A tapered pulsed solenoid as optical matching device for the undulator-based ILC positron source

Overcoming limitations of long-pulse positron focusing elements

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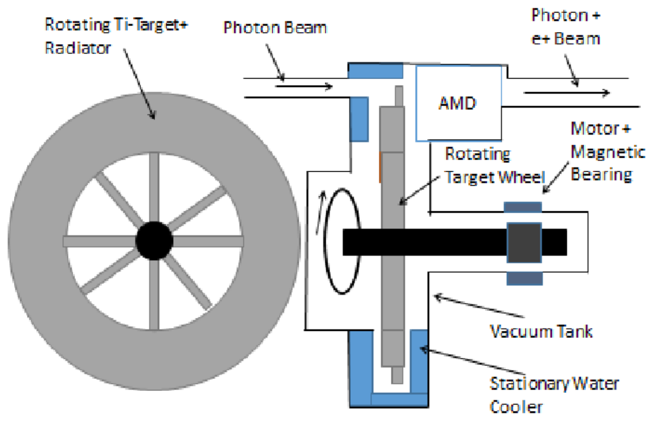
DESY.

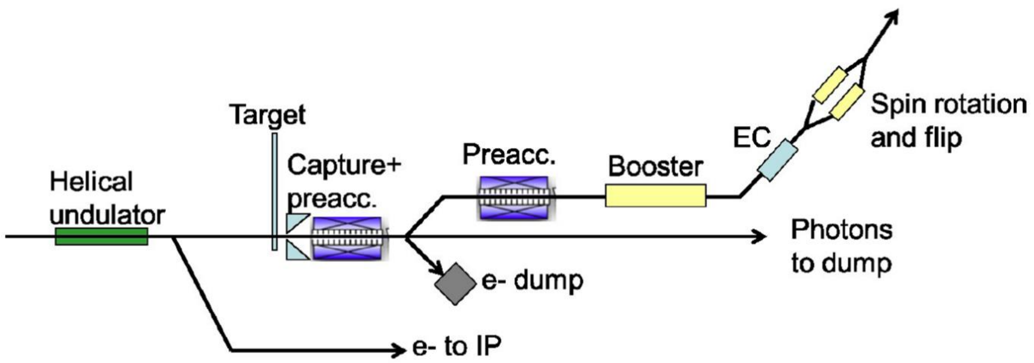
ILC undulator-based positron source

Introduction to layout and technical challenges

- Fast rotating target wheel
- 1ms-positron pulse duration
- OMD for positron capturing
  - Flux concentrator
    - *Focus variation during long pulses*
  - Quarter-wave transformer
    - *Limited yield*

Principal Layout: Ti-Wheel with a Diameter of 1.0 m, rotating at 100 m/s, 2000 rpm.



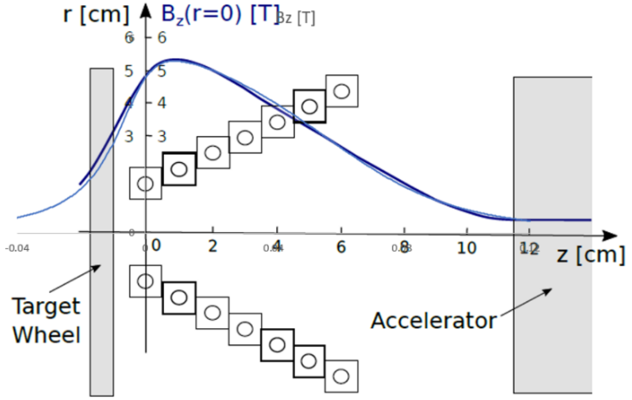


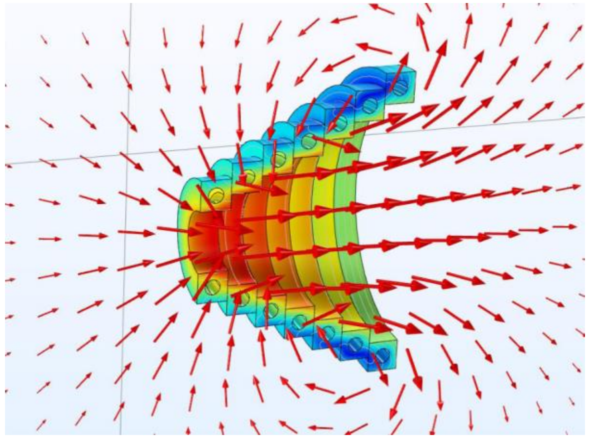
- New approach: Pulsed solenoid
  - Stable and reproducible focus
  - High magnetic flux density
  - Compatible with long pulse duration
  - Manageable heat load in solenoid
  - Manageable heat load on target (!?)
  - Mechanical stress (!?)

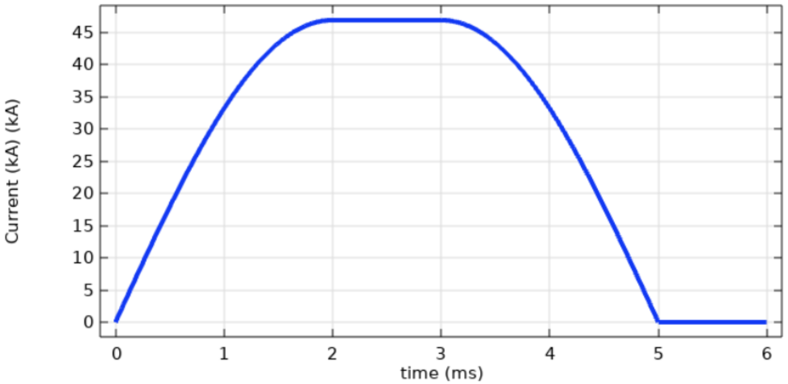
Pulsed solenoid for positron focusing

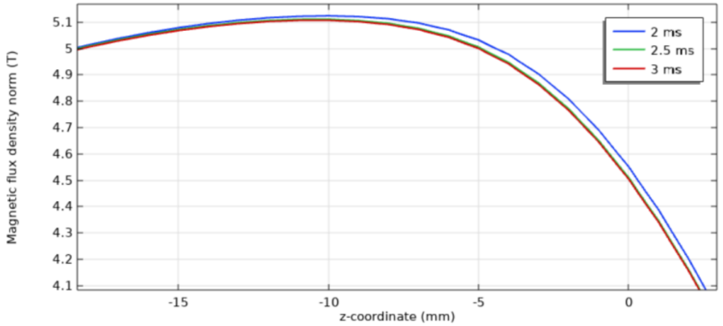
Background and previous work

- Pulsed solenoid was e.g. used at LEP
- Constant, small coil winding cross-section for uniform current density
- Pulsed to reduce power/thermal load
- Potentially higher yield (!?)
- Prel. parameters:
  - ~50 kA peak current
  - 4 ms half-sine pulse + 1ms flat-top
  - 7 turns, linear taper (20mm → 80mm)
  - Peak field ~5 T
  - Average heat load on target: 73 W + 711 W
  - Peak force on wheel 612 N



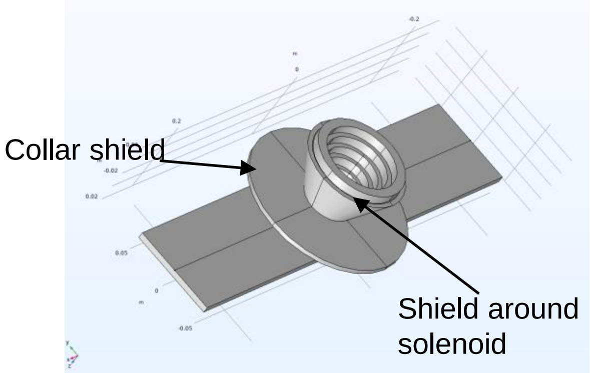


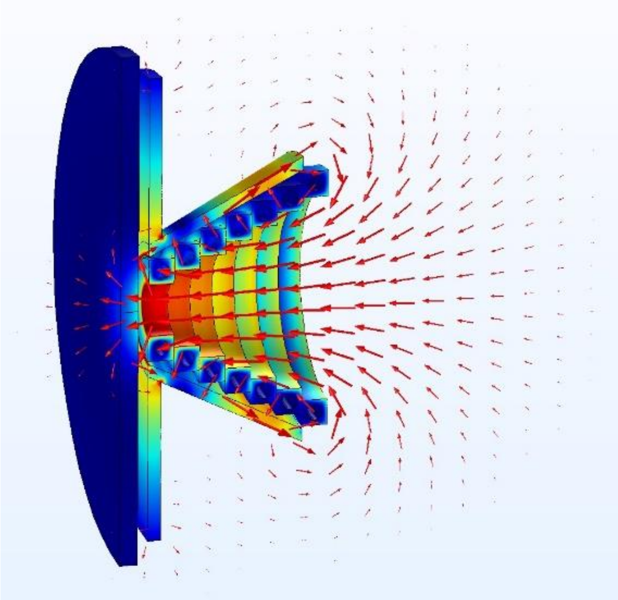




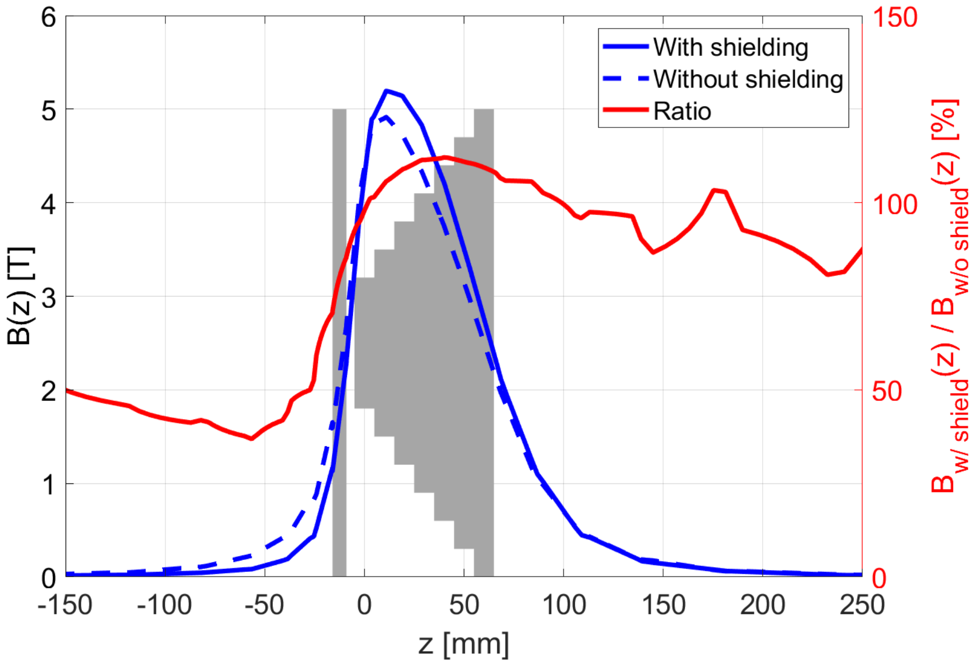
Ferrite shielding

Summary





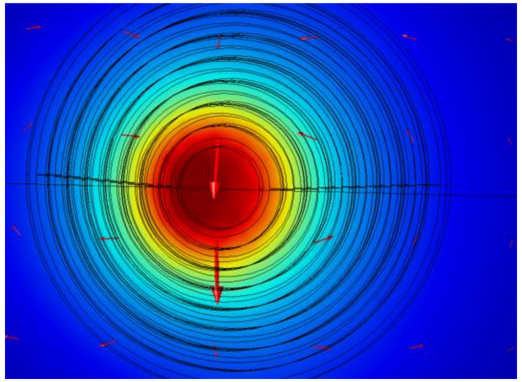
- ▶2D & 3D simulation in Comsol
- ▶Movement of titanium plate included (100m/s)
- ▶Peak solenoid current: 46886 A
- ▶Combined shield geometry model: coil shield w/ min. distance to shielding (~1mm) + collar shield
- ▶→ reduction of force & heat load on target
- ▶→ Increase of peak B(z) ~10%
- ▶Shielding material:
Alloy Powder Core Ferrite H 150000 Mu (Comsol)



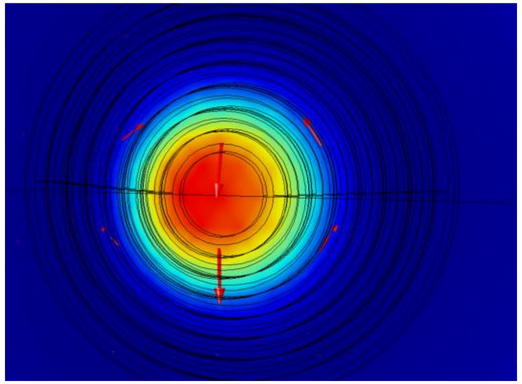
Ferrite shielding

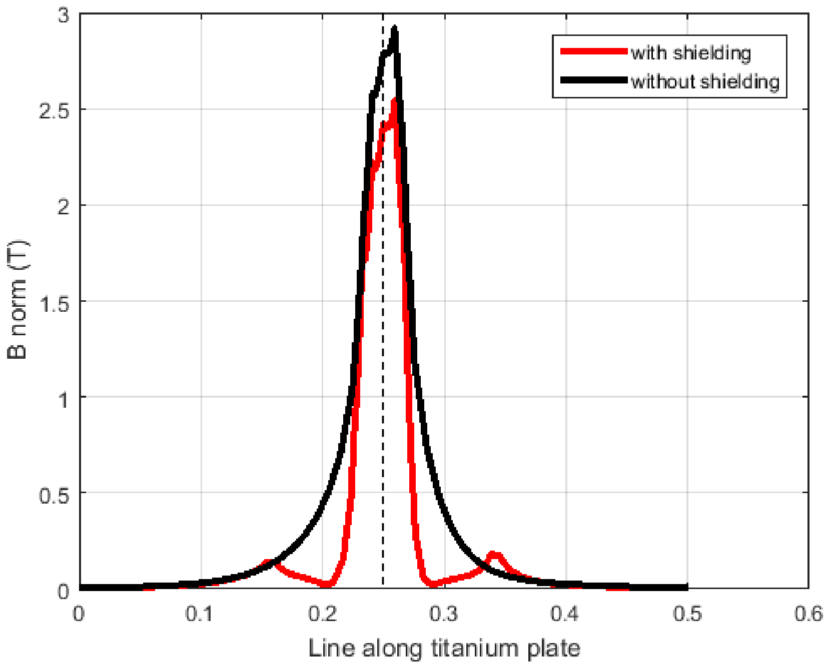
Heating of titanium wheel

Without shielding



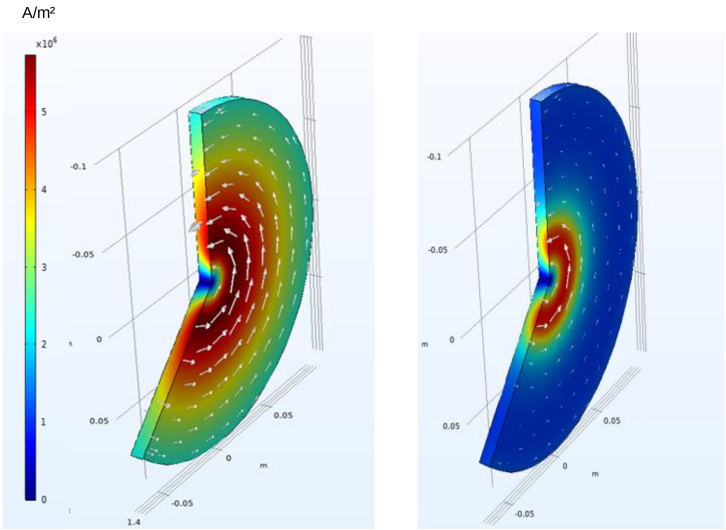
With shielding





Magnetic flux density B(z) on titanium wheel [T]

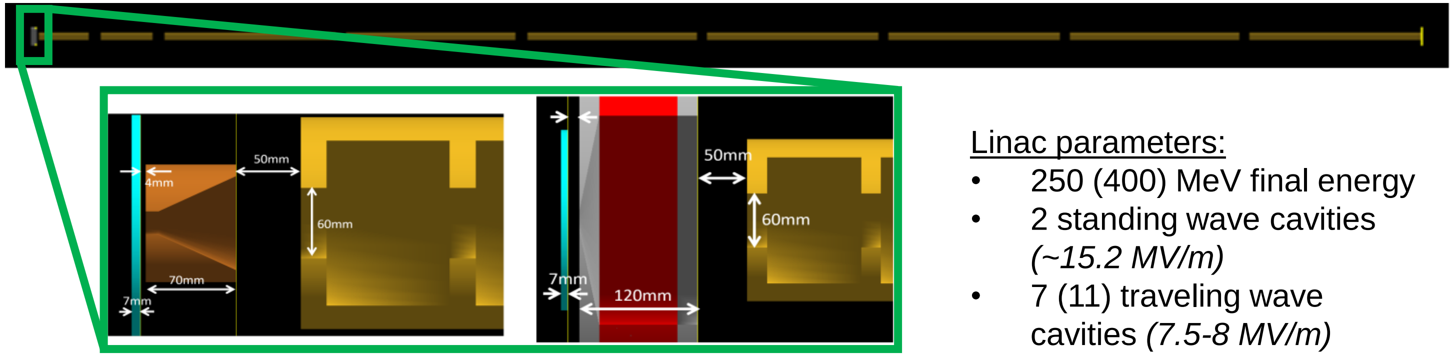
- ▶Reduction of induced heat 73W + 711W → 31W + 298W
- ▶Reduction of peak force on target 612N → 263N
- ▶Slight field drag (by target movement)
- ▶→ Further optimization along with mechanical design



e+ yield simulations: OMD & capture linac

Simulation from target to end of pre-accelerator (M. Fukuda, K. Yokoya, T. Okugi)

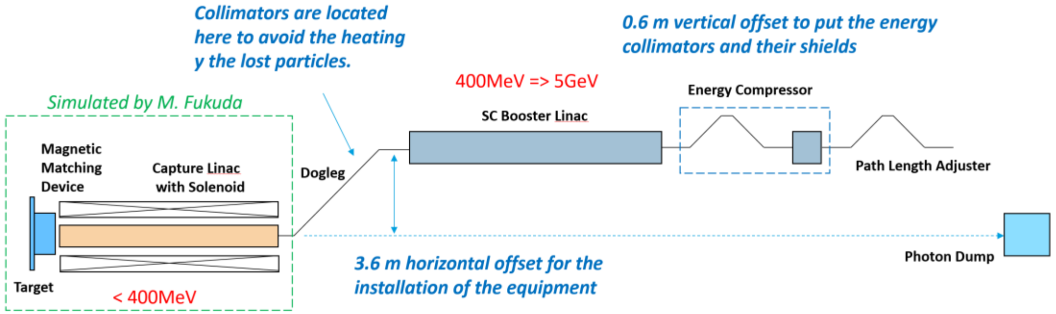
- Yield simulated for:
  - Shielded solenoid
  - Unshielded solenoid
  - Quarter-wave transformer (ref.)



<u>Linac parameters:</u>
- 250 (400) MeV final energy
- 2 standing wave cavities *(~15.2 MV/m)*
- 7 (11) traveling wave cavities *(7.5-8 MV/m)*

- Simulation with
  - Geant4
  - Comsol (pulsed solenoid field, incl. target/eddy currents)
  - POISSON (magnetic field pre-accelerator, QWT)

- Cavity phases scanned for max. yield



Yield simulations: summary

Simulation results target → damping ring

- Significant yield improvement w.r.t. QWT
- Yield for 250/400 MeV (capture linac) similar
- Bunch lengths similar (QWT & solenoid)
- Possible trade-off: target/linac heat load ↔ yield

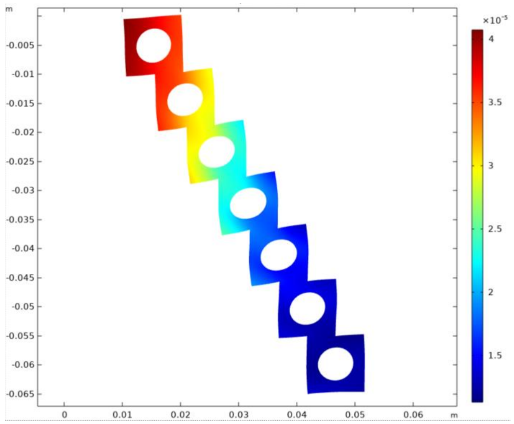
- Further optimization might be possible

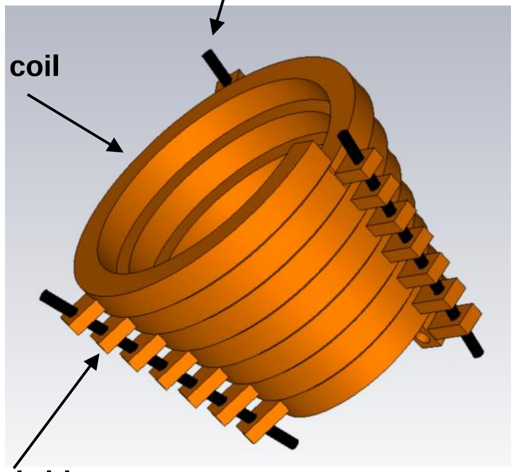
	Beamloss Power				Positron Yield
	@dogleg	@booster	@EC	@DR	@DR
QWT	0.677 kW	0.014 kW	4.01 kW - 5.56 kW	13.15 kW - 14.3 kW	**~1.1**
Pulse solenoid w/o shield	0.927 kW	0.055 kW	5.86 kW - 7.93 kW	17.39 kW - 16.01 kW	**1.91**
Pulse solenoid with shield	0.871 kW	0.064 kW	5.58 kW - 7.90 kW	17.73 kW - 16.24 kW	**1.74**

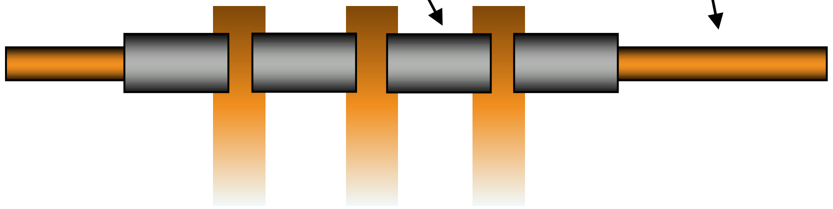
Solenoid mechanical design

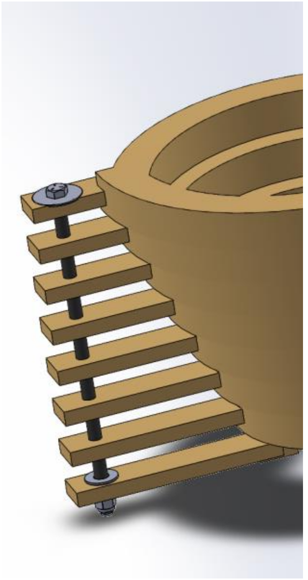
Stresses and possible support construction

- Max. peak von-Mises stress ~146 MPa
  - Soft Cu tensile strength ~200MPa
- Average power dissipation in Cu coil: ~11.5 kW
- Solenoid coil
  - Tapered windings / planar windings with interconnections
  - Conductor cooled from inside
- Metal supports to hold coil
- Support rods insulated from support bridges
  - Washers e.g. of SiN ceramics
- Magnetic shielding cut at support locations
  - Influence on field t.b.d., main shielding to target unaffected









Summary & Outlook

Recent progress and next steps

- Design of pulsed solenoid is evolving
  - → *First fields*
  - → *Heat load on target*
  - → *Shielding for heat load reduction*
  - → *Yield simulations*
- So far no show stoppers
  - → *Target heat load under control*
  - → *Head space in pulse length/shape*
- Significant yield improvement to quarter wave transformer
- Next steps
  - Prel. mechanical design
  - Influence of field variations on yield
  - Global optimization

Thank you for your attention!

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