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Simulation of Conventional and Unconventional Photo-cathode Geometries

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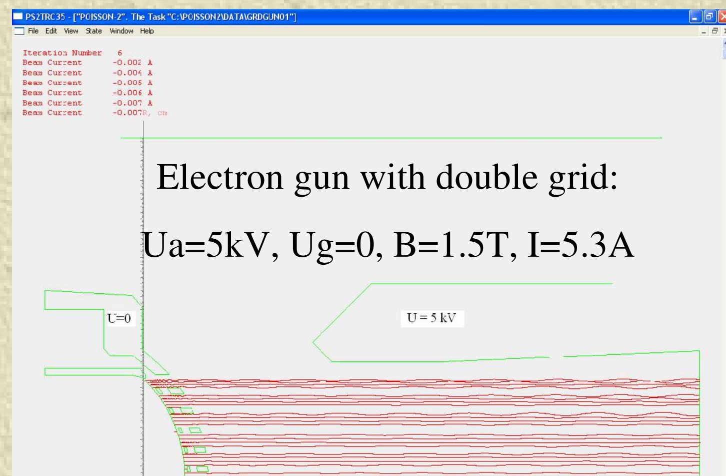
20 July 2009

1st Workshop on Photo-cathodes

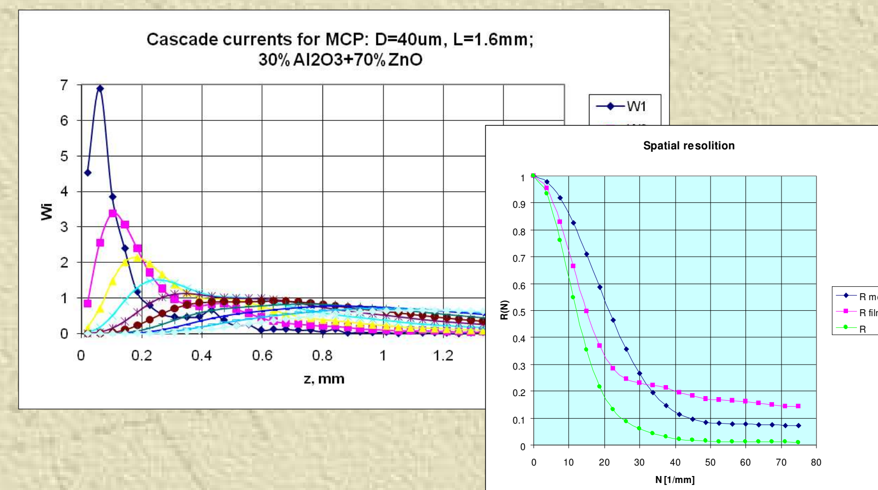
Outline

- Brief review of numerical toolkit for micro channel plate simulation;
- Optimization of the photo electron capturing for Funnel MCP;
- Conventional MCPs with composite secondary emitters;
- Comparison of emission properties for different analytic models;
- Future problems;
- Resume.

Original software toolkit to simulate the MCPs



General purpose 2D electron optical relativistic code “PO



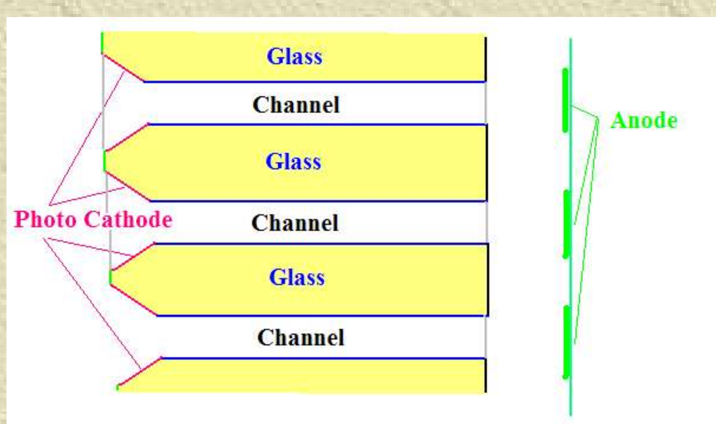
Micro channel plate simulator MCPS

Monte Carlo simulator MCS

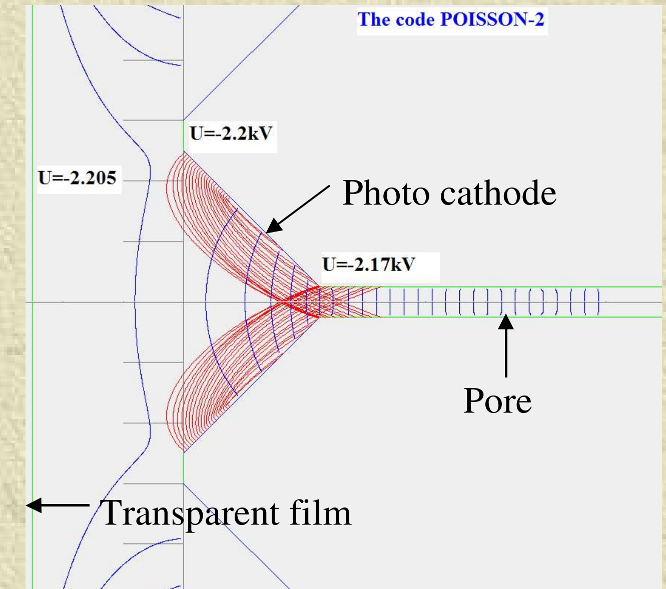
Part 1.

Funnel MCP

Funnel type MCP (FMCP)

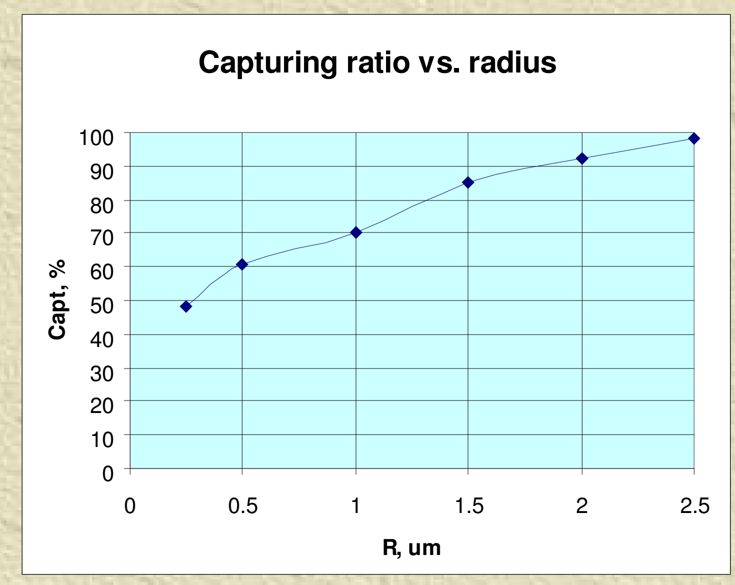


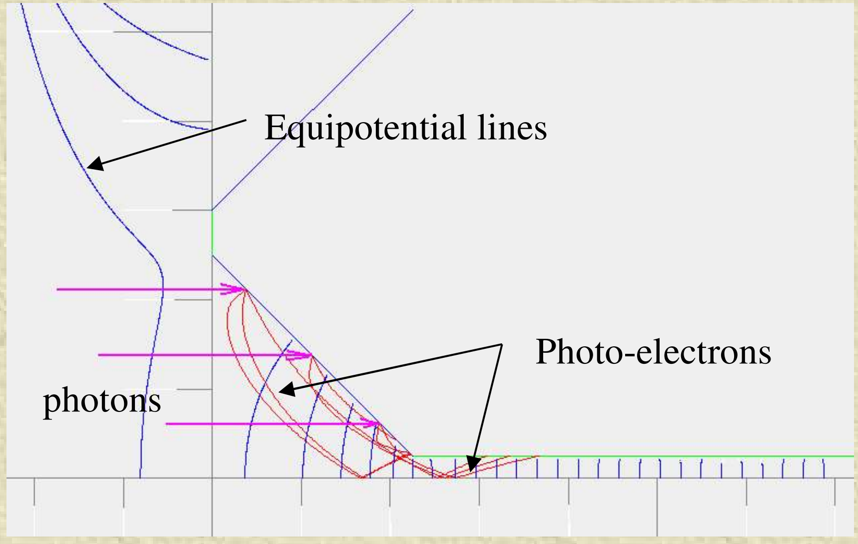
FMCP is an alternative version of conventional MCP which can prevent the ion feedback damage. FMCP also makes easier the first-strike problem.



Optimization of capturing ratio for photo-electrons by varying the outer radius and resistance of photo cathode

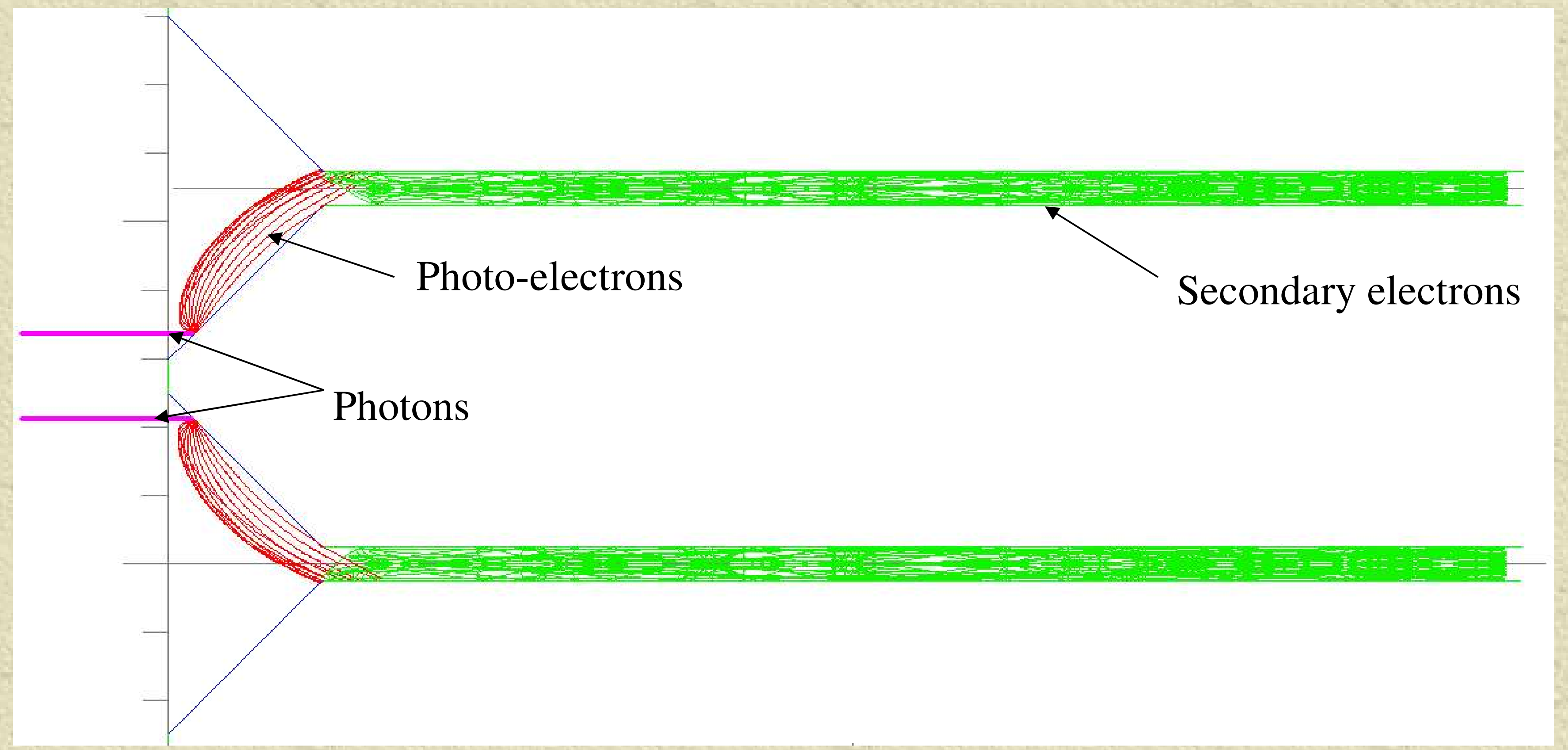
Efficiency of photo emission





The efficiency of photo-electron capturing depends on many factors (funnel geometry, photo-cathode resistance, voltage etc.). It is strongly depends on the position at the cathode surface

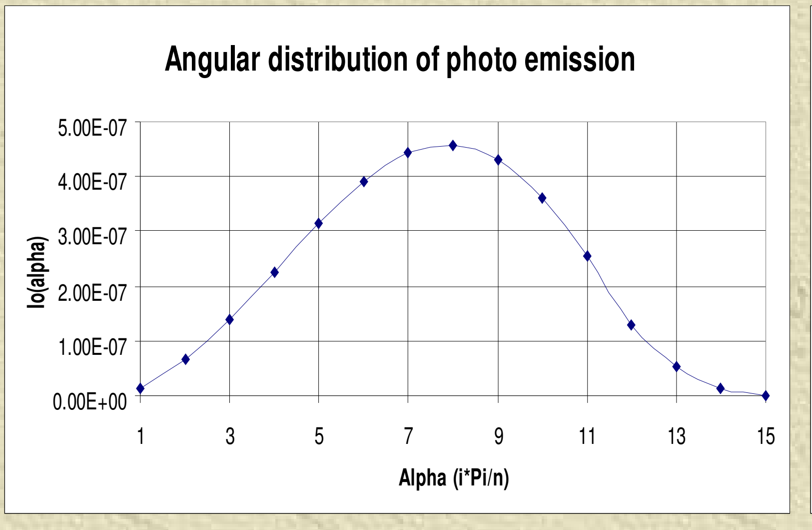
Electron multiplication in the funnel MCP

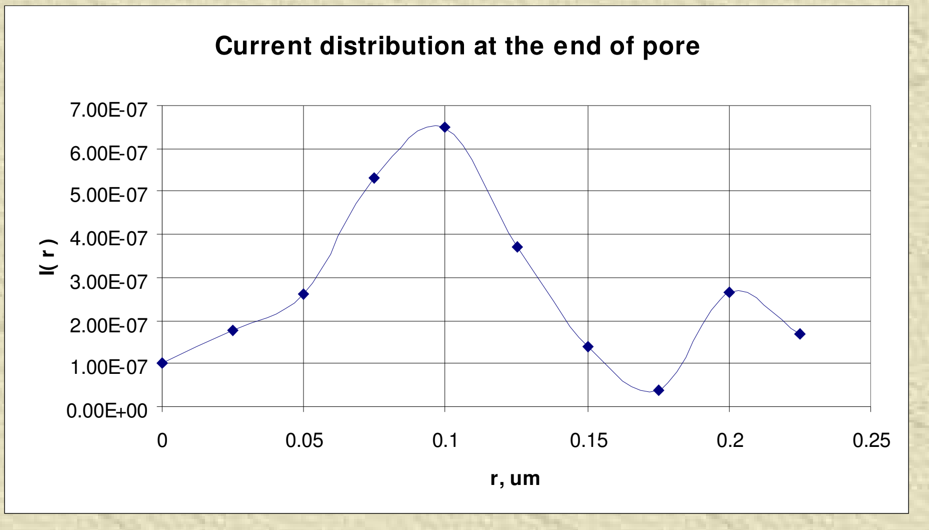


The result of numerical simulation for the electron multiplication in 5um pores.

Parameters: L/D=40; Material properties: Sigma max=3; Umax=400V.

Numerical results for FMCP simulation





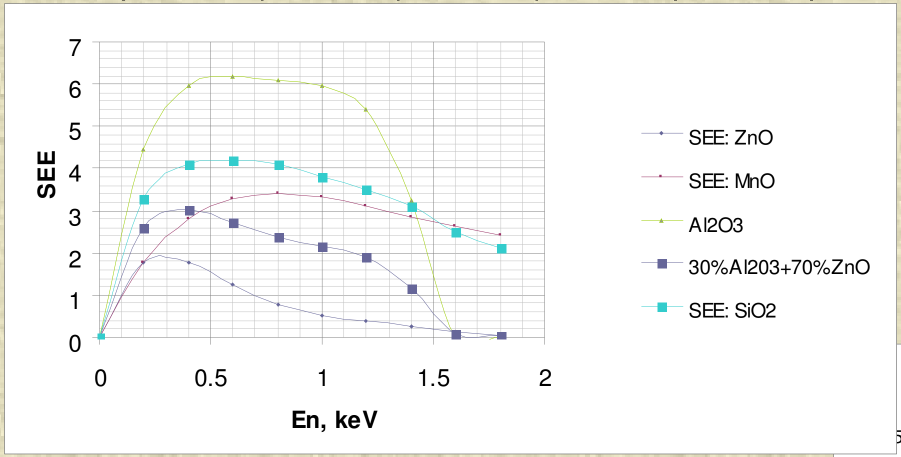
Angular distribution of photo emission is described by Cos(Theta) dependence

Current distribution of secondary electrons at cross-section Z=20um

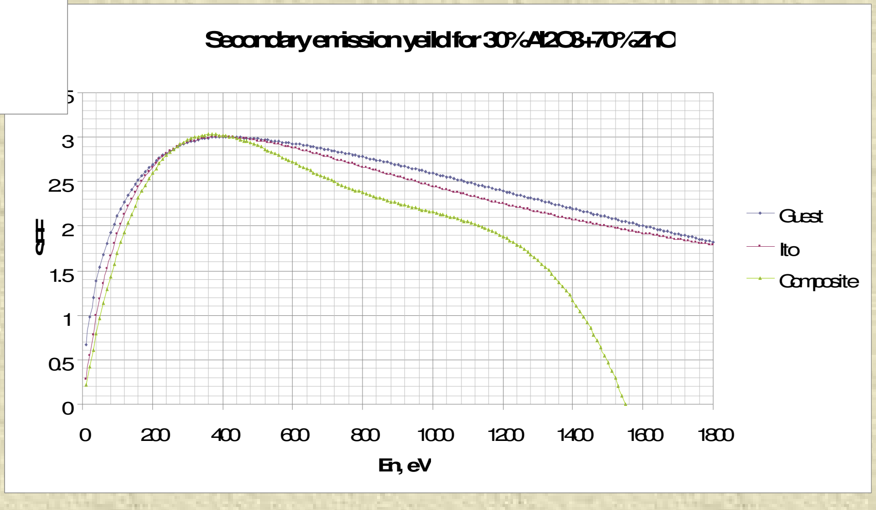
Part 2.

Conventional MCP

Secondary emission for composite materials



Secondary emission properties for different materials common used as the emitters in MCP



The approximations of SEE curve for composite material (30%Al2O3+70%ZnO) used in different semi-analytical models

These approximations were used in simulation of the INCOM MCP with parameters: D=40um, L/D=40, L=1.6mm, Voltage U=1kV

Comparison for different Secondary-emission models

1. Guest's Model

$$\sigma(\theta, V) = \left(\frac{V}{V_{max}}\sqrt{\cos(\theta)}\right)^{\beta} \exp\left[\alpha\,(1-\cos(\theta)) + \beta\left(1 - \frac{V}{V_{max}}\sqrt{\cos(\theta)}\right)\right],$$

$0.55,\ V < V_{max},$

$0.25,\ V > V_{max}.$

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$\beta =$ ¿ { ¿ ¿ ¿

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θ – incident angle, V – impact energy,

V_{max} – impact energy corresponds to a maximum of SEE yield,

α – surface absorption factor, β – smooth factor

2. Ito's Model

$$\sigma(\theta, V) = \frac{4x}{(x+1)^2} exp[\beta(1 - \cos\theta)]$$

$$x = \frac{V}{V_{max}}\sqrt{\cos\theta},$$

3. Lie-Dekker Model

$$\sigma_{max}(\theta) = \sigma_{max}(0)\left(1 + \frac{k\theta^2}{\pi}\right), V_{max}(\theta) = V_{max}(0)\left(1 + \frac{k\theta^2}{\pi}\right),$$

$$\sigma = \sigma_{max} g_n(z_m V / V_{max}) / g_n(z_m),$$

$$g_n(z) = \frac{1 - \exp(-z^{n+1})}{z^n},$$

k=0 for textured carbon, 1.5 for polished surface, 2 for crystalline (1 – default);

z_m - is an argument value corresponds to the maximum of $g_n(z)$,

n – is an adjustable parameter (default value is 0.35 for $V \leq V_{max}$, z_m=1.84, $g_n(z_m)$=0.725, and 1 for $V > 3\,V_{max}$);

4. Agarwal's Model

$$\sigma = \sigma_{max} \frac{2V/V_{max}}{1 + (V/V_{max})^{1.85(\frac{2Z}{A})}}$$

Z is atomic number and A the atomic weight

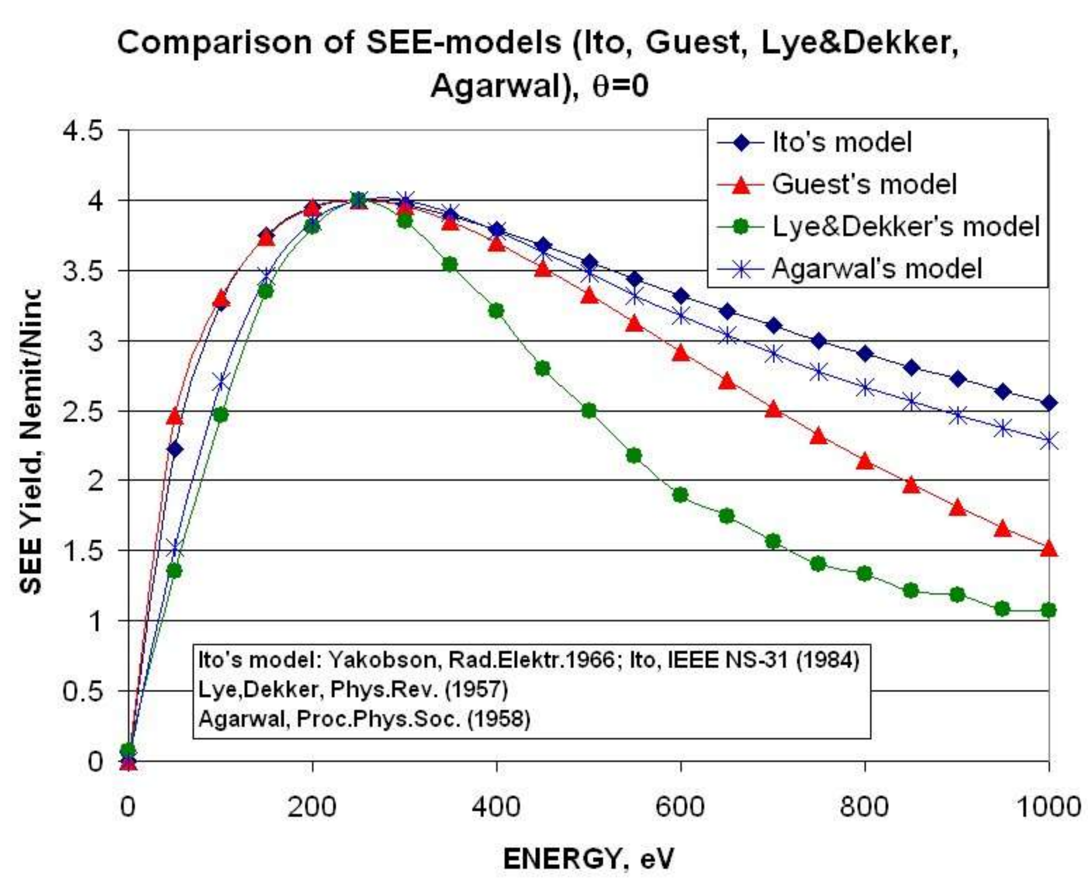
5. Rodney-Vaugham's Model

$$\sigma = \sigma_{max}(ve^{1-v})^s, v = \frac{V - V_0}{V_{max} - V_0},$$

s=0.62 for $v<1$, and s=0.25 for $v>1$.

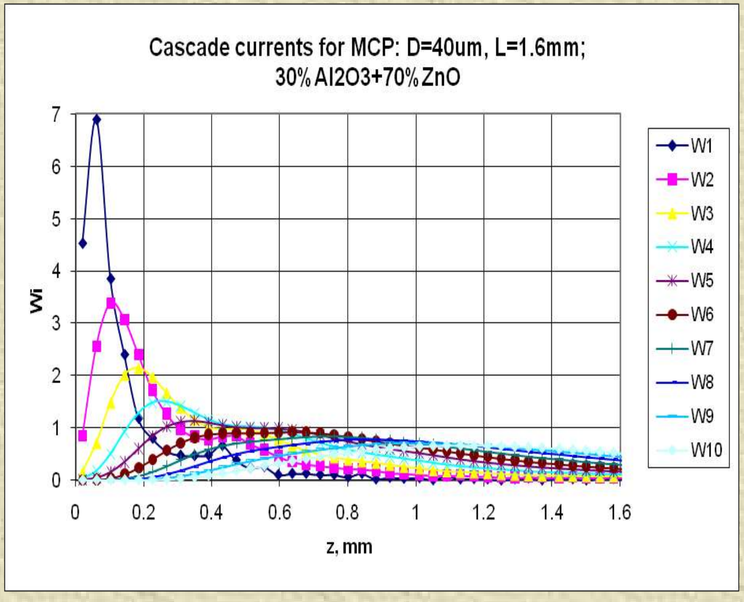
V_o is biggest value for SEE curve $\sigma(V_0)=1$

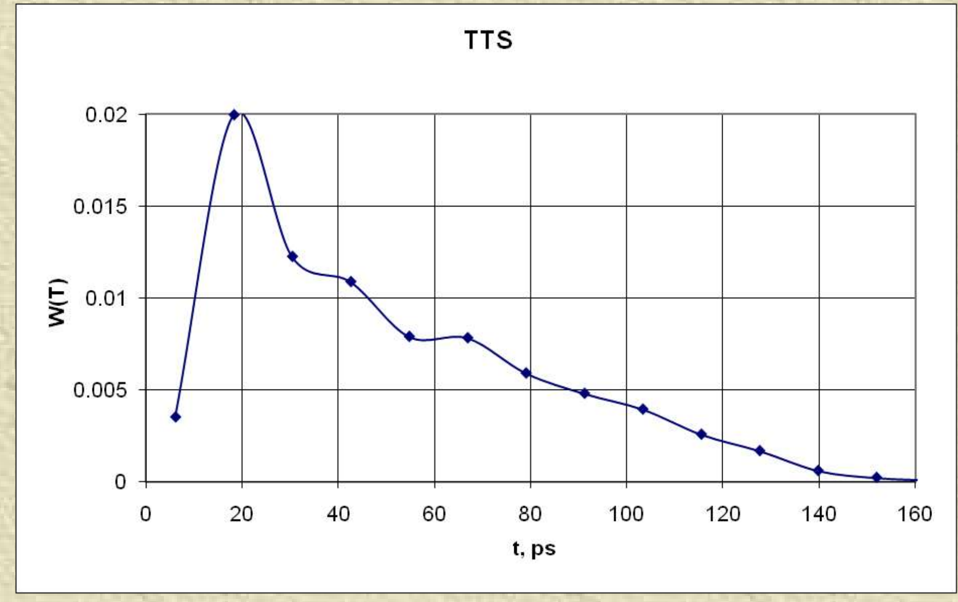
Comparison for different models (cont.)



Courtesy of Z.Insepov

The results of INCOM MCP simulation





MCP parameters: D=40um, L/D=40, L=1.6mm, Voltage U=1kV.

Time resolution for the MCP Rt=33.1 ps. Actual resolution with PC-MCP and MCP-anode gaps will be bigger. Different emission models give difference in the gain computation about 30-40%.

Nearest future plans

- Extend the field representation in the pores to take into account the tilted electric field in chevron-pair plates which can substantially increase the gain;
- Incorporate the saturation model to our numerical codes;
- Provide systematic comparison for emission models with experimental data.

Resume

- Numerical optimization of funnel MCP parameters substantially increased the capturing of photo-electrons and total gain factor;
- Simulation of conventional MCP with secondary emitter of composite material detects a big difference in the gain factor for different analytical models;
- Existing numerical codes should be improved to satisfy the main requirements in simulation of modern MCP photo-detectors.