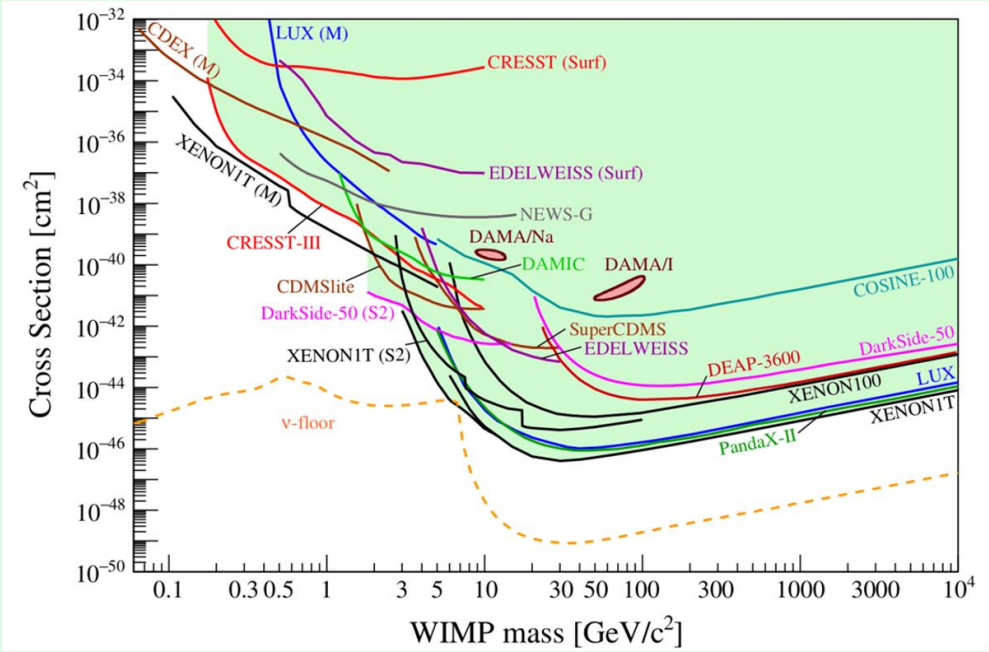
Quenching factor measurements for the NEWS-G experiment

Neha Panchal

NEWS-G

- NEWS-G experiment searches for Light Dark Matter
- Uses SPCs as detector: Metallic vessel filled with a noble gas mixture, with a single high voltage anode
- Low A target atoms increases sensitivity to low-mass dark matter
- Low capacitance (~10 pF) decreases electronic noise and Townsend avalanche provides large gain
- Single ionization detection threshold!

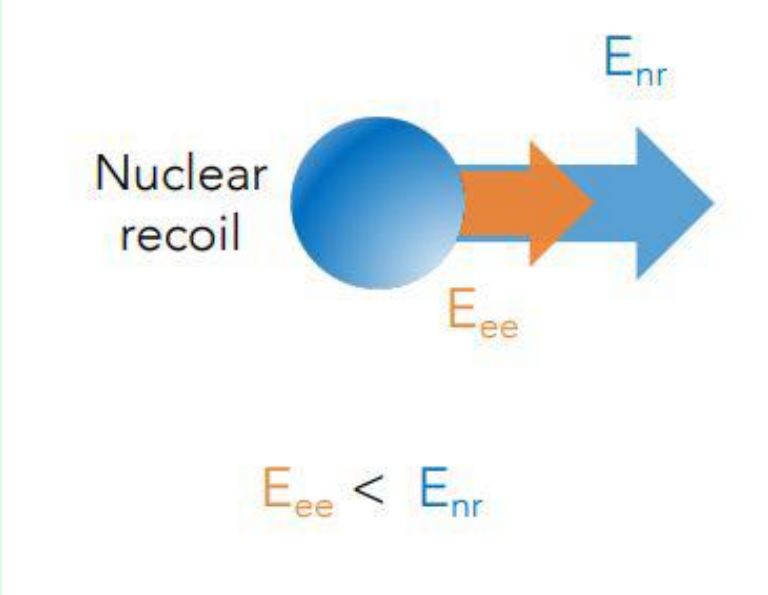


Quenching factor

Definition

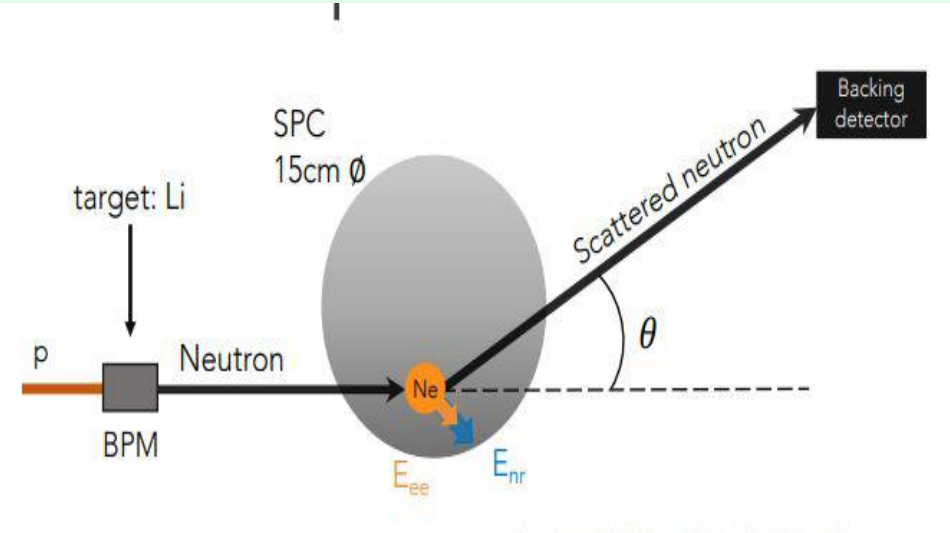
- Dark matter sensitivity: Very important to know actual nuclear energy spectra
- As nuclear recoil and an electronic recoil of same energy do not produce same amount of primary ionization

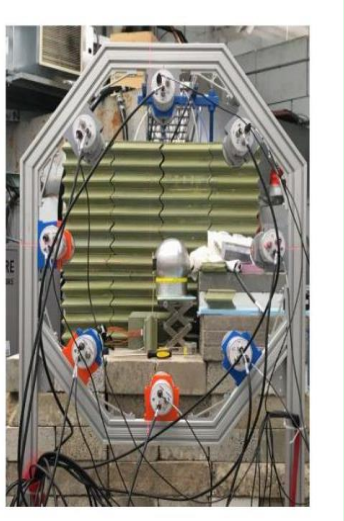
$$QF(E_{nr}) = \frac{E_{ee}}{E_{nr}}$$

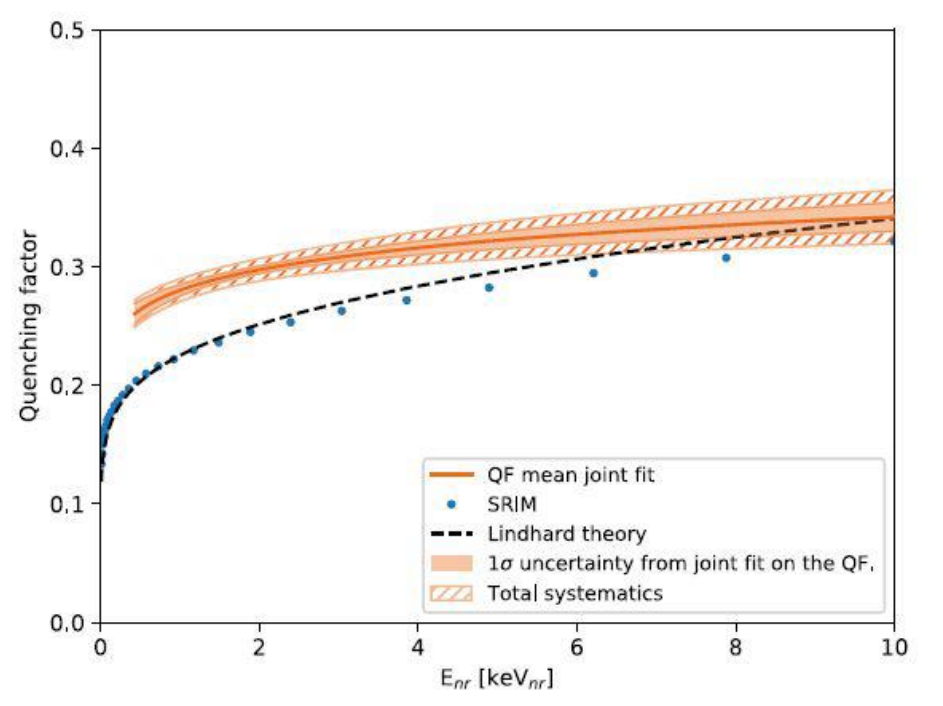


Past measurement at TUNL

- **Quenching factor measurements at TUNL (Duke tandem facility)**
- The nuclear recoil energies covered were 0.34 to 6.8 keVnr





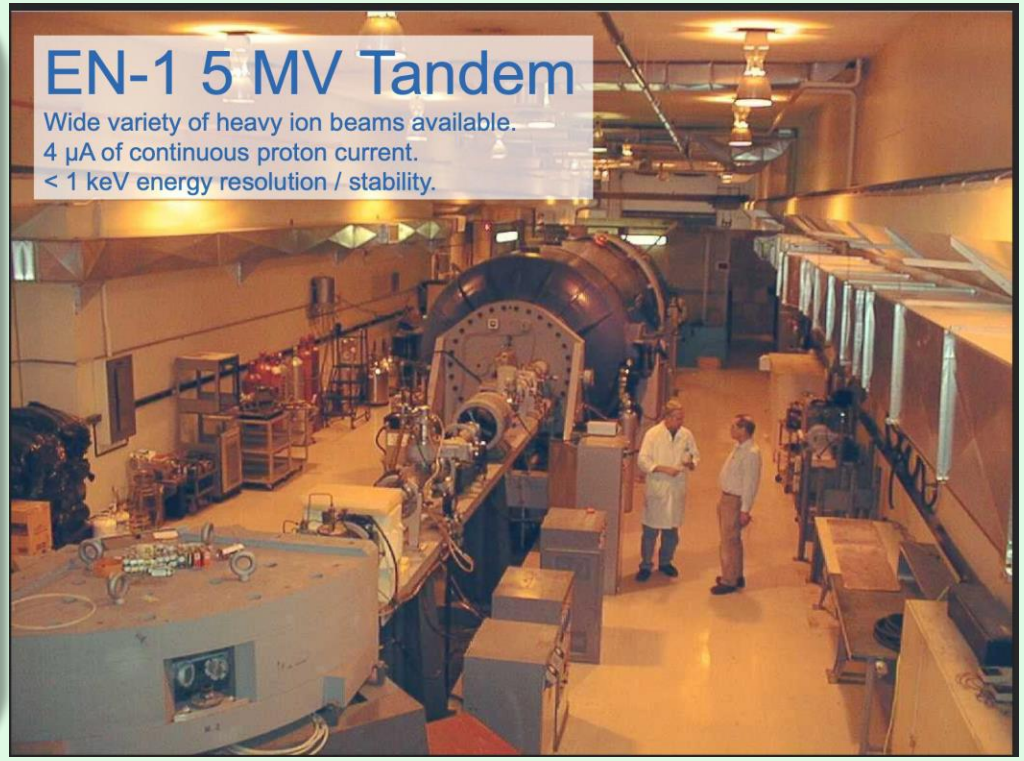


Marie et al.

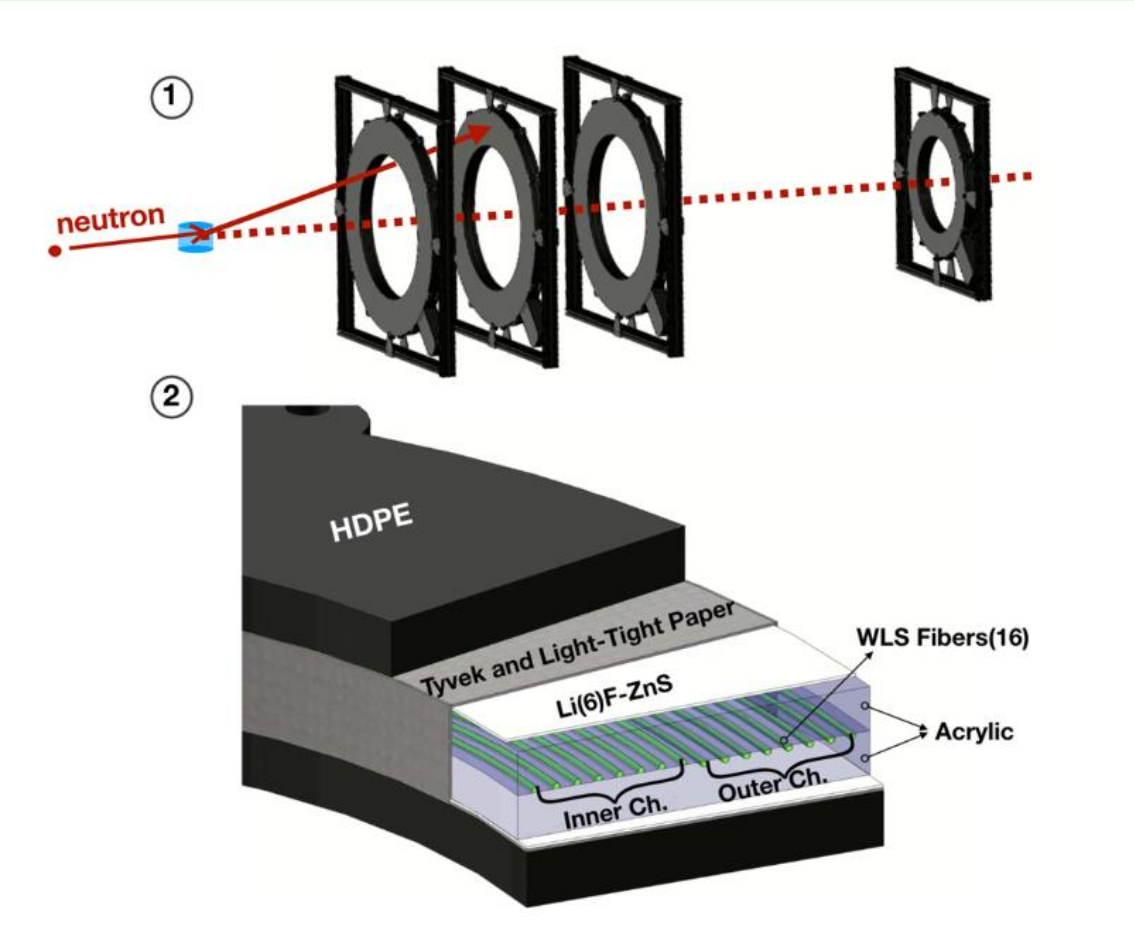
Current plans

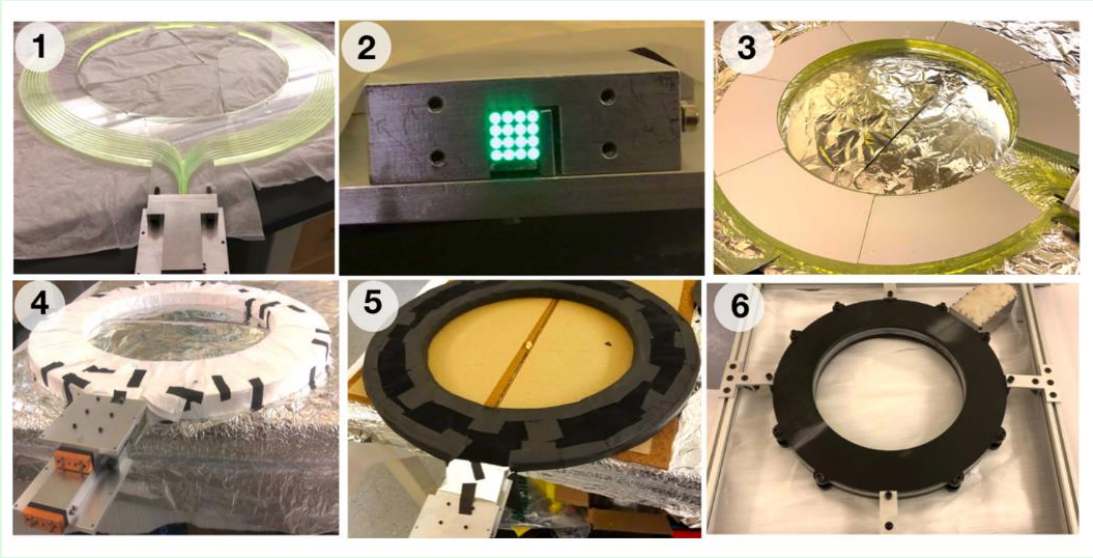
UdeM tandem accelerator: planning to do QF measurements

- Possibility to go to ~10 times lower energy than TUNL ~5keV
- $^{51}V(p,n)$ as target offering large number of near threshold resonances
- Better rejection to gamma background by B-10 neutron capture
- Working on building a new backing detector



New Backing Detector





- The Backing Detector is an annulus structure
- Provides better angular coverage
- Based on n-capture on Li
- Detection efficiency 27% at 2keV
- Mean neutron capture time 17usec

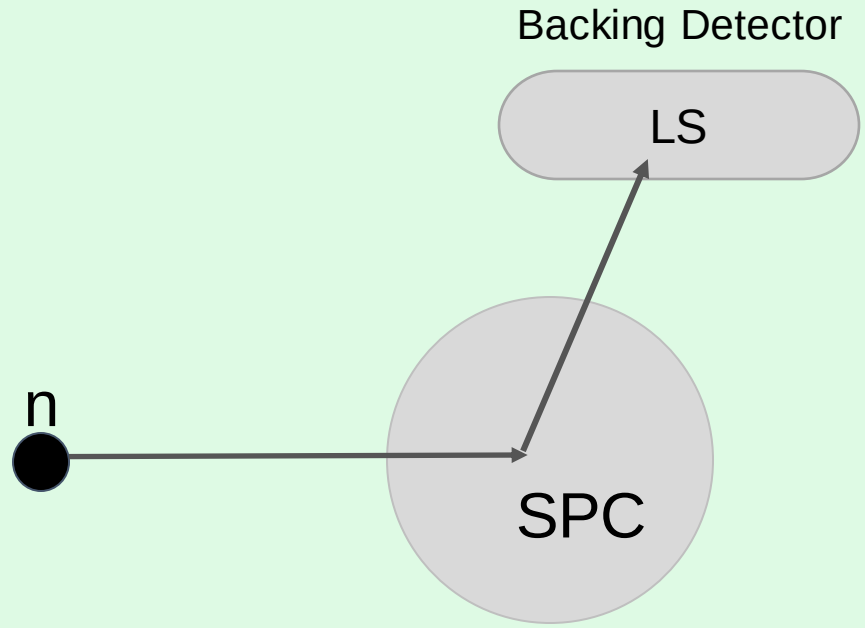
Pratyush Patel et al.

Neutron scattering @ Queen's

To observe the scattered neutrons from SPC using a source in lab.

Motivation

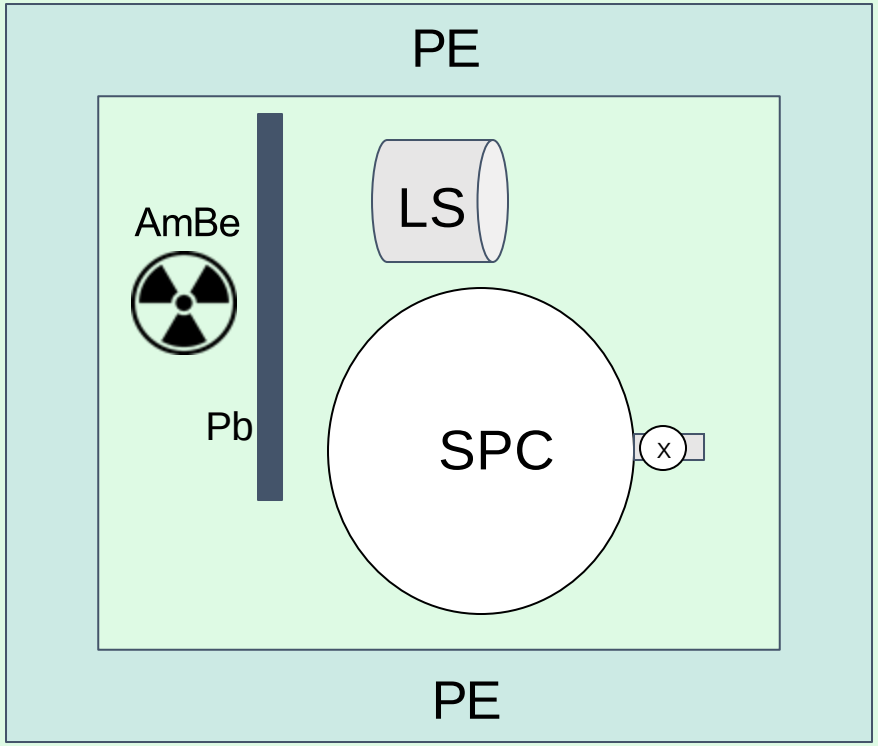
- **A crucial step towards in-beam experiment**
- Establishing the DAQ and analysis tools
- Easy access to systematic investigation:
  - different gas mixture
  - gas pressure
  - gas volume (sphere size)
  - ionization voltage
- Characterization tool for new gases and sensor designs in the future



Experiment

Setup

- **Detector:** S15/S30
- **Backing detector:** EJ-309 Liquid Scintillator
- **Source:** 30 mCi AmBe (10000 n/s)
- **Shield:**
  - A layer of few mm of Pb for gammas
  - 5 cm PE for neutrons

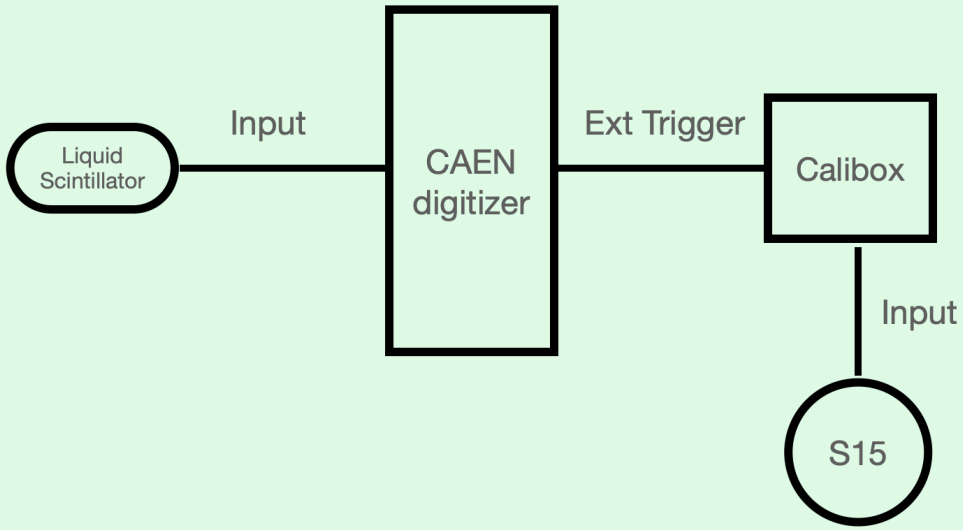


Experiment

Setup: Pictures

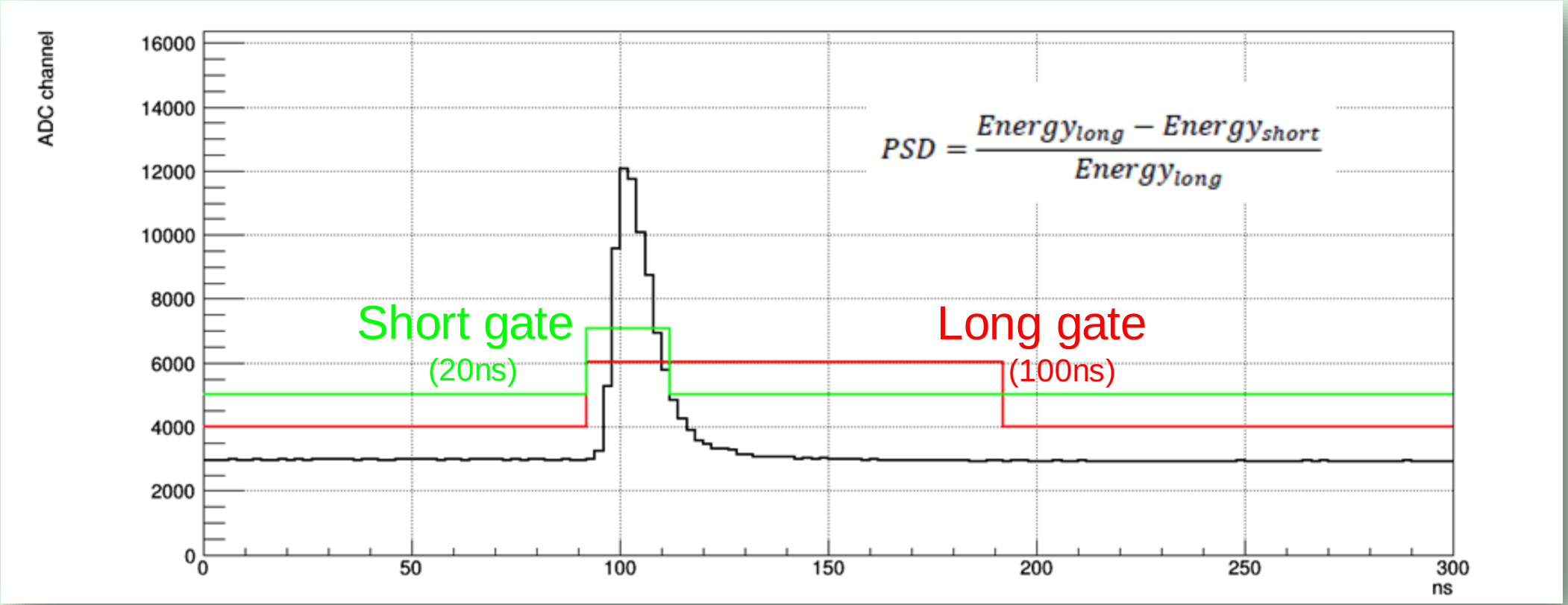
Experiment

Setup: DAQ



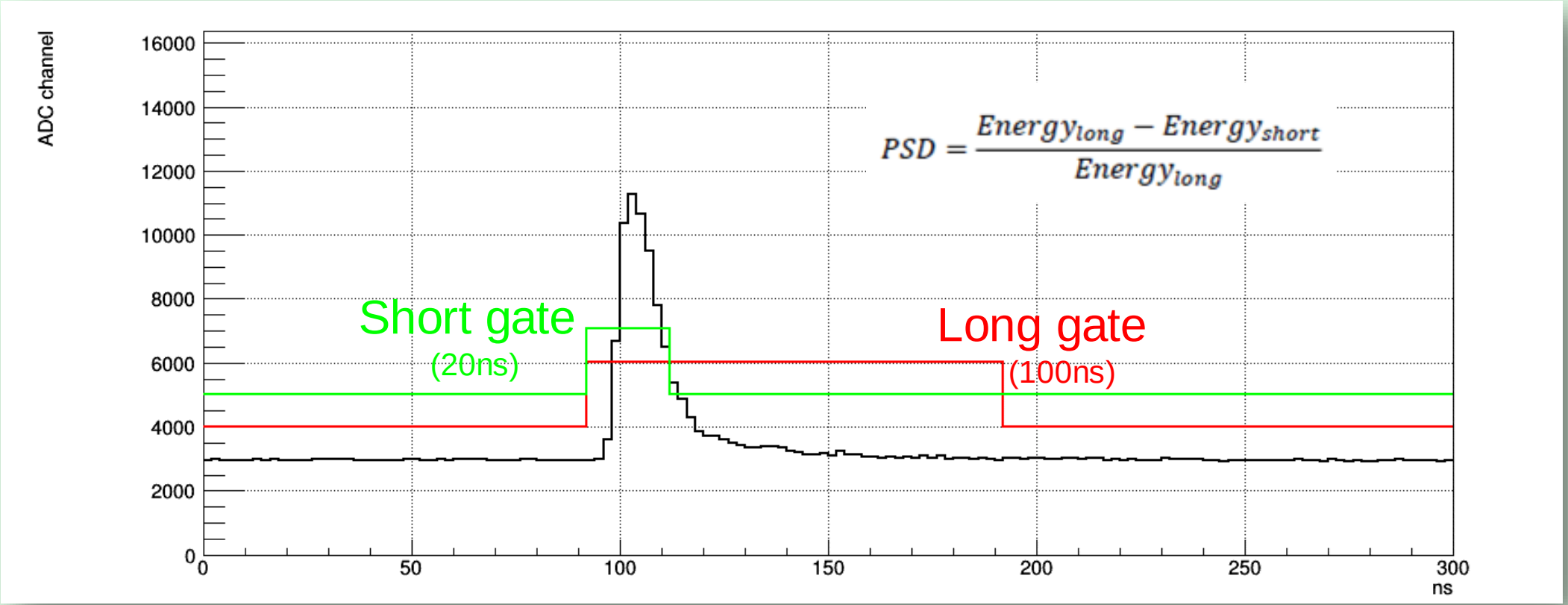
CAEN V1730S Digitizer
16 Channel 14 bit 500 MS/s
CoMPASS DAQ

Sample pulse



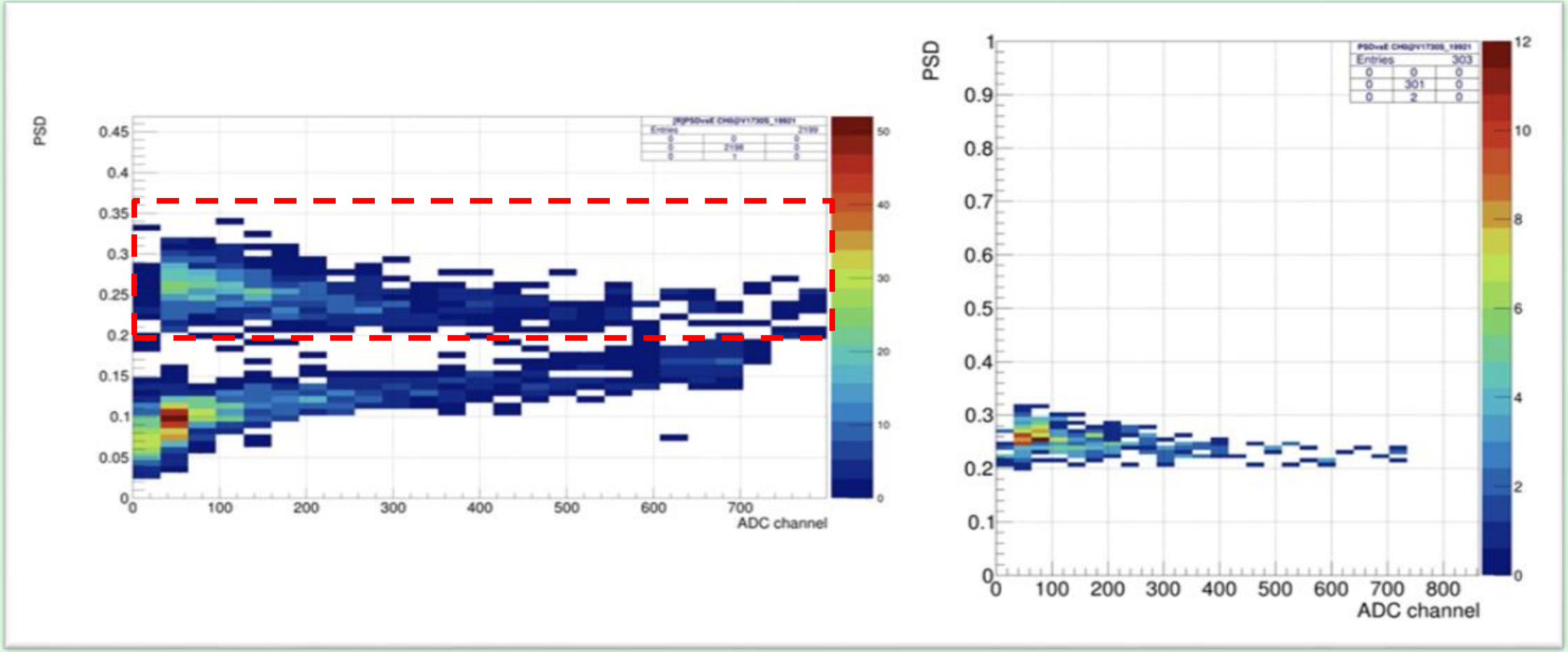
Sample **gamma** pulse acquired with CoMPASS

Sample pulse



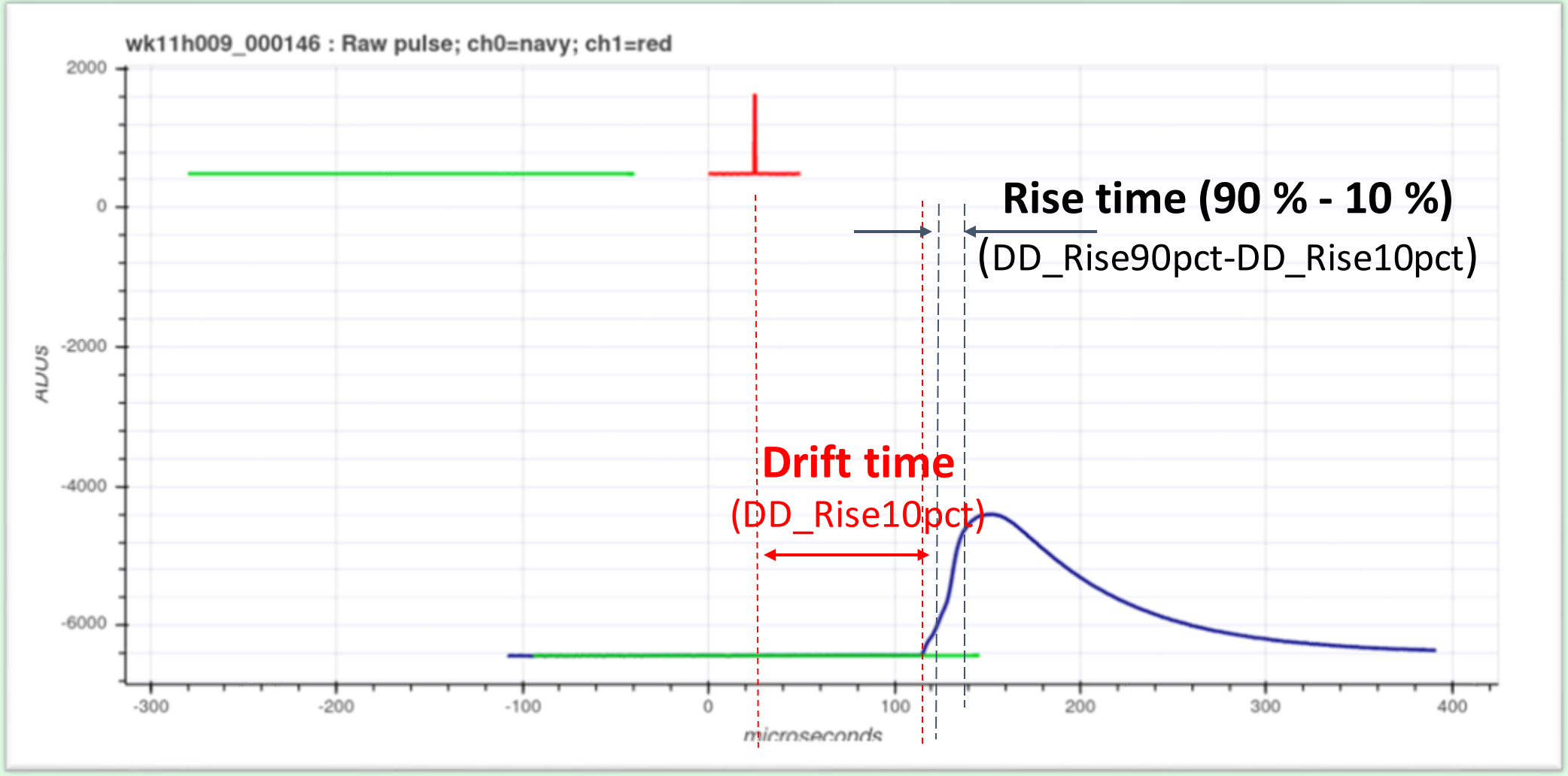
Sample **neutron** pulse acquired with CoMPASS

PSD cut



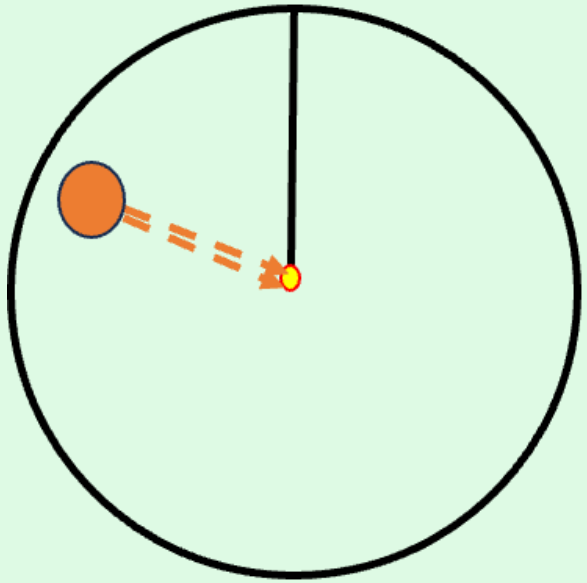
Trigger from CAEN

Analysis

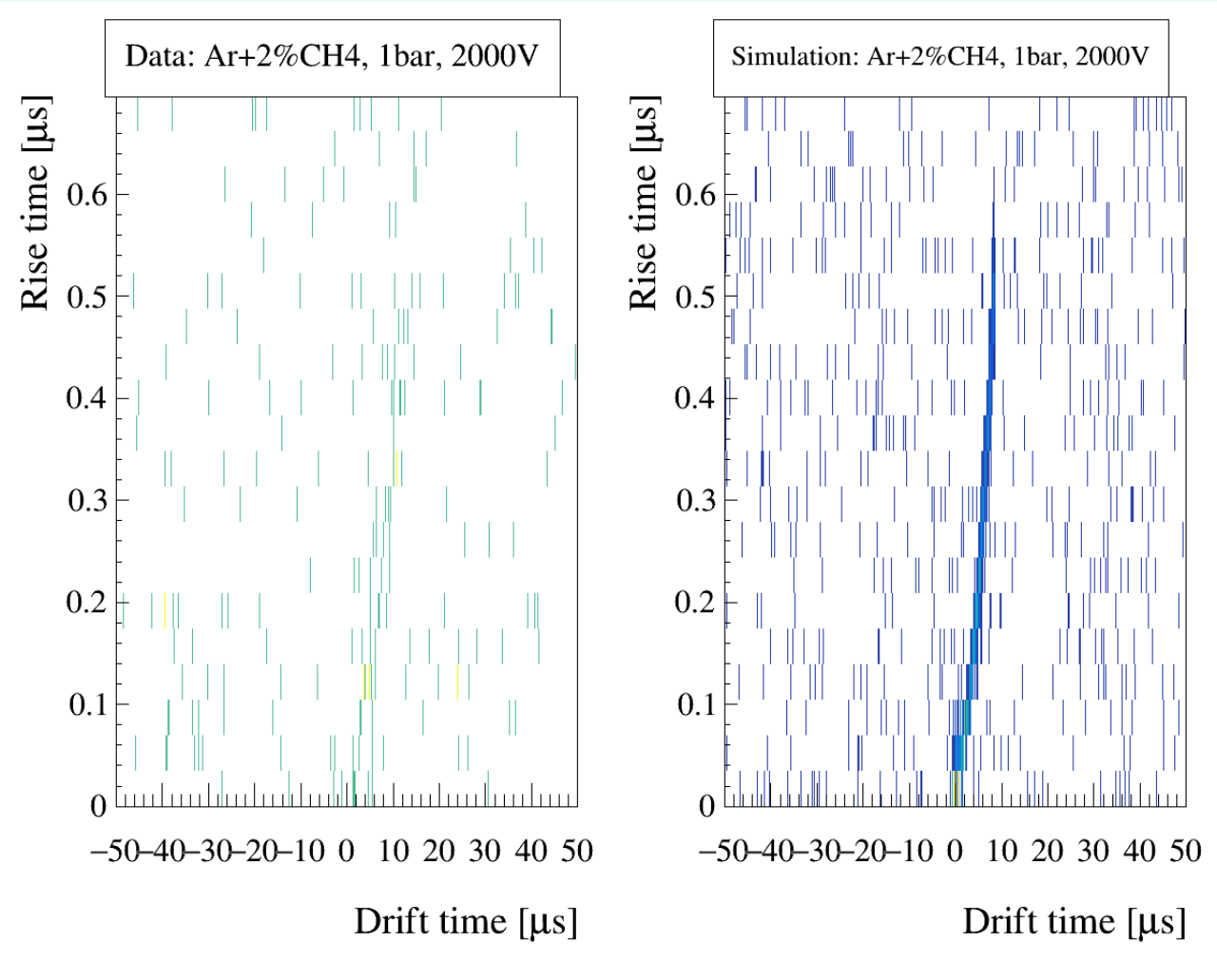

wk11h009_000146 : Raw pulse; ch0=navy; ch1=red
2000
0
-2000
-4000
-6000
ADUS
-300
-200
-100
0
100
200
300
400
microseconds
Rise time (90 % - 10 %)
(DD_Rise90pct-DD_Rise10pct)
Drift time
(DD_Rise10pct)

Event Discrimination

- Drift time in an SPC is proportional to the radial position of the event
- Two types of events: point-like and track-like
- Point-like event:
  - risetime is an indicator of the diffusion of electrons moving towards anode
  - **Risetime is proportional to drift-time**

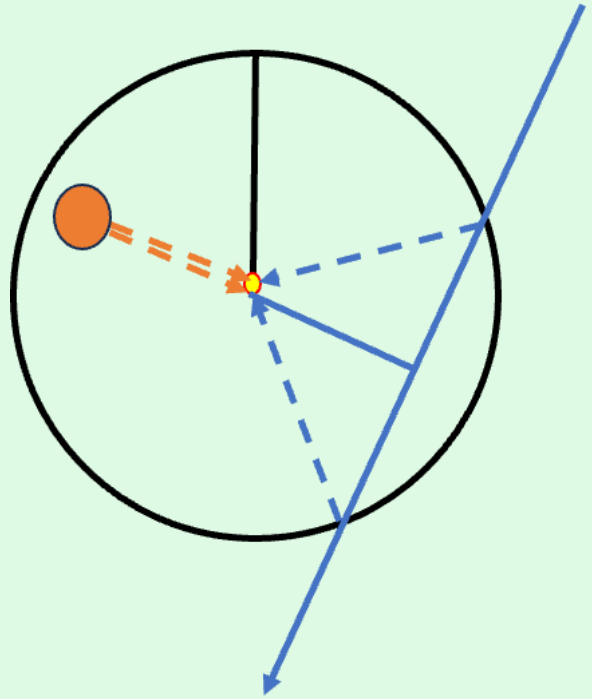


First observation in Ar (+ simulation)

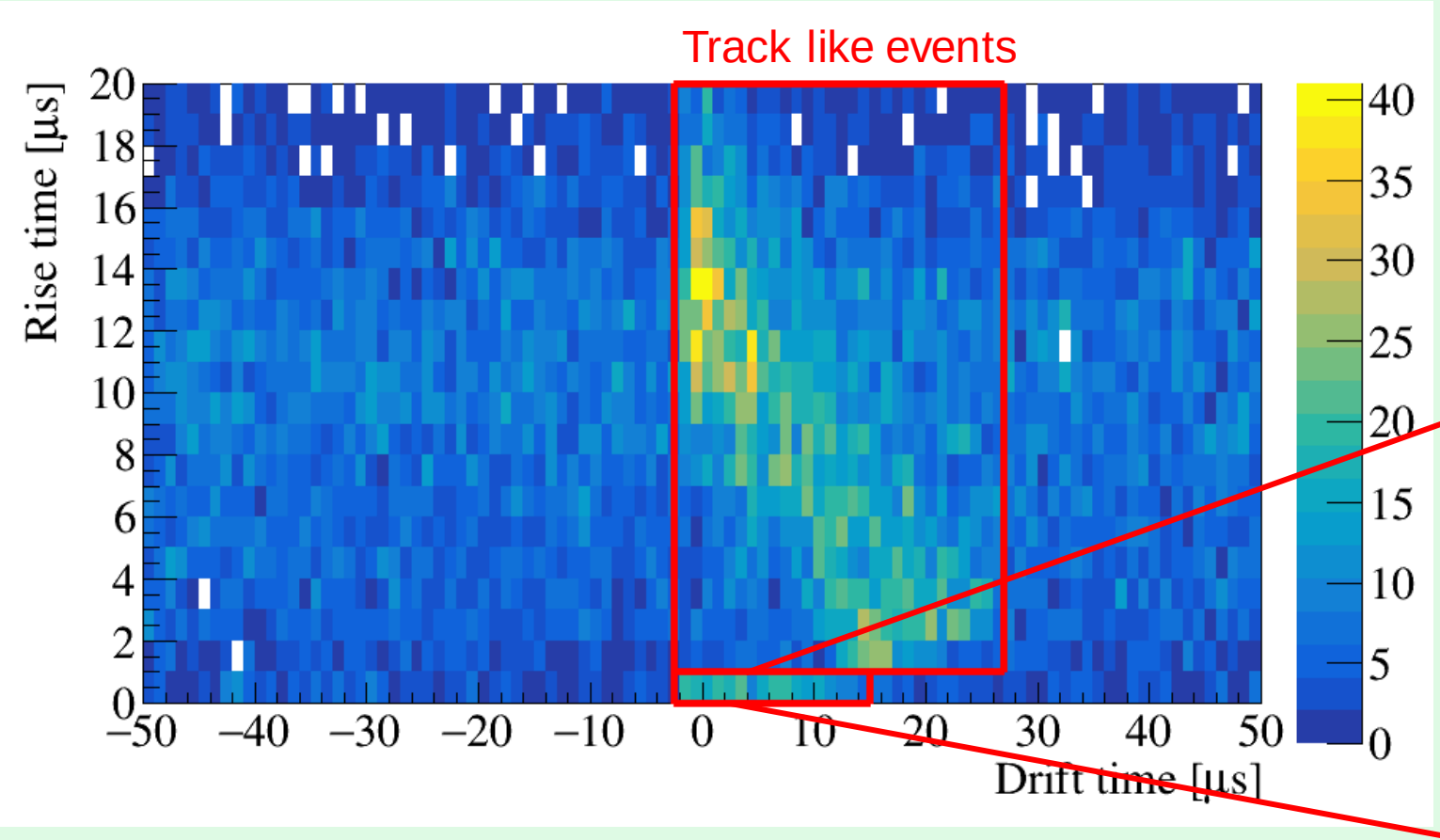


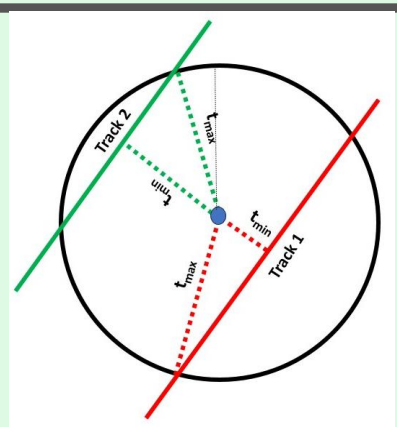
Event Discrimination

- Drift time in an SPC is proportional to the radial position of the event
- Two types of events: point-like and track-like
- Track-like events:
  - risetime is no longer governed by the diffusion time of the electrons
  - difference in the arrival time of the e- closer and farther to the anode
  - **Risetime is higher than the point-like case**

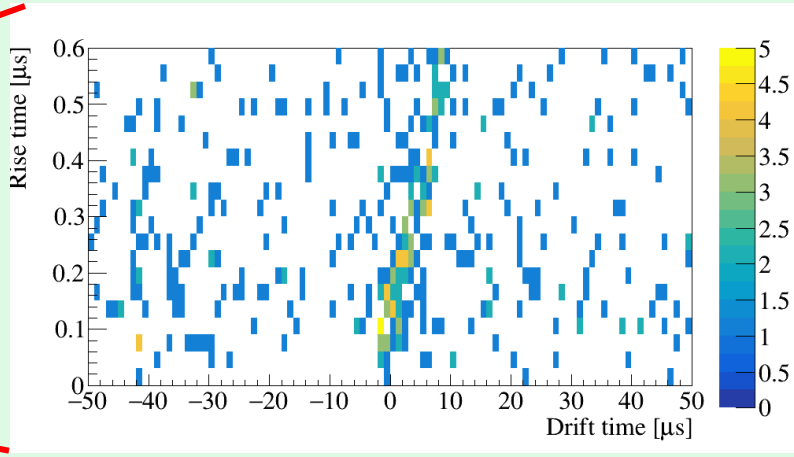


Results from Ar mixture (S15)



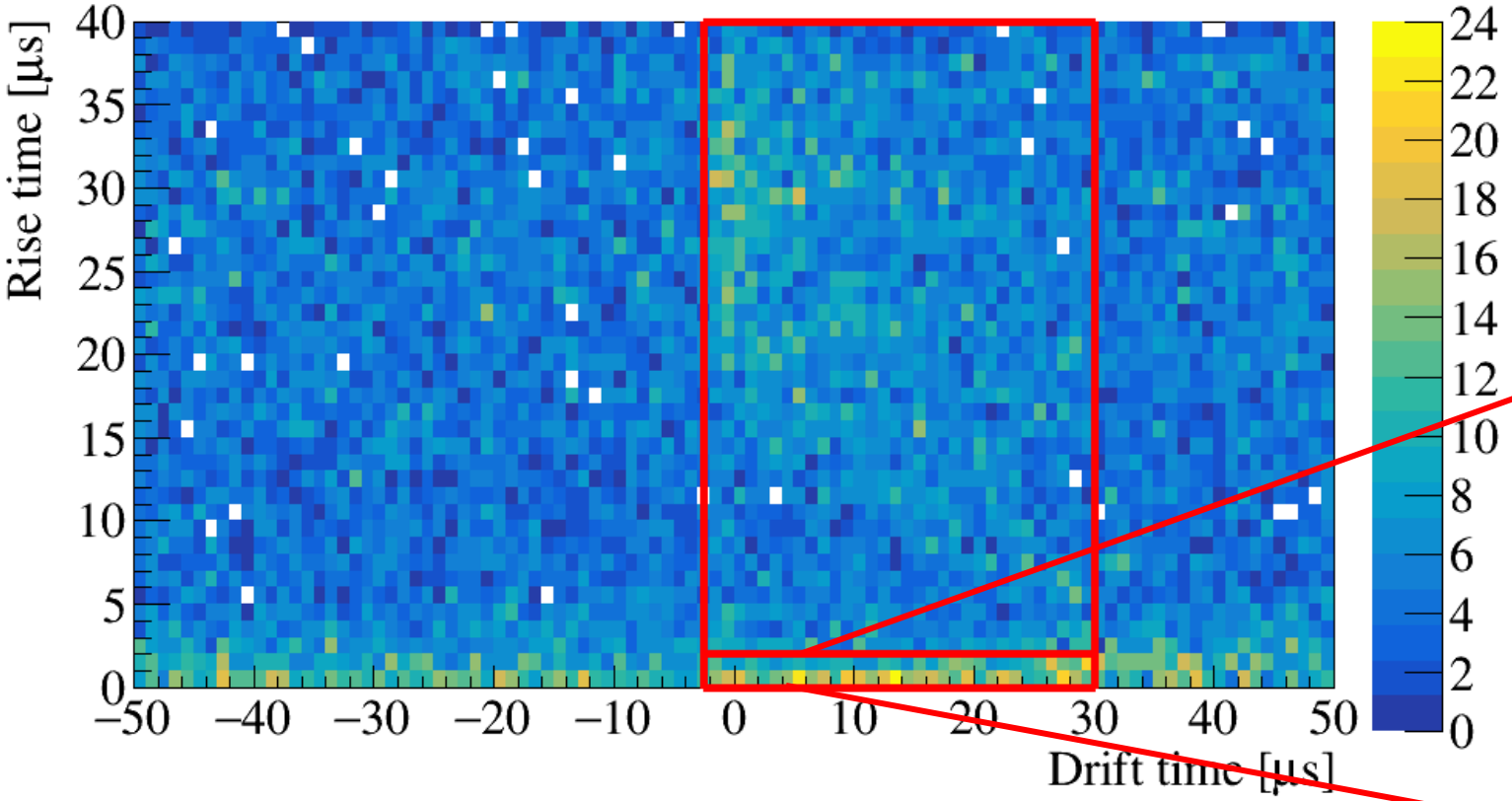


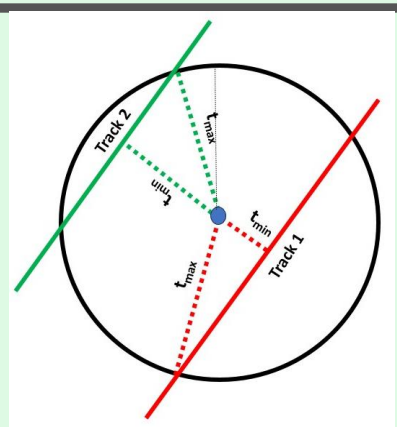
Point like events



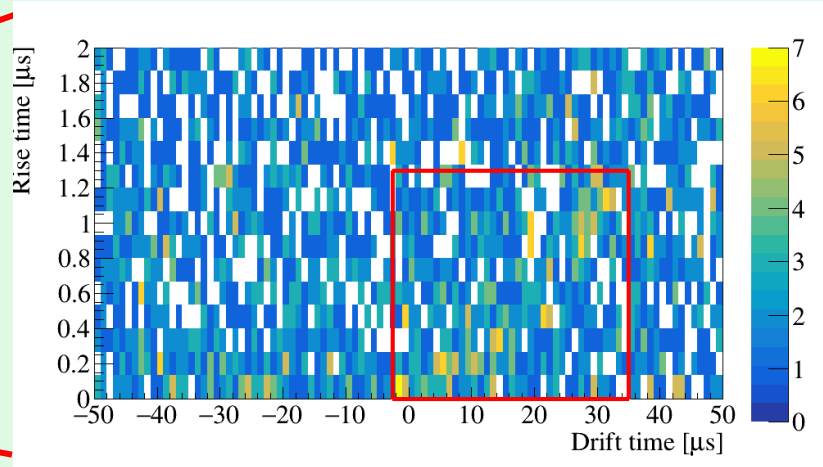
Results from Ar mixture (S30)

Track like events

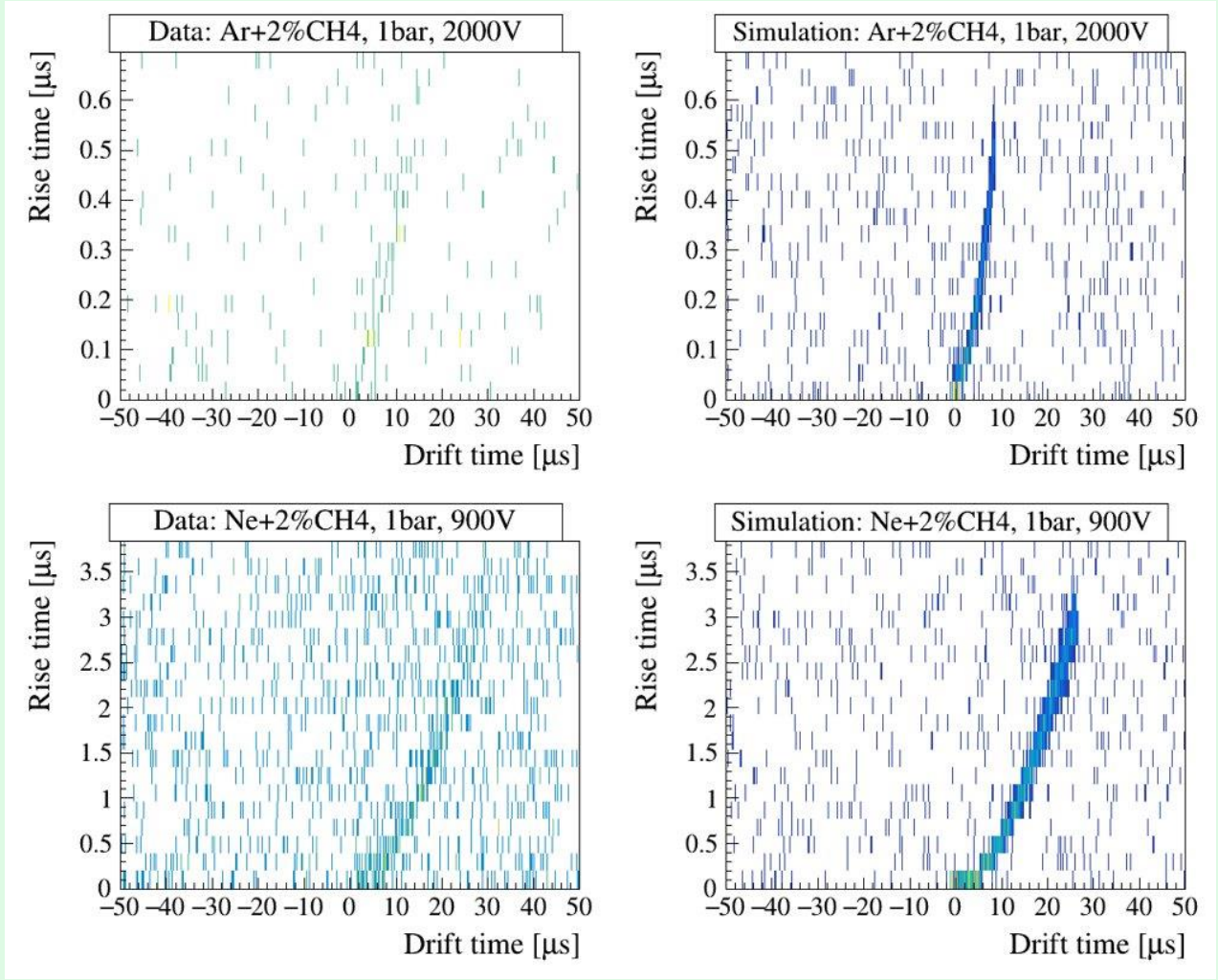




Point like events



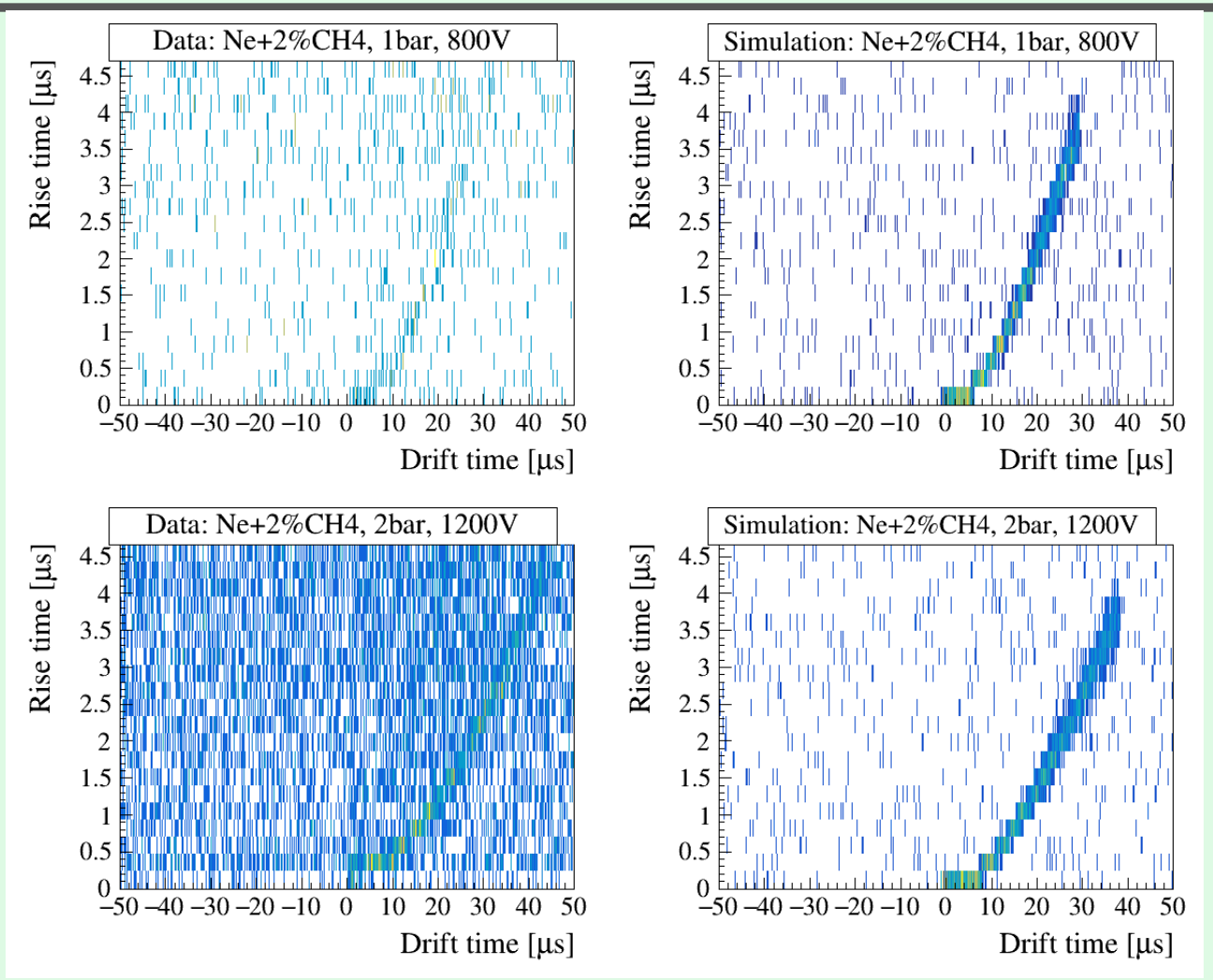
Different gases: Ne and Ar @ 1 bar



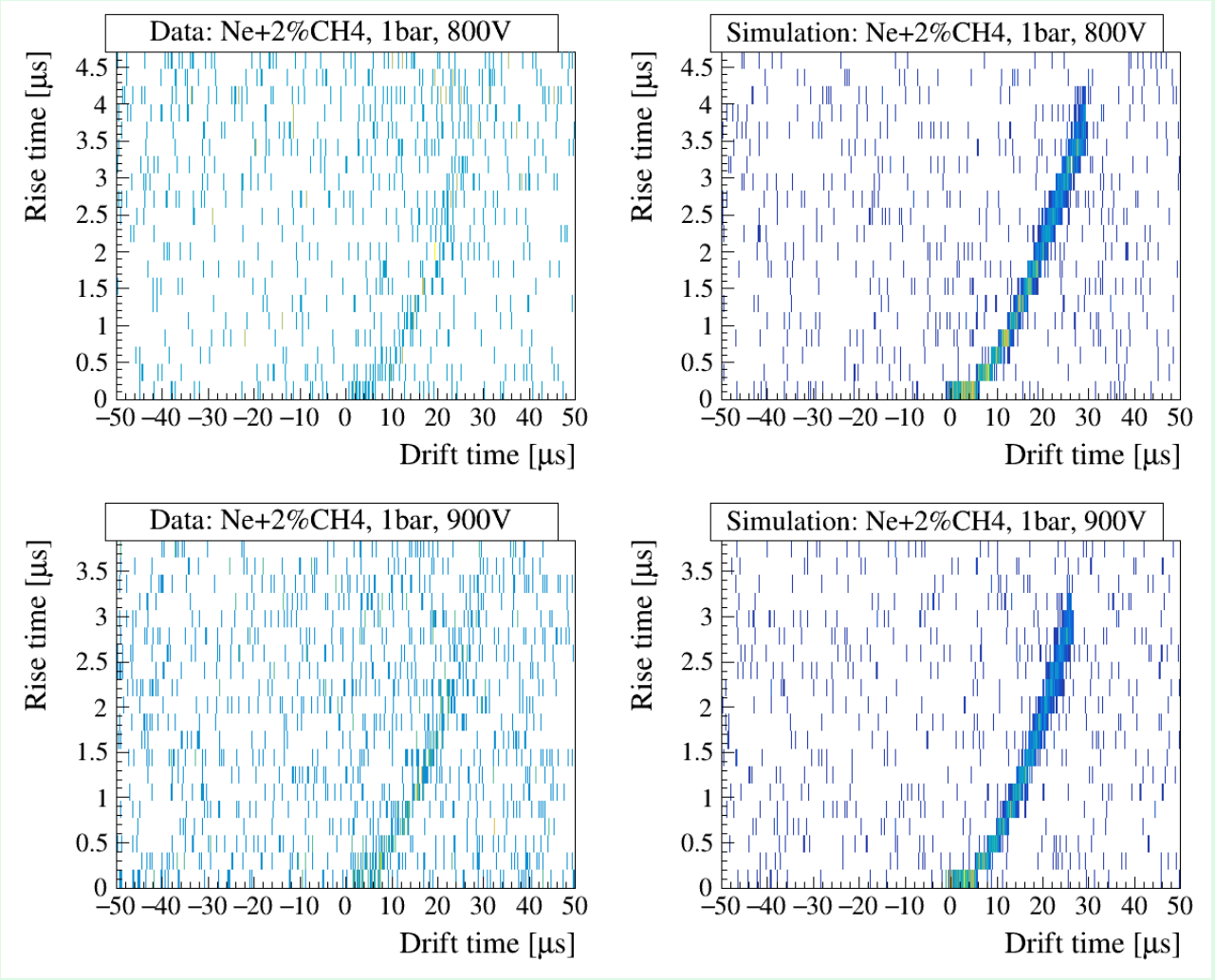
Note
Scale for risetime is different

Observed Rate
~ 30 mHz

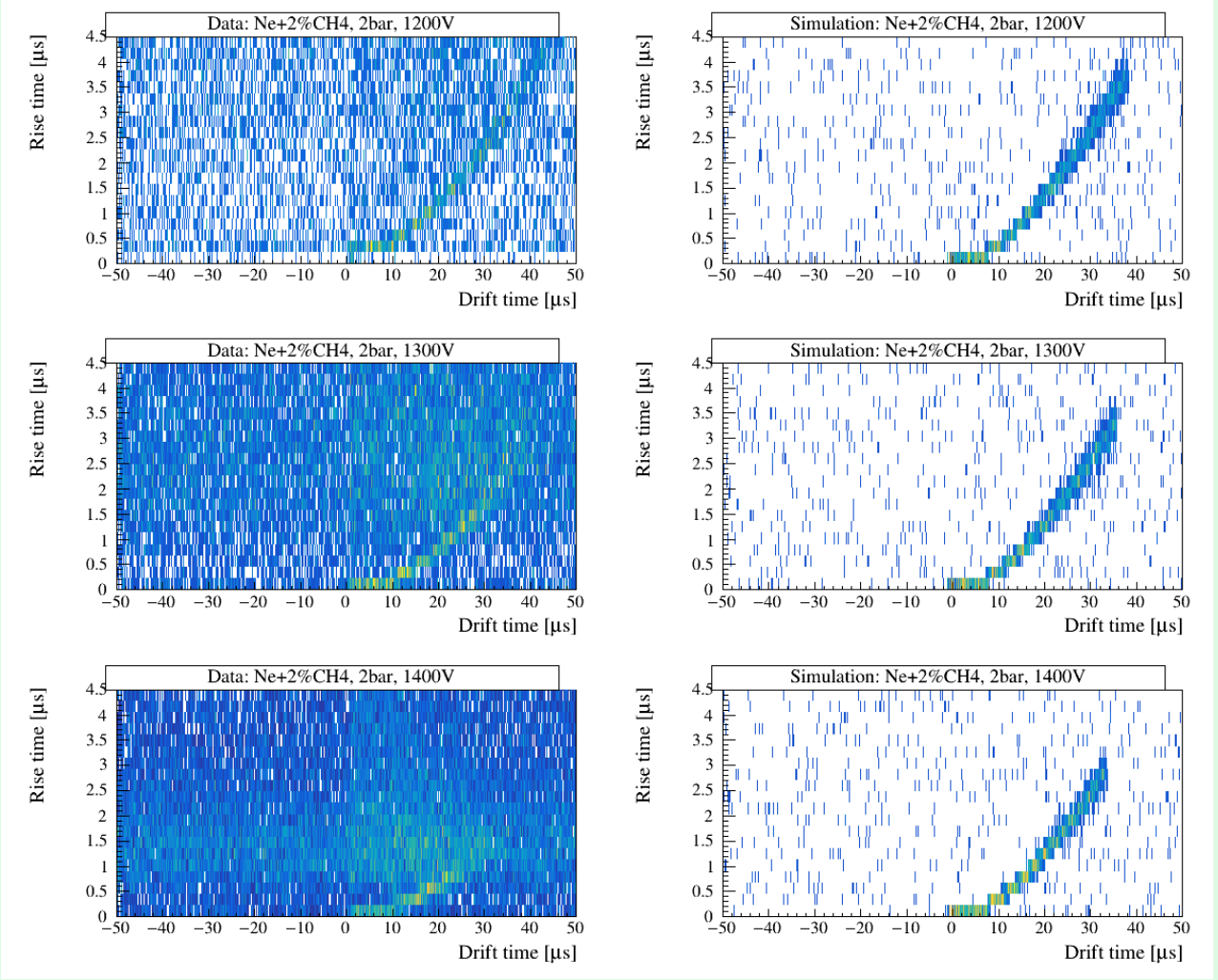
Different pressures: Ne @ 1 and 2 bar



Different HV: Ne (1 bar)



Different HV: Ne (2 bar)

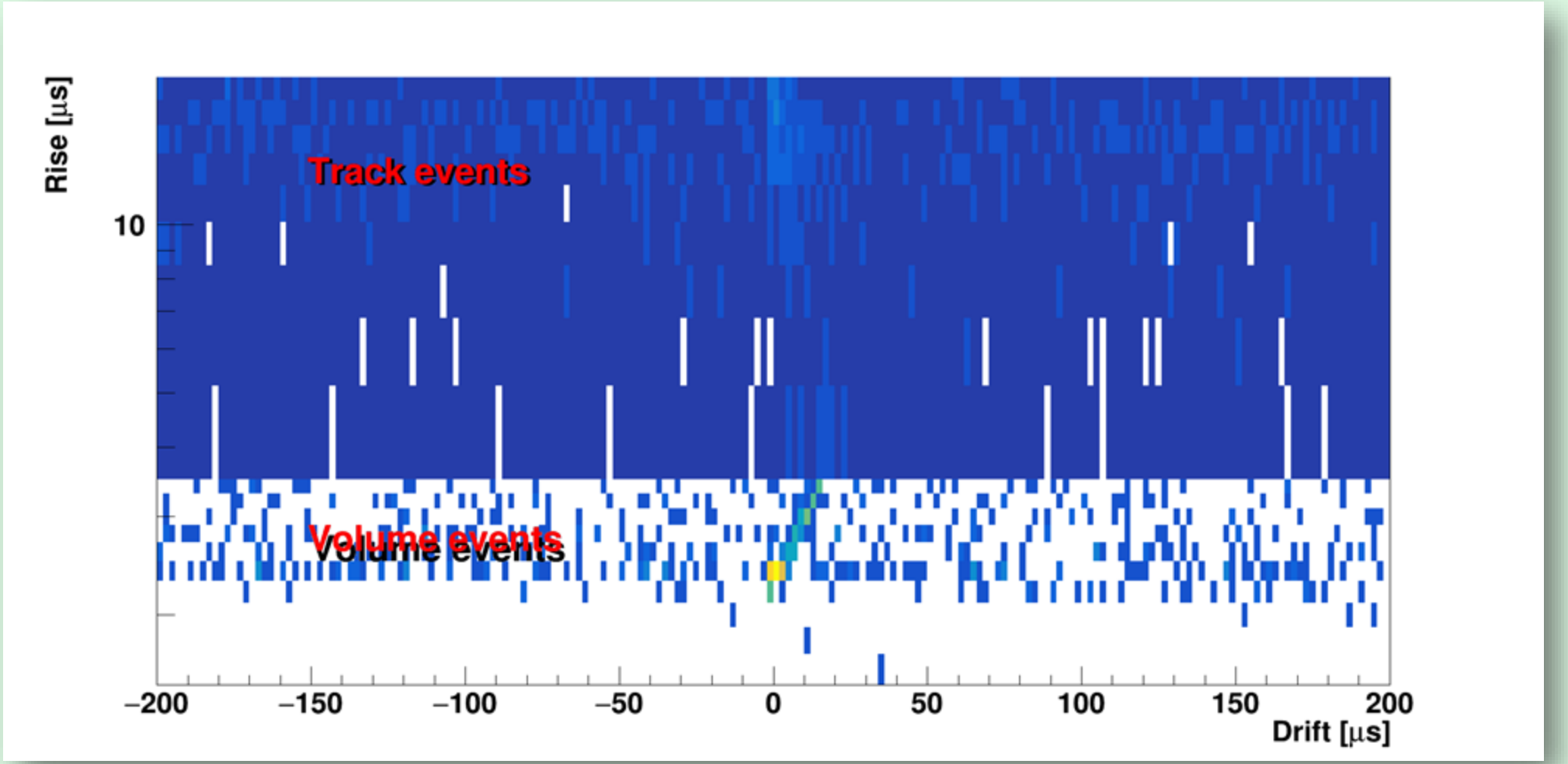


Conclusions

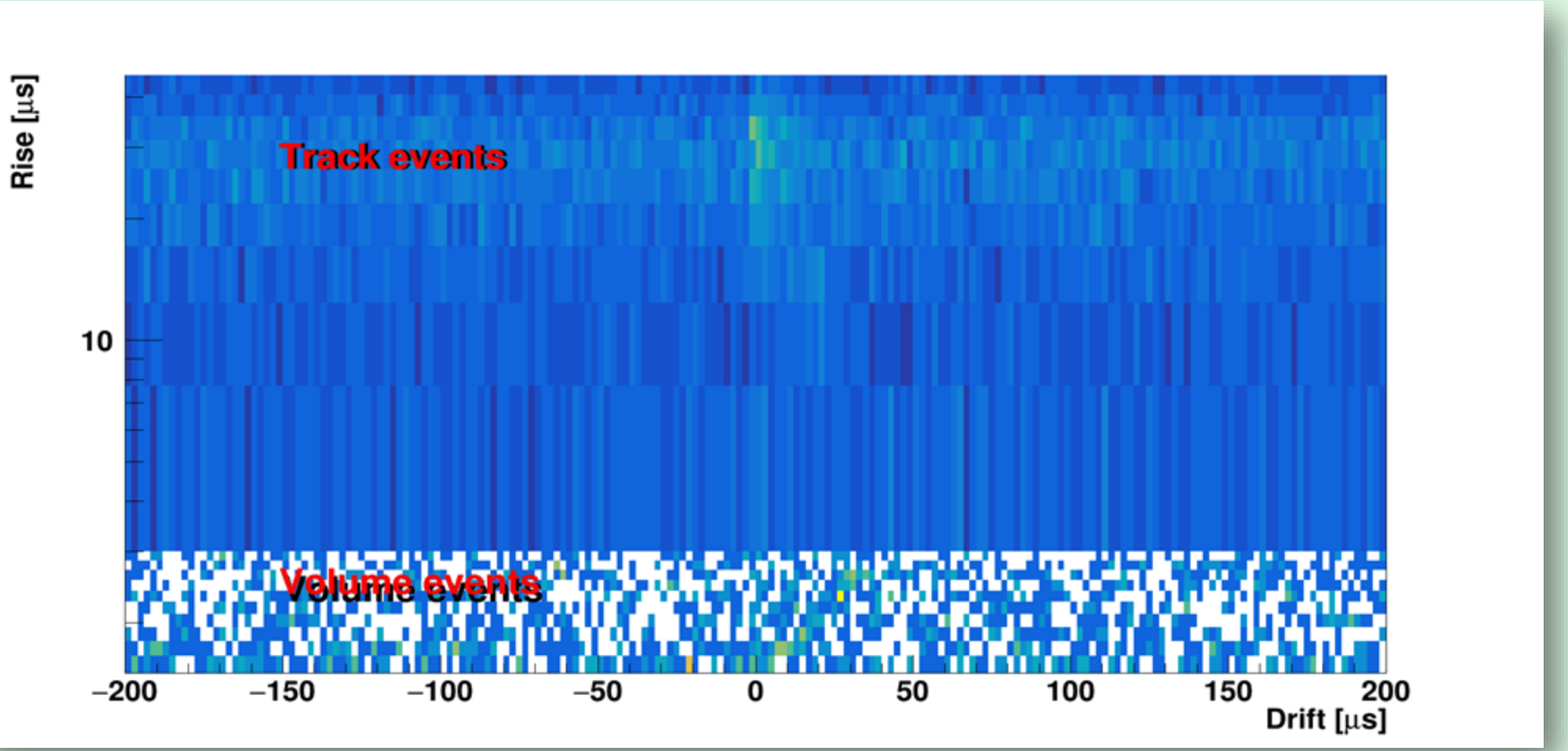
- Past measurements at TUNL in Ne + CH_4 by Marie et al.,
- Another campaign at TUNL is under discussion
- Possibilities at UdeM is being pursued
- Neutron scattering observed in a table top experiment with AmBe source as a crucial step towards QF measurement with neutron beam
- The manuscript for neutron scattering work is ready for submission
- Working towards a new backing detector

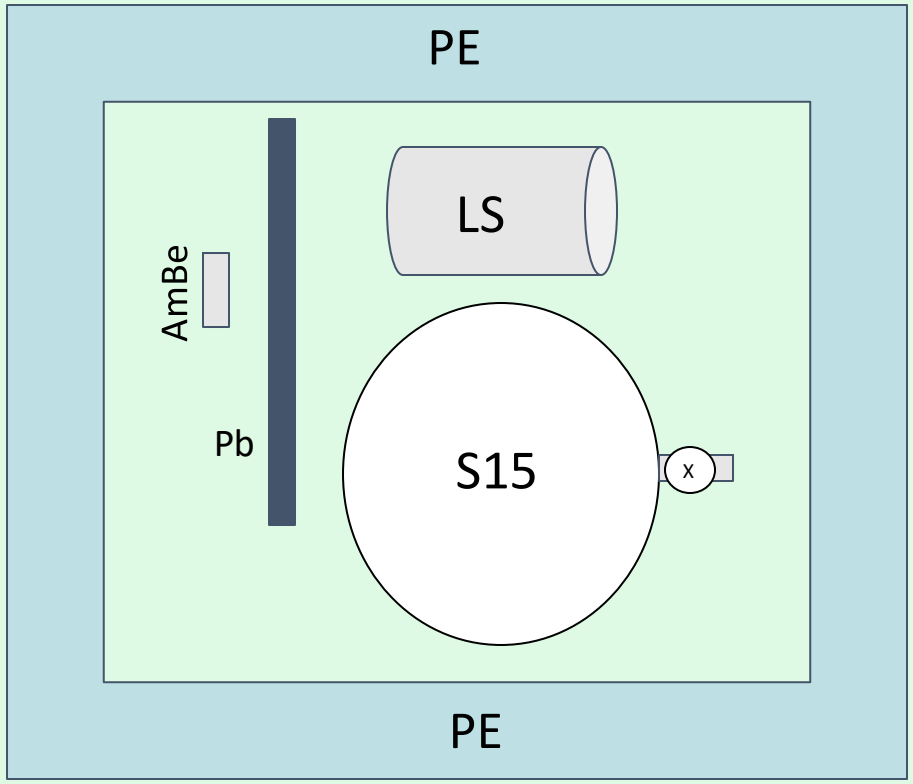
Backup slides

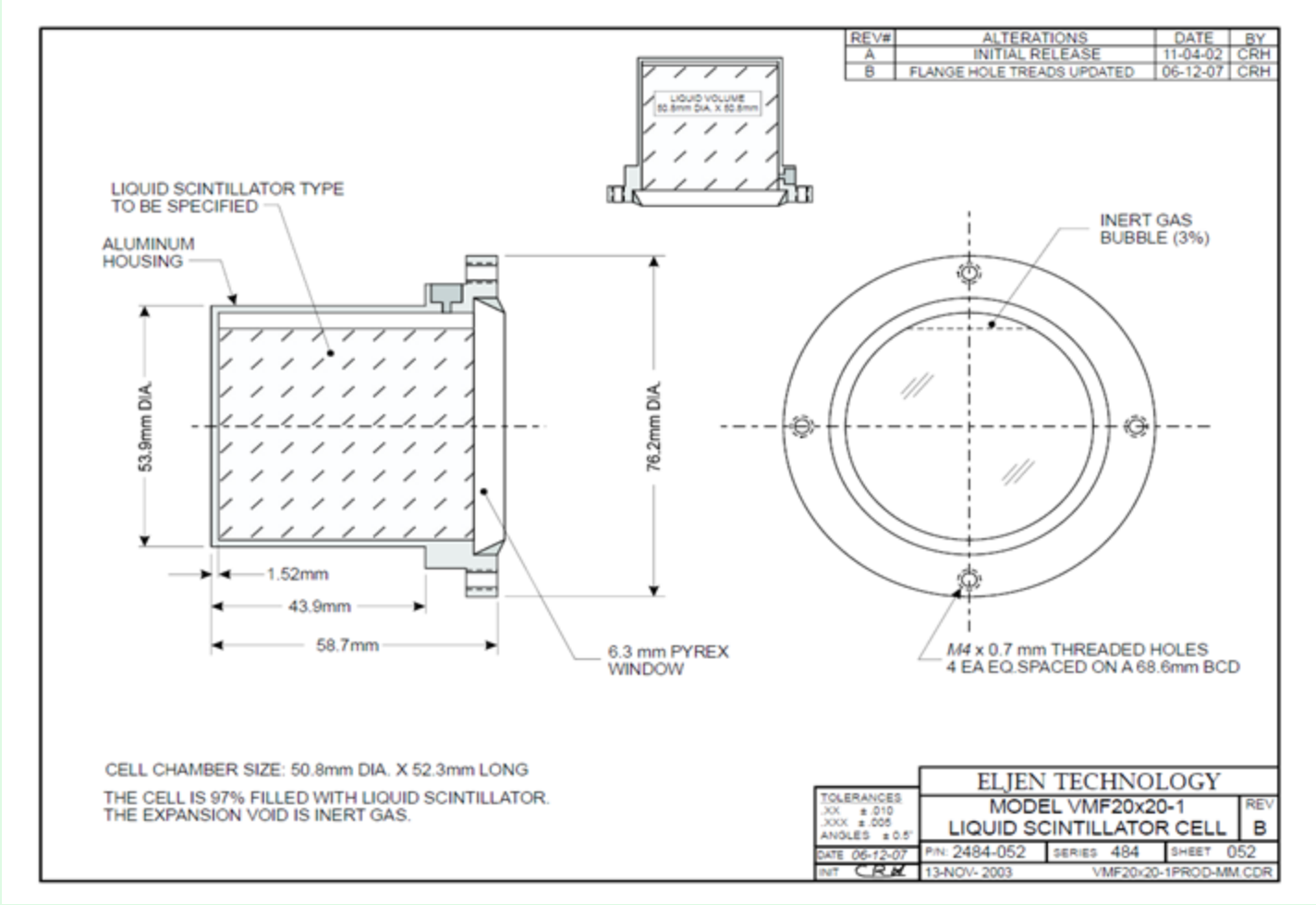
Different sizes of sphere: S15



Different sizes of sphere: S30




PE
LS
AmBe
Pb
S15
X
PE


REV#
ALTERATIONS
DATE
BY
A
INITIAL RELEASE
11-04-02
CRH
B
FLANGE HOLE TREADS UPDATED
06-12-07
CRH
LIQUID VOLUME
50.8mm DIA. X 52.3mm
LIQUID SCINTILLATOR TYPE
TO BE SPECIFIED
ALUMINUM
HOUSING
53.9mm DIA.
76.2mm DIA.
1.52mm
43.9mm
58.7mm
6.3 mm PYREX
WINDOW
INERT GAS
BUBBLE (3%)
M4 x 0.7 mm THREADED HOLES
4 EA EQ.SPACED ON A 68.6mm BCD
CELL CHAMBER SIZE: 50.8mm DIA. X 52.3mm LONG
THE CELL IS 97% FILLED WITH LIQUID SCINTILLATOR.
THE EXPANSION VOID IS INERT GAS.
TOLERANCES
XX ± .010
XXX ± .005
ANGLES ± 0.5°
DATE 06-12-07
INIT CRH
ELJEN TECHNOLOGY
MODEL VMF20x20-1
LIQUID SCINTILLATOR CELL
REV
B
P/N: 2484-052
SERIES 484
SHEET 052
13-NOV- 2003
VMF20x20-1PROD-MM.CDR

Rate Estimation

Monte Carlo simulation

- Simple MC simulation by Irina to calculate the geometric factor
- Assumed Isotropic distribution of neutron-gas interactions in SPC
- **10%** total interactions in SPC will be recorded in the liquid scintillator

$$\text{rate} = (\text{neutron rate}_{\text{source}})\sigma_{Ar} l (\frac{N_A}{V_{m,stp}})(\frac{\Omega_{\text{source}\rightarrow\text{sphere}}}{4\pi})$$

Rate ~ 300 mHz
for 1 bar Ne

Rate ~ 30 mHz

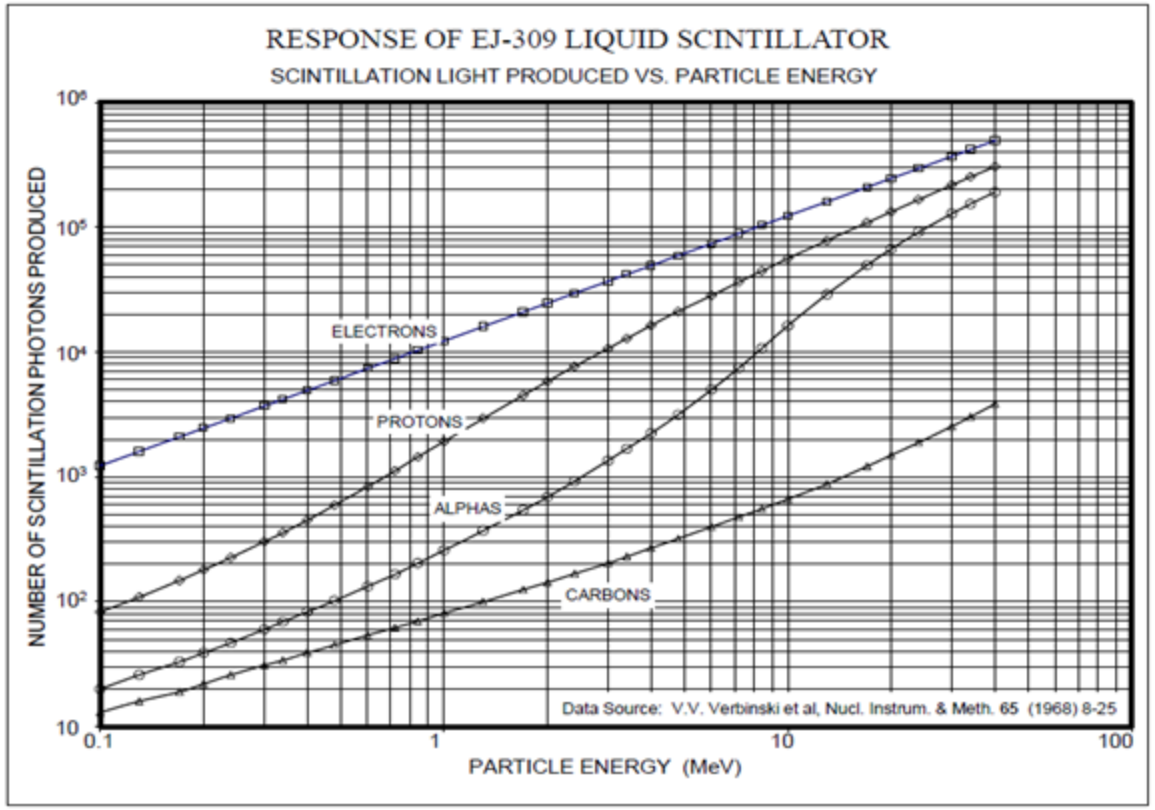
ELJEN TECHNOLOGY

Electrons	
MeV	# Photons
0.10	1,230
0.13	1,600
0.17	2,090
0.20	2,460
0.24	2,950
0.30	3,690
0.34	4,180
0.40	4,920
0.48	5,900
0.60	7,380
0.72	8,860
0.84	10,330
1.00	12,300
1.30	15,990
1.70	20,910
2.00	24,600
2.40	29,520
3.00	36,900
3.40	41,820
4.00	49,200
4.80	59,040
6.00	73,800
7.20	88,560
8.40	103,320
10.00	123,000
13.00	159,900
17.00	209,100
20.00	246,000
24.00	295,200
30.00	369,000
34.00	418,200
40.00	492,000

Protons	
MeV	# Photons
0.10	83
0.13	109
0.17	148
0.20	180
0.24	226
0.30	303
0.34	357
0.40	449
0.48	594
0.60	834
0.72	1,119
0.84	1,445
1.00	1,921
1.30	2,934
1.70	4,502
2.00	5,812
2.40	7,688
3.00	10,652
3.40	12,817
4.00	16,322
4.80	21,131
6.00	28,413
7.20	36,285
8.40	44,526
10.00	55,965
13.00	78,228
17.00	108,609
20.00	132,840
24.00	166,050
30.00	217,710
34.00	252,150
40.00	305,040

Alphas	
MeV	# Photons
0.10	20
0.13	26
0.17	33
0.20	39
0.24	47
0.30	60
0.34	69
0.40	83
0.48	102
0.60	133
0.72	166
0.84	204
1.00	258
1.30	371
1.70	542
2.00	691
2.40	923
3.00	1,353
3.40	1,679
4.00	2,232
4.80	3,143
6.00	5,006
7.20	7,466
8.40	10,701
10.00	16,236
13.00	28,905
17.00	49,569
20.00	66,912
24.00	91,143
30.00	128,166
34.00	153,012
40.00	190,650

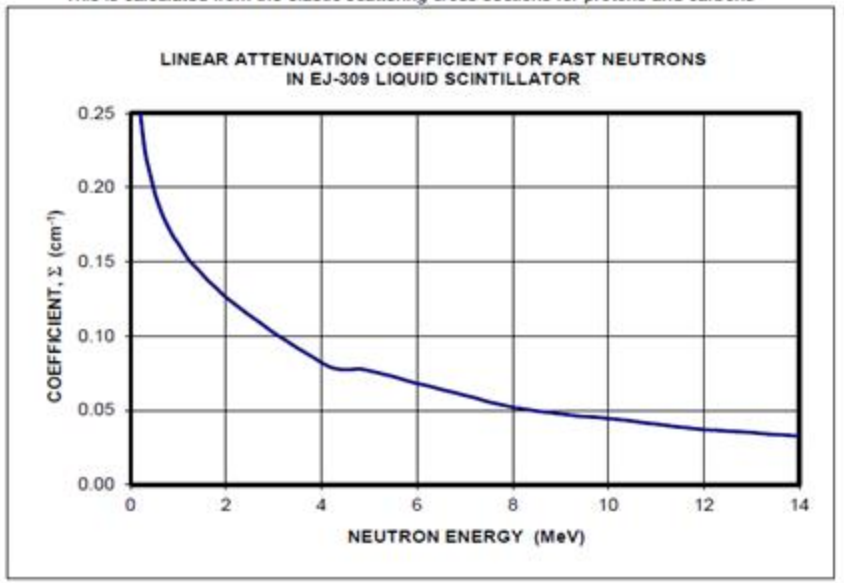
Carbon	
MeV	# Photons
0.10	13
0.13	16
0.17	19
0.20	22
0.24	26
0.30	31
0.34	34
0.40	39
0.48	45
0.60	54
0.72	62
0.84	70
1.00	81
1.30	100
1.70	125
2.00	143
2.40	168
3.00	204
3.40	230
4.00	269
4.80	320
6.00	398
7.20	477
8.40	555
10.00	664
13.00	878
17.00	1215
20.00	1494
24.00	1888
30.00	2539
34.00	3028
40.00	3843



ELJEN TECHNOLOGY

Neutron Energy MeV	Lin. Attn. Coeff. $\Sigma(cm^{-1})$	Neutron Energy MeV	Lin. Attn. Coeff. $\Sigma(cm^{-1})$
0.2	0.2500	6.8	0.0617
0.3	0.224	7.0	0.0600
0.4	0.2100	7.2	0.0585
0.5	0.1970	7.4	0.0565
0.6	0.1870	7.6	0.0548
0.7	0.1790	7.8	0.0534
0.8	0.1725	8.0	0.0520
0.9	0.1665	8.2	0.0510
1.0	0.1620	8.4	0.0500
1.2	0.1520	8.6	0.0490
1.4	0.1450	8.8	0.0483
1.6	0.1380	9.0	0.0475
1.8	0.1320	9.2	0.0468
2.0	0.1258	9.4	0.0460
2.2	0.1210	9.6	0.0456
2.4	0.1160	9.8	0.0452
2.6	0.1114	10.0	0.0444
2.8	0.1068	10.2	0.0438
3.0	0.1020	10.4	0.0431
3.2	0.0980	10.6	0.0422
3.4	0.0938	10.8	0.0413
3.6	0.0898	11.0	0.0407
3.8	0.0860	11.2	0.0399
4.0	0.0820	11.4	0.0390
4.2	0.0788	11.6	0.0384
4.4	0.0775	11.8	0.0376
4.6	0.0775	12.0	0.0369
4.8	0.0777	12.2	0.0366
5.0	0.0766	12.4	0.0362
5.2	0.0750	12.6	0.0357
5.4	0.0735	12.8	0.0355
5.6	0.0717	13.0	0.0350
5.8	0.0697	13.2	0.0344
6.0	0.0680	13.4	0.0338
6.2	0.0666	13.6	0.0335
6.4	0.0649	13.8	0.0330
6.6	0.0632	14.0	0.0325

This is calculated from the elastic scattering cross sections for protons and carbons



FAST NEUTRON DETECTION

EJ-309 and Similar Eljen Plastic Scintillators

CALCULATED DETECTION EFFICIENCY

	Σ: 0.132	0.0766	0.0444	0.0325
Scint		Neutron Energy		
Thickness	2.5MeV	5MeV	10MeV	14MeV
50mm	0.483	0.318	0.199	0.150
25mm	0.281	0.174	0.105	0.078
10mm	0.124	0.074	0.043	0.032
1mm	0.013	0.008	0.004	0.003
0.25mm	0.0033	0.0019	0.0011	0.0008
0.05mm	0.0007	0.0004	0.00022	0.00016