MCP: Theory/Simulations

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Large Area Photodetector Photocathode Godparent Review
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Part 1: Material properties

Z.Insepov, V.Ivanov – theory & simulations,
S.Jokela - measurements

Outline

- Monte Carlo (MC) simulations, empirical theories were applied to identify the influence of back-scattered (BS) electrons and saturation effects on the emissive properties of materials and to study the gain and transit times for various microchannel plates (MCPs).
- Al2O3 and MgO of various thickness and surface quality were studied.
- SEY, BS data were calculated at oblique angles of the primary electrons in the interval of 0-80° and compared to Argonne experiments.
- SEY, BS data were submitted to our trajectory simulation MC code which is capable of gain and transit time calculations.
- The deposition and characterization experiments were conducted for the Large Area Picosecond Photodetector project at Argonne National Laboratory .

Motivation

- Theoretical studies of secondary electron emission yields (SEYs) are necessary as a preliminary step in developing new emissive materials for particle detectors based on microchannel plates (MCPs) in high-energy physics, such as Cherenkov, neutrino, and astroparticle detectors.

- Secondary electrons also play a significant role in the development of new scanning electron microscopes.

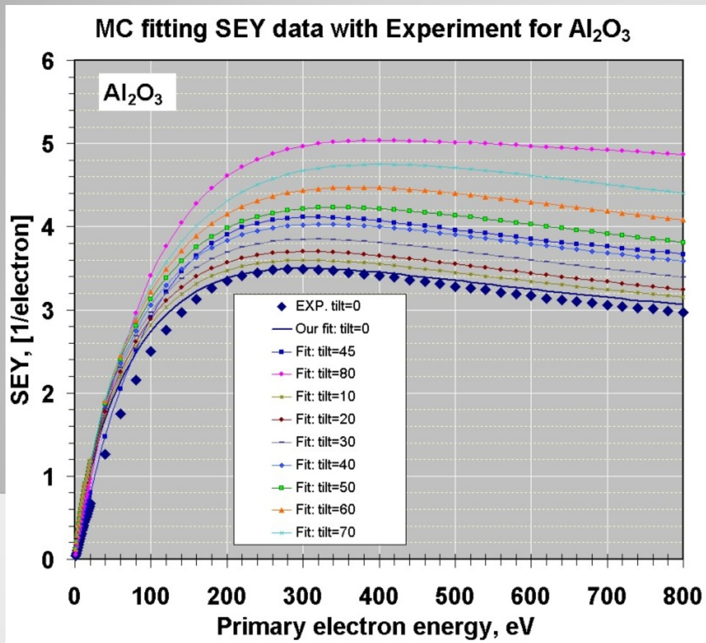
- The back-scattering electrons can make a substantial contribution to the total MCP gain and can alter the transit time.

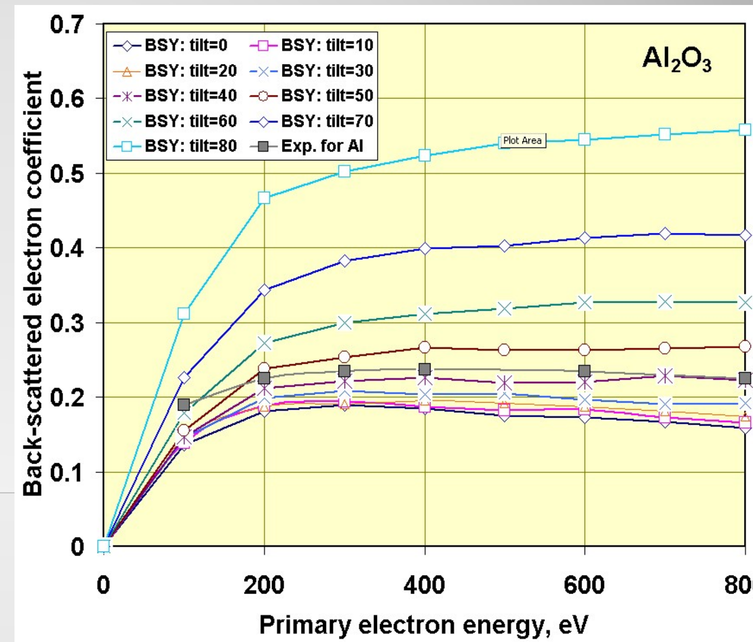
- To our knowledge, BSC contributions to gain and transit times were not taken into account so far.

Introduction

- The goal of this work is to develop a parameterized set of the SEY dependencies in two variables: the energy of the primary electron and the angle of incident electrons for Al_2O_3 and MgO that are of interest for collaboration in the Large Area Picosecond Photodetector project at Argonne National Laboratory.
- This parameterization can be done by using results obtained from Monte Carlo (MC) calculations.
- The transit times, gains, and spatial resolution critical for the new large-area photo-detectors have not been available with the conventional glass MCPs.
- The new MCP concept is based on micron-scale pores fabricated in alumina by Atomic Layer Deposition method.

SEY and BSC of Al2O3



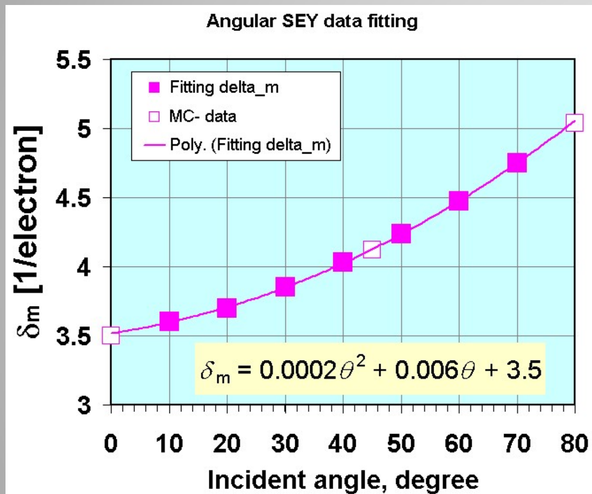


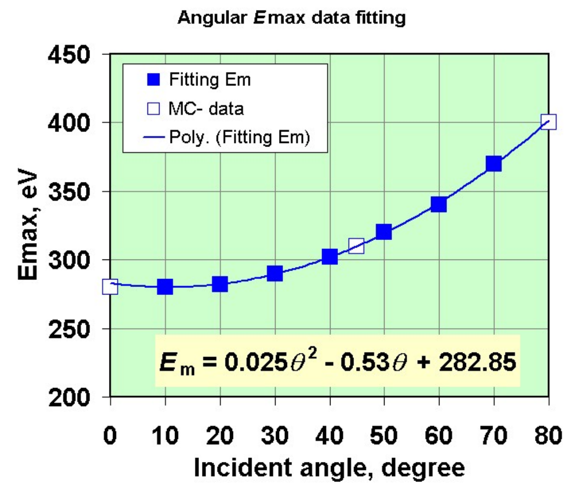
$$\delta / \delta_m = 1.11 \cdot \left(E / E_m \right)^{-a} \left[1 - e^{-2.3 (E/E_m)^b} \right],$$

where $a = 0.225$, $b = 1$.

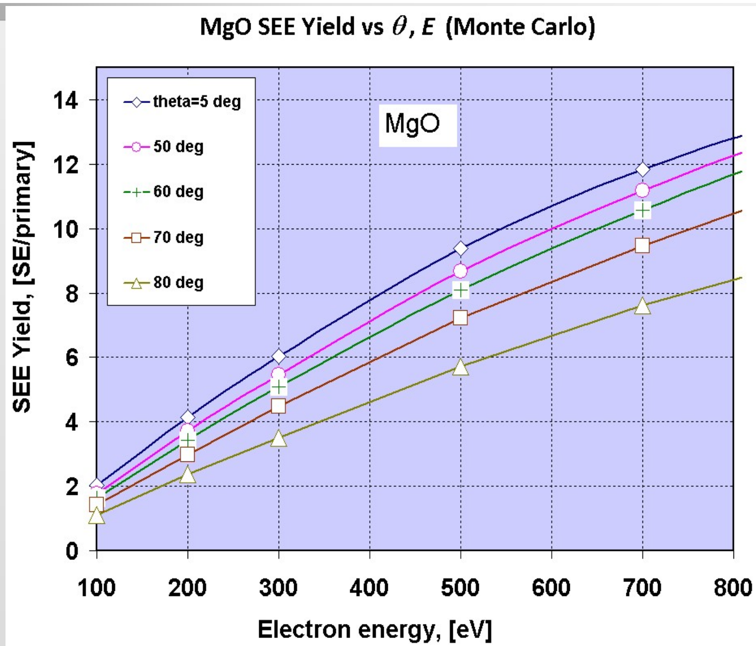
The values of δ_m and E_m at various incidence angles were obtained by a smooth interpolation of the appropriate SEY and *E* values for the computed data.

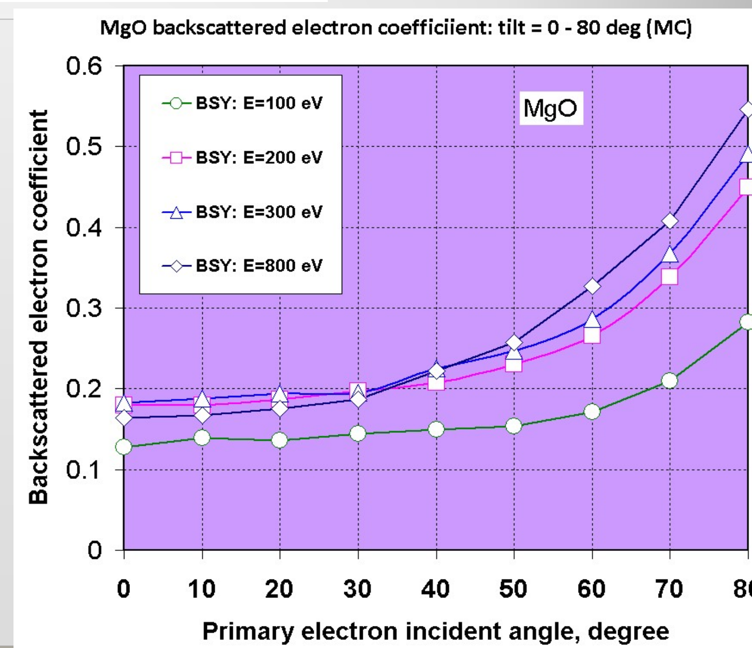
BS coefficients for MgO



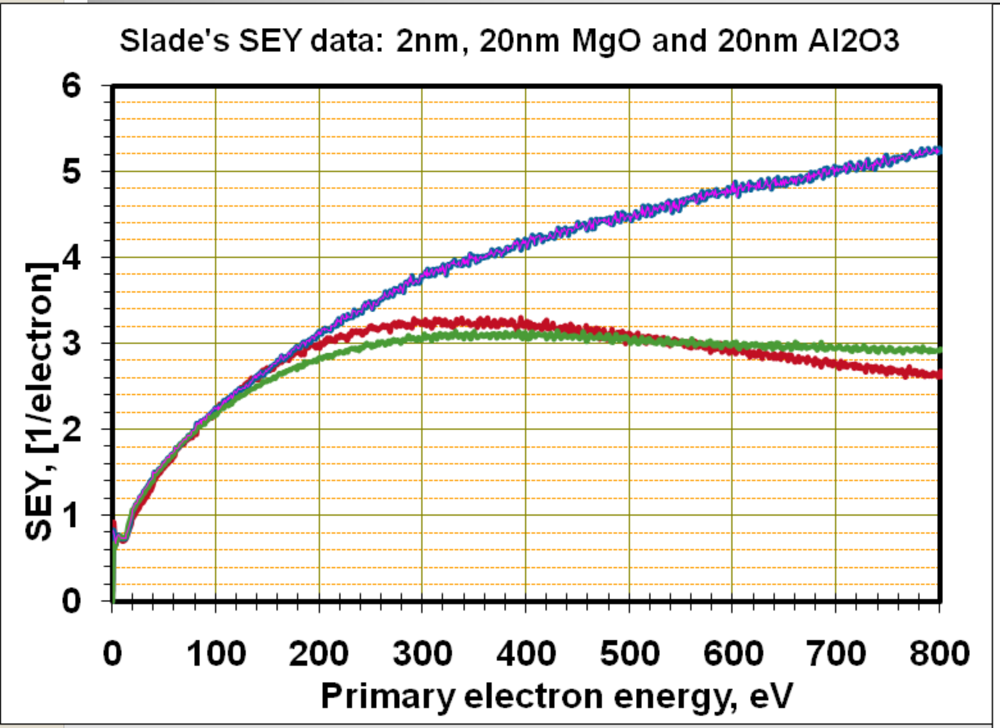


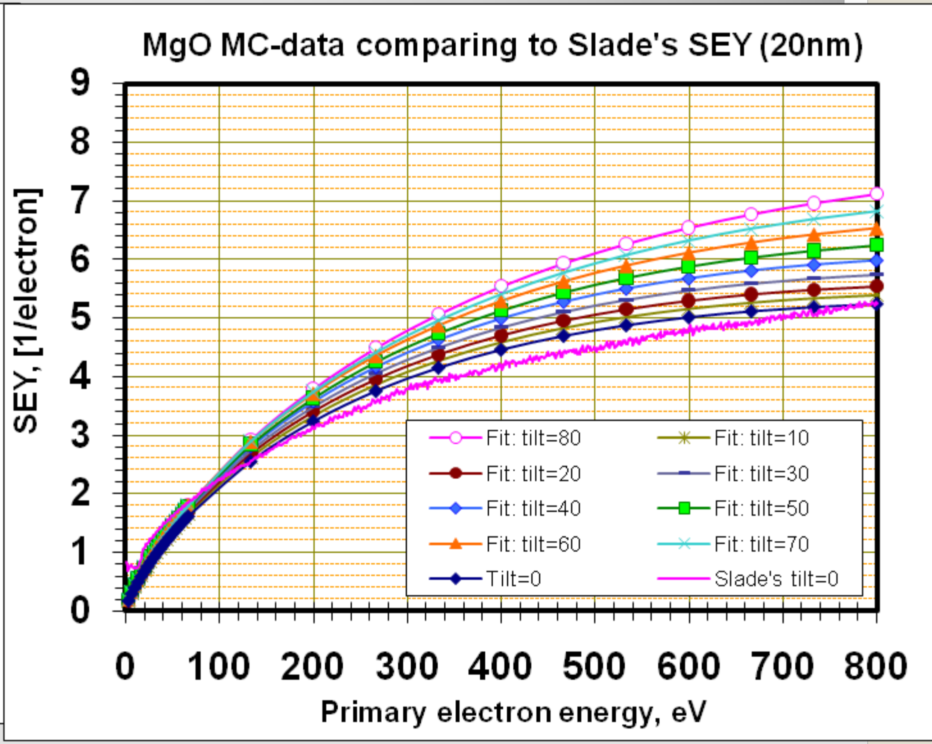
SEY, BSC data were used for MCP gain and transit time simulations that simulates avalanche inside an MCP pore. The feedback from the gain code was used to stimulate further search for better MCP materials.





Experimental measurements of the material properties





Measurements by S.Jokela have good agreement with the Monte Carlo simulations by Z.Insepov. Pink – 20nm MgO; red – 2nm MgO; green – 20nm Al2O3.

Part 2: MCP simulations

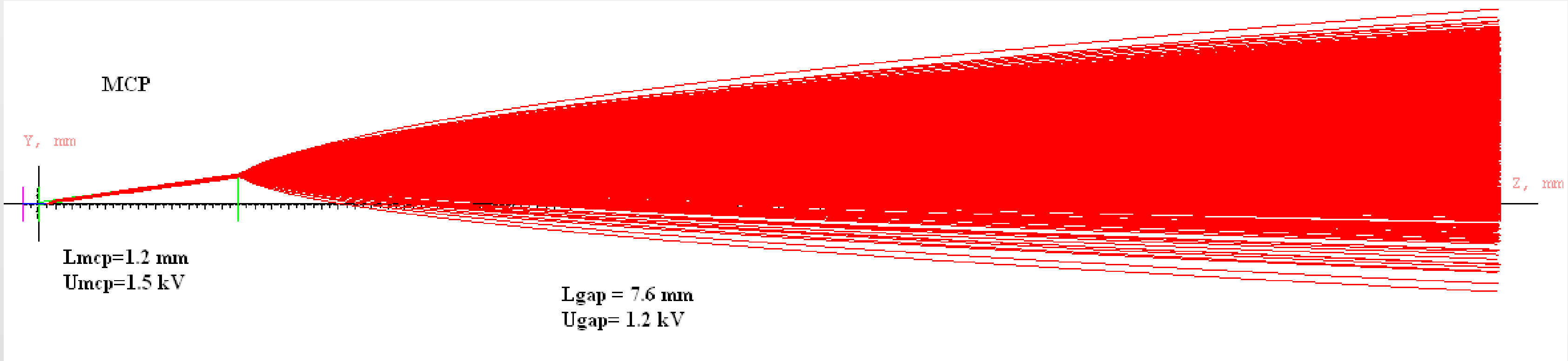
Valentin Ivanov

The status of 3D code "Monte Carlo Simulator"

- The code "MCS" can simulate the main parameters of MCP amplifiers (gain, arrival time, timing resolution, statistical properties) from photocathode to the anode with taking into account the properties of photo emissive and secondary emissive materials (angular and energy distributions for true secondary and back-scattering electrons);
- The measurable parameters in MCP testing that can be compared to simulation are: averaged gain, arrival time, timing resolution, pulse shape, angular and energy distributions for the bean coming to the anode;
- We have the numerical tool and inputs to make a consistent picture of how an MCP works, and to validate this with measurements.

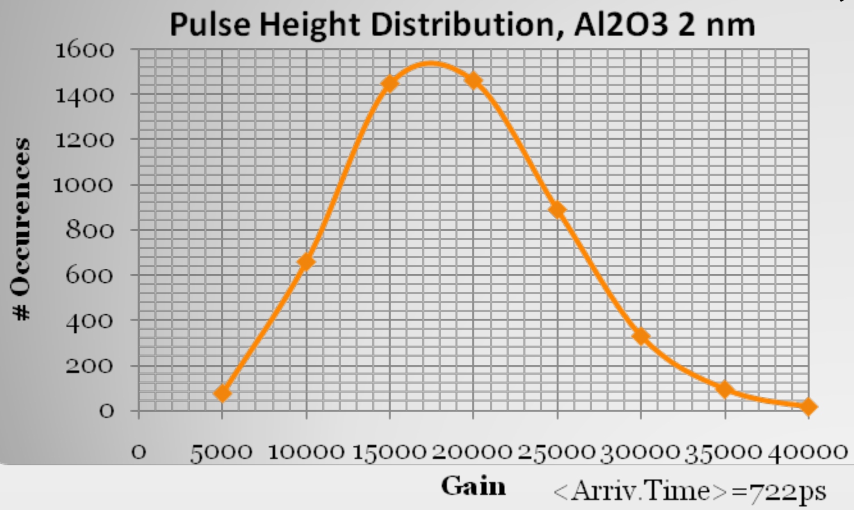
Simulation parameters

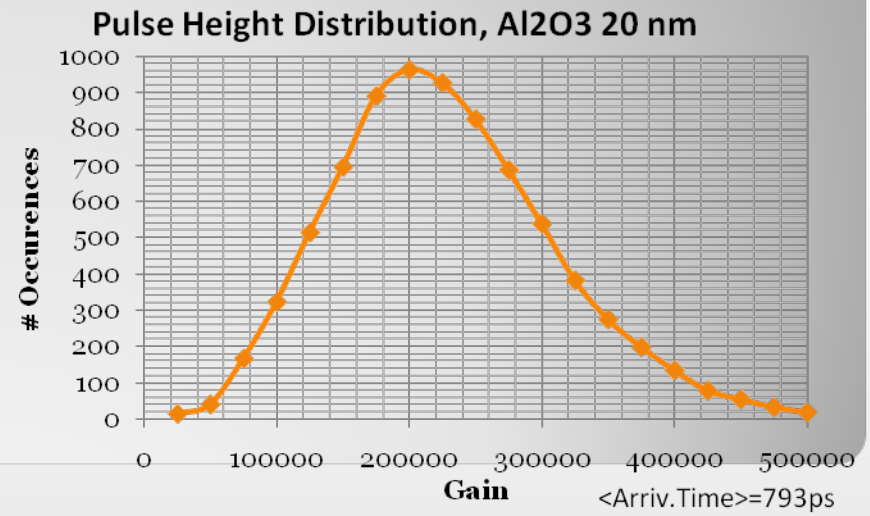
- Single MCP of 1.2mm length, 20nm pore diameter; 8 degrees of bias angle; 1.5 kV applied voltage;
- Photo electron energy in the MCP entrance is 300 eV;
- Pulse height distribution (PHD) and arrival time distribution (ATD) are averaged over 5,000 single photo electrons coming to the MCP;
- MCP-anode gap is 7.6mm, applied voltage is 1.2kV.

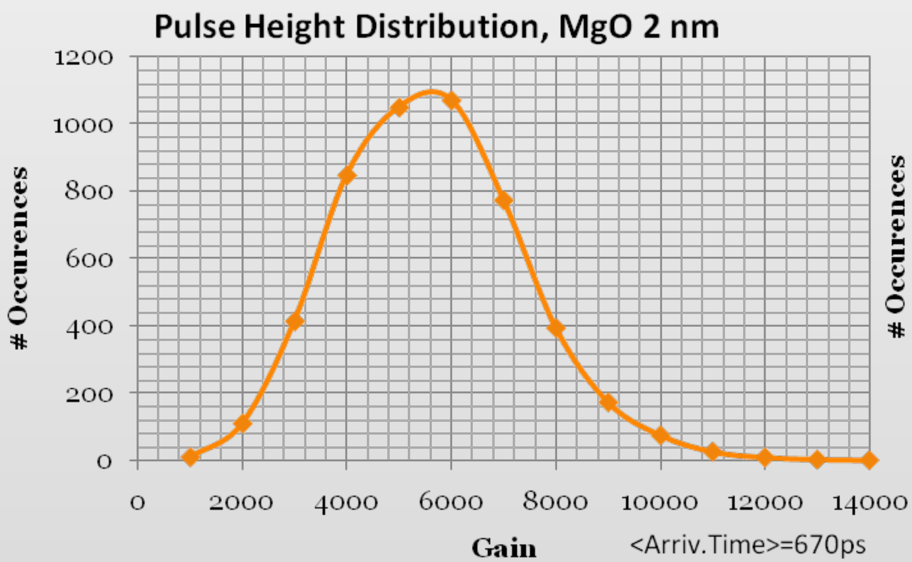


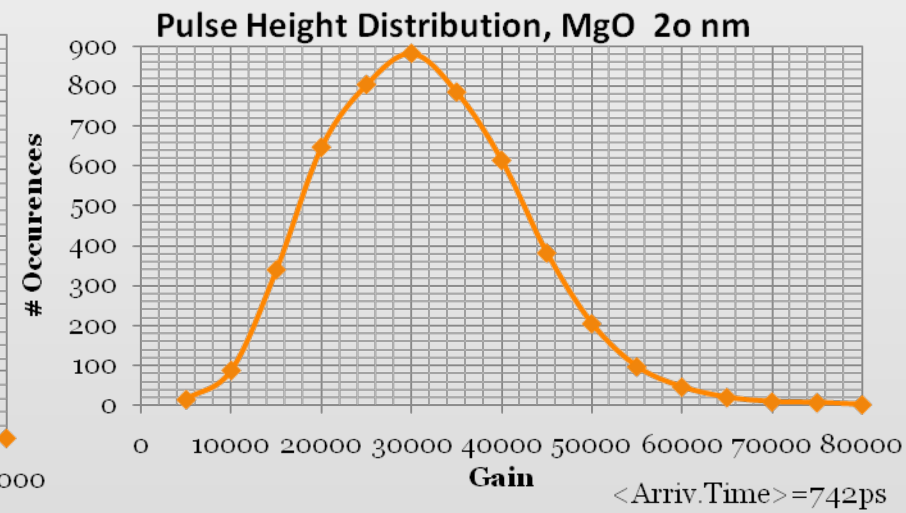
An example of single MCP simulation with the code “MCS”

Comparison: PHD for 2 materials, 2 thickness



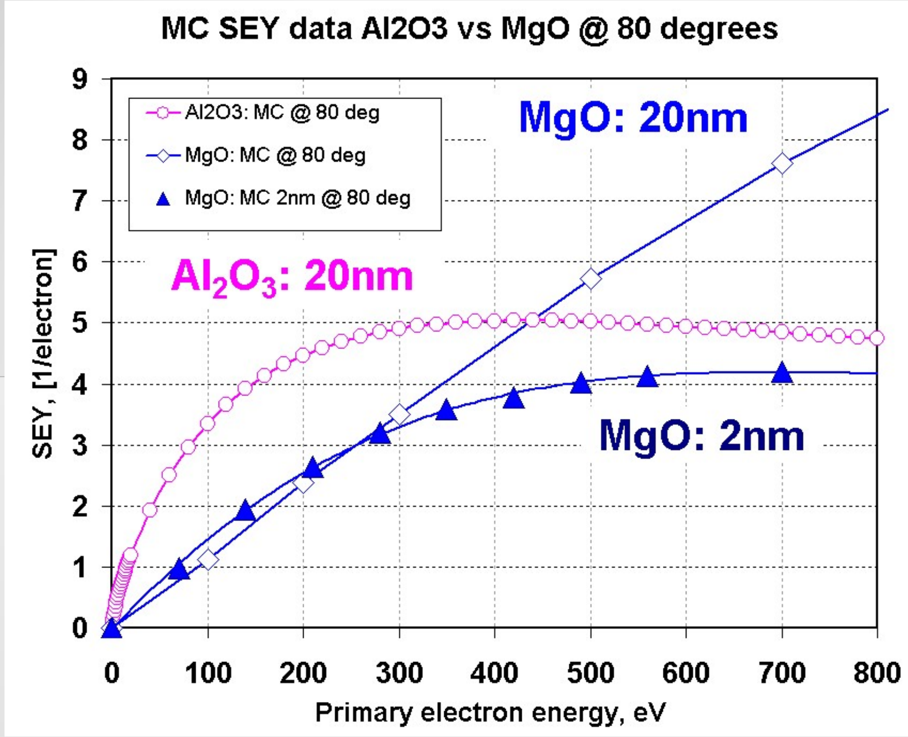






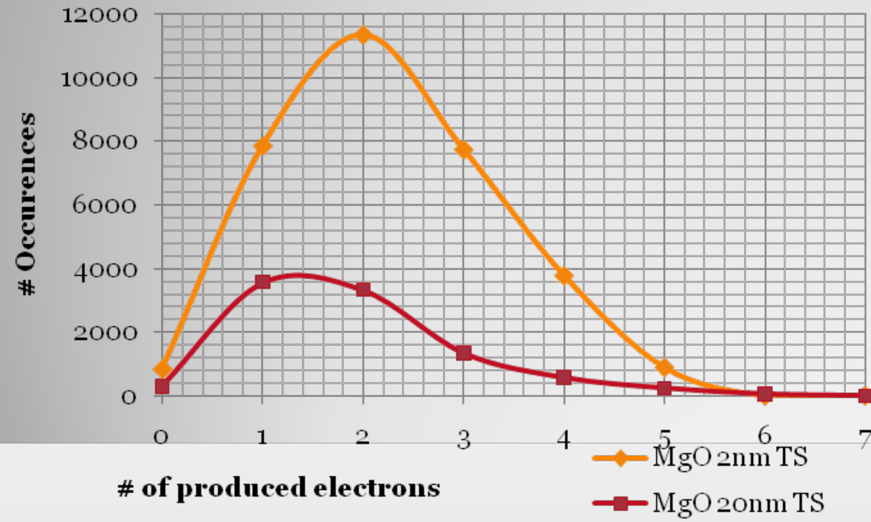
The data averaged over 5,000 events

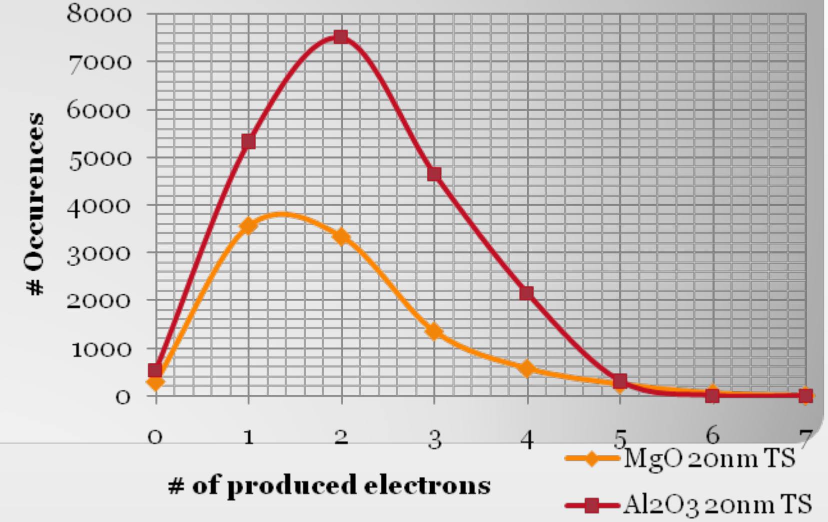
Comparative emission property for Al and MgO

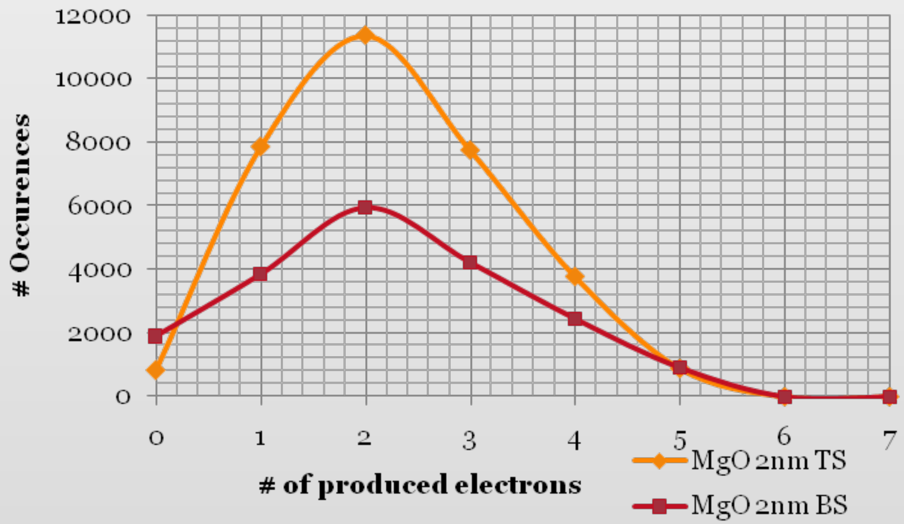


SEY in low energy range (60-80eV) is higher for Al2O3 then for MgO. Most part of secondary electrons are produced in 20nm pores in this range of energies and incident angles.

How many secondary particles produced in hits per one primary

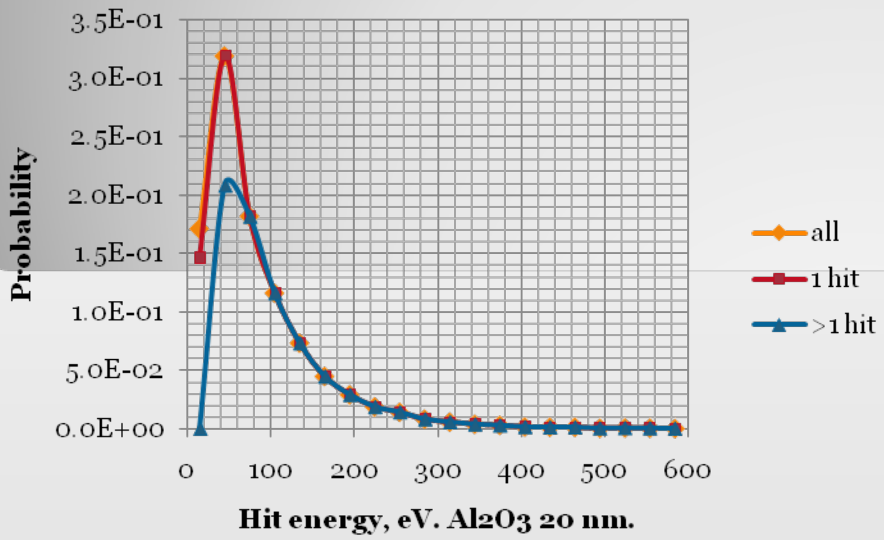


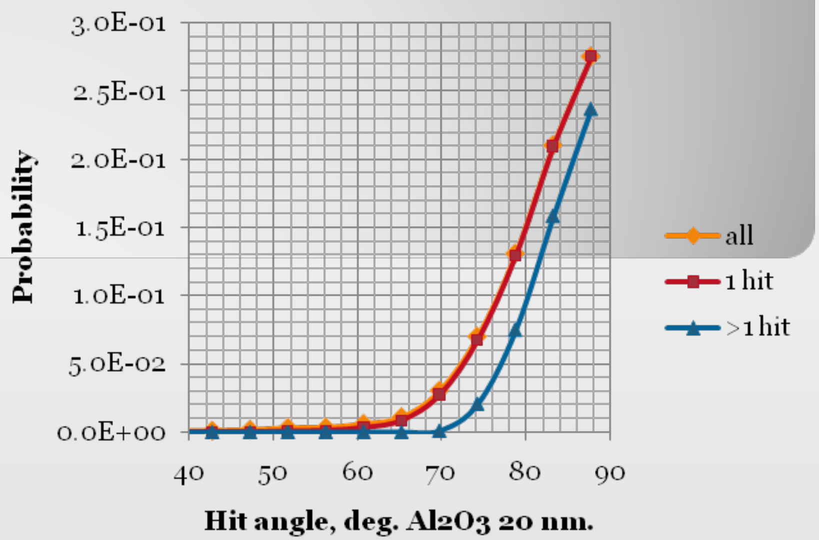




If <n> is mean value of produced secondary particles, G is a gain, and X is a mean number of cascades, then <n>^x=G. We have about 18 cascades for Al2O3, and 15 cascades for MgO.

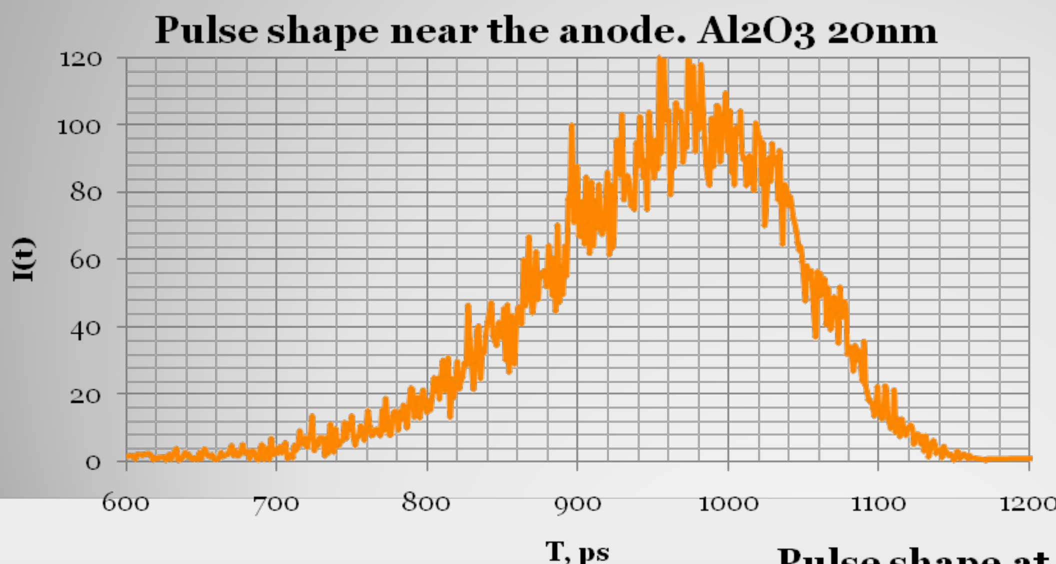
Strike's statistics: energy & angular distributions





Simulations show that the most probable strike energy Em, and incident angle Am depend on the MCP diameter, and applied voltage. In our case Em~70-80 eV; Am~ 87 degrees. Orange – all particles; red – particles produce 1 new secondary ; blue – particles produce more than one new particle.

Pulse shape profile



There are much more oscillations in the pulse shape profile near the anode, because the beam has big divergence in the gap.