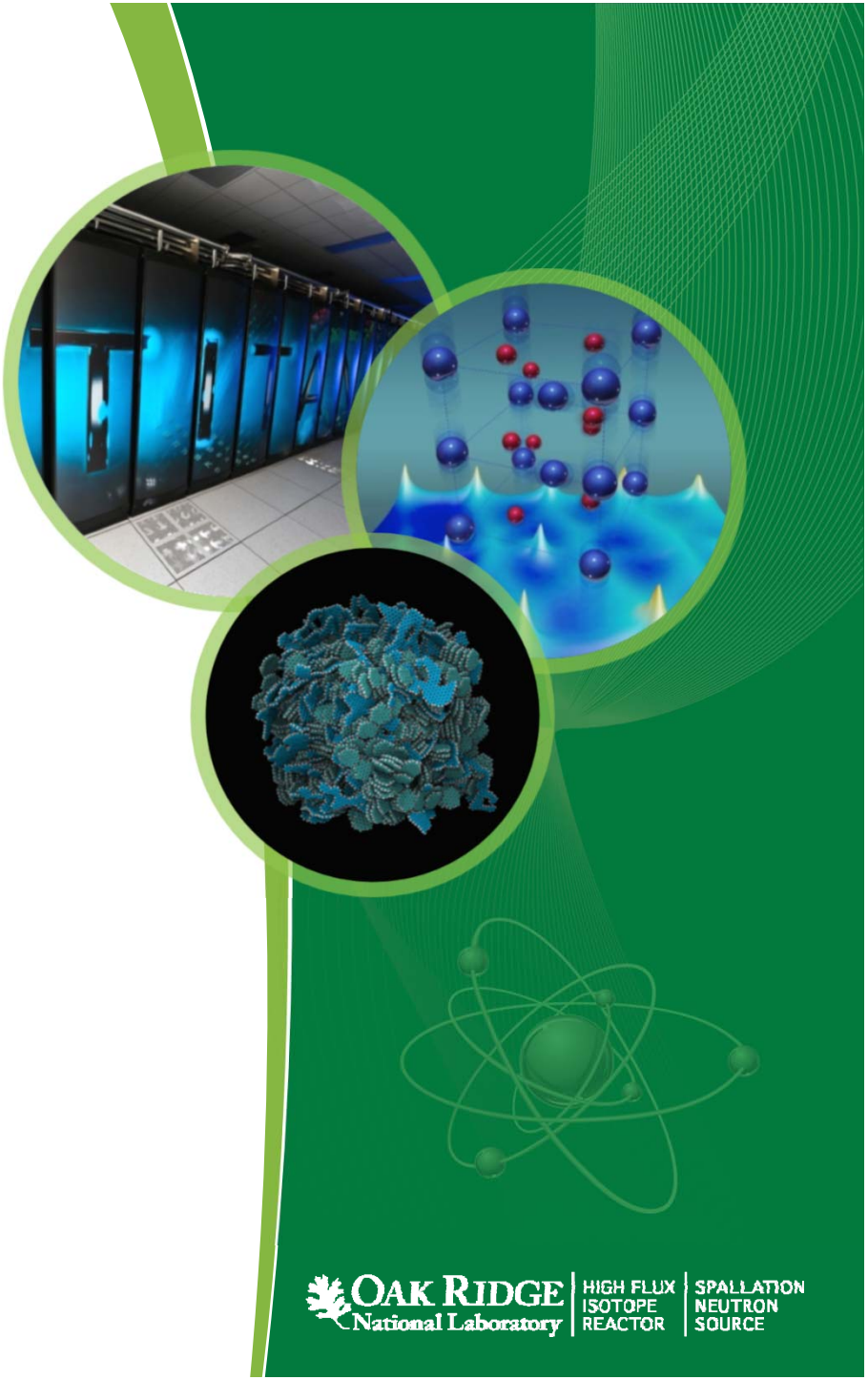
Scintillator Detectors

HFIR & SNS

Jason P Hodges

July 21st, 2016

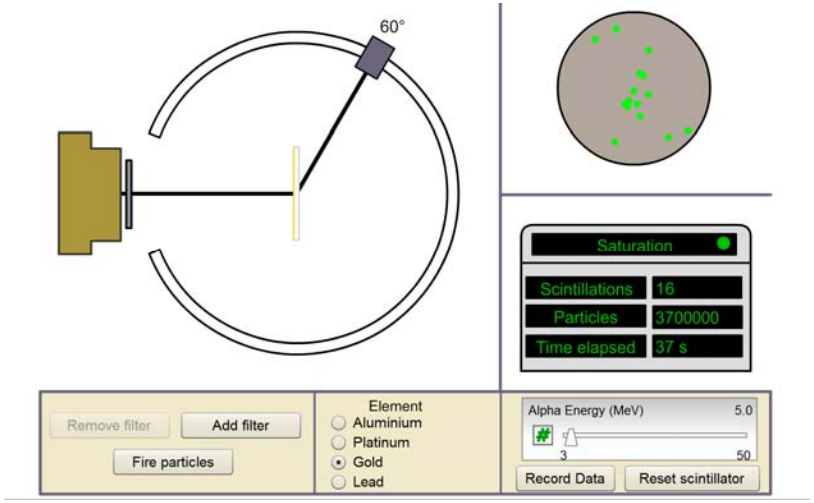


Rutherford, Chadwick and Geiger

- Rutherford & collaborators used ZnS scintillation screens:
  - in the discovery of the proton:

$$^{14}N + \alpha \rightarrow {}^{17}O + p$$

  - 'Classic' scattering experiment:
    - displaced Thomson model of atom with nuclear model



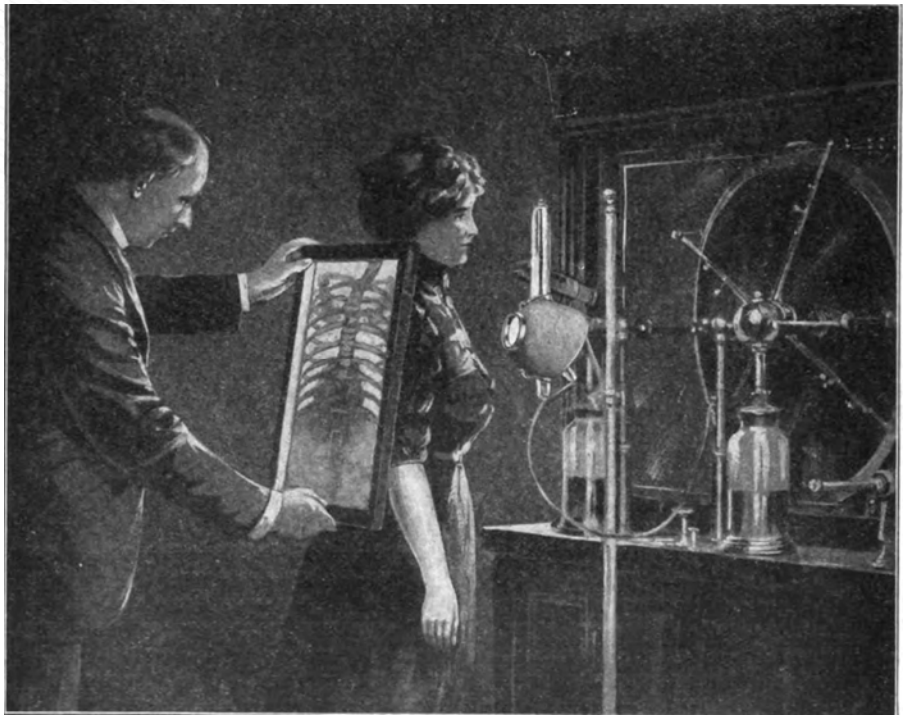
Credit: King's Centre for Visualization in Science

www.kcvs.ca/site/projects/physics_files/rutherford/historical_resources/exploration_frames/explorationFrame.html

- Chadwick went onto discover the neutron.

Scintillators in radiography & fluoroscopy

- Then (1909) and now:



Probably a $CaWO_4$ screen

Gd_2O_2S:Tb screen.
Credit: Finger Lakes Instrumentation

Edwin J. Houston, "Elementary Electricity Ch. 13: The X-rays" in Popular Electricity magazine, Popular Electricity Publishing Co., Chicago,

Some Physical Properties:

Scintillator	Light yield (photons/keV)	Light ouput (%) of NaI(Tl) bialkali pmt	Temperature coefficient of light output (%/C) 25°C to 50°C	1/e Decay time (ns)	Wavelength of maximum emission lm (nm)	Refractive index at lm	Thickness to stop 50% of 662 keV photons (cm)	Thermal expansion (/C) x 10^{-6}	Cleavage plane	Hardness (Mho)	Density g/cm^3	Hygroscopic	Comments
BrilLanCe™380 $LaBr_3(Ce)$	63	165	0	16	380	~1.9	1.8	8	<100>		5.08	yes	General purpose, best energy resolution, rate of change of light output w/temperature is small
NaI(Tl)	38	100	-0.3	250	415	1.85	2.5	47.4	<100>	2	3.67	yes	General purpose, good energy resolution
Polyscin®NaI(Tl)	38	100	-0.3	250	415	1.85	2.5	47.4	none	2	3.67	yes	Polycrystalline NaI(Tl), for extra strength
BrilLanCe™350 $LaCl_3(Ce)$	49	70-90	0.7*	28	350	~1.9	2.3	11	<100>		3.85	yes	General purpose, excellent energy resolution
CsI(Na)	41	85	-0.05	630	420	1.84	2	54	none	2	4.51	yes	High Z, rugged
PreLude ™420 $Lu_{1.8}Y_{.2}SiO_5(Ce)$	32	75	-0.28	41	420	1.81	1.1	--	none		7.1	no	Bright, high Z, fast, dense, background from ^{176}Lu activity
$CdWO_4$	12 - 15	30-50	-0.1	14000	475	~2.3	1	10.2	<010>	4 - 4.5	7.9	no	High Z, low afterglow, for use with photodioides
$CaF_2(Eu)$	19	50	-0.33	940	435	1.47	2.9	19.5	<111>	4	3.18	no	Low Z, a & b detection
CsI(Tl)	54	45	0.01	1000	550	1.79	2	54	none	2	4.51	slightly	High Z, rugged, good match to photodiodes
BGO	8 - 10	20	-1.2	300	480	2.15	1	7	none	5	7.13	no	High Z, compact detector, low afterglow
YAG(Ce), $Y_3Al_5O_{12}(Ce)$	8	15	--	70	550	1.82	2	~80	none	8.5	4.55	no	b-ray, X-ray counting, electron microscopy
CsI(pure)	2	4-6	-0.3	16	315	1.95	2	54	none	2	4.51	slightly	High Z, fast emission
BaF_2	1.8	3	0	0.6 - 0.8	220(195)	1.54	1.9	18.4	<111>	3	4.88	slightly	Fast component (subnanosecond)
	10	16	-1.1	630	310	1.50	1.9	18.4	<111>	3	4.88	slightly	Slow component
ZnS(Ag)	~50	130	-0.6	110	450	2.36	--	--	--	--	4.09	no	Multicrystal, 15m stops 5.5 MeV a (n detection with ^6Li)

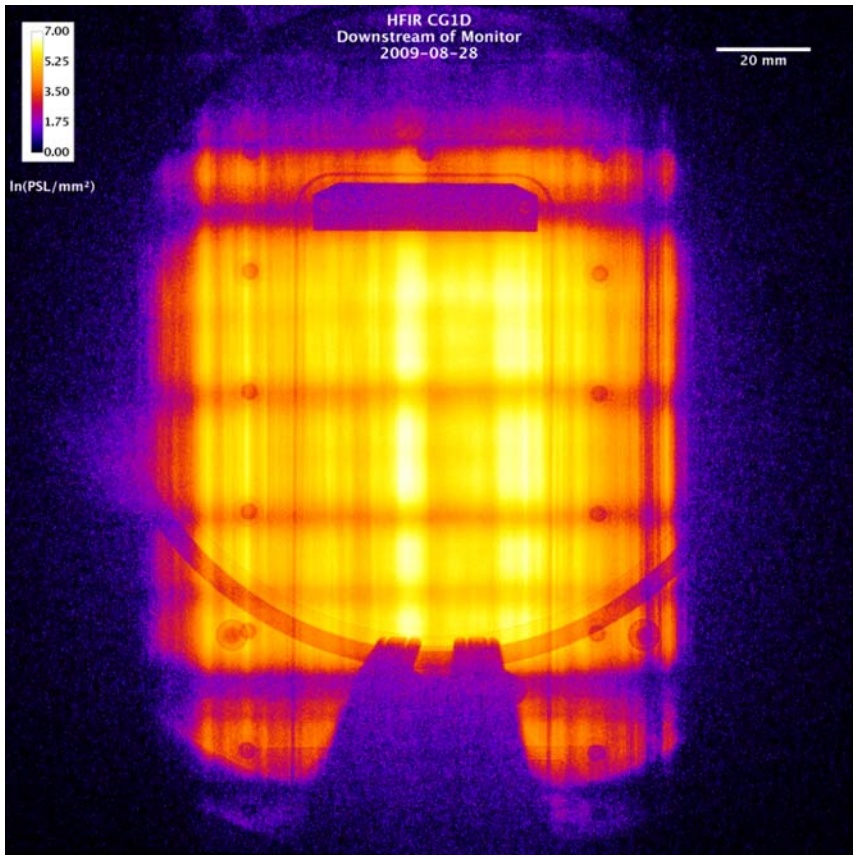
Credit: www.saint-gobain.com

Some Useful Nuclear Reactions:

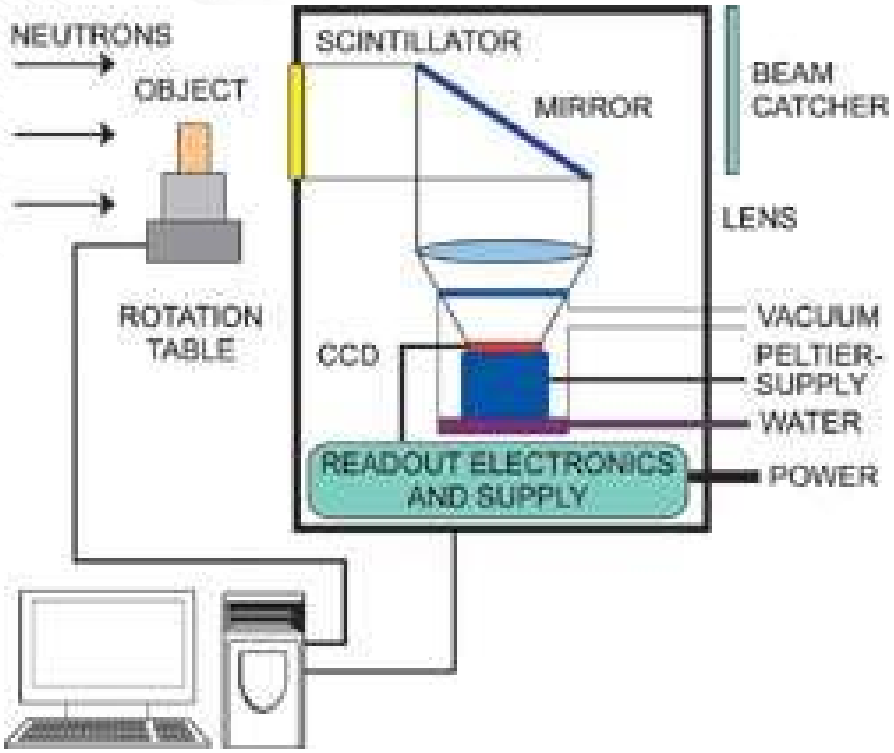
Converter	Cross-section (barns)	Products
^{3}He	5333	p 0.57 MeV + T 0.19 MeV
^{6}Li	940	α 2.05 MeV + T 2.74 MeV
^{10}B	3835	93% α 1.47 MeV + ^{7}Li 0.83 MeV + γ 0.48 MeV 7% α 1.77 MeV + ^{7}Li 1.01 MeV
^{nat}Gd	29400	β 0.07 – 0.182 MeV
^{235}U	681	2 fission products ~169 MeV

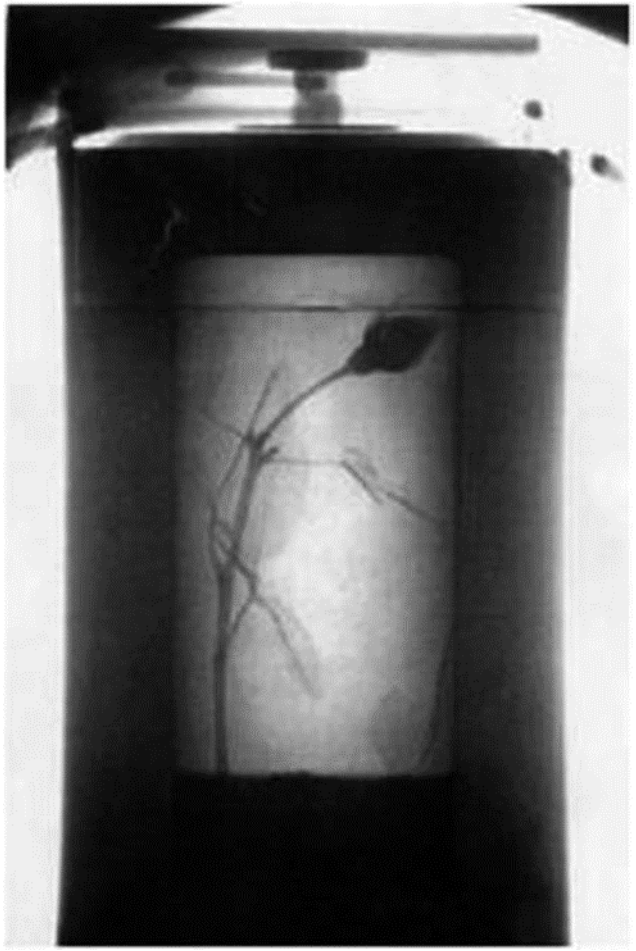
Image Plate

- Single crystal diffractometer: IMAGINE
- Instrument beam characterization:

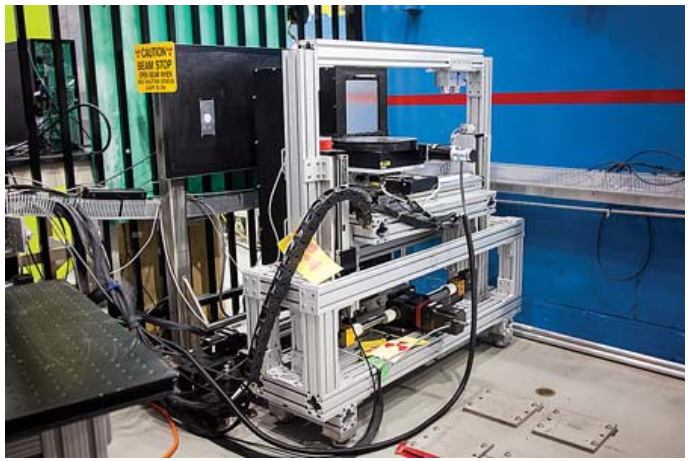


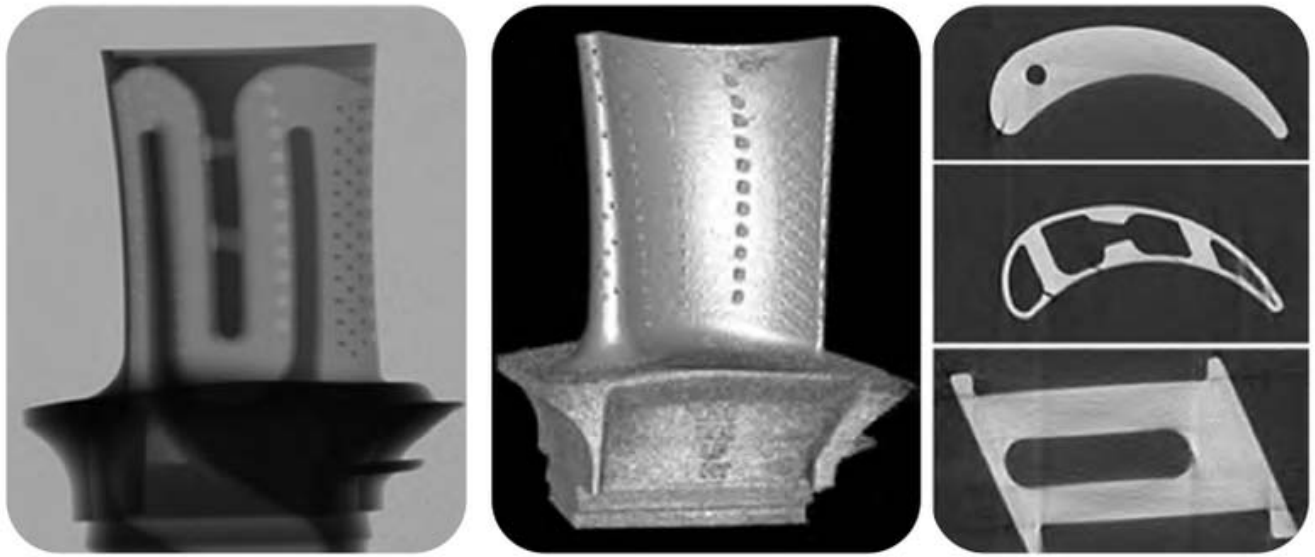
Neutron Radiography





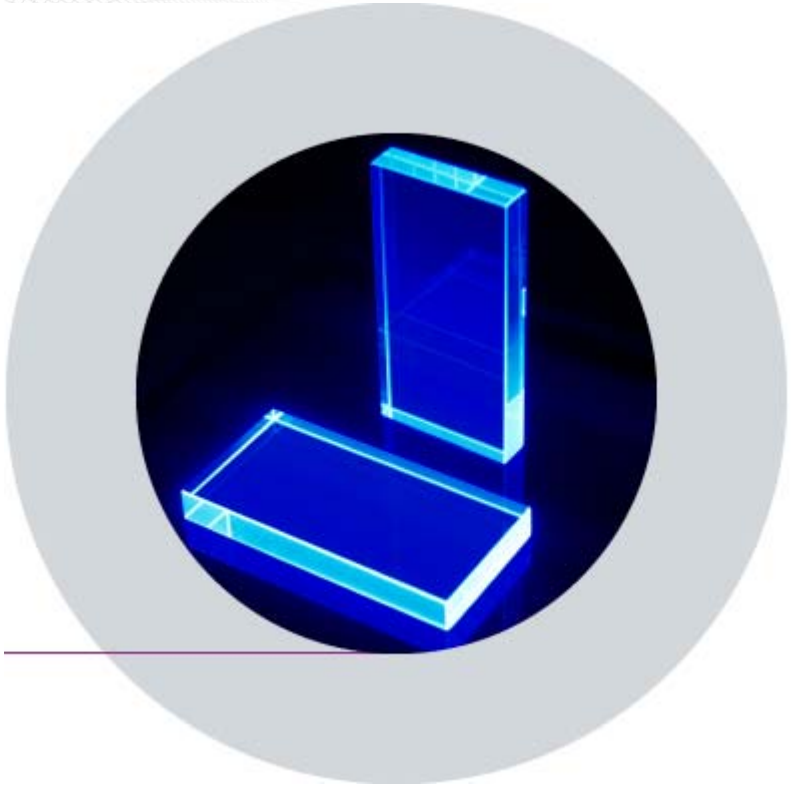
Neutron Tomography at HIFR





https://HIFR Turbine Blade

Neutron Scintillating Glass:



products

Type	Isotopic Ratio	Total Lithium
GS1	Natural	2.4%
GS2	95% ^{6}Li	2.4%
GS3	99.99% ^{7}Li	2.4%
GS10	Natural	6.6%
GS20™	95% ^{6}Li	6.6%
GS30	99.99% ^{7}Li	6.6%
KG1	Natural	7.5%
KG2	95% ^{6}Li	7.5%
KG3	99.99% ^{7}Li	7.5%

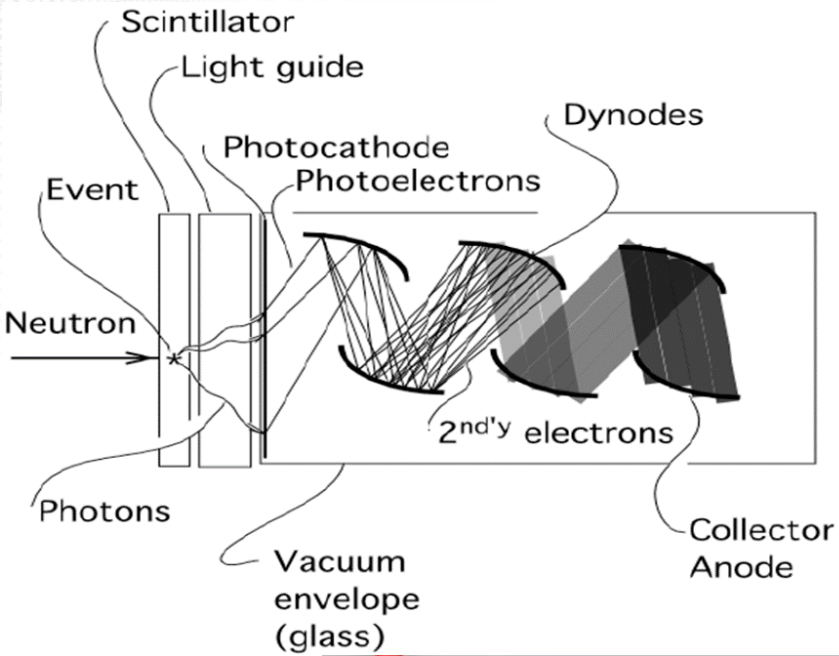
specification

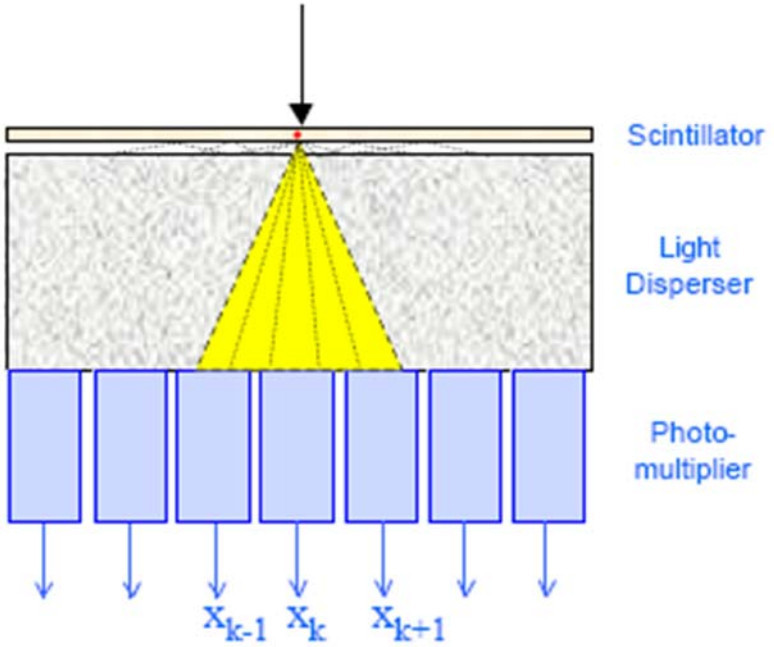
Properties	GS1/GS2/GS3	GS10/GS20™/GS30	KG1/KG2/KG3
Density [g/cm³]	2.64	2.50	2.42
Coefficient of linear expansion/ °C	7.0×10^{-6}	9.23×10^{-6}	100×10^{-6}
Light output relative to anthracene*	22-34%	20-30%	20%
Decay times†, neutron excitation, ns	none	18, 57 & 98	18, 62 & 93
Decay times†, alpha excitation, ns	20, 48 & 88	16, 49 & 78	15, 45 & 56
Decay times†, beta excitation, ns	19, 57 & 103	20, 58 & 105	17, 51 & 96
Wavelength of maximum emission	395	395	395
Refractive index at maximum emission	1.58	1.55	1.57
Resolution on the thermal neutron "peak" obtained with moderated Po/Be neutrons	13~22%	15~28%	20~30%
Peak/through ratio of above "peak" (range) for thermal neutrons	15:1~40:1	10:1~40:1	10:1~20:1

* Determined by thickness, increasing with decreasing thickness down to approximately 2mm.
† Fast component, slow component and 90-10% respectively

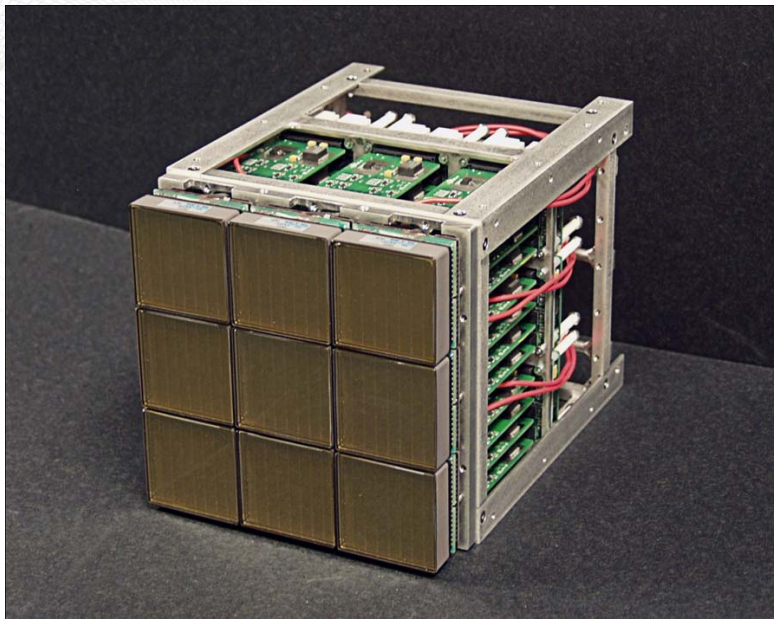
~ 6000 photons/n

Neutron Anger Camera



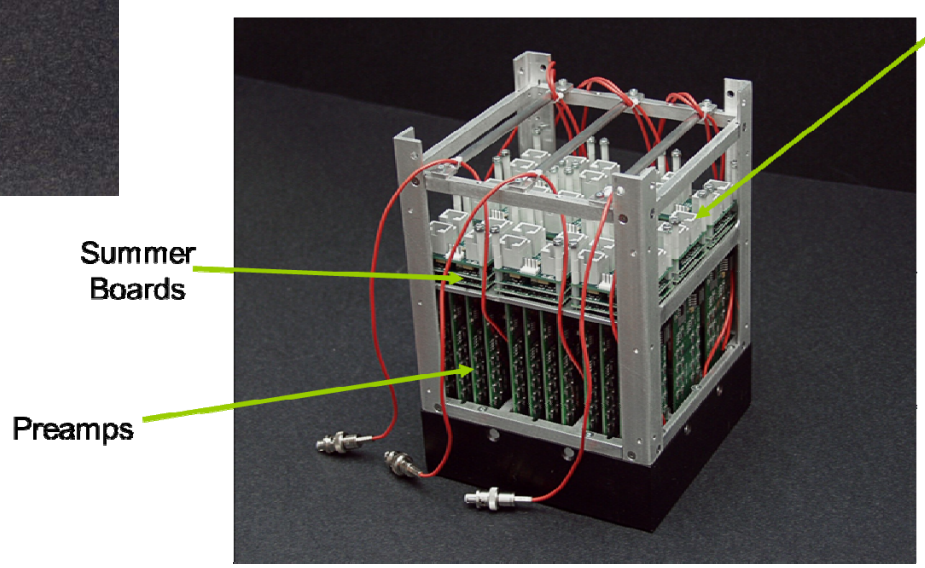


Anger Cameras at SNS

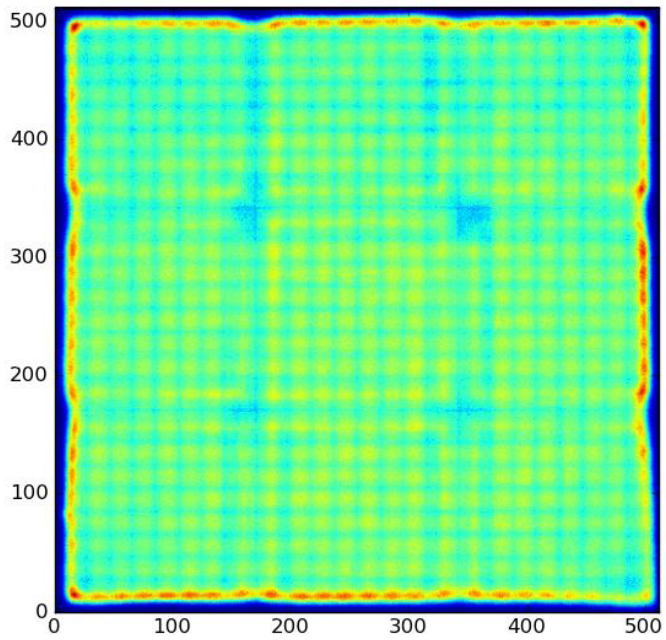


Row, Column
Outputs

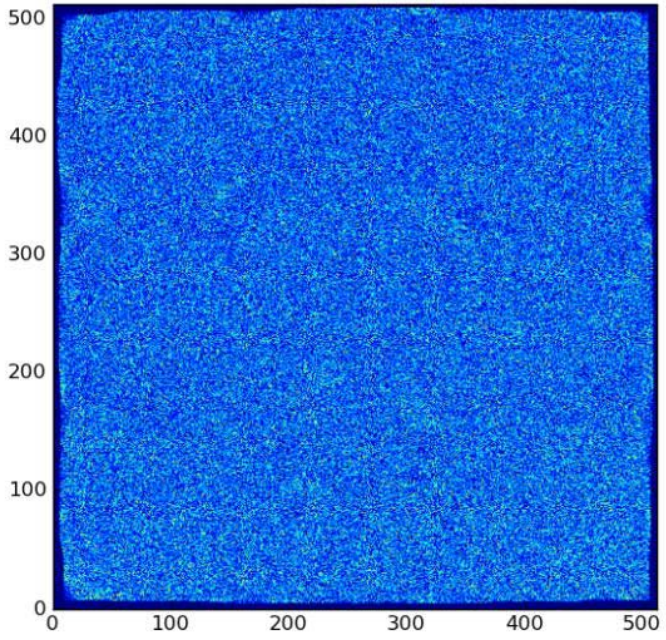
Total of 16 signals per photo
tube x 9 photo tubes



Flat field Correction



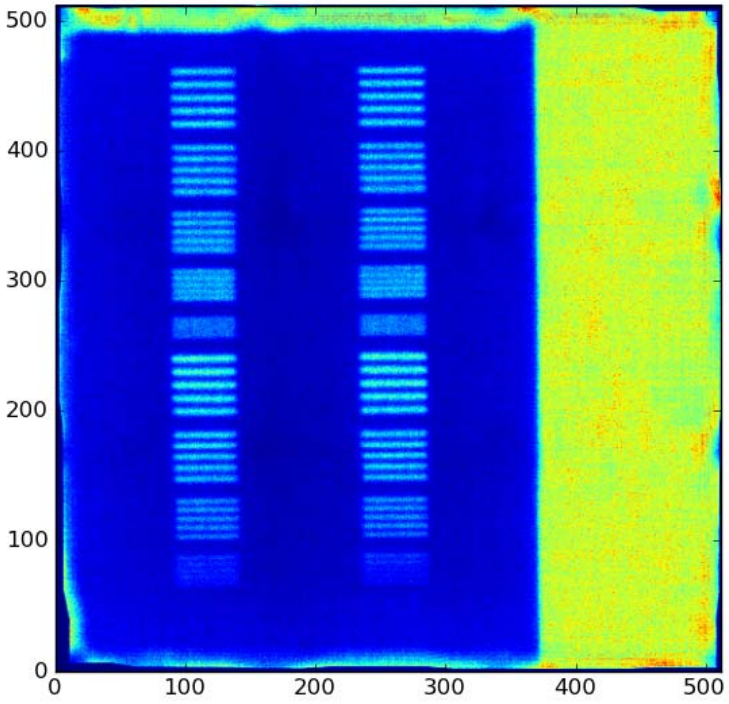
Before



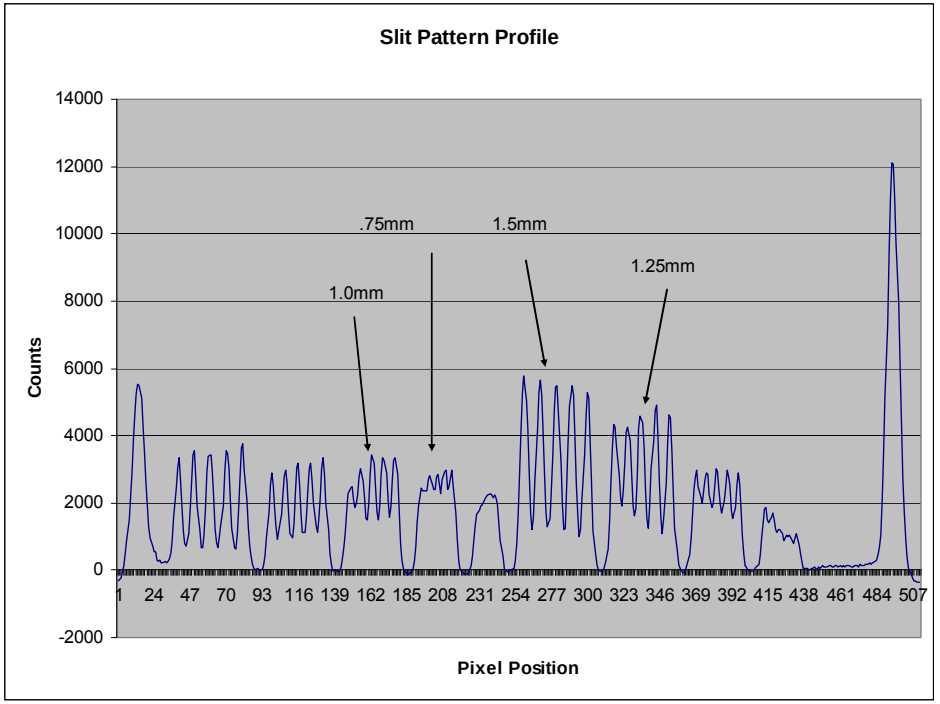
After

Vanadium flood field data collected on TOPAZ

Resolution measurement at TOPAZ:

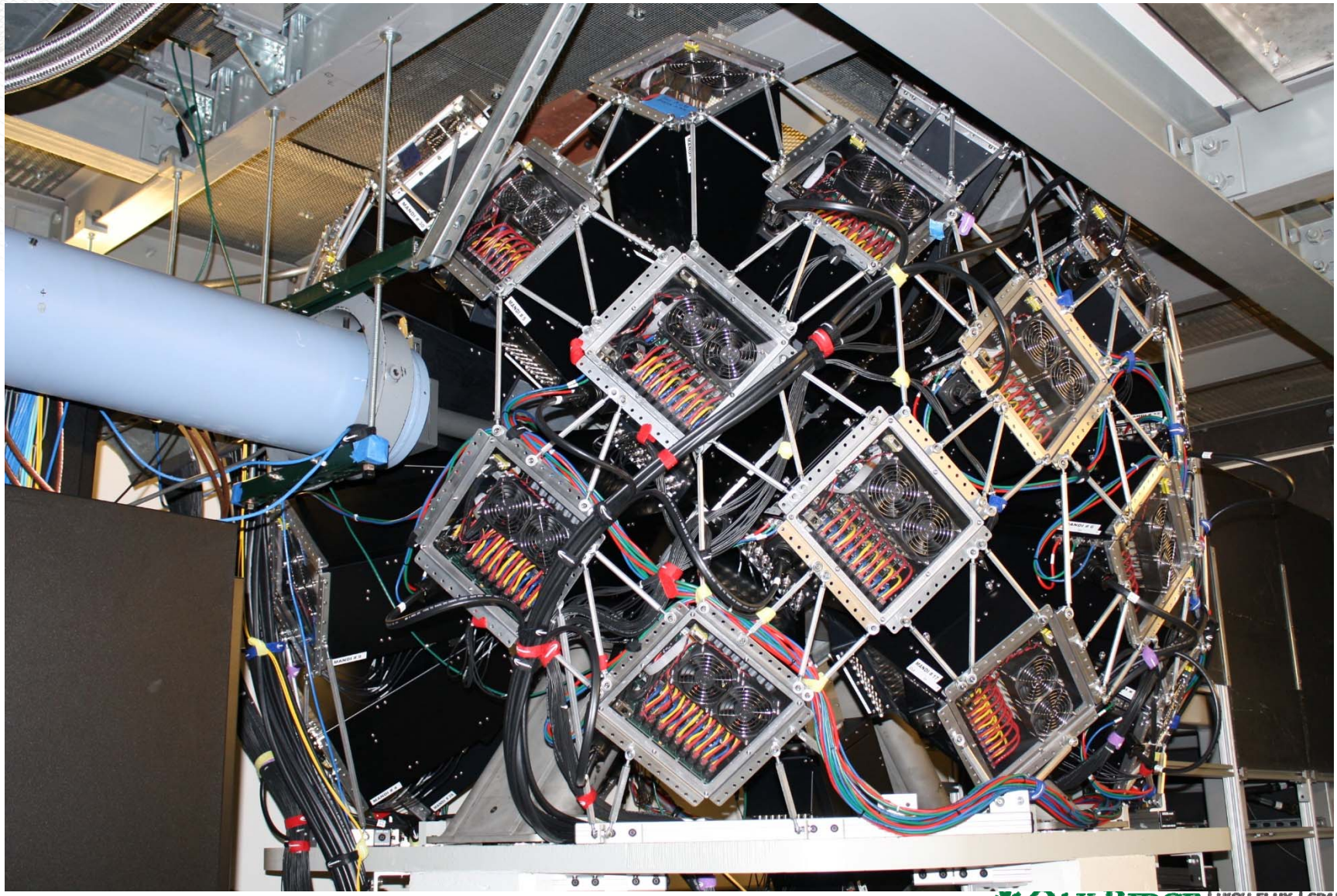


Detector Image

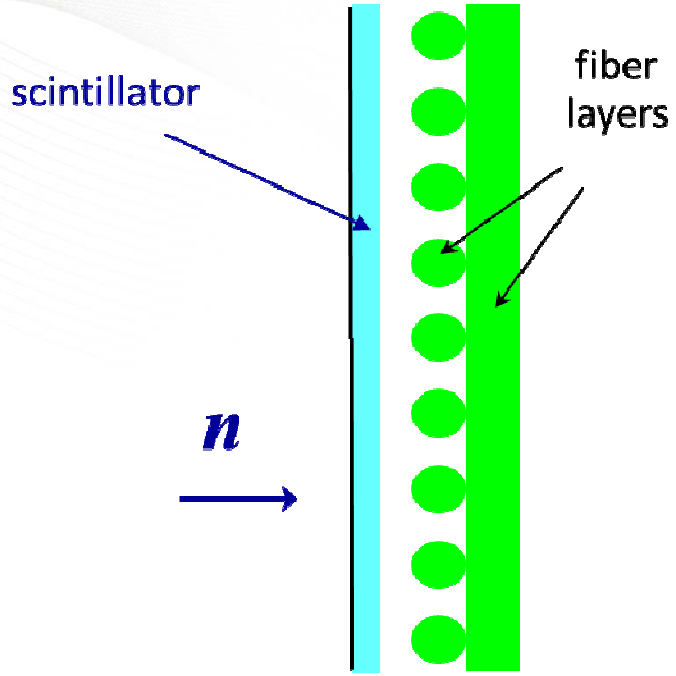


Spatial resolution ~ 1.2 mm

MaNDi Instrument: 36 Anger Cameras

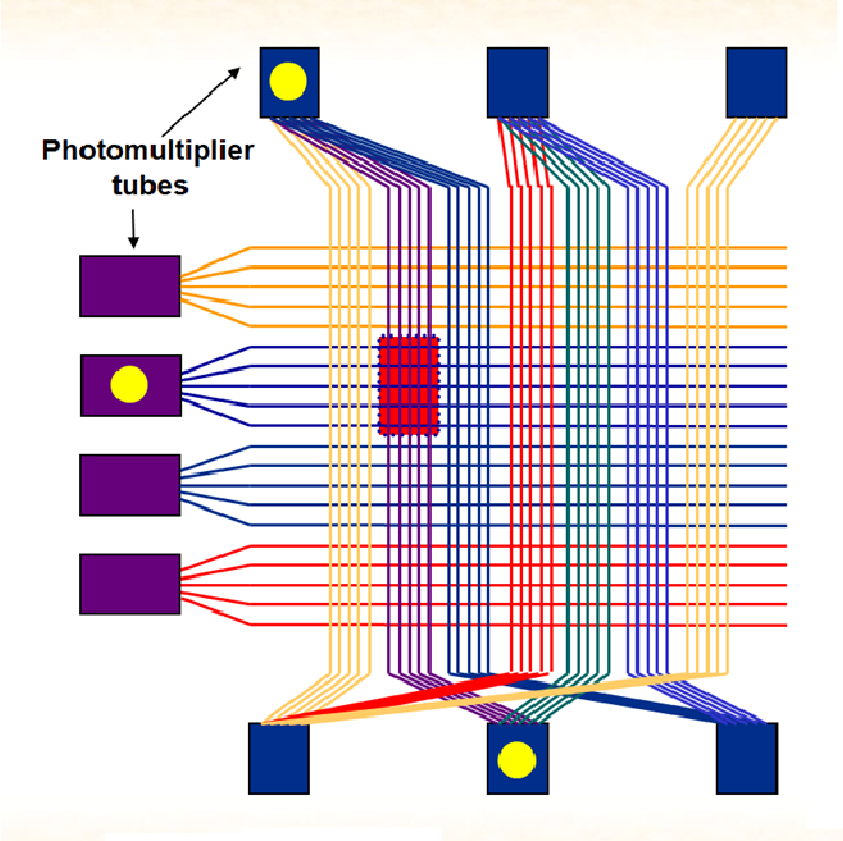


WLSF Neutron Detector

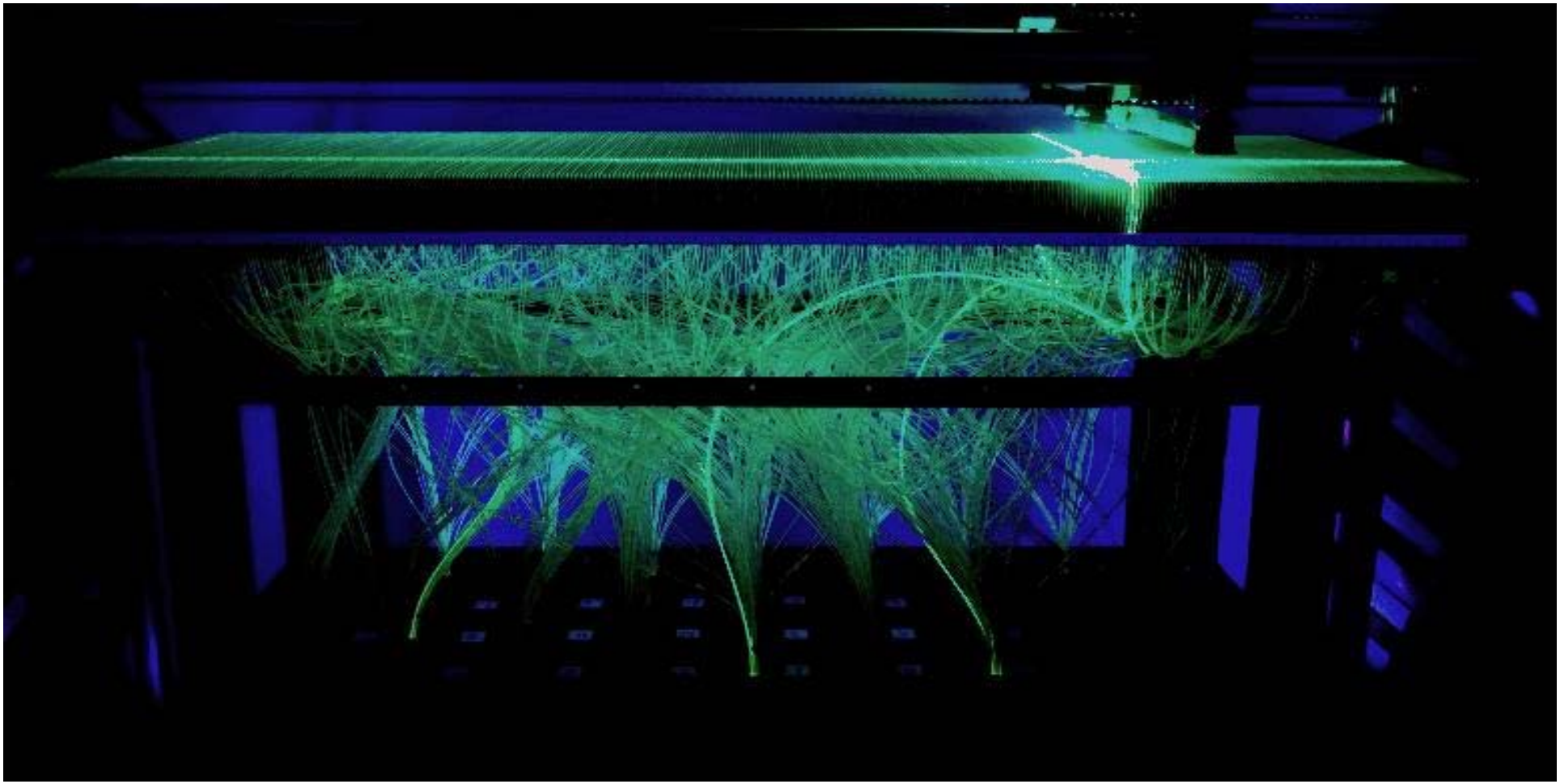


^{6}LiF ZnS(Ag) scintillator emits blue light

wavelength-shifting crossed optical fibers convert light to green wavelengths



Q.A. of WLSF module

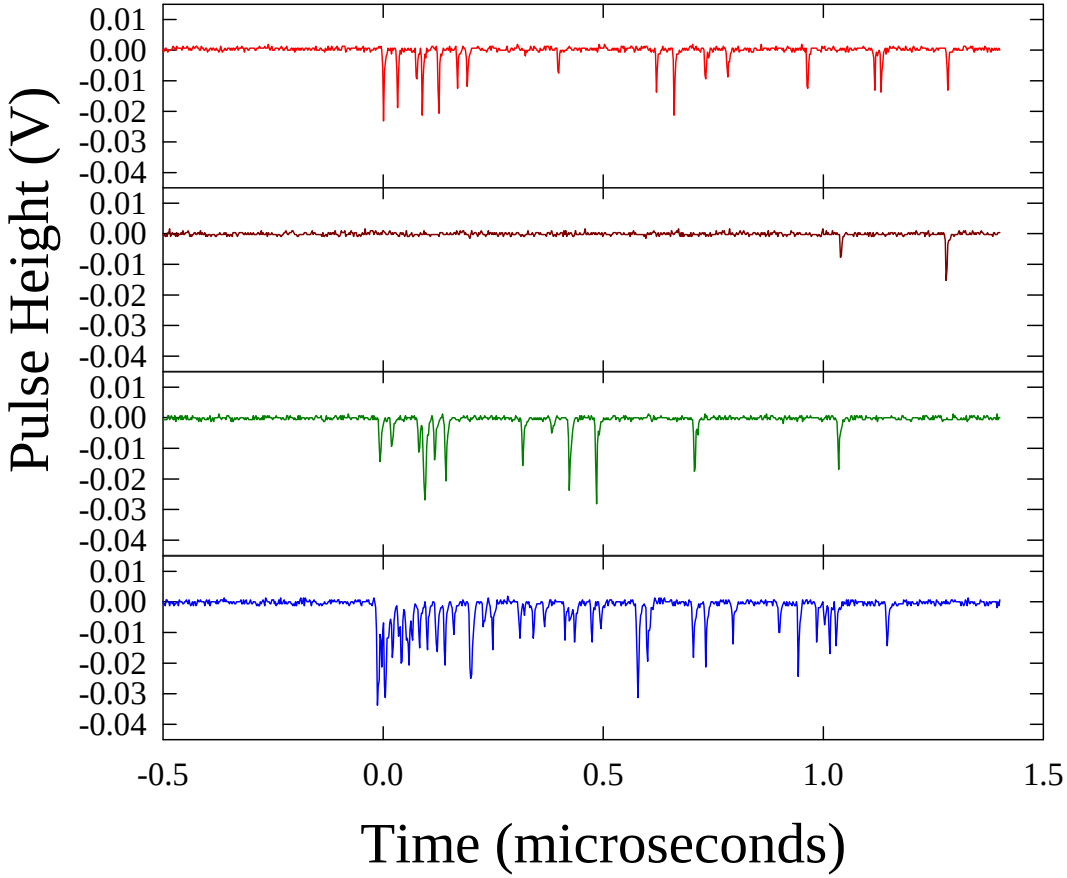


WLSF Detector cont'd

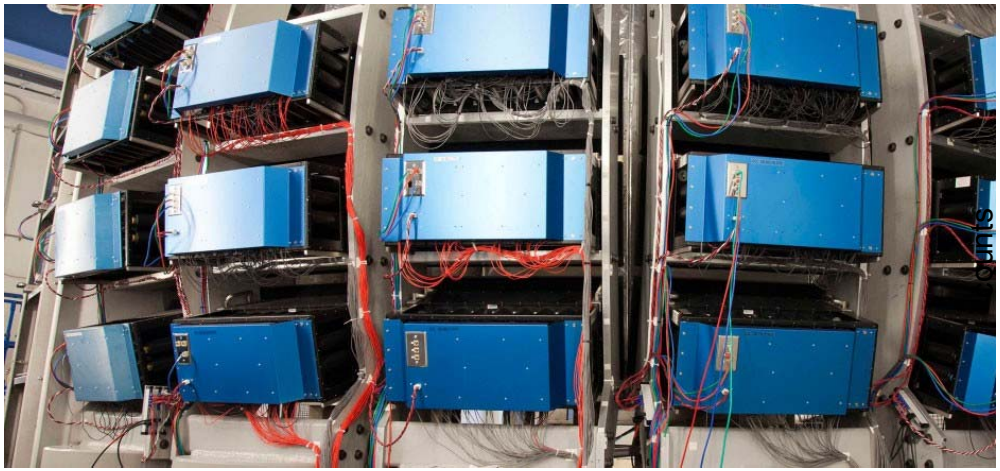
optical fibers terminate into PMTs

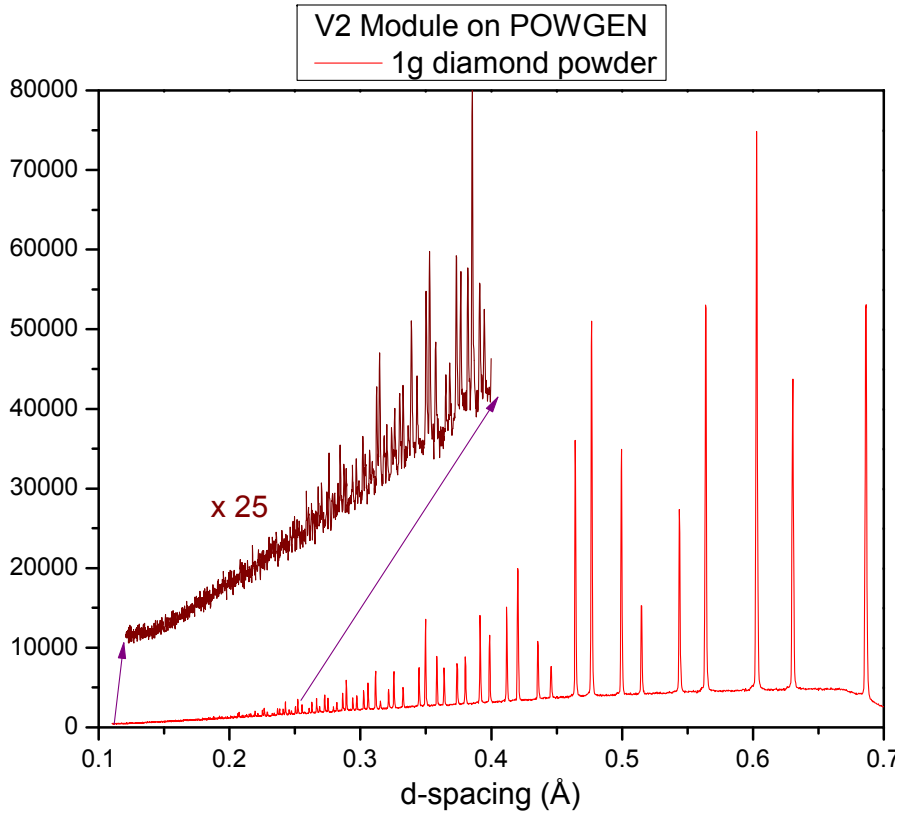
scintillator screen in place

Time Coincidence of Pulses Maps Neutron Event



WLSF Detectors at POWGEN:





- 30 detector modules in place