Development of a beam profile monitor for CLIC using laser-wire systems

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Laser-wire systems

- Measuring transverse beam profile
- Essential for determining transverse beam emittance
- Focused laser beam scans across particle beam
- e^--machines: → Compton Effect
  - laser photons scattered by e^- are detected as gamma rays in a calorimeter
  - Scattered e^- over-focused by magnets
- H^--machines: → Photo-ionisation of H^- into H^0
  - H^0 and/or released e^- detected downstream

PETRA-III

- Newly completed accelerator at DESY, Hamburg
- World's most brilliant synchrotron light source
- Understanding emittance important to achieve ultimate performance
- Beam size: ~10 µm

PETRA-III

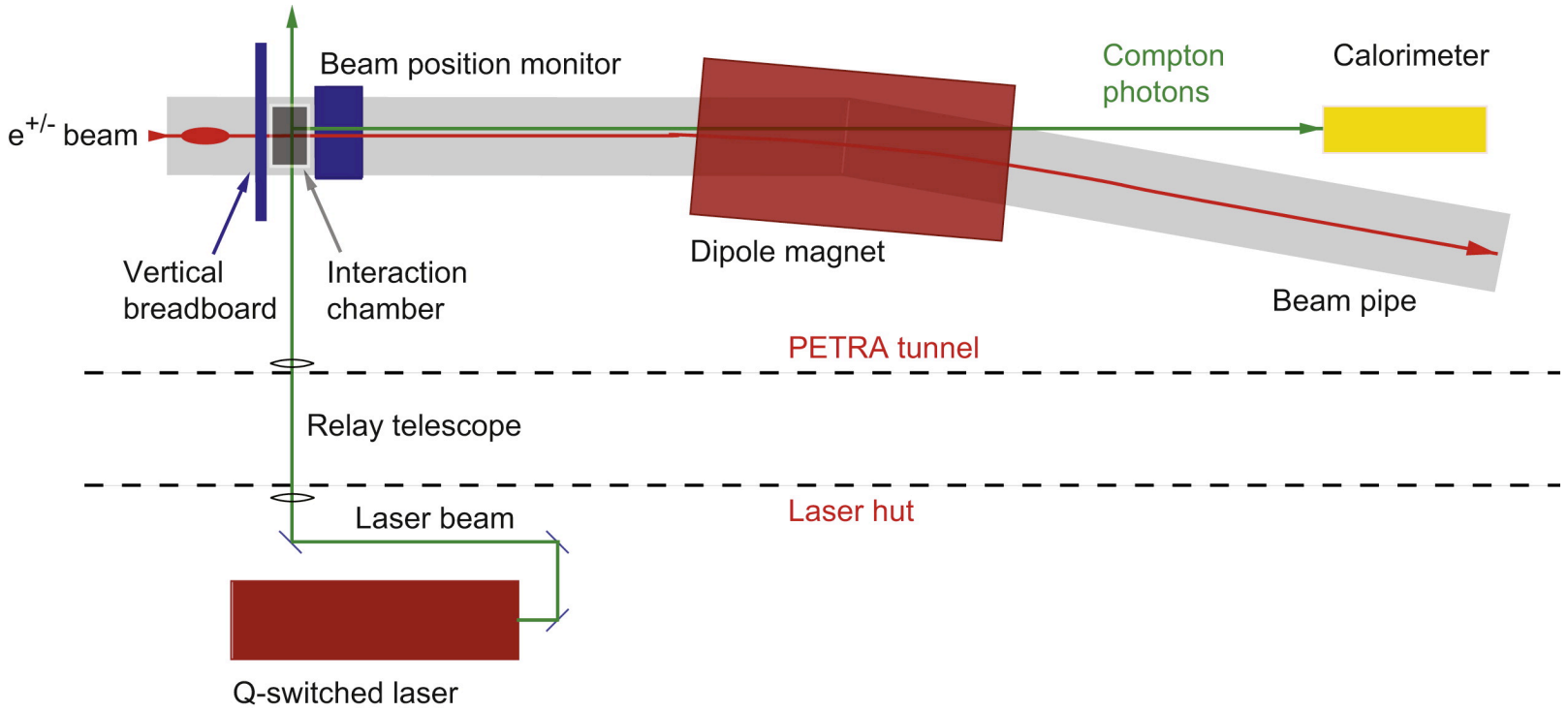
3rd generation synchrotron radiation source

Parameter		Value		Unit
Energy	E	6		[GeV]
Circumference	C	2304		[m]
Horizontal emittance	ε_x	~1		[nmrad]
Vertical emittance	ε_y	~0.01		[nmrad]
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)	$\times 10^{10}$

Laser-wire @ PETRA-III

- Installed in early 2009
- Green laser light (λ=532 nm)
- Produced first data within a week
- Using a vertical optical table: vertical and horizontal scans possible
- Current emphasis: automation and integrating into PETRA system
- Next step: taking and analysing data in the context of P3 optimisation

Overview of LW layout



The laser-wire system at PETRA-III is 2D bunch profiler: laser beam can be sent to collision in horizontal or vertical plane

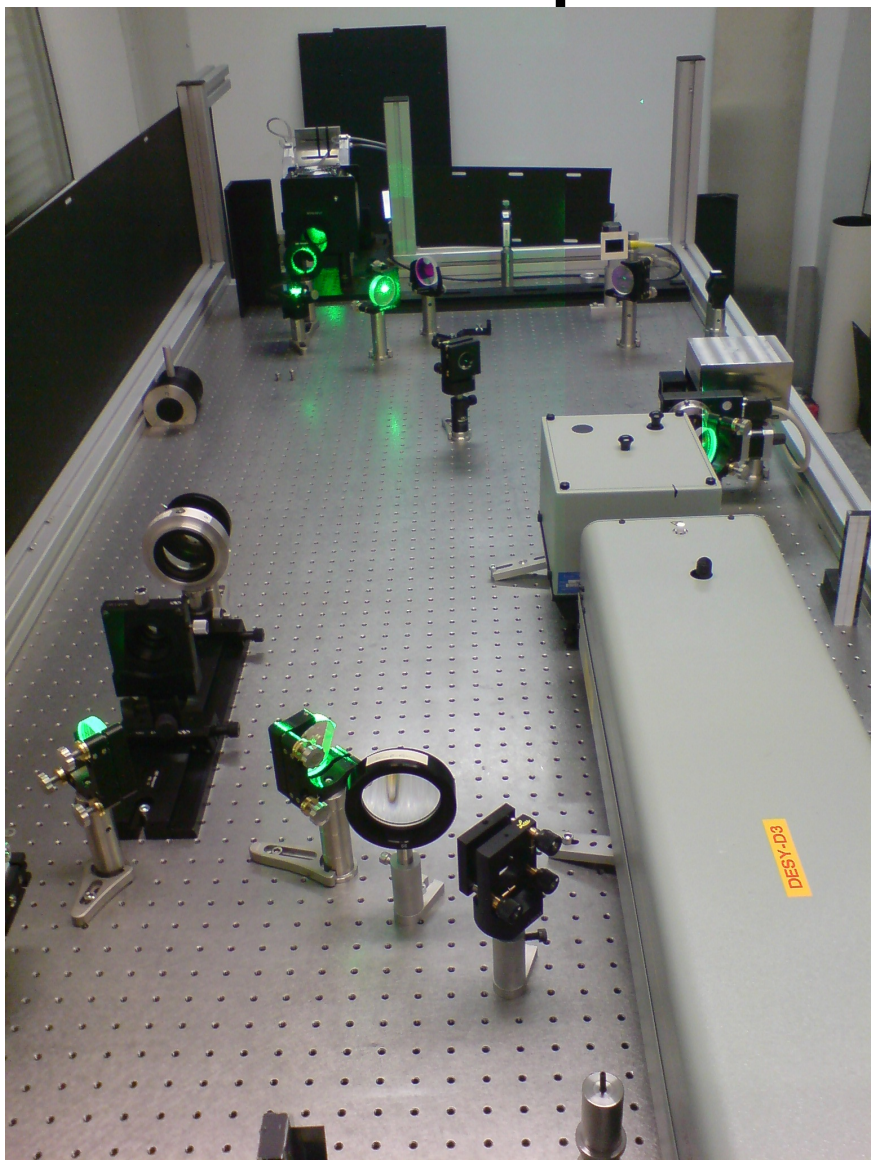
Optical scanning components

- Nd:YAG laser (1064 nm, frequency doubled)

Parameter	Value	Unit
Pulse energy at 532 nm	60 ± 5	mJ
Peak power at 532 nm	12 ± 1	MW
Repetition rate	20	Hz
Pulse duration	5 ± 1	ns
RMS pulse jitter (rel. to ext. trigger)	1	ns
Mode quality factor (M^2)	2.68 ± 0.05	
Horizontal angular jitter	18.8	µrad
Vertical angular jitter	9.4	µrad

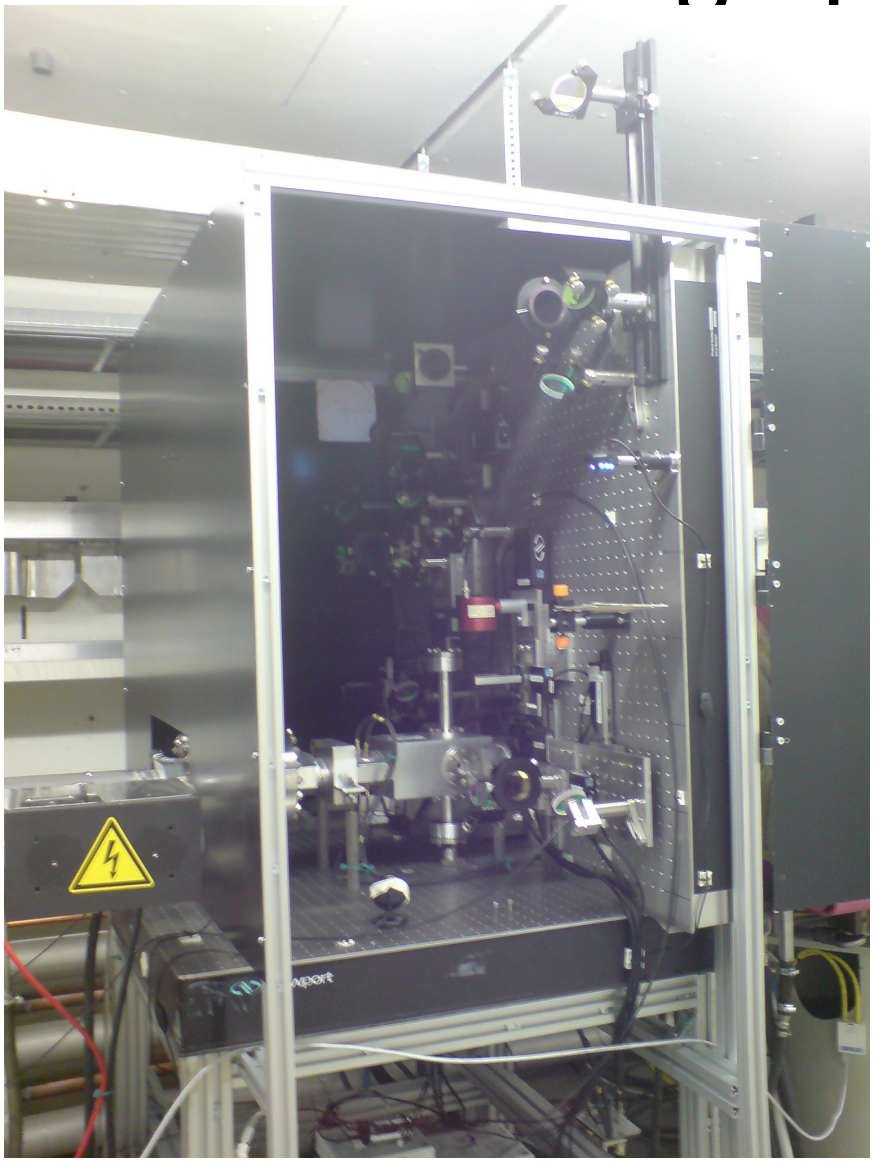
- 2" high reflective static mirrors, 2 scanning mirrors
- Horizontal scan: 750 mm lens
- Vertical scan: 250 mm lens
- 3 webcams with alignment crosses (monitor laser-alignment remotely)

Laserhut - photo

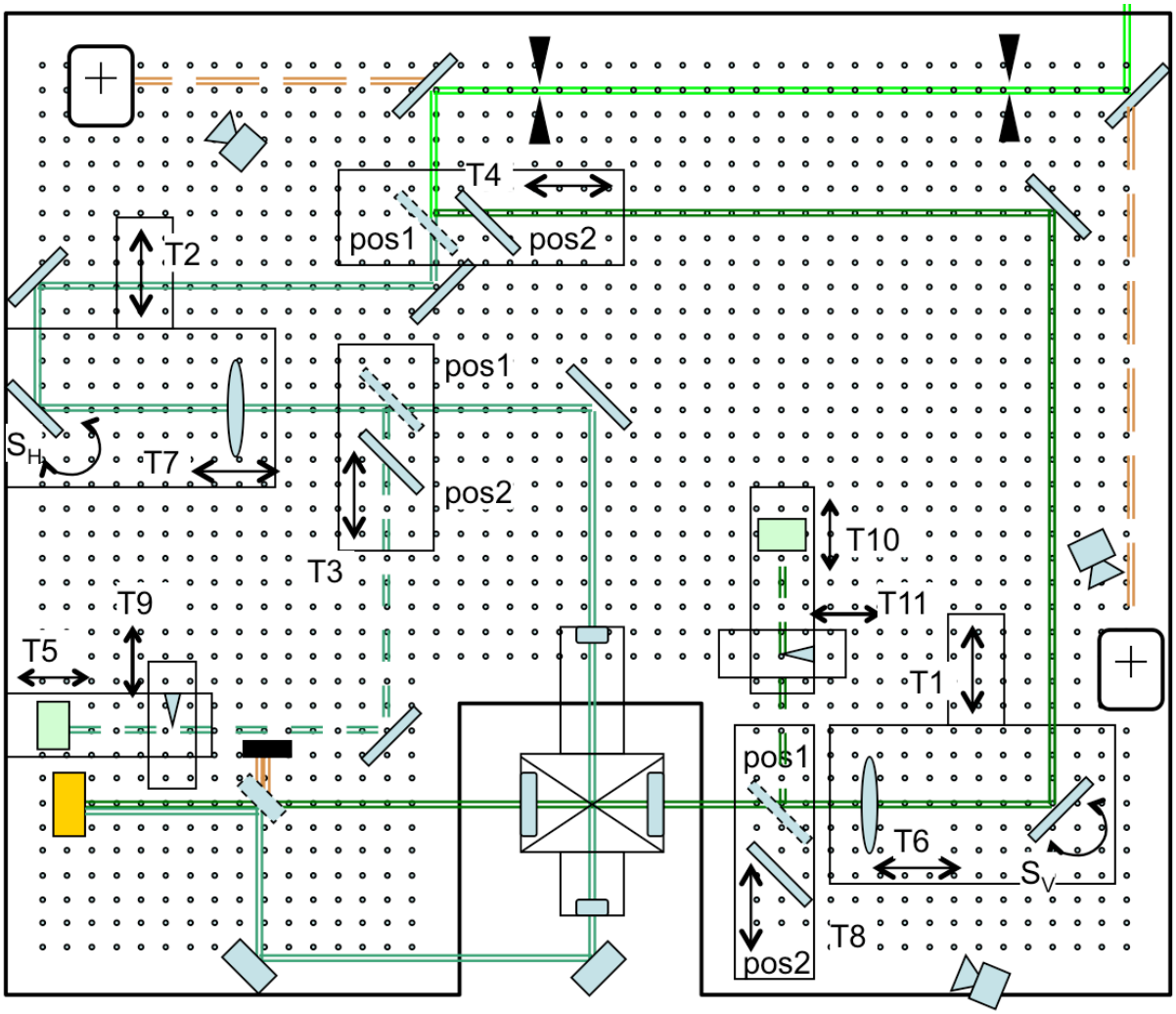


Laser transport - photo

Breadboard housing - photo

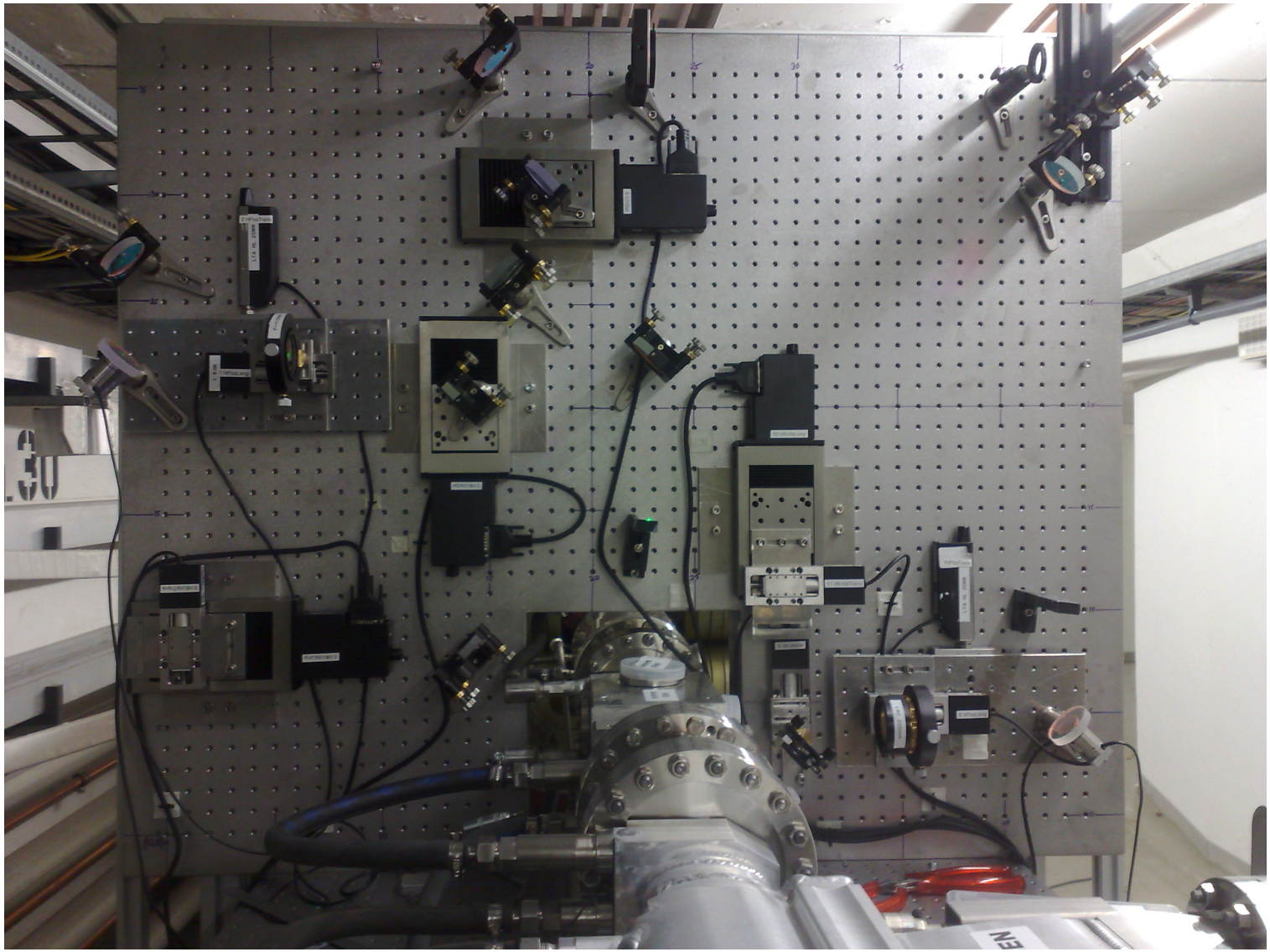


Breadboard layout

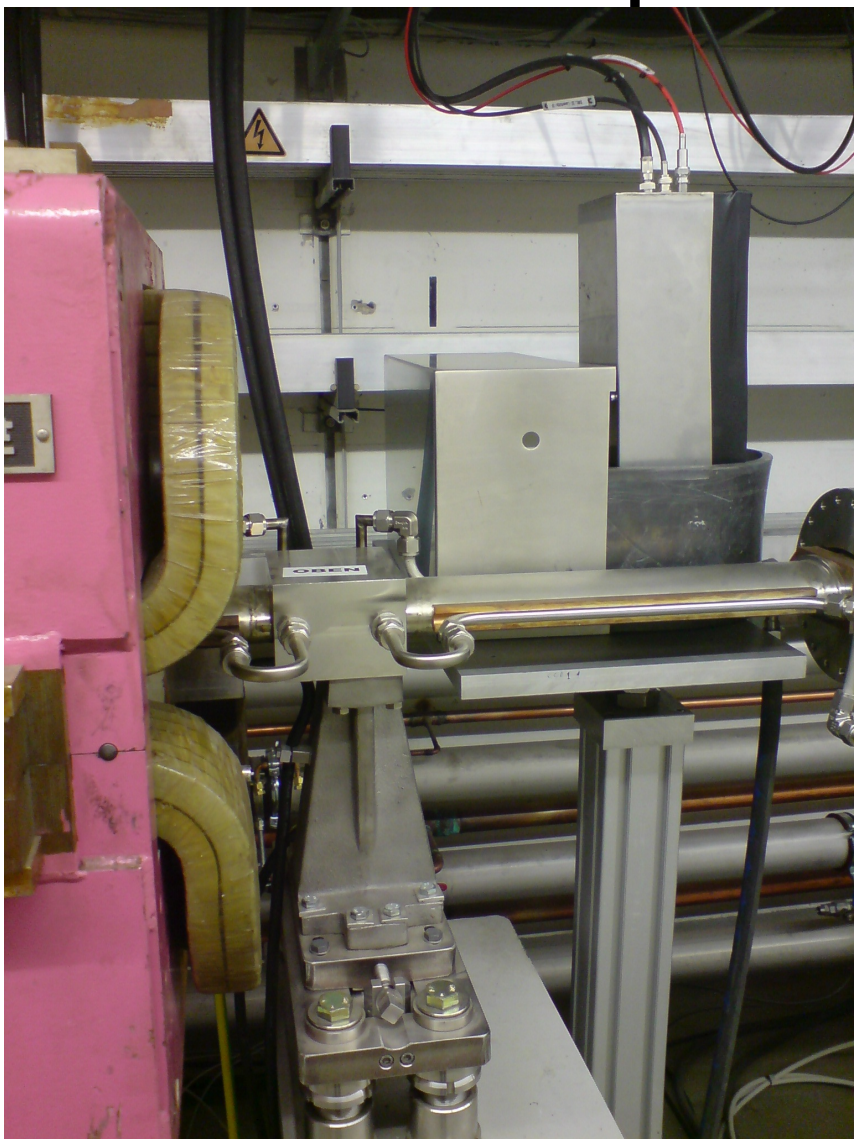


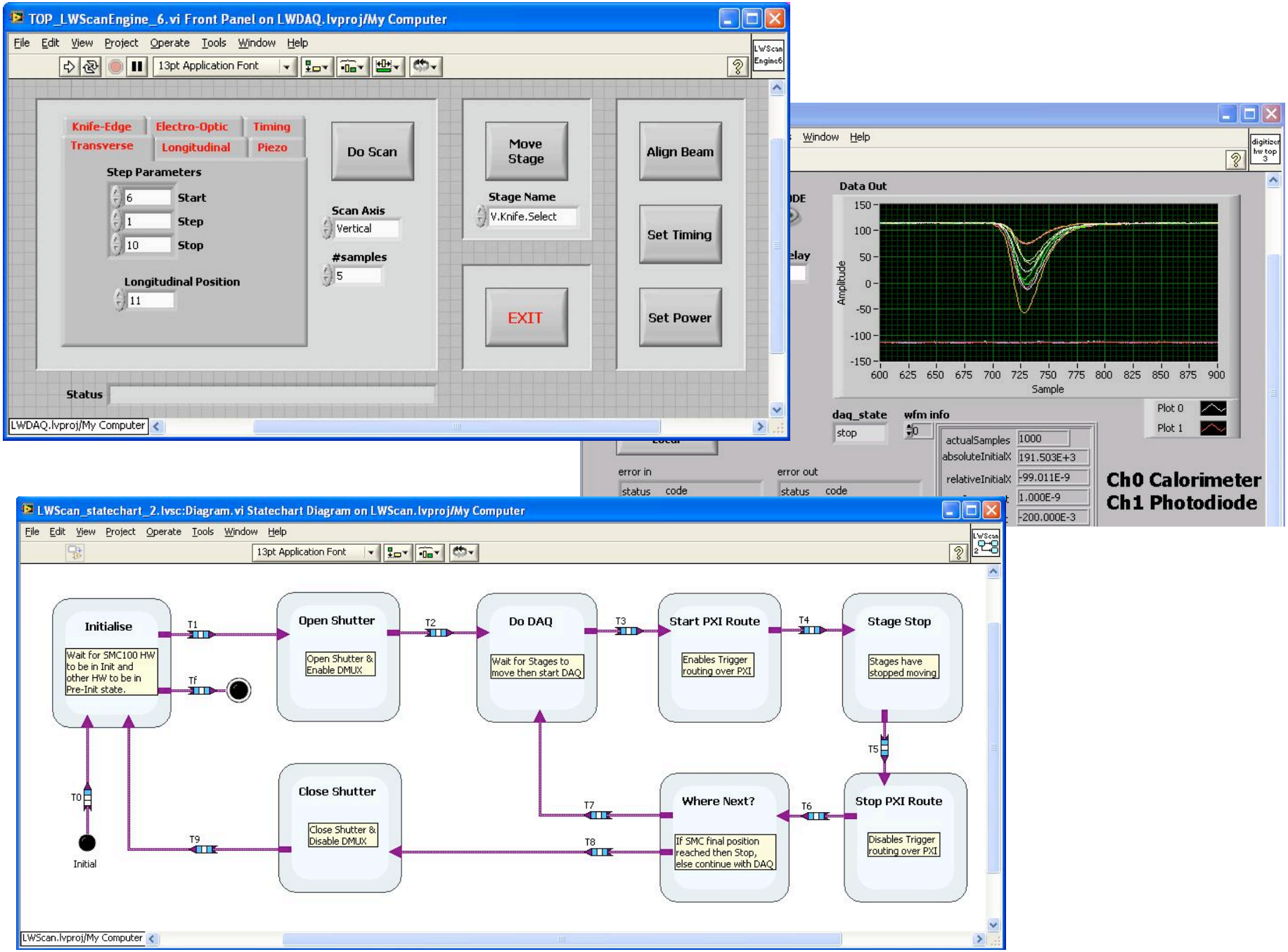
During shutdown in May 2009 motorised translation stages (T1-T11) were positioned with laser aligned for IP.

Breadboard layout - photo



Calorimeter - photo




TOP_LWScanEngine_6.vi Front Panel on LWDAQ.lvproj/My Computer
File Edit View Project Operate Tools Window Help
13pt Application Font
LWScan Engine6
Knife-Edge
Electro-Optic
Timing
Transverse
Longitudinal
Piezo
Step Parameters
6 Start
1 Step
10 Stop
Longitudinal Position
11
Do Scan
Scan Axis
Vertical
#samples
5
Move Stage
Stage Name
V.Knife.Select
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Align Beam
Set Timing
Set Power
Status
LWDAQ.lvproj/My Computer
Window Help
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Data Out
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status code
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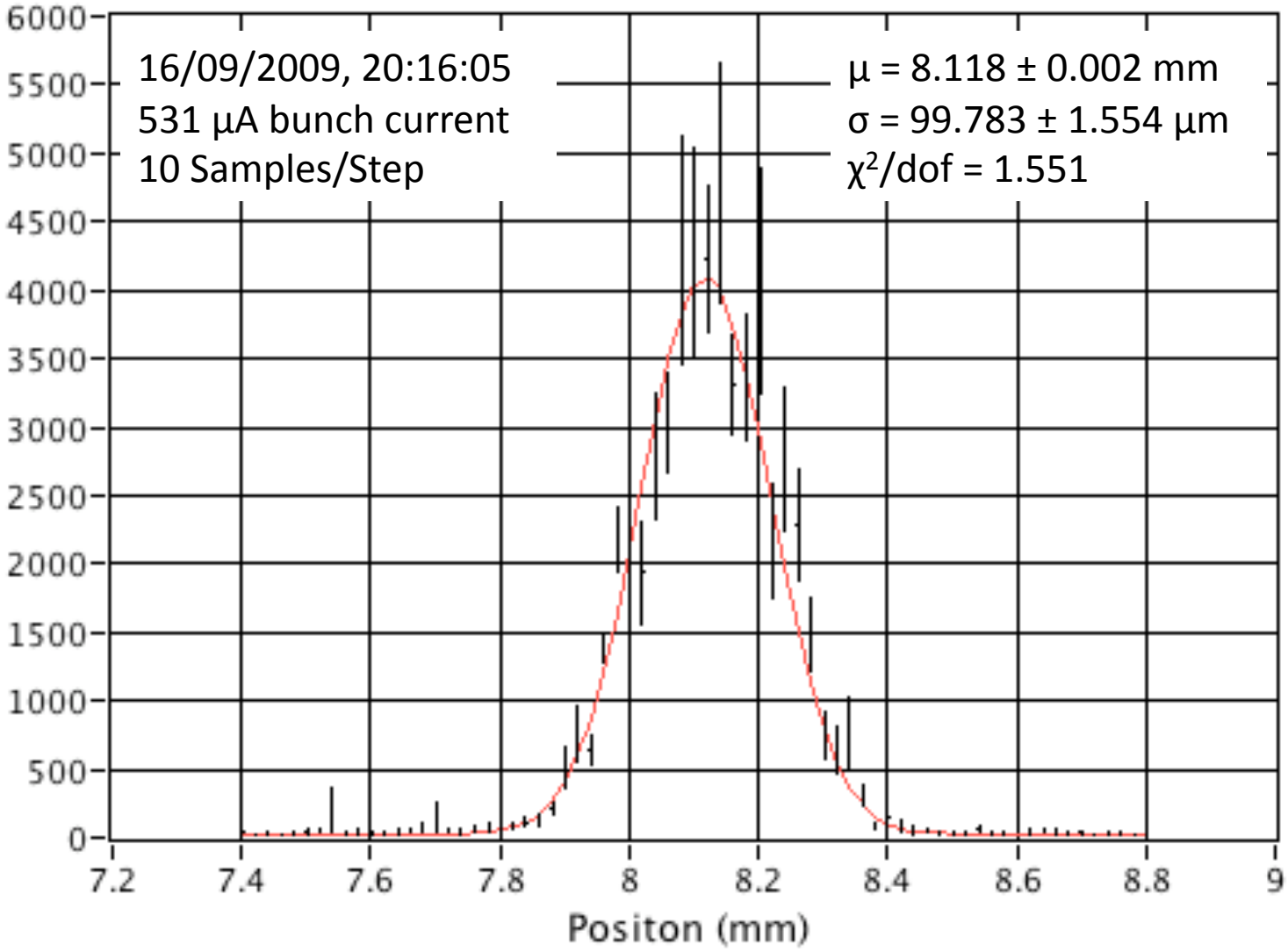
status code
Ch0 Calorimeter
Ch1 Photodiode
LWScan_statechart_2.lvsc:Diagram.vi Statechart Diagram on LWScan.lvproj/My Computer
File Edit View Project Operate Tools Window Help
13pt Application Font
LWScan 2
Initialise
Wait for SMC100 HW to be in Init and other HW to be in Pre-Init state.
T1
Tf
Open Shutter
Open Shutter & Enable DMUX
T2
Do DAQ
Wait for Stages to move then start DAQ
T3
Start PXI Route
Enables Trigger routing over PXI
T4
Stage Stop
Stages have stopped moving
T5
Stop PXI Route
Disables Trigger routing over PXI
T6
Where Next?
If SMC final position reached then Stop, else continue with DAQ
T7
T8
Close Shutter
Close Shutter & Disable DMUX
T9
T0
Initial
LWScan.lvproj/My Computer

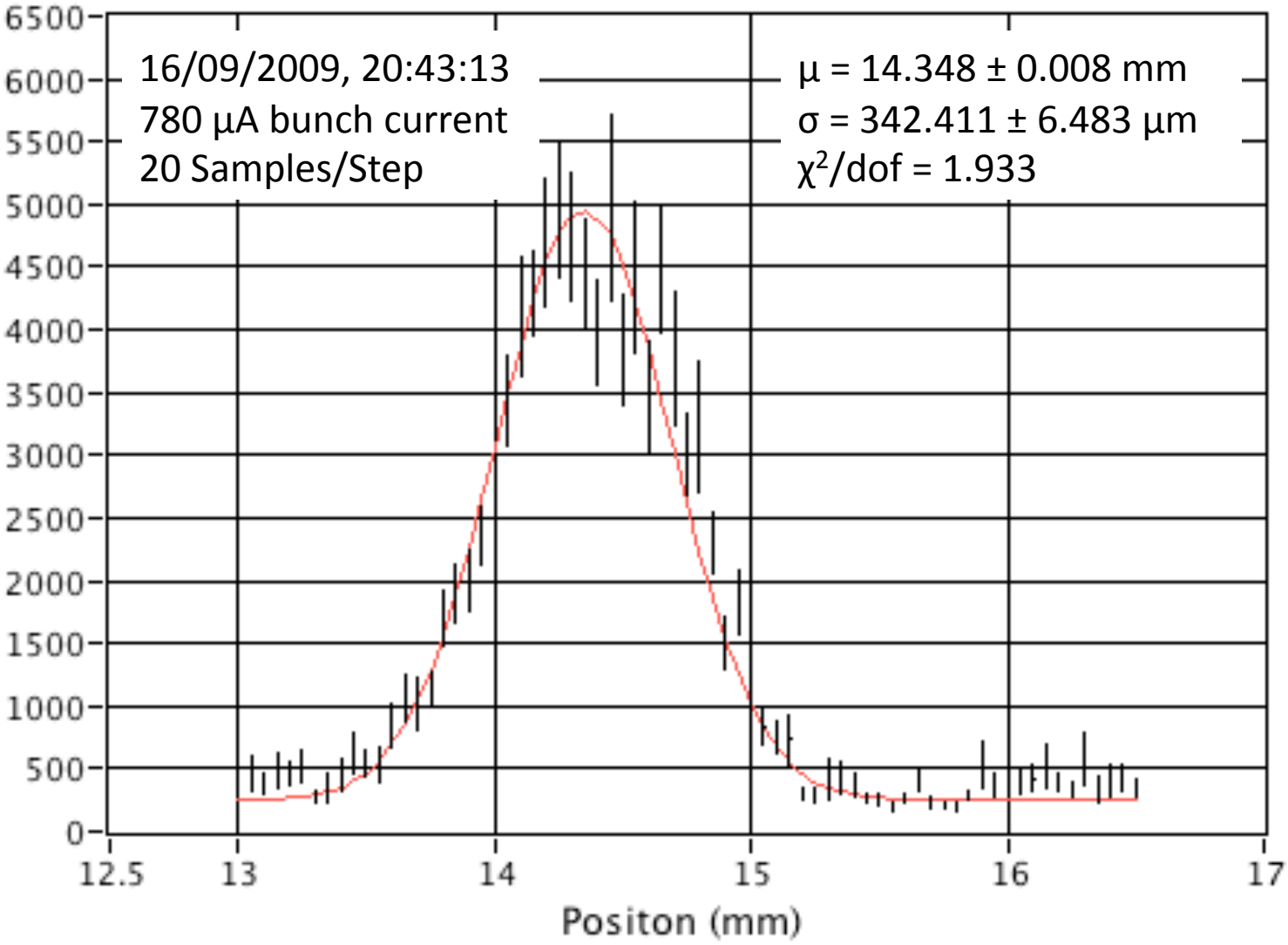
Scan Types

- Transverse scan using piezo ≤ 1 µm
  - Scanning range: < 1 mm
  - After moving the stages into place:
    20 steps and 5 shots per step = 5 * 50ms * 20 = 5s
- Transverse scan using motorised stage, resolution ≤ 1 µm
  - Scanning range: 25 mm
  - 500 ms overhead for stepping the stages:
    20 steps and 5 shots per step = (5 * 50ms + 500ms) * 20 = 15s
- 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



Horizontal scan



Outlook

- More automatic operation of LWDAQ (self-optimising scans, beam finding, laser timing adjustments, piezo calibration, etc.)
- Online analysis of beam size (understanding other errors and including corrections)
- More data taking!
- Displaying results (BKR, TINE)