

AEGIS / AD-6
Antihydrogen experiment:
Gravity, Interferometry and Spectroscopy

**Status report for 2012 and
outlook for 2013/14**

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AEgIS collaboration



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University Bern,
Switzerland



University Zürich,
Switzerland



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Italy



ETH Zurich,
Switzerland

Topics

Schematic overview

Work in 2012 on apparatus

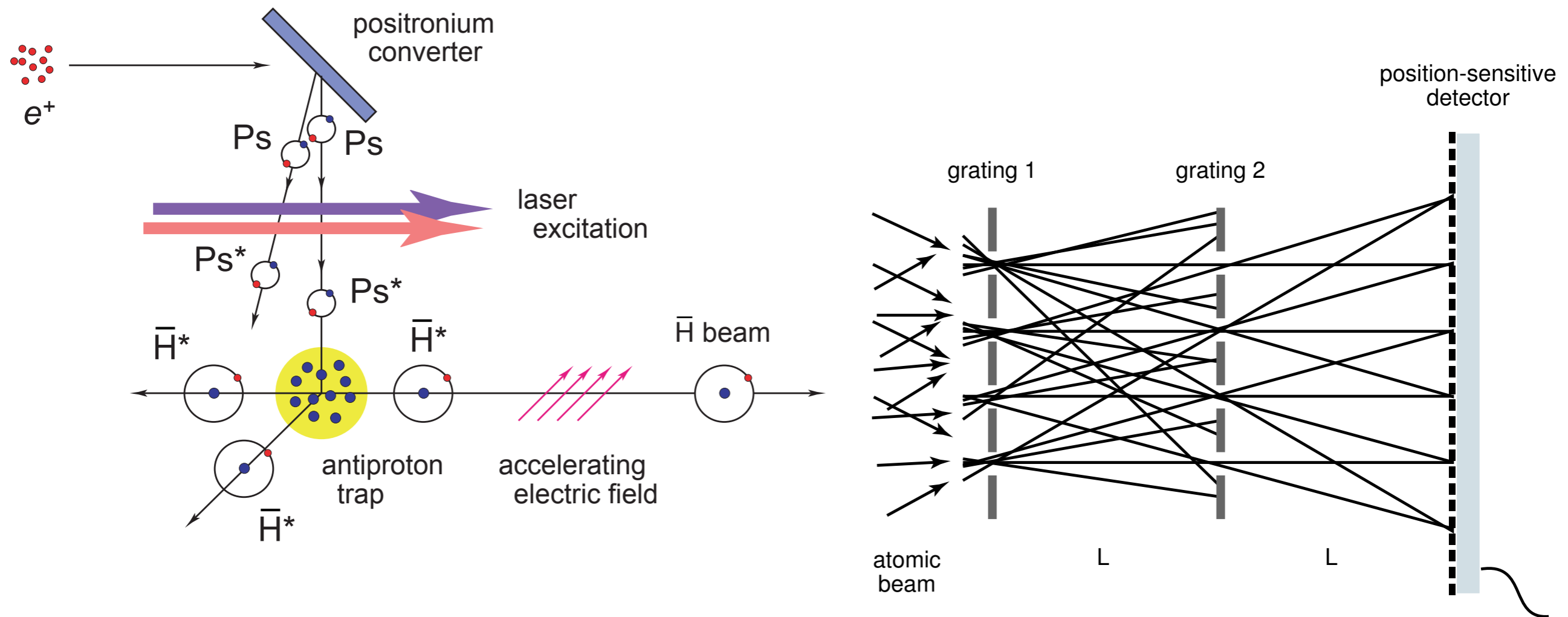
Results of measurements with antiprotons and positrons

R&D

proton source, Ps formation studies

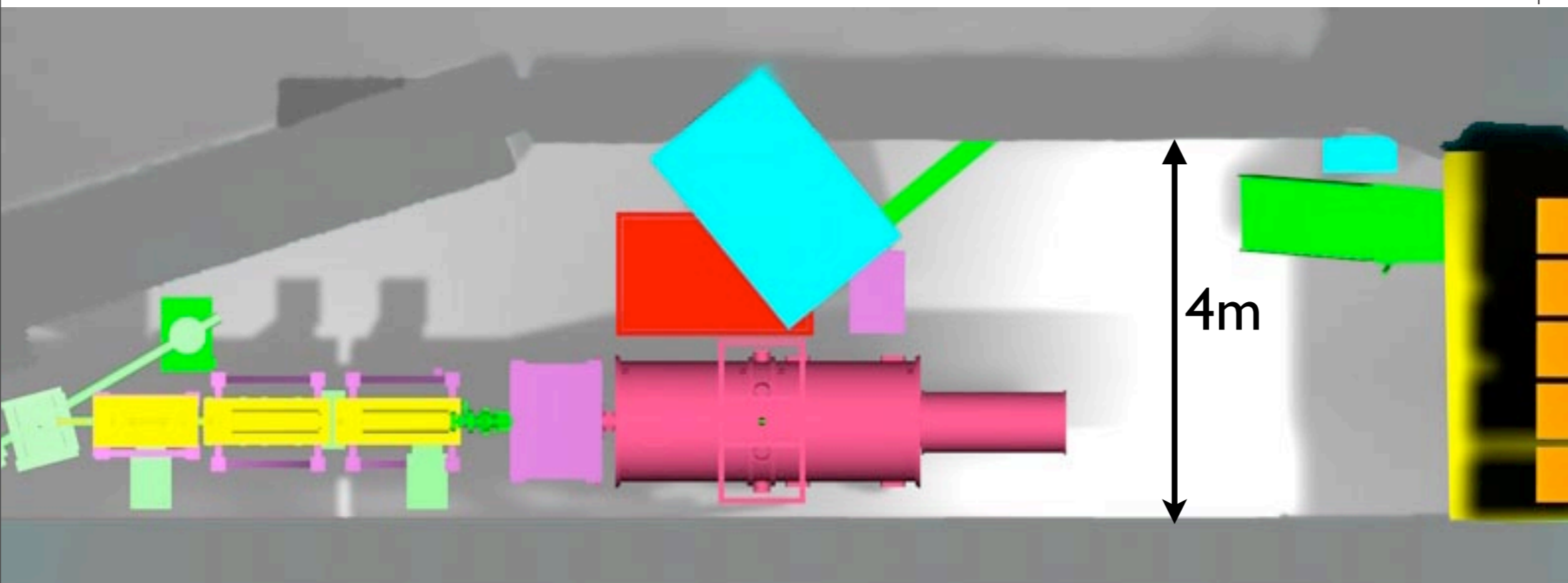
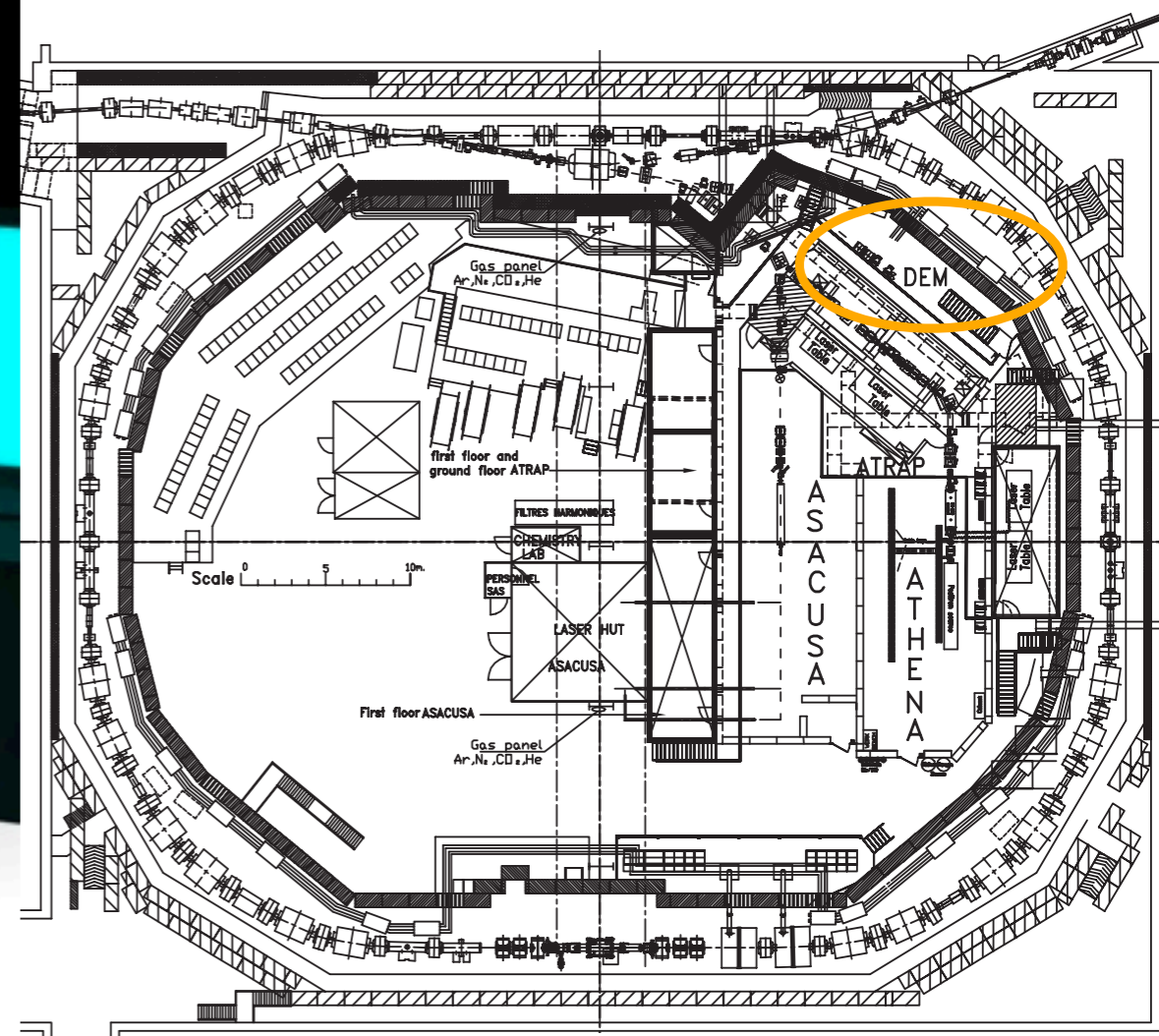
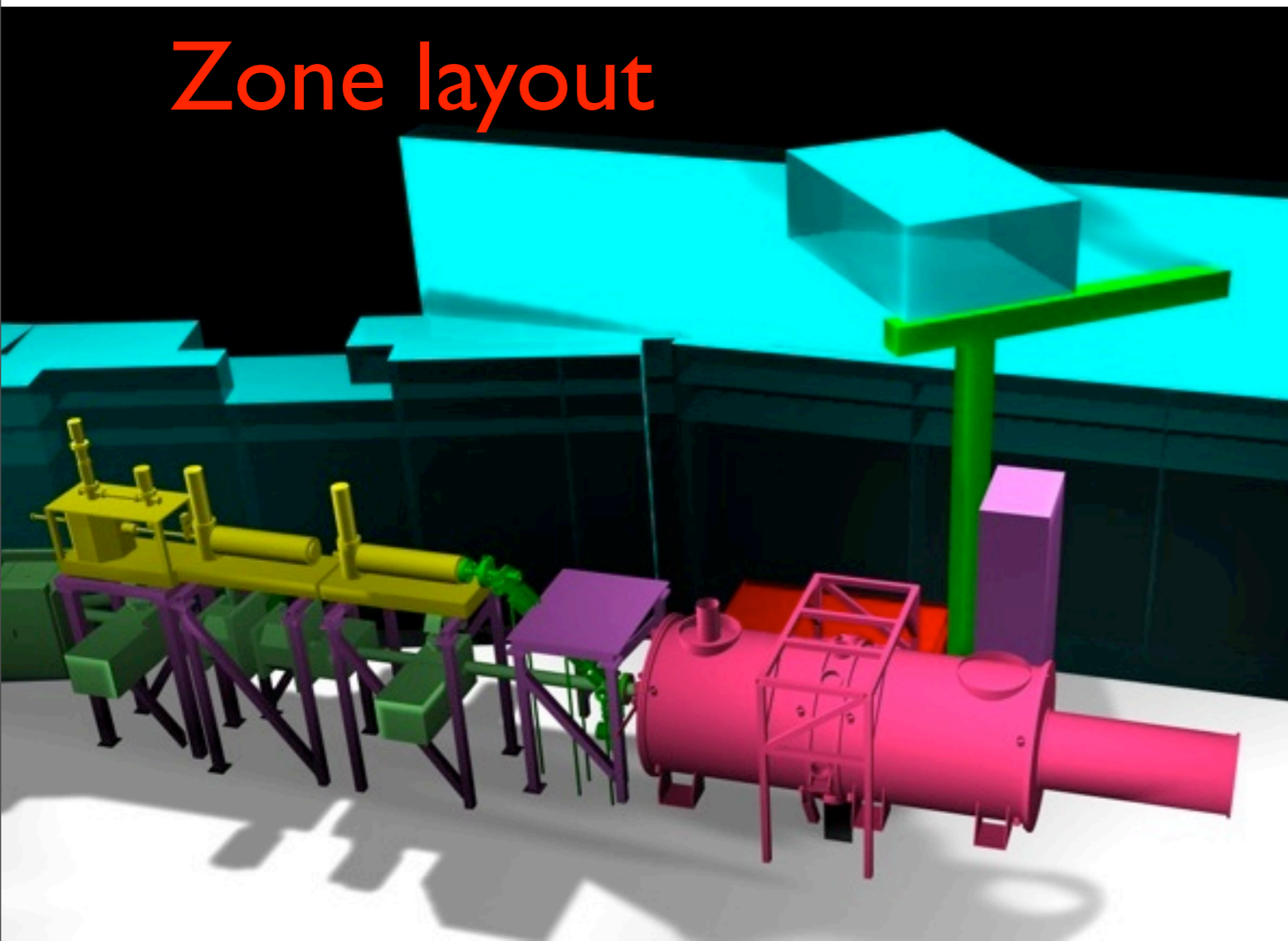
Outlook for 2013 and 2014

Schematic overview

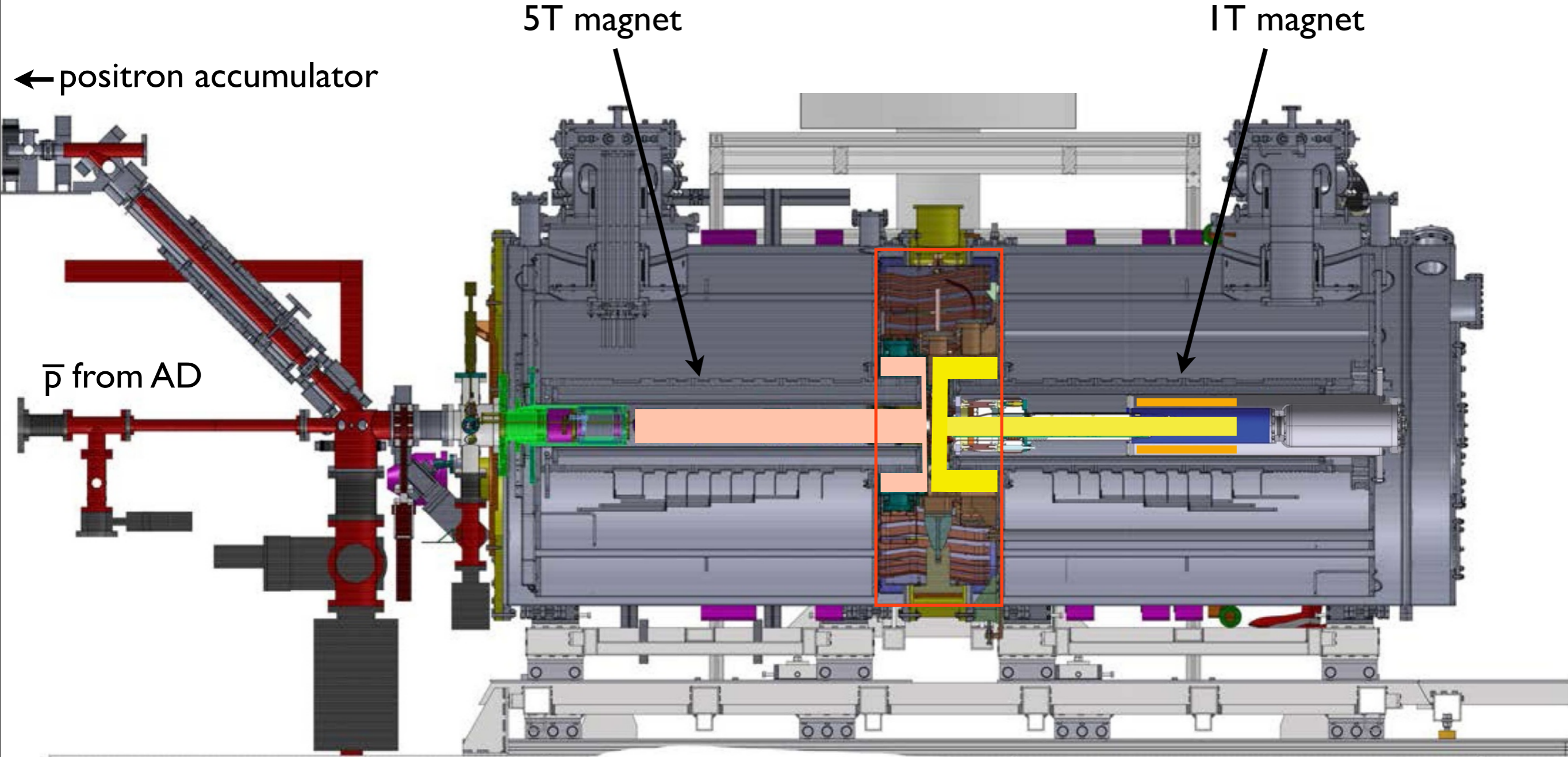


Physics goals: measurement of the gravitational interaction between matter and antimatter, \bar{H} spectroscopy, ...

Zone layout



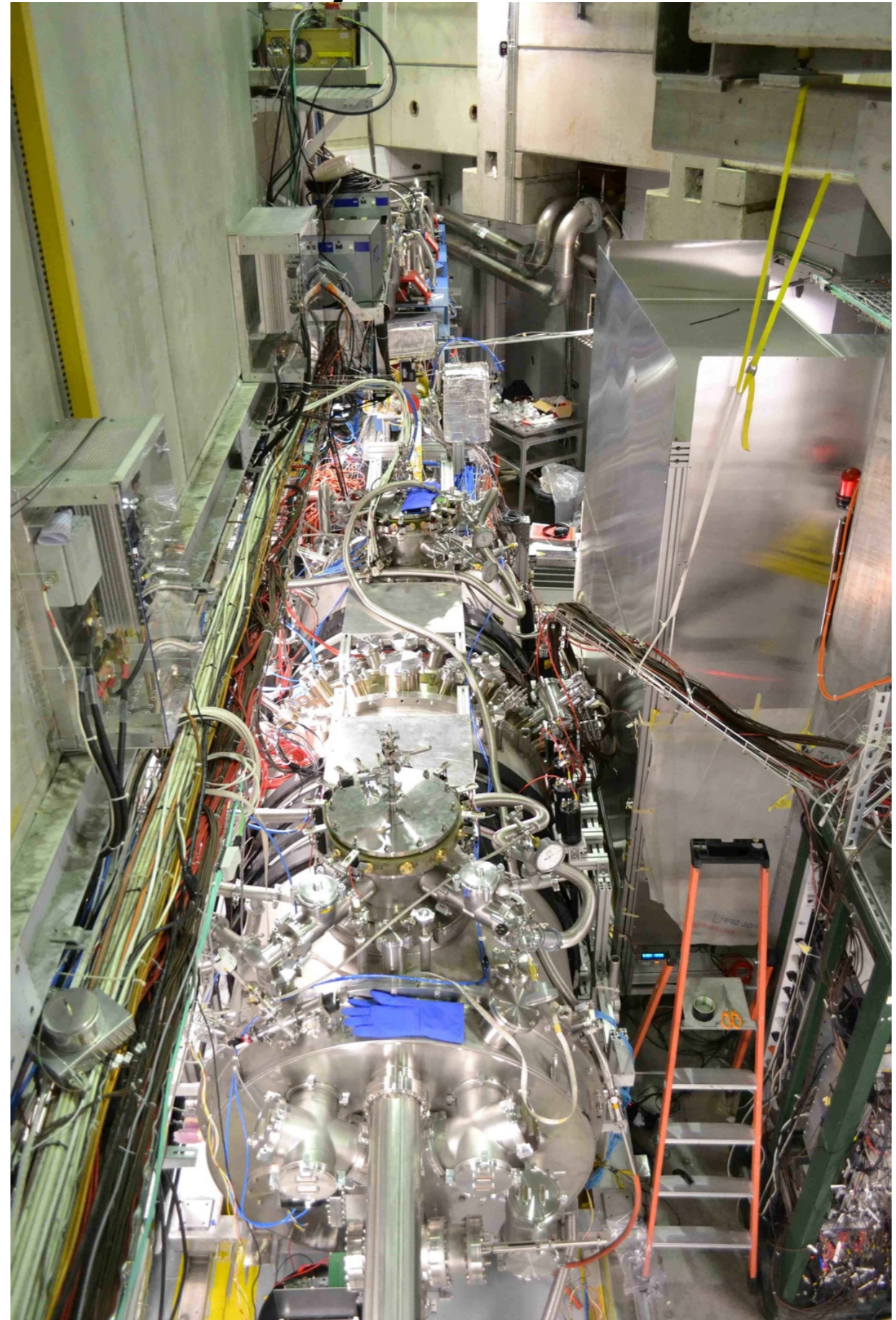
Central apparatus design



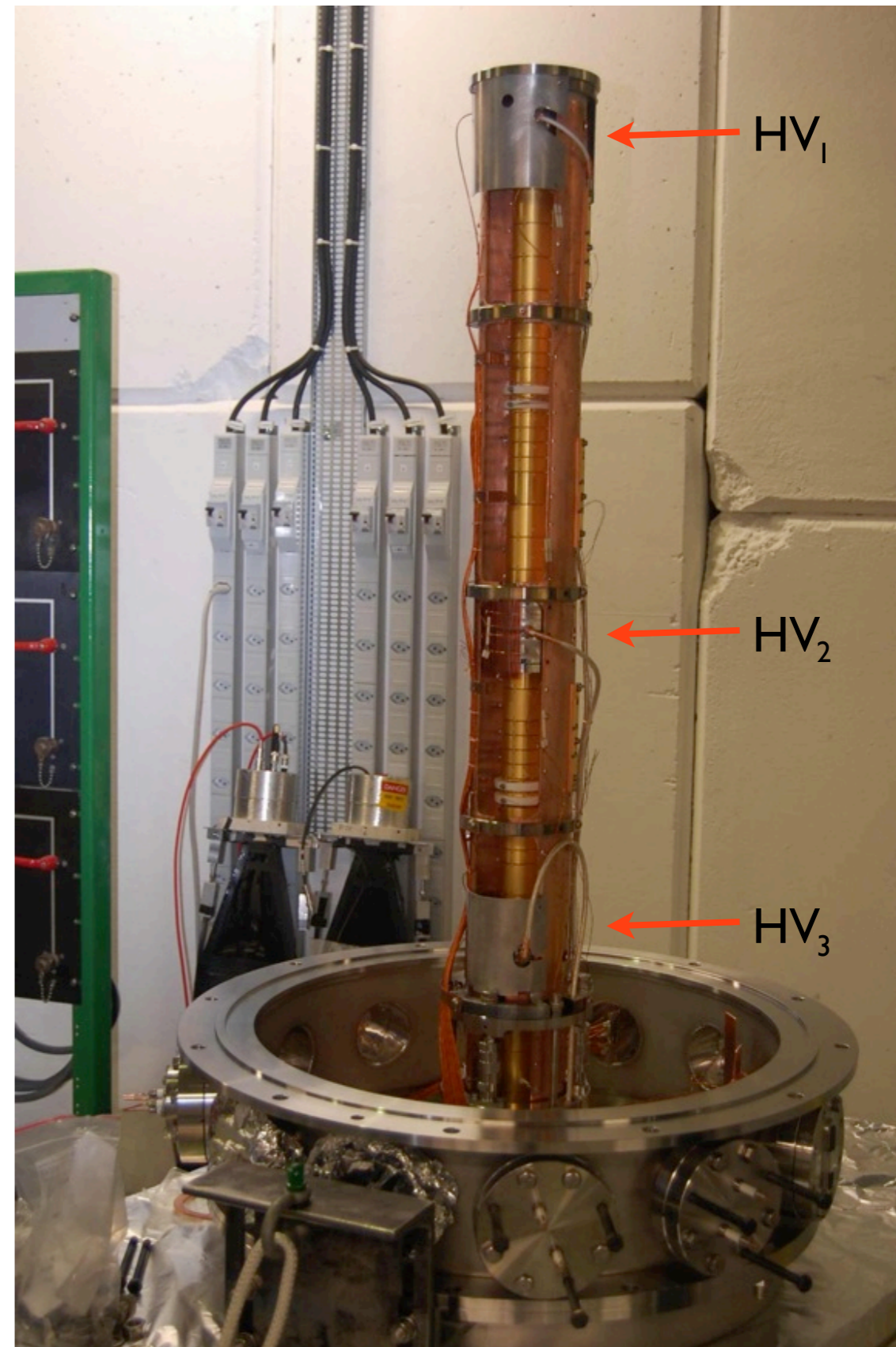
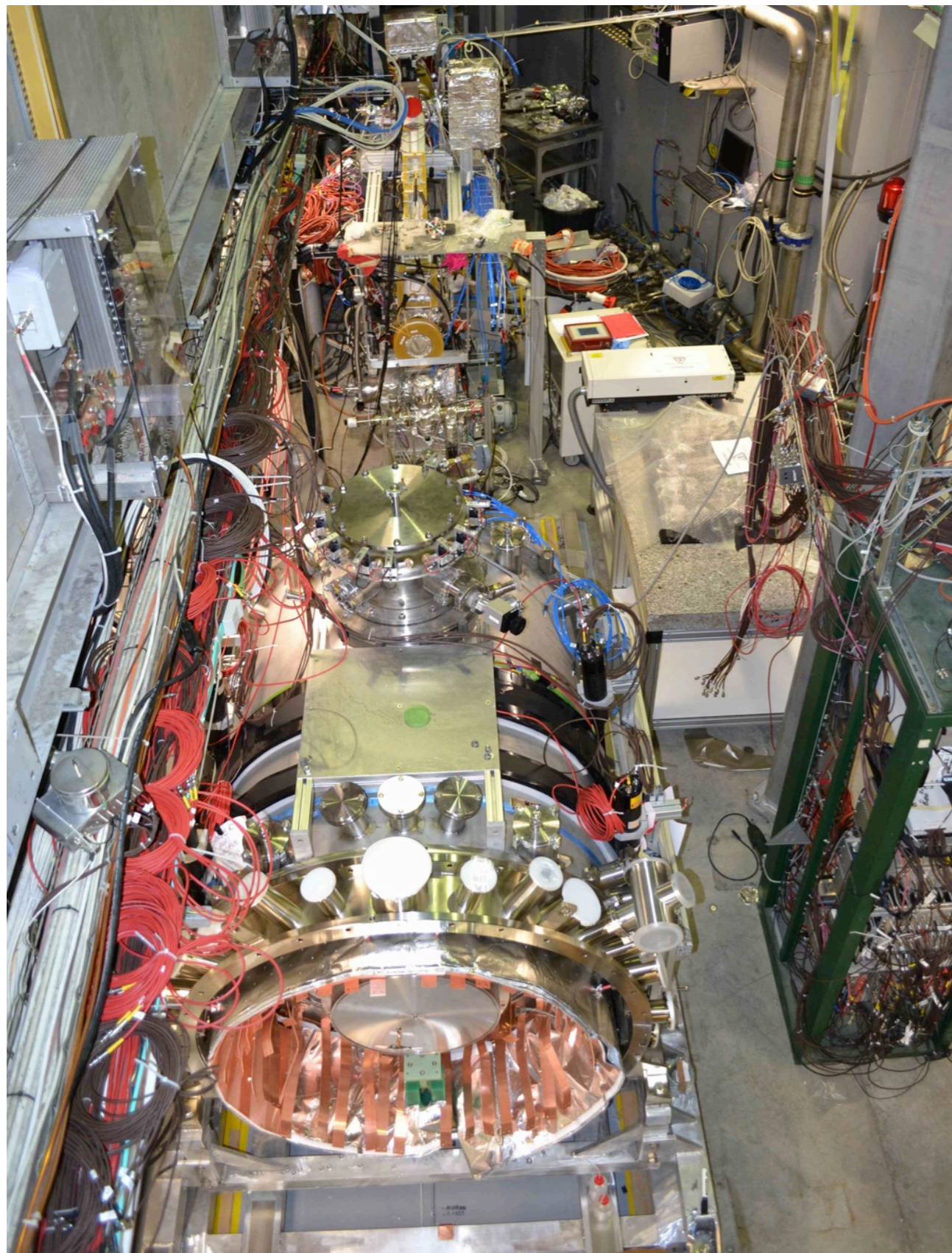
Zone layout early 2011



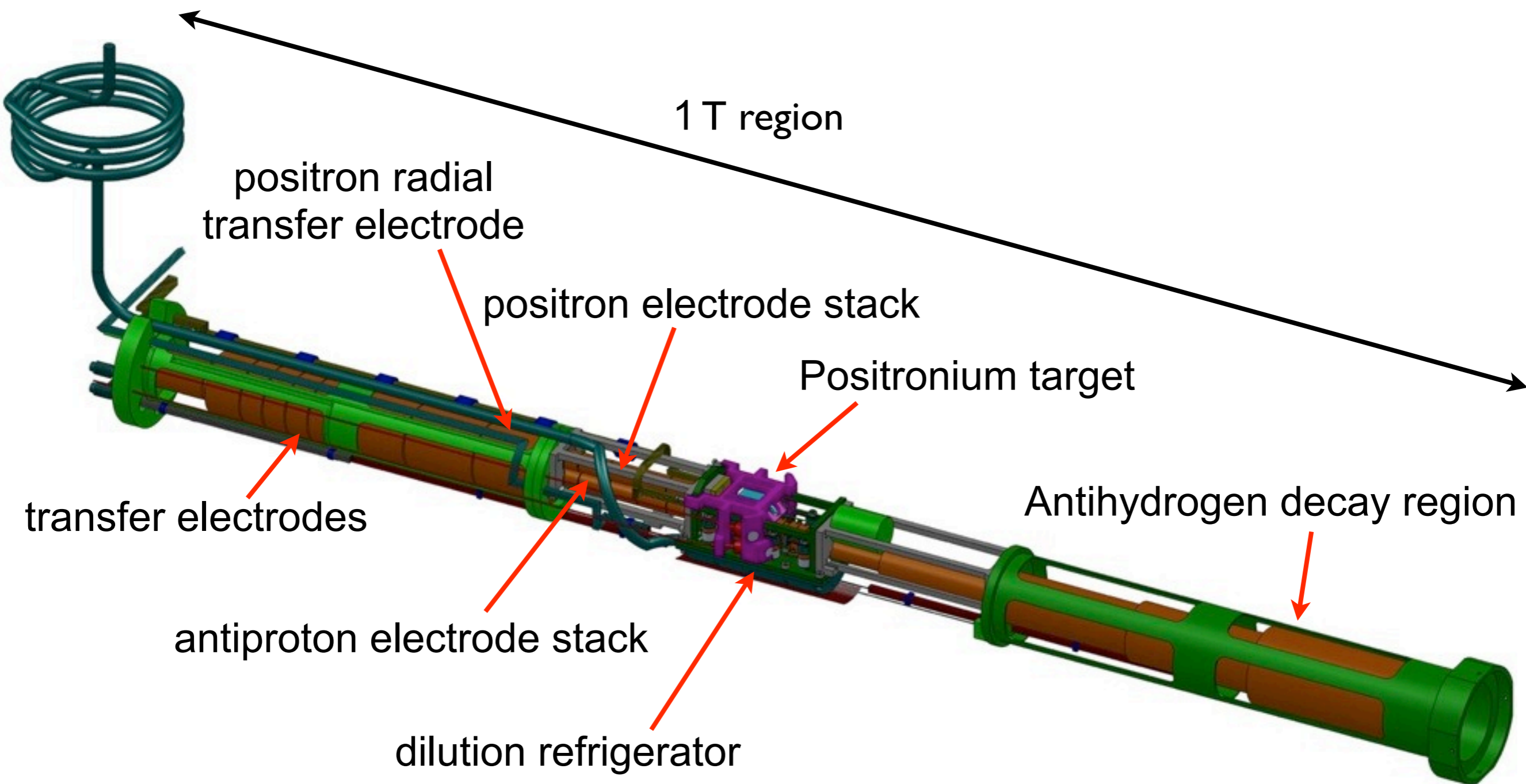
Zone layout late 2012



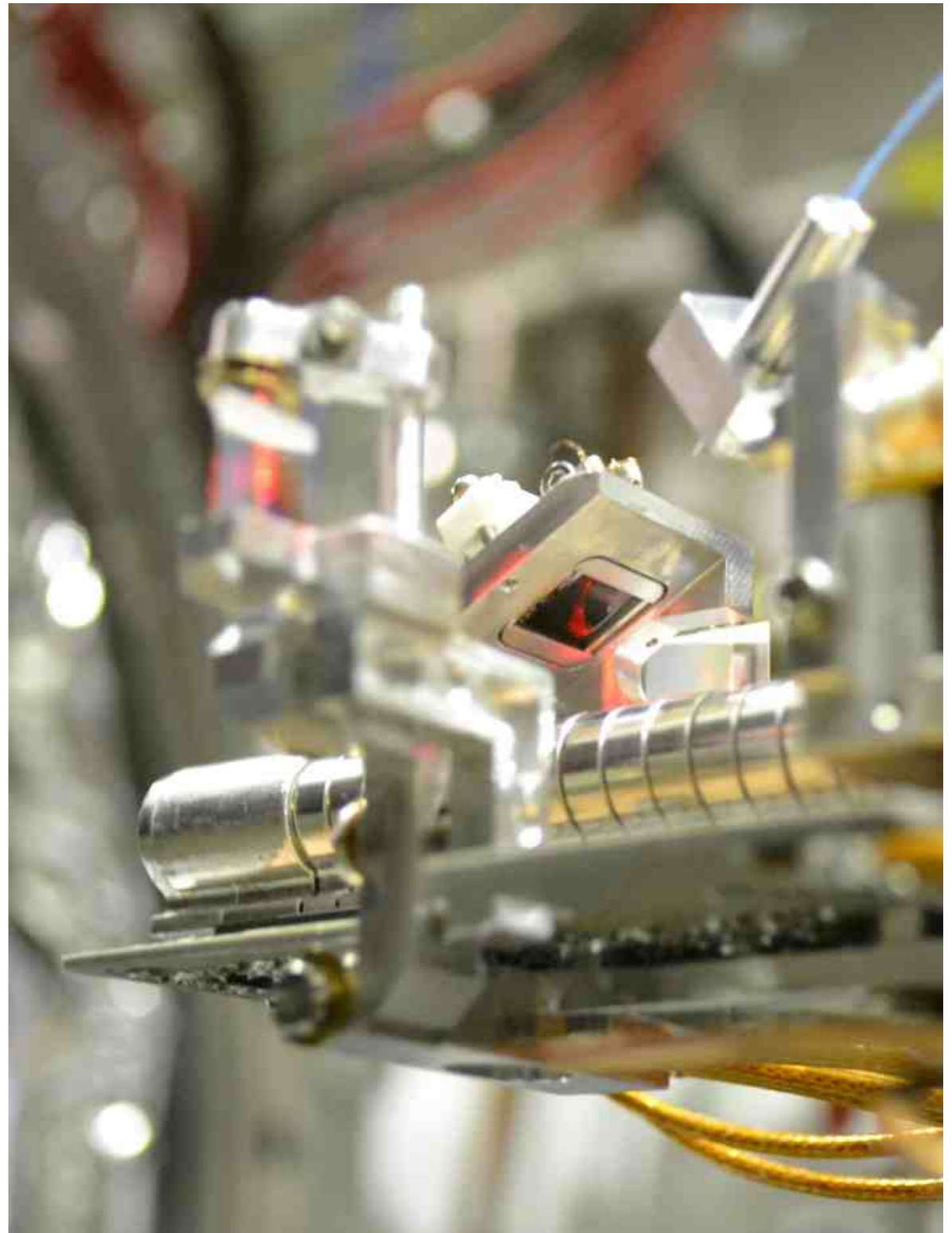
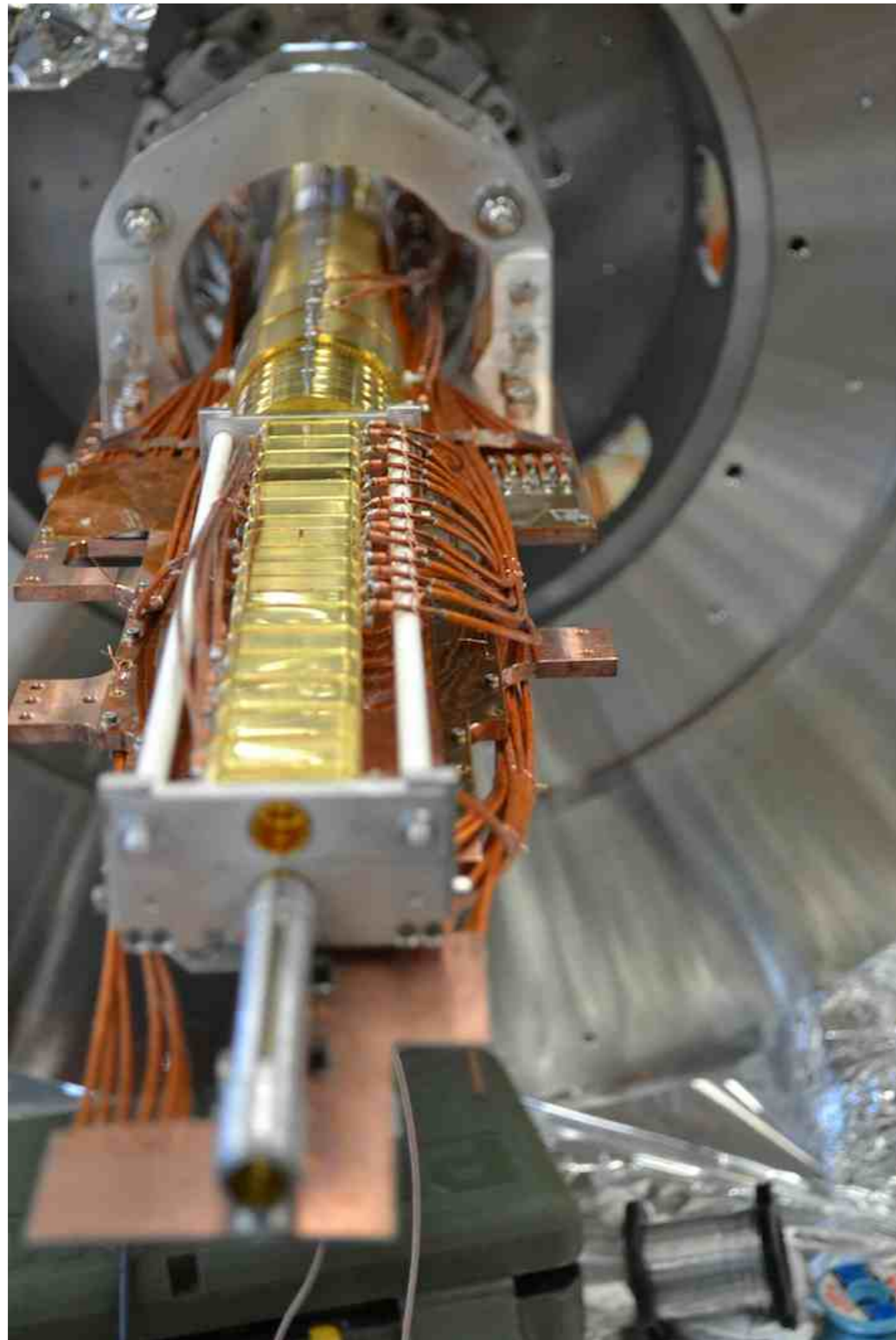
5T magnet and traps



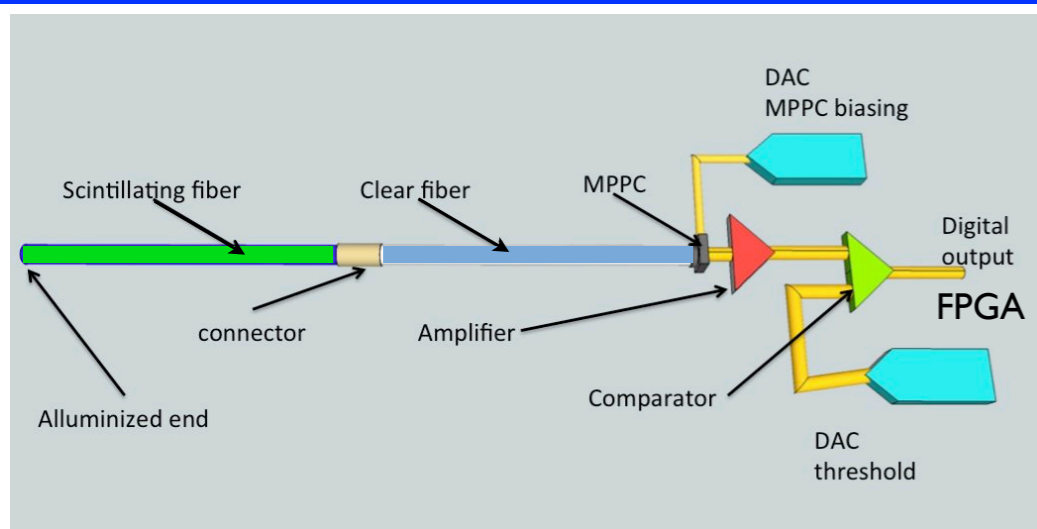
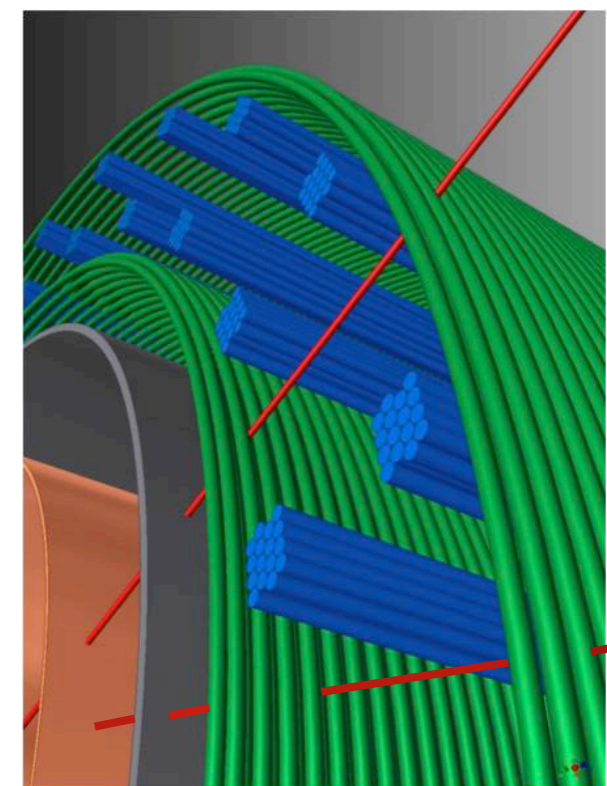
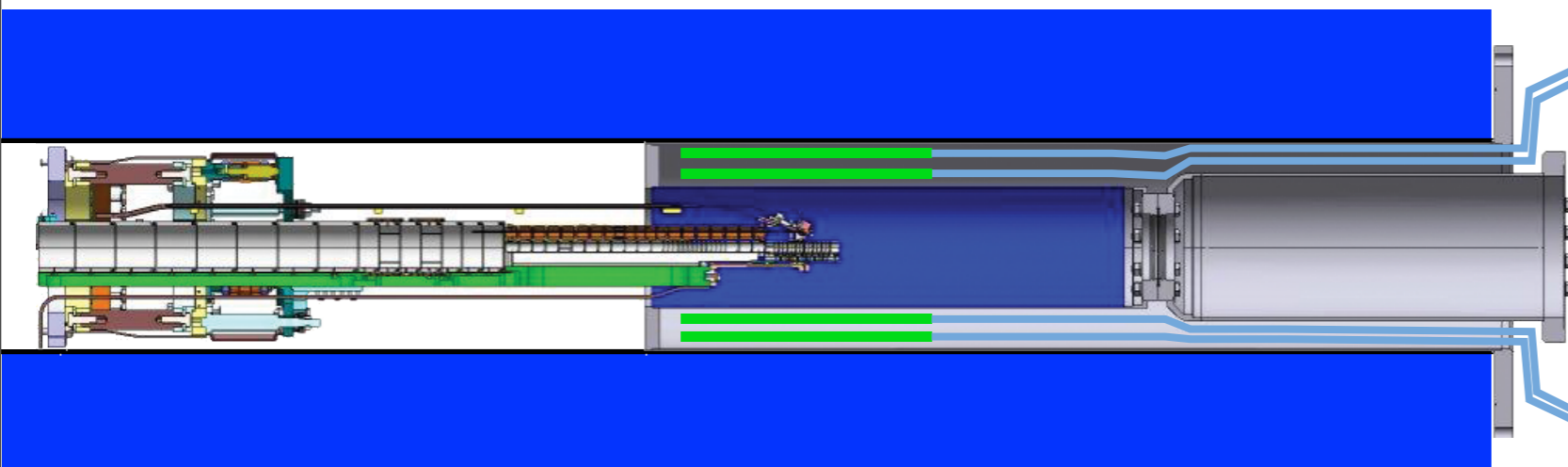
IT magnet traps: conceptual design



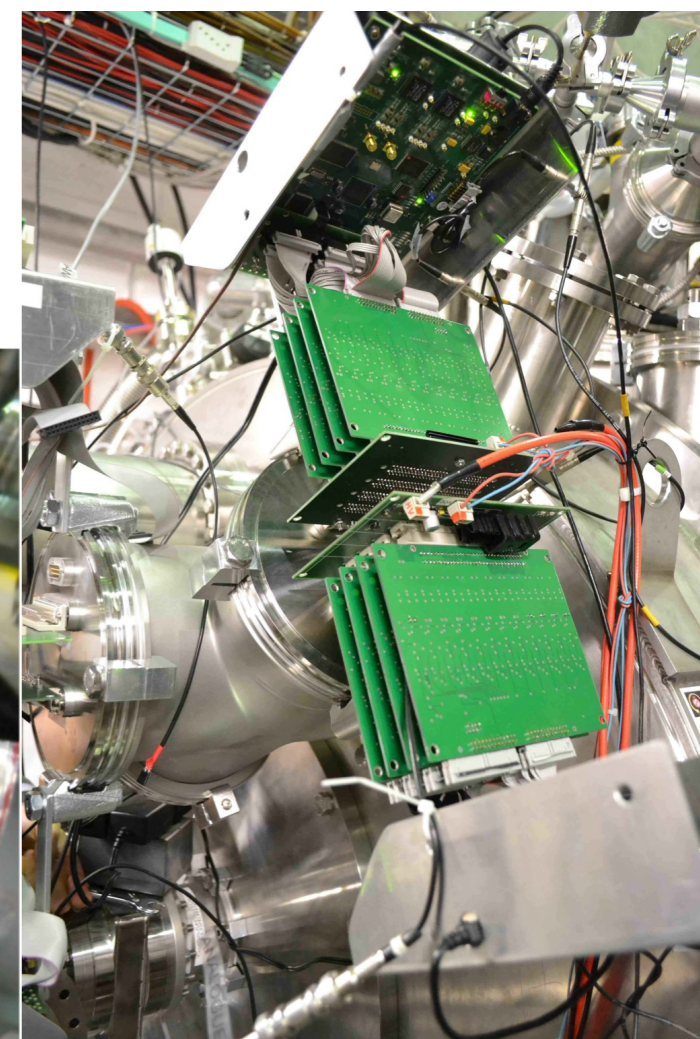
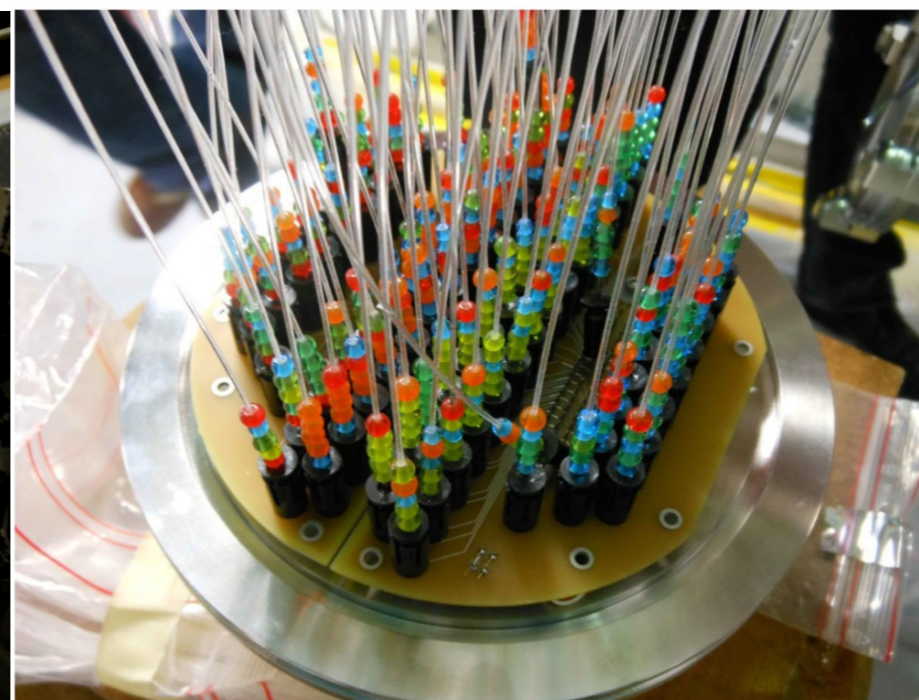
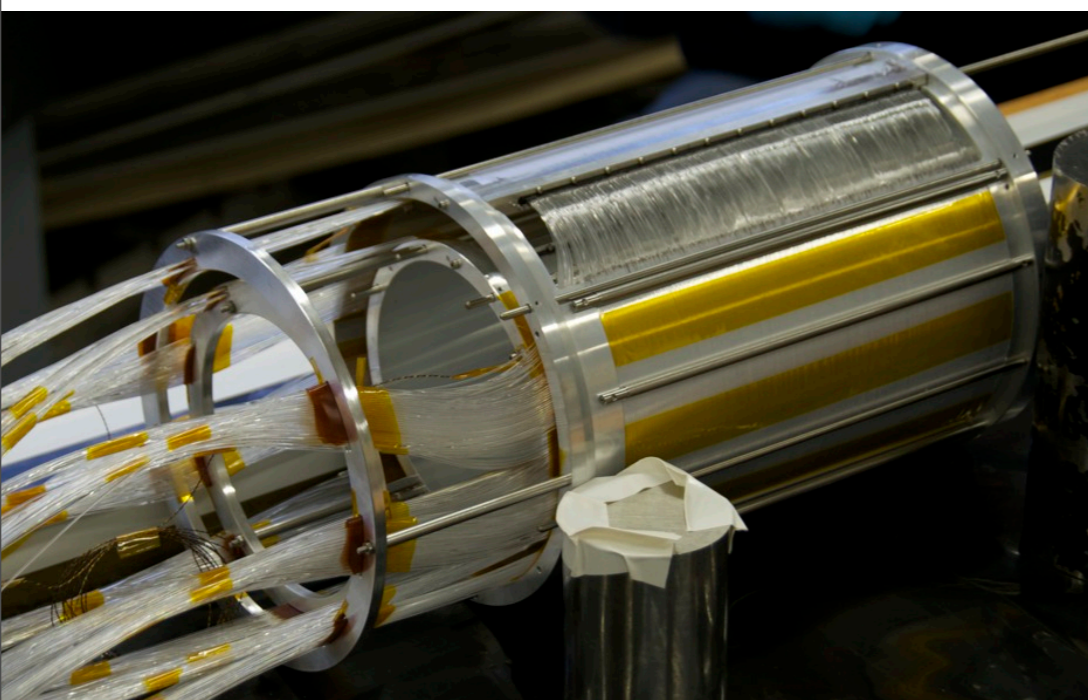
IT magnet traps: the reality



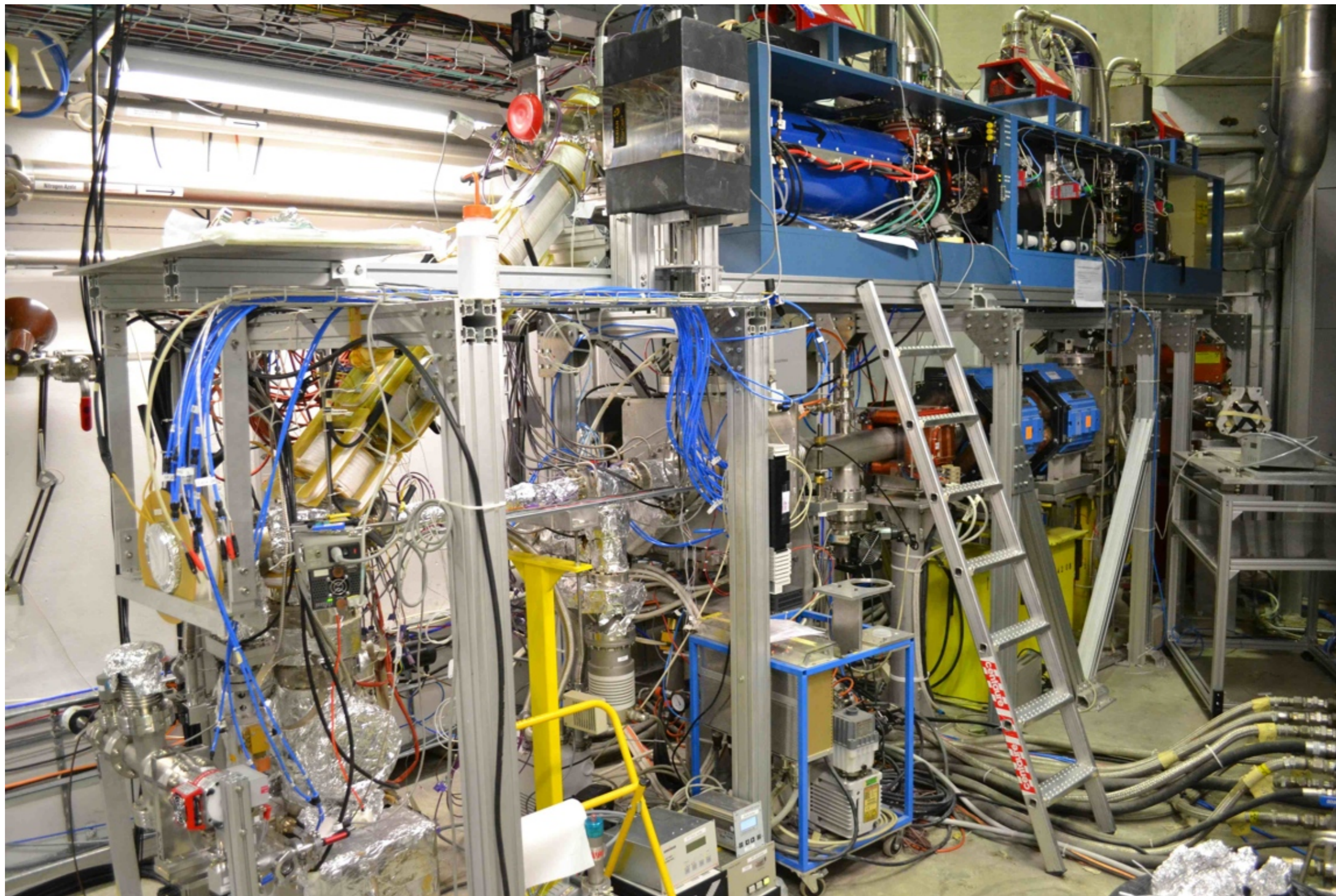
Central antihydrogen detector (@ 4K)



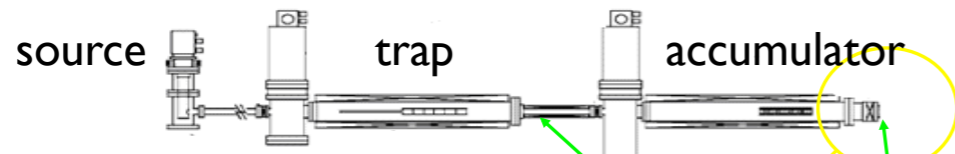
hit pattern (0,1)
vs. time [200 MHz]
(deadtime-free readout)



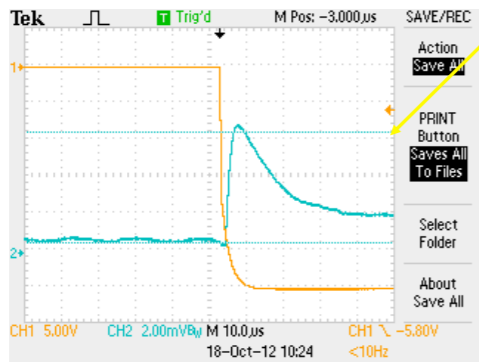
Positron system



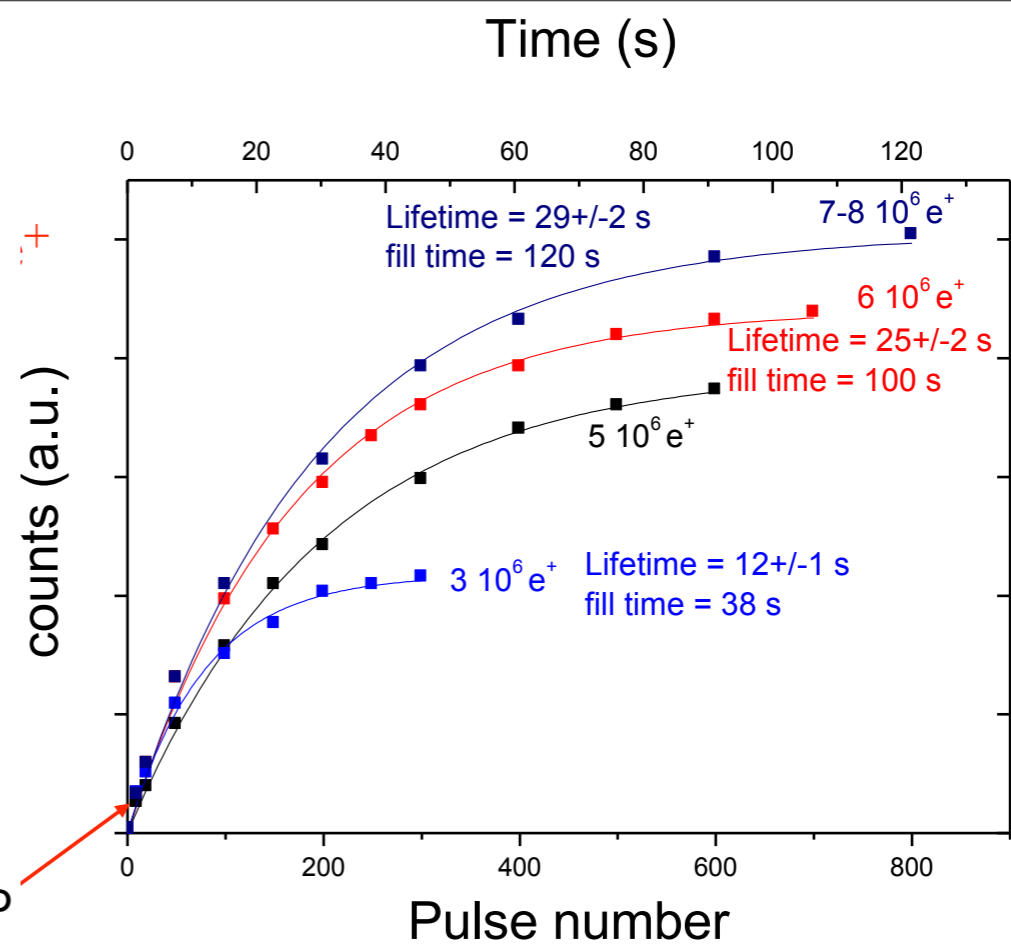
Completed and commissioned in October



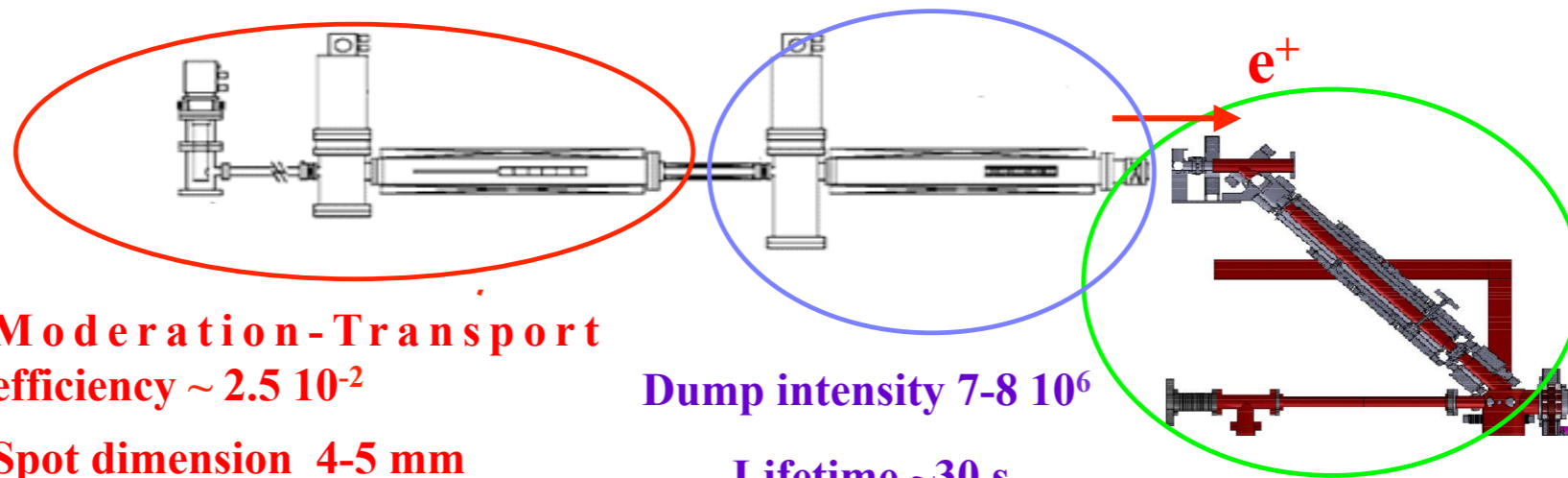
Accumulator characterization
(positron lifetime and dump intensity)



CsI + photo diodes scintillators



$5-6 \times 10^4 e^+$ from trap



Moderation-Transport efficiency $\sim 2.5 \times 10^{-2}$

Spot dimension 4-5 mm

Trapping-dumping efficiency ~ 0.14 **Fill time** ~ 120 s

Spot dimension 1-2 mm

Dump intensity $7-8 \times 10^6$

Lifetime ~ 30 s

Transport efficiency $\sim 80-90\%$

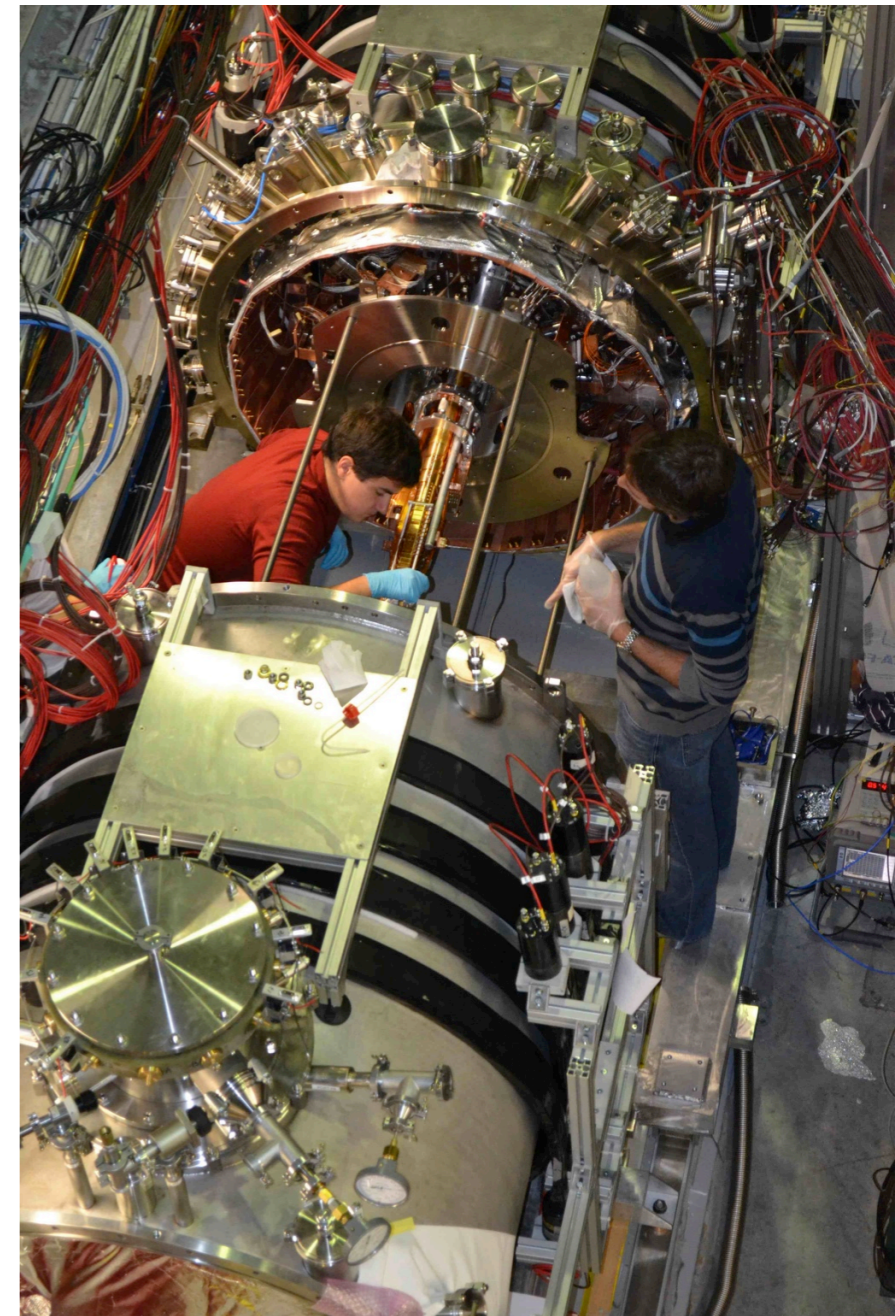
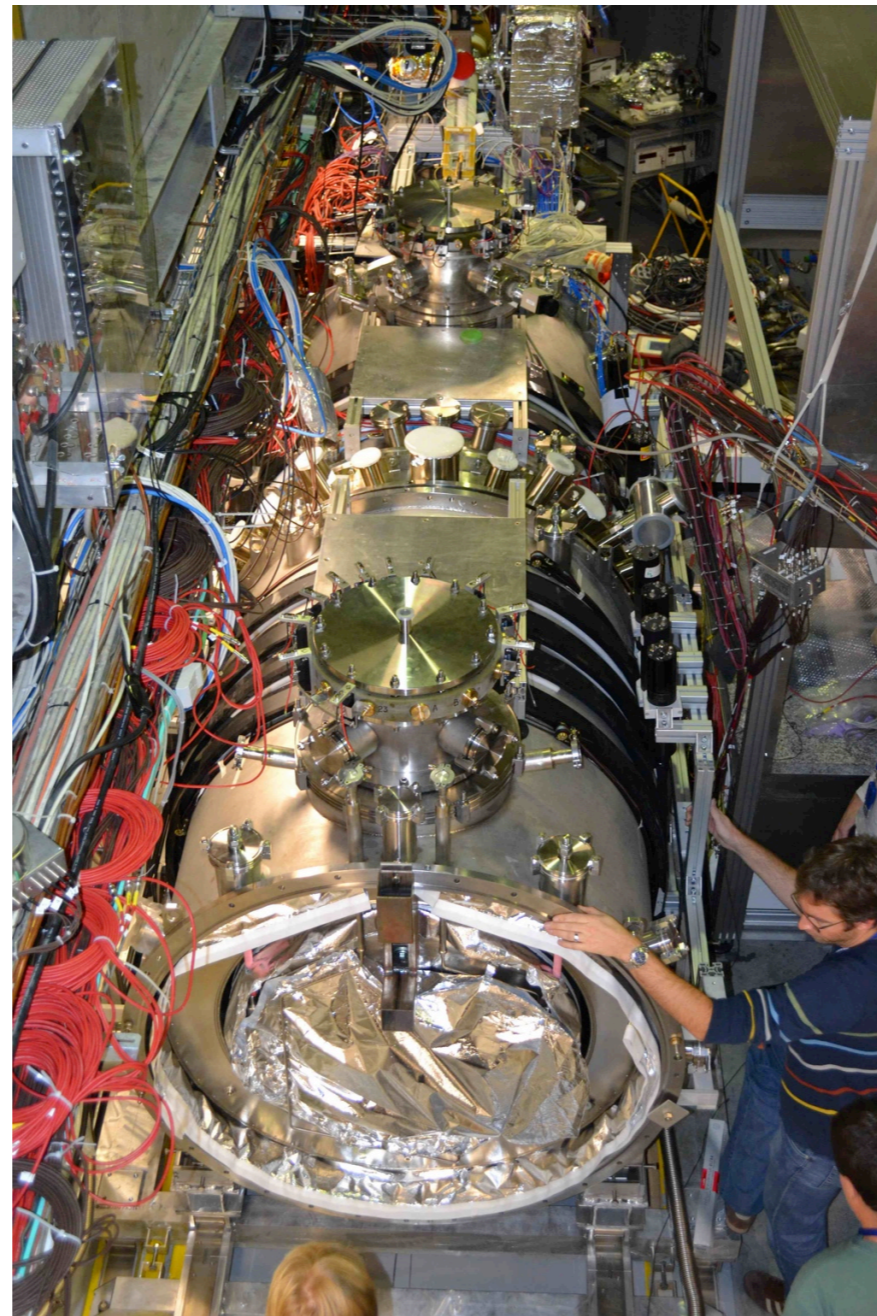
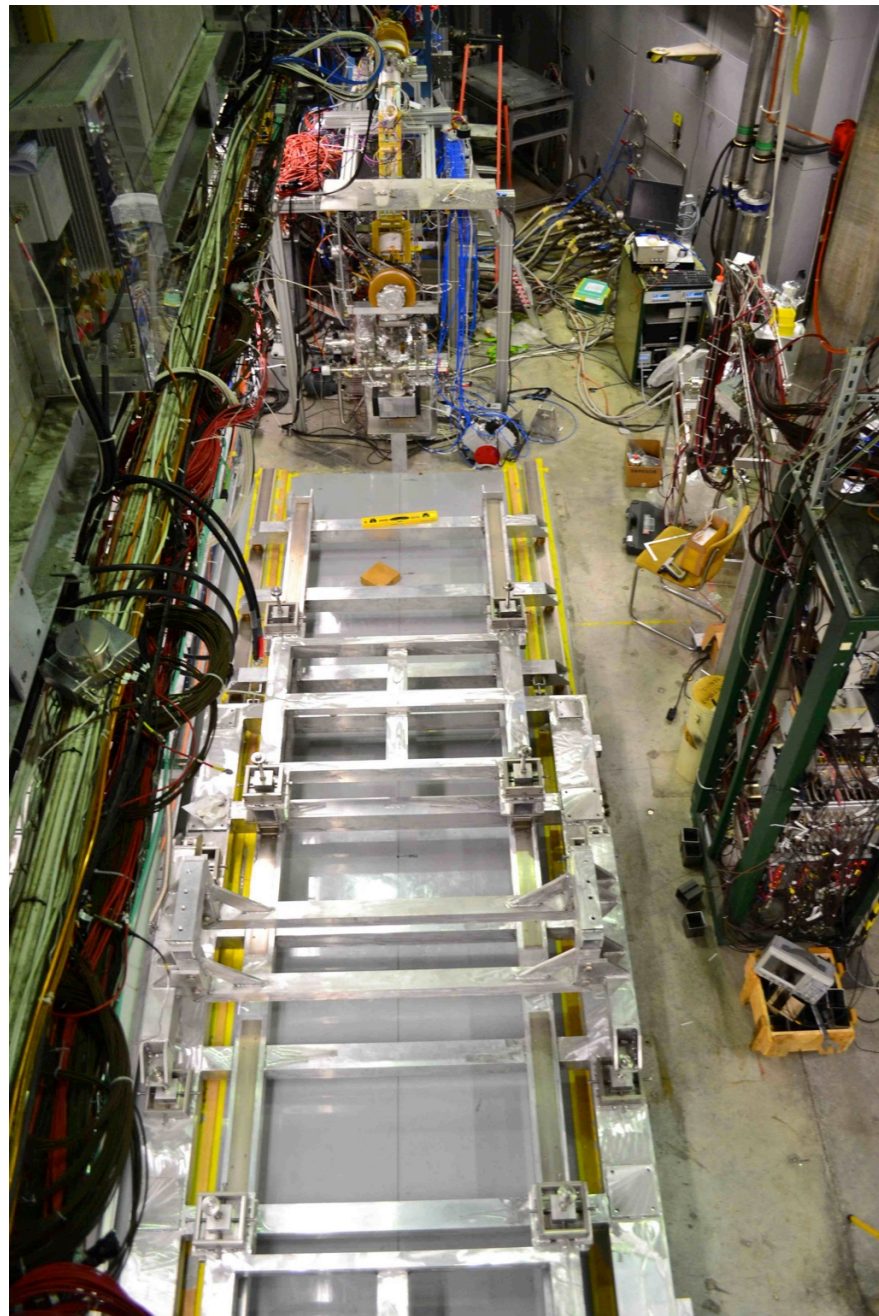
Ongoing work to increase the rates and efficiencies

Ps excitation laser system



Transported to CERN and installed in October

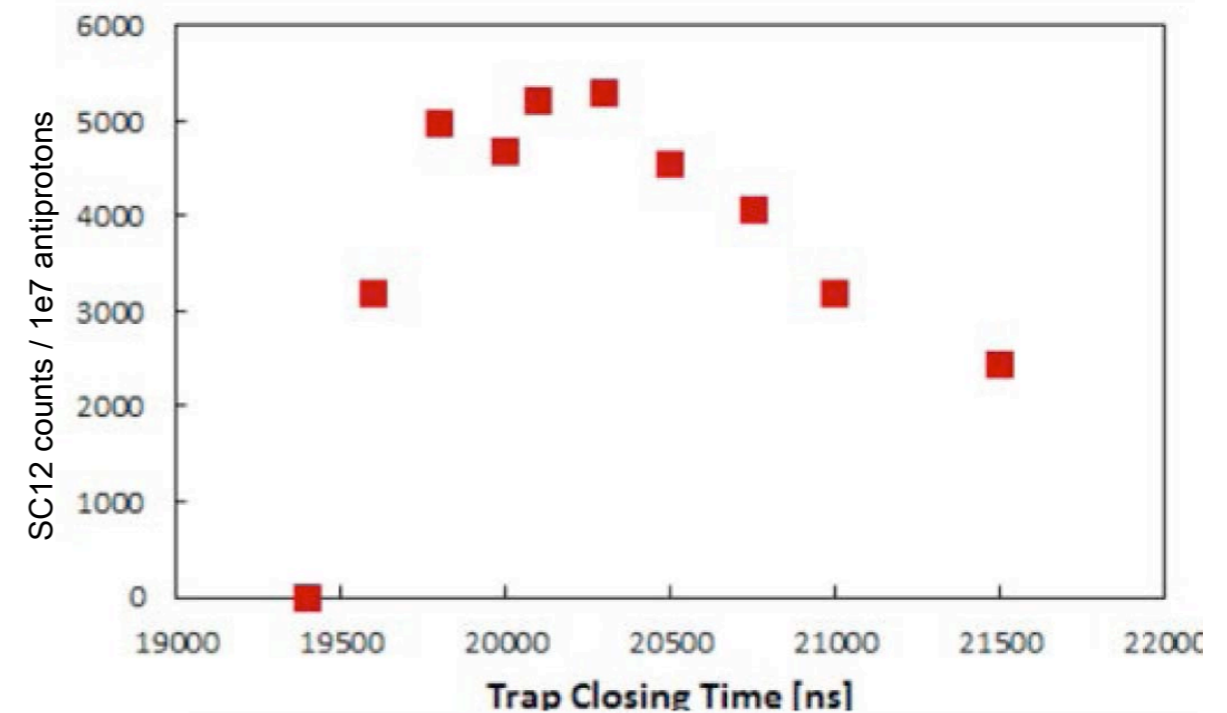
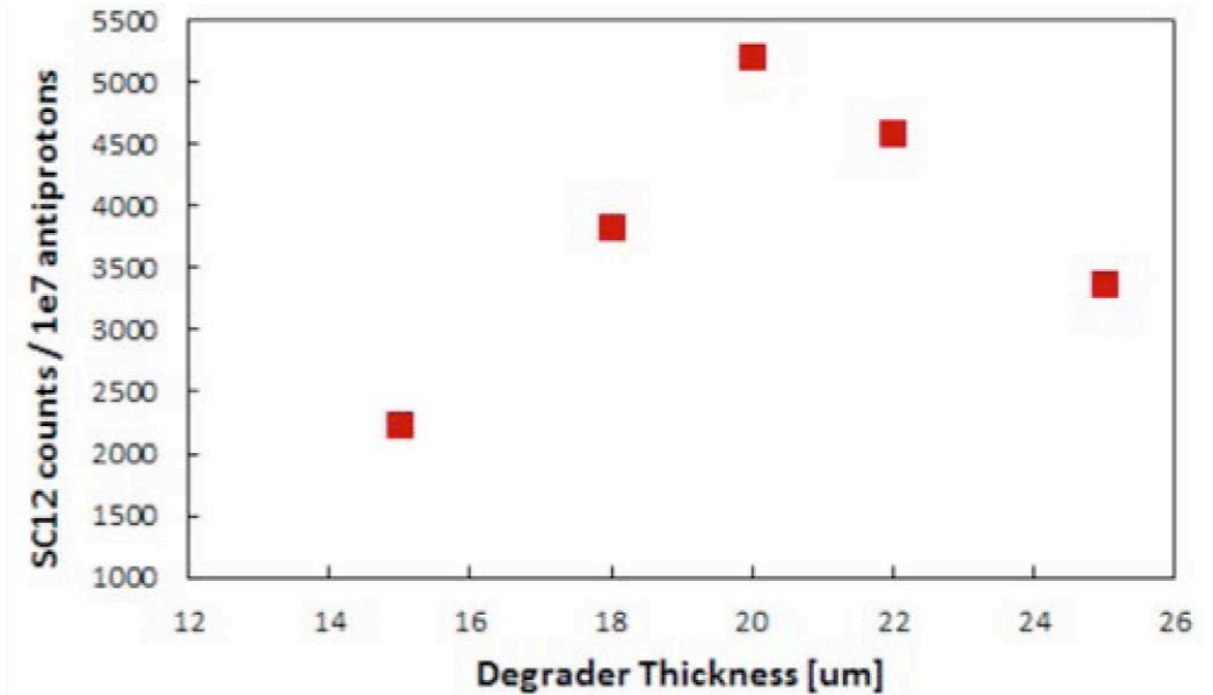
Assembly



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

Beam in 2012: first run (May/June)

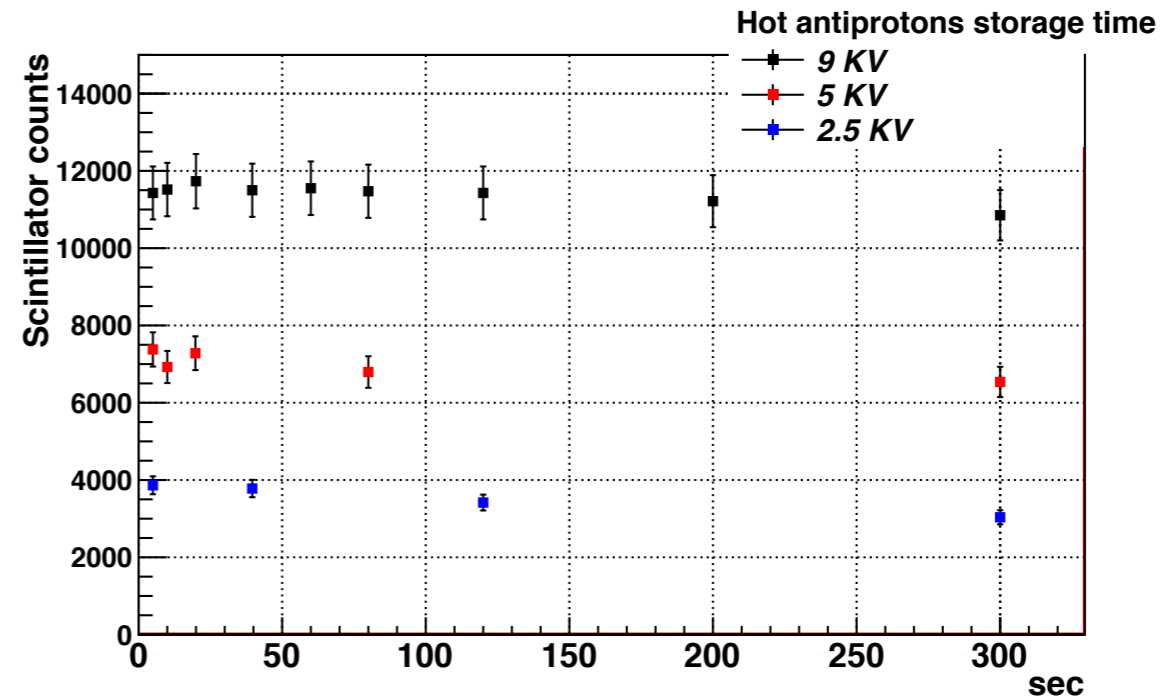
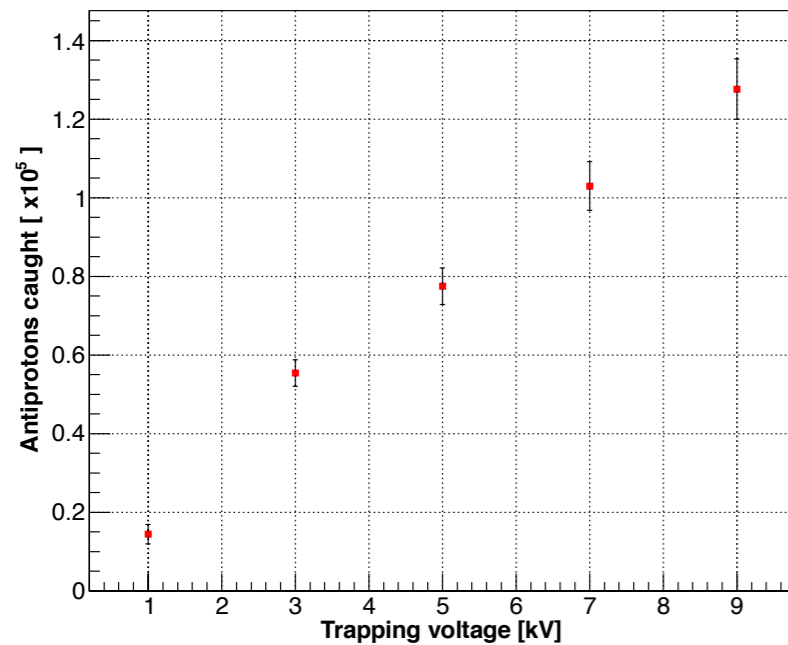
Commissioning run of 5T magnet: trapping, debugging, ...



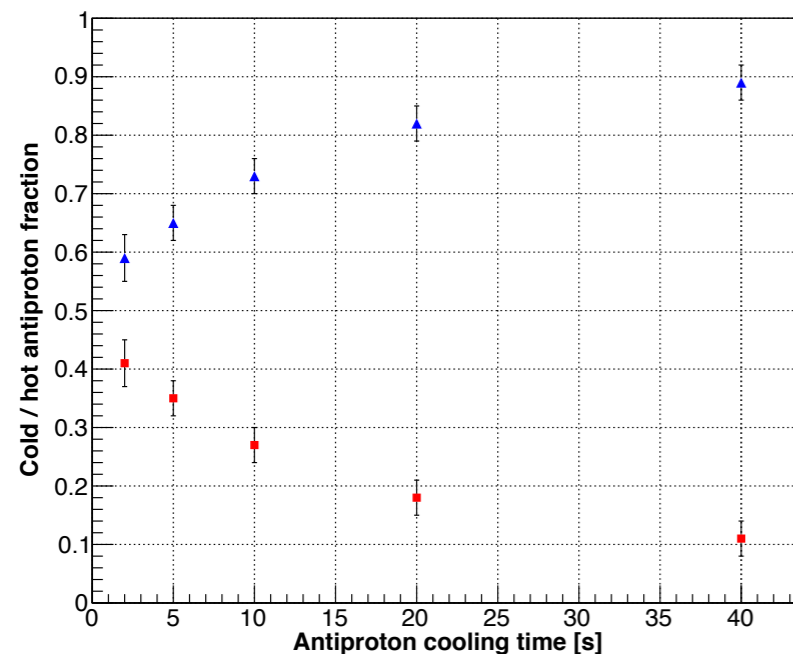
Beam in 2012: second run (November/December)

Commissioning run of full apparatus: trapping, cooling, manipulations, positron transfers, detector tests, ...

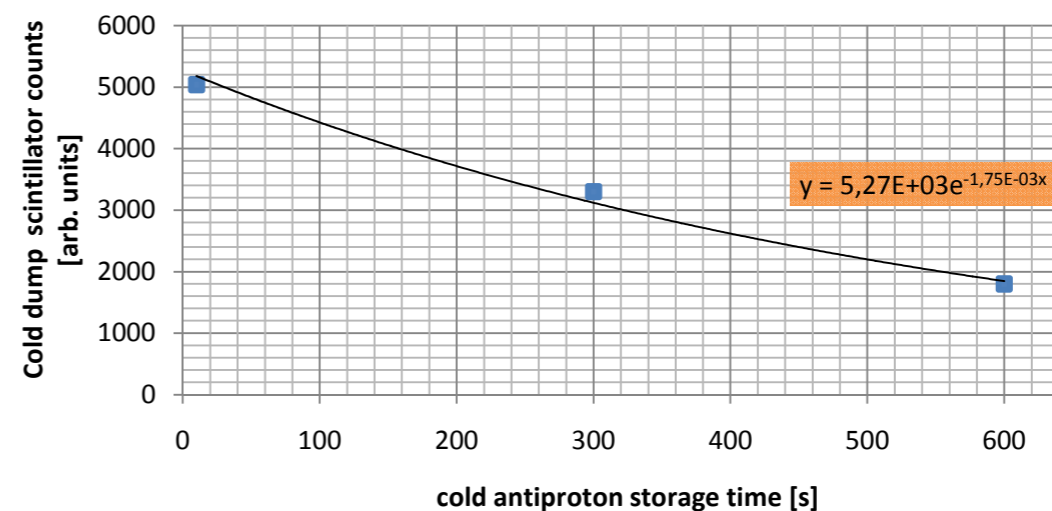
Antiproton catching vs applied high voltage



Cold and hot antiproton fractions vs. electron cooling time



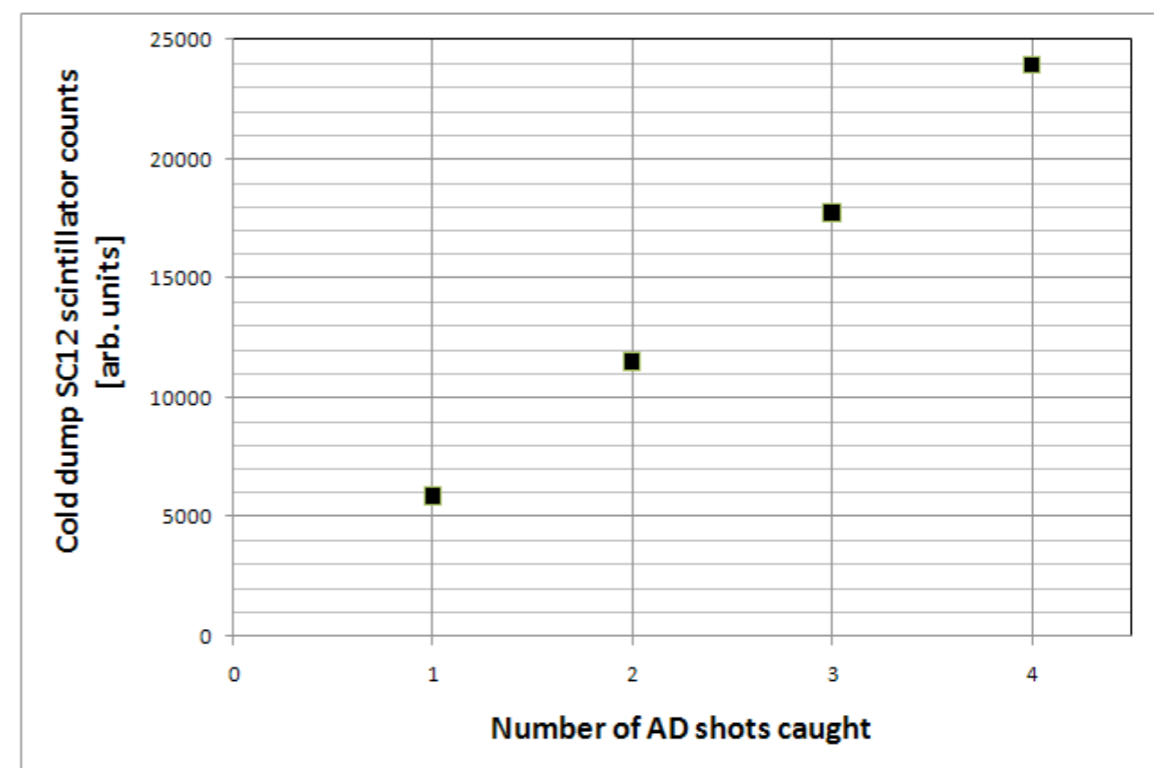
Cold antiproton lifetime



Beam in 2012: second run (November/December)

Commissioning run of full apparatus: trapping, cooling, manipulations, positron transfers, detector tests, ...

stacking of AD shots



further tests carried out: trapping vs. B-field, transfers, calibrations, measurements of the antiproton energy distributions before/during/after cooling, mixing of antiprotons with positrons, vacuum tests, internal diagnostics, ...

Beam in 2012: second run (November/December)

Commissioning run of full apparatus: trapping, cooling, manipulations, positron transfers, detector tests, ...

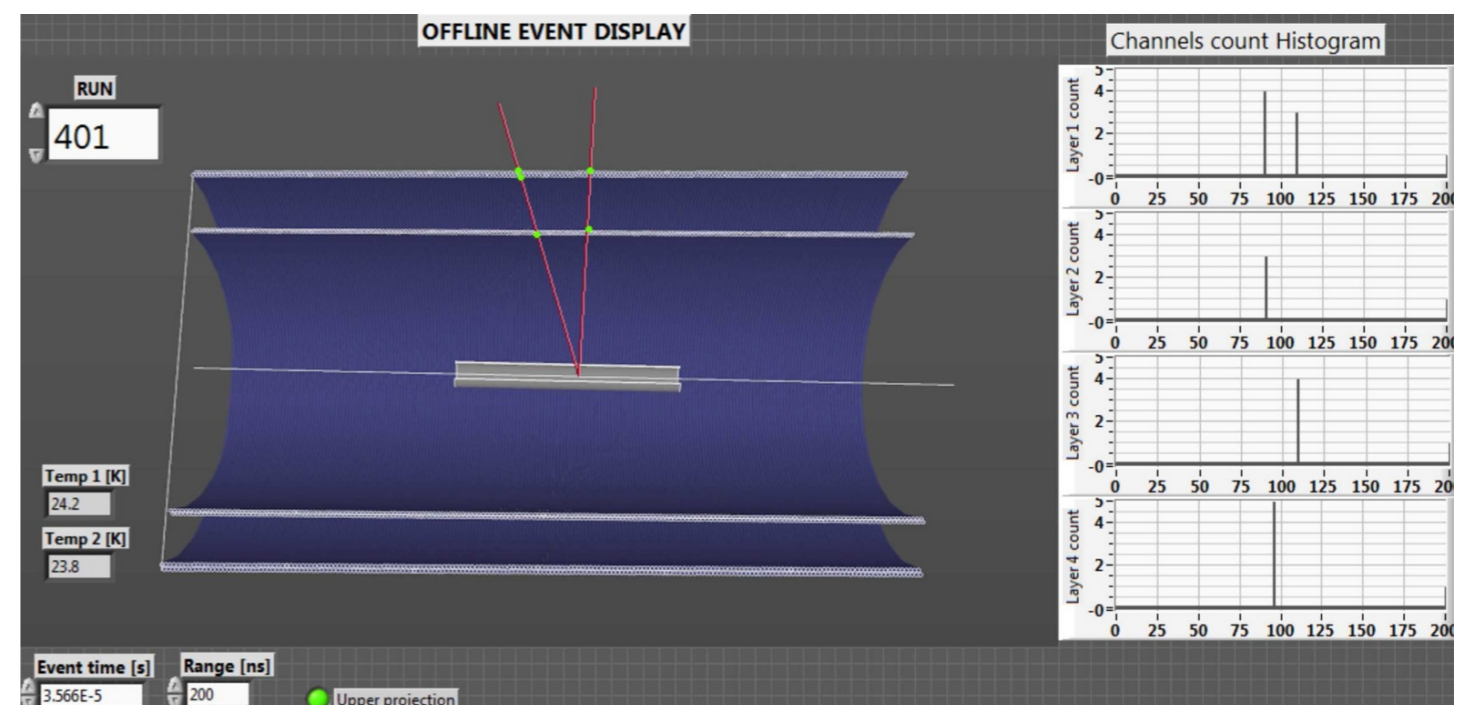
positron transfers from accumulator through transfer section and 5T magnet into IT magnet



extraction pulse from accumulator

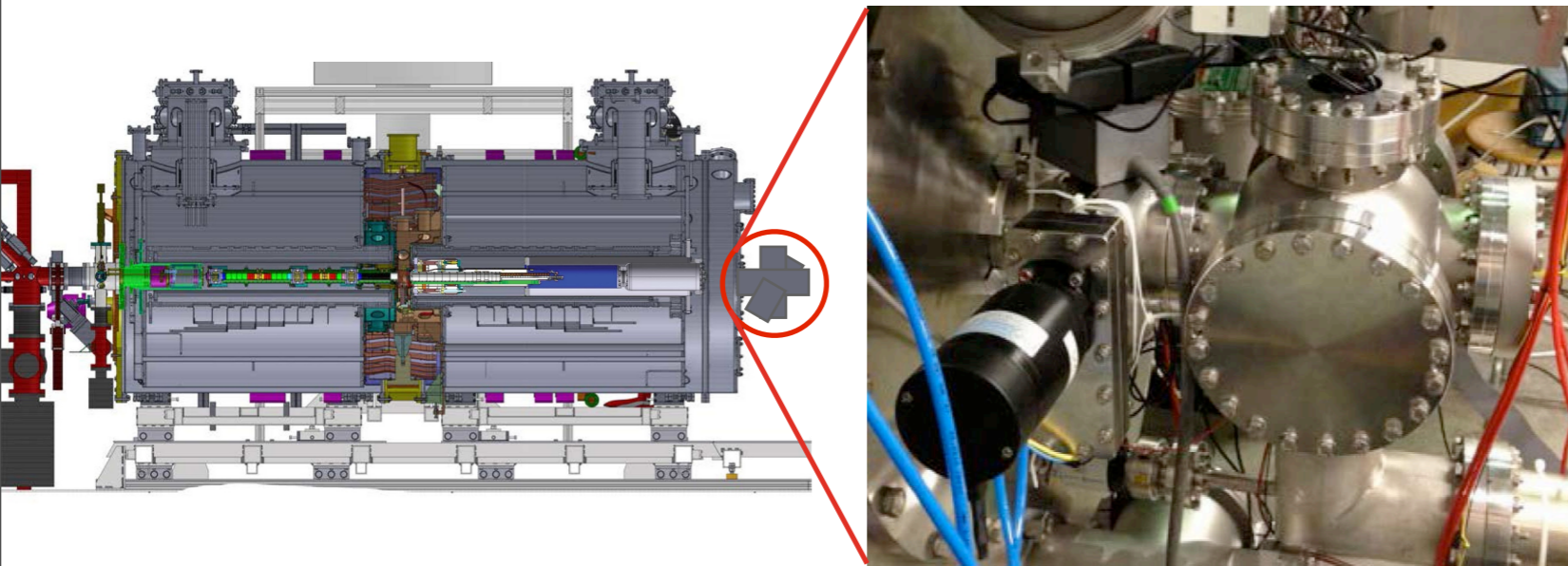
scintillator pulse from positron annihilation in IT

antiproton annihilations in IT magnet as seen by the scintillating fiber tracker around the \bar{H} formation region



Beam in 2012: both runs

Parasitic tests:

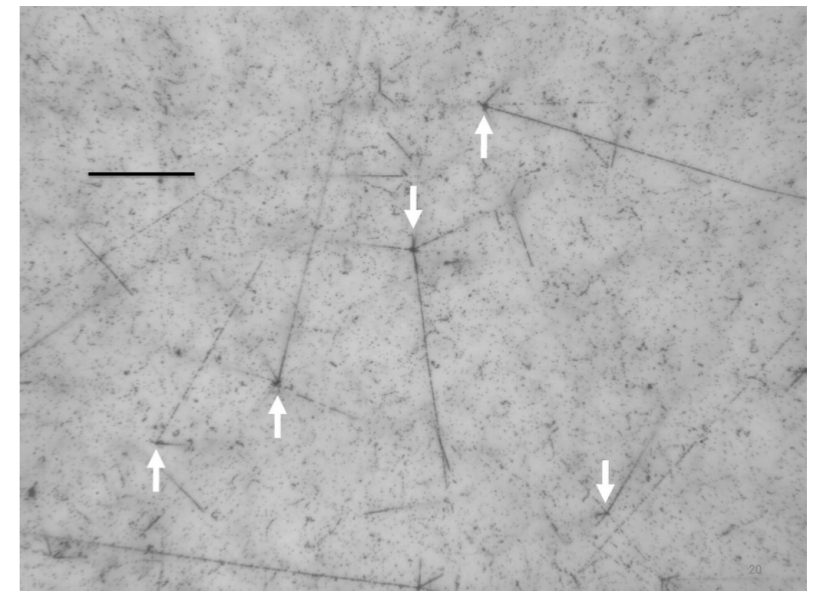
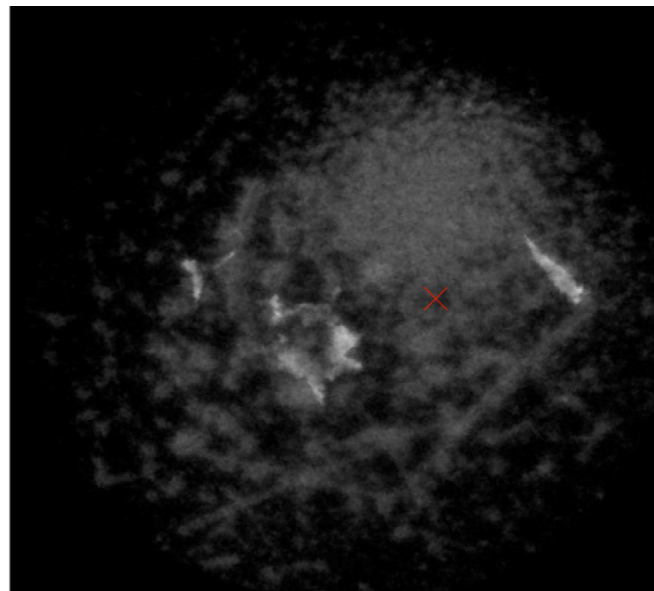
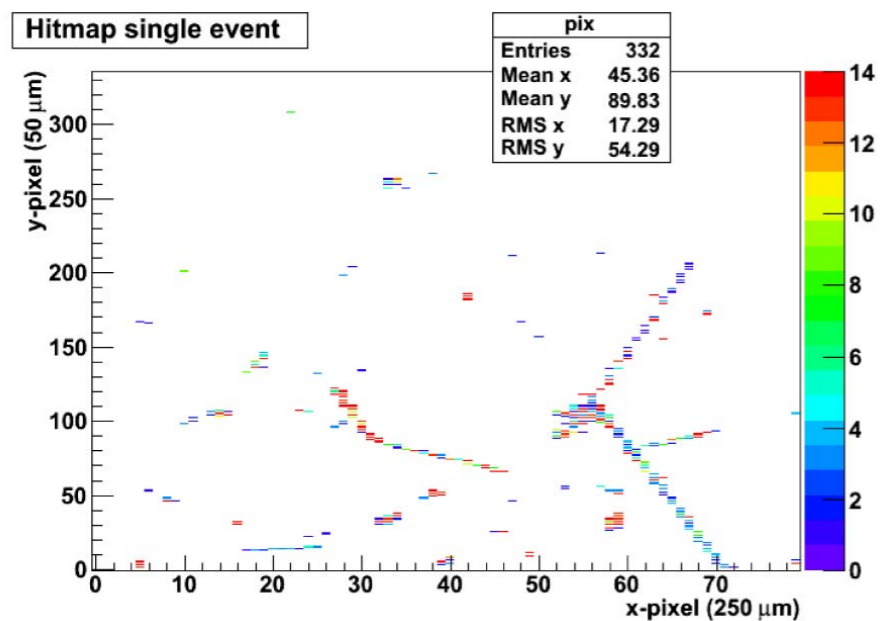


explore/validate different candidate technologies for the (downstream) antihydrogen detector by annihilating (low energy) antiprotons in the detectors

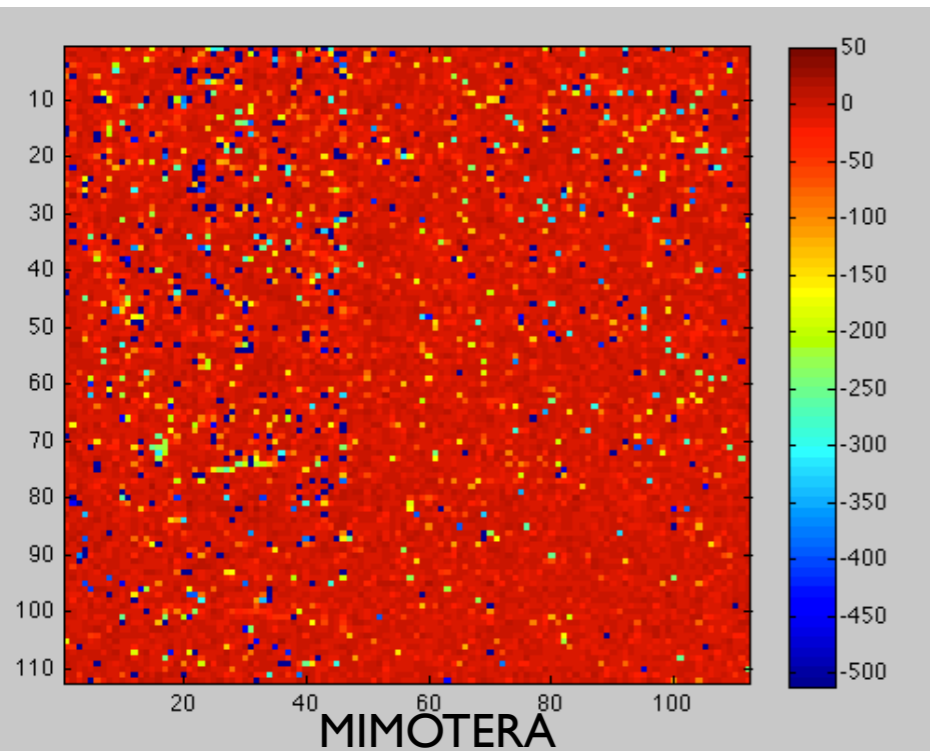
Silicon detectors (strip, pixel)

MCP

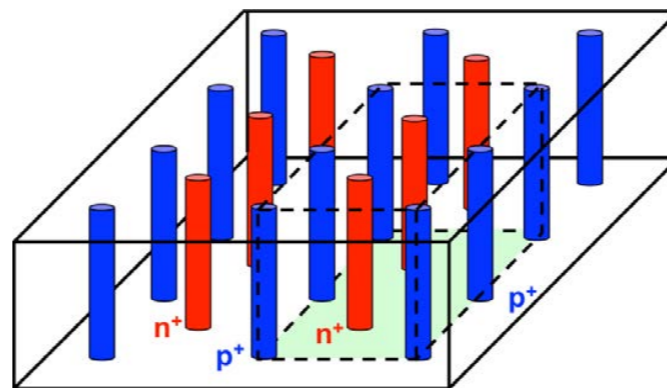
emulsions



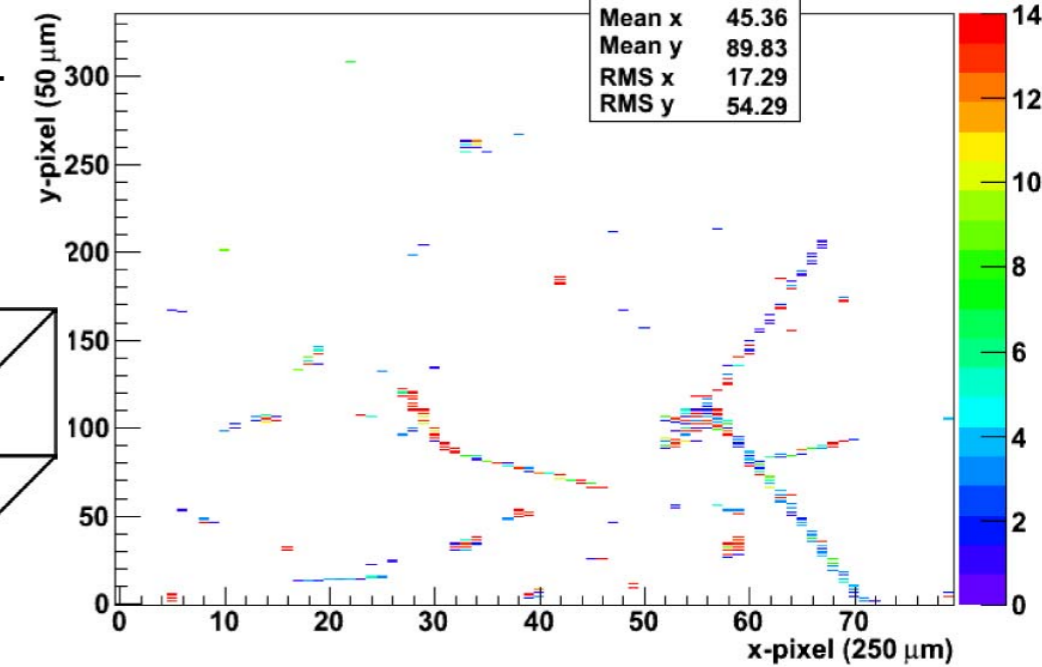
Silicon detectors (MIMOTERA, pixel detector, strip detector)



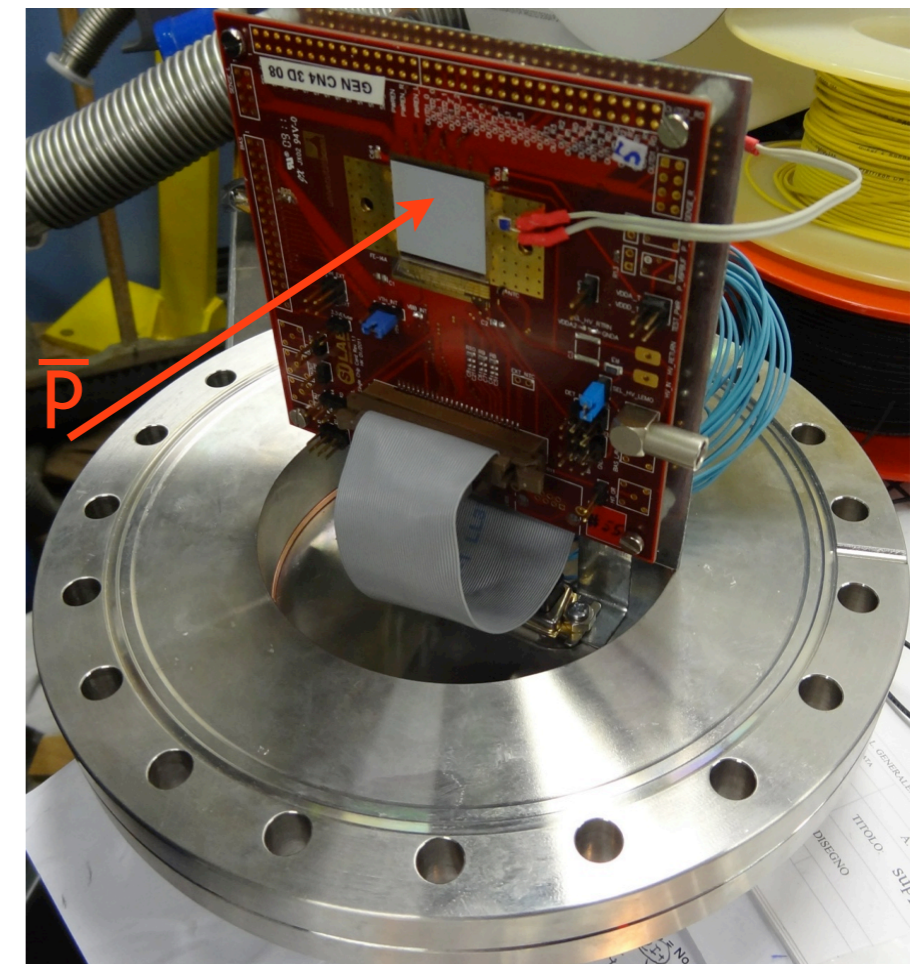
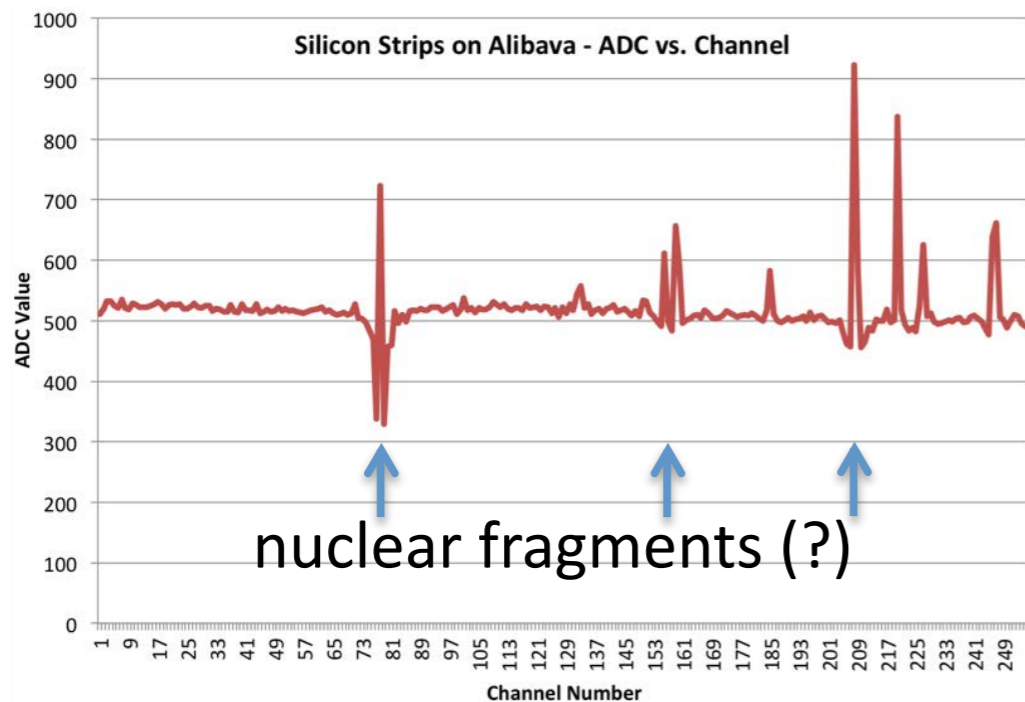
CNM-55-3D pixel sensor bump-bonded to FE-I4 R/O chip designed for the ATLAS Insertable B layer upgrade



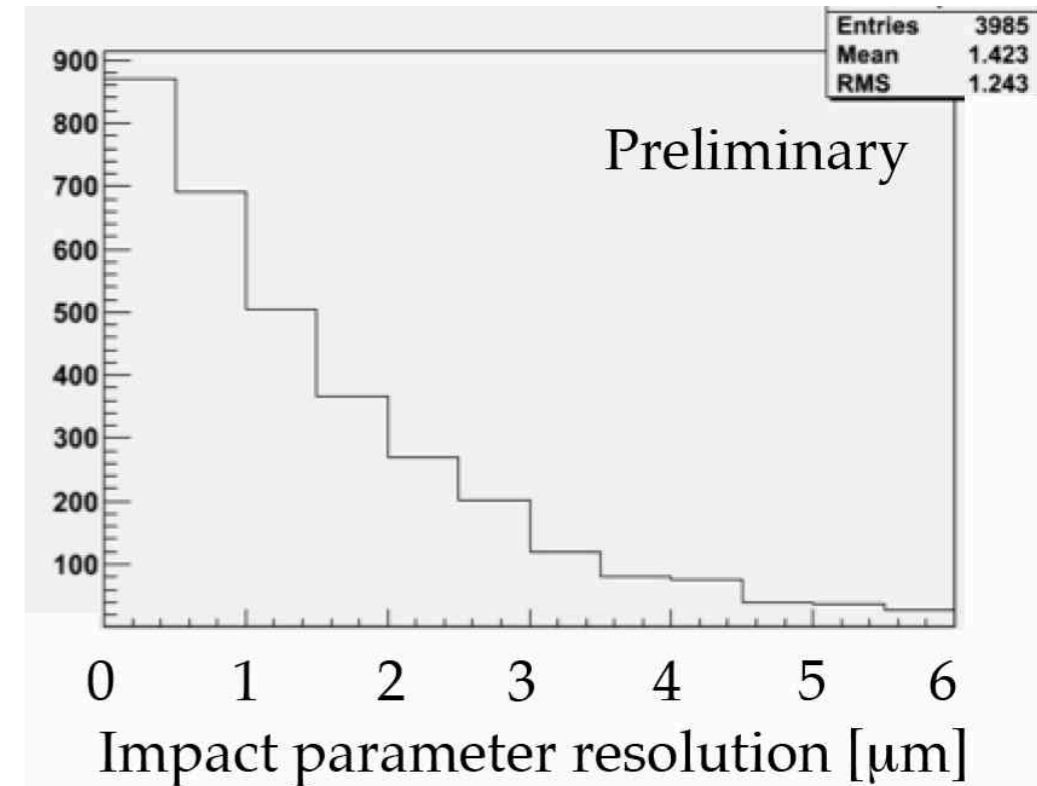
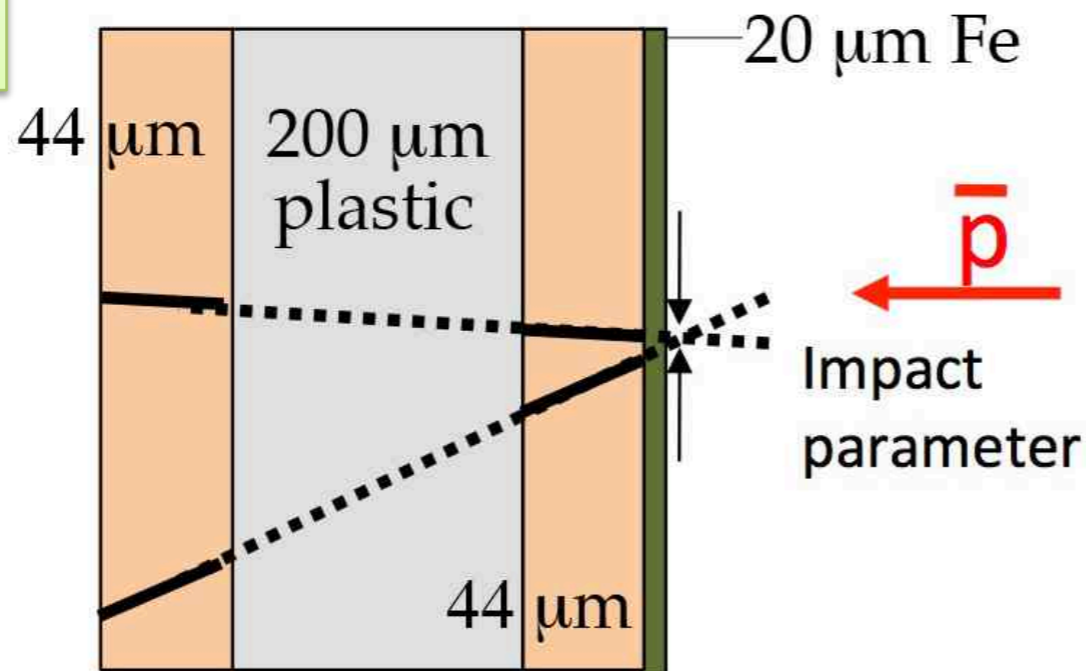
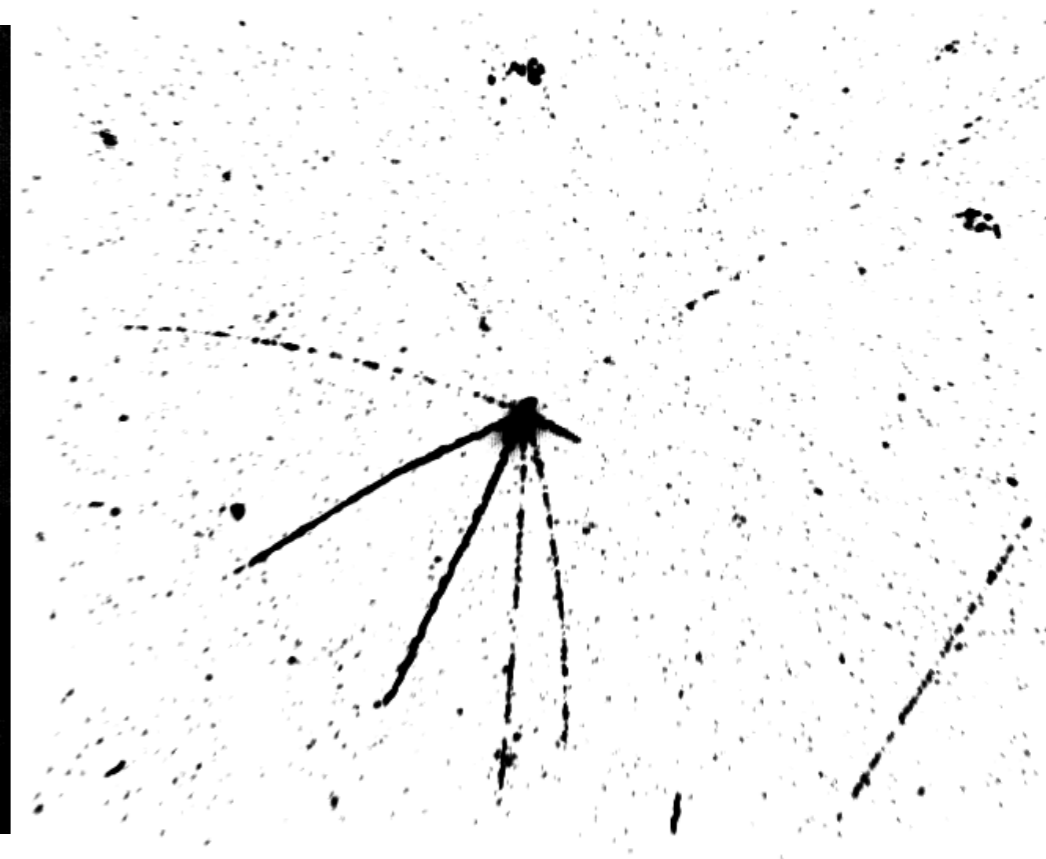
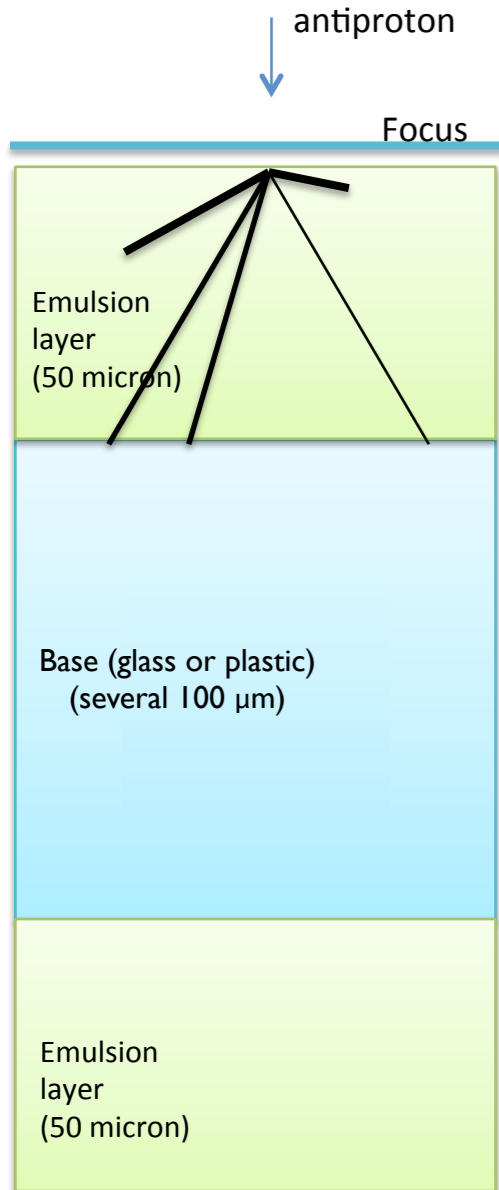
Hitmap single event



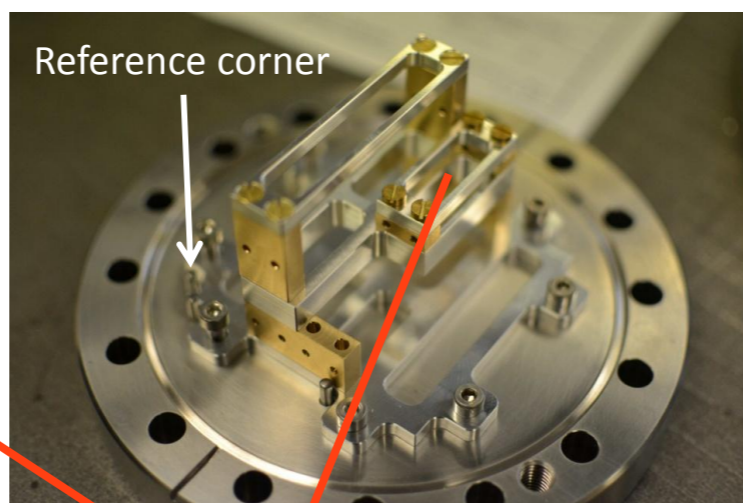
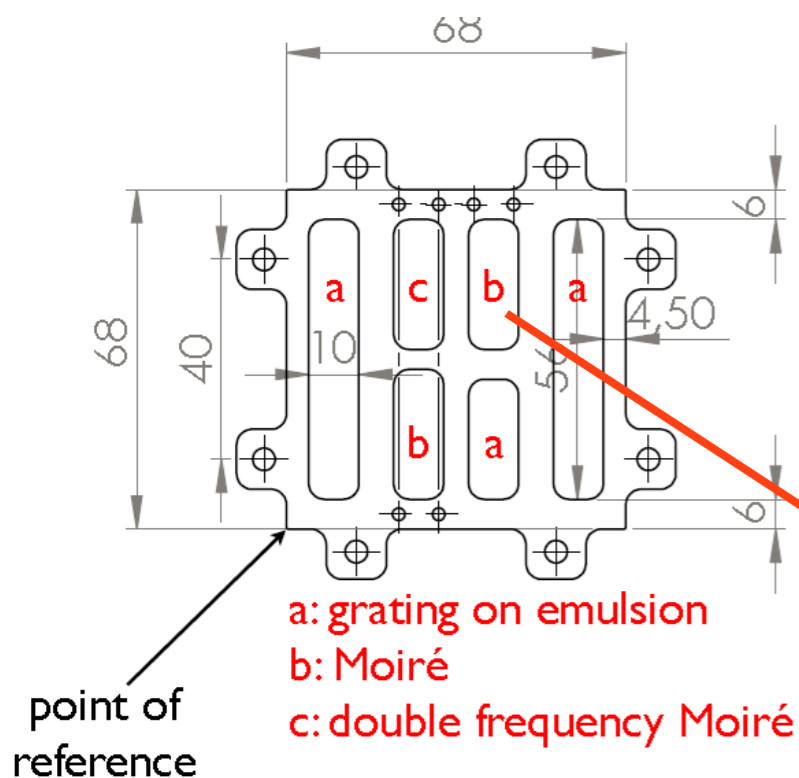
Strip sensors 50 and 80 μm pitch
300 μm thickness
Beetle based - Alibava readout



Emulsion: annihilation in emulsion & in thin foils of different composition

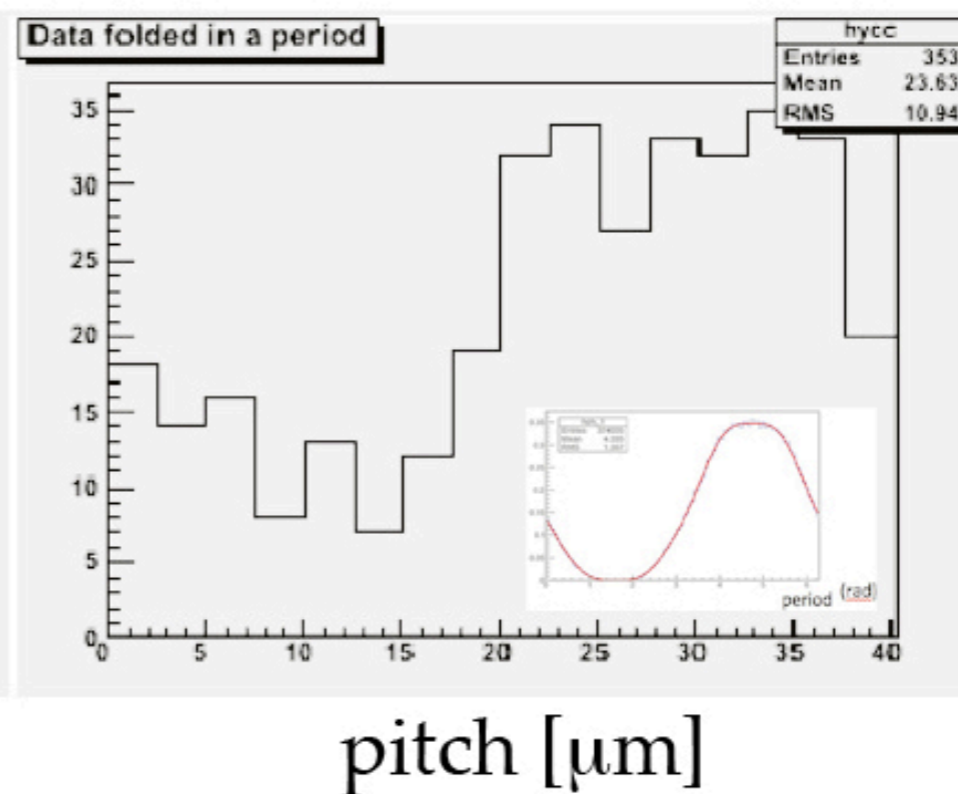
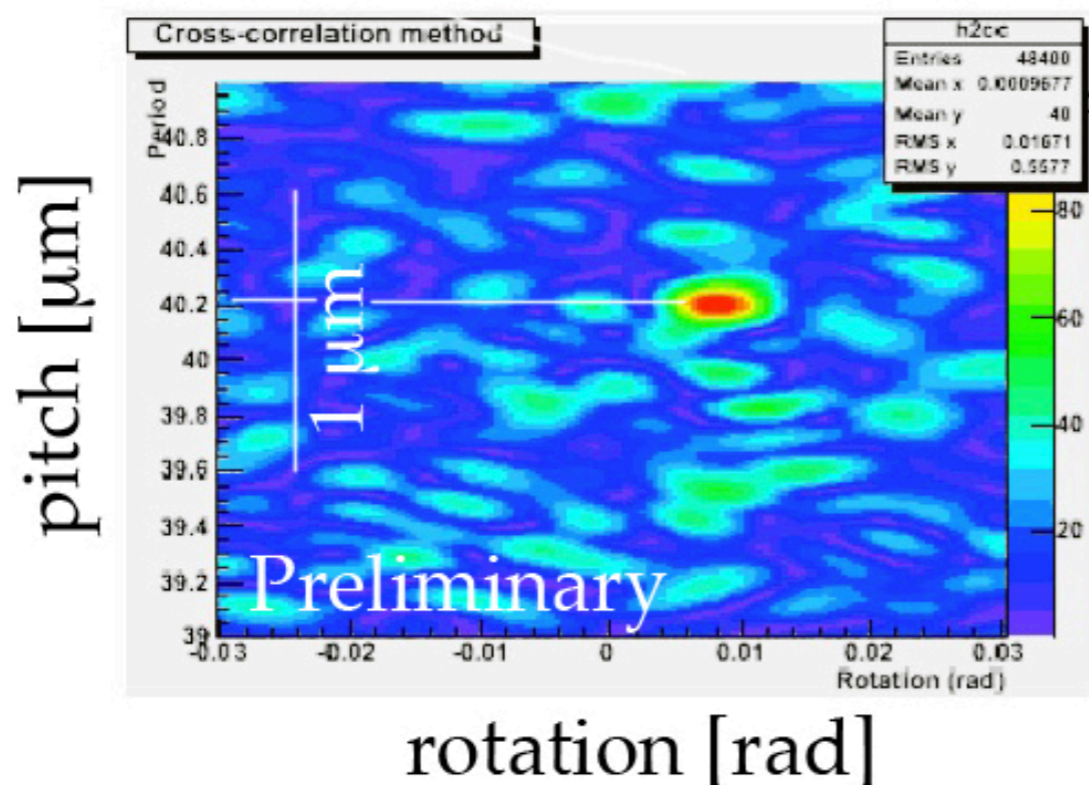
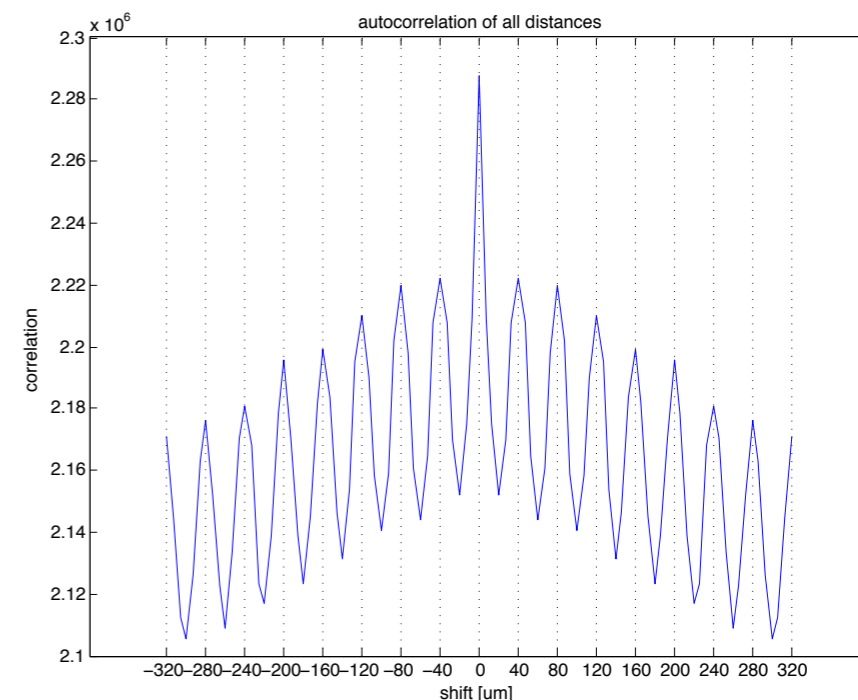


Test of moiré deflectometer with antiprotons



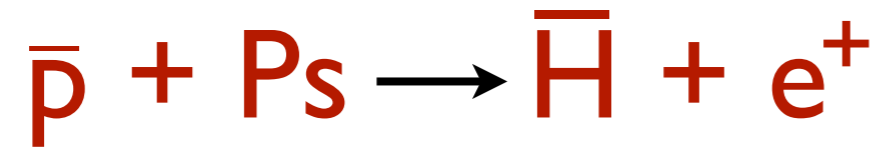
first look at data in zone b)
353 vertices in $\sim 1 \text{ cm}^2$

vertex-to-vertex autocorrelation

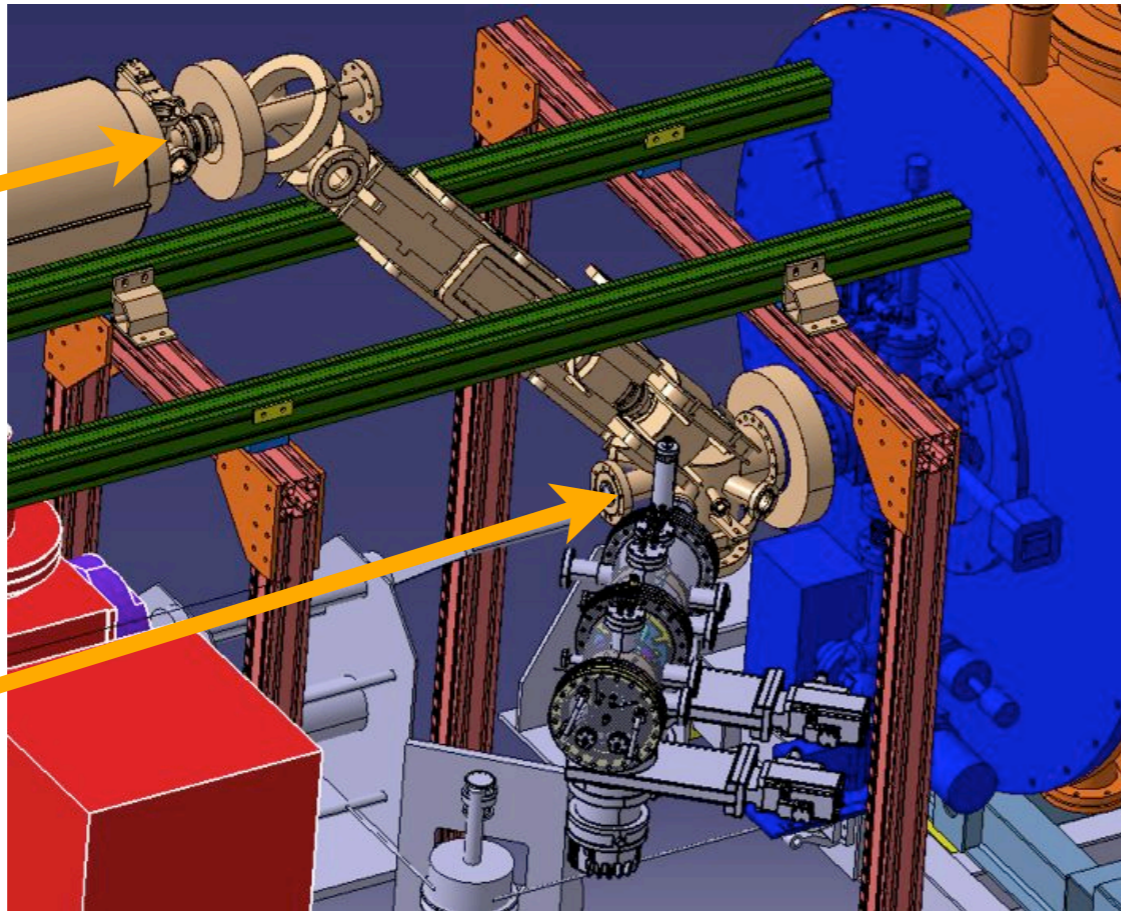


First demonstration of the moiré deflectometer technique with antiprotons!

ongoing work: Proton source

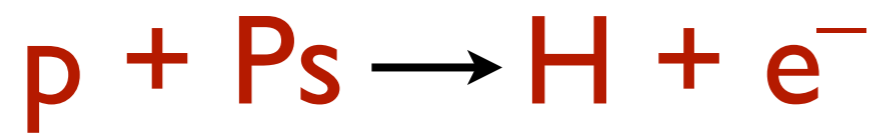


positrons

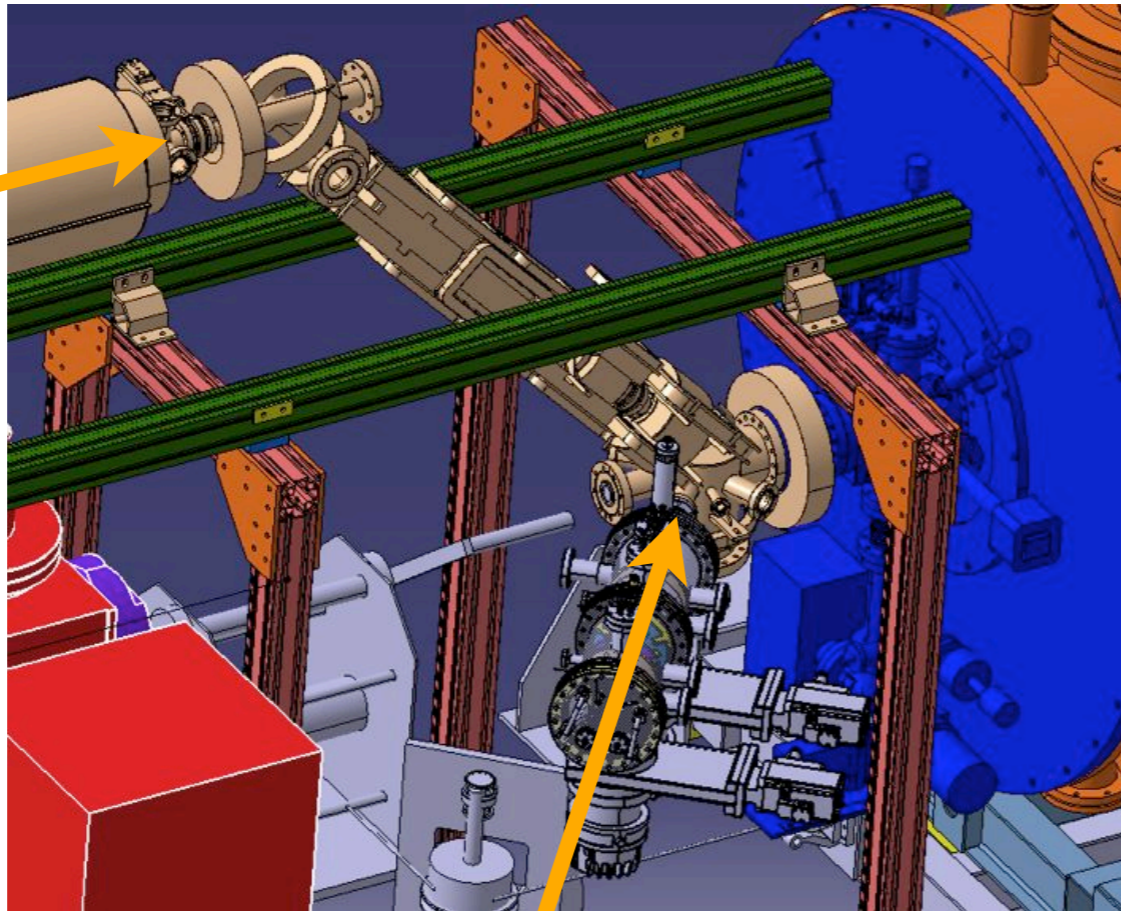


anti-
protons

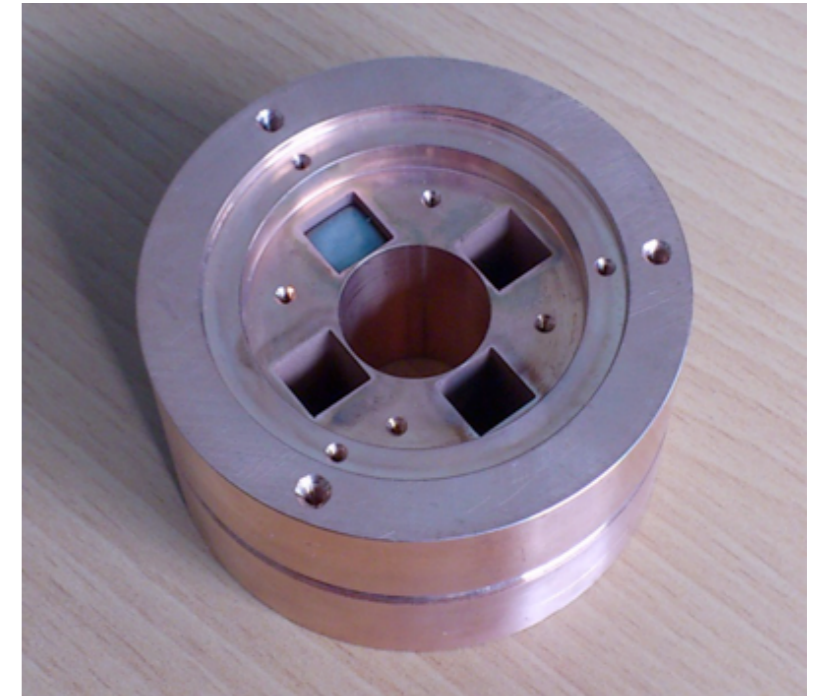
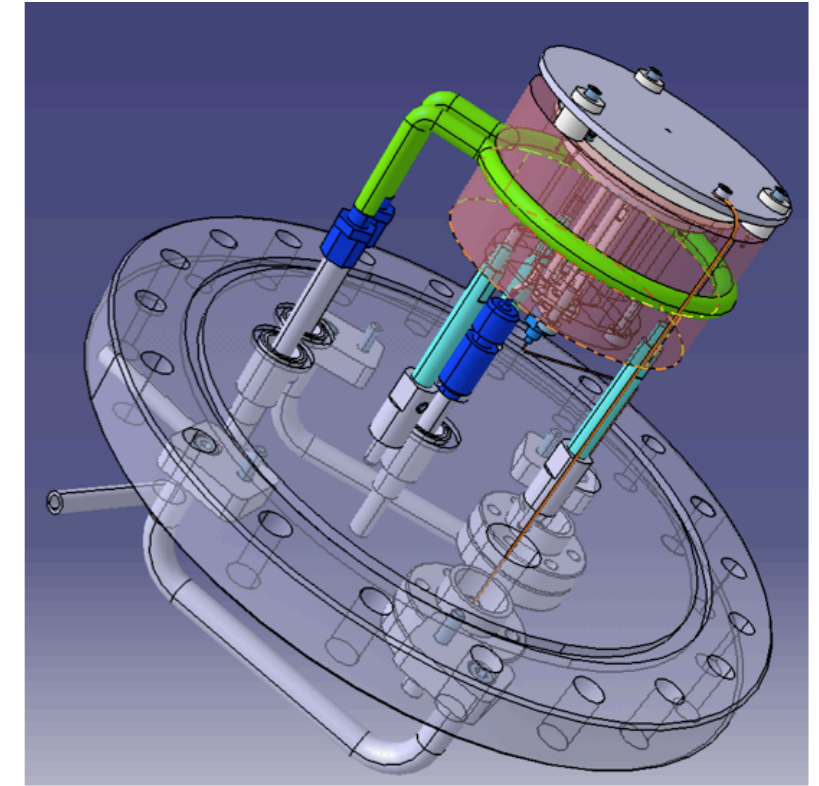
ongoing work: Proton source



positrons

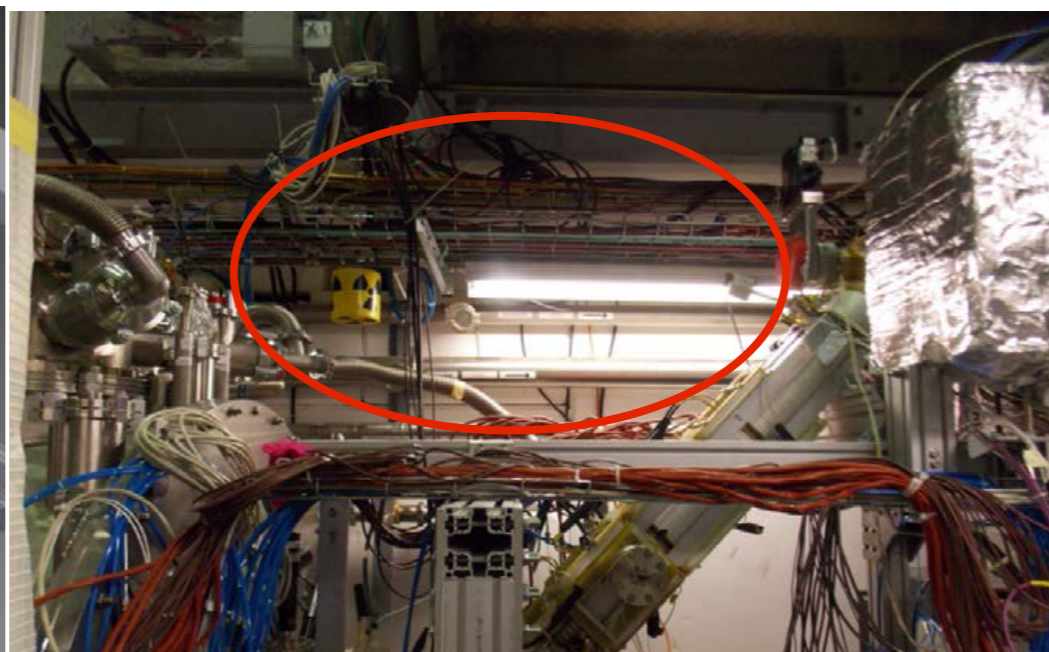
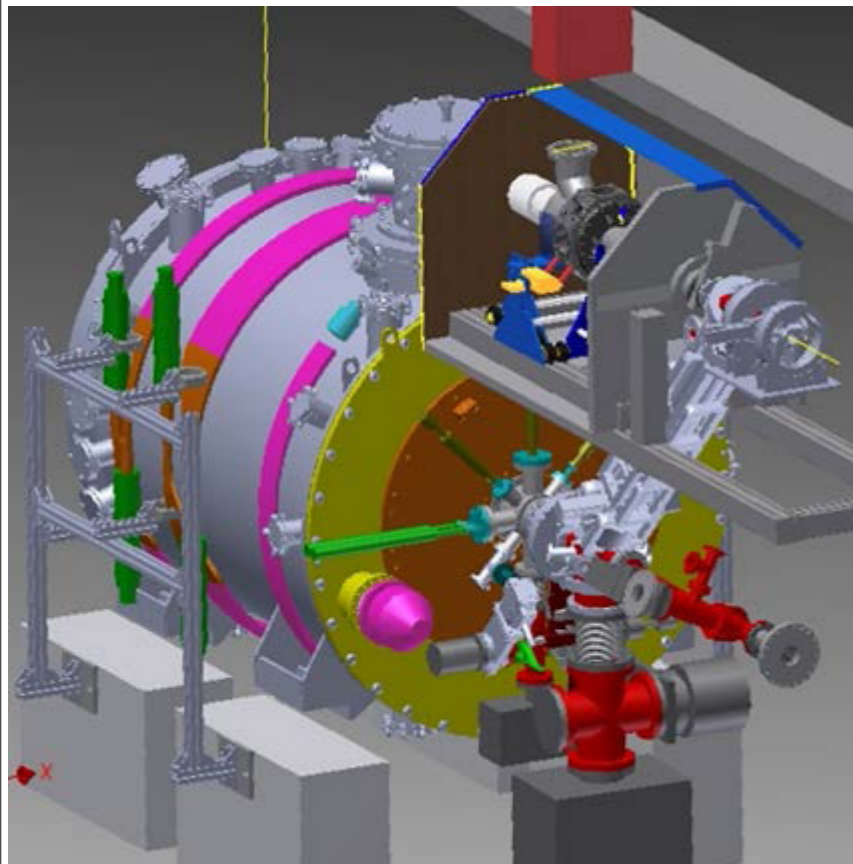
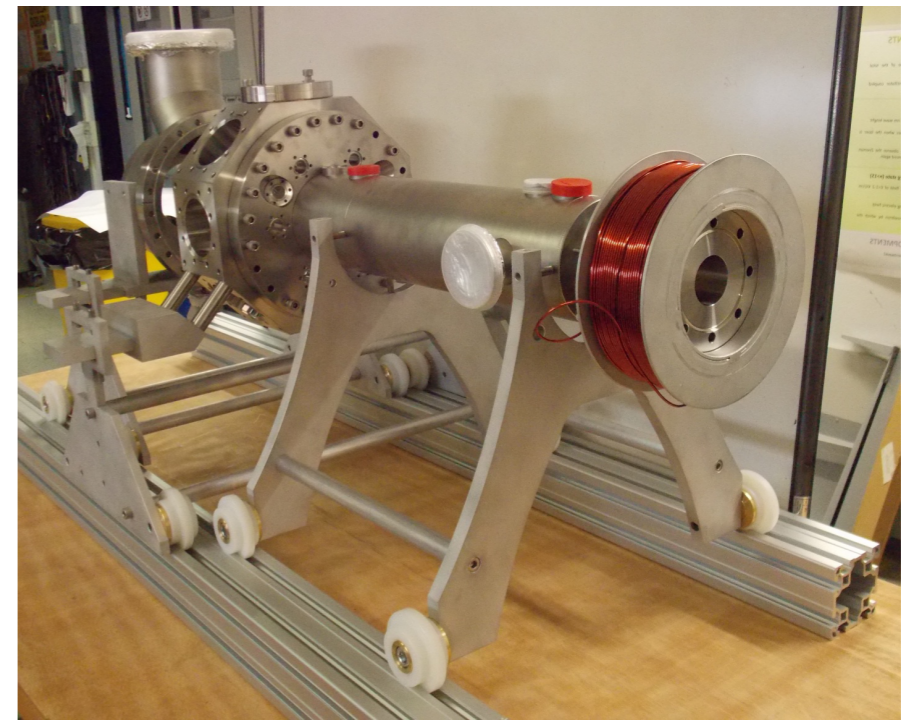
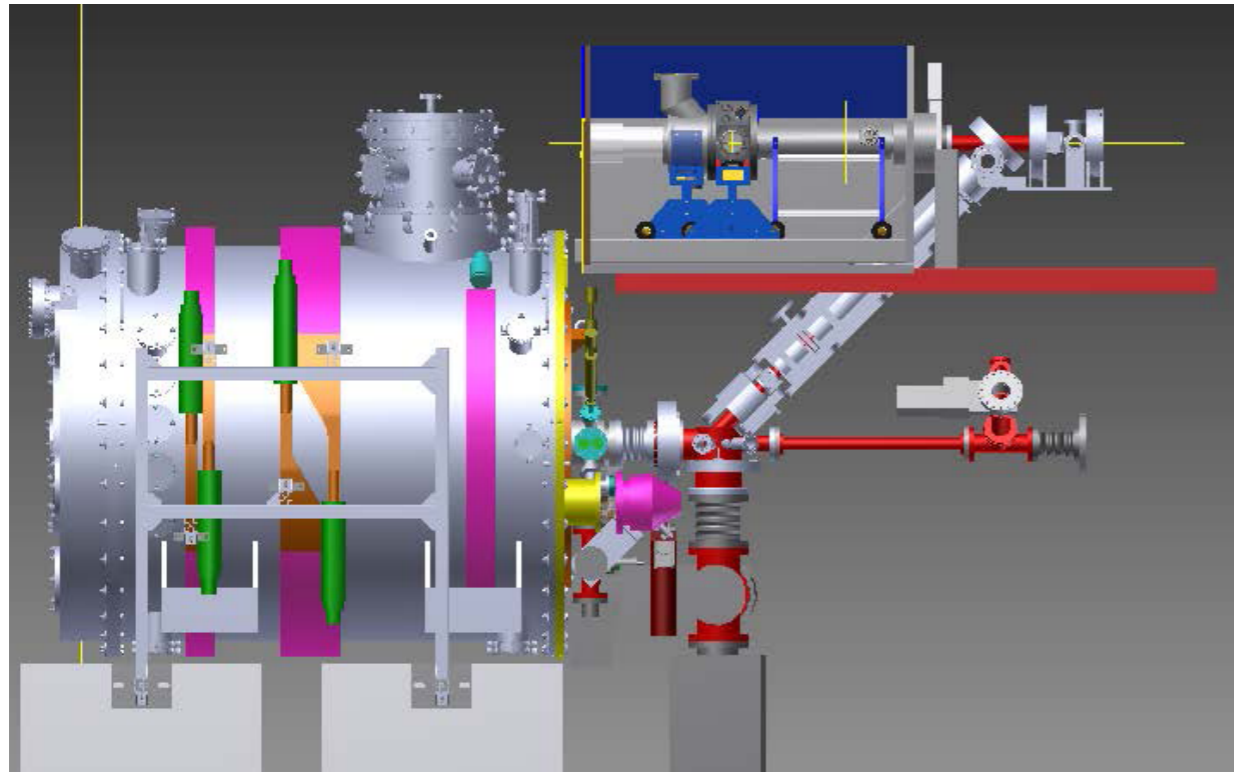


protons

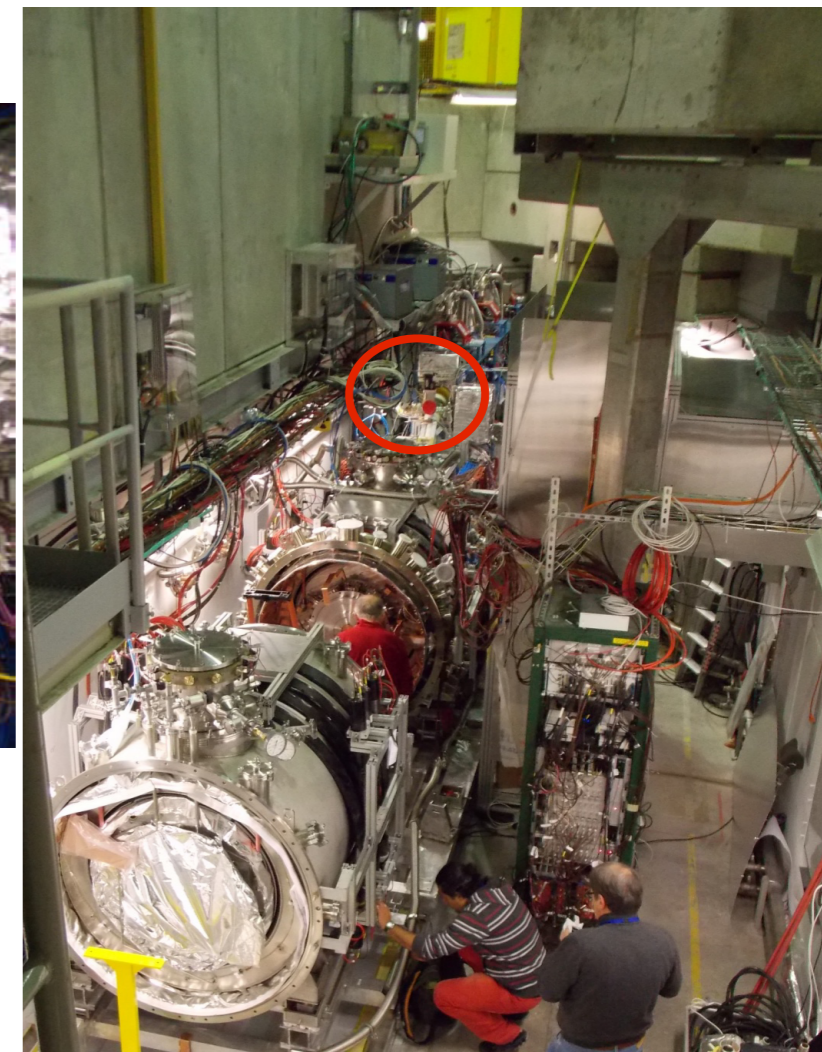


under construction; to be installed in spring 2013

ongoing work: Positronium test station



ready for installation



Outlook for 2013/2014

next months:

- continue testing/commissioning apparatus with electrons, positrons
- commission laser system
- install positronium test station

spring:

- install minor improvements to diagnostics
- install Hydrogen detector
- install proton source

remainder of year:

- work toward formation and characterization of Ps, Ps*, hydrogen
- validate Ps characteristics (test station & in IT magnet)
- Ps spectroscopy (test station)
- design work on downstream interface (beyond IT magnet)
- R&D work on downstream antihydrogen detector
- R&D work on cooling of antiprotons

goal for summer 2014: be in a position to form antihydrogen beam

Conclusion and outlook

Installation of apparatus largely completed and commissioned with antiprotons

Beam times were extremely valuable in understanding apparatus

Parasitic measurements were very successful - essential information obtained to design optimal deflectometer+detector layout

We have had a very busy year 2012, and 2013 / 2014 will not be much easier, requiring a sustained effort with the now-existing infrastructure.

request: essentially uninterrupted access to cryogenics (lHe), power & cooling water

