非中性陽電子プラズマの形成とその応用

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b) 理研・原子物理

Motivation

RIKEN Project :
Cold HCI beam (<~eV/q) generation project.

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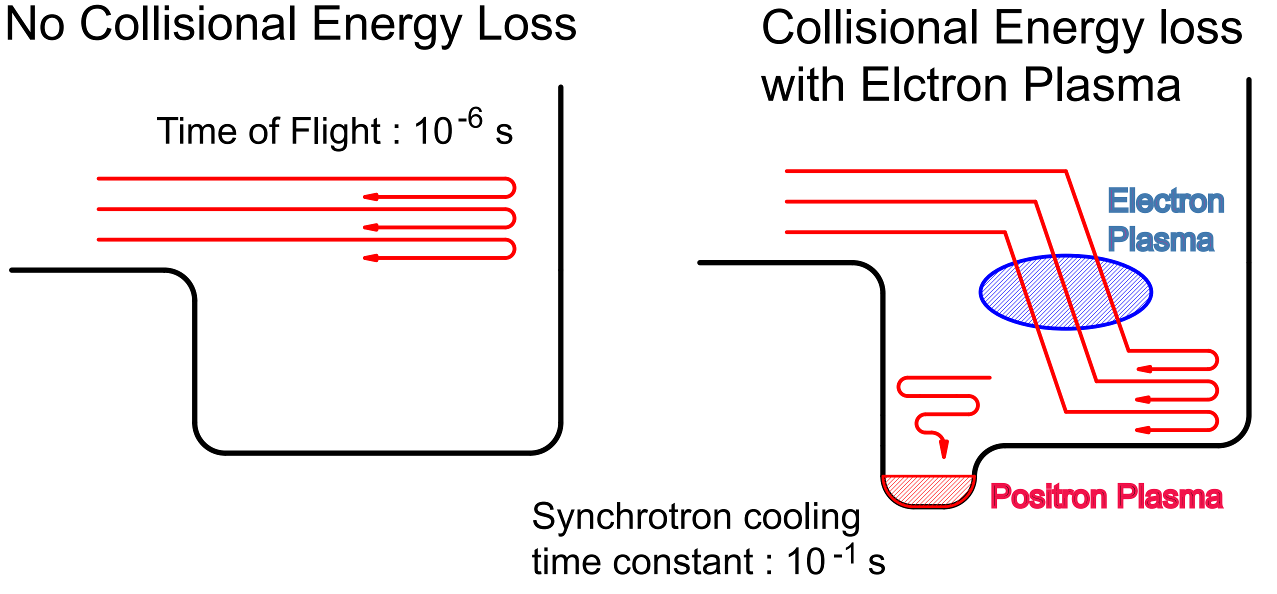
Requirements :
* Positrons of $>10^6$ for positron cooling of HCIs
* UHV ($<10^{-11}$Torr) to avoid recombination loss of HCIs

e$^+$ accumulator works in UHV
with relatively high efficiency

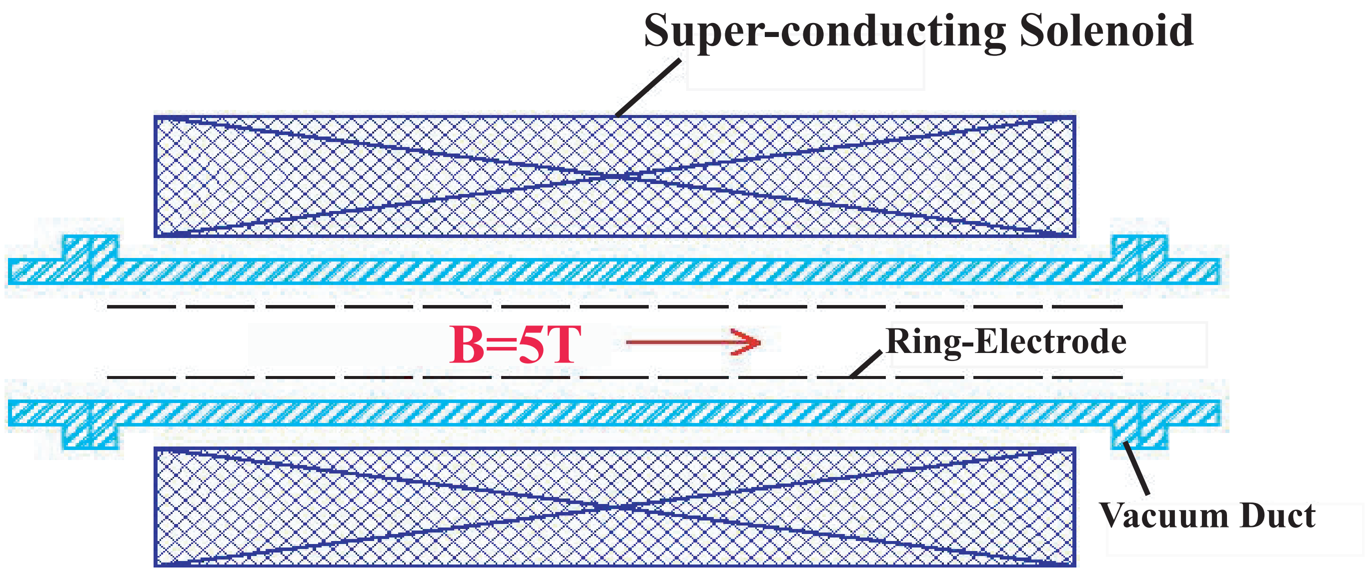
Concept of the new accumulation

Collisional dumping with trapped electrons : GAS FREE

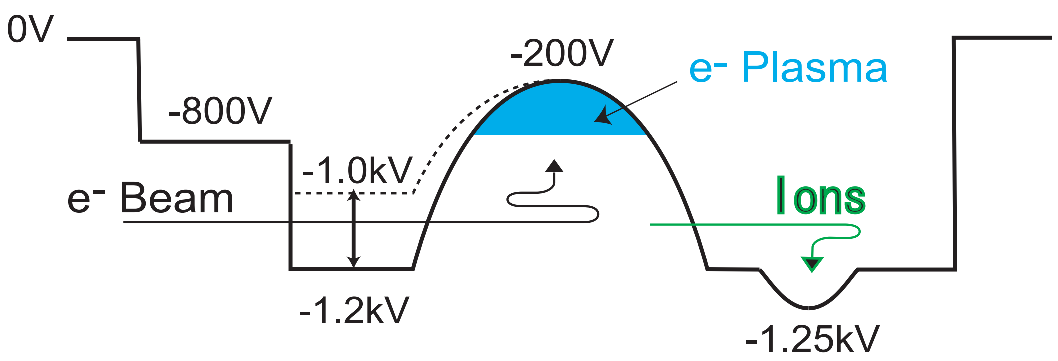


Positron Accumulation Scheme

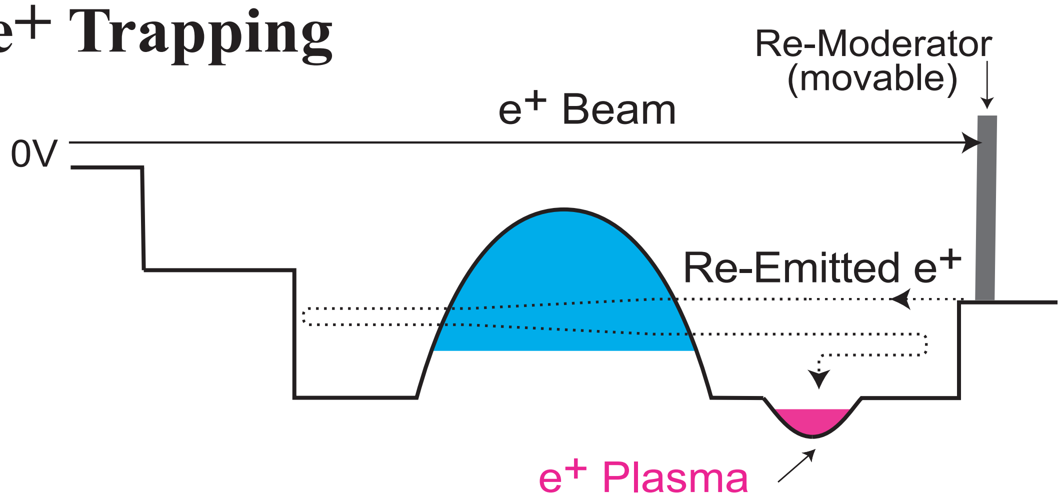
Multi-Ring Trap (MRT)



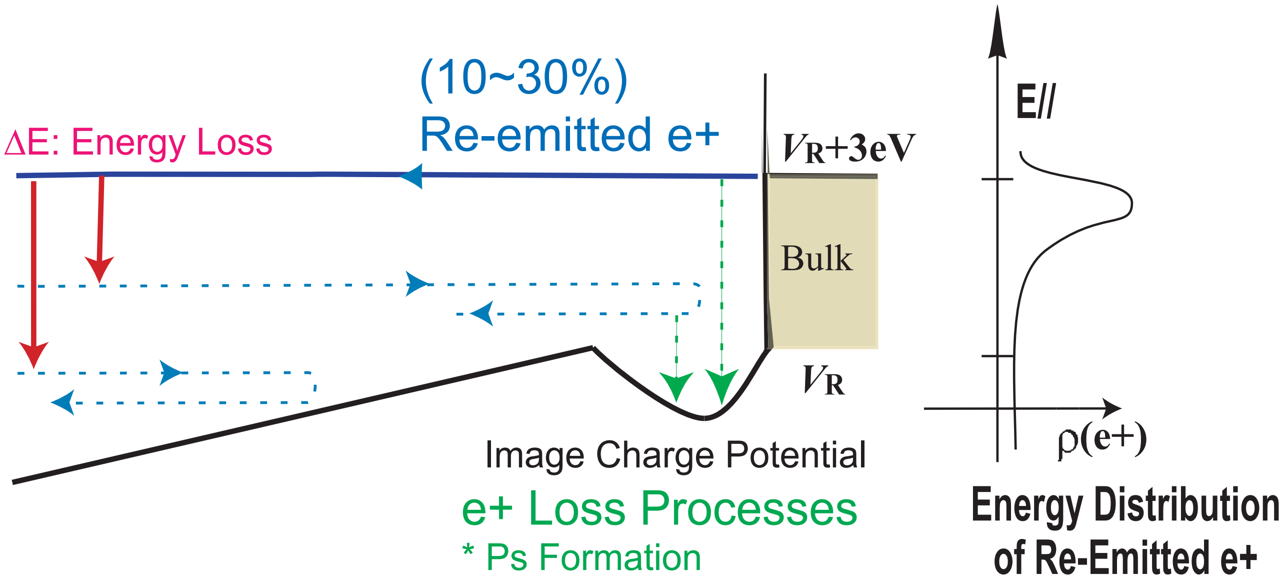
a) e^- Plasma Formation



b) e^+ Trapping

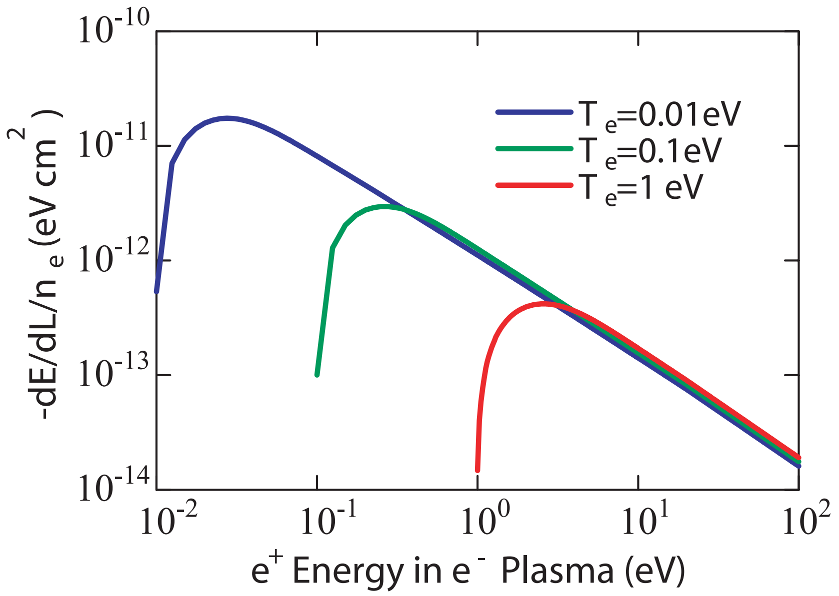


Required ΔE of e^+ for Thier Accumulation



(In case of W)
If ΔE is >~3eV, re-emittd e+ would be accumulated.

Required e^- Plasma for e^+ Accumulation



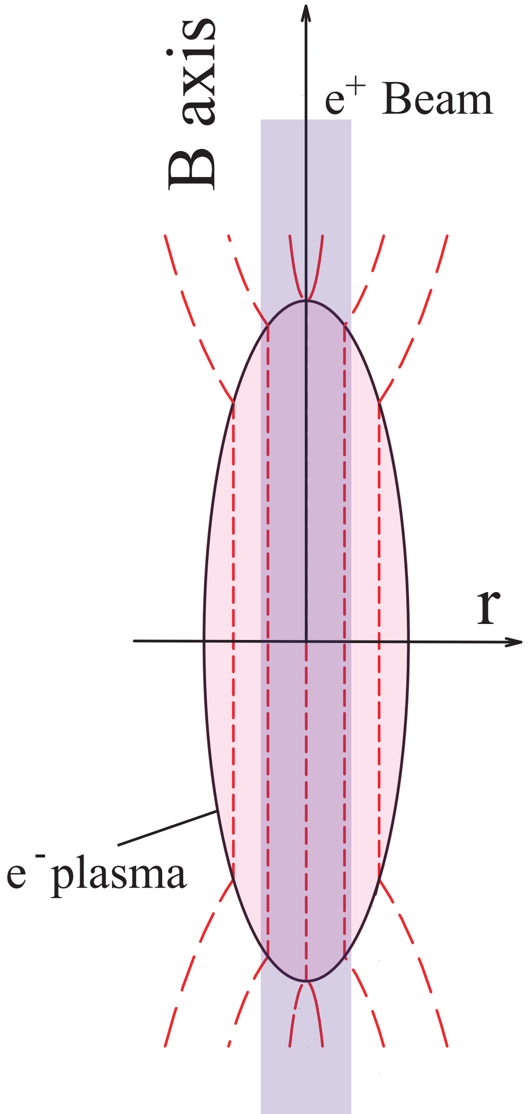
$-dE/dL(eV/cm) = \alpha\, n_e(cm^{-3}) / E(eV)$ (α=~1.5×10^{-12}, if $T_e < E$)

$$E_{in} = (\Delta E/2) + (\alpha\, n_e\, L / \Delta E)$$

$$\Delta E_{in} < (2\, \alpha\, n_e\, L)^{1/2}$$

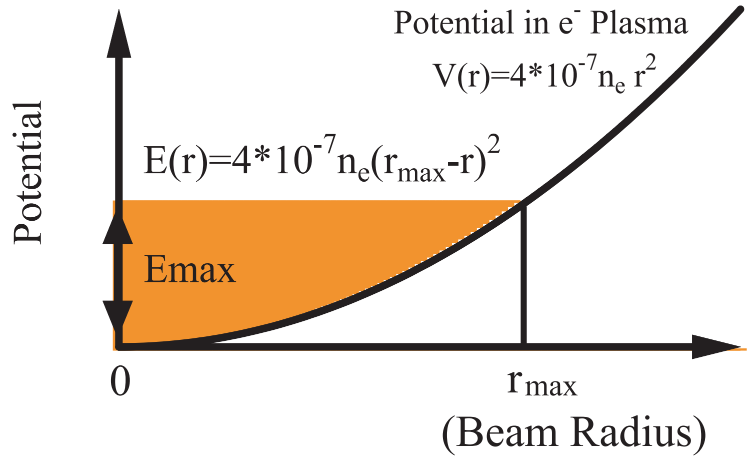
E_i: e^+ injection Energy
ΔE: Required Energy Loss (~3eV)
n_e: e^- Plasma Density
L : e^- Plasma Length

e^+ Injection Energy into e^- Plasma

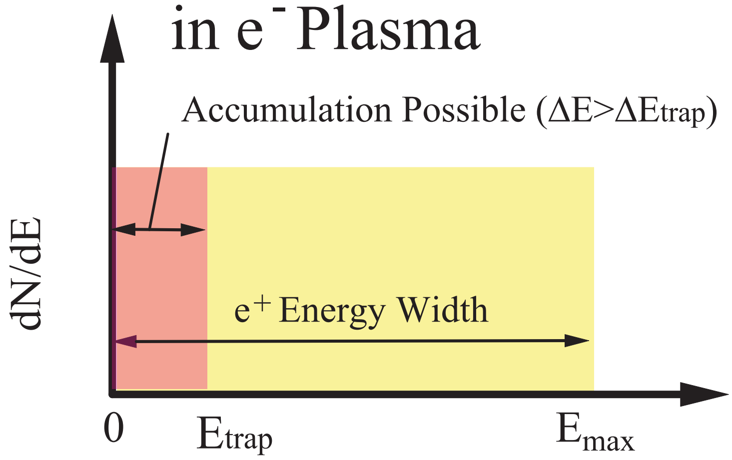


$$V(r)=(n_e e\, r^2)/(4\varepsilon_0)$$
$$= \beta\, n_e(cm^{-3})\, r^2\,(cm)$$
$$(\beta = \sim 4\times10^{-7}\,Vcm)$$

Potential in e^- Plasma



e^+ Energy Distrubution in e^- Plasma



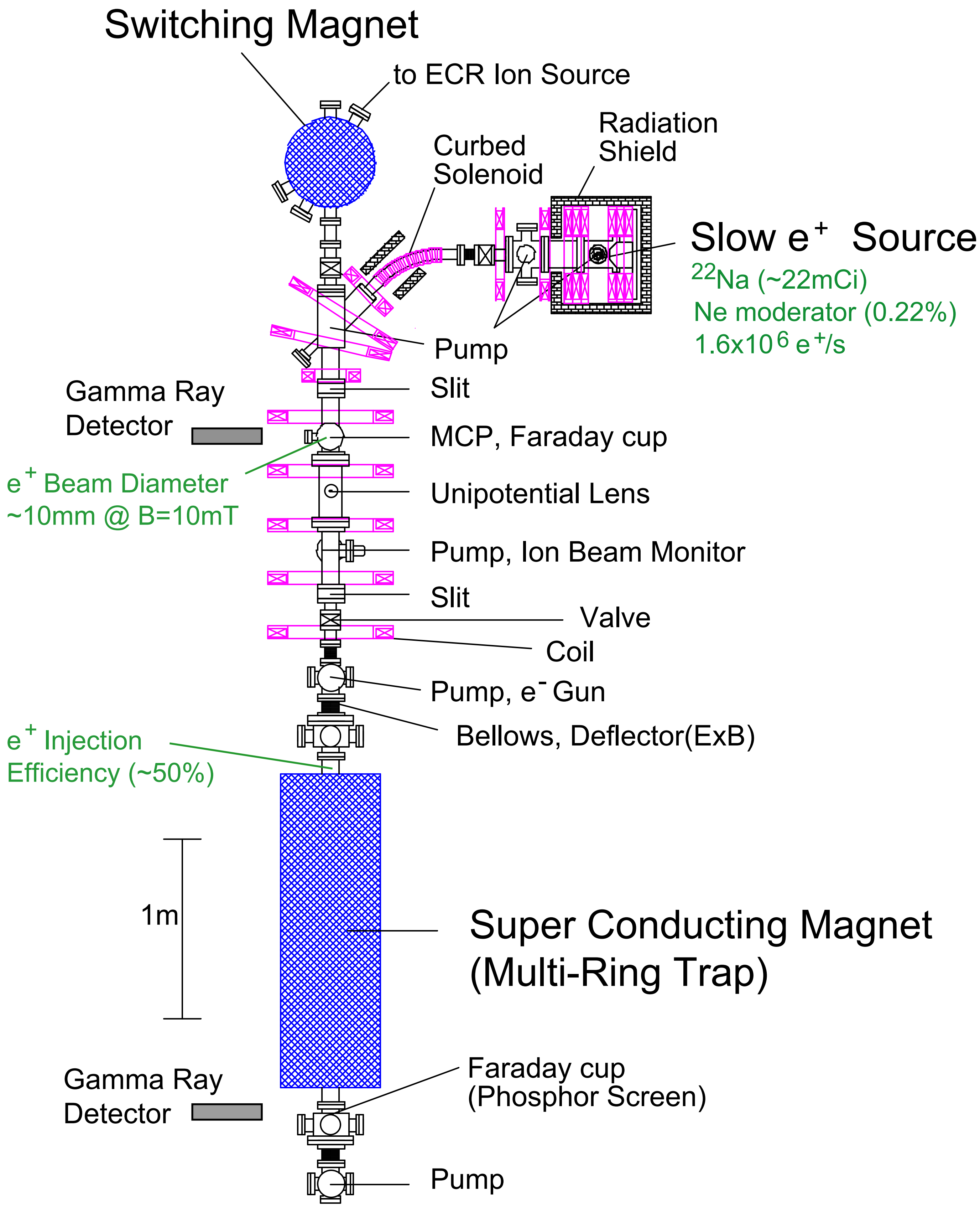
If e^+ beam flux density is flat,
$dN/dE=dN/dr \times dr/dE=1/E_{max}$

Accumulation Efficiency of Re-emitted e^+

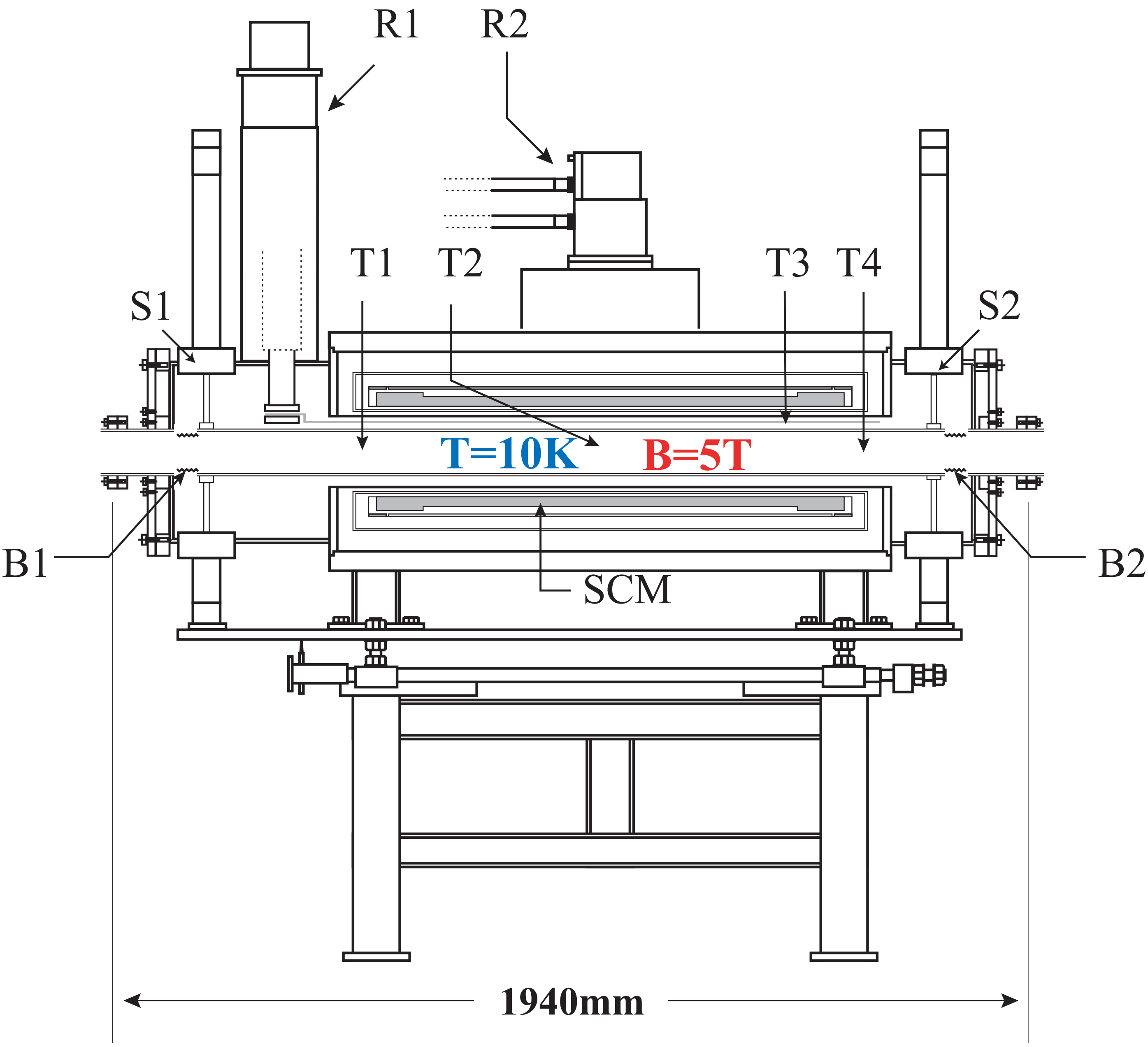
(Order Estimation)

$$\frac{E_{trap}}{E_{max}} = \frac{(\Delta E_{trap}/2) + (\alpha\, n_e\, L/\Delta E_{trap})}{\beta\, n_e r^2_{max}}$$

$(\alpha=1.5\times10^{-12}\,cm^2 eV^2,\ \beta=4\times10^{-7}\,cm\ eV)$

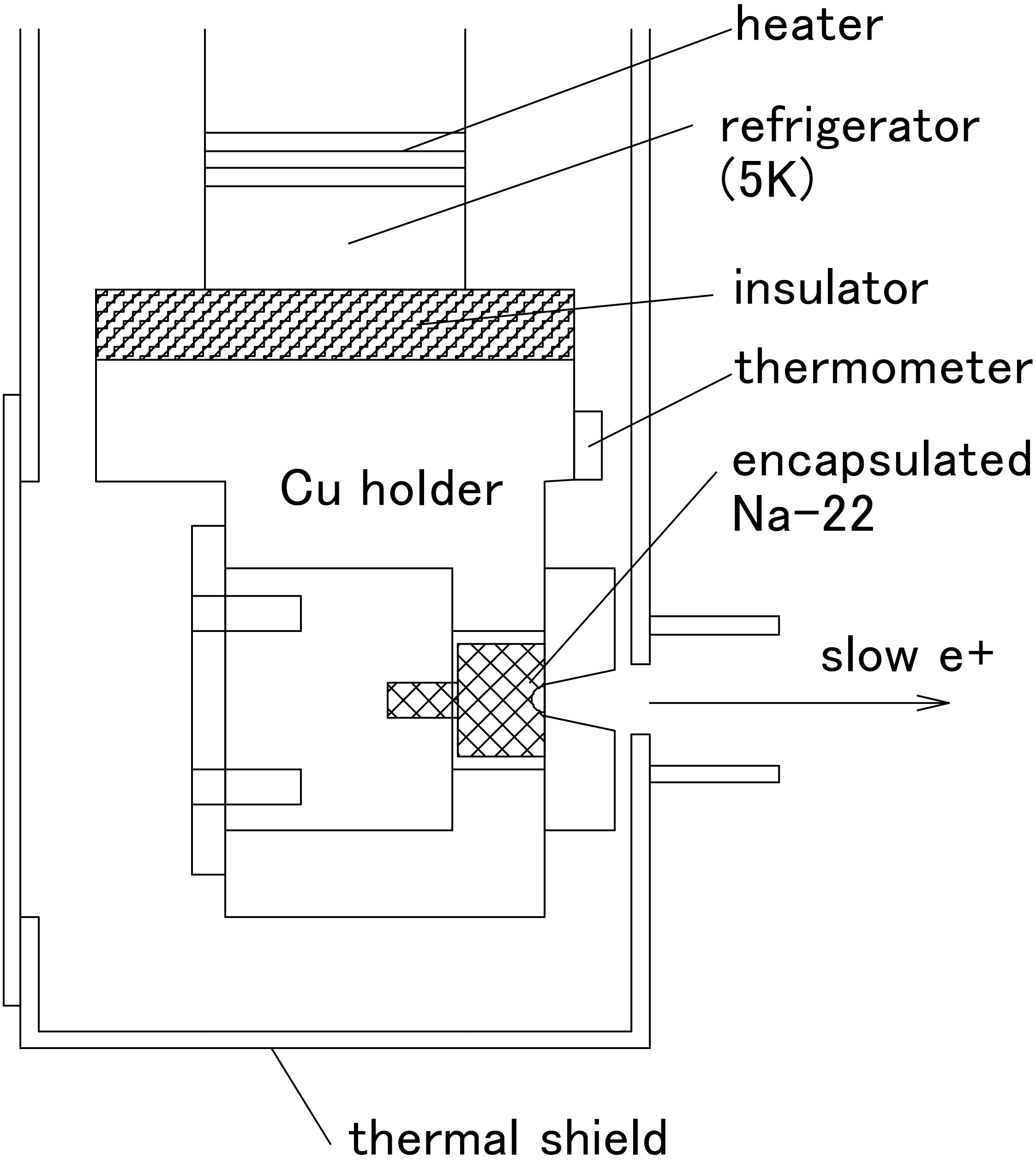

Switching Magnet
to ECR Ion Source
Curbed
Solenoid
Radiation
Shield
Slow e+ Source
22Na (~22mCi)
Ne moderator (0.22%)
1.6x10 6 e+/s
Pump
Gamma Ray
Detector
Slit
MCP, Faraday cup
e+ Beam Diameter
~10mm @ B=10mT
Unipotential Lens
Pump, Ion Beam Monitor
Slit
Valve
Coil
Pump, e- Gun
Bellows, Deflector(ExB)
e+ Injection
Efficiency (~50%)
1m
Super Conducting Magnet
(Multi-Ring Trap)
Gamma Ray
Detector
Faraday cup
(Phosphor Screen)
Pump

Superconducting Solenoid

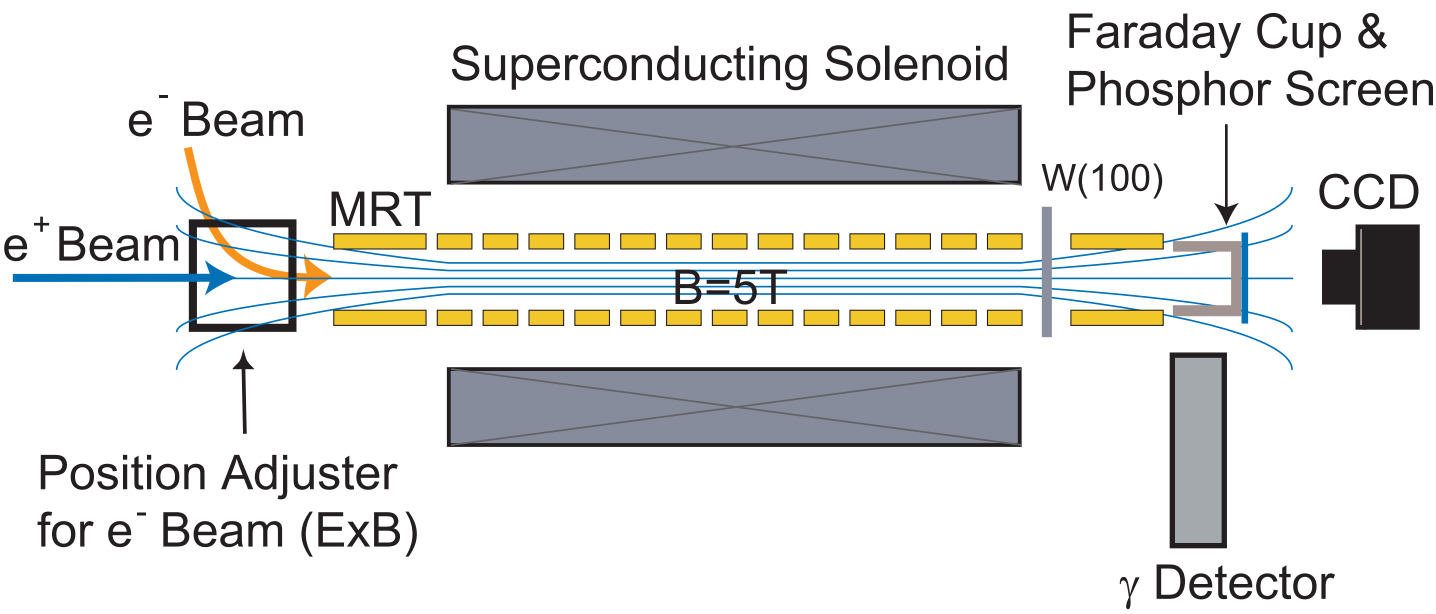


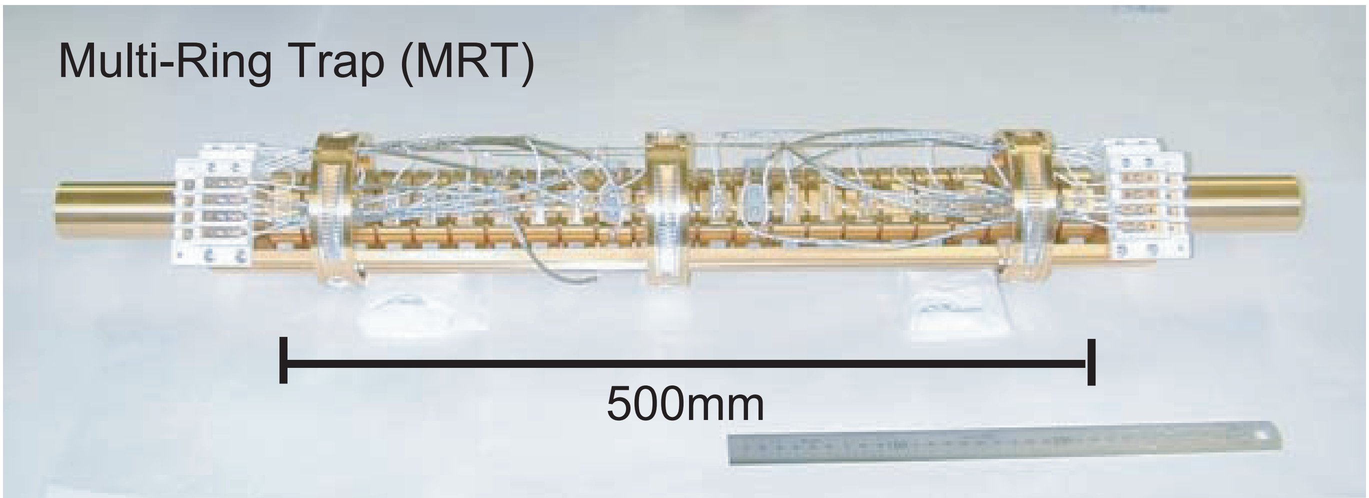
B1, B2	Bellows
SCM	Superconducting Solenoid
R1, R2	Refrigerator
S1, S2	Stepping Motor
T1, T2, T3, T4	Thermometer

Slow Positron Source

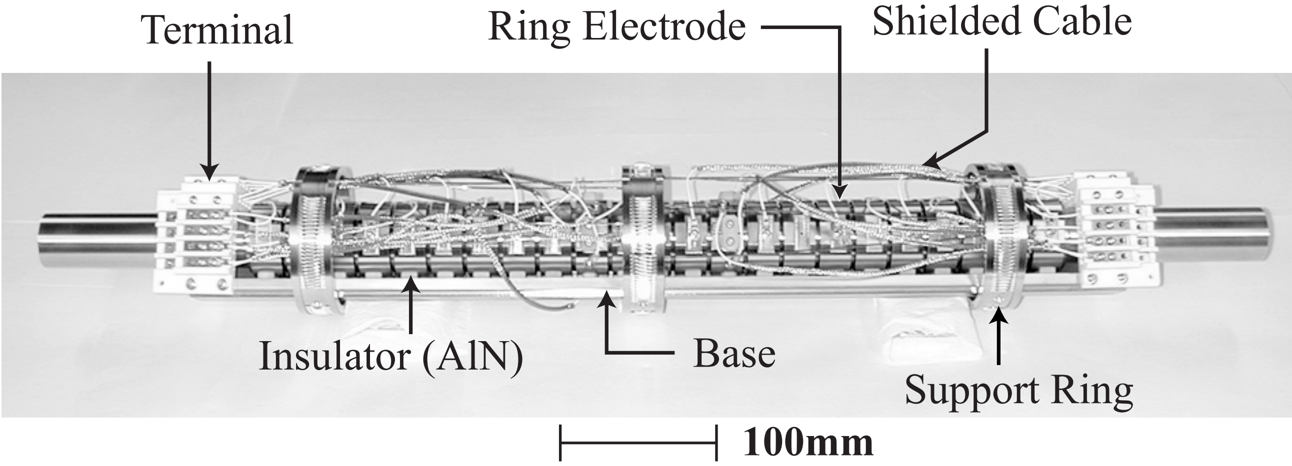


Experimetnal Setup

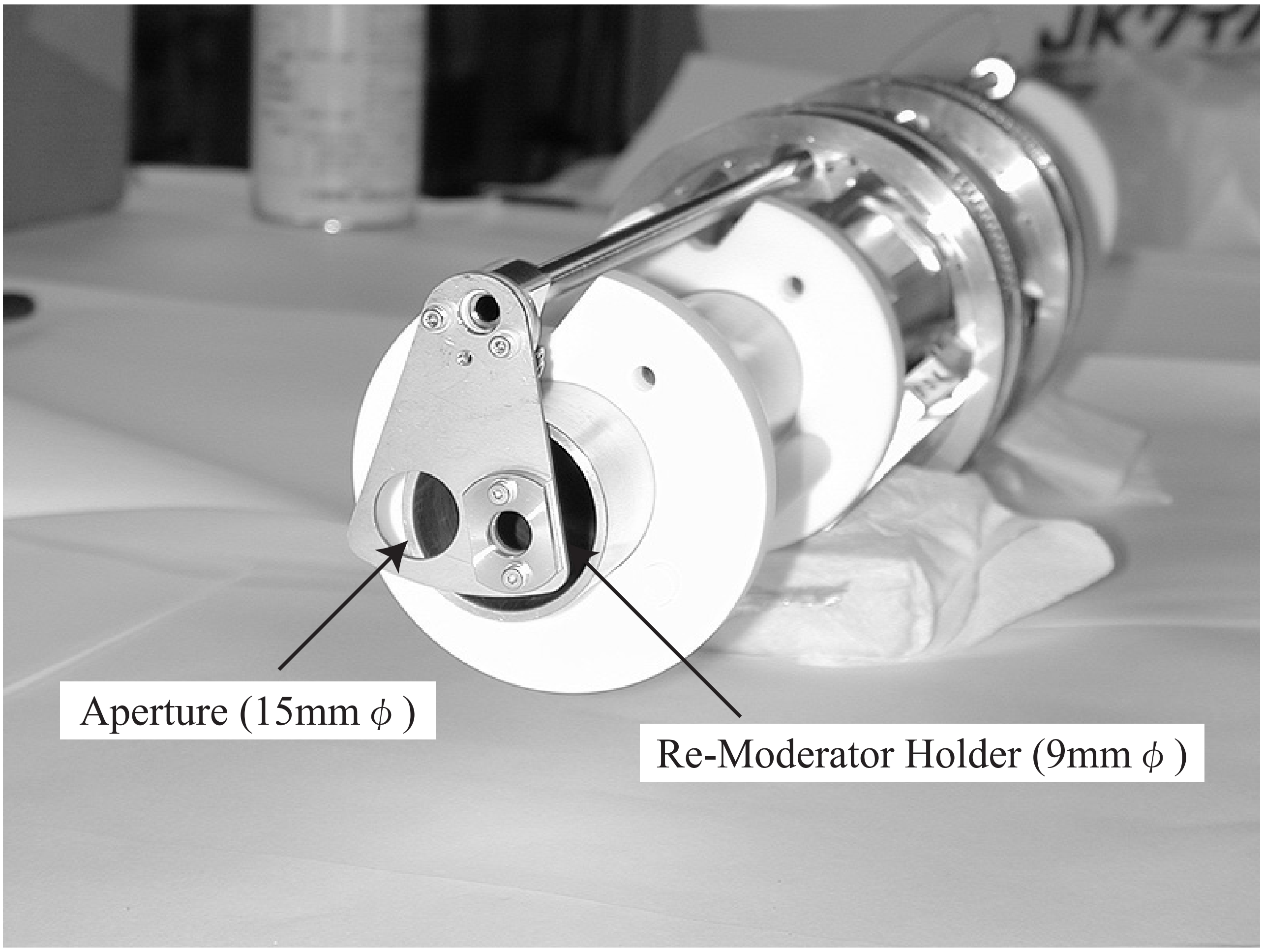




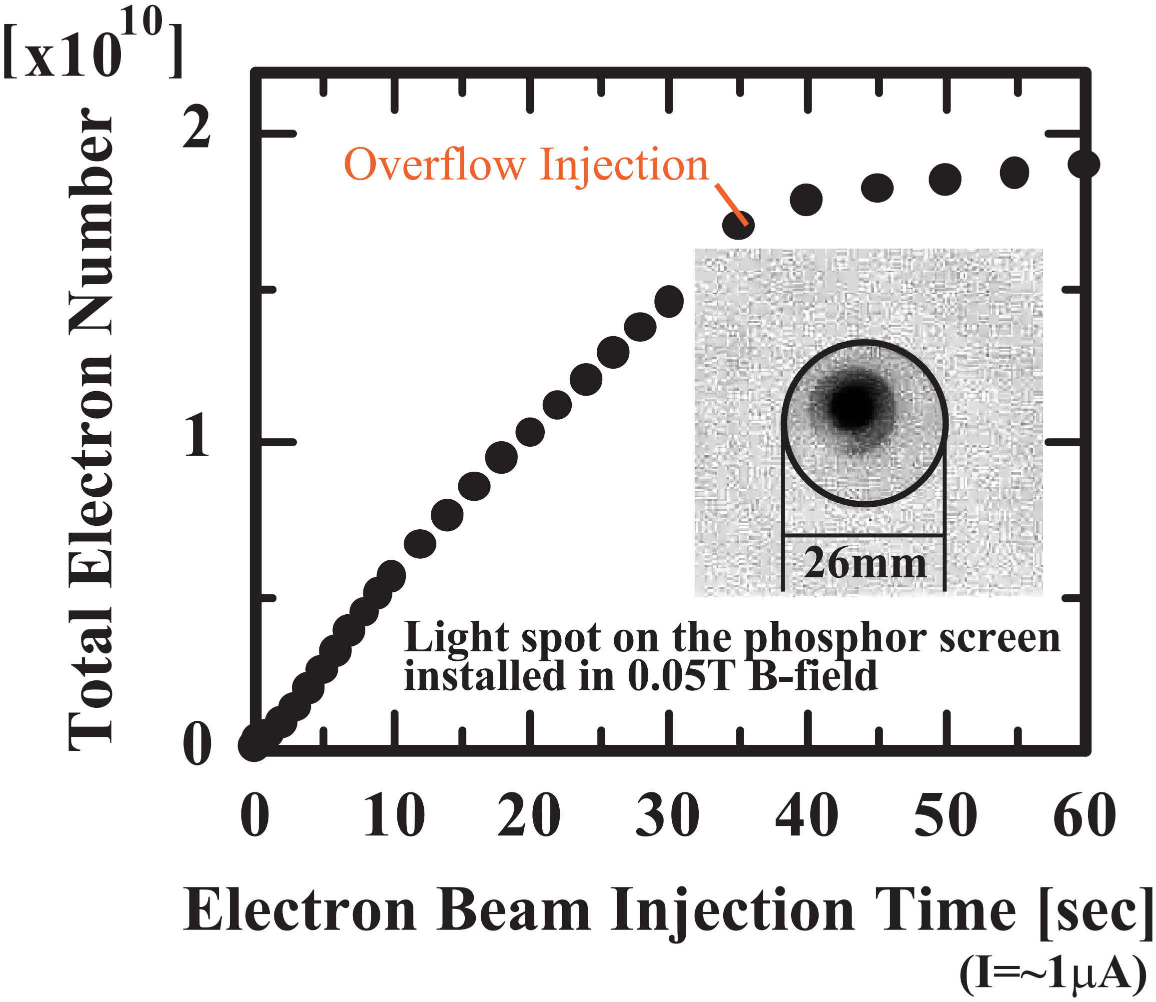
a) Multi-Ring Trap (MRT)



b) Re-Moderator Holder (movable)



Confiment of e⁻ Plasma



Plasma Parameters

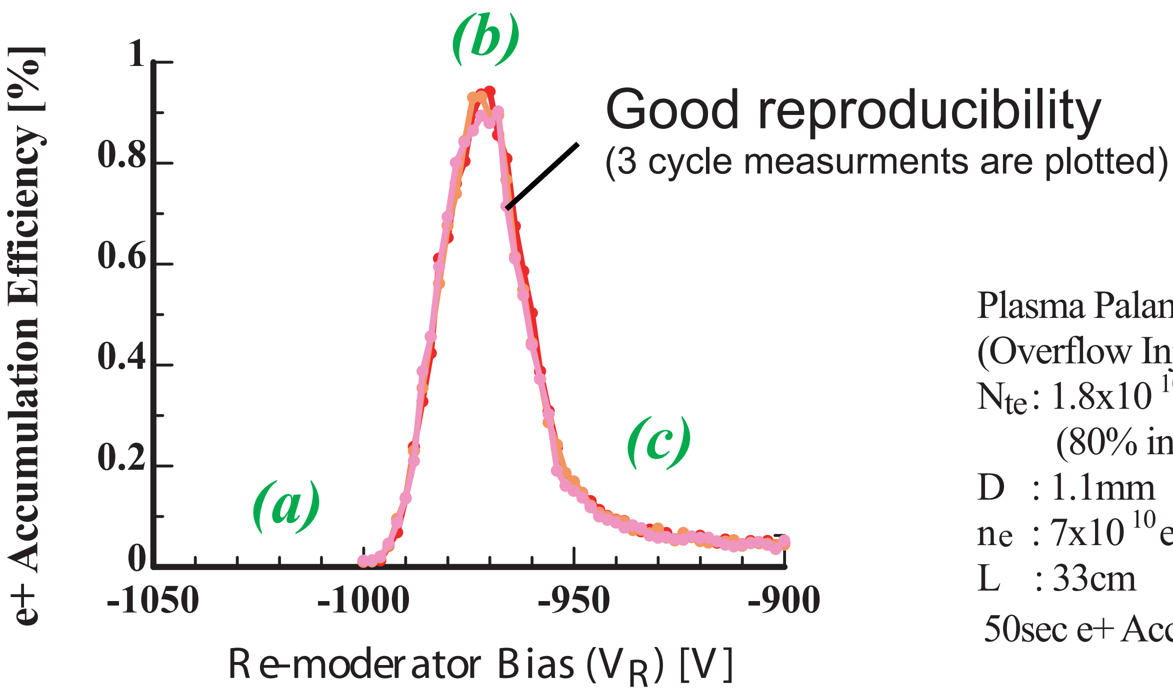
Total e^- Number : $N_{te}=1.8\text{x}10^{10}$
(80% in Spheroid)

Plasma Diameter : $D_{pla}=1.1$ (mm)

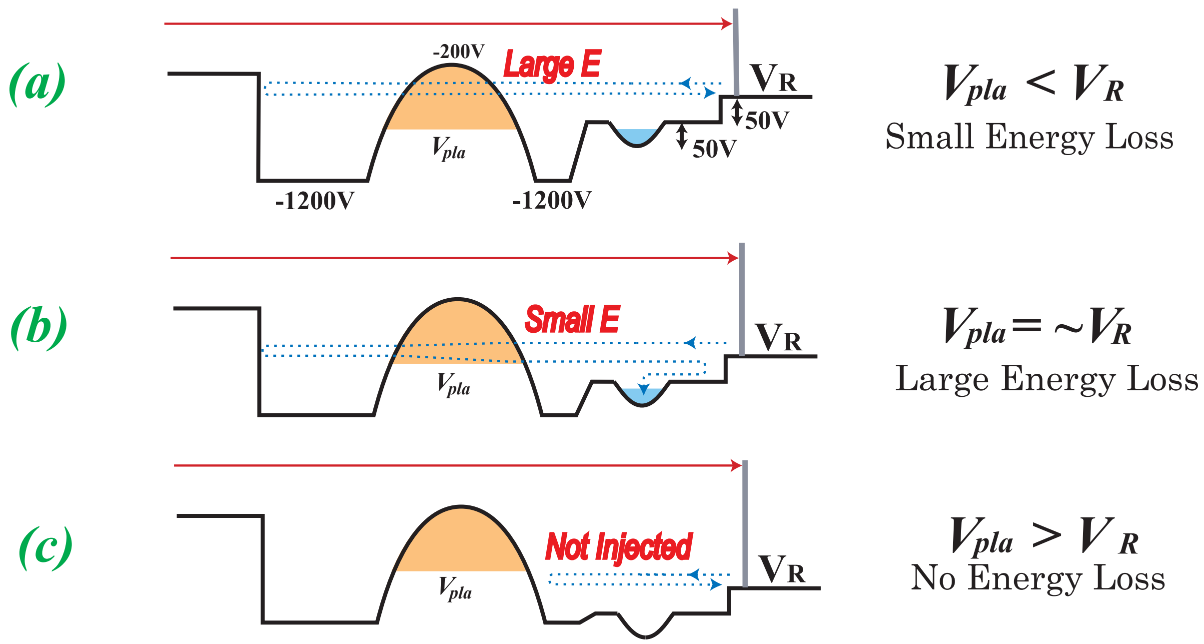
Plasma Length : $L_{pla}=33$ (cm)

e^- Density : $n_e=7\text{x}10^{10}(\text{cm}^{-3})$

Optimization of Re-moderator Bias



Plasma Palameters
(Overflow Injection)
N_{te}: 1.8×10^{10} e^-
(80% in Spheroid)
D : 1.1mm
ne : $7 \times 10^{10} e^- /cm^3$
L : 33cm
50sec e+ Accumulation



Estimation of e^+ Accumulation Efficiency (ε)

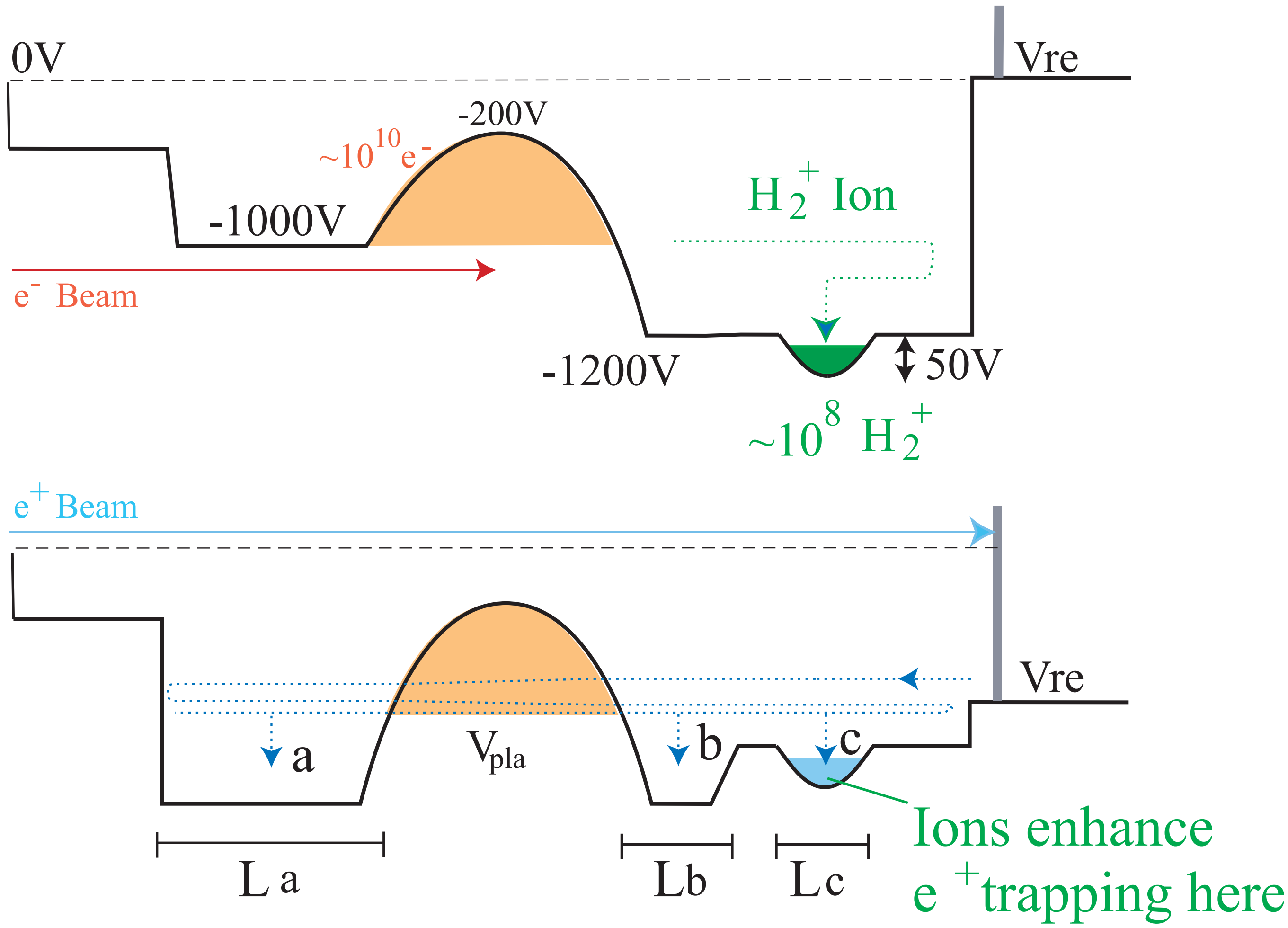
$$\varepsilon = \eta \times E_{trap} / E_{max} = \sim 0.02$$

$\eta = \sim 0.1$: Re-moderation Efficiency

$$\frac{E_{trap}}{E_{max}} = \frac{(\Delta E/2) + (\alpha\, n_e L / \Delta E)}{\beta\, n_e r_{max}^2} = \sim 0.20$$

$\Delta E = \sim 3\text{eV}$, $r_{max} = 2.5 \times 10^{-2}$ cm
($\alpha = 1.5 \times 10^{-12}$ cm^2 eV^2, $\beta = 4 \times 10^{-7}$ cm eV)

Effect of Positive Ions



$$L_c/(L_a+L_b+L_c) = \sim 0.14$$

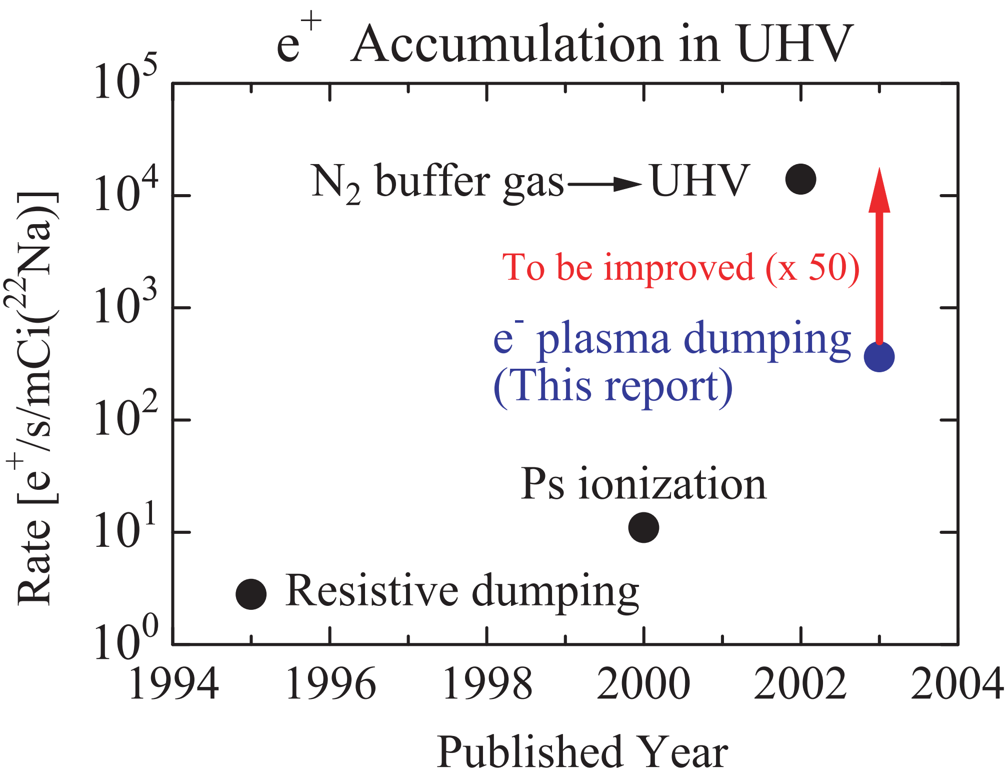
(Experimental Result)

$$\frac{\varepsilon\,(\text{WITHOUT ions})}{\varepsilon\,(\text{WITH ions})} = \sim 0.1$$

ε : e^+ Accumulation Efficiency into the Harmonic Well

Summary

* e^+ were accumulated directly into UHV trap with an e^- plasma
* Accumulation Efficiency
  1% (v.s. injected e^+ into re-moderator)
* Accumulation Rate
  $3.6\text{x}10^2$ e^+/s/mCi (^{22}Na)



To be improved	Accumulation Rate (x~50)
Ne moderator efficiency : 0.22% ---> 0.7%	x 3
e^+ injection efficiency : 50% ---> 100%	x 2
e^+ beam daiameter (@B=10mT) : 10mm ---> 5mm	x 4
e^- plasma length : 30cm ---> 60cm	x 2
Re-moderator	
W(-3eV) ---> Cu(-1eV) : low required energy loss	x ?
In site annealing : higher re-moderation efficiency	x ?

SPring8 Positron Source

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Positron Trap

Positron Trap Applications

Plasma Physics

(e+ e- Plasma,   Astrophysics, e+ cooling)

Low Energy Collision

(Interaction with Gases)

Anti-Matter Production

(Cold Hbar Production)

High Quality Positron Beam Source

(Ultra Low Energy Beam / Micro Beam)

High Density Positronium Production

(Ps TOF, Ps BEC, Ps Beam, Hbar Production)