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Update on e+ Source Modeling and Simulation

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U.S. Department of Energy

UChicago Argonne LLC

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Outline

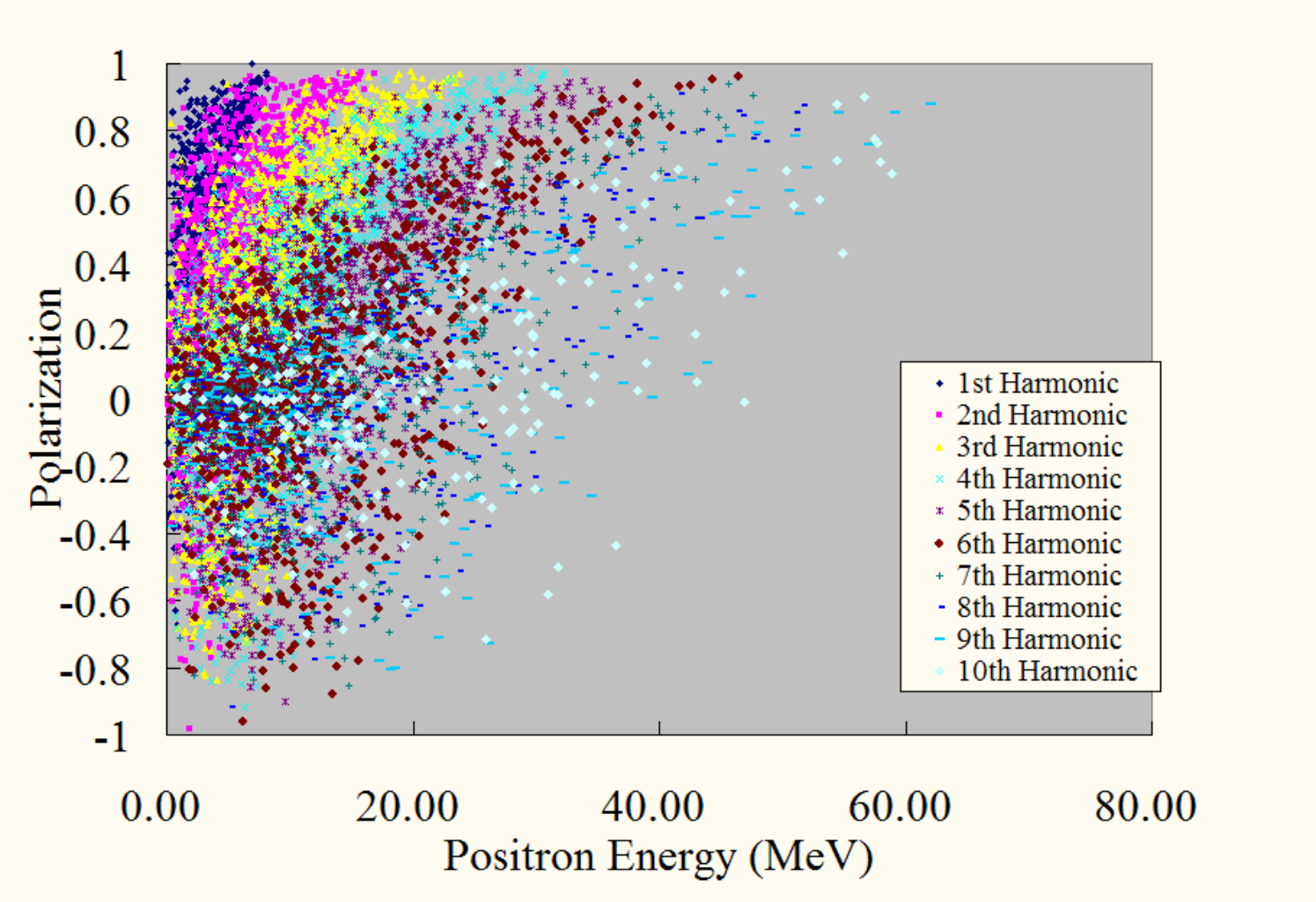
- Result presented in Beijing meeting
- OMD study
  - Immersed and Non-immersed AMD
  - Quarter wave transformer
  - Lithium lens
- The effect of spot size
- Tungsten target vs Ti target

Comparison of positron yield from different undulators

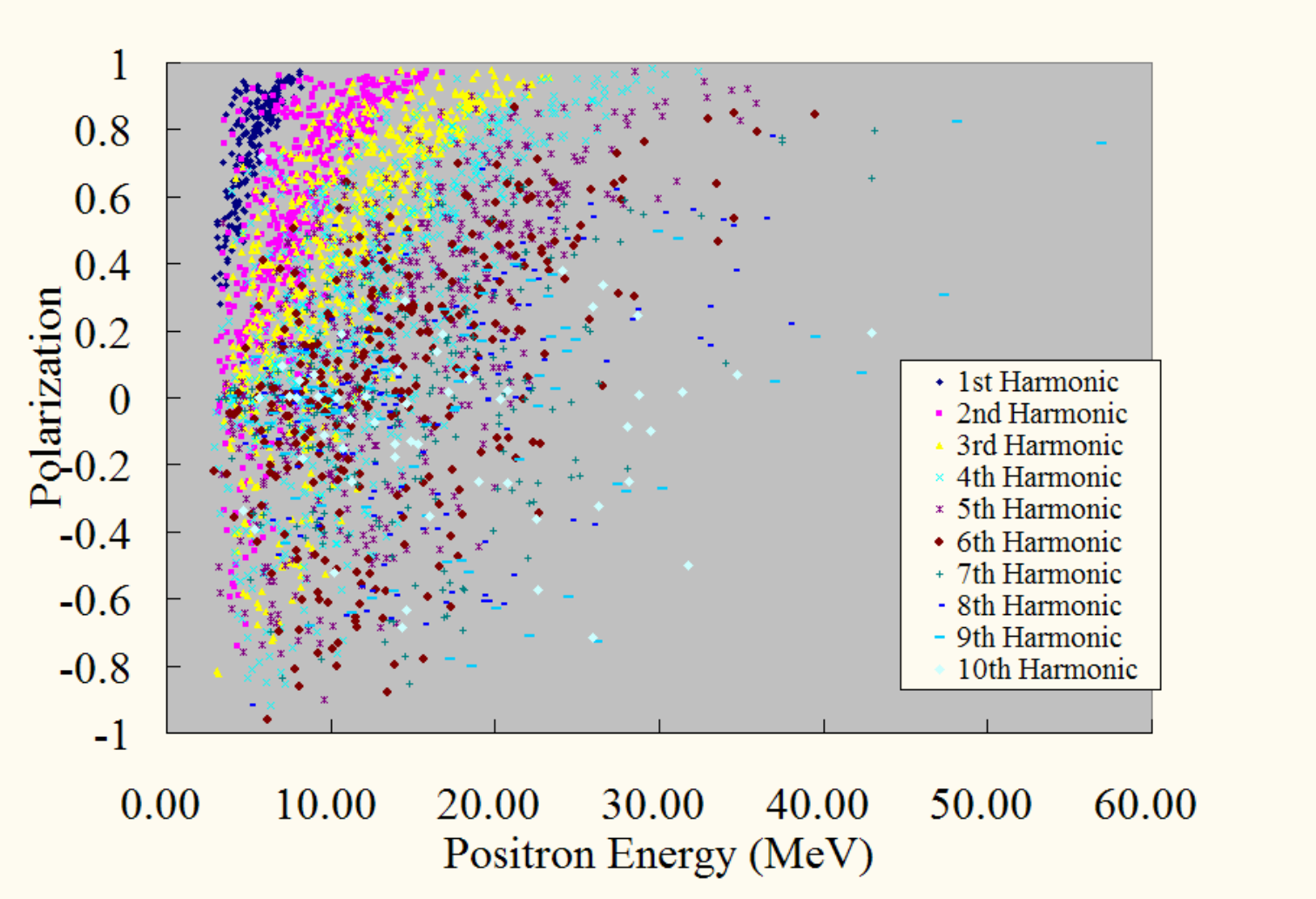
	High K Devices				Low K Devices		
	BCD	**UK I**	**UK II**	**UK III**	**Cornell I**	**Cornell II**	**Cornell III**
Period (mm)	10.0	11.5	11.0	10.5	10.0	12.0	7
K	1.00	0.92	0.79	0.64	0.42	0.72	0.3
Field on Axis (T)	1.07	0.86	0.77	0.65	0.45	0.64	0.46
Beam aperture (mm)	Not Defined	5.85	5.85	5.85	8.00	8.00	
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(Pol)	~1.1	~0.7	~0.66	~0.53	~0.32	~0.49	~0.44

Target: 1.42cm thick Titanium

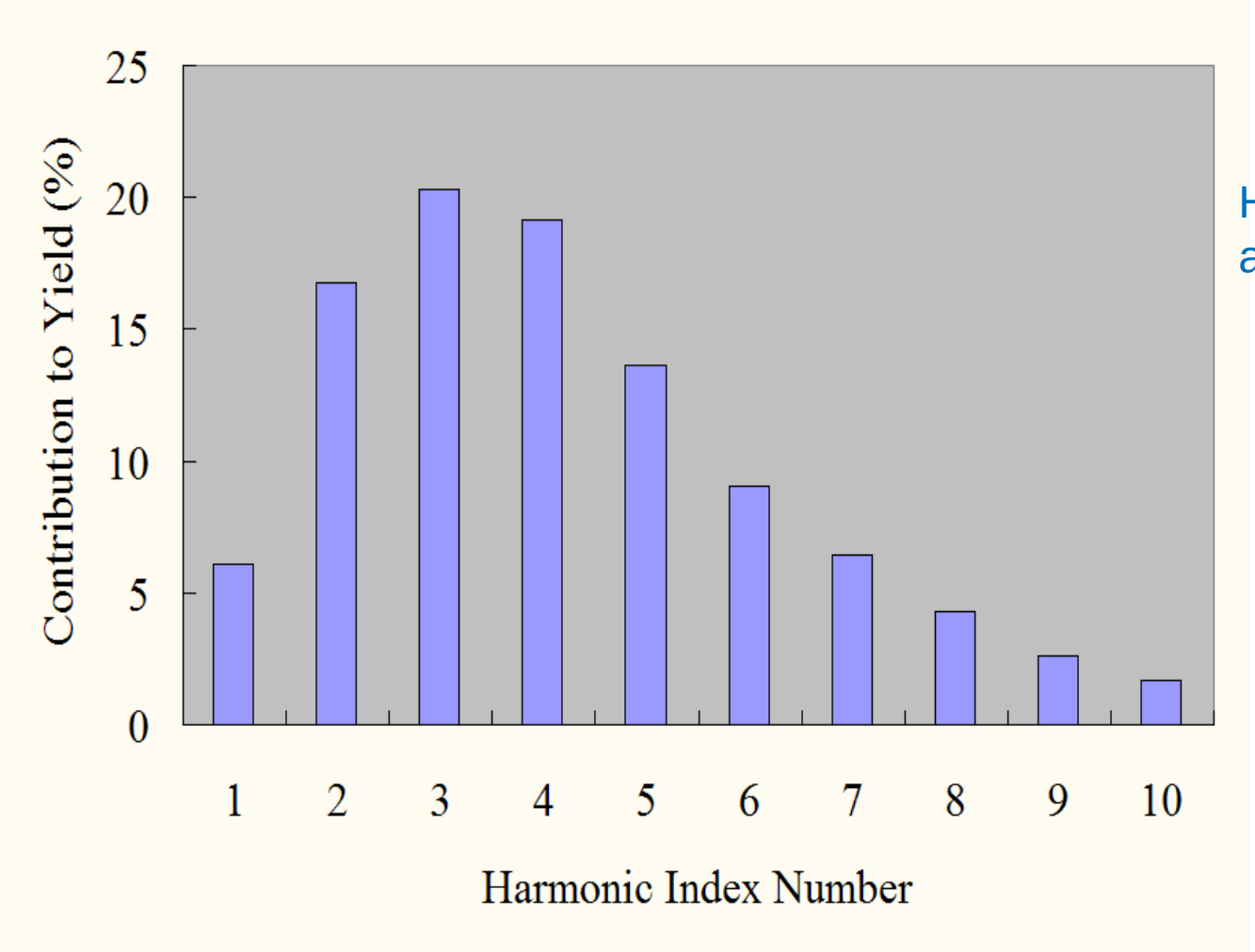
Initial Polarization of Positron beam at Target exit(K=0.92 λu=1.15)



Initial Pol. Vs Energy of Captured Positron Beam



Yield contribution from different harmonics – new baseline undulator, without collimator

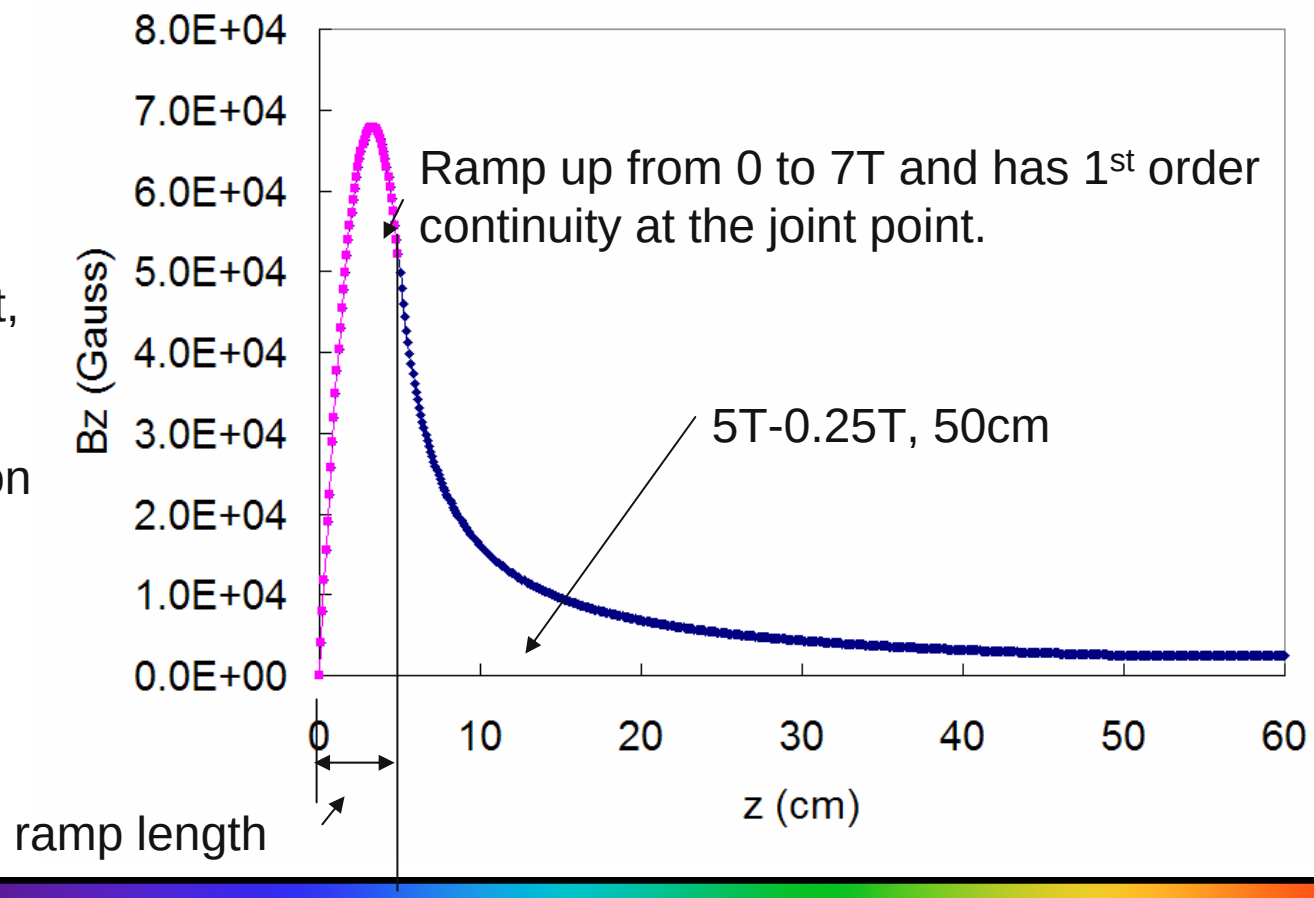


High order harmonics are important

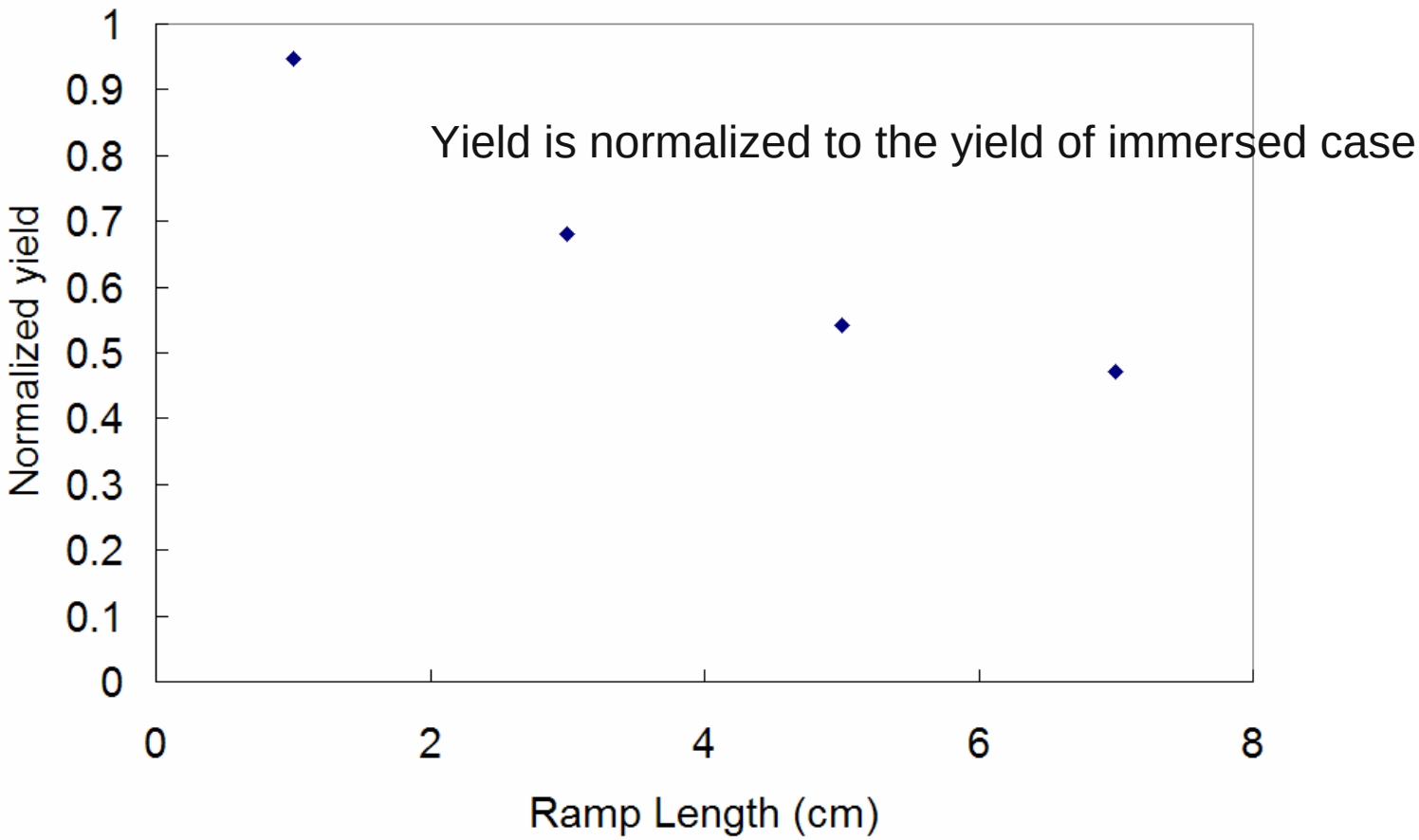
Non-immersed/Partially Immersed Target

- 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



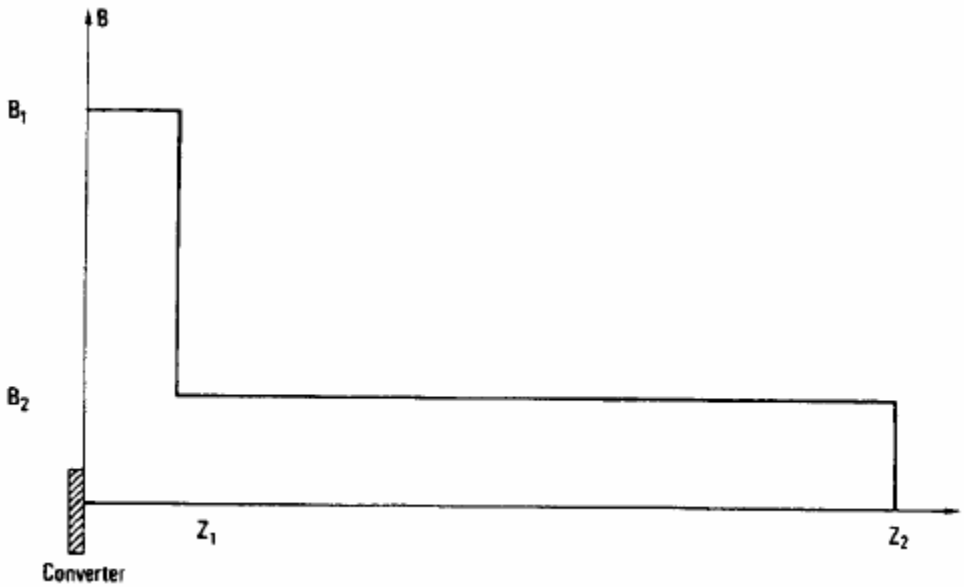
We would like to have the ramp as short as possible to minimize the lost of yield

2. OMD studies

- K=0.92, λu=1.15cm, 100m long
- 0.4rl Ti target
- Gradient and aperture in comply with RDR
- Drift to target 450m
- OMD compared:
  - Immersed target (6T-0.5T in 20 cm)
  - Non immersed target (0-6T in 2cm, 6T-0.5T 20cm)
  - Quarter wave transformer
  - Back ground solenoid only
  - Lithium lens

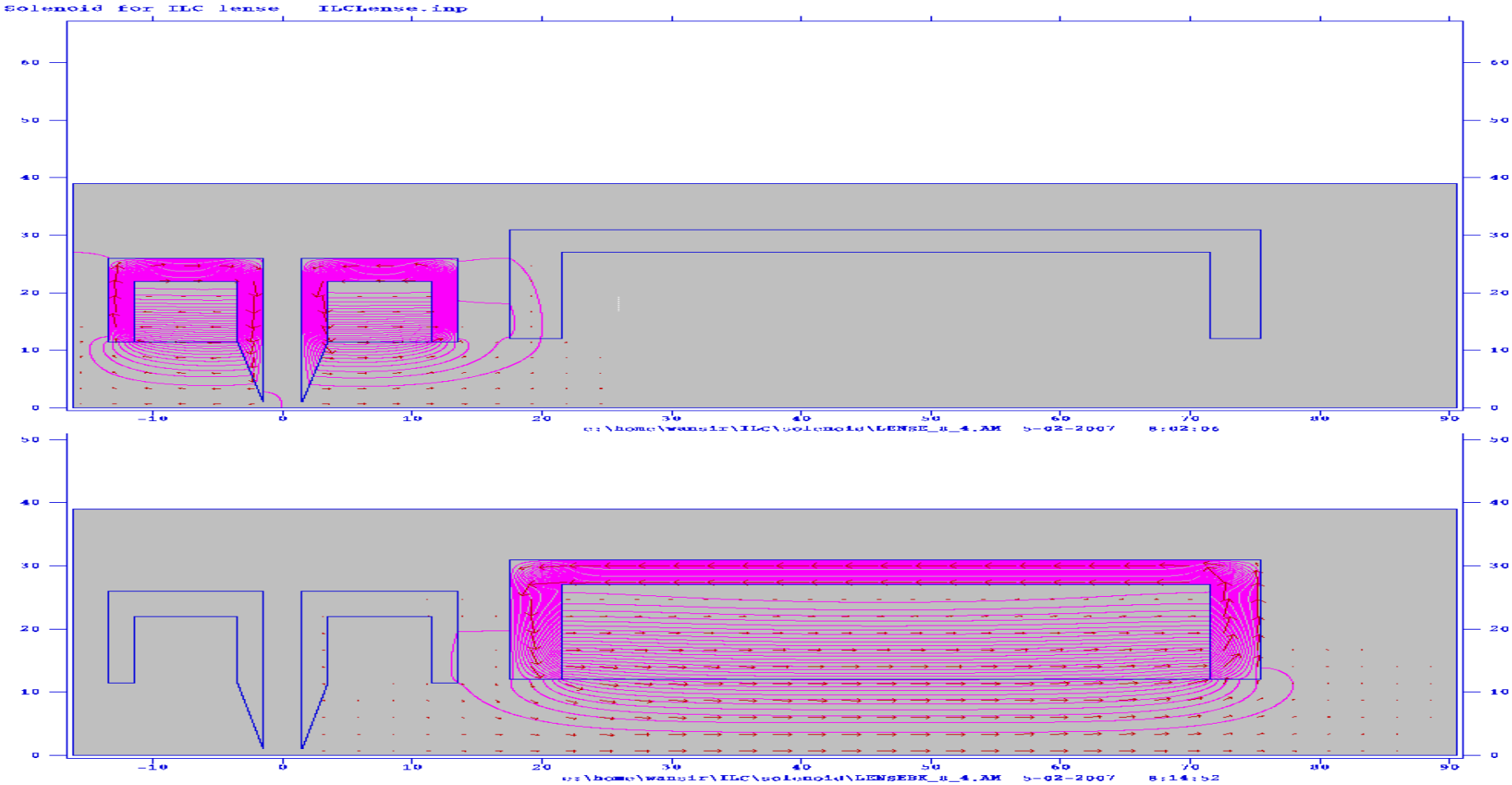
Quarter wave transformer simulation

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

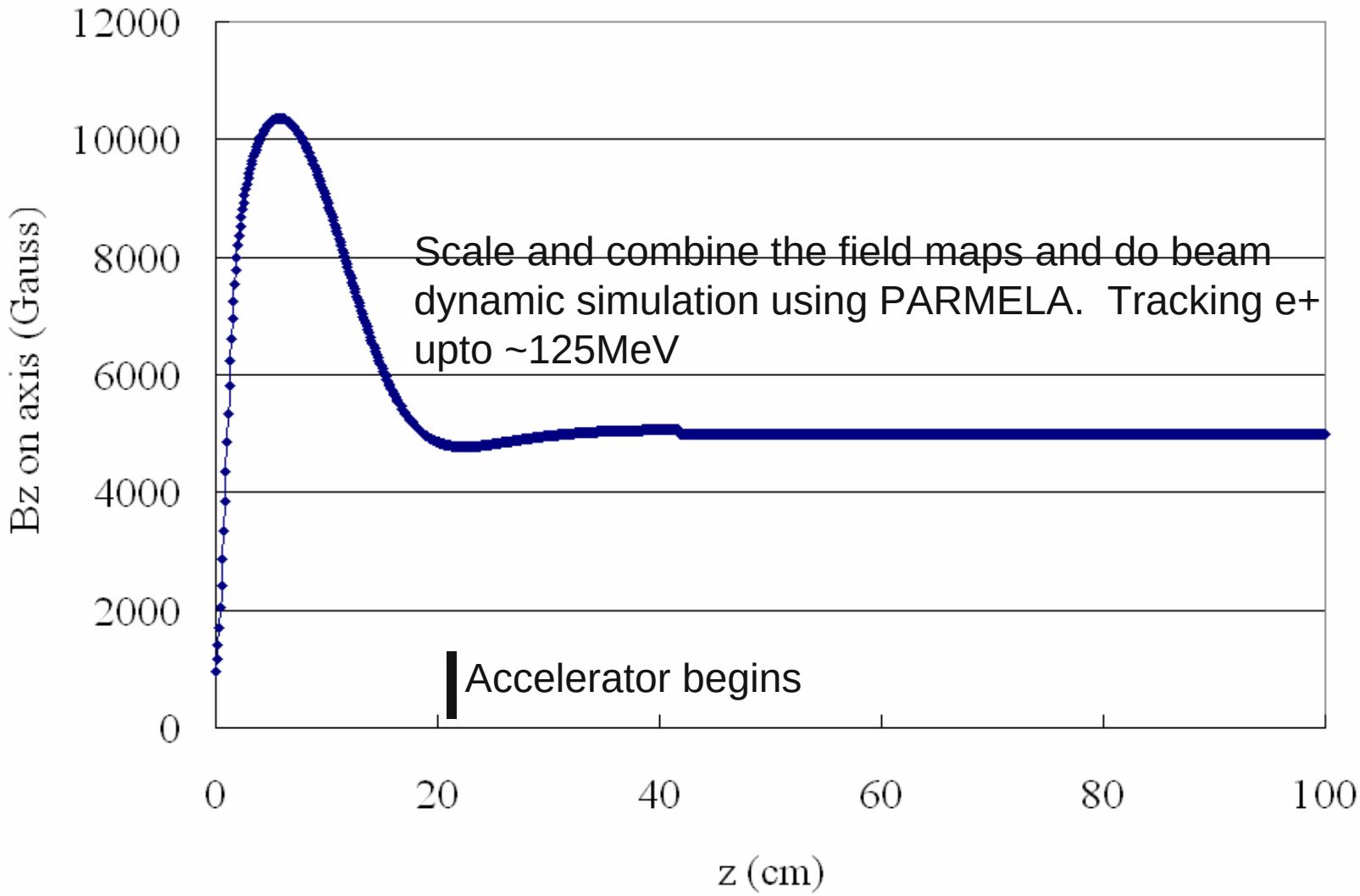


Field profile of quarter wave transformer

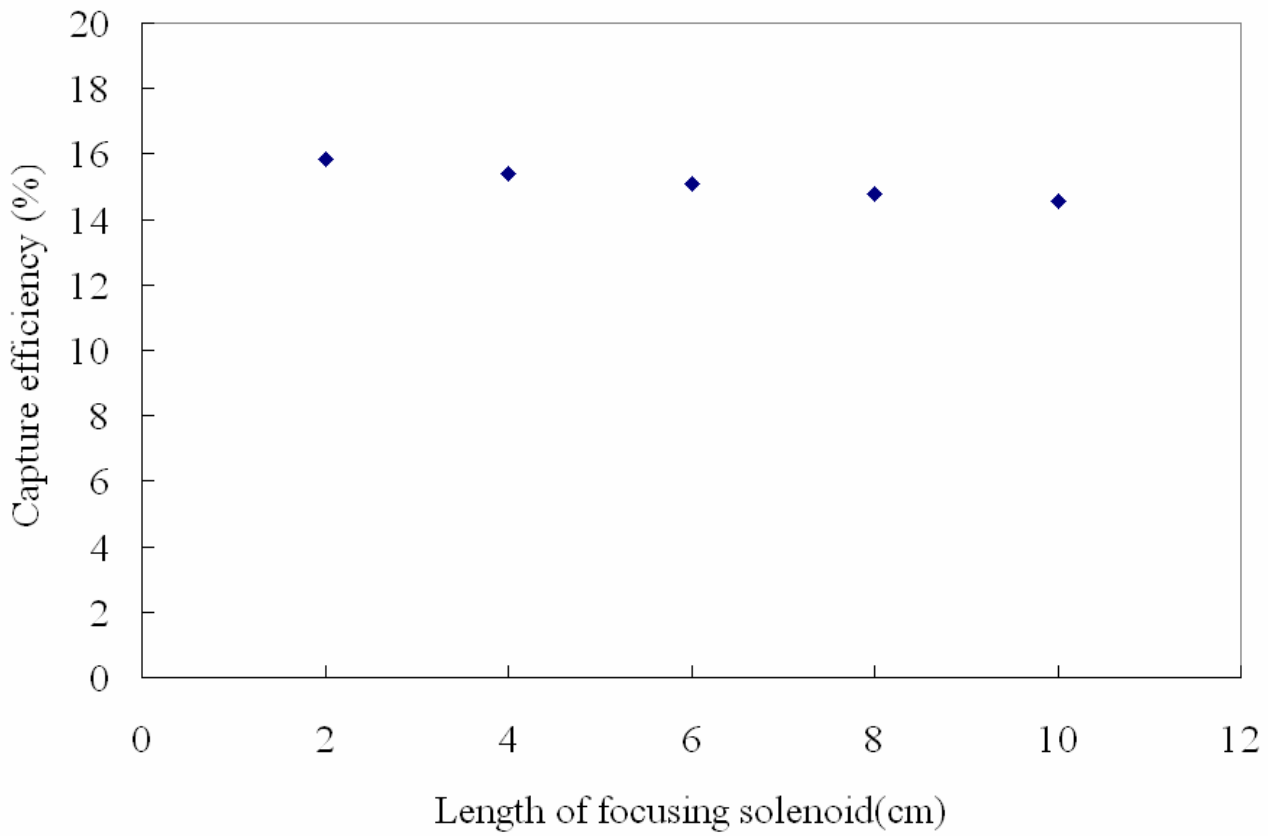
Magnetic field profile: Superposition of two field maps.



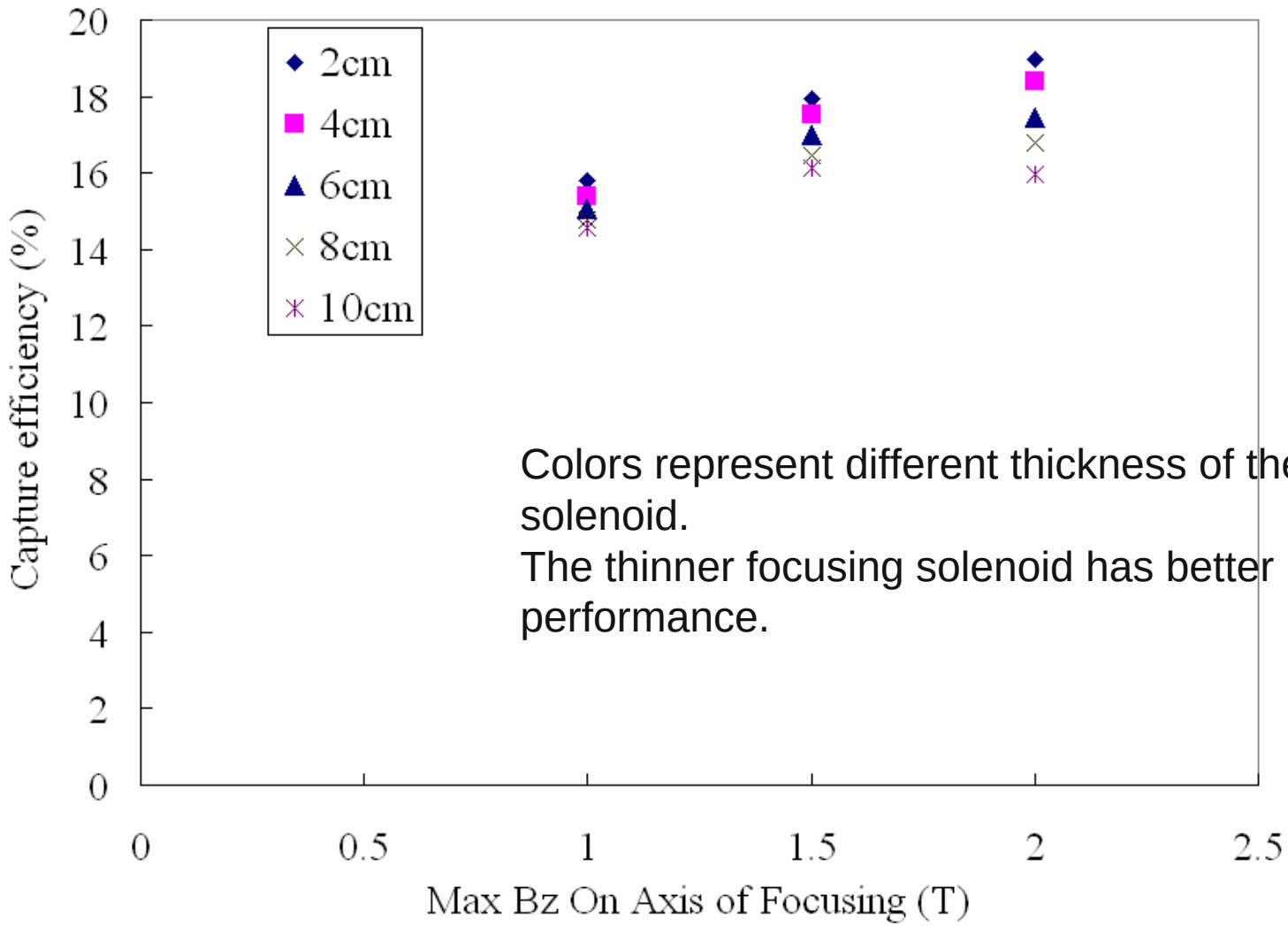
On axis Bz profile



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.

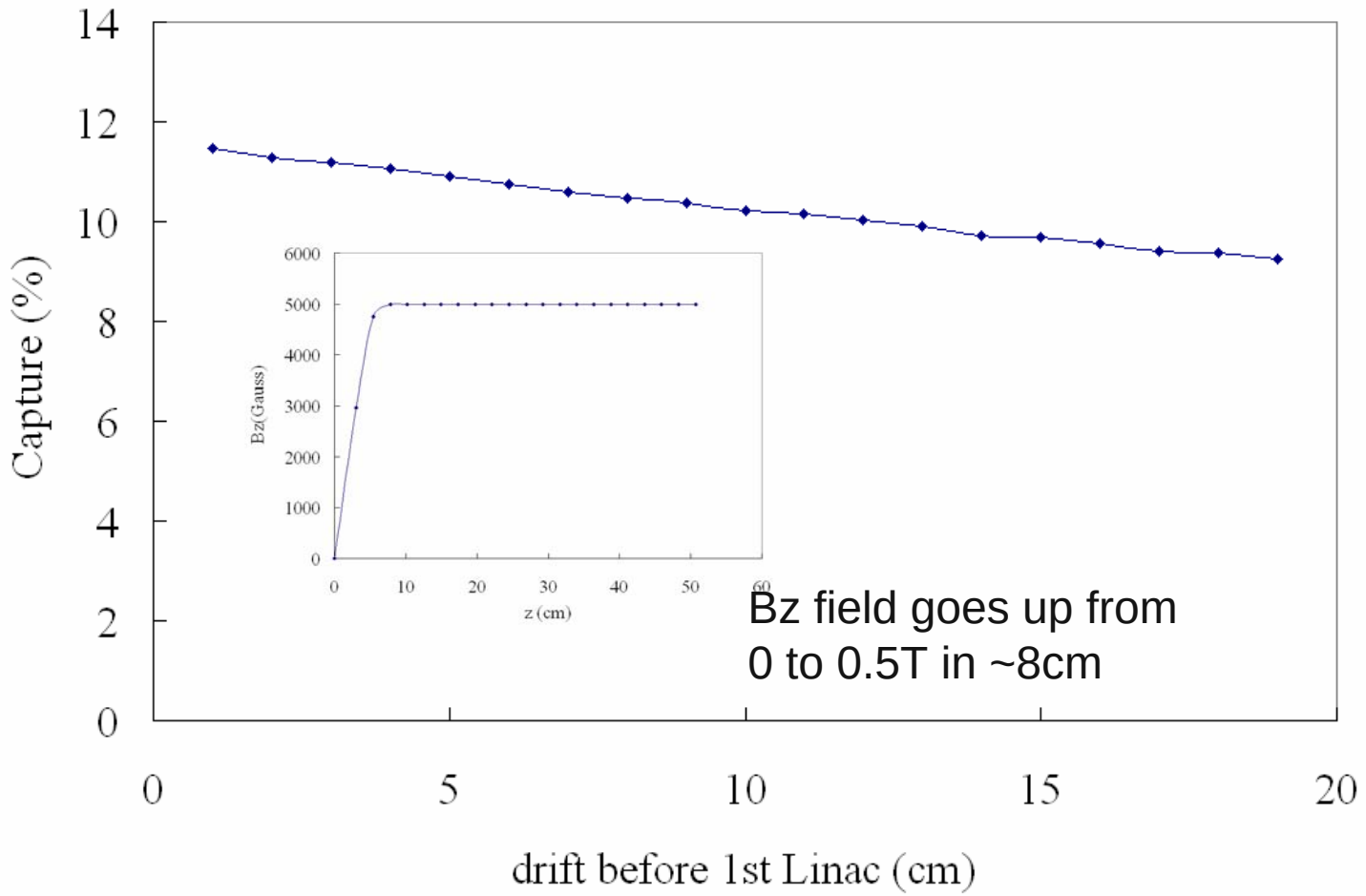


Capture as function of focusing field



Colors represent different thickness of the focusing solenoid.
The thinner focusing solenoid has better performance.

Capture efficiency with only 0.5T background solenoid

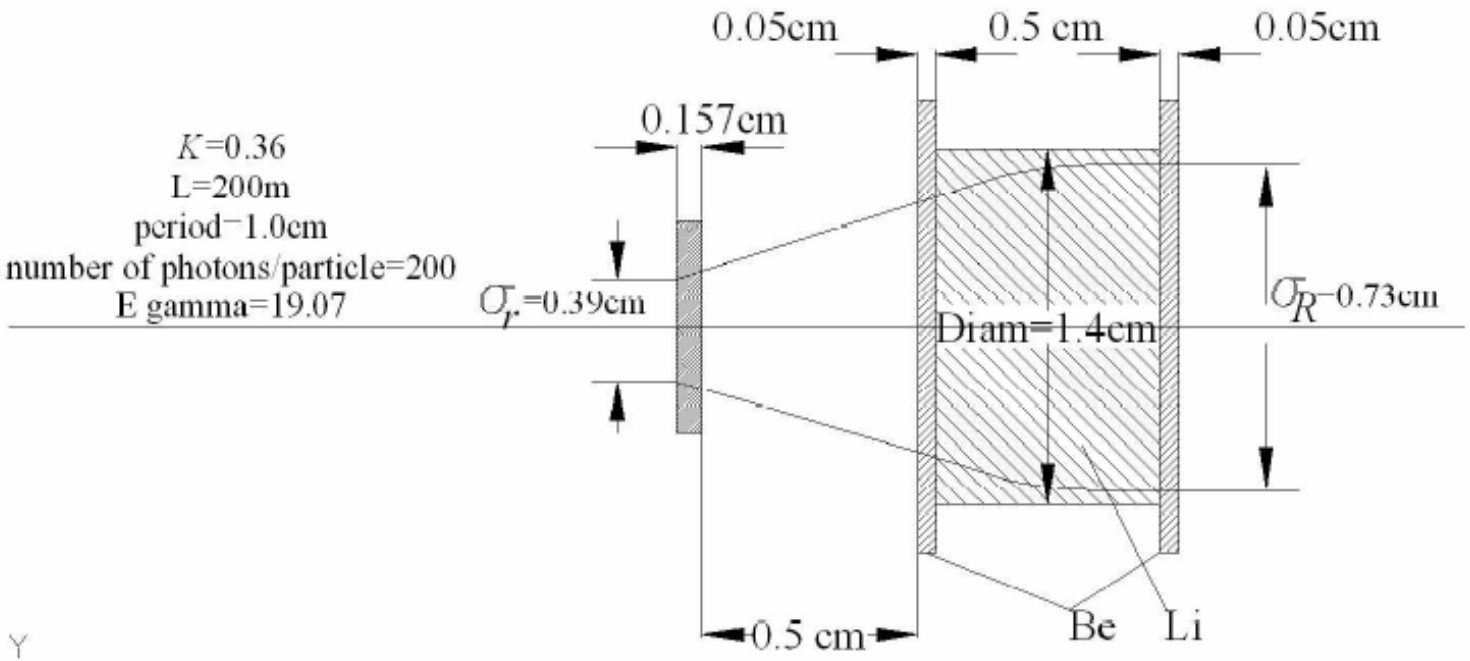


Bz field goes up from
0 to 0.5T in ~8cm

A.M. Aug 20, 2007

TARGET AND LENS

Shown below is W target

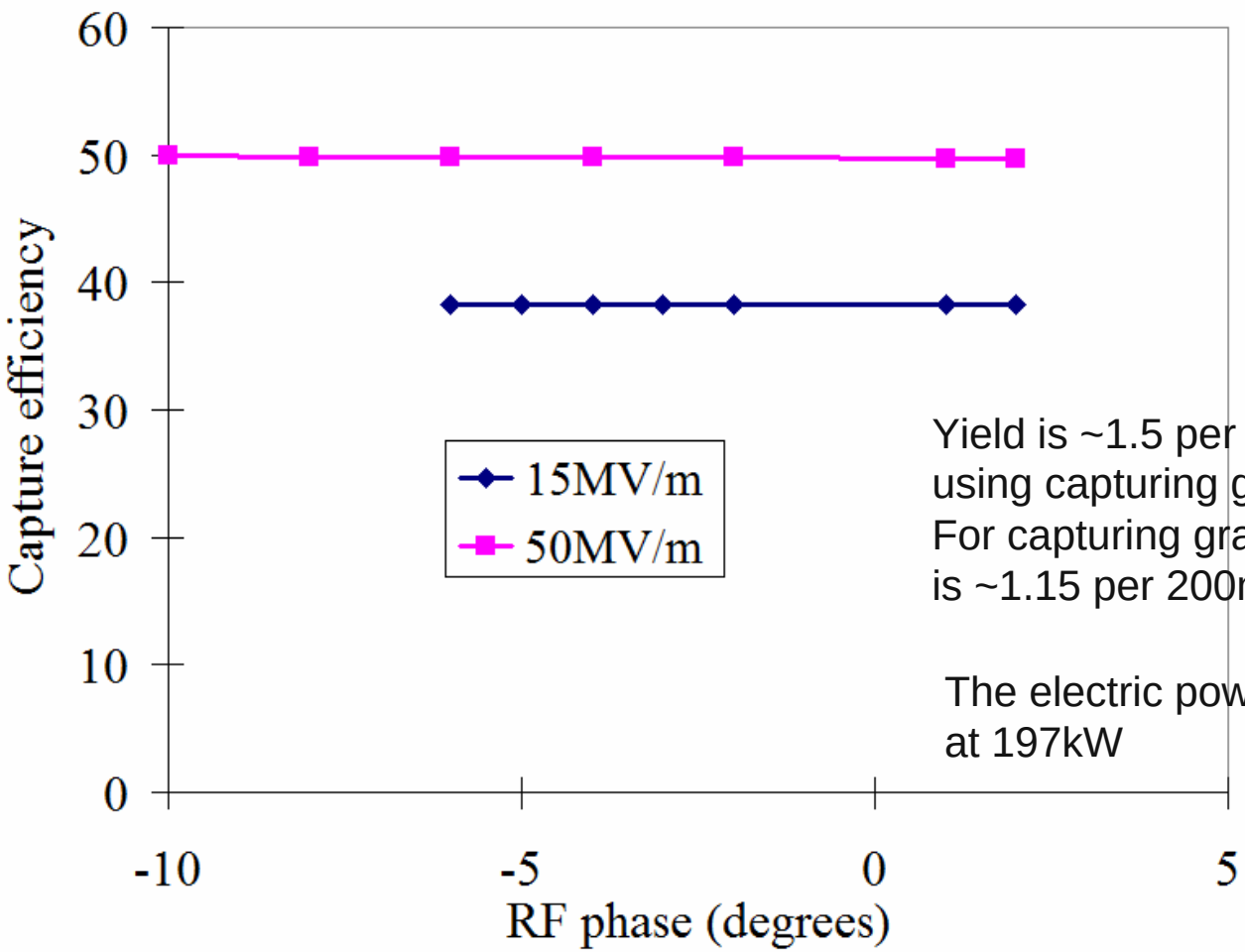


Total current in lens =156 kA. Be and Li stay in good thermal contact. Lithium is liquid and runs ~10m/sec.
Shown is beam envelope with R.M.S. values.
Efficiency of conversion is 1.68.

Conditions:

- Undulator: k=0.36, λu=1.0cm, length:200m
- Drift to target: 350m
- Drive beam energy: 150GeV
- Capture: at ~125MeV, using +/-7.5 degree phase cut, $\varepsilon x+\varepsilon y$ <0.09m.rad, energy spread +/-25MeV.
- Capturing RF gradient: 15MV/m and 50MV/m
- Assume uniform current distribution in lithium lens

Yield and capture efficiency



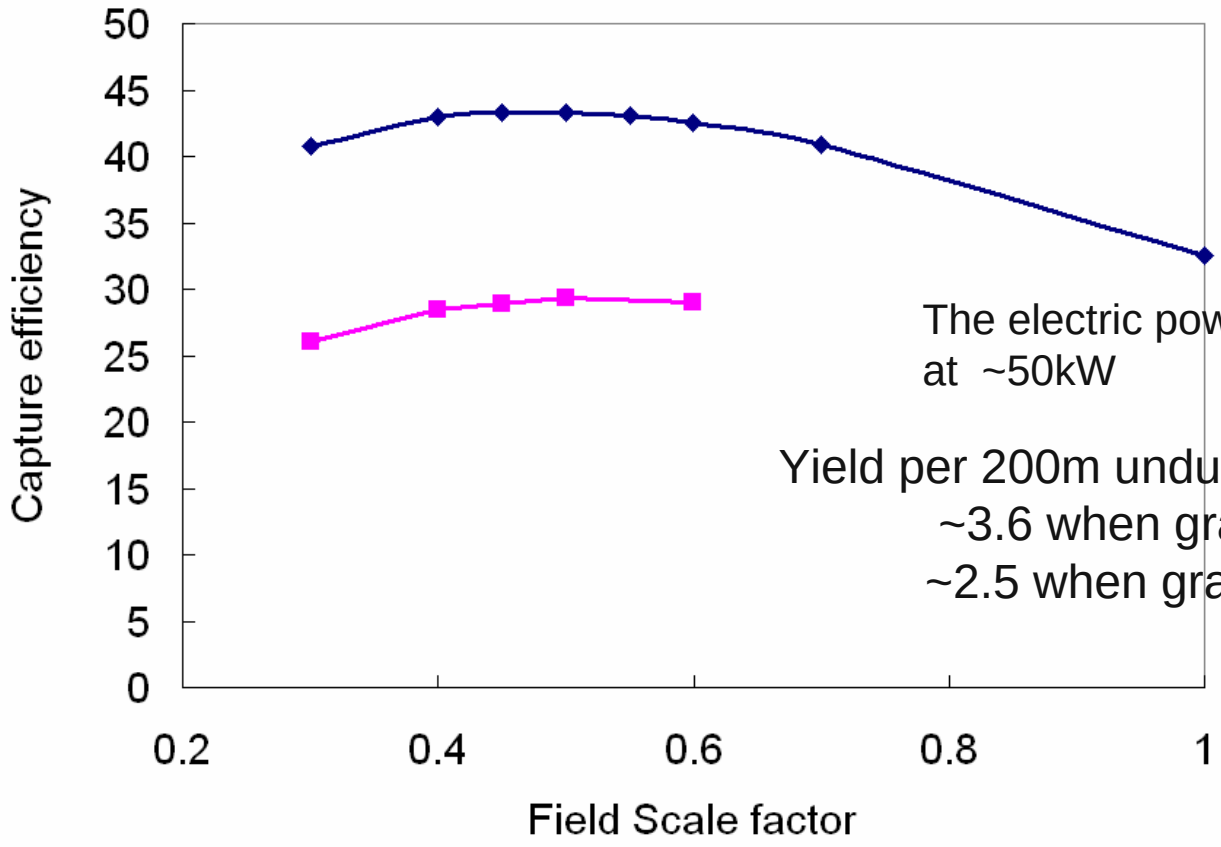
Yield is ~1.5 per 200m undulator when using capturing gradient of 50MV/m
For capturing gradient of 15MV/m, the yield is ~1.15 per 200m undulator

The electric power required is estimated at 197kW

Using baseline undulator and target with Lithium lens

- Undulator: K=0.92, λu=1.15cm, 100m
- Titanium target:0.4 rl
- Drift to target: 450m
- Drive beam energy: 150GeV
- Capture: at ~125MeV, using +/-7.5 degree phase cut, $\varepsilon x+\varepsilon y$ <0.09m.rad, energy spread +/-25MeV.
- Capturing RF gradient: 50MV/m

Yield and capture efficiency using baseline undulator and target with lithium lens



The electric power required is estimated at ~50kW

Yield per 200m undulator:
~3.6 when gradient is 50MV/m
~2.5 when gradient is 15MV/m

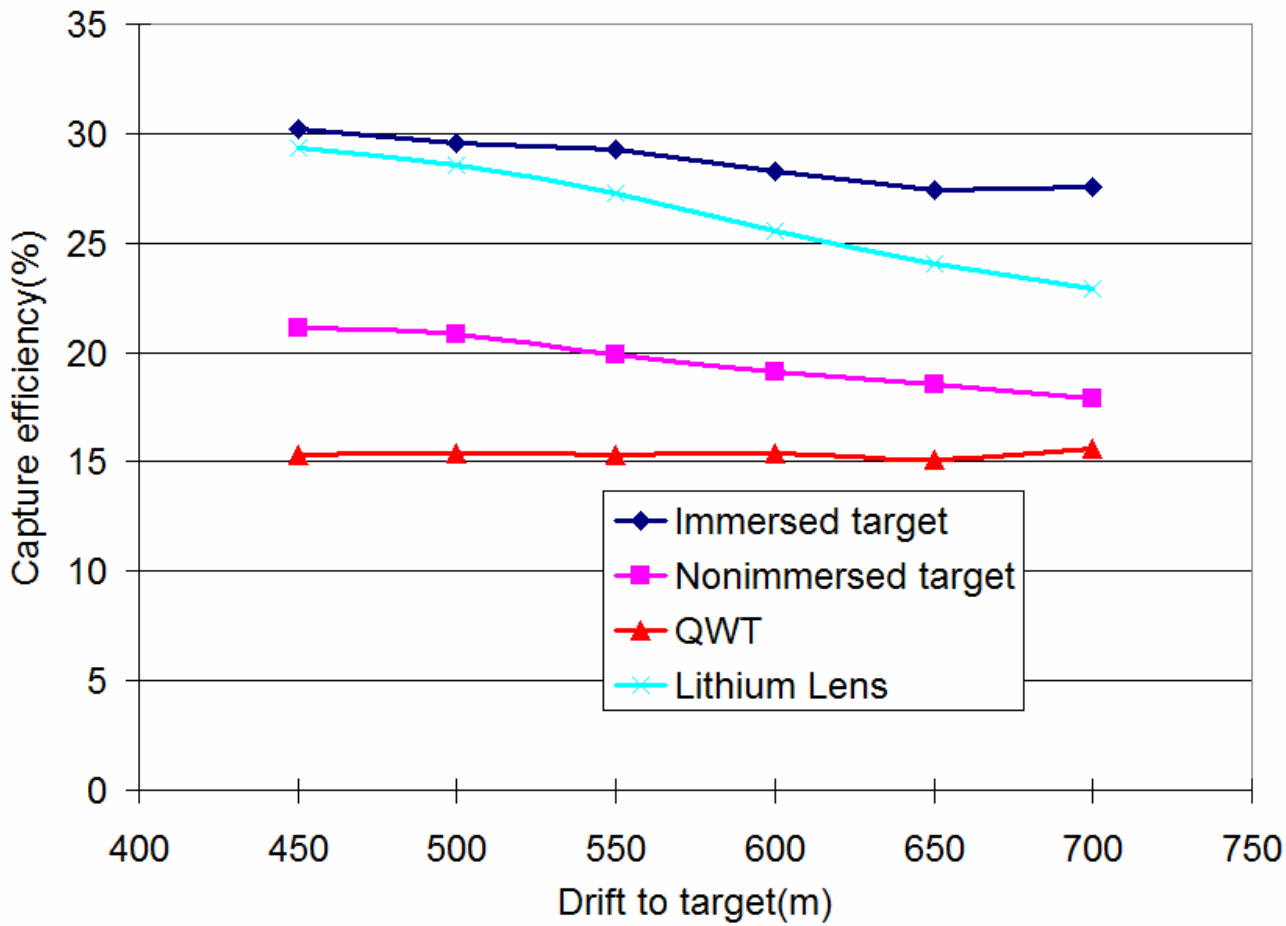
Capture Efficiency of Different OMD

OMD	Capture efficiency
Immersed target (6T-0.5T in 20 cm)	~30%
Non-immersed target (0-6T in 2cm, 6T-0.5T 20cm)	~21%
Quarter wave transformer (1T, 2cm)	~15%
0.5T Back ground solenoid only	~10%
Lithium lens	~29%

3. The effect of spot size on positron capture efficiency

- 100m undulator, K=0.92, λu=1.15cm
- Target: Ti, 0.4 rl
- Drift to target: from 450m up to 700m(spot size: 1.5mm up to 2.3mm)
- Immersed case: 6T-0.5T, 20cm
- Non Immersed case: ramp(0-6T) 2cm, 6T-0.5T 20cm
- Quarter wave transformer: 1T-0.5T, 2cm DC coil

Capture efficiency as function of spot drift to target (spot size)



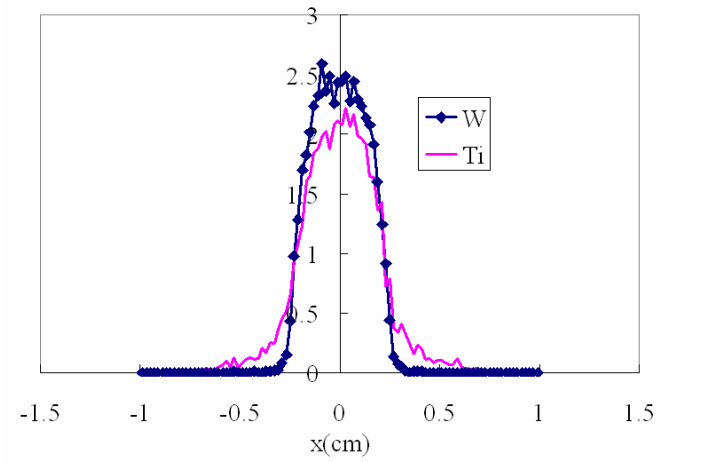
Capture efficiency lowered by 10% for immersed target when spot size increased from σ ~1.5mm up to ~2.3mm.
For non immersed case, the capture efficiency dropped by ~ 14%.
For quarter wave transformer, the capture efficiency doesn't change with spot size within the range of 1.5mm to 2.3mm
For lithium lens,

4. Comparing Tungsten target and Titanium target

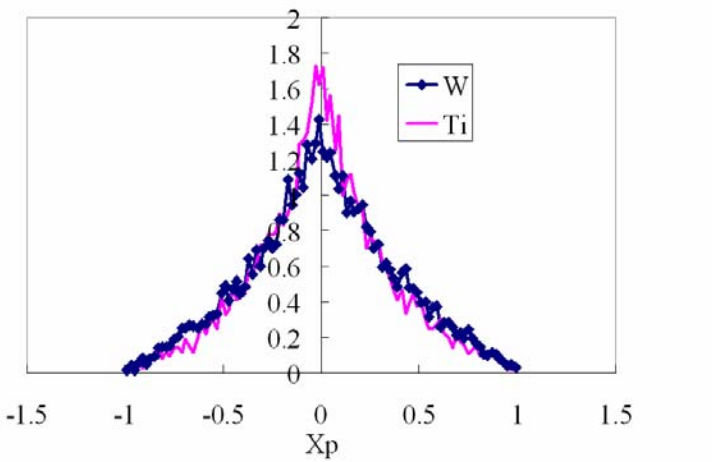
- Same undulator
- Same target length (measured in radiation length)
- Same beam line
- Same collimator settings

Tungsten target gives about 50% higher raw yield in positron production but the captured yield only enhanced by ~10% due to broader divergence distribution of e+ produced in tungsten target.
The density of deposited energy in tungsten target is about 10 times higher than titanium target.

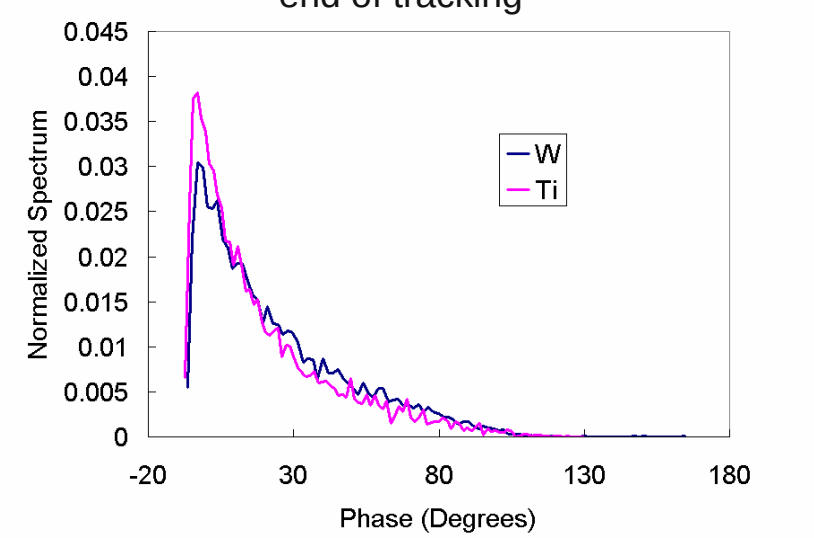
Normalized transverse distribution of e+ when exiting from target



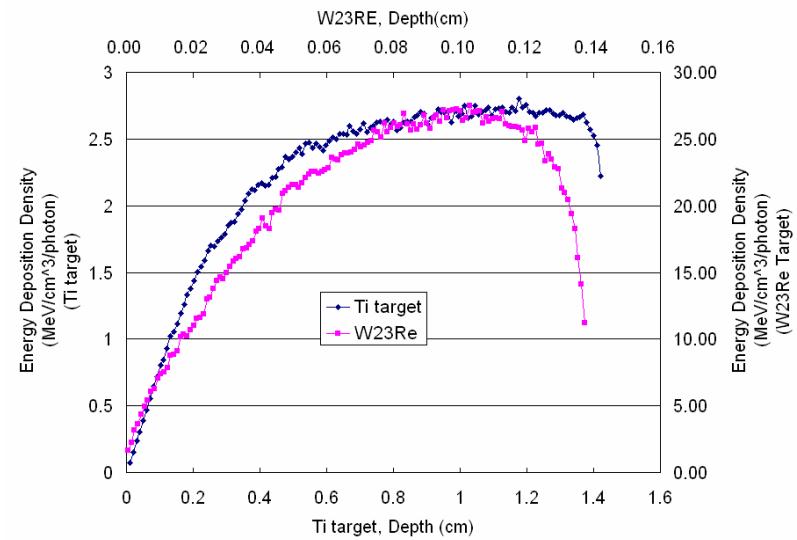
Normalized divergence distribution of e+ when exiting from target



Normalized longitudinal distribution of e+ at end of tracking



On beam axis profile of deposit energy density



Summary

- Comparing the capture efficiency, lithium lens has about the same efficiency as immersed AMD
- Increase the spot size will lower the capture efficiency except for quarter wave transformer. The exactly trade off need to be determined.
- Tungsten target can give ~50% more on raw yield. But given the same in put condition, the density of energy deposition for tungsten target is 10 times higher than for titanium target. And due to the wider divergence distribution of e+ from tungsten target, the enhancement to e+ yield will be limited

The end