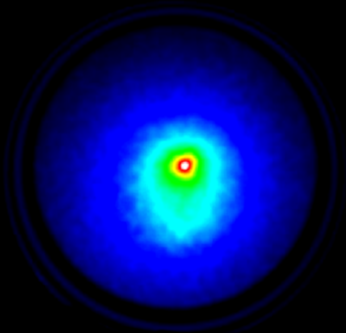
AEḡIS Latest Results

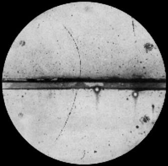
Francesco Guatieri (TIFPA/INFN)
on behalf of the AEgIS Collaboration



In the picture: MCP imaging of a positron bunch - Several shots averaged

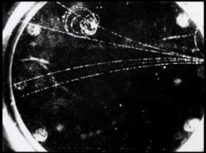
TIFPA
Trento Institute for
Fundamental Physics
and Applications

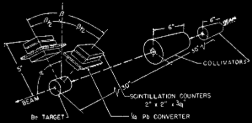
INFN
Istituto Nazionale di Fisica Nucleare



ELECTROMAGNETIC
1932
(Discovery of positron)

WEAK
1936
(Discovery of muon)





STRONG
1950
(Discovery of neutral pion)

Matter

$$\left| \frac{m_i}{m_g} - 1 \right| < 2.1 \; 10^{-13}$$

C.L. >95%

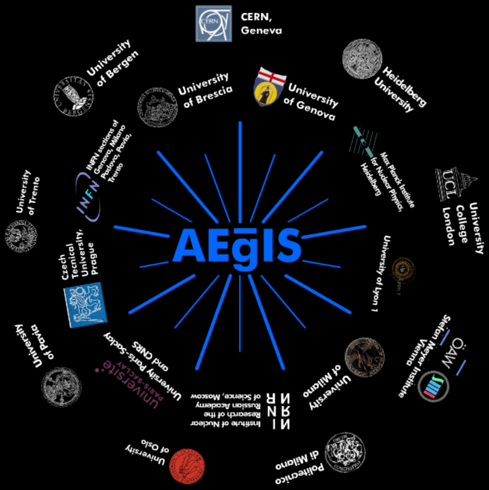
T. A. Wagner et Al. 2012.

Antimatter

$$\left| \frac{m_i}{m_g} - 1 \right| < 110$$

C.L. 95%

Alpha collaboration 2013



The AEḡIS Experiment

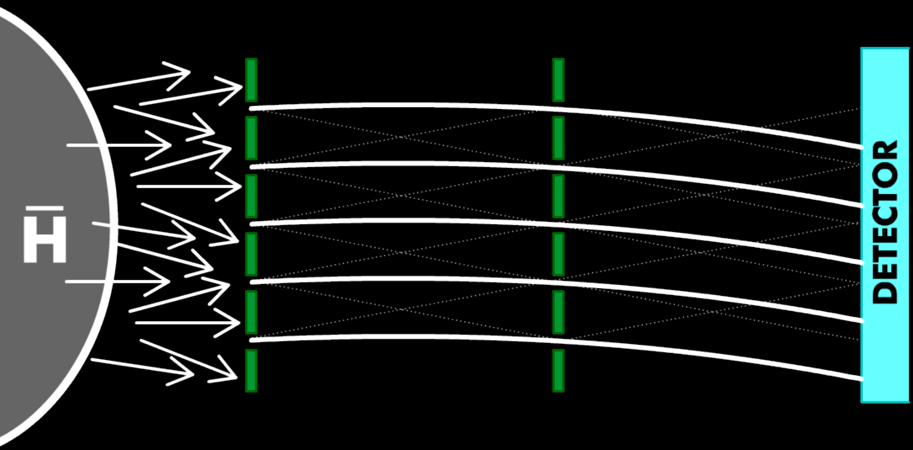
18 Institute collaboration

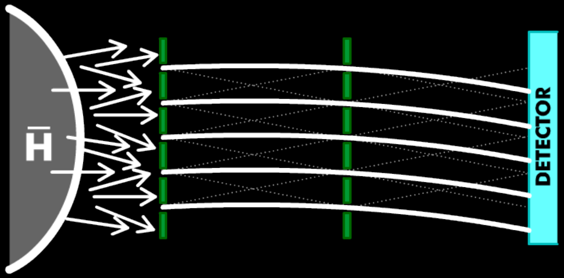
Located in the AD Hall at CERN

Accepted in 2008

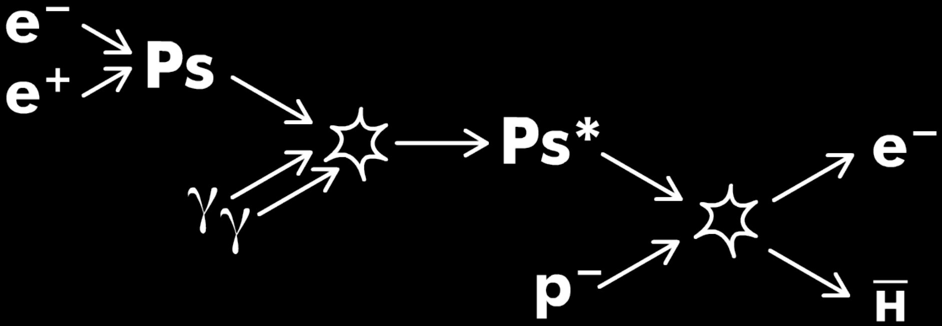
Aims at first gravity measurement on $\bar{H}$

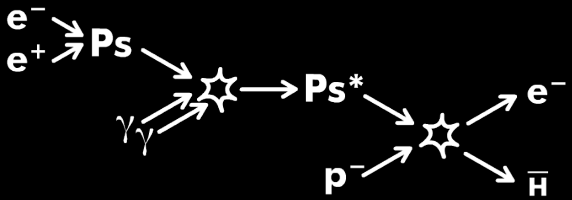
Receiving antiprotons since 2012


H̄
DETECTOR

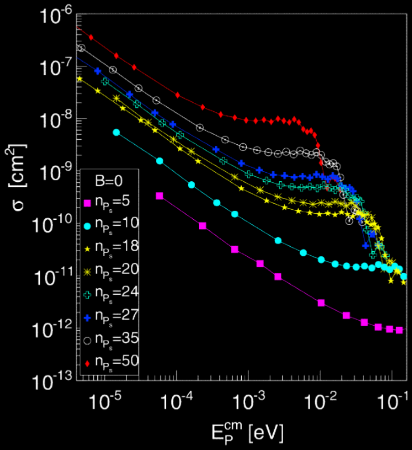


- Highly shielded region, neutral probe
- g obtainable from Δy and Δt
- Δt obtained through TOF
  (requires pulsed production)
- 1% of g with 1000 detected $\bar{H}$ at 0.1 K

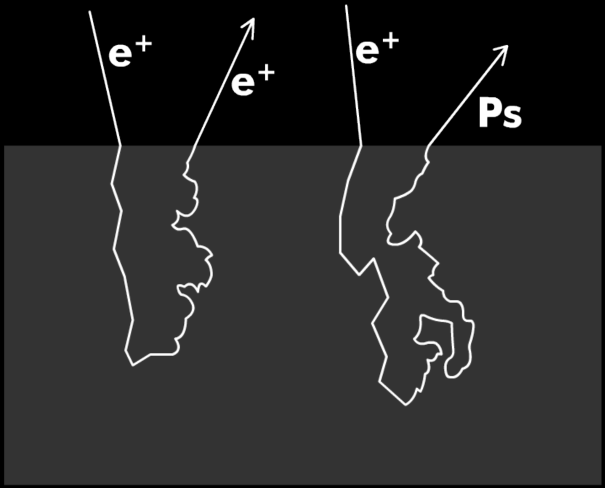

e⁻
e⁺
Ps
γ
γ
Ps*
p⁻
e⁻
H̄



- Higher cross-section
- Reduced reionization
- Pulsed production
- Potentially colder $\bar{H}$



D. Krasnický et Al. Phys. Rev. A 94, 022714 (2016)

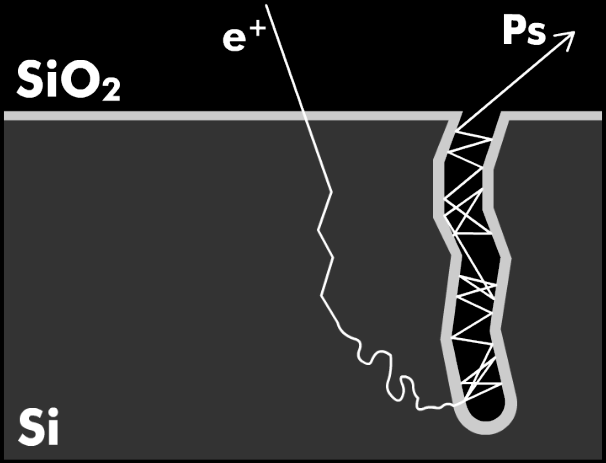


Positronium

Spontaneously formed during re-emission of e^+ from surfaces

Production energy and abundance both depend on e^+ work function

Difficult to generate cold Ps in large amounts



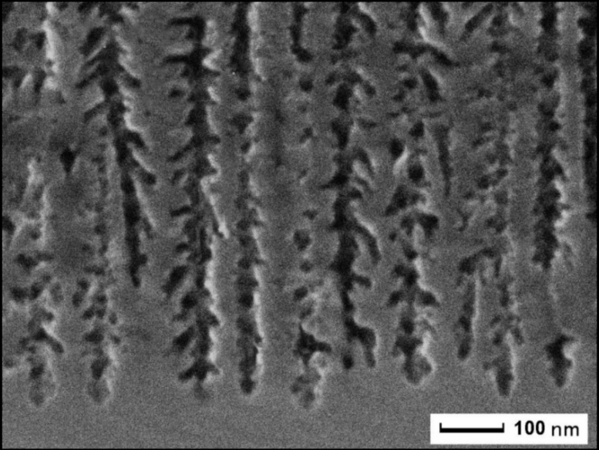
NANOCHANNEL PLATE

Thin channels etched in monocrystalline silicon covered in SiO_2

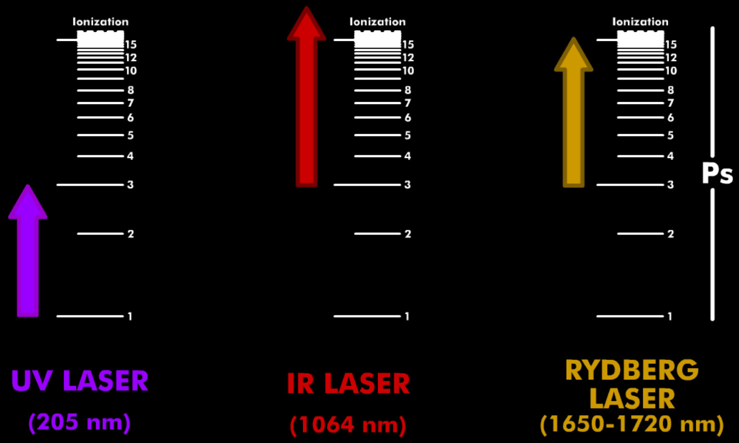
Channels typically
$5 \sim 20$ nm in radius
$0.5 \sim 2$ μm in length

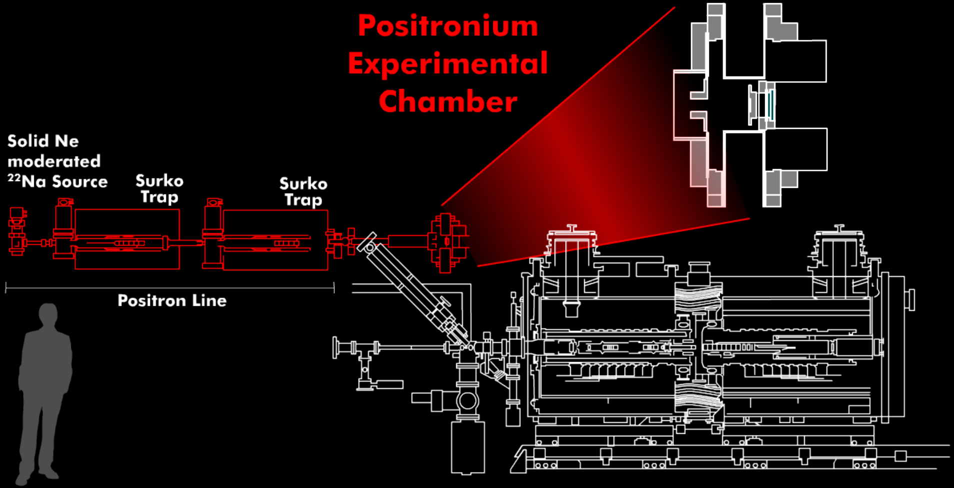
SiO_2 grants a high yield of Ps at 3eV (>44% of the e^+ reaching the surface re-emitted as Ps)

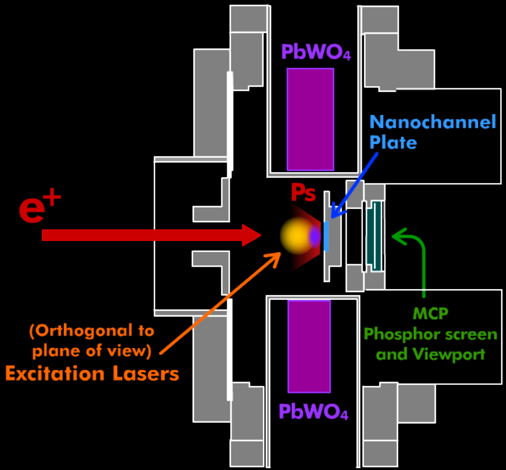
Cooling from interaction with channel walls


100 nm

AE$\bar{g}$IS Laser System




Positronium Experimental Chamber
Solid Ne moderated ^{22}Na Source
Surko Trap
Surko Trap
Positron Line



Positronium Test Chamber

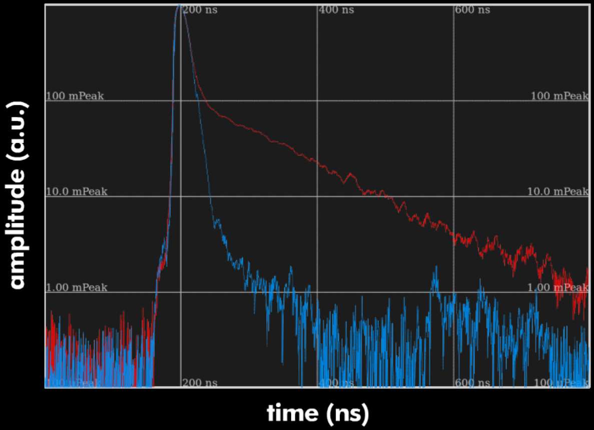
Study of Ps production through Nanochannel plates

Ps Spectroscopy

Diagnostic through imaging or TOF spectra

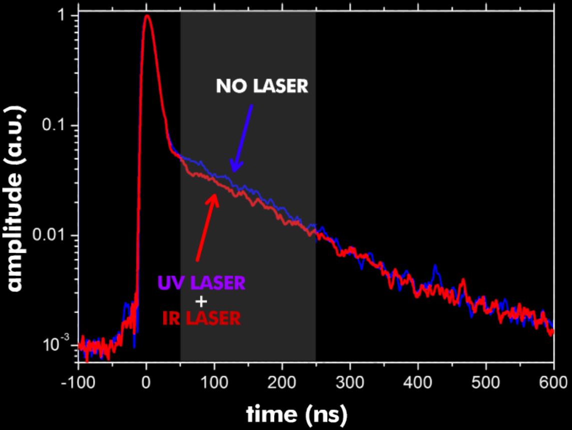
Testing and calibration of the laser and positron subsystems

SSPALS Spectra



In Red an SSPALS spectrum with PS production

In Blue an SSPALS spectrum without PS production



Ps n=3 level excitation

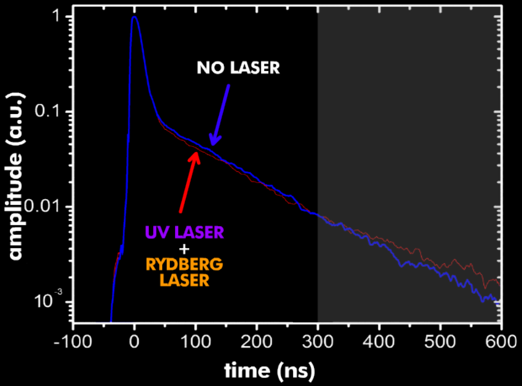
Blue curve acquired without laser light

UV laser excites n=3 level
IR laser ionizes n=3 Ps

n=3 production shows as a decrease in the SSPALS spectrum

Relative decrease of area under the spectrum in the highlighted region is 15.5±1.5 %

S. AGHION et al. - PHYSICAL REVIEW A 94, 012507 (2016)



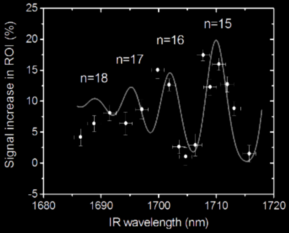
Ps Rydberg excitation

Rydberg levels are long-lived enough to directly compare the SSPALS spectra

Rydberg formation seen as an increase of the spectrum at long timing

Relative ratio of areas in the highlighted range used as probe

Rydberg Laser tuning allows detection of Rydberg levels resonances

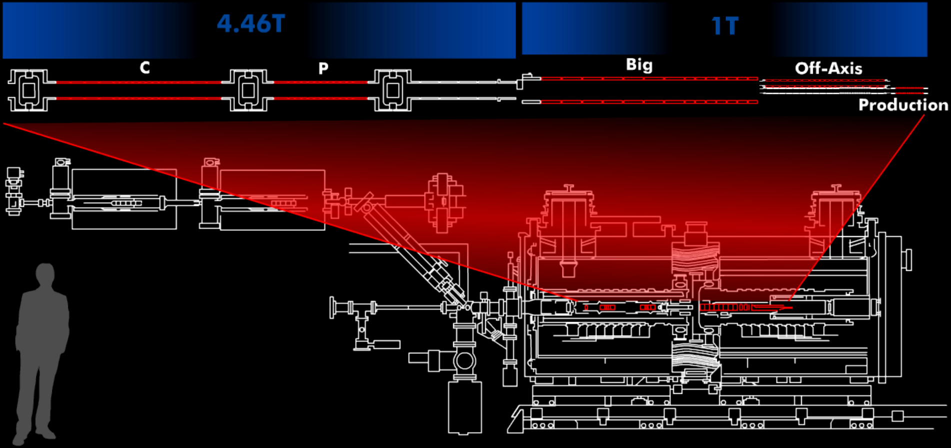


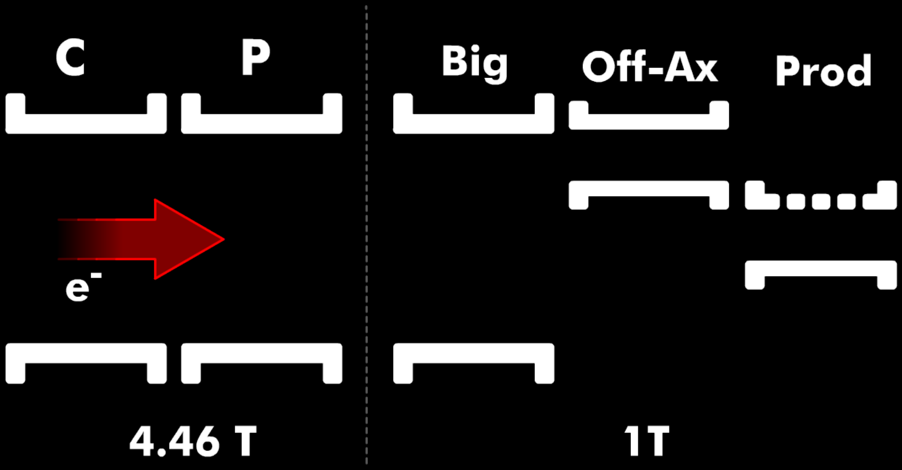
S. AGHION et al. - PHYSICAL REVIEW A 94, 012507 (2016)

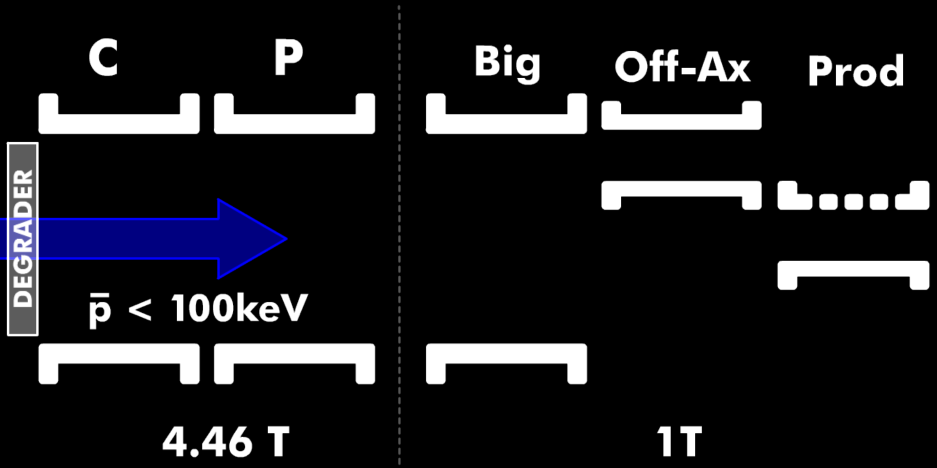
FUTURE

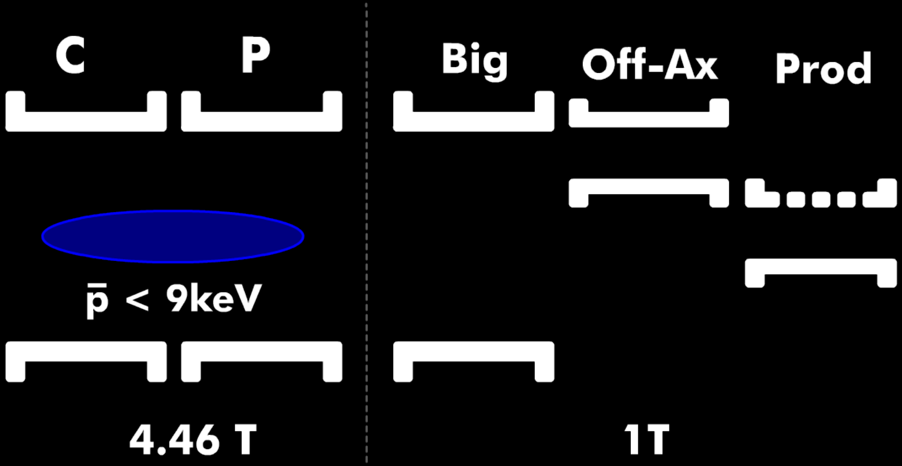

Ionization
15
12
10
8
7
6
5
4
3
2
1
13.4%
SPONTANEOUS
EMISSION
UV LASER
Ps

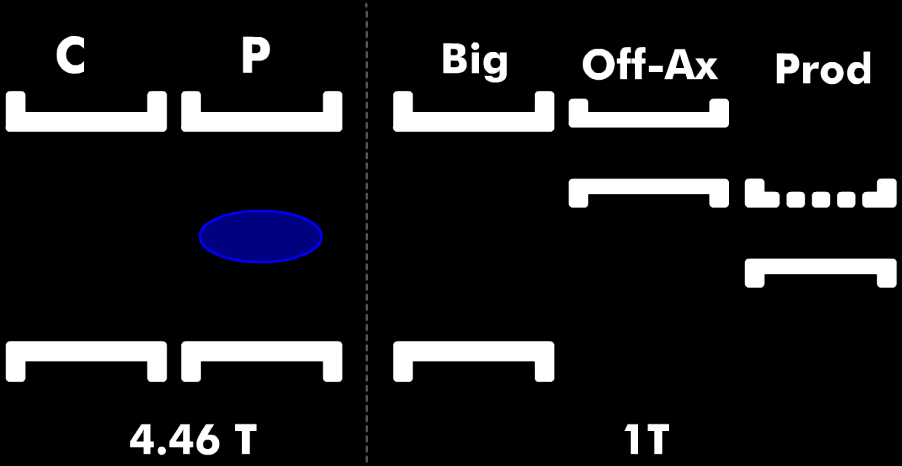
AEḡIS Trap System

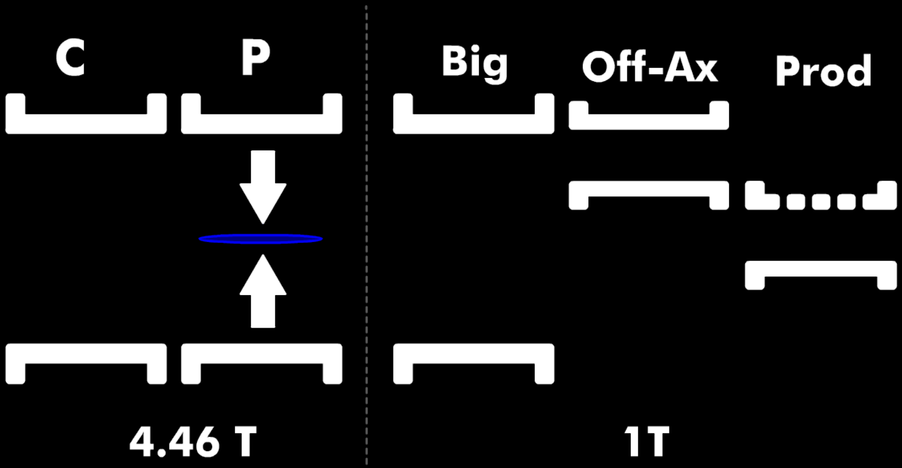


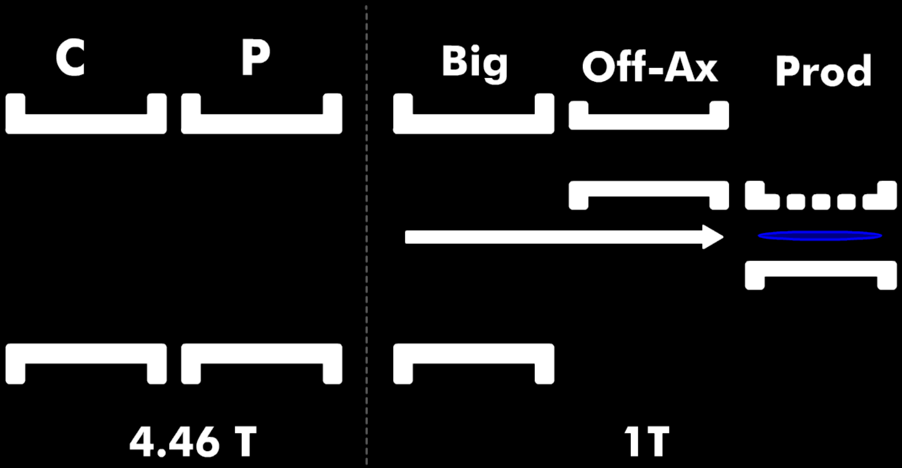

C
P
Big
Off-Ax
Prod
e-
4.46 T
1T

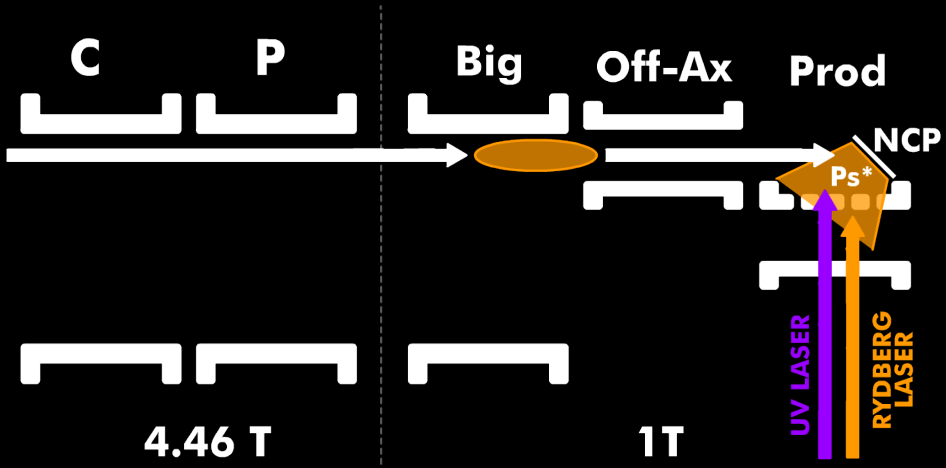

C
P
Big
Off-Ax
Prod
DEGRADER
p̄ < 100keV
4.46 T
1T

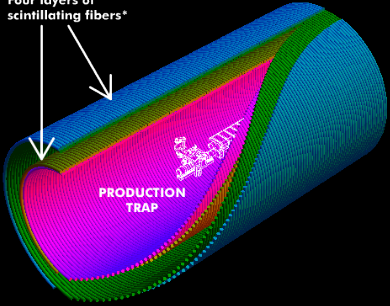

C
P
Big
Off-Ax
Prod
p̄ < 9keV
4.46 T
1T


C
P
Big
Off-Ax
Prod
4.46 T
1T


C
P
Big
Off-Ax
Prod
4.46 T
1T


C
P
Big
Off-Ax
Prod
4.46 T
1T


C
P
Big
Off-Ax
Prod
NCP
Ps*
UV LASER
RYDBERG LASER
4.46 T
1T



* fiber diameter has been scaled up four times to allow visualization

The FACT Detector
(Fast Annihilation Cryogenic Tracking)

800 scintillating fibers arranged in four concentrial layers

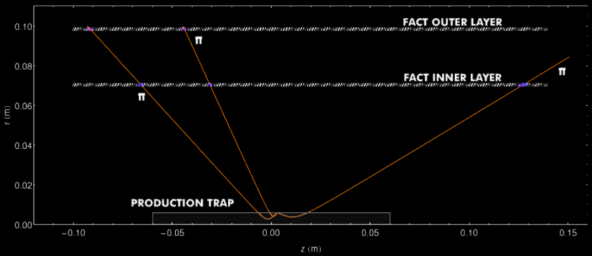
Arranged around the production trap

Operates at 4K in a 1T magetic field

Fibers are read out through MPPCs (multi-pixel photon counters) signal is discriminated before recording

Thresholds are calibrated individually for each fiber

Time resolution of 5ns

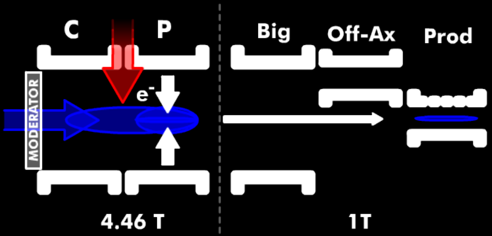


$\bar{H}$ detection with FACT

Specific time signature
fiber coincidence several ms after e^+ prompt

If vertices can be reconstructed annihilation on trap wall
long lifetime of $\bar{p}$ makes it characteristic

Where are we now?



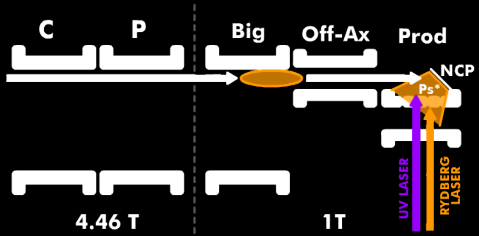
Catching, Compression and Accumulation of $\bar{p}$

Done.

$2 \cdot 10^5$ antiprotons accumulated per AD shot

Energy of a few meV

Production trap lifetime >500s



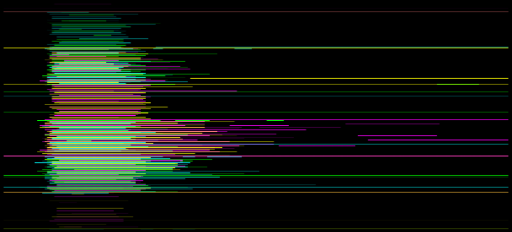
Transport of e^+, Ps production and Excitation in 1T

Partially done.

We are able to transport 10^7 e^+ to the NCP target per shot

Ps production in 1T magnet is confirmed

Laser excitation under way



Construction and Calibration of FACT

Done.

FACT is able to record data.

Its calibration can be performed automatically

Data analisys of its output is ongoing

PRELIMINARY

What next?

(not in chronological order)

$\overline{H}$ production

Cooling (0.1K) of $\overline{p}$

WEP measurement

ELENA

Upgrade of AD

LS2 (2019-2020)

Two years without antiprotons

Ps experiments

Thanks