CHARACTERISATION, PLANS AND PROSPECTS OF POSITRONIUM FORMATION IN THE AEGIS EXPERIMENT

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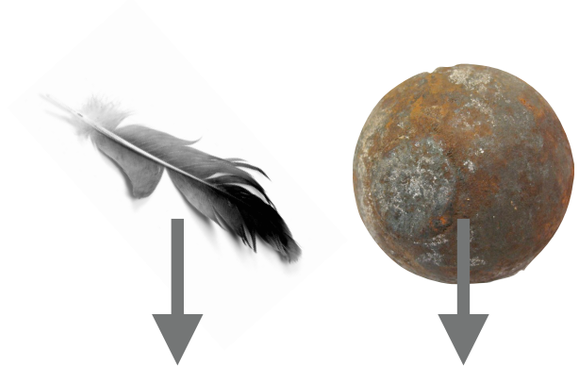
on behalf on the AEgIS collaboration

24th Nordic Particle Physics Meeting, 2-7 January 2016

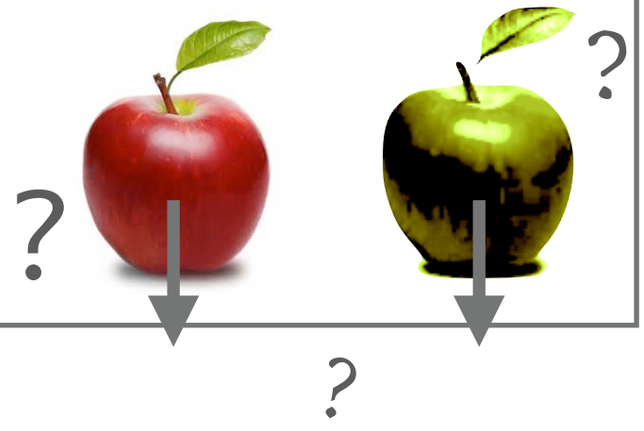
THE ANTIMATTER MYSTERY

Why are we here?

Universality of free fall
(the Weak Equivalence Principle)

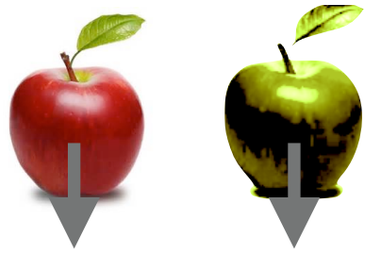


But how does antimatter fall?

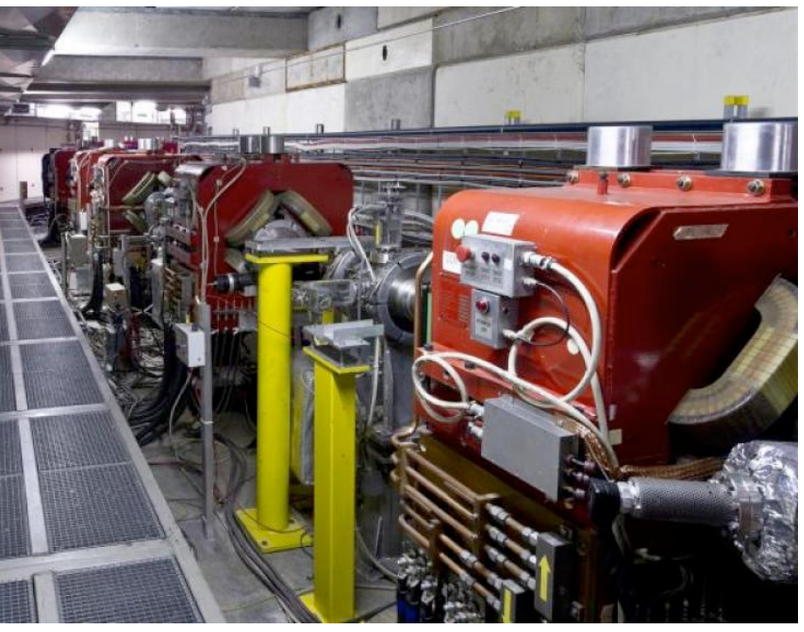


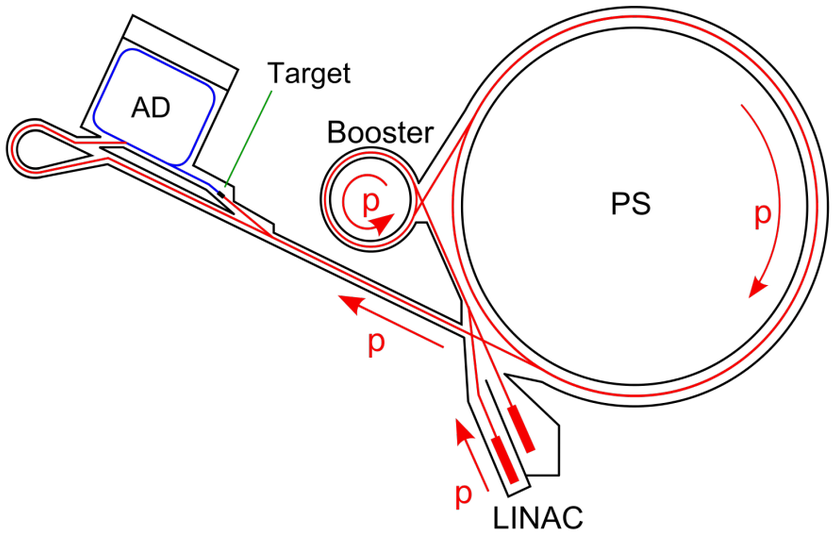
One of the many questions we ask ourselves about antimatter…

THE AEGIS EXPERIMENT



- Antimatter Experiment: Gravity, Interferometry, Spectroscopy.
- The AEGIS experiment aims to carry out the first direct measurement of a gravitational effect on an antimatter system.
- Under construction.
- Located at the Antiproton Decelerator (AD) at CERN.





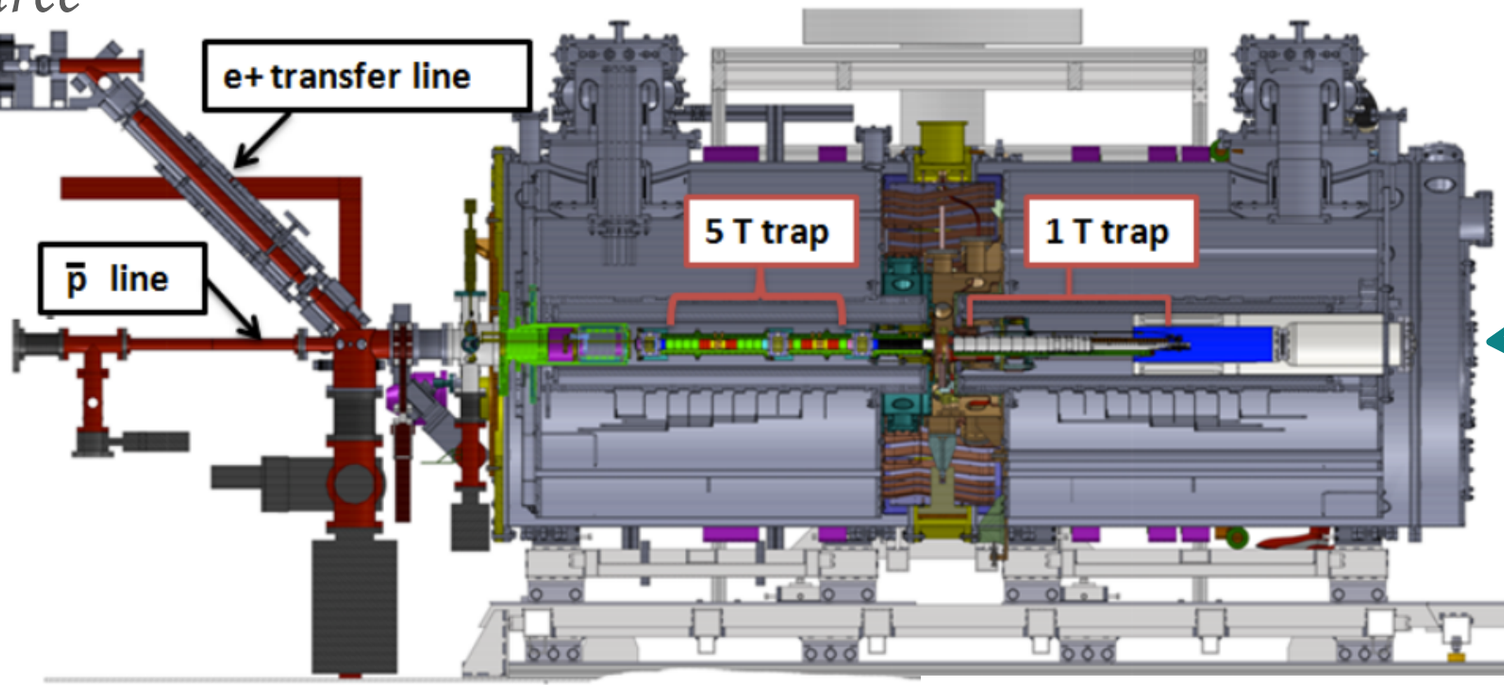
THE EXPERIMENTAL SETUP

From a ^{22}Na source

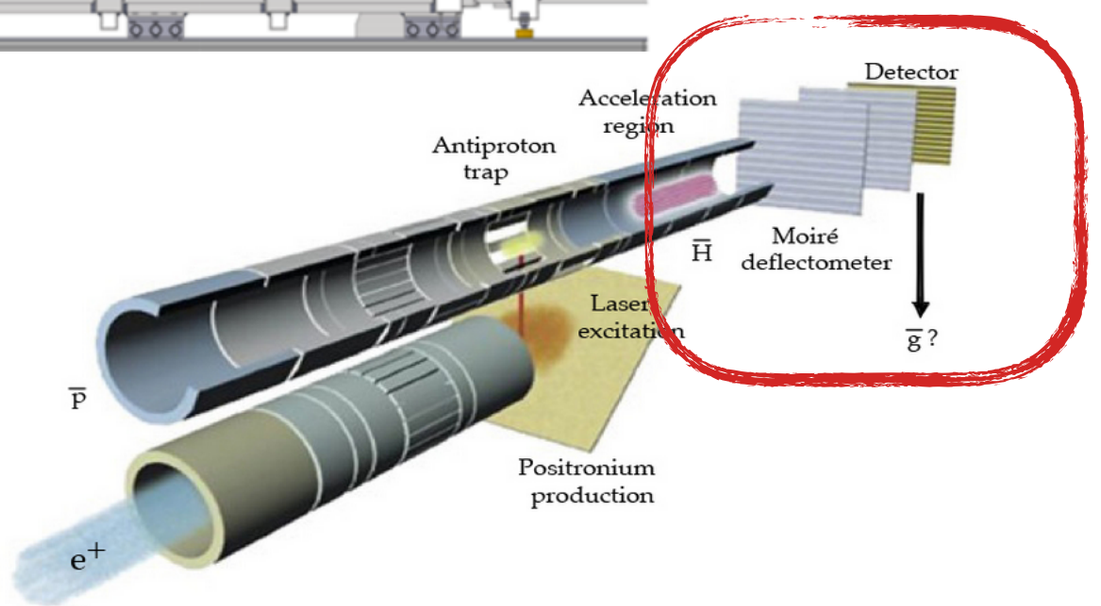
e^+ →

From the AD

$\bar{p}$ →

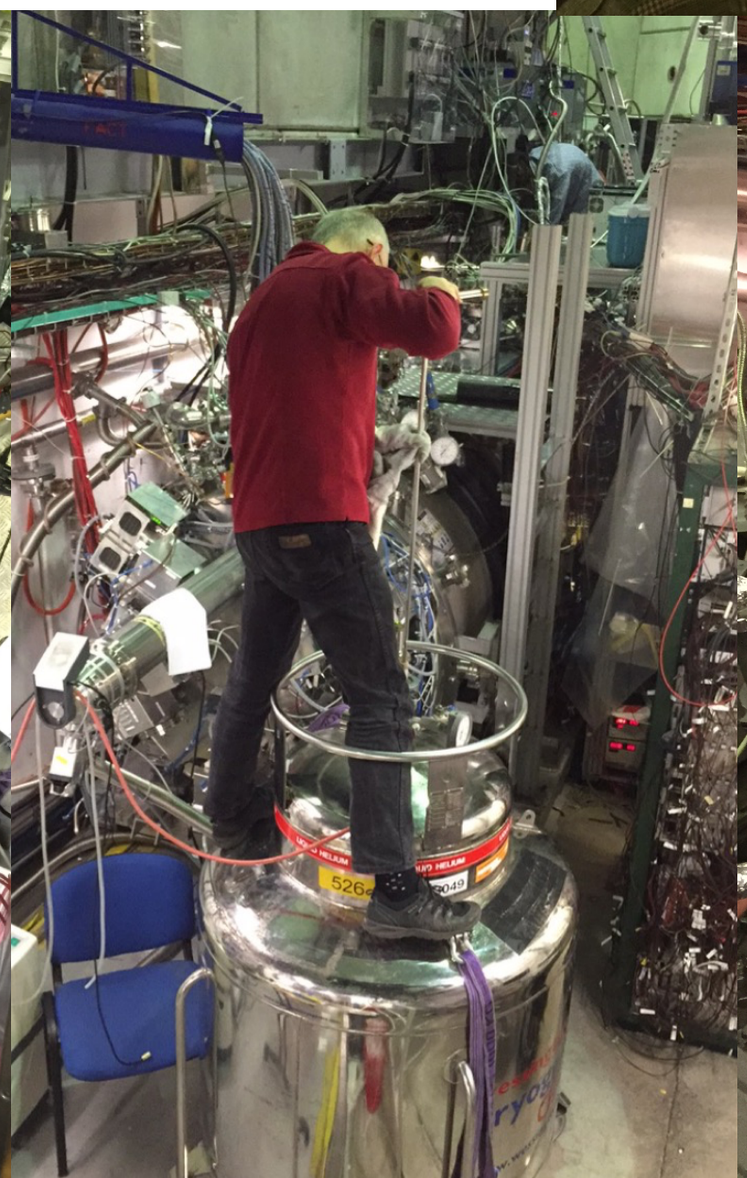


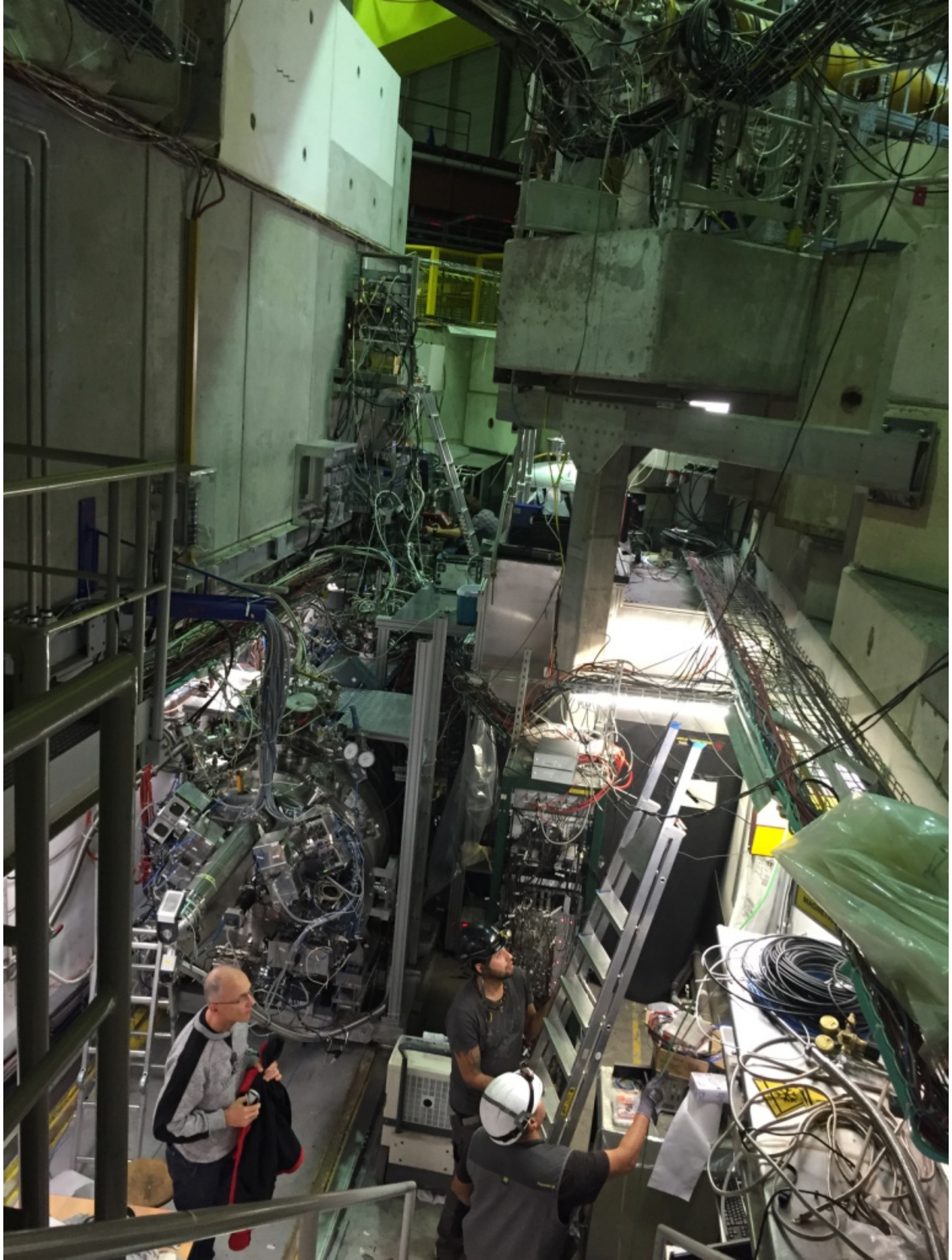
Not in place yet



THE EXPERIMENTAL SETUP

It looks a bit more like this…

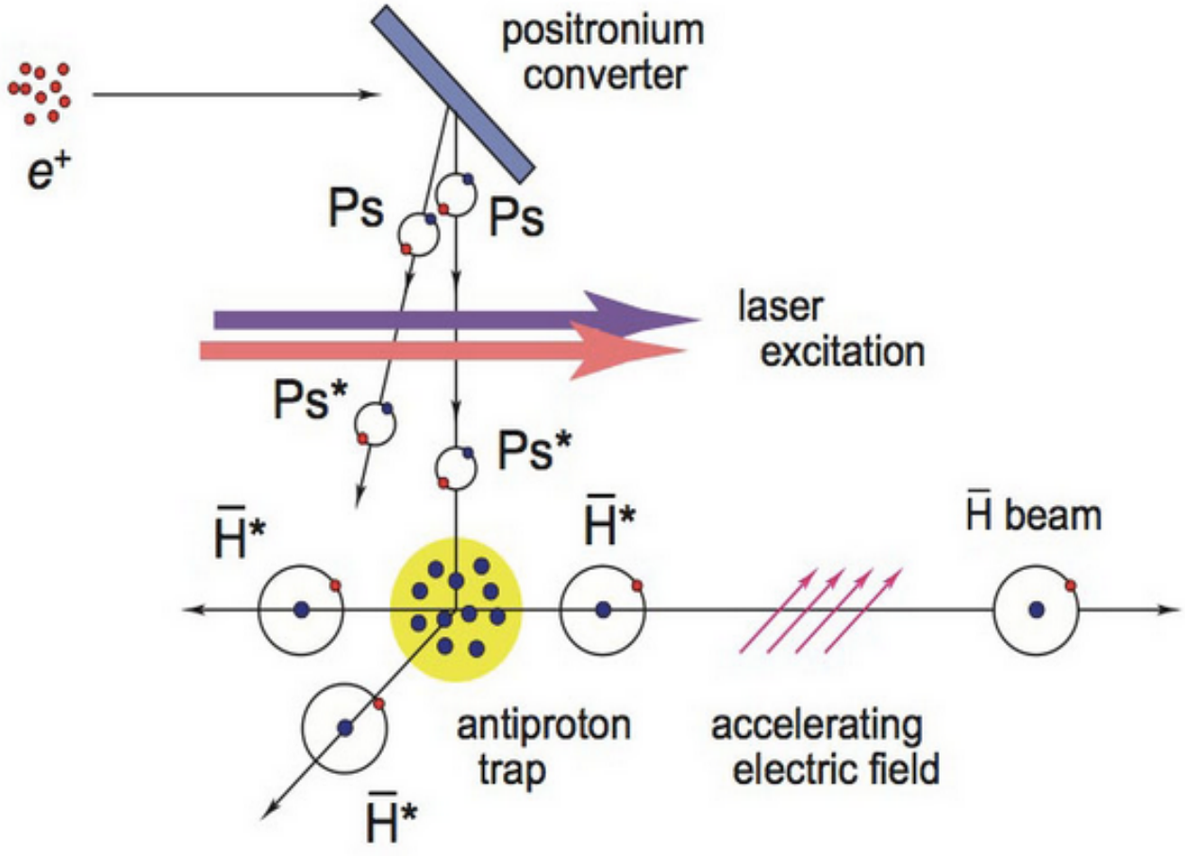


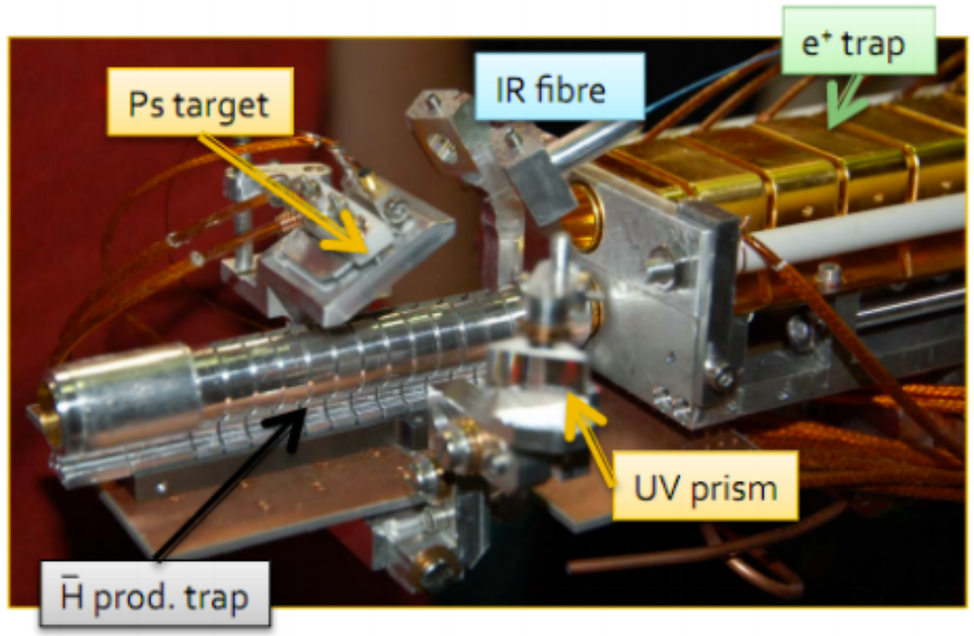


ANTIHYDROGEN PRODUCTION IN AEGIS

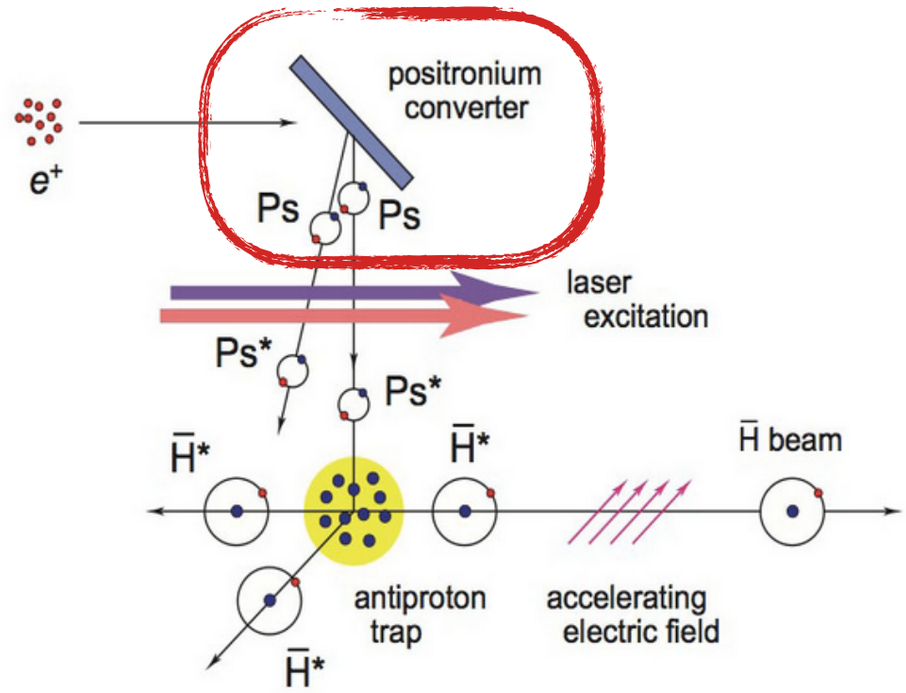
Different from other experiments at the AD hall:
via ***charge-exchange***

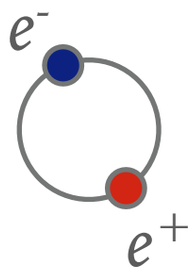
$$Ps^* + \bar{p} \rightarrow \bar{H}^* + e^-$$





POSITRONIUM: AN IMPORTANT PIECE OF THE PUZZLE



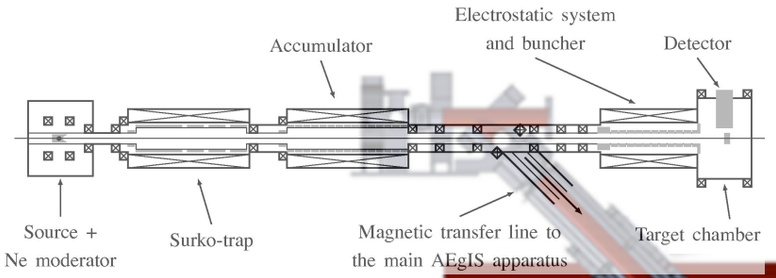


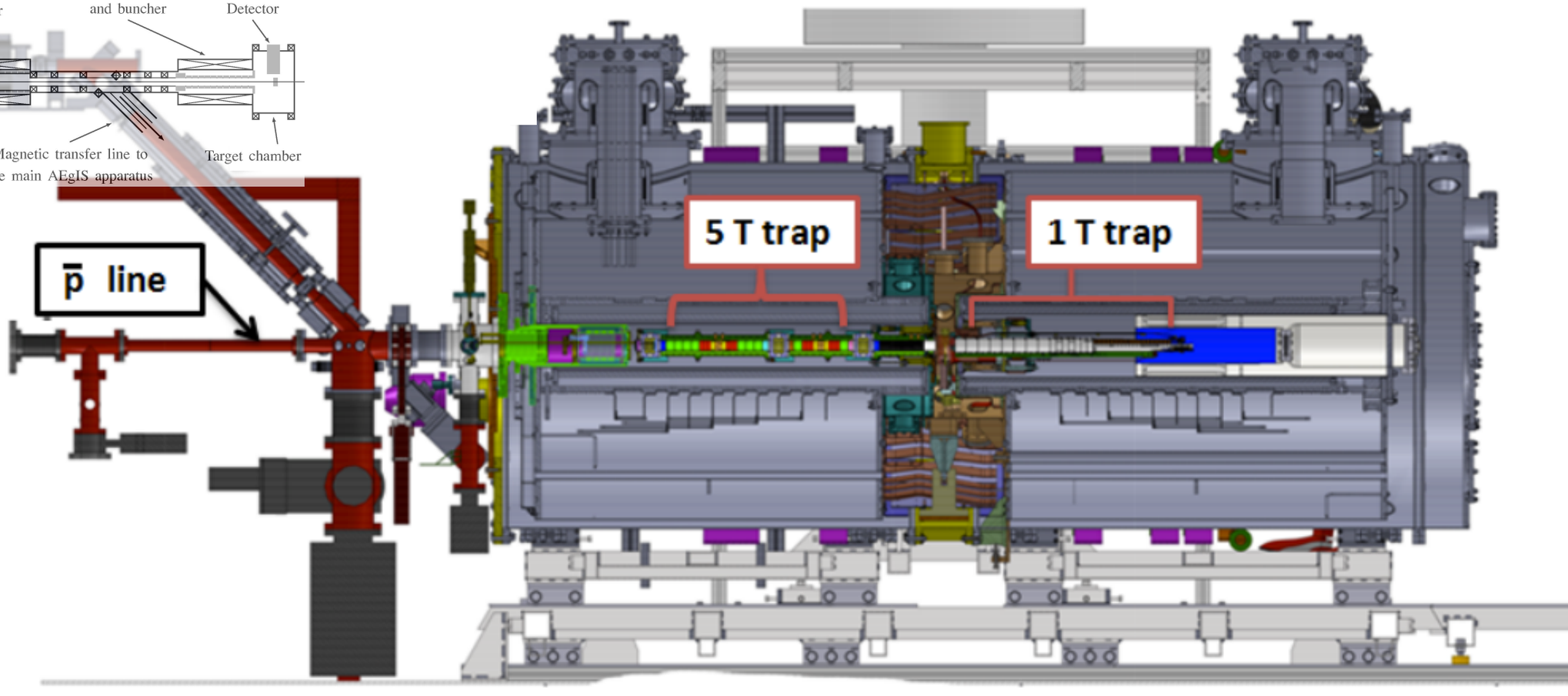
$\uparrow\downarrow - \uparrow\downarrow \quad 1^1S \quad$ *para-positronium (p-Ps): lifetime = 125 ps* $\quad p\text{-}Ps \rightarrow 2\gamma$

$\uparrow\uparrow, \downarrow\downarrow, \uparrow\downarrow + \uparrow\downarrow \quad 1^3S \quad$ *ortho-positronium (o-Ps): lifetime = 142 ns* $\quad o\text{-}Ps \rightarrow 3\gamma$

THE POSITRON TEST-SETUP

Described in NIMB 362 (2015) 86–92





THE POSITRON TEST-SETUP

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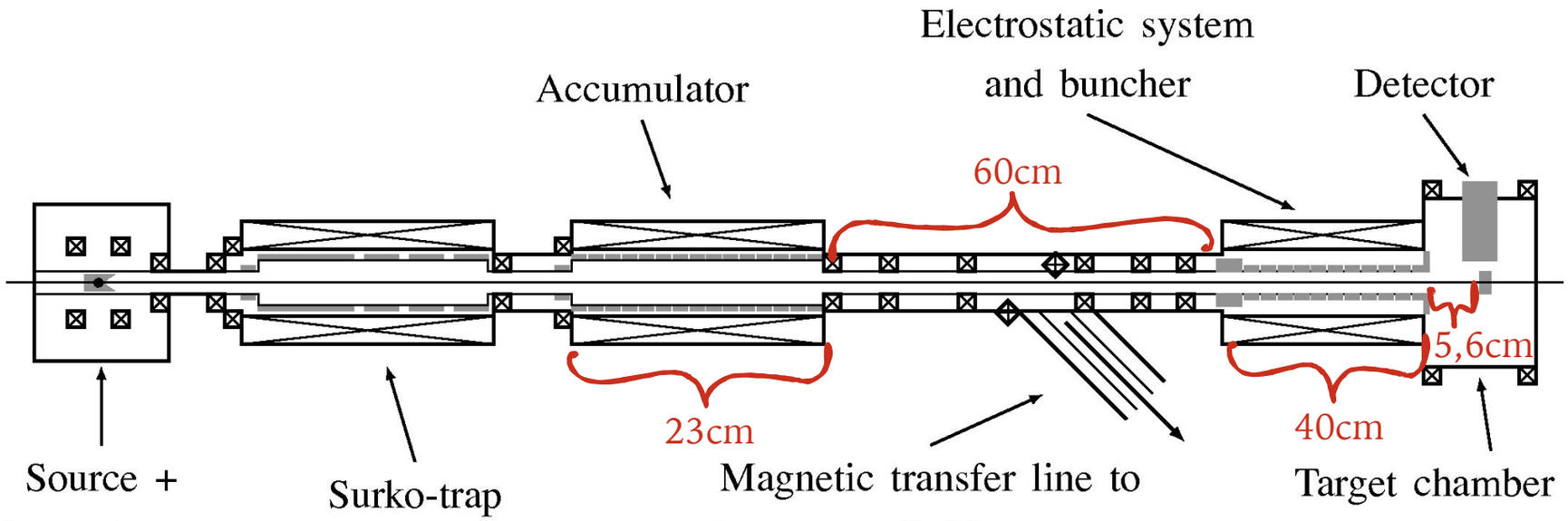
^{22}Na source 11mCi

— soon

~7×stronger



- System can deliver bunches of up to $8 \cdot 10^7$ positrons in 450 s (3000 pulses)
- Cooled, stored, compressed
- Electrostatic transport
  - Target region is free of magnetic field
  - Guides, accelerates and focuses the positron bunch
- Tuneable implantation energy from 3.3-9 keV

Different from other positron systems

THE POSITRON TEST-SETUP

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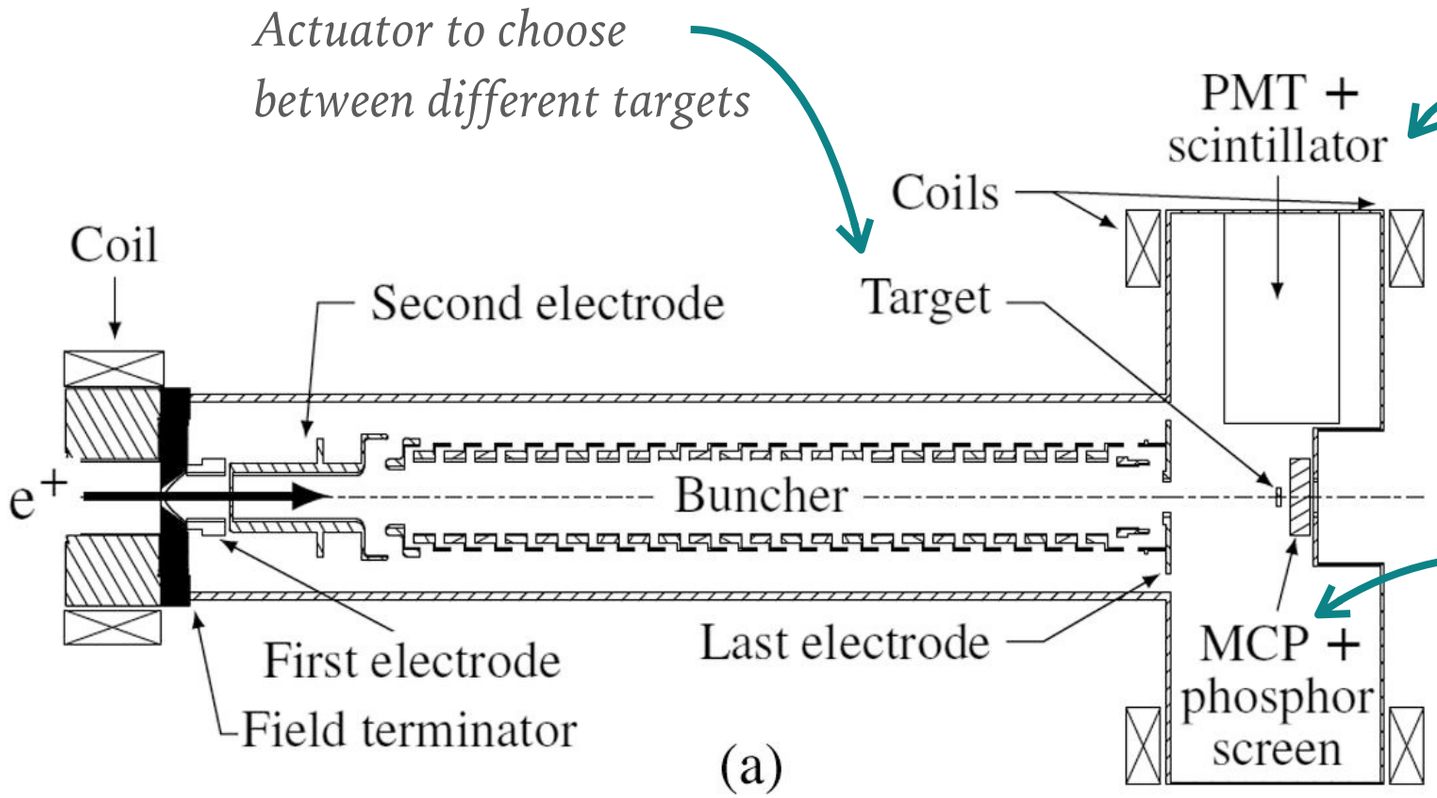


Actuator to choose between different targets

PbF_2 or $PbWO_4$ crystal

To characterise positron spot and target position + provide background measurement of Ps production

Coils to produce a magnetic field of up to 300 Gauss for quenching of o-Ps

POSITRONIUM PRODUCTION AND DETECTION

Nano-channeled silicon target

Single-Shot Positron Annihilation Lifetime Spectroscopy (SSPALS)

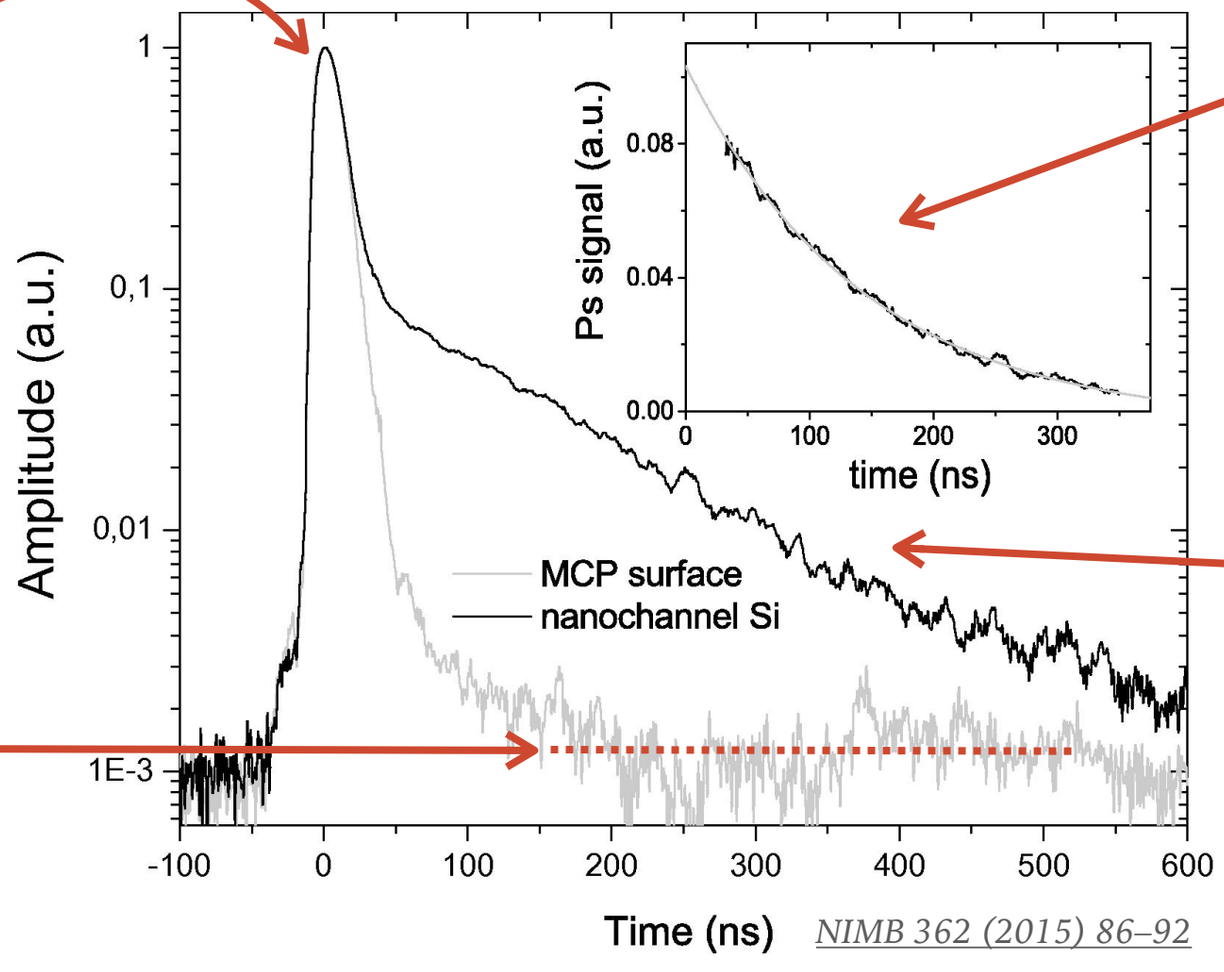
Prompt peak; e+ pulse annihilating on the material

Exponential fit to difference of the spectra, $e^{-t/\tau}$

τ=142 ns

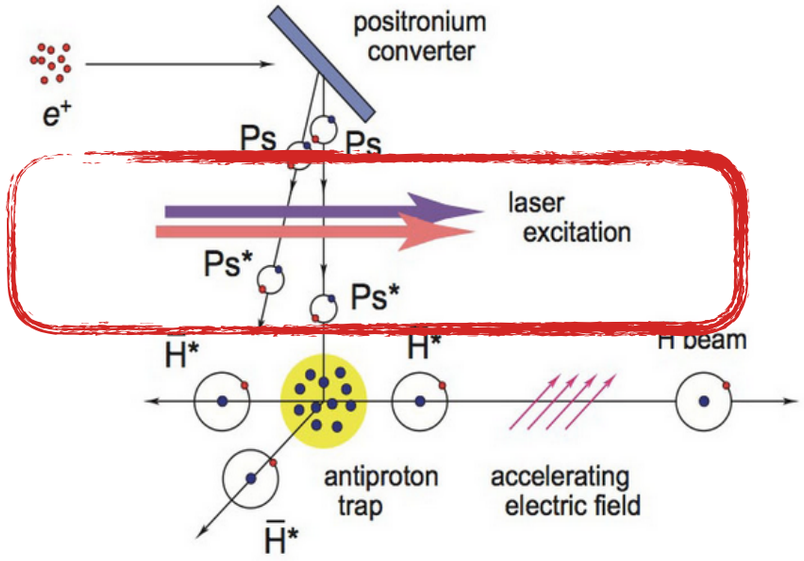
Positronium production!

Background level



NIMB 362 (2015) 86–92

LASER EXCITATION OF POSITRONIUM



UV; λ=203-206 nm

IR

Excite o-Ps to ***n=3***

Never done before

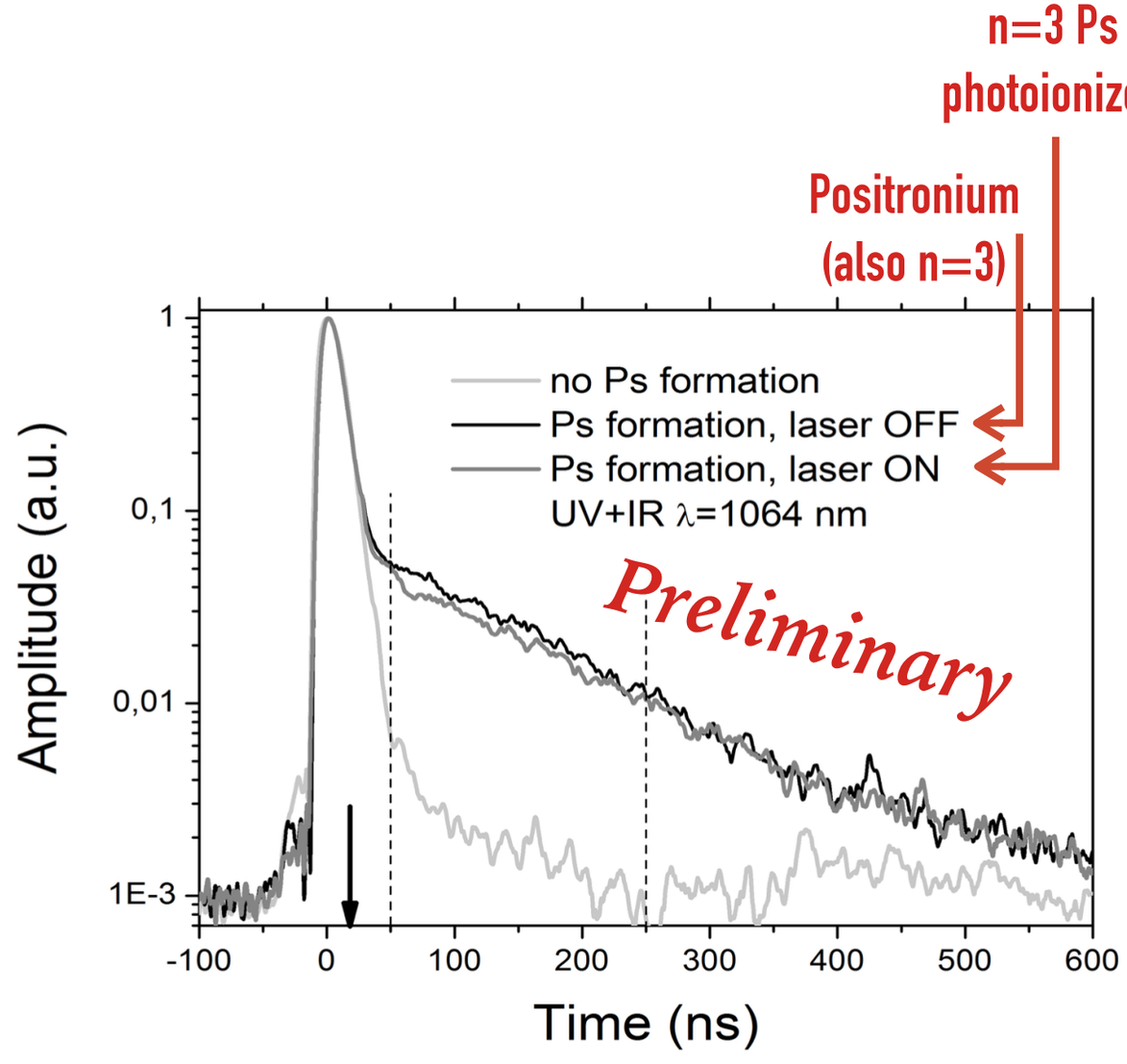
Checked by

1) Quenching (3^3P mixed with 3^1P) → *1^1S*

2) ***Photoionisation***

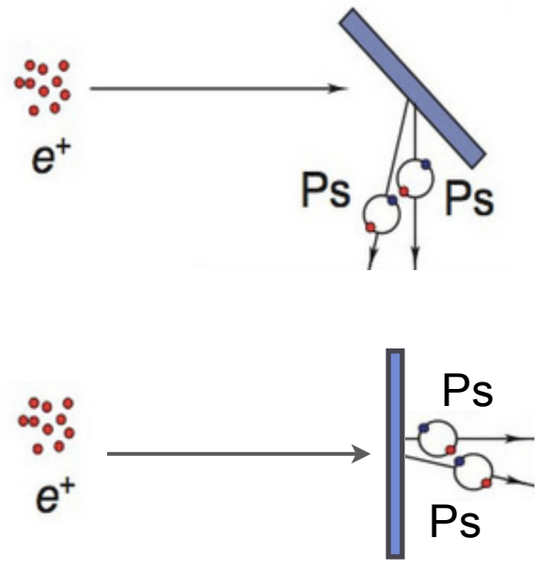
3) Excitation to Rydberg state

Fraction excited to n=3 estimated by the area of the curves; ~15%



A WORD ON PLANS – PRODUCTION MODE

Want to change setup



from

reflection mode production

to

on-axis transmission mode production

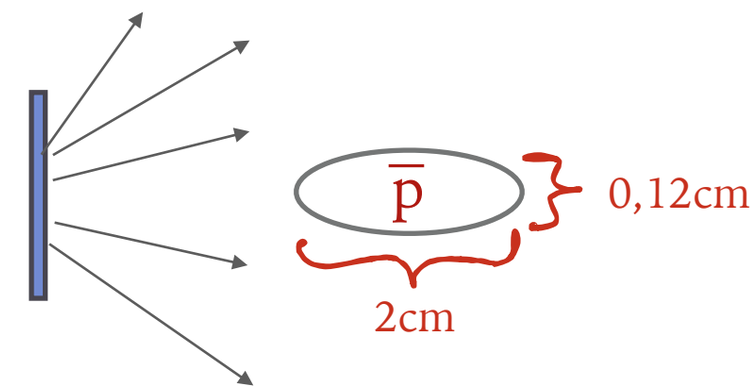
Likely to result in an improvement of $\overline{H}$ production

Distance to antiproton cloud

Emission pattern

Thermalisation

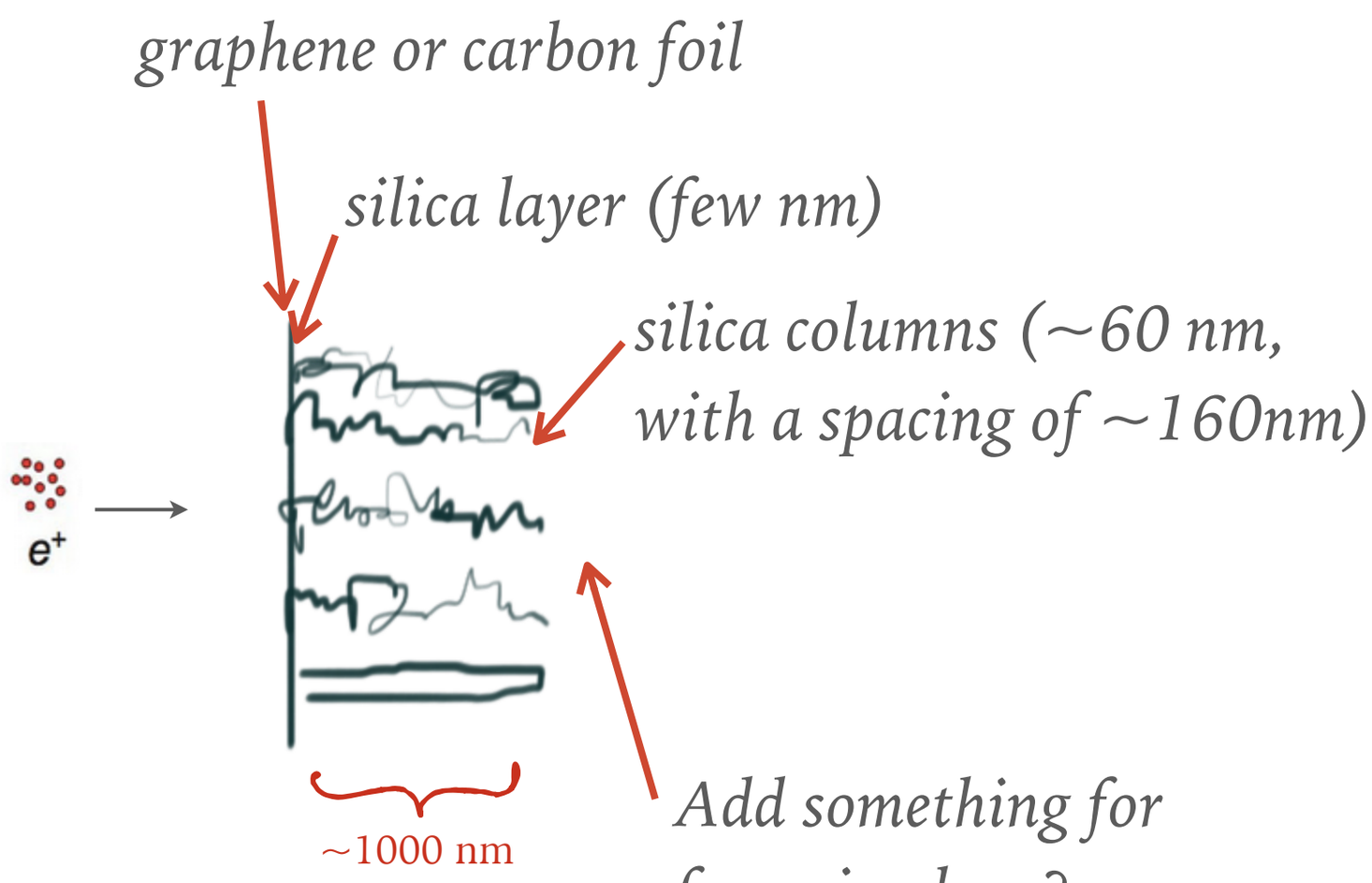
Remove the need for Stark acceleration of antihydrogen??

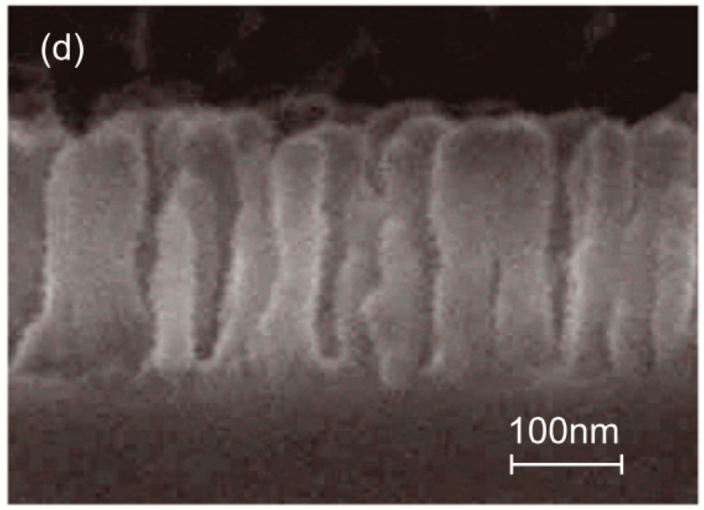


Normal or isotropic emission?

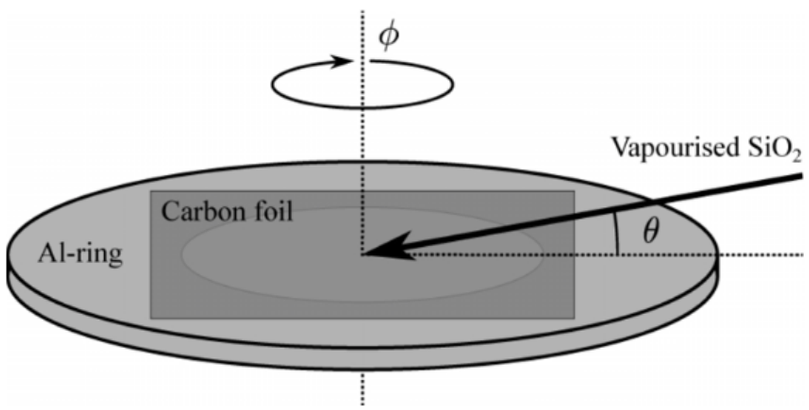
Great gain: all Ps overlaps with antiproton cloud

A WORD ON PLANS – TARGET CONSTRUCTION





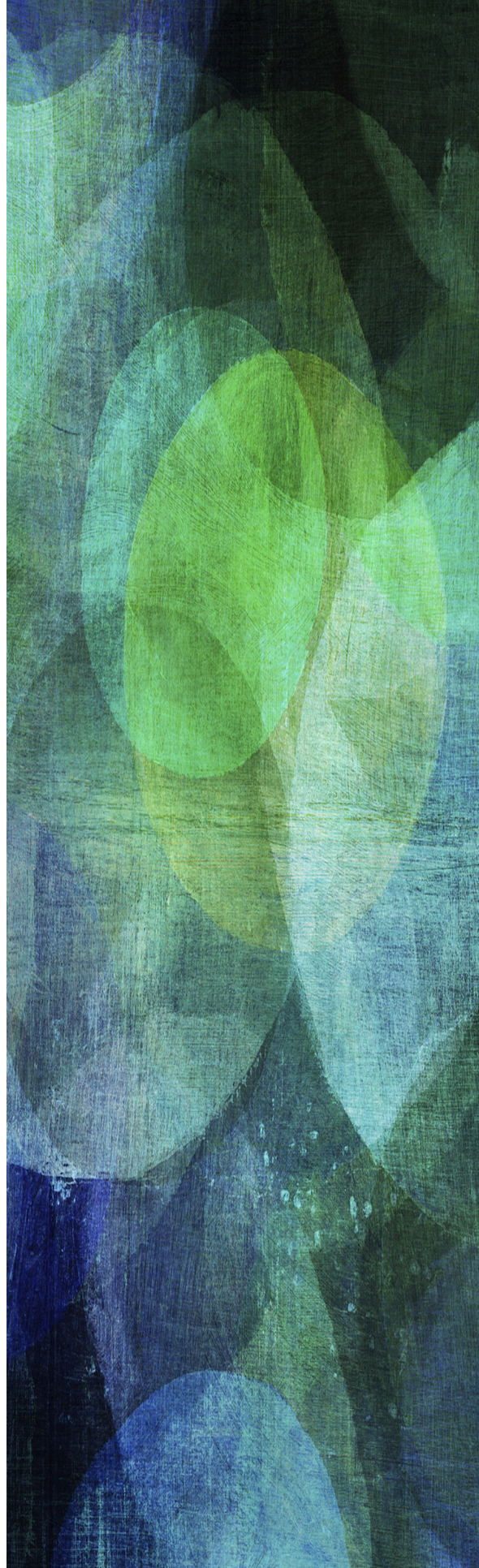
Eur. Phys. J. D (2014) 68: 124



SUMMARY

- The AEgIS experiment aims to carry out the first direct measurement of gravity on antimatter.
- Positronium is an important ingredient in the formation method of antihydrogen in AEgIS
- The first Ps excitation to n=3 has been performed
- Work is in progress to improve to Ps formation for the purpose of antihydrogen production

Thank you for your attention!



LASER EXCITATION OF POSITRONIUM

Excite o-Ps to $n=3$

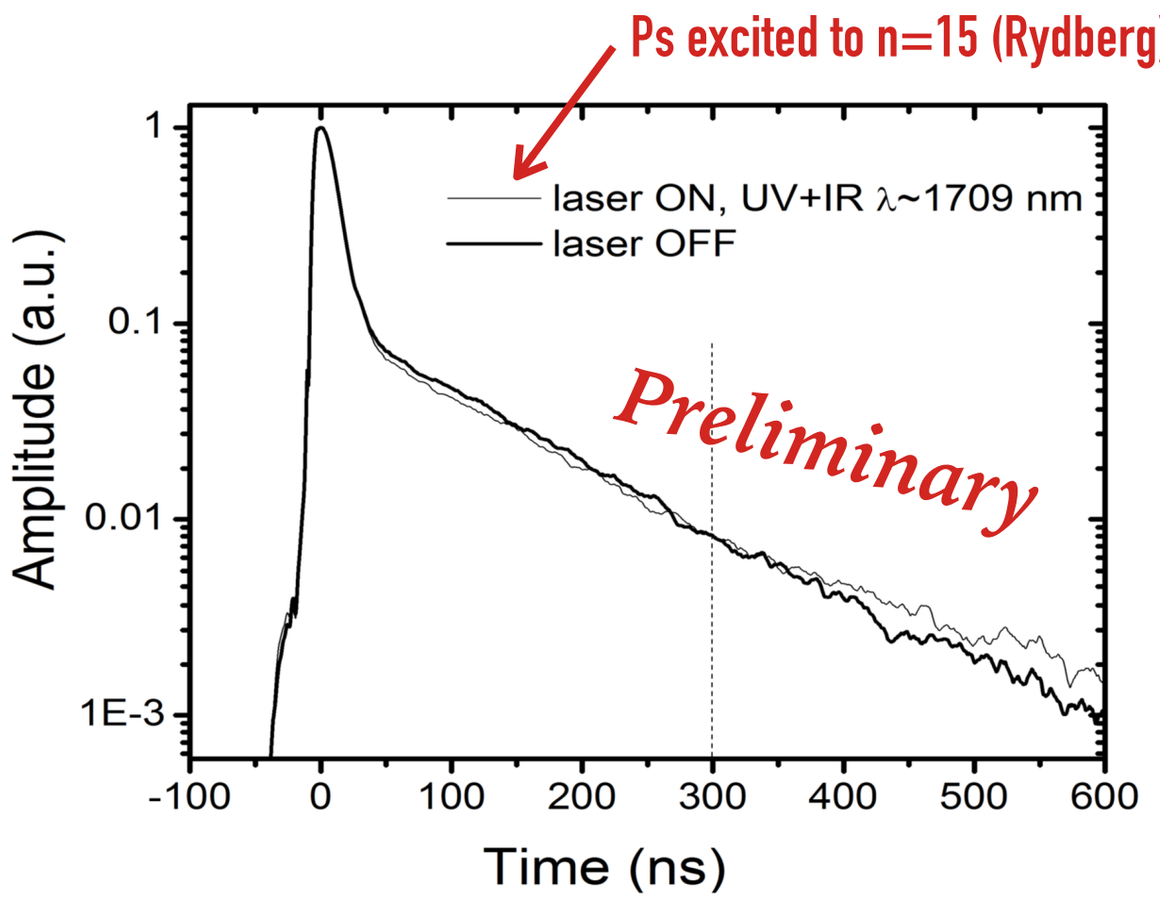
Never done before

Probed by

1) Quenching (3^3P mixed with 3^1P)

2) Photoionisation

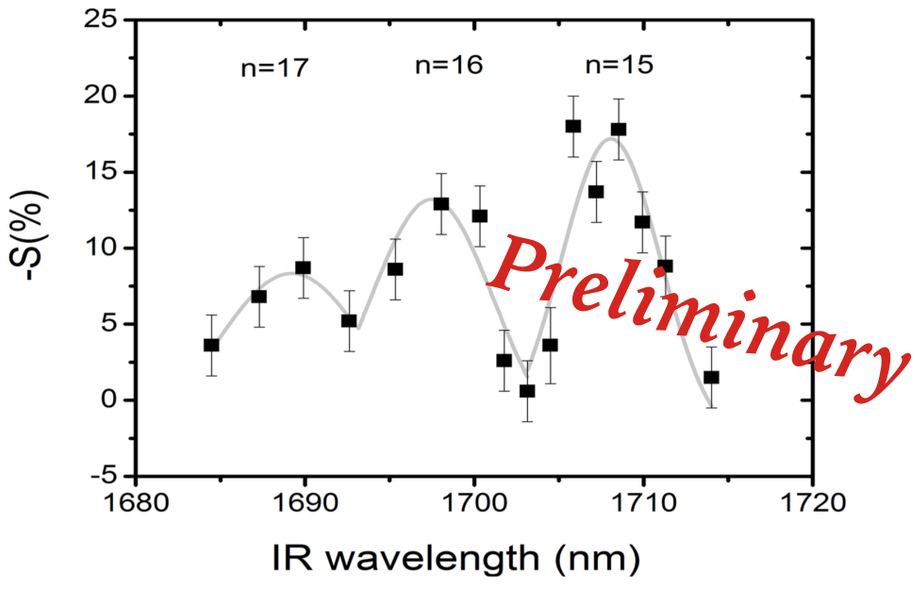
*3) **Excitation to Rydberg state***



Scanning the IR laser for excitation to different Rydberg states

f is the area under the SSPALS curve, on/off = laser on/off

$$S = (f_{off} - f_{on})/f_{off}$$



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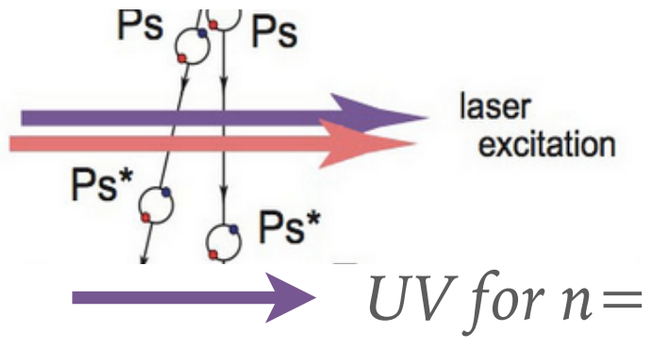
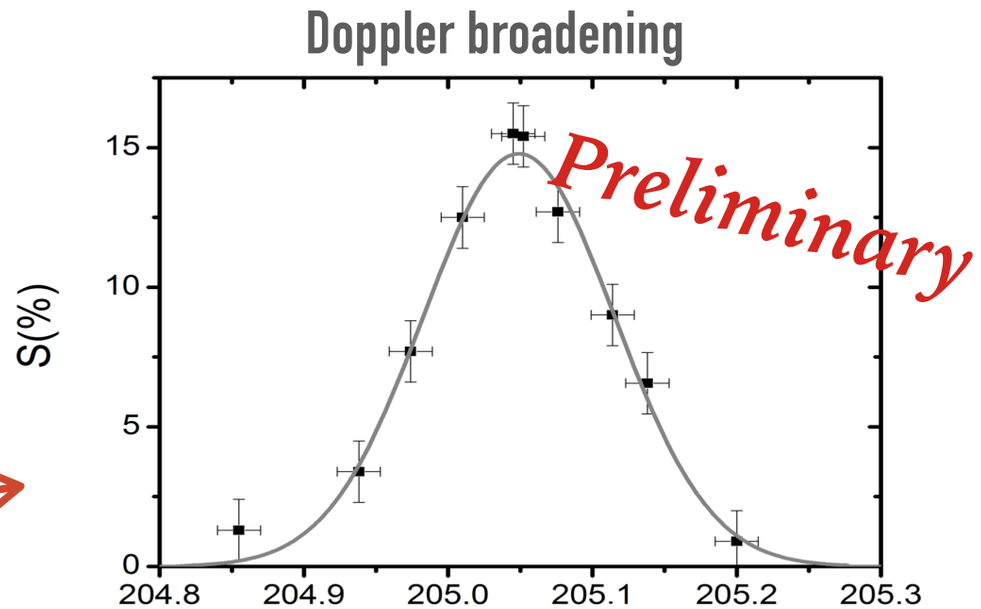


UV for n=3 excitation:

$\lambda = 205{,}05 \pm 0.02$ *nm*

(Theory: $\lambda = 205{,}0474$ *nm)*

Dominated by thermal distribution of Ps $\Longrightarrow T \approx 1300\ K$



Saturation energies:

1S→3P ***not*** *fully saturated*

3P→continuum fully saturated