AEgIS – Silicon Detector Development

An overview of the experiment with a focus on the silicon detector

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Outline

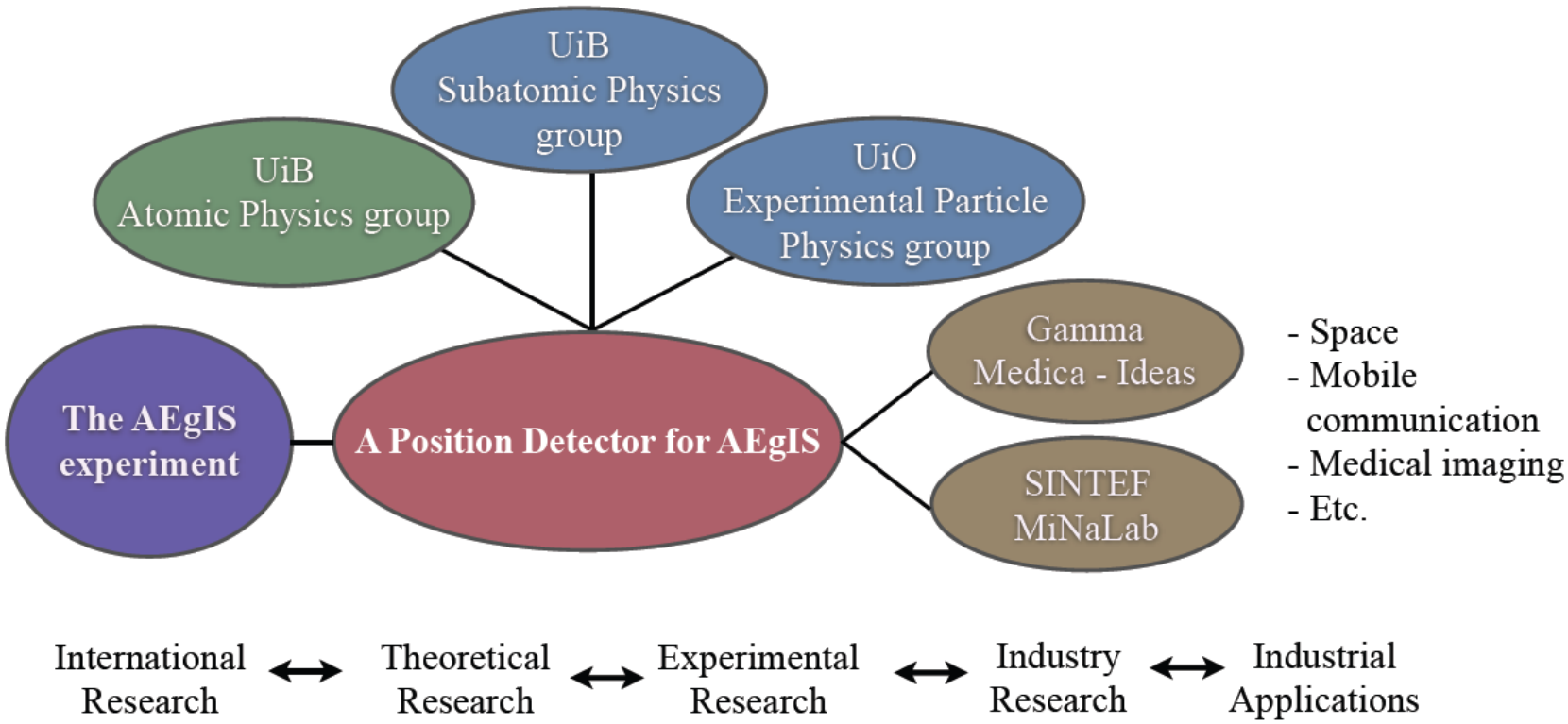
- The AEgIS collaboration, Norwegian involvement
- AEgIS – motivations and aims
- AEgIS – experimental overview
  - Measuring the free fall of antiH
  - The experiment into the AD complex
  - AEgIS experiment overview
  - AntiH production and detection
  - ATHENA – detecting antiproton annihilation with silicon sensors
  - Silicon Strip Sensors for AntiH detection – requirements
- R&D effort outline
  - Current Time Schedule
  - Current R&D efforts
- Summary

The AEgIS collaboration

~ 80 researchers take part to the experiment, from several institutes:

- CERN
- INFN Genova, Italy
- MPI-K Heidelberg
- Kirchoff Institute of Physics, Heidelberg
- INFN, Università degli Studi and Politecnico di Milano, Italy
- INFN, Firenze, Italy
- INFN, Pavia-Brescia, Italy
- INR, Moscow, Russia
- Université Calude Bernard, Lyon, France
- University of Oslo and University of Bergen, Norway
- Czech Tech. University, Prague, Czech Republic
- INFN, Padova-Trento, Italy
- ETH Zurich, Switzerland
- Lab. Aimé Cotton, Orsay, France
- University College, London, United Kingdom
- Stefan Meyer Institut, Vienna, Austria
- Universities of Bern and Zurich, Switzerland

Norwegian involvement in AEgIS



Norwegian involvement in AEgIS

People involved: 1 PhD, 2 postdocs, in addition to the team members in each institute.

a) Sensor development - SINTEF
b) ASIC development - GM-I
c) Construction (hybrid development, module assembly, electrical readout, testing and operation) - UiO
d) Integration and data preparation (integration with Moire and in AEgIS, readout, testing and operation, software and analysis) - UiB
e) Theoretical studies - Atomic Physics group, UiB is part of AEgIS and will perform important theoretical studies to determine the initial properties of anti-Hydrogen.

AEgIS – Motivations

General Relativity is based on the weak equivalence principle (WEP):

"It is only when there is numerical equality between the inertial and gravitational mass that the acceleration is independent of the nature of the body." – A. Einstein

The weak equivalence principle has been experimentally verified for ordinary matter up to a precision of ~10^{-13} (Baeßler et al., 1999)

All today's physics accepted models, assume the correctness of the WEP. However, the assumption of the WEP is "automatically extended" from matter to antimatter, THOUGH NO EXPERIMENTAL VERIFICATION HAS BEEN MADE!

AEgIS

AEgIS

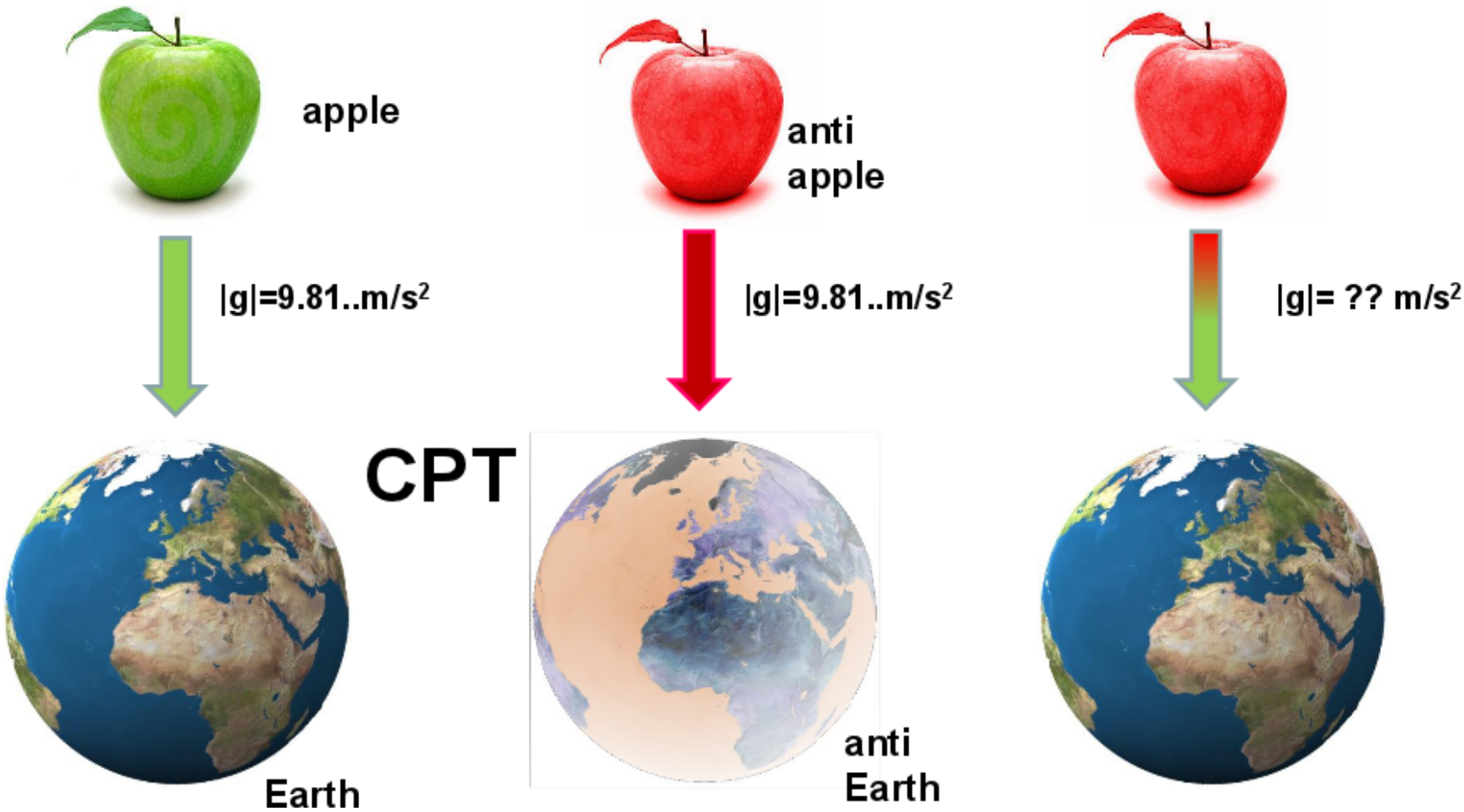
Antimatter Experiment:

gravity – aim of the aegis experiment is to measure the sign, and then the value (with an accuracy of 1%) of the gravitational acceleration of a "free falling" antihydrogen atom

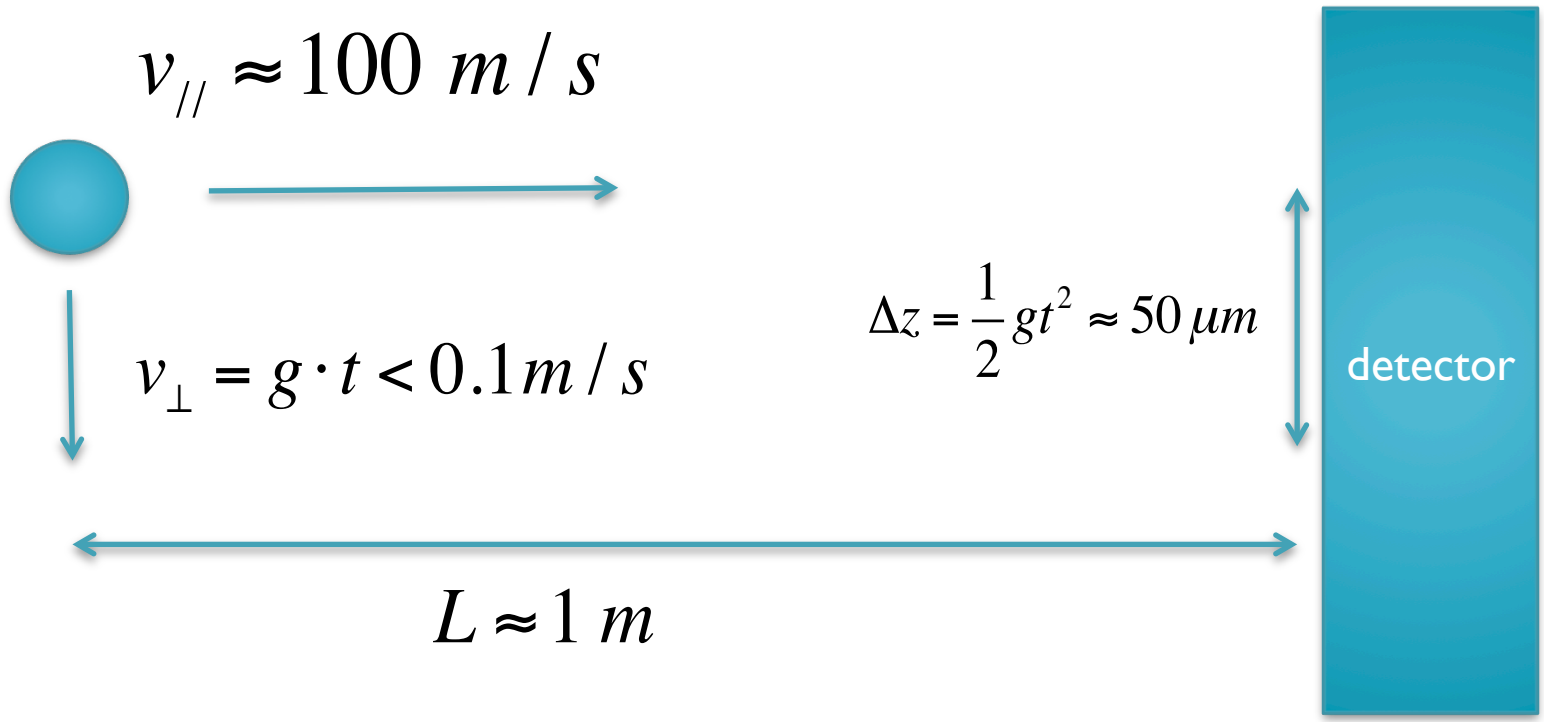
Interferometry – as we are going to see, interferometry is a way to deal with the fact that thermal velocity of antihydrogen is in the best (cold) case comparable to the velocity in the "free fall" trajectory

Spectroscopy – Antihydrogen spectroscopy, study of Rydberg states

Falling apples and antiapples….



Antihydrogen free fall – not a trivial problem

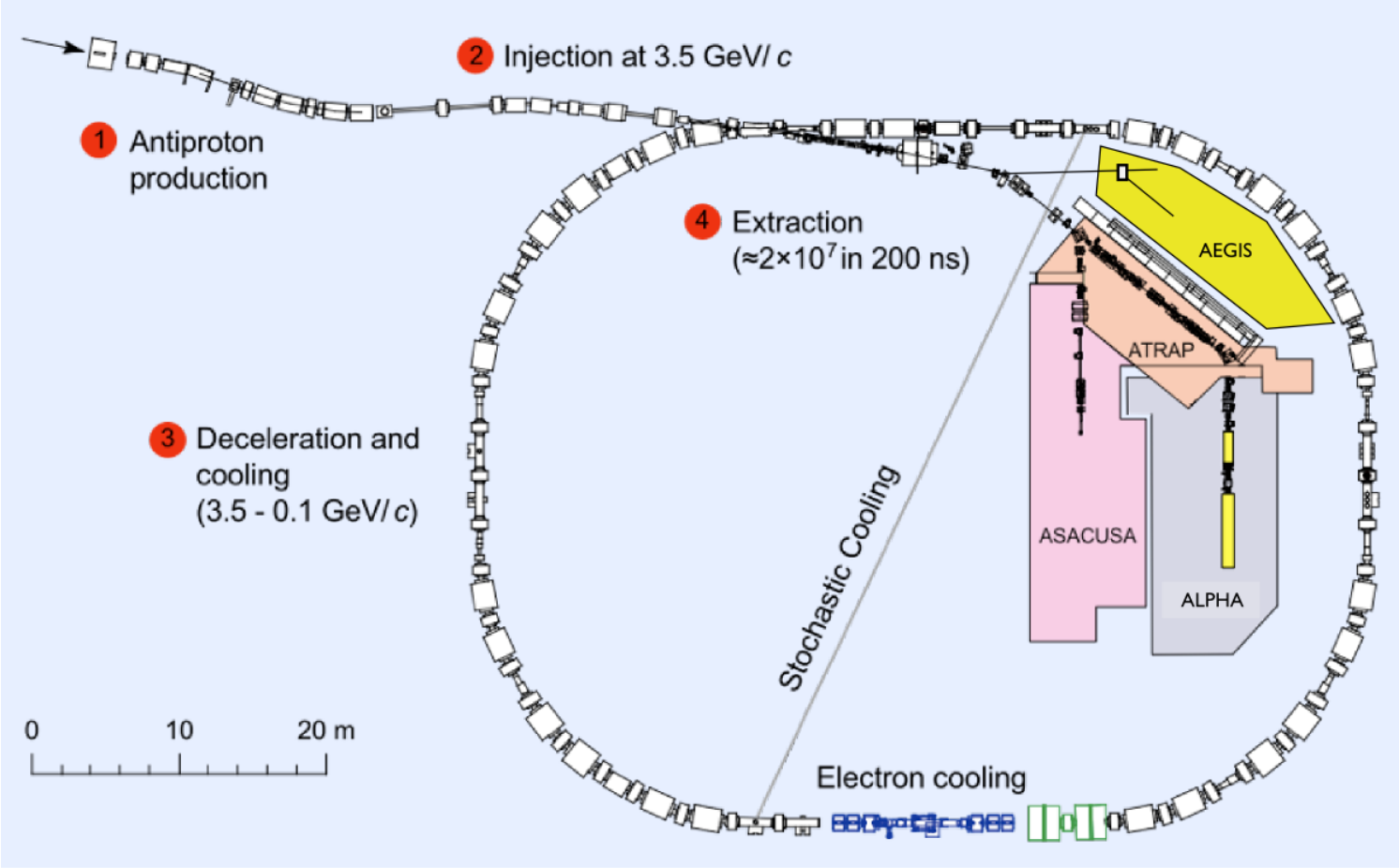


But…

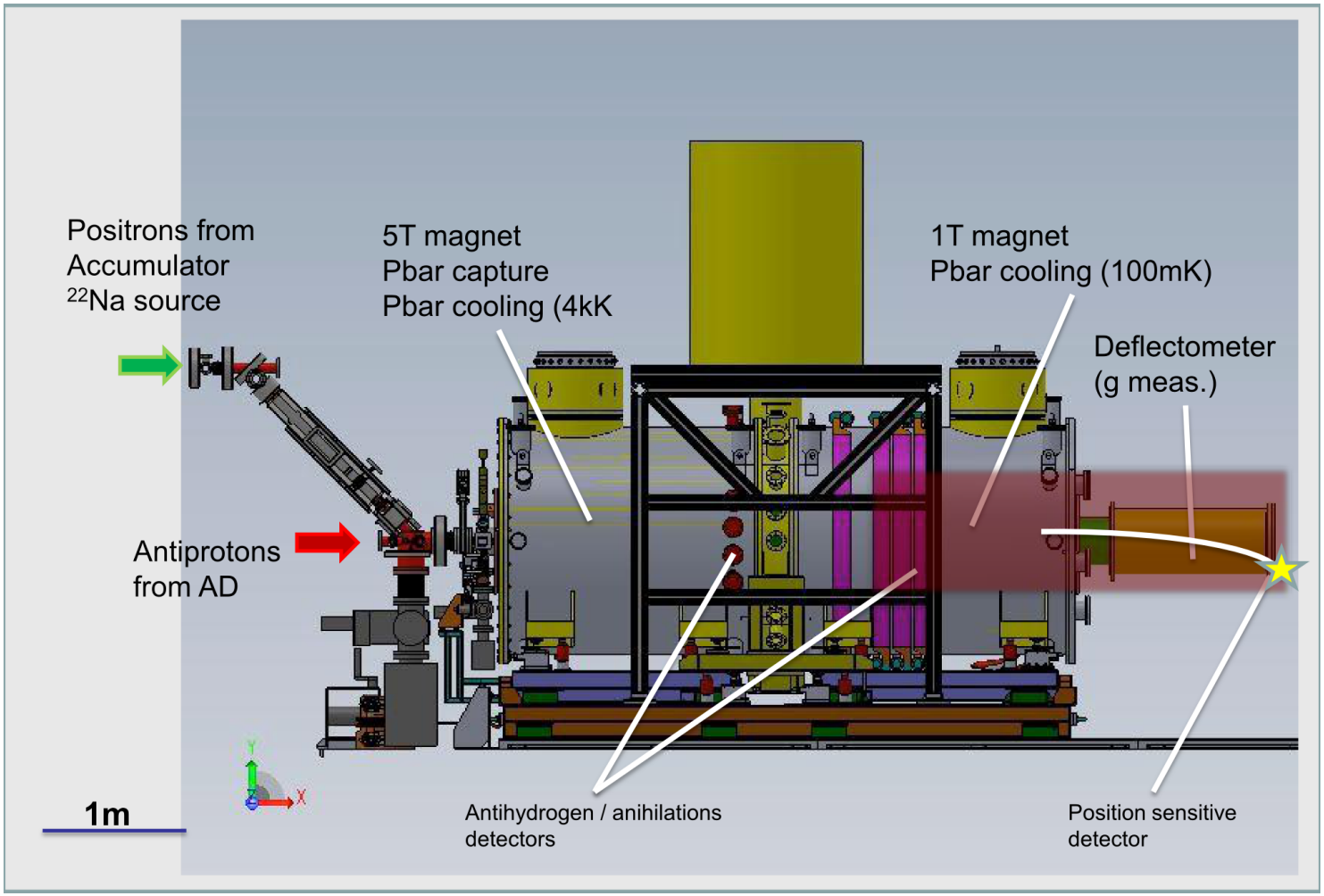
$$v_{thermal} \approx 300\ m/s @ 5K$$

$$v_{thermal} \approx 70\ m/s @ 0.3K$$

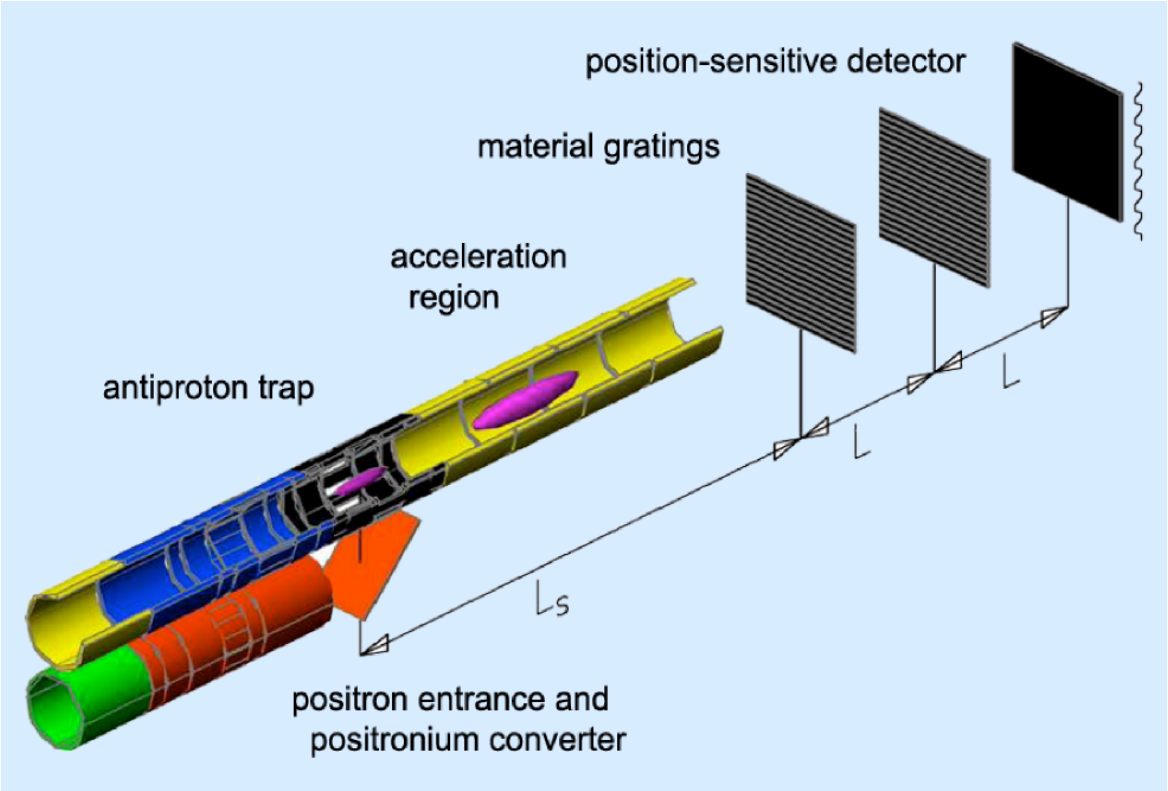
Antihydrogen production chain: down to 100 MeV/c



The AEgIS experiment



AEgIS – A schematic overview



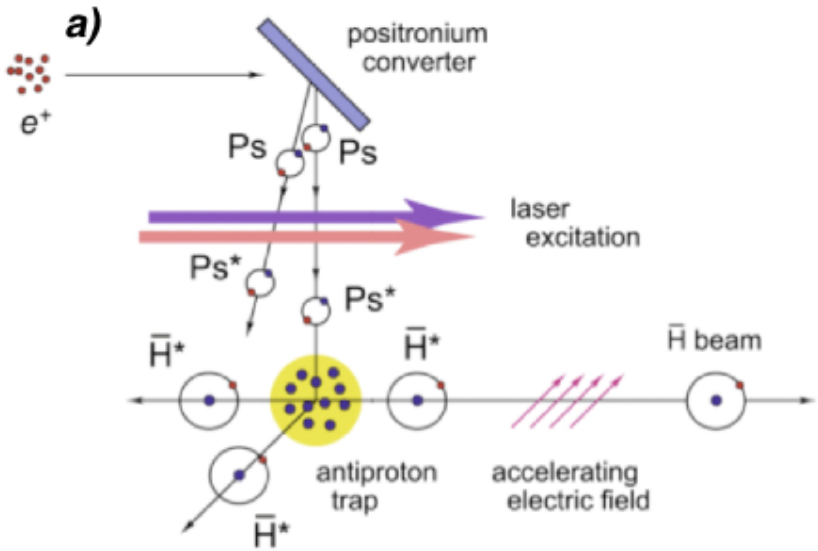
The two gratings constitute what goes by the name of a "Moire Deflectometer"

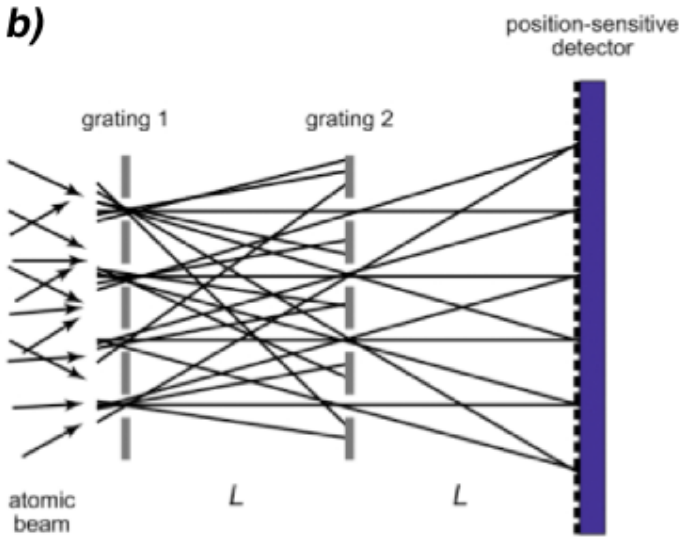
Fringes are formed on the position sensitive detector, with enough statistics

Detection of the vertical fringe shift gives a better extimation of the "free fall"

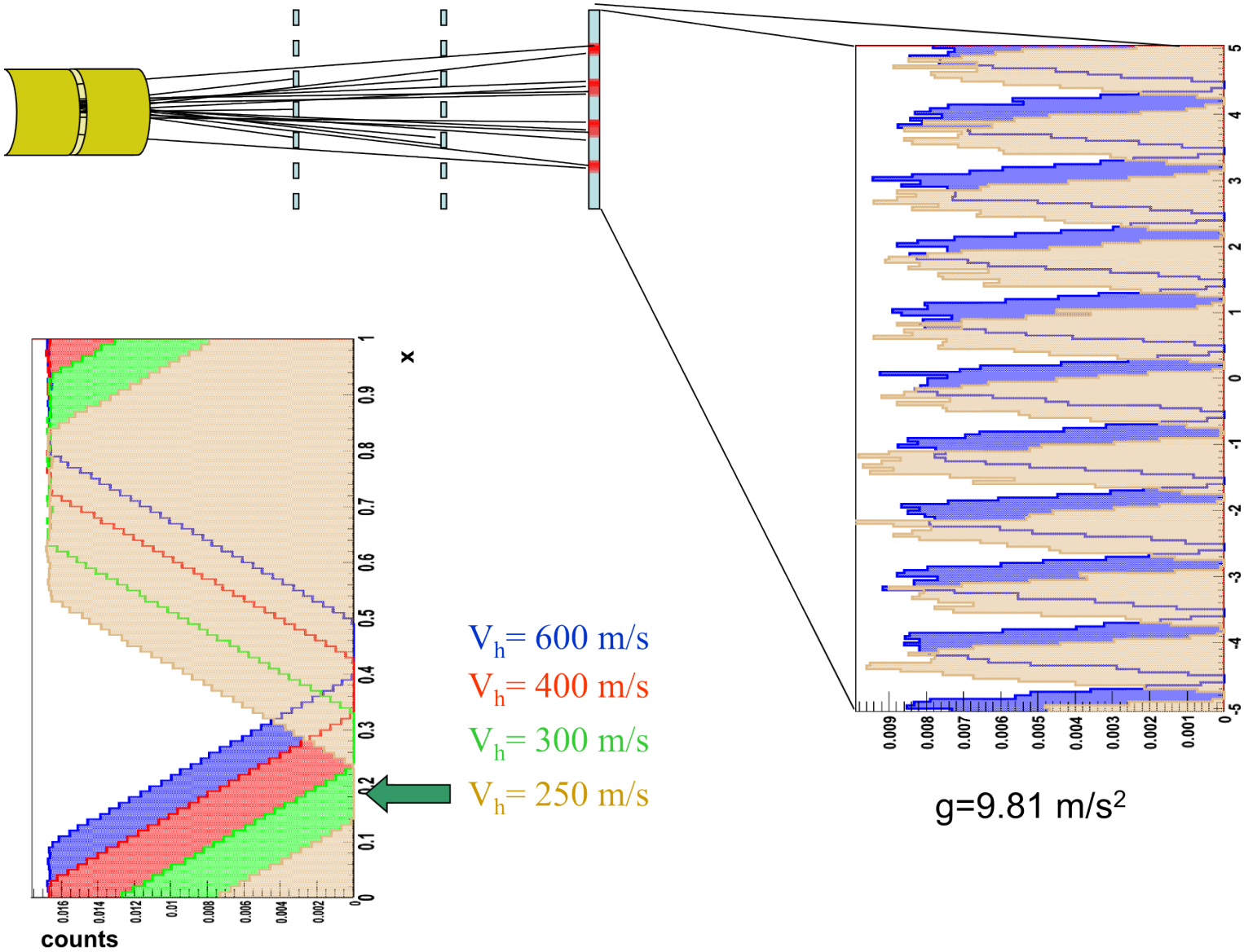
Later on, the deflectometer is going to be used for investigating wave-like properties of antihydrogen…

Producing and detecting the antihydrogen

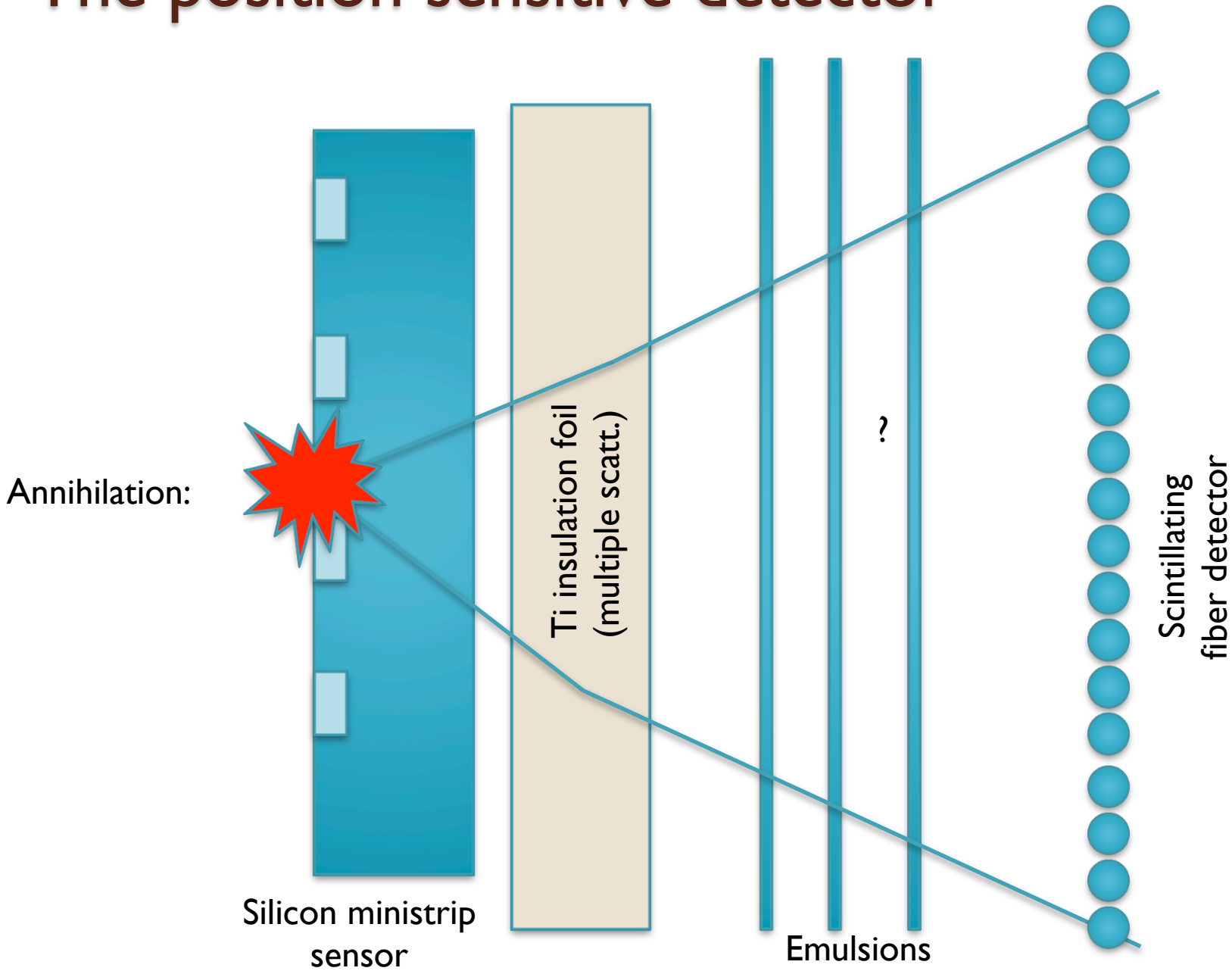




Shift of interference fringes



The position sensitive detector



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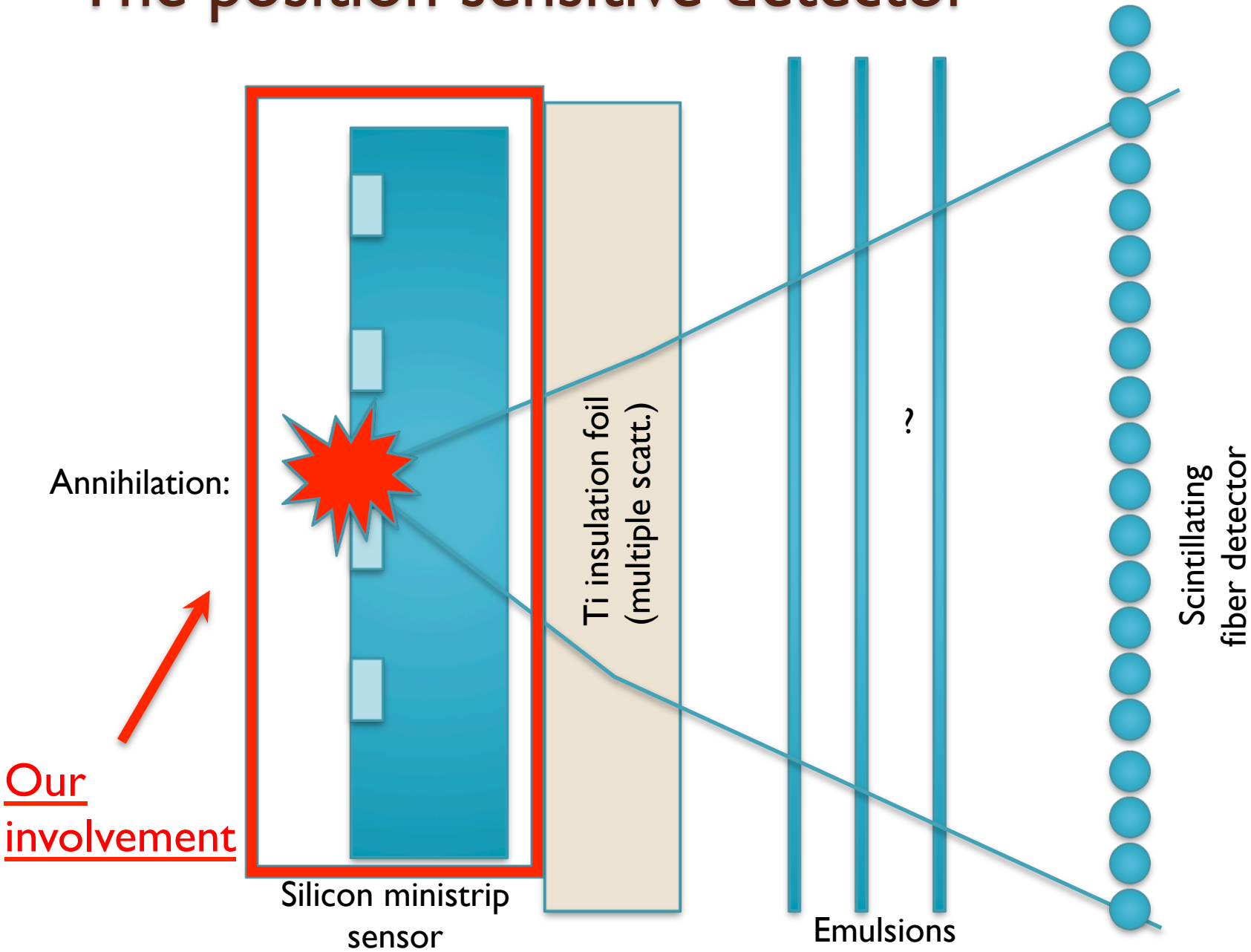
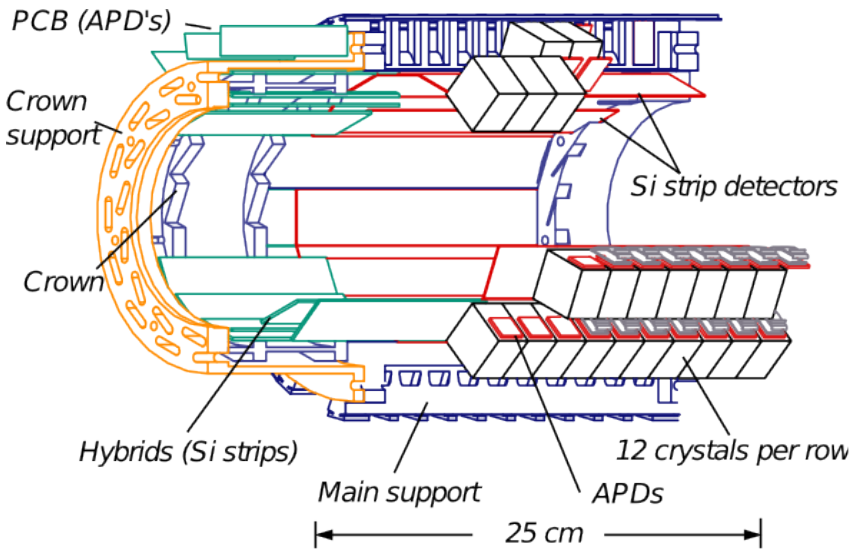
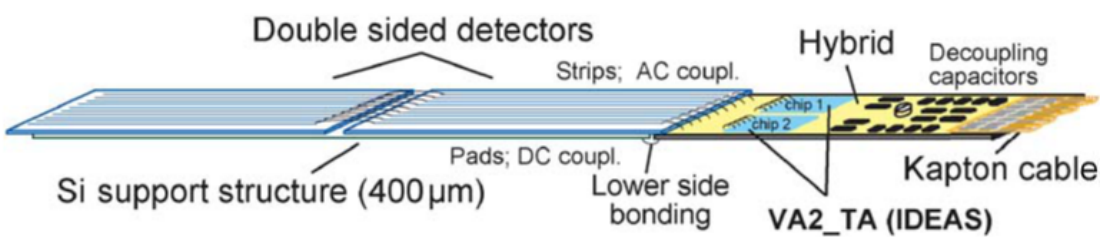


The ATHENA silicon detector

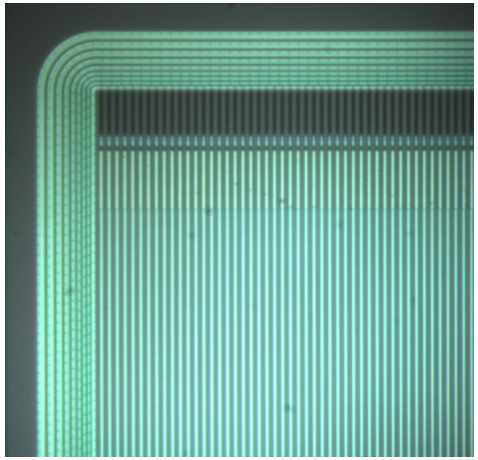


ATHENA, the AEgIS "ancestor", was already using silicon detectors to detect the annihilation products of antihydrogen, but annihilation in this case did not happen "on-sensor".



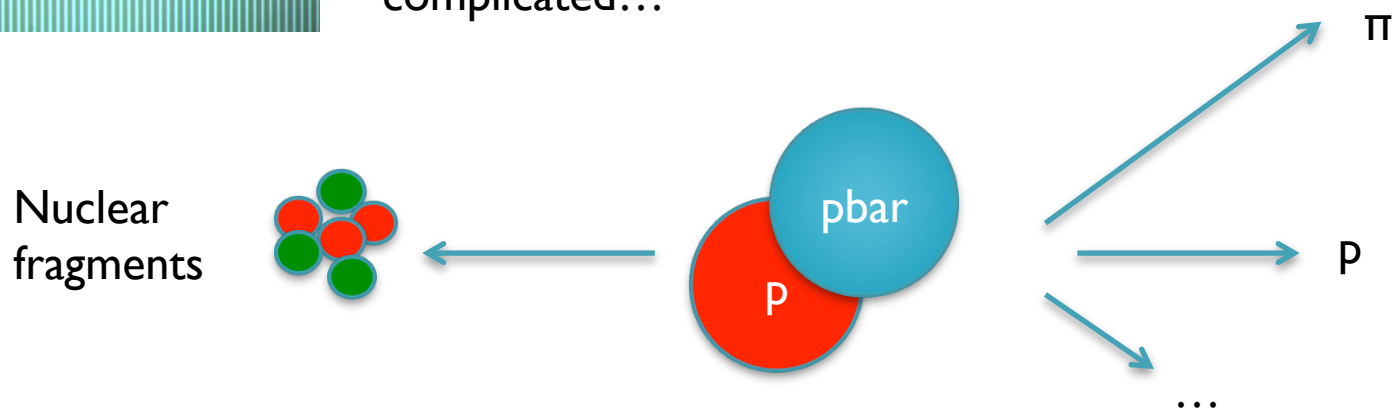
Silicon as an anti-H detector

Silicon detectors are used since decades to detect Minimum Ionizing Particles (MIPs) in HEP experiments.



Ministrip detectors allow a spatial resolution down to ~10 μm with a strip pitch of 80 μm, since center-of-gravity calculation allows to interpolate the precise crossing position.

However, in our case, we are not detecting a single MIP, so the situation can get much more complicated…



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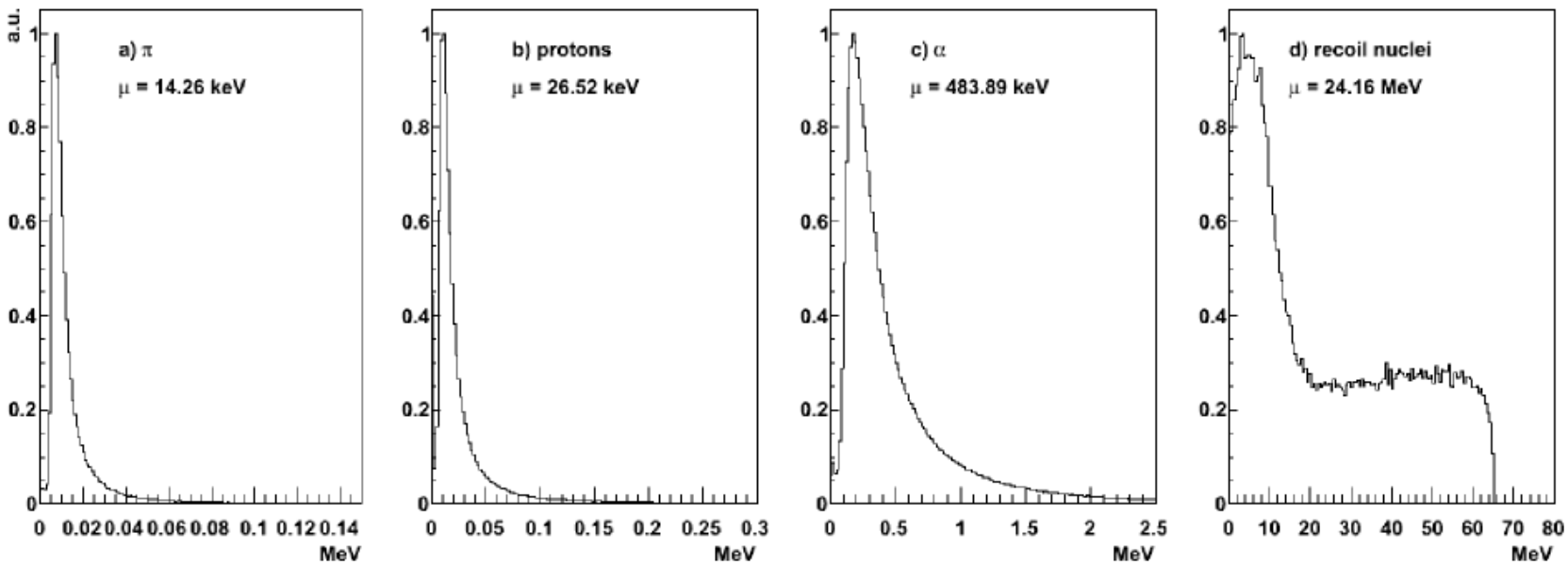
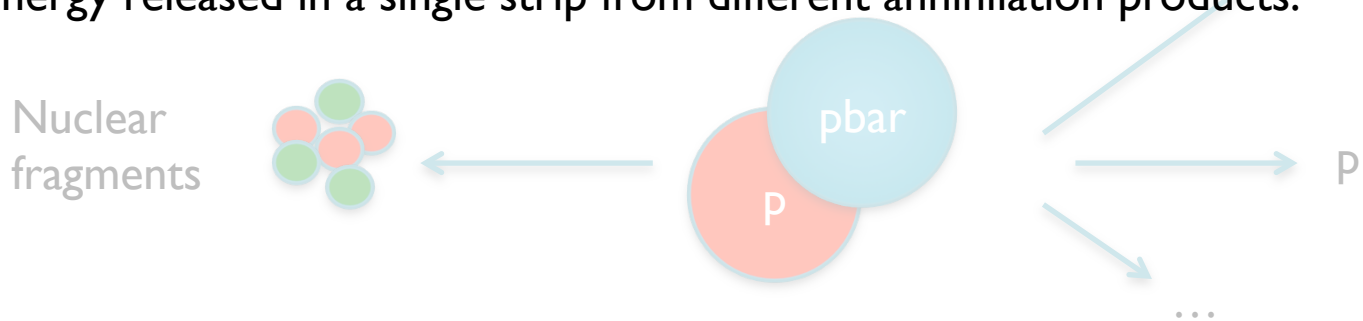


Energy released in a single strip from different annihilation products.



Requirements for the anti-H silicon sensor in AEgIS

- Reaction products of different nature and with big uncertainty about the sensor crossing probability (quasi-static interaction: no big momentum is transferred from the impinging anti-H) ➔High spatial resolution is required, with a strip pitch of ~20~25 μm
- Silicon sensor will act as the interface between the UHV and the outside OVC environment➔Has to withstand UHV
- Cryogenic operation – The sensor will have to be kept really cold (down to 5 K, possibly) – This temperature is still unreached in HEP experiments (may be military research has been done, but of course is not accessible)
- Thickness – This is not a requirement of the silicon sensor (the thicker, the better) but a very small thickness is required to avoid multiple scattering phenomena to degrade the resolution of the emulsion detector…

(Resuming…)

Silicon strip sensor – 50 μm physical thickness (figuring out if it is possible to go even thinner), 20 μm strip pitch (resolution expected <10 μm), UHV tolerant, Cryogenically operated…

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A NICE R & D challenge!

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Our time schedule:

The project for a position sensitive silicon sensor to be used in AEgIS started in spring 2011. By now we can already count on data acquired with a anti-proton test beam on a monolitic pixel detector (May 2012, see next presentation from Angela).

Following are the two main milestones of this project:

1. Antiproton silicon sensors – currently available prototypes (not AEgIS specific) are going to be tested on beam before LHC Long Shutdown (~2 years starting from December) – no strict requirements in terms of detector thickness and geometries (of course, the closer we get to our specs, the better)
   Primary aim: investigation of signal and vertex "reconstruction" capabilities on silicon strip sensors.
2. Specific development of the detector for the final AEgIS implementation with partner companies (SINTEF for the sensor and Gamma Medica Ideas for the readout electronics)➔We have to come out with the definitive model by the end of Long Shutdown for starting immediately data acquisition.

Current R&D

Test Beam

Test beam in May 2012 with the mimotera pixel sensor: data analysis is currently in progress (see next talk from Angela)

Test beam planned for September-October:
Currently evaluating the option to use existing silicon sensors and the first prototypes coming from SINTEF and Gamma Medica Ideas.

Detector prototyping

Requirements for the silicon sensor are now defined. Contacts with SINTEF are going to take place in the forthcoming months to match our needs with their capabilities.

Testing of the readout (manufactured by Gamma Medica) chip in ultra-cold, UHV conditions.
Prototyping of the interfaces on the flanges

Summary

- AEgIS is a collaboration involving several institutes, with the aim of making fundamental physics measurements, the first of which is going to be the measurement of the gravitational constant of antimatter
- Bergen and Oslo Universities, SINTEF, GM-I and CERN are together in charge of developing and building a high resolution, position sensitive silicon strip sensor for precise measurements of the trajectory of a free falling antihydrogen atom.
- A first deliverable was provided by test beam measurements, with a publication on the way, constituting the first data on detection of antiprotons by on-sensor annihilation.
- A further test beam is planned for the months of September-October this year, on ministrip sensors, using the readout prototype for AEgIS
- By the end of the current year, prototypes will be defined for the AEgIS silicon detector with SINTEF and GM-I.
- All our efforts are pointing towards the aim of getting the operational detector by the end of LHC long shutdown!