- Beam dynamics and Instrumentational Challenges at CLIC Daniel Schulte
- Beam Dynamics and Instrumentational Challenges in the X-FEL T. Limberg, DESY

Beam dynamics and Instrumentational Challenges at CLIC   Daniel Schulte

More ambitious than other projects

Smaller emittance

Shorter beam

Higher energy

Drive beam

High intensity

Long pulse

Low energy

Challenges CLIC

- Pulsed operation: short trains of bunches separated by long gaps
  - Need resolution within a bunch train
    - Correction of static effects
  - Feedback/forward
    - Correction of pulse to pulse jitter
  - Instrumentation needs to be fast

Comments

- Pre solved
  - Gradient
- Difficult to prove fully
  - Laser wire
- Rely on simulations
  - Emittance preservation

Main beam

- Studies
  - Beam generation
  - Small emittance in damping ring
  - Emittance preservation during transport
  - Luminosity
- Needs Integrated Studies
  - Banana effects, linac tuning, Dynamic and static imperfections,

Drive Beam

- Stable RF   error < 0.15º
- Reasonable losses

- Integrated Studies
  - Longitudinal stability
  - Stability and losses

Drive Beam Challenges

- Injector
- Accelerator
- Bunch compressor
- Delay loop combiner
- Beam transport
- Deaccelerator
- Collimation
- Feedback systems

Conclusion

- Drive beam simulations
  - RF stability
  - Low losses
- Main Beam Simulations
  - Luminosity
  - Backgrounds
  - Machine protection
- Instrument design is critical

Beam Dynamics and Instrumentational Challenges in the X-FEL

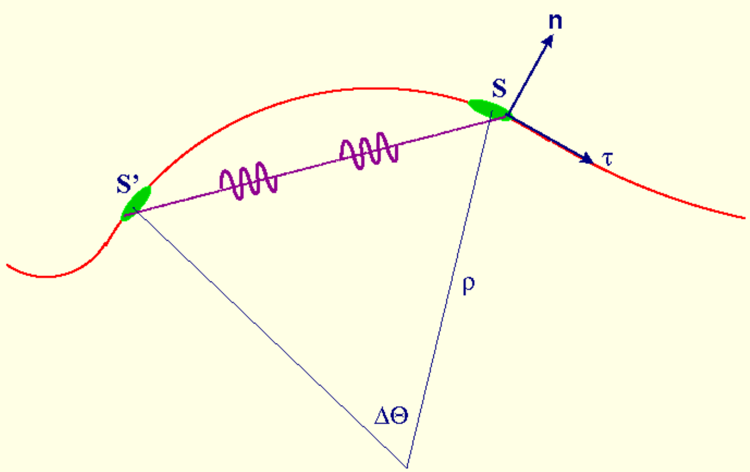
T. Limberg, DESY

Performance Goals for Electron Beam

Parameter	Value
beam energy	20 GeV
emittance (norm.)	1.4 mrad x mm
electron bunch charge	1 nC
electron bunch length peak current	80 fs 5 kA
uncorrelated energy spread	2.5 MeV rms

`Overtaking Fields´ lead to Coherent Synchrotron Radiation

Background (CNT'D)



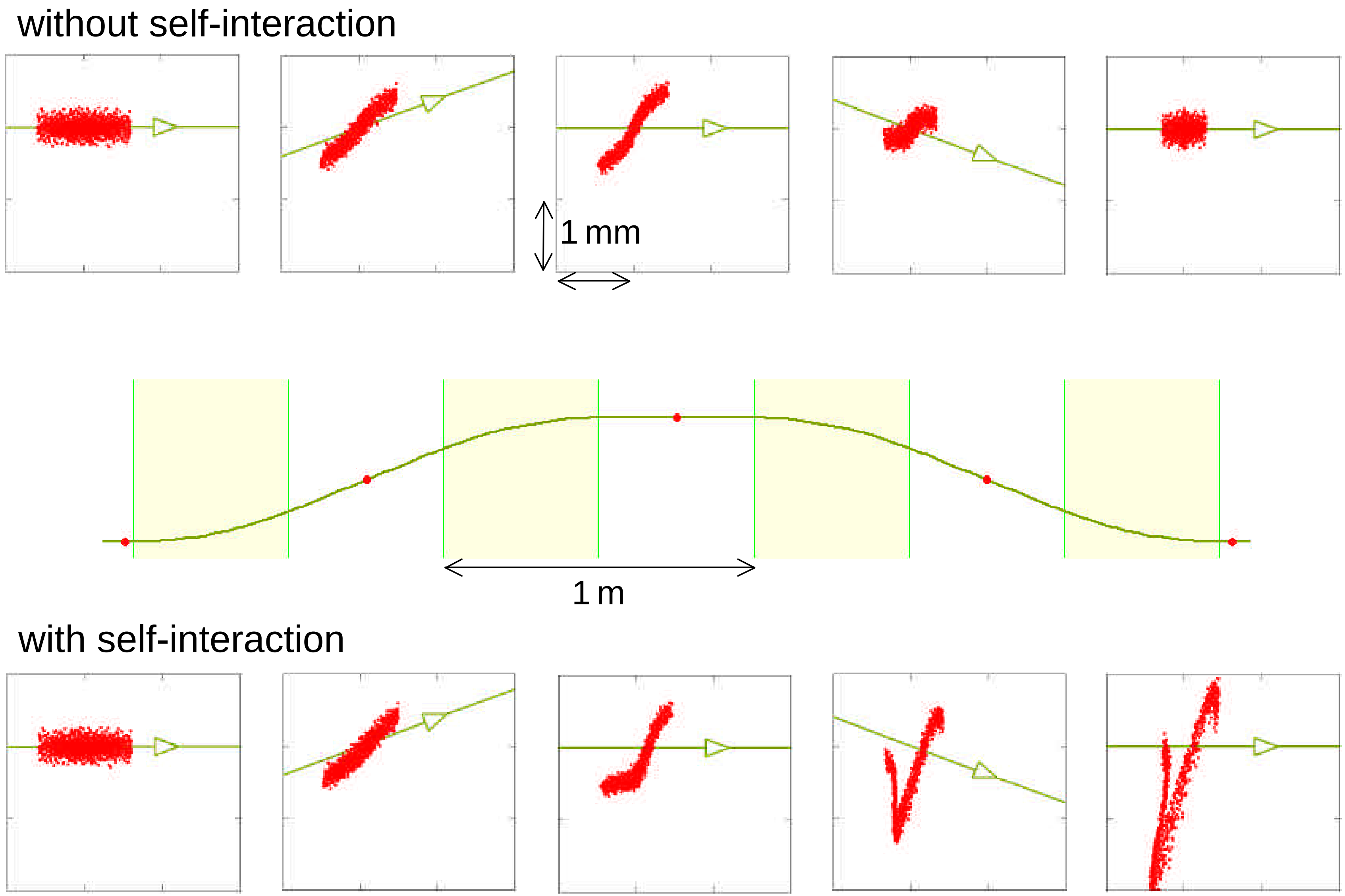
- radiation emitted at a retarded time can interact with e- ahead in the bunch.

S e- bunch at present time

S' e- bunch at retarded time

- interaction effective if bunch travel on a curved path for a distance $> L_o \simeq (24\sigma_z\rho)^{1/3}$ self-interaction via field component with $\lambda \sim \sigma_z$.

- NA: TTF1, ρ=1.6 m, $\sigma_z = 250\mu$m, $L_o \sim 0.25\mu$m so $L_o >$ path length in bend.



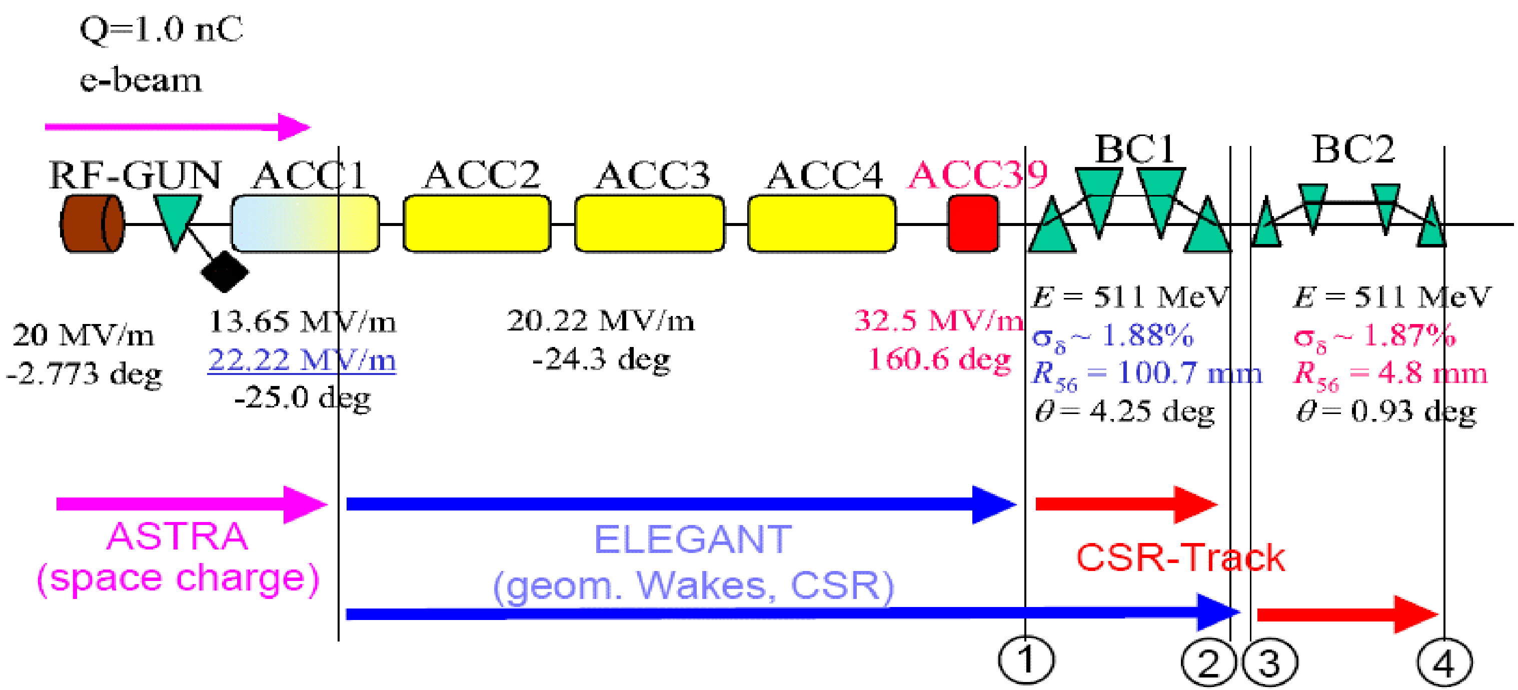
without self-interaction
1 mm
1 m
with self-interaction

Start-to-End (S2E) Simulations

- Beam dynamics for the high intensity bunches of a SASE FEL driver linac is dominated by self-induced fields:
  - Coherent Synchrotron Radiation Fields
  - Space Charge Fields
  - Wake Fields

  As all these depend on details of the longitudinal bunch profile and there is no ‘memory-erasing’ device like a damping ring, we need to trace the bunch from cathode to undulator.

S2E for XFEL



1 entrance of BC1 ASTRA/ELEGANT calculation with 200000 particles by Y.Kim
2 exit of BC 1
3 entrance of BC2 ASTRA/ELEGANT calculation with 200000 particles by Y.Kim
4 exit of BC2

Instrumentational Challenges

- Timing and Synchronization Accuracy and Measurement
- Precise Longitudinal Profile Measurement
- Measure Beam Parameters vs. longitudinal position
- The Deterministic Network Enhancer

Instrumentation and Diagnostics

9:00	Single-shot longitudinal profile characterisation of 500fs electron bunches	Steven Jamison
9:25	First results from FELIX of a Smith-Purcell longitudinal profile monitor	George Doucas
9:40	Confocal Resonator BPM	Volker Ziemann
10:05	Precision measurements of beam current, position and phase for an e+e- linear collider	Roberto Corsini
10:35	Precision Energy Spectrometry	David Miller
11:00	Coffee	
11:25	Measurement of the beam polarisation from annihilation data	Klaus Moenig
11:50	Laser-Based Profile Monitor	Grahame Blair
12:15	Hilbert spectroscopy as a tool for pulsed electron beam diagnostics	Ulrich Poppe
12:40	Electron beam diagnostics at ELBE	Pavel Evtushenko

13:05 Discussion

"EUROTeV" Instruments

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ELAN

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ELAN

Instrumentation and Diagnostics

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9:25	First results from FELIX of a Smith-Purc... longitudinal profile monit...	...rge Doucas
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10:0...	... position ... der	Roberto Corsini
10:3...	Precision Ener... ...metr...	D...
11:00	Coffee	
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11:50	Laser-Based Pro...	Grahame Blair
12:15	Hilbert sp... as a tool for pulsed electron ...stics	Ulrich Poppe
1...	... beam diagnostics at ELBE	Pavel Evtushenko

13:05 **Discussion**

Covered issues related to 8 out of 8 EUROTeV Diagnostic Instruments!

Longitudinal Profile Monitoring

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Single-shot longitudinal profile characterisation of 500fs electron bunches

Steven Jamison

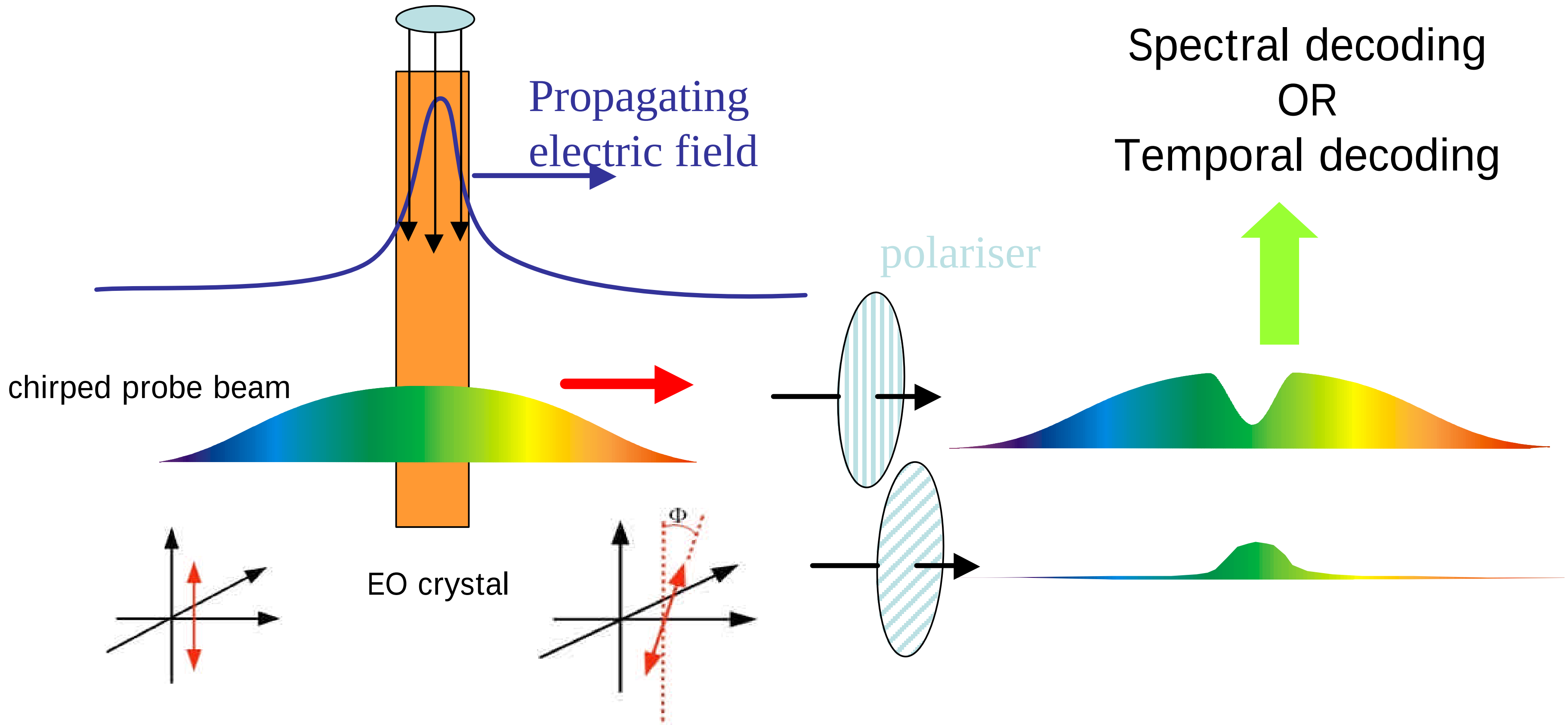
- Single-shot electro-optic detection of ultra-short bunches
  - spectral-decoding
  - temporal decoding

- FELIX electron bunch measurements

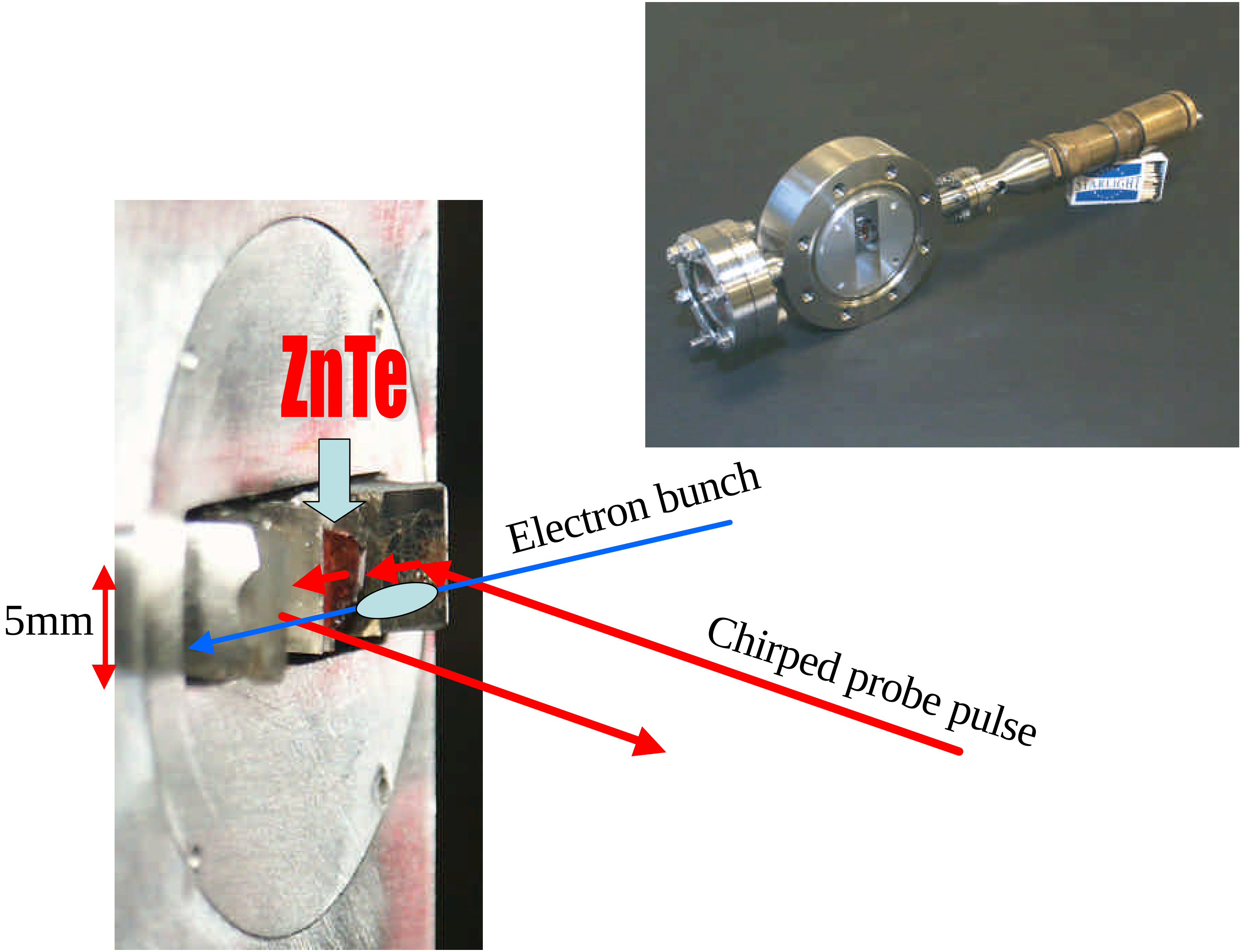
  real time bunch profile adjustment
  bunch timing jitter
  charge dependence

- Sub-100fs bunch diagnostic ?

Single-shot EO measurement of Coulomb field

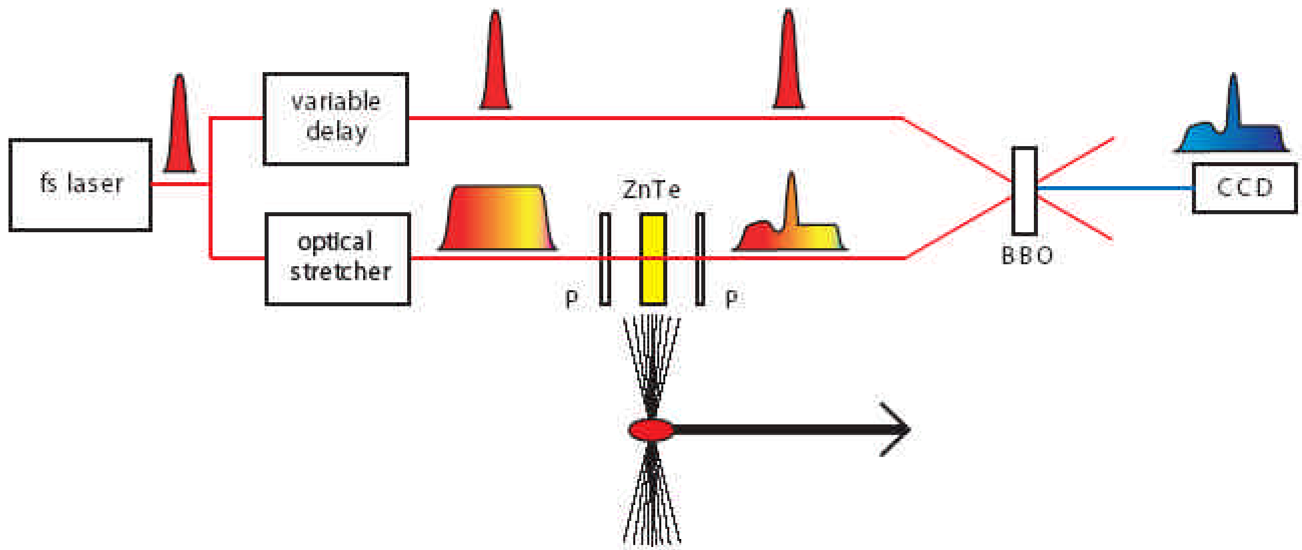


Effective polarisation rotation proportional to coulomb field


ZnTe
Electron bunch
5mm
Chirped probe pulse

(Temporal decoding)

Electro-optic detection of Coulomb field: 'Cross correlation method'

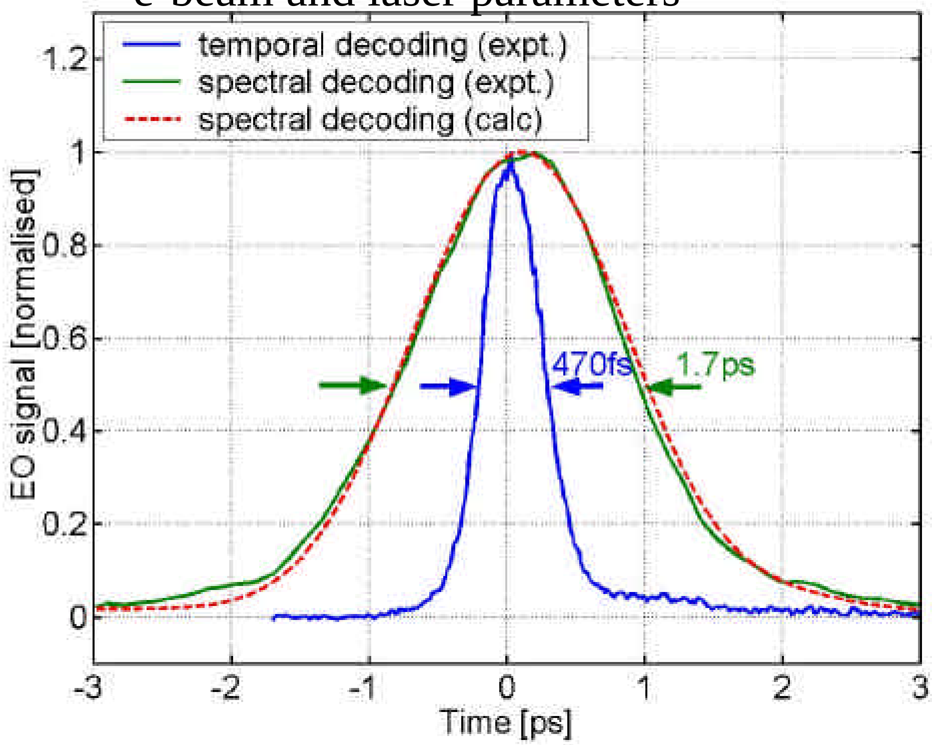


Temporal to spatial mapping of optical probe pulse

- Avoids problems of inseparability of frequency-time
- *Decoding* time-resolution ~ 30fs

Comparison of temporal and spectral decoding at FELIX

contemporaneous measurements with identical e-beam and laser parameters



(Data from December 2003)

Confirms time resolution improvements of TD technique

Degradation of SD signal in excellent agreement with calculation

NO free parameters in SD calculation – based on bunch profile inferred from TD and measured laser parameters.

Need even better time-resolution….

(measuring sub-200fs bunches) .

Optical spectrum-envelope interdependence	>300fs bunch duration limitation Solved by envelope-cross-correlation ~30-50fs possible (?)
EO phase matching	>200fs limitation for undistorted measurement Rigorous retrieval of true field possible
EO crystal absorption	Alternative EO materials. (GaP, GaSe, DAST…) Approximate interpolation… ~30fs possible (?)
Coulomb field angle	100 MeV electrons $\Rightarrow$ ~ 30 fs @ 1 mm distance Improves with higher energy beams
Optical bandwidth	Time resolution approx. optical pulse duration. ~30 fs. Improvements through X-FROG, ….?

First results Smith Purcell from FELIX

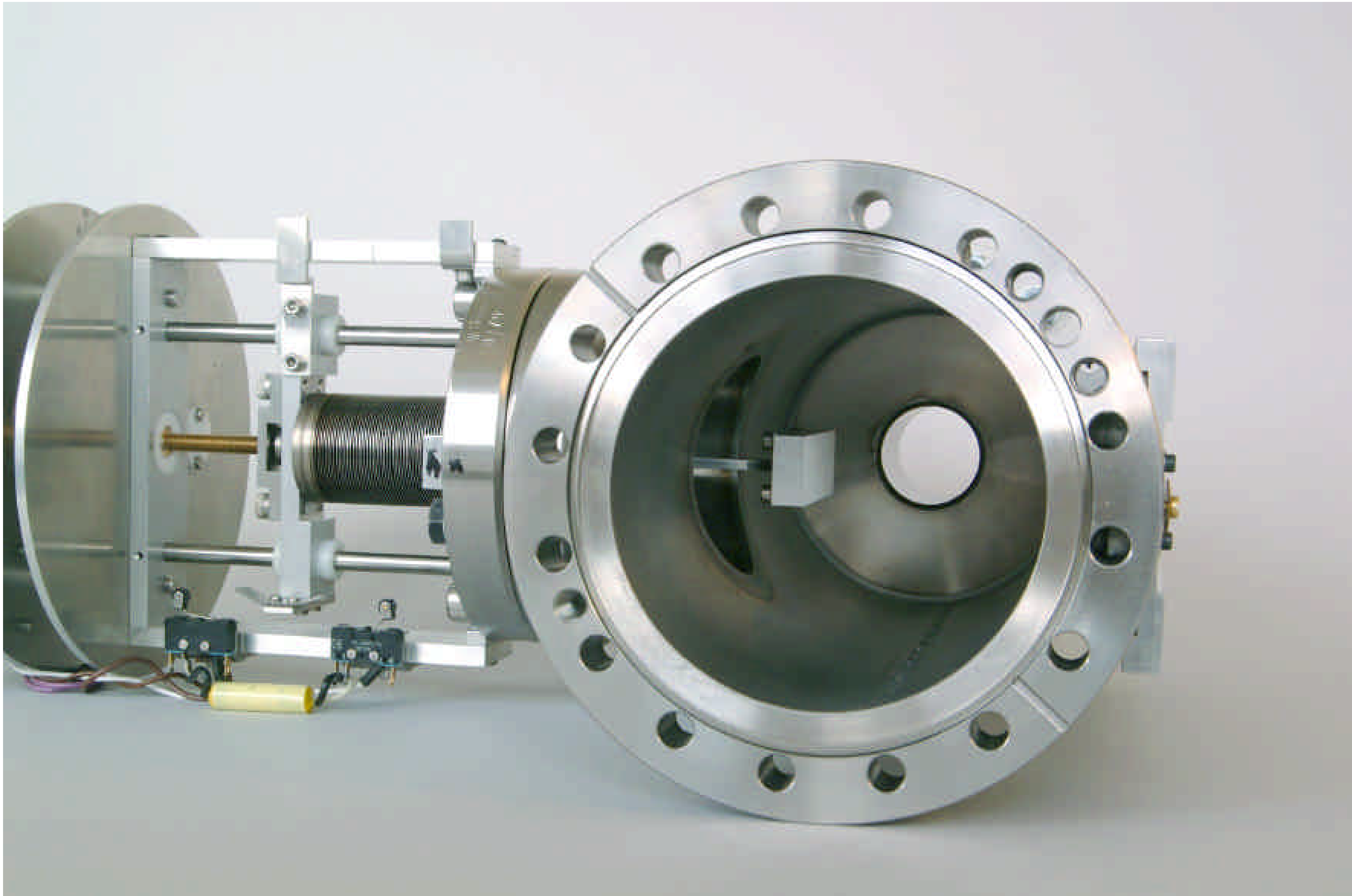
G. Doucas, W. Allison, A. Crichton, C. Perry and M.F. Kimmitt *

Dept. of Physics, Univ. of Oxford

**Dept. of Physics, Univ. of Essex*

In collaboration with: Lex van der Meer & B. Redlich (FOM)

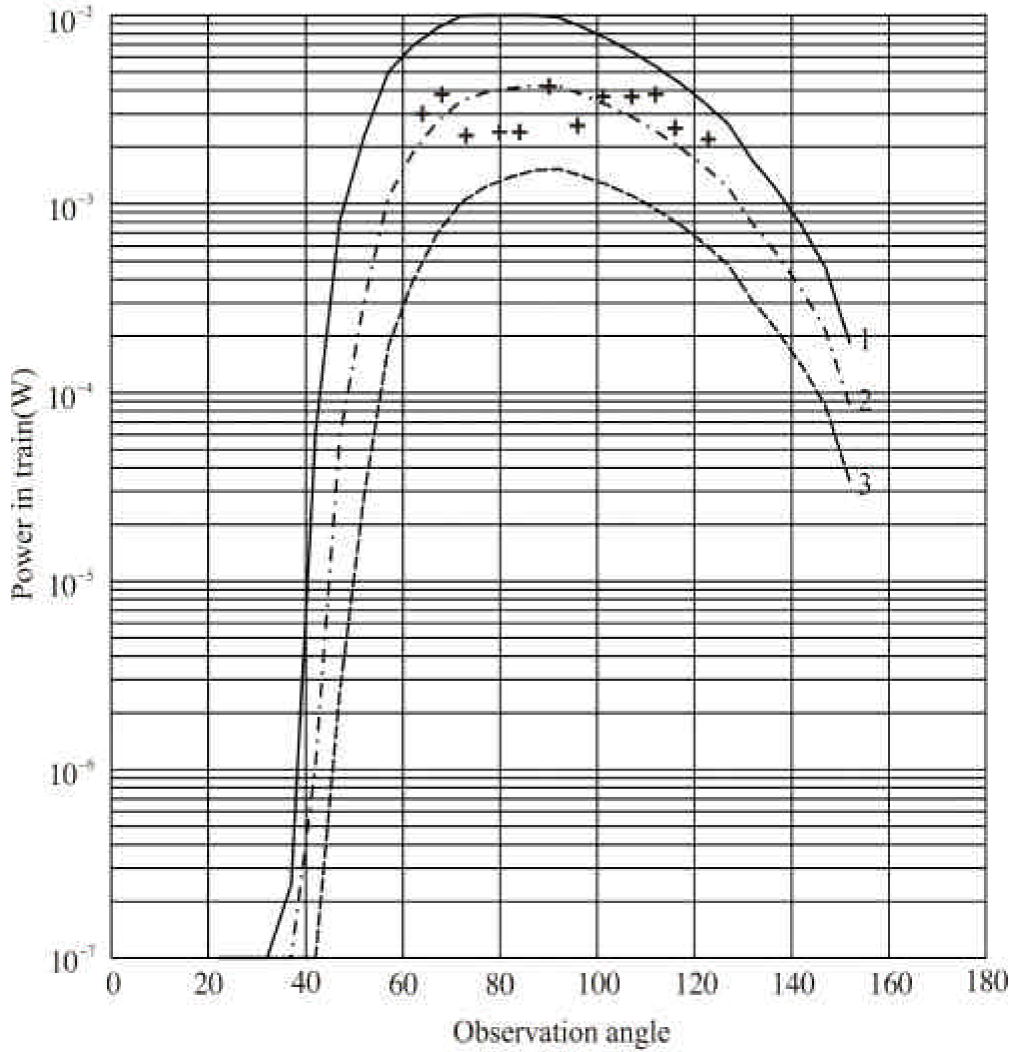
Chamber and grating



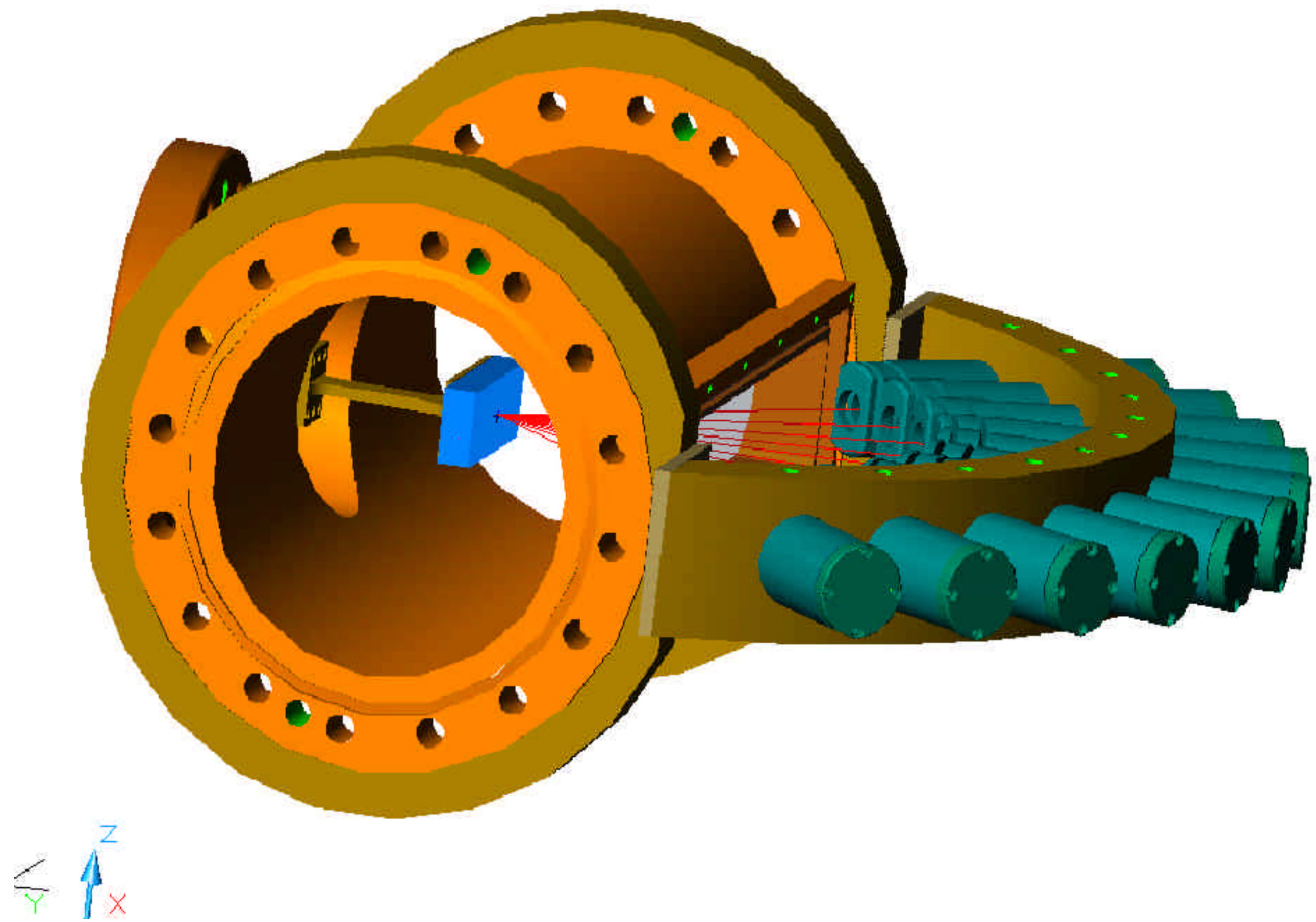
February '04 run

- Curves (GD calculation) correspond to what will impinge on the detector, at the given position & orientation, from Gaussian bunches with 90% of the particles inside;

(1) 2ps, (2) 2.5ps and (3) 3ps



11- detector scheme

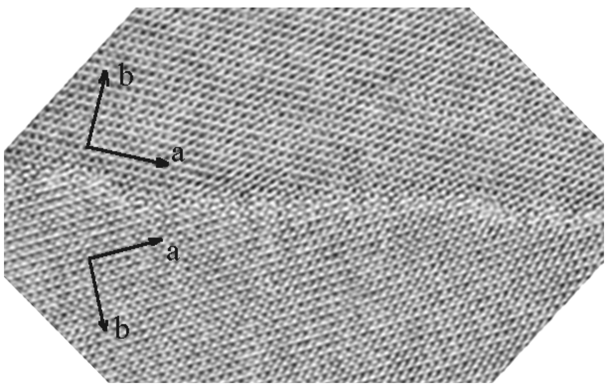


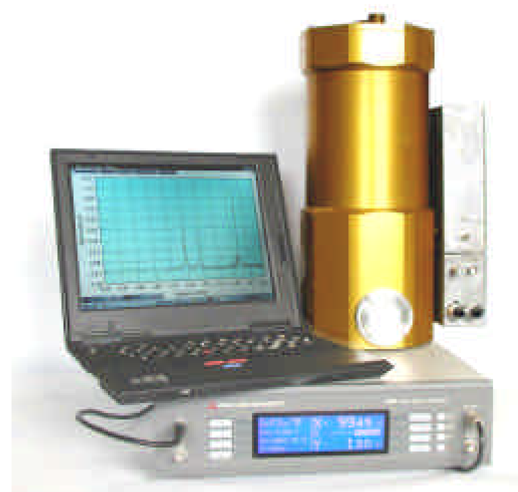
Hilbert Spectroscopy as a Tool for pulsed Electron Beam Diagnostics

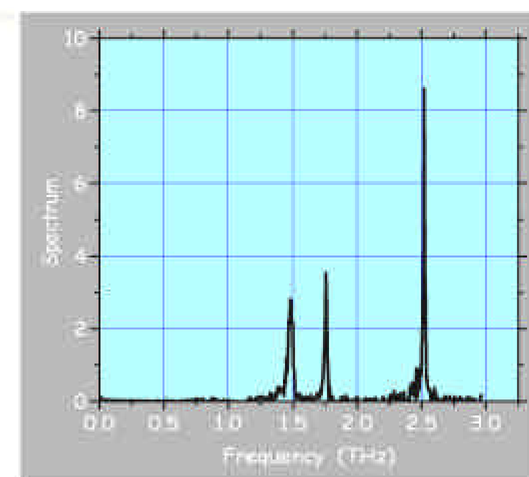
Y. Y. Divin, U. Poppe, K. Urban IFF-IMF,
H. Larue, E. Zimmermann, A. Ahmet, H. Halling ZEL, *Forschungszentrum Juelich, D-52425 Juelich, Germany*
V. Shirotov , O.Y. Volkov, V.N. Gubankov
IRE RAS, Moscow 101999, Russia
P. Schmueser, M. Geitz, K. Hanke
DESY, Notkestr. 85, D-22603 Hamburg, Germany
M. Tonutti
III. Phys. Inst., RWTH-Aachen, D-52056 Aachen, Germany

Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft
IRE
DESY

Terahertz Hilbert Spectroscopy using High-T_c Josephson Junctions: from Nanophysics to Applications







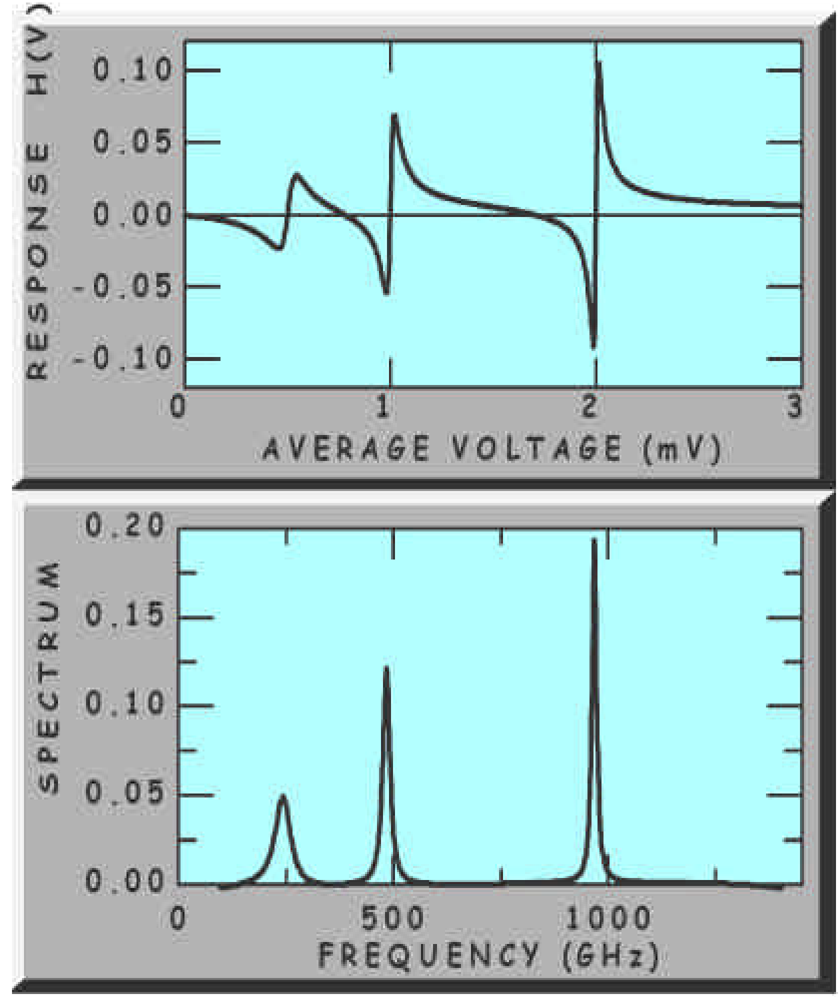
Principles of Hilbert spectroscopy

- Hilbert spectroscopy is based on the ac Josephson effect.
- Response of Josephson junction to signal with arbitrary spectrum

$$\Delta I(V) = -\left(\frac{2e}{h}\right)\frac{\pi \cdot I_c^2 \cdot R_n^2}{8 \cdot I(V) \cdot V} \cdot \left(\frac{1}{\pi}\right) \cdot P\int_{-\infty}^{\infty} \frac{S_{I_S^2}(f) \cdot df}{f - f_j}$$

$$S_{I_S^2}(f) = \left(\frac{1}{\pi}\right) \cdot P\int_{-\infty}^{\infty} \frac{H(f_j) \cdot df_j}{f_j - f}$$

$$H(V) = \left(\frac{8}{\pi}\right) \cdot \left(\frac{h}{2e}\right)\frac{I(V) \cdot V \cdot \Delta I(V)}{I_c^2 \cdot R_n^2}$$



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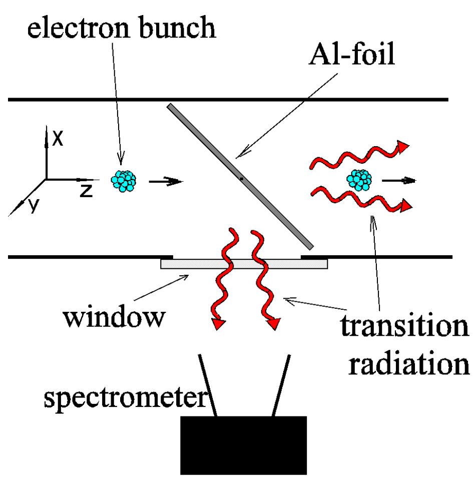
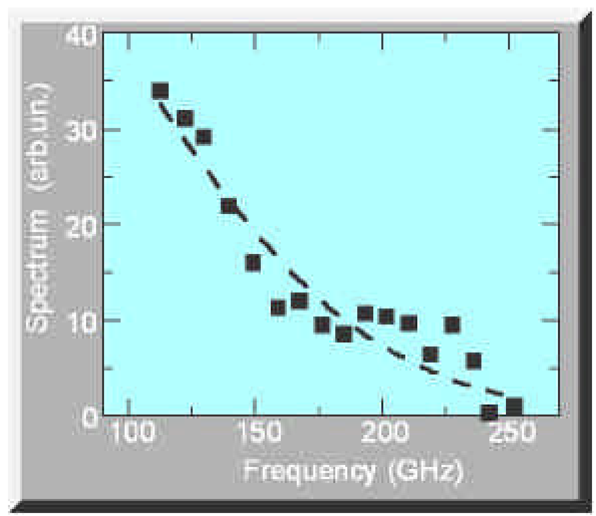
Applications of Terahertz Hilbert Spectroscopy

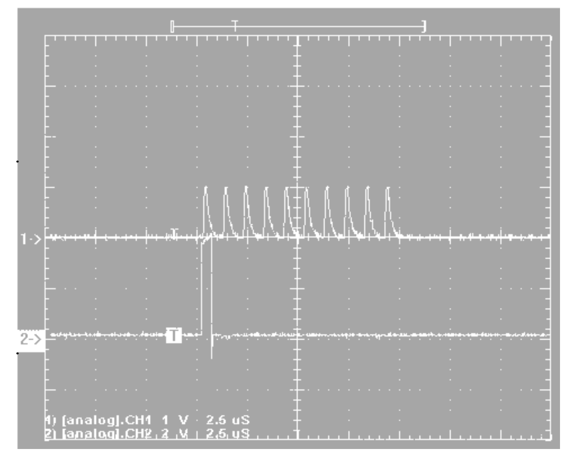
Frequency-resolved electron bunch diagnostics at linear accelerators*

Our goal:

Fast electron bunch analysis for next generation of large accelerators







In collaboration with TESLA Test Facility at DESY (Hamburg)

V. Shirotov, Y. Divin, U. Poppe, H. Larue, E. Zimmermann, A. Ahmet, H. Halling and K. Urban. IEEE Trans. Appl. Supercond., v.13, n.2, pp.172-175 (2003)

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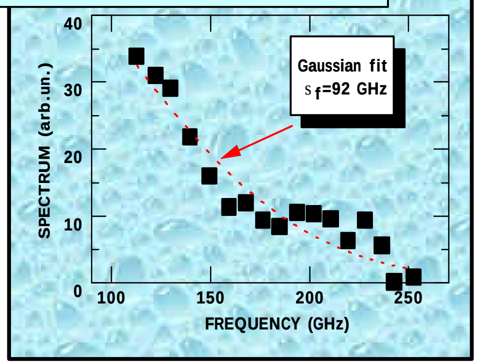
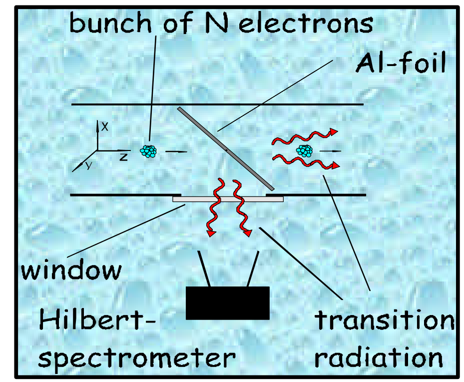
Hilbert Spectroscopy of Coherent Transition Radiation in TESLA Test Facility Linear Accelerator at DESY

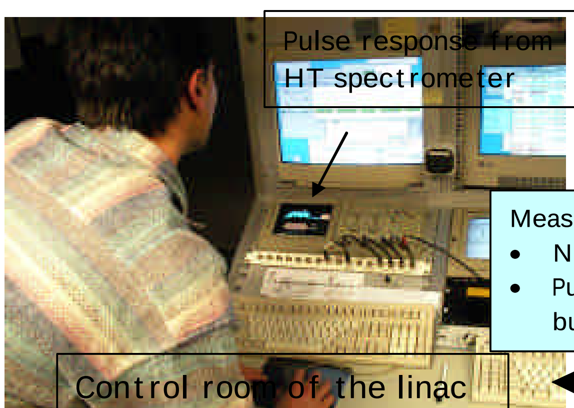
First measurements at DESY, 1997

- Thermoionic gun, $N = 2.3\times10^{8}$ electrons
- Macrobunch averaging
- Bunch length measured by HTS: $s_z = 0.4$ mm



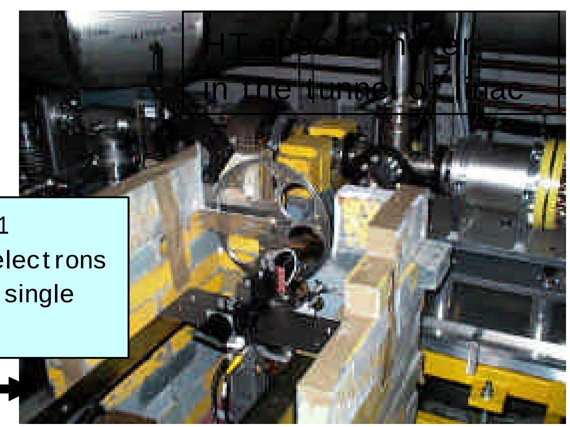
$$I_{total}(\lambda) = I_1(\lambda)\cdot\left[N + N(N-1)\left|\int \rho(\vec{r})\cdot\exp\left(\frac{2\pi i(\vec{n}\cdot\vec{r})}{\lambda}\right)d^3r\right|^2\right]$$





Measurements at DESY, 1999, 2001

- New Photoinjector, $N = 1.6\times10^{10}$ electrons
- Pulse response detection from a single bunch



Conclusions:

- Fast Hilbert spectrometer based on high-Tc Josephson junctions for pulsed coherent transition radiation at TESLA Test Facility at DESY.
- Characterization in the laboratory :
  power dynamic range of 50 dB,
  spectral range from gigahertz range to terahertz range (50 GHz til 4.5 THz)
- Spectrometer with digital data transfer tested at TESLA Test Facility.
- Spectrum of transition radiation e.g. averaging 9 pulses bunches in one macrobunch delivered spectrum spreading from 50 to 500 GHz.

Outlook and Goals:

- Developed spectrometer allows measurements of whole spectrum during a single macrobunch, when a number of more than 500 bunches are provided (projected are 7200 bunches at TESLA).
- Hilbert spectrometer, integrated not into a liquid nitrogen cryostat but into a Stirling cooler.
- Extension to shorter pulses (ca. 10 THz, 100fs)

Electron Beam Diagnostics at the radiation source ELBE

Pavel Evtushenko

Radiation source ELBE

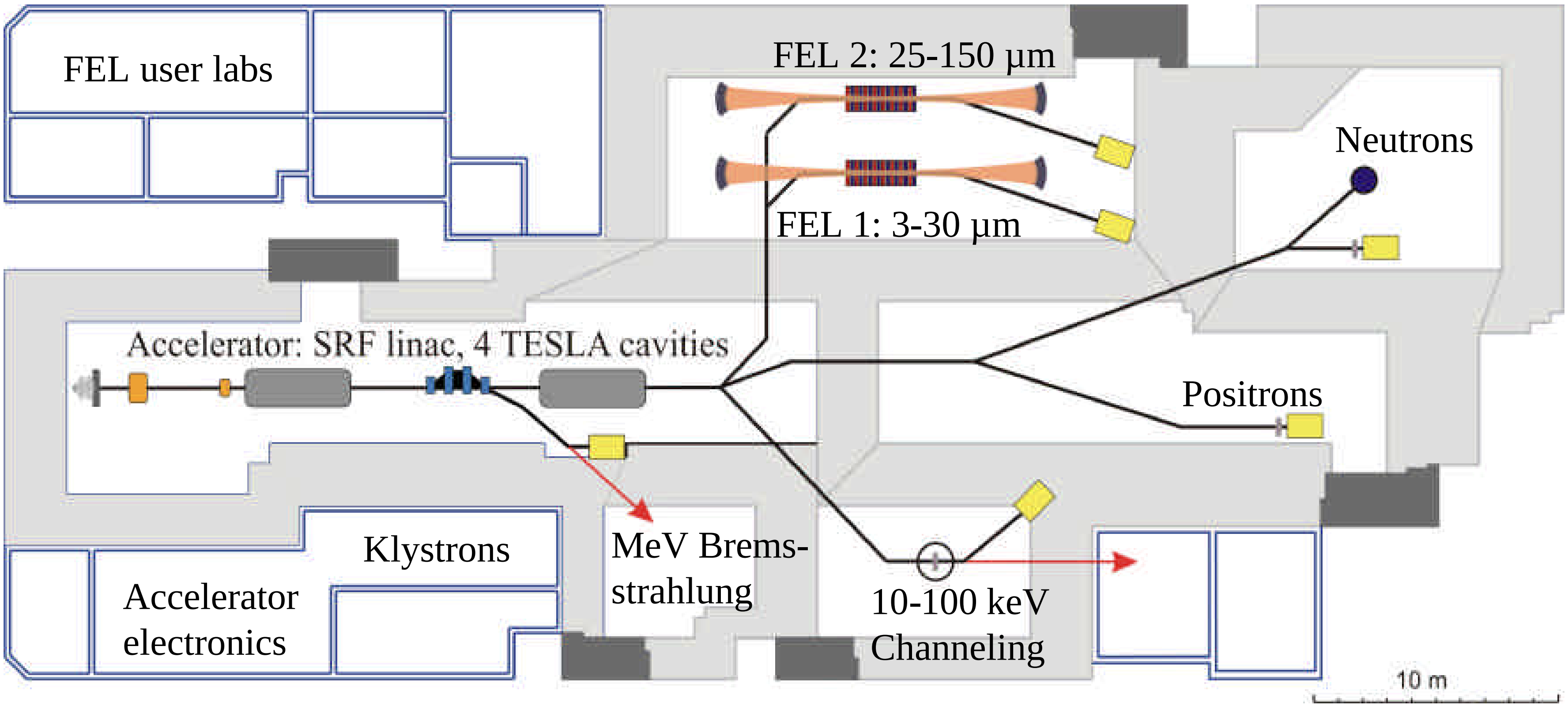
Bunch length measurements

BPM system

Video acquisition

Beam loss & machine protection

The radiation source ELBE



- nuclear physics experiments are running since January 2002
- channeling radiation since September 2003

  FEL 1 commissioning now

  FEL2 in the design phase

ps bunch length measurements using CTR

1. Transition radiation is produced when the electron bunch passes a boundary of two media.

2. Respond time is zero. Shape of the radiation pulse is a “copy” of the electron bunch shape.

3. When the wave length of the radiation becomes more than the bunch length the radiation becomes COHERENT. ($\lambda >> L$)

4. Power is proportional to:

   incoherent radiation $\sim N$

   coherent radiation $\sim N^2$

   at 77pC $N \sim 5 \times 10^8$

5. Measurements of the radiation spectrum give information about the bunch length.

How to measure the spectrum ? the Martin-Puplett interferometer

Bunch length reconstruction

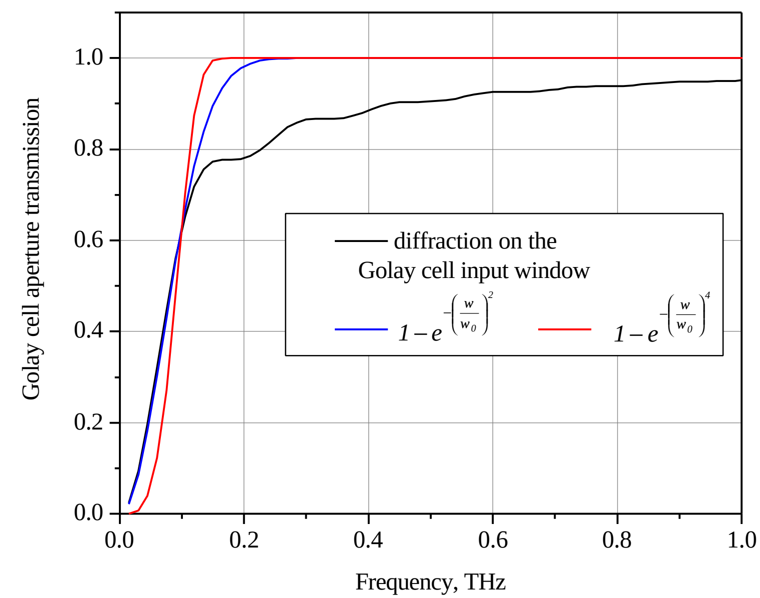
- the Gaussian shape of the bunch is assumed

$$n(t) = \frac{Q}{cs_t\sqrt{2p}} e^{-\left(\frac{t}{s_t\sqrt{2}}\right)^2}$$

- its power spectrum is also Gaussian

$$\tilde{P}(w) = C\, e^{-(ws_t)^2}$$

- low frequency cut-off diffraction on the Golay cell input window



two filter functions were considered:

$$F1_{filter}(w) = 1 - e^{-(w/w_0)^2}$$

$$F2_{filter}(w) = 1 - e^{-(w/w_0)^4}$$

- The fit function is used

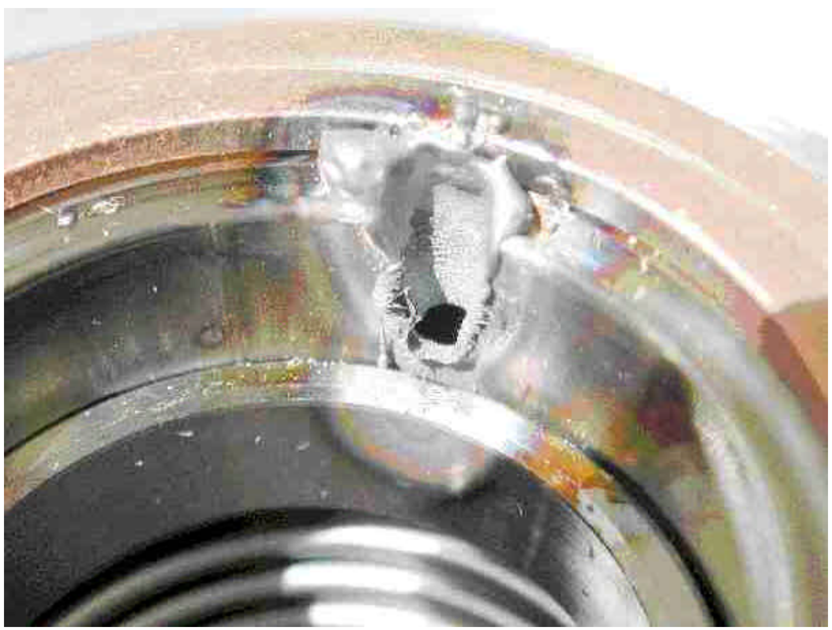
$$f_{fit}(w) = \left(1 - e^{-(w/w_0)^4}\right) C\, e^{-(ws_t)^2}$$

BPM

¼λ BPM	¾λ BPM
40 mm	144 mm
85 mm	235 mm
brazed	e^- beam welded
-24 dBm @ 1 mA	-24 dBm @ 1mA
0.8 dBm/mm	0.8 dBm/mm
1500 Euro	2800 Euro

Beam loss monitoring and machine protection

- The motivation:
  40 MeV×1 mA=40 kW of CW beam,
  and some bad experience.



- The solution:
  two completely independent systems.

  1. Current difference measurements
  2. Ionization chamber based
     beam loss monitors

- Sensitivity: ~100nA of beam loss

What is to improve on the diagnostic

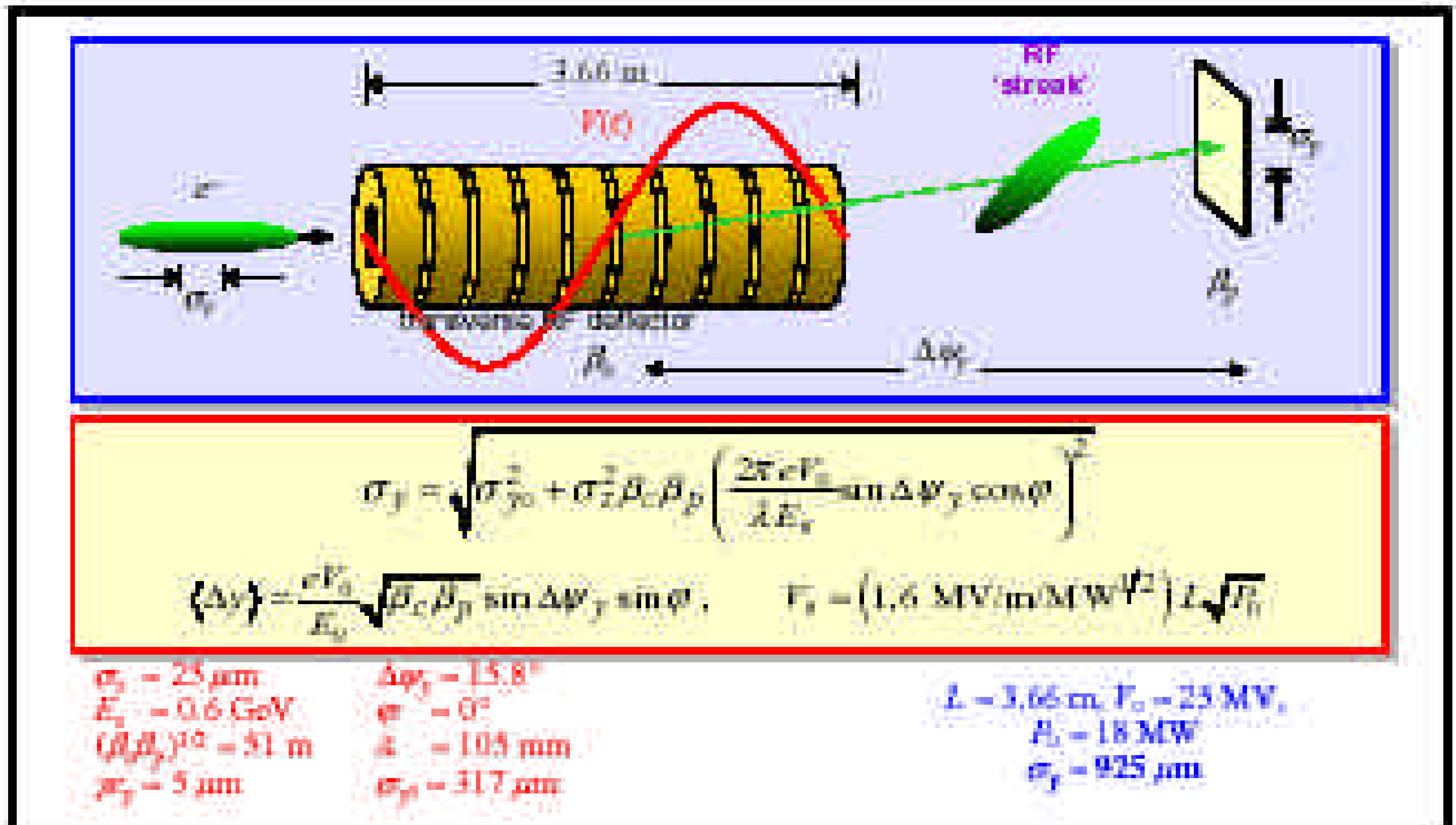
- the bunch length reconstruction procedure
  (might be too empirical;
  different bunch shapes)

- understand better the low frequency cut-off
  (the best way – measure
  0 – 200 GHz how?)

- Make a crosscheck measurements with completely different method
  (we are working on the electro-optical sampling)

- The same measurements can be done with
  the CSR and with the diffraction radiation
  to make the diagnostic nondestructive.

TTF2 XFeL The Theory of Lola…



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13:05 **Discussion**

Precision Spectrometry

David J.Miller, U.C.L.

1. Physics motivation and requirements.

2. Range of inputs needed, including detector-based.

3. Pathologies to be measured.

4. BPM technologies.

5. Test beam plans.

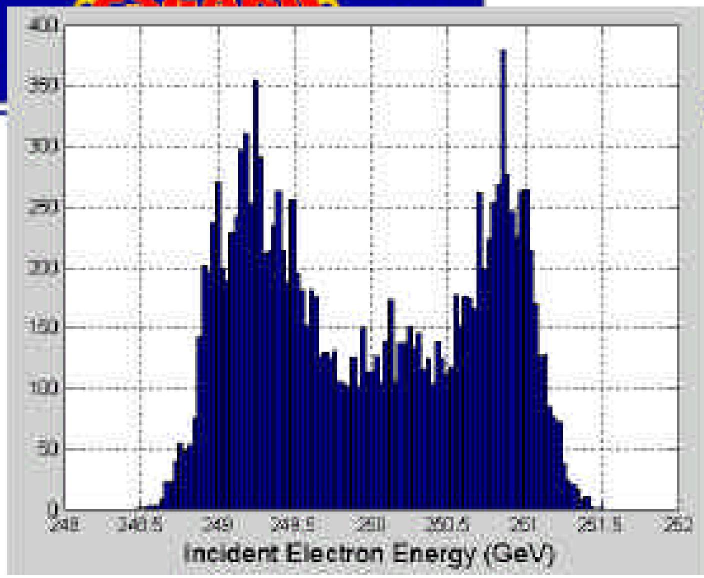
6. Summary of where we are.

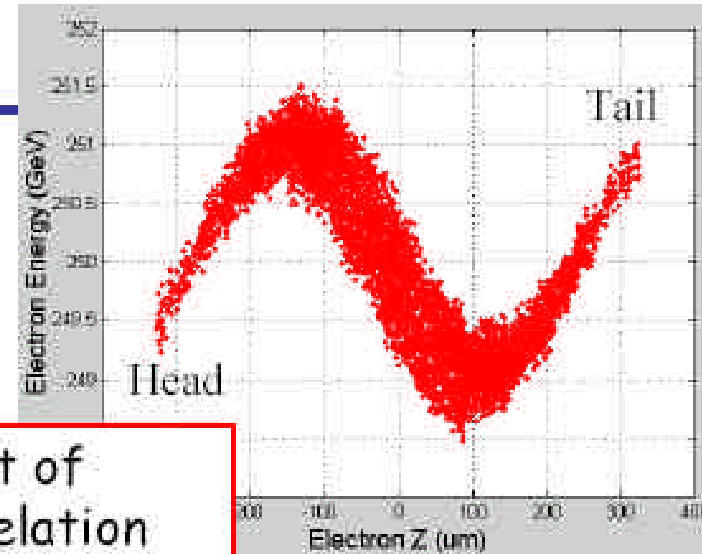
Beam Energy Spread

TESLA ~0.1%, Gaussian(?), better for e^+ than e^- because of e^+ source.

Warm machine ~0.3%, nongaussian, with front to back correlation in each bunch.

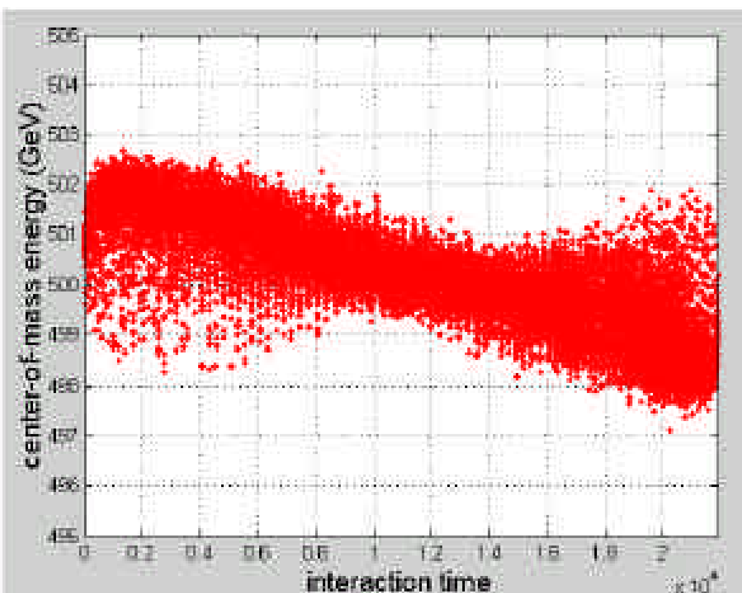
NLC-500 Results (Mike Woods, SLAC)

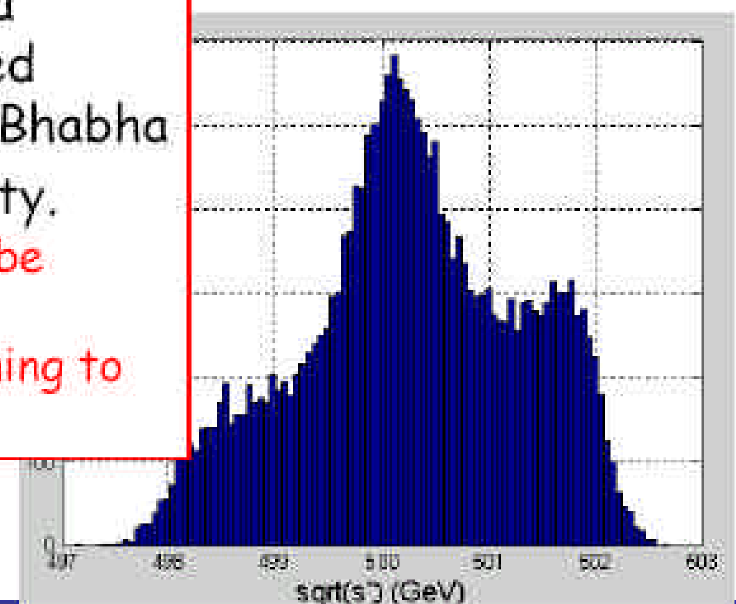




This sort of big correlation Will have a complicated effect on Bhabha acollinearity.

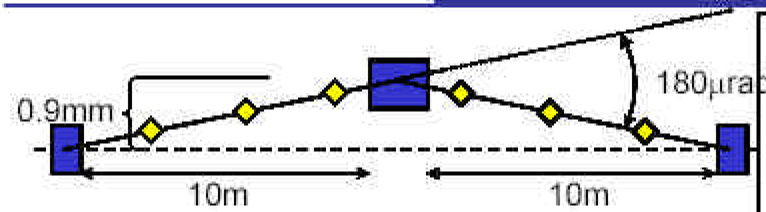
How can it be measured?
Just beginning to find out.

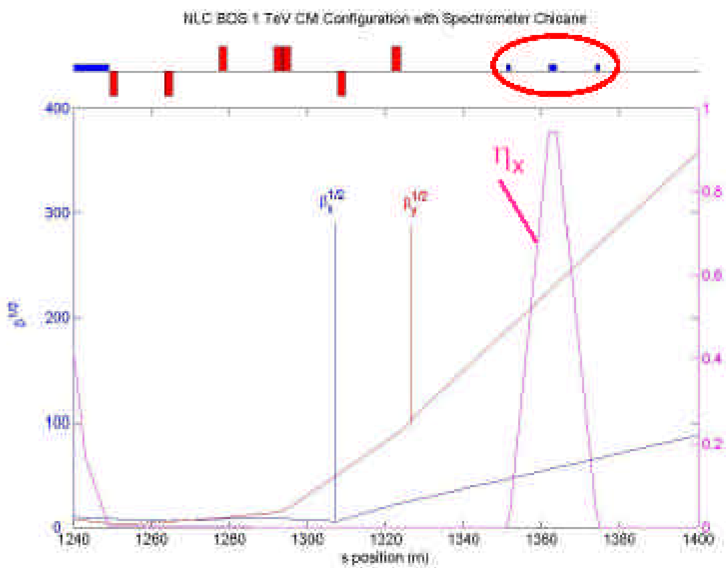




Upstream BPM-based Spectrometer

(Mike Hildreth + Peter Tenenbaum's optics)





Design Considerations:

- limit SR emittance growth
  - 360mrad total bend ⇒ 0.5%
- available space in lattice
  - no modifications necessary, yet
- 10m drift space maximum one can consider for mechanical stabilization, alignment
- 37m total empty space allows for BPMs outside of chicane to constrain external trajectories
- *Tiny* energy loss before IP $\begin{pmatrix} 1.2\text{MeV} @ 250 \\ 11.9\text{MeV} @ 500 \end{pmatrix}$
- non-ideal b-variation?

⇒ Constraints lead to a required BPM resolution of ~100nm (Resolution ⊕ Stability)

Plan to get our BPM technology
From EITHER:-

NanoBPM Collaboration

(Y.Kolomensky, UCB)

- Collaboration between SLAC, KEK, LLNL, UCB
- Ambitious goals
  - Position resolution for a single pulse at ~ nm scale
  - Similar accuracy and position stability of the BPM structure
  - Demonstrate beam tilt measurement with tens of mrad resolution
- Operational experience with precision devices
  - Nanometer resolution: push technology to the limit
  - Mechanical stability: Final focus, beam energy spectrometer
  - Tilt measurement: find (and correct for) sources of emittance growth in the linac → luminosity optimization.

Measuring beam polarisation with e^+e^- interactions at high energy

Klaus Mönig

DESY -Zeuthen

- Introduction
- W-pairs with e^- polarisation only
- Positron polarisation and effective polarisations
- The Blondel scheme with 2-fermion events and W-pairs
- Experimental issues
- Special case: GigaZ
- Conclusions

Blondel scheme with 2-fermion events

Assume only s-channel vector exchange

Four independent measurements:
(4 combinations with positive/negative electron/ positron polarisation)

$$\begin{aligned}
\sigma_{++} &= \sigma_u \left[1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + A_{\mathrm{LR}}(\ \ \mathcal{P}_{e^+} - \mathcal{P}_{e^-})\right] \\
\sigma_{-+} &= \sigma_u \left[1 + \mathcal{P}_{e^+}\mathcal{P}_{e^-} + A_{\mathrm{LR}}(-\mathcal{P}_{e^+} - \mathcal{P}_{e^-})\right] \\
\sigma_{+-} &= \sigma_u \left[1 + \mathcal{P}_{e^+}\mathcal{P}_{e^-} + A_{\mathrm{LR}}(\ \ \mathcal{P}_{e^+} + \mathcal{P}_{e^-})\right] \\
\sigma_{--} &= \sigma_u \left[1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + A_{\mathrm{LR}}(-\mathcal{P}_{e^+} + \mathcal{P}_{e^-})\right]
\end{aligned}$$

$\Longrightarrow$ Can measure $\mathcal{P}_{e^+}$, $\mathcal{P}_{e^-}$ simultaneously with A_{LR} if $A_{\mathrm{LR}} \neq 0$

$$\mathcal{P}_{e^\pm} = \sqrt{\frac{(\sigma_{+-} + \sigma_{-+} - \sigma_{++} - \sigma_{--})(\mp\sigma_{+-} \pm \sigma_{-+} - \sigma_{++} + \sigma_{--})}{(\sigma_{+-} + \sigma_{-+} + \sigma_{++} + \sigma_{--})(\mp\sigma_{+-} \pm \sigma_{-+} + \sigma_{++} - \sigma_{--})}}$$

Only difference between $|\mathcal{P}_{e\pm}^{+}|$ and $|\mathcal{P}_{e\pm}^{-}|$ needs to be known from polarimetry

Correlations

In formulae for the Blondel scheme and in effective polarisations products of $\mathcal{P}_{e^+}$ and $\mathcal{P}_{e^-}$ enter

$\Rightarrow$ have to understand correlations between $\mathcal{P}_{e^+}$ and $\mathcal{P}_{e^-}$

- correlation inside bunch, e.g. via interaction time
  ➠ negligible according to CAIN
- correlated time dependencies
  - effect quadratic with polarisation change
  - changed both polarisations for $\pm 5\%$ for half of the time

  ➠ 0.25% effect on polarisation
  - Blondel scheme reproduces effective polarisation worse than polarimeter measurement.
    ($\Delta\mathcal{P}_{\mathrm{eff}} = 0.16\%$ for polarimeter, $\Delta\mathcal{P}_{\mathrm{eff}} = 0.25\%$ for Blondel scheme)
  - need polarimeters to track time dependencies and possibility to change polarisation fast, e.g. parallel spin rotators for positrons

Conclusions

- The polarisation can be measured from the data themselves.
- Each measurement from data involves some physics assumptions.
- The errors are in the per mille region for 500 fb^{-1}
- The exact requirements have to be studied by the different analyses separately
- Polarimeters are needed for corrections with slightly different requirements
- Polarimeter and data methods are largely complementary and both are needed to get the ultimate precision.

Instrumentation and Diagnostics

9:00	Single-shot longitudinal profile characterisation of 500fs electron bunches	Steven Jamison
9:25	First results from FELIX of a Smith-Purcell longitudinal profile monitor	George Doucas
9:40	Confocal Resonator BPM	Volker Ziemann
10:05	Precision measurements of beam current, position and phase for an e+e- linear collider	Roberto Corsini
10:35	Precision Energy Spectrometry	David Miller
11:00	Coffee	
11:25	Measurement of the beam polarisation from annihilation data	Klaus Moenig
11:50	Laser-Based Profile Monitor	Grahame Blair
12:15	Hilbert spectroscopy as a tool for pulsed electron beam diagnostics	Ulrich Poppe
12:40	Electron beam diagnostics at ELBE	Pavel Evtushenko

13:05 **Discussion**

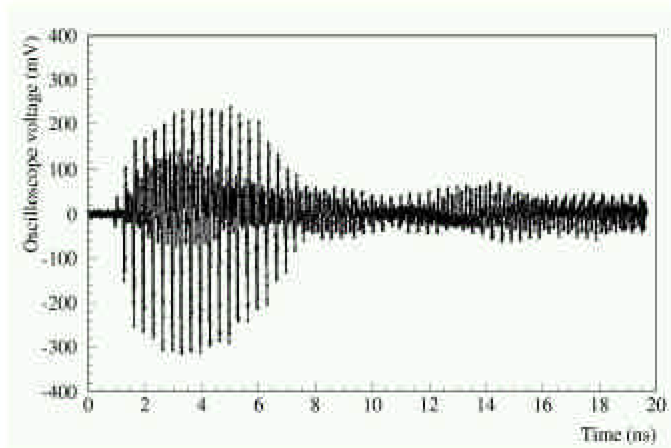
Confocal Resonator BPM Volker Ziemann

V. Ziemann, A. Ferrari, T. Lofnes, Uppsala University
I. Syratchev, F. Caspers, CERN

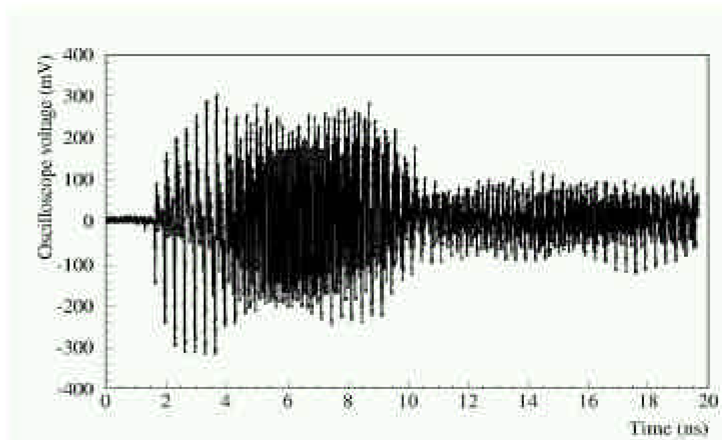
Frascati, May 5, 2004

- Motivation and "The Problem"
- Fritz Caspers idea
- Analytical Design
- Numerical Simulations
- Engineering Issues
- Position Monitor
- Bunch Length Monitor

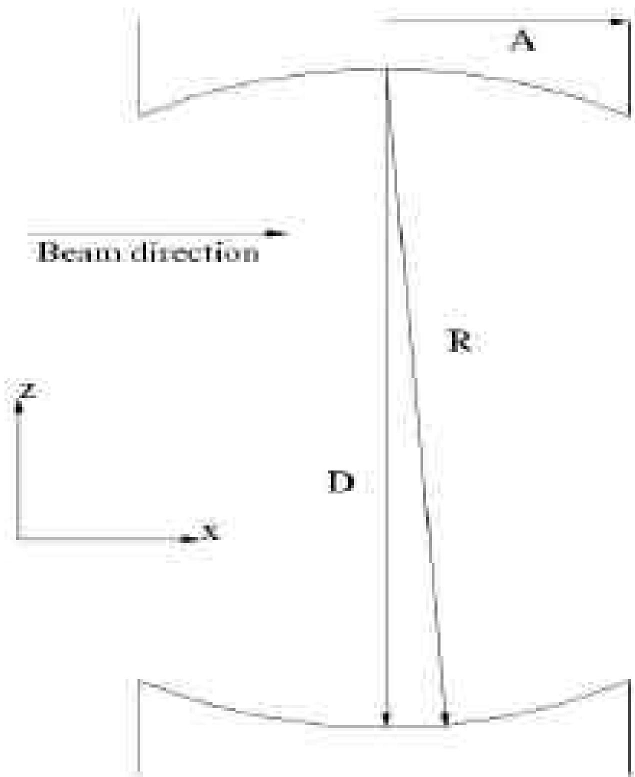
- Microwaves (wake-fields) that co-propagate with the beam disturb measurements of beam properties.
- Clearly disturb the bunch frequency measurements in CTF3pre
- One bunch train with 20 bunches (Pictures from CLIC Note 557)
- Bunch train propagates right to left



- Five bunch trains interleaved



- A sketch:



- Make the domes a confocal resonator by choosing the distance between the domes equal to the radius of curvature.
- Very similar to an optical cavity laser-resonator.
- Same theory applicable (Gauss-Laguerre)
- But wavelength similar to geometric dimensions.

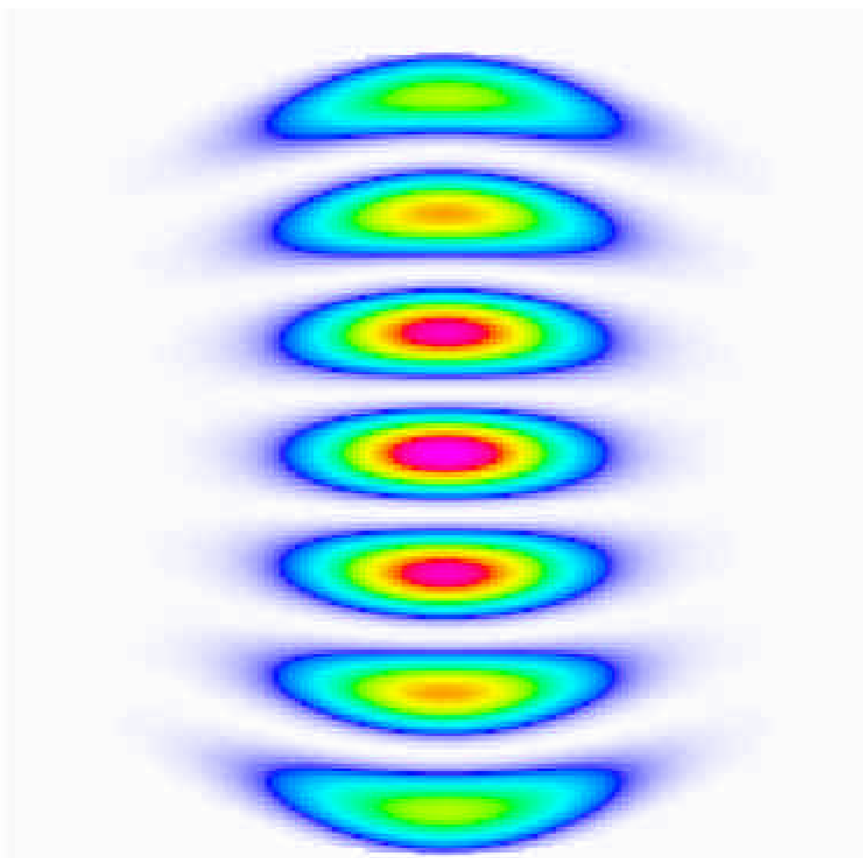
- Choose distance D between mirrors to have zero field on mirrors.

$$D = \left(l + \frac{3}{4}\right)\lambda$$

- Waist w_0 is then given by

$$w_0^2 = \frac{D\lambda}{2\pi}$$

- Choose l=3 and λ=2 cm, and n=m=0:



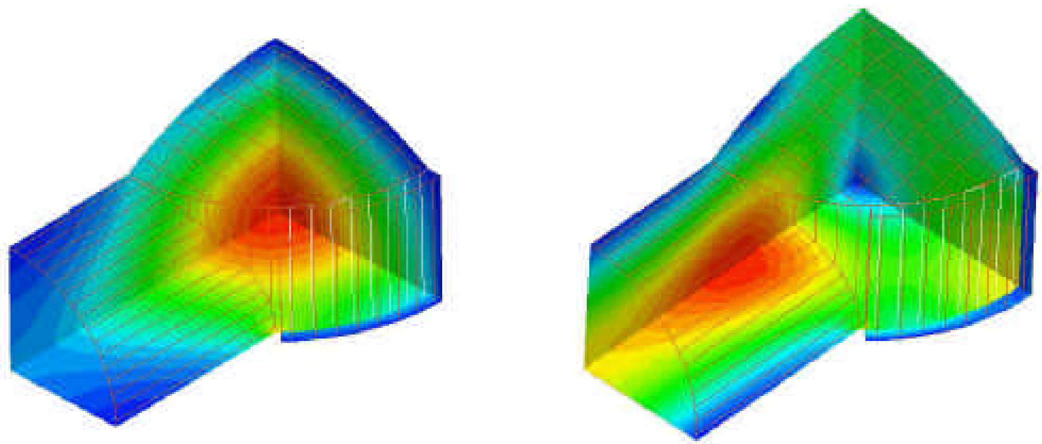
Analytical Design: Losses

- Follow standard literature about Resonators.
- **Diffraction Losses** are determined by the lateral size of the mirror and how much power in the side lobes is not captured by the mirrors.
- Fresnel Number: $N = A^2/D\lambda$

Numerical Simulations

$Q = 4.3 \times 10^4$

- Two examples of unwanted modes, left: l=0 at 3 GHz, Q=175, right at higher frequency of 4.1 GHz, Q=89.



- Q-value of the unwanted modes around 100.

Engineering Issues

- Suppress unwanted modes by filters in the extraction wave guide.
- Need circulator to have freedom in the filter choice.
- May need to make dampers in stripes with conducting material inbetween in order to reduce losses due to wall currents.
- Suppress the low frequency modes by making the extraction waveguide small aperture. Then they are below cutoff.
- Select polarization by rectangular waveguide shape.

Position Sensitive Monitor

- Compare excitation of two modes, one with zero field on axis and the other with maximum field on axis, e.g. l=3 and l=4 and relate that to position of the beam.
- Lots of simulation work needed.

ELAN

1st Workshop of ELAN

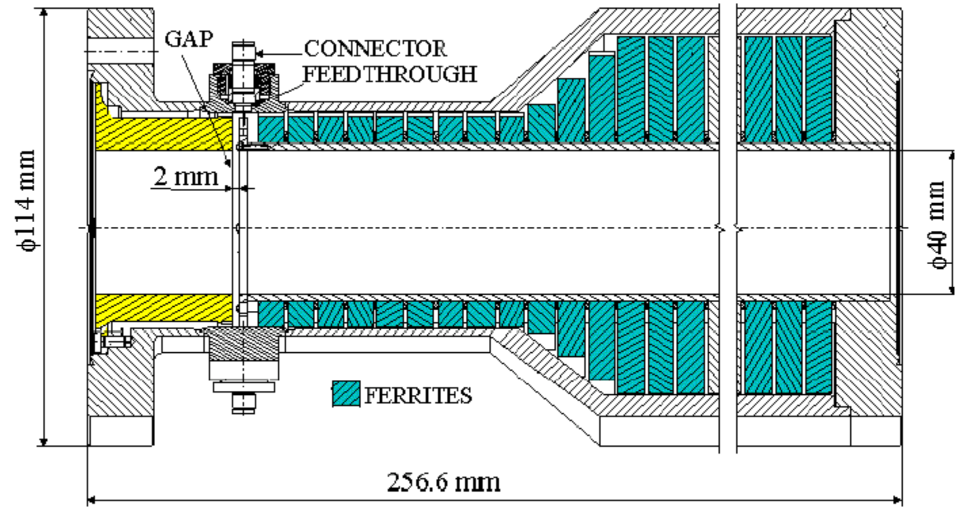
INFN-LNF, Frascati, 4-6 May 2004

Precision measurements of beam current, position and phase for an e+e- linear collider

R. Corsini on behalf of H. Braun, M. Gasior, S. Livesley, P. Odier, J. Sladen, L. Soby

THE CTF3 WIDE BAND Wall Current Monitor (WCM)

P. Odier,
"A New Wide Band Wall Current Monitor",
6th European Workshop on Beam Diagnostics and Instrumentation for Particle Accelerators DIPAC 2003 , Mainz, Germany



Impedance	0.5 ohms
Resolution	~4mA
Absolute precision	~ 1%
Low frequency cut off	10kHz
High frequency cut off	10GHz
Calibration	No
Number of feed-troughs	8
Gap length	2mm
ID / Length	40mm / 256.6mm
Flange types	DN63CF
Max. bake-out temperature	165 °C

PRECISION BEAM POSITION MONITOR

BPM with < 100 nm resolution, < 10 μm precision, < 15 ns rise-time, aperture > 4 mm

Beam position monitoring in LC main beam and beam delivery with performance as required from beam dynamics studies.

– Tentative CERN participants

- Lars Soby
- Marek Gasior

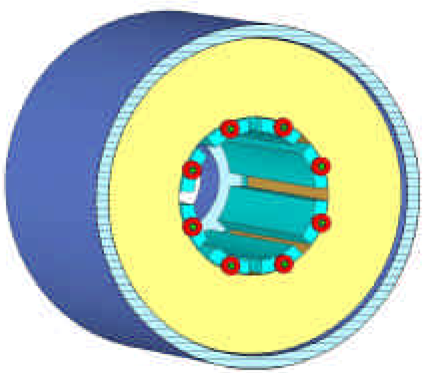
THE CTF3 BPM (INDUCTIVE PICK-UP)

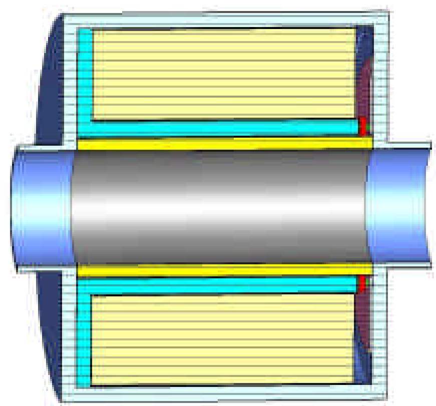
An Inductive Pick-Up (IPU) senses the azimuthal distribution of the beam image current.

Its construction is similar to a wall current monitor, but the pick-up inner wall is divided into electrodes, each of which forms the primary winding of a toroidal transformer.

The beam image current component flowing along each electrode is transformed to a secondary winding, connected to a pick-up output.

Four pick-up output signals drive an active hybrid circuit (AHC), producing one sum (S) signal, proportional to the beam current, and two difference (?) signals proportional also to the horizontal and vertical beam positions.





Aperture 40 mm

Resolution < 10 μm

Rise time ~ 2 ns

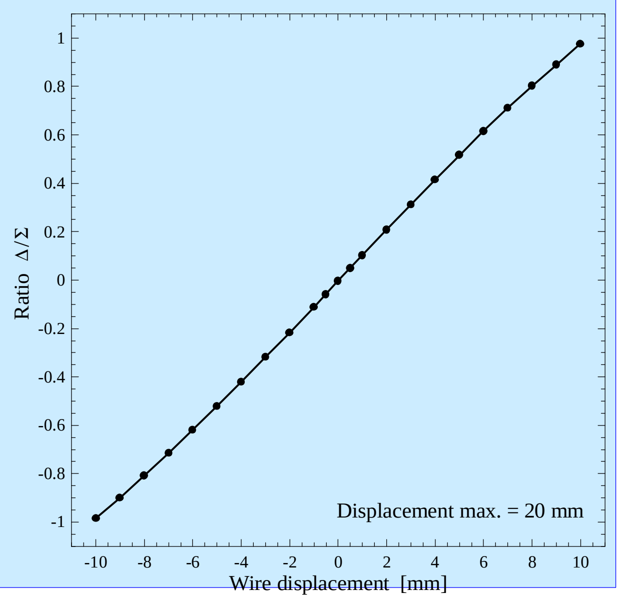
THE CTF3 BPM - PERFORMANCES

Rise time ~ 2 ns

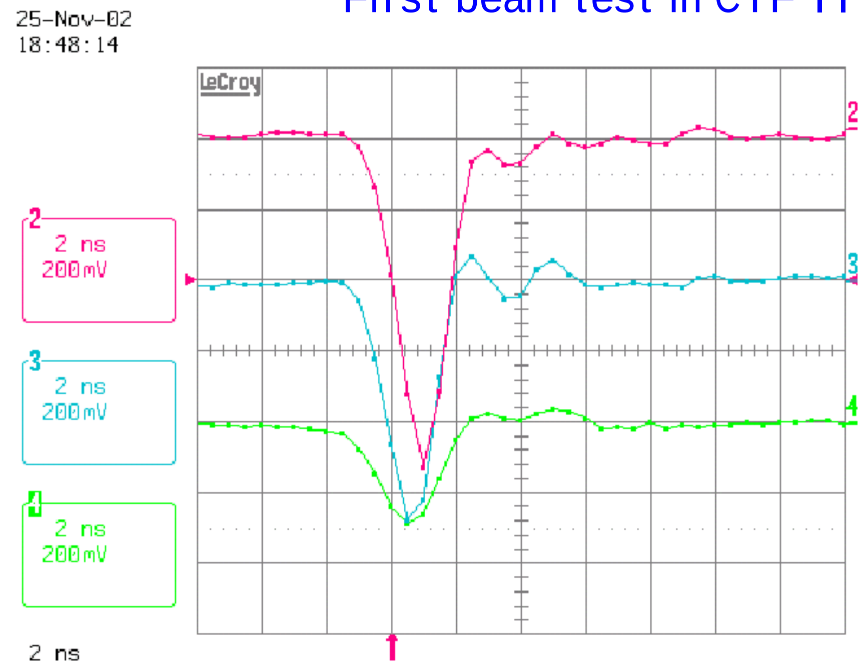
(Beam tests)

Resolution < 10 µm

(Lab tests – wire method)



First beam test in CTF I I



S - CH2 | DH - CH3 | DV - CH4

- Electron beam of one 1 nC , 5 ps_{RMS} bunch
- The signals have the rise time of about 2 ns

PRECISION BEAM PHASE MEASUREMENT

Phase reference with stability better 15 fs rms over long distances (km).

Needed for timing of LC collider beams to fulfil stability requirements on phasing and IP collision timing.

– Tentative CERN participants

- Jonathan Sladen
- Steven Livesley

Laser Wire R&D

- Laser-wire at PETRA
  - Environment at PETRA
  - Installation of Hardware

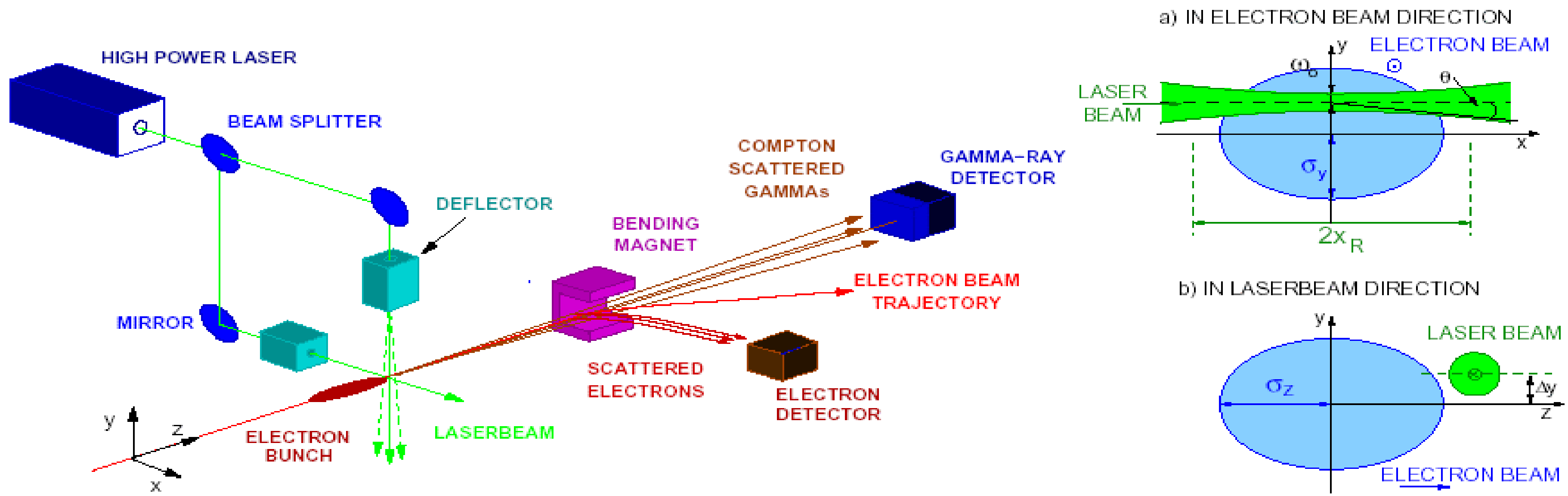
G. A. Blair

Royal Holloway Univ. London

ELAN Workshop

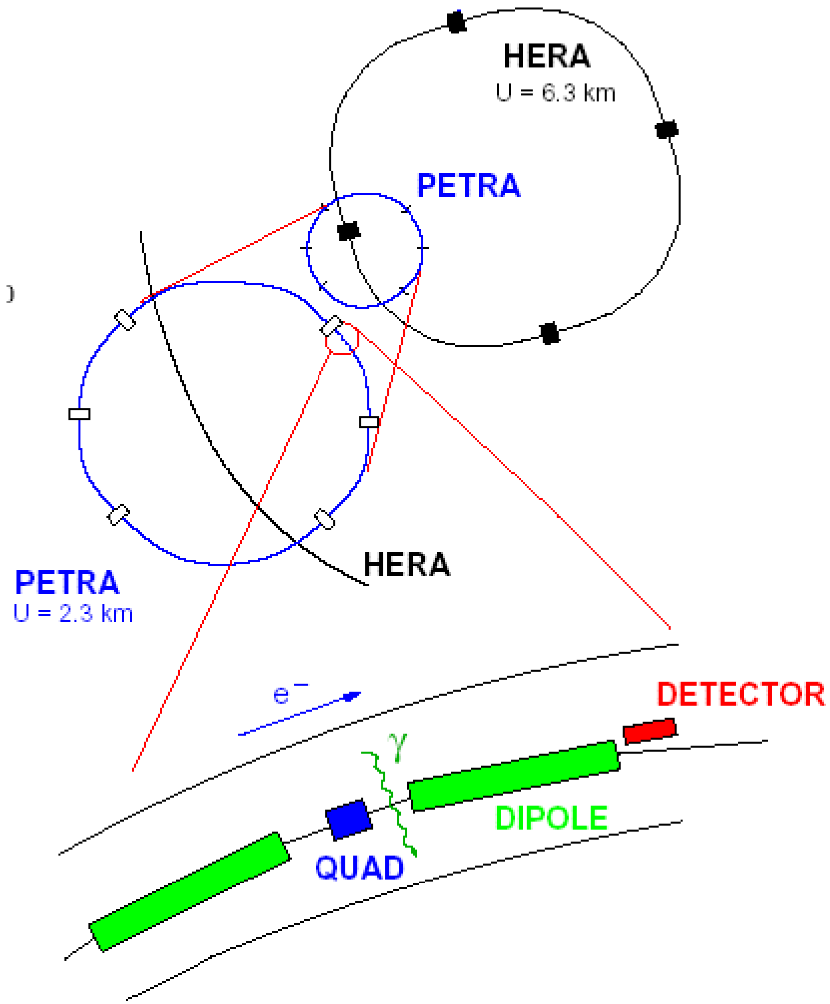
Frascati

Laser-wire Principle



- **Scan finely focused laser beam through electron beam**
- **Detection of Compton photons (or degraded electrons) as function of relative laser beam position**
- **Challenges**
  - **Produce scattering structure smaller than beam size**
  - **Provide fast scanning mechanism**
  - **Achieve efficient signal detection / background suppression**

Laserwire for PETRA



PETRA parameters

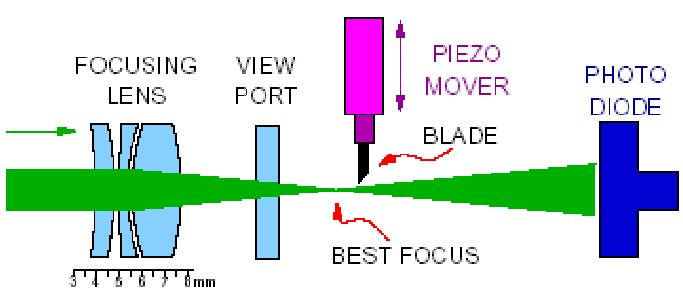
Energy	E/GeV	4.5 to 12
Bunch Length	s_z/ps	~100
Charge/bunch	nC	1 to 3
Hor. beam size	s_x/mm	.5 to .1
Ver. beam size	s_y/mm	~.1

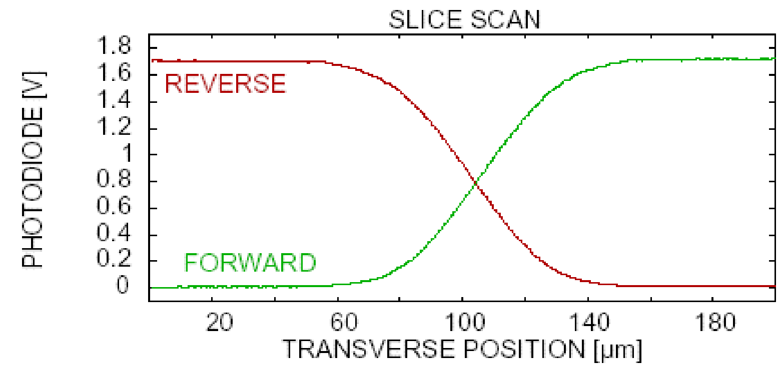
Laser parameters

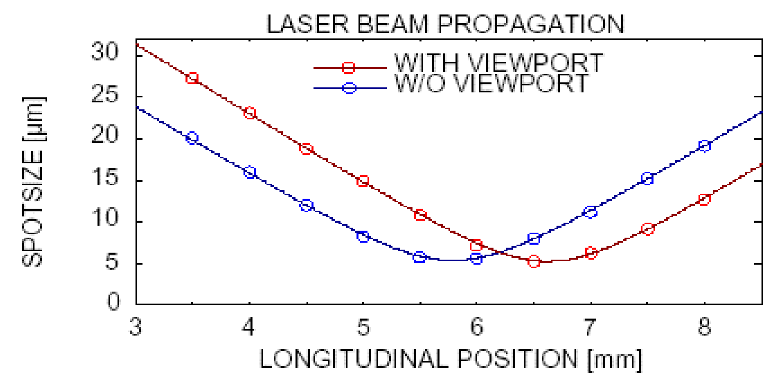
Wavelength	l/nm	1064/532
Energy	E/mJ	250/90
Pulselength	dt/ns	10
Reprate	f_{rep}/Hz	30
Beam size	$s_{x,y}$/mm	~7
Divergence1	q/mrad	0.7

Lab Measurements at RHUL

- Measurement of spot size at focus and beam propagation with knife edge technique
- Slicing of beam at several longitudinal positions
- Piezo movement controlled by interferometer
  - high precision ~30 nm
- Tested with beam at CTF2 Laserwire experiment

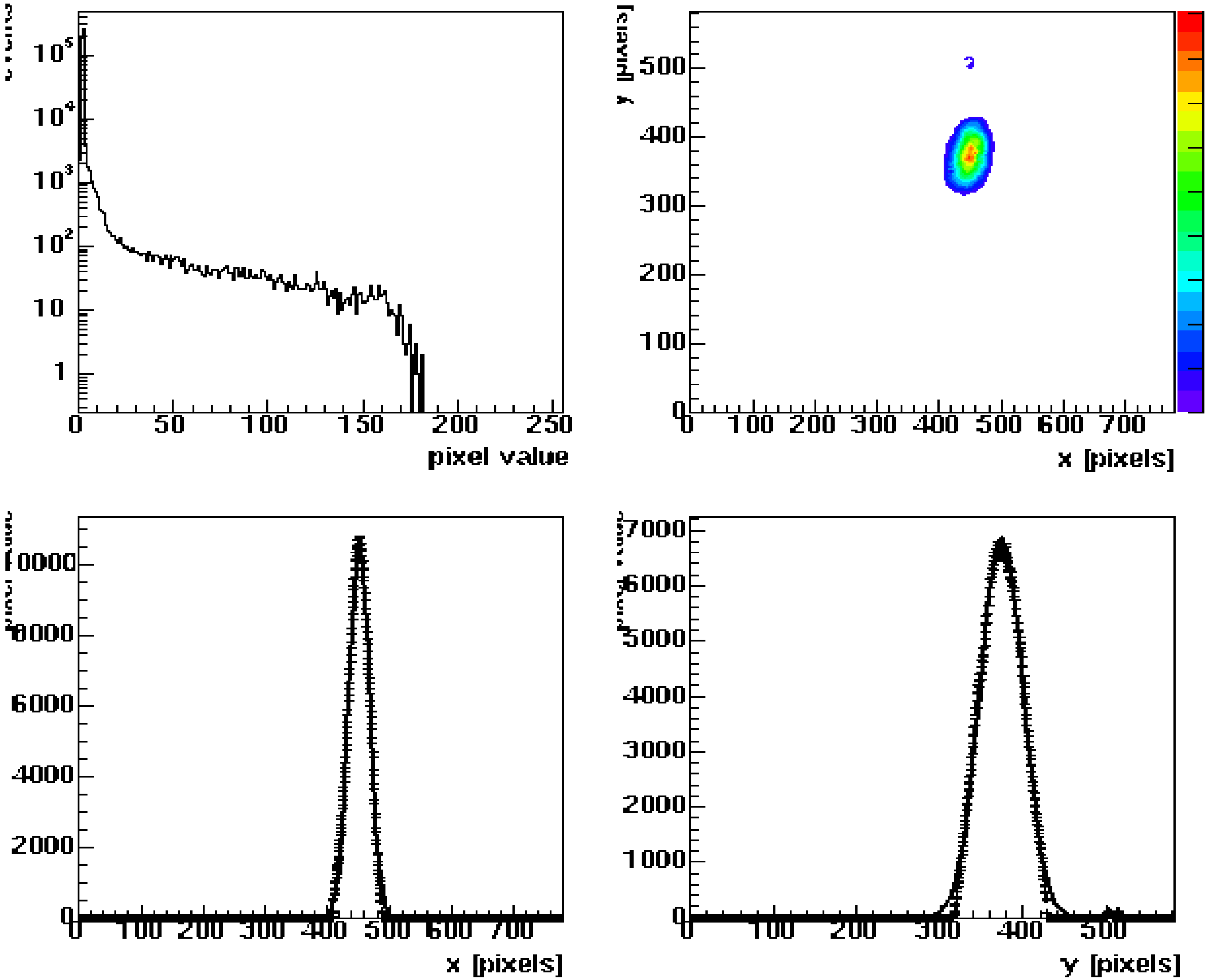




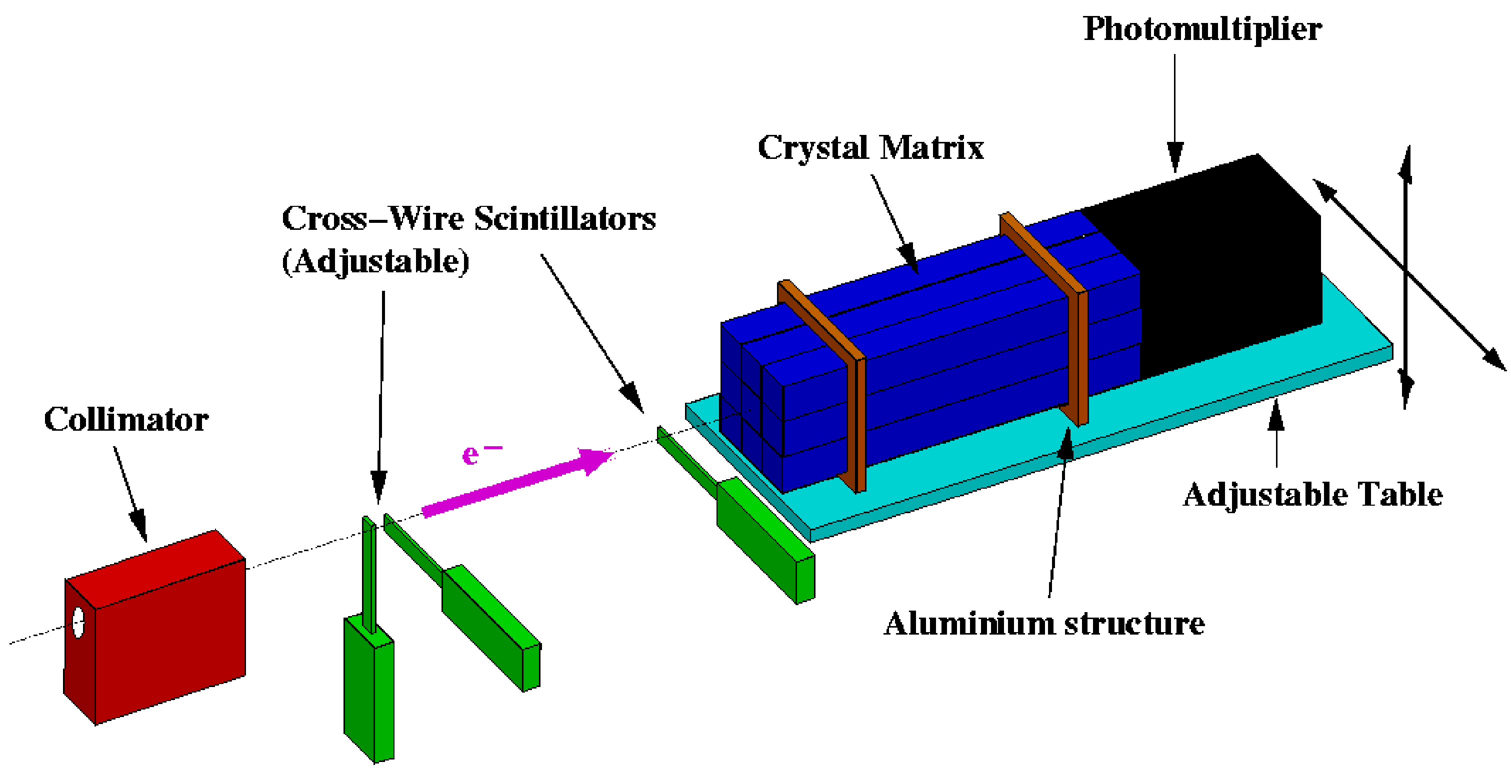


	σ_o [μm]	z_{off} [mm]
with	$5.34 \pm 0.02 \pm 0.07$	$5.79 \pm 0.01 \pm 0.08$
without	$5.21 \pm 0.03 \pm 0.07$	$6.62 \pm 0.01 \pm 0.08$

CCD image analysis



Energy Calibration

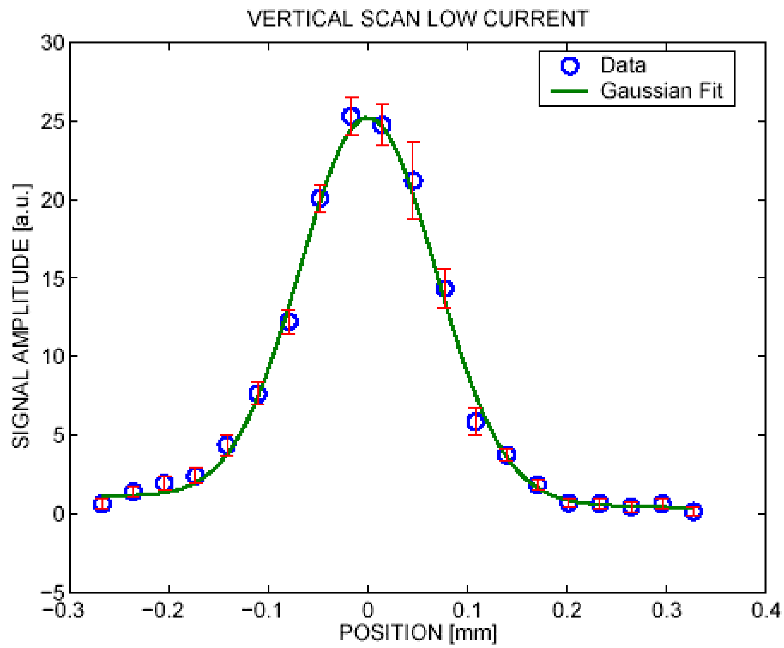


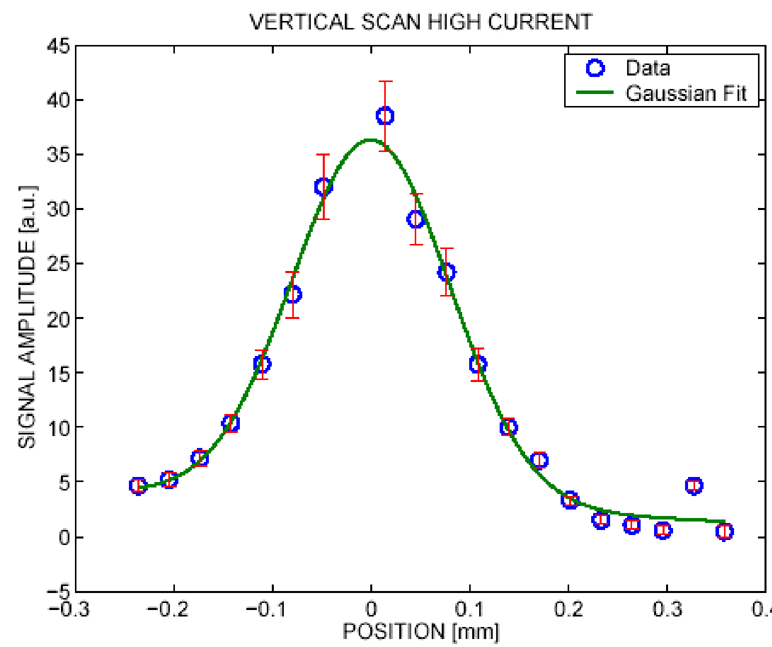
Results 04.12.03 Data

Gaussian approximation of beam shape

s_m =(68 ± 3 ± 20) µm at low current

s_m =(80 ± 6 ± 20) µm at high current





International ATF Laser-wire Project

- Aim towards single-shot fast scanning, extending work at PETRA to sub-micron spot-sizes and high frequencies.
- Scan across single 60ns-300ns trains for single-shot projected profile.
- Use calorimeter time stamp to resolve individual bunch profiles from many scans.
- Test scanning mechanisms: acousto/electro-optics, or others.
- Possibly integrate laser-wire with fast-feedback systems to remove jitter.

Laser		**Electron beam**	
Power per shot	~300 mJ in green	sigma x	~50 μm
M^2	~1.25	sigma y	~5 μm
Wavelength	YAG: 532 nm	Bunch length	~ 30 ps
pulse length	~50ps	Energy	1.3 GeV
Repetition rate	10 Hz	Charge	$\sim 1 \times 10^{10}$

Next steps

Laserwire at PETRA produced first compton photons and measured vertical beam size. Next steps:

- Full characterisation of laser: beam size, divergence, and power (stability) with slot scans and imaging techniques
- Update all readout software, merge BPM and PMT software
- Do more systematic scans with the fast scanner; increase speed.
- Go to smaller spot sizes and reduce errors
- Build second dimension (x) scanner.

- Start designing a complete laser-wire emittance measurement system for the LC BDS.
- Look to ATF for micron-scale, ultra-fast laserwire system

Inside Beampipe