

# Gravitational Behavior of Antimatter at Rest

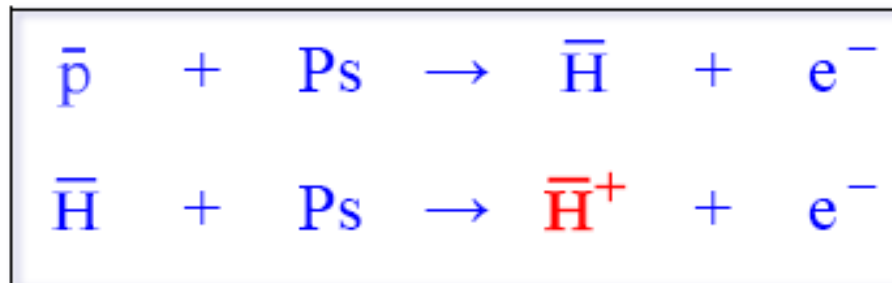
David Lunney (on behalf of the GBAR/AD-7 Collaboration)

*CSNSM (IN2P3-CNRS)*

*Université de Paris Sud, Orsay*

Goal: measure  $g$  for (first) WEP test using antimatter

Method: “easier” manipulation of  $\bar{\text{H}}^+$  (Walz & Hänsch, 2004)



GBAR (AD-7; SPSC-P-342): P. Perez, spokesperson; SPP/IRFU-Saclay; Collaboration: CSNSM/IN2P3-Orsay; ETH-Zurich; RIKEN; U. Swansea; U. Mainz; LKB/ENS-UPMC; NCBJ-Otvošk; LPI-Moscow; Uppsala U.; Tokyo U.; U. Tokyo; ILL-Grenoble; IPCMS-Strasbourg

# GBAR Timeline

Letter of Intent  
SPSC-2007-038

Research Board  
AD-7

ELENA  
BPPC

2007

2011

2012/05

2012/06

2012/09

2012/11

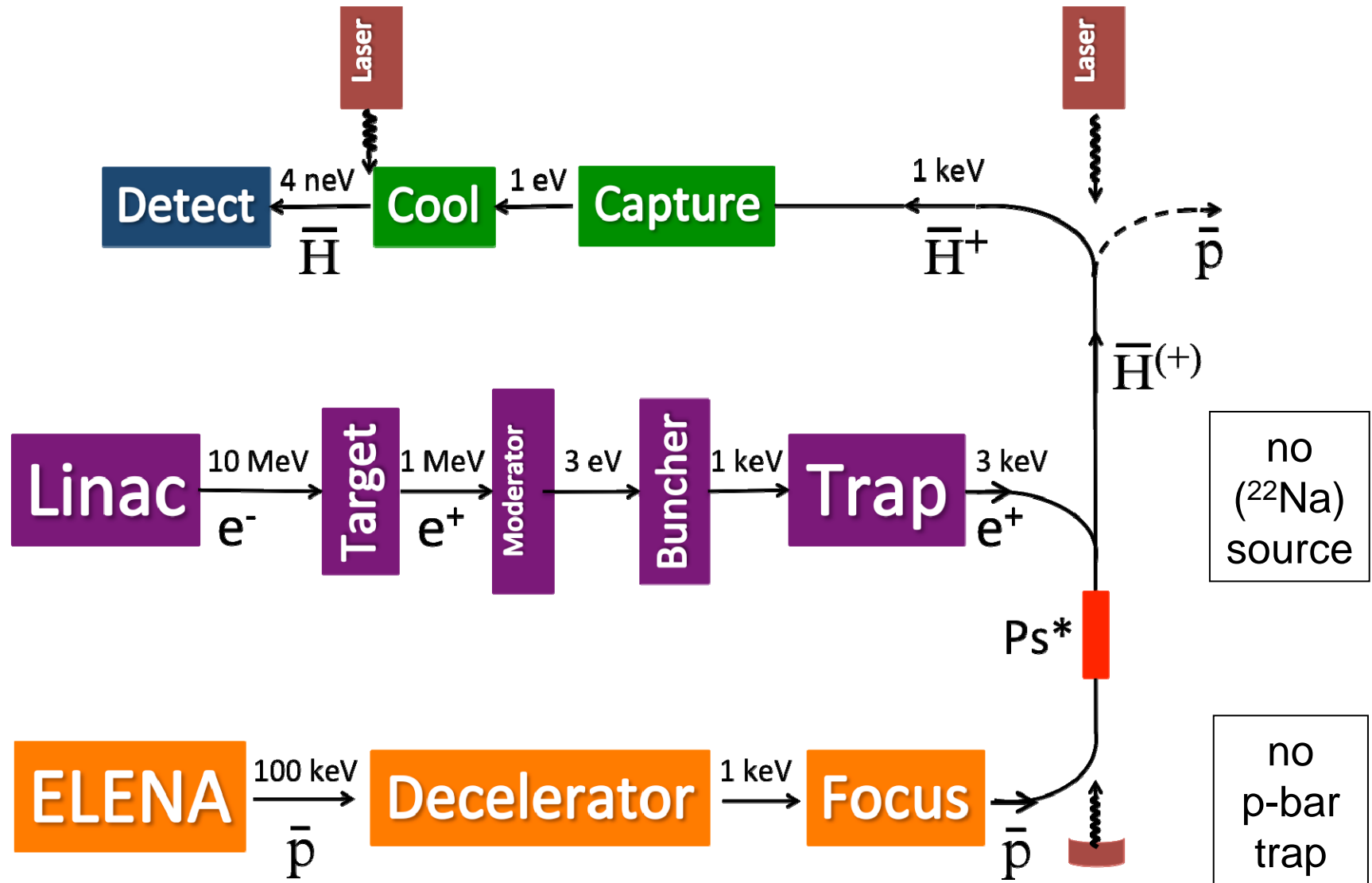
2013

Proposal  
SPSC-P-342

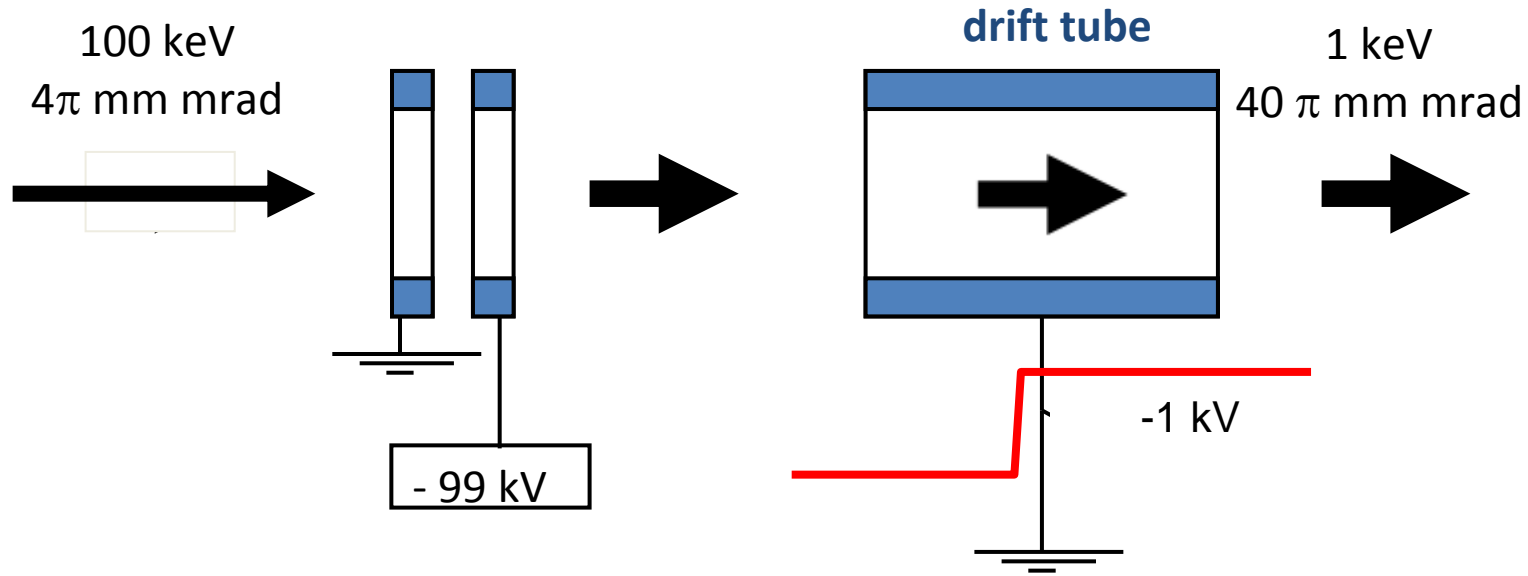
ADUC

ADUC

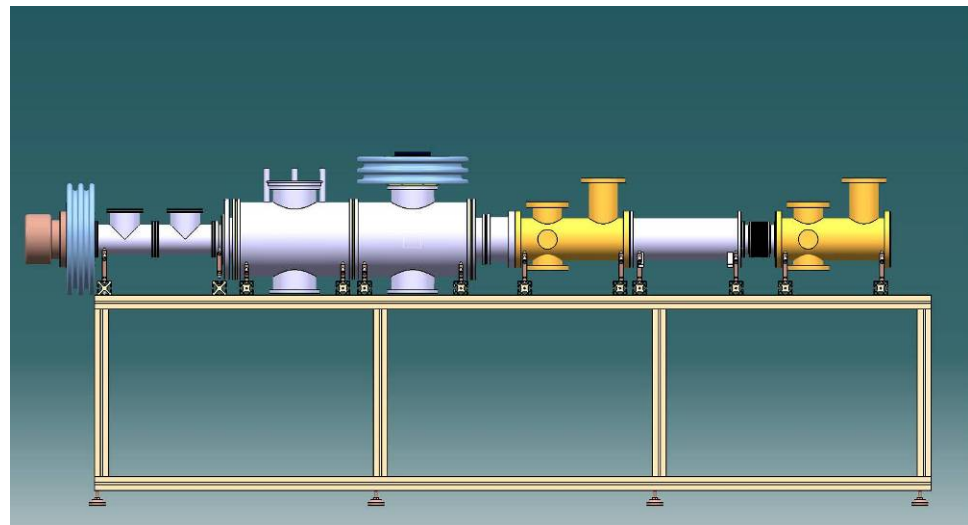
# GBAR Schematic



# GBAR antiproton decelerator

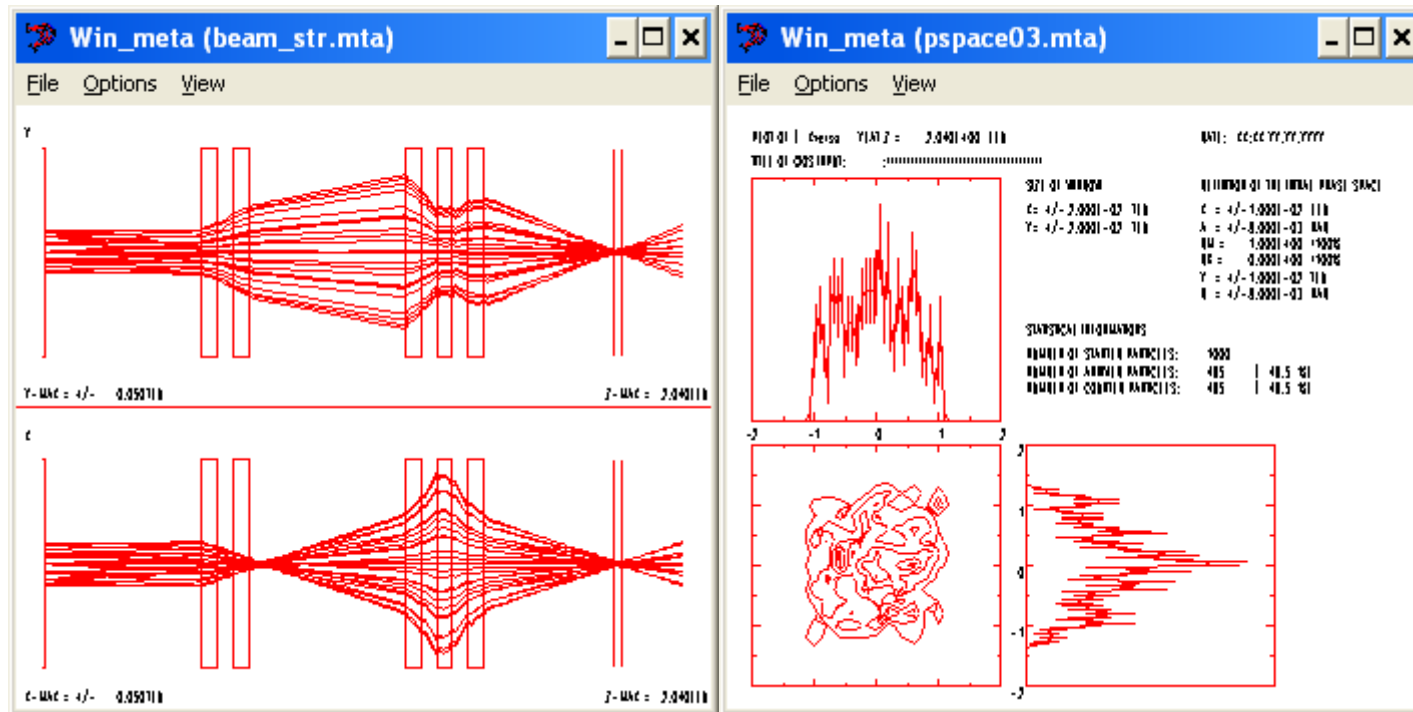


pulsed drift tube  
(ion elevator)  
used at ISOLDE  
and with many  
Trap setups



← 4 meters →

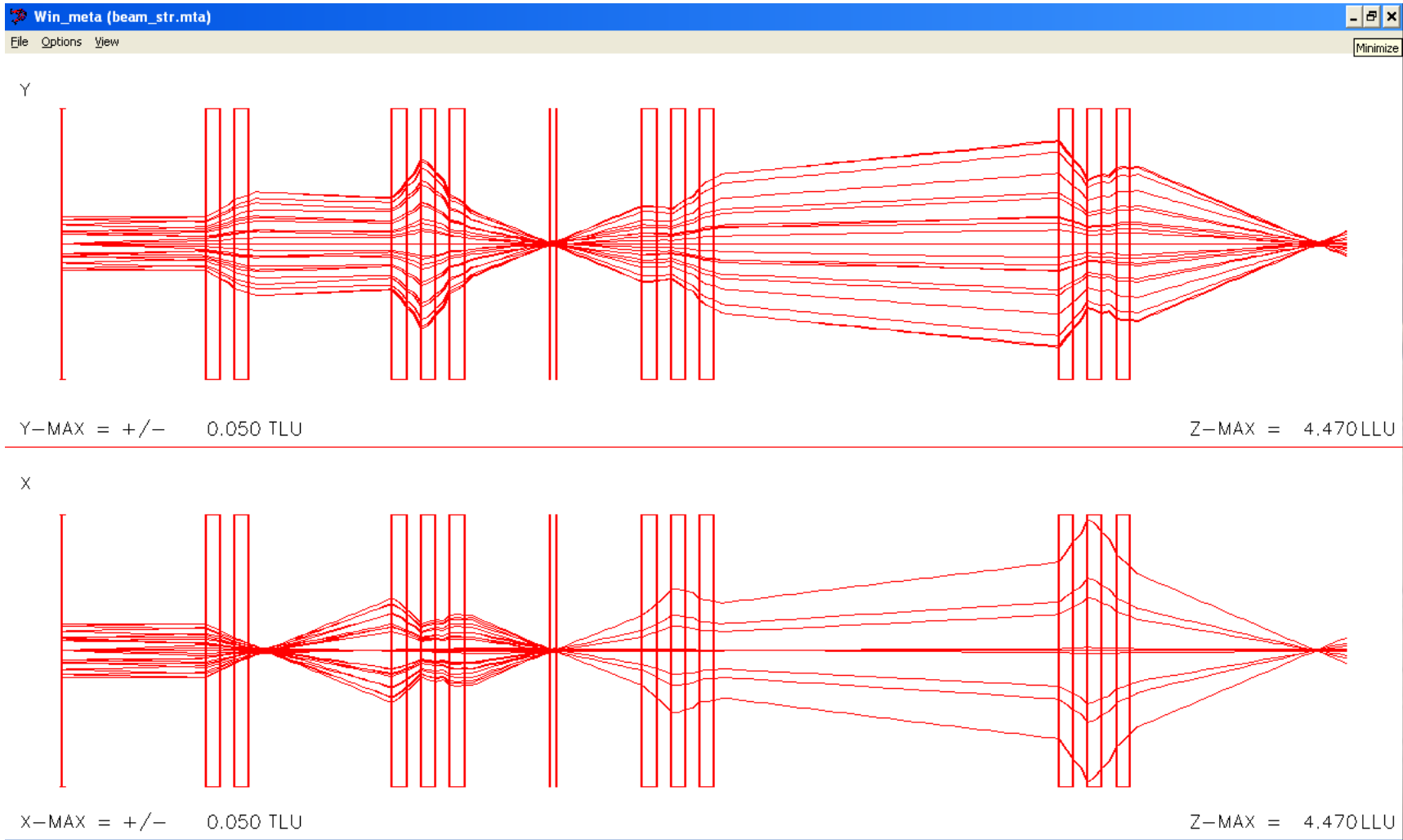
# transport to Ps reaction chamber (GIOS)



From first discussions with referees before approval: 46% but  $\delta p/p$  of  $10^{-4}$

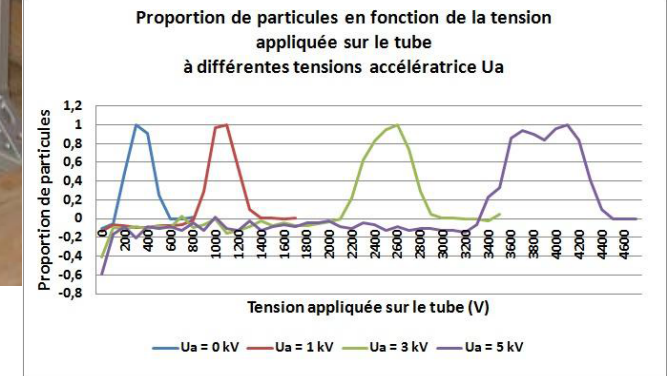
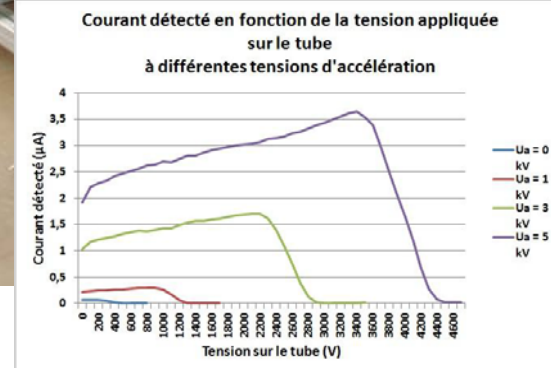
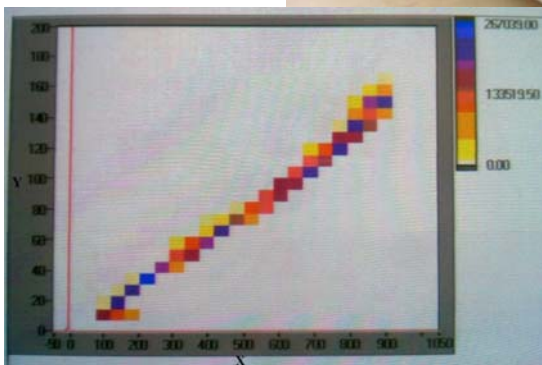
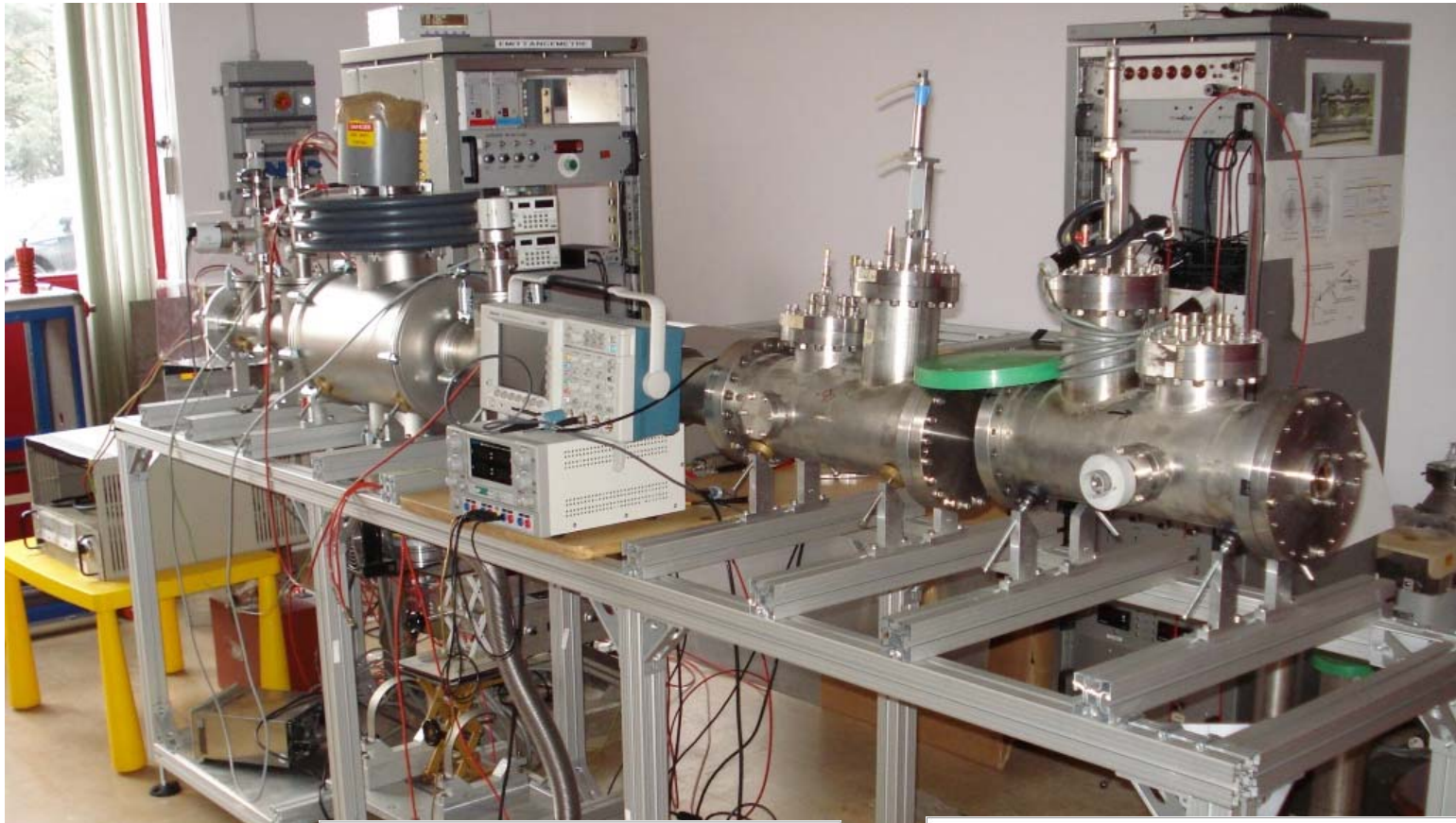


# H<sup>+</sup> transport 3 meters past Ps chamber



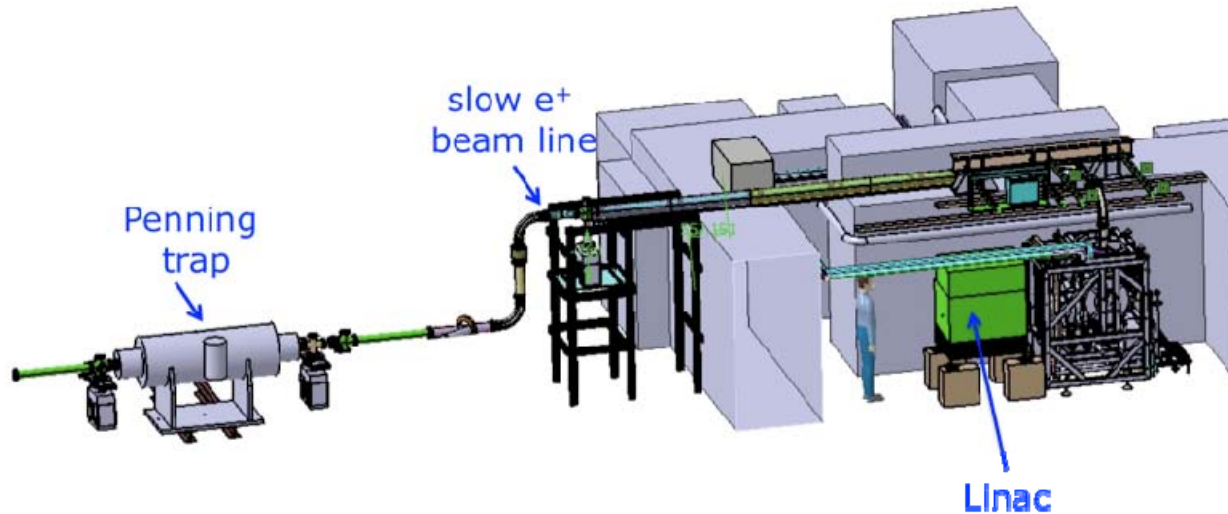
# Decelerator test-bench in Orsay

5 keV  
N<sup>+</sup> beams  
1  $\mu$ A CW  
or 100 ns  
pulses





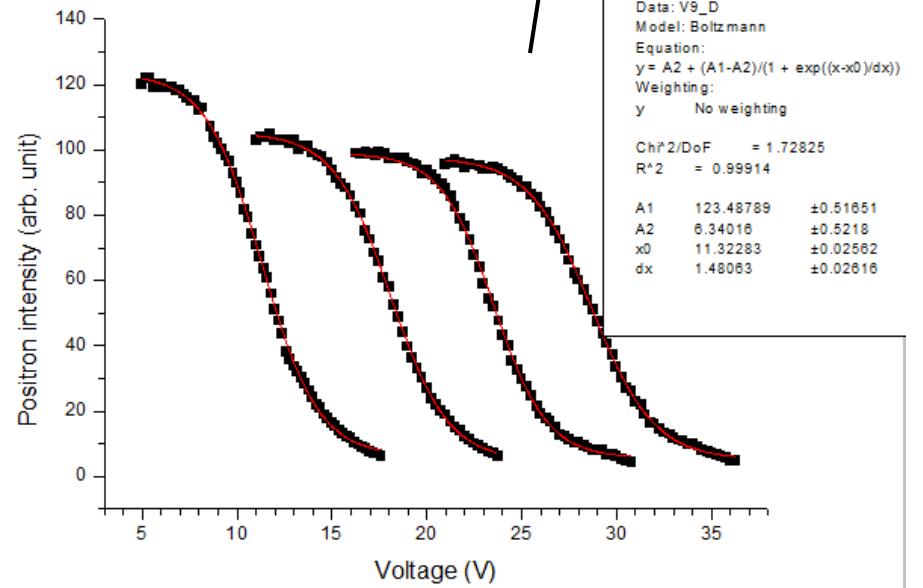
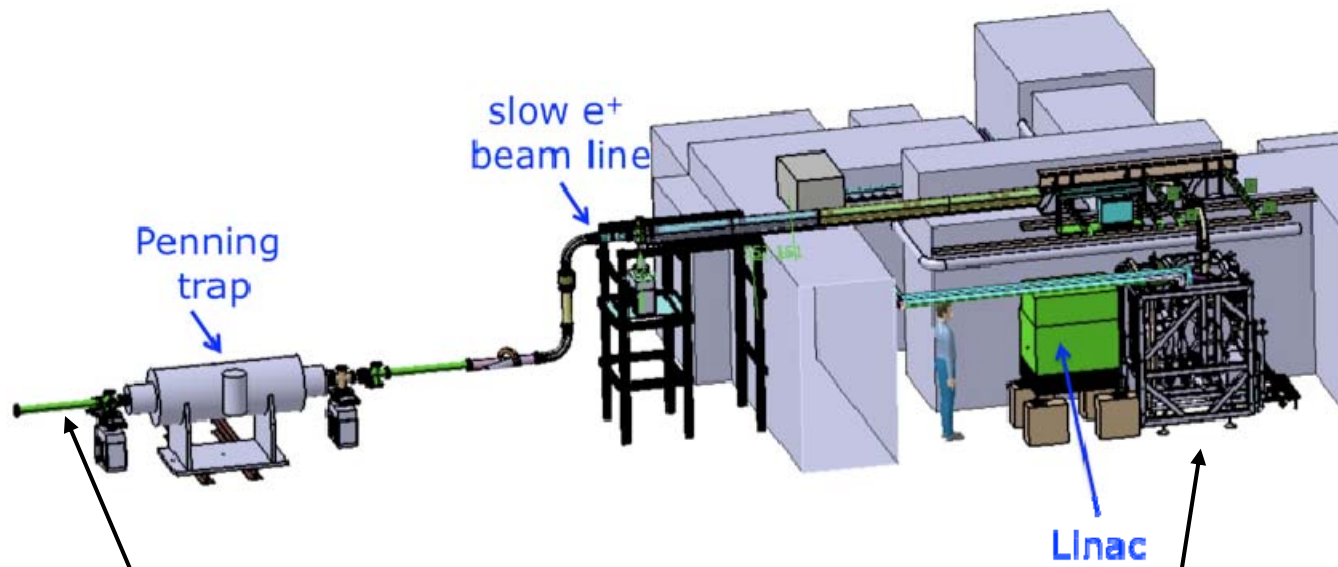
# $e^+$ /Ps demonstrator in Saclay



- 4.3 MeV / 200 Hz / 2.5  $\mu$ s / 120  $\mu$ A
- $3 \times 10^6$  slow  $e^+$ /s
- with first W mesh moderator
- Penning trap on beam line (from RIKEN)



P. Dupré, *A new scheme to accumulate positrons in a Penning-Malmberg trap with a Linac-based pulsed source*, 10th International Workshop on Non-Neutral Plasmas, 27-30 August 2012, Greifswald (Germany); AIP Conf. Proc. (2013) in print.



L. Liskay (2012)

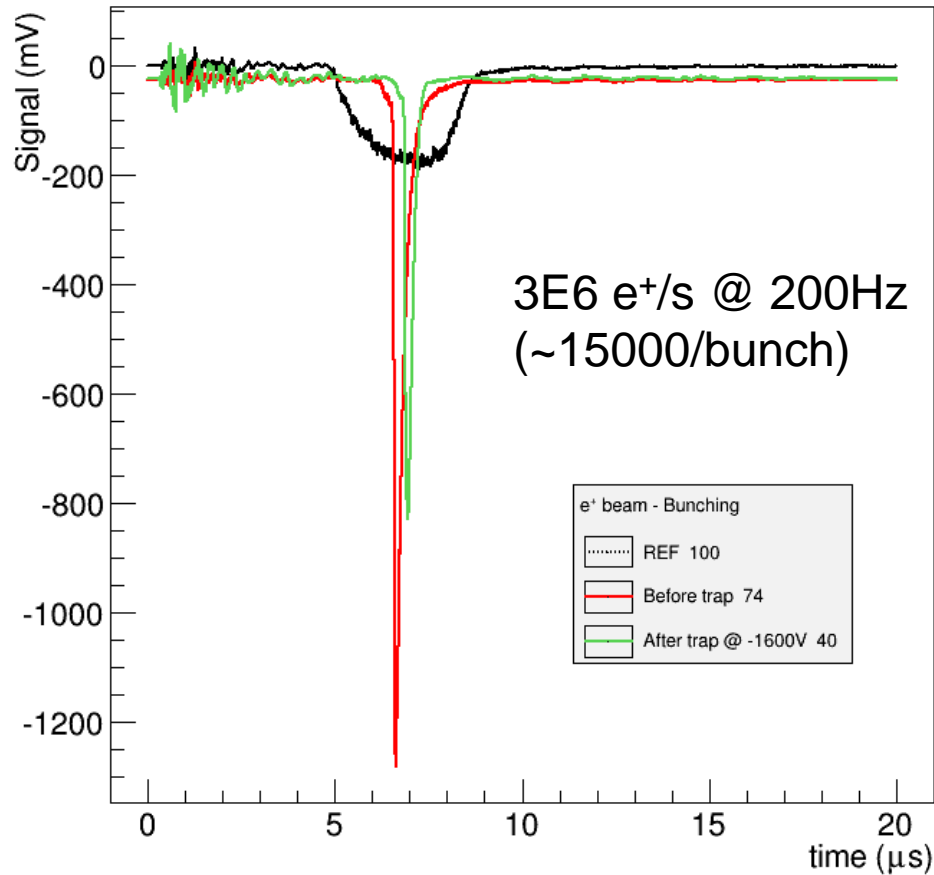


Figure 1: En noir REF (faisceau non bunched). En Rouge faisceau bunched avant TRAP, l'intégrale du signal est de 74% de la REF. en vert Signal sur PS avec l'ensemble du piège à -1600V

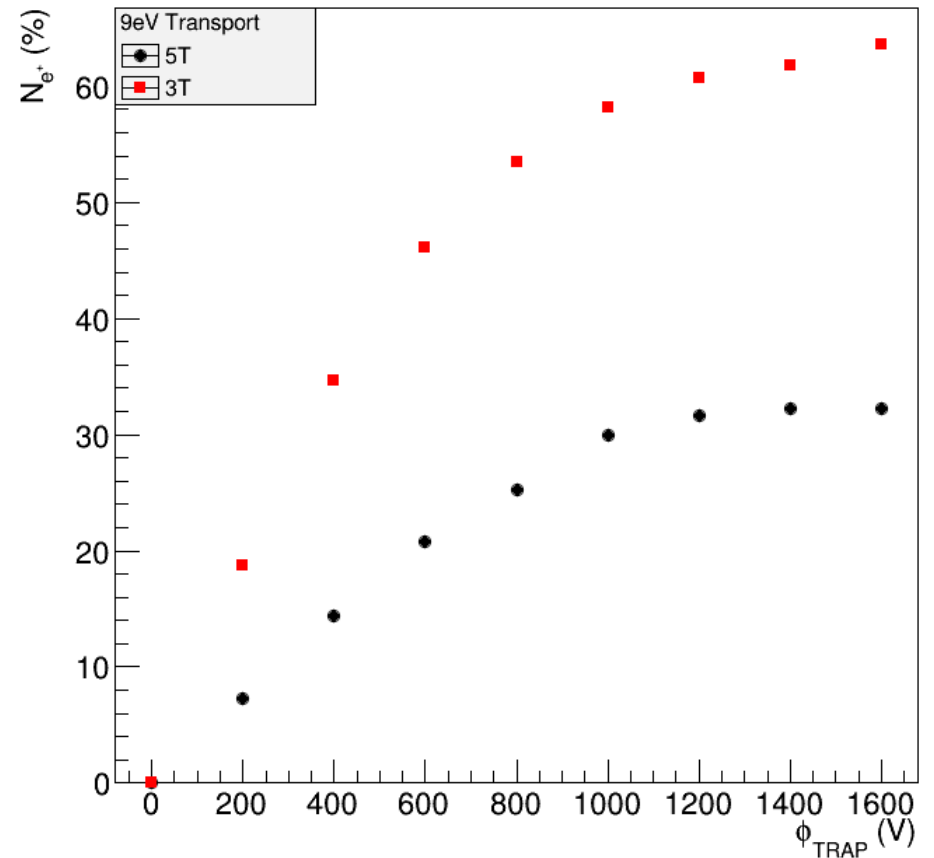
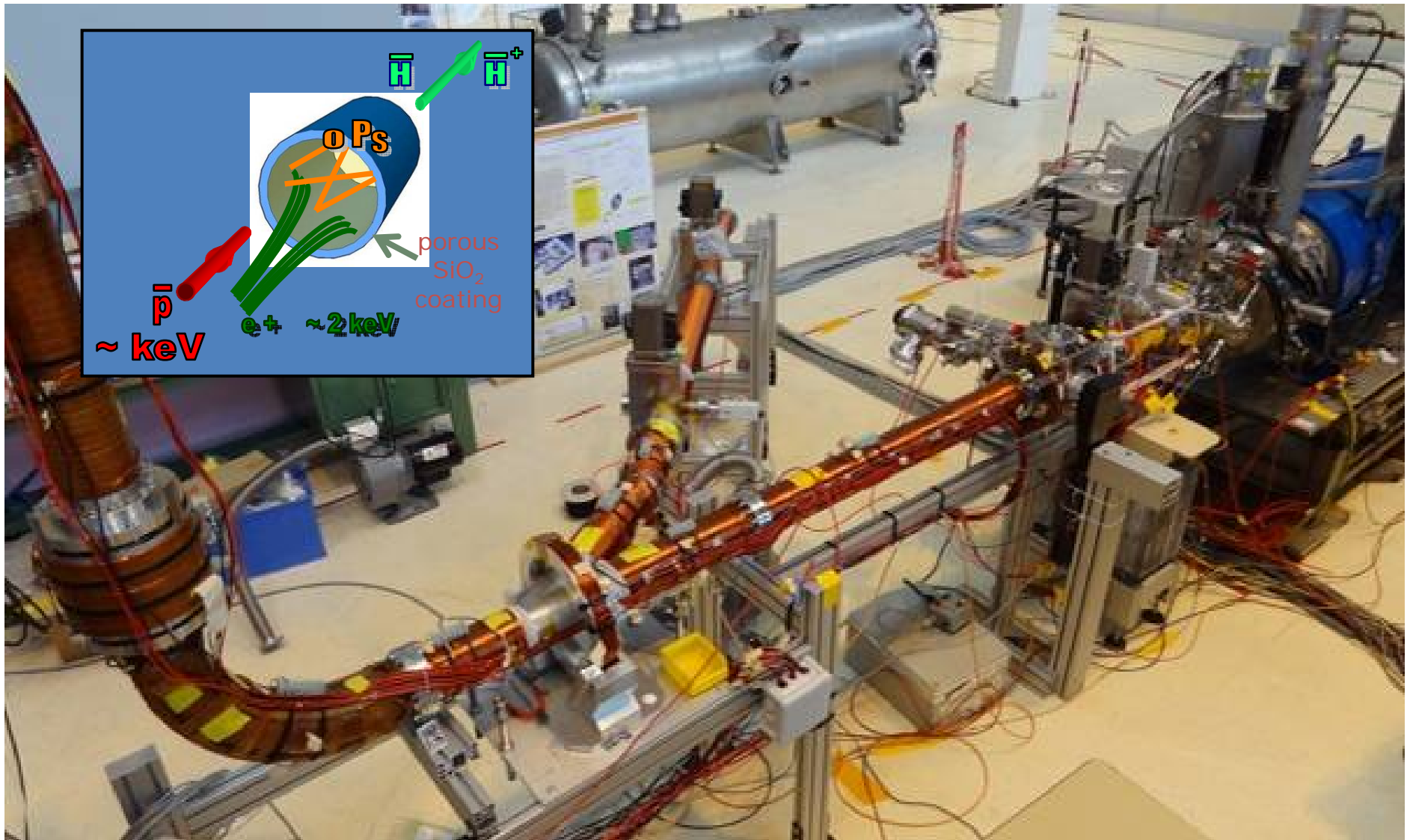


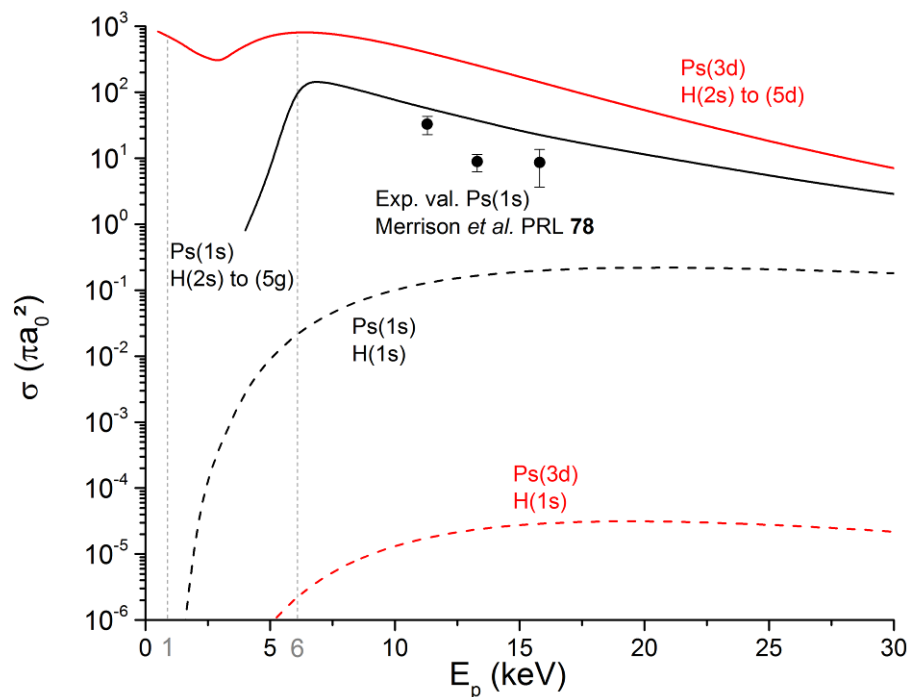
Figure 2 : Franchissement du miroir magnétique pour des positons mono énergétiques à 9eV.

# new $e^+$ line for Ps and materials research



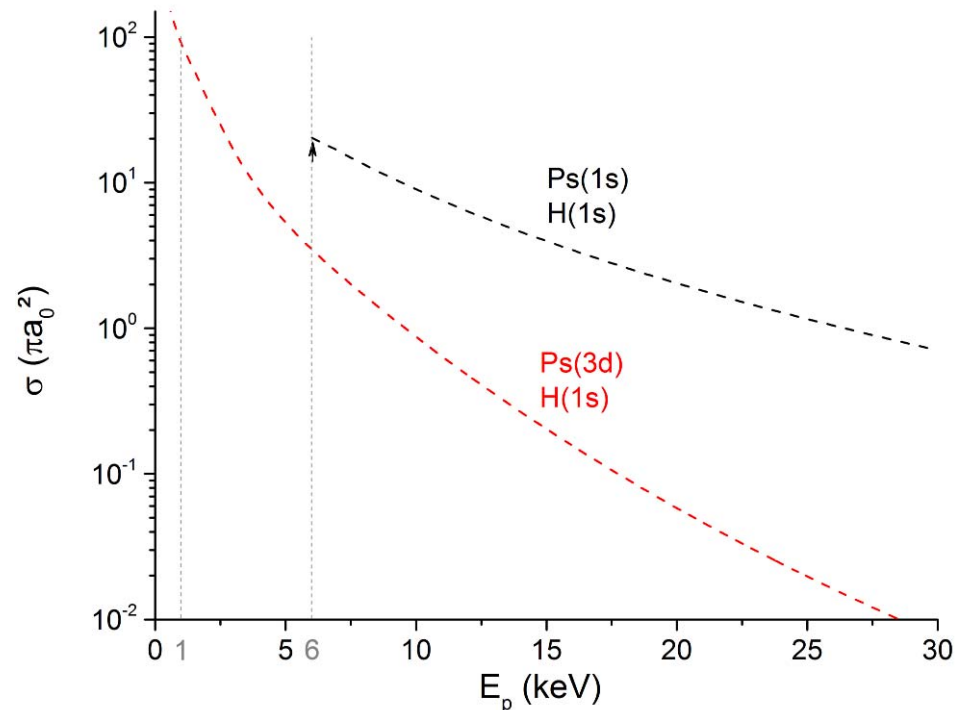
# Calculation of $H^+$ production

Reaction 1



Production of excited  $\bar{H}$  from  $\bar{p}$

Reaction 2



Production of  $\bar{H}^+$  from  $\bar{H}(1s)$

$\bar{H}$  de-excitation required

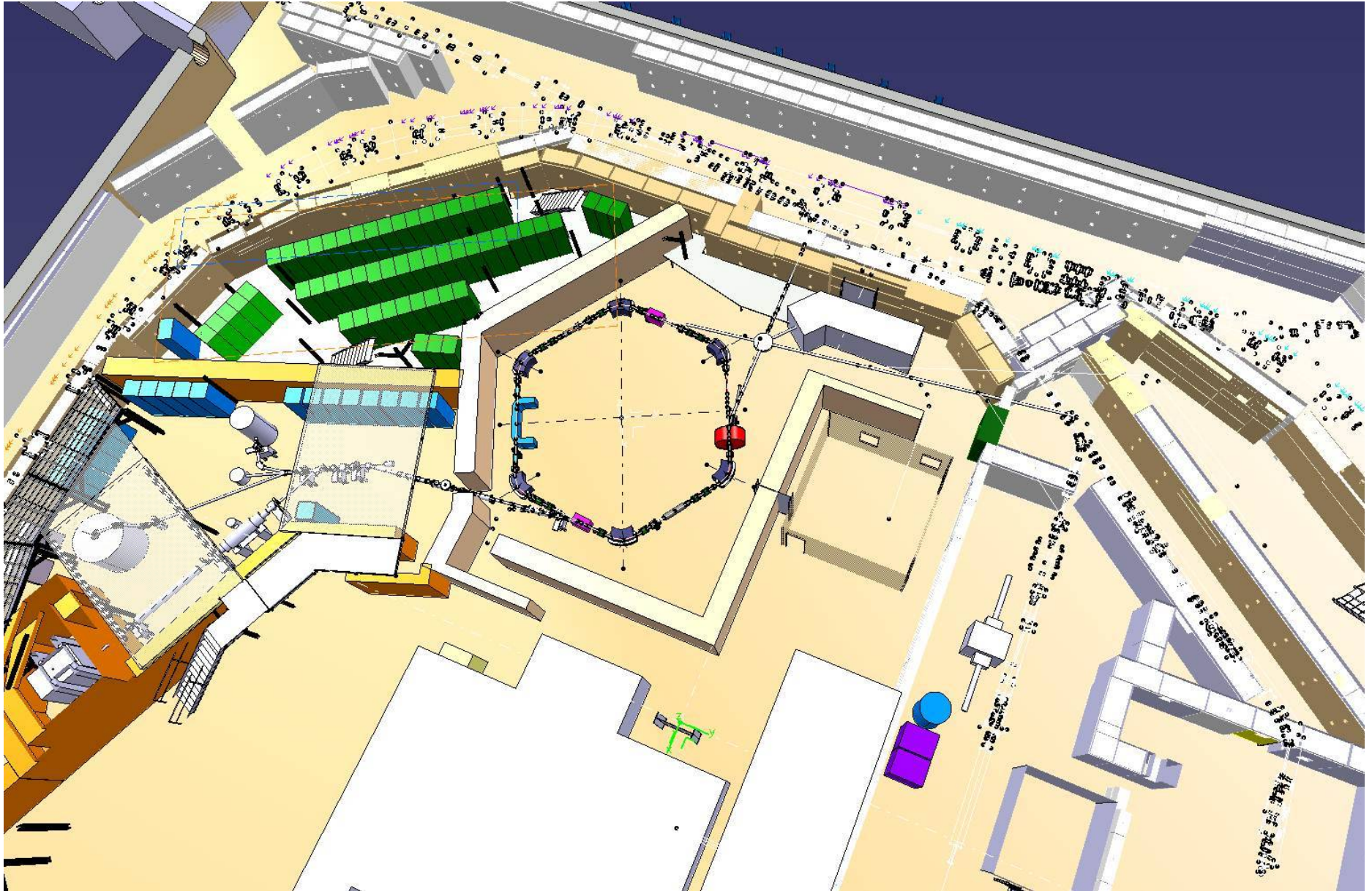
Laser: 410 nm; 1-mJ, 50-ns pulse  $\rightarrow$  30% Ps(3d) available

*Realisation in progress with LKB (thesis work of P. Comini)*

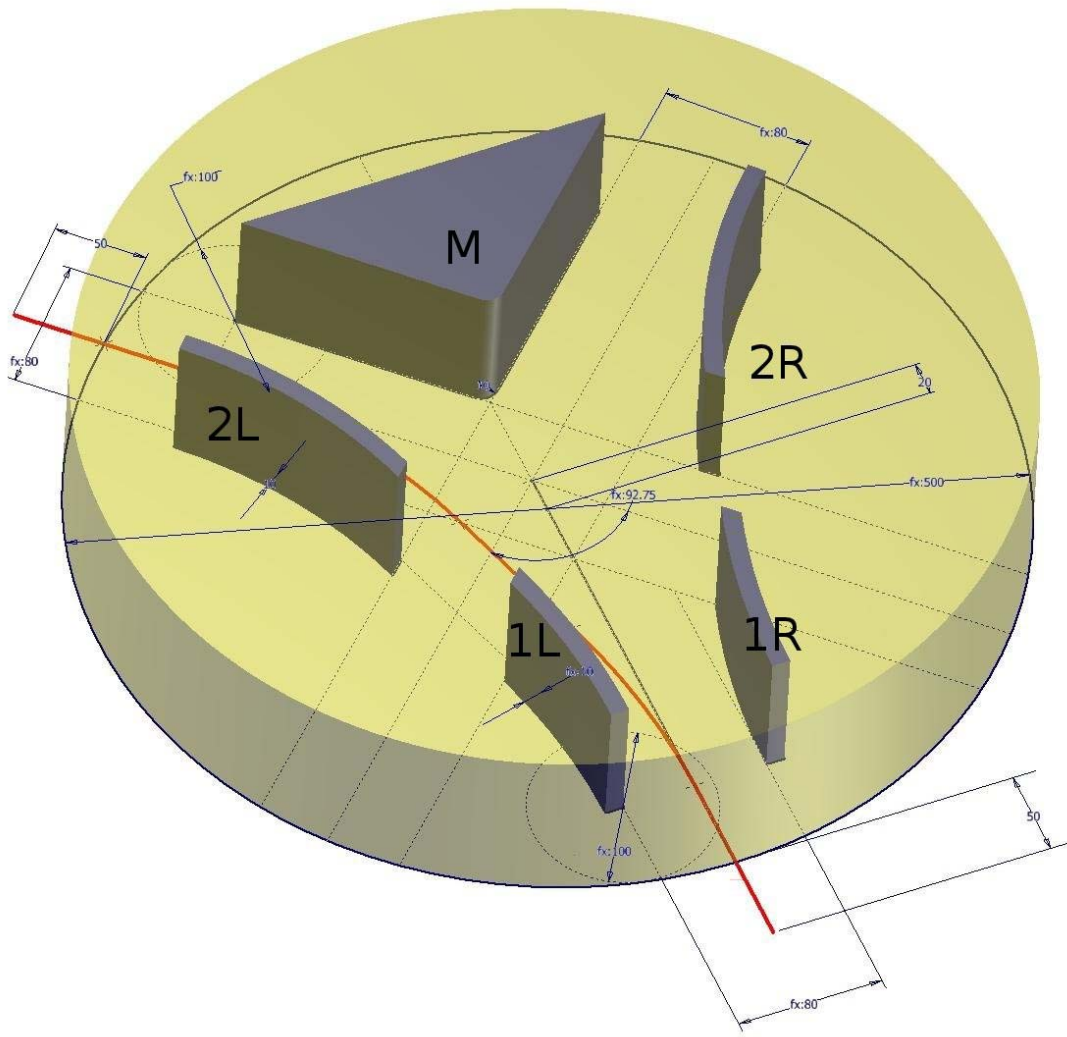
P. Comini and P-A. Hervieux,  $\bar{H}$  and  $\bar{H}^+$  production cross sections for the GBAR experiment, Proceedings 16th Int. Conf. on Positron Annihilation, 19-24 August 2012, Bristol, UK (2013) in print



# AD Hall with ELENA (and GBAR)



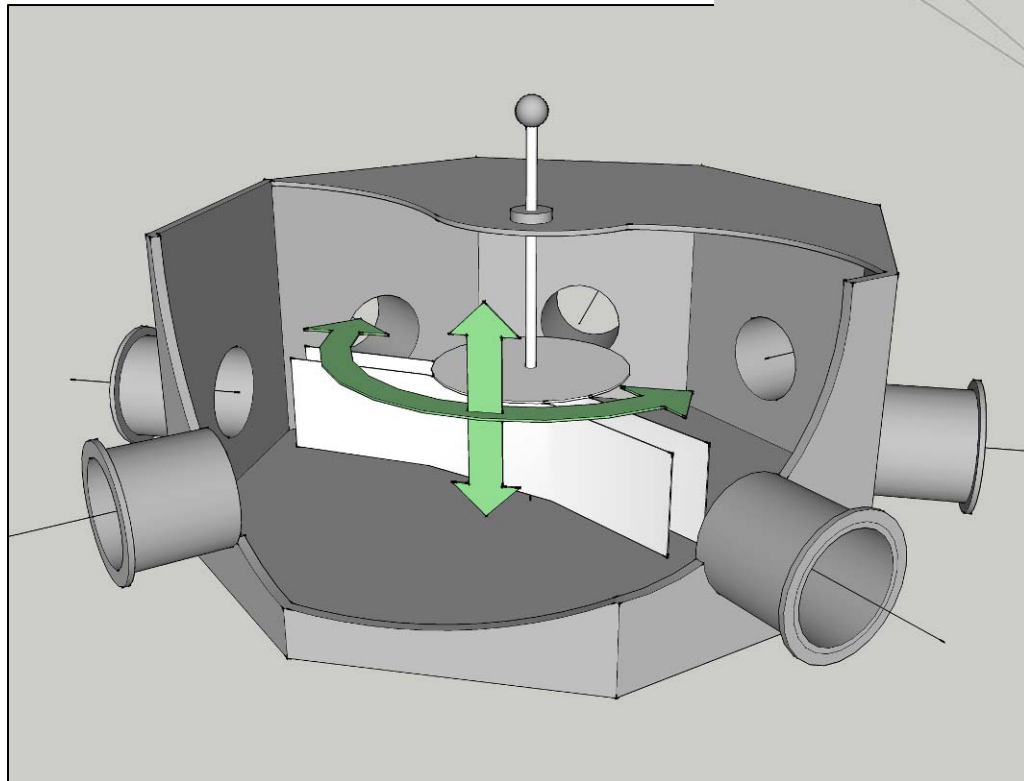
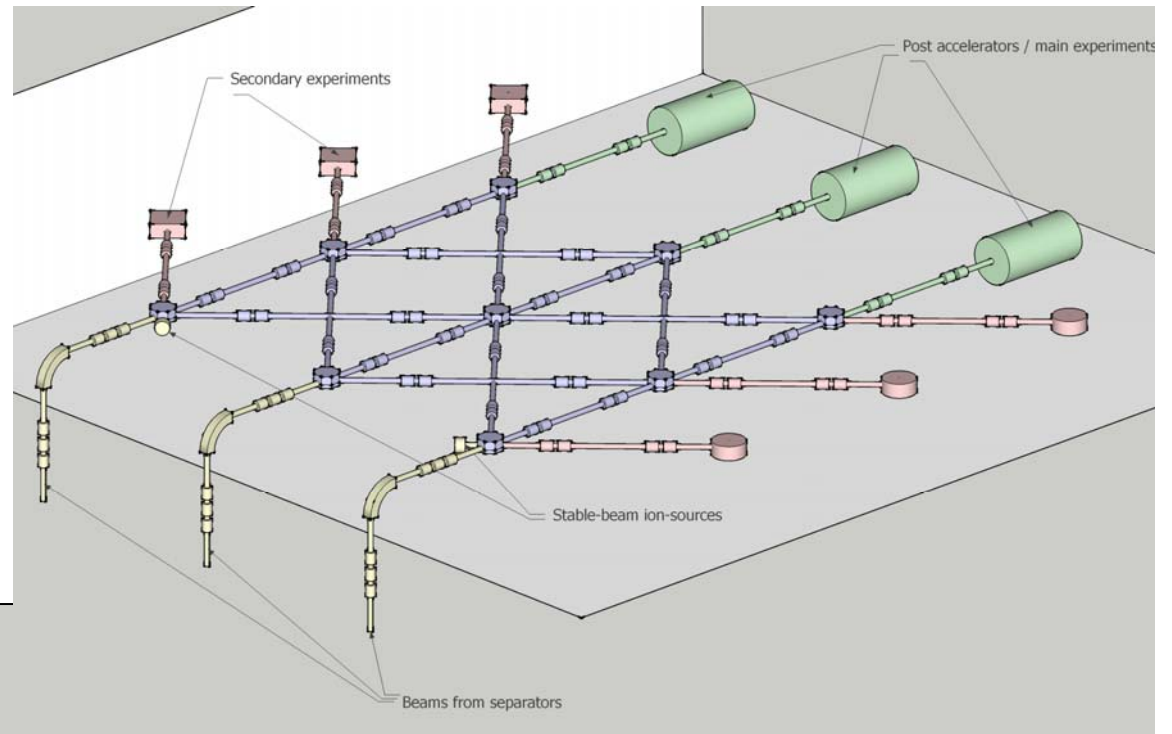
# Crossing device



Seems feasible but  
difficult to simulate  
performance

Protons only via  
injection channel →  
much simpler crossing  
device

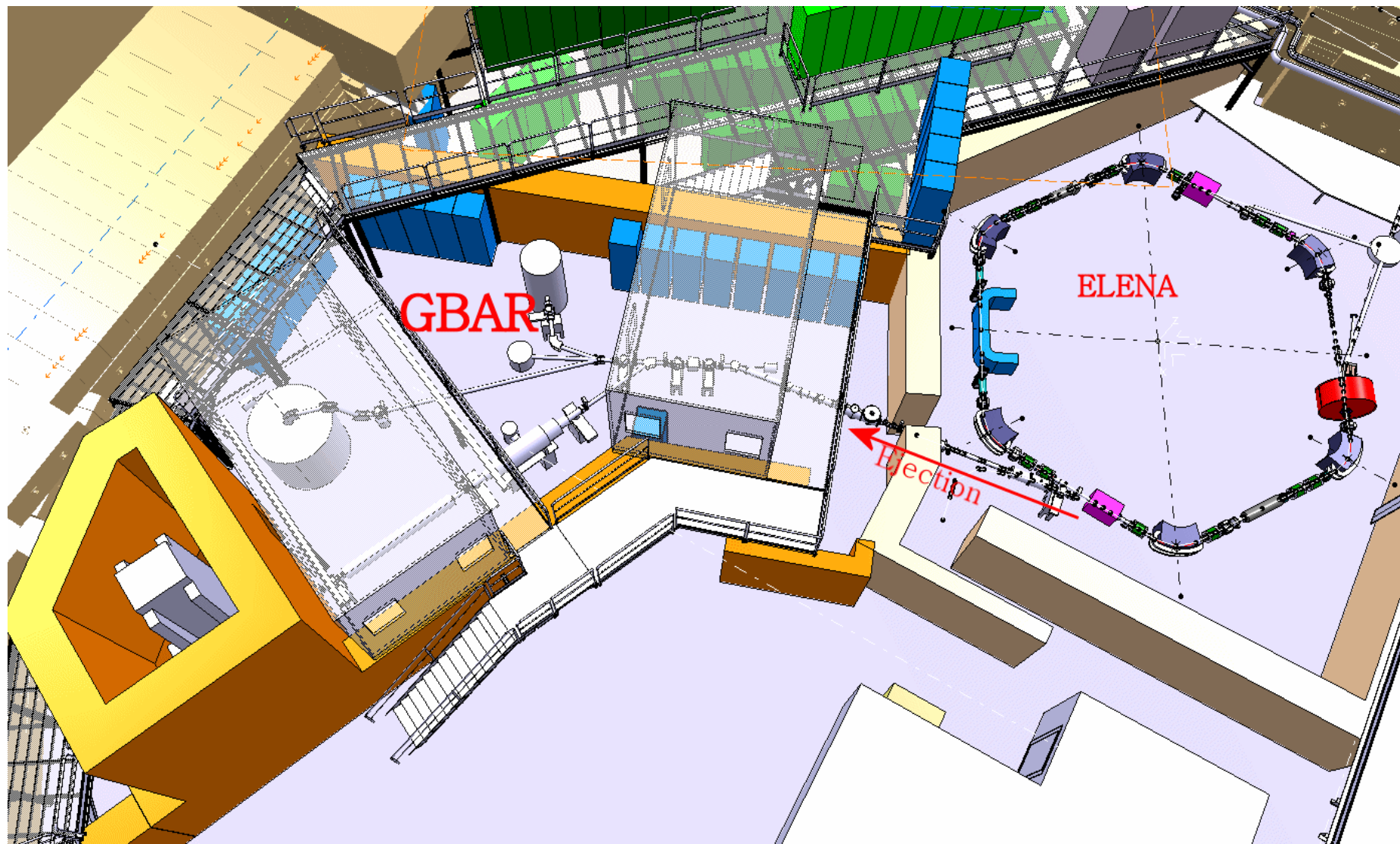
EURISOL Design Study  
Beam transport report:  
D. Lunney, Orsay  
and T.J. Giles, CERN



Prototype exists in Orsay, which  
could be tested/loaned for ELENA!



# present GBAR layout



## Other activities

- NCBJ will produce an 18 MeV linac in 2013  
(if funding found: clone at CERN in 2014-2015)
- Conceptual Design Report (D.P. Van der Werf)
- MoU in progress

Work Package	Institutes
Fast $e^+$	NCBJ, IRFU
Slow $e^+$	IRFU, Swansea, TUS
$e^+$ accumulation	RIKEN, IRFU, CSNSM
Positronium	LKB, IRFU, ETHZ
Antiproton deceleration	CSNSM, IRFU, LKB, Tokyo
$\bar{H}$ & $\bar{H}^+$	Swansea, IRFU, LKB
$\bar{H}^+$ cooling	Mainz, LKB, ILL
Detector	ETHZ, IRFU, Mainz
Theory	IPCMS, LKB, Lebedev, Uppsala
Slow control, DAQ	IRFU, all
Quantum States	ILL, LKB

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ADUC

ADUC

GBAR  
development

GBAR off-line  
commissioning

GBAR  
installation

GBAR on-line  
commissioning

Run?

2013

2014

2015

2016

2017

GBAR  
MoU

ELENA  
installation

ELENA  
commissioning

# Conclusion

- Measurement challenging → stimulating
- Developments in parallel progressing nicely
- Layout in the ELENA hall almost established
- CDR and MOU underway with 2013 target

