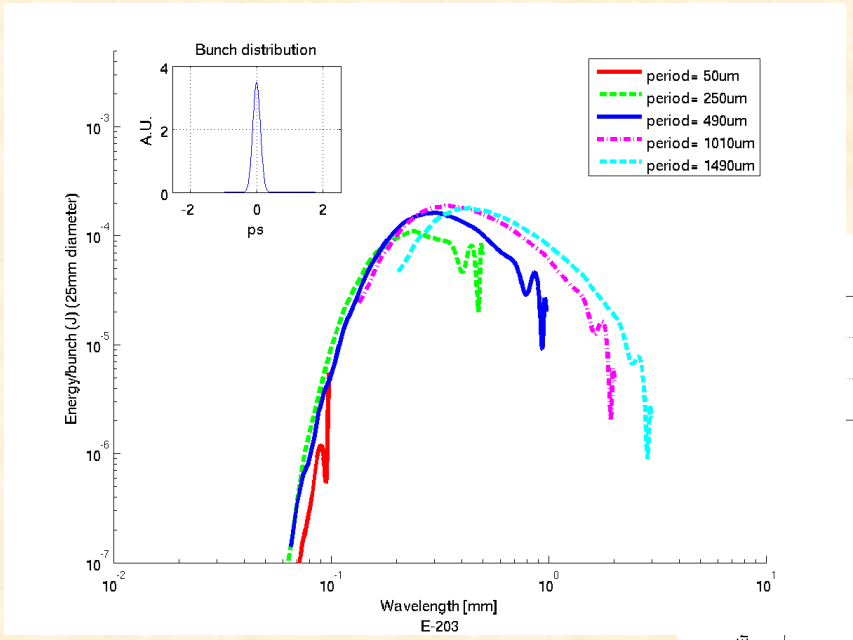


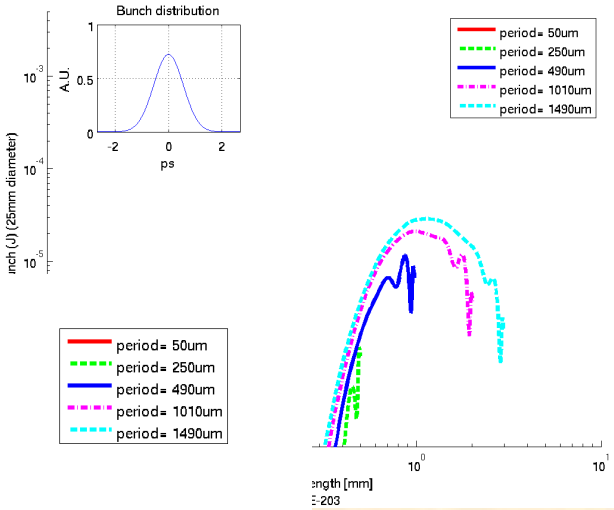


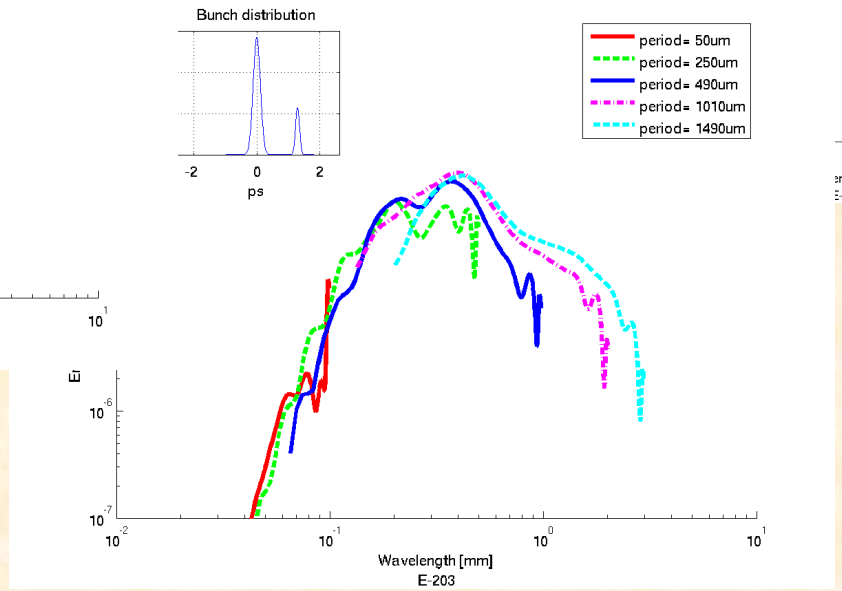
Future measurement
Notch collimator



- Simulations indicate that we should be sensitive to the effect of the notch. Measurements to come…





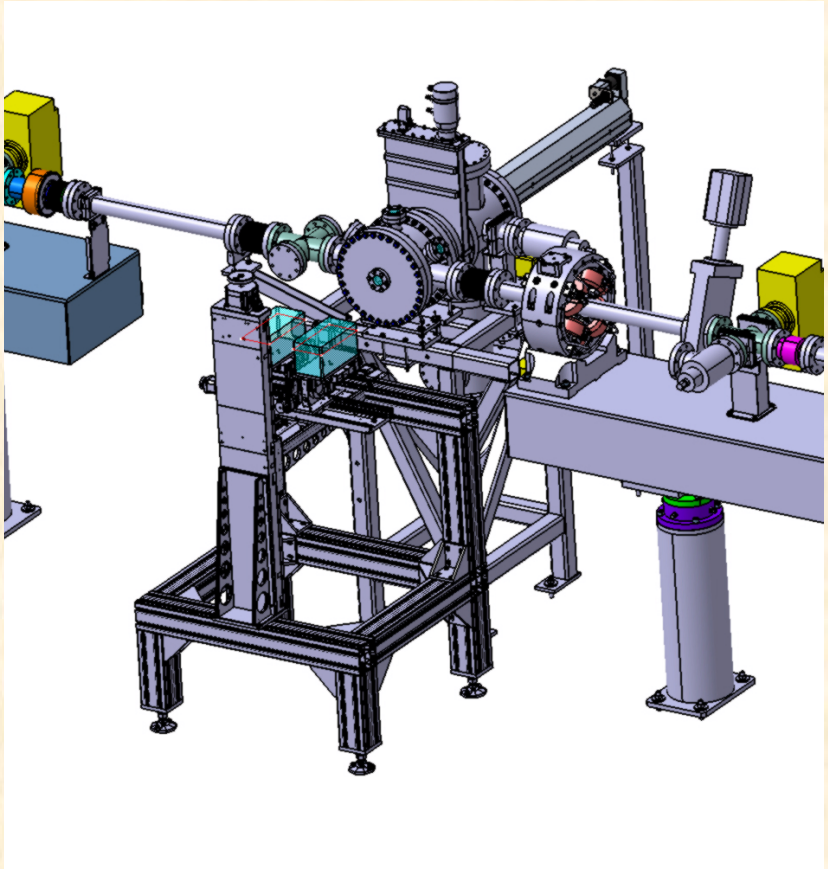


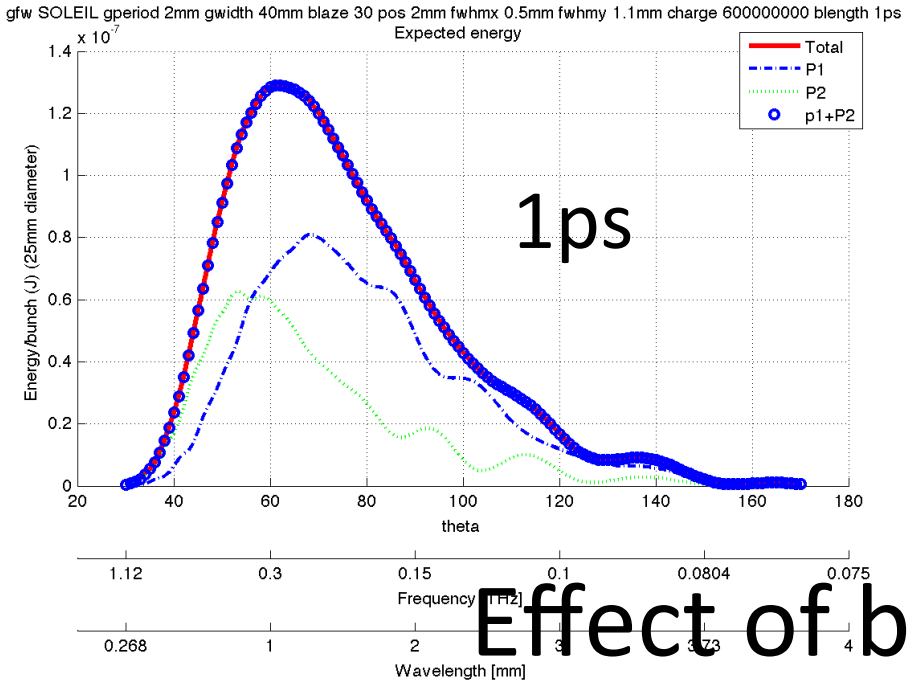
Toward single shot

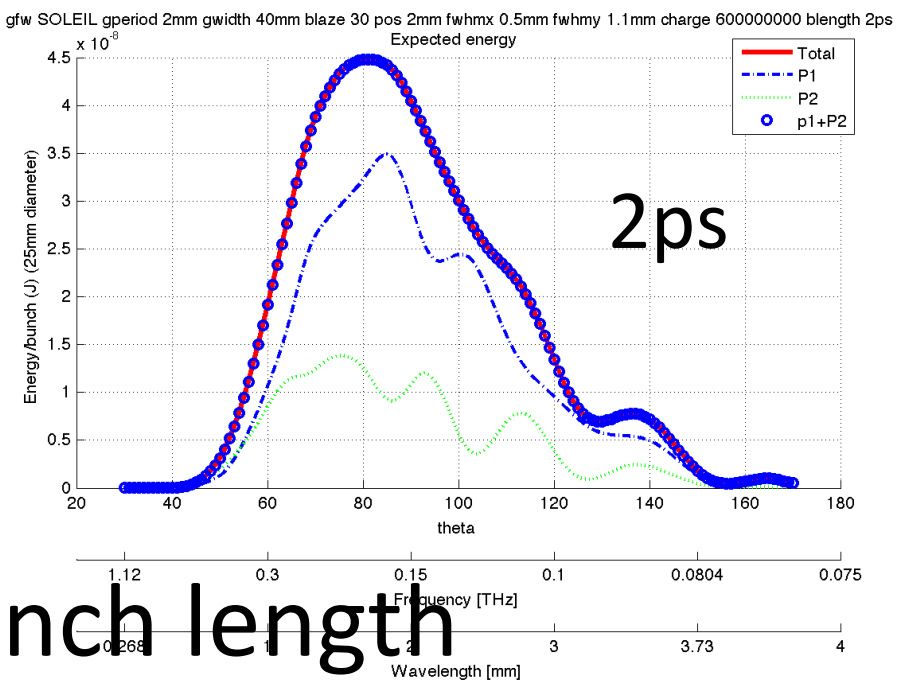
- At the moment our R&D has been mostly on classical accelerators.
- We do the background subtraction on a different shot than the signal measurement.
  => we need a strategy to get signal and background in the same shot.
- The get a good profile reconstruction it is also useful to use several gratings (better dynamic range)
  => need to develop a strategy to record signal from several gratings in a single shot.

SPESO: Smith Purcell Experiment at SOLEIL

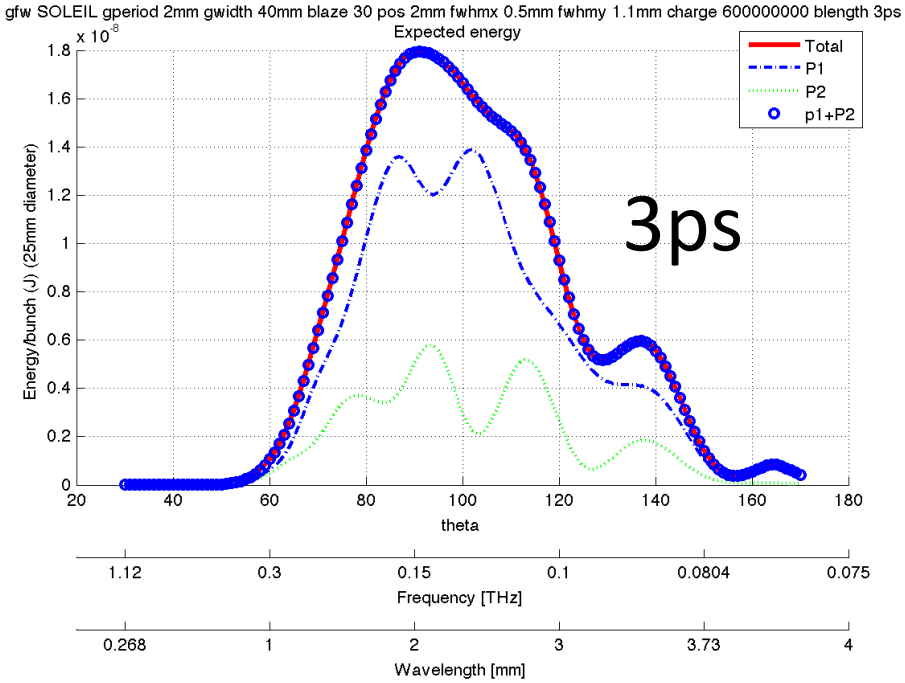
- To make a single shot measurement we need to be able to measure background and signal at the same time.
- => need to understand the 3D distribution of CSPR to find where to measure the background radiation. Polarisation measurements are also important.
- SPESO: 5D robot to scan the distribution of CSPR.
- Aim: build a single shot monitor, including background subtraction, based on CSPR in 2014.

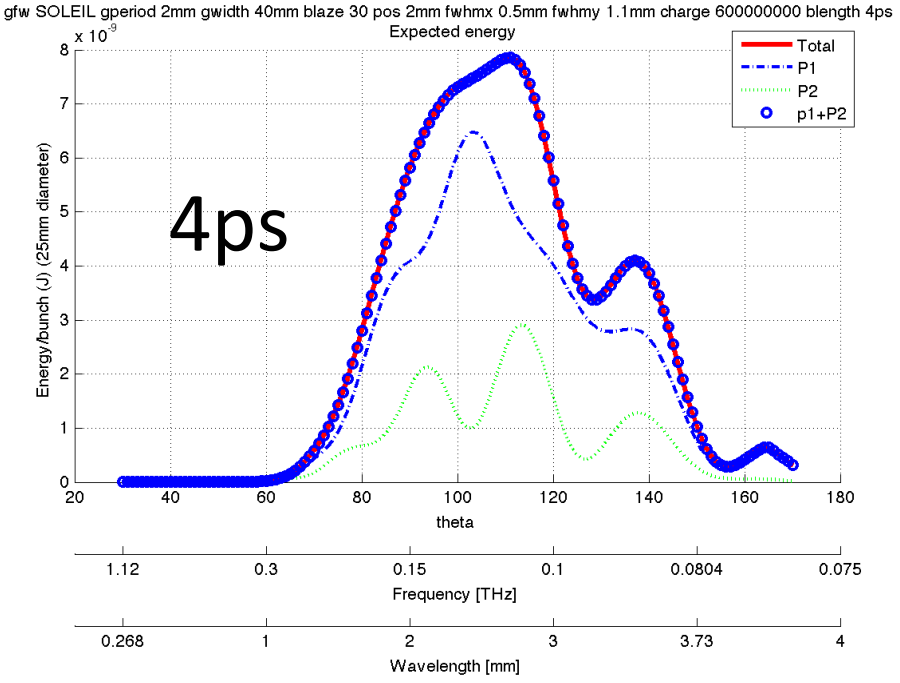




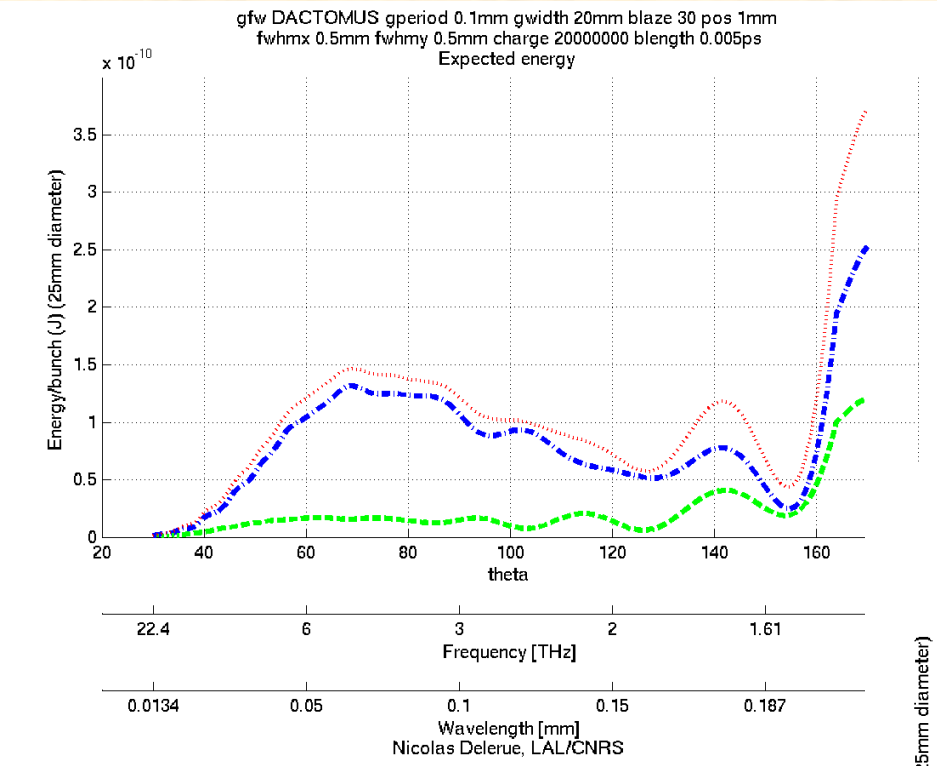


Effect of bunch length

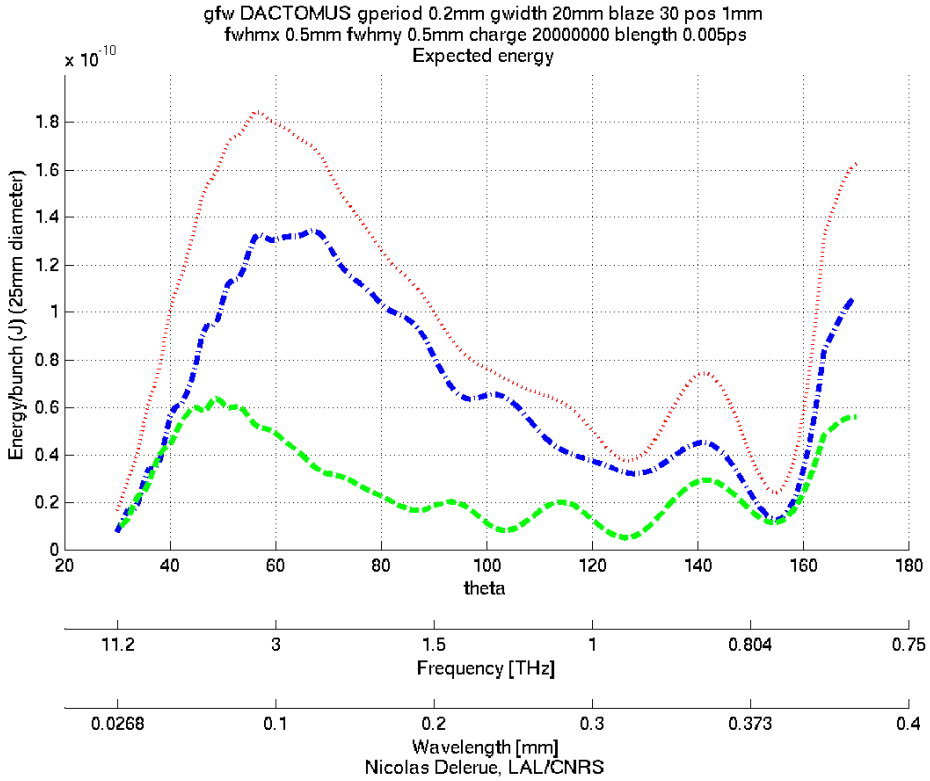




5fs bunch / 1pC



- Very low signal level => will require good amplification and background control.



Outlook

- CSPR can be used as a non interceptive longitudinal bunch profile diagnostic suited for the ps/fs range.
- Currently being tested on classical accelerators (FACET, SOLEIL,…).
- To make it a single shot diagnostic we need to find how to measure the background independently of the signal.
- Measurements to address this issue to start soon at SOLEIL.