양성자-포지트로늄 반응에서 수소원자 생성 단면적 측정 실험의 개요

SNU

Bongho Kim

Contents

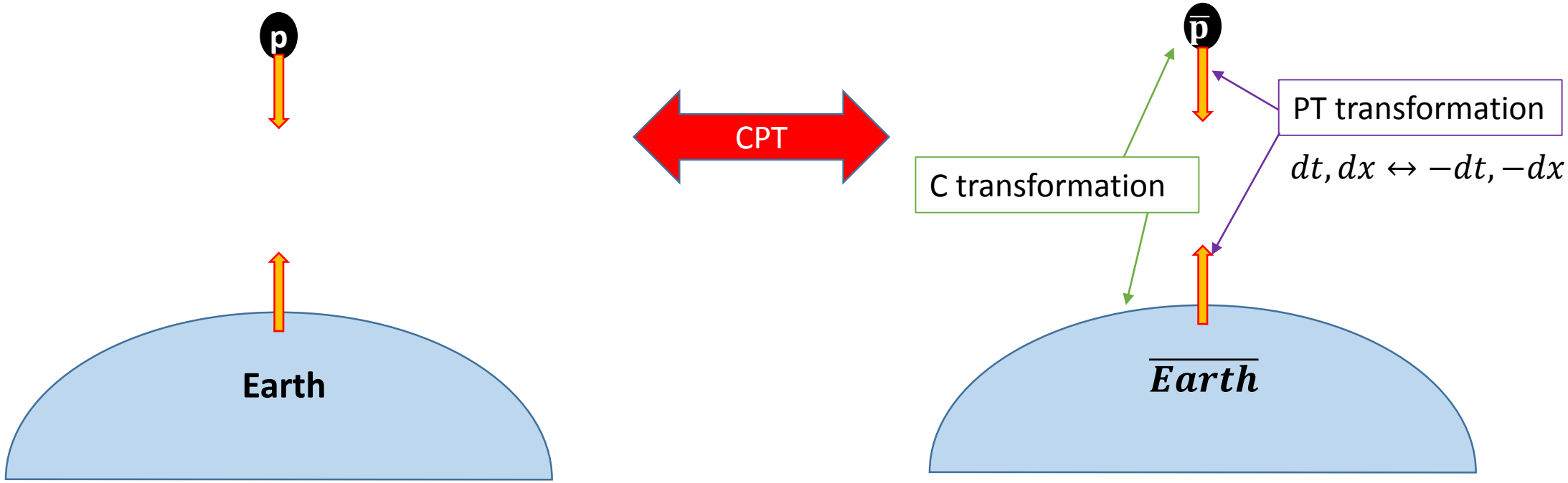
- About anti-matter gravity measurement
- GBAR Beam line overview
- Antion project

- Positronium studies
- Anti-hydrogen ion cross section
- How to measure

- Etc

Why we believe that gravity btw anti-matter and matter is attractive?

- In the aspect of CPT conservation, there's nothing about interaction btw the particle and the anti-particle.
- Inertia mass would be same btw particle & anti-particle but gravitational mass can be different.



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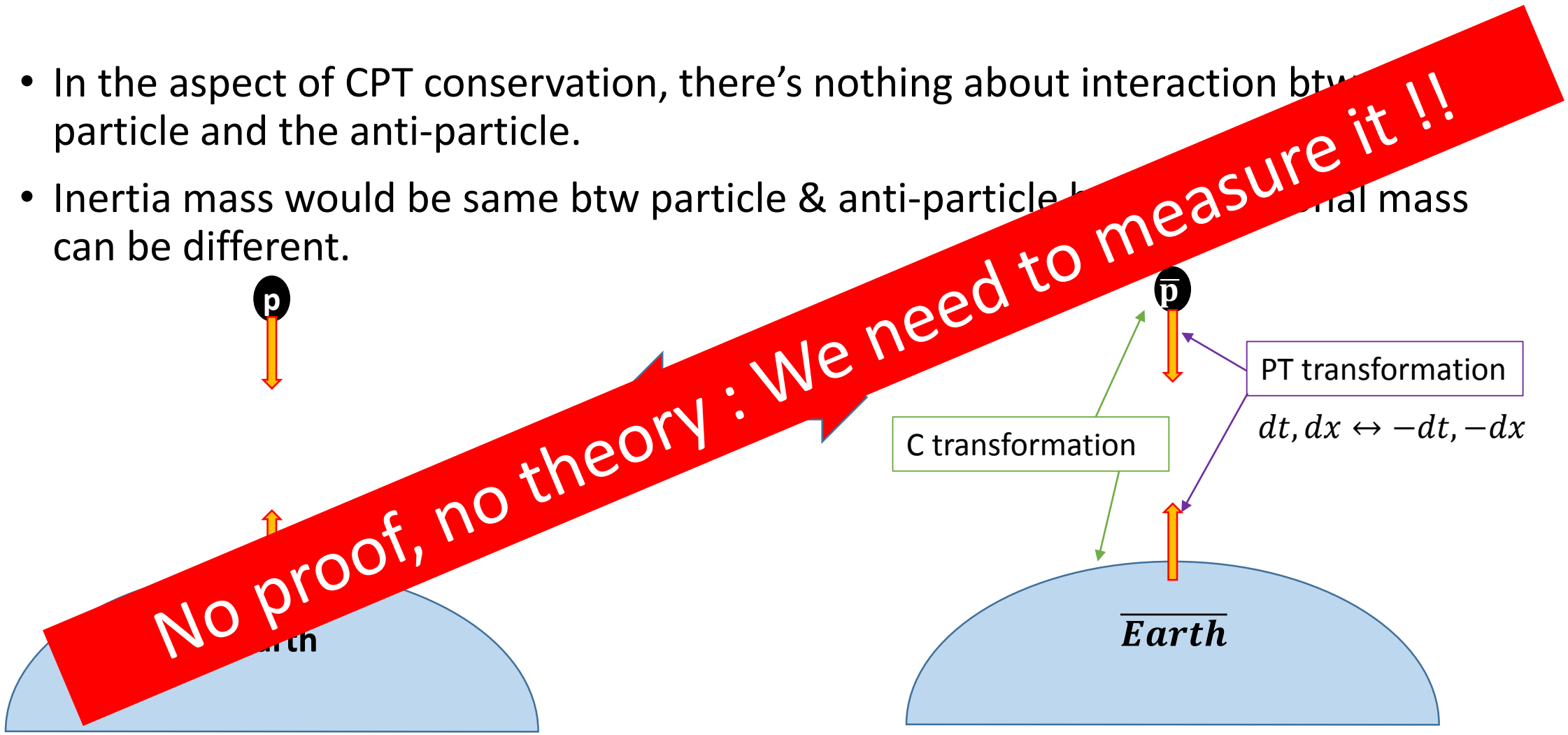


If you feel that motivation is not enough

It can solve mystery of the Universe !!!

- Universe expension (Dark Energy)

- Substitue Dark energy? :Why we need Dark energy?

General Relativity with cosmological constant(Steady universe)
→Cosmic expansion discovered (RED shift) → implanation
→Accelerating expansion discovered(Supernova) →Dark energy (repulsion) required…

Why we believe anti-matter and matter gravity is attraction?

- Baryogenesis : Baryon and Anti-Baryon asymmetry can't be explained..

- Matter x Anti-matter gravity interaction can differ with Matter x Matter

→Anti-matter is gathered somewhere else.

→Large-scale voids can be anti-matter?

- Anti-Matter would have different characteristics compared with matter.. (CPT violation ?)

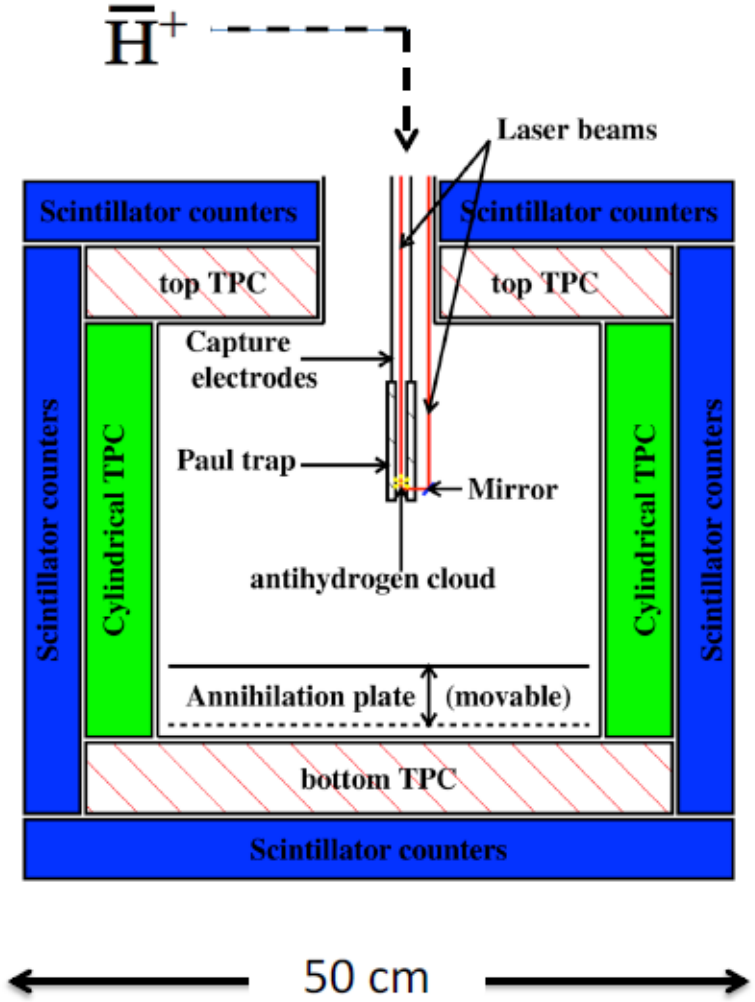
GBAR & Beam line overview

So we will fall down anti-apple Hydrogen

- Cool down anti-particle as many as possible (3neV=20uK=0.5m/s)← To reduce uncertainty

(Precision measurement requires good statistical, systematic errors)

- Make anti-particle neutral ←Subtract other force to anti-particle.
- Make enough space to fall down ←Make anti-particle accelerated enough by gravity

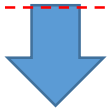


Main process to the goal

- $e^+ + e^-(target) \rightarrow Ps\ (Para(1^1S), Ortho(1^3S))$
- $Ortho - Ps + hv \rightarrow Ps(2P, 3D)$

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

← What I contribute now

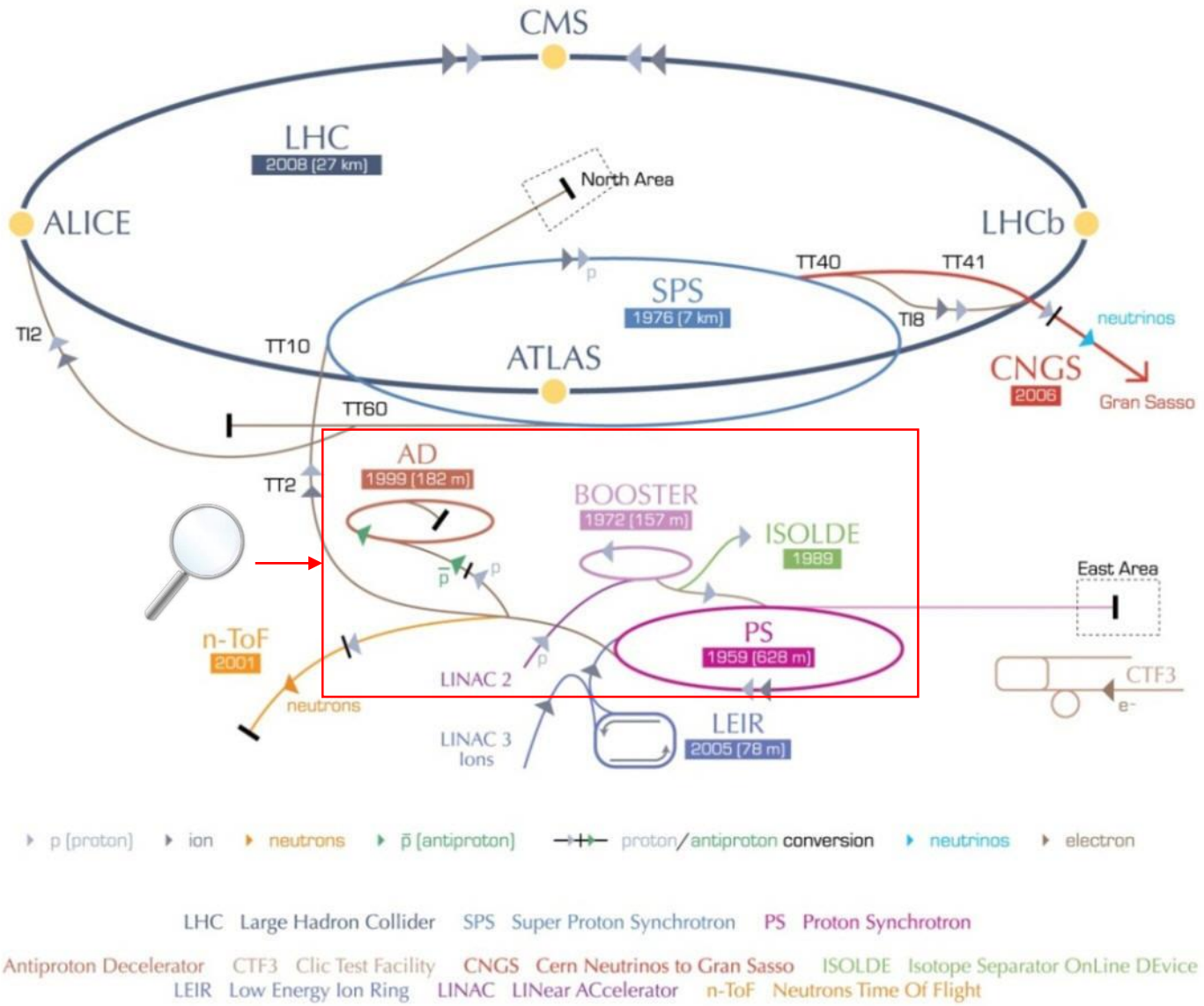


Cooling, trapping

- $\bar{H}^+ + hv \rightarrow \bar{H} + e^+$

←Why we need to attache and then detache positron?
: Our goal is neV but this is too low to make anti-proton neutral. So we need to attach 2 positron first and cool down then detach positron without raising energy.

CERN's accelerator complex



From Google

- Proton beam from Proton Synchrotron(PS) hit the metal block and generate proton & anti-proton pair.
- Anti-proton Decelerator tame these random direction and energy anti-proton to anti-proton with 10% of speed of light (5.3MeV).

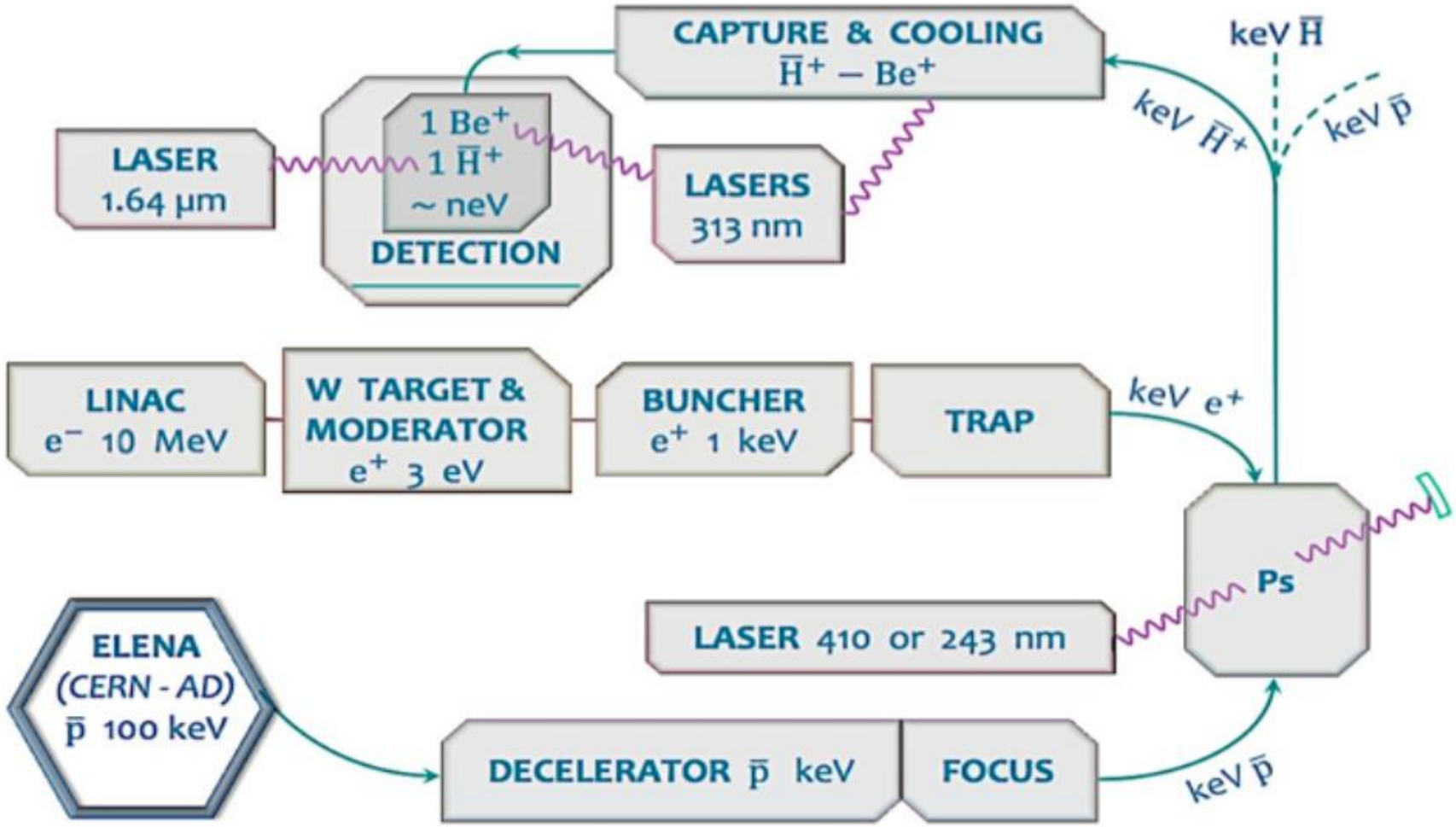
←Electro-magnetic field cooling (1st),

←Cooling by electron cloud

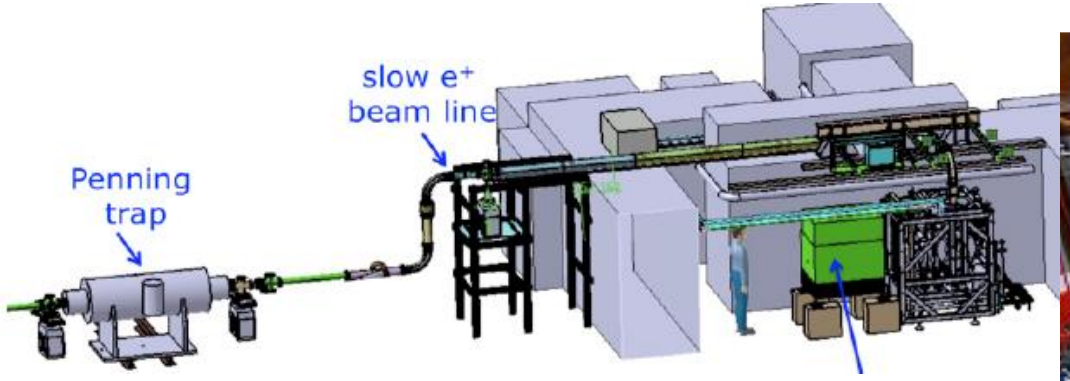
Beam line Overview

Positron beam line

Anti-proton beam line



Picture at last year



- No penning trap(Riken trap) now.
- Buffer Gas trap is installed now.
- Proton beam is installed.

Antion project

Positronium study

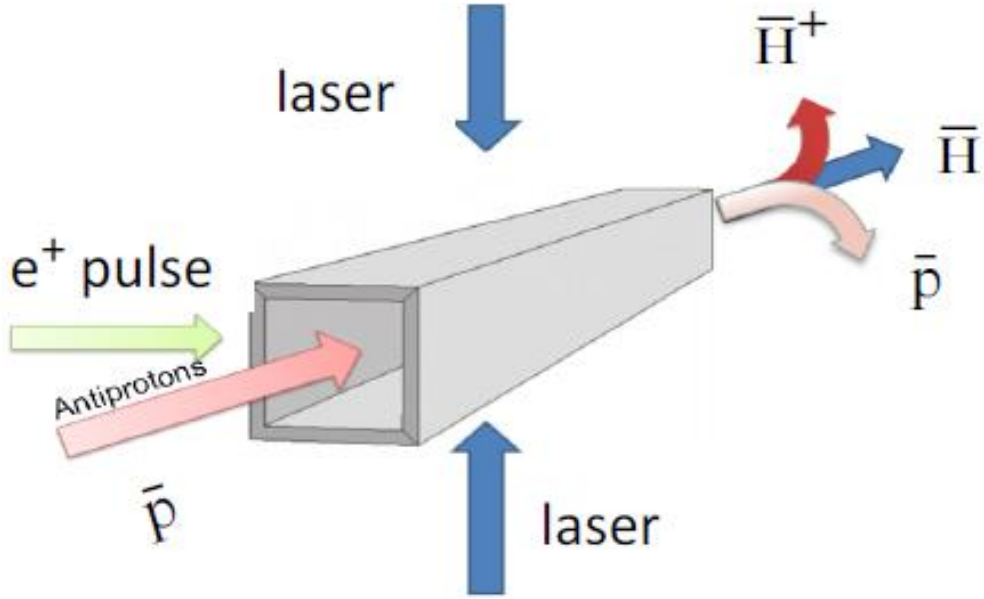
- Positronium(meV) is made by collision btw positron beam and porous silica film.

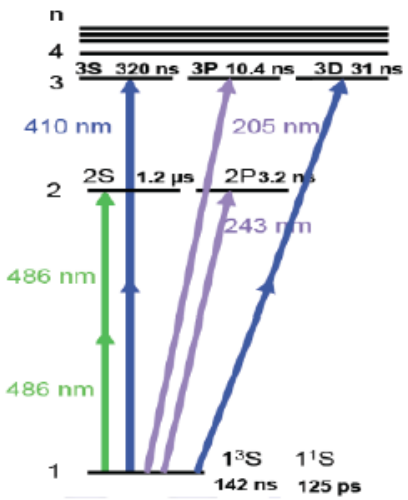
→positron beam lose their energy with short penetration and make positronium with few eV binding energy.

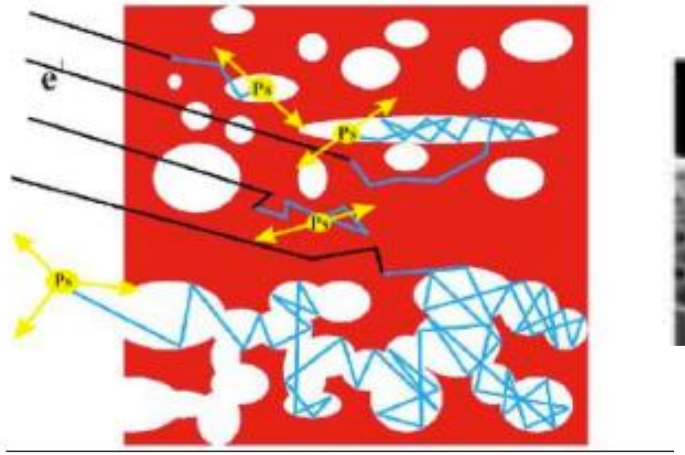
- SiO_2 cavity is used to make positronium cloud

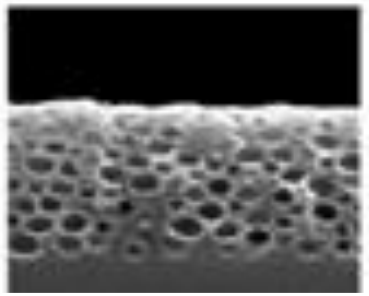
→positronium will be reflected inside of cavity

- Laser will be injected before positronium decay.









Anti-hydrogen ion cross section

- Anti-Hydrogen production and Anti-hydrogen ion production will be done as one step.
- Positronium : 10^{12}Ps/1cm^2
- Anti-proton : 0.5x10^7 /bunch (every 110s)

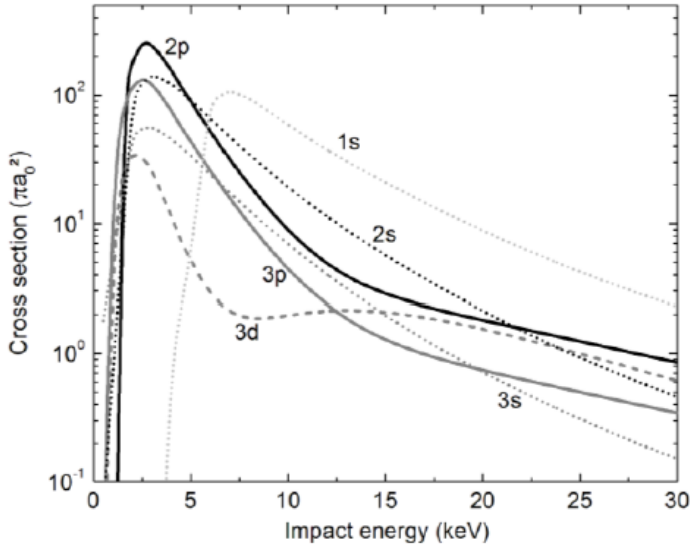
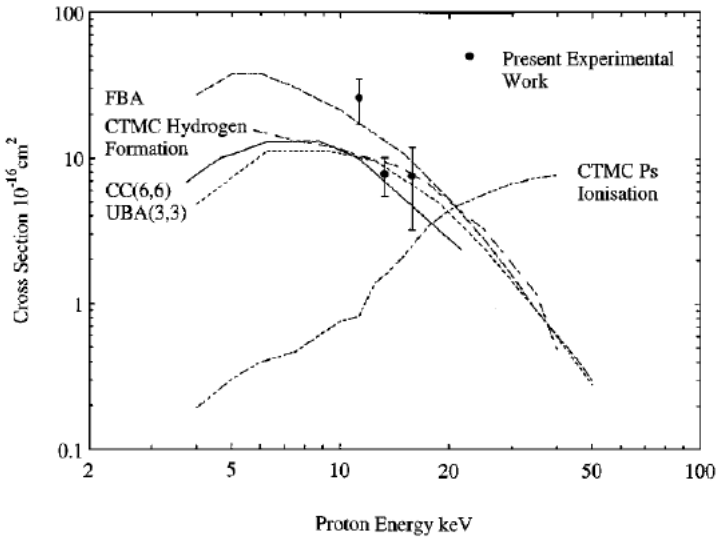


Figure 2. $\bar{H}$ production cross sections (summed over n_H from 1 to 4) as a function of the antiproton impact energy, for Ps(1s) to Ps(3d).

$$p + Ps \rightarrow H + e^+$$



Merrison *et al*,, Phys. Rev. Lett. 78, 2828(1997)

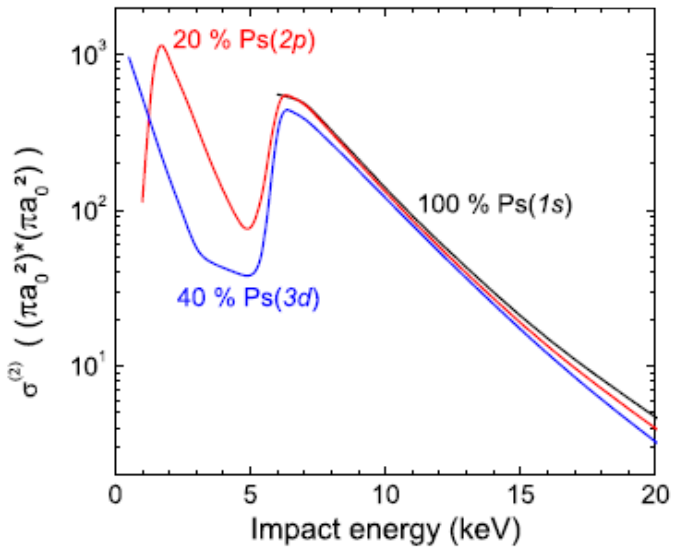
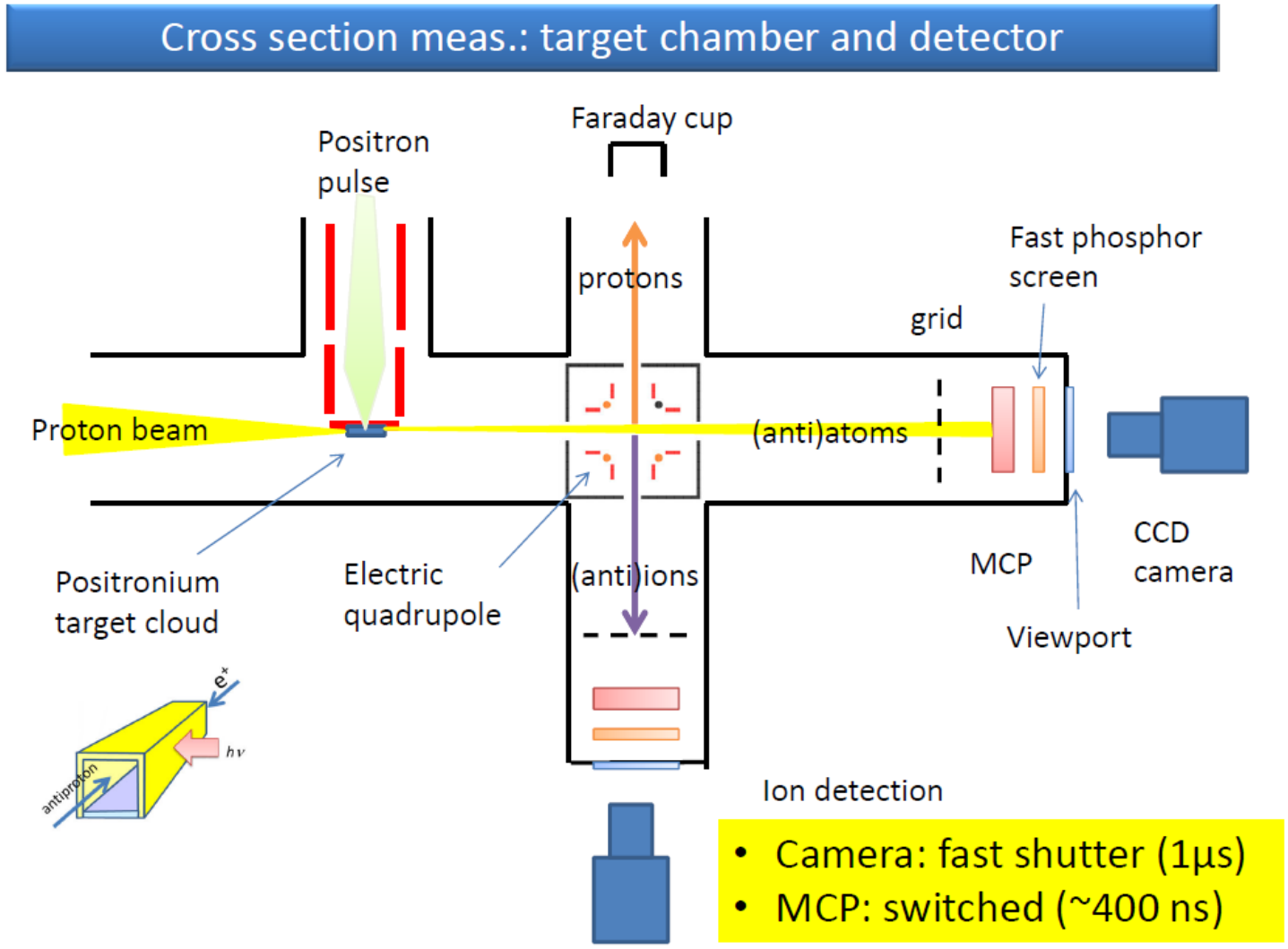


Figure 20. Comparison between the global (i.e. both reactions combined) $\bar{H}^+$ production cross sections for different simple solutions of Ps excitation.

How to measure

- Positronium density will be measure by PWO detector
- Anti-Proton beam intensity will be measured by Faraday cup(collecting charge)
- Anti-Hydrogen and Hydrogen ion intensity will be measured by MCP+CCD assembly

← Absolute Intensity measurement is quite challengeable.



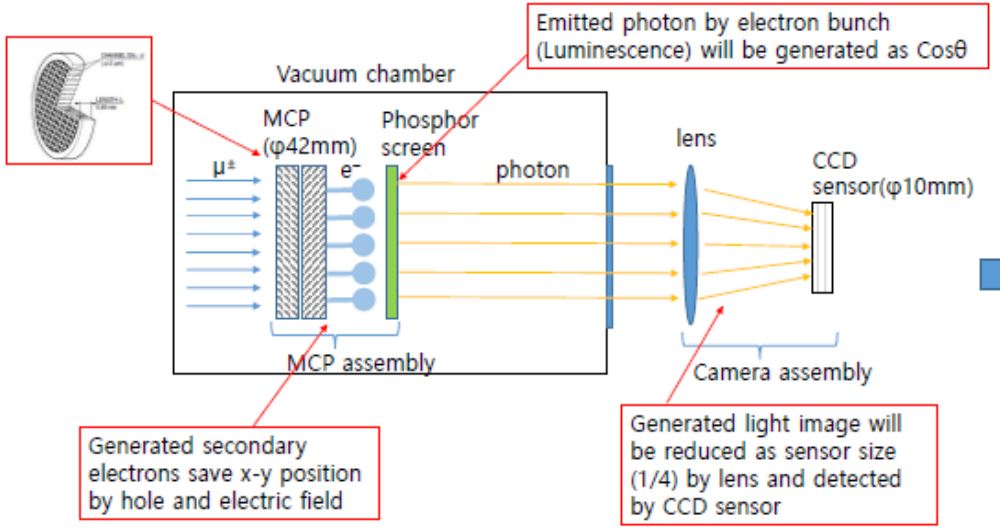
How to measure

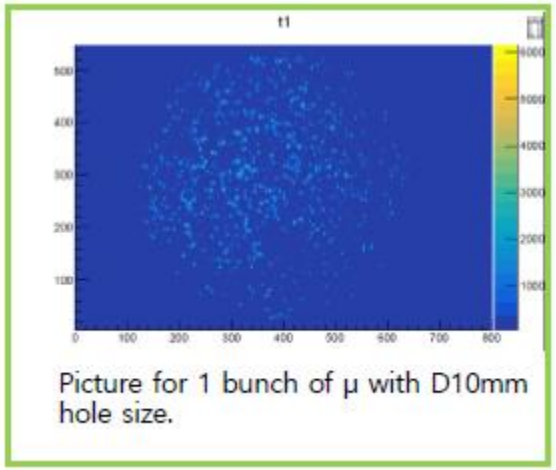
- Beam diagnostics is normally done inside of beam line

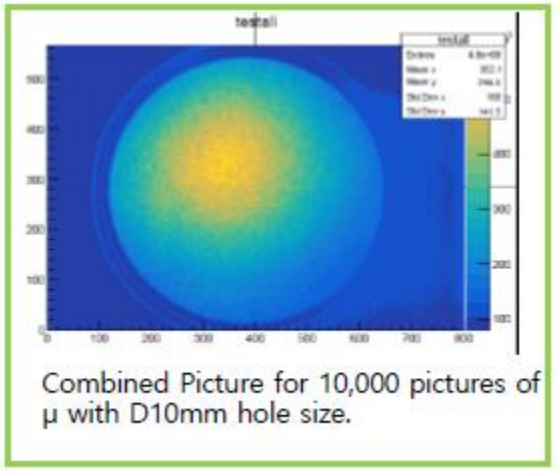
→Vacuum state, no obstacle (Pb block)

→Different detector used like MCP, Faraday cup

→MCP + CCD give 2-D beam profile with intensity information

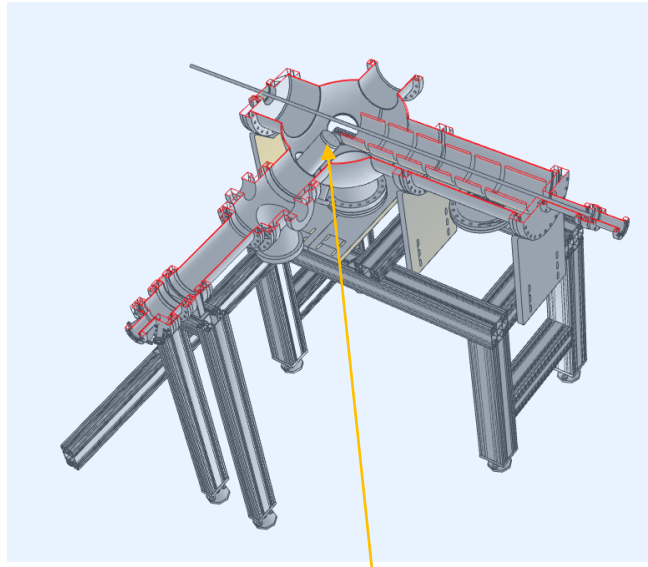


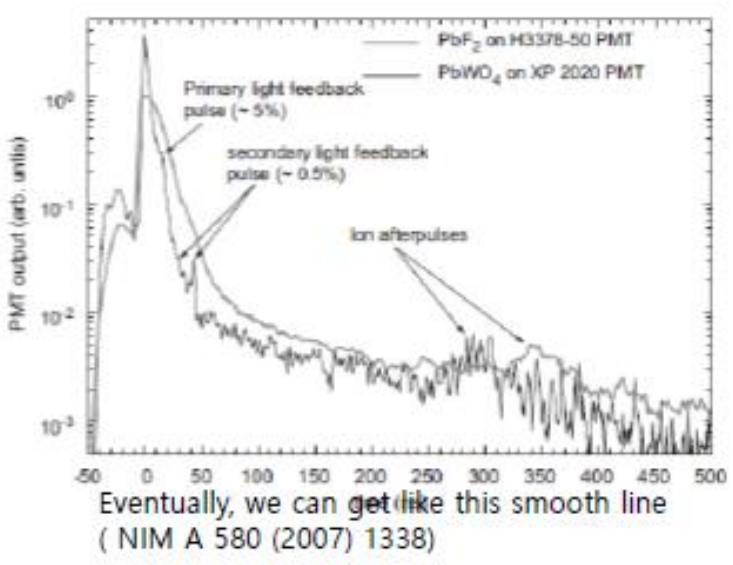




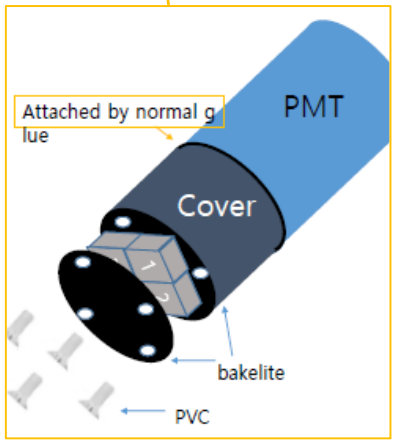
How to measure Ps

- Para-Ps→gamma(0.511) + gamma(0.511) (back to back)
- Ortho-Ps→3 gamma (random direction)
- By measuring gamma, we need to estimate number of ortho-Ps cloud density
- Para-Ps decay pico second order
- Ortho-Ps decay with 142ns life time





Eventually, we can get like this smooth line
(NIM A 580 (2007) 1338)



Cross-section measurement

- $\sigma\begin{pmatrix} \bar{p} + Ps \to \overline{H} + e^{-} \\ \overline{H} + Ps \to \overline{H}^{+} + e^{-} \end{pmatrix} = \dfrac{\#_{\mathrm{det}}(\overline{H})/(\#(\bar{p}) \times \#(Ps) \times \varepsilon)}{\#_{\mathrm{det}}(\overline{H}^{+})/(\#(\overline{H}) \times \#(Ps) \times \varepsilon)}$
- Efficiency for both measurement will be same.
- But Systematice error would be differ by some processes...

So

- To measure anti-matter's free fall effect, we need to get high statistics and precision.
- To achieve this, we need to know about not only Anti-Hydrogen ion intensity but also cross-section.
- Beam line and detectors have been develop