Valutazione dell'esposizione umana a campi magnetici in bassa frequenza: casi studio

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Introduction

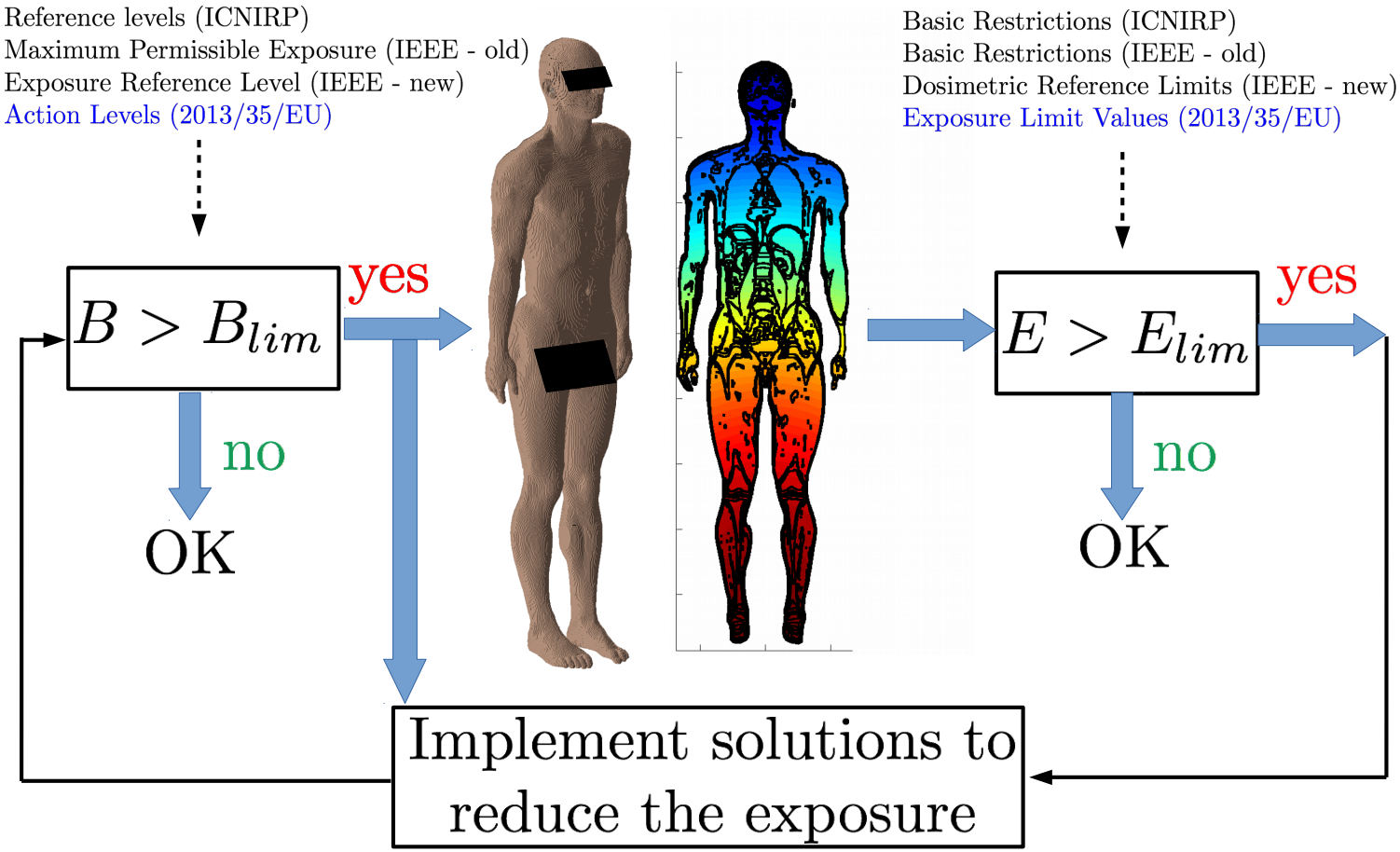
- This talk focuses on industrial field sources.
- Three case studies will be presented:
  - **Case 1**: Magnetic particle inspection.
  - **Case 2**: Industrial demagnetizing system.
  - **Case 3**: Arc welding.
  - **Case 4**: Resistance Spot Welding.

- The case studies can be classified considering the following aspects:

Case study	Exposure	Field shape	Magnetic field
Case 1	occupational	complex waveform	necessary
Case 2	occupational	isofrequential	necessary
Case 3	occupational	complex waveform	unnecessary
Case 4	occupational	complex waveform	unnecessary

Exposure assessment strategy: two-step approach

1. assess the B-field against *action levels*
2. assess the E-field against *exposure limit values*



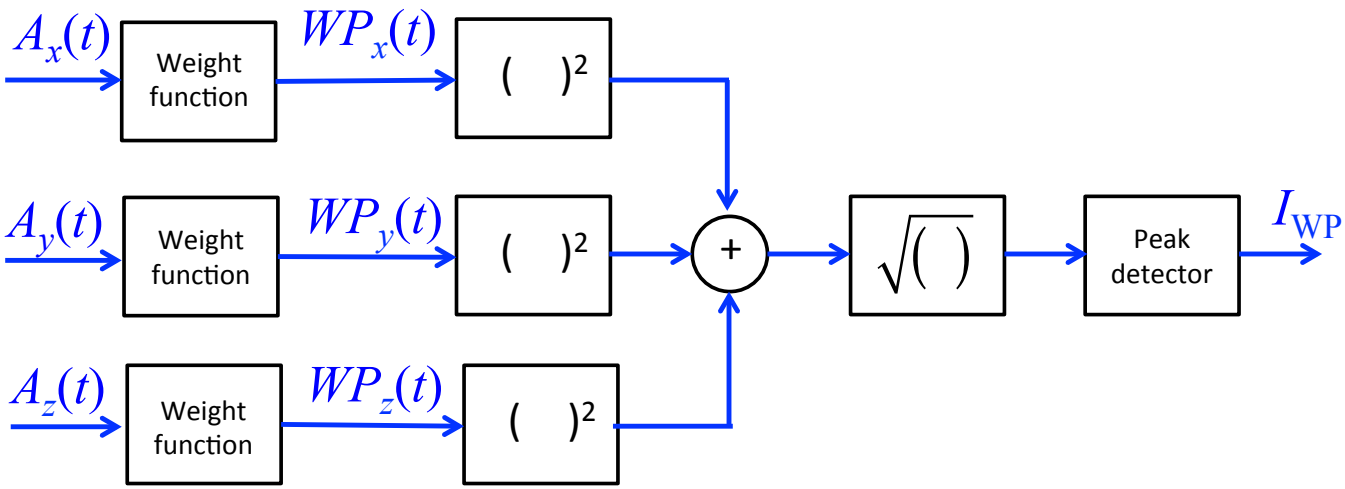
Which methodology?

1. which measuring instrument?
2. which software?
3. are special assessment methods necessary?

Which methodology?

WEIGHTED PEAK METHOD in the time domain:

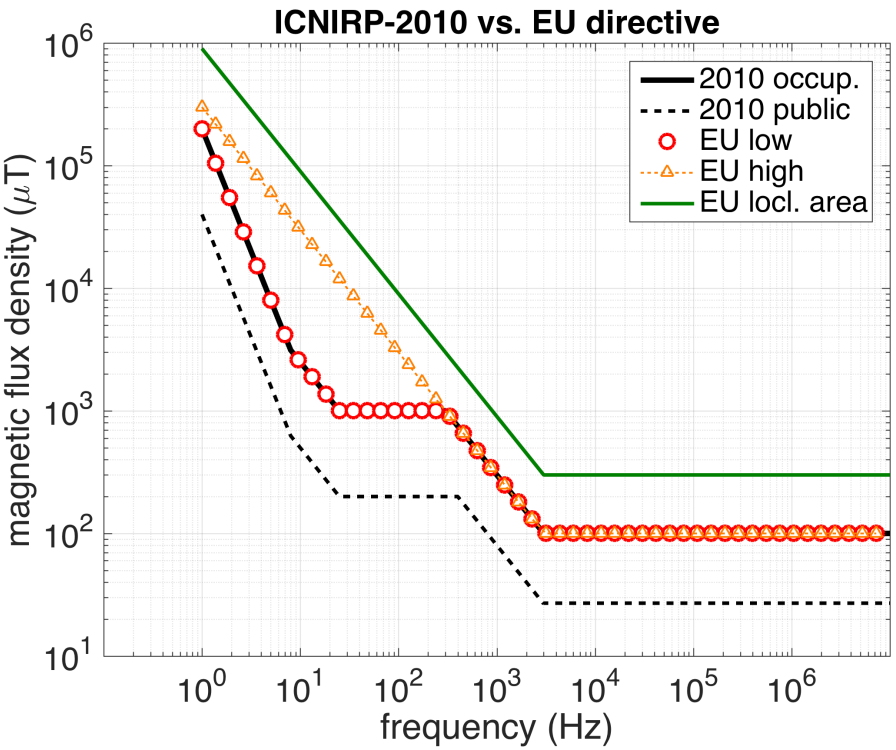
- weighting/filtering in the time domain.
- further processing defines the exposure index.



- **The exposure is compliant if** $I_{\mathrm{WP}} < 1$ $(I_{\mathrm{WP}} < 100\%)$

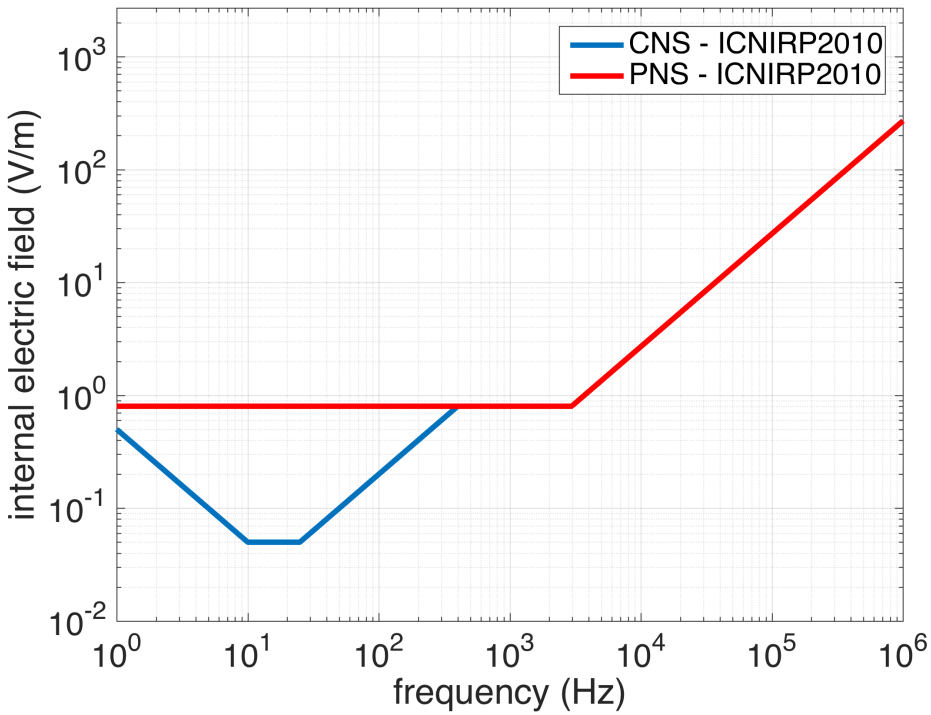
Which limits?

Action Levels



Magnetic flux density
(B-field)

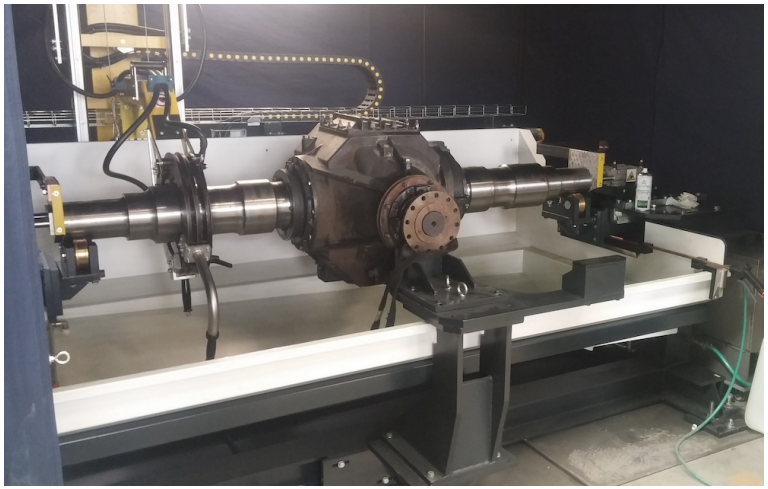
Exposure Limit Values

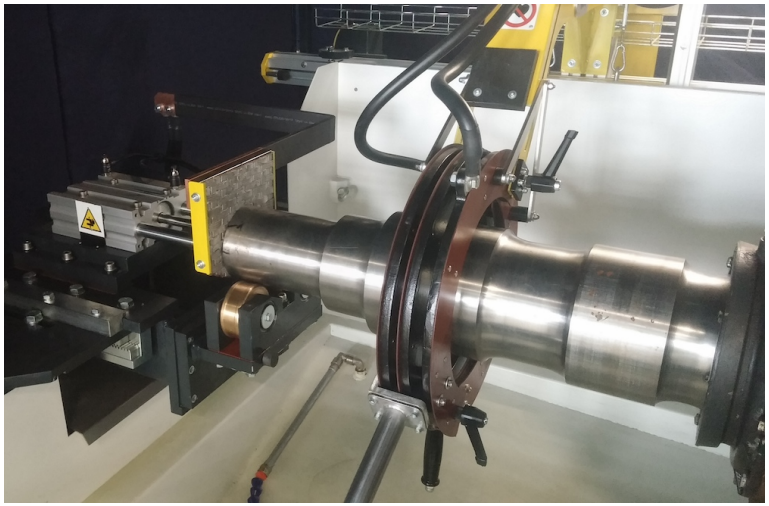


(induced) Electric field
(E-field)

Magnetic particle inspection

- Magnetic particle inspection is an NDT technique largely used to detect superficial or sub-superficial defects of metallic objects.
- This talk analyzes an equipment for the detection of defects in railway axles





Magnetic particle inspection

PAF > CAMPI ELETTROMAGNETICI > BANCA DATI

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Vibrazioni Corpo Intero
Campi Elettromagnetici
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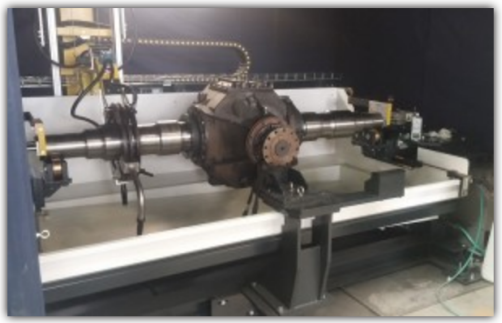
Scheda Macchinario



Marca: DeltaFlux Impianti s.r.l.

Modello: DF G 60 MC AC/DC

Tipologia: Magnetoscopi: banco magnetico

Costruito nel 2015

Potenza: 40 kW

Alimentazione: Elettrica 220V-380V

Norma di riferimento: Non Identificata

Frequenza di lavoro: 0 - 1000 Hz

Tipologia di emissione: Pulsata

Tipologia elemento radiante: Induttivo

Categoria di cui alla norma 12198-1-12009: Non disponibile

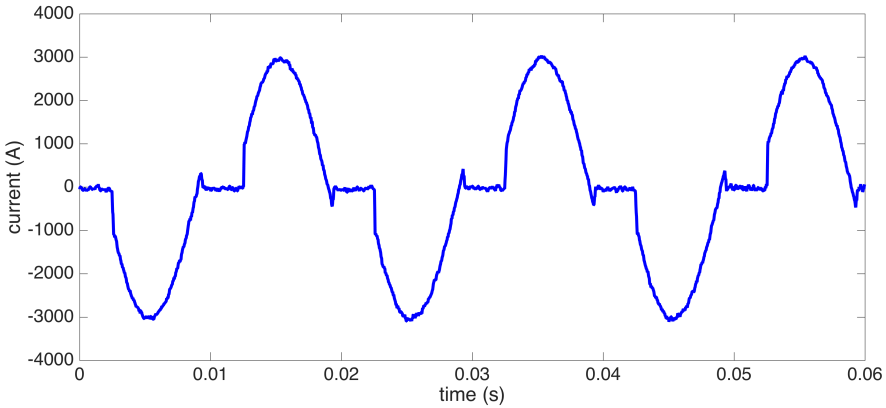
Misure di tutela necessarie:

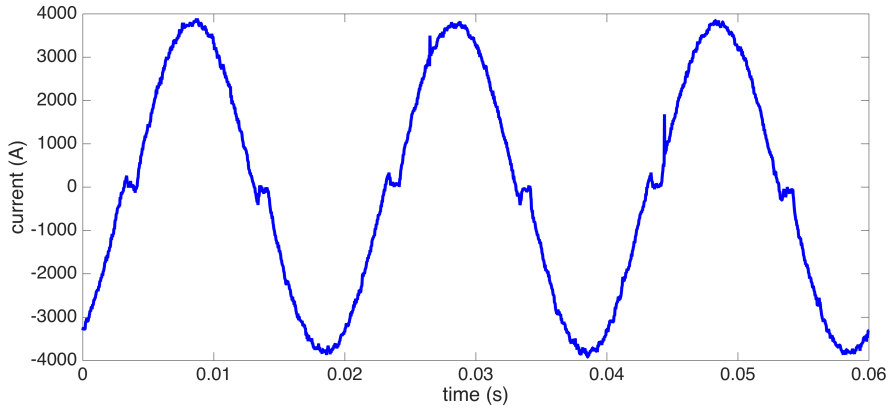
1. Delimitare Zona 1: valori di esposizione superiori ai livelli di riferimento per la popolazione

Misure sul Campo (Clicca per visualizzare le misure in campo)

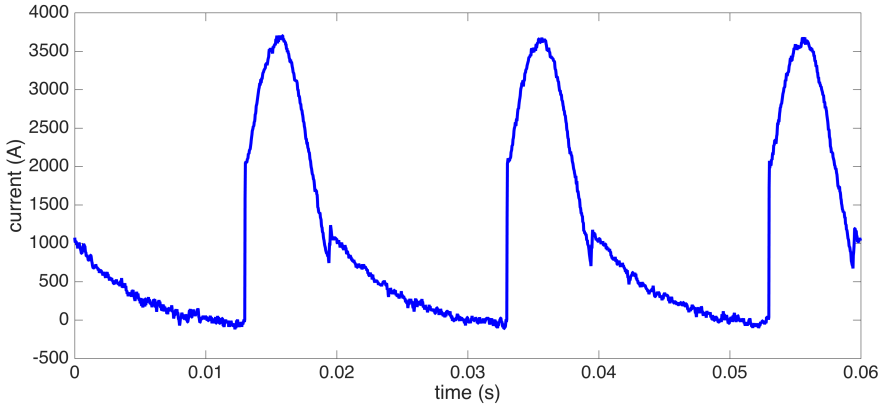
DELTAFLUX IMPIANTI S.R.L. DF G 60 MC AC/DC COMPARTO: TRASPORTI SU ROTAIA (INCLUSE TELEFERICHE)	POTENZA 40000 W FREQUENZA DI LAVORO 50 KHZ
DELTAFLUX IMPIANTI S.R.L. DF G 60 MC AC/DC COMPARTO: TRASPORTI SU ROTAIA (INCLUSE TELEFERICHE)	POTENZA 40000 W FREQUENZA DI LAVORO 50 KHZ

MPI - field waveforms





example of AC current

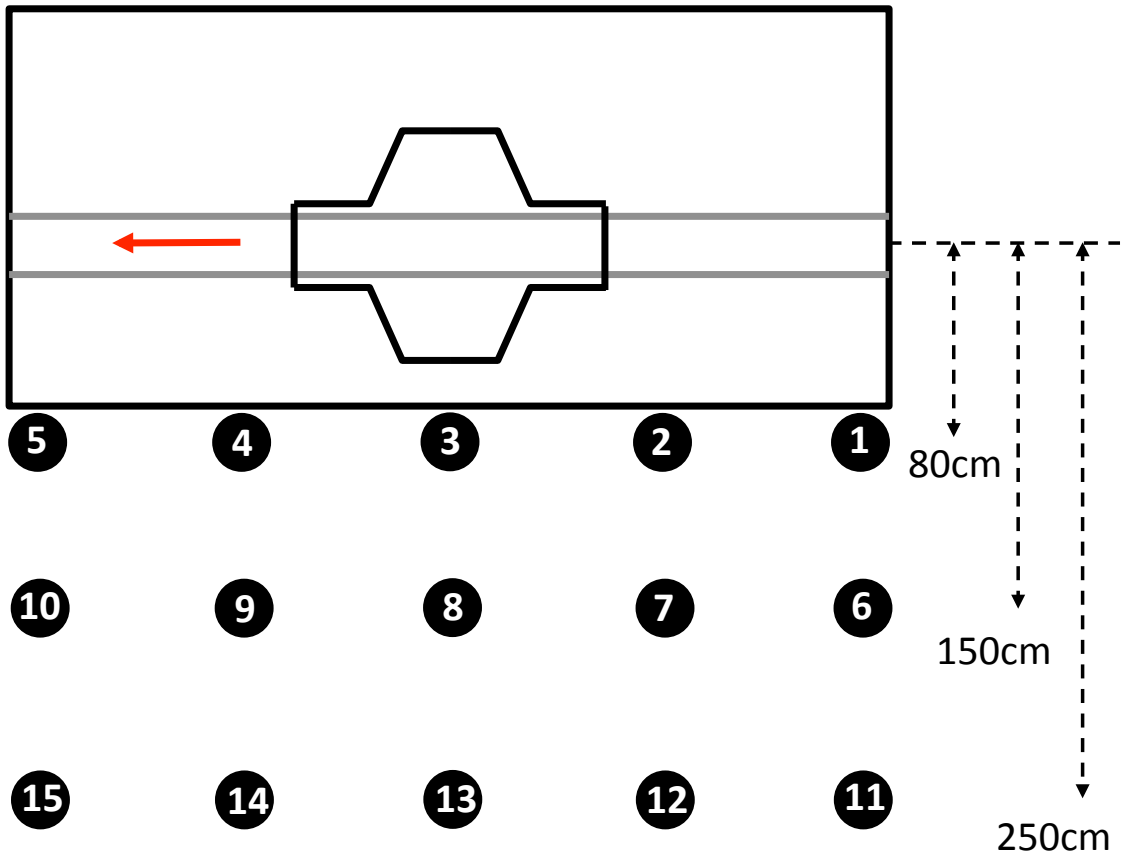


example of DC current

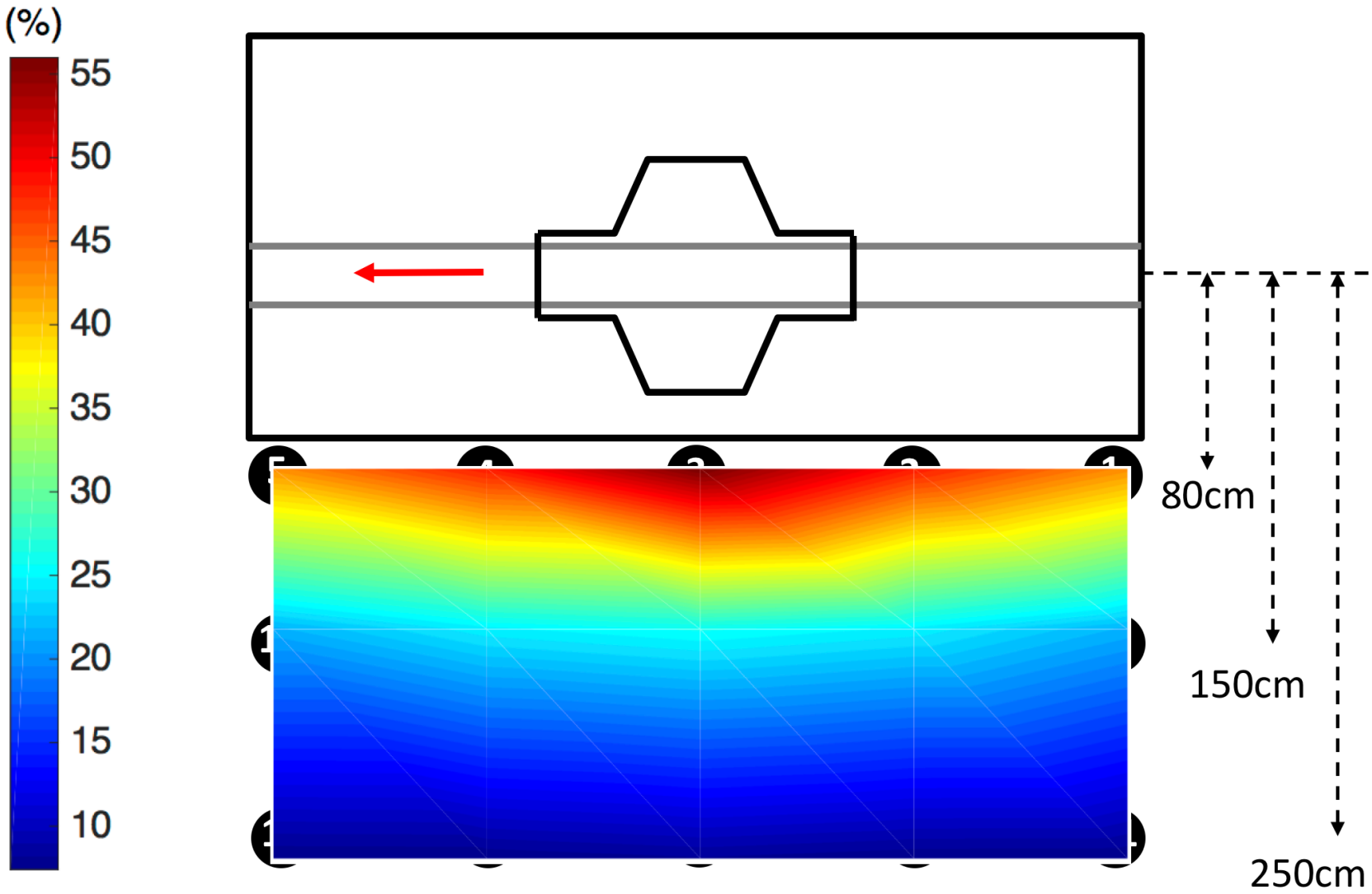
Assessment under axial configuration

AC current

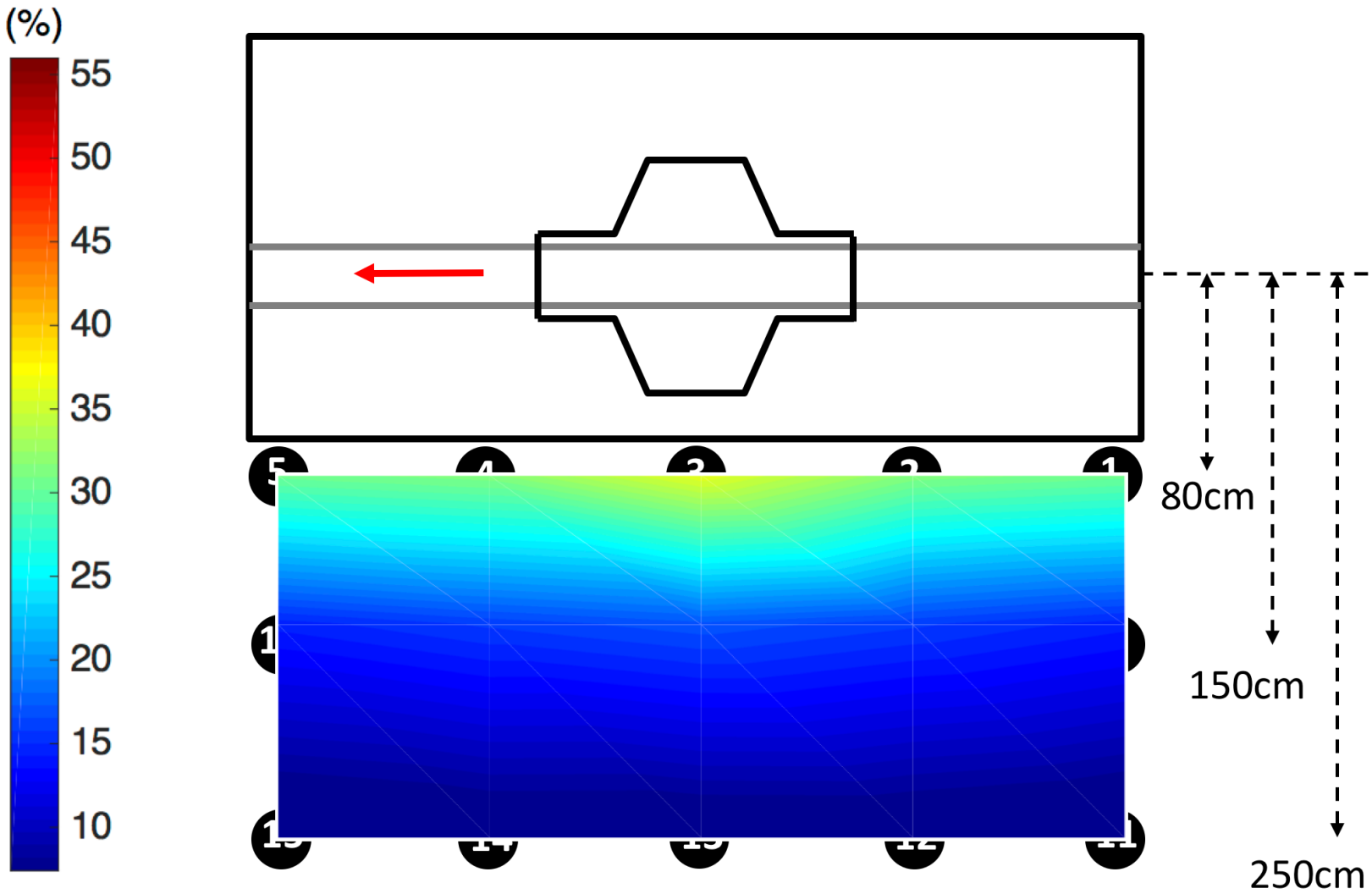
- 5000 A
- 2500 A
- 500 A



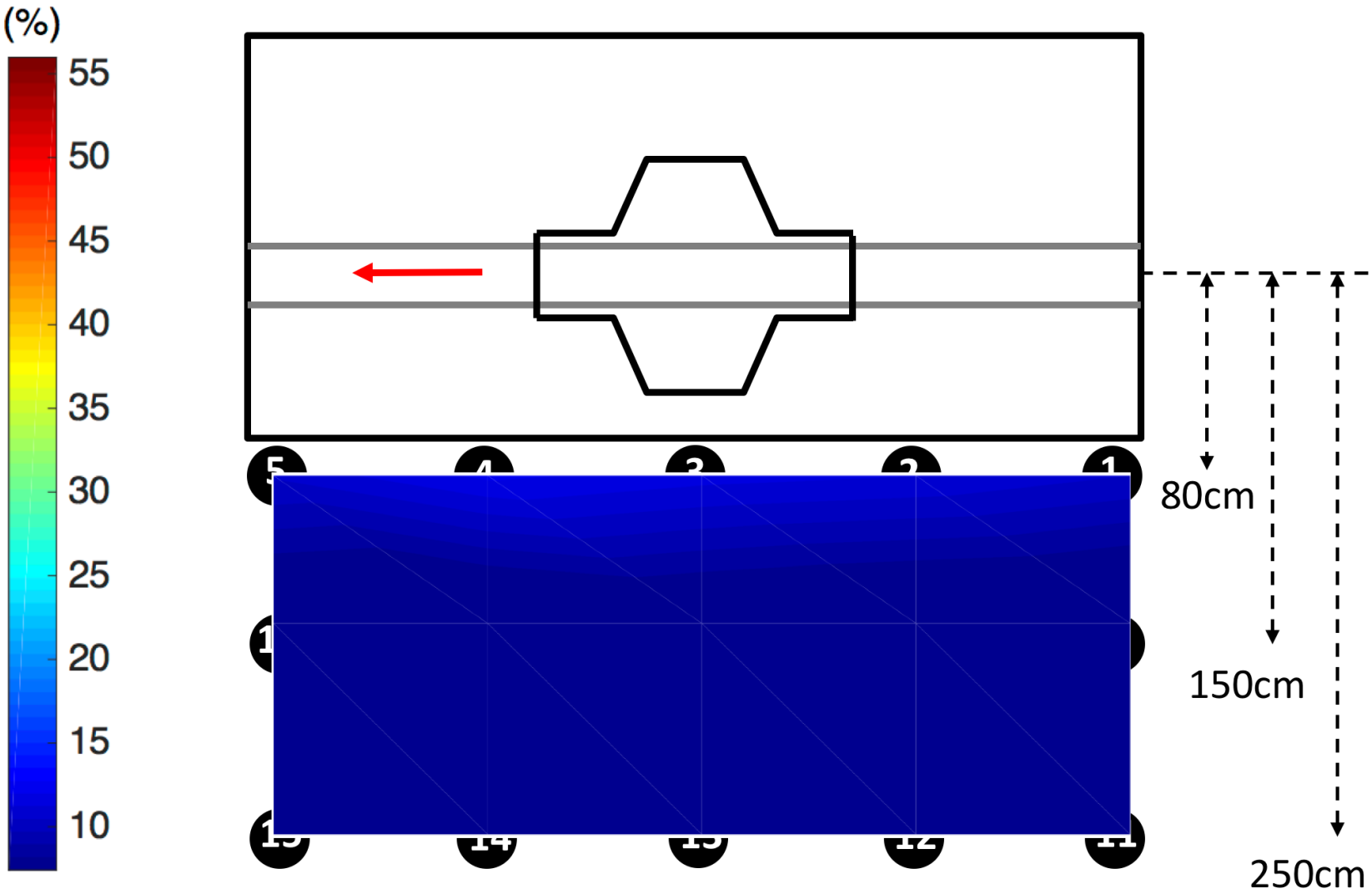
Assessment under axial configuration: 5000 A



Assessment under axial configuration: 2500 A



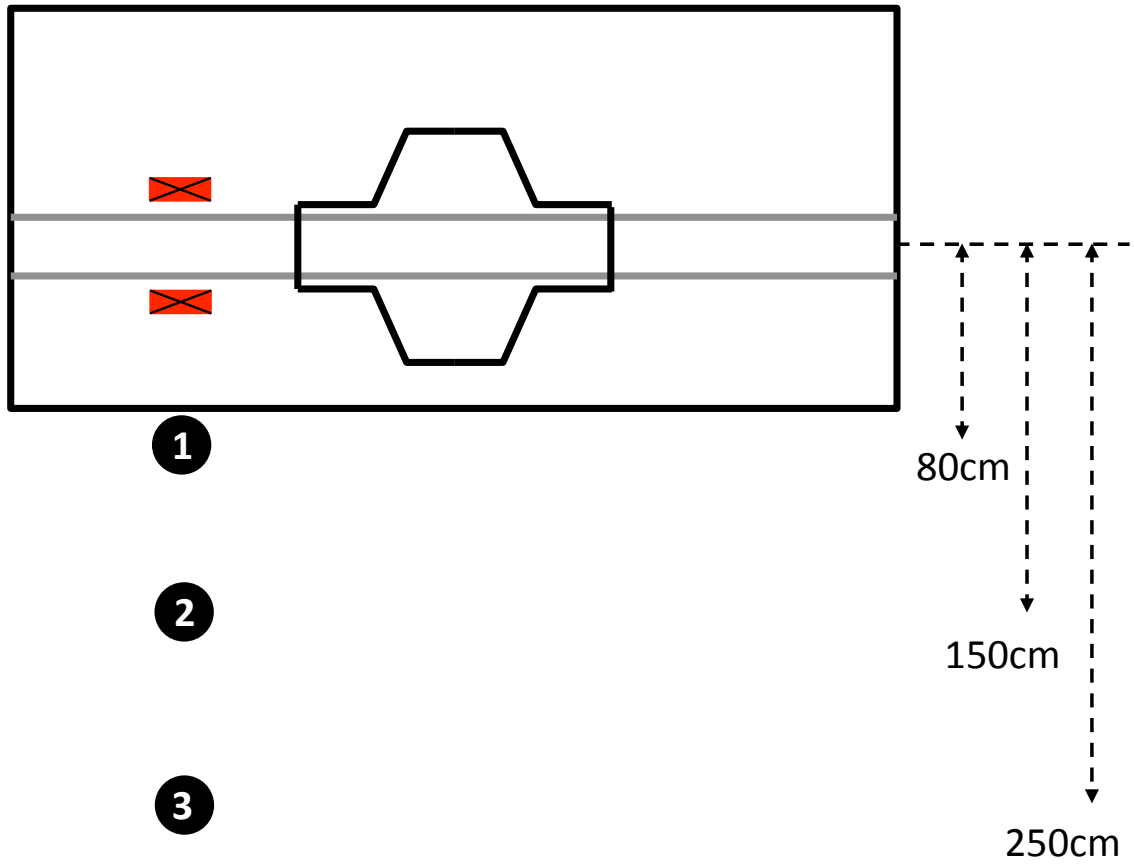
Assessment under axial configuration: 500 A



Assessment under circumferential configuration

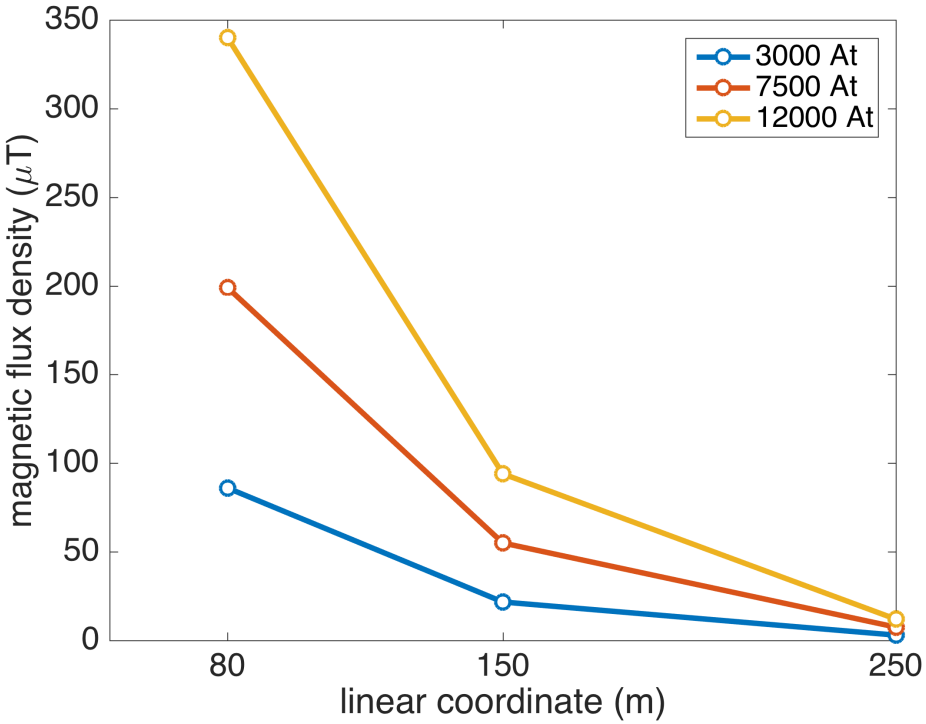
AC current

- 3000 At (1000 A)
- 7500 At (2500 A)
- 12000 At (4000 A)

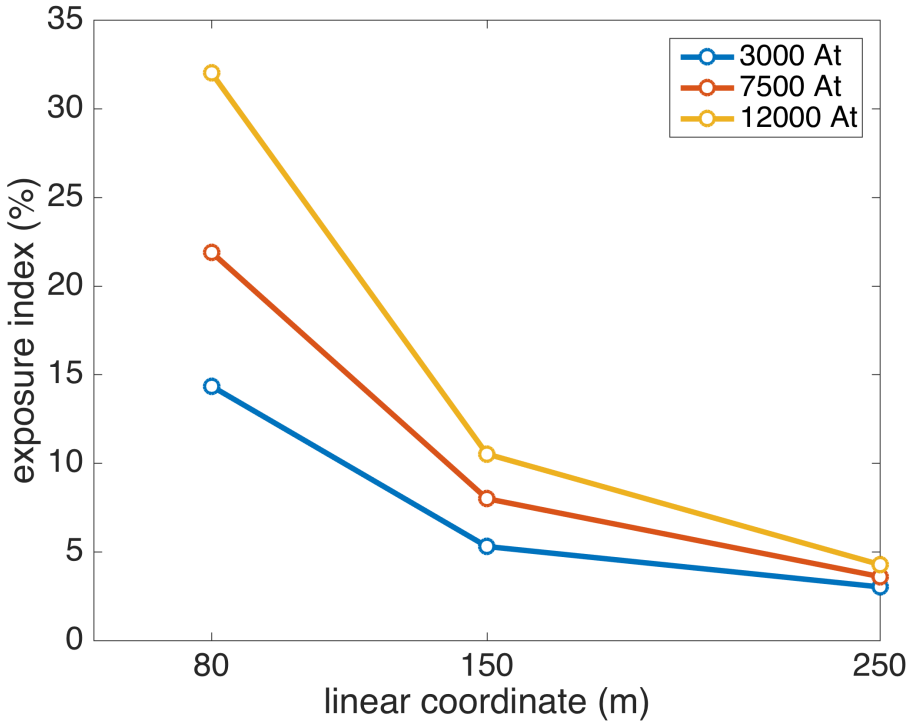


Assessment under circumferential configuration

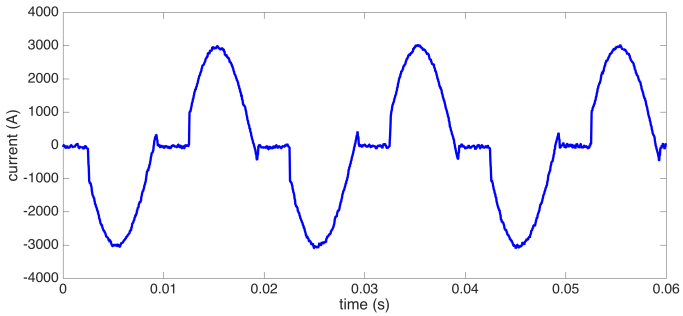
peak of B-field

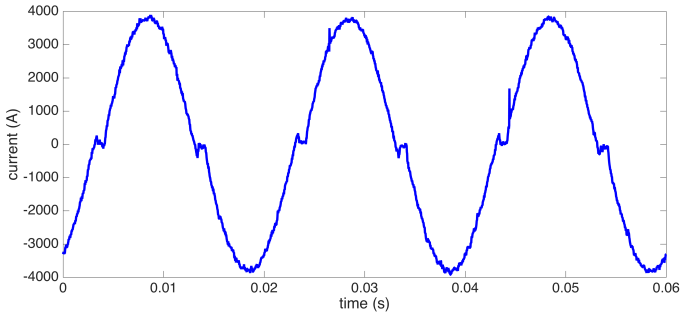


Exposure index

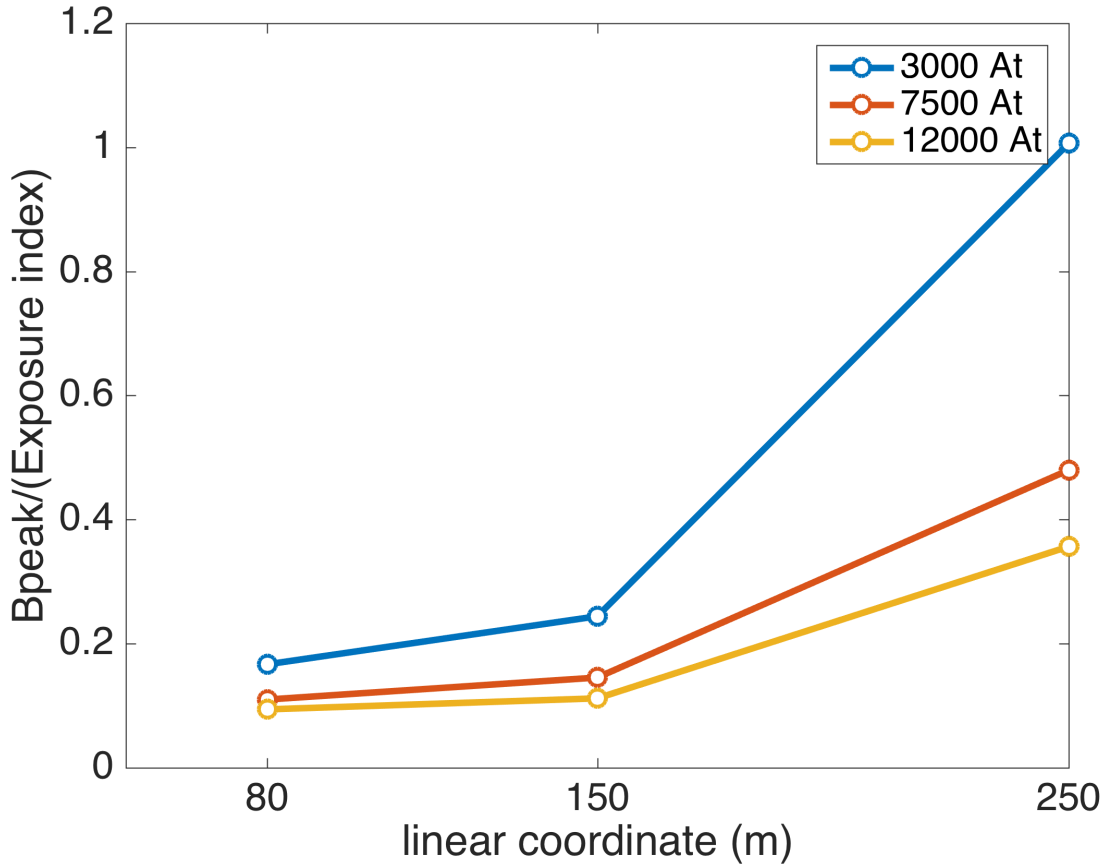


Assessment under circumferential configuration





B-peak over Exposure index



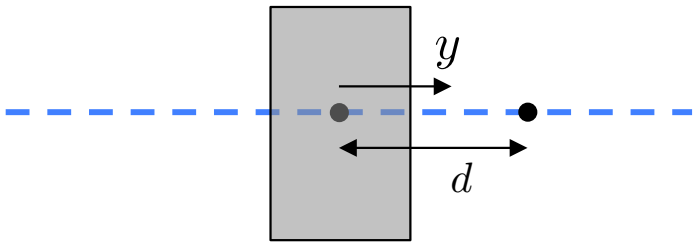
Industrial demagnetizing system: description

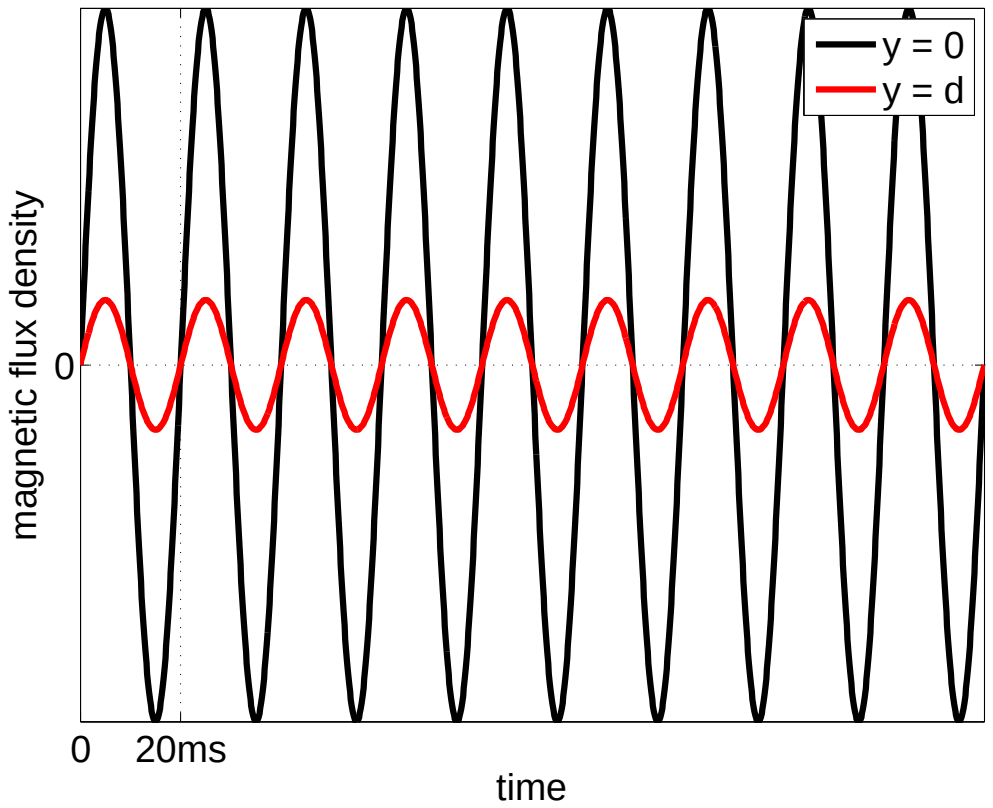
Demagnetizing system

- Ferromagnetic materials are characterized by a nonlinear and hysteretic $B - H$ relationship.
- For some applications the presence of a residual magnetization is a problem.
- The demagnetizing systems make it possible to erase the residual magnetization.

Industrial demagnetizing system: working principle

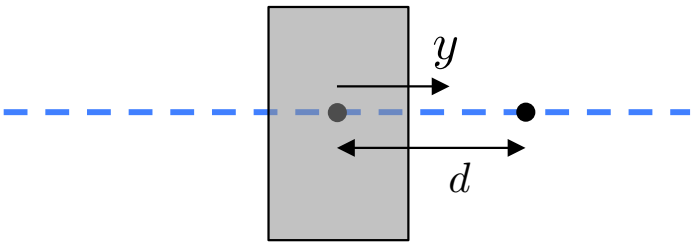
- The magnetic field decreases with the distance.

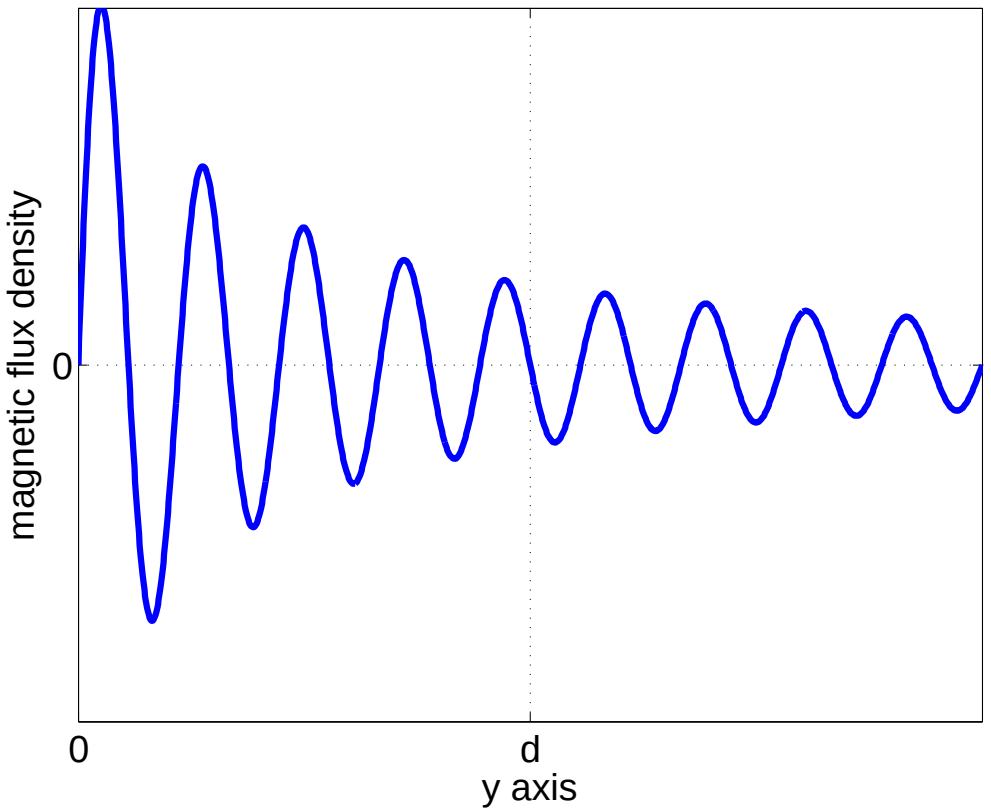




Industrial demagnetizing system: working principle

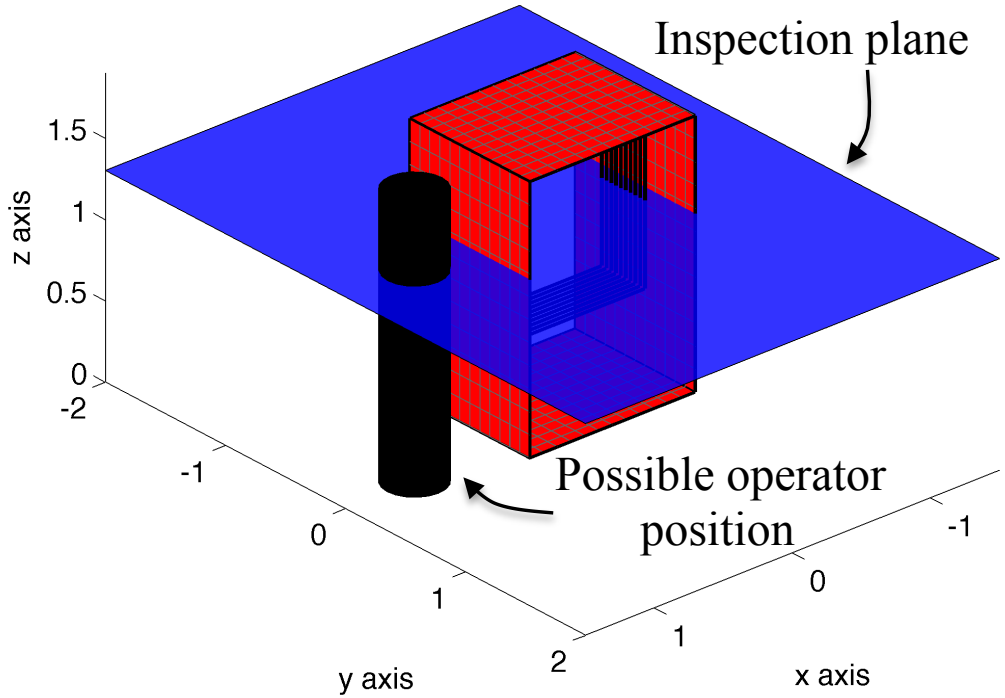
- The magnetic field decreases with the distance.
- During the motion, the body is subject to a decreasing magnetic field that erases the residual magnetization.





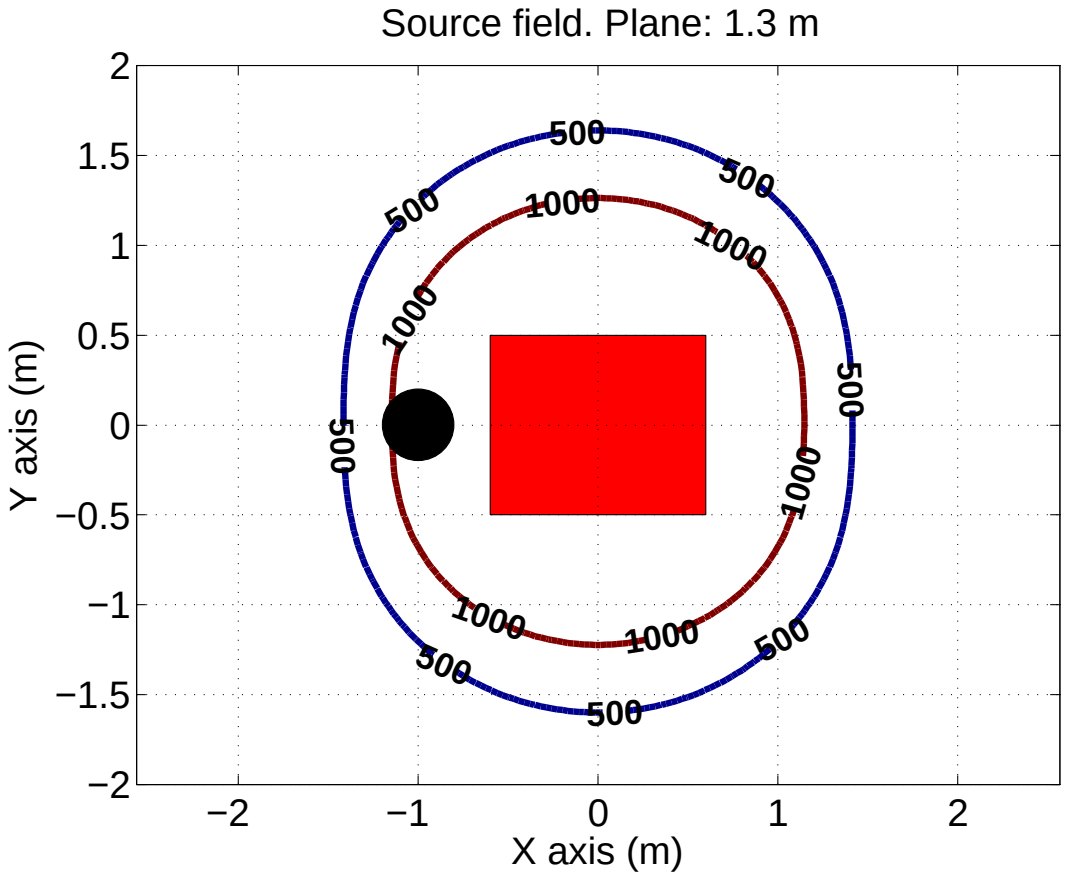
Industrial demagnetizing system: source field

- In the region nearby the demagnetizing system the magnetic field reaches very high levels.
- The operator is sometimes very close to the side of the demagnetizing system.



Industrial demagnetizing system: source field

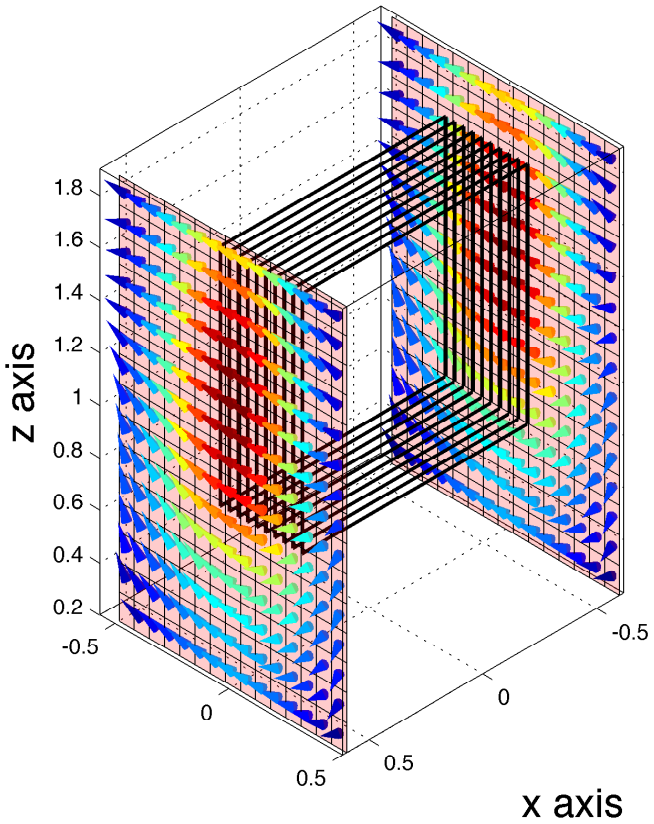
- The old limit is $500\ \mu\mathrm{T}$ (ICNIRP 1998)
- The new limit is $1000\ \mu\mathrm{T}$ (ICNIRP 2010)
- Both limits are exceeded in the area where the operator is likely to be (described by the black circle).



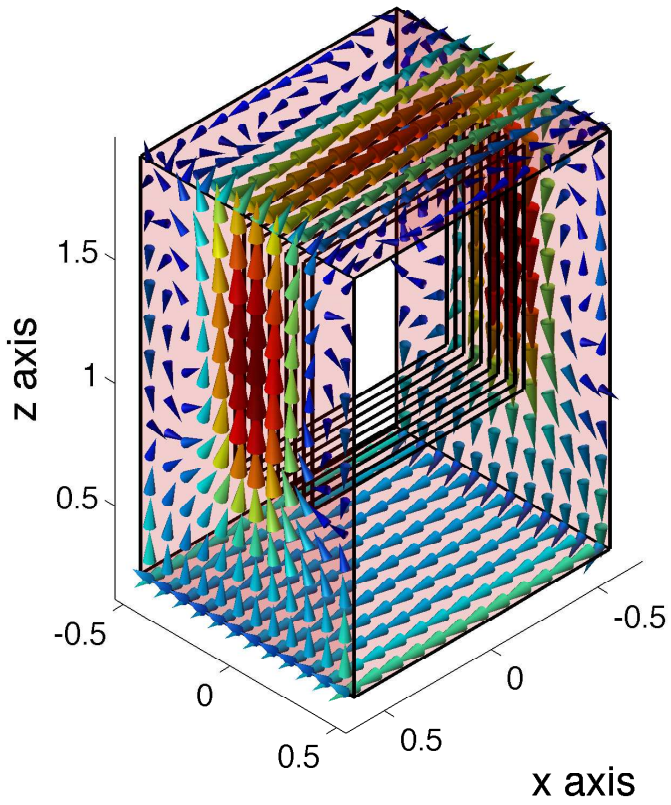
Industrial demagnetizing system: design

Virtual design using in-house simulation codes:

- μ-shield: 4 plates of grain oriented iron (2×0.35 mm-thick)
- σ-shield: aluminum plates (2 mm-thick)



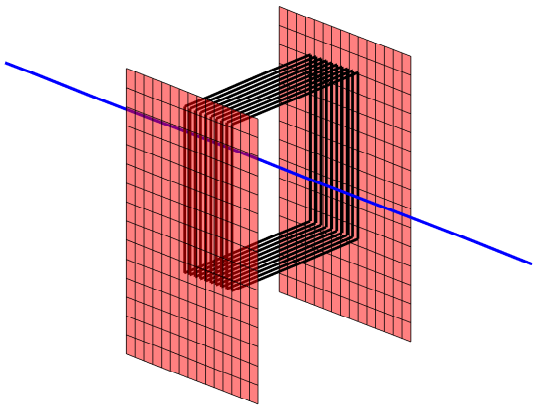
Magnetization $(\mathrm{A/m})$

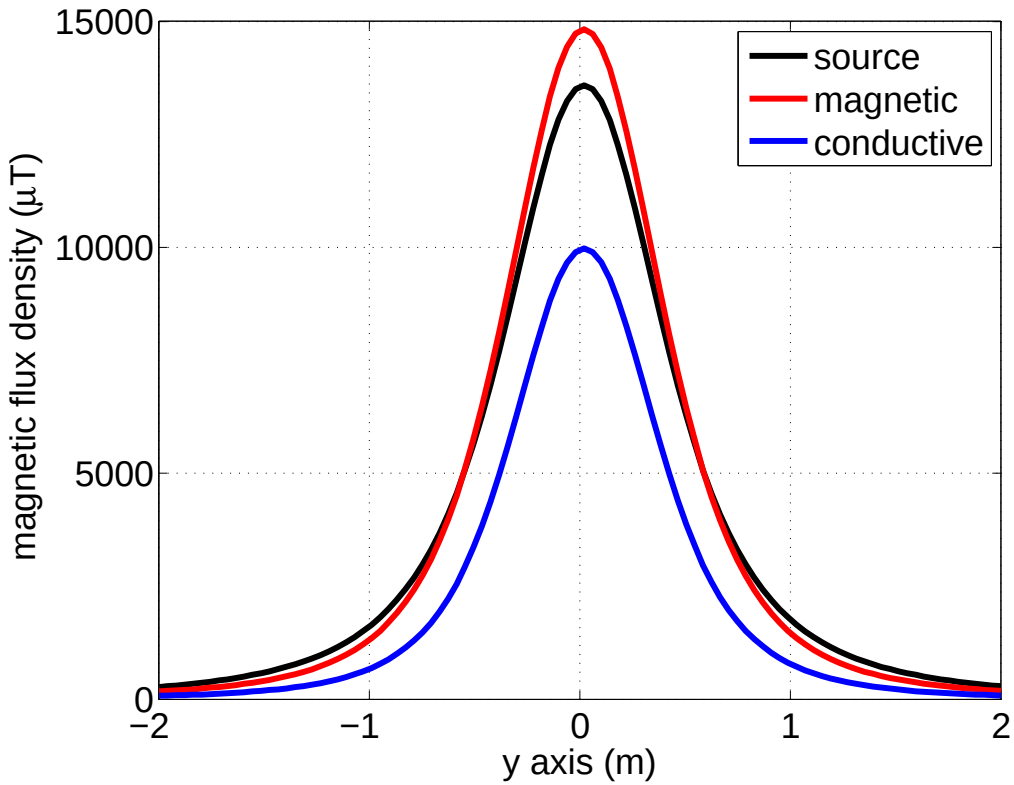


Current density $(\mathrm{A/m^2})$

Industrial demagnetizing system: design

- The shield must not influence the behavior of the device.
- The gradient along y-axis and the maximum field value at the center of the device have to be preserved.

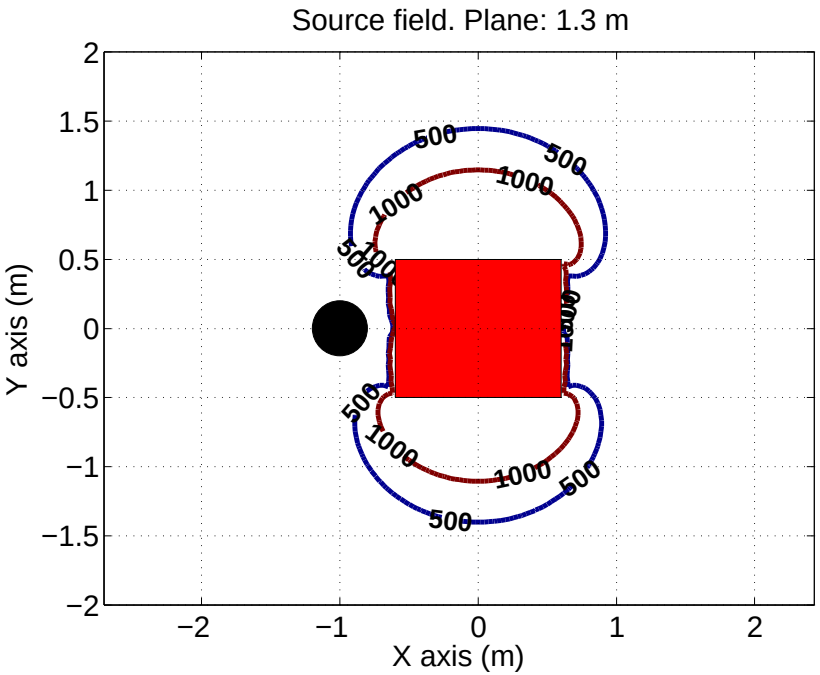




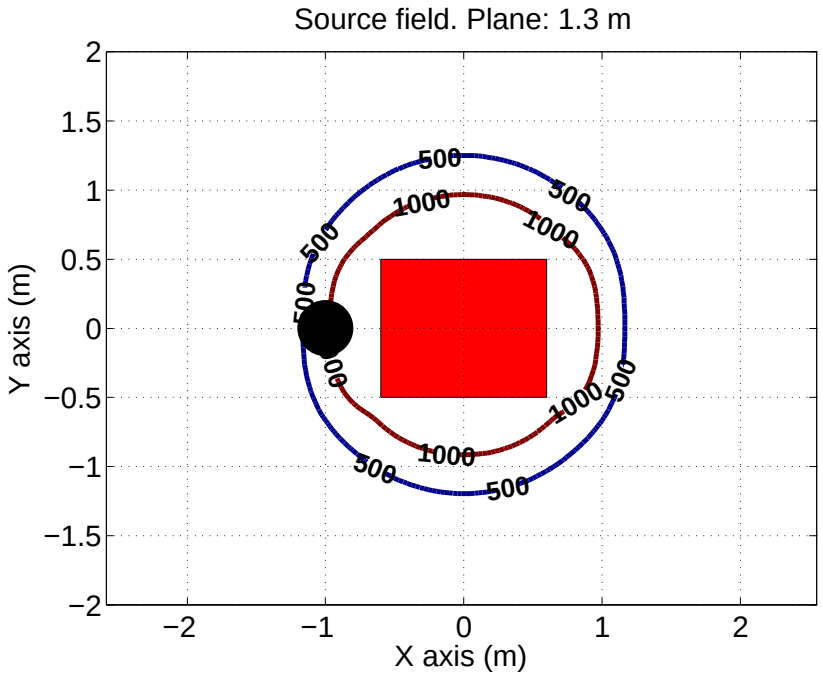
- The μ-shield is more suitable from the technical point of view.

Industrial demagnetizing system: design

- Comparison over the inspection plane:



μ-shield

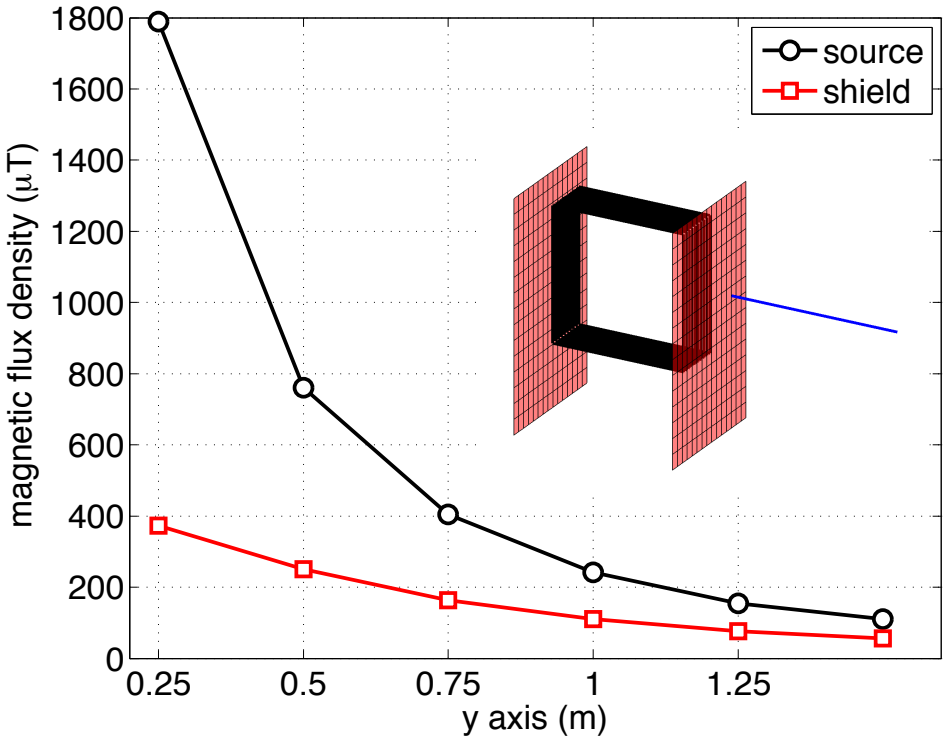


σ-shield

- The σ-shield modifies the magnetic field more internally than externally
- Hence, the final solution is clearly the μ-shield.

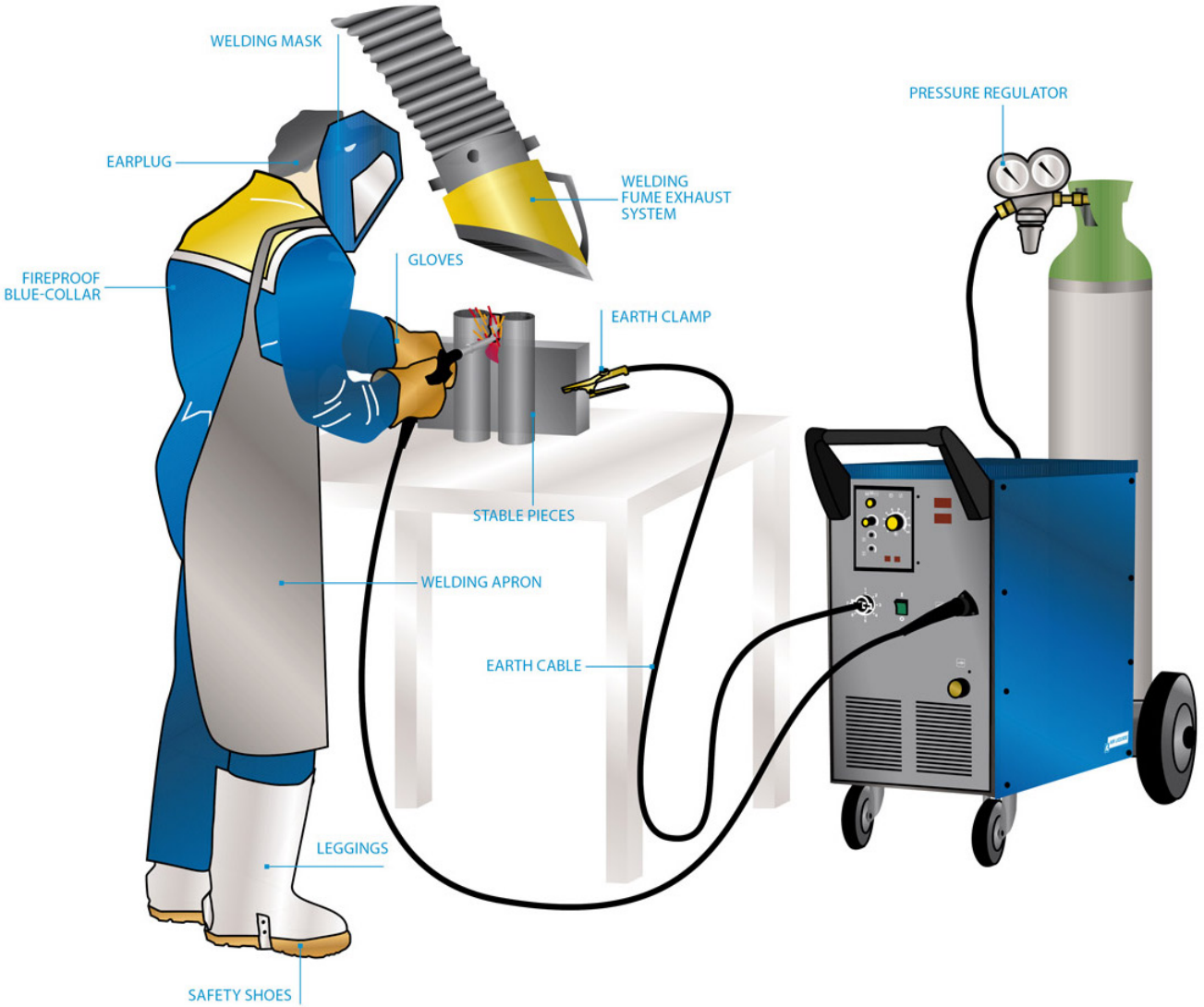
Industrial demagnetizing system: installation and tests

- The μ-shield were installed and tested.
- The experimental results confirmed the efficiency of the μ-shield for this application.



Measurement along the inspection line

Arc Welding


WELDING MASK
EARPLUG
WELDING FUME EXHAUST SYSTEM
PRESSURE REGULATOR
FIREPROOF BLUE-COLLAR
GLOVES
EARTH CLAMP
STABLE PIECES
WELDING APRON
EARTH CABLE
LEGGINGS
SAFETY SHOES

Arc Welding: the position ⇒ CEI EN 50444

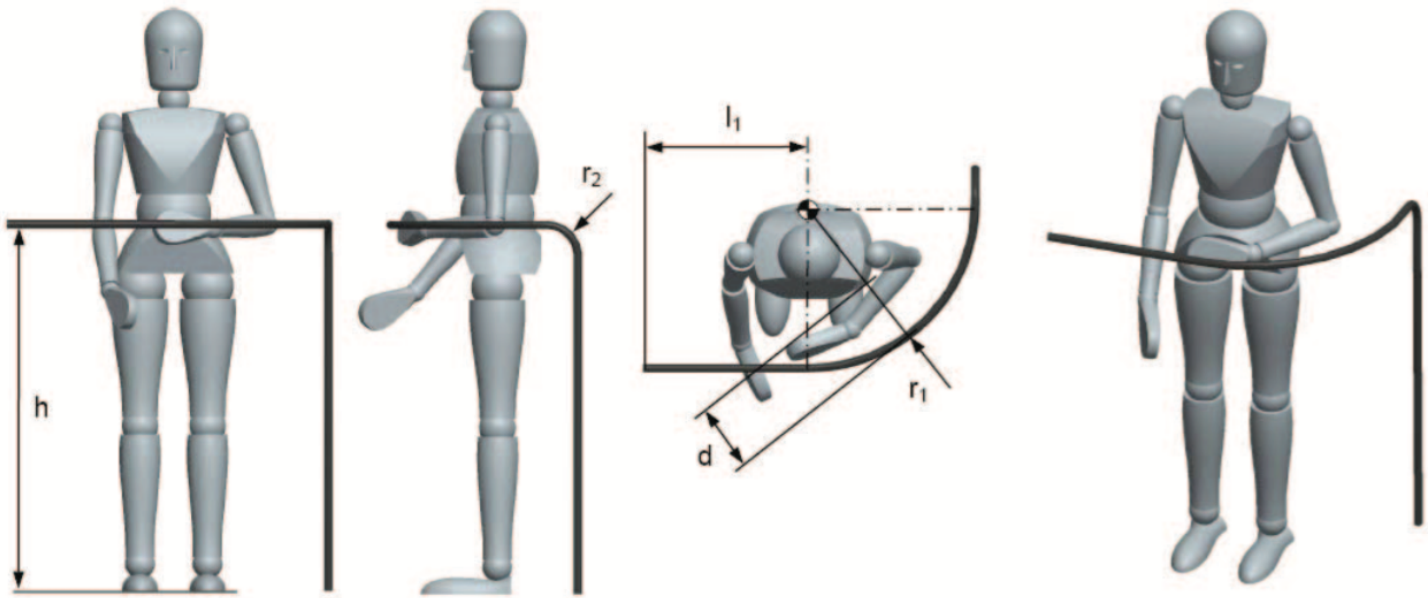
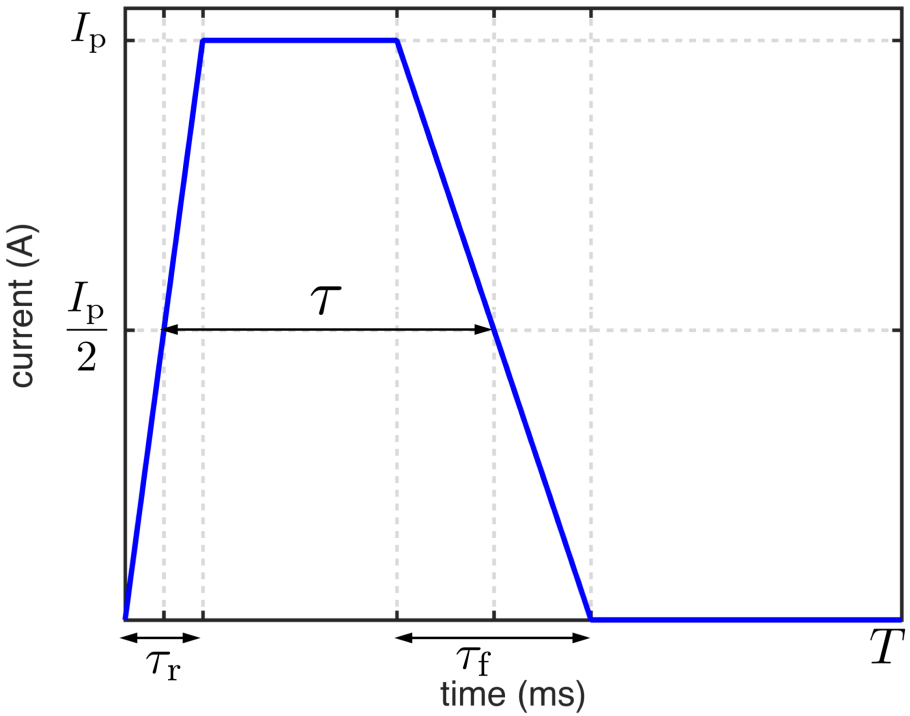


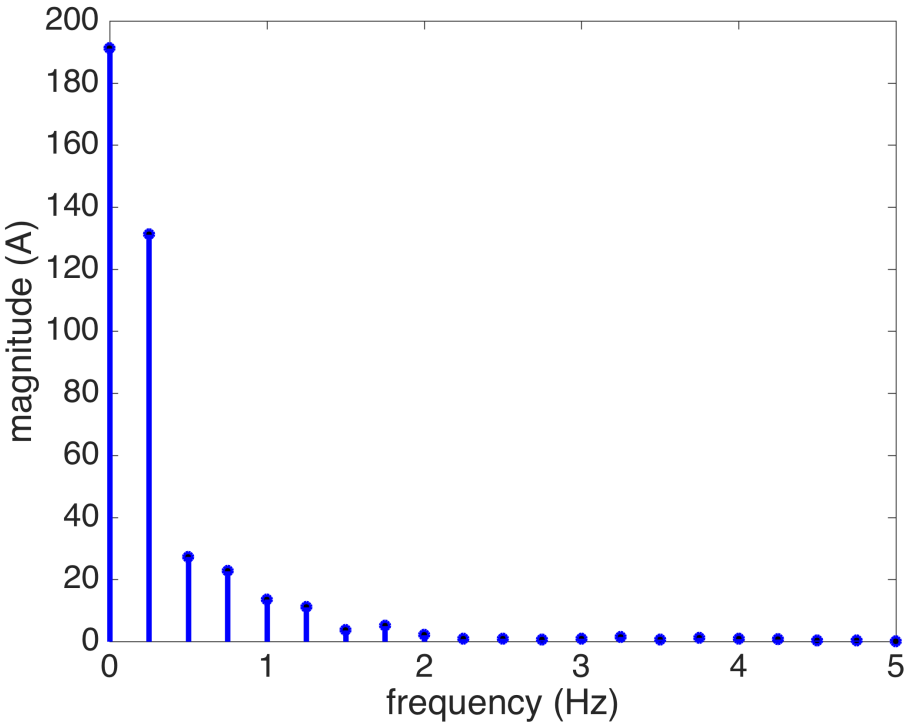
Figure A.2 – Topology of welding cable for numerical simulations

Arc Welding: the current

welding current



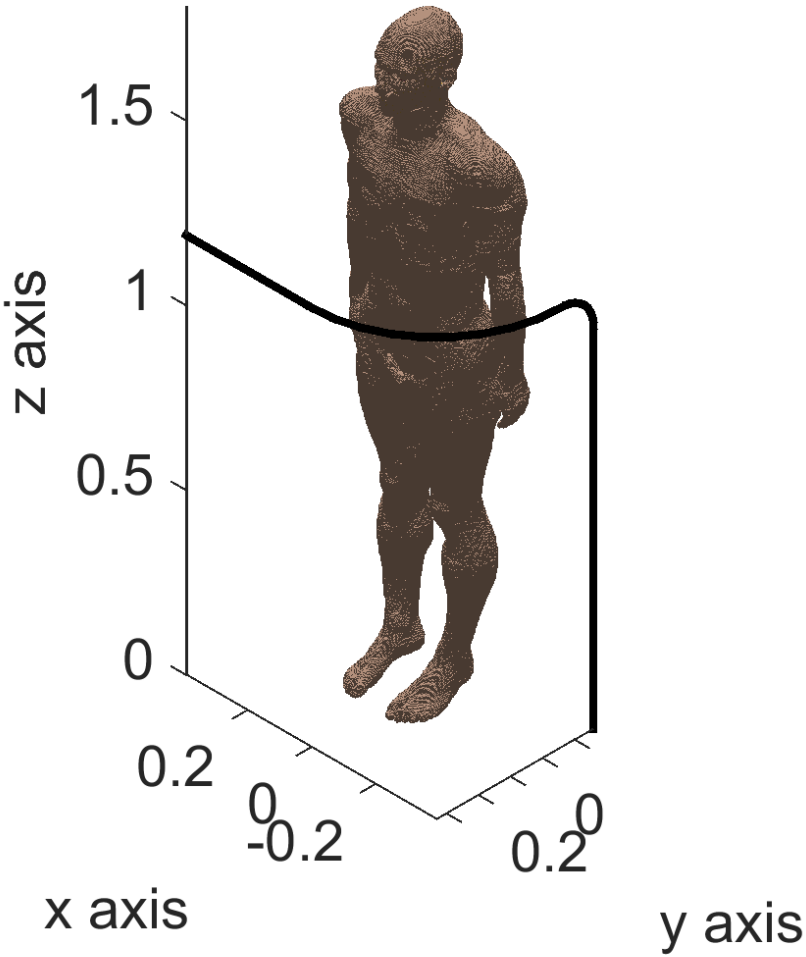
spectrum



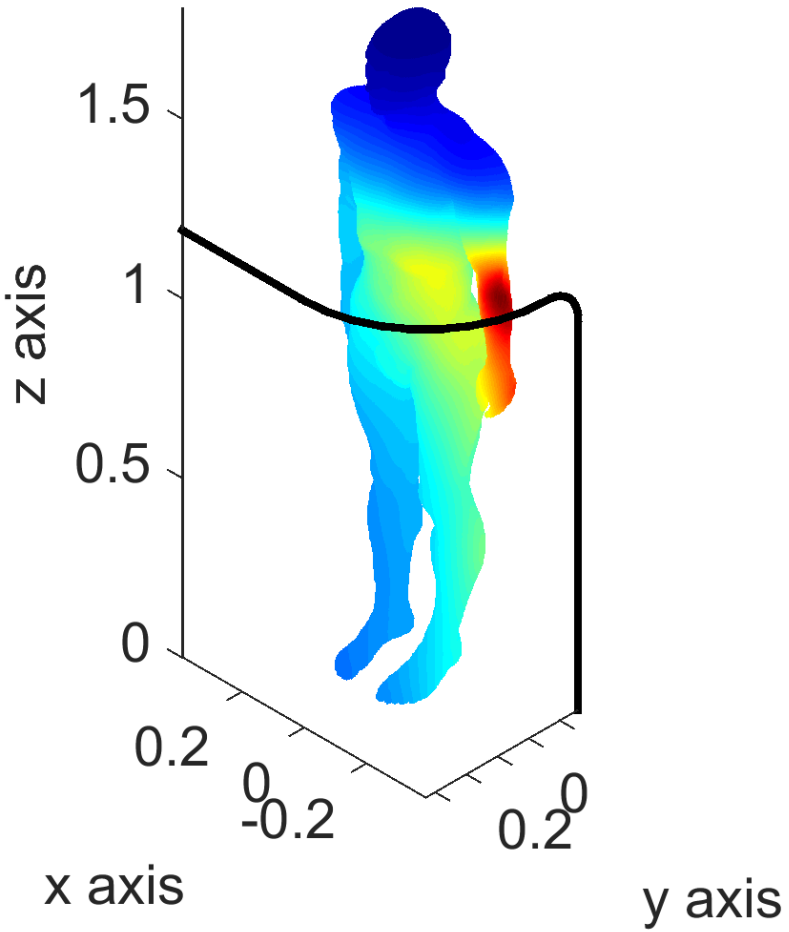
- rise-time (τ_r) 0.4 ms
- pulsewidth (τ) 1.7 ms
- fall-time (τ_f) 1 ms and period (T) 4 ms.
- current peak (I_p) 450 A.

Human model and B-field distribution

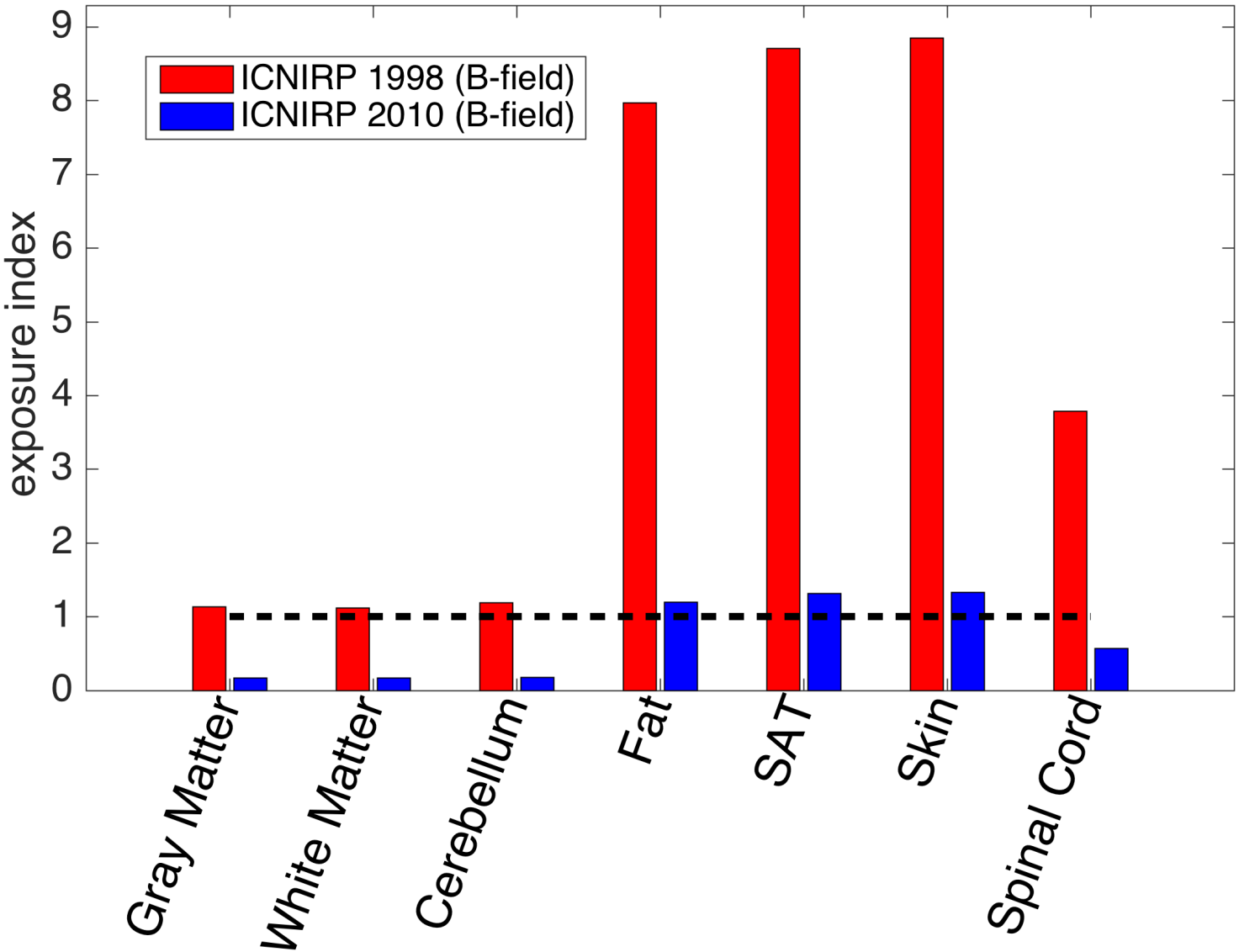
Human model



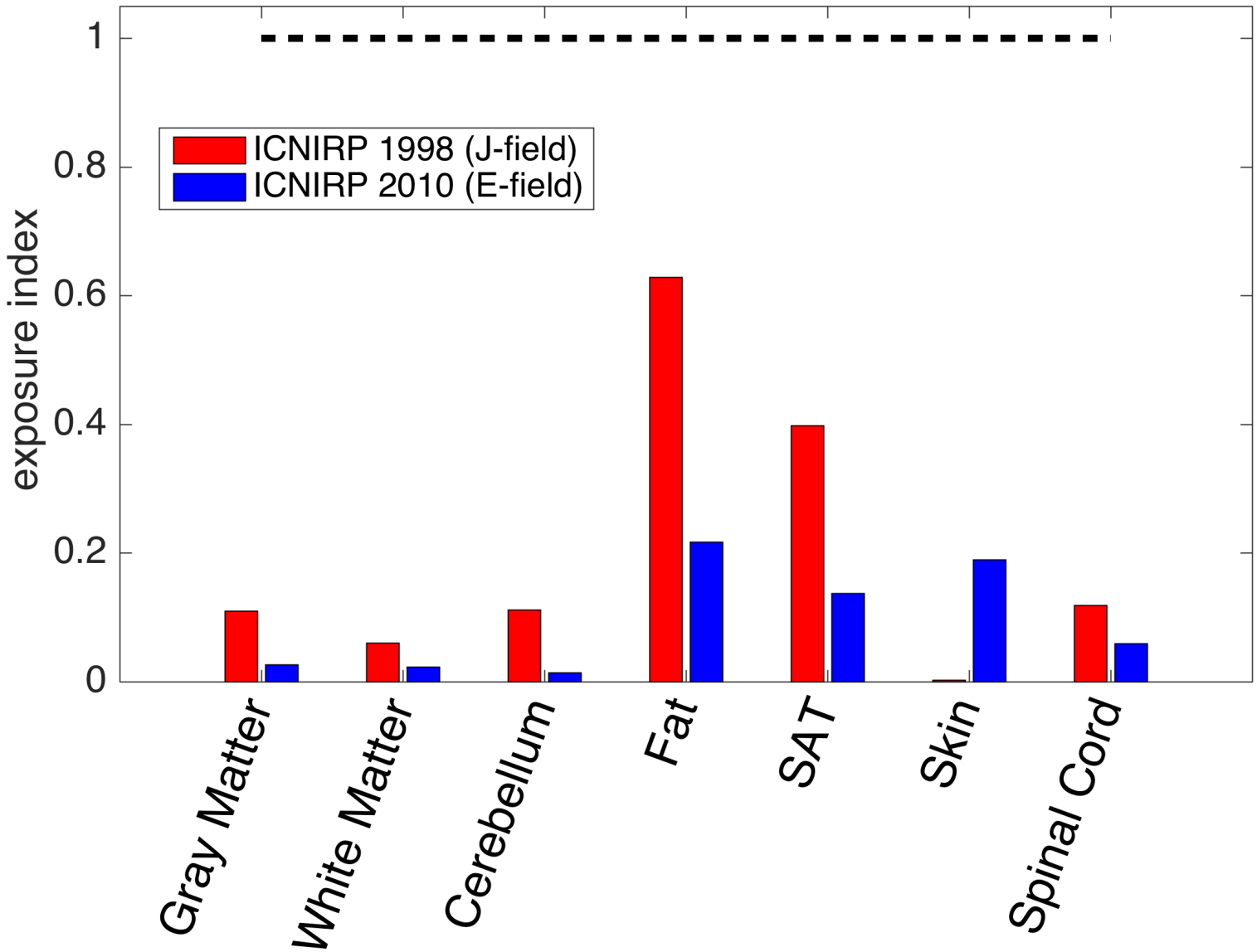
Map of B-field



Arc Welding: asses the B-field



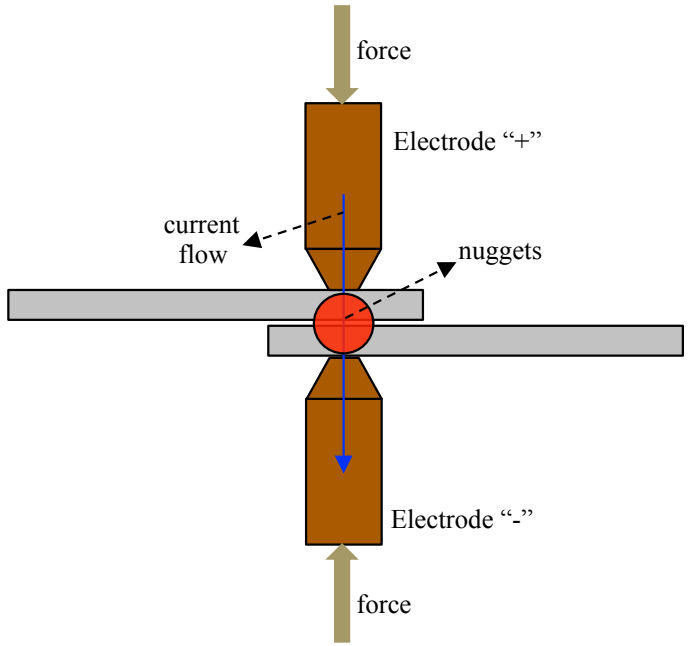
Arc Welding: asses the exposure quantities



Resistance Spot Welding: general description

- The welding process can be performed by several technologies
- In some industrial sectors the welding process is almost completely based on Resistance Spot Welding (RSW) devices.

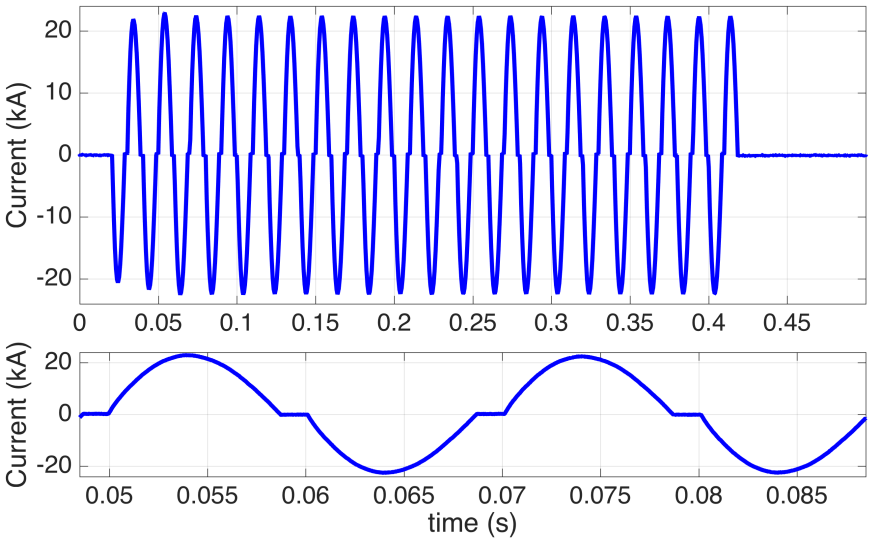
- A RSW gun is made of two electrodes that during the welding process carry a high amount of current (≈ 10 kA).
- Exploiting the Joule effect, the parts to be welded together are heated until the melting temperature.
- When the electrodes are released, the two parts are naturally cool down obtaining the junction of them in the welding point (namely, the nuggets).



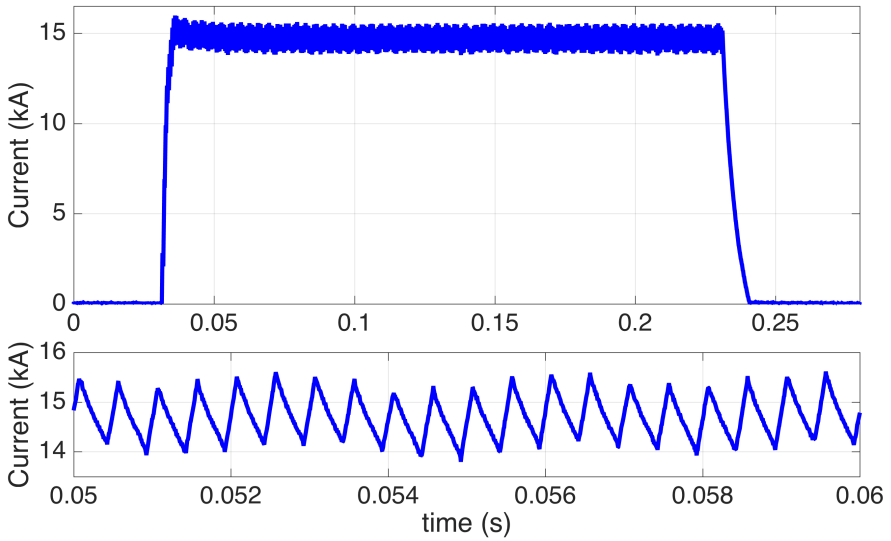
Resistance Spot Welding: pulsed waveforms

- Pulse shape depends on the welding technology

AC gun



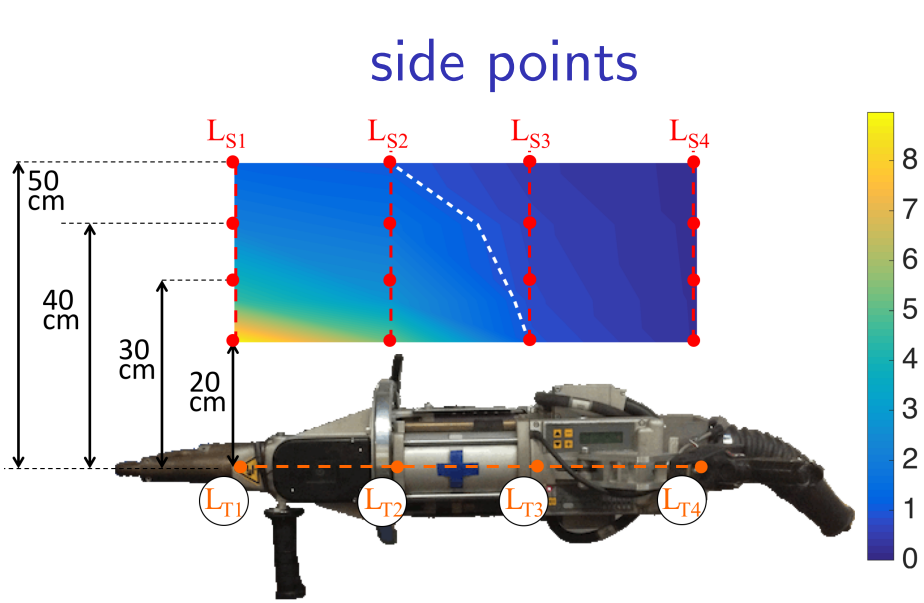
MFDC gun

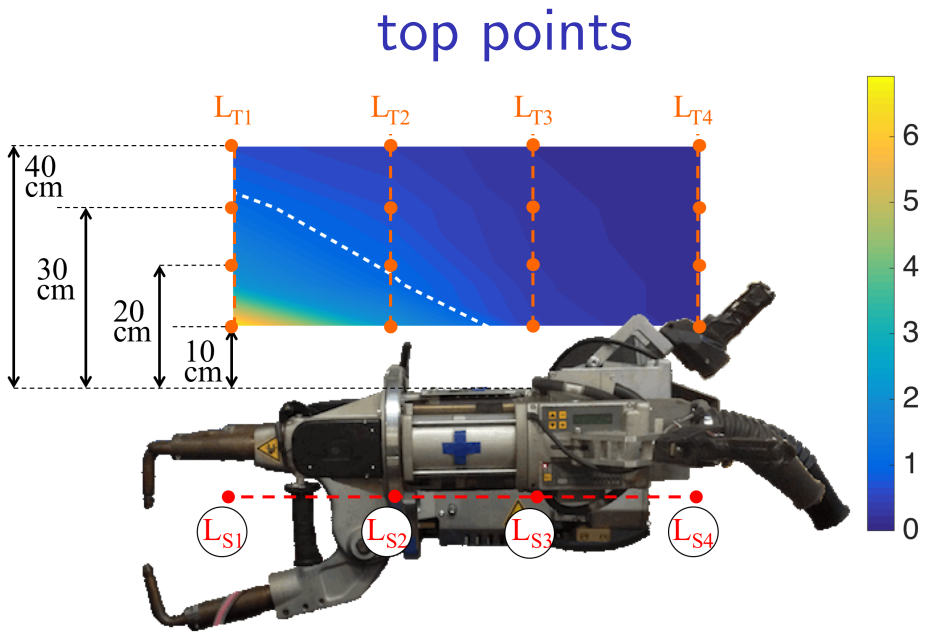


- $B \propto I \Rightarrow B$-field has the same shape of the current.
- The process is clearly pulsed.

AC gun: assessment of the B-field

- Grid point at which the exposure index is measured,
- definition computation of the safety area





MFDC gun: assessment of the B-field

- Grid point at which the exposure index is measured,
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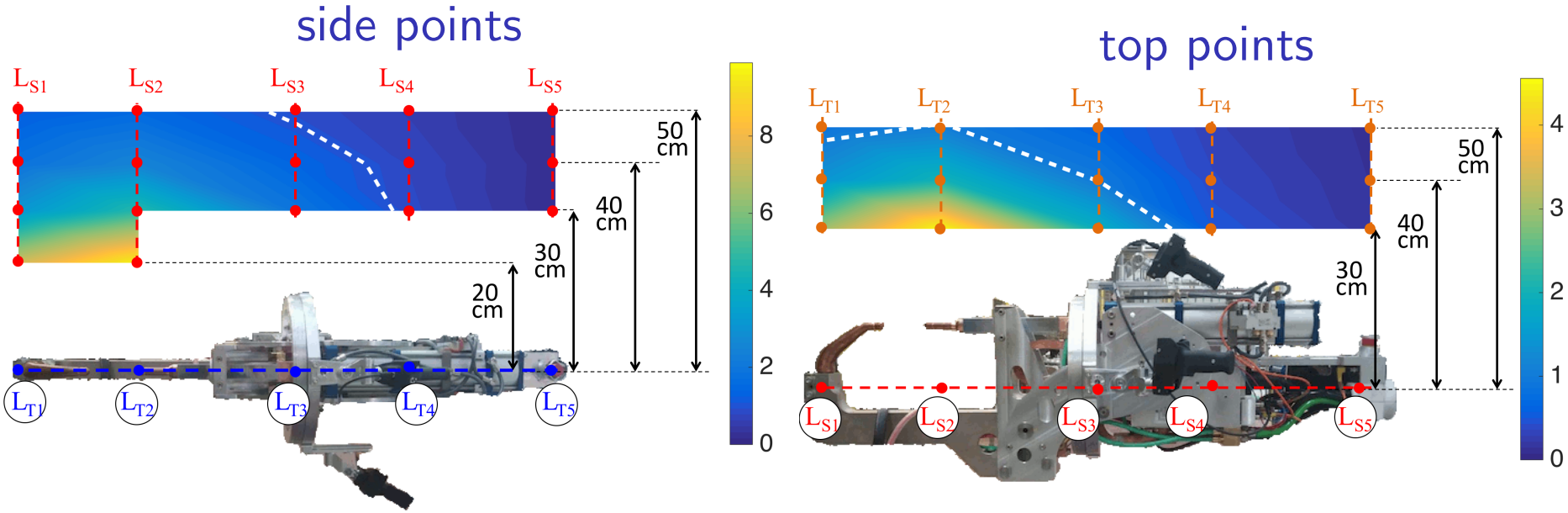
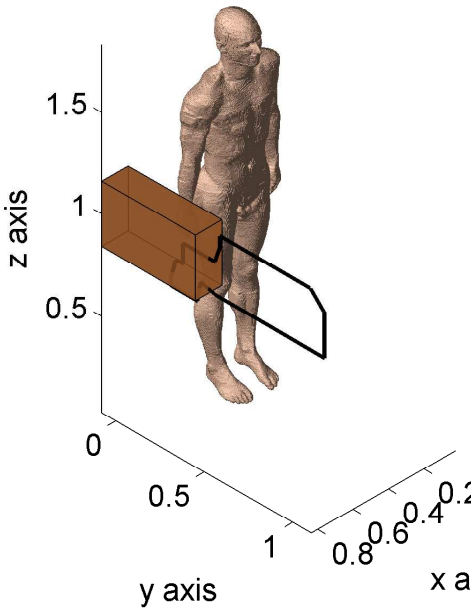
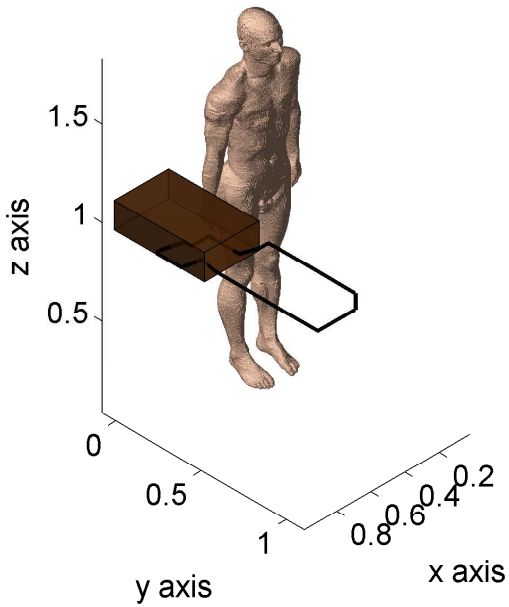


Dosimetric assessment

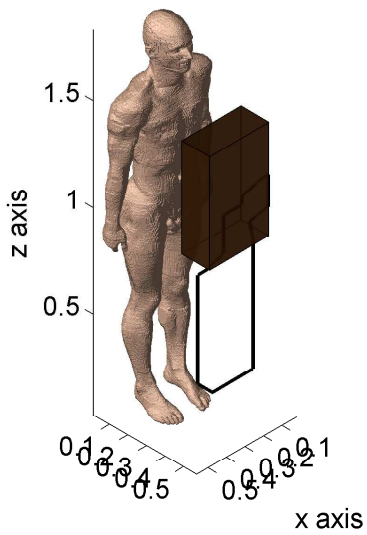
Side 1



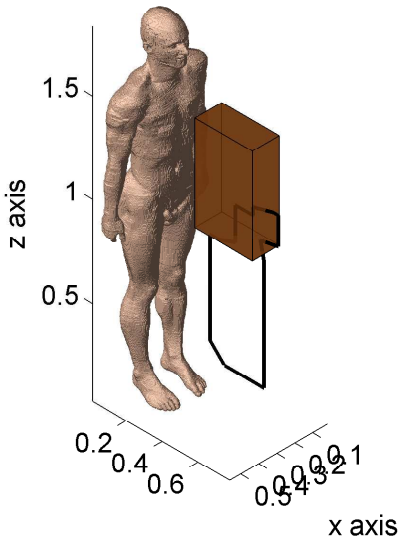
Side 2



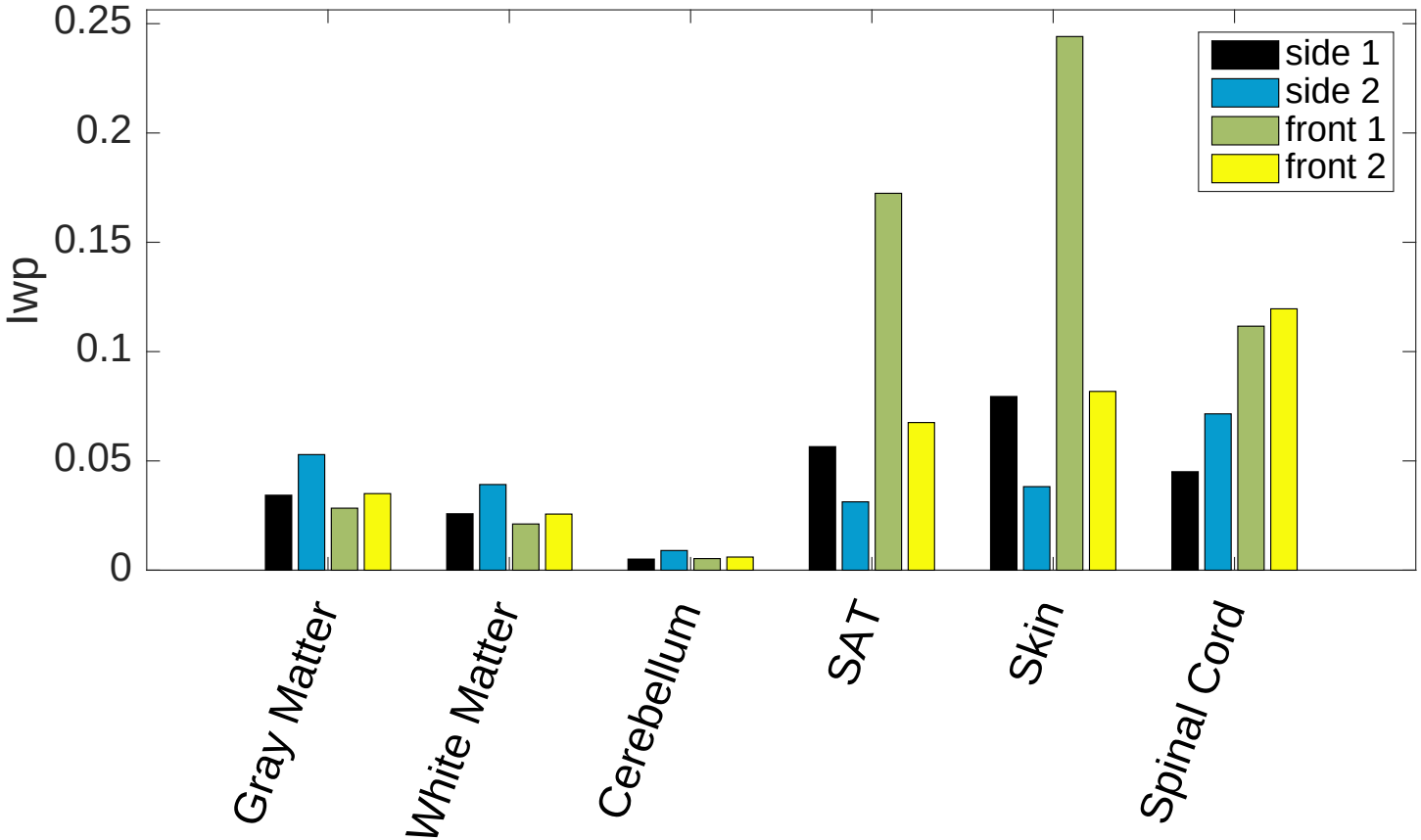
Front 1



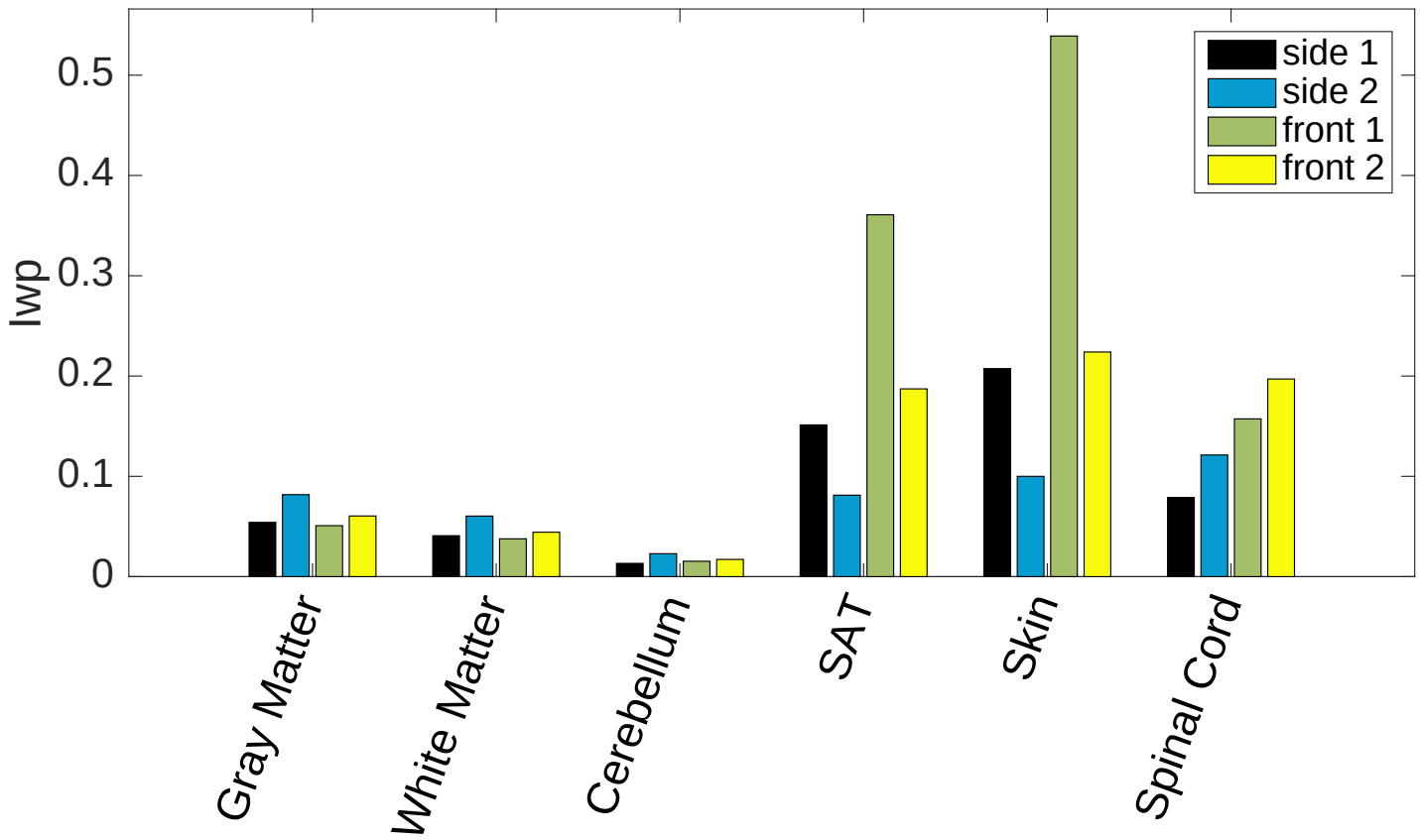
Front 2



Dosimetric assessment: AC gun



Dosimetric assessment: MFDC gun



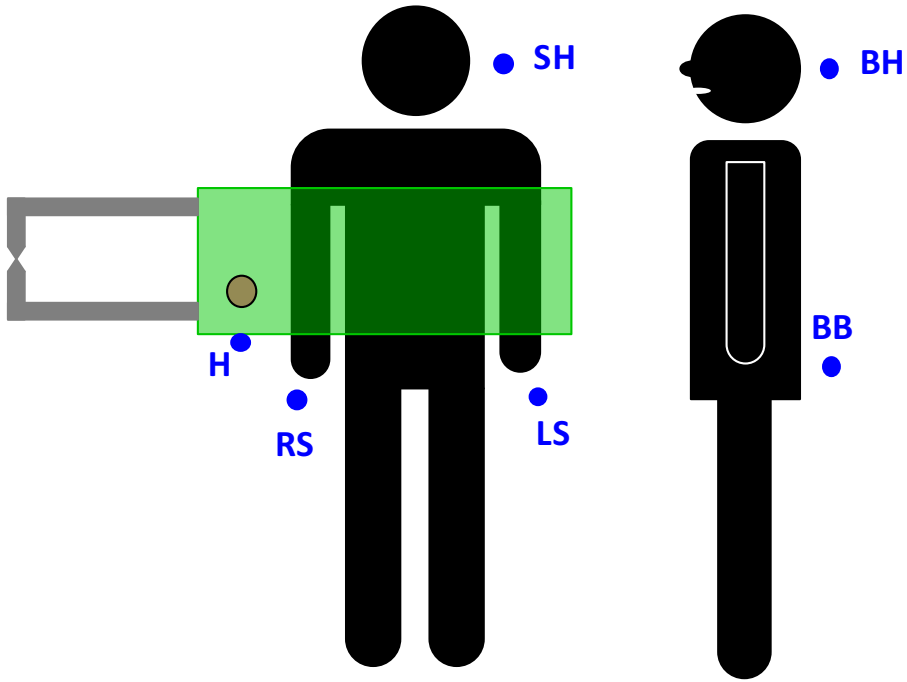
Actual working conditions

Actual working conditions

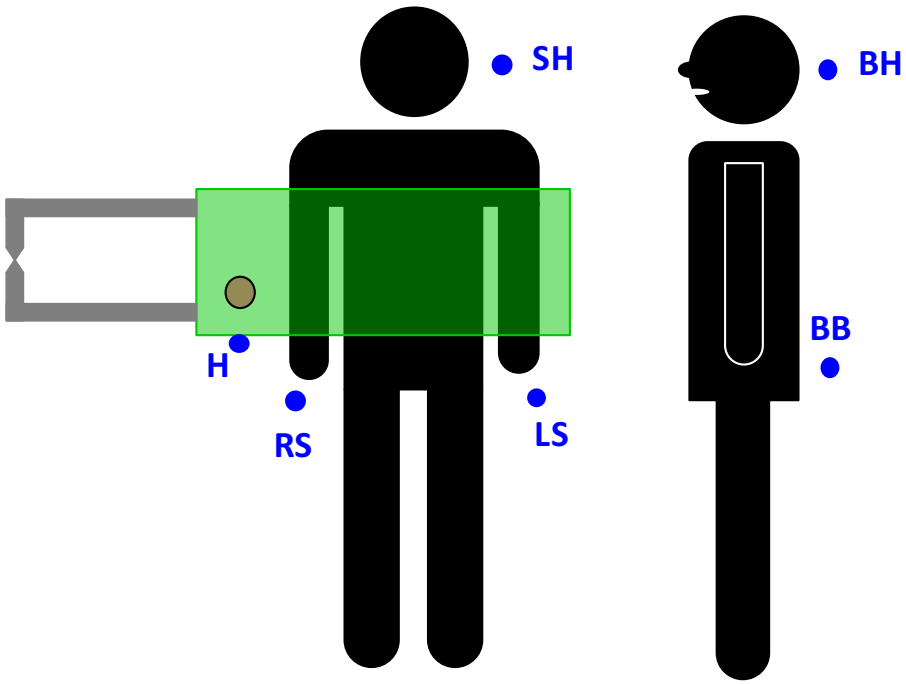
The following scenarios were investigated:

- minimum of two welding guns working at the same
- maximum of six welding guns working at the same time
- gun with different sizes
- gun handled in different positions

BH: behind head
SH: side head
RS = right side
LS = left side
BB = behind back
H = handle



Actual working conditions



field point	value	exposure index
BB	min	0.05
	average	0.09
	max	0.11
LS	min	0.22
	average	0.42
	max	0.60
RS	min	0.12
	average	0.15
	max	0.18
BH	min	0.05
	average	0.07
	max	0.12
SH	single point	0.08
H	min	0.37
	average	0.47
	max	0.60

Thanks for the attention.

Comments and questions are welcome.