The Fission Time Project Chamber Project

Mike Heffner, Lawrence Livermore National Laboratory
for the NIFFTE Collaboration

10 Sept 2014

FIESTA 2014

Improvements in Nuclear Fission Measurements are Still Needed

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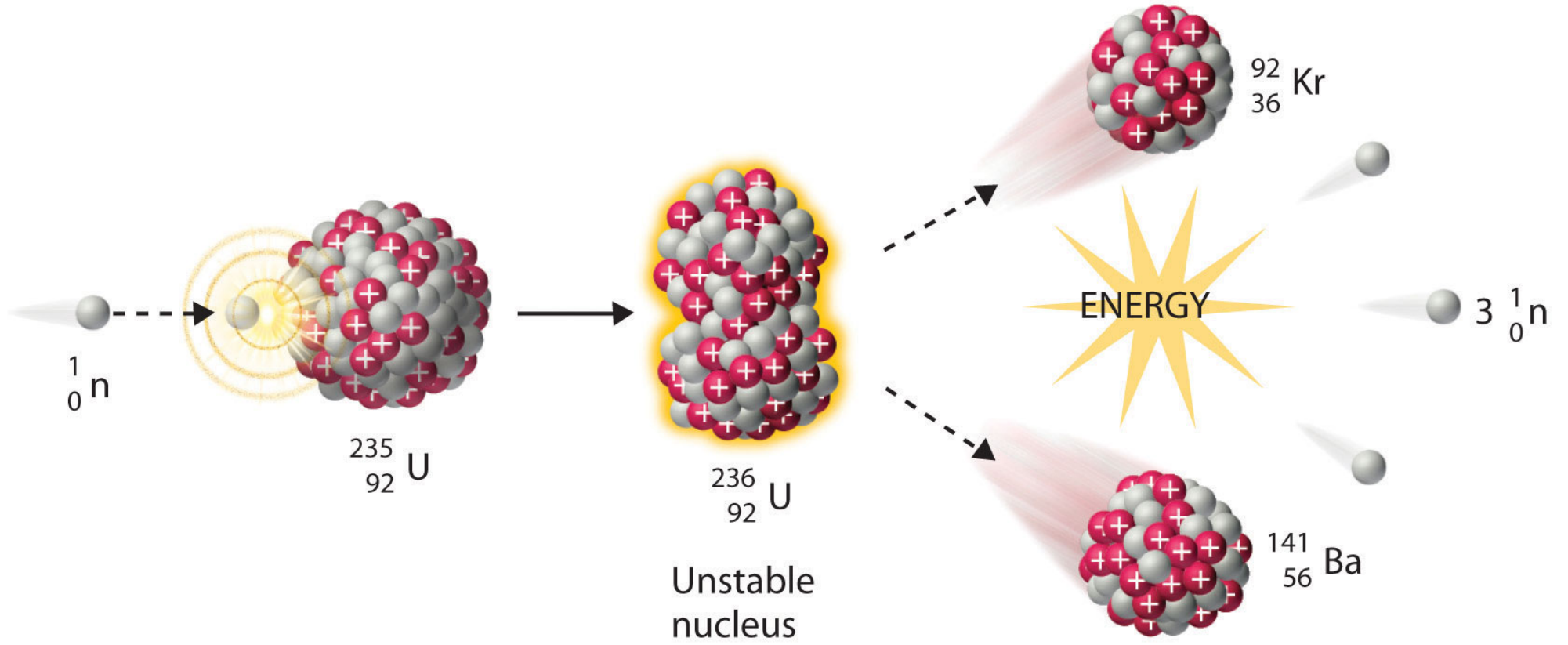

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ChiNu

fissionTPC

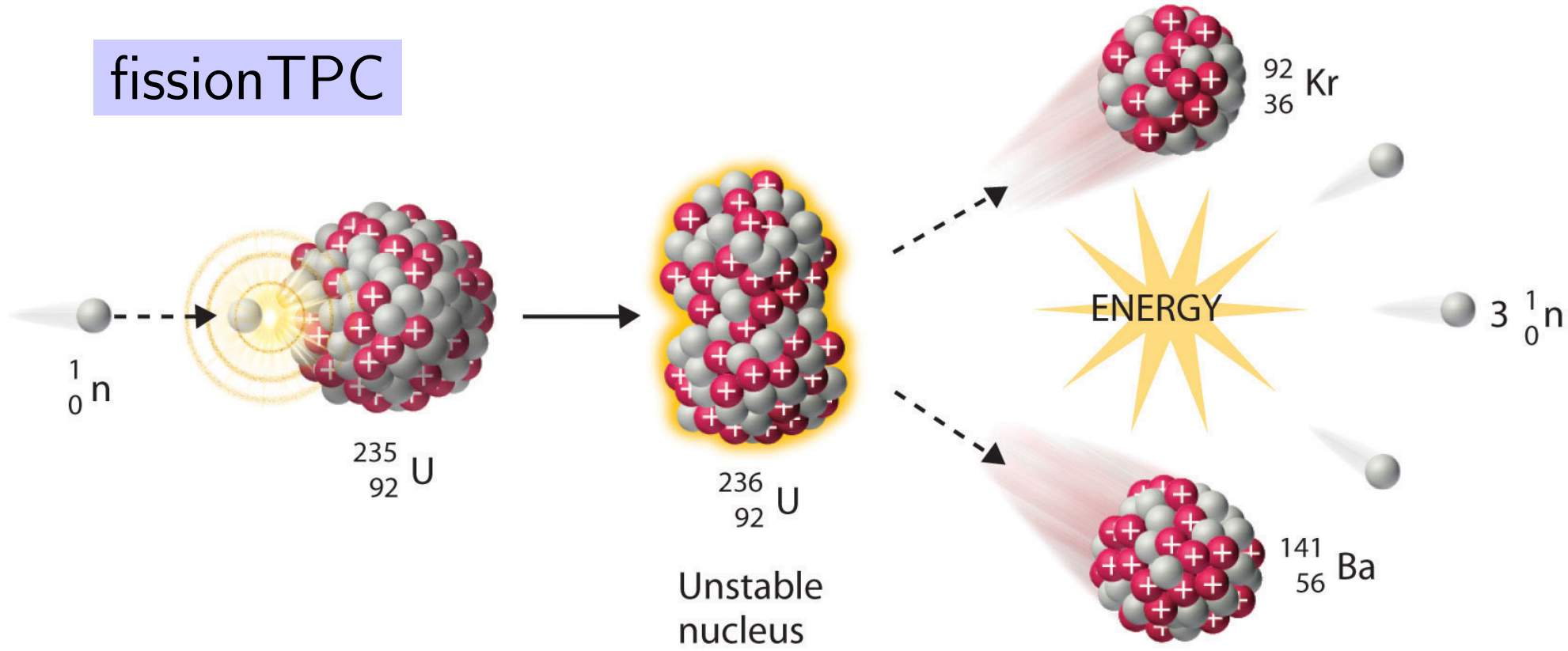

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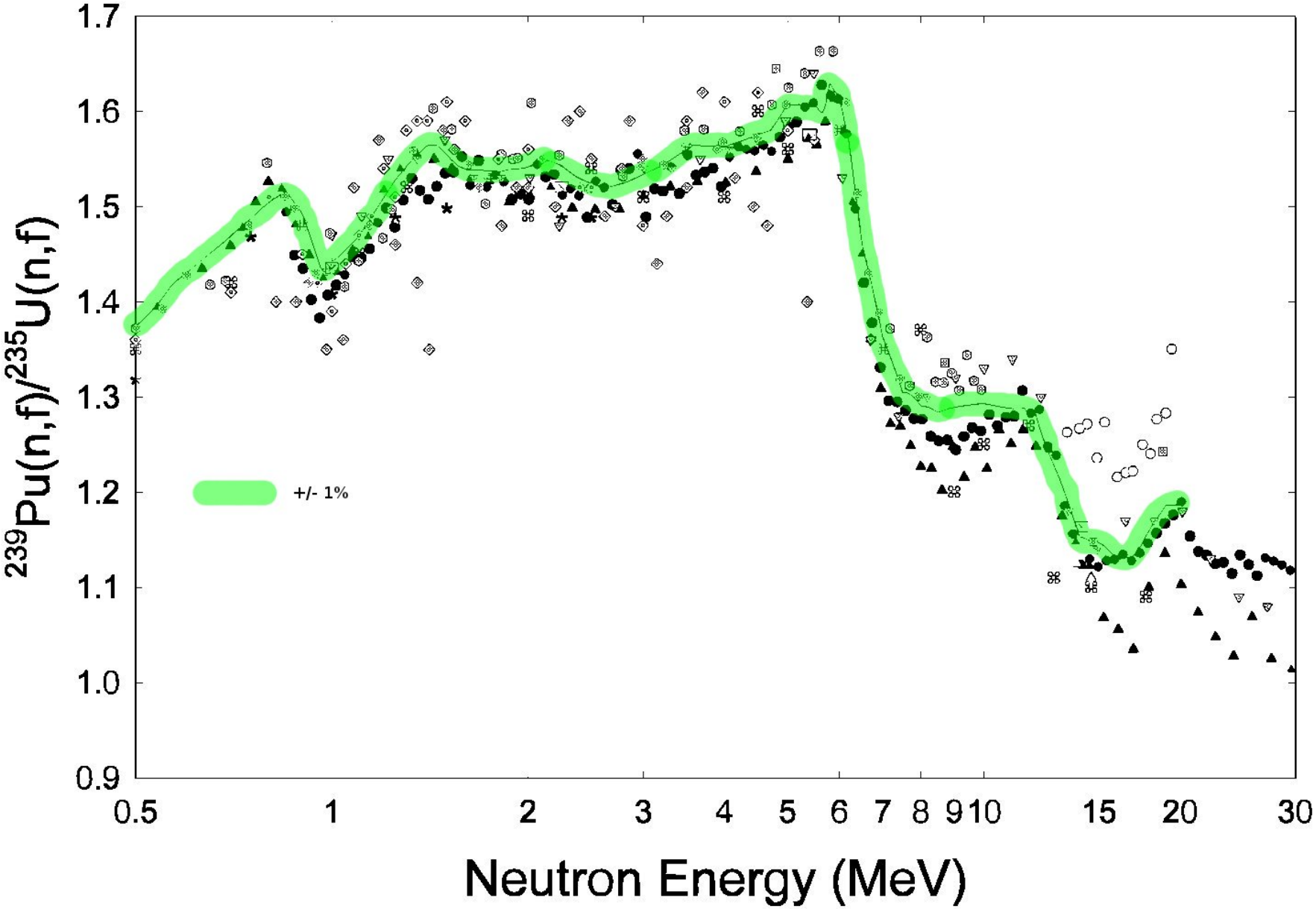
Table 38
Results of the target accuracy study for the LFR reactor

Isotope	Cross-section	Energy range	Uncertainty		Isotope	Cross-section	Energy range	Uncertainty		Isotope	Cross-section	Energy range	Uncertainty	
			Initial	Required				Initial	Required				Initial	Required
U-238	σ_{capt}	1.35 MeV–498 keV	5	2.9	Pu-240	σ_{capt}	1.35 MeV–498 keV	20	8.4	Zr-90	σ_{el}	498–183 keV	20	9.8
		498–183 keV	5	2.4			498–183 keV	20	5.8			183–67.4 keV	20	10.8
		183–67.4 keV	5	2.4			183–67.4 keV	20	5.4			67.4–24.8 keV	20	10.3
		67.4–24.8 keV	5	2.4			67.4–24.8 keV	20	5.7		σ_{inel}	6.07–2.23 MeV	20	8.6
		24.8–9.12 keV	5	2.7			24.8–9.12 keV	10	6.8	Pb-206	σ_{capt}	183–67.4 keV	20	9.8
	σ_{fiss}	6.07–2.23 MeV	5	2.6		σ_{fiss}	6.07–2.23 MeV	5	4.1		σ_{el}	1.35 MeV–498 keV	20	6.3
		2.23–1.35 MeV	5	2.6			2.23–1.35 MeV	5	3.7			498–183 keV	20	7
	σ_{inel}	6.07–2.23 MeV	15	3.8			1.35 MeV–498 keV	5	2.1		σ_{inel}	19.6–6.07 MeV	40	15.9
		2.23–1.35 MeV	10	3.1			498–183 keV	5	4.1			6.07–2.23 MeV	40	4.6
		1.35 MeV–498 keV	10	2.9		ν	1.35 MeV–498 keV	2	1.8			2.23–1.35 MeV	40	4.4
		498–183 keV	10	4.2	Pu-241	σ_{fiss}	1.35 MeV–498 keV	10	4.9			1.35 MeV–498 keV	45	5.3
		183–67.4 keV	10	4.8			498–183 keV	10	3.5	Pb-207	σ_{el}	1.35 MeV–498 keV	20	6.8
Pu-238	σ_{fiss}	1.35 MeV–498 keV	10	4.5			183–67.4 keV	10	3.5			498–183 keV	20	7.5
		498–183 keV	10	4.5			67.4–24.8 keV	10	4.2		σ_{inel}	19.6–6.07 MeV	40	26.6
		183–67.4 keV	10	6.2			24.8–9.12 keV	10	4.9			6.07–2.23 MeV	40	5.5
		67.4–24.8 keV	30	7.4			9.12–2.03 keV	10	7.3			2.23–1.35 MeV	40	6.7
		24.8–9.12 keV	30	8.7	Pu-242	σ_{fiss}	1.35 MeV–498 keV	10	5.3			1.35 MeV–498 keV	45	4
		9.12–2.03 keV	30	12.8	Am-241	σ_{capt}	498–183 keV	10	7.3	Pb-208	σ_{el}	6.07–2.23 MeV	20	8.4
Pu-239	σ_{capt}	498–183 keV	15	5.7			183–67.4 keV	10	7.1			2.23–1.35 MeV	20	7.7
		183–67.4 keV	15	5.4		σ_{fiss}	1.35 MeV–498 keV	10	7.1			1.35 MeV–498 keV	20	3.7
		67.4–24.8 keV	10	6	Am-242m	σ_{fiss}	498–183 keV	20	10.9			498–183 keV	20	4.7
		24.8–9.12 keV	10	6.1	Cm-244	σ_{fiss}	1.35 MeV–498 keV	40	8.6		σ_{inel}	19.6–6.07 MeV	40	9.4
	σ_{fiss}	6.07–2.23 MeV	5	3.3	Cm-245	σ_{fiss}	1.35 MeV–498 keV	40	13.8			6.07–2.23 MeV	40	4.9
		2.23–1.35 MeV	5	2.9			498–183 keV	40	9.6		$\sigma_{n,2n}$	19.6–6.07 MeV	100	53.1
		1.35 MeV–498 keV	5	1.4			183–67.4 keV	40	10	B-10	σ_{capt}	1.35 MeV–498 keV	15	6.1
		498–183 keV	5	1.1			67.4–24.8 keV	40	11.5			498–183 keV	15	3.3
		183–67.4 keV	5	1.2			24.8–9.12 keV	40	14.1			183–67.4 keV	10	3
		67.4–24.8 keV	5	1.5	Fe-56	σ_{el}	183–67.4 keV	10	7.1			67.4–24.8 keV	10	3.7
		24.8–9.12 keV	5	1.9		σ_{inel}	6.07–2.23 MeV	15	8.5			24.8–9.12 keV	8	4.3
		9.12–2.03 keV	5	3			2.23–1.35 MeV	10	5.6			9.12–2.03 keV	8	6.7
	ν	498–183 keV	1	0.9			1.35 MeV–498 keV	20	4.8					

		9.12–2.03 keV	30	12.8	
Pu-239	σ_{capt}	498–183 keV	15	5.7	
		183–67.4 keV	15	5.4	
		67.4–24.8 keV	10	6	A
		24.8–9.12 keV	10	6.1	C
	σ_{fiss}	6.07–2.23 MeV	5	3.3	C
		2.23–1.35 MeV	5	2.9	
		1.35 MeV–498 keV	5	1.4	
		498–183 keV	5	1.1	
		183–67.4 keV	5	1.2	
		67.4–24.8 keV	5	1.5	F
		24.8–9.12 keV	5	1.9	
		9.12–2.03 keV	5	3	
	ν	498–183 keV	1	0.9	



Staples, NUCLEAR SCIENCE AND ENGINEERING VOL. 129 JUNE 1998

Live time fraction

Neutron fluence

Number of target nuclei

Background events

$$C(E) = w(E)\left[\epsilon(E)\cdot\Phi(E)\sum_{i=1}^{N_{\text{isotopes}}} N_i\,\sigma_i(E) + C^{\text{bkg}}(E)\right]$$

Detected fission fragments

Detection efficiency

Sum over isotopes in target

Fission cross section

Tovesson, Hill,et al, LA-UR-06-7318

Relative dection efficiency

Neutron beam distribution

Detector line time

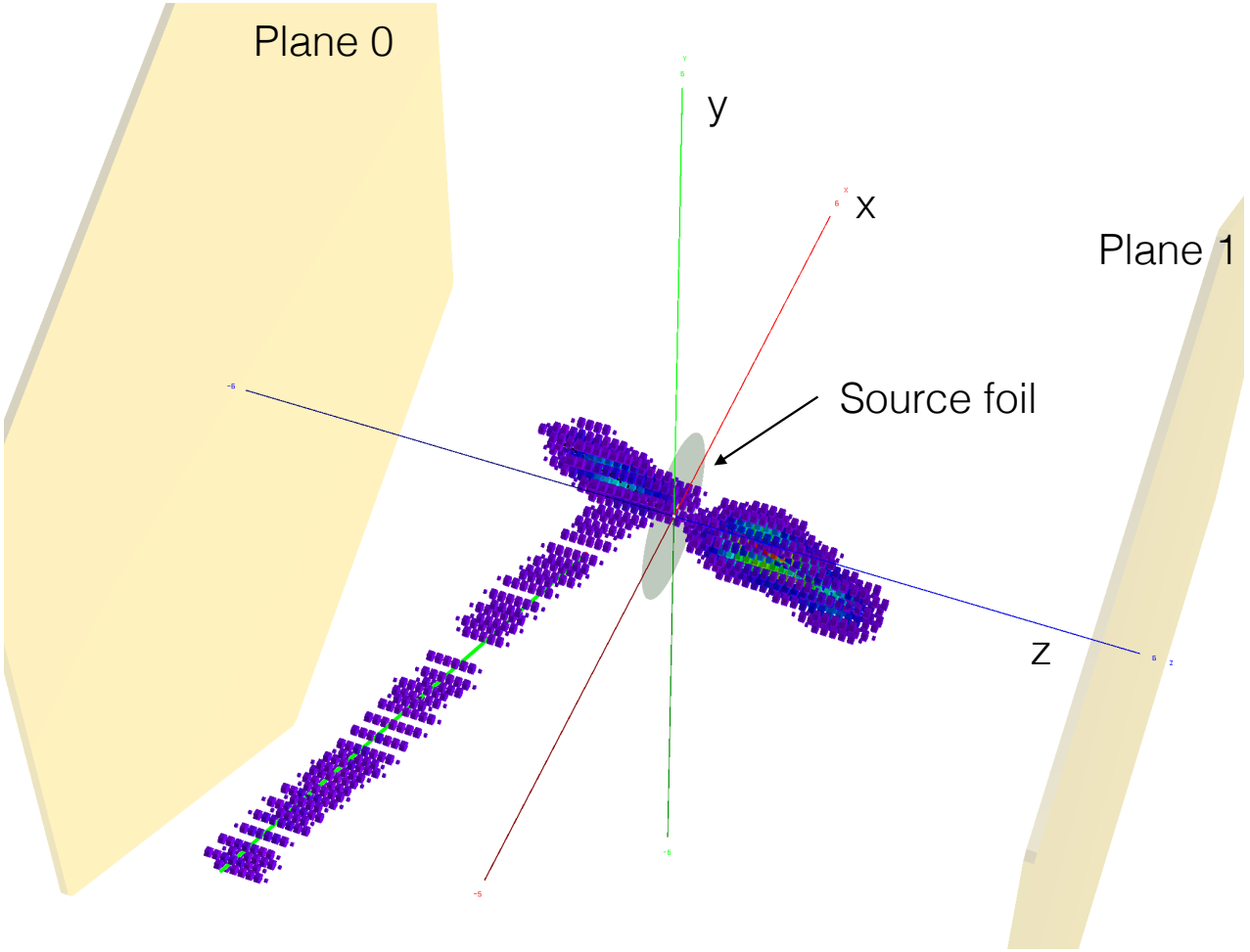
Number of detected FF

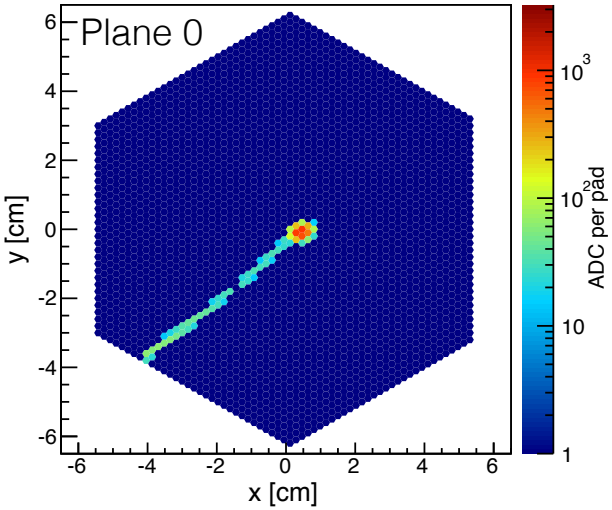
$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{\text{bkg}}}{w_2^{-1} \cdot C_2 - C_2^{\text{bkg}}}$$

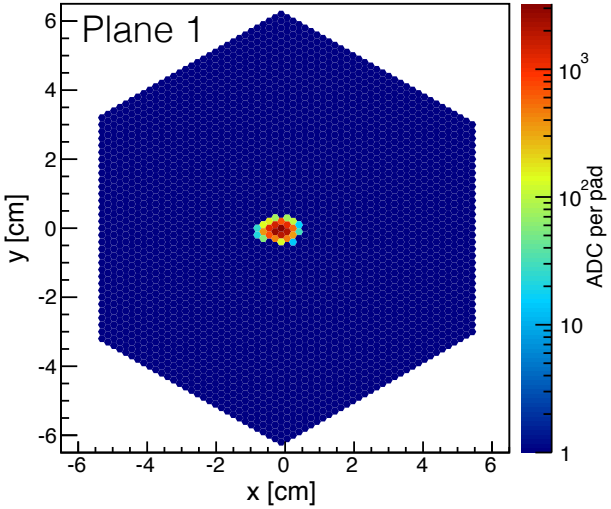
Background

Cross section ratio

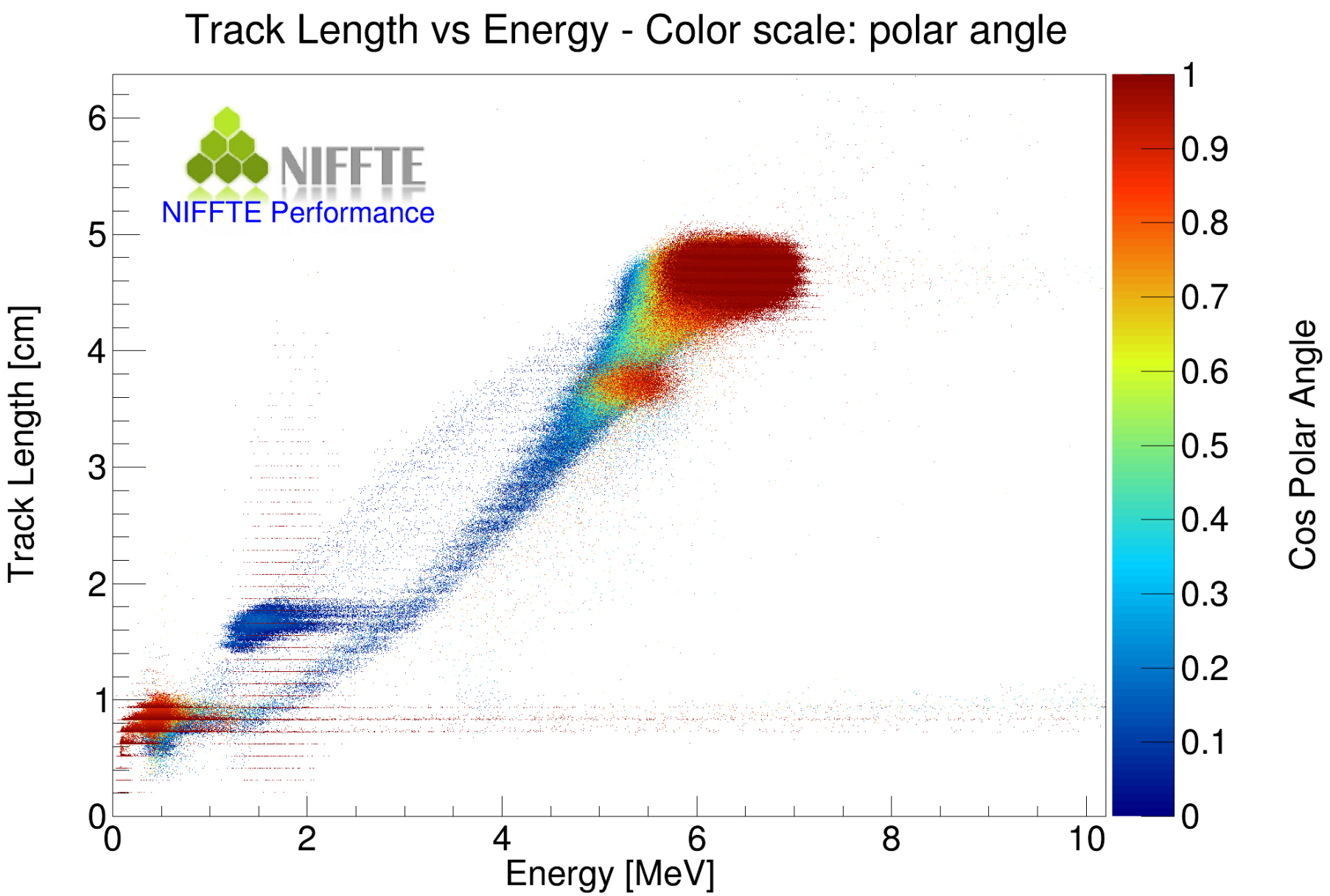
Atom density distribution

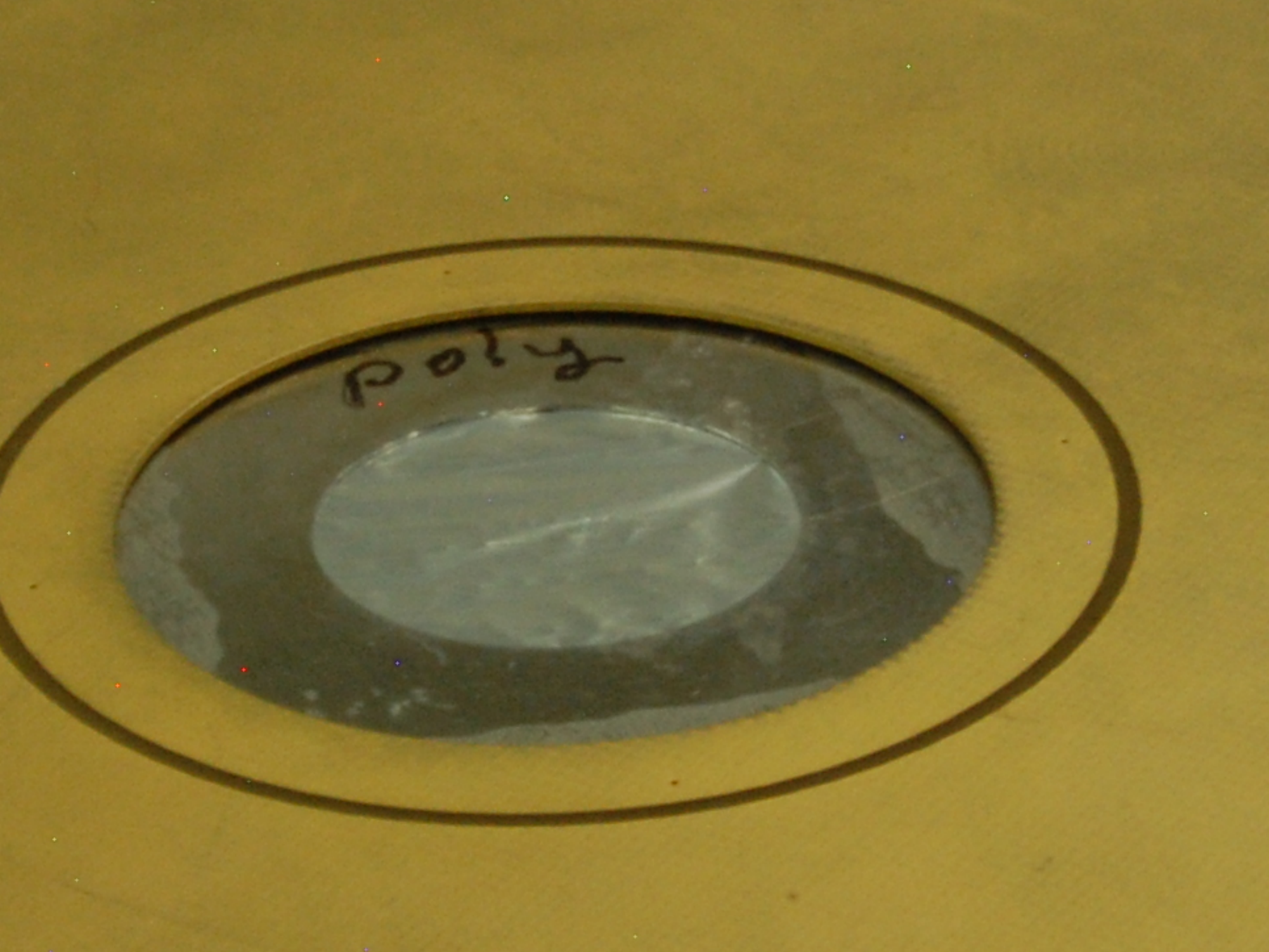

Plane 0
y
x
Plane 1
Source foil
z


Plane 0
y [cm]
x [cm]
ADC per pad
10^3
10^2
10
1

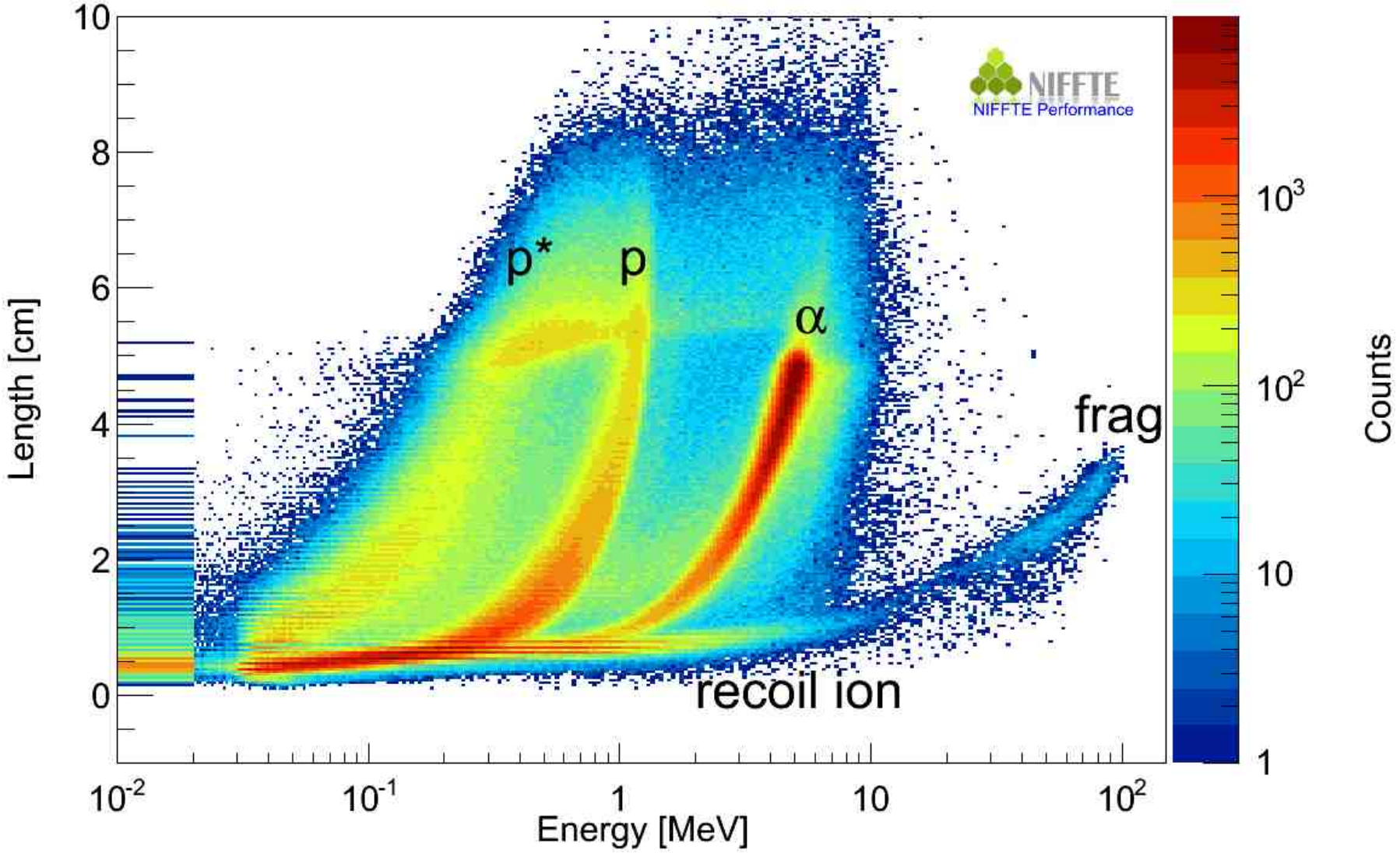

Plane 1
y [cm]
x [cm]
ADC per pad
10^3
10^2
10
1

$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{bkg}}{w_2^{-1} \cdot C_2 - C_2^{bkg}}$$

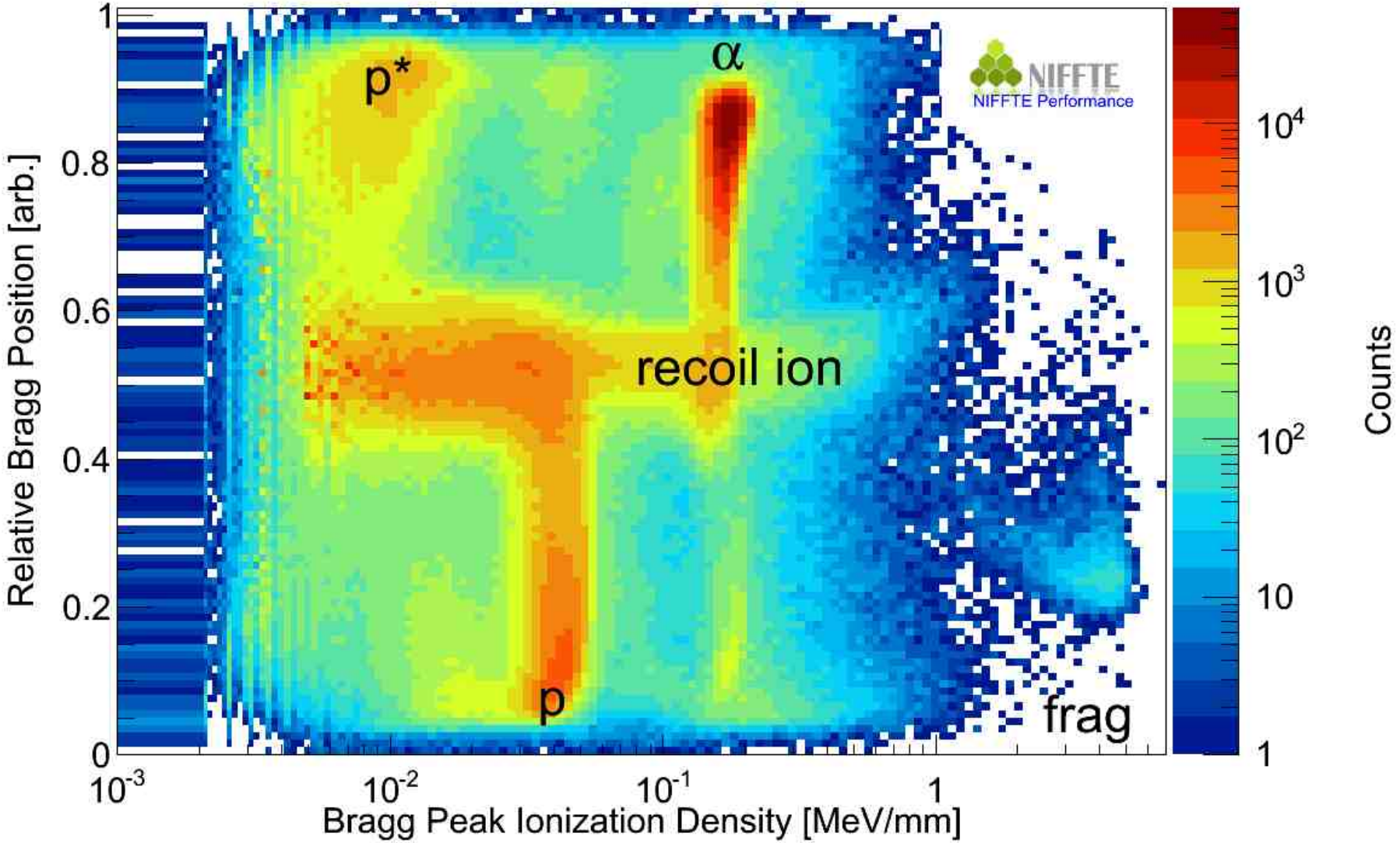



poly

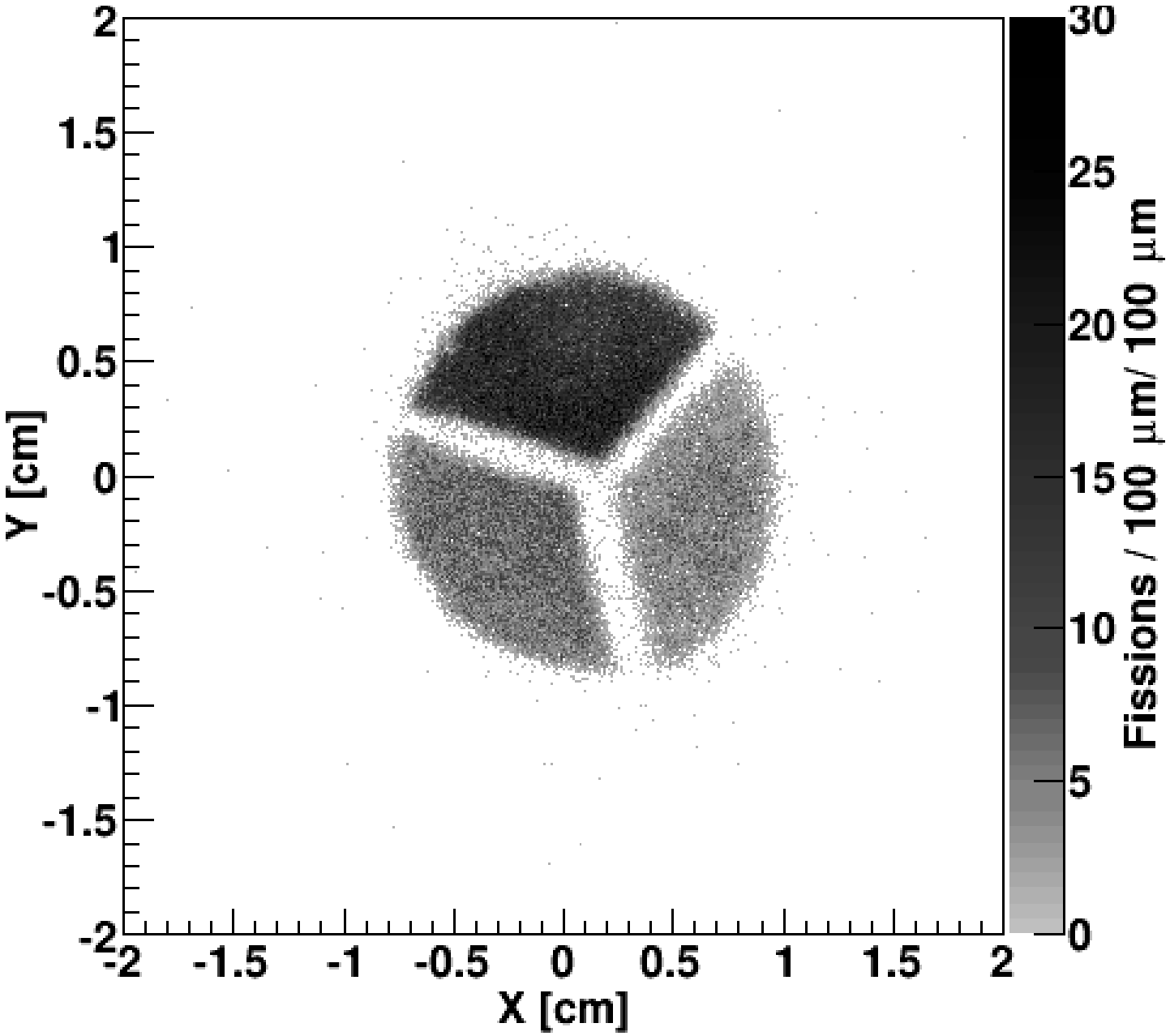
$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{bkg}}{w_2^{-1} \cdot C_2 - C_2^{bkg}}$$



$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{bkg}}{w_2^{-1} \cdot C_2 - C_2^{bkg}}$$

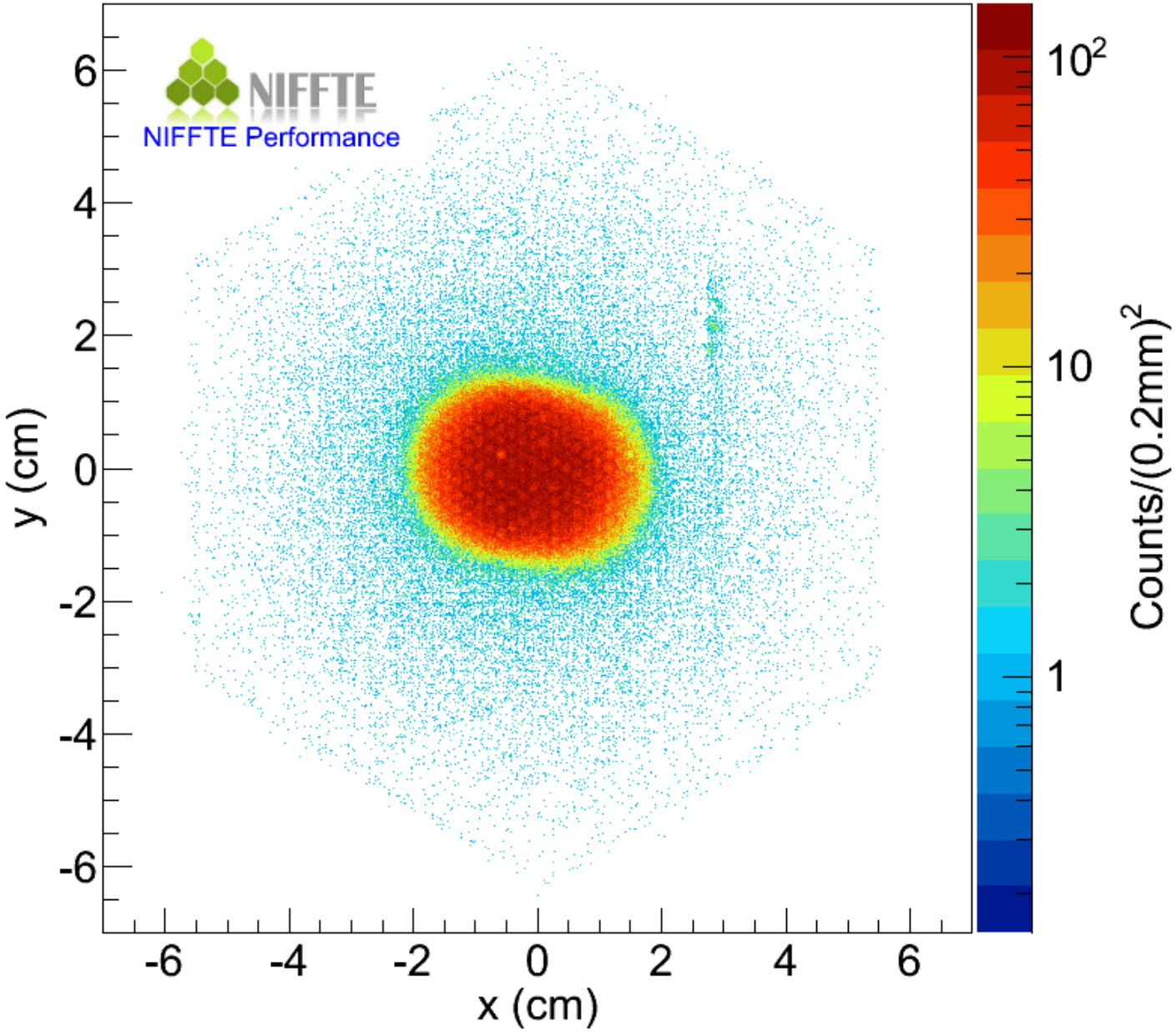


$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{\text{bkg}}}{w_2^{-1} \cdot C_2 - C_2^{\text{bkg}}}$$

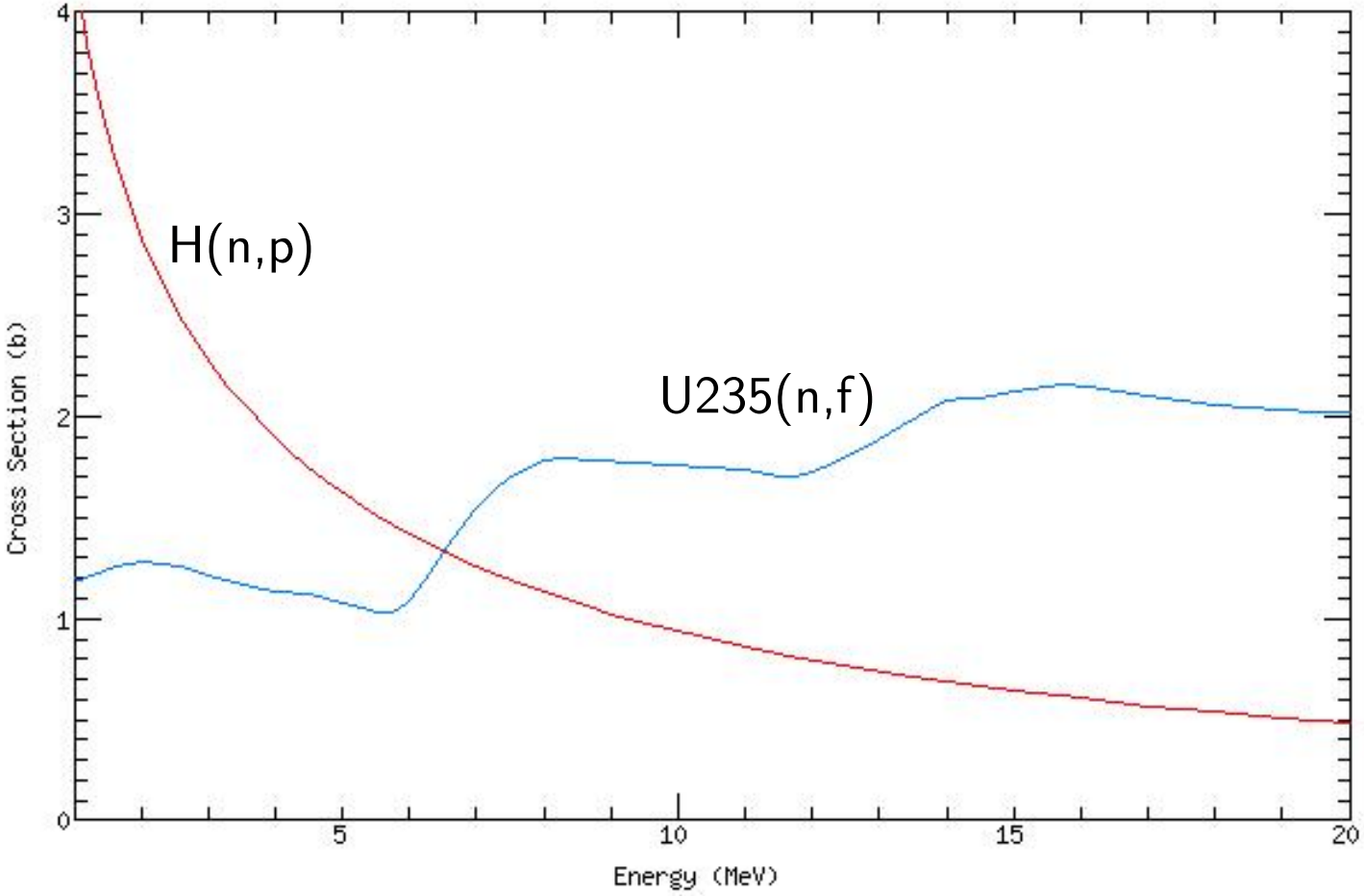


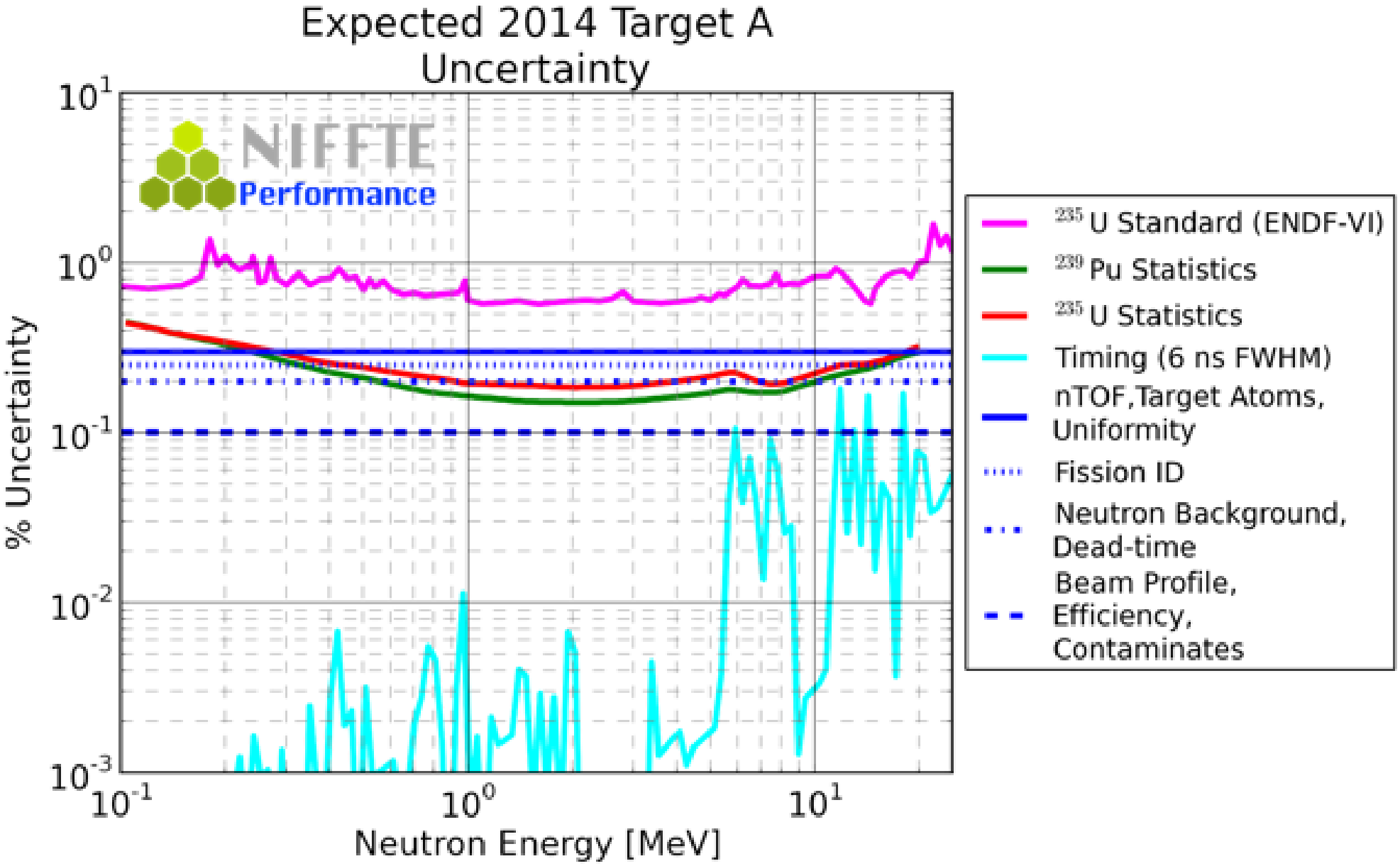
P-3
739
567

$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{\mathrm{bkg}}}{w_2^{-1} \cdot C_2 - C_2^{\mathrm{bkg}}}$$

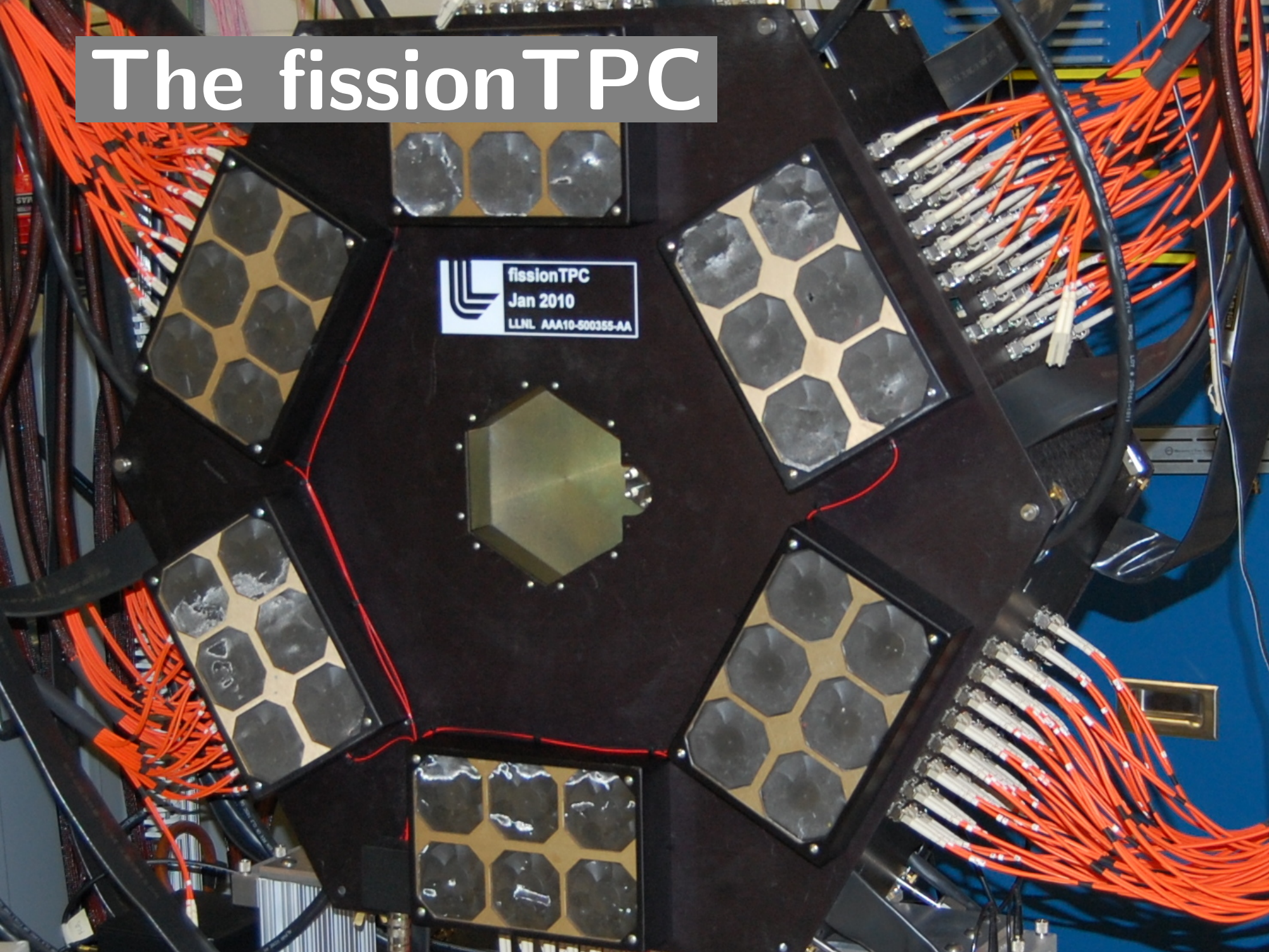


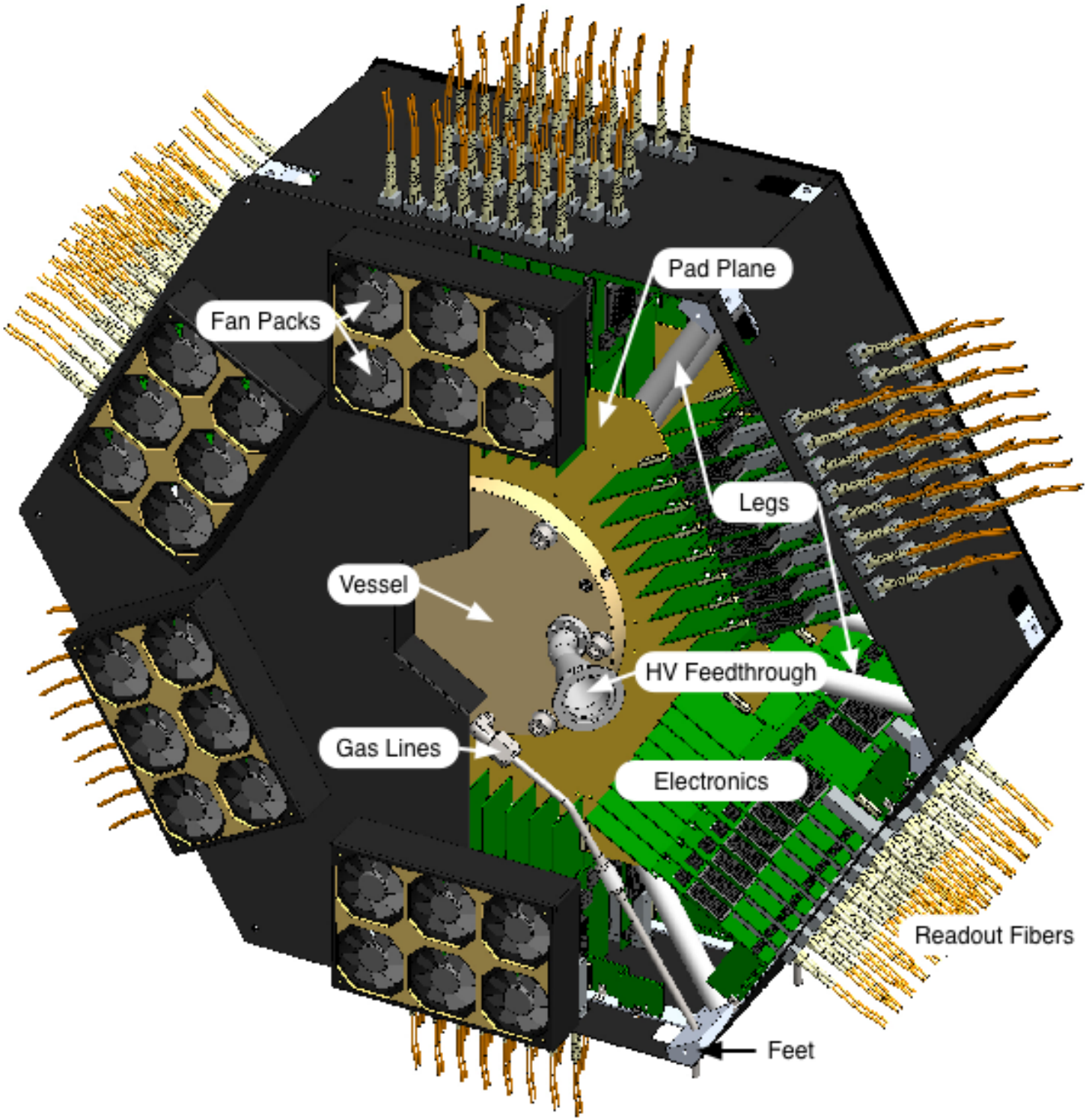
$$\frac{\sigma_{P39}}{\sigma_{U35}} = \frac{\epsilon_2}{\epsilon_1} \cdot \frac{N_{U35}}{N_{P39}} \frac{\Phi_2}{\Phi_1} \cdot \frac{w_1^{-1} \cdot C_1 - C_1^{bkg}}{w_2^{-1} \cdot C_2 - C_2^{bkg}}$$

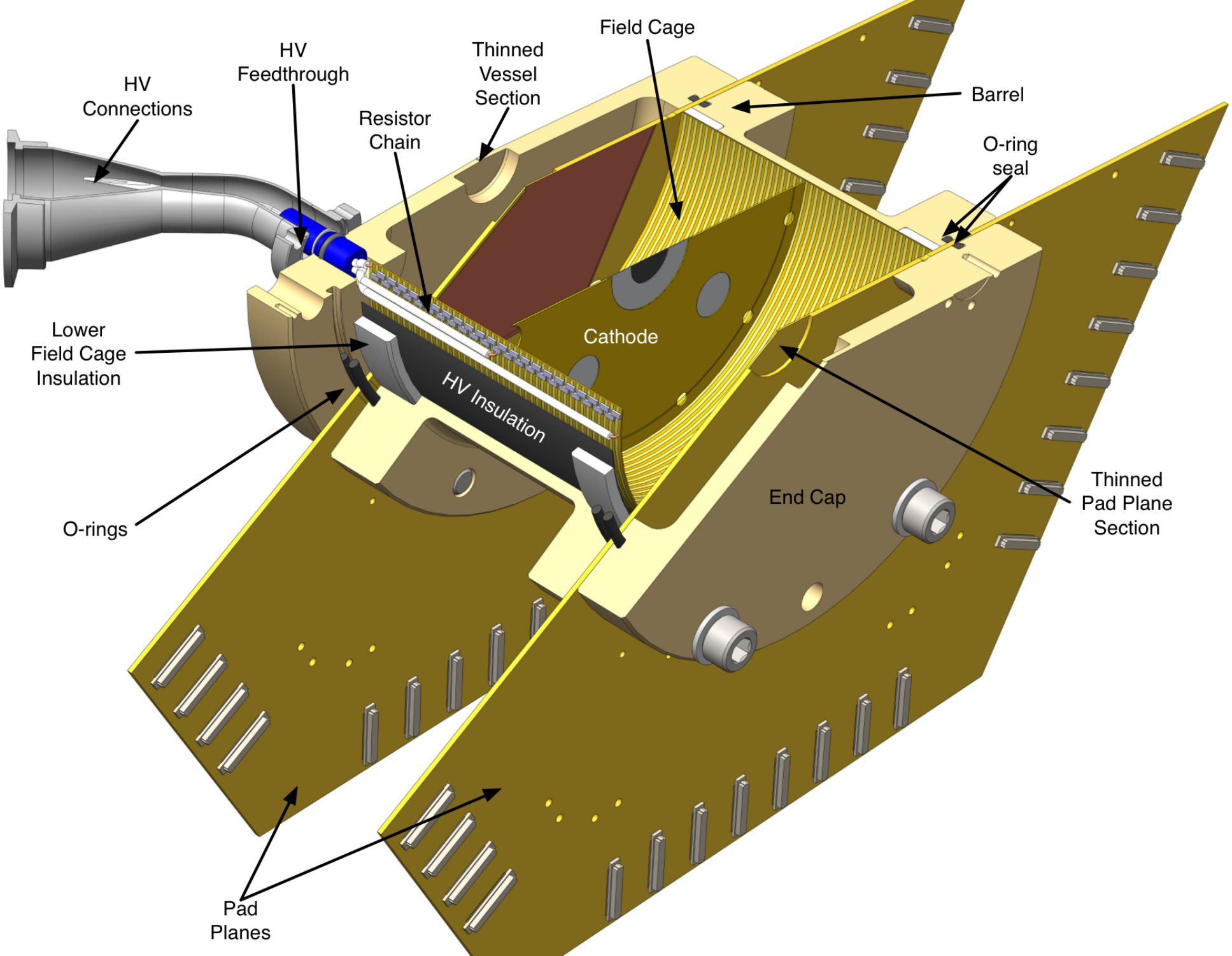



Expected 2014 Target A
Uncertainty
NIFFTE
Performance
% Uncertainty
Neutron Energy [MeV]
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-1}
10^{0}
10^{1}
^{235}U Standard (ENDF-VI)
^{239}Pu Statistics
^{235}U Statistics
Timing (6 ns FWHM)
nTOF,Target Atoms, Uniformity
Fission ID
Neutron Background, Dead-time
Beam Profile, Efficiency, Contaminates

The fissionTPC




Pad Plane
Fan Packs
Legs
Vessel
HV Feedthrough
Gas Lines
Electronics
Readout Fibers
Feet


HV Connections
HV Feedthrough
Resistor Chain
Thinned Vessel Section
Field Cage
Barrel
O-ring seal
Lower Field Cage Insulation
Cathode
HV Insulation
O-rings
End Cap
Thinned Pad Plane Section
Pad Planes

I. Giomataris NIMA 376 (1996) 29-35

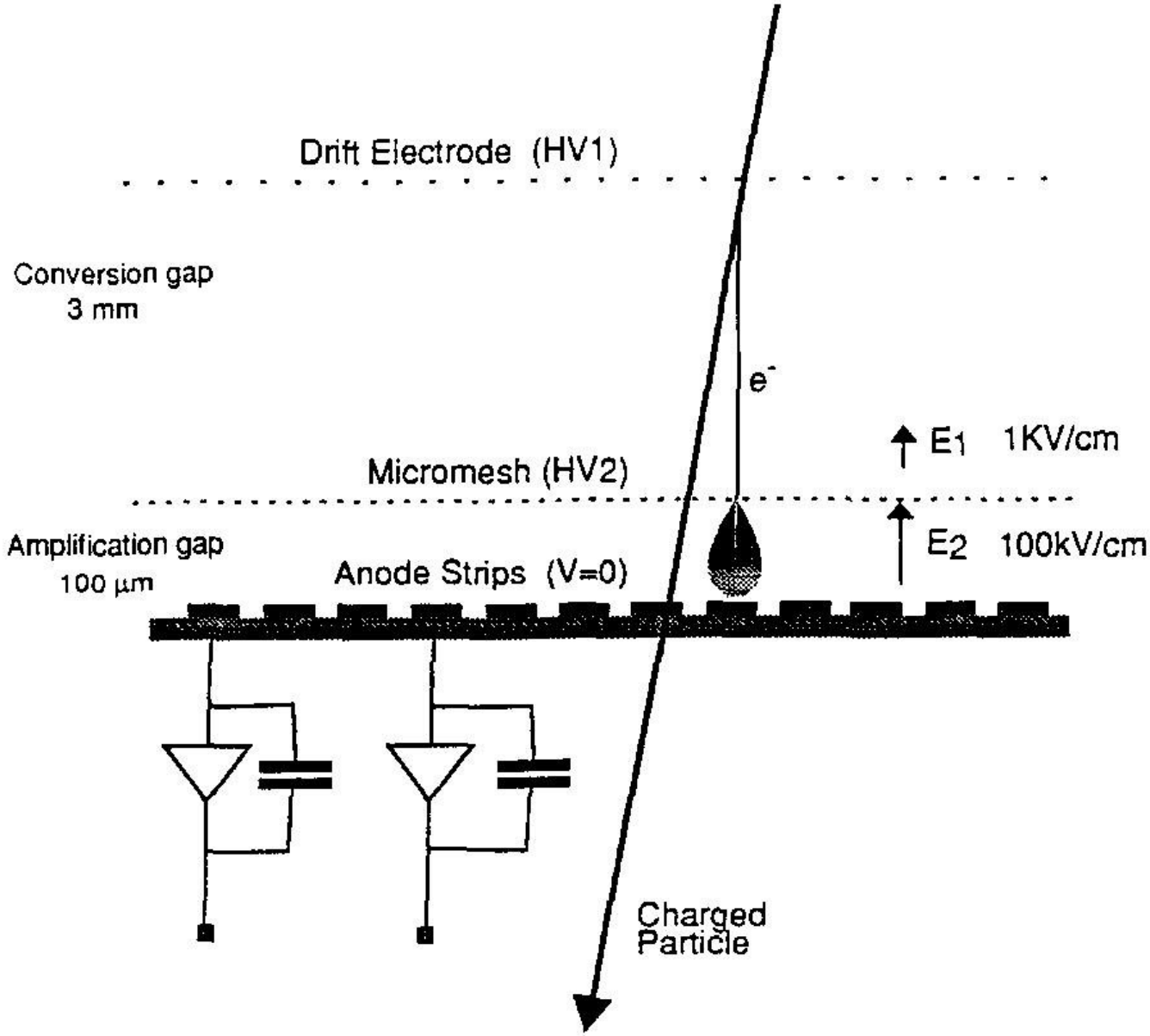
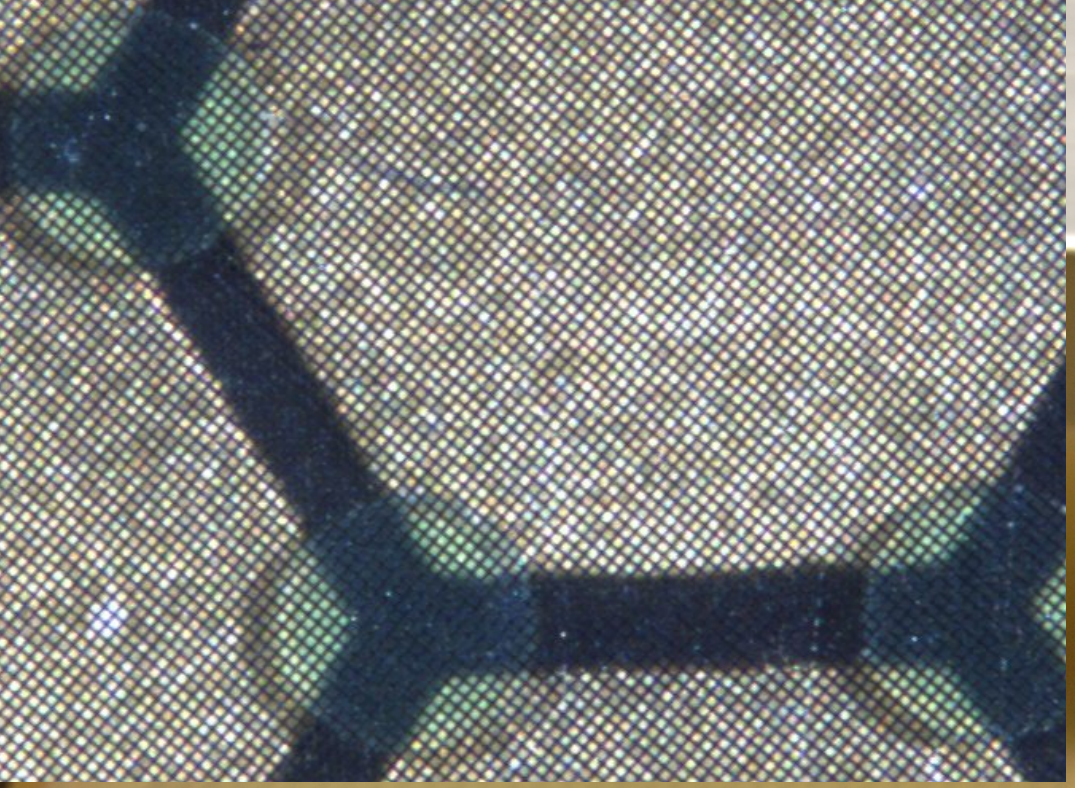
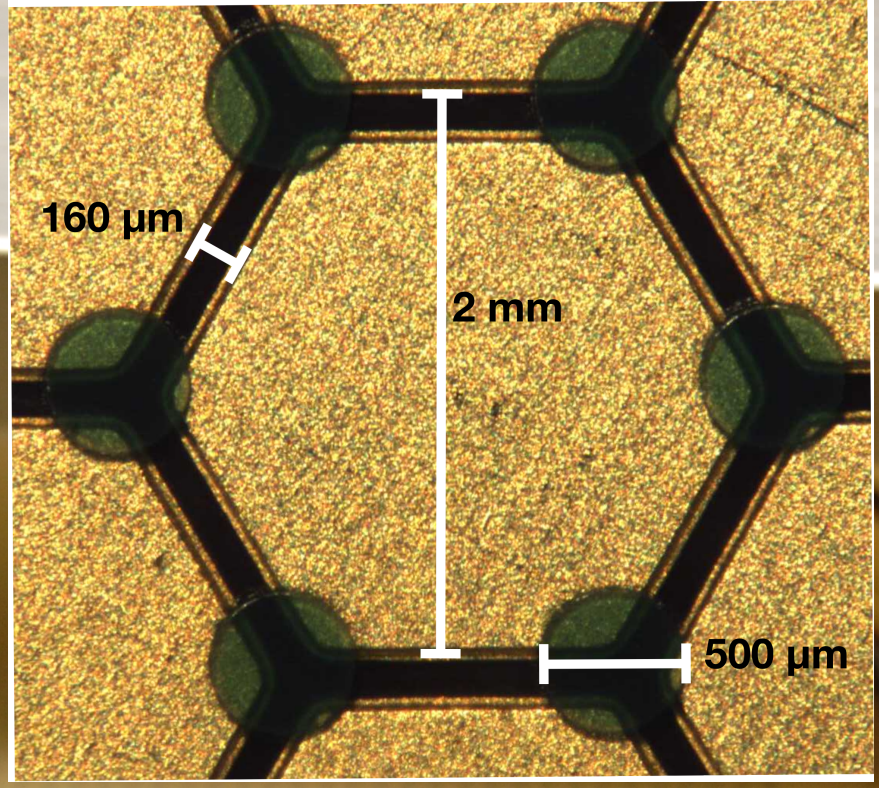
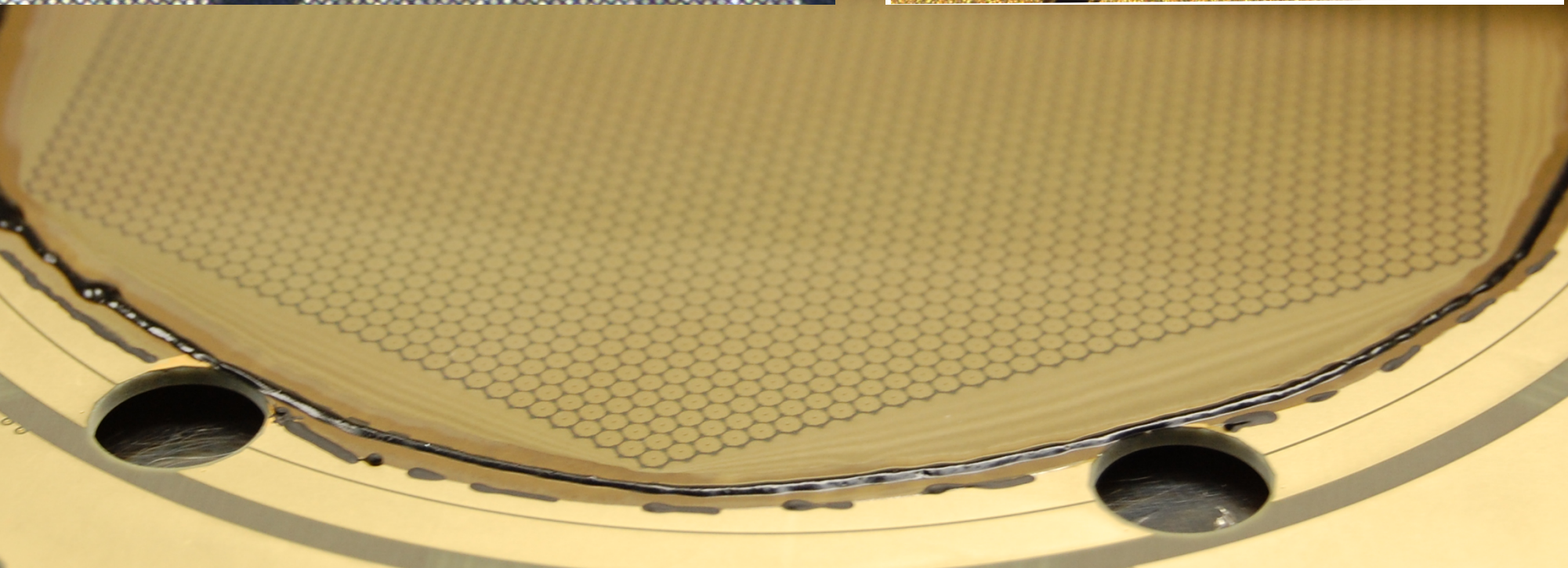
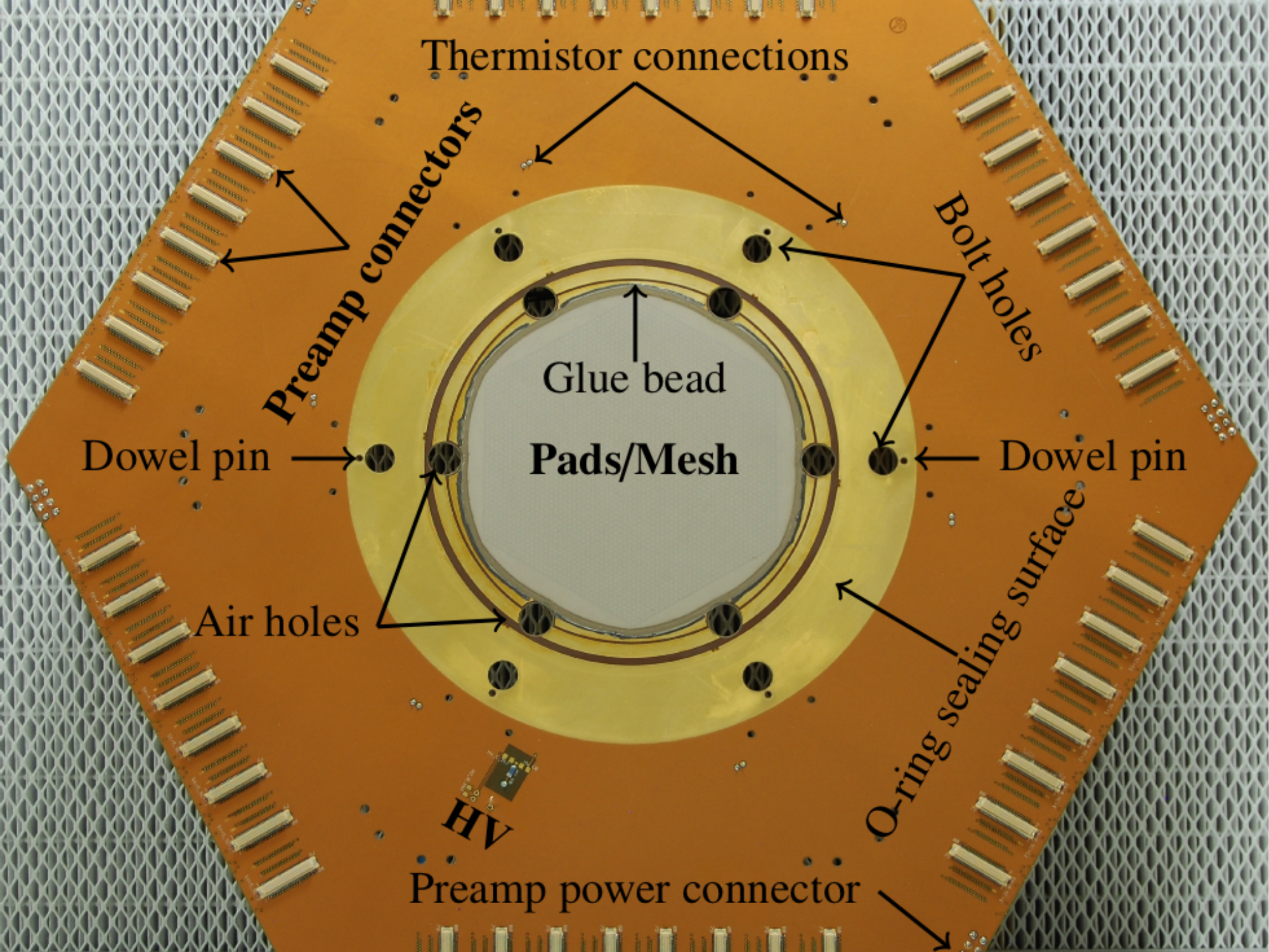


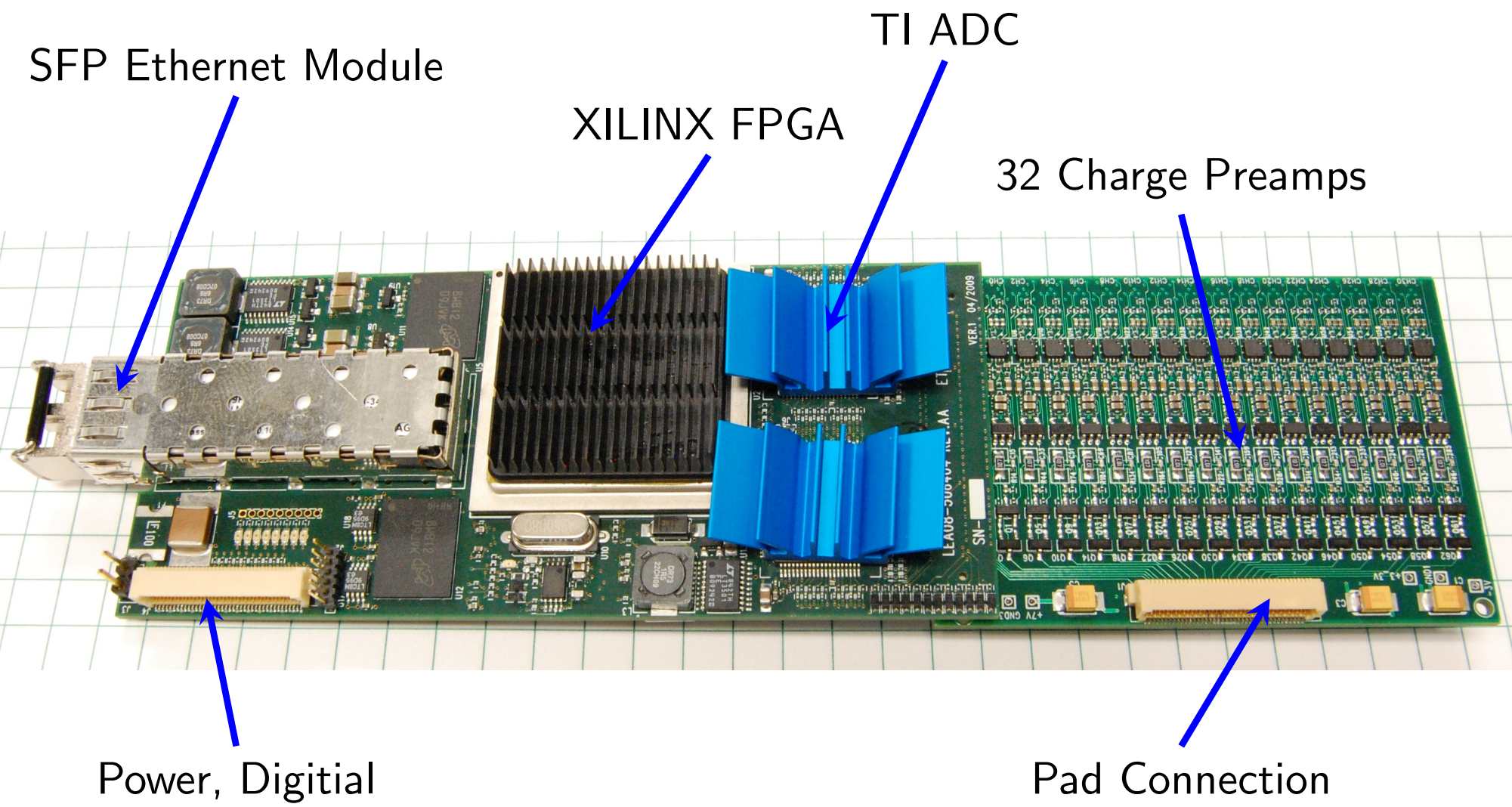
Fig. 1. A schematic view of MICROMEGAS: the 3 mm conversion gap and the amplification gap separated by the micromesh and the anode strip electrode.

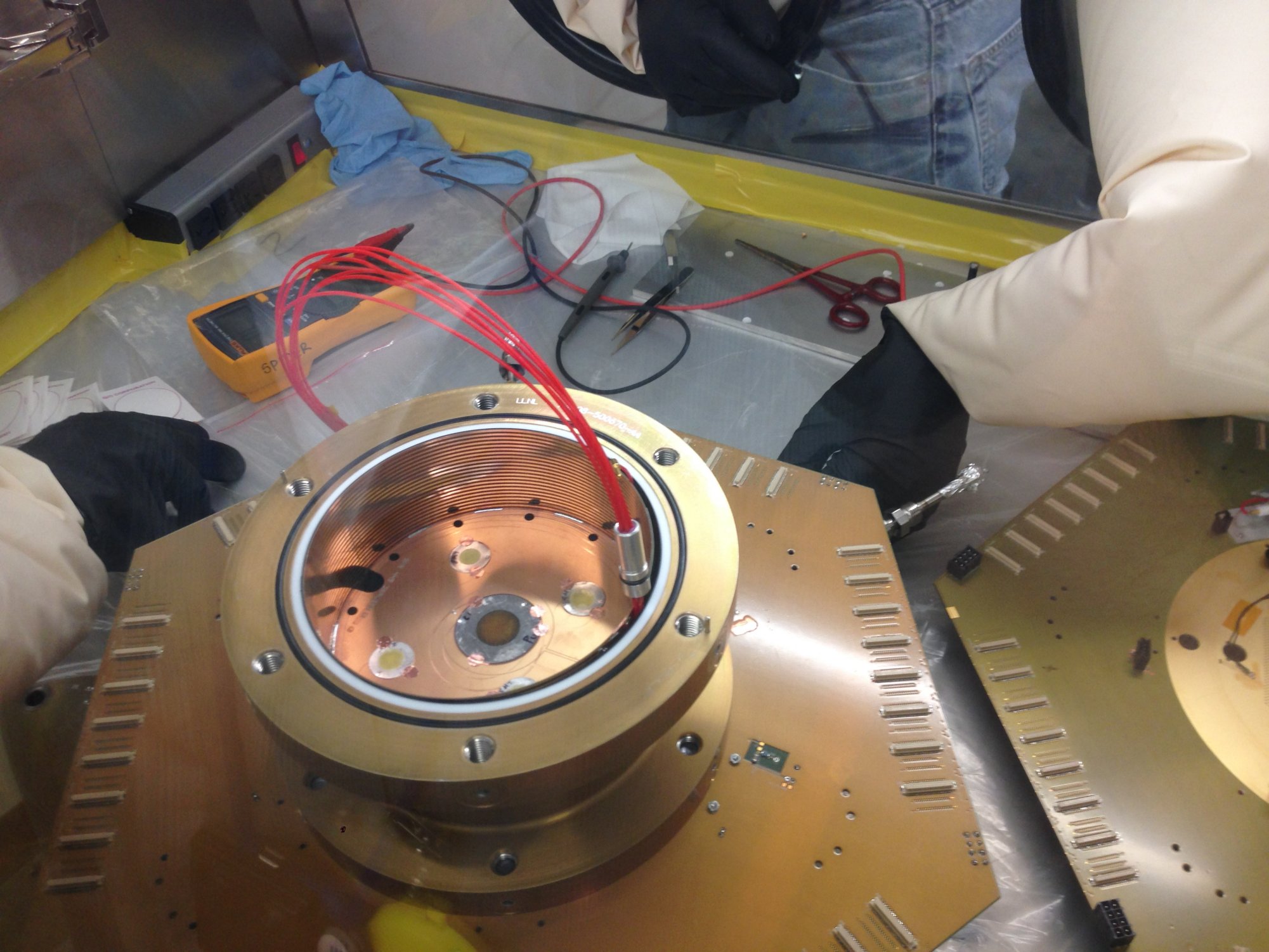


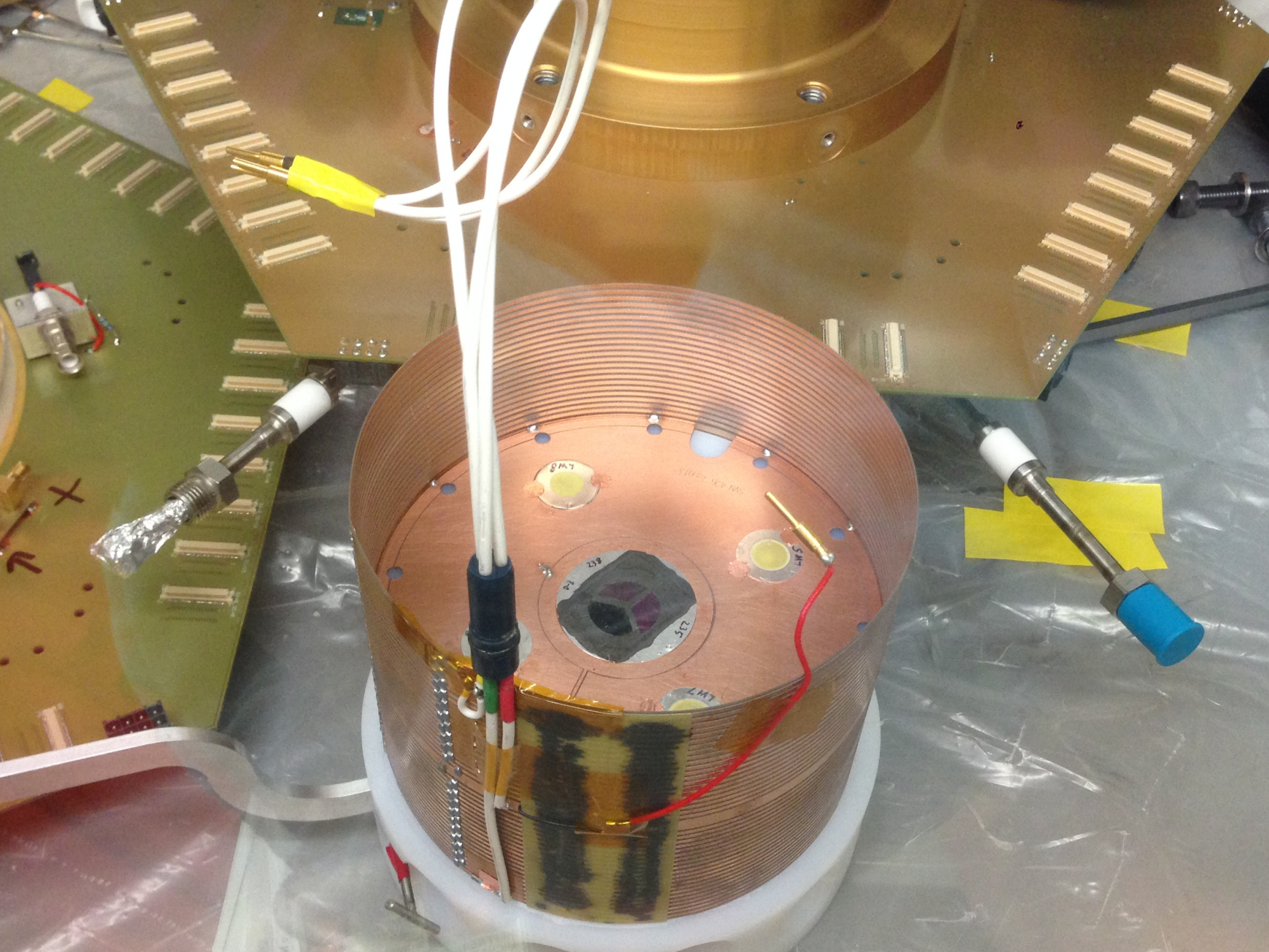

160 µm
2 mm
500 µm

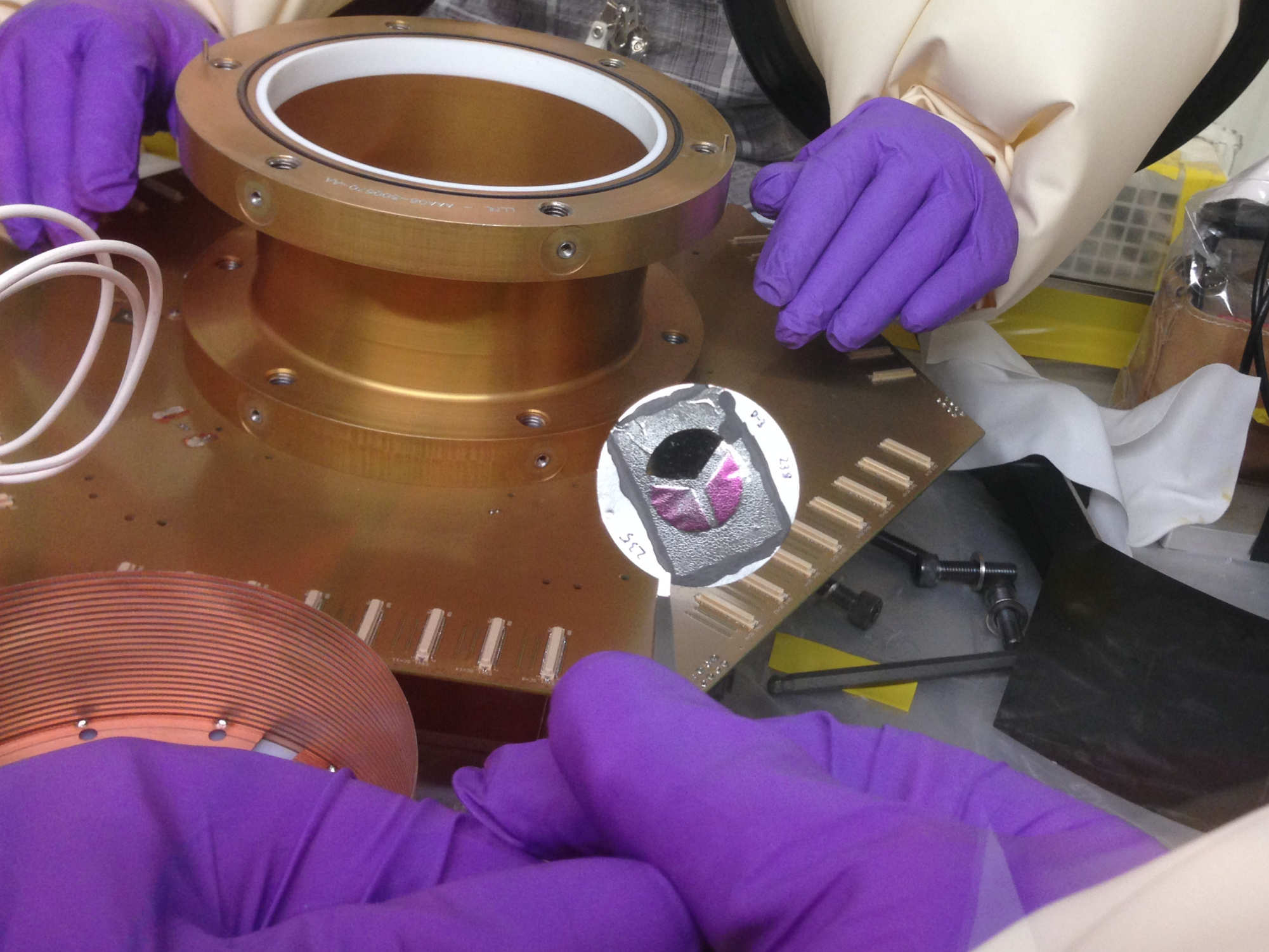



Thermistor connections
Preamp connectors
Bolt holes
Glue bead
Pads/Mesh
Dowel pin
Dowel pin
Air holes
O-ring sealing surface
HV
Preamp power connector


SFP Ethernet Module
XILINX FPGA
TI ADC
32 Charge Preamps
Power, Digitial
Pad Connection







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A time projection chamber for high accuracy and precision fission cross-section measurements

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NIFFTE Collaboration

ARTICLE INFO

ABSTRACT

Conclusions

- Achieving better than 1% total uncertainty for $^{239}Pu(n, f)$ is difficult and requires analysis of many issues
- The fissionTPC project has shown the potential to illuminate a number of factors simultaneously
- Construction is largely completed; data taking and analysis are now the focus.