

3rd International Workshop on Antimatter and Gravity (WAG 2015)

4-7 August 2015
UCL
GB timezone

<https://indico.cern.ch/event/361413/>

Search

Welcome Reception - 8pm Tuesday the 4th of August (North Cloisters, UCL).

Overview
Registration
Timetable
Call for Abstracts
Speaker List
Participant List
Committees

Information:

- Payment Instructions
- Visa
- Accommodation
- Pubs and Bars
- Restaurants
- Tourist Info
- Transport for London

UCL:

- Travel
- Campus Map

Support

- ✉ d.cassidy@ucl.ac.uk
- ✉ a.deller@ucl.ac.uk

Pubs and Bars

There are 1600 pubs within 3 miles of UCL and at least 300 within one mile! A small selection is given below. (Collated by UCL, HEP group for [Boost2014](#))

Map: <https://www.google.com/maps/d/edit?mid=zGqj8ngU63lo.kuIT4xL>

Pubs Local to UCL

Jeremy Bentham

31 University Street

The spiritual drinking ground of UCL named after its utilitarian founder. The closest pub (besides the student union) to UCL and consequently is frequented 7pm with UCL types and surgeons from the local hospitals limbering up.

Carpenters Arms

68-70 Whitfield Street

Wide range of beers on three floors. Hob-nob with Saatchi and Saatchi executives and try and get in the next Kit-Kat advert.

Euston Tap

190 Euston Road

Craft beer in an old station lodge building. The Euston Tap was truly unique recently, when the near identical Cider Tap opened in the opposite direction, exactly the same thing, but with cider.

The Bree Louise

69 Cobourg Street

Pub popular for its frequently changing real ale and cider selection and homemade pies

The King & Queen

1 Folev Street

WAG2015- UCL

WAG 2015

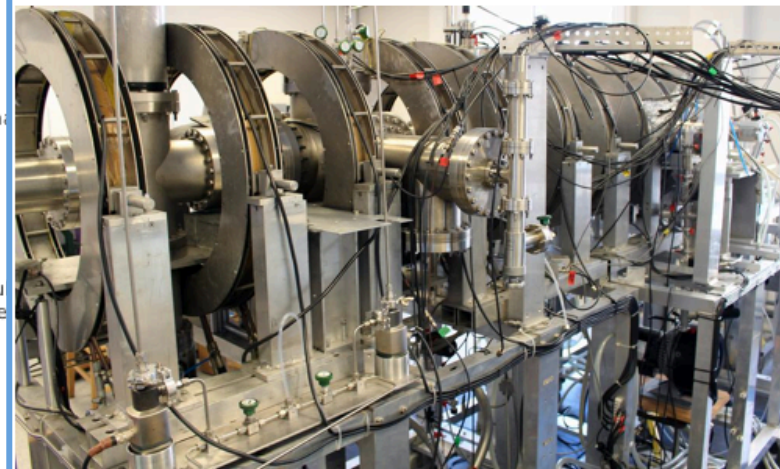
Summary

P. Pérez

[UCL Home](#) / [Mathematical & Physical Sciences](#) / [Revealed: positronium'](#)

Revealed: positronium's behaviour in particle billiards

14 July 2015



Collision physics can be like a game of billiards. Yet in the ¹ microscopic world, the outcome of the game is hard to predict.

First, the anti-summary! *i.e. what was not presented...*

Invited speakers who could not attend:

- N. E. J. Bjerrum-Bohr et al., *PRL* 114, 061301 (2015)

→ *Photons do not follow geodesics; trajectories depend on helicity*

Same result previously obtained using different approach: A. Bérard, H. Mohrbach / Physics Letters A 352 (2006) 190–195; P. Gosselin, A. Bérard, and H. Mohrbach, Phys. Rev. D 75, 084035 (2007)

- L. Bernard and L. Blanchet, *Phys. Rev. D* 91, 103536 (2015)

→ *bi-metric extension of GR* → *gravitational dipolar dark matter*

→ *negative masses*

Present dogma may not be the ultimate truth!

The origins

M. Holzscheiter

- Start with ions then apply to e^- and later to e^+
- *Fairbank-Witteborn 1967*
- Measure : $mg + qE_{\text{ambient}}$
- Schiff-Barnhill, DMRT, patch effect ...
- Tried with next simplest: \bar{p} but LEAR closed 1996
- Next generation turned to neutral particles although M. Holzscheiter optimistic wrt charged particle measurement!
- Impressive bibliography search: please distribute!

Outline

- **Hadrons**
 - ALPHA
 - AEGIS
 - GBAR
 - BASE
 - GRANIT
 - ELENA
- **Leptons**
 - Ps accelerated
 - Ps decelerated
 - Ps spectroscopy
 - Ps Rydberg Stark
 - Mu
- **Astrometry**
 - GAME/AGP, QVADIS
- **Theory**
 - Elementary Process Theory
 - Gravitational dipoles
 - ~~Emergent gravity~~
 - Polyamory
- **Next**

Any difference wrt matter \rightarrow signature of new physics

\bar{H} trapping \rightarrow HFS & 1S-2S spectroscopy as CPT tests

\bar{g} limit, \bar{H} neutrality to be improved

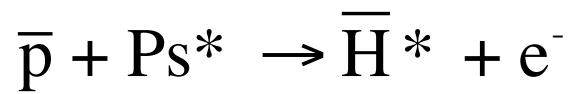
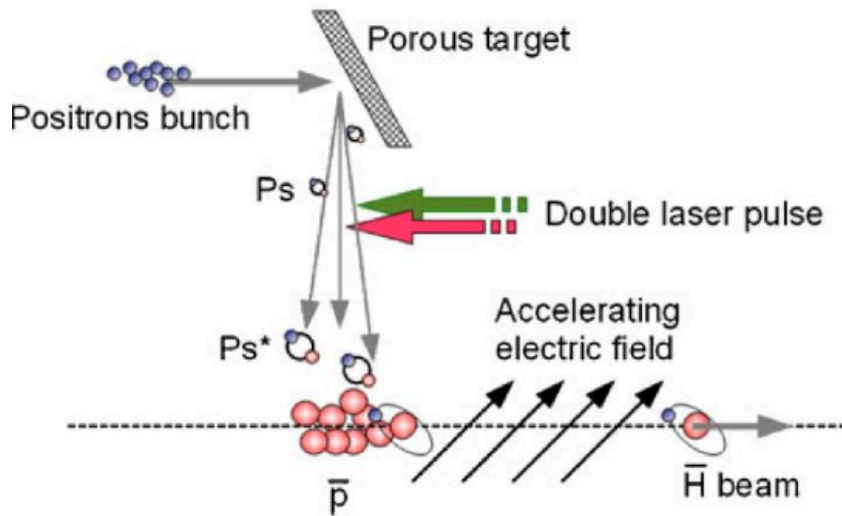
Hope for 100 kHz resolution on 1S-2S this year i.e. $\sim 10^{-10}$

New project on gravity “ALPHA-g”

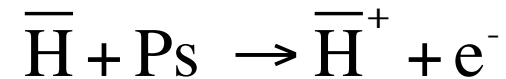
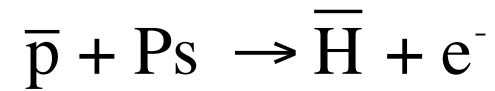
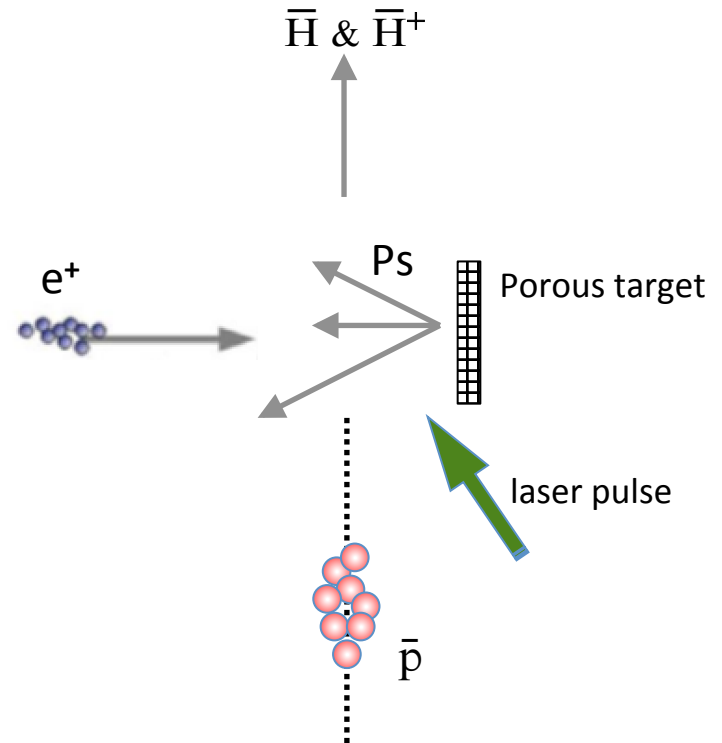
Pulsed Ly- α transition on \bar{H} any day

Hope to measure sign of \bar{g} before 2019

AEgIS



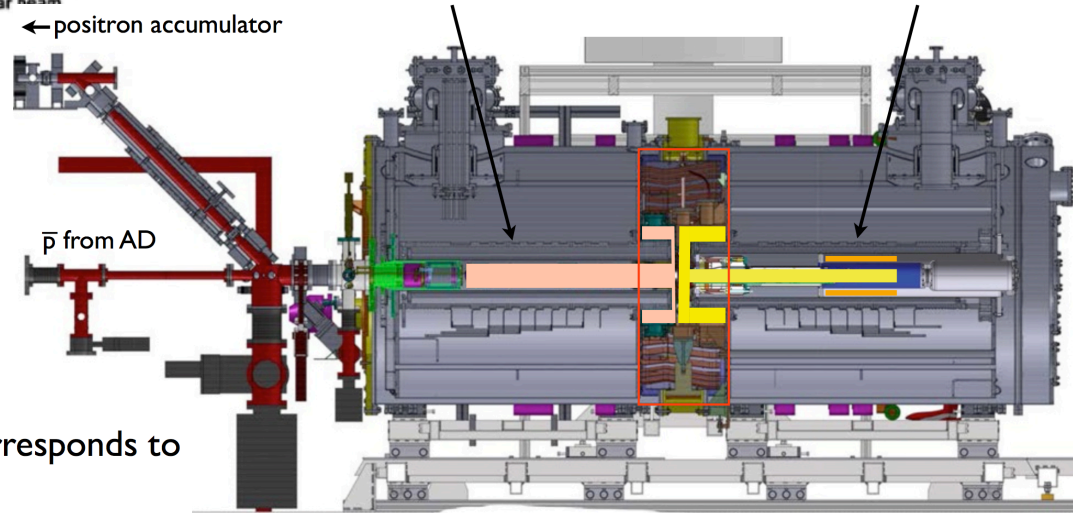
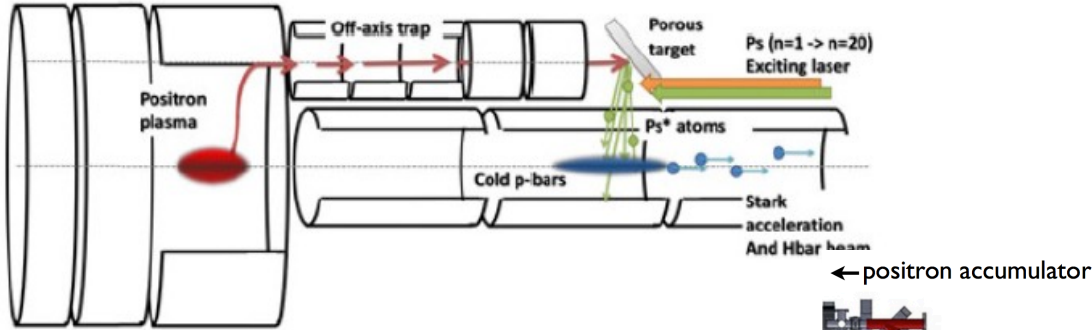
GBAR



AEGIS : particle trapping

R. Caravita

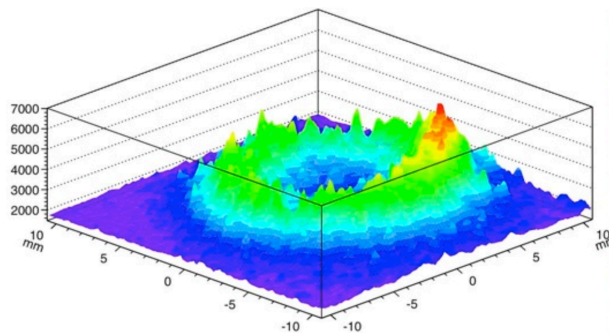
100 electrodes,
4.5 to 1 T



→ from measured e^- density we estimate T_{min} which corresponds to traps' temperature of 10K

5T CCD img 0 Run 9268

$$KT_{min} = \frac{1}{8\epsilon_0^2} m_p q^2 \left(\frac{nr}{B} \right)^2$$



AEgIS : Ps excitation *Z. Mazotta*

increase lifetime to reach \bar{p} & increase cross section $\propto n^4$

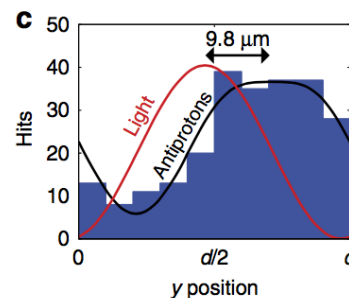
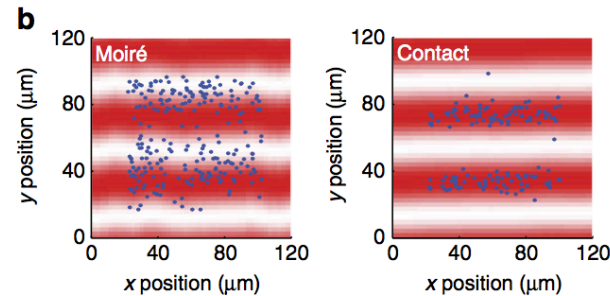
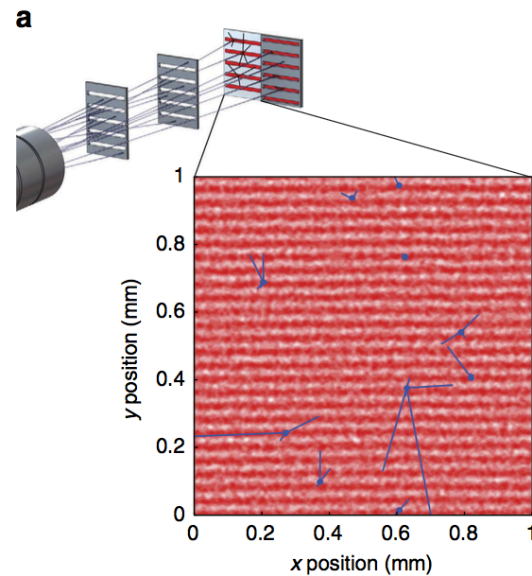
$n=3$ then $n=15-24$

Detection: photoionise or Rydberg excite

Doppler broadening $\rightarrow 1200 \pm 100$ K \rightarrow partial thermalisation (room temp)

$n=15-17$: shift lifetime, scan IR laser

AEgIS : detection *P. Bräunig*



10 μm deflection from B field on \bar{p}

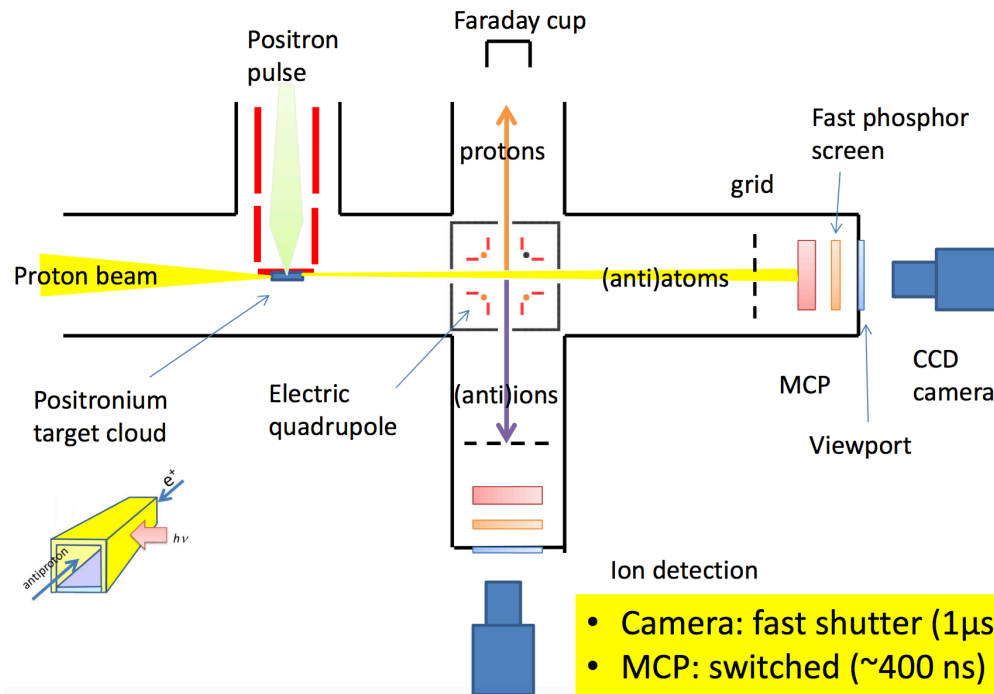
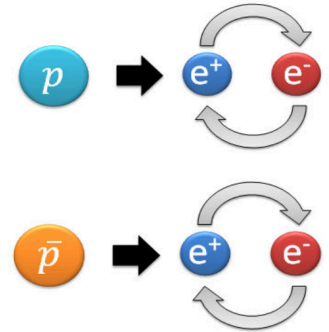
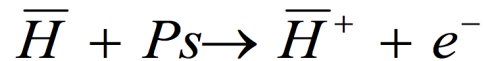
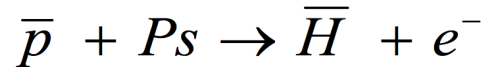
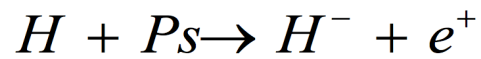
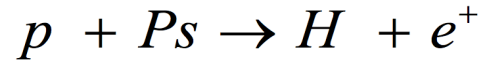
wave/classical regime from visibility



\bar{H}^+ production & detection

L. Liskay

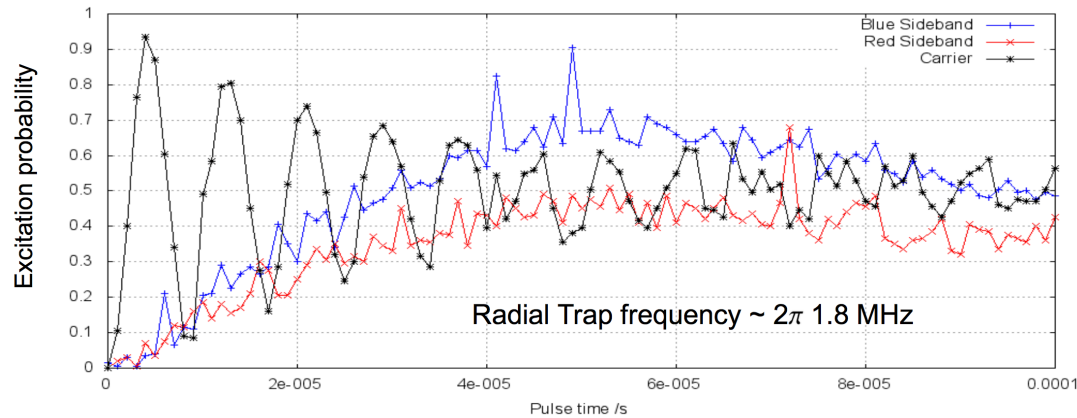
Preparing for production
cross section measurement





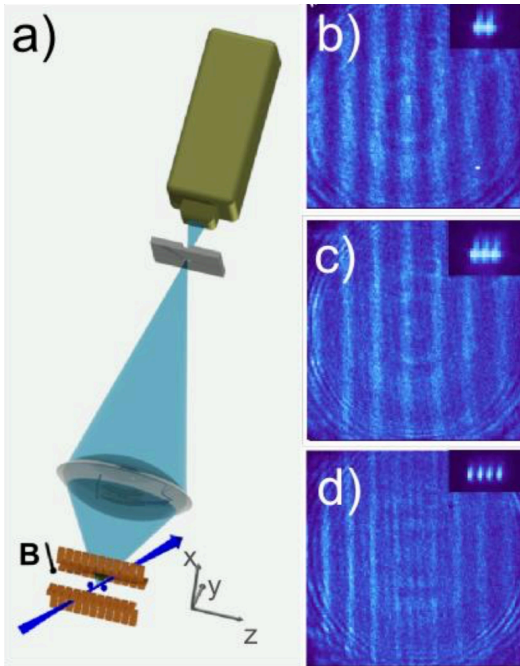
\bar{H}^+ cooling

S. Wolf

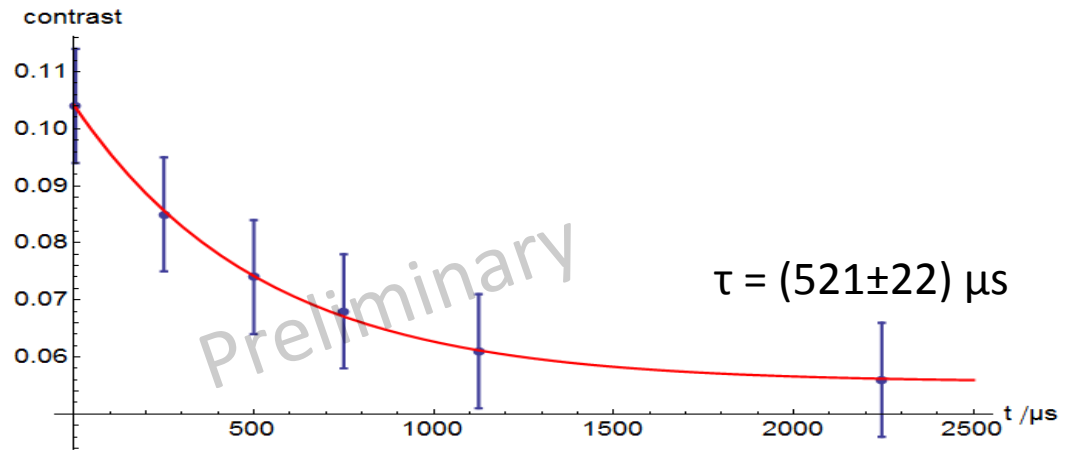


Sideband spectroscopy and cooling

$\bar{n} \sim 1.9$



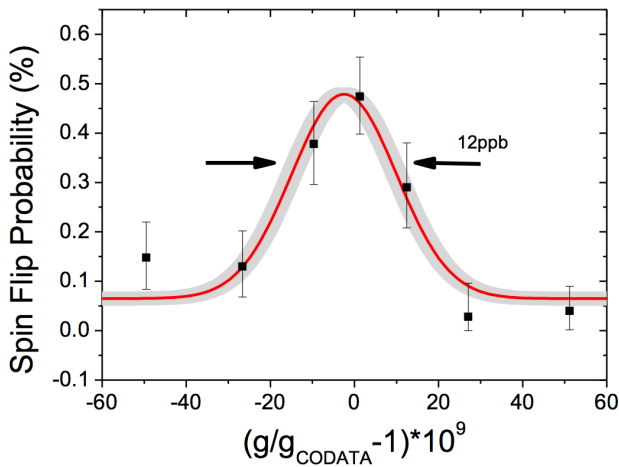
Young interference with 2 ions \rightarrow thermometry



properties of \bar{p}

C. Smorra

Double trap method
proton magnetic moment



$$g/2 = 2.792847350 (7) (6)$$

Preparing for antiproton measurement:
Many improvements in processes

→ x 10 faster

→ Should stay tuned for 1000 times
improvement soon!

- First direct high precision measurement of the proton magnetic moment.
- Improves 42 year old MASER value by factor of 3.
- Value in agreement with accepted CODATA value, but 2.5 times more precise

GRANIT: UCNs *D. Roulier*

Ultra Cold Neutrons (anti neutrons difficult to slow down) < 330 neV , < 8 m/s

Chameleon: field screened in dense matter
squeezes wave function & dilation of energy levels

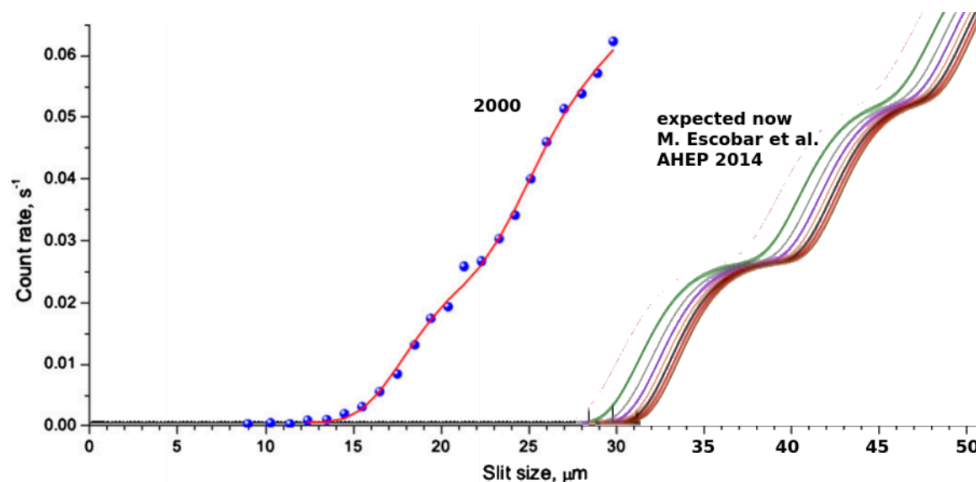
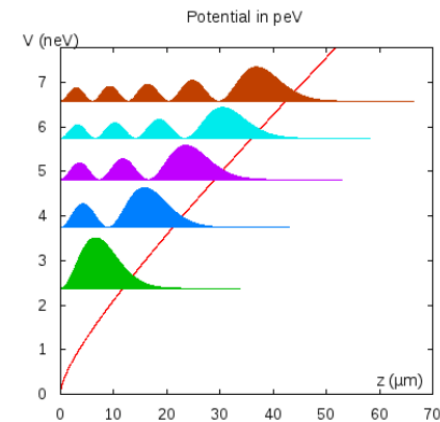
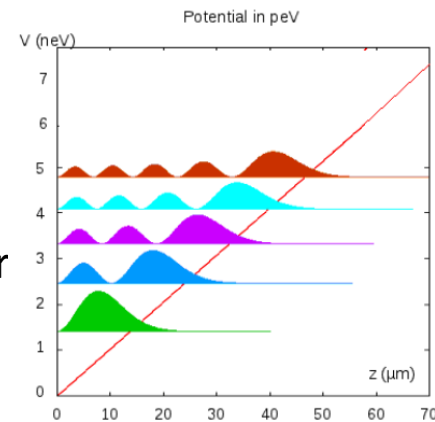
Resolution $\times 20$ wrt 2009

Storage time 30.4 ± 0.7 s 5.1 ± 0.1 m/s

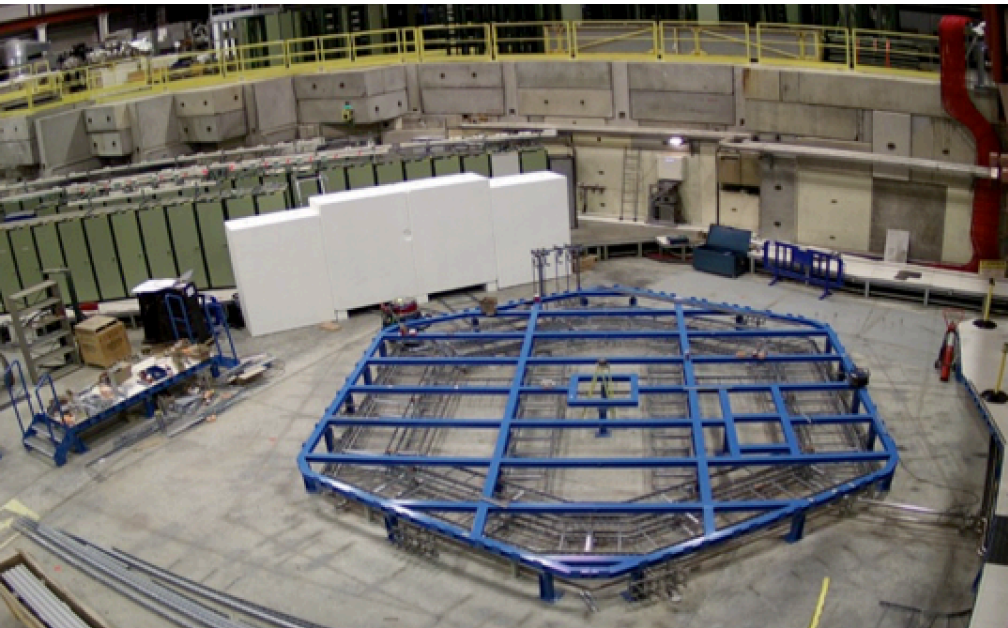
$\times 30$ rate of UCN presently in continuous mode

$1.3 \mu\text{m}$ resolution : B10 + Hamamatsu CCD sensor

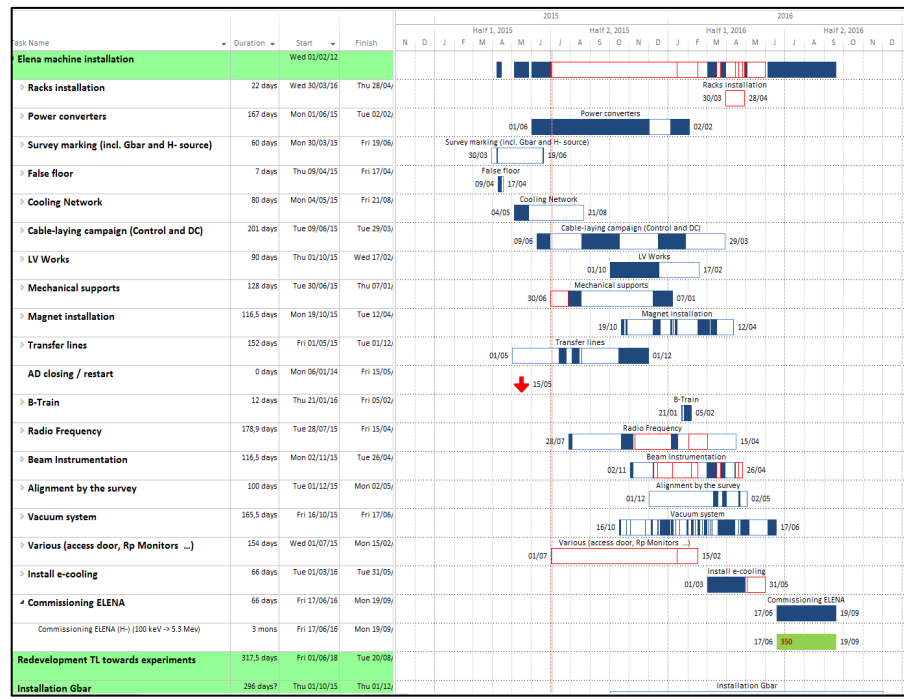
$300 \mu\text{m}$ with fibres for free fall detector



Needed Consolidation work on AD \approx 24 MCHF



Planned end of construction April 2016



Start building ring \rightarrow 100 keV \bar{p}

Interrogating Ps with lasers



Ps: high precision spectroscopy

D. Cooke

ETHZ team

1S-2S @ 0.1 ppb

Gravitational redshift seasonal variation 10^{-10}

Photoionise to detect 2S

Lifetime method

Tube geometry + carbon foil window

700 W damage threshold to finesse of buildup cavity

TOF resolution 30 MHz $\sim 3 \cdot 10^{-8}$

First signal consistent with expectations

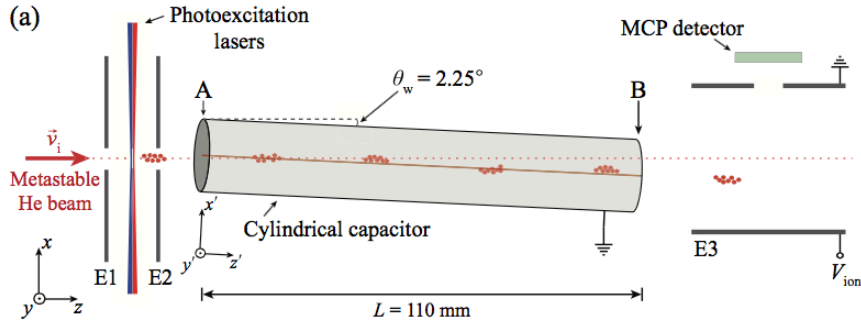
Next:

buffer gas+ bunching, colder Ps by Starck deceleration of $n=22$ Rydberg Ps

Eff 10^{-4} then 2S excite \rightarrow flux: 1 atom /s in 2S state

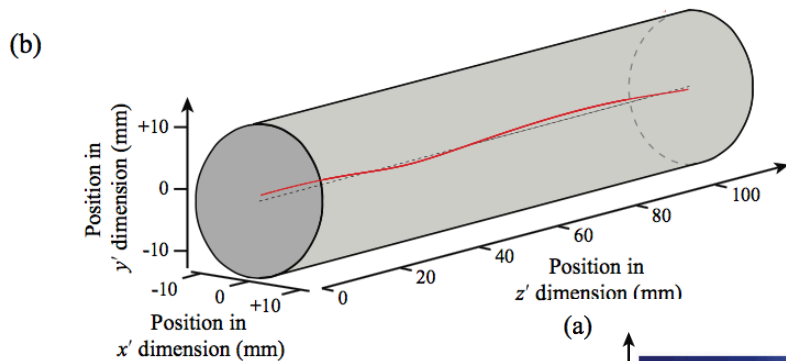
Ps Rydberg deceleration

S. Hogan

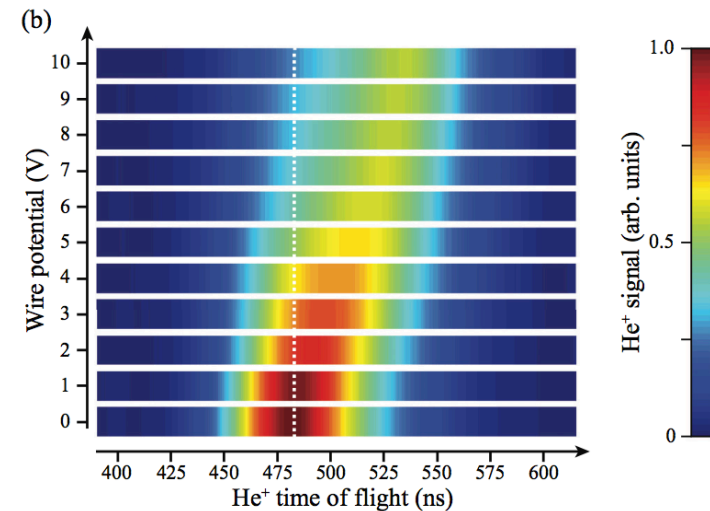
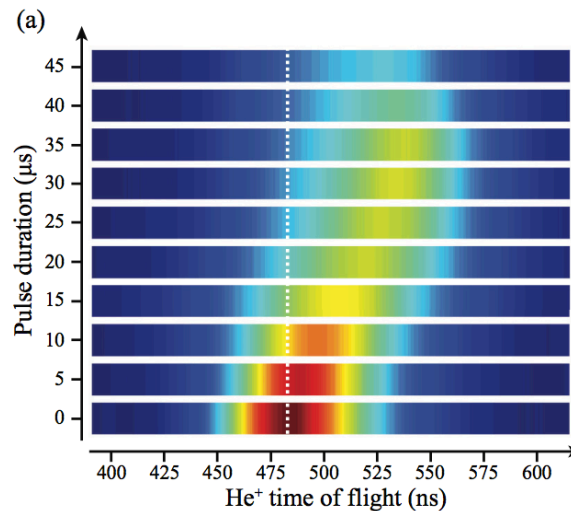


Charged wire guide for high field seeking
52p He

WF expt with neutral Rydberg He atoms
Then Ps



Spectro: change separation e+/e- i.e 10-100 kHz or 10 -100muV/cm
Microwave 20 muV/cm
Few weeks-years?



Ps beam (accelerated) optically guided

M. Charlton

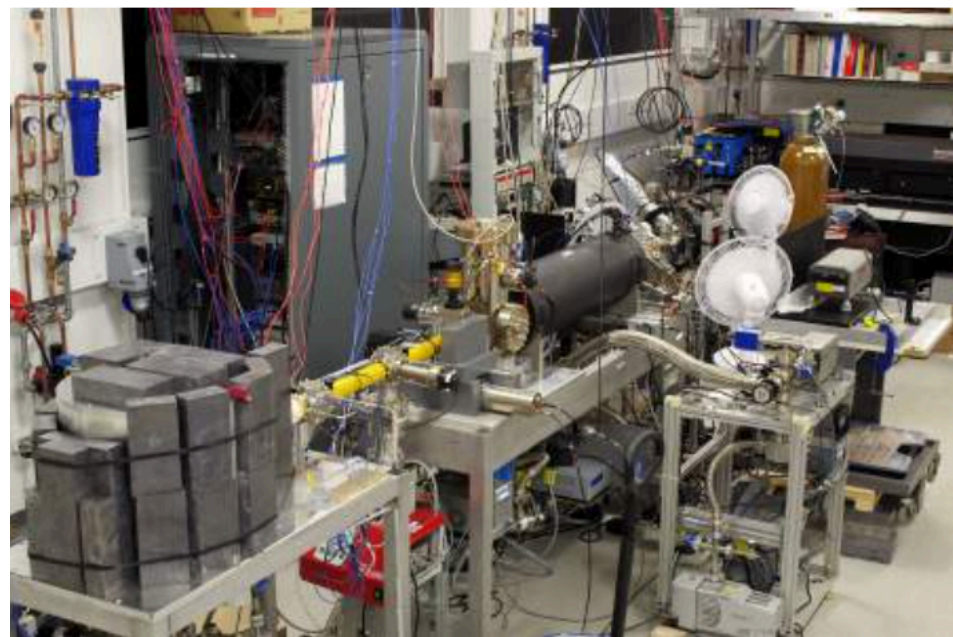
Lattice at ~ 180 degrees from 2 beams

Change freq \rightarrow accelerate by induced E dipole $U = -1/2 \alpha \langle |E_1 + E_2|^2 \rangle$

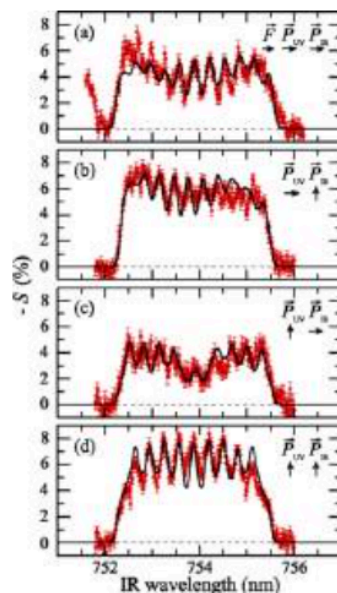
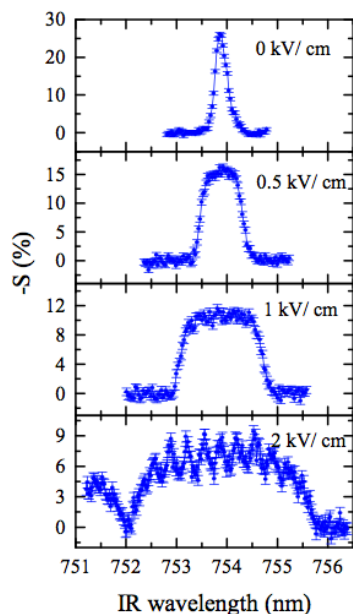
Velocity of lattice = velocity of trapped particle $1\,000 \pm 2$ eV

Can also decelerate!

Toward Ps gravity measurement
 Installed lab in less than 2 years
 243 + 532 nm
 SPPALS and TOF
 Magnetic quenching
 $n=11$
 Stark states for deceleration \rightarrow Hogan



Rydberg Stark states Ps ($n = 11$)



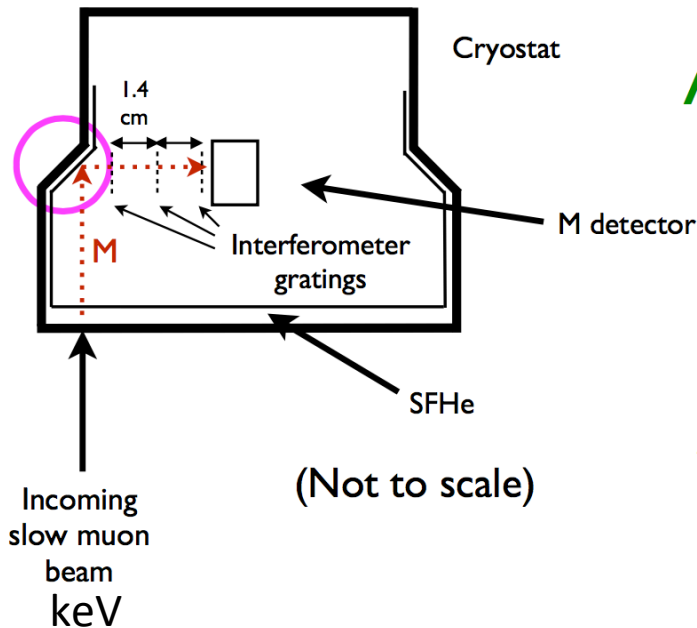
A. Deller *et al.* (2014) *New J. Phys.*, **16**:073028
 D. B. Cassidy, *et al.* *Phys. Rev. A* (2014) **81**:012715
 A. Deller, *et al.* *New. J. Phys.* (2015) **17**: 043059
 T. Wall, *et al.* (2015) *Phys. Rev. Lett.*, **114**:173001
 S. Hogan, and D. Cassidy (2014) *Int. J. Mod. Phys. Conf. Ser.* **30**, 1460259

<http://antimattergravity.com/>

Mu (μ^+e^-) free fall

D. Kaplan

μ stops in Superfluid He
 $\rightarrow \text{Mu}@6300 \text{ m/s}, \Delta E/E = 0.2\%$



A “ship in a bottle!”

Sensitivity estimate
 @ 100 kHz:

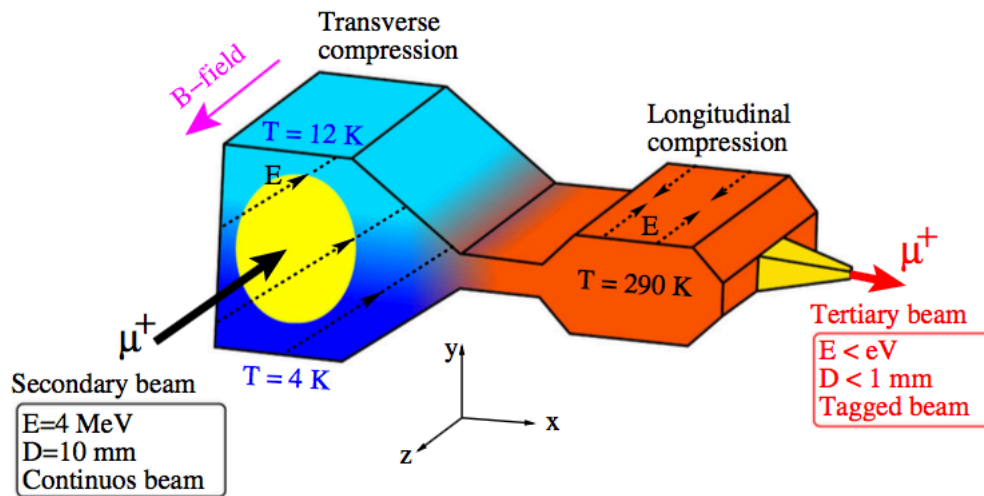
$$S = \frac{1}{C\sqrt{N_0}} \frac{d}{2\pi} \frac{1}{\tau^2}$$

$$\approx 0.3 \text{ g per } \sqrt{\#\text{days}}$$

Grating pitch $d = 100 \text{ nm}$

muCool Collaboration at PSI

A. Eggenberger



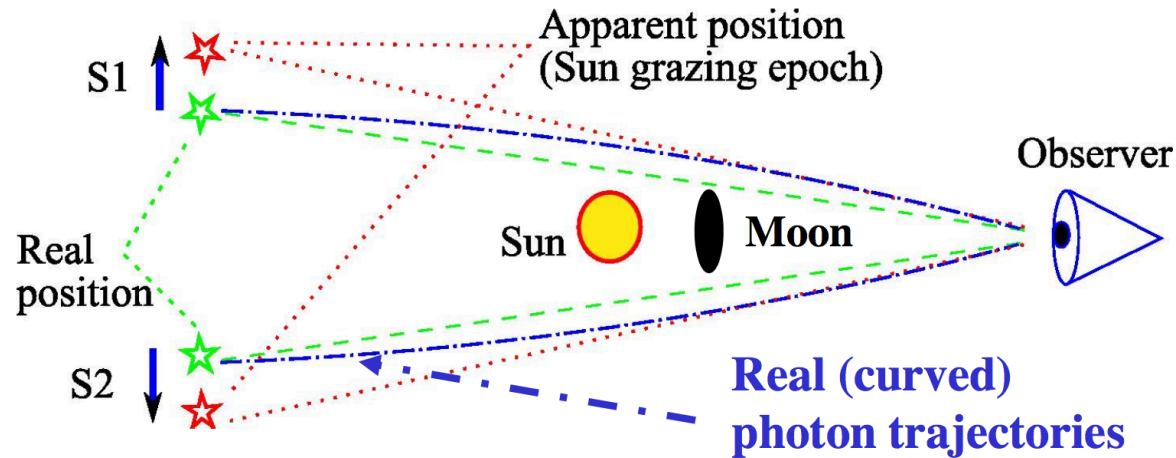
500 keV
 10^4 mu/s , eff. 10^{-3}

Astrometry @ μas i.e. 10^{-12} rad

M. Gai

- Detection limit of dilaton
- Limits for Lorentz invariance
- Preferred frame detection
- Anisotropy of light deflection

Dyson-Eddington-Davidson experiment (1919)



GAME over \rightarrow Astrometric Gravity Probe

High precision astrometry + coronagraphy

Gravitational lensing using Sun as lens 10^{-8} precision, discriminate gravity theories at solar system scale

Looking for Equivalence Principle, Lorentz violating (SME) ... effects with matter

Orbit monitoring \rightarrow detection of external force (quant. vacuum grav. Dipoles)

EPT: elementary process theory

M. Cabbolet

Arguments of principle

QM and GR inconsistent with repulsive gravity

EPT out if no antigravity

What if quantum vacuum fluctuations are virtual gravitational dipoles?

D. Hajdukovic

Random orientation of virtual dipoles might be broken by the immersed Standard Model matter

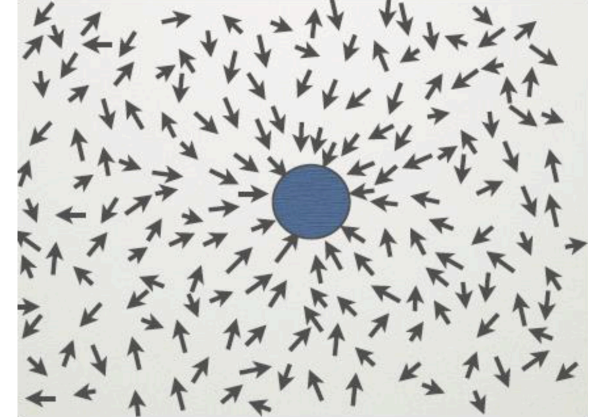
- A gravitational polarization density \vec{P}_g (i.e. the gravitational dipole moment per unit volume) may be attributed to the quantum vacuum.
- The spatial variation of \vec{P}_g , generates a gravitational bound charge density of the quantum vacuum

$$\rho_{qv} = -\nabla \cdot \vec{P}_g$$

$$\rho_{ve}^* = \frac{\pi}{2} \frac{M_c}{\lambda_{Mc}^3} \frac{\lambda_{Mc}}{R}$$

Dipole factor

$$10^{14} \rightarrow 10^{-27} \text{kg/m}^3$$



Explains local Dark Matter and global Dark Energy

Inflation not needed

Cyclic matter-antimatter universe

Do black holes create polyamory?

J. Oppenheim

Entanglement in time saves causality!

Next

Initially WAG to motivate theorists before experiments come to a measurement → pre-diction

But: 3 theorists/22 talks!

We heard of several types of experiments that may well obtain results before any firm/precise prediction
Too late for post-diction!

Learn hopefully more at next WAG?

Many thanks to the local organisers !

