

Transverse Diagnostics: Laser Wire

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CLIC-UK Kickoff Meeting

CERN

12th April 2011

- Introduction
- PETRAIII
- ATF2 LW
- Fibre laser R&D
- Summary



Laser-wire People

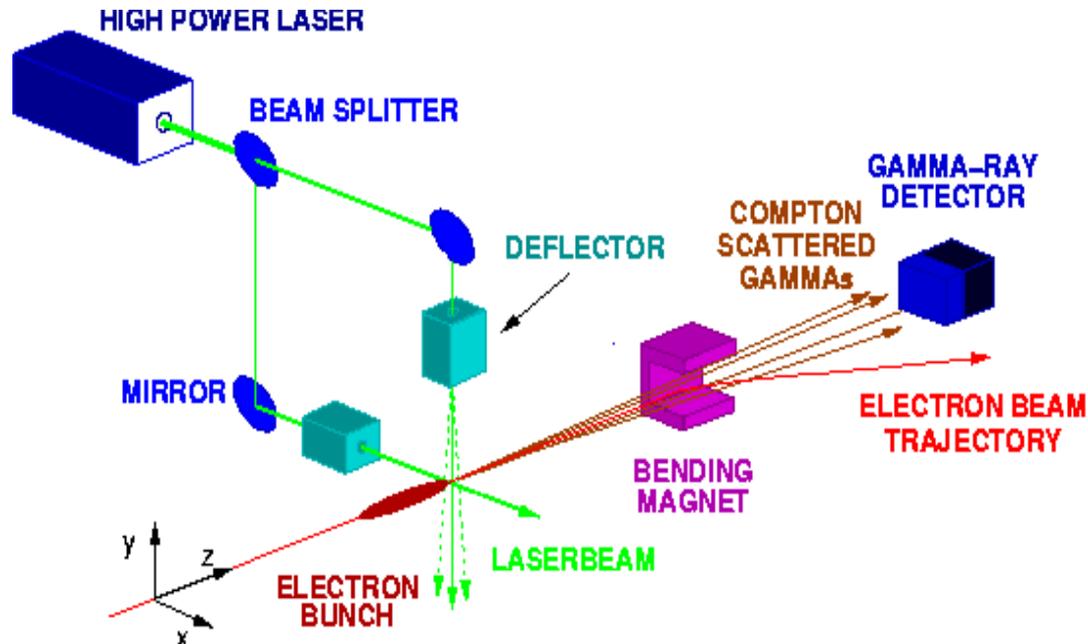
DESY : V. Gharibyan, G. Kube, K. Wittenburg

JAI@Oxford: L. Corner, L. Nevay, R. Walczak

JAI@RHUL: T. Aumeyr, G. Blair, S. Boogert, G. Boorman, A. Bosco, P. Karataev.

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

CERN: T. Lefevre (L. Deacon)



PETRA-III

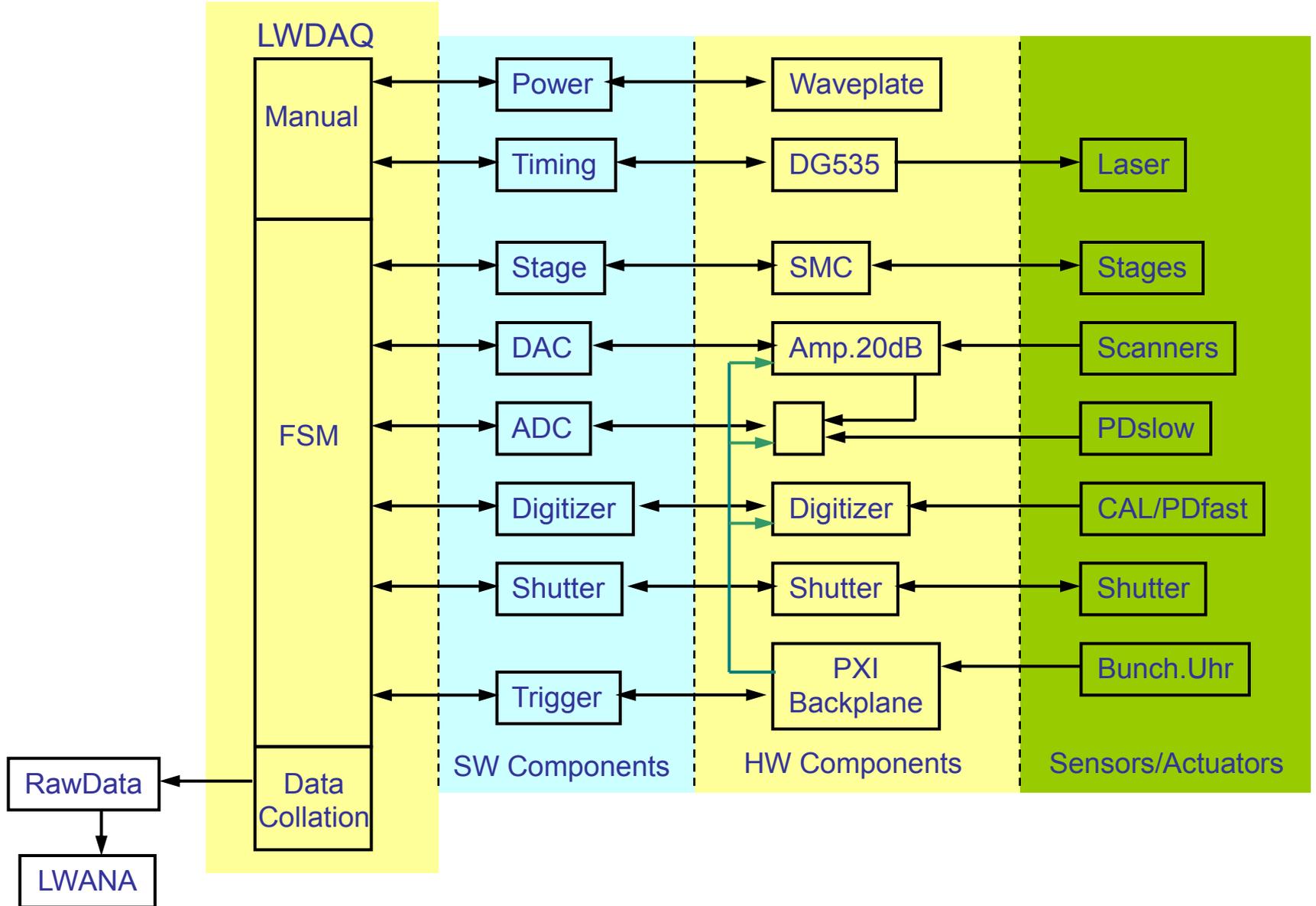
3rd generation synchrotron light source

Parameter		Value	Unit
Energy	E	6	[GeV]
Circumference	C	2304	[m]
Horizontal emittance	ϵ_x	~1	[nm rad]
Vertical emittance	ϵ_y	~0.01	[nm rad]
Train repetition rate	f	130.2	[kHz]
Number of bunches per train	N_{train}	960 (40)	
Interbunch spacing		8 (192)	[ns]
Bunch length RMS	L_b	~12	[mm]
Number of electrons per bunch	N_e	0.25 (12)	$\times 10^{10}$

Breadboard layout - photo



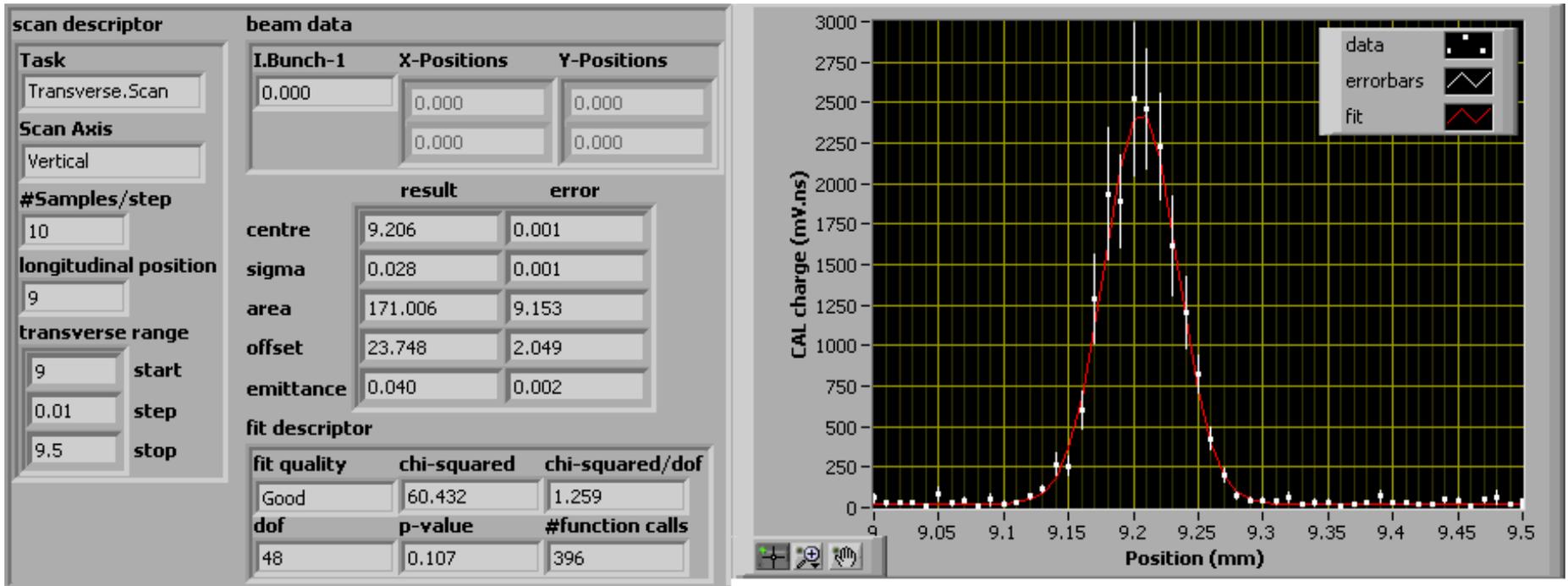
LWDAQ



Petrall Scan Types

- Transverse scan using piezo, resolution $\leq 1 \mu\text{m}$
 - Scanning range: $< 1 \text{ mm}$
 - After moving the stages into place:
20 steps and 5 shots per step = $5 \times 50\text{ms} \times 20 = 5\text{s}$
- Transverse scan using motorised stage, resolution $\leq 1 \mu\text{m}$
 - Scanning range: 25 mm
 - 500 ms overhead for stepping the stages:
20 steps and 5 shots per step = $(5 \times 50\text{ms} + 500\text{ms}) \times 20 = 15\text{s}$
- Longitudinal scan using motorised stage
- Knife-edge scans to check waist and Rayleigh range of laser
- Can adjust laser timing and laser power

Vertical scan



470 μ A bunch current
10 Samples/Step

$\mu = 9.206 \pm 0.001$ mm
 $\sigma = 0.028 \pm 0.001$ mm
 $X^2/\text{dof} = 1.259$

Horizontal scan

scan descriptor

Task
Transverse.Scan

Scan Axis
Horizontal

#Samples/step
10

longitudinal position
14

transverse range
9.5 start
0.05 step
12 stop

beam data

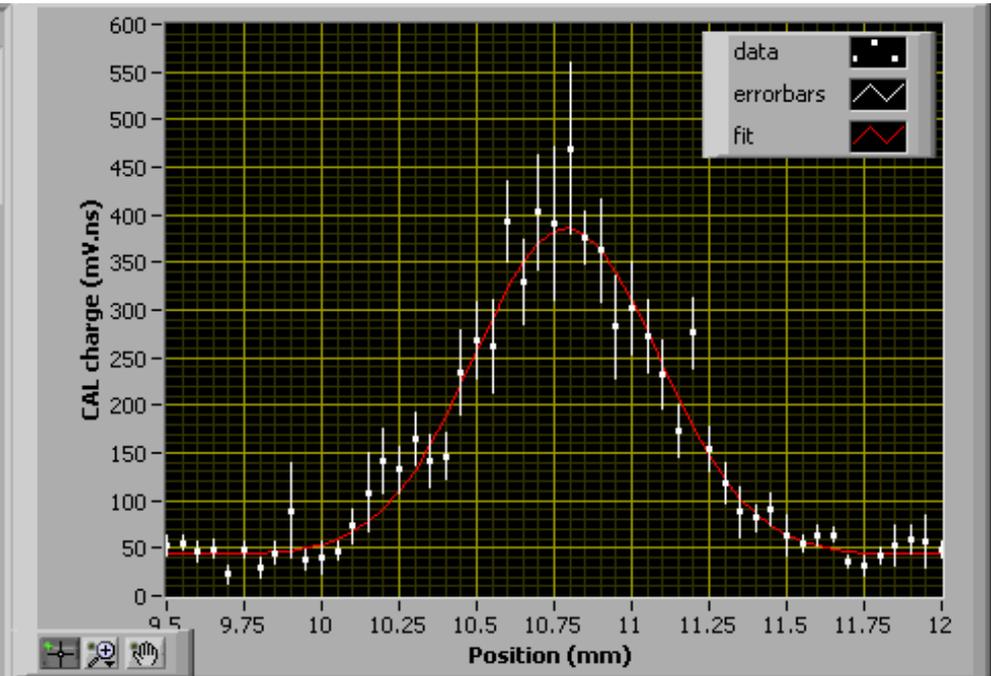
I.Bunch-1	X-Positions	Y-Positions
0.000	0.000	0.000
	0.000	0.000

	result	error
centre	10.791	0.012
sigma	0.298	0.011
area	255.799	10.627
offset	43.479	2.497
emittance	4.587	0.595

fit descriptor

fit quality	chi-squared	chi-squared/dof
Good	50.775	1.080

dof	p-value	#function calls
47	0.327	135

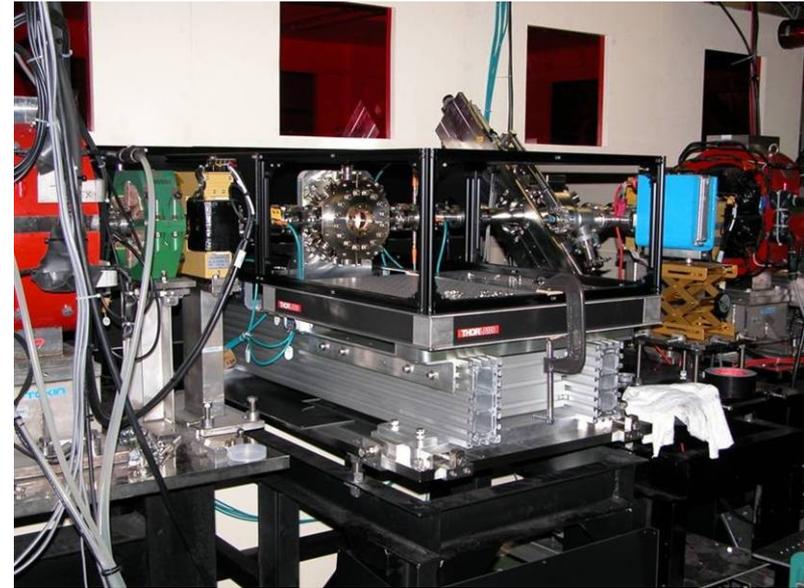


470 μ A bunch current
10 Samples/Step

$\mu = 10.791 \pm 0.012$ mm
 $\sigma = 0.298 \pm 0.011$ mm
 $X^2/\text{dof} = 1.080$

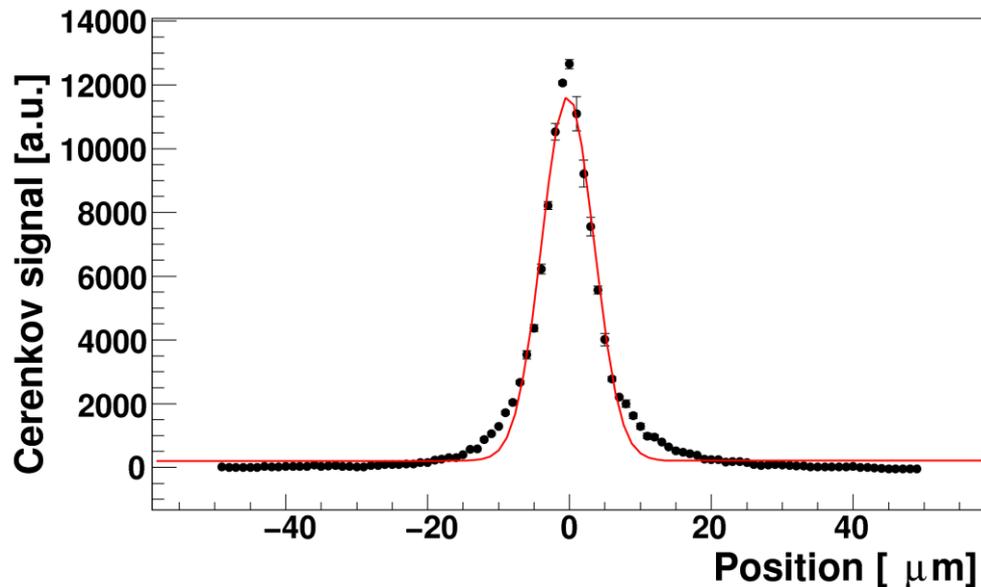
ATF Parameters

Beam energy :	1.28 GeV
Beam intensity single bunch operation :	1.0×10^{10} electrons/bunch
multi bunch operation :	0.7×10^{10} electrons/bunch x 20 bunch
Beam repetition :	0.7 - 6.4 Hz
X emittance (extrapolated to 0 intensity) :	1.0×10^{-9} rad.m (at 1.28 GeV)
Y emittance (extrapolated to 0 intensity) :	1.0×10^{-11} rad.m (at 1.28 GeV)
Typical beam size :	70 μ m x 7 μ m (rms horizontal x rms vertical)



ATF Extraction line: Smallest Scan

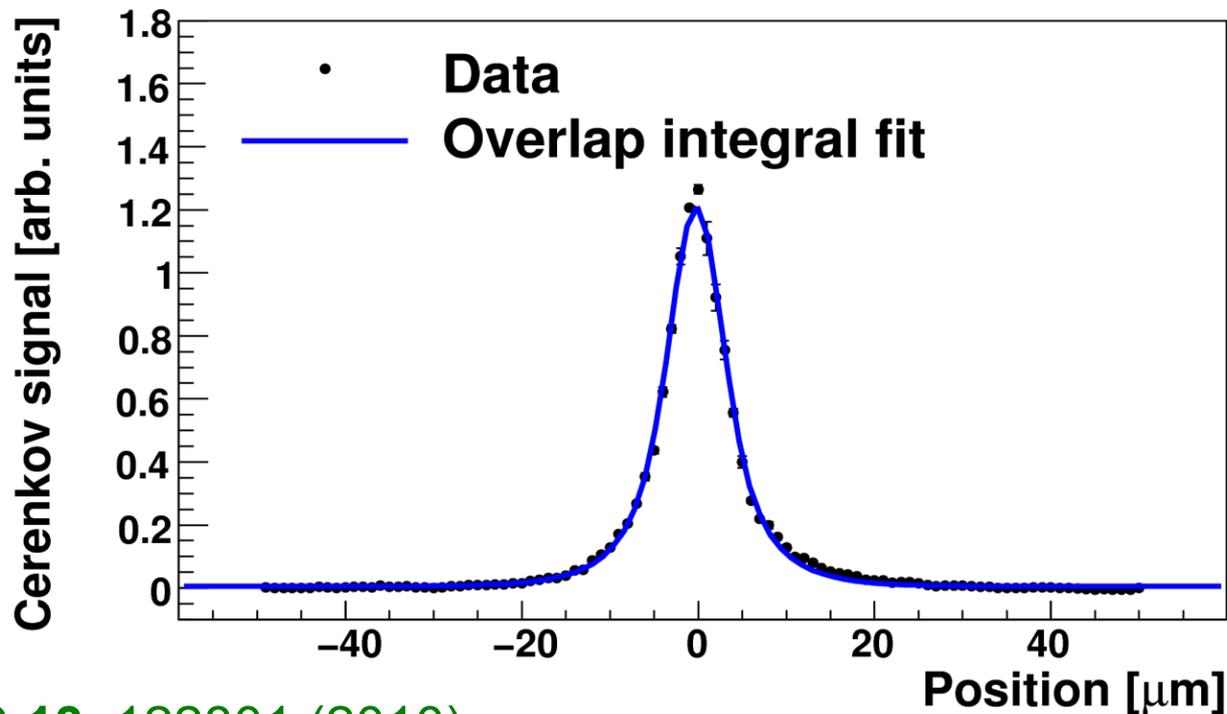
- Size of electron/laser beam overlap with Gaussian fit: $\sigma = 3.65 \pm 0.09 \mu\text{m}$
- Subtracting laser beam in quadrature gives $\sigma_e = 2.9 \pm 0.2 \mu\text{m}$ – this is consistent with the measured emittance
- The tails could be due to Rayleigh range or spherical aberration effects



Fit to overlap integral

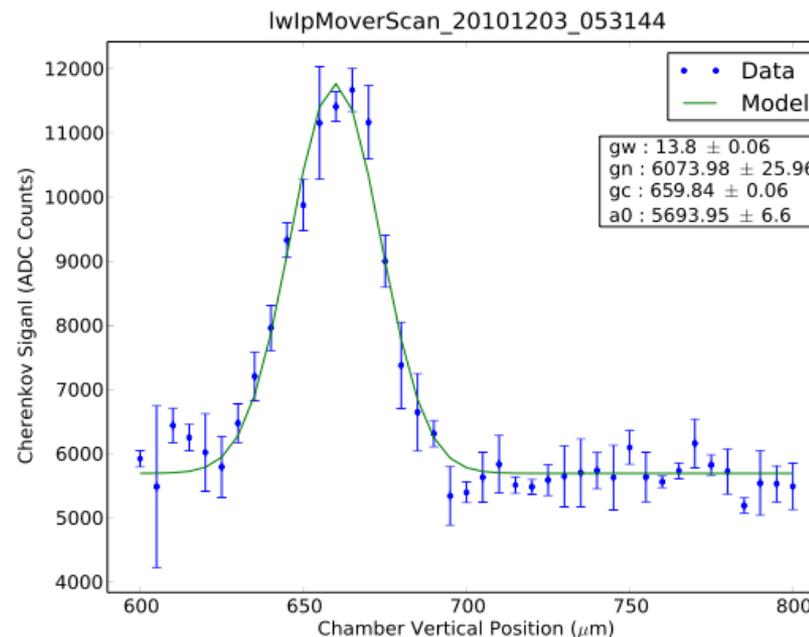
- The fit gives results for the vertical beam size of the right order of magnitude. The fit is good, implying that the tails in the distribution are due to Rayleigh range effects.
- However, the horizontal electron beam size was not directly measurable. Fit results:

$$\sigma_x = 58 \pm 20 \mu m \quad \sigma_y = 1.8 \pm 0.2 \mu m$$



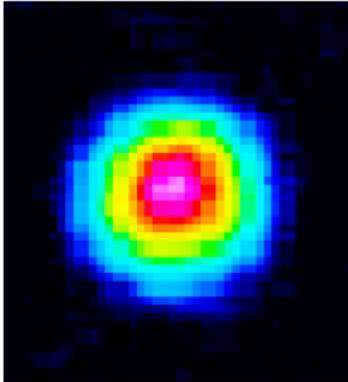
ATF2 current status (Dec 2010)

- Signal extraction (over 27m) now achieved.
- Improved data taking + analysis tools
- Nano BPM systems to correct bunch jitter
- Currently taking data.



- Preliminary scans
- ATF2 tuning required for smaller spot-sizes

< 1 μm spot size

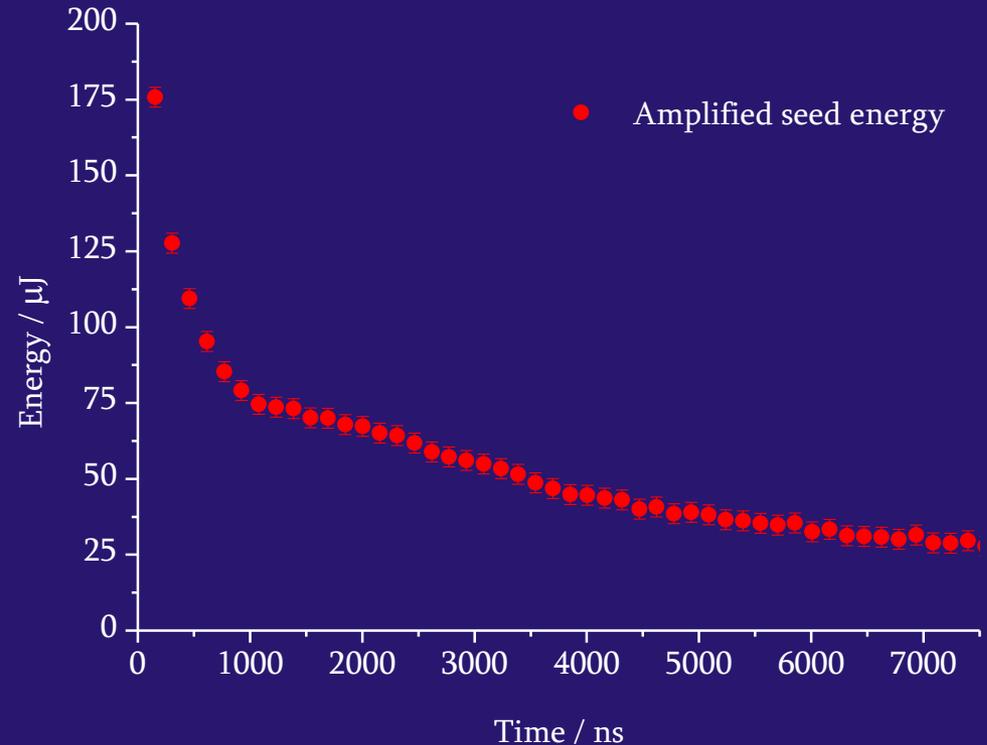


Fibre laser - Photonic crystal fibre, large core, single mode

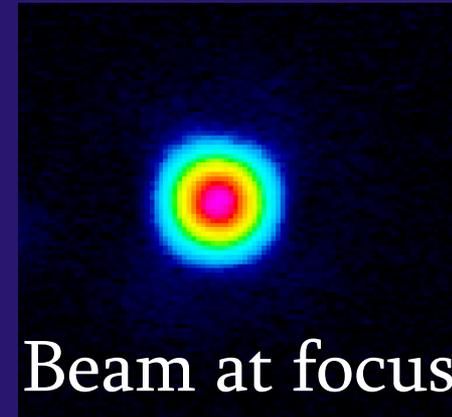
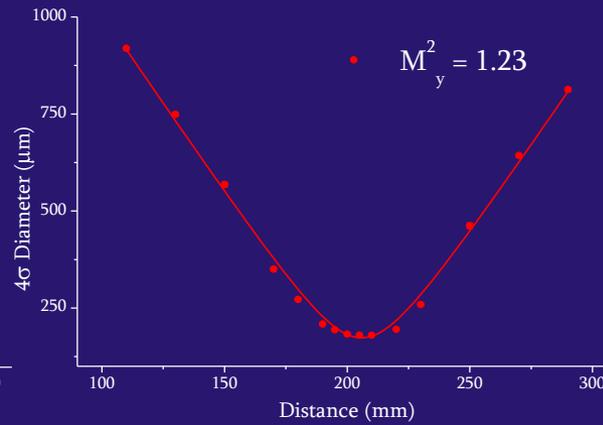
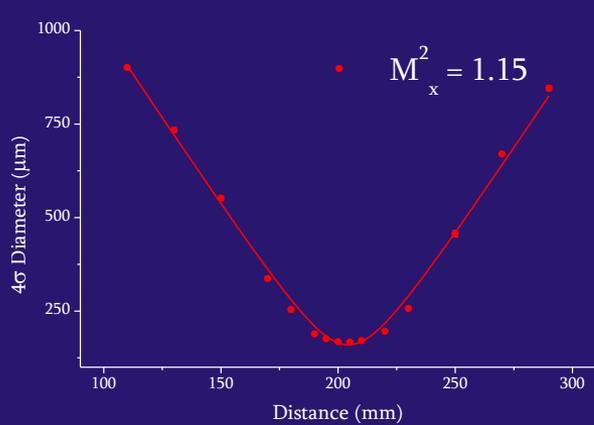
Amplification of seed burst in PCF



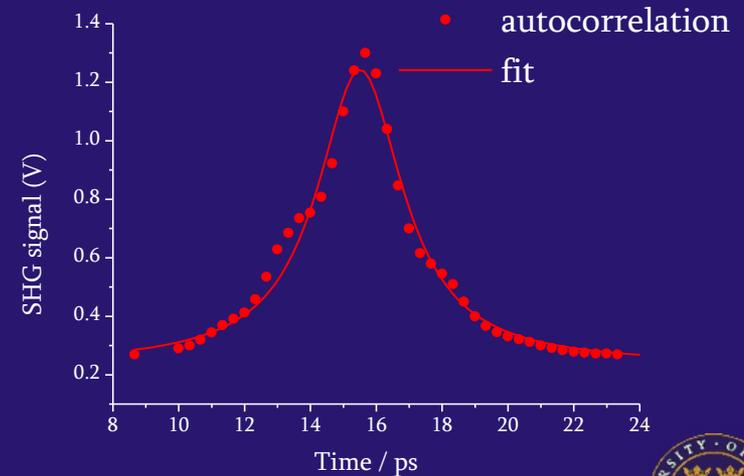
Input pulse energy $1.4\mu\text{J}$
Output energy $175\mu\text{J}$
3 pulses $> 100\mu\text{J}$ (spec)
Gain = 30dB/m



Beam properties



Beam nearly perfectly Gaussian
Second harmonic spectral width < 0.5nm
Unamplified pulses compressed to < 2ps



Future plans

Complete fibre laser to laser-wire specification – efficient second harmonic generation, amplified pulse compression.

Installation of fibre system at ATF2 – take data, optimisation of laser-wire for highest resolution, comparison with current solid state laser.

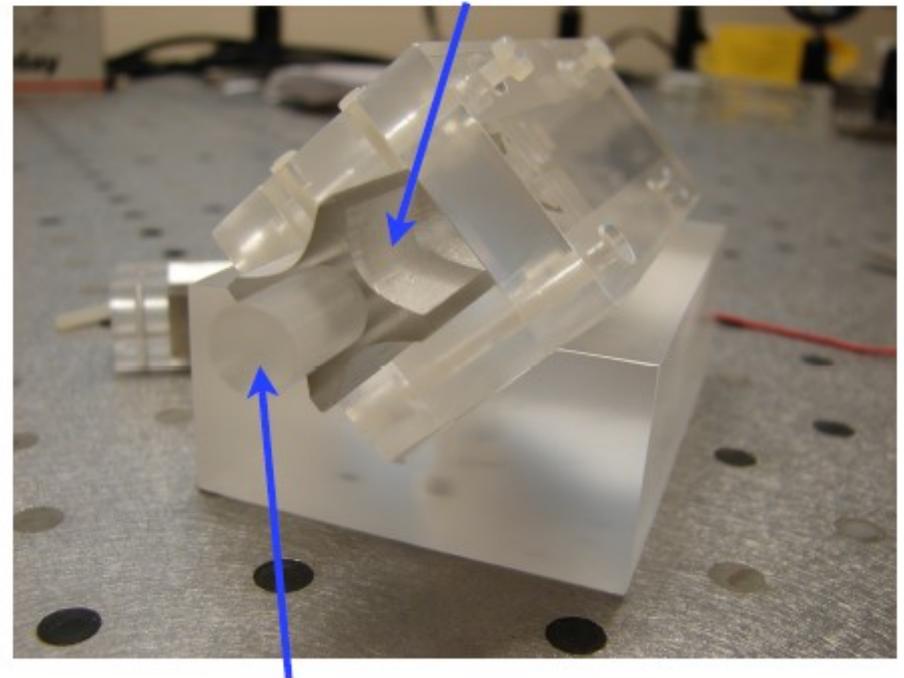
Application of fibre technology to other accelerator applications – photoinjectors, laser plasma wakefield acceleration etc.



Prototype scanner

- First stage of high power scanner prototype
 - Simple EO crystal geometry
- Currently using
 - Lithium Niobate
 - Diameter 8.5 mm
 - Length 45 mm
- Different crystals
 - Damage thresholds
 - Electro-optic coefficient

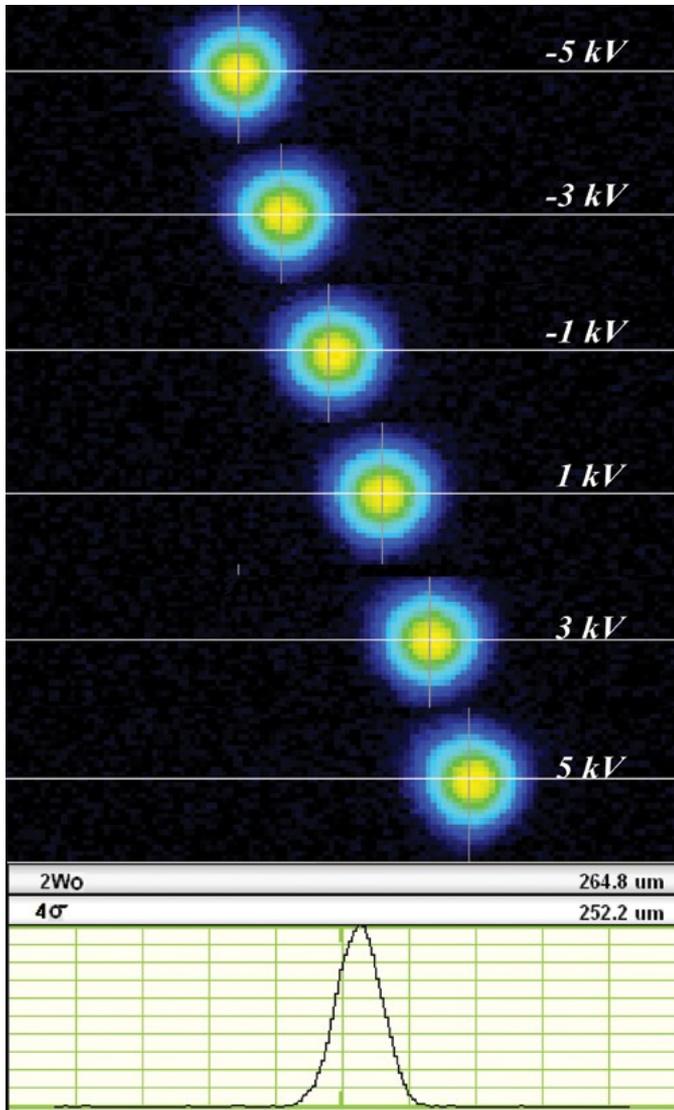
Quadrupole electrodes on outer surface



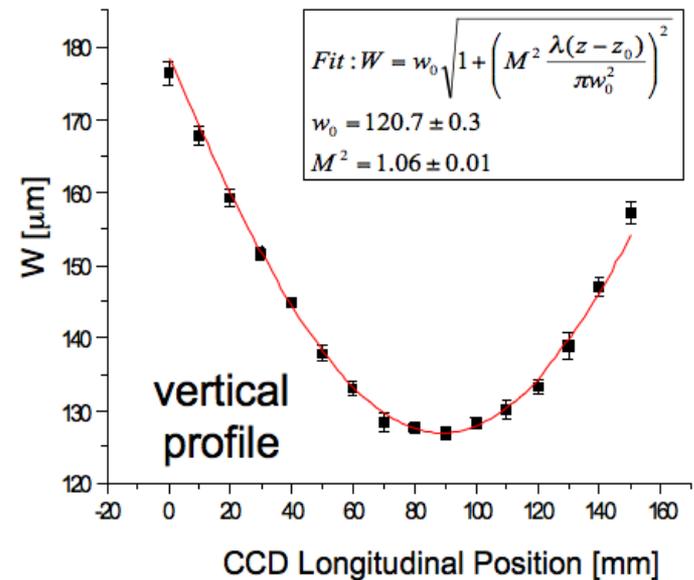
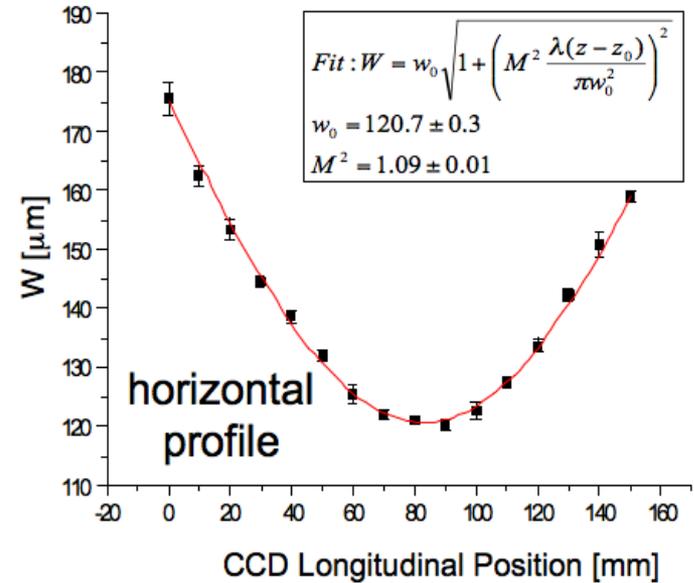
Cylindrical crystal hole

A .Bosco et al
Appl Phys Lett. **94** 1 (2009).

Beam images and profiles during scan



M² measurements with 5 kV applied



Summary

- **PETRAIII:**
 - Upgraded system now running.
 - Emphasis on speed of scans, ease of use.
 - Send out mode-locked laser (130kHz) for fast scans.
- **ATF**
 - Signal extraction over 27m solved.
 - Very promising initial results.
 - Awaiting recovery of earthquake.
- **Fiber Laser**
 - Work continuing on advanced fibre laser at Oxford.
 - Key to ILC/CLIC laser-wire solution.
 - World-leading work in this area.
- **Fiber light transport**
 - Intend to study realistic system at PETRAIII
- **Fast scanning**
 - Concept studied; intend to implement at PETRAIII.