High rate studies of TRD at GSI

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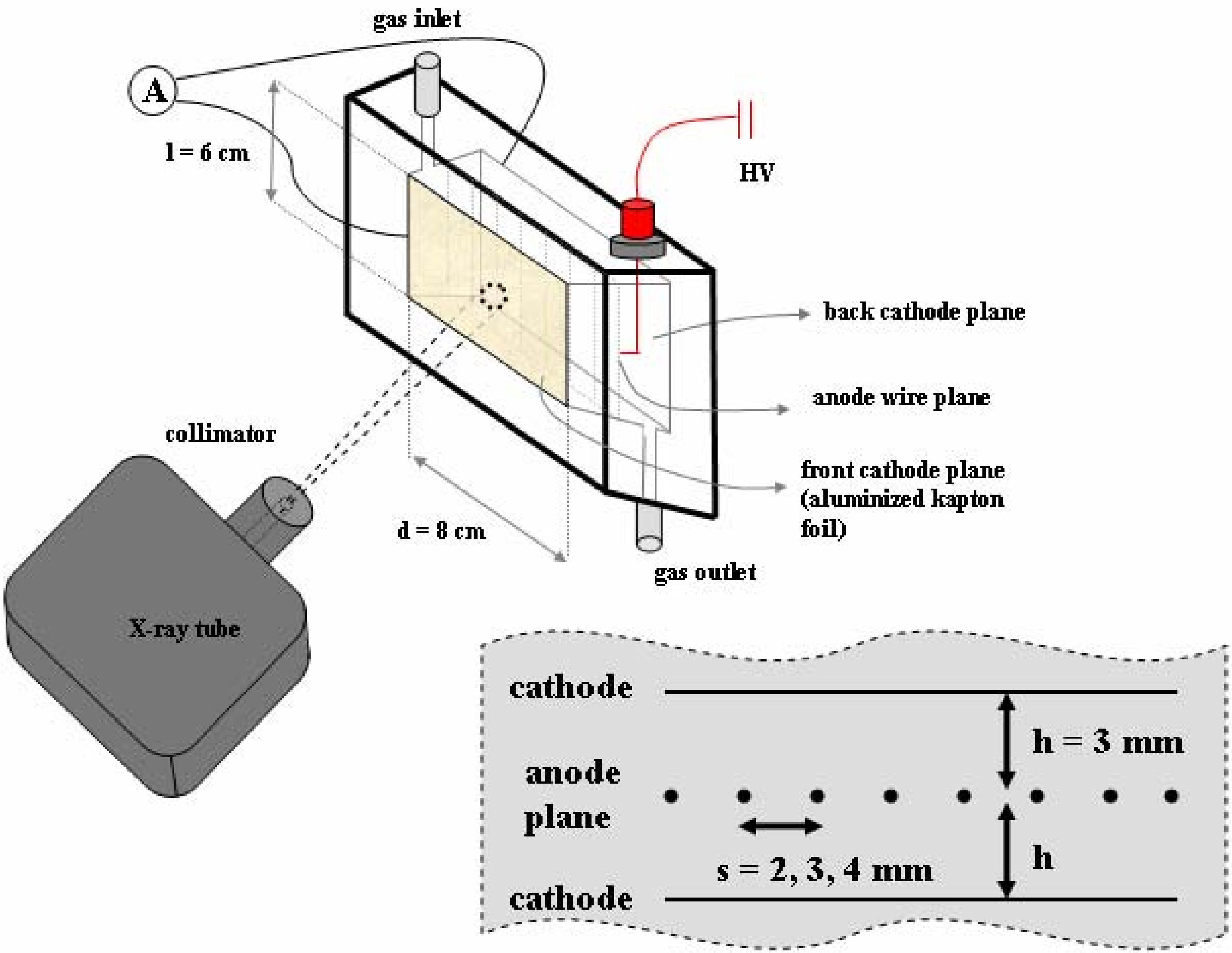
27-09-2007

1. Experimental setup.
2. Measurements on gain.
3. Measurements on rate capability.

1. Experimental setup

Experimental setup (I).



F. Uhlig

Experimental setup (II).

X-ray tube   Cu-anode
max. HV: 30 kV
max. I: 20 mA
20 Sv/h

Experimental procedure for gain measurements.

- The rate was monitored with a CAMAC scaler and corrections for the system dead-time applied. In these measurements this correction is at most 13%.

- The current was measured with a power supply of 1 nA resolution. At low gains, a Keithley picoamperemeter with resolution below pA was used.

- The pressure and temperature were monitored continuously, and the operating voltage re-normalized to the corresponding voltage at P=1000 bar and T=20 ^oC, to account for changes in density.

- The rate over the chamber was kept at the level of 10 kHz for gains $M>10^5$ and at the level of 120 kHz for gains $M<10^5$ (this reduces the space-charge at high gains, simplifying the theoretical description). This was achieved for all the gas mixtures studied, by accommodating the different X-ray conversion probabilities with changes in the current of the tube.

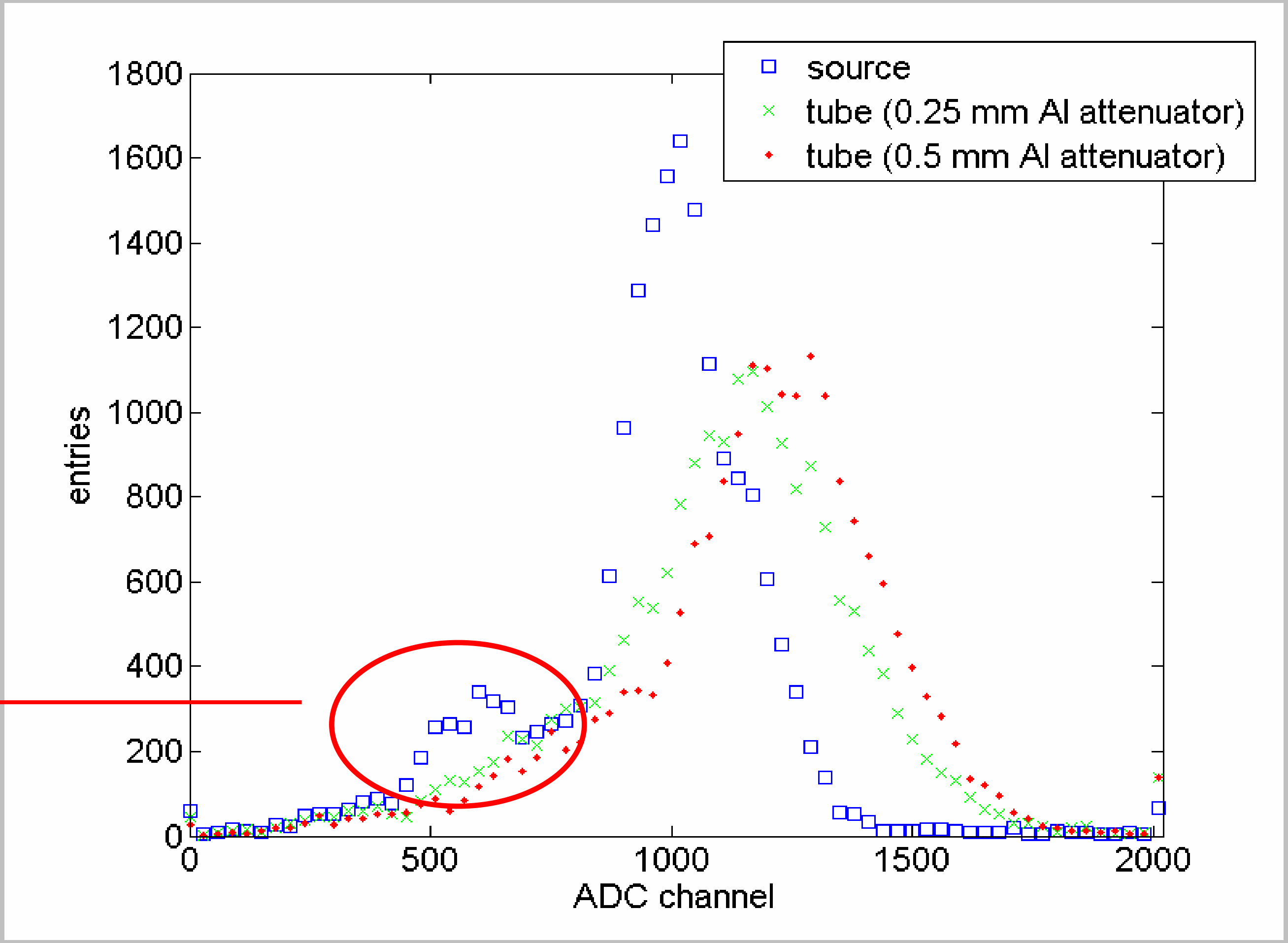
- Measurements for **s = 2, 3, 4 mm** and gas mixtures of **Ne,Ar,Xe/CO_2** at concentrations of noble gas **f = 0, 10, 20, 40, 60, 80, 90, 99** were performed

X-ray tube vs (reference) Fe^{55} source (I).

The energy distributions are very similar but, in the case of the source, the measured distribution is dominated by the detector resolution and in the case of the tube it is dominated by the shape of the primary X-ray distribution.

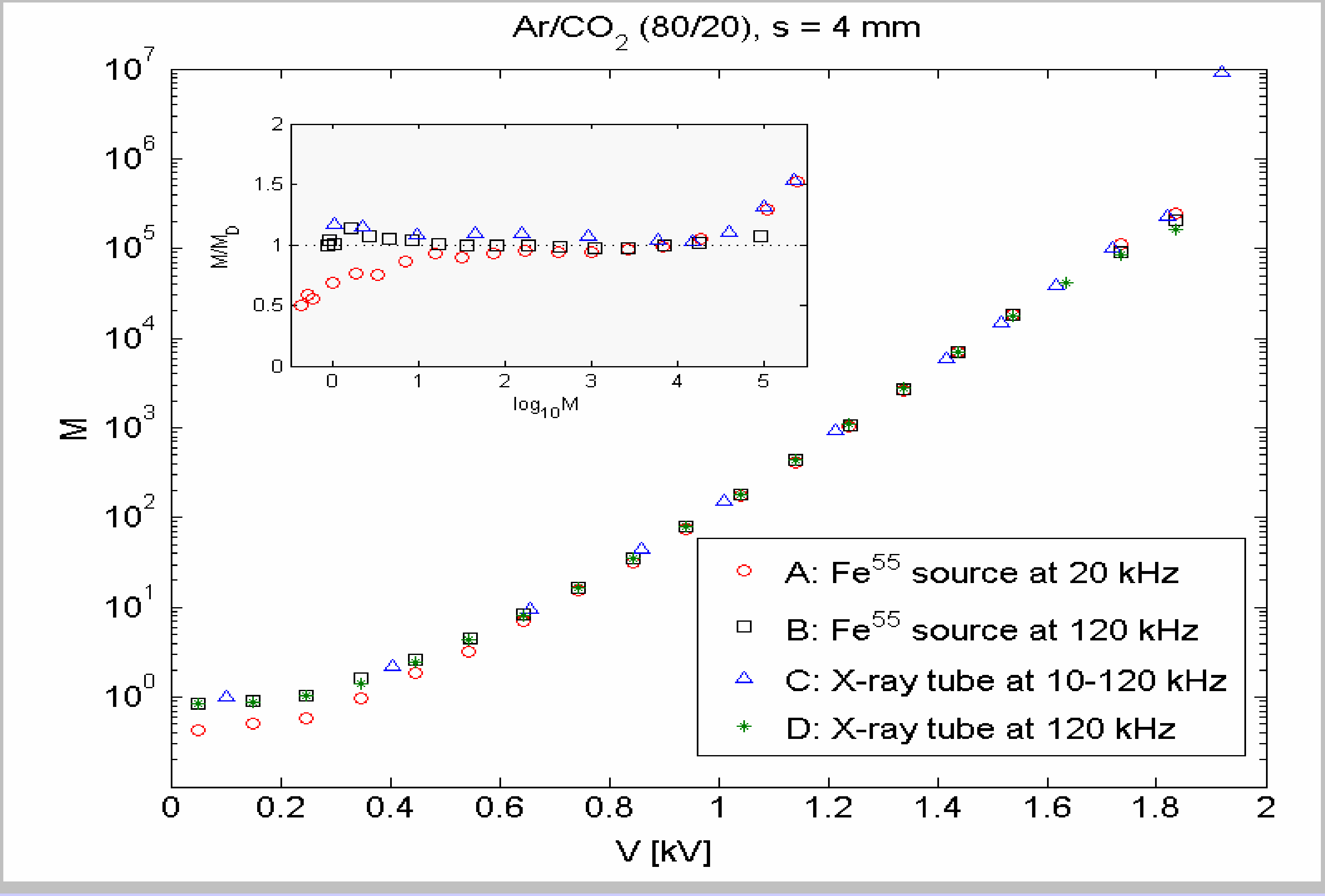
Ar/CO_2 (80/20)

escape peak



X-ray tube vs (reference) Fe^{55} source (II).

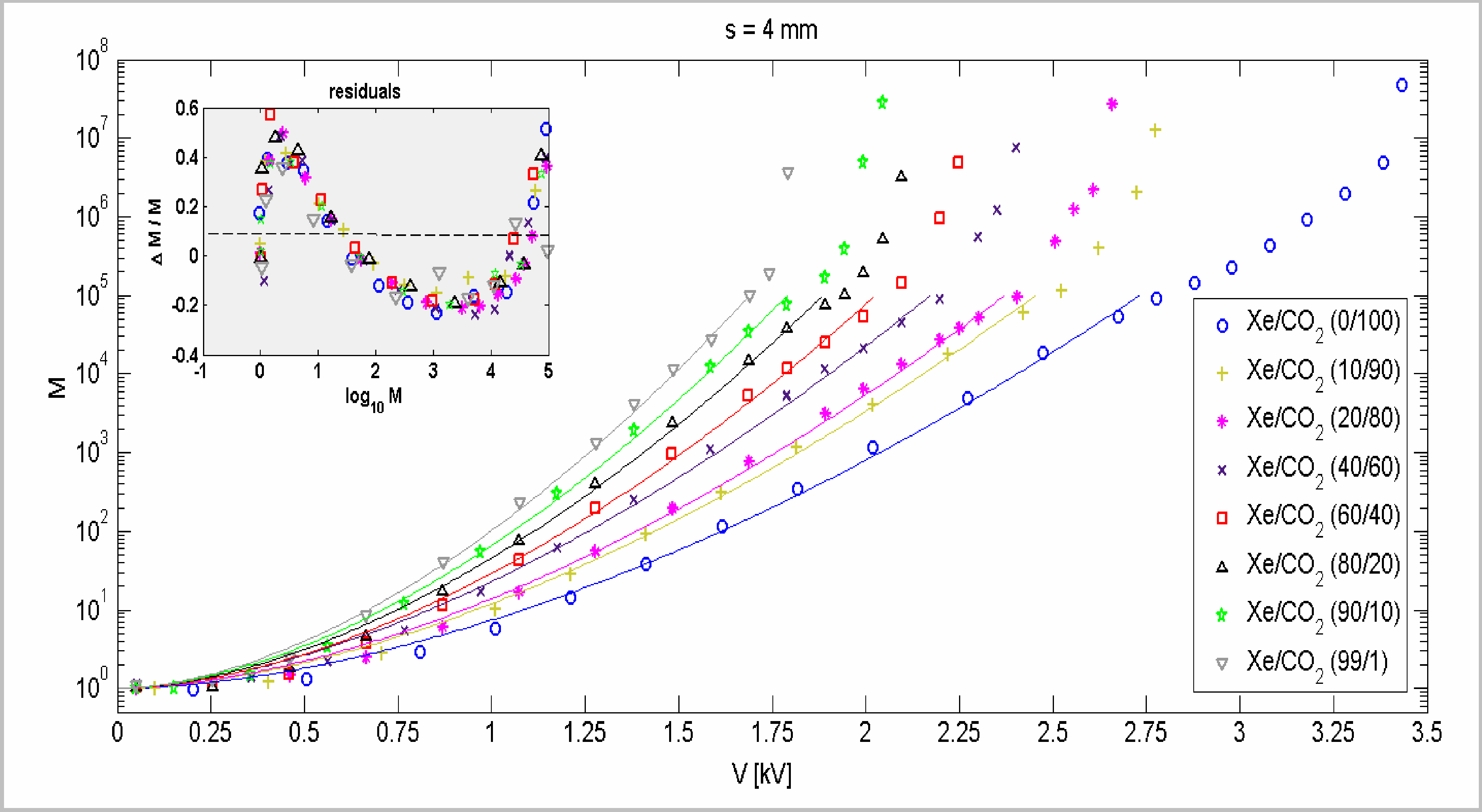
Good mutual agreement (below 5%) between both!



SO: Once calibrated in energy, the tube was used for the whole data taken

2.1. Measurements on gain.

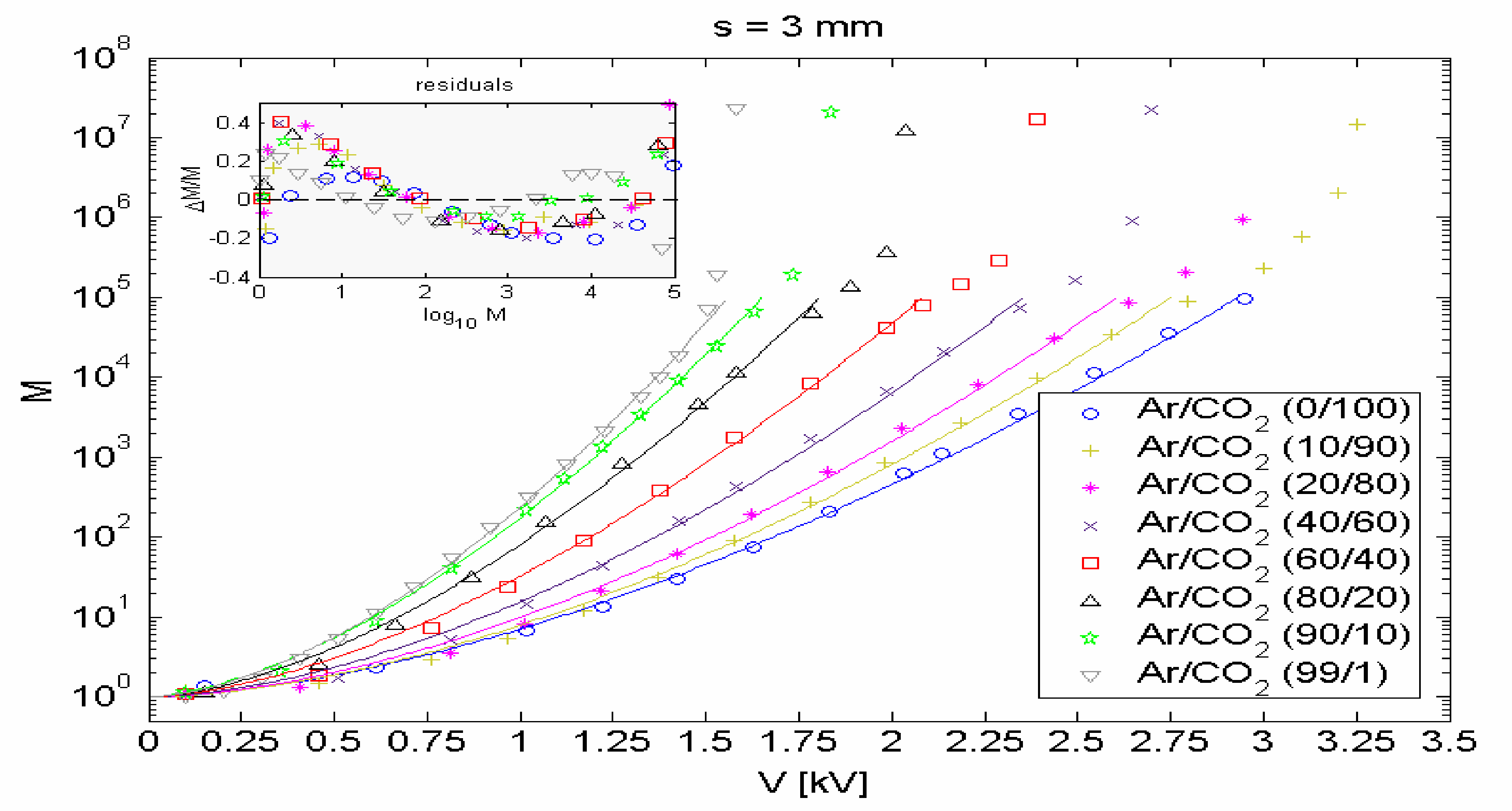
Typical measurements (Xenon).



Curves fitted to the phenomenological expression

$$\ln M = (aV)^b$$

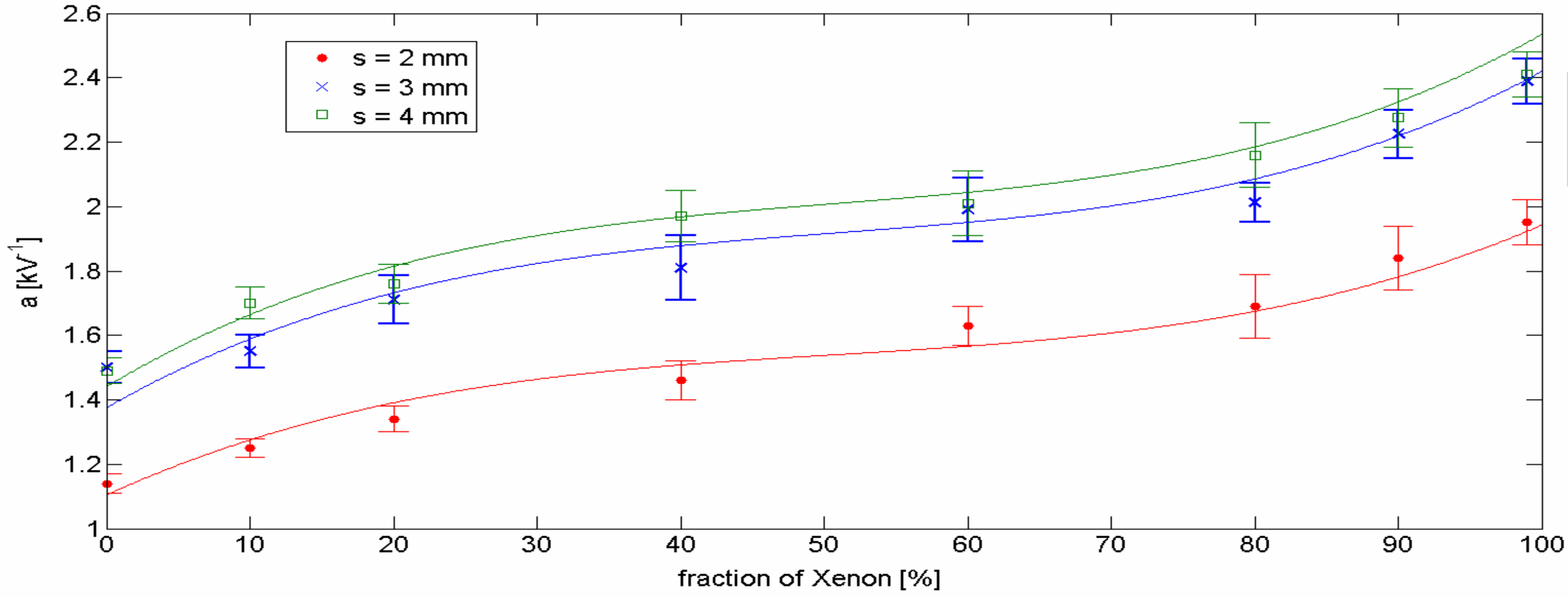
Typical measurements (Argon).



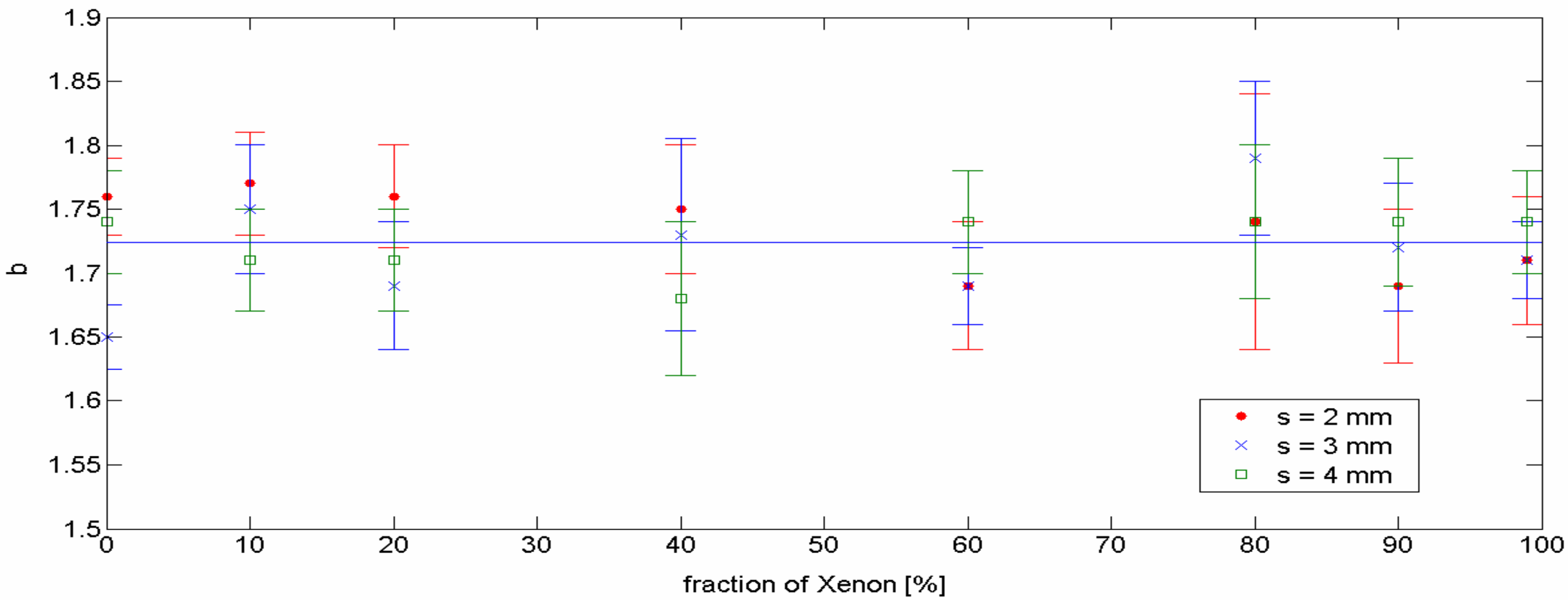
Curves fitted to the phenomenological expression

$$\ln M = (aV)^b$$

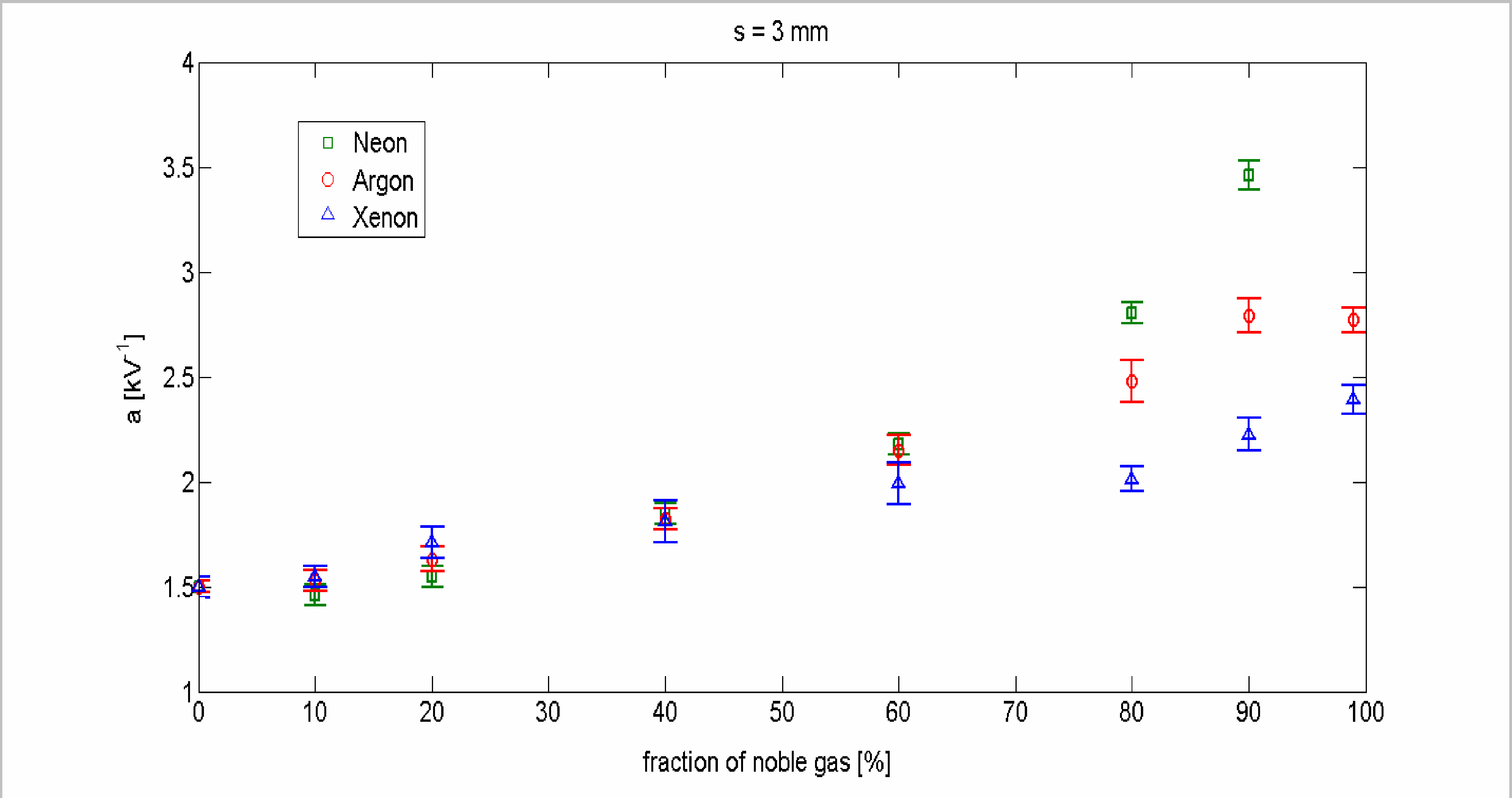
Gain systematics as a function of the fraction of Xenon and chamber pitch s.



$$\ln M = (aV)^b$$



Gain systematics as a function of the gas mixture.

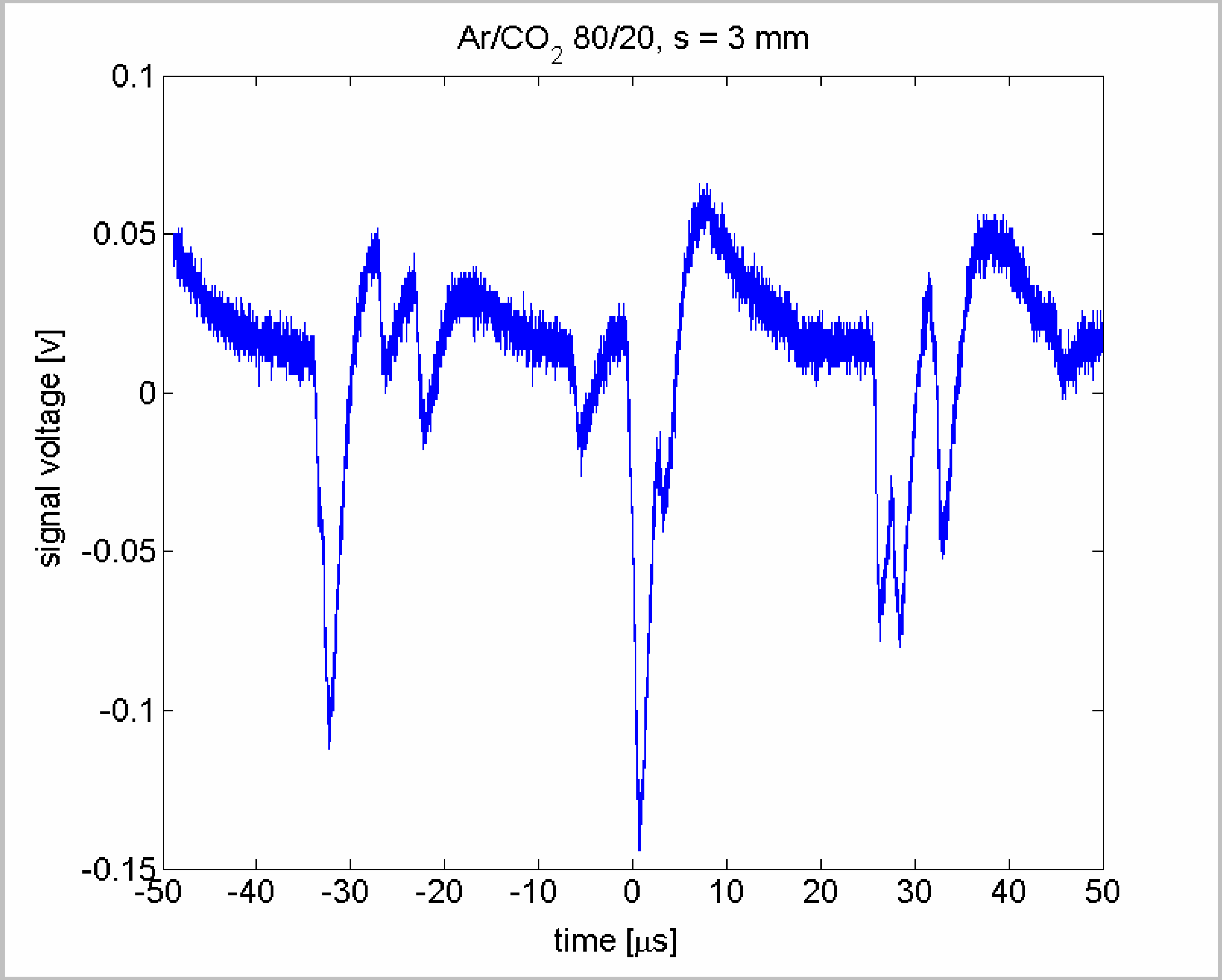


2.2 The glow-discharge.

A. Battiato

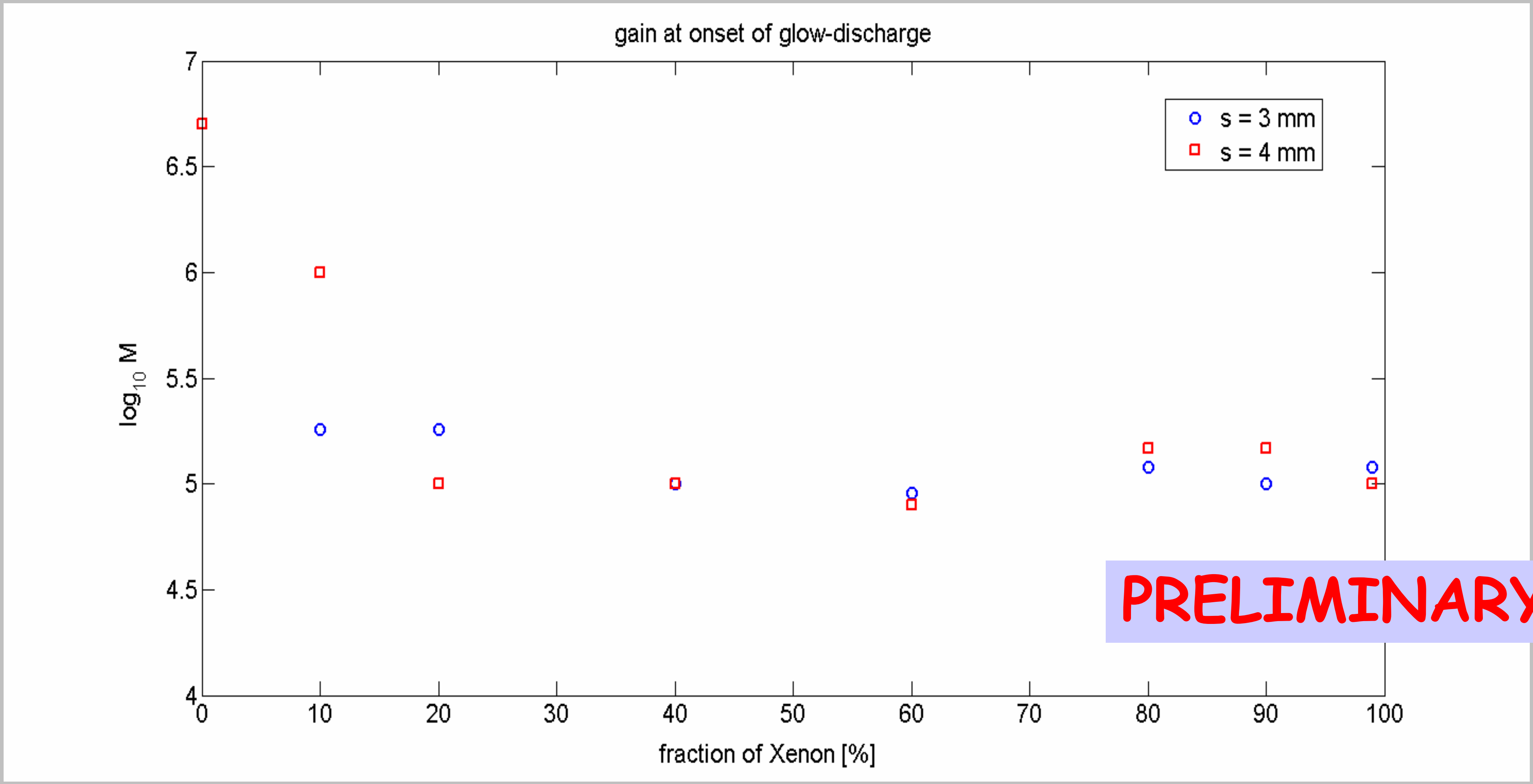
The glow discharge.

Photon or ion feedback may result in re-generation of electrons close to the cathode that causes a self-sustained current in the detector (glow-discharge).



In this kind of mixtures and at this temperature and pressure conditions, it is the main cause of gain limitation of the detectors

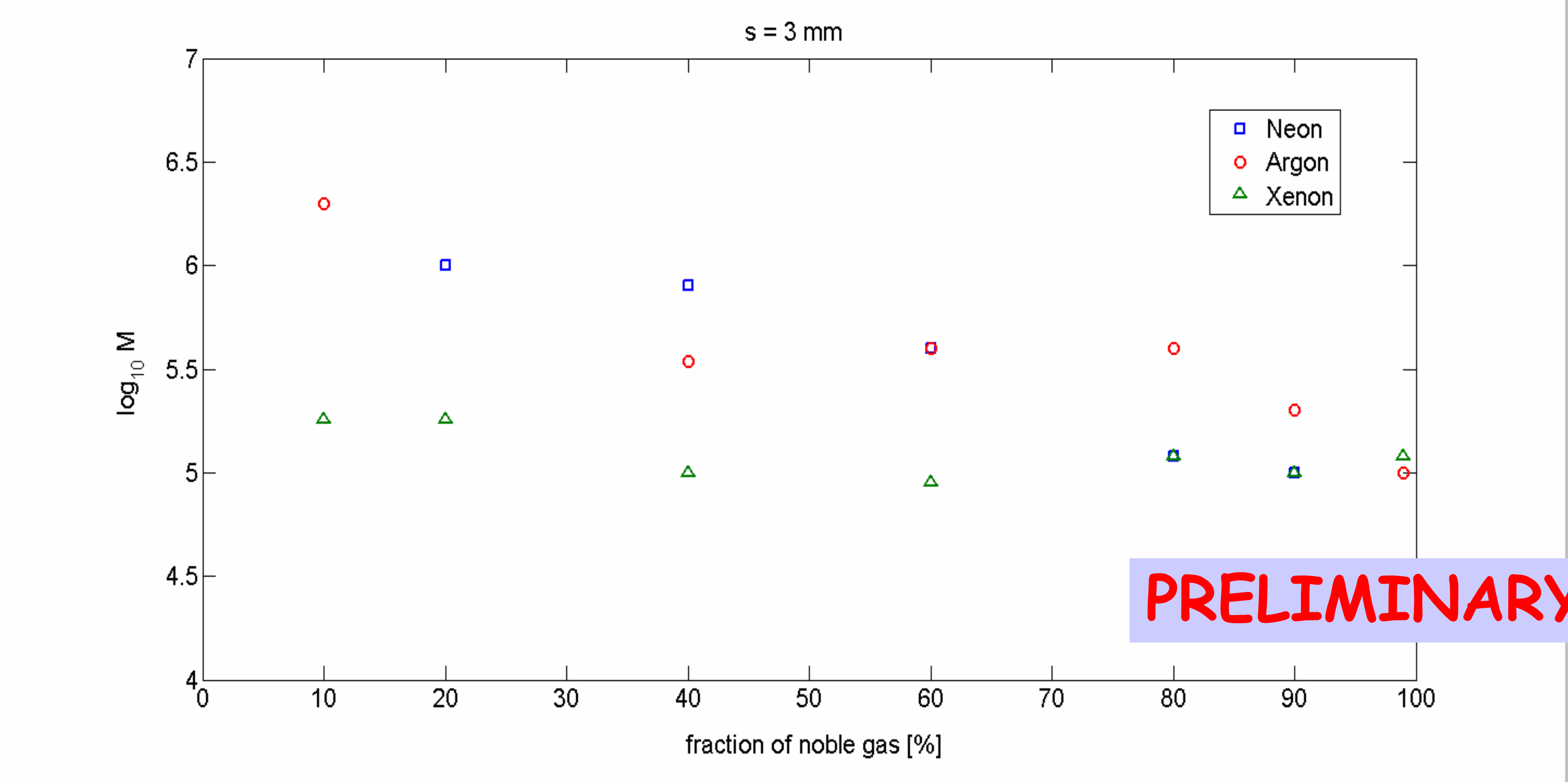
Maximum gain before the onset of the glow discharge for Xenon.



PRELIMINARY!

The maximum achievable gain is rather independent on the quencher, being suggestive of the presence of ion feedback.

Maximum gain before the onset of the glow discharge for different gas mixtures.



PRELIMINARY!

Maximum gain in Neon and Argon mixtures depend strongly on the quencher, being suggestive of photon feedback.

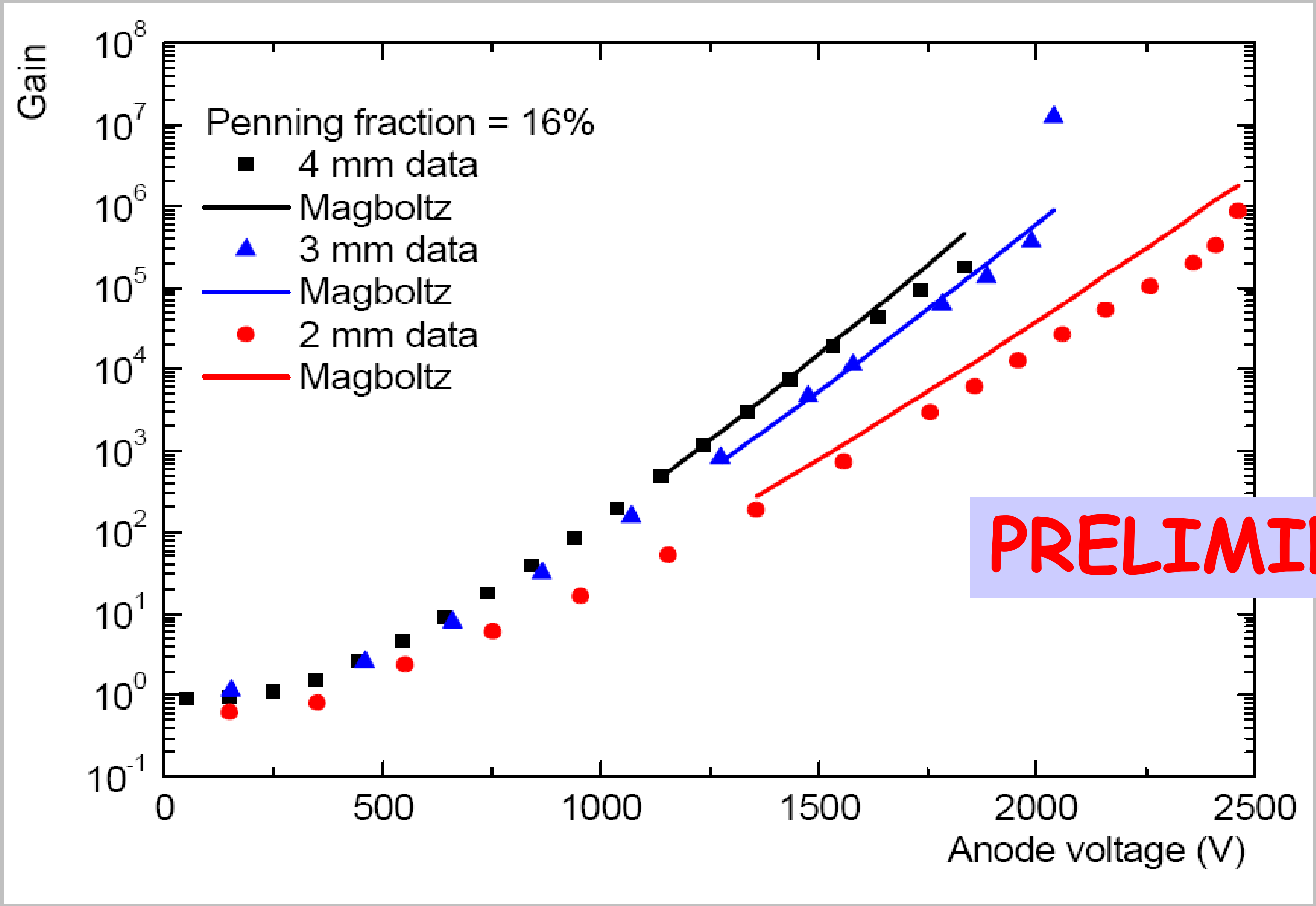
C. Garabatos

Comparison with models (Magboltz).

Meta-stable Ar* always appear during the avalanche process. If Ar* finds a CO_2 molecule, it can be de-excited upon ionization of it (Penning effect).

The fraction of Ar* atoms that undergoes Penning or 'Penning fraction' is a free parameter, but can be constrained by our data since it depends only on the mixture.

Ar/CO_2 (80/20)



PRELIMINARY!

2. Measurements on rate capability.

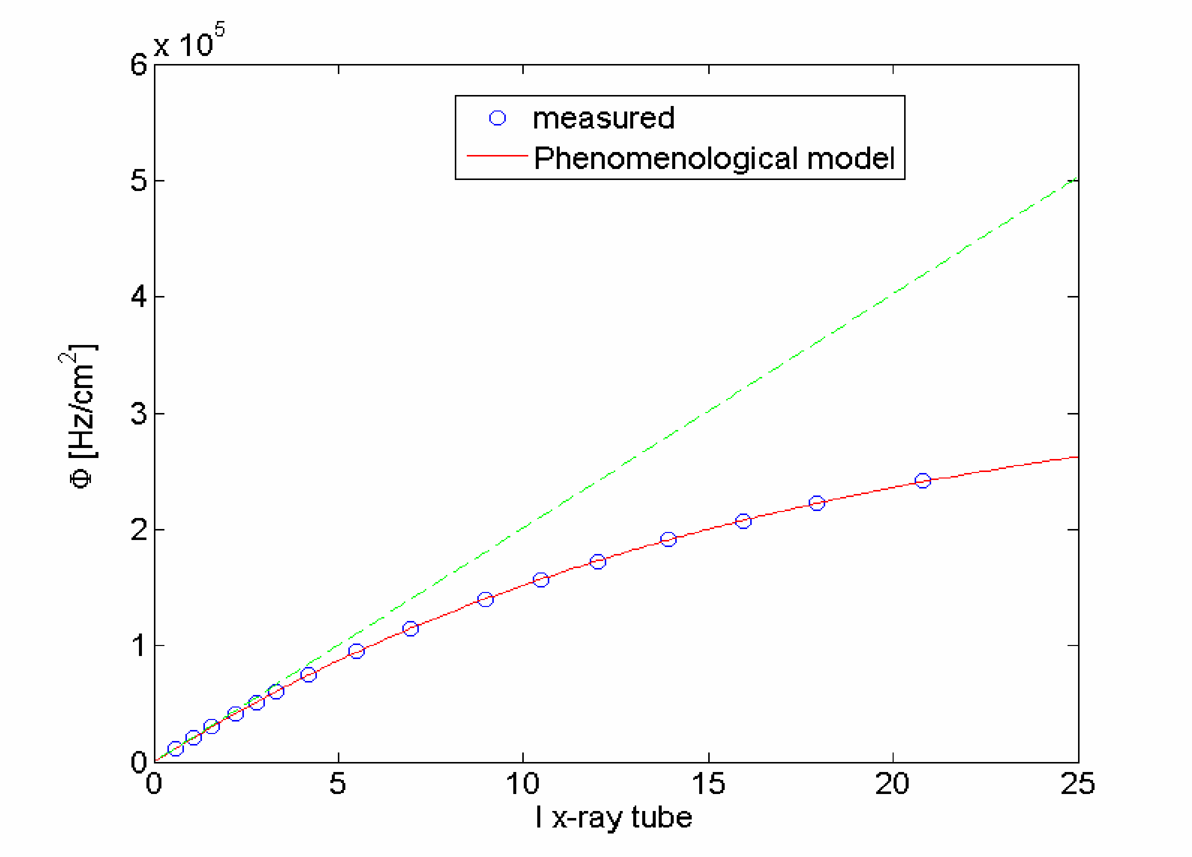
Experimental procedure for rate capability measurements.

- The gain was measured as a function of the primary rate. The dead-time of the system was estimated (and corrected) by making use of the proportionality between the current of the X-ray tube and the primary rate, and using a phenomenological model with only 1 free parameter.

- The area of illumination has been measured by exposing a Polaroid film.

- The current was measured through the power supply.

- The rate was measured with a NIM scaler.



Rate capability. The 'standard model' (I).

E. Mathieson, NIM A 249(1986)413

In the particular case where $\ln M = (aV)^b$, the dependence of the gain with rate is given by the transcendental equation:

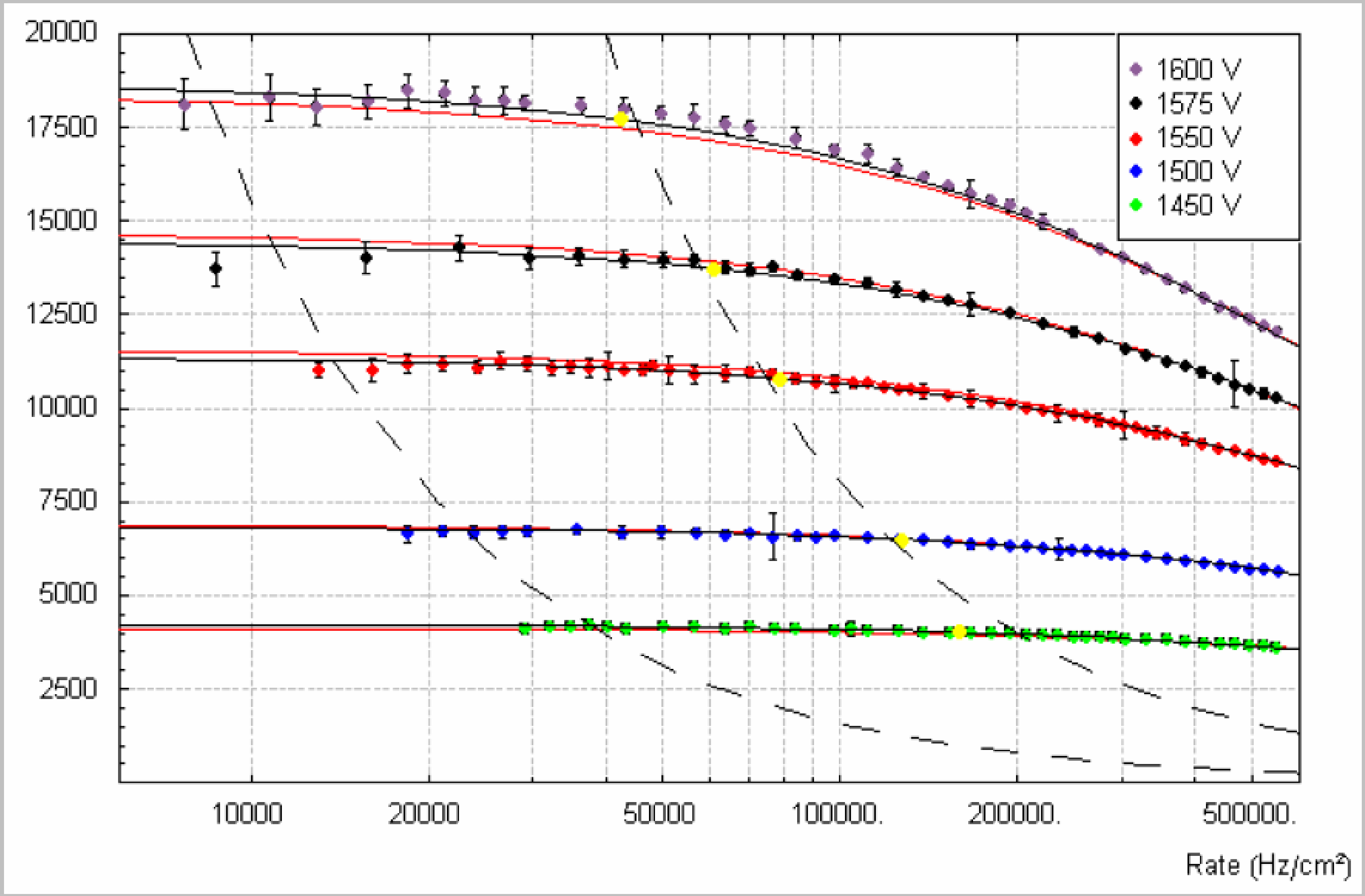
$$M = M_o \exp(-q_e n_o ba \frac{sh^2}{2\mu V C_l} (\ln[M])^{1-\frac{1}{b}} M\phi)$$

Where n_o is the initial number of clusters, φ the primary flux in [Hz/cm²], C_l is the capacitance per unit length, μ the ion mobility, s the wire pitch and h the gap between anode and cathode.

A. Kalweit

Rate capability. Data and model. XENON.

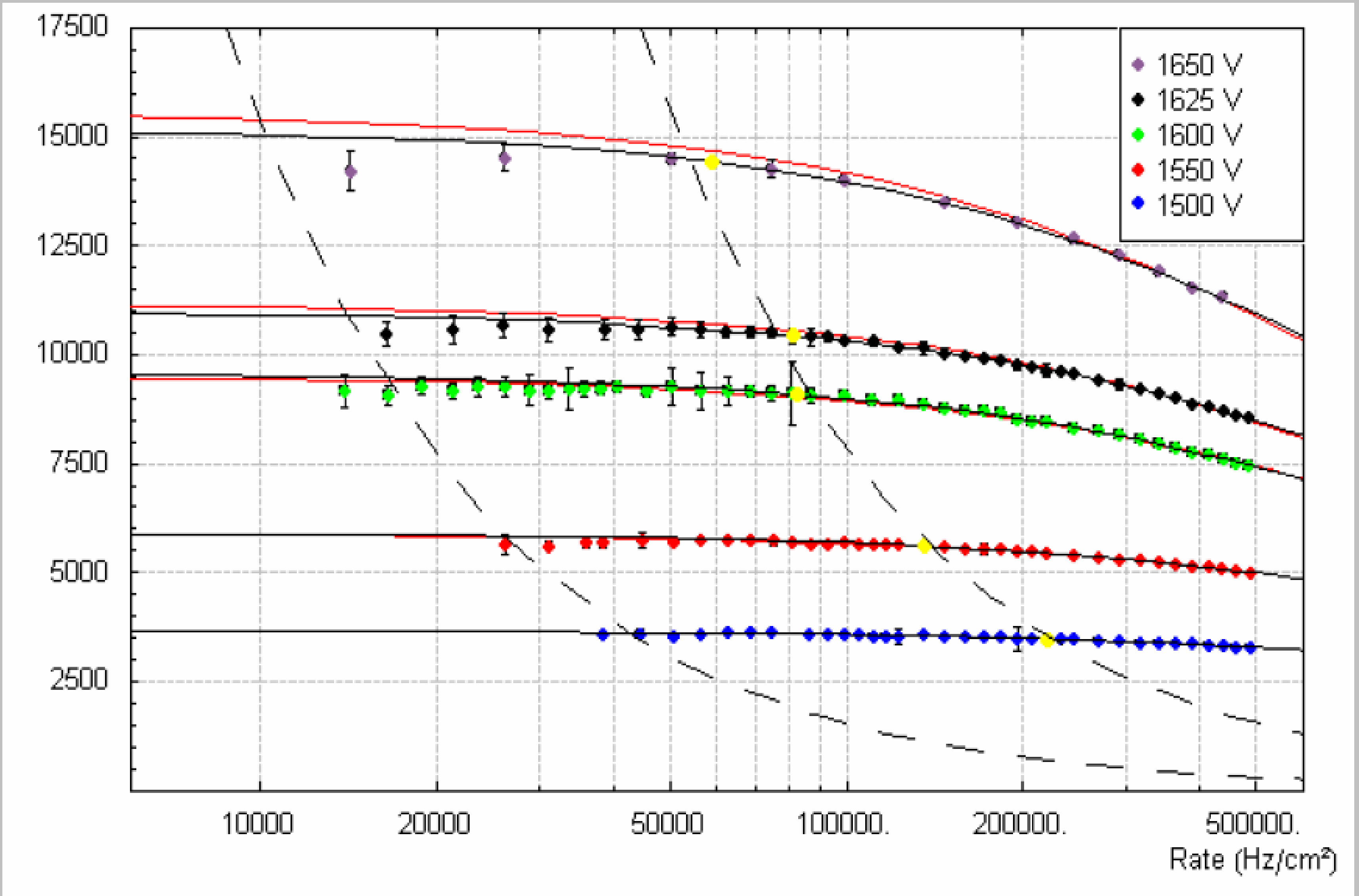
Xenon/CO_2 (90/10)



A. Kalweit

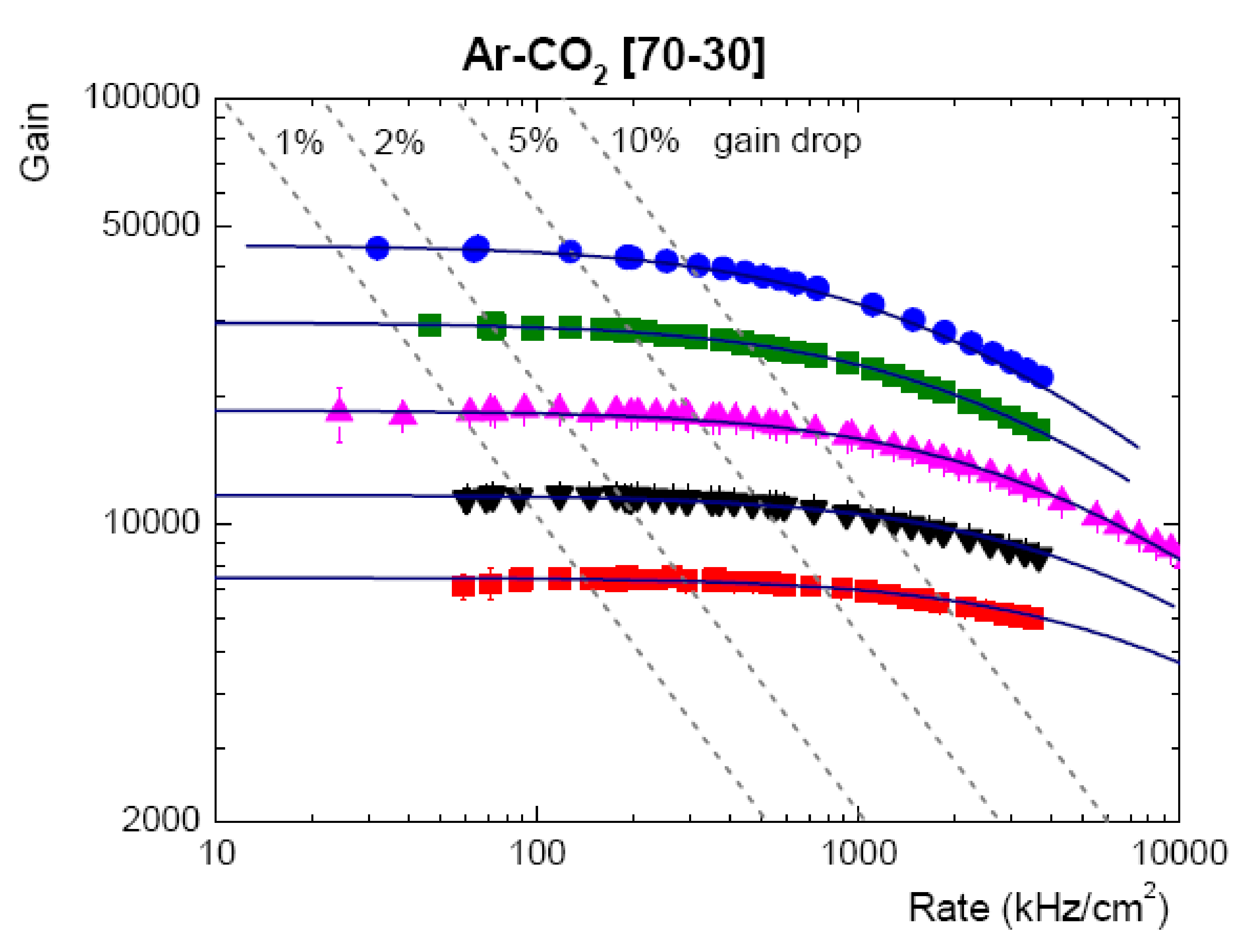
Rate capability. Data and model. XENON.

Xenon/CO_2 (80/20)

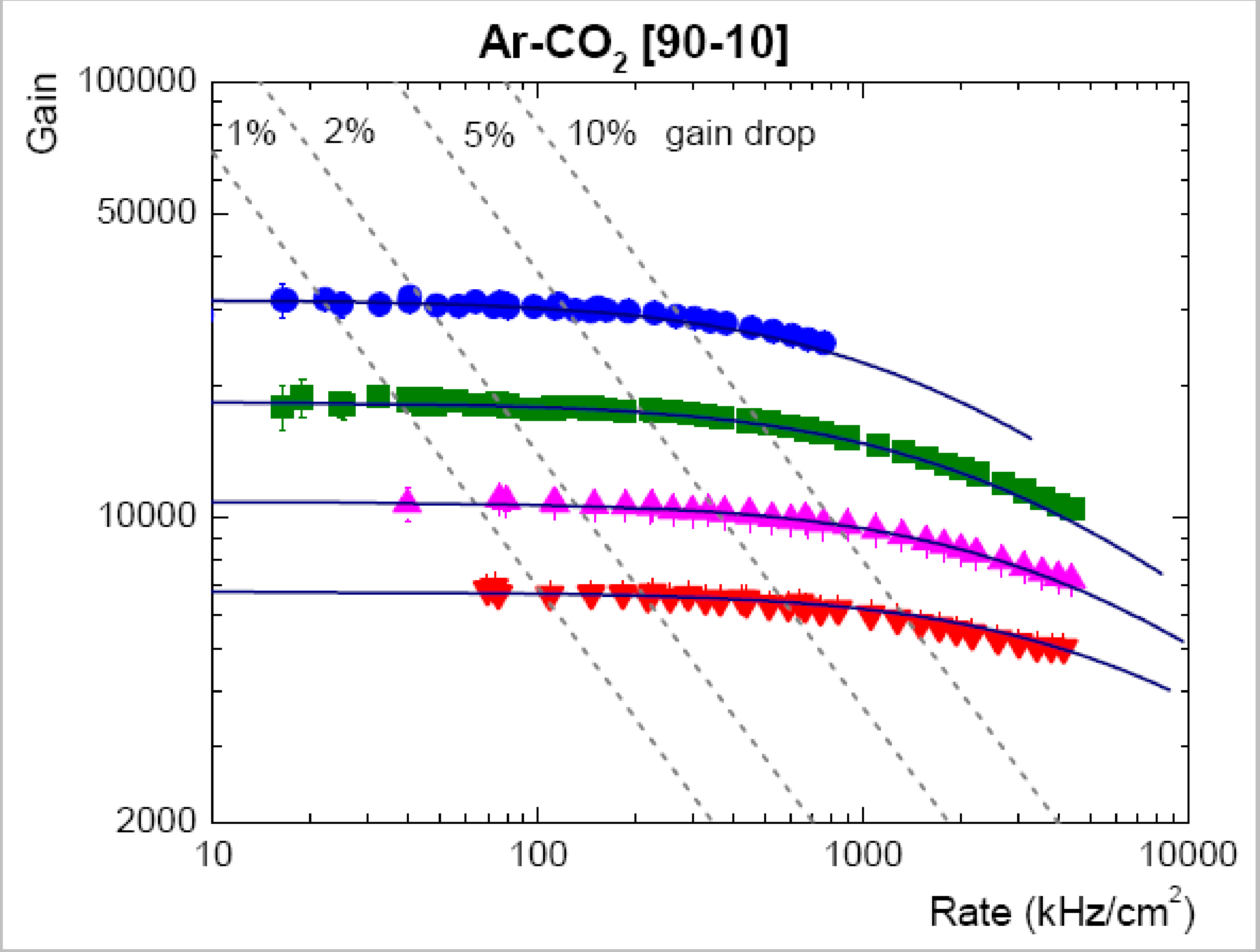


G. Hamar

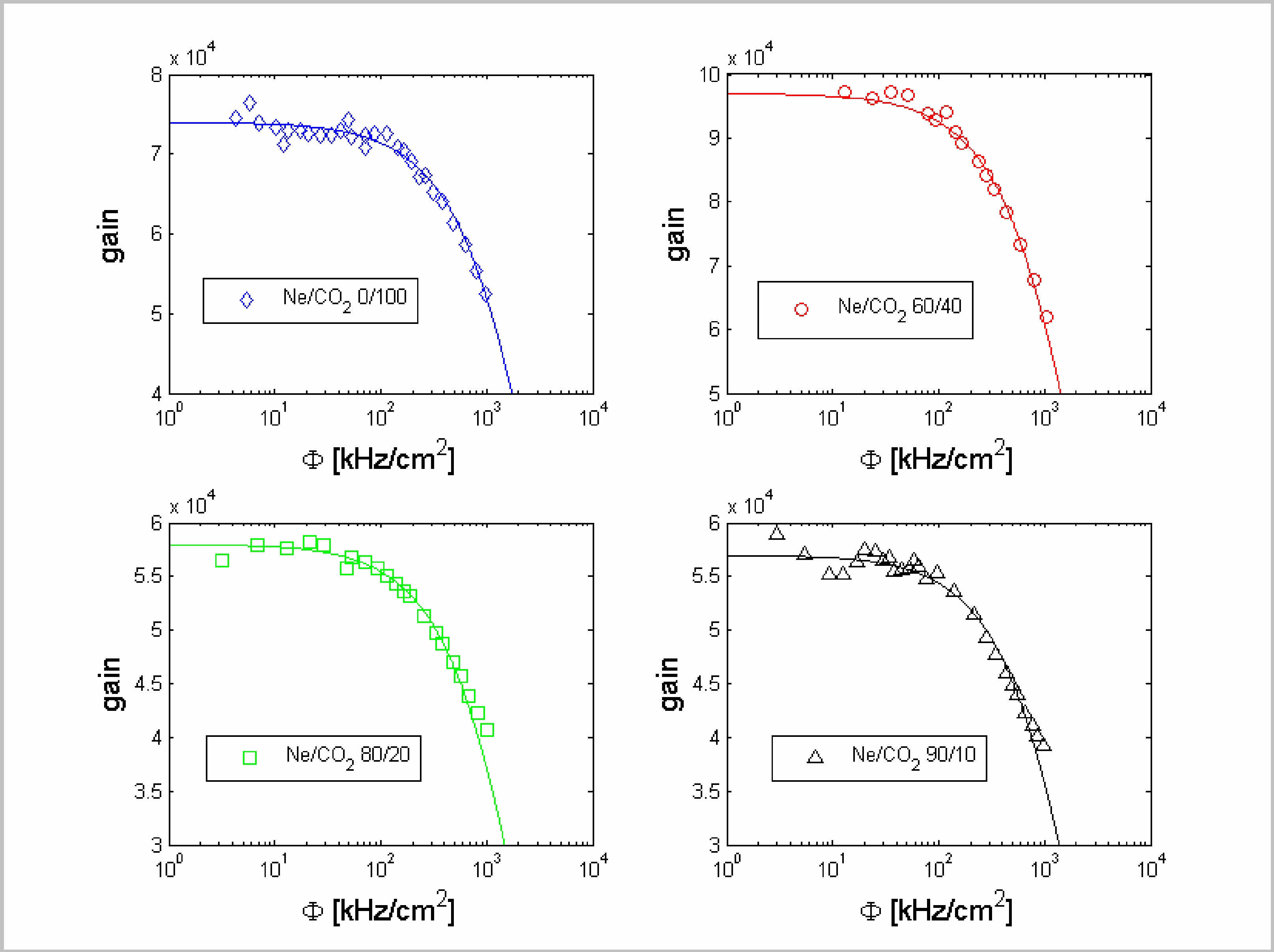
Rate capability. Data and model. ARGON.



Rate capability. Data and model. ARGON.



Rate capability. Data and model. NEON.



Rate capability. The 'standard model' (2).

From expression:

$$M = M_o \exp\left(-q_e n_o b a \frac{sh^2}{2\mu V C_l} (\ln[M])^{1-\frac{1}{b}} M\phi\right)$$

The flux at arbitrary drop in gain (F), can be obtained:

$$\phi(F) = \frac{\ln[(1-F)M_o]^b}{(1-F)M_o} \frac{C_l}{sh^2} \frac{1}{ba^2} \frac{\mu}{n_o} \frac{2}{q_e} \frac{1}{\ln[1-F]}$$

That we denote as 'rate capability'

Rate capability. The 'standard model' (3).

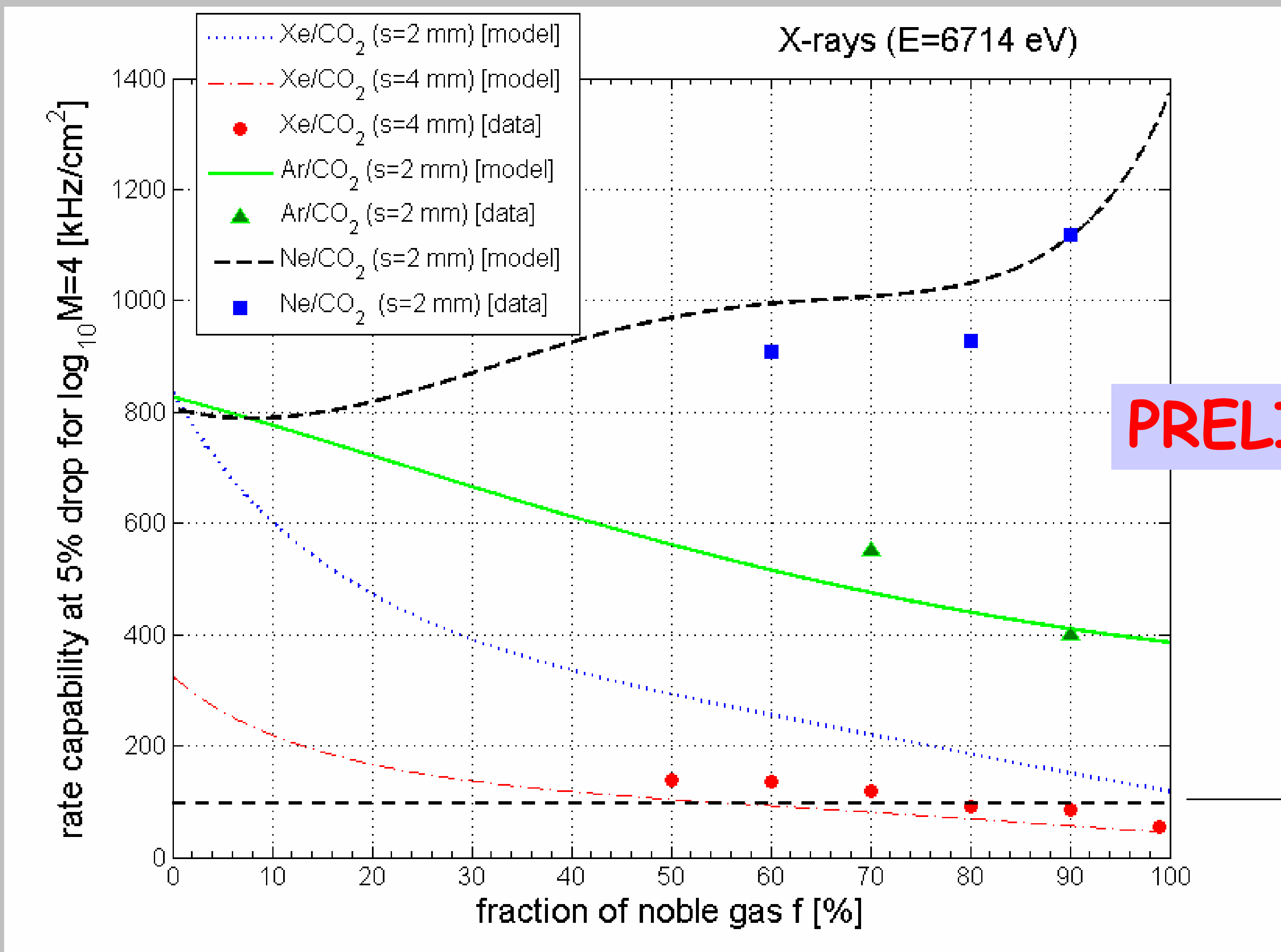
Parameters of the model:

- For the mobility it is assumed that it is the CO_2 who actually drifts and the Blanc's additive law is valid. The values of the mobility in pure gases are then obtained from existing tables. For simplicity, the mobility at zero field is taken and assumed to be constant.

- For the primary ionization, the values reported in Sauli's yellow paper are used.

- The mobility of CO_2^+ in Xe has not been directly measured (up to my knowledge) so I took as an ansatz that the mobility of Xe^+ in Xe scales to the one of CO_2^+ in Xe in the same way that Ar^+ in Ar scales to CO_2^+ in Ar.

Rate capability. All in one.



PRELIMINARY!

required by CBM

Conclusions.

- The gain and rate capability has been measured for several chambers and gases, and seems to be reasonably well described by transport models (Magboltz).

- The maximum operating gain in Xenon mixtures is systematically below Argon and Neon.

- The rate capability of the chambers has been measured and is well described within 20% for Xenon, Argon and Neon mixtures by using the Mathieson formula. The good agreement gives some confidence on how to extrapolate to different geometries, mixtures and primary ionization.

- Given the energy loss for mips in Xe ($\Delta E \sim 5$ KeV/cm), it seems that the rate capability in Xe/CO_2 based mixtures for 4 mm chambers and $M=10^4$ fits to the CBM requirements. Drops in gain are expected to be below 5%.

Outlook.

- Improve the quality of the analysis of the existing data on rate capability under X-ray illumination. In particular, the existing data has been analyzed independently by different people.

- An assessment of the dependence of the rate capability with the beam size must be pursued before extracting further conclusions.

- Analysis of data under illumination with ionizing particles will be pursued in short term.