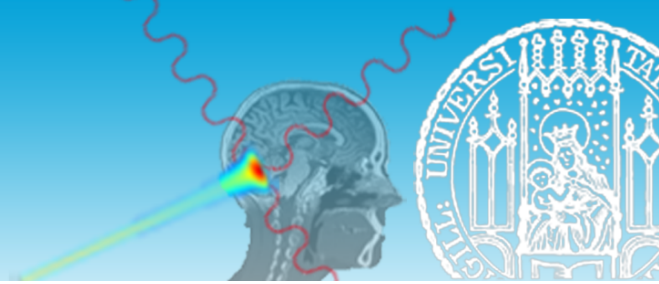

Pixel detectors for laser-driven proton and carbon ion acceleration at CALA

Franz Englbrecht[1], Florian Lindner[1], Katia Parodi[1], Jörg Schreiber[1,2]

[1]Ludwig Maximilian University Munich, Department of Medical Physics, Munich

[2]Max Planck Institute for Quantum Optics, Munich

Workshop Low-energy ion-beam diagnostics, ICL, 19.03.2019

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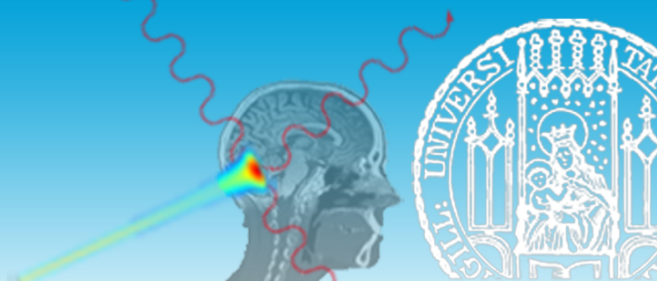


Low energetic ion-beams?

- Radiotherapy: p : $75 - 245\mathrm{MeV}$, $^{12}\mathrm{C}$: $150 - 430\mathrm{MeV/u}$
- 300TW Ti:Sa Laser (LEX Munich): $\mathrm{p}^{+}/\mathrm{e}^{-} < 20\mathrm{MeV}$, $^{12}\mathrm{C} < 50\mathrm{MeV}$

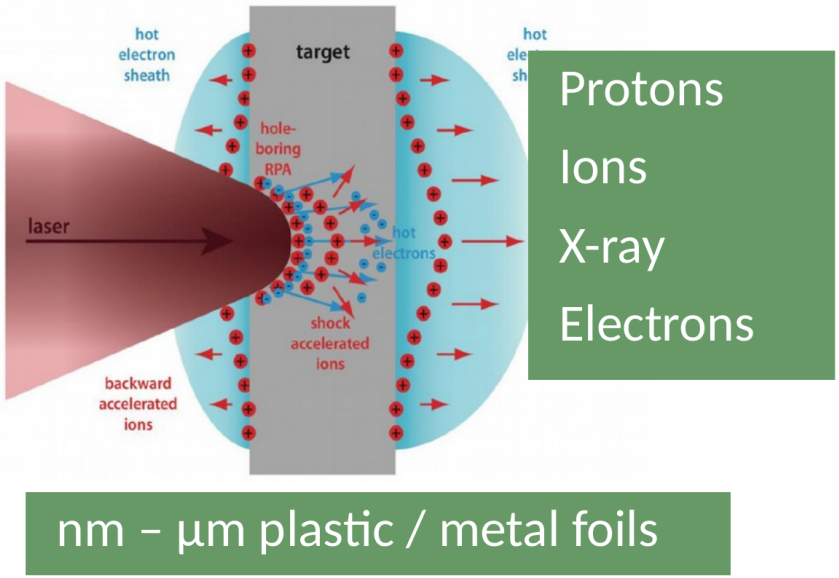
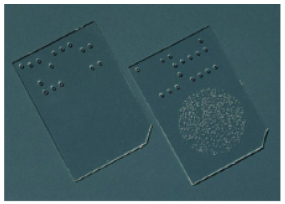


Figure: Scheme for Laser pulse based acceleration of particle bunches

Shot frequency historically: 1/h

Now: 1Hz

Established Laser-Ion detectors

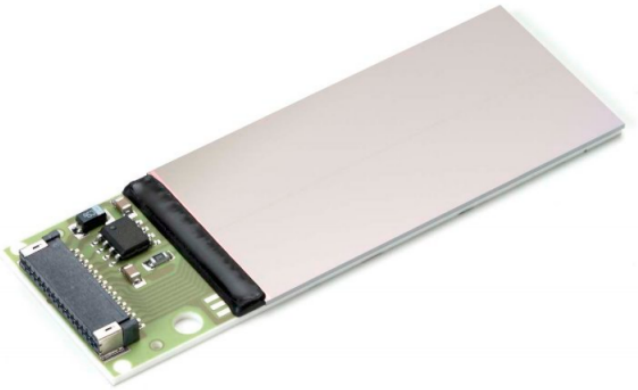


Current LION detectors	Online	Light / x-ray sensitive	Drawbacks
CR-39	-	-	Chemistry, Microscope
Image plates	-	x	Hours of scanning, $
Dosimetric Film	-	x	Scanning, Handling

Difficulties for (not only) electronic detectors @ Laser:

- Vacuum compatible sensor & readout & cables?
- Shield the intense Laser light?
- Shield the intense EMP?
- Feed signals from Vacuum to air online?
- $10^{10}\mathrm{protons/ns}$ bunches
- Darkcurrent from lack of cooling?

Radeye Sensor



- Commercial CMOS used for X-ray detection in air (scintillator)
- 1024 x 512 Pixels, $48\mu\mathrm{m} \times 48\mu\mathrm{m}$
- 14-bit
- $2\mu\mathrm{m}$ active Si thickness
- $2.5\mathrm{Hz}$ readout
- 4 sensors can be combined
- Radiation hard
- High saturation $4 \times 10^7 \mathrm{protons/cm}^2$ [a]
- Single proton sensitive [b]

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[a] S. Reinhardt et al.: Test of pixel detectors for laser-driven accelerated particle beams, J. Instrum. 6, 2011

[b] S. Reinhardt et al.: A Pixel detector system for laser-accelerated ion detection, J. Instrum. 8, 2013

Radeye System in vacuum

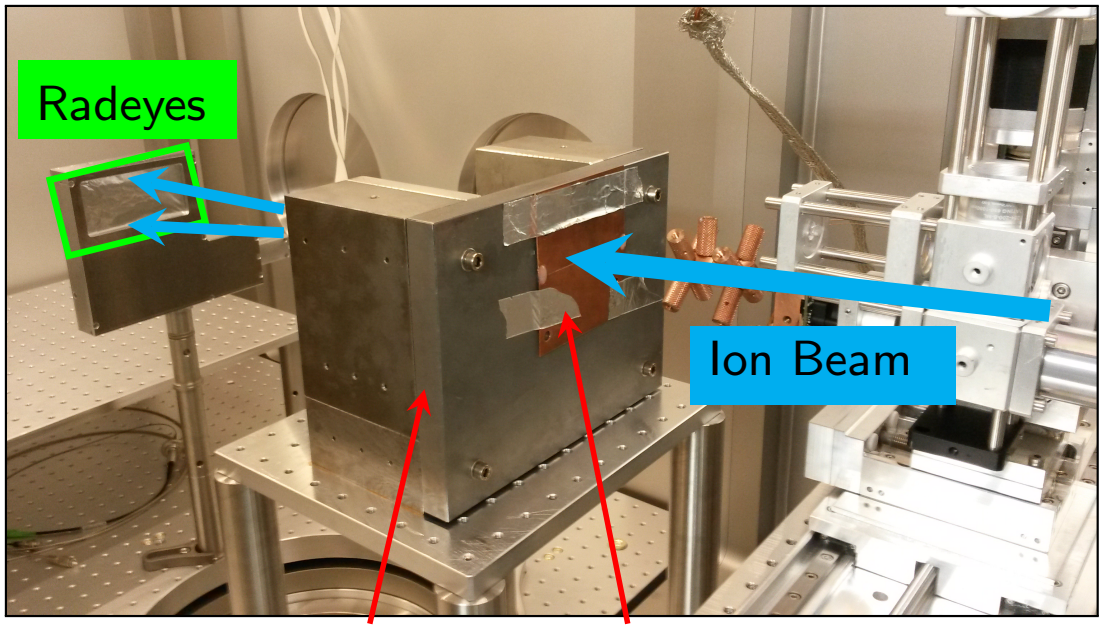
Detector housing:

- Detaches sensors from readout
- Sensors in vacuum
- Shields EMP (5mm Al)
- Shields Laser (15μm Al)
- 5*cm* $\times$ 10*cm* sensors
- Dissipates heat
- DVI adapterboard to feedthrough

Wide Angle Spectrometer

- 150mT permanent magnet
- 2 cm iron front plate
- 200μm $\times$ 10cm slit

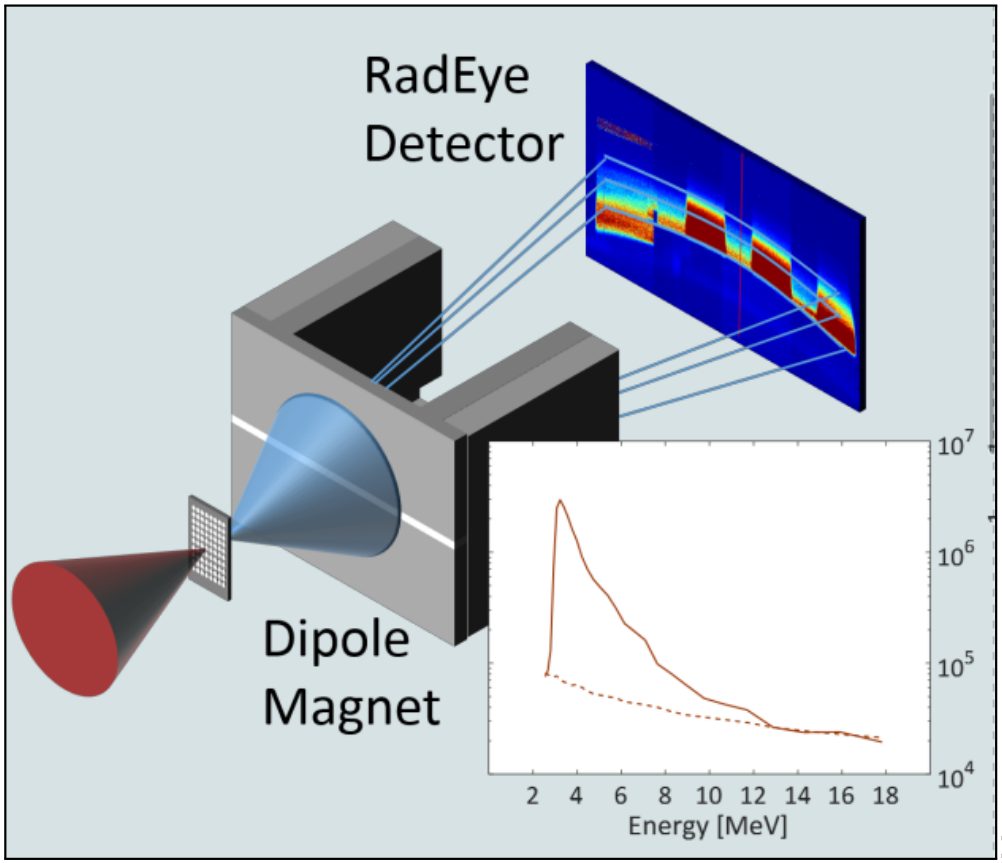
- 5 $\times$ 10cm Radeyes
- Used in 1000 laser shots[1]
- (Quadrupole Duplet Focus diagnostic)



[1] Y. Gao et al.: An automated, 0.5 Hz nano-foil target positioning system for intense laser plasma experiments, High Power Laser Science and Engineering, (2017), Vol. 5,

Wide Angle Spectrometer

- 1 - 35 MeV p^+
- +- 4 degree angle
- Allows different slit spacings
- Online- proton spectrum for parameterscans



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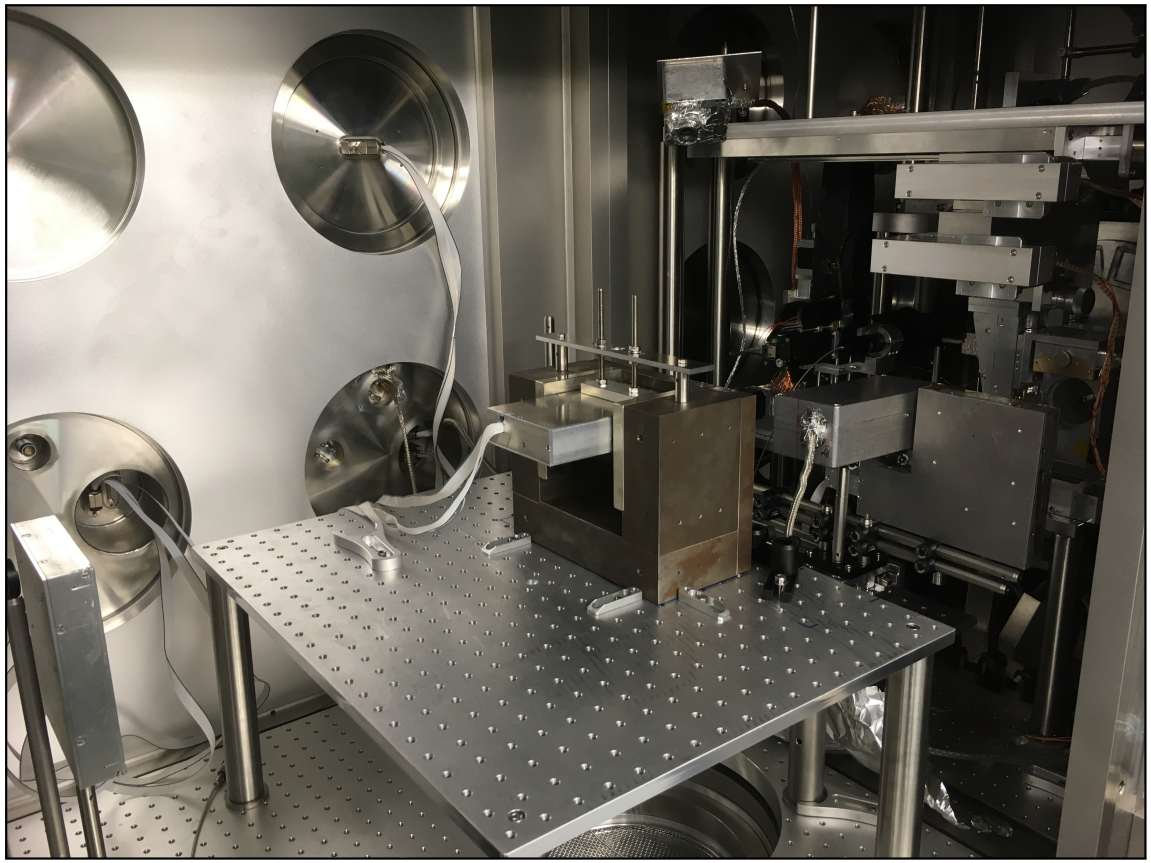
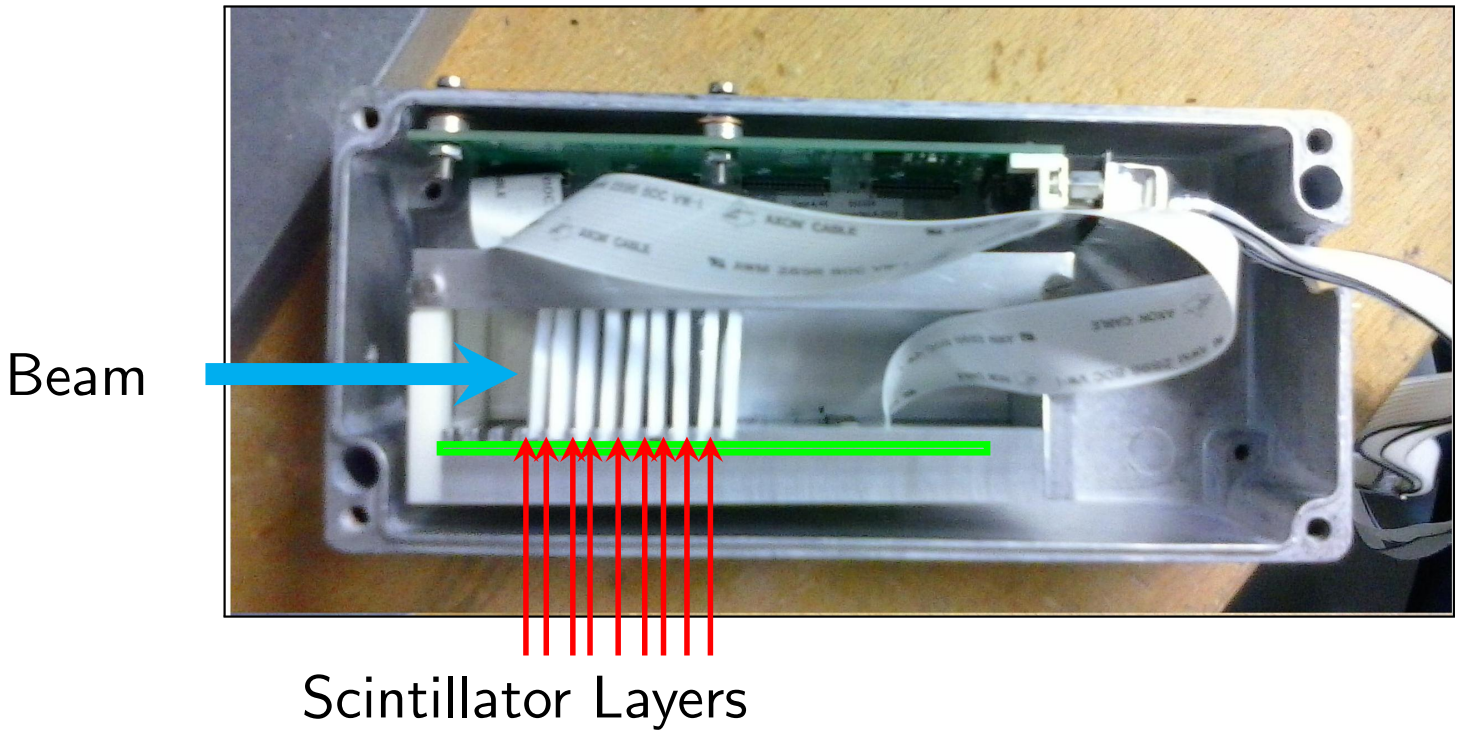
Combined proton electron WASP

- Combined p^+ / ^{12}C and e^- detection
- $5\text{cm} \times 10\text{cm}$ Lanex e^- scintilator
- e^- housing between magnets
- Correlation / Anticorrelation of spectra



Scintillator stack using Radeye

- Built for up to 20 MeV[2]
- Radiation hard Polysiloxane & Teflon layers molded edge-on to Radeye
- Radeye as position sensitive photon integrating detector



[2] F. Englbrecht et al., An online, radiation hard proton energy-resolving scintillator stack for laser-driven proton bunches, Radiation Protection Dosimetry 1-5, 2018

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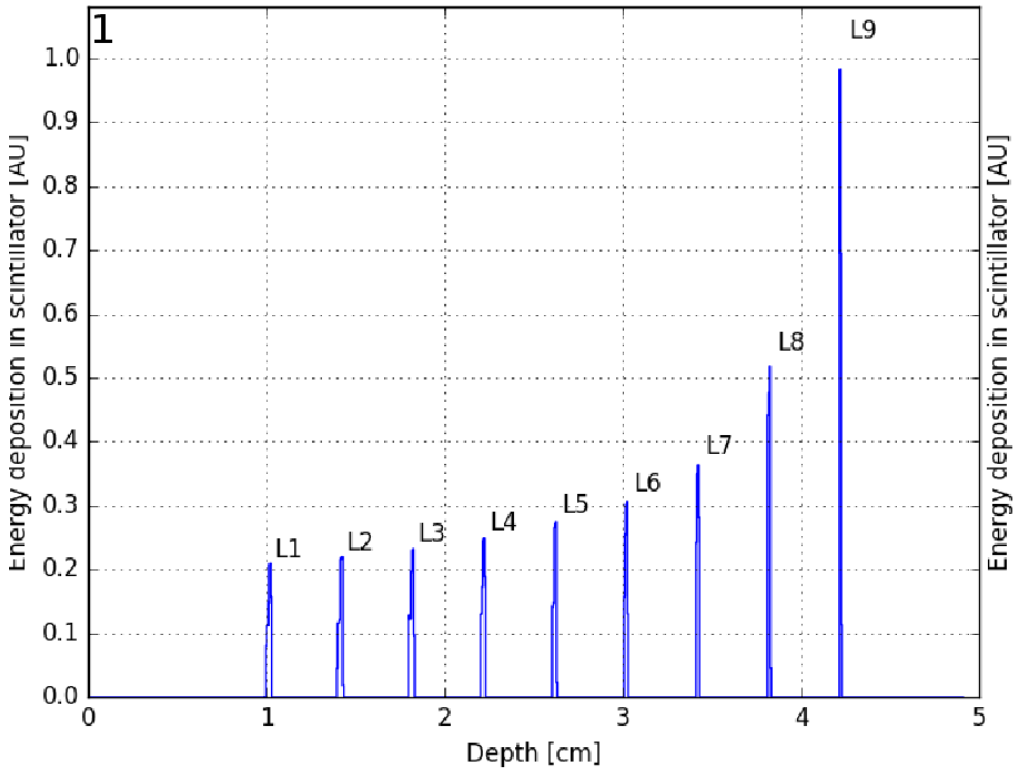

[2] F. Englbrecht et al., An online, radiation hard proton energy-resolving scintillator stack for laser-driven proton bunches, Radiation Protection Dosimetry 1-5, 2018

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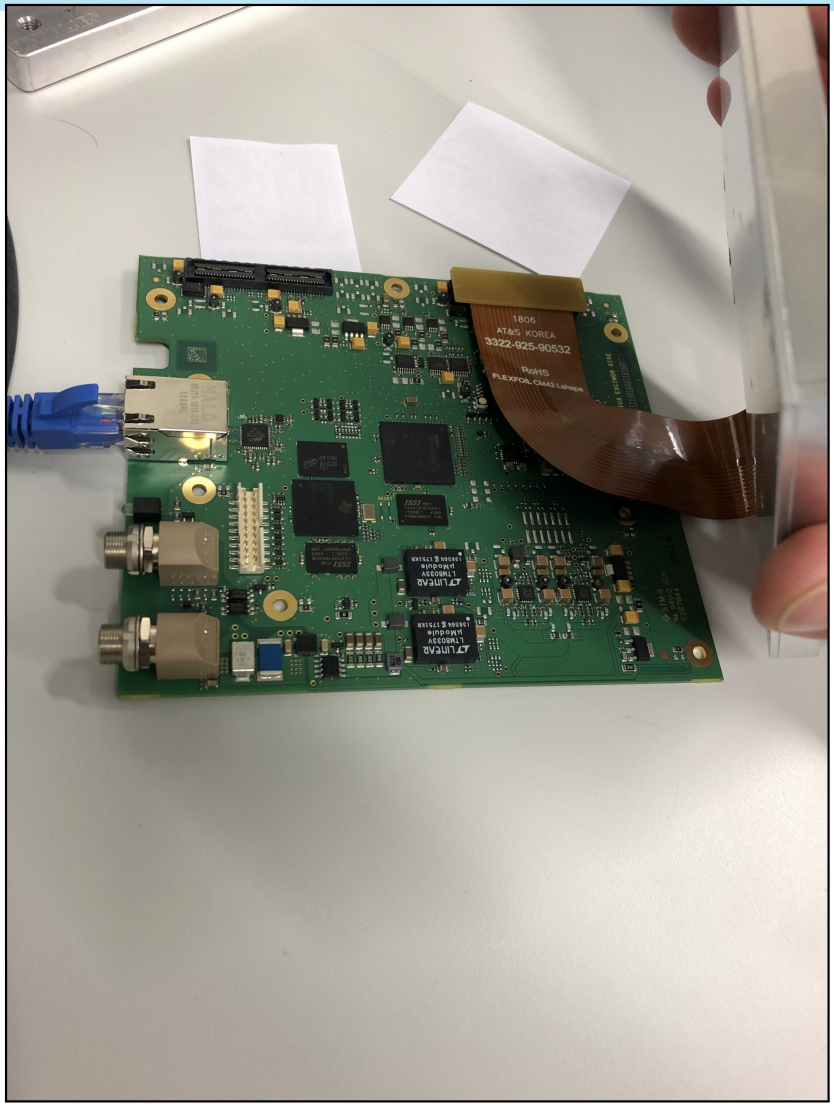
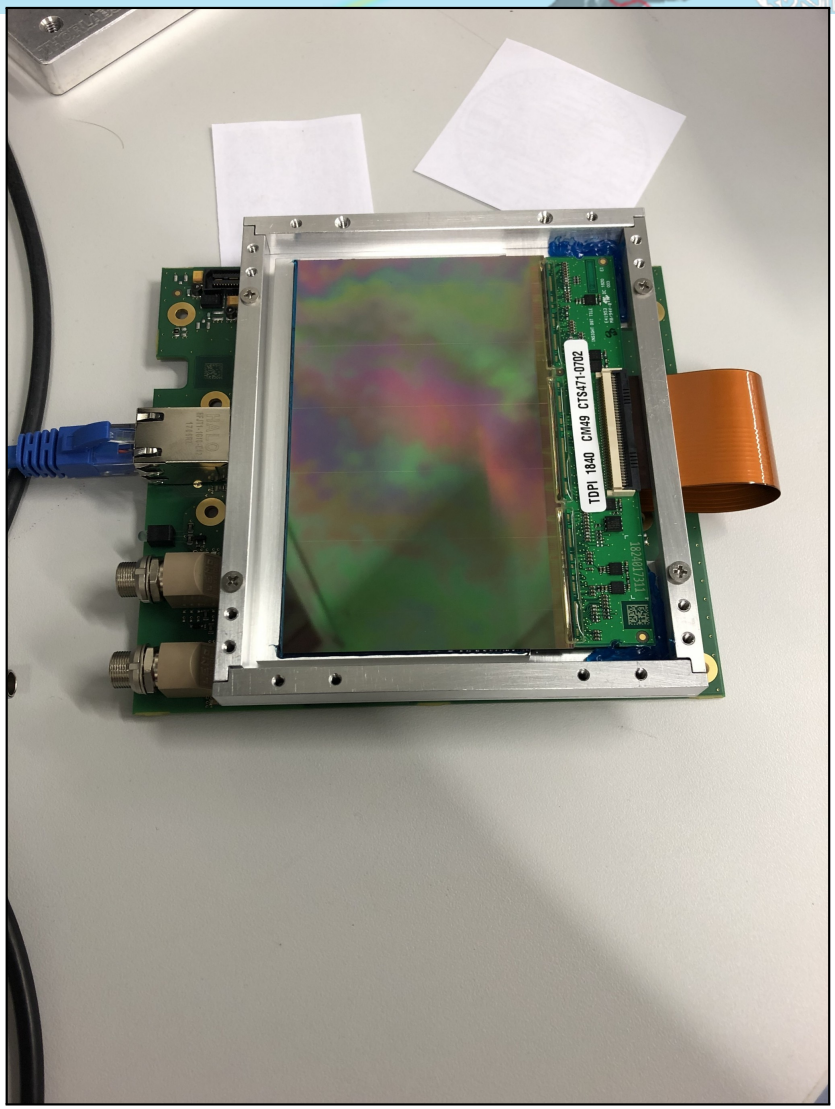
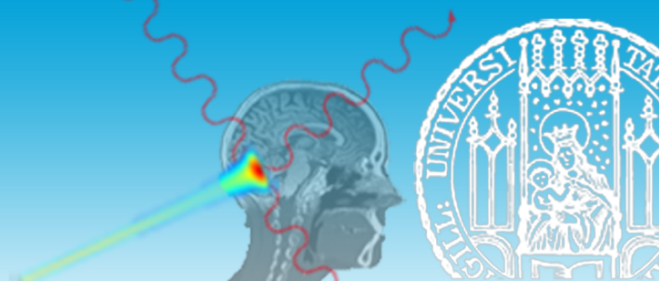
Characterization of follow up product: Vacuum, Cooling,

Proton sensitivity, radiation hardness, linearity







Summary

- Radiation hard, online, vacuum compatible, pixelated detector Radeye
- Multi-use:
  - Magnetic spectrometer
  - Scintilator stack
  - Thompson parabola
  - Quadrupole diagnostic
  - Detector stack?
- 3 PW Ti:Sa Sytem Centre for advanced laser applications CALA starting operation mid 2019
- 100 MeV protons?
  - Non-invasive diagnostics?
  - Spectrometer?
  - Scintilator?
  - Ionoacoustics?

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