ASACUSA – Beamtime 2012

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for the

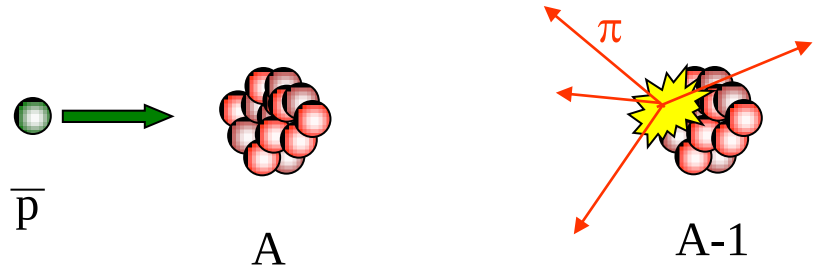
ASACUSA Collaboration

ADUC/ELENA Meeting 11/20/2012

ASACUSA – 2012 Physics Program

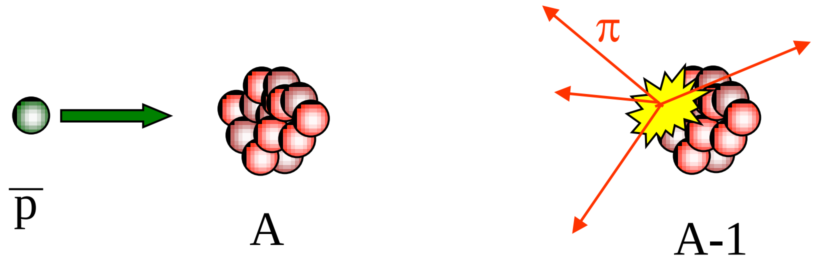
- Brescia Subgroup and collaborators
  - Nuclear Collisions with Low Energy Antiprotons (April – End May)
- CUSP subgroup (Including MUSASHI and SMI)
  - Progress towards the production of a spin polarized antihydrogen beam
- pbar Helium subgroup
  - Further improvement of precision on pbar/He laser spectroscopy

Brescia Collaboration



Investigation of Low Energy
Antiproton Collision
Cross-Sections

Nuclear collisions with antiprotons



Measurements of antiproton-nucleus annihilation cross section for:

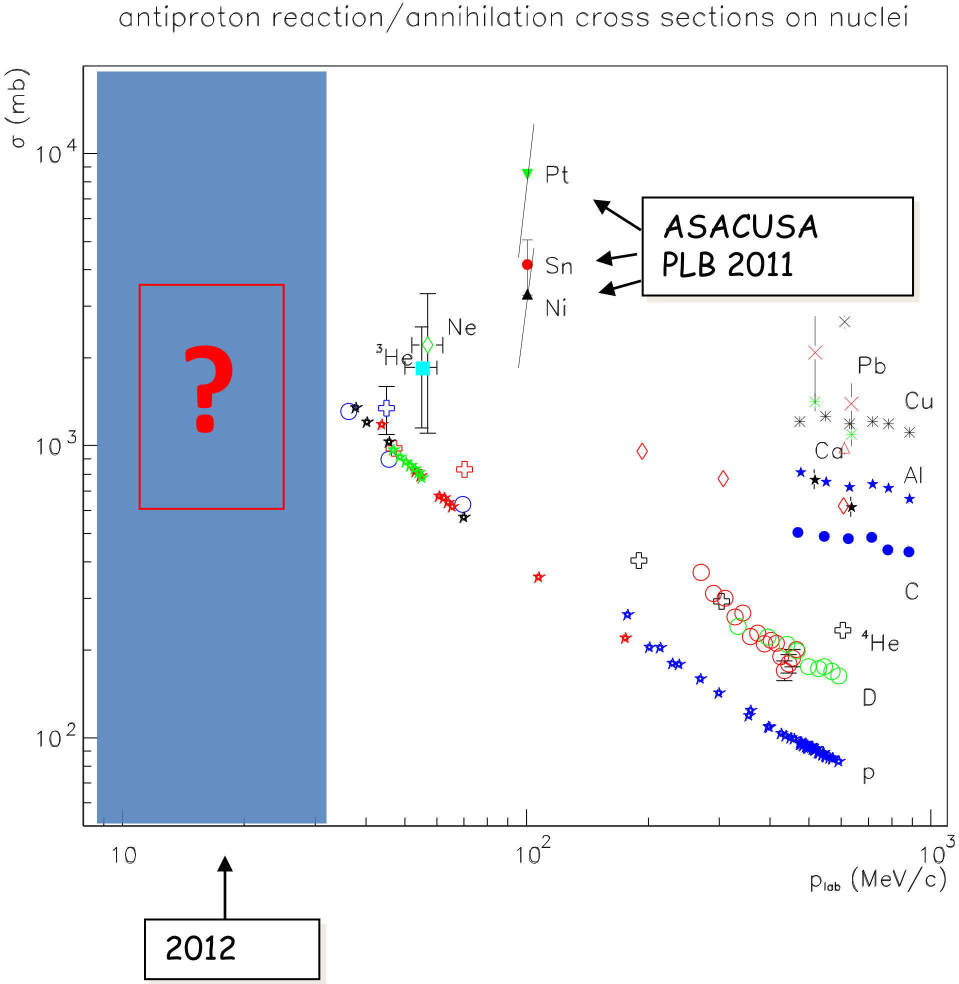
- Nuclear Physics interest: saturation with target mass number

- Fundamental Cosmology interest: matter-antimatter asymmetry in the Universe

Energy range: 100 keV – 5 MeV

Light and heavy nuclear targets

Low Energy Antiproton Scattering



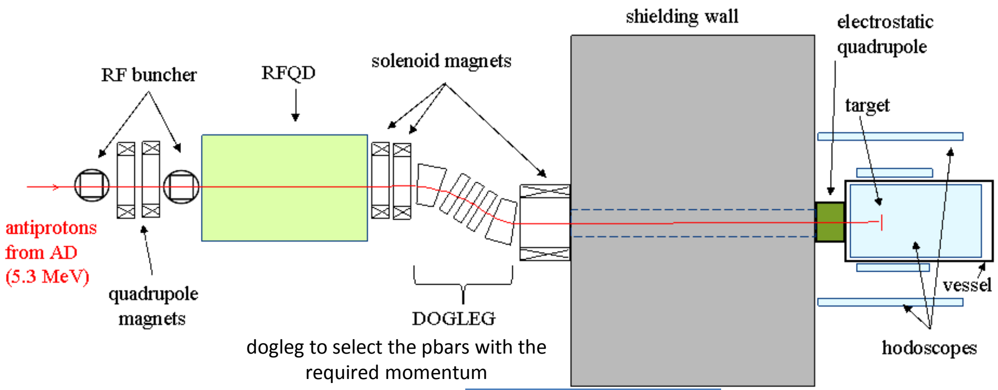
Medium-heavy and heavy nuclear targets

Results consistent with theoretical expectations

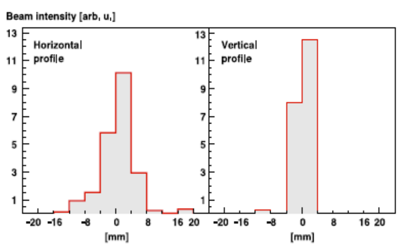
Bianconi et al. Phys. Lett.B 2011

- the number of stopped pbars in the target not negligible
- Ultra-thin targets needed.
- Targets less than 100 nm in thickness -> Carbon target
- Other targets: Platinum and Palladium deposited on carbon film

2012 - Annihilations cross-sections @ 130 keV



Beam monitor @ target position



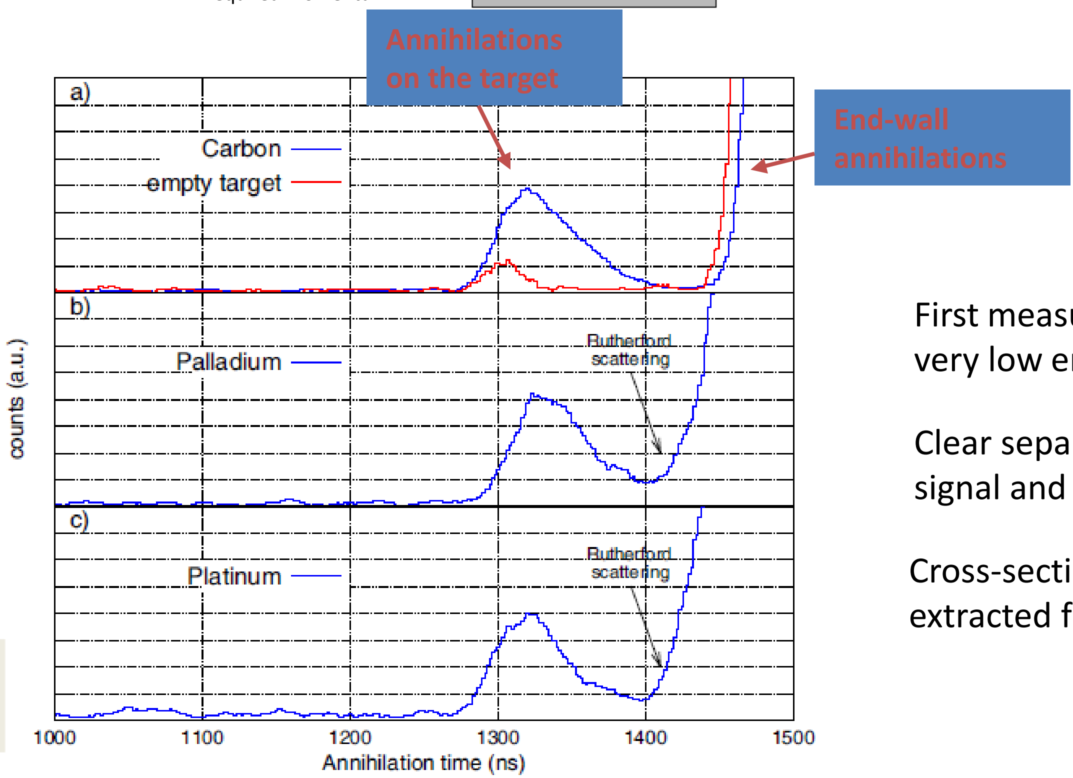


Fig. 3. The $\bar{p}$-annihilation time distributions for a) C target (blue line) and empty target (red line), b) Pd target and c) Pt target.

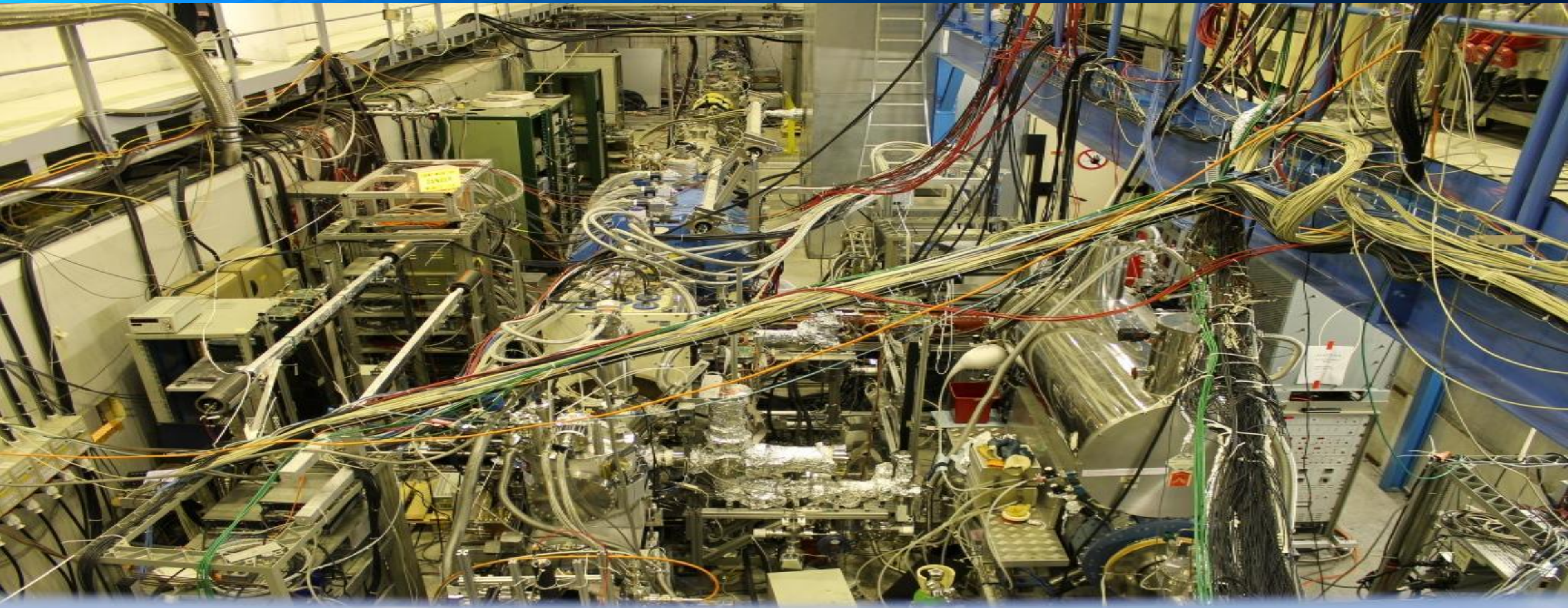
First measurement at these very low energies

Clear separation between signal and background

Cross-sections values to be extracted from data

Aghai-Khozani et al.
Eur. Phys. J. Plus 2012

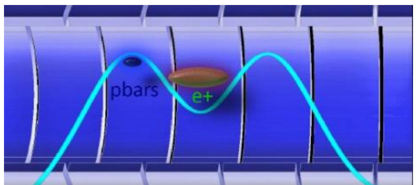
CUSP Collaboration

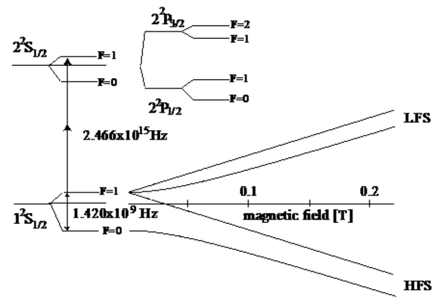


PROGRESS TOWARDS THE PRODUCTION OF A POLARIZED ANTIHYDROGEN BEAM

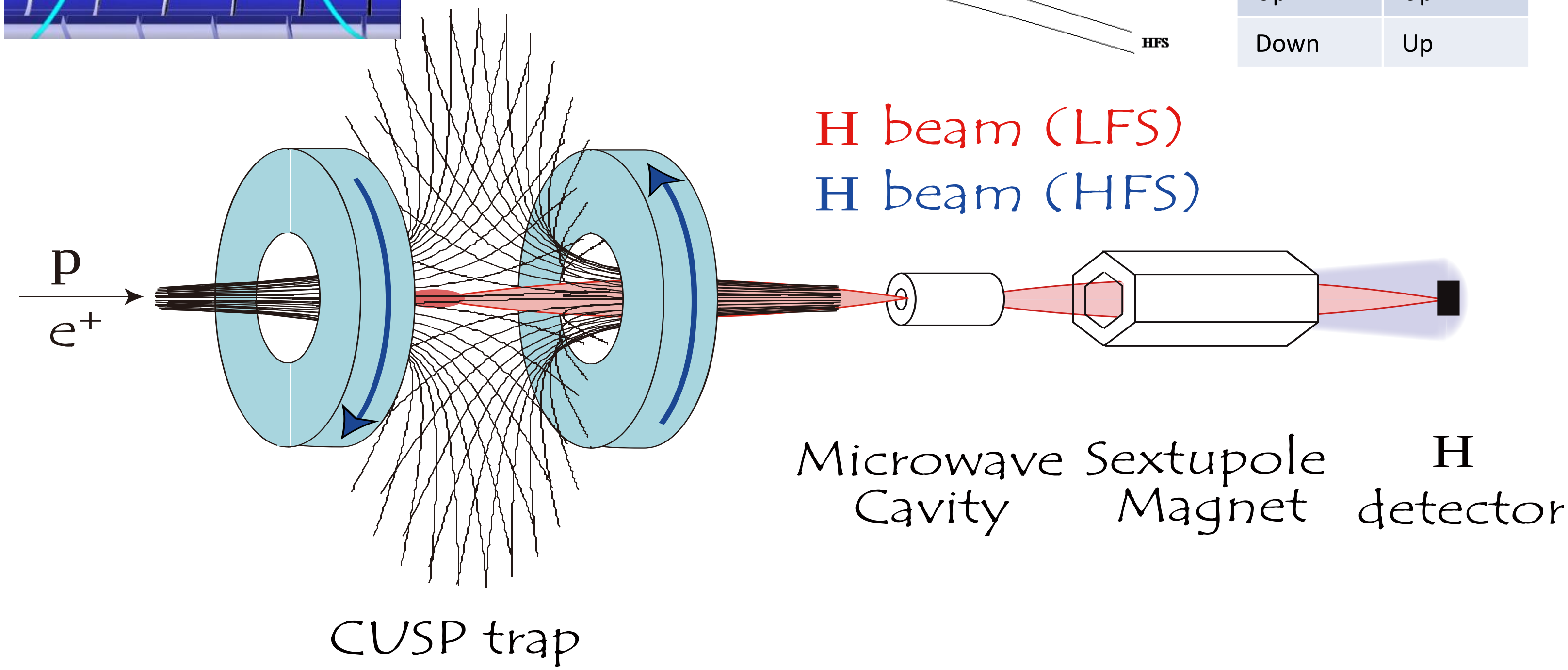
Basic Spectroscopy

Physics Goal: precise spectroscopy of antihydrogen hyperfine structure using a polarized beam.





Pbar	e+
Up	Down
Down	Down
Up	Up
Down	Up

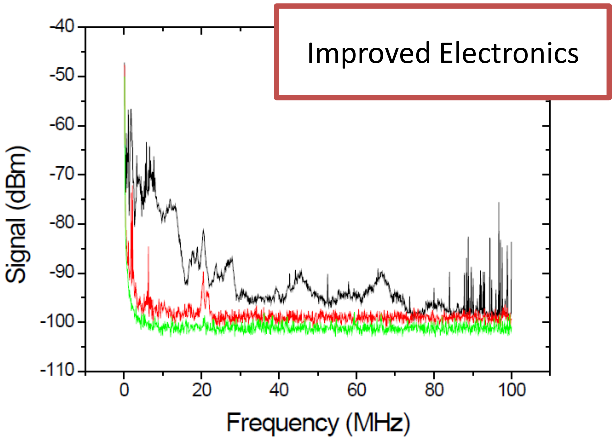


Some indication of hbars at detector but 2011 signal was very weak

2012 Strategy

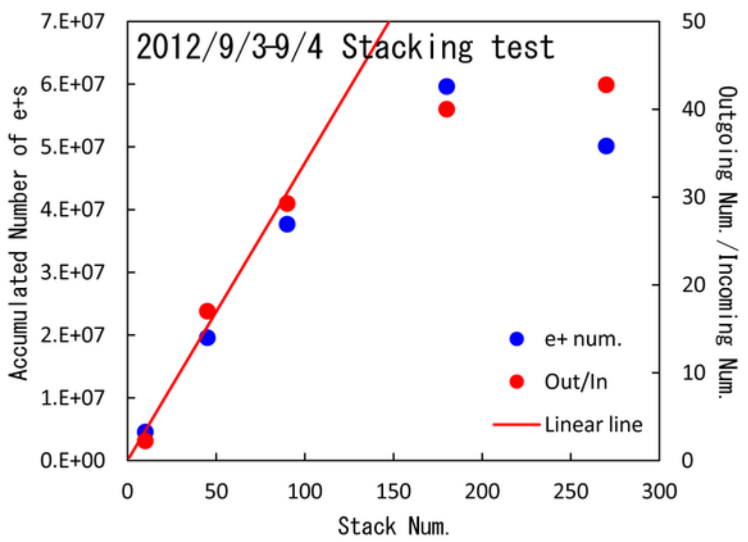
- Improvement of antihydrogen yield
  - More positrons using a rare-gas moderator (accumulated earlier 4 million in 40 minutes, only)
    - More experiments
    - Higher particle density
    - Improved reaction cross section
  - Direct compression of antiprotons

- Improve noise on apparatus
  - Lower plasma temperature
  - Improved reaction rate



Positron Progress

RGM: 10 times more moderated positrons



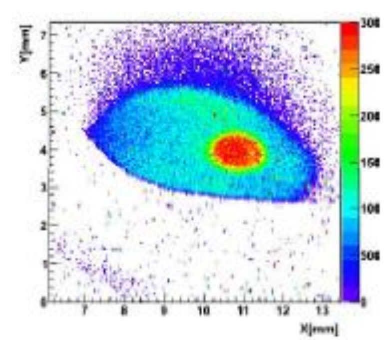
60 million in 50 minutes

Compared to 2011:

Improved by a factor of 12

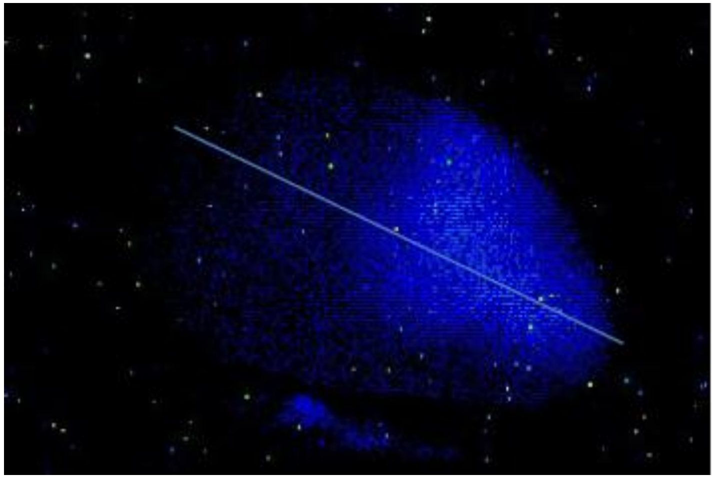
Much more experiments conducted in 2012 beamtime at much higher positron densities

Worked out smooth potential procedures -> Particles remain compressed



Direct Compression of Antiprotons

- Found pbar compression conditions (100k -> 220k in 200s)

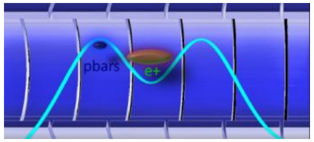


- First direct compression of pbars
- Best compression achieved: 3mm diameter in CUSP trap

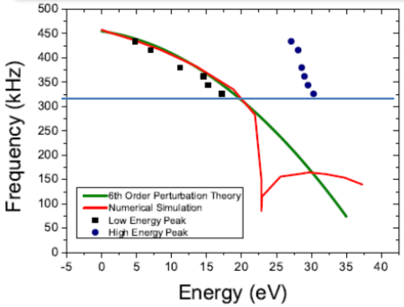
Improved interaction density of pbars before mixing

RF Assisted Direct Injection

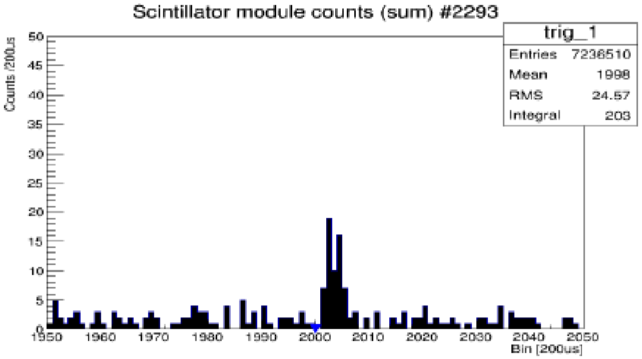
- Prepare 40 million positrons in the nested
- Inject directly from MUSASHI trap
- Apply RF during interaction

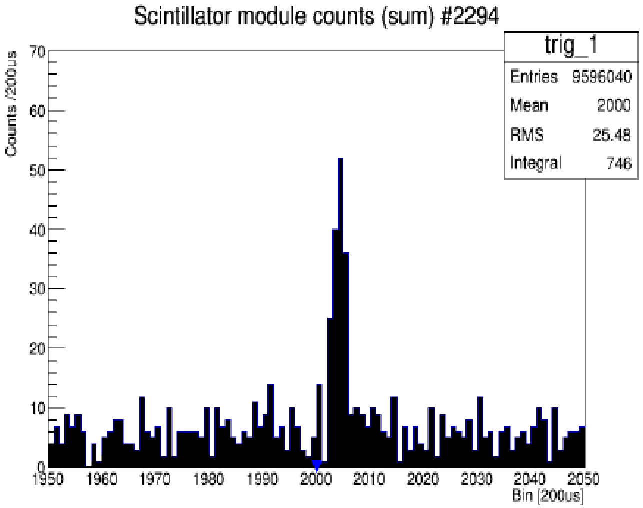


Frequency Scaling in Nested Well



RF assisted Mixing





Produced encouraging results – further evaluation in progress

Pbar Helium Collaboration

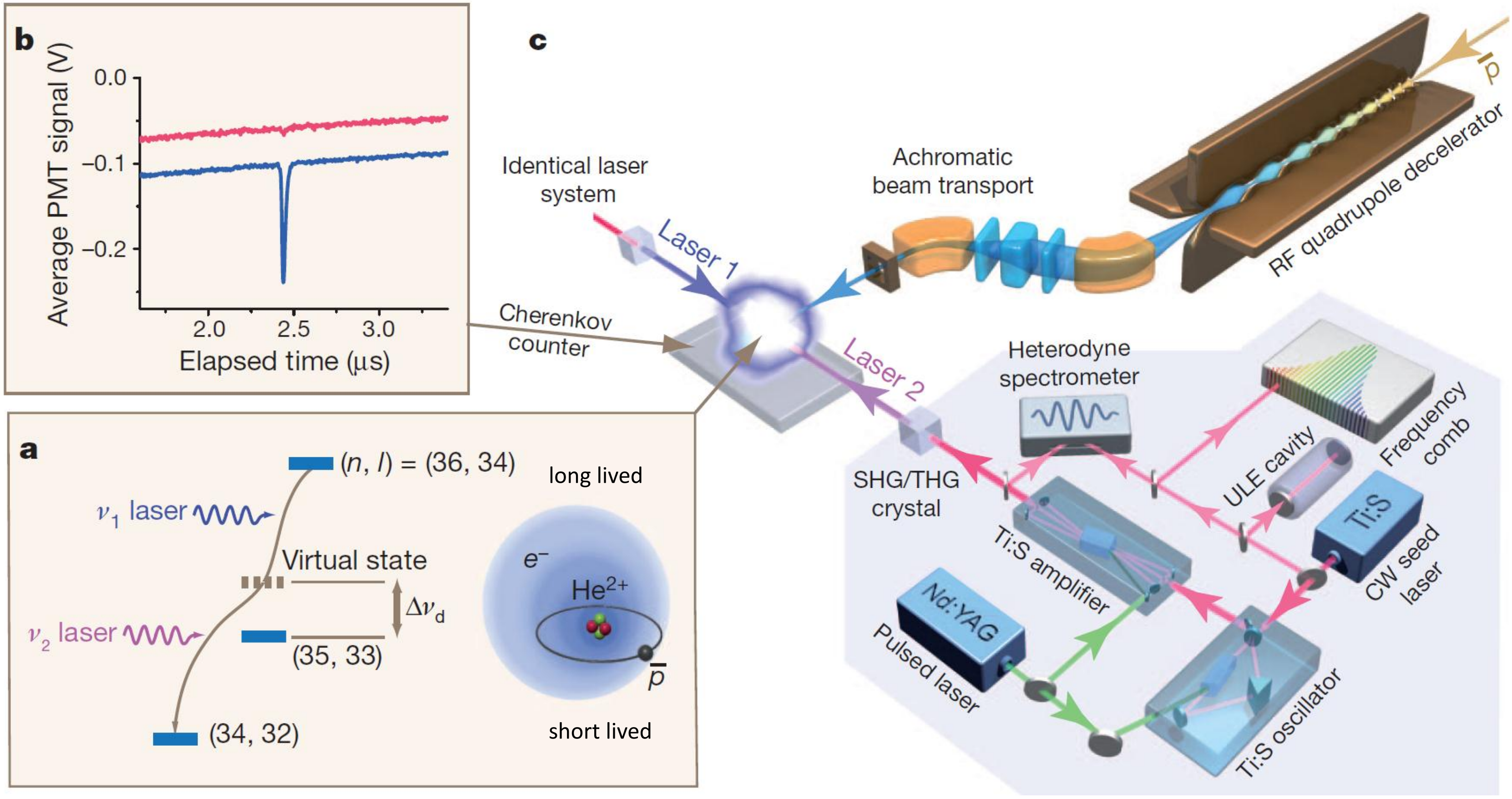
Further improvement of laser spectroscopy of pbar/Helium and precise determination of the antiproton to electron mass ratio

Antiprotonic Helium Laser Spectroscopy

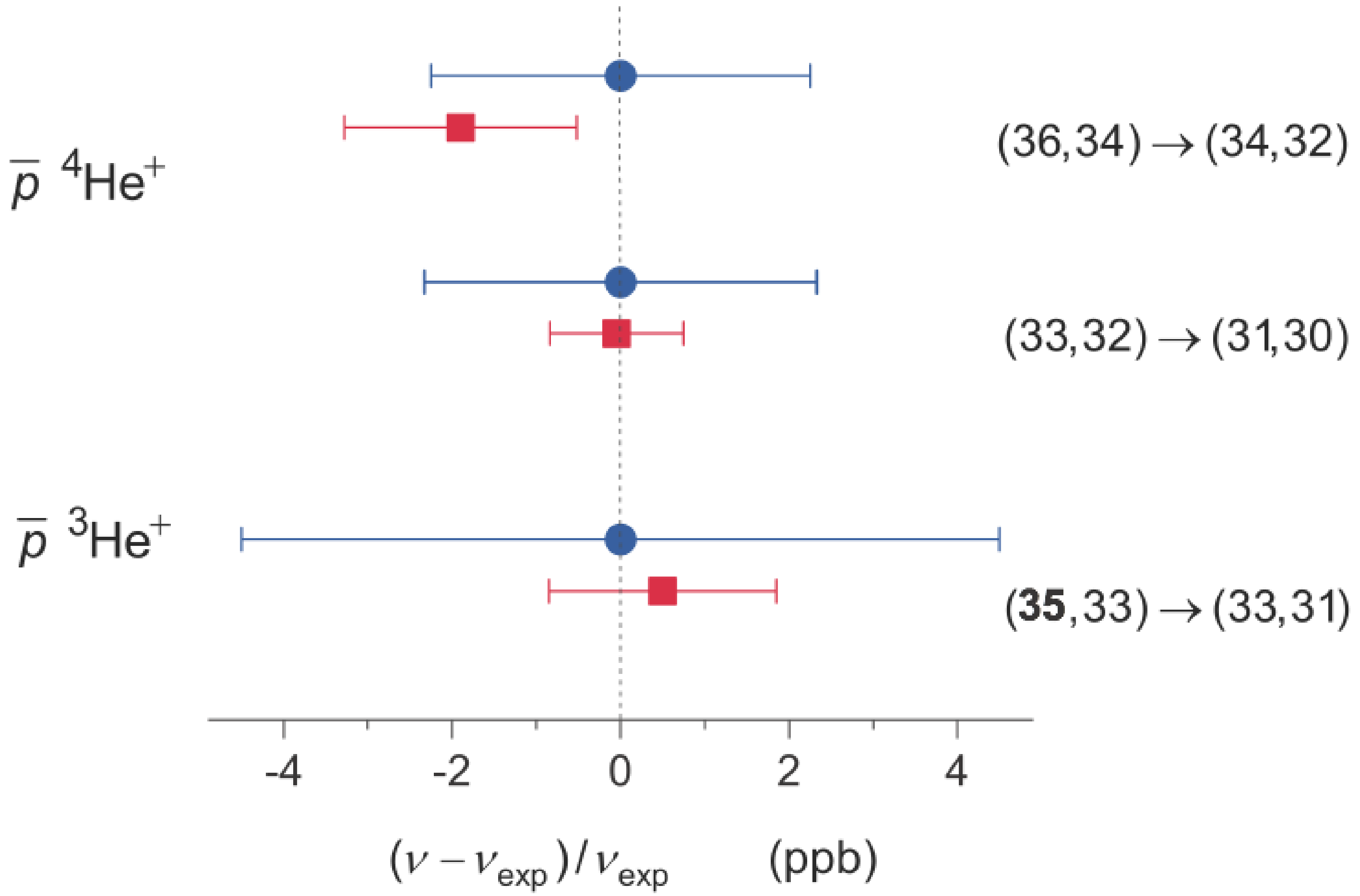
2 photon spectroscopy on antiprotonic Helium: (n,l) -> (n-2, l-2) type

Anti-collinear lasers: **Doppler broadening** cancels partly -> **Narrow lines**

$\nu\sqrt{8k_{\mathrm{B}}T\log(2)/Mc^2}$ $\qquad$ $|\nu_1-\nu_2|/(\nu_1+\nu_2)$

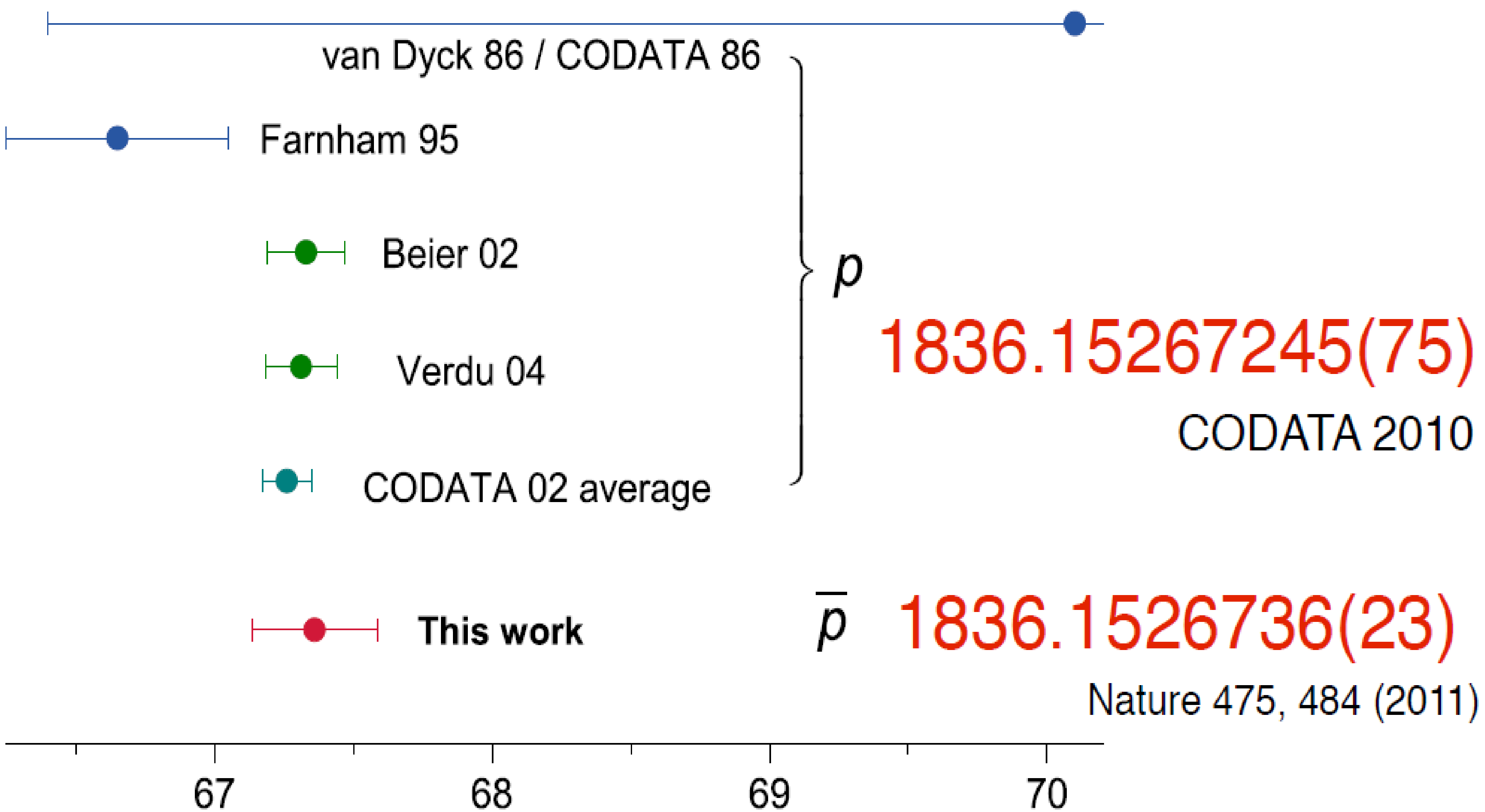


Experiment-Theory Comparison of Spin-Averaged Transition Frequencies Published in 2011



Three transition frequencies agreed with QED calculations with a fractional precision of 2.3 - 5 ppb.

Status so far



Physics program in 2012

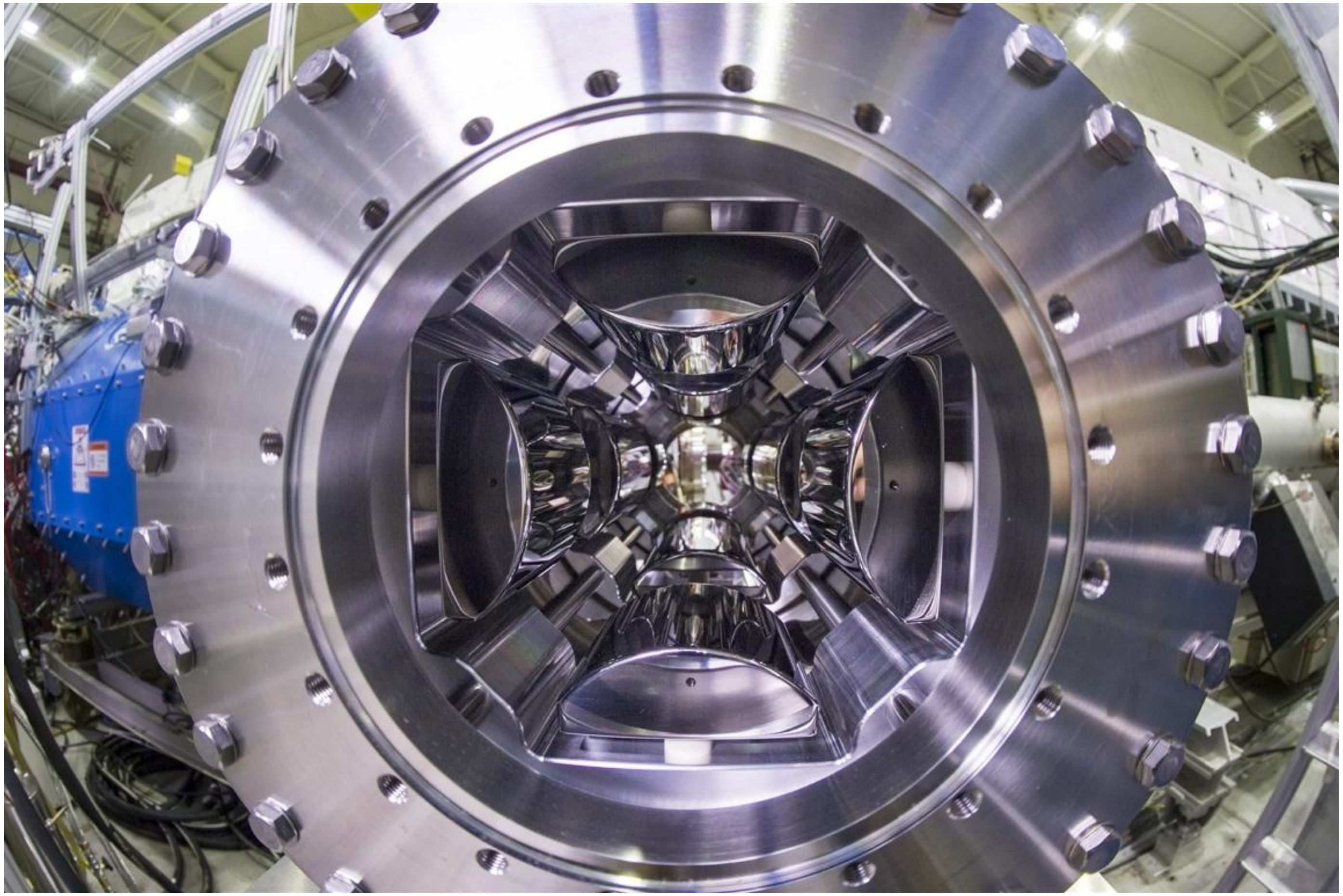
1. Attempts to cool down atoms to lower temperatures by collisional gas buffer cooling **-> Improved Precision**

2. Systematic laser spectroscopy studies to evaluate experimental uncertainties.

3. Many instrumentation changes compared to results published in 2011:
   1. Developed cw semiconductor diode injection-seeded laser system. Easy to handle
   2. New long-pulse DPSS Nd:YAG laser and dye lasers. Narrower lines
   3. Raman shifter to access mid-infrared regions. Access higher n-states
   4. Three new experimental targets. More cooling power, colder target
   5. …many more…

4. Added ability to carry out second parasitic spectroscopy experiment in parallel to main precision experiment, using residual undecelerated antiproton component near beam dump at the end of RFQD (very confined space 30 cm and large beam diameter 40 mm, only good for certain types of experiments).
   1. Parasitic experiment to **search for weak transitions at mid-infrared regions** >1150 nm.
   2. Parasitic experiment to **search for transitions in atoms embedded in superfluid helium** (condensed matter physics).

Electrostatic quadrupole triplet – ELENA prototype



Bore diameter   100 mm

Length 700 mm

Tested for 70-130 keV antiprotons for several weeks stable operation

More (burning) results will be presented at next SPSC meeting

! Thanks a lot for your attention !