LINAC4 Laser Profile and Emittance Meter Commissioning

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Concept

LINAC4 accelerates H^- ions up to 160 MeV

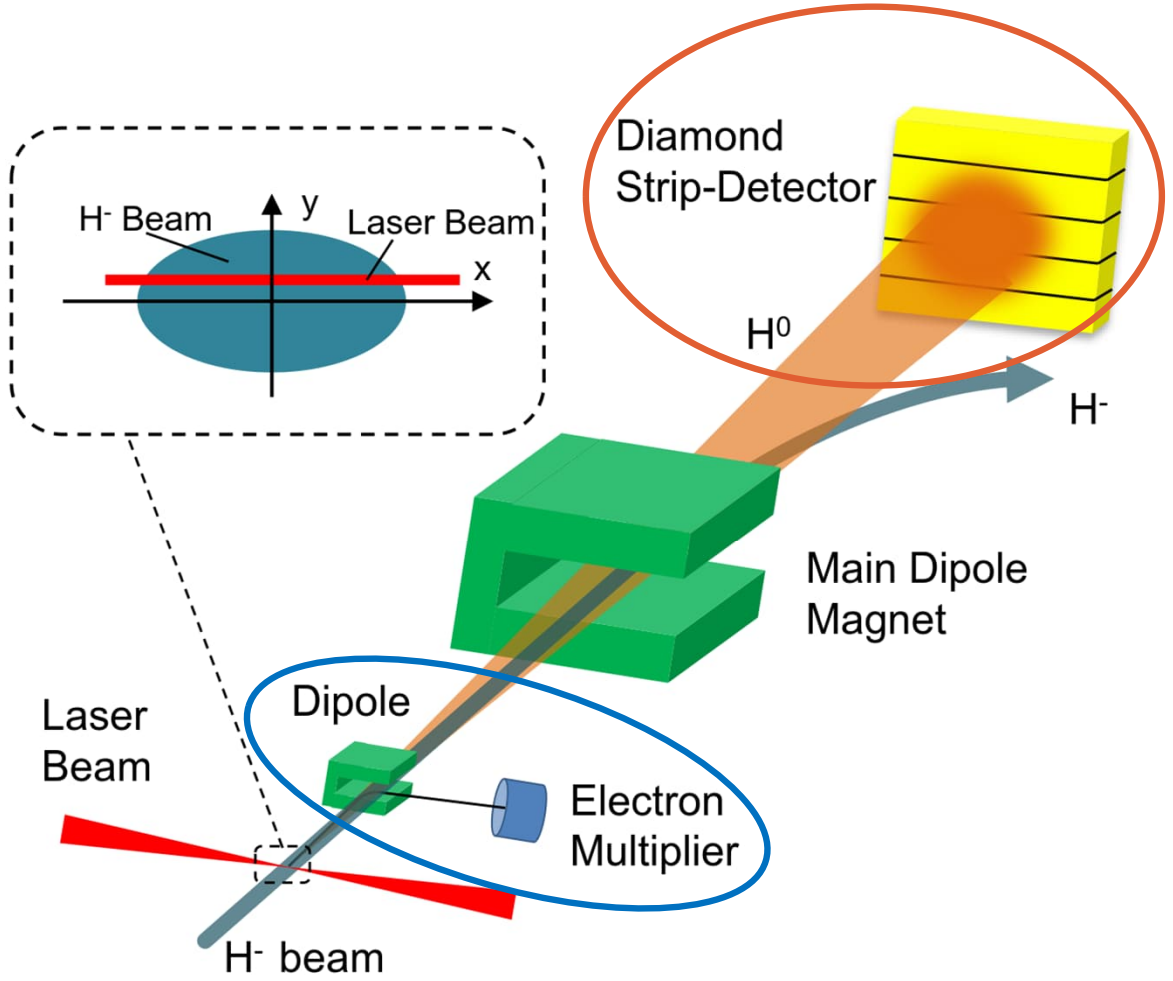
Conversion into protons at the injection of the booster synchrotron (PSB)

e^- stripping by photon interaction

(*photo detachment* principle)

Scan of the focused laser beam through the H^- beam

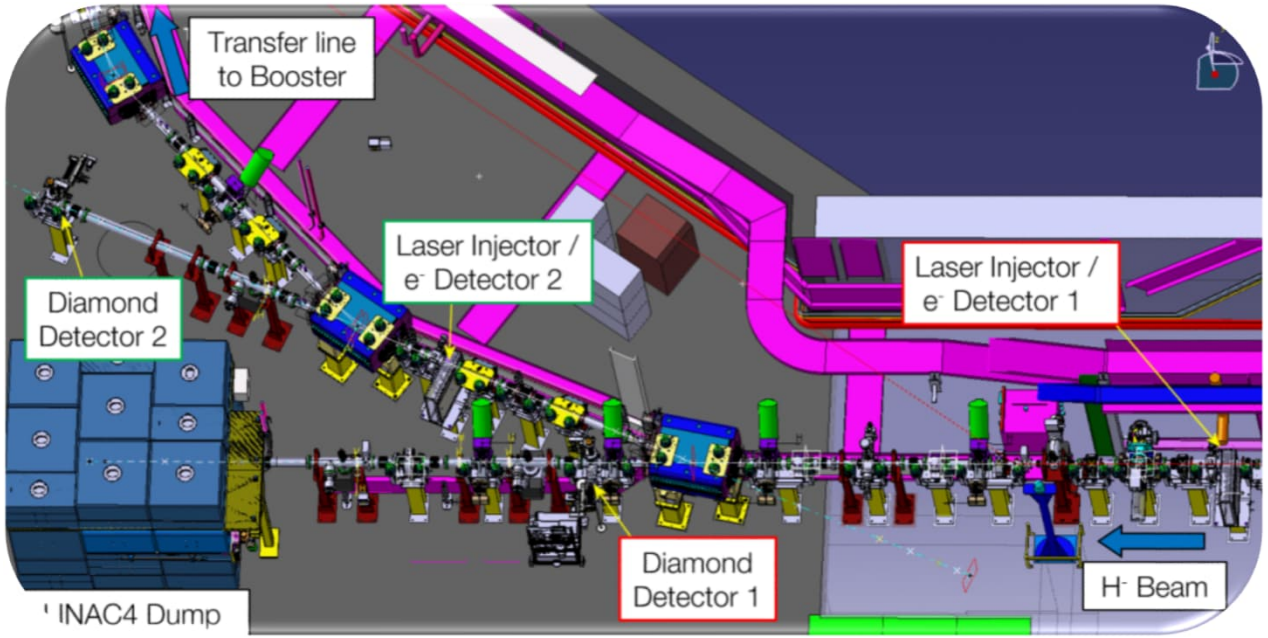
- e^- bent into electron multiplier
  ⟶ profile measurement
- H^0 measured on diamond strip detector
  ⟶ emittance and profile measurement

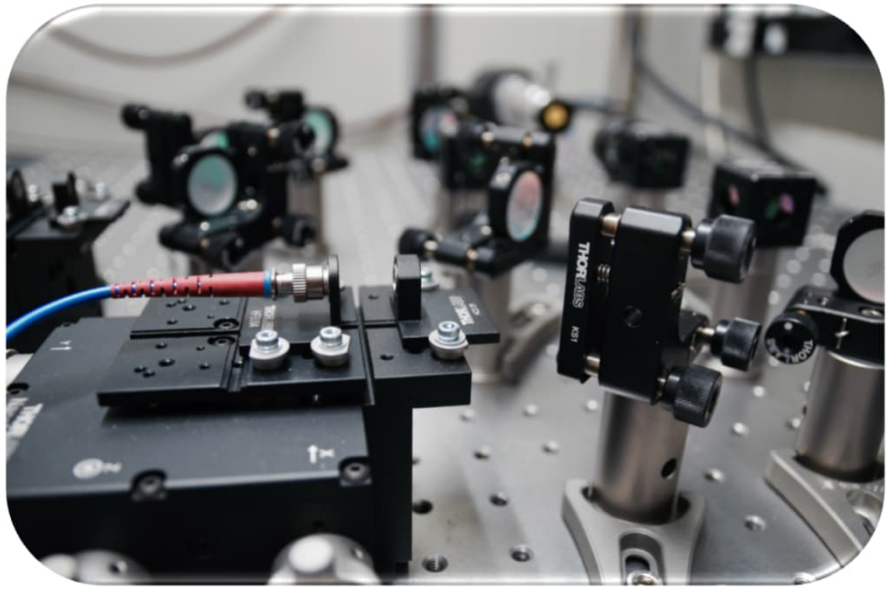


Hardware

System 1: in straight line towards the dump
→ low dispersion

System 2: between two dipole magnets
→ low H^0 background level





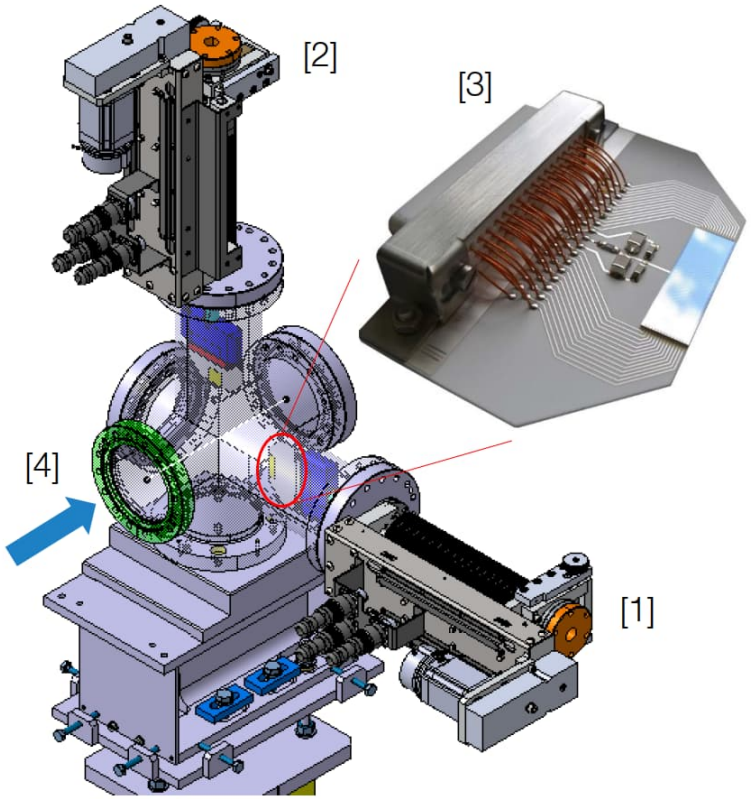
Short pulsed fiber laser (Ytterbium 1064nm) tunable power, freq and pulse width

Large mode area transport fibers

Diagnostics

Diamond Detectors:

- pCVD
- Radiation tolerant
- 28 channels, pitch 0.34mm
- Shapes: 20×20 or 32×10mm
- Stepping movable stages
- **Emittance and profile**



Electron multiplier:

- Hamamatsu RS2362
- Input aperture 20mm
- Gain 1.0 x 10^6
- **Profile only**

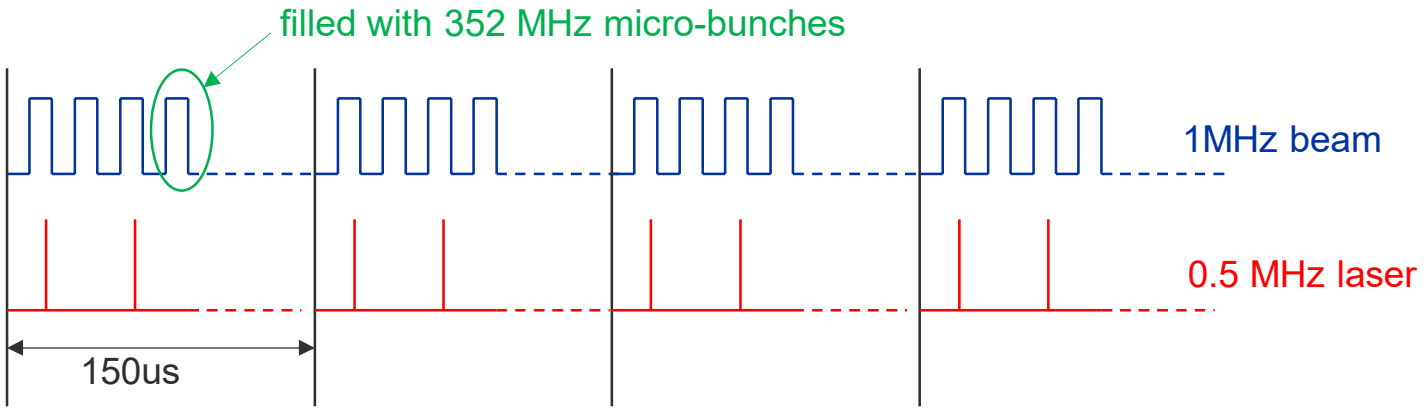
Additional:

- 5GHz photodiodes
- Energy meters
- Cameras

DAQ & Control

- LINAC4 macro-pulse (600us) every 1.2s, divided into 4x150us long bunch trains to inject in the 4x PS Booster rings
- Each bunch train is then chopped at 1 MHz (i.e. PSB revolution frequency)
- 1us period reconstructed with LINAC4 RF of 352MHz

- Laser synchronized with PSB 1MHz
- Tunable division factor, typically used 500kHz pulse width 100ns
- Acquisition synchronized with Start and Stop triggers



Controler NI PXIe, LabView

Cards:

- Digitizer/FPGA
- Timing/synchronization
- General-purpose DAQ
- Preamplification

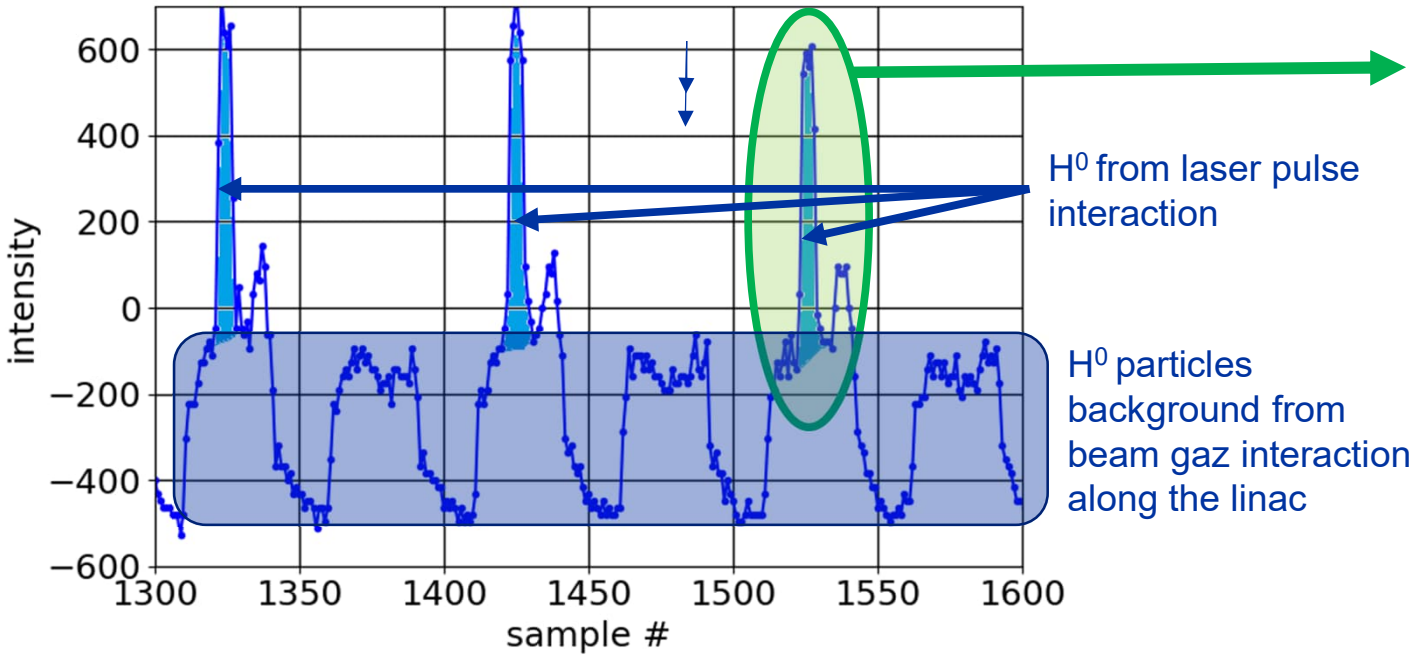
Sampling frequencies:

- Diamond 50MHz
- PD and EMT 120MHz

Fully Integration into CERN control infrastructure (FESA)

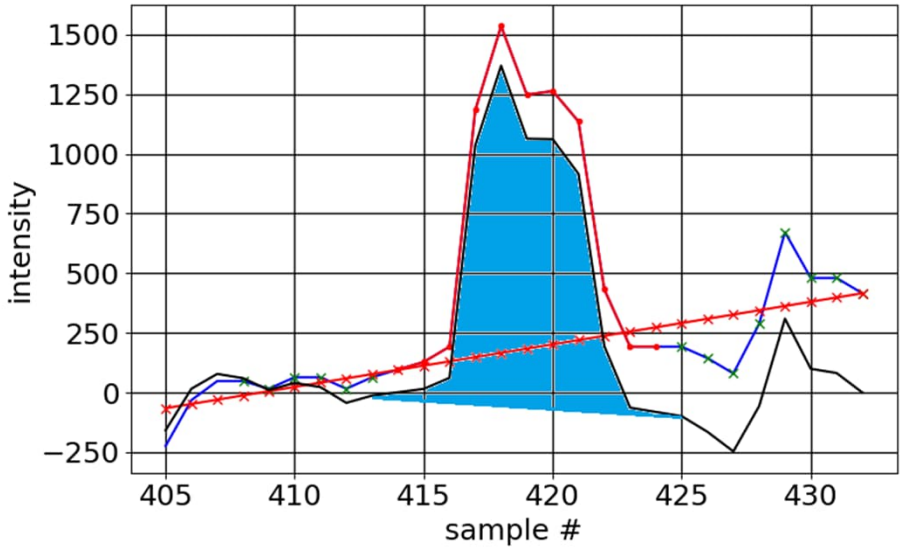
Diamond Data Processing (real-time)

Diamond 1 channel raw data



H^0 from laser pulse interaction

H^0 particles background from beam gaz interaction along the linac

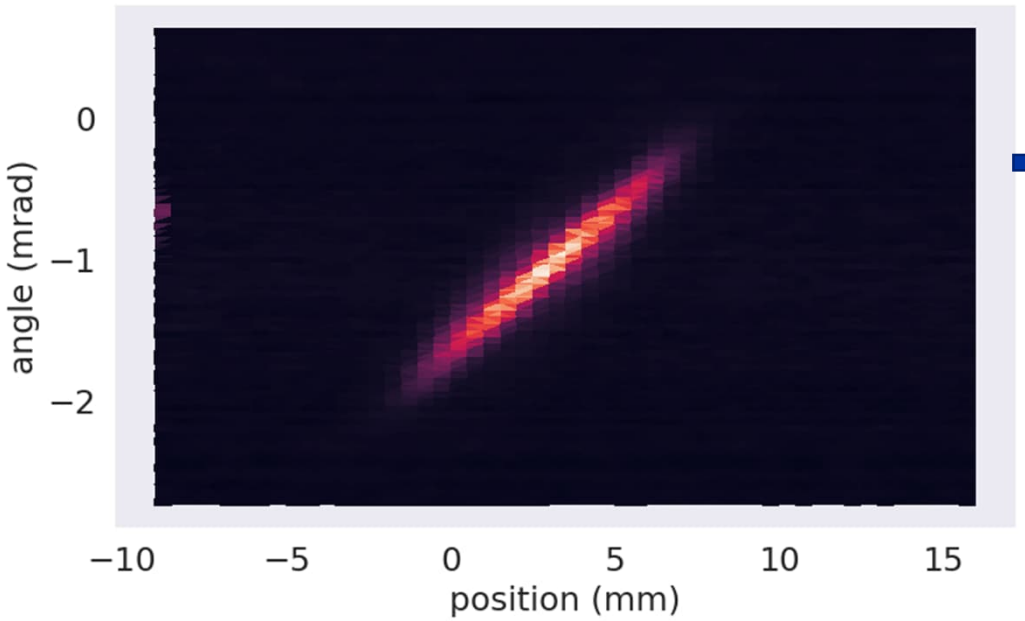


For each channel / pulse:

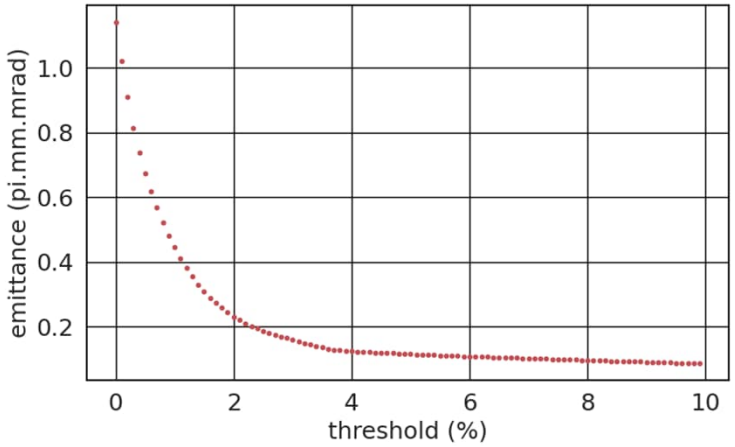
- Window selection
- Background subtraction
- Pulse integration
- Published: integrated data → 1 value per channel / pulse

Diamond Data Processing (real-time)

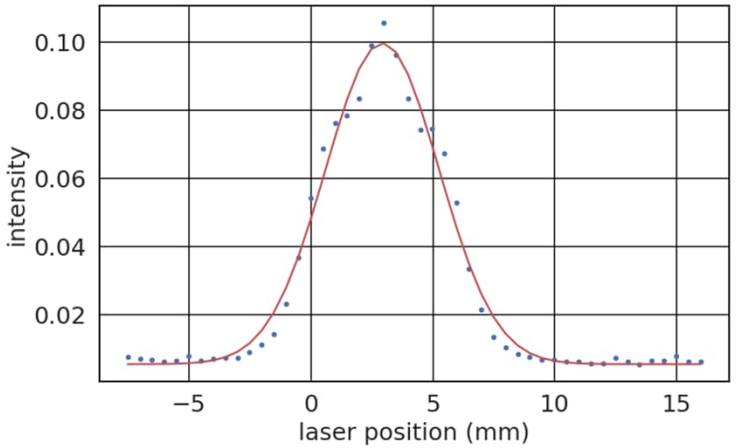
Phase space ellipse (1 pulse)



Emittance vs threshold (1 pulse)



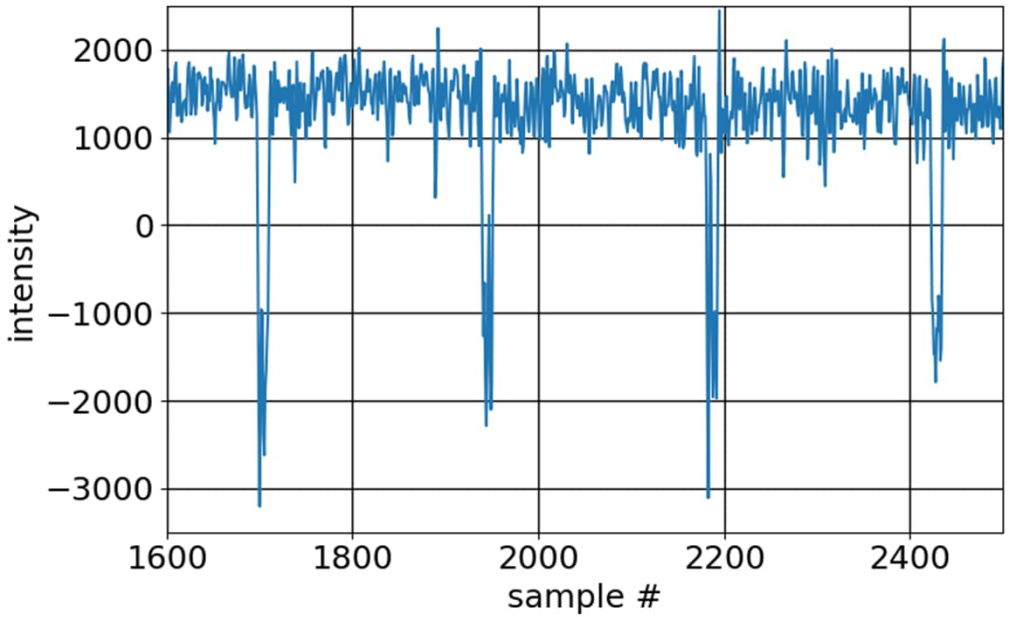
Profile from phase space projection (1 pulse)



A full laser/diamond scan for good phase space ellipse resolution takes ~10min (1 laser/diamond step every 1.2s)

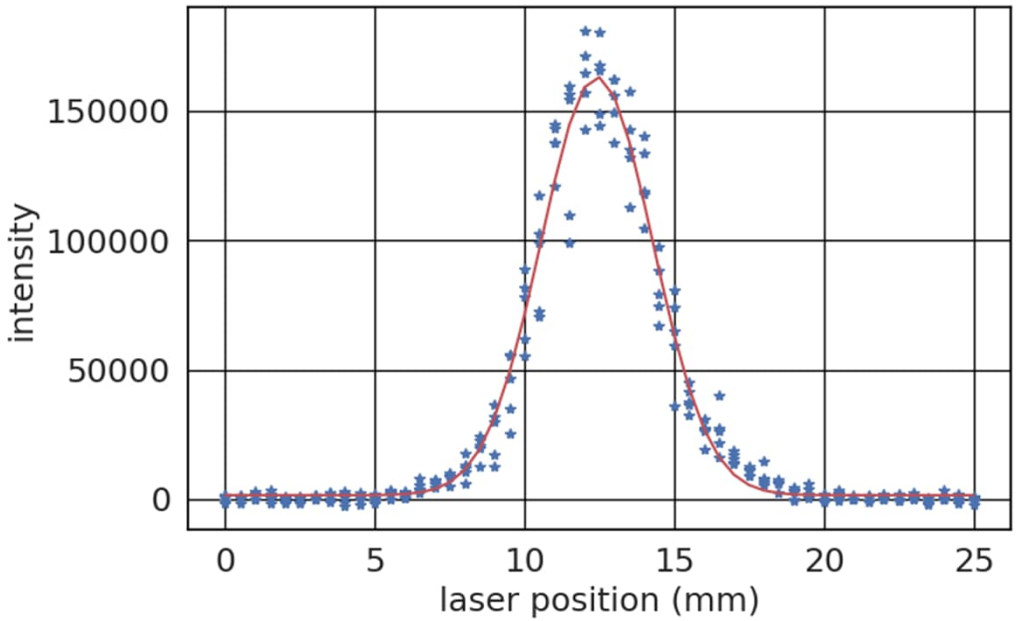
EMT Data Processing (offline)

EMT raw data

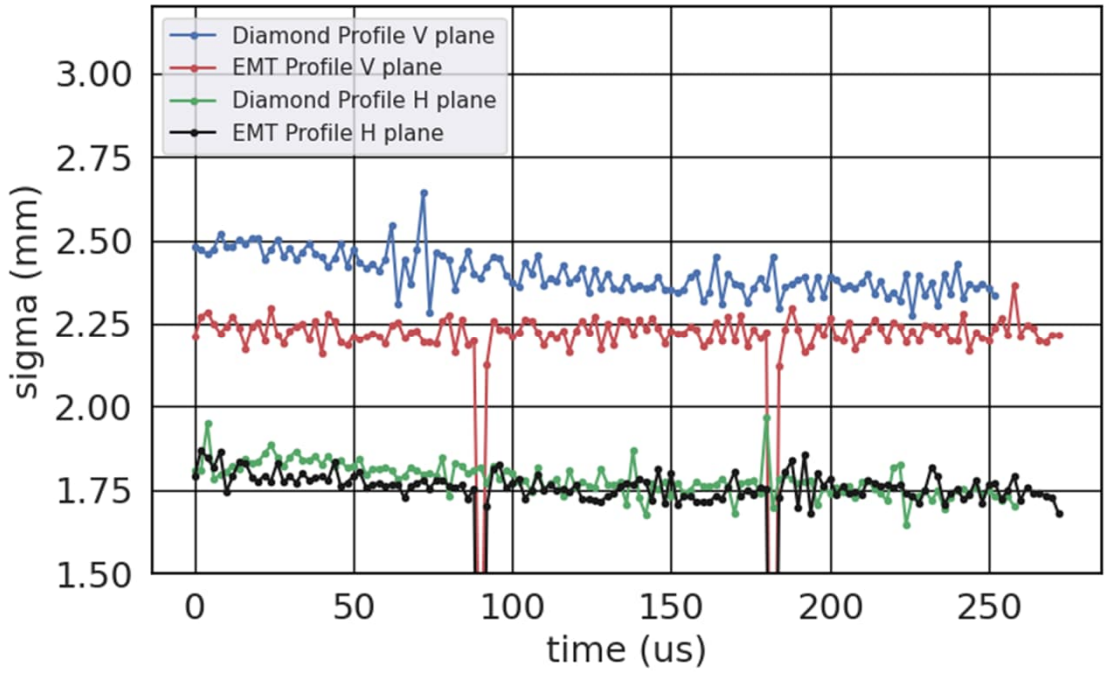


For each pulse:
- Window selection
- BG subtraction
- Pulse integration

EMT profile (1 pulse)



EMT and Diamond Profiles Comparison



H plane: good agreement (0.5%)

V plane: beam sizes from EMT smaller than diamond

Possible causes:

- Limited EMT detector acceptance
- V beam size at this location larger than H
- Setting of the EMT magnet
- Tilt of the bending magnet → coupling, vertical kick

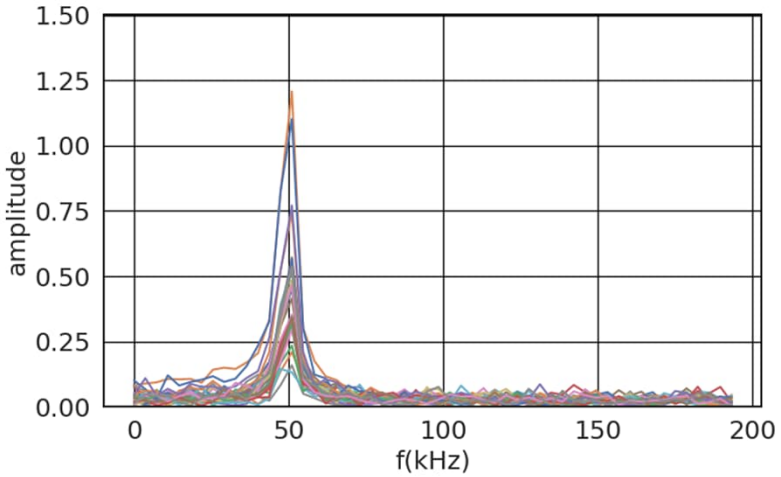
Diamond Detector Perturbation

- **Common to all diamond channels**
- **Strong harmonic at ~ 50kHz (2MHz on raw data)**

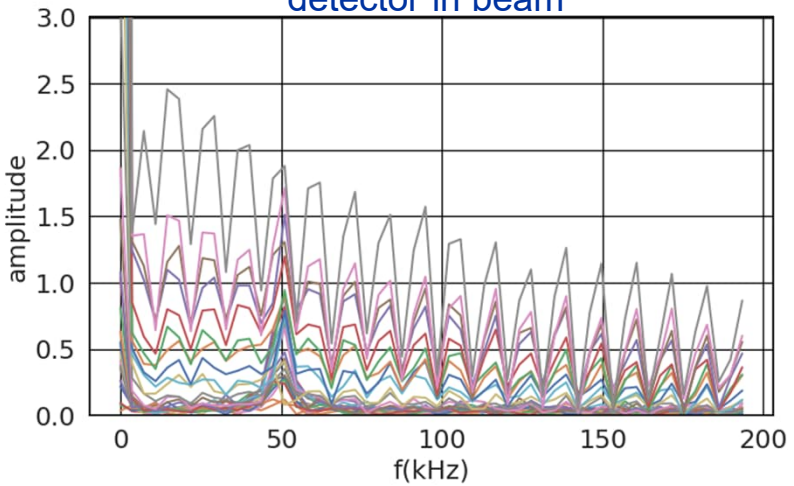
- Higher than emittance variation along pulse
- H^0 beam itself contains multiple frequencies

- For now: use of 50kHz digital notch filter
- Next winter stop: review of cables shielding

Diamond integrated signals FFT detector out of beam



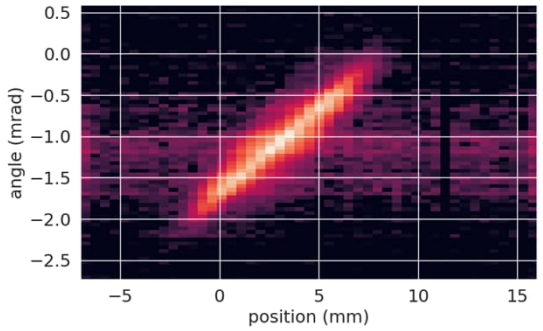
Diamond integrated signals FFT detector in beam



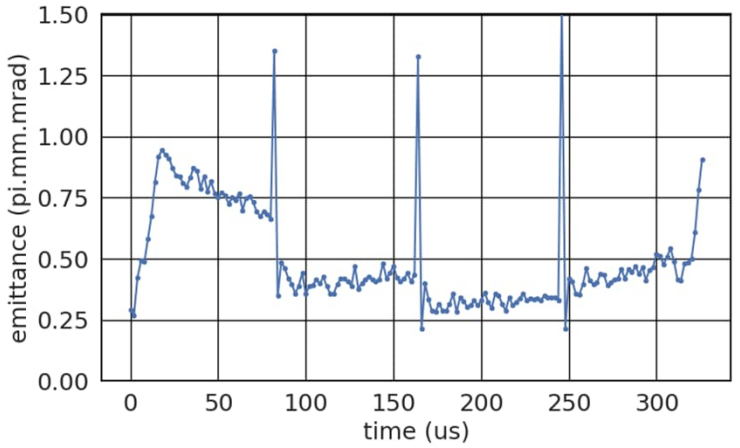
Emittance Measurements

Measurement from 21st June 2022

Vertical phase space (1 pulse)

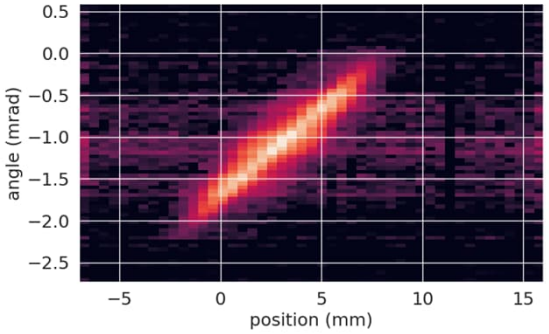


Emittance along pulse

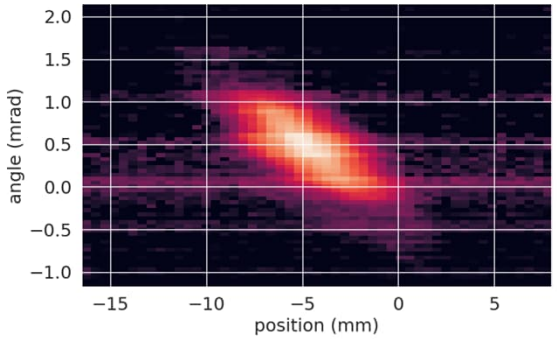


Measurement from 28th June 2022

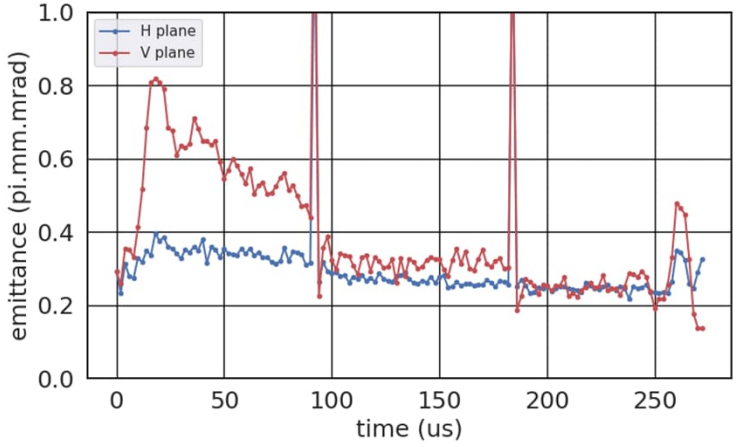
V phase space (1 pulse)



H phase space (1 pulse)



Emittance along pulse



Some variations in vertical emittance observed along the train

Conclusion and Perspective

- First systematic measurements of the L4 laser profile and emittance monitor performed this year

- Presence of perturbations **from electrical source** and transported by LINAC4 beam

→ digital notch filter used so far as a mitigation technique

→ improvement of cables shielding foreseen next winter stop

- EMT and diamond **profiles comparison shows good agreement** in H plane

discrepancy in V plane probably linked to EMT sensor size and bending magnet

- Emittance measurements:

→ More analysis needed to understand if the variation in vertical emittance along the train are real

→ **Cross calibration measurements with Wire Scanners** in beam dump line will be performed