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Update on electron transparency simulation and comparion to ExMe Studies

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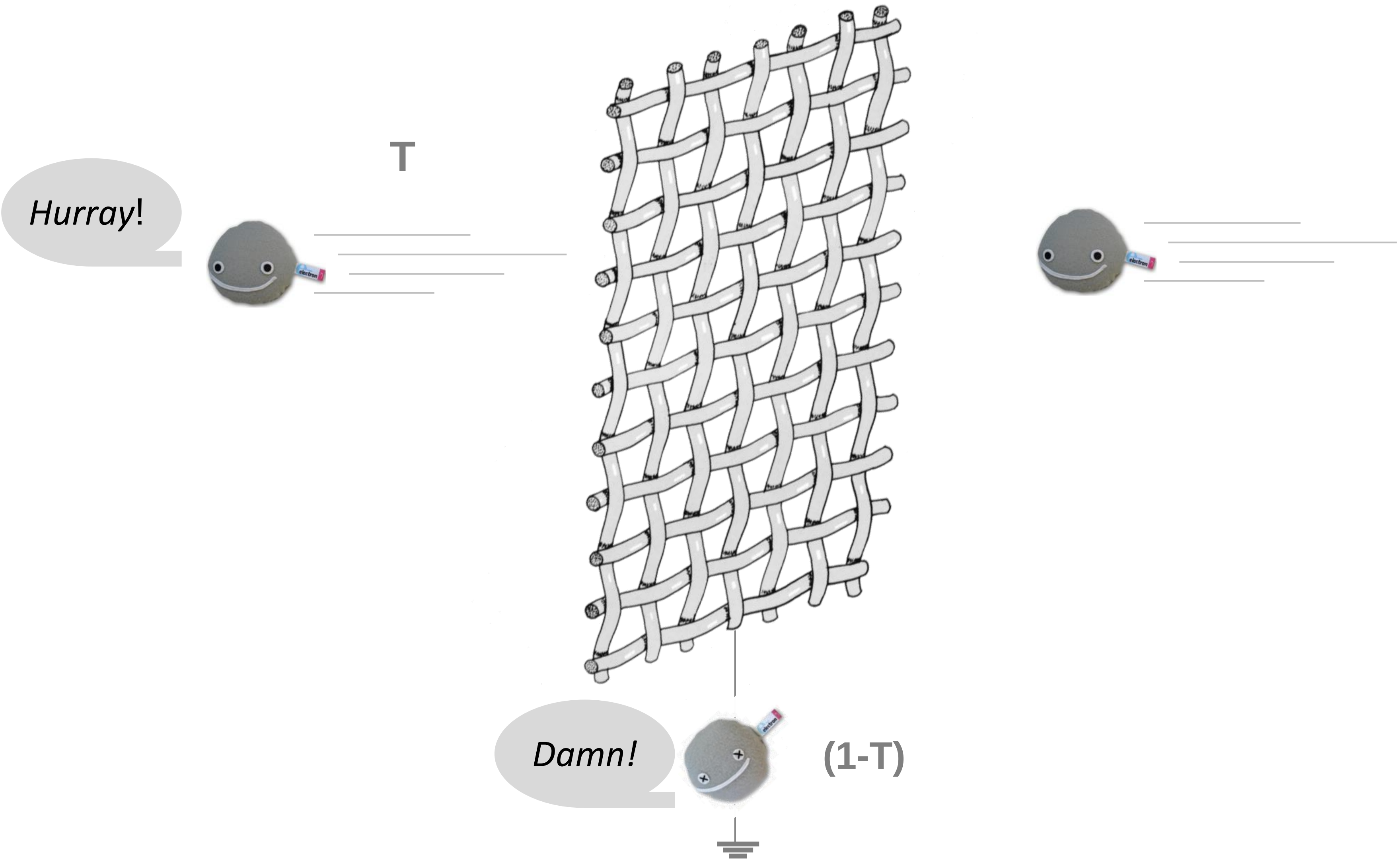
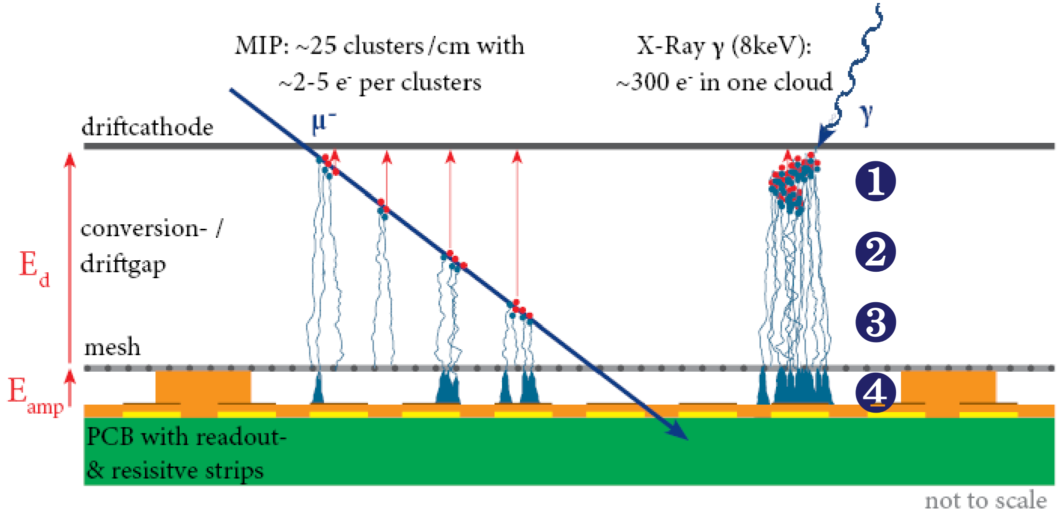

T
Hurray!
electron
Damn!
(1-T)

Processes in a Micromegas
- Well understood!? -

Which *gas-processes* contribute to the signal formation a Micromegas?



❶ Primary ionization / conversion ✓
→ Typical energy loss tables (e.g. HEED)

❷ Electron drift (diffusion, attachment…) ✓
→ cross section databases (e.g. Magboltz, GARFIELD)

❸ Electron losses at the mesh ✗

❹ Electron amplification ✓
→ including additional e^- production mechanisms
(*"Understanding avalanches in a Micromegas from single-electron response measurement", NIM A 772 - 2015)*

(+ ❺ signal capture, readout, amplification etc.)

❸: Electron transparency of the mesh $T = \frac{\#_{e^-} \text{ passing trough the mesh}}{\#_{e^-} \text{ approaching the mesh}}$, depends on

- mesh geometry: wire-diameter, mesh -opening width -> open area, mesh thickness & structure…
- approaching behavior of the electrons:

gas & electrical field
(composition, temperature, pressure) (geometry + voltages on drift, mesh & readout)

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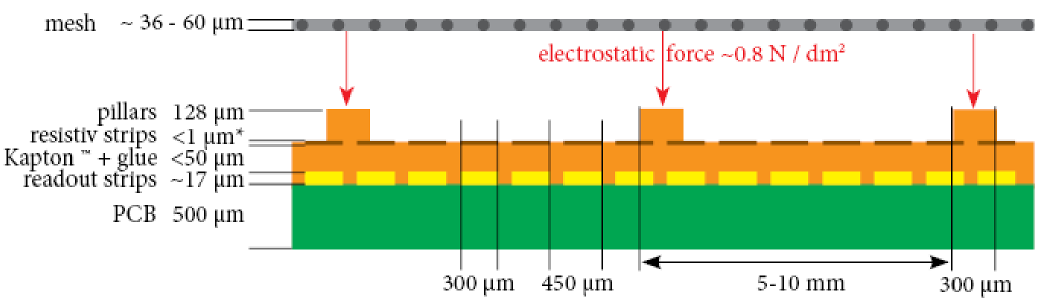
Concept of an **Ex**changeable **Me**sh Micromegas (ExMe)

CERN

To study different meshes under ideally comparable conditions we designed and build a Micromegas with an **exchangeable mesh**:

→ **Presented during IWAD & 14th RD51 Meeting (2014, Kolkata)**

- Following the **floating mesh** concept
(as for seen for ATLAS NSW Micromegas)



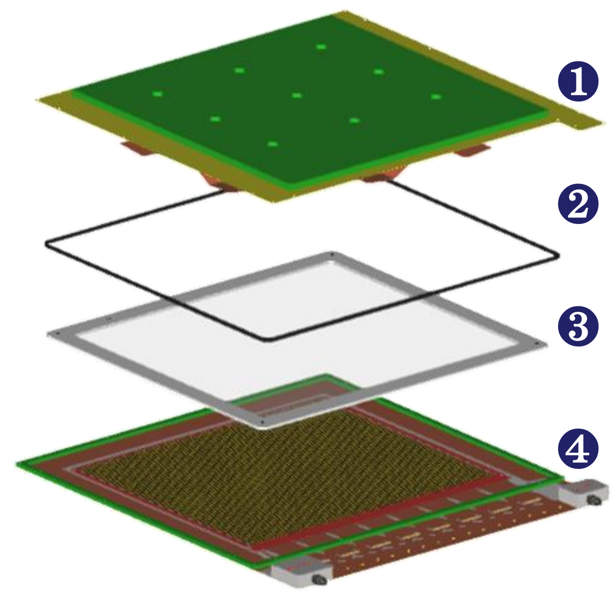
* for sputtered resistive carbon layers, screenprinted layers ~ 10 µm

Not to scale.

- **Independent mesh frames** allow easy mesh exchange
(ATLAS NSW: mesh will be fixed on the drift panel)

→Most detector **inherent parameters** (amplification- and drift gap thickness, readout surface etc.) are kept constant and allow direct mesh comparison

Schematic view of the ExMe1 components



❶ Drift panel (stiff-back, internal gas lines, drift cathode, springs)

❷ O-Ring

❸ Mesh frame

❹ Readout panel (readout strips, Kapton foil with sputtered resistive pattern, connectors…)

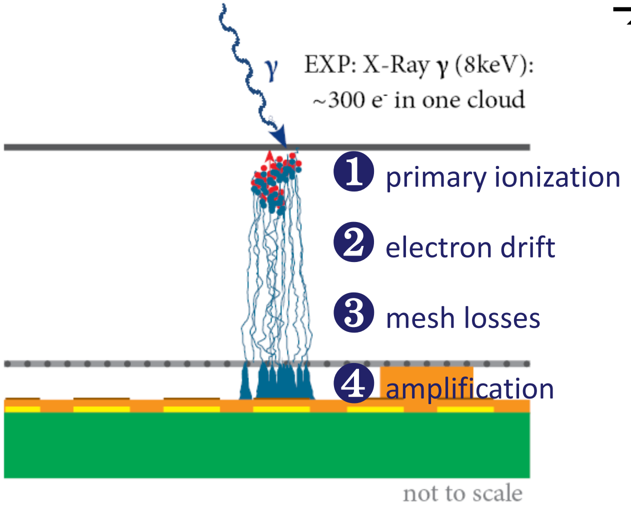
Experimental method

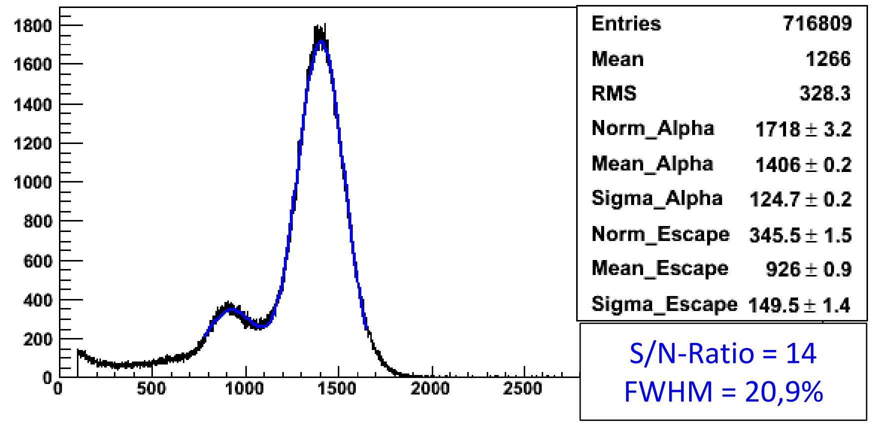
On the **experimental** side…

- Single processes can not be measured directly

→ Spectrum of the signals induced by γ from Cu-X-Ray

→ Position of the K_{α}-Peak (and Ar-Escape-Peak)





- Disentangling a single process (❸) requires control and stabilization of all other

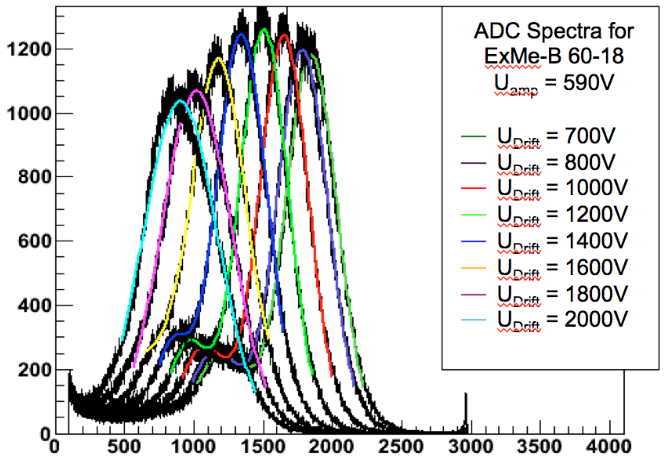
$$S = n_{e_{primary}} \cdot (1 - A) \cdot T \cdot G \cdot c_{readout} \cdot c_{Signal\ processing} \rightarrow S \propto T$$

❶ ❷ ❸ ❹ ❺

underlying assumption

S = Signal (measured in ADC counts), A = fraction of electrons lost to attachment, G = Gain per electron

Experimental method & setup



- **Variation of the drift voltage** causes a systematic shift of the spectrum, and accordingly the K_α-Peak

  → signal loss corresponds to a loss of amplified e^-

  → caused by decreased Transparency with increasing U_{drift}

  (increase of mean energy for electrons approaching the mesh)

→ **Presented during IWAD & 14th RD51 Meeting (2014, Kolkata)**

Intense Measurement program (Jan/Feb):

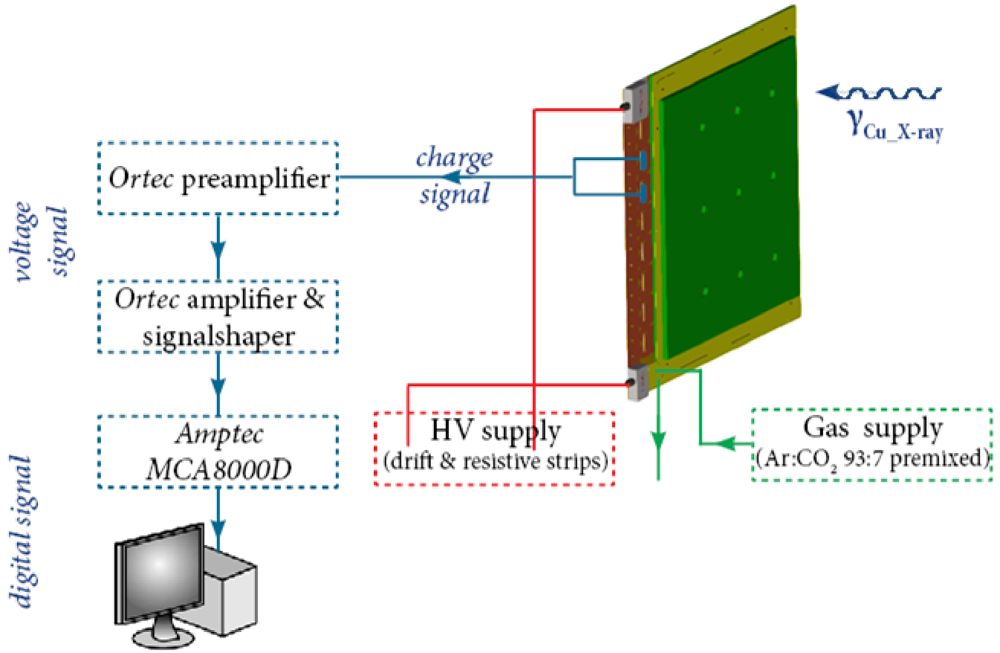
- 3 Spectra each ≈ $3 \cdot 10^5$ events
- screening U_{Drift}: 10V – 2000V (over 5mm)
- for different U_{amp}: 540V – 600V (over 128µm)

- repeated in each Sector A,B,C & D:

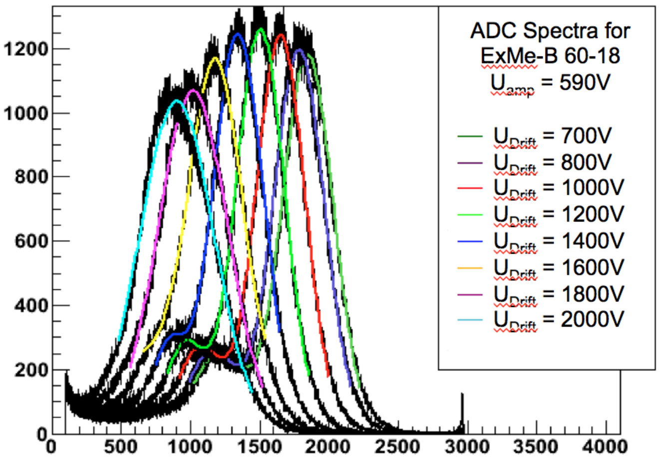
  5, 7, 8.5 & 10mm pillar distance
- with 4 different meshes:

  45-18, 60-18, 50-30, 71-30

→ **≈ 10.000 spectra recorded**

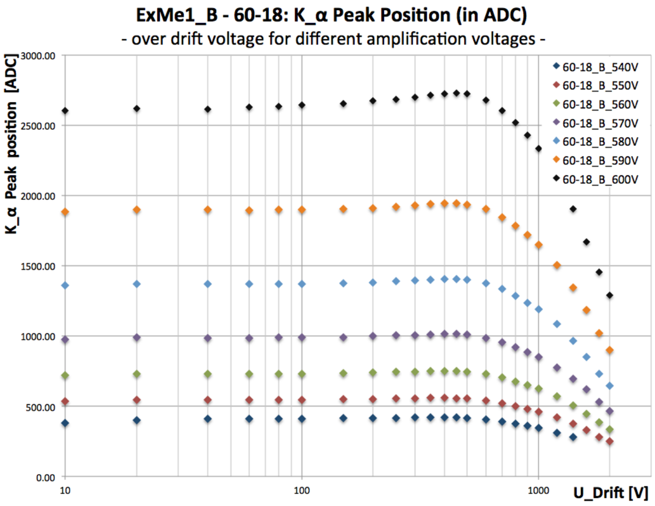


Experimental data analysis



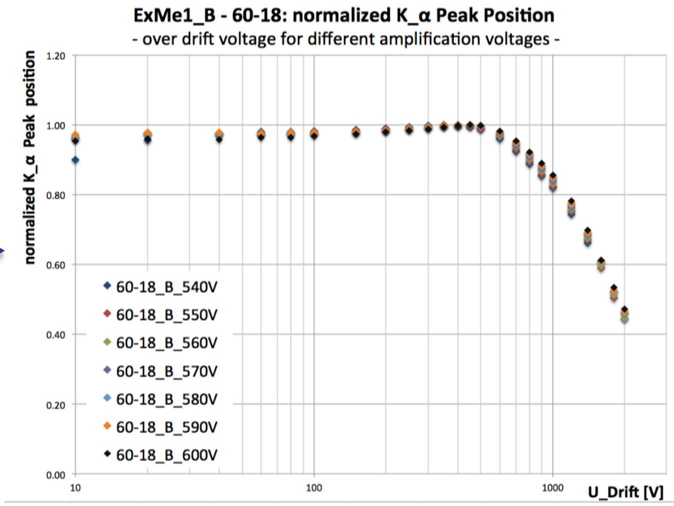
- Spectra are fitted with a two-gauss-function (K_α- & Esc peak)
  (K_β and its contribution to the Esc peak are not (jet) considered)
- Each K_α-Peak position corresponds to one point in the 'Transparency' curve
- Normalizing the curves corrects for all proportional factors
  (Normalization to 1, from expectation of 100% Transparency for ideal E-field settings)

K_α-Peak Position over U_{Drift}



Normalization to Maximum = 1

→ Transparency

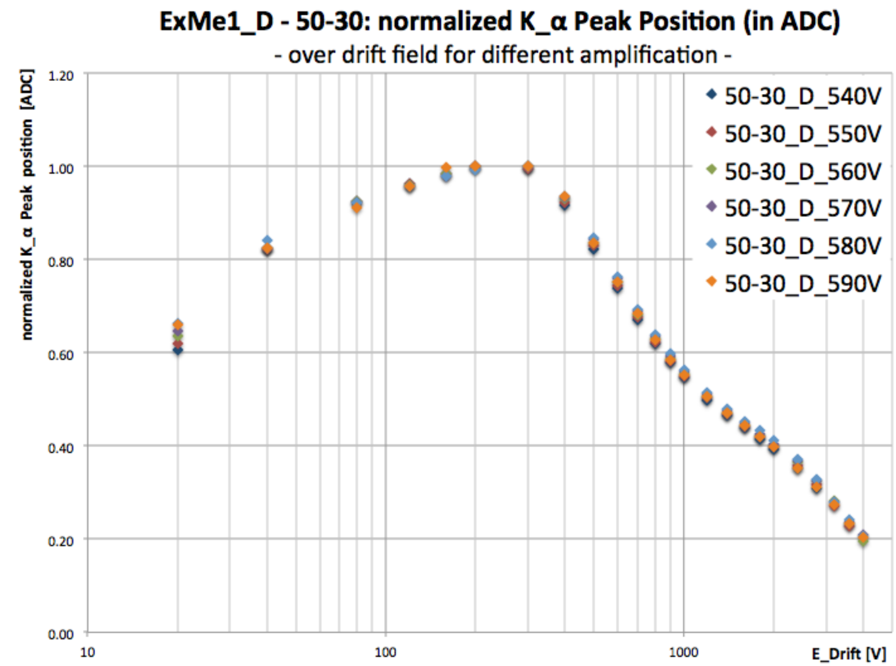


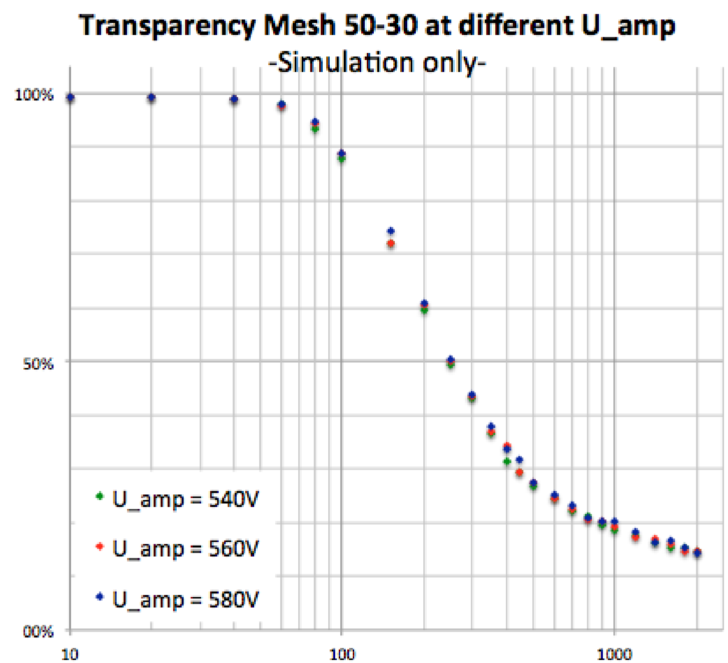
Results – U_{amp} (In-) Depencency of T

- T is assumed to be dependent from the electrical fields on **both** sides of the mesh:

  ~~$T(E_{drift}/E_{amp})$~~ → ~~$T(E_{drift;}E_{amp})$~~ → $T(E_{drift})$

- Data taken over **the full working-range** of the MM (540V - 600V → 42,2kV/cm - 46,9kV/cm) shows very small dependence (<2% effect) of T on U_{amp}.

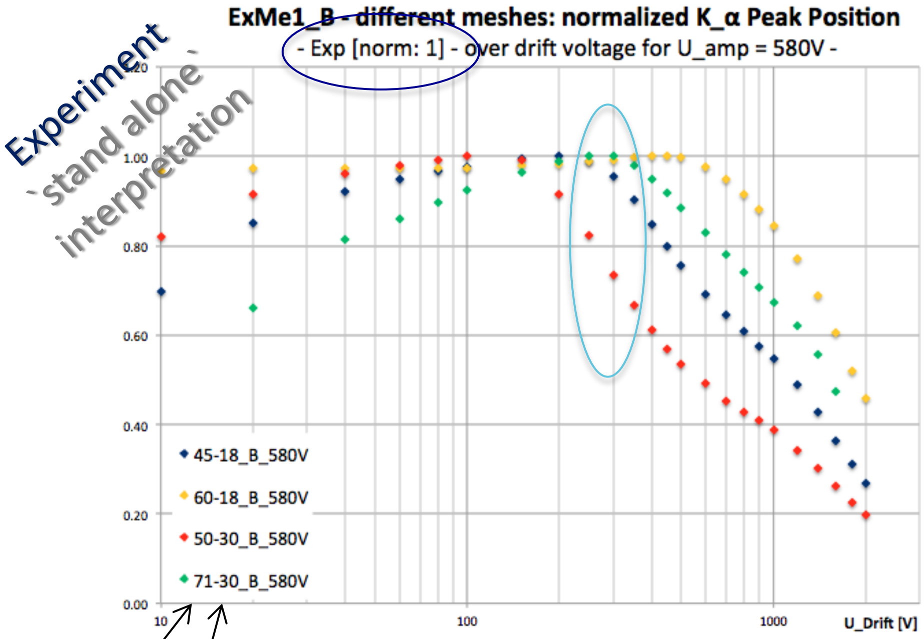




- Simulation with different U_{amp} confirms this results (small systematic deviation at ≈1% level).

Results – Experiment only

Comparing the **experimental** results for **different meshes**:

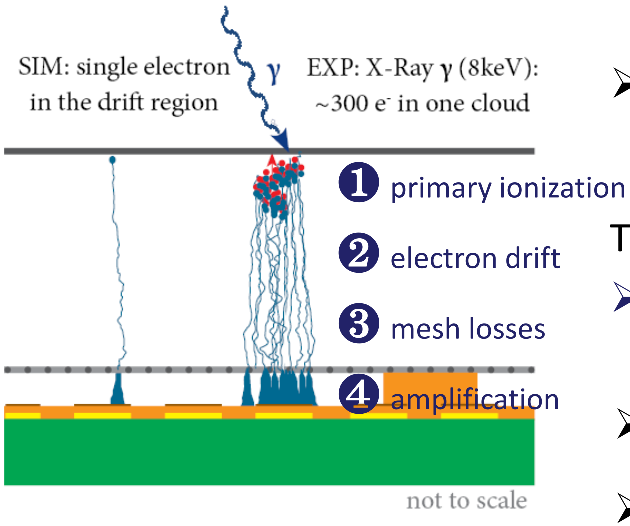


Mesh	T $|U_{drift}$=300V
45-18	95,5%
60-18	99,3%
50-30	73,6%
71-30	100,0%

mesh-opening & wire-diameter [µm]

Modeling and simulation approach

On the **simulation** side…

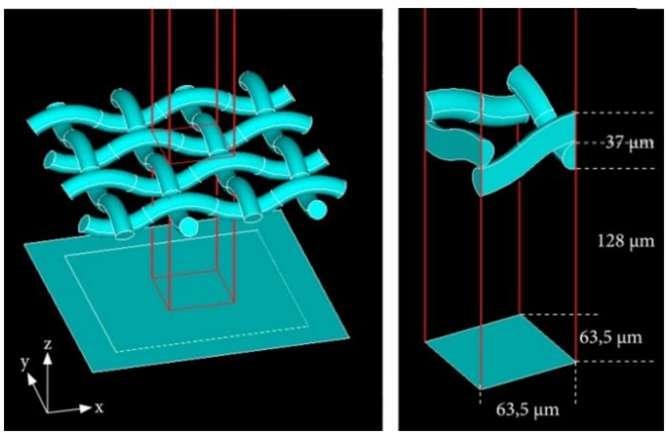


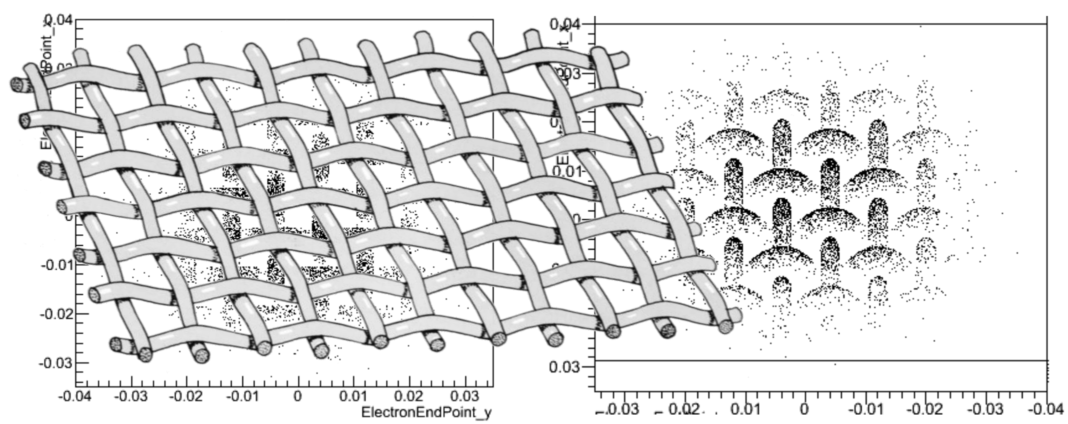
- Full simulation of e.g. a single 8keV-γ-event (by chaining the simulation of all processes) is extremely CPU intensive
- Single process simulation is more reasonable (statistics)

To simulate the mesh transition ❸:

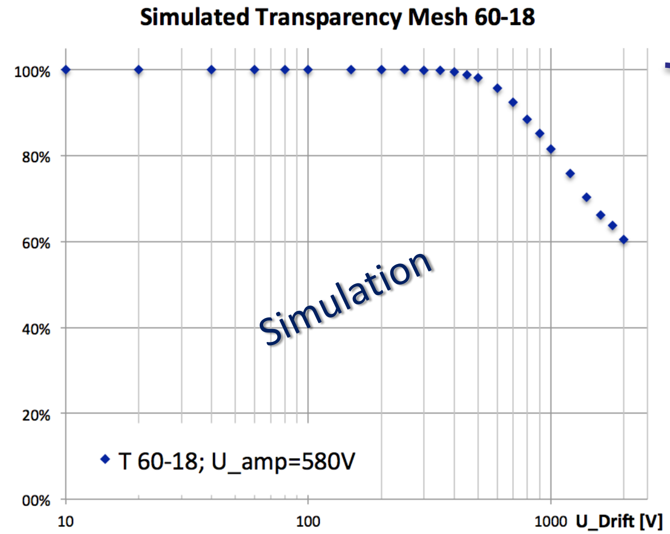
- the geometry has been modeled and the **electrical field** calculated using **FEM** (Ansys, > 50.000 elements / unit cell)
- **electron microscopic tracking** performed in Garfield++
- Electron end points yield **T**

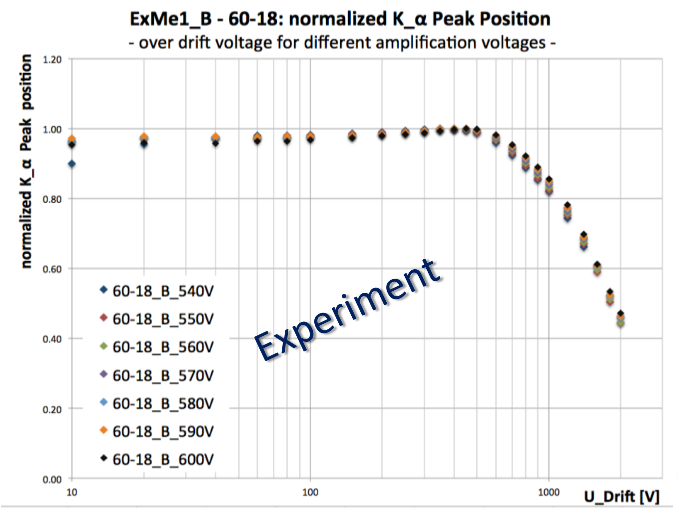
$$T = \frac{\#_{e^-} \text{ passing trough the mesh}}{\#_{e^-} \text{ approaching the mesh}}$$





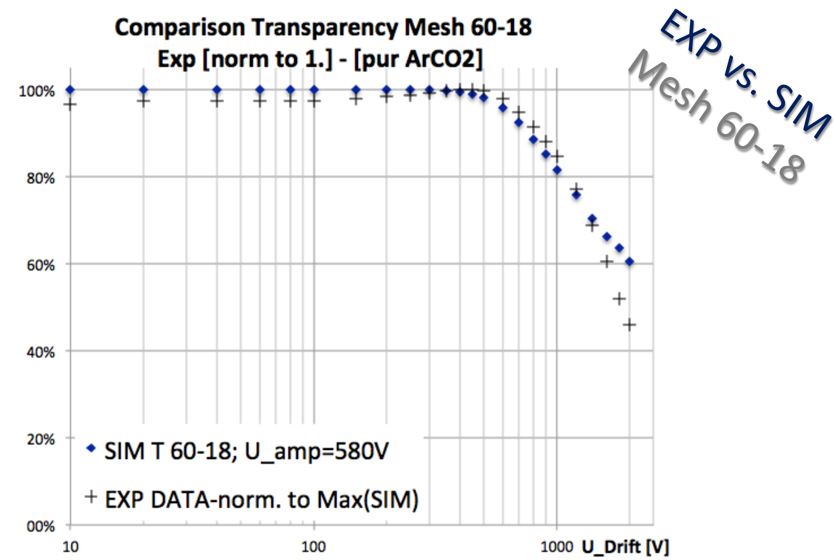
Comparing Exp & Sim for mesh 60-18





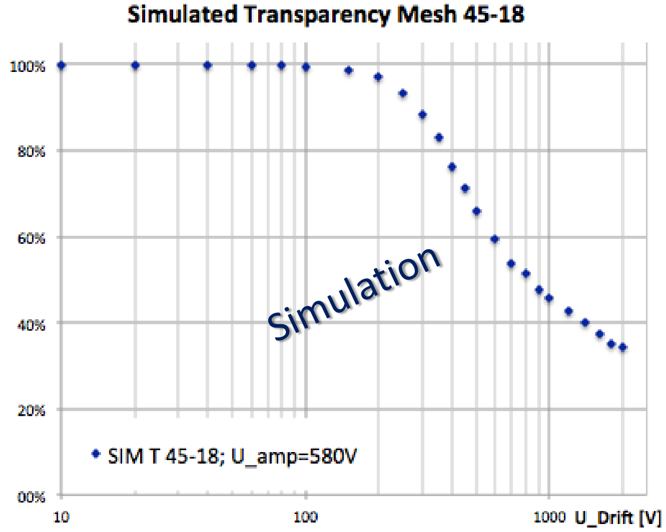
Comparing simulation and experimental results reveals:

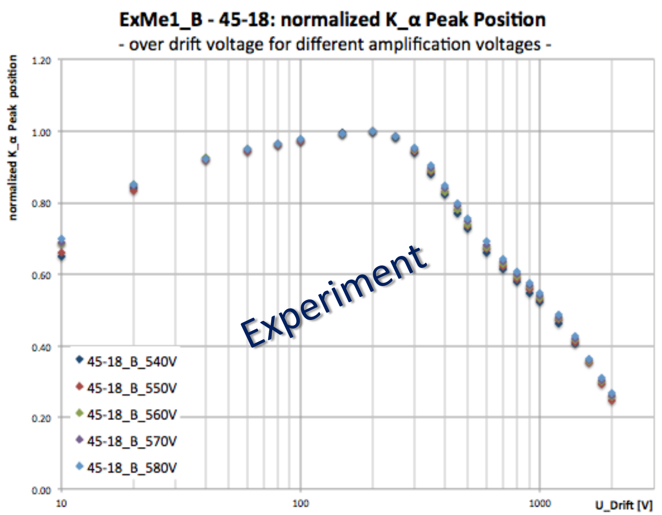
✓ Good agreement in the overall T estimation



✗ Systematic deviations at the low and high drift field region

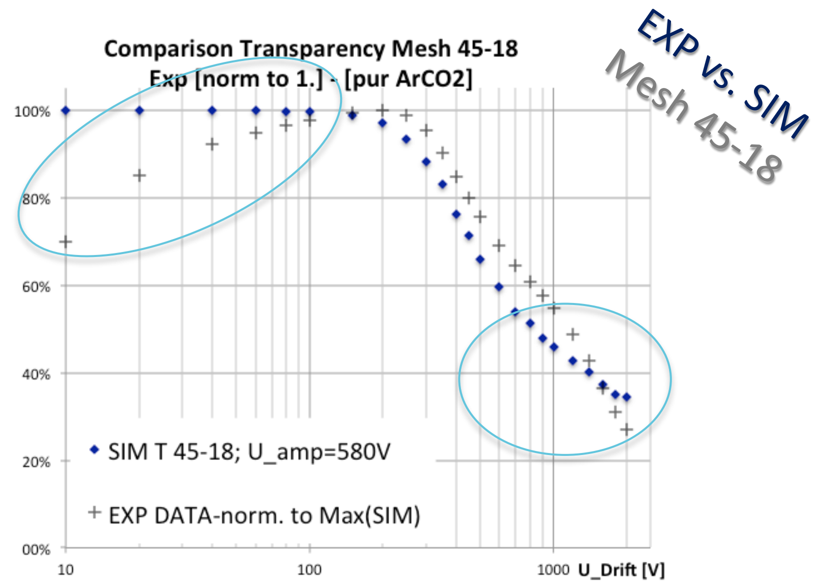
Comparing Exp & Sim for mesh 45-18





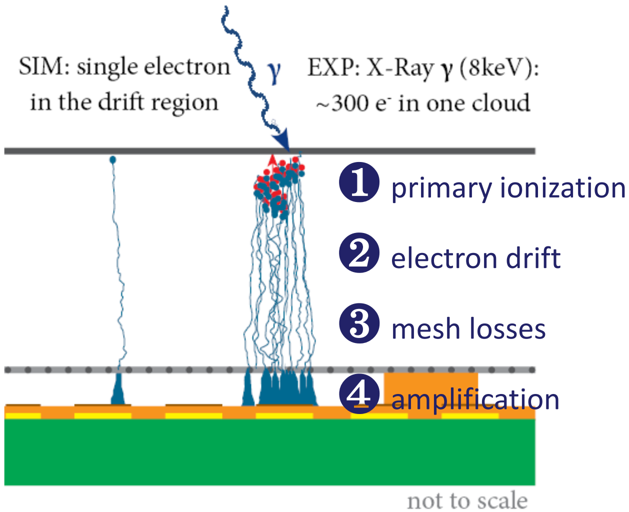
More pronounced discrepancies with other Exp data:

- ✗ Agreement looks less convincing



- ✗ Systematic deviations at the low drift field are much more pronounced
- ✗ Same 'crossing' of simulated and experimental data is observable at high U_{Drift}

Comparing experiment and simulation



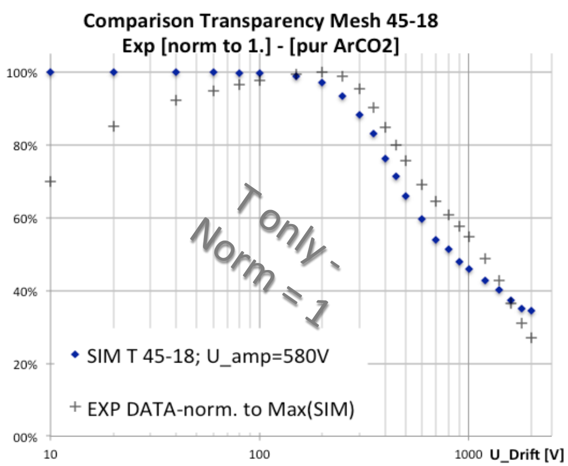
Reviewing the underlying assumption

~~$S \propto T$~~ → $S \propto (1 - A) \cdot T$ (❷ (1 − A), ❸ T)

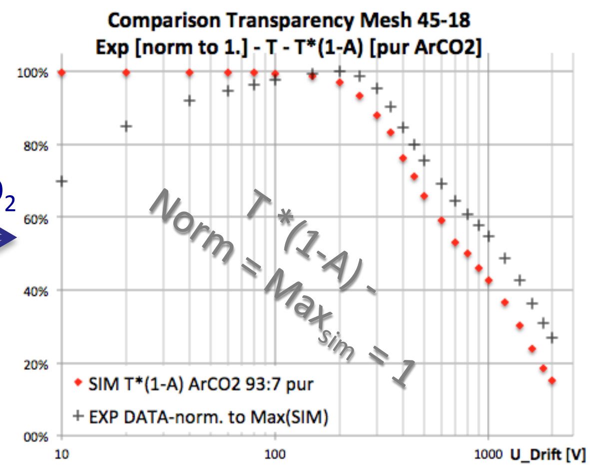
rejected — **revised assumption**

Simulation of the attachment losses during electron drift (❷) :

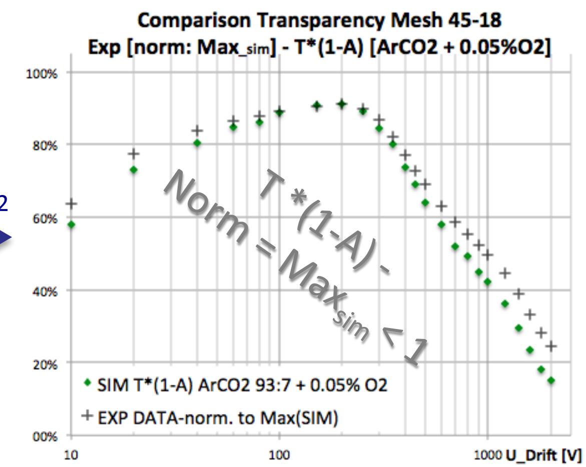
- non-negligible attachment to CO_2 at high e^- energy
- crucial effect of small gas impurities ($< + 0.1$ % O_2) at low U_{Drift}



$+CO_2$ →

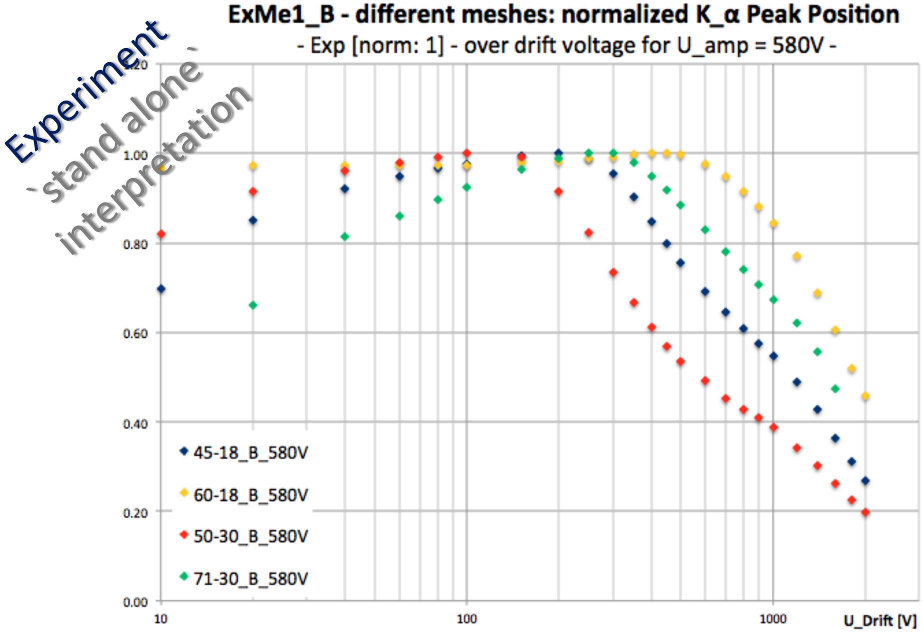


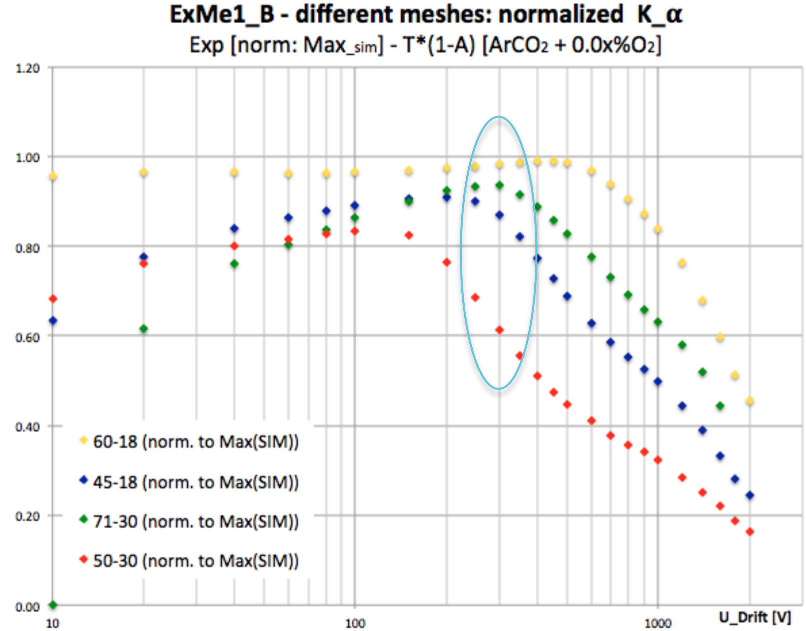
$+O_2$ →



Results – combined interpretation: Experiment & Simulation

Comparing the experimental data under interpretation of simulation results:





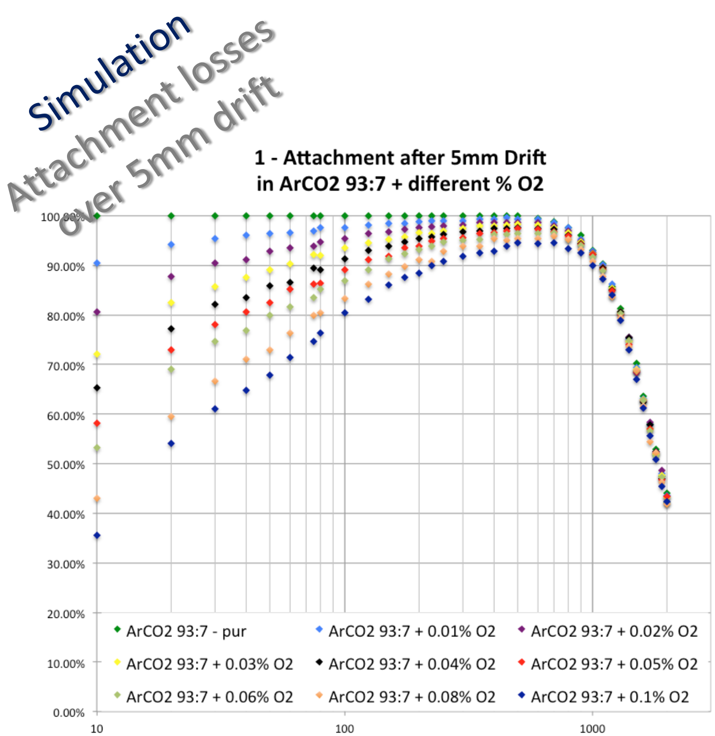
Mesh	T $\vert U_{drift}$=300V
45-18	95,5%
60-18	99,3%
50-30	73,6%
71-30	100,0%

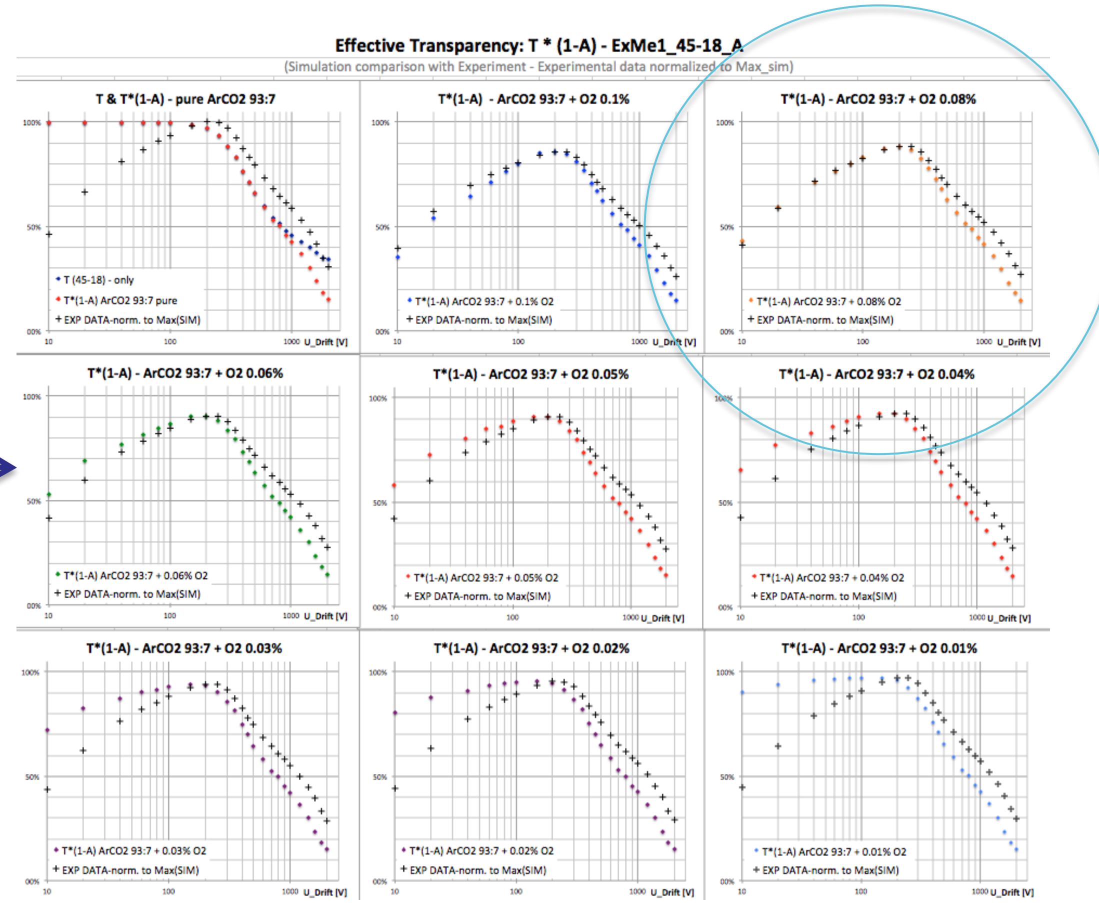
Mesh	T *(1-A) $\vert U_{drift}$=300V
45-18	86,9%
60-18	98,4%
50-30	61,3%
71-30	93,4%

Matching Data to impurities concentrations

Problem: Oxygen-Impurities in <0,1% concentration varies during hours / days

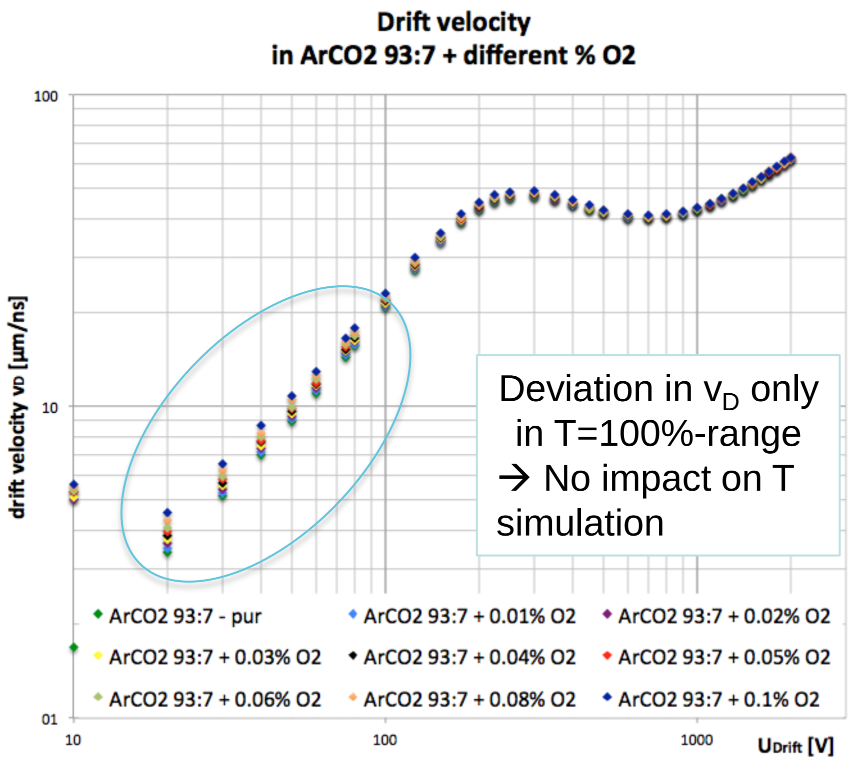
→ Different curves / data taken must be individually matched to the right concentrations

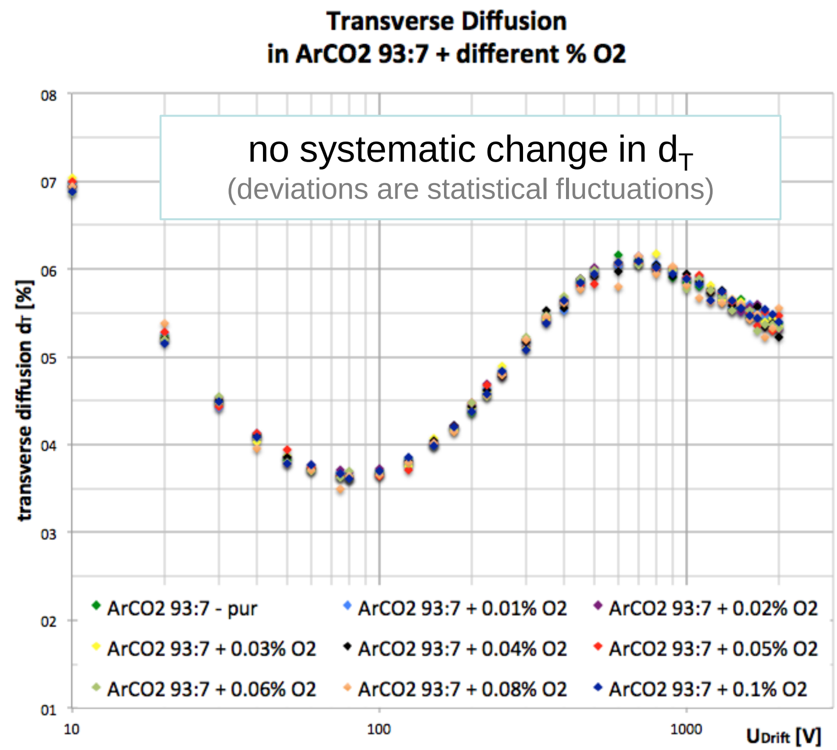




Matching Data to impurities concentrations

Follow-up question: Does this tiny (<0.1%) O_2 impurity effect the gas properties sufficiently to influence transparency simulations (simulated with pure $ArCO_2$ 93:7) ?

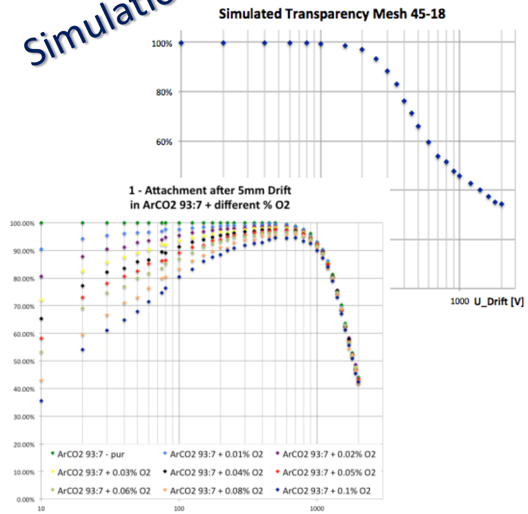




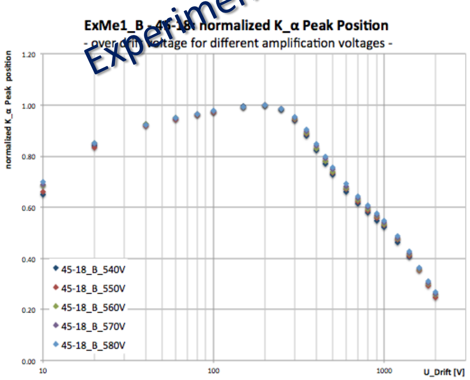
→ **No 'adjusted' Transparency simulation** (due to tiny O2 impurities) **necessary!**

Matching Data to impurities concentrations

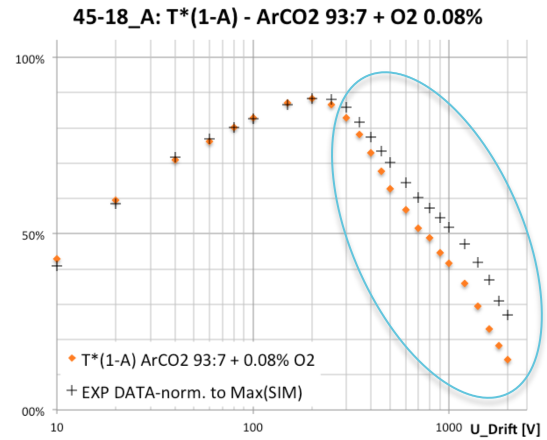
Simulation

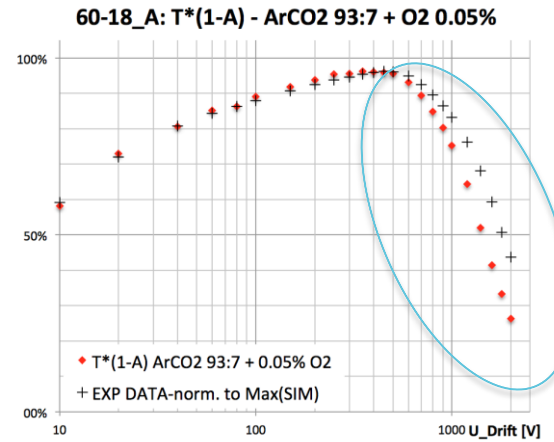


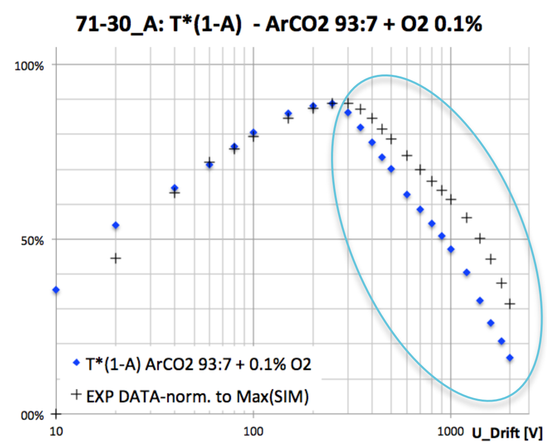
Experiment

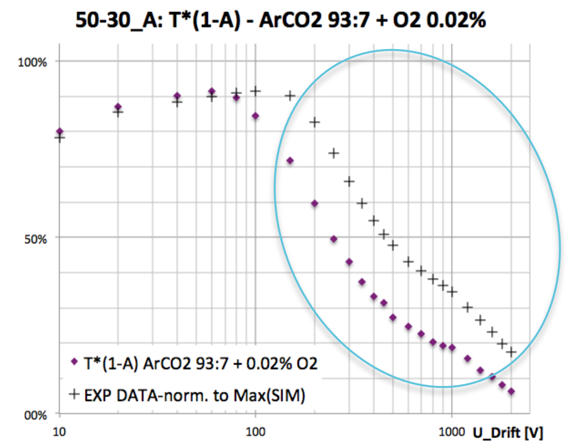


✓ Convincing overall agreement for all meshes







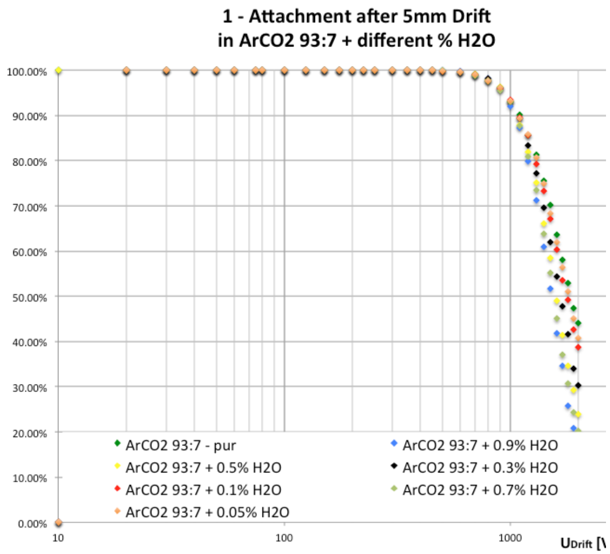


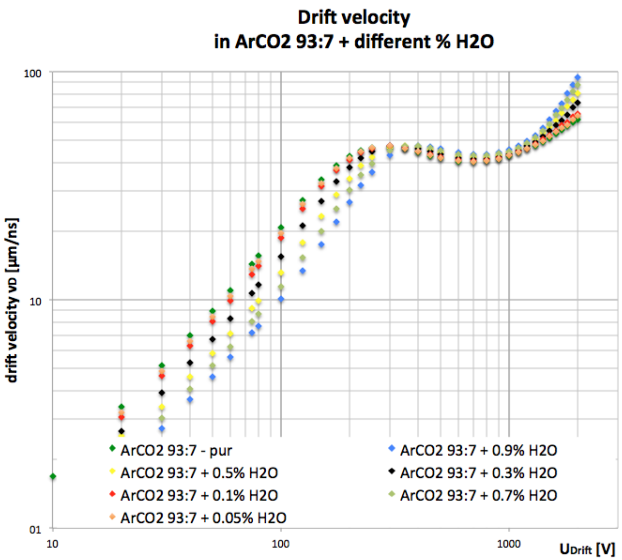
✗ Still systematic deviations

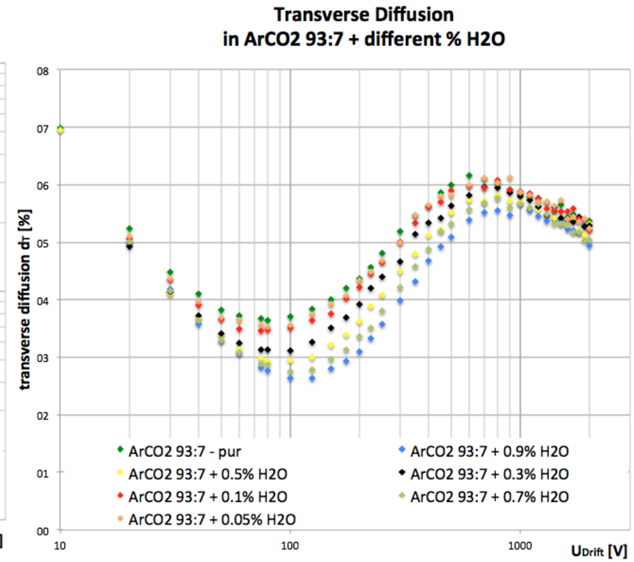
→ other gas impurities(H_2O …) ? Exp? Sim?

Matching Data to impurities concentrations

Simulating impact of H_2O contamination (very recent results!)**:**







Higher H_2O concentrations (<1%) increase attachment at high U_{drift} …

… and have significant impact on v_D and d_T

→ Adjusted Simulation of T necessary?
→ Verify/ reject H2O concentration in experiment

→ **Tiny H_2O impurities are unlikely to cause the visible systematic effect!**

→ Further possible contaminants to be studies

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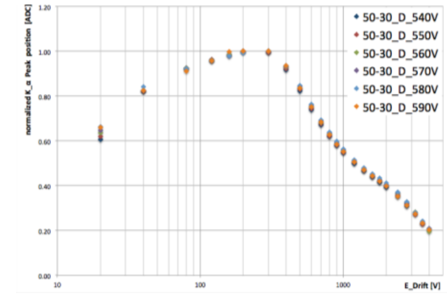
Summary

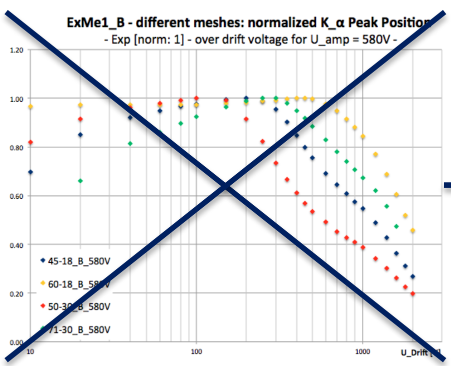
➢ Experimental data & simulation show little effect of **amplification voltages U_{amp}** on the transparency

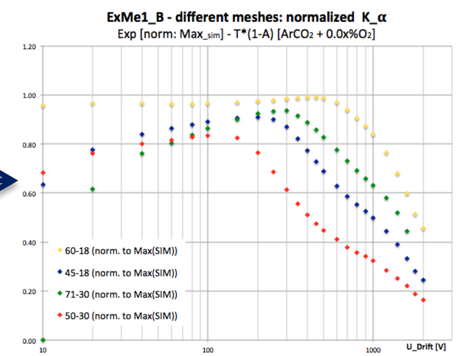
~~$T(E_{drift};E_{amp})$~~ → $T(E_{drift})$



➢ Measured 'effective transparency' ≠ mesh transparency

Double-checking experimental assumptions (and data interpretation) by correct modeling & simulation is crucial





Mesh	EXP: $T \mid_{U_{drift}=300V}$	EXP & SIM: $T*(1-A) \mid_{U_{drift}=300V}$
45-18	95,5%	86,9%
60-18	99,3%	98,4%
50-30	73,6%	61,3%
71-30	100,0%	93,4%

➢ Identification of further 'impurity-effects' is ongoing (H_2O, N_2, H_2...)

➢ Next measurements should be done with an improved gas-system and within shorter time periods

Acknowledgements

Sincere thanks to…

You

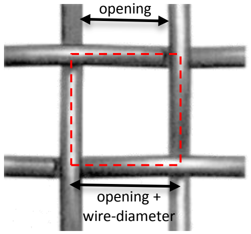
- for your attention -

- Rui de Oliveira and the CERN PCB workshop for final design and of production of the Exchangeable Mesh Micromegas prototype
- the CERN GDD Laboratory, in particular Patrik Thuiner & Eraldo Oliveri for their support during the experimental set-up, data-acquisition and –analysis
- Rob Veenhof for fruitful discussions on simulation details

BACKUP

Preliminary results: Meshes open area effect on T

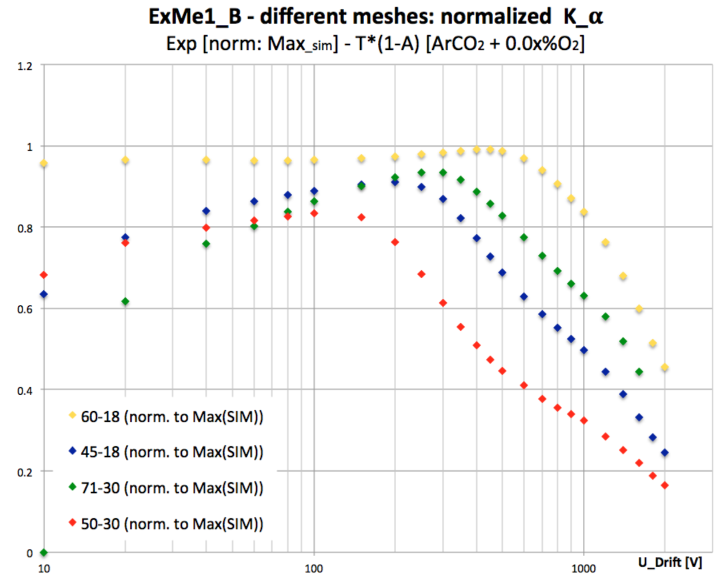
The open area of a mesh is assumed to be a good predictor for the transparency $\left(\frac{opening}{opening + d_{wire}}\right)^2$

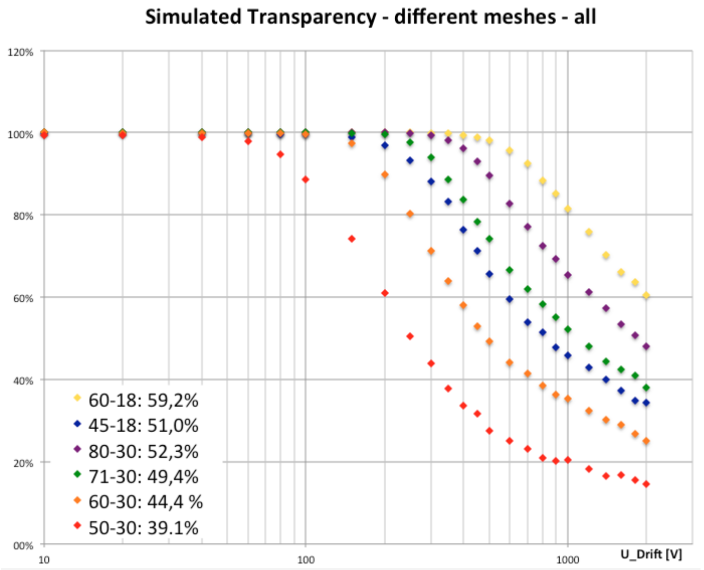


- However: Simulation shows deviation from the rule

  higher open area → better transparency,

  when comparing meshes with different wire diameters.





- Experimental Data confirms this ‘order’ of mesh transparencies (≠ order of open area)

Backup – ExMe detailed layer description

Drift panel

- with internal gas distribution and HV conduct
- mounted on honeycomb + FR4 stiff-back
- carrying springs pressing down the mesh frame

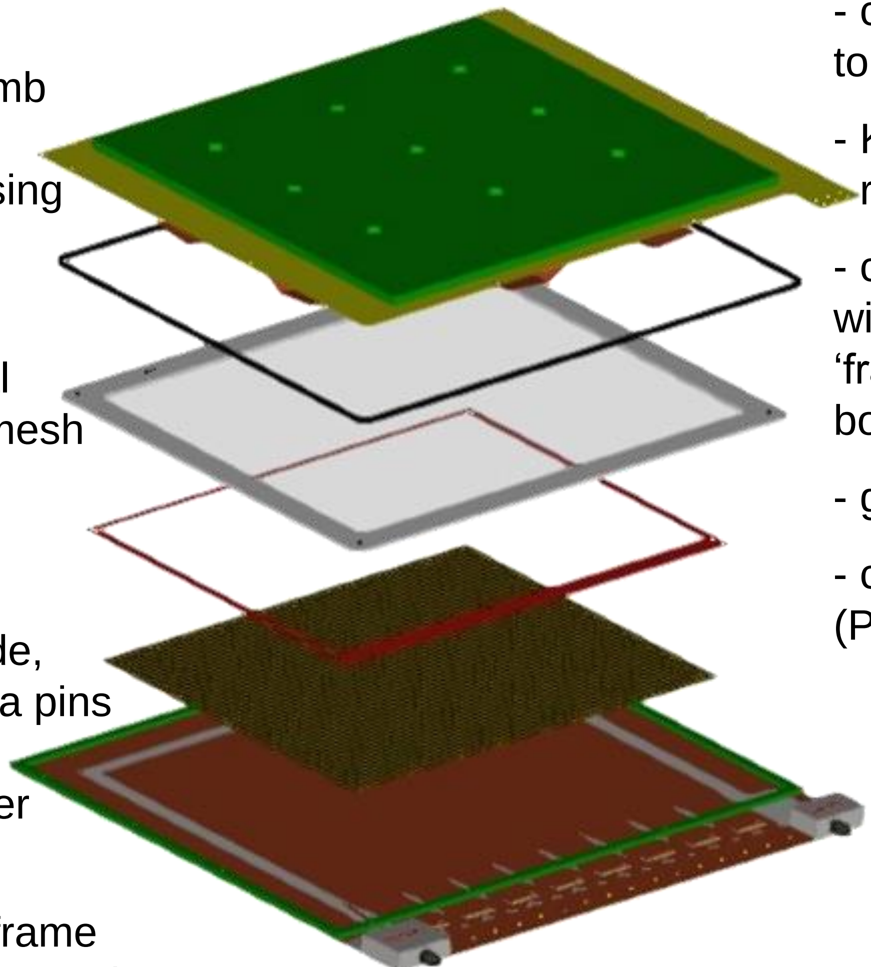
O-ring

placed between external FR4 frame (5mm) and mesh frame (4mm+springs)

Mesh frame

Mesh glued on lower side, aligned with r/o board via pins in the corner.
Ground contact to copper ground on r/o plane.

(! Non-flatness of the frame due to mesh tension ~500µm!)

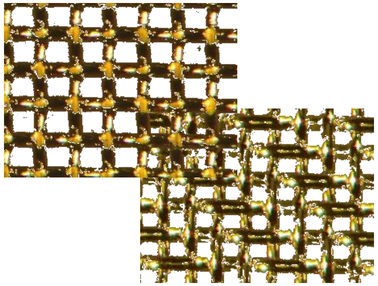


Readout panel

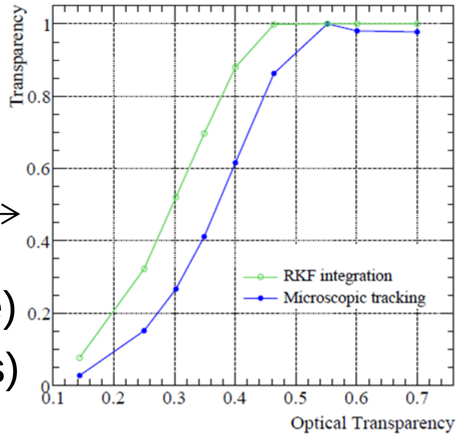
- copper readout strips routed to Panasonic connectors
- Kapton™ foil with sputtered resistive pattern
- cover lay (128µm pyralux) with pillar structure and 'frame' to define mesh boarder height
- glued outer FR4 frame
- connectors for HV, r/o (Panasonic) and grounding

Backup ExMe Study subjects

- A variety of **mesh specification** details can be studied:

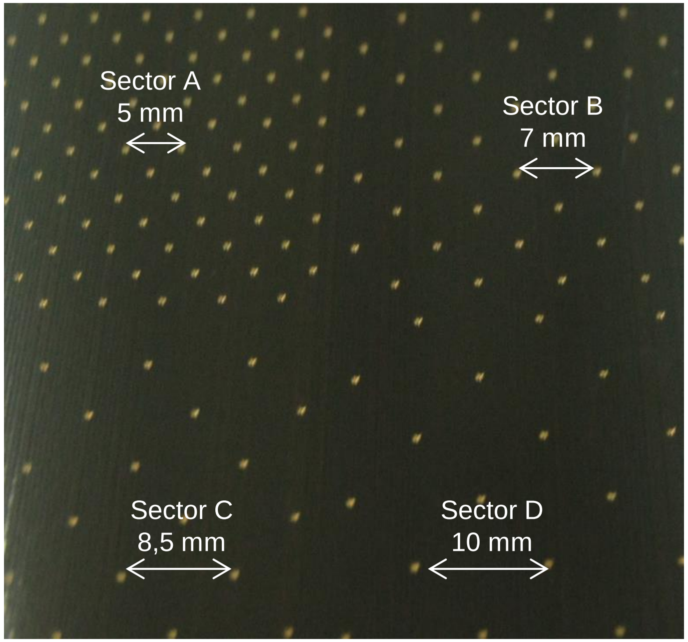


- different wire diameter
- different openings with same wires
- no/ soft / strong calendared meshes
- different types of weaving (plain vs. twill weave)
- alternative mesh material (metalized synthetics)



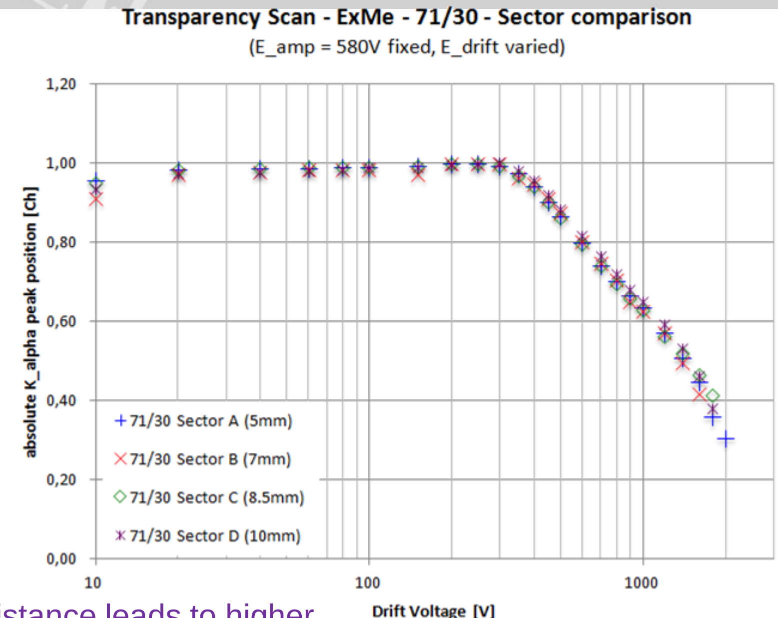
→ First measurements show the severe impact of mesh geometry on gain behavior

- The ExMe readout is divided in four sectors, covered **by different spaced pillar** patterns.
(Pillar-arrangement in regular triangles with different side-length between 5-10mm)
→ Impact on gain behavior is observed



- Second ExMe chamber is available, where the **sputtered resistive layer** is replaced by a **screen-printed** one.

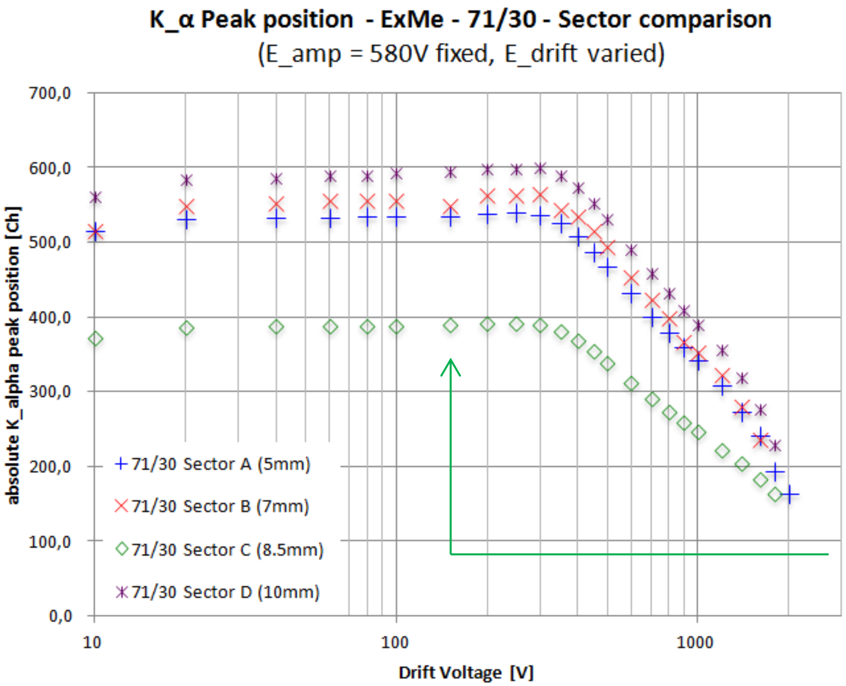
Backup – ExMe results: Influence of pillar pattern on gain



Transparency is (as expected) not depended on the supporting pillar pattern / distances.

→ Difference in inactive area are discarded during normalization to T_{max}

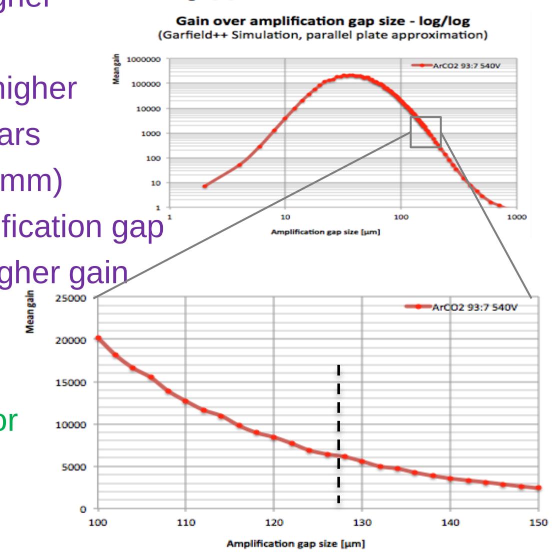
The mean gain on the contrary is effected:



Greater pillar distance leads to higher mean gain (10-15%)

→ Larger pillar distance leads to higher sagging of the mesh between pillars (<1µm at 5mm few, ~2µm with 10mm)

→ Yielding a lower effective amplification gap Leading at this working point to higher gain



Deviating behavior in one spot

→ Hint to non-flatness in the r/o or deviation in the pillar height