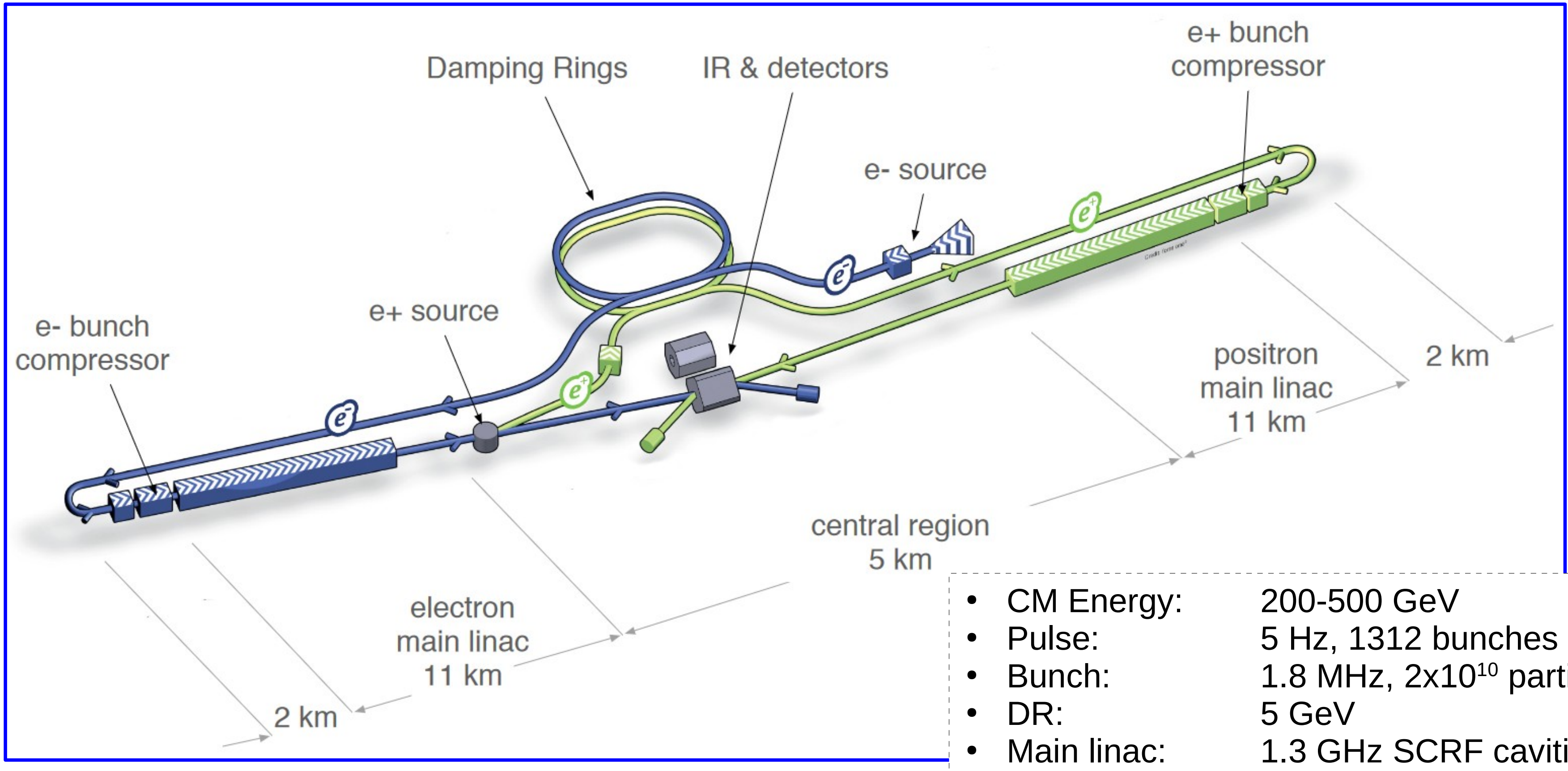
Plasma Lenses for the Positron Source

G. Moortgat-Pick, K. Floettmann,
S. Riemann, M. Formela, N. Hamann

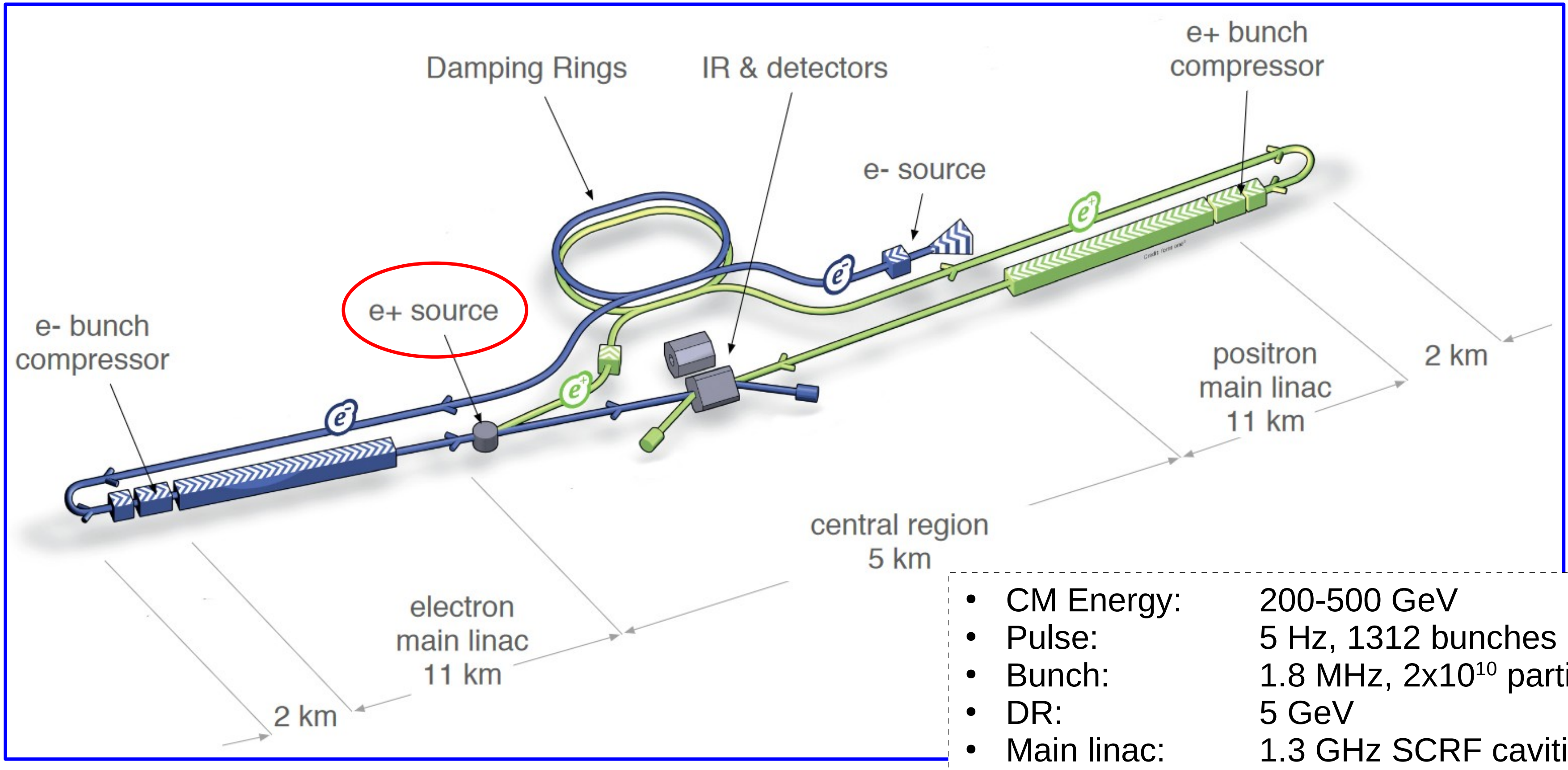
ILC



- CM Energy: 200-500 GeV
- Pulse: 5 Hz, 1312 bunches
- Bunch: 1.8 MHz, 2×10^{10} particles
- DR: 5 GeV
- Main linac: 1.3 GHz SCRF cavities, 31.5 MV/m

Source: Behnke, Ties, et al. "The international linear collider technical design report-volume 1: Executive summary." arXiv preprint arXiv:1306.6327 (2013).

ILC



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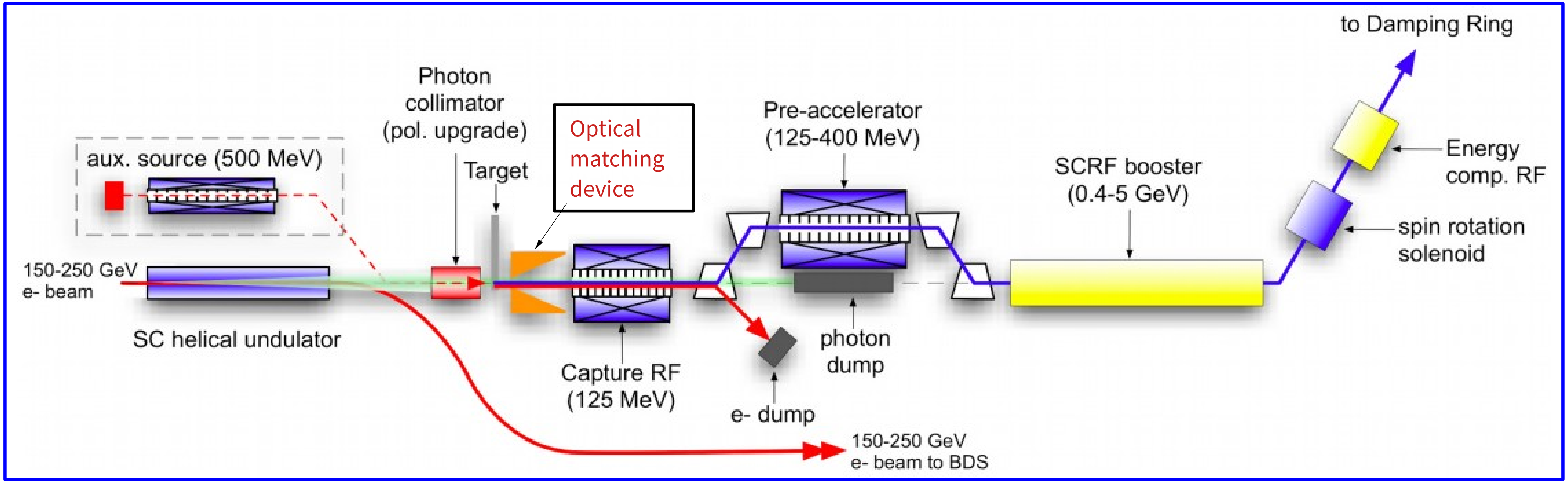
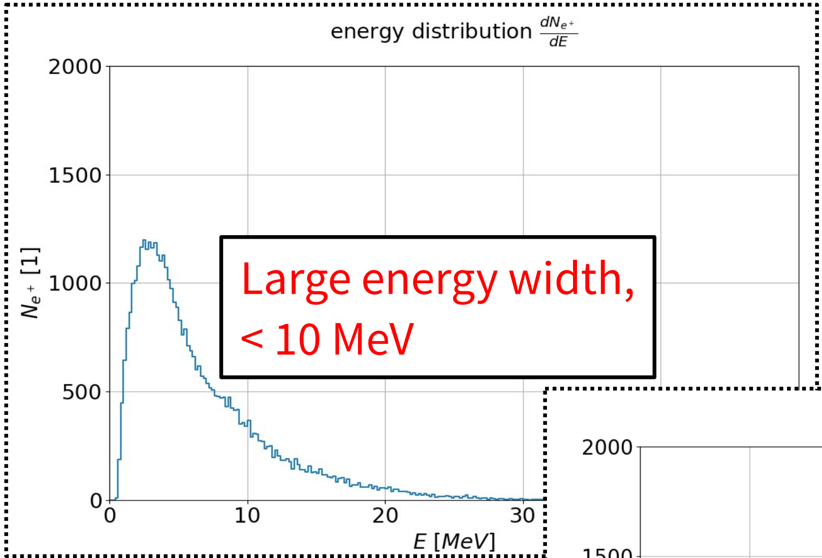
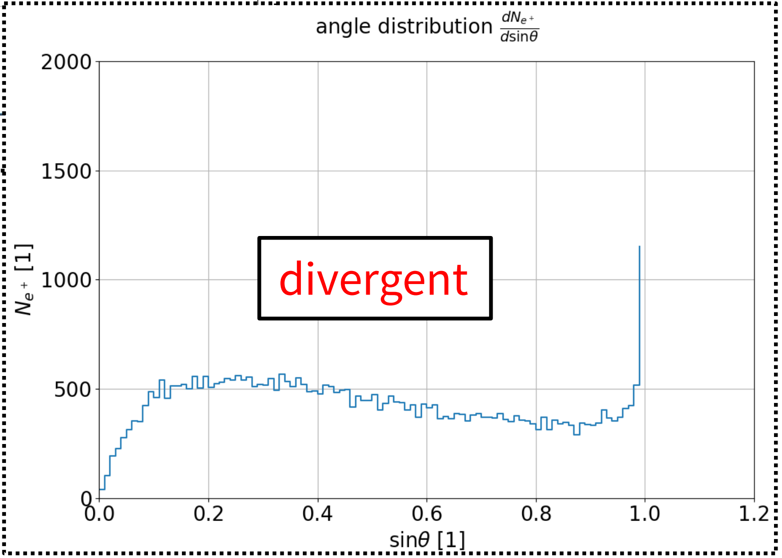
Positron Source

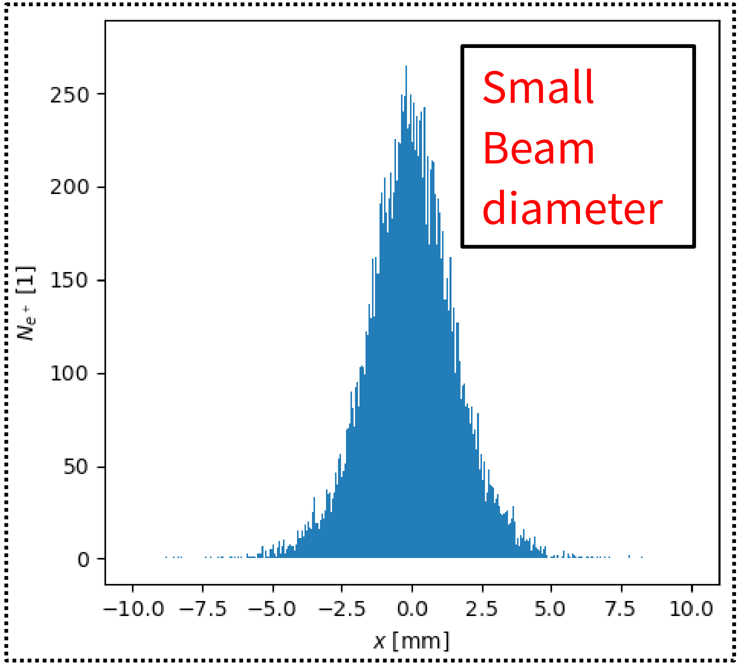


Source: Adolphsen, Chris, et al. "The International Linear Collider Technical Design Report-Volume 3. II: Accelerator Baseline Design. " No. arXiv: 1306.6328. CERN, 2013.

Positron Source: Bunch Properties

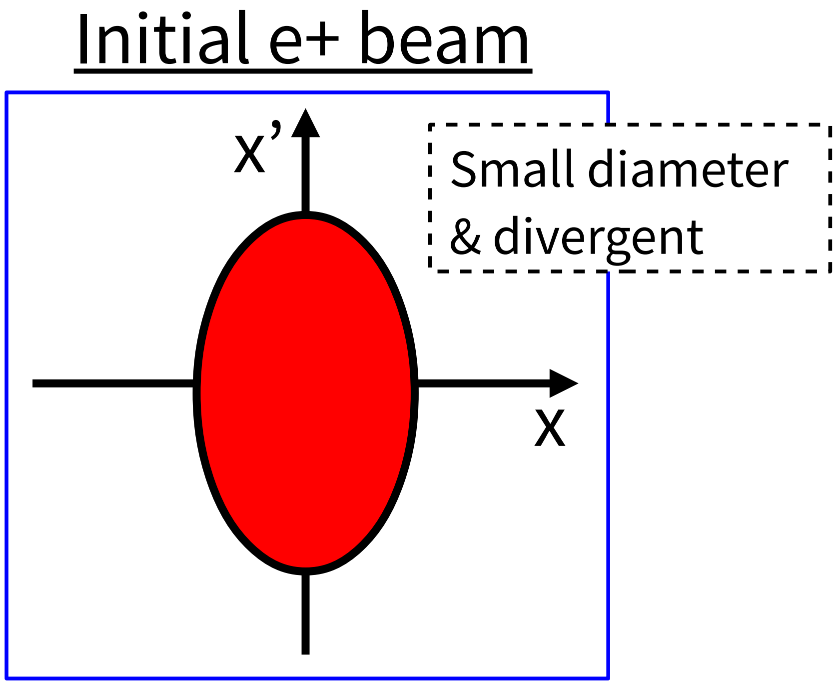






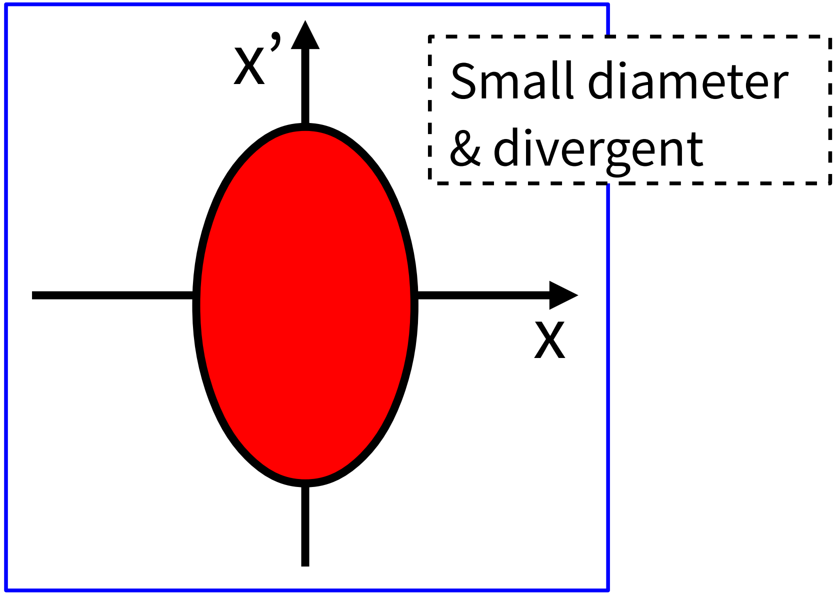
Emission time: ~80 ps emission

Matching: why?

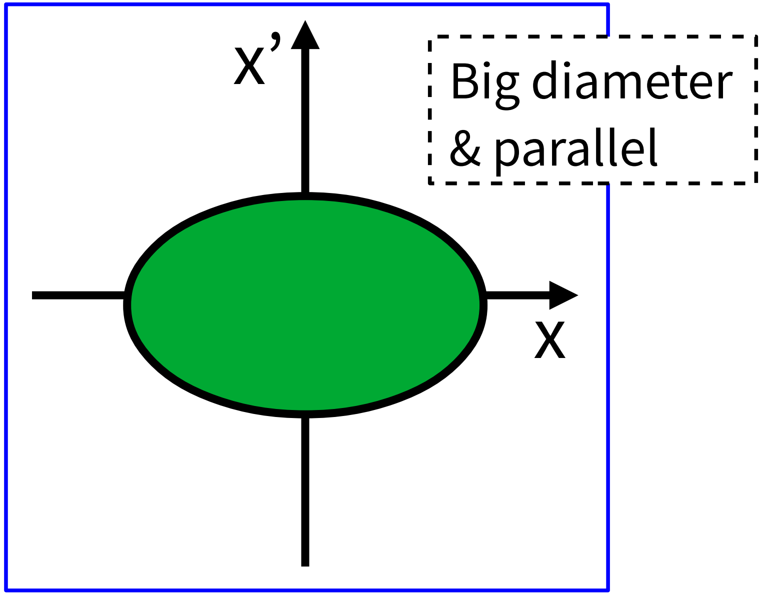


Matching: why?

Initial e+ beam



Accepted phase-space
by accelerators



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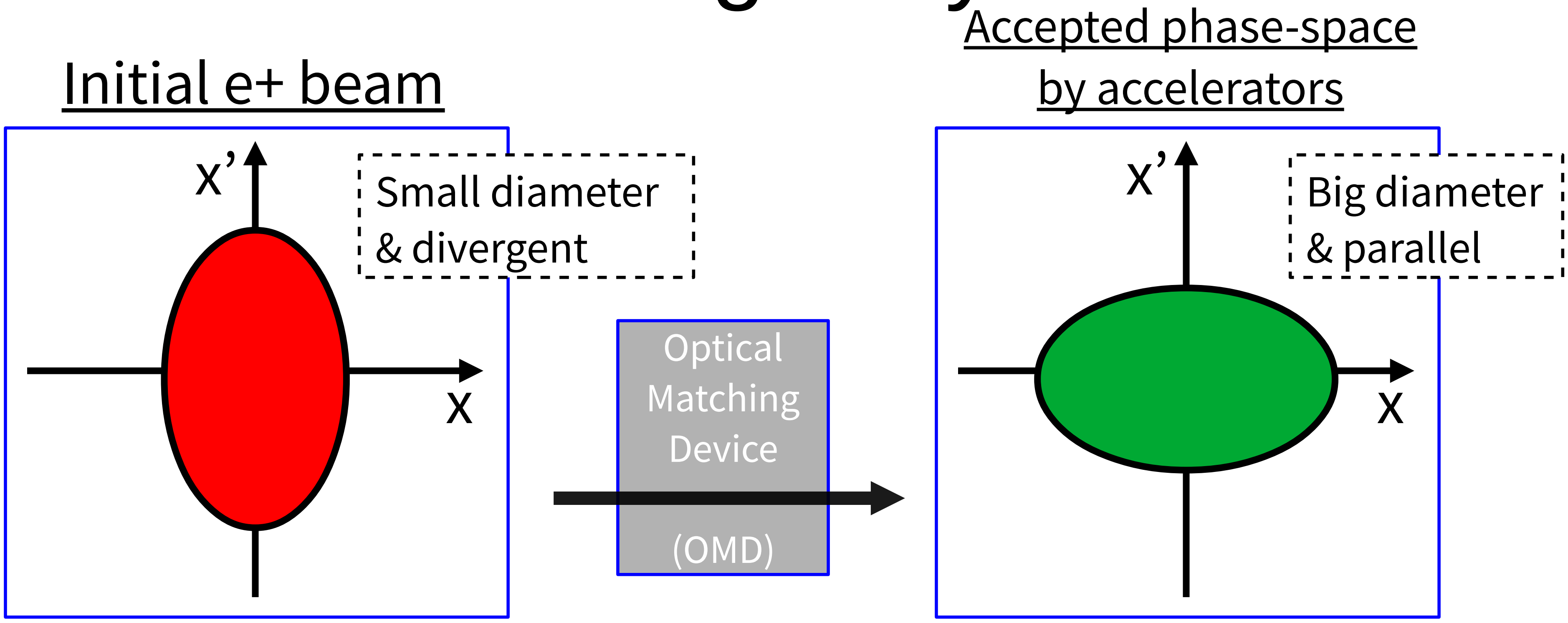

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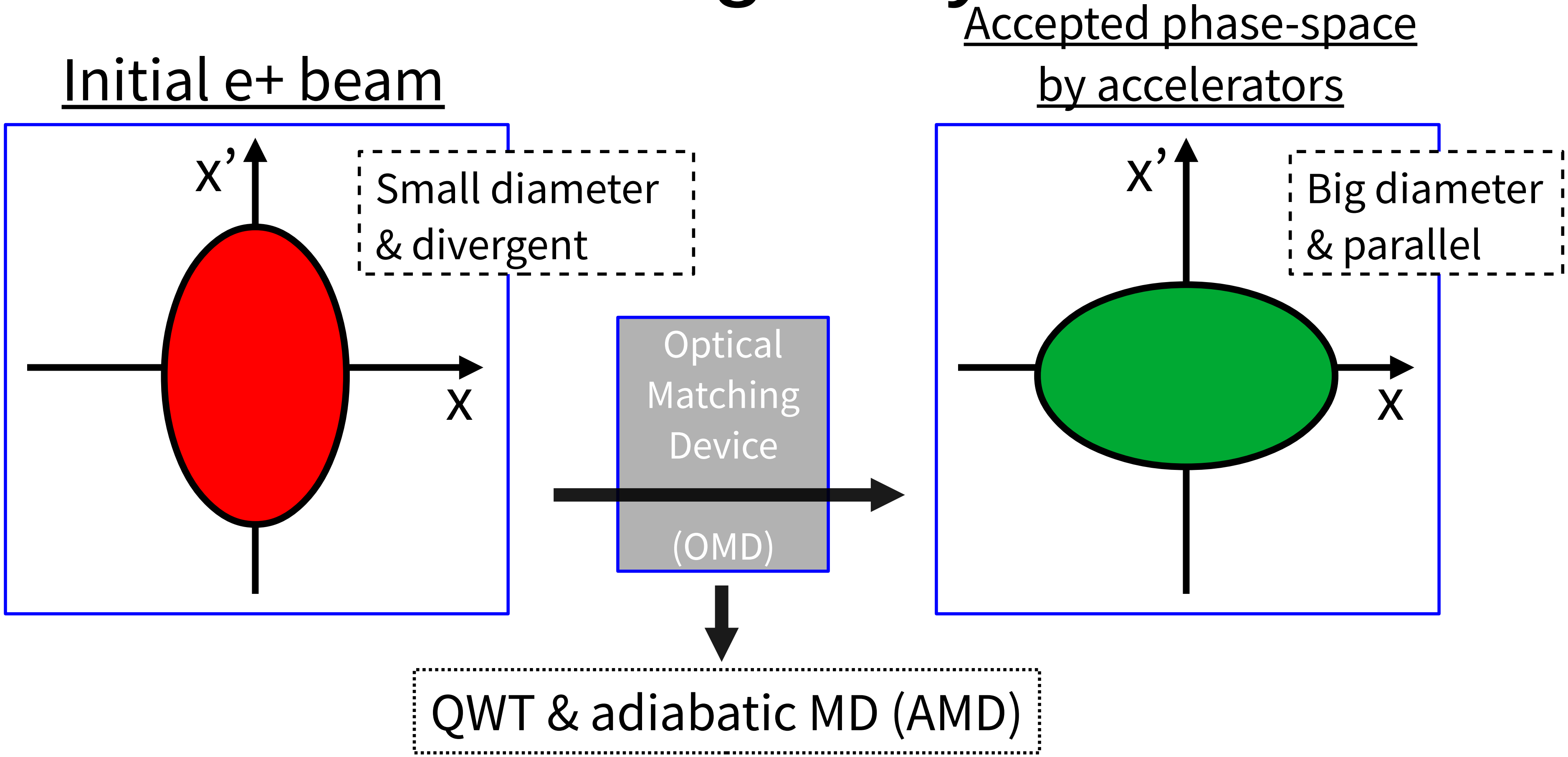
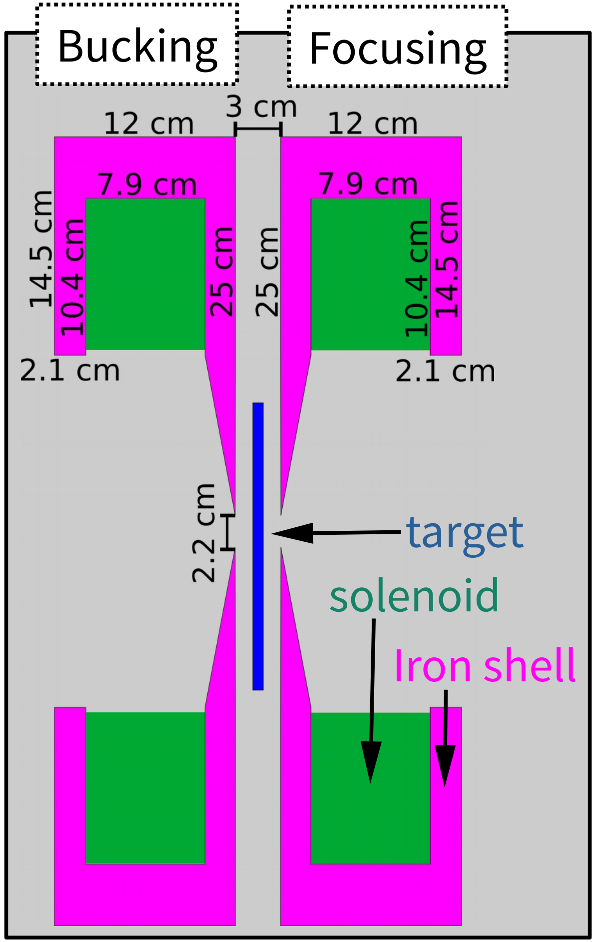
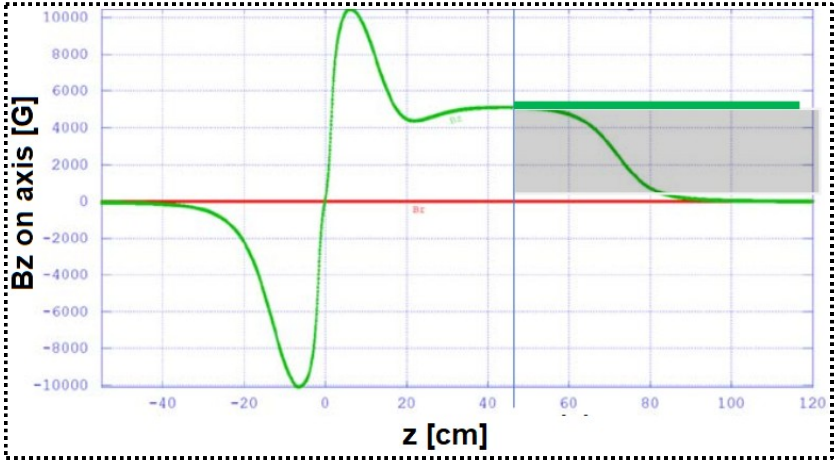


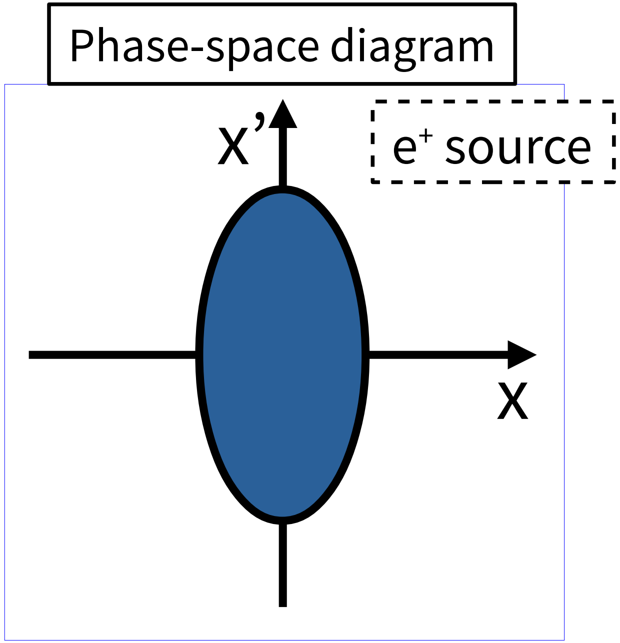
Quarter Wave Transformer (QWT)



- Peak magnetic field:
  1.04 T
- Focussing coil:
  match e^+ source to accelerator acceptance
- Bucking coil & iron shell:
  minimize eddy current in rotating target



If narrow energy width:



Source: M. Fukuda, 'Undulator Positron Source Capture Simulation' LCWS 2019

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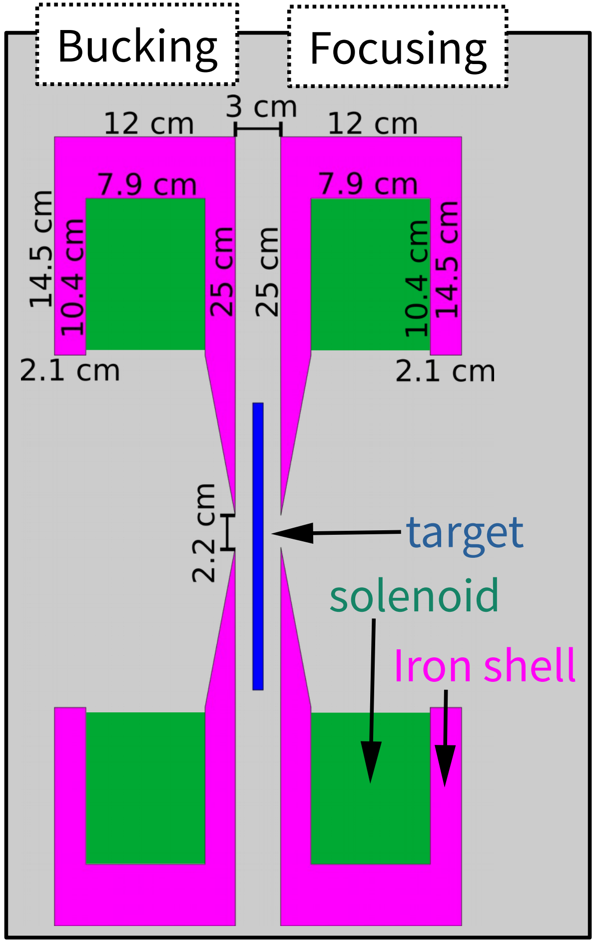

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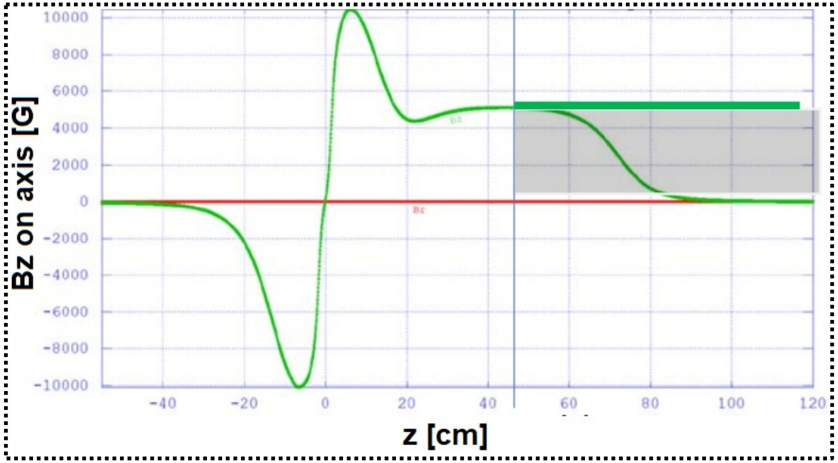

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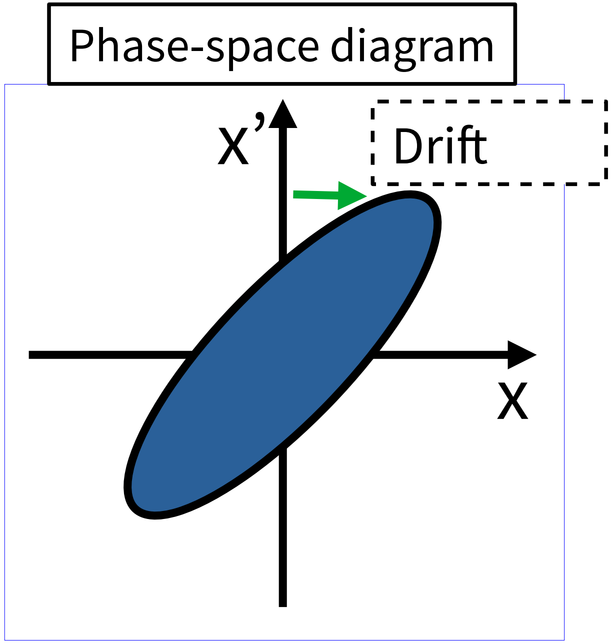

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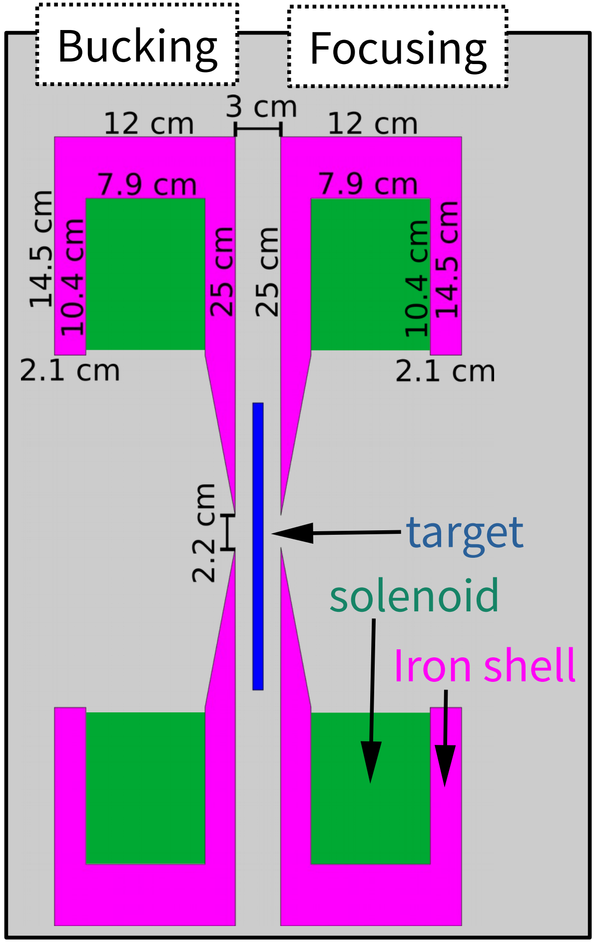

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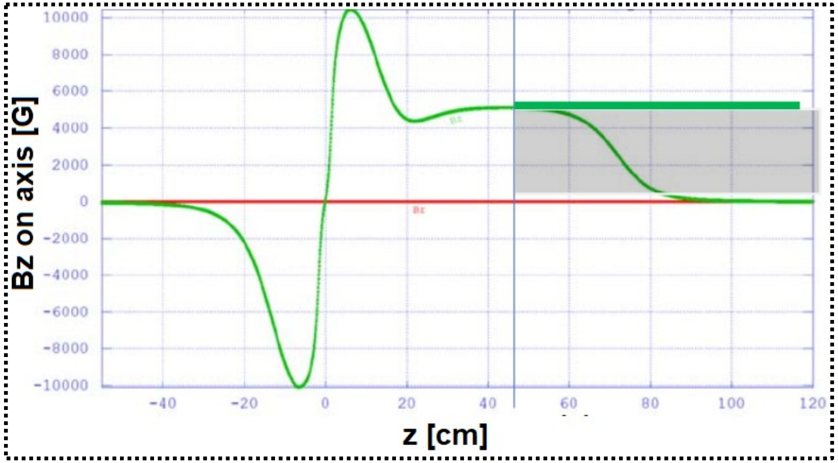

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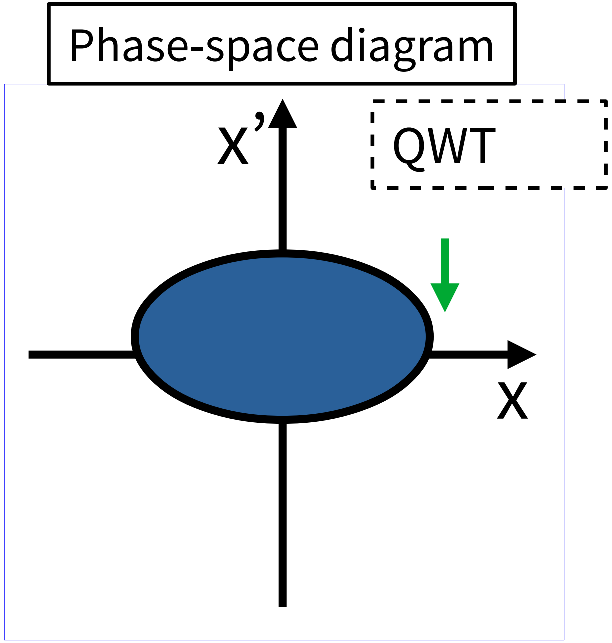

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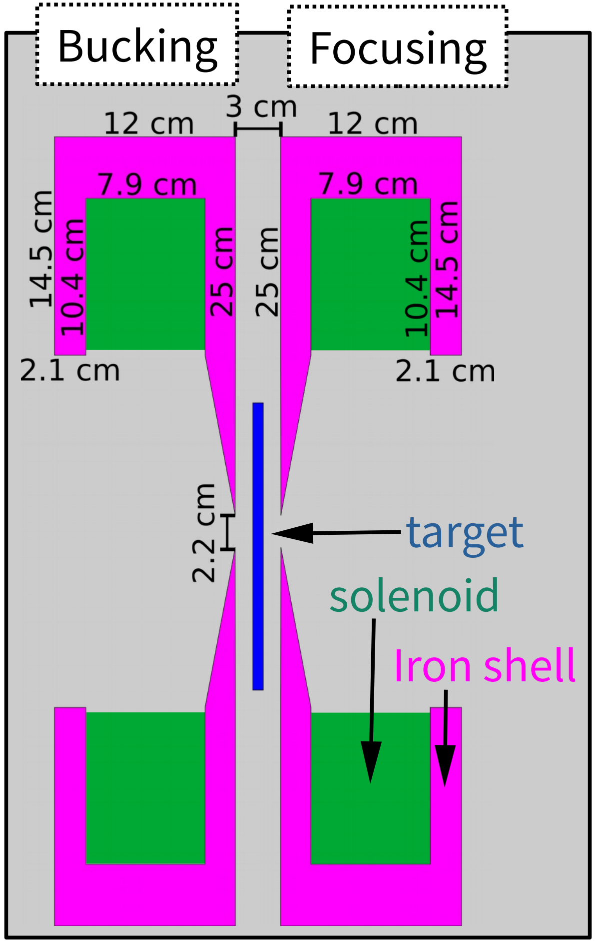

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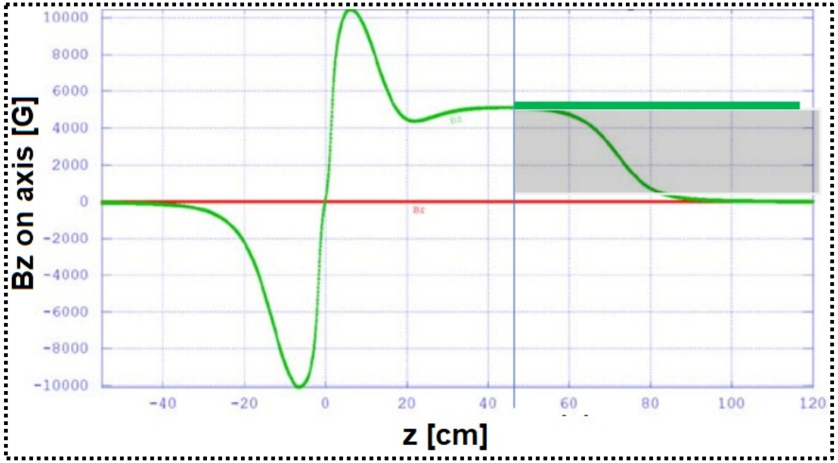

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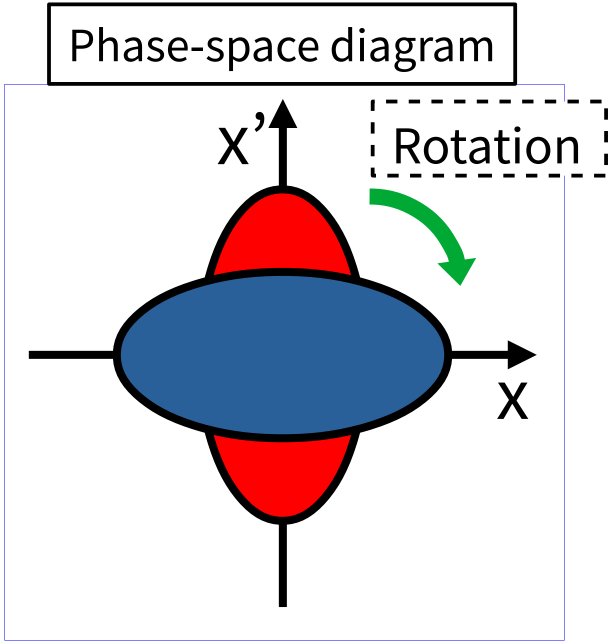

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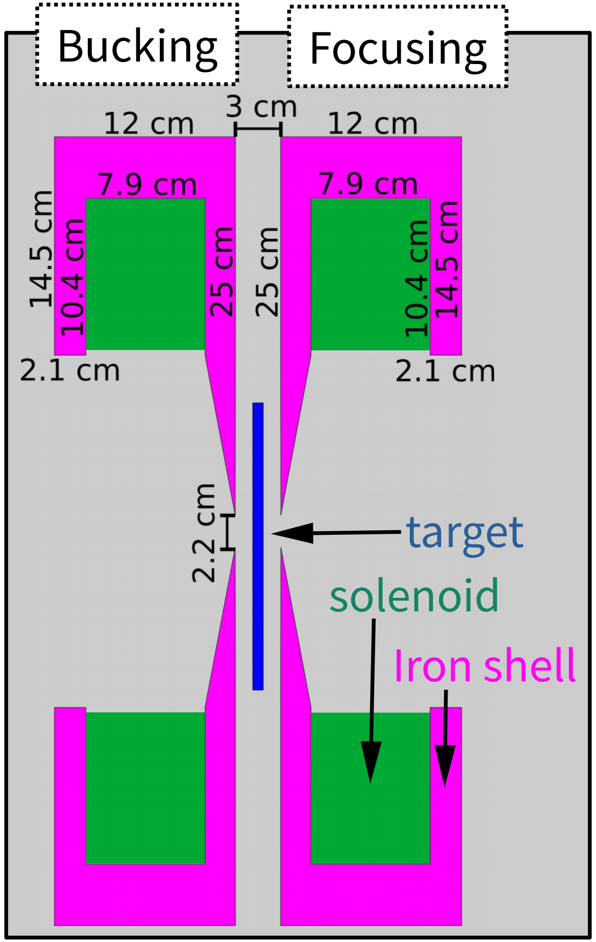

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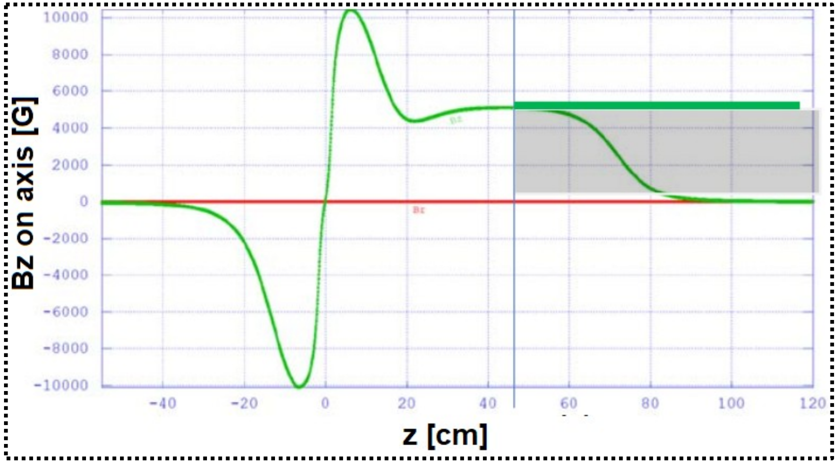

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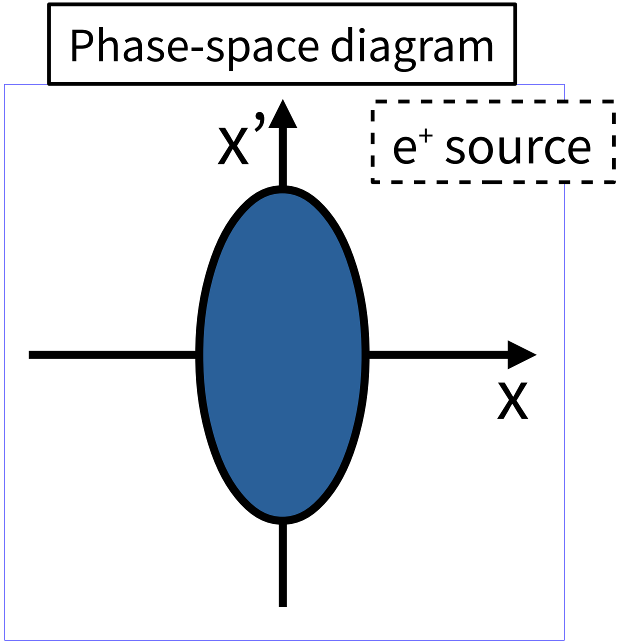

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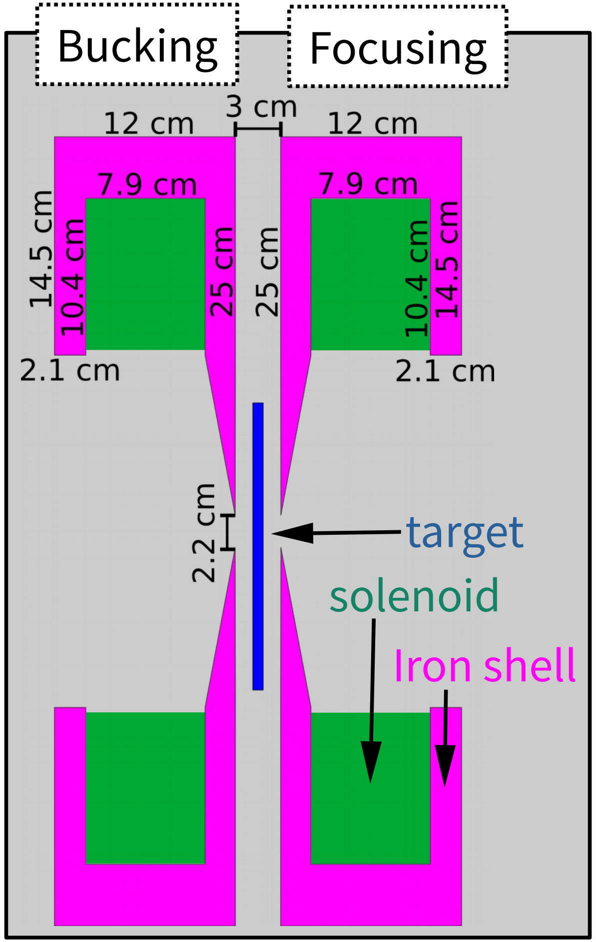

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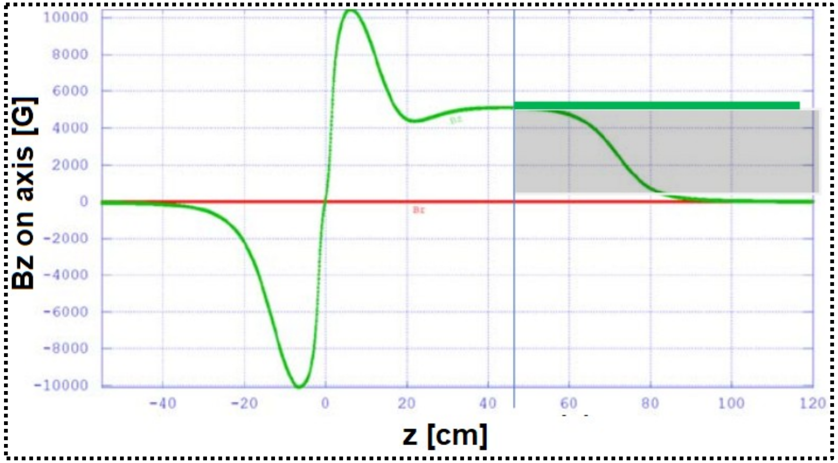

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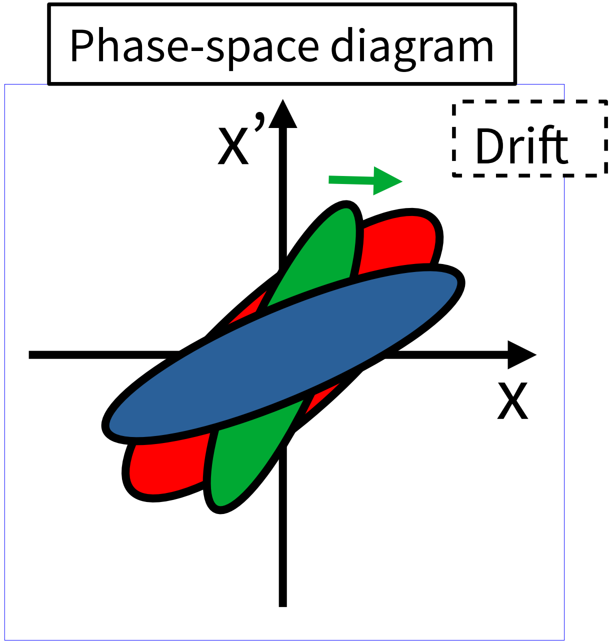

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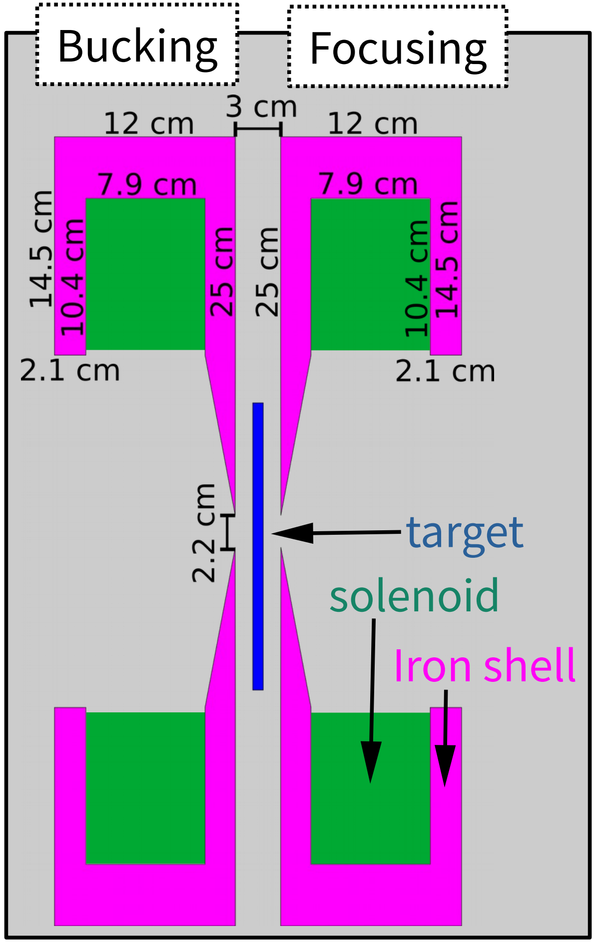

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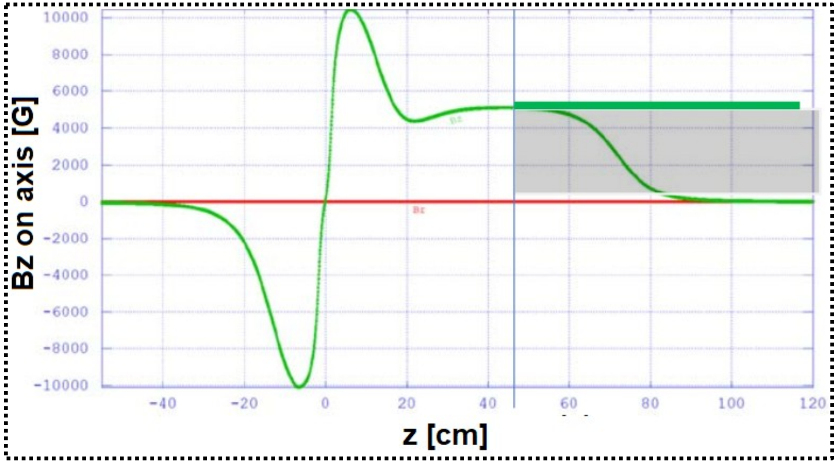

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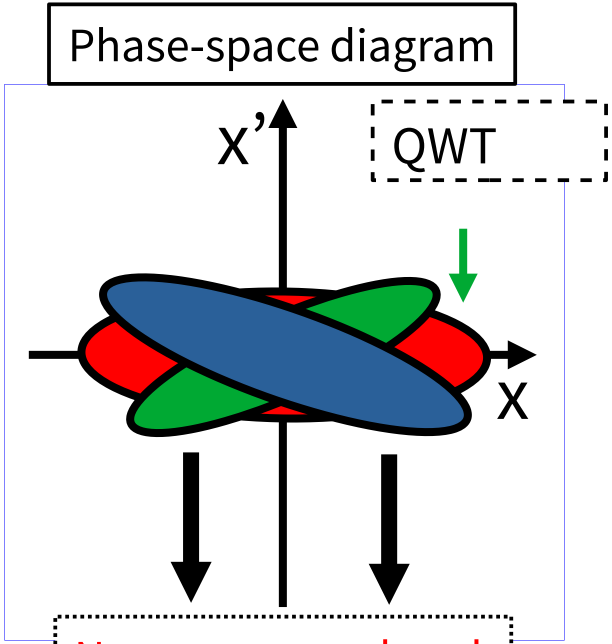
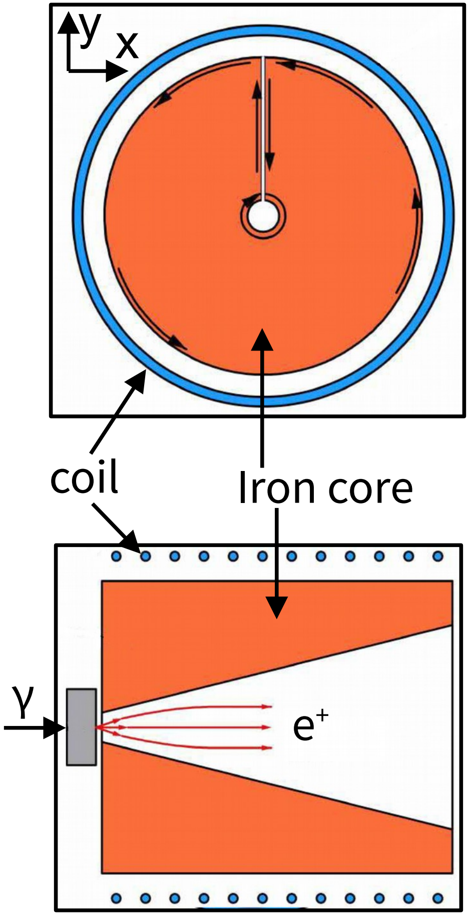


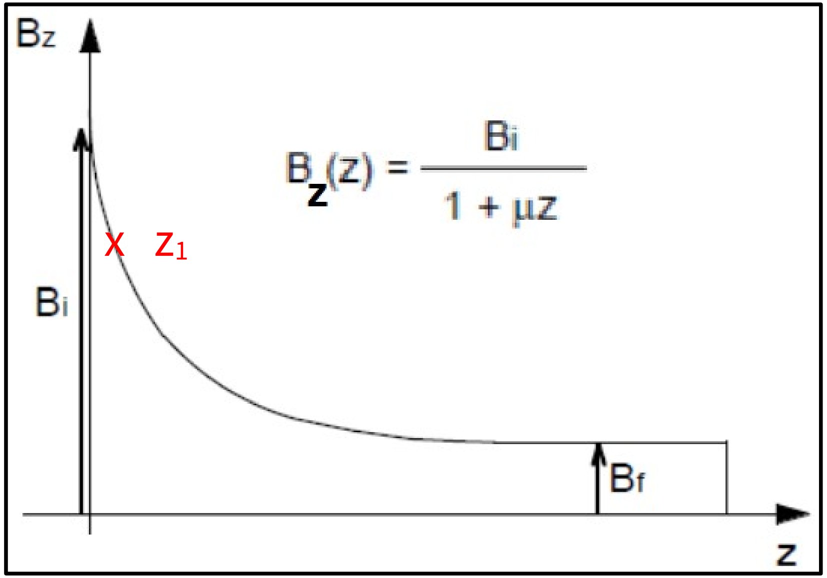
Narrow energy band device!

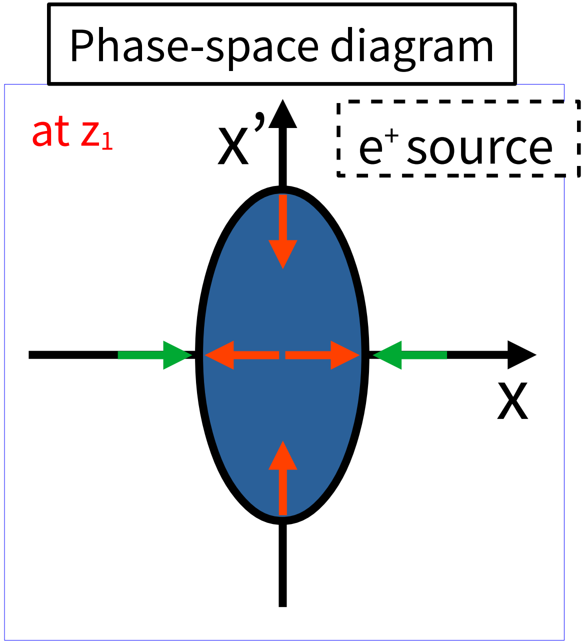
Source: M. Fukuda, 'Undulator Positron Source Capture Simulation' LCWS 2019

AMD: Flux Concentrator (FC)

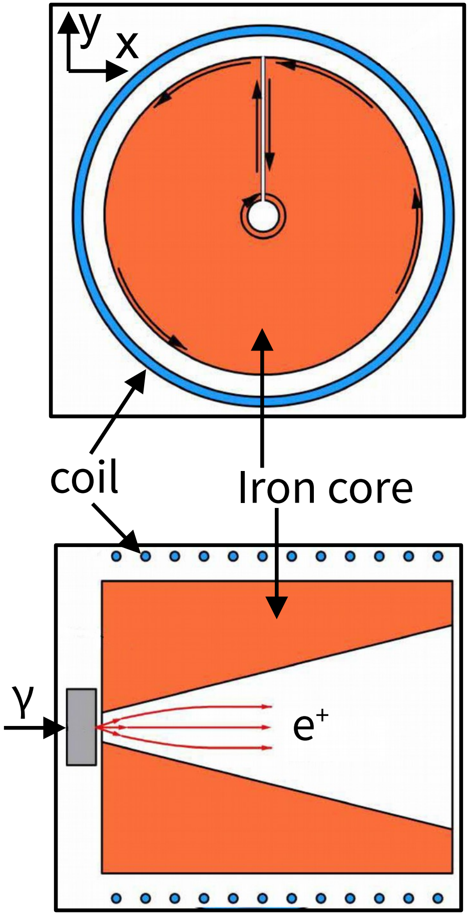


Normal conducting, pulsed magnetic field:
3.2 T close to target, 0.5 T downstream



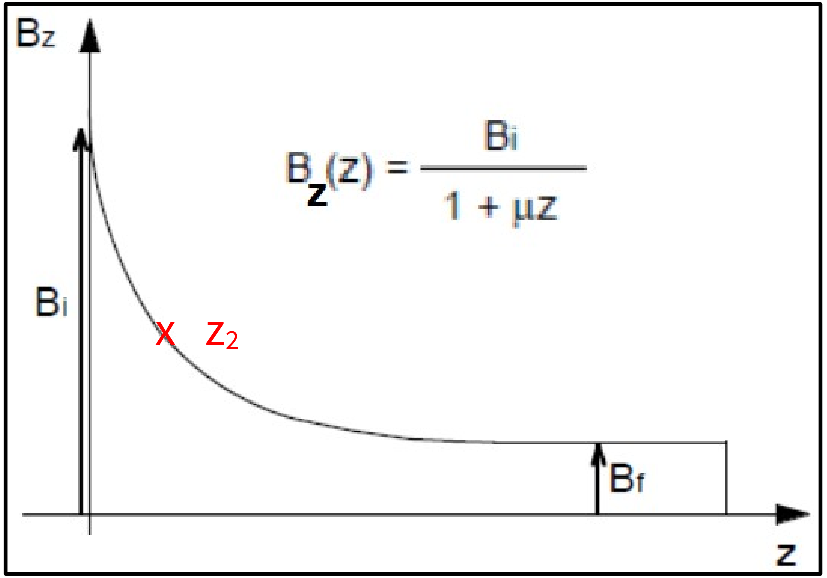


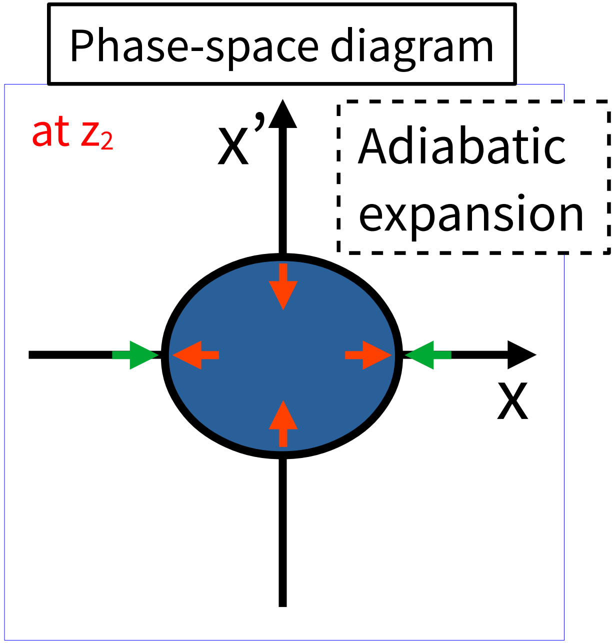
Source: T. Kamitani, kamitani20070824.pdf (2007)
T. Kamitani, kamitani20061101.pdf (2006)



- <u>Normal conducting, pulsed magnetic field:</u>
  3.2 T close to target, 0.5 T downstream

- Drag force → heat load, stronger drive motor,
  5 Hz resonance effects





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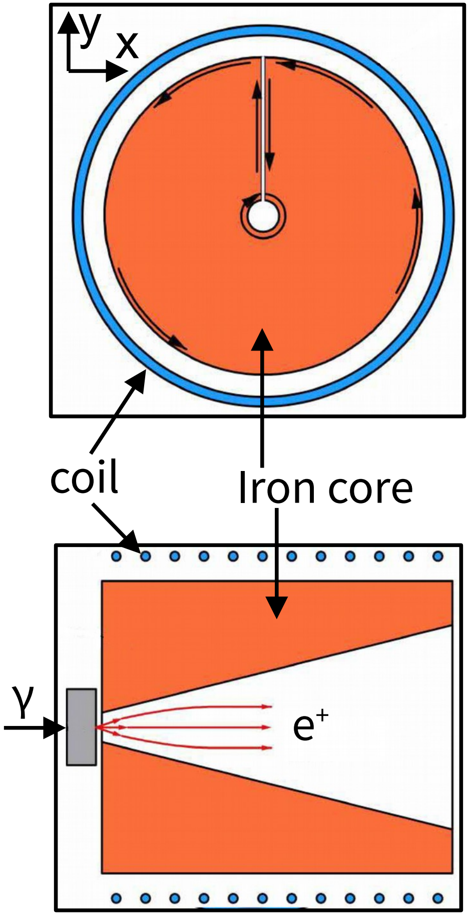

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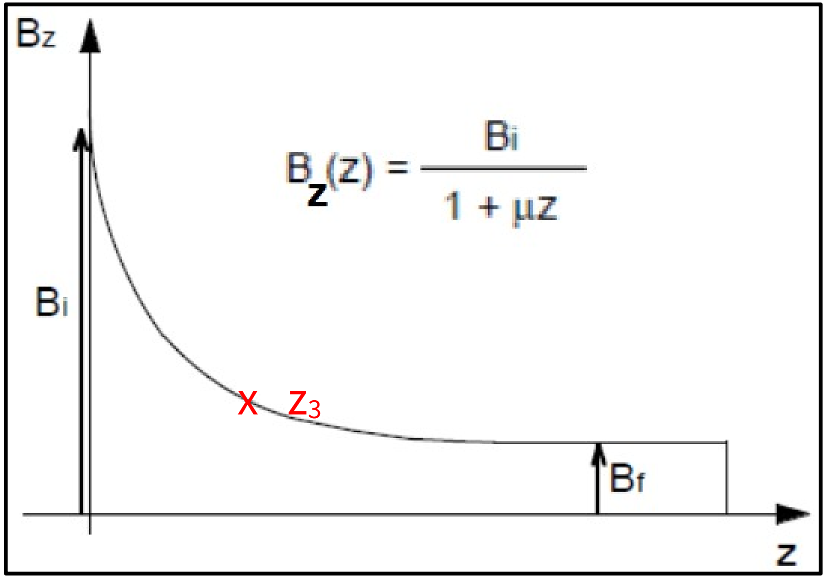

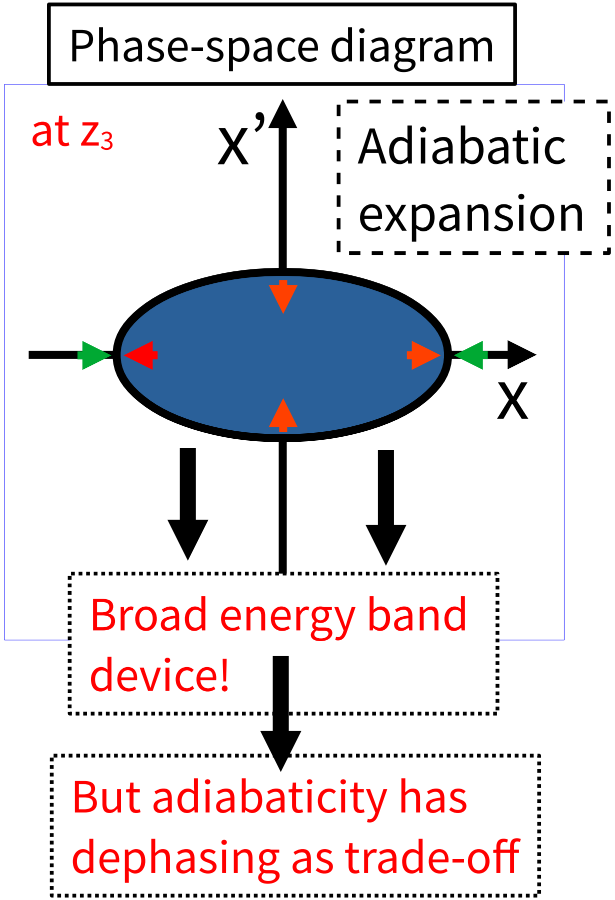

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QWT & FC: Summary

	QWT	FC
1) Dephasing	- helical path	- helical
2) Chromaticity	- large	+ low
3) Eddy current	+ manageable	- problematic

QWT & FC: Summary

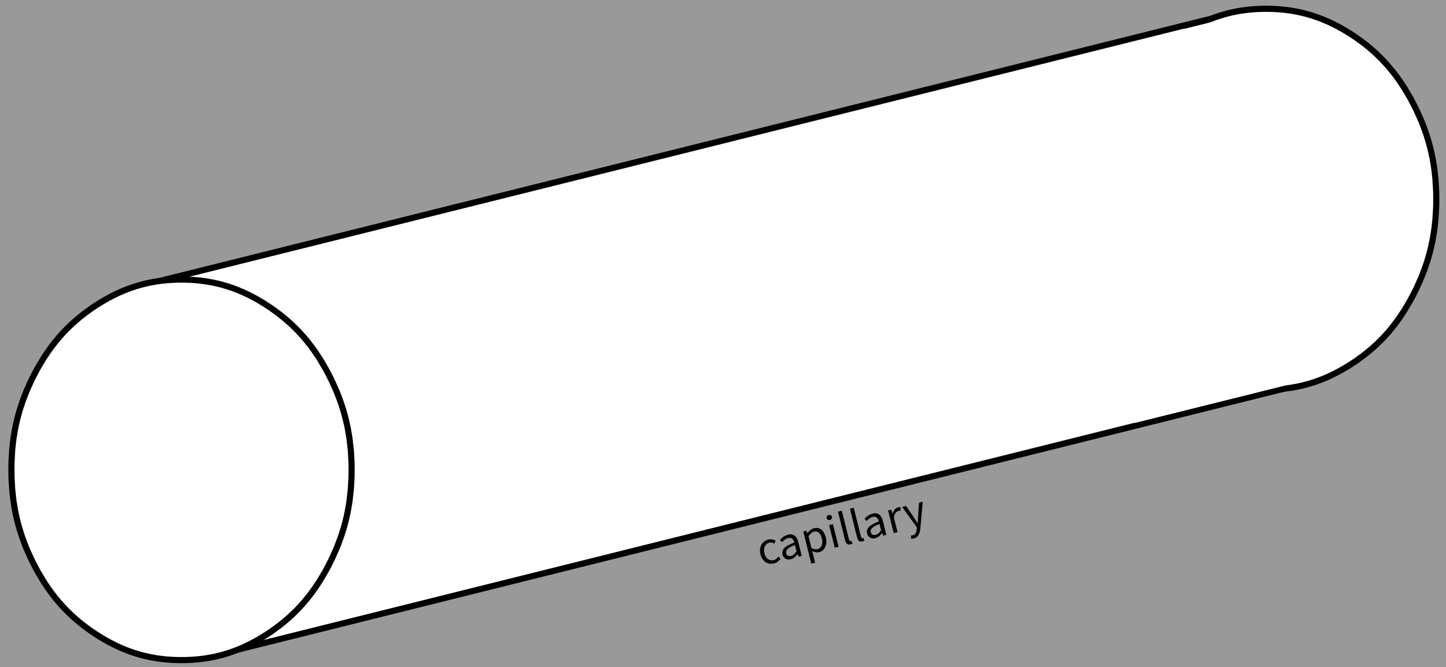
	QWT	FC
1) Dephasing	- helical path	- helical
2) Chromaticity	- large	+ low
3) Eddy current	+ manageable	- problematic → Works for slowly rotating targets (SLC) → but difficult for fast target at ILC!

QWT by Fukuda for ILC ←

Plasma Lens: Potential

	QWT	FC	tapered PL
1) Dephasing	- helical path	- helical	+ sinusoidal
2) Chromaticity	- large	+ low	+ low
3) Eddy current	+ manageable	- problematic	+ very little

Active Plasma Lens: Principle



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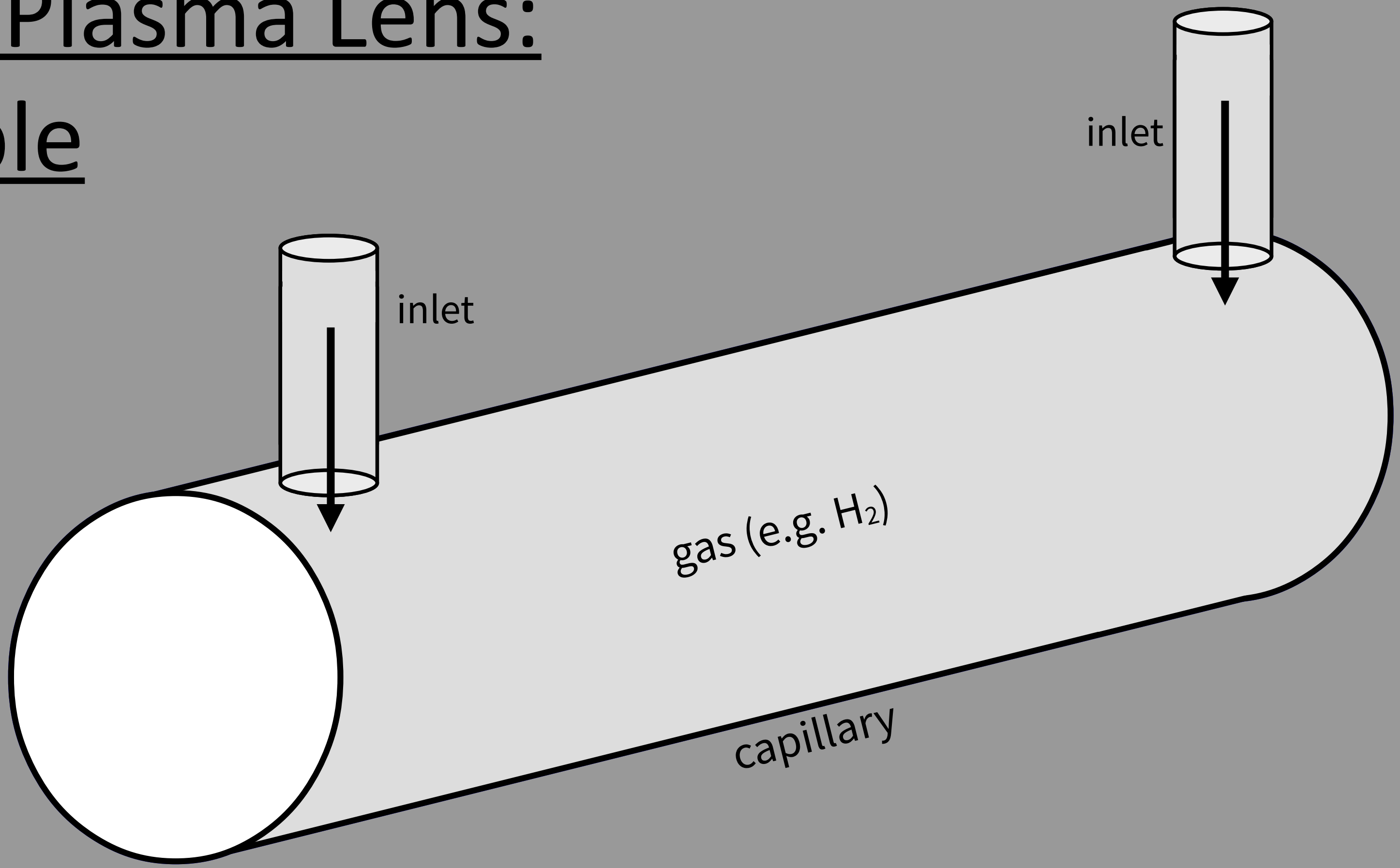

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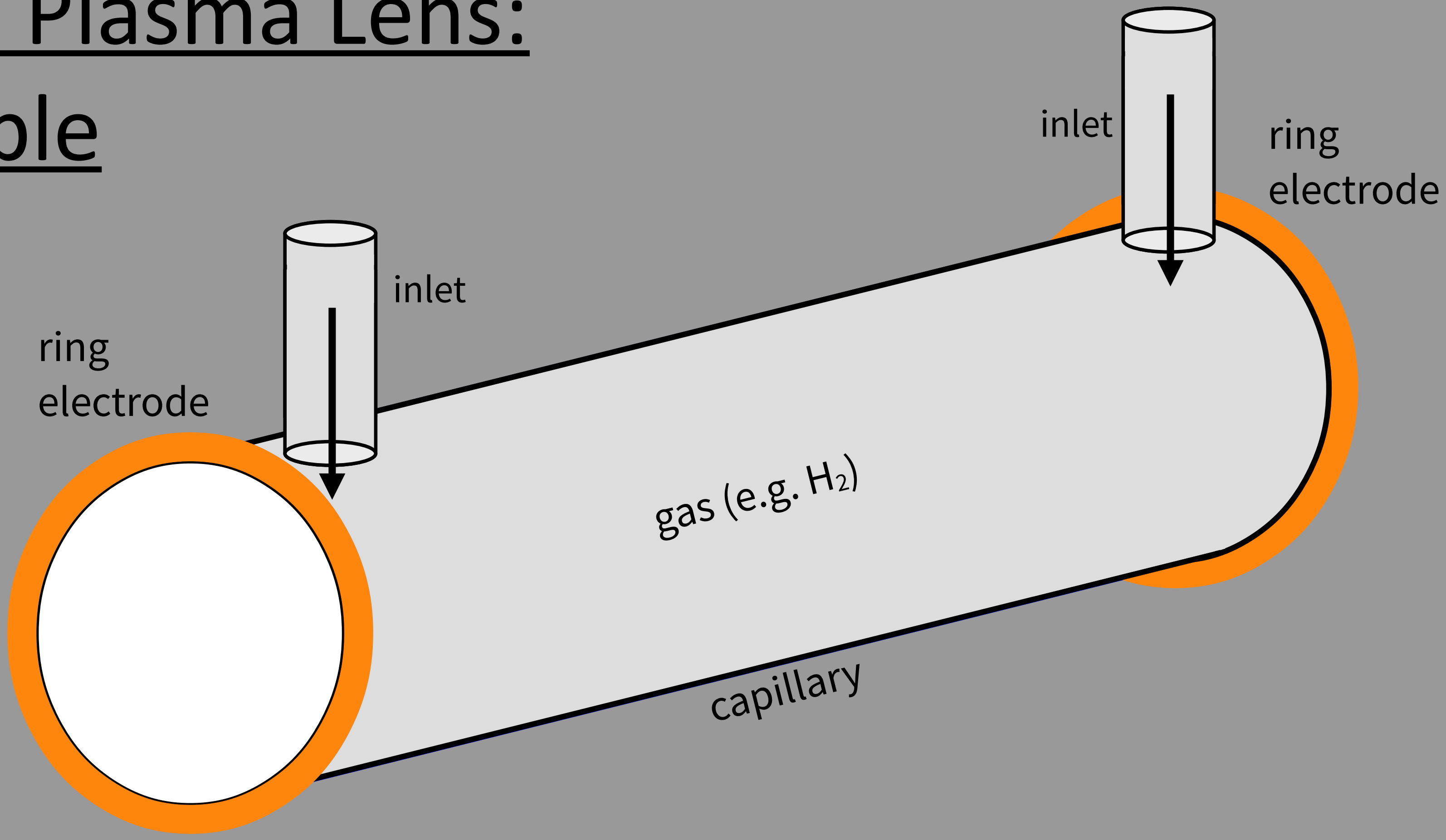

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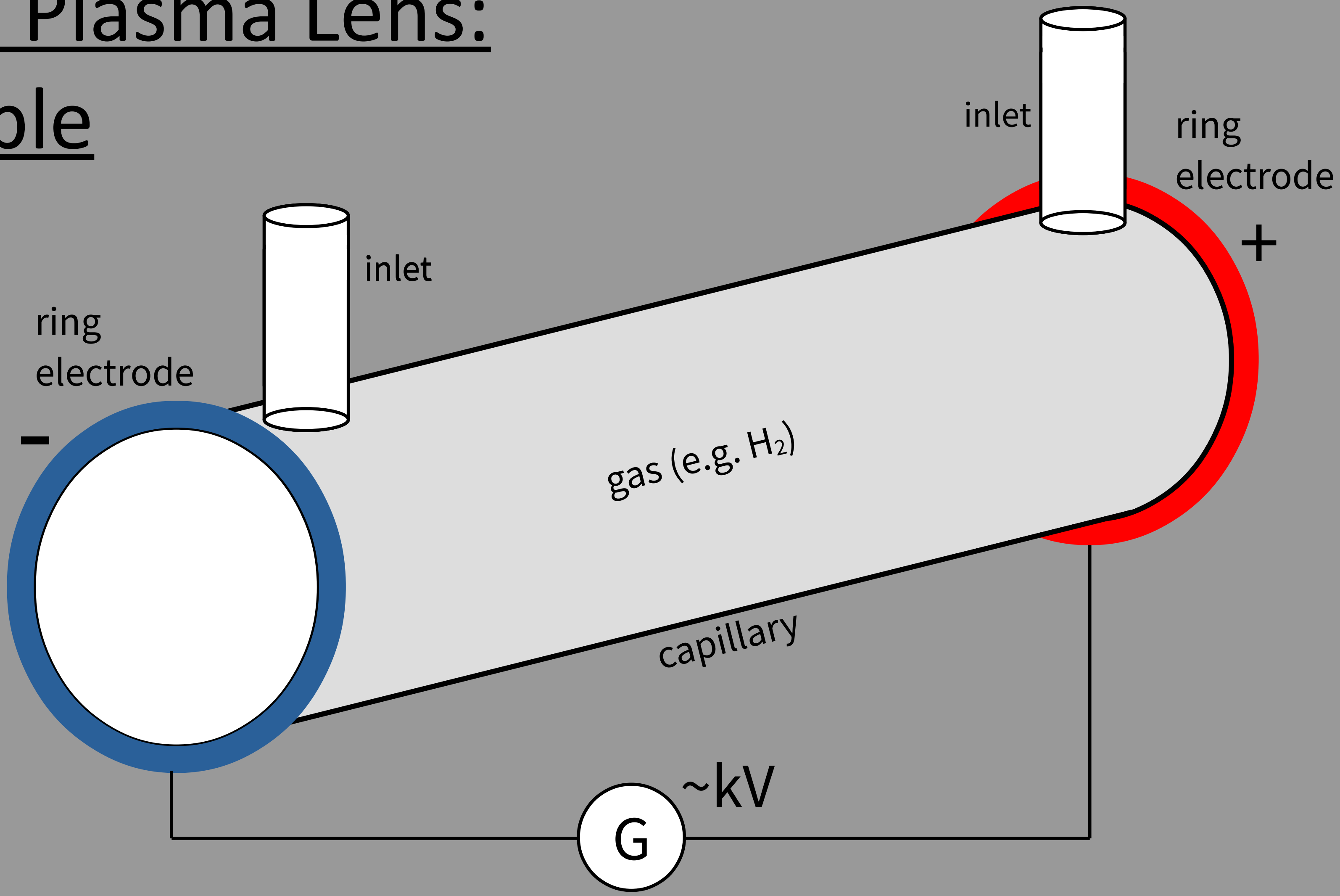

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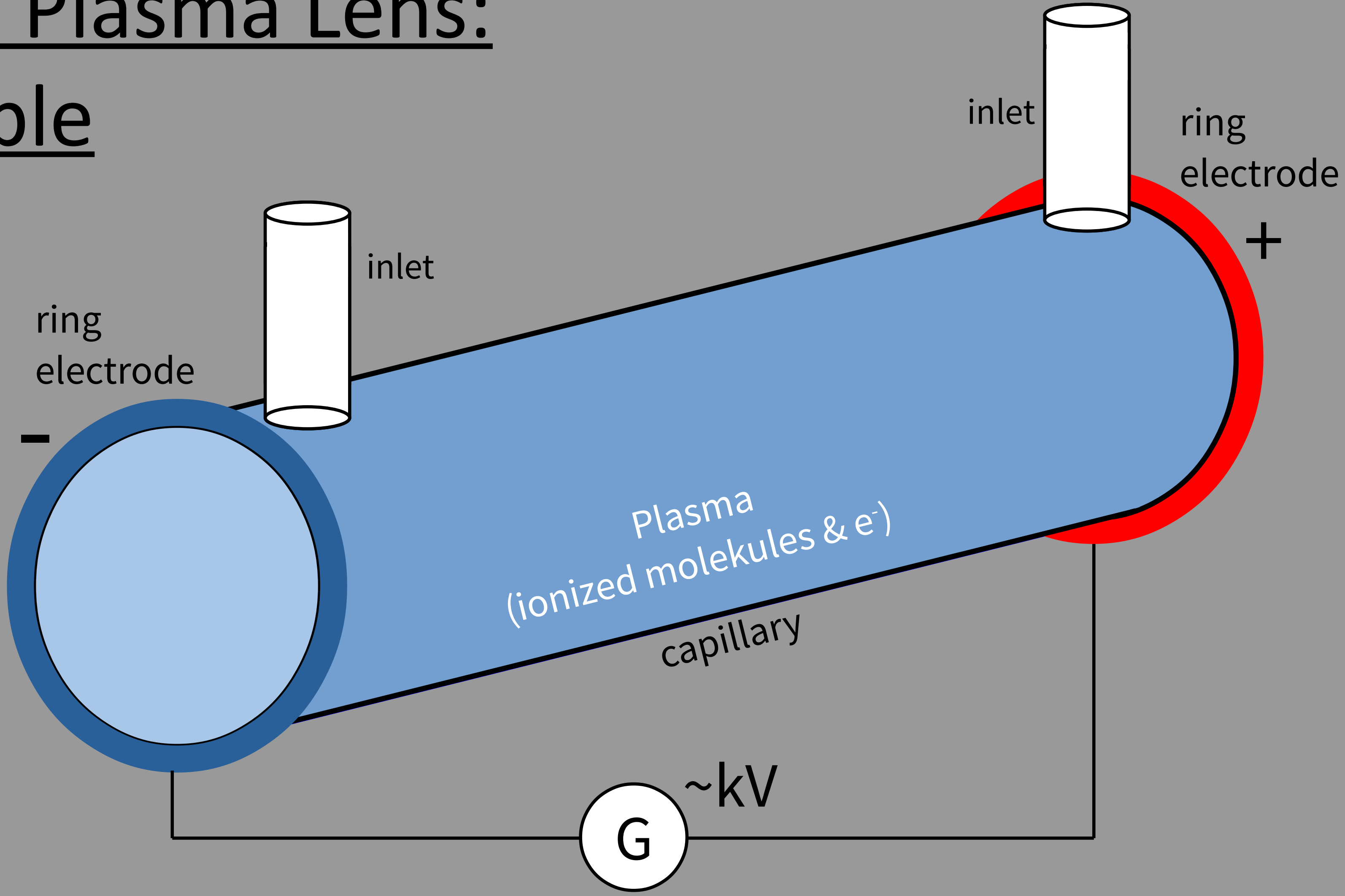

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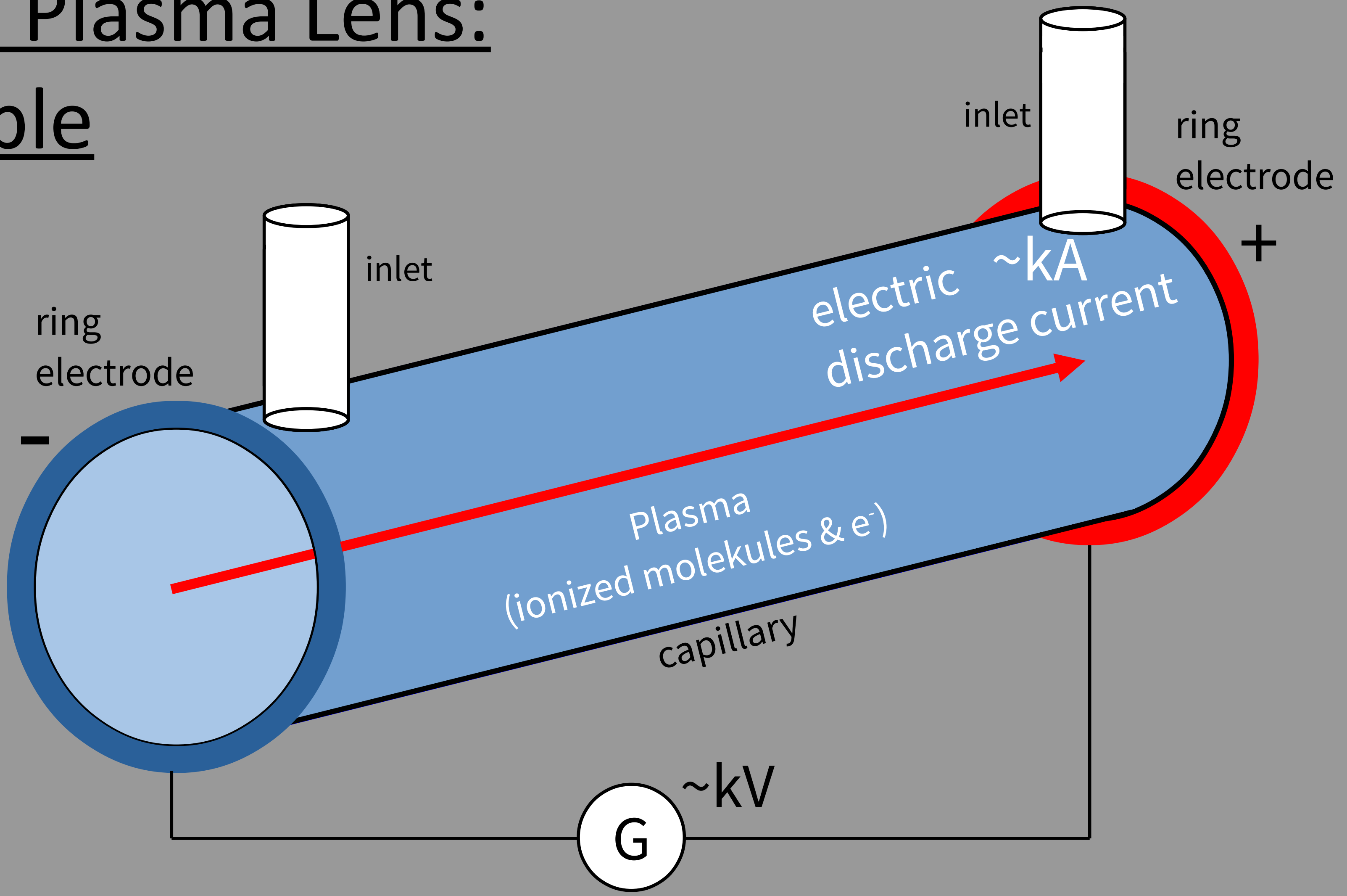

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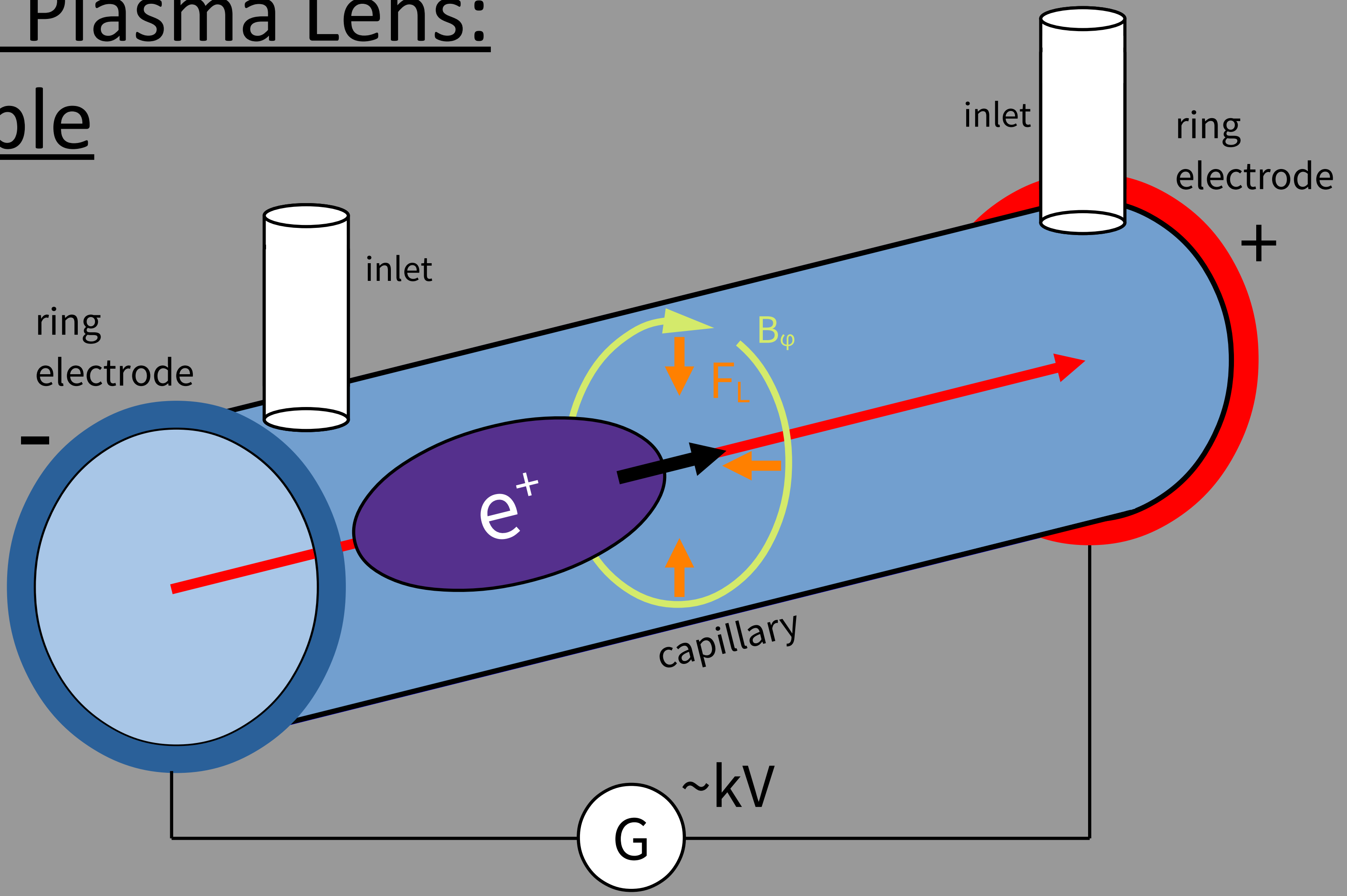

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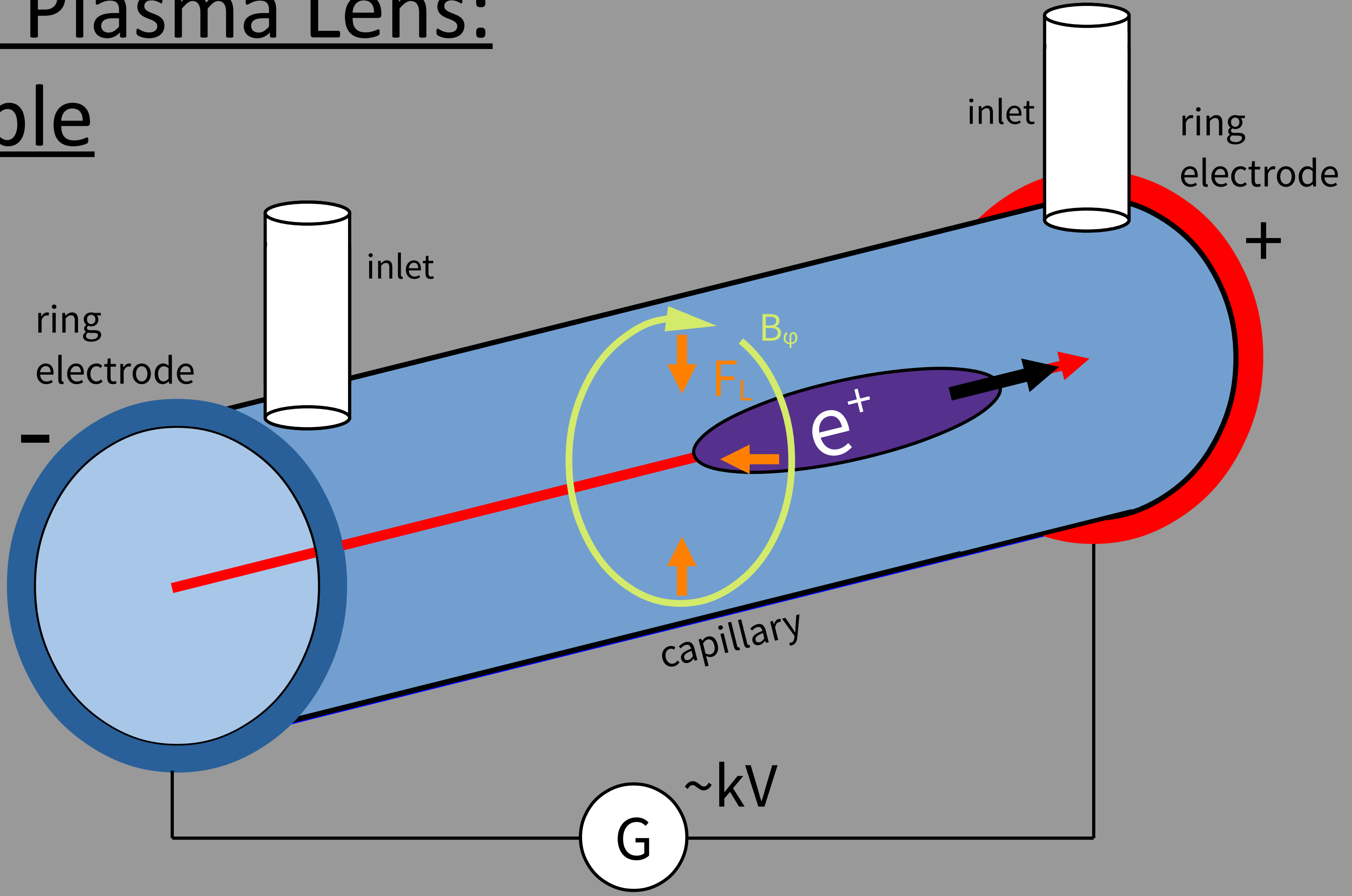

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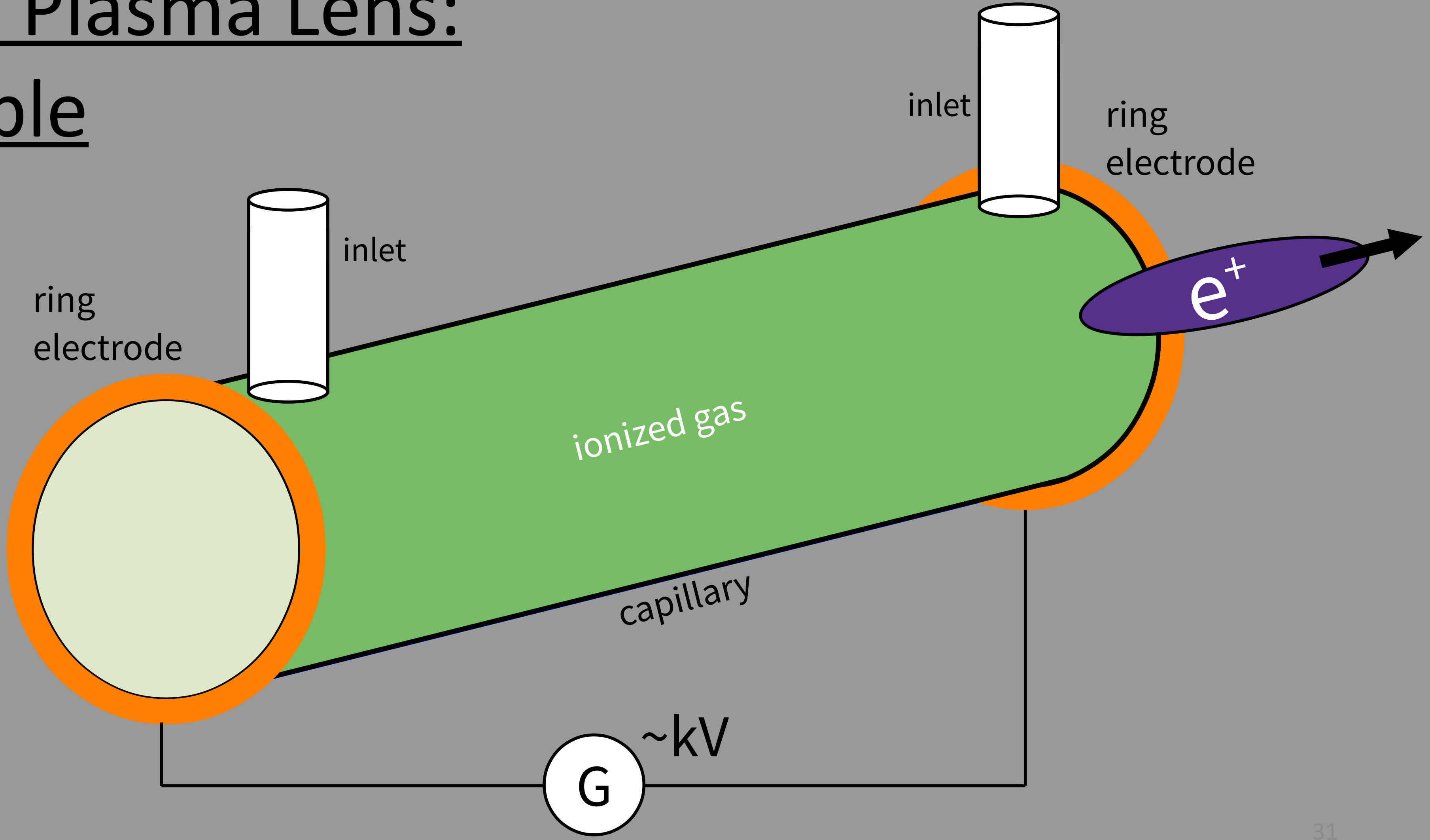

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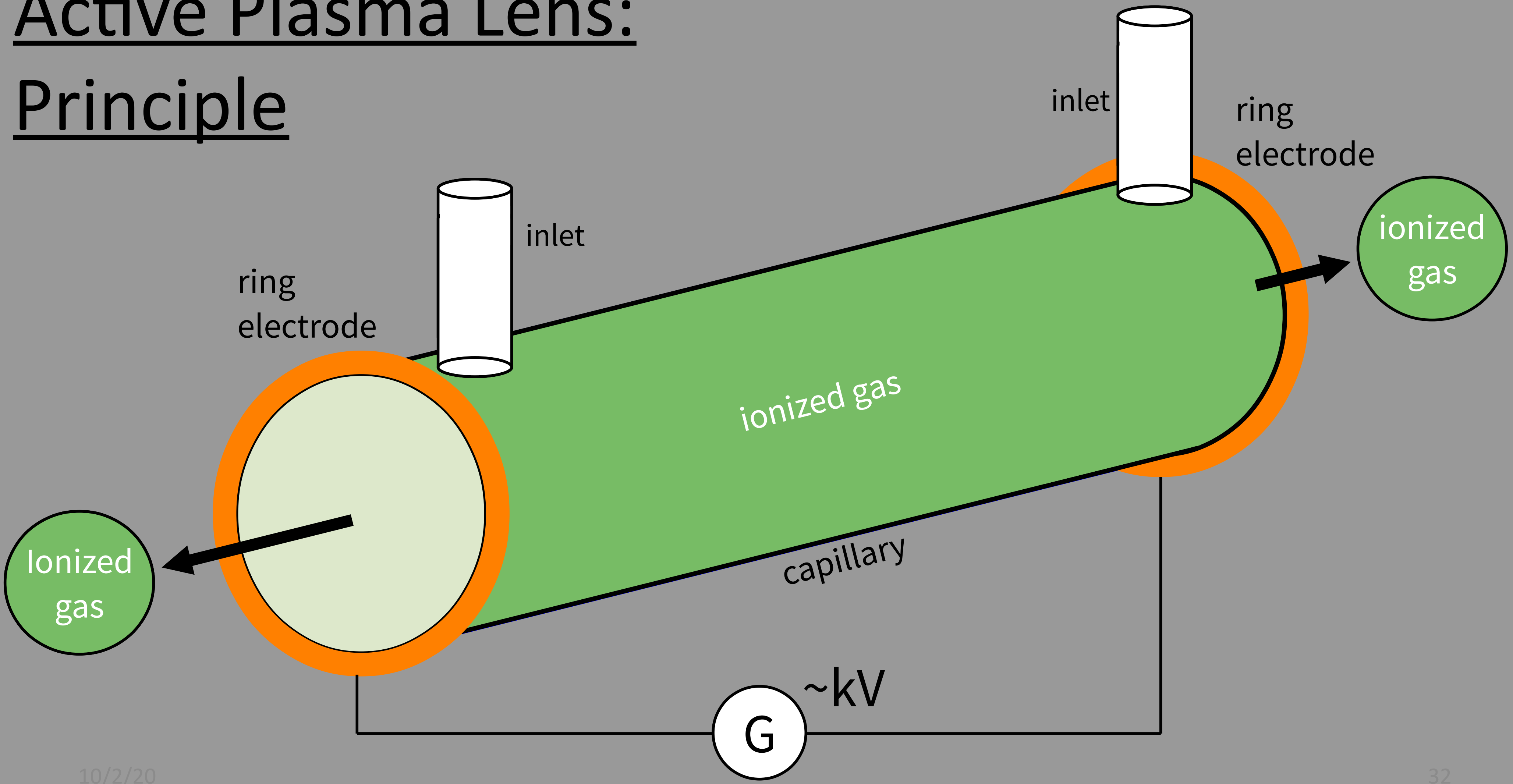

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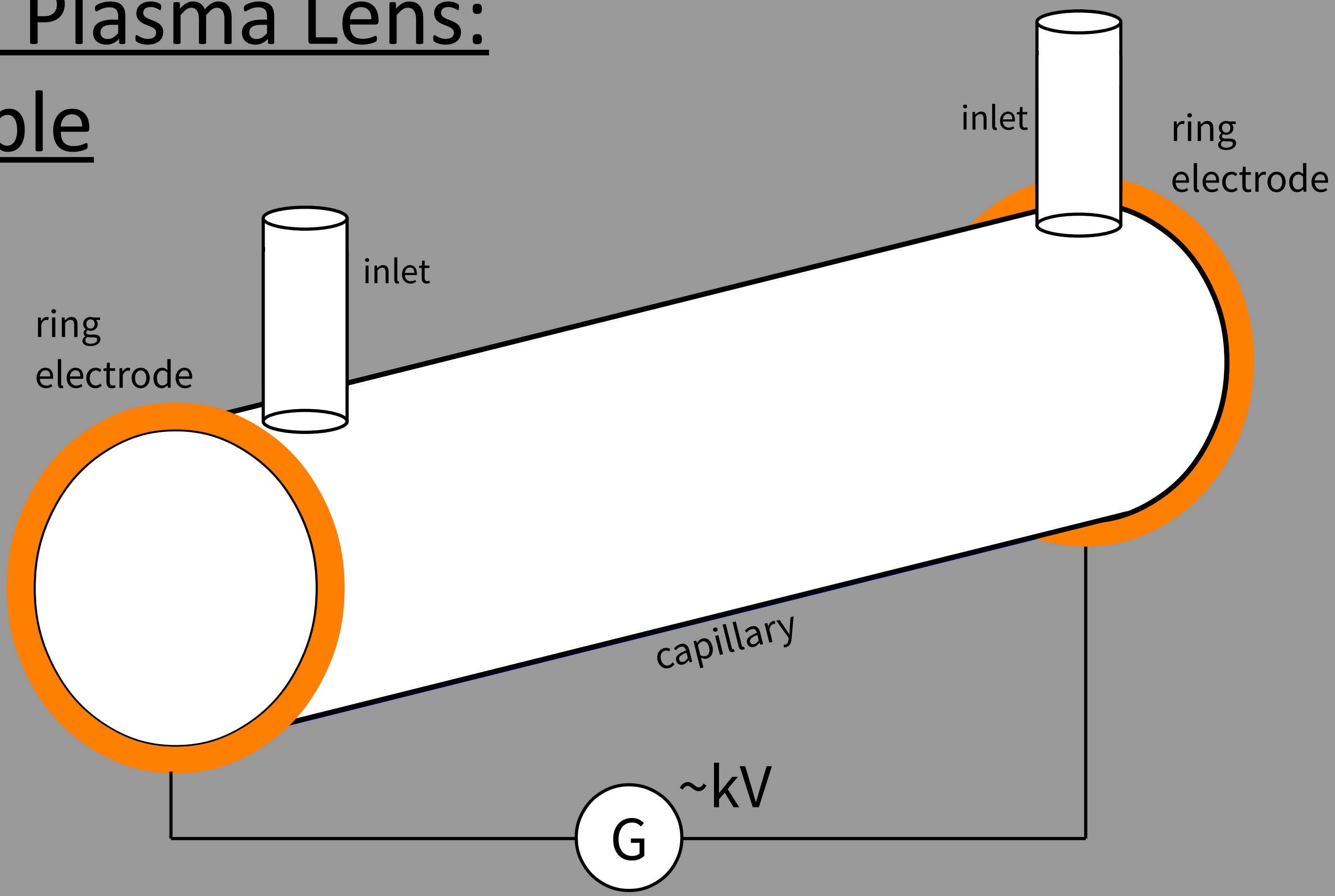

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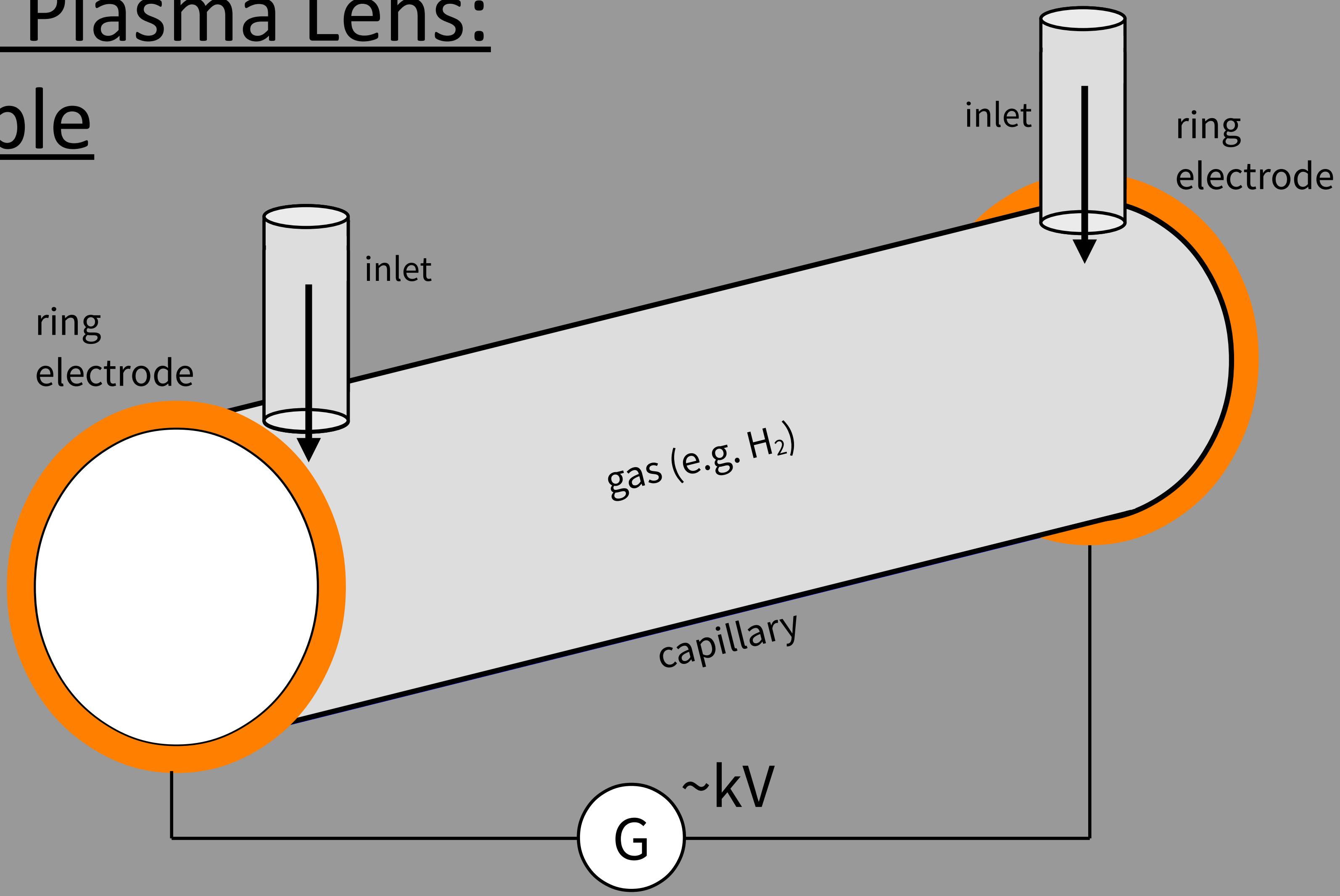
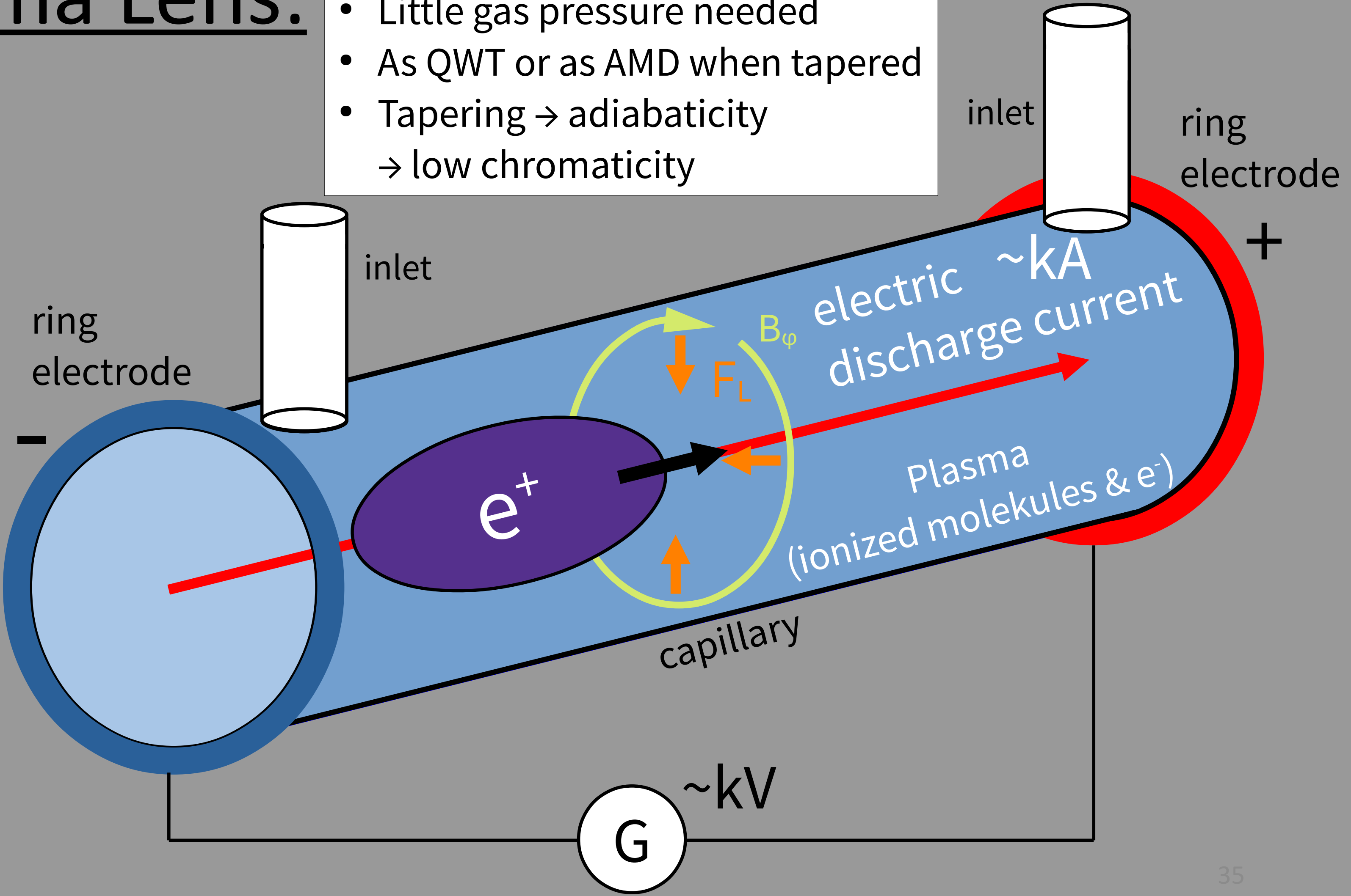
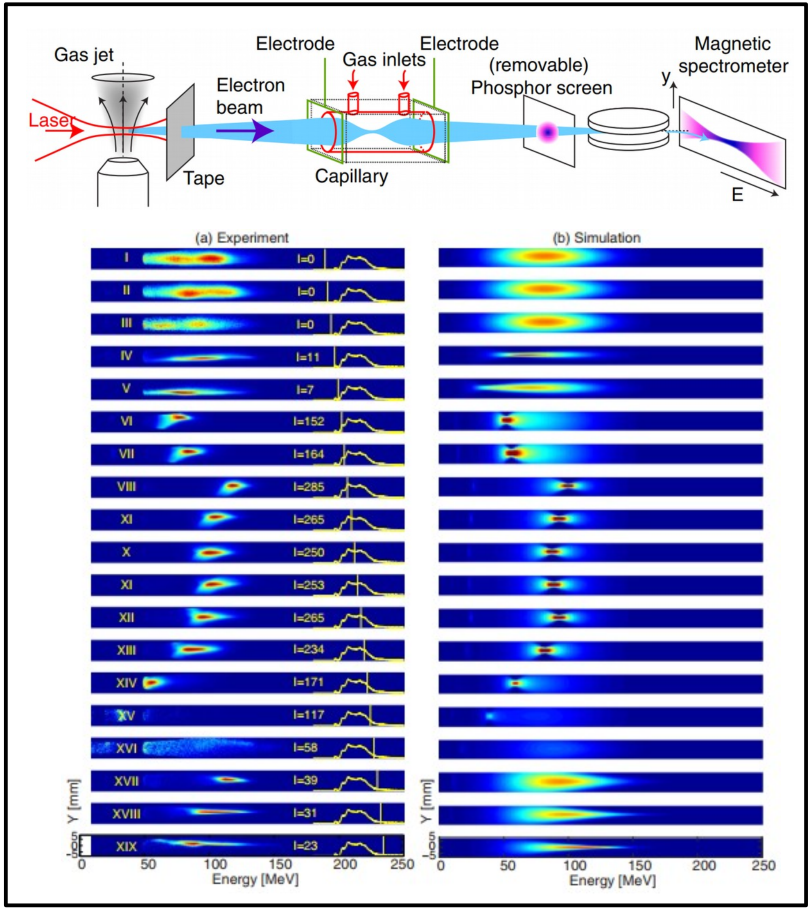


Active Plasma Lens: Principle

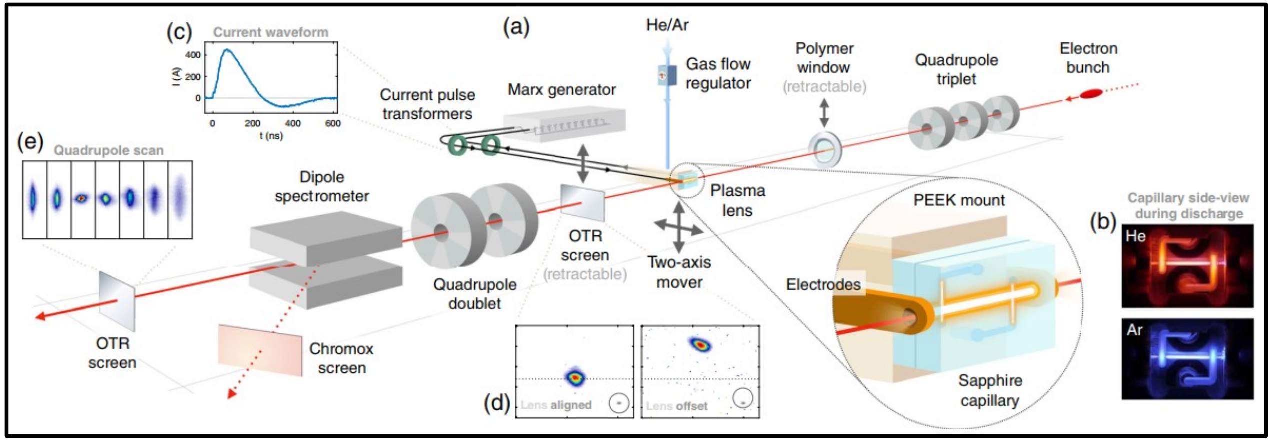
- Little plasma-beam scattering
- Little gas pressure needed
- As QWT or as AMD when tapered
- Tapering → adiabaticity
  → low chromaticity



Active field of research!



Source: Van Tilborg, Jeroen, et al. "Active plasma lensing for relativistic laser-plasma-accelerated electron beams." Physical review letters 115.18 (2015): 184802.



Source: Lindstrøm, Carl A., et al. "Emittance preservation in an aberration-free active plasma lens." Physical review letters 121.19 (2018): 194801.

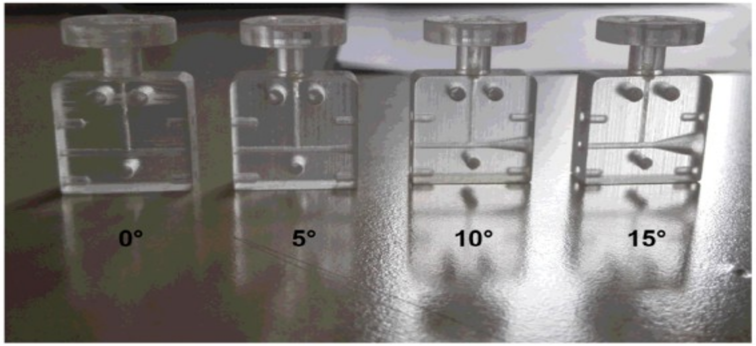
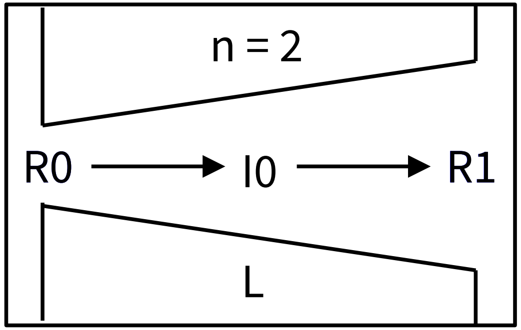


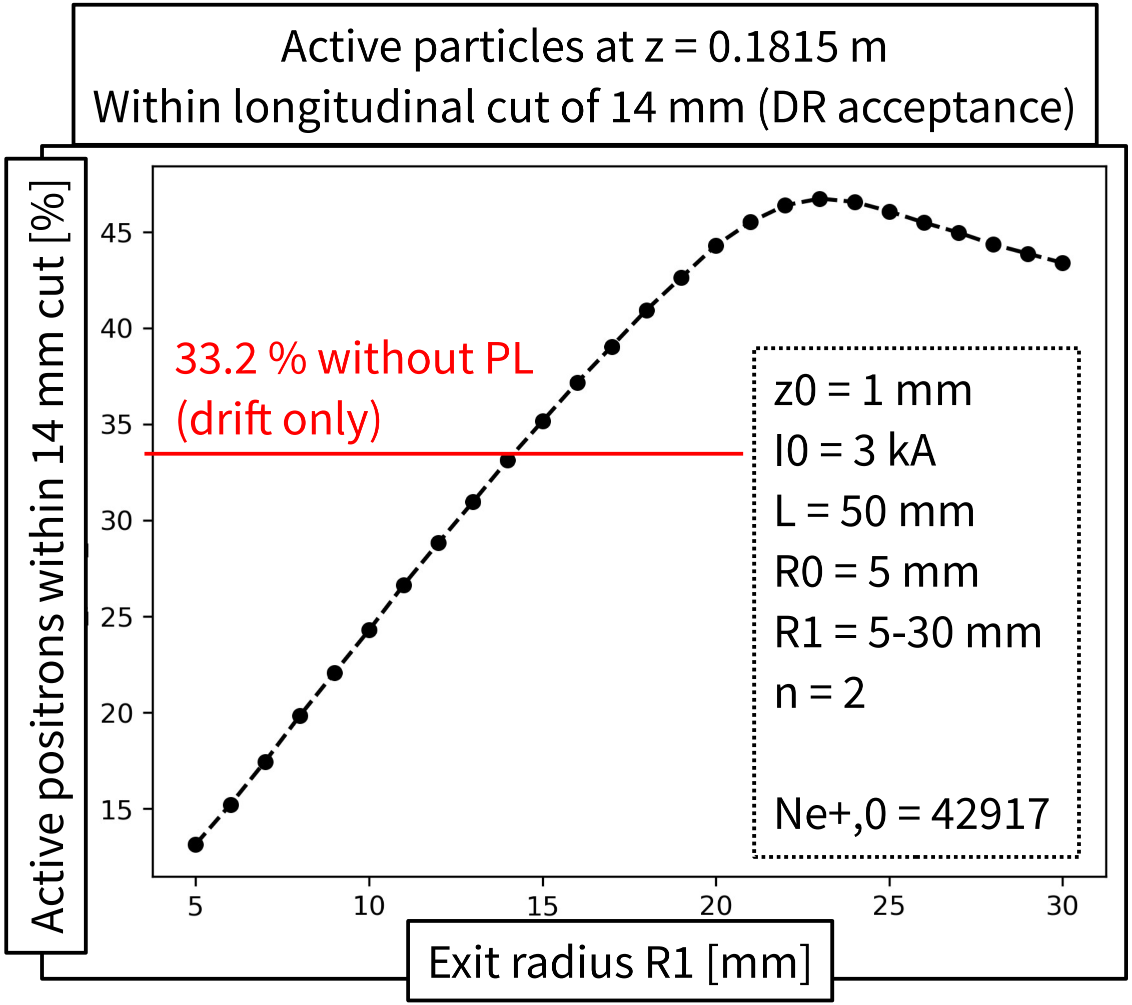
Fig. 4. Set of 3D printed capillaries with different tapering angle which will be investigated in the next experimental campaign.

Source: Filippi, F., et al. "Tapering of plasma density ramp profiles for adiabatic lens experiments." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 909 (2018): 339-342.

First step: simulation & optimization

AMD:
Tapered Plasma Lens





Outlook

- No windows? Is an exit window possible due to widened beam?
- Electrode implementation?
- Gas inlets?
- Wakefields? Avoided by neutral e^--e^+ beam passing the capillary?
- Cavity behaviour under vacuum conditions near the target?
- What discharge routine? One for each bunch? For each pulse?
- …

Thank you for your attention!