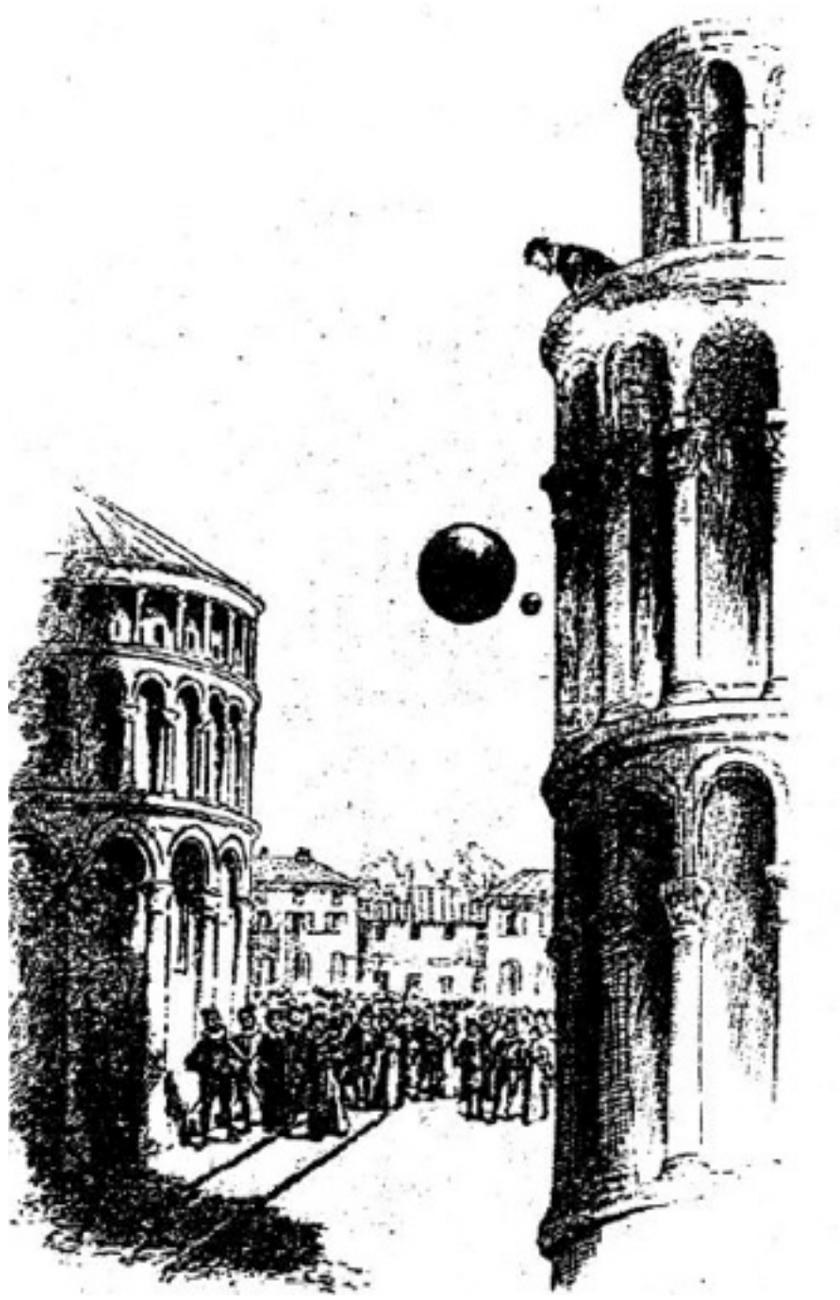


The AEgIS Experiment

Measuring the Gravitational Interaction of Antimatter

Michael Doser / CERN

AEgIS Collaboration

CERN, Switzerland

INFN Genova, Italy
INFN Bologna, Italy

Kirchhoff Institute of Physics,
Heidelberg, Germany

Max-Planck-Institut für
Kernphysik Heidelberg, Germany

INFN, Università degli Studi and
Politecnico Milano, Italy

INFN Pavia-Brescia, Italy

INR Moscow, Russia

Université Claude Bernard,
Lyon, France

University of Oslo and University
of Bergen, Norway

Czech Technical University,
Prague, Czech Republic

INFN Padova-Trento, Italy

ETH Zurich, Switzerland

Laboratoire Aimé Cotton,
Orsay, France

University College, London,
United Kingdom

Stefan Meyer Institut,
Vienna, Austria

University of Bern, Switzerland

AEgIS Experimental Goal

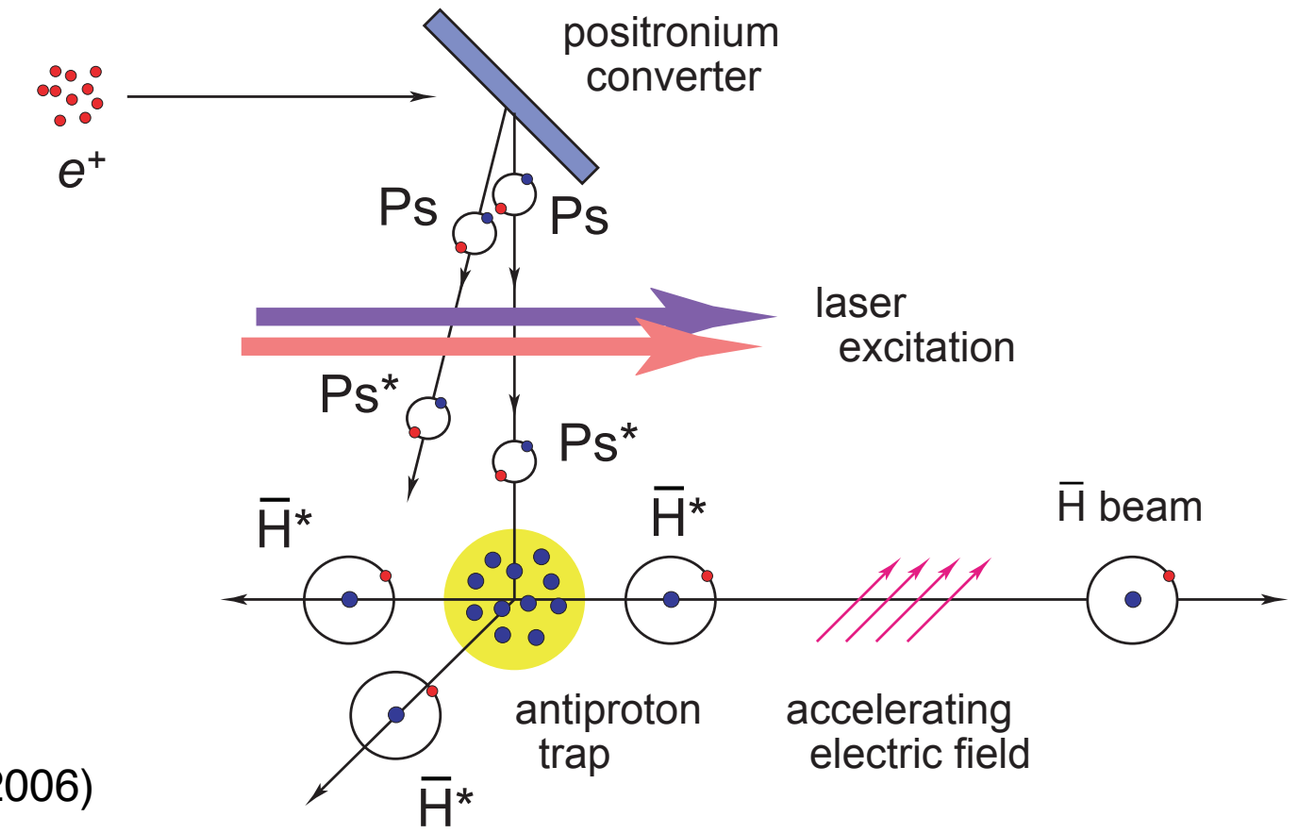
- Primary goal:
  - Measurement of gravitational acceleration **g** for antihydrogen with 1% accuracy

- Secondary goals:
  - Spectroscopy of antihydrogen
  - Study of Rydberg atoms
  - Positronium physics: formation, excitation, spectroscopy
  - PALS with different materials

AEgIS Experimental Strategy

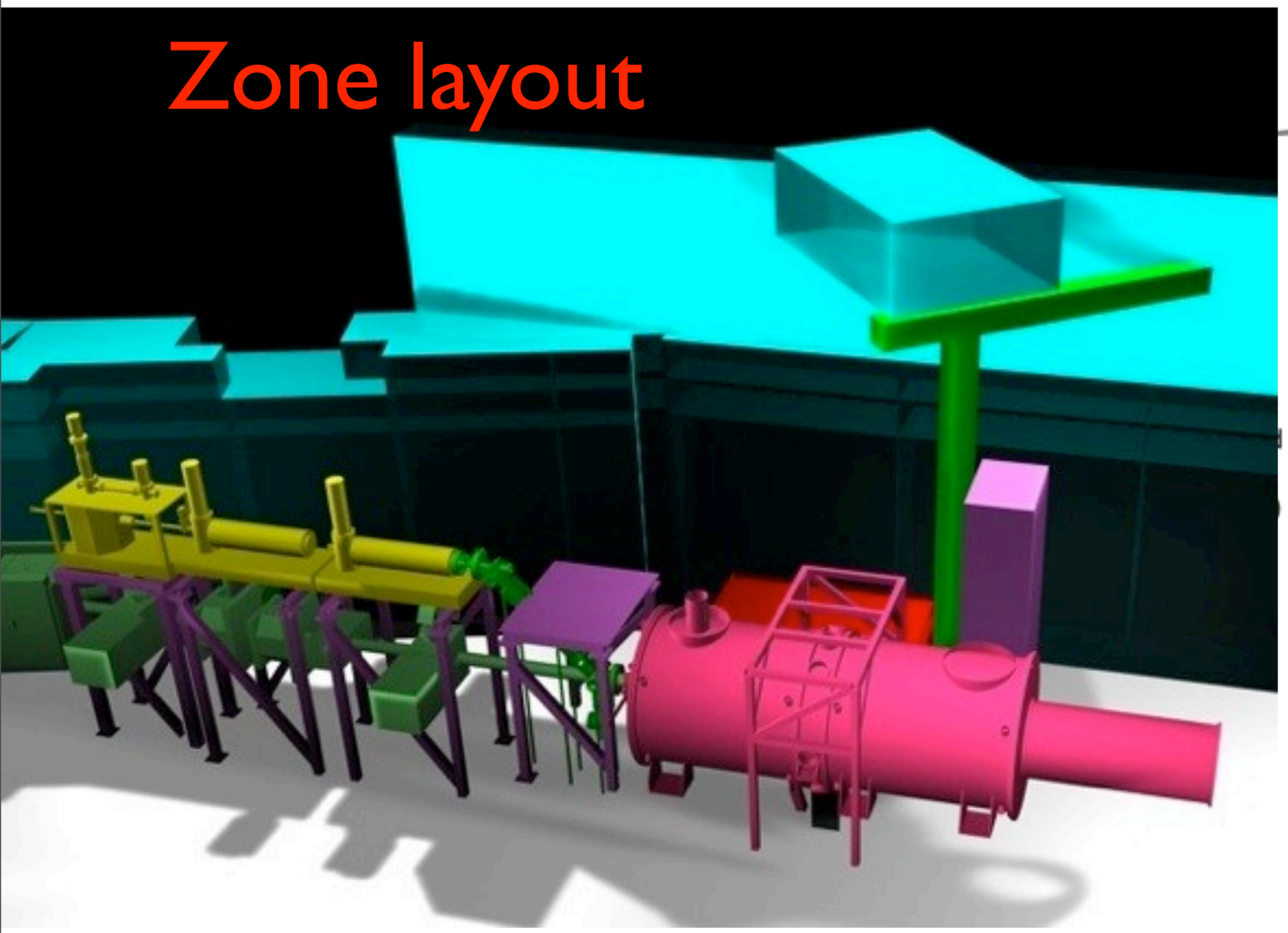
- Produce ultra cold antiprotons
- Form positronium by interaction of positrons with a porous target (pulsed)
- Laser excite Ps to get Rydberg Ps (pulsed)
- Form Rydberg cold antihydrogen (pulsed) by $Ps^* + \overline{p} \rightarrow \overline{H}^* + e^-$
- Stark accelerate the antihydrogen with inhomogeneous electric fields

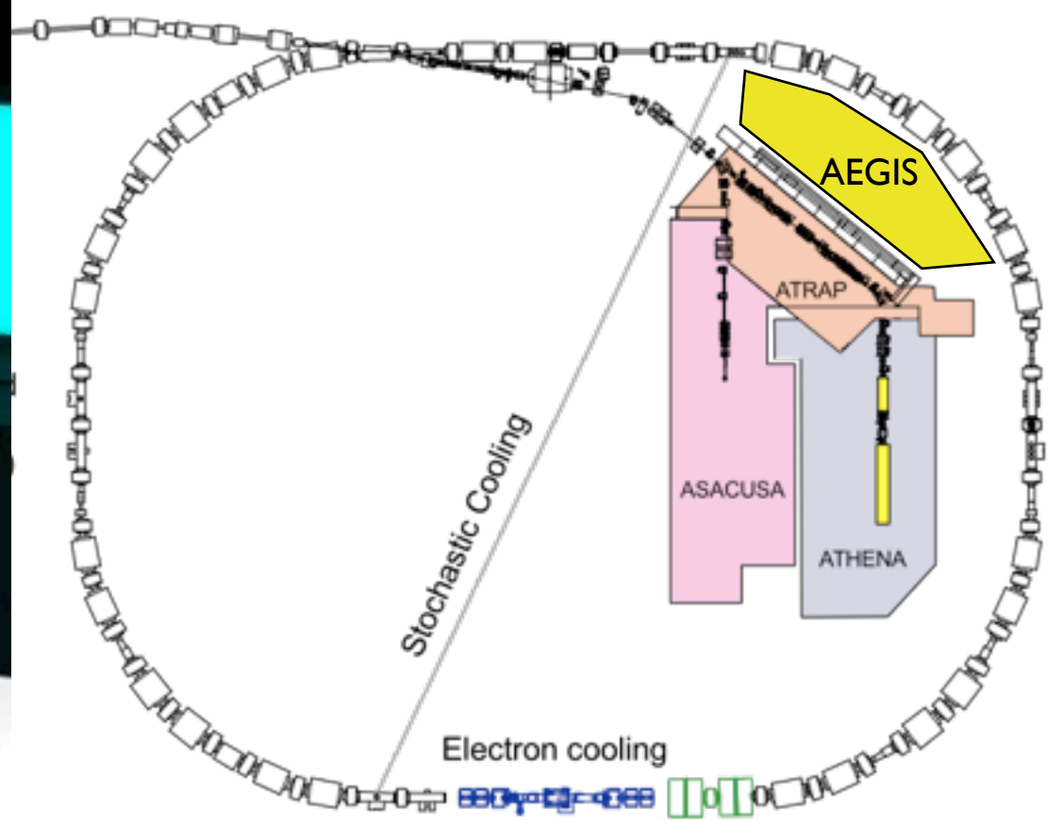
→ Pulsed production of a cold beam of antihydrogen

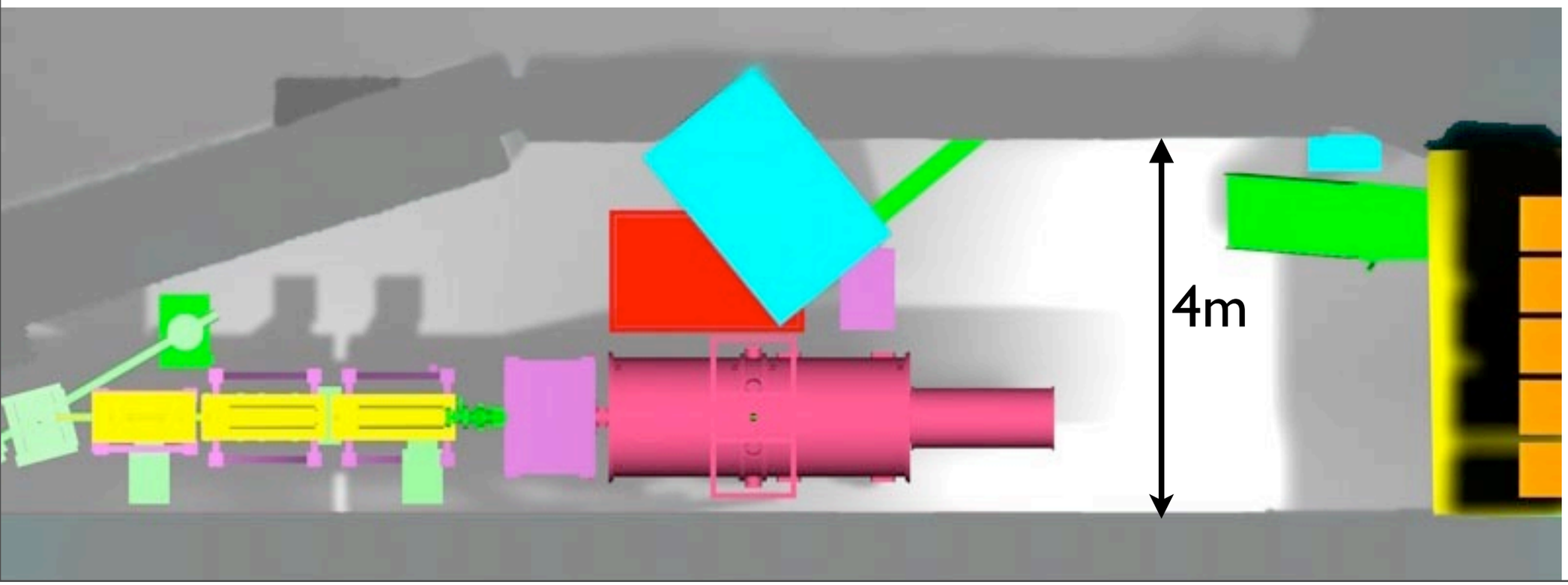


Storry et al., PRL **93**, 263401 (2004)
Vliegen and Merkt, J. Phys. B:
At. Mol. Opt. Phys. **39**, L241 (2006)

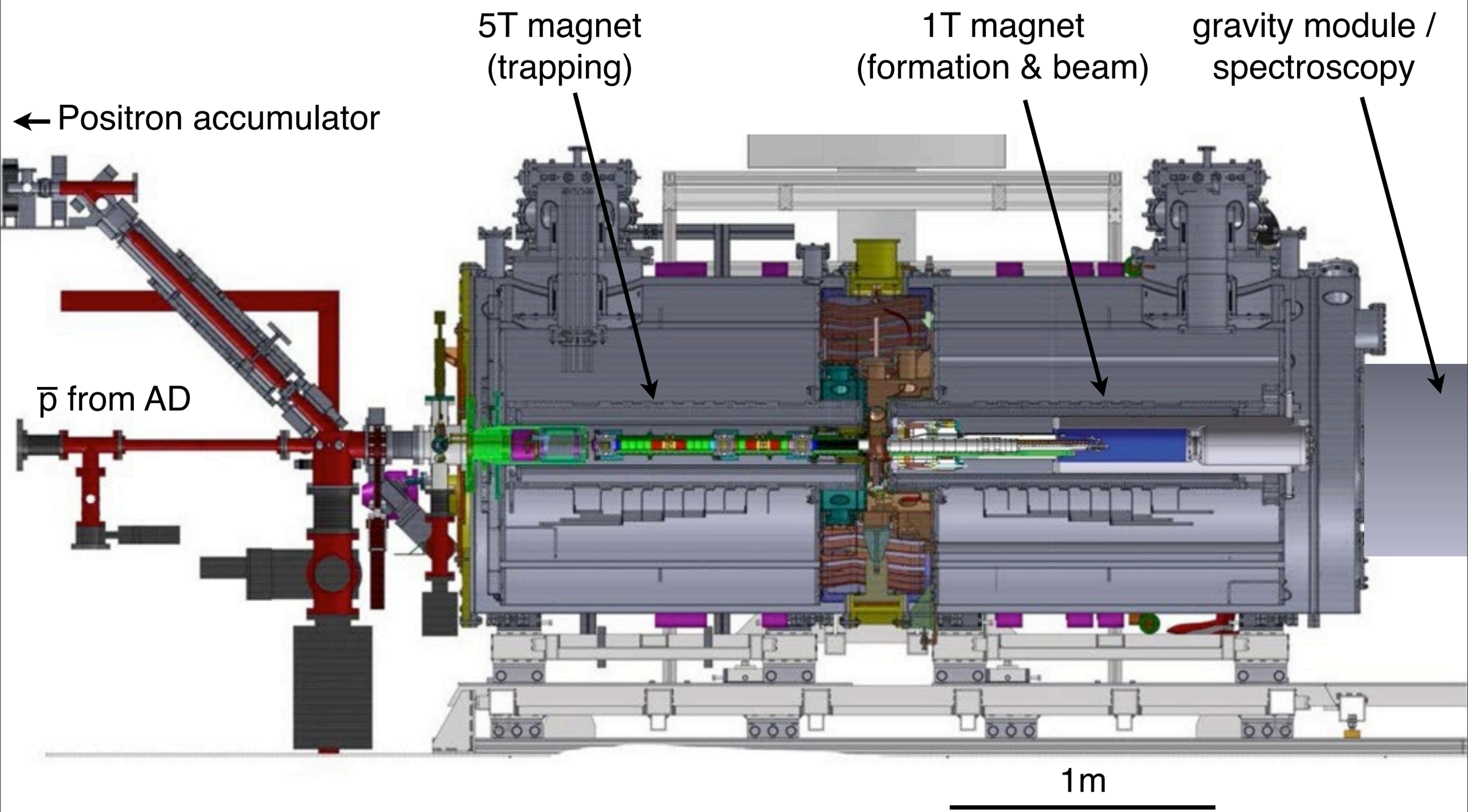
Zone layout




AEGIS
ATRAP
ASACUSA
ATHENA
Stochastic Cooling
Electron cooling

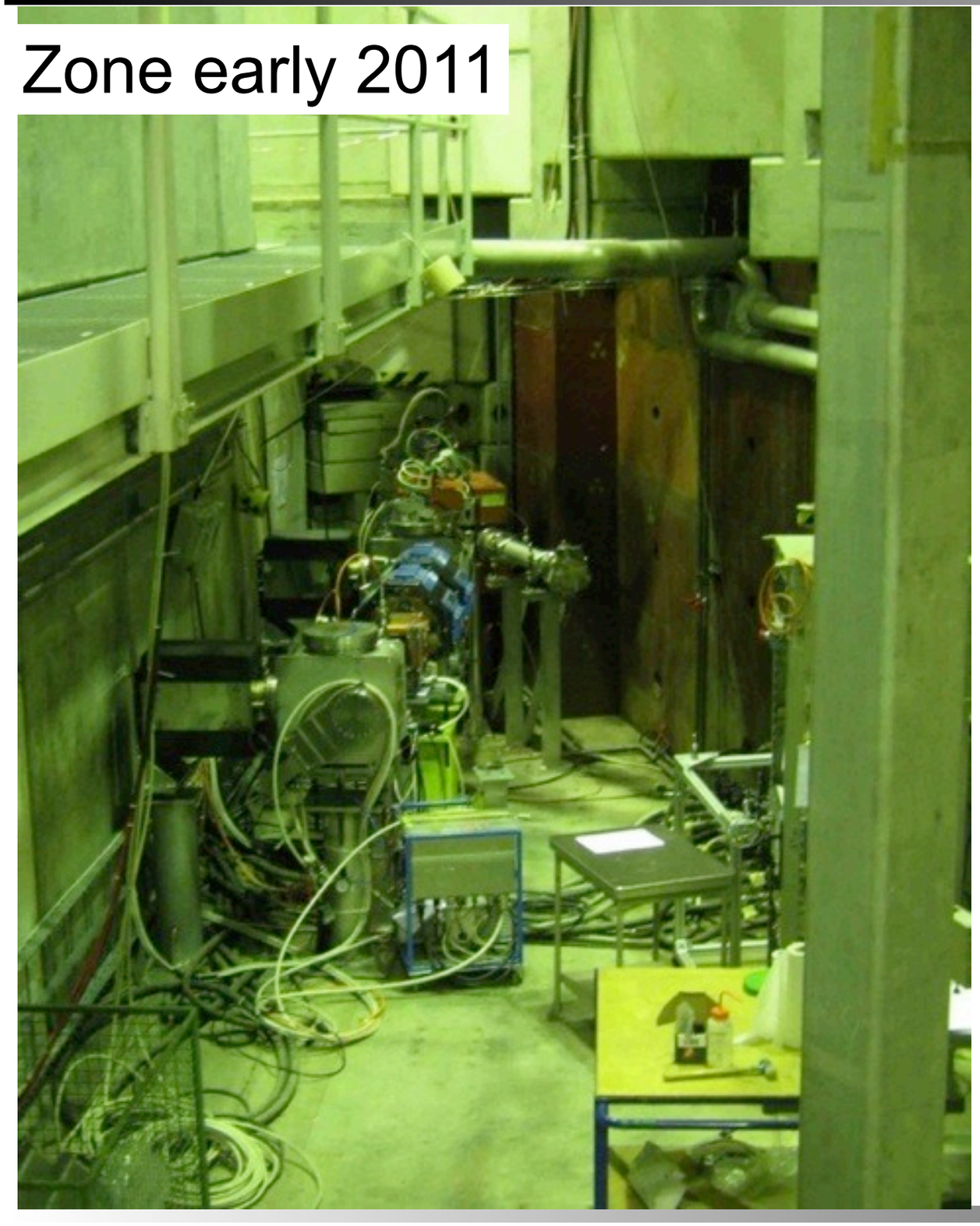

4m

Experimental Apparatus @ CERN



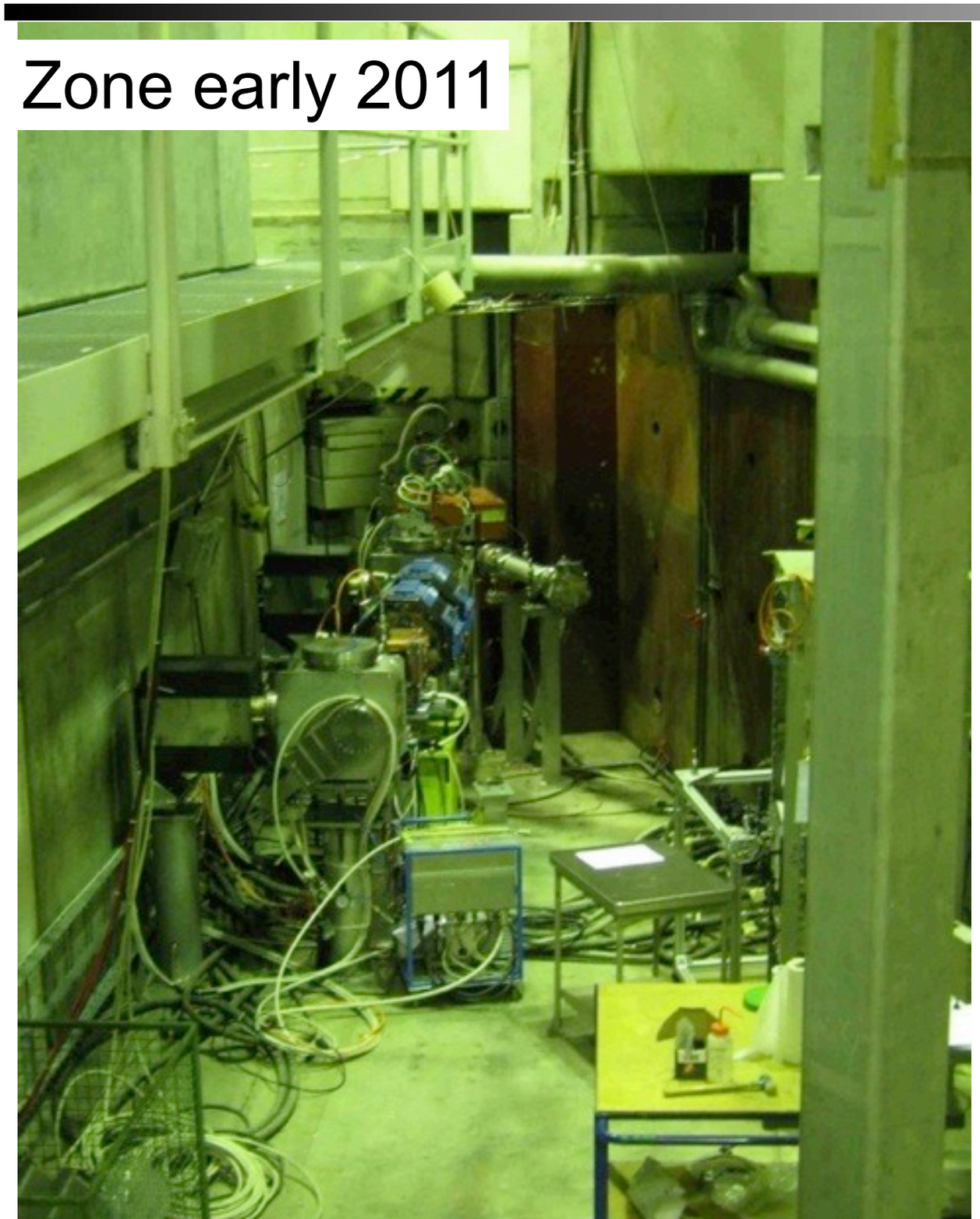
Experimental Installation

Zone early 2011

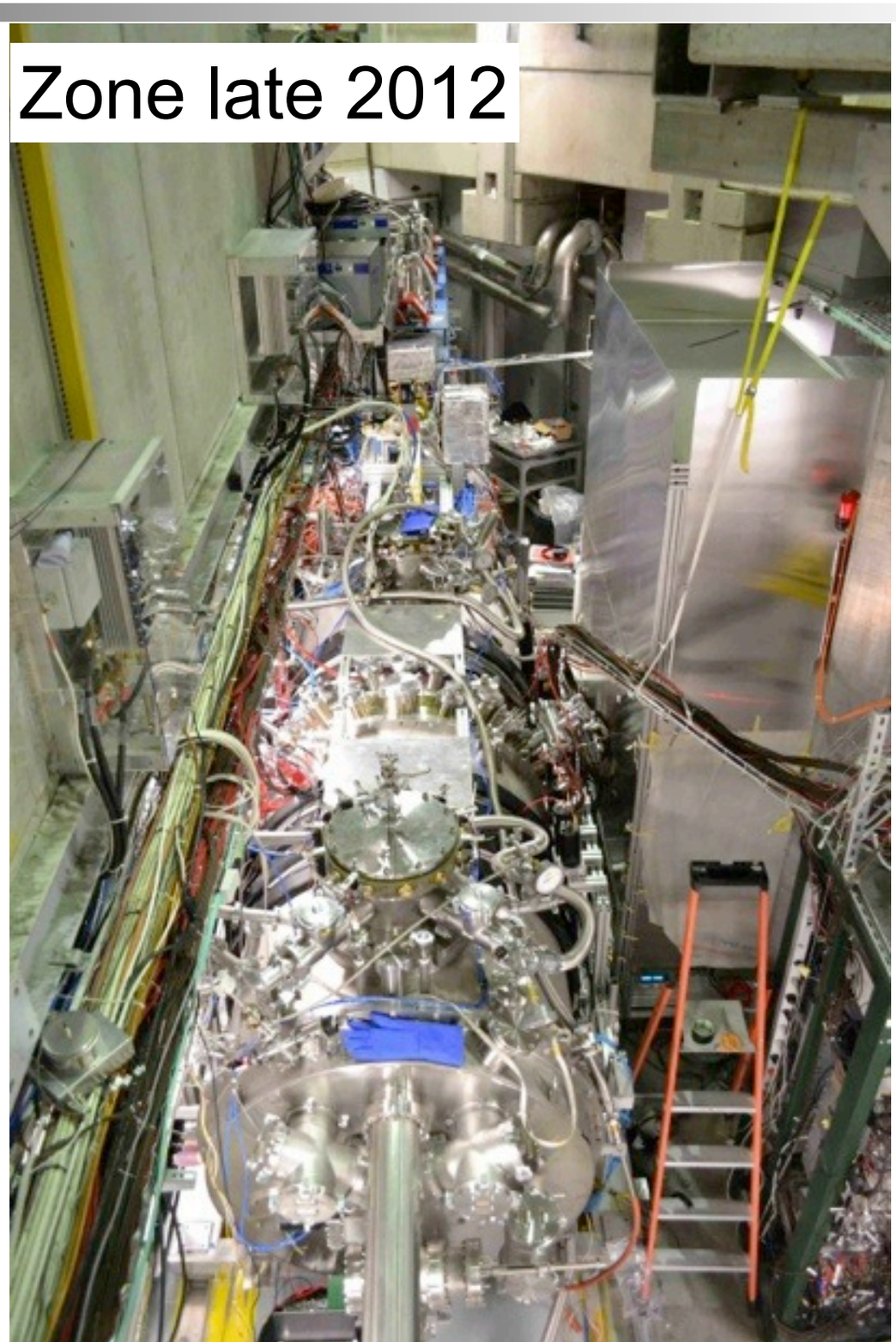


Experimental Installation

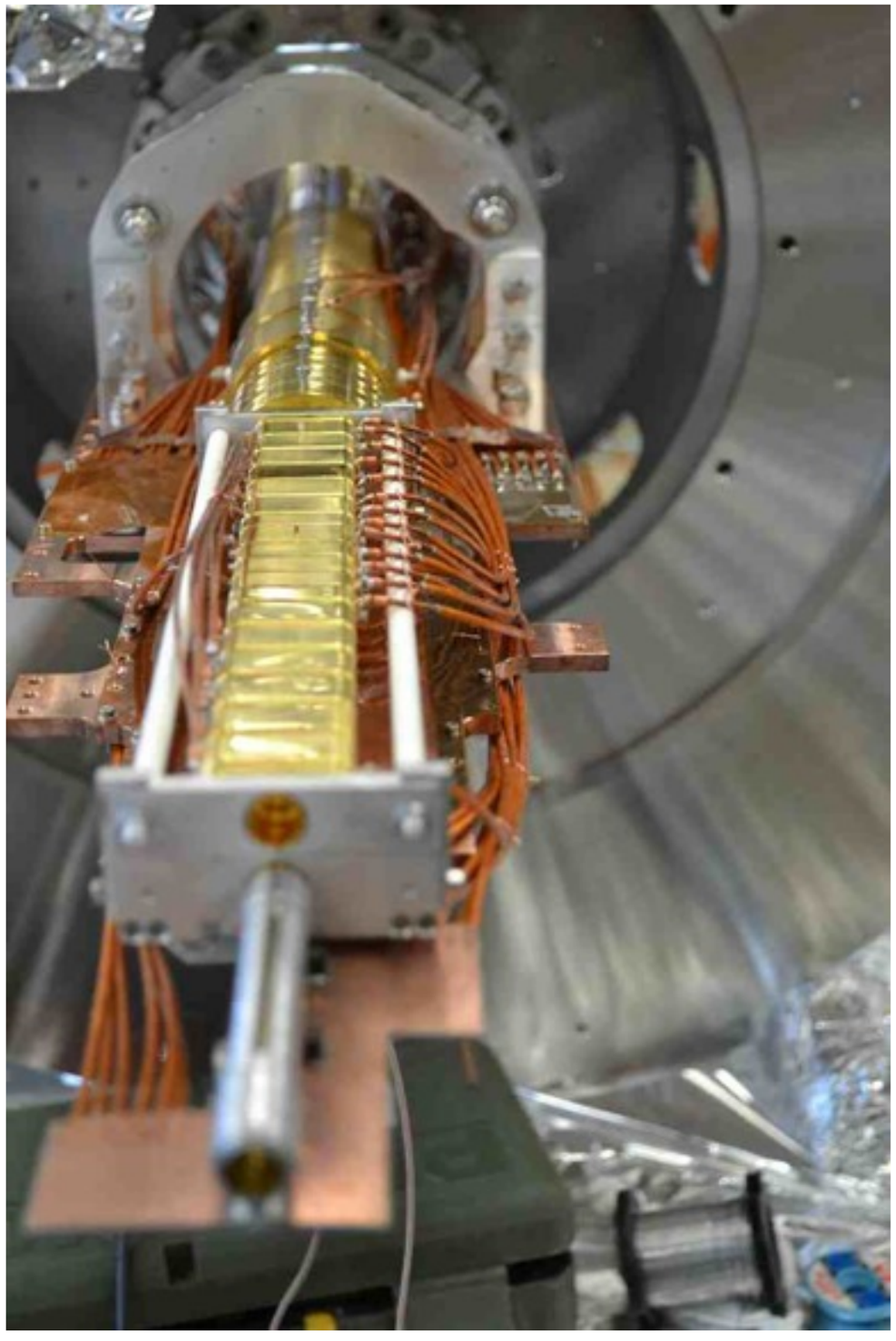
Zone early 2011

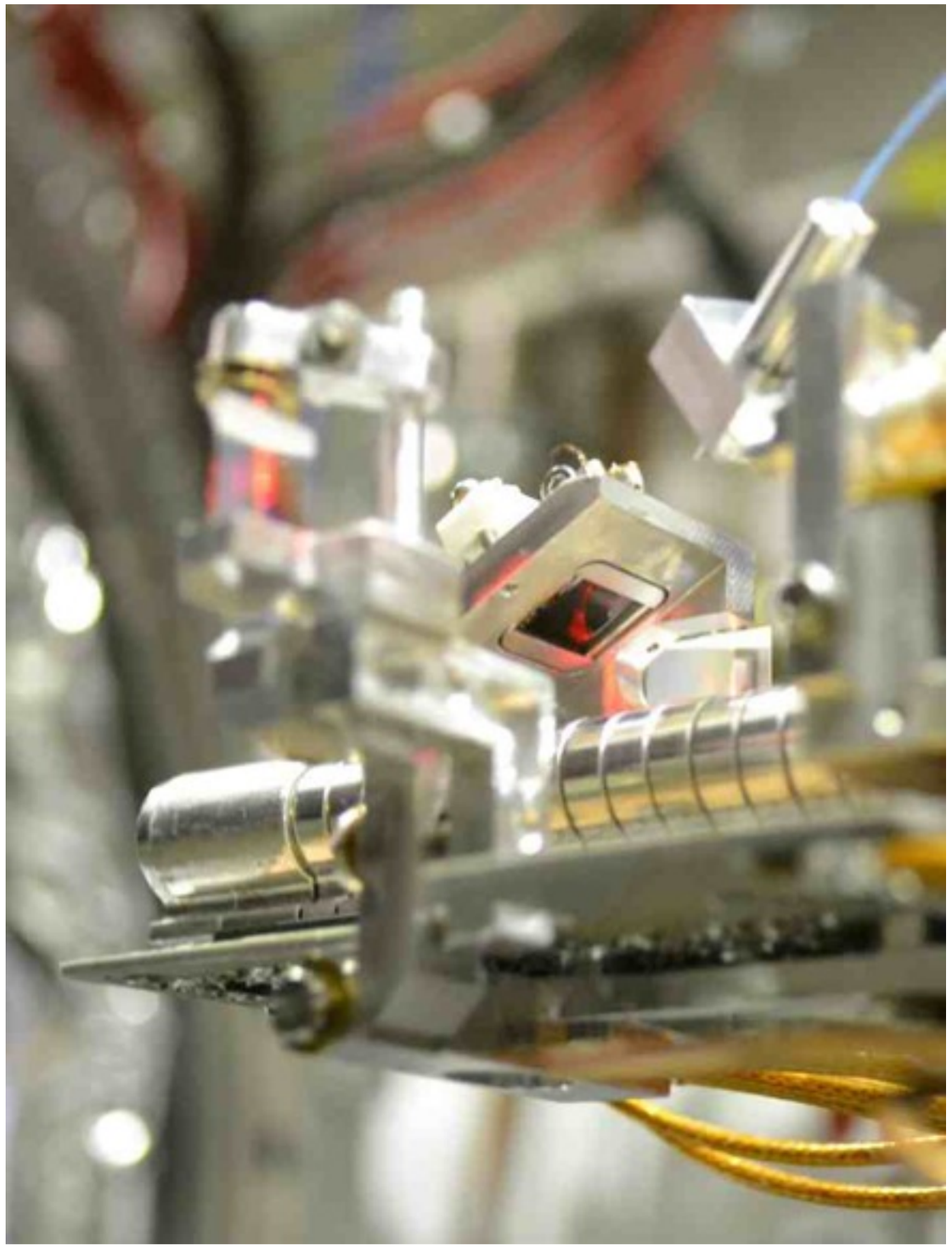


Zone late 2012

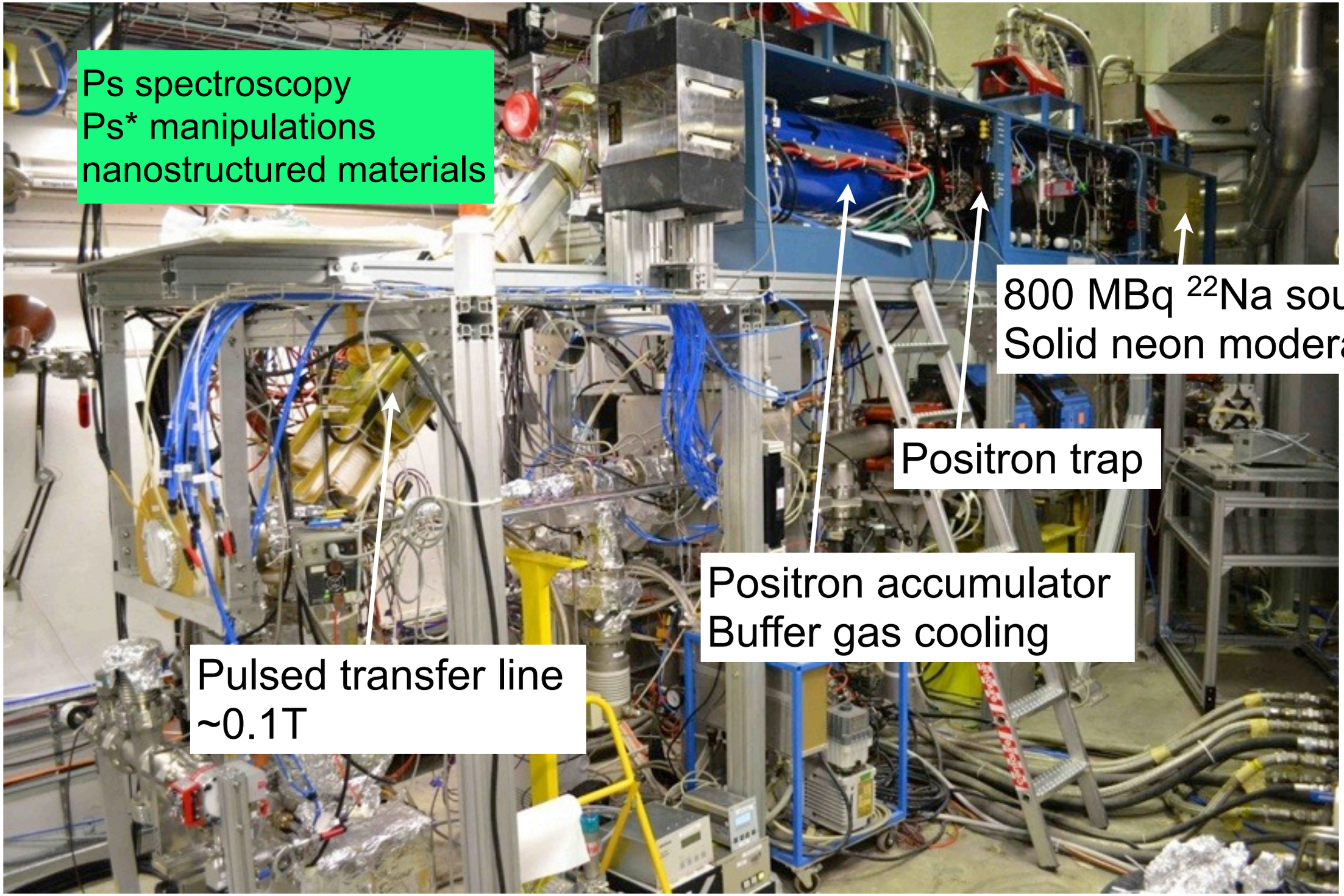


IT Formation Traps

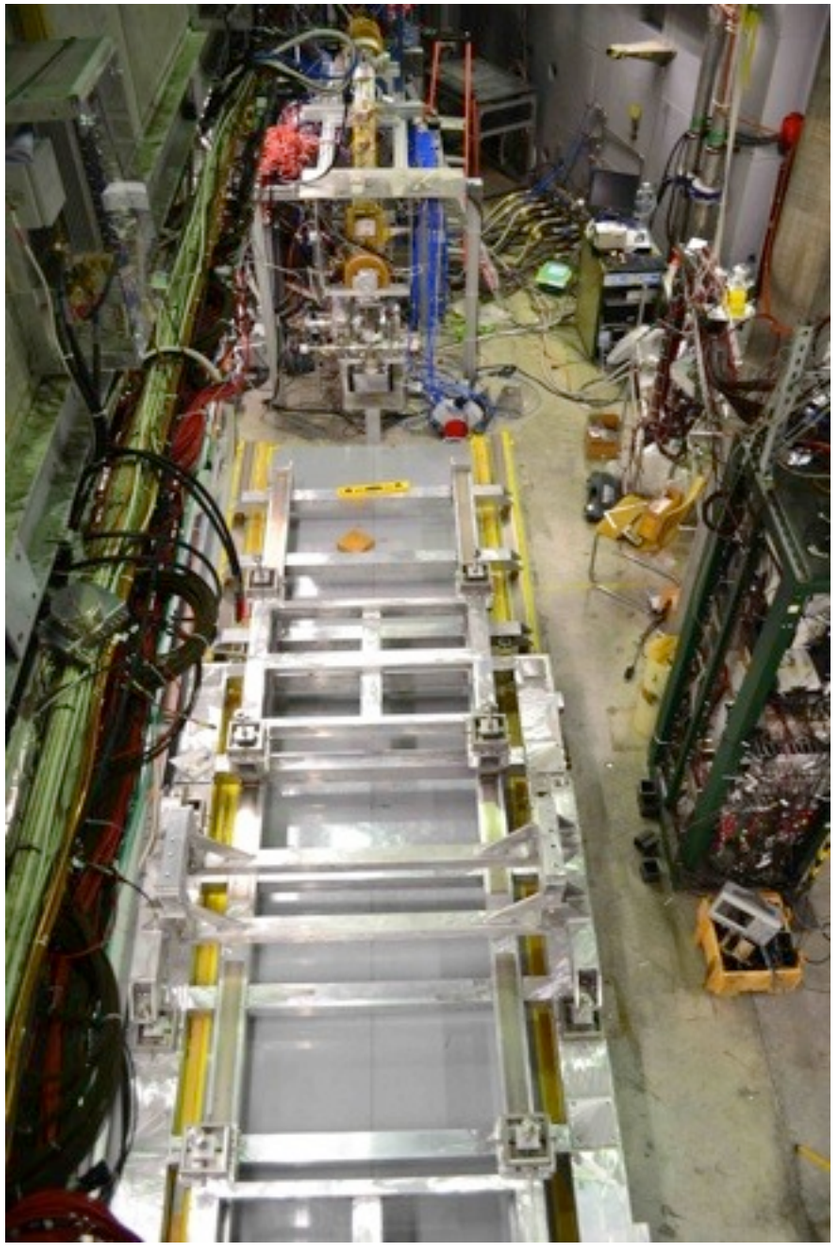
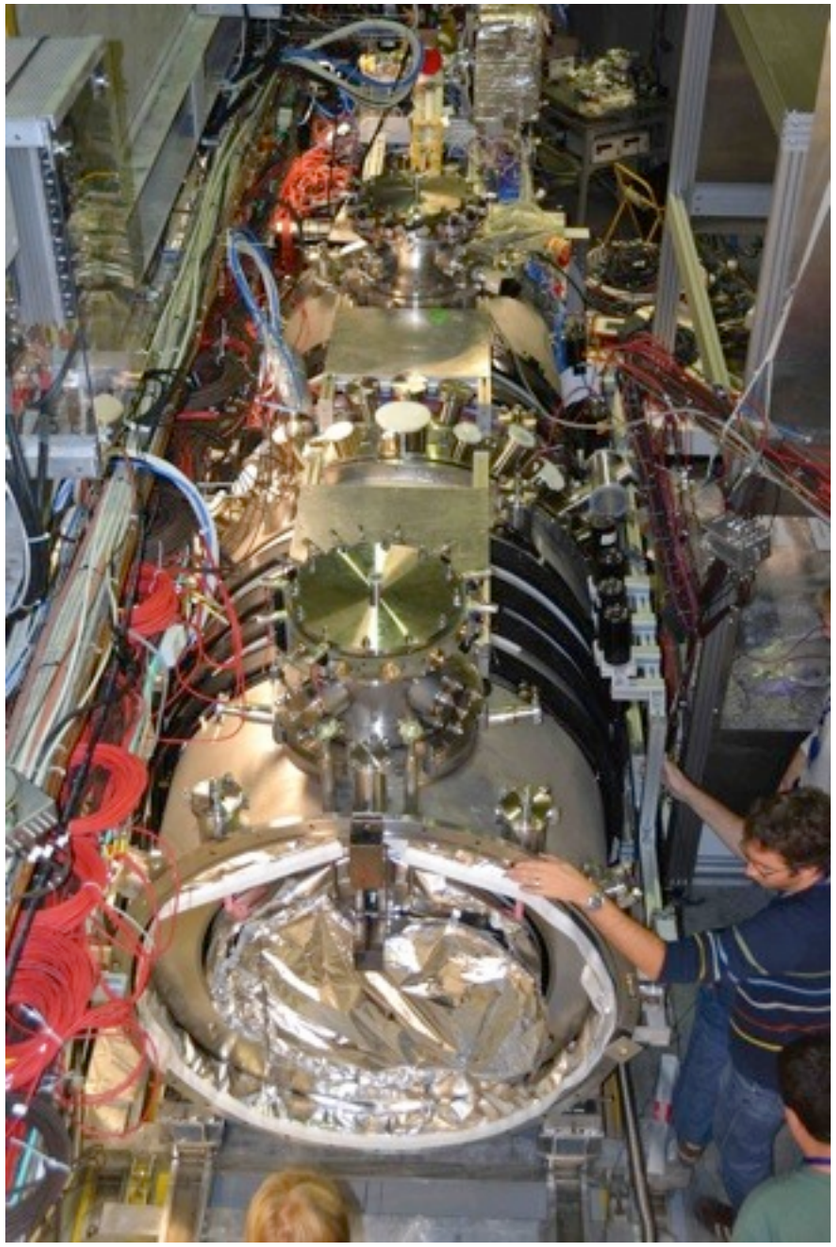
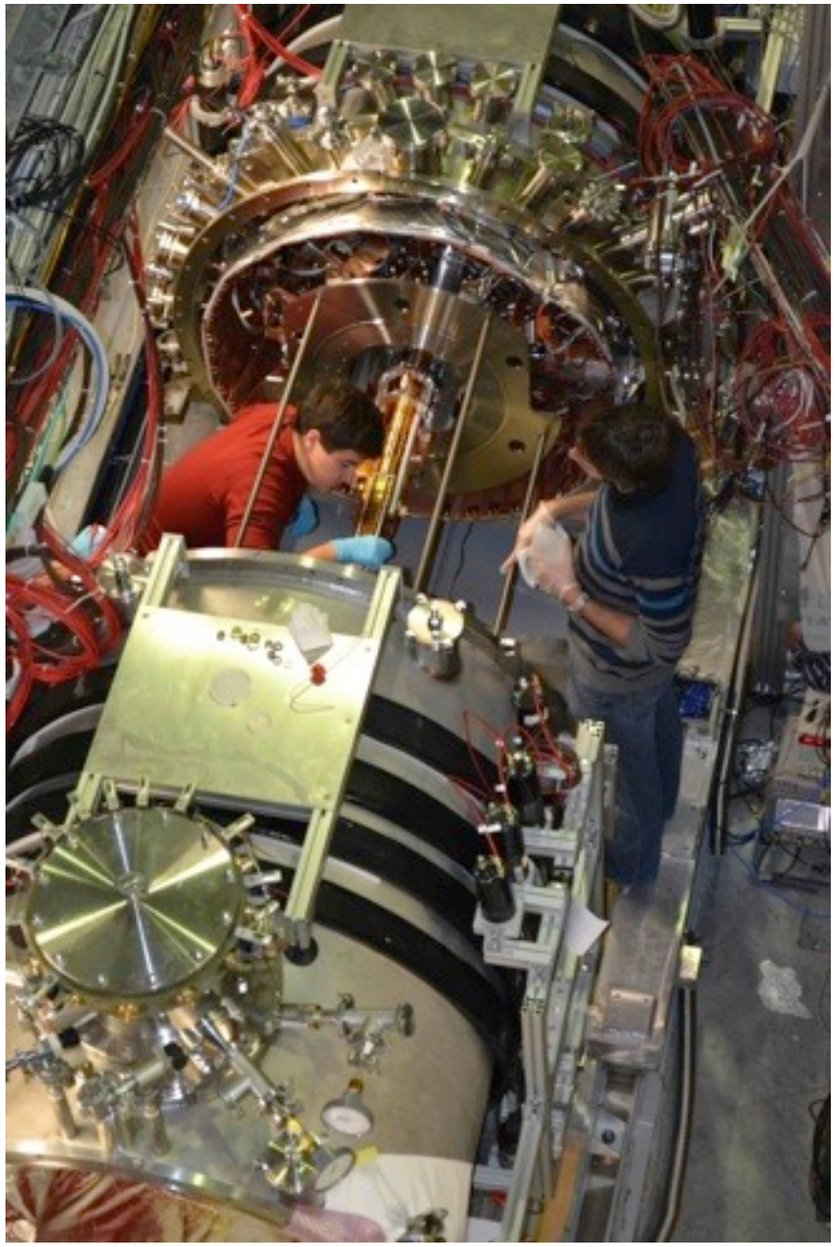




Positron System



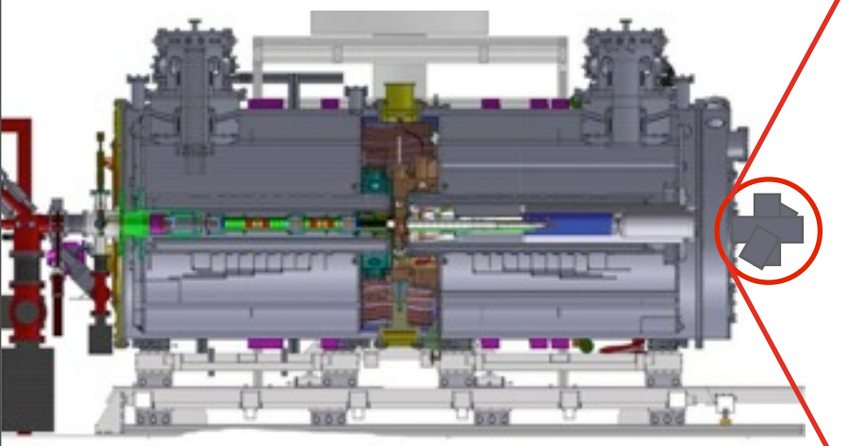
Assembly in 2012

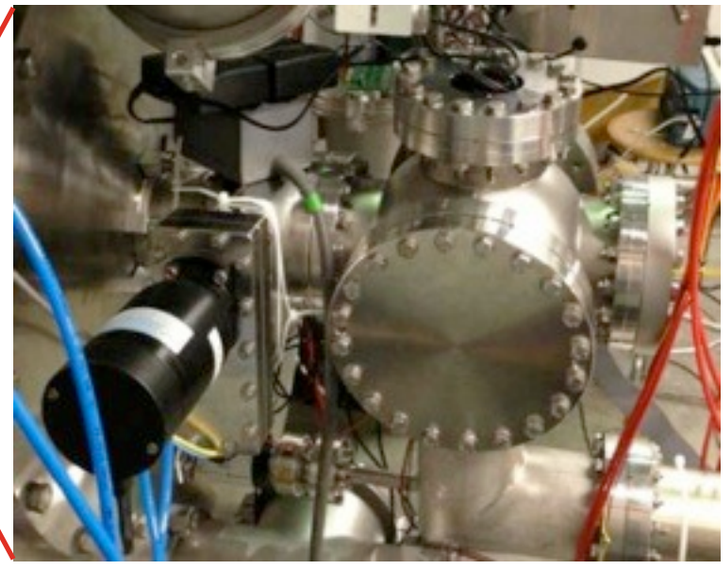




Assembly completed end of November 2012; immediate pump-down and cool-down (10 days) during which commissioning with antiprotons and positrons could take place

Detector Tests: use $\overline{p}$ to test technologies

Parasitic tests:

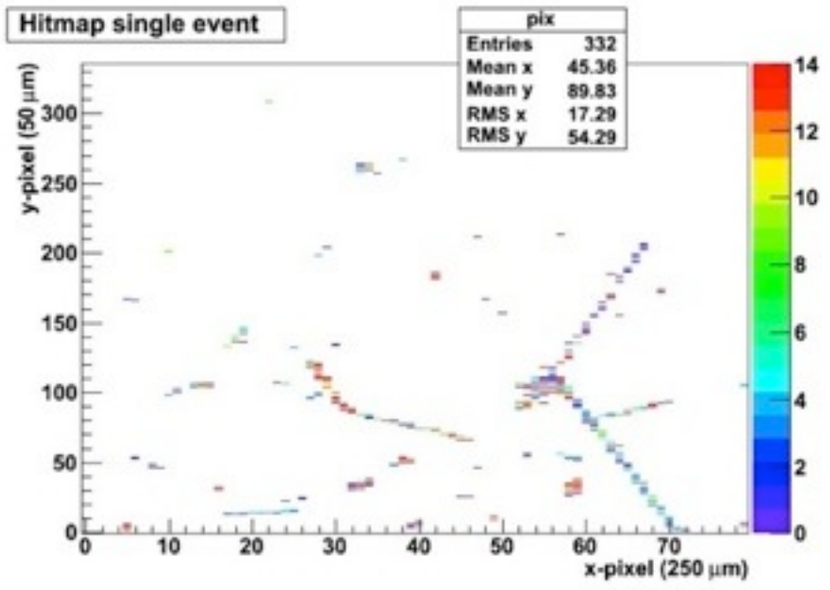




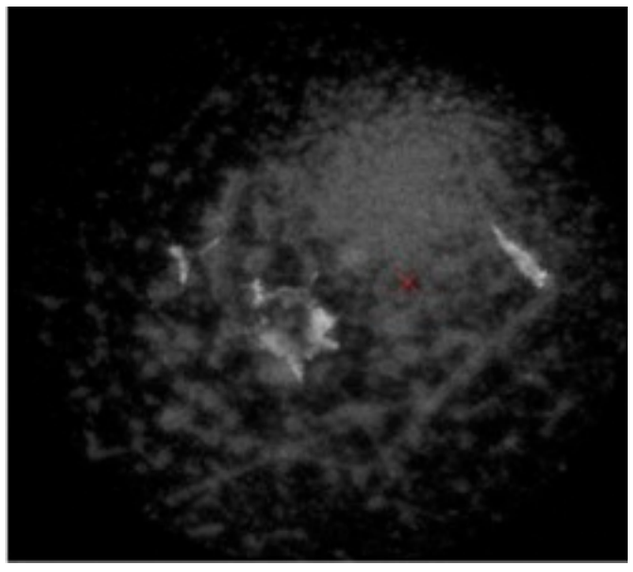
Explore different candidate technologies for the (downstream) antihydrogen detector

high spatial resolution (~ 1μm)
good timing (~ 10 μs)

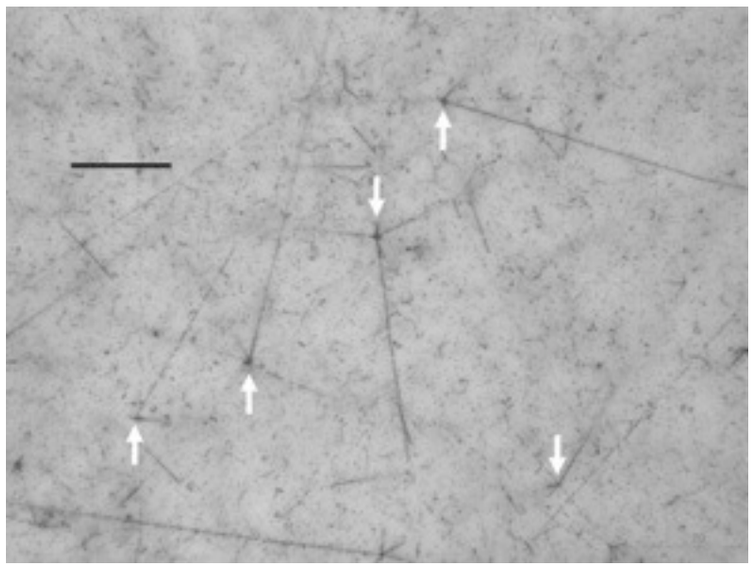
Silicon detectors (strip, pixel)



MCP

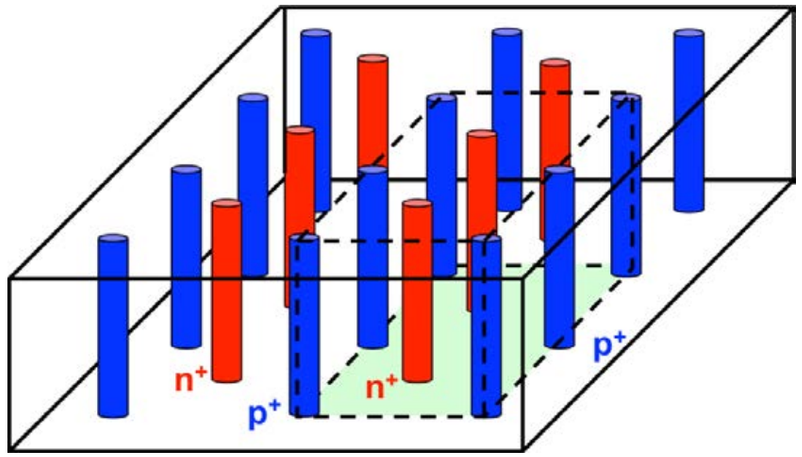


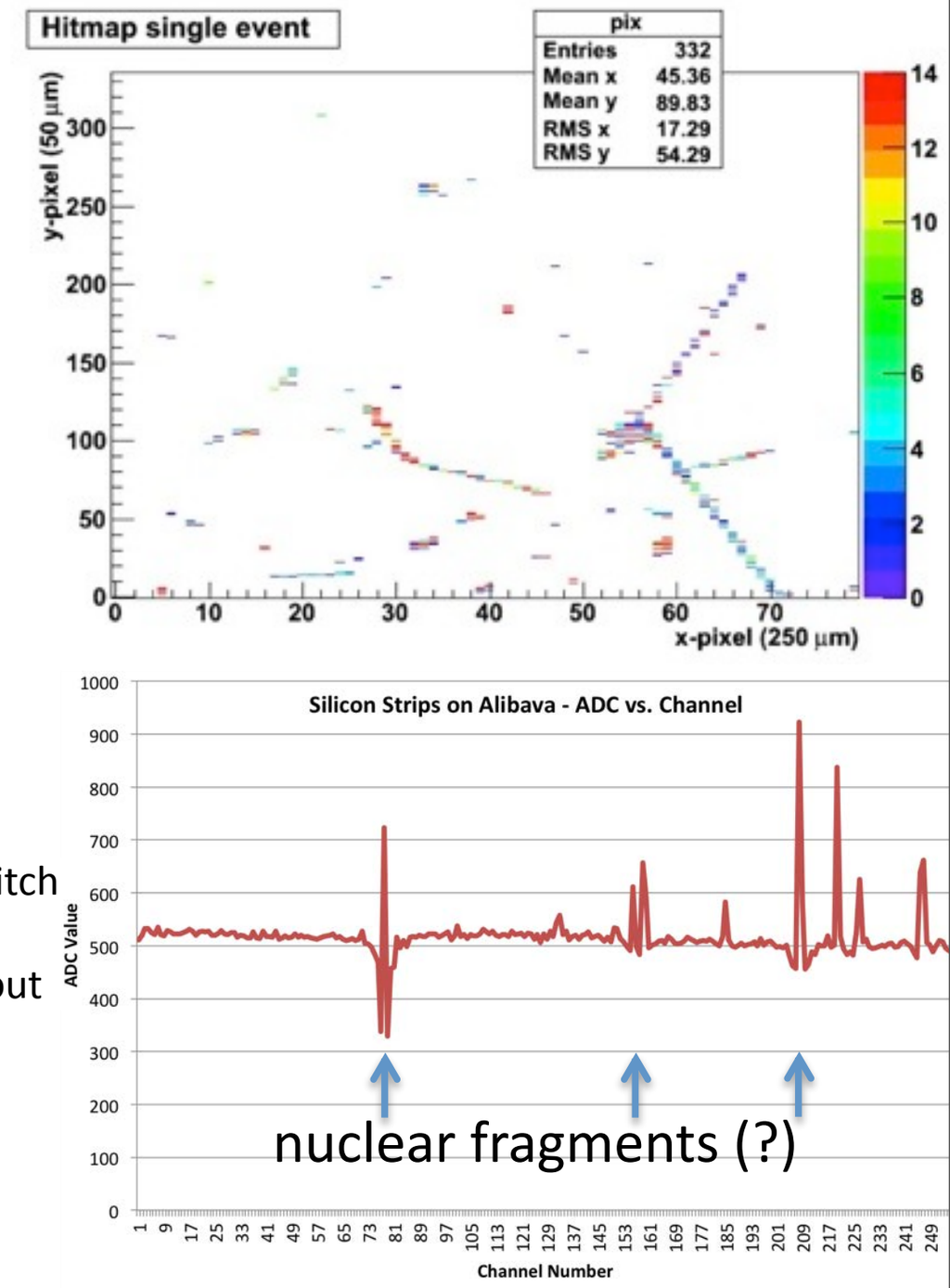
Emulsions

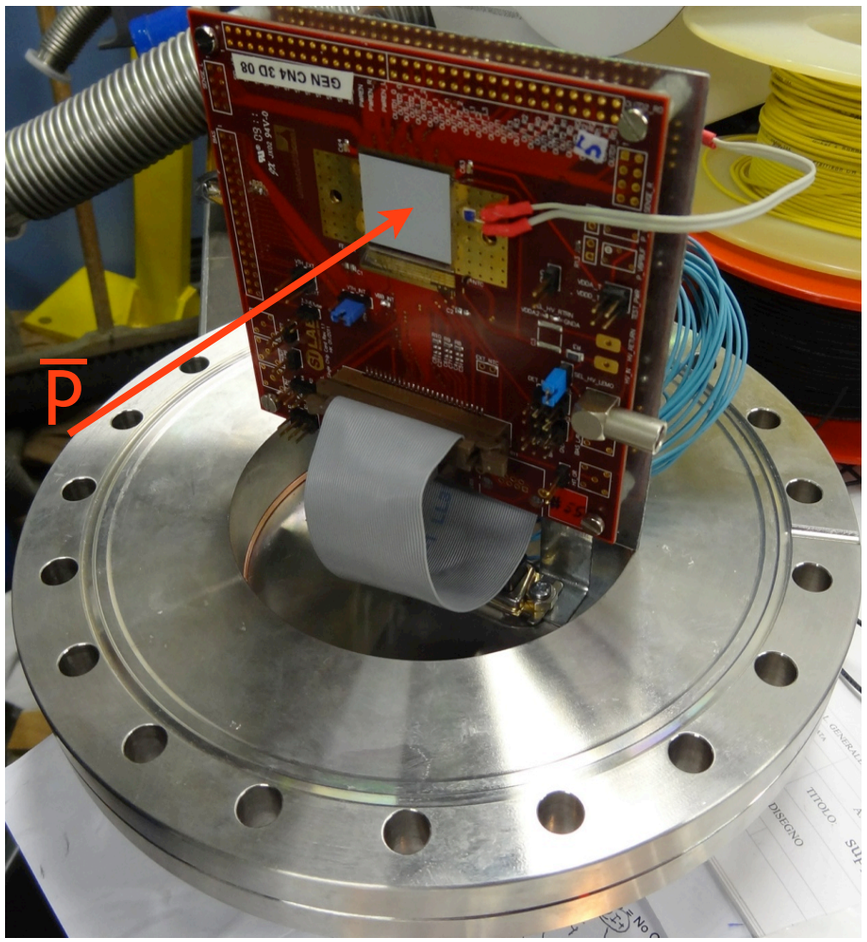


Silicon Detectors

CNM-55-3D pixel sensor bump-bonded to FE-I4 R/O chip designed for the ATLAS Insertable B layer upgrade

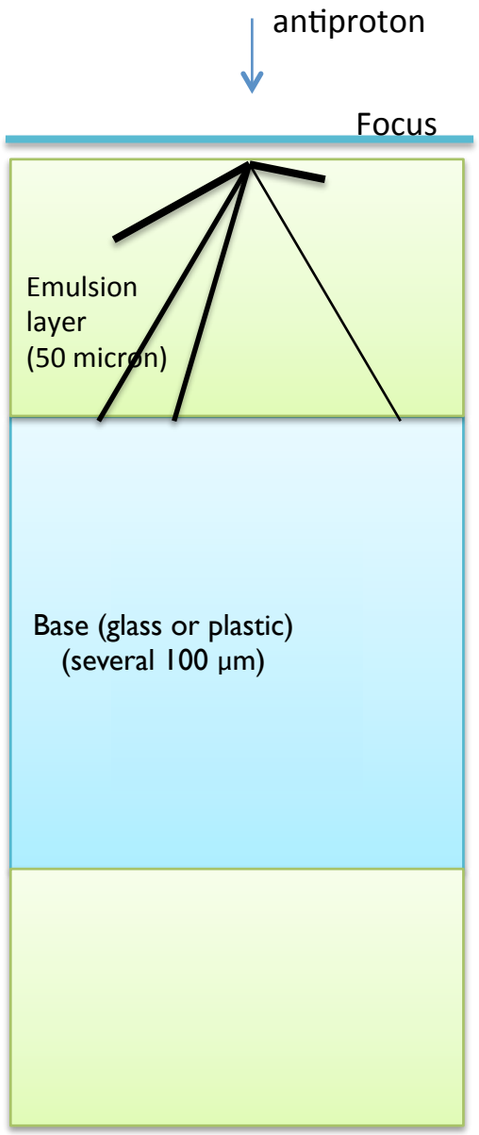






Strip sensors 50 and 80 um pitch
300 um thickness
Beetle based - Alibava readout

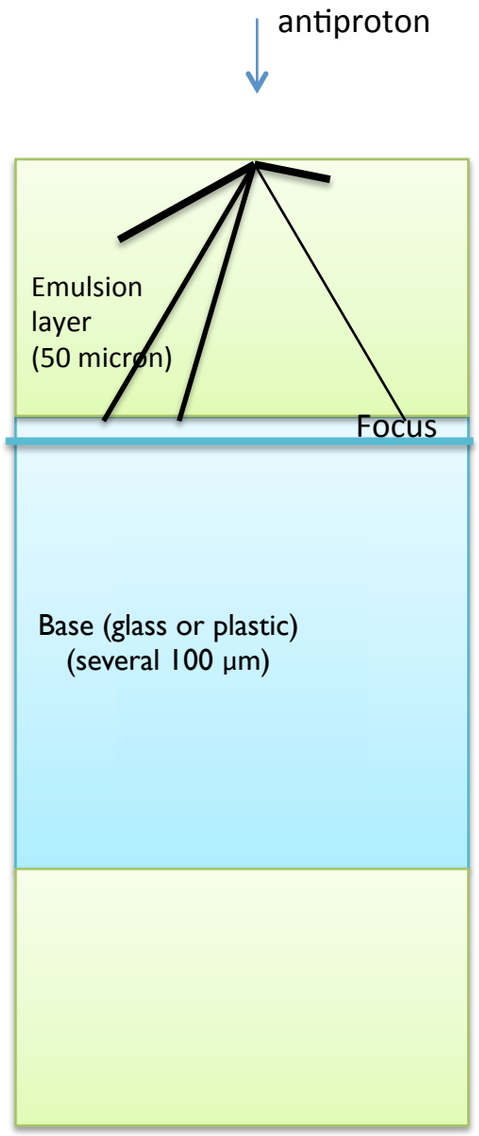
Emulsion tests

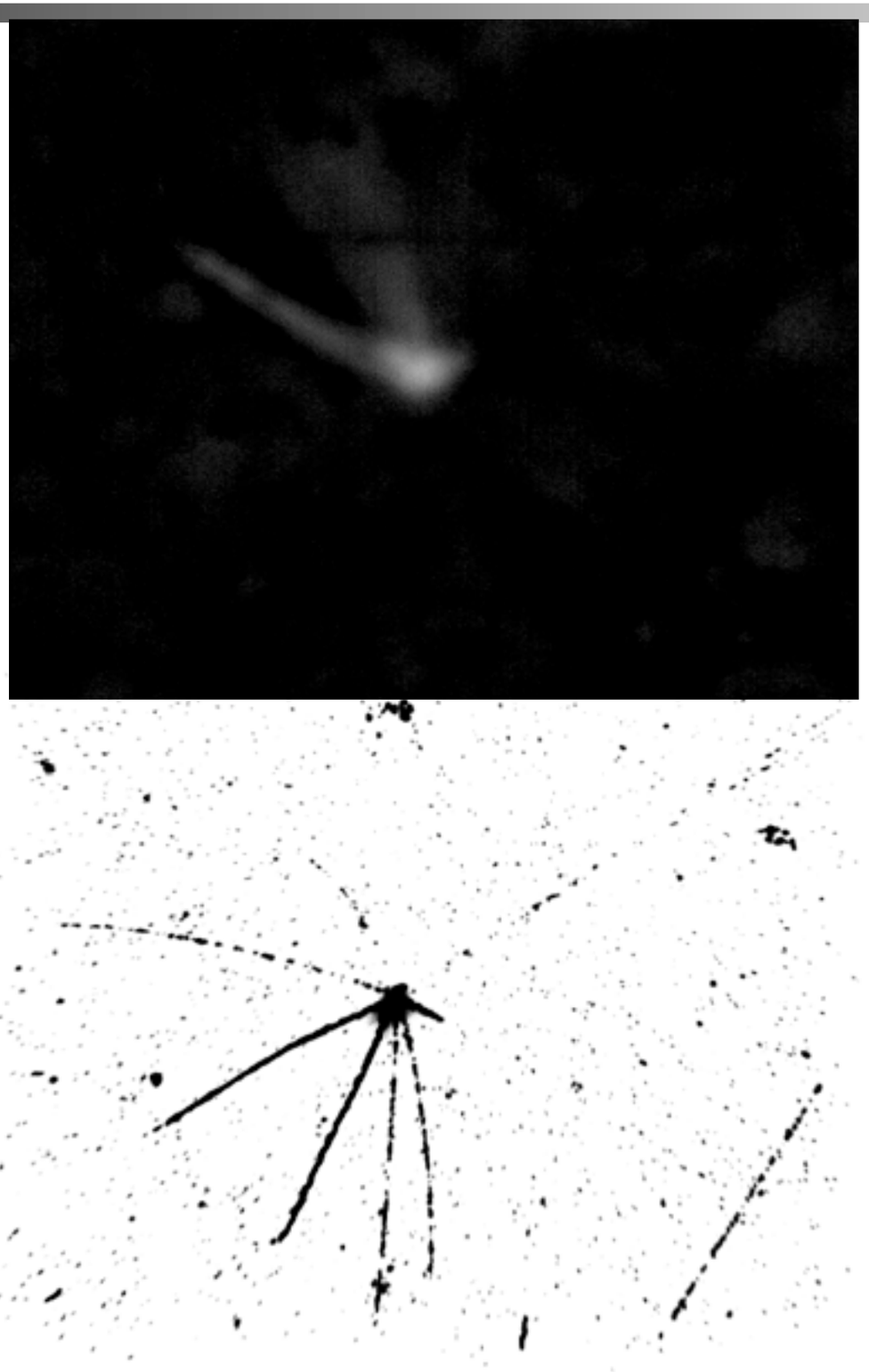


- Exposure of emulsion
- Development in dark room
- Scanning on automated microscopes

→ S. Aghion et al., J. of Instrumentation 8 (2013) P08013

Emulsion tests





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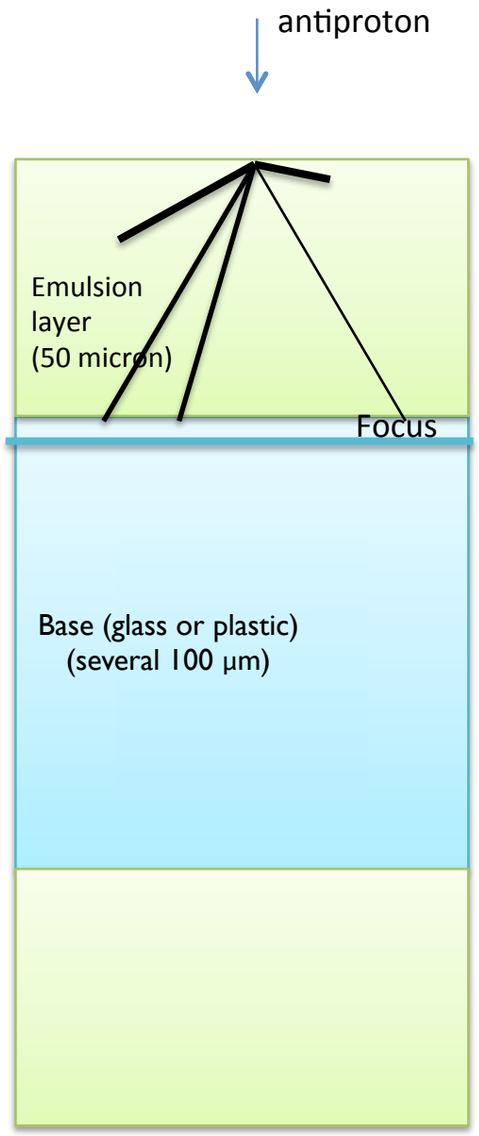
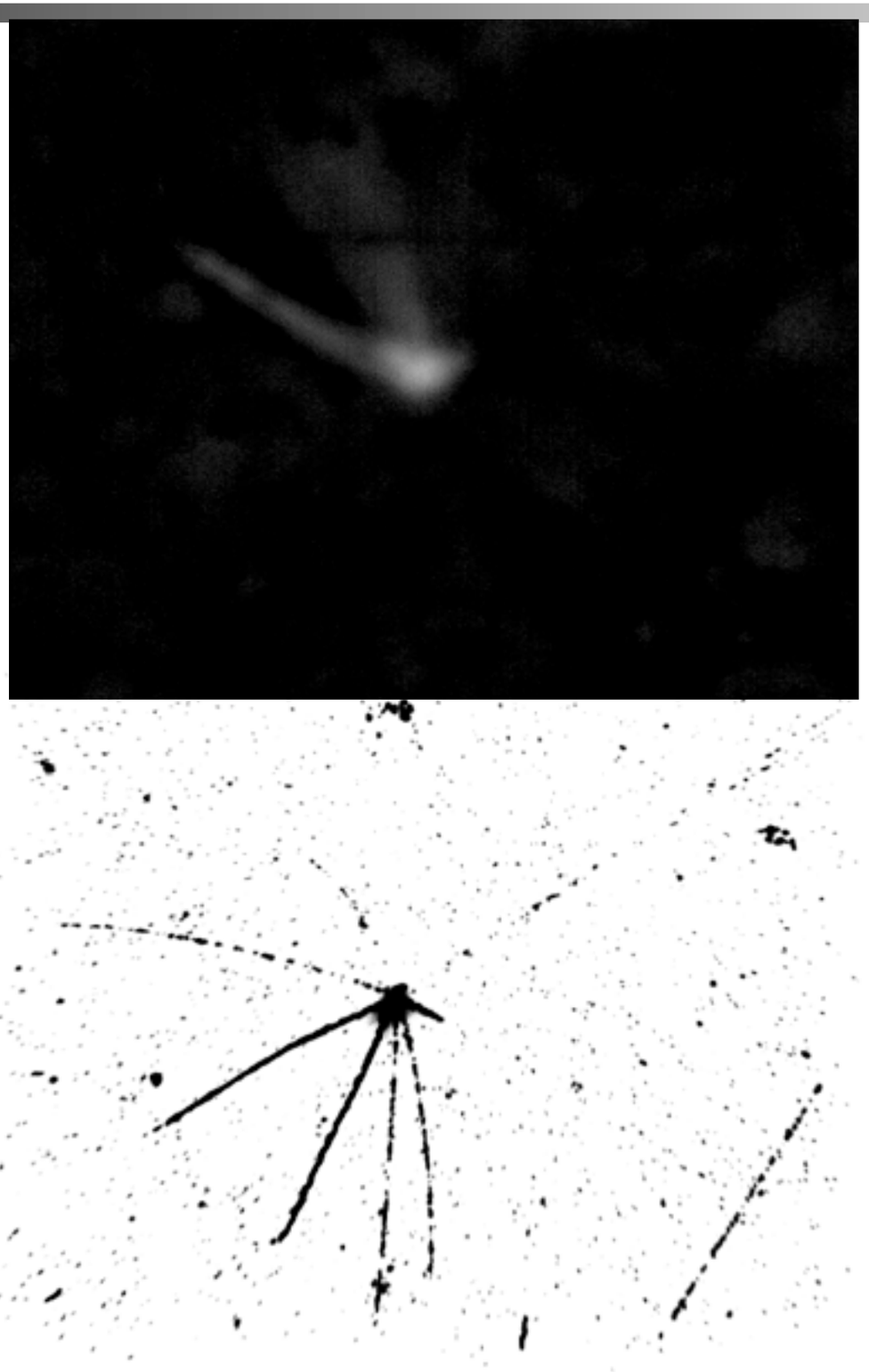
→ S. Aghion et al., J. of Instrumentation 8 (2013) P08013

Emulsion tests

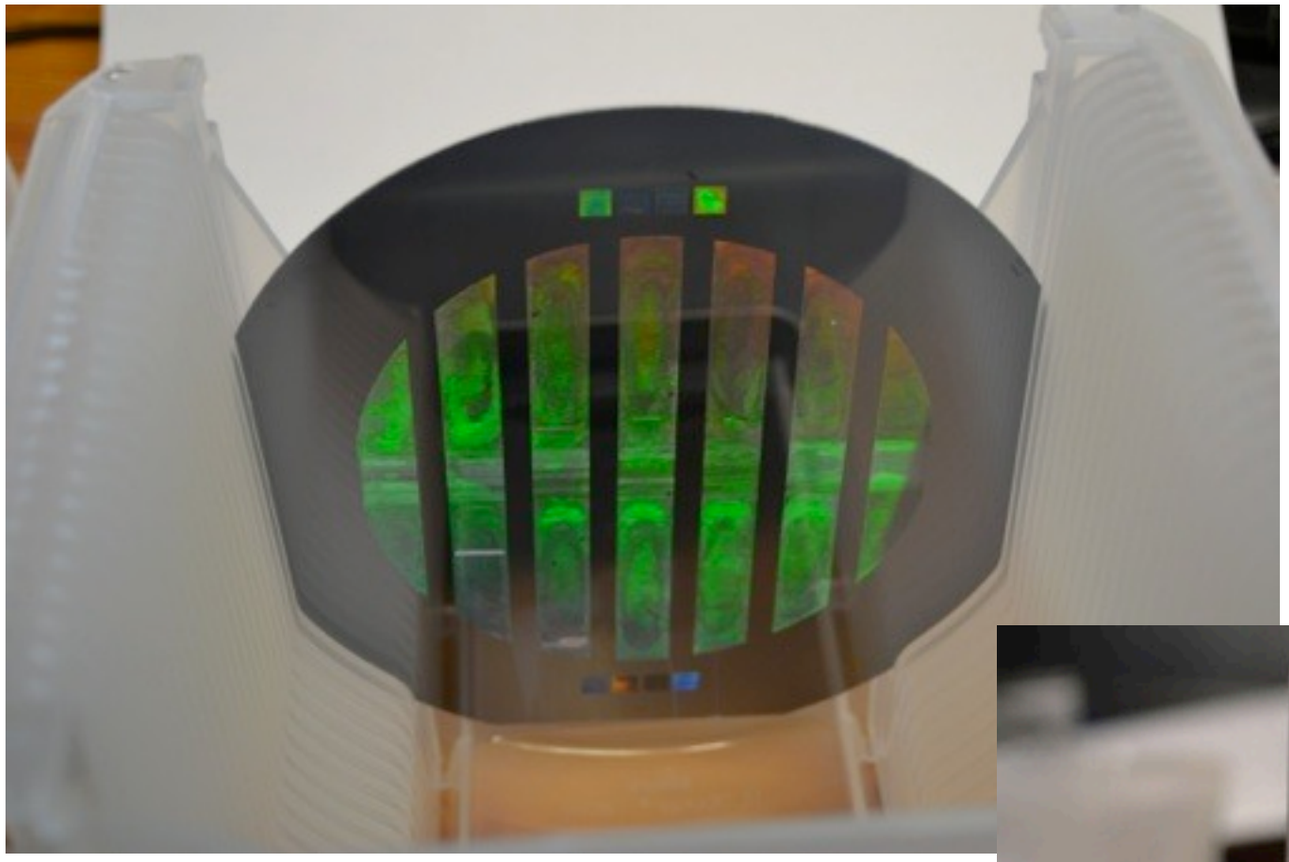


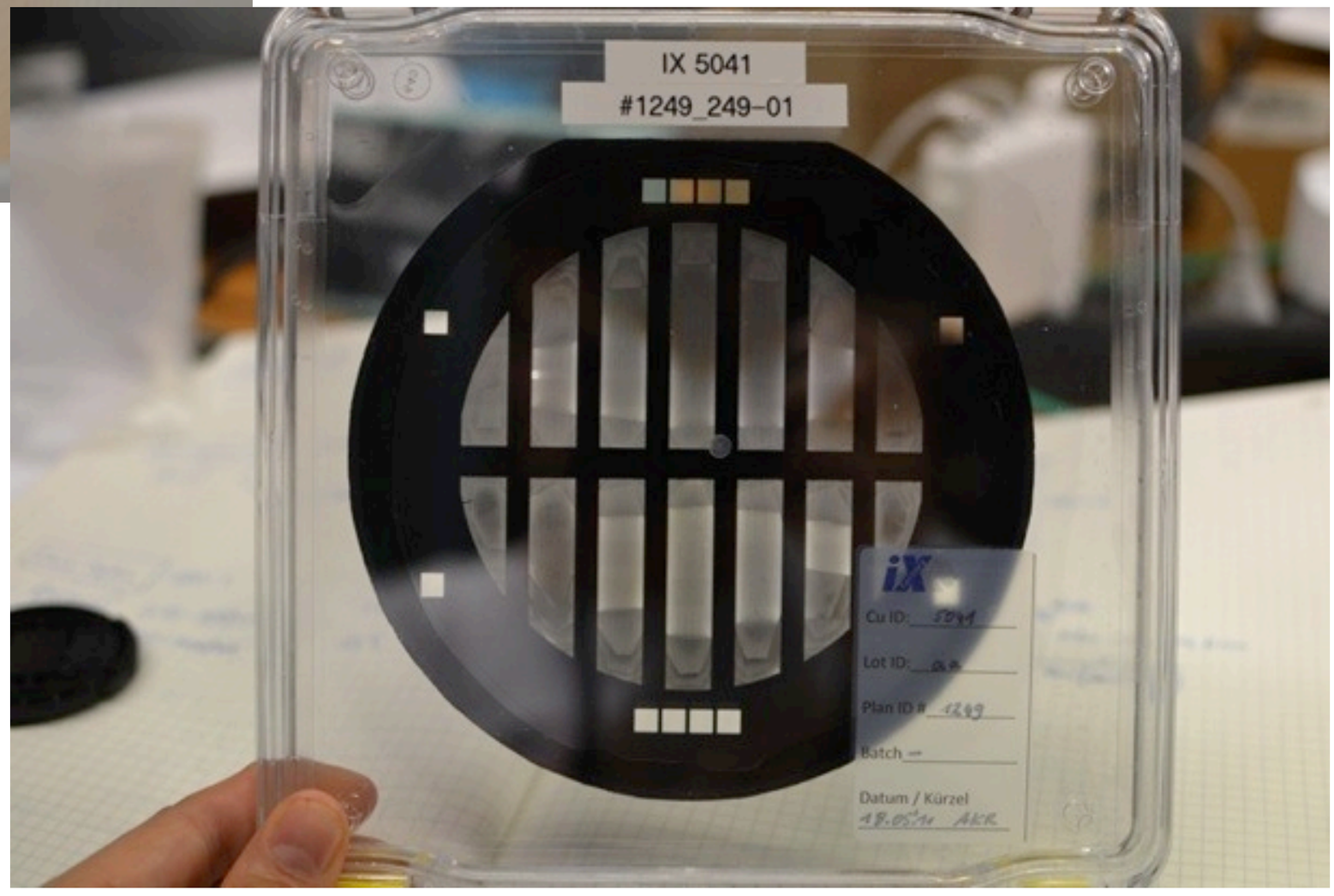


- Exposure of emulsion
- Development in dark room
- Scanning on automated microscopes

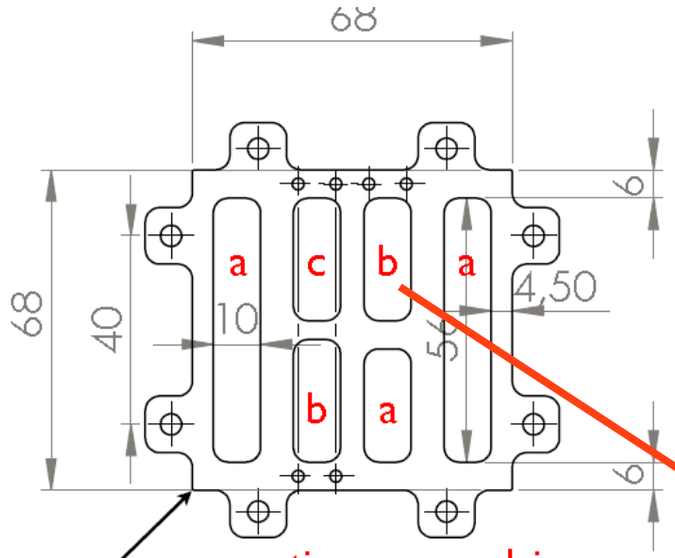
→ S. Aghion et al., J. of Instrumentation 8 (2013) P08013

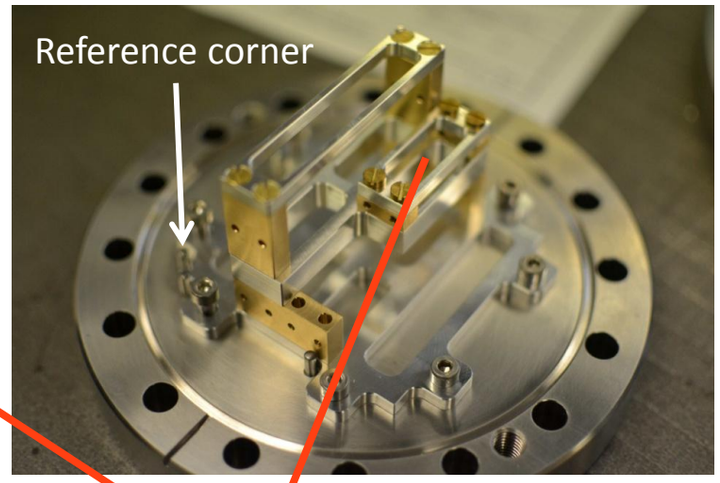
Moiré deflectometer: 6” (full size) grating prototype

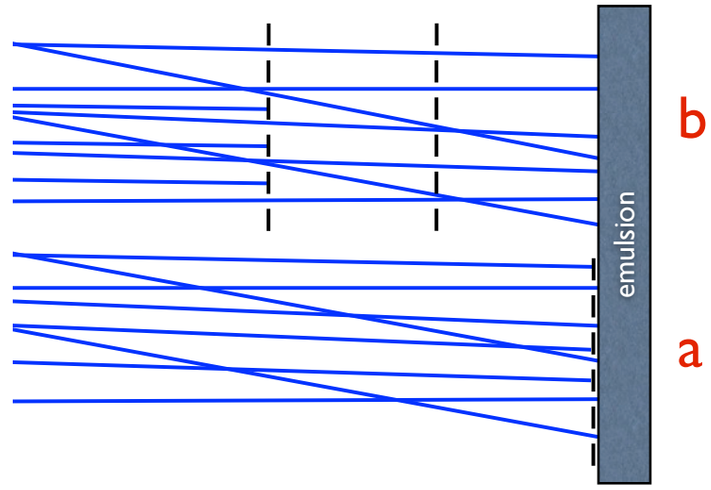




Test of moiré deflectometer with antiprotons

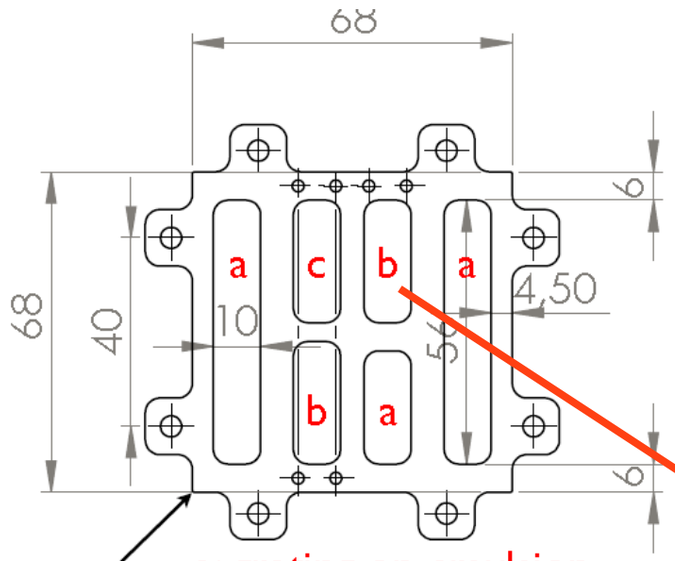


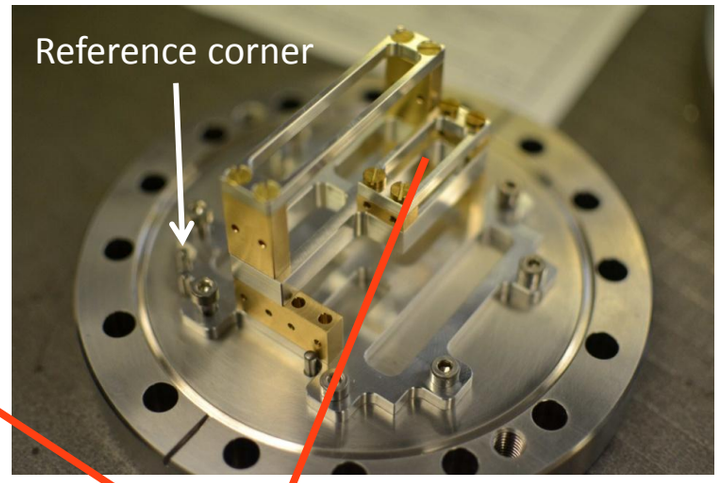


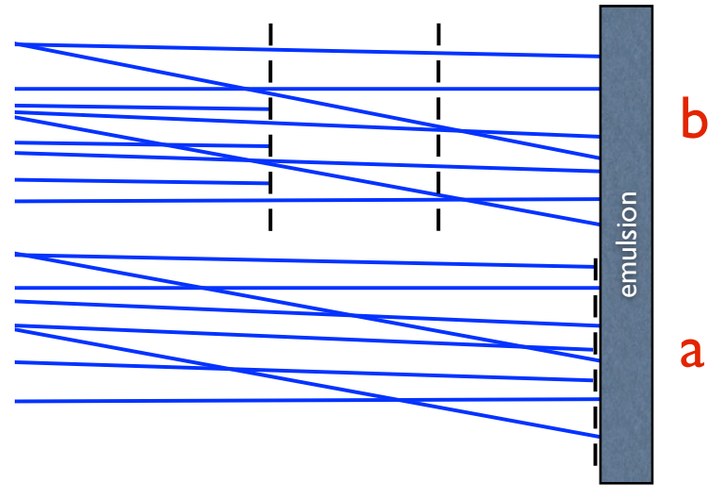


first look at data in zone b) 353 vertices in ~ 1 cm^2

Test of moiré deflectometer with antiprotons







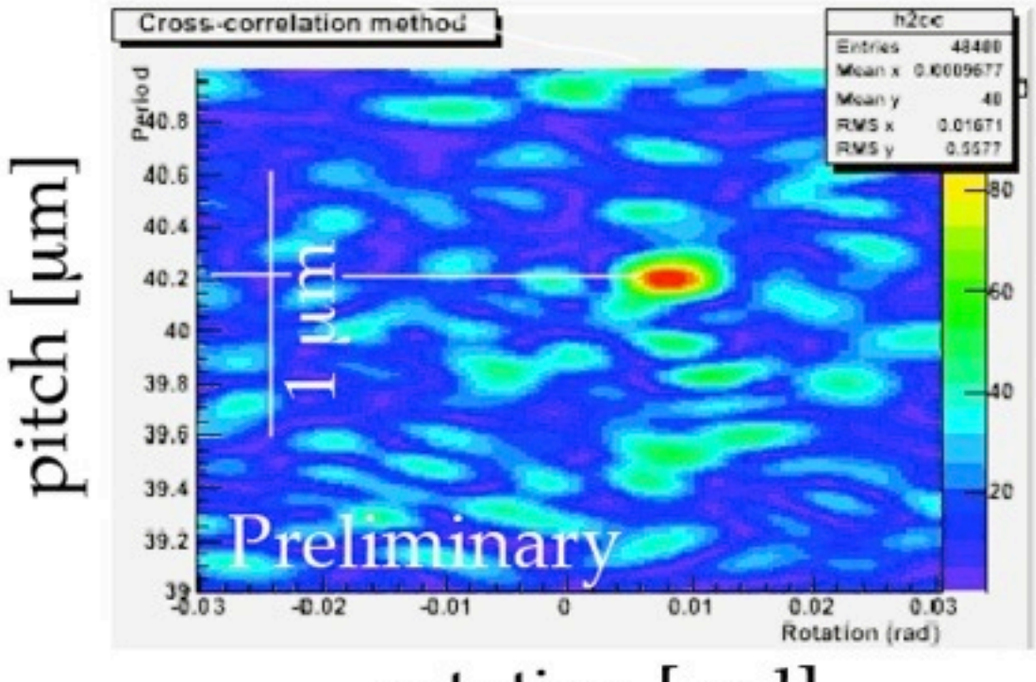
a: grating on emulsion
b: Moiré
c: double frequency Moiré

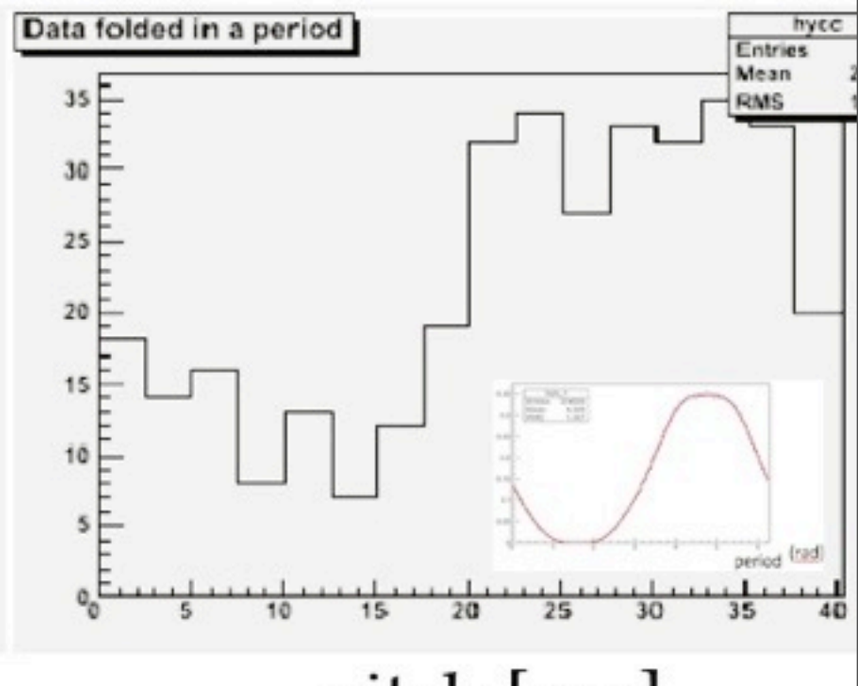
point of reference

first look at data in zone b) 353 vertices in ~ 1 cm^2

353 vertices

vertex-to-vertex autocorrelation

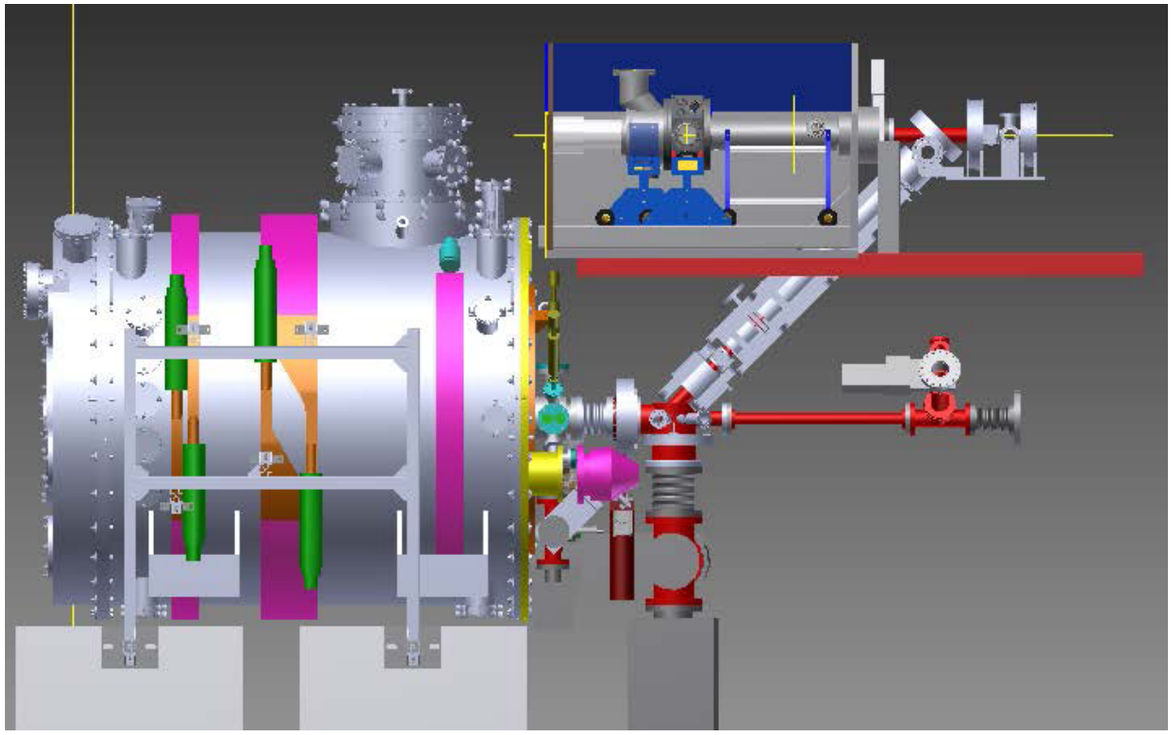


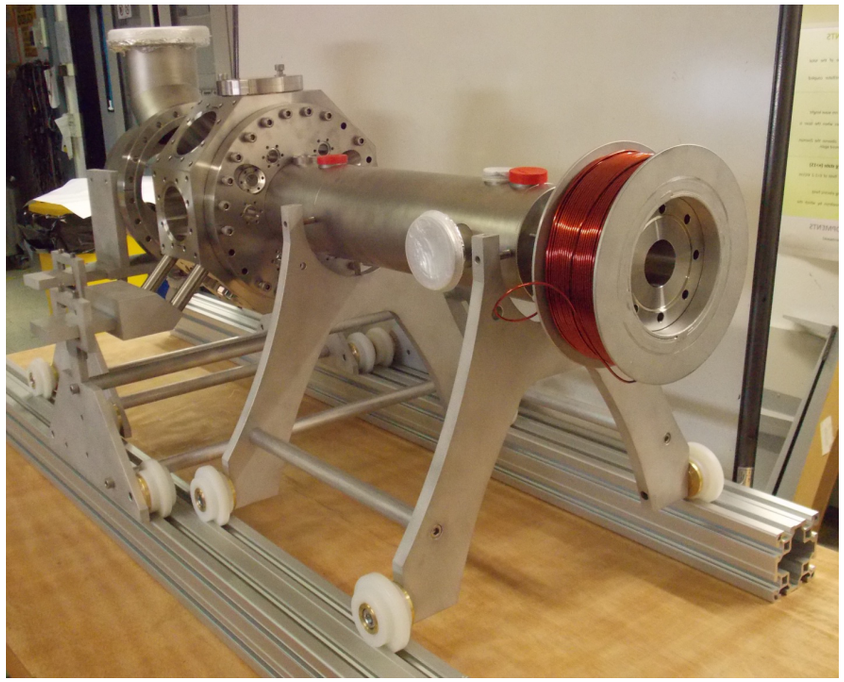


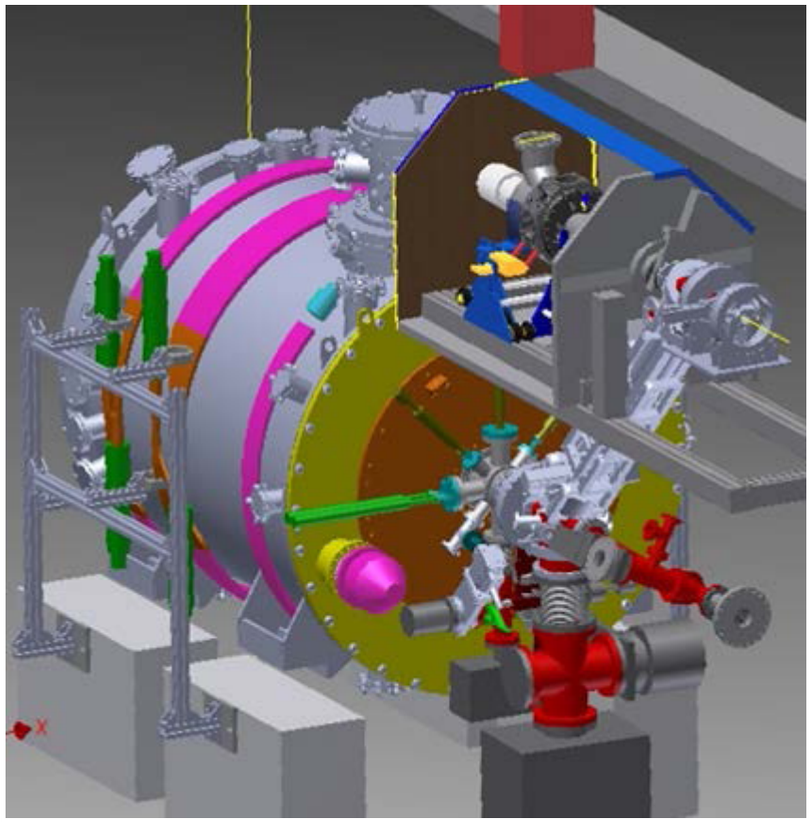
First demonstration of the moiré deflectometer technique with antiprotons

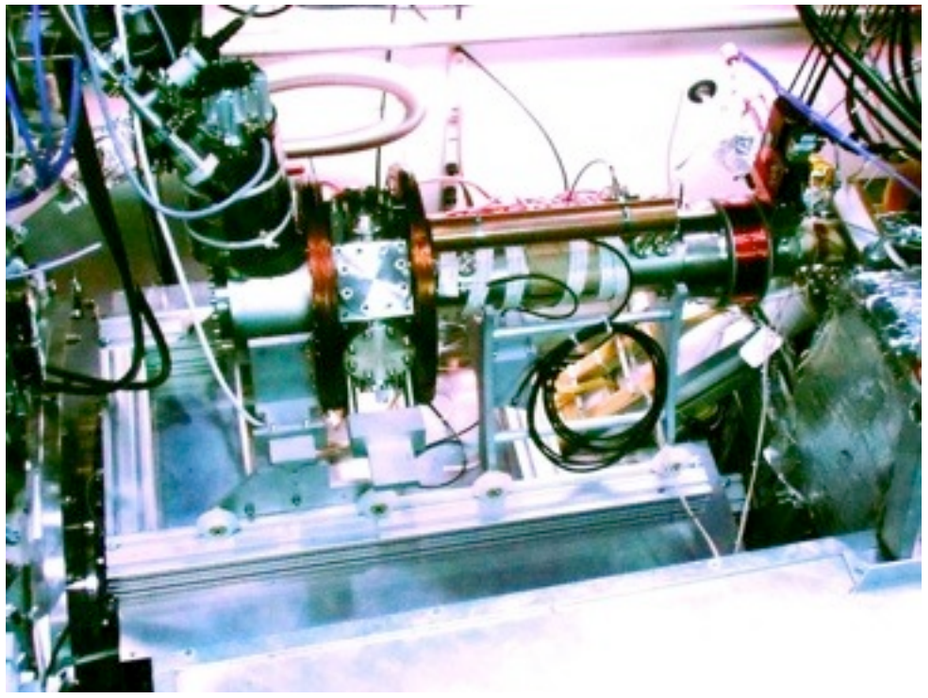
→ Publication submitted

ongoing work: Positronium test station

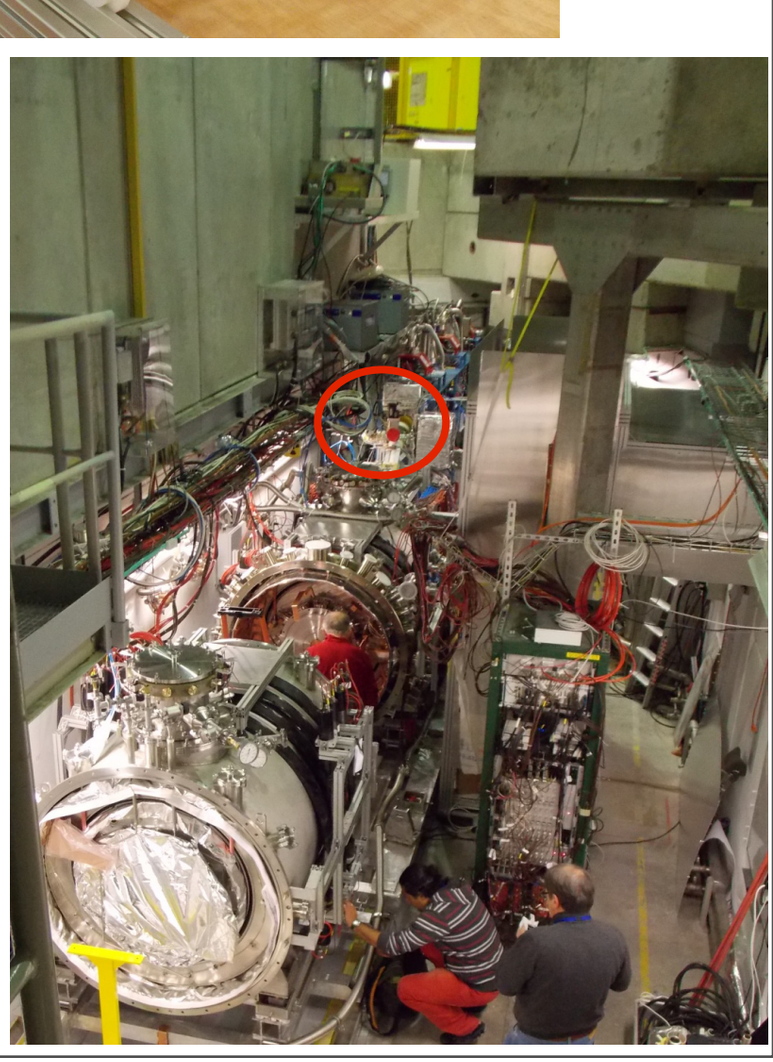






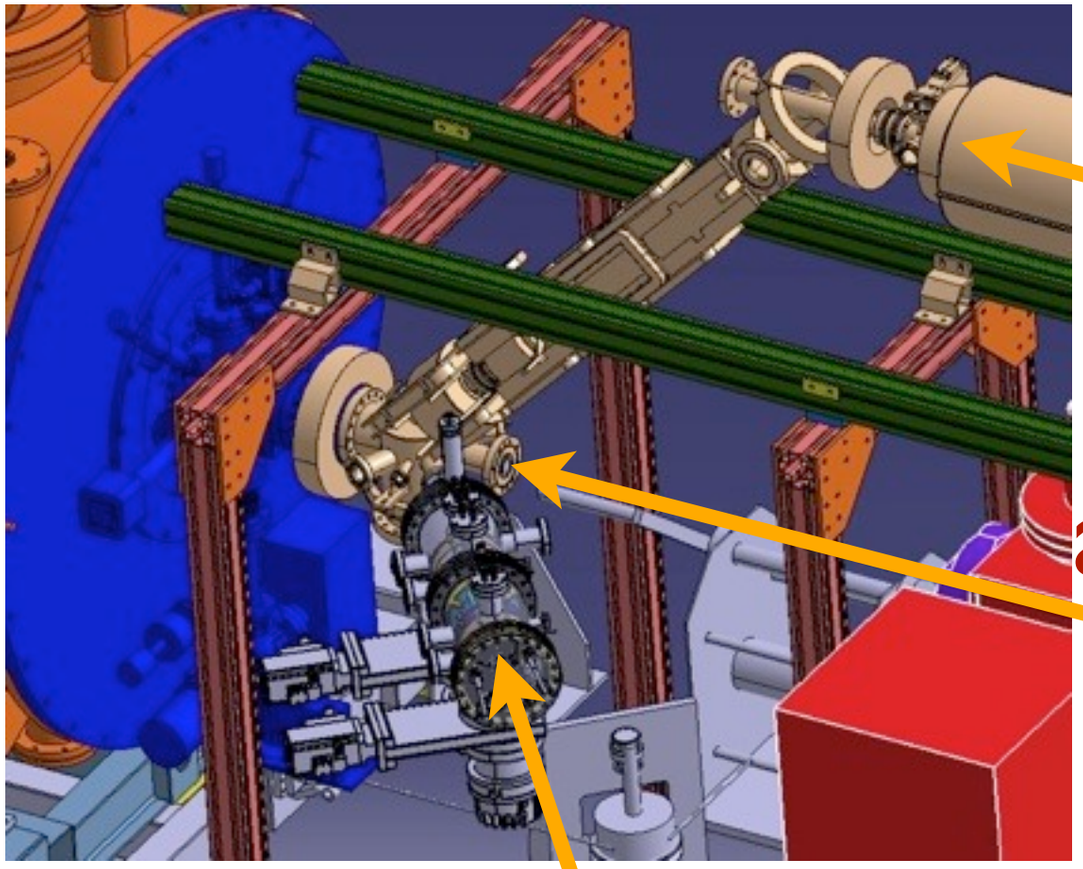


installed and under commissioning



ongoing work: Proton source

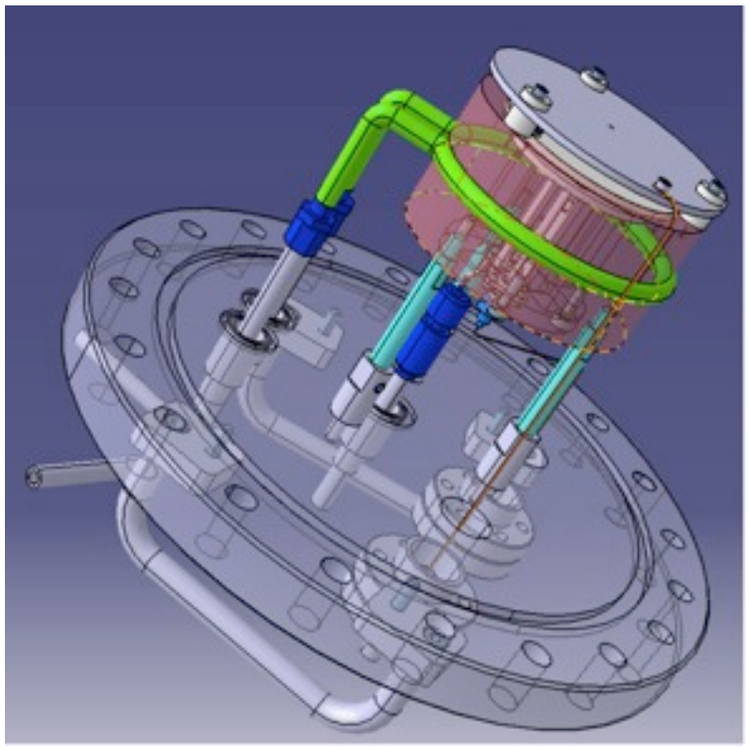
$$p + Ps \longrightarrow H + e^+$$

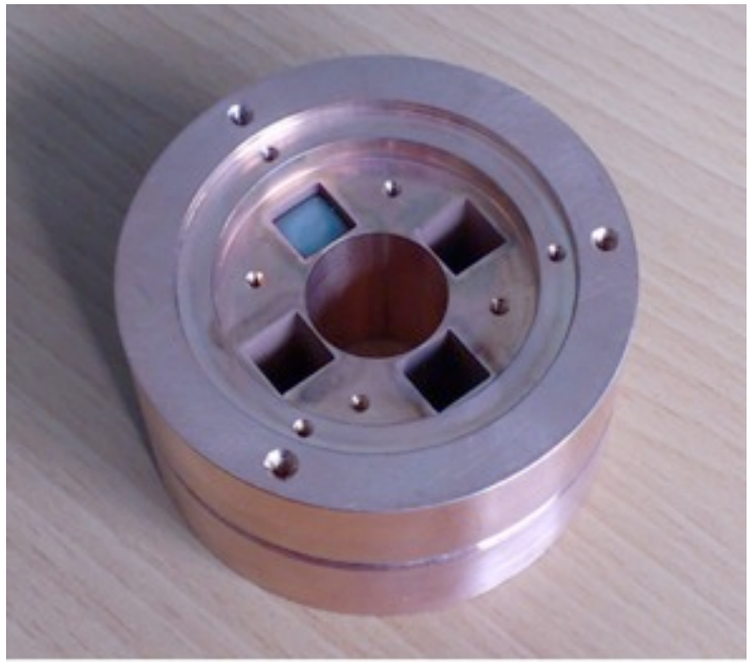


positrons

antiprotons

protons





completed and ready for installation

Conclusions and Outlook

- Installation of base apparatus largely completed and commissioned
- Parasitic measurements essential in converging to an optimal deflectometer/detector layout ➠ nice to have a test beam line @ ELENA

- Ongoing work:
  - install proton source, hydrogen detector
  - commission Rydberg positronium formation (targets, lasers, atomic physics)
  - work on hydrogen formation/characterization
  - design gravity module, flight tube
  - goal: be ready for antihydrogen formation in autumn 2014

- In parallel:
  - prepare deflectometer, microwave spectroscopy, interface, hybrid detector, ...