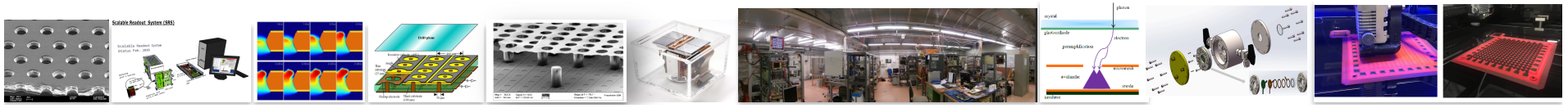
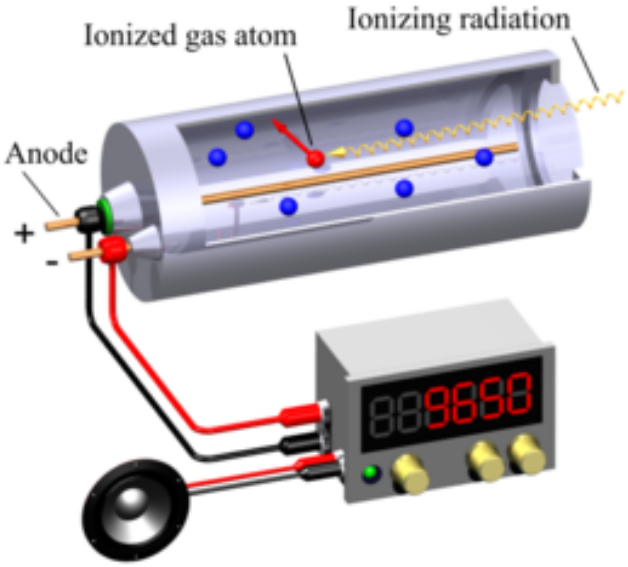
Micro Pattern Gas Detectors

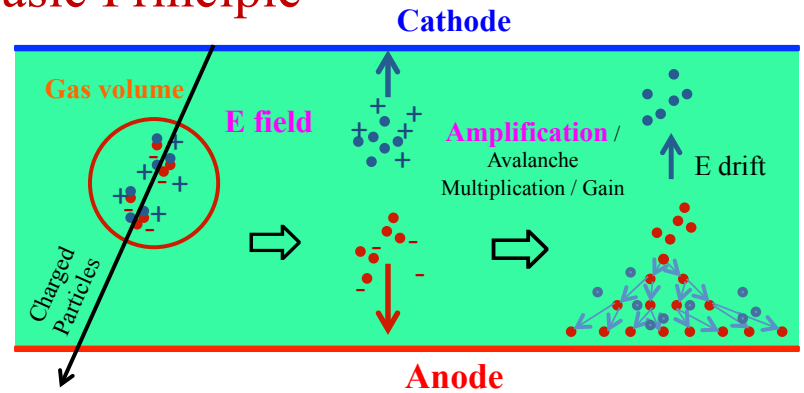
Nilanga Liyanage

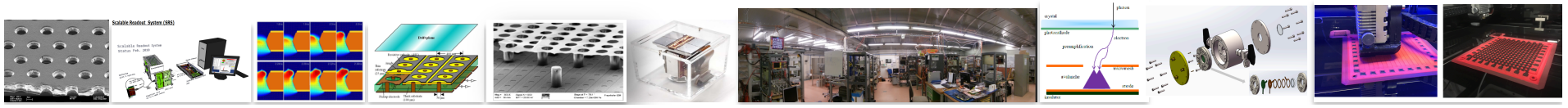
University of Virginia, Charlottesville VA



Gaseous detectors: Basic Principle





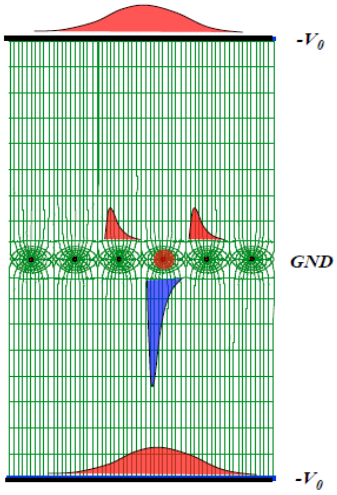


Gaseous detectors: Multi Wire Proportional Chamber

[G. charpak (1968)]: Nobel Prize 1992

MWPCs:

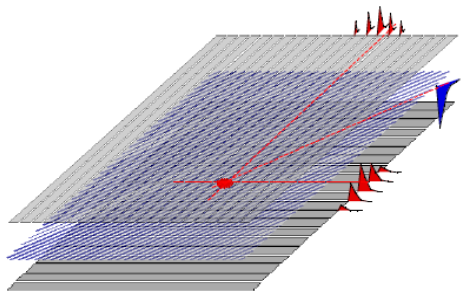
- ⇨ Fast Position Sensitive Devices, High rate capability, Sub mm position accuracy
- ⇨ Insensitive to particle type or energy for high energy particles ⇒ Ideal for tracking charged particle



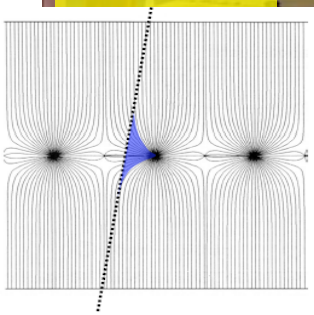
G. Charpak et al, Nucl. Instr. and Meth. 62(1968)235

TWO-DIMENSIONAL COORDINATE READOUT
Center of gravity of induced signals on cathodes

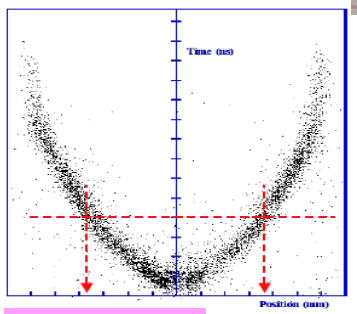
$$X = \sum \frac{X_i A_i(X)}{A(X)} \qquad Y = \sum \frac{Y_i A_i(Y)}{A(Y)}$$



G. Charpak and F. Sauli, Nucl. Instr. and Methods 113(1973)381



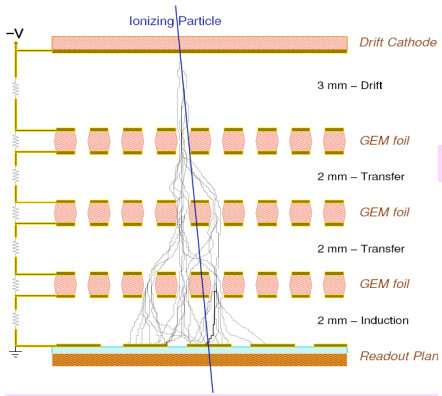
A. H. Walenta, J. Heintze and B. Scürlein, Nucl. Instr. and Meth. 92(1971)373



Drift chambers

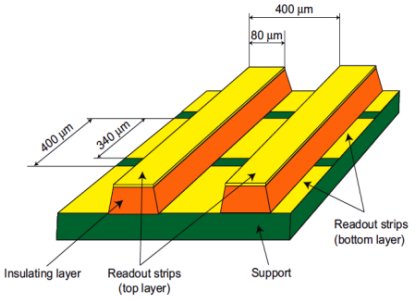
Micro Pattern Gas Detectors

GEM: Gas Electron Multipliers



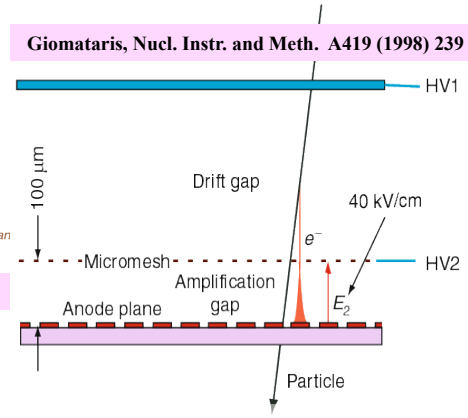
F. Sauli, Nucl. Instr. and Meth. A386 (1997) 531

readout using pixels or strips



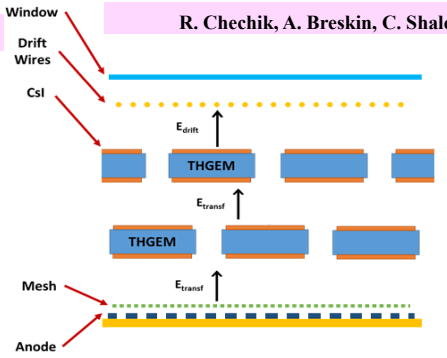
Micromegas: Micro Mesh Gaseous Structure

Giomataris, Nucl. Instr. and Meth. A419 (1998) 239



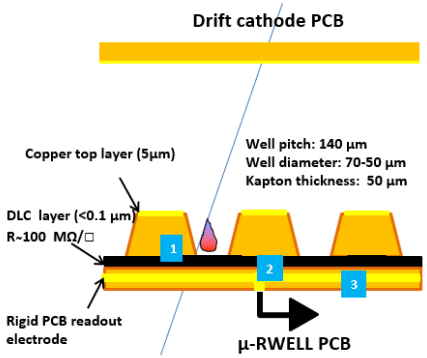
THGEM: Thick GEM

R. Chechik, A. Breskin, C. Shalem



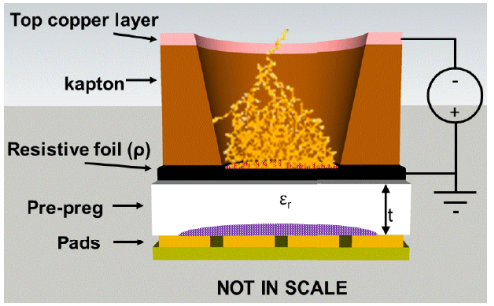
µRWELL: Resistive micro-WELL Detector

G. Bencivenni et al., 2015_JINST_10_P02008

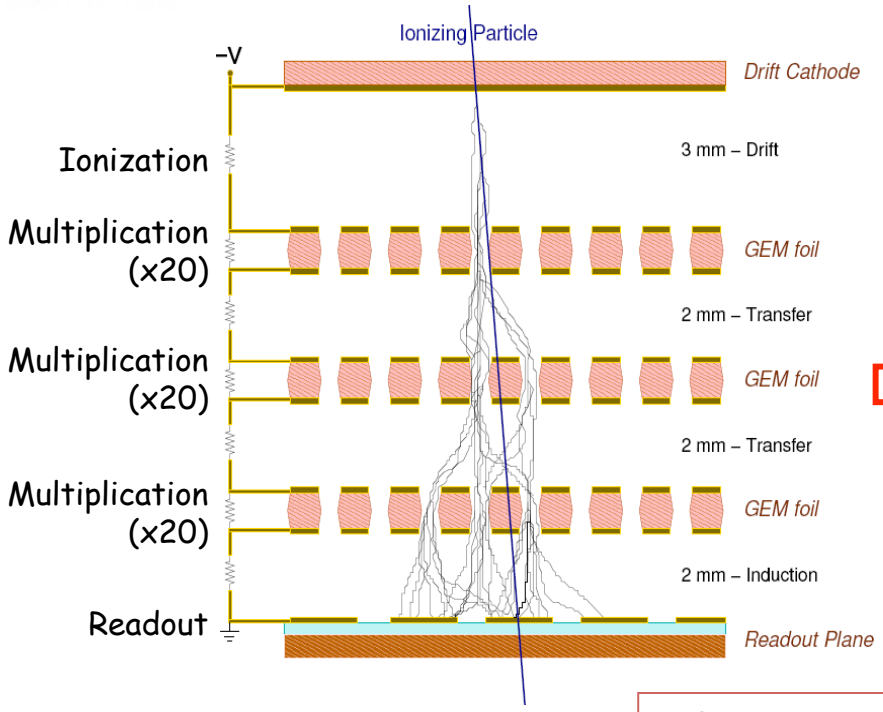


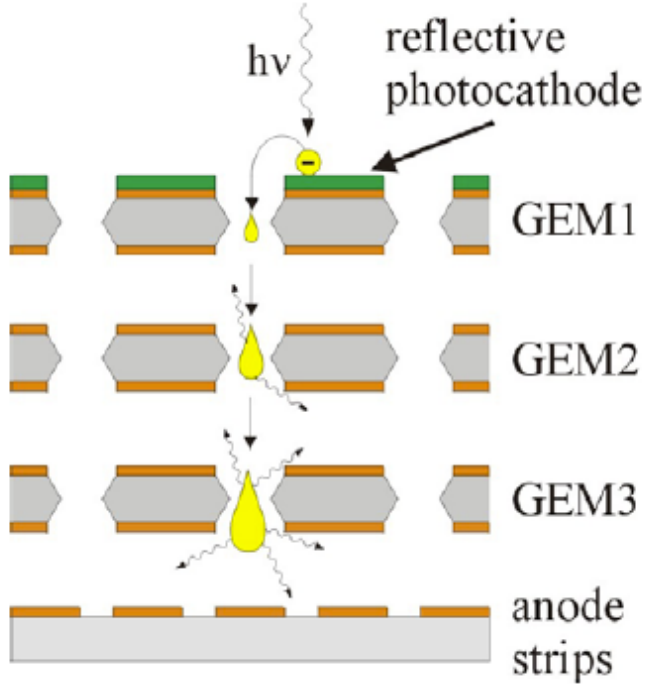
G. Bencivenni et al.; 2015_JINST_10_P02008

- ⇨ **Fabrication using photolithographic processing.**
- ⇨ **High rate capability ~ 10s of MHz/cm²**
- ⇨ **Low material thickness ~ 0.4% Radiation length**
- ⇨ **Good spacial resolution ~ 50 µm**
- ⇨ **Good time resolution ~ 5-10 ns**
- ⇨ **Radiation Hard and Robust**
- ⇨ **highly cost effective ~ 250 k$/m²**

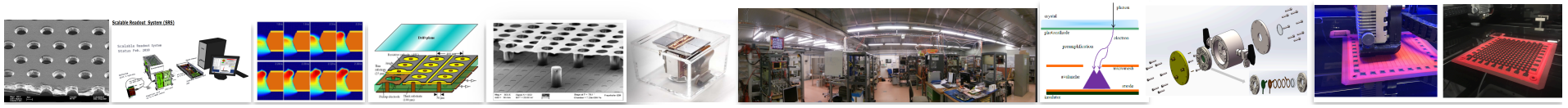


X-Ray and Gamma-Ray photon detection with MPGD



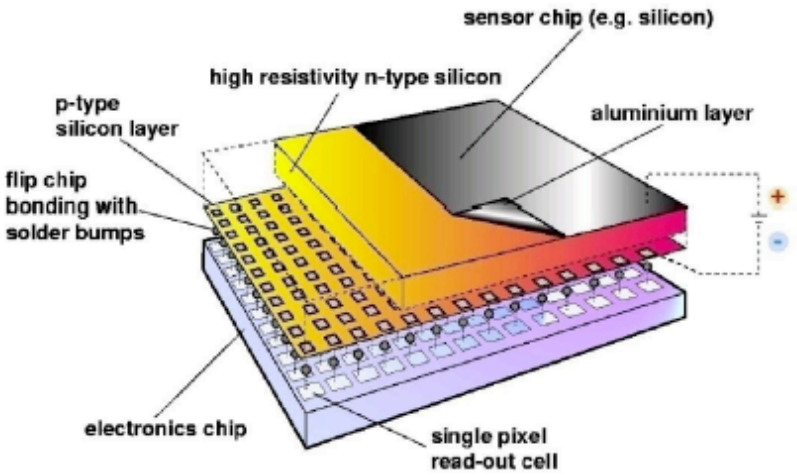


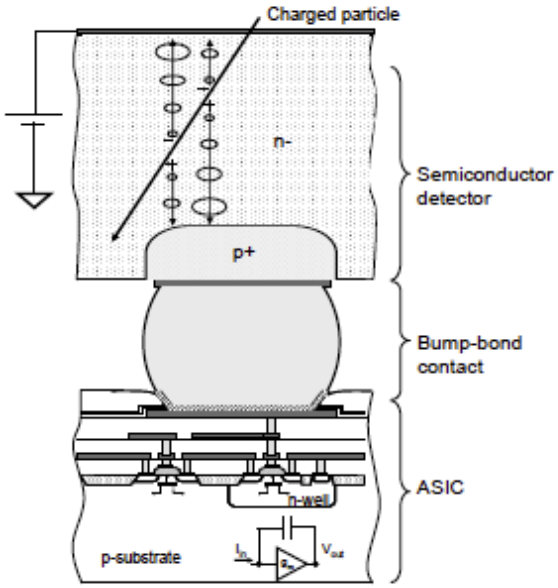
- CsI is widely used photo-cathode
- Efficiency ~ 25-30%



Pixelated MPGD readout : MPGD on a chip

- Strip readout gives good resolution, but limited at very high rates: x-y combinations due to multiple hits difficult to resolve.
- Need to go to pixel readout for good resolution at high rates





The semiconductor sensor

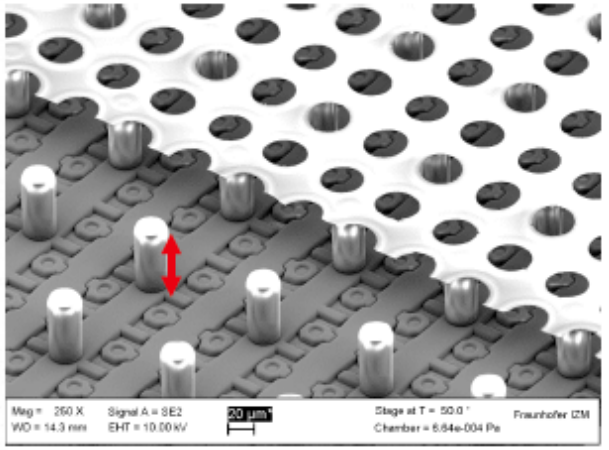
Timepix3 and Timepix4

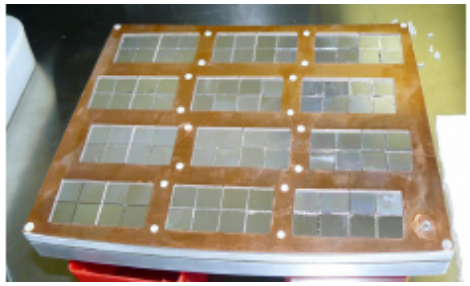
			Timepix3 (2013)	Timepix4 (2018/19)
Technology			130nm – 8 metal	65nm – 10 metal
Pixel Size			55 x 55 µm	55 x 55 µm
Pixel arrangement			3-side buttable 256 x 256	4-side buttable 512 x 448
Sensitive area			1.98 cm^2	6.94 cm^2
Readout Modes	Data driven (Tracking)	Mode	TOT and TOA	
		Event Packet	48-bit	64-bit
		Max rate	<80 Mhits/s	<358 $MHz/cm^2/s$
		Max pix rate	1.3kHz/pixel	10.6kHz/pixel
	Frame based (Imaging)	Mode	PC (10-bit) and iTOT (14-bit)	CRW: PC (8 or 16-bit)
		Frame	Zero-suppressed (with pixel addr)	Full Frame (without pixel addr) CRW (8-bit / 16-bit) Up to 44 KHz frame @8b
		Max count rate	82 $Ghits/cm^2/s$	~800 $Ghits/cm^2/s$
TOT energy resolution			< 2KeV	< 1Kev
Time resolution (bin size)			1.56ns	~200ps
Readout bandwidth			≤5.12Gb (8 x SLVS@640 Mbps)	≤163 Gbps (16 x 10.24 Gbps)
Target global minimum threshold			<500 e^-	<500 e^-

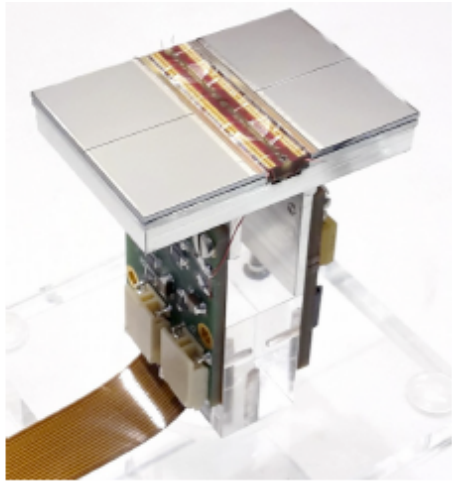
From M. Campbell

GridPix on Timepix

- Invented at Dutch National Institute for subatomic physics: Nikhef.
- Micro-mess structure directly built on Timepix chip.
- Single electron/photo-electron counting
  - every signal above threshold corresponds to one primary electron
  - high energy resolution for X-ray detection
- Position resolution ~ 15 μm
- A large array of 160 GridPixes has been tested.

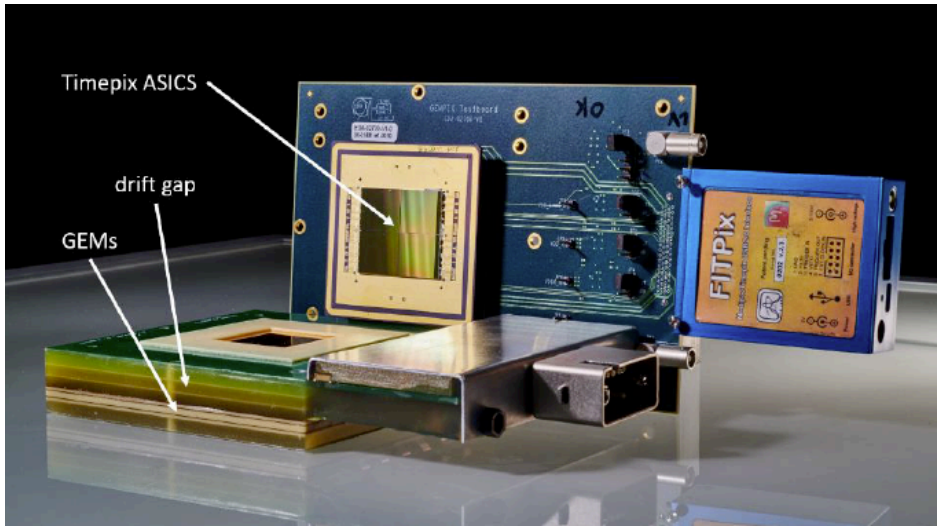


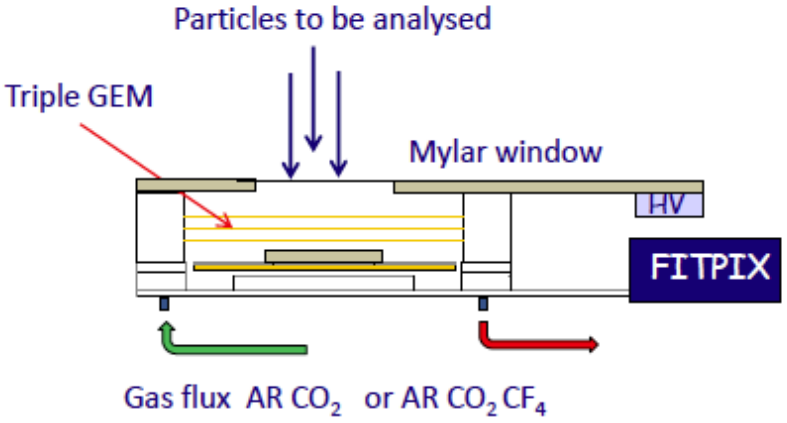




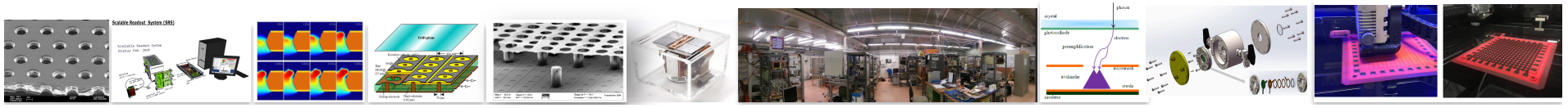
From Jochen Kaminski

Pixelated GEM readout

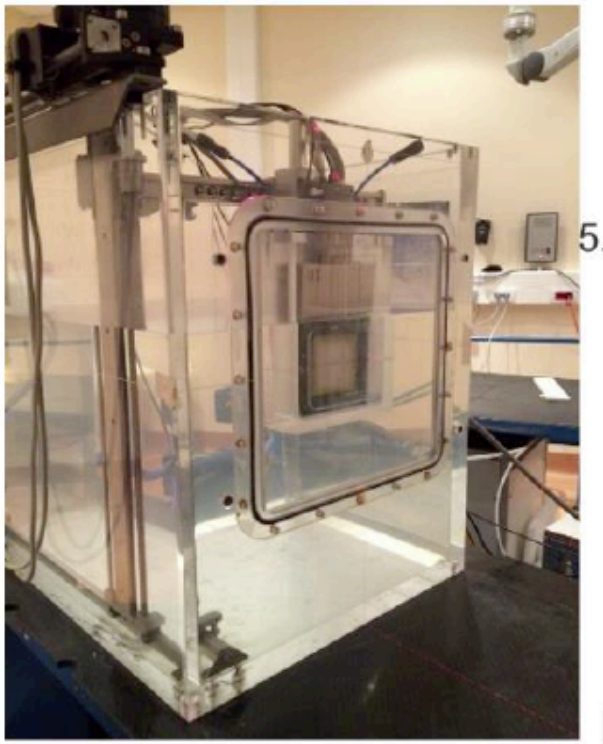


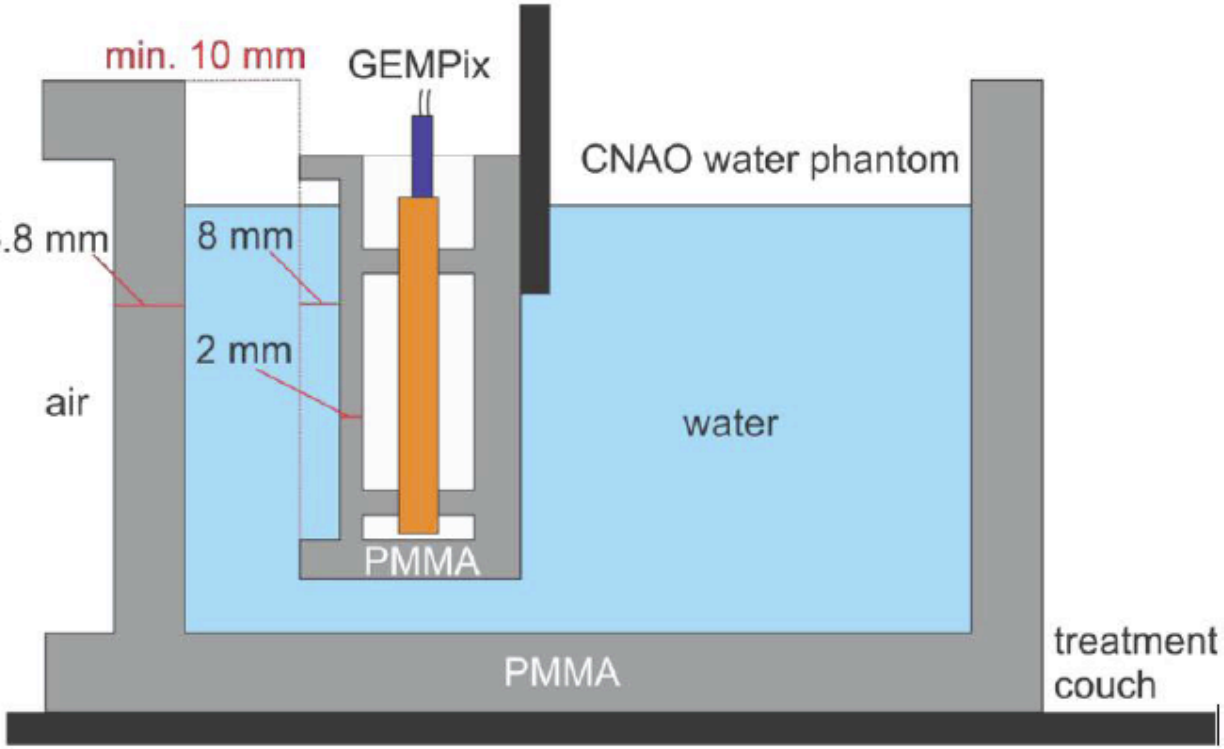


F.Murtas, The GEMPix detector. Radiation Measurements Vol. 138, Nov. 2020, 106421

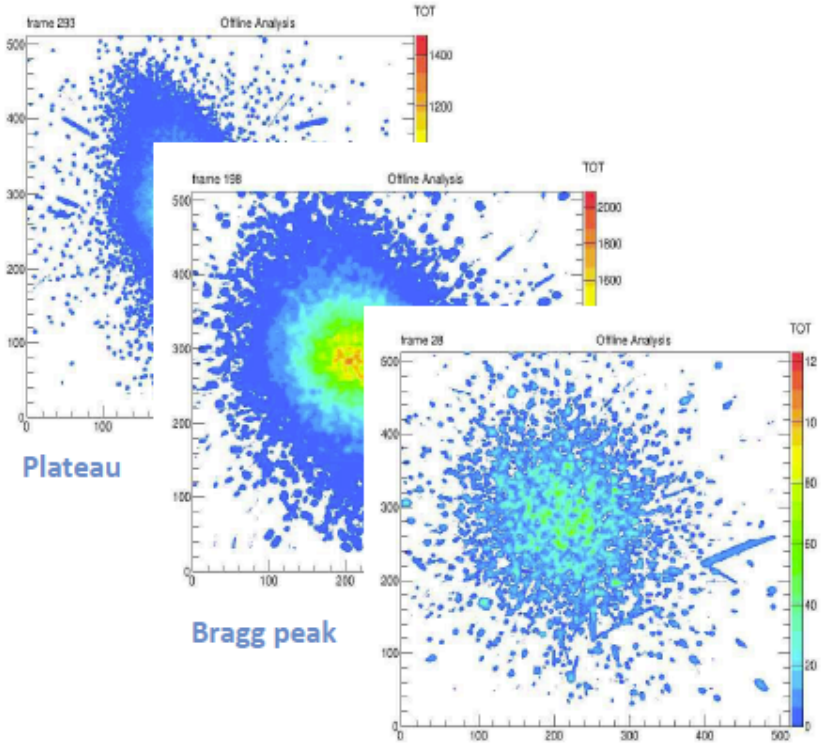


Verification of treatment plan in hardon therapy





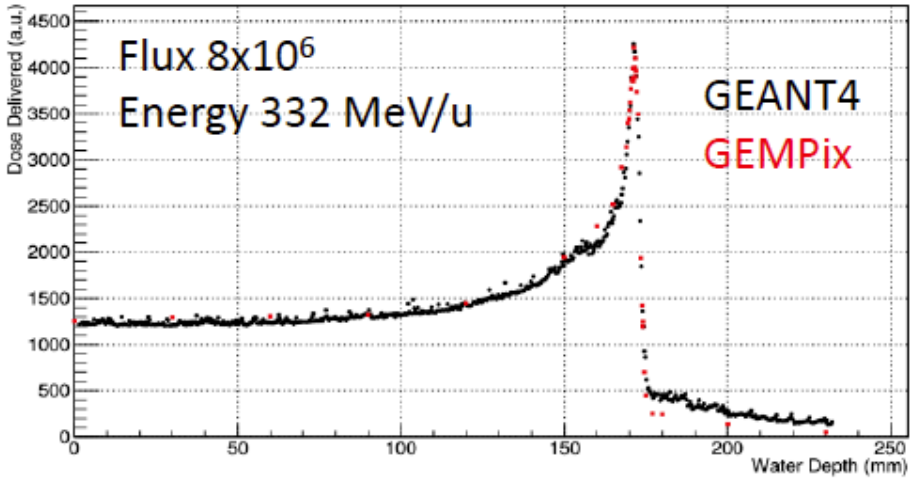
3D reconstruction of Bragg peak Carbon Ion Beam

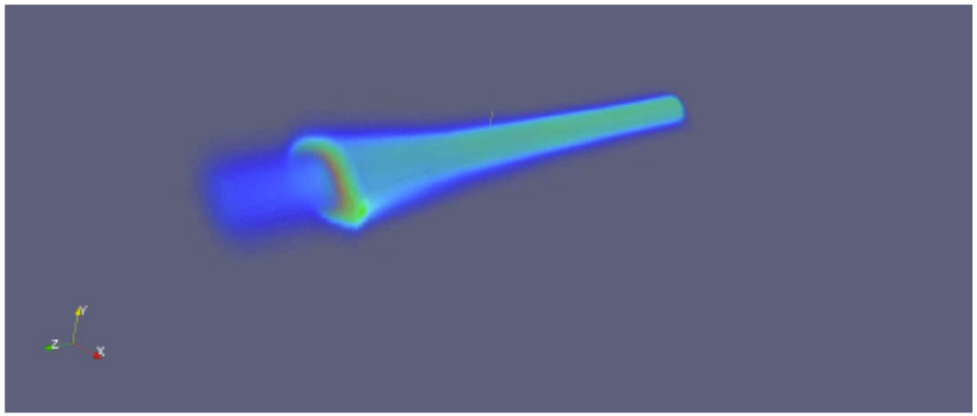


Plateau

Bragg peak

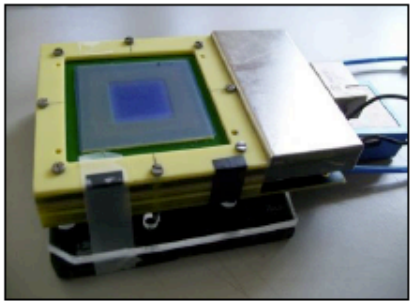
Tail

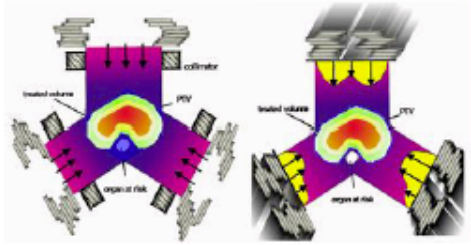




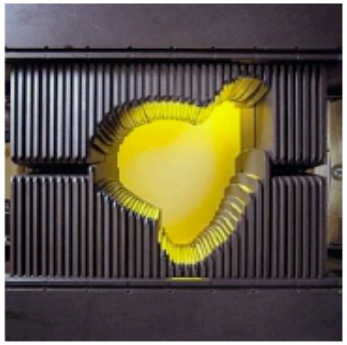
GEMPix for Radiotherapy

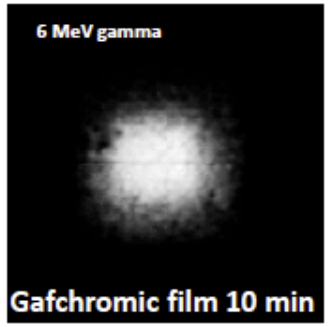
2D measurements of energy released in IMRT (Policlinico Tor Vergata Roma)

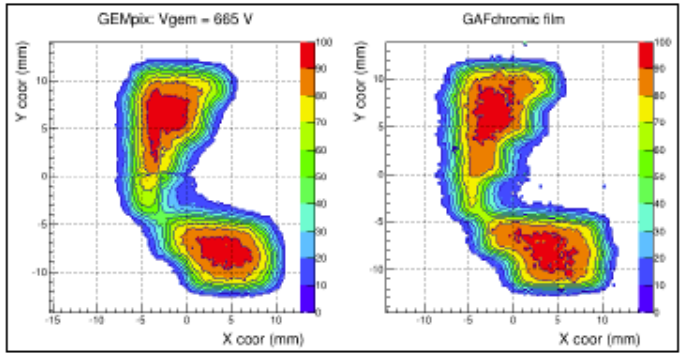




Intensity Modulated Radiation Therapy (IMRT)







Real-time measurements with GEMPix allows fast Quality Assurance procedure

G.Claps