WG5 SUMMARY

PART 2 ELECTRON BEAM DIAGNOSTIC

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TADPOLE for longitudinal electron-bunch diagnostics based on EO upconversion.

- Jan-Patrick Schwinkendorf
- Steffen Wunderlich, Bernhardt Schmidt and Jens Osterhoff

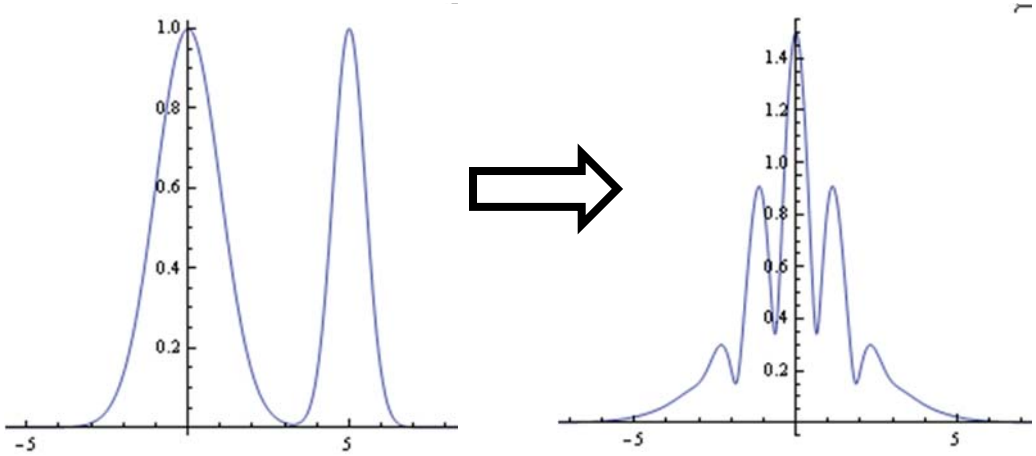
- FLA - Plasma Acceleration Group (http://plasma.desy.de)
- LAOLA Collaboration
- Deutsches Elektronen-Synchrotron DESY

TADPOLE for longitudinal electron-bunch diagnostics based on EO upconversion

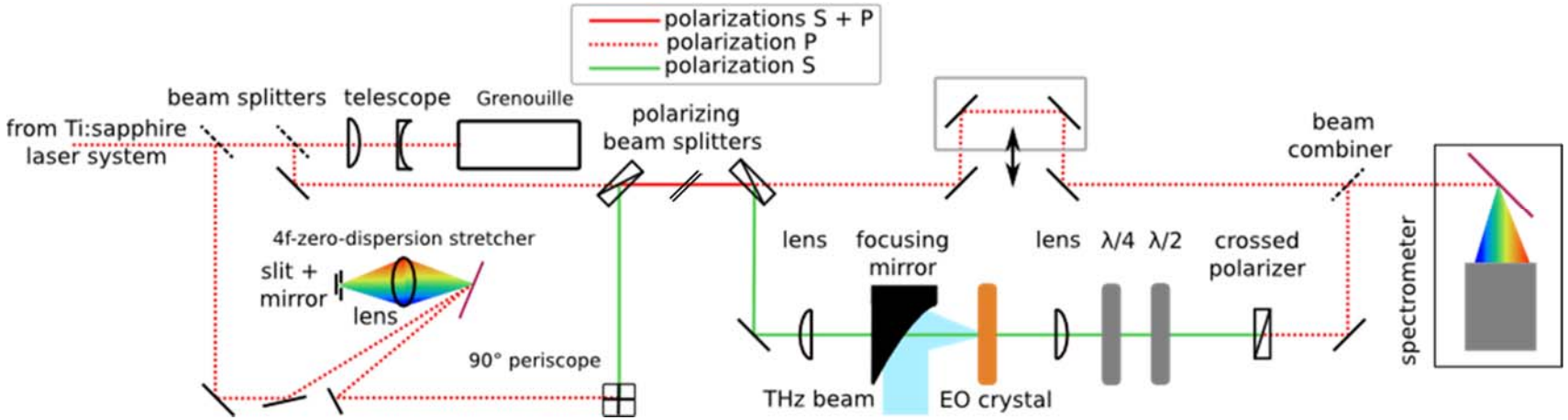
- Aim: measure phase to overcome phase retrieval e.g. via Kramers-Kronig relation
- Temporal Analysis by Dispersing a Pair Of Light E-fields (TADPOLE)

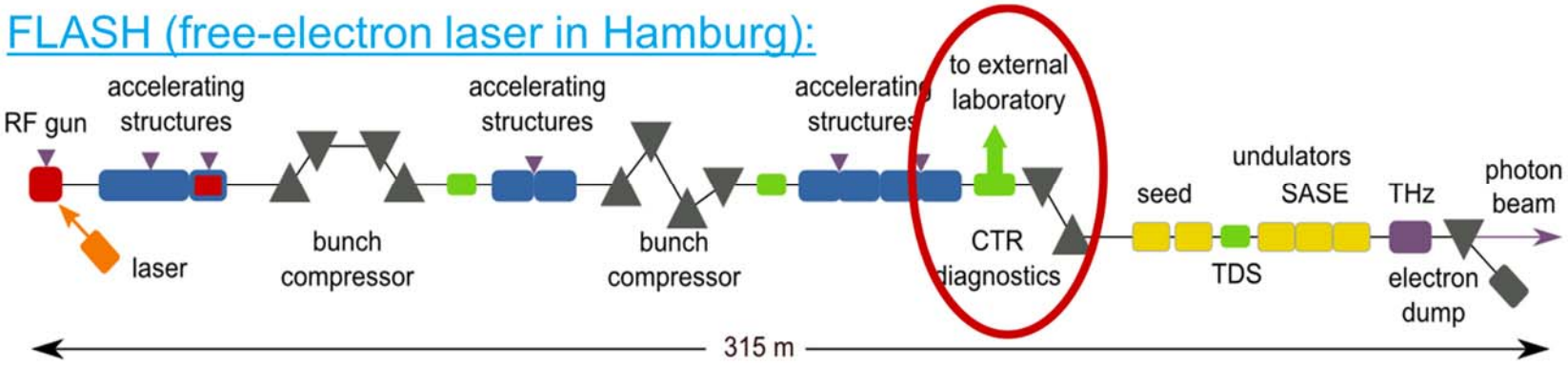
  =

  Spectral Interferometry + Frequency Resolved Optical Gating (FROG)
- $S_{SI}(\omega)=S_{ref}(\omega)+S(\omega)+2\,(S_{ref}(\omega)S(\omega))^{1/2}\cos(\varphi_{ref}(\omega)-\underline{\varphi(\omega)}+\omega T)$ *T*: temporal displacement
- EO upconversion:
- frequency-mixing leads to the generation of new spectral components:
  $E(\omega) \propto E_{THz}(\omega) * E_{opt}(\omega)$



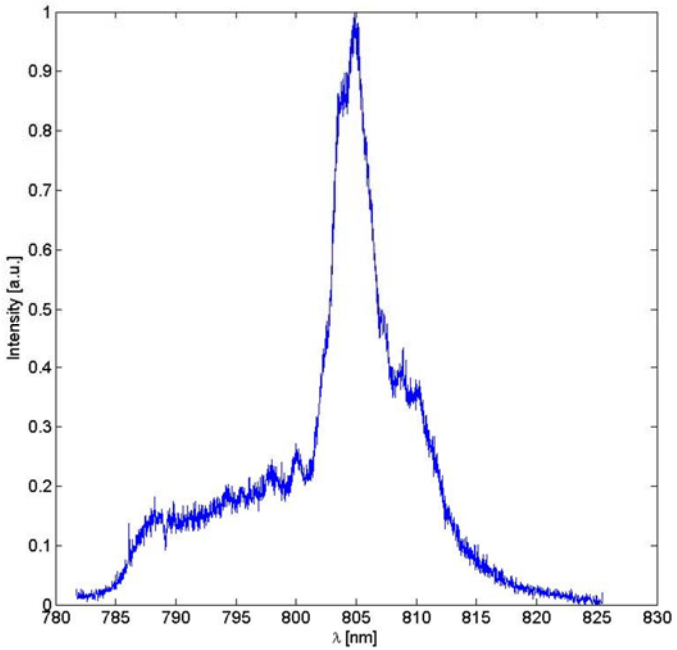
SETUP

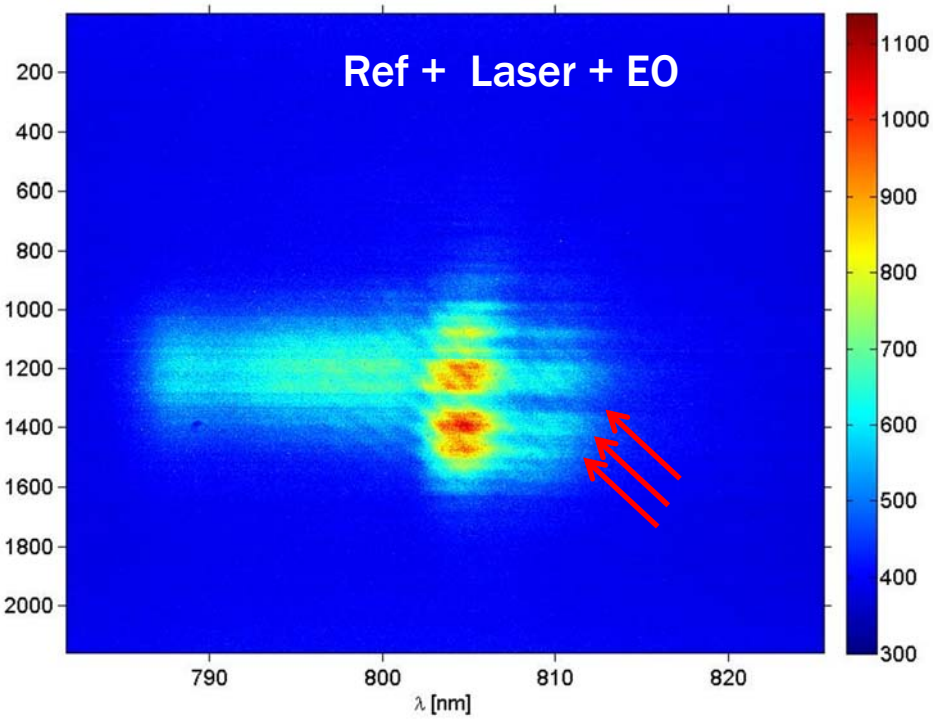

polarizations S + P
polarization P
polarization S
beam splitters
telescope
Grenouille
from Ti:sapphire laser system
polarizing beam splitters
beam combiner
4f-zero-dispersion stretcher
slit + mirror
lens
90° periscope
lens
focusing mirror
lens
λ/4
λ/2
crossed polarizer
spectrometer
THz beam
EO crystal


FLASH (free-electron laser in Hamburg):
RF gun
accelerating structures
accelerating structures
accelerating structures
to external laboratory
laser
bunch compressor
bunch compressor
CTR diagnostics
seed
undulators
SASE
TDS
THz
photon beam
electron dump
315 m

TADPOLE for longitudinal electron-bunch diagnostics based on EO upconversion

- Measurement with CTR (generated by e-bunch)
- Ongoing Data analysis





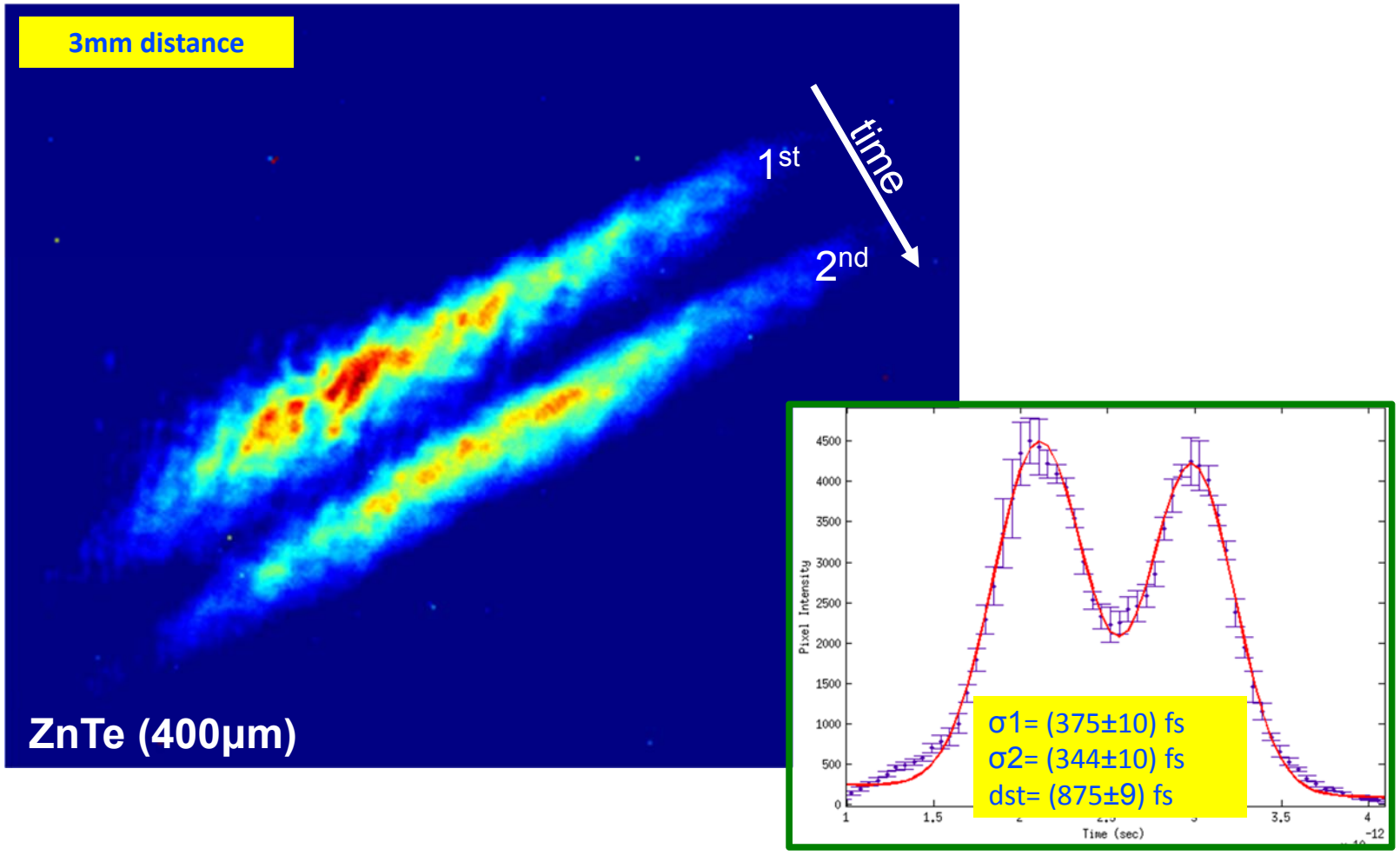
- Future: EO-interaction directly at e-beam to bypass CTR

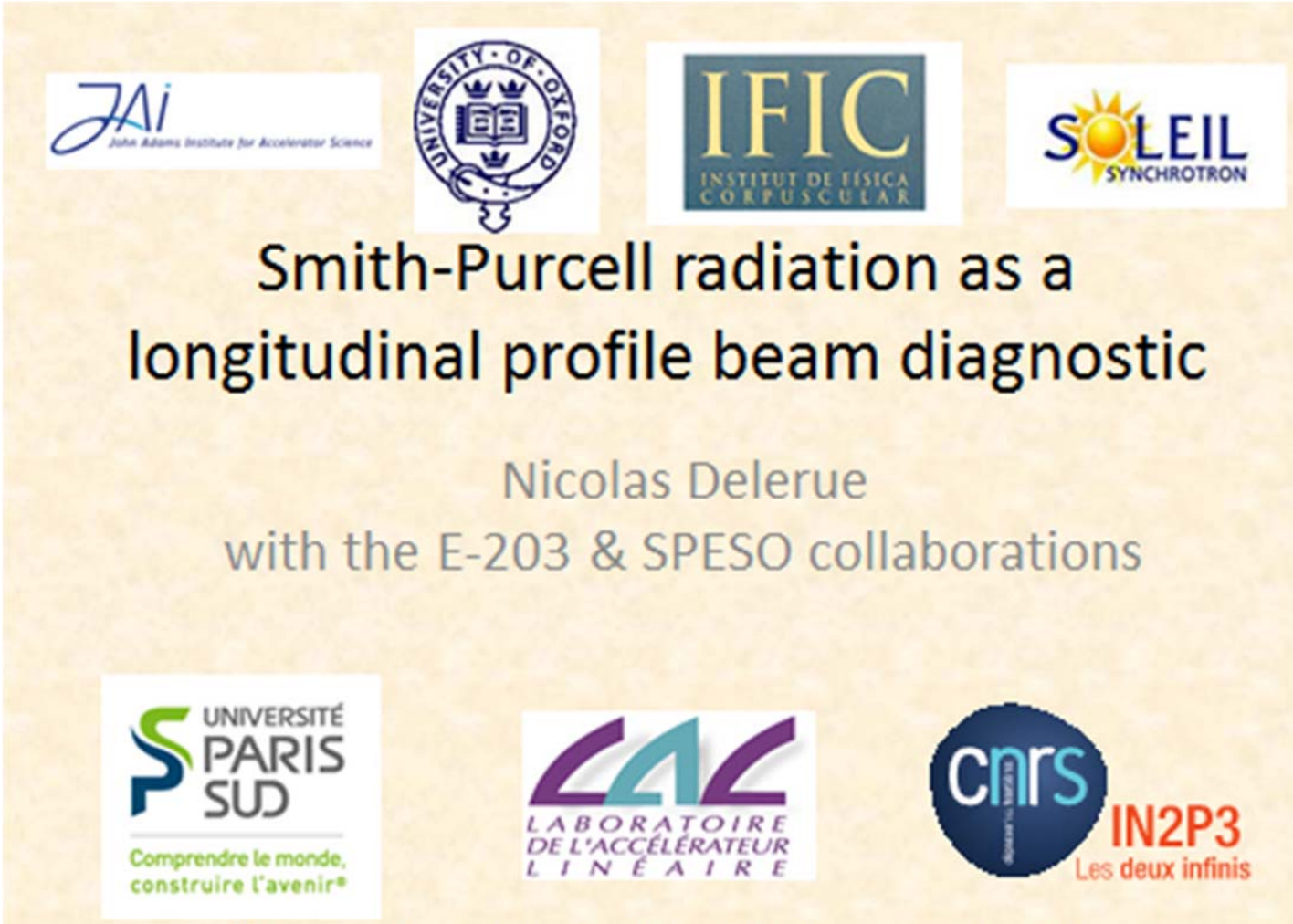
First single-shot and non-intercepting longitudinal bunch diagnostics for comb-like beam by means of Electro-Optic Sampling

- Riccardo Pompili
- University of Rome Tor Vergata and LNF

- PWFA: need to correlate incoming and outgoing beams from the plasma → non-intercepting & single-shot diagnostics for beams to be injected in plasma.
- Electro-Optical Sampling (EOS) to measure bunch longitudinal profile using nonlinear crystals (ZnTe, GaP).
- In spatial encoding Laser crosses the crystal with an incident angle of 30° → no high energy laser needed
- EOS @ SPARC_LAB uses the photocathode's laser →
  - No independent laser needed
  - Laser self synchonized with electron bunches
  - No intensified and Fast gated CCD camera needed
- With both ZnTe and GaP crystals electron beams consisting of two pulses (generated by Laser COMB technique) are measured
- Spacing measured with EOS well reproduces the RFD data.
  - Need some improvements (laser compressor, thinner crystals) to be able to measure ultrashort bunches
- Time Jitter evaluated to, in good agreement with what expected.

EOS ZnTe First Results




JAI
John Adams Institute for Accelerator Science
UNIVERSITY OF OXFORD
IFIC
INSTITUT DE FÍSICA CORPUSCULAR
SOLEIL
SYNCHROTRON
Smith-Purcell radiation as a longitudinal profile beam diagnostic
Nicolas Delerue
with the E-203 & SPESO collaborations
UNIVERSITÉ PARIS SUD
Comprendre le monde, construire l'avenir®
LAL
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE
cnrs
IN2P3
Les deux infinis
Work supported by seed funding from Université Paris-Sud, program « Attractivité »,
University of Oxford, John Fell Fund and by the ANR (France) under contract ANR-12-JS05-0003-01.

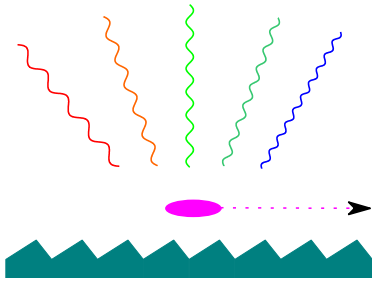
Coherent Smith-Purcell radiation as a longitudinal diagnostic

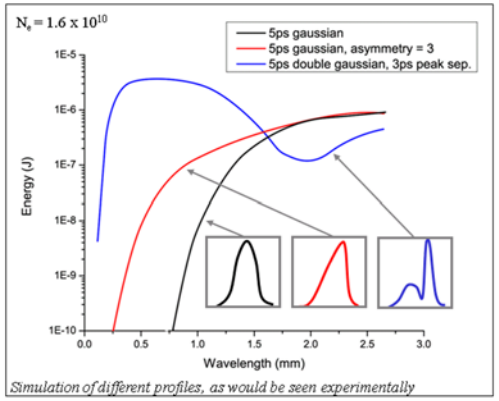
2 collaborations working on CSPR as a single shot bunch length diagnostics in the fs range:

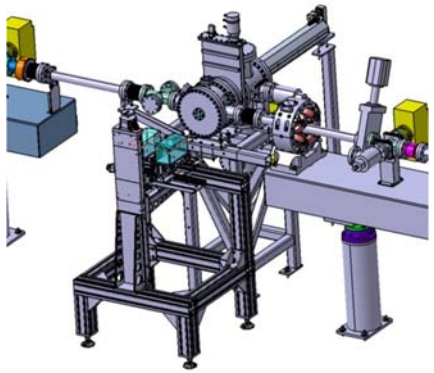
- E-203 (Oxford, SLAC et al.) at FACET
- SPESO (LAL, SOLEIL et al.) at SOLEIL

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

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



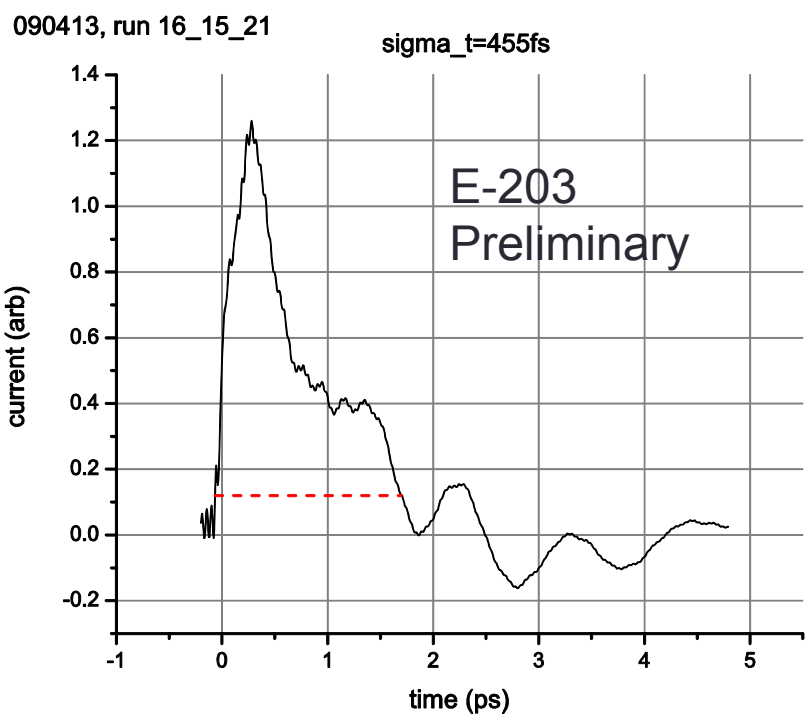


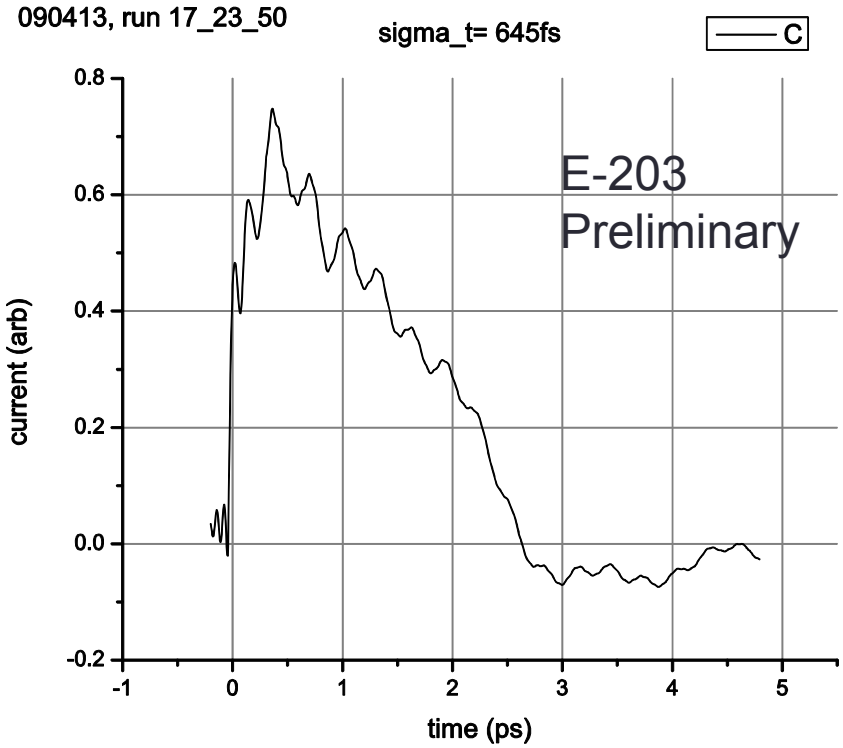


$$\left(\frac{dI}{d\Omega d\omega}\right)_{N_e}(\Omega,\omega) \approx \left(\frac{dI}{d\Omega d\omega}\right)_{sp}(\Omega,\omega)\cdot\left[N_e + N_e(N_e-1)\,|F(\omega)|^2\right]$$

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).





Pickup design for arrival-time measurements at REGAE

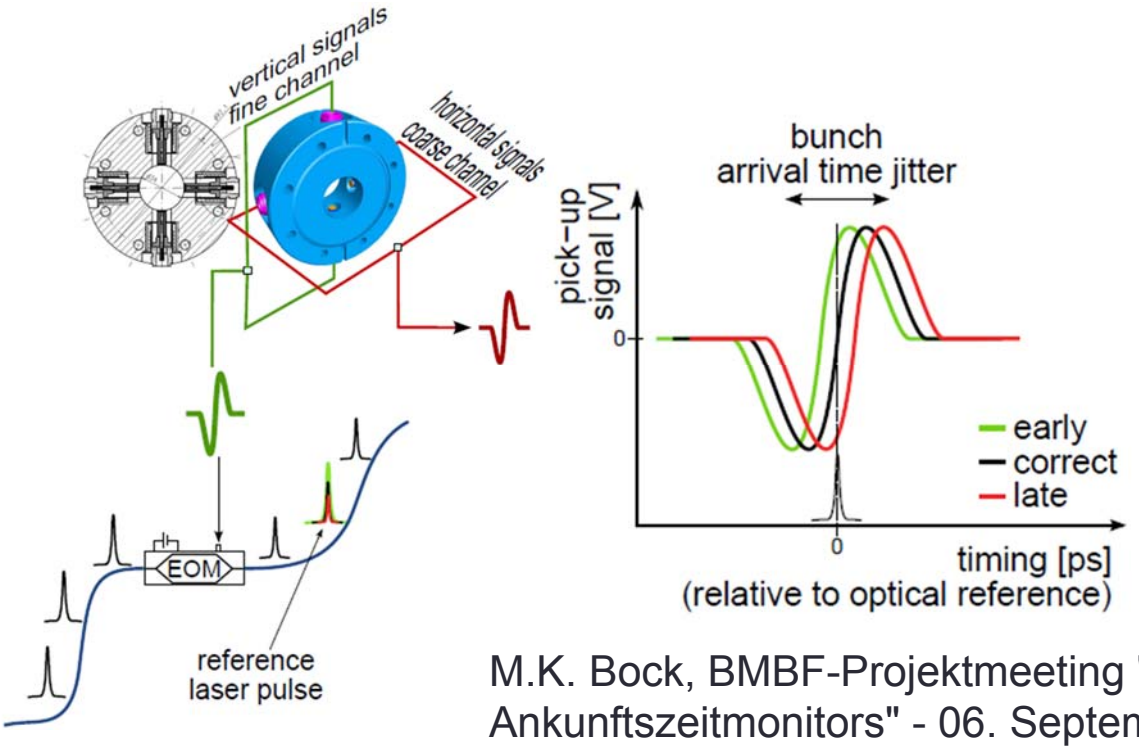
- A. Angelovski,[1] M. Hansli,[1] I. Dornmair,[2,3] B. Zeitler,[2,3] A. Penirschke,[1] F. Grüner[2,3] and R. Jakoby[1]

[1] Technische Universität Darmstadt, Institute for Microwave Engineering and Photonics

[2]Center for Free-Electron Laser Science, [3]University of Hamburg

Arrival-time measurement techniques BAMs at FLASH

- **Bunch Arrival-time Monitors (BAMs) at FLASH**
  - **Electro-optical detection scheme**
  - **Sub-10 fs time resolution for bunch charges higher than 100 pC**



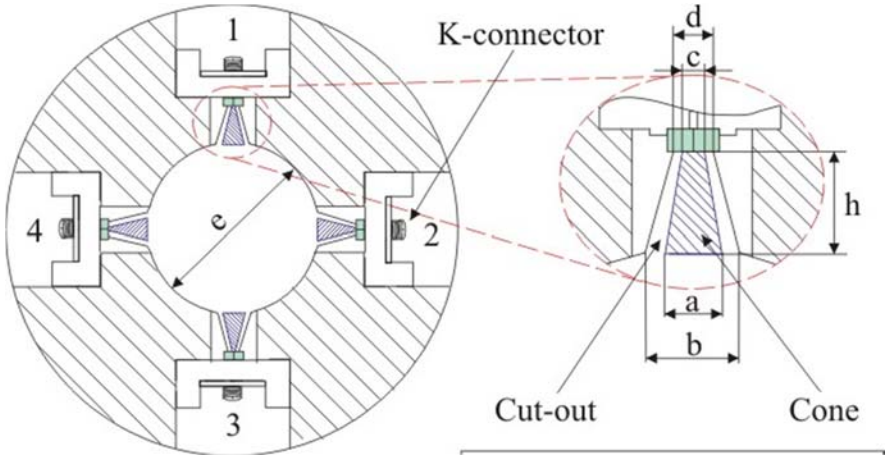
➔ **The arrival-time of the electron bunch is encoded onto the laser pulse amplitude**

M.K. Bock, BMBF-Projektmeeting "Weiterentwicklung eines Ankunftszeitmonitors" - 06. September 2010

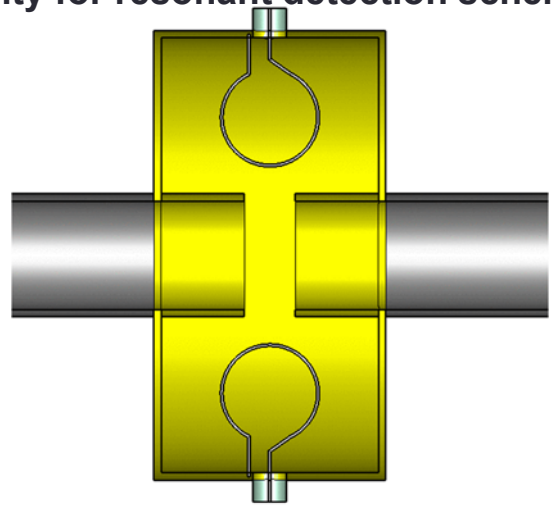
Pickup design for arrival-time measurements at REGAE

- High quality electron bunches from Relativistic Electron Gun for Atomic Exploration - REGAE for laser-driven wakefield
  - Synchronization between the driving laser and electron bunch in order of 10 fs
- Two detection schemes for arrival time measurement: Resonant and Broadband
- Very low bunch charges of 100 fC ➔ Small induced pickup voltage
  - Optimization of the pickups for maximum induced pickup signal

Cone-shaped pickups for broadband detection scheme



Cavity for resonant detection scheme



Laserwire: high resolution non-invasive beam profiling for advanced accelerators

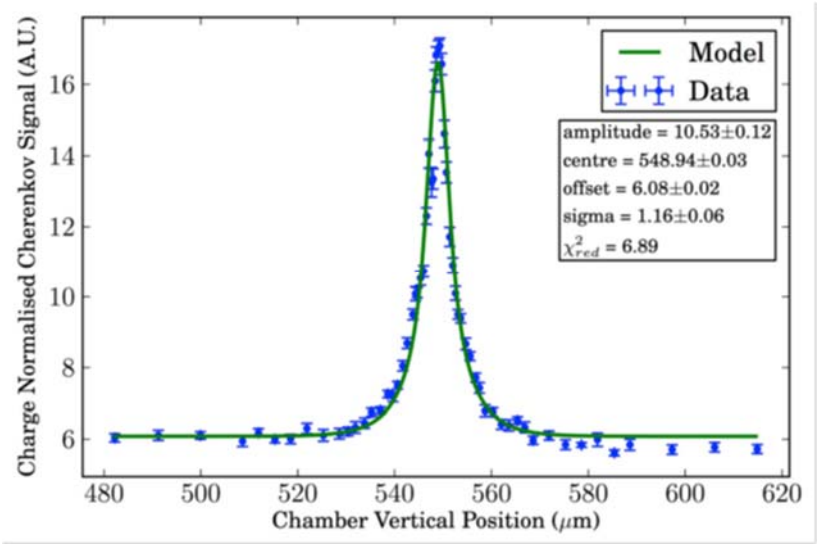
L. J. Nevay, S.T. Boogert, P. Karataev, K. Kruchinin,
JAI @ RHUL, Egham, UK

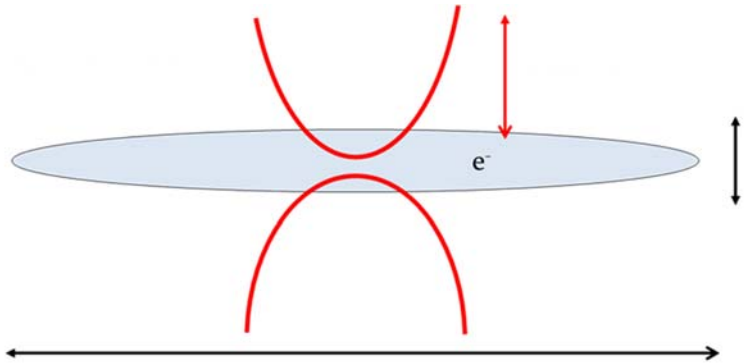
L. Corner, R. Walczak,
JAI @ Oxford University, UK

G. Blair,
STFC, UK

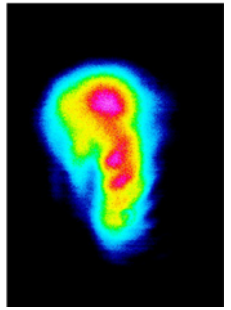
A. Aryshev, N. Terunuma, J. Urakawa,
KEK, Japan

ATF2 laserwire





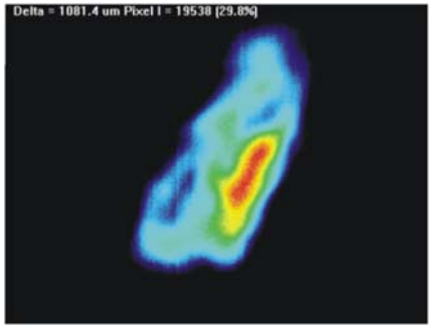
Despite a large electron beam aspect ratio and poor laser spatial quality, the laserwire at the ATF2 at KEK has consistently and accurately measured beam sizes of 1 μm.



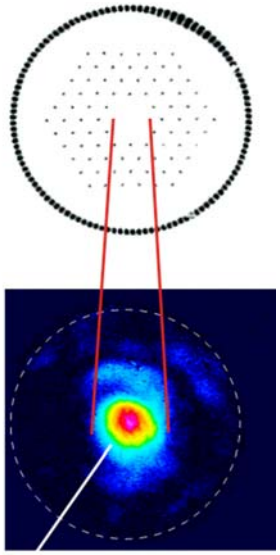
L. Corner et. al., JAI @ RHUL, Oxford and KEK.

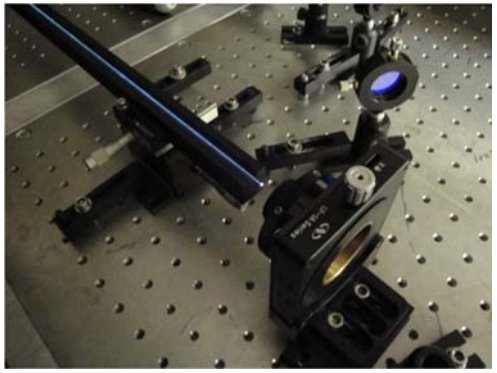
Laser improvements

- Laser at the ATF not completely suitable for laser-wire.
- Poor spatial quality – larger focus, worse resolution.
- Temporal profile (77 ps) not ideally matched to electron bunch (30 ps).
- Inefficient (flashlamp pumped), limited in repetition rate – no intratrain scanning.



Project in Oxford to develop new fibre laser system for laserwire.





Fibres: efficient, waveguides, excellent spatial mode quality, high repetition rate, diode pumped, no active cooling.

Standard SM fibre amplifiers – low energy. Solution – very large mode area photonic crystal fibre – still single mode, energy 100uJs/pulse.

ISSUES WITH PHASE SPACE CHARACTERIZATION OF LASER-PLASMA GENERATED ELECTRON BEAMS

A. Cianchi
University of Rome “Tor Vergata”and INFN

Geometrical vs Normalized

$$\varepsilon_n^2 = \left\langle x^2 \right\rangle \left\langle \beta^2 \gamma^2 x'^2 \right\rangle - \left\langle x \beta \gamma x' \right\rangle$$

$$\sigma_E^2 = \frac{\left\langle \beta^2 \gamma^2 \right\rangle - \left\langle \beta \gamma \right\rangle^2}{\left\langle \gamma \right\rangle^2}$$

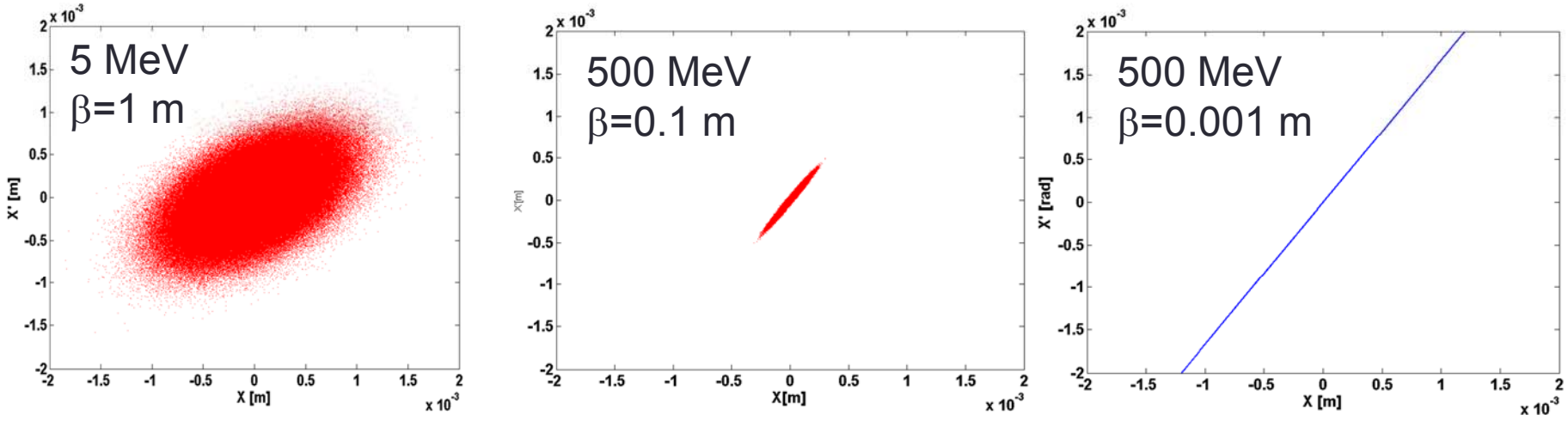
$$\varepsilon_n^2 = \left\langle \gamma \right\rangle^2 \sigma_\varepsilon^2 \left\langle x^2 \right\rangle \left\langle x'^2 \right\rangle +$$

$$+ \left\langle \beta \gamma \right\rangle^2 \left(\left\langle x^2 \right\rangle \left\langle x'^2 \right\rangle - \left\langle x x' \right\rangle^2 \right)$$

$$\varepsilon_n^2 = < \gamma >^2 \left(\sigma_\varepsilon^2 \sigma_x^2 \sigma_{x'}^2 + \varepsilon^2 \right)$$

P. Antici, et al., Journal of Applied Physics 112, 044902 (2012)

Pepper pot limits

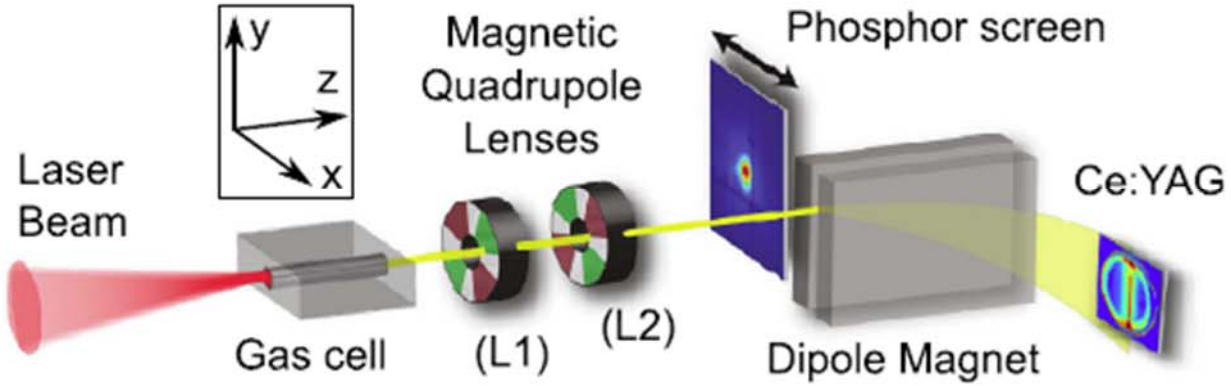


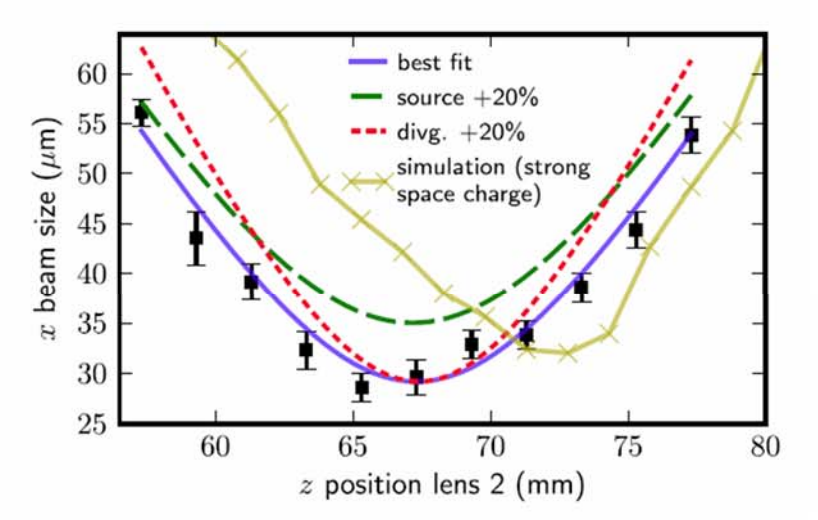
Simulations clearly show that when your phase space is so thin the result is meaningless

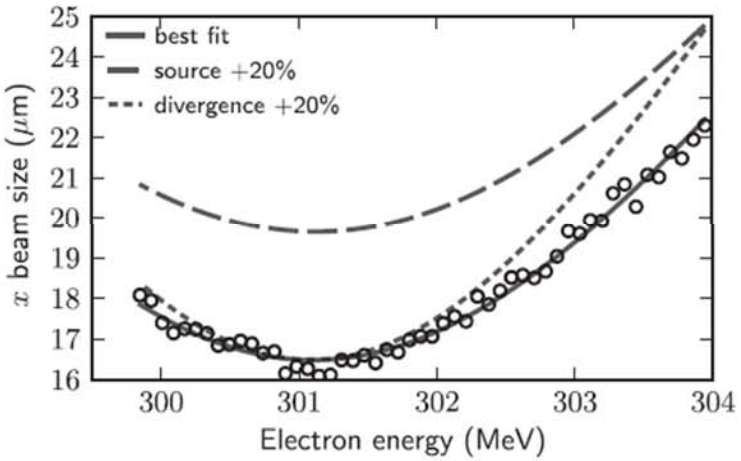
Alternatives:

- Single shot:
  - Multiple screens
    - Good only for GeV beams
    - Need a magnetic optics
  - Betatron radiation
    - The spectroscopy has sometimes the limit that a PIC code must be run in order to compare results with model
    - Diffraction from an edge gives an insight of the original dimension of the beam
- Multi shot
  - Quadrupole scan
    - Chromatic effect under control if the beam size is still small
    - First measurement of quad scan with permanent magnets is interesting.

A new kind of Quadscan







- R. Weingartner and al., PRST-AB 15, 111302 (2012),

Conclusions

- A lot of very interesting material
- Really fruitful discussions
- Nice preliminary and encouraging results

- Please keep in contact!!!!
- It is important to share results and to exchange information not only in the workshops.

- Thanks to all the speakers and participants