LINAC4 Laser Emittance Meter

FCC EPOL WORKSHOP

Aurelie Goldblatt SY-BI-PM

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LINAC4 Laser Emittance meter

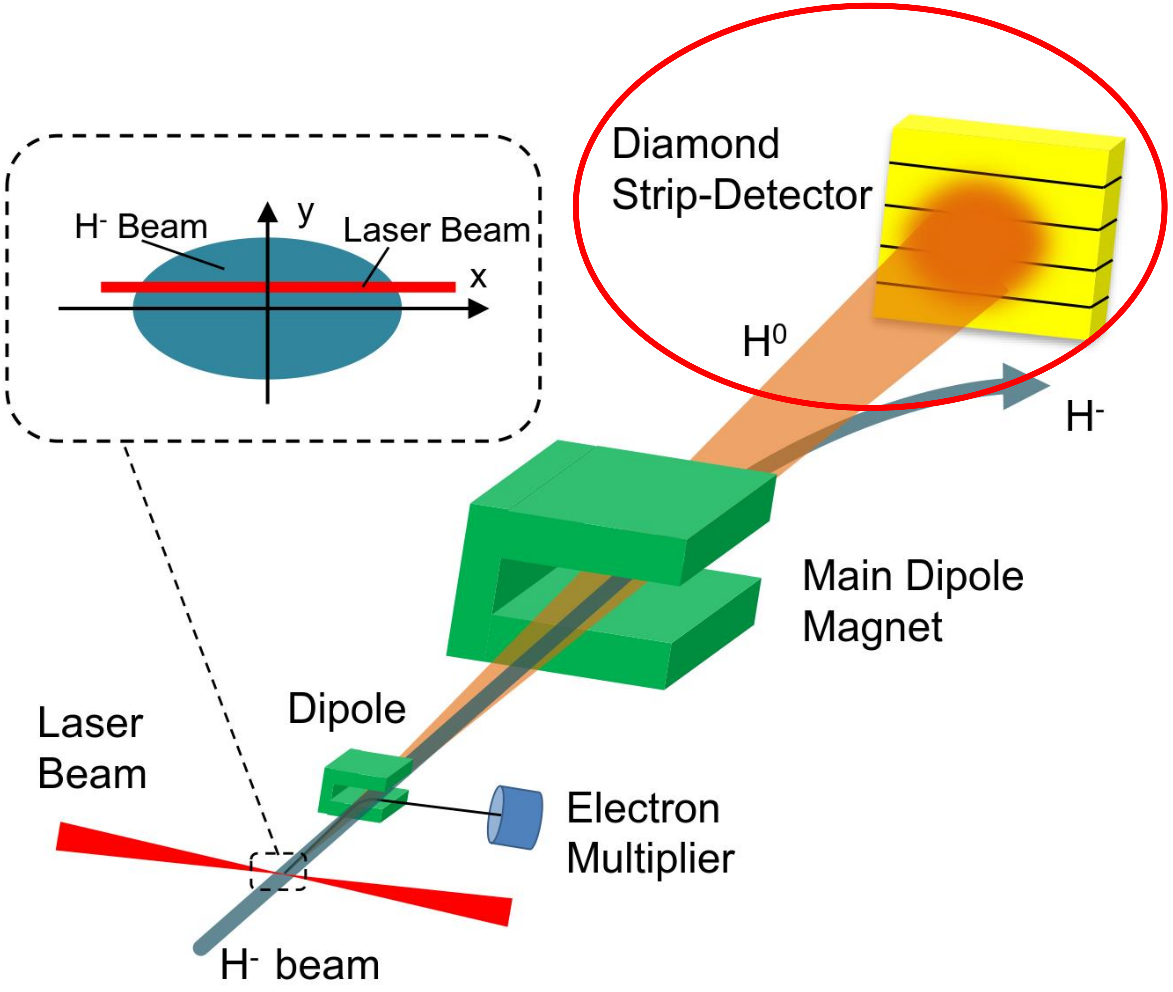
LINAC4 accelerates H^{-} ions up to 160MeV

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

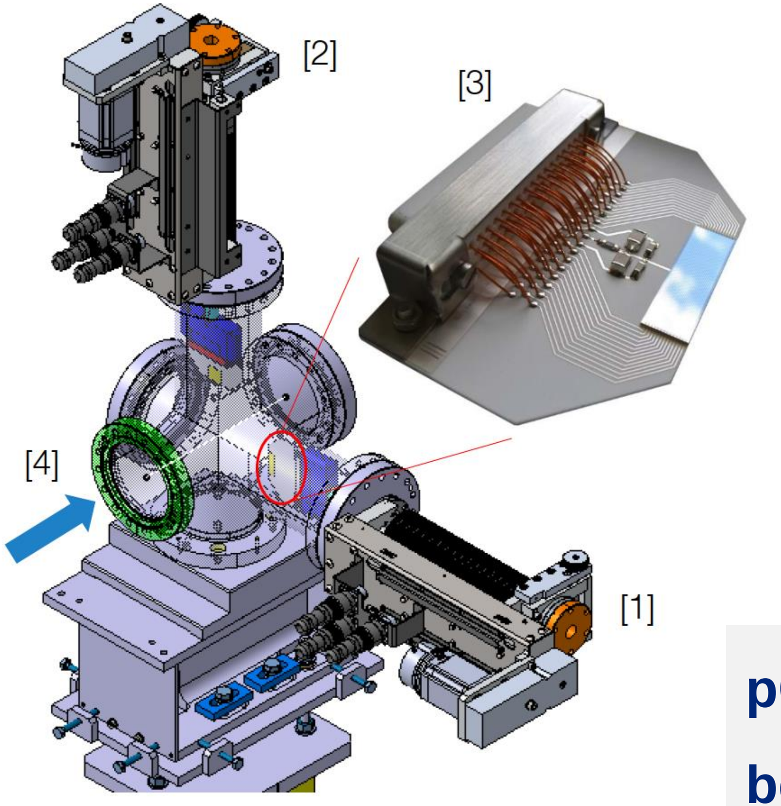
e^- stripping by photodetachment

Scan of focused beam through H^{-} beam

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



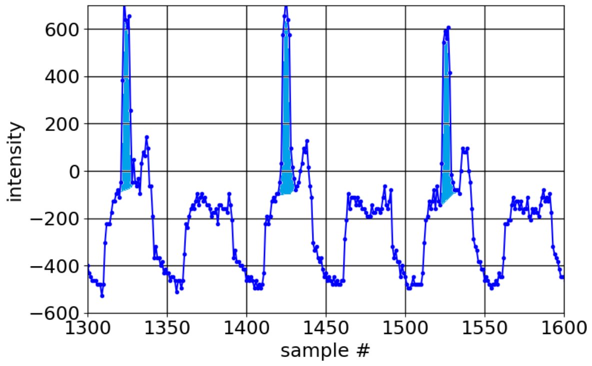
Emittance Diagnostics



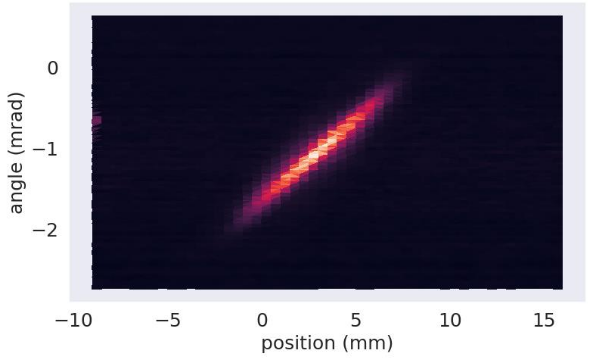
- 2 E-meters in LINAC4
- **pCVD diamond detectors**
- 4 sensors covering H & V planes separately

pCVD also used in SY group for beam loss monitoring

Diamond channel raw data



Phase space ellipse



Why pCVD Diamond ?

- **Sensitivity:** multiple background sources

  → high signal to noise ratio needed

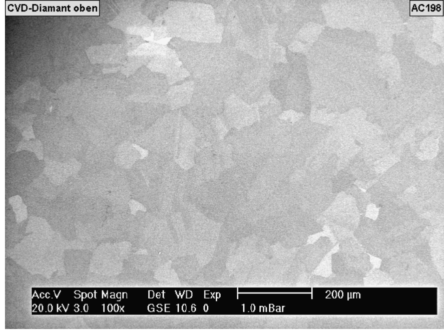
- **Time resolution:** enough to detect pulses 10-100ns

- **Excellent radiation hardness**

- **Ultra High vacuum compatible**

- **High dynamic range:** used from 3MeV to 160MeV

- **Big detector size**



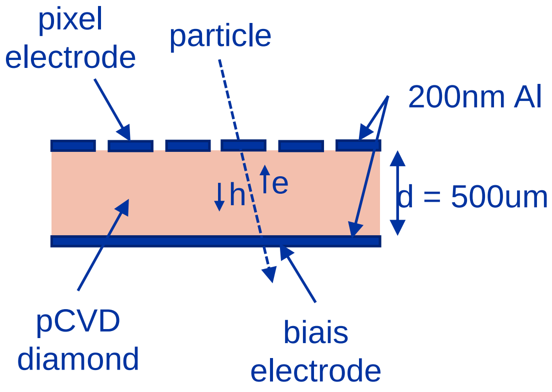
Diamond microscopy

Other systems reviewed:

SEM, scintillating screens, Multi Channel Plates, Gaz Electron Multipliers, semiconductors

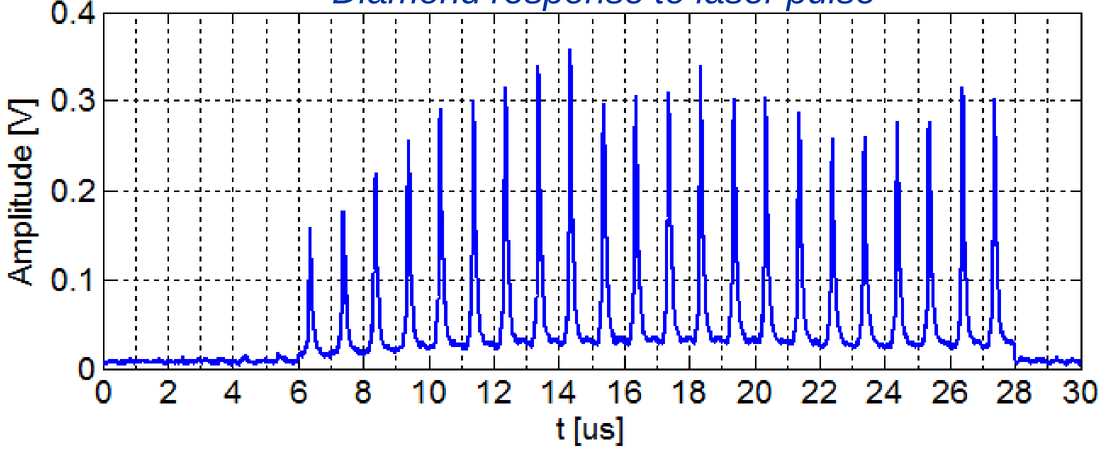
→ **All show at least one weakness**

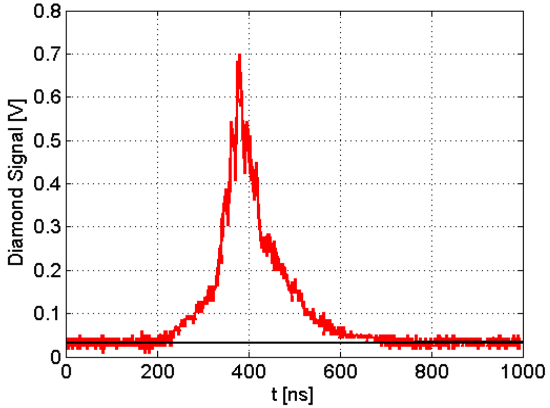
Collected Charge @ 160MeV



- e- of H^0 stripped in the diamond surface → proton ionisation
- H^0 atoms fully traverse 500um diamond → no piled up charge
- Charge collection efficiency (CCE) of 36%
- E loss inside diamond simulated with SRIM : 820keV/H^0
- For beam current of 64,5mA*, ~1e5 H^0 (laser @ beam center) → detector output ~0.2V

Diamond response to laser pulse





*40 mA beam average current as specified in [GV+06] scaled with 1/0.62 chopping ratio

Radiation Damage

Excellent radiation hardness but damage due to atomic displacement when exposed to high energy particles
→ Critical for profile measurement (acceptable degradation 10%)

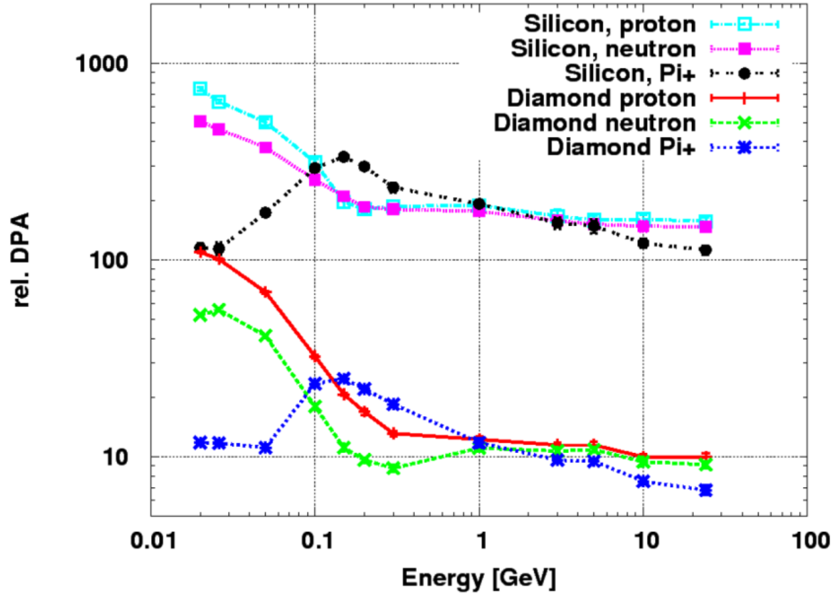
Fluences by radiation type :

- Laser stripped H^0: 2,9 · 10^6 H^0/L4macropulse* · mm^2
- Direct H^0 background: 4,4 · 10^5 H^0/L4macropulse · mm^2
- Ambient radiation 9,1 · 10^6 n^0/day · mm^2

Damages to:

- Diamond bulk → dominant effect
- Electrode-diamond interface
- Polarisation building up due to implanted / trapped charges

- Highest radiation damage in the detector's central mm2
- **Estimated detectors life time with 1 emittance scan per hour : 9 years**



Radiation damage measured as relative Displacement Per Atom (DPA)

* Calculated for LINAC4 macropulse of 400us

Diamond Sensor Design & Testing

- 28 channels, 0.34mm strips → less than 10% charge sharing

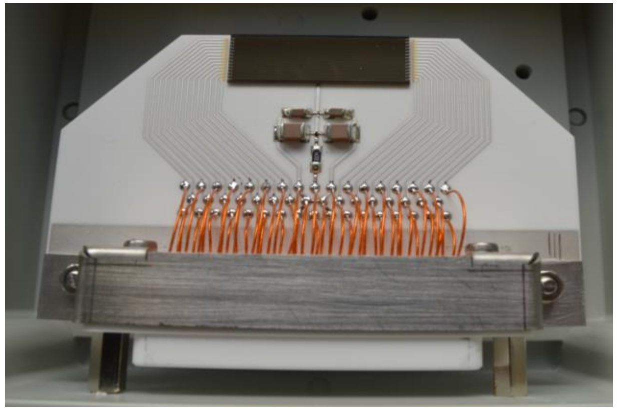
(→ long drift space needed to increase angular resolution)

- Detector sizes: 32x10mm or 20x20mm
- Ceramic PCB, thermoplastic adhesive film

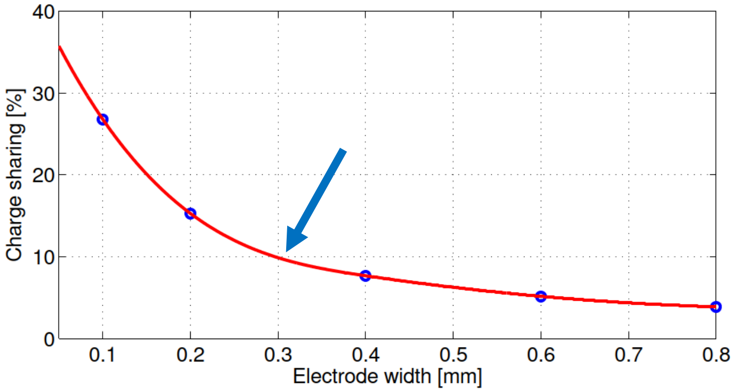
  → UHV compatible

- Tests show really good channels homogeneity & linearity

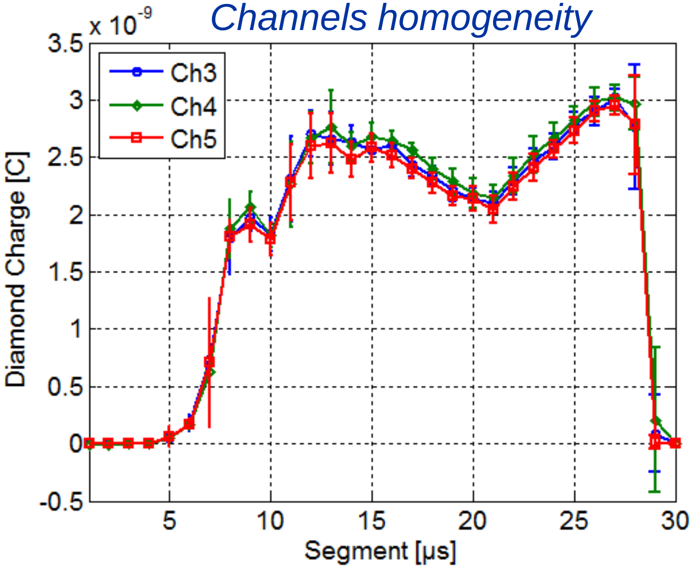
Diamond sensor



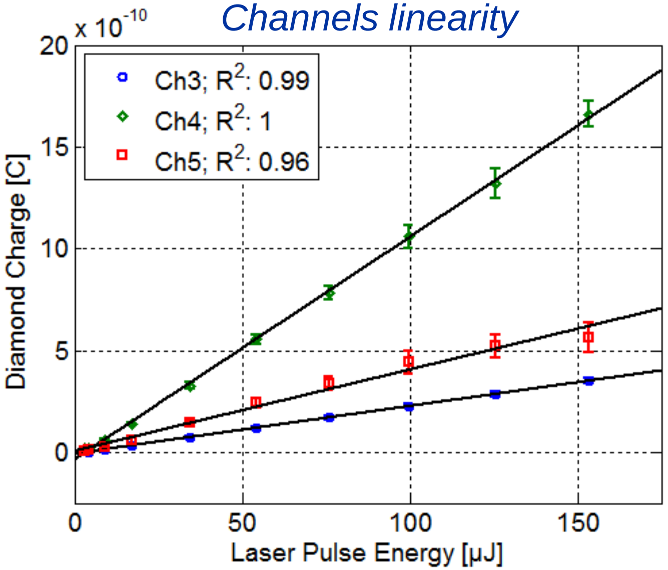
Charge sharing for different strip widths



Channels homogeneity

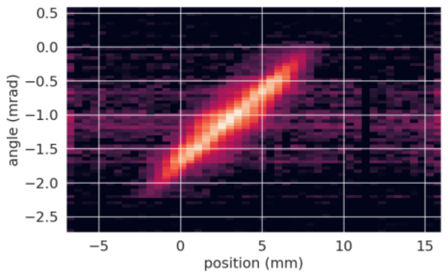


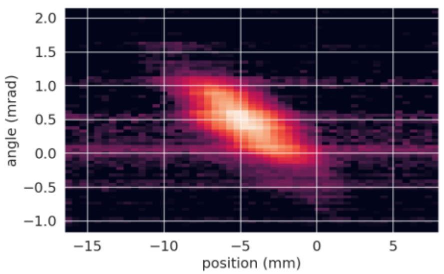
Channels linearity



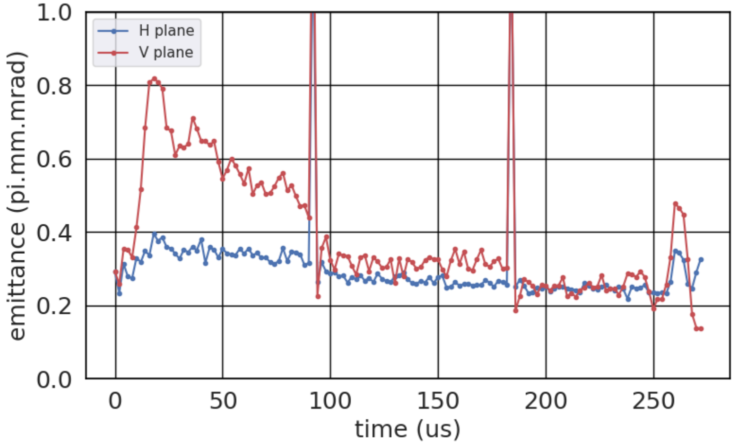
Laser E-meter Commissioning

Measurement from 28th June 2022



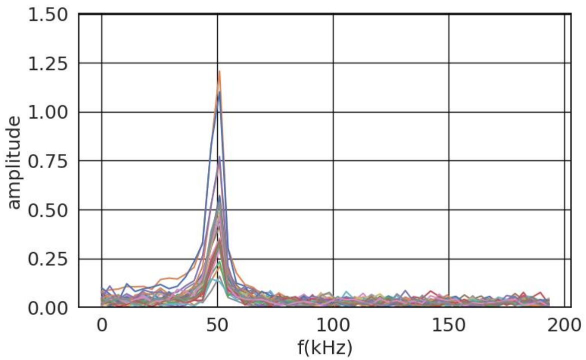


Emittance along pulse

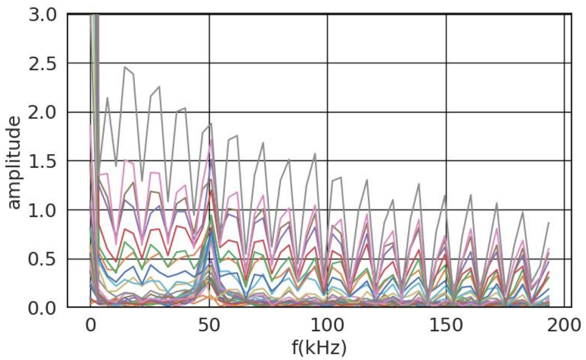


- Perturbation common to all diamond channels
- ~ 50kHz (2MHz on raw data)
- H^0 beam itself contains multiple frequencies
- For now: use of 50kHz digital notch filter
- Next winter stop: review of cables shielding

Diamond integrated signals FFT detector out of beam



Diamond integrated signals FFT detector in beam



References

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