Detector for NMX instrument

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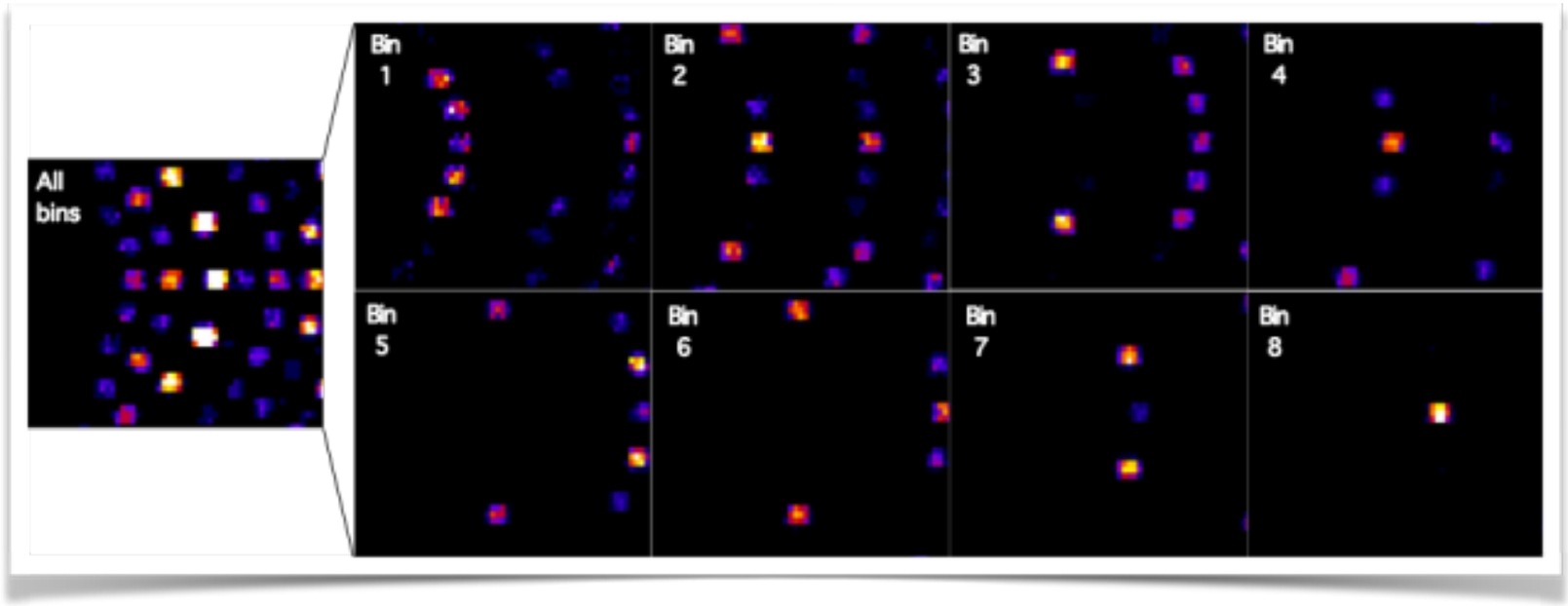
IKON8 - Milton Hill House and ISIS - February 4th, 2015

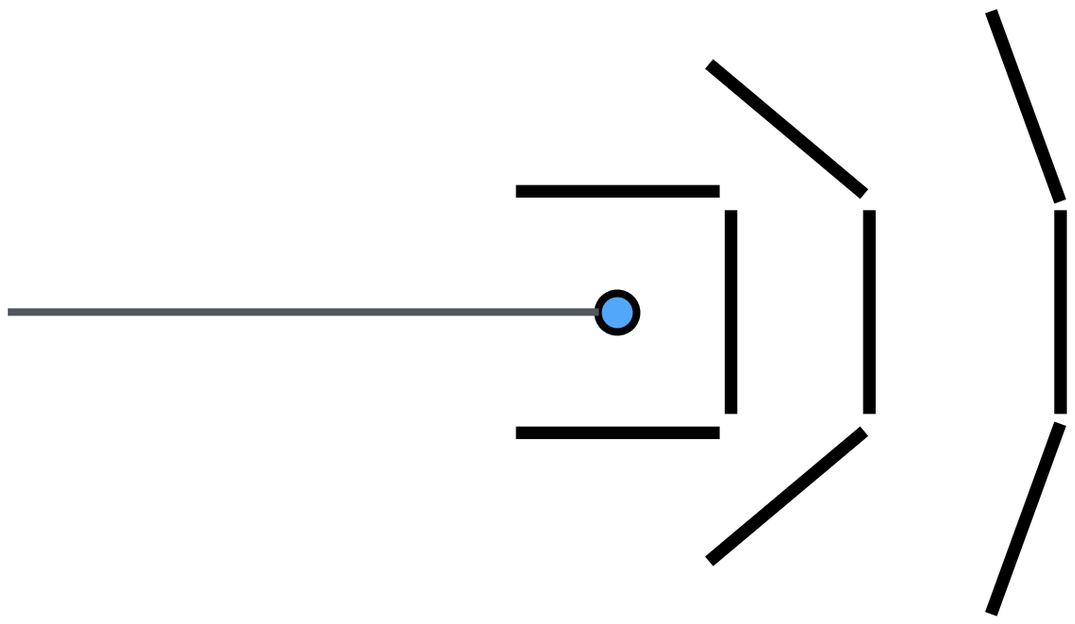
NMX



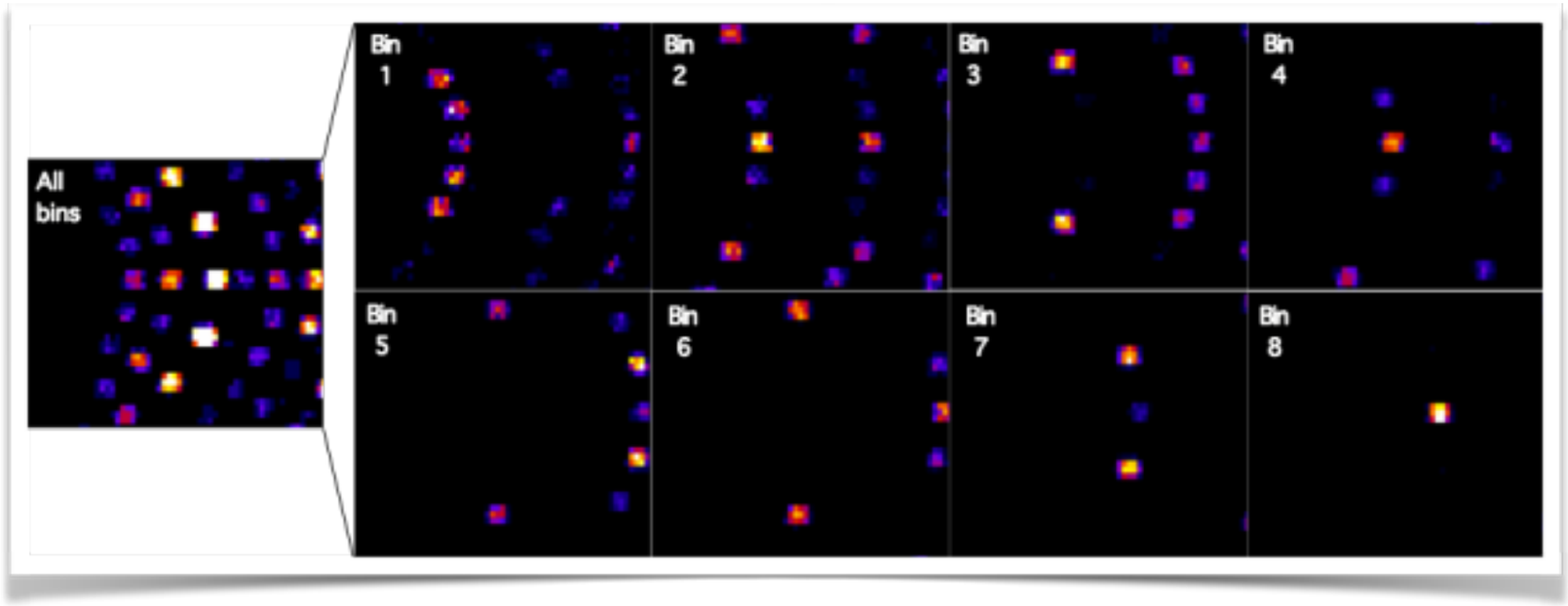
Time binned diffraction pattern (simulation) from a 5mm crystal of perdeuterated rubredoxin at 20cm from the detector (45º)

Detector requirements:

- 3x 60x60cm^2 movable
- 20-100cm operation distance
- time resolved
- 200µm X&Y spatial resolution
- <100kHz/mm^2 local flux
- >20% efficient
- γ rejection not critical



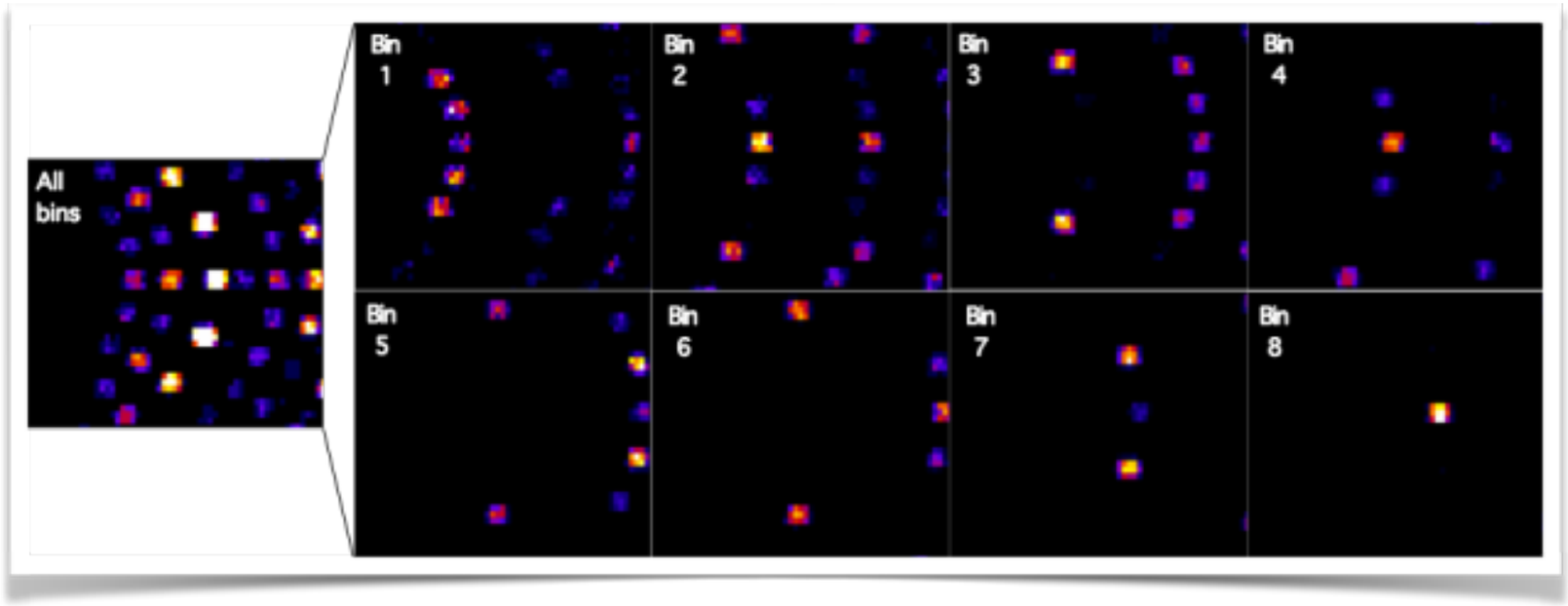
NMX



Time binned diffraction pattern (simulation) from a 5mm crystal of perdeuterated rubredoxin at 20cm from the detector (45º)

Detector requirements:	**That translates into:**
- 3x 60x60cm^2 movable	- engineering challenges
- 20-100cm operation distance	- perpendicular conversion layer
- time resolved	- ✓
- 200µm X&Y spatial resolution	- length of secondaries
- <100kHz/mm^2 local flux	- space charges
- >20% efficient	- single conversion layer?
- γ rejection not critical	- ✓

NMX



Time binned diffraction pattern (simulation) from a 5mm crystal of perdeuterated rubredoxin at 20cm from the detector (45º)

Gaseous Electron Multiplier (GEM) detectors
may be the solution
Challenging but on track

That translates into:
→ - engineering challenges
- perpendicular conversion layer
- ✓
→ - length of secondaries
→ - space charges
- single conversion layer?
- ✓

CERN

European Organisation for Nuclear Research:
- Provide prolific environment for pure scientific research
- Publish results and make them generally available

Scientific achievements:
- Neutral currents
- W and Z bosons
- Only three neutrinos
- Anti-Hydrogen
- Oscillation of $\nu_\mu \rightarrow \nu_\tau$
- CP violation
- Higgs boson

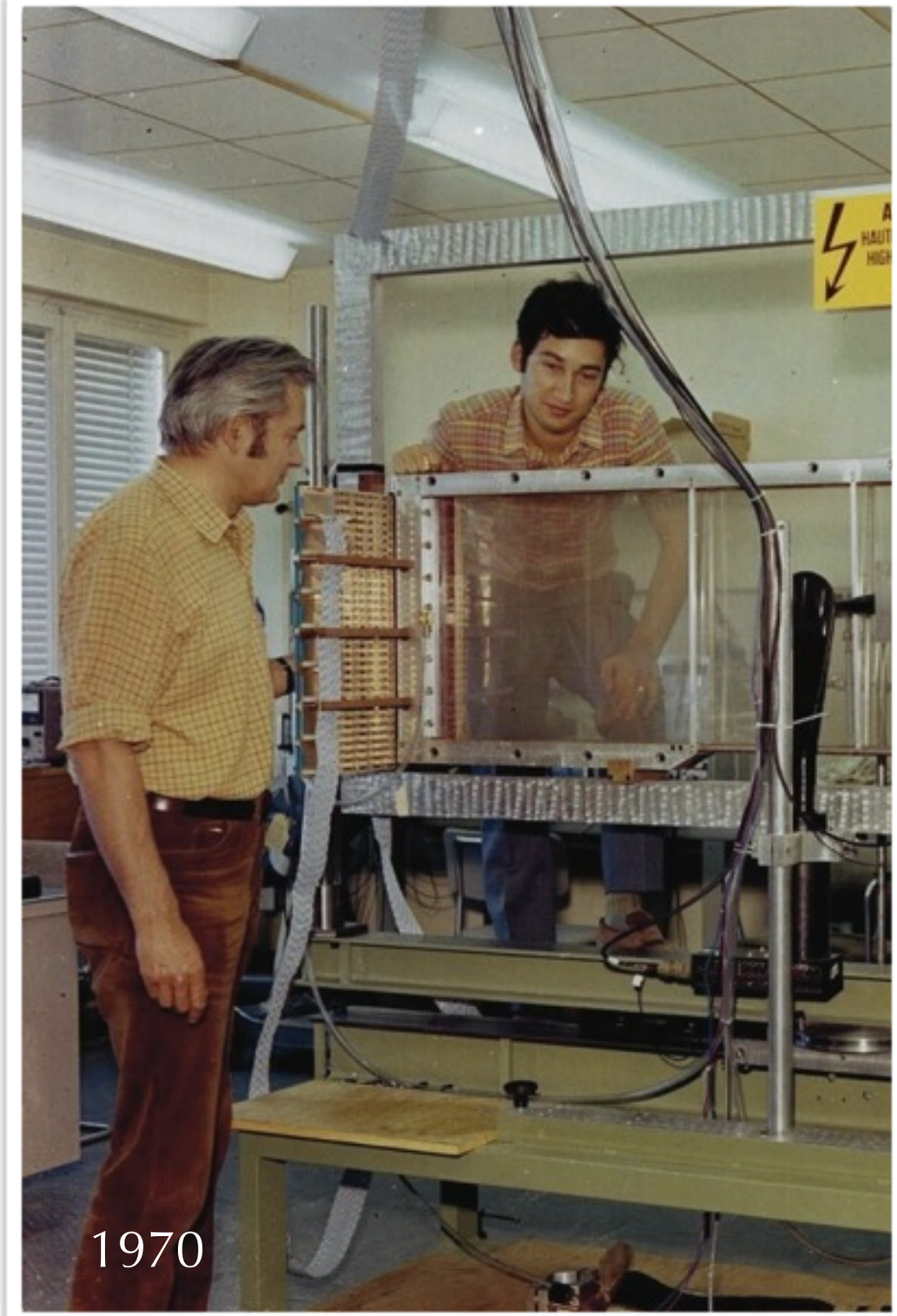
Big efforts for R&D on new technologies

CERN GDD

Gaseous Detector Development group has important legacies

Georges Charpak
Inventor of the MWPC for which he was awarded the Nobel Prize in 1992

Several other developments:
MicroPattern Gaseous Detectors

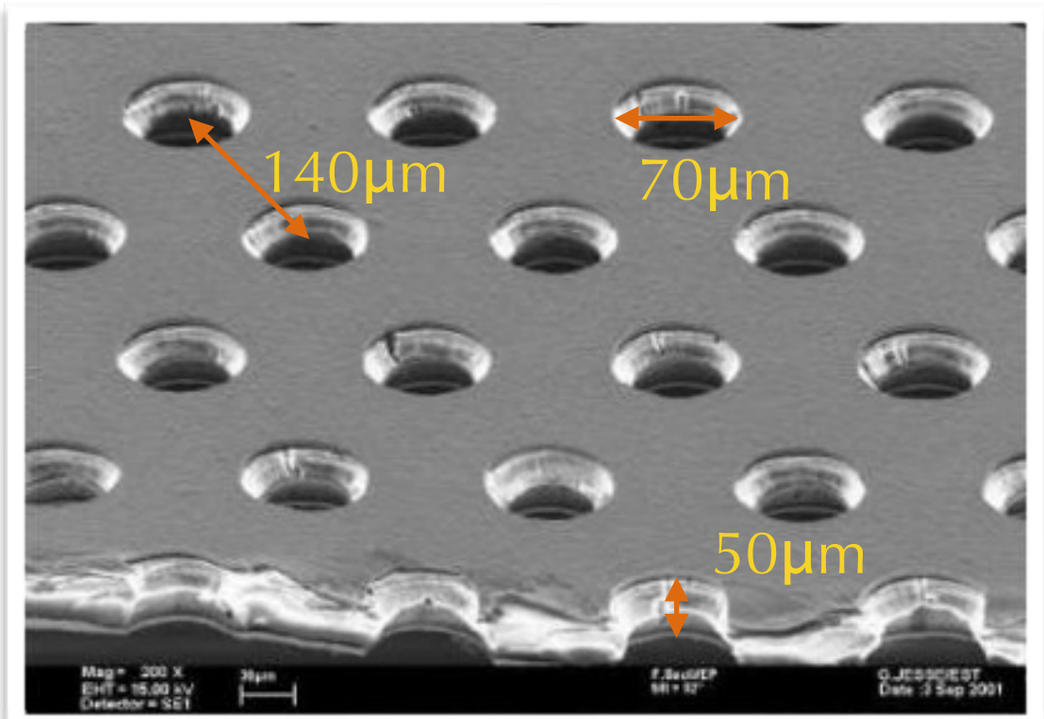

1970

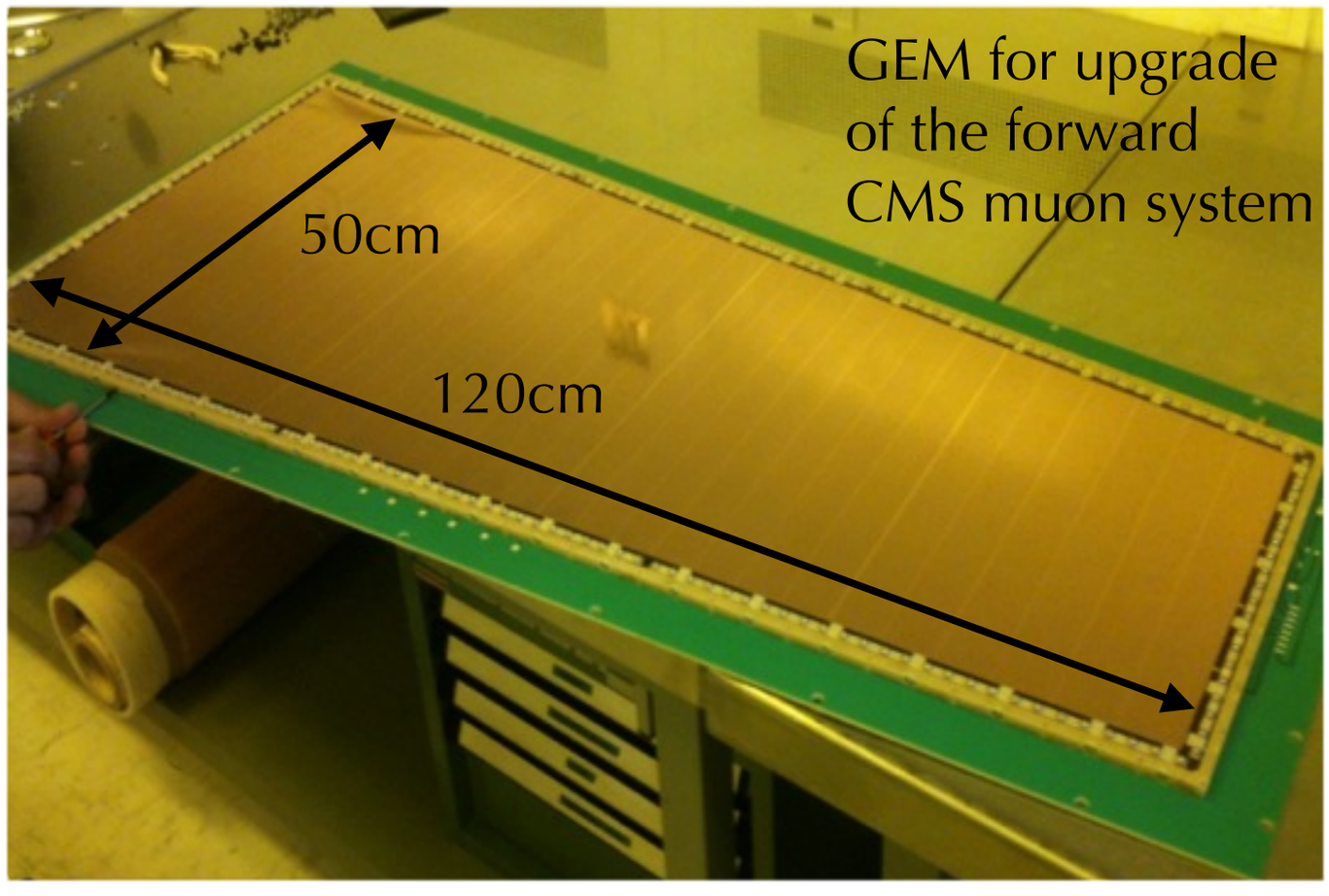
Fabio Sauli
Inventor of the GEM detector wide spread in the upgrade of the LHC experiments

GDD is leader of RD51 community the world largest collaboration for R&D on MPGDs

GEM

Signal amplification device (in gas):
Polyimide film metal cladded on both sides with holes chemically etched

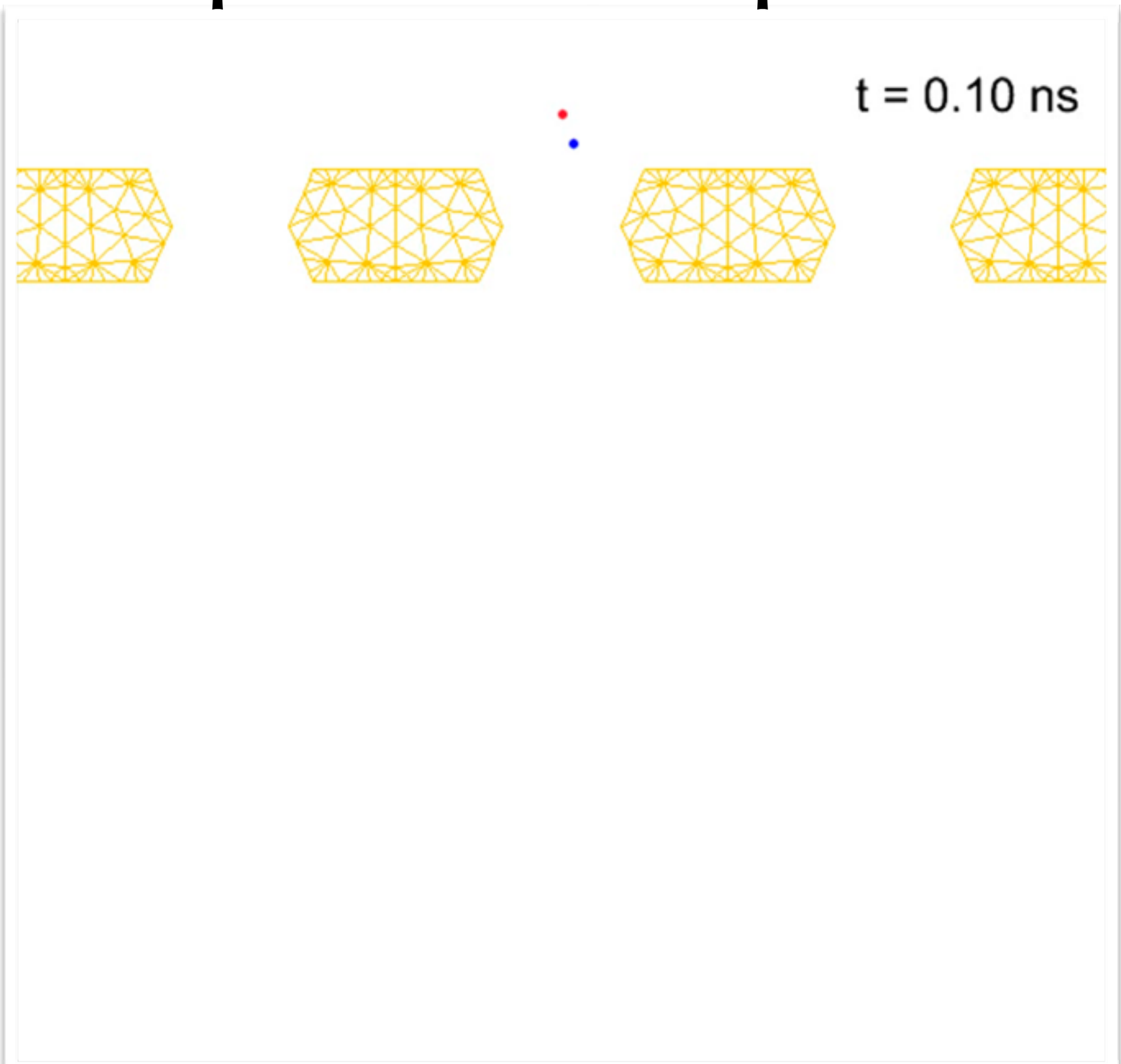




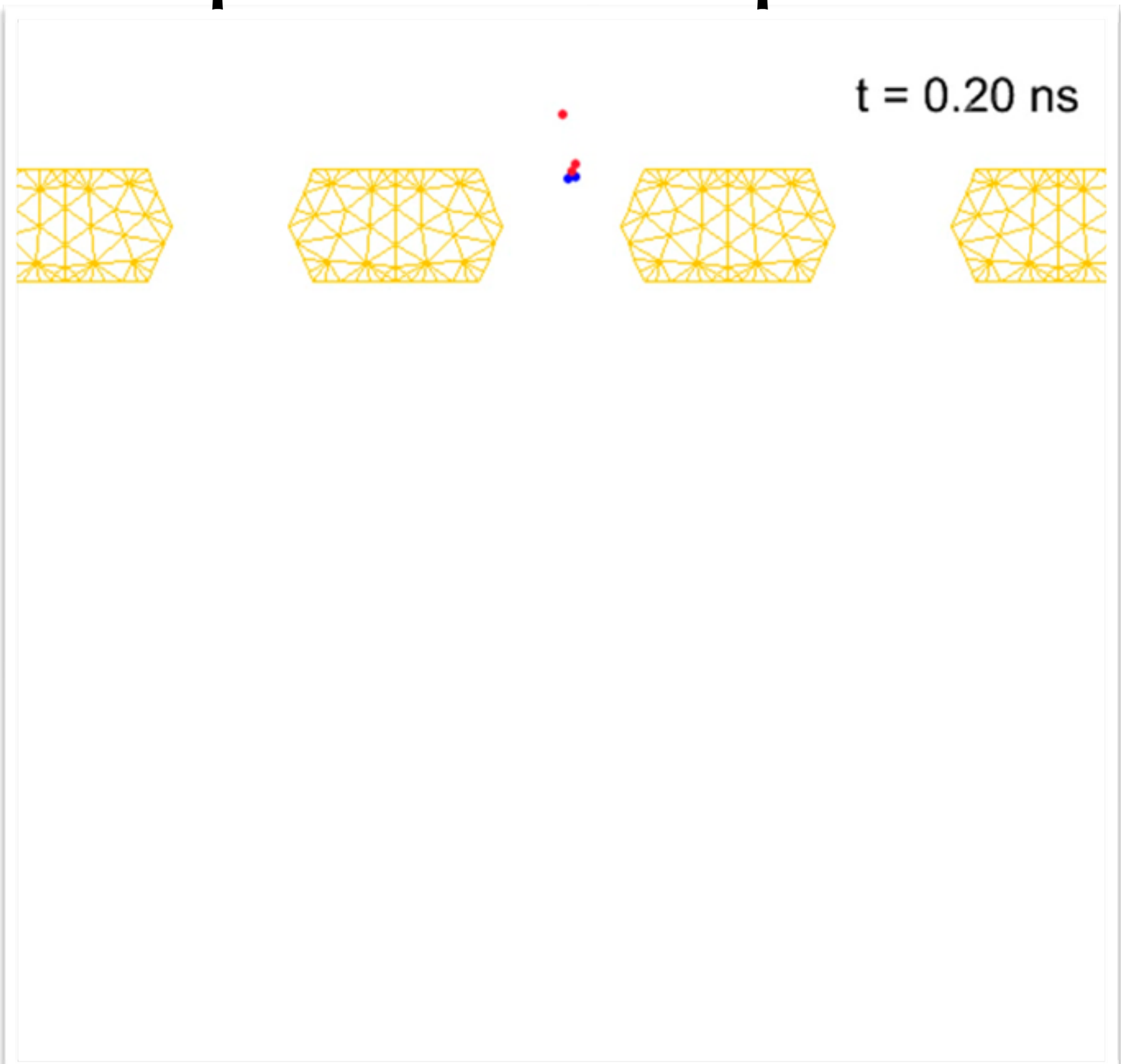
Widespread HEP detectors:
- High gain
- High flux capabilities
- Excellent spatial resolution
- Large size
- Not expensive

PCB techniques for the production developed at CERN
Industrialisation of the processes ongoing

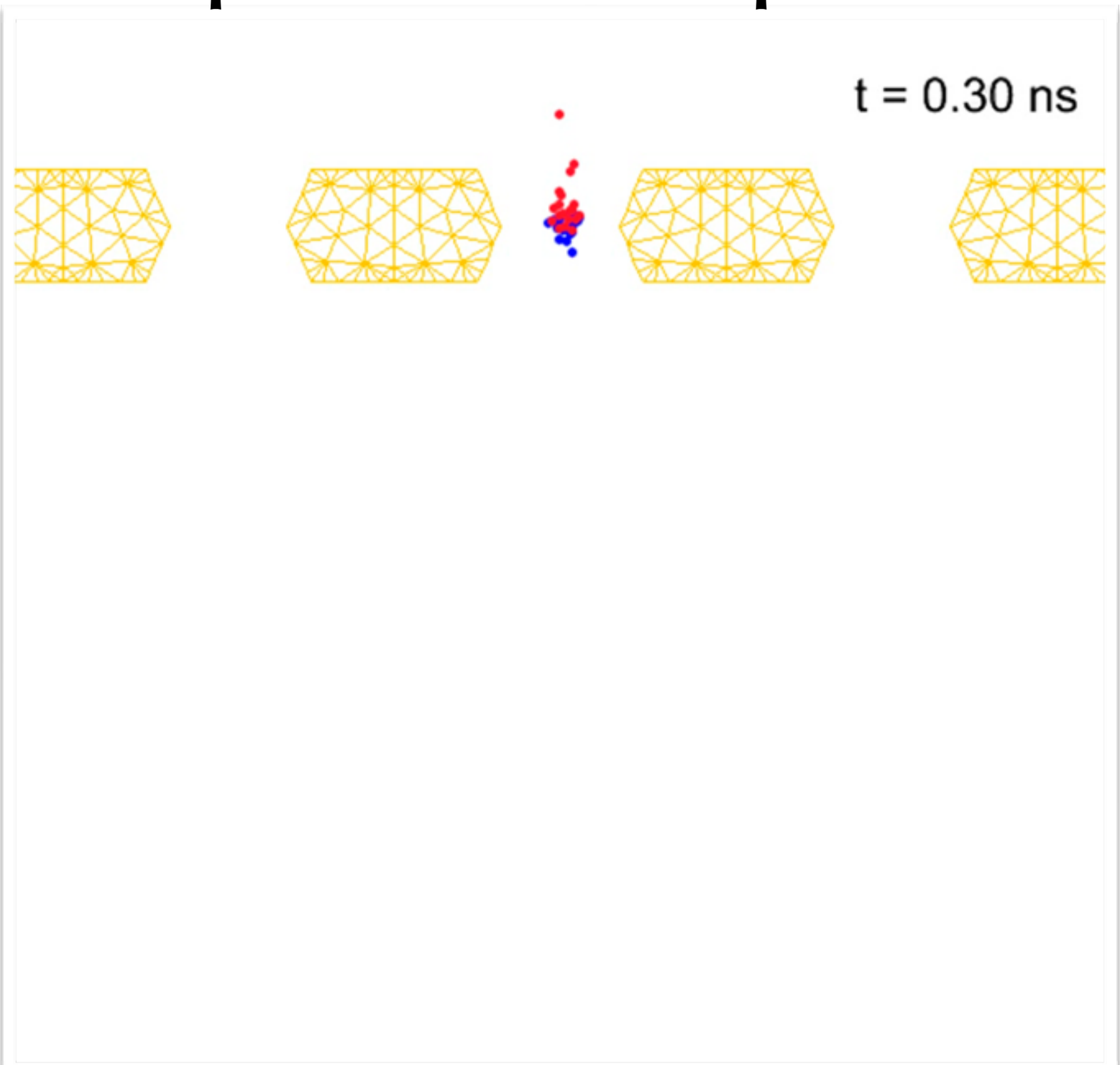
GEM amplification process



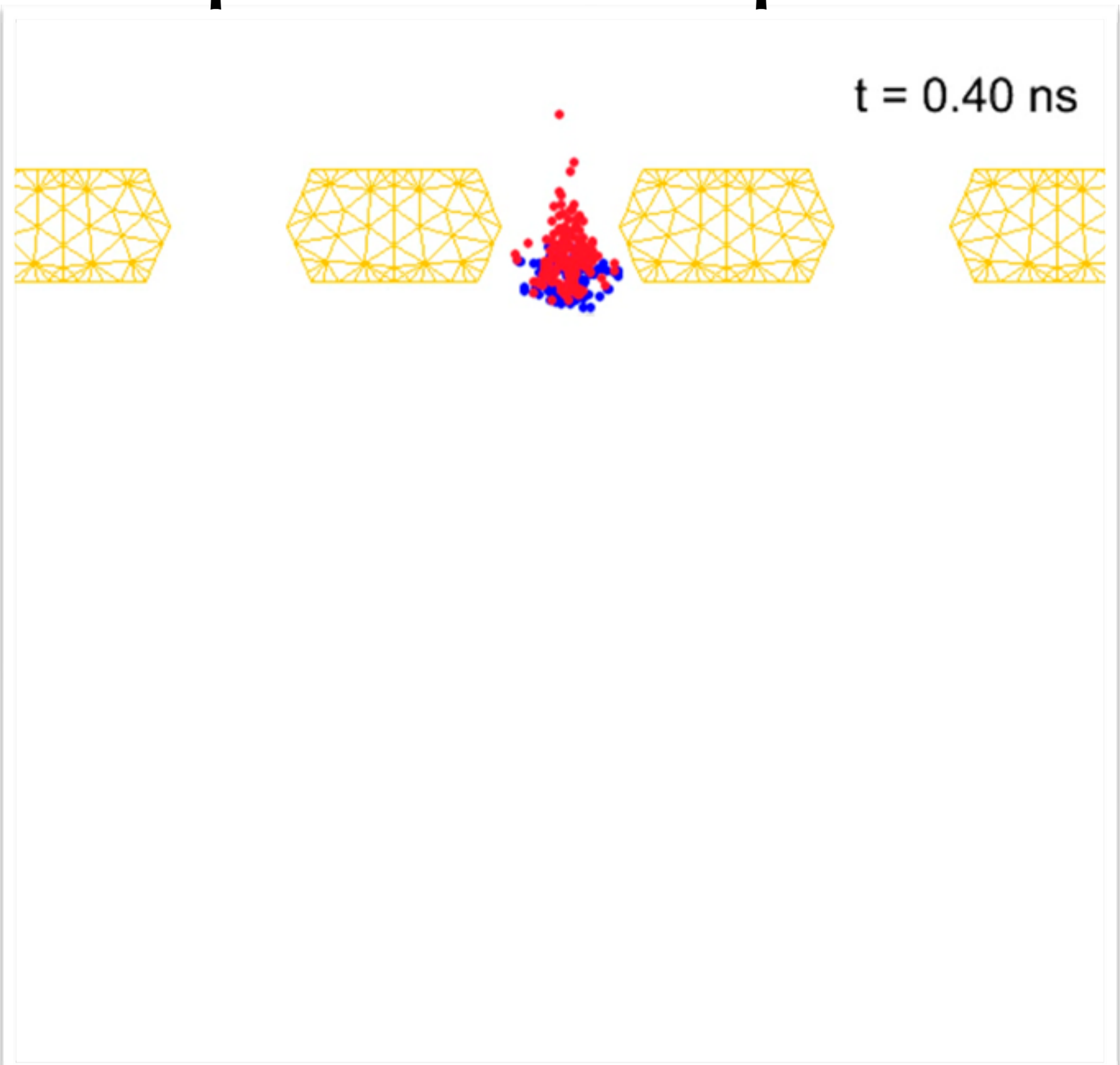
GEM amplification process



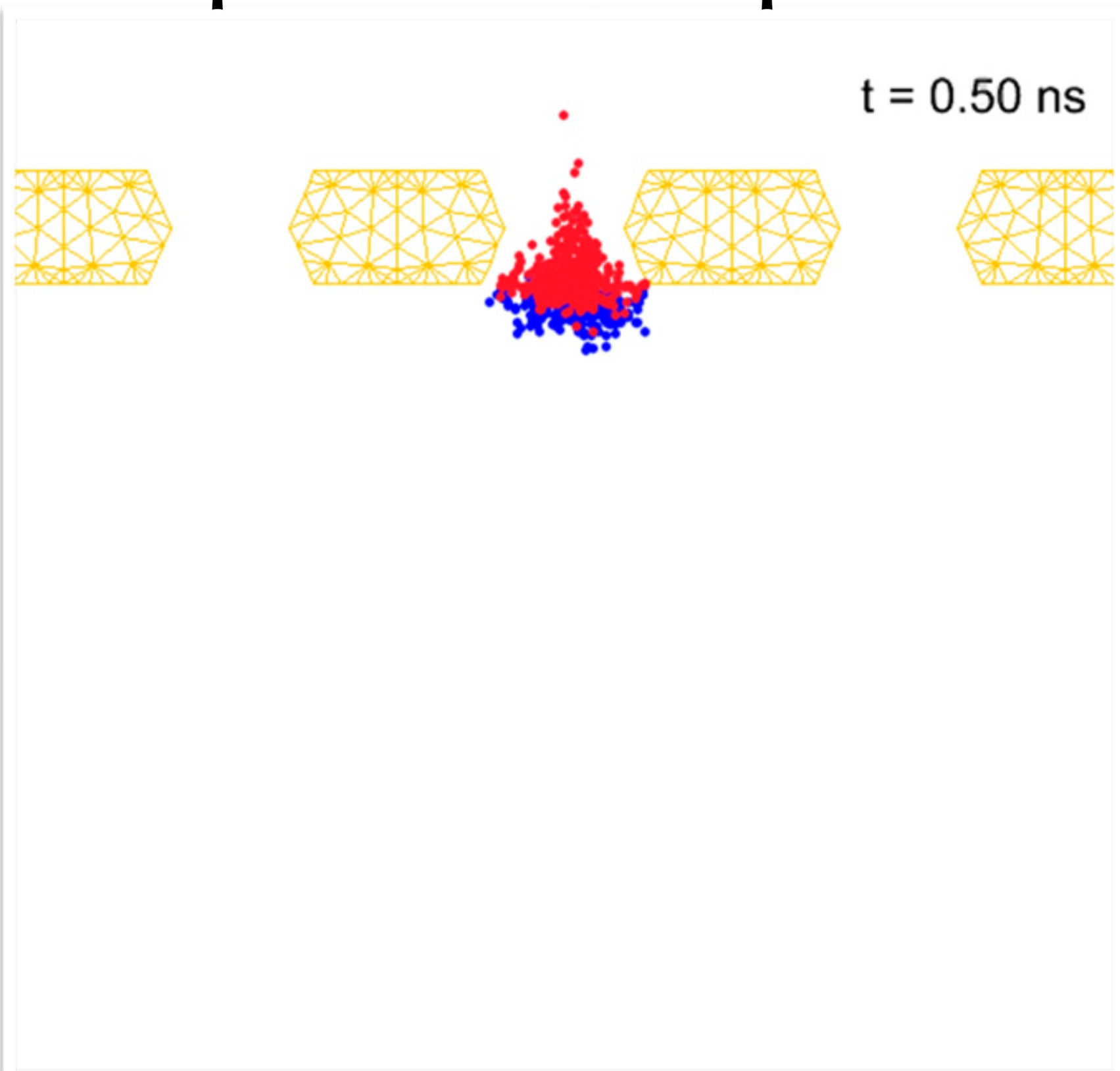
GEM amplification process



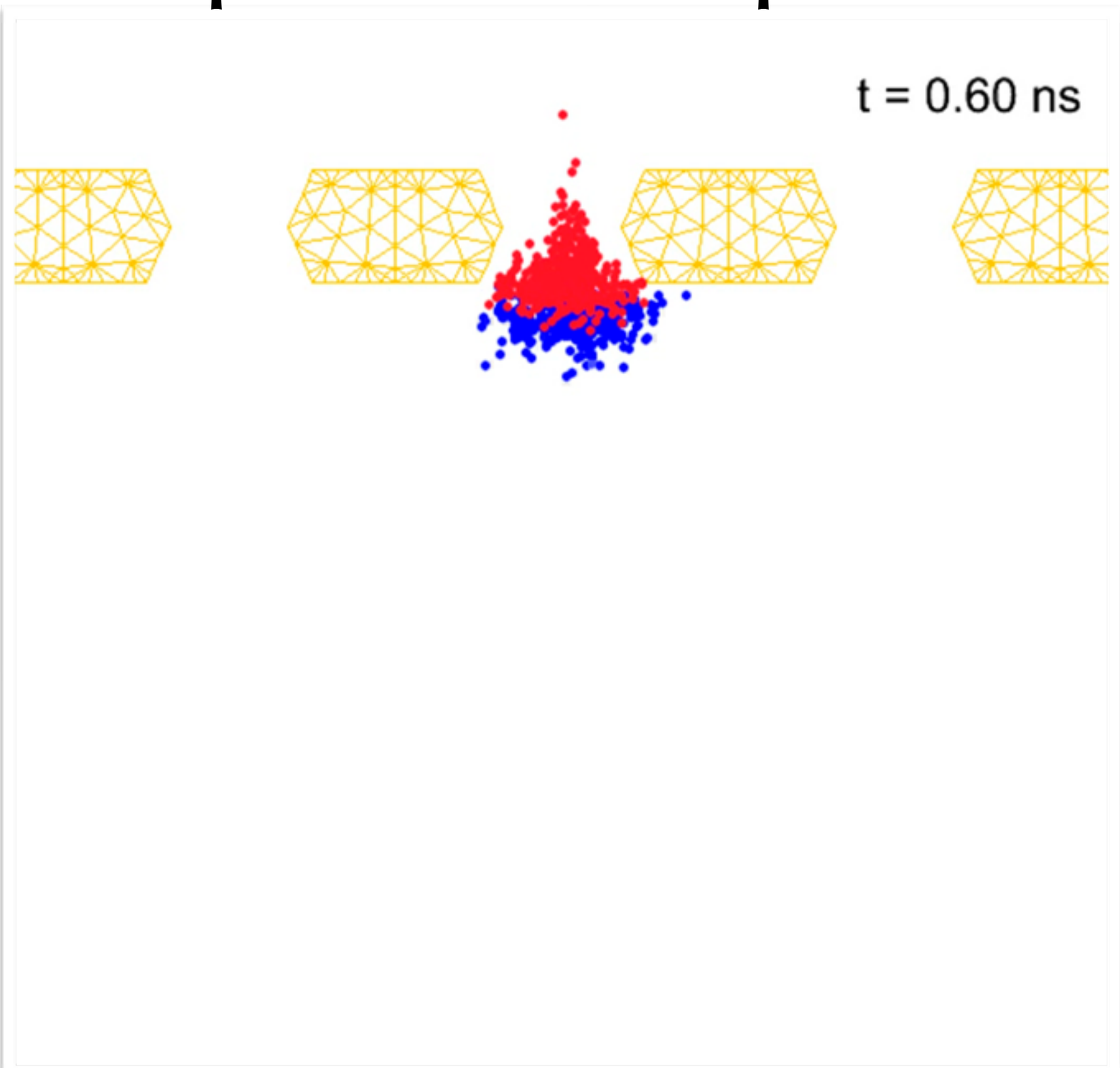
GEM amplification process



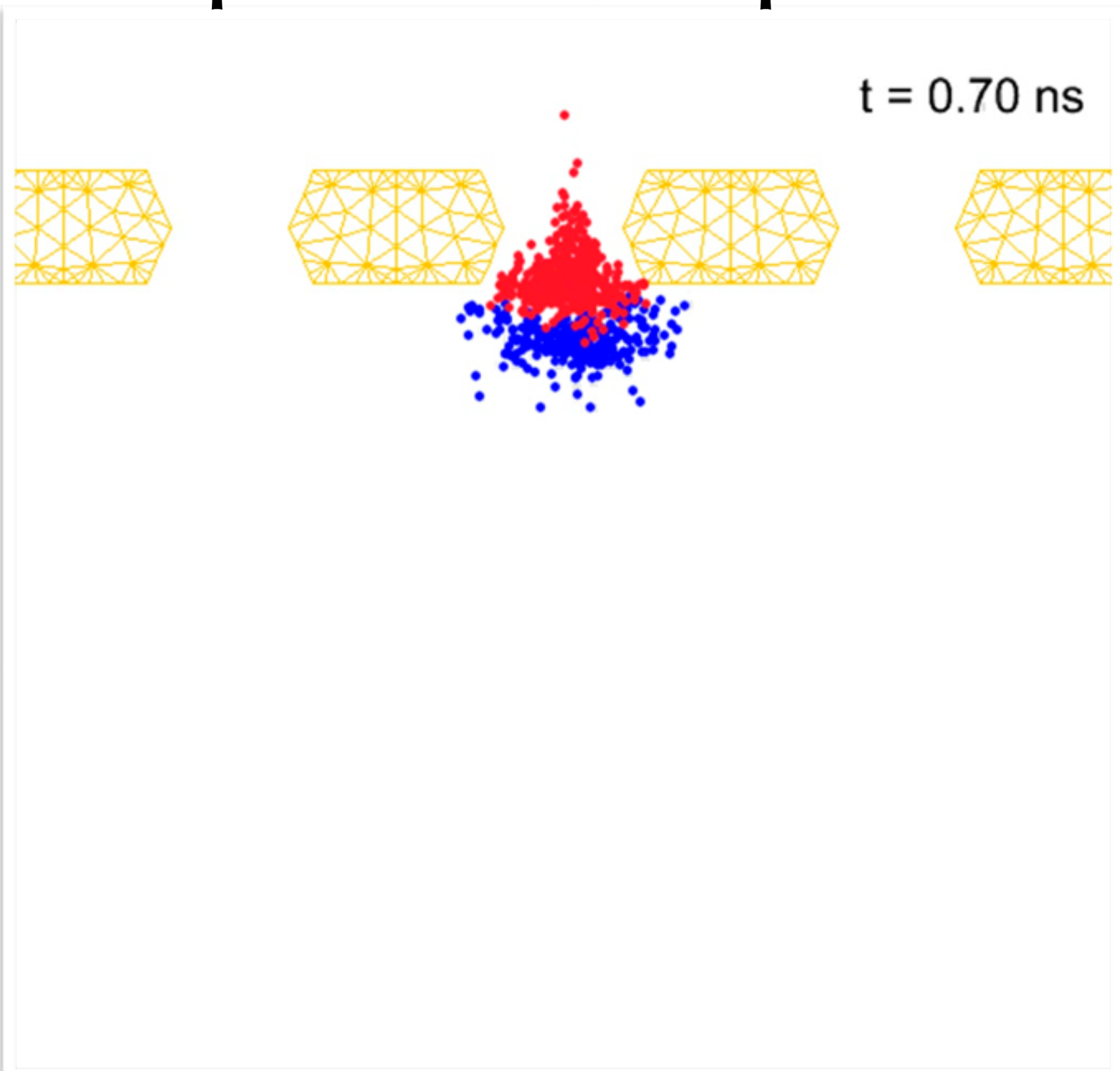
GEM amplification process



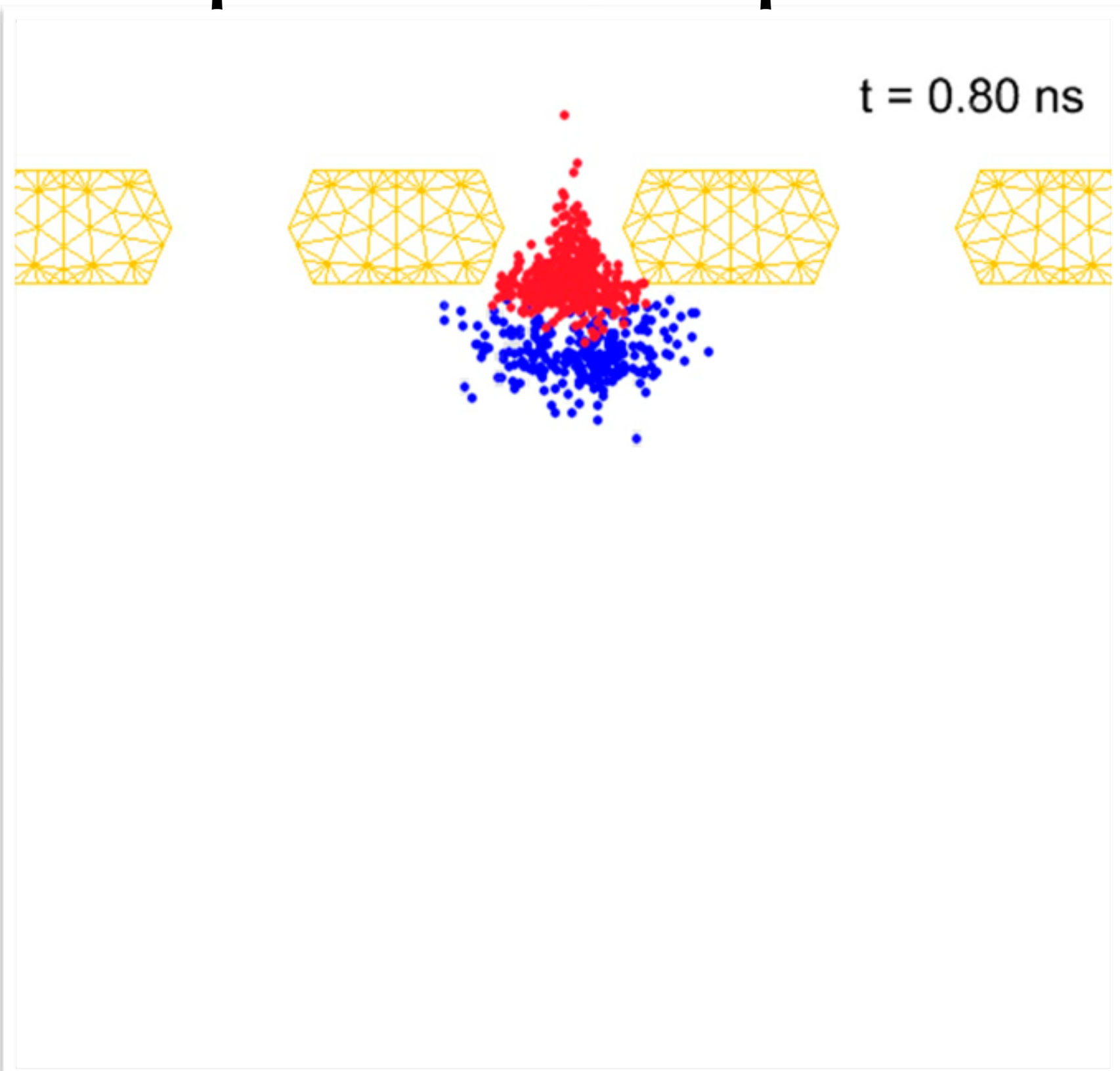
GEM amplification process



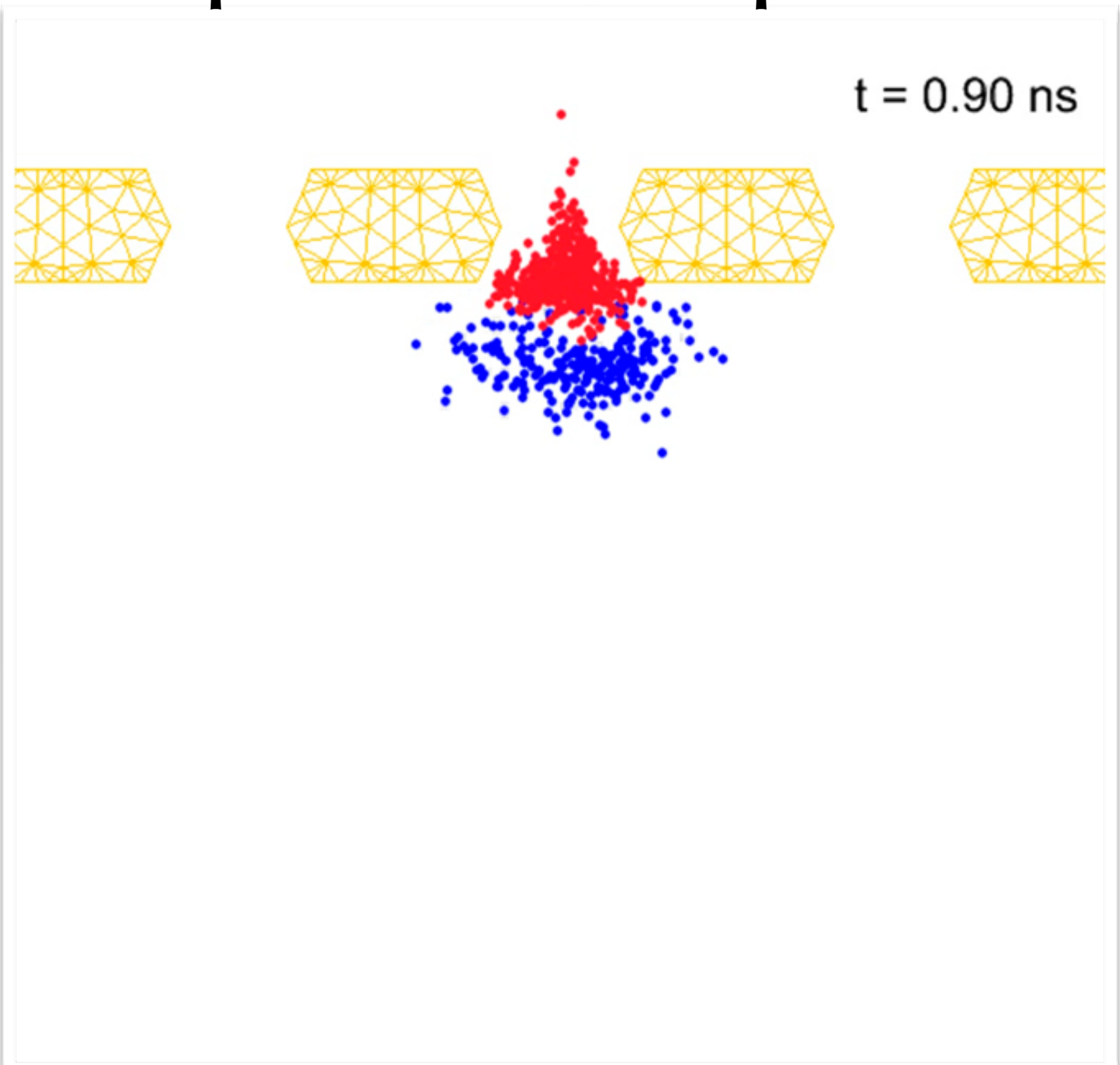
GEM amplification process



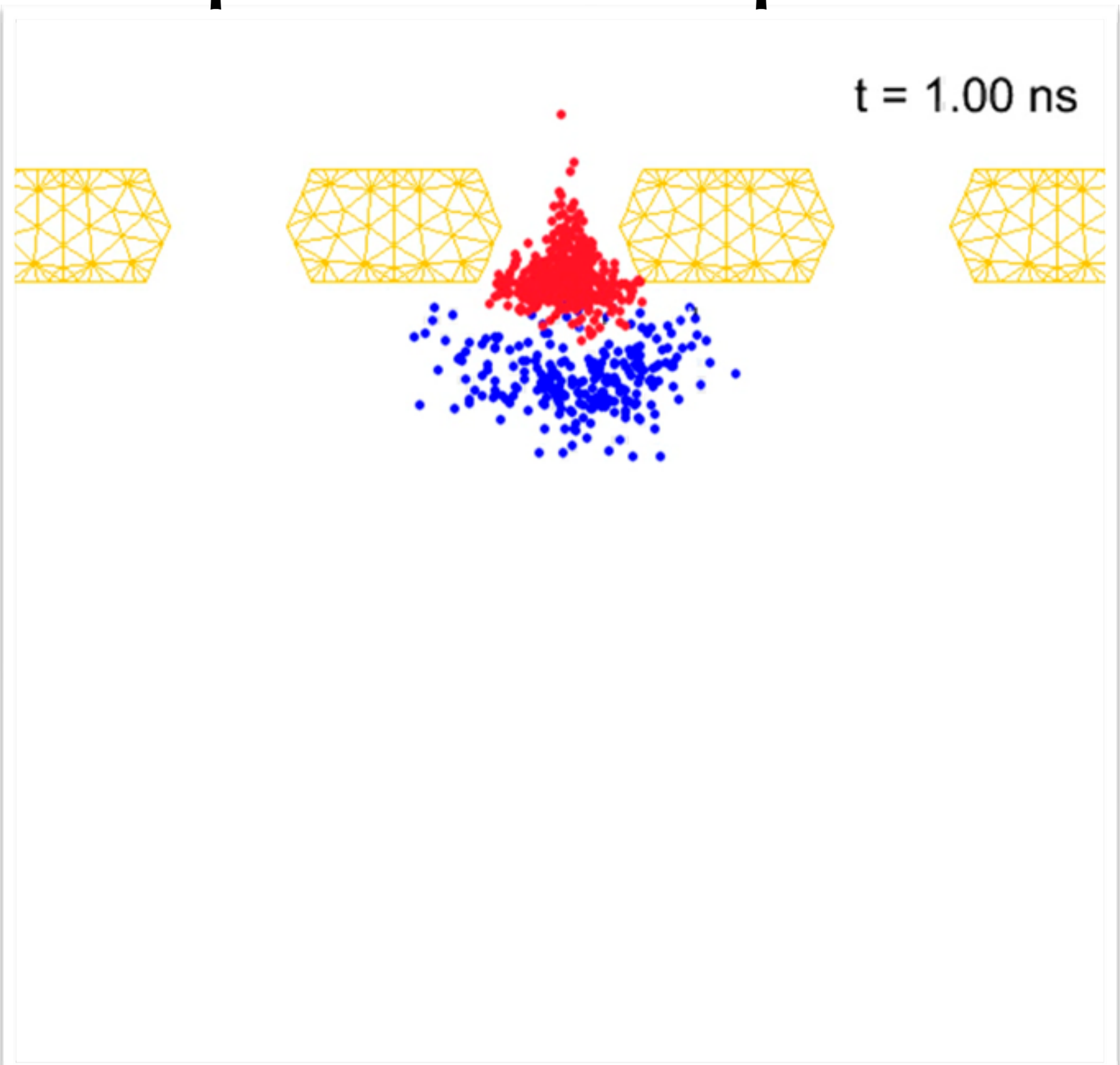
GEM amplification process



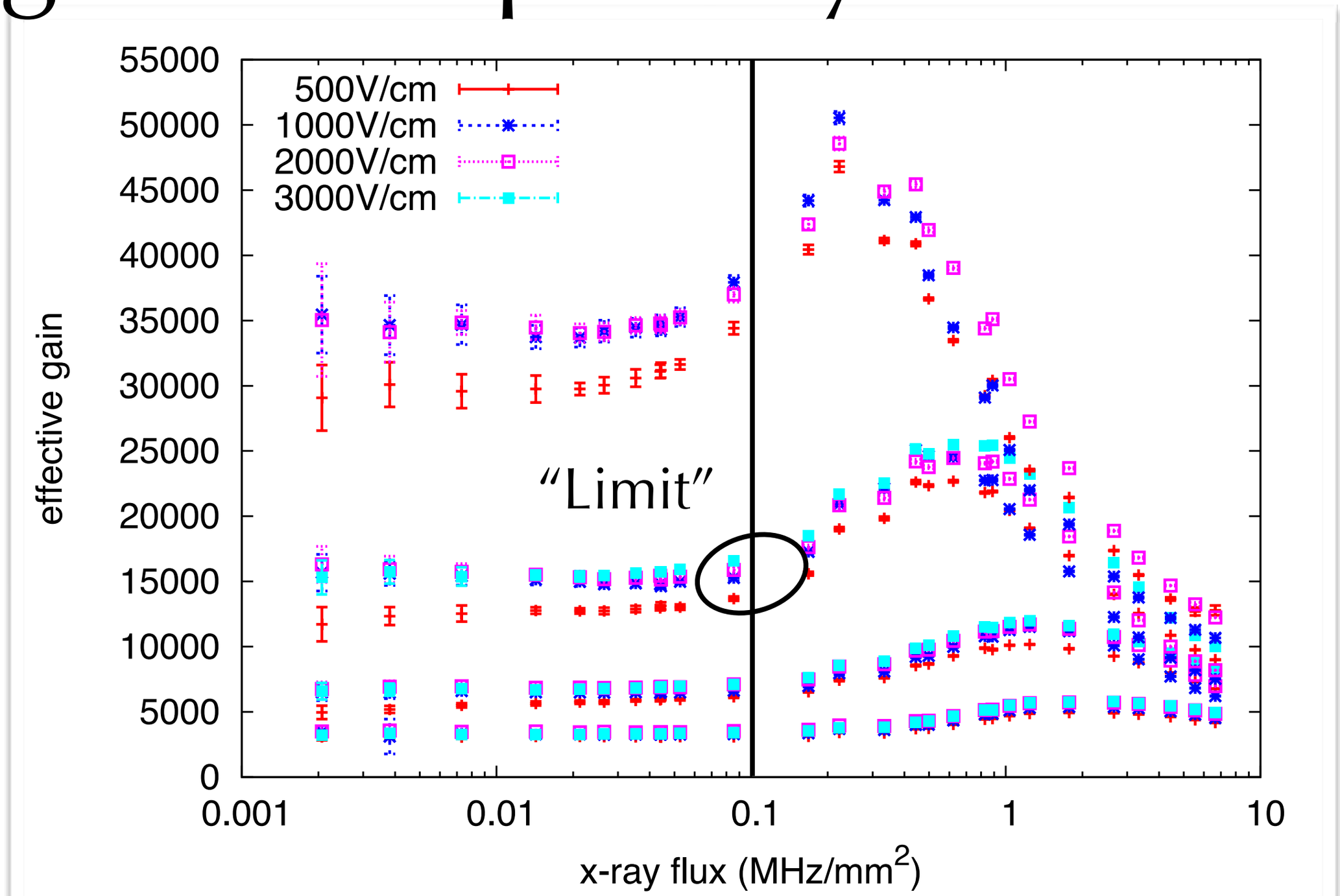
GEM amplification process



GEM amplification process



High flux capability



Extrapolating for 1.5MeV α @ G = 50

Limit **~100kHz/mm²**

Conversion layer

^{10}Boron

Form: typically $^{10}B_4C$

Reactions: $^{10}B(n, \alpha)^7Li$ and $^{10}B(n, \alpha\gamma)^7Li$

Energies: α and ^7Li O(1MeV)

Efficiency: about 5% for few μm

Gadolinium

Form: metal of Gd_2O_3

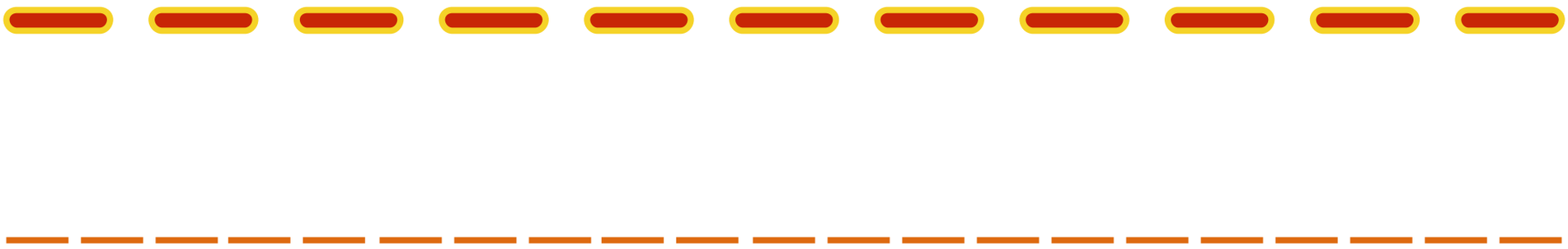
Reactions: $^xGd(n, e^-\gamma)^{x+1}Gd$

Energies: e^- O(50keV)

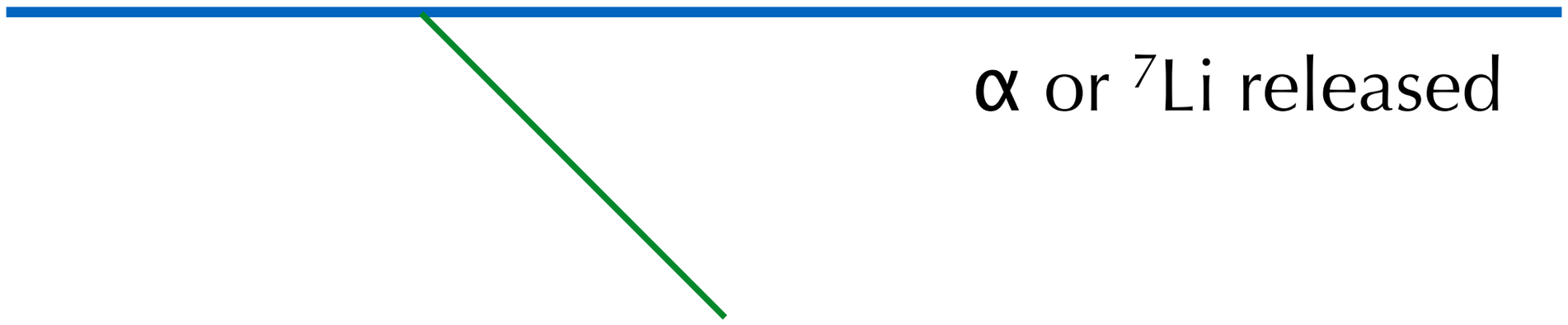
Efficiency: up to 40% for several μm

B-GEM TPC

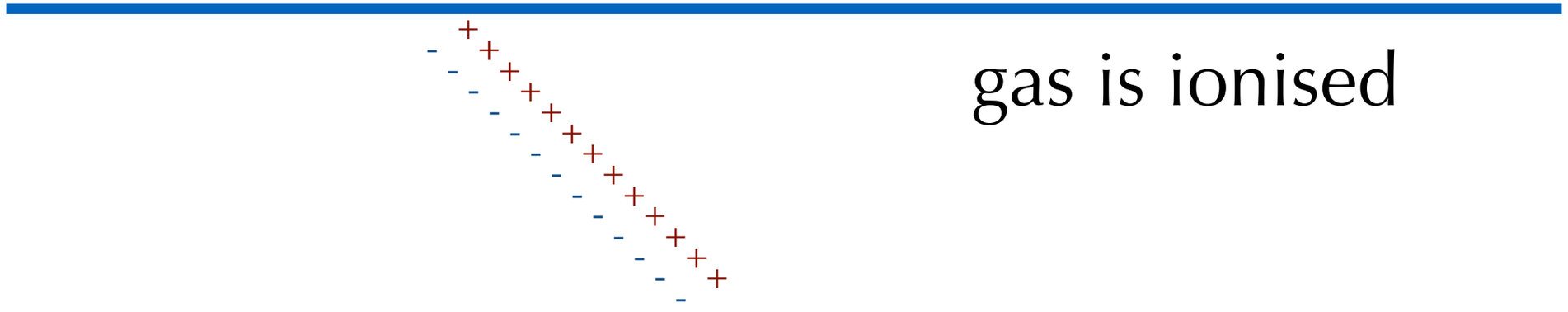
n captured by ^{10}B



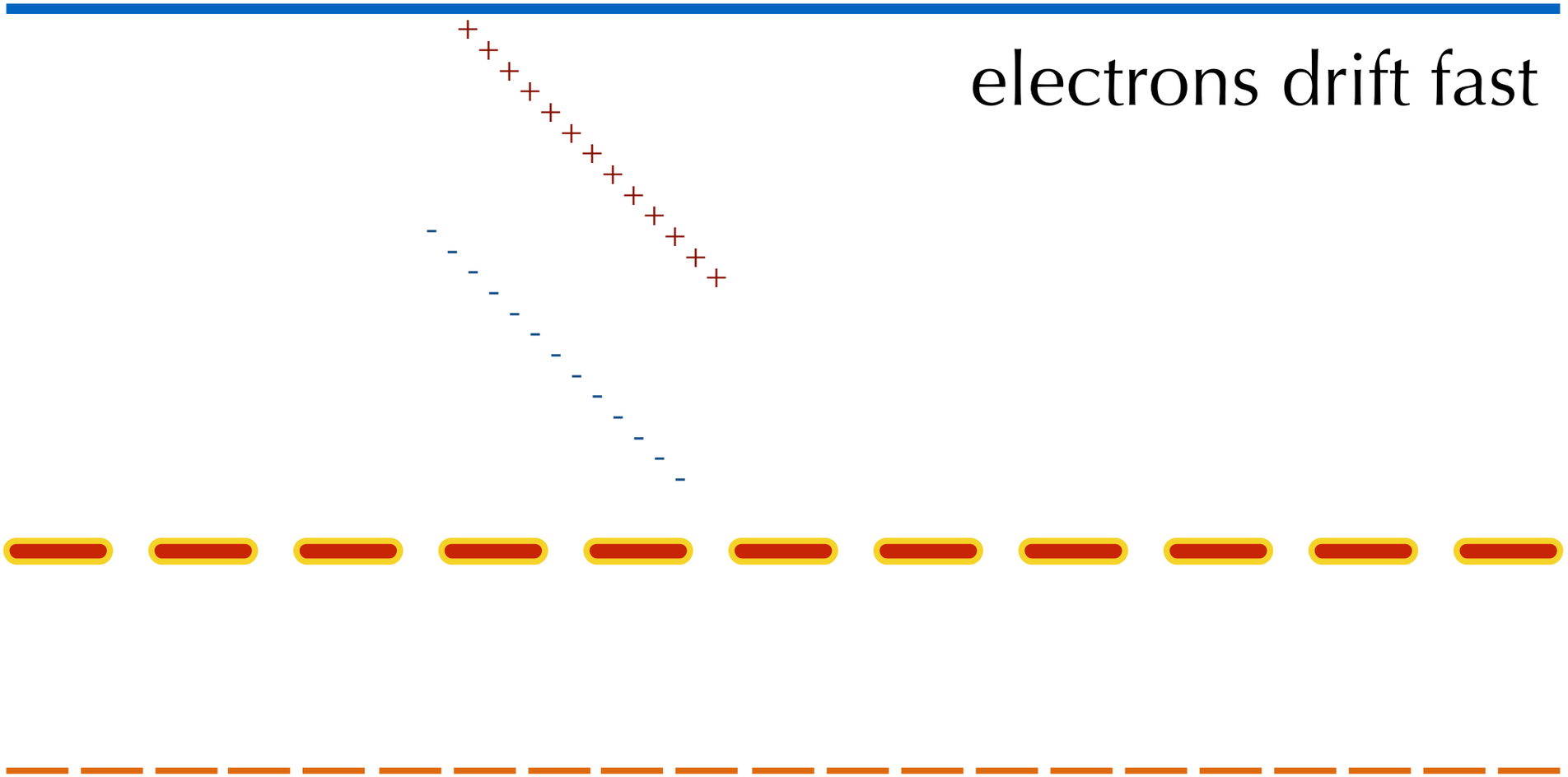
B-GEM TPC



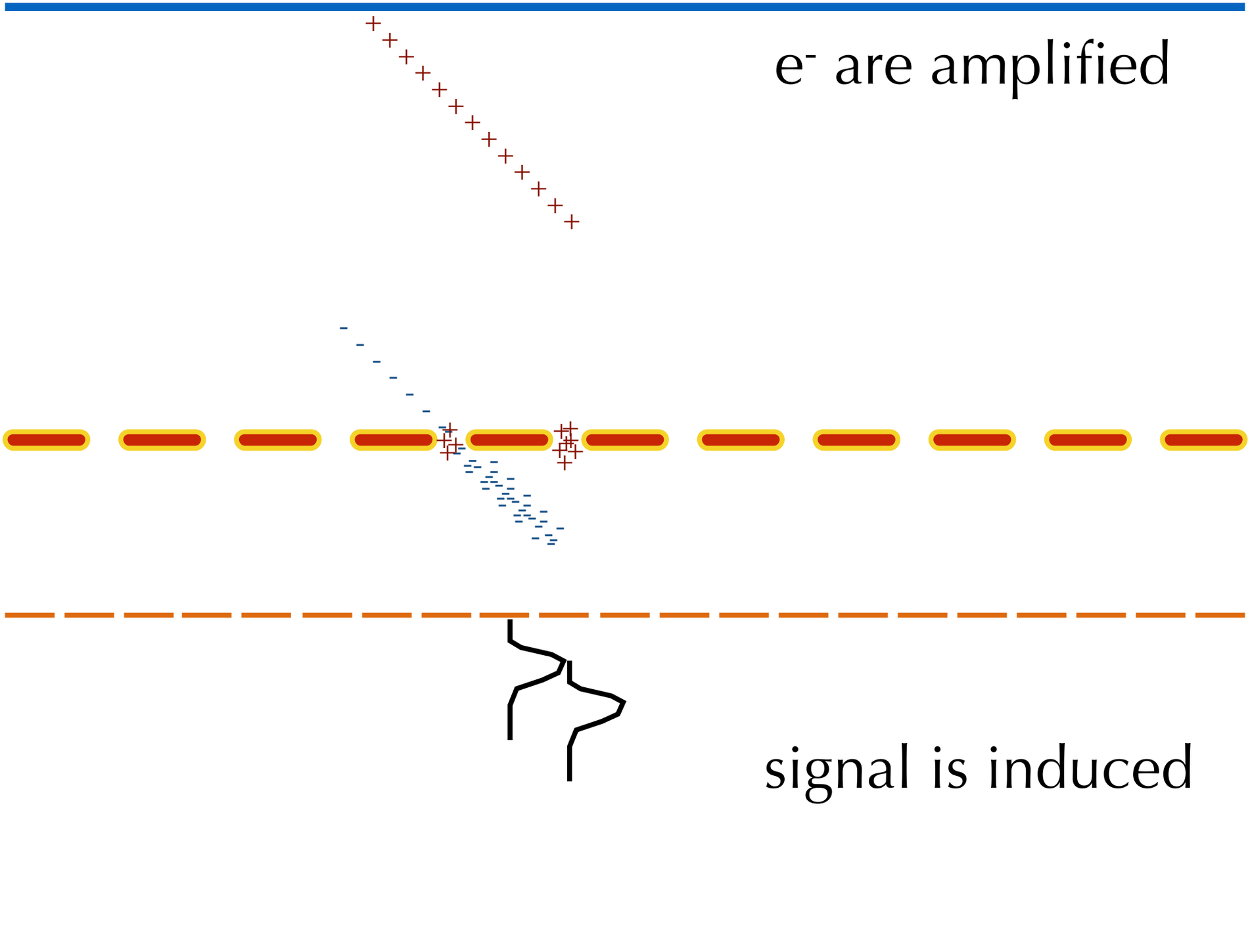
B-GEM TPC



B-GEM TPC

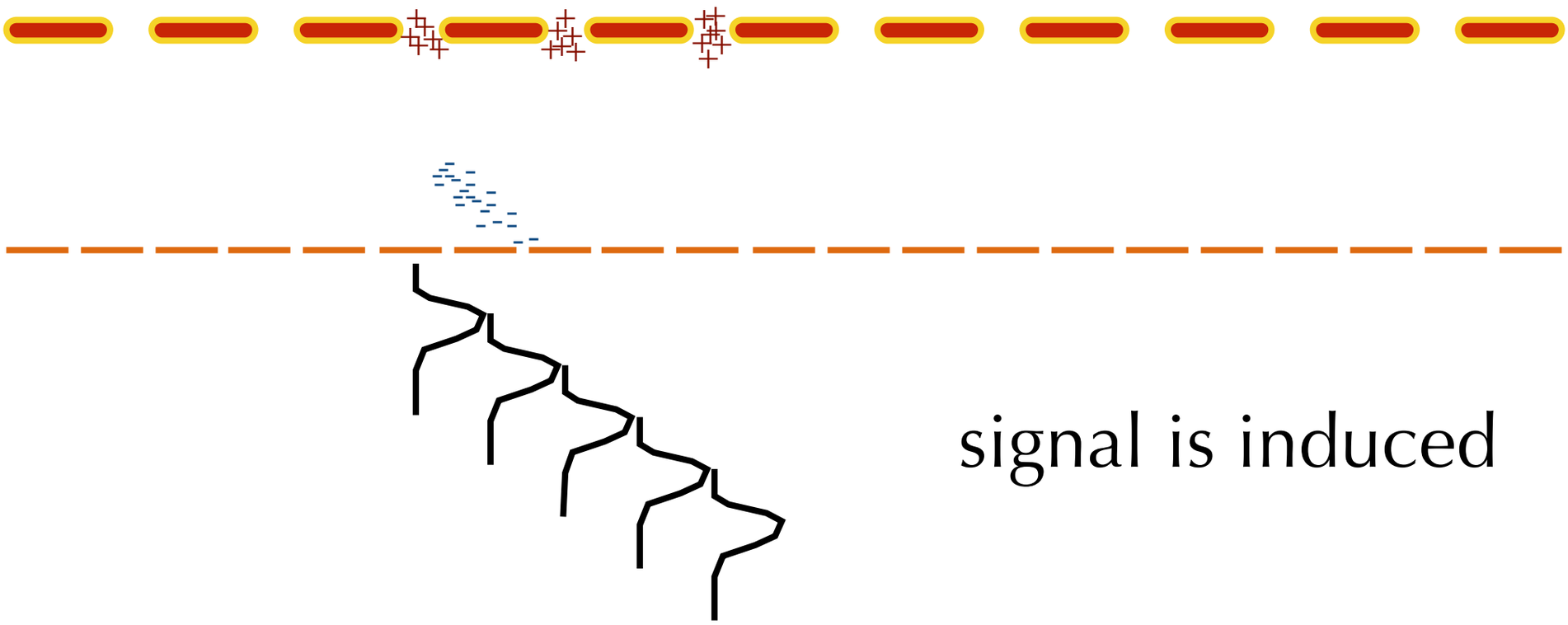


B-GEM TPC



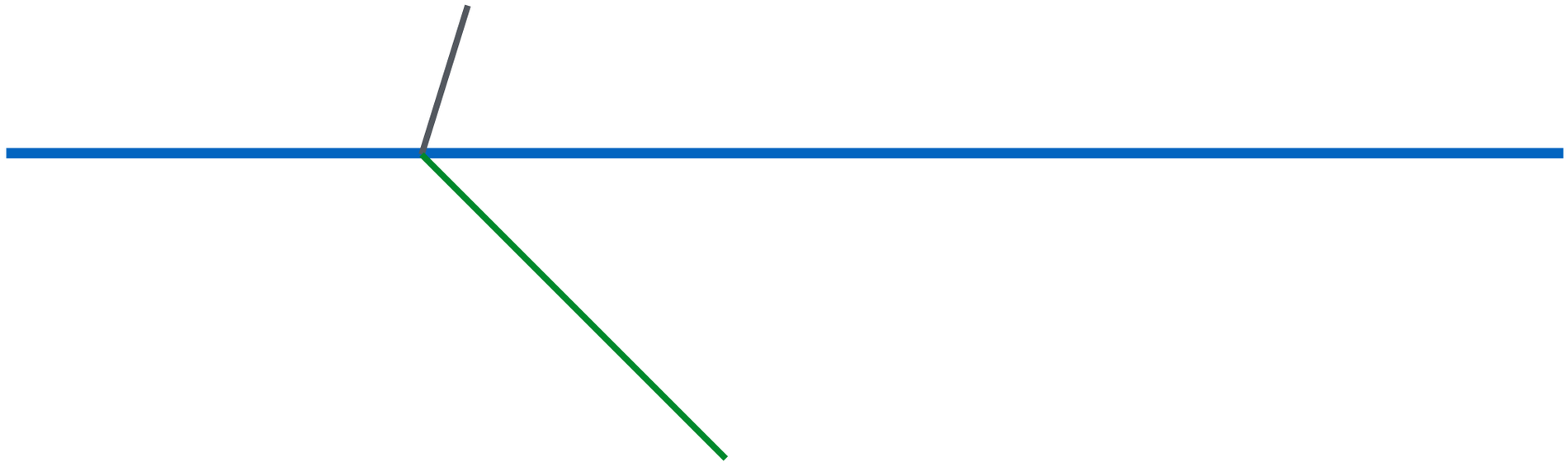
B-GEM TPC

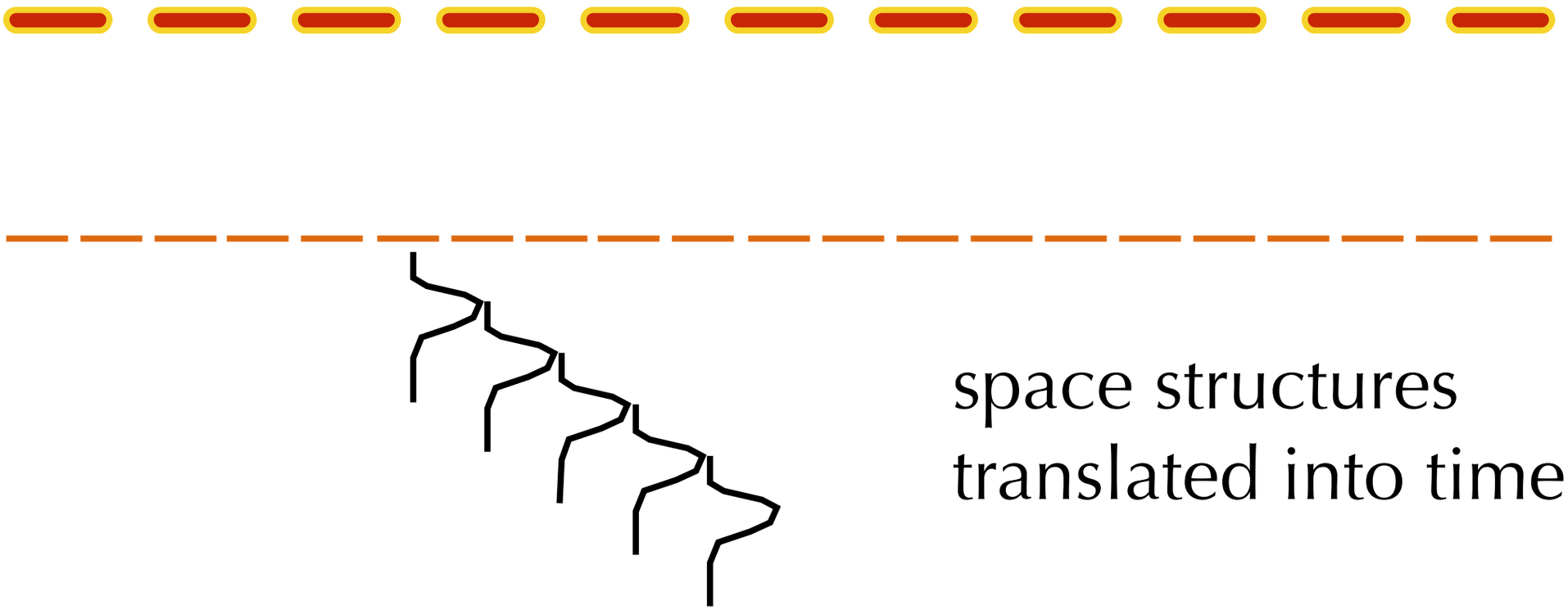
e^- are evacuated



signal is induced

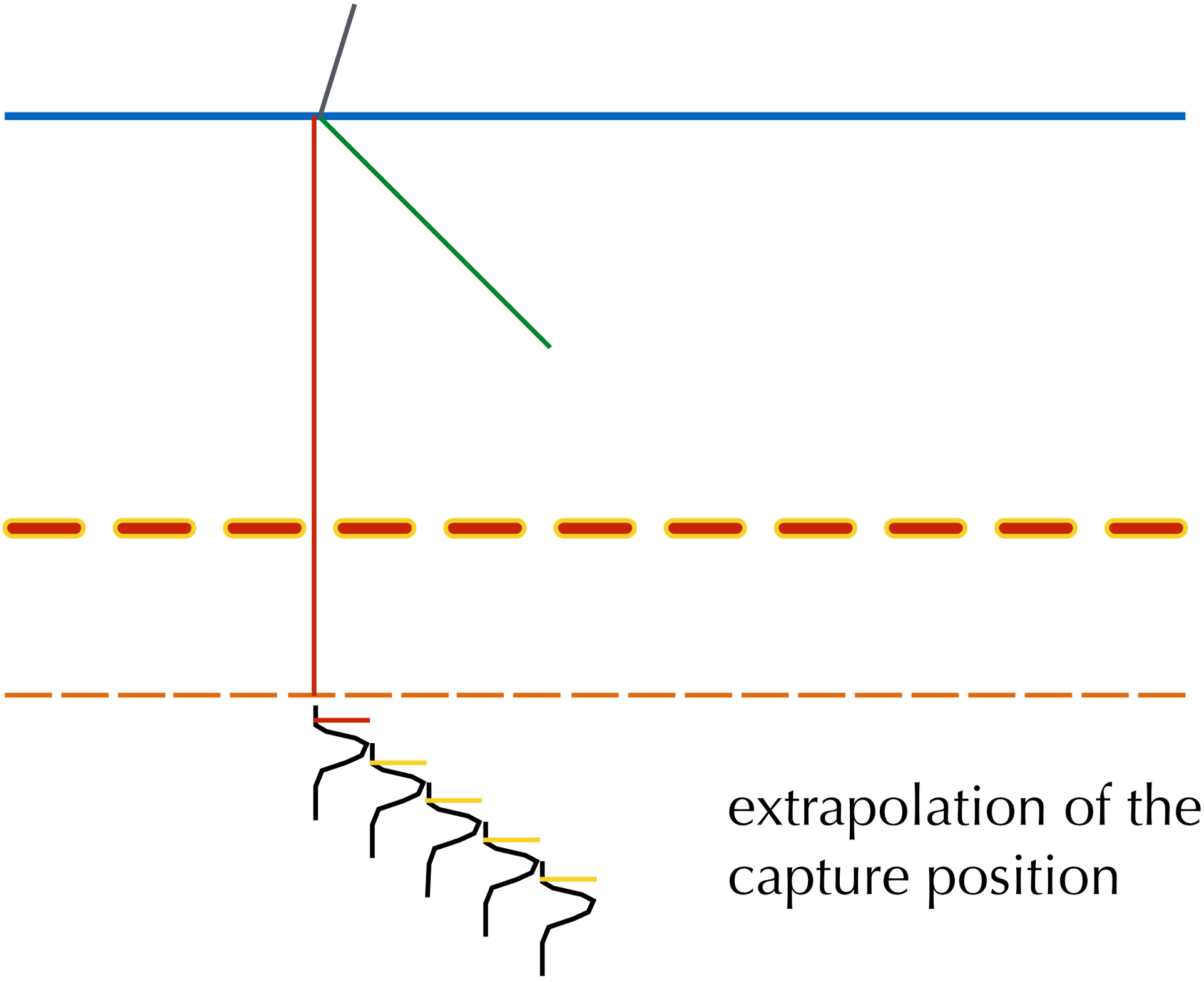
B-GEM TPC





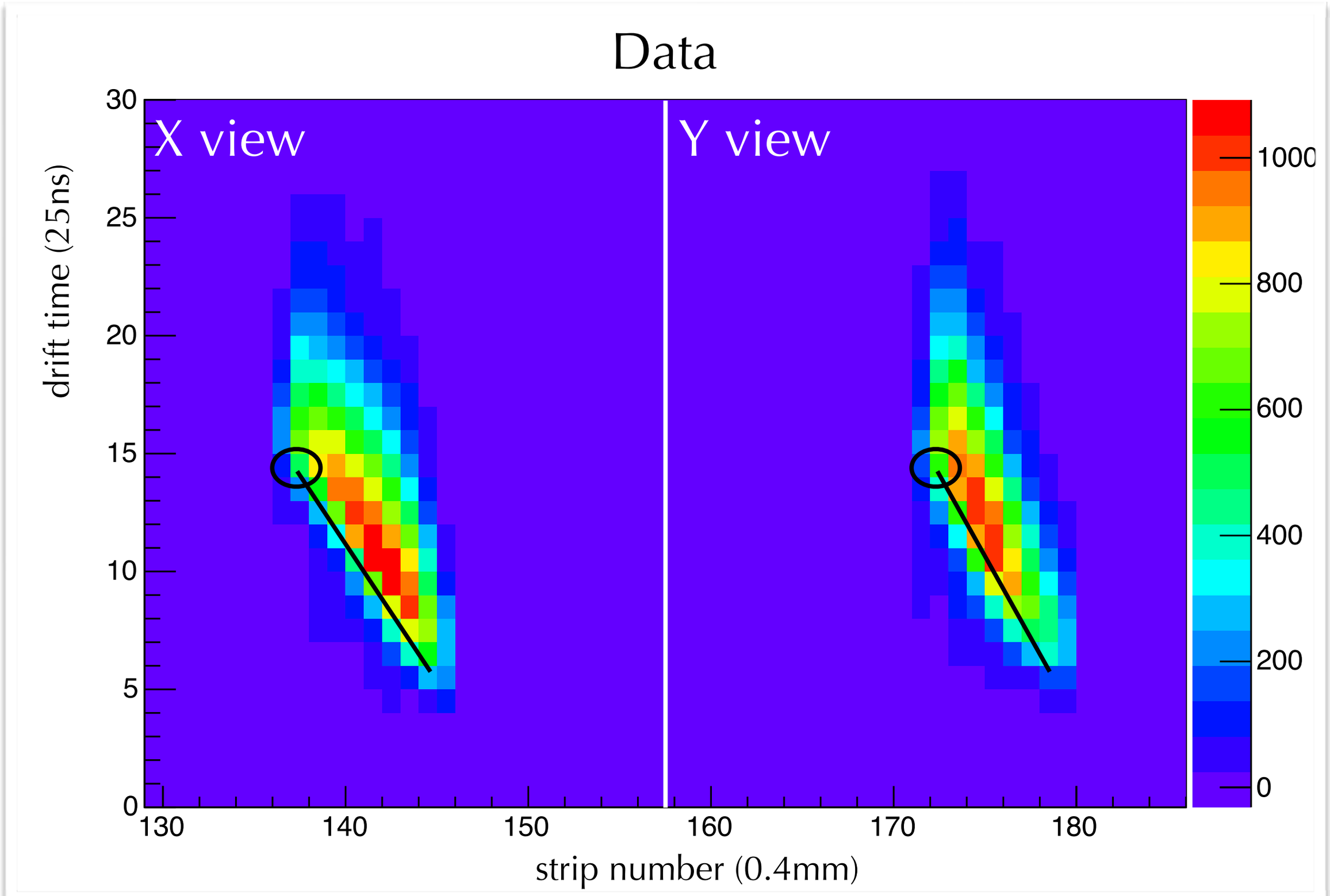
space structures
translated into time

B-GEM TPC



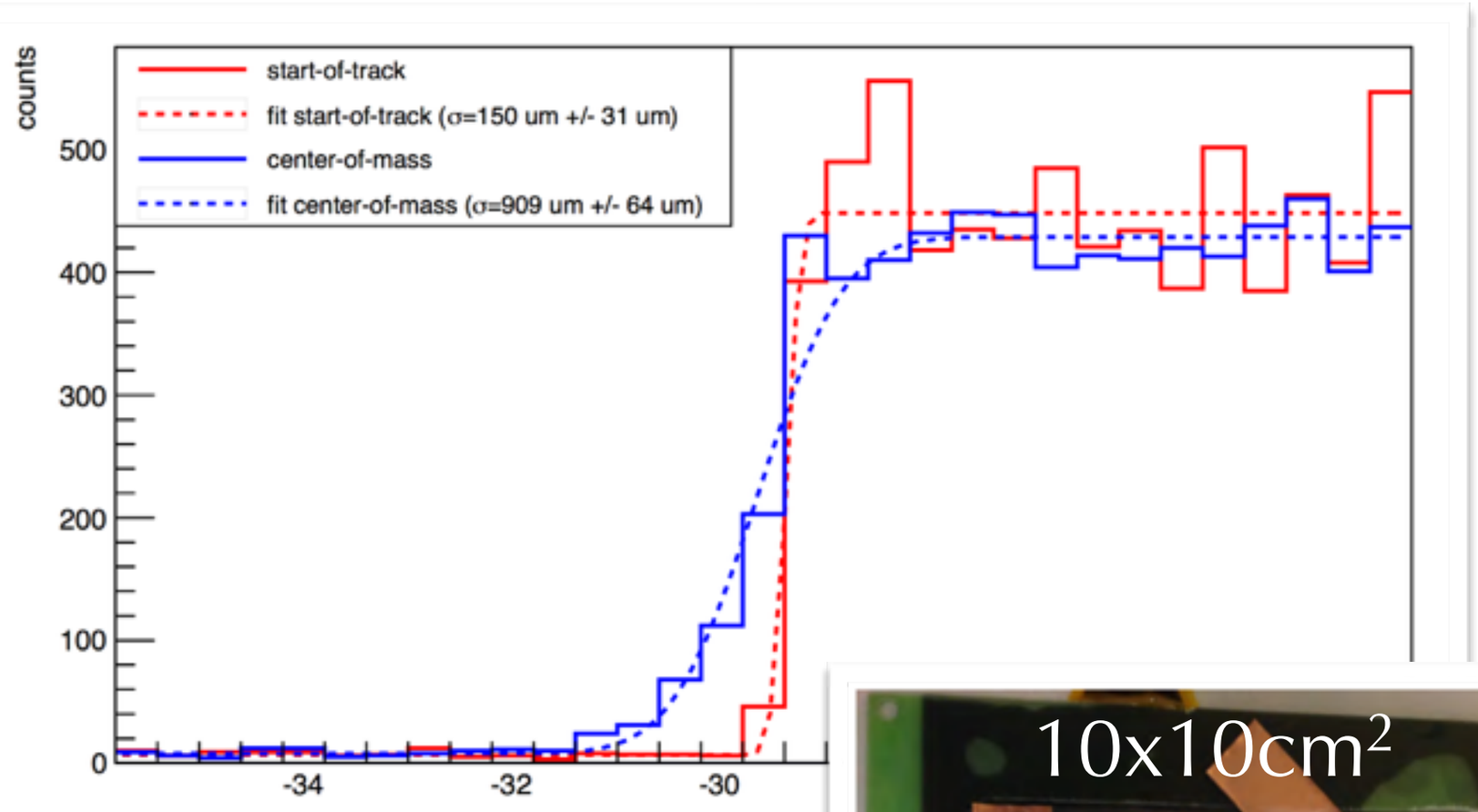
extrapolation of the capture position

B-GEM TPC


Data
X view
Y view
drift time (25ns)
signal amplitude (ADC)
strip number (0.4mm)
0
5
10
15
20
25
30
130
140
150
160
170
180
0
200
400
600
800
1000

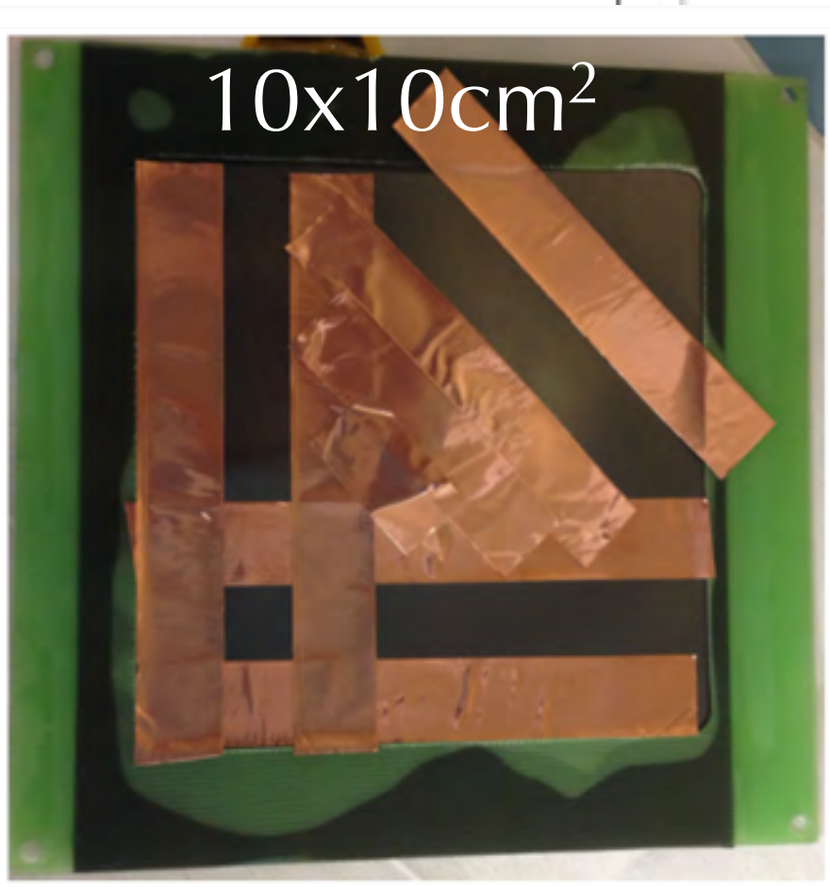
B-GEM TPC

arXiv:1501.05022
submitted to JINST

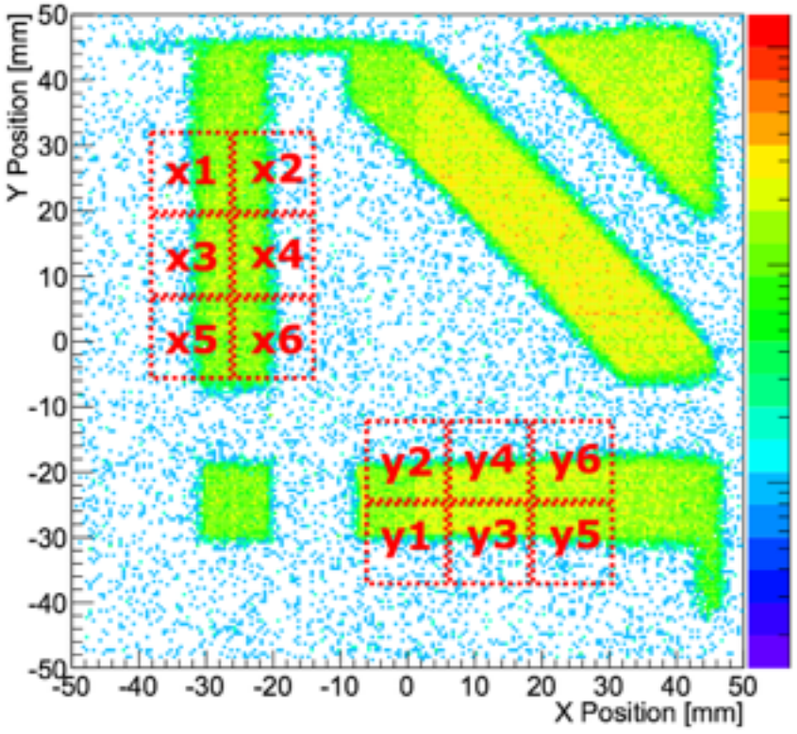


Proof of principle and demonstrator:
spatial resolution from 1mm to **150um**

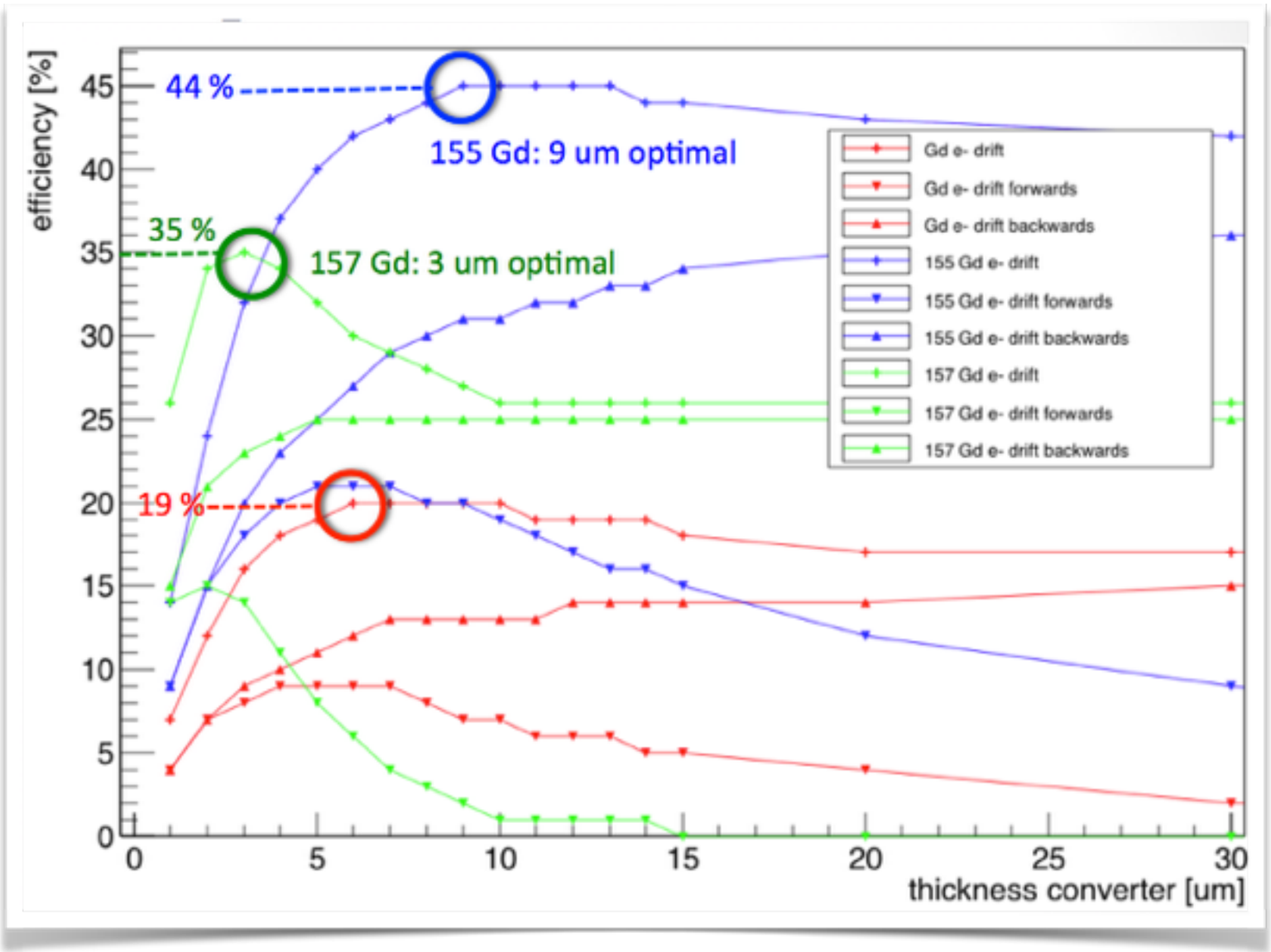
γ events easily distinguishable from the signal amplitude



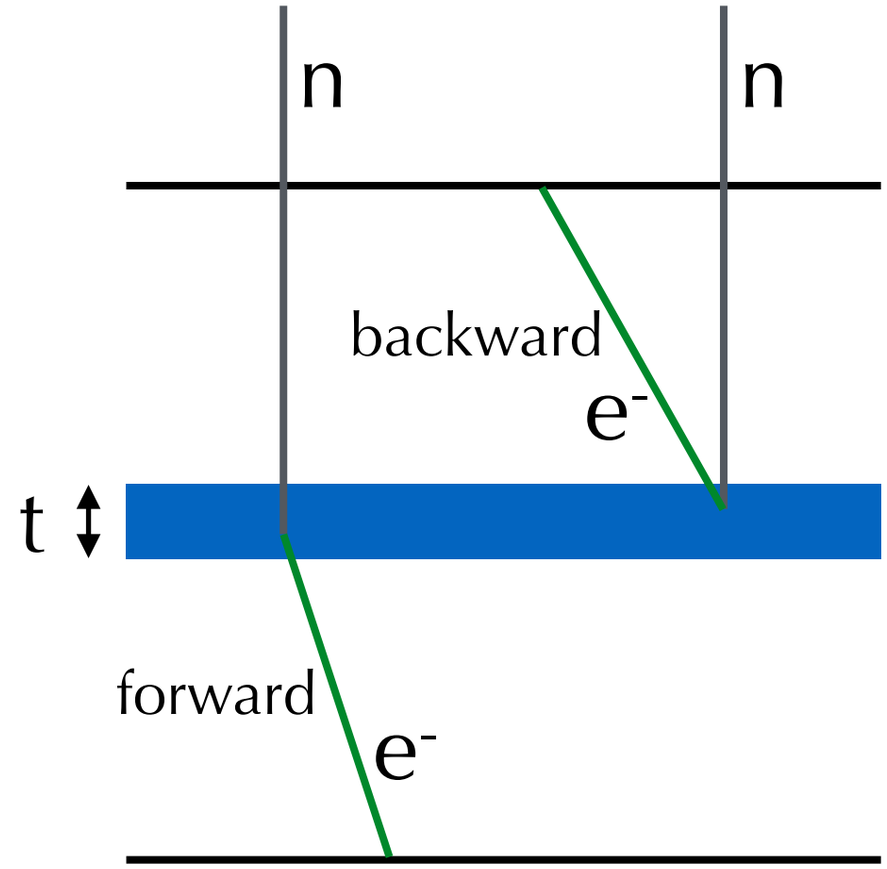
^{241}AmBe source



Gd as converter

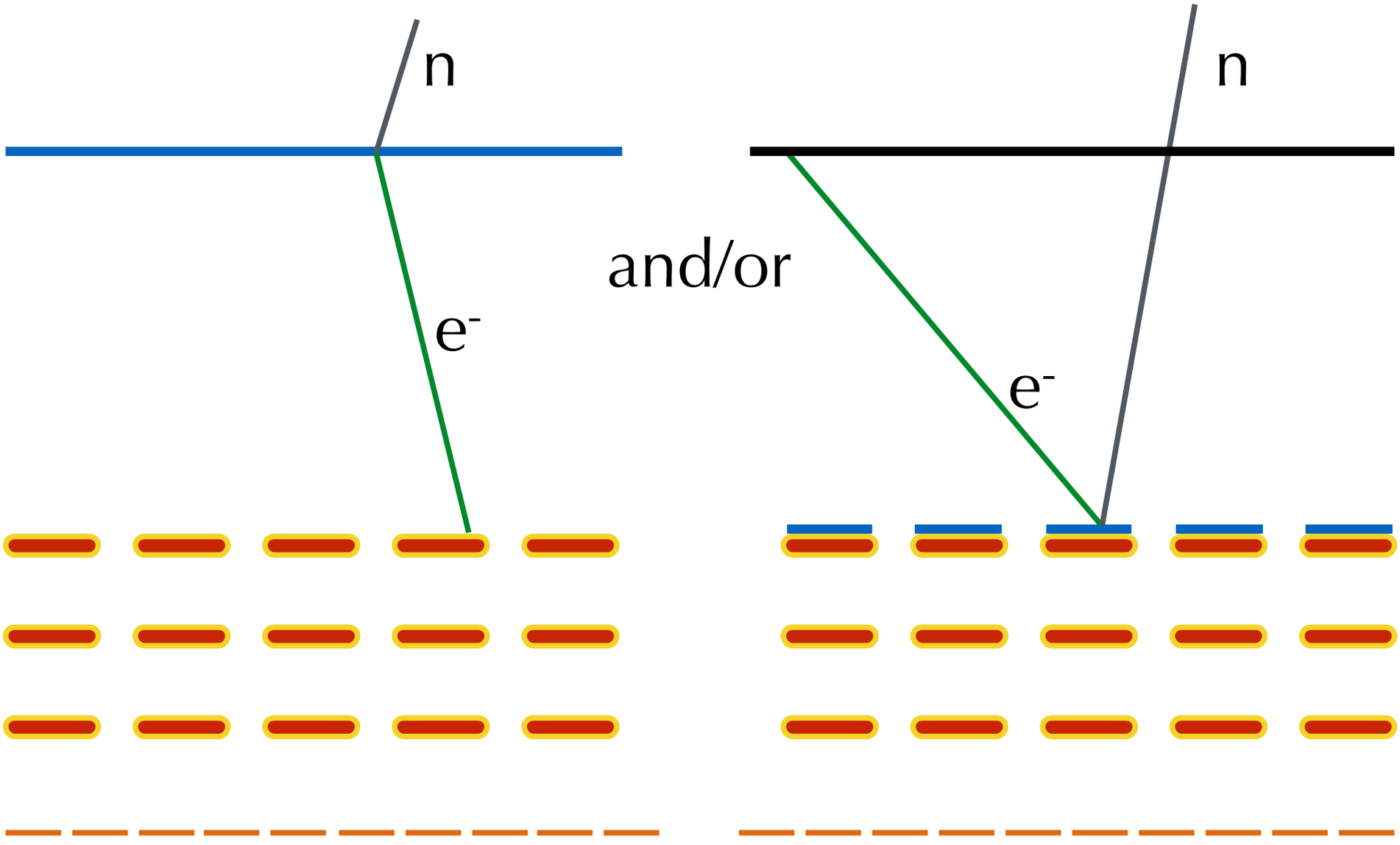


Simulation 25meV neutrons



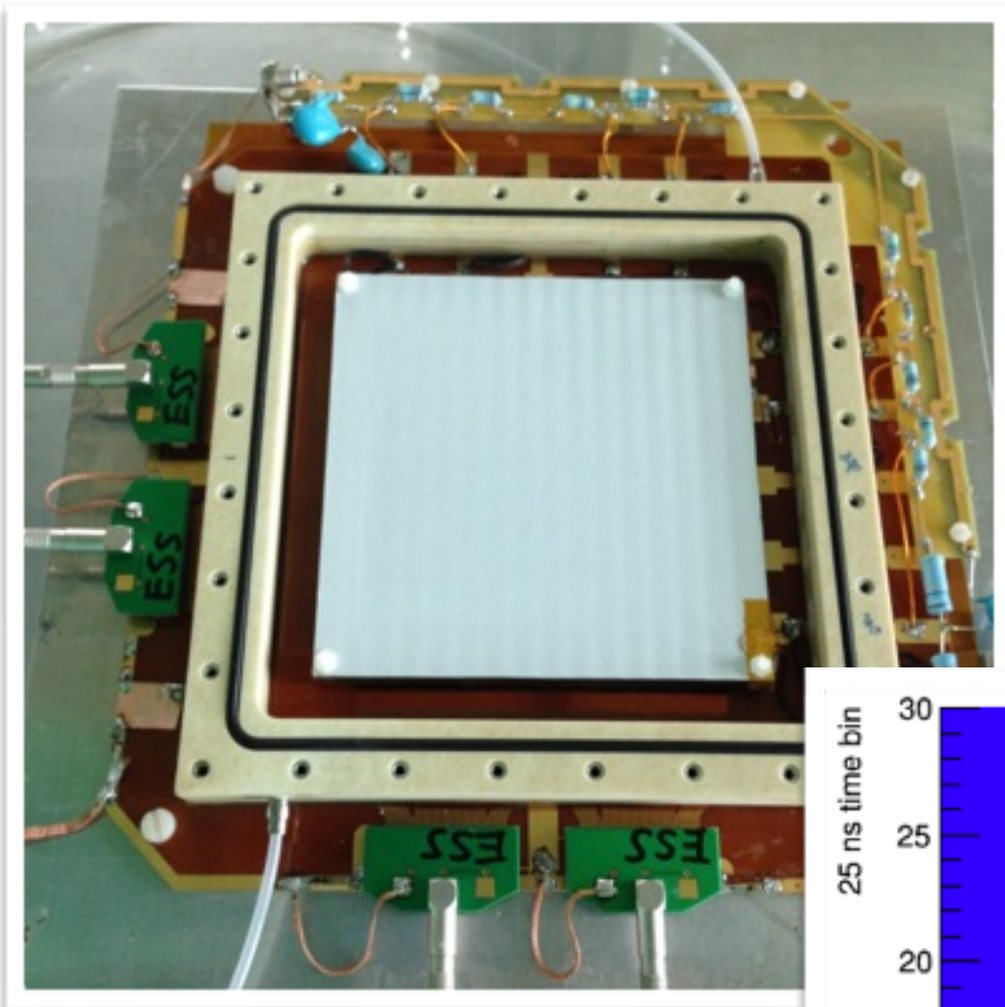
Increase efficiency
Lower energy events
Poorer γ rejection power
TPC analysis applicable

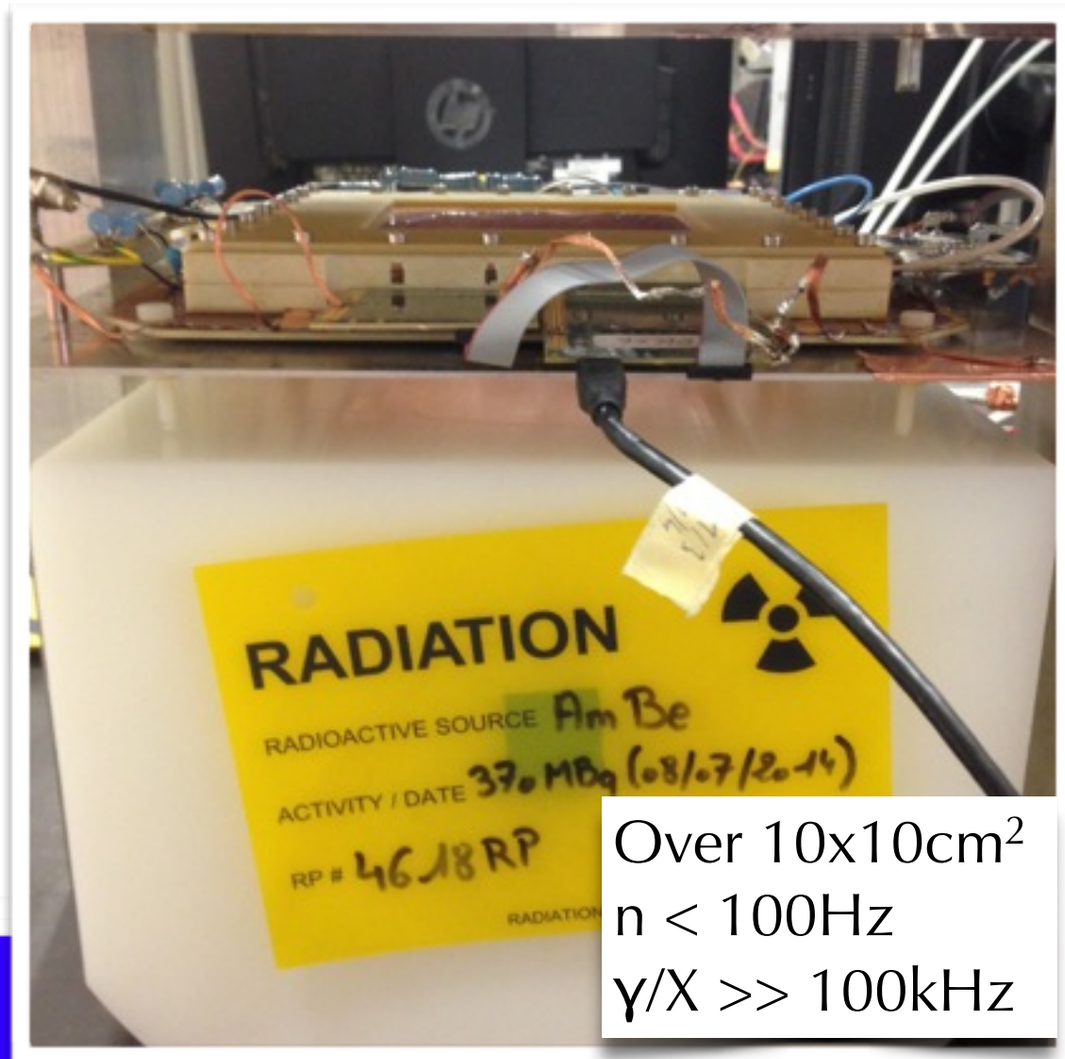
Gd-GEM TPC



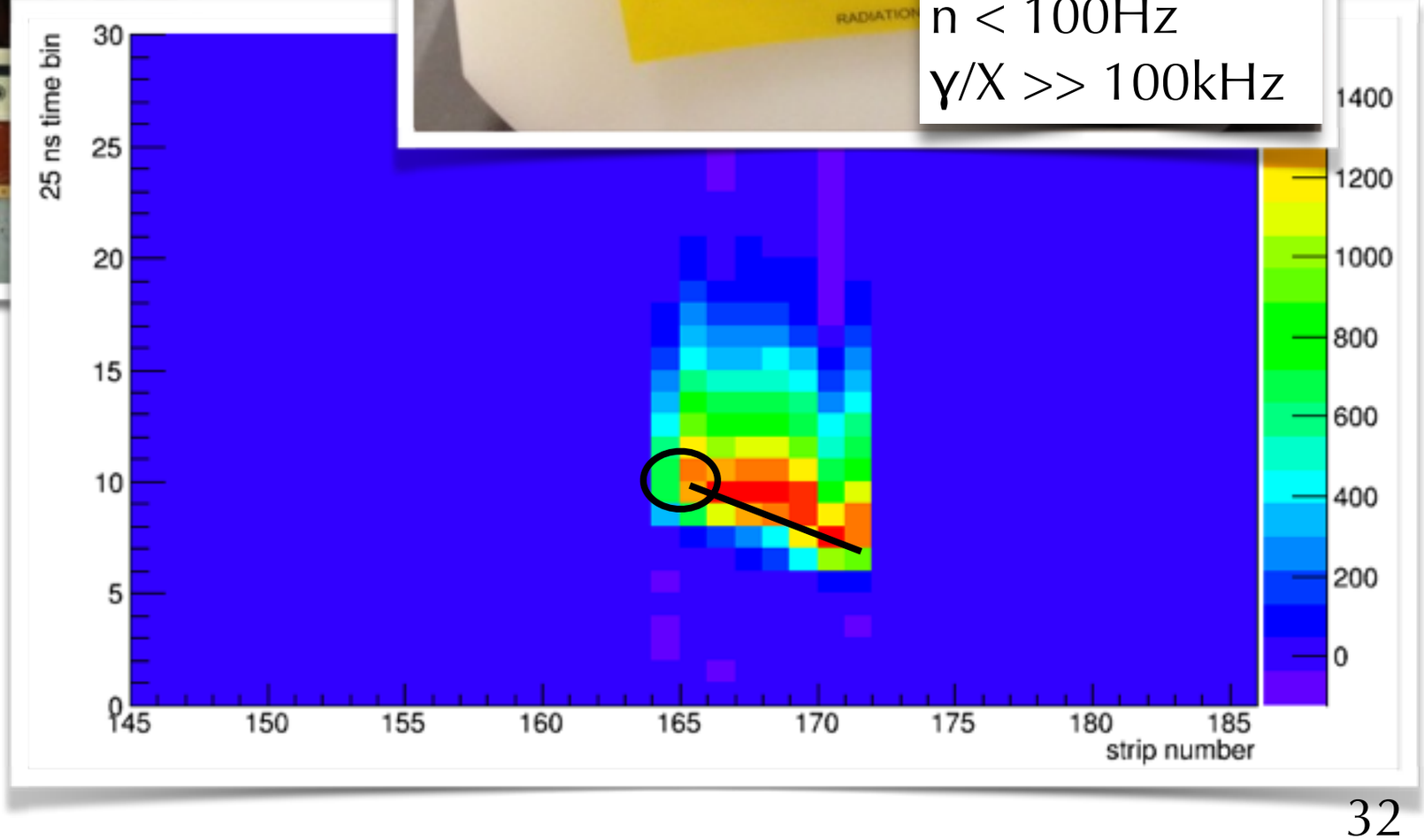
Gain of 10^3-10^4: three amplification stages are required
Normal GEM operation in HEP experiment

Gd-GEM TPC





Over 10x10cm²
n < 100Hz
γ/X >> 100kHz



Signals are there!

Too many γ/X rays from the source

Need a thermal neutron pencil beam

Conclusions & outlook

Challenging requirements!
Developments started last March
Identified path to the success
Proof of principle of the TPC analysis
B-GEM fully tested with ^{241}AmBe source
Gd-GEM proof of concept