Current status of the AIST slow positron facility

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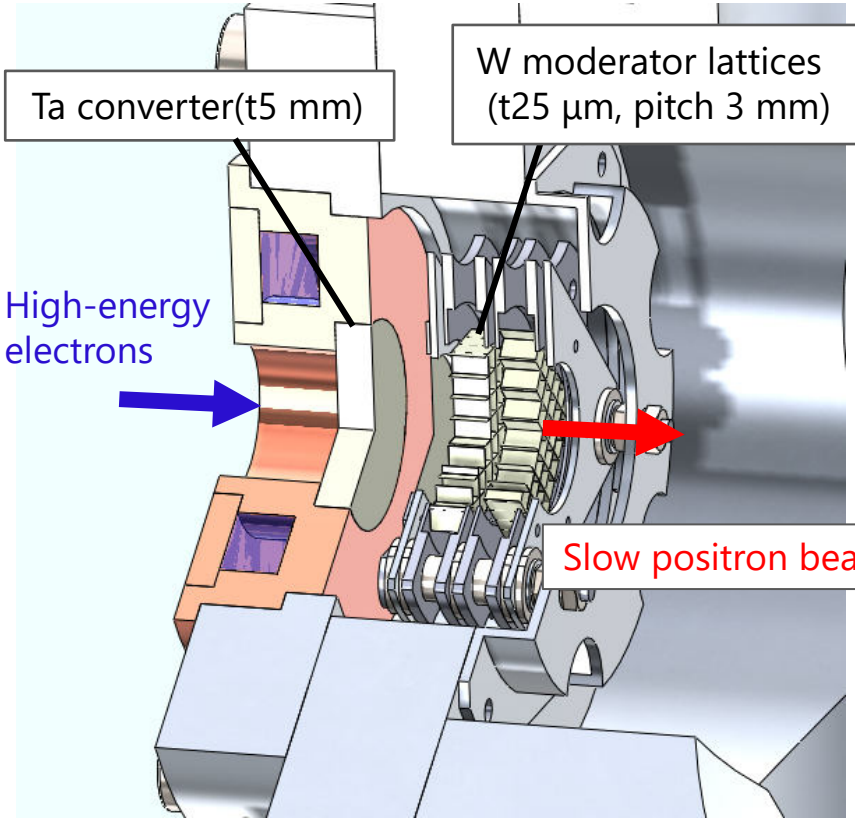
Outline

- AIST slow positron facility
- Beamline reconstruction
- Vertical positron beam for PALS
- Positron microbeam (PPMA)
- Positron trap
- Summary

AIST slow positron facility

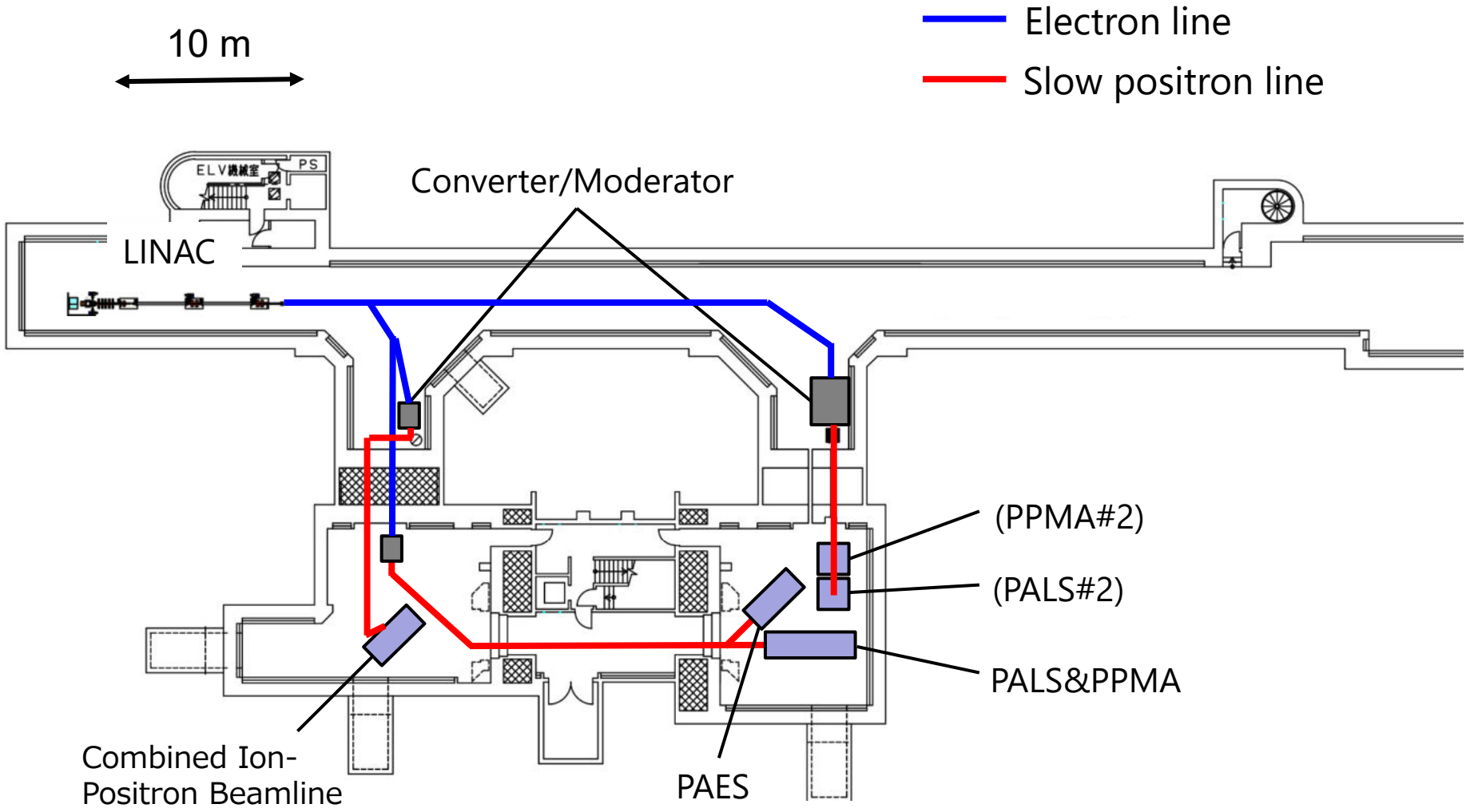
Dedicated electron LINAC

- Acceleration energy：40 MeV
- Power：several hundreds W
- Pulse width：2 μs
- Repetition rate：1- 70 Hz

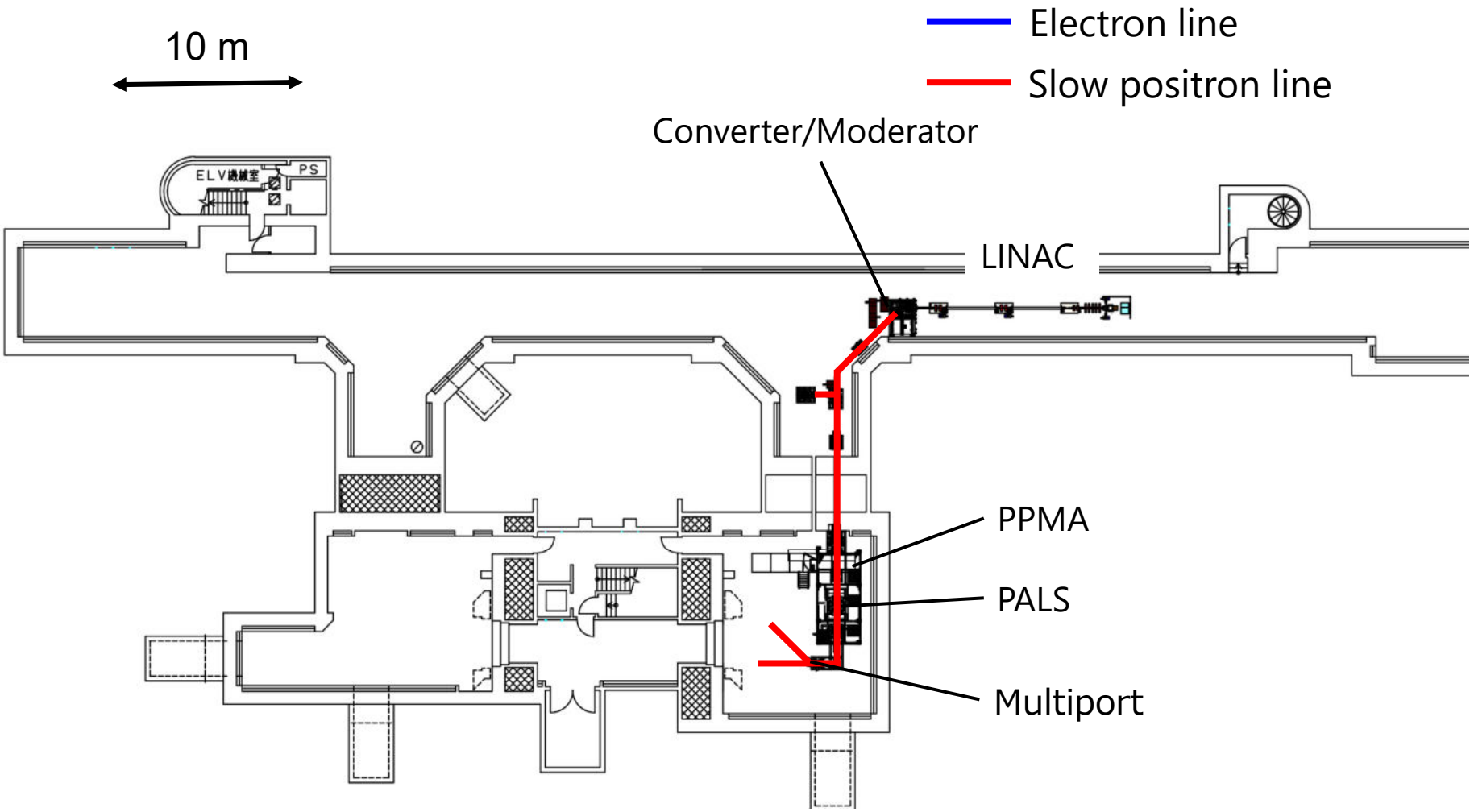


- Intensity：~10^7 slow e^+/s
- diameter：~15 mm
- transport energy：10 eV

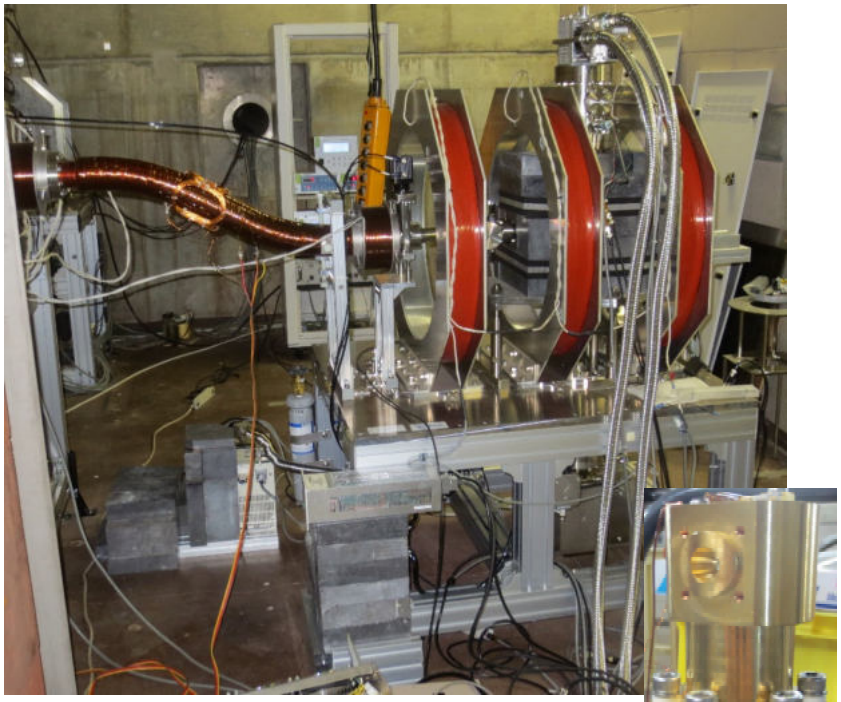
Beamline reconstruction(2014)



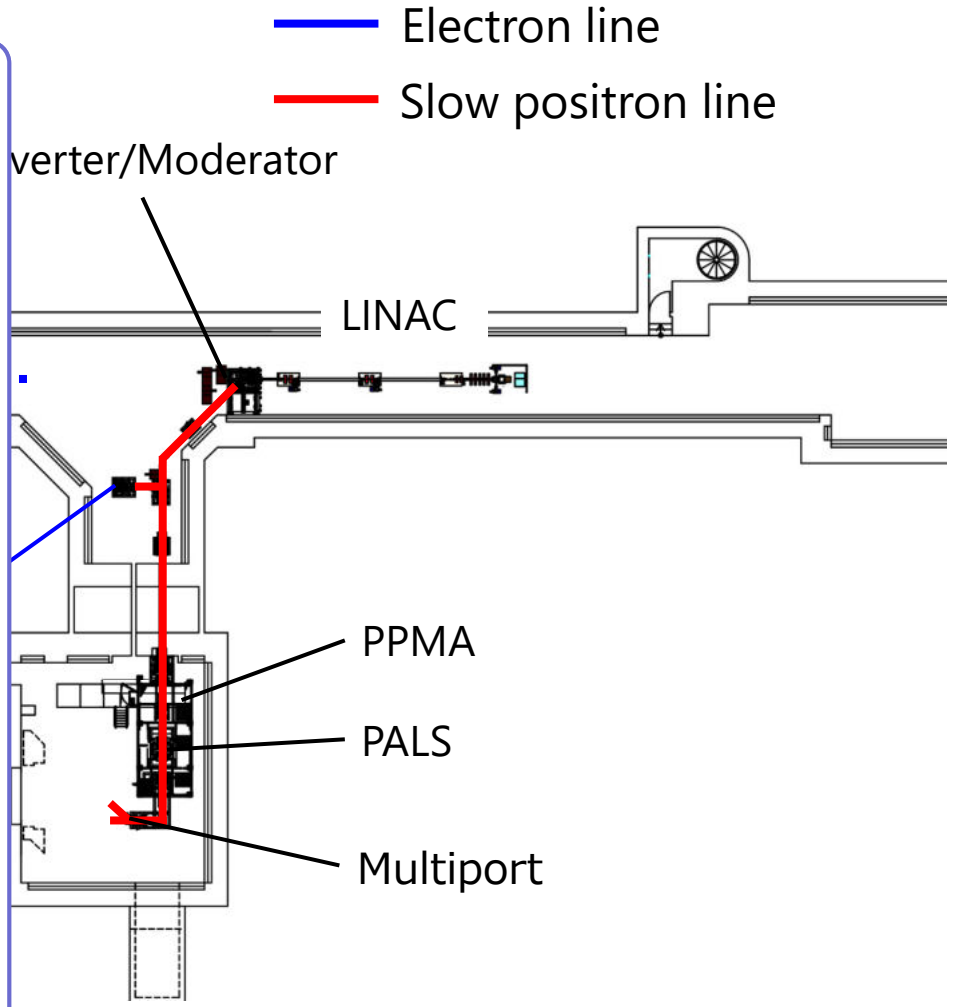
Beamline reconstruction(2019)

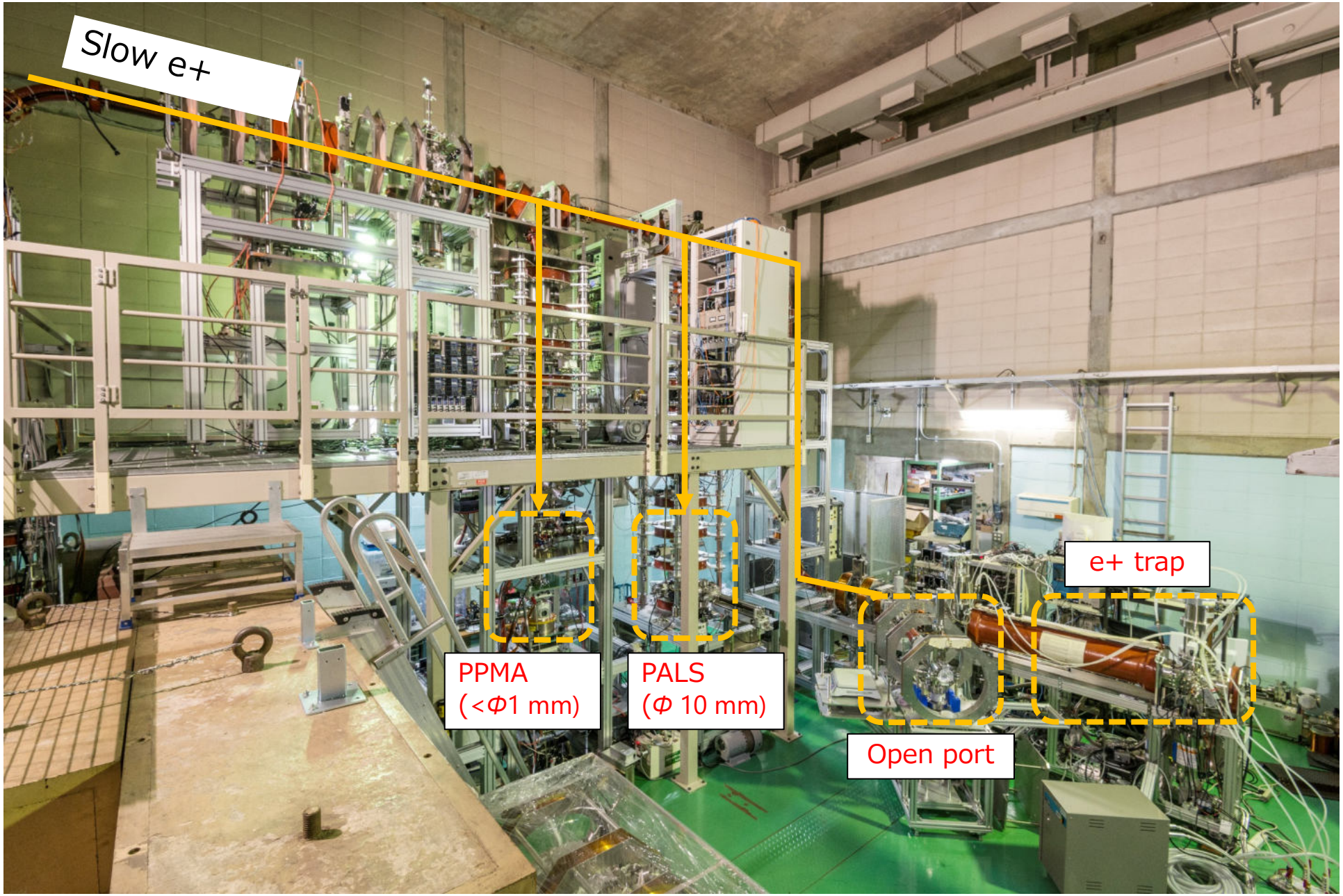


Beamline reconstruction(2019)



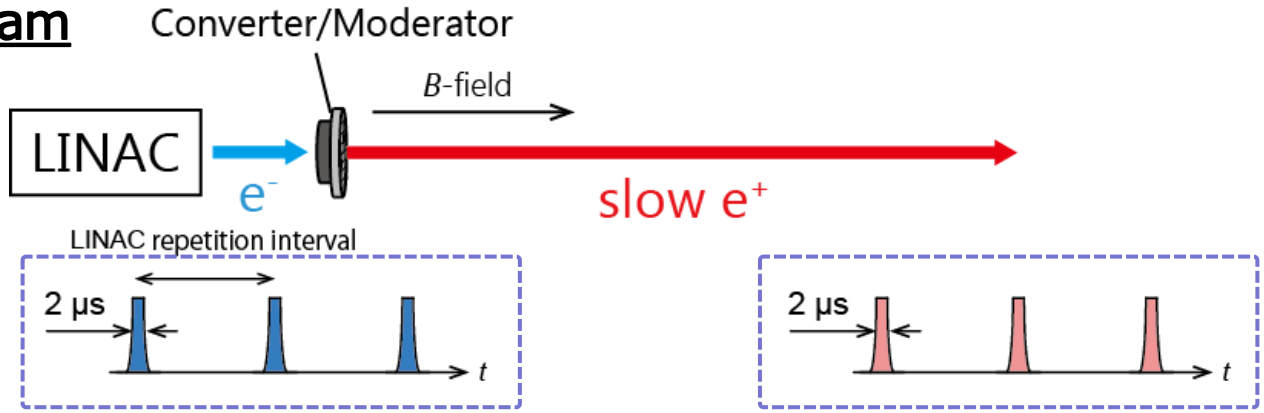
RI based slow e^+ beam
- moderator : solid Ne
- moderation eff. : ~0.7%
- used for tuning systems and DB measurements



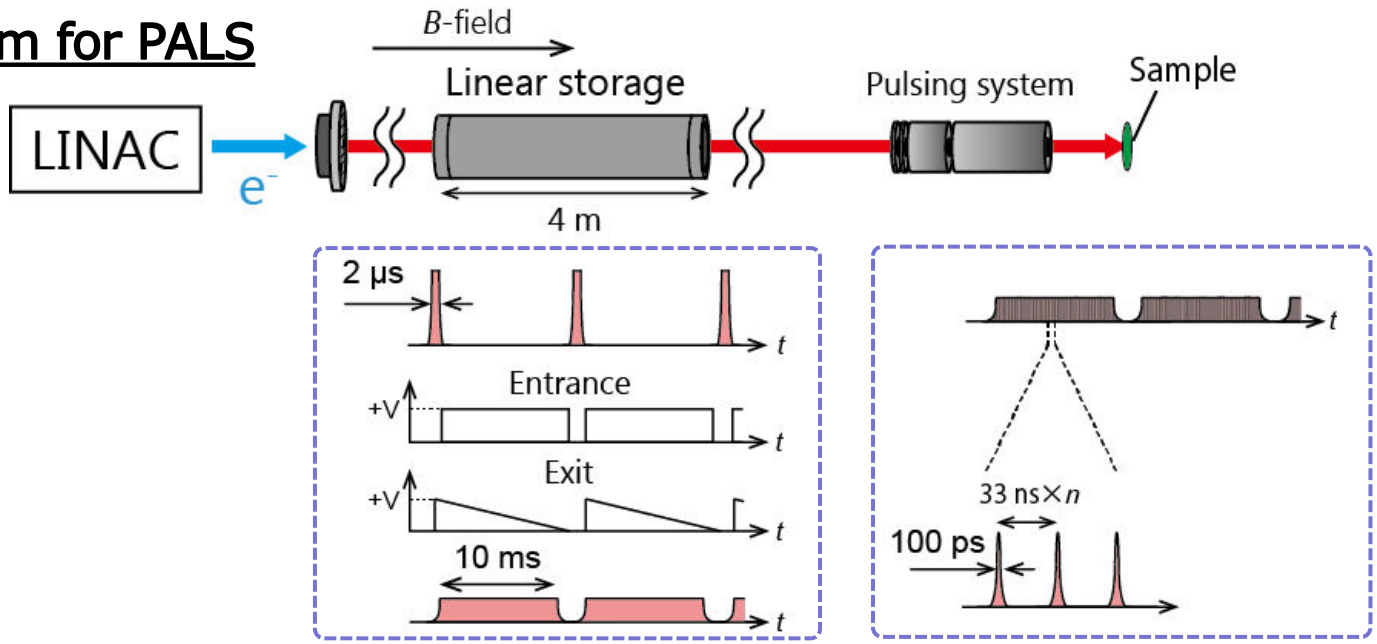

Slow e+
PPMA
(<Φ1 mm)
PALS
(Φ 10 mm)
e+ trap
Open port

Time structure of slow posittrons

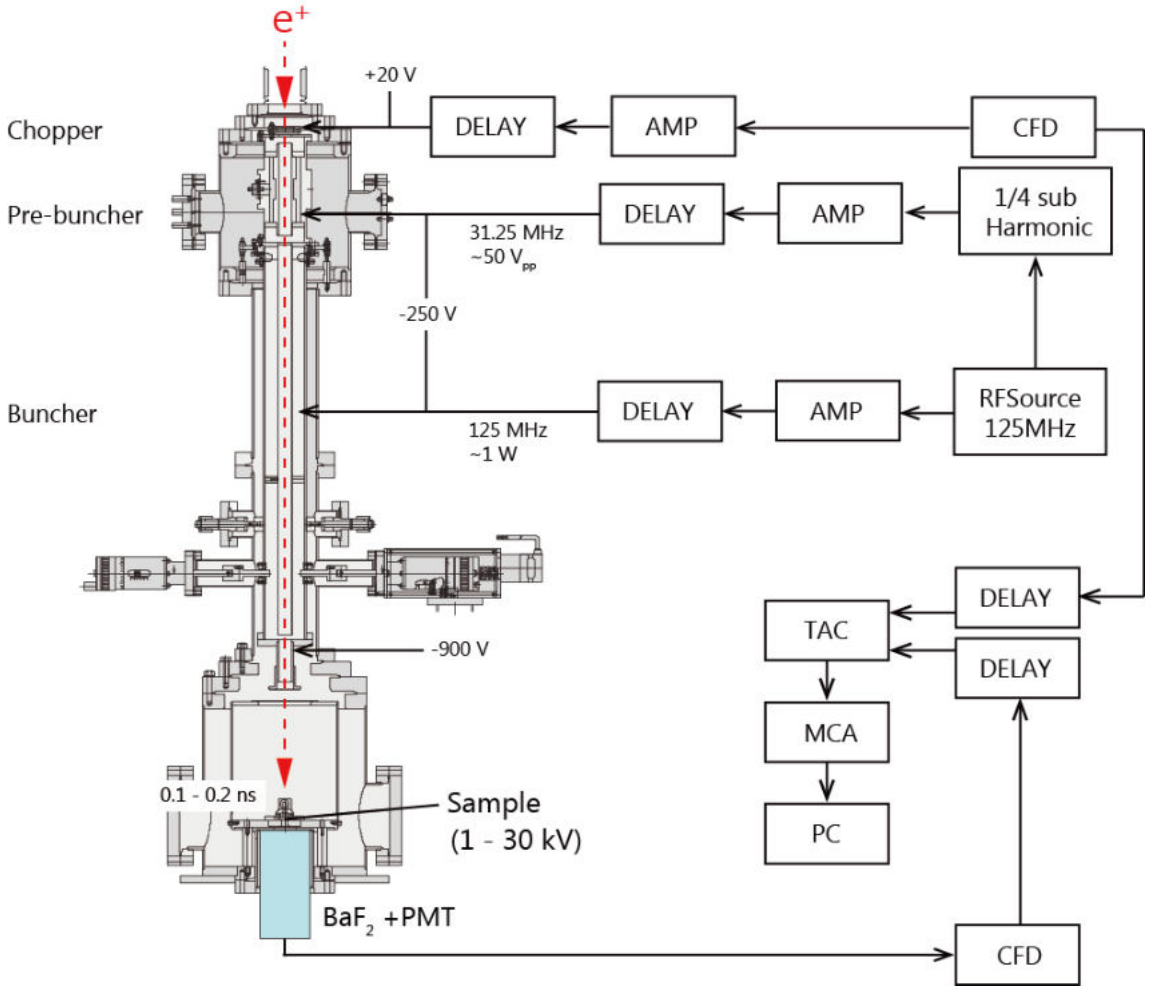
Primary beam



Pulsed beam for PALS



Vertical positron beam for PALS



- Acc. Energy : 1 – 30 keV
- Time resolution :<250 ps
- Beam diameter : 5 mm, 10 mm
- Sample : film, liquid, powder…

Load-lock chamber
multi-sample holder (5 pic.)

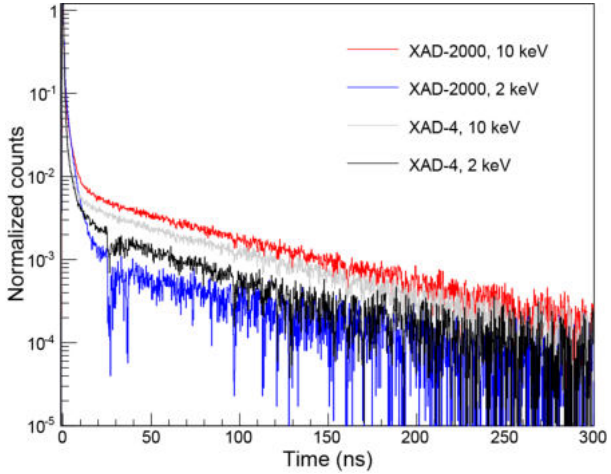
B. E. O'Rourke *et al*, JJAP-conf. proc. **2**, 011304 (2014)

Vertical positron beam for PALS

Powder-sample measurement

・Sample：Synthetic adsorbent; Amberlite XAD

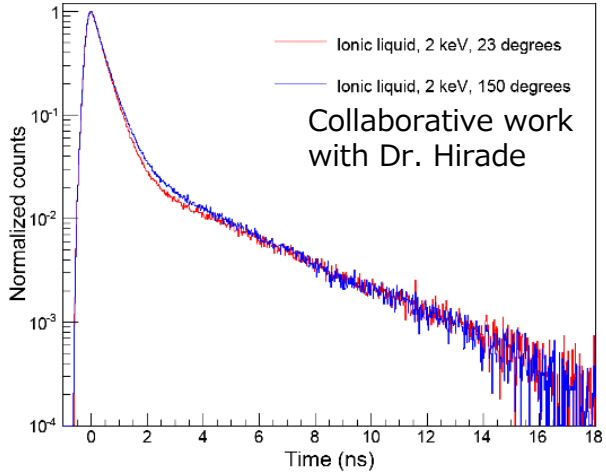
	XAD-2000	XAD-4
Particle size (mm)	0.32-0.44	0.49-0.69
Specific surface area (m^2/g)	607	876
Pore diameter (Å) (mode)	72	122



Liquid-sample measurement

・Sample：
N,N,N-Trimethyl-*N*- propylammonium bis (trifluoromethanesulfonyl) imide (TMPA TFSI)

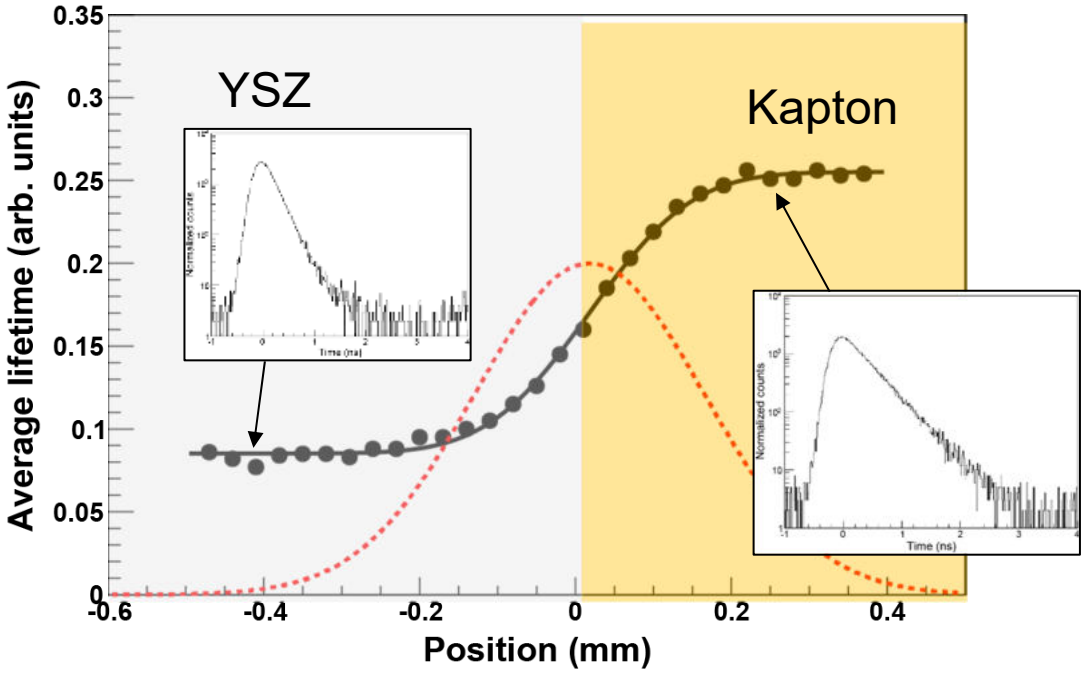
・OFC cup holder & heating stage ：
T_{room} - 200 ℃

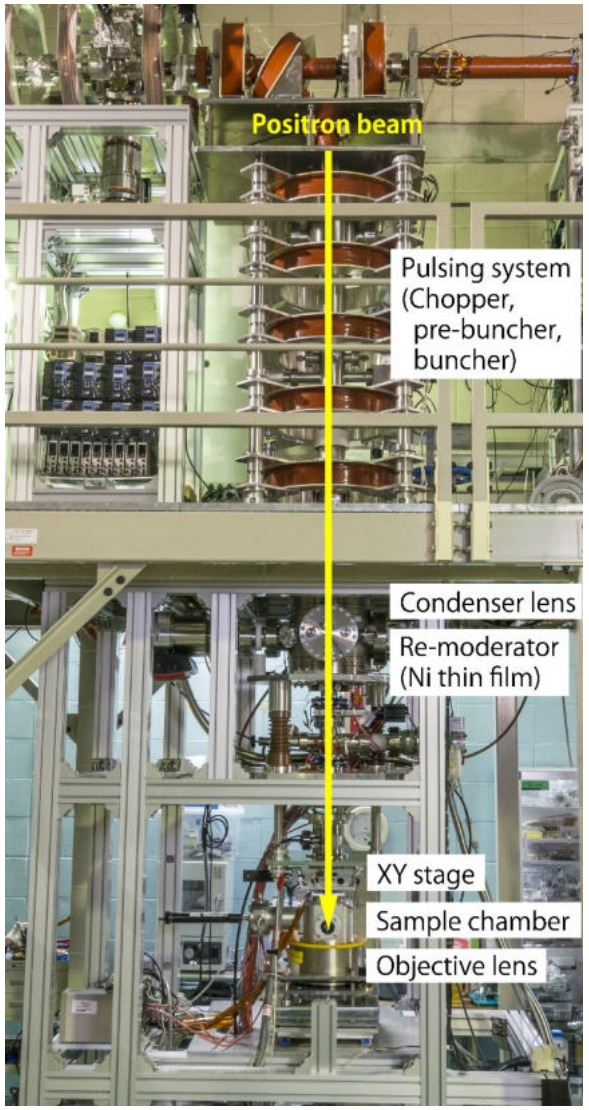


Positron probe microanalyzer (PPMA)

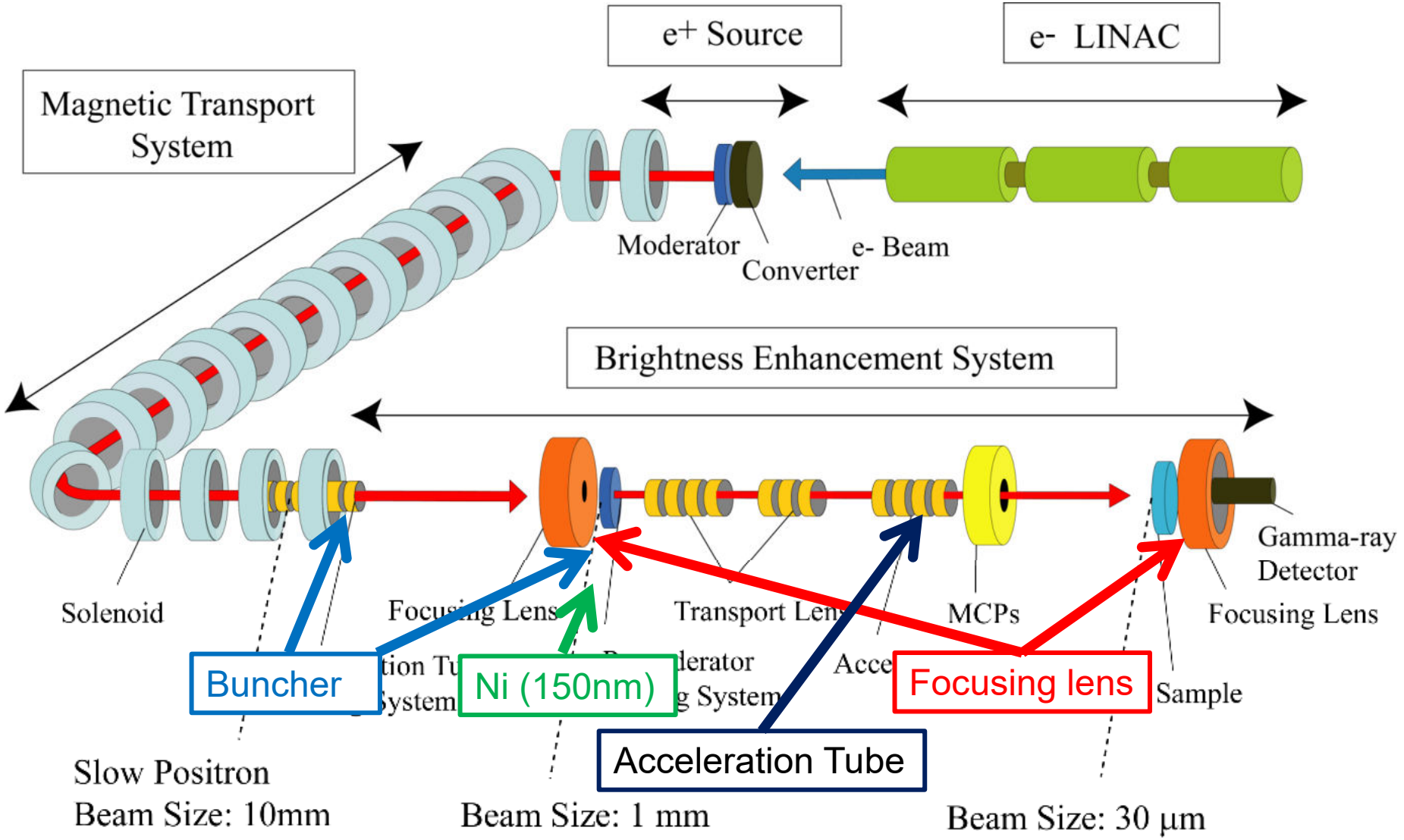
Scanning positron microprobe

Time resolution: <250 ps
Spatial resolution : 240 um (FWHM)
Counting rate : 200 cps – 600 cps
Scanning area: 15 mm x 15 mm



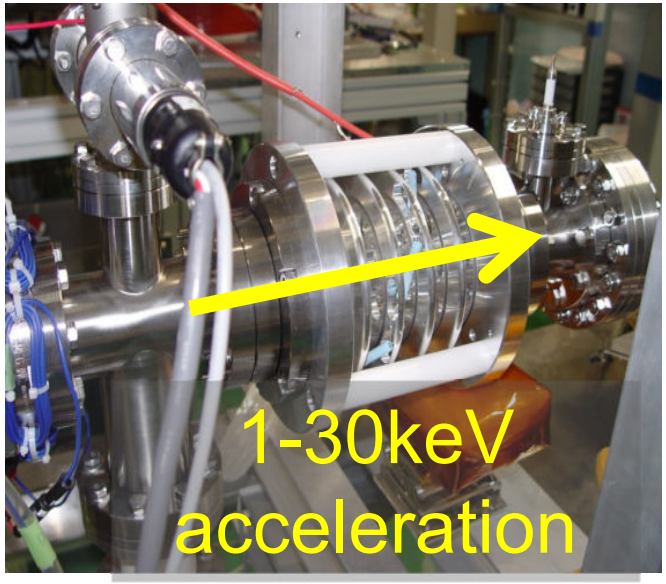


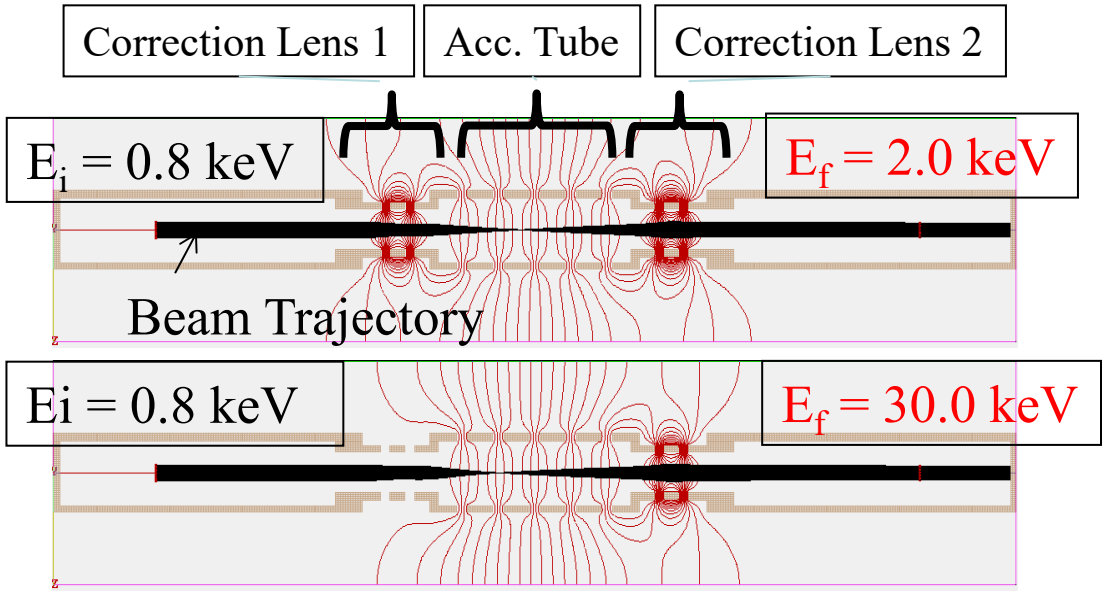
Positron probe microanalyzer (PPMA)



Rad. Phys. Chem. 78, 1096 (2009)

Electrostatic Acceleration System

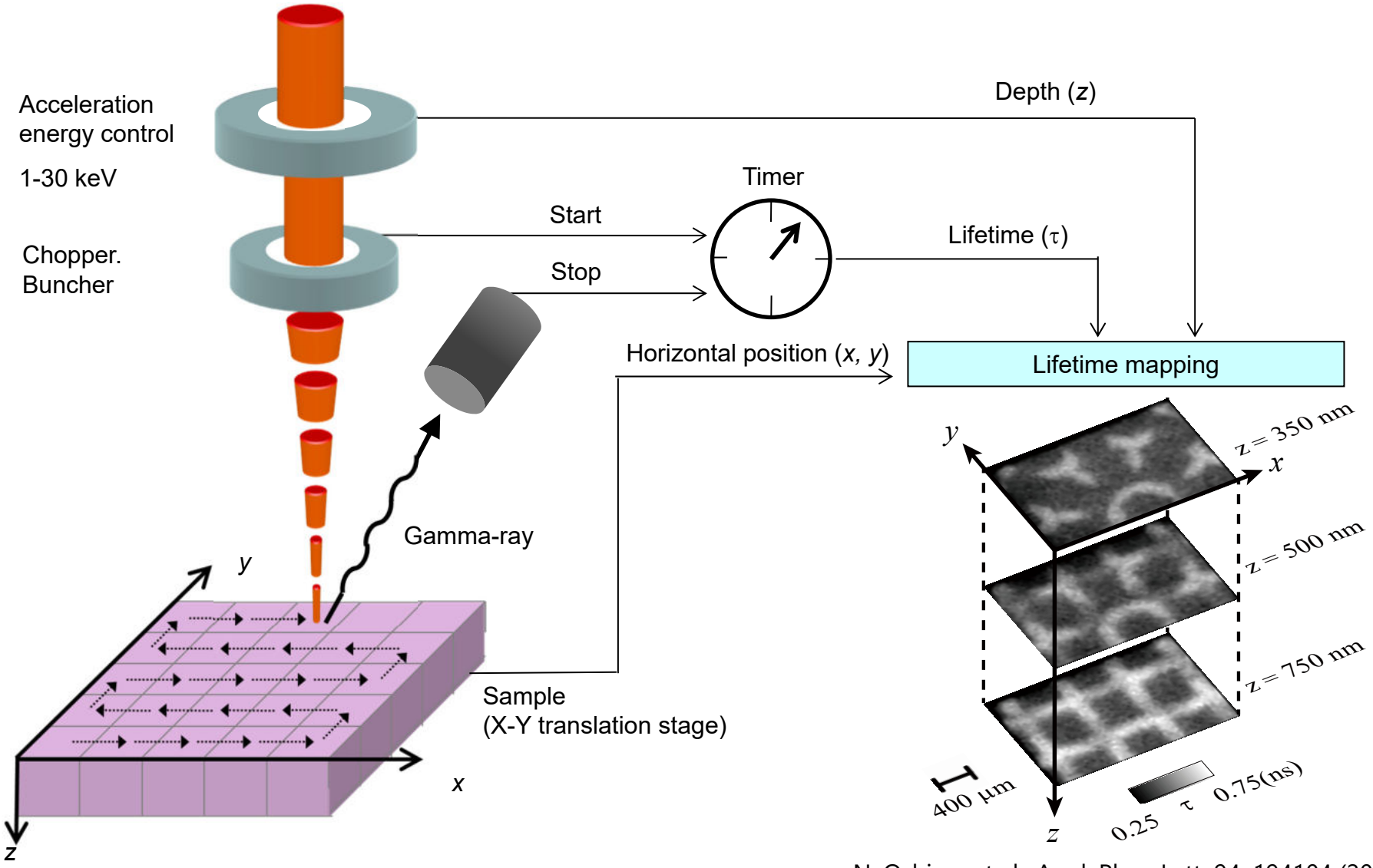




Slow positrons accelerated from 1 to 30 keV while maintaining a small beam divergence.

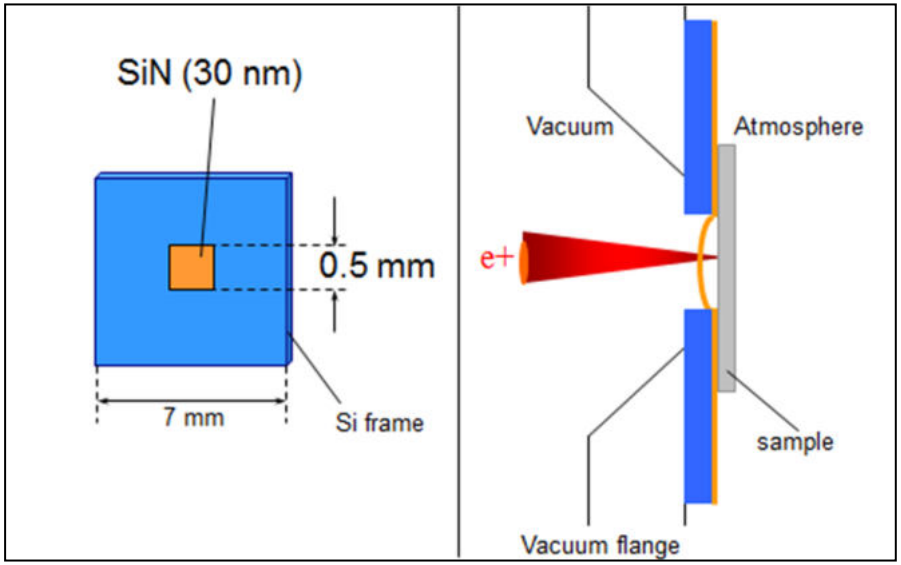
This system which consists of an acceleration tube and two correction lenses can guide positrons with arbitrary acceleration energy with almost the same beam trajectory.

3-D lifetime mapping by PPMA

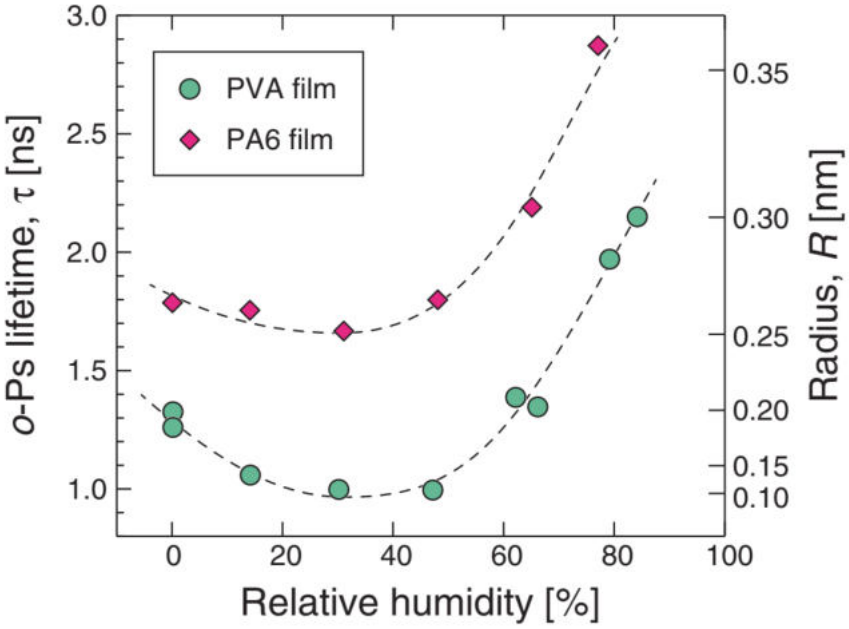


N. Oshima et al., Appl. Phys. Lett. 94, 194104 (2009).

Measurement of Free Volume Under Humidity Control



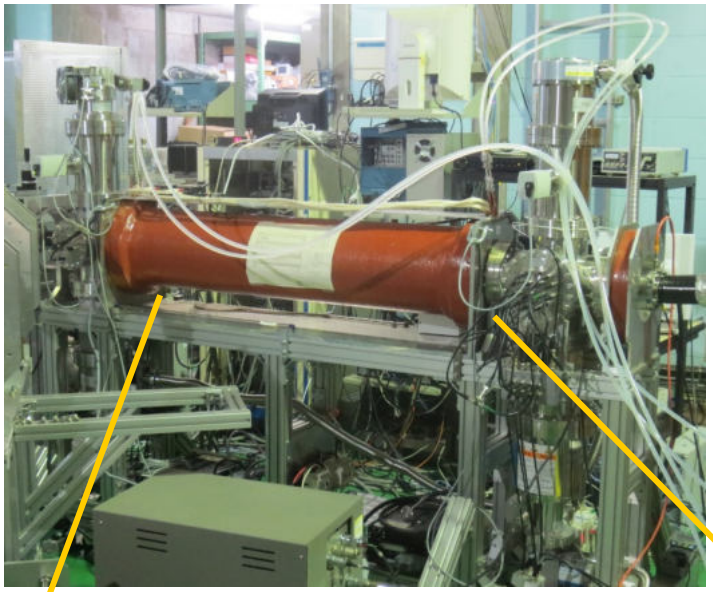
A positron beam can be extracted into the atmosphere while keeping the energy low.

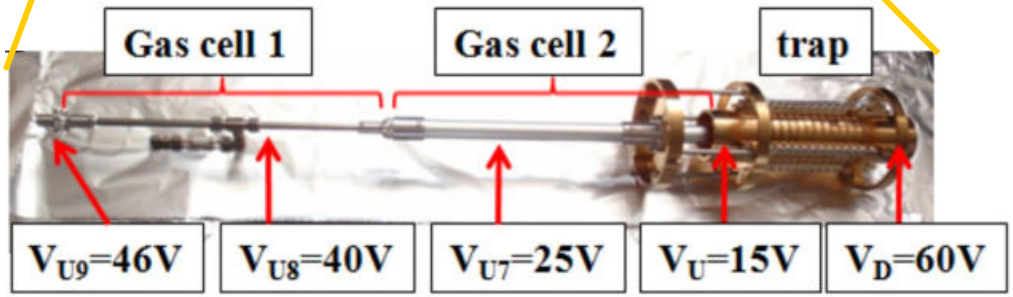


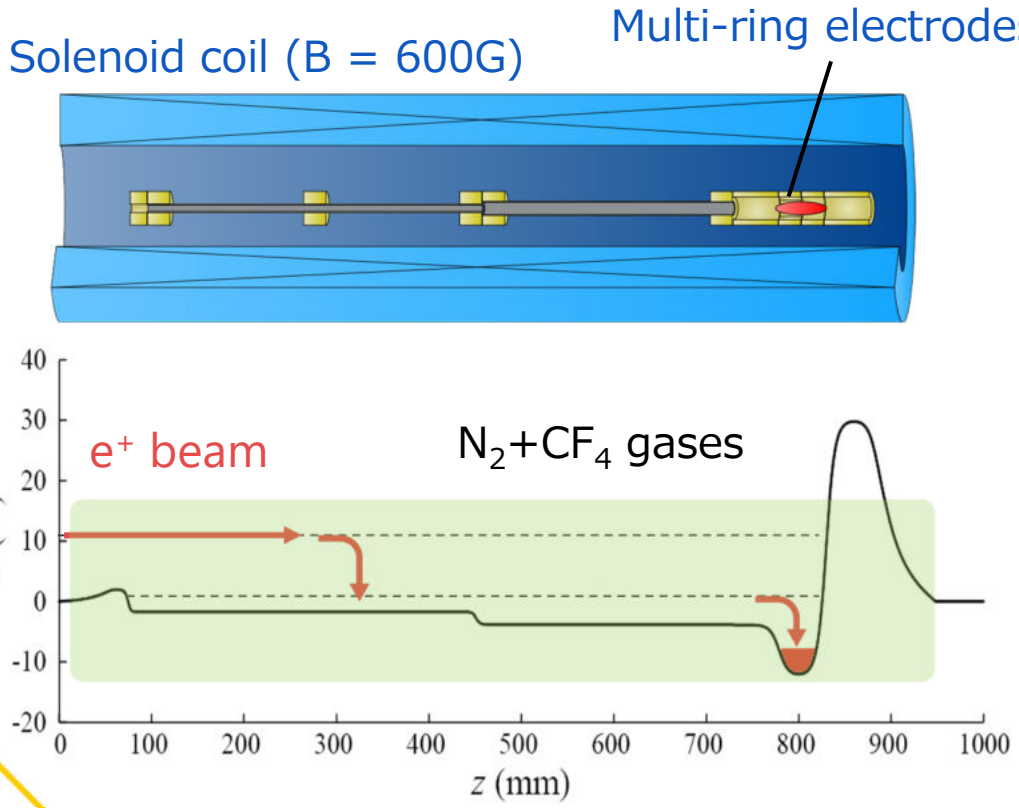
Measurement of free volume in polymer films (PVA and PA6) as a function of humidity

N. Oshima et al., Appl. Phys. Express 4, 066701 (2011).
W. Zhou et. al., Appl. Phys. Lett. 101, 014102 (2012).
K. Ito et al., Appl. Phys. Lett. 112, 083701 (2018).

Positron trap



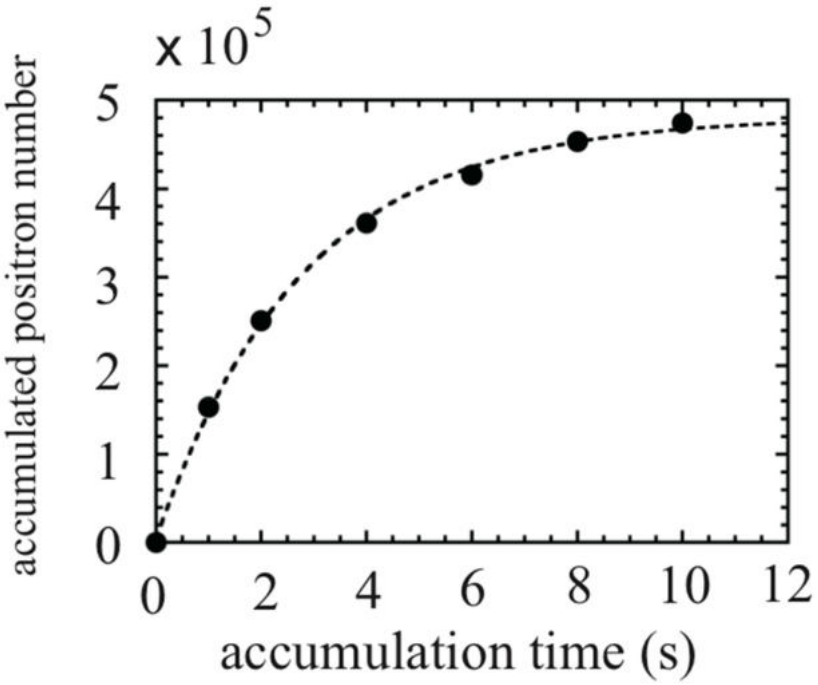




・Buffer-gas positron trap in conjunction with the accelerator based e^+ beam.

H. Higaki et. al., Appl. Phys. Express. 13, 066003 (2020)

Experimental result of positron trapping

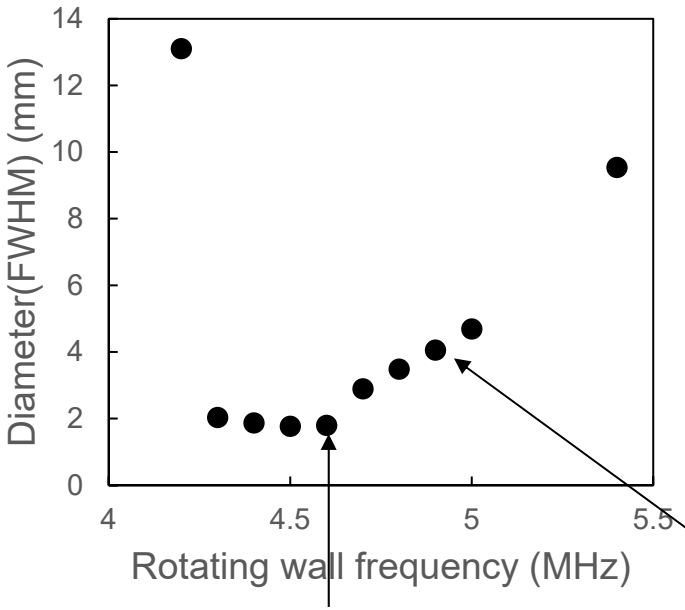


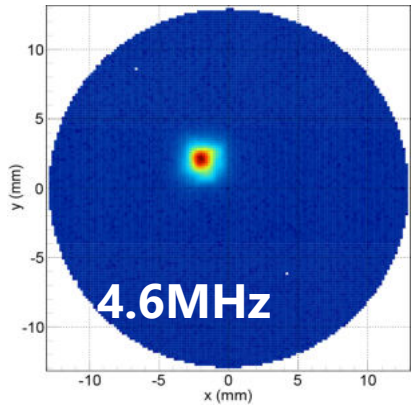
Positron energy ：～ 10 eV
Rotating wall：f ~4.8 MHz, V_{pp}~3V
Trapping efficiency：~4 %
Lifetime constant: ~2.8 s

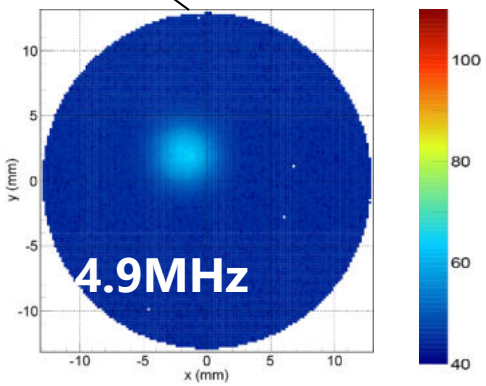
・Slow positrons generated by LINAC were accumulated in the buffer gas trap.
・The trap efficiency (~ 4%) is lower than the results of previous experiments using RI-based positrons (efficiency ~ 20%).
・The main reason for this low trapping efficiency is due to the large longitudinal energy spread of incident positrons in the trap.

H. Higaki et. al., Appl. Phys. Express. 13, 066003 (2020)

Experimental result of radial compression of positron clouds using rotating wall



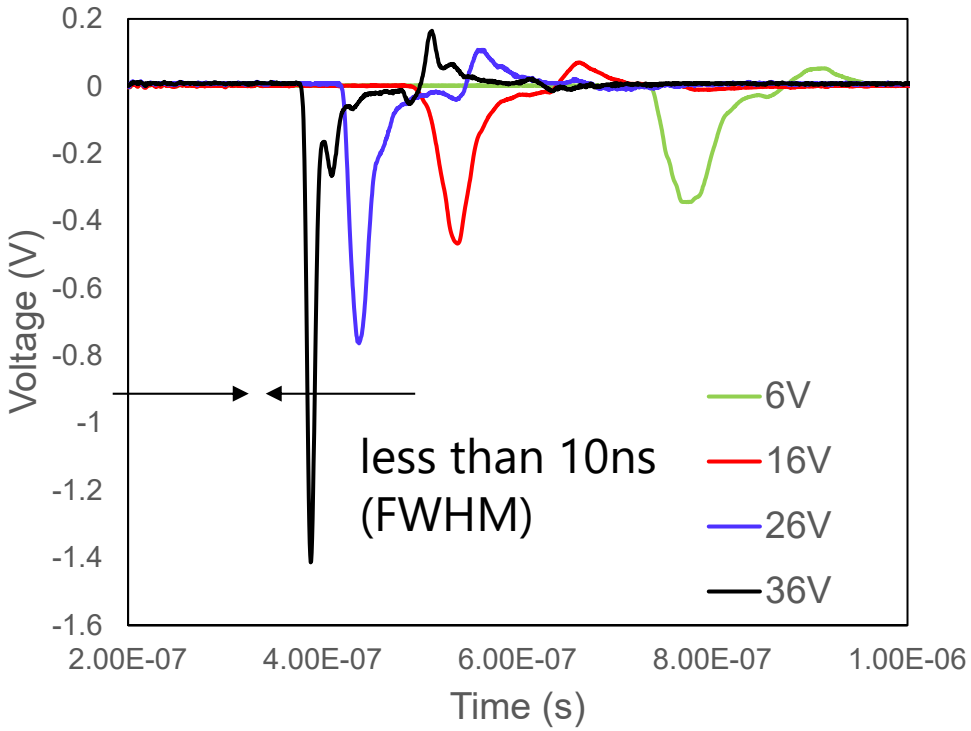




- Positrons were extracted from the trap after applying a rotating electric field (3 Vpp, 4 seconds) in the trap.
- The profile of the extracted positron was observed by MCP
- Beam brightness increased due to radial compression by the rotating electric field.
- The beam diameter could be compressed during the linac pulse interval (25 ms).

H. Higaki et. al., Appl. Phys. Express. 13, 066003 (2020)

Experimental result of pulse extraction of slow positrons from the trap



・The pulse width can be controlled by changing the extraction voltage.
・A short pulse of 10ns or less is achieved.

We plan to develop a next-generation PPMA that uses a highly efficient and high-intensity positron focusing beam using a positron trap as an injector to a brightness enhancement system.

H. Higaki et. al., Appl. Phys. Express. 13, 066003 (2020)

Technology transfer to commercial analyzers

Desk-top PALS

The basic technology was developed by Dr. Yamawaki.

Anti-coincidence type
Count rate: ~ 80 cps / 1MBq

Beam PALS

The basic technology was developed by Dr. Ohdaira.

Beam energy : ~1- 20 keV
Count rate: ~ 2000 cps / 0.5GBq

Summary

- Over the last few years, the layout of positron beamlines has changed.
- A newly developed **vertical beamline** for PALS and PPMA is now **operational**.
- A positron trap is under development and will be planed to be use as an injector for the next generation PPMA.
- The developed technologies are being transferred to a commercial analyzers.

Thank you for your attention

PPMA Applications

(i) defect/pore analysis of small samples

[1] Jpn. J. Appl. Phys. 48, 120222 (2009) .
[2] Proc. 2009 IEEE Inter Interconnect Tech. Conf., 75 (2009).
[3] J. Phys.-Conf. Ser. 262, 012060 (2011).
[4] J. Appl. Phys. 114, 084506 (2013).
[5] J. Appl. Phys. 114, 184504 (2013).
[6] J. Appl. Phys. 116, 134501 (2014).
[7] JJAP Conf. Proc. 2, 011102 (2014).
[8] Rev. Sci. Instr. 91, 083907 (2020)

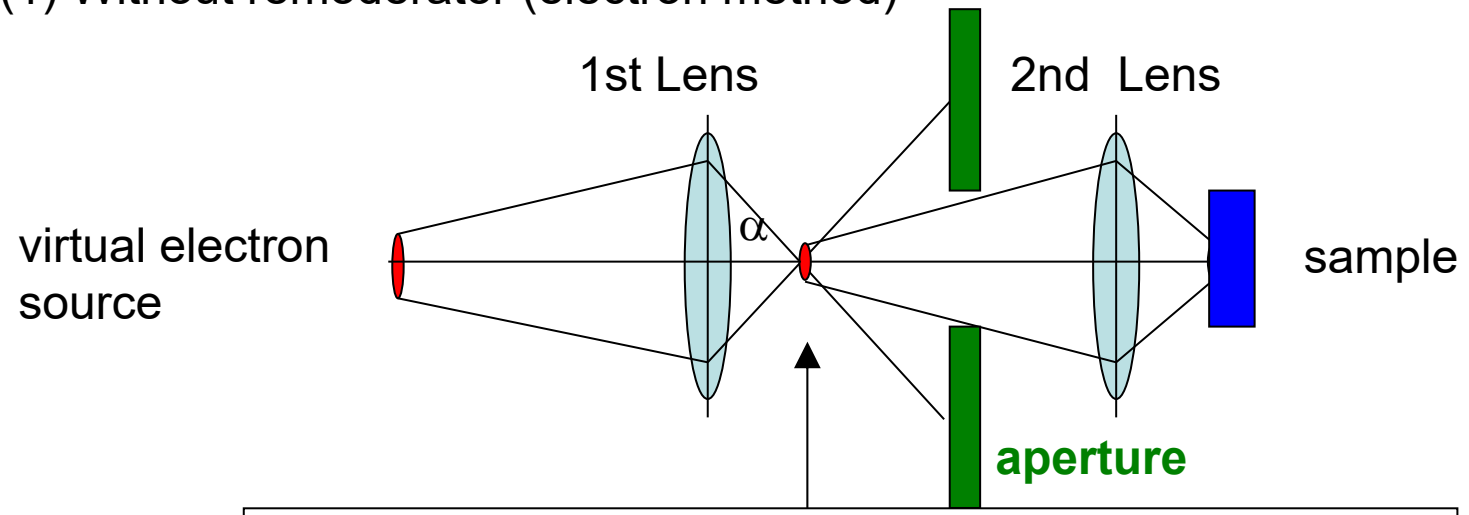
(ii) defect/pore analysis for many local spots in one sample

[9] Appl. Phys. Lett. 94, 194104 (2009).
[10] J. Phys.-Conf. Ser. 262, 012044 (2011).
[11] ISIJ Int.52, 198 (2012).
[12] Appl. Phys. Lett. 101, 203108 (2012).
[13] JJAP Conference Proceedings 2, 011306 (2014)

(iii) defect/pore analysis of thin films in air

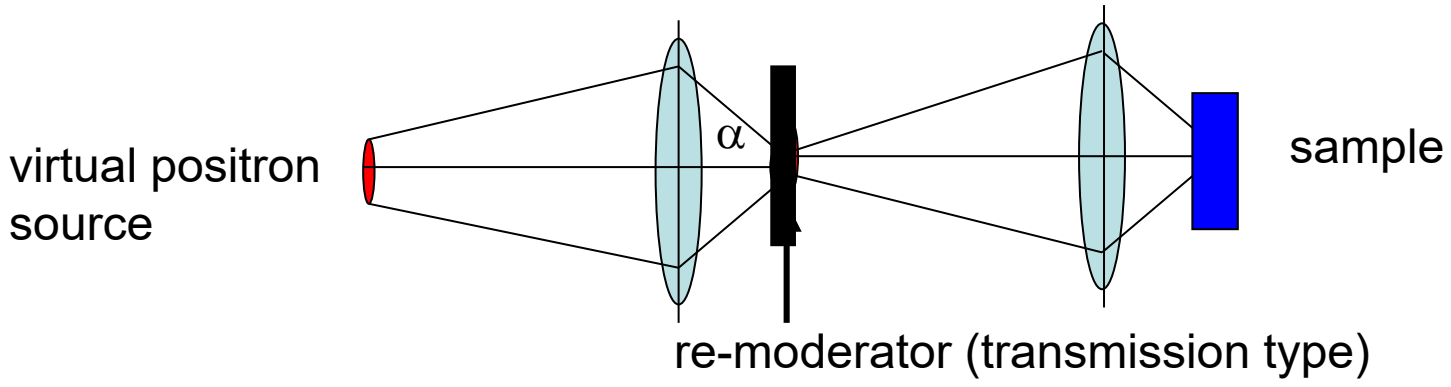
[14] Appl. Phys. Express 4, 066701 (2011).
[15] Appl. Phys. Lett. 101, 014102 (2012).
[16] Appl. Phys. Lett. 112, 083701 (2018).

(1) Without remoderator (electron method)



Beam divergence α : Large → Guiding Efficiency : Low

(2) With remoderator (positron method)



Beam divergence α : Small → Guiding Efficiency : High

AIST slow positron facility