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# *ILC Positron Production and Capturing Studies: Update*

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Work performed for the ILC e+ collaboration (SLAC, LLNL, RAL, CCRL, Cornell, KEK)

U.S. Department of Energy

UChicago Argonne LLC

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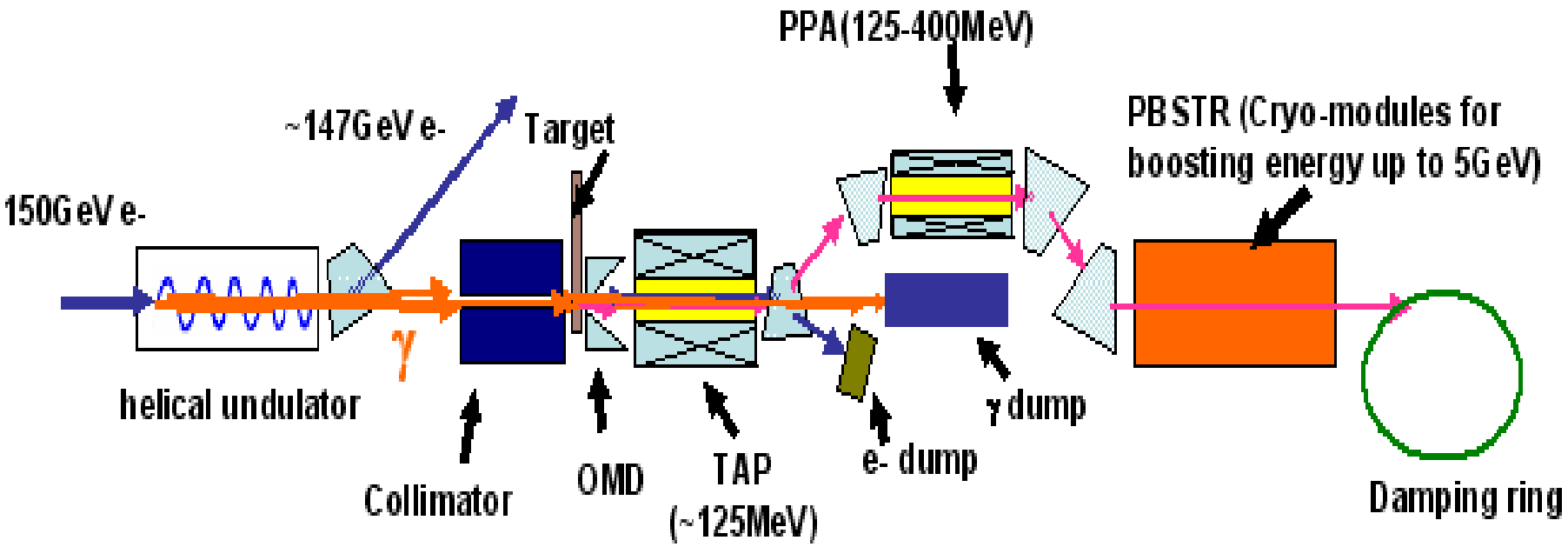
## *Outline*

1. Undulator Based Scheme with OMD Simulation Update
2. Spinning target in the OMD field and beam dynamics.
3. Alternative Approaches Toward Beam Capturing Studies:
   - Quarter Wave Transformer
   - Lithium Lens
4. Summary

# 1. The Undulator Based ILC e+ system Simulation Update



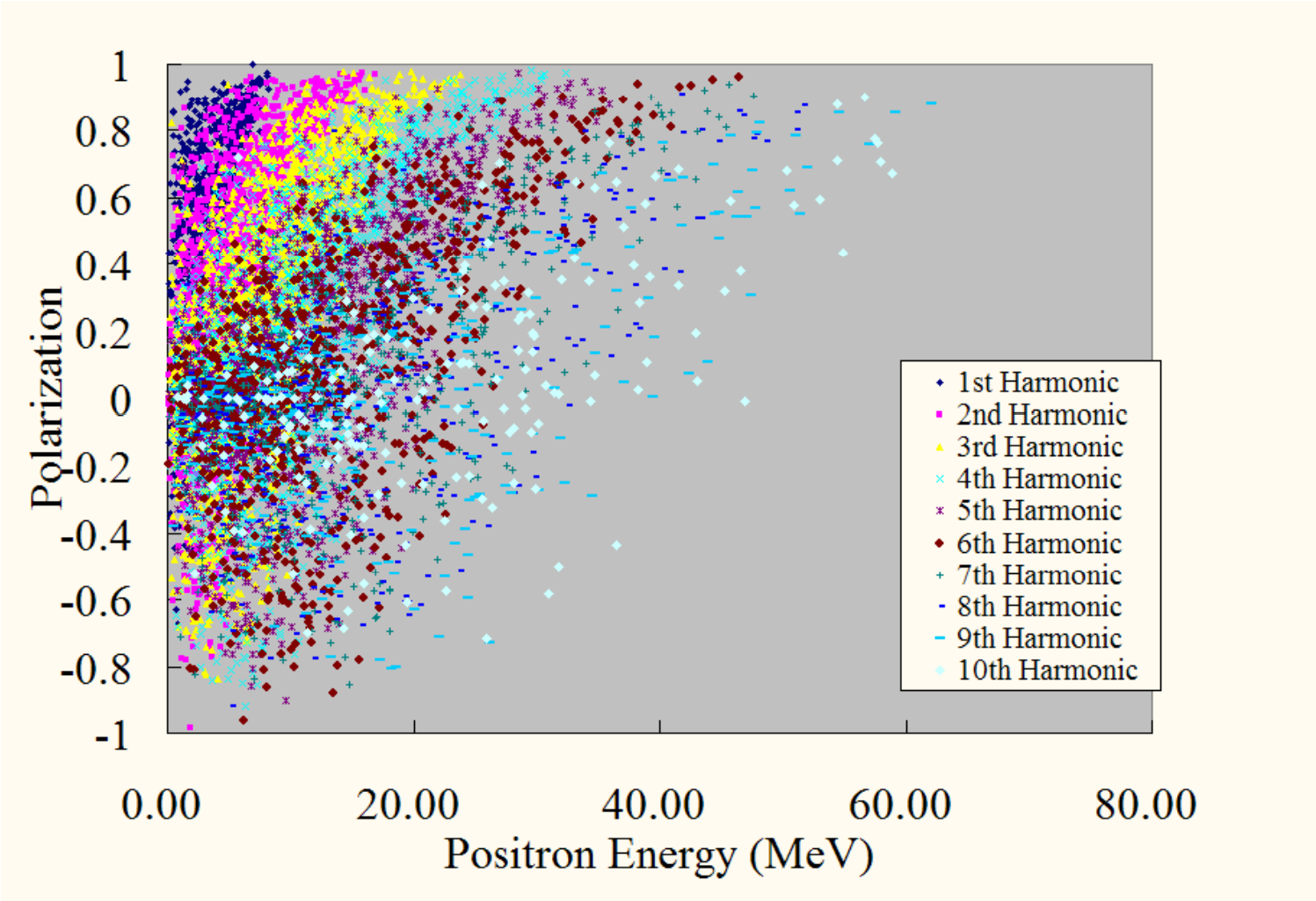
## *Positron yields from different undulator parameters*

| | BCD | UK I | UK II | UK III | Cornell I | Cornell II | Cornell III |
|---|---|---|---|---|---|---|---|
| Period (mm) | 10.0 | 11.5 | 11.0 | 10.5 | 10.0 | 12.0 | 7 |
| K | 1.00 | 0.92 | 0.79 | 0.64 | 0.42 | 0.72 | 0.3 |
| Field on Axis (T) | 1.07 | 0.86 | 0.77 | 0.65 | 0.45 | 0.64 | 0.46 |
| Beam aperture (mm) | Not Defined | 5.85 | 5.85 | 5.85 | 8.00 | 8.00 | |
| First Harmonic Energy (MeV) | 10.7 | 10.1 | 12.0 | 14.4 | 18.2 | 11.7 | 28 |
| Yield(Low Pol, 10m drift) | ~2.4 | ~1.37 | ~1.12 | ~0.86 | ~0.39 | ~0.75 | ~0.54 |
| Yield(Low Pol, 500m drift) | ~2.13 | ~1.28 | ~1.08 | ~0.83 | ~0.39 | ~0.7 | ~0.54 |
| Yield(60% Pol) | ~1.1 | ~0.7 | ~0.66 | ~0.53 | ~0.32 | ~0.49 | ~0.44 |

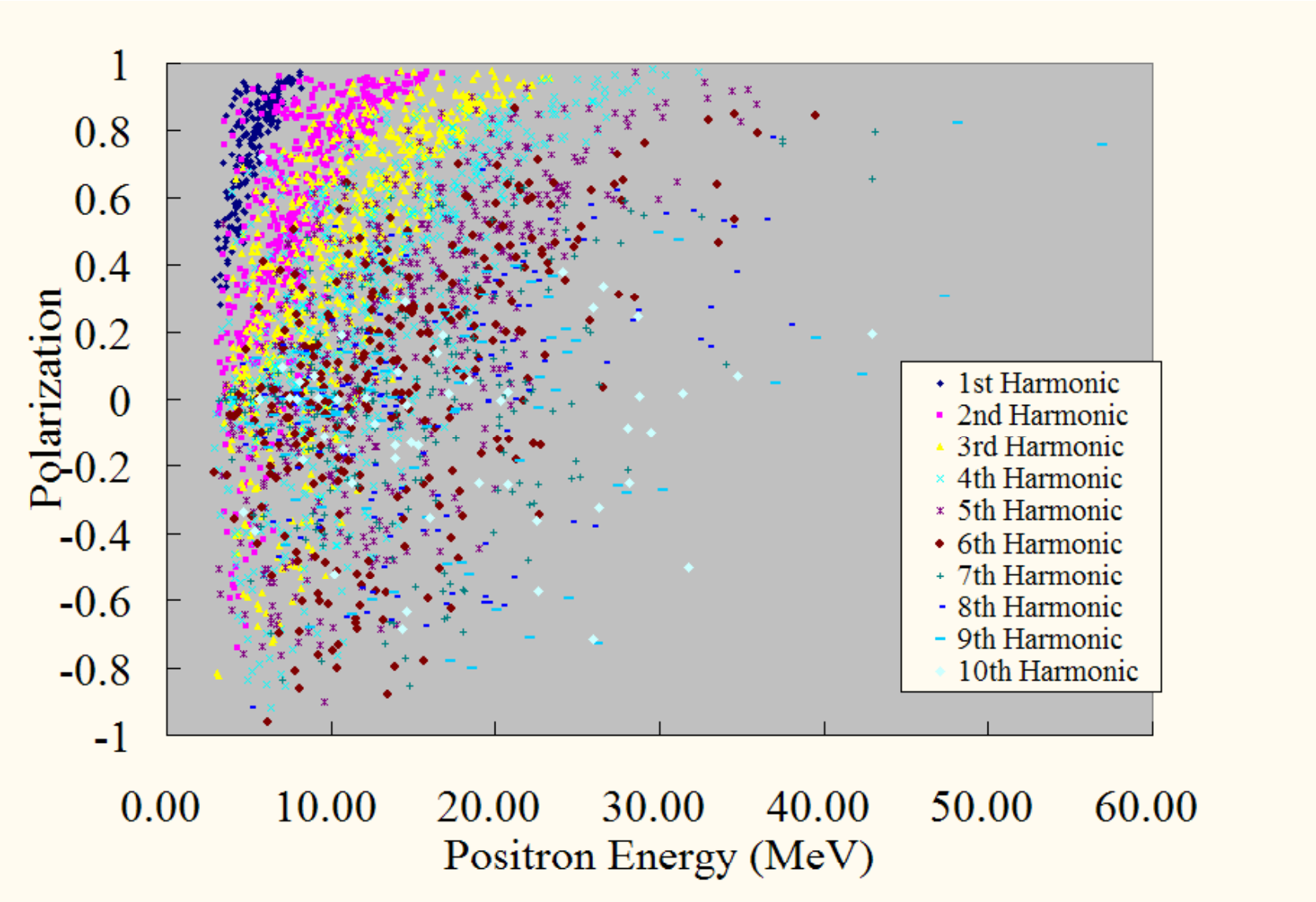
Target: 1.42cm thick Titanium

AT 5 GeV beam energy

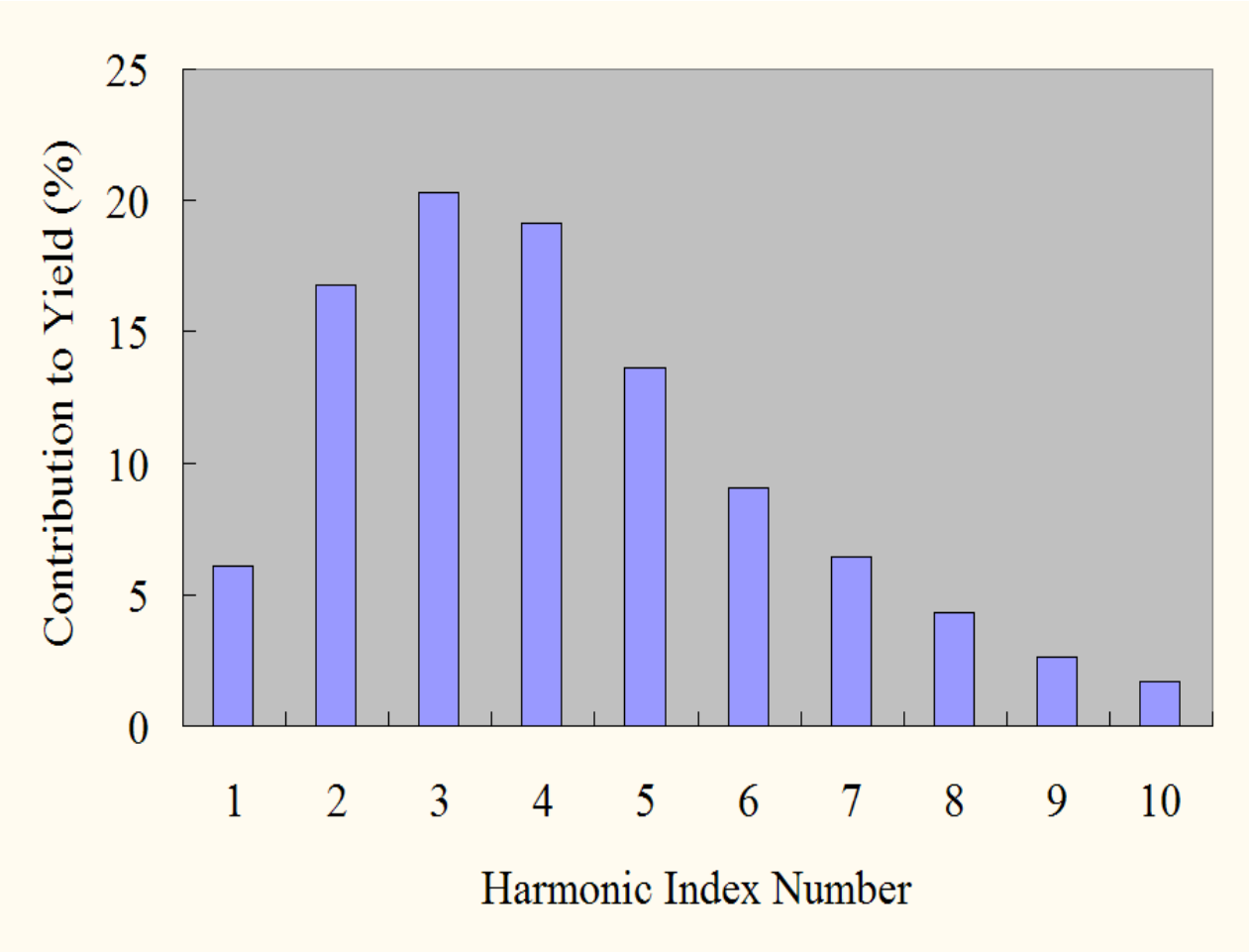
## *Initial Polarization of Positron beam at Target exit(K=0.92 λu=1.15)*



## *Initial Pol. Vs Energy of Captured Positron Beam*



## *Yield contribution from different harmonics*



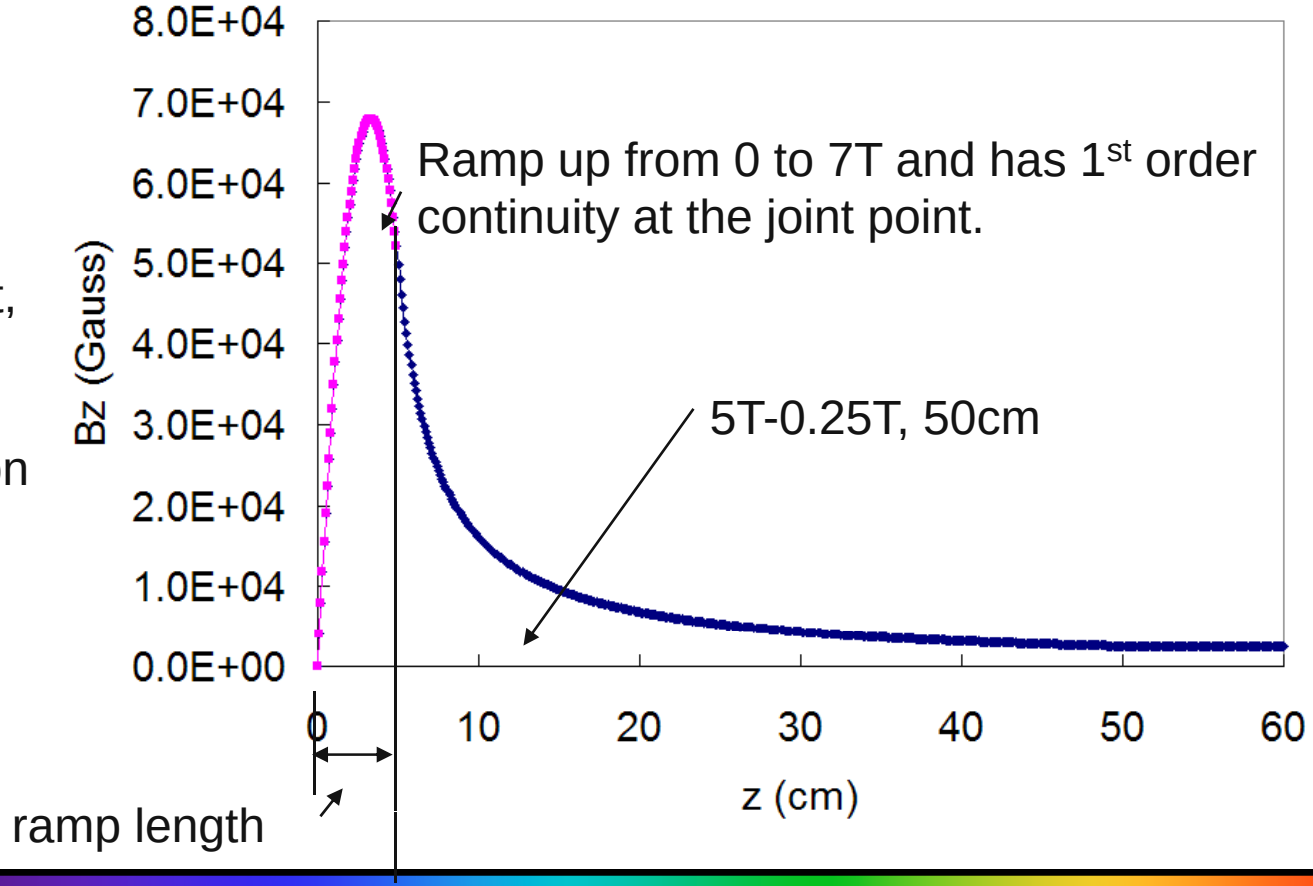

The contribution from harmonics will change with the length of drift between undulator and target. The result showing here is when drift length at ~ 100 m.

For longer drift, the contribution from 1st harmonic will increase and contribution from high order harmonics will decrease.

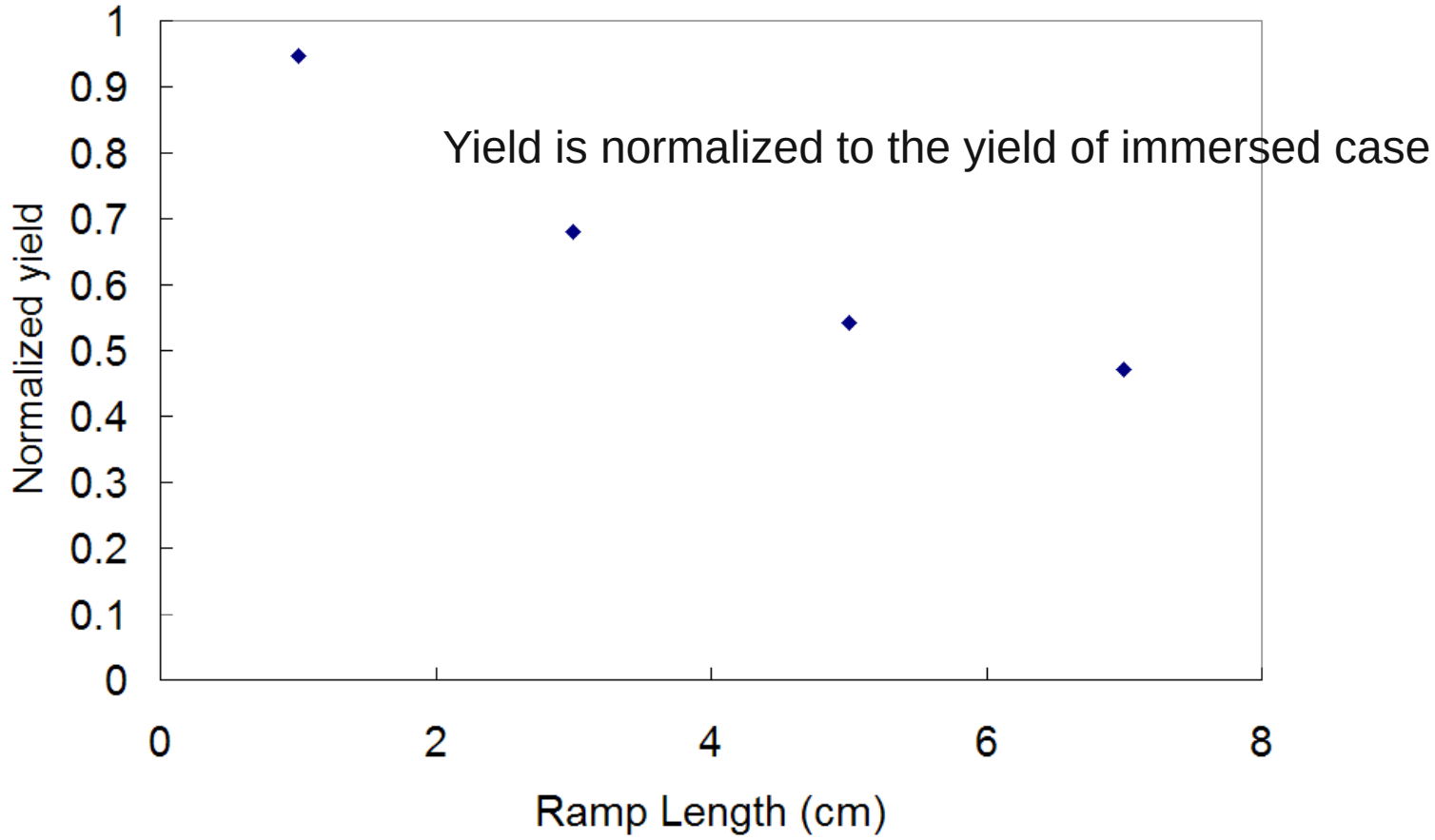
## *Non-immersed/Partially Immersed Target*

- For cases with non-immersed target, the yield varies with the ramp length d.
- For Partially immersed target, the yield also varies with the Bz at z=0.

Since the dragging force exerted on target is proportional to Bz^2 on the target, a partially immersed target can lower the power requirement on driving the target while maintaining a reasonable yield.

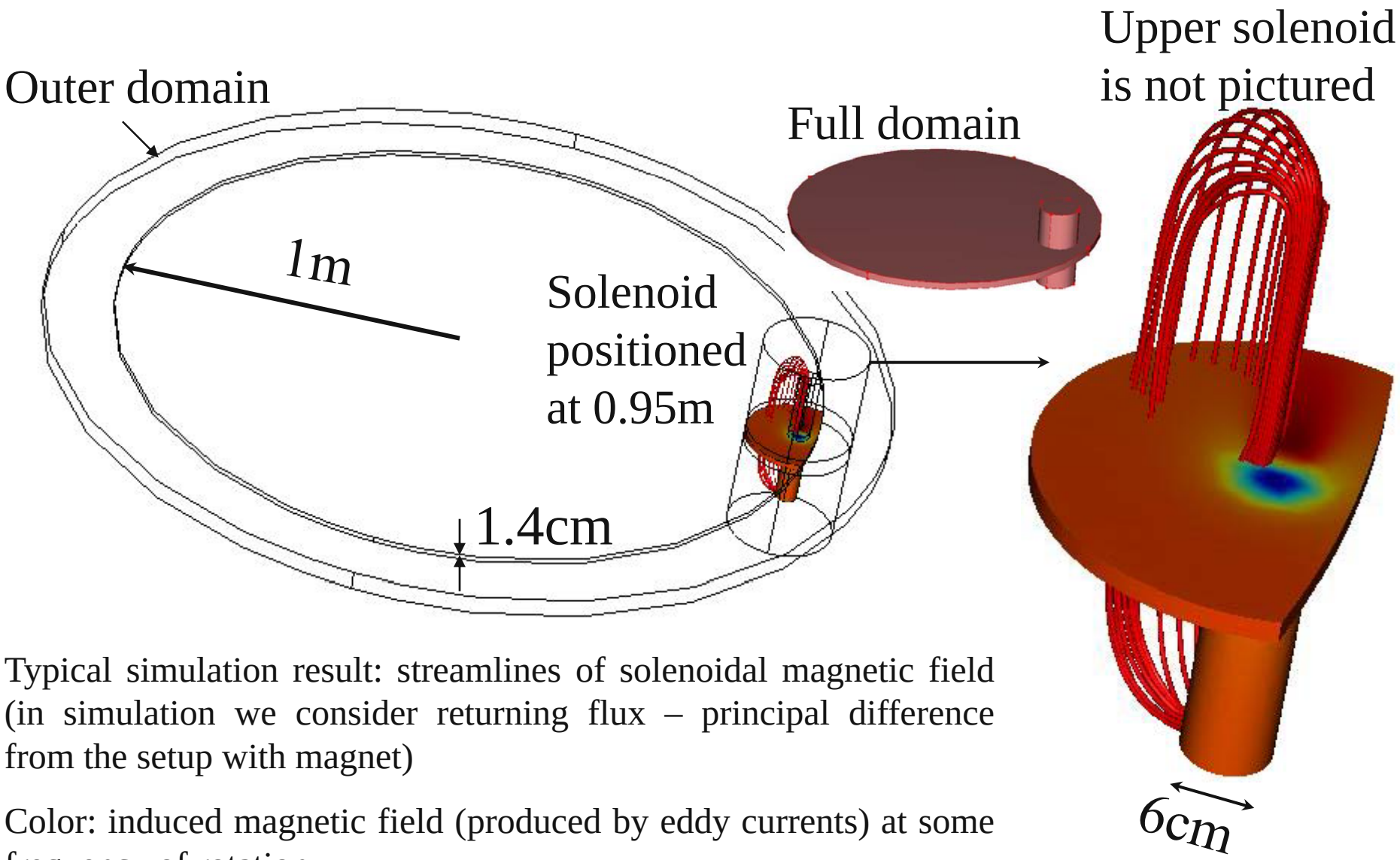


## *Normalized Yield as a Function of the Ramp Length*




We would like to have the ramp as short as possible to minimize the lost of yield

## 2. Spinning target in the OMD field and beam dynamics.

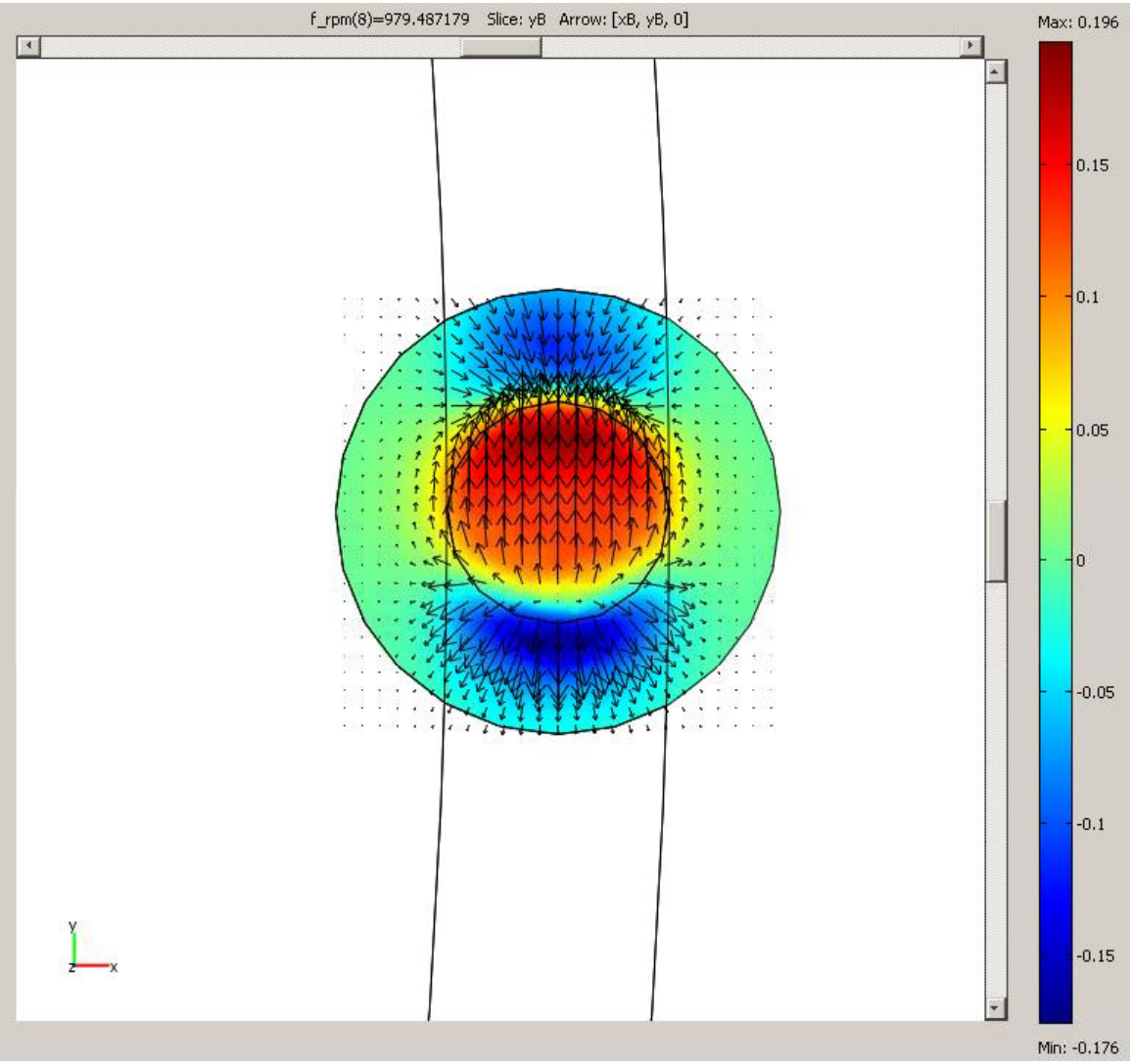



Typical simulation result: streamlines of solenoidal magnetic field (in simulation we consider returning flux – principal difference from the setup with magnet)

Color: induced magnetic field (produced by eddy currents) at some frequency of rotation, $\omega$.

# *Bx and By components, a deflection force on the beam.*

tesla



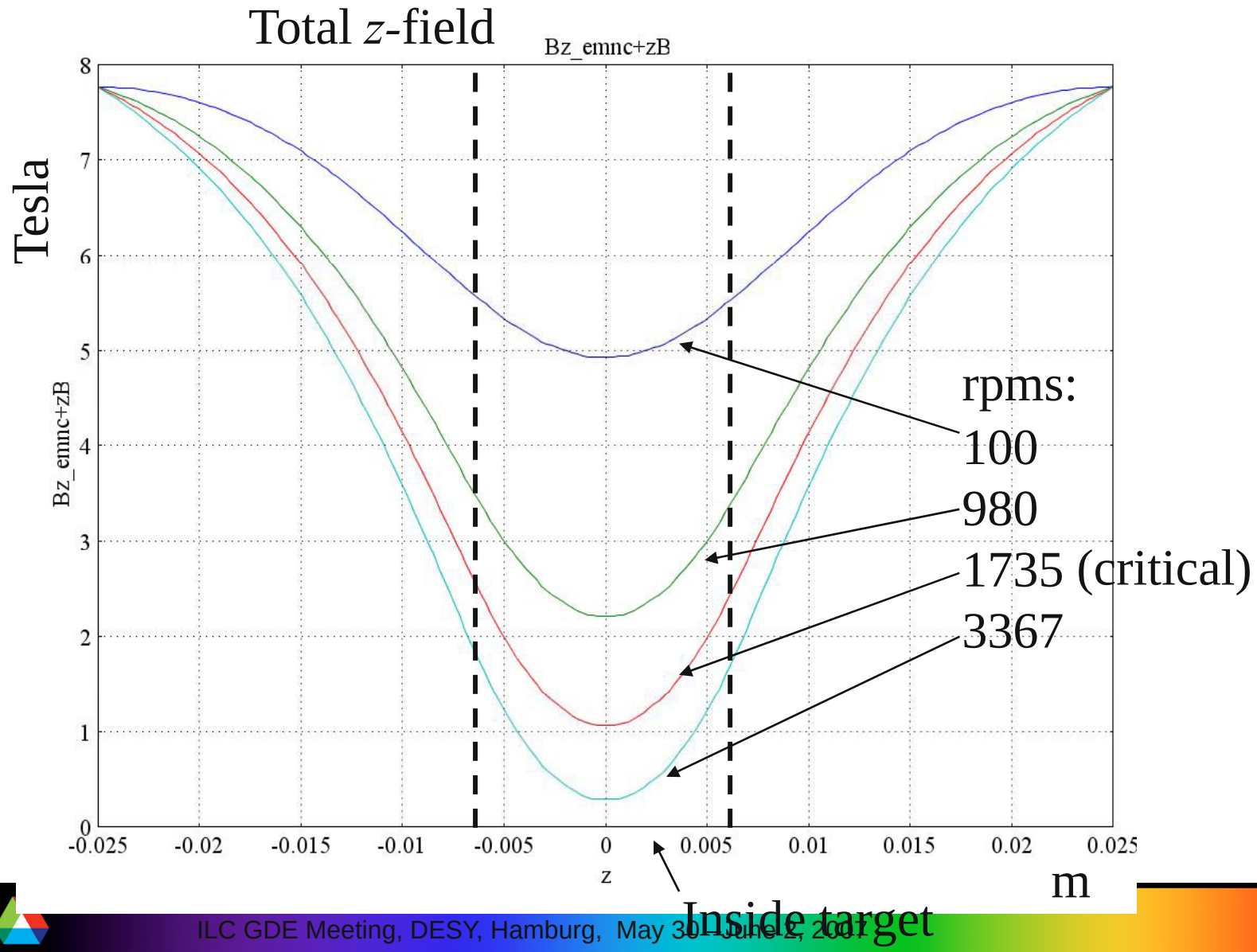

Color – $B_y$

Arrows $\{B_x, B_y\}$

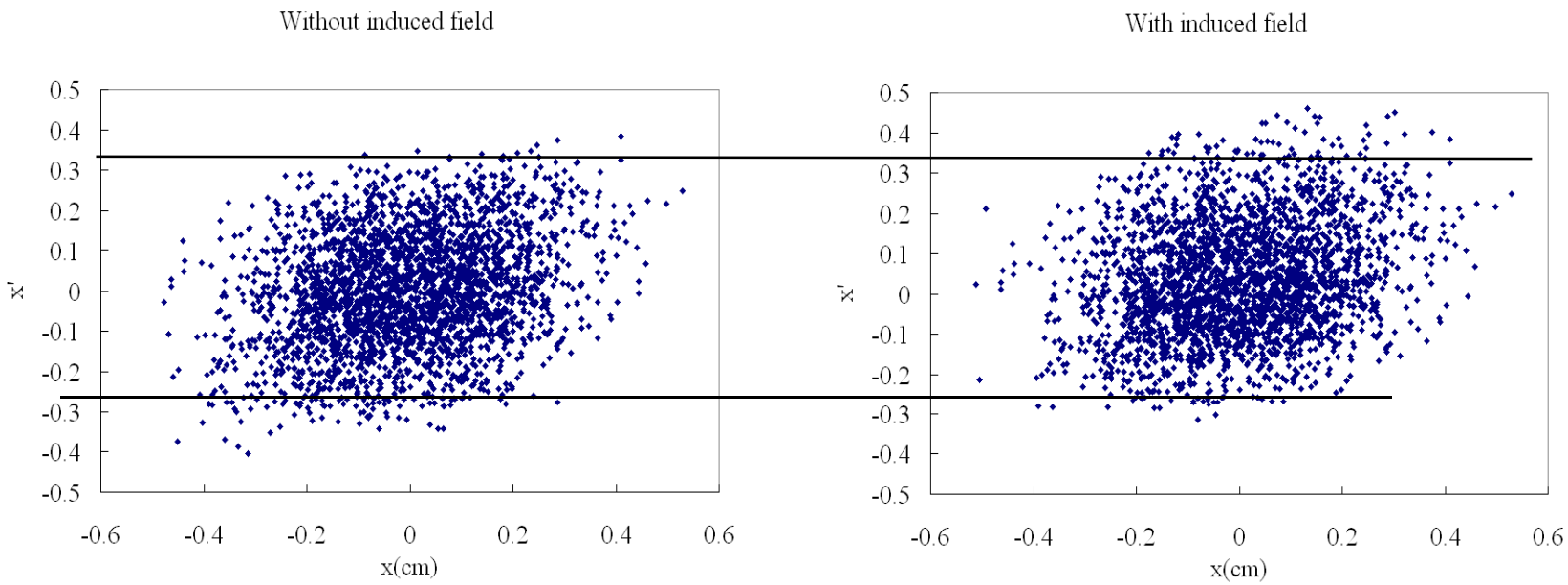
The level of transverse (to the beam) components is one order lower than the *z*-component

Plotted *5mm* from the surface of the target at *980rpms*

# *Frequency study of total field*



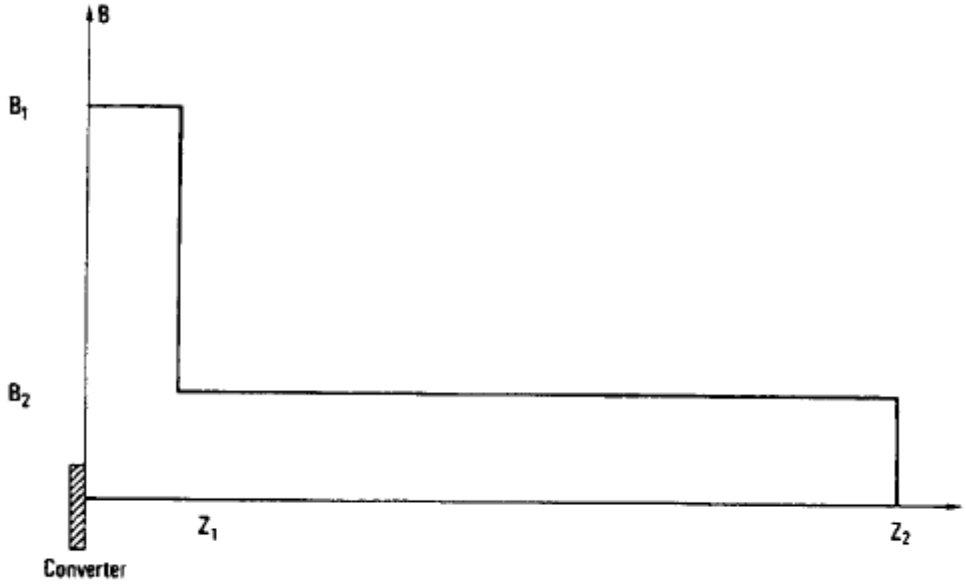
# Initial x-x' of captured positrons




Induced field kicked some positrons out but also kicked some in. The lost of yield is only ~5%( from ~1.27 down to ~1.20) for conductivity of 3e6. No noticeable changes in e+ yield for target with conductivity of 1.5e6. Sine the titanium alloy has a conductivity of 0.56e6, so from beam dynamic point of view, the eddy current has no noticeable effect.

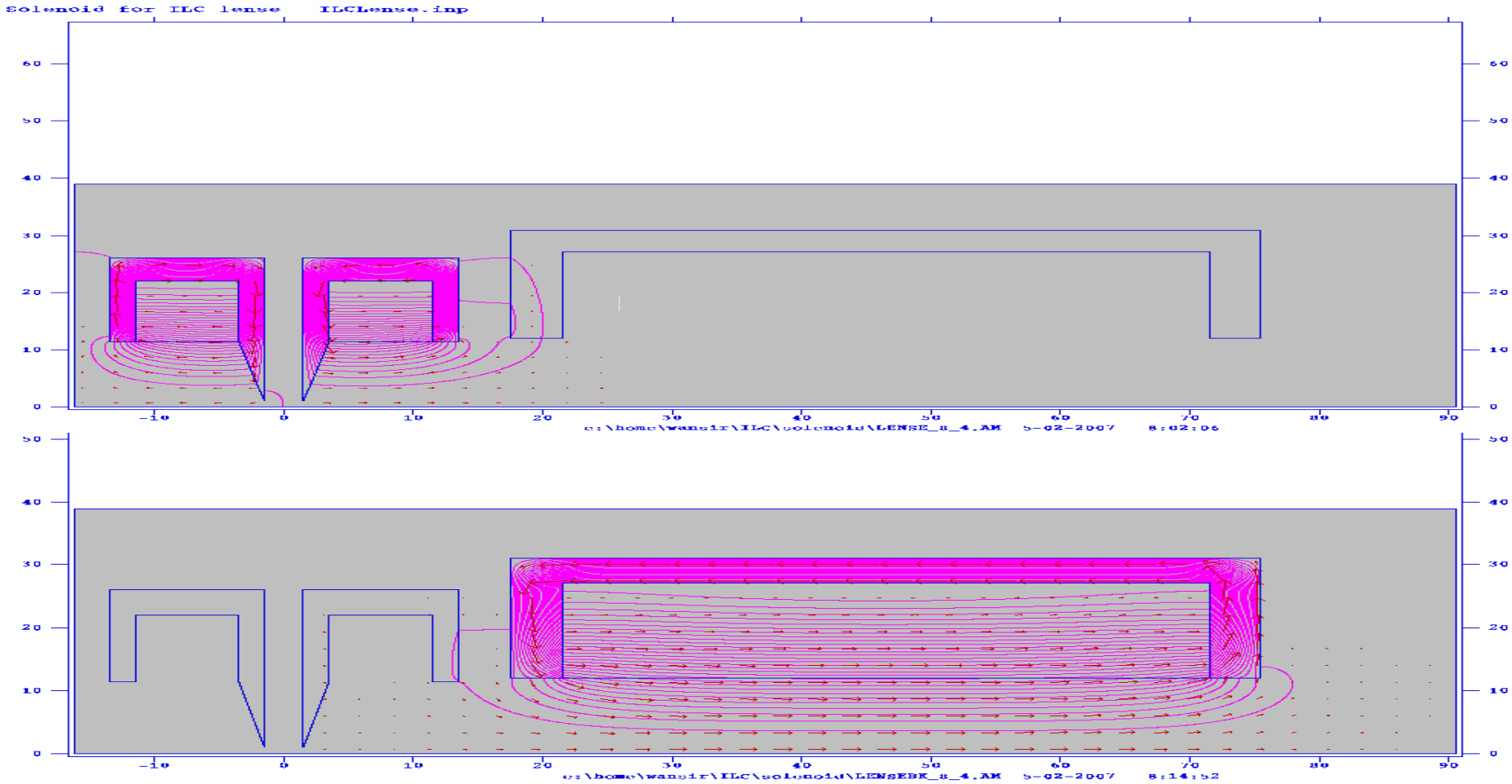
## *3.a. Quarter wave transformer simulation*

a short lens with a high magnetic field and a long solenoidal magnetic field.

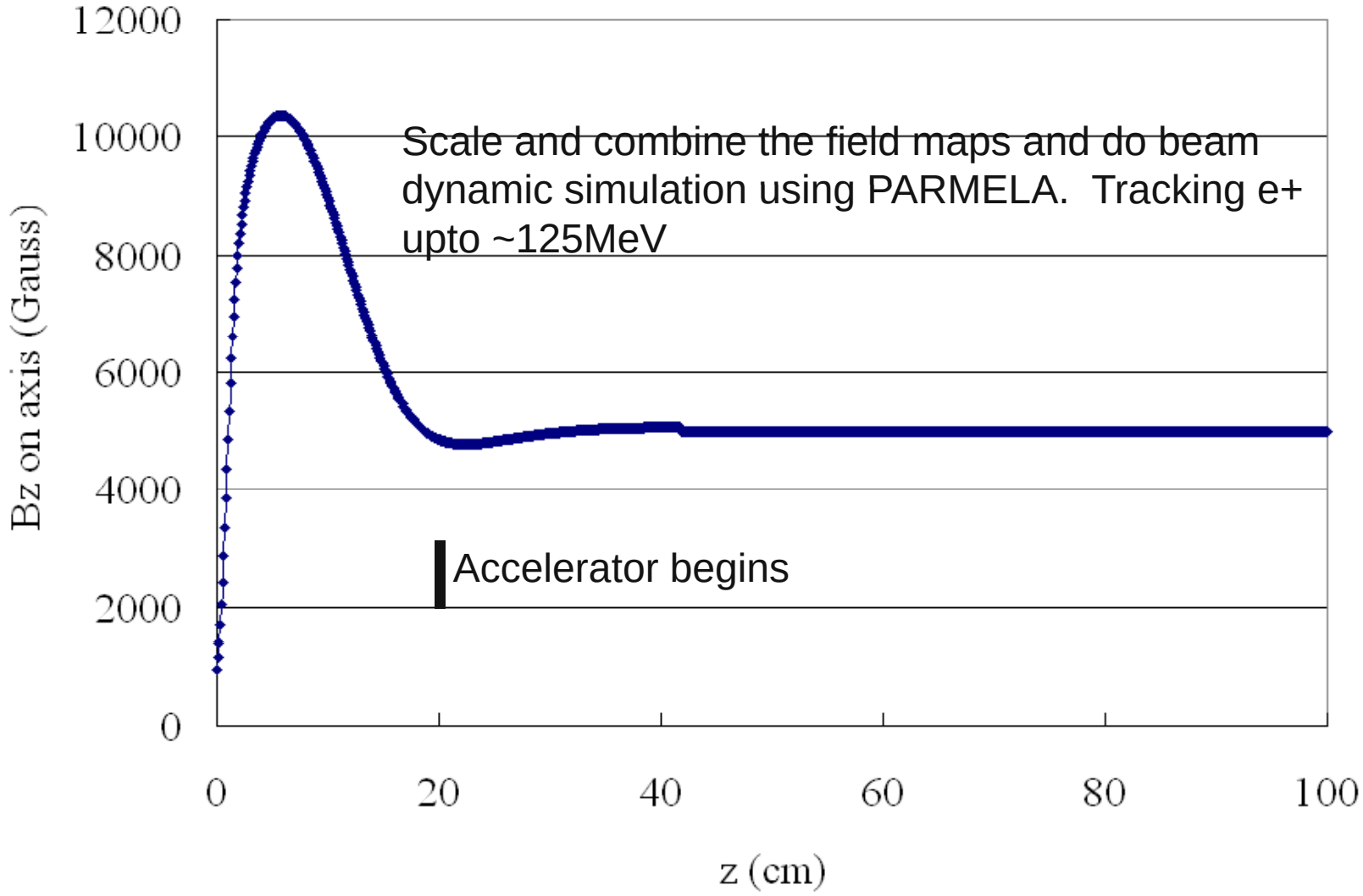



Field profile of quarter wave transformer

Magnetic field profile:  Superposition of two field maps.



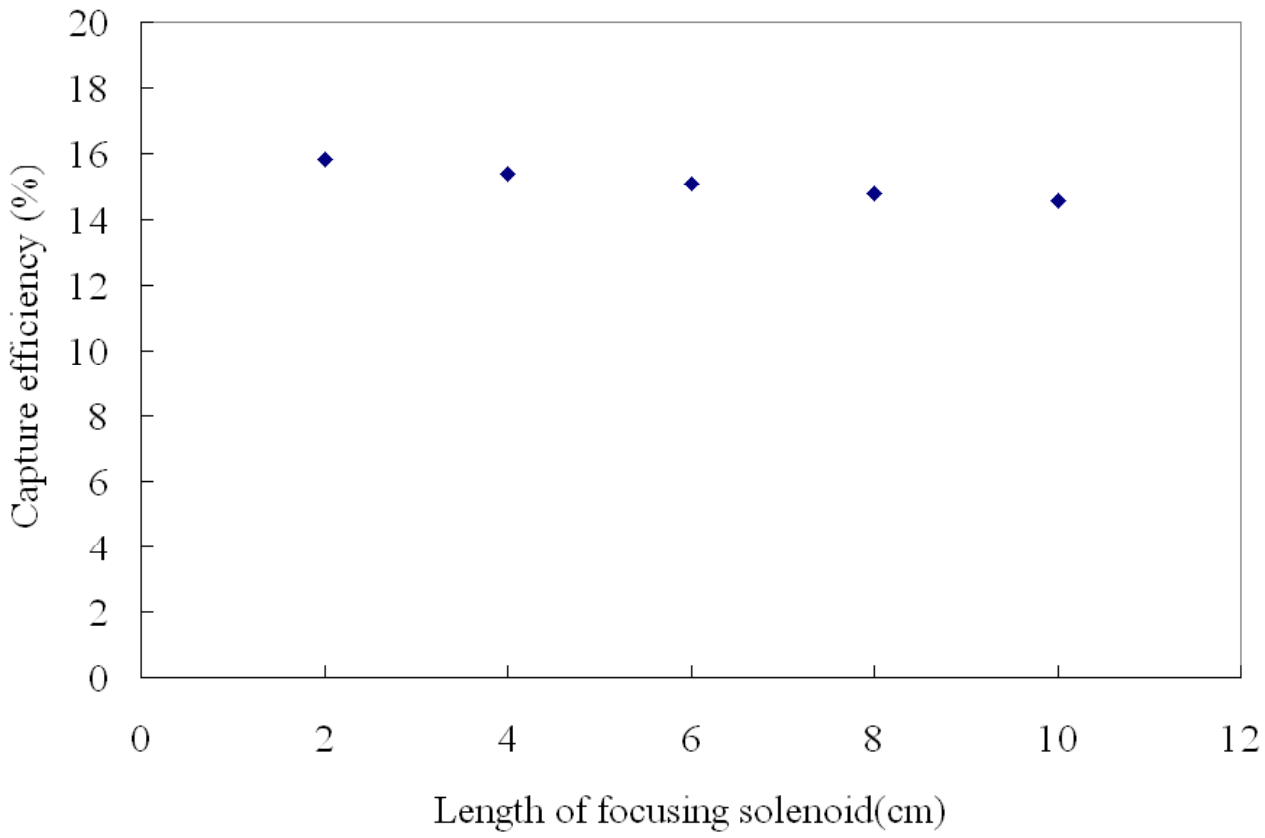
# *On axis Bz profile*



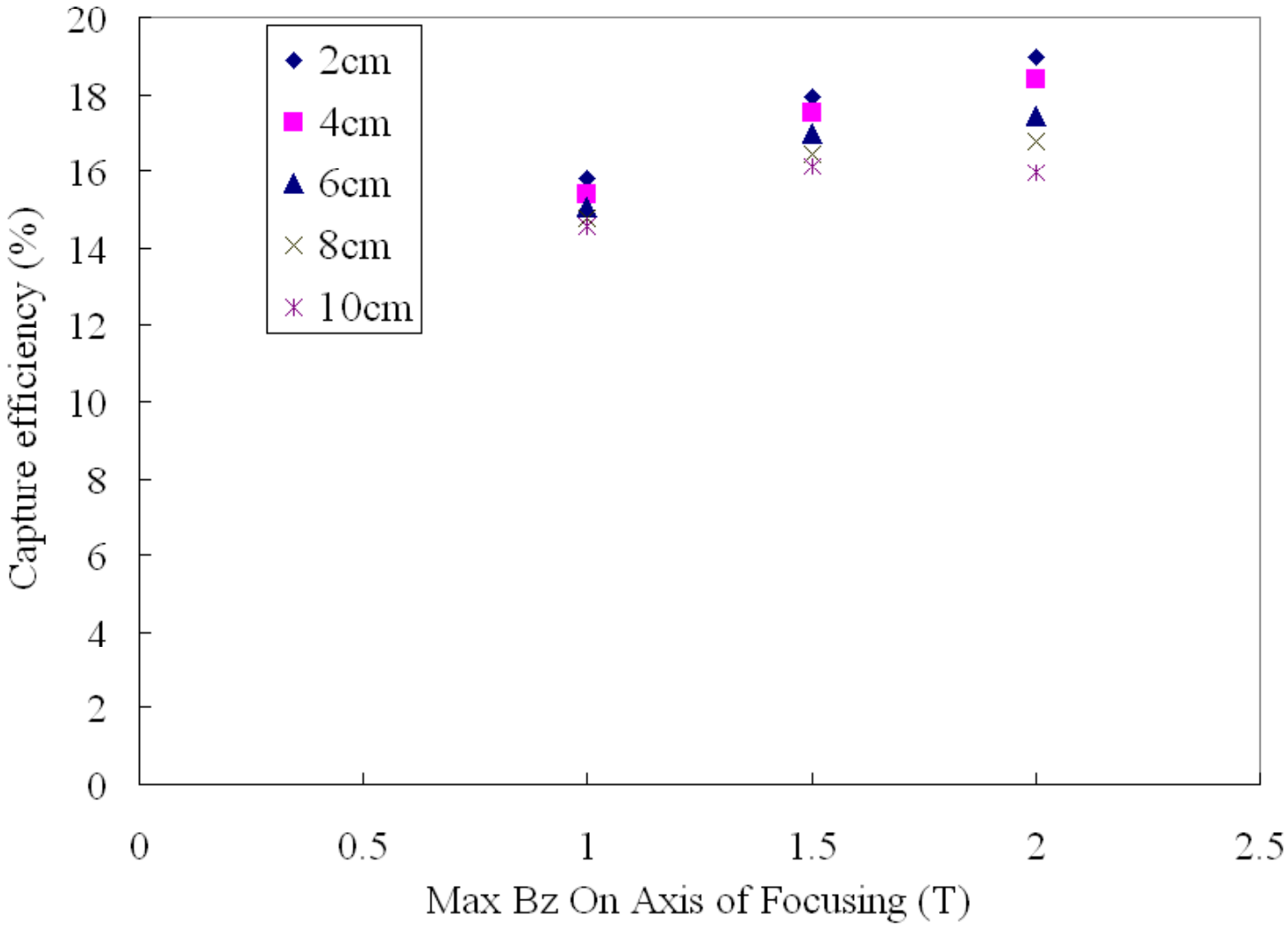
## *Conditions and assumptions*

- Combine the field maps and then do beam dynamic simulation using PARMELA. Tracking e+ up to ~125MeV
- B field is fixed at 0.5T after quarter wave transformer.
- The first Linac section starts at 20cm as in RDR.
- The longitudinal center of target is the center between focusing and bucking solenoids.
- The capture efficiency is calculated at end of the TAP, ~125MeV, using phase cut +/- 7.5 degrees, Energy cut 50MeV. **For reference,** the capture efficiency calculated using same cut for case with OMD as 5T-0.5 in 20cm**, we have ~35% for immersed case and ~26% for non-immersed case**

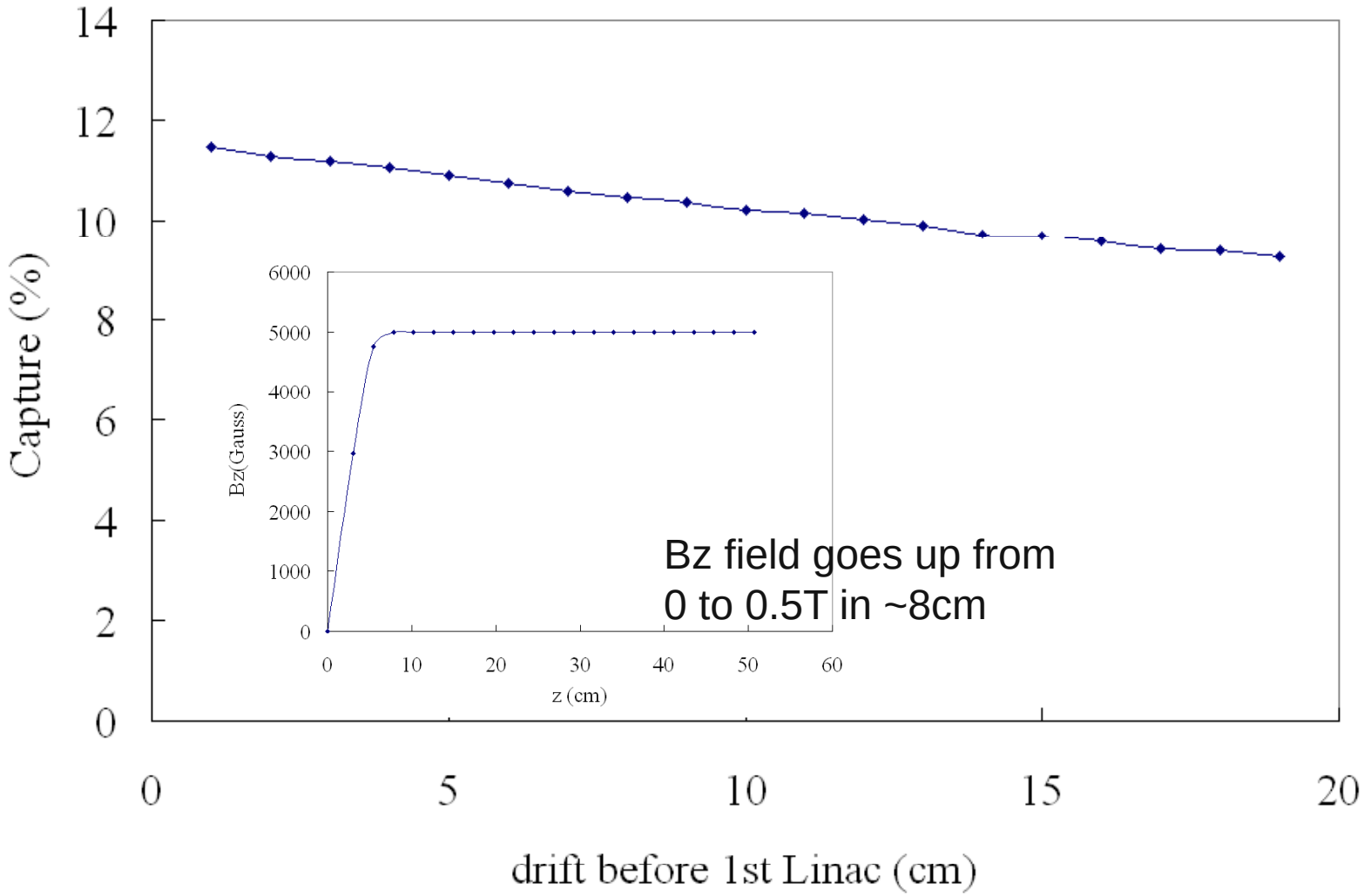
**Capture efficiency as function of length of focusing solenoid. Max B field on axis is ~1T. Gap between bucking and focusing is at 2cm. Separation between focusing and matching is 0.**



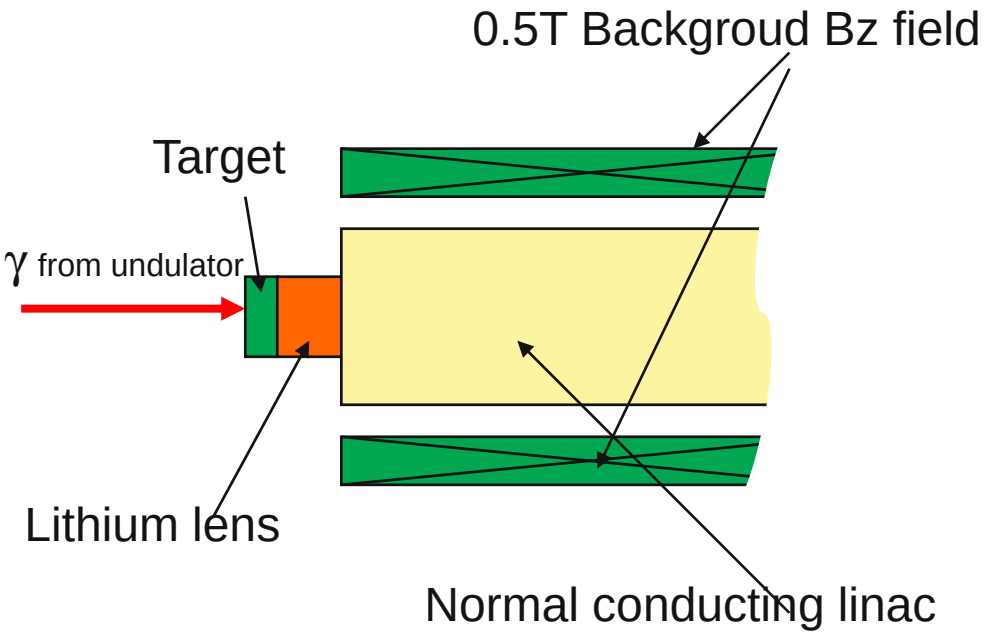
## *Capture as function of focusing field*



## *Capture efficiency with only 0.5T background solenoid*



## *3.b. Schematic Layout and Conditions for Lithium Lens Simulation*




Target: 0.4 rl, Ti and W23Re

Undulator compared :

K=0.92,λu=1.15

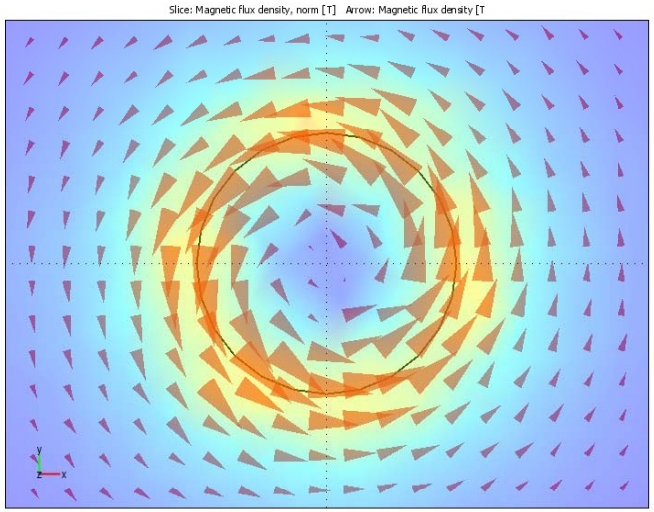
K=0.3, λu=0.7

Yield and capture efficiency were calculated at ~125MeV

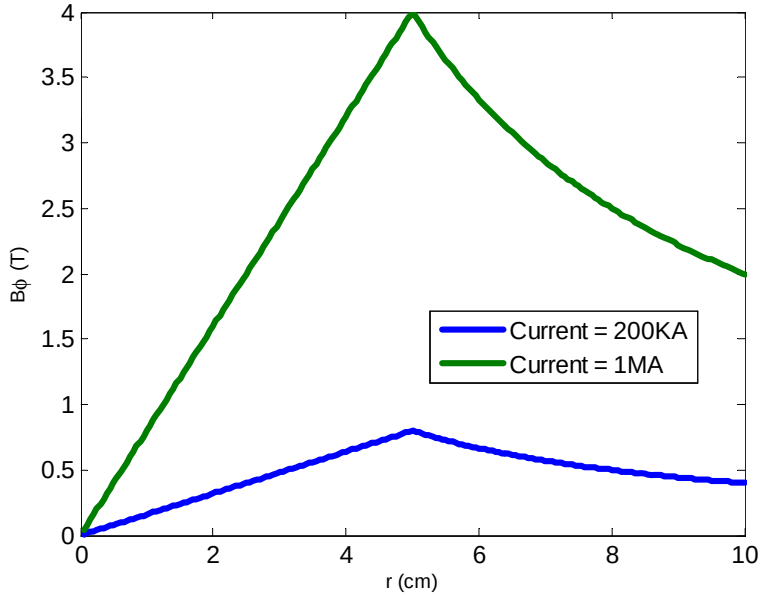
Gradient and aperture of linac are in comply with RDR

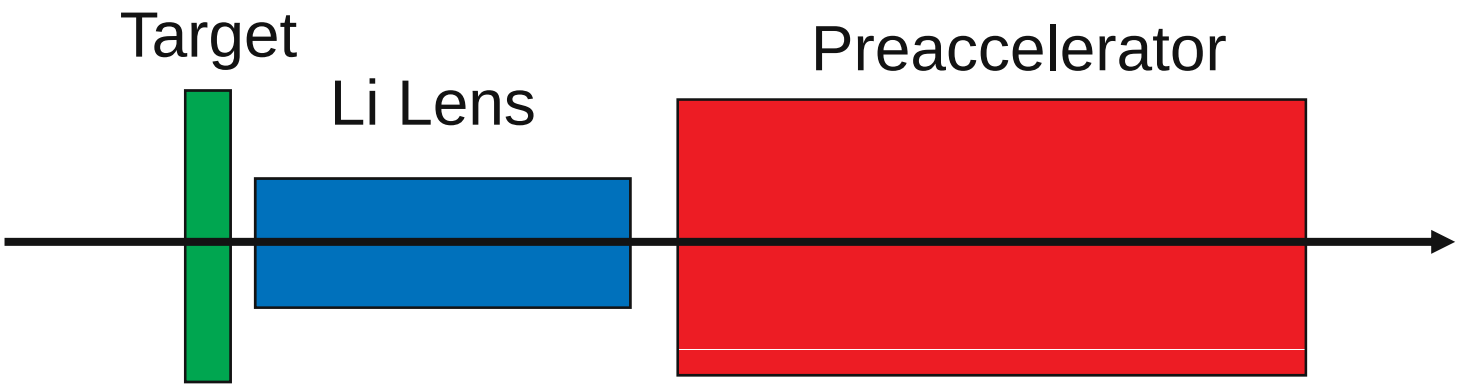
Variables are length and driving current of lithium lens.

# 3. b. Capturing Study Using Lithium Lens

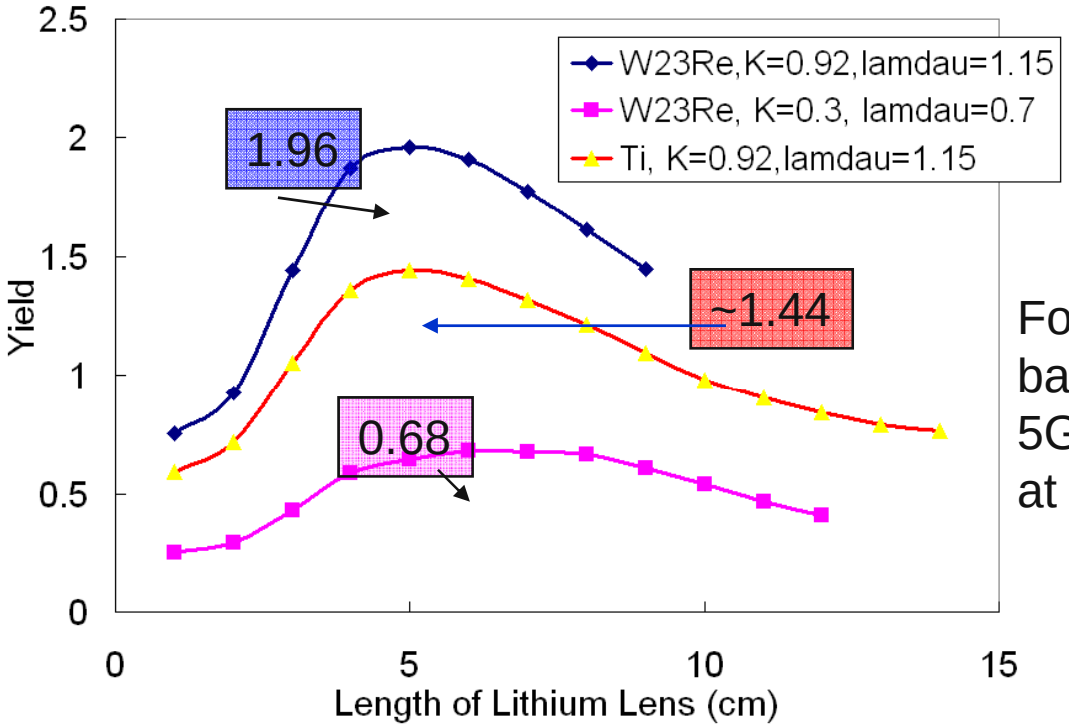



Li lens field map



## *Yield calculated at ~125MeV as a Function of the Length of Lithium Lens*




Acceptance window: phase +/-7.5$^0$, $\Delta$E=50MeV, $\varepsilon_x+\varepsilon_y$<=0.09$\pi$m.rad

For reference: yield for new baseline undulator calculated at 5GeV is ~1.28, it's yield calculated at 125MeV is 1.44 here.

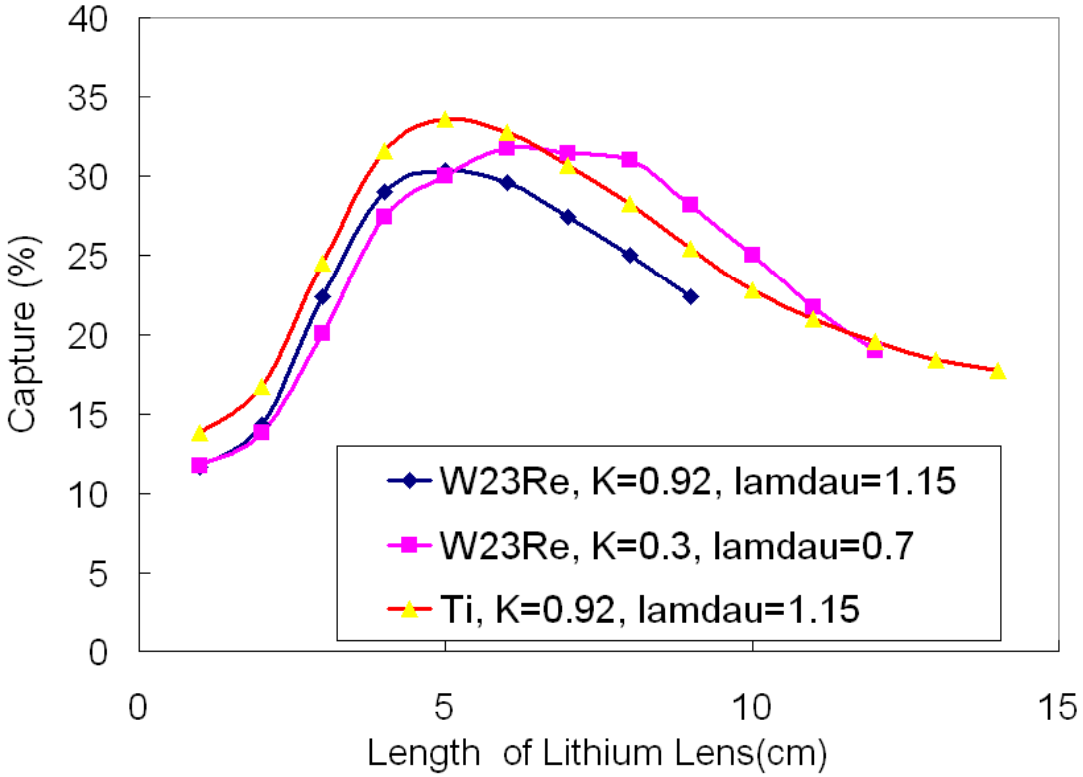
Lithium lens current: 200KA

The drift to target for K=0.3, $\lambda$u=0.7 is chosen to be 10m to maximize it's yield. For other twos, the drift to target is 450m.

$$Yield = \frac{Num.\ of\ Positrons\ in\ Capturing\ Window}{Num.of\ Electrons\ in\ the\ 150GeV\ drive\ beam\ Passing\ through\ a\ 100m\ undulator}$$

## *Capture Efficiency Calculated at ~125MeV as a Function of the Length of Lithium Lens*

Acceptance window: phase +/-7.5$^0$,
$\Delta E$=50MeV, $\varepsilon_x+\varepsilon_y$<=0.09$\pi$m.rad




Lithium lens current: 200KA

The drift to target for K=0.3, $\lambda$u=0.7 is chosen to be 10m to maximize it's yield. For other two the drift to target is 450m.

$$CaptureEfficiency = \frac{Num.of\ \ positons\,in\ capturing\ window}{Num.of\ \ positron\,came\,off\ the\,target} \times 100$$

## *Summary*

- Systematic e+ capturing studies performed. Various options considered.
- Will integrate these studies into the EDR works.

- Thank you.