Simulations of multi-layer GEM systems from single to quadruple GEMs

Aera JUNG, **Yong BAN, Dayong WANG, Yue WANG, Licheng ZHANG**
- *school of physics, Peking University (PKU), China*

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Introduction

- **Major advantage:** With a multi-GEM layer structure, a very high effective gain (up to 10^6 with some gases) can be attained with each GEM layer working at an individually much lower gain thus avoiding discharge problems.

- **Simulation:** Comparative simulation results for single, double and triple GEMs, along with some preliminary triple and quadruple layer results

Simulation steps (characteristics of the detector)

- **Commercial software ANSYS + free software GARFIELD++**

Step 1 — Building field map

Step 2 — ANSYS

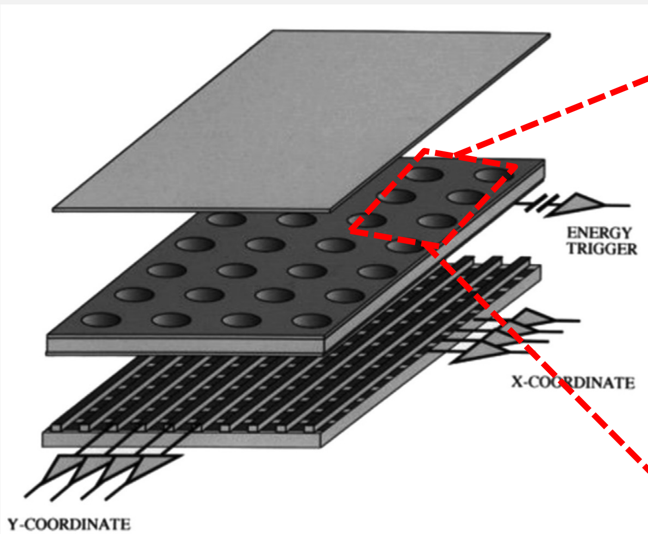
- design the detector geometry
- set boundary conditions
- optimize the mesh of the structure for the electric potential calculation of each finite element
- ANSYS https://www.ansys.com/

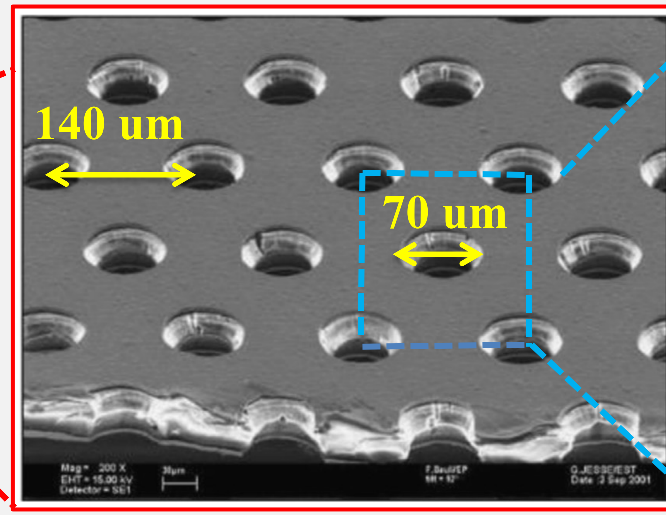
Step 3 — Garfield++

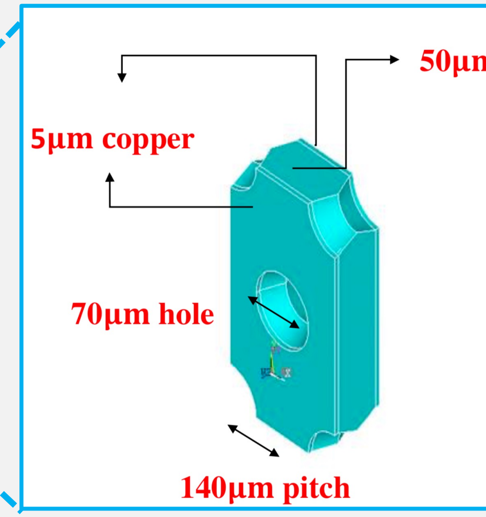
- Garfield++ initialization
- primary ionization
- charge transportation
- signal readout
- Garfield++ https://garfieldpp.web.cern.ch/garfieldpp/

01 Simulation model – GEM foil geometry and gas

- **Schematics of single GEM detector**
- **Microscope view of GEM foil**
- **Standard hexagonal GEM foil**





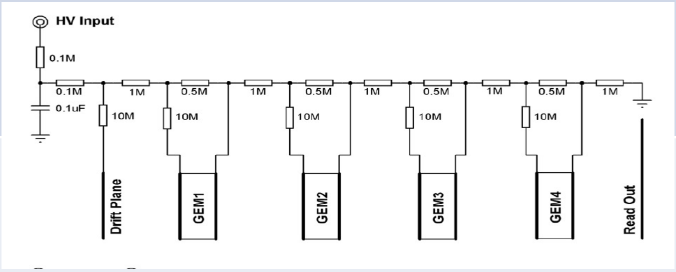


Fabio Sauli, The gas electron multiplier (GEM): Operating principlesand applications, Nuclear Instruments and Methods in Physics Research A 805 (2016) 2-24

https://garfieldpp.web.cern.ch/garfieldpp/examples/triplegem/

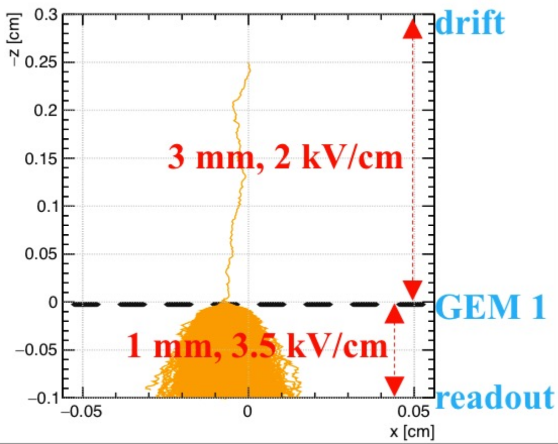
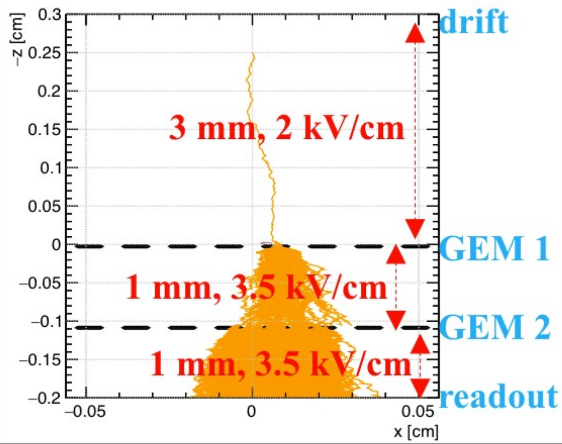
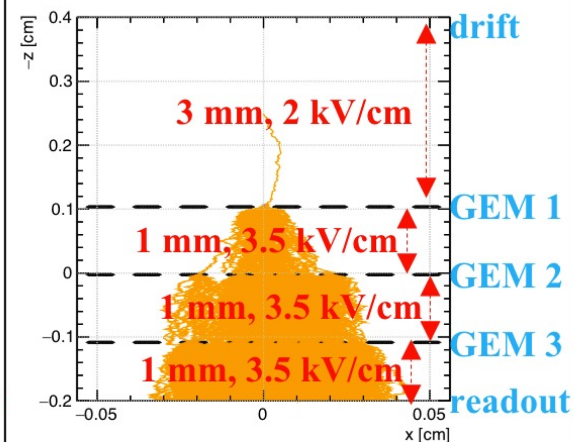
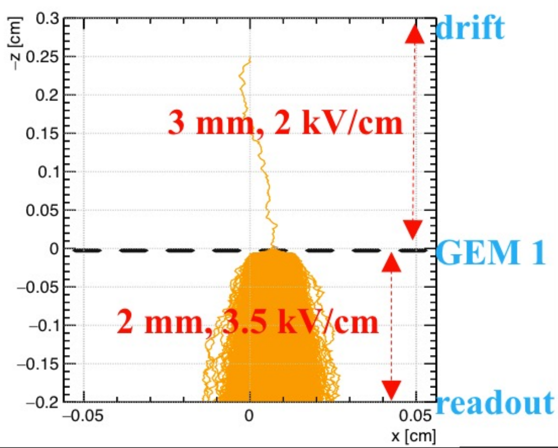
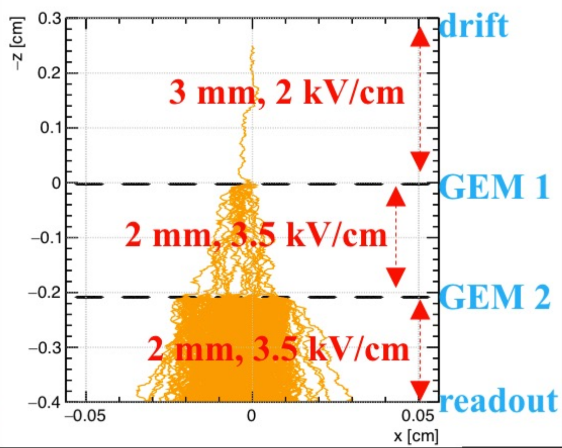
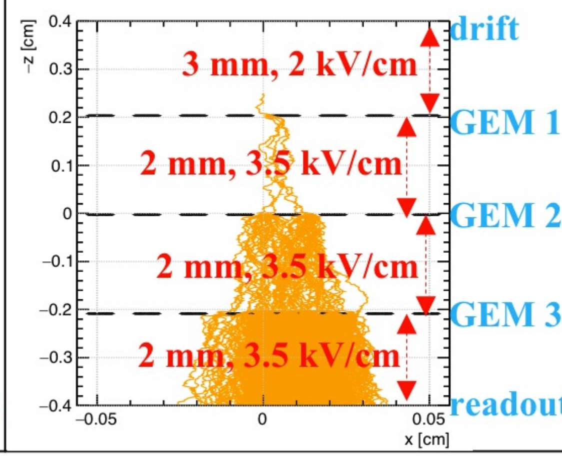
- The foil (e.g. 50 um thick kapton) is metalized on both sides (e.g. 5 um copper) and has a pattern of holes (e.g. 70 um with a 140 um pitch).
- Gas: 70% Ar + 30% CO_2

- Summary of detector configuration in the simulation

Source		drift distance [mm]	transfer distance [mm]	induction distance [mm]	HV divider		
					drift field [kV/cm]	transfer field [kV/cm]	induction field [kV/cm]
S.Bachmann's paper *[S. Bachmann, et al., Nucl. Instrum. Meth. A 479, 294-308 (2002)]*	single	3	1 / 2	1 / 2	2	3.5	3.5
	double	3	1 / 2	1 / 2	2	3.5	3.5
	triple	3	1 / 2	1 / 2	2	3.5	3.5
Rajendra Nath Patra's paper *[Rajendra Nath Patra, et al., Nucl. Instrum. Meth. A 906, 37-42 (2018)]*	triple	4.8	2	2			
	quadruple	4.8	2	2			

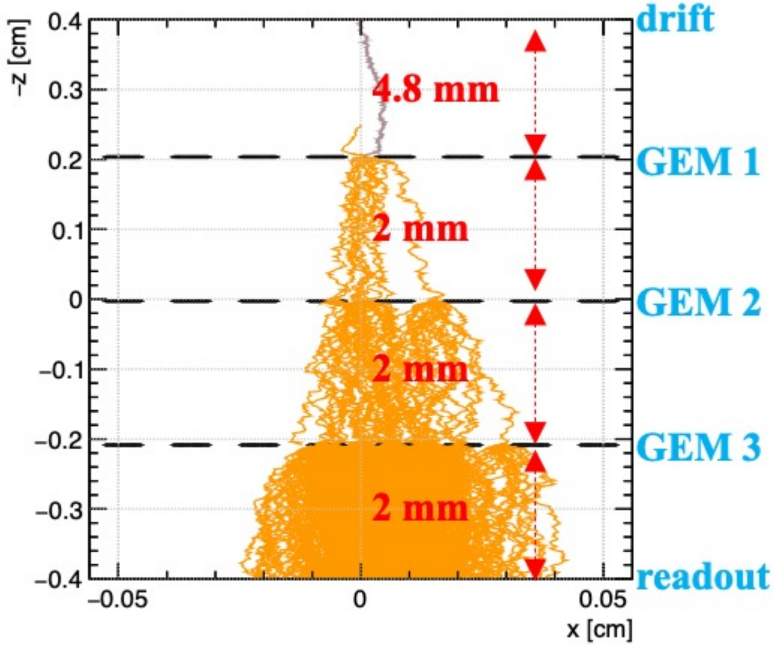
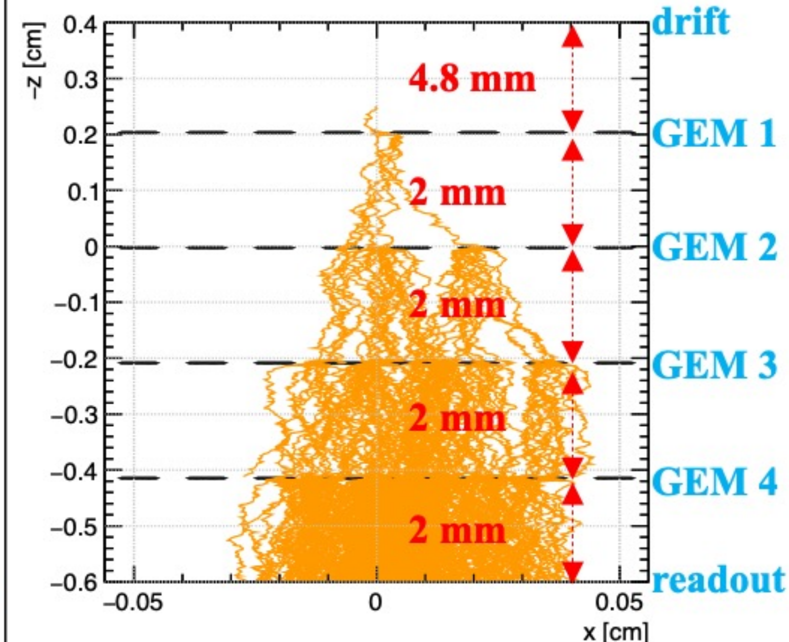
01 **Simulation model**

- Electron's drift lines produced by one initial electron in a **single, double and triple GEMs** using Garfield++
- Detector model: S. Bachmann's paper *[S. Bachmann, et al., Nucl. Instrum. Meth. A 479, 294-308 (2002)]*

	single	double	triple
3 mm (drift) / 1 mm (transfer, induction)			
3 mm (drift) / 2 mm (transfer, induction)			

Simulation model

- Electron's drift lines produced by one initial electron in a **triple and quadruple GEMs** using Garfield++
- Detector model: Rajendra Nath Patra’s paper *[Rajendra Nath Patra, et al., Nucl. Instrum. Meth. A 906, 37-42 (2018)]*

<table>
<tr><td></td><td>triple</td><td>quadruple</td></tr>
<tr><td>4.8 mm
(drift)
/
2 mm
(transfer,
induction)</td><td>
</td><td>
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- Introduction (including simulation steps, geometry of GEM foil and detector configuration)
- Simulation results of single, double and triple GEMs
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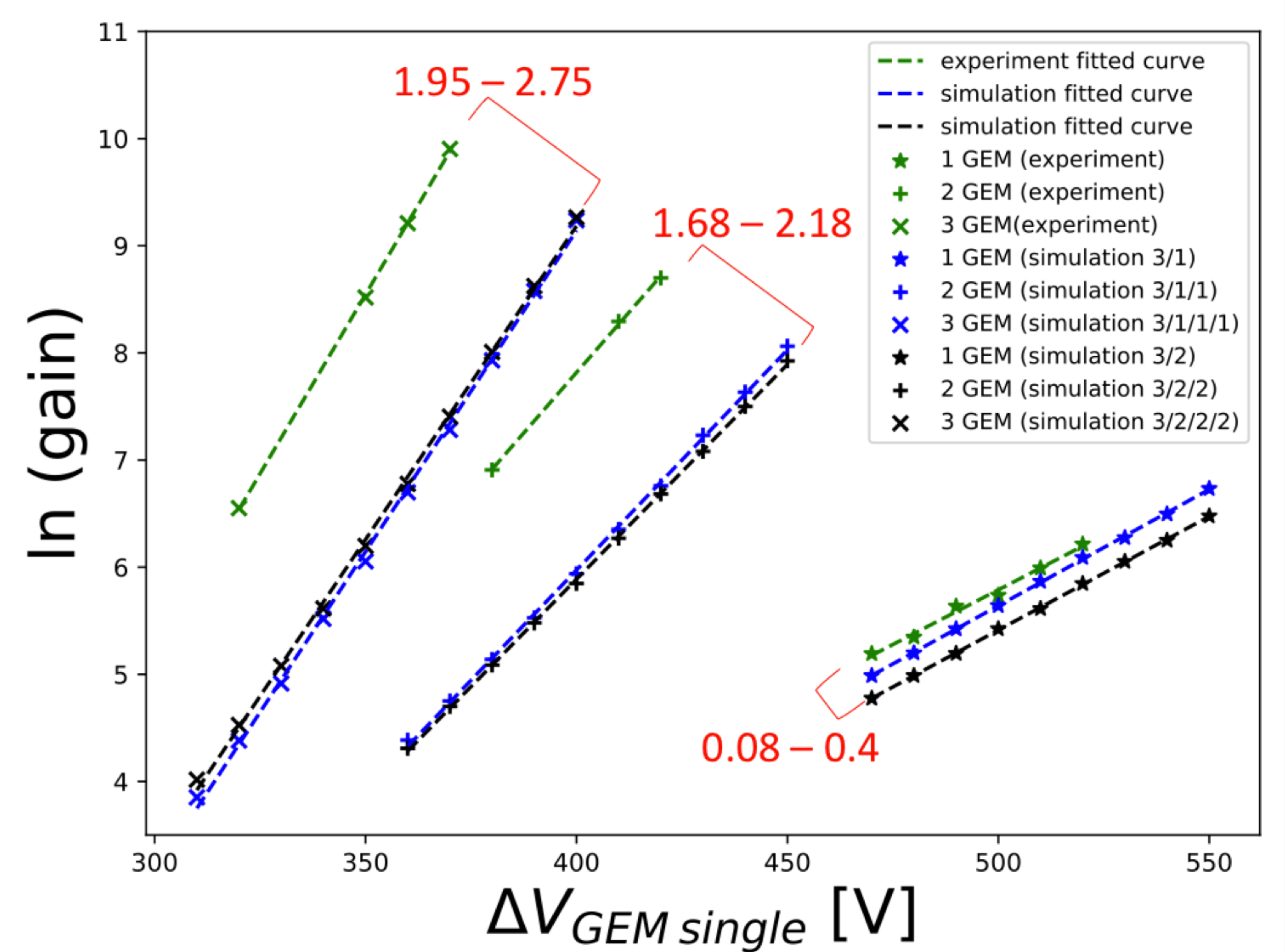
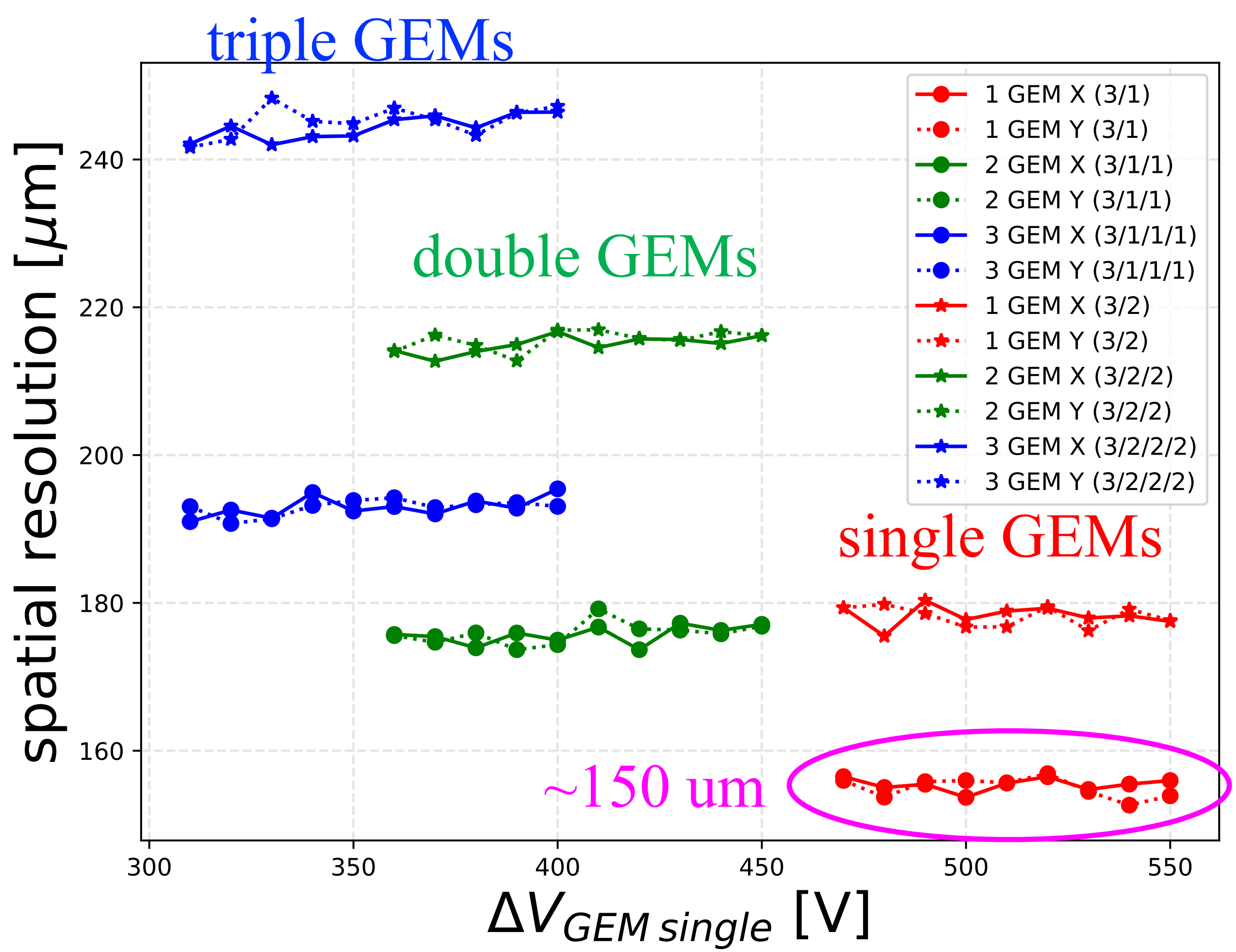
- **Gain:** given by the number of electrons created by each primary electron that reaches the anode



The experimental data (green) originally from Bachmann's paper *[S. Bachmann, et al., Nucl. Instrum. Meth. A 479, 294-308 (2002)]*

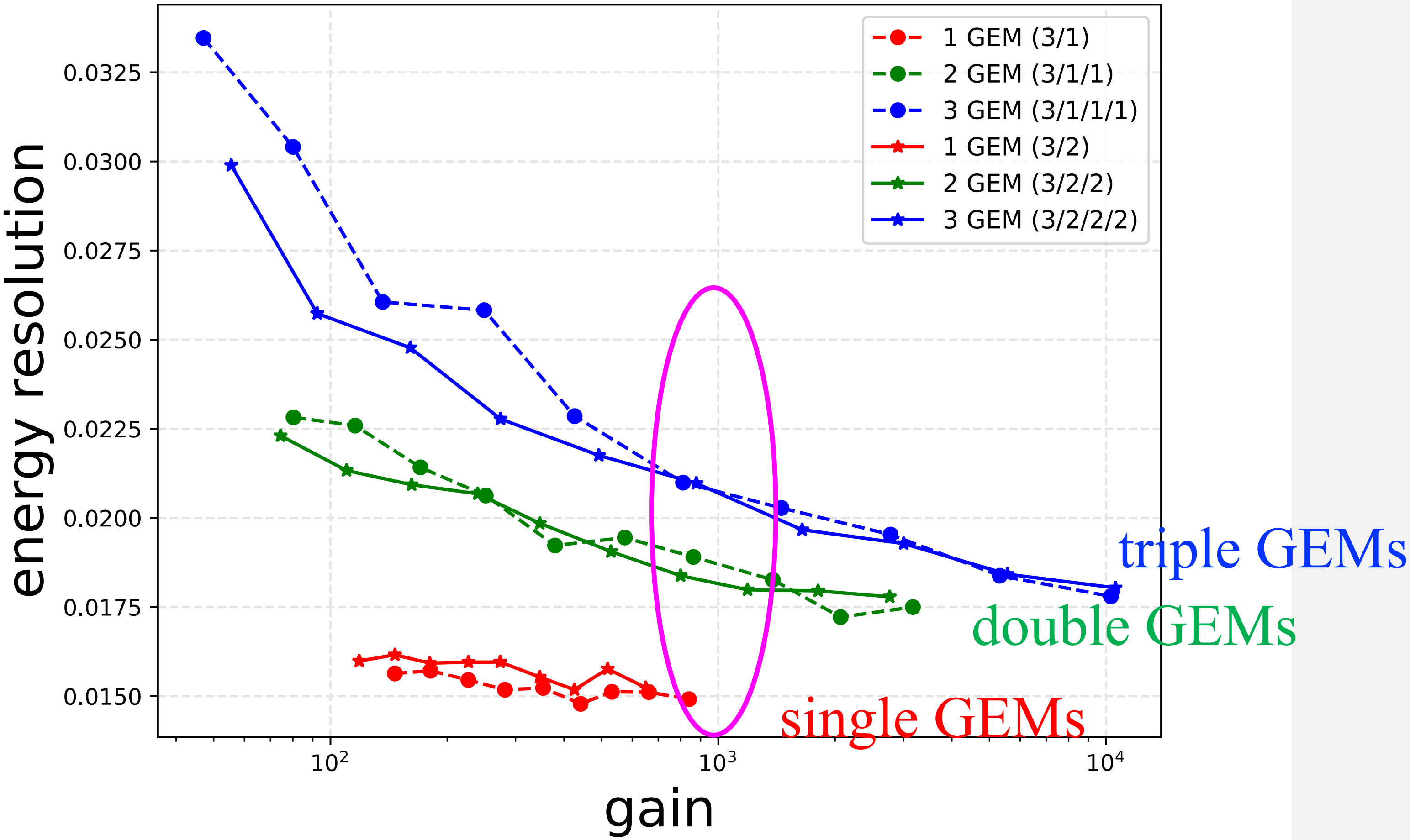
- **Spatial resolution:** key parameters for tracking systems and extracted from the **<u>width of the residual distribution reached on the anode/readout plate</u>**



- distance from the first GEM to the readout plate increases by about **15 um/mm**

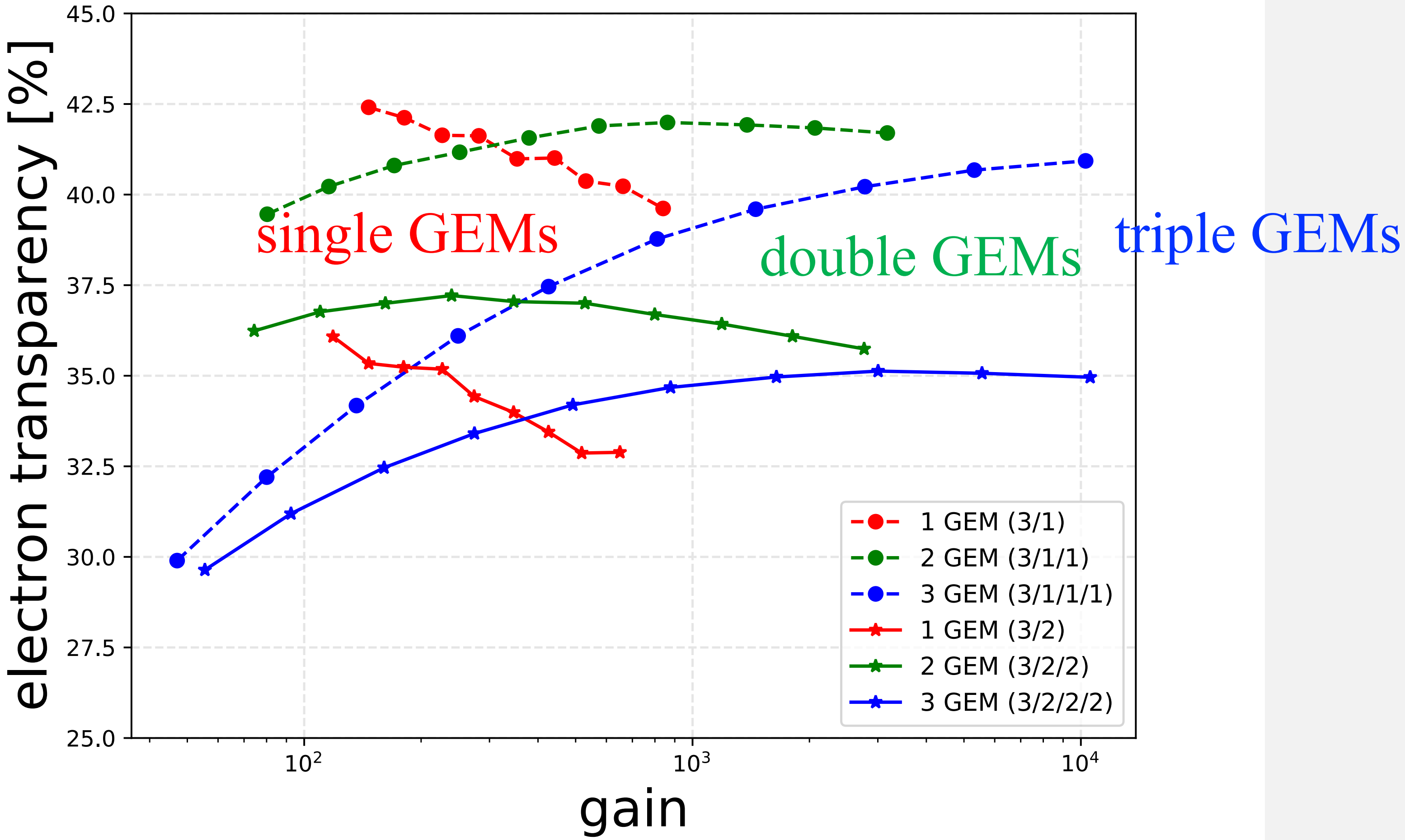
- i.e. triple GEM (3/2/2/2) has a spatial resolution of ~ 240 um (=150 + 15 x 6)

- **Energy resolution:** central for GEM detectors working in proportional mode and other devices aiming for a measurement of the deposited energy



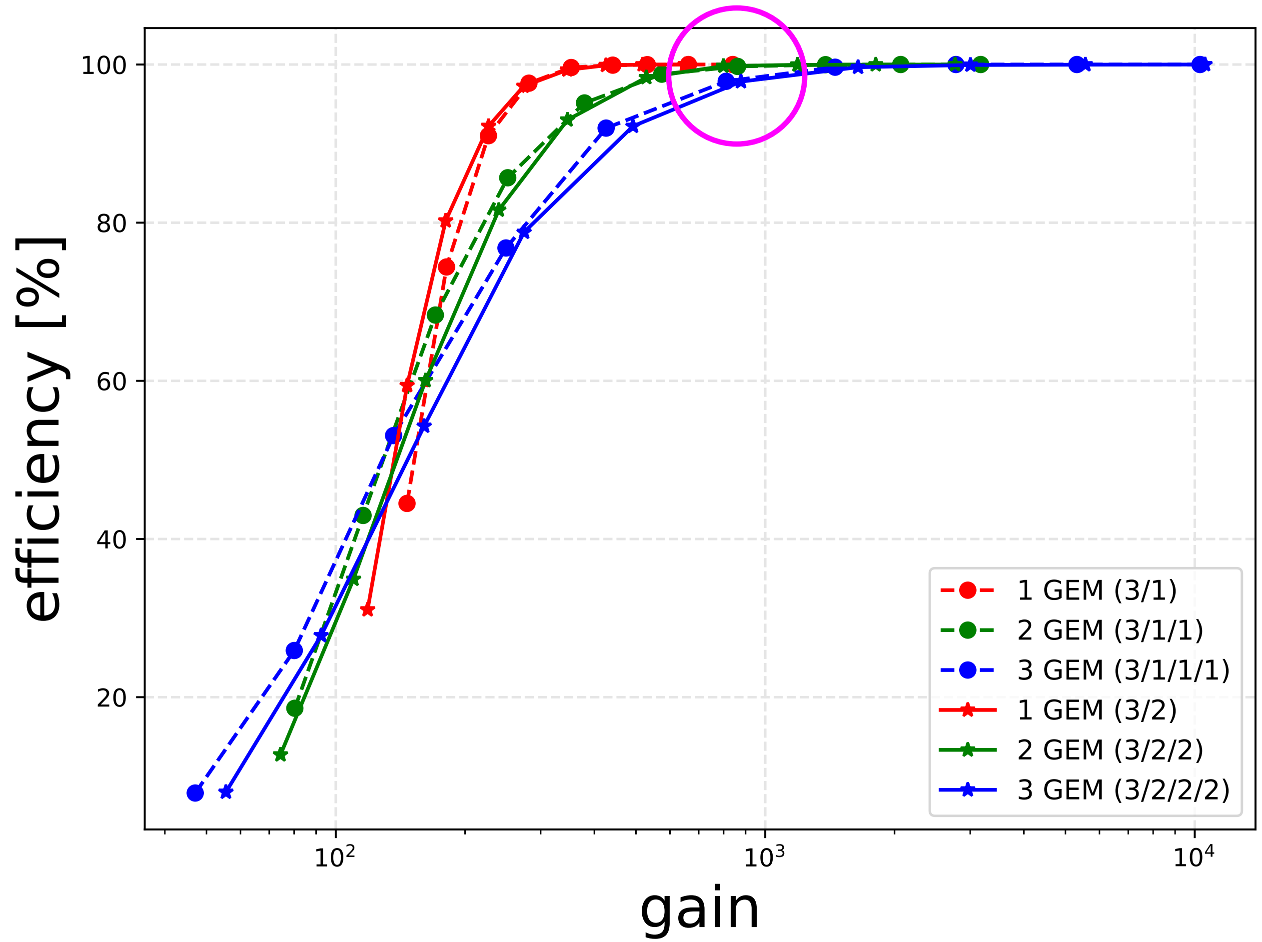
01 **Simulation results**

- **Electron transparency:** the ratio of secondary electron arrived at the readout and all of secondary particles (especially electron)



Simulation results

- **Efficiency:** the probability of a trespassing particle to yield the expected signal and, if applicable, to overcome a threshold value needed have this signal recognized



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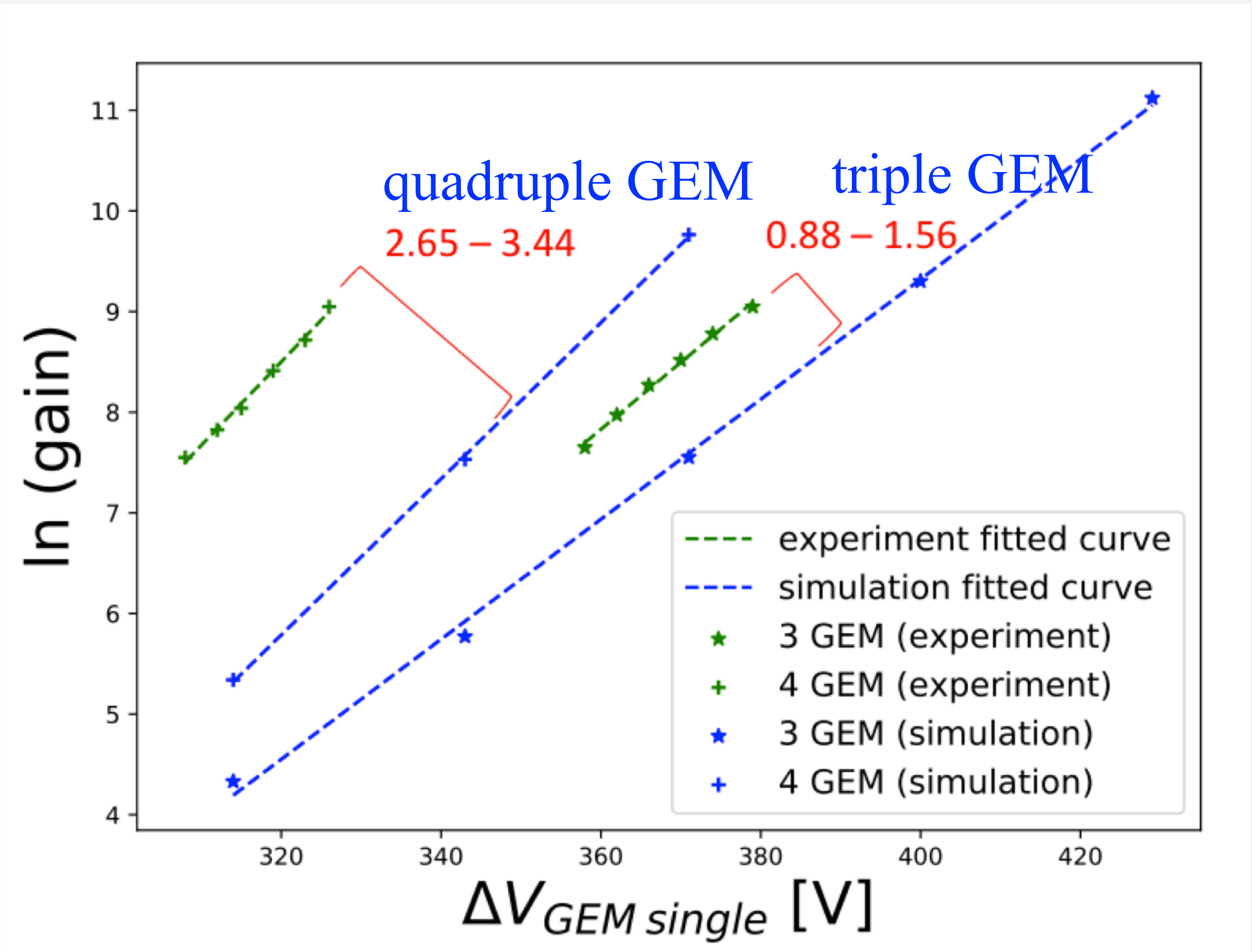

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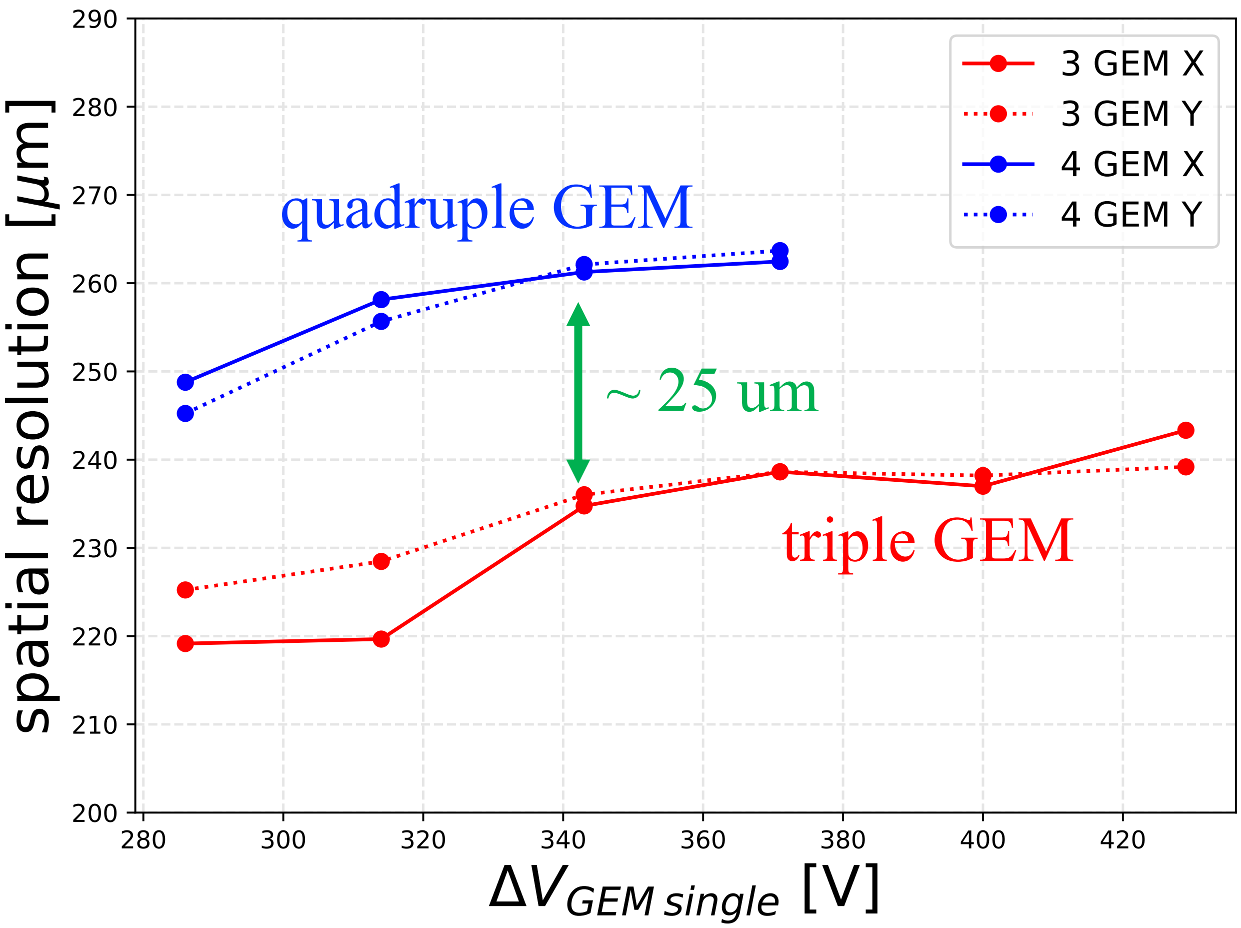
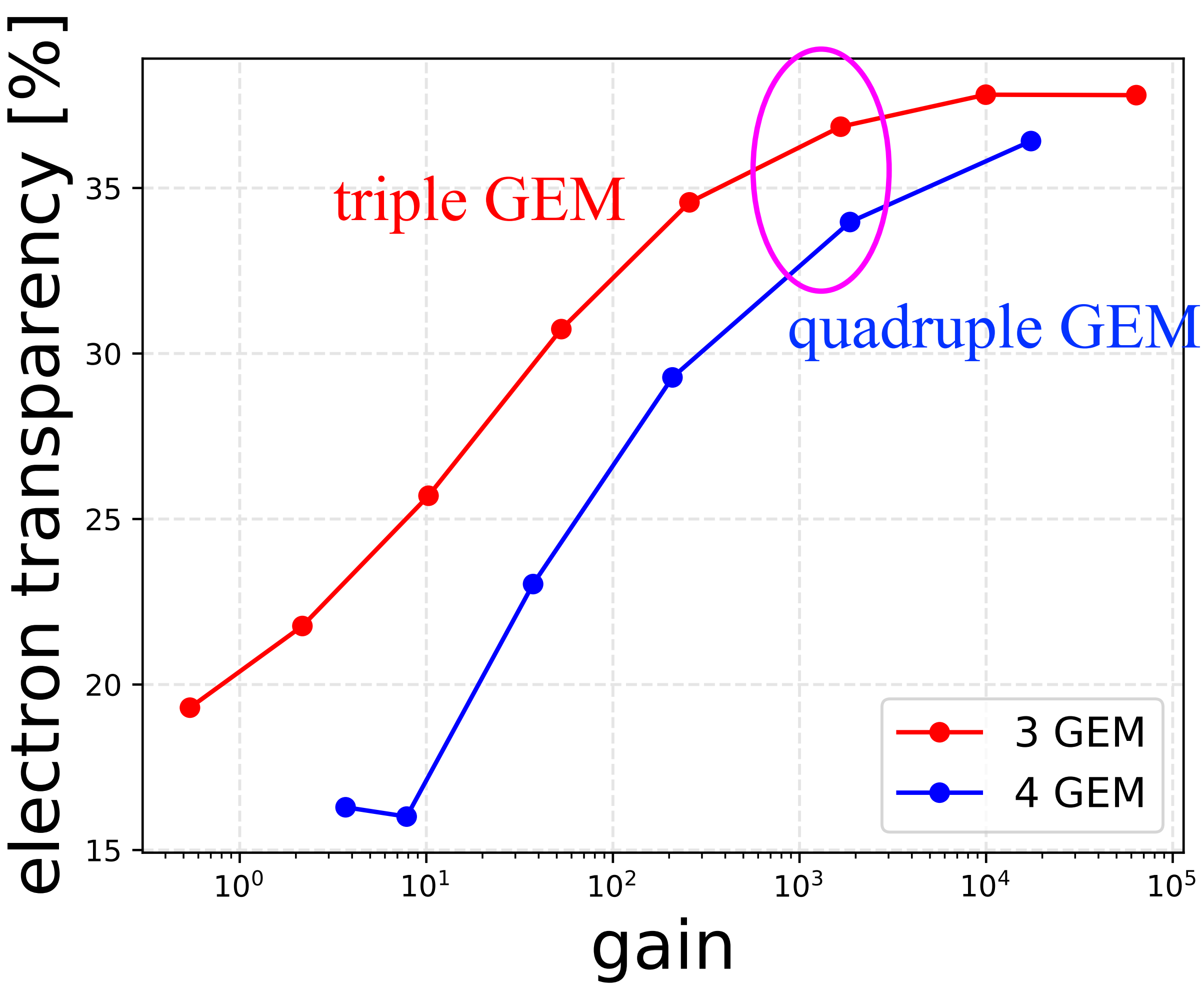


- Difference between triple and quadruple GEMs is about **25 um/mm**

- **Electron transparency:** the ratio of secondary electron arrived at the readout and all of secondary particles (especially electron)



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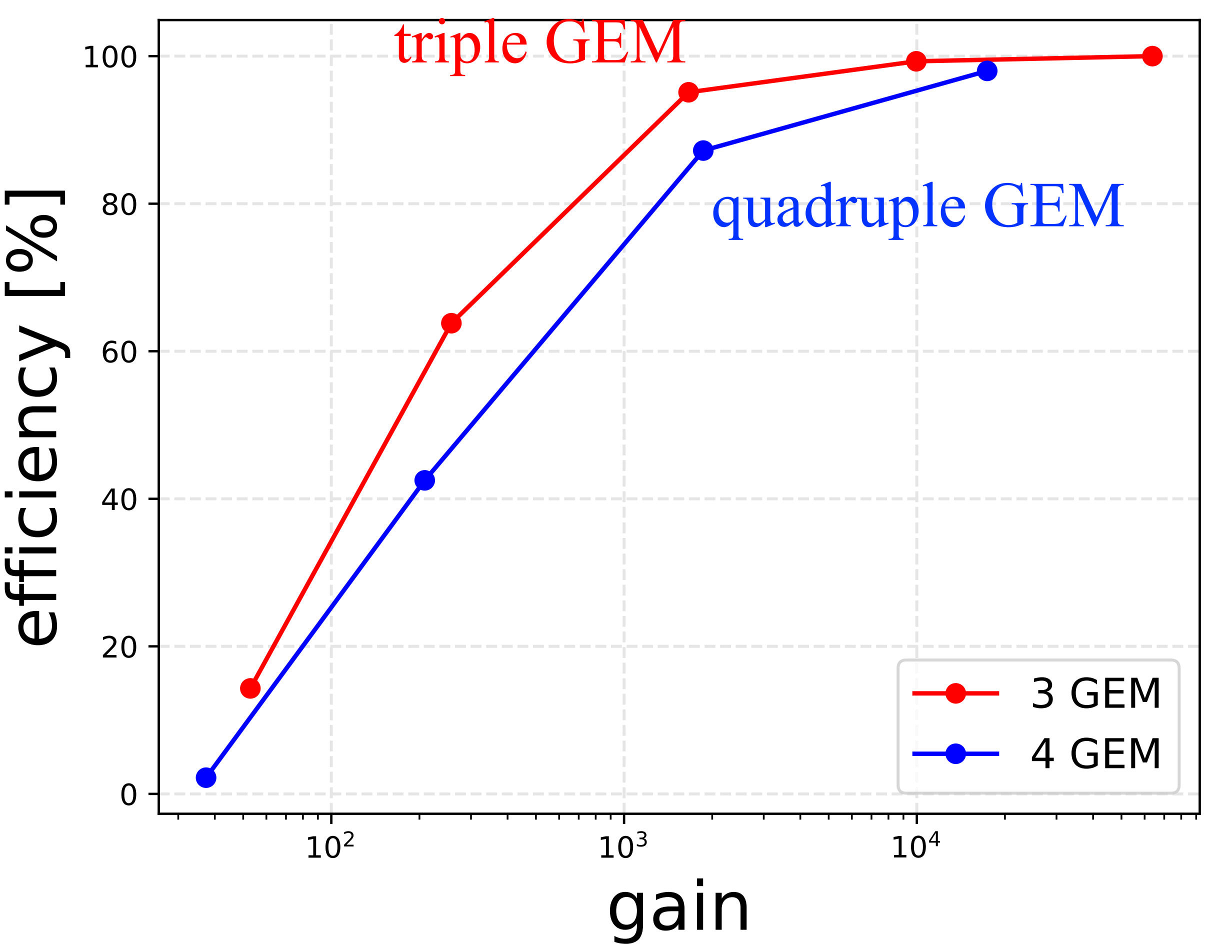

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Summary

- **Simulation study with Garfield++ and ANSYS**
- **Single, double and triple GEMs**
  - As the number of GEM layers is increased, the gain difference between experiment and simulation increases
  - Energy resolution deteriorates with additional GEM layers
  - Spatial resolution becomes poorer as the distance between the first GEM and the anode increases
  - While there are some difference in electron transparency, single, double, and triple GEMs are pretty much the same
  - The smaller GEM layer is faster, arriving soonest at 100% efficacy

- **Triple and quadruple GEM**
  - Gain, spatial resolution, electron transparency and efficiency are studied and results are similar with single, double and triple GEMs
  - To conduct simulations in various delta GEM V and increase the number of events and study the energy resolution and so on and compare these with triple and quadruple detectors