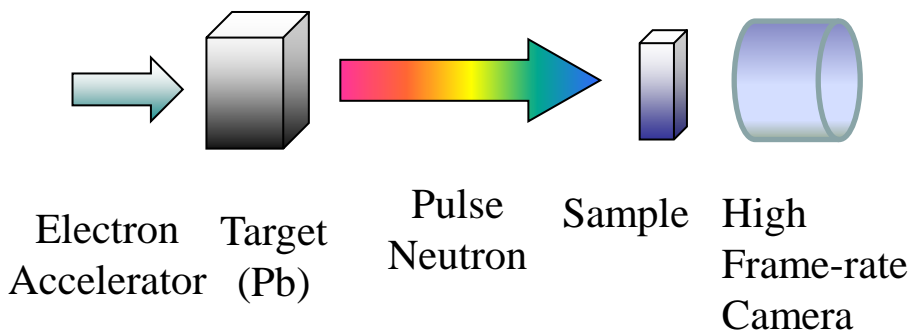


パルス中性子透過分光撮像法のための の高速カメラの開発

東京都市大学 持木 幸一

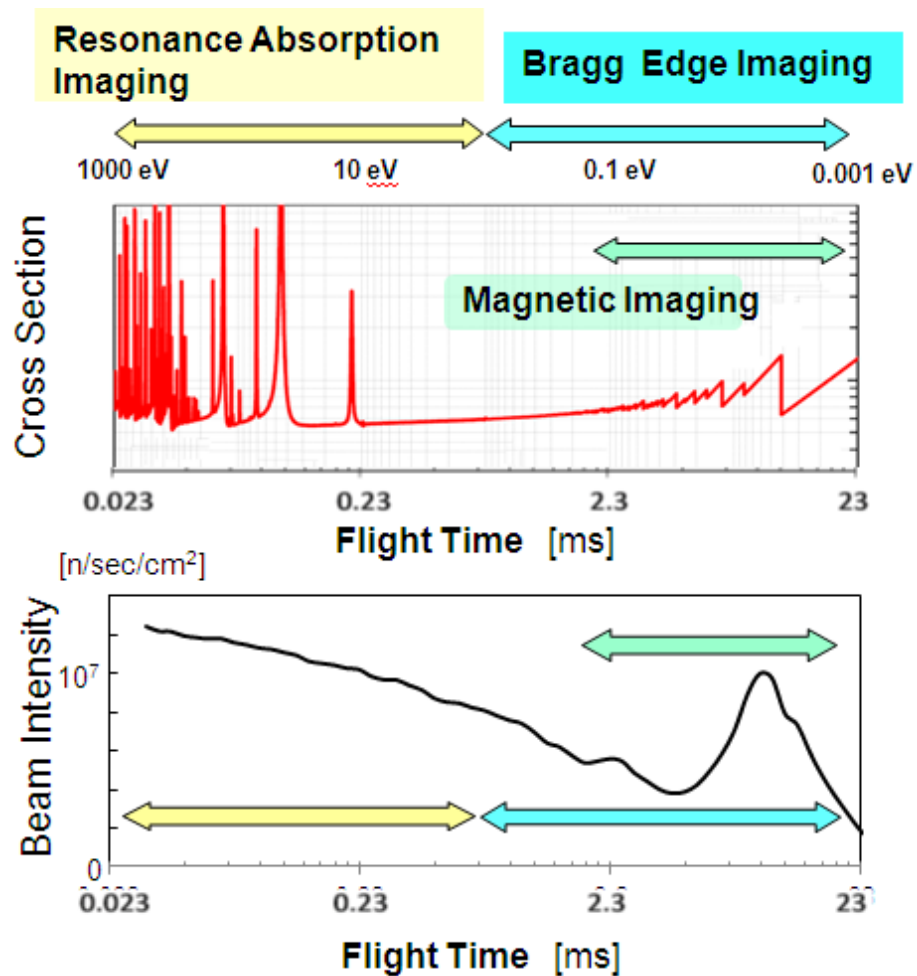
パルス中性子透過分光撮像法

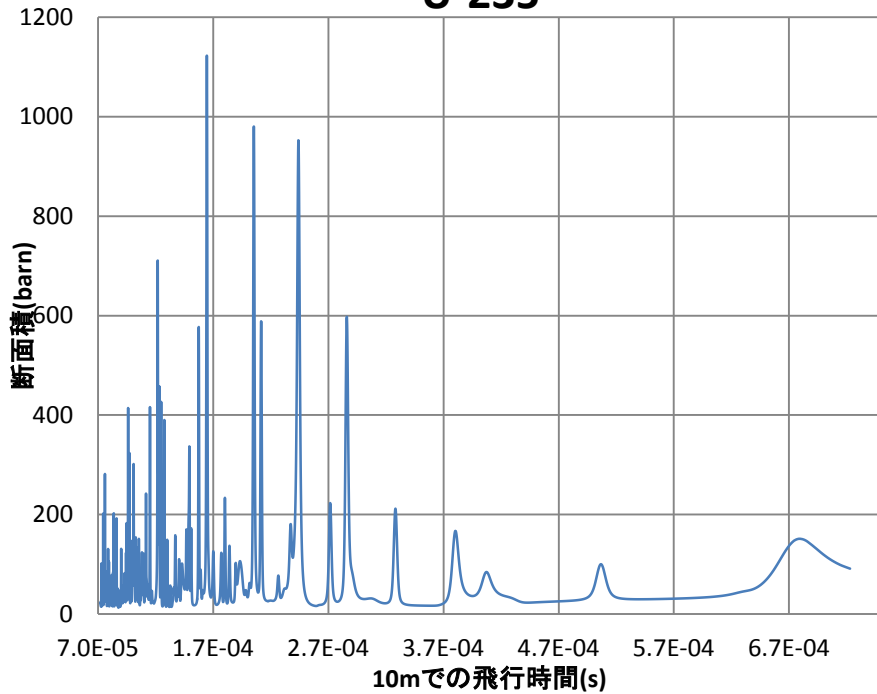
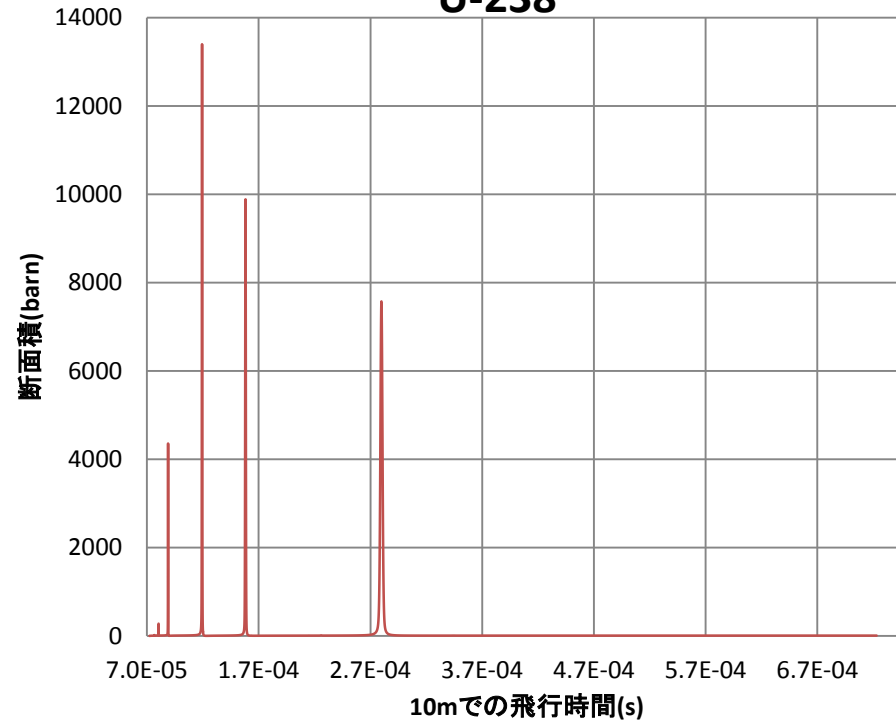
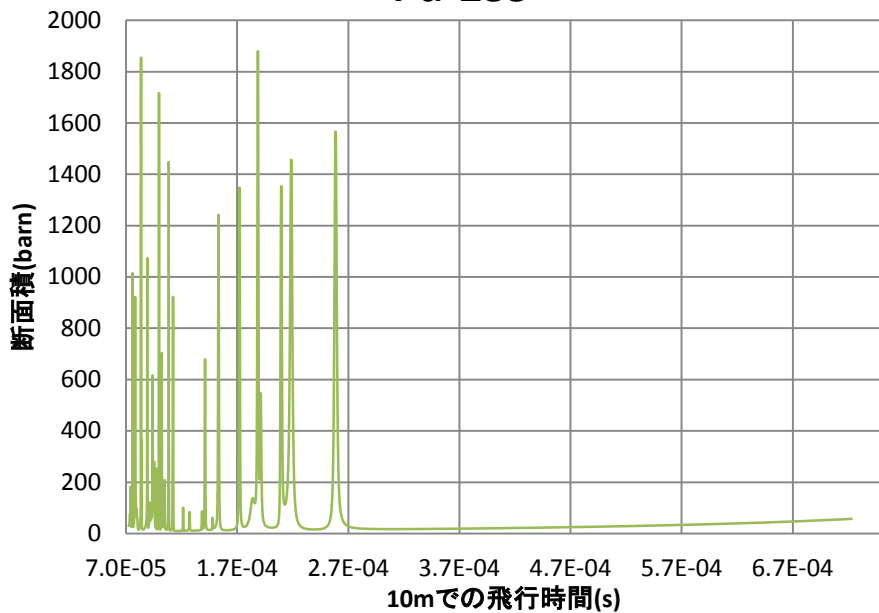
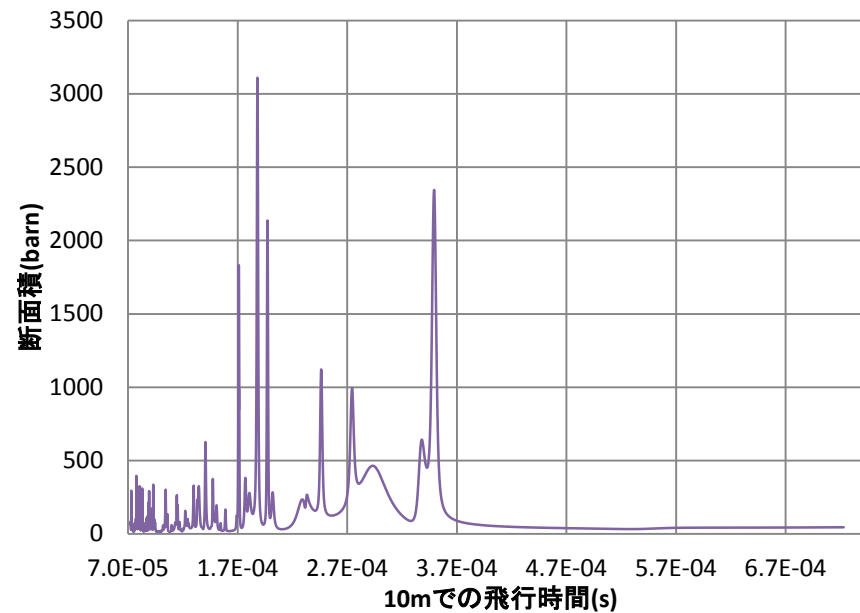


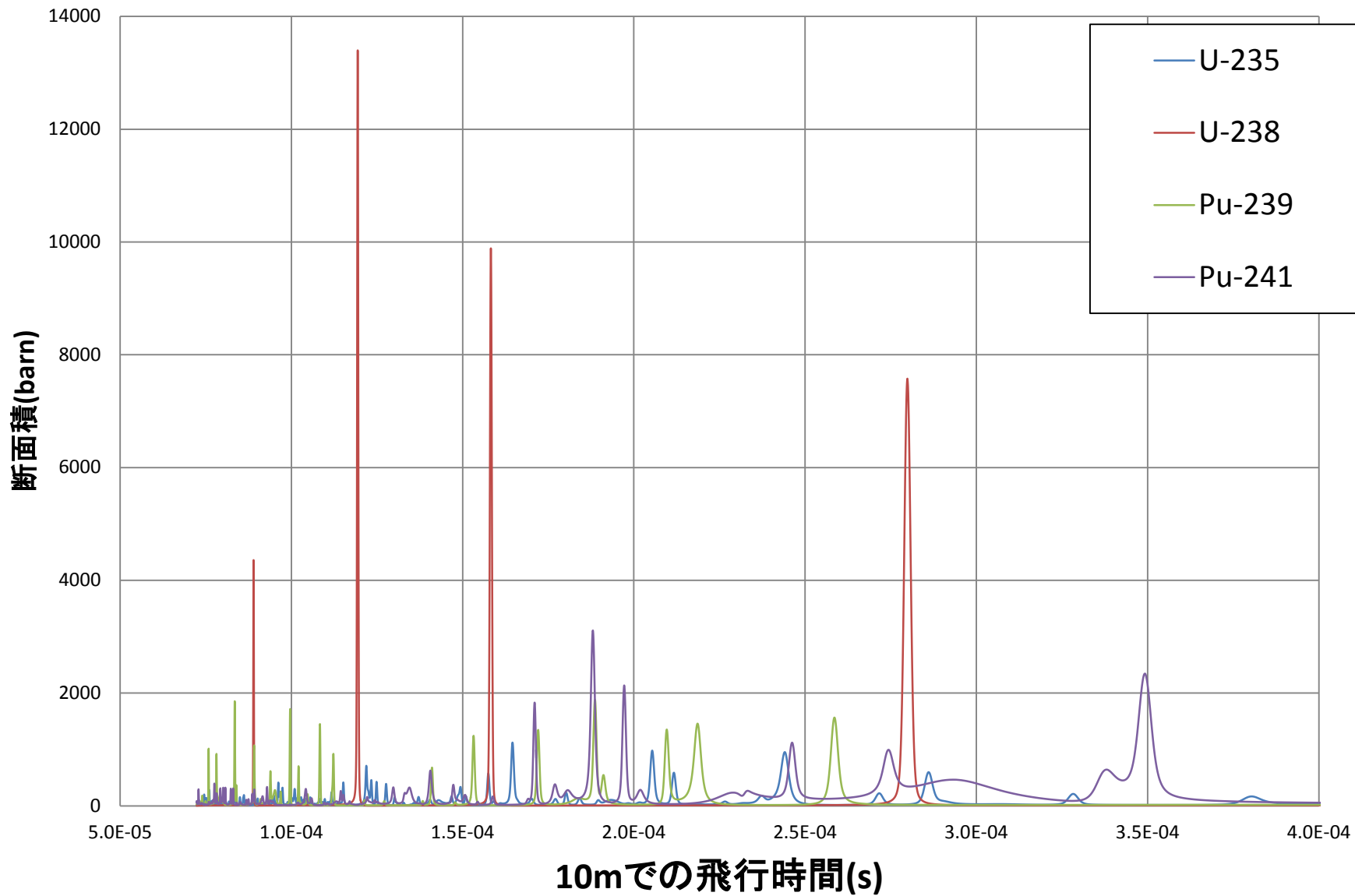
Based on the energy-analysis of neutron by Time-of-Flight method (TOF)

Three major application

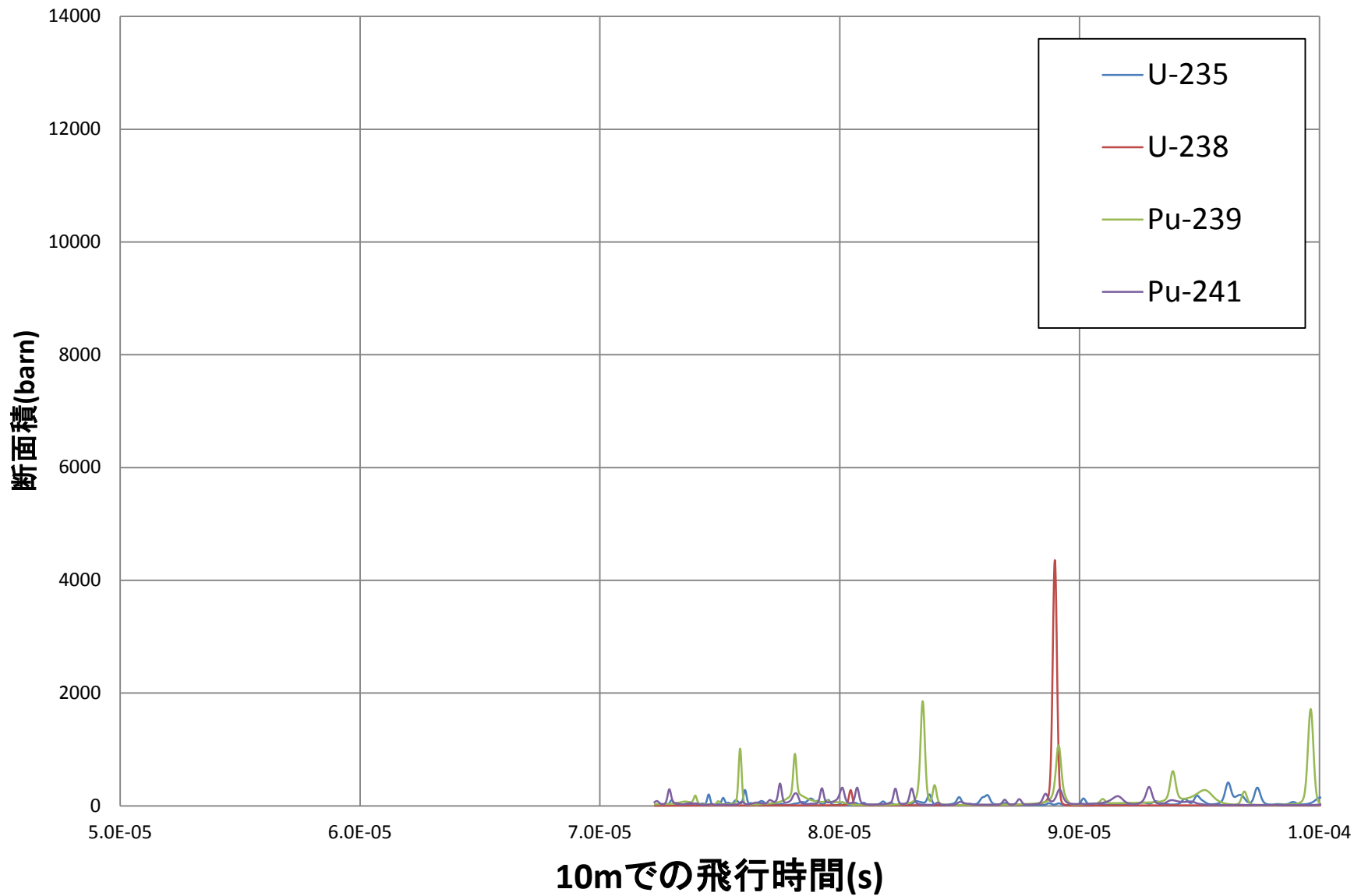
- 1) Resonance absorption imaging to distinguish nuclei
- 2) Bragg edge imaging for crystallography
- 3) Magnetic field imaging



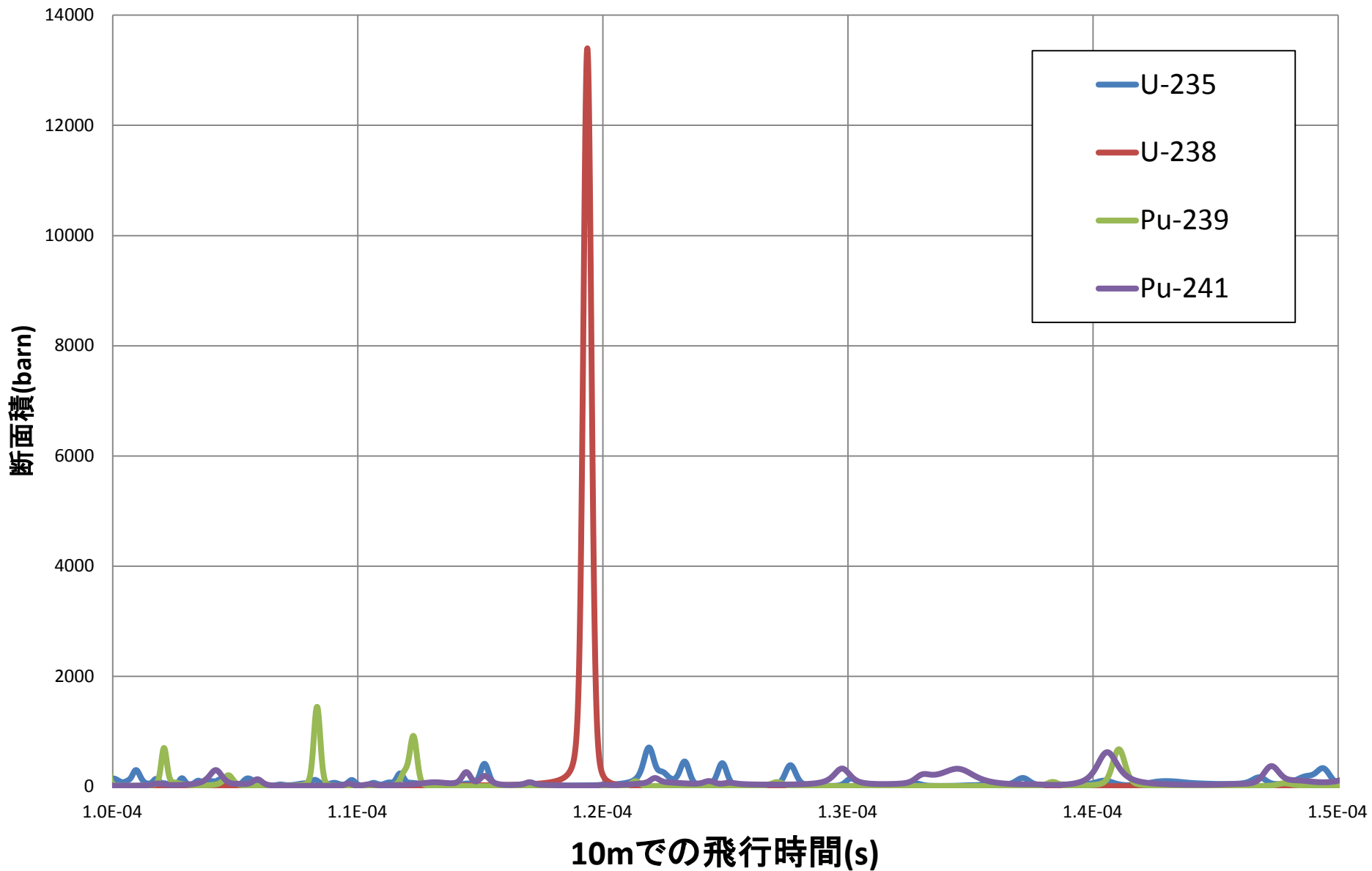
U-235**U-238****Pu-239****Pu-241**



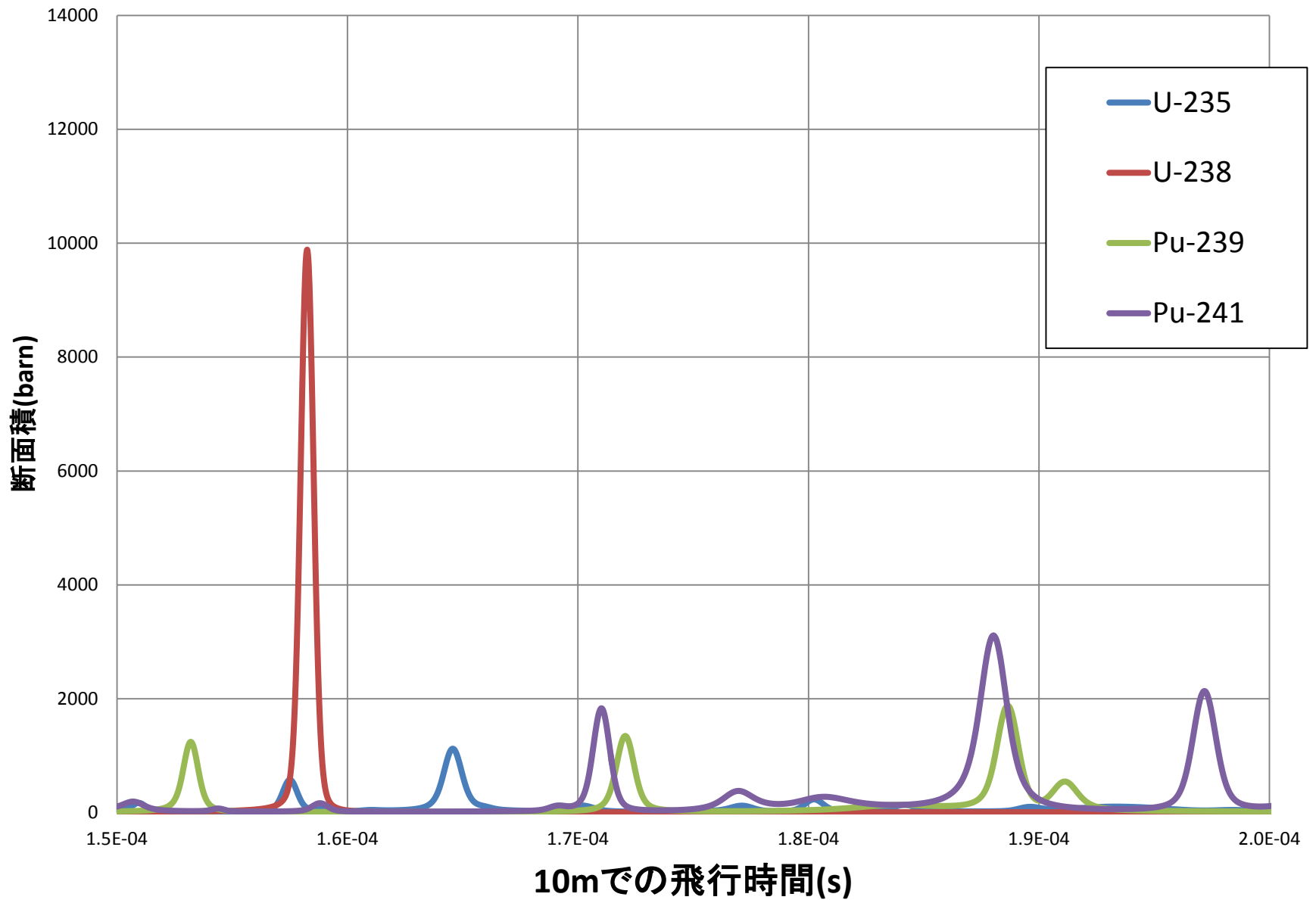
中性子エネルギーEが1eV~100eV



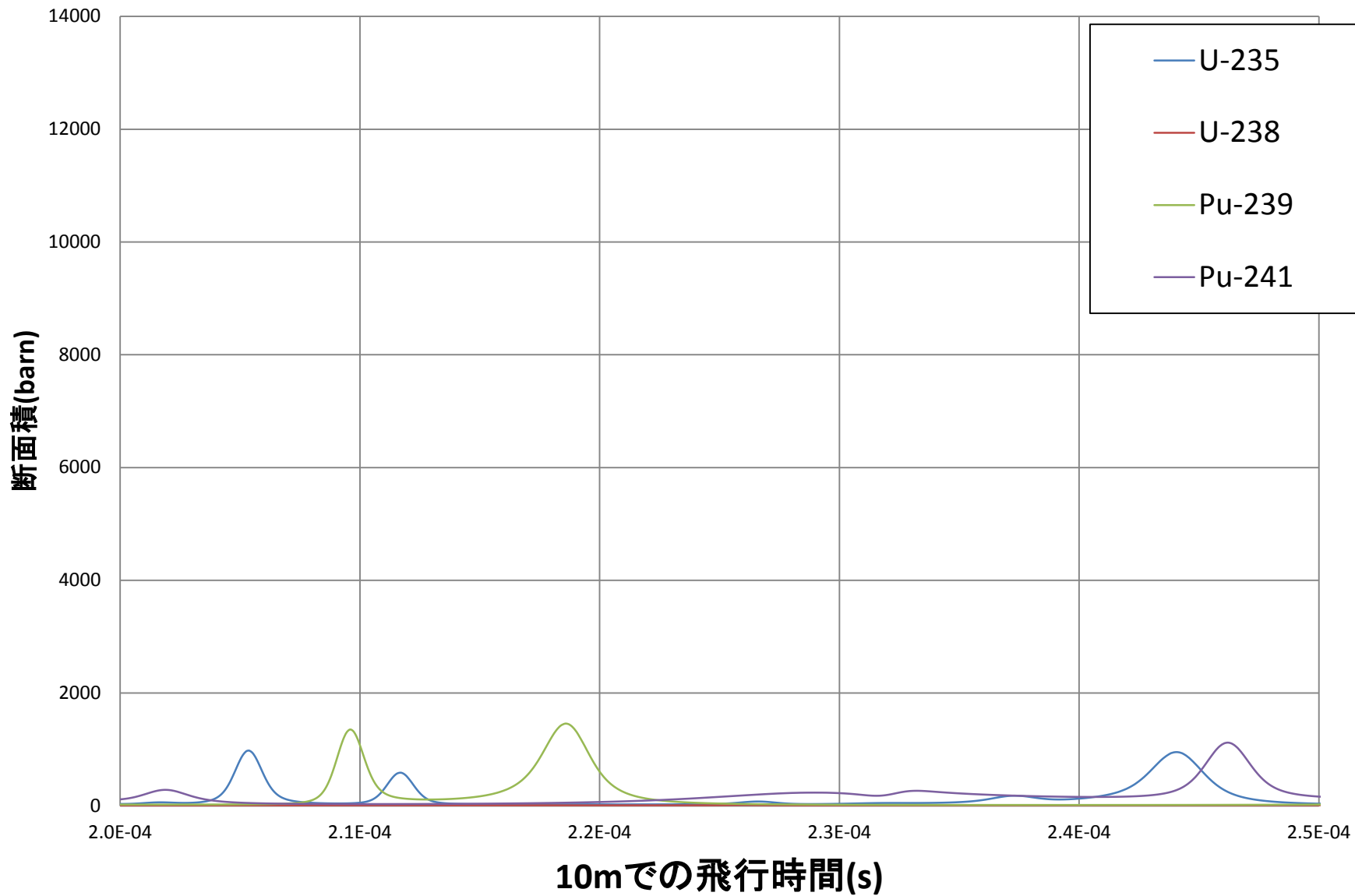
中性子エネルギーEが1eV~100eV



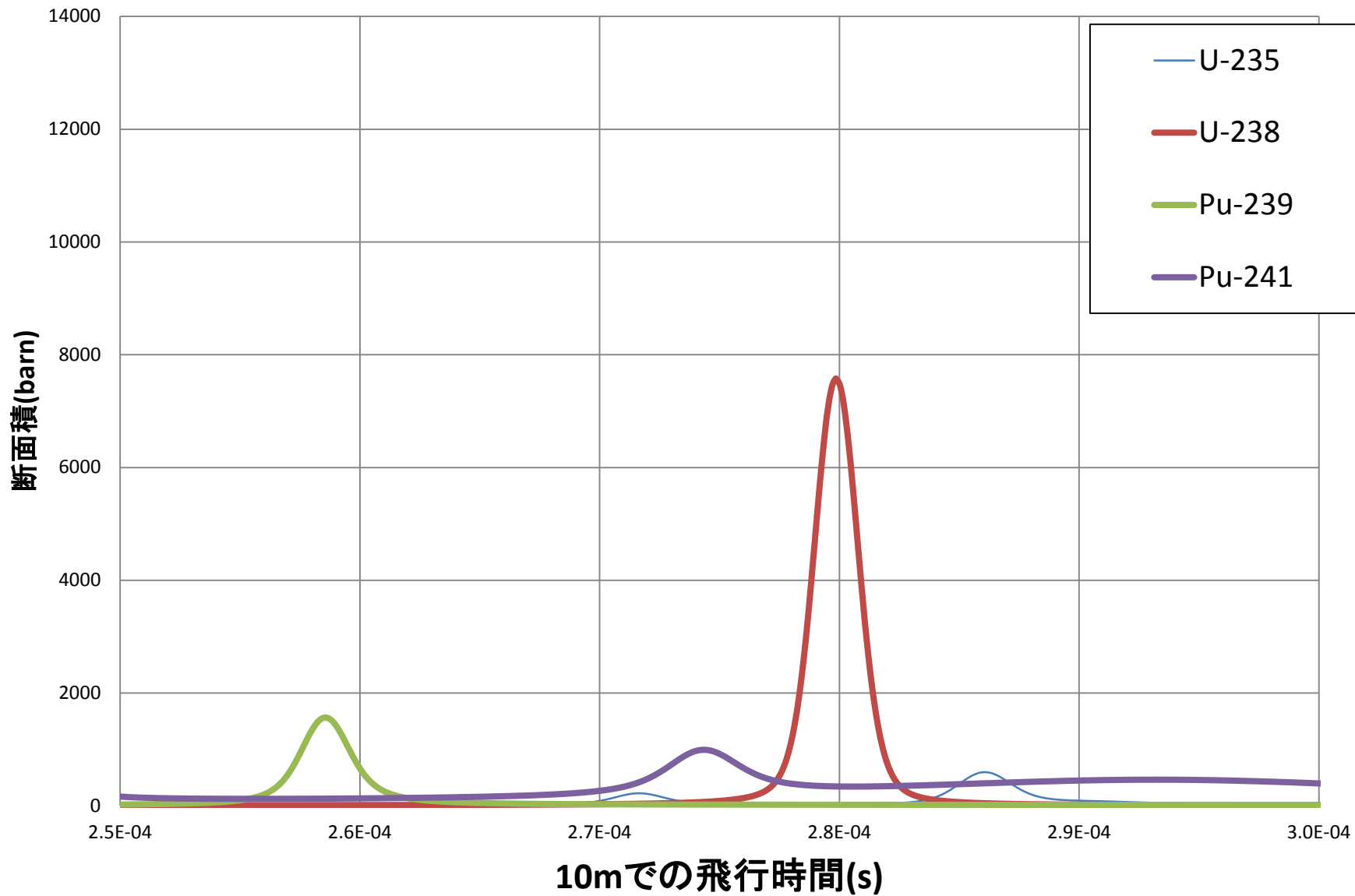
中性子エネルギーEが1eV~100eV



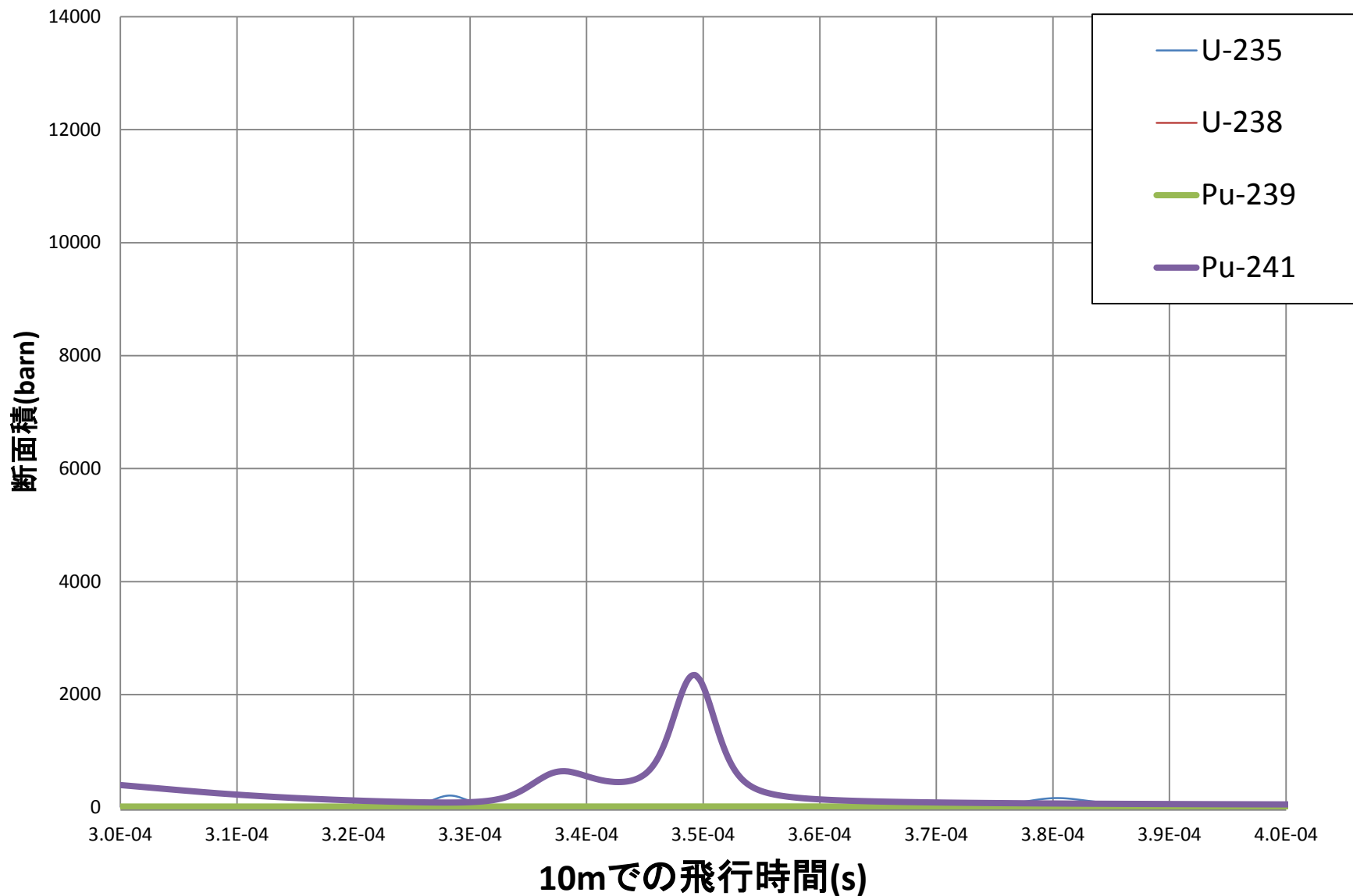
中性子エネルギーEが1eV~100eV



中性子エネルギーEが1eV~100eV



中性子エネルギーEが1eV~100eV

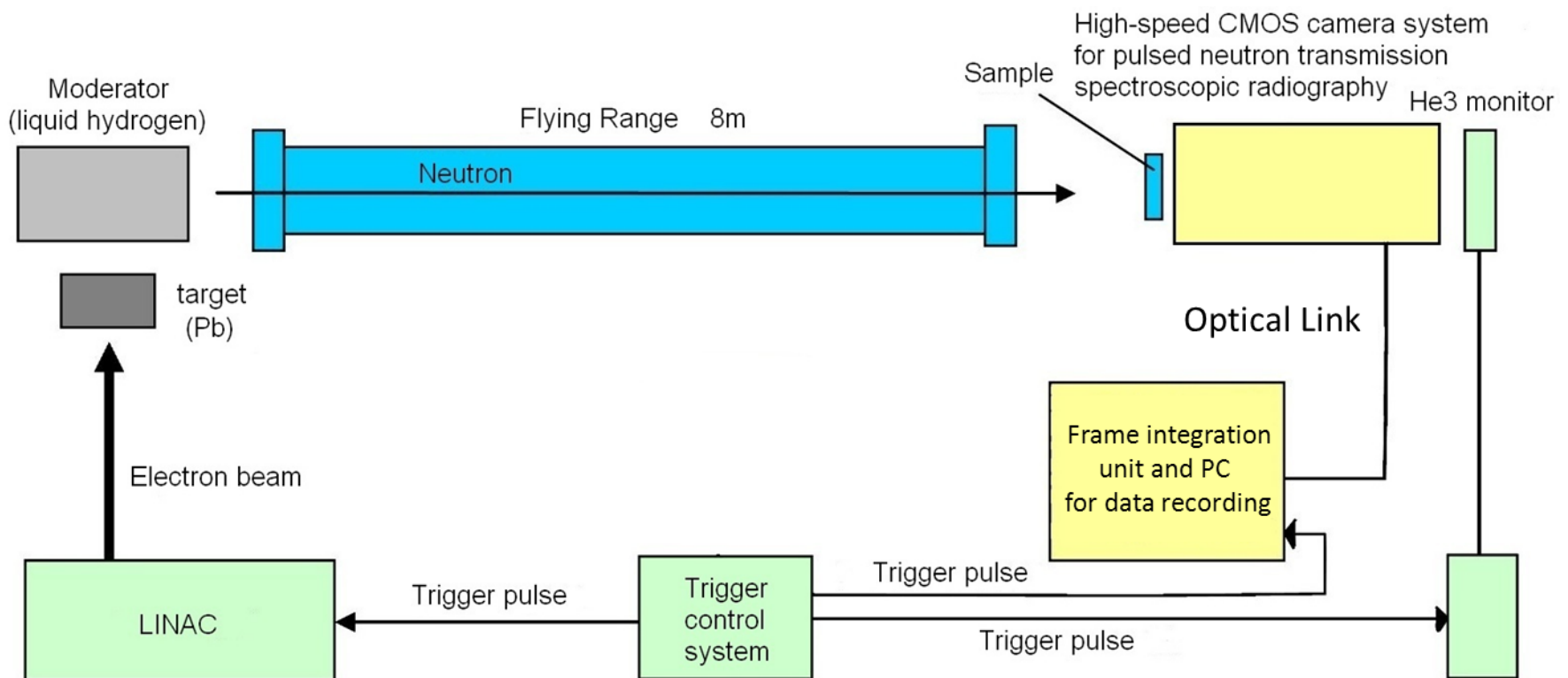


中性子エネルギーEが1eV~100eV

システムと撮像系

Hokkaido University LINAC (Linear Accelerator)

- Accelerated beam : electron
- Energy : 45MeV
- Repetition rate : 50pps

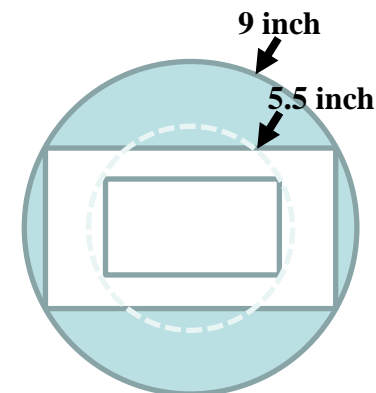


高速度カメラの仕様

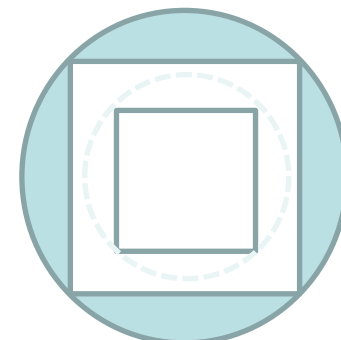
フレームレート(時間分解能)、画素数、解像度

Mode	Resonance Absorption Imaging	Bragg Edge Imaging	Magnetic Imaging
Neutron Energy and Resolution	High 1 keV-1 eV	Low < 1 eV	Low < 0.1 eV
ΔT	10 μ s	33 μ s	100 μ s
Frame Rate (fps)	100k	30k	10k
Number of Frames per Pulse	2000	600	200
Active Area [mm]	(9in) 201 × 109 (5.5in) 123 × 67	(9in) 162 × 162 (5.5in) 99 × 99	(9in) 199 × 112 (5.5in) 122 × 69
Pixel Number	384 × 208	512 × 512	1280 × 720
Pixel Size	(9in) 523 μ m (5.5in) 320 μ m	(9in) 316 μ m (5.5in) 193 μ m	(9in) 156 μ m (5.5in) 95 μ m

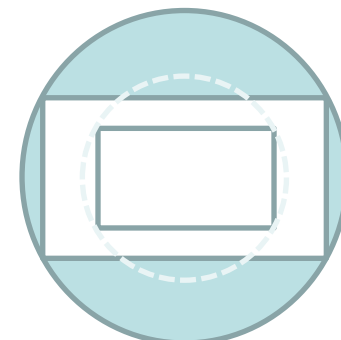
露光時間は1 μ s単位で調整可



100 kfps mode



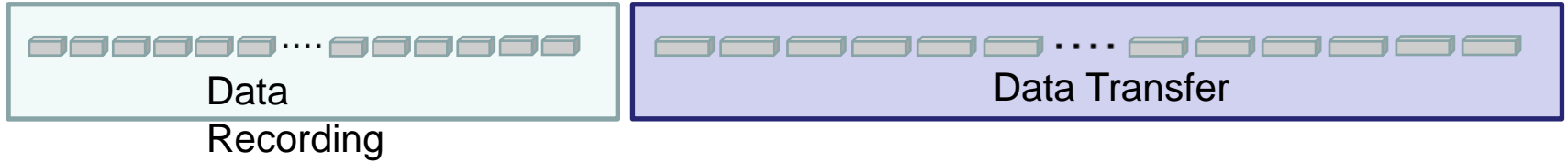
30 kfps mode



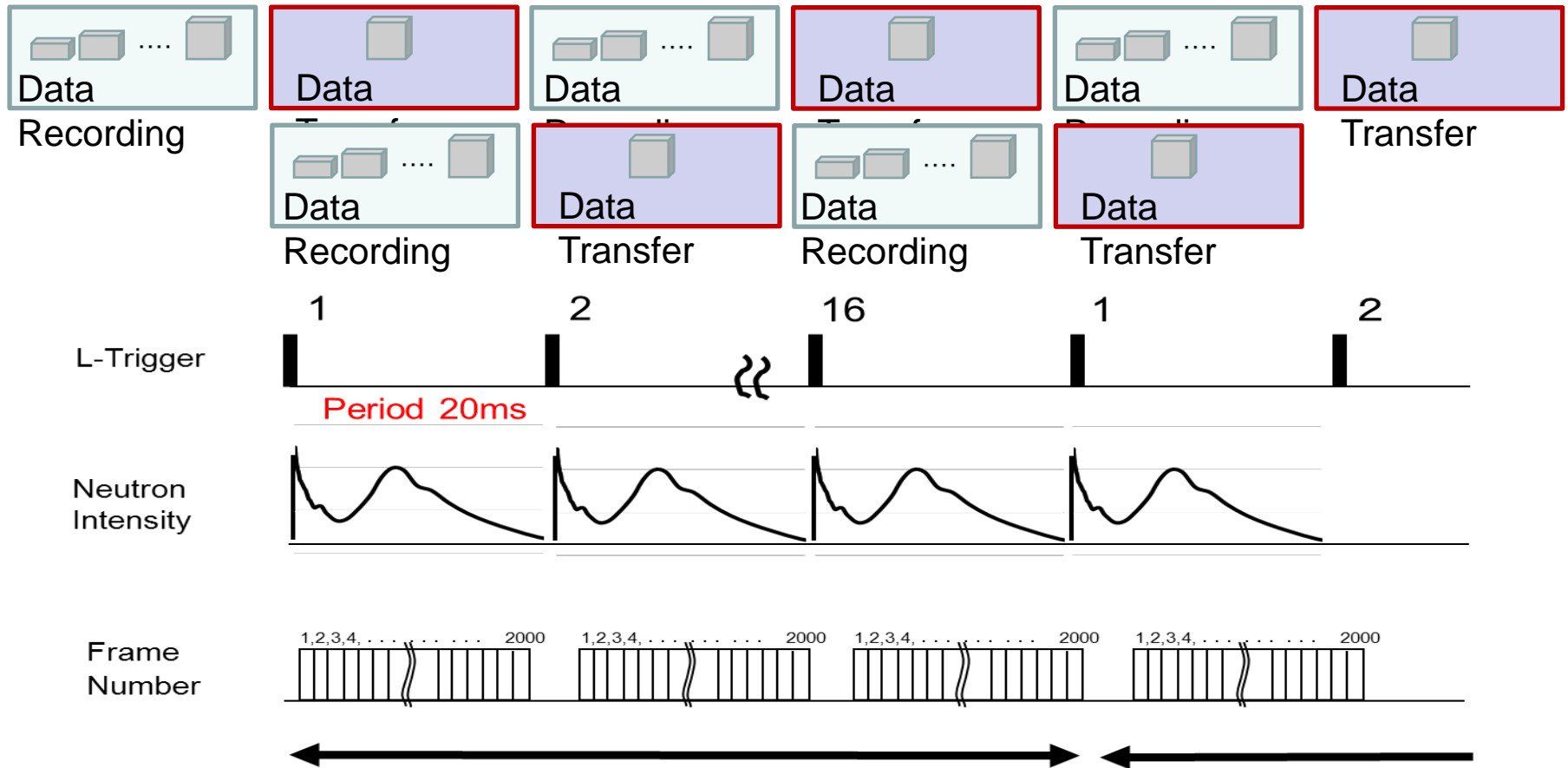
10 kfps mode

データの記録方法 (間断のない測定が可能)

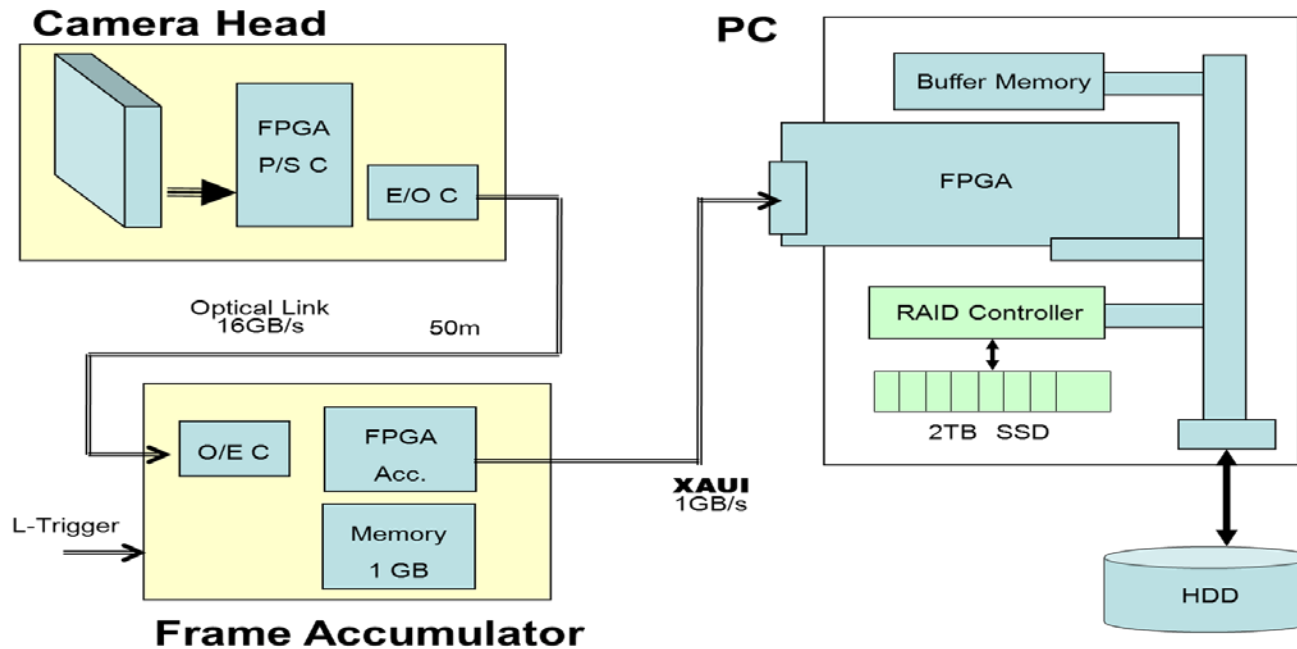
The common high-frame-rate camera causes interruption of data recording.



The interruption can be avoided by data pre-accumulation in the camera prior to data transfer



高速度カメラの構成と記録時間

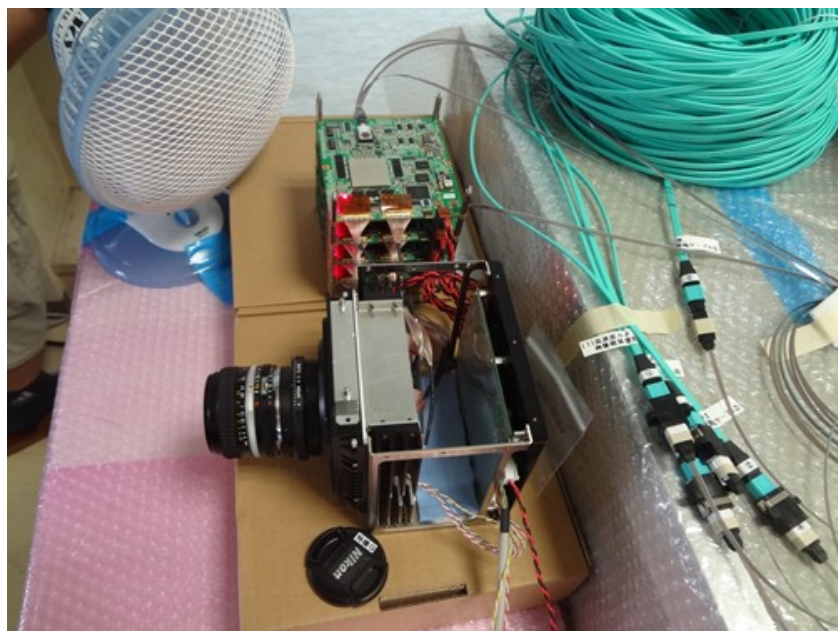


Accumulation Times	Data Length	Accumulation Period	100 kfps (10us, 2000f)			30 kfps (33.3us, 600f)			10 kfps (100us, 200f)		
			File Volume	Data Transfer Rate	Recording Time	File Volume	Data Transfer Rate	Recording Time	File Volume	Data Transfer Rate	Recording Time
[Pulse]	[bit]	[s]	[Gbit]	[MByte/s]	[hr]	[Gbit]	[MByte/s]	[hr]	[Gbit]	[MByte/s]	[hr]
16	16	0.32	2.38	952.15	0.61	2.34	937.50	0.62	2.75	1098.63	0.53
64	18	1.28	2.68	267.79	2.18	2.64	263.67	2.21	3.09	308.99	1.89
256	20	5.12	2.98	74.39	7.83	2.93	73.24	7.95	3.43	85.83	6.79
1024	22	20.48	3.27	20.46	28.48	3.22	20.14	28.92	3.78	23.60	24.68
4096	24	81.92	3.57	5.58	104.42	3.52	5.49	106.05	4.12	6.44	90.49

Accumulation Time and Recording Period

平成25年度

高速度カメラの開発

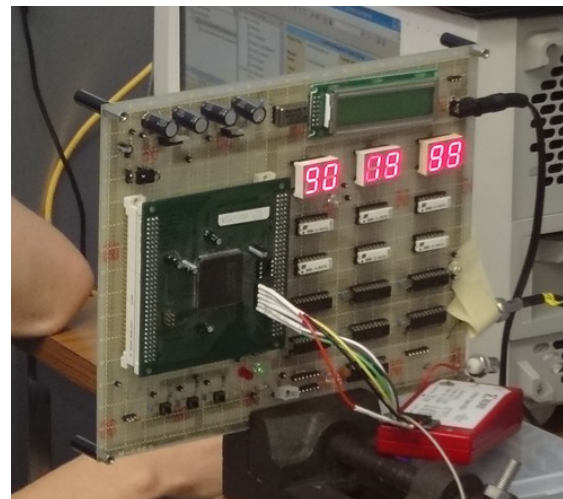


カメラと画像積算装置

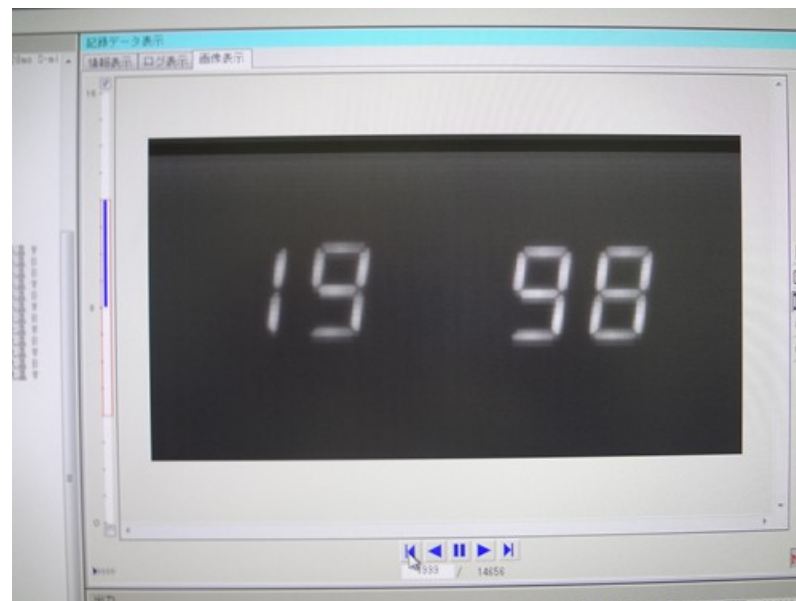
性能テスト

100kfps ($10\mu\text{s}$)
50Hzトリガー(20ms)

4096回積算
0000 - 1999
(実際は 0000 - 1998)



リセットトリガー付
100 kHz カウンター



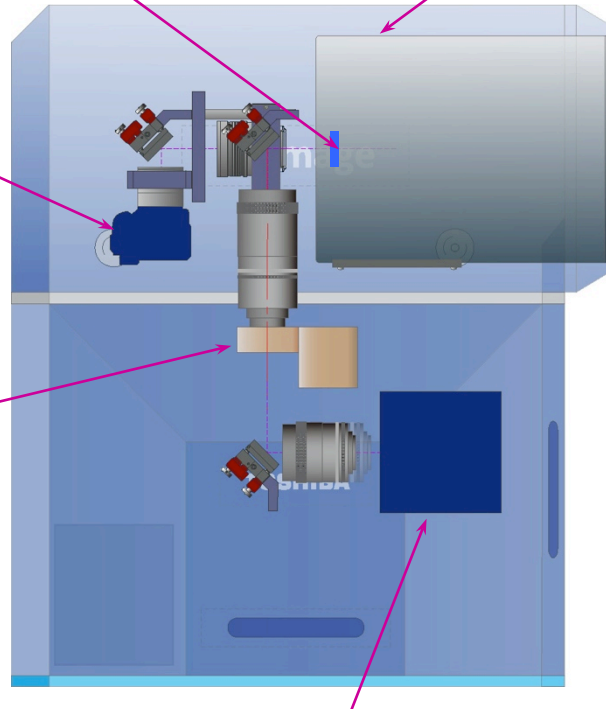
撮像部の外観

Short afterglow phosphor
($Y_2SiO_5:Ce$)

Neutron color I.I.
Ultimage TCN9100B nab
(TOSHIBA)

High resolution CMOS
sensor with 36.3
effective megapixels
(Nikon)

High-speed gated image
intensifier unit
C9547-02 MOD
(HAMAMATSU)



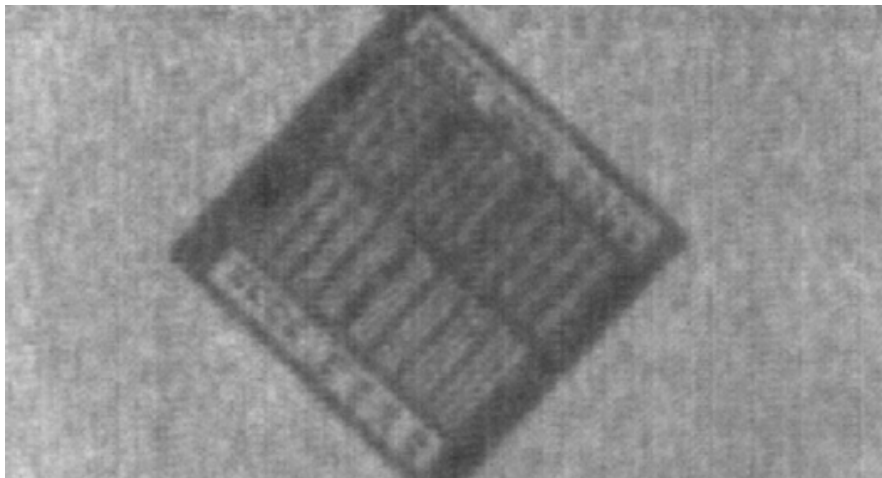
Frame accumulator



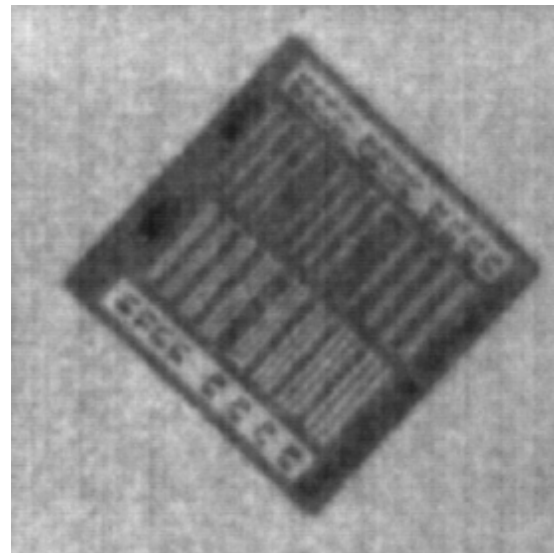
High-frame-rate Camera
MEMRECAM ST-821-HX
(nac)

性能試験

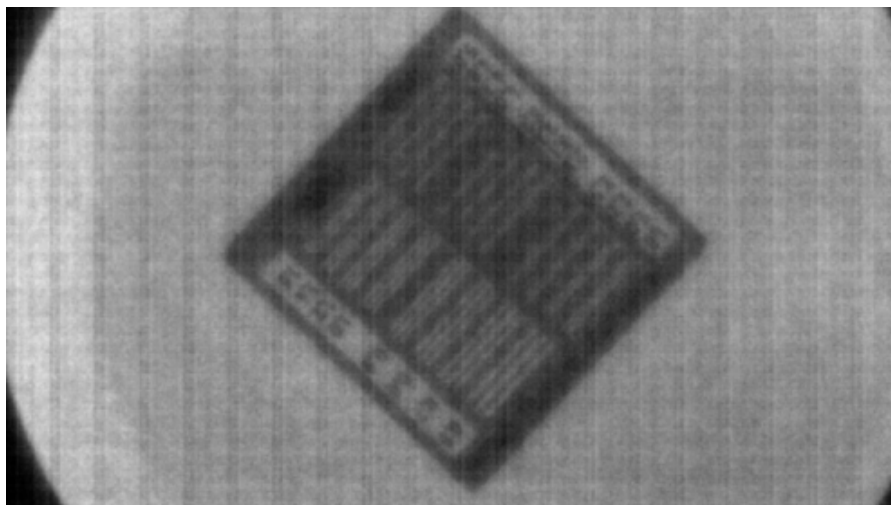
X-ray



100kfps_64回_5_5inch_IIGain845_Gate10us



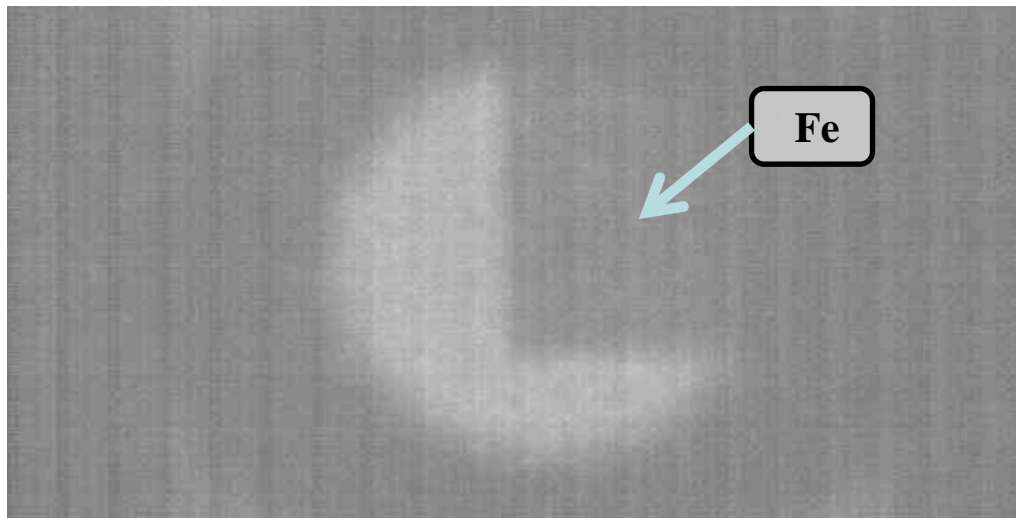
30kfps_64回_5_5inch_IIGain792_Gate110us



10kfps_64回_5_5inch_IIGain760_Gate300us

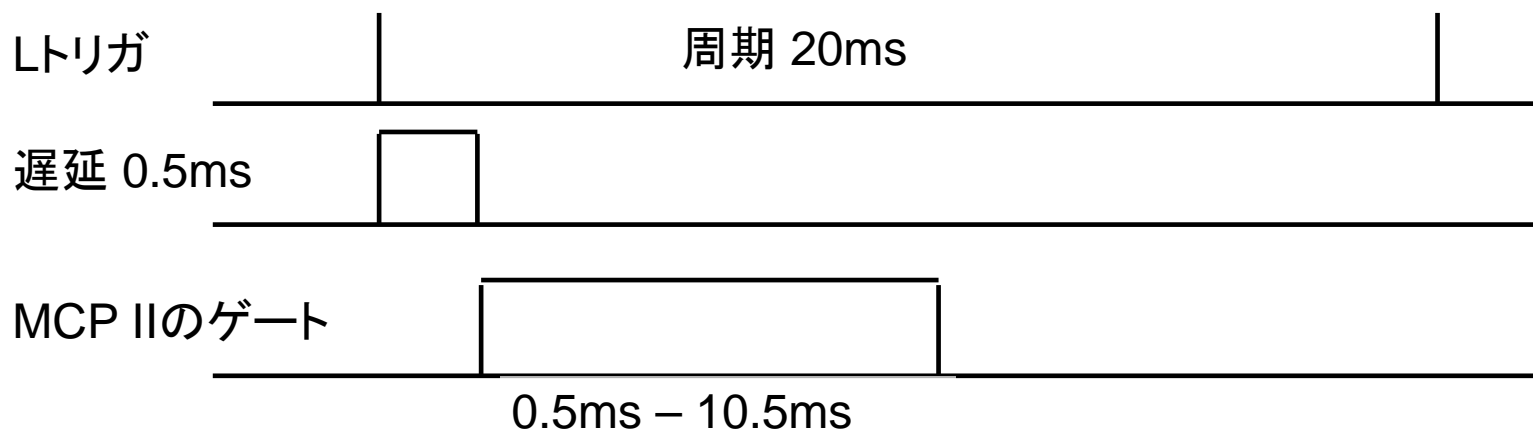
性能試験

Neutron



5.5inch
1280 × 720 画素

10kfps_64回_IIGain892_Gate_off500us+_on10000us



短残光ゲート付 II

浜松ホトニクス製 C9547-02MOD (-06)

入力光電面: GaAsP (280 - 720nm)

出力蛍光体: P46

青緑(480 - 670nm、ピーク530nm)

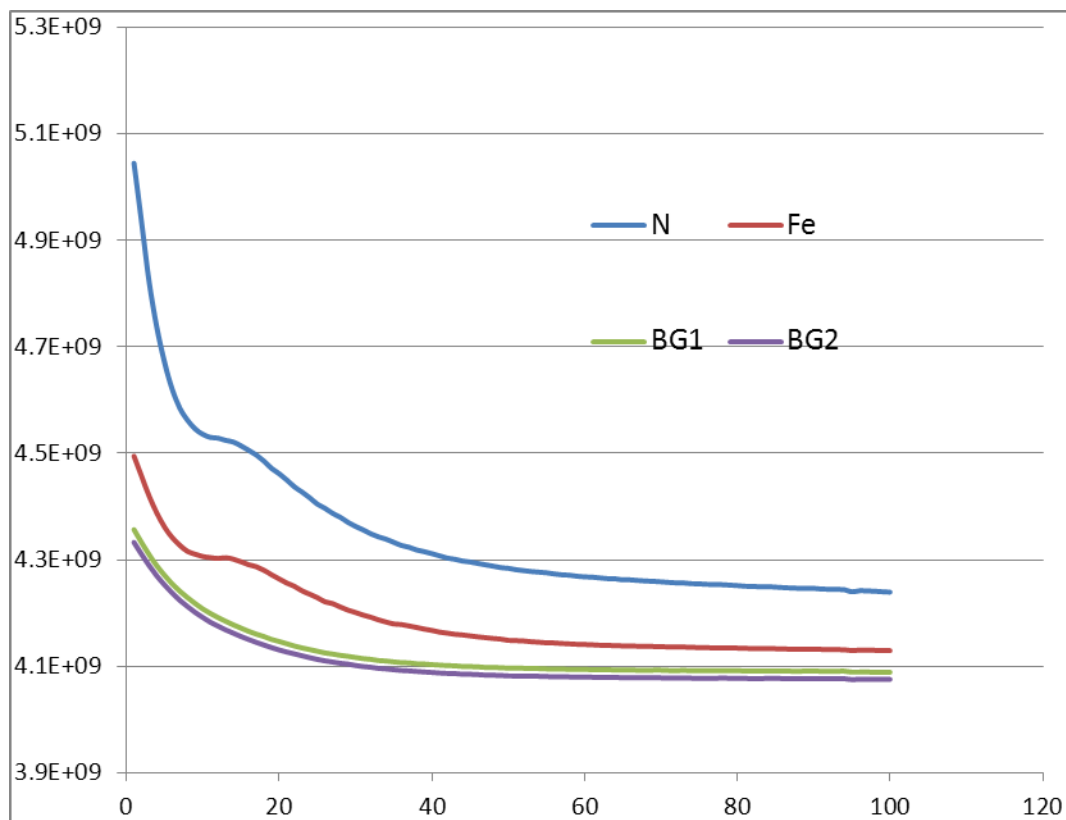
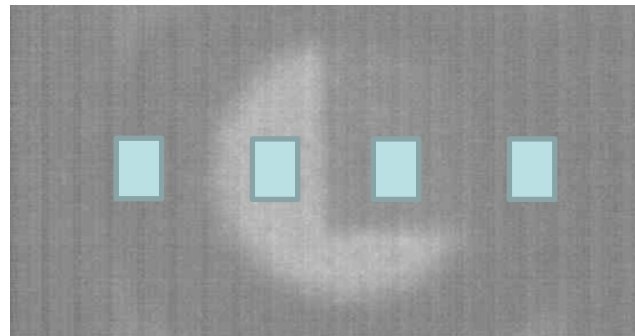
残光特性: ~300ns(10%減衰)

限界解像度: 450TV本

性能試験

Neutron

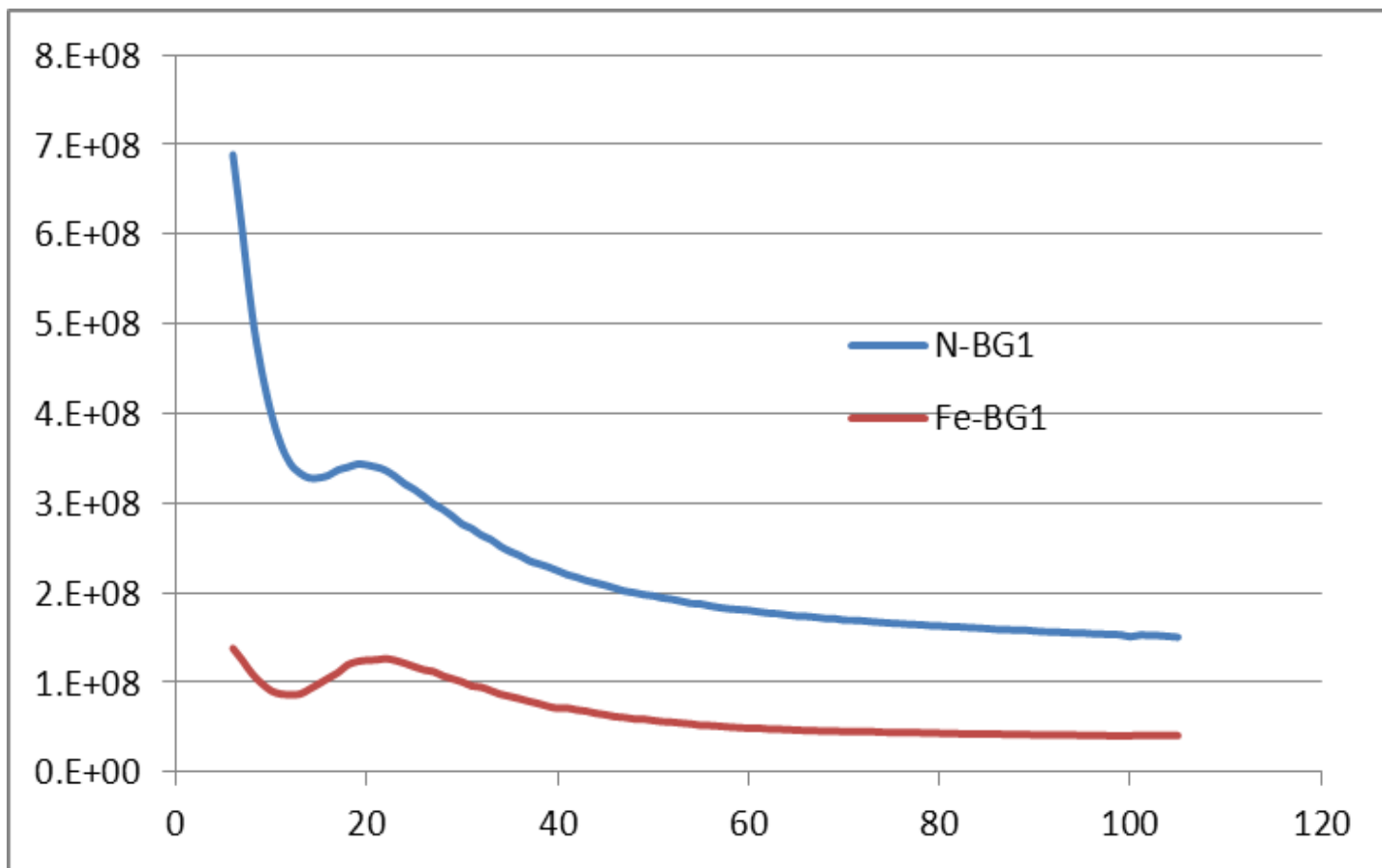
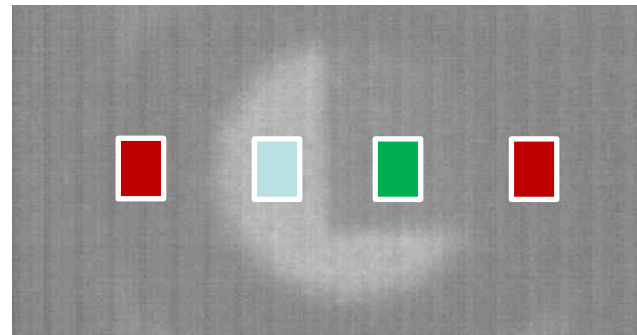
10kfps_64回_IIGain892_
Gate_off500us+_on1000us



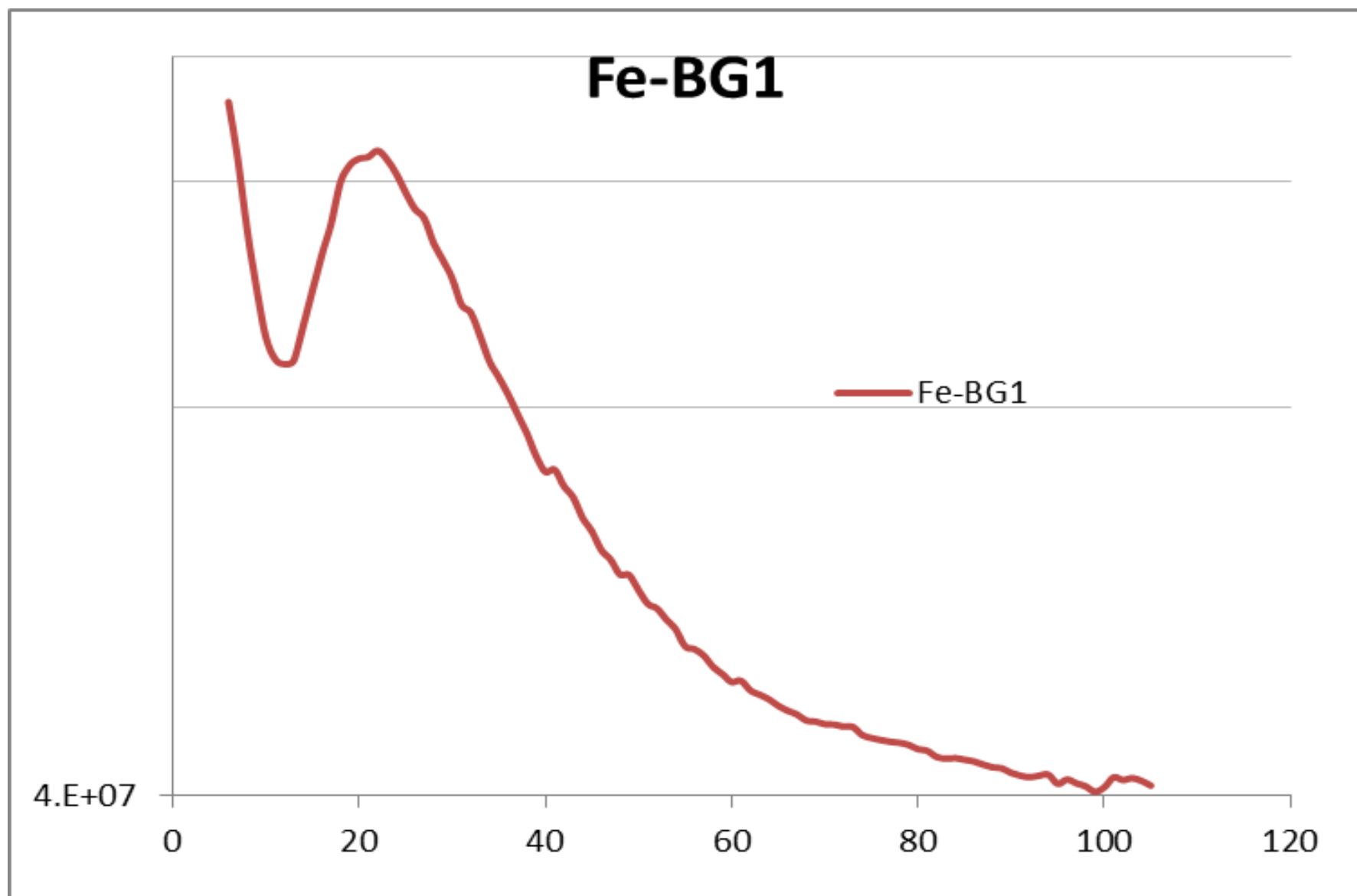
性能試験

Neutron

10kfps_64回_IIGain892_
Gate_off500us+_on1000us



性能試験



まとめ

◆ パルス中性子透過分光撮像用の高速度カメラを開発

- 1) 3種類の動作モード（時間分解能・画素数）
- 2) 中性子の有効利用（無駄なく録画）
- 3) 露光時間は1 μ s単位で調整可

◆ 今後 北大で詳細な特性を取得するための実験を計画

中性子IIのブランキングを併用して γ バーストの影響を抑制

◆ 開発要素 ソフトウェア

被検体位置確認、準リアルタイムでの積算画像表示など