

## **Air-kerma determination using a variable-volume cavity standard at the BIPM**

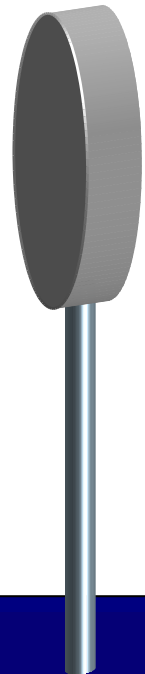
**D T Burns, C Kessler, P Roger**

**LNE-LNHB / BIPM Workshop on  
Absorbed Dose and Air Kerma Primary Standards  
May 2007**



# Outline

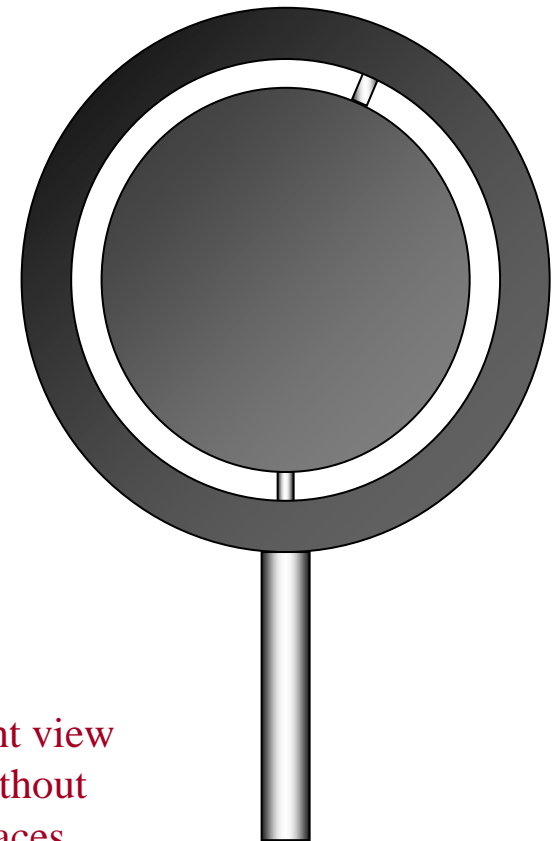
- Principle of measurement
- Chamber design
- Volume measurements
- Ionization current measurements
- Monte Carlo calculations
- Results and conclusions



# Principle of measurement

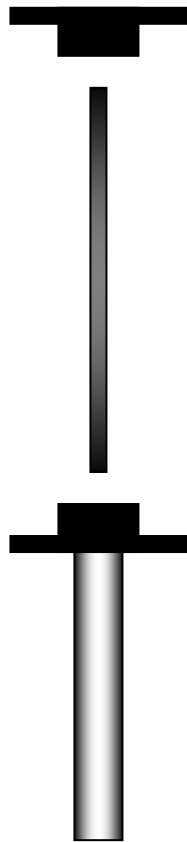
- Motivation
  - international comparison results for  $K_{\text{air}}$ 
    - high degree of correlation
  - treatment of ‘difficult’ volume components
- Differential measurement
  - replace  $(I / m)$  by  $(\Delta I / \Delta m)$
  - measure  $I$  for different chamber volumes
  - ‘difficult’ volume components cancel

# Chamber design

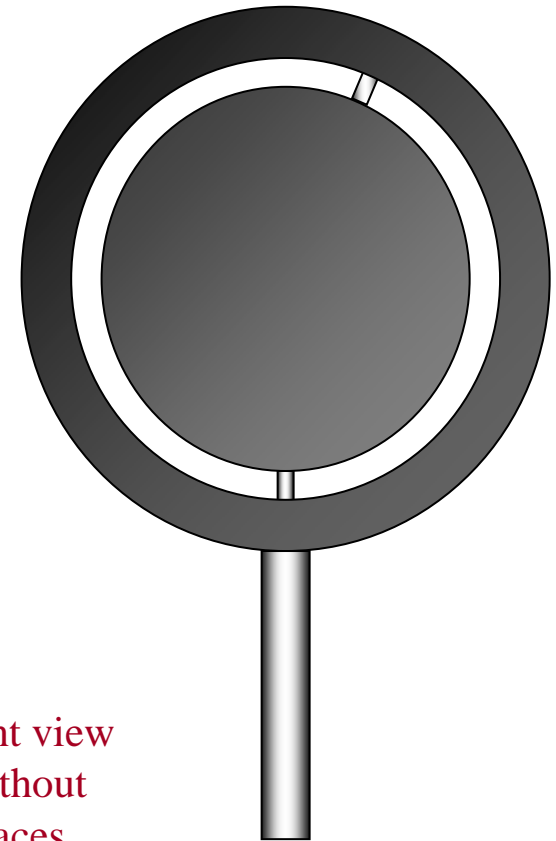


Front view  
without  
faces

# Chamber design

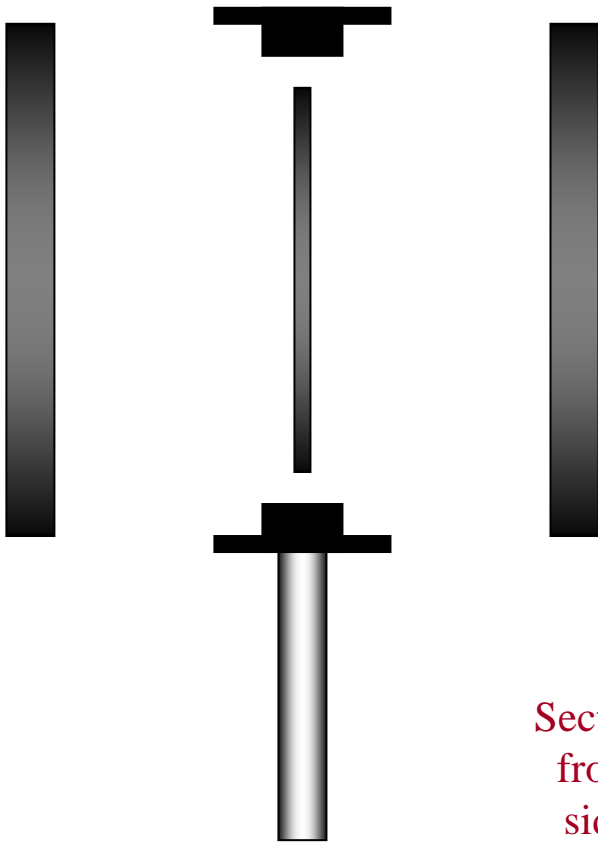


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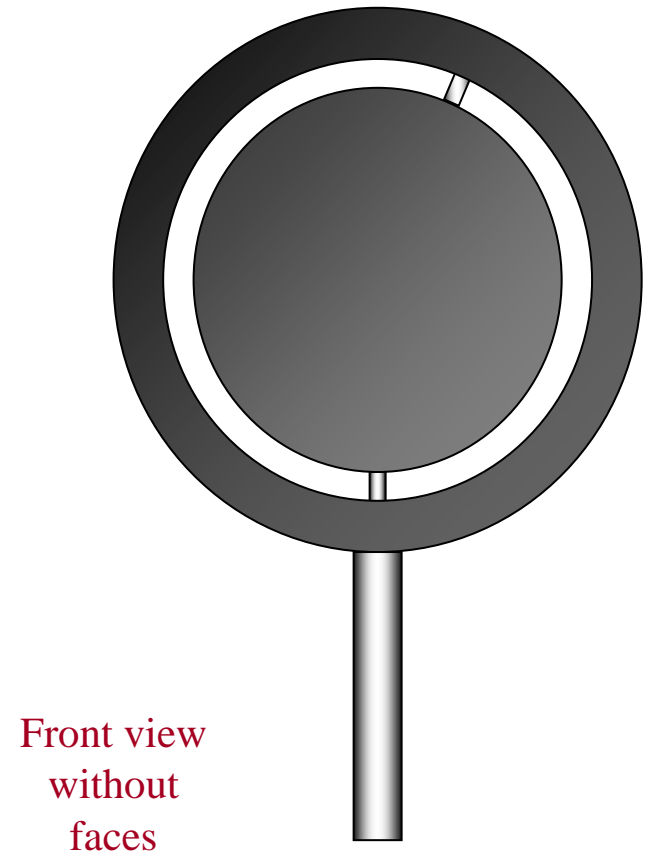


Front view  
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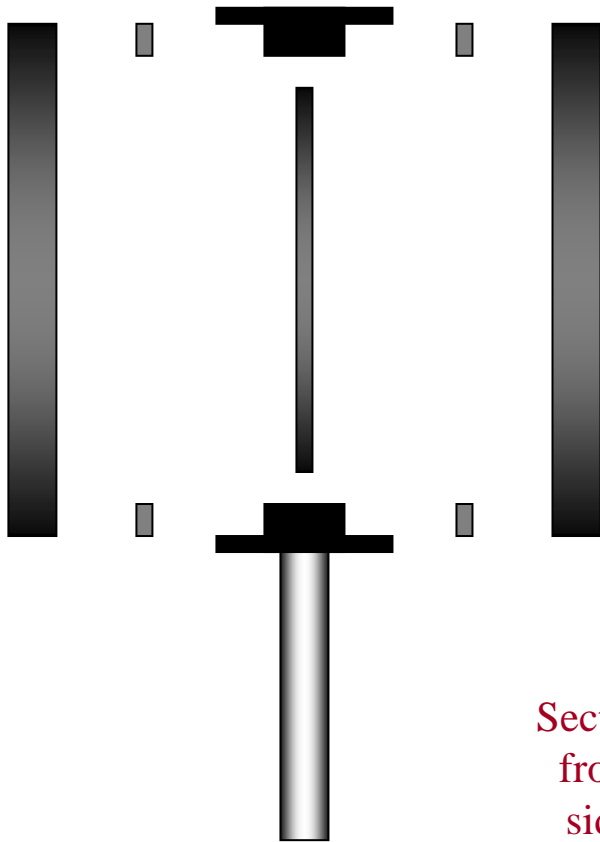


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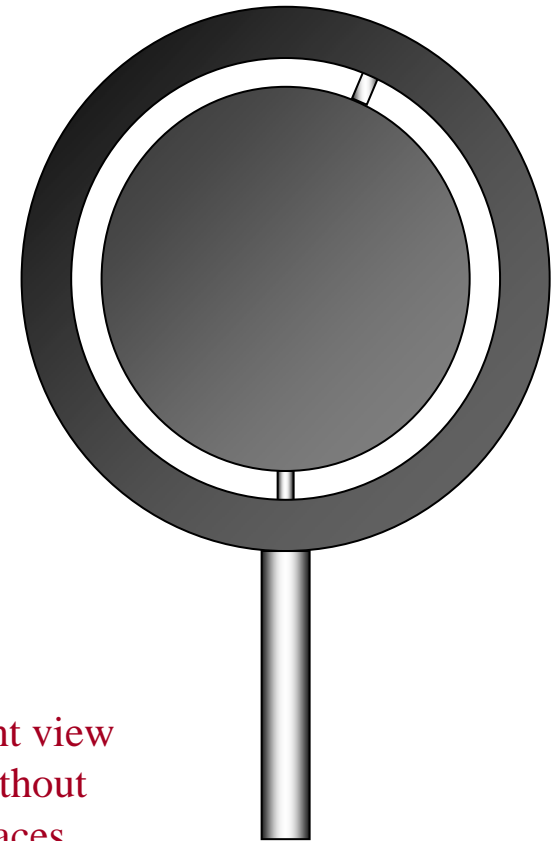


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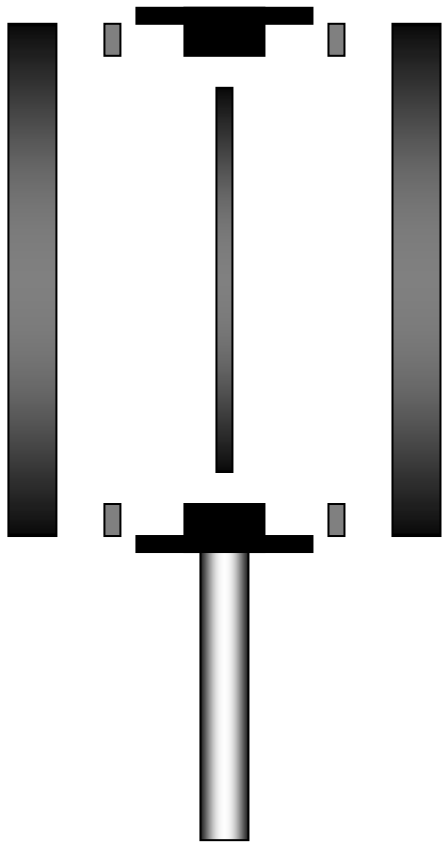


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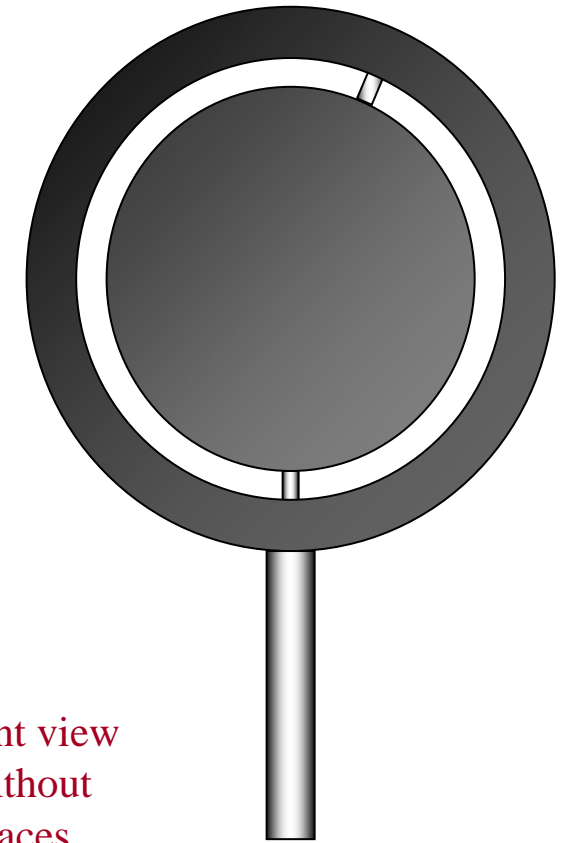


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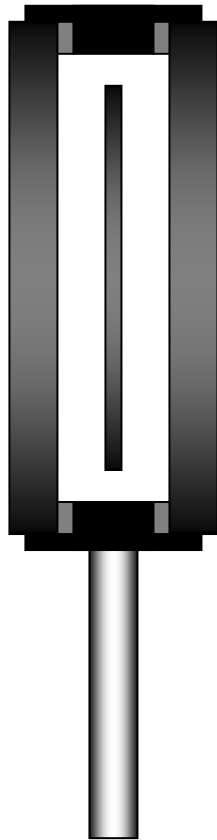


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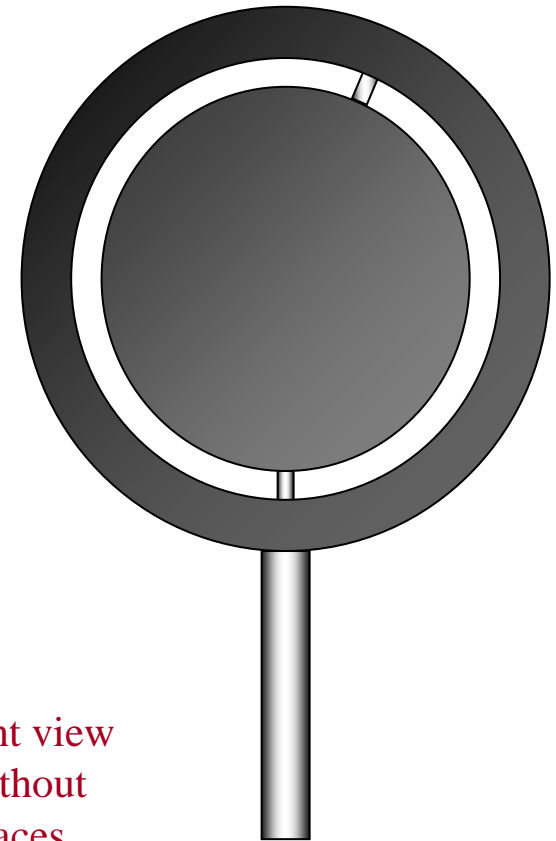


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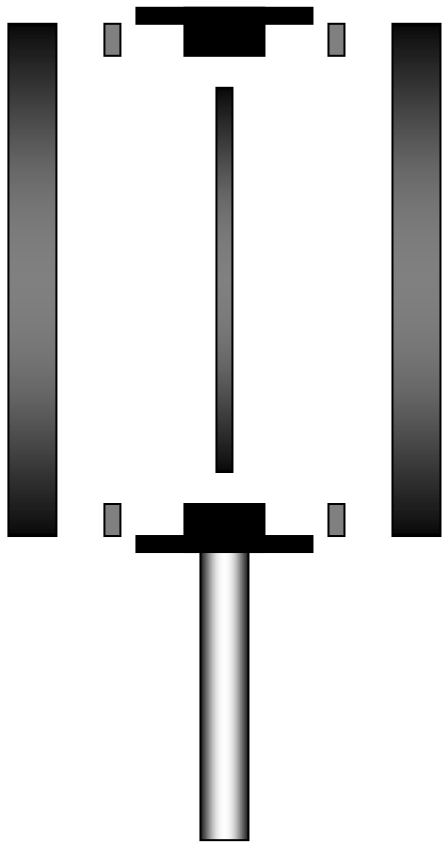


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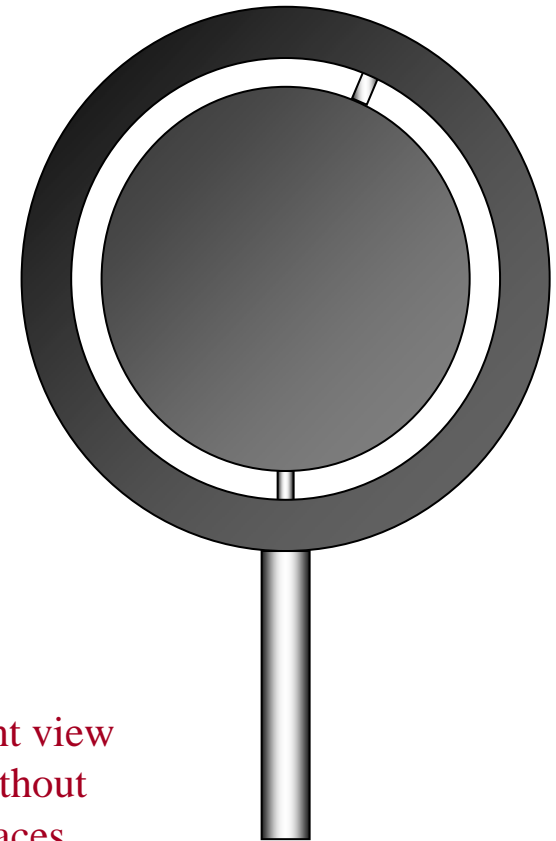


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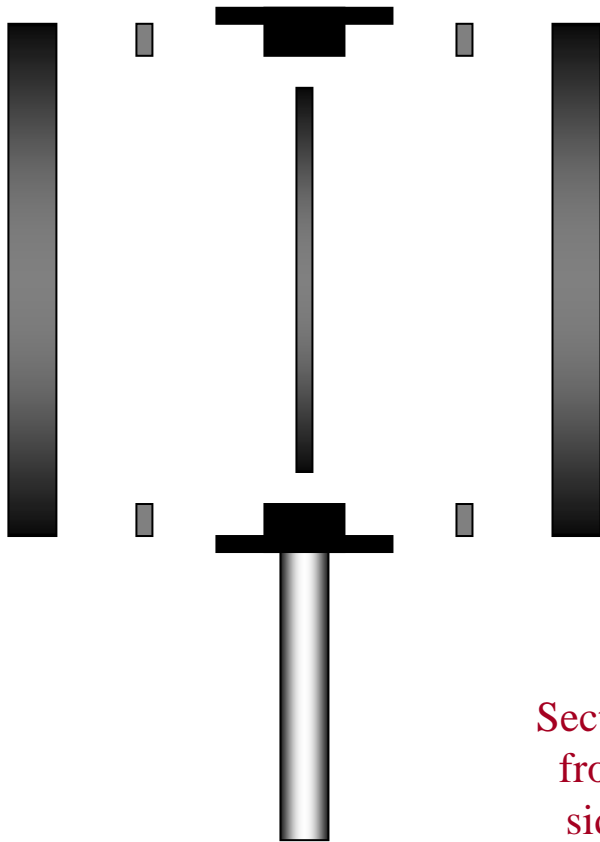


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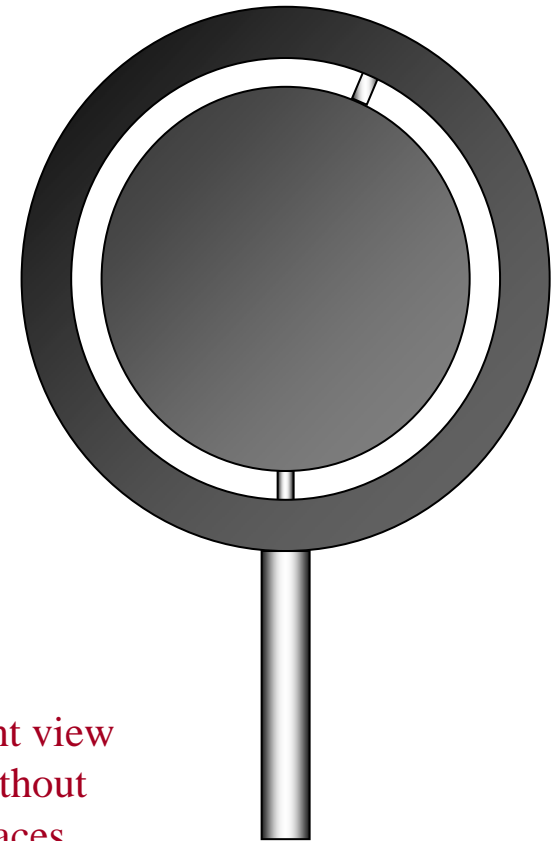


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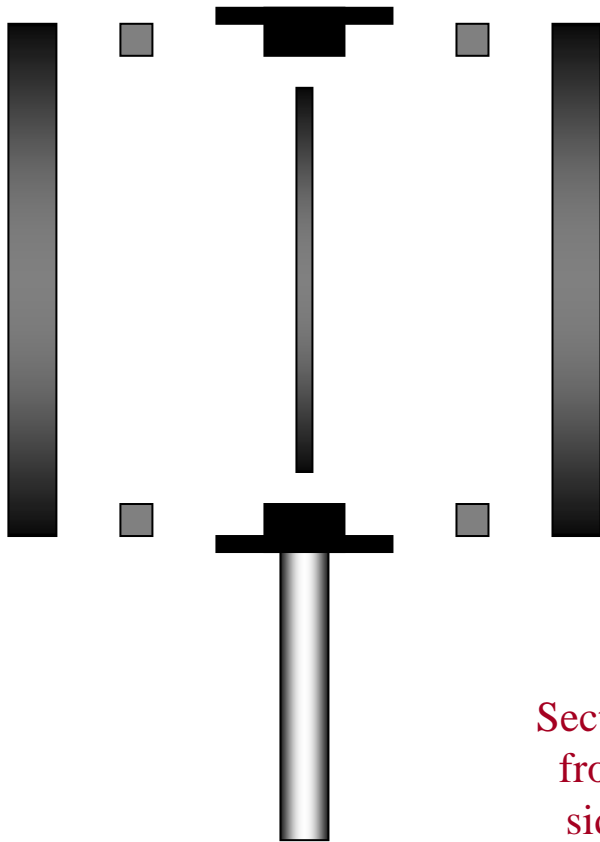


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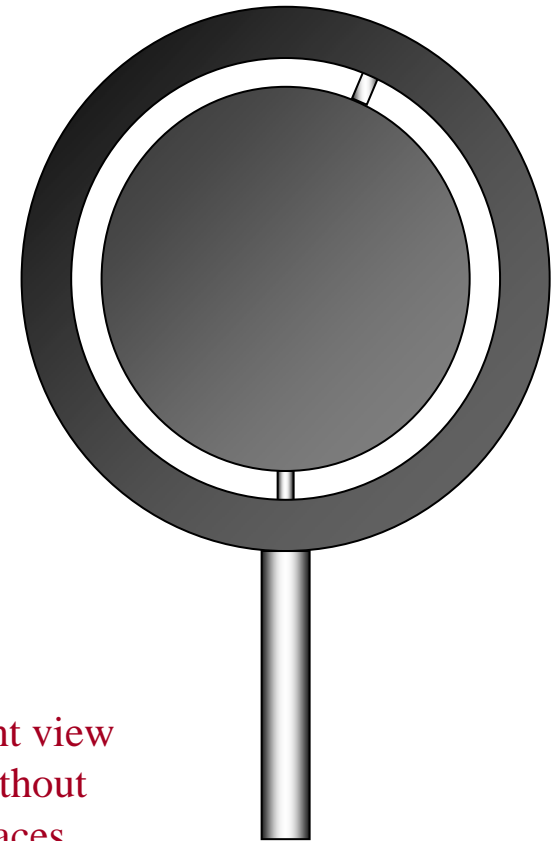


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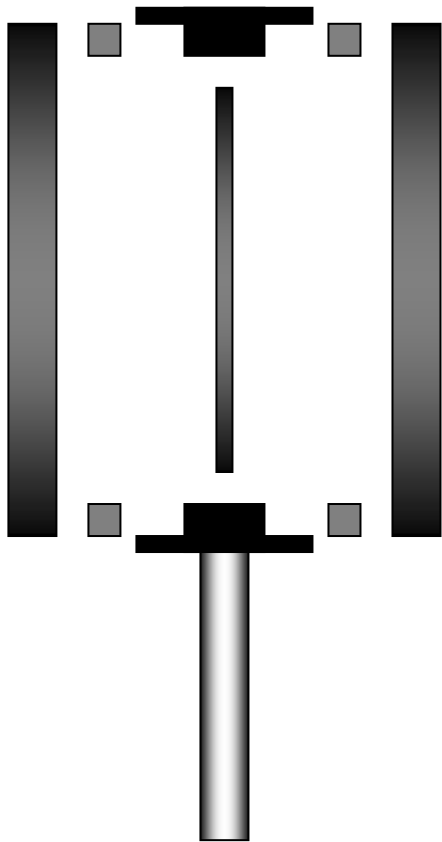


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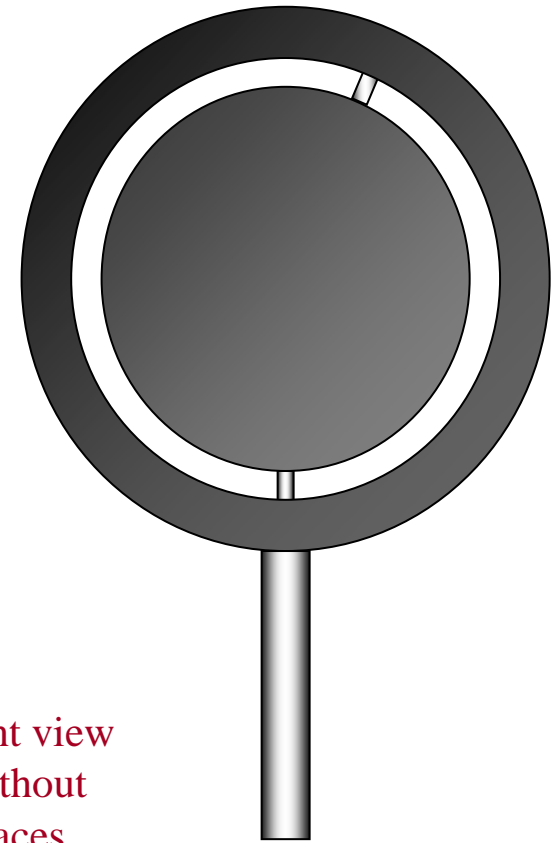


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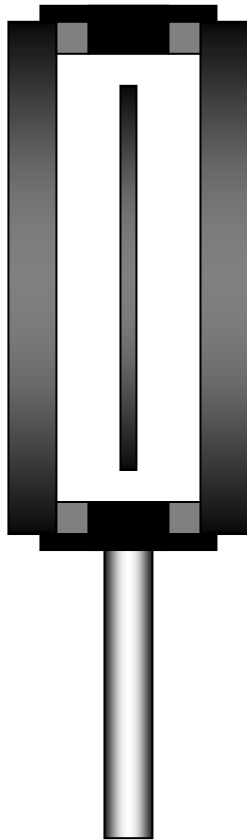


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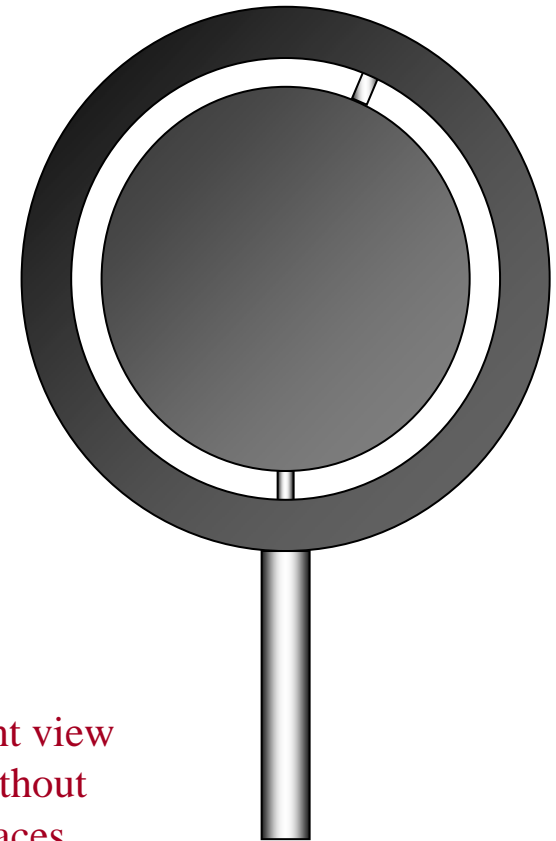


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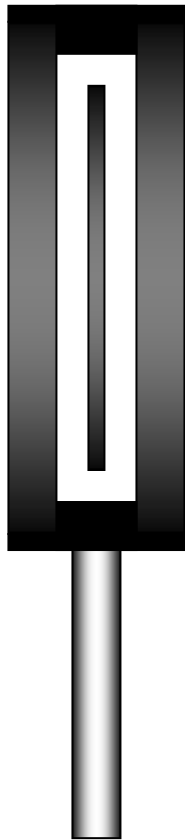


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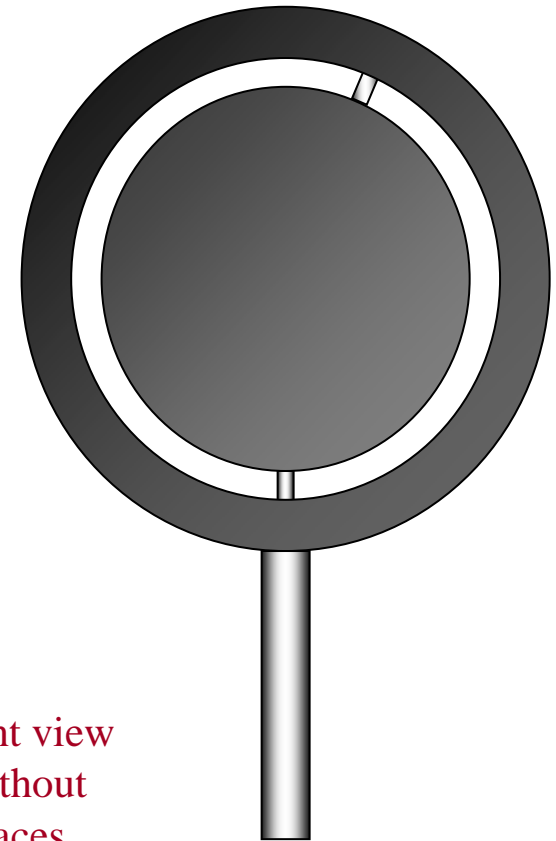


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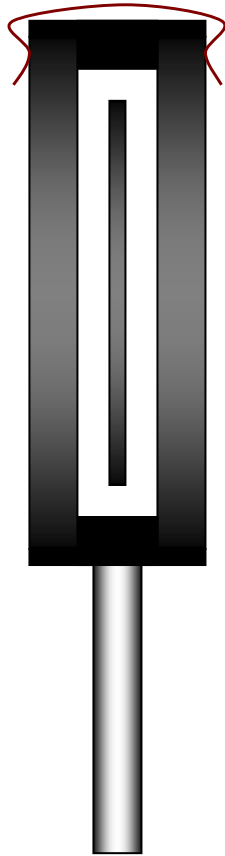


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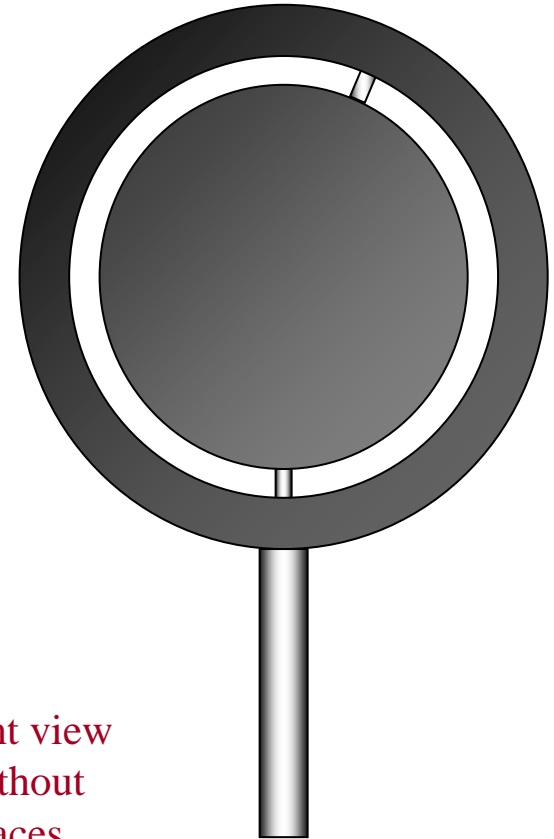


Front view  
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# Chamber design



Section  
from  
side



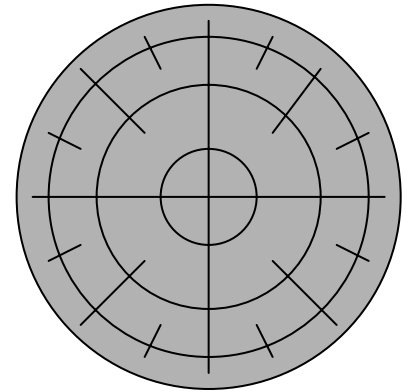
Front view  
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faces

# Volume measurement

- Co-ordinate measuring machine (CMM)
  - micrometer resolution
  - regular re-calibration using reference blocks
- Measurements before any assembly:
  - thickness of faces and collector
  - area of cavity, collector and rings
- Measurements at each assembly:
  - total outer thickness

# Volume measurement - thickness

- Each thickness measured at 29 points
  - 1 at centre, 4 at  $r_1$ , 8 at  $r_2$ , 16 at  $r_3$
  - radii chosen so each measurement represents same area
  - mean thickness correctly weighted for volume determination
- Each component measured several times
  - mean thickness reproducible to  $0.3 \mu\text{m}$
  - calibration uncertainty  $1 \mu\text{m}$



# Volume measurement - area

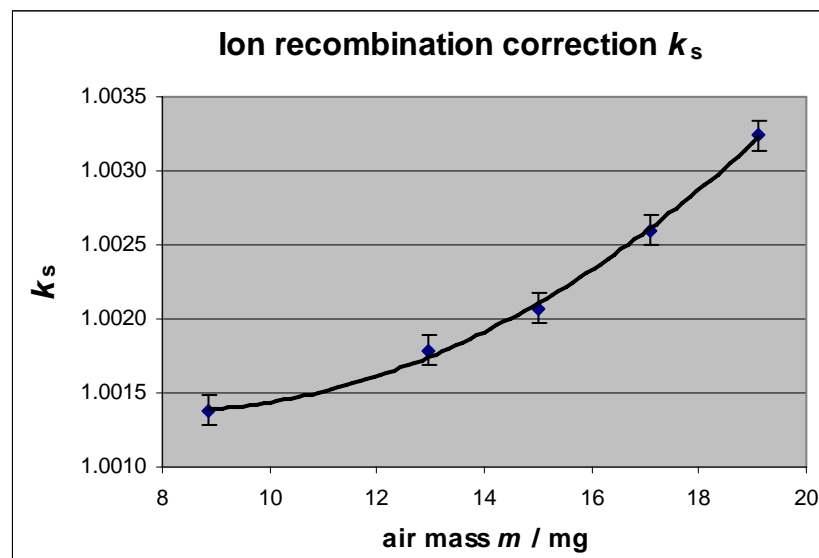
- Each circumference measured at 32 points
  - CMM in diameter mode
    - yields mean diameter
  - analyse data independently
    - use computer-assisted drawing package to evaluate area from same input data
  - agreement always better than 2 parts in  $10^4$

# Volume measurement - other

- Two aluminium supports for collector
  - total of  $11.5 \text{ mm}^3$
  - standard uncertainty  $1 \text{ mm}^3$
- Volume at base of collector
  - $2.3 \text{ mm}^3$
  - standard uncertainty  $1 \text{ mm}^3$
- Estimates not required for differential method

# Ionization measurements

- BIPM reference conditions
  - 20 °C, 101.325 kPa, 50 % RH
  - 10 cm square field, 1 m
- Correct for:
  - polarity effect
  - stem scatter
  - ion recombination

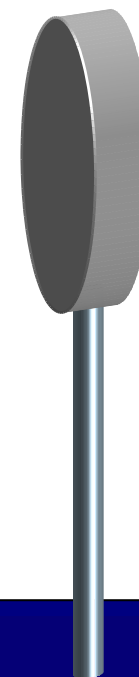


# Ionization measurements

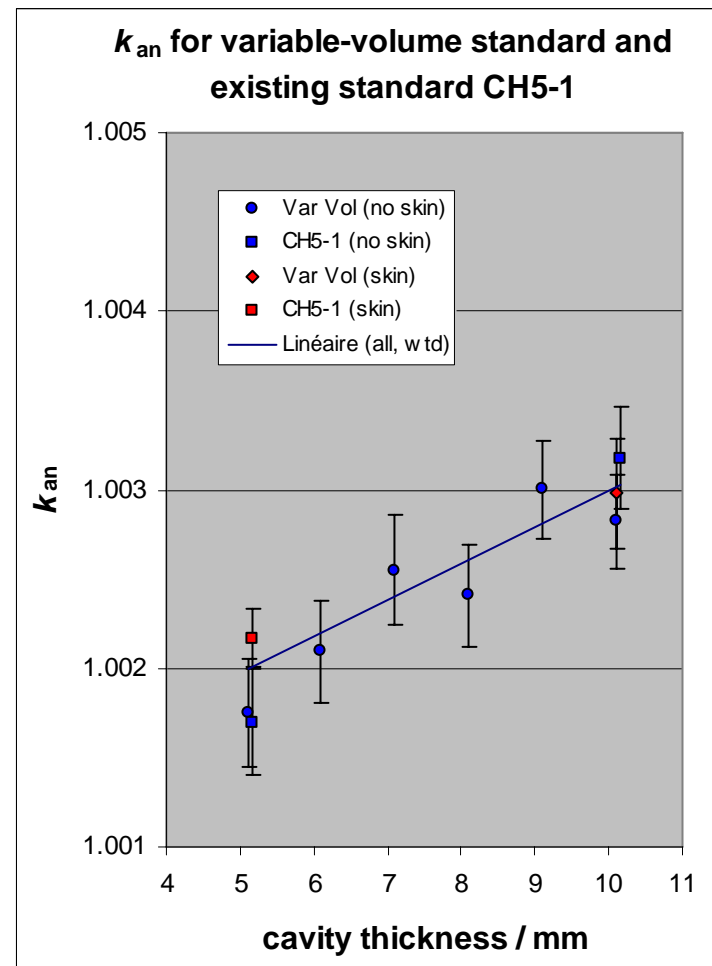
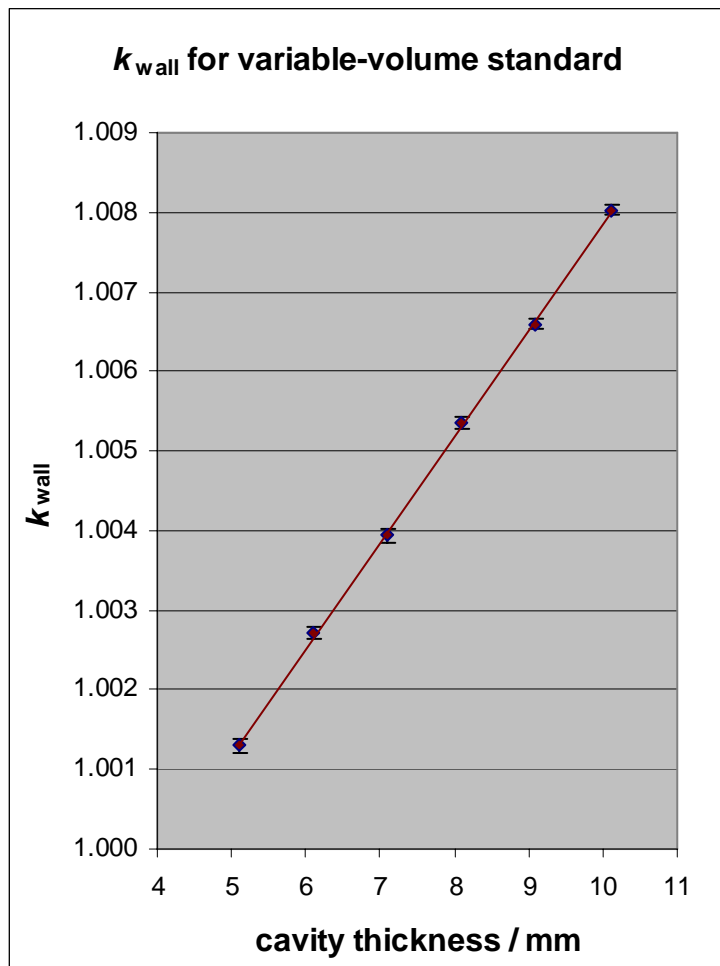
- Chamber mounted 16 times
  - 3 or 4 times for each of 5 configurations
- Reproducibility of  $I / m$  for each configuration
  - measure of extent to which volume changes can be evaluated from changes in external thickness measurement
  - typically 1.5 parts in  $10^4$

# Monte Carlo calculations

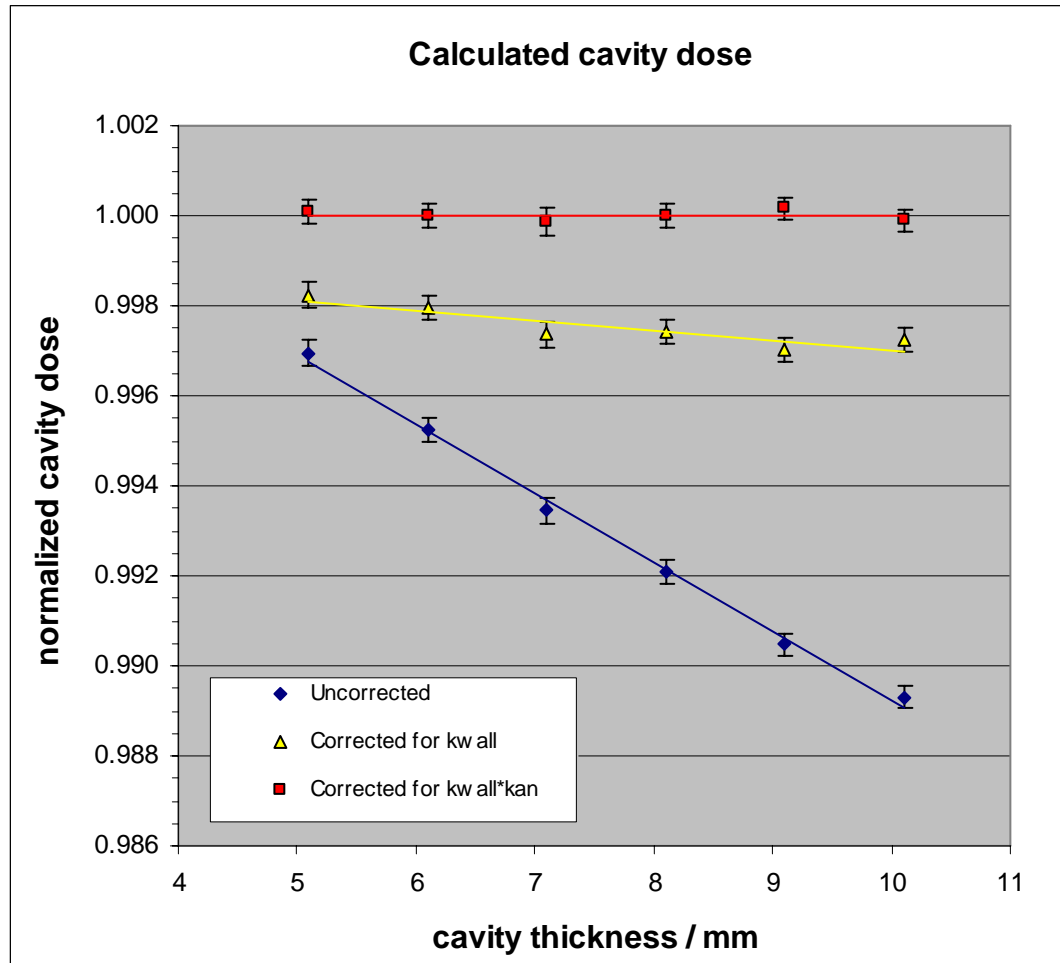
- Follow on from calculation of correction factors for BIPM air-kerma standard using PENELOPE
  - now published as Burns D T (2006) Phys. Med. Biol. **51** 929–942



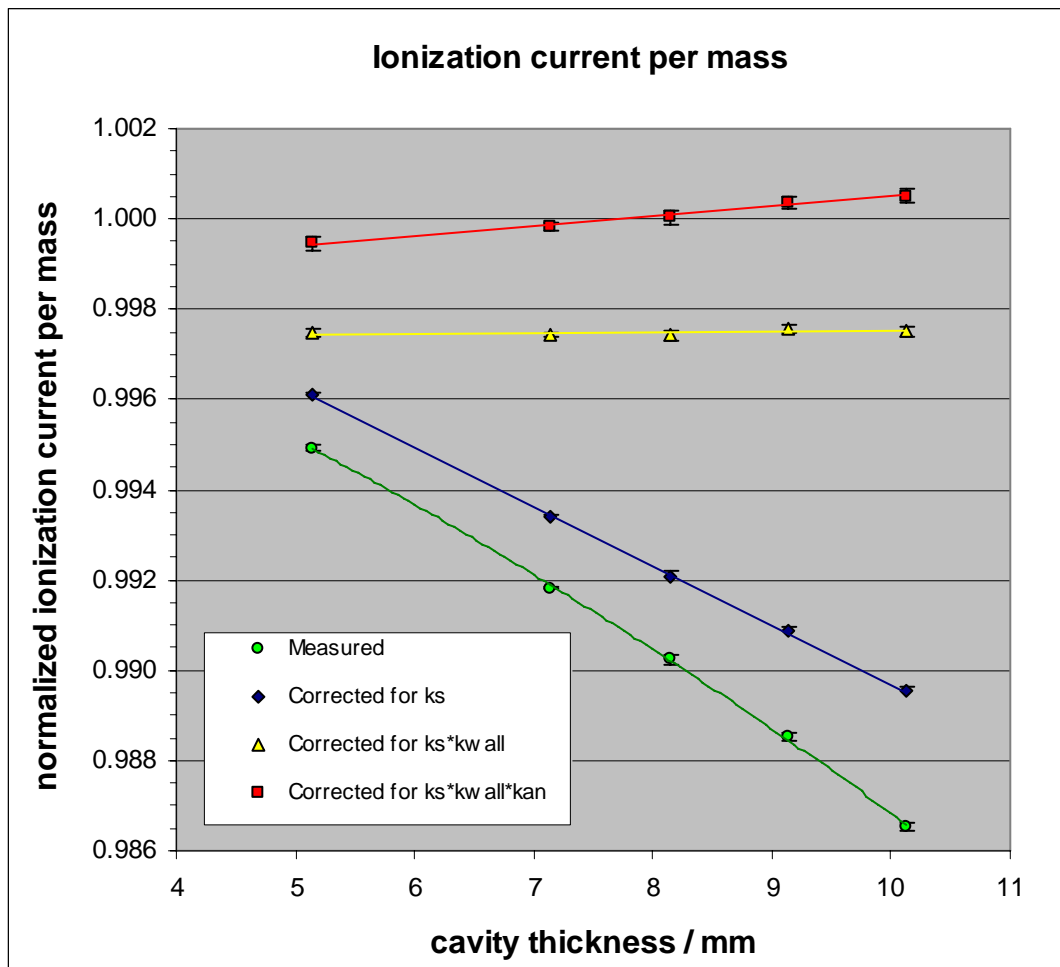
# Monte Carlo $k_{\text{wall}}$ and $k_{\text{an}}$



# Monte Carlo cavity dose



# Results



# Conclusions

- Possible explanations for trend
  - constant error in volume estimate
    - need to reduce all estimates by  $13 \text{ mm}^3$
    - implies largest configuration closest to true  $K_{\text{air}}$
  - $k_{\text{wall}}$  overestimate
    - need to reduce  $(k_{\text{wall}} - 1)$  by 15 %
    - implies smallest configuration closest to true  $K_{\text{air}}$
  - some other effect in chamber ?