

# PF-AR BT 3.7 GeV 化検討 (その3)

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放射光源研究系

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# 前回までの検討内容

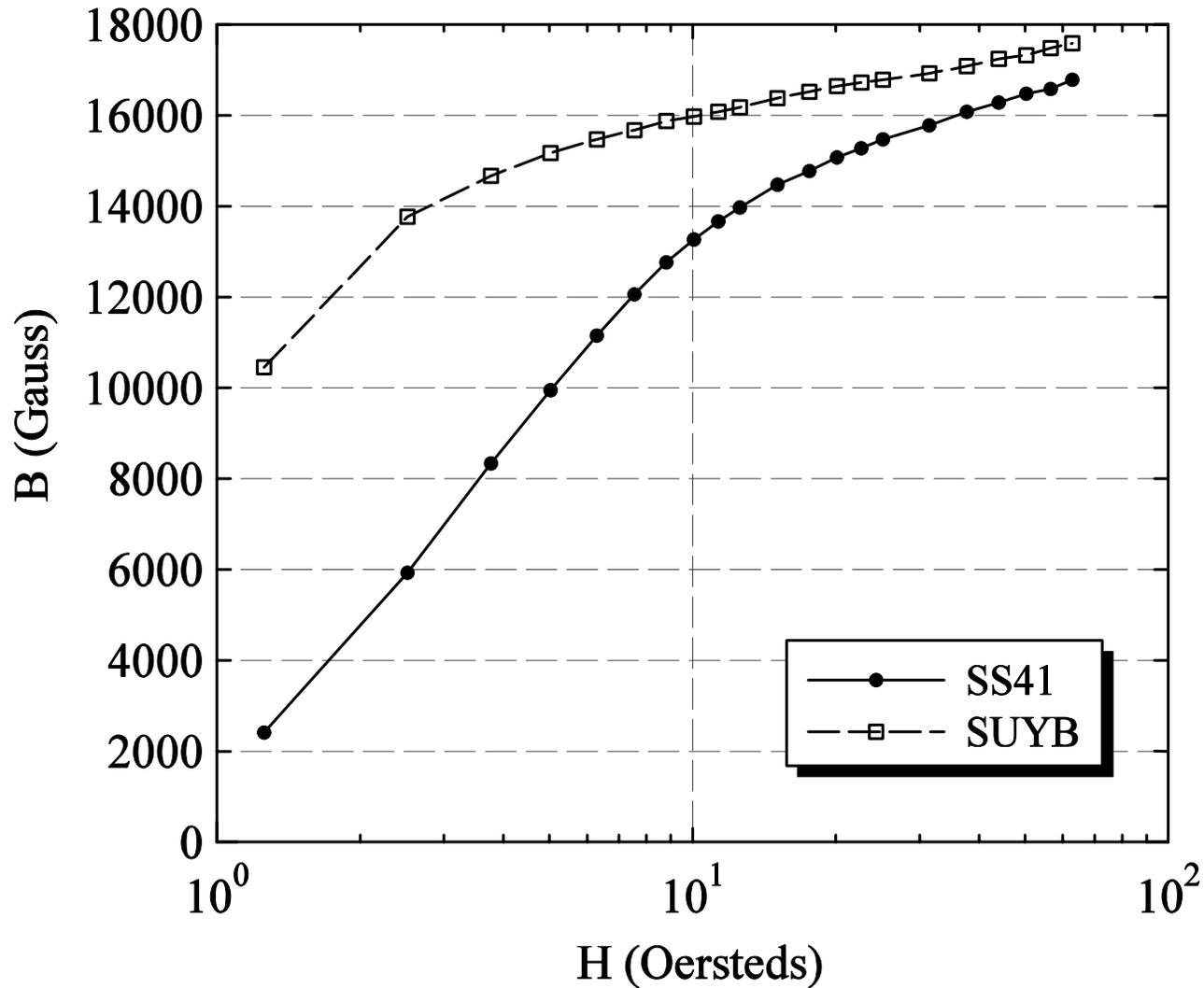
- 現状の設備で 3.25 GeV までビームを輸送可能
- 3.7 GeV 化する際の検討項目：
  1. 四極電磁石は変更なしで対応可能
  2. 偏向電磁石: 最大積分磁場 1.38 Tm が必要
- 検討した案
  1. 偏向電磁石の電源を増強
    - BHR2E\_1\_14, BHR3E 2台の電源の増強が必要
    - 鉄心の飽和 2次元磁場計算を行った
  2. 偏向電磁石のギャップを縮小(34 mm → 28 mm)
    - 15台の電磁石、真空チェンバーの改造が必要
    - 積分磁場の分布はどうなっているか？

# 今回検討した事柄

- 積分磁場のx方向分布を調べるために、3次元磁場計算を行った
- Opera 3D を使用
  
- 計算したモデル
  1. Gap 34 mm (現状の偏向電磁石)
  2. Gap 28 mm (ギャップを縮めたモデル)
  
- 鉄心の材質
  1. 磁極: SUYB
  2. リターンヨーク: SS41

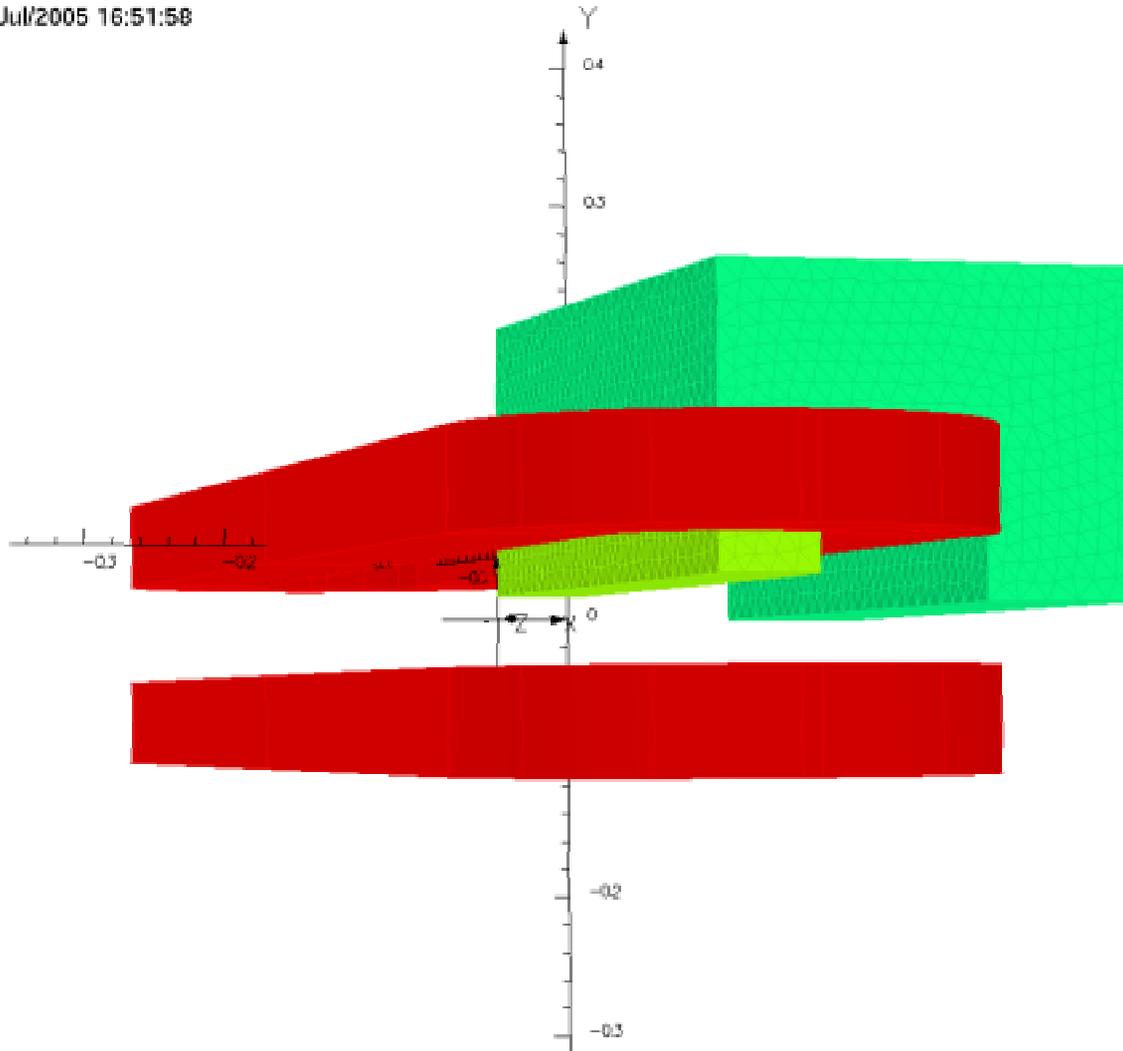
# BH 曲線

BH curve (SS41, SUYB)



# 電磁石の形状

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## UNITS

Length	m
Magn Flux	T
Density	
Magn Field	$A\ m^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	$Wb\ m^{-1}$
Elec Flux Density	$C\ m^{-2}$
Elec Field	$V\ m^{-1}$
Conductivity	$S\ m^{-1}$
Current Density	$A\ m^{-2}$
Power	W
Force	N
Energy	J

## PROBLEM DATA

g34\_m1\_db01.op3  
TOSCA Magnetostatic  
Non-linear materials  
Simulation No 1 of 1  
137706 elements  
103553 nodes  
1 conductor  
Nodally interpolated fields

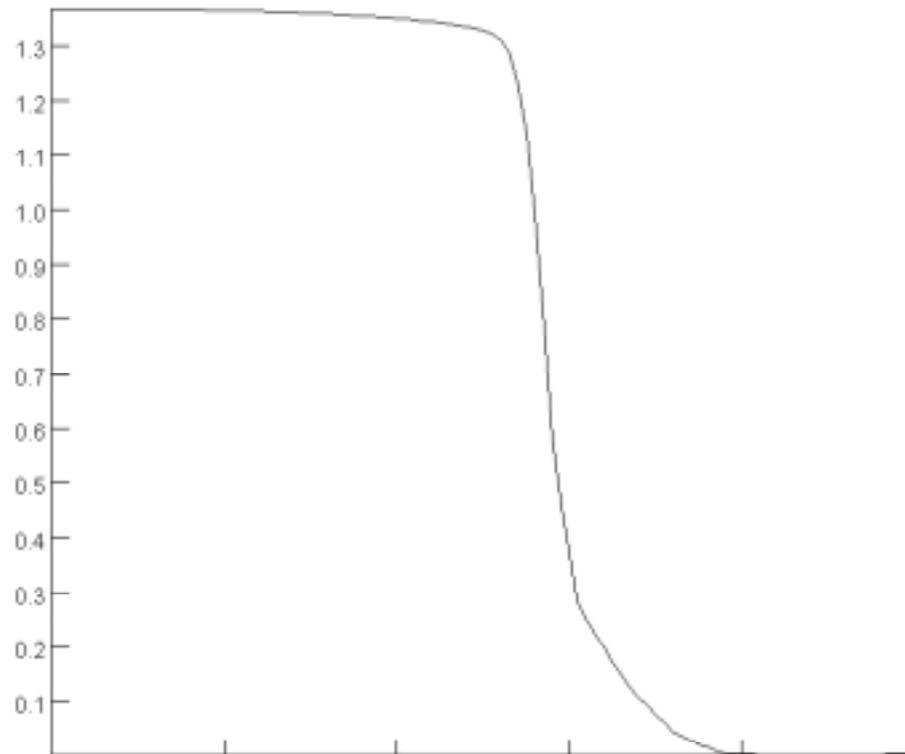
## Local Coordinates

Origin: 0.0, 0.0, 0.0  
Local XYZ = Global XYZ

# Gap 34 mm : Z方向の By の分布

$I = 250 \text{ A}$ ,  $x = 0 \text{ mm}$ ,  $y = 0 \text{ mm}$

7/Jul/2005 14:42:39



Local X coord	0.0	0.0	0.0	0.0	0.0	0.0
Local Y coord	0.0	0.0	0.0	0.0	0.0	0.0
Local Z coord	0.0	0.18	0.36	0.54	0.72	0.9

Component: -BY, Integral = 0.71981992486843

## UNITS

Length	m
Magn Flux	T
Density	
Magn Field	$\text{A m}^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	$\text{Wb m}^{-1}$
Elec Flux Density	$\text{C m}^{-2}$
Elec Field	$\text{V m}^{-1}$
Conductivity	$\text{S m}^{-1}$
Current Density	$\text{A m}^{-2}$
Power	W
Force	N
Energy	J

## PROBLEM DATA

g34\_m1\_db01.op3  
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Non-linear materials  
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103553 nodes  
1 conductor  
Nodally interpolated fields

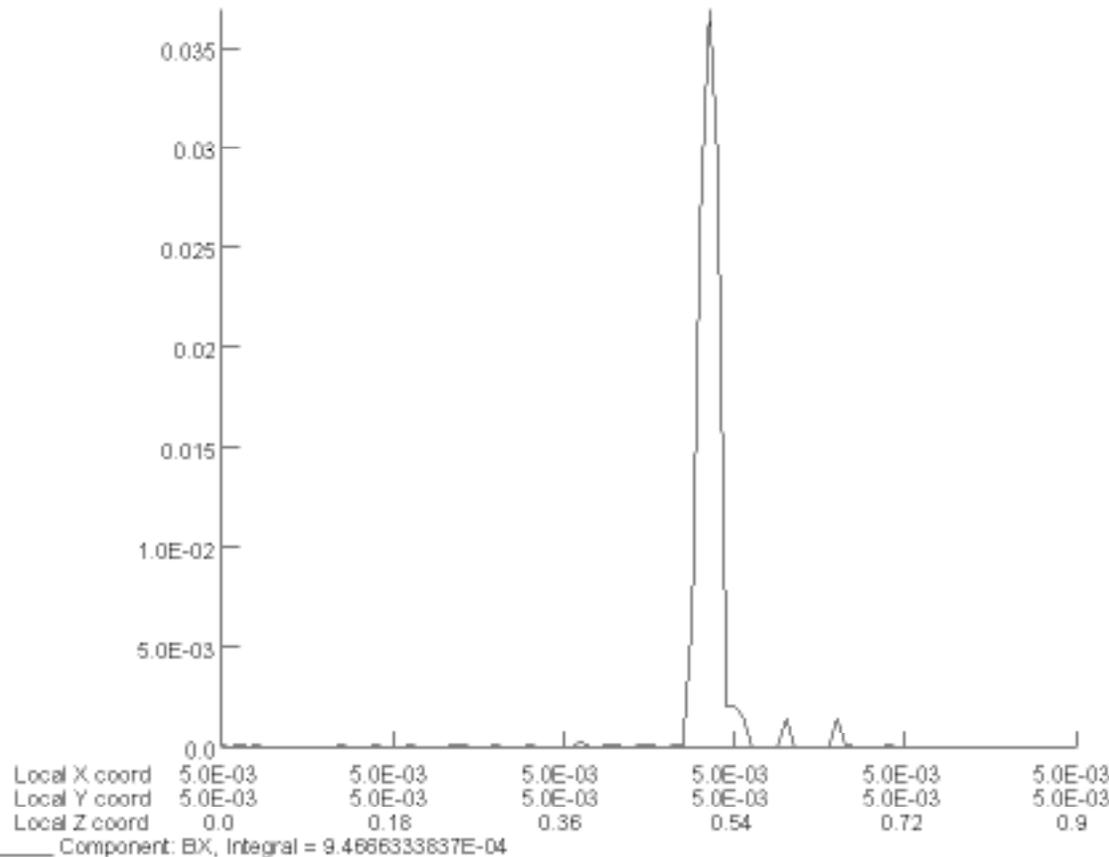
## Local Coordinates

Origin: 0.0, 0.0, 0.0  
Local XYZ = Global XYZ

# Gap 34 mm : Z方向の $B_x$ の分布

$I = 250 \text{ A}$ ,  $x = 5 \text{ mm}$ ,  $y = 5 \text{ mm}$

7/Jul/2005 14:43:05



## UNITS

Length	m
Magn Flux	T
Density	
Magn Field	$\text{A m}^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	Wb
	$\text{m}^{-1}$
Elec Flux Density	$\text{C m}^{-2}$
Elec Field	$\text{V m}^{-1}$
Conductivity	$\text{S m}^{-1}$
Current Density	$\text{A m}^{-2}$
Power	W
Force	N
Energy	J

## PROBLEM DATA

g34\_m1\_db01.op3  
 TOSCA Magnetostatic  
 Non-linear materials  
 Simulation No 1 of 1  
 137706 elements  
 103553 nodes  
 1 conductor  
 Nodally interpolated fields

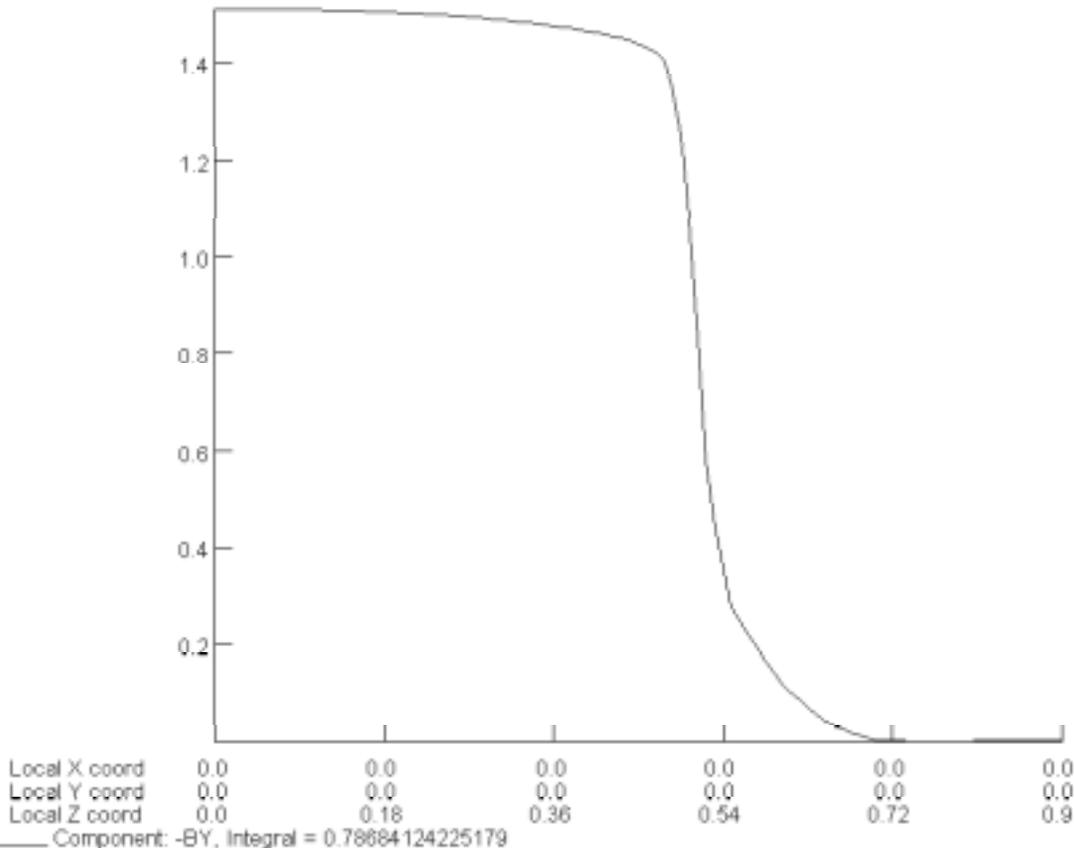
## Local Coordinates

Origin: 0.0, 0.0, 0.0  
 Local XYZ = Global XYZ

# Gap 28 mm : Z方向の $B_y$ の分布

## $I = 250 \text{ A}$ , $x = 0 \text{ mm}$ , $y = 0 \text{ mm}$

7/Jul/2005 11:47:09



UNITS	
Length	m
Magn Flux	T
Density	
Magn Field	$\text{A m}^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	Wb
	$\text{m}^{-1}$
Elec Flux Density	$\text{C m}^{-2}$
Elec Field	$\text{V m}^{-1}$
Conductivity	$\text{S m}^{-1}$
Current Density	$\text{A m}^{-2}$
Power	W
Force	N
Energy	J

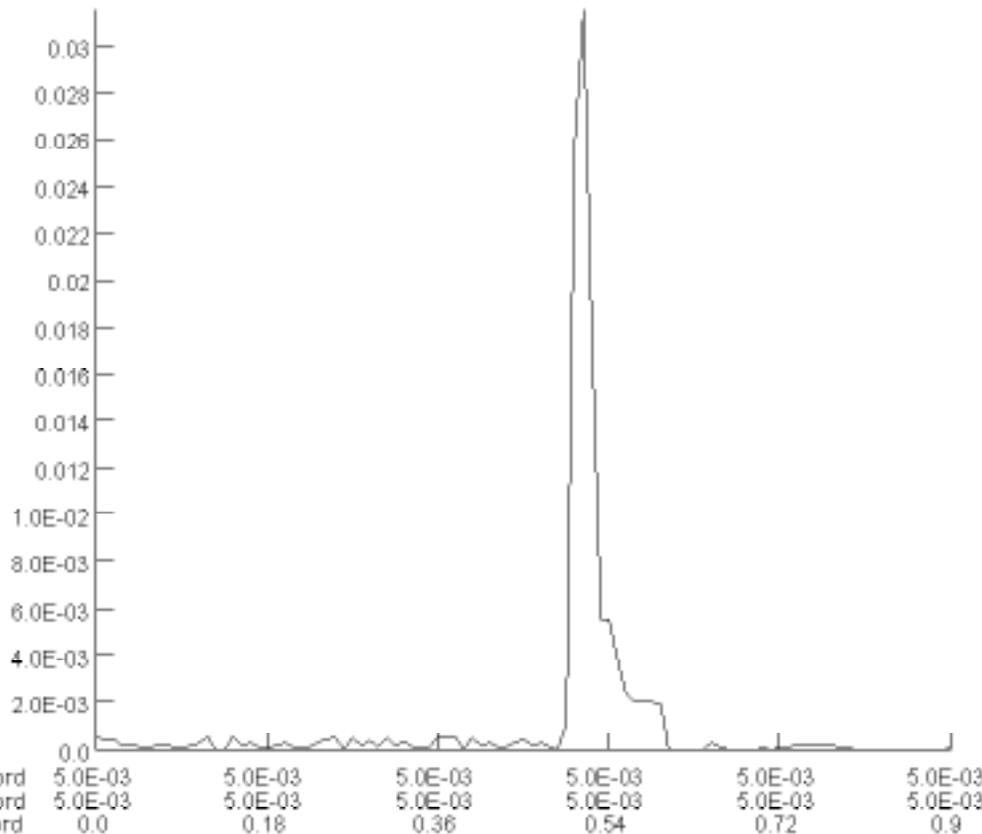
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g28\_m1\_db01.op3  
TOSCA Magnetostatic  
Non-linear materials  
Simulation No 1 of 1  
130199 elements  
89176 nodes  
1 conductor  
Nodally interpolated fields

**Local Coordinates**  
Origin: 0.0, 0.0, 0.0  
Local XYZ = Global XYZ

# Gap 28 mm : Z方向の $B_x$ の分布

$I = 250 \text{ A}$ ,  $x = 5 \text{ mm}$ ,  $y = 5 \text{ mm}$

7/Jul/2005 11:48:16



Component:  $B_x$ , Integral =  $1.003114344\text{E-}03$

UNITS	
Length	m
Magn Flux	T
Density	
Magn Field	$\text{A m}^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	$\text{Wb m}^{-1}$
Elec Flux Density	$\text{C m}^{-2}$
Elec Field	$\text{V m}^{-1}$
Conductivity	$\text{S m}^{-1}$
Current Density	$\text{A m}^{-2}$
Power	W
Force	N
Energy	J

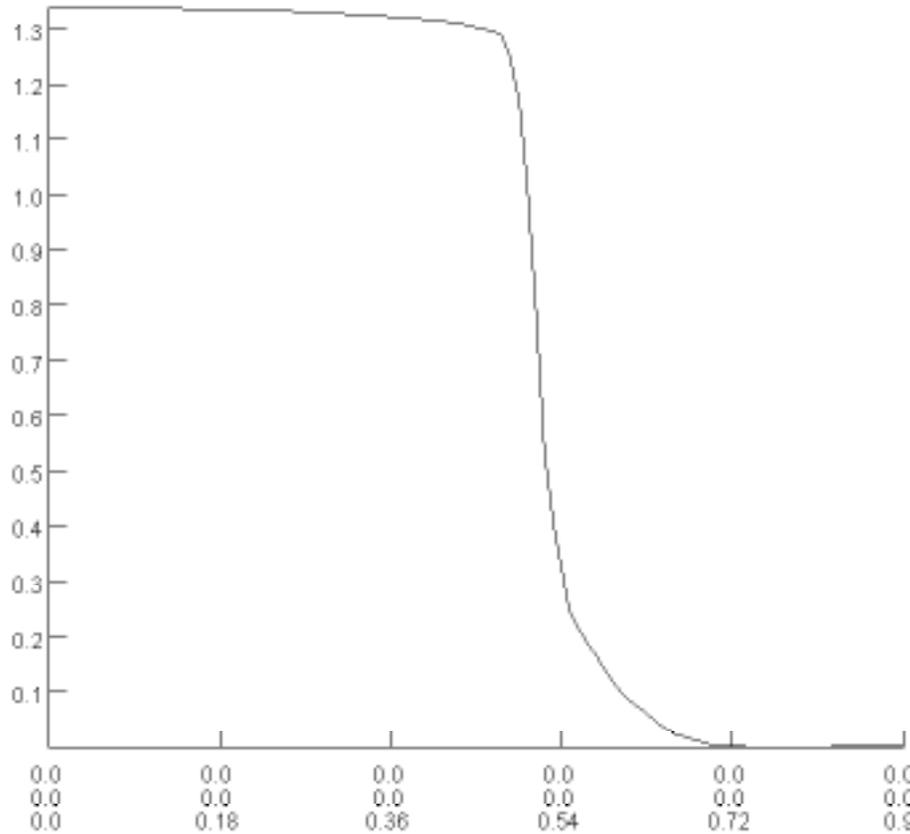
**PROBLEM DATA**  
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 TOSCA Magnetostatic  
 Non-linear materials  
 Simulation No 1 of 1  
 130199 elements  
 89176 nodes  
 1 conductor  
 Nodally interpolated fields

**Local Coordinates**  
 Origin: 0.0, 0.0, 0.0  
 Local XYZ = Global XYZ

# Gap 28 mm : Z方向の By の分布

$I = 200 \text{ A}$ ,  $x = 0 \text{ mm}$ ,  $y = 0 \text{ mm}$

7/Jul/2005 11:26:12



## UNITS

Length	m
Magn Flux	T
Density	
Magn Field	$\text{A m}^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	$\text{Wb m}^{-1}$
Elec Flux Density	$\text{C m}^{-2}$
Elec Field	$\text{V m}^{-1}$
Conductivity	$\text{S m}^{-1}$
Current Density	$\text{A m}^{-2}$
Power	W
Force	N
Energy	J

## PROBLEM DATA

g28\_m1\_db02.op3  
TOSCA Magnetostatic  
Non-linear materials  
Simulation No 1 of 1  
130199 elements  
89176 nodes  
1 conductor  
Nodally interpolated fields

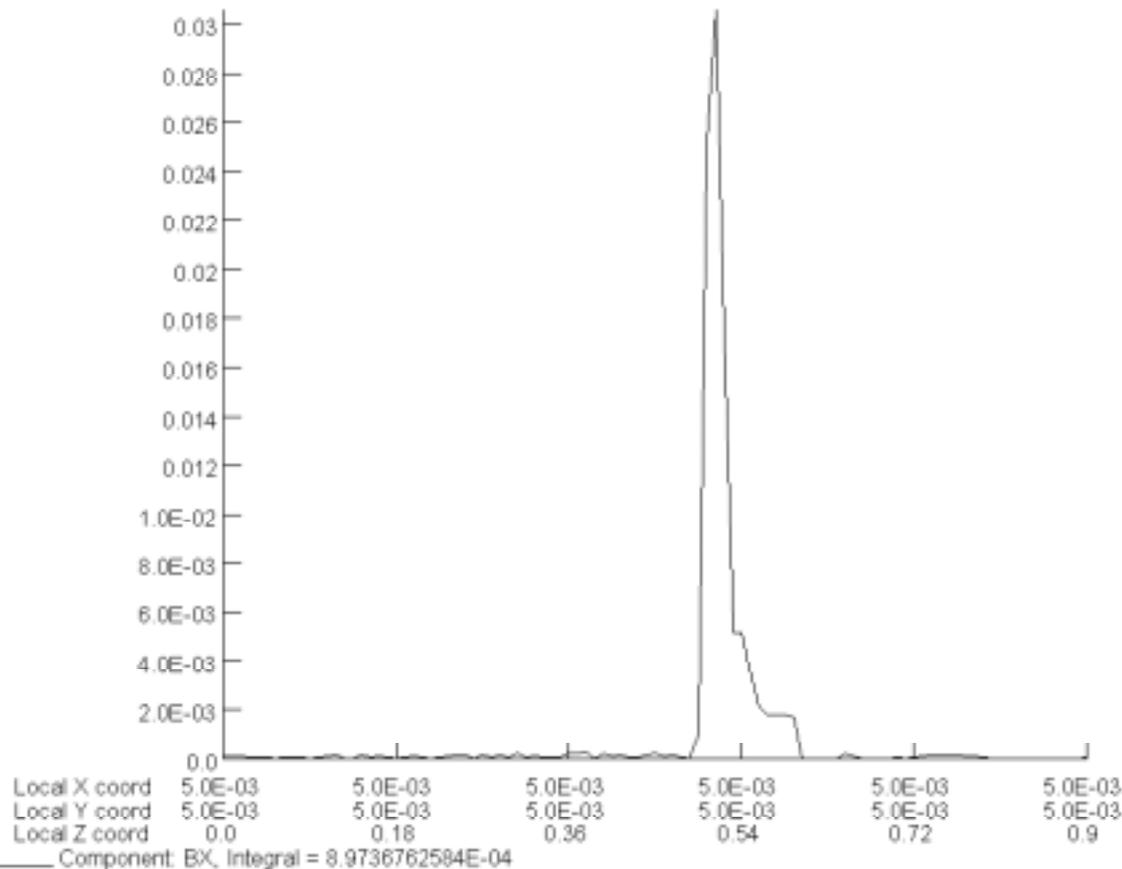
## Local Coordinates

Origin: 0.0, 0.0, 0.0  
Local XYZ = Global XYZ

# Gap 28 mm : Z方向の $B_x$ の分布

$I = 200 \text{ A}$ ,  $x = 5 \text{ mm}$ ,  $y = 5 \text{ mm}$

7/Jul/2005 11:31:54



## UNITS

Length	m
Magn Flux	T
Density	
Magn Field	$\text{A m}^{-1}$
Magn Scalar Pot	A
Magn Vector Pot	Wb
	$\text{m}^{-1}$
Elec Flux Density	$\text{C m}^{-2}$
Elec Field	$\text{V m}^{-1}$
Conductivity	$\text{S m}^{-1}$
Current Density	$\text{A m}^{-2}$
Power	W
Force	N
Energy	J

## PROBLEM DATA

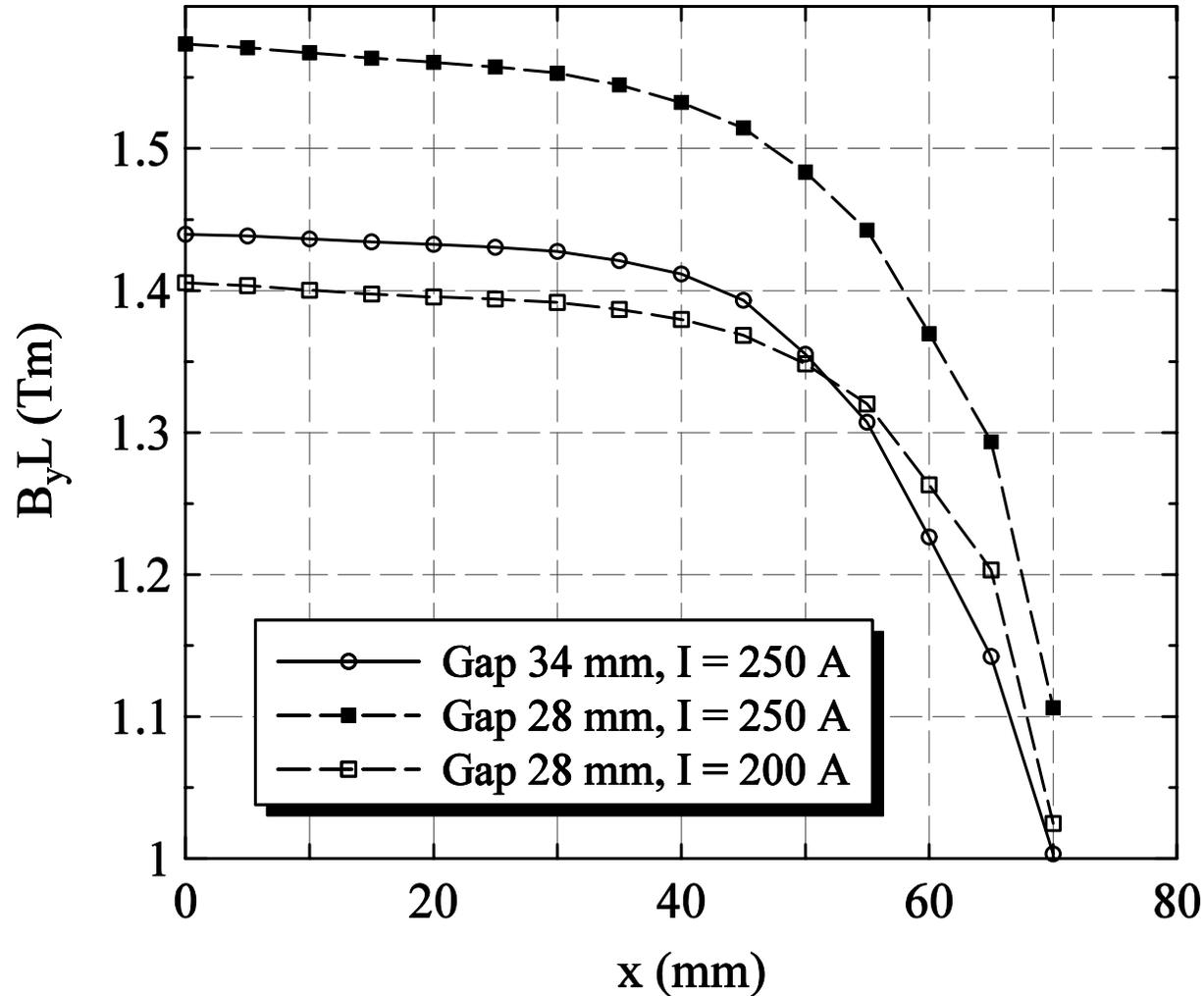
g28\_m1\_db02.op3  
 TOSCA Magnetostatic  
 Non-linear materials  
 Simulation No 1 of 1  
 130199 elements  
 89176 nodes  
 1 conductor  
 Nodally interpolated fields

## Local Coordinates

Origin: 0.0, 0.0, 0.0  
 Local XYZ = Global XYZ

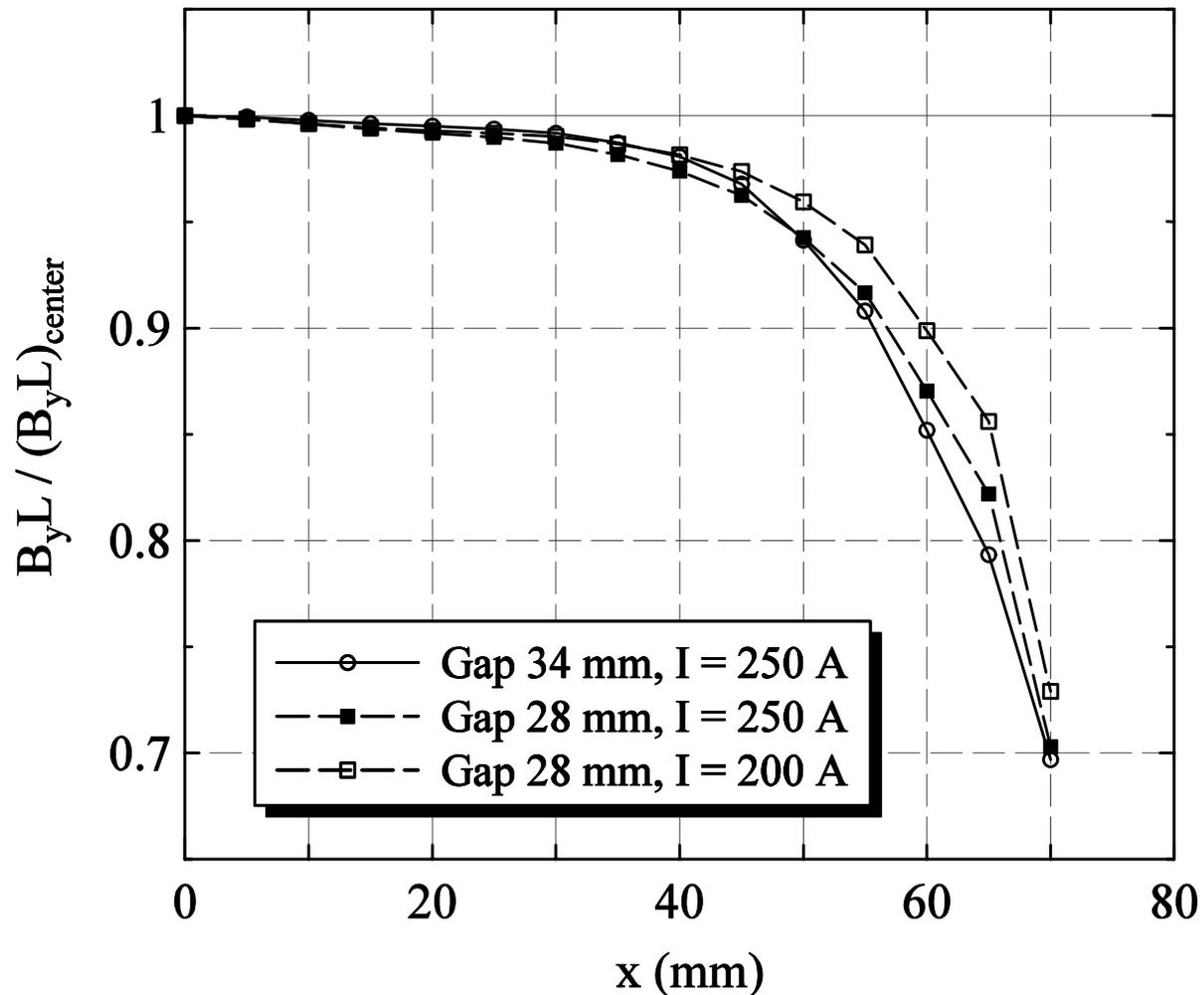
# Z方向積分磁場 $B_{yL}$ のx方向分布

ARBT Bending Magnet (Opera 3D)



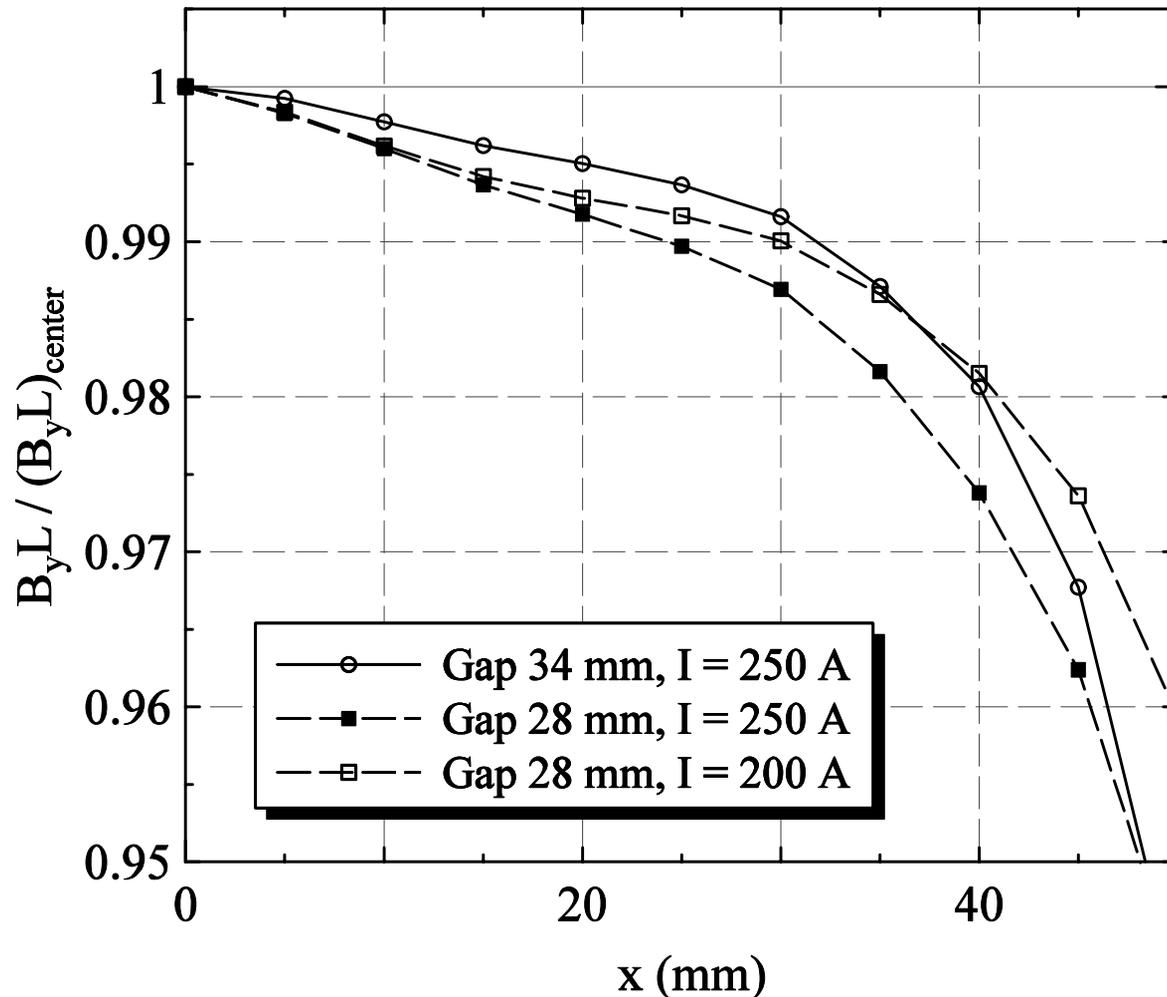
# Z方向積分磁場 $B_{yL}$ のx方向分布 ( $x = 0$ mm の値で規格化)

ARBT Bending Magnet (Opera 3D)



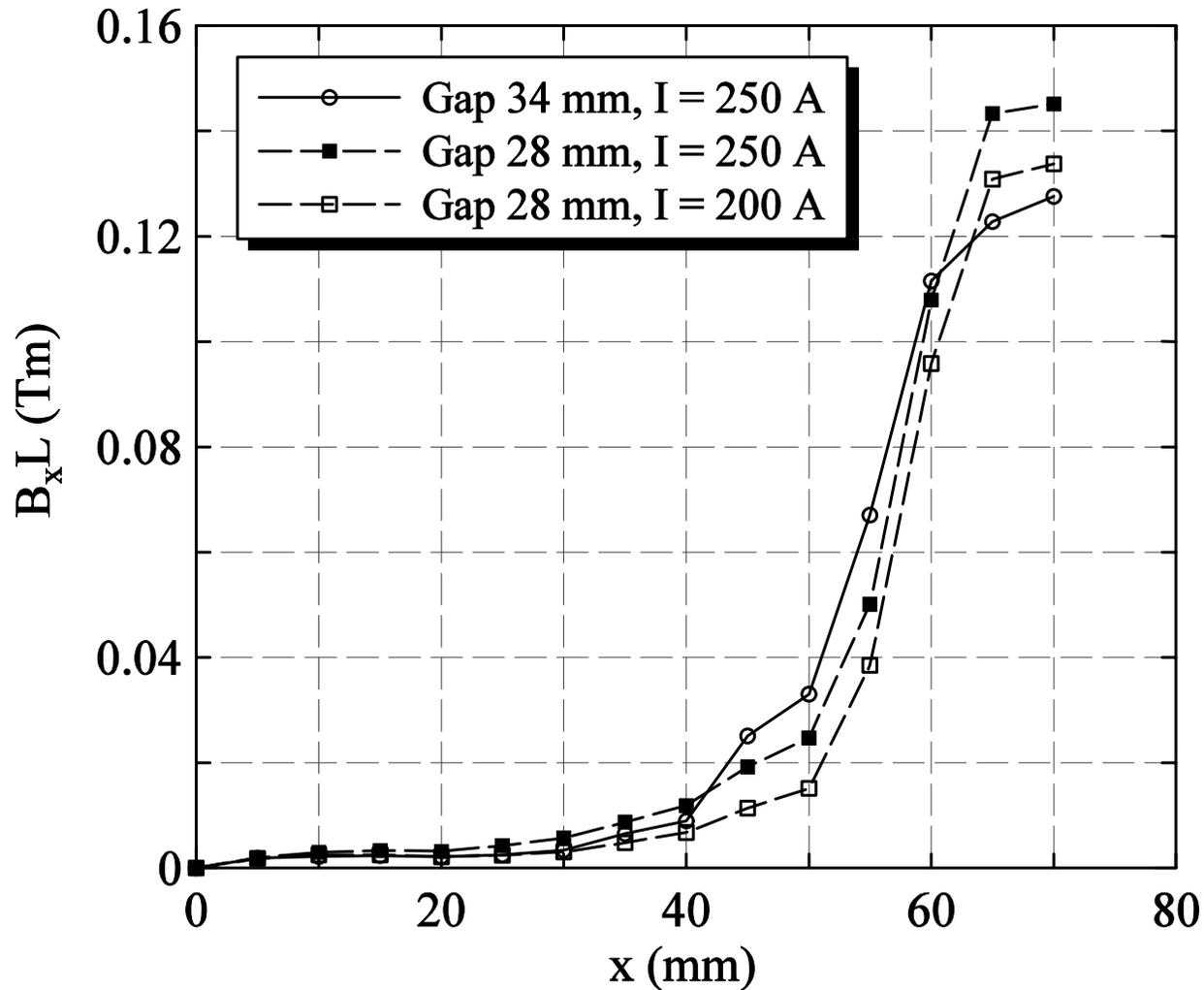
# Z方向積分磁場 $B_{yL}$ のx方向分布 ( $x = 0$ mm の値で規格化、中心付近を拡大)

ARBT Bending Magnet (Opera 3D)



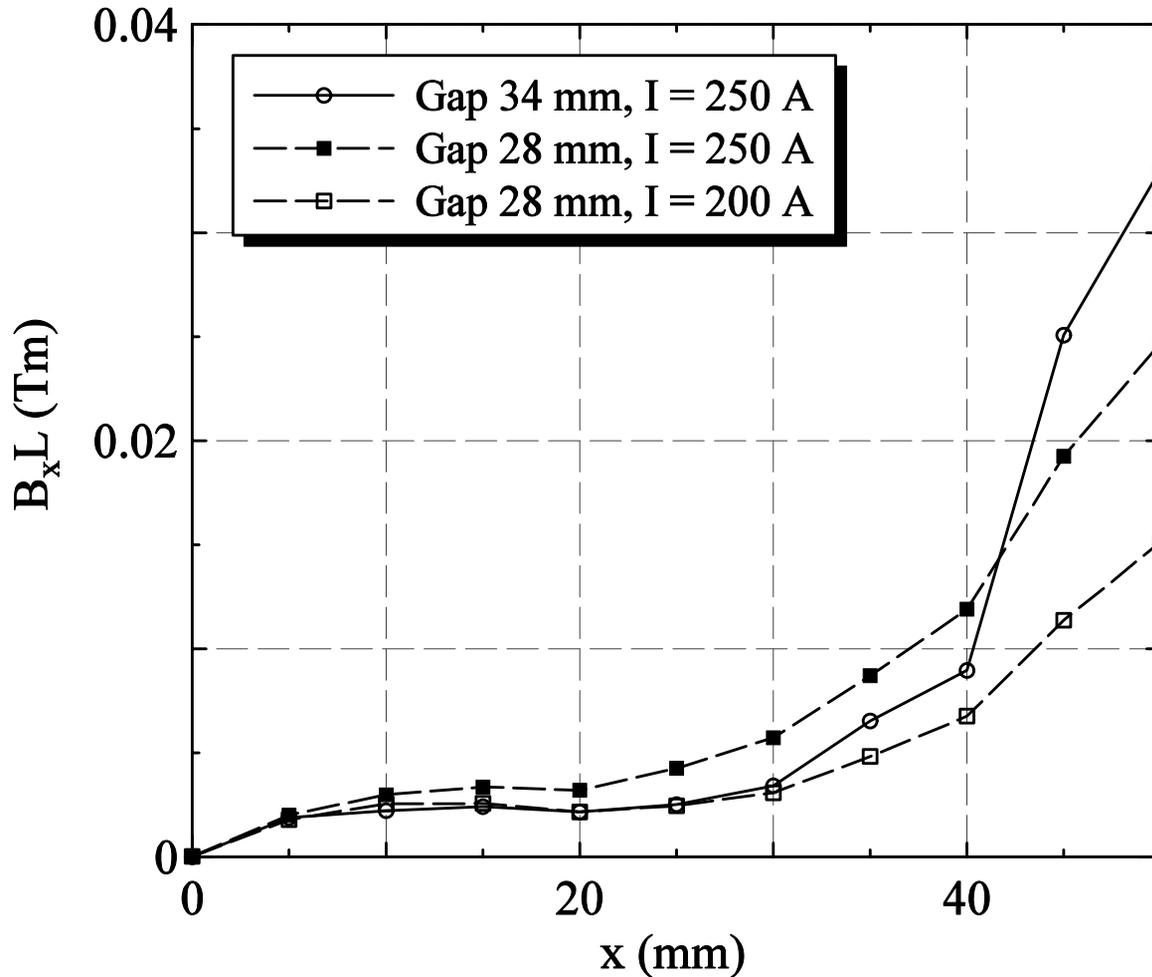
# Z方向積分磁場 $B_x L$ のx方向分布

ARBT Bending Magnet (Opera 3D)  
 $y = 5$  (mm)



# Z方向積分磁場 $B_x L$ のx方向分布 (中心付近を拡大)

ARBT Bending Magnet (Opera 3D)  
 $y = 5$  (mm)



# 結果のまとめ

- Gap 34 mm : I = 250 A
  1.  $B_y = 1.3676$  (T)
  2.  $B_{yL} = 1.4396$  (Tm)
  
- Gap 28 mm : I = 250 A
  1.  $B_y = 1.5120$  (T)
  2.  $B_{yL} = 1.5616$  (Tm)
  
- Gap 28 mm : I = 200 A
  1.  $B_y = 1.3387$  (T)
  2.  $B_{yL} = 1.4056$  (Tm)

# まとめ

- Opera 3D を用いて3次元磁場計算を行った
- 鉄心: SUYB, SS41 に分割
- ByL は目標とした 1.38 (Tm) を超えることを確認
- By のz方向に積分した値のx方向分布を求めた
- $x > 30$  mm で ByL が1% ずれる
- 今回の3次元磁場計算では、シムの形状が最適化されていない
  - シムを最適化する。メッシュの切り方の影響を考慮する