WG4 – Calculations

Summary of activities since January 2011

Gas properties

- Noble gas elastic cross sections:
  - Steve Biagi: working with the LXcat group
- Noble gases, UV production:
  - Carlos Bastos: publication submitted
- Noble gases, IR production:
  - Aveiro: starting a study
- Xenon ionisation
  - Özkan Şahin & Steve Biagi: ionisation cross section update
  - Start of Penning study
- Work function and Fano factor
  - Heinrich Schindler & Steve Biagi:

LXcat

- LXcat (pronounced *elecscat*) is an open-access website for collecting, displaying, and downloading ELECtron SCATtering cross sections and swarm parameters (mobility, diffusion coefficient, reaction rates, etc.) required for modeling low temperature plasmas. [...]”
- URL: `http://www.lxcat.laplace.univ-tlse.fr/`

LXcat people

- Art Phelps,
- Leanne Pitchford – Toulouse,
- Klaus Bartschat – Iowa,
- Oleg Zatsarinny – Iowa,
- Michael Allan – Fribourg,
- Steve Biagi
- …

Leanne Pitchford

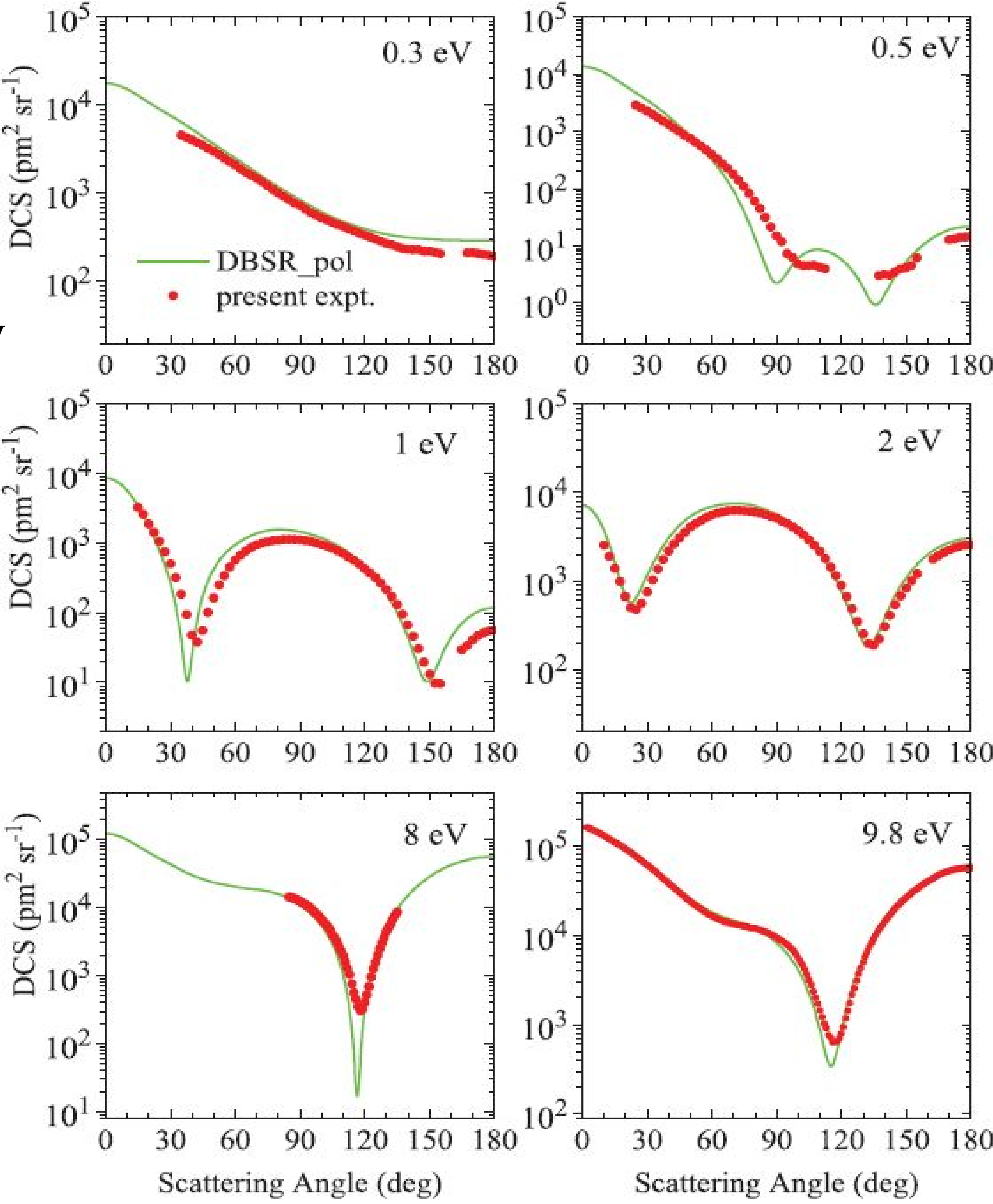
Michael Allan

Klaus Bartschat

Krypton data

- A remarkable joint study with high-precision experimental data and a theoretical model has just been published:

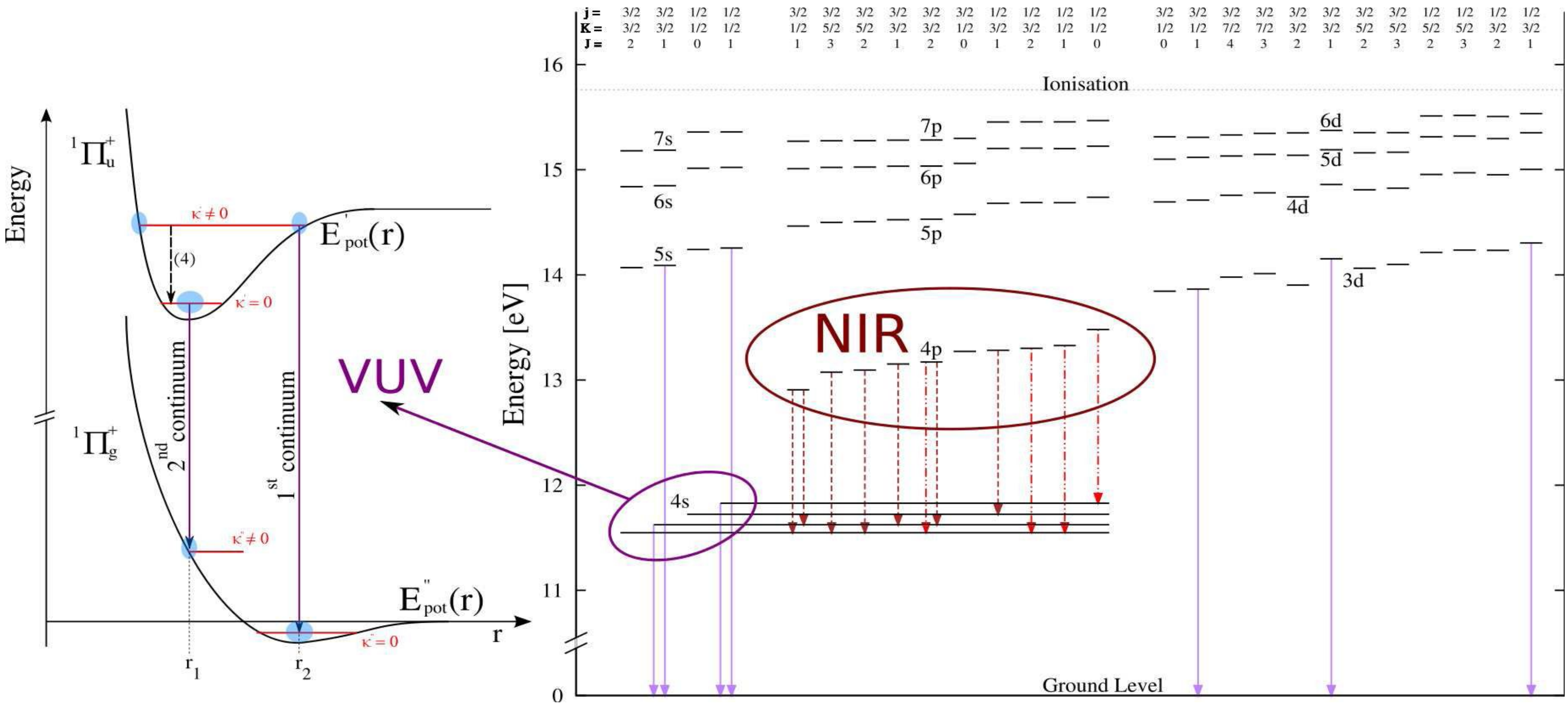
O. Zatsarinny et al. (2011)
10.1103/PhysRevA.83.032713



Plans on elastic cross sections

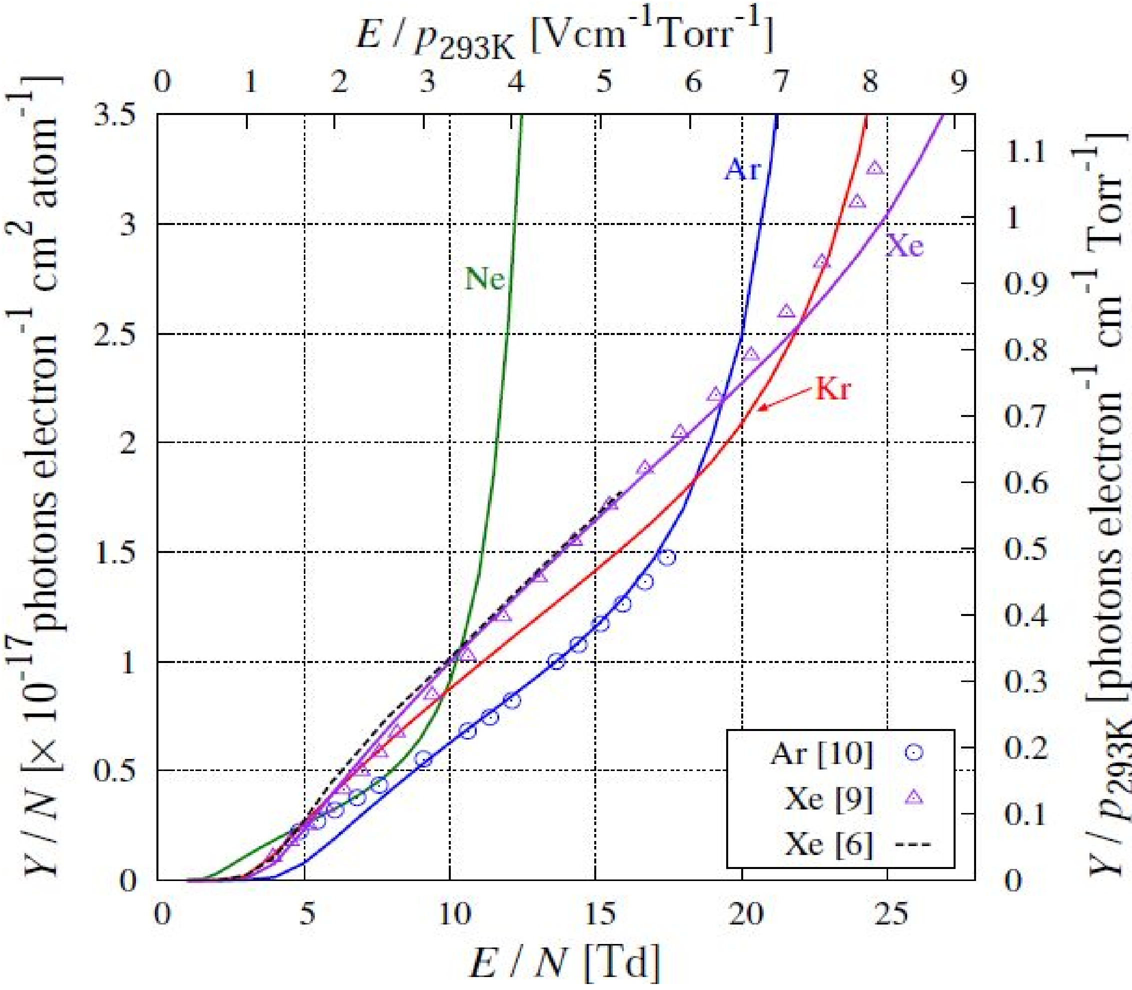
- It is notoriously difficult to measure absolute electron elastic cross sections – the associated uncertainties are amongst the most important in Magboltz.
- The goal is establishing a reference set of elastic cross sections at the maximum in Ar, Kr and Xe.
- Currently, the accuracy of σ_{mt} is ~ 5 % and the hope is that this will reduce to 2-3 %.

Origin of UV and IR radiation



VUV check

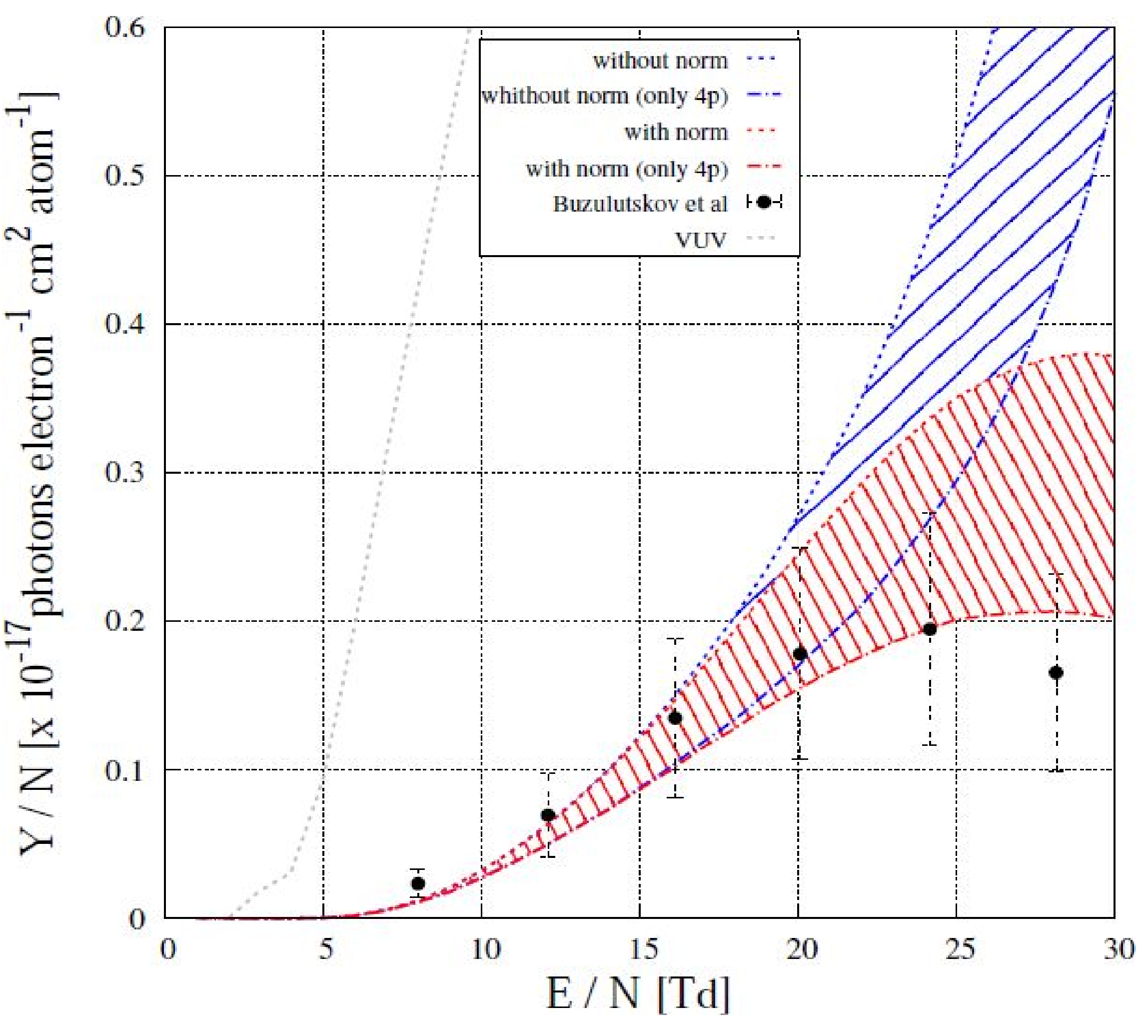
- Data and calculations agree on VUV yield in uniform fields.
- Submitted: Phys. Lett. B



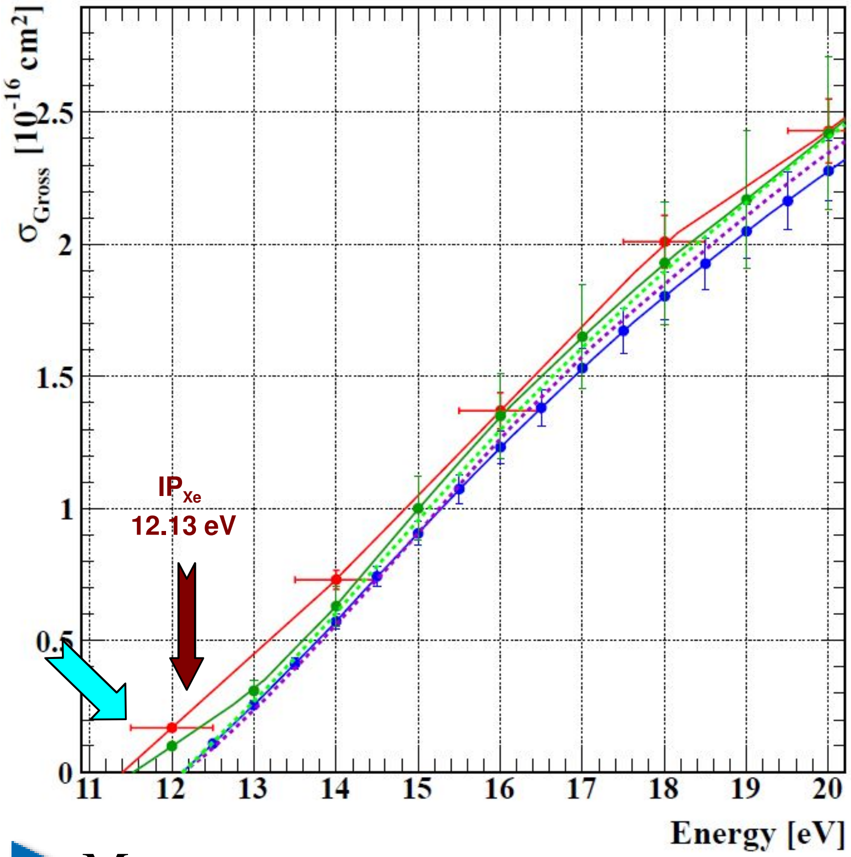
IR

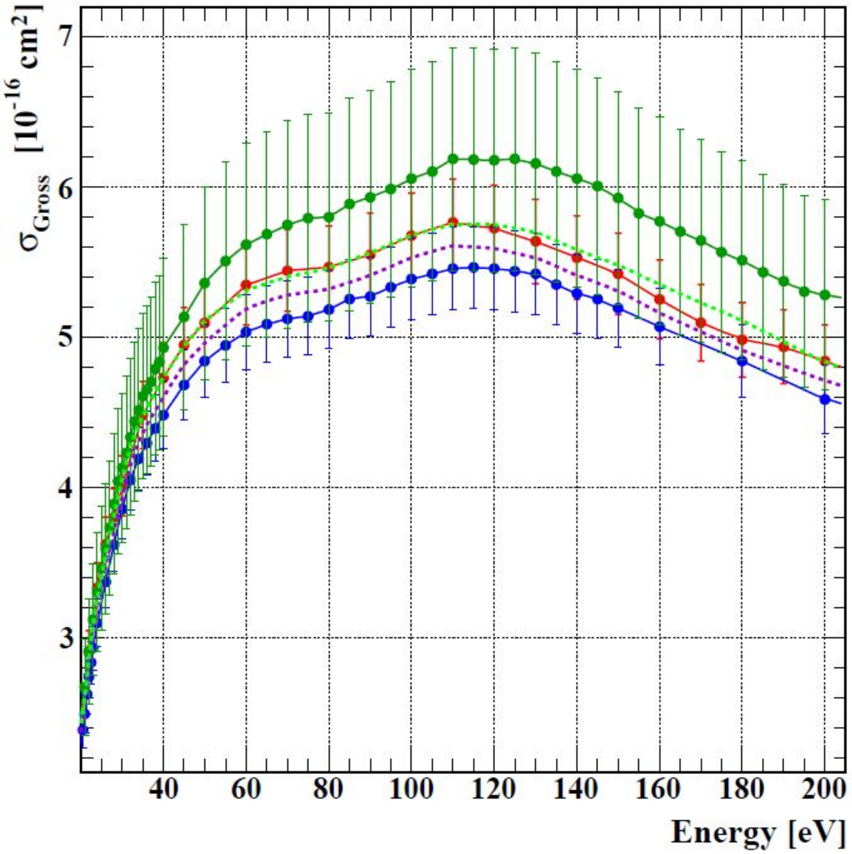
- Next goal: reproducing the IR measurements of A. Buzulutskov et al. RD51-Note-2011-002

- Our feedback attempts stand to benefit greatly from this work.



Comparing ionisation cross sections

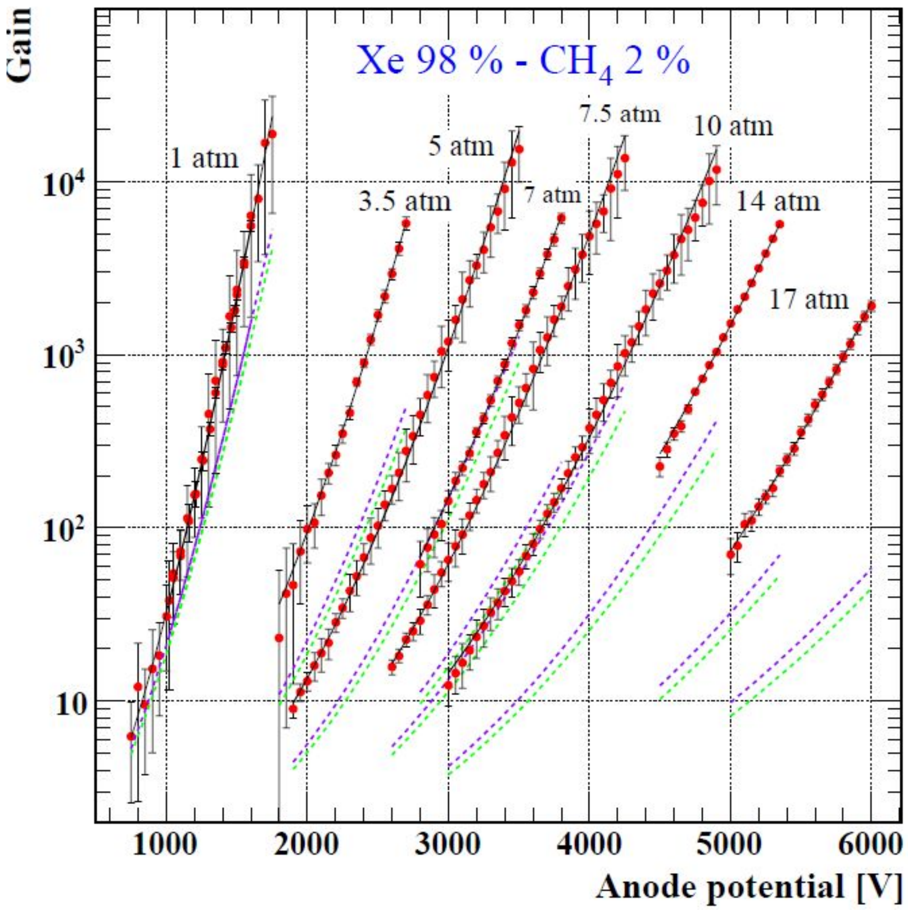


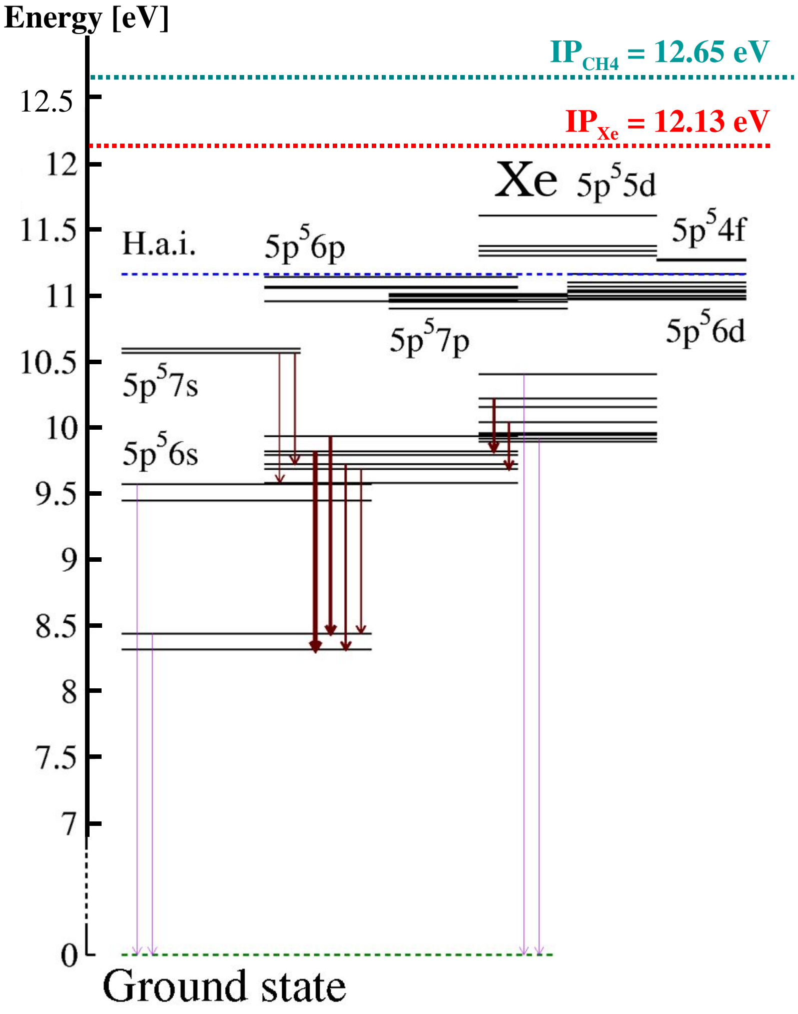


- Measurements:
  - D. Rapp and P. Englander-Golden, blue lines, 5 % errors;
  - R.C. Wetzel et al., straight dark-green lines, up to 12 % errors;
  - R. Rejoub et al., red lines, 5 % errors on x-section, 0.5 eV uncertainty on energy;
- Parametrisations:
  - Magboltz 8.9.1, dashed purple lines;
  - Magboltz 8.9.3, dashed green lines.

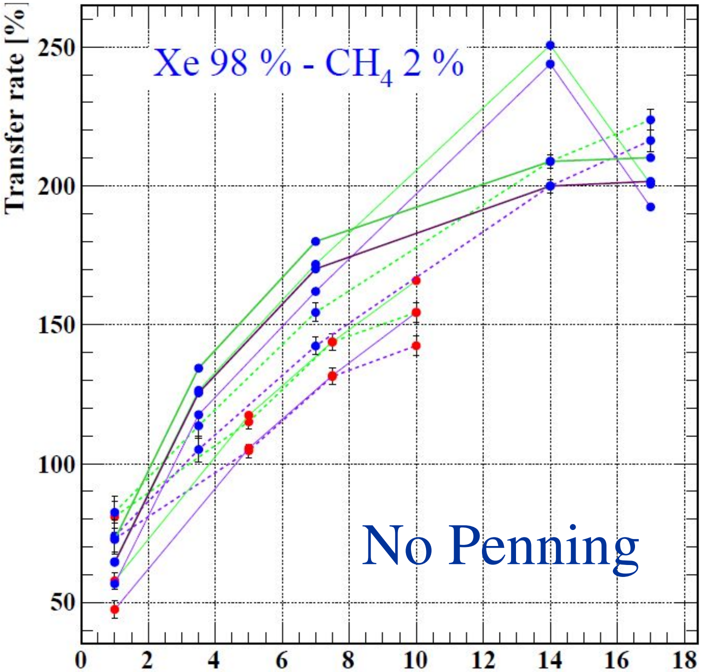
The Xe-CH_4 puzzle

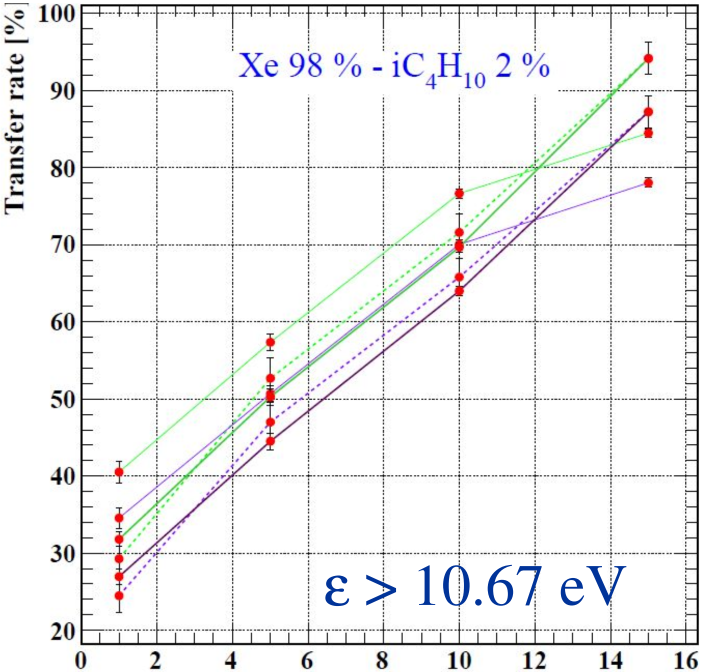
- Xe-CH_4 is not a Penning mixture;
- $Xe^* + Xe \rightarrow Xe_2^+ + e^-$ can happen.

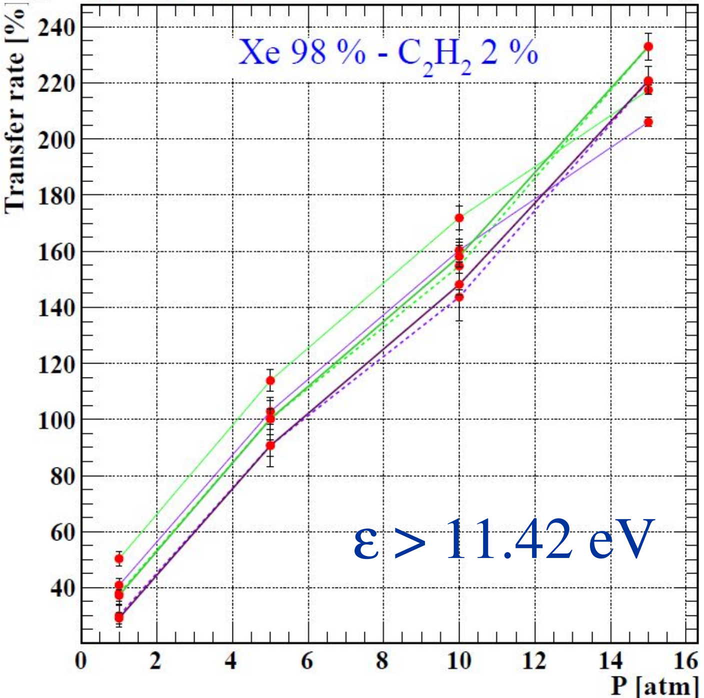


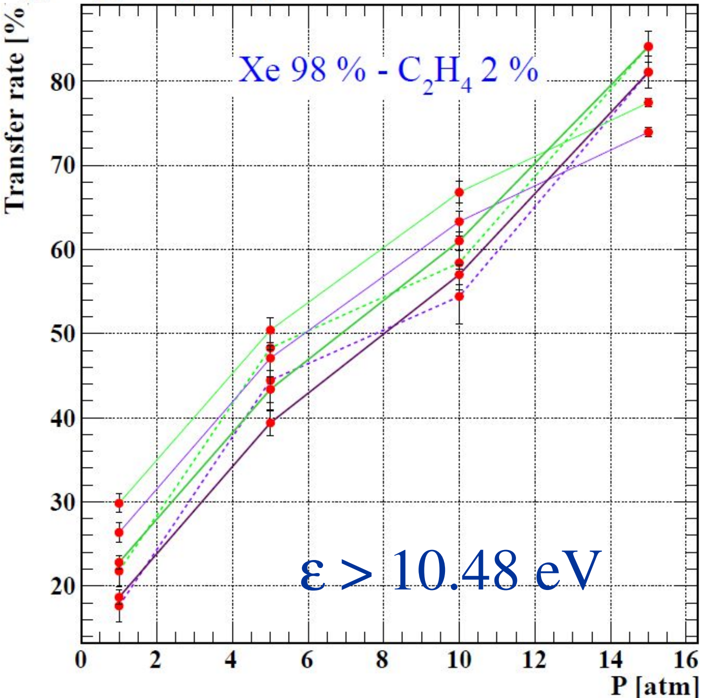


Transfer rates



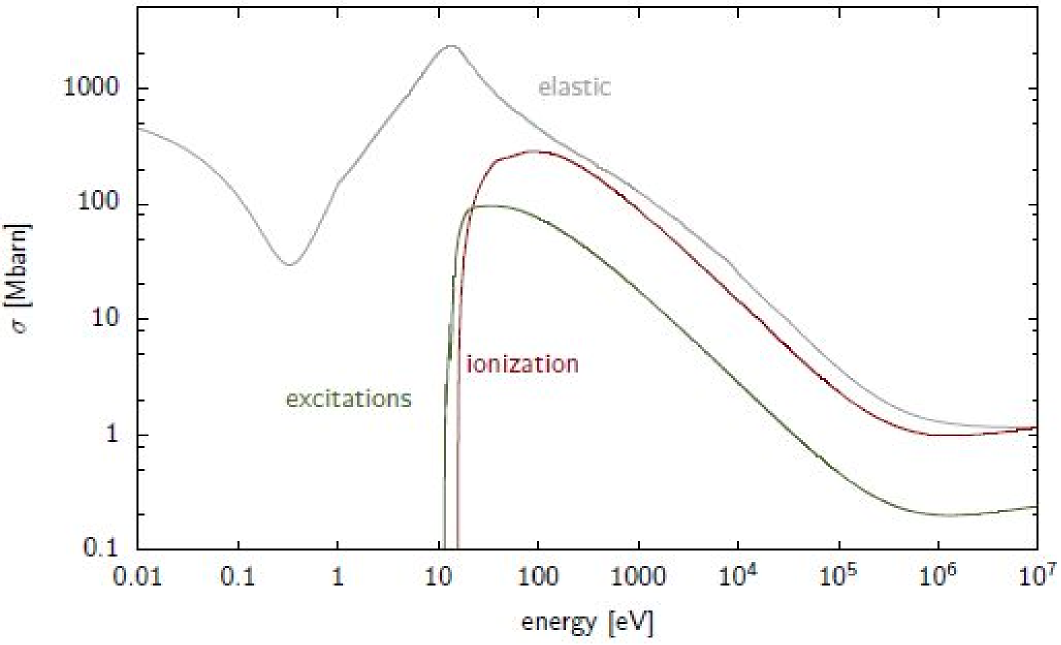


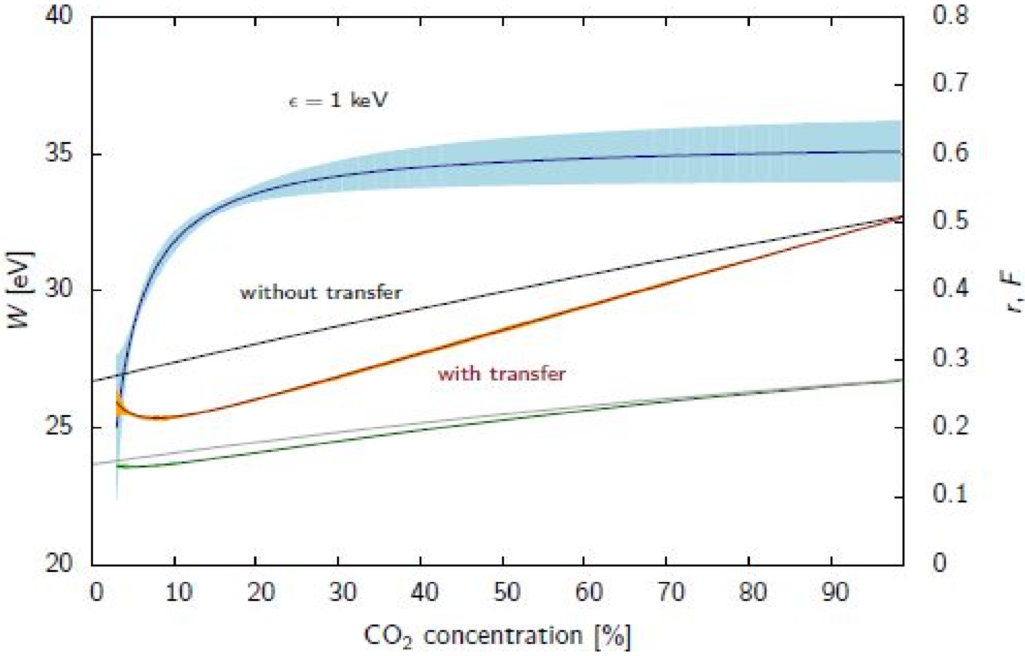




One σ from 10 meV to 10 MeV !

- *W* and *F* for pure gases match;
- Predictions can be made for Penning mixtures.



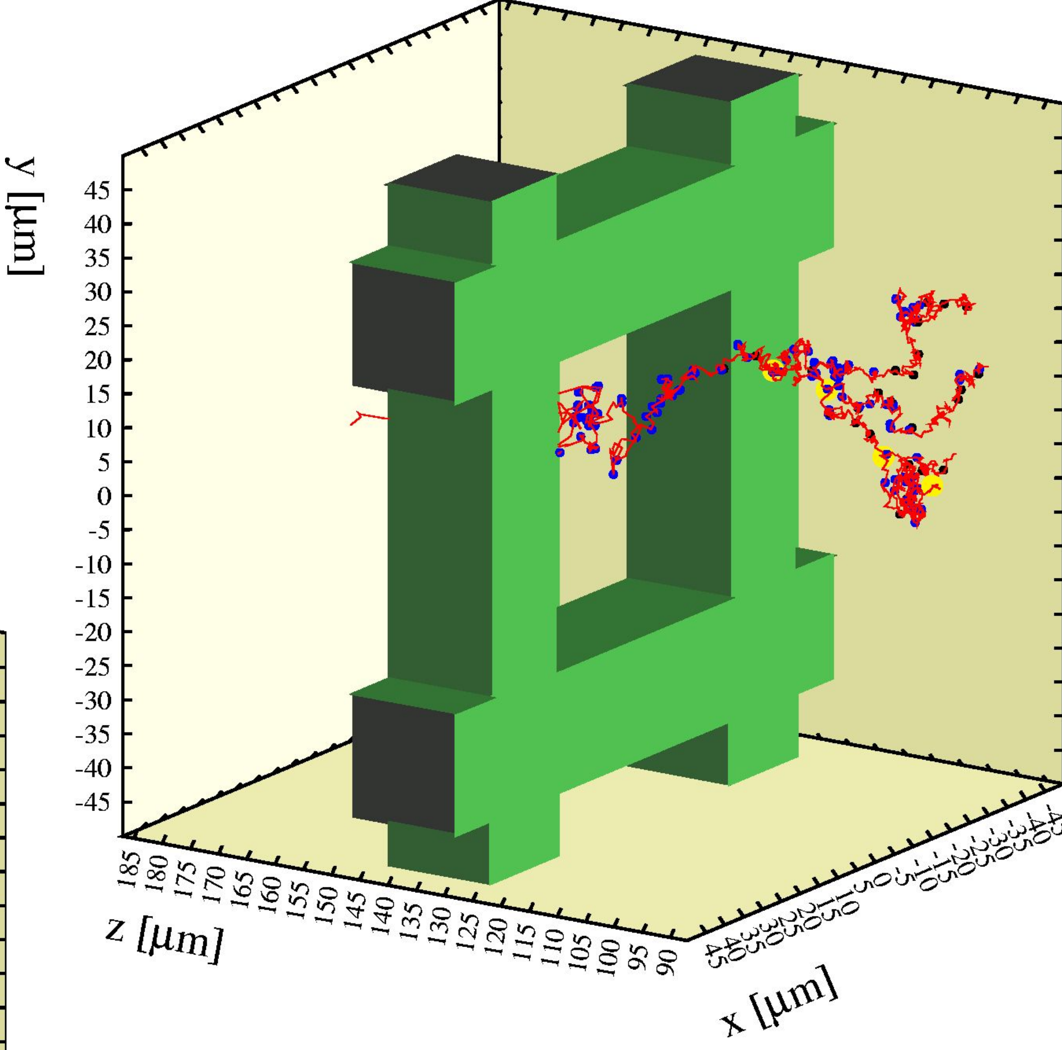


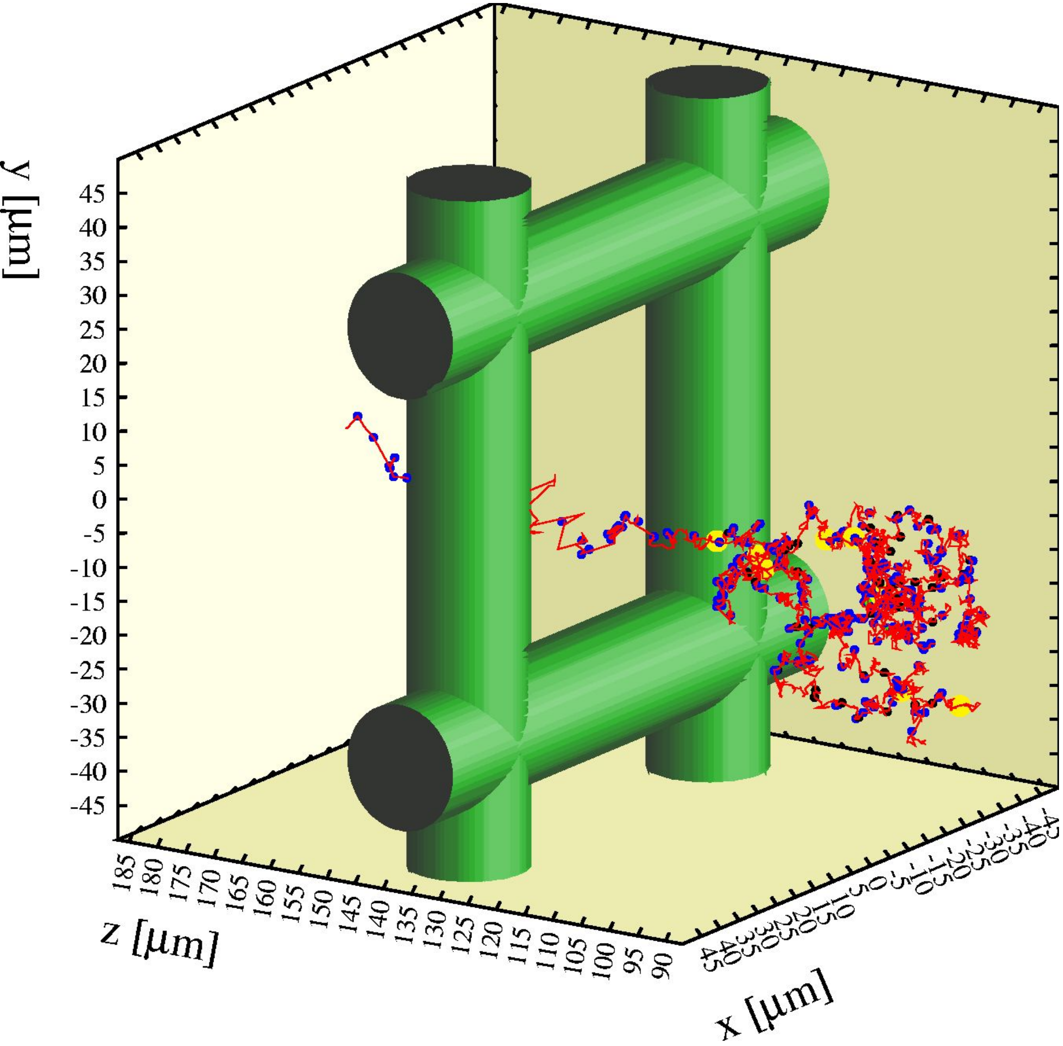
Microscopic tracking

- Micromegas transparency:
  - Saha: wire elements added;
  - neBEM calculation added;
  - Kostas Nikolopoulos: paper submitted.

- GEM transmission:
  - Heinrich Schindler: Compared with measurements;
  - B field added.

Microscopic tracks

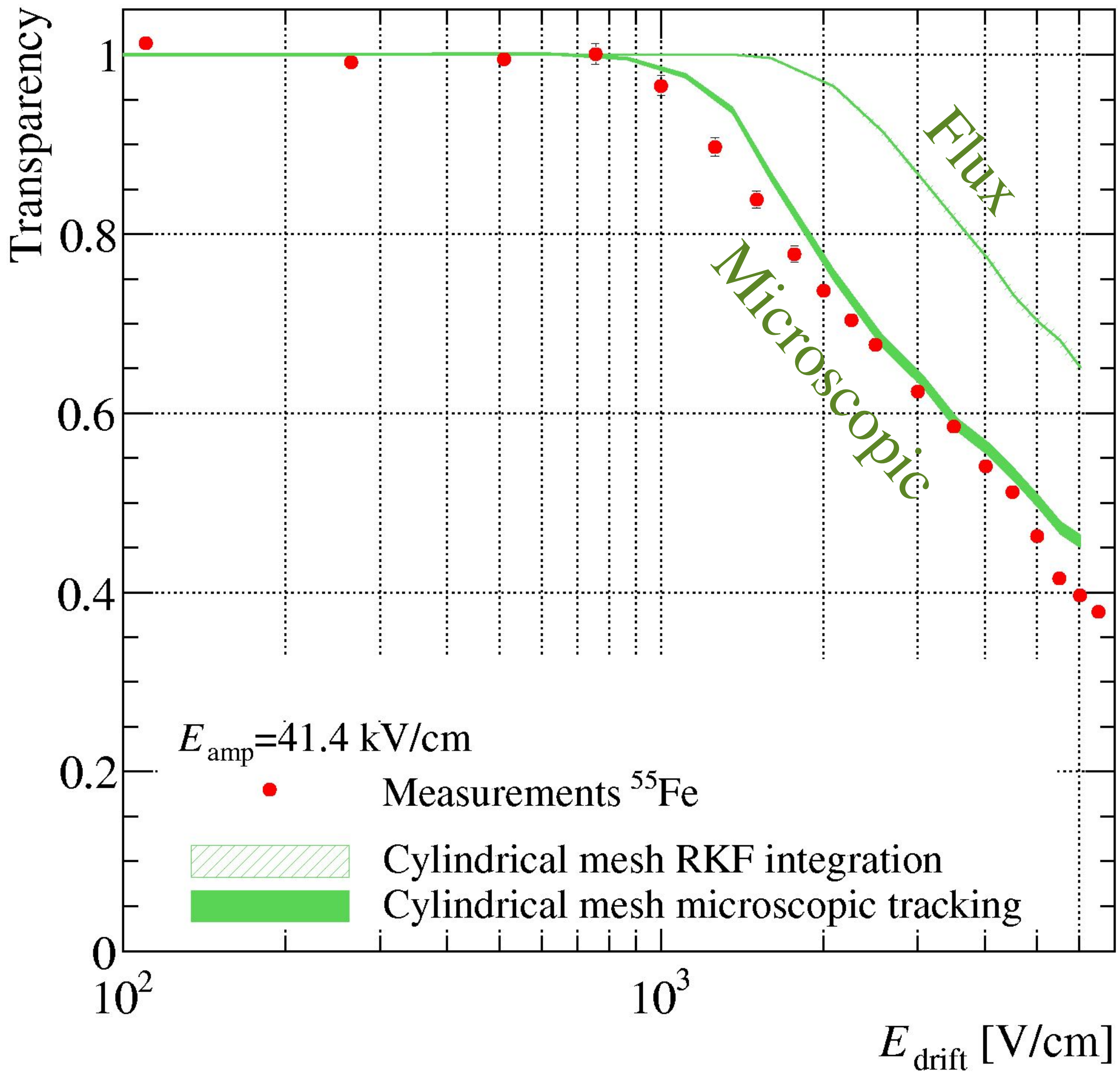




- Legend:
  - – electron
  - ○ inelastic
  - ○ excitation
  - ○ ionisation

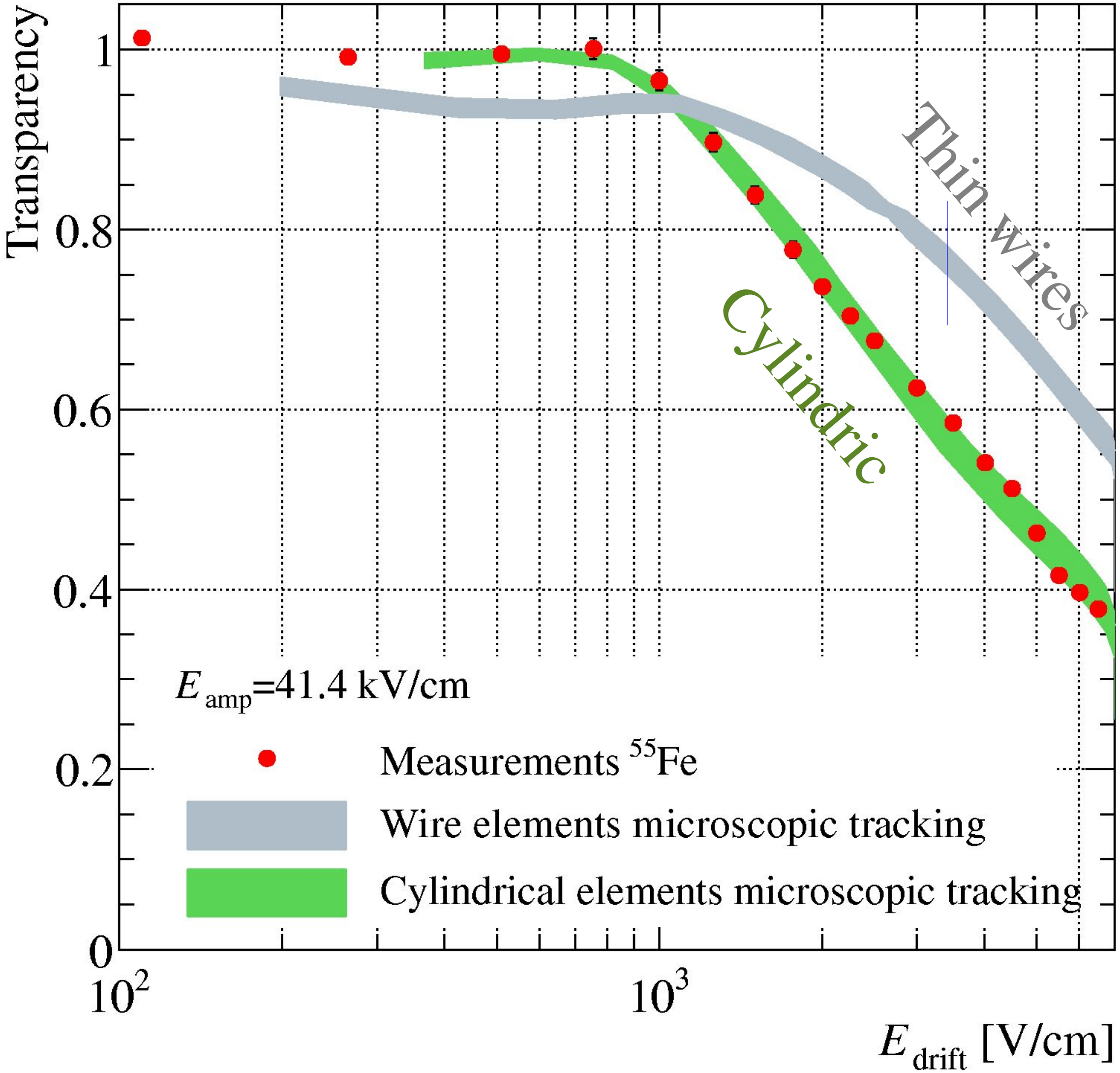
Flux vs microscopic ?

- A diffusion-free flux argument does not reproduce the data.
- The microscopic approach works.
- Calculations done using finite elements.



Thin-wire approximation ?

- The thin-wire approximation is usual in wire chambers – but is not adequate here.
- Calculations done using neBEM.



What we learned ...

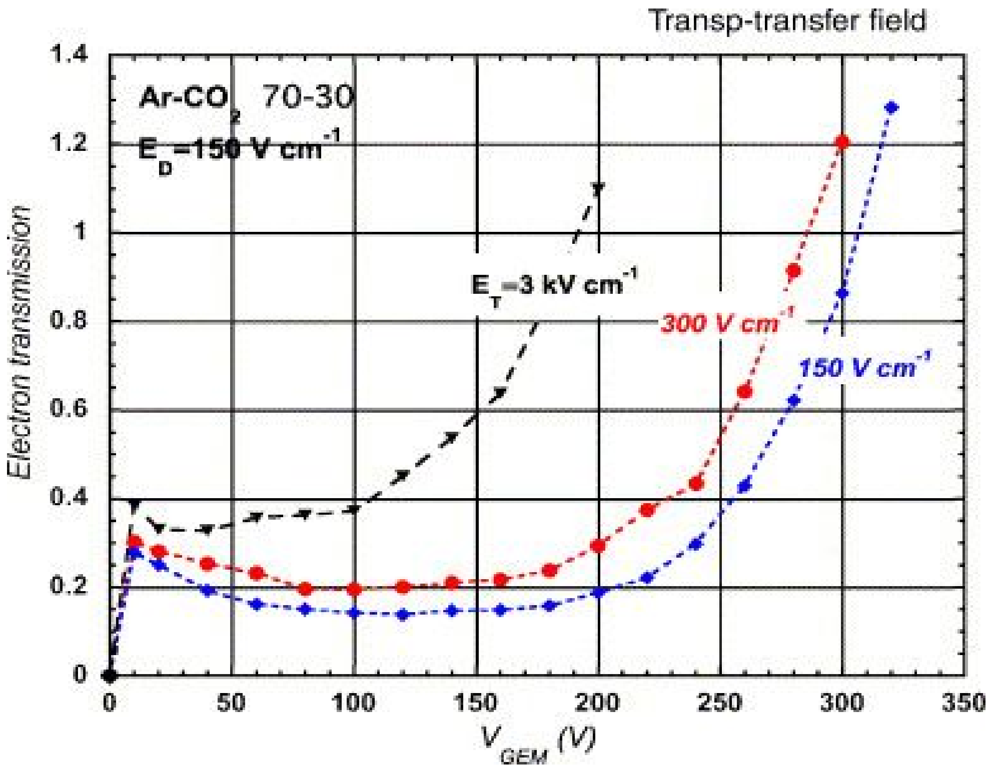
- Simulation of small scale devices requires that:
  - diffusion is taken into account;
  - structures are modeled without oversimplification;
  - dipole moments are included.

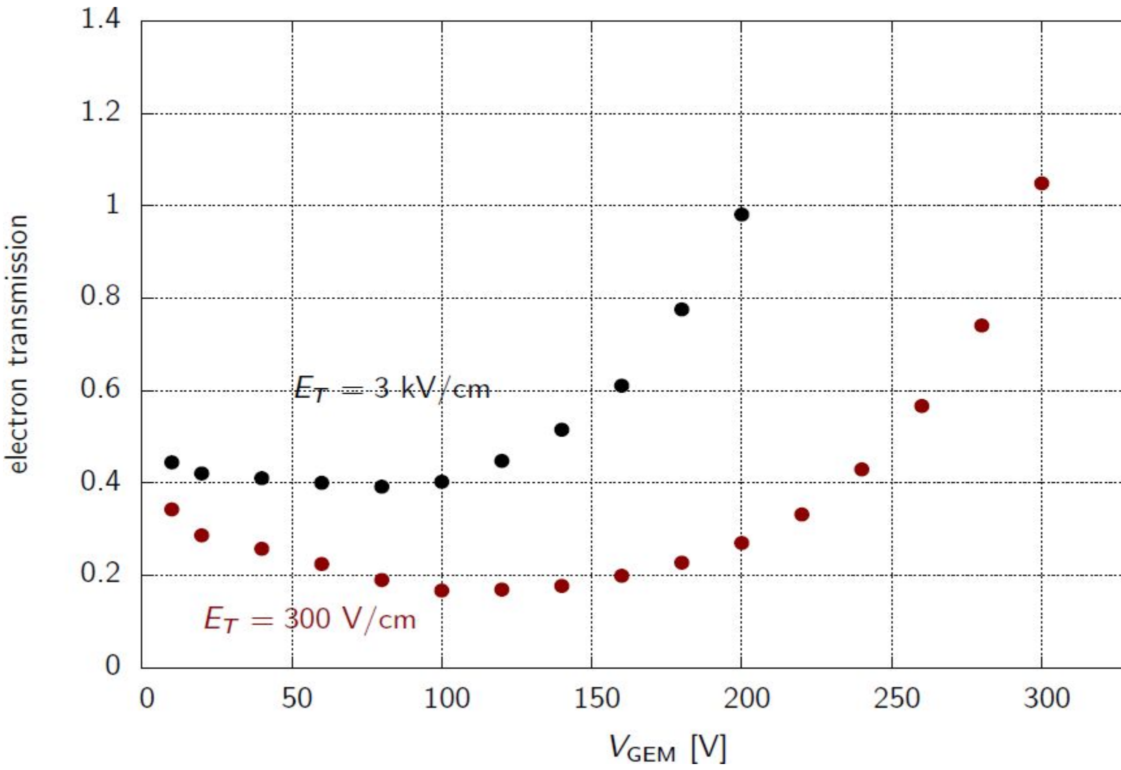
- Microscopic tracing, both using finite element and using boundary element fields, successfully reproduces the transparency.

- [Submitted to JINST, JINST_006P_0411]

Electron transmission of a GEM

- Computed with Magboltz 8.9.3 and Garfield++:

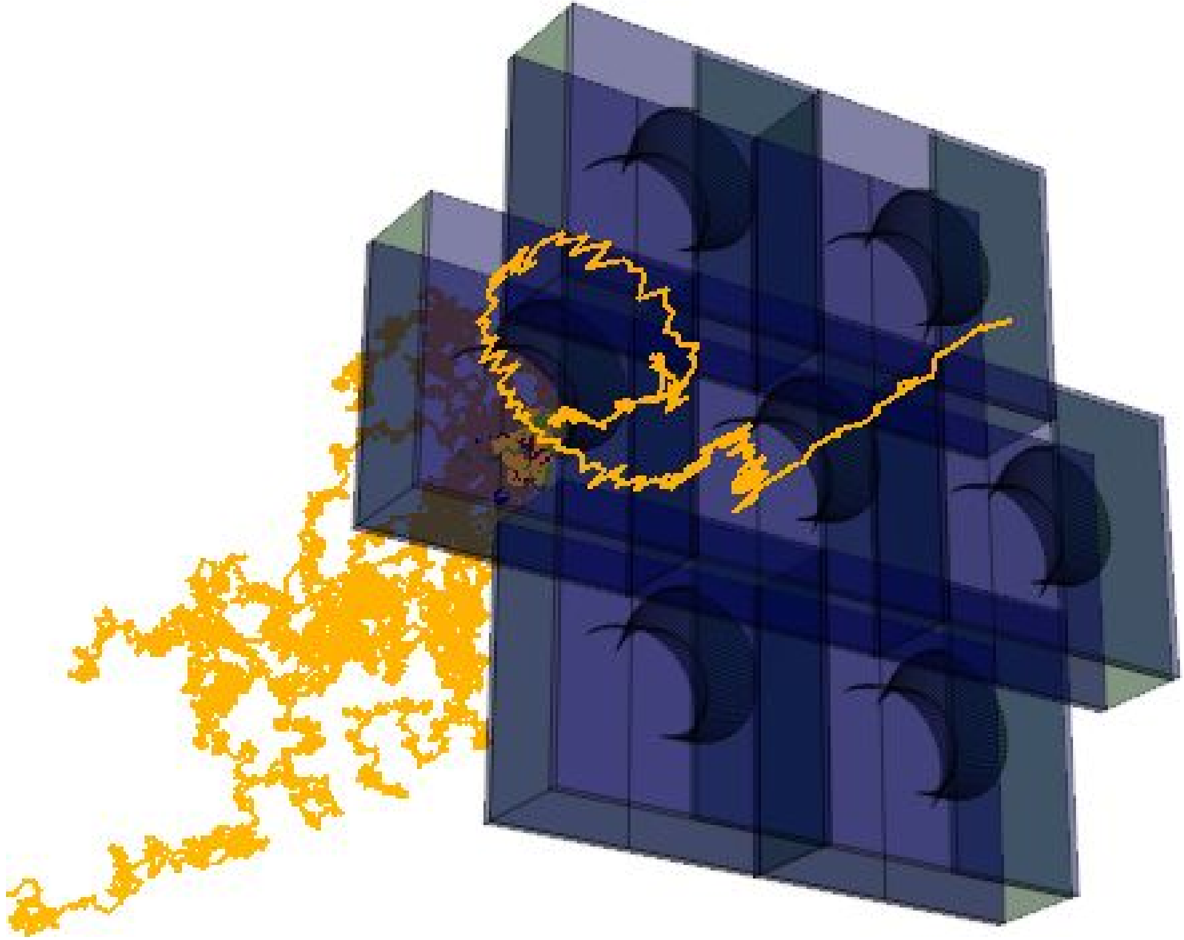




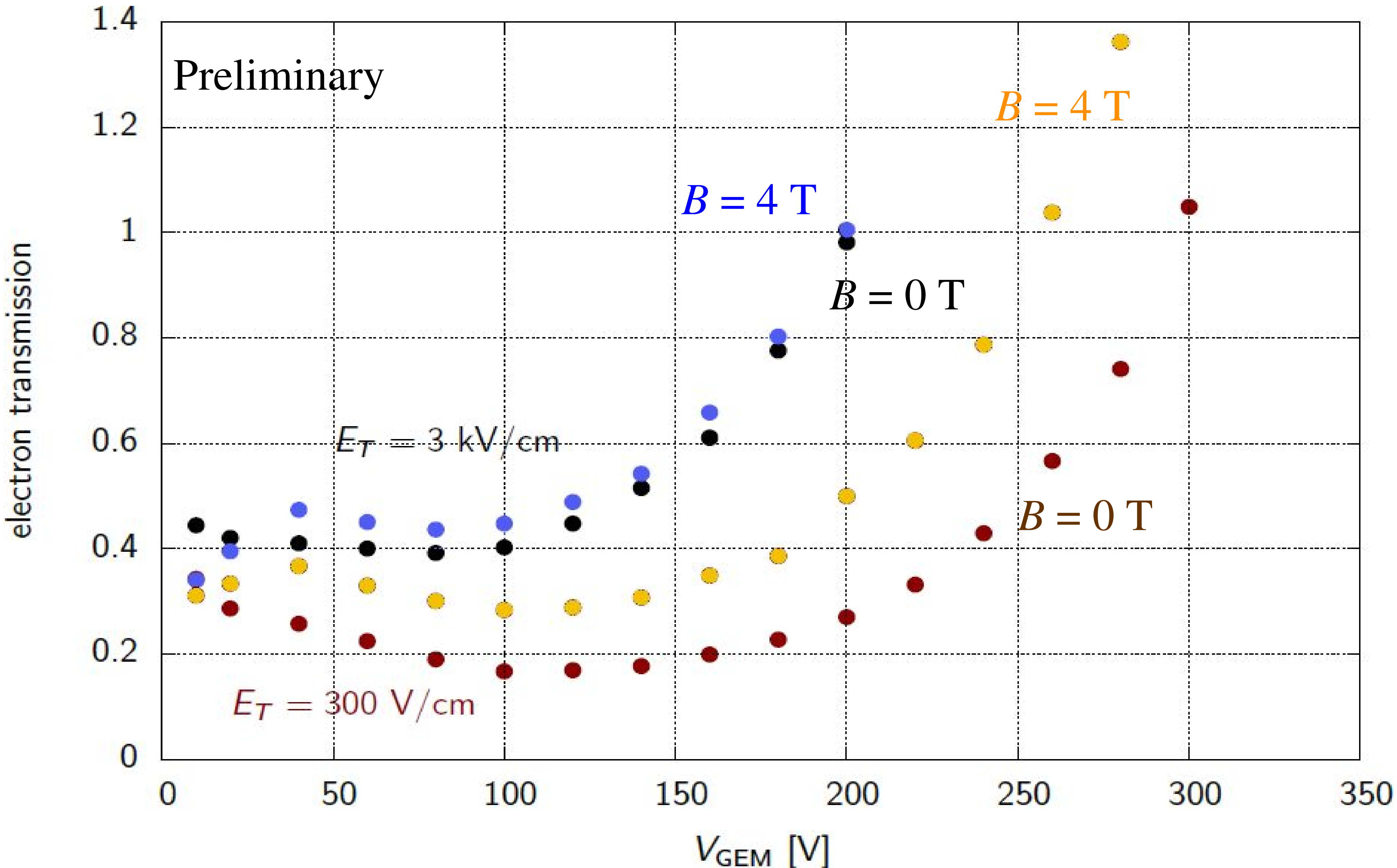
- F. Sauli, L. Ropelewski, P. Everaerts, NIM A **560** (2006) 269-227.

Electron transport in a GEM

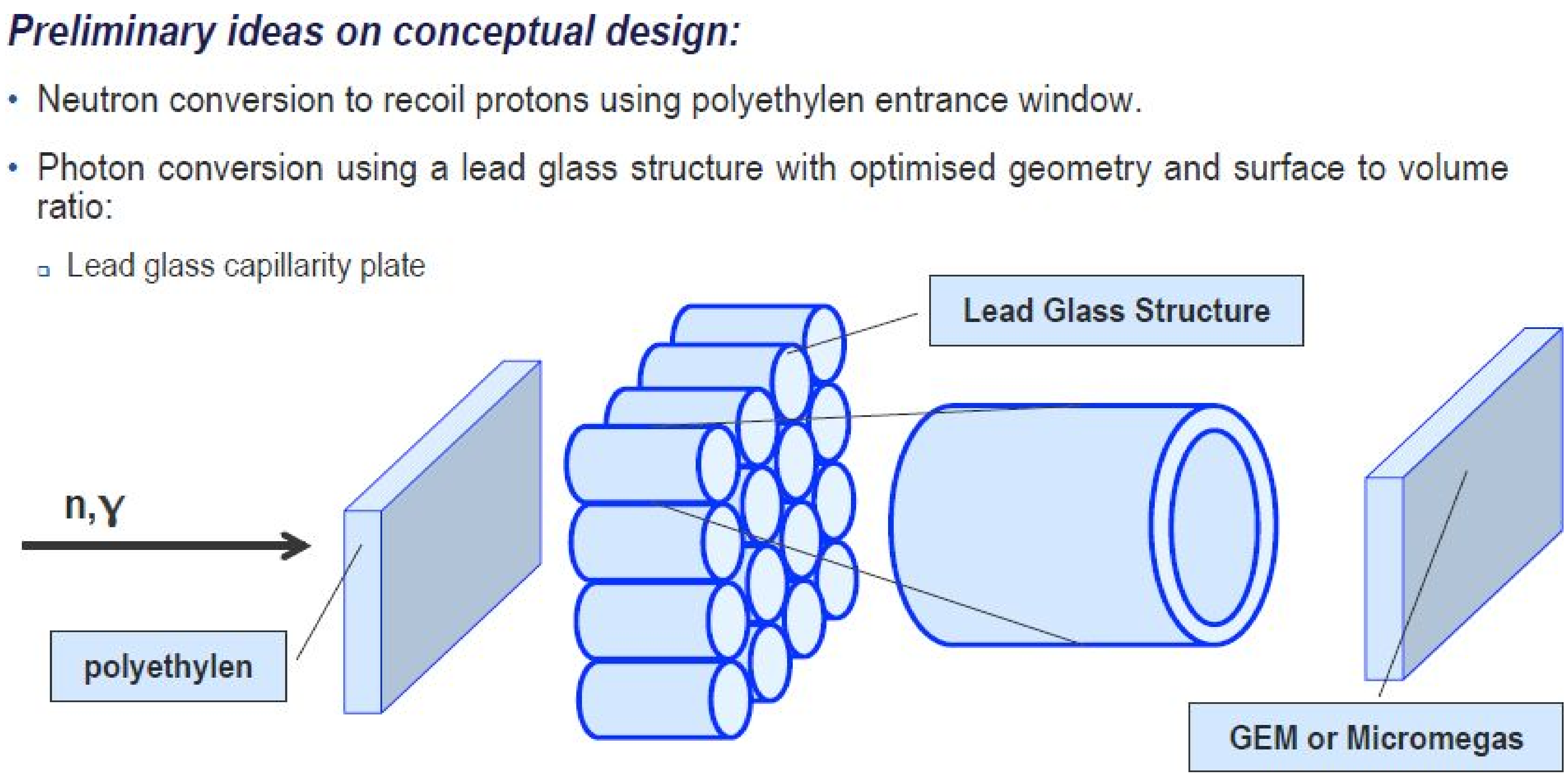
- $B = 4$ T ⊥ GEM, T2K gas:



Effect of B on GEM transmission



The idea



Preliminary ideas on conceptual design:

- Neutron conversion to recoil protons using polyethylen entrance window.
- Photon conversion using a lead glass structure with optimised geometry and surface to volume ratio:
    - Lead glass capillarity plate

- More detail: Hartmut Hillemanns' presentation in WG1.

Photon detection

- Four-step process:
  - Compton scattering of the γ producing a recoil e^-, or e^+e^- production in the nuclear field;
  - e^- traverses the absorber and enters the gas;
  - transport of the e^- through the gas;
  - amplification and detection.
- Losses occur at all stages and need to be controlled.

γ-Mean free path in some materials

- As provided by NIST:

	λ 3 MeV [cm]	λ 4 MeV [cm]	λ 5 MeV [cm]	λ 6 MeV [cm]	Density [g/cm^3]	*Z/A* [-]
W	1.27	1.28	1.26	1.23	19.30	0.403
Pb	2.08	2.10	2.06	2.01	11.34	0.396
Lead glass	3.94	4.08	4.10	4.06	6.22	0.421
Pyrex	12.40	14.30	15.80	17.00	2.23	0.497
PET	19.50	22.80	25.60	28.10	1.38	0.520
Bakelite	21.30	24.90	28.00	30.80	1.25	0.528

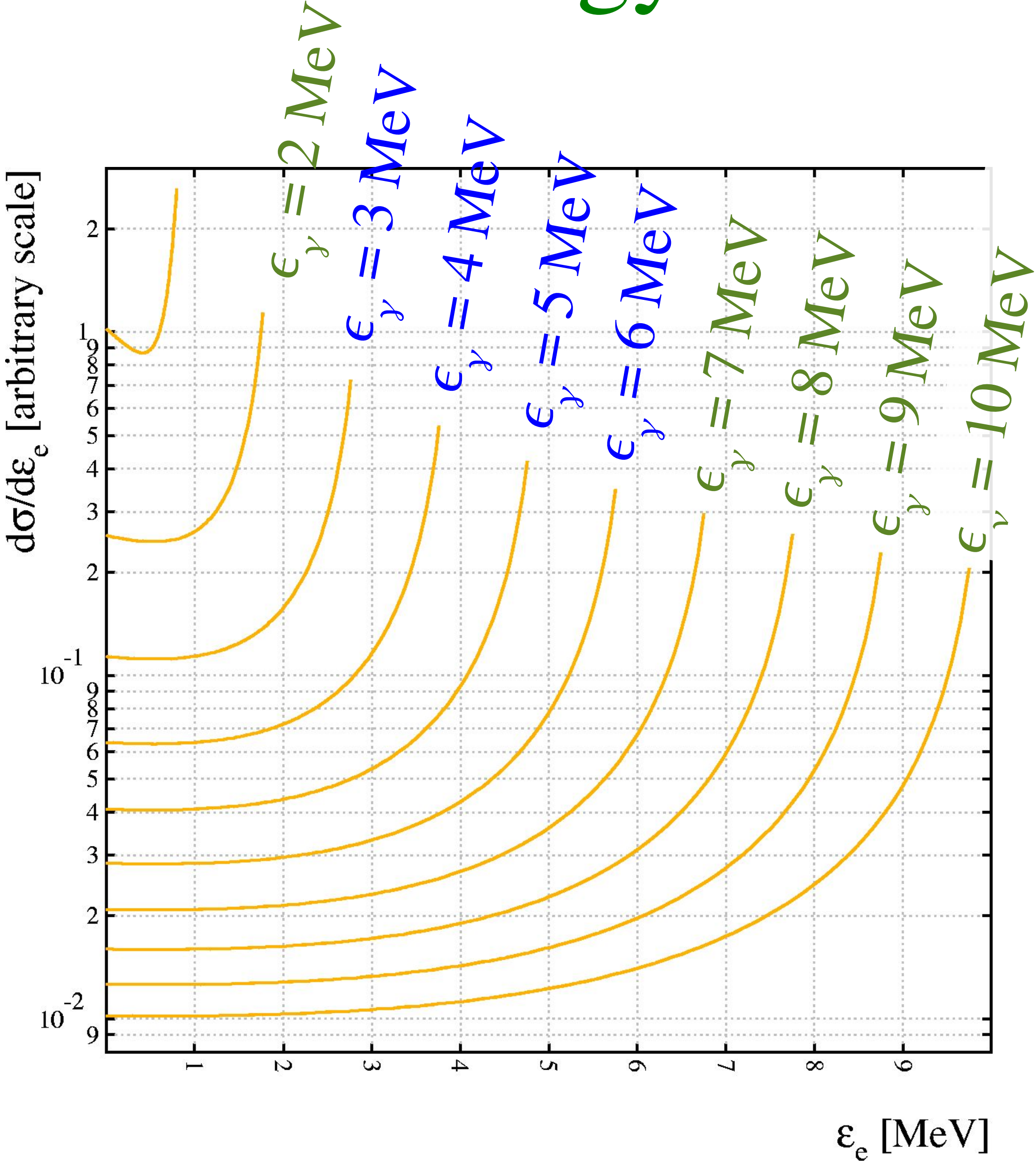
Compton recoil electron – energy

- The energy ϵ_e of the recoil e$^-$ peaks at the kinematic maximum:

$$\epsilon_e^{max} = \epsilon_\gamma \frac{2a}{1+2a}$$

$$a = \epsilon_\gamma / m_e$$

- This is independent of the absorber.



e^- Range in lead glass

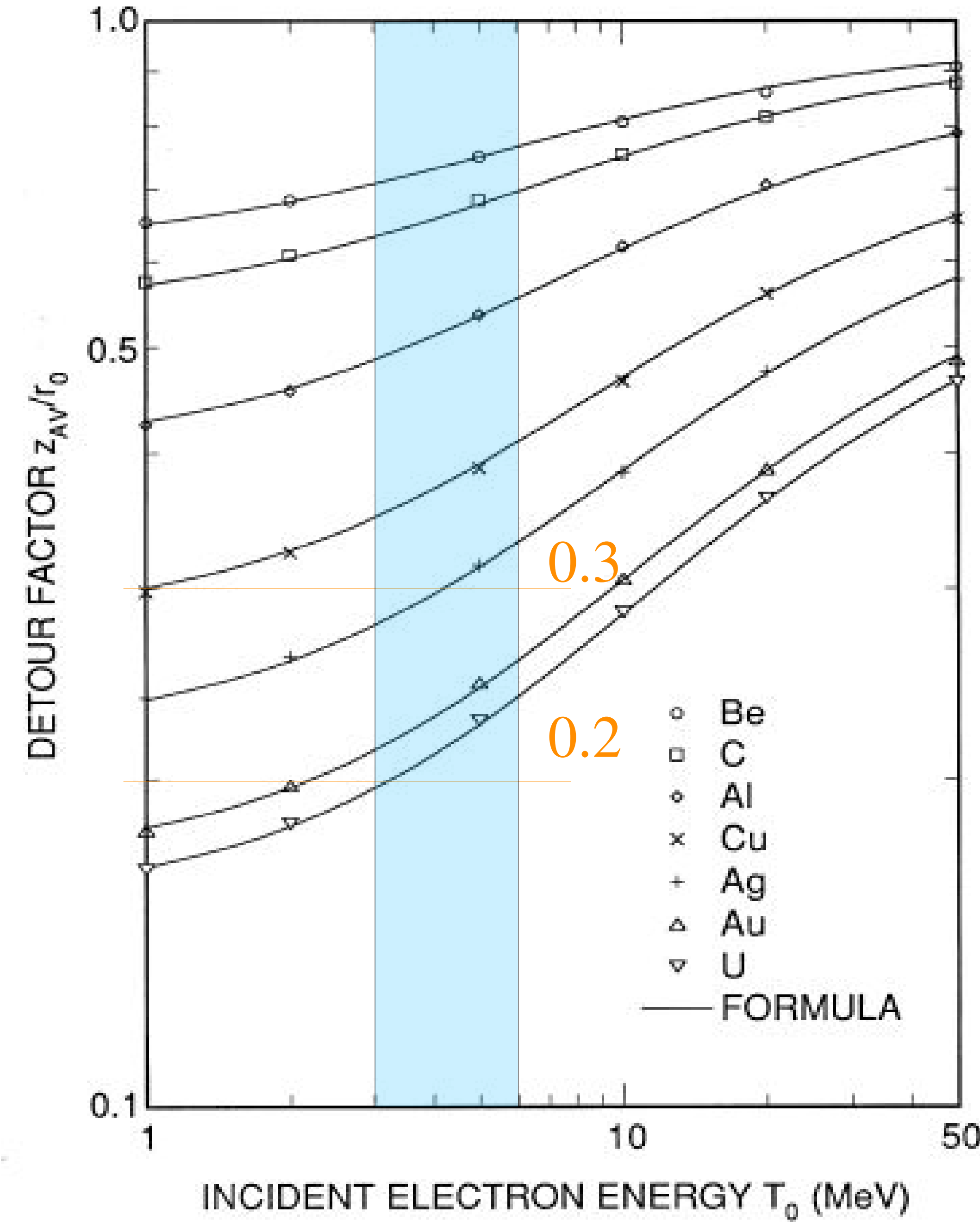
- PbO (25 %) + SiO_2 (75 %) with density 6.22 g/cm^3:

Energy	Stopping power			Range	
	Collision	Radiation	Total	CSDA	
MeV	MeV cm^2/g	MeV cm^2/g	MeV cm^2/g	g/cm^2	mm
0.100	3.043	0.0152	3.058	0.020	0.03
1.000	1.395	0.0440	1.439	0.574	0.92
2.000	1.395	0.0828	1.478	1.263	2.03
3.000	1.424	0.1256	1.550	1.924	3.09
4.000	1.451	0.1711	1.622	2.554	4.11
5.000	1.474	0.2183	1.692	3.158	5.08
6.000	1.493	0.2669	1.760	3.737	6.01

- Catching electrons below 1 MeV is a challenge.

Detour factor

- The projected distance covered by the electrons is smaller than the CSDA range by the *detour factor*.
- For heavy materials, the factor seems to be ~ 0.25.



[Tatsuo Tabata and Pedro Andreo, 10.1016/S0969-806X(98)00184-4]

Required granularity

- The precise projected range remains to be worked out. Assuming a detour factor of 0.25 and a CSDA range of 4 mm (lead glass), absorber material more than 1 mm from a gas channel is likely to be inefficient.

- Higher density absorbers require finer granularity.

Parameters

- Absorber:
  - Assuming a high-ρ lead glass, 25 % conversion efficiency requires > 1 cm of absorber (net).
- Gas channels:
  - in high-ρ lead glass, absorber material > 1 mm from a gas channel can go undetected;
  - channel diameter should be > 2 mm if length > 2 cm;
- Density scaling:
  - absorber thickness: $\propto \rho$,
  - channel diameter: $\propto \sqrt{\rho}$,
  - inter-channel gap: $\propto \rho$.

Next step

- Photon detection draws on “neighbouring” physics: whilest being well-understood, it is an opportunity to enlarge our horizon.

- Some institutes manifestly encourage developing devices which are of practical use.

- Simulation-wise, the real challenge is detecting the neutrons. Volunteers welcome !

The latest thing: schools ...

- We've been involved in:
  - RD51 school – 1 month of preparation, 1 week of practical exercises;
  - EDIT – 2 weeks of preparation and 2 weeks of daily demonstrations with lecturing for 1 week;
  - Marie Curie – largely drawing on EDIT, 2 days of lectures and demonstrations;
  - NNK Quark travels – 2 days of lectures.

- Upcoming:
  - EIRO – 1 week of preparation, 1 week of school.