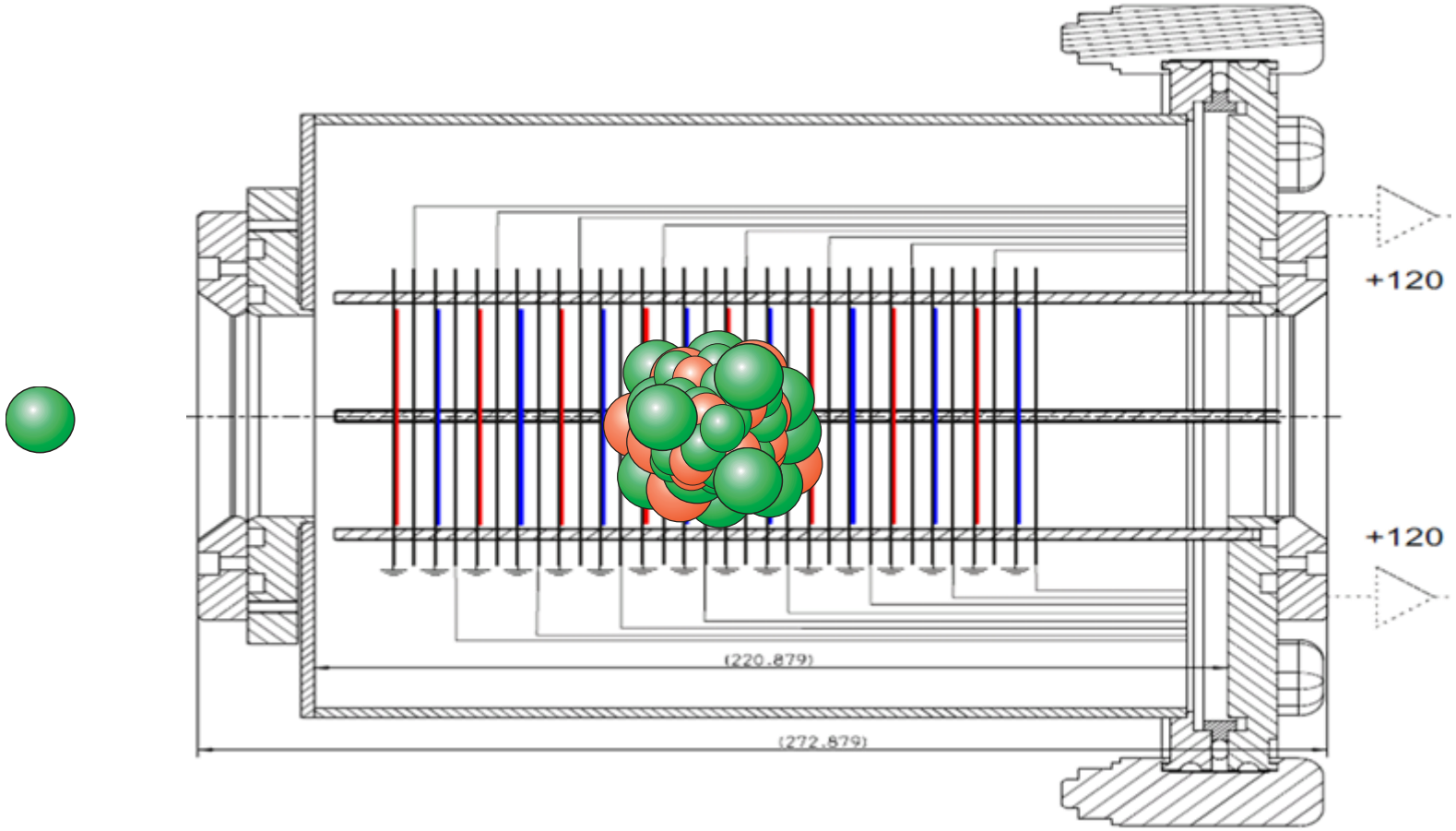


The nELBE (n,fis) experiment

Simulations related to actinide fission chambers

Data needs for ADS

http://nextbigfuture.com/2012/01/first-for-accelerator-driven-nuclear.html

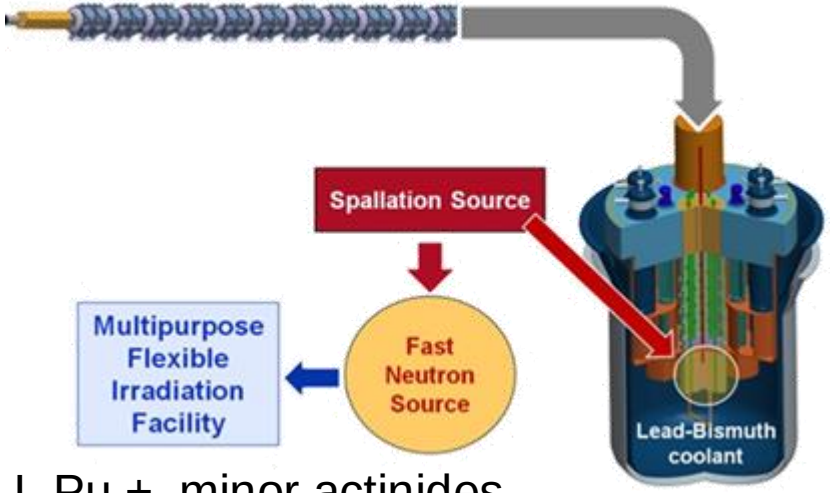


Table 32. Summary of Highest Priority Target Accuracies for Fast Reactors

		Energy Range	Current Accuracy (%)	Target Accuracy (%)
U238	σ_{inel}	6.07 ÷ 0.498 MeV	10 ÷ 20	2 ÷ 3
	σ_{capt}	24.8 ÷ 2.04 keV	3 ÷ 9	1.5 ÷ 2
Pu241	σ_{fiss}	1.35MeV ÷ 454 eV	8 ÷ 20	2 ÷ 3 (SFR,GFR, LFR) 5 ÷ 8 (ABTR, EFR)
Pu239	σ_{capt}	498 ÷ 2.04 keV	7 ÷ 15	4 ÷ 7
Pu240	σ_{fiss}	1.35 ÷ 0.498 MeV	6	1.5 ÷ 2
	ν	1.35 ÷ 0.498 MeV	4	1 ÷ 3
Pu242	σ_{fiss}	2.23 ÷ 0.498 MeV	19 ÷ 21	3 ÷ 5
Pu238	σ_{fiss}	1.35 ÷ 0.183 MeV	17	3 ÷ 5
Am242m	σ_{fiss}	1.35MeV ÷ 67.4keV	17	3 ÷ 4
Am241	σ_{fiss}	6.07 ÷ 2.23 MeV	12	3
Cm244	σ_{fiss}	1.35 ÷ 0.498 MeV	50	5
Cm245	σ_{fiss}	183 ÷ 67.4 keV	47	7
Fe56	σ_{inel}	2.23 ÷ 0.498 MeV	16 ÷ 25	3 ÷ 6
Na23	σ_{inel}	1.35 ÷ 0.498 MeV	28	4 ÷ 10
Pb206	σ_{inel}	2.23 ÷ 1.35 MeV	14	3
Pb207	σ_{inel}	1.35 ÷ 0.498 MeV	11	3
Si28	σ_{inel}	6.07 ÷ 1.35 MeV	14 ÷ 50	3 ÷ 6
	σ_{capt}	19.6 ÷ 6.07 MeV	53	6

➔ U, Pu + minor actinides structural & coolant materials

- neutron induced fission of:
  - ^{235}U (reference)
  - ^{242}Pu
  - (^{241}Am)

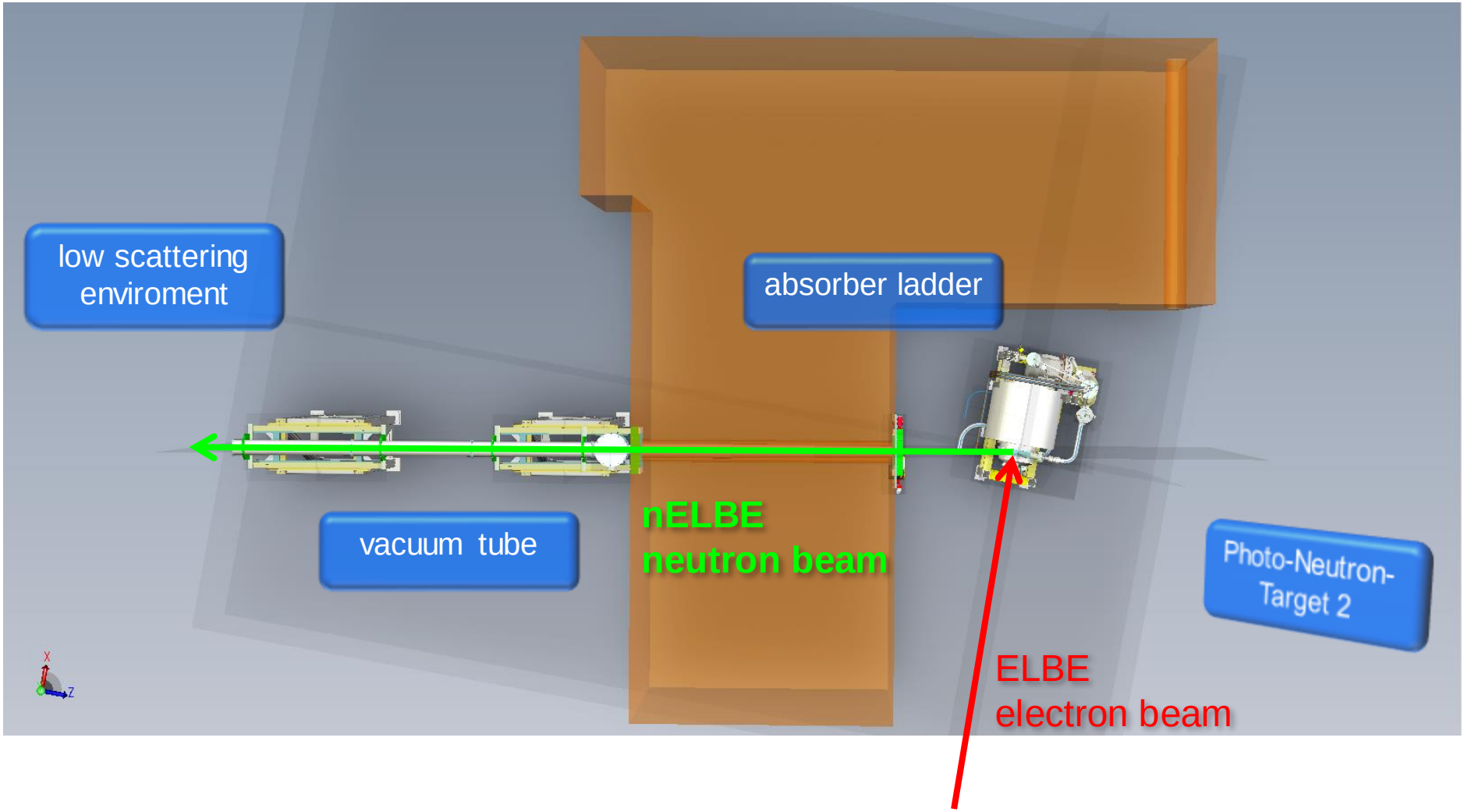
\+ flux determination of nELBE experiments

➔ construction of a parallel plate fission ionization chamber for nELBE

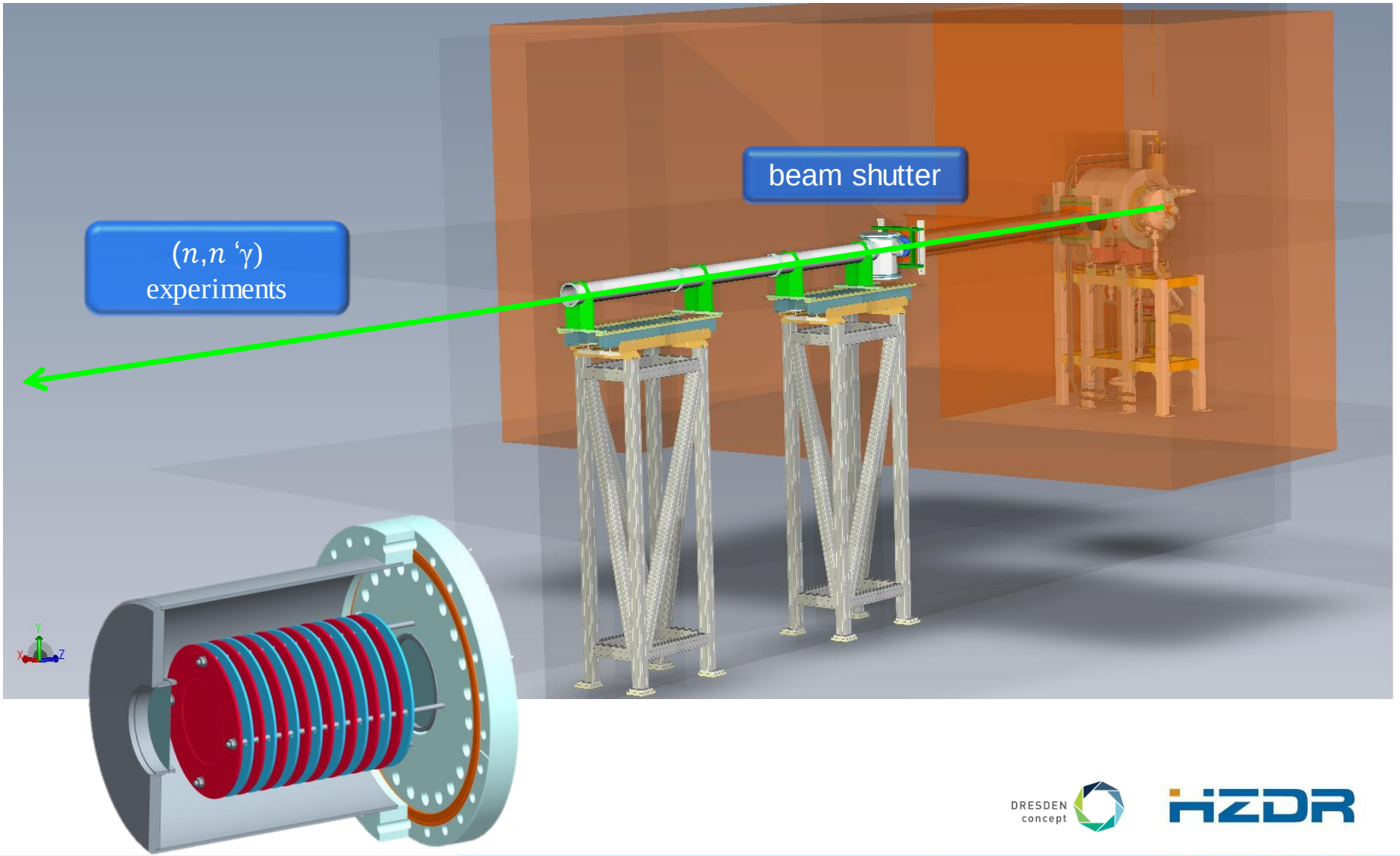
➔ $^{56}Fe\ (n,n'\gamma)^{56}Fe$

http://www.nea.fr/html/science/wpec/volume26/volume26.pdf
and the NEA High Priority Request List

The new nELBE beamline



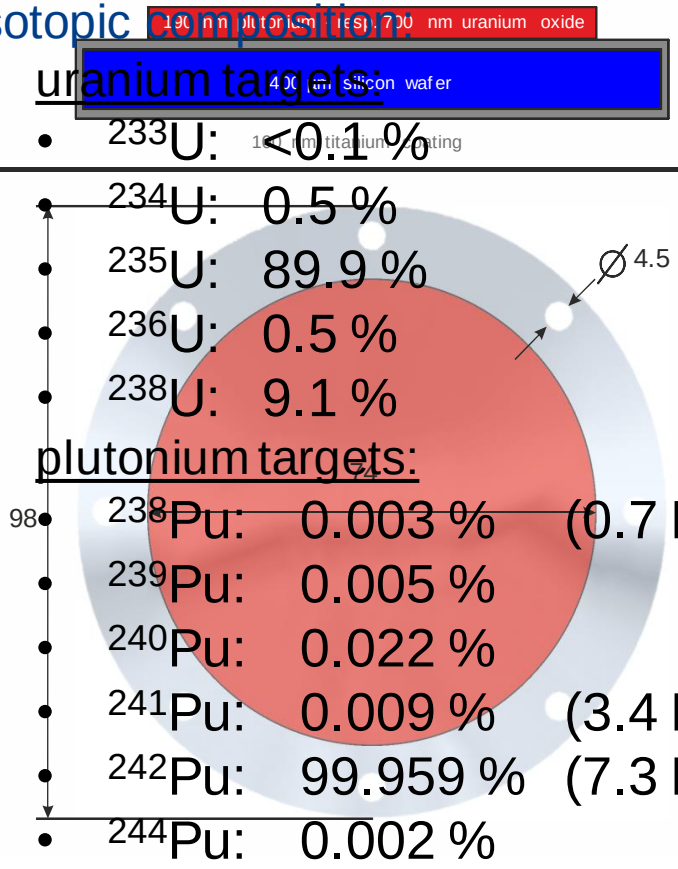
The new nELBE beamline



Properties of the nELBE targets

- production @ Institute of Radiochemistry JGU Mainz (A. Vascon & K. Eberhardt)
- deposition of target material on silicon wafer via „molecular plating“

Isotopic composition:



uranium targets:

- ^{233}U: <0.1 %
- ^{234}U: 0.5 %
- ^{235}U: 89.9 %
- ^{236}U: 0.5 %
- ^{238}U: 9.1 %

plutonium targets:

- ^{238}Pu: 0.003 % (0.7 MBq)
- ^{239}Pu: 0.005 %
- ^{240}Pu: 0.022 %
- ^{241}Pu: 0.009 % (3.4 MBq)
- ^{242}Pu: 99.959 % (7.3 MBq)
- ^{244}Pu: 0.002 %

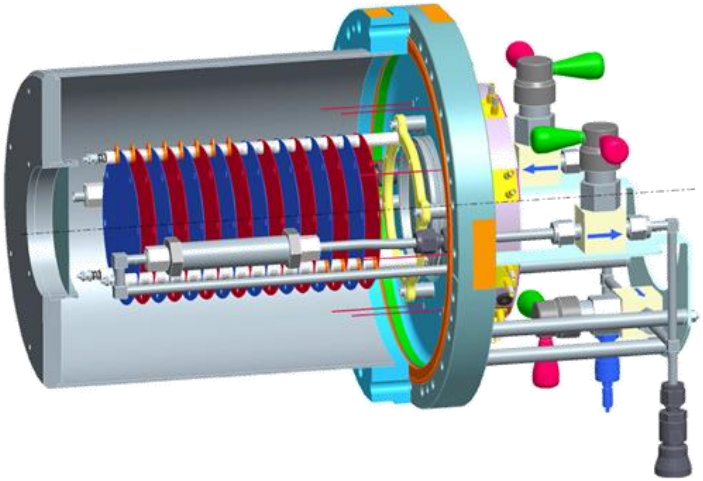
backing:

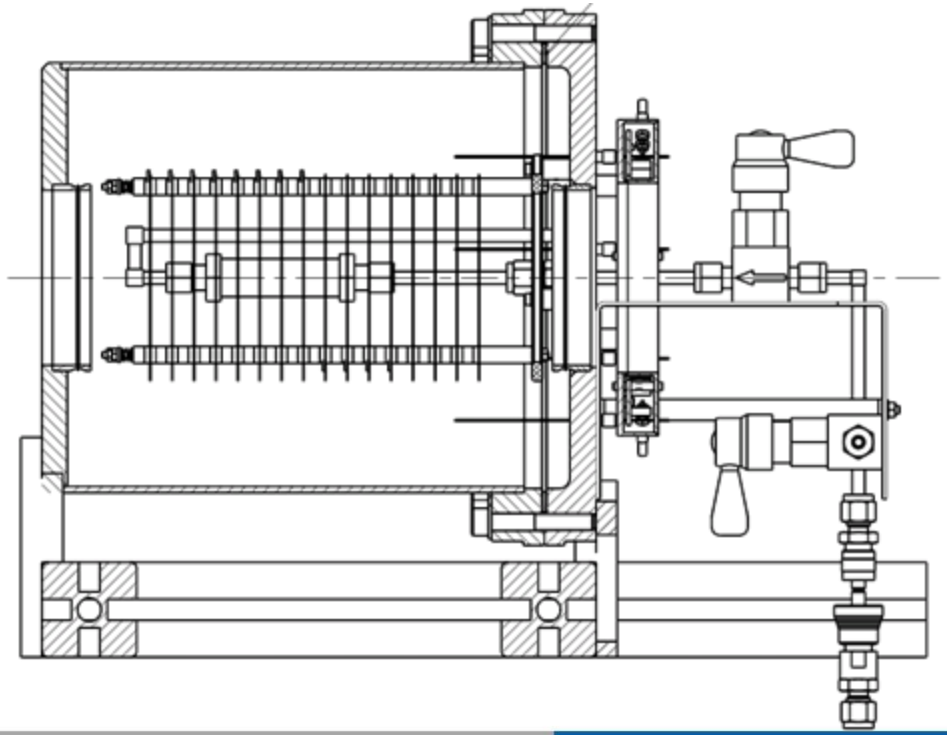
- 400 µm Si-wafer
- 100 nm Ti-coating

deposits:

- ^{235}U-Targets:
  - $m_{tot} = 200$ mg (8 backings)
  - $A_{tot} = 270$ kBq
- ^{242}Pu-Targets:
  - $m_{tot} = 50$ mg (8 backings)
  - $A_{tot} = 12$ MBq

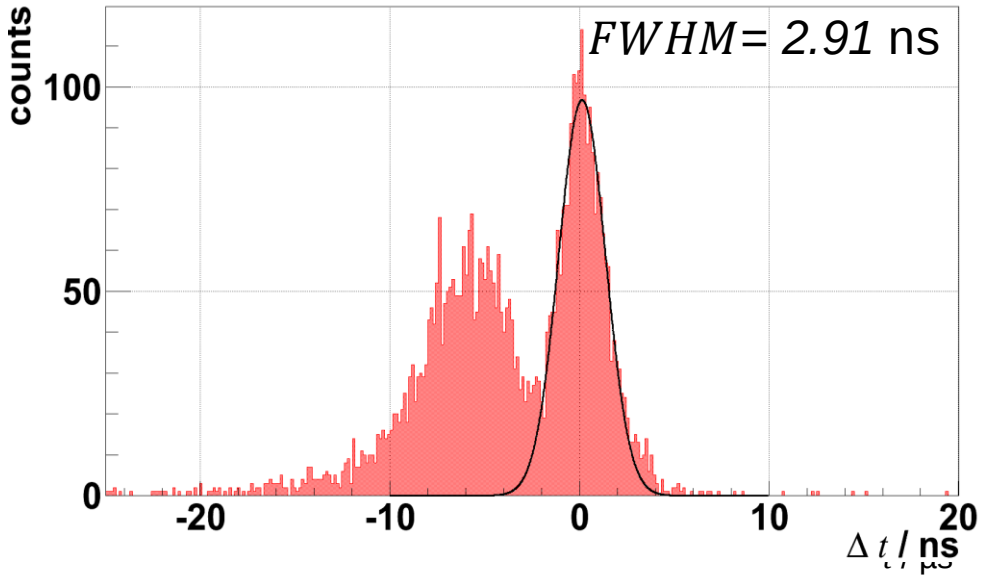
Design of the fission chamber



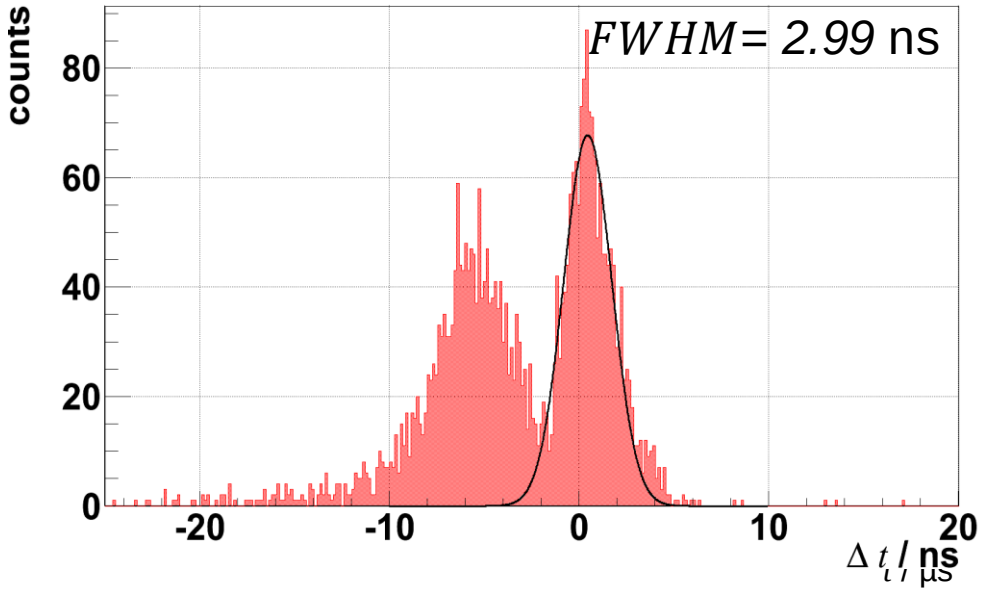


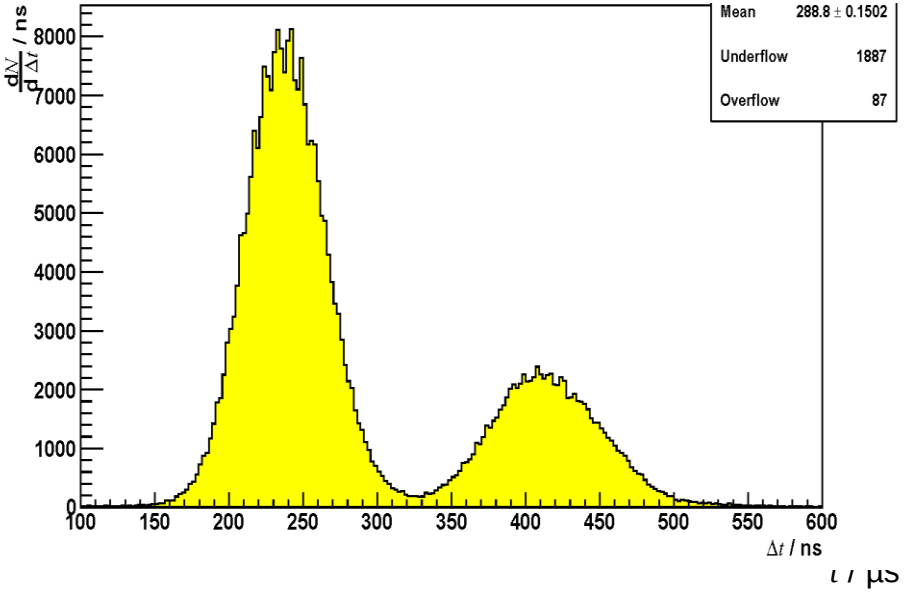
- Vacuum sealed ionization chamber with parallel arranged minor actinides (^{235}Uran and ^{242}Pu)
- Challenge: 50 mg ^{242}Pu produce an α-activity of $\approx$12 MBq distributed on 8 targets → separate readout necessary
- use of fast pre-amplifiers (development of HZDR) + digital DAQ to reduce pile-up

Design of the fission chamber

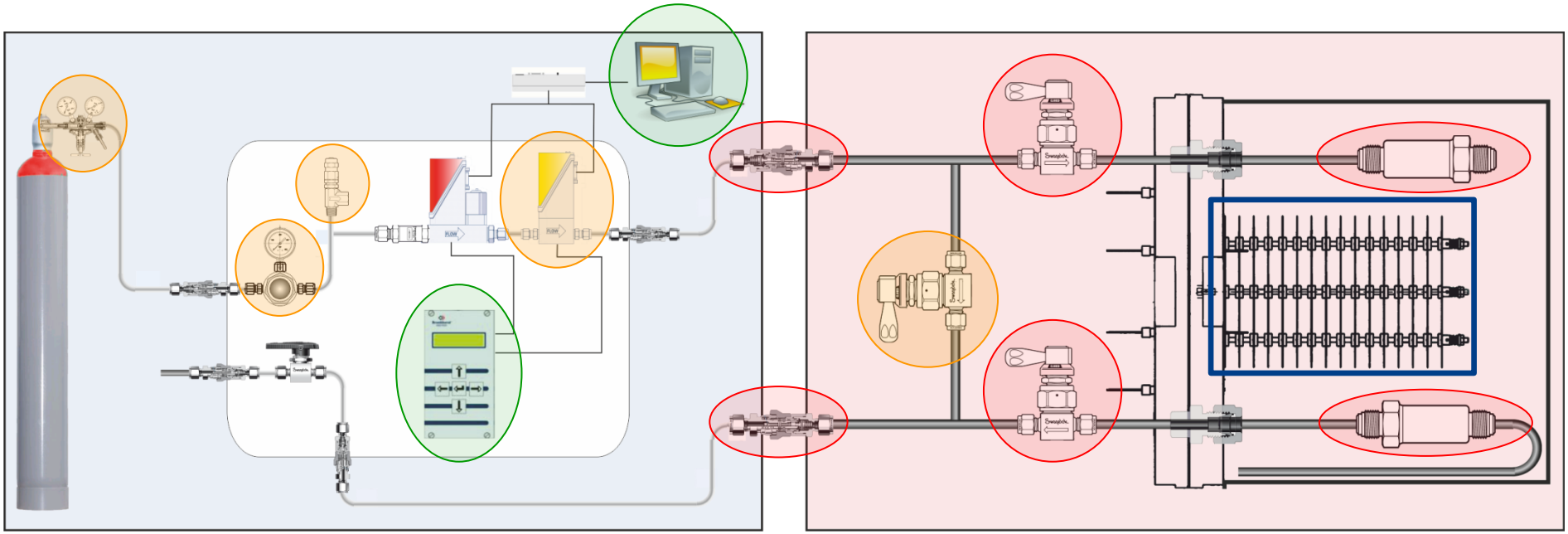


- Vacuum sealed ionization chamber with parallel arranged minor actinides (^{235}Uran and ^{242}Pu)
- Challenge: 50 mg ^{242}Pu produce a α-activity of ≈12 MBq distributed on 8 targets → separate readout necessary
- use of fast pre-amplifiers (development of HZDR) + digital DAQ to reduce pile-up
- fast working gas Ar+CH_4 (P10)





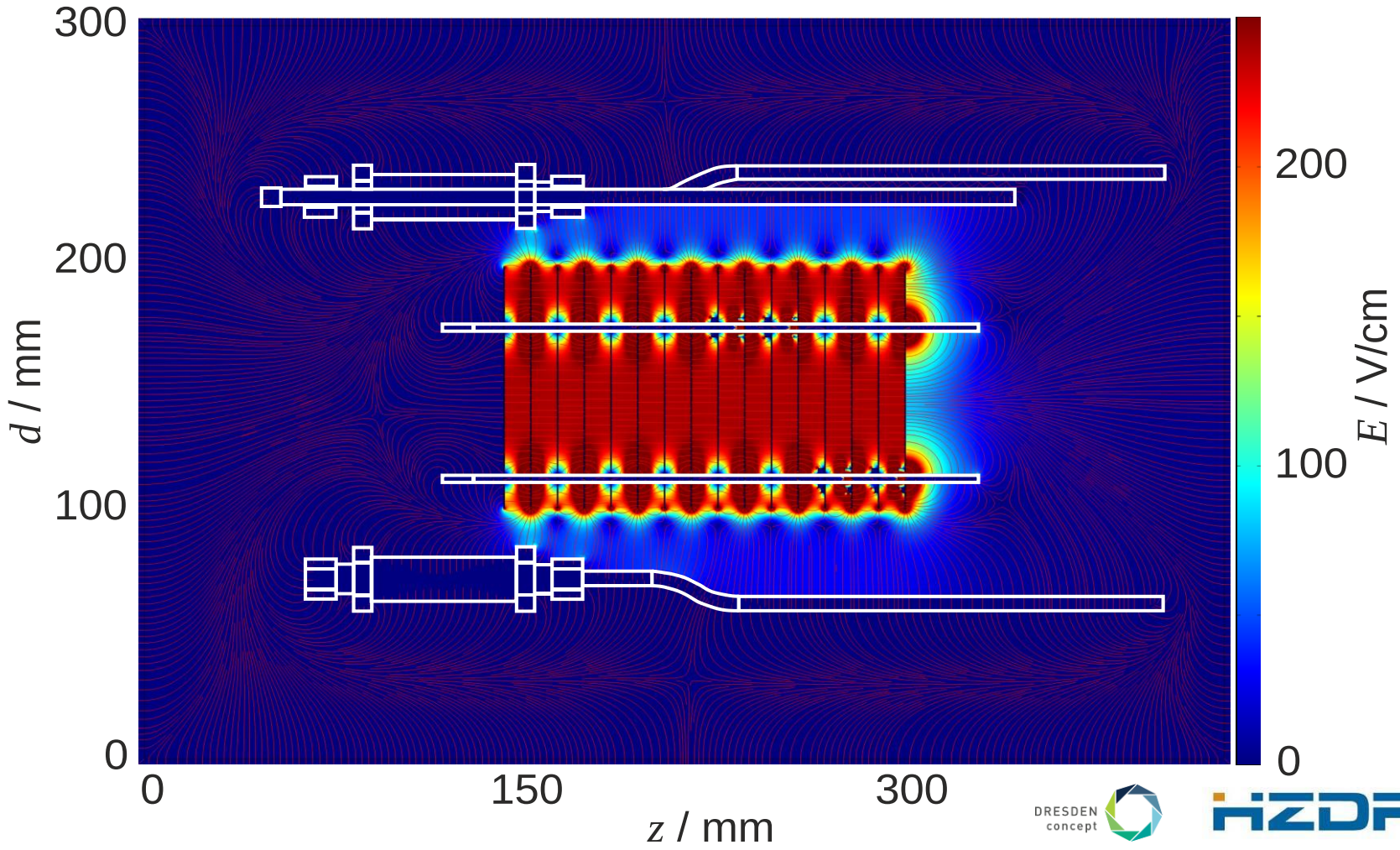
Safety and gas support



- protect against:
  - degradation of signals due to oxygen and water in counting gas
  - oxidation of fission deposits
  - leakage of radioactive material
  - overpressure
- remote control / monitoring

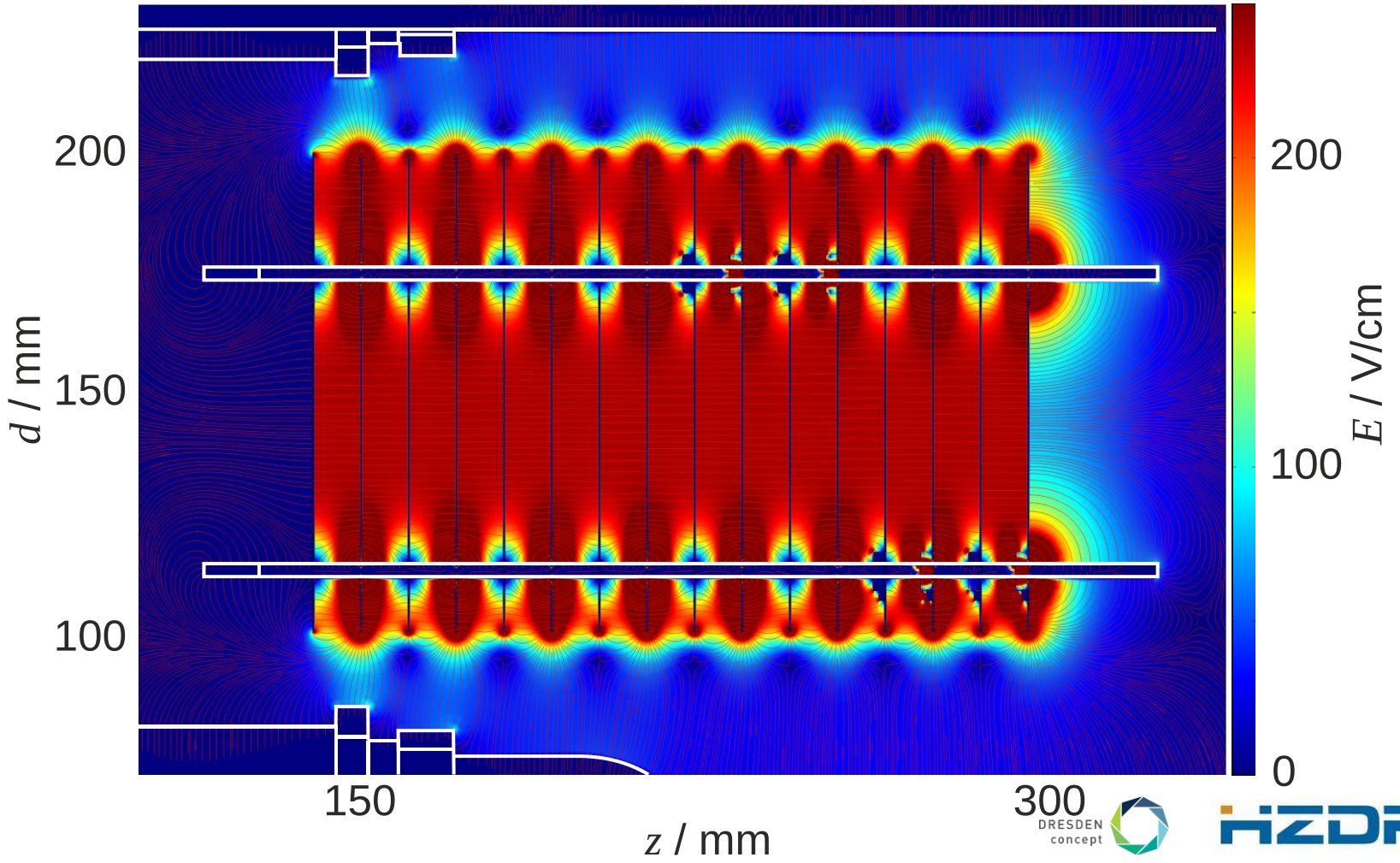
Optimization of the electric field

- filter & support rods disturbing the homogeneity of $\vec{E}$-field inside
- optimization of interior using Comsol Multiphysics® simulations



Optimization of the electric field

- filter & support rods disturbing the homogeneity of $\vec{E}$-field inside
- optimization of interior using Comsol Multiphysics® simulations



Simulations related to the fission chamber

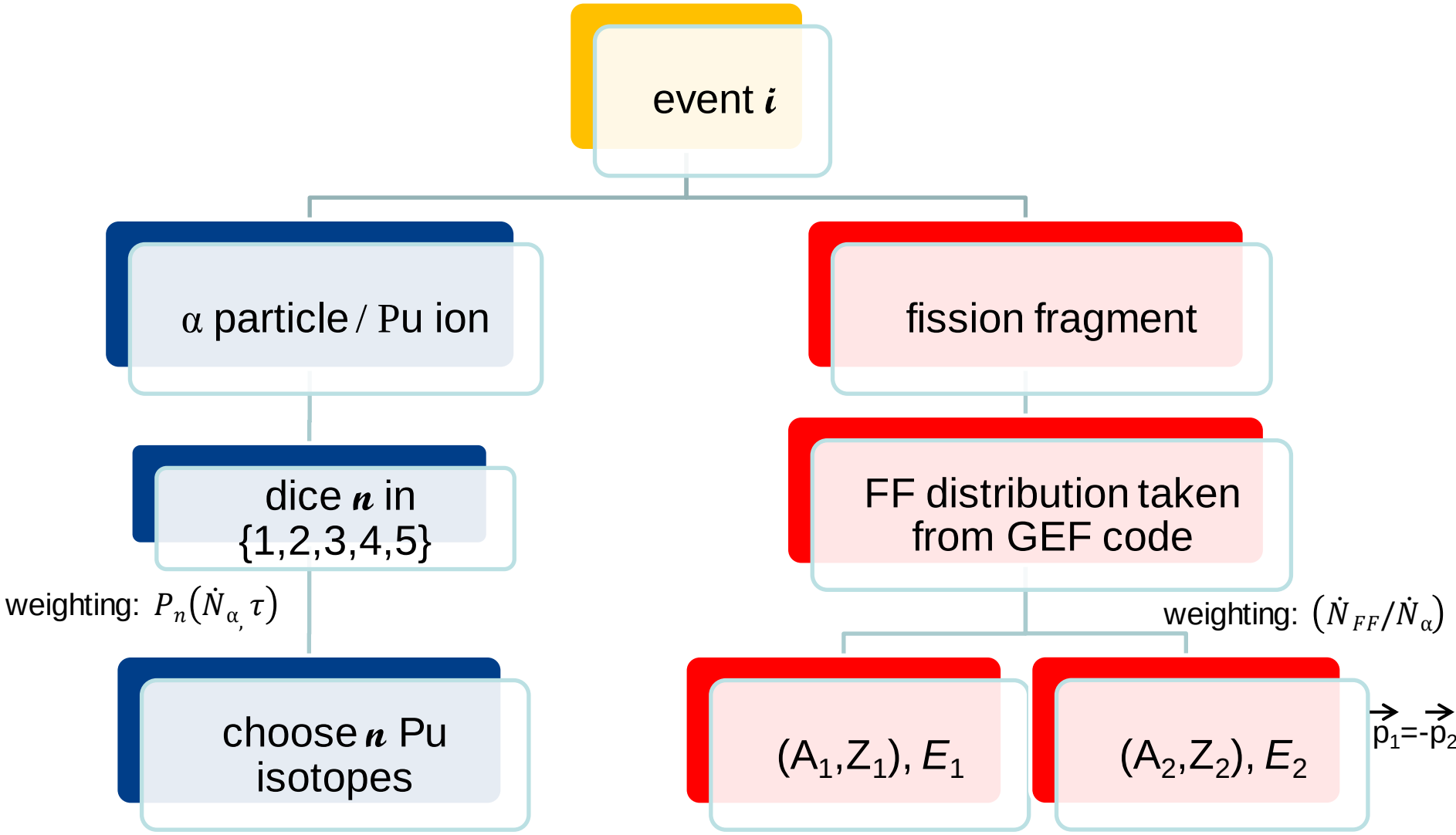
Motivation

- creating a realistic energy spectrum of both fission fragments and α–particles from ^{242}Pu decay
- get a feeling about the overlap of both distributions

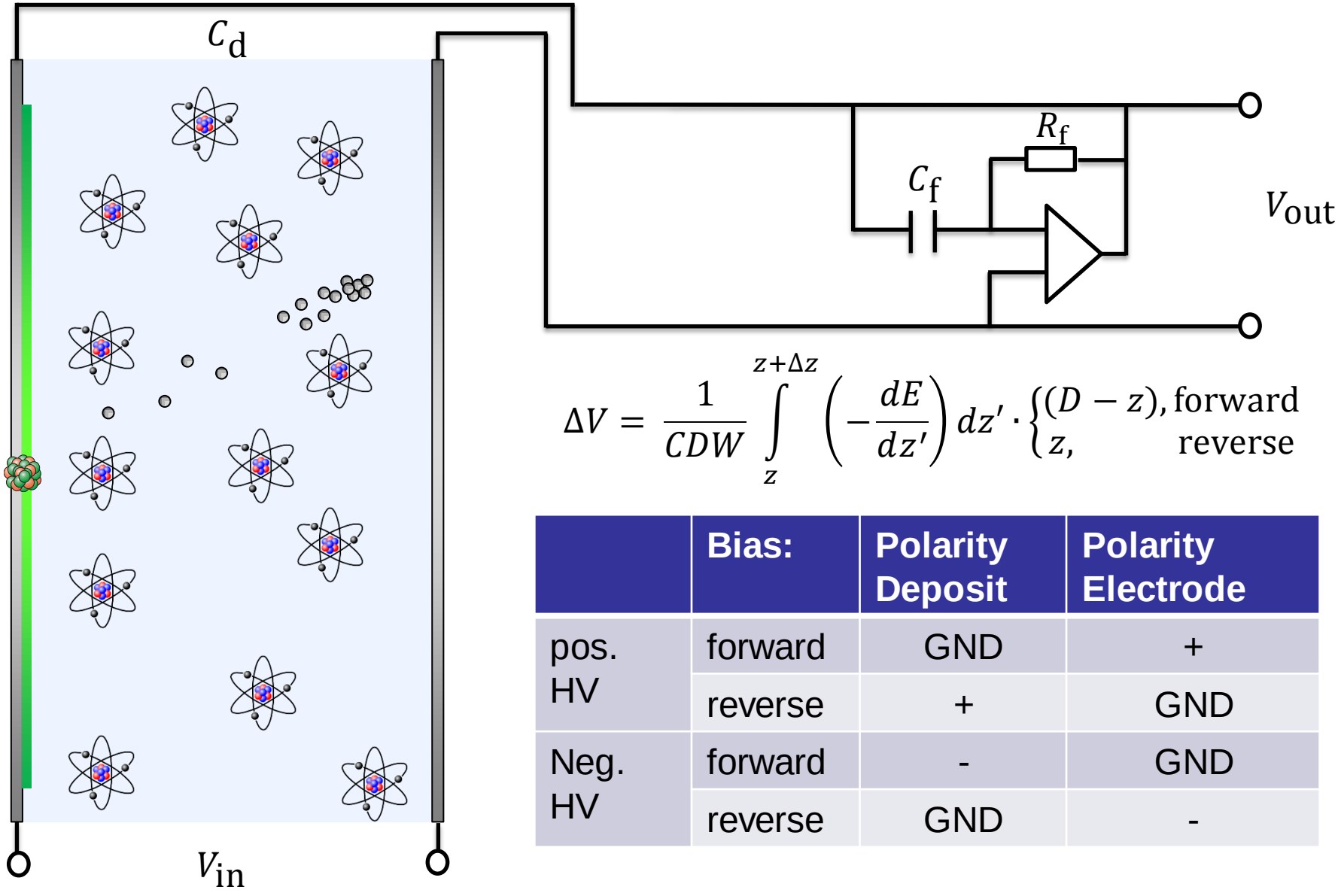
The pile-up problem

- "piled up" signals are able to produce a fission fragment signature
- due to the high α–activity of the target, higher orders of pile up events are probable
- $P_n(R,\tau) = \frac{(R\tau)^n e^{R\tau}}{n!}$
  - R…detected rate (=A*Ω=750000 1/s)
  - τ… total pulse width (HZDR preamp: 325 ns for α-particles)
  - n…number of additional signals to trigger signal in τ

Structure of the simulation



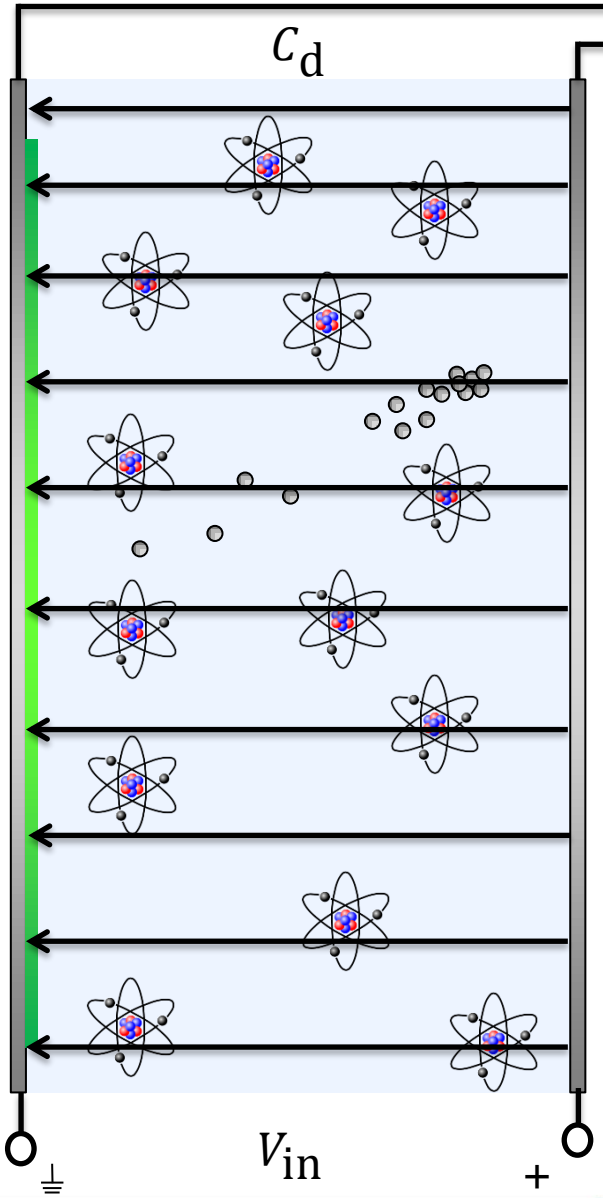
Simulation of pulse shape

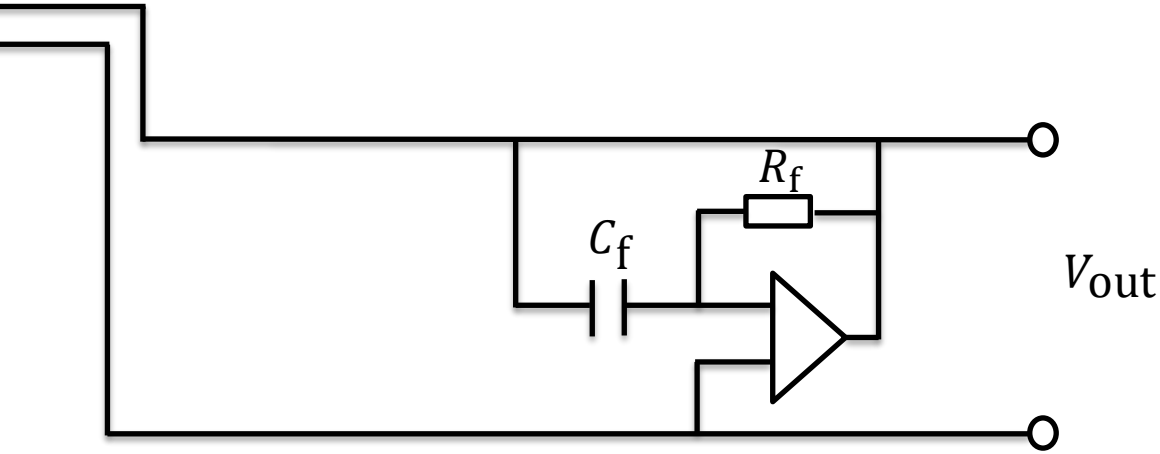


$$\Delta V = \frac{1}{CDW} \int_{z}^{z+\Delta z} \left(-\frac{dE}{dz'}\right) dz' \cdot \begin{cases} (D-z), & \text{forward} \\ z, & \text{reverse} \end{cases}$$

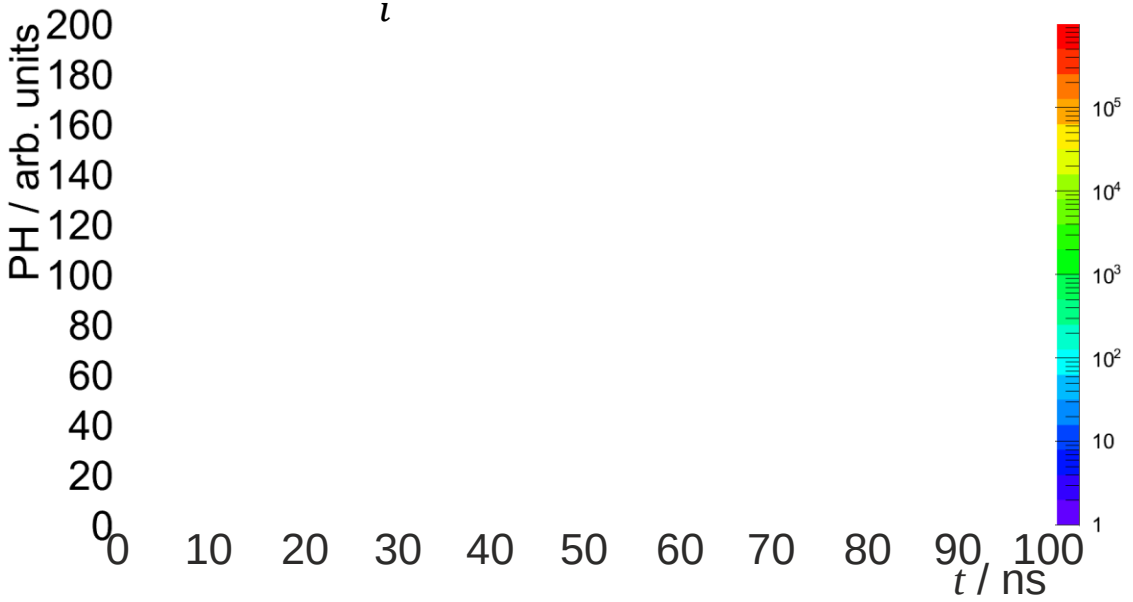
	Bias:	Polarity Deposit	Polarity Electrode
pos. HV	forward	GND	+
	reverse	+	GND
Neg. HV	forward	-	GND
	reverse	GND	-

Simulation of pulse shape (forward biasing)

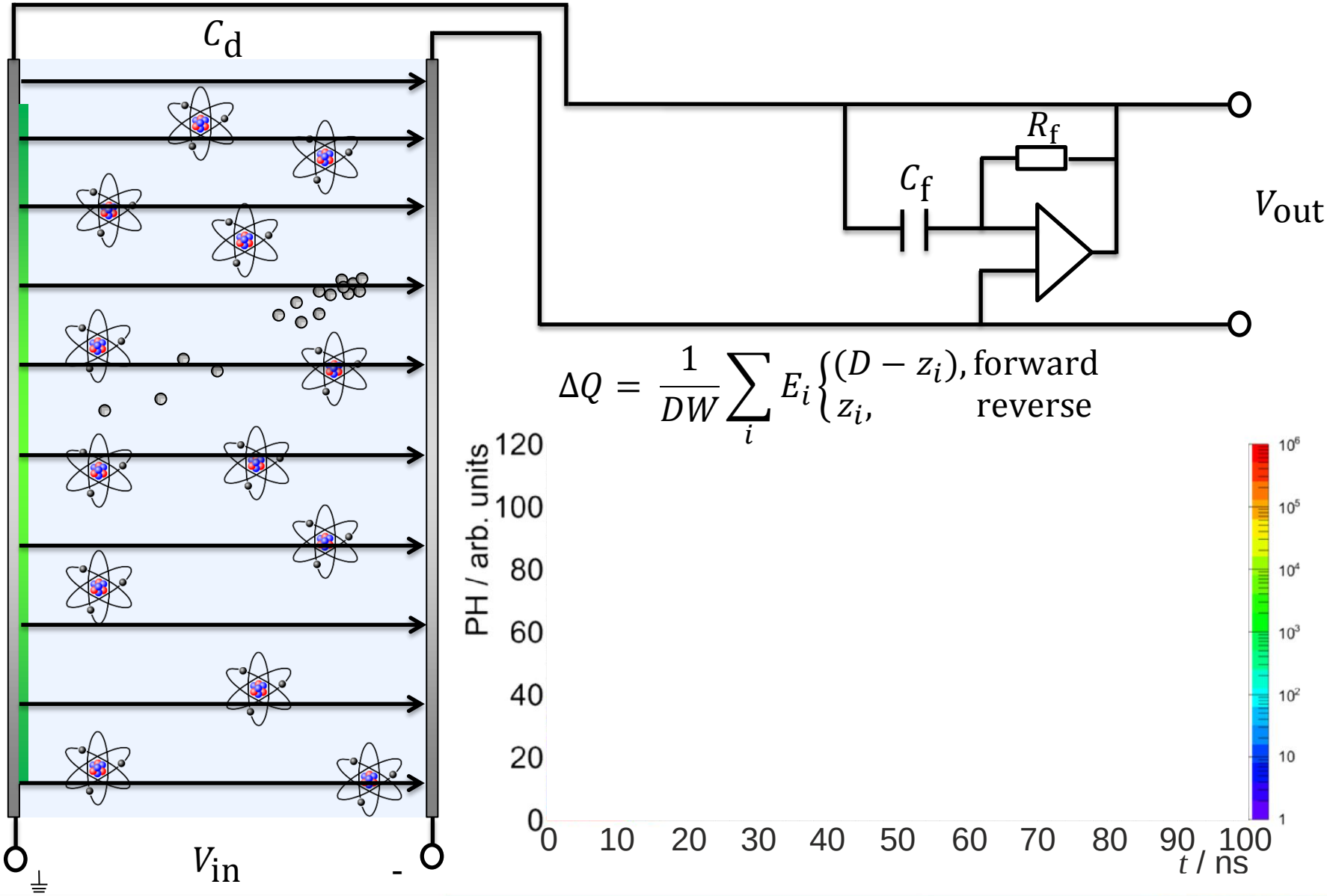




$$\Delta Q = \frac{1}{DW}\sum_i E_i \begin{cases} (D - z_i), & \text{forward} \\ z_i, & \text{reverse} \end{cases}$$

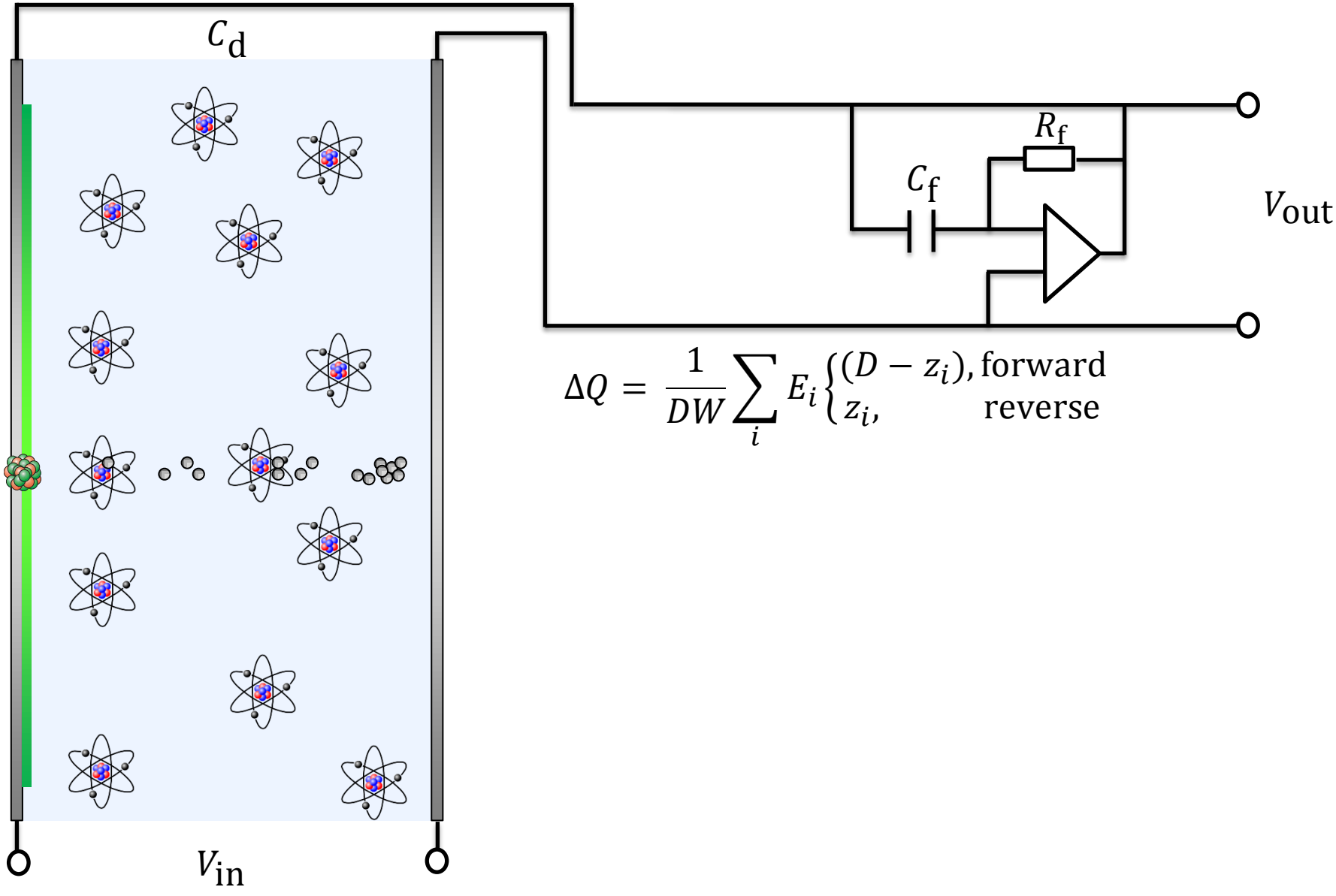


Simulation of pulse shape (reverse biasing)



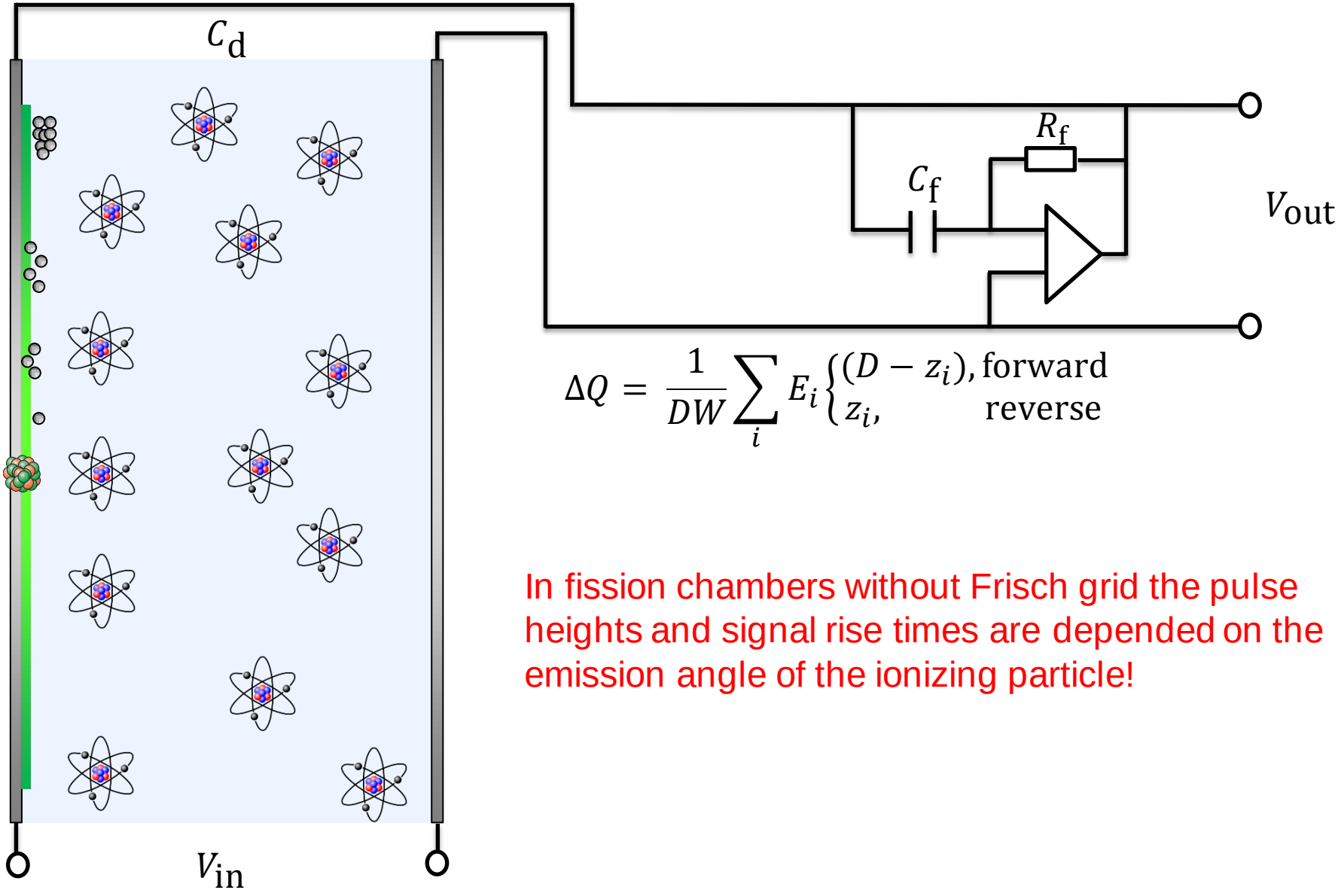
$$\Delta Q = \frac{1}{DW}\sum_i E_i \begin{cases} (D - z_i), & \text{forward} \\ z_i, & \text{reverse} \end{cases}$$

Simulation of pulse shape



$$\Delta Q = \frac{1}{DW}\sum_i E_i \begin{cases} (D - z_i), & \text{forward} \\ z_i, & \text{reverse} \end{cases}$$

Simulation of pulse shape

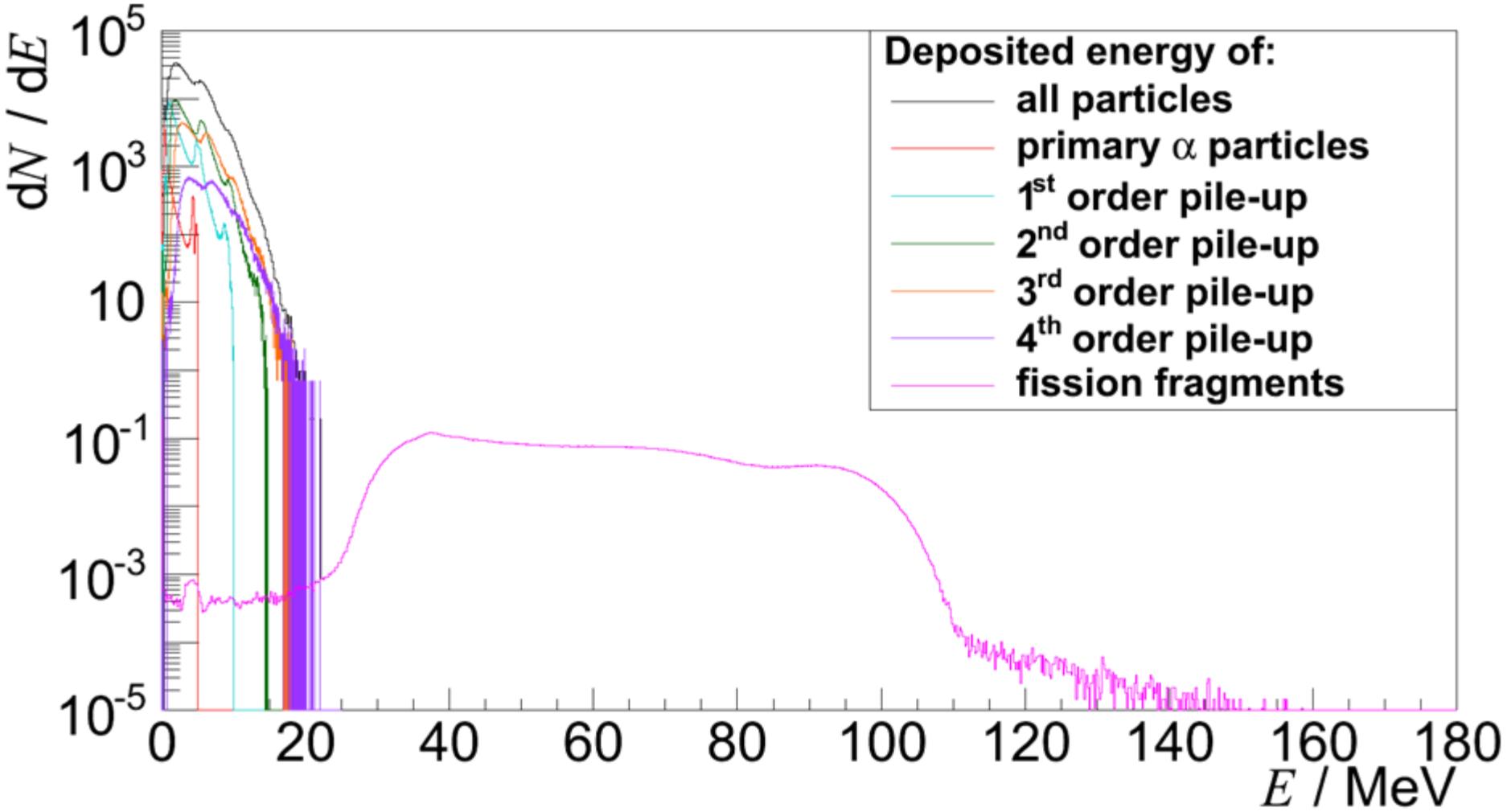


$$\Delta Q = \frac{1}{DW}\sum_i E_i \begin{cases} (D - z_i), & \text{forward} \\ z_i, & \text{reverse} \end{cases}$$

In fission chambers without Frisch grid the pulse heights and signal rise times are depended on the emission angle of the ionizing particle!

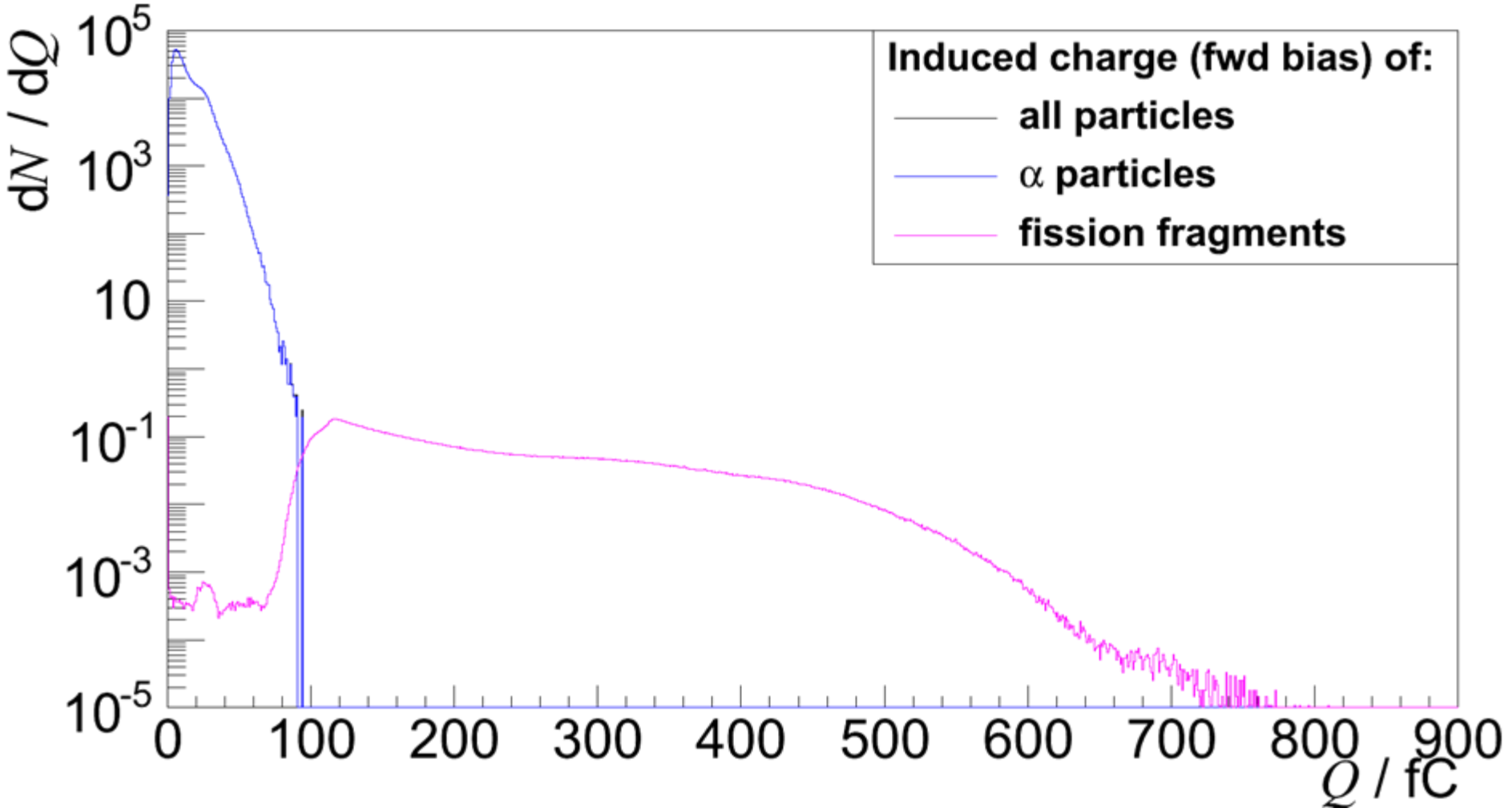
Deposited energy spectrum

5 mm spacing



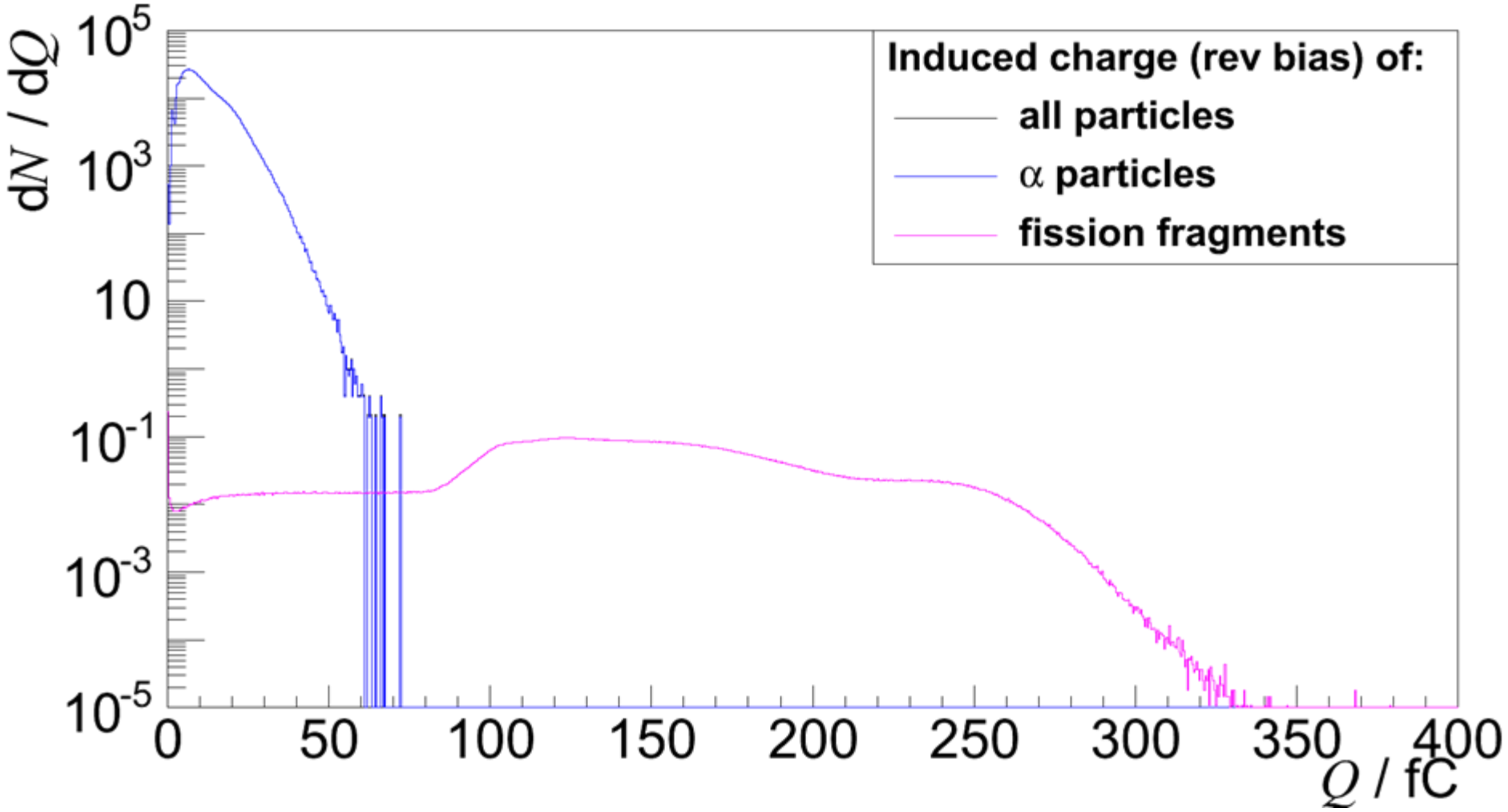
Induced charge spectrum

5 mm spacing, forward biased



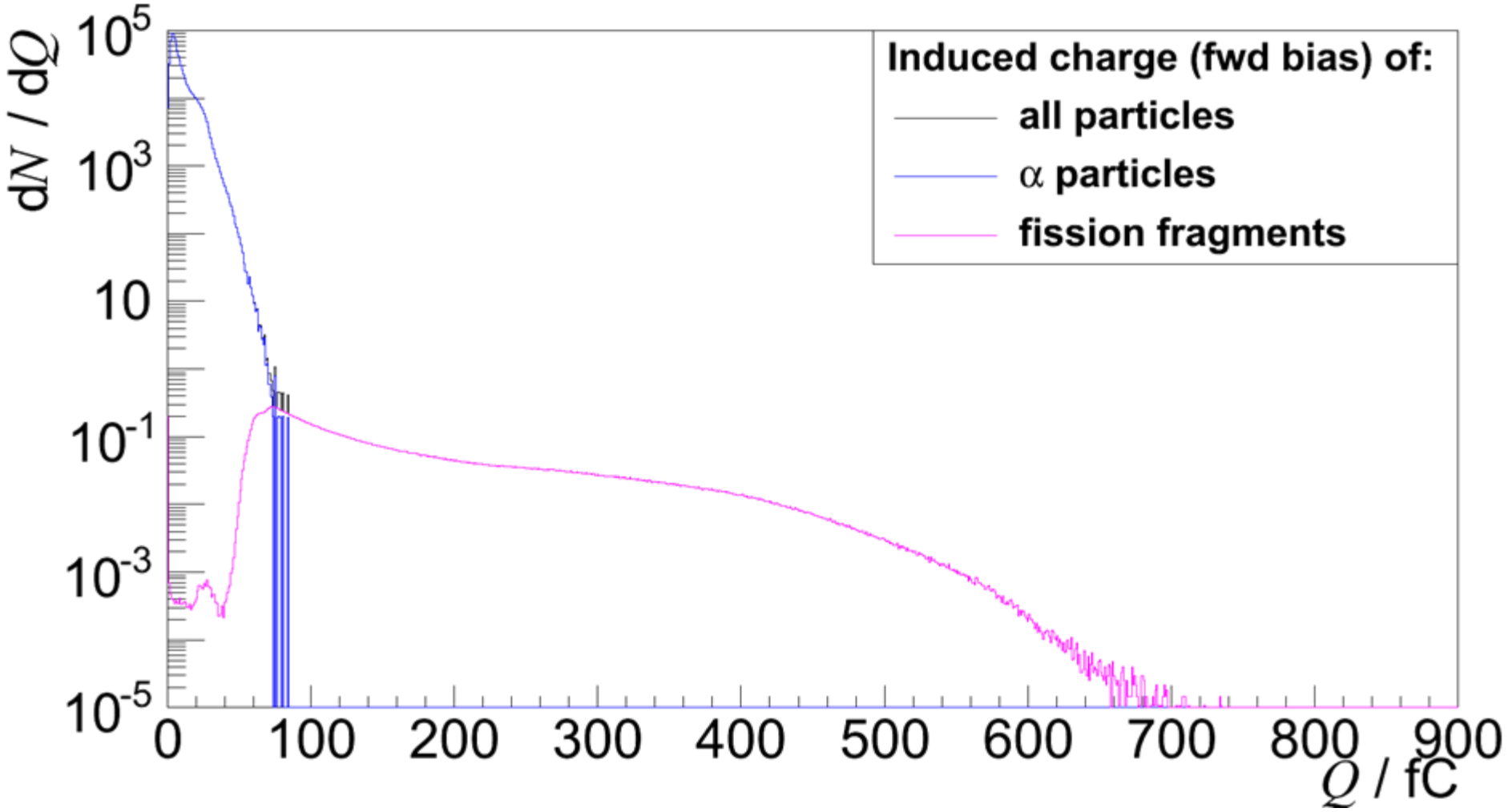
Induced charge spectrum

5 mm spacing, reversed biased



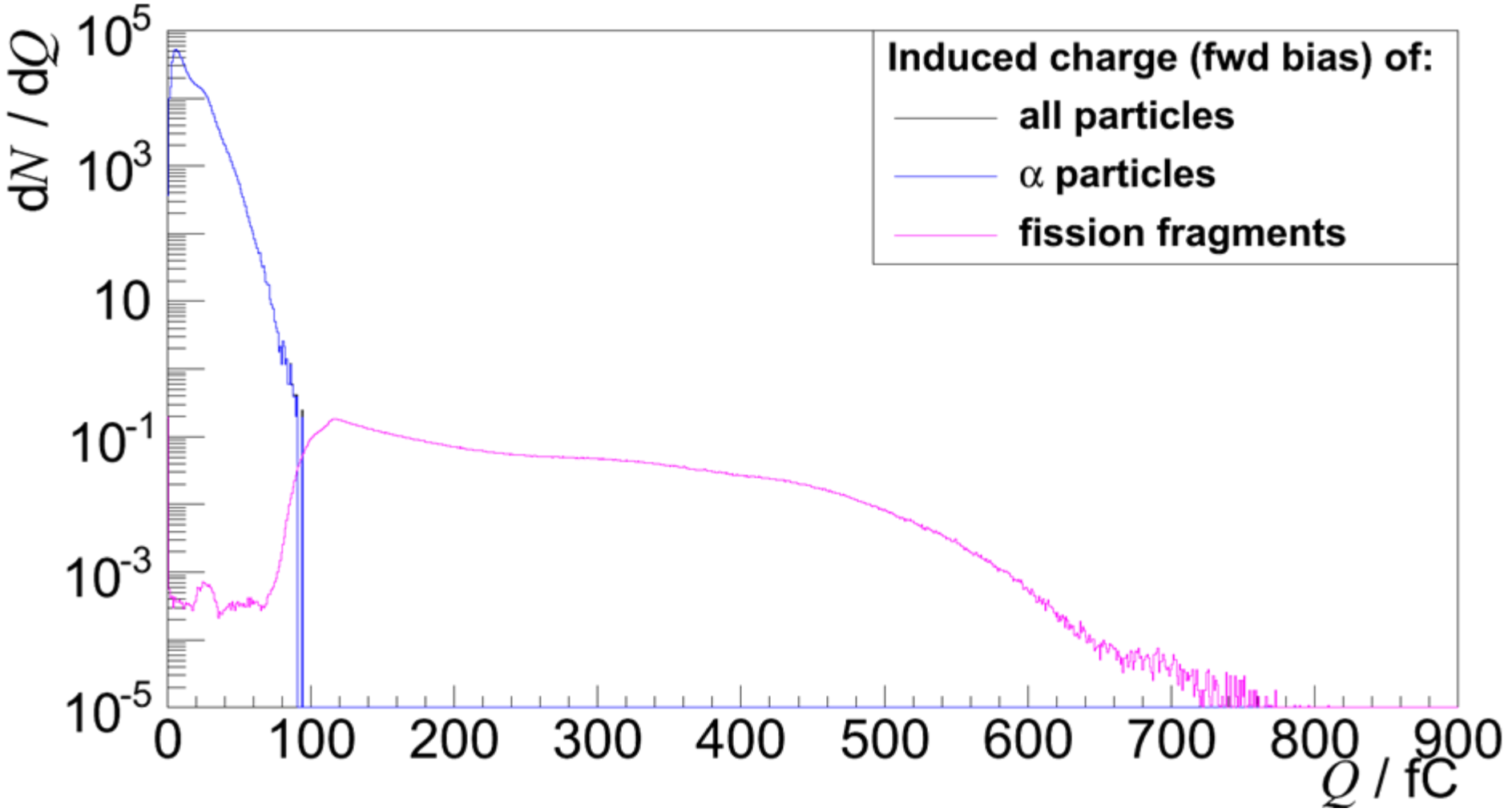
Induced charge spectrum

3 mm spacing, forward biased



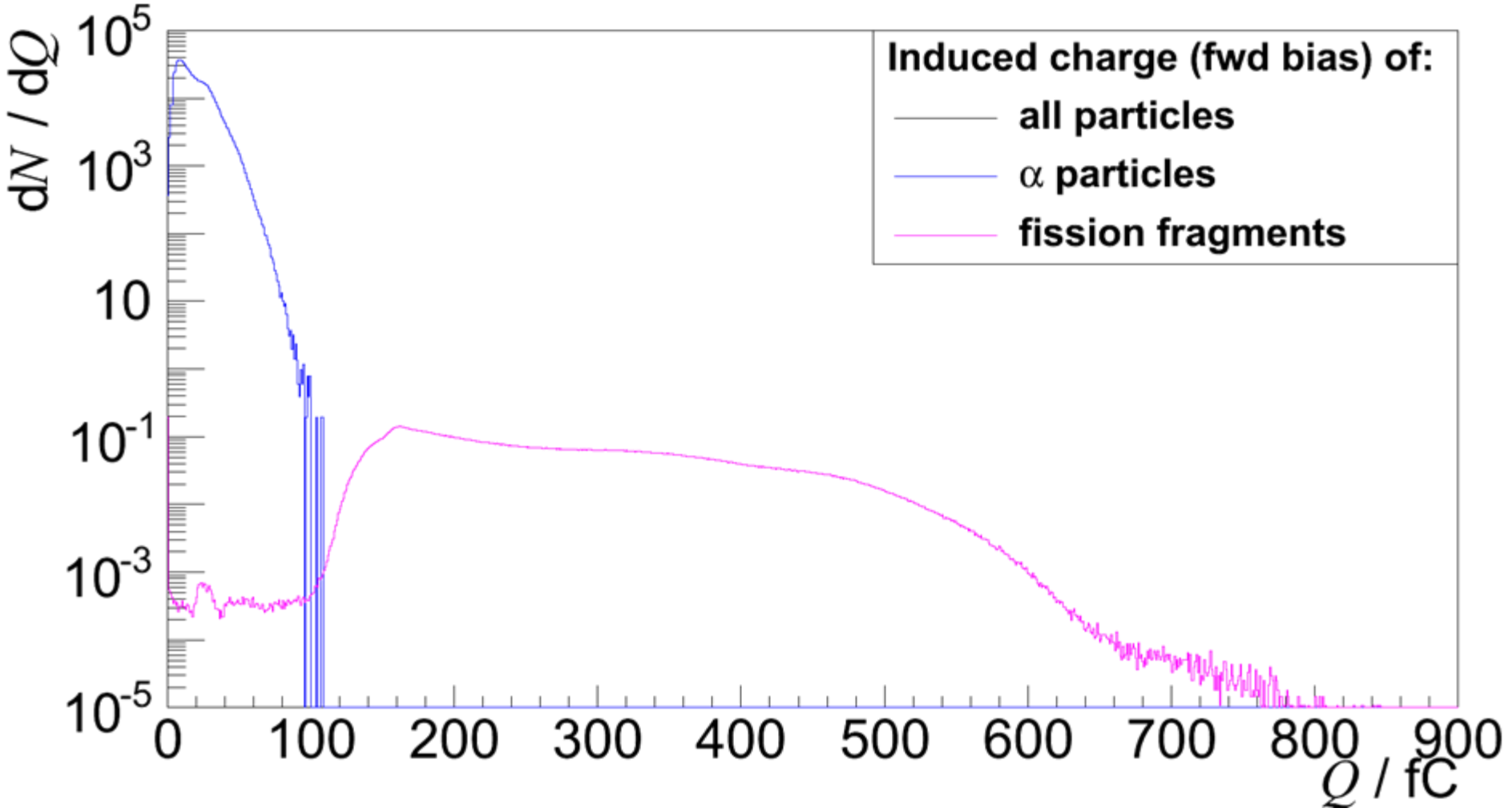
Induced charge spectrum

5 mm spacing, forward biased



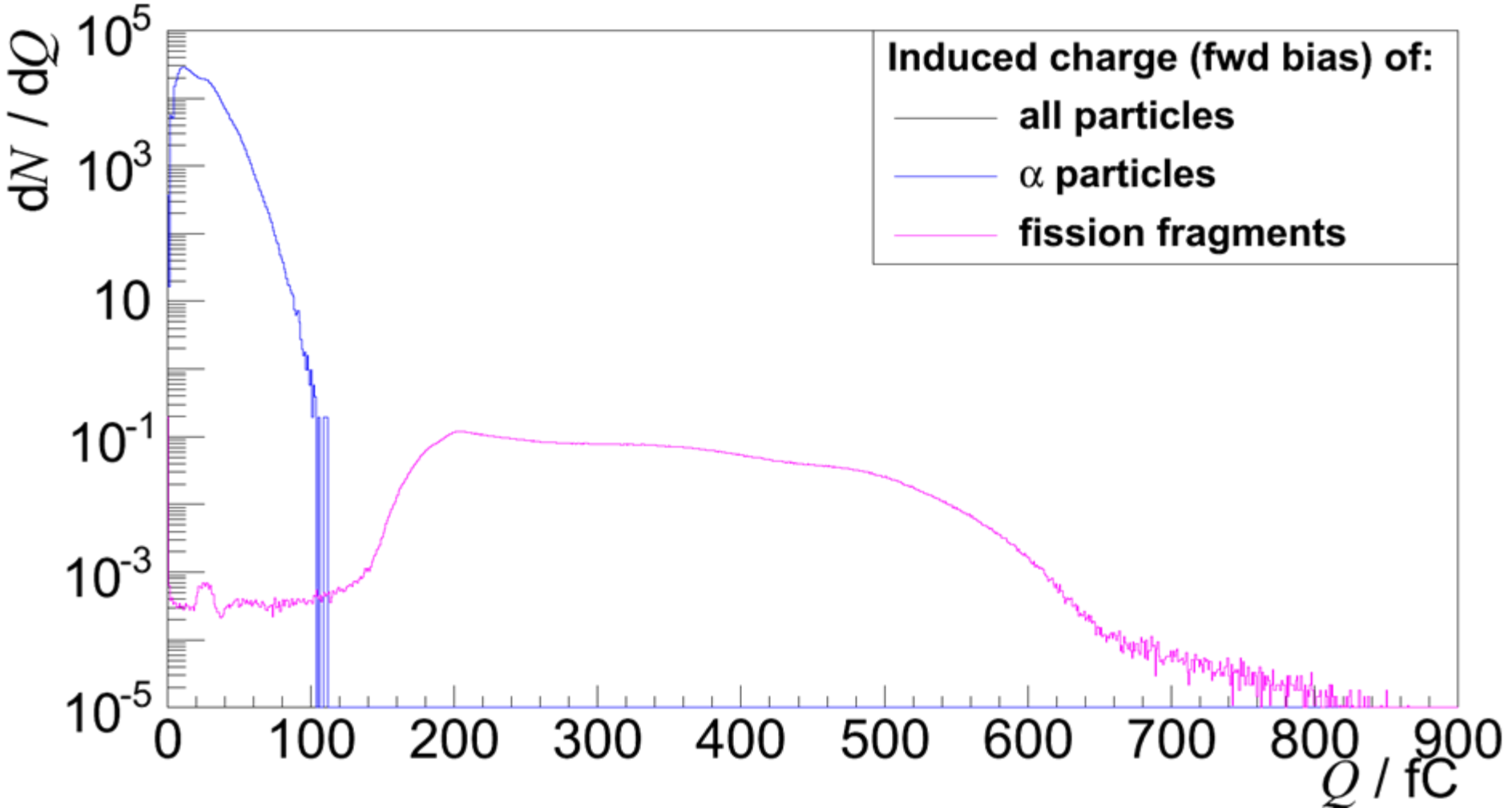
Induced charge spectrum

7 mm spacing, forward biased



Induced charge spectrum

9 mm spacing, forward biased

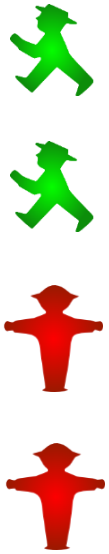


Comparison of stopping powers

Gas	Method	^{134}Te (80,4 MeV)	^{104}Mo (104,0 MeV)	α (5,0 MeV)
		Range [mm]	Range [mm]	Range [mm]
Methane	NIST aStar			40.290
	SRIM 2008	22.500	25.700	37.200
	MCUNED	12.140	17.690	42.640
	Geant 4	18.159	23.589	40.403
Argon	NIST aStar			38.460
	SRIM 2008	23.500	26.600	39.000
	MCUNED	15.300	20.520	45.380
	Geant 4	17.791	22.554	38.599

Conclusions

- design of nELBE FC has been optimized
- first digital data has been acquired @ nELBE2 with the PTB H19 transfer device
- for 50 mg ^{242}Pu an electrode spacing of larger than 7 mm have to be applied
- encountered large discrepancies in dE/dx tables



Outlook

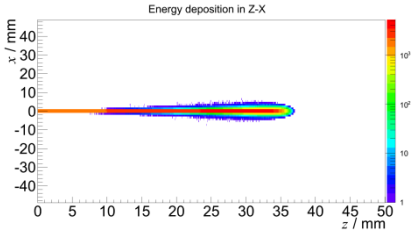
- setup nELBE ^{235}U FC and gas support
- finish multi-threading digital data acquisition (Qt+root)
- perform first detector tests @ nELBE2
- characterize U targets & H19 @ PTB Braunschweig

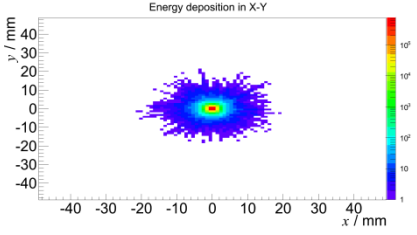
Back-up slides:

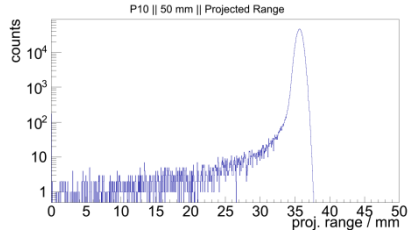
α- and fission fragment beam

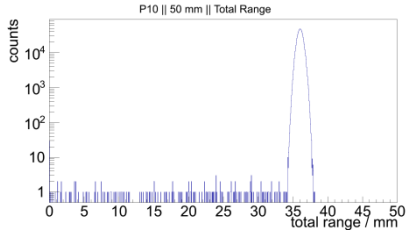
50 mm electrode distance

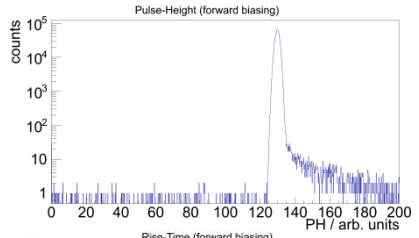
α particles

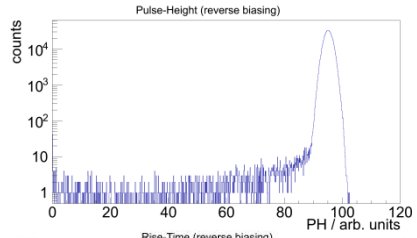


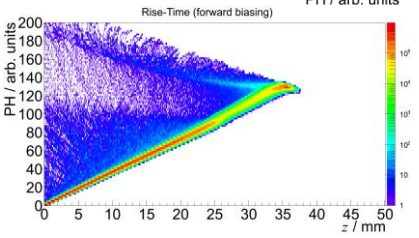


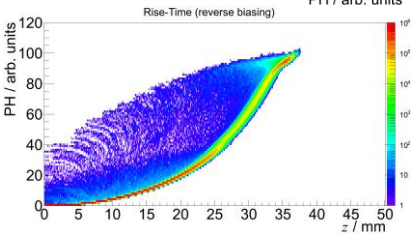




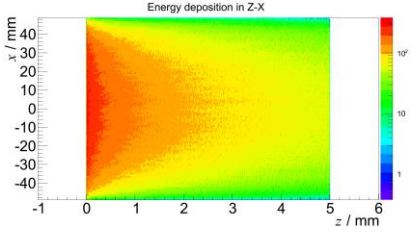


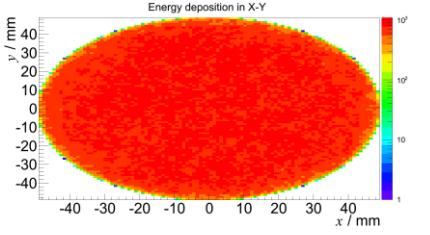


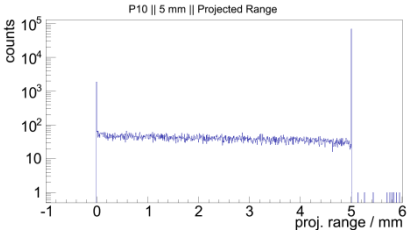


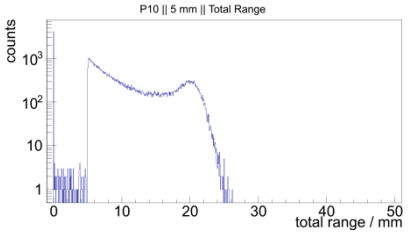


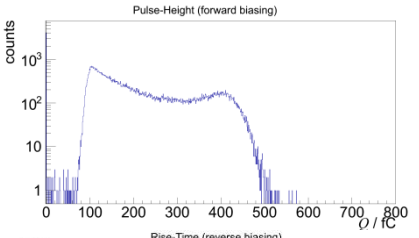
fission fragments

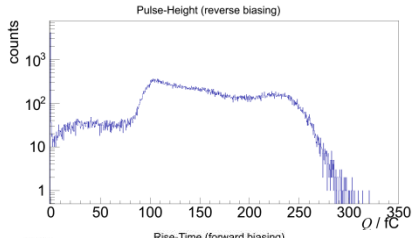


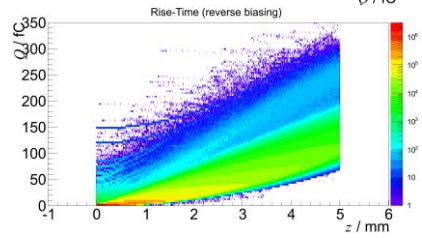


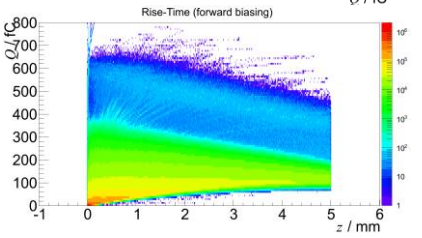








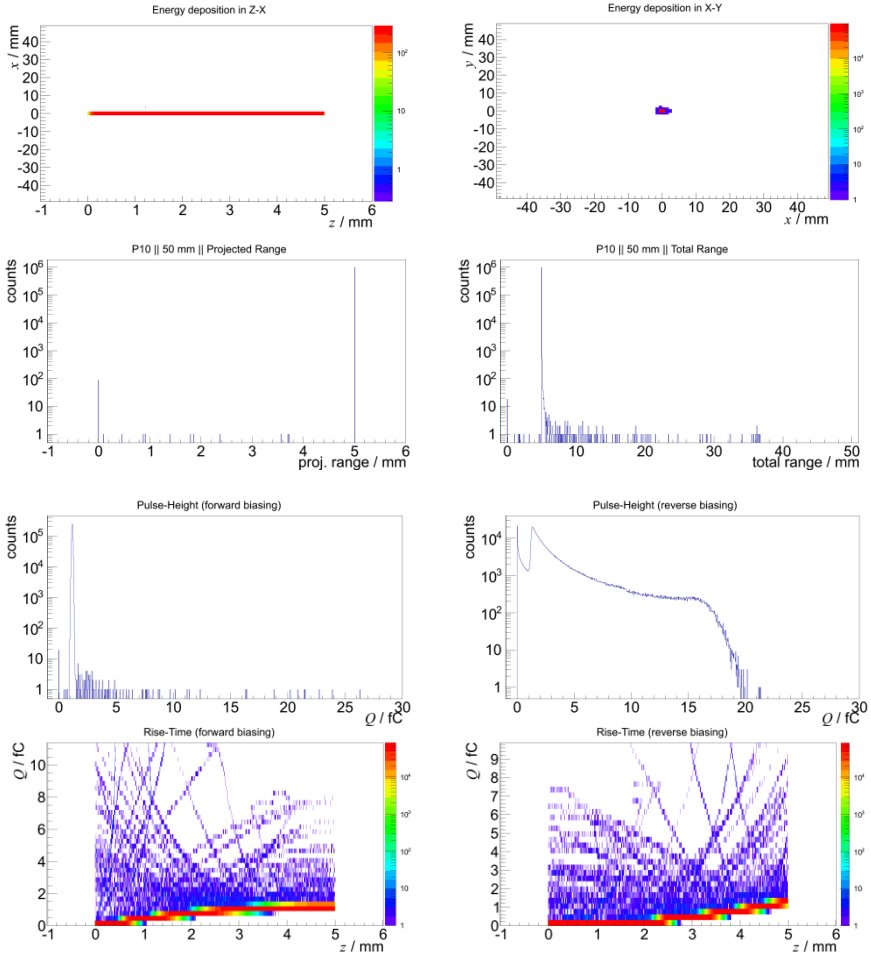




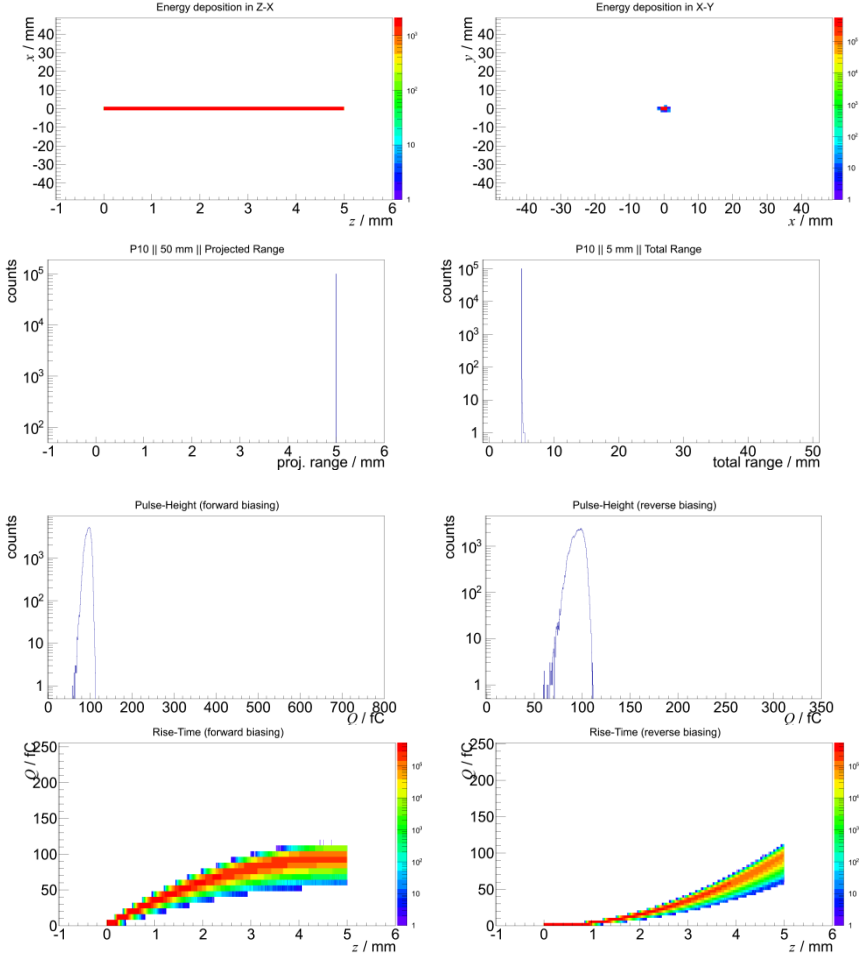
α- and fission fragment beam

5 mm electrode distance

α particles



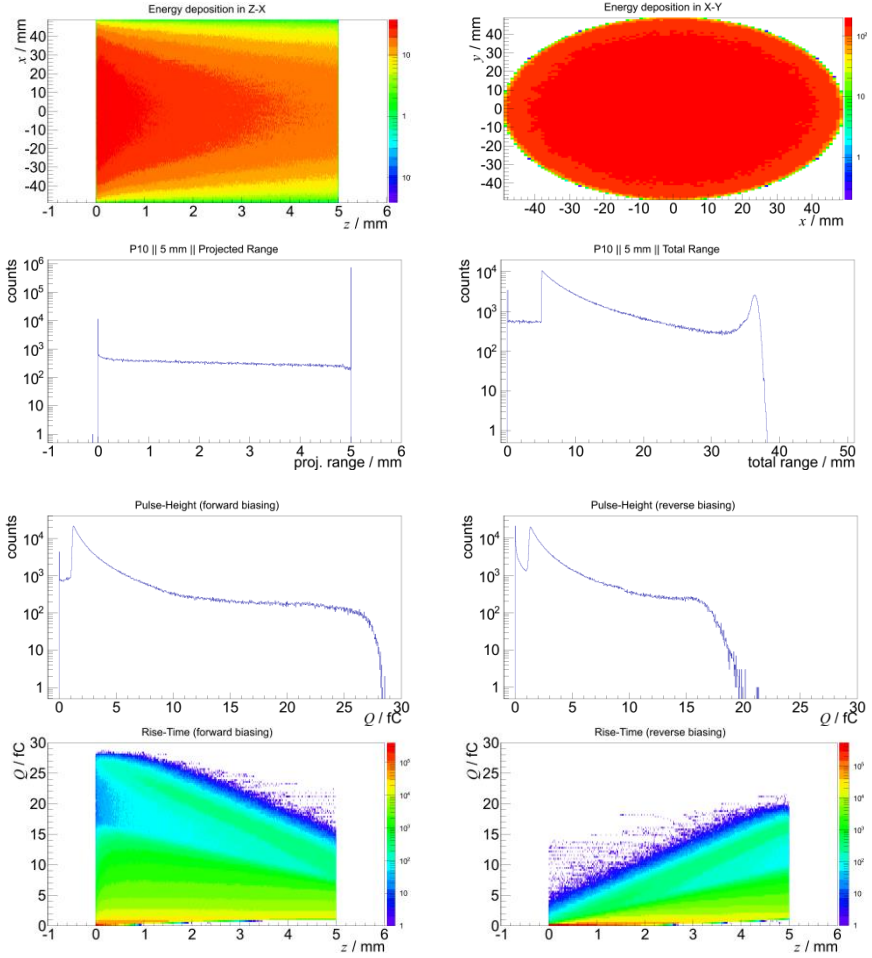
fission fragments



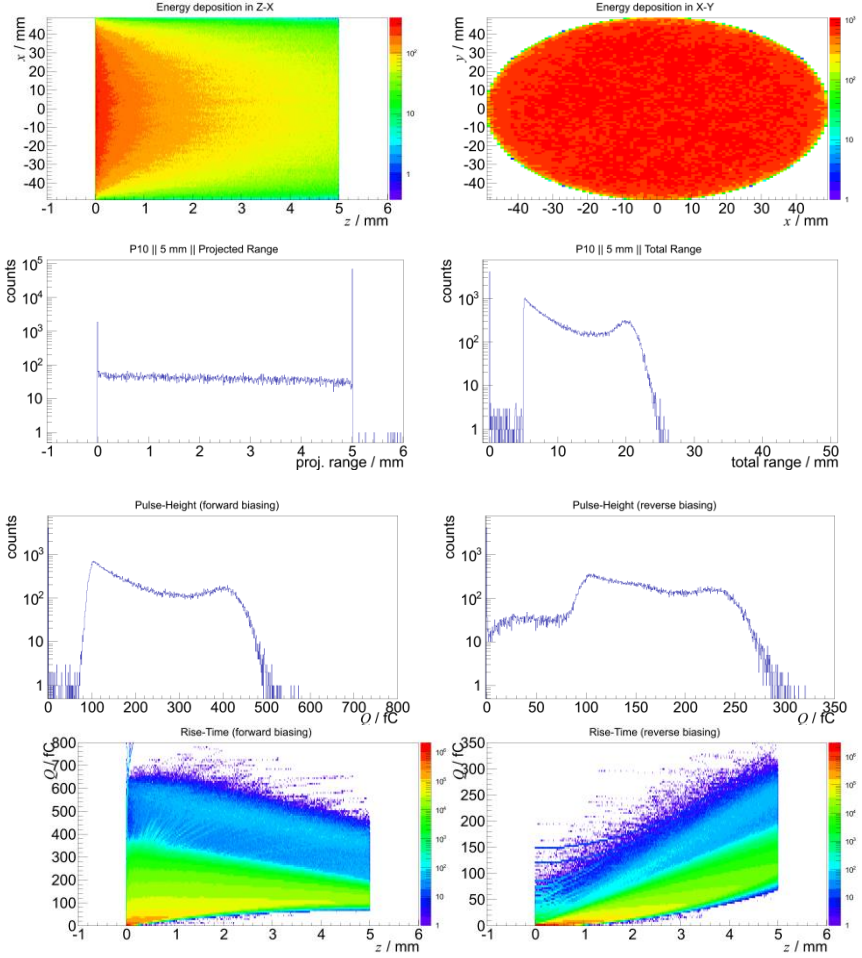
Isotropic emission of α‘s and fission fragments

5 mm electrode distance

α particles

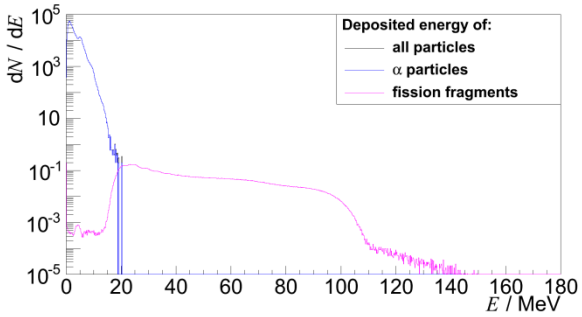


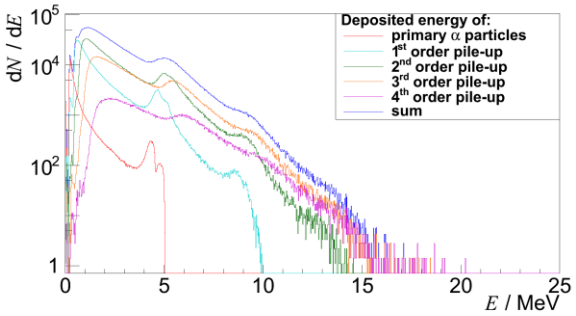
fission fragments



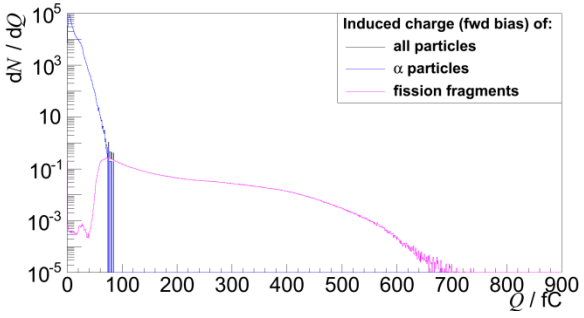
3 mm

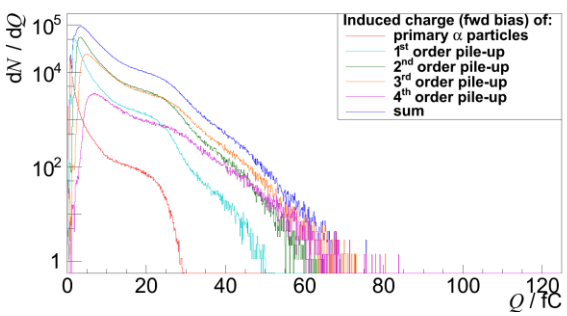
energy deposition



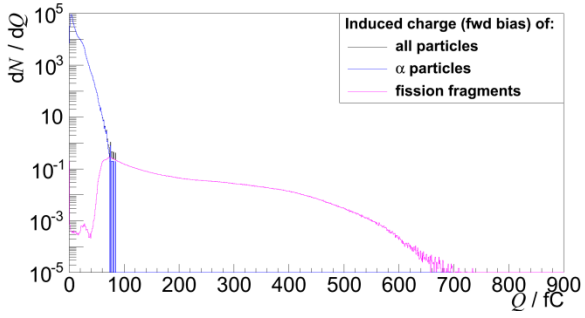


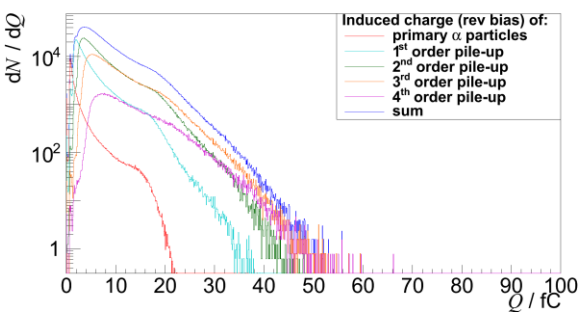
forward biasing





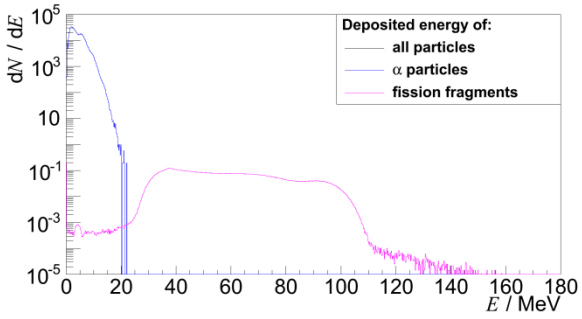
reverse biasing

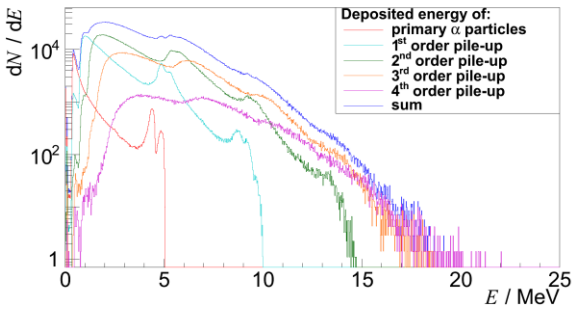




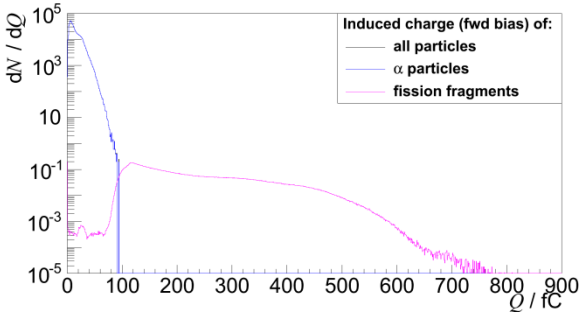
5 mm

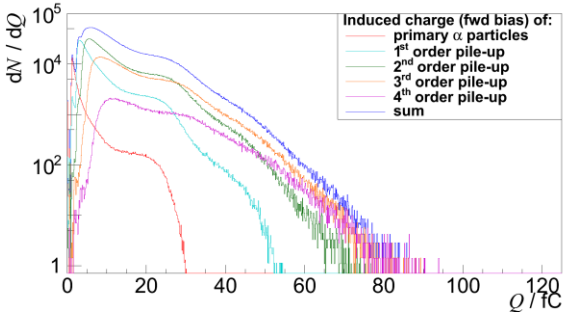
energy deposition



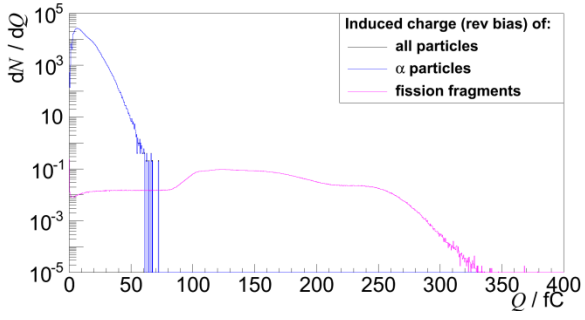


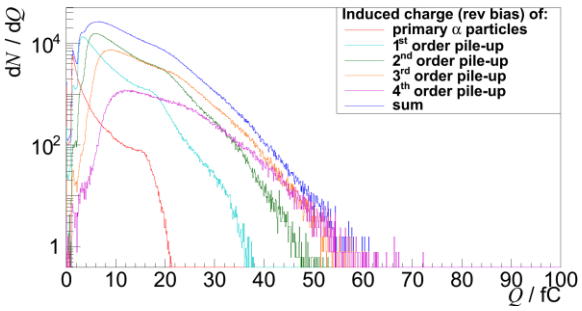
forward biasing





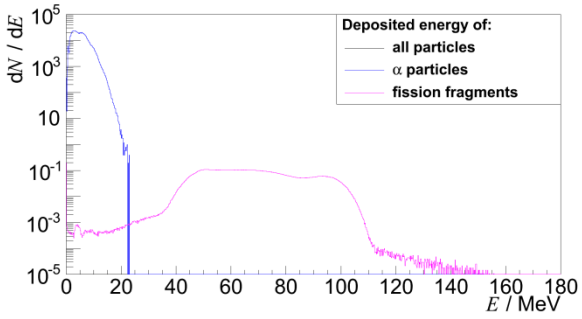
reverse biasing

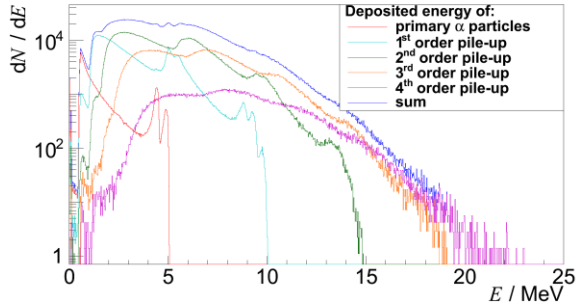




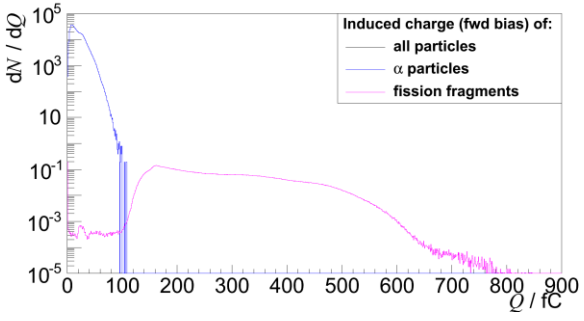
7 mm

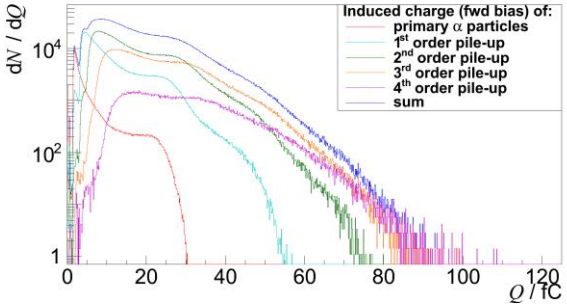
energy deposition



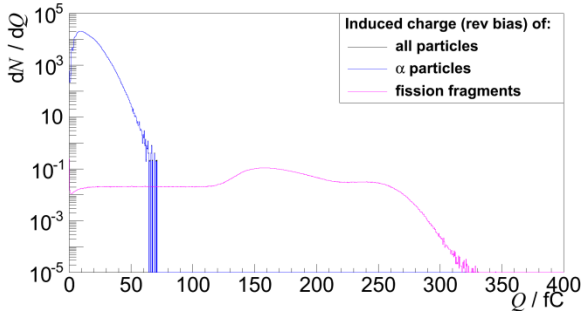


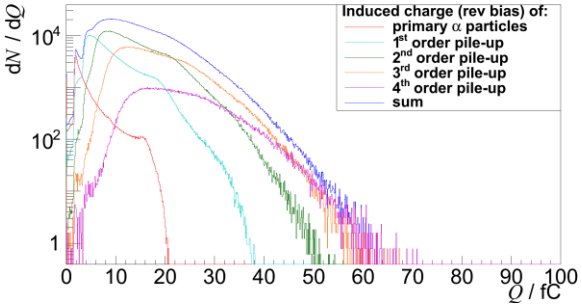
forward biasing





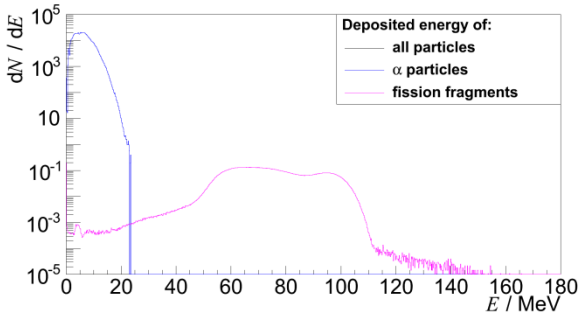
reverse biasing

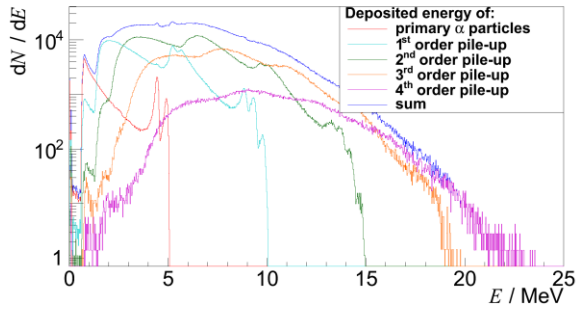




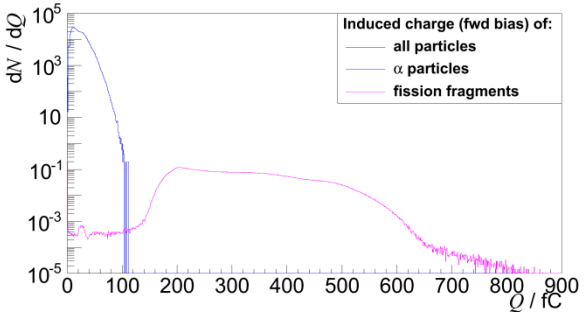
9 mm

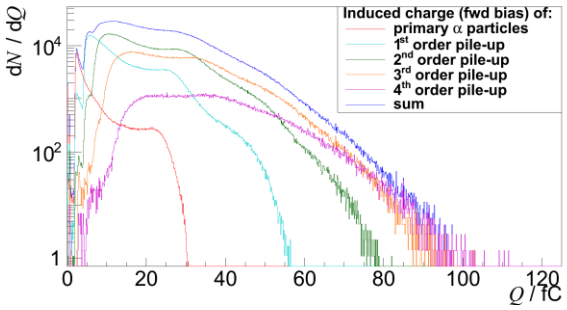
energy deposition





forward biasing





reverse biasing