^{55}Fe Measurements in Radioactive Waste with a Triple GEM Detector

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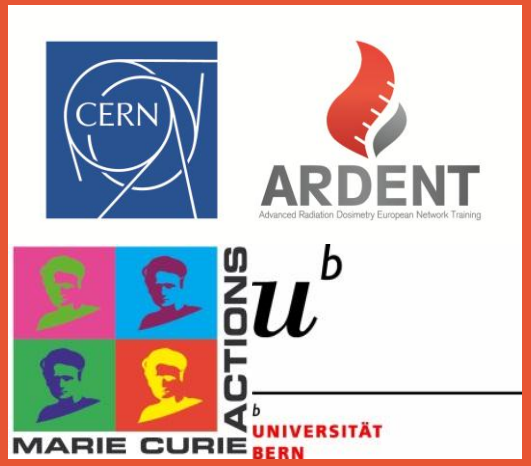
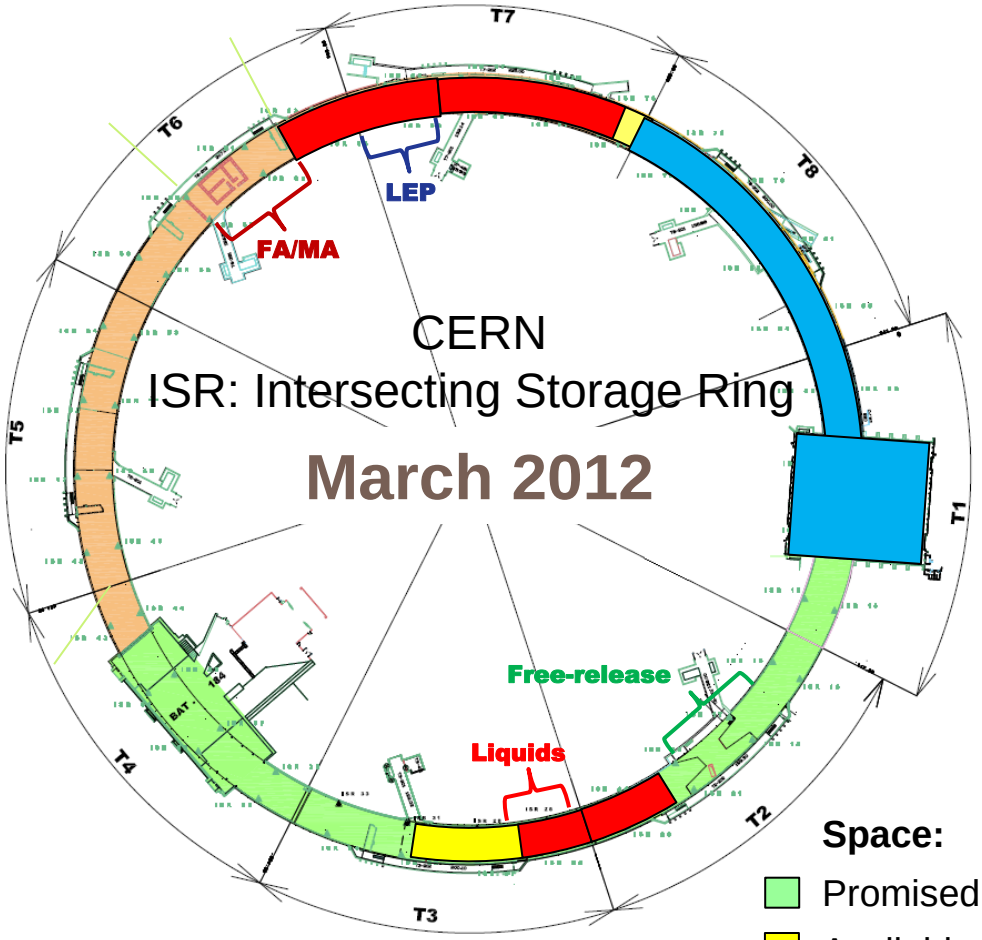
IEEE-NSS 2013 SEOUL



MOTIVATION

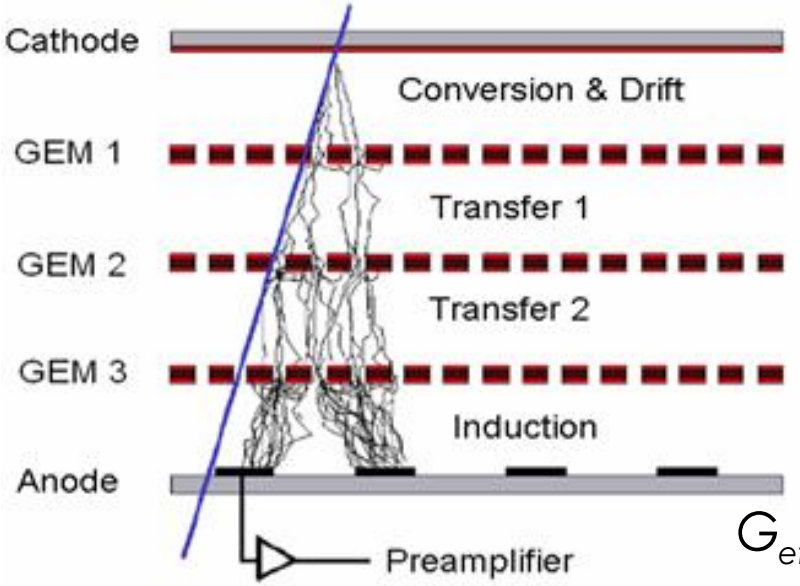


- Materials in accelerator environment are activated by radiations[1]
- In order to treat this materials after the decommissioning, it is necessary a characterization to know the nuclide population
- Gamma emitters are easily recognised by γ spectrometry
- The challenge is to measure the ^{55}Fe amount
- A detector with high efficiency to ^{55}Fe and high γ rejection to is needed

1: F.P. La Torre et al. Radiological Hazard Classification of materials in CERN's accelerators, CERN technical note 2012 1184236

By Y.Algoet, L.Bruno: EDMS 1261586 . DGS-RP Group Meeting 17-01 2013

GAS ELECTRON MULTIPLIER



9 mm

1 mm

2 mm

1 mm

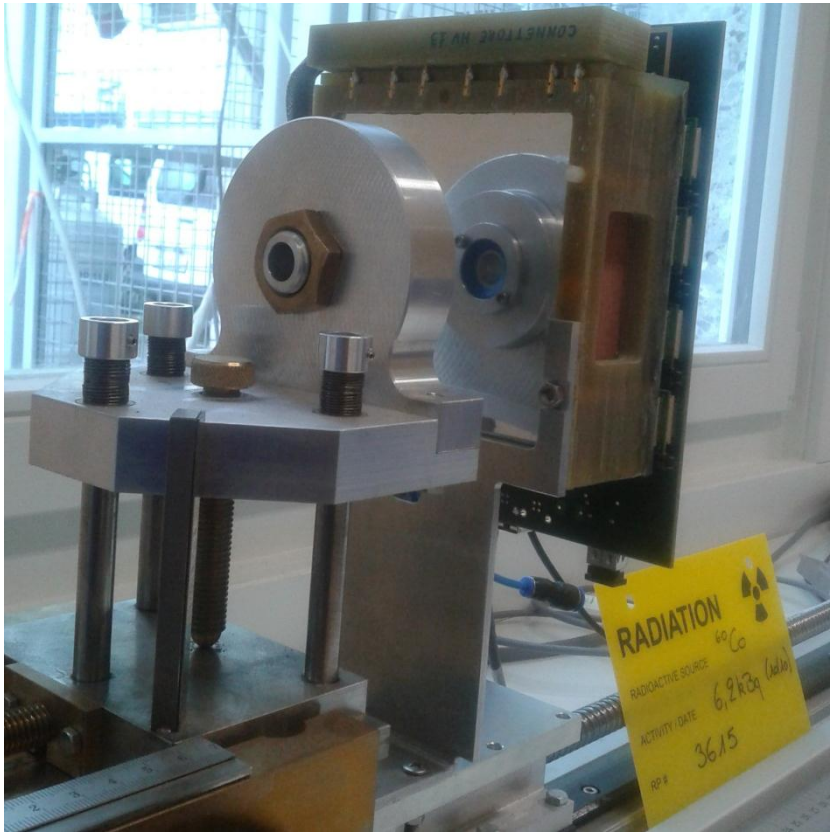
$$G_{eff} \propto \sum V_{G_i}$$

F. Sauli NIM A386 531

M. Alfonsi et al., The triple-Gem detector for the M1R1 muon station at LHCb, N14-182, 2005 IEEE-NSS

- Autoshielding: only surface contribues to x-ray emission when for γ is the whole volume
- Efficiency for x-ray and γ rejection unknown

Characterization with calibration sources

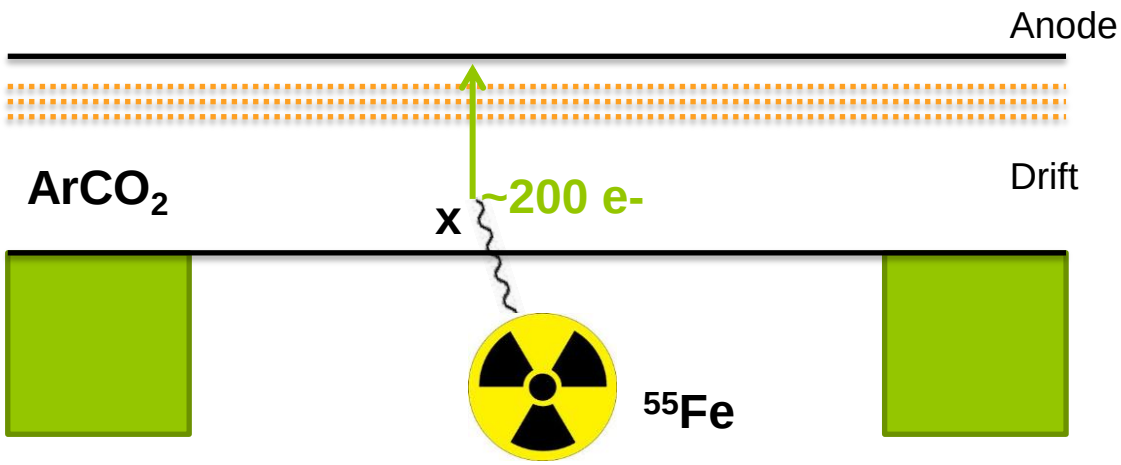


MATERIAL BUDGET AND MEASUREMENT WITH SOURCES

	6keV			
	Width(μm)	Density (g/cm3)	Attenuation length (cm)	Losses photons
Air		0.0012	35	
Mylar	11.5 μm	1.4	0.05	2.5%
Aluminium	0.5 μm	2.7	0.0032	1.5%
ArCo2 70/30	0.9 cm	0.0018	3	29.0%
Copper	5 μm	8.9	0.0010	40.0%
Kapton	50 μm	1.4	0.05	10.0%

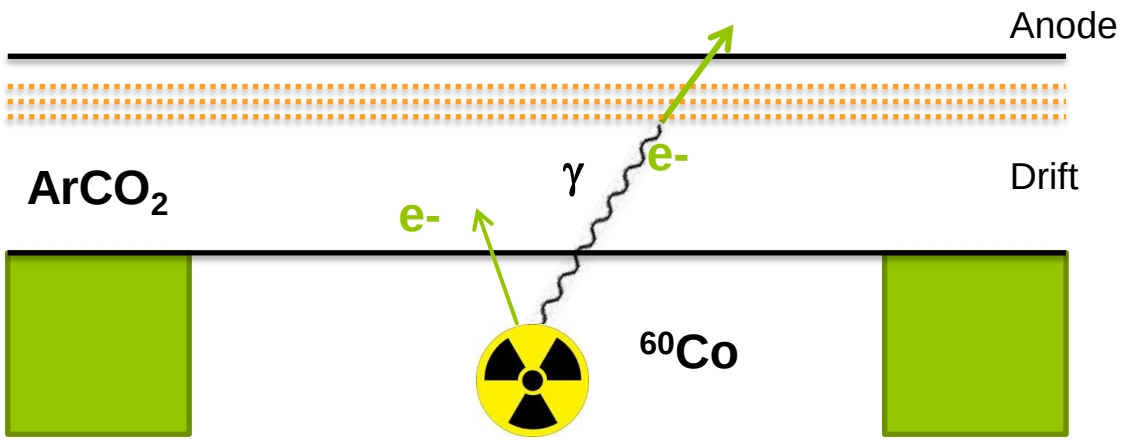
X-ray source: ^{55}Fe

- $^{55}Fe \rightarrow {}^{55}Mn * \rightarrow (\sim 28\%)\ {}^{55}Mn + 6keV$
- Not negligible attenuation in air
- Conversion in gas mixture through photoelectric effect
- Avalance produced by low energy electron ~ 200 e- created in the drift
- Conversion efficiency untill 9 mm of $ArCO_2$: 39%



MATERIAL BUDGET AND MEASUREMENT WITH SOURCES

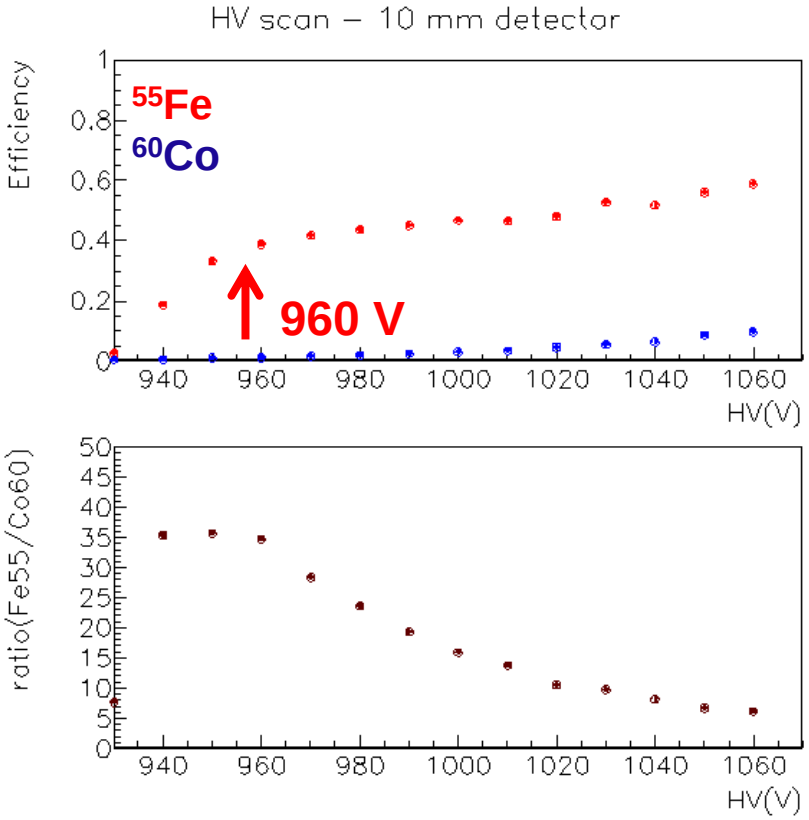
			1.17MeV	1.33MeV	
	Width	Density (g/cm3)	Attenuation length (cm)	Attenuation length (cm)	Losses
Air		0.0012	14077	14858	
Mylar	11.5 μm	1.4	11.8	12.6	0.0090%
Aluminium	0.5 μm	2.7	6.3	7.0	0.0007%
ArCo2 70/30	0.3 cm	0.0018	9890	10560	0.0097%
Copper	5 μm	8.9	2.1	2.2	0.0200%
Kapton	50 μm	1.4	11.7	12.5	0.0400%

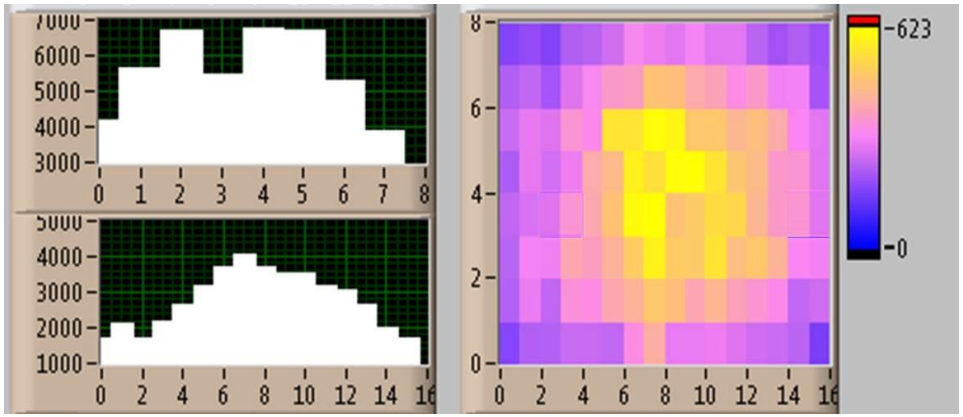


Gamma source: ^{60}Co

- $^{60}Co \rightarrow {}^{60}Ni* + \beta + \bar{\nu} \rightarrow (100\%)\ {}^{60}Ni + (1.17MeV) + (1.33\ MeV)$
- Almost no attenuation in air or gas mixture
- Conversion through Compton effect in producing a MIP e-: $\gamma + e^- \rightarrow \gamma' + e^-(MIP)$
- Conversion efficiency untill 9 mm of $ArCO_2$: 1.14%
- Electrons from β decay

CHARACTERIZATION WITH SOURCES





Photons:	9 mm
Working point	960
Efficiency ^{55}Fe	39%
Efficiency ^{60}Co	1.14%
Rejection Factor	**34**

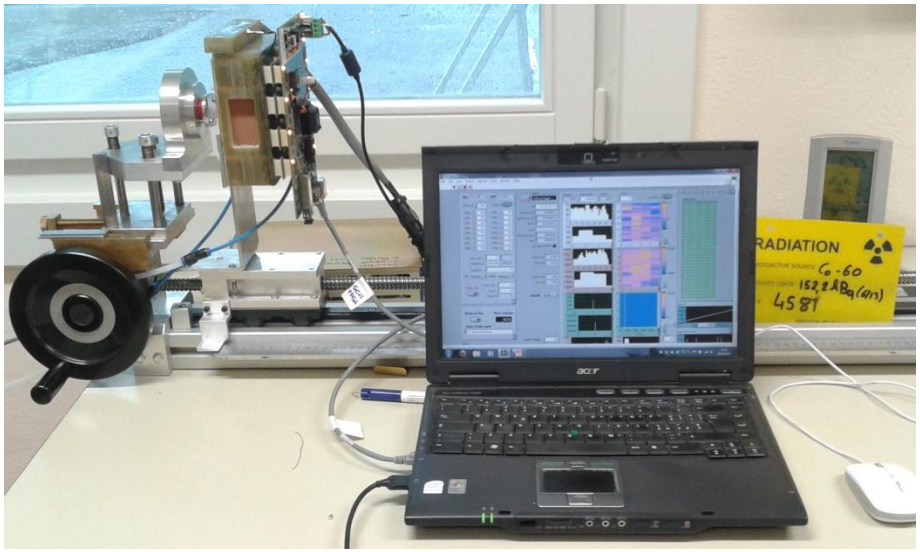
Solid angle: $\Omega = 2\pi\left(1 - \frac{d}{\sqrt{d^2+r^2}}\right)$

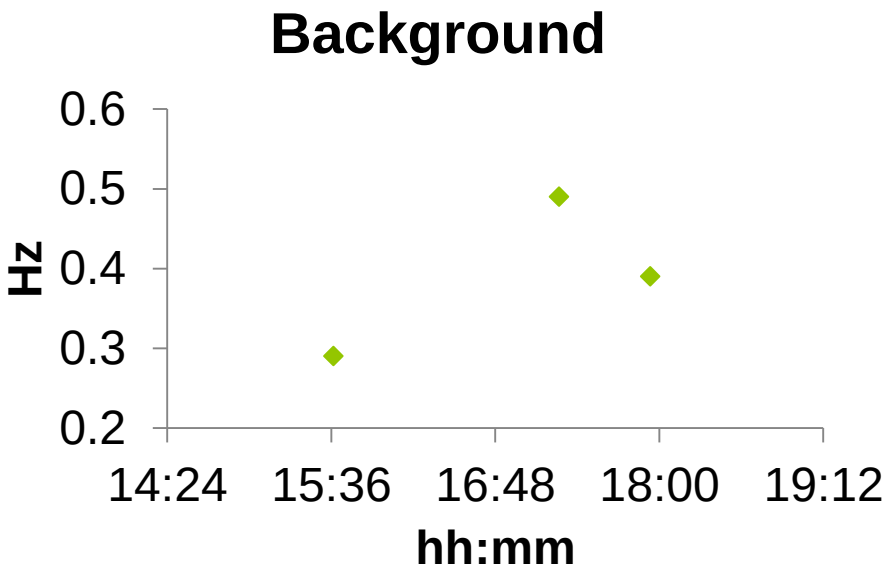
Efficiency: $\varepsilon = \frac{rate/Clsz}{Activity} \times \frac{4\pi}{\Omega}$

MEASUREMENTS WITH SAMPLES: PROCEDURE

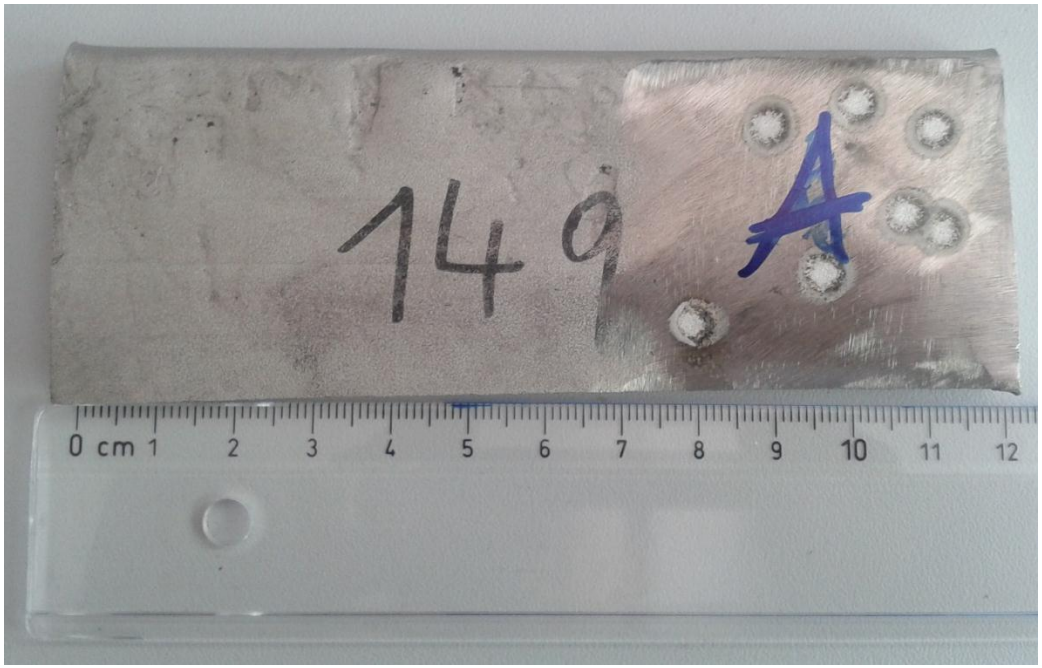
Distance Detector-Sample: 2 cm
WP: 960 V
Gate: 1000 ms
Efficiency X: 39%
Efficiency gamma: 1.14%

- First measurement with the sample in front of the detector
- Second measurement with a shielding made with 0.4 mm of Al in order to shield x-rays and to get the amount
- Several measurements of background





MEASUREMENTS WITH SAMPLES: STS PIPE SAMPLES



Sample from STS pipes with well known isotope composition from radiochemical analysis and gamma spectroscopy.

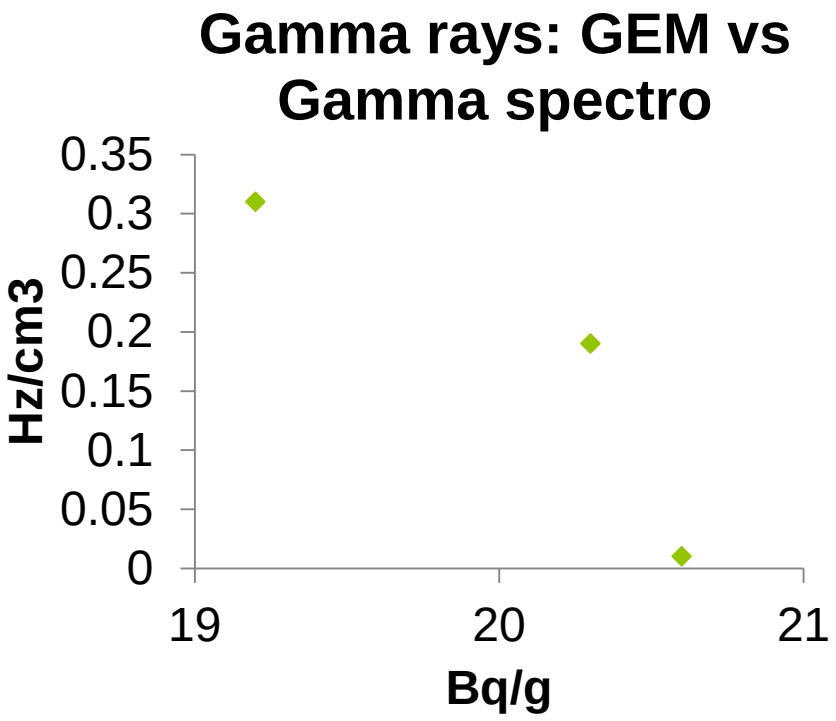
Sample	Surface cm2	Volume cm3	Co-60 Bq/gr	Fe-55 Bq/gr
149	20.6	15.5	3	14
62	19.2	6.79	66	24
63	20.3	8.26	57	22

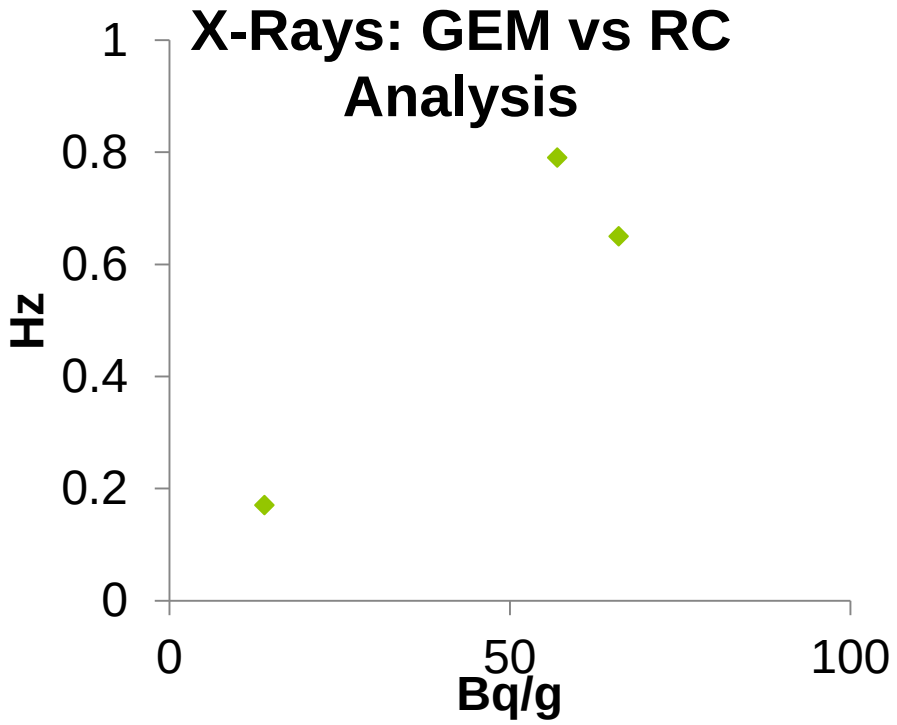
MEASUREMENTS WITH SAMPLES: STS PIPE SAMPLES

Sample	No Shielding	Shielding	Gamma Norm Vol	X rays
149	0.63	0.46	0.01	0.17
62	3.22	2.57	0.31	0.65
63	2.73	1.94	0.19	0.79

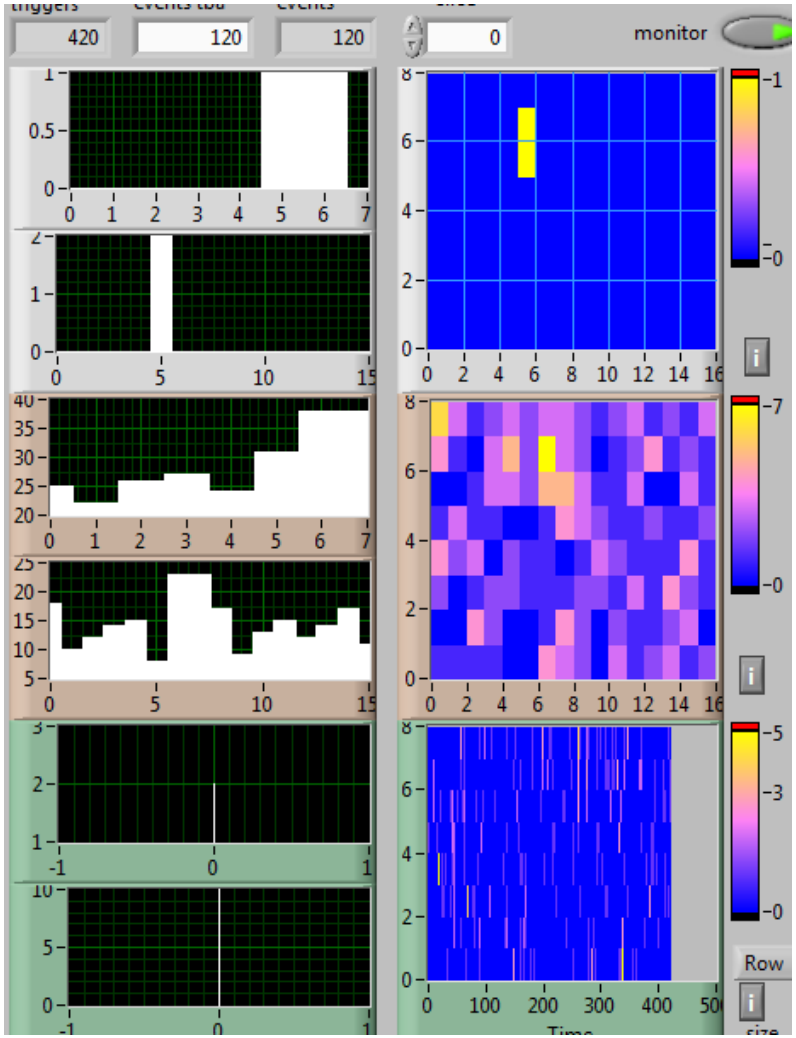
$$\gamma = \frac{Sh - Bck}{Sample\ Volume}$$

$$X = No\ Sh - Sh$$





MEASUREMENTS WITH SAMPLES: SC (SYNCHROCYCLOTRON) SAMPLE

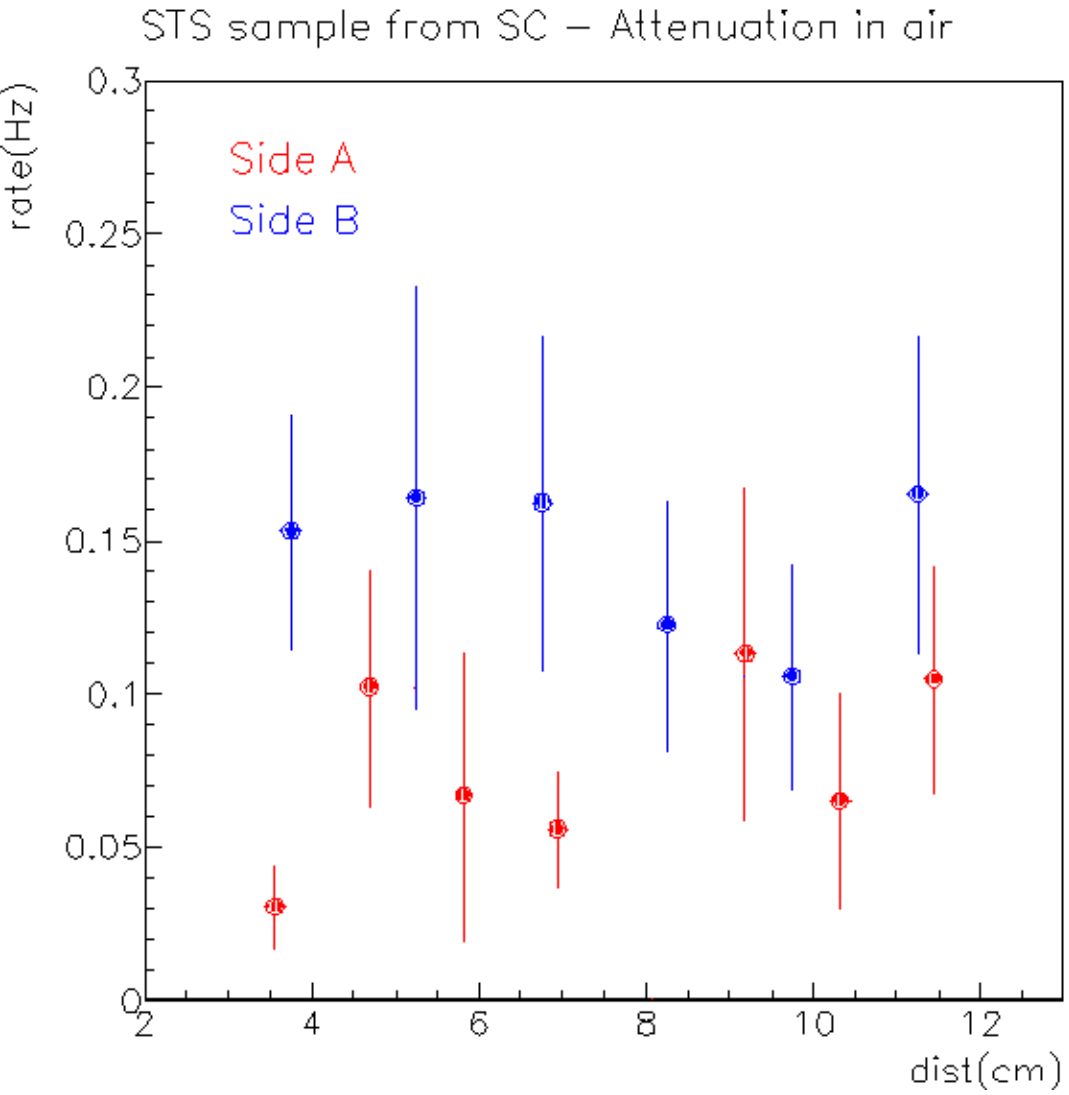


SC sample STS
Screenshot after 120 events
WP 960 V

Only results from gamma spectroscopy

Sample from SC	
Surface cm2	7.07
Volume cm3	2.8
Co-60 Bq/gr	4
Fe-55 Bq/gr	?

MEASUREMENTS WITH SAMPLES: SC (SYNCHROCYCLOTRON) SAMPLE



Lead collimators in front of the sample. Hole diameter 0.2 cm
Thickness 0.23 cm
WP=960 V

Shielding	0.39
No shielding	0.43
Gamma norm vol (Hz)	0.05
X rays (Hz)	0

MEASUREMENTS WITH SAMPLES: SAMPLE IN TAPE

- Sample in powder
- Higher granularity
- Higher contribution from ^{55}Fe

Sample	GEM Rate (Hz)	Spectro Co-60 (Bq/gr)	Spectro Fe-55 (Bq/gr)
Background	0.28±0.02		
149	0.27±0.02	3.0	14.0
52	0.24±0.02	7.8	7.1
62	0.33±0.03	66.0	24.0
ISR 71	0.25±0.03	2.1	?

CONCLUSIONS

- **A fully characterization of a 9 mm drift camera has been done:**
  - $\varepsilon_X = 39\%$ **Rejection: 34**
  - $\varepsilon_\gamma = 1.14\%$
- **Several radioactive samples have been measured with several procedures**
- **PROBLEM: since the attenuation length in waste material is 8 μm for x rays, while for γ is 23 cm, the x-rays intensity is always extremely low**
- **We started to work with other detector as GEMPix and to scratch the waste to obtain a powder in order to have more granularity**