MultiGEM:

A neutron detector for the SNS

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Data Size Estimates

Parameter	Backscat. Spect.	Magnetism Reflect.	Liquids Reflect.	Powder Diff.	Single Xtal Diff.	Chopper Spect.	Disord. Mat'ls Diff.
Spatial pixel area (cm^2)	1	0.01	0.01	1.2	0.01	6.25	1.2
Total # of pixels	7,000	10,000	10,000	230,000	5,000,000	50,400	150,000
Time of flight precision (microsec)	1	10	10	0.5	1	0.2	0.2
Max # of time channels	8,400	1,500	1,500	60,000	1,000	2,000	1,000
Max instantaneous rate/pixel (cts/sec)	4,000	1.3×10^6	1.30×10^6	40	3.8×10^4	30,000	2,000
Max total instantaneous rate (cts/sec)	3×10^7	1.2×10^8	1.2×10^8	1.4×10^6	1.7×10^7	1.5×10^9	8.4×10^7
Max time-average rate/pixel (cts/sec)	12	6.2×10^5	6.2×10^5	4	2.8	4	360
Max total time-average rate (cts/sec)	8.5×10^4	5.9×10^7	5.9×10^7	1.4×10^5	1.4×10^7	2.0×10^5	1.6×10^7
Total # of channels per data set	5.9×10^7	1.5×10^7	1.5×10^7	1.4×10^{10}	5.0×10^9	1.0×10^8	1.5×10^8
Typical # of channels per data set	6×10^7	7×10^6	7×10^6	3×10^9	1×10^9	5×10^7	8×10^7
Total # of counts per data set	7.7×10^7	3.5×10^9	3.5×10^9	1.2×10^8	4.3×10^9	2.4×10^8	3.0×10^{10}
# of data links	1	6	6	1	2	1	2
Preprocessor Memory Required	256MB Ch / 640MB Ev	5GB per board Ev. / 256MB ch.	5GB per Board Ev. / 256MB ch.	1GB Ev only	10GB per Board (Ev. Or Ch.)	2GB ev. / 512MB ch.	1GB per Board (ch. Only)

Specification Targets

- **Resolution <~ 1mm**
- **Efficiency ~> 50%**
- **Area m^2**
- **Speed > 10^5**
- **Cost < <comparable multiwire detector**

Technologies

- **Multi-wire Gas chamber (^3He)**
- **Semiconductor: Si/Ge/GaAs/Amorphous Si?**
- **Image Plate**
- **Scintillator (ISIS/GEM, Wavelength shifting)**
- **Micropattern devices**

The Menagerie

Nuclear Instruments and Methods in Physics Research A 471 (2001) 109–114

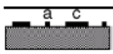
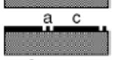
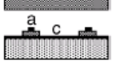
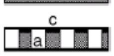
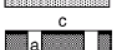
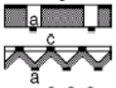
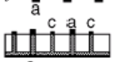
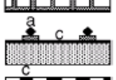
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

www.elsevier.com/locate/nima

Micro pattern structures for gas detectors

A. Oed*

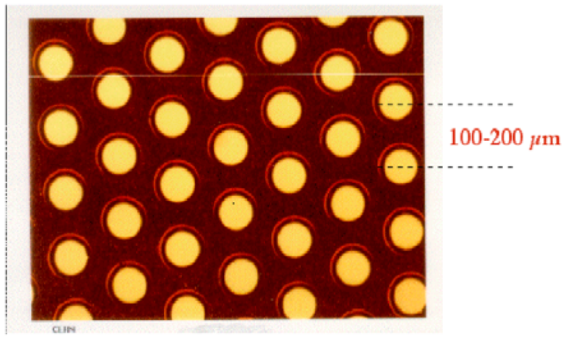
Institute Laue-Langevin, P.B. 156x, F-38042 Grenoble, Cedex, France

Structure	Name	Abbreviation
	Micro Strip Gas Chamber	MSGC
	Small Gap (micro strip) Gas Chamber	
	Micro Gap Chamber	MGC
	Compteur à Trous = Micro Well counter	CAT
	Micro Trench Gas Counter = Micro Groove	MGD
	Micro Dot Gas Avalanche Detector	
	Micro Slit Gas Detector	
	Micro Wire Detector	
	Micro Pin Array Detector	MIPA
	Micro Gap Wire Chamber	
	Capillary Plate Proportional Counter	
	Gas Electron Multiplier	GEM
	Micromesh Gaseous Structure	MICROMEGAS

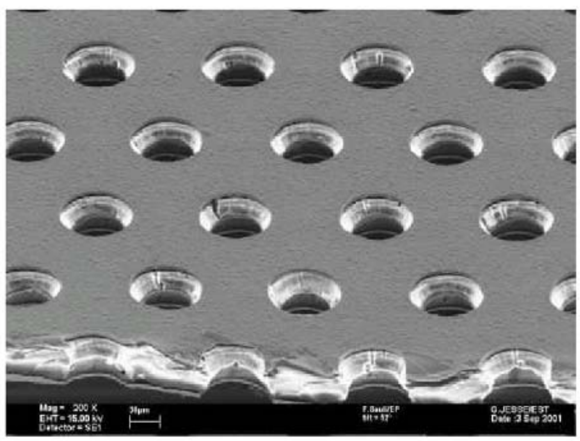
Gaseous Electron Multiplier - GEM: Sauli - 1996

http://gdd.web.cern.ch/GDD/gembasic.htm

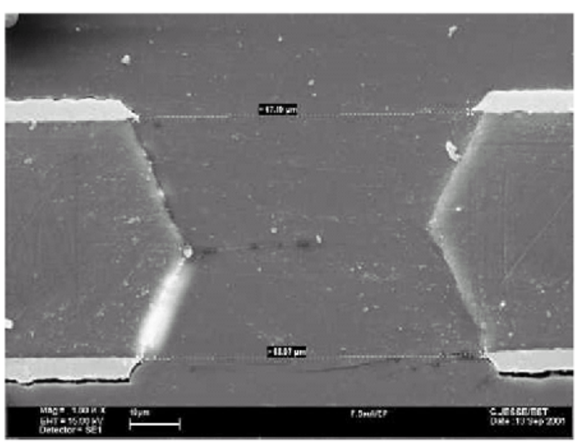
Close view of a GEM electrode:



Electron microscope wiew of a GEM foil:



Cross section through a hole. The double-conical shape is characteristic of the chemical etching of the polymer:

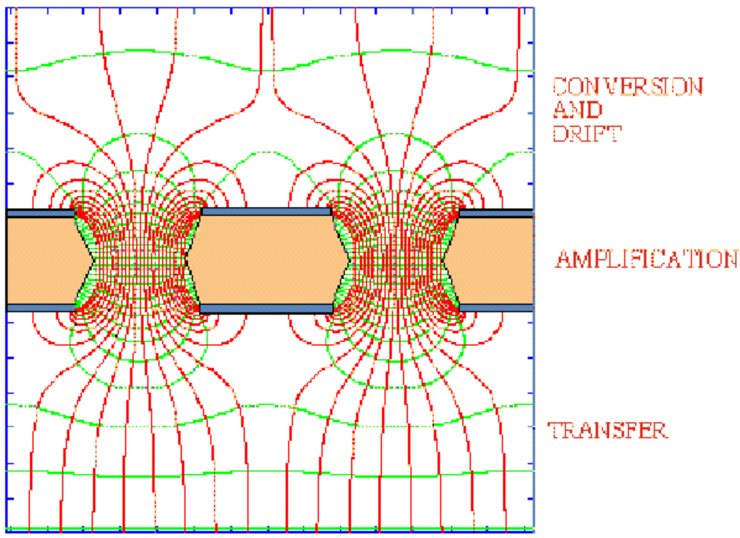


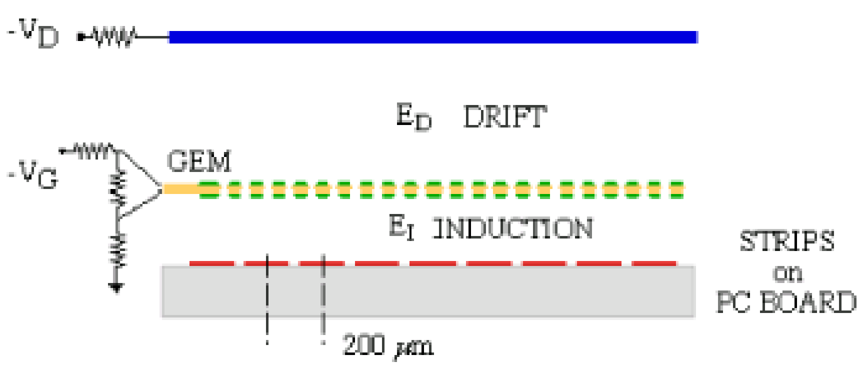
Electron microscope pictures by G. Jesse (CERN-EST-SM)

GEM - Operation

http://gdd.web.cern.ch/GDD/singlegem.htm

Electric field in the GEM holes:



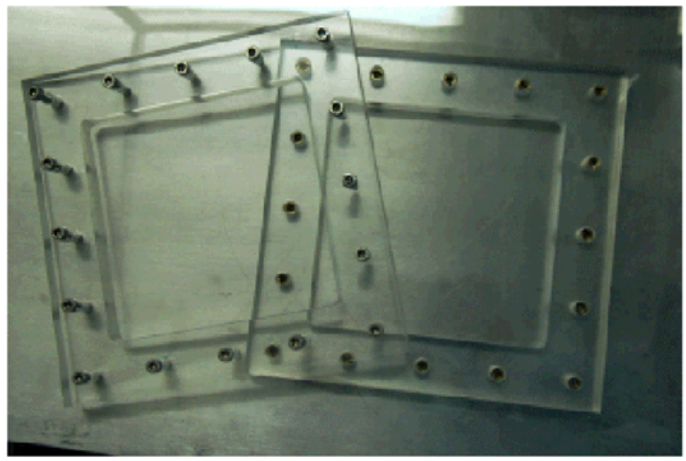


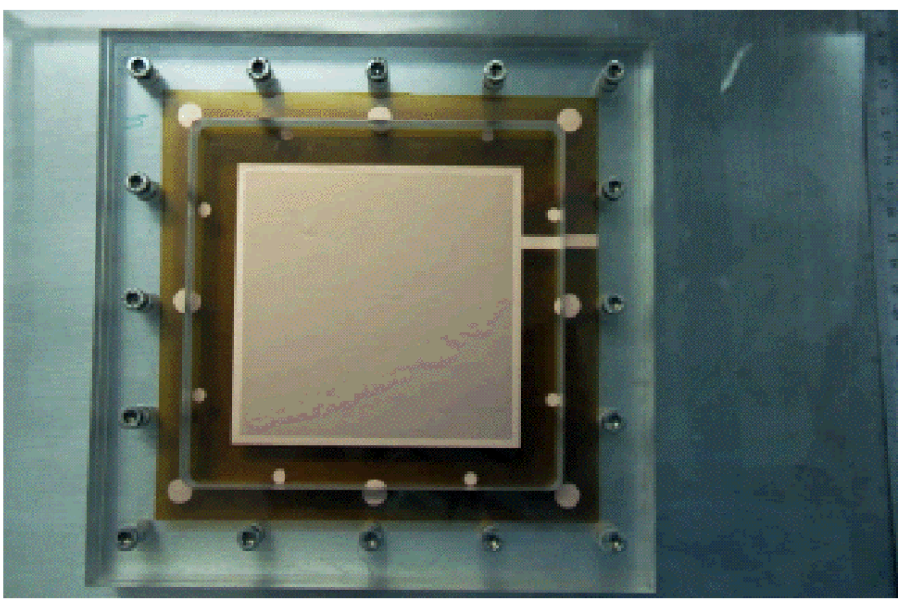
GEM - Assembly

http://gdd.web.cern.ch/GDD/using.htm

A raw GEM foil, about 15x15 cm2 area with 10x10 cm2 active:

Two thick Plexiglas frames with an inner size exceeding the GEM active area are used as stretching tool:

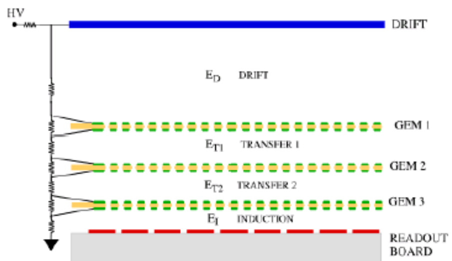




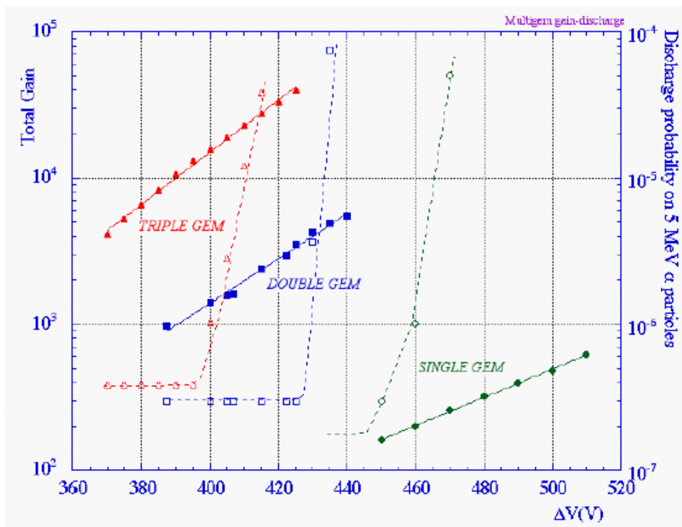
Epoxy is spread over the sides of two thin Fiberglas frames, and they are carefully placed on top and bottom of the GEM foil (still stretched by the hot Plexiglas holding frame). The stack is placed again in the oven for the time needed to cure the epoxy:

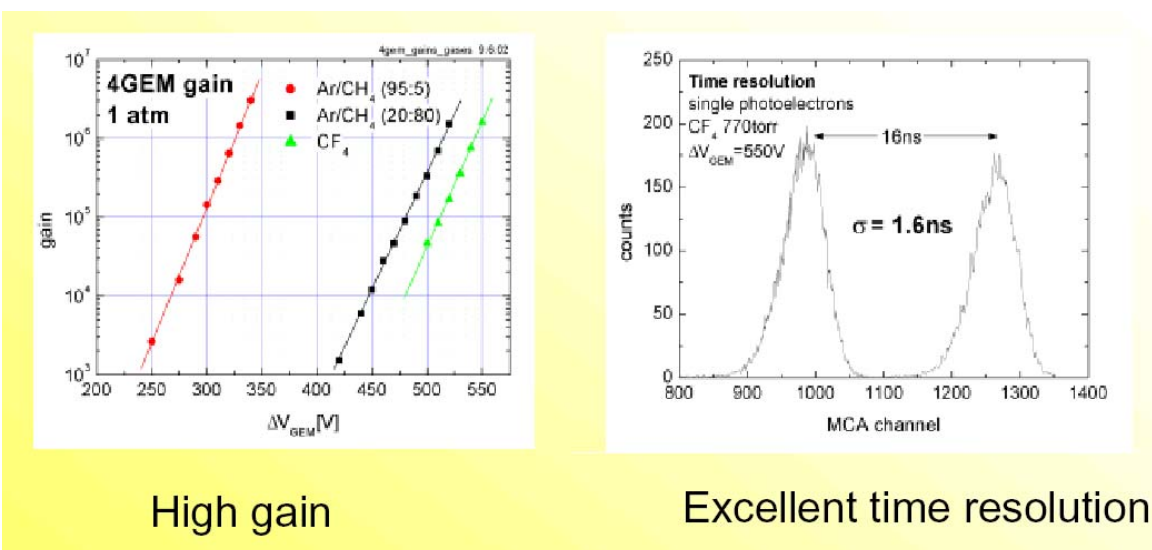
GEM - Performance

http://gdd.web.cern.ch/GDD/multigem.htm



Gain an discharge probability on irradiation with alpha perticles for the single, double and triple GEM:

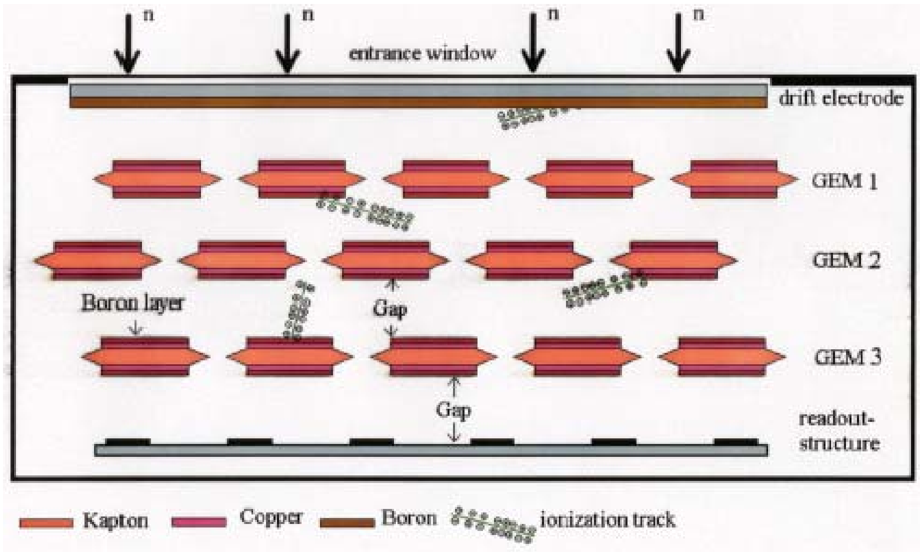


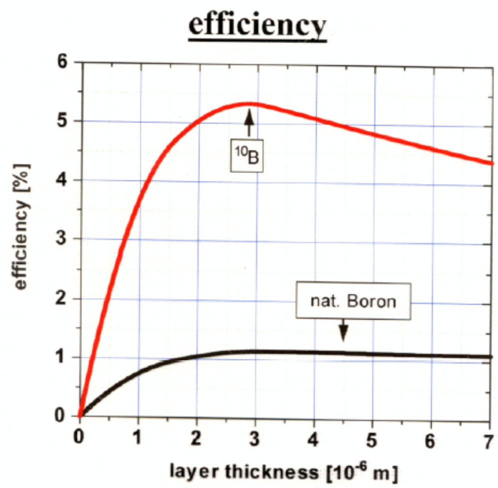


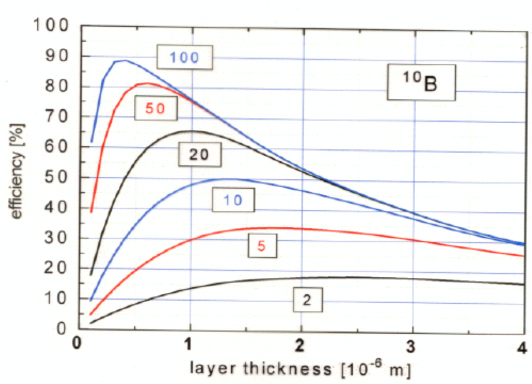
Dirk Mormann, Amos Breskin, Rachel Chechik, Marcin Balcerzyk and Bhartendu Singh, “GEM based gaseous Photomultipliers for UV and visible photon imaging”, 3rd Beaune Conference, June 17-21, 2002.

GEM-Neutron Converters

Martin Klein and Christian J. Schmidt, Physikalisches Institut, Heidelburg







M. Klein, H. Abele, D. Fiolka, C. Schmidt, "Cascade: A new efficient and position sensitive detector for thermal neutrons on large areas", *International Workshop on Position Sensitive Neutron Detectors: Status and Perspectives*, Hahn-Meitner-Institute, Berlin, Germany, June 28-30, 2001.

MultiGEM - The Concept

A. Multiple GEM-converter foils (as in Cascade)

B. Investigation of candidate converter materials (^{155}Gd, ^{157}Gd, ^{nat}Gd, ^{6}Li, ^{6}LiF, ^{10}B)

C. CsI low-work function electron emitter cover.

Dangendorf and co-workers, Physilalish-Technische Bundesanstalt, Braunschweig

Chechik, Mormann, Breskin and co-workers, The Weizmann Institute of Science, Rehovot, Israel

Chkhalo, Gebauer and co-workers, Hahn-Meitner Institut, Berlin, Germany

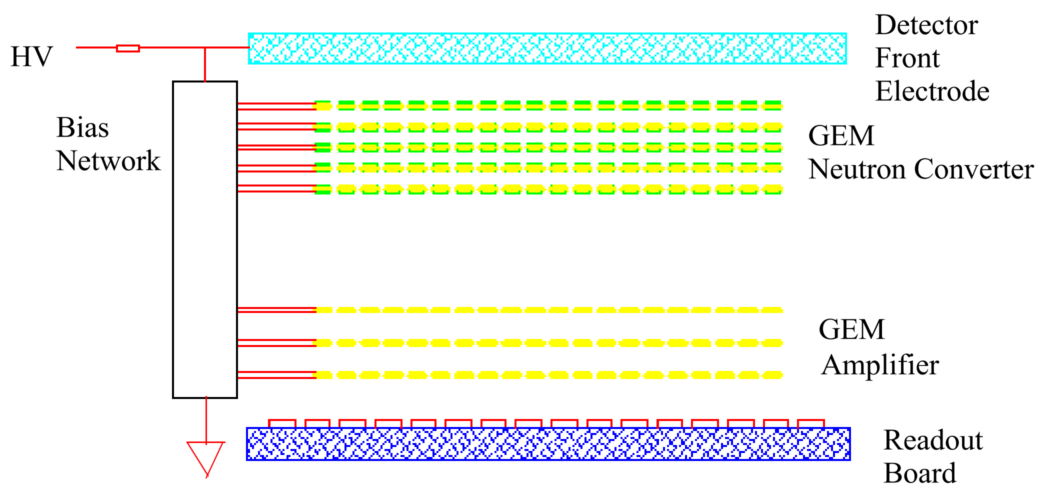
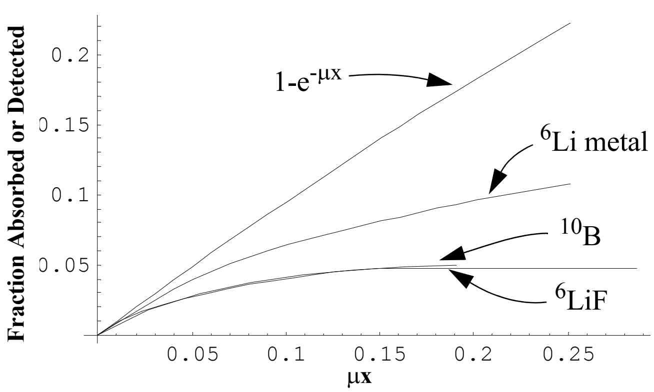
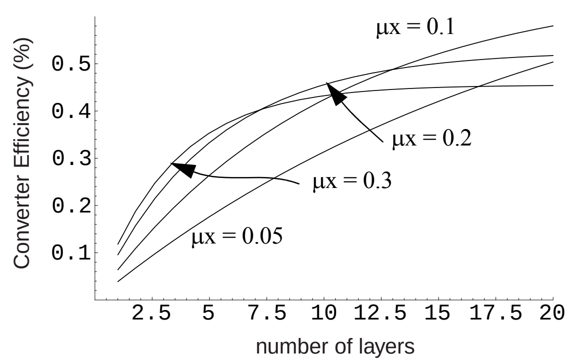


FIGURE 1. MultiGEM detector cross section.[34]

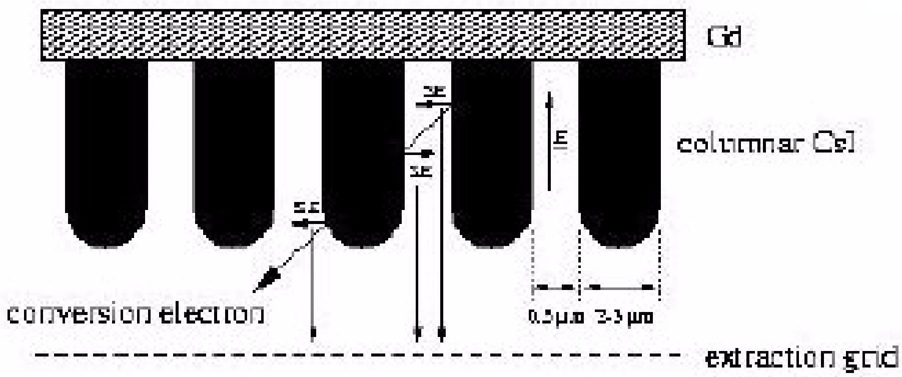


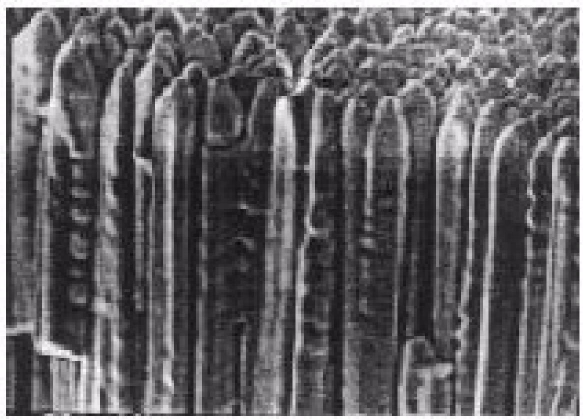
Neutron absorption and detection fraction in a neutron converter.



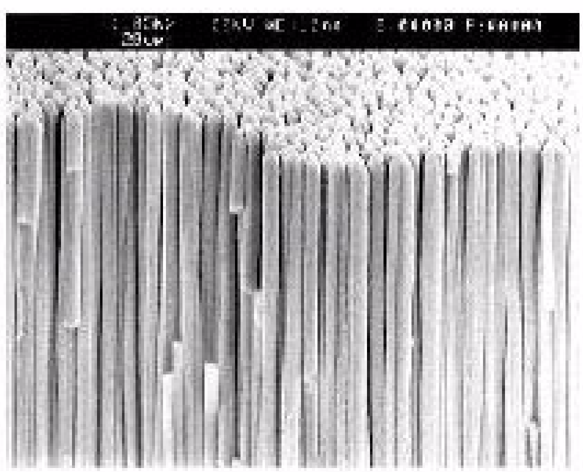
^{6}Li metal CsI covered neutron converter efficiency as a function of metal thickness and number of layers.

Columnar CsI





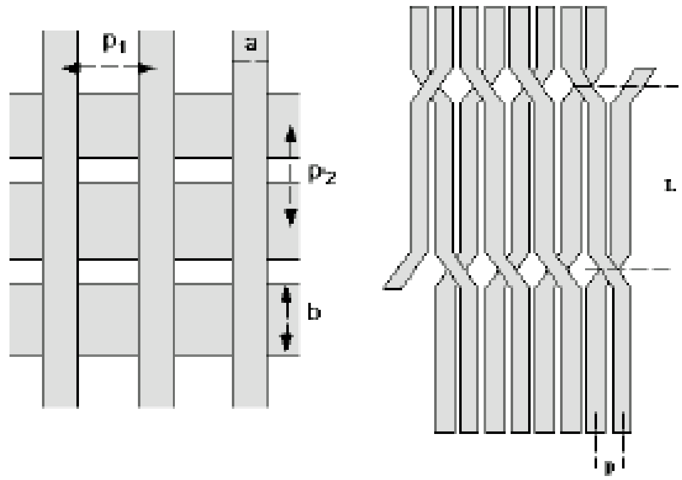
H.S. Cho et al., IEEE Trans. Nucl. Sci. Vol. 45 (1998)



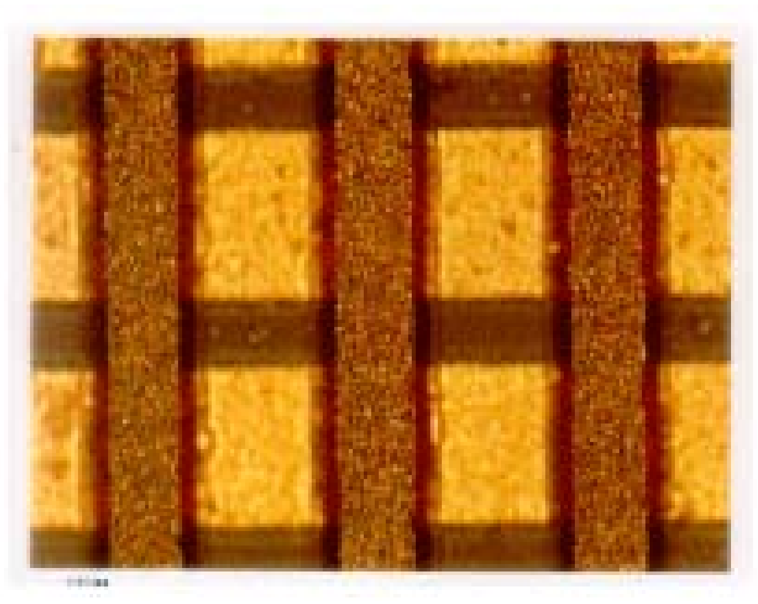
TRIXELL, Moirans, France

MultiGEM - Detector Readout I

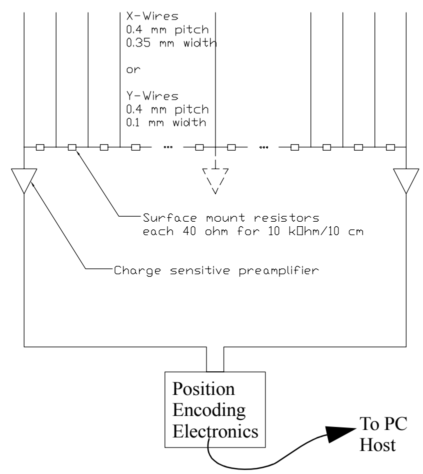
http://gdd.web.cern.ch/GDD/gemreadout.htm



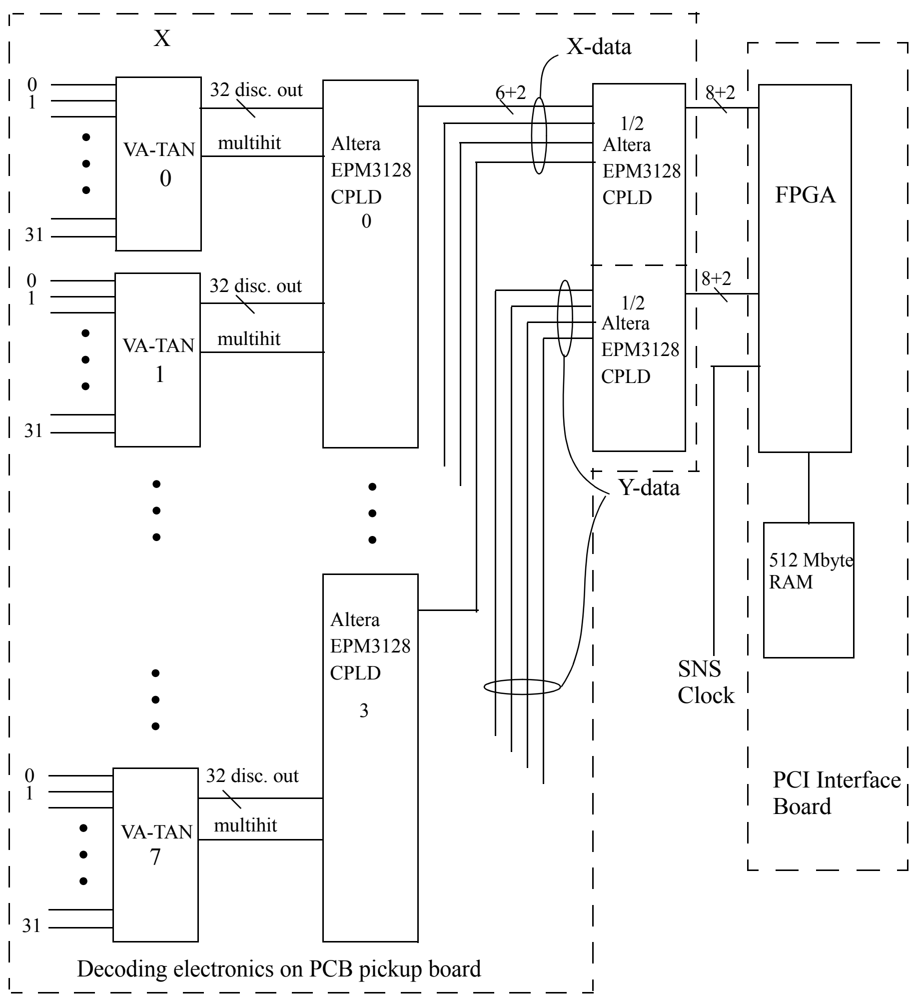
Micro-photograph of a cartesian 2-D readout pattern. The distance between strips is 200 µm, and the strip width 50 ans 150 µm on the top and bottom layer respectively. The kapton ridge separating the two layers is 25 or 50 µm thick:



MultiGEM - Detector Readout II



Position decoding schematic.



Conceptual design of the signal processing for the MultiGEM prototype X- and Y-strip readout.

Facilities

A. MultiGEM Laboratory in Phoenix Lab.

A 400 ft2 space for electronics assembly, software development and testing located int he Phoenix Laboratory next to the Ford Nuclear Reactor.

B. X-Ray Diffraciton Facilities

The College of Engineering at the University of Michigan maintains extensive X-ray analytical instrumentation which is available for an hourly fee. We have budgeted funds for X-ray analysis of the SEE CsI films that are to be grown for this research. The available equipment is listed below:

- Phillips 1140 3kw x-ray generator with High-precision, double-crystal camera with d/d 10-7 sensitivity. Dedicated image capture and processing software for topography.
- Phillips XRG5000 3kw x-ray generator with Crystal alignment stage and Rigaku thin film camera and texture determination.
- Siemens KRISTALLOFLEX generator with Four crystal plane wave camera and Four-circle goniometer.

J. D. Hanawalt X-Ray Diffraction Laboratory

FIGURE B. J. D. Hanawalt X-ray Laboratory.

- Rigaku 12 kw high intensity rotary anode generator with wide-angle horizontal diffractometer equipped with low-temperature camera.

- Complete on-line JCPDS powder data file for automated phase identification.
- Horizontal diffractometer with fully computer automated pole figure device.
- Rigaku 2 kw standard x-ray generator with: Theta - Theta diffractometers with high temperature (1400 degrees Celsius) stage for use with vacuum or controlled atmosphere.
- Two-crystal topographic diffractometers

Other Instrumentation

- Six Nikon Optiphot optical microscopes.
- Nion SMZ10 stereo microscope.
- Leco CS-244 Carbon/Sulfur Determinator with HF-1000 induction furnace.
- Leco RO-316 Oxygen Determinator with EF-100 electrode furnace.
- Leco TN-114 Nitrogen Determinator with EF-100 electrode furnace.
- Perkin Elmer 503 atomic absorption spectrophotometer.
- Fully-equipped metallographic facilitie

SPACE PHYSICS RESEARCH LABORATORY

SPRL Introduction

Thomas Zurbuchen

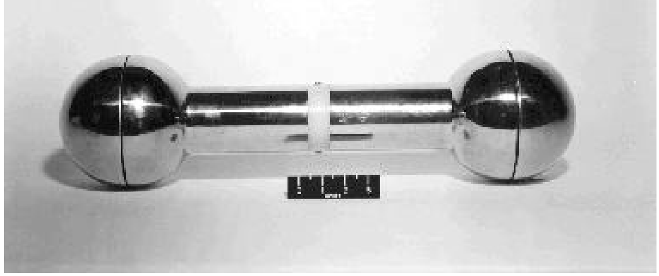
734-647-6835

thomasz@umich.edu

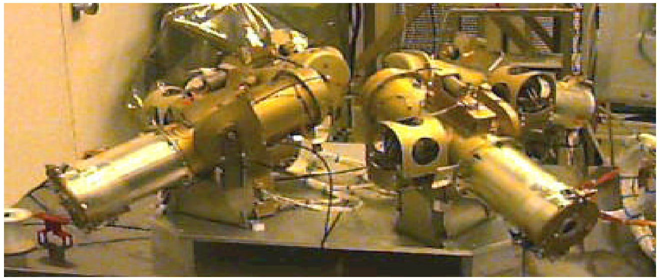
SPRL Engineering History

- **Supported PIs in development of space research instruments since 1946**
- **Over 100 rocket, aircraft & balloon experiments developed to-date**
- **Over 35 major space instruments developed to-date**

Home of SPRL Today



Early "Double Probes" flown on V2's



TIDI Flight Hardware for TIMED Mission

Primary Engineering Expertise

- **Space mission design and instrument design and analysis**
- **Laboratory-grade instrument design and development**

Typical Designs Emphasize:

- **Rigorous, top-down requirements development**
- **High reliability, low-power, low-mass, small size, high autonomy**
- **Thorough understanding of launch & space environments**
- **Processes compliant with/certified to NASA and Military standards**
- **Detailed project planning, tracking and management**

Major Instrument Classes

- Optical Spectrometry and Interferometry
- LIDAR
- Mass Spectrometry
- Particles & Fields (ESA, ToF, Langmuir Probes)
- Microwave Radiometry
- Solar EUV
- Tethered Satellite Instrument Systems
- Chemiluminescent gas analysis
- HF RADAR (coastal wave and current analyses)
- Remote, autonomous instrument control and data collection systems

Major Technologies

- CCD detectors
- Custom optics
- Fiber-optic systems
- Active and passive thermal control systems
- Space mechanisms
- High-efficiency power systems
- Programmable logic
- Hybrid circuits
- Embedded microprocessors
- Electronics packaging
- Image acquisition and analysis
- Custom magnetics
- High-reliability real-time software
- Ground control systems
- Ultra-high vacuum systems
- Ultralight structures
- Composite structures
- Exotic structural materials and processes
- Surface treatments
- Cryogenic systems
- Lasers

Primary Design Resources

- Computer-aided design and analysis
  - Aldec EDA (design capture and analysis)
  - SYNARIO EDA (design capture and analysis)
  - HSPICE analog circuit analysis
  - ACTEL FPGA design, analysis and programming
  - DATA I/O PLD/FPGA design, analysis and programming
  - PADS PCB Printed circuit board design
  - SolidWorks, AutoCAD
- Mission planning and simulation
  - Satellite Tool Kit
- Optical design and analysis
  - ZEMAX
  - Custom Software
- Structural analysis
  - NASTRAN
  - IDEAS
  - FEMAP
  - COSMOS
- Thermal analysis
  - TRASYS
  - SINDA
- Radiation environment and effects
  - Space Radiation

Major Engineering Facilities

- 63,000 sq. ft. Physical Plant
- Class 10,000 High-Bay Integration Clean Room
- High-Bay Integration and Test Laboratory
- Electronics Fabrication Clean Room
- EMI/EMC Test Screen Room
- Instrument Machine Shop w/ CNC Capabilities
- Thermal and Thermal-Vacuum Test Chambers
- Optical Test Laboratories
- Extensive Computing and Network Infrastructure

Notable Engineering Projects

- Galileo Probe Mass Spectrometer - Developer
- Total Ozone Monitor (TOMS) Joint Development w/ Orbital Sciences
- Cassini Huygens Probe Mass Spectrometer- Electronics Development
- GSFC/Long Duration Antarctic Mars Balloon - Integrator & Field Operations
- TSS-1R Shuttle Electrodynamic Tether System (SETS) - Integrator & Operator
- Contour Mass Spectrometer - Joint Development w/ GSFC
- ProSEDS Tether Mission - Development, MO&DA
- ICARUS Student Satellite - Development, MO&DA

Space Instrument Development Experience (1)

Year	Instrument	Sponsor	R&QA Level	Safety Program	Part Level
1969	OGO F/ETDP	GSFC			
1970	SAN MARCO/Omegatron	CRA/GSFC	NPC200		PPL
1972	AEROS/NATE	GfW/GSFC	NPC200, 250		PPL
1973	AE-C/NATE,NACE, VAE	GSFC	NHB5300.4 (1A&B)		PPL Grade 2
1974	AEROS/NATE	GfW/GSFC	NPC200, 250		PPL
1975	AE-D/NATE,NACE, VAE	GSFC	NHB5300.4 (1A&B)		PPL Grade 2
1975	AE-E/NATE,NACE, VAE	GSFC	NHB5300.4 (1A&B)		PPL Grade 2
1978	PV/OETP,ONMS	ARC/GSFC	PC-412, NHB5300.4 (1A&B)		Grade 1(PS201)

Specific Instrument Development Experience (2)

Year	Instrument	Sponsor	R&QA Level	Safety Program	Part Level
1981	DE-A/LANG	GSFC	NHB5300.4 (1A&C)		PPL/975 Grade 2
1981	DE-B/NACS, WATS, FPI	GSFC	NHB5300.4 (1A&C)		PPL/975 Grade 2
1981	STS-2 IECM/MS1	MSFC	NHB5300.4(1C)	Mil-Std-1522	Class C
1981	STS-3 IECM/MS2	MSFC	NHB5300.4(1C)	Mil-Std-1522	Class C
1982	STS-4 IECM/MS1	MSFC	NHB5300.4(1C)	Mil-Std-1522	Class C
1983	STS-9 (SL1) IECM/MS	MSFC	NHB5300.4(1C)	Mil-Std-1522	Class C
1983	STS-9 SL1/ISO	MSFC	NHB5300.4(1C)	JA-012	Grade 2
1988	SAN MARCO/WATI	CRA/GSFC	NHB5300.4 (1A&C)		PPL/975 Grade 2
1989	STS-34 GALILEO/ NMS	ARC/GSFC	JP-512, NHB5300.4(1B)	JP-512	Grade 1(GS201)
1991	STS-48 UARS/HRDI	GSFC	430-1702-001	K&NHB1700.7A	PPL/975 Grade 2
1994	MSX/CEMS	APL/DOD	Mil-Q-9858	WSMCR127-1	APL Grade 3

Specific Instrument Development Experience (3)

Year	Instrument	Sponsor	R&QA Level	Safety Program	Part Level
1994	TOMS/ELM FM3, 4, 5	PE/GSFC	SPAR-3 Class B	WSMCR127-1	PPL/975 Grade 2
1996	STS-75 TSS-1R/SETS	MSFC	NHB5300.4(1C)	K&NHB1700.7A	MSFC-STD-603 'Gr.3'
1997	CASSINI/INMS	JPL/GSFC	SPAR-3 Class B	ESMCR127-1	PPL/975 Grade 2
1997	HUYGENS PROBE/GCMS	ESA/GSFC	SPAR-3 Class B	ESMCR127-1	PPL/975 Grade 2
1998	IMAGE EUV/HV PS	U. Arizona	Cassini-like QA		Provided
1998	PLANET-B/NMS	GSFC/ NASDA	SPAR-3 Class B		PPL/975 Grade 2
1998	GP-B, GSS/Aft Power Unit	Stanford U	Cassini-like QA		Provided
1999	TIMED/TIDI	APL/GSFC	SPAR-3 Class C/D	WRR127-1	APL Grade 2/3

Specific Instrument Development Experience (4)

Year	Instrument	Sponsor	R&QA Level	Safety Program	Part Level
2000	ProSEDS	MSFC	COTS	ERR127-1	COTS
2000	ROSETTA/ROSINA DFMS	BERN/LOC	ISO9001 LIKE		311-INST-001 Lvl2-3
2001	CONTOUR/NGIMS	GSFC/APL	GSFC MAG 300-PG-8730.4.2		311-INST-001 Lvl 2
2003	Messenger/FIPS	APL	APL ProcPAR		311-INST-001 Lvl 2