FETS Laser diagnostics schedule and proposal for Linac4

on behalf of
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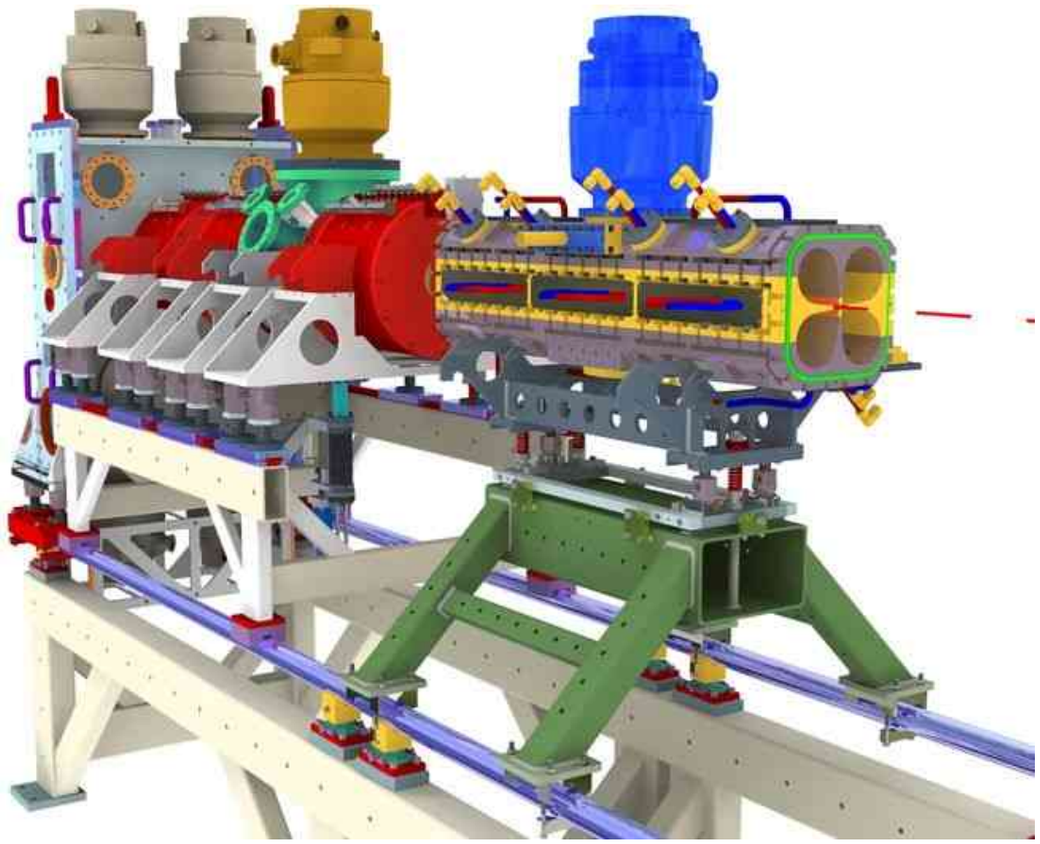
S. Boogert, G. Boorman, A. Bosco, S. Gibson – RHUL
in collaboration with CERN BE/BI group

Outline

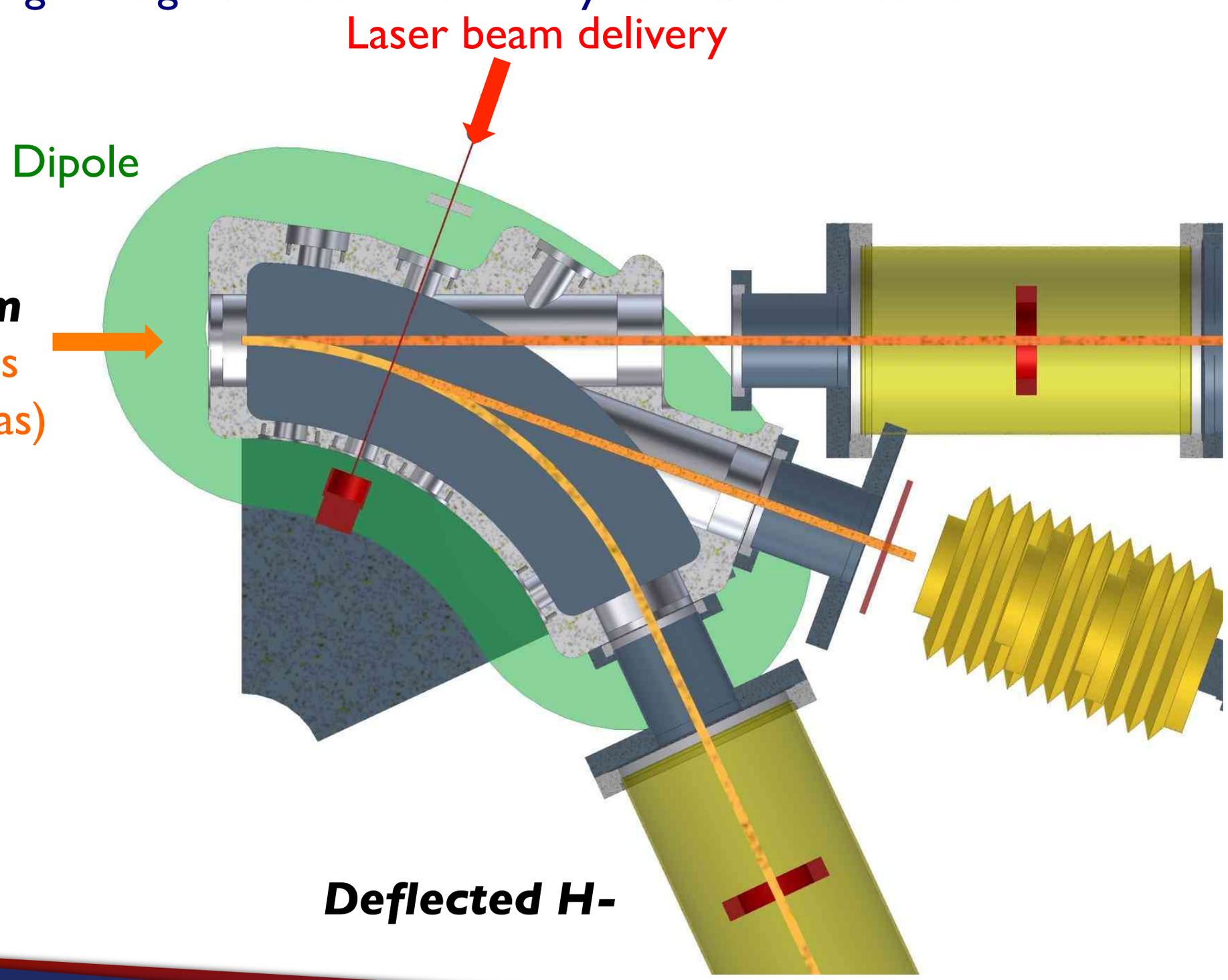
FETS Meeting, UCL
8/05/2013

- Emittance via photo-detachment
- Component status
- FETS laser diagnostics schedule.
- Linac4 layout and plans
- Proposal for integration



Emittance via photo-detachment

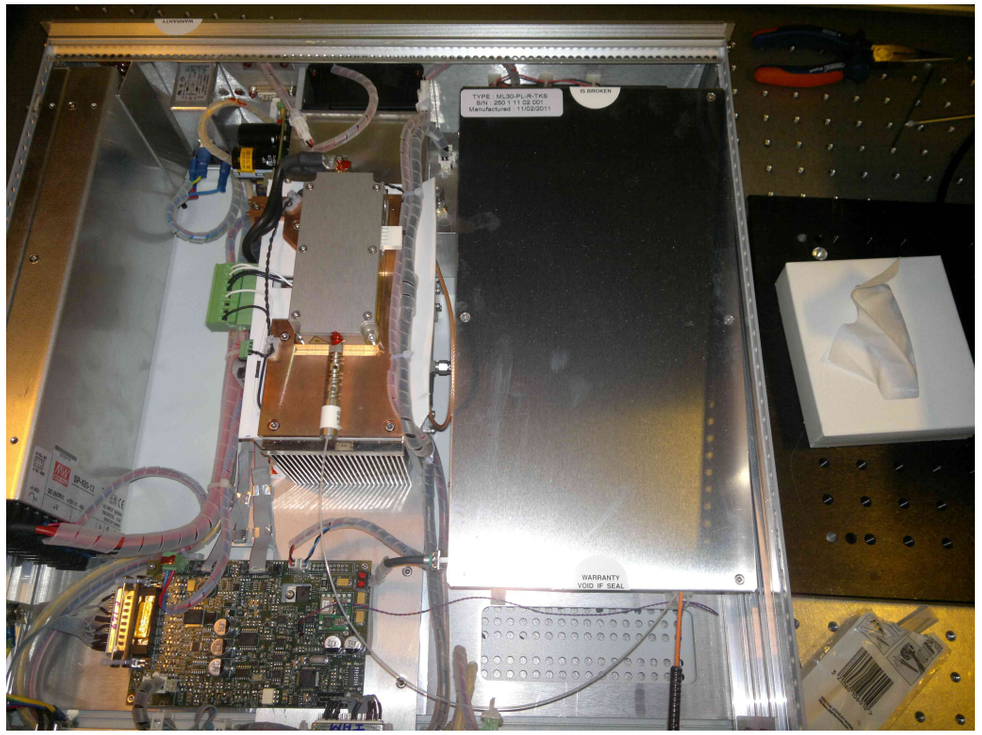
- Basic principle: laser interacts with H- in chamber to photo-detach electrons, leaving H0 signal to be measured by scintillator + camera.



Laser characterization and status

- Light source is a Q-switched, diode pumped, all fibre master oscillator and power amplifier (MOPA) laser.
- ML-30-PL-R-TKS by Manlight S.A.S (Lannion France).

Wavelength	1064 nm
Average power	30 W
Repetition rate	Up to 30 kHz
Energy per pulse	1 mJ @ 30 kHz
Pulse duration (FWHM)	150 ns
Pulse peak power	6.7 kW
Beam quality:	Gaussian profile. M^2 not specified.



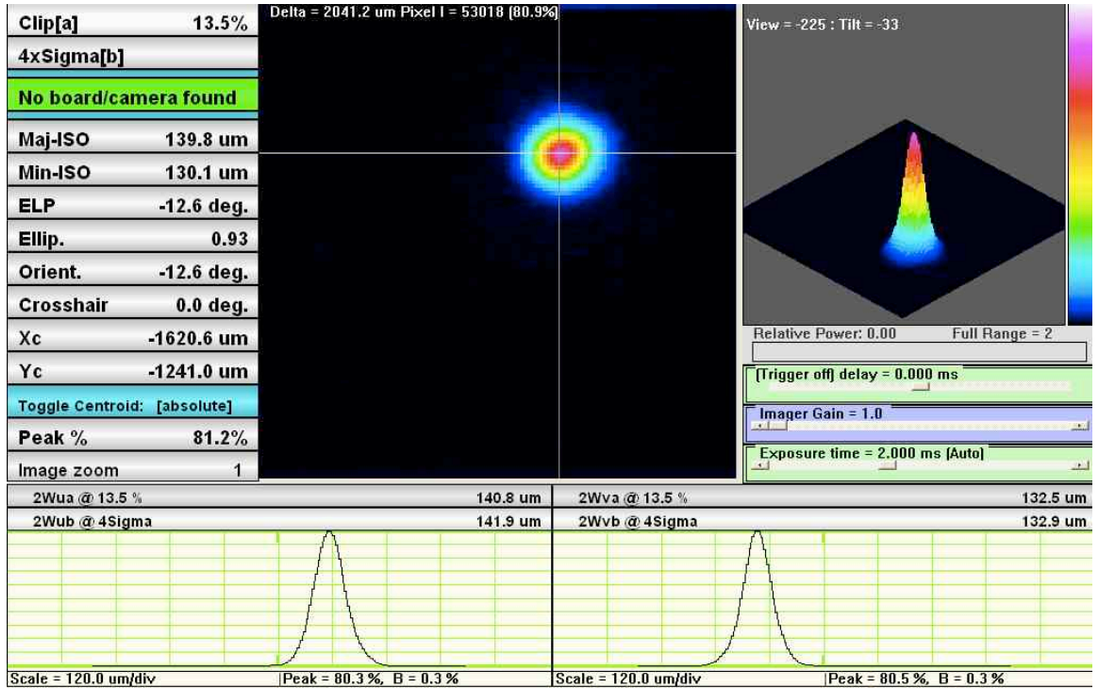
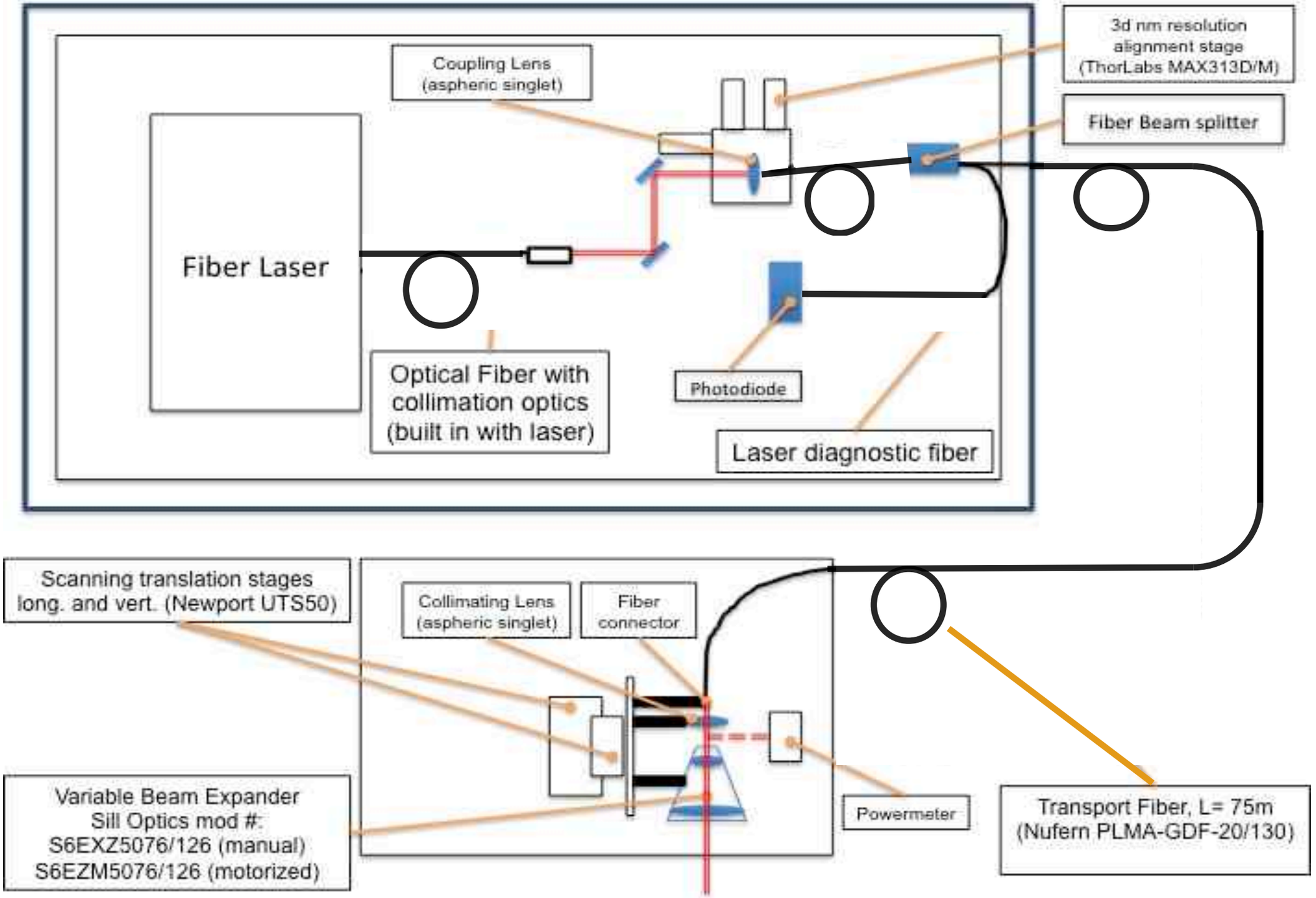


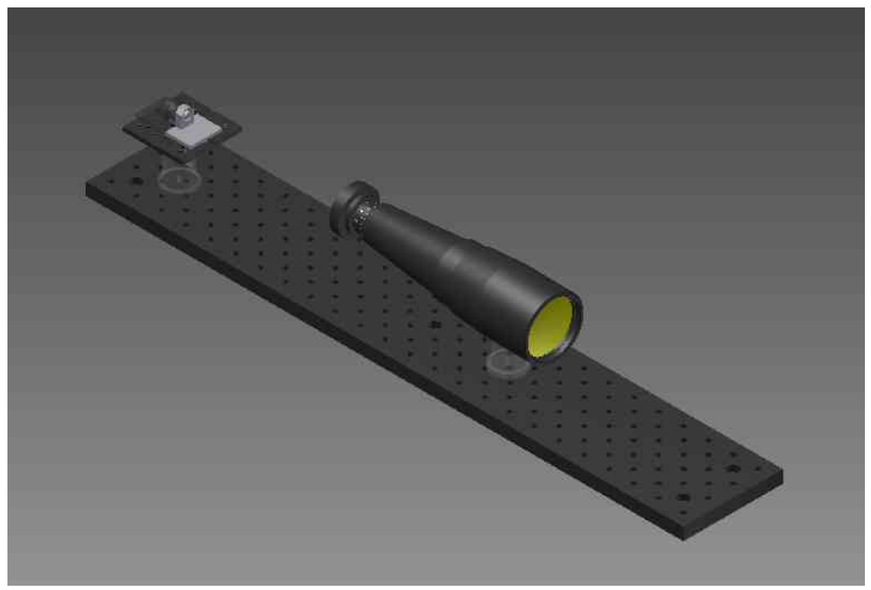
Fig. 6. Laser spot image recorded at the focal plane of the 500 mm plano-convex singlet lens.

Overview


3d nm resolution alignment stage (ThorLabs MAX313D/M)
Coupling Lens (aspheric singlet)
Fiber Beam splitter
Fiber Laser
Optical Fiber with collimation optics (built in with laser)
Photodiode
Laser diagnostic fiber
Scanning translation stages long. and vert. (Newport UTS50)
Collimating Lens (aspheric singlet)
Fiber connector
Variable Beam Expander Sill Optics mod #: S6EXZ5076/126 (manual) S6EZM5076/126 (motorized)
Powermeter
Transport Fiber, L= 75m (Nufern PLMA-GDF-20/130)

Component status

- Most components now delivered to RAL and brought to RHUL.
  - Thorlabs order complete, including:
    - Translation stage, breadboards, mechanics, optics…

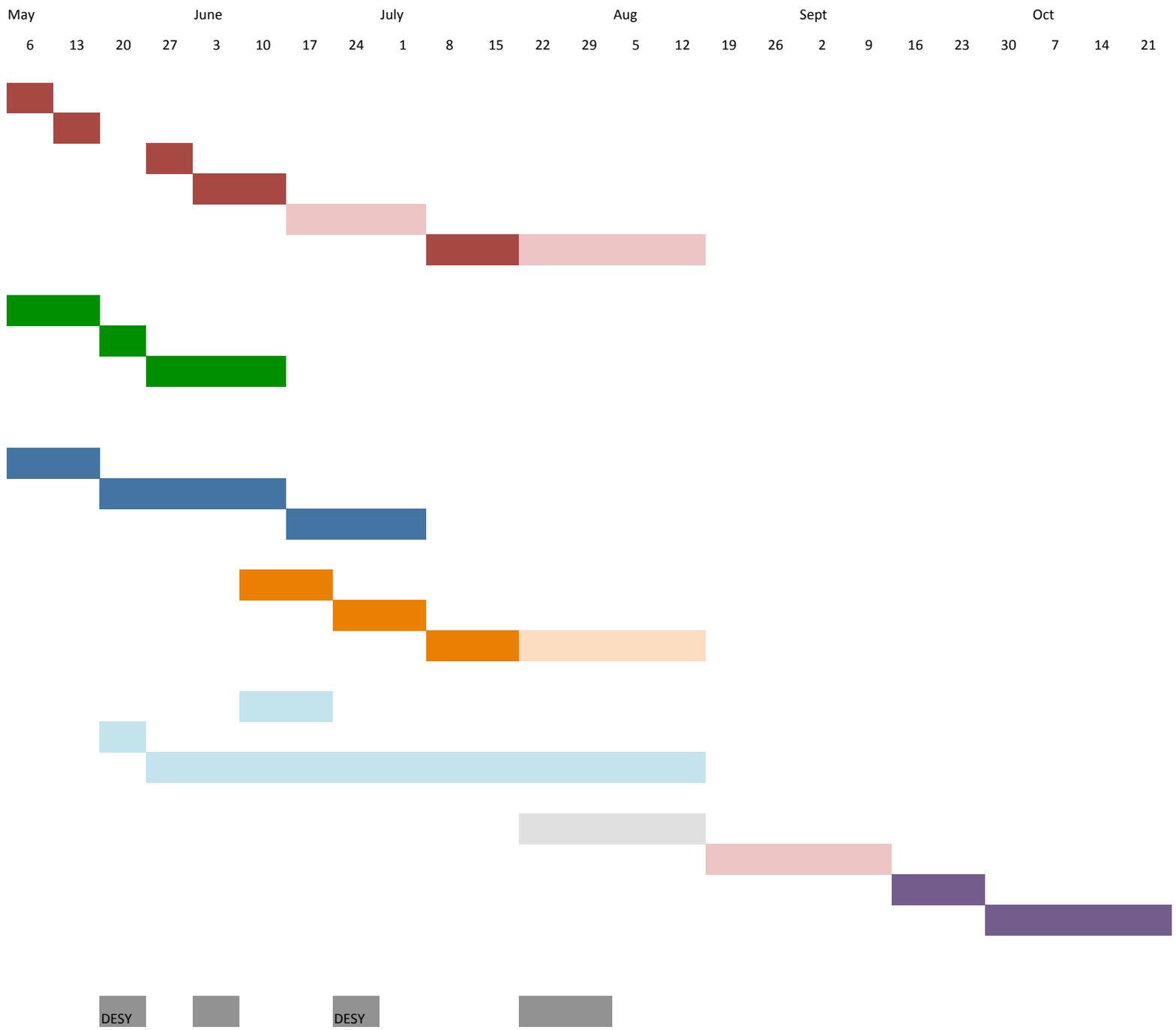


Outstanding items:

- Silloptics Beam expander: nearing end of expected lead time.
- Fibre from Nufern (despite short lead time, no sign yet.)
  - Purchase order initiated by Alan through RAL:
    - Process seems to have stalled? Nufern's last e-mail expects prepayment while RAL has company already on system (no prepayment).
    - Being followed up by Alan.

Laser-diagnostics schedule

	Task
Laser characterisation tests at RHUL	Power vs duty cycle
	Mode quality
	Fibre coupling efficiency
	Fibre optimization and mode quality
	Integration with mechanics
	Beam expanded mode quality
Fibre coupling	Delivery of fibre from Nufern ?
	Prepare armoured fibre & termination
	Test fibre coupling
Beam delivery system	Beam expander order completed?
	Mechanics design in workshop
	Assemble mechanics: stages, optics
Control and DAQ	Develop translation stage control
	Develop beam expander control
	Combined test
Safety	Interlocked box
	Laser safety specification meeting
	RAL laser room preparation
	Contingency for further tests
Possible to test at RAL?	
Proposed ship date to CERN	
Proposed tests at Linac4	
	A Bosco

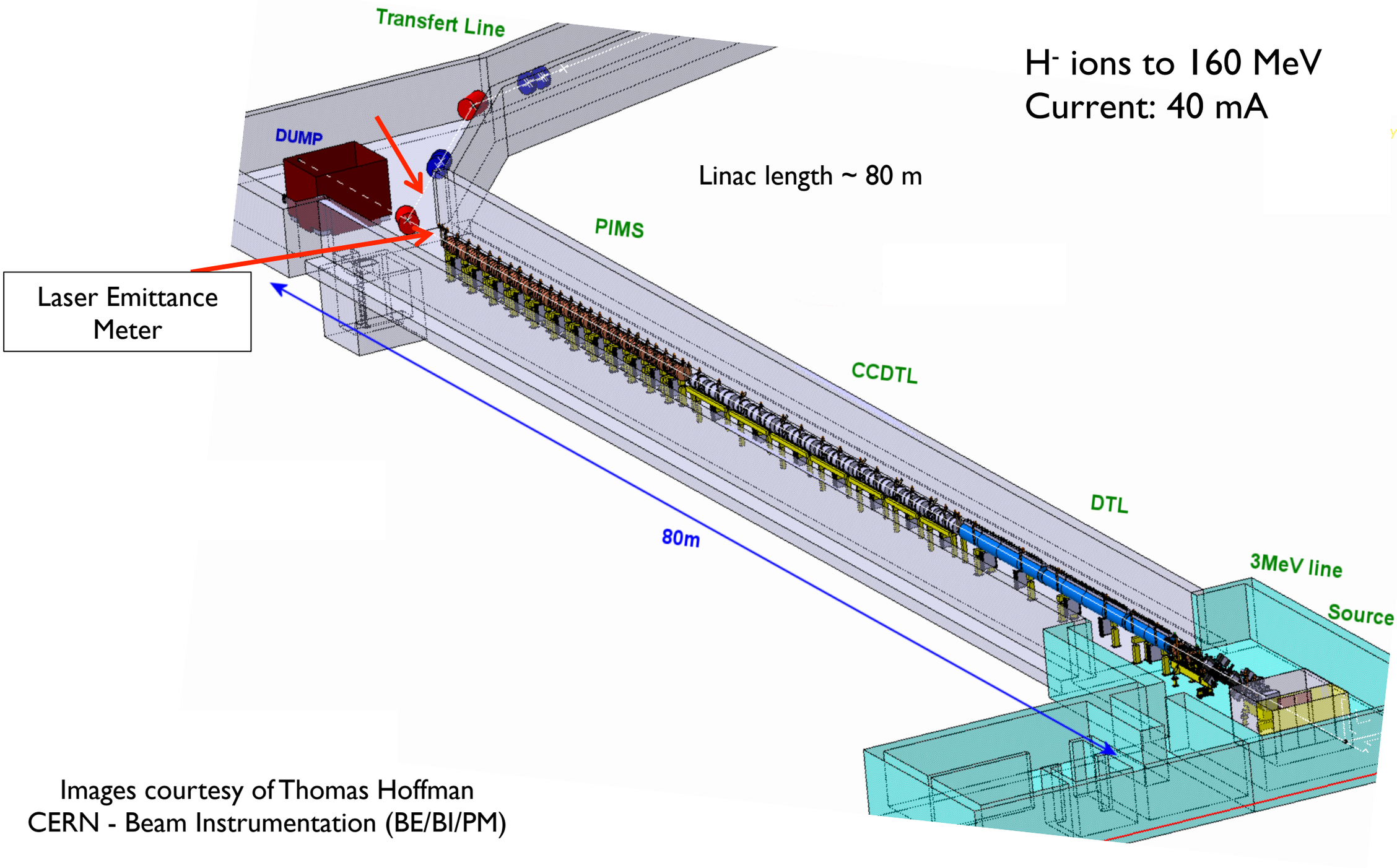


Linac4 overview

- Linac2 will be replaced by Linac4 as the main injector for the LHC / HL-LHC.

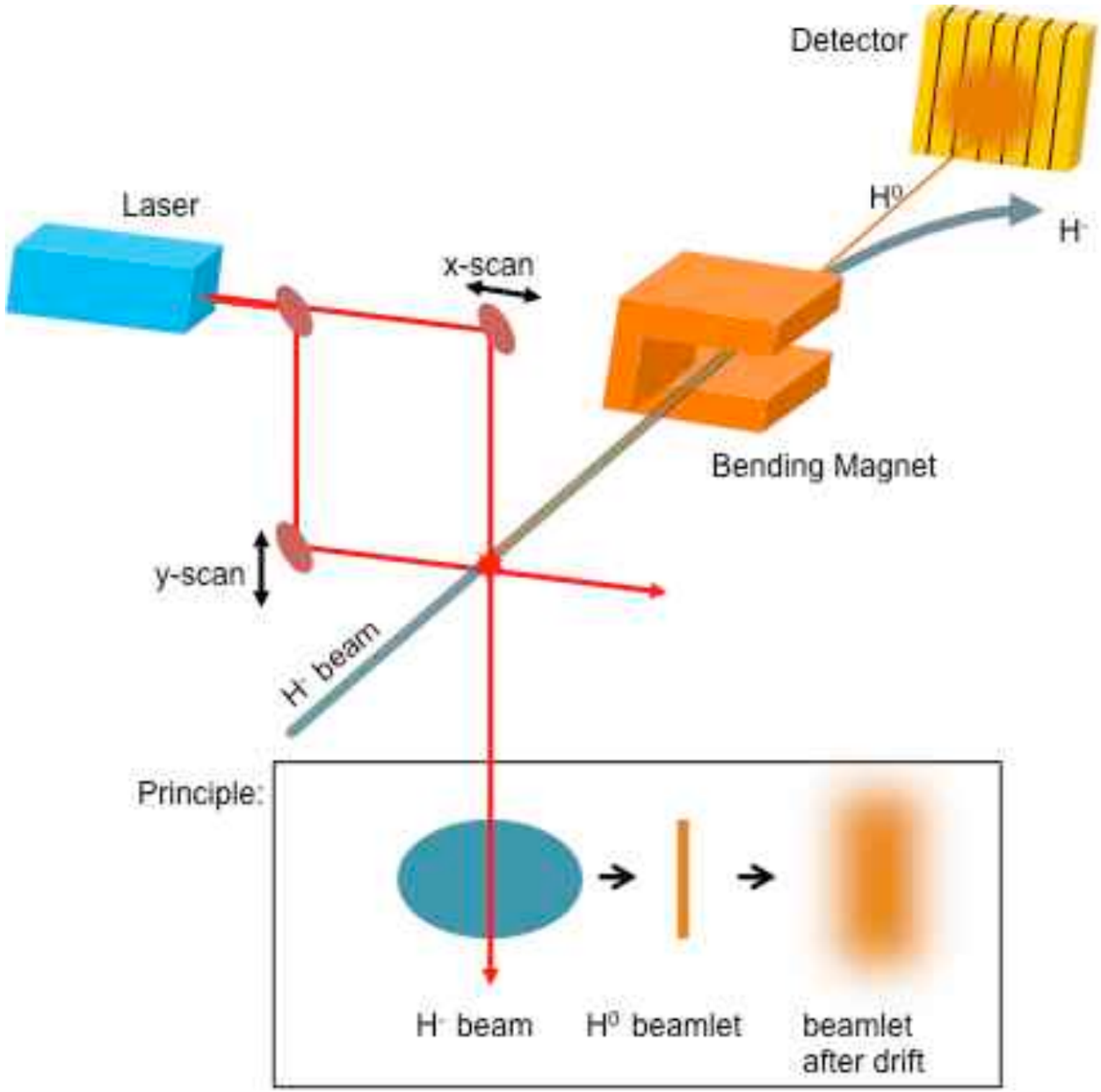
H^- ions to 160 MeV
Current: 40 mA

Linac length ~ 80 m



Images courtesy of Thomas Hoffman
CERN - Beam Instrumentation (BE/BI/PM)

Concept for emittance at 160 MeV



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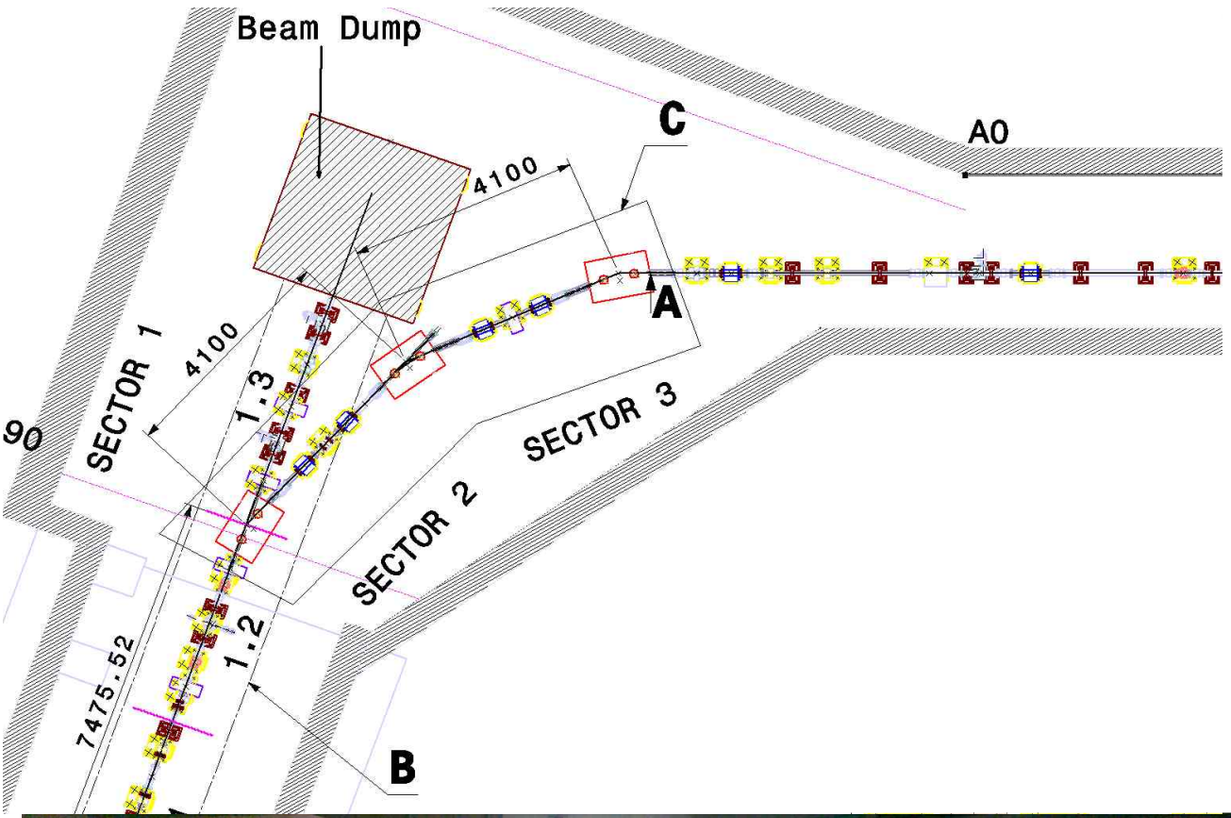
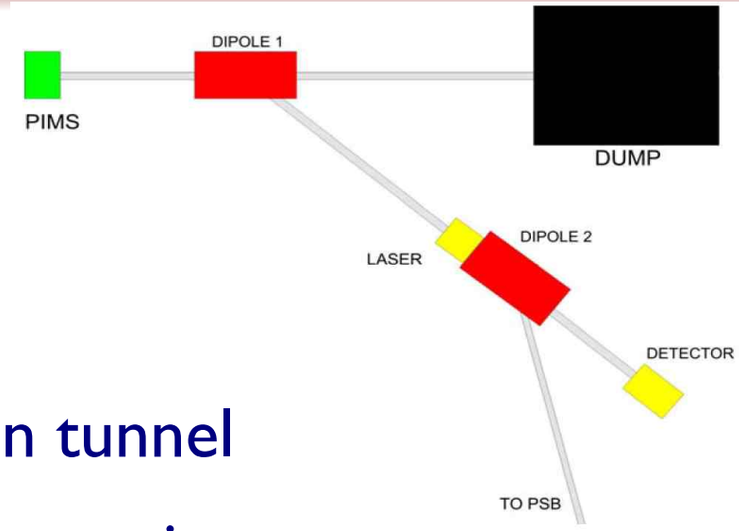
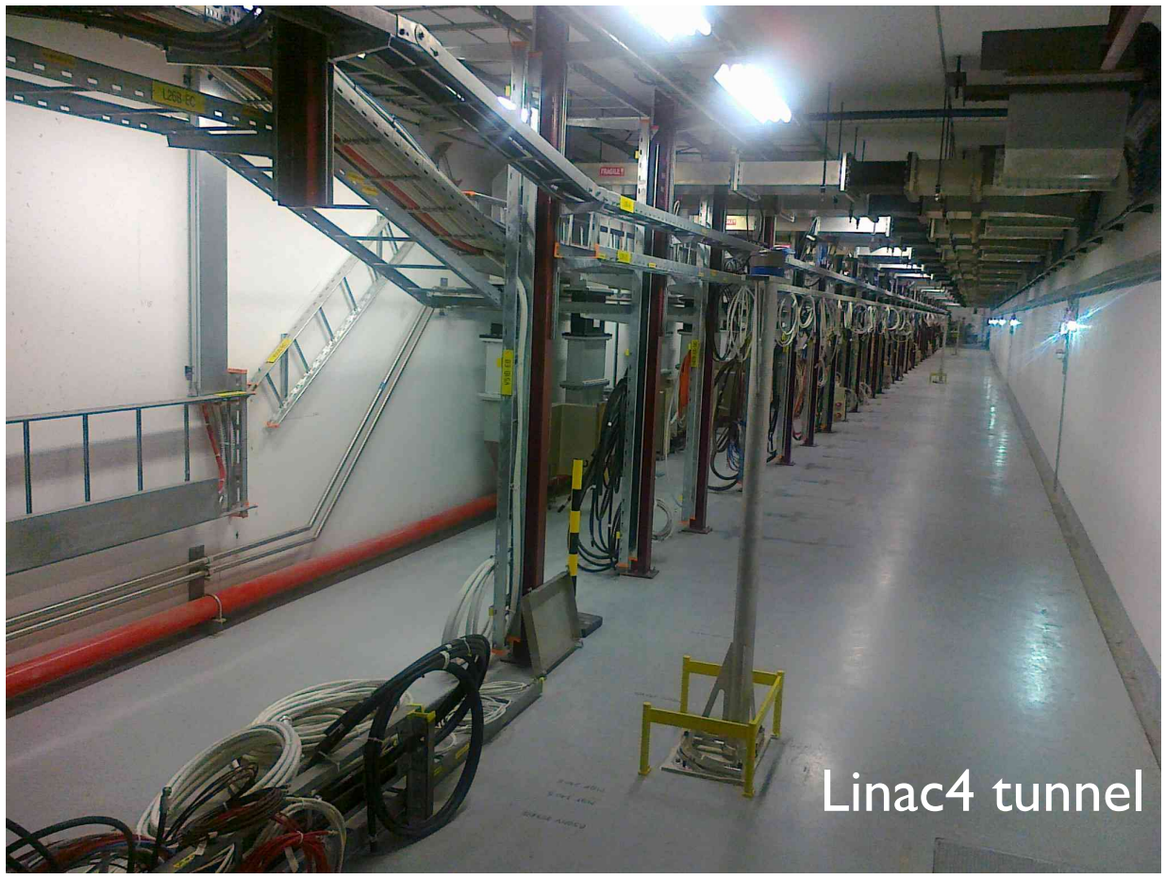
Linac4 tunnel





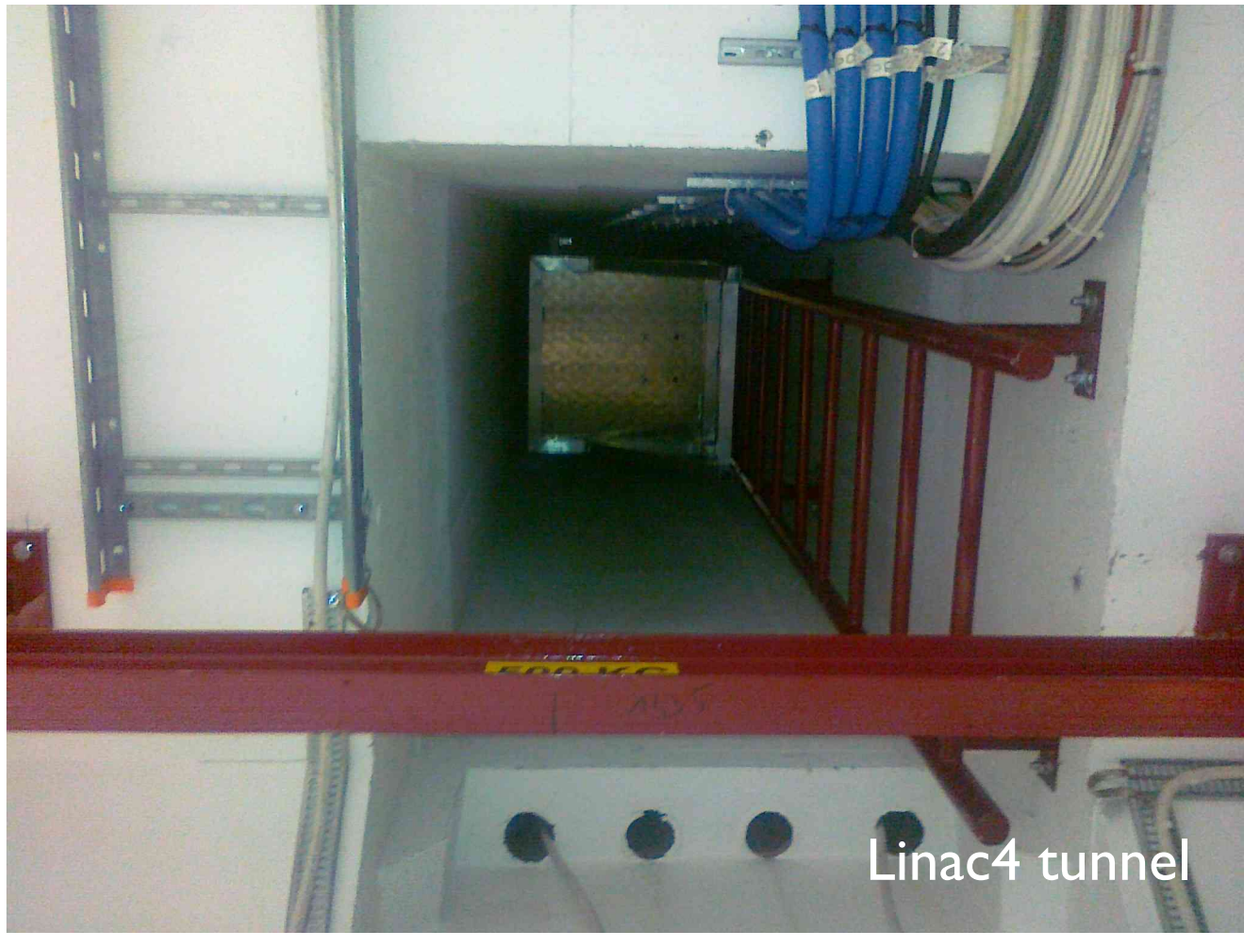
- Infrastructure in tunnel
- Final location for emittance meter within three dipoles.


Transfer line


Linac4 tunnel

Linac4 vertical shaft for fibre(s)

- Proposed stages for laser installation:
  - Initial tests of 3 MeV beam: rack mount laser close to ion source at start of tunnel.
  - Longer term surface laser room planned with far end of Linac4 tunnel near beam dump, accessible via vertical shaft to run fibre delivery.

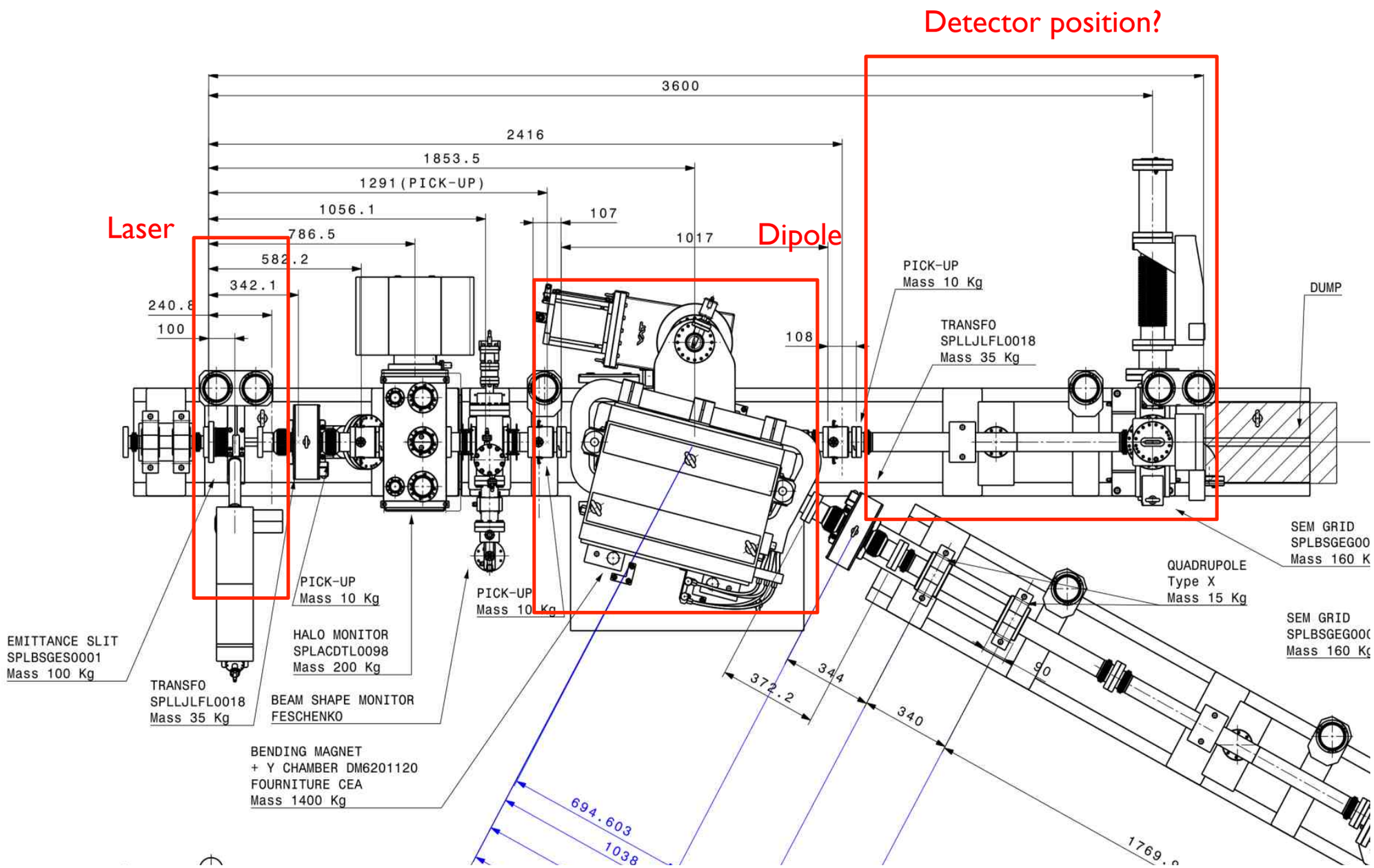


Linac4 tunnel

The Linac4 Test Stand

Diagnostics at 3MeV L4 test stand

- Diagnostics set up currently in operation at Linac4 Test Stand in separate surface building: to be moved over summer to Linac4 tunnel.



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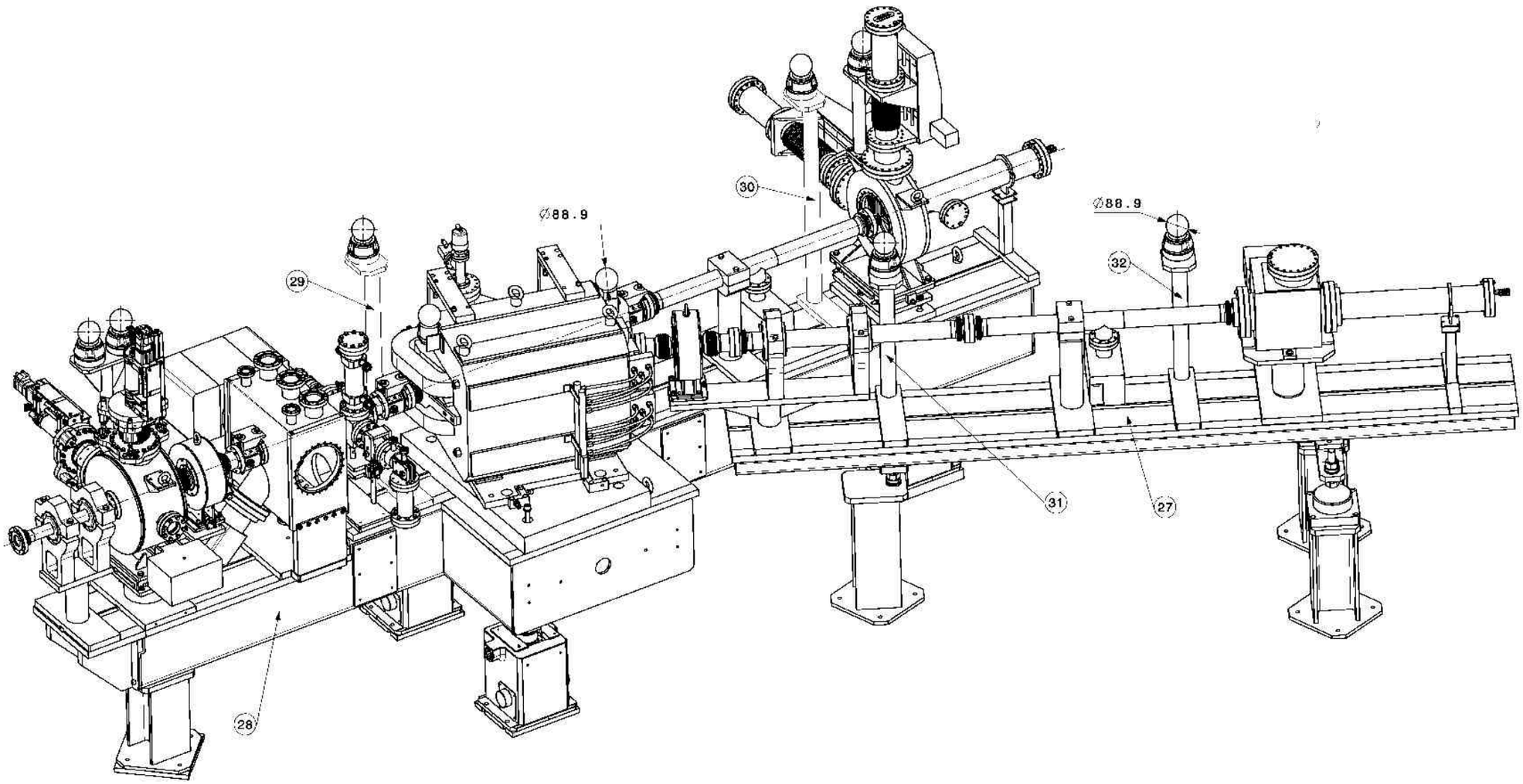
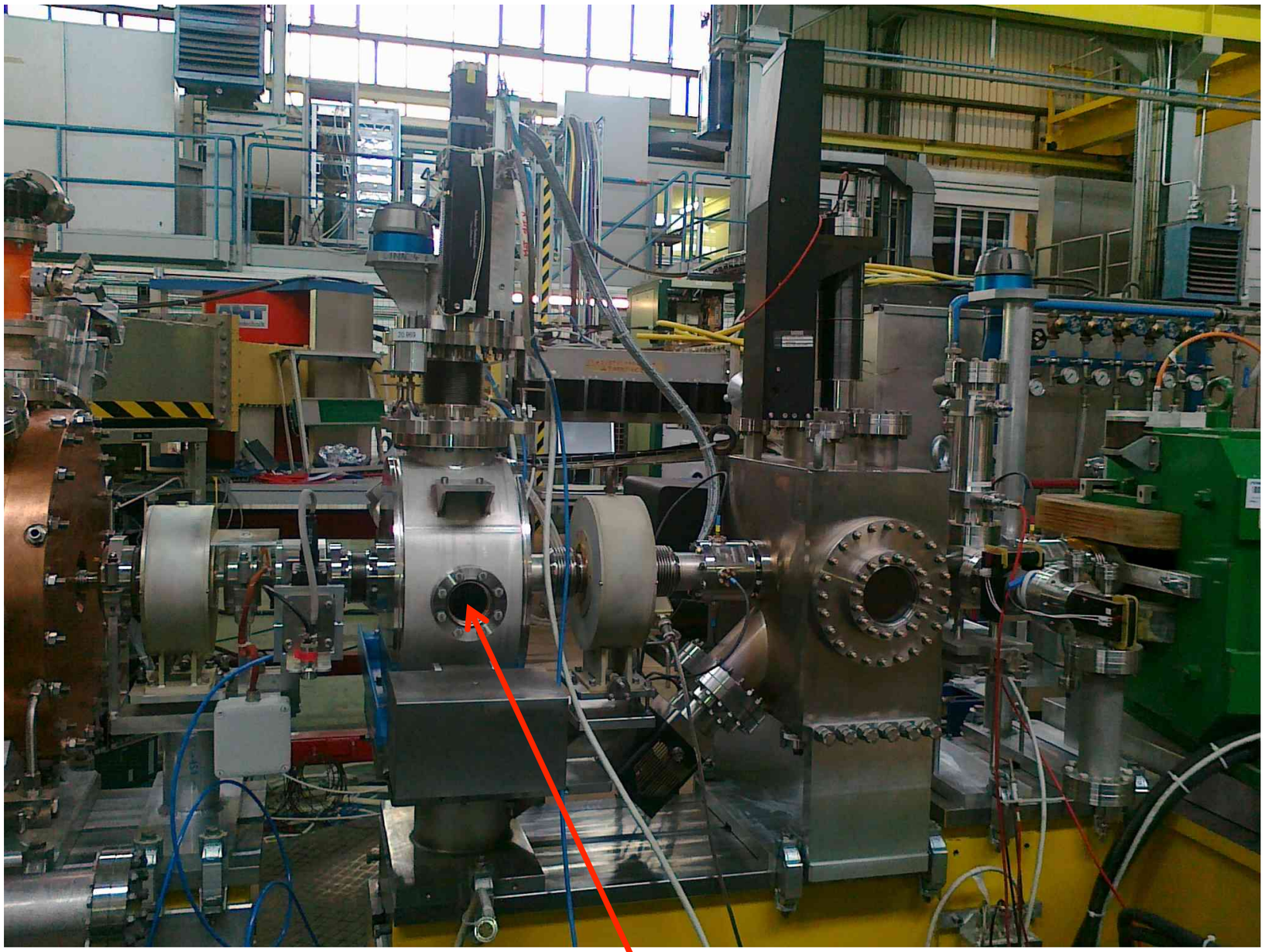


Existing Linac4 test stand

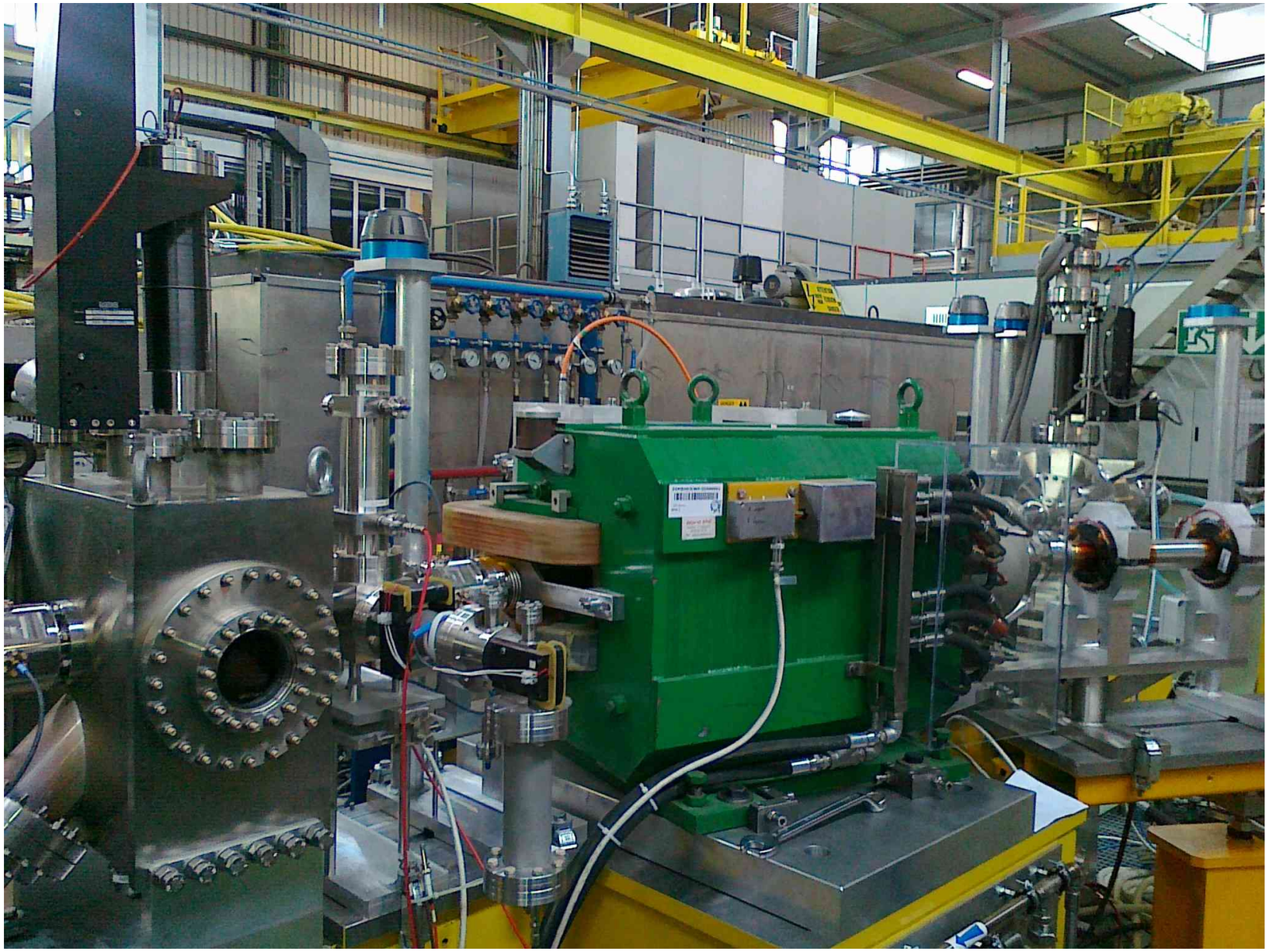


Emittance slit

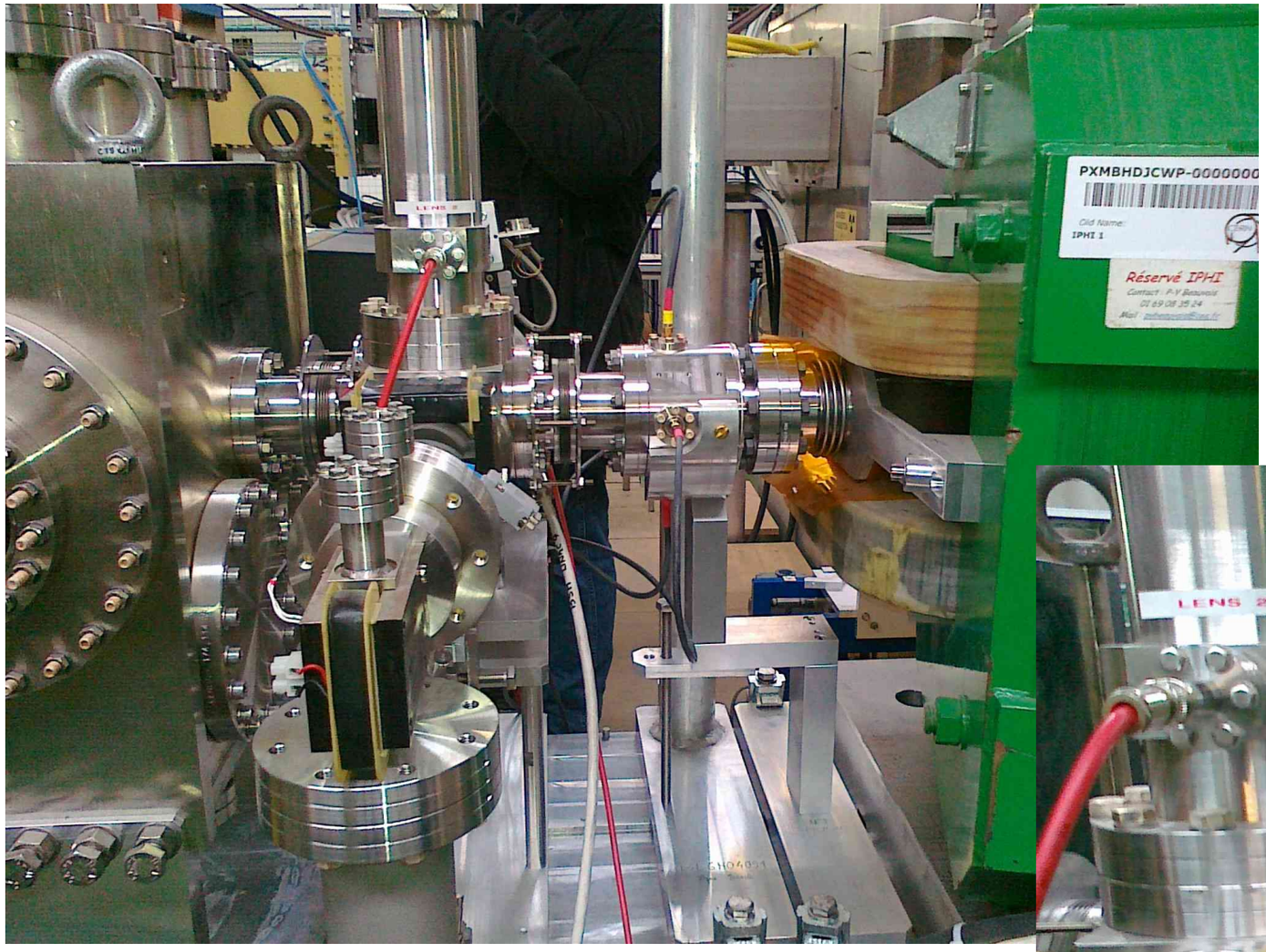
Halo monitor

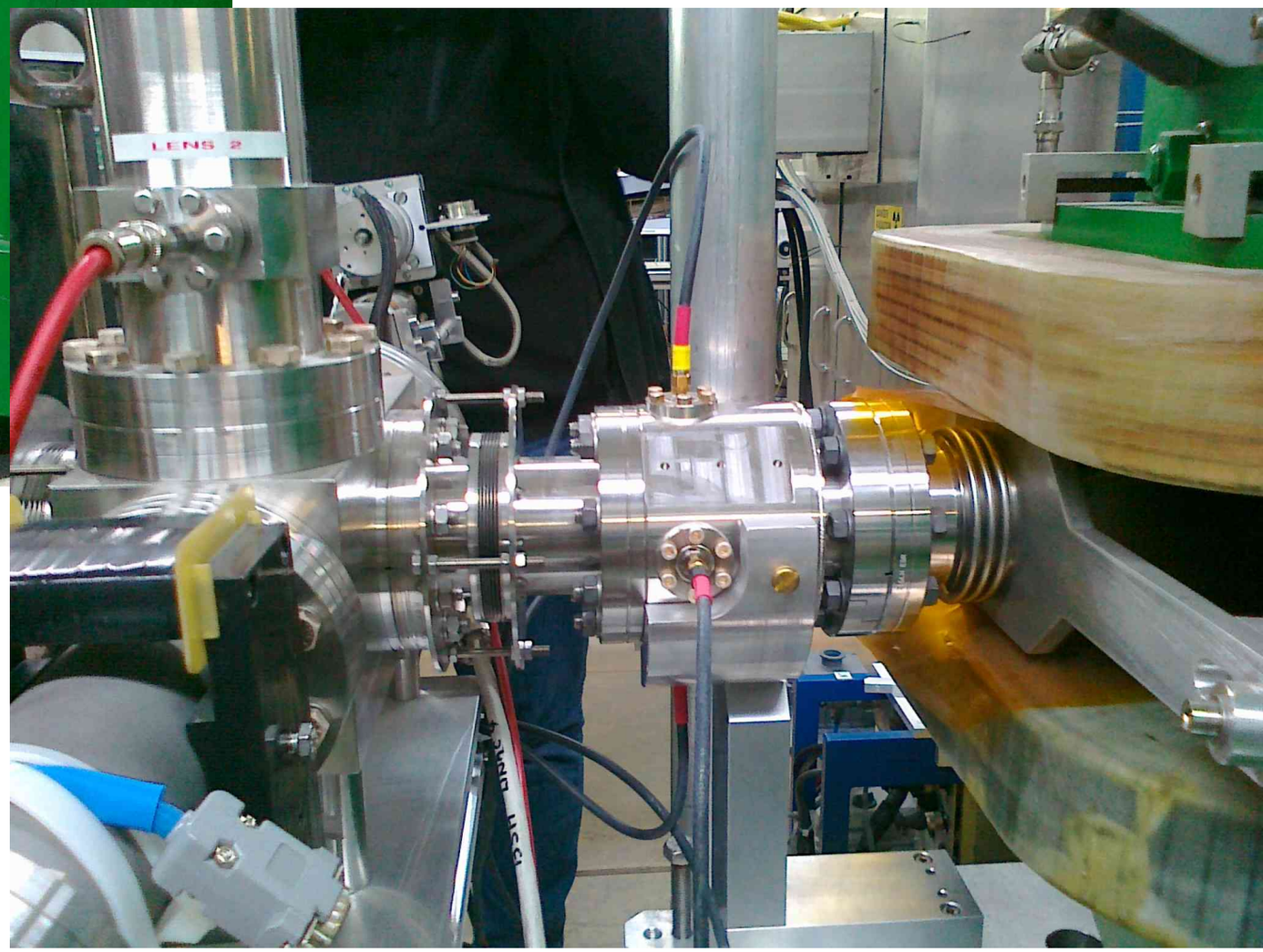
- Window port for laser, before dipole.

Dipole magnet



CERN BPM before dipole





Space for detector after dipole

Space for new detector

Current SEM grid

H0 line

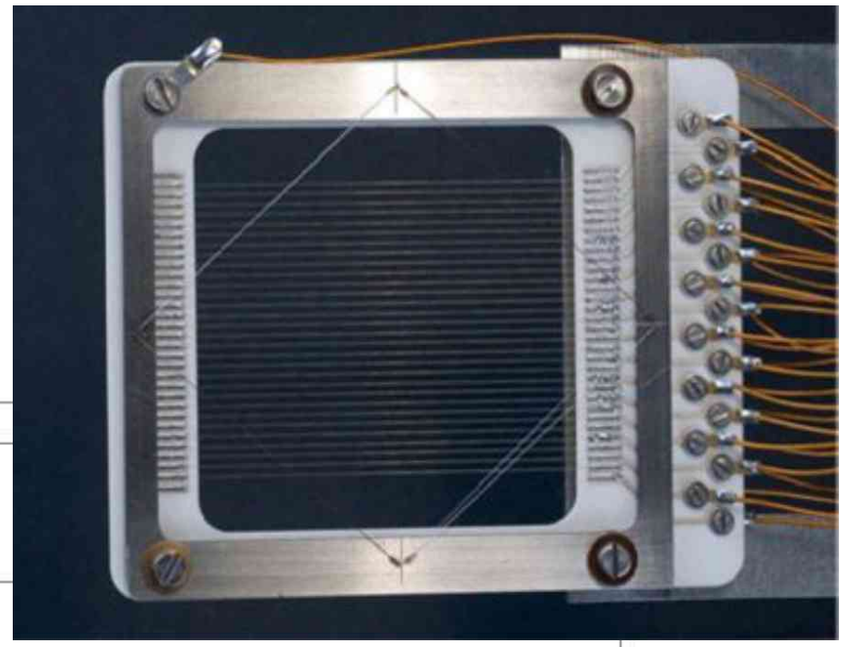
H- line

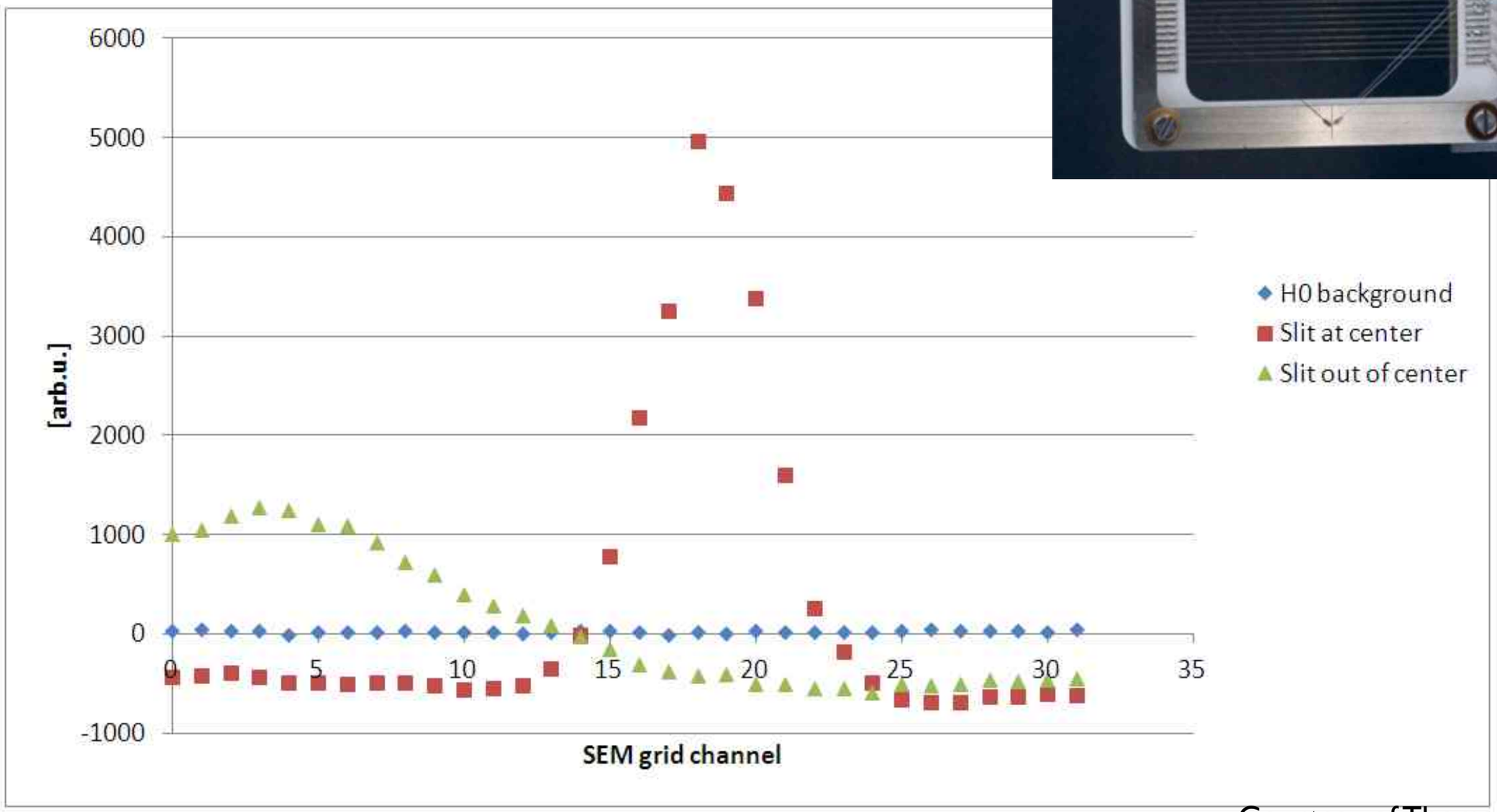
dipole

Results from Linac4 test stand

Current detector: SEM grid

- 24 x 24 mm
- 32 wires
- Resolution enhancement by moving the grid
- Enhancement by factor 15 possible



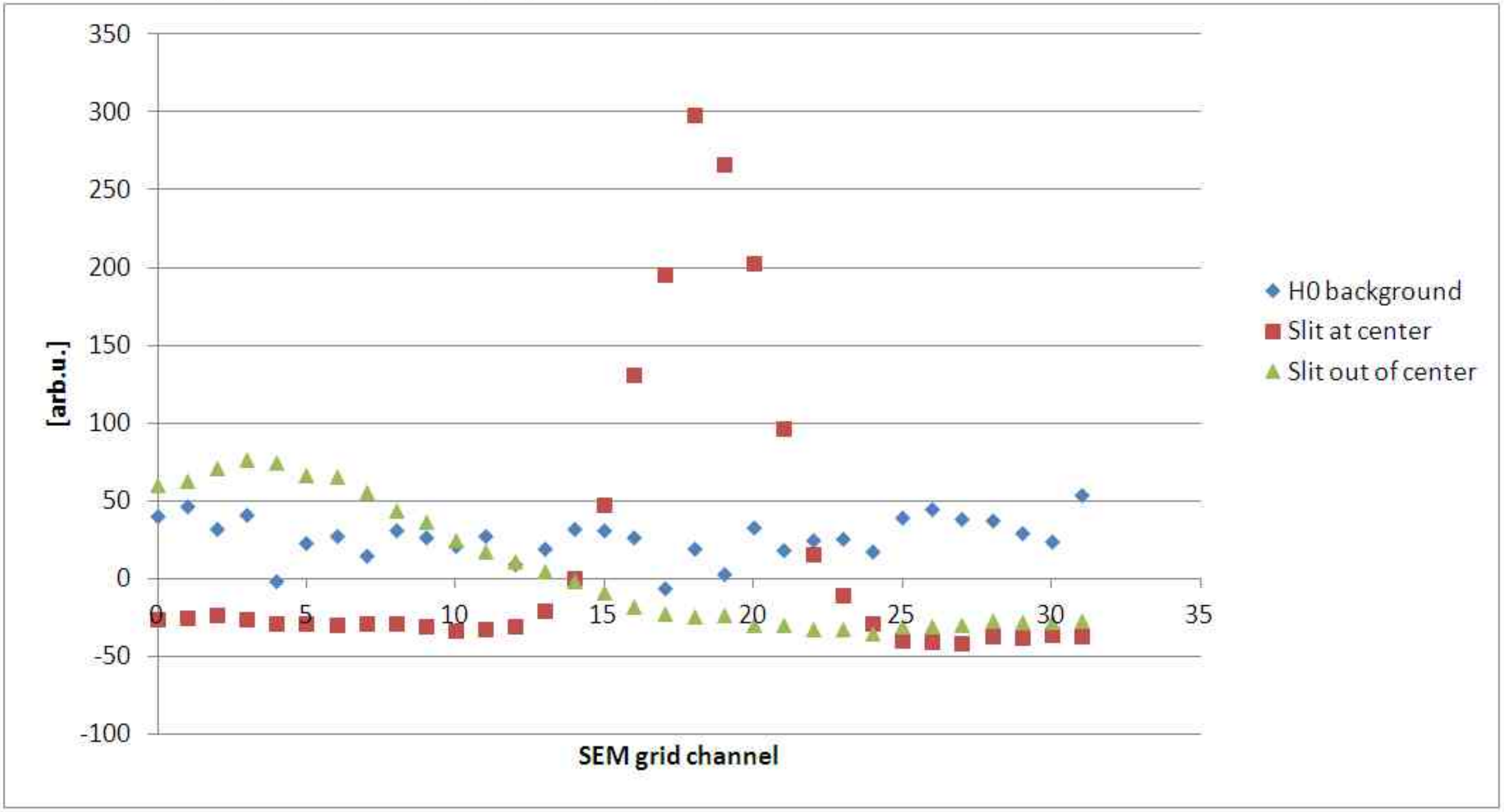


Courtesy of Thomas Hoffman
CERN - Beam Instrumentation (BE/BI/PM)

Results from Linac4 test stand

200 μm Slit

6 % of Slit signal (Fiberlaser stripping efficiency)



Courtesy of Thomas Hoffman
CERN - Beam Instrumentation (BE/BI/PM)

Proposed collaboration with CERN

- Simulations of T. Hoffman indicate parameters of existing FETS laser are well suited to Linac4 beam (even though limited by H^0 background without laser within dipole).
- Win-win:
  - Presents opportunity to test our laser with real particle beam, prior to beam at FETS.
  - Can validate our optical set-up and learn much about photo detachment signal.
  - Benefits CERN by offering laser and expertise. (CERN offers BPM DAQ in return).
  - Date of CERN test in October decoupled from FETS activities at RAL and does not impact FETS laser-diagnostics development schedule.
- Pending discussion, next step would be to define agreement within Memorandum of Understanding…

Back up

Propose fibre delivery solution

- Propose laser system and diagnostic optics are housed in a remote laser room alleviating several constraints:
  - Air conditioned, thermally stable environment for risk free laser operation.
  - Away from radiation environment.
  - Development time decoupled from FETS activities.
  - Diagnostic optics can be within laser room, reducing space needed within FETS.
  - Class 4 safety interlocks easily installed on laser room door.
  - Additional (gravity fail safe) safety shutter to block light when triggered by an external signal (in case of access to FETS / beam delivery optics).
- Fibre delivers light via simple and adaptable optics within shielding. No need for human access.
- Experience with similar system in operation at PETRA III in DESY.

Laser characterization and status

- Laser specification tested, M^2 of collimated output measured as ~1.81 H and 1.61 V.
- Output power lower than specified – laser returned and under repair at manufacturer (indication that part has been replaced for minimal cost).
- Laser tests written up in summary document.

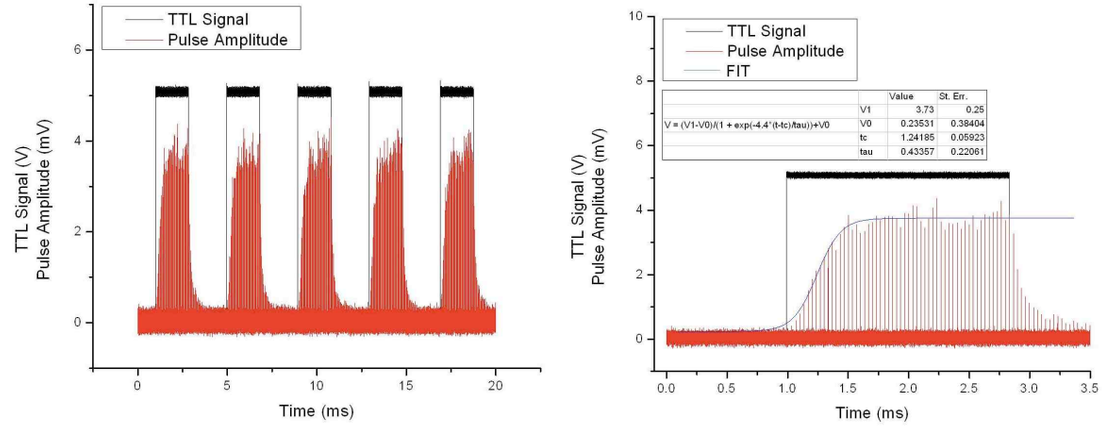
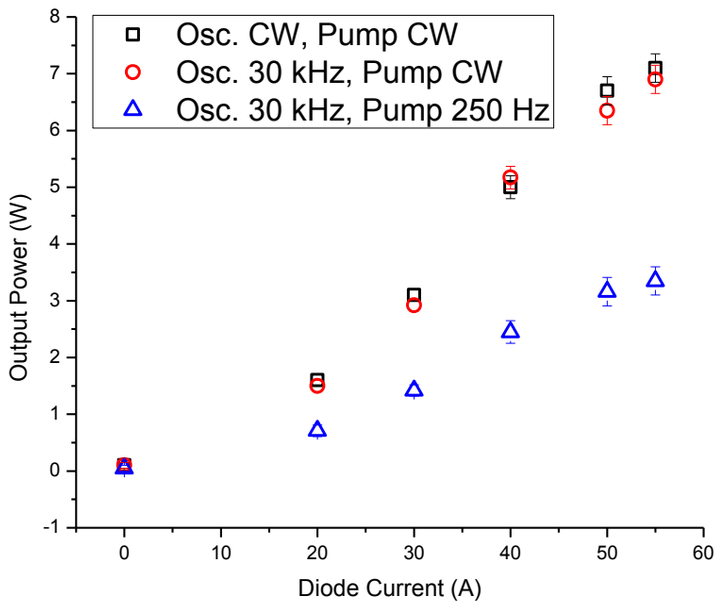
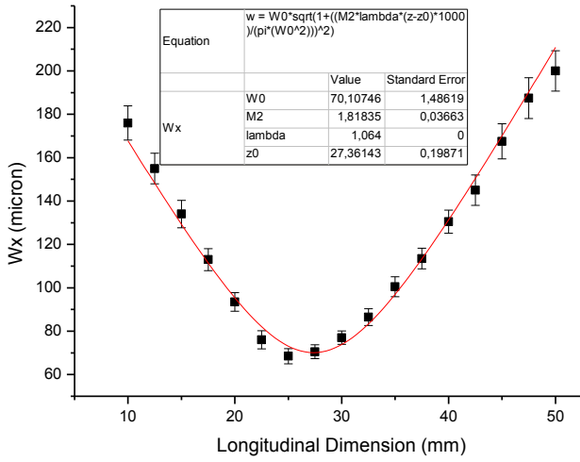
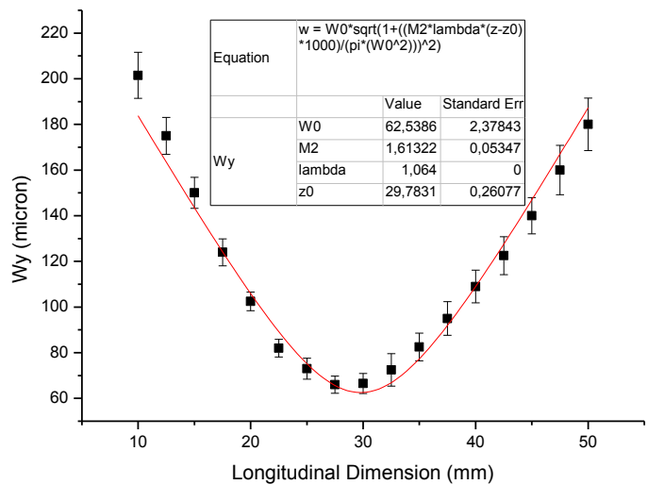


Fig. 3. a) Scope trace of amplified pulses with pump diode driven by a 250 Hz TTL (2 ms pulses). b) Zoom on a single macro-pulse for analysis.



Power measurements Vs diode current for different amplification regimes.

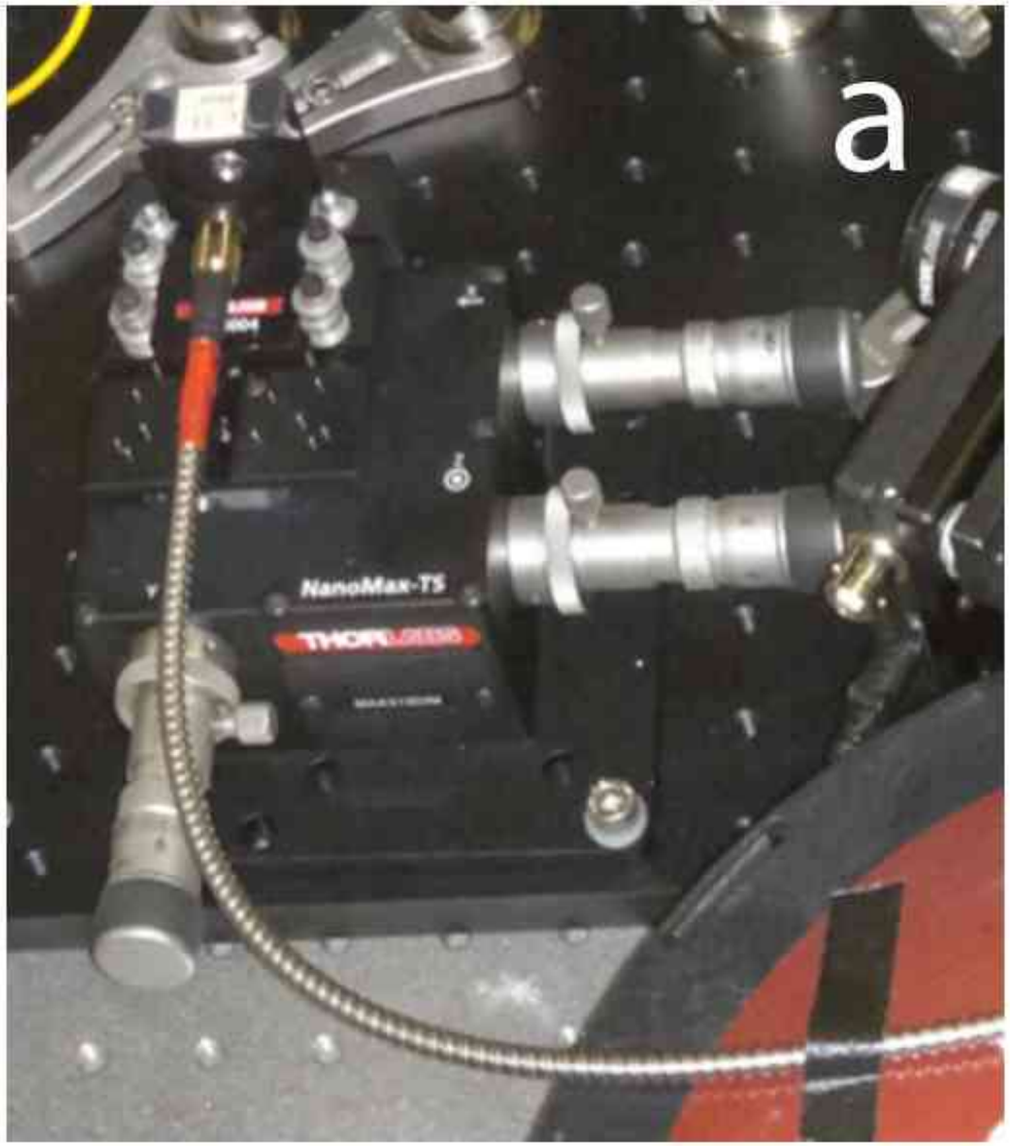


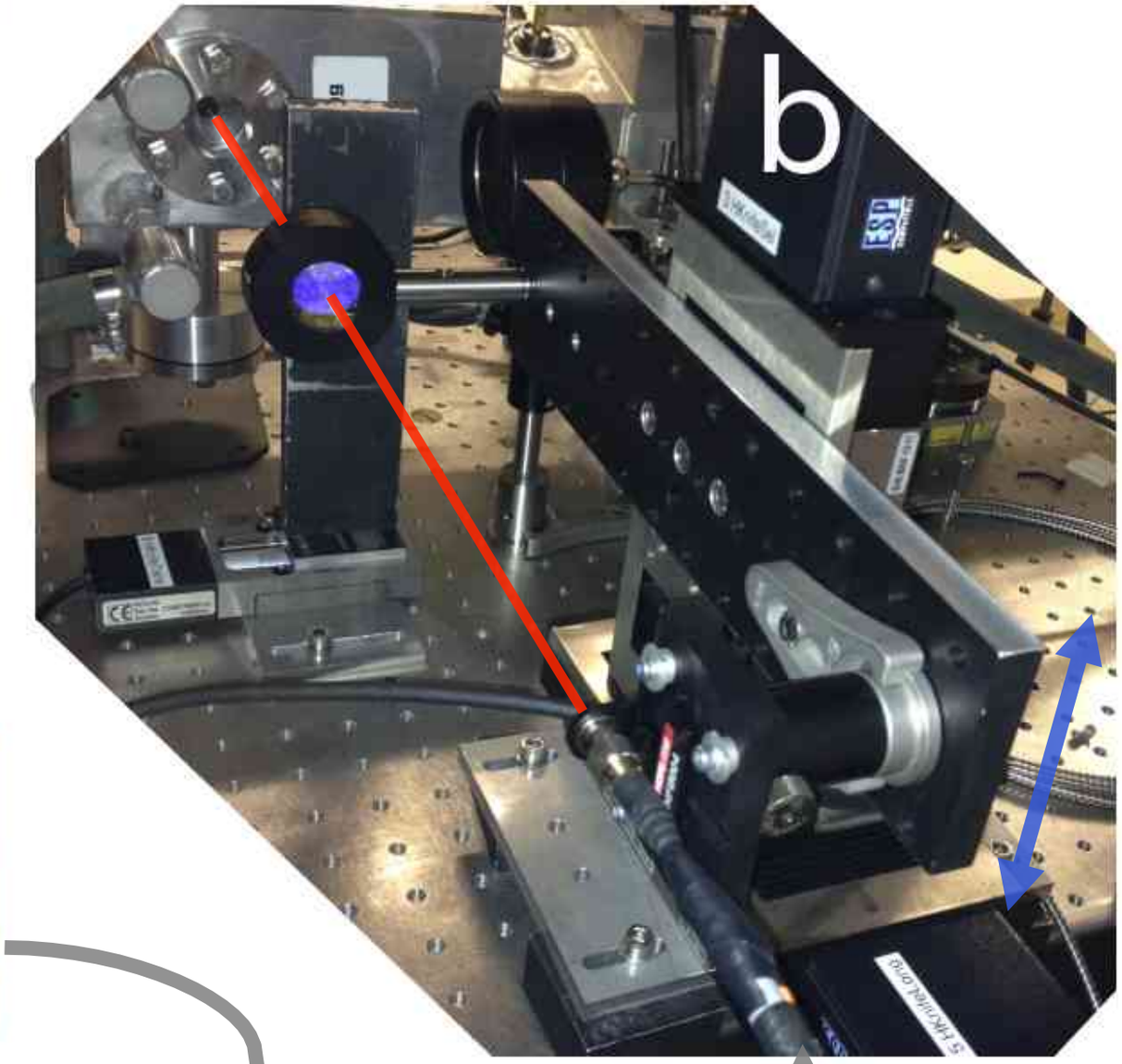


Fibre-coupled laserwire at DESY

Petra III fibre-coupled laserwire

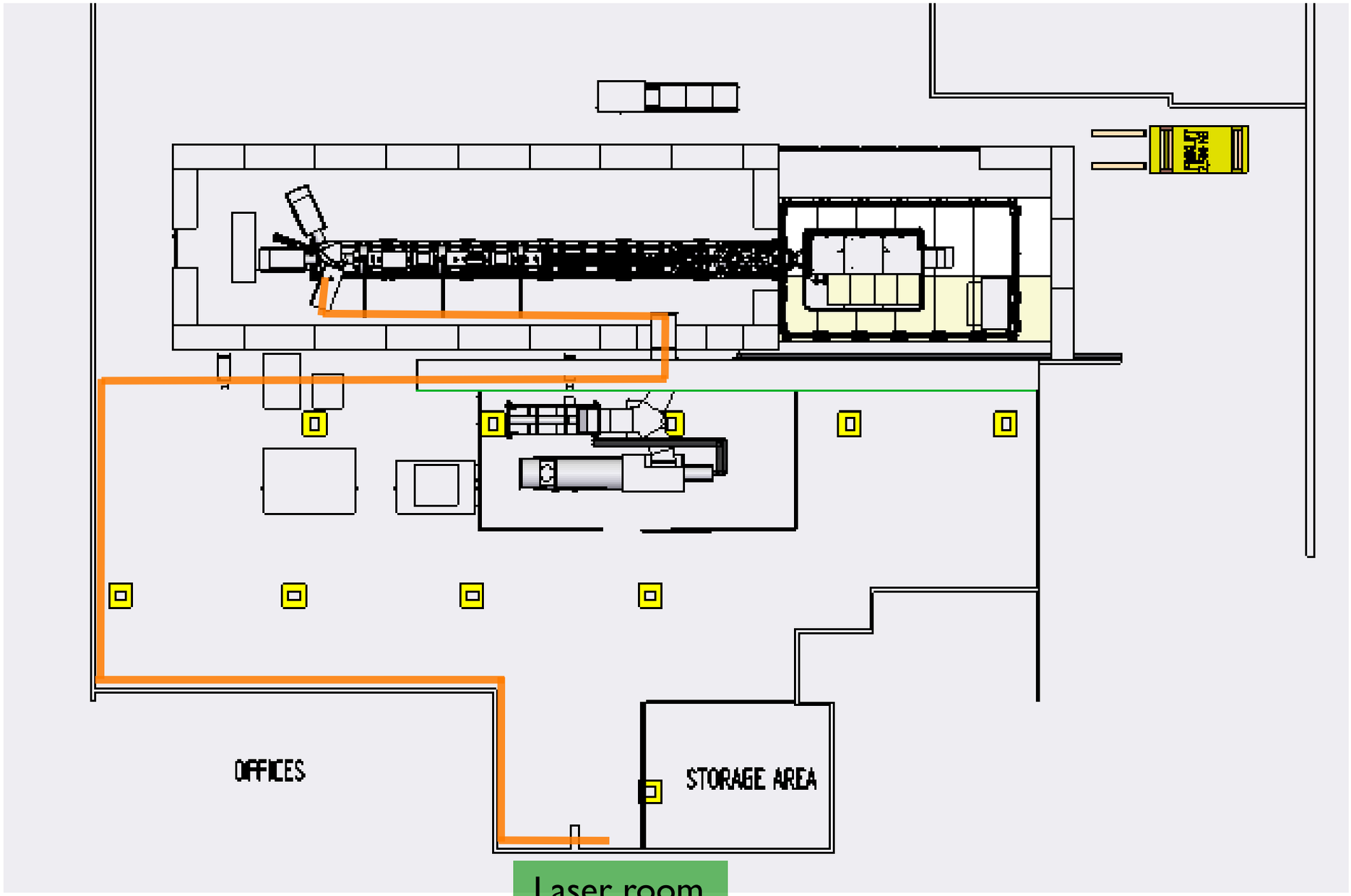
- Free space laser beam coupled into fibre using standard lens and Thorlabs stage
- Simple beam delivery optics on base plate, which is mounted to pair of stages.
- Fibre-coupled collimated output directed via lens to vacuum window.





Proposed laser location in R8

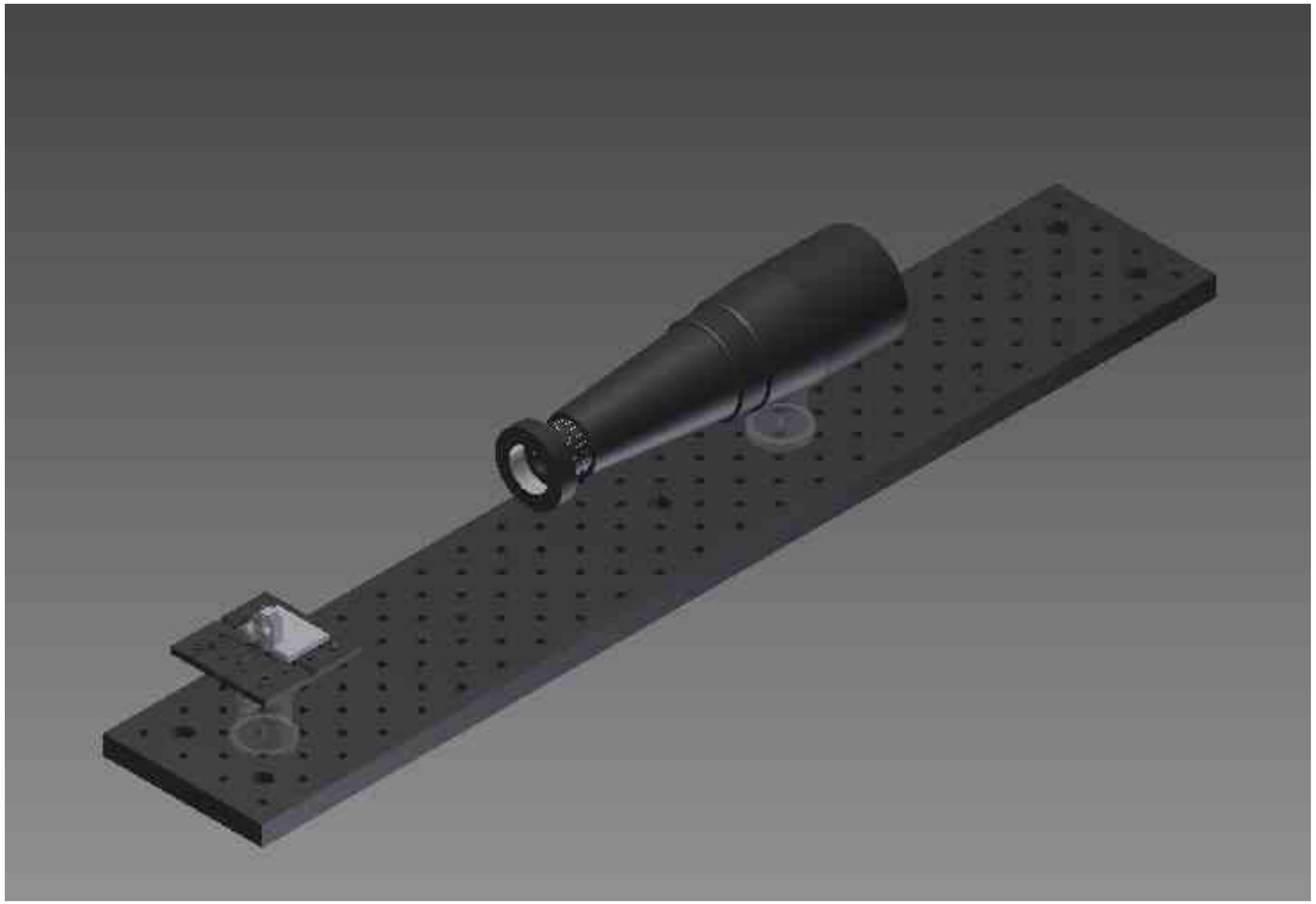
- Safety interlocked laser room, with fibre to convey light to FETS.
- Route of existing cable tray shown (~75m)



R8 layout thanks to Mike

Beam delivery optics

- Simple optics for final beam delivery: fibre, lens and beam expander



Base plate mounted to crossed pair of vertical and horizontal translation stages (existing stages have 50mm travel and 1um resolution – more than adequate)

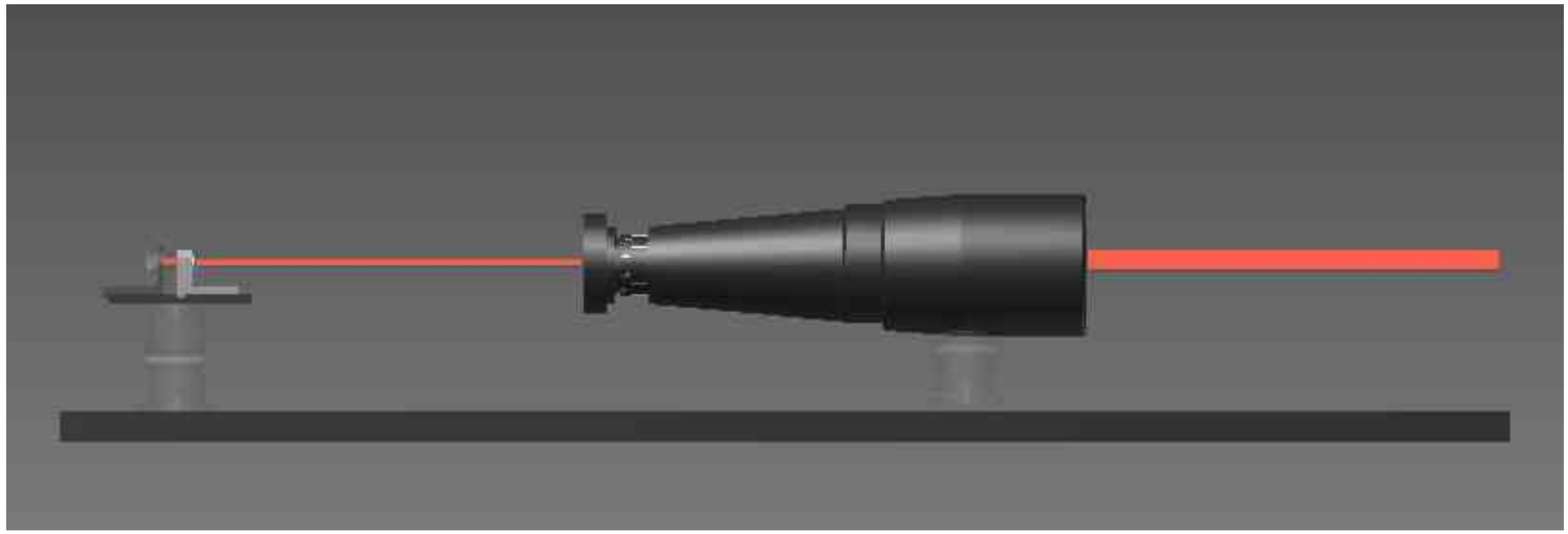
Beam delivery optics

- Simple optics for final beam delivery: fibre, lens and beam expander

Collimation lens:
(4.55, 6.20, 8.07mm)

Silloptics beam expander
manual zoom 1x to 8x
(or motorized option available)

Space reserved to add
short focal length lens
for 2D confocal scans

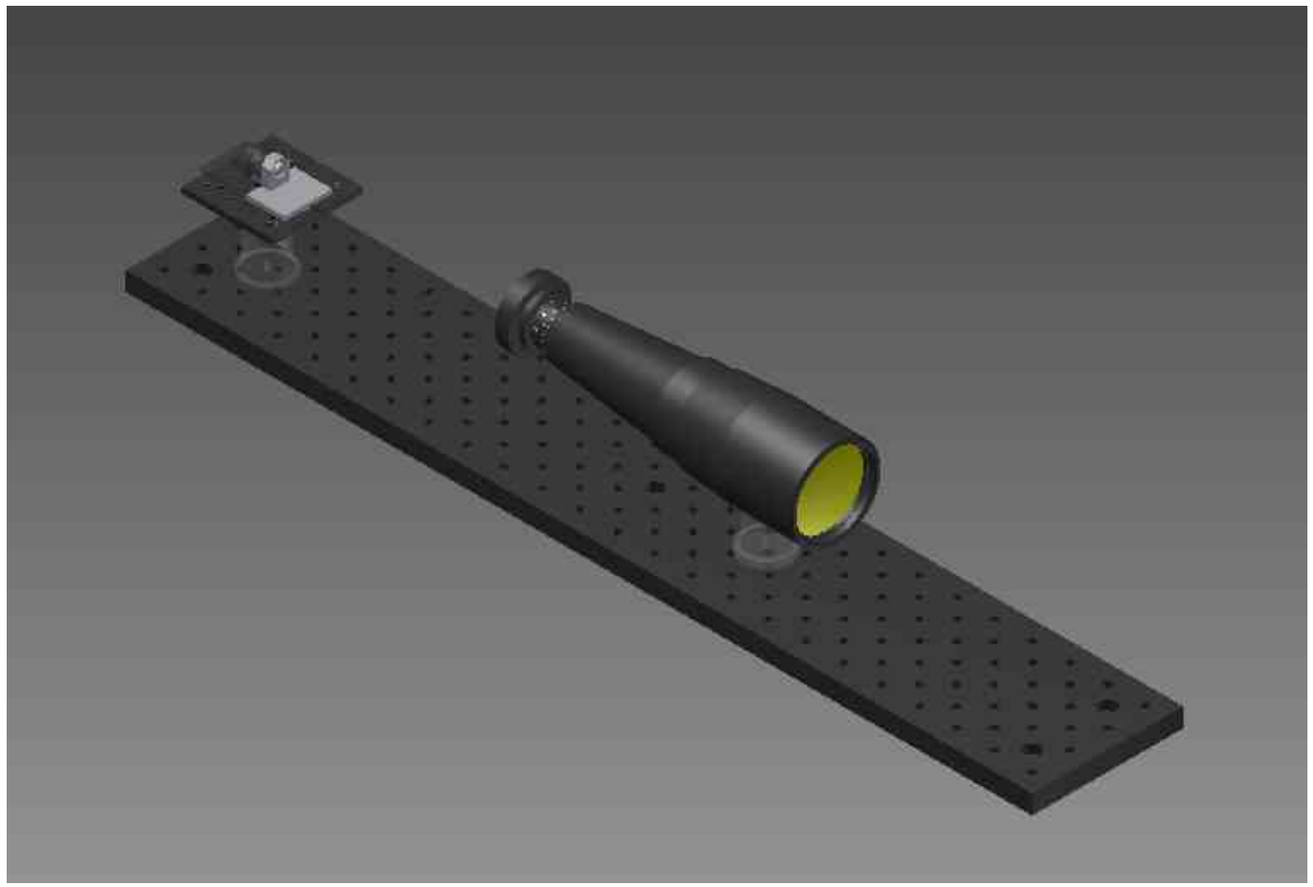


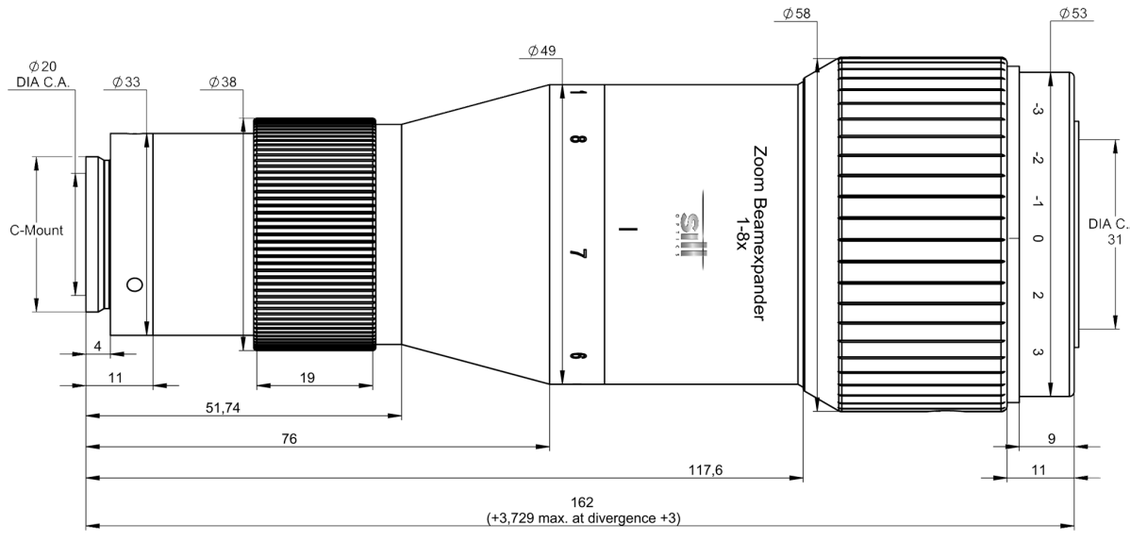
Light conveyed by fibre to input FC connector

To window in vacuum chamber

Base plate mounted to crossed pair of vertical and horizontal translation stages
(existing stages have 50mm travel and 1um resolution – more than adequate)

Zoom beam expander





Beam expander (Thorlabs above)
Silloptics S6EXZ2075/126
manual zoom 1x to 8x
(or motorised option available)

part number standard	*part number* motorized	*magnification*	*max. exit-Ø* [mm]	*length* [mm]	*max. outside-Ø* [mm]	*thread*	*adjustable divergence*
S6EXZ2075/126	S6EZM2075/126	1.0x - 8.0x	30.0	157.0	58.0	C-Mount	✓