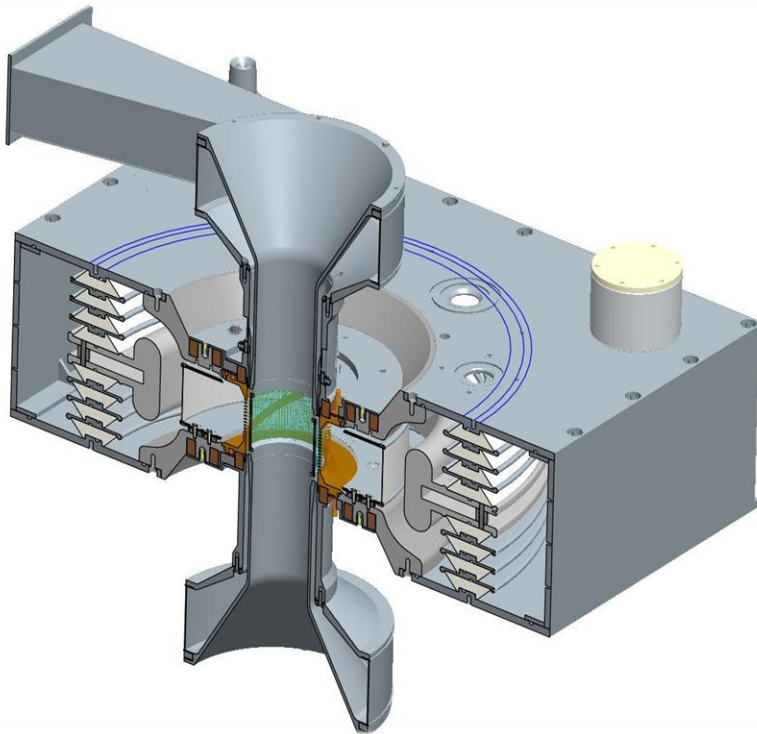


# A NOVEL ELECTRON BEAM SOURCE

- for simplified irradiation of 3D-shaped surfaces -



Workshop – Industrial and environmental  
application of electron beams  
Warschau, November 6<sup>th</sup> – 7<sup>th</sup>



**André Weidauer**

**Fraunhofer Institute for Organic  
Electronics, Electron Beam and  
Plasma Technology FEP**

Dresden, Germany



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# Content

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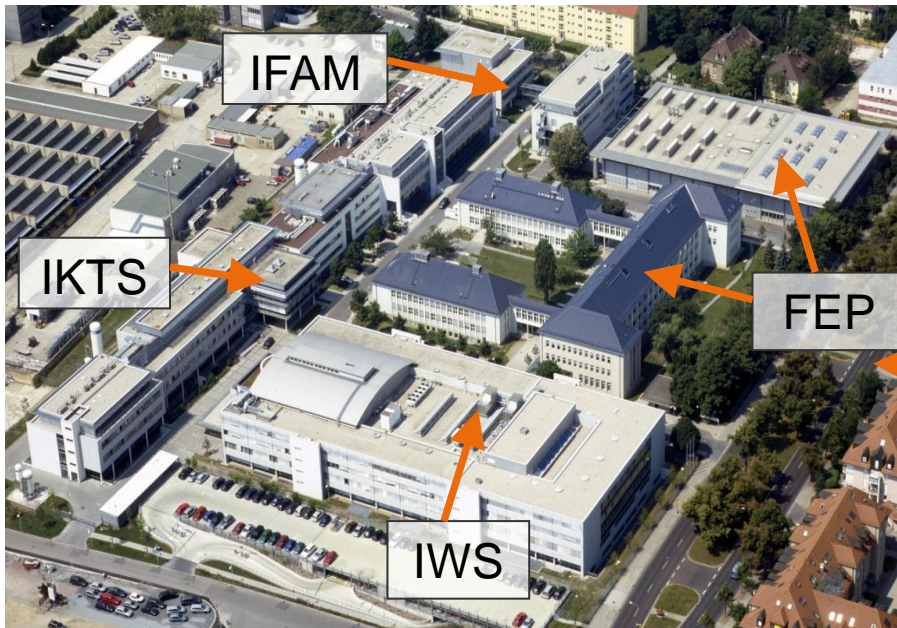
## Fraunhofer FEP

Development of the toroidal source

Application

# Fraunhofer FEP

## Fraunhofer Institute Center Dresden



- **founded in 1991**
- **premises: approx. 8,000 m<sup>2</sup>**
- IFAM: Fraunhofer Institute for Manufacturing Technology and Advanced Materials
- IKTS: Fraunhofer Institute for Ceramic Technologies and Systems
- IWS: Fraunhofer Institute for Material and Beam Technology

# Fraunhofer FEP

## Technical Equipment

### Laboratory System



### Pilot System

Upscaling of processes



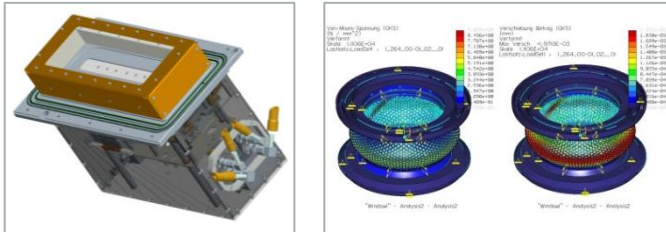
# Fraunhofer FEP

## Development of key components

### ■ Division Systems

- Group Mechanical Development
- Group Electronic Development
- Manufacturing

Mechanical Development:  
3-D-Design / Strenght analyses FEP



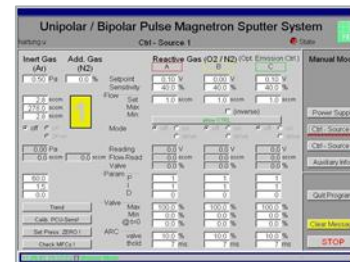
Design, Installation und put into use of regulation units and power supplies



Manufacturing:  
production of turned and milled parts

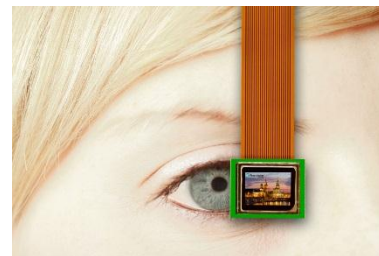
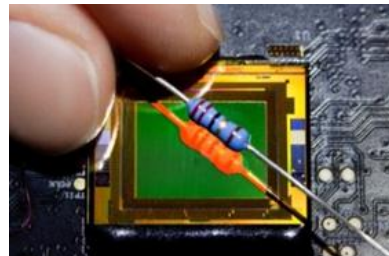
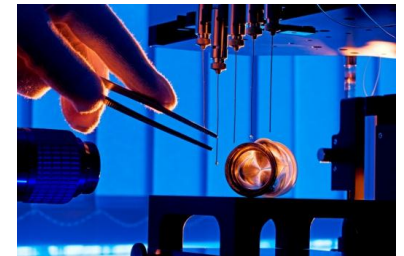
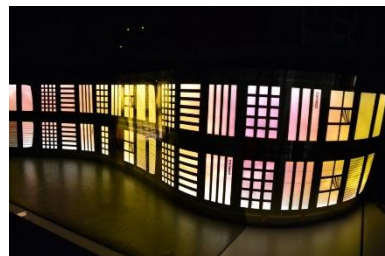


Software Development for all visualizations of processes:



# Fraunhofer Institute for Organic Electronics, Electron Beam and Plasma Technology FEP

## *Evolution of Surface.*



Fraunhofer FEP

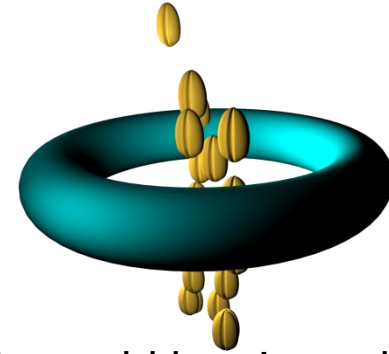
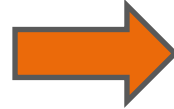
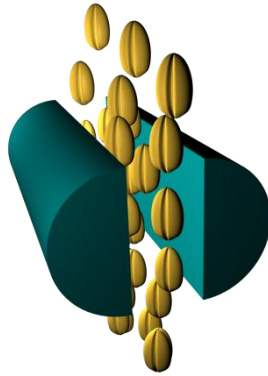
## Development of the toroidal source

Application

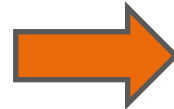


# Electron treatment of surfaces

Treatment of seed or bulk goods

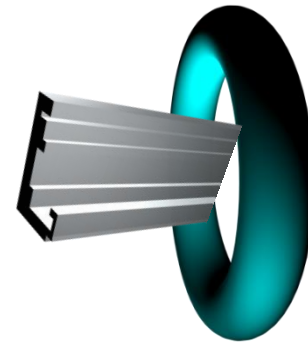


Surface sterilization of medical products



It would be nice to have a toroidal source for homogeneous dose application onto 3D-surfaces

Lacquer curing on 3D-products





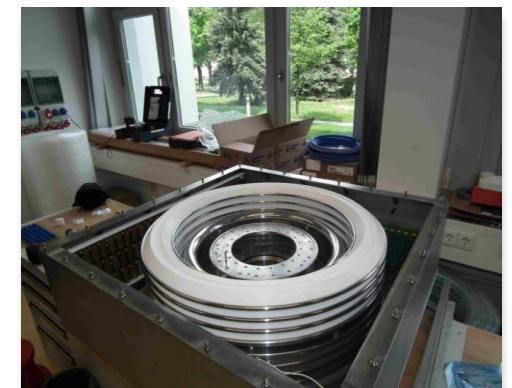
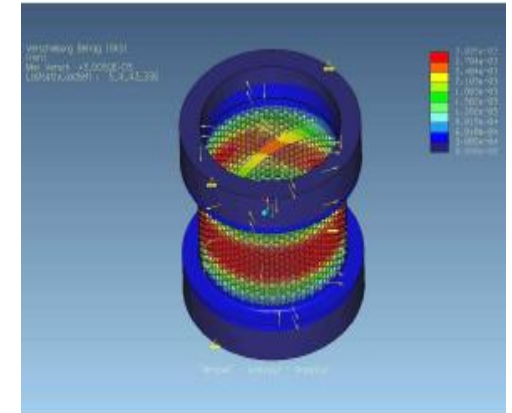
# Development of the toroidal source

## Development steps

Concept phase 2008 - 2011

Development phase 2011 – 2013

Application development 2013 – 2017



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# Development of the toroidal source

## Concept phase – Plasma EB

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### WHY COLD CATHODE?

- Free formable
- Fine-vacuum level required only
- Simple, cheap and longlife cathode principle without sensitive thin and hot wires
- Initial glow discharge plasma follows naturally the cathode shape -> different electron source shaping possible
- Easy controllable beam current by plasma density
- Decoupling of electron generation process and acceleration

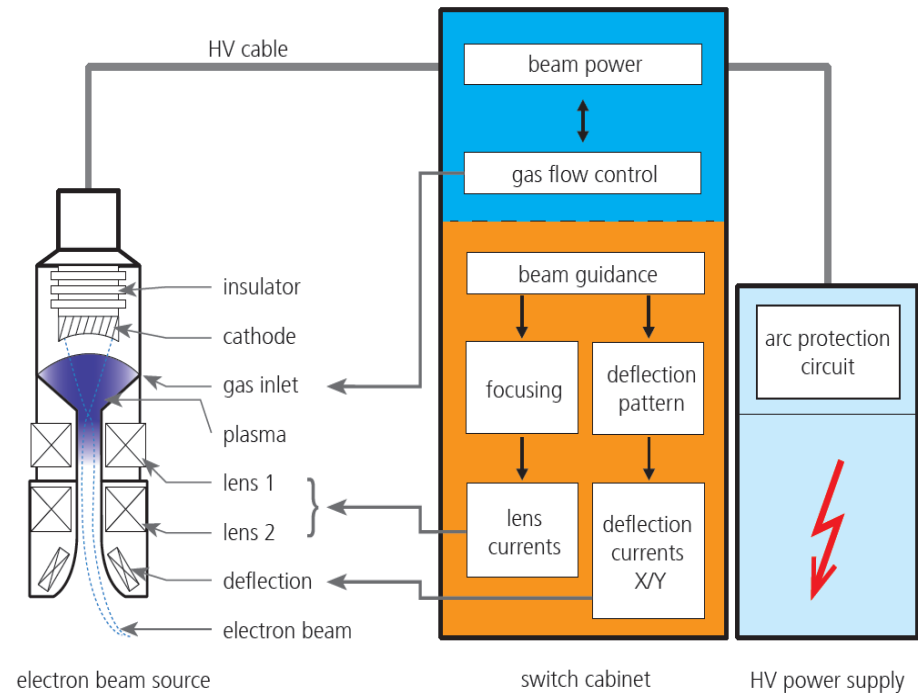
# Development of the toroidal source

## Concept phase – Plasma EB

- Cold Plasma – EB Sources
- Approved for high power axial guns

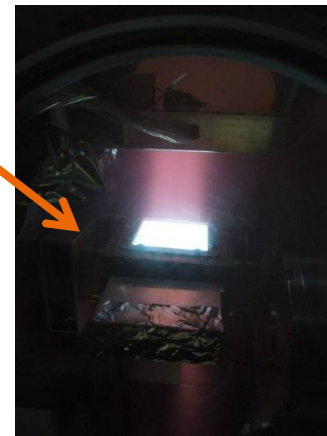
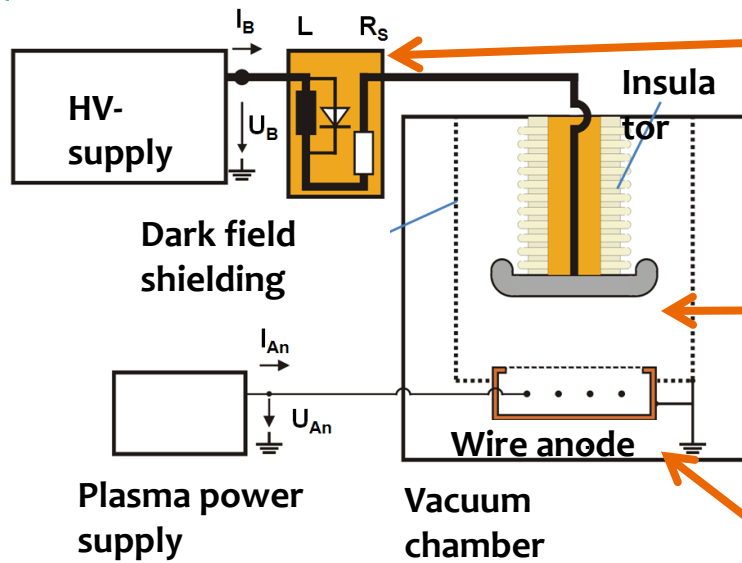
### SPECIFICATION

Acceleration Voltage:	<b>20 ... 45kV</b>
Beam Current:	0 ... 15 A
Rated Power:	≤ 600 kW
Focus diameter:	≤ 20 mm
Deflection angle:	± 45°
Scanning frequency:	≤ 1 kHz
Cathode material:	Aluminum
Plasma work gases:	H <sub>2</sub> , He, ...
Cathode service life:	≥ 120 h
Operation pressure:	≤ 2.0 Pa



# Development of the toroidal source

## Concept phase – first tests



### ■ Proof of concept

#### Experimental experience

- Necessary pressure ( $\leq 2$  Pa)
- HV electrons / Arc-Handling
- Insulation of high voltage

# Development of the toroidal source

## Development phase - Concept

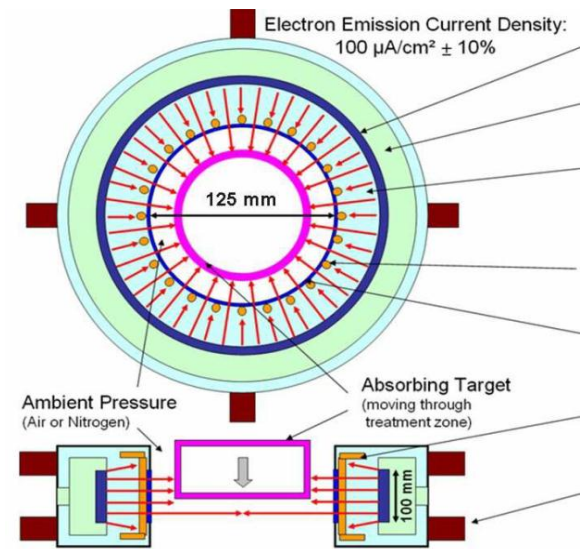
projected application area, state of development

### ■ EB-Source for non-thermal processing

- Sterilization
- Seed treatment
- Polymer modification

### ■ New development

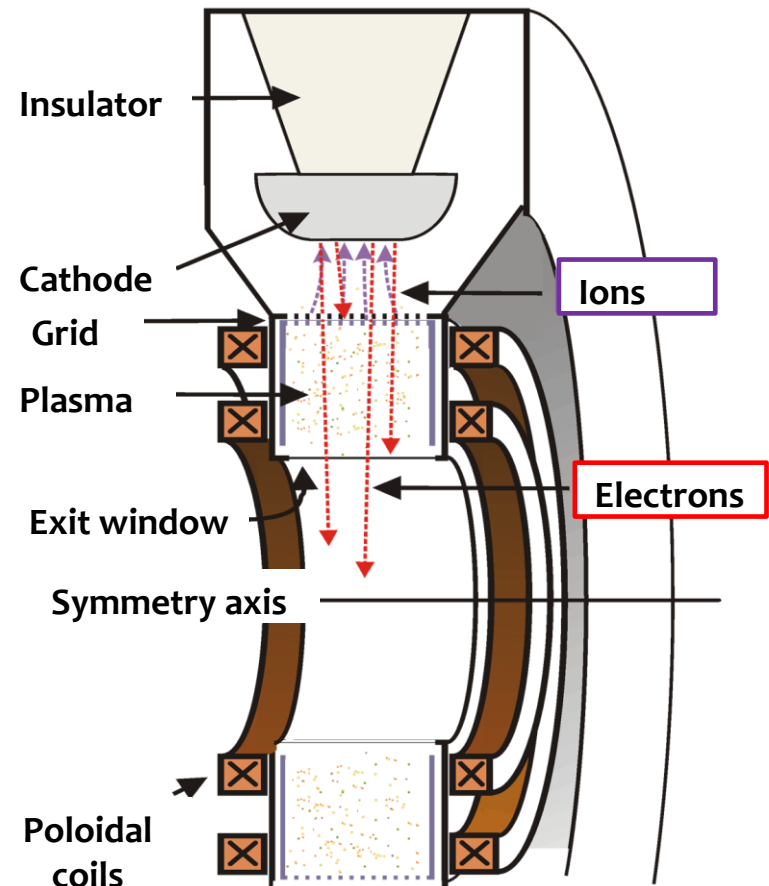
- Cold cathode electron source, which is stimulated by low pressure DC plasma
- Acceleration voltage > 100 kV
- Radial converging beam in order to have an all side product treatment in single pass



# Development of the toroidal source

## Development phase - Geometry

- New geometry (ring shaped convergent beam)
- Wire anode based on auxiliary discharge is replaced by magnetically driven ExB discharge  
→ Simple design!
- However: It is required an accurate knowledge of the coils and their effects
  - No previous experimental study was possible
  - Does the axial magnetic field disturbs the radial beam propagation?
- Numerical simulation of electron beam traces are the basis of dimensioning

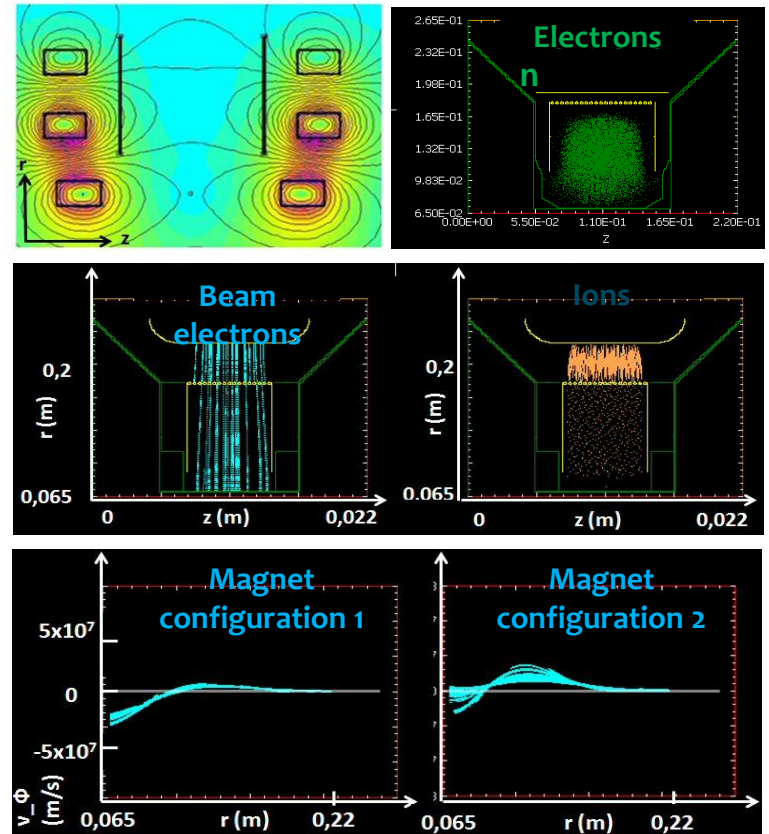


# Development of the toroidal source

## Development phase – Simulation

### TOROIDAL SOURCE WITH $E \times B$ - discharge

- The auxiliary discharge ignition can be enhanced by the magnetic field at  $\sim 1$  Pa,  $< 2000$  A\*N,  $< 1$  kV
- Different magnet configurations were found allowing useful beam traces
- To satisfy the plasma and beam trace conditions 3 coil pairs are necessary

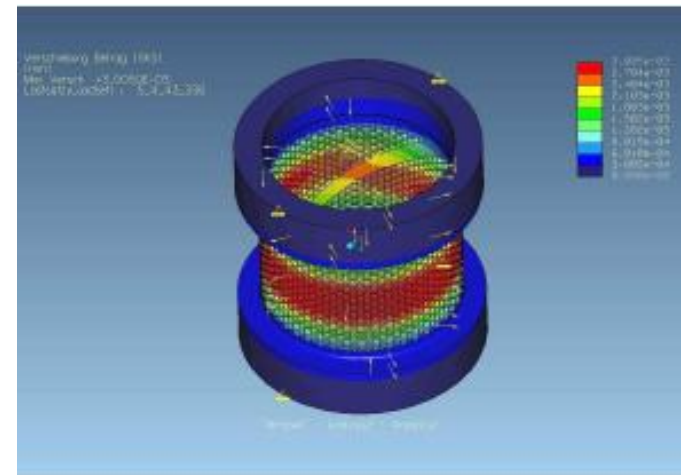
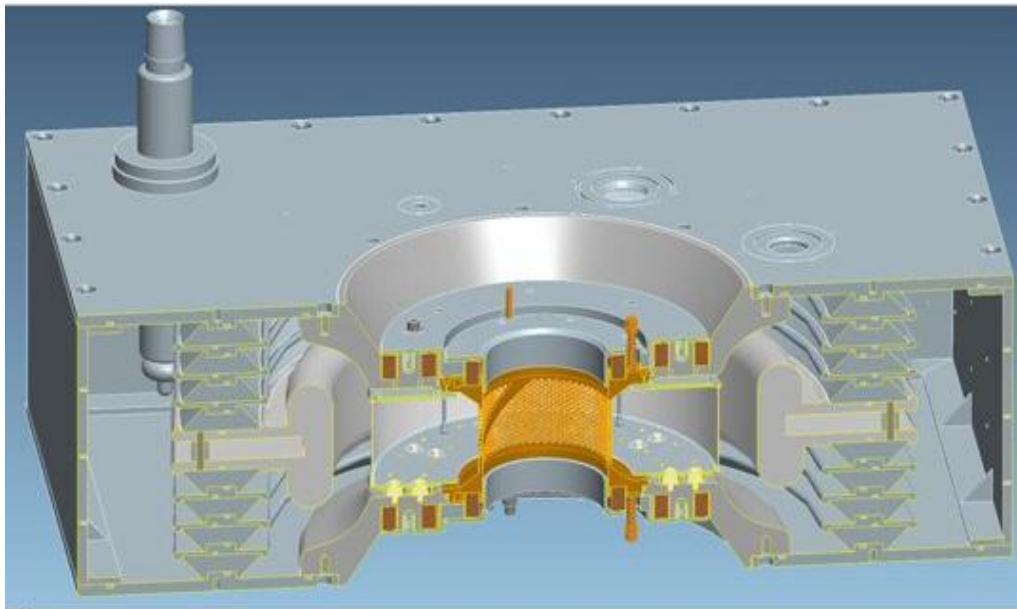


# Development of the toroidal source

## Development phase – Design

### REQUIREMENTS

- Compact setting, reasonable price of basic raw materials
- Integrated protection and arc inhibition circuit
- Operating parameters:  $\varnothing$  120 mm,  $U_B = 120$  kV,  $P < 5$  kW ( $j < 0,2$  mA/cm<sup>2</sup>)





# Development of the toroidal source

## Development phase – Final assembly

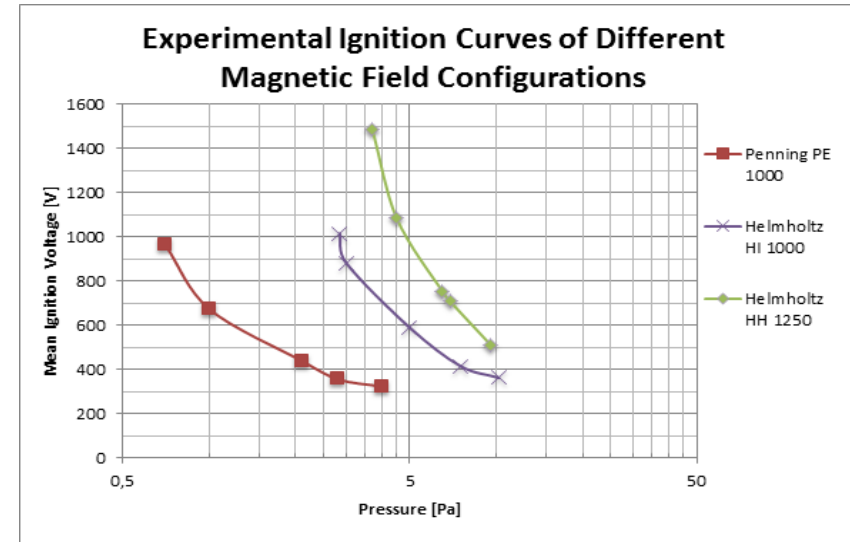
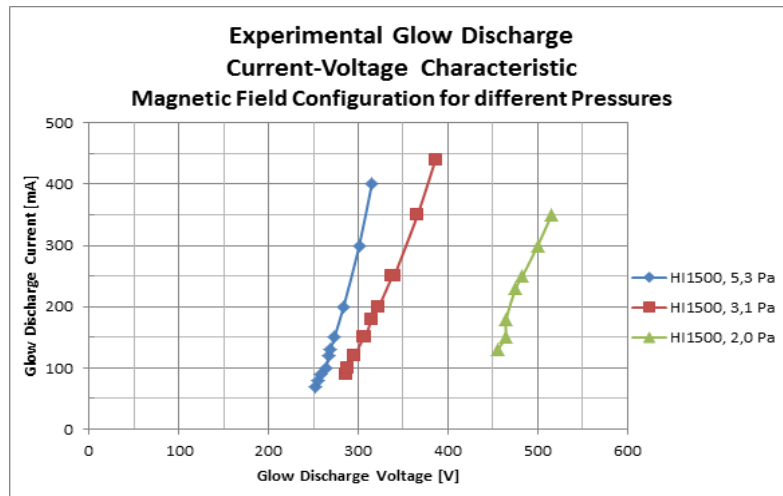


# Development of the toroidal source

## Development phase – Characterization

### CHARACTERIZATION OF AUXILIARY DISCHARGE

- Investigation of ignition voltage behavior for possible working pressure
- Dependency of ignition voltage from the magnetic field configuration and power



- The experimental results are predicted by the simulation with several magnetic field configurations
- Working pressure (1 – 5 Pa) can be lower than ignition pressure

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Fraunhofer FEP

Development of the toroidal source

## Application



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# Application

## Applications of non-thermal electron beams

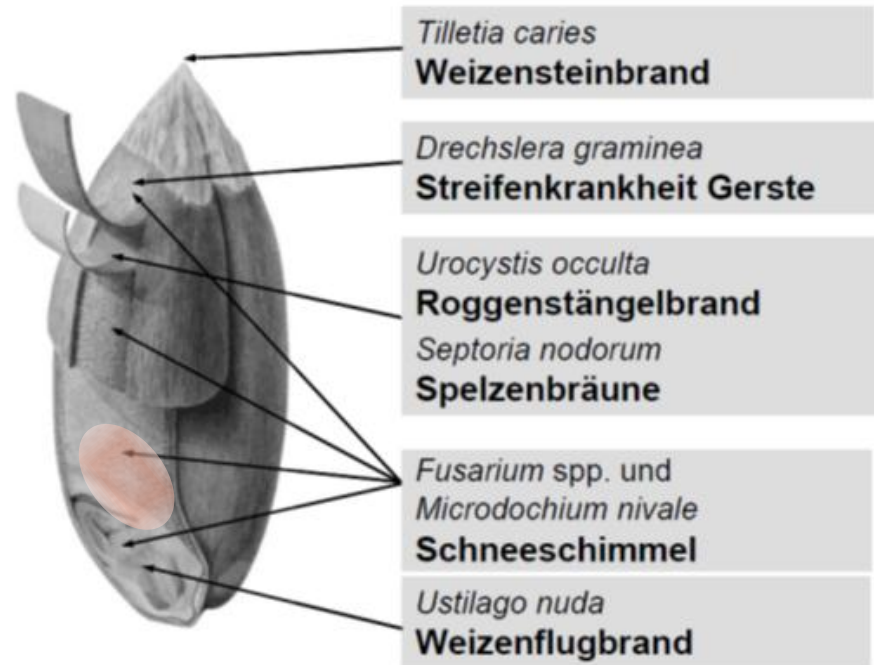
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# Application

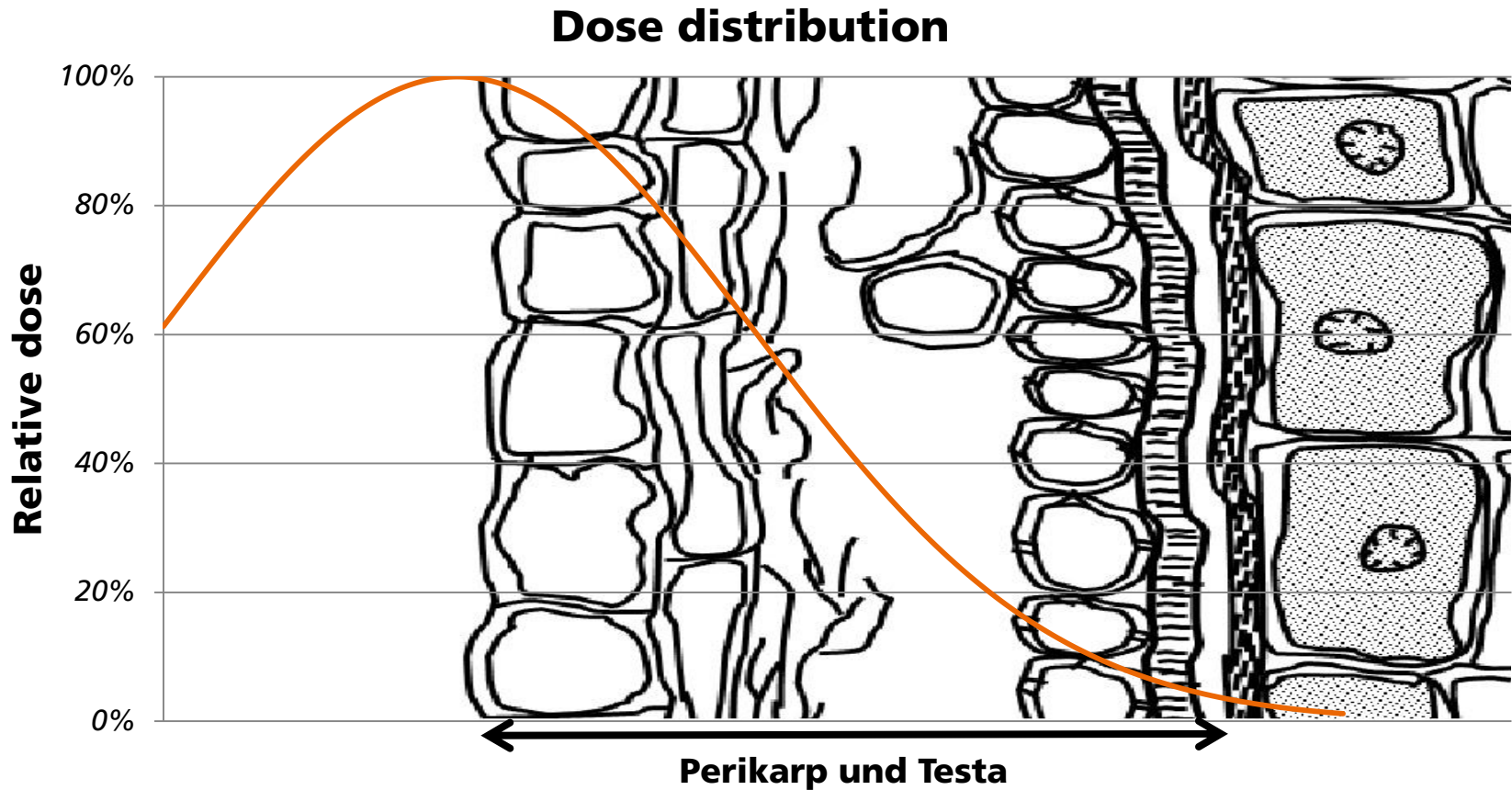
## Electron treatment of seed

- relevant pathogens onto or within the seed coat
- Pathogens inside the seed body and at the embryo can't be processed
- Cereal seed with *ustilago* affection will not accredited as seed
- *Fusarium* spp. can be treated partially only, but the practical experience is good, the economic significance under German conditions is low



# Application

## Electron treatment of seed - Basic principle

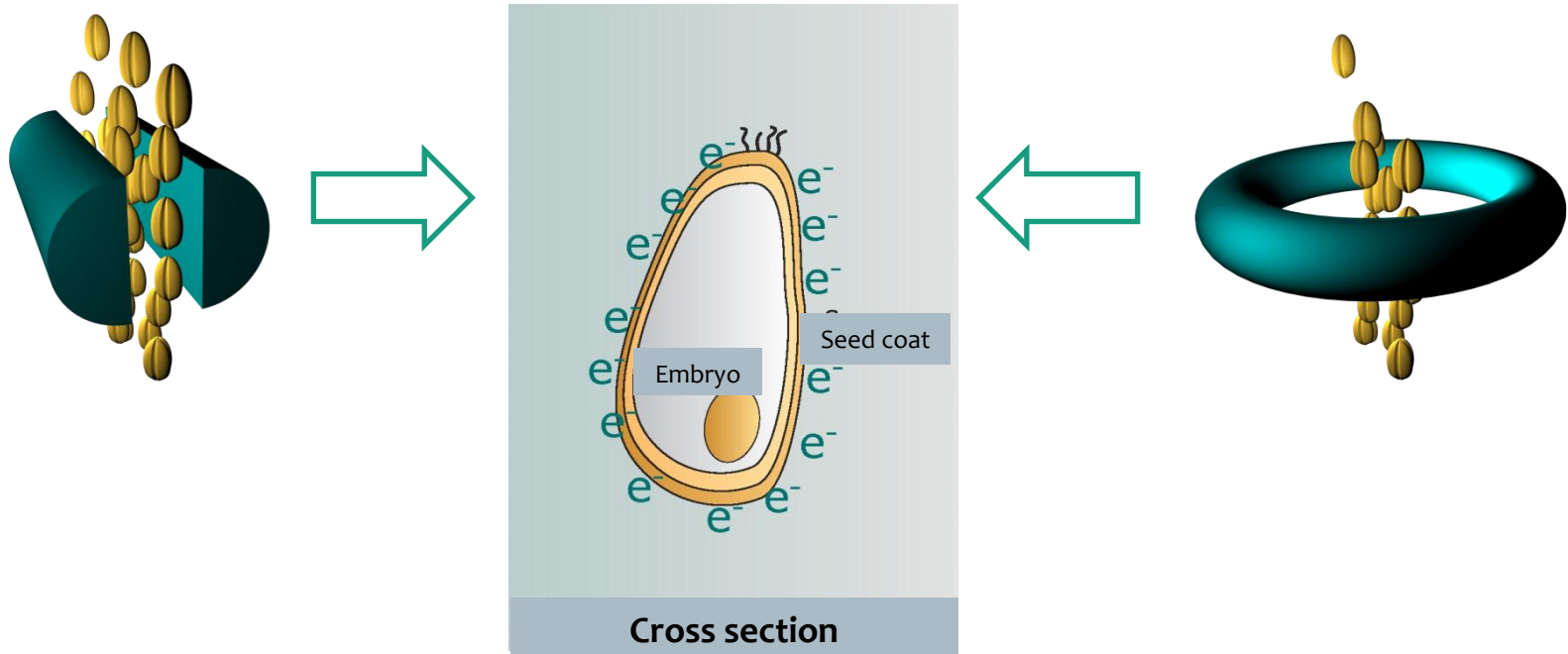


# Application

## Electron treatment of seed – state of the art

- Governmental funded project (Federal Ministry of Food, Agriculture and Consumer Protection)

→ compact, modular electron beam sources for seed treatment



# Application

## Electron treatment of seed – new toroidal source

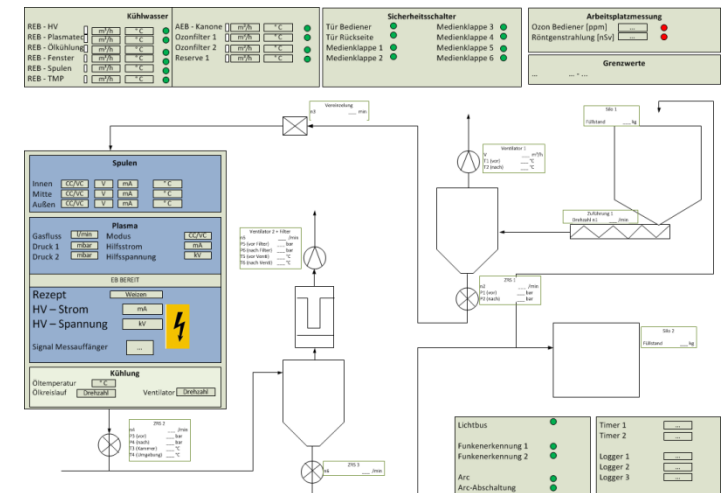
### ■ Basic requirements for seed treating

- $U_{Bmax} = 150 \text{ kV}$
- $I_B = 10 \text{ mA}$
- $m/t = 5 \text{ t/h}$
- Continuous process → stable plasma



### ■ Additional requirements

- Visualization
- Window protection and cooling
- Seed supply system





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# Application

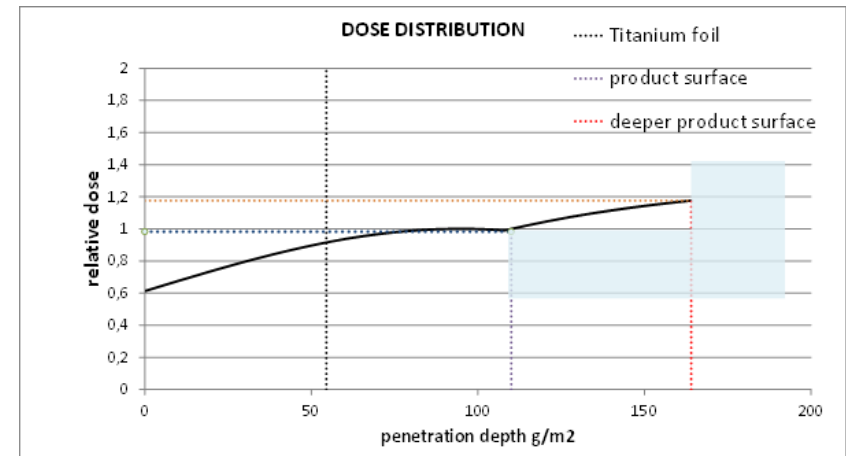
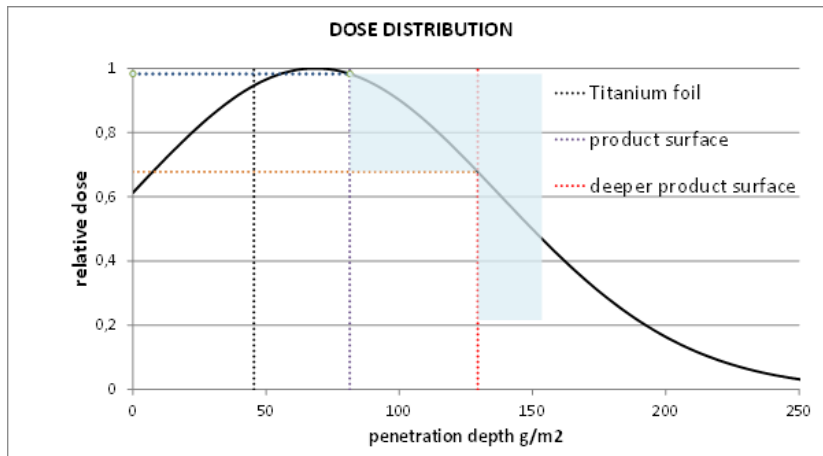
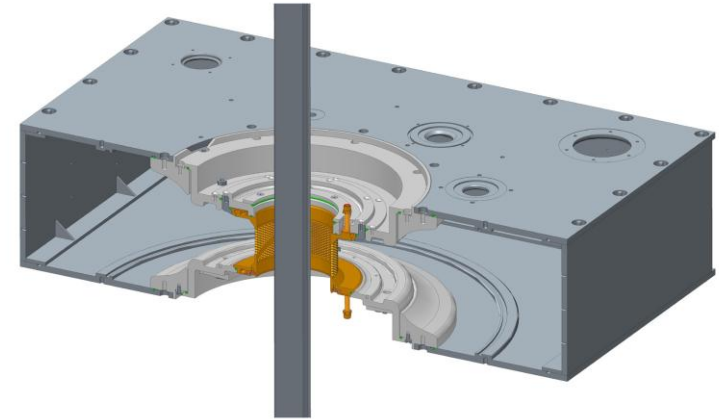
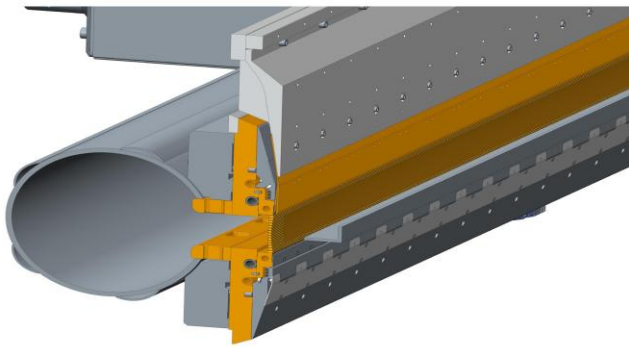
## Future projects

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- Treatment of new products
  - Nuts
  - Fruits (Banana, Apples)
  
- Treatment of 3D- shaped products
  - Medical products
  - Polymer shapes
  - Lacquered products

# Application

## Future projects – L-shaped product

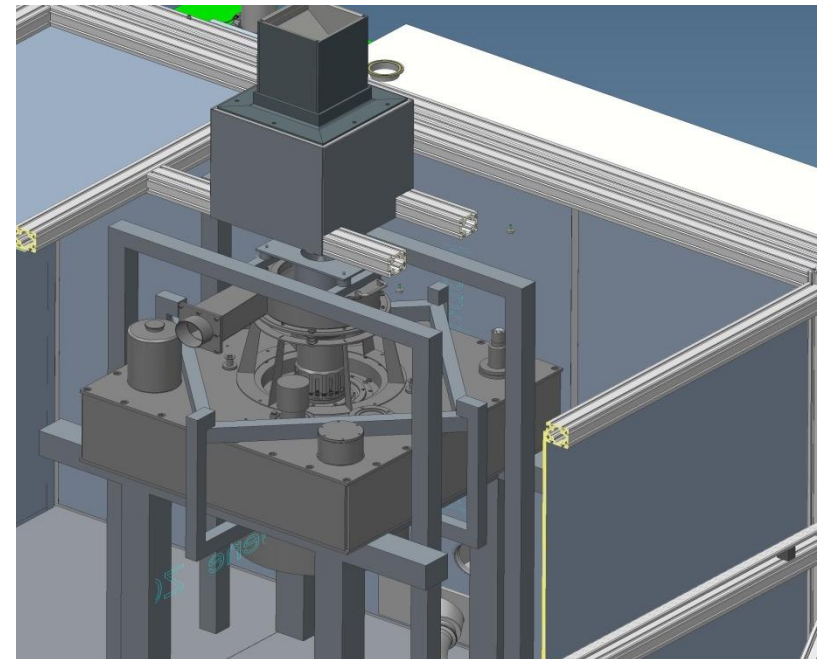


# Application

## Electron treatment of seed – status

### ACKNOWLEDGMENT

- Dr. Gösta Mattausch at all
  - Dr. P. Feinäugle
  - F. Winckler
  - S. Schmidt
- Fraunhofer Gesellschaft
  - Funding the basic research
- Federal Ministry of Food, Agriculture and Consumer Protection
  - Funding the actually application development



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# Thank you for your attention

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