Muons, Inc.

Design and Simulated Performance of Reflection Photo-cathode/MCP Geometries

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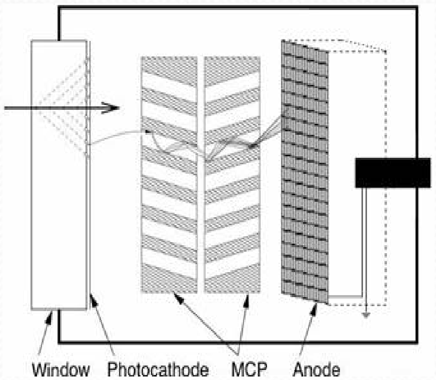
Outline

- Analytical model for the electric field in the pore;
- MCP gain vs. geometrical parameters;
- New 3D Monte Carlo code MCS3D;
- Chevron type MCP simulation:

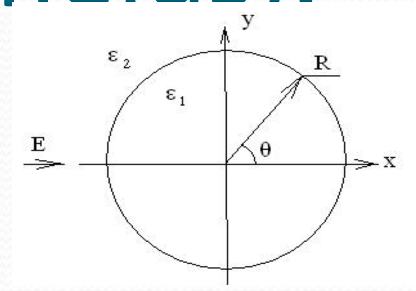
1. First strike problem;
2. Gain & TTS vs. pore diameter variations.

Analytical model for the electric field in the tilted pore (no fringe fields).



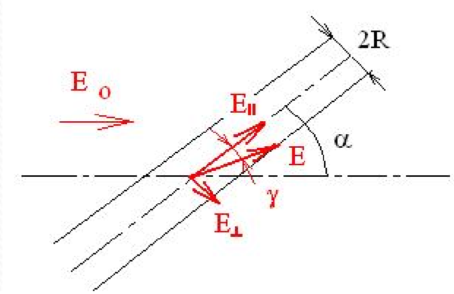
Chevron type MCP

1. Potential distribution and electric field for a straight cylindrical pore in a uniform external field (polarization effect)



$$\varphi(\rho,\theta) = \begin{cases} -\dfrac{2\varepsilon_1}{\varepsilon_1+\varepsilon_2} E\rho\cos\theta, & \rho < R, \\ -Ex - E\dfrac{\varepsilon_1+\varepsilon_2}{\varepsilon_1+\varepsilon_2}\dfrac{R^2}{\rho}\cos\theta, & \rho > R. \end{cases} \qquad E(\rho,\theta) = \begin{cases} \dfrac{2\varepsilon_1}{\varepsilon_1+\varepsilon_2} E\cos\theta, & \rho < R, \\ E - E\dfrac{\varepsilon_1+\varepsilon_2}{\varepsilon_1+\varepsilon_2}\dfrac{R^2}{\rho^2}\cos\theta, & \rho > R. \end{cases}$$

2. The external field can be expanded into parallel and perpendicular components



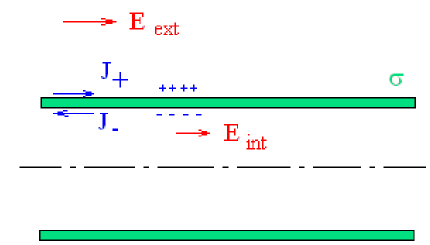
$$E_0 = E_{\|} + E_{\perp}, E_{\|} = E_0\cos\alpha, E_{\perp} = E_0\sin\alpha. \quad E_{\perp}(\rho,\theta) = \frac{2\varepsilon_1}{\varepsilon_1+\varepsilon_2}E_0\cos\theta\sin\alpha, \quad \tan\gamma = \frac{E_{\perp}}{E_{\|}} = \frac{2\varepsilon_1}{\varepsilon_1+\varepsilon_2}E_0\cos\theta$$

$$E_{\|} = E_0\cos\alpha.$$

3. The field relaxation ratio for an infinitely thin layer with conductivity σ is

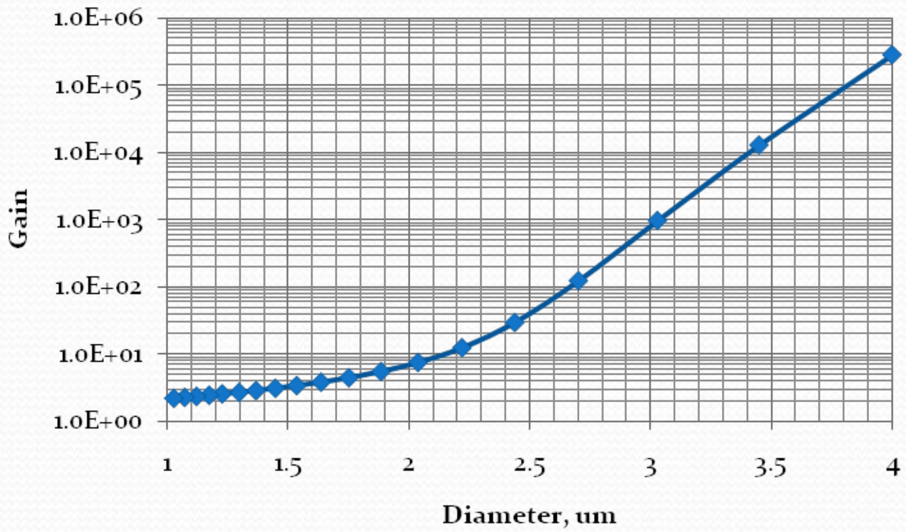
$$k(\sigma) = \frac{E_{int}}{E_{ext}} = \frac{\sigma_0}{\sigma},$$

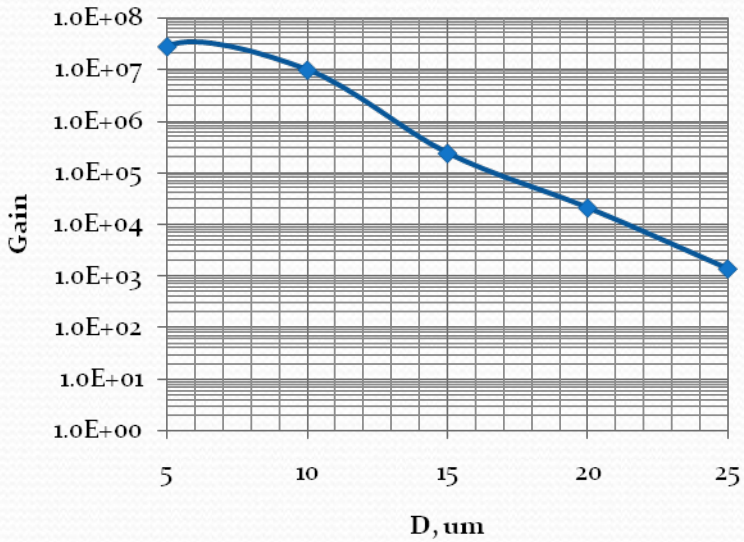
$$\sigma_0 = \frac{1}{Z_0} = \sqrt{\frac{\varepsilon_0}{\mu_0}} = \frac{1}{376.73\Omega}.$$



Fringe fields, see “The direction of the E-field in Glass Pores” by S.Antipov, Z.Insepov.

MCP gain vs. geometrical parameters

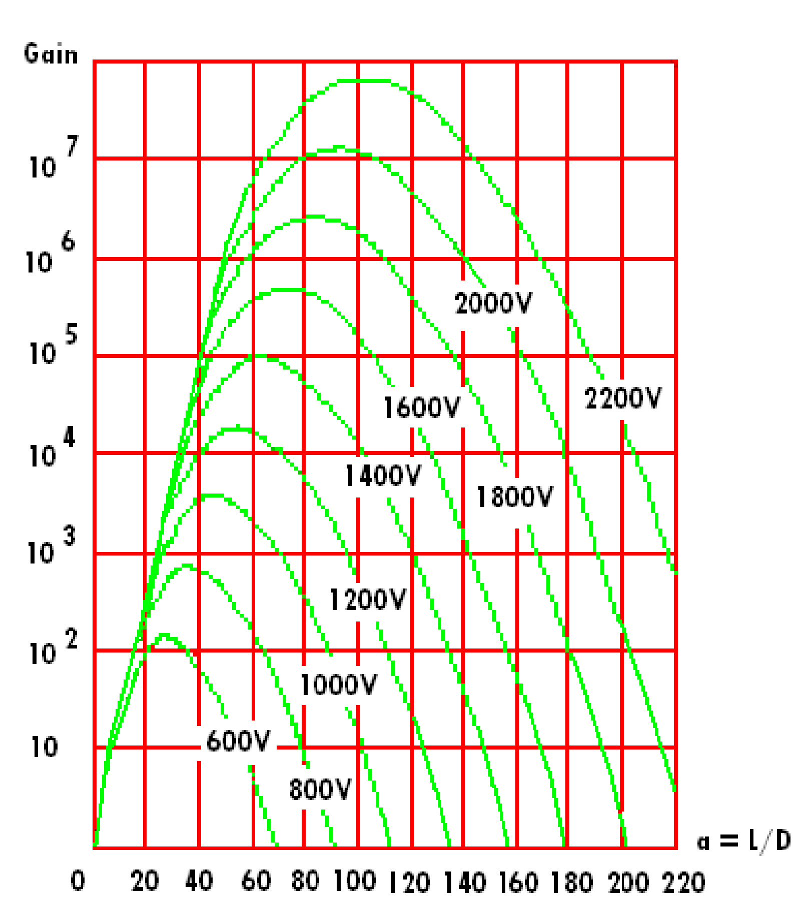




Gain variations vs. pore diameter for the MCP thickness of L =0.5 mm.

The goal of this computation is to determine, which minimal diameter of the pore does work.

Parameterization for the gain curves

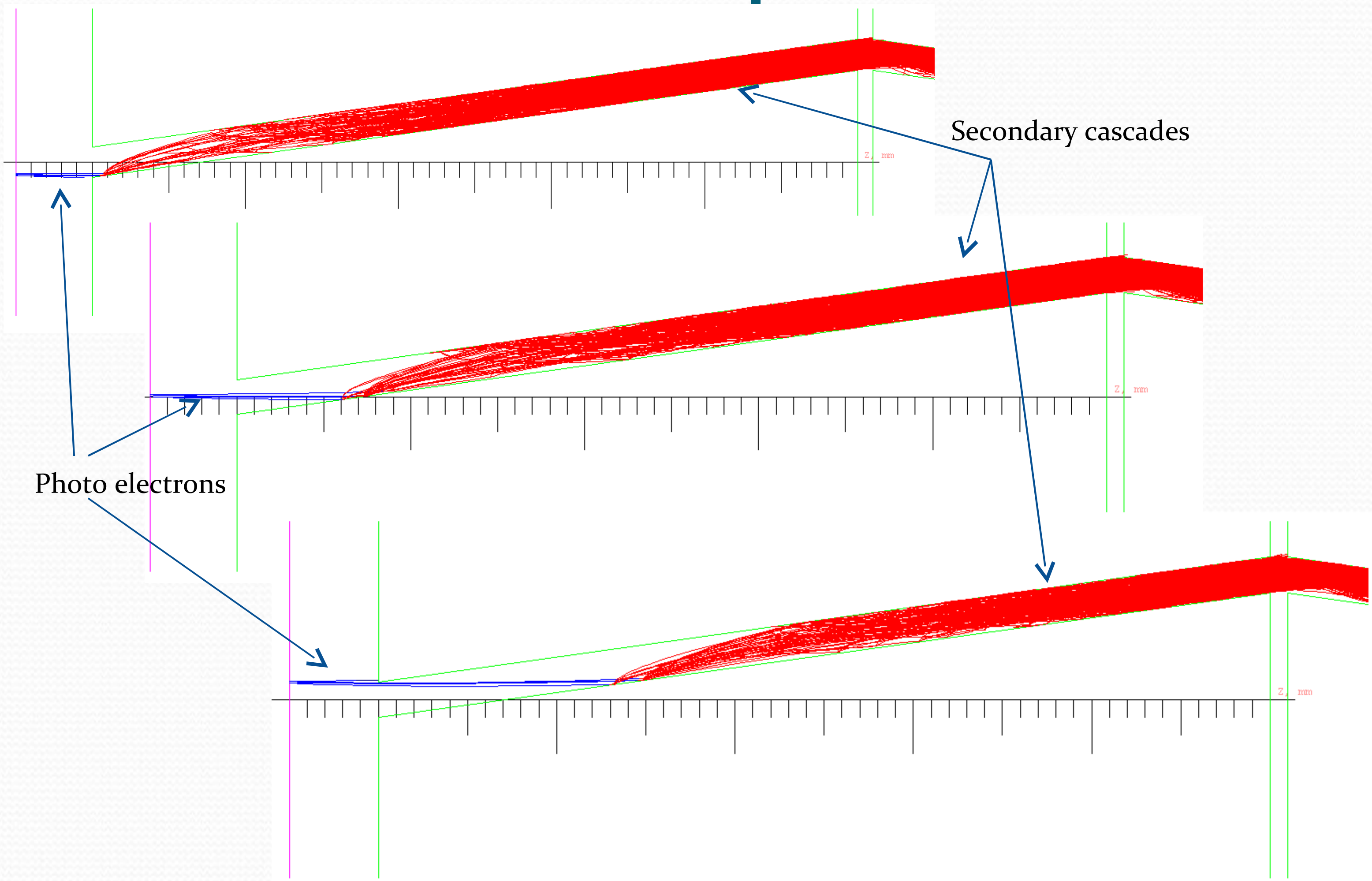


A set of universal gain curves for voltage and geometry variations. D – pore diameter, L – thickness of the MCP plate.

New 3D Monte Carlo code MCS3D

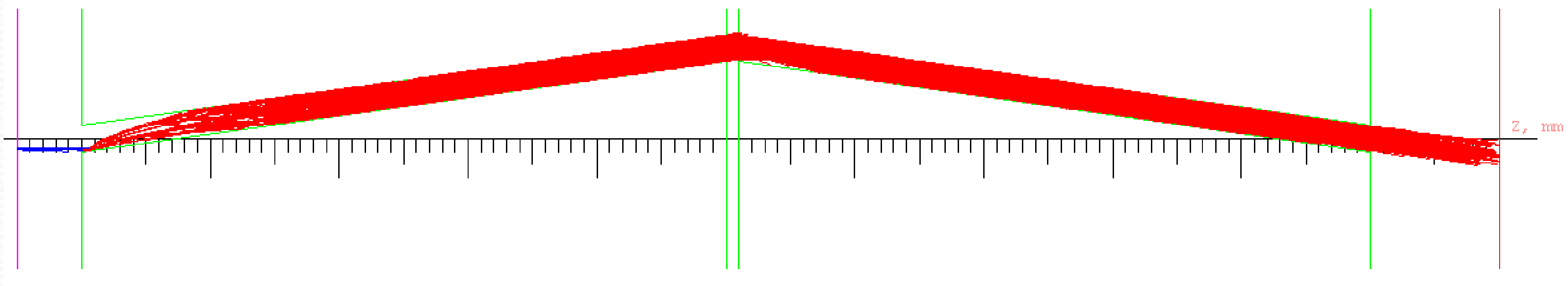
- The code MCS3D can simulate all types of MCP: straight channel, chevron, Z-stack & funnel MCP;
- Photo emission is described by a set of parameters: quantum yield, mean photon energy, energy & angular distributions, mean position, temporal & time profiles;
- Secondary emission models are represented by the analytical dependences for angular & energy distributions or by the tables of computed data for different materials;
- External electric & magnetic fields are determined by the analytical formulas or by the tables of computed data for three-dimensional fringe fields;
- The results are represented with an embedded computer graphics and saved in database for further post-processing.

First-strike problem study



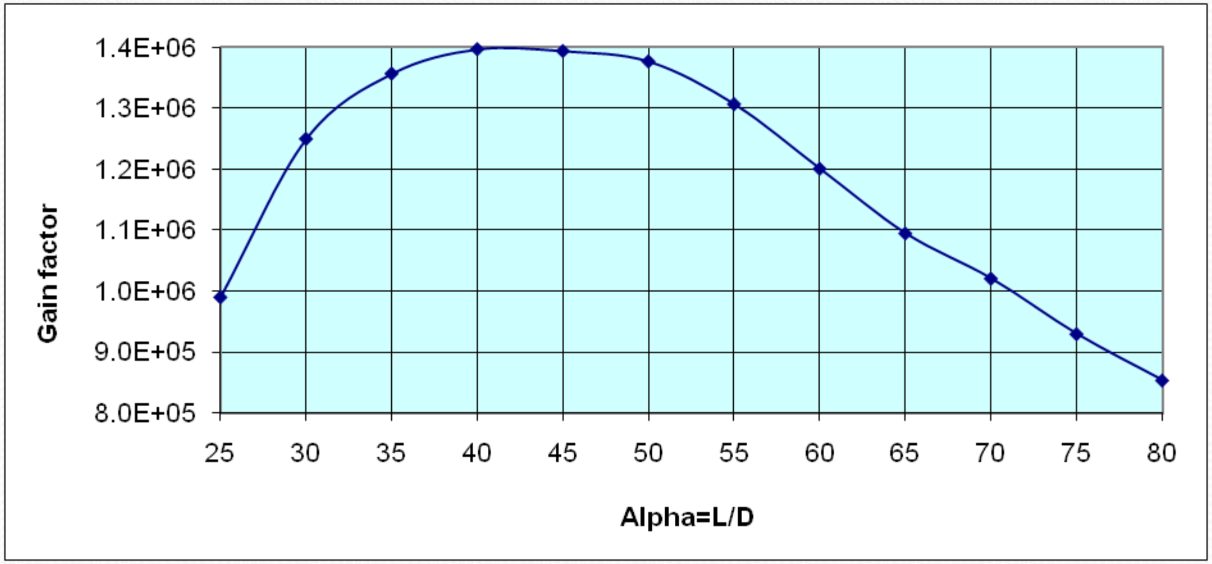
Gain factor strongly depends on the position of first strike

Gain computation for the Chevron MCP



MCP parameters: Ugap = 350 V; Umcp=1000V; Umcp-anode = 500V; L=0.5 mm

The set of parameters (voltage, first-strike position, number of photo electrons, time step, pore diameter etc.) were varied to study the gain & TTS depenedence.



What to do?

- Develop a Particle Player (post-processor) to show the particle dynamics in real time with getting data from the results database, phase space, TTS and other parameters;
- Accumulate the data for the energy and angular dependence of SEY for all needed materials from numerical Monte Carlo simulations (See "Comparison and Discussion of Candidate SEE Material" By Z.Insepov, this Meeting);
- Incorporate the saturation effects to the new code MCS3D;
- Provide a systematic comparison for numerical simulations with experimental results.

Summary

- Analytical solution for the E-field in tilted cylindrical pore with dielectric media and resistive layer have been obtained to estimate the field direction far from the ends of pore;
- The gain dependence vs. geometrical parameters was studied to determine, which minimal diameter of the pore does work;
- Three- dimensional Monte Carlo code MCS3D have been developed to simulate all types of MCPs;
- Chevron type MCP was simulated from photo cathode to the anode with varying of different parameters to study the gain and temporal parameters.