Diamond Detectors for Profile and Emittance Measurements at LINAC4

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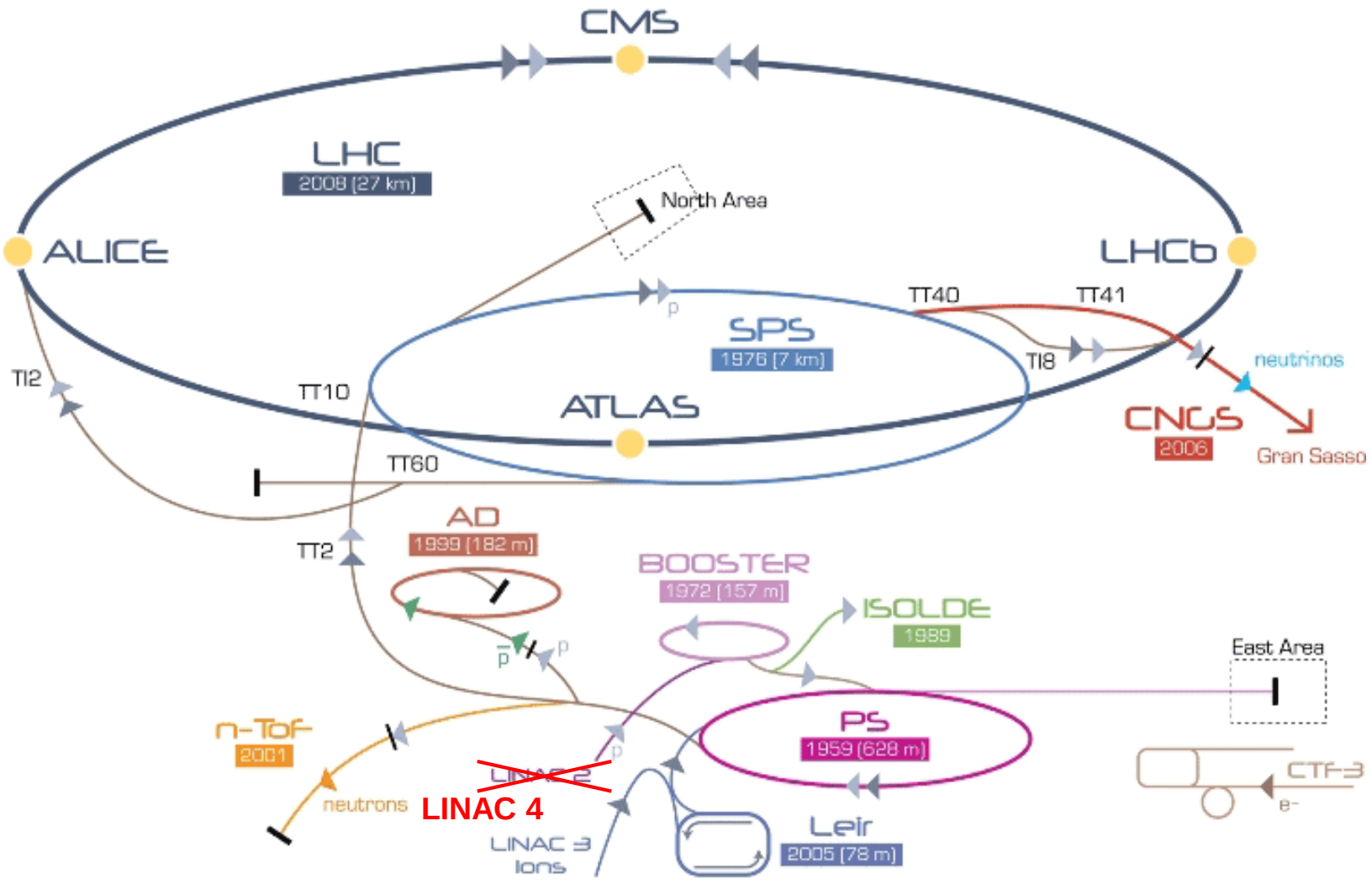
Outline

- Overview LINAC4
- What do we measure, why diamond?
- Prototype Tests at 3 & 12 MeV H^- beam
- Recent Tests at 50 MeV H^- beam


LINAC4

CERN Accelerator overview



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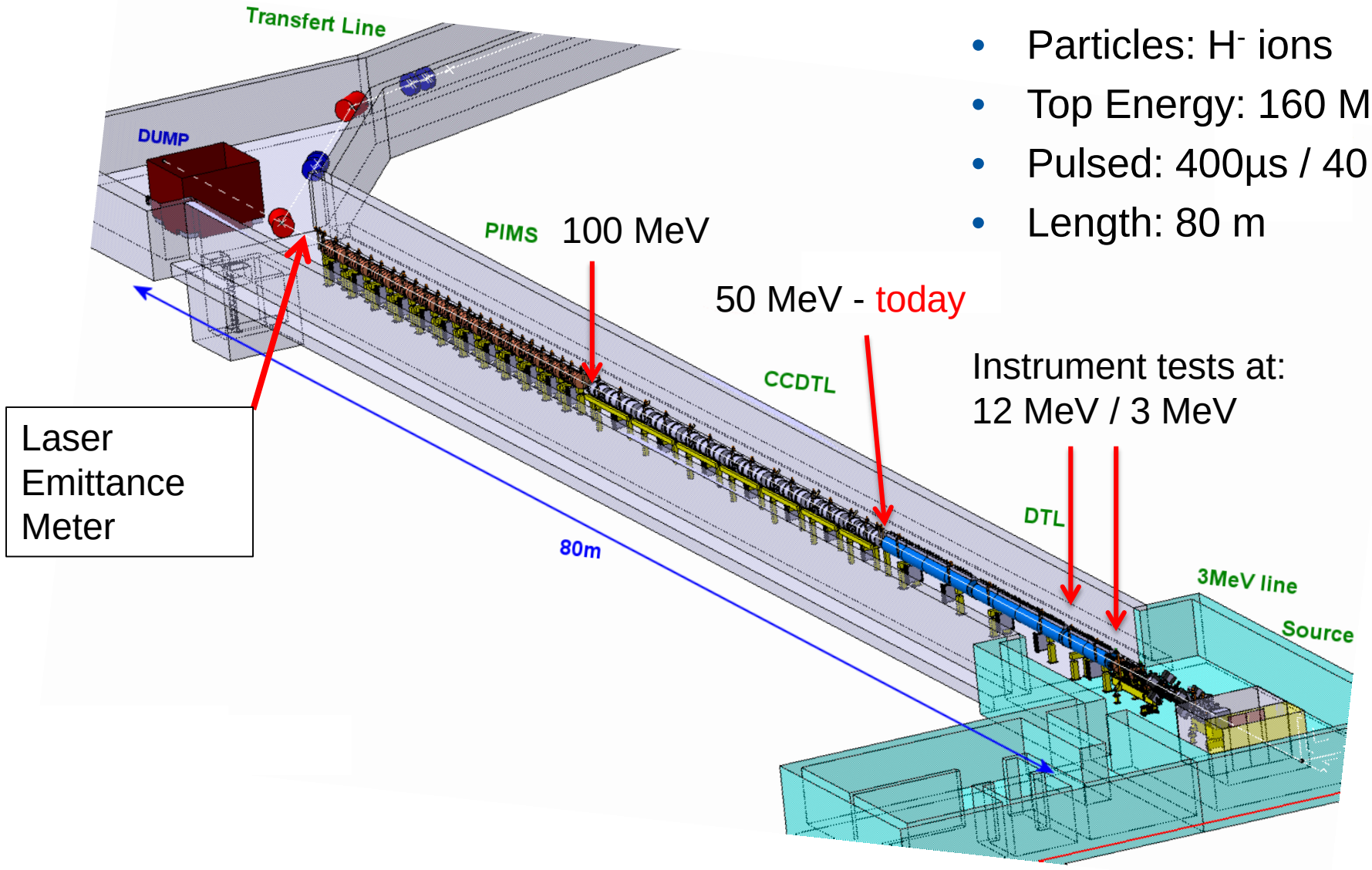
LINAC 4 – Commissioning Steps



- Particles: H^- ions
- Top Energy: 160 MeV
- Pulsed: 400µs / 40 mA
- Length: 80 m

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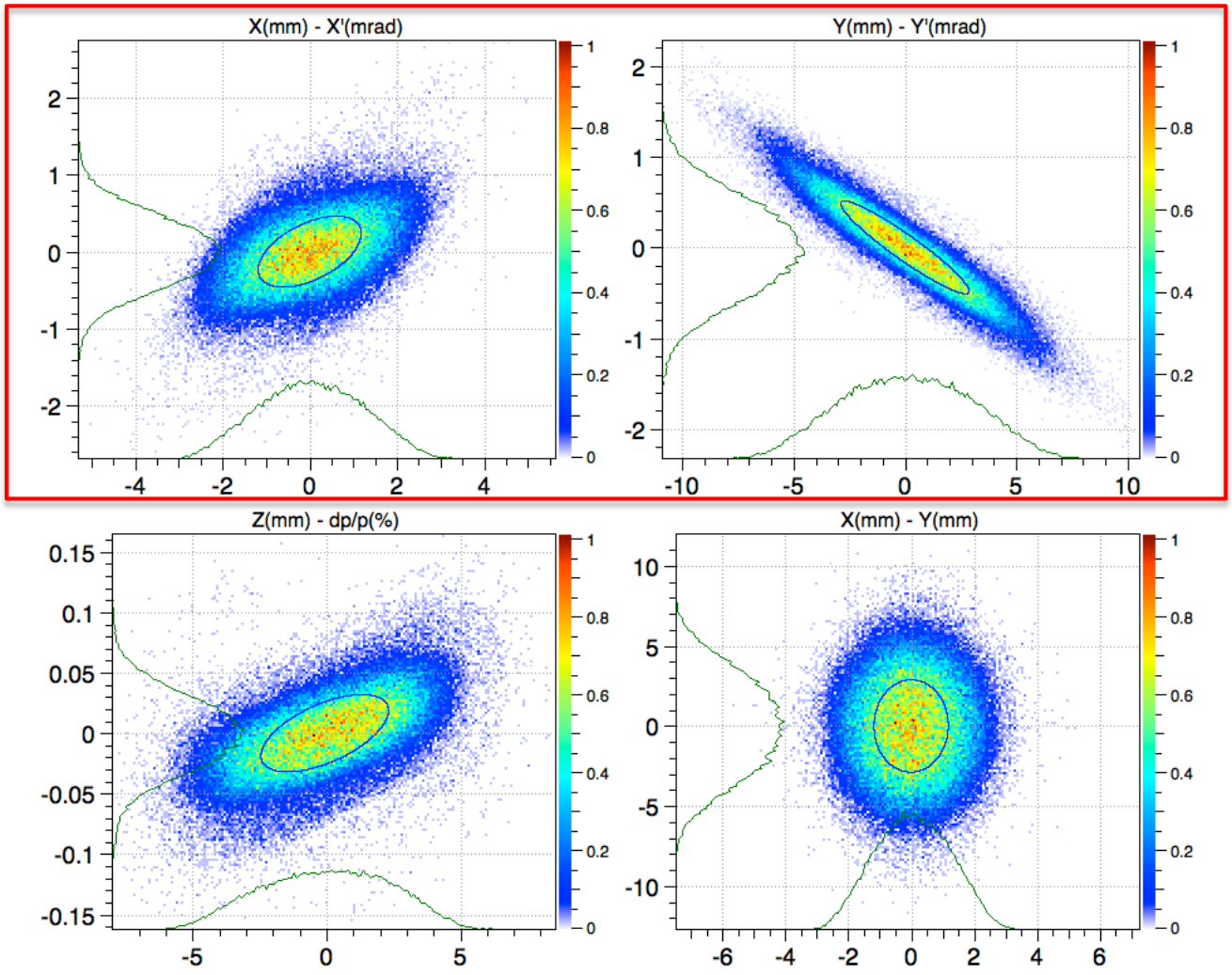
What do we measure?

- Transverse Phasespace
  - Position (x,y)
  - Angle (x‘,y‘)



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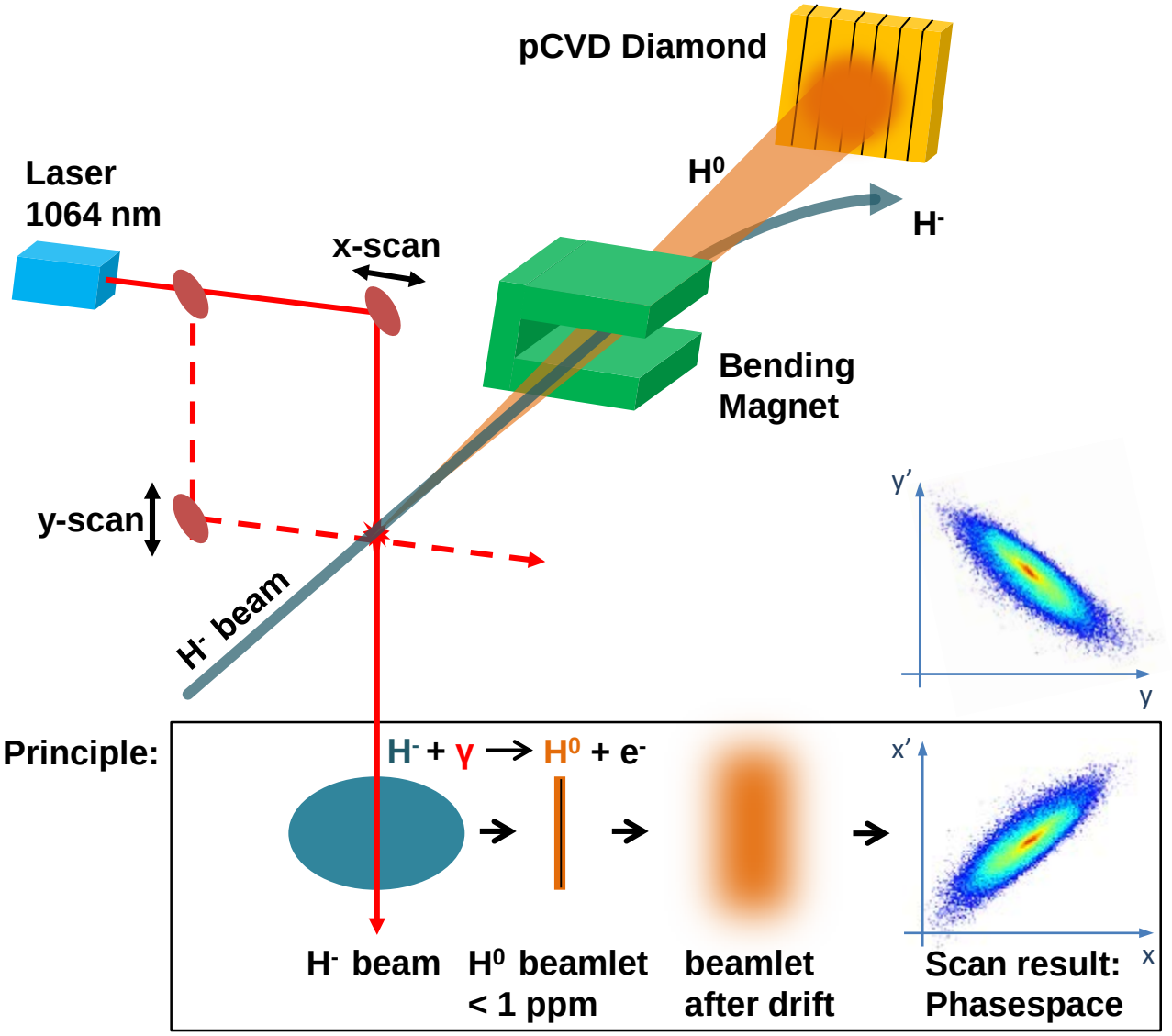
Concept the Laser Emittance Meter



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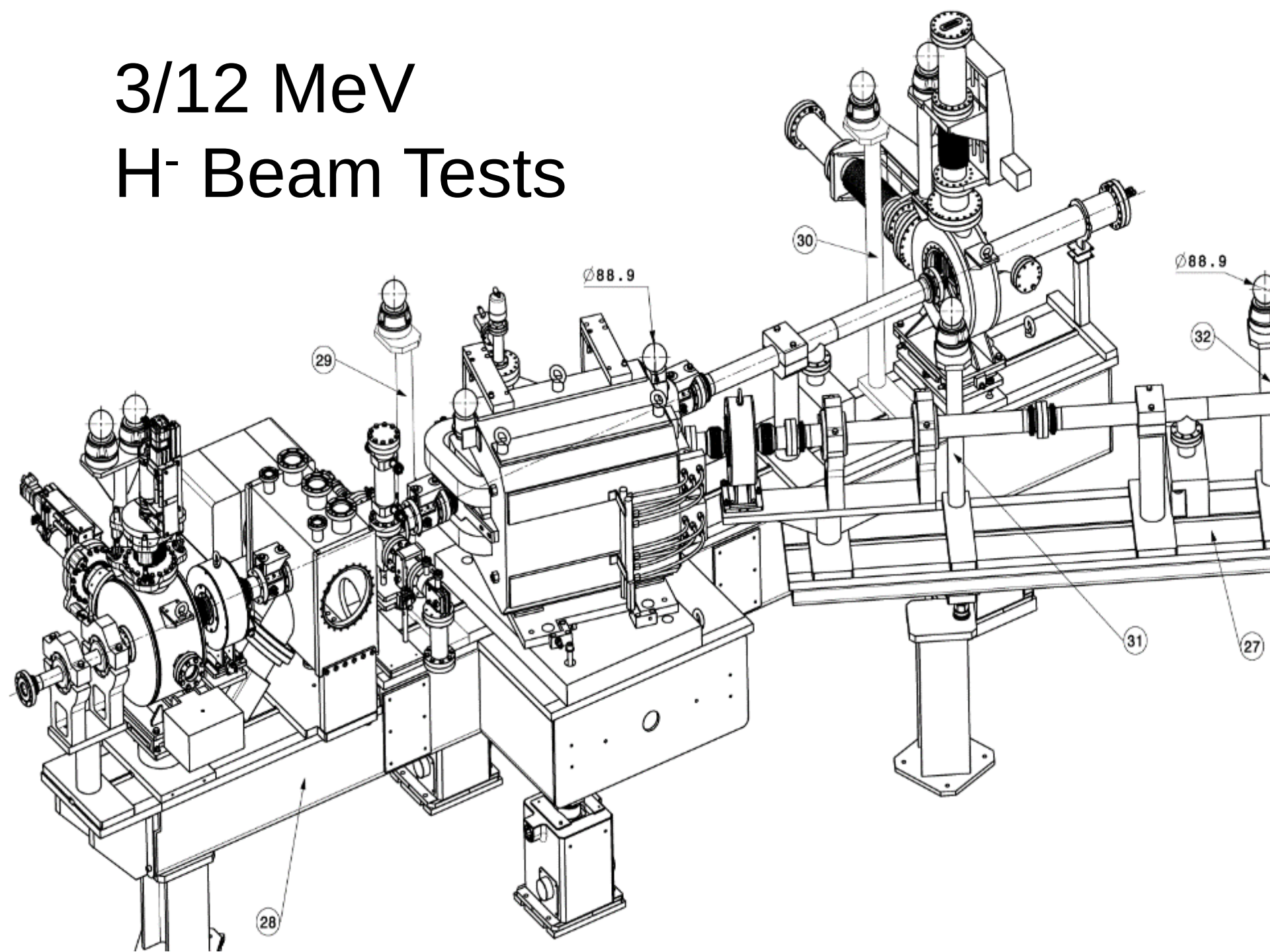
WHY Diamond?

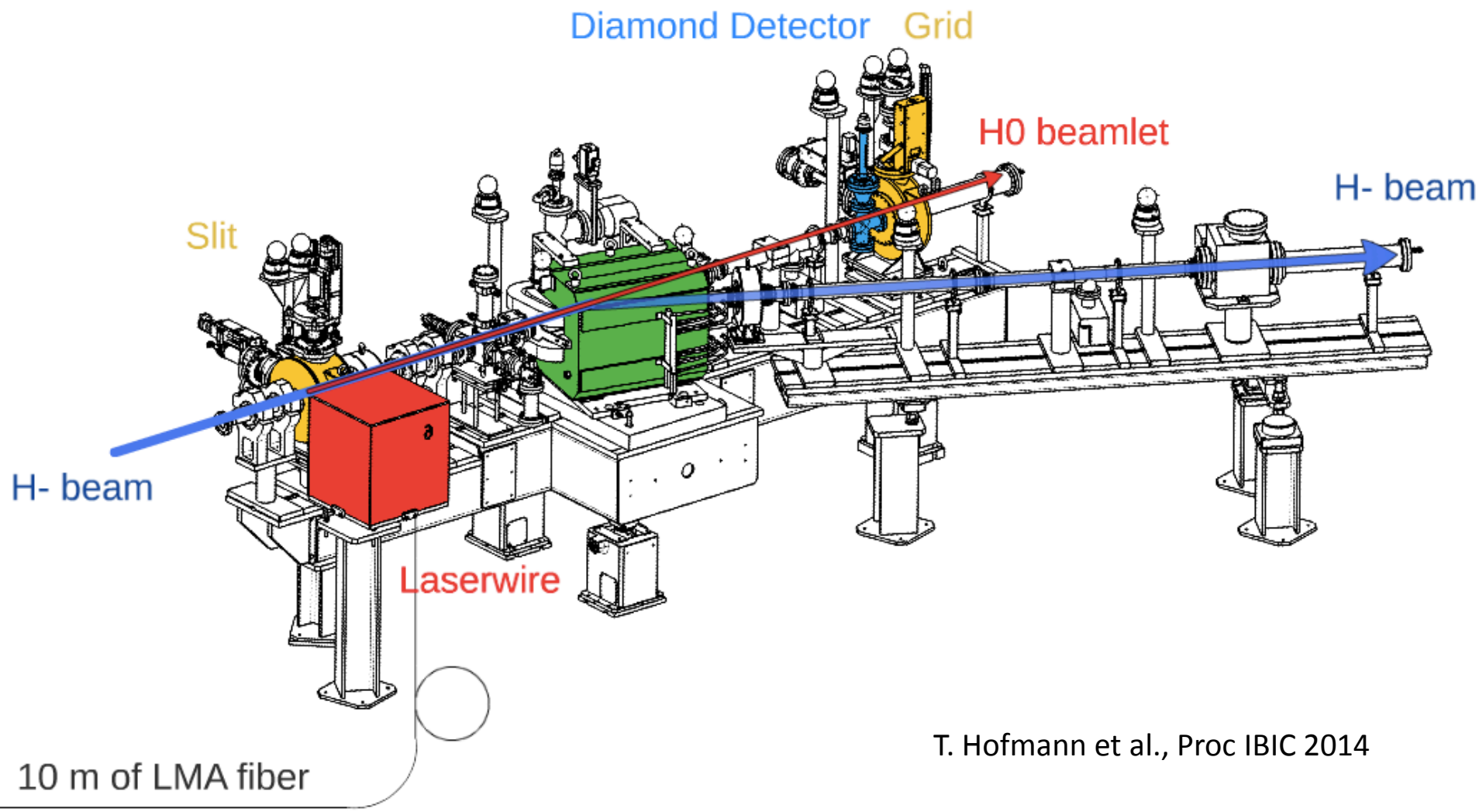
- What are our needs?
  - High bandwidth ~10 MHz (100 ns laserpulses)
  - Raidiation hardness (10^7 H^0 per LINAC4 pulse)
  - Internal Gain
  - Homogenity (Profile measurement)
  - Size ~20x20 mm (depending on beam dynamics)
  - UHV compatible

- Detector Alternatives
  - Silicon: Radiation hardness
  - MCP: Radiation hardness
  - Scintillator: Radiation hardness & bandwidth
  - Secondary Emission Grid: No internal gain

3/12 MeV
H^- Beam Tests



3 / 12 MeV Prototype Test Setup



T. Hofmann et al., Proc IBIC 2014

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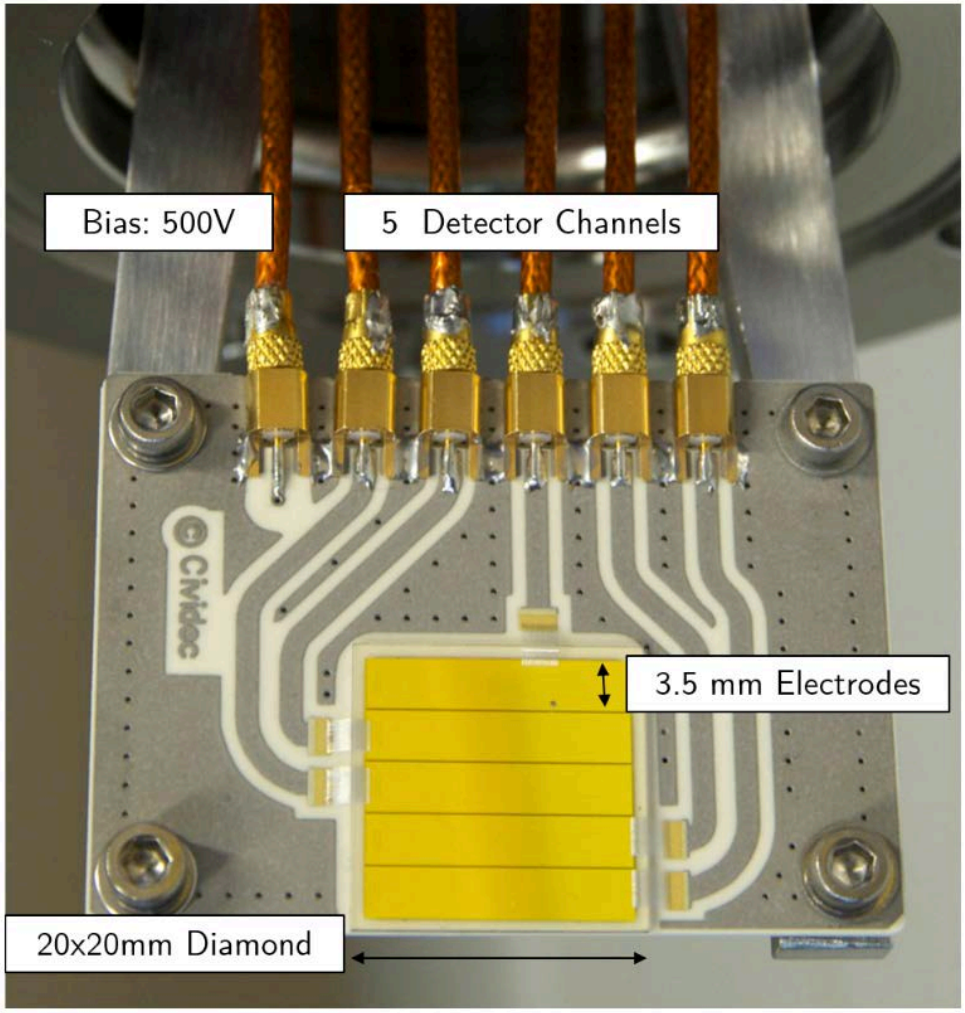
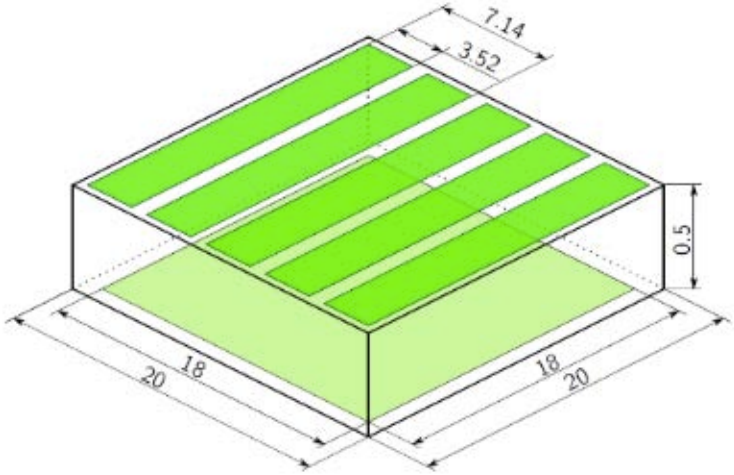
pCVD diamond strip-detector



- Dimensions



- 5x 200 nm aluminium strip electrodes
- 500V applied on backside

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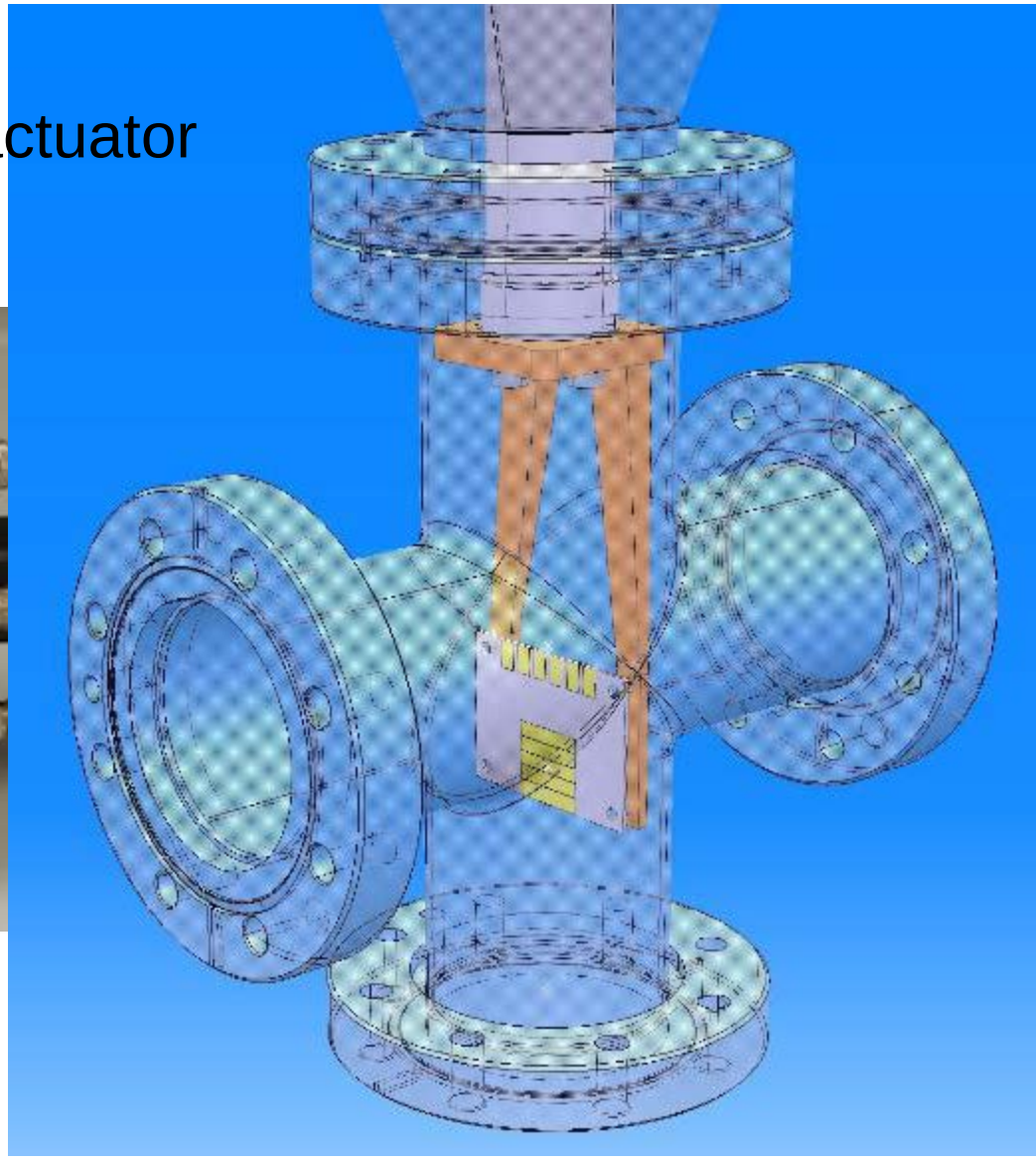
pCVD Diamond Detector

- Mounting in beampipe on actuator



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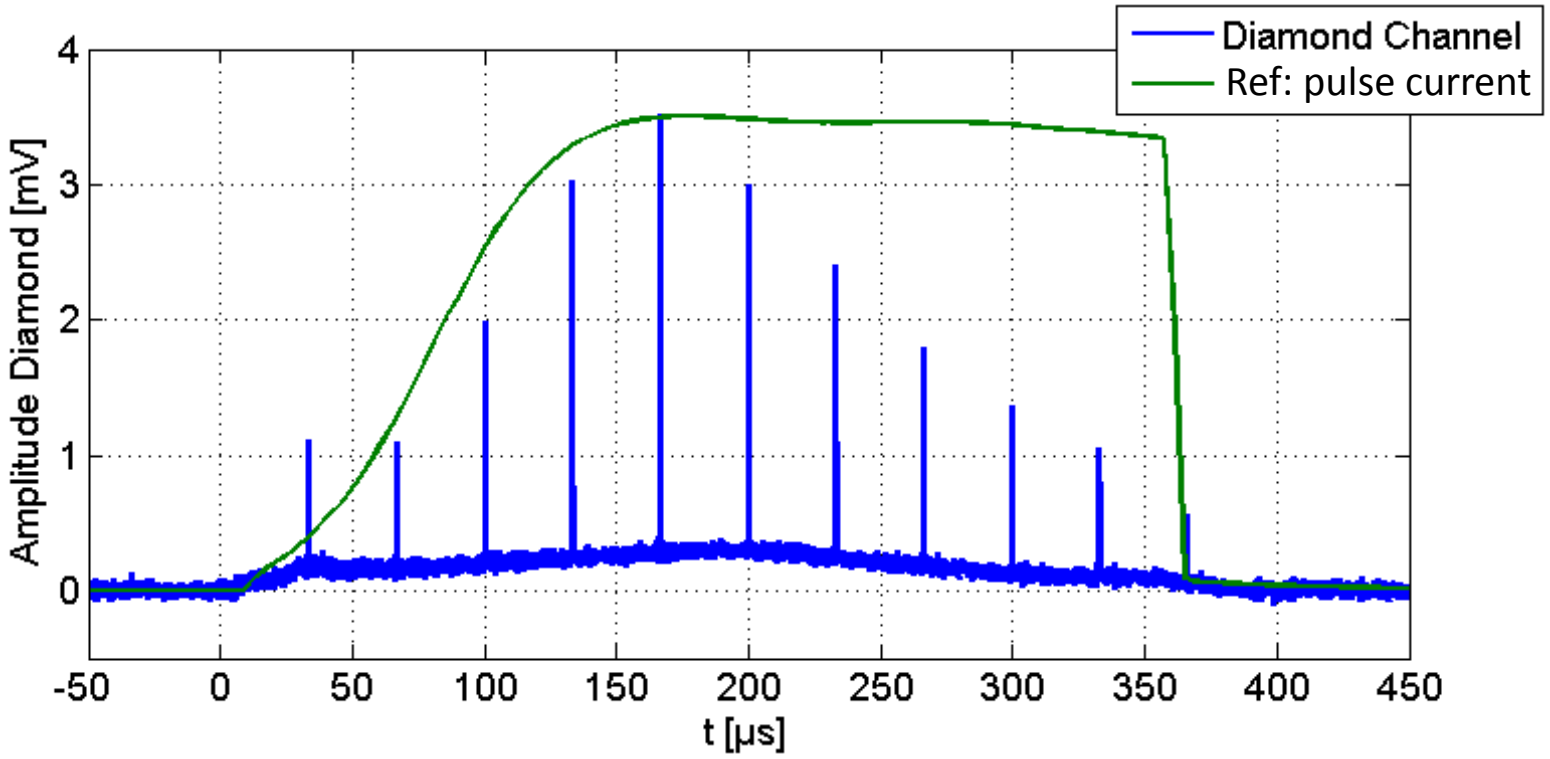
Raw Signal at 3 MeV H^- Beam



- Diamond signal clearly caused by laser stripping: approx. 10^5 H^0/channel
- Very low signal amplitude
- LINAC4 pulse background floor
- Comparison with pulse current: Sensitivity declines during 2^{nd} part of LINAC4 pulse

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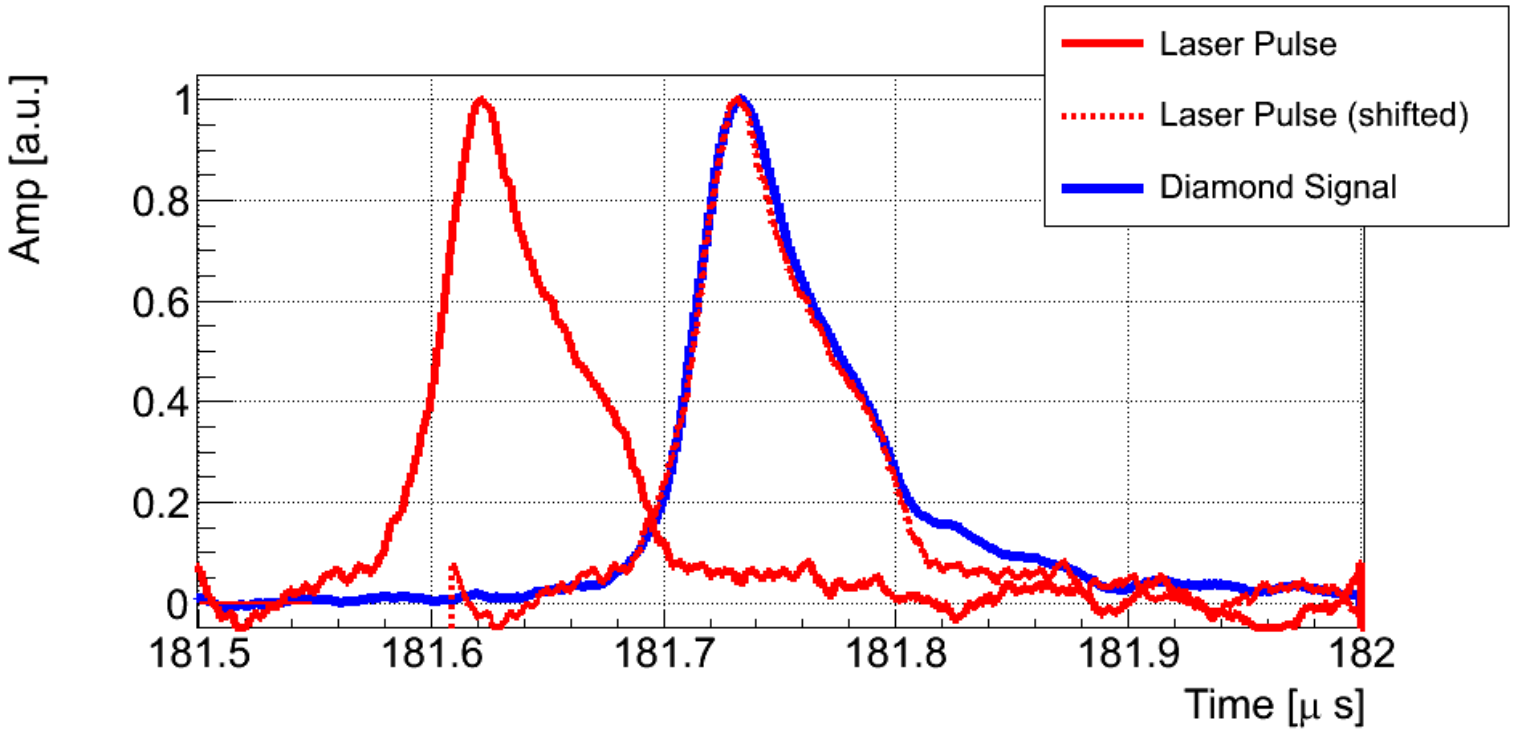
Raw Signal at 3 MeV H^- Beam



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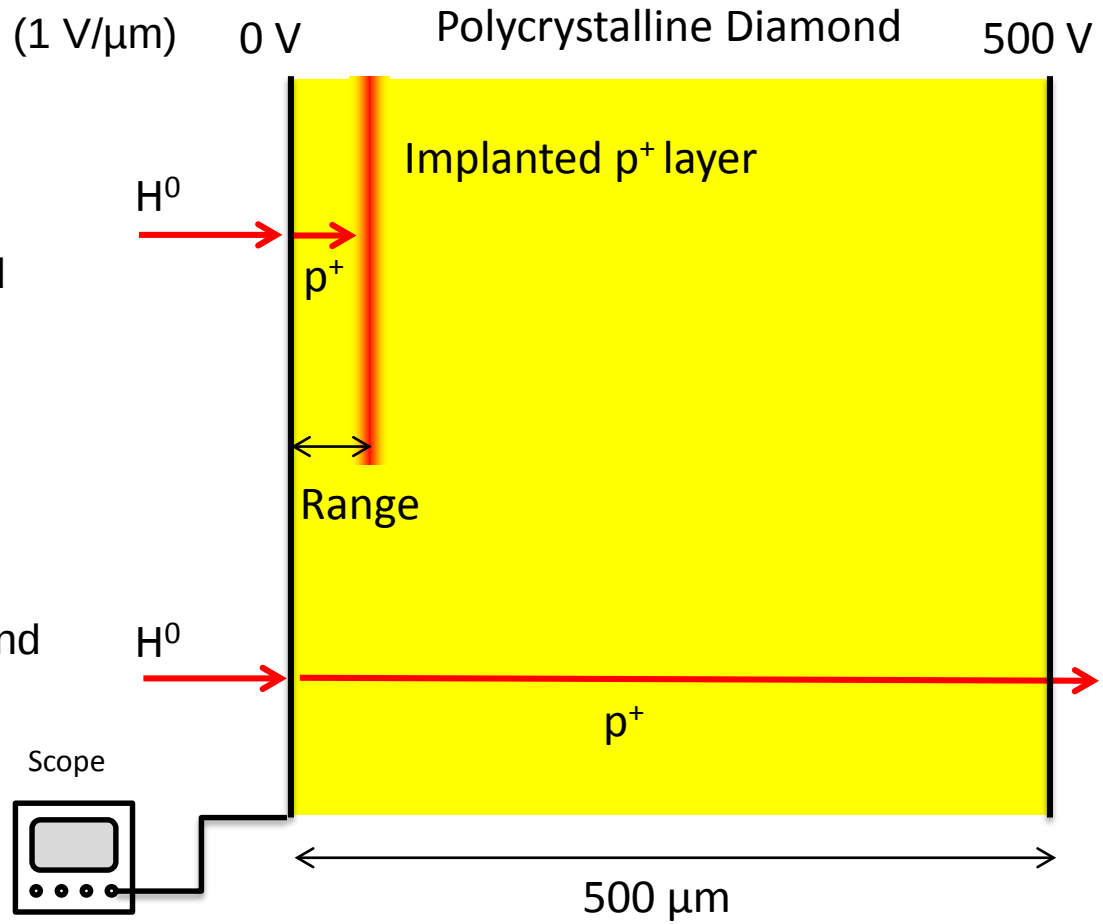
pCVD Diamond – Particle Interaction

- Signal creation in Diamond:
  - Ionisation of Electron – Hole pairs
  - Readout of charge with E-Field (1 V/µm)
- 3 MeV:
  - Range: 48 µm
  - Proton Implantation in diamond
- 12 MeV:
  - Range: 540 µm
  - 9.3 MeV lost in 500 µm diamond
  - Proton exits diamond material



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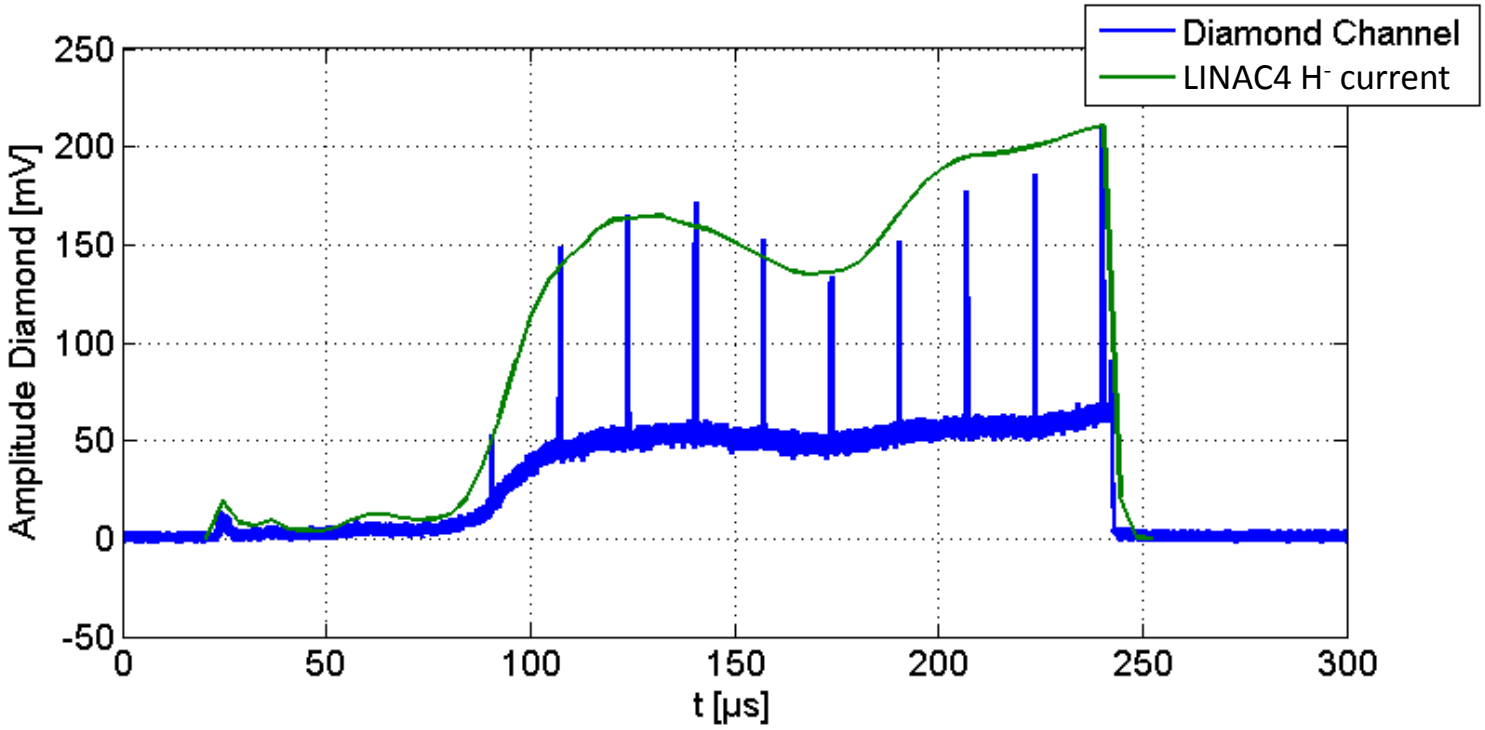
12 MeV Signal on Detector Strip



- $2.5*10^5$ H^0 particles originating from laserpulses
- Background from H^0, produced by residual gas collisions
- -> Diamond capable to detect H^0 beamlets with high linearity and sensitivity

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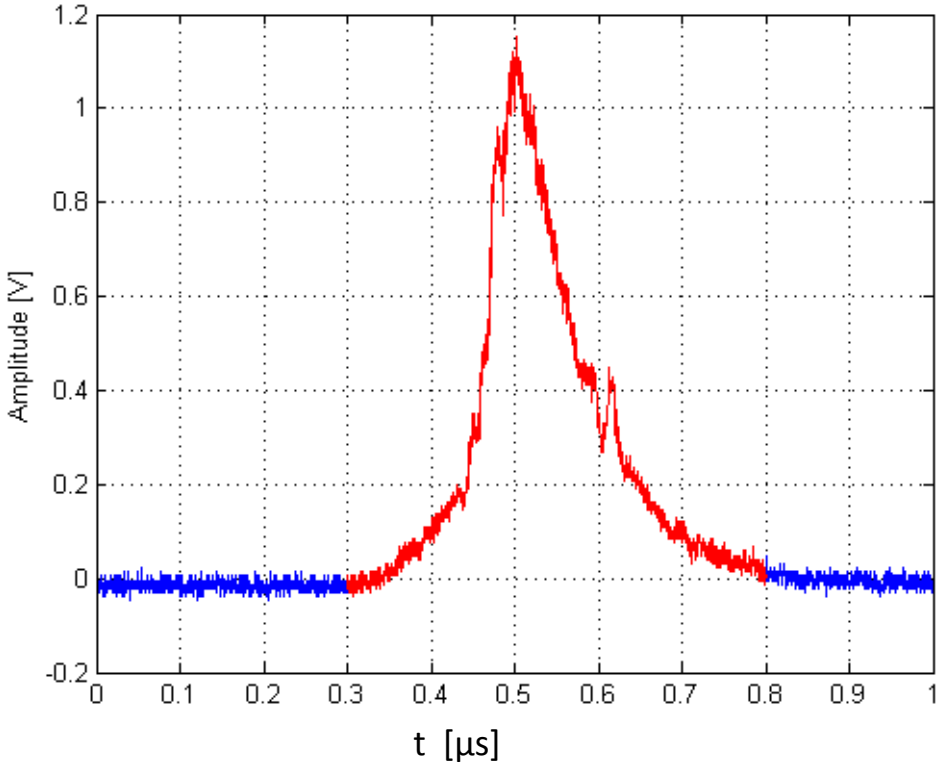
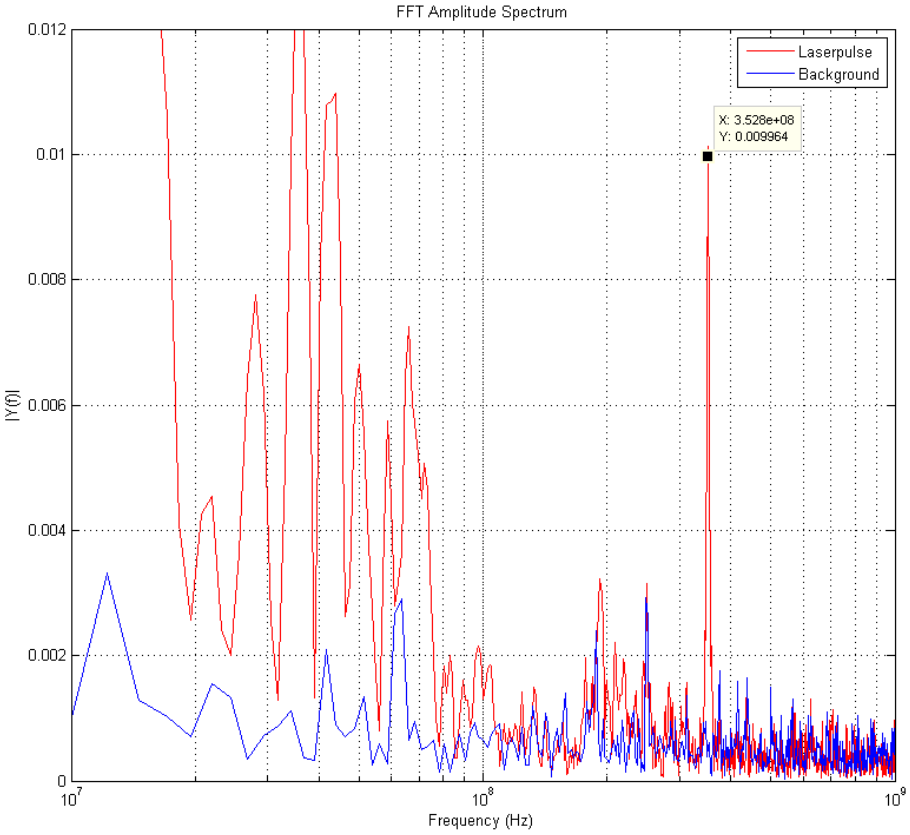
12 MeV Results – Bunch Structure



Diamond Detector raw signal

LINAC4 RF system: 352 MHz
-> 2.8 ns bunch spacing



352 MHz bunch structure found in diamond signal!

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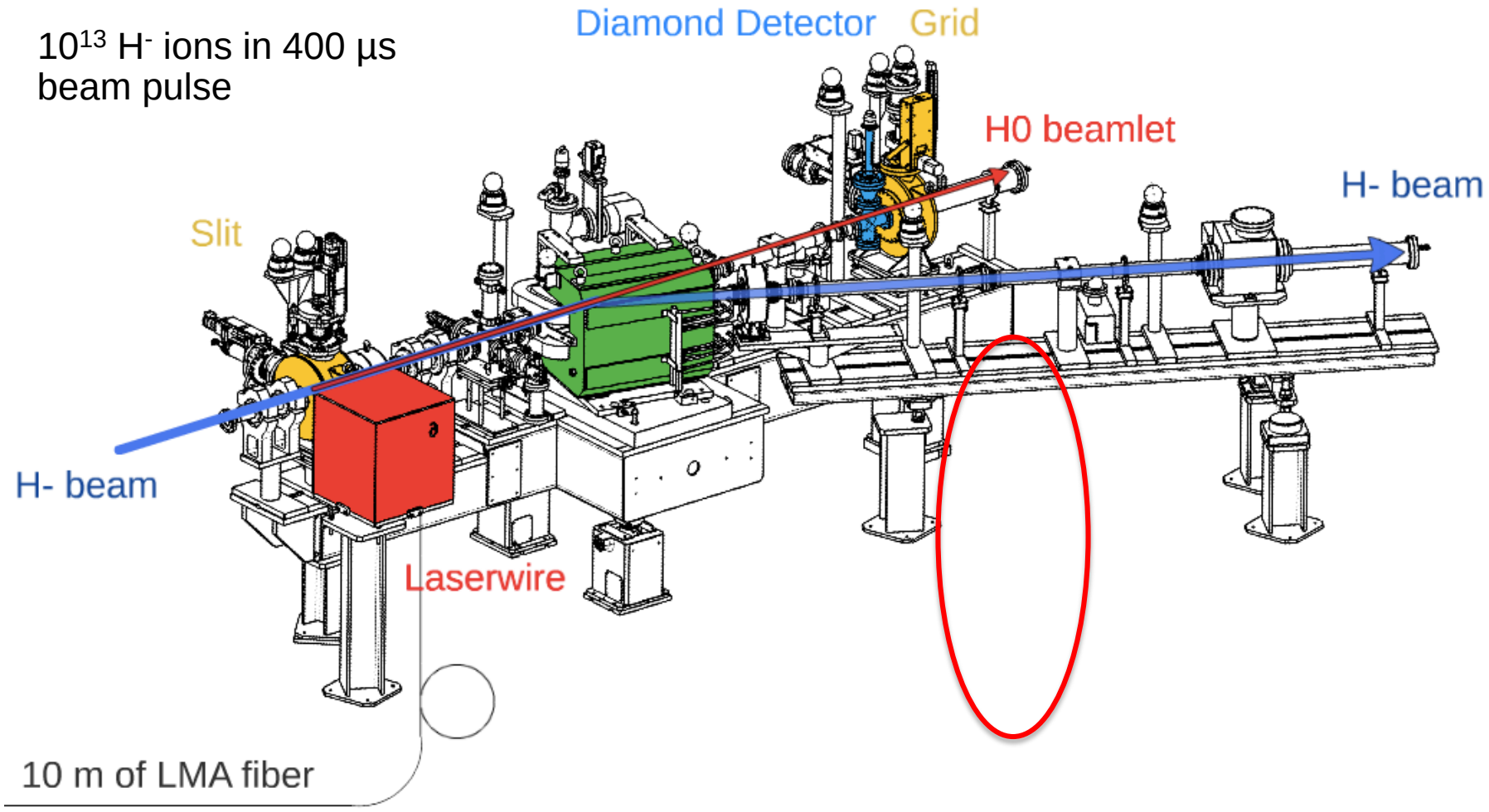
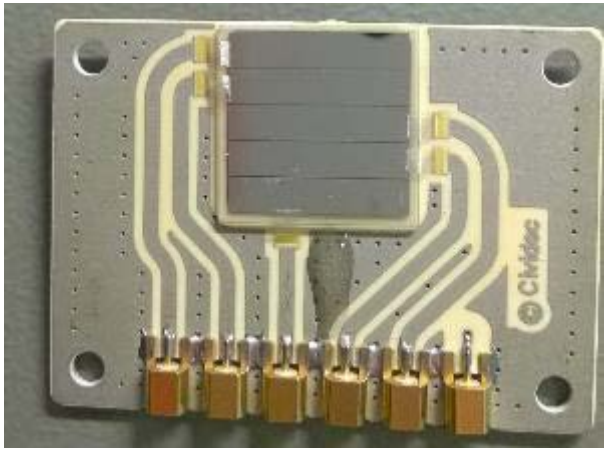
Accident: Full LINAC4 Pulse to Diamond

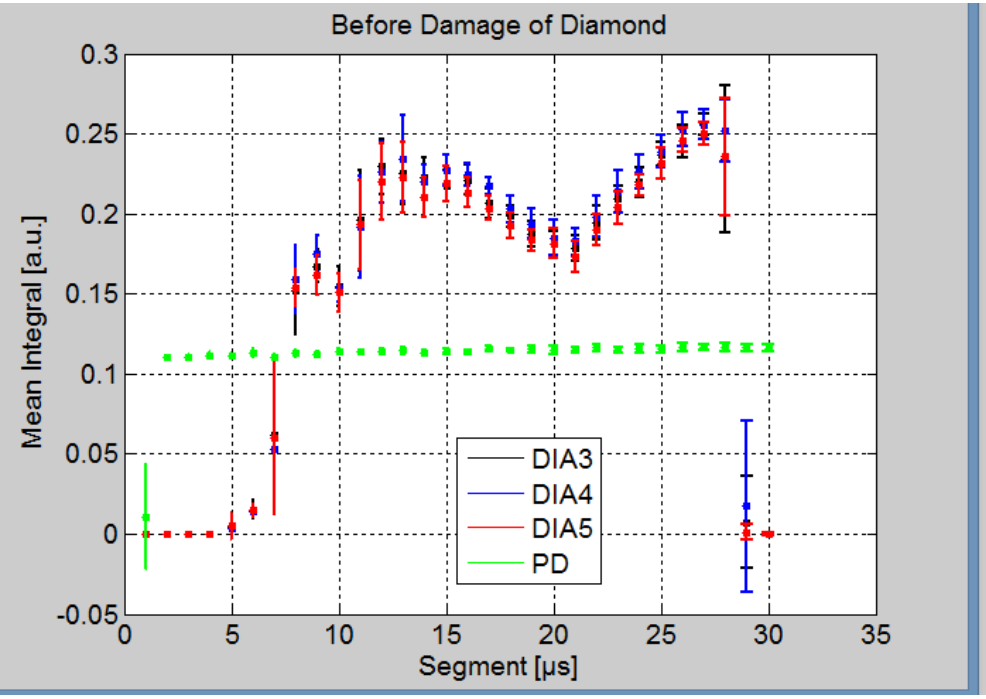
- 10^{13} H^- ions in 400 µs beam pulse

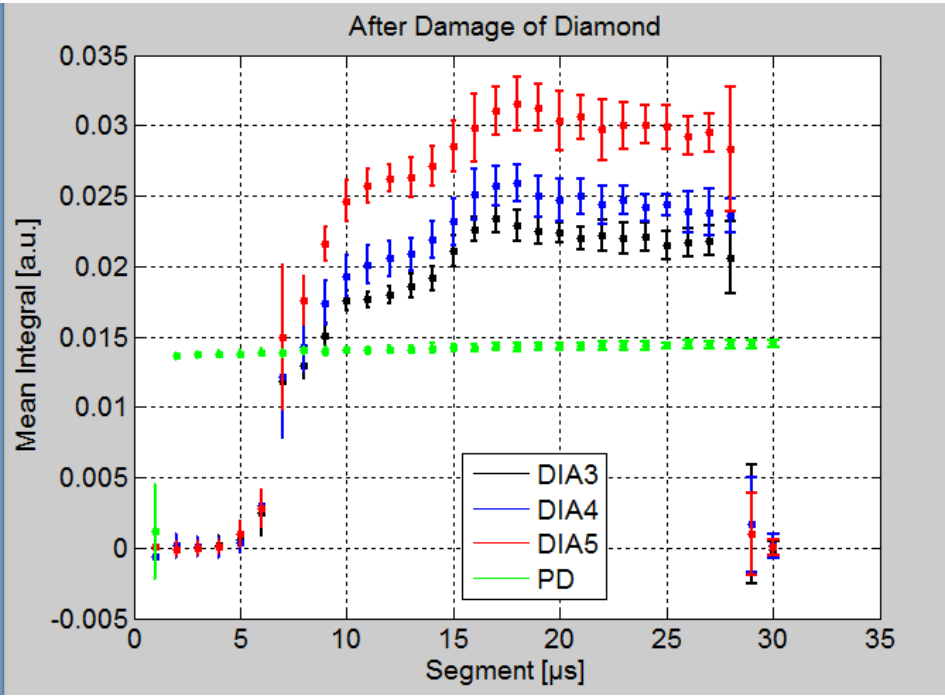


Accident: Full LINAC4 Pulse to Diamond

- Approx 10x 10^{13} H^- ions in 400 µs beam pulse to diamond
- Sensitivity 10x lower than before
- Crack in ceramics pcb found after dismanteling







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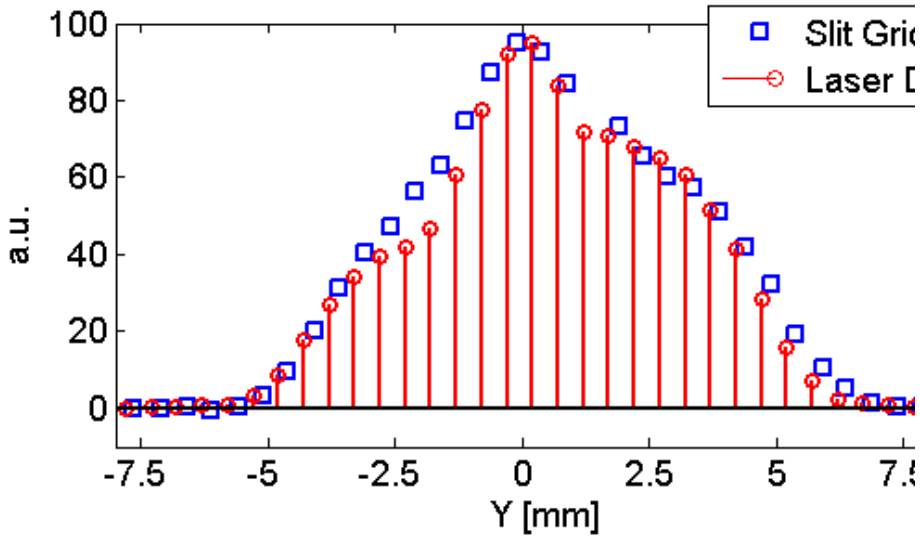
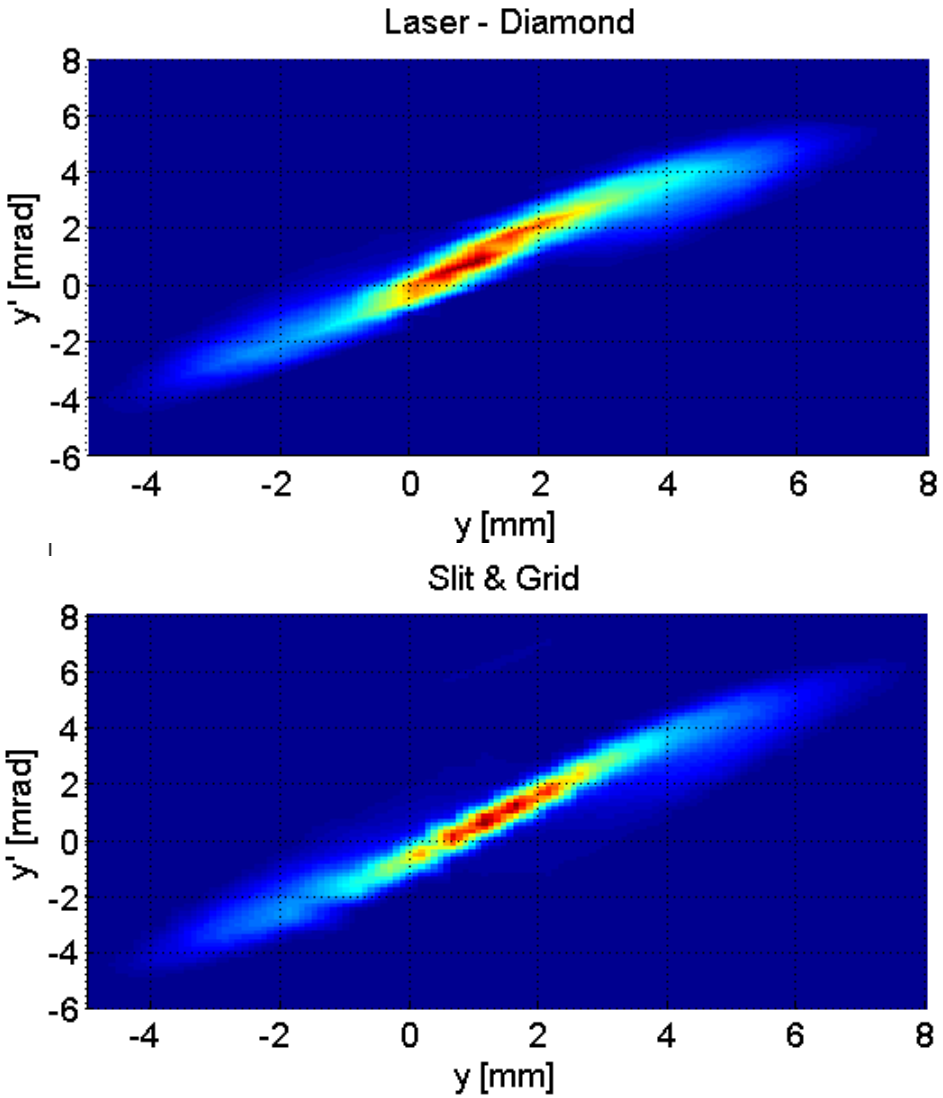
Results – Beam Profile and Phasespace

- Comparison with Slit & Grid
  - Beam Profile
  - Phasespace





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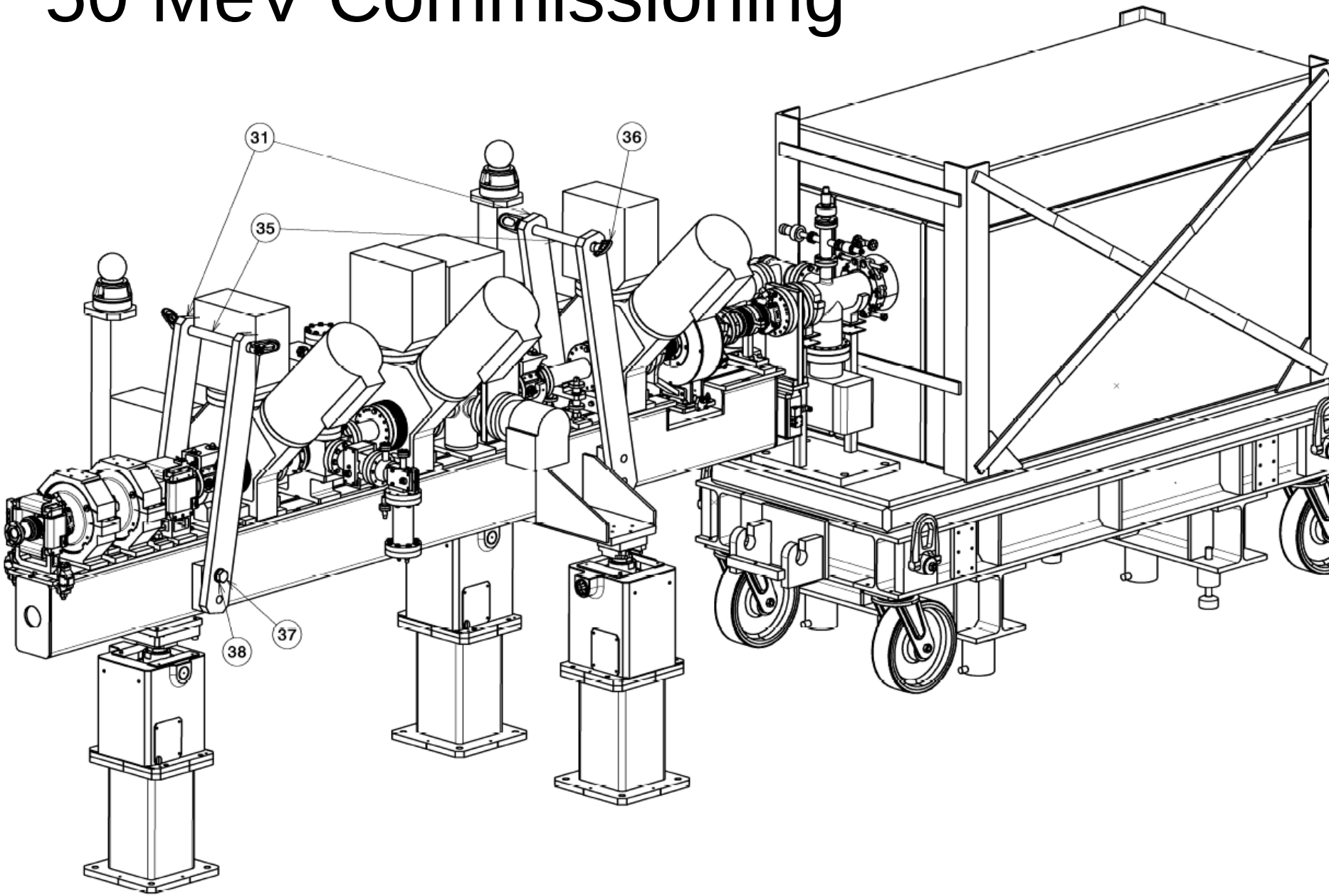
50 MeV Commissioning

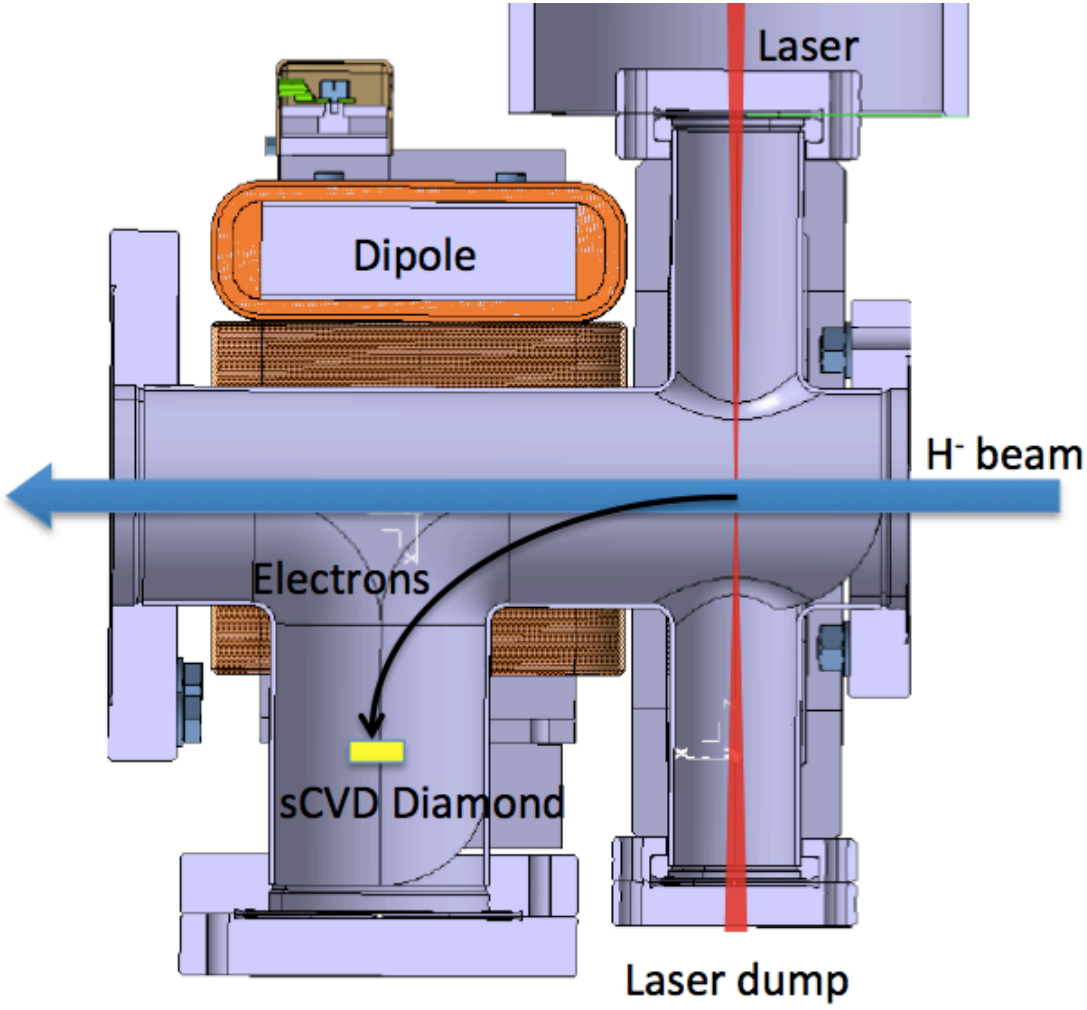


50 MeV

- Profile Measurement with sCVD Diamond

- No H^0 detection
- <u>27 keV Electrons</u>

- sCVD Diamond
- 4.5x4.5x0.5mm
- Single channel



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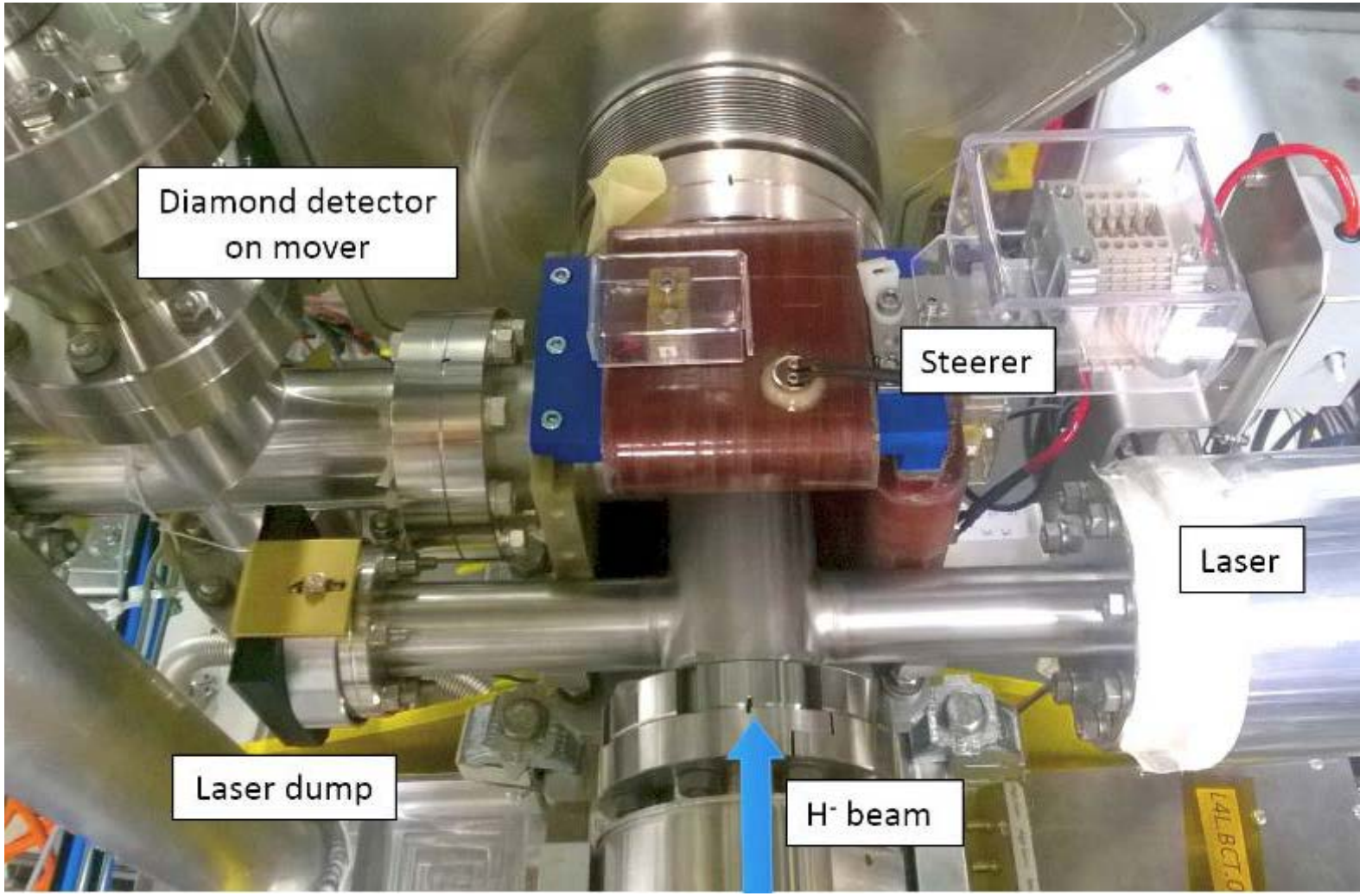
Installation on 50 MeV Testbench



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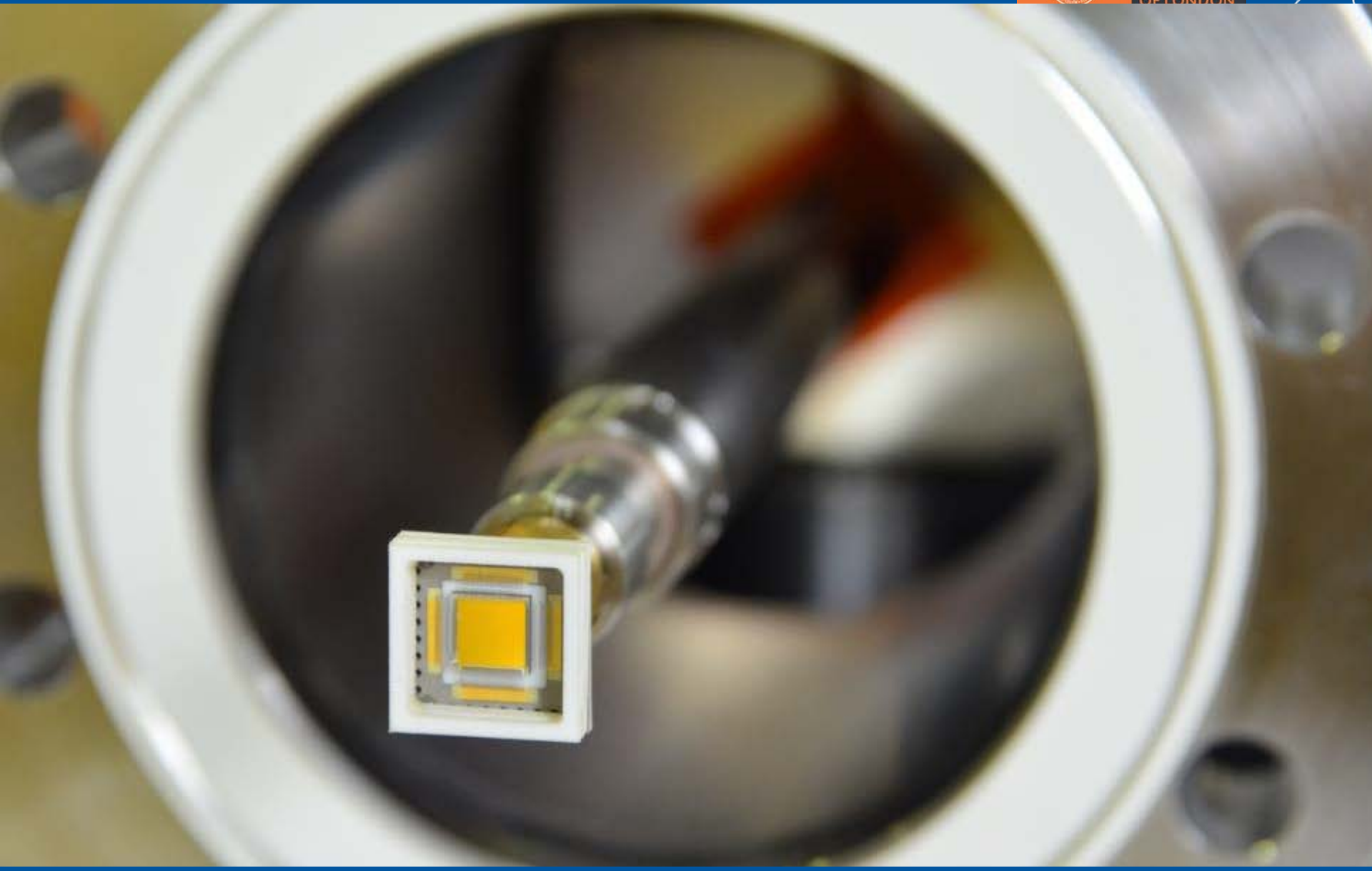
sCVD Detector for Electron Detection



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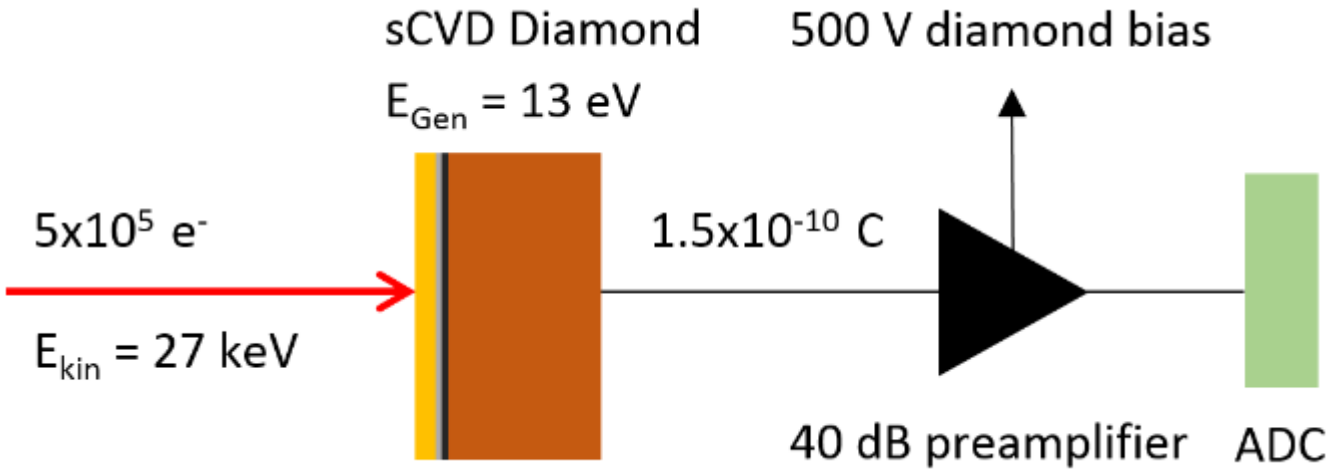
Signal formation at 50 MeV setup

- Front electrode layer composition and energy loss

Layer	Thickness	Energy Loss of e^-
Gold	250 nm	2.3 keV
Platin	120 nm	0.7 keV
Titan	100 nm	0.2 keV
Diamond	500 μm	23.8 keV



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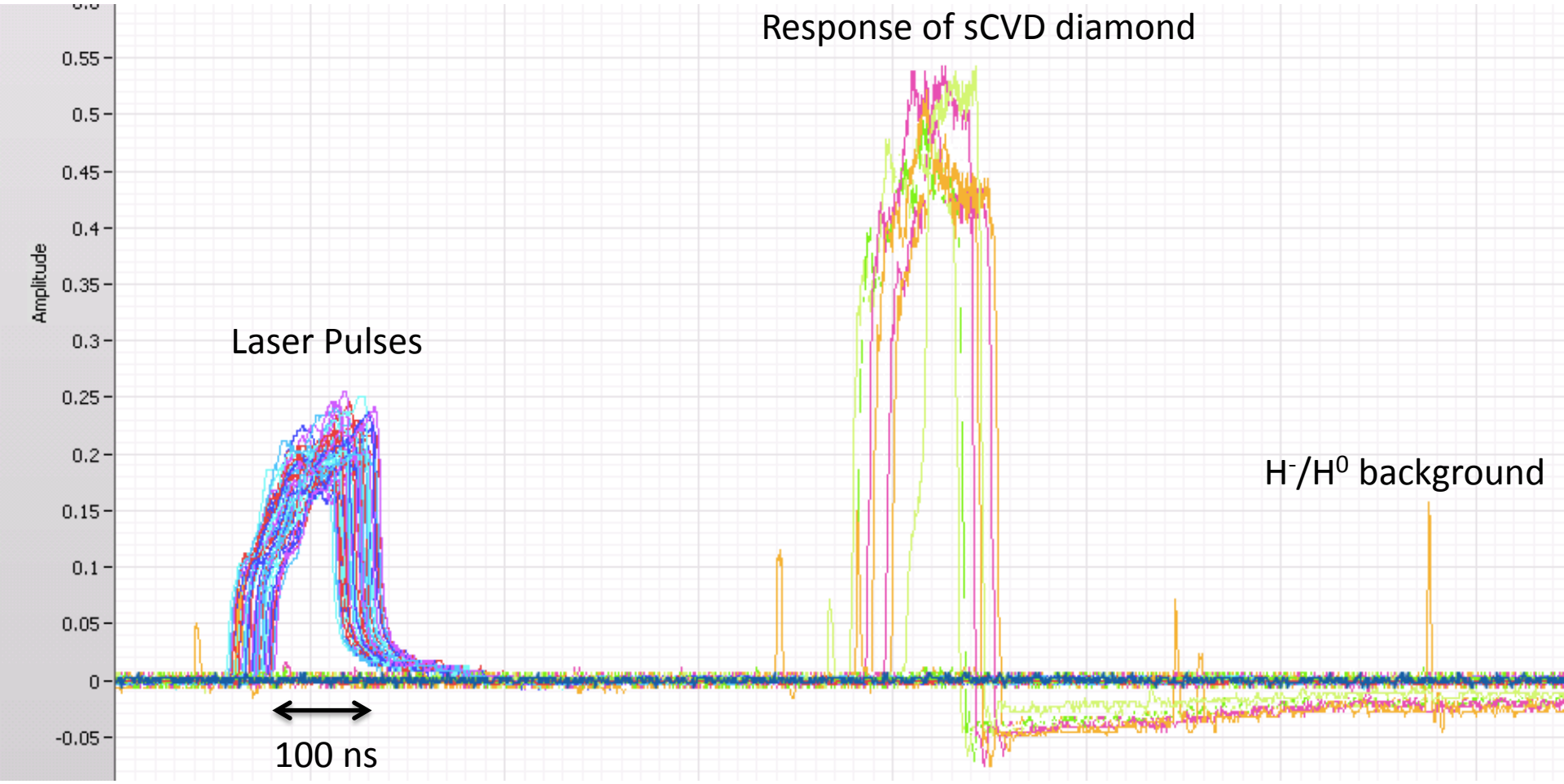
Raw Signal Overlay – sCVD detector



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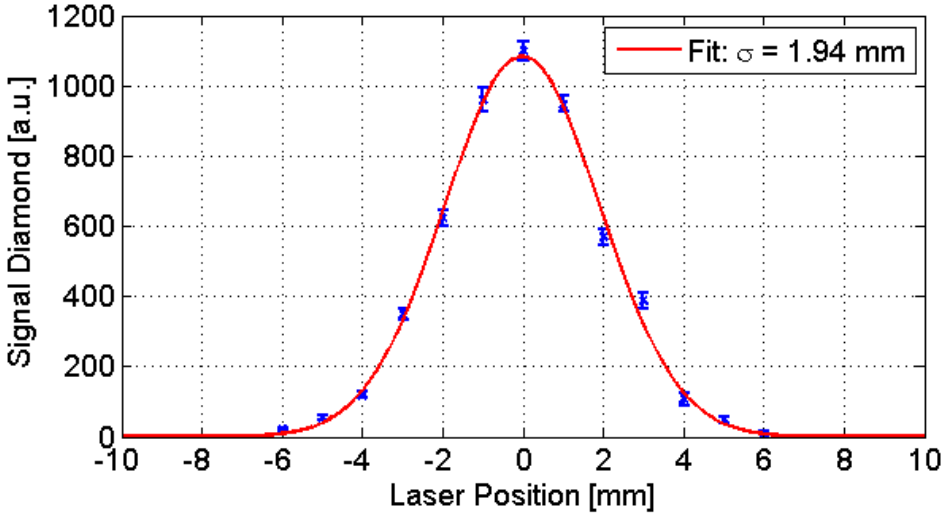
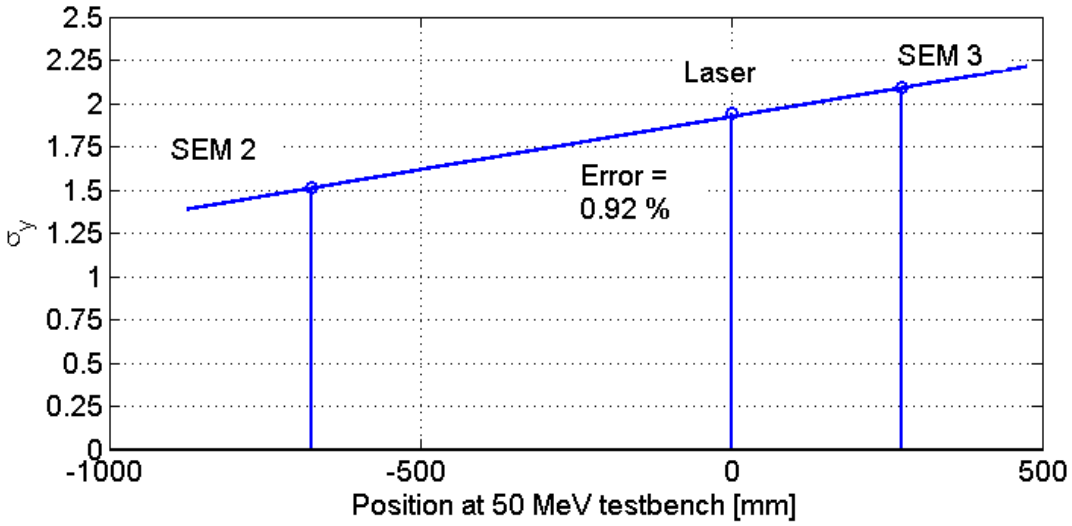
Preliminary results at 30/50 MeV

- Vertical Beam Profile



- Comparison with SEM grid



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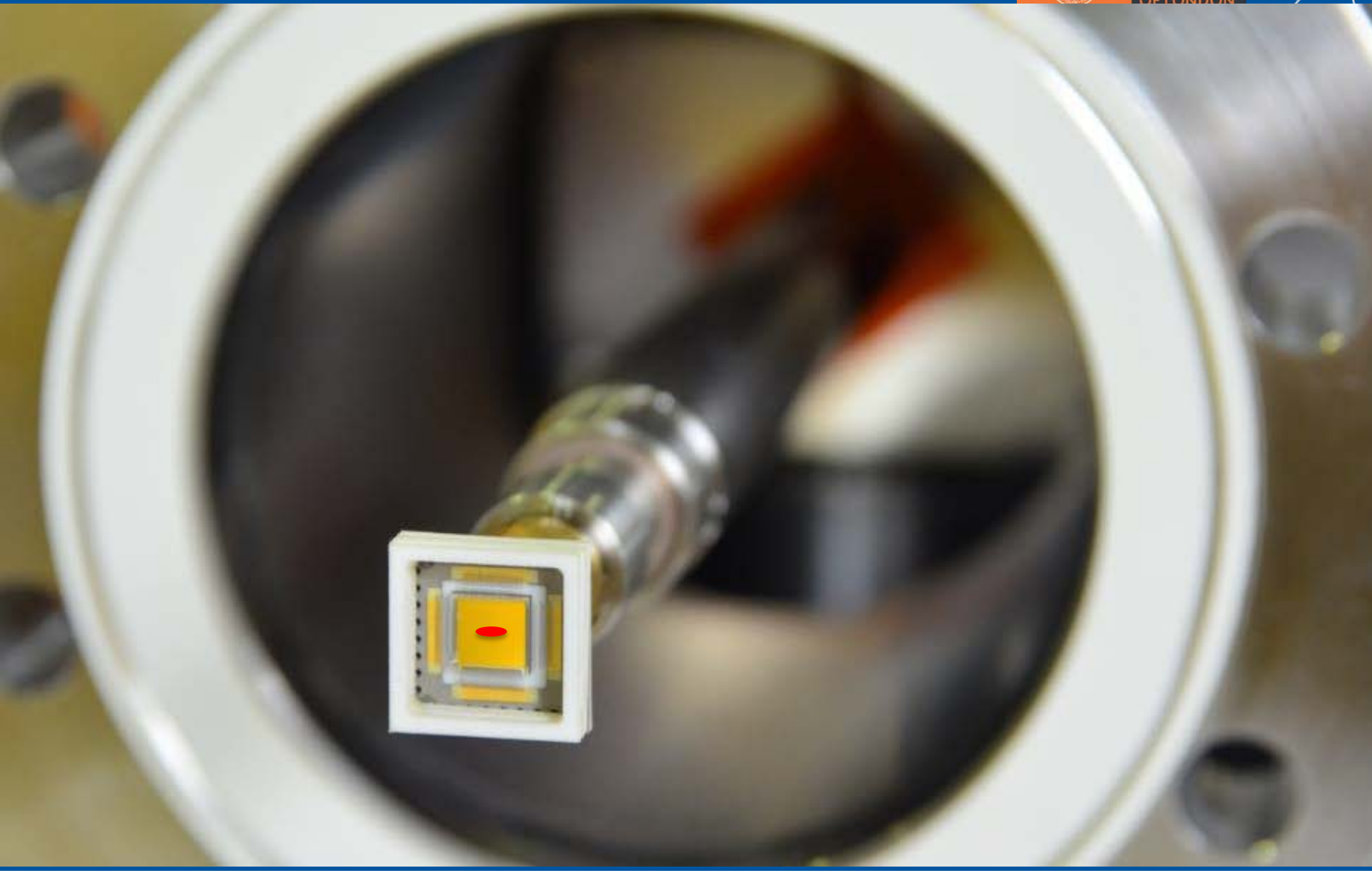
sCVD Detector for Electron Detection



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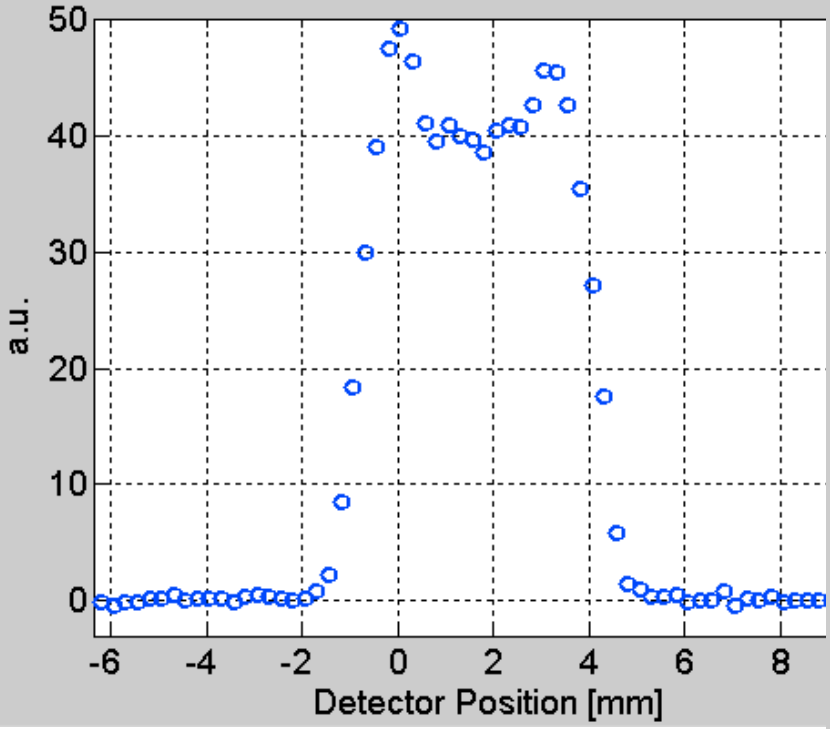
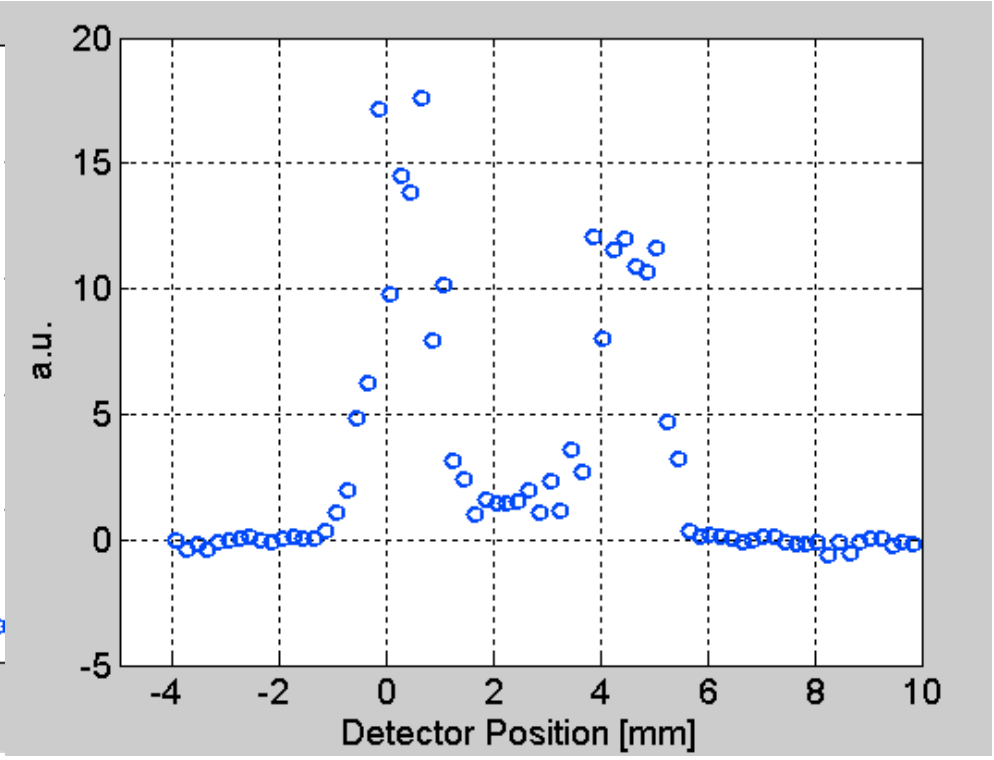
Detector Position Scan

- 50 MeV



- 30 MeV



- No energy loss in edges of detector – no electrode!

Summary – Diamond for Beam Profiling

- pCVD Diamond Strip Detector
  - 3 & 12 MeV H^0 Detection
  - 3 MeV:
    - Problems due to implantation effects
    - Emittance measurement successful
  - 12 MeV:
    - Strong signal due to high ionisation
    - „Test“ of radiation hardness survived
- sCVD Diamond Detector
  - 27 keV Electron Detection
    - Preliminary results look promising
    - Edge effect for low electron energies reduces usable size of diamond

Thanks

- Financial support by Marie Curie Networks oPAC & LA3NET
- LINAC4 operations team for having the opportunity to test our prototype
- BE-BI group at CERN for support
- Cividec for great detectors and electronics
- And U. Raich, F. Roncarolo, G. Boorman, A. Bosco, S. Gibson, K. Kruchinin, Christoph Vuitton, A. Vorozhtsov and J. Bauche

- References:

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- S. Gibson et al., Proc of IBIC13
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