



# Electron beam technology for preservation of cultural heritage artefacts

1st ARIES Annual Meeting Ryga 22/05/2018

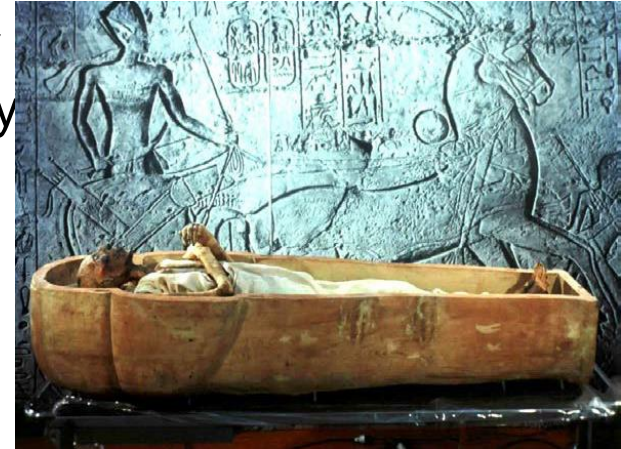
Dagmara Chmielewska-Śmietanko/INCT

# Electron beam technology for preservation of cultural heritage artefacts

---

## HISTORY

- 1977 the mummy of Ramses II, Nucléart laboratory CEA's Grenoble Research Centre, dose 18 kGy
- 1980 The Gantt papers (U.S.A.), dose 4.5 kGy
- 1992 book collection, Leipzig University Library dose 12 kGy



- 1997 500 000 books, wet, library of the Colorado University, dose 15 kGy
- the end of 1990, National Film Archive of Romania, photographic films, dose 25-50 kGy



# Electron beam technology for preservation of cultural heritage artefacts

- 1997-2006 almost 1500 complete altars, Ruđer Bošković Institute (RBI)-Zagreb, dose 2-20 kGy
- 2002 The church in Izvoarele, IRASM Radiation Processing Center- Romania, dose 4.4-7.6 kGy



- 2006 the Peace Palace Library- The Hague, about 15 kilometers of shelves of materials, dose 10 kGy



- 2009 mummified animals. Presidential Museum of Carthage – Tunisia, dose 2 kGy



# Electron beam technology for preservation of cultural heritage artefacts

- 2010 Khroma- the frozen baby mammoth, Nucléart laboratory CEA's Grenoble Research Centre, dose 20 kGy



- 2011 archives of the Secretary of Education for the State of São Paulo:, dose 15 kGy

- since November 2001 - irradiation of mail to recipients at the Congress, the White House and federal agencies – **electron beam and X-rays**

# Electron beam technology for preservation of cultural heritage artefacts

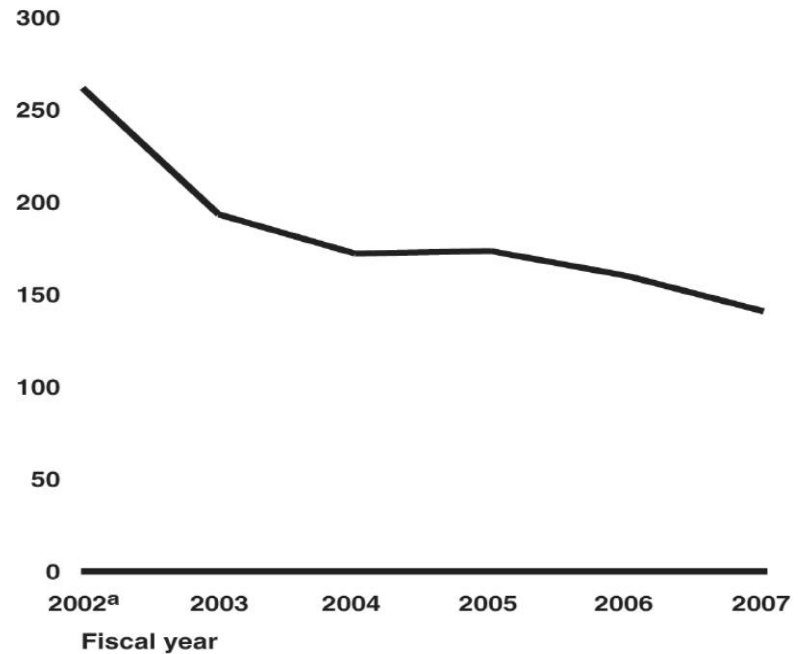


Source: United States Postal Service.

A facility in Bridgeport, New Jersey, operated by Sterigenics International, uses a Rhodotron continuous wave electron beam accelerator built by IBA Industrial,

About 1.2 million containers of D.C. federal mail were irradiated from November 2001 through April 30, 2008.

Number of containers (in thousands)



Source: GAO analysis of United States Postal Service contractor data.

- Methods

- **EtO**

- The pressure is lowered to 750-800 mbar, the temperature is elevated to 30-45 °C, RH 50%, gas concentration 100-250 g/m<sup>3</sup>.
- Decontamination time 24-36 h, several hours of air washing in order to extract the leftover gas from the books. Quarantine: min. 2-3 days.
- To retain significant amounts of residual ethylene oxide subsequent to a fumigation treatment.
- Chronic exposure to ethylene oxide can increase the risk of leukemia, brain tumors and other cancers; it can cause chromosome damage and may also affect the reproductive system.

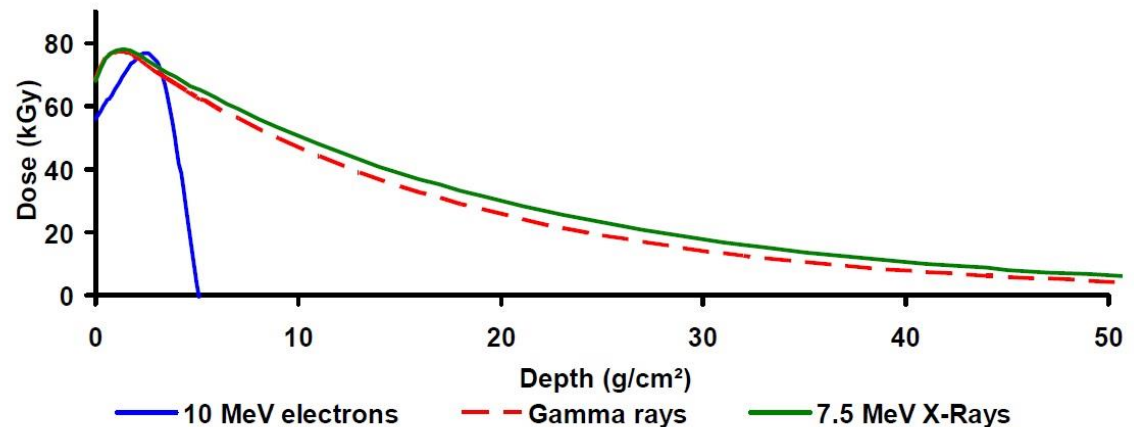
## • Methods

### ➤ **Gamma rays**

- Neutral conditions
- Any harmful residues
- Gamma allows treating dense and thick products
- Exposition time depends on the dose rate of the gamma cell (minutes-days)
- Oxidative degradation
- Safety precautions

### ➤ **Electron beam**

- Fast process
- Neutral conditions
- Exposition time: short
- Much lower probability of oxidative degradation
- Any harmful residues
- Limited depth of penetration



*EB, Gamma Ray and X-ray Penetration*

# Electron beam technology for preservation of cultural heritage artefacts

## *Application of radiation for cultural objects preservation in Poland*



Gothic sculpture of  
Madonna with Child,  
Museum of Łódź Archdiocese



60.000 pieces of prisoners' shoes from  
the Majdanek concentration camp,  
State Muzeum at Majdanek



Uniforms, documents, atrefacts,  
The Katyń Museum, Warsaw



Sulpture of Jan Nepomucen,  
Museum of Łódź Archdiocese



Furniture from Wedel shop,  
DeJa VU Hotel in Łódź



Sculpture of Madonna with Child,  
National Museum in Warsaw



# Electron beam technology for preservation of cultural heritage artefacts

## Biological factors in deterioration of paper Fungi [1]

Material	Paper, cardboard	Leather	Parchment	Ink	Glue	Fabric	Photographs	Audiotapes
<b>Fungi</b>								
<i>Rodotorula</i>	X	X						
<i>Mucor</i>	X	X	X			X		
<i>Rhizopus</i>	X	X	X			X	X	
<i>Chaetomium</i>	X	X	X			X	X	X
<i>Gymnoascus</i>	X							
<i>Aspergillus</i>	X	X	X	X	X	X	X	X
<i>Penicillium</i>	X	X	X	X	X	X	X	X
<i>Phoma</i>	X					X		
<i>Trichoderma</i>	X	X	X			X	X	
<i>Paecilomyces</i>	X	X				X	X	
<i>Trichothecium</i>	X				X			
<i>Cephalosporium</i>	X							
<i>Scopulariopsis</i>	X	X				X	X	
<i>Monilia</i>	X		X			X		
<i>Verticillium</i>	X					X		
<i>Aureobasidium</i>	X	X				X		
<i>Hormiscium</i>	X							
<i>Helminthosporium</i>	X				X			
<i>Stachybotrys</i>	X				X	X		
<i>Cladosporium</i>	X	X	X			X		
<i>Altermaria</i>	X	X	X		X	X		
<i>Stemphylium</i>	X	X			X	X		
<i>Fusarium</i>	X	X	X		X	X	X	
<i>Doratomyces</i>	X					X		

# Electron beam technology for preservation of cultural heritage artefacts

## Biological factors in deterioration of paper Bacteria [1]

Material	Paper, cardboard	Leather	Parchment	Glue	Fabric	Photographs	Audiotapes
<b>Bacteria</b>							
<i>Cellvibrio</i>	X						
<i>Cellfacicula</i>	X						
<i>Serratia</i>			X	X			
<i>Bacillus subtilis</i>		X	X		X		
<i>Cytophaga</i>	X						
<i>Sporocytophaga</i>	X						
<i>Nocardia</i>	X						
<i>Streptomyces</i>		X	X			X	X

[1] Fausta Gallo (1985) Biological factors in deterioration of paper. International Centre for the Study of the Preservation and Restoration of Cultural Property



## Coordinated Research Project (CRP)

F23032 „Developing Radiation Treatment Methodologies and New Resin Formulations for Consolidation And Preservation of Archived Materials and Cultural Heritage Artefacts

- May 2015-May 2019
- 18 countries (Poland, Brasil, Portugal, Romania, Iran, Tunisia, Croatia, Italy, France, Bangladesh, Turkey, Ukraine, Cuba, Egypt, Sri Lanka, Slovakia, Bulgaria, Serbia).
- INCT contract „Electron beam for preservation of biodeteriorated cultural heritage paper-based objects,,

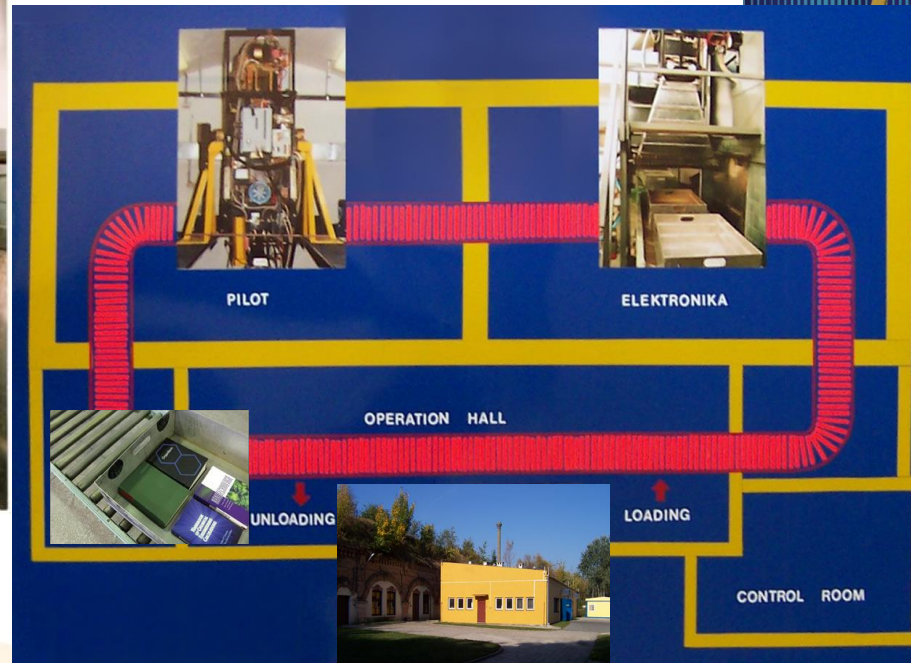
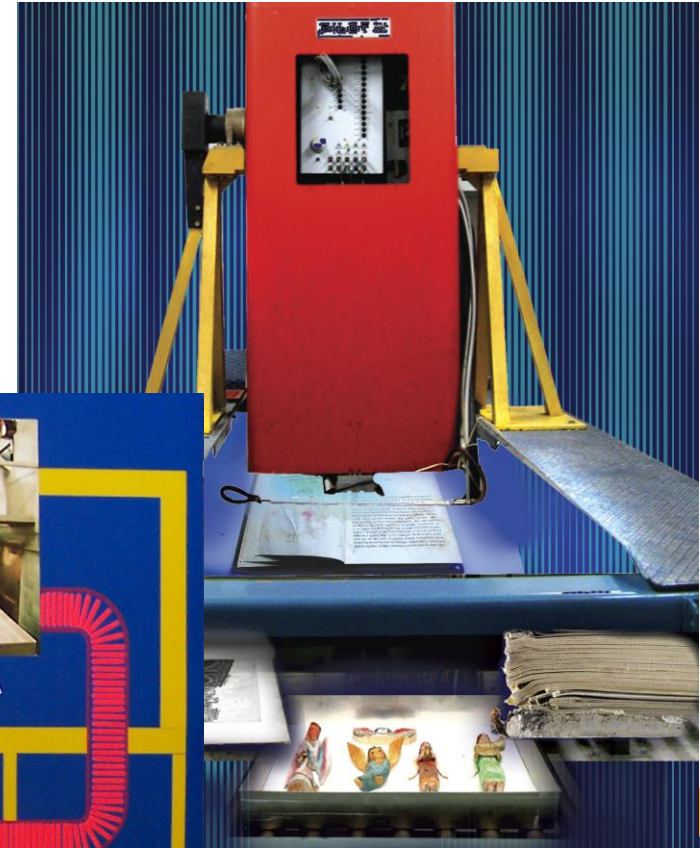
### **Specific research objectives**

- Understand effect of specific irradiation conditions on functional properties of CH artefacts and establish appropriate irradiation methodologies
- Develop new radiation curable resins with enhanced compatibility with CH artefacts
- Establish appropriate procedures for irradiation of CH artefacts including dose mapping and simulation techniques

# Electron beam technology for preservation of cultural heritage artefacts

- Application of EB irradiation for decontamination of books and archives in INCT – research and applications

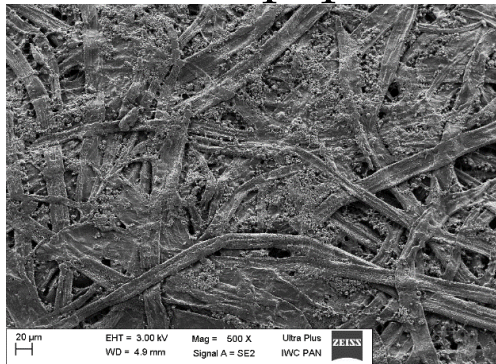
Accelerator	Manufacturer	Power	Energy	Mode	Scanning length
<b>Elektronika 10/10</b>	NPO Torij, RU	10 kW	10 MeV	linear, pulsed 400Hz, RF 1886 MHz	65cm



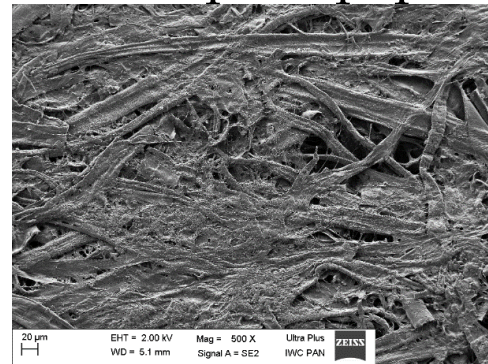
# Electron beam technology for preservation of cultural heritage artefacts

- INCT current works

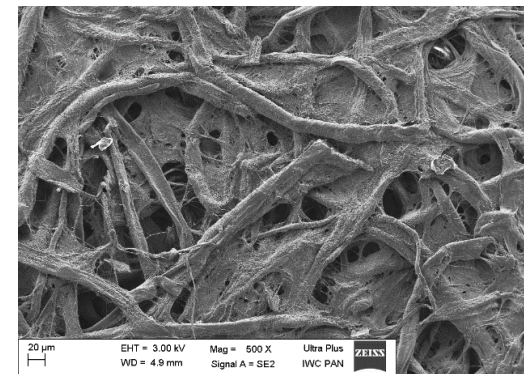
Office paper



Newsprint paper

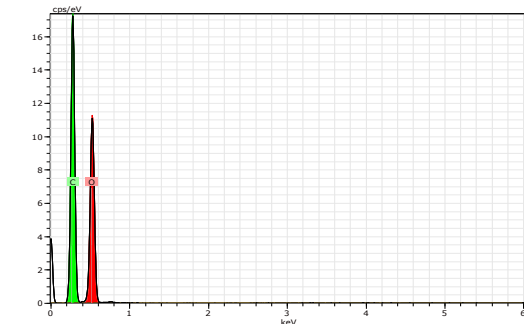
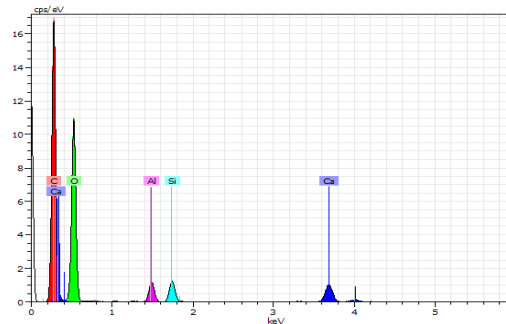
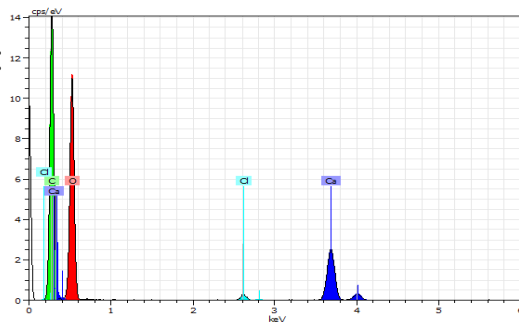


Whatman CHR1



Surface morphology:

Composition:



Grammage [g/m<sup>2</sup>] :

80

48.8

88

Thickness [mm]:

106

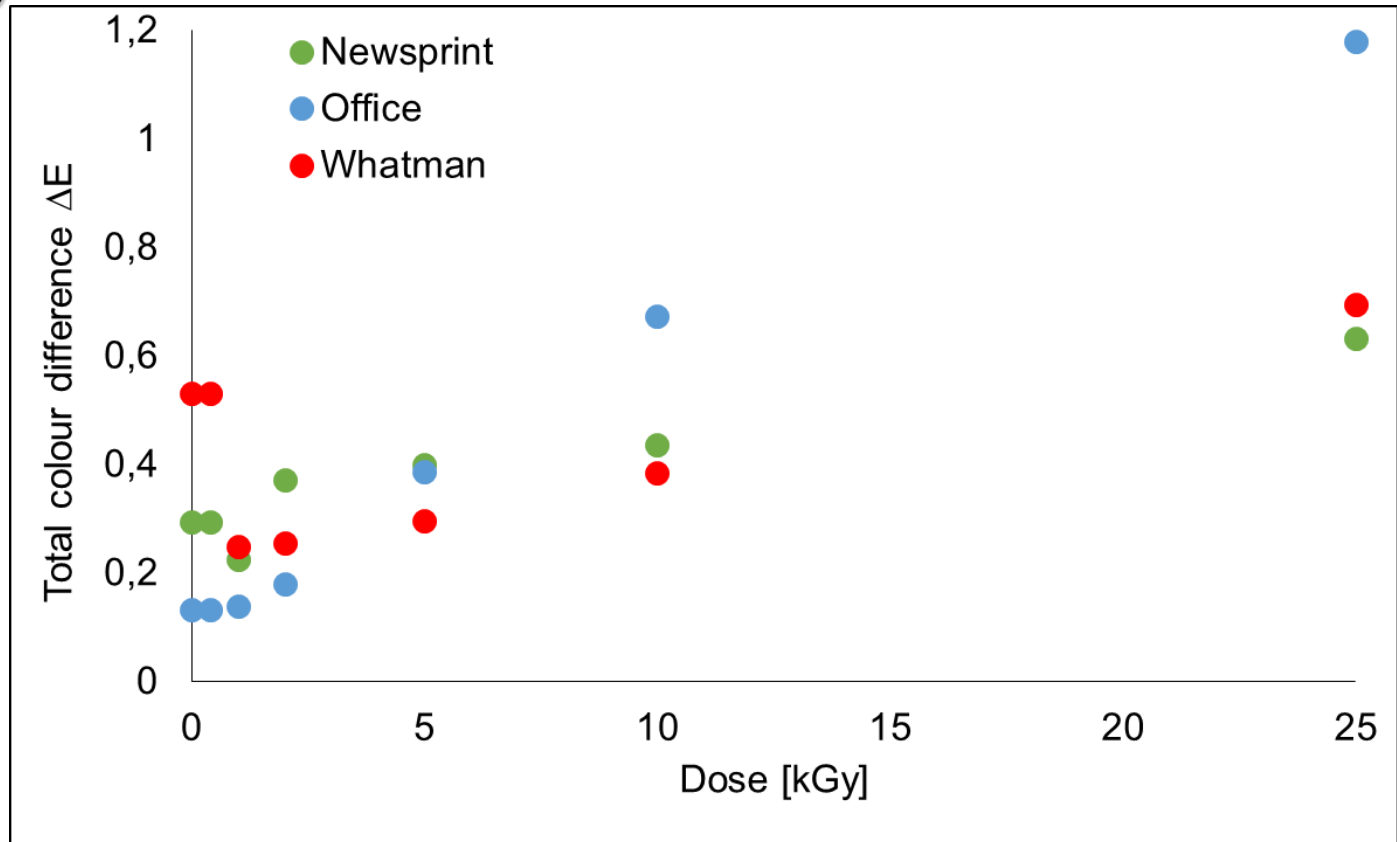
103

180

- INCT current works

## Colour parameters

*ISO 11475:2004 Paper and board -- Determination of CIE whiteness, D65/10 degrees (outdoor daylight)*



- INCT current works

## Chemical parameters

*TAPPI T 529 - Surface pH measurement of paper*

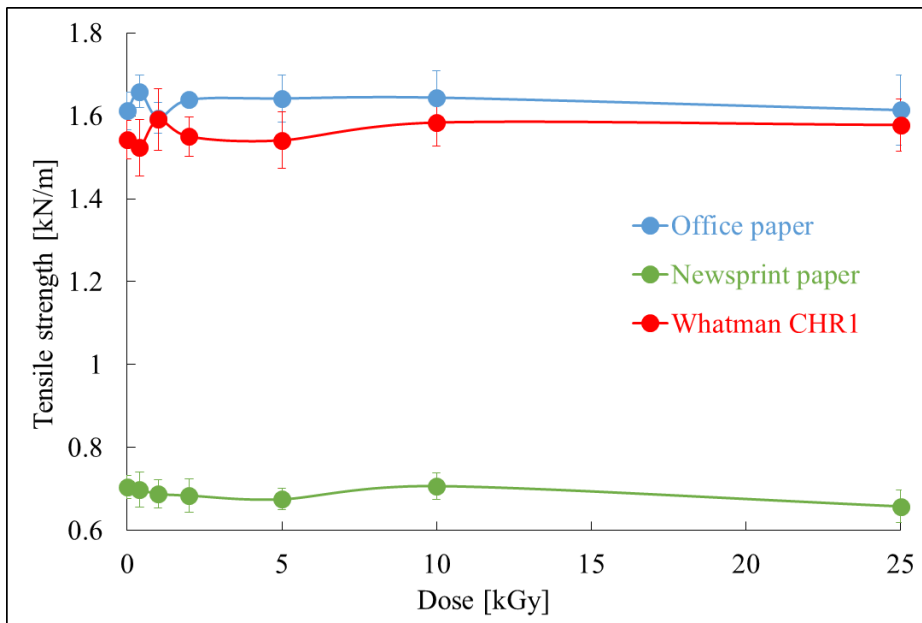
Dose [kGy]	Whatman CHR1	Office paper
0	7.13	7.03
0.4	6.66	7.02
1	6.86	7.13
2	6.56	7.20
5	7.14	7.08
10	7.15	7.10
25	6.82	7.92

# Electron beam technology for preservation of cultural heritage artefacts

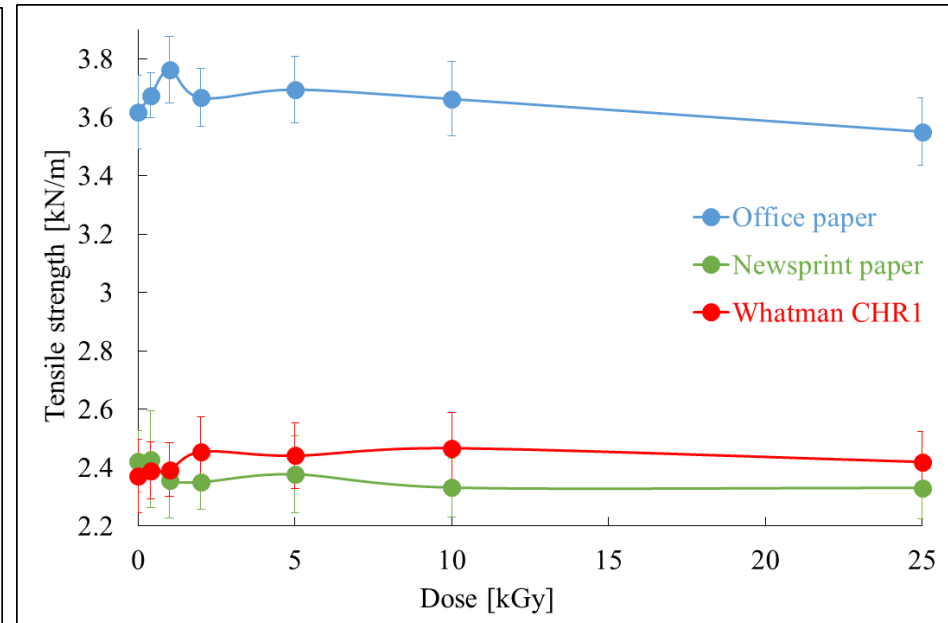
- INCT current works

## Mechanical parameters

*ISO 1924-2:2008 Paper and board -- Determination of tensile properties -- Part 2: Constant rate of elongation method (20 mm/min)*



*Cross machine direction (CD)*



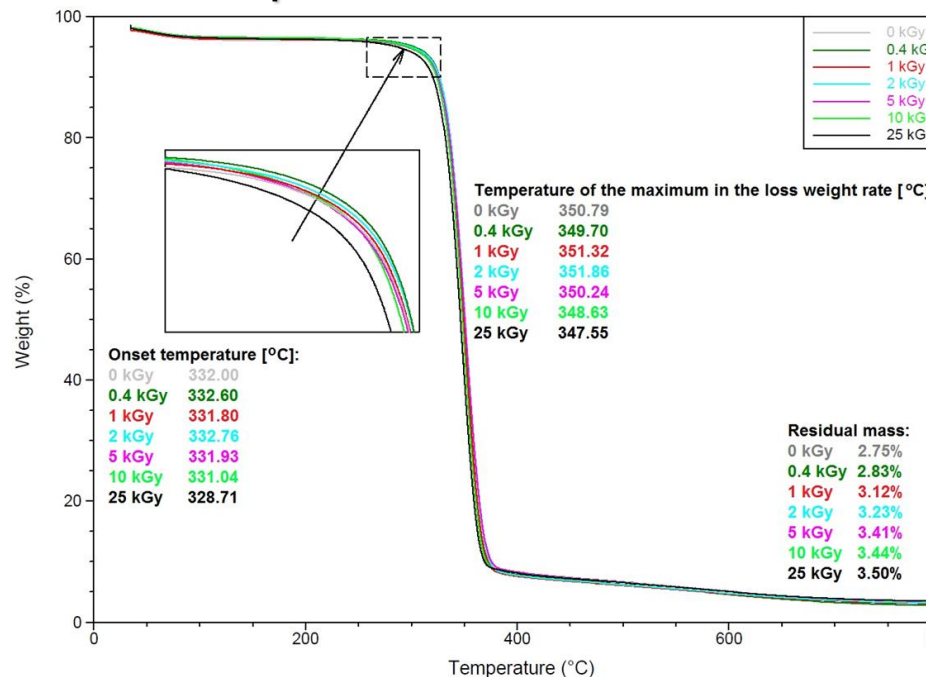
*Machine direction (MD)*



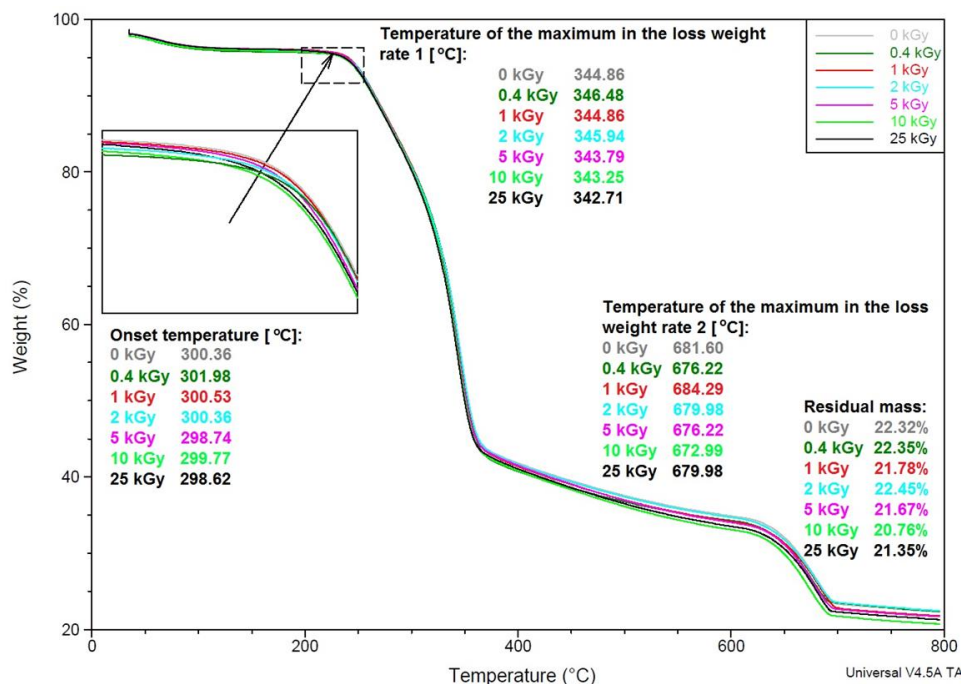
# Electron beam technology for preservation of cultural heritage artefacts

- INCT current works

## Thermal parameters

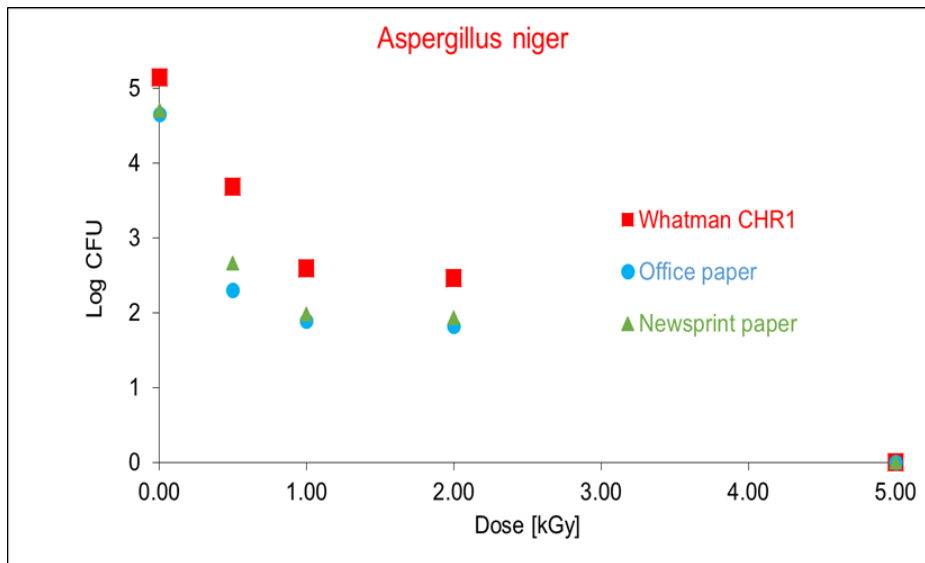


Whatman CHR1



Office paper

- Different kinds of paper: Whatman, office, newsprint
- Real objects: books
- Doses: 0.4-25 kGy
- Parameters studied: chemico-physical, thermal, mechanical, microbiological, colour, radicals etc.
- Influence of the natural and accelerated aging



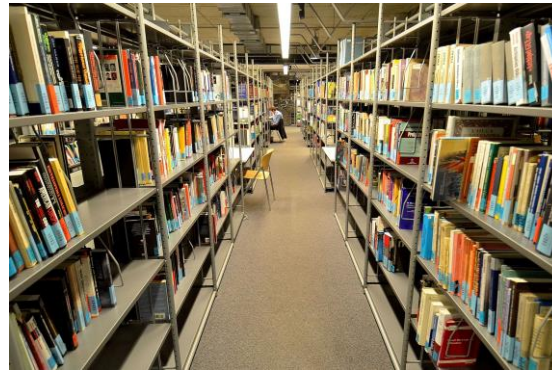
## CONCLUSION

Dose of 5 kGy as sufficient for the complete elimination of *A. niger* from all types of paper and did not influence the investigated parameters of different papers.

## *Application of electron beam for paper objects preservation*

### University of Warsaw Library

- surface of the Library 40 000 m<sup>2</sup>
- over 3 000 000 items
- 3500 visitors daily
- one of the three biggest collections of scientific and academy literature
- 40 m<sup>3</sup>



## *Application of electron beam for paper objects preservation*

### Faculty of Modern Languages Library

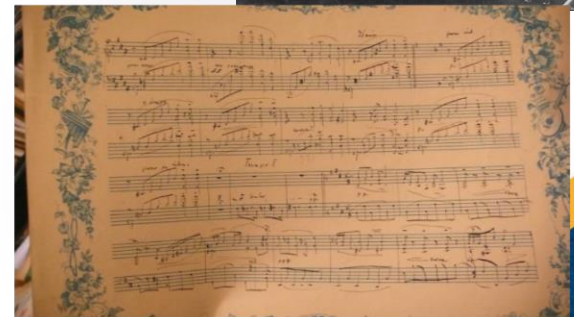
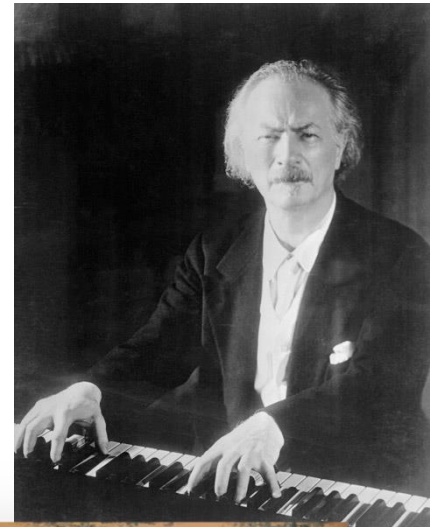
- 6 different institutes, 4 libraries
- over 300 000 items
- 150 m<sup>3</sup>



## *Application of electron beam for paper objects preservation*

### The Fryderyk Chopin University of Music Library

- over 120 000 items
- collection gathered since the 19th century (autographs, scores and books)
- original music notation composed by Ignacy Paderewski



# Electron beam technology for preservation of cultural heritage artefacts

## *Application of electron beam for paper objects preservation*

### **The Sejm (Polish Parliament) Library**

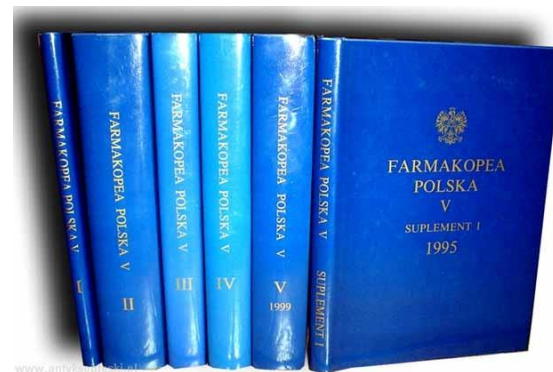
- over 500 000 items (books, archives, audio recordings, video recordings, photographs)
- 4 m<sup>3</sup>



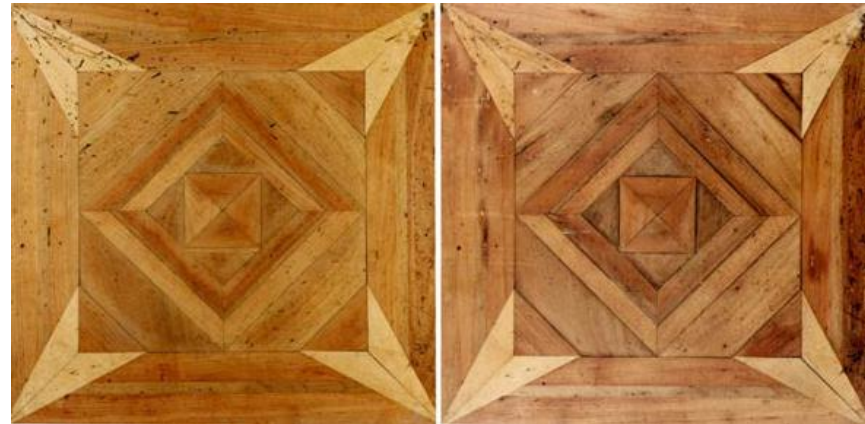
## *Application of electron beam for paper objects preservation*

### **The Office for Registration of Medicinal Products, Medical Devices and Biocidal Products**

- marketing authorization of medicinal products, biocidal products, marketing and use of medical devices
- clinical trials, including veterinary clinical trials
- 30 m<sup>3</sup>



- Other trends in EB application to CH treatment
- Radiation consolidation
  - 18th century parquet from the old city hall, Nucléart laboratory CEA's Grenoble Research Centre, the monomer MMA as consolidant (the thermoplastic polymer formed is PMMA, Plexiglas)



Before

After



# Electron beam technology for preservation of cultural heritage artefacts

- Terracotta army, preservation of the polychromic layer by hydroxy-ethyl methacrylate (HEMA), University of Munich (impregnation) and Lintong-e-beam curing (40 kGy)



- Conclusions

- Safe and fast method, suitable for mass conservation of archival and library collections
- Innovative technology (still few application)
- Different possibilities of application: disinfection, consolidation, cleaning...

Thank you for your attention