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Monte Carlo simulations as a tool for the development of a new reference ionisation chamber

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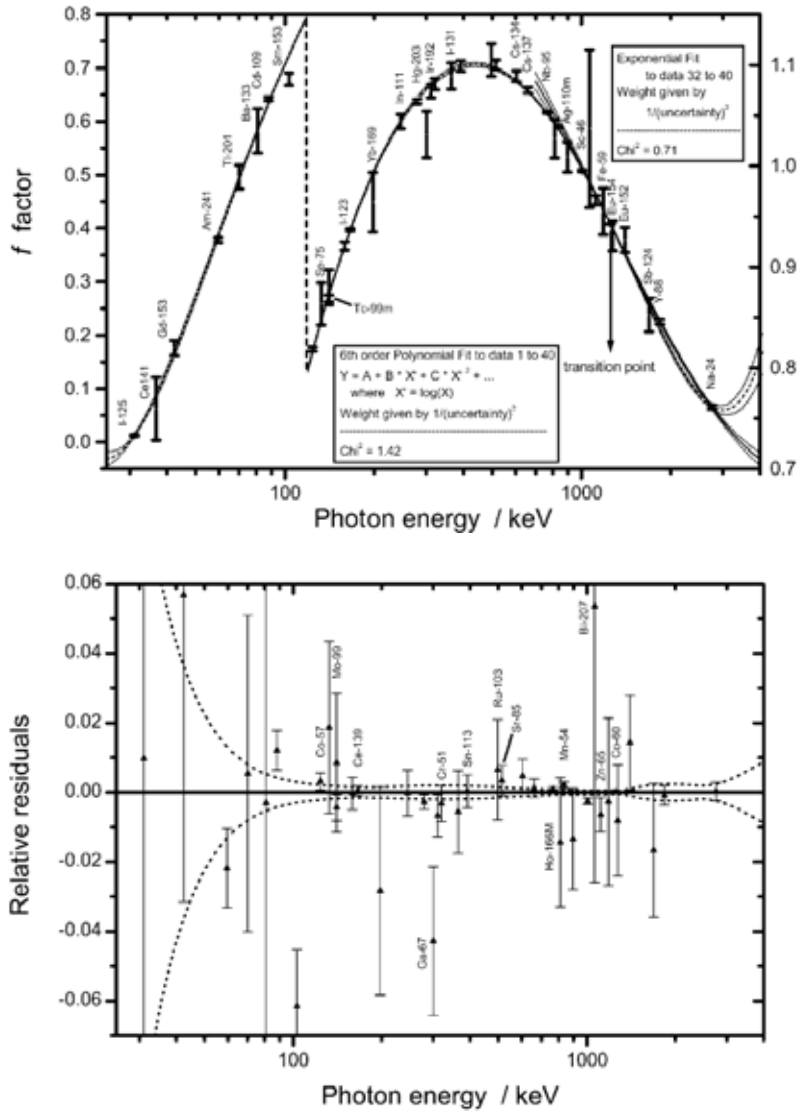
Motivation ……



SIR (Système International de Référence) chamber at BIPM

- 4π well-type ionisation chamber (IG11, 2 MPa N_2)
- 30 years of calibrations, >60 radionuclides (photon and pure beta)
- Comparison with ^{226}Ra reference source (equivalent activity A_e)

BUT

- What if any component breaks down?
- Sensitivity to low photon energies

C. Michotte, Appl. Rad. Isot. 56 (2002)15-20

Motivation ……

Development of a new reference IC:

"determination of design and operation criteria for a cylindrical IC system which should guarantee a reproducible output at the level of a few tenths of a percent for different chambers constructed according to these criteria"

- Original idea : Reher (IRMM), Woods (NPL), Denecke (IRMM)
- Proto-type chamber based on NPL IC
- MC simulations :
  - L. Johansson, A. Švec/J. Gasparro (EGS-4),
  - this work (MCNP)

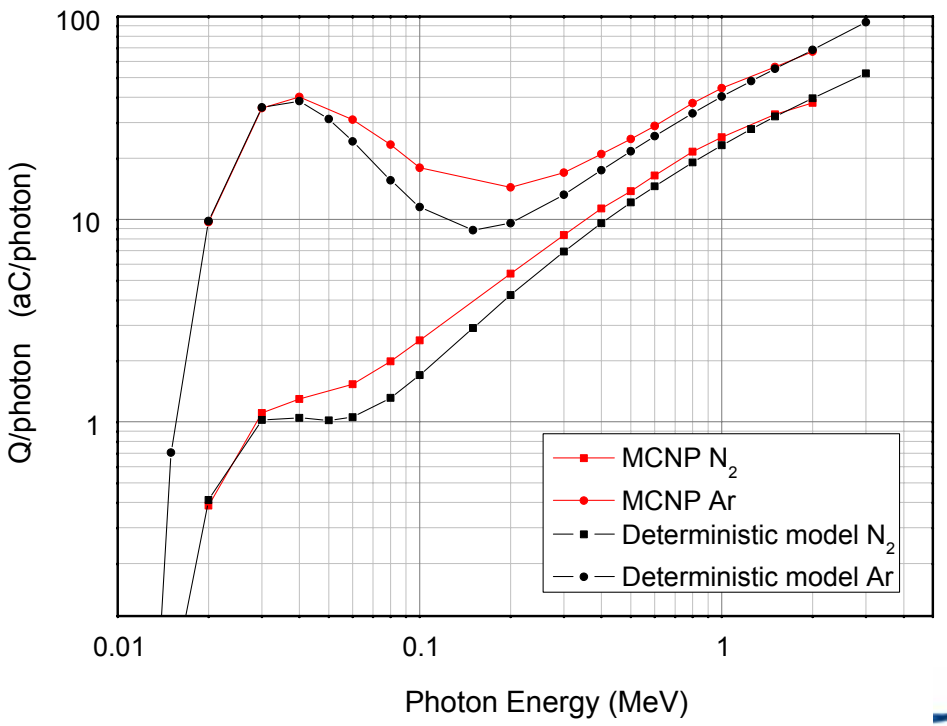
.. MC simulations ....

In development process several methods used :

- Deterministic model of cylindrical IC
- Measurements with proto-type chamber
- MC simulations

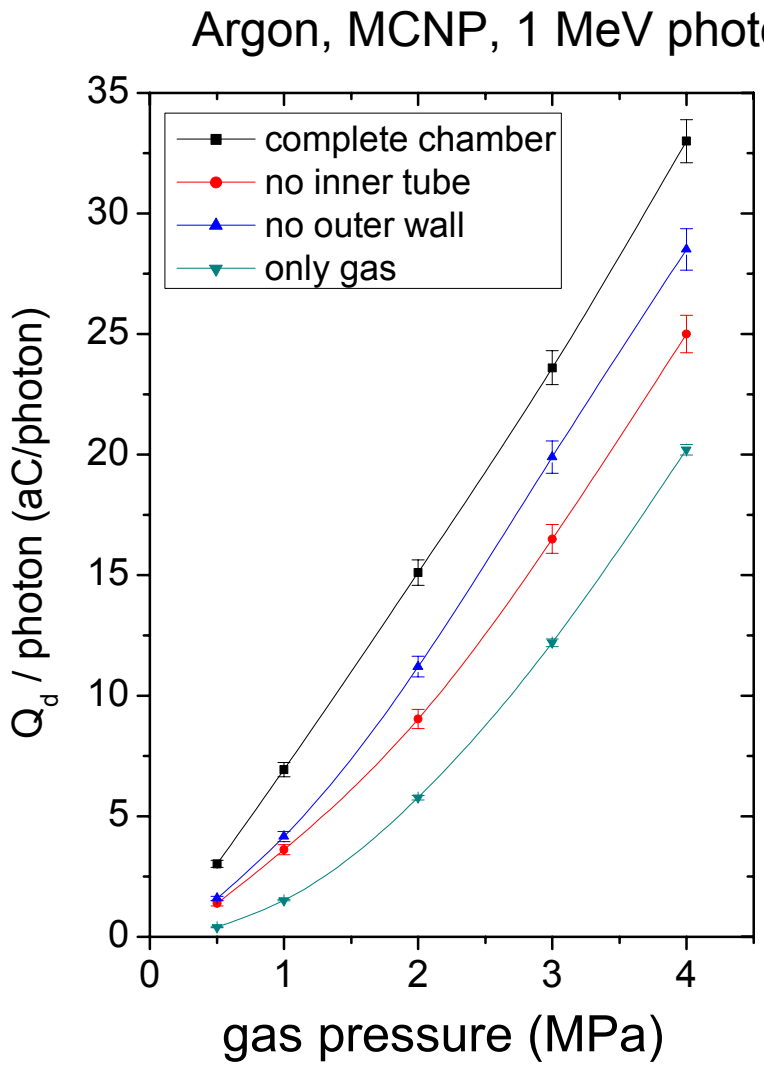
  MCNP4c

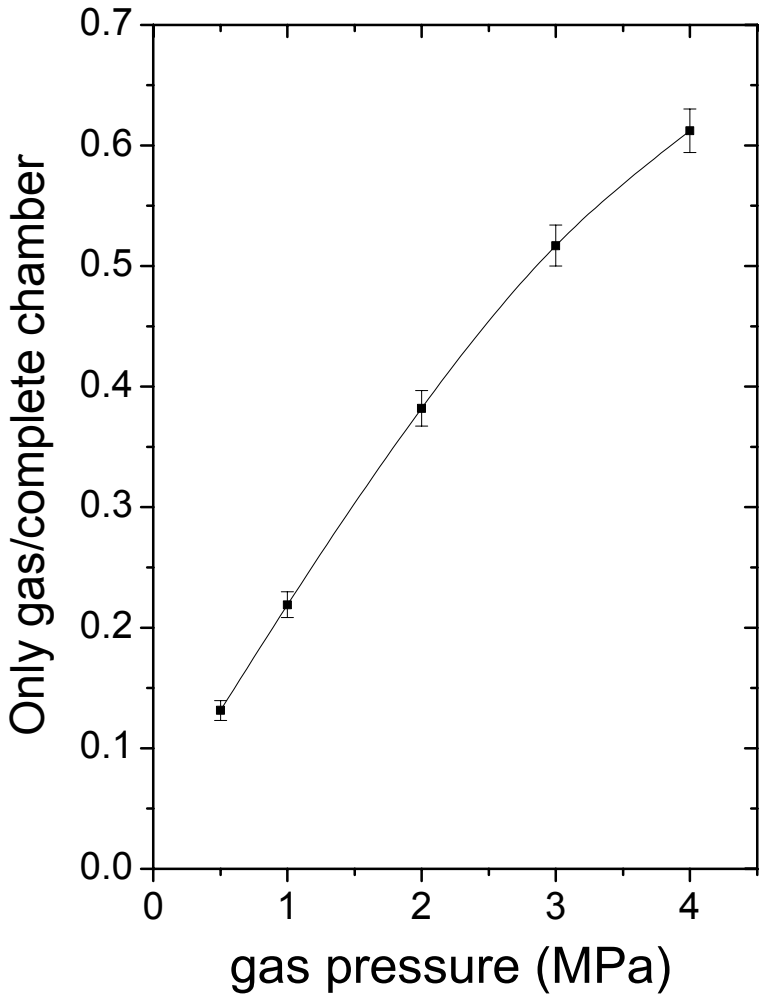
  MCNP5.1



.. MC simulations ....

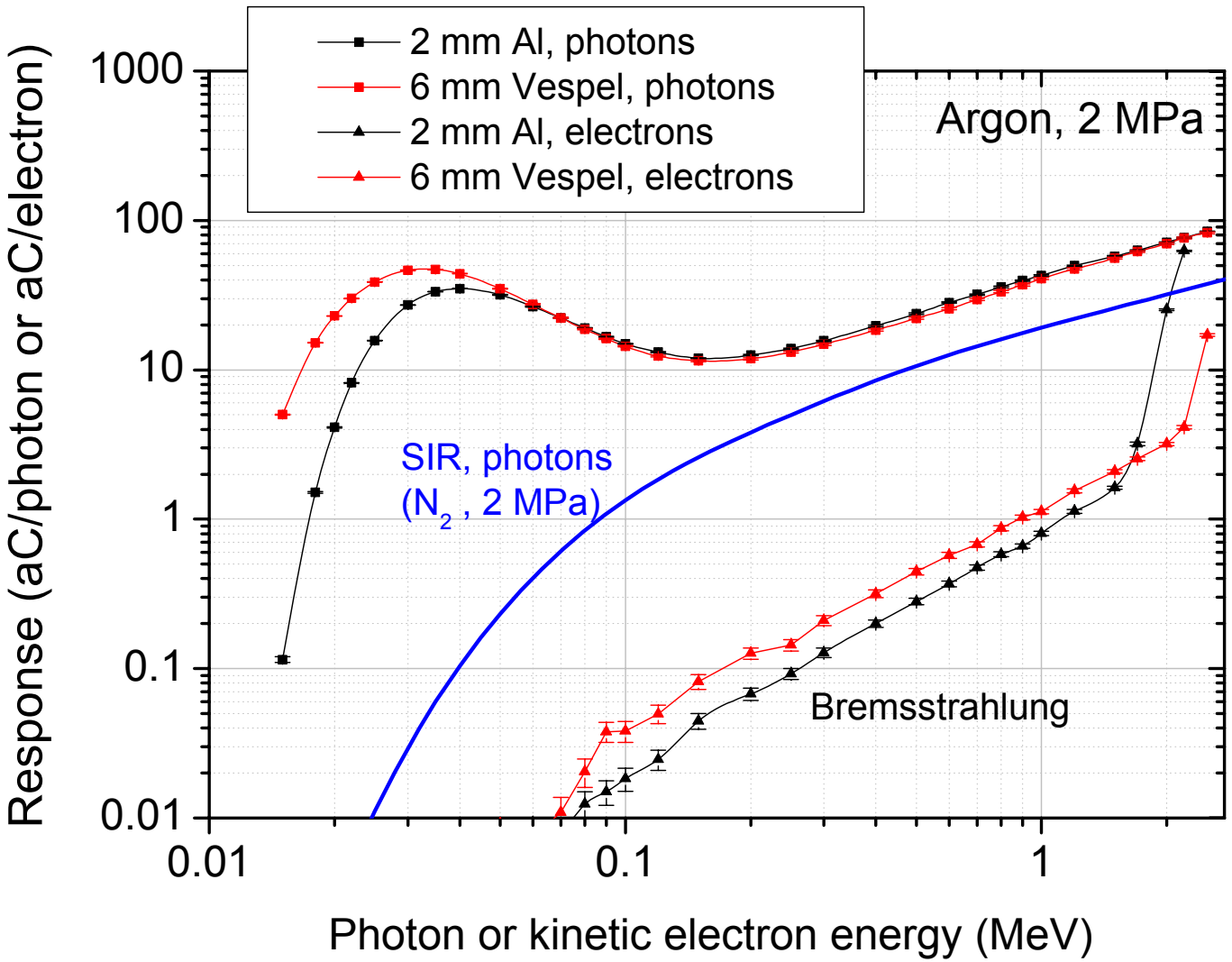
Several contributions to ionisation current





.. MC simulations ....

Start from proto-type IC: photon and electron response (MCNP)

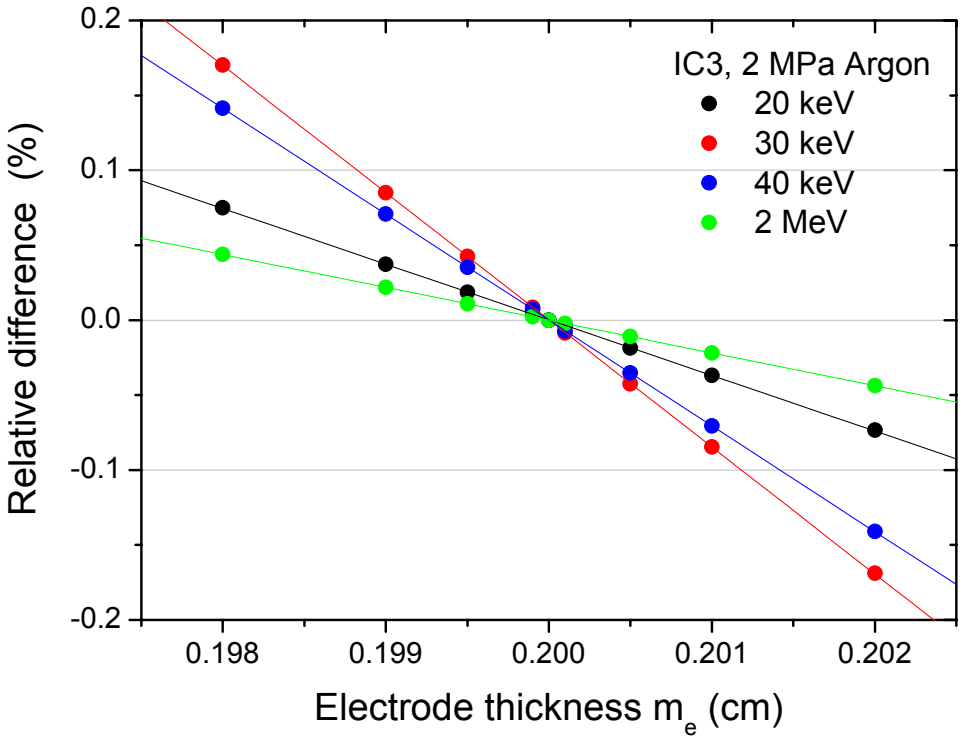


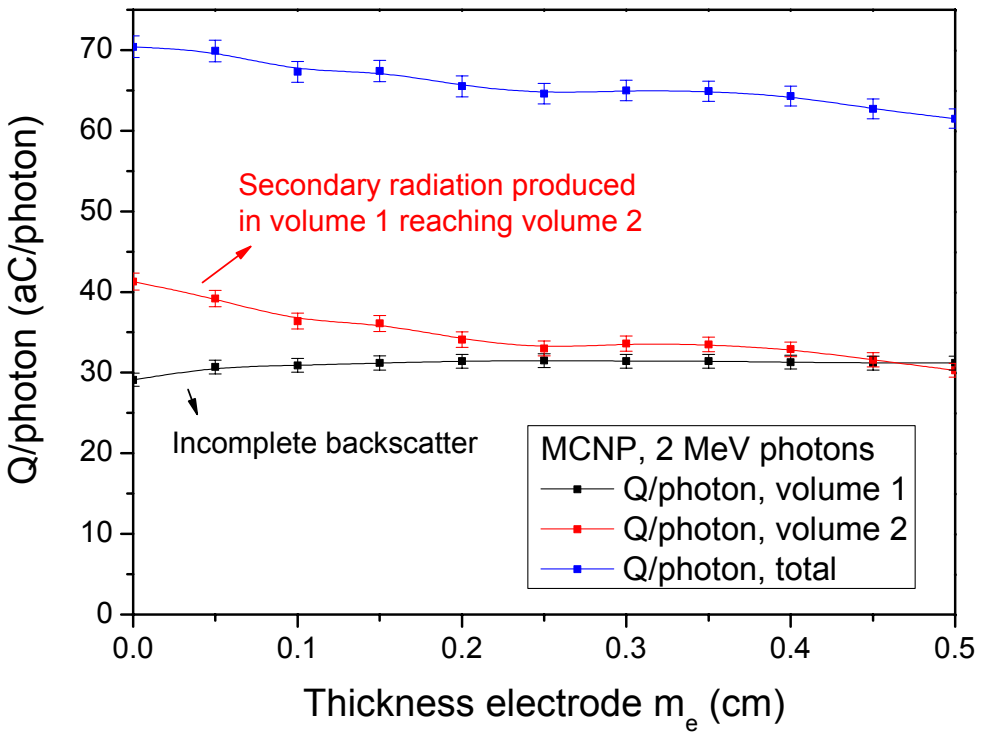
Vespel
$C_{22}H_{10}O_5N_2$

.. MC simulations ....

Determination of tolerances on IC system parameters for a 0.1% variation in output (20 keV to 2 MeV)

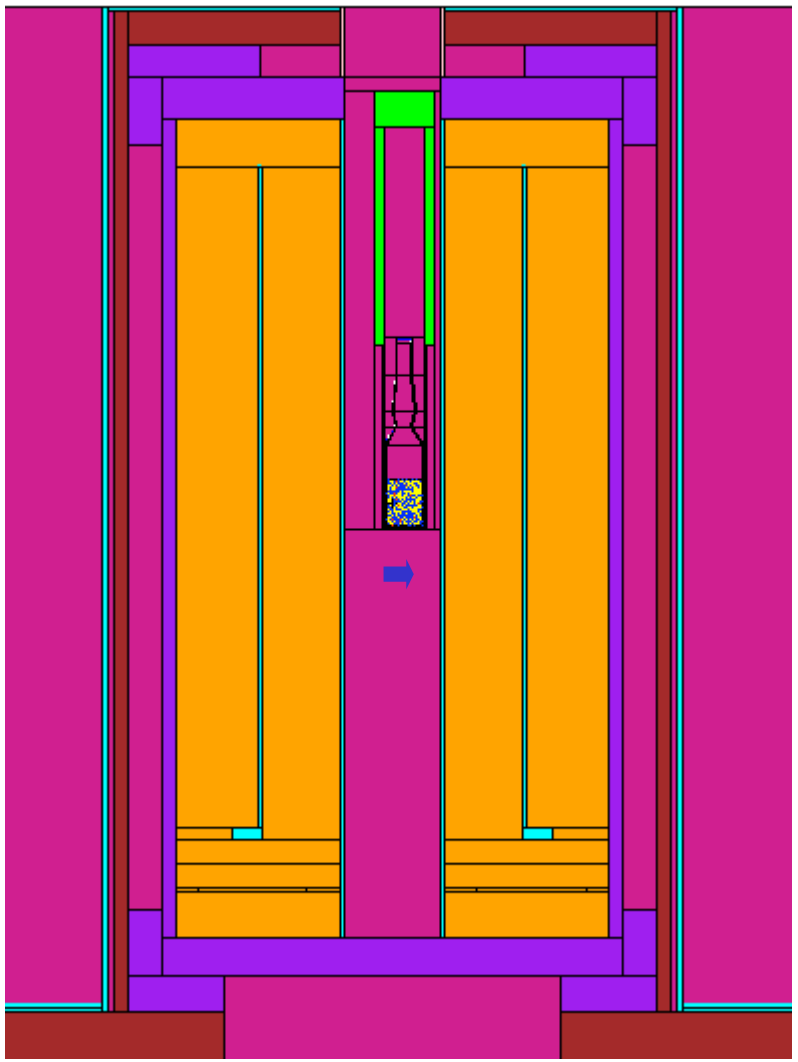
Example 1. IC response as a function of electrode thickness

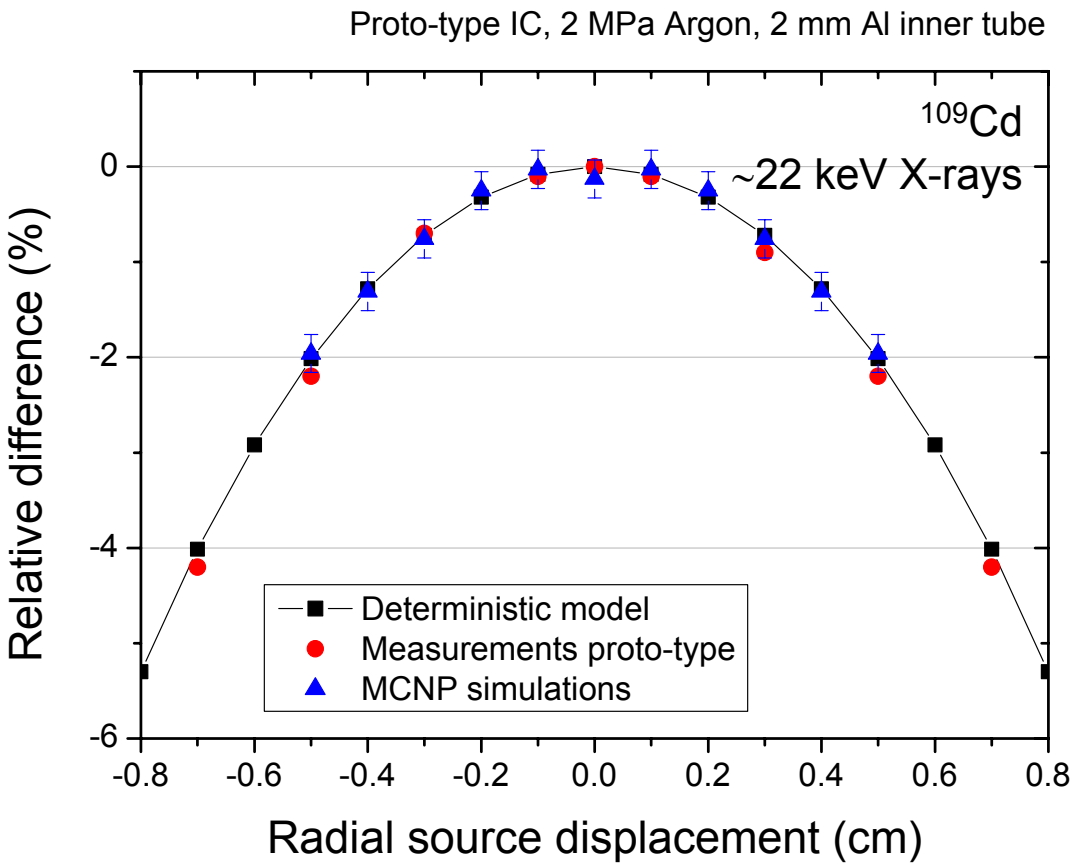




.. MC simulations ....

Example 2. Determination of effect of radial source displacements

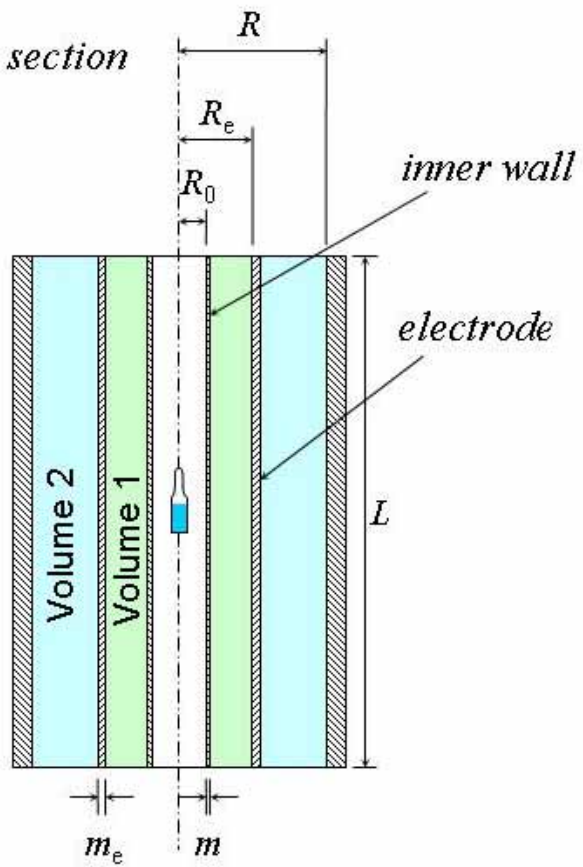




→ tolerance for 0.1% : 0.9 mm for optimised design

.. MC simulations ….

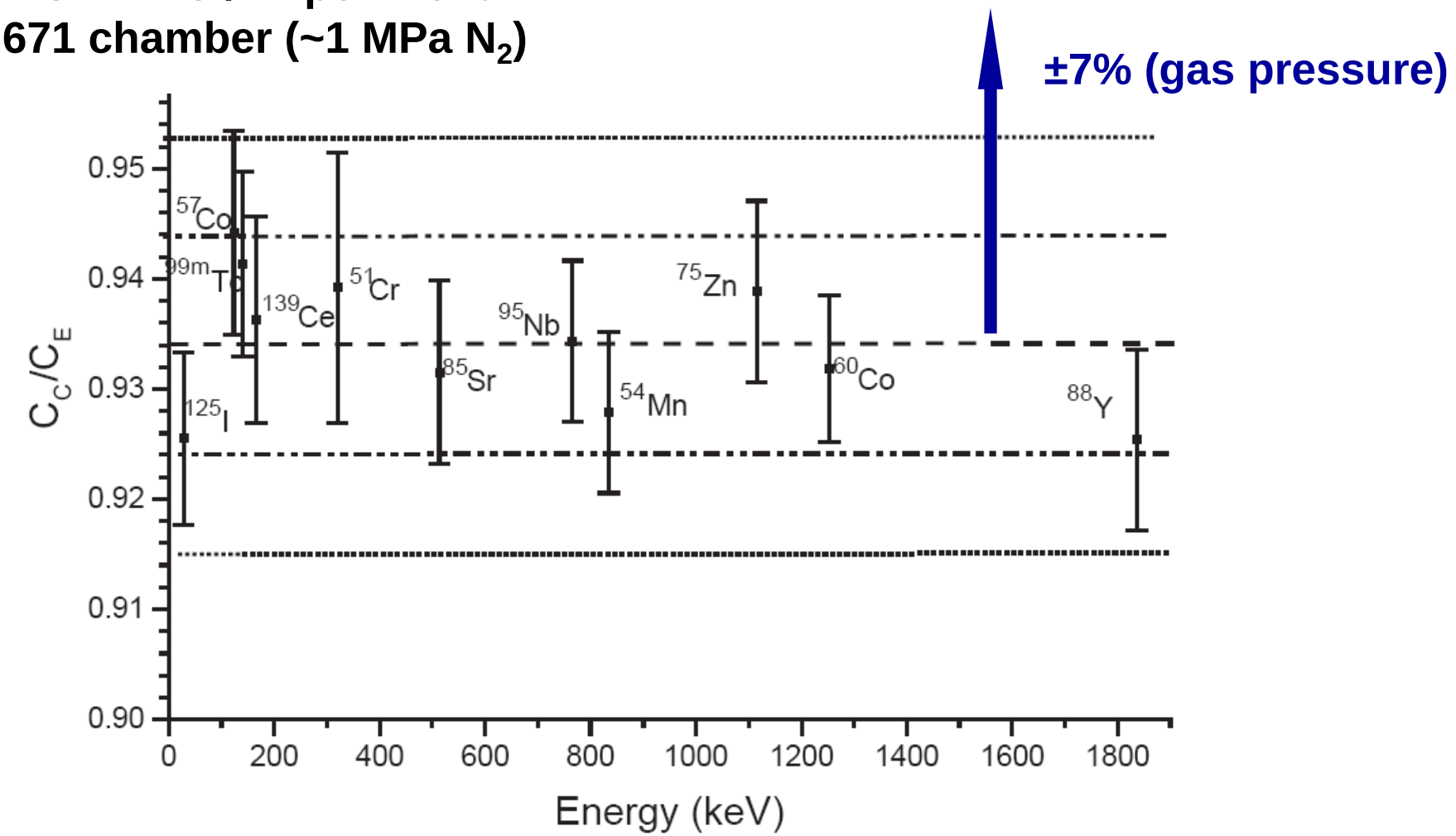
New reference chamber …



Item	Value/statement	Required tolerance
L	35-40 cm	1.6 mm (2 MeV)
R	9 - 9.5 cm	70 µm (2 MeV)
R_0	2.5 – 3 cm	55 µm (30 keV)
R_e	5.5 cm	60 µm (20 keV)
Inner wall	Aluminium/Vespel	
m (thickness inner wall)	0.2 cm Al / 0.6 cm Vespel	1 µm/15 µm (20 keV)
Electrode	Aluminium	
m_e (thickness electrode)	0.3 cm	14 µm (30 keV)
Filling gas	Argon	
Gas pressure	2 MPa	2 kPa (2 MeV)
Source positioning	center	0.9 mm (20 keV, Al)

…. Towards absolute MC ..

PENELOPE MC / Experiment
Vinten 671 chamber (~1 MPa N_2)



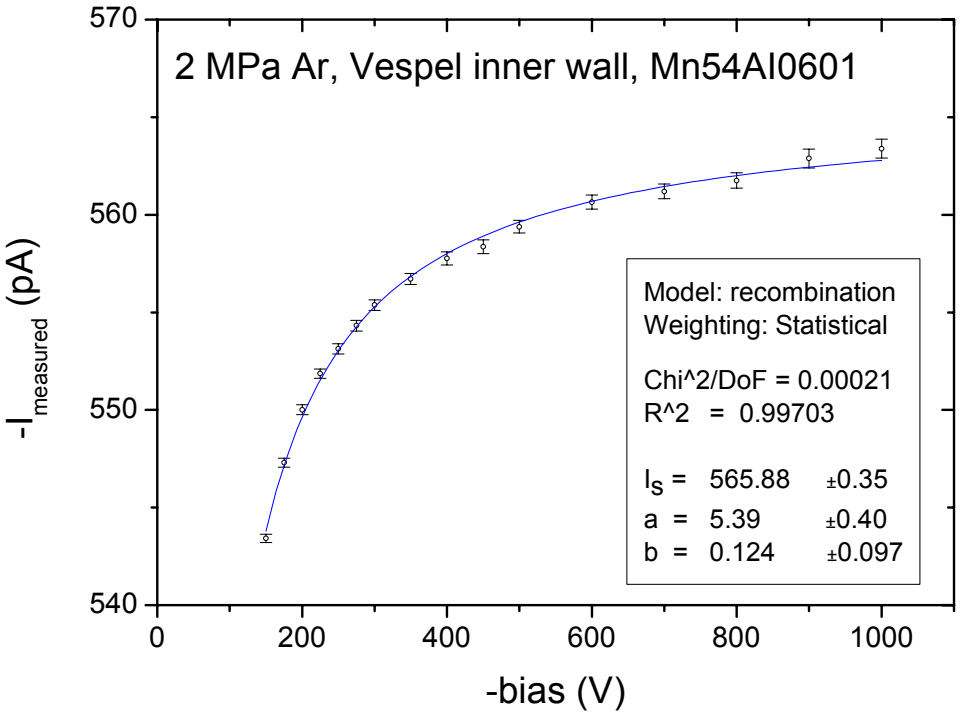
A. De Vismes, M.N. Amiot, Appl. Rad. Isot. 59 (2003) 267-272

…. Towards absolute MC ..

Can we get absolute agreement between MC and measurements ?

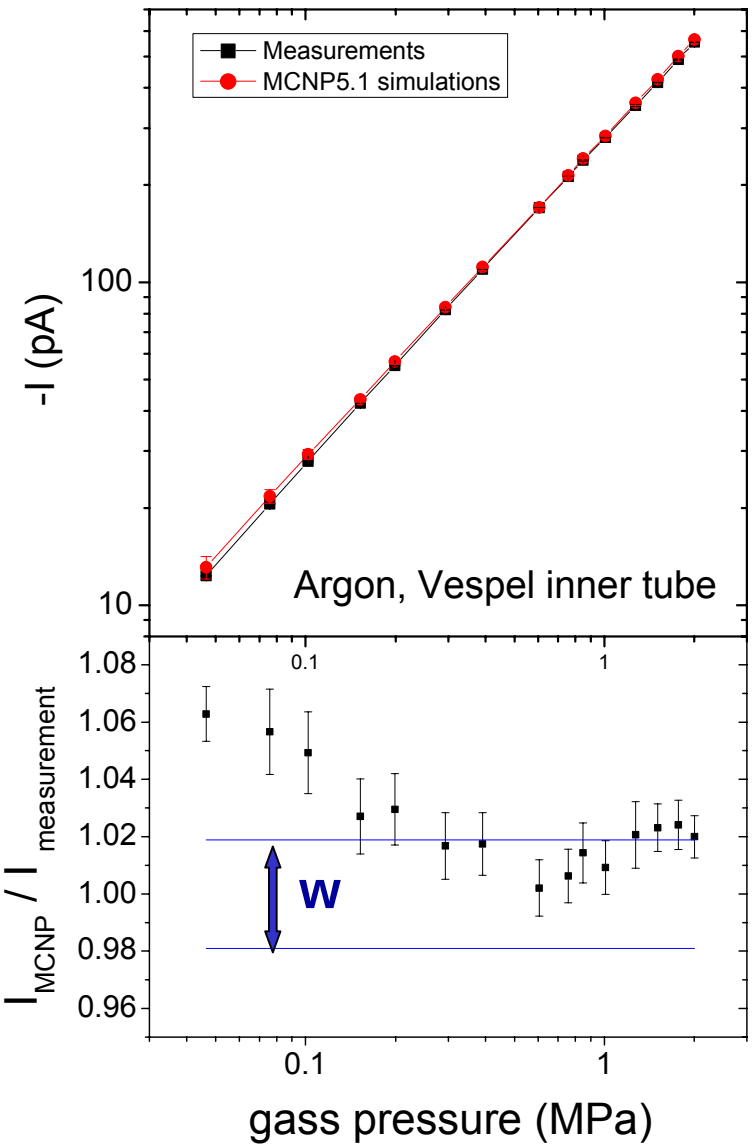
- Proto-type IC : Geometrical parameters well-known
- Pressure controlled with traceable RUSKA pressure balance
- Measurement of ^{54}Mn source (834.8 keV) as function of gas pressure
- Ion loss (recombination, diffusion)?

  → determination of saturation current (I_s)



$$\frac{I}{I_s} = 1 - \frac{a}{U} - \frac{b}{U^2} \quad I$$

.... Towards absolute MC ..



Measurements :

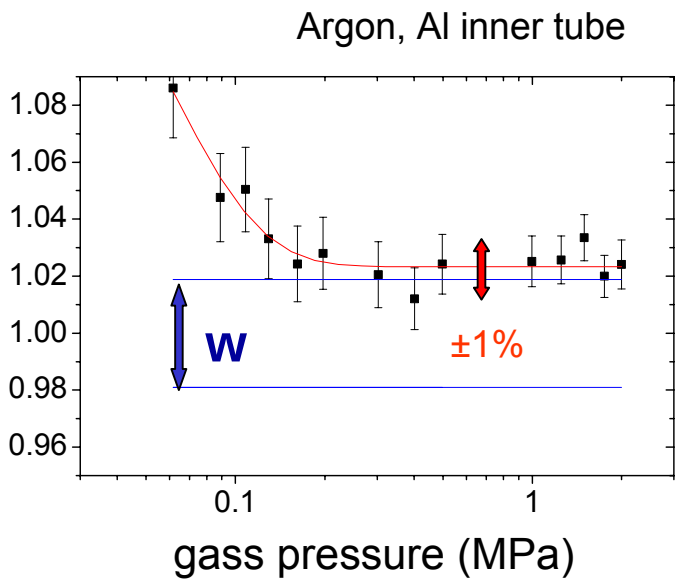
absolute measurement of current ($\delta I/I > 1\%$)

Simulations :

MCNP, *F8 tally : E_d (MeV/particle)

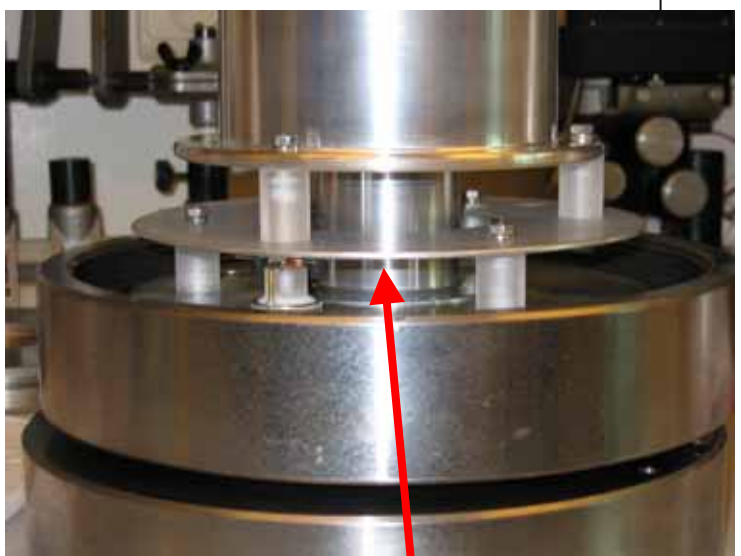
$$Q_d = \frac{e\,E_d}{W}$$

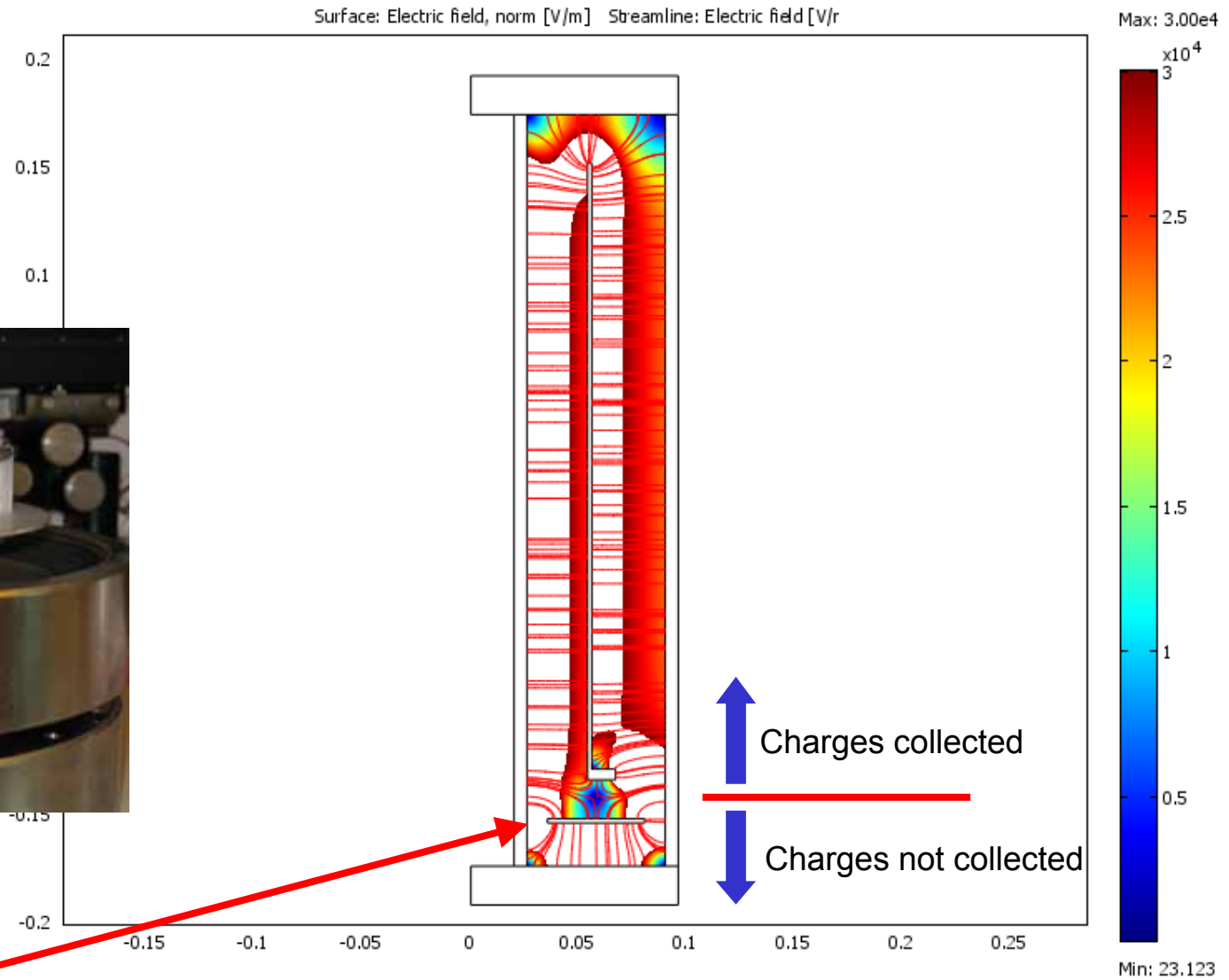
W_{Ar} = 26.4 eV ± 0.5 eV (ICRU31)



.... Towards absolute MC ..

Definition of volume





Guard ring

……Conclusions

- **Tolerances on geometrical and operational parameters for a new reference IC system were determined with MC simulations (MCNP)**
- **Absolute agreement between measurements and MC simulations (limited by uncertainty on W-value!)**
- **New reference chamber will be built and tested in near future**