Position resolution of Gd-GEM detectors for the NMX instrument

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RD51 miniweek

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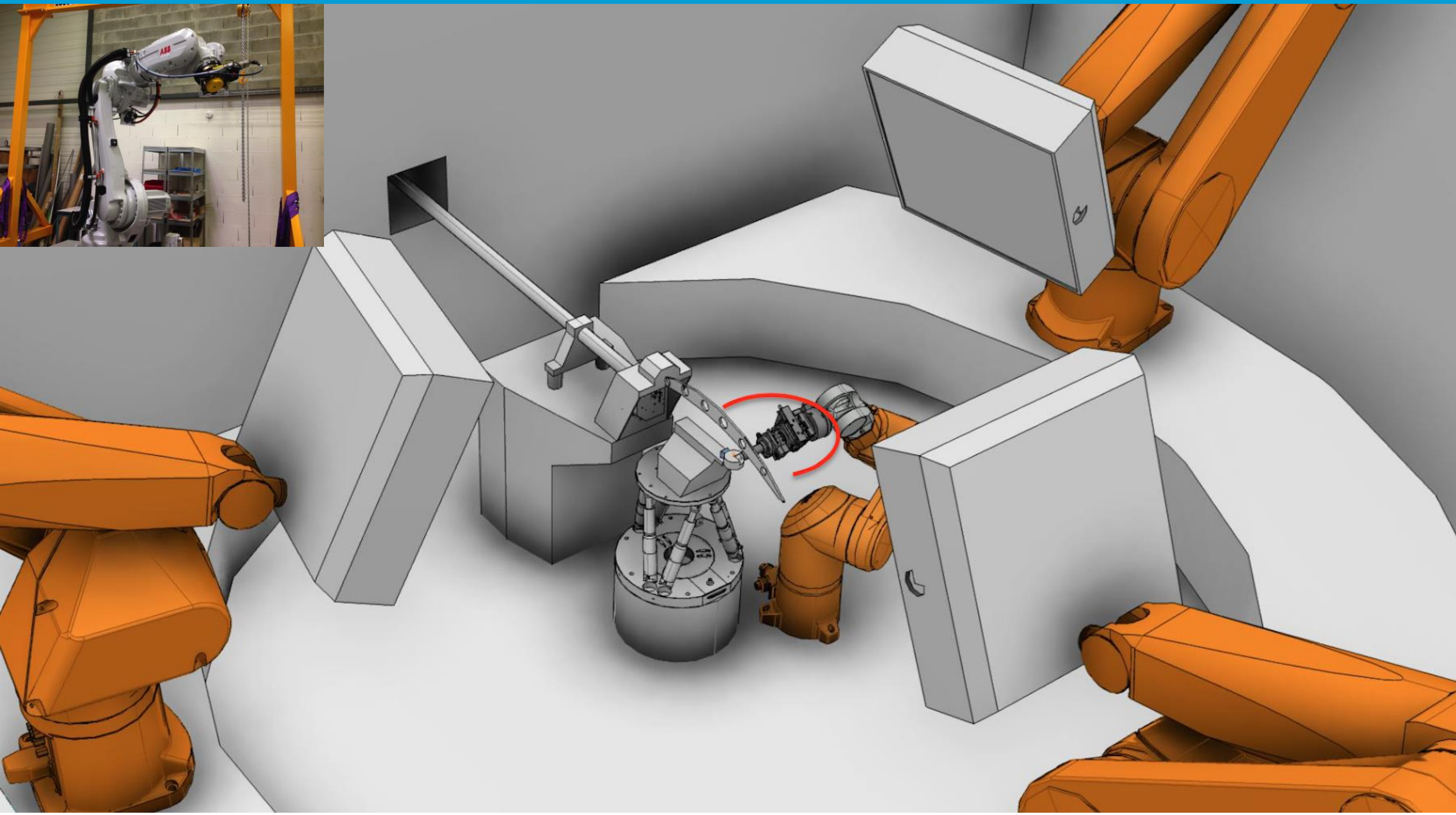
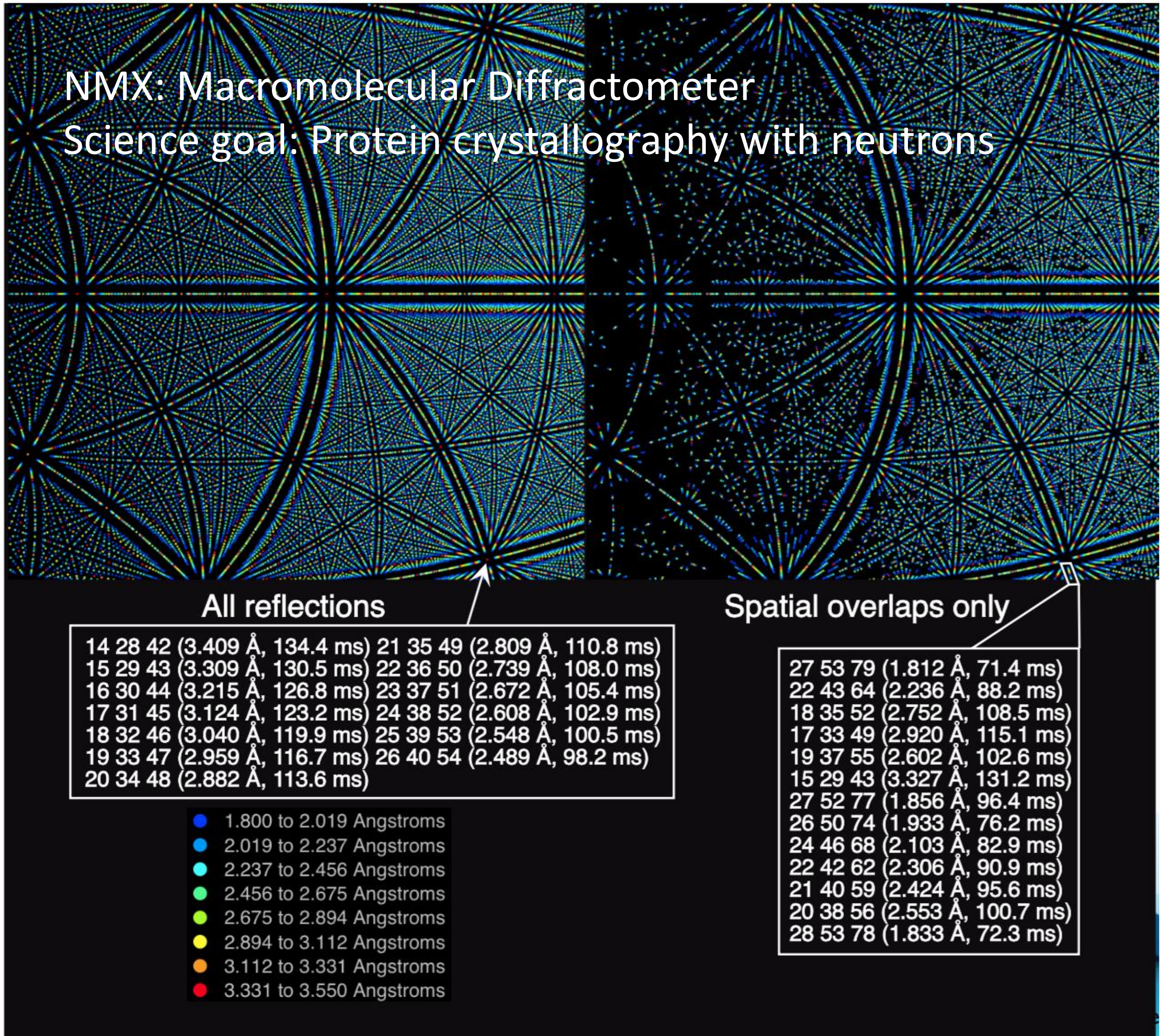
NMX detectors

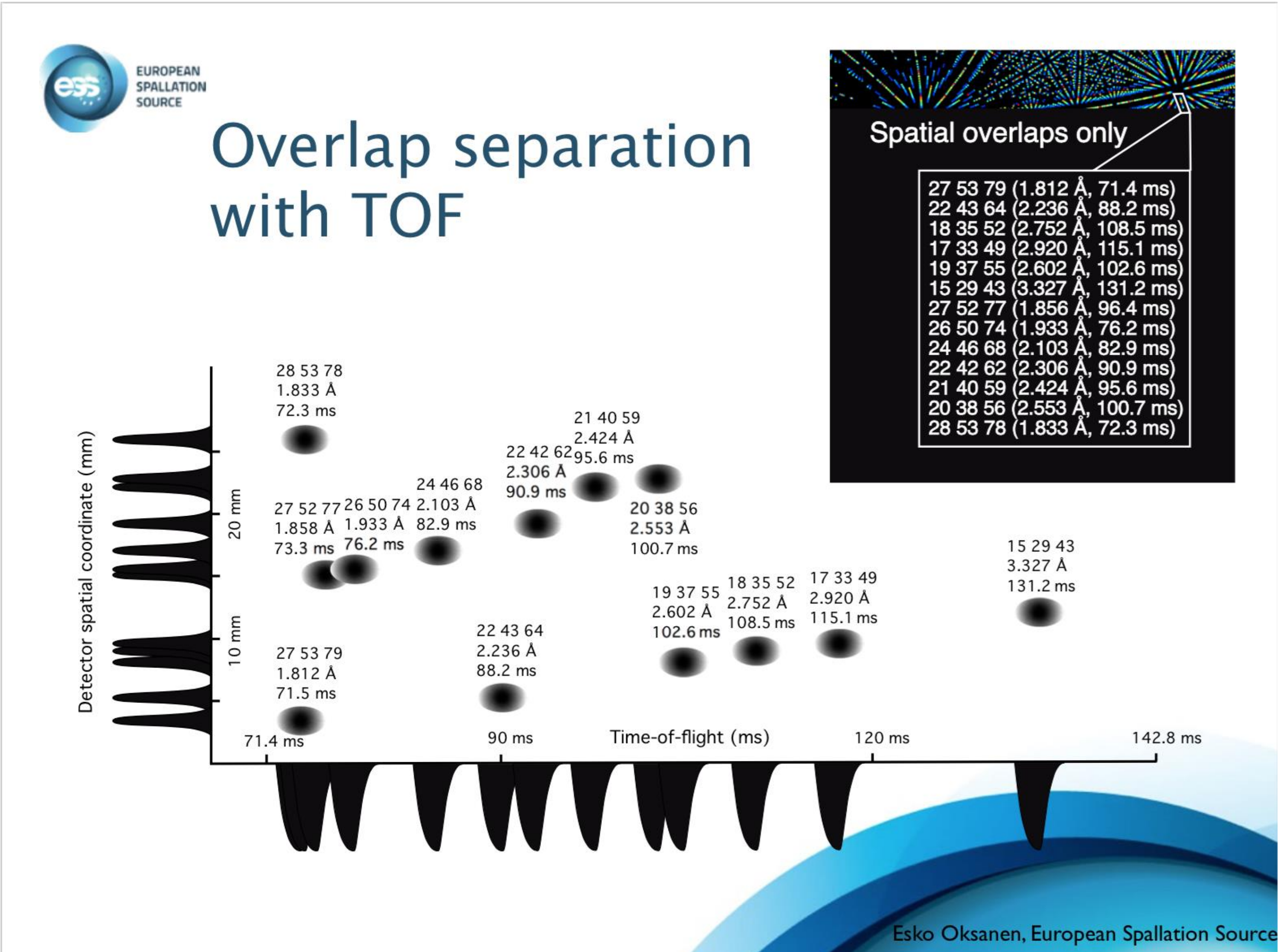


Reflections of example crystal

Bovine heart
cytochrome c oxidase
$P2_12_12_1$
a = 182.59 Å
b = 205.40 Å
c = 178.25 A
Detector distance 1 m

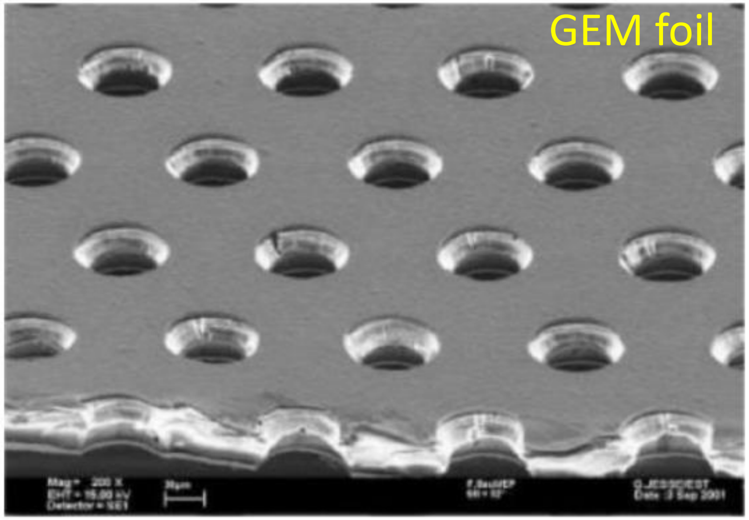


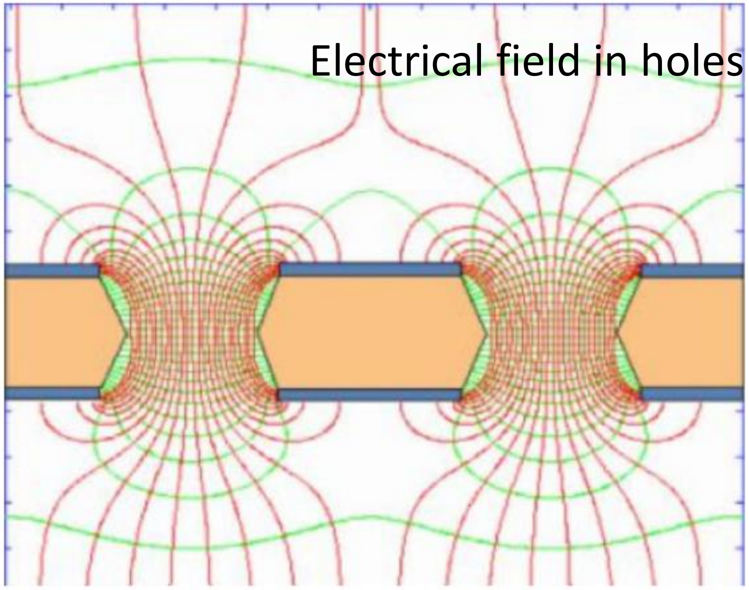
TOF separation of reflections



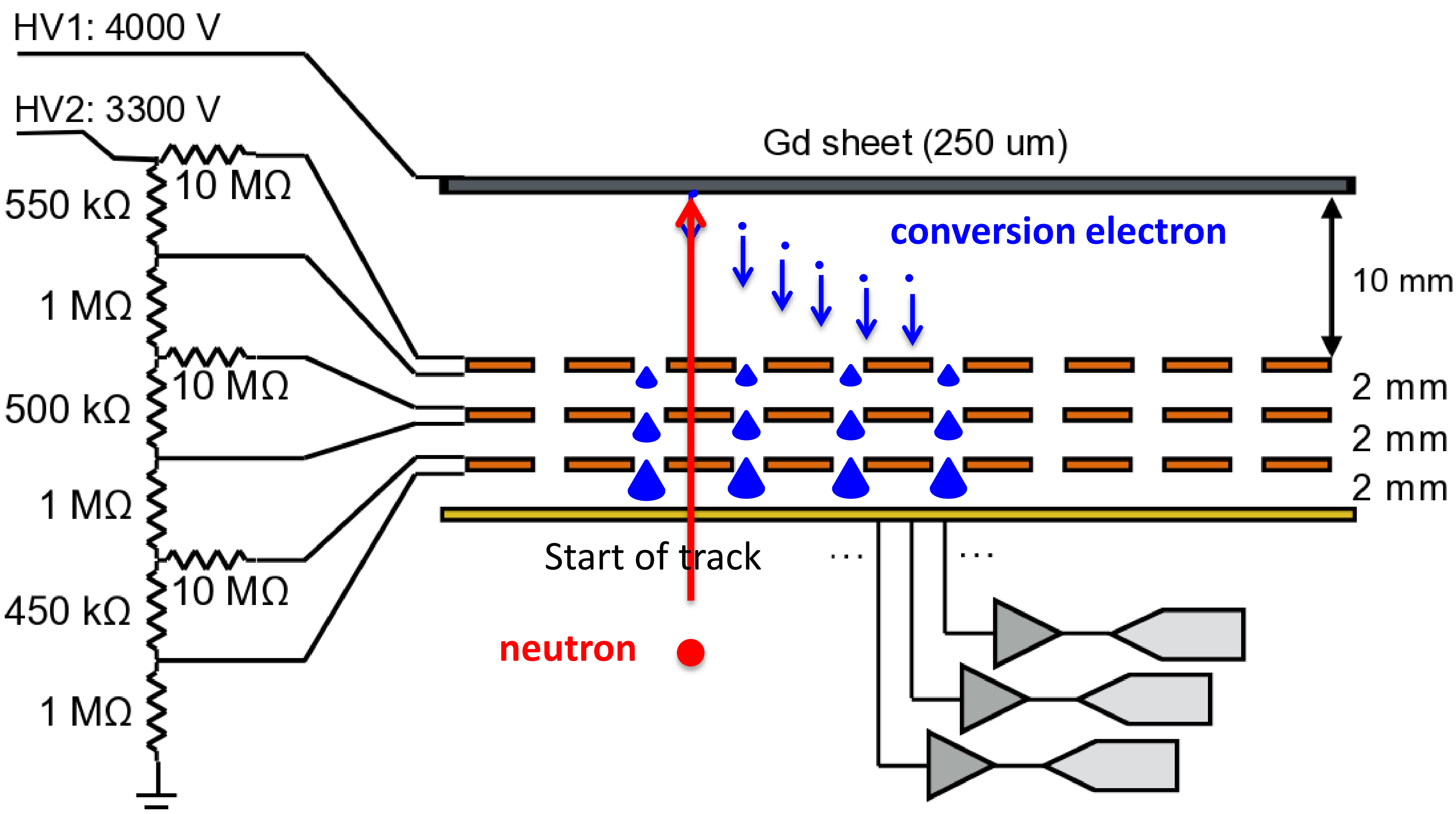
Requirements and challenges

- 200 µm position resolution (beyond state of art for time resolved neutron detectors)
- High rate requirements with up to MHz/cm^2
- High gain stability and count rate stability
- Mechanical robustness (detectors mounted on freely movable robotic arms)
- Reasonable gamma suppression
- Idea: Use GEM detector with Gd converter

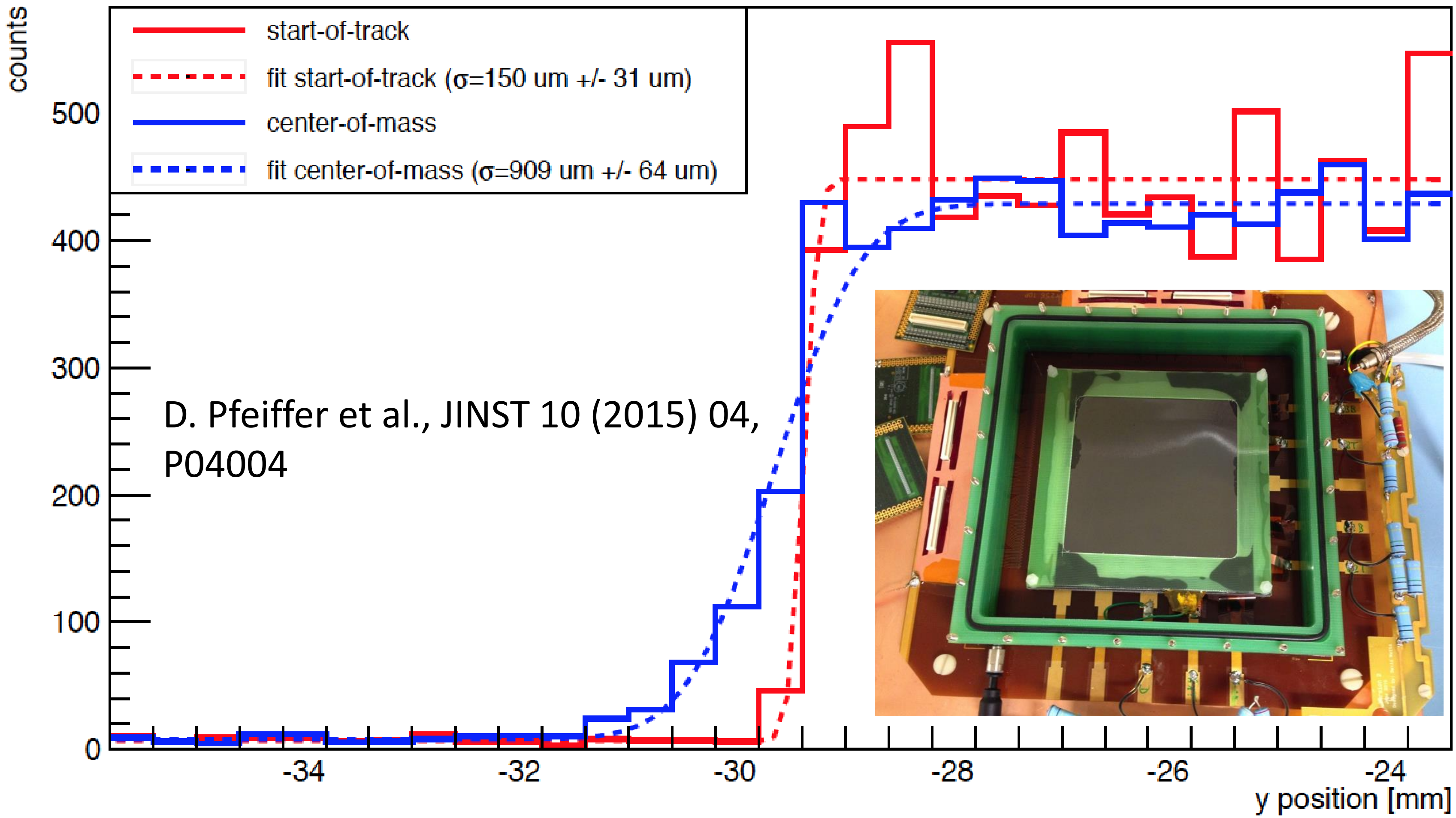




Gd-GEM backwards setup

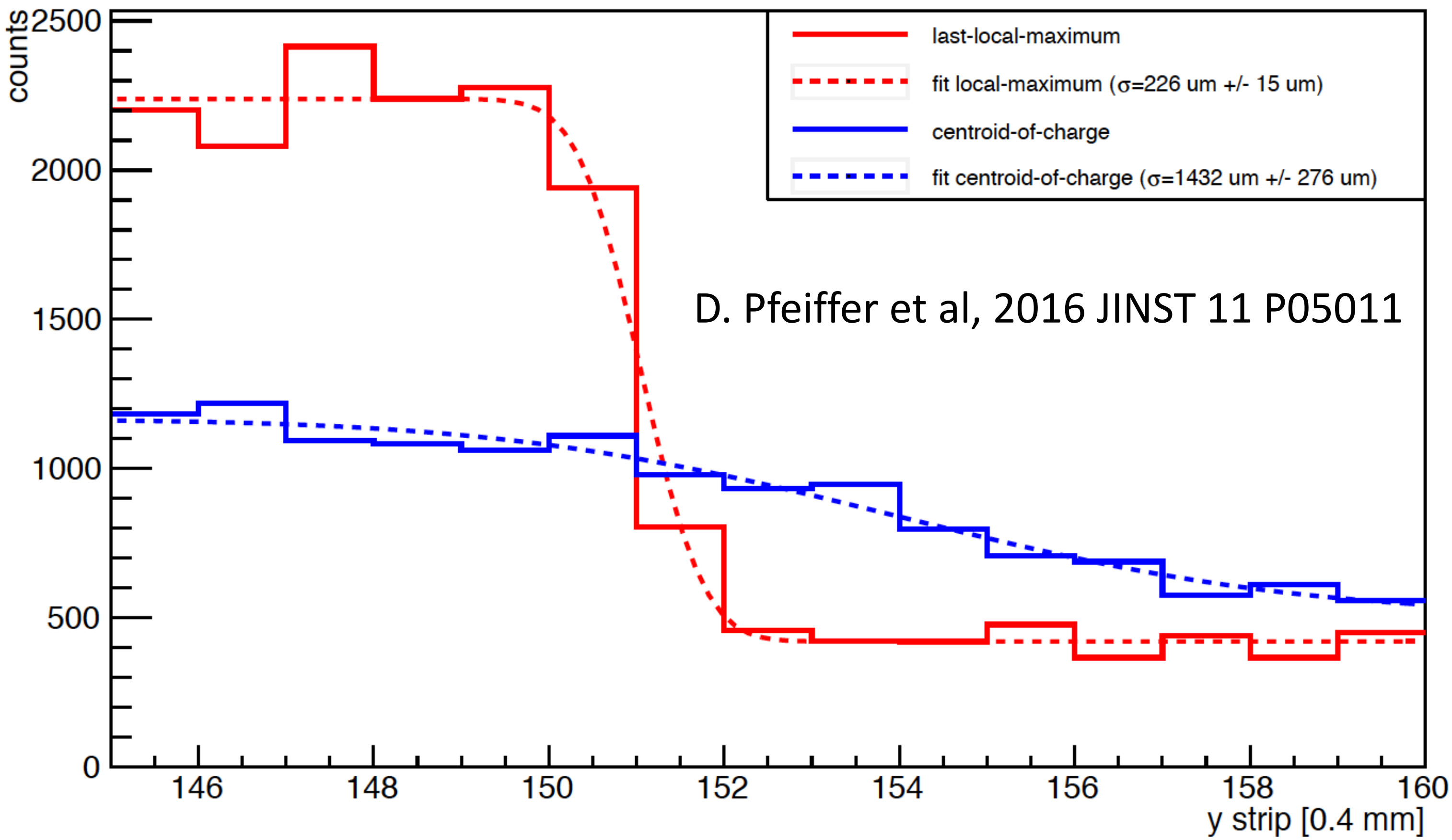


$^{10}B_4C$ GEM µTPC Results



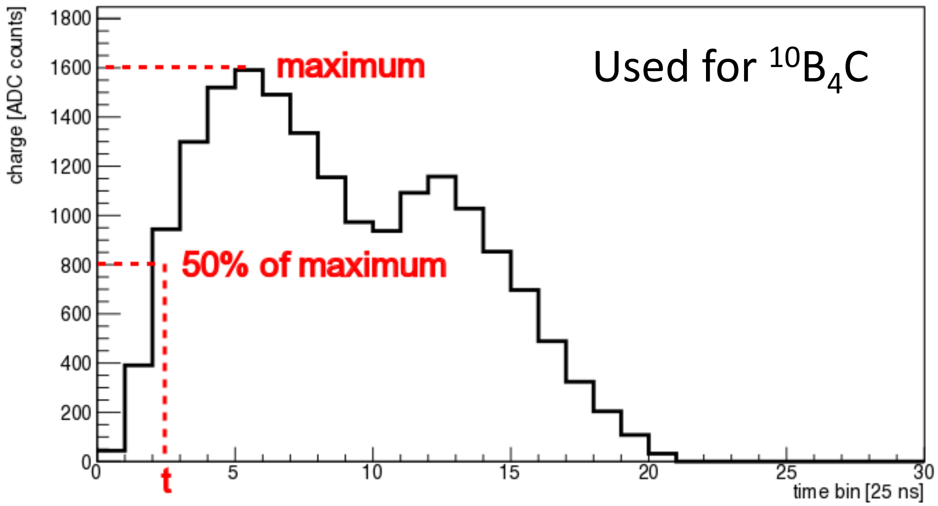
- Pristine position resolution σ <200 µm reached with Single GEM
- Detection efficiency < 5 % at normal incidence of neutron

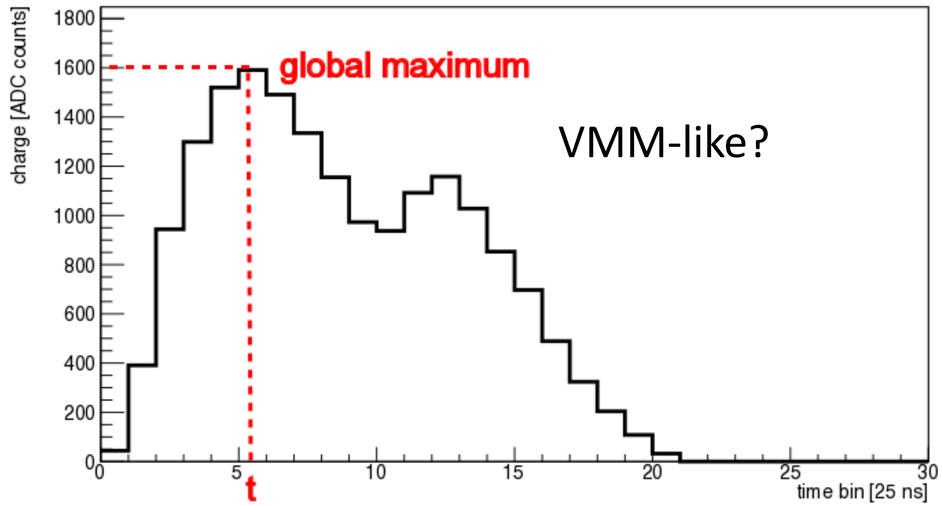
Gd-GEM µTPC Results

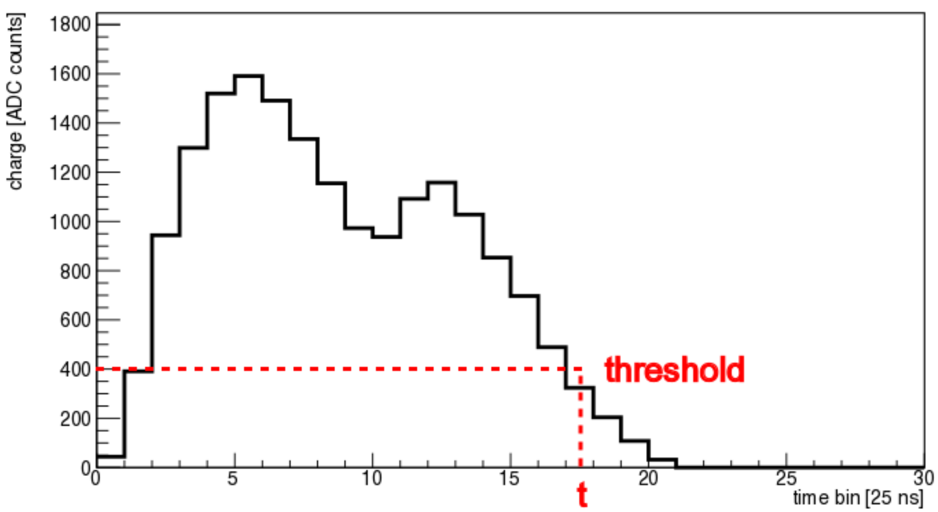


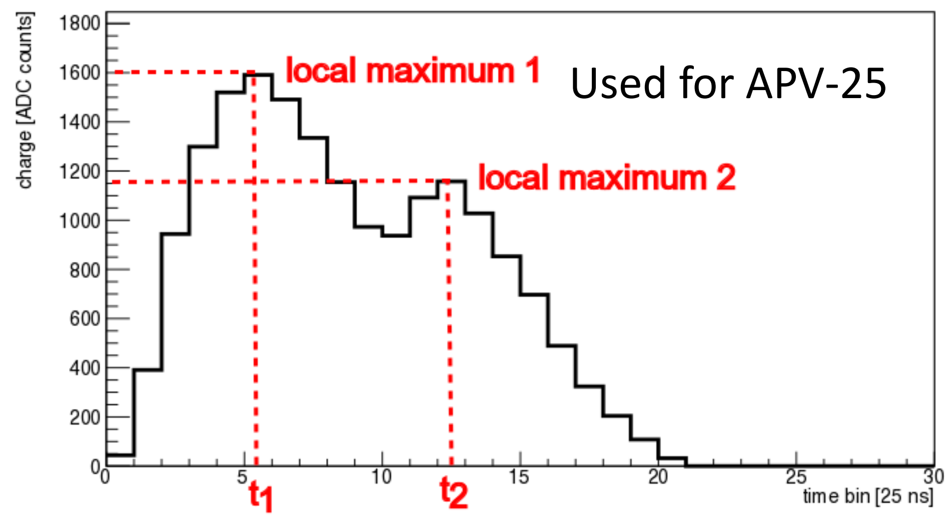
- Position resolution σ <300 µm reached with Triple GEM, APV-25
- Detection efficiency < 12 % at normal incidence of neutron

Better tracking algorithms needed

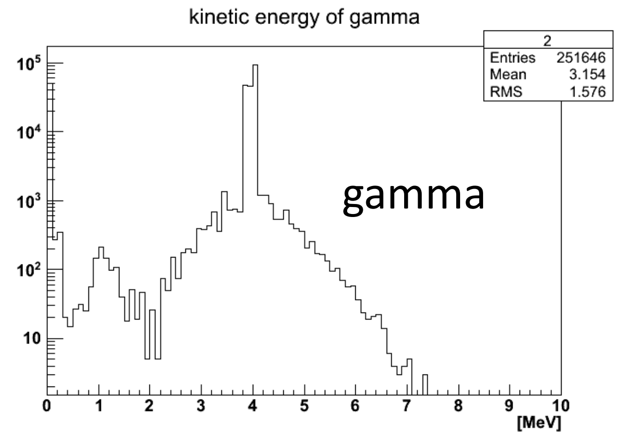




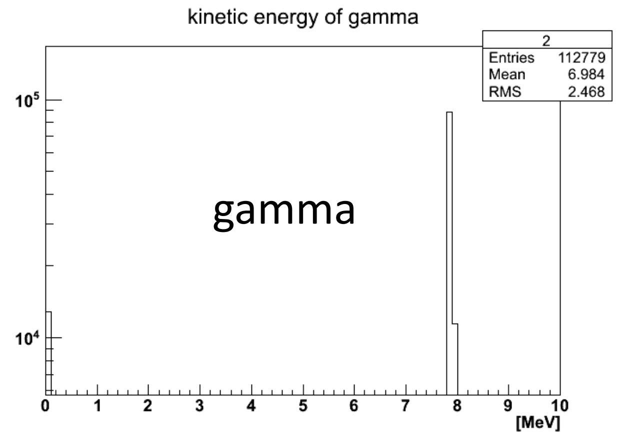




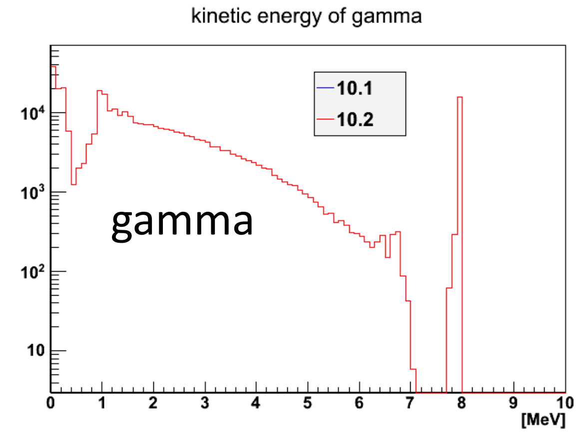
Geant4 Gd simulation problems Getting worse in 10.2.p02



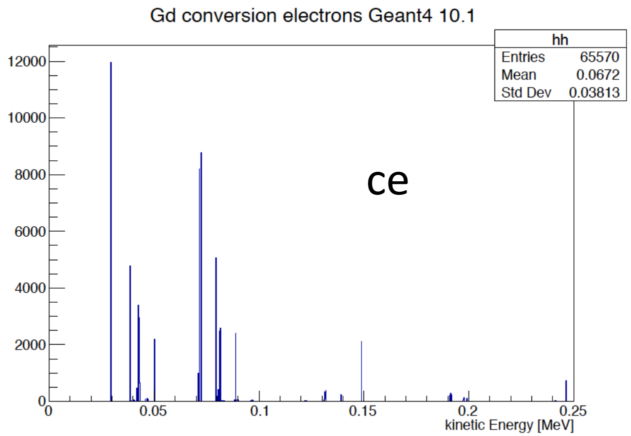
Photon Evaporation 10.1

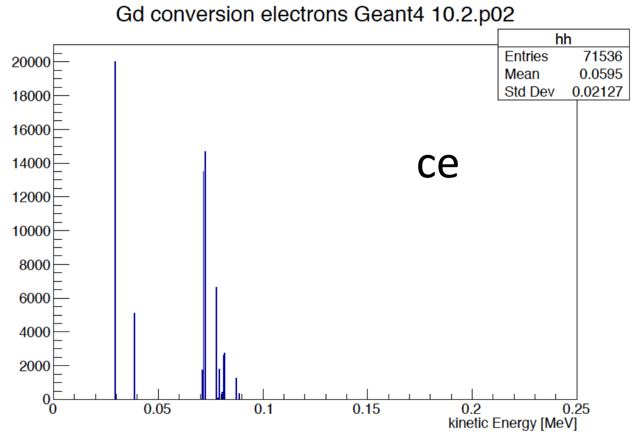


Photon Evaporation 10.2



Without Photon Evaporation





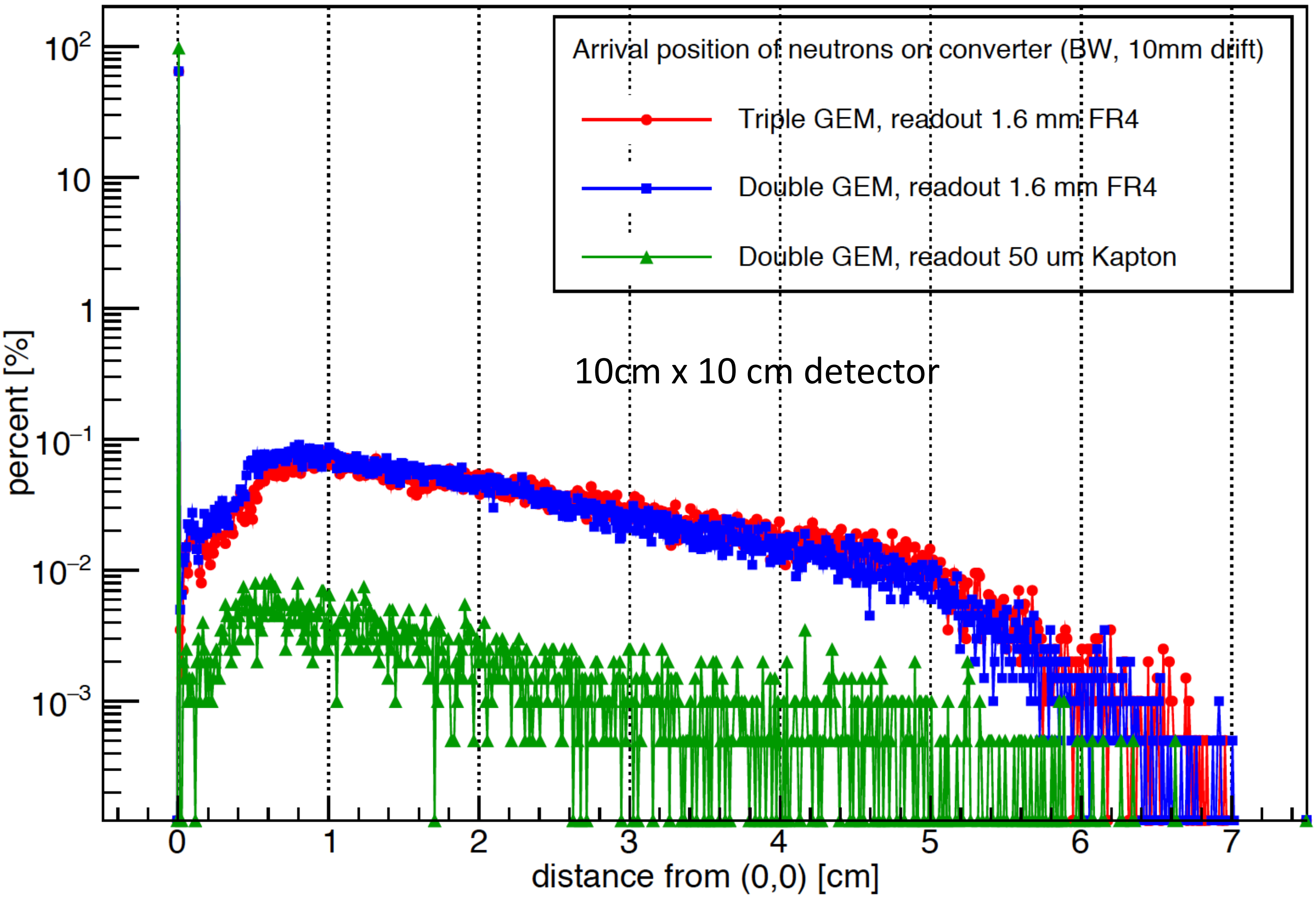
Problems with gamma spectra:
https://zzz.physics.umn.edu/lowrad/_media/meeting8/ychen_gdgammas_aarm2015.pdf

Task division Geant4/Garfield++

EUROPEAN SPALLATION SOURCE

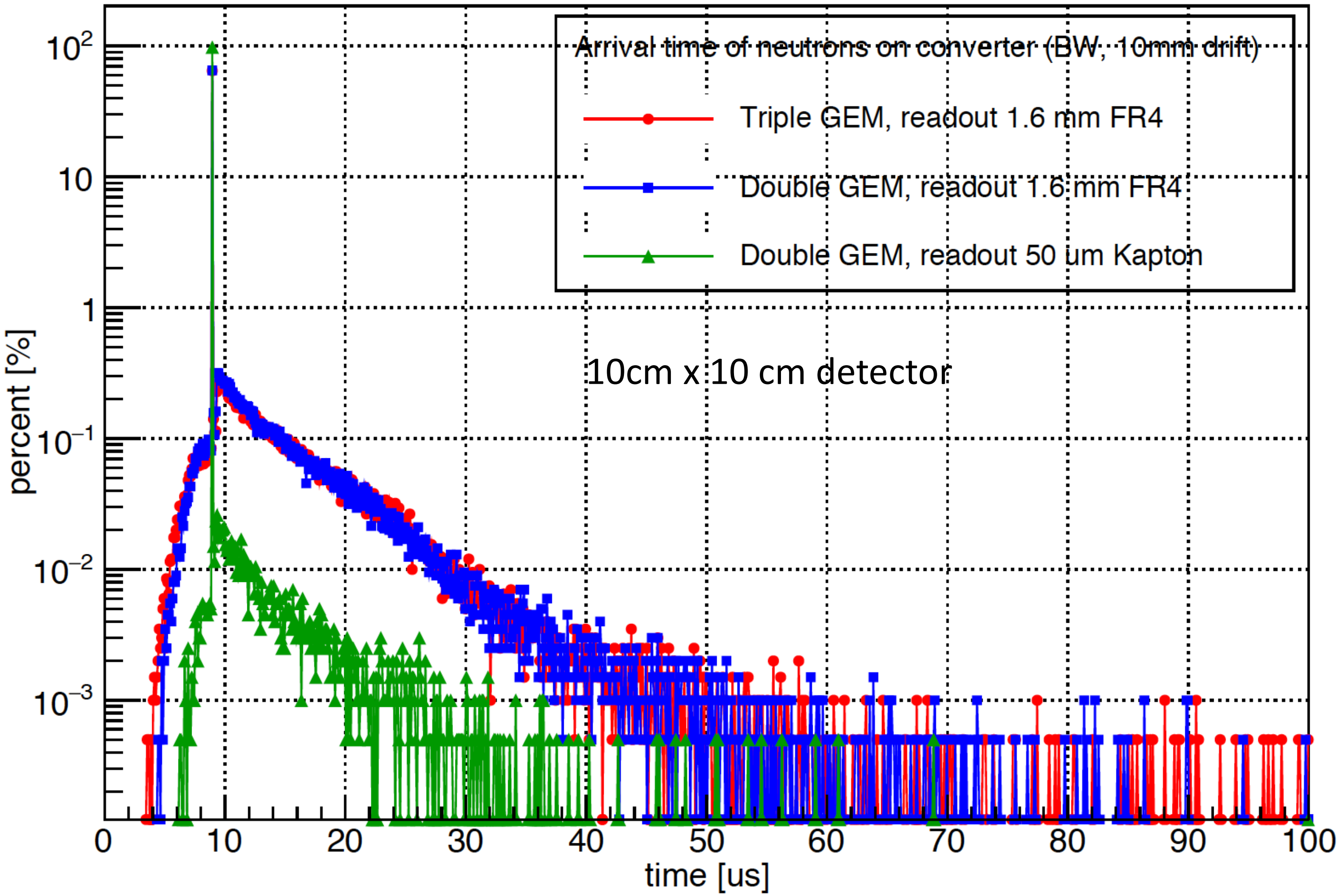
		1a	1b	2
Geant4	Primary particle entering gas	Charged particle	Charged particle	gamma
Geant4	Physics model in Geant4	PAI/PAIPhot Model In gas region	(Standard and low energy EM physics)	(Standard and low energy EM physics)
Geant4	Point of transfer of Control between Geant4/Garfield++	“Kill” secondary e^- produced in gas region in Geant4	“Kill” primary when entering gas region in Geant4	“Kill” gamma when entering gas region in Geant4
Garfield++	TrackHeed Method in Heed/Garfield++	TransportDeltaElectron()	SetParticle() NewTrack()	TransportPhoton()
Garfield++		Garfield++ simulation according to needs		

Arrival position neutron on converter

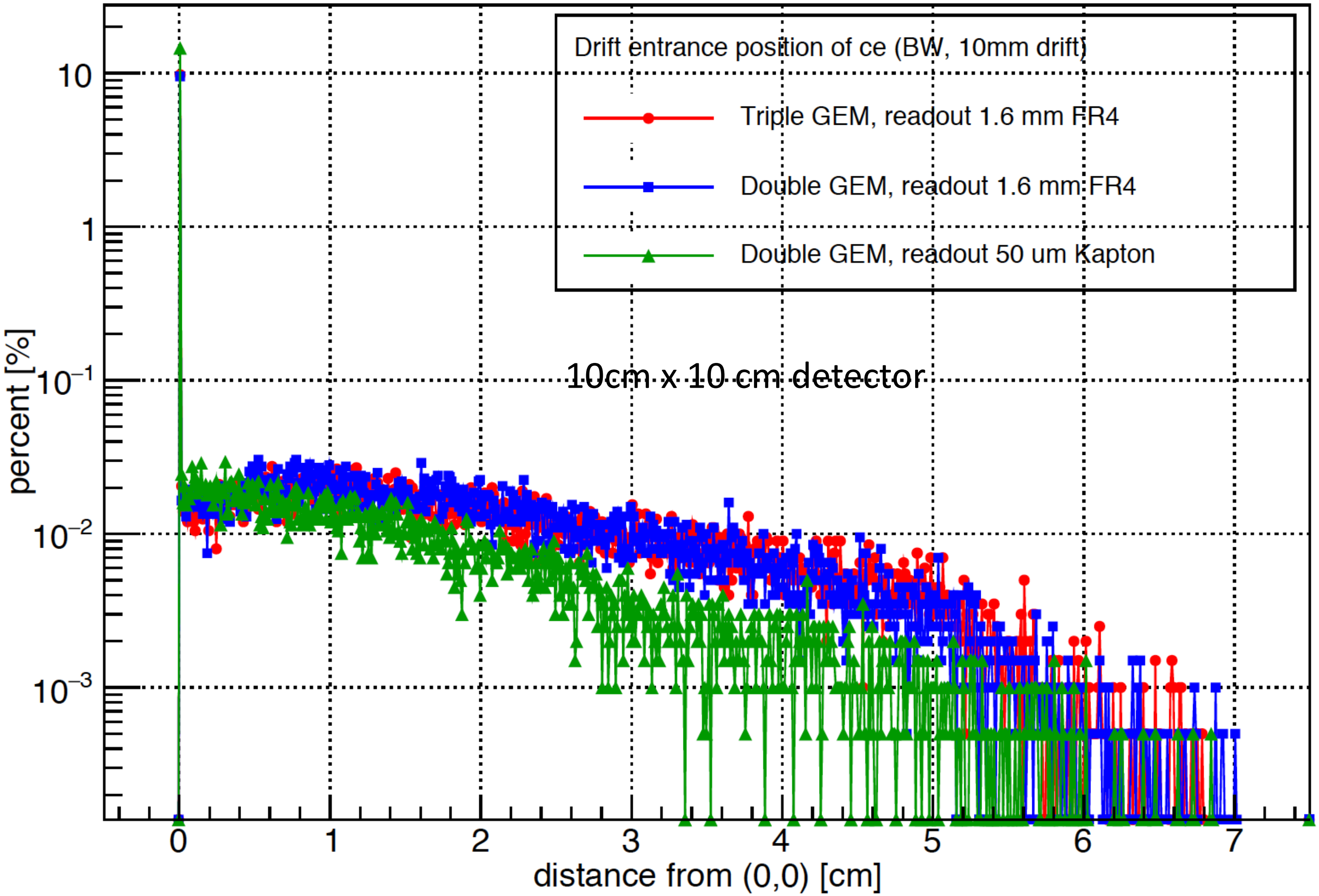


10cm x 10 cm detector

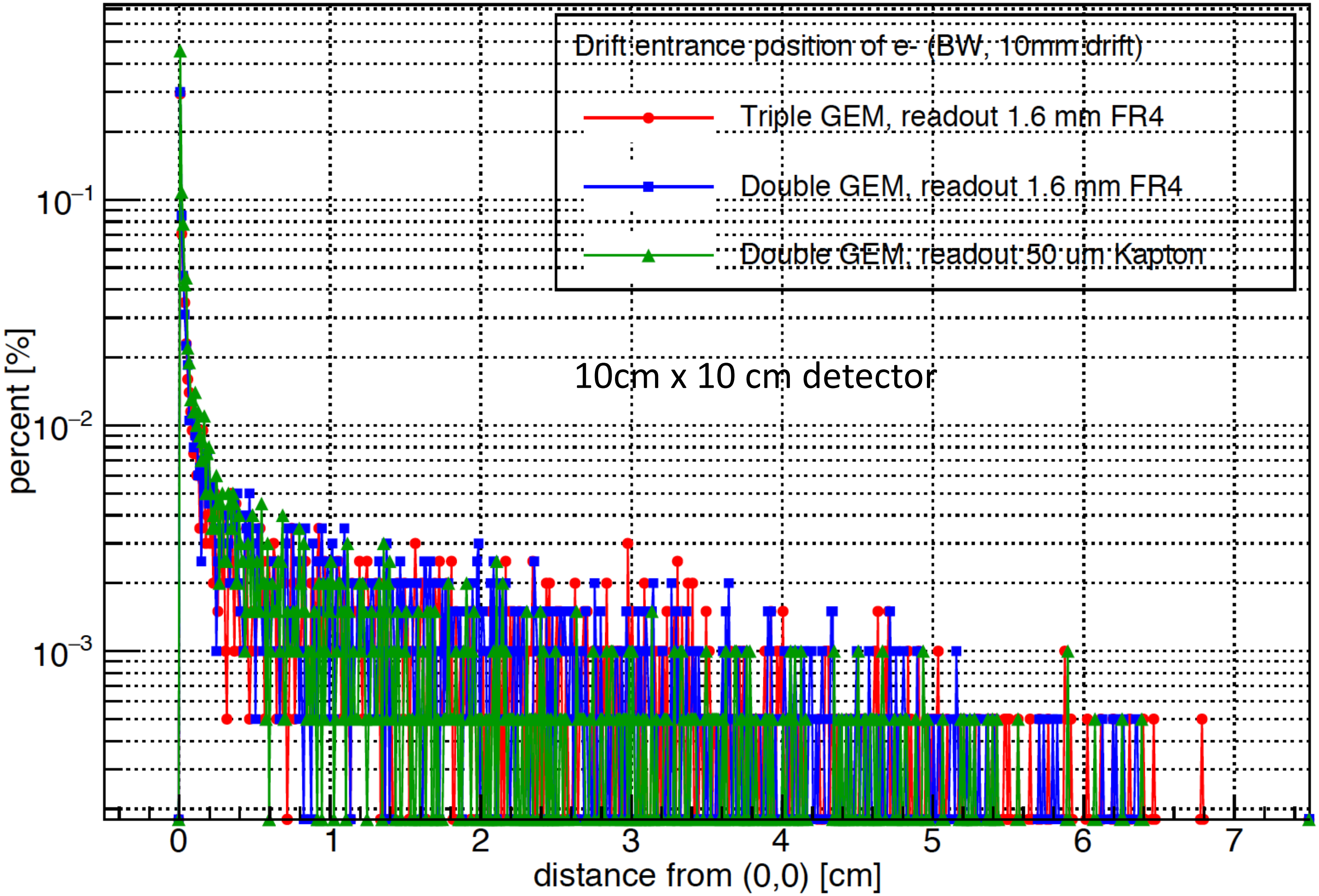
Arrival time neutron on converter



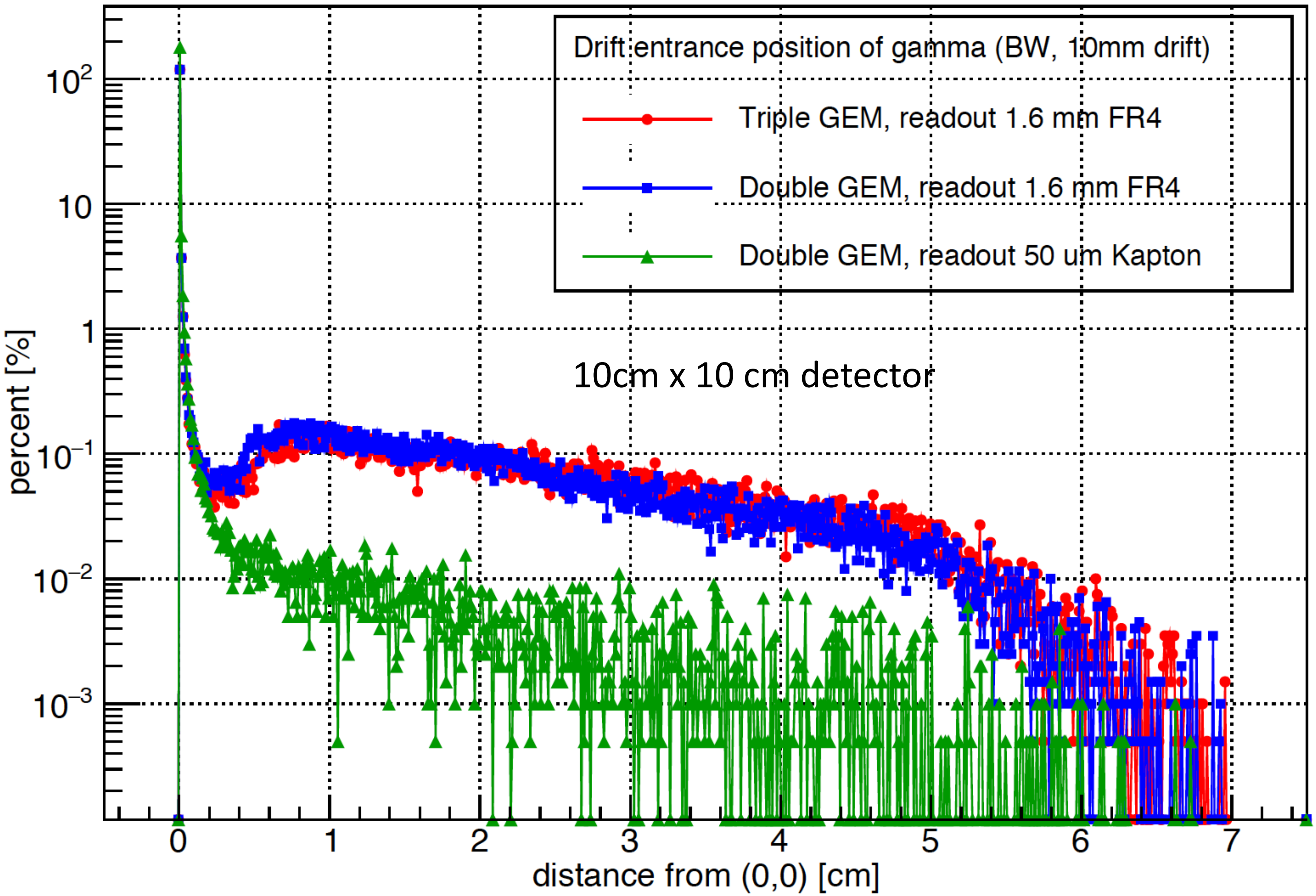
Arrival position ce in drift



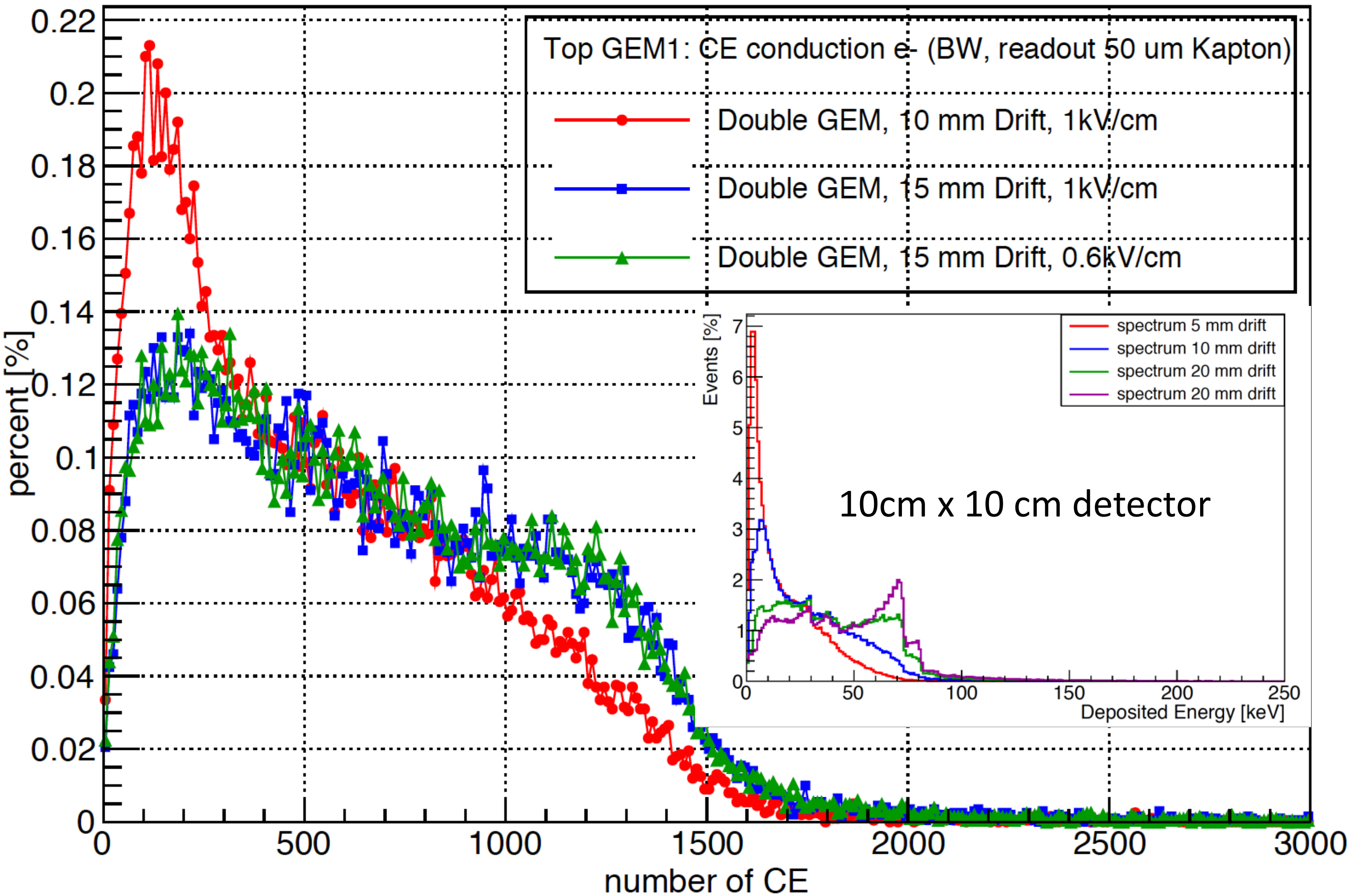
Arrival position Compton e^- in drift



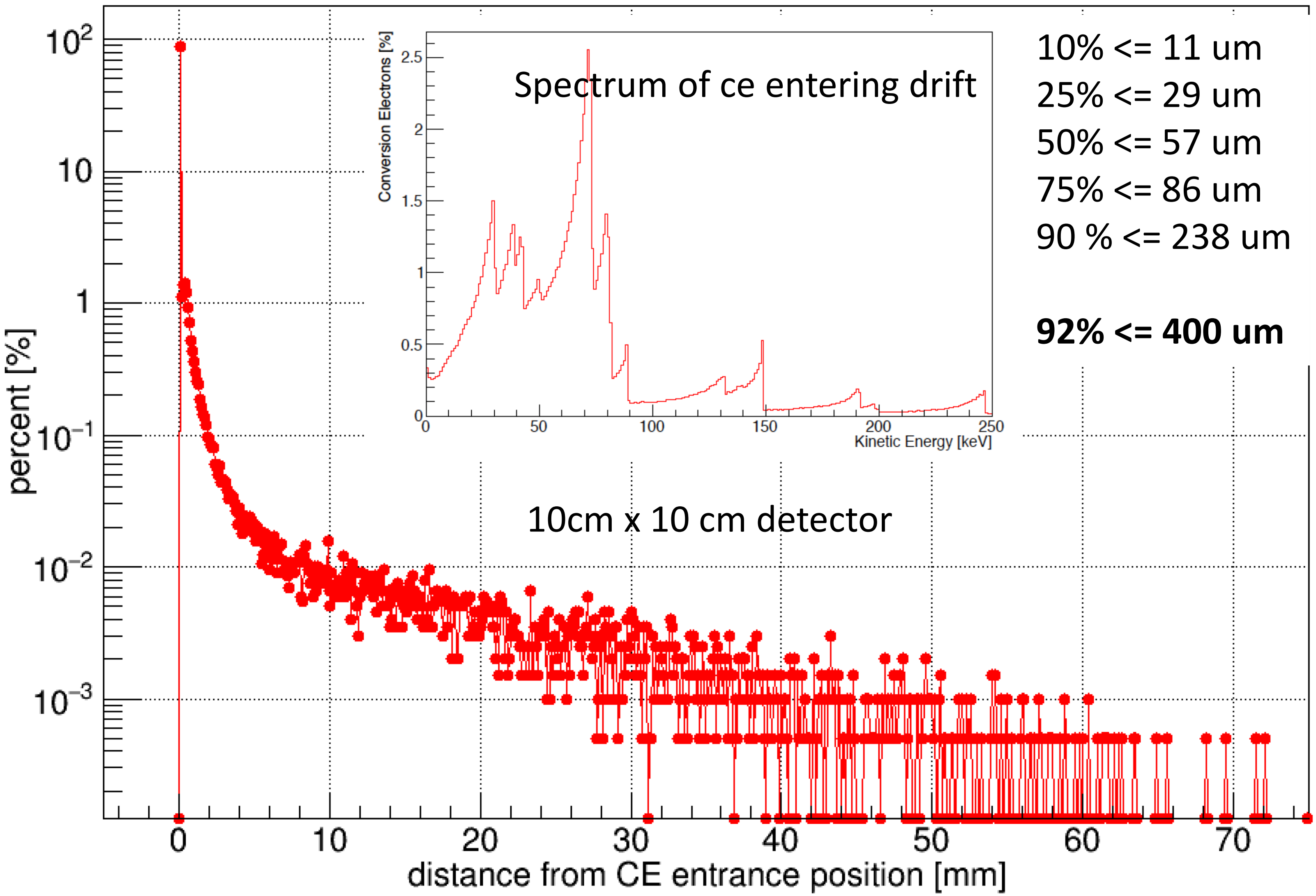
Arrival position gamma in drift



Number of conduction electrons in drift



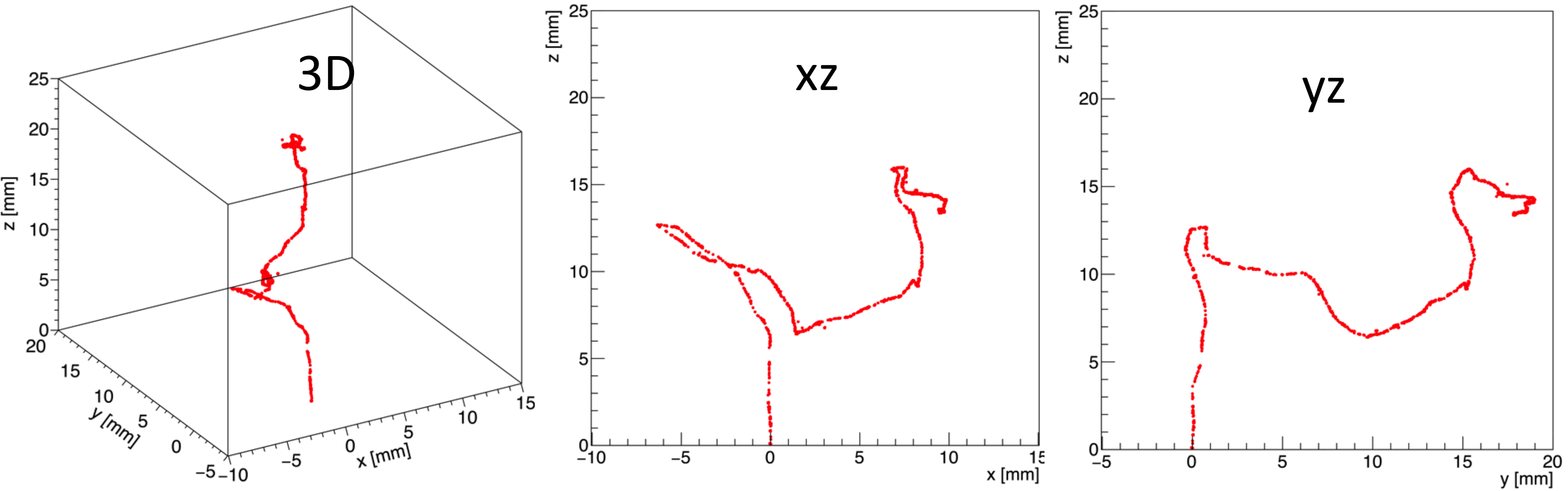
Position of conduction electron that arrives last in time on first GEM



10% <= 11 um
25% <= 29 um
50% <= 57 um
75% <= 86 um
90 % <= 238 um

92% <= 400 um

Degrad Simulations



DEGRAD simulation of 70 keV electron in Ar/CO_2 70/30

DEGRAD by Steve Biagi: http://magboltz.web.cern.ch/magboltz/

- Only Monte Carlo program that incorporates all relevant physics processes for electrons in gas
- Simulations with Geant4/Garfield interface have to be benchmarked against Degrad
- Check of primary ionization distribution in Geant4/Garfield++

Degrad: Obtainable position resolution in um

EUROPEAN SPALLATION SOURCE

keV	10%	25%	50%	75%	90%	< 400 um
10	1	3	7	115	600	83%
20	1	3	8	32	1638	78%
30	1	3	8	380	3473	75%
40	1	3	8	265	5921	75%
50	1	3	8	122	8076	76%
60	1	3	7	26	9809	79%
70	1	2	7	21	12788	82%
80	1	3	6	15	7306	87%
90	0	2	7	15	437	89%
100	0	2	6	13	53	91%
110	0	2	6	13	57	92%
120	0	2	6	11	25	94%
130	0	2	6	12	29	95%
140	0	2	5	11	23	97%
150	0	2	6	11	24	96%
160	0	2	5	11	21	98%
170	0	2	5	10	20	98%
180	0	2	5	11	21	98%
190	0	2	6	12	20	98%
200	0	2	5	11	22	98%

Infinite volume

- The (x,y) position of the electron with the smallest z position was taken
- 2-25% of tracks turn back depending on energy
- No drift and diffusion

Summary

- Scattering of neutron considerably deteriorates position resolution
- Two GEM foils instead of three and low material budget readout lead to major improvement
- The position where the conversion electron enters the drift can be reconstructed with <= 400 um precision for ca 90% of all conversion (without diffusion from amplification)
- **Announcements from Stephen: New Magboltz version 11 is out, includes better simulation of molecular light emission by using the null collision technique**
- **New Degrad 3.1 before Xmas will inlcude C2H6 update**