

# WEBEXPIR

## Windowless target **E**lectron Beam **E**xperimental **I**rradiation

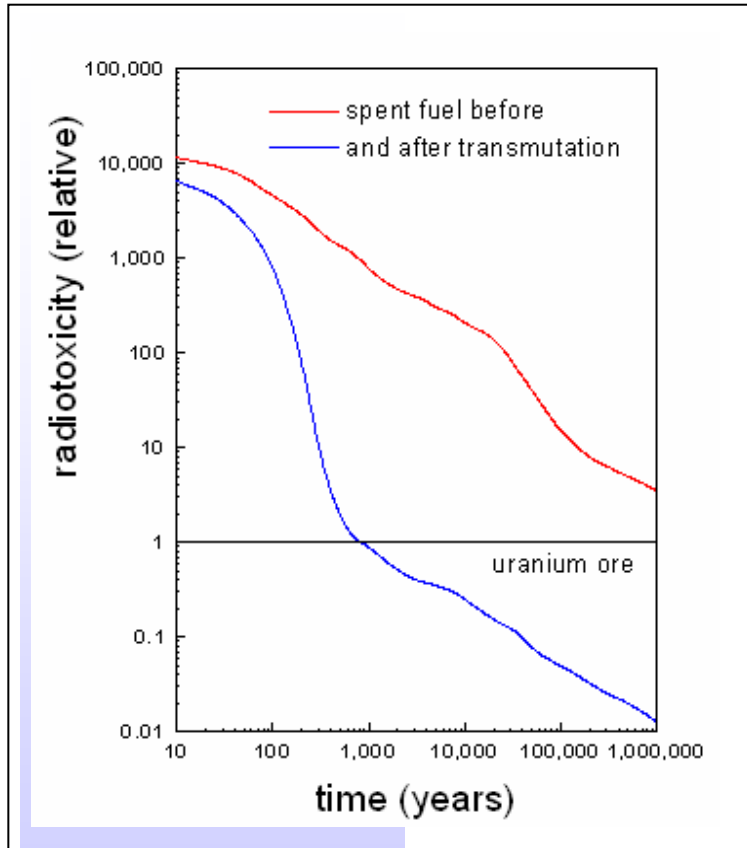
**HPPA, Mol, May 2007**

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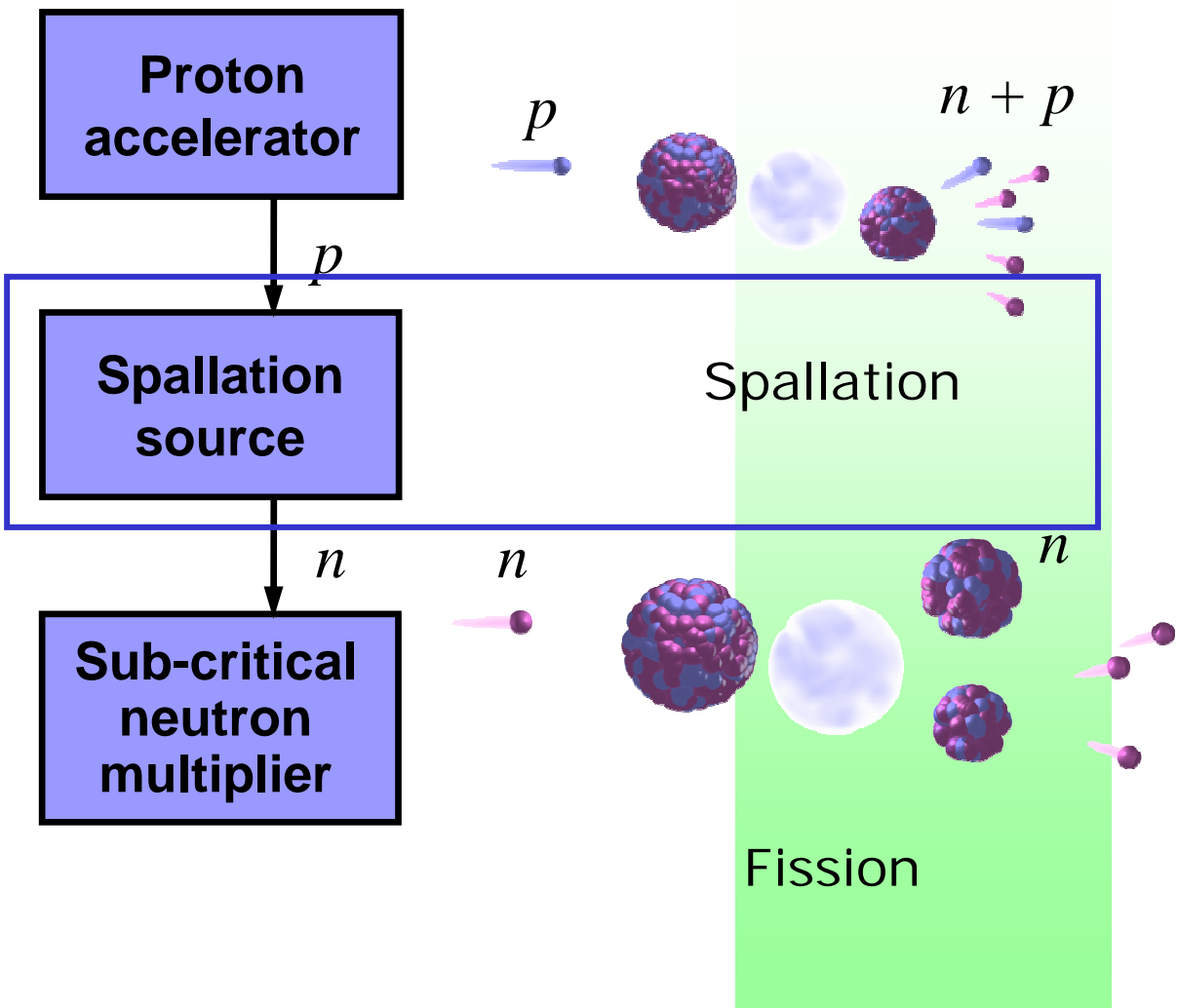
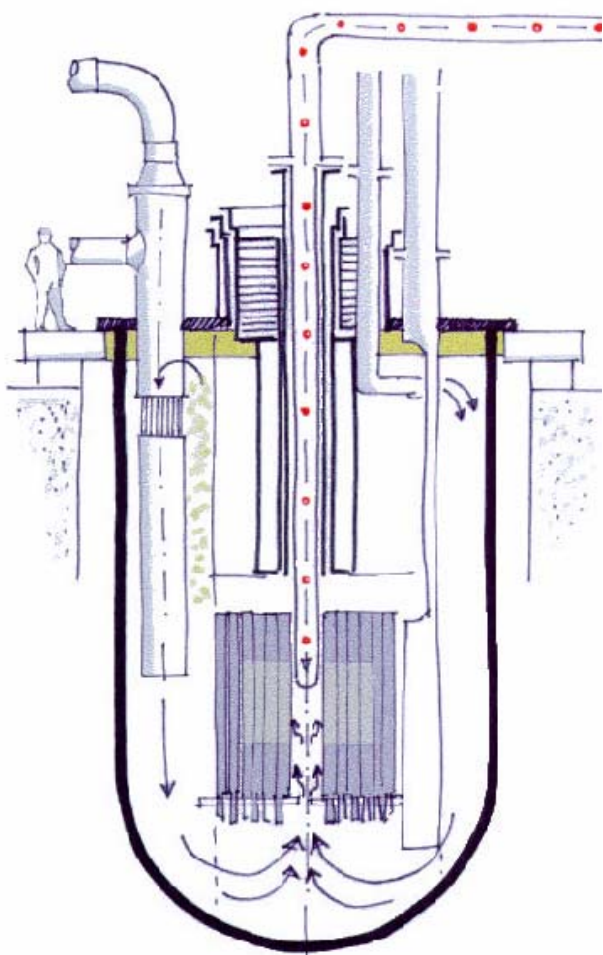
# Nuclear Fission in the EU



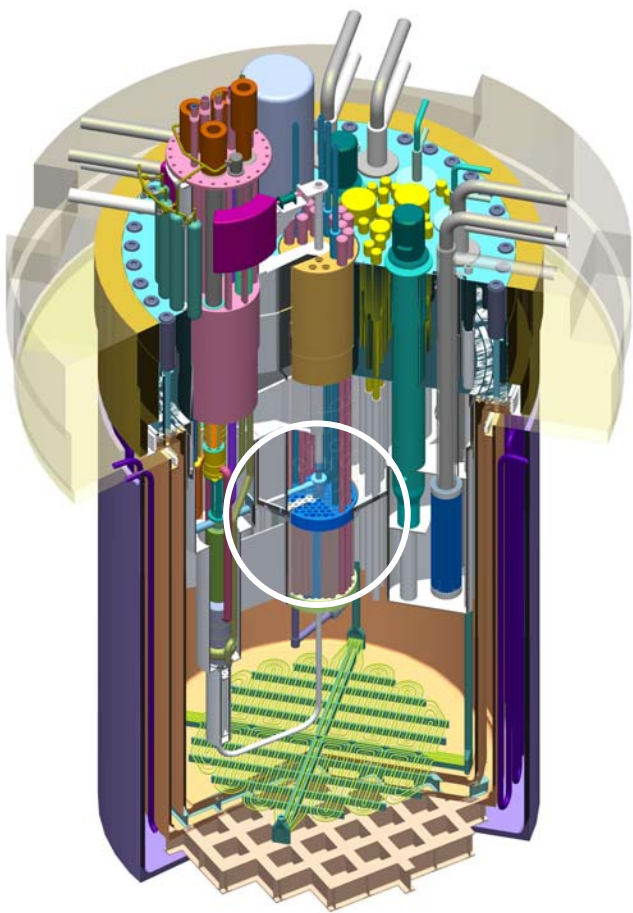
- Europe : 35% of electricity from nuclear energy
- This produces about 2500 t/y of spent fuel: 25 t Pu, 3.5 t Minor Actinides (Np, Am, Cm) and 3 t Long Lived Fission Products.
- A technical, social and environmental satisfactory solution is needed for the waste problem.
- Partitioning & Transmutation (P&T) of MA and LLFP can lead to this acceptable solution by reducing time scales for waste storage.

⇒ **Accelerator Driven Systems** operate in a flexible and safe way at high transmutation rates due to their sub-criticality.

# ADS Concept

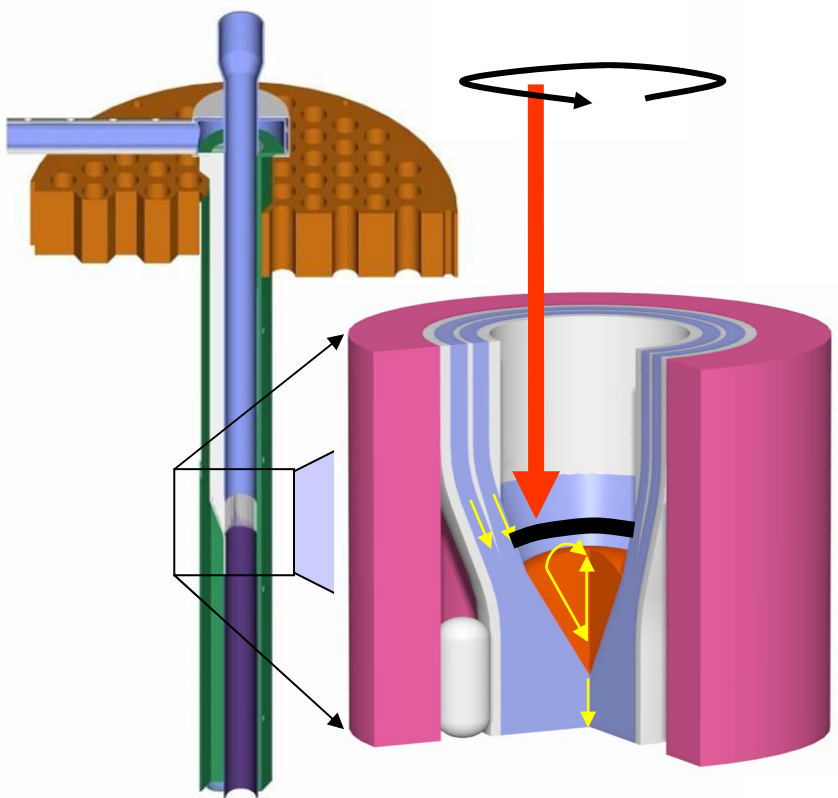


# XT-ADS target specifications



	XT-ADS target
Coolant / target	liquid Pb-Bi
Beam energy	600 MeV
Beam current	3(4) mA
Lifetime	9 months
Accumulated charge	20Ah
Target diameter	Ø10 cm
Accumulated charge / m <sup>2</sup>	2500 Ah/m <sup>2</sup>
Beam interface	<b>windowless</b>

# Windowless spallation issues



**1. Compatibility** of hot LBE reservoir (~350°C) in contact with the beam line **vacuum** ( $10^{-6}$  bar)

⇒ **OK (PCV)**

**2. Outgassing** of the LBE and the spallation target circuit

⇒ **OK (PCV)**

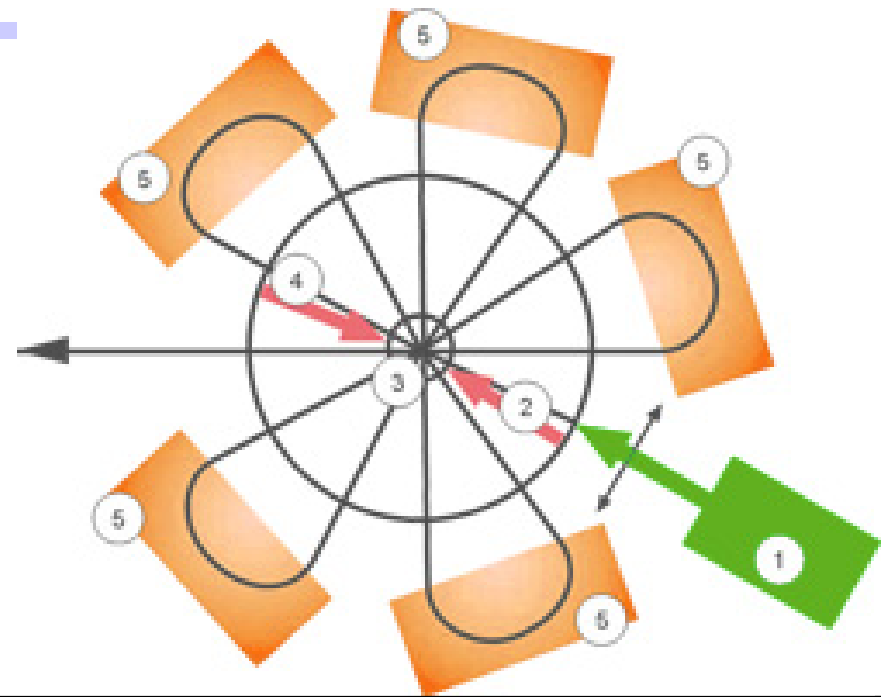
**3. Beam-surface interaction:** high density power deposition at the free surface

⇒ **WEBEXPIR**

# WEBEXPIR

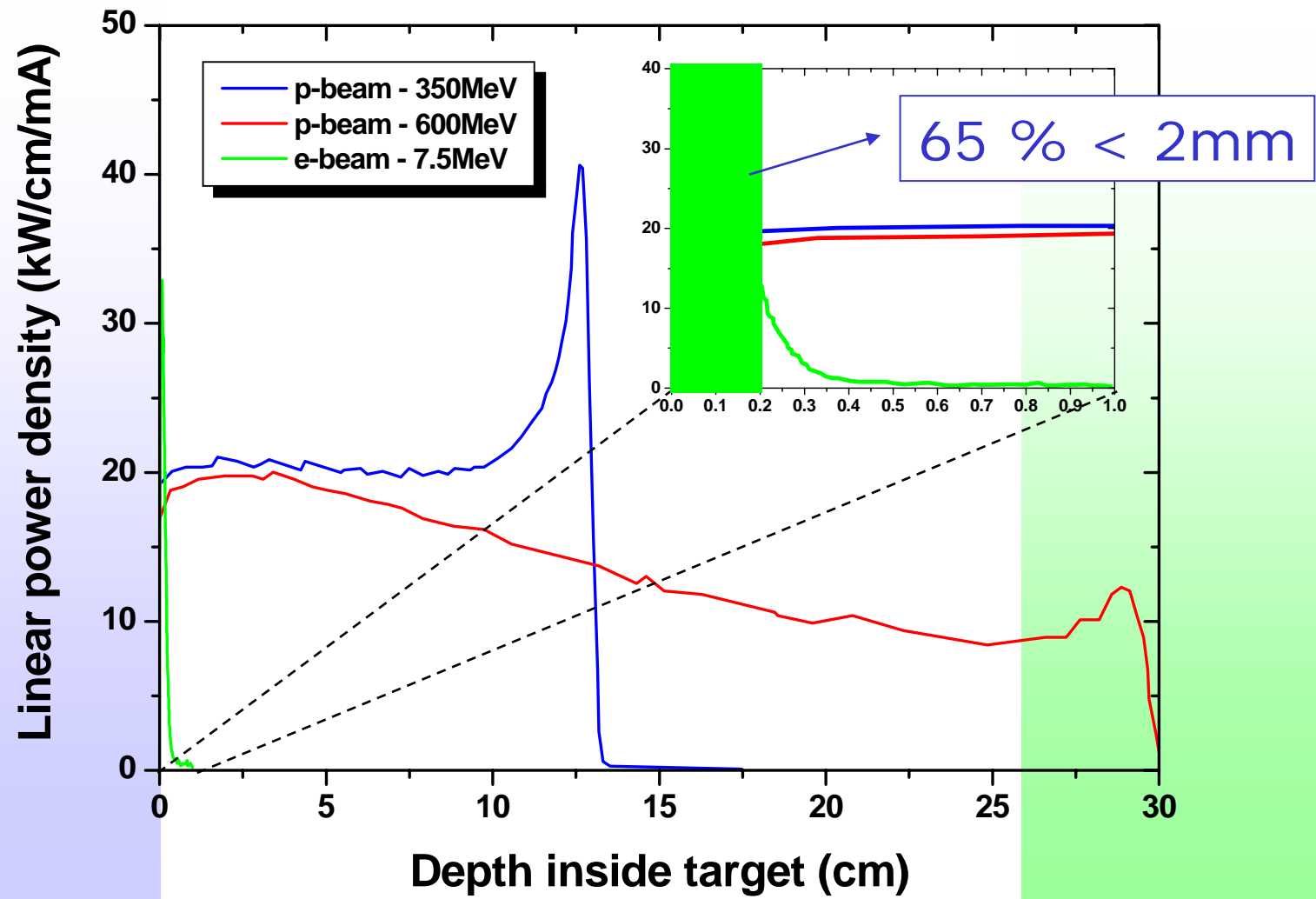
- = **W**indowless target **E**lectron **B**eam  
**EXP**erimental **IR**radiation
- Purpose
  - Check enhanced **evaporation** due to surface heating
  - Surface **distortion** and shockwave effects due to sudden beam on/off (droplet ejection, ...)
- Experiment
  - Small scale LBE **loop**
  - Beam – surface interaction in circumstances **representative** for XT-ADS spallation target
  - Surface heating with high intensity 7 MeV electron beam
    - TT1000 Rhodotron available at **IBA**
    - No activation issues

# Rhodotron TT1000



<b>Energy</b>	7 MeV e <sup>-</sup>
<b>Beam power range</b>	0.5 – 700 kW
<b>FWHM</b>	10 mm x 3 mm
<b>Number of passes</b>	6
<b>Diameter</b>	3.0 m
<b>Height</b>	3.3 m

# Power deposition in LBE

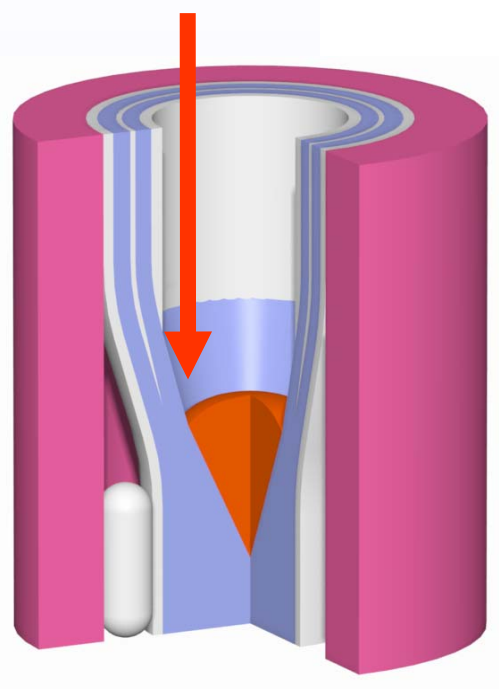




# WEBEXPIR power deposition

	XT-ADS target	WEBEXPIR target
Coolant / target	liquid Pb-Bi	liquid Pb-Bi
Beam energy	600 MeV p	7 MeV e <sup>-</sup>
Power deposition < 2mm	2 kW/mm/mA	2.2kW/mm/mA
LBE velocity	2.5 m/s	2.5 m/s
Beam "width"	170 mm c.f.	3 mm FWHM
Beam current	4 mA	<b>0.25 mA</b>

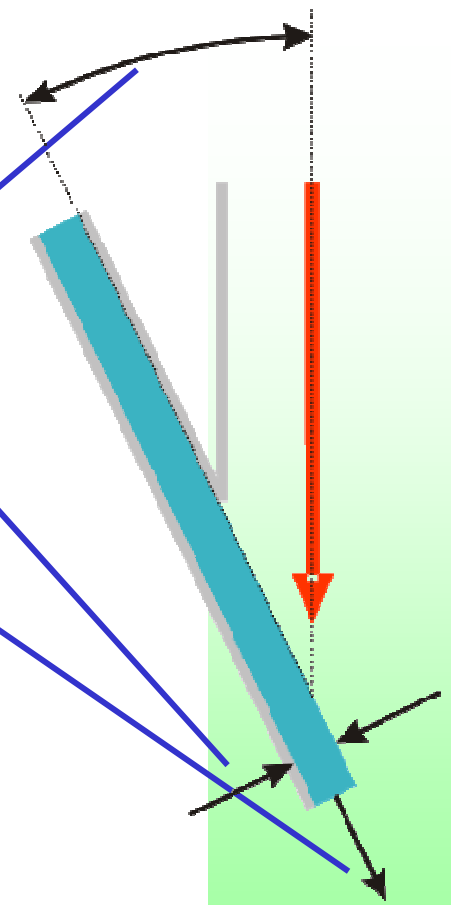
# Beam interaction point



XT-ADS

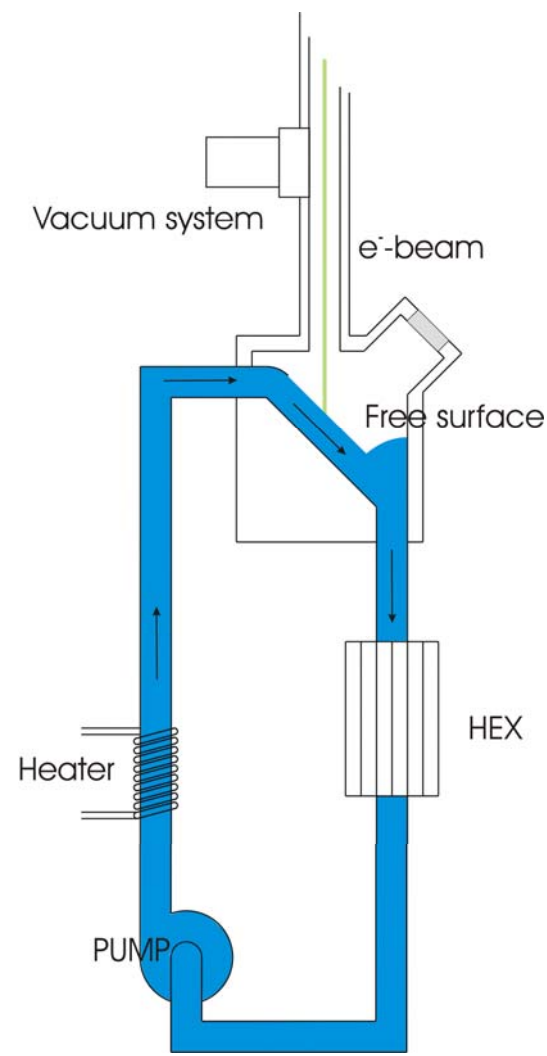
Unfolded nozzle with:

1. Angle : 26 deg
2. dLBE : 14.35 mm
3. Flow : 2.5 m/s
4. Confined
5. "Drag limitation"

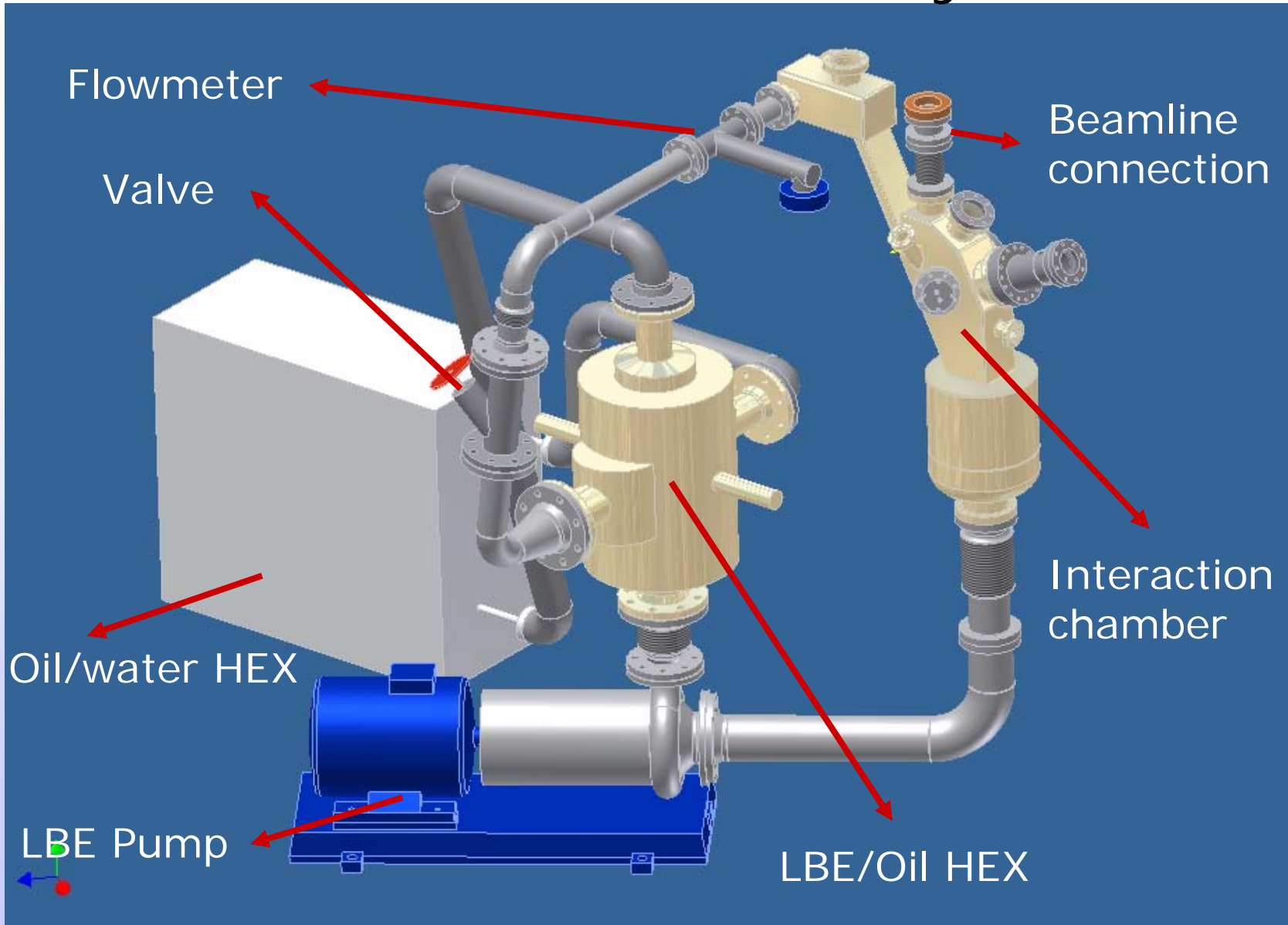


WEBEXPIR

# WEBEXPIR Loop layout (draft)



# WEBEXPIR Final layout

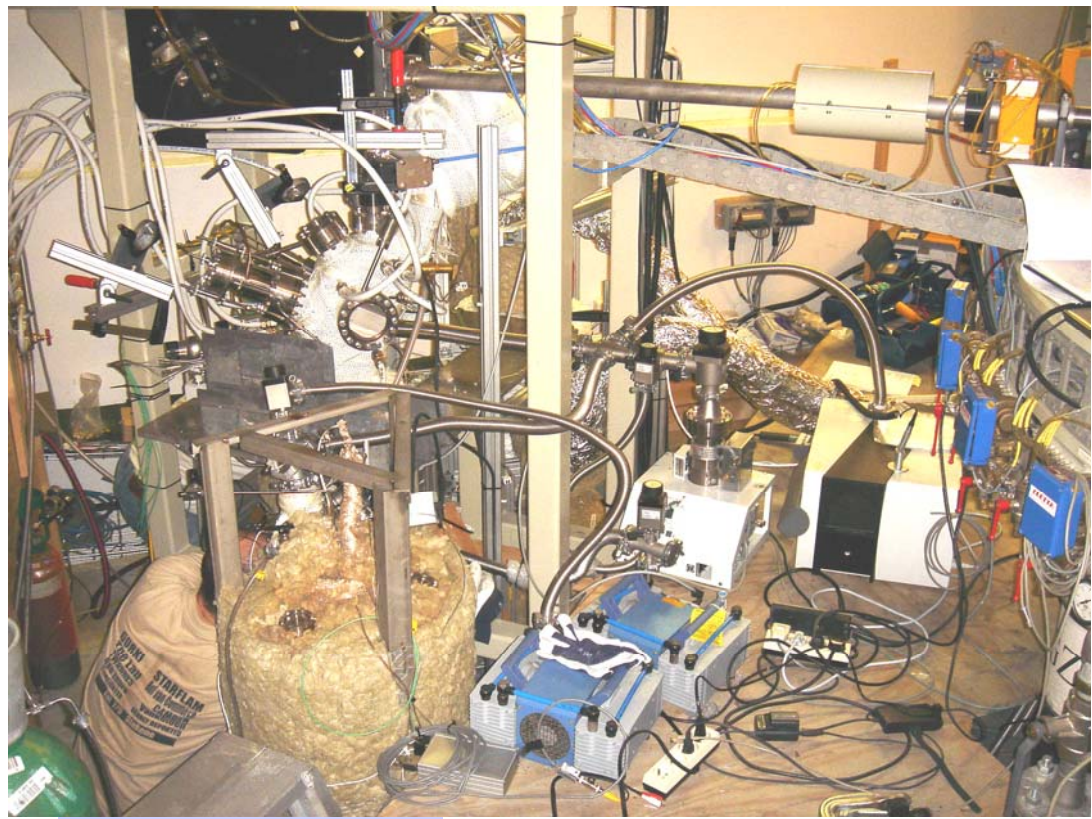


# Space constraints





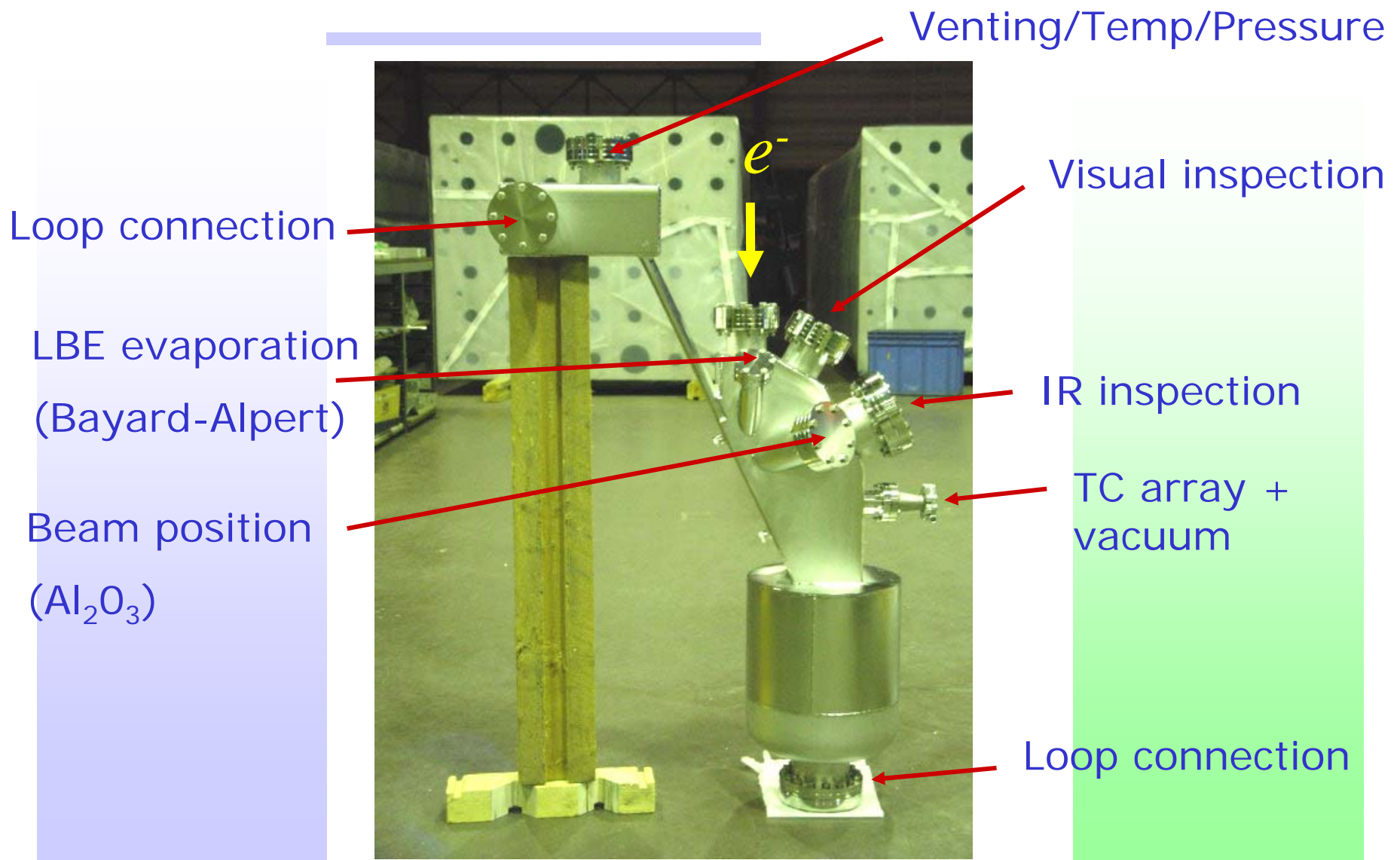
# WEBEXPIR Setup



# Diagnostics

- **Free surface distortion**
  - Visual observation: video + IR recording
  - Pressure transducers underneath flow
- **Enhanced evaporation**
  - Vacuum pressure gauges (BA + Pirani)
  - Condensation station (LBE evaporation)
- **Monitoring**
  - Temperature
    - Thermocouples
    - IR camera on beamspot
    - Thermocouple array downstream from beam spot
  - LBE flow
  - Beam current + shape

# WEBEXPIR Interaction chamber





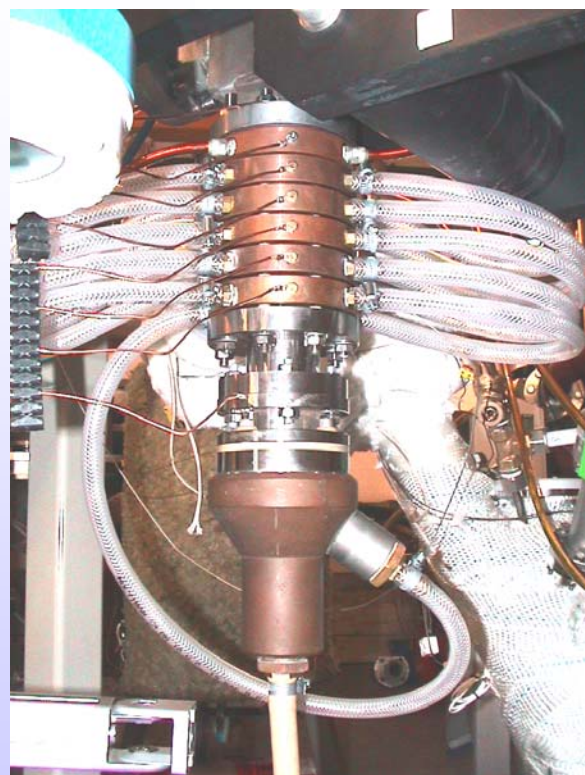
# Tests

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- Beam profile measurements
  - 100  $\mu$ A – 4 mA
- Visual inspection
  - 100  $\mu$ A – 5 mA
- IR inspection
  - 100  $\mu$ A – 7.5 mA
- LBE evaporation
  - 100  $\mu$ A – 10 mA
- Pressure, flow and temperature measurements

# Beam profile

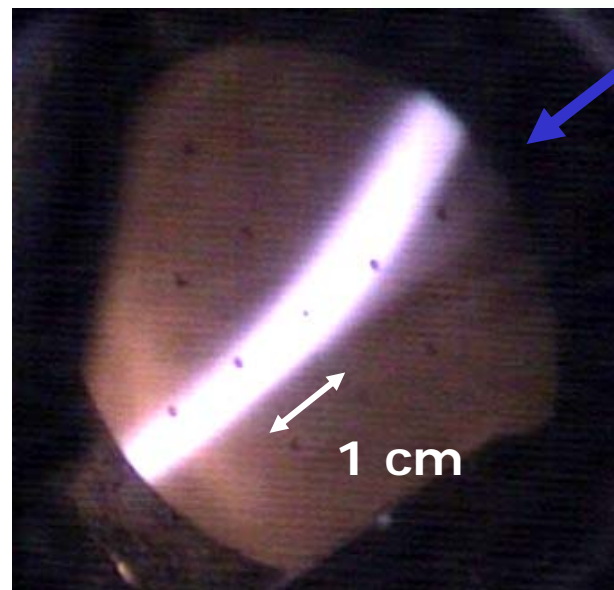
## Collimator stack



100  $\mu$ A – 4 mA

$\text{Al}_2\text{O}_3$

LBE



→ FWHM / flow	10 mm
→ FWHM $\perp$ flow	3 mm

# Visual inspection

- Visual inspection : 100  $\mu\text{A}$  – 5 mA
  - No shockwave effects detected
  - “Blue light”
  - Droplets ejection : impossible to see



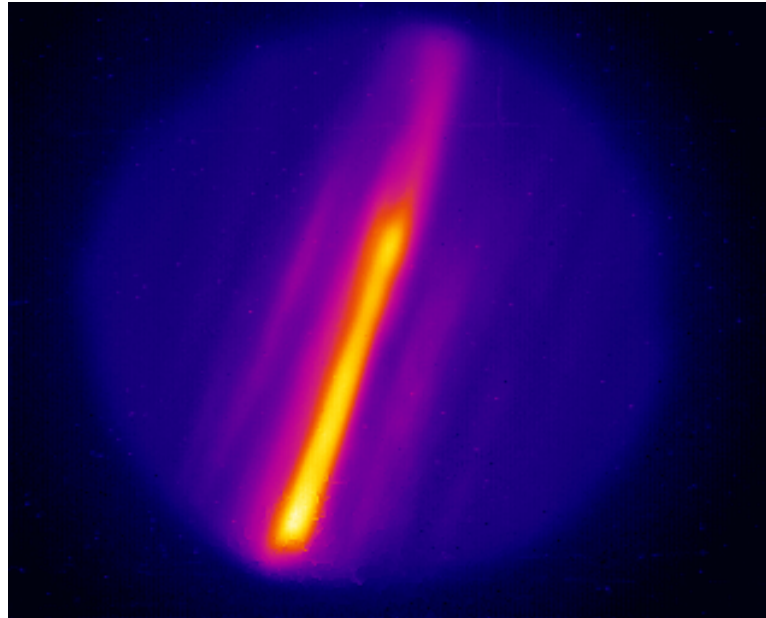
**0  $\mu\text{A}$**



**400  $\mu\text{A}$**

# IR inspection

- Thermocouple array : 100  $\mu\text{A}$  – 500  $\mu\text{A}$
- IR inspection : 100  $\mu\text{A}$  – 7.5 mA
  - Significant surface heating verified (  $\gg 100^\circ\text{C}$  )
  - Significant flow “mixing” detected



**1500  $\mu\text{A}$**

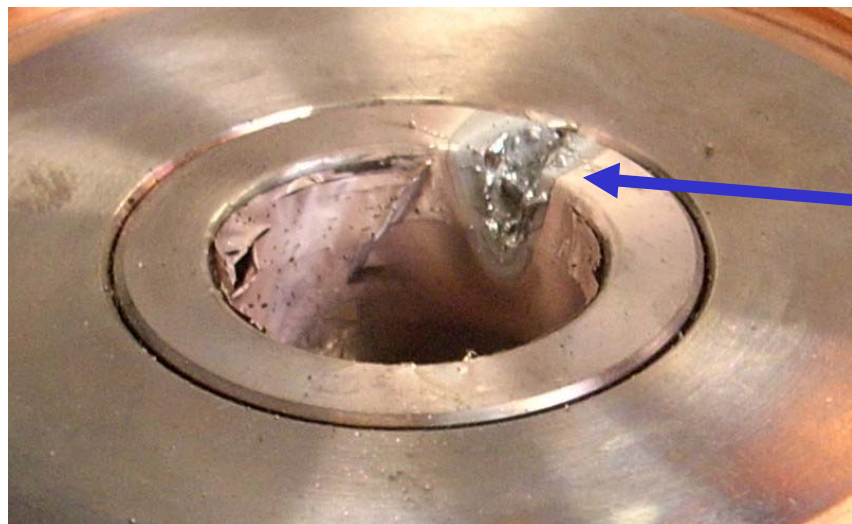
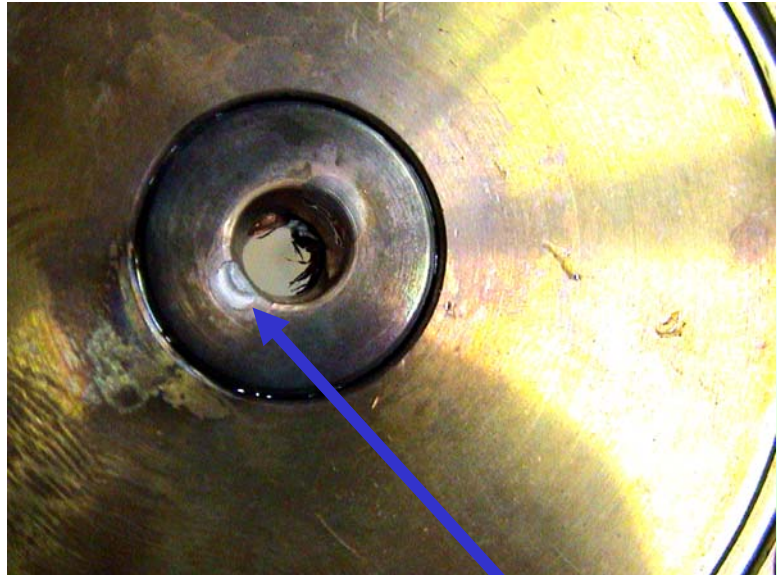
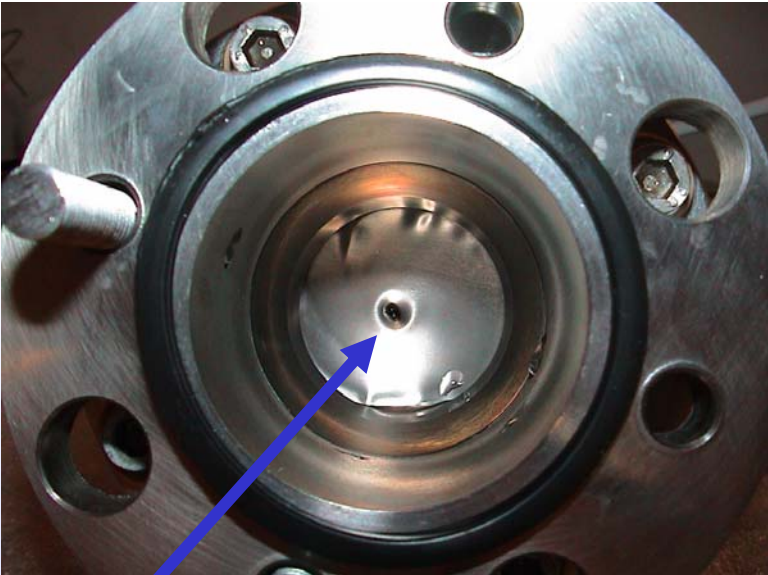
# Enhanced evaporation

- Pressure measurement (BA + Pirani):  
100  $\mu\text{A}$  – 10 mA
  - Pressures stay well below  $10^{-4}$  mbar at 10 mA
  - Pressure “flashes” > 5 mA might point to droplet evaporation
- Condensation
  - Under analysis





# More power ...



# Conclusions

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- Various tests at beam currents up to 10mA (= 40 x XT-ADS)
  - No shockwave effects detected
  - No significant droplet ejection effects
  - No significant evaporation enhancement
- ➔ WEBEXPIR free surface flow was not disturbed by the interaction with the electron beam and that vacuum conditions stay well within the design specifications

# Contributors

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