Hydrodynamic Simulations of an Argon-filled Tapered Plasma Lens for Optical Matching at the ILC e^+ Source

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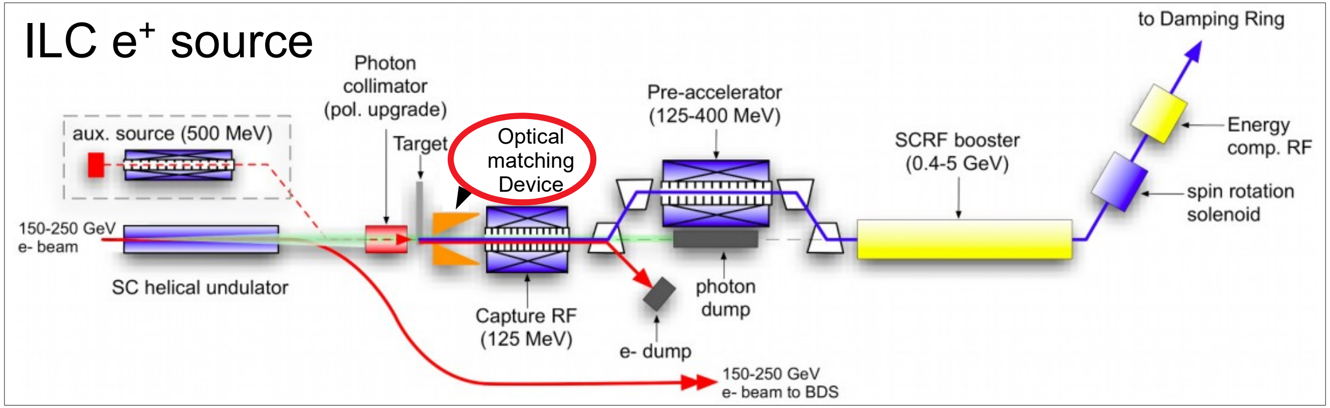
Motivation

Need to collimate divergent e+

➔ Optical Matching Device

➔



•Principle of Plasma Lens:

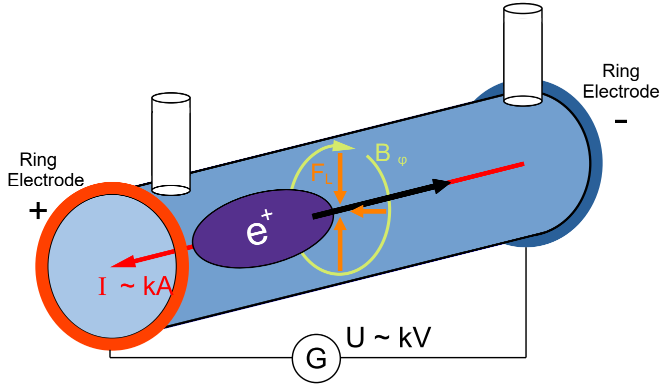
1) Inlets fill capillary with gas (e.g. $H2$, Ar)

2) Voltage on electrodes ignites plasma

3) Electrons are accelerated (Electric current)

4) Current induces azimuthal magnetic field B_{φ}

5) Magnetic field focuses incoming charged particle beam



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

Optmization of PL Design

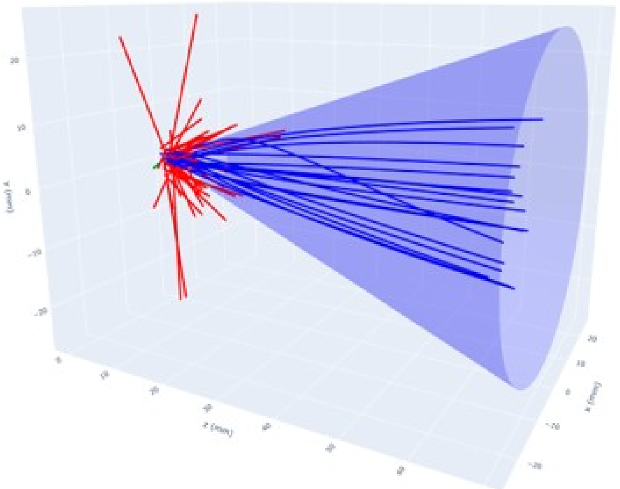
Simulations with ASTRA

Particle Tracking Simulations

•Goal: find optimized PL design

•Conditions:
1) ILC e+ distribution
2) No Beam self-interaction
3) Idealised plasma lens:
➔ No Plasma dynamics
➔ Ideal magnetic field (from j(x,y,z,t) = $j_z(z)$)

➔ Result: ~43% captured e+ with <u>Tapered</u> capillary profile!



	Electric Current	Taper Type	Opening Radius	Exit Radius	Capillary Length
Full Scale:	9000 A	linear	4.30 mm	25.5 mm	60 mm
Prototype:	350 A		0.85 mm	5.0 mm	12 mm

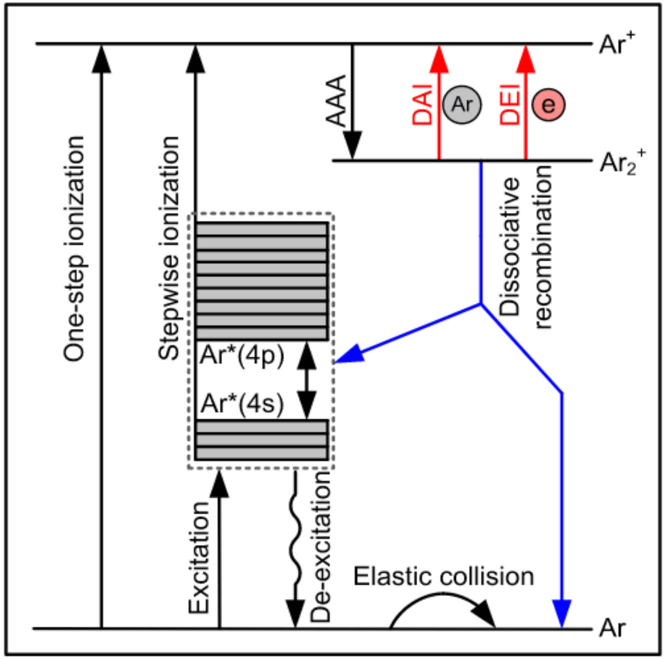
Downscaled by factor ~5

Large dimensions!

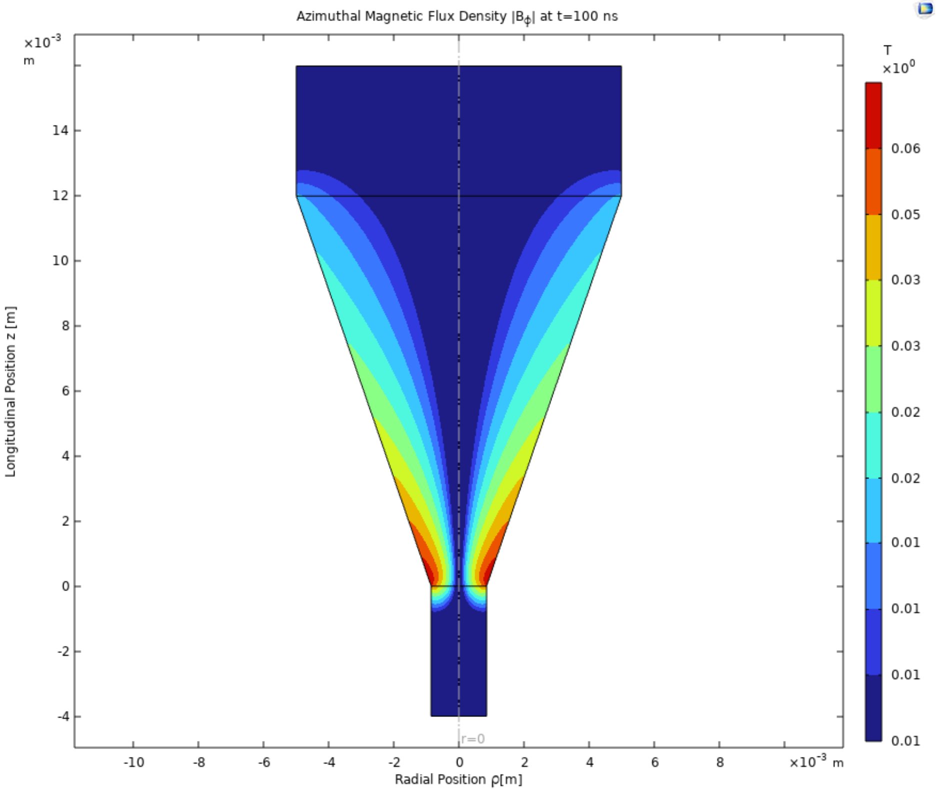
Preliminary HD Results

Model by M. Mewes

Physical process	Reaction expression
AAA: Atom assisted association	$2Ar + Ar^+ \rightarrow Ar + Ar_2^+$
DR: Dissociative recombination	$e + Ar_2^+ \rightarrow Ar + Ar^*$
DAI: Dissociation by atom impact	$Ar + Ar_2^+ \rightarrow 2Ar + Ar^+$
DEI: Dissociation by electron impact	$e + Ar_2^+ \rightarrow e + Ar + Ar^+$

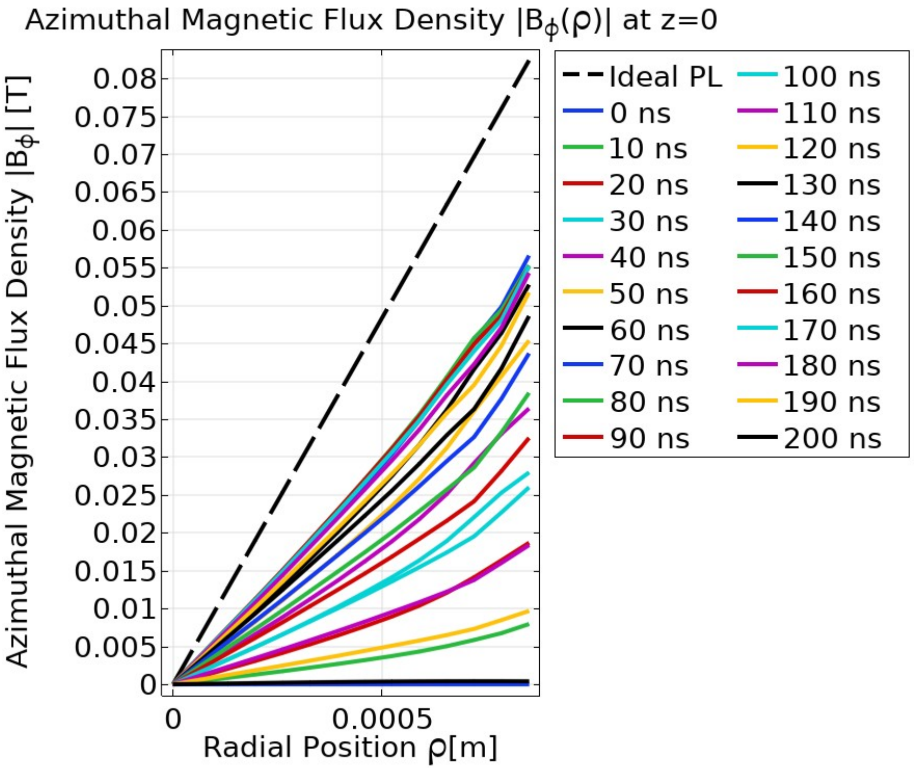


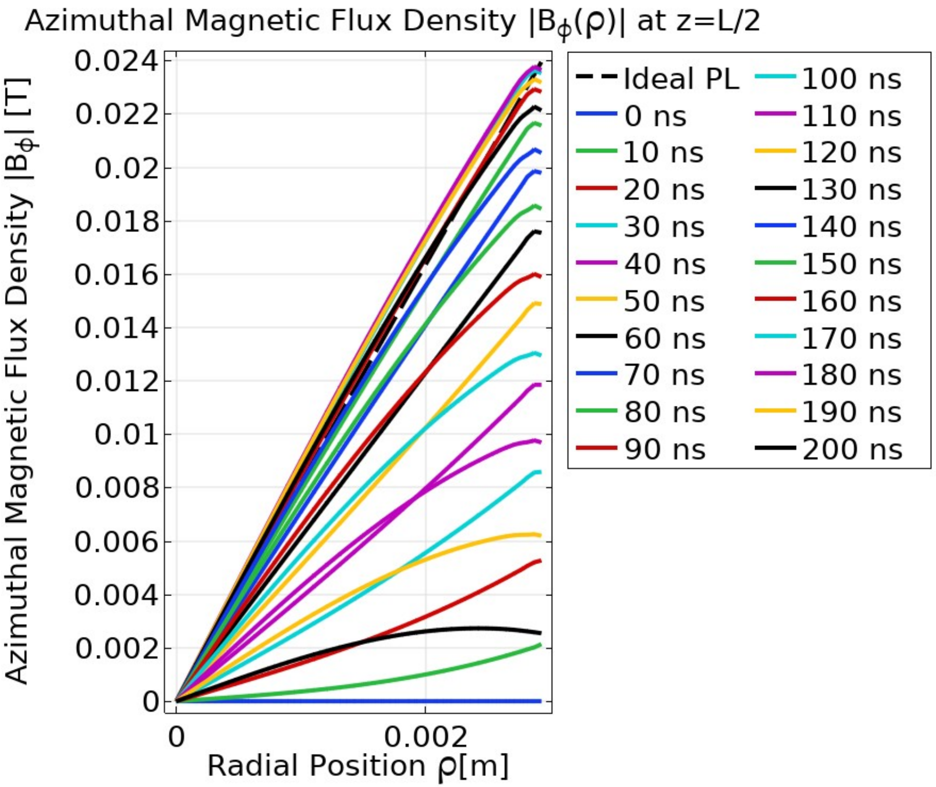
- Simulations in COMSOL
- Effective 3D Model (2D with axial sym.)



Preliminary (M)HD Results

Model by M. Mewes





Outlook

- Implementations needed:
  1) Improve Momentum-Transfer Model
  2) Angled Inlets
  3) Realistic materials of components
  4) Rotating target
  5)
- To study:
  1) Plasma response to multi-pulse discharges
     ➔ Demanding e+ beam time structure

	Repetition rate	Duration	Spacing
Pulse	5 Hz	727 μs	199 ms
Bunch	1.8 MHz	538 ps	554 ns

  2) Gas flow into downstream accelerator
     ➔ Discharges in cavity possible (no acceleration)
  3) Heat load on geometries
- Compare with prototype experiments by Niclas Hamann (next talk)

Thank you for listening!