The 21st INTERNATIONAL CONFERENCE FOR CONDENSED MATTER NUCLEAR SCIENCE

Experimental hydrogen reactor for Rydberg and Ultra Dense Hydrogen States for Energy Applications

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The Research Council of Norway

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- Ultra Dense Hydrogen 2.3 pm
- Particle emission from Ultra Dense Deuterium
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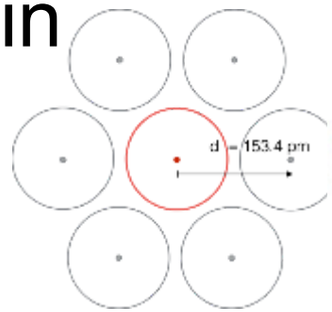
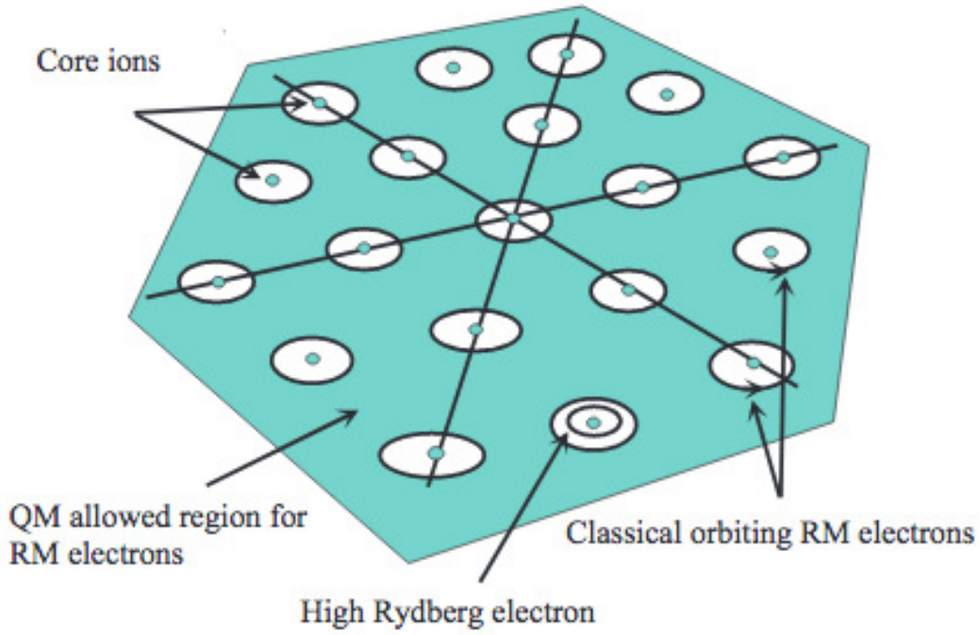
Rydberg Atoms and Rydberg Matter

- Predicted by Manykin et Al in 1980
- Rydberg Matter detected by Prof. Leif Holmlid in 1989
- Bond distance measured in 2008





Holmlid, L. (2008). Clusters (N=4, 6, 12) from condensed atomic hydrogen and deuterium indicating close-packed structures in the desorbed phase at an active catalyst surface. Surface Science, 602(21), 3381–3387
Holmlid, L (2000), A novel model for the interpretation of the unidentified infrared (UIR) bands from interstellar space: deexcitation of Rydberg Matter

Rydberg excitation

Any experiment on Rydberg states can be divided into three phases:

- The atoms are first prepared in more or less isolated states, with selective or nonselective preparation.
- A modification of this situation then arises, either spontaneously (radiation) or under the influence of external perturbations such as collisions, external fields, or coupling with external radiation.
- Finally atoms in the different Rydberg states are then more or less selectively detected.

Preparation methods

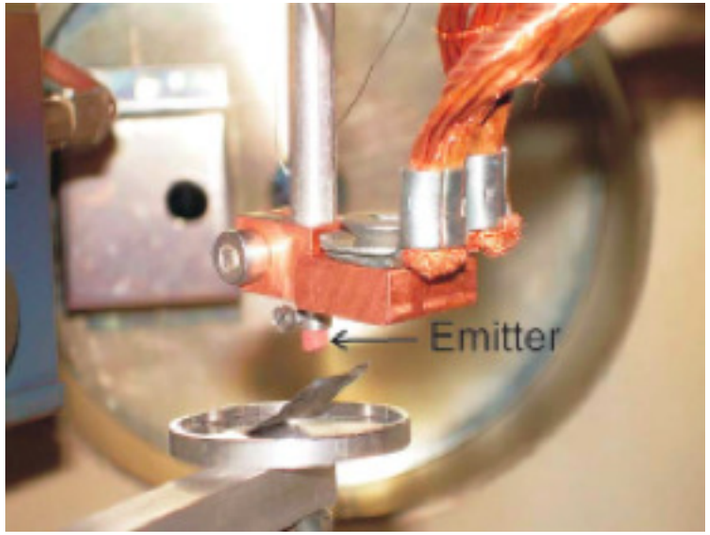
- Preparation by Electron Transfer
  - Electron capture
- Preparation by Electron Bombardment

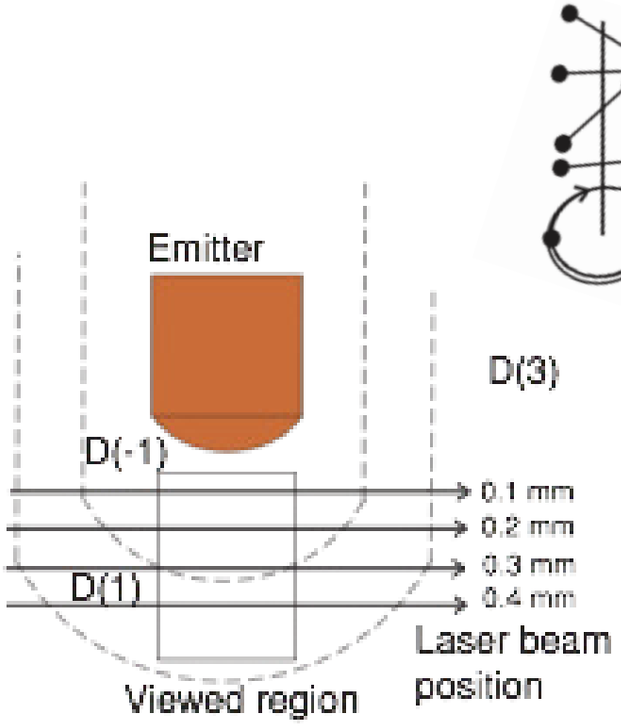
- Optical Excitation
  - One step
  - Multistep

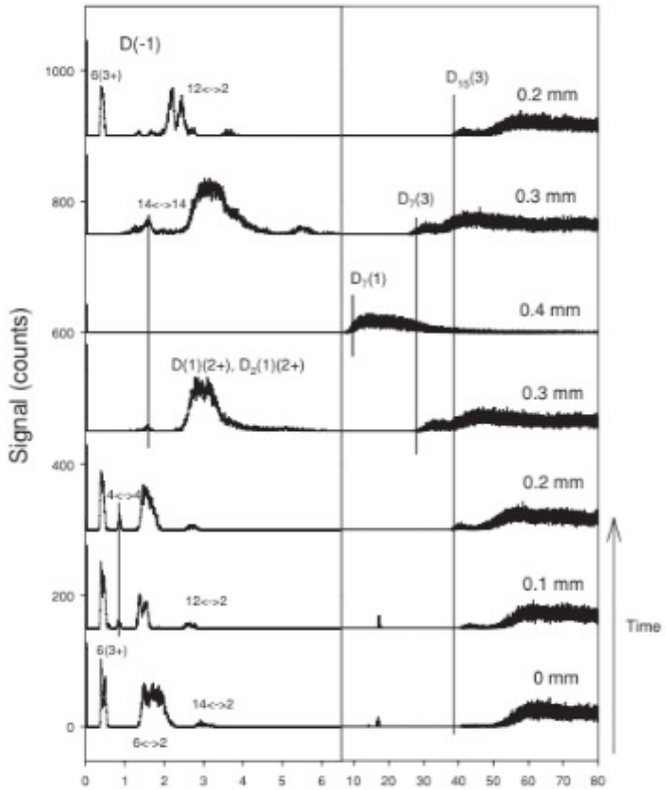
Any element can can in principal become a Rydberg atom but the usual elements for Rydberg excitation is:

- Yttrium
- Strontium
- Barium
- Cesium
- Lithium
- Potassium
- Hydrogen

Ultra Dense Hydrogen



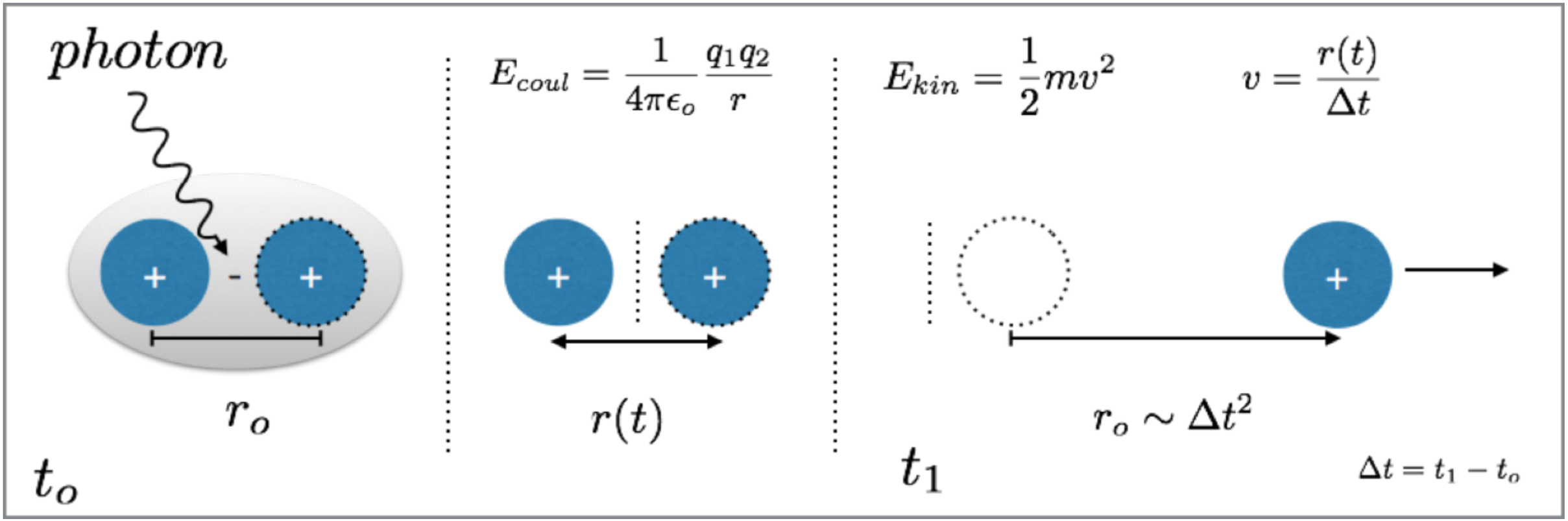




Andersson, P. U., Lönn, B. & Holmlid, L. Efficient source for the production of ultradense deuterium D(-1) for laser-induced fusion (ICF). Rev. Sci. Instrum. 82, 13503 (2011).

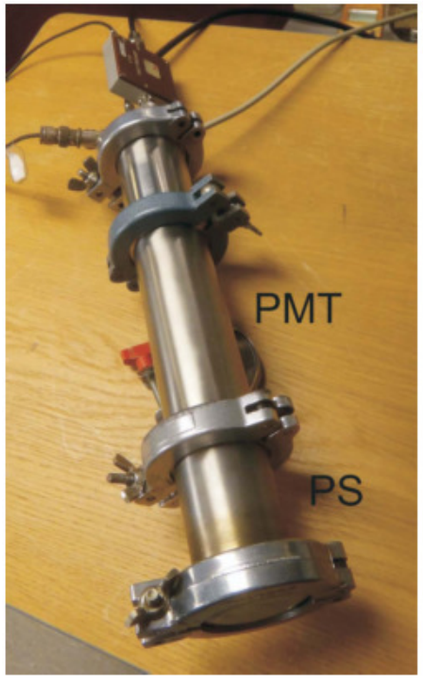
Holmlid, L., S. Zeiner-Gundersen, S. to be published

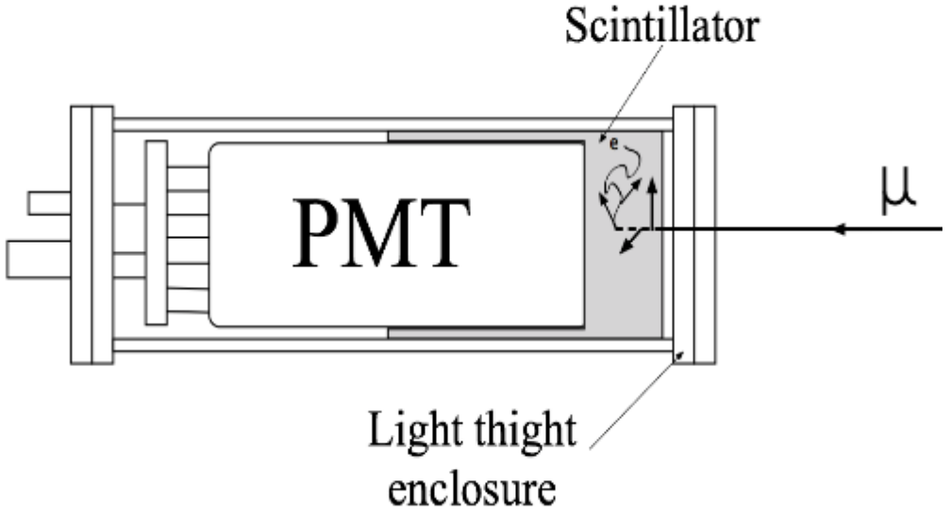
Time Of Flight Analysis

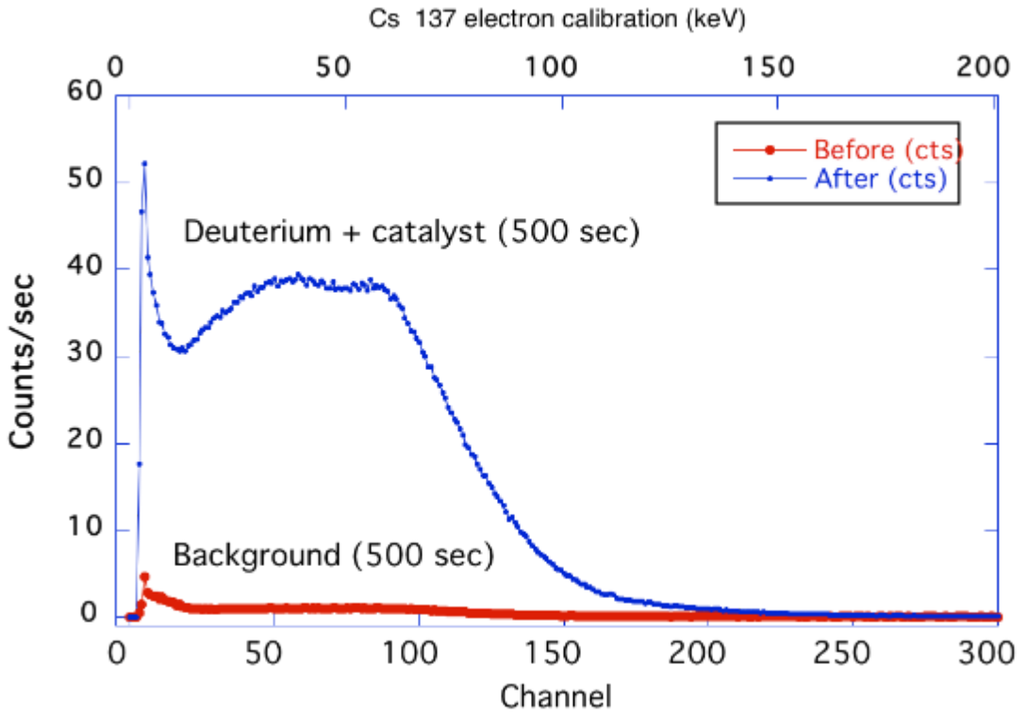


$D_N(0) \rightarrow \ldots \rightarrow \ldots \rightarrow K^{\pm} \rightarrow \pi^{\pm} \rightarrow \mu^{\pm} \rightarrow e^{\pm}$

Leif Holmlid. Particle emission, Muons

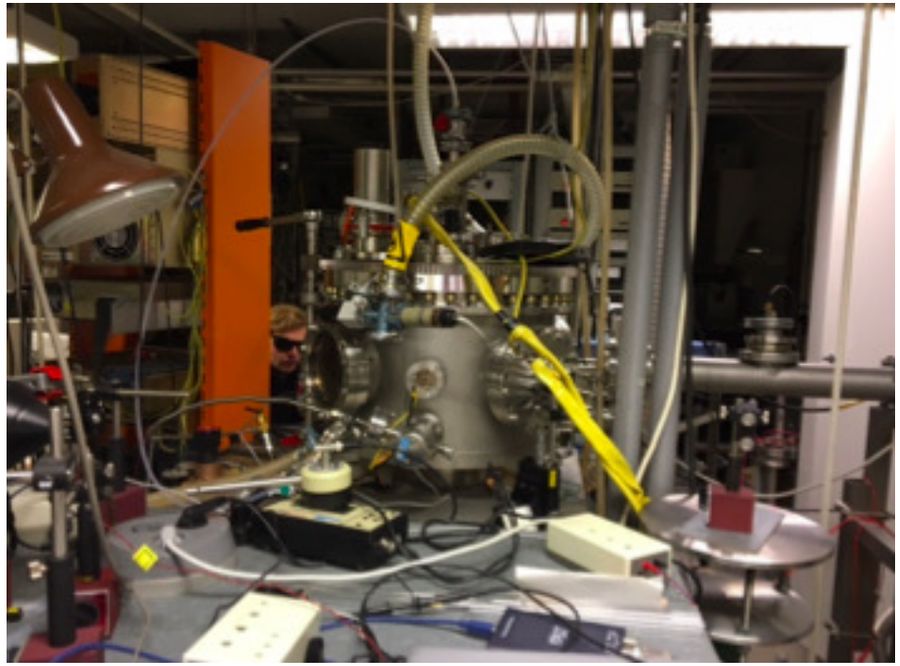


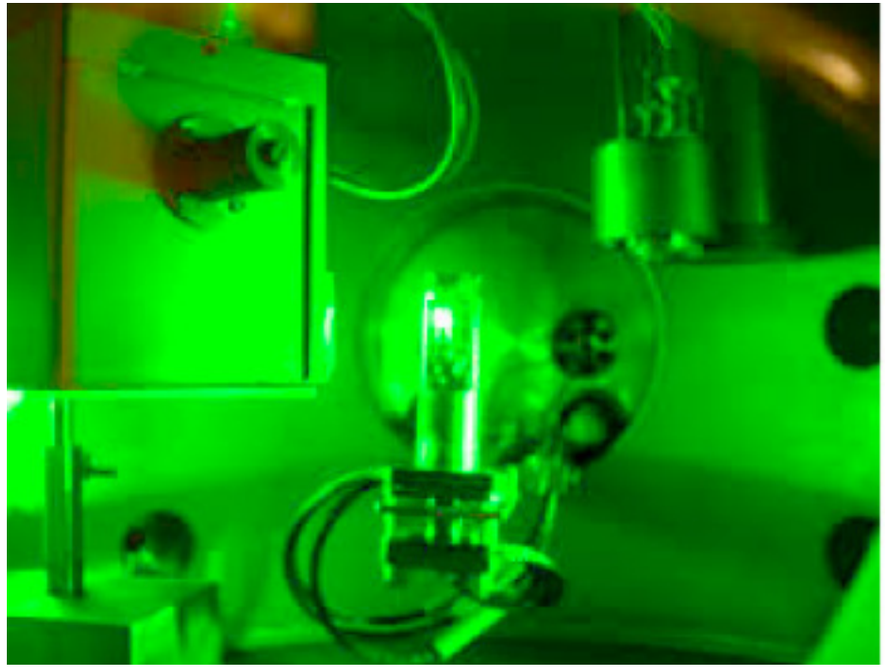




Holmlid, L. & Olafsson, S. Muon detection studied by pulse-height energy analysis: Novel converter arrangements. Rev. Sci. Instrum. 86, (2015).

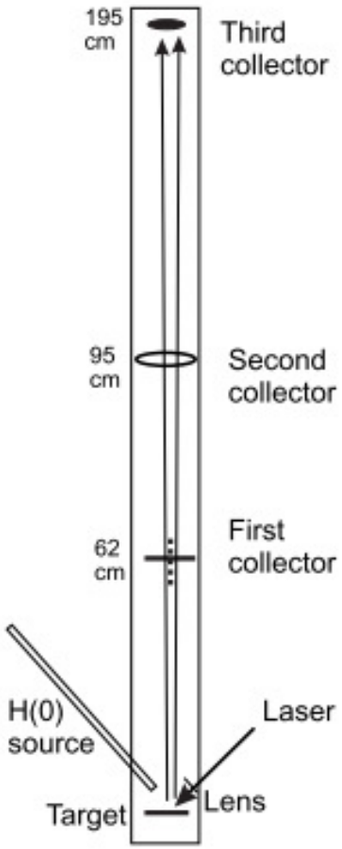
Gøteborg University





https://www.asme.org/engineering-topics/articles/energy/small-reactor-with-big-potential

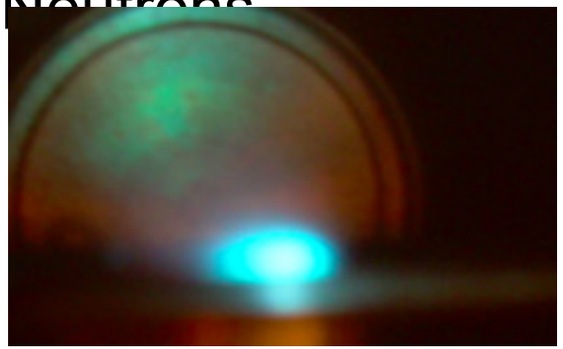
Laser induced TOF results Leif Holmlid



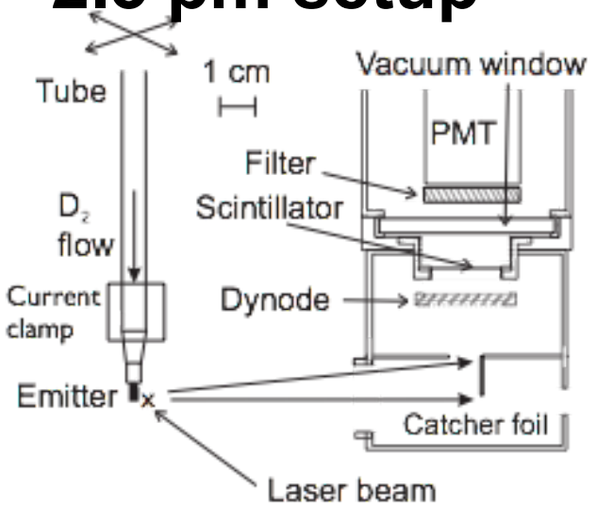
- Muons
- Pion
- Kaons,

- Electrons
- Positron
- Neutrons

Particle Decay



2.3 pm setup



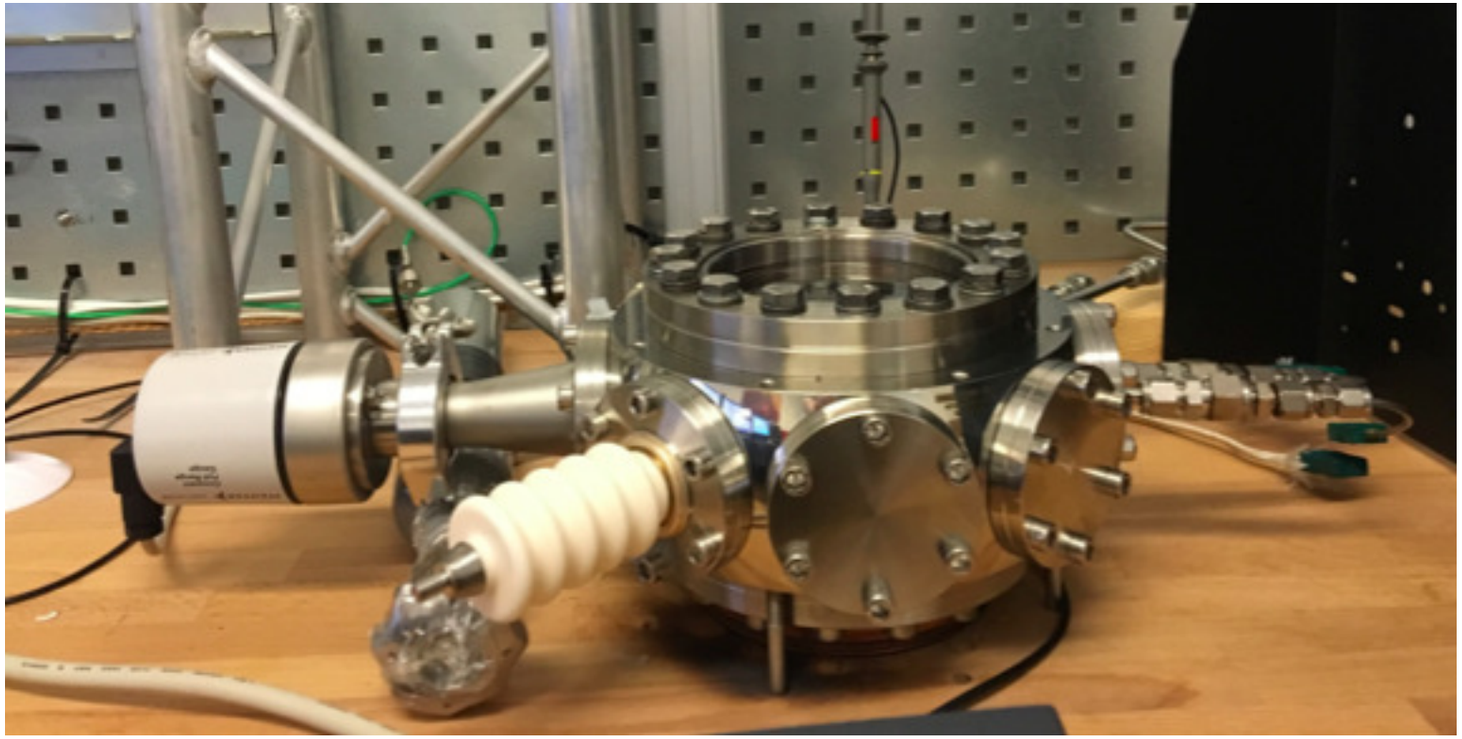
Emitter increases and maintains the D(0), p(0) phase

Holmlid, L. Mesons from Laser-Induced Processes in Ultra-Dense Hydrogen H(0). PLoS One 12, e0169895 (2017).

Holmlid, L. (2018). Neutrons from Muon-Catalyzed Fusion and Muon-Capture Processes in an Ultradense Hydrogen H(0) Generator. Fusion Science and Technology, 1055(0),

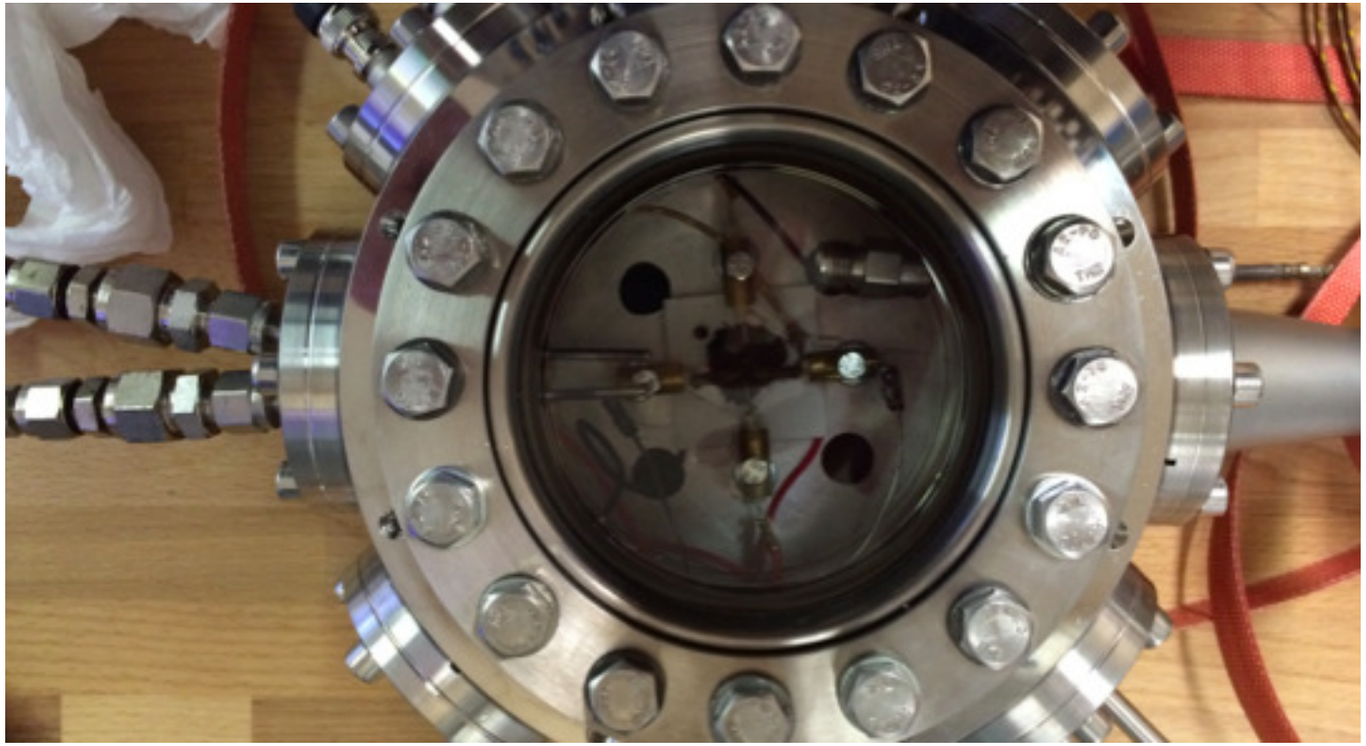
Replication

- Labview acquisition of:
  - Temp
  - Pressure
  - Voltage
  - Current
  - Resistance



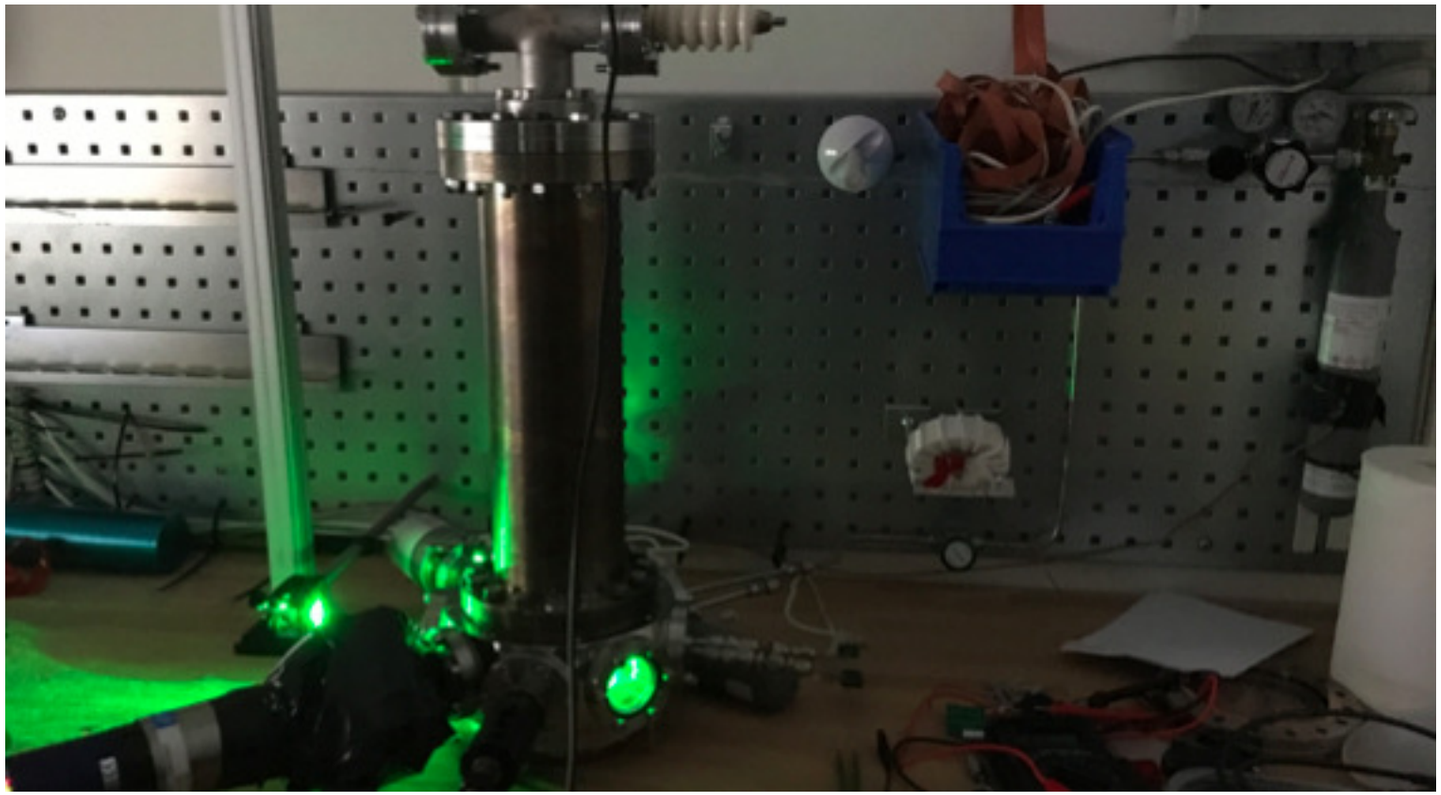
Replication

- Labview acquisition of:
  - Temp
  - Pressure
  - Voltage
  - Current
  - Resistance

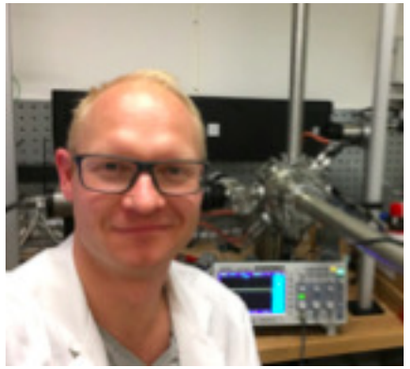


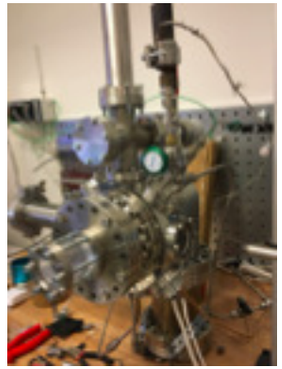
Replication

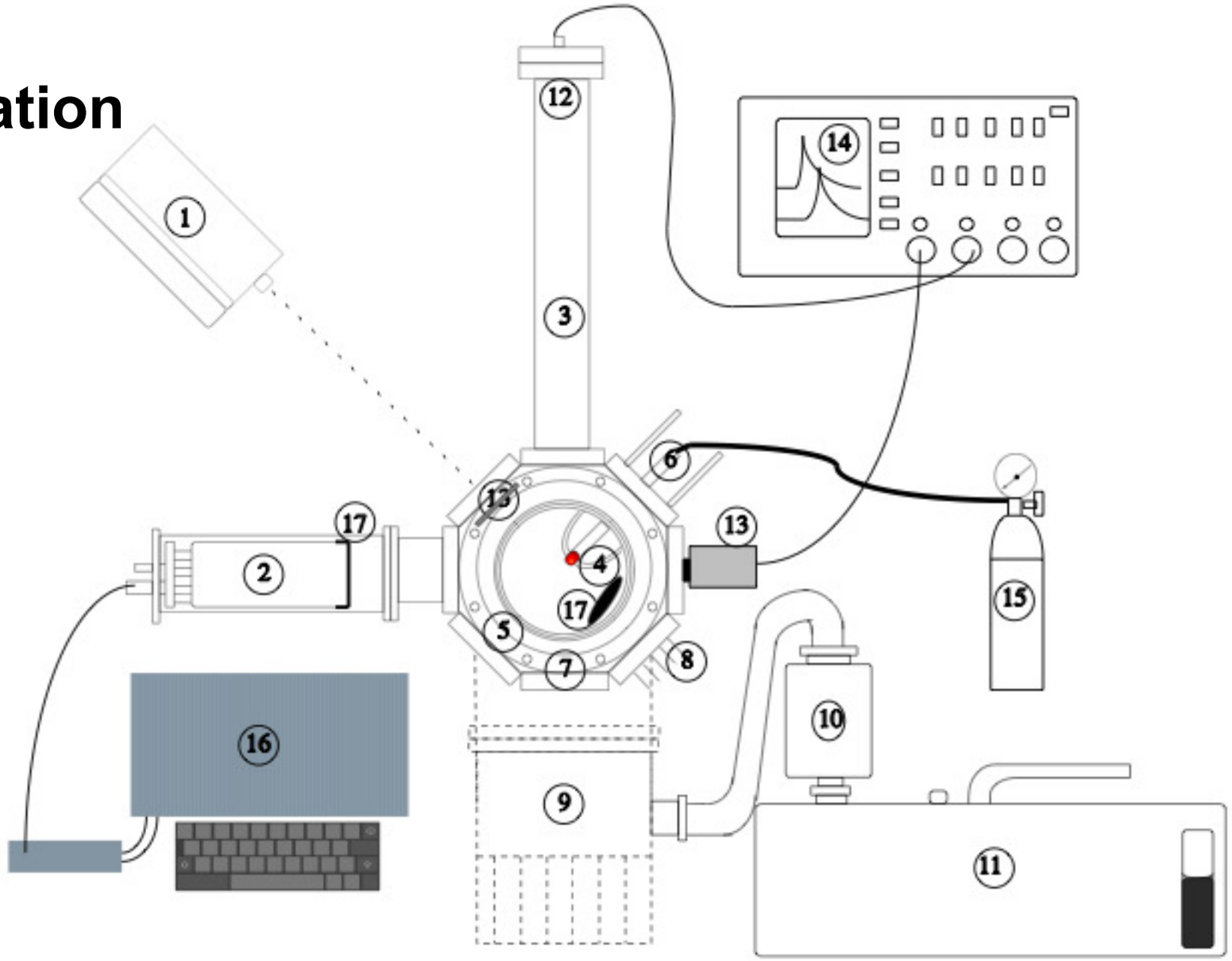
- Labview acquisition of:
  - Temp
  - Pressure
  - Voltage
  - Current
  - Resistance



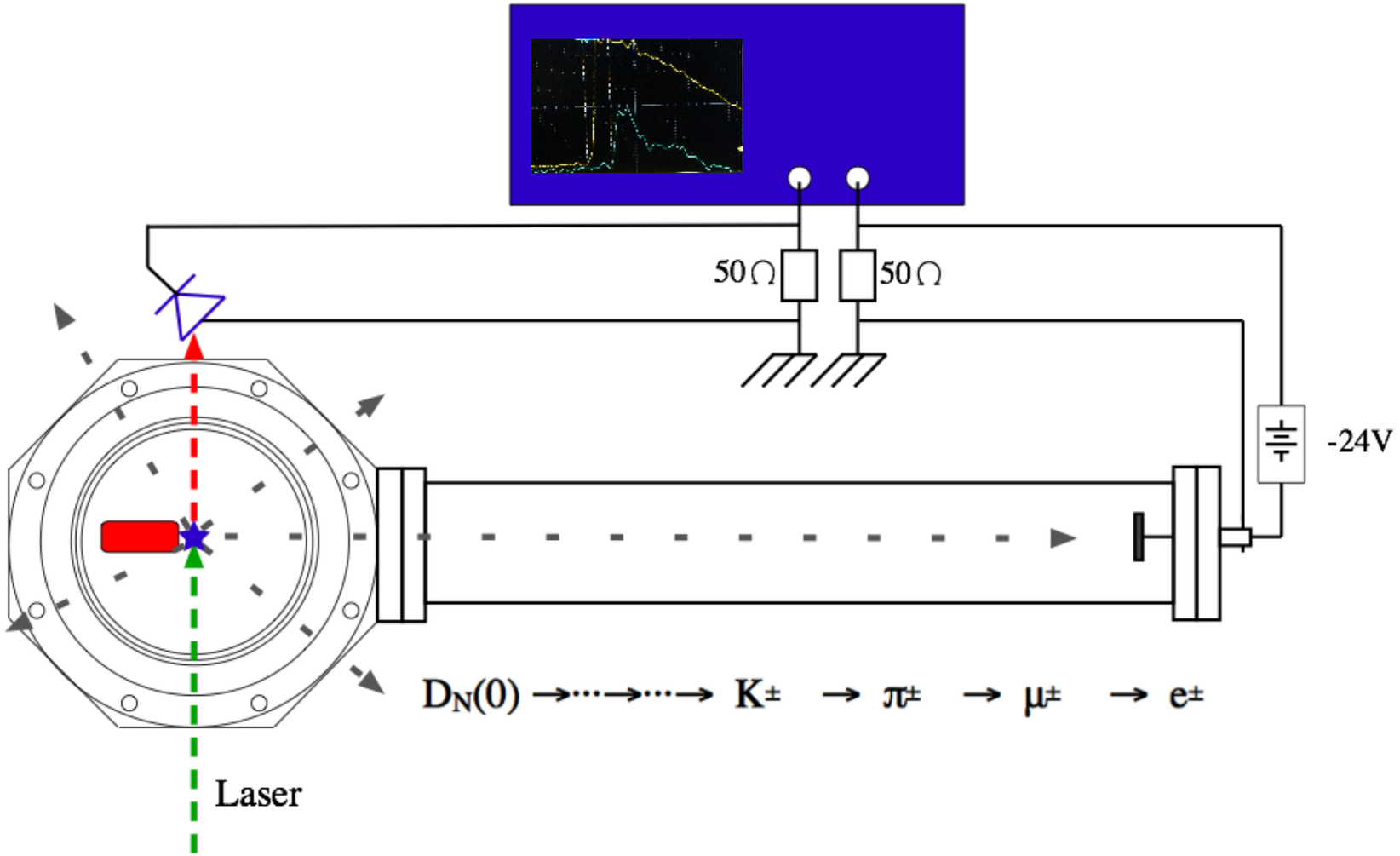
Experimental replication after 3 years work!





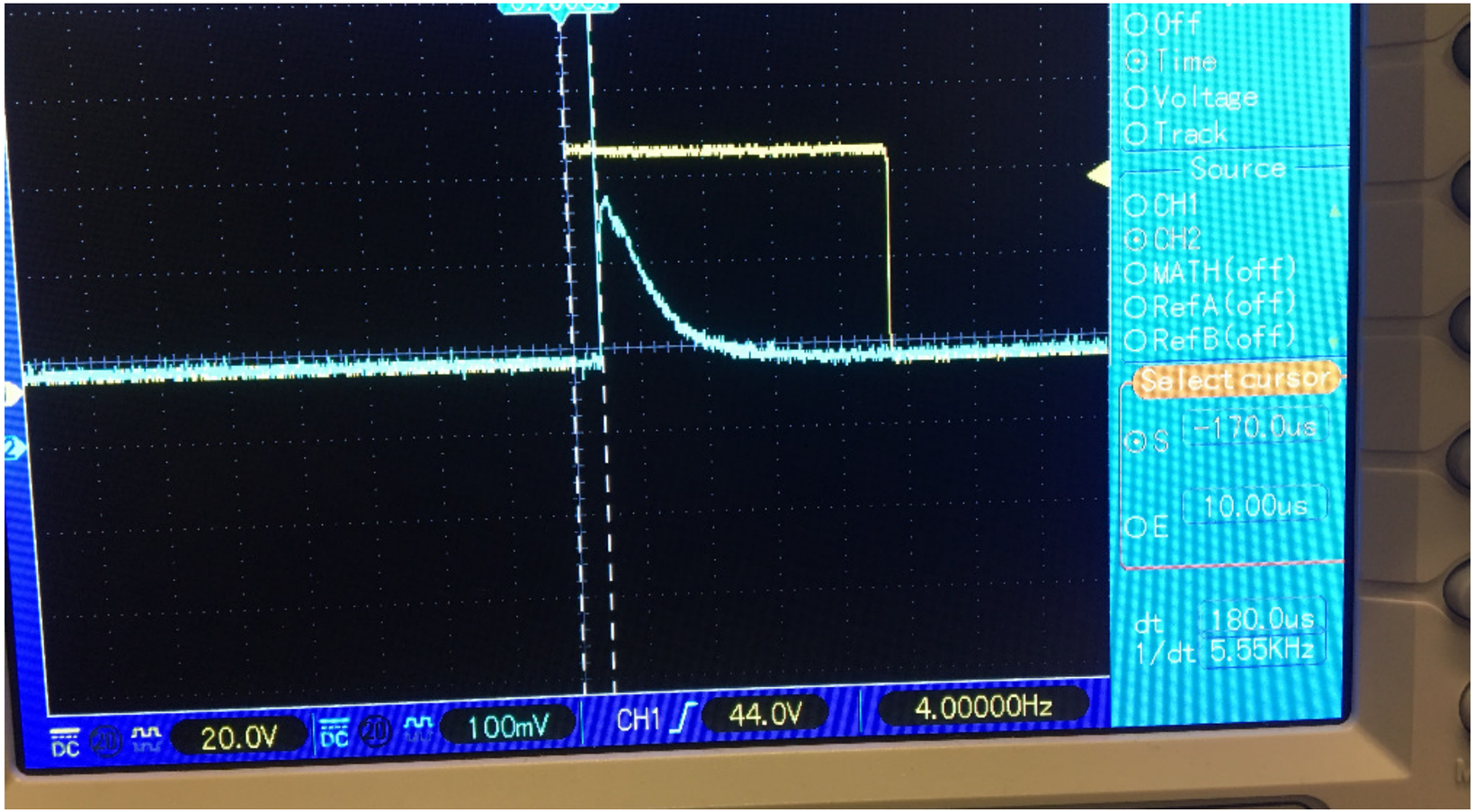


TOF (Time Of Flight) setup



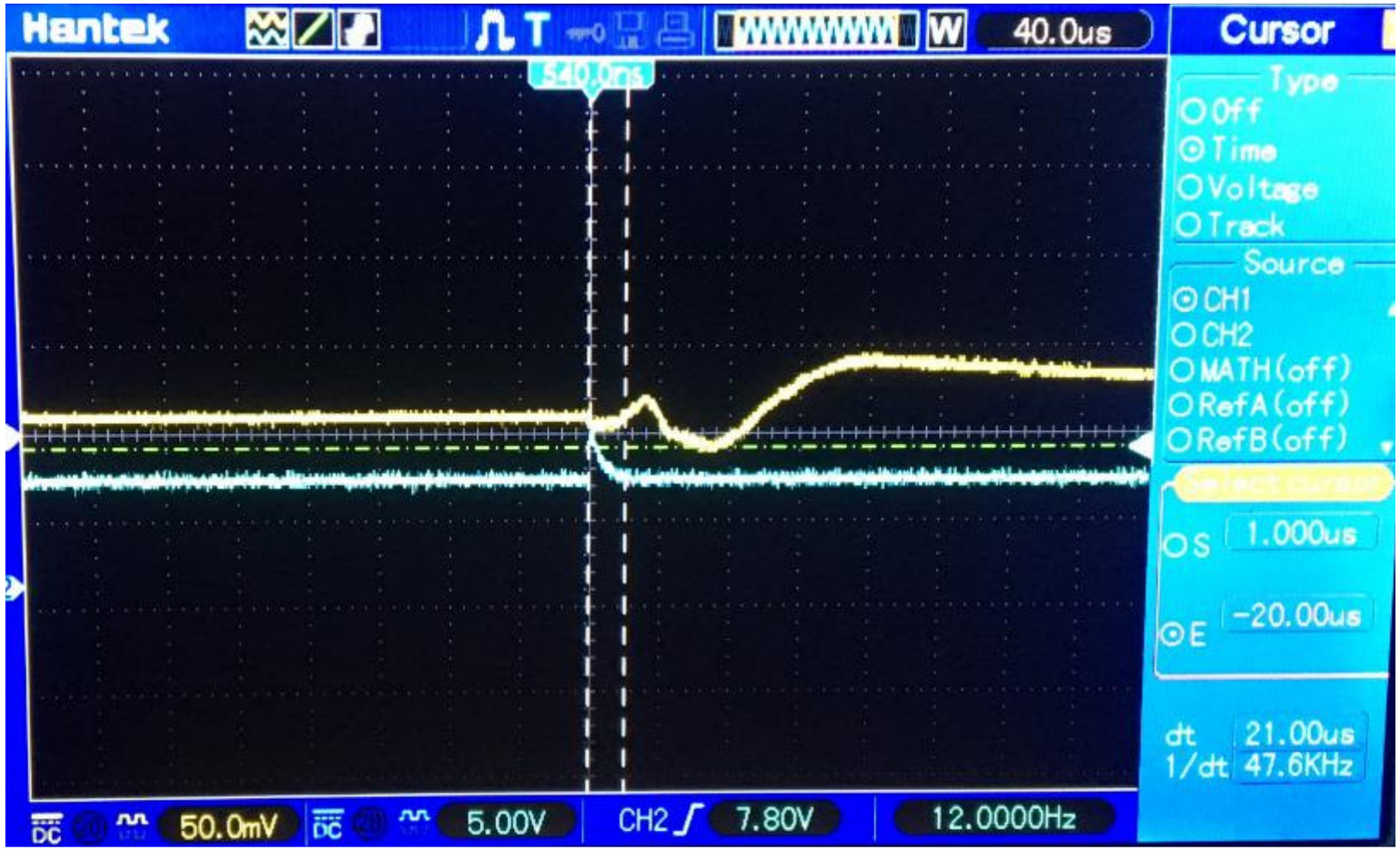
Hydrogen ions

- Tof: 180 us
- Tof length: 100 cm



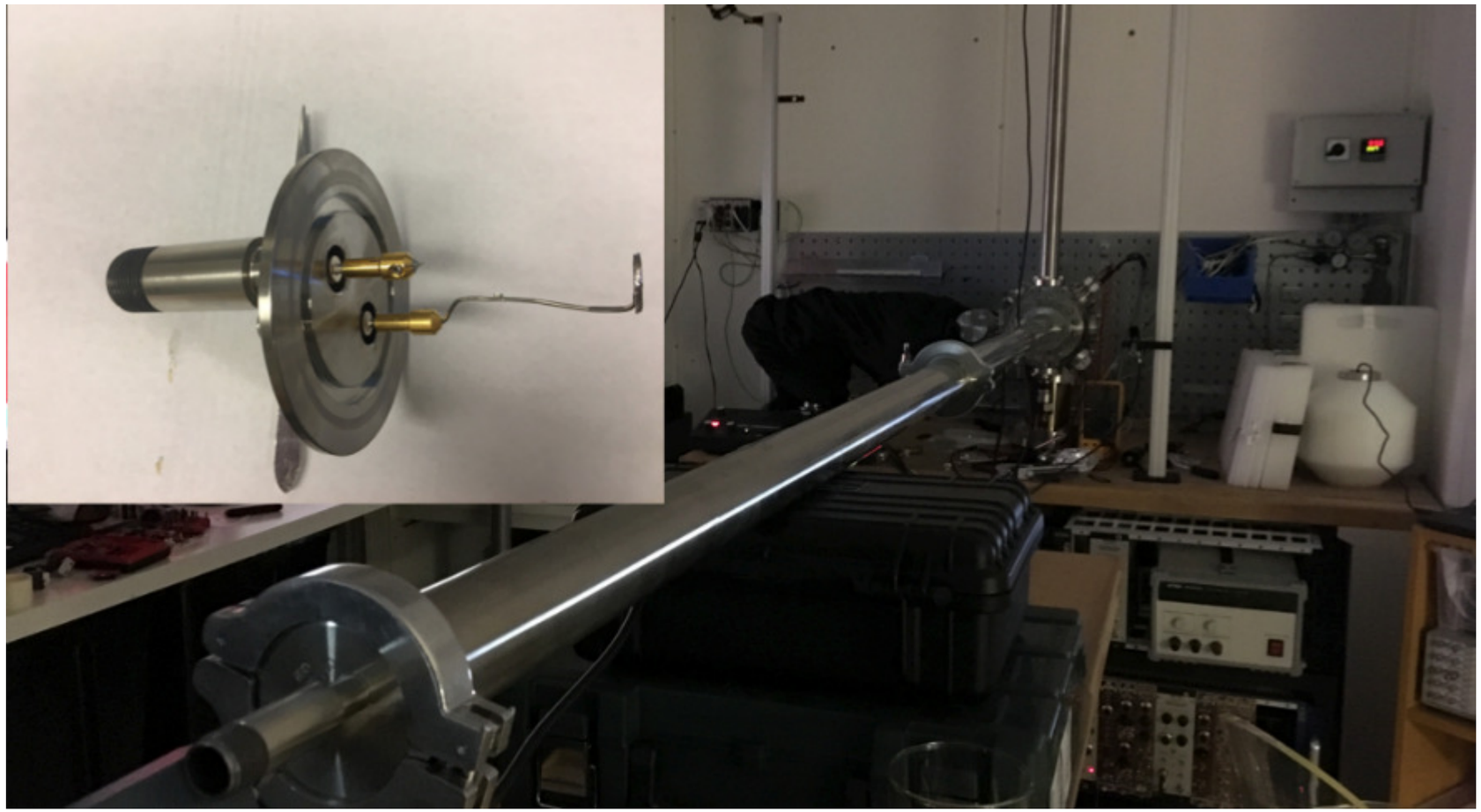
Ordinary Rydberg Matter detected

- TOF : 21 us
- TOF length: 100 cm
- 9,4 eV
- H(1)



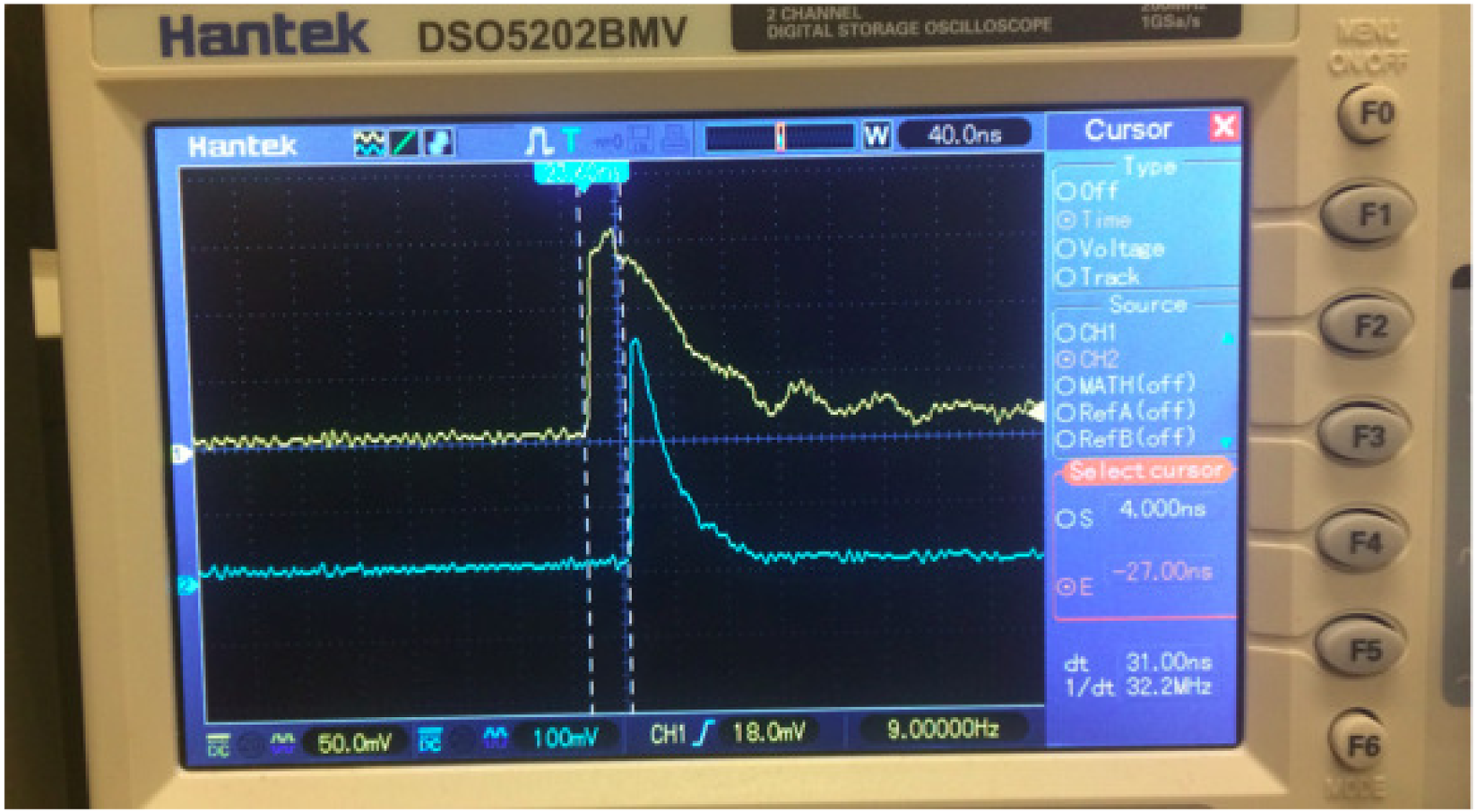
Increasing the time of flight tube

- Oscilloscope 200Mhz
- TOF length: 236 cm



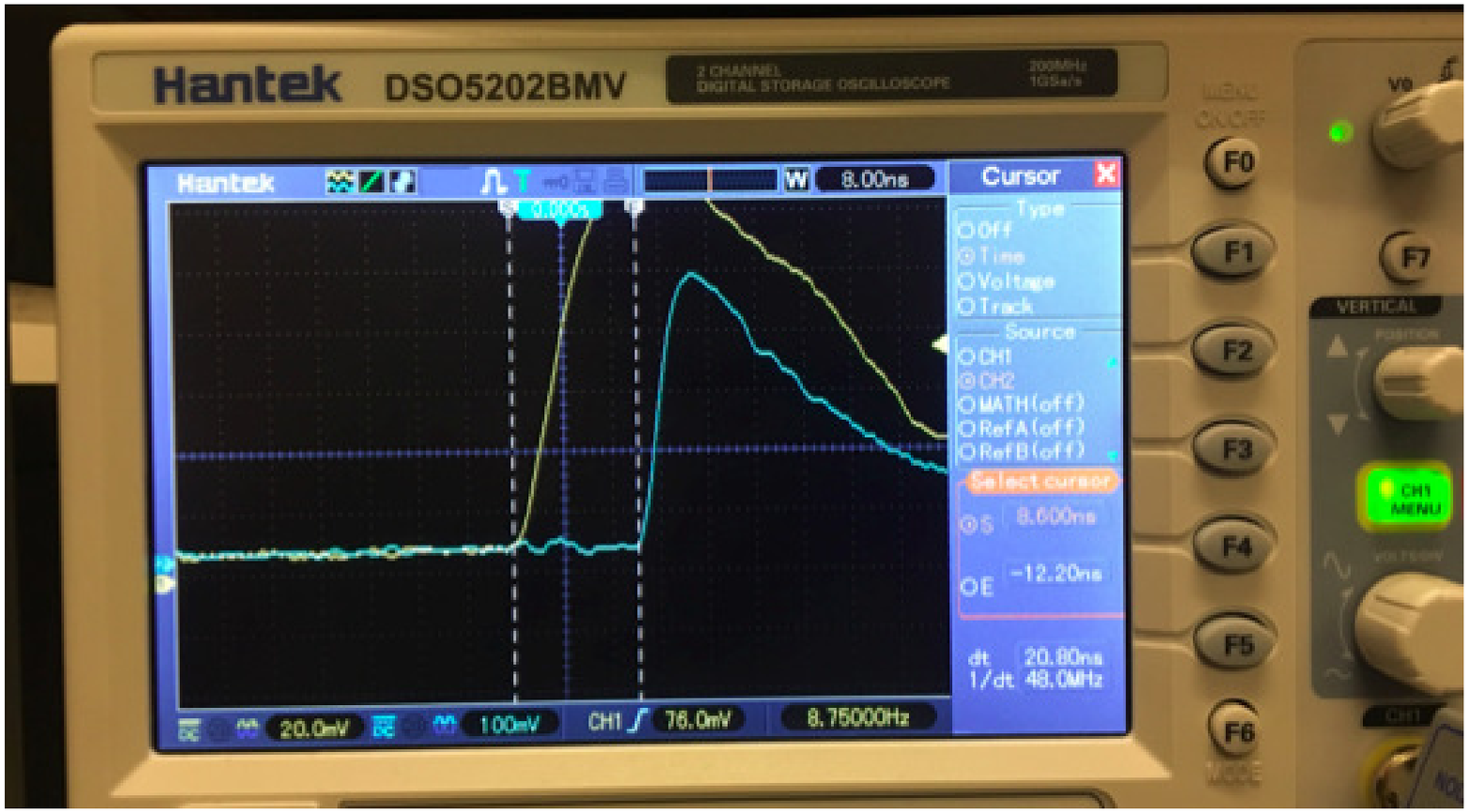
TOF 31 ns

- Oscilloscope 200Mhz
- TOF length: 236 cm
- TOF: 31 ns



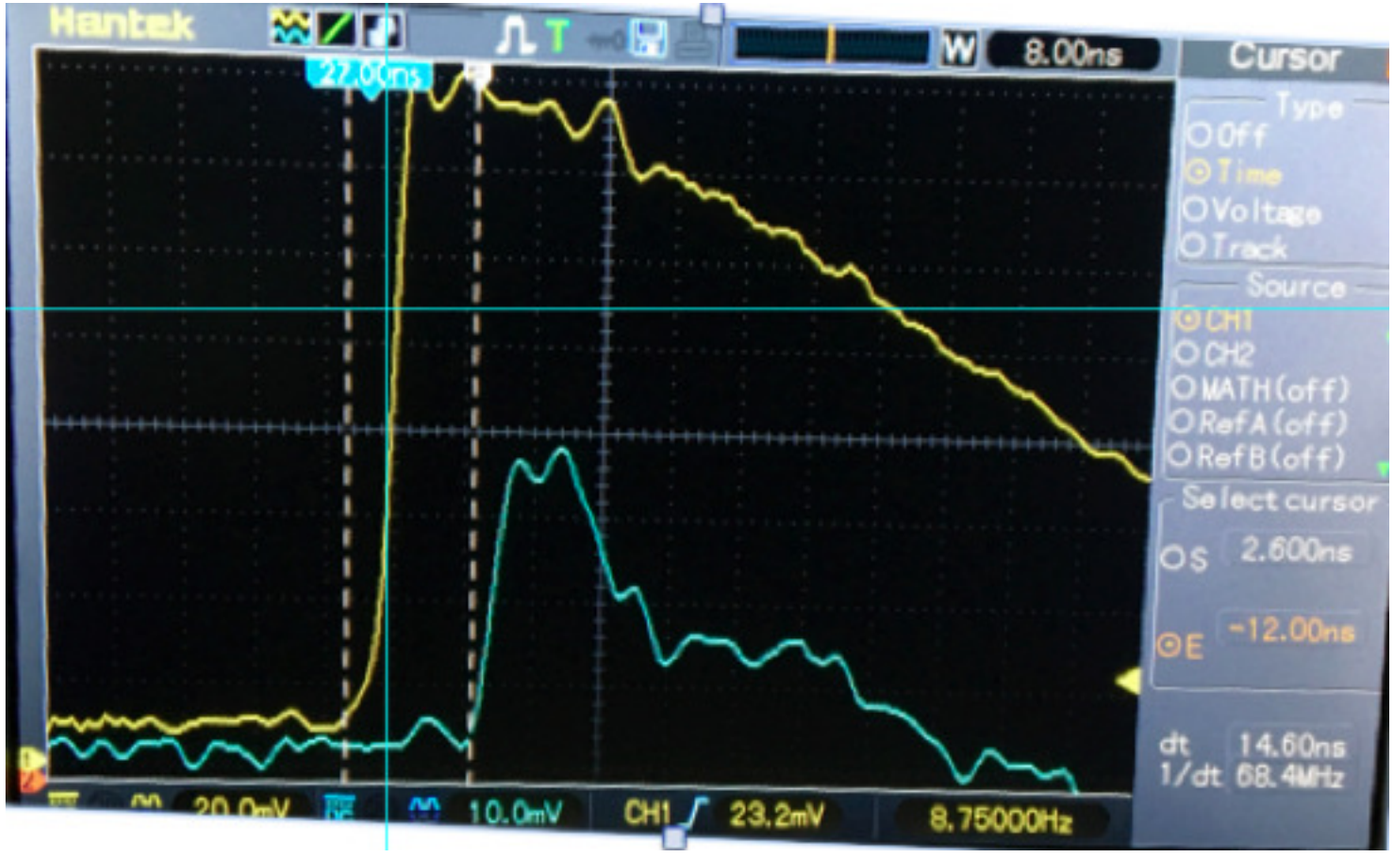
TOF 20,8 ns

- Oscilloscope 200Mhz
- TOF length: 236 cm
- TOF: 20,8 ns



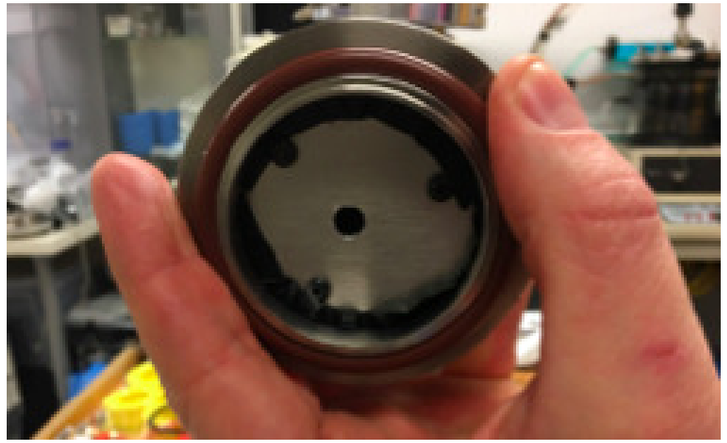
TOF Ultra Dense Deuterium signal observed!

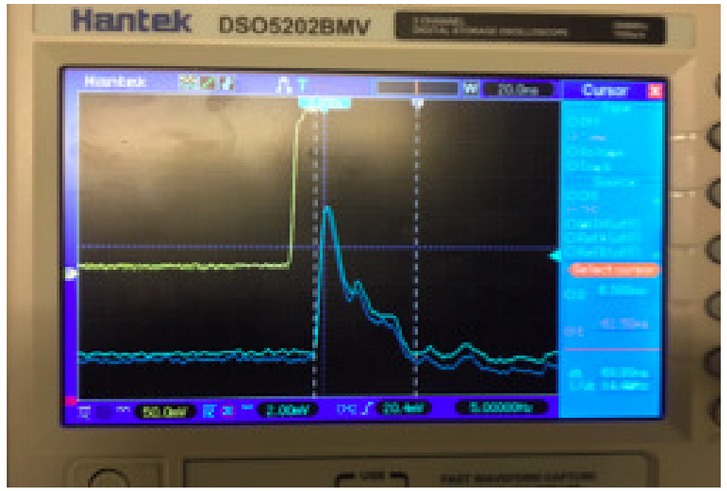
- TOF : 14,6 ns
- TOF length: 236 cm
- 47 MeV assuming π-mesons
- Leif's work confirms π mass in mass filtering experiments.
- To be replicated also.

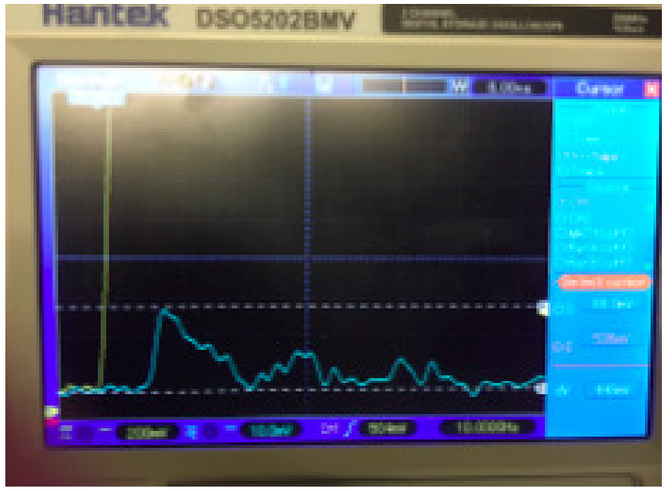


Wave or particle?

- Collimator to check for microwave radiation
- 5 mm slit, 50 mm length

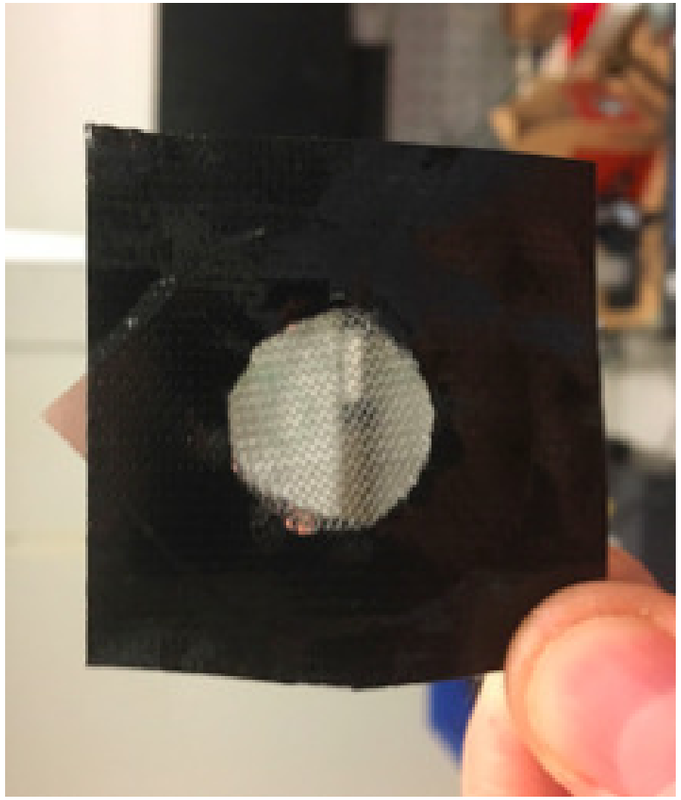






Wave or particle?

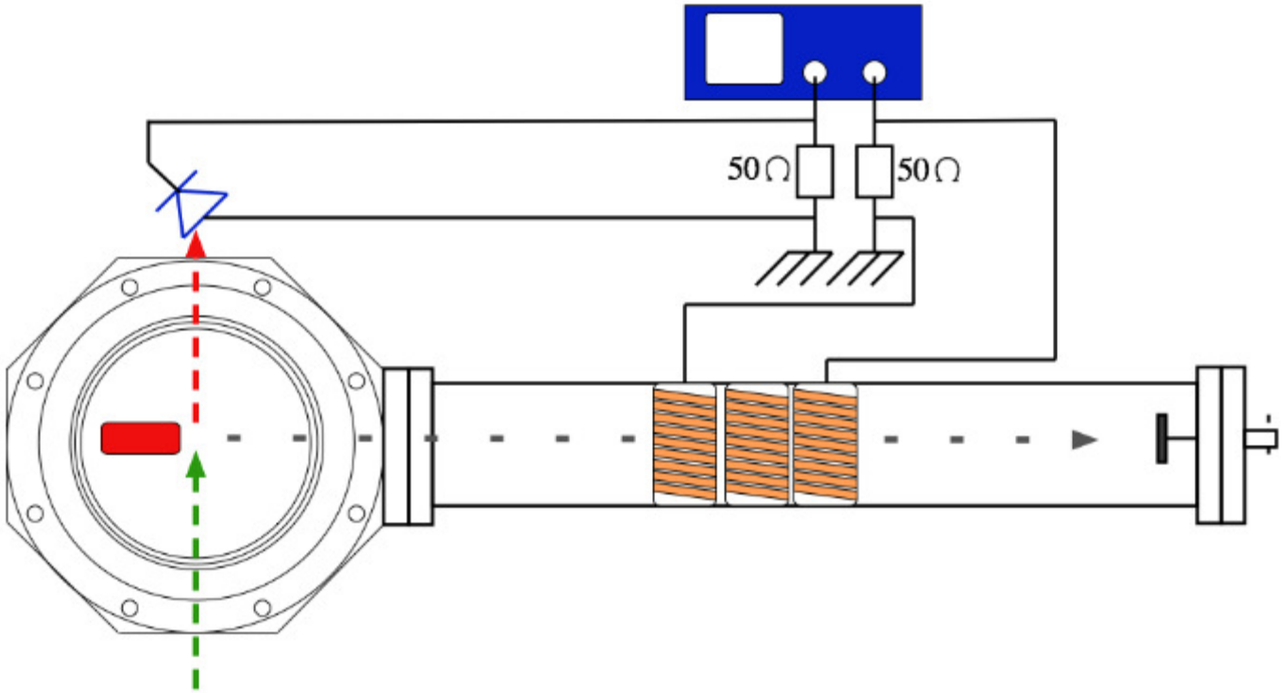
- Metal grid covering the TOF tube

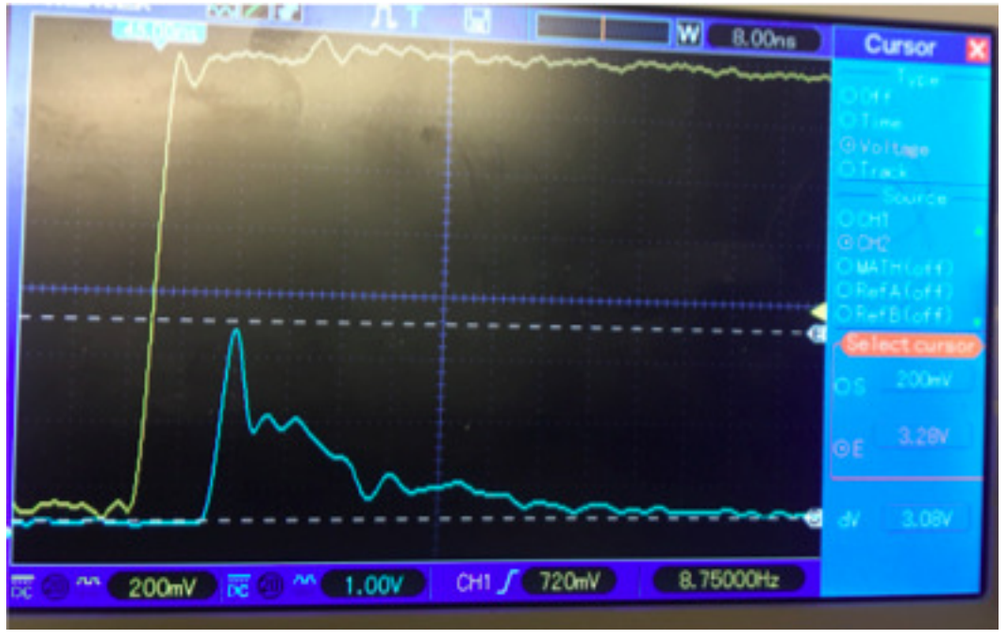


Coil detector

- Ferrite core
- N: 14
- Id:30 mm
- Od:51 mm

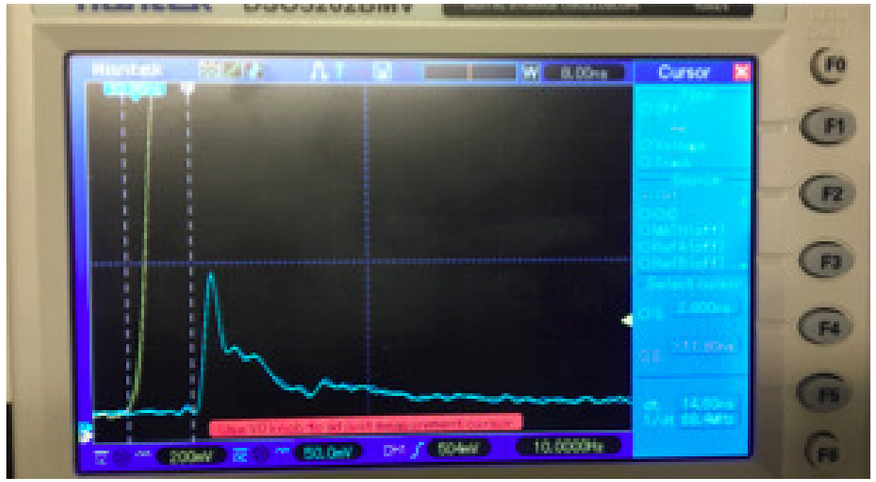
Charged particles signal observed

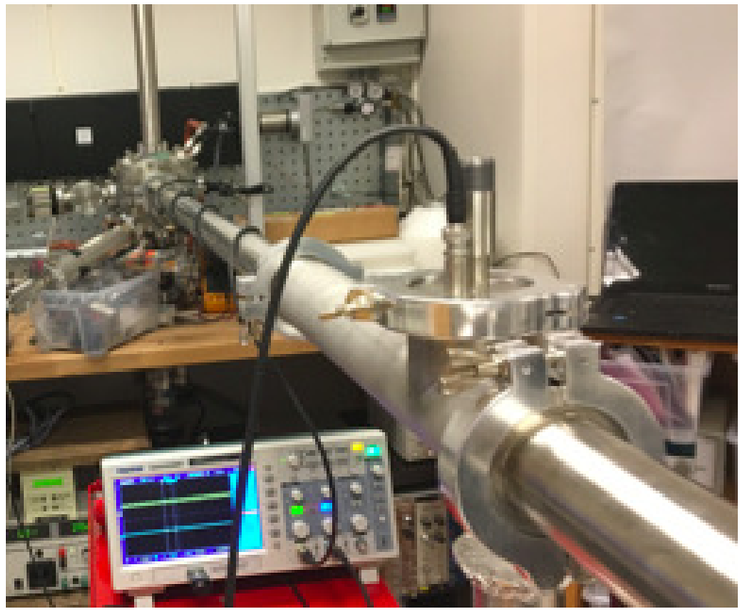


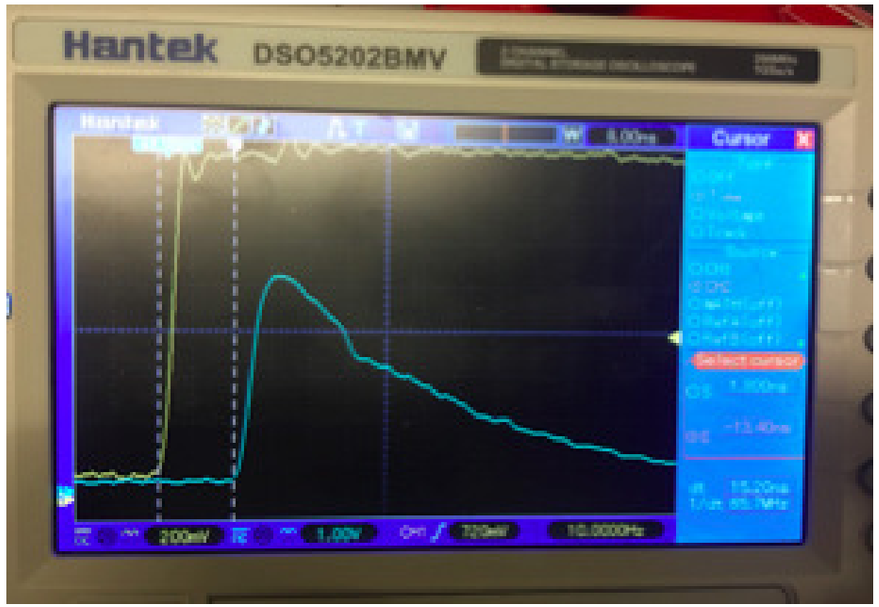


TOF coil

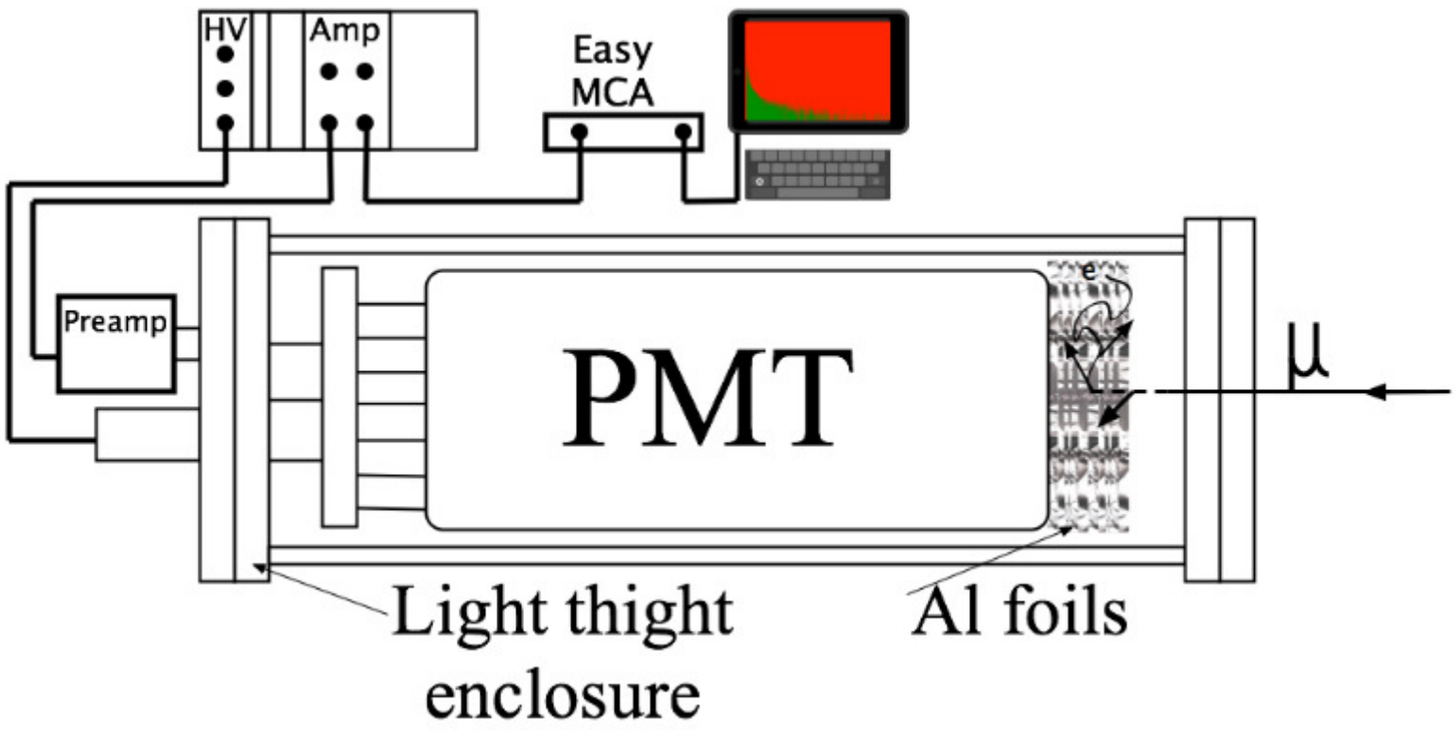
- Length to coil:159 cm
- Tof coil: 14,6 ns
- Tof detector: 277 cm
- Tof detector:15,2 ns







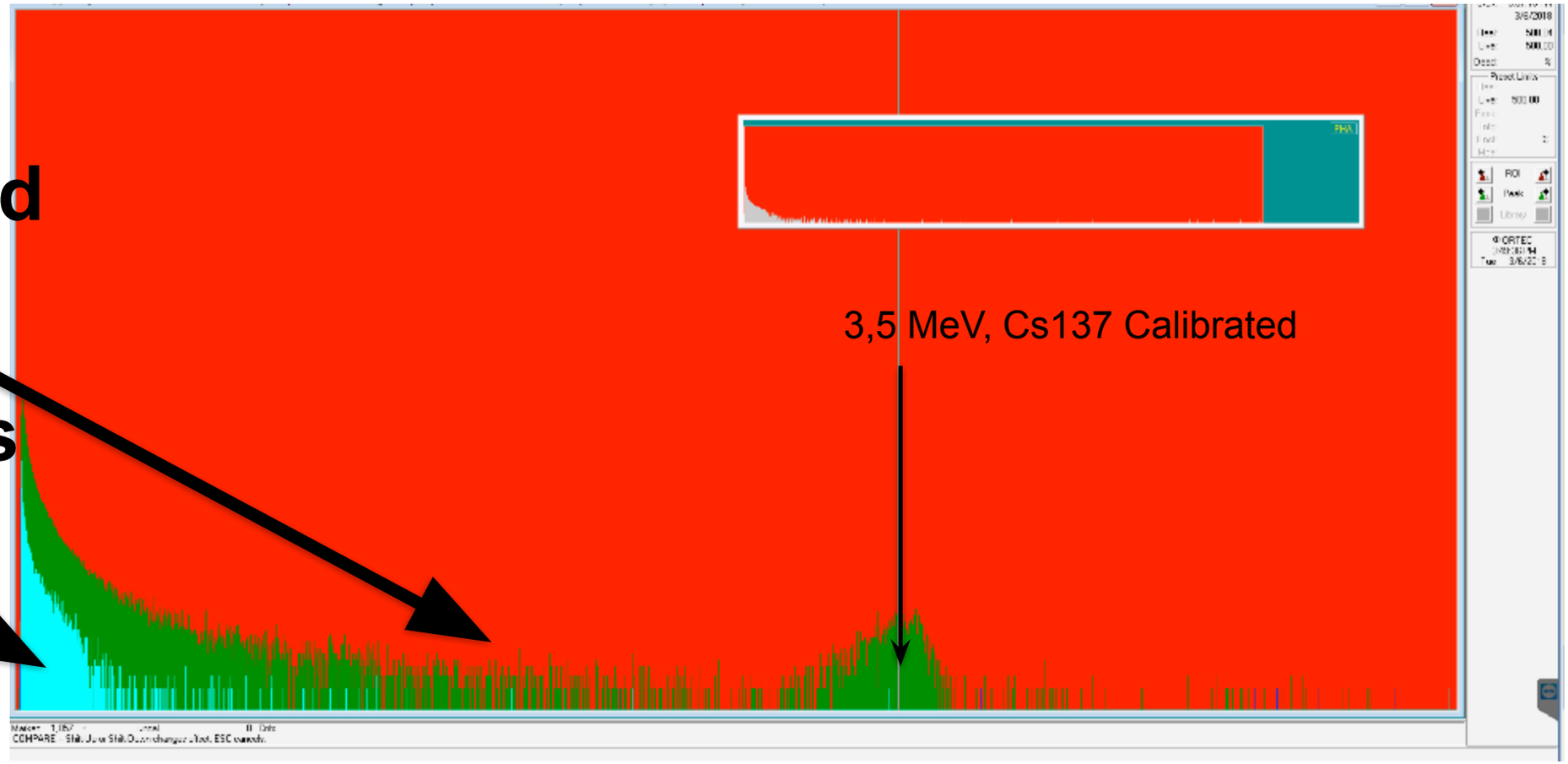
Muon detector in Oslo



Muon signal observed!

With D_2 gas and emitter

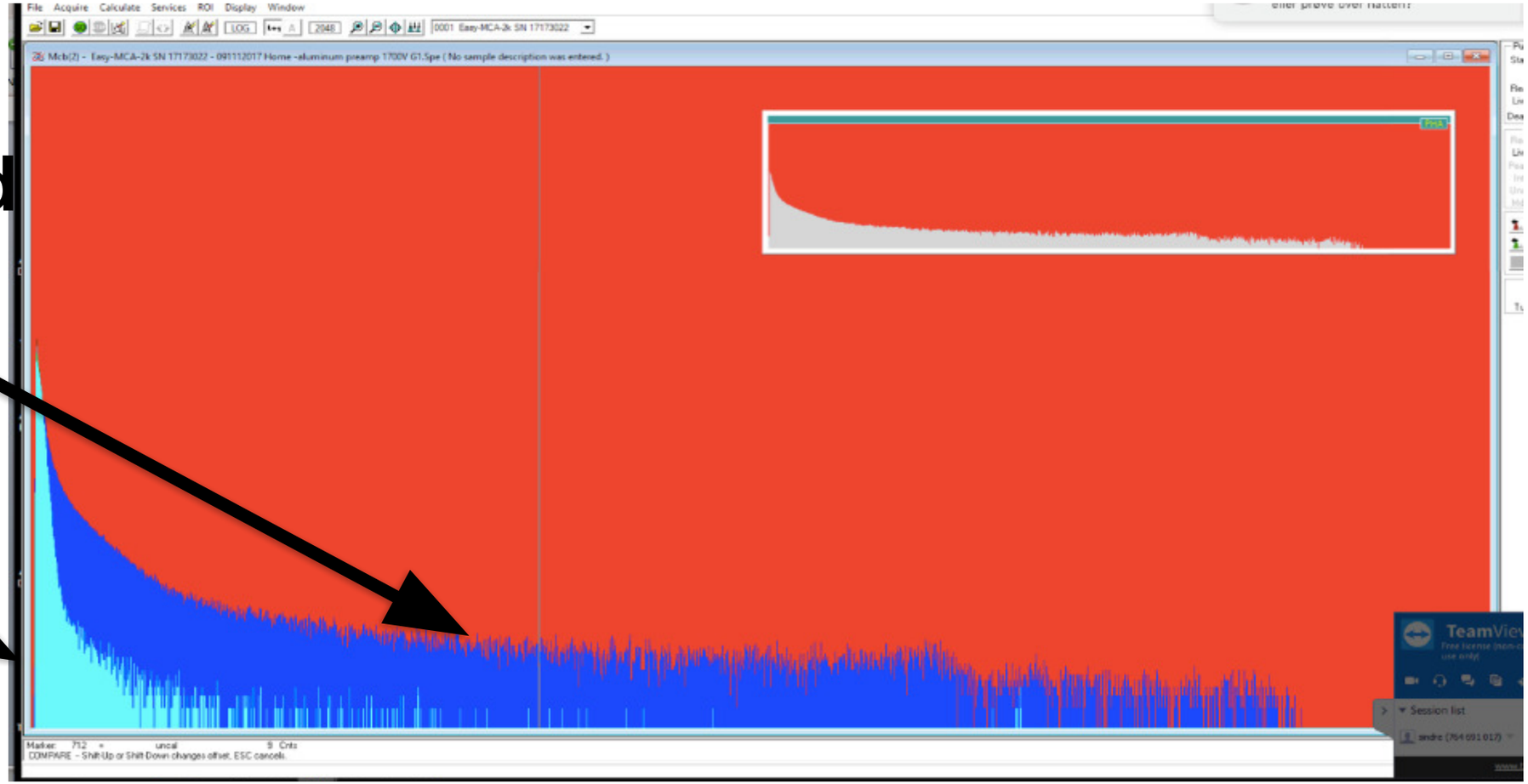
Without D_2 gas and emitter



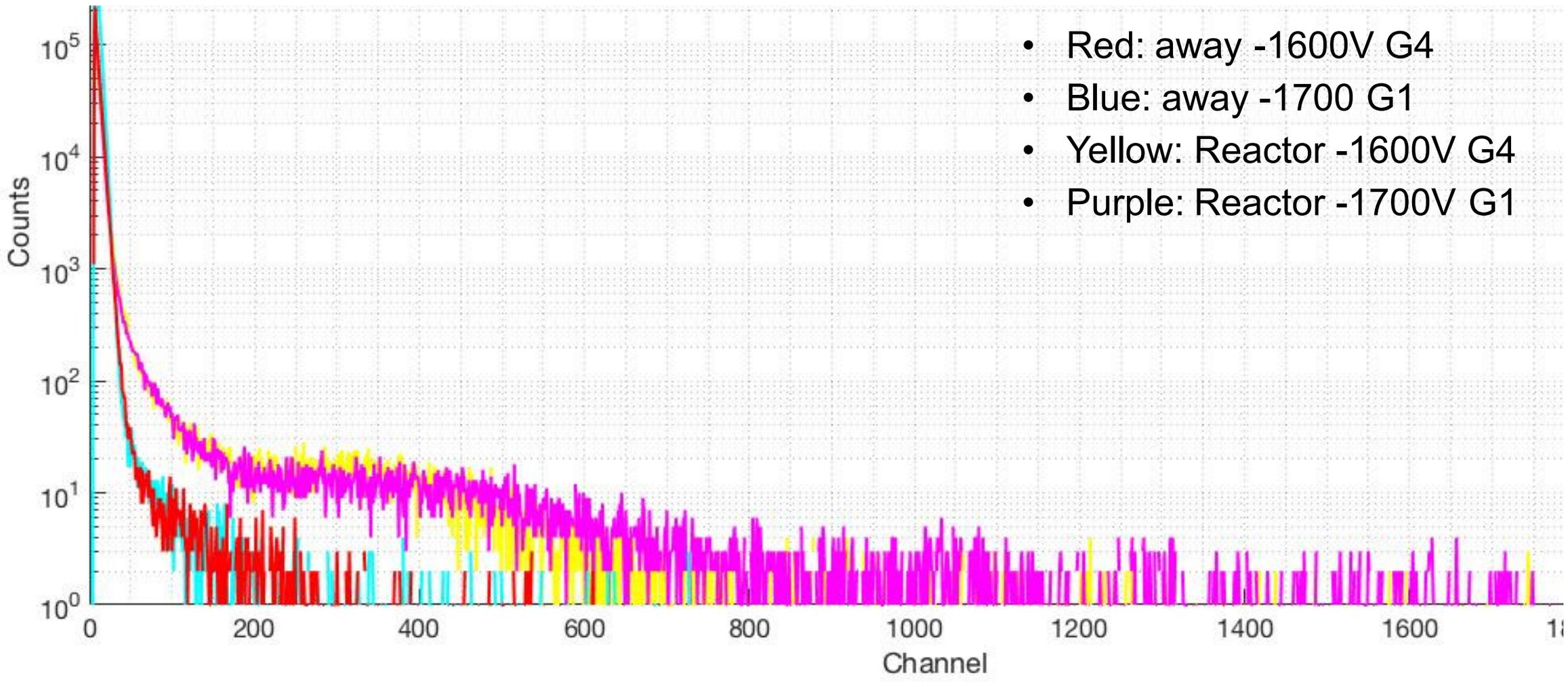
Muon signal observed!

With D_2 gas and emitter

Without D_2 gas and emitter

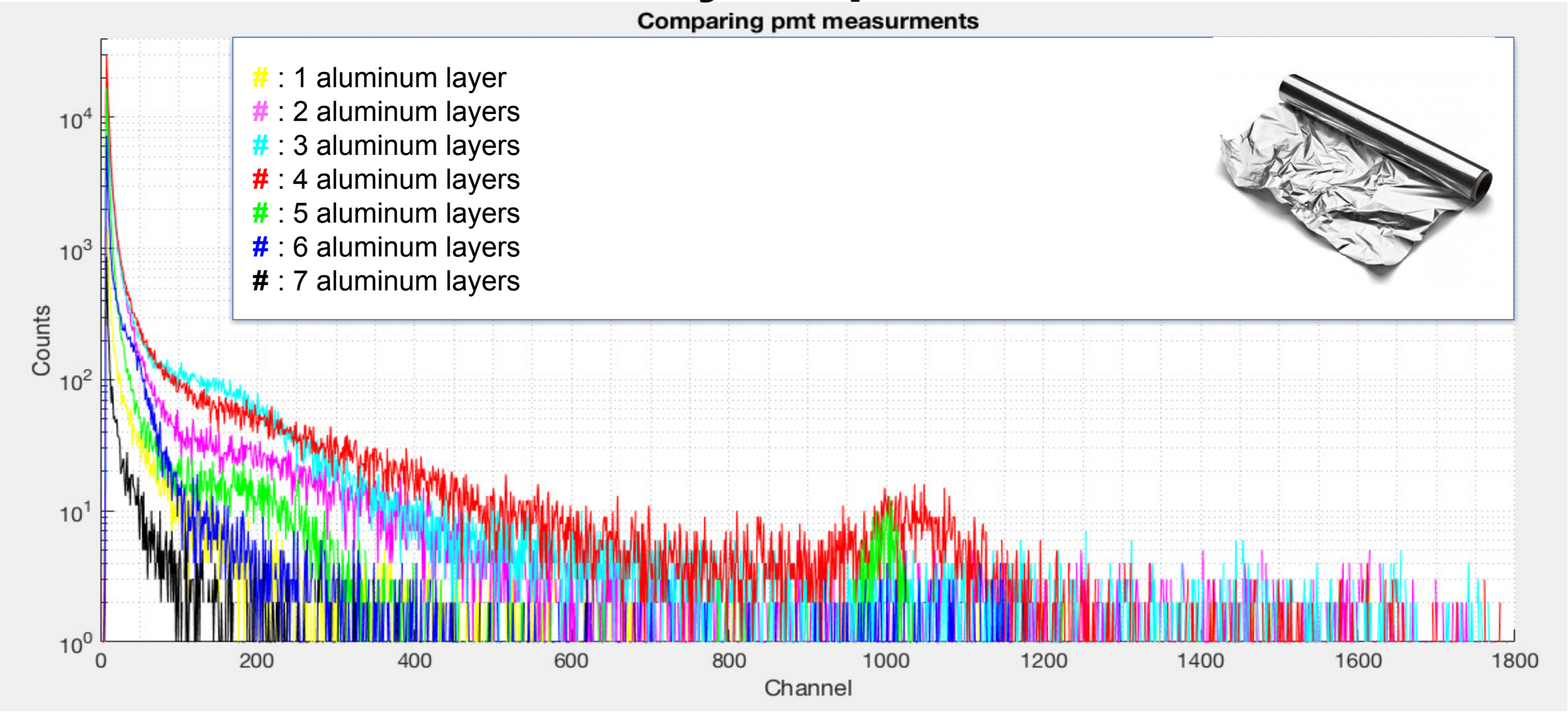


Spectra comparison



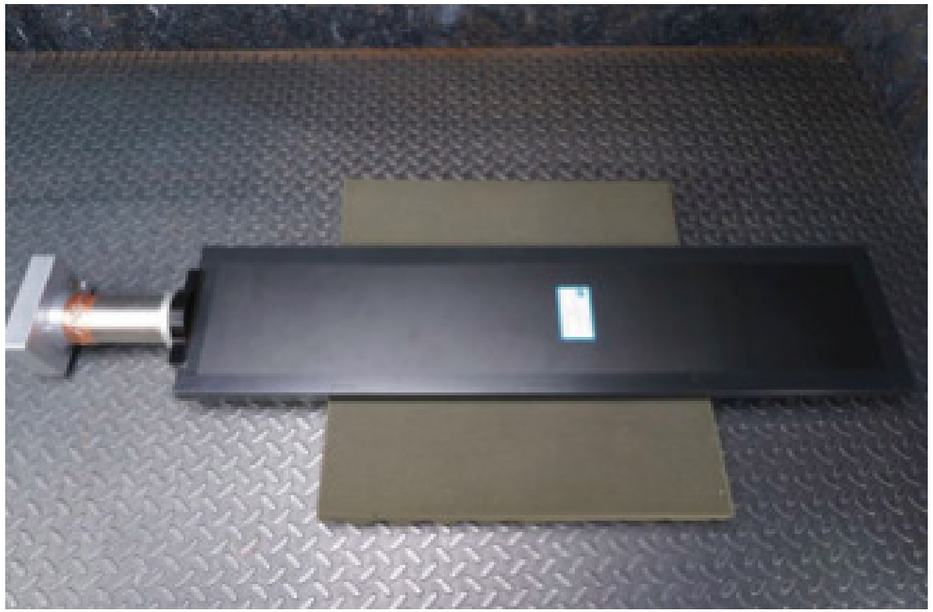
- Red: away -1600V G4
- Blue: away -1700 G1
- Yellow: Reactor -1600V G4
- Purple: Reactor -1700V G1

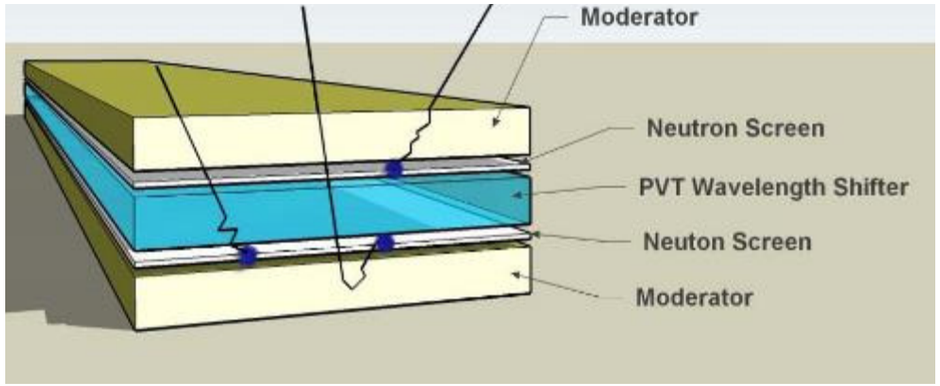
Aluminum layer optimization



Neutron detectors

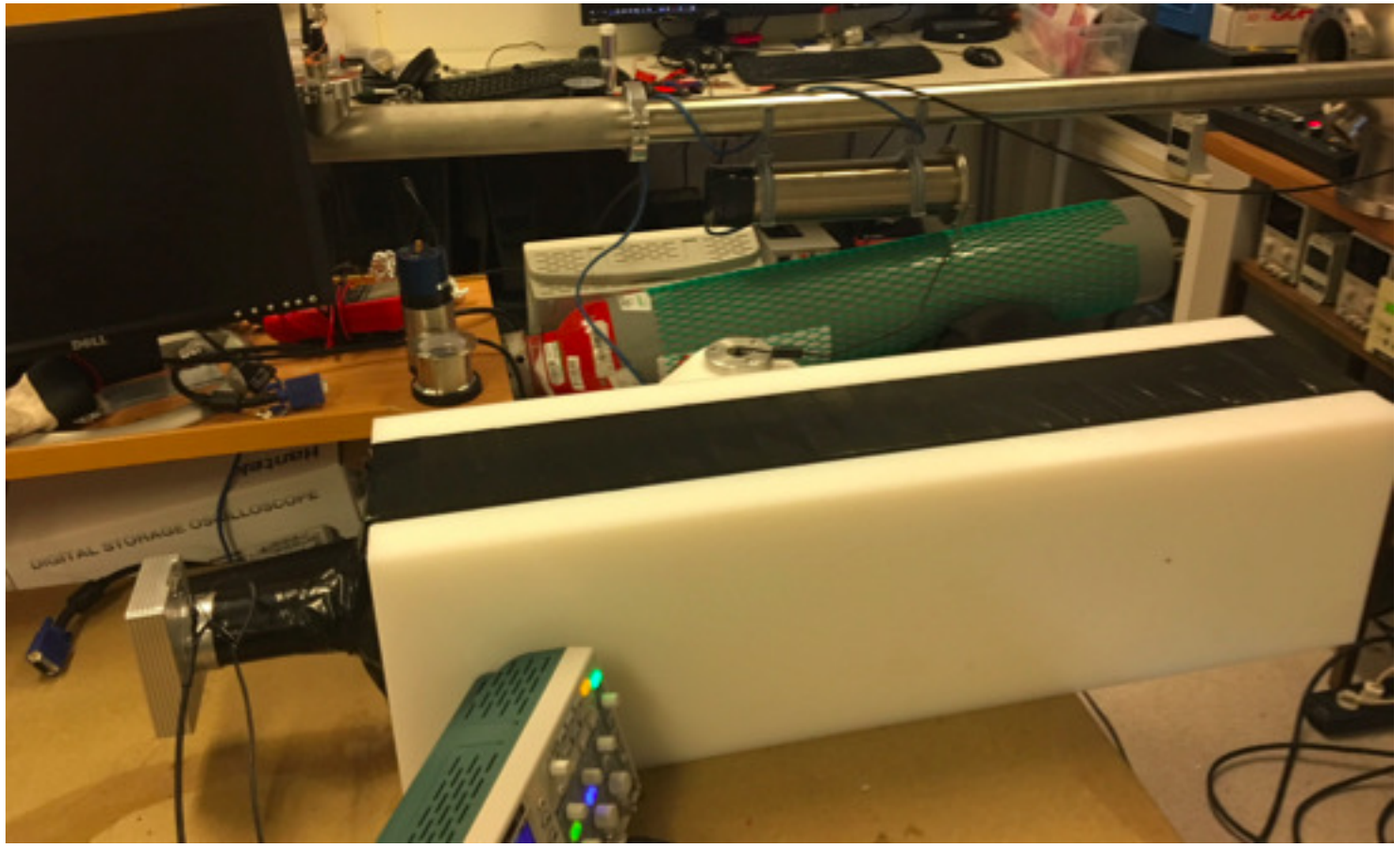
- Kromek TN15- high sensitivity thermal neutron detector, SiPM technology
- Symetrica Large Area detector 0.3 m wide by 1.0m long, 2” PMT 6Li plus ZnS(Ag) coating serves as neutron absorber



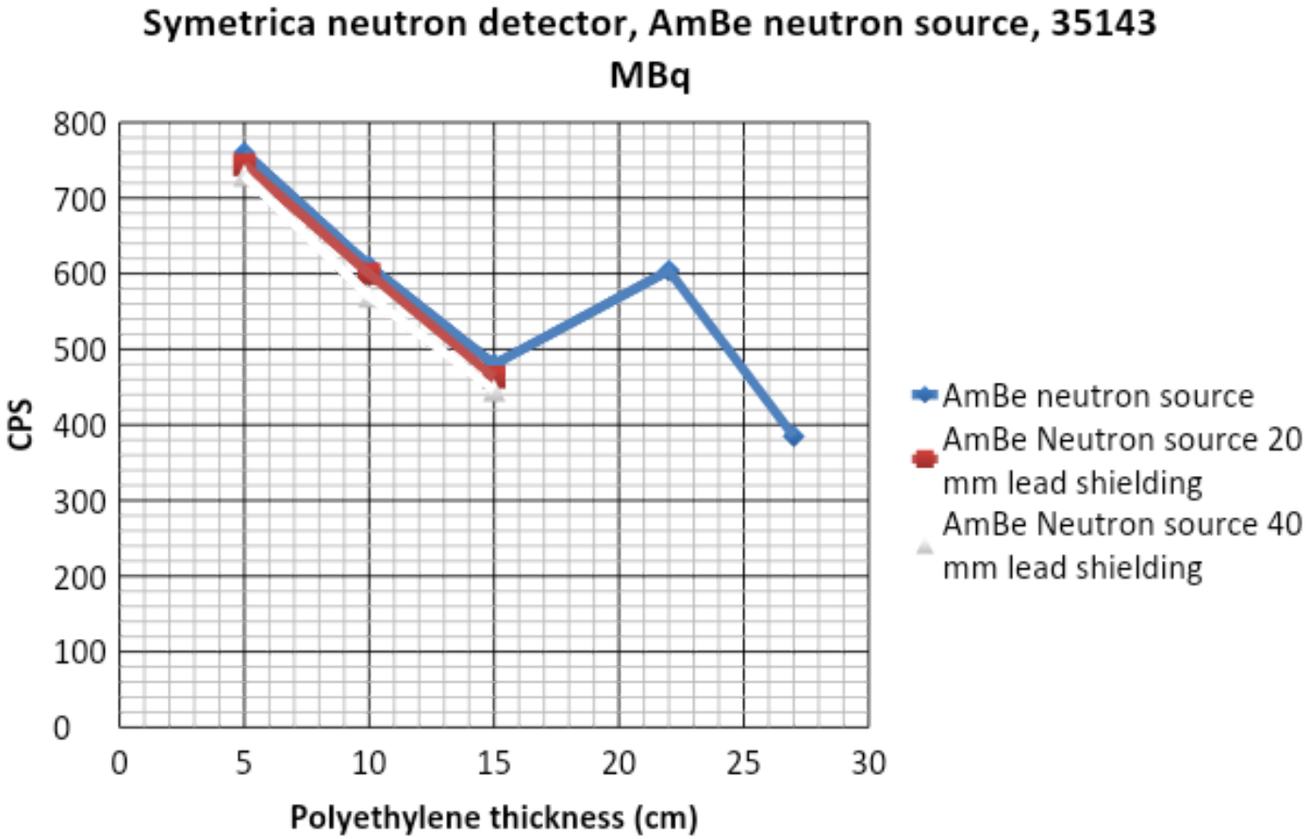


Neutron detector setup

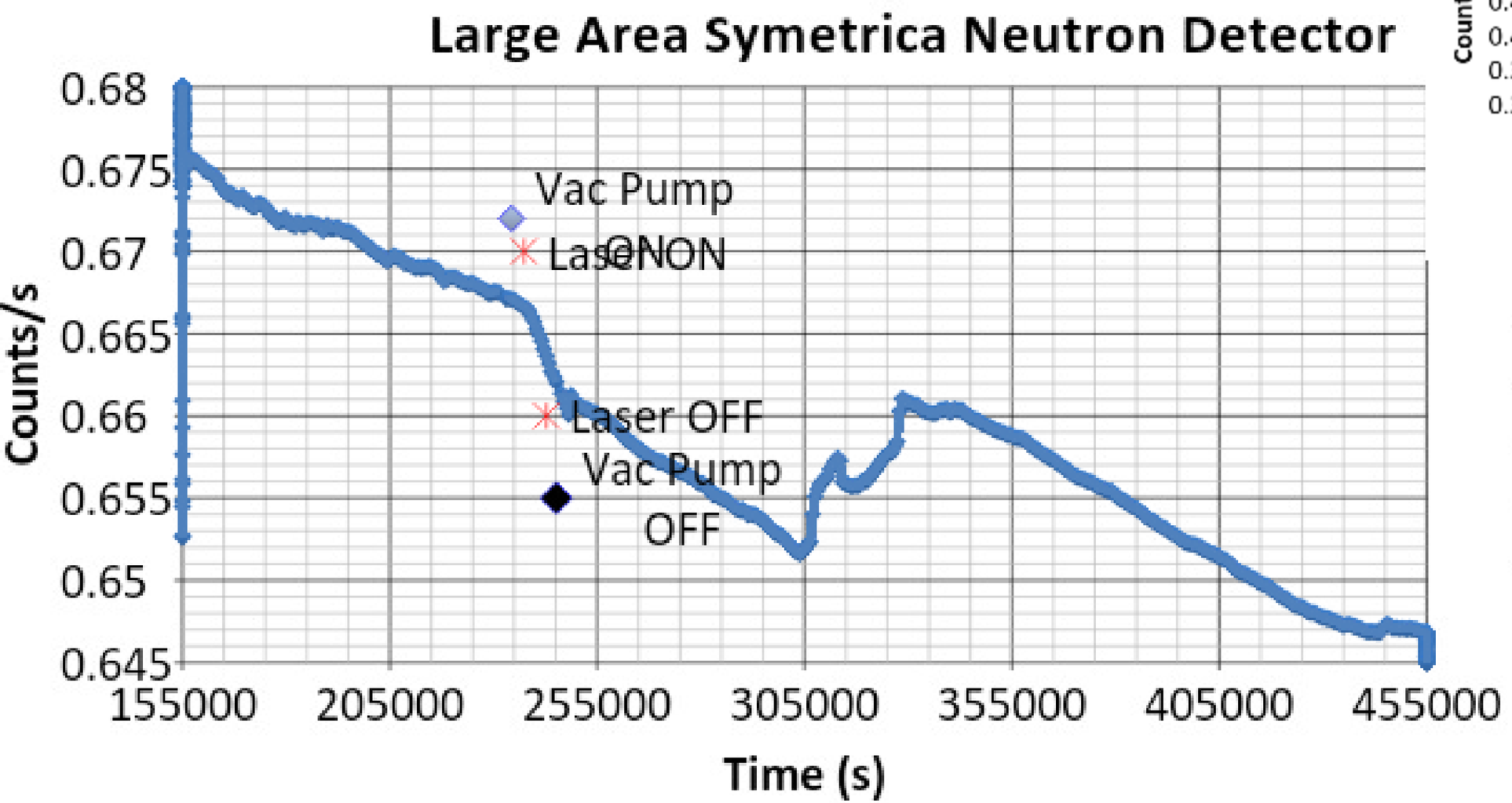
- 50 mm HDPE plate moderators
- Deuterium bottle, 10 ltr, 220 Bar

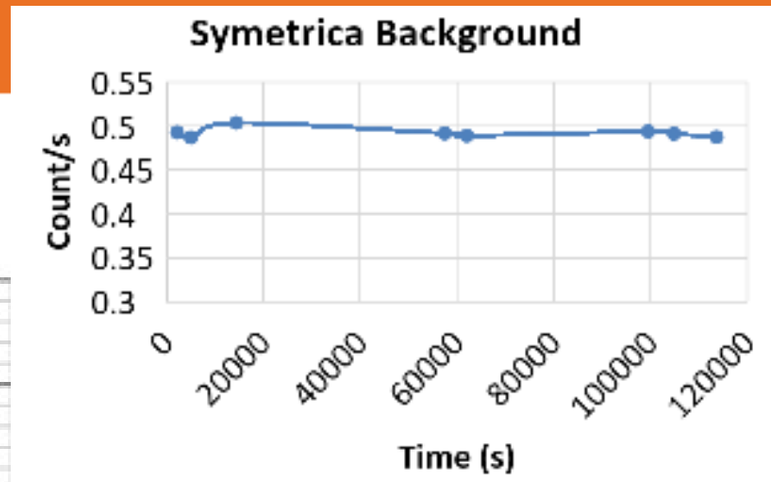


Neutron detector calibration- IFE



Neutron reduction

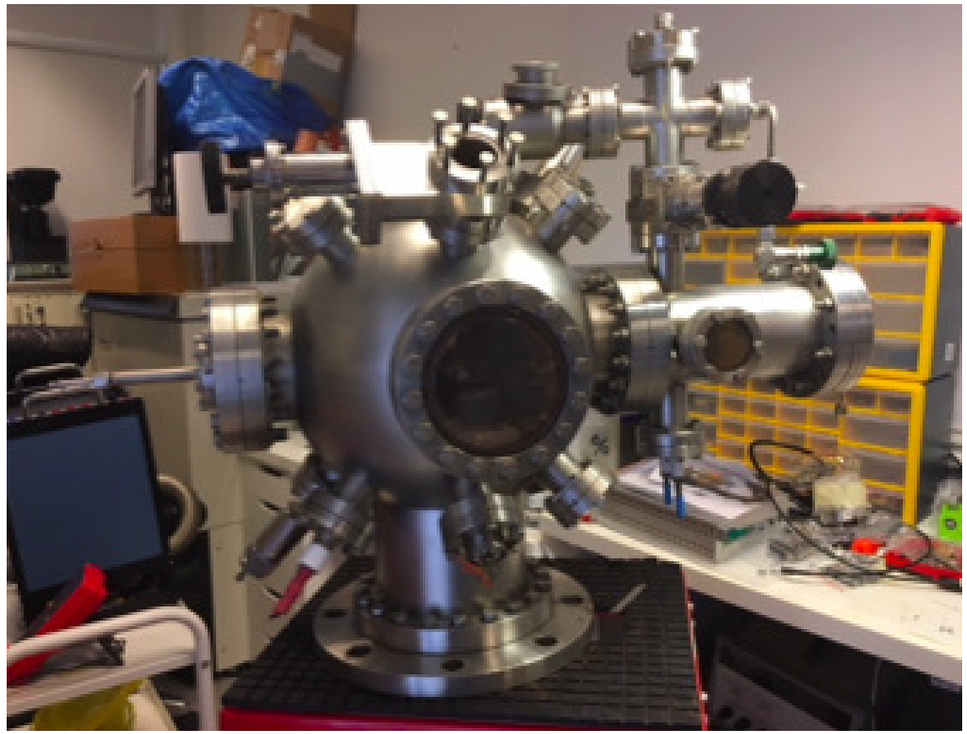




- Counts/s
- Laser ON
- Laser OFF
- Vac Pump OFF
- Vac Pump ON

Future work

- Improved reactor and system
- Multiple detectors
- New larger research facility



Annihilation

Theoretical possibility*

*Prof. Sveinn Olafsson

Nucleon annihilation $3p^{+} \rightarrow 3L^{+}$ into antileptons can later give showers of mesons, which finally decay to electrons, photons and neutrinos.

Energy mass density of:

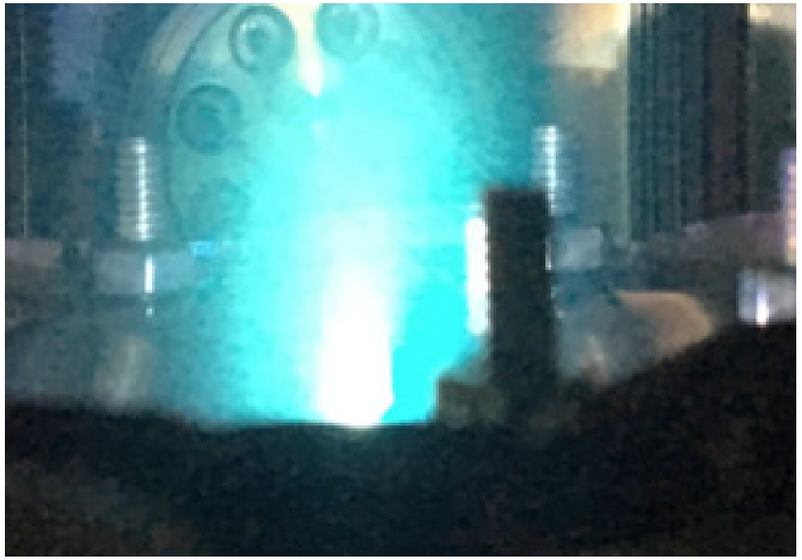
Chemical reactions	10 MJ/Kg
Nuclear fission U^{235}	80 TJ/Kg
Nuclear fusion D_2	300 TJ/Kg
Annihilation	3000 TJ/Kg

Holmlid, L., & Olafsson, S. (n.d.). Annihilation energy production : pulsed-laser impact on ultra-dense hydrogen H (0) creates relativistic particle showers, (0), 1–22.

Olofson, F., & Holmlid, L. (2014). Electron-positron pair production observed from laser-induced processes in ultra-dense deuterium D(-1). Laser and Particle Beams, 32(4), 537–548. https://doi.org/10.1017/S0263034614000494

Conclusions

- Replication Leif Holmlid's ultra dense hydrogen experiments.
  - Rydberg matter signal verified
  - Ultra dense Hydrogen signal verified
  - Charged particles verified
  - Muon signals verified
  - Strange reduction in neutron counts
  - Annihilation? 70-100 MeV particles



Hydrogen or deuterium is supplied in gas form

H

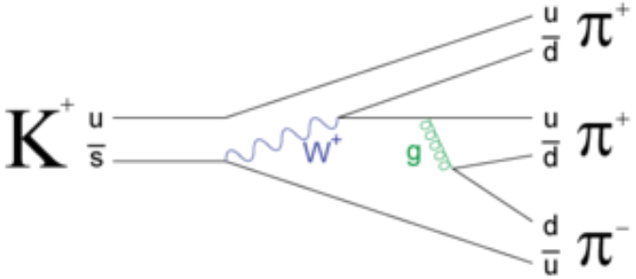
D

2

Hydrogen or Deuterium is processed to a ultra-dense phase .

Annihilation of hydrogen clusters

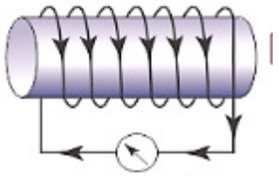
- K- & Pi Mesons and decays into Muons
- D(0) →⋯→⋯→ K±(kaon) → π±(pion) → μ±(Muon) → e±(electron)



$$\pi^0 \rightarrow \gamma_1 + \gamma_2,$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu \rightarrow e^+ + \nu_e + \bar{\nu}_\mu + \nu_\mu,$$

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu \rightarrow e^- + \bar{\nu}_e + \nu_\mu + \bar{\nu}_\mu.$$



Direct Electrical Power

Muon Catalyzed Fusion

Thank you!

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