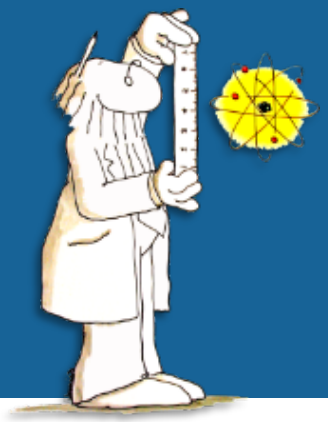
Investigation of the energy dependence of W_{air} in high energy electron beams



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1 -Carleton University, Ottawa, Ontario, K1S 5B6, Canada

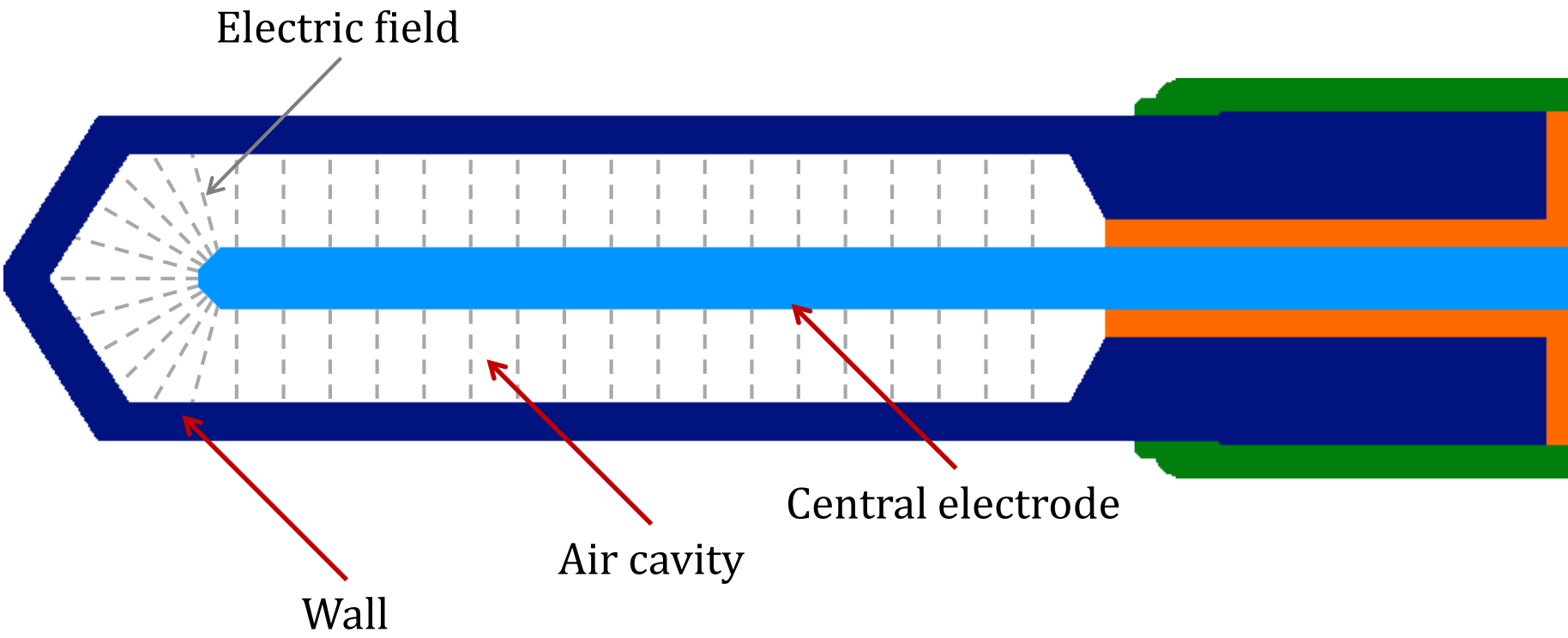
2 -Ionizing Radiation Standards, National Research Council of Canada, Ottawa, Ontario, K1A 0R6, Canada

April 16-18, 2018 - NIST, Gaithersburg, MD

CIRMS 2018 Annual Meeting

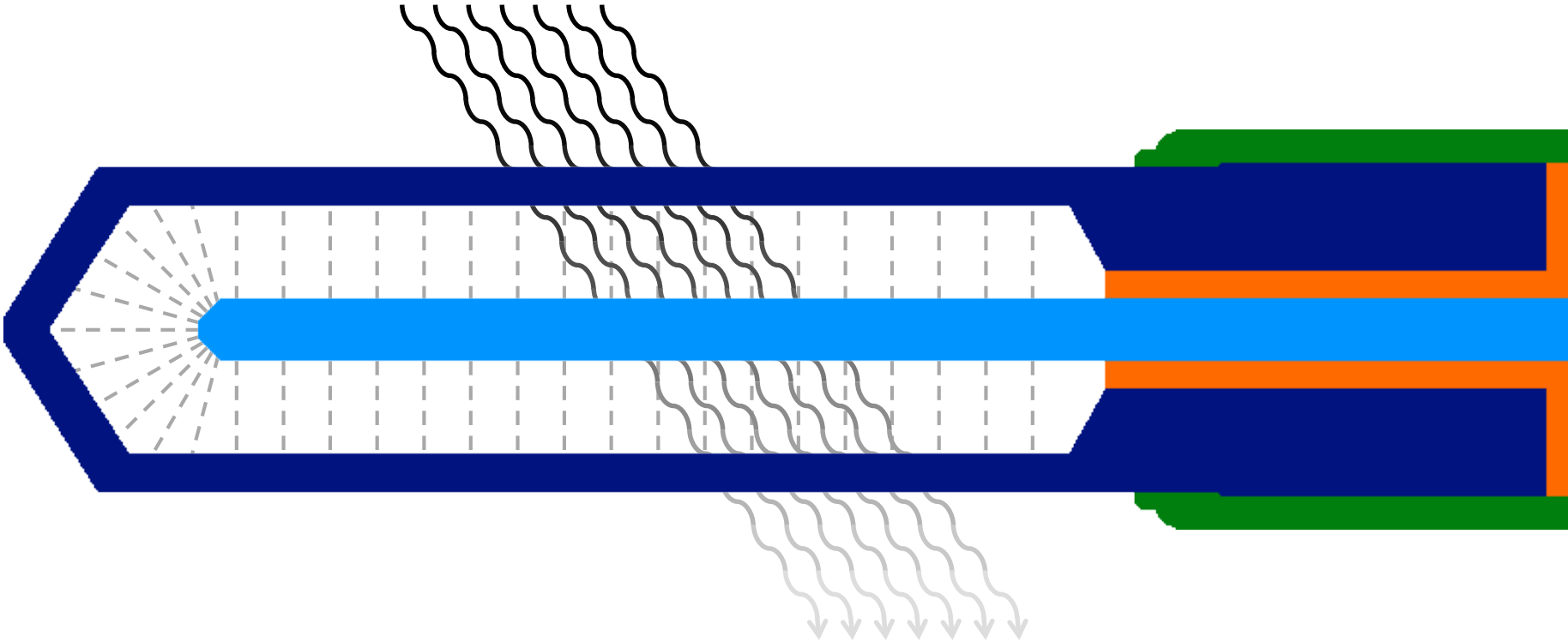
Radiotherapy clinic: standard dosimetry

Farmer Ion chamber (IC)



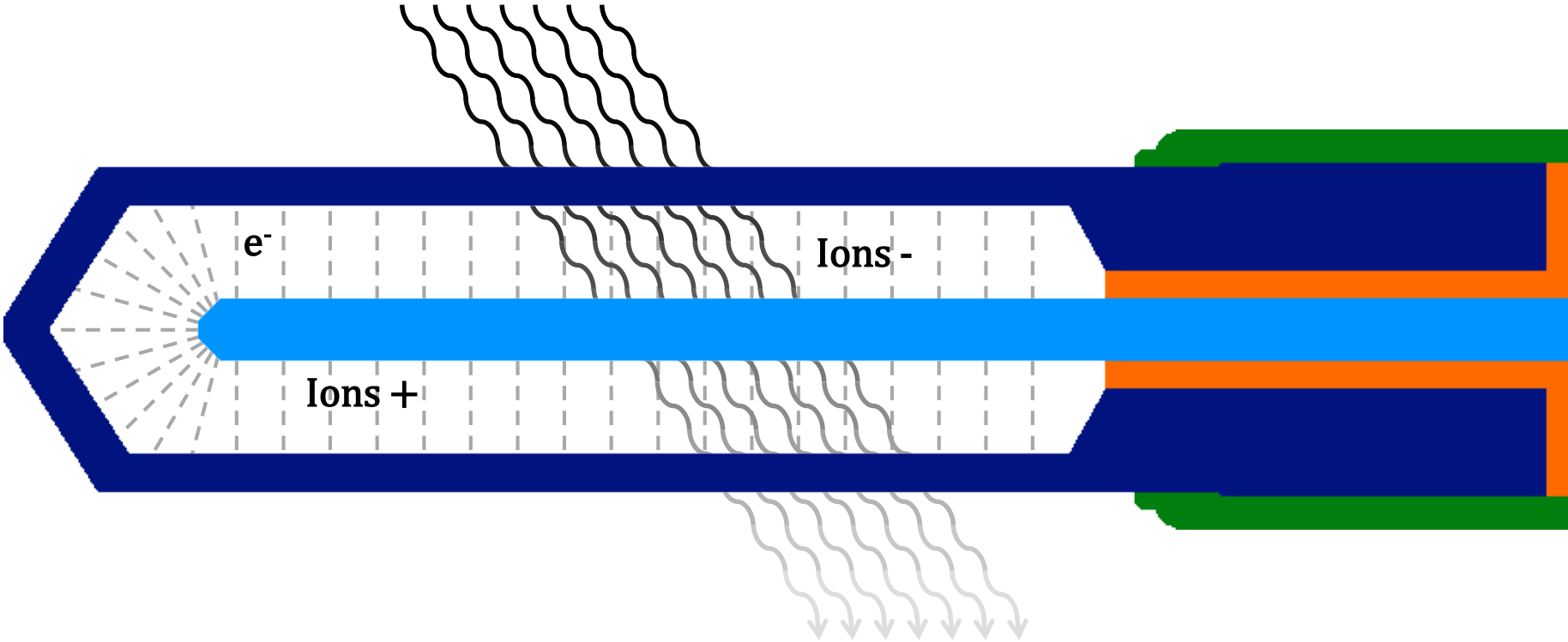
The underlying physics

Radiation ⟶ Loss of energy



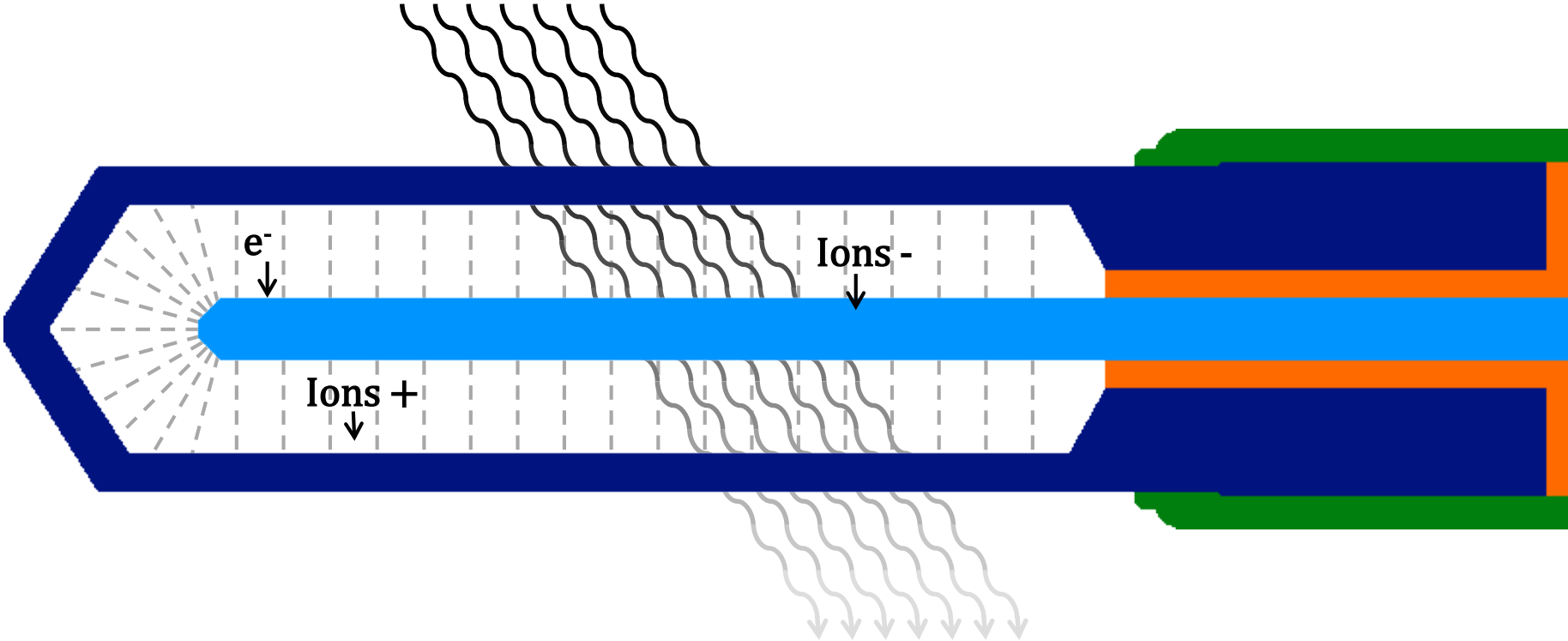
The underlying physics

Radiation ⟶ Loss of energy ⟶ Ionization of air

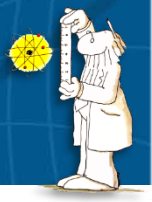


The underlying physics

Radiation → Loss of energy → Ionization of air → Charge collection Q_{gas}



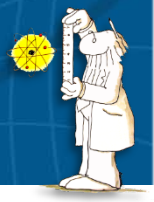
Measurement vs quantity of interest



Radiation $\longrightarrow$ Loss of energy $\longrightarrow$ Ionization of air $\longrightarrow$ Charge collection Q_{gas}

What we are able to measure

Measurement vs quantity of interest



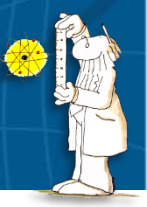
Radiation $\longrightarrow$ Loss of energy $\longrightarrow$ Ionization of air $\longrightarrow$ Charge collection Q_{gas}

Related to the absorbed dose

What we are able to measure

$$D_{gas} = \frac{\langle \mathrm{d}\epsilon \rangle}{\mathrm{d}m} \approx \frac{\text{Energy deposited}}{\text{Mass}}$$

How to relate them ?



Radiation → Loss of energy → Ionization of air → Charge collection Q_{gas}

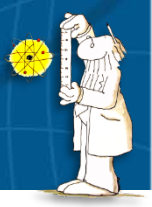
W_{air}

Related to the absorbed dose

What we are able to measure

$$D_{gas} = \frac{\langle \mathrm{d}\epsilon \rangle}{\mathrm{d}m} \approx \frac{\text{Energy deposited}}{\text{Mass}} \propto \frac{Q_{\text{gas}} W_{\text{air}}}{m_{\text{gas}}}$$

Consensus on W_{air}

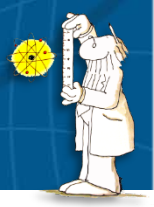


Radiation ⟶ Loss of energy ⟶ Ionization of air ⟶ Charge collection

D_{gas} ⟷ $\boldsymbol{W_{air}}$ ⟶ Q_{gas}

W_{air} is the mean energy required to create ion pair in air

Consensus on W_{air}

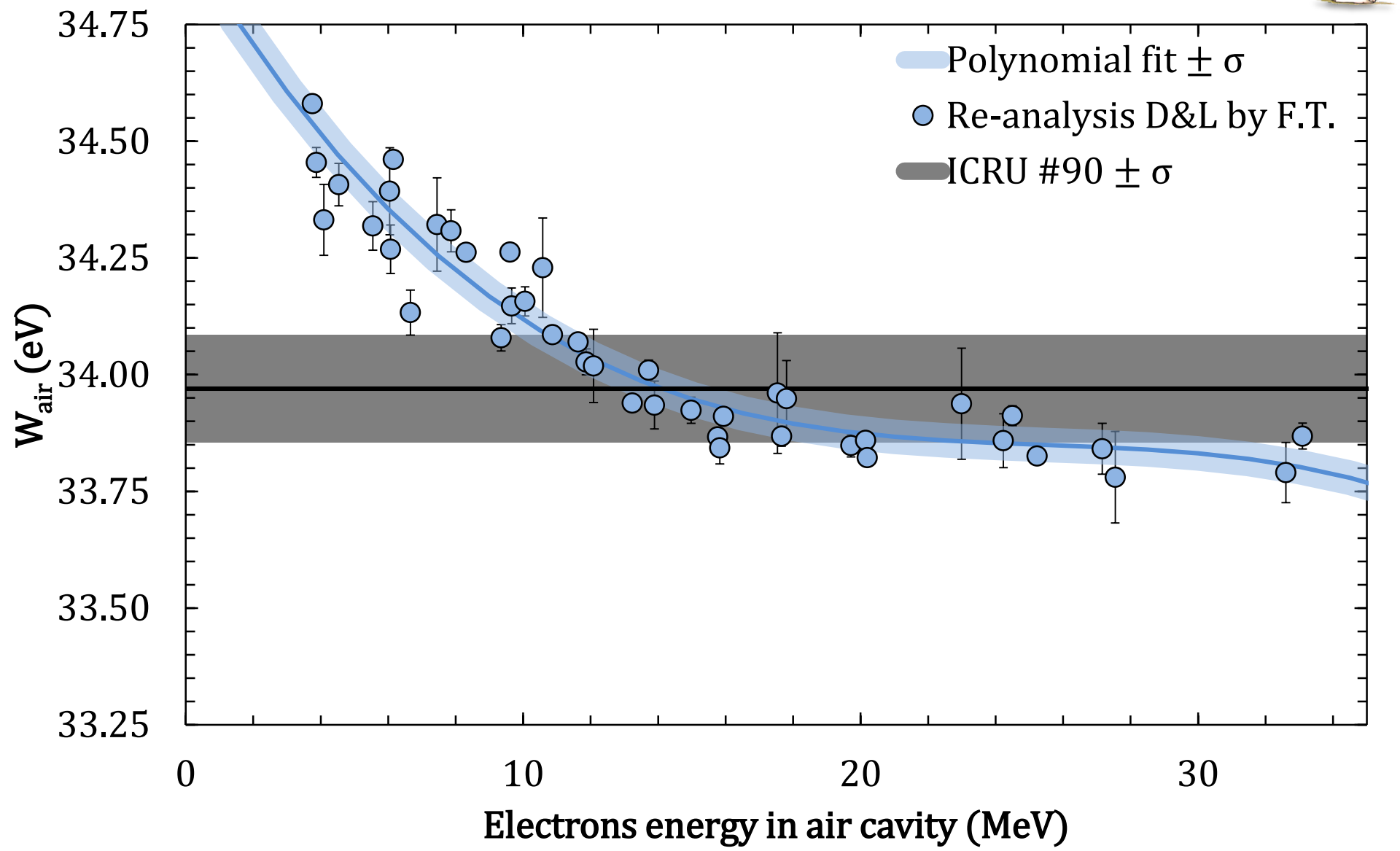


ICRU report 90 (2016)

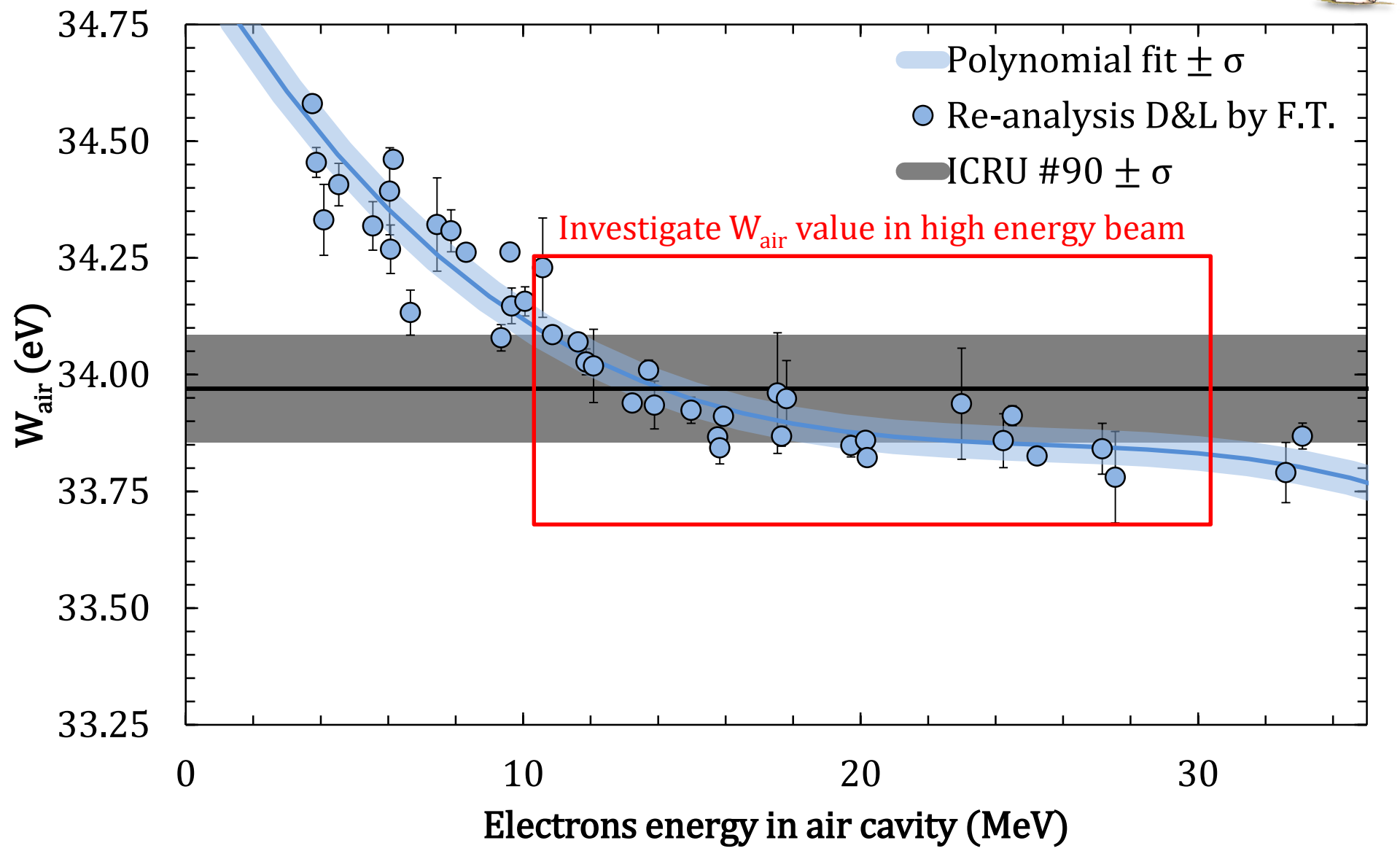
$$\mathbf{W_{air} = 33.97 \pm 0.12\ eV}$$

"For electron energies well above 10 keV, [...], ***in the absence of any data to the contrary,*** *W_{air} is taken to be* ***independent of energy.****"*

Re-analysis of Domen & Lamperti by Tessier *et al.*



Re-analysis of Domen & Lamperti by Tessier *et al.*



How can we obtain W_{air} ?

$$D_{gas} = \frac{Q_{gas}}{m_{gas}} W_{air}$$

$$W_{air} = \frac{D_{gas}\ m_{gas}}{Q_{gas}}$$

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Measurement of charge in ion chamber (corrected)

How can we obtain W_{air} ?

$$D_{gas} = \frac{Q_{gas}}{m_{gas}} W_{air}$$

$$W_{air} = \frac{D_{gas}\ m_{gas}}{Q_{gas}}$$

→ Volume x density

→ Measurement of charge in ion chamber (corrected)

How can we obtain W_{air} ?

$$D_{gas} = \frac{Q_{gas}}{m_{gas}} W_{air}$$

$$W_{air} = \frac{D_{gas}\ m_{gas}}{Q_{gas}}$$

Hard to measure…

Volume x density

Measurement of charge in ion chamber (corrected)

How can we obtain W_{air} ?

$$D_{gas} = \frac{Q_{gas}}{m_{gas}} W_{air}$$

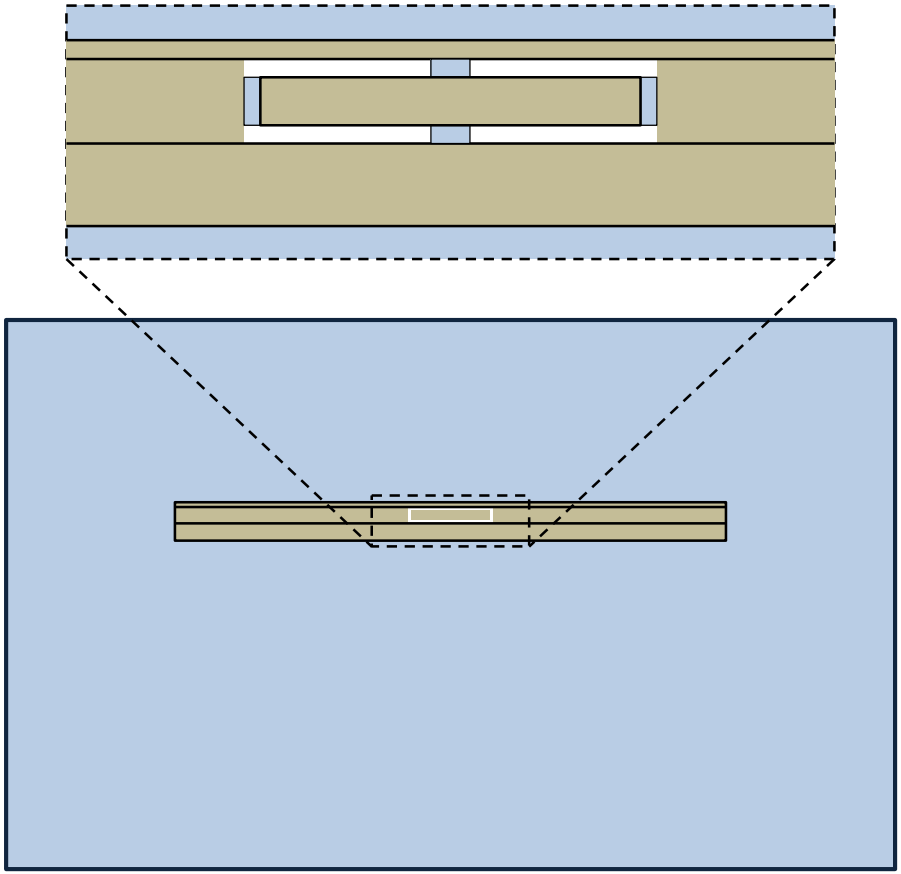
Calorimetric measurement

$$W_{air} = \frac{D_{med}\, m_{gas}}{Q_{gas}} \left(\frac{D_{gas}}{D_{med}} \right)_{MC}$$

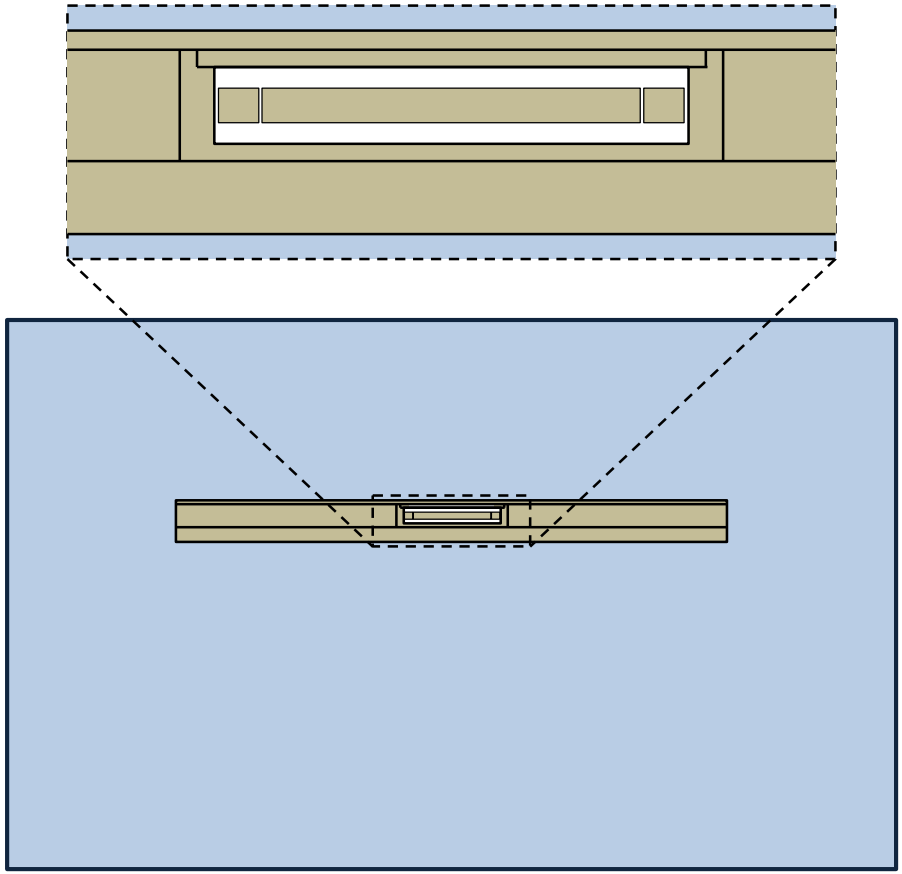
Monte Carlo

Detector phantom

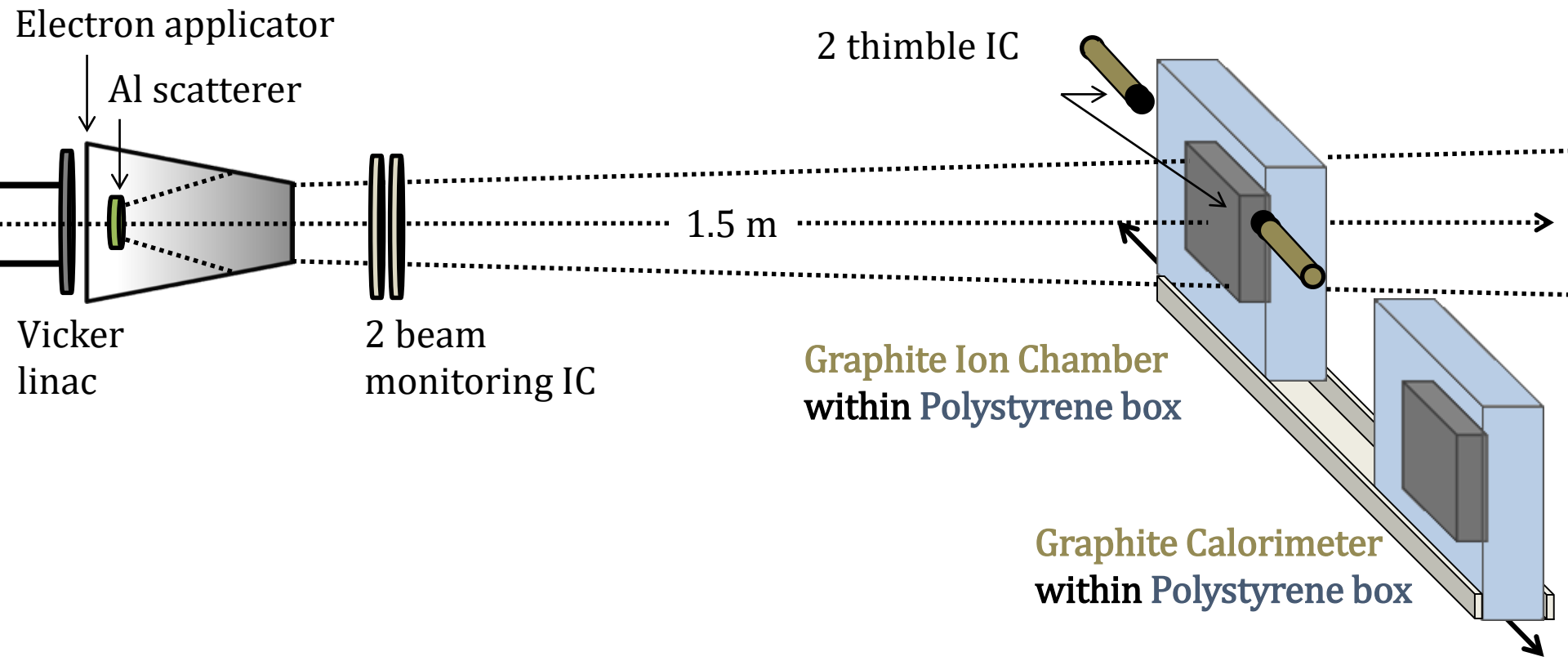
Graphite Calorimeter within Polystyrene box



Graphite Ion Chamber within Polystyrene box



Radiation set-up



Variation of configurations

Graphite buildup

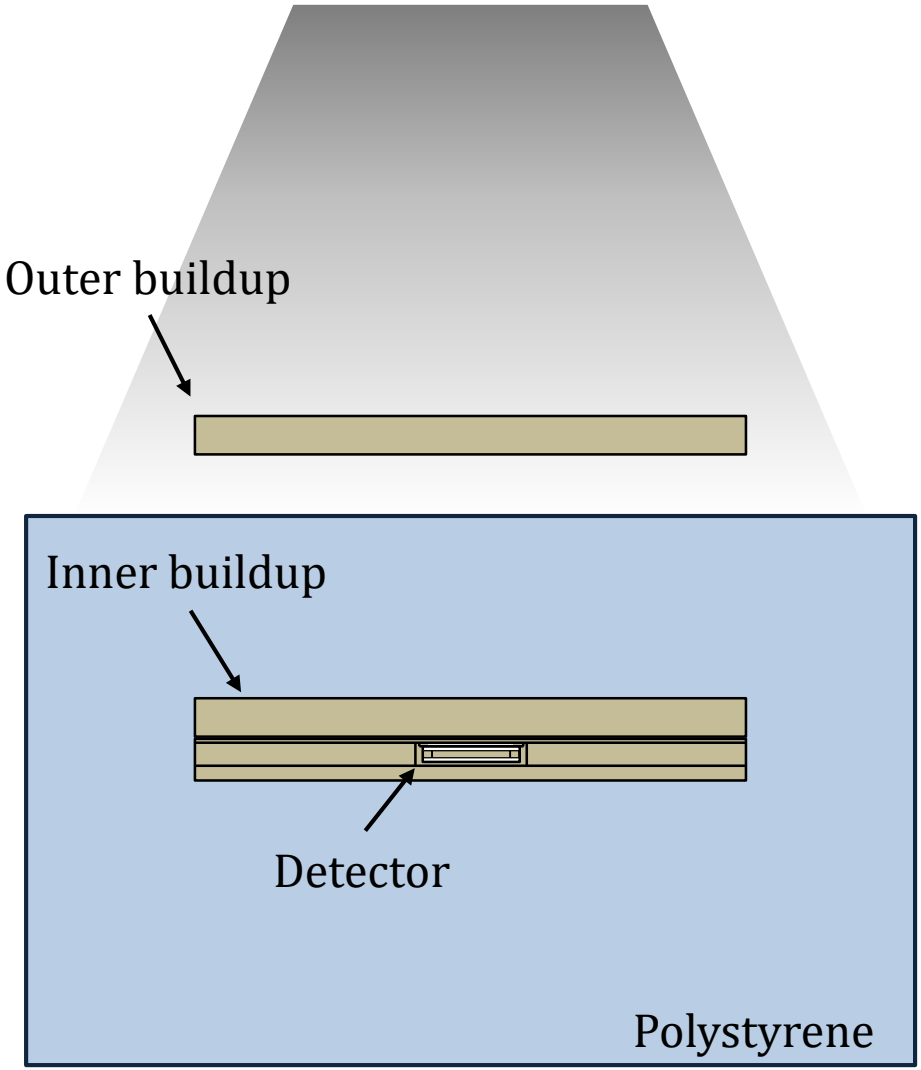
Outer **OR** inner to the Styrofoam
Between 0 to 4 cm

Irradiation time

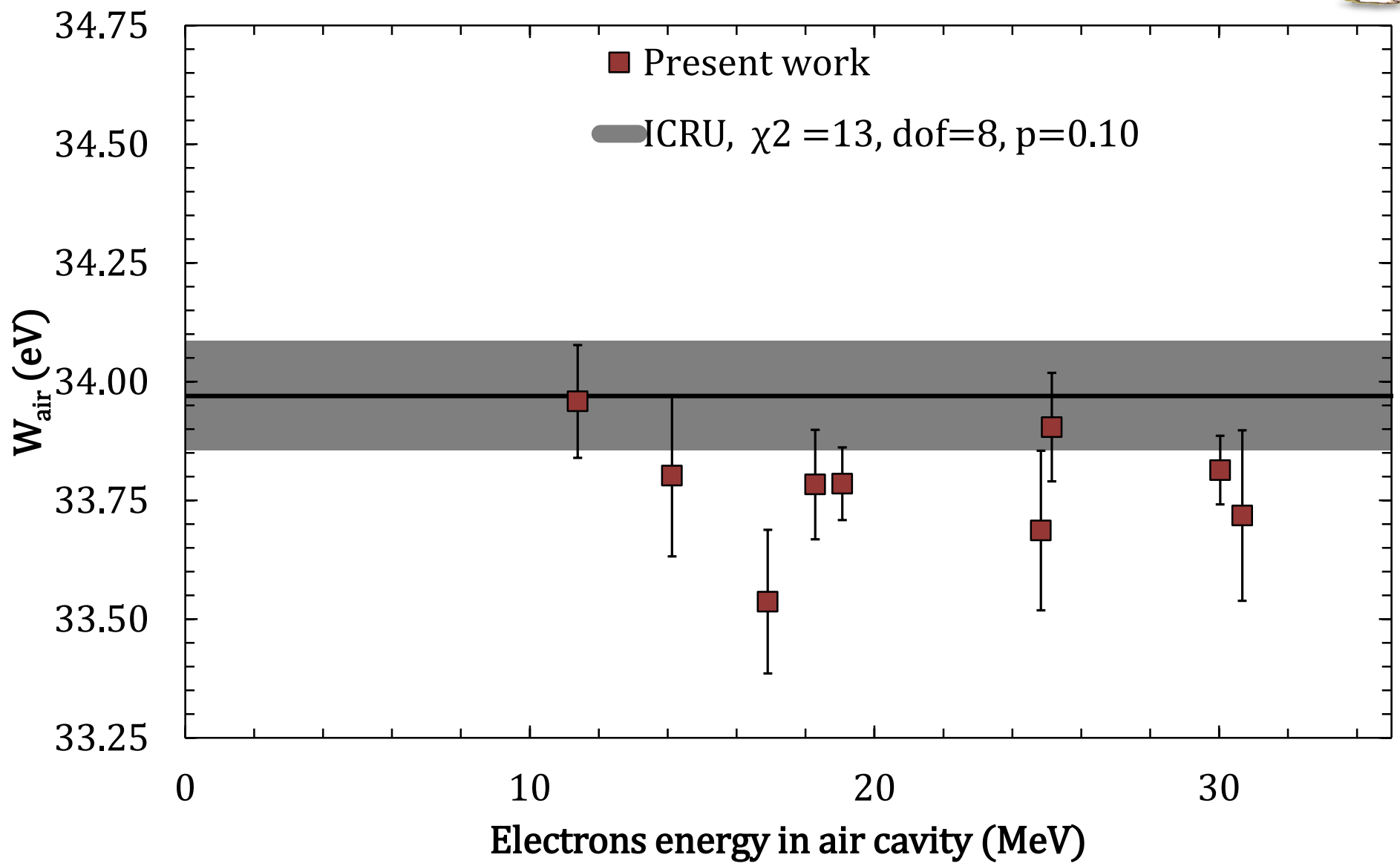
15 or 30 seconds

Electron beam energy

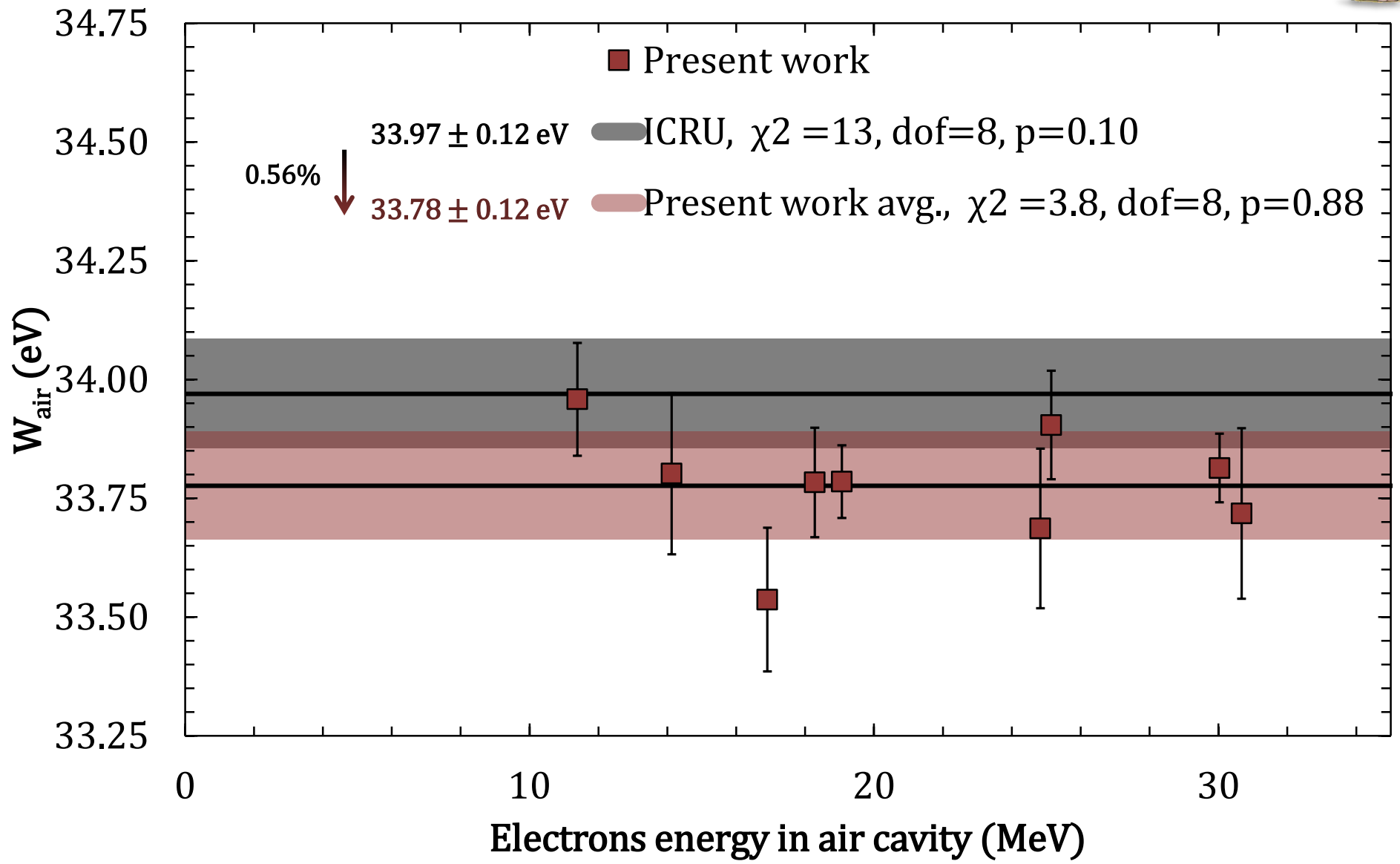
20 and 35 MeV



Results


Present work
ICRU, χ2 =13, dof=8, p=0.10
34.75
34.50
34.25
34.00
33.75
33.50
33.25
W_air (eV)
0
10
20
30
Electrons energy in air cavity (MeV)

Results


Present work
33.97 ± 0.12 eV
ICRU, χ2 =13, dof=8, p=0.10
0.56%
33.78 ± 0.12 eV
Present work avg., χ2 =3.8, dof=8, p=0.88
34.75
34.50
34.25
34.00
33.75
33.50
33.25
W_air (eV)
0
10
20
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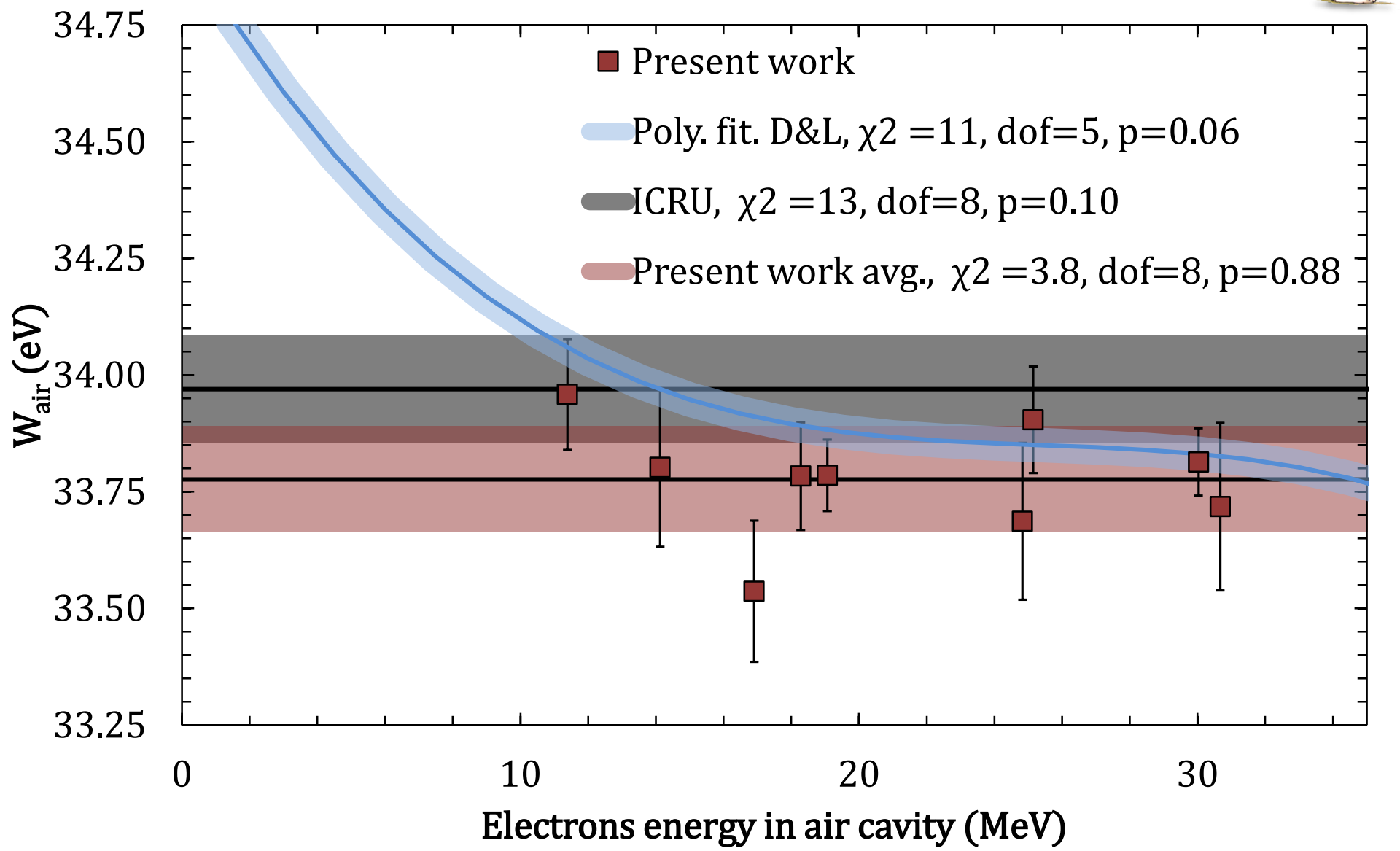
Electrons energy in air cavity (MeV)

Results


Present work
Poly. fit. D&L, χ2 =11, dof=5, p=0.06
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34.75
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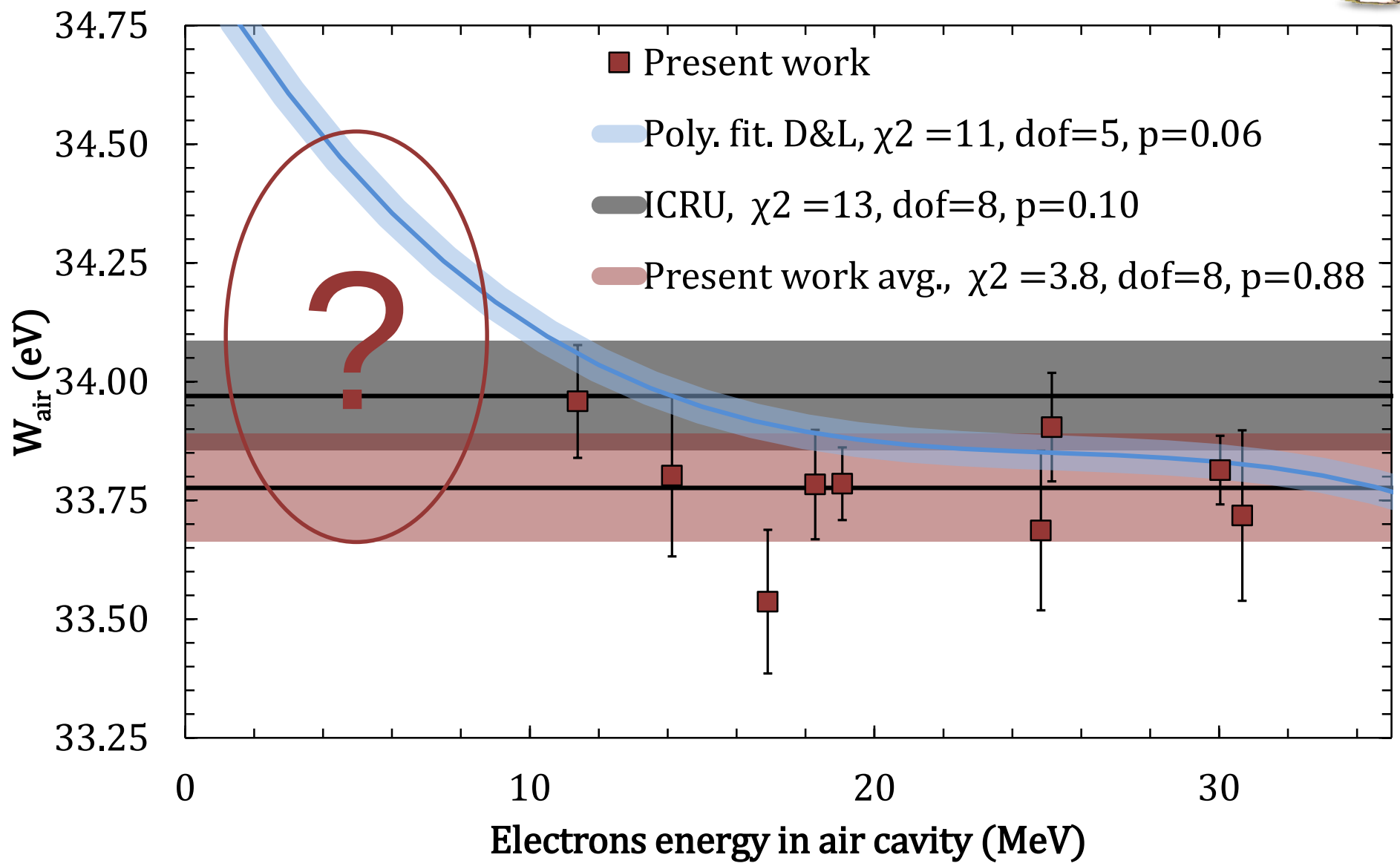
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34.50
34.25
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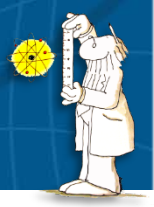
33.25
W_air (eV)
0
10
20
30
Electrons energy in air cavity (MeV)

Conclusion



Results consistent with a constant value of 33.78 ± 0.12 eV

Inconclusive on the energy dependence

Further focus is required:

→ Increase number of measurements

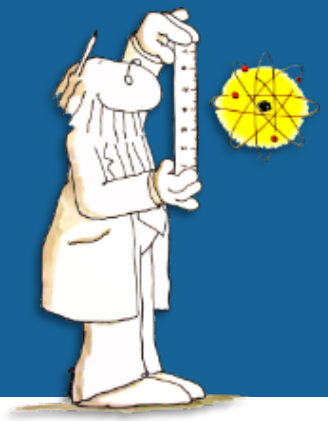
→ Increase energy range

→ Improve uncertainties

Come see my poster for more details

Acknowledgements

Malcolm McEwen
Frédéric Tessier
Ernesto Mainegra-Hing
Claudiu Cojocaru
Carl Ross



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