

Test of WEP : Measurement of antimatter free fall

A scheme to produce $\bar{H}^+(\bar{p} e^+ e^+)$ for gravity

Letter of Intent

CERN-SPSC-2007-038

Saclay, RIKEN & U. Tokyo

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Possible collaboration with ASACUSA at CERN

Institutes from Japan

Dept of Physics, University of Tokyo, Hongo
Institute of Physics, University of Tokyo, Komaba
Atomic Physics Lab and RI Beam Science Lab,
RIKEN, Wako-shi, Saitama

+

Institutes from

Austria, Denmark, Germany, Hungary, Italy,
Switzerland and United Kingdom

Theory and Experiment

$$V = -G \frac{mm'}{r} \left(1 \mp a e^{-\frac{r}{v}} + b e^{-\frac{r}{s}} \right)$$

\uparrow \uparrow \uparrow
 Newton Supergravity :
 component of
 repulsive gravity

J. Scherk, Phys. Lett. B (1979) 265.

–Experimental Constraints : range < 1 pc *Bellucci & Faraboni, Phys. Lett. B 377 (1996) 55.*

Indirect limits

$K_0 - \bar{K}_0$

SN1987a

Cyclotron frequency p/\bar{p}

Direct Tests

Charged antimatter

e^+ or \bar{p} (e.m. shielding)

Neutral antimatter

\bar{n} hard to slow down

\bar{H} cooling limit mK

\bar{H}^+ cooling limit μK

No direct measurement exists

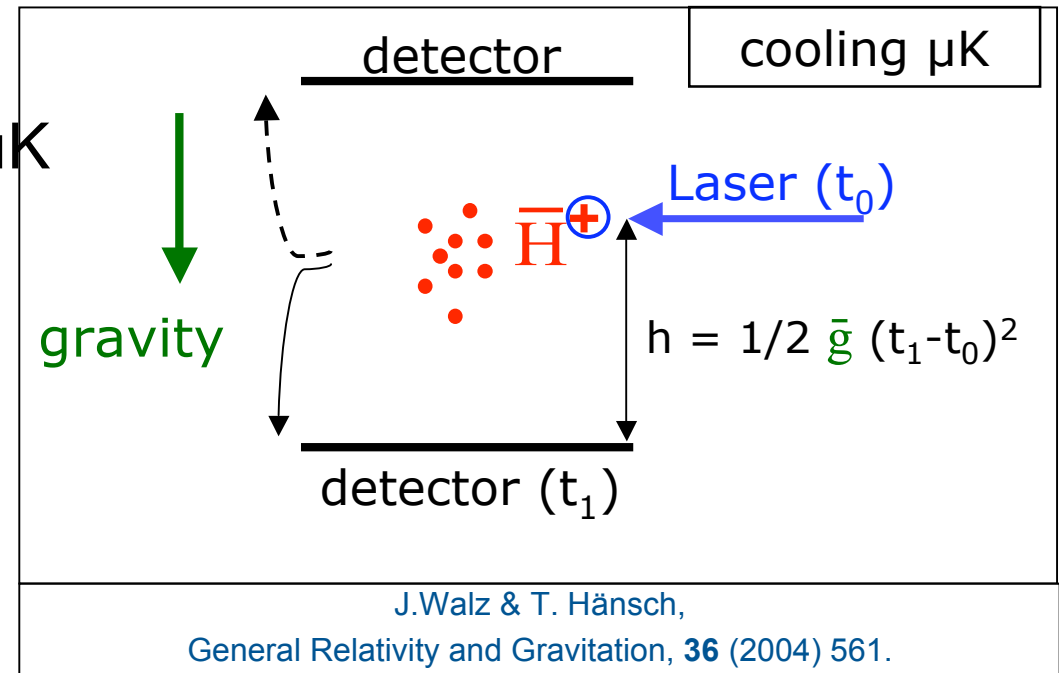
Using \bar{H}^+ (*J. Walz & T. Hänsch*)

- Capture ion \bar{H}^+ \rightarrow cooling few μK
- Ejection of extra e^+ with laser
- Time of flight

Error dominated by temperature of \bar{H}^+

Relative Precision on \bar{g} :

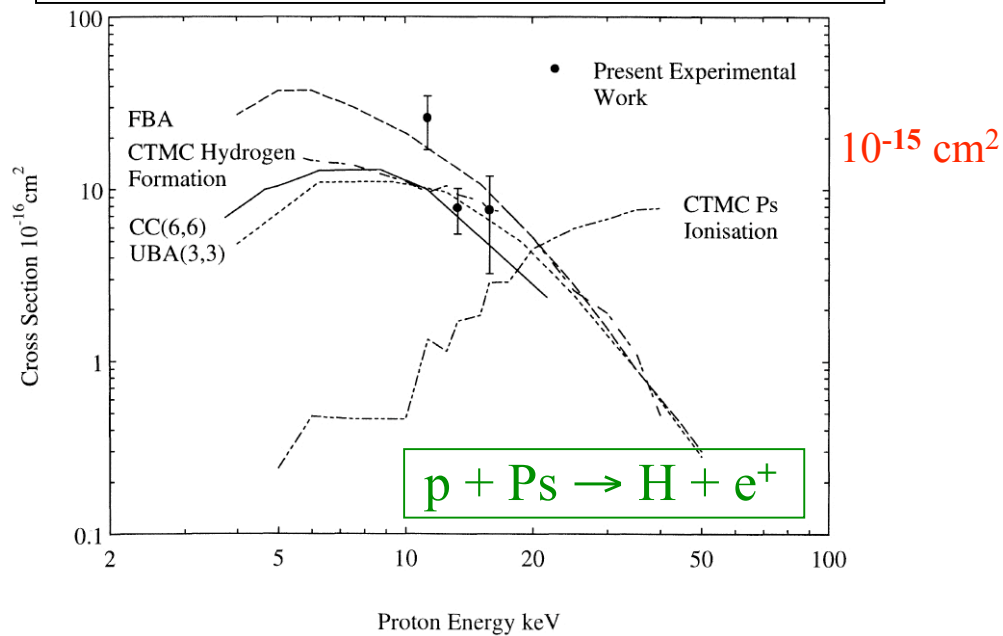
\bar{H}^+ in ion trap	$\Delta g/g$
$5 \cdot 10^5$	0.001
10^4	0.006
10^3	0.02



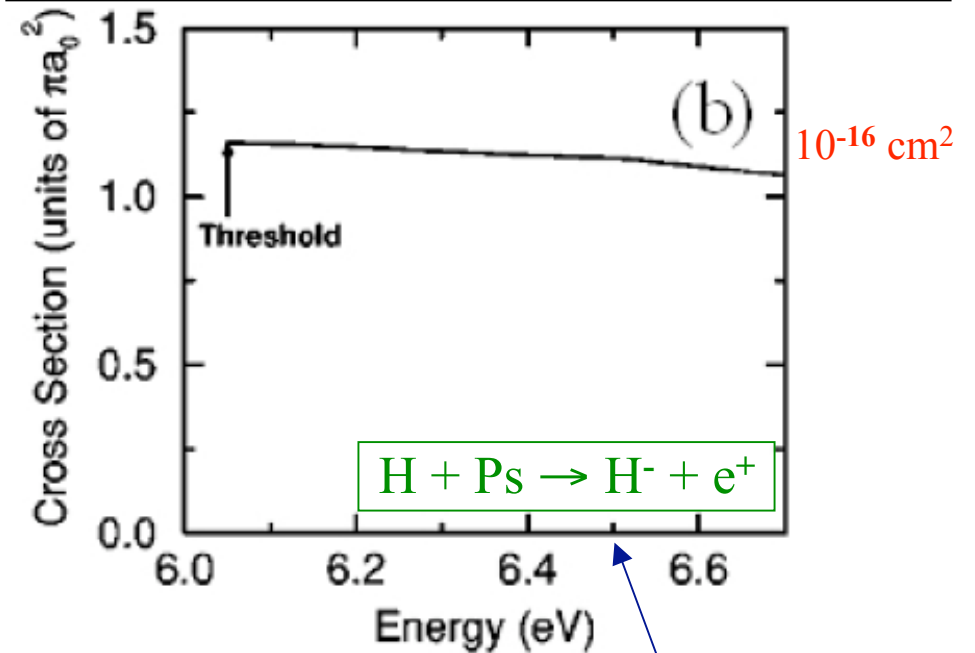
$$h = 10 \text{ cm} \rightarrow \Delta t = 143 \text{ ms}$$

Cross-sections on P_s

J. P. Merrison et al., Phys. Rev. Lett. **78**, 2728 (1997)



H.R.J. Walters and C. Starett, Phys. Stat. Sol. C, 1-8 (2007)



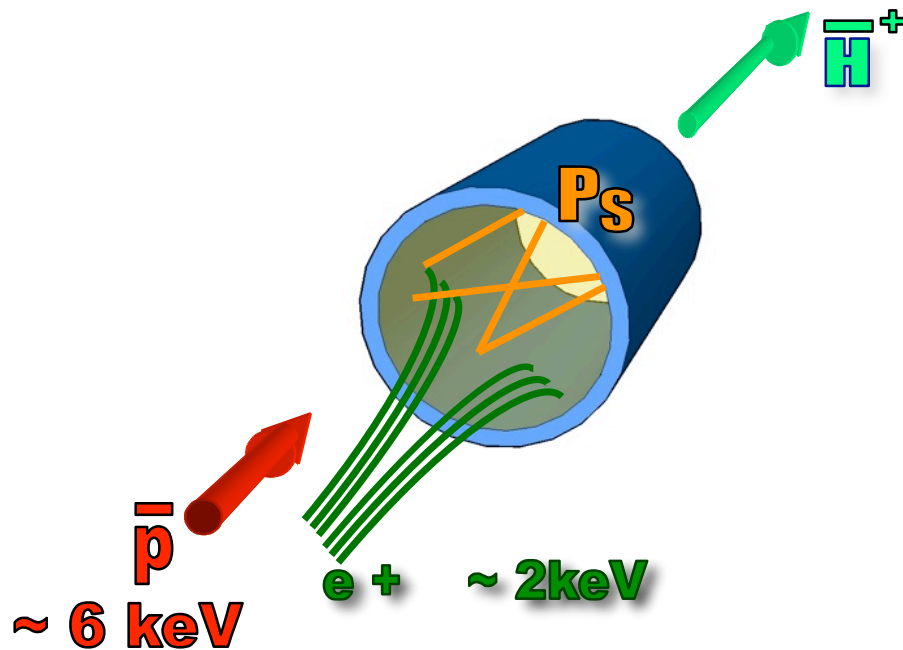
ASACUSA
12 AD shots



$E(p) = 6 \text{ keV in } P_s \text{ frame}$

How to produce \bar{H}^+

In $e^+ \rightarrow Ps$ converter :
High density of Ps $\sim 10^{12} \text{ cm}^{-2}$ in a few ns



Standard Method						
\bar{p}	+	e^+	\rightarrow	\bar{H}^*		
New Method						
\bar{p}	+	Ps	\rightarrow	\bar{H}	+	e^-
\bar{H}	+	Ps	\rightarrow	\bar{H}^+	+	e^-

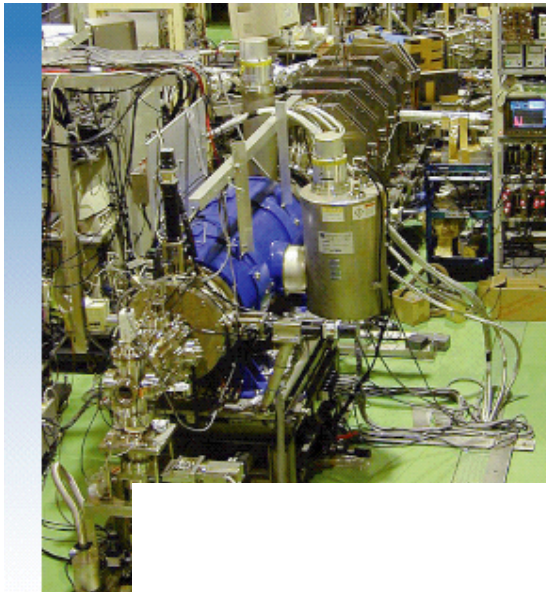
\rightarrow extraction in $\leq 50 \text{ ns}$ of $10^{10-11} e^+$
 from positron trap

and defocus towards converter

Note: *cross-section $\propto n^4$*

If Ps is excited to $n=4$, all \bar{p} are transformed into \bar{H} for $E(\bar{p}) \ll 1 \text{ keV}$

Binding energy $Ps(n=3) \sim 0.75 \text{ eV} \sim$ Binding E of \bar{H}^+



RIKEN MRT trap

電子プラズマを用いた陽電子蓄積装置の開発

Development of a positron accumulator with an electron plasma

小島 隆夫*, 大島 永康*†, 新垣 恵*†, 毛利 明博*, 山崎 泰規*†

Takao M. Kojima*, Nagayasu Oshima*†, Megumi Niigaki†, Akihiro Mohri*, and Yasunori Yamazaki*†

RIKEN Project
Cold HCl beam

Requirements:
* Positrons of:
* UHV ($<10^{-11}$)

e+ with

Concern

Collisional duration

No Collisional time

Time of Flight

Position Adjuster
for e⁻ Beam (ExB)

Synchrotron cooling
time constant: 10^{-11} s

Positron Plasma

10¹¹

10¹¹

e+ Plasma

γ Detector

$E_{ac} < (\Delta E/2) + (\alpha n_e L / \Delta E)$

α: Required energy Loss (~3eV)
n_e: e- Plasma Density
L: e- Plasma Length

tion

>

(e+)
Distribution
Emitted e+

lated.

tion

[e < E]

Fast extraction from trap

T. Hassan, A. Mohri, P. Pérez, H. Saitoh, Y. Yamazaki

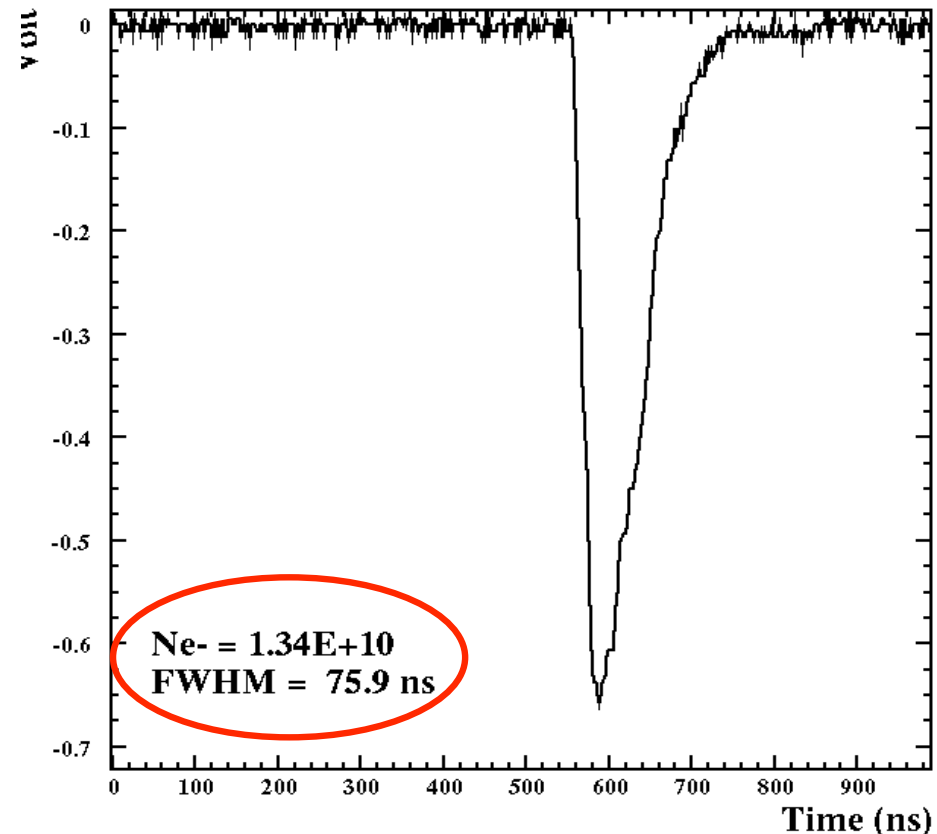
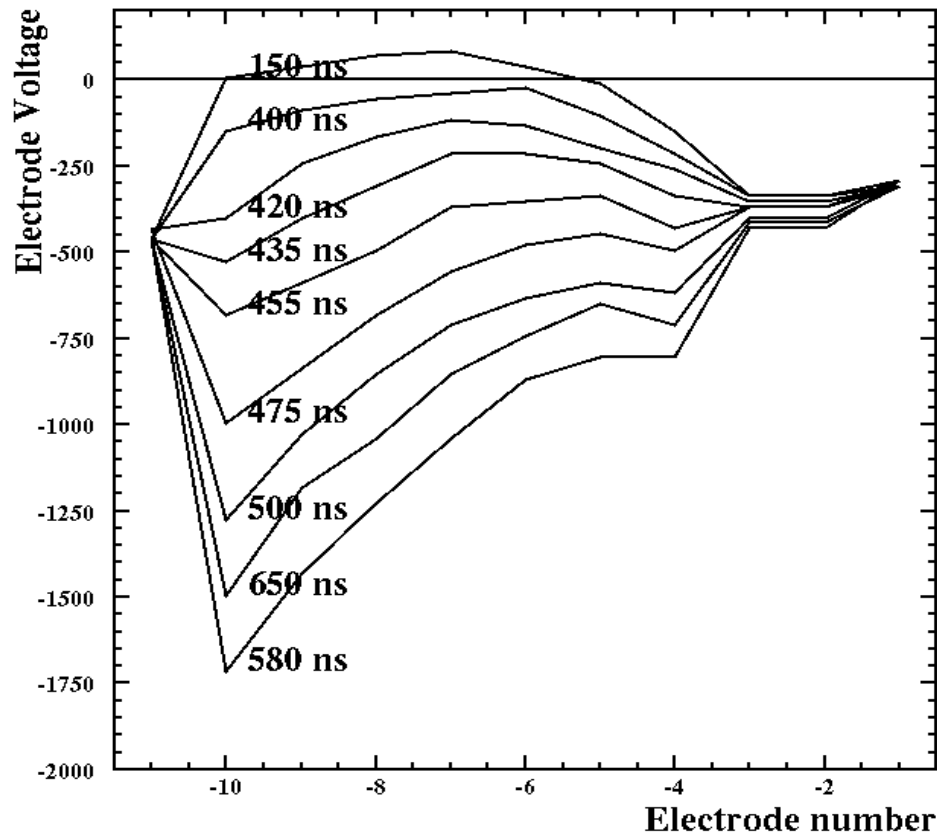
RIKEN MRT Test of fast ejection with electrons (Nov '05)

Apply fast deformation of potential well

Limitation due to speed of switch



Buncher (< 10 ns)



Porous SiO₂ as converter

AIST

R. Suzuki, T. Ohdaira

ETHZ

P. Crivelli, U. Gendotti, A. Rubbia

RIKEN

M. Hassan, A. Mohri, H. Saitoh, Y. Yamazaki

CNRS/CERI

M.F. Barthe, P. Desgardin

CNRS/LCPME

M. Etienne, A. Walcarius

CNRS/LMPC

V. Valtchev

ECOLE POLYTECHNIQUE

J-P. Boilot

CEA/DSM/IRFU

SACM *J-M Rey, A. Curtoni, O. Delferrierre, L. Liskay*

SEDI *J-P. Bard, P. Legou, X. Coppolani*

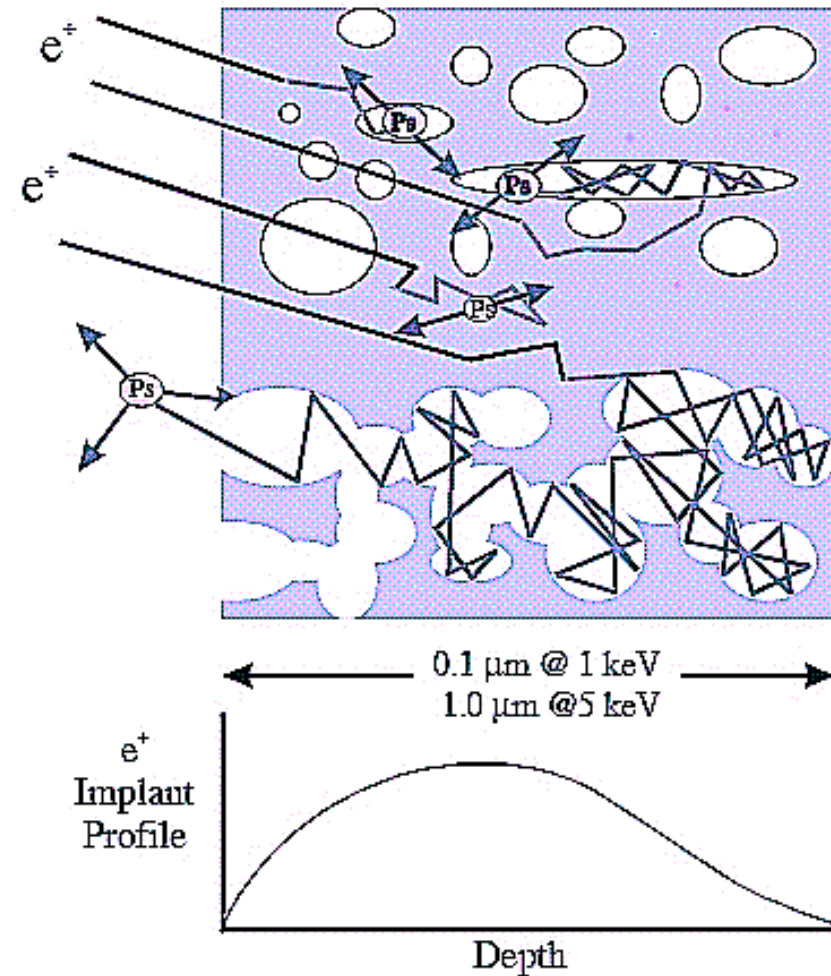
SENAC *V. Blideanu*

SIS *M. Carty, Y. Sauce*

SPP *B. Mansoulié, J-P. Pansart, P. Pérez, Y. Sacquin*

CEA/DSM/IRAMIS

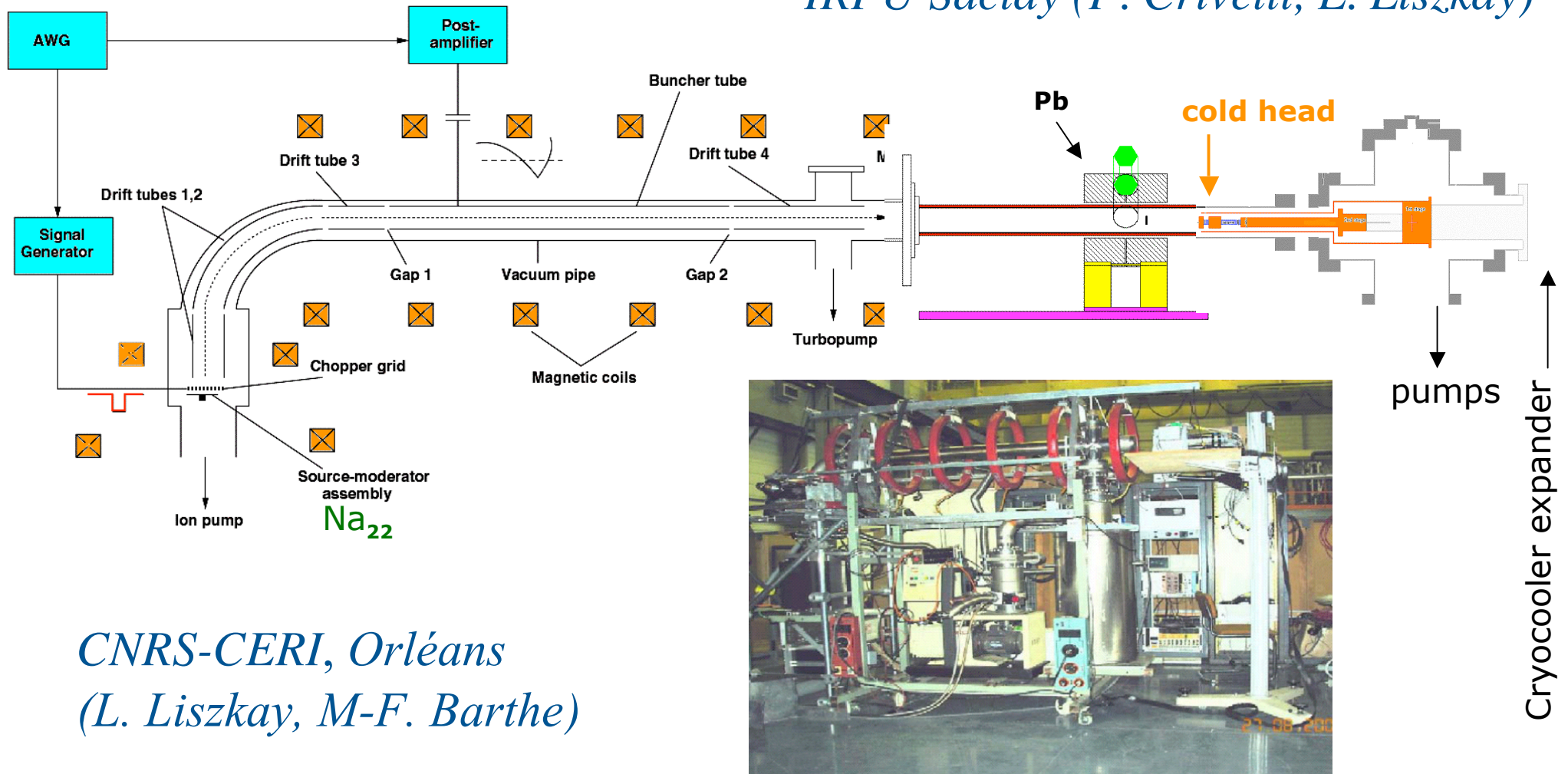
C. Corbel



Slow e^+ beams

*AIST Tsukuba
(R. Suzuki, T. Ohdaira)*

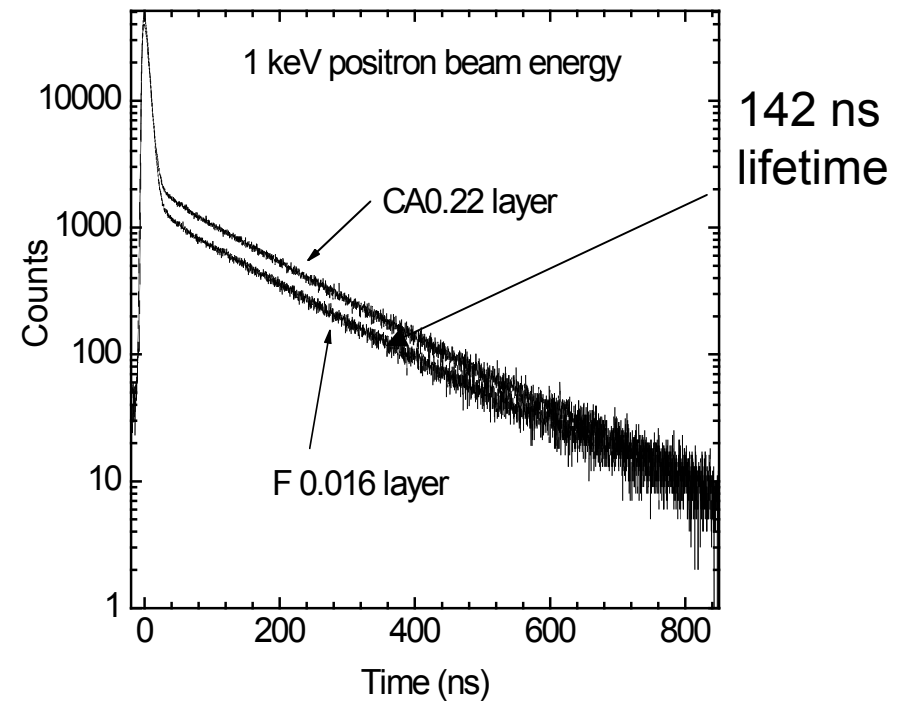
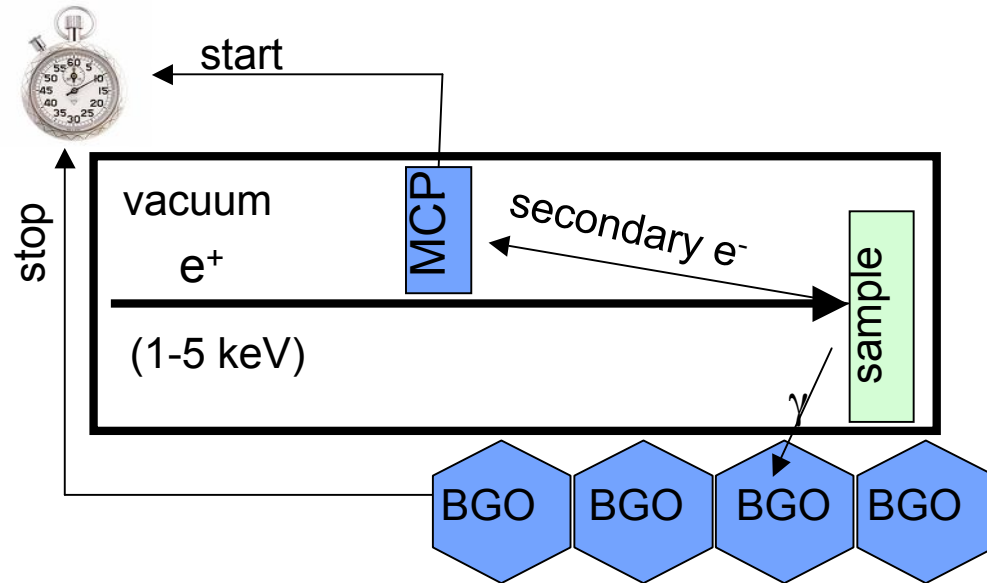
*E.T.H Zurich (A. Rubbia, U. Gendotti)
IRFU Saclay (P. Crivelli, L. Liskay)*



*CNRS-CERI, Orléans
(L. Liskay, M-F. Barthe)*

N. Alberola et al., Nucl. Instr. Meth. A 560 (2006) 524.

Measure conversion efficiency $e^+ \rightarrow \text{Ps}$ (lifetime)

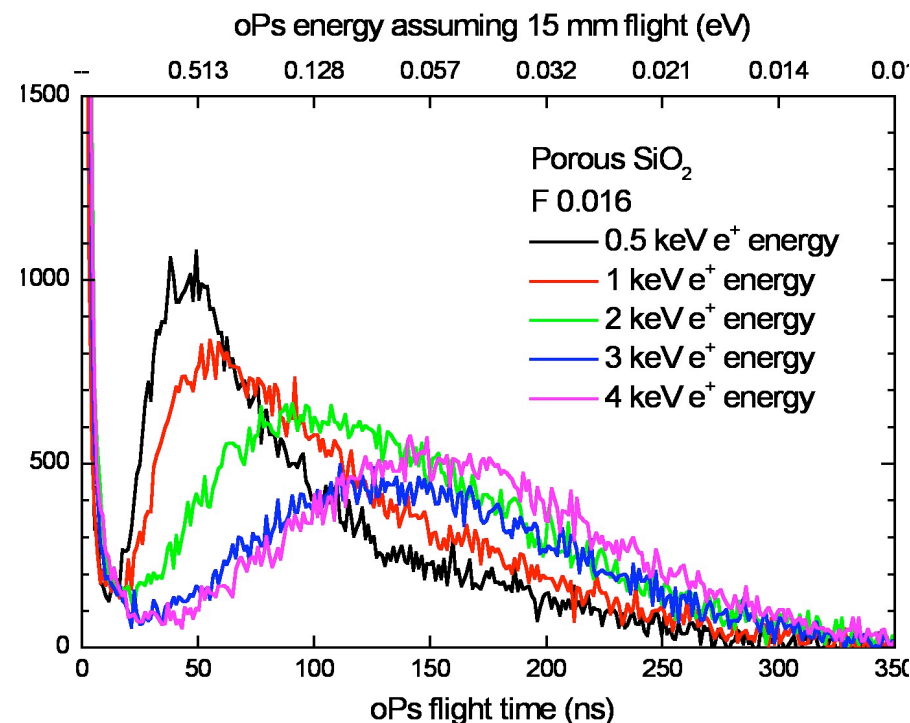
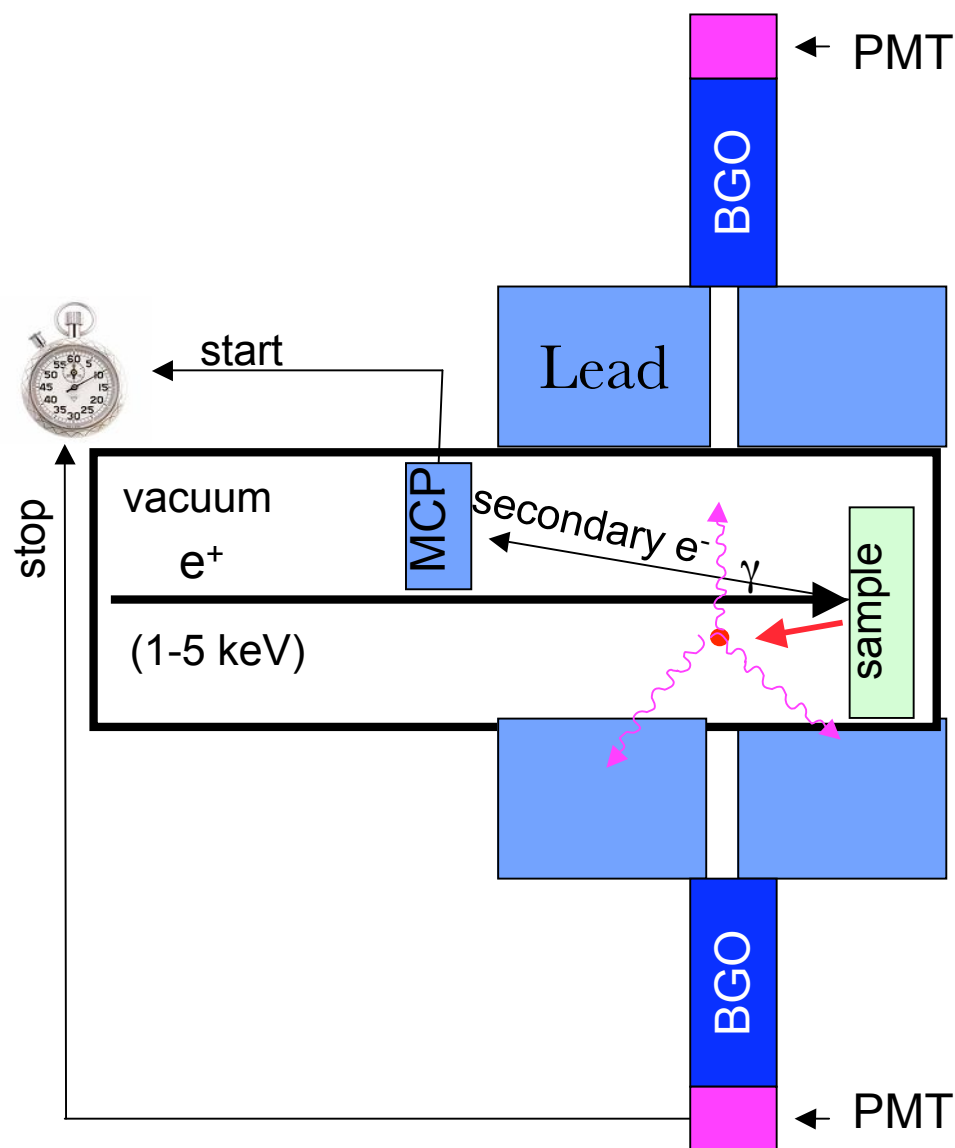


L. Liskay, P. Crivelli (Saclay)
U. Gendotti (ETHZ)

> 35% $e^+ \rightarrow \text{Ps}$
conversion efficiency

L.Liskay et al., Appl. Phys. Lett. **92** (2008) 063114

Measure conversion efficiency $e^+ \rightarrow \text{Ps}$ (time of flight)



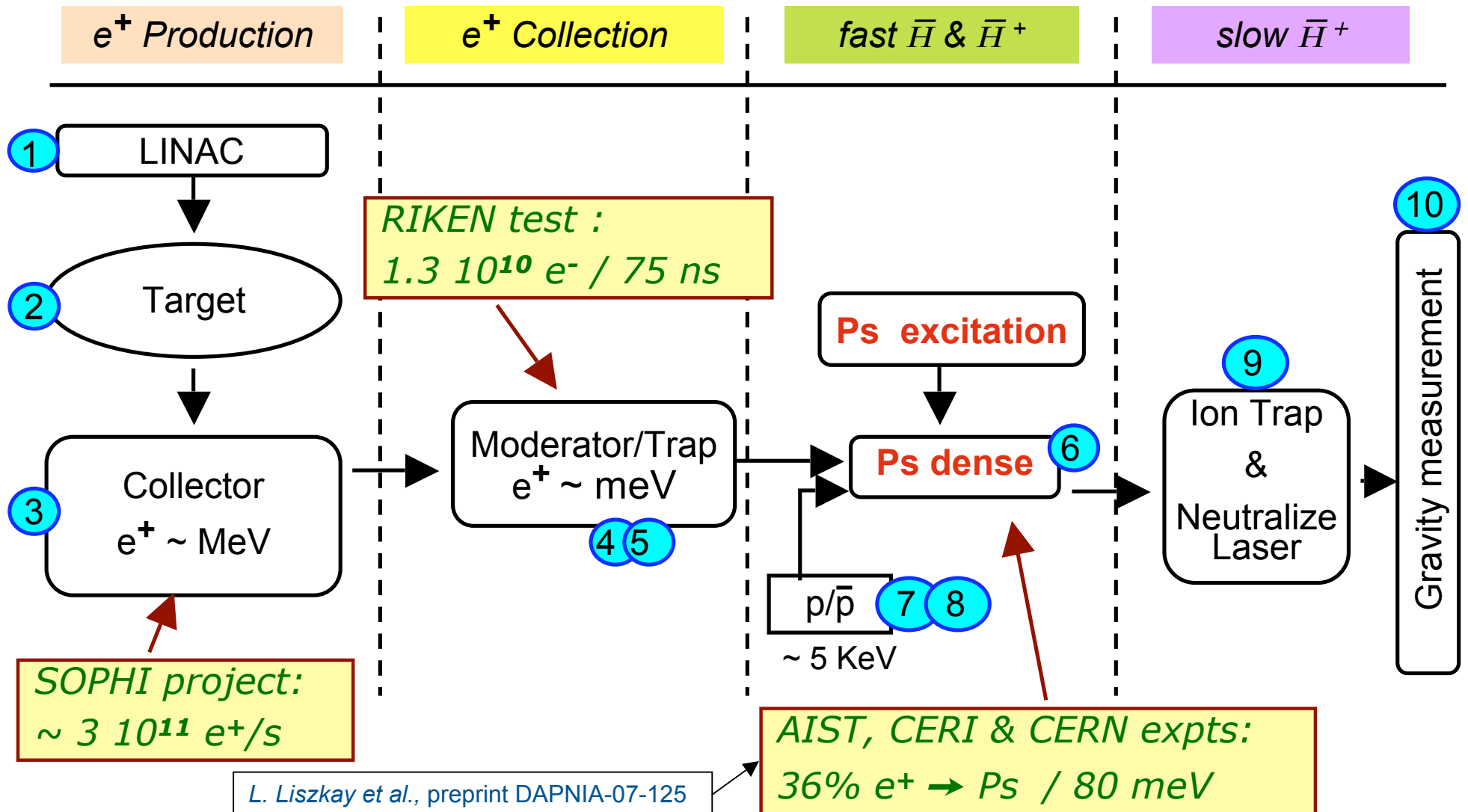
L. Liskay (Saclay)

P. Crivelli, U. Gendotti (ETHZ)

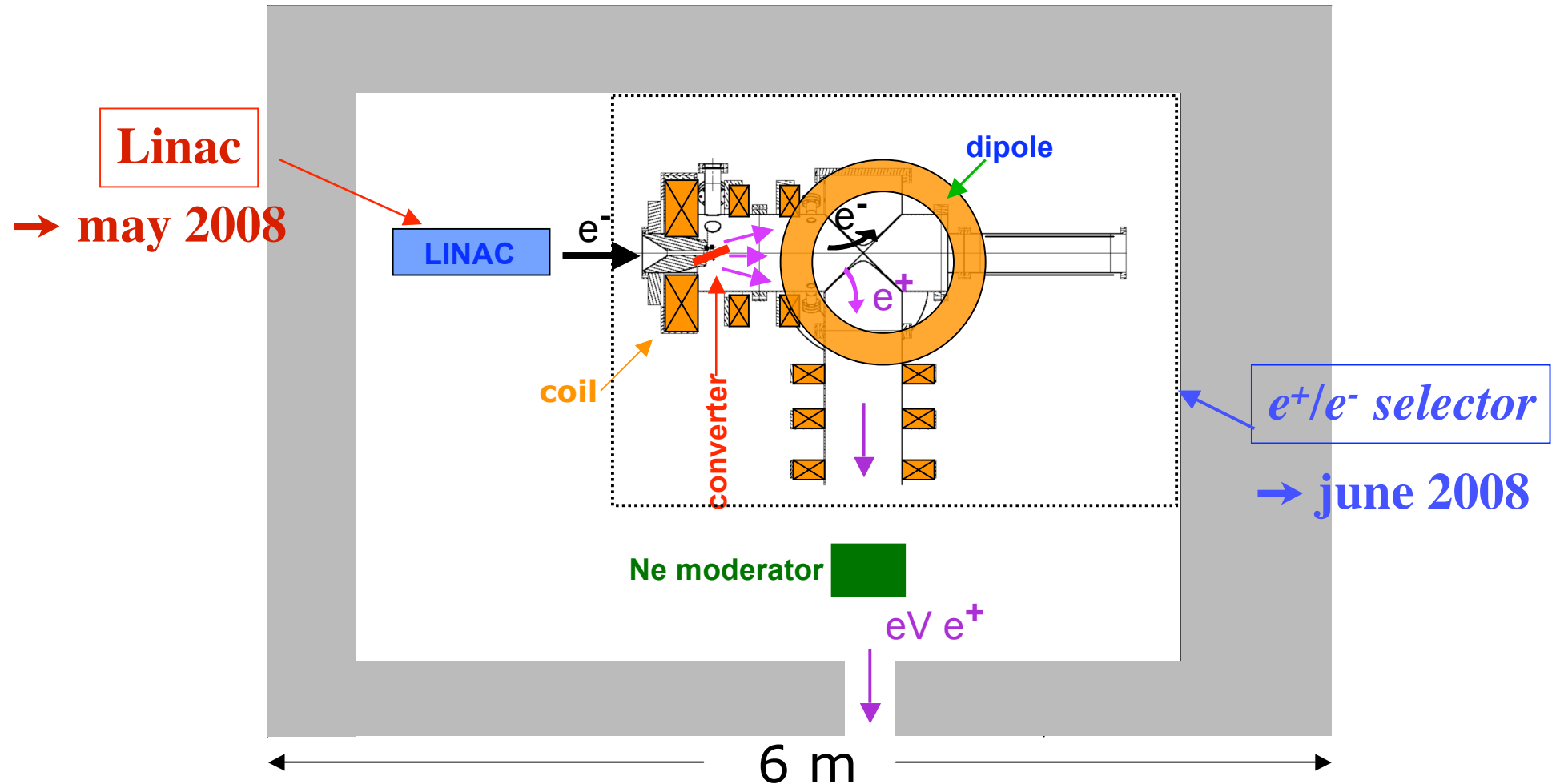
R. Suzuki, T. Ohdaira (AIST Tsukuba)

Gravity Experiment with \bar{H}^+

P. Pérez and A. Rosowsky, Nucl. Inst. Meth. A 545 (2005) 20-30.

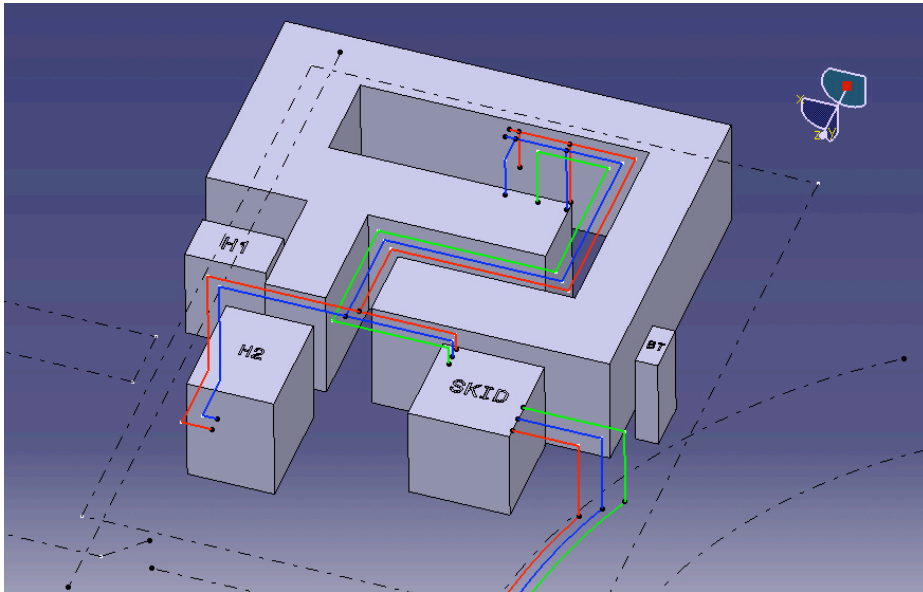


Project of intense e^+ source

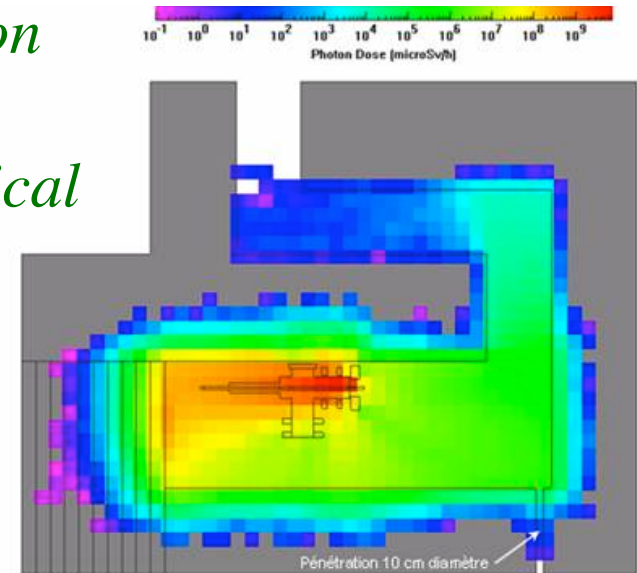


http://www-dapnia.cea.fr/Phoce/Vie_des_labos/Ast/ast_technique.php?id_ast=784

Installation Hall 126 (Saclay)



*Simulation
for
radiological
safety*



Summary

Produce Slow e^+ beam (W moderator)	Dec 2008
Neon moderator	2009
Trapping (wo buffer gaz) <i>Collab. with RIKEN</i>	2009

Depending on available money,

duplicate/improve or move slow e^+ source to CERN experiment(s) ?

Propose \bar{H}^+ experiment in ASACUSA framework (Nov. 2008)

Backups

Industrial Linac

$E(e^-) = 6 \text{ MeV}$ ($<$ neutron activation threshold)

$\nu = 220 \text{ Hz}$

$I = 0.2 \text{ mA}$

bunch length 2 - 4 μs

Magnetron 1.9 MW peak

Total electric power 35 kVA

RF frequency 3 GHz

Acceleration length 21 cm

Beam diameter 1 mm , 6 mm at target

Overall dimensions 1 m x 1 m x 0.8 m



Install March 2008

e^+ production and transport

Yields with $I = 0.2$ mA

- W moderator $\varepsilon = 10^{-4}$
 $> 10^7$ slow e^+ /s
- Ne moderator
transport efficiency 55%
 $> 10^8$ slow e^+ /s
- Large beam size to be
reduced for trap filling

