日本物理学会　春の分科会
平成 12 年 3 月 24 日　於 関西大

超低速反陽子実験のための荷電粒子蓄積トラップの開発 II

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発表内容

（1）ASACUSA トラップ

（設計思想・性能）

（2）回転電場による

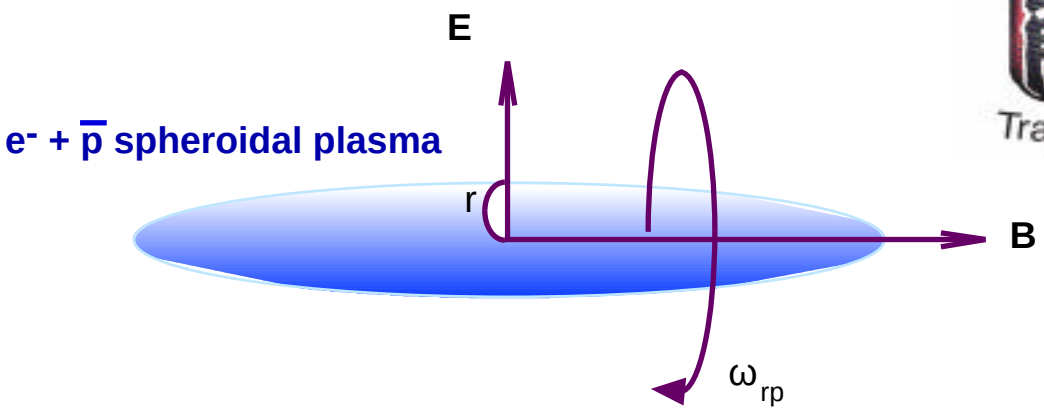
電子プラズマの制御

（3）H^-イオンの閉じ込めと電子冷却

（4）まとめ

今後の実験計画

The Brillouin limit



Radial force balance on a charged particle with mass m, charge e :

$$-\frac{mv^2}{r} = -eE + evB$$

$$-\left(\frac{v}{r}\right)^2 = -\frac{1}{2}\frac{e^2 n}{m\varepsilon_0} + \frac{eB}{m}\frac{v}{r}$$

From : $v = r\omega_r$, $E = \frac{enr}{2\varepsilon_0}$

$$\omega_r^2 + \frac{1}{2}\omega_p^2 - \omega_c\omega_r = 0 \qquad \left(\omega_c^2 \geq 2\omega_p^2\right)$$

$$n \leq \frac{\varepsilon_0 B}{2m} \quad \text{(The Brillouin limit)}$$

For an antiproton, this is given :

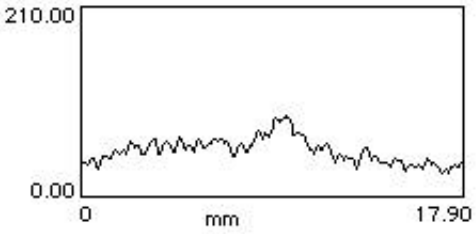
B[T]	1	5
n_p [cm^{-3}]	2.6 x 10^9	1.3 x 10^{10}

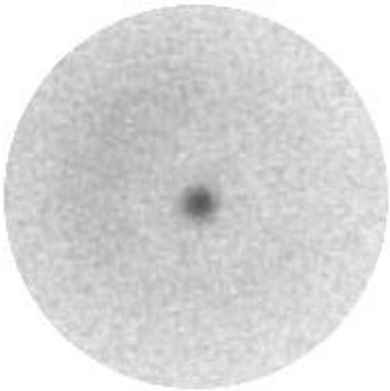
Electron density should not exceed the Brillouin limit of antiproton

Profile change by an application of rotating E-field

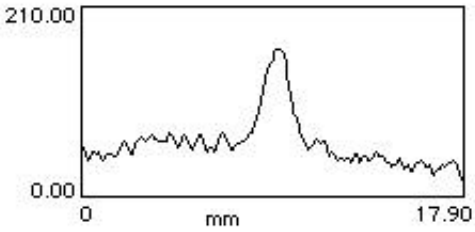
e- ~ 1.3 x 10^{8}
pressure ~ 1.6 x 10^{-9} Torr

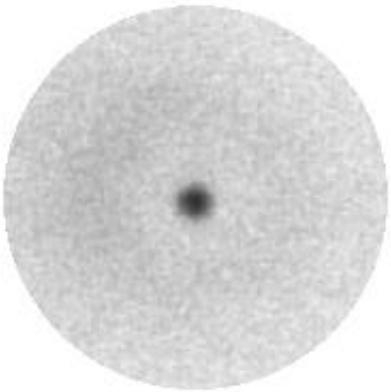
30sec



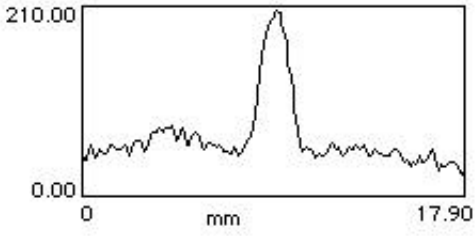


60sec



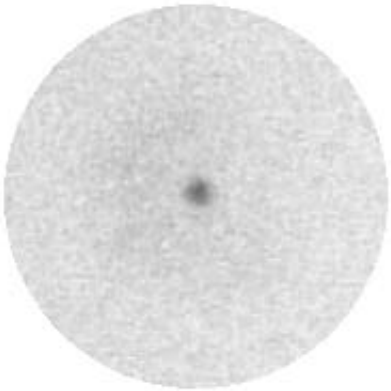


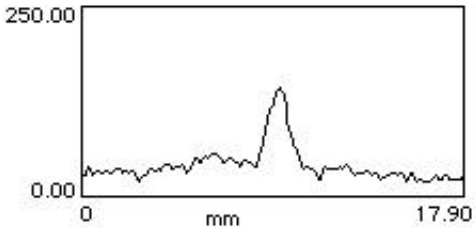
120sec



Profile difference by total charge

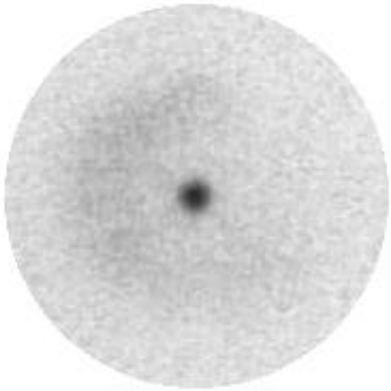
1.3 x 10^7 e^-

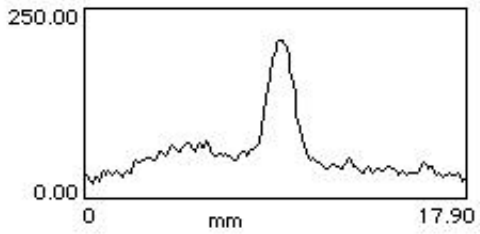




diameter~1.2mm

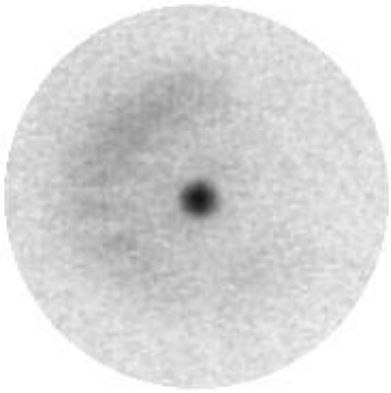
3.6 x 10^7 e^-

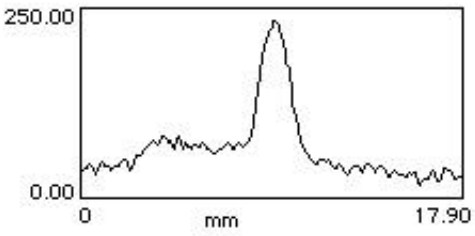




diameter~1.5mm

5.4 x 10^7 e^-

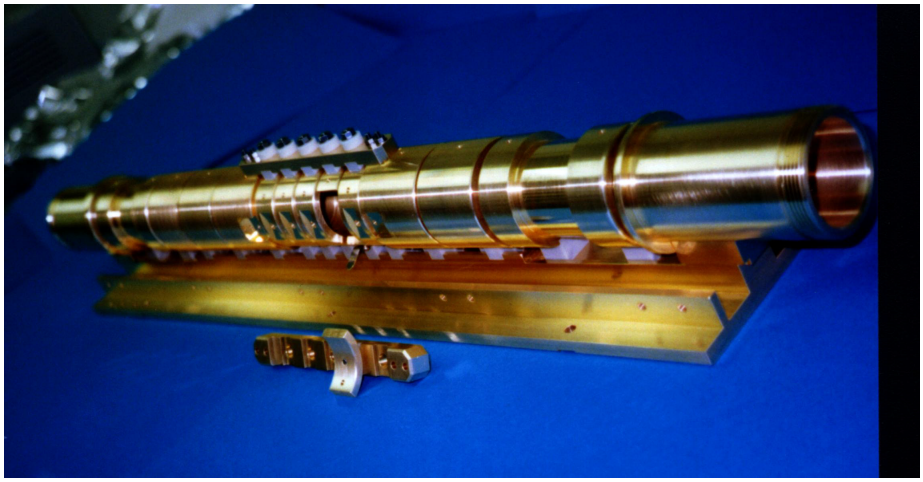




diameter~1.7mm

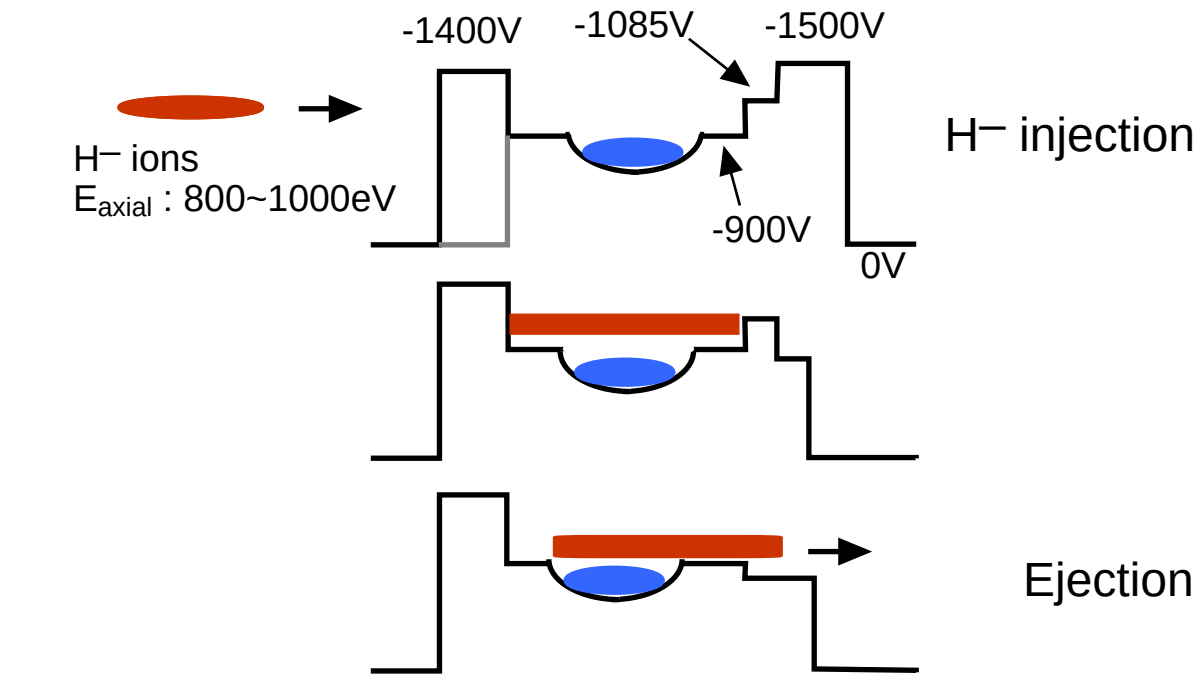
pressure ~ 1.2 x 10^{-9} Torr
60sec wait + 60sec rot-E

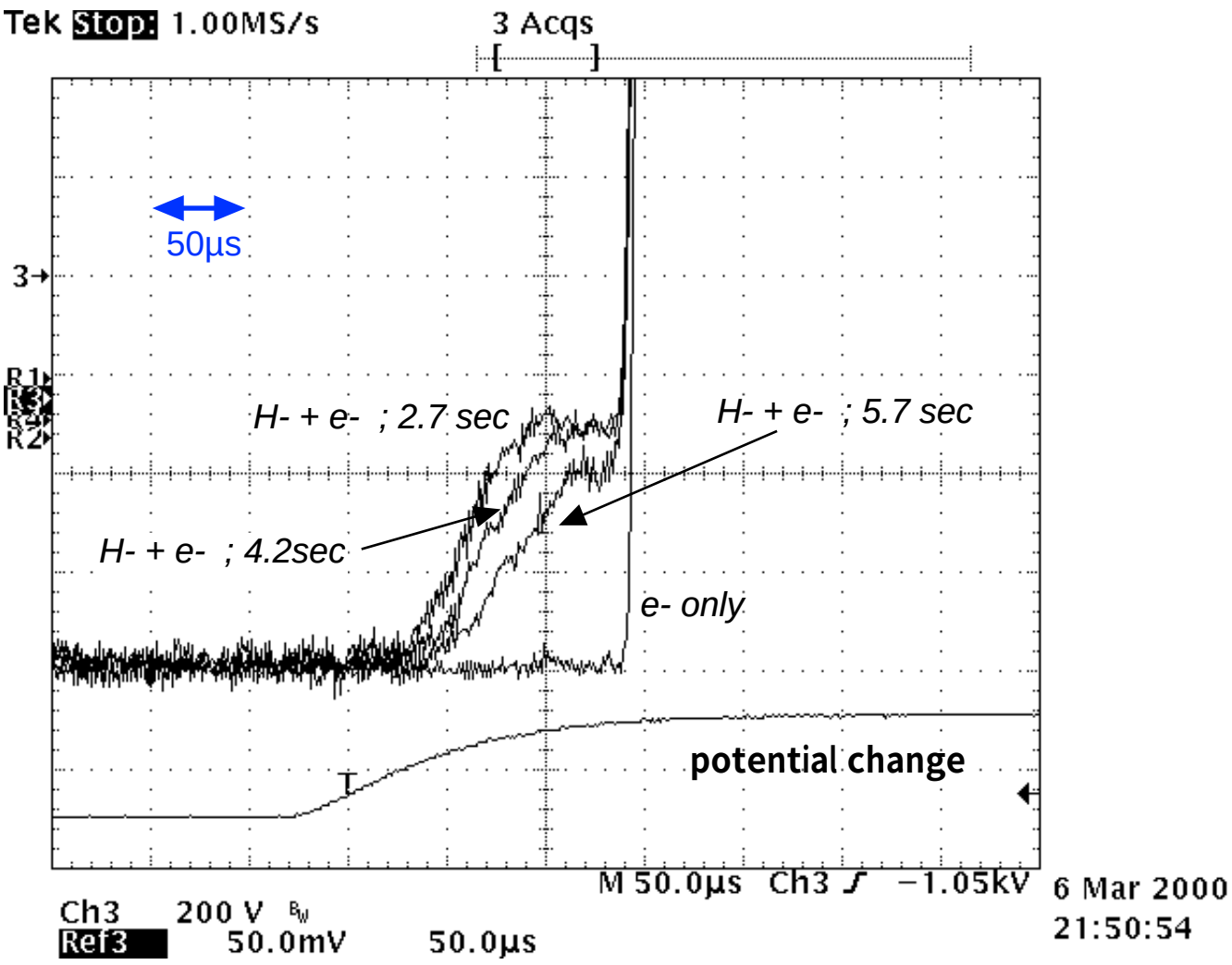
ASACUSA Trap design



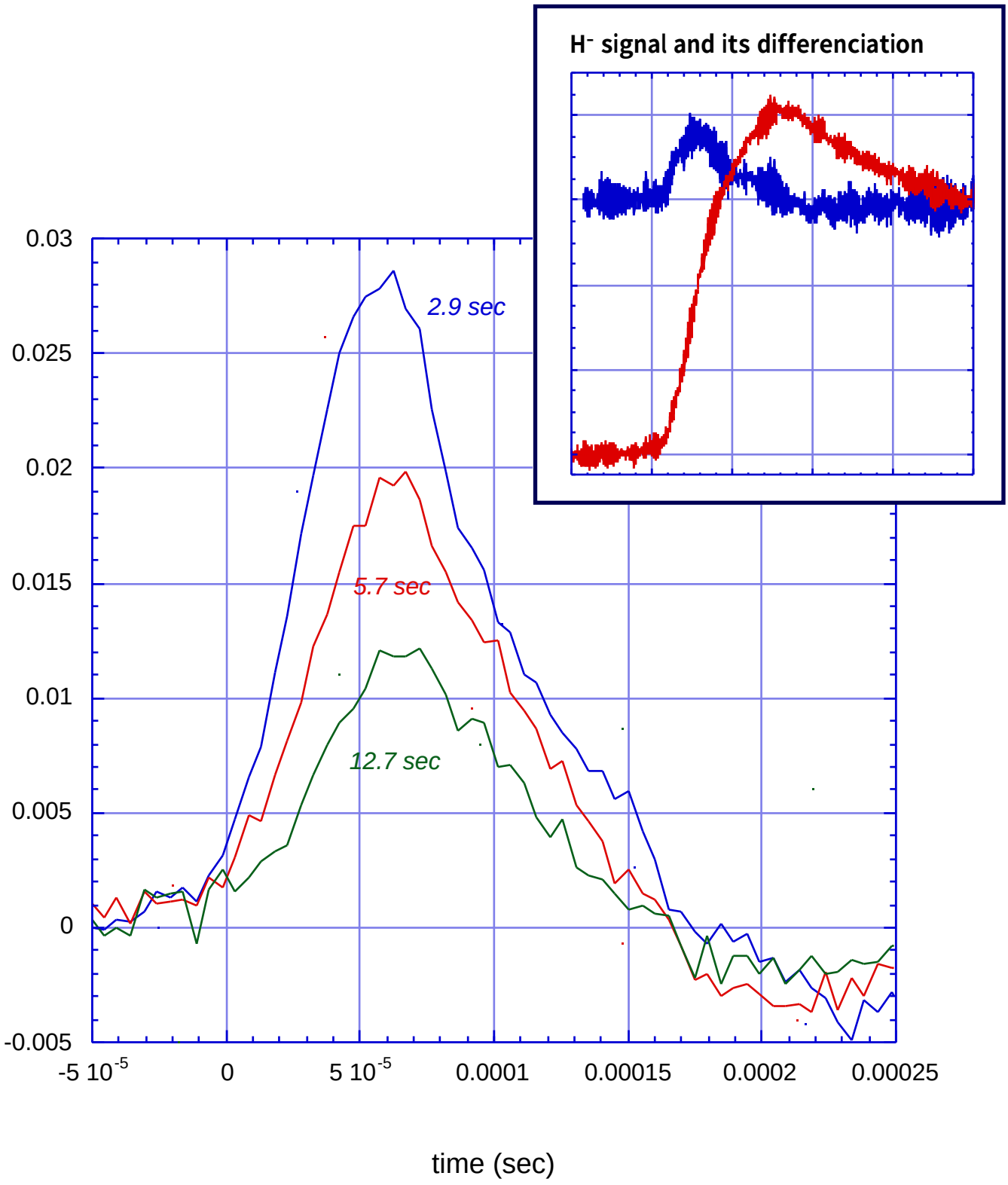
Requirements	solutions
* Stable storage and cooling of $10^{6\sim8}$ antiprotons * Monitoring of plastma modes	# Penning type trap # Harmonic potential well # 10μm precision # Gold plating
* Pulse length of 50keV antiprotons from the RFQ = 300ns	# Trap length = 50cm (Harmonic region = 10cm)
* Vacuum in the magnet bore ~ 10^{-12} Torr or better	# Oxygen free copper # AlN (high thermal conductivity)
* Injection from RFQ * Extraction of stored antiprotons * $n_e + n_{\bar{p}} < 1.3 \times 10^{10}$ (Brillouin limit of $\bar{p}$)	# Cylindrical electrodes # Central harmonic potential region ~ 10cm
* Control of plasma shape and density by rotational RF field	# One segmented electrode
* System control from outside the area	# LabView + GPIB + CAMAC

H^- cooling : raw signals

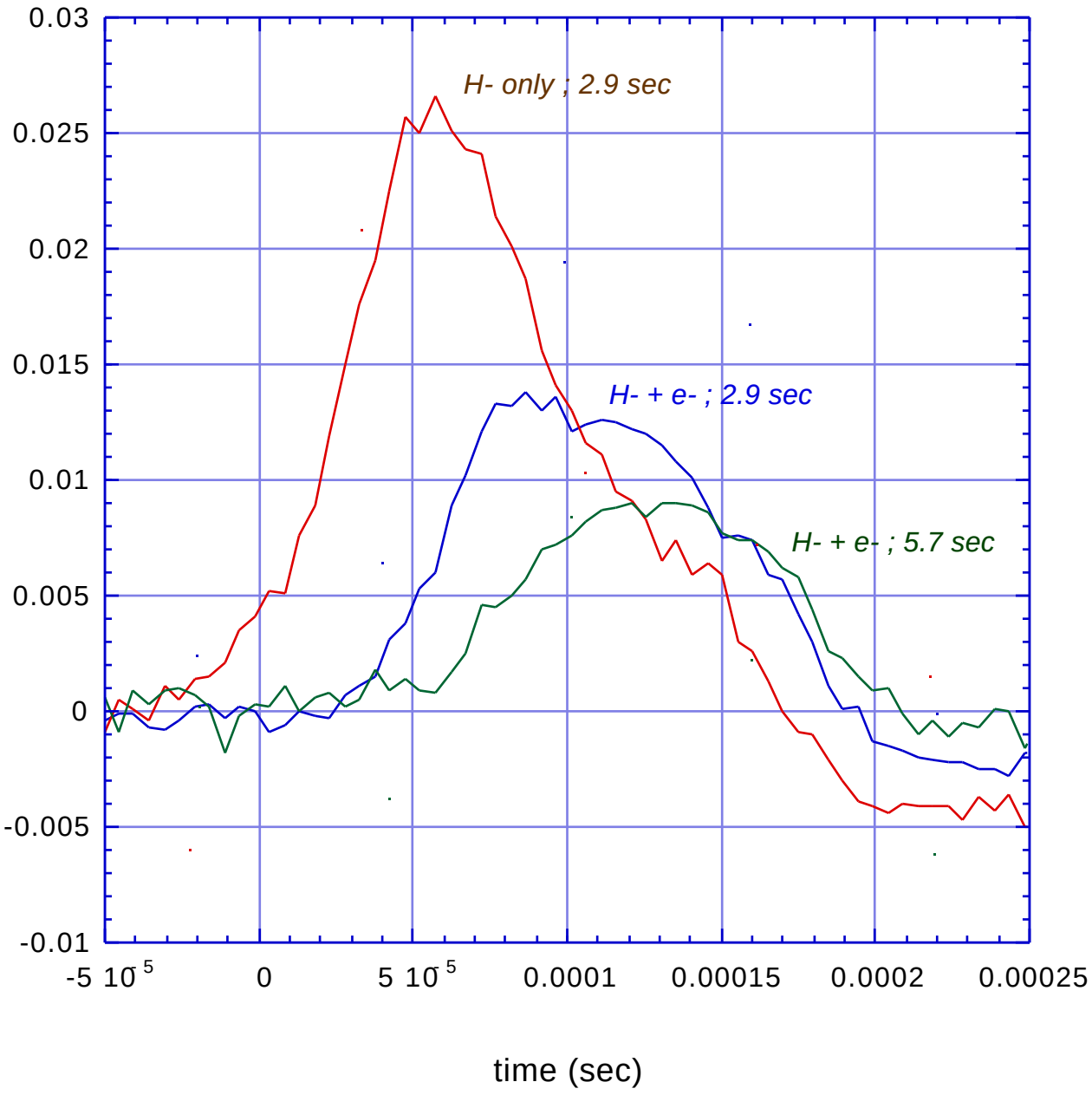




Time distribution of extracted H^- (H^- only)



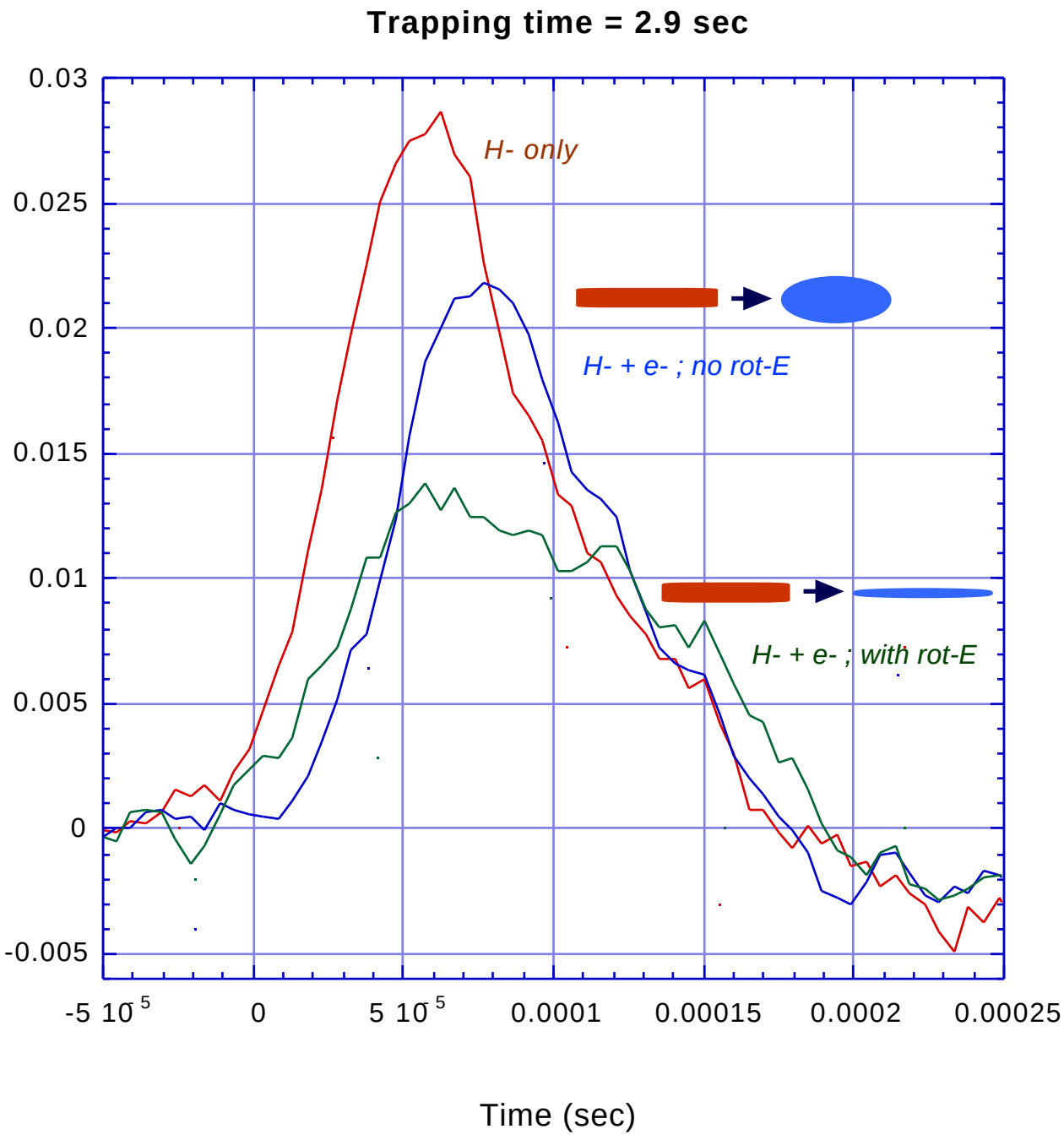
Time distribution of extracted H^-



H^- ~ 2x10^6 for H^- only, 2.9 sec trapping

e^- ~ 1.5x10^8, loaded 70 sec before H^- injection

H^- cooling with/without rotating field



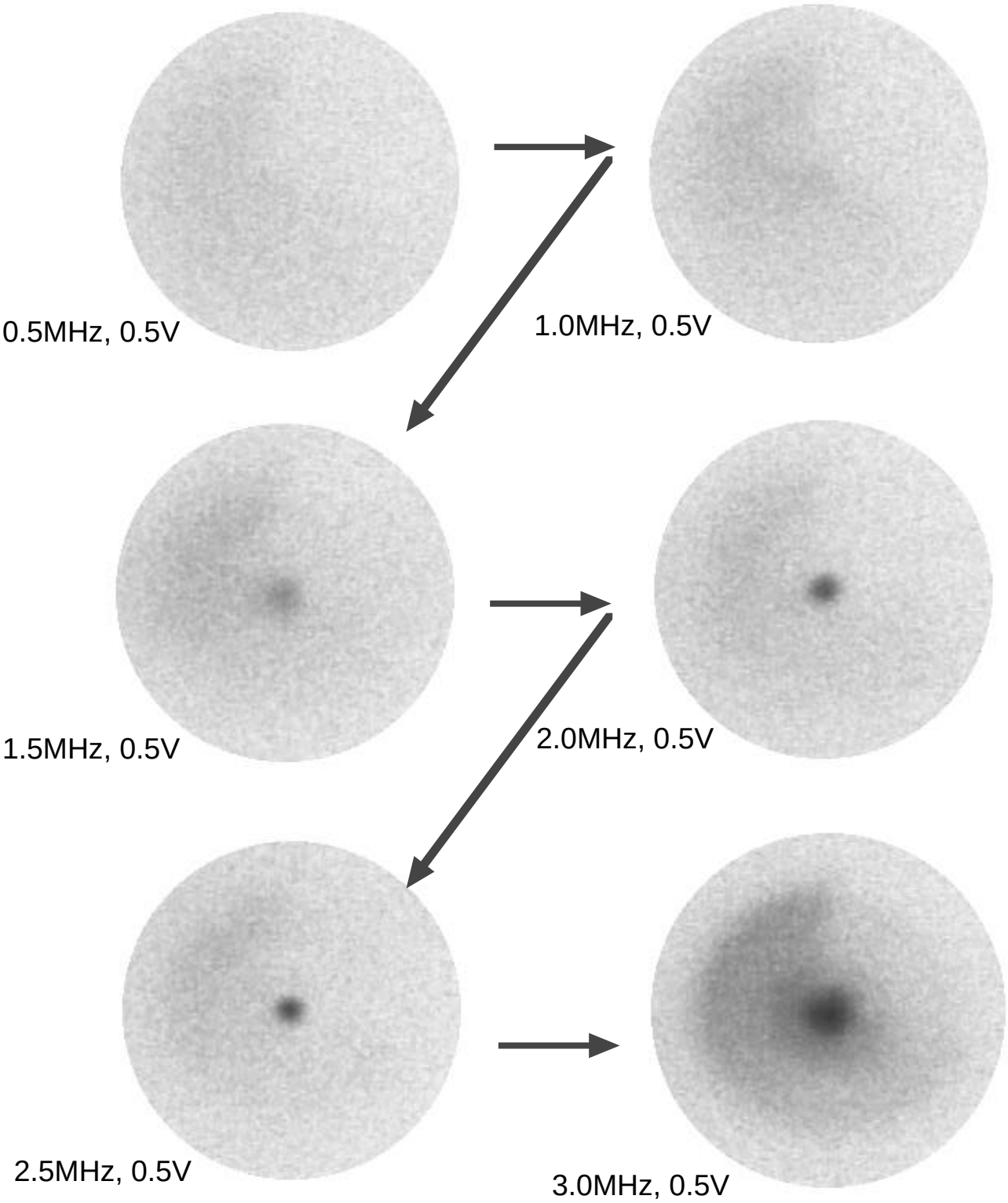
H^- ~ 2x10^6

e^- ~ 9x10^7

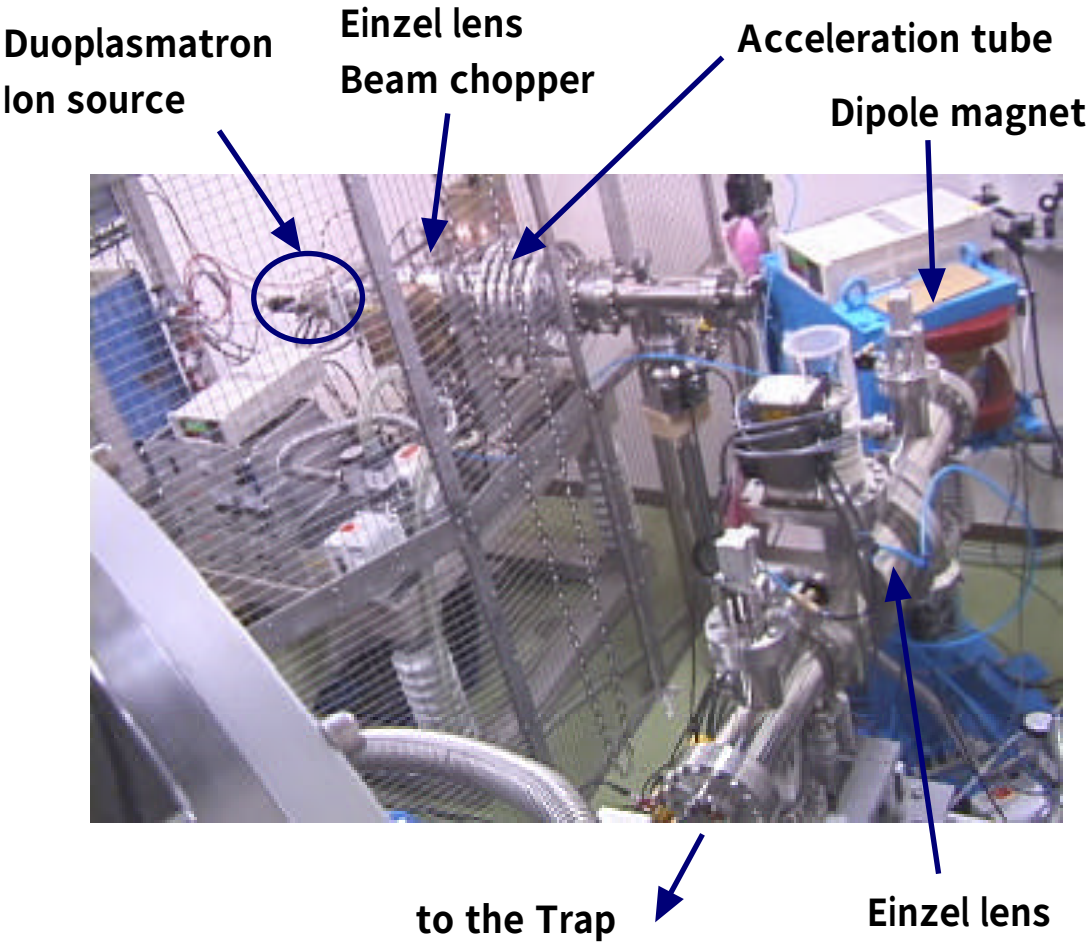
no rot-E : electrons loaded 70 sec before H^- injection
with rot-E : 60 sec wait
120 sec rotating field at 2MHz, 0.5V
30 sec wait before H^- injection

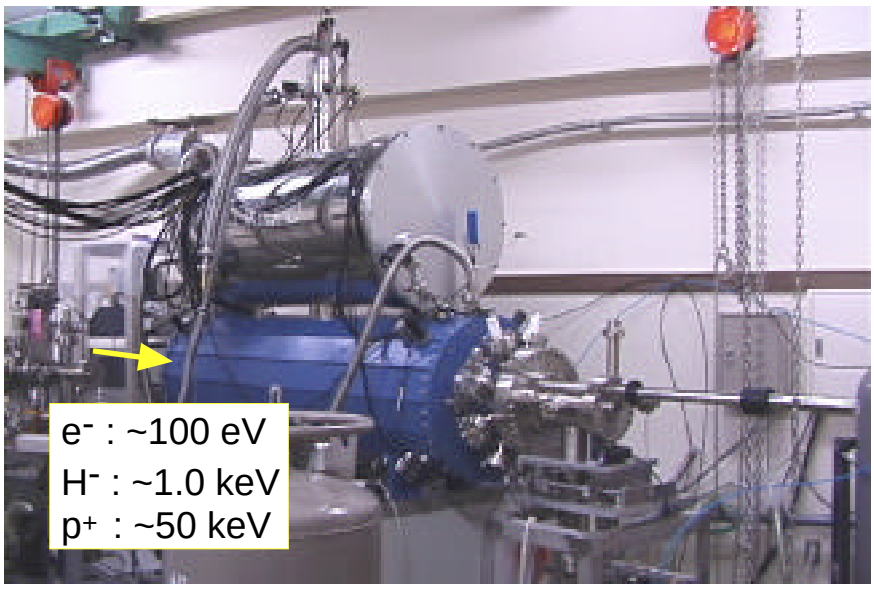
Change in the profile

$e^- \sim 1.3 \times 10^8$
60sec wait + 60sec rot-E



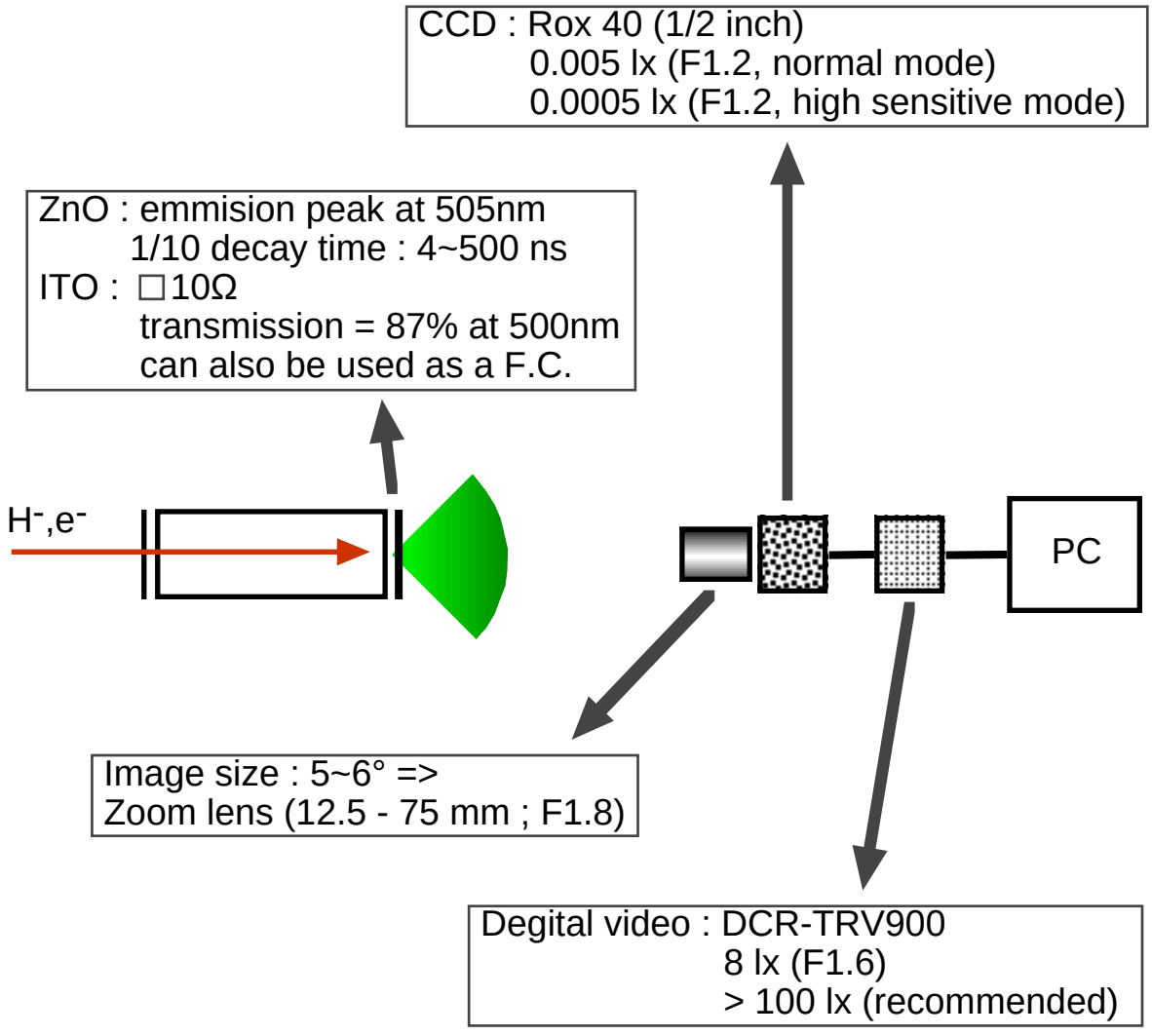
Ion beam line





ASACUSA
Trap group

Luminescence detection scheme



0.005 lx, 1000V acceleration => 4 x 10^7 electrons can be detected.

まとめ

(1) AD and ASACUSA project

Production of meV ~ eV antiprotons is essential to the experiments.

(2) Design of the ASACUSA trapping system

- Multi-ring harmonic trap
  (harmonic region ～ 10cm)
  Electron cooling of $10^{6\sim 8}$ antiprotons
  Active control and monitoring of plasma

(3) Experiment with electrons

- life time measurement > 1000 sec
- Centering of electron plasmas
  by rotating E-field : ø < 2mm

(4) Simulation experiments with negative hydrogens

- electron cooling was observed.

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