Radiation studies on resistive bulk-micromegas chambers at the CERN Gamma Irradiation Facility

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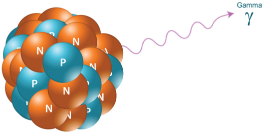
Overview

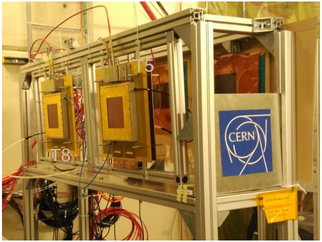
- Introduction
- Gamma Irradiation Facility
- Towards HL-LHC
- MicroMegas set-up
- Results
- Conclusions

MicroMegas: *Micro mesh gaseous structure*

Introduction

- Study the detector behavior under **high irradiation** and **long-term aging** of resistive MicroMegas detectors

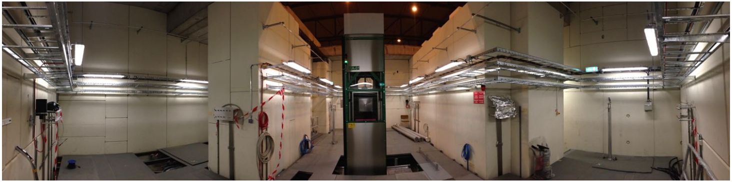




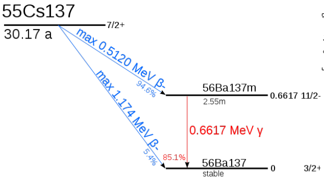
- Two **resistive bulk-Micromegas detectors** were installed in **May 2015** at the *CERN Gamma Irradiation Facility* **(GIF++)**
- Those detectors were exposed to an intense gamma irradiation
- The desired accumulated charge of more than **0.2 C/cm^2** has been reached corresponding to 10 years of **HL-LHC** operation

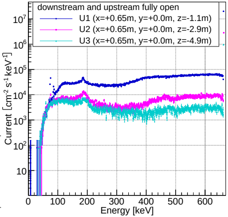
Results after 2 years of irradiation will be presented

CERN Gamma Irradiation Facility (GIF++)



- Located in the north area of the SPS accelerator at CERN
- Flux of **high energy photons** *(662 KeV)* together with the availability of **high energy charged particle beams**
- **^{137}Cs $\sim$14 TBq** gamma source of irradiation, half-life of 30 years

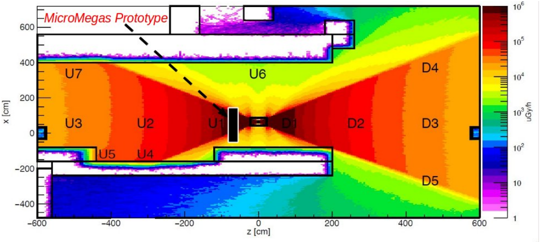




^{137m}Ba emits **gamma rays** with a main photon peak at **662 keV**

CERN Gamma Irradiation Facility (GIF++)

- Measurements and simulations (*Geant4*) of the **photon field** were provided and used as benchmarks for our measurements

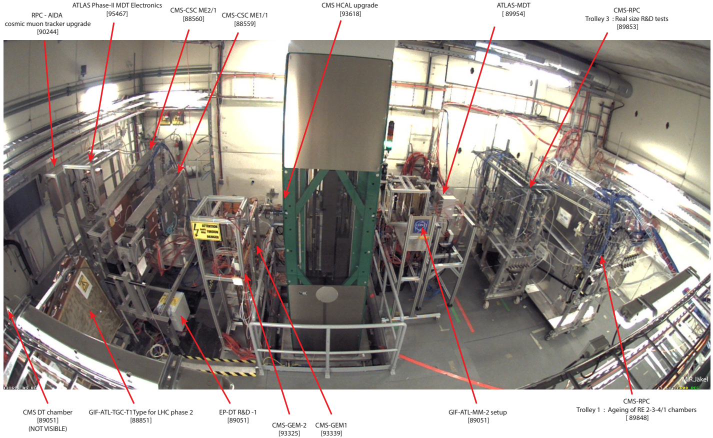


- **Filter system** permits the attenuation of the photon rate in several steps to reach **attenuation factors** of several orders of magnitude ($\sim 10^4$ - 10^5)

Nominal Attenuation	Filter Combination	Measured data: Dose Rate [mGy/h]	Measured data: Dose Attenuation
1	A1 B1 C1	470.00	-
1.5	A1 B2 C1	400.00	1.2
2.2	A1 B1 C2	211.00	2.2
4.6	A1 B1 C3	105.00	4.5
10	A2 B1 C1	55.00	8.8
100	A3 B1 C1	6.50	72.3
100	A1 B3 C1	6.20	75.8
464	A1 B3 C3	1.59	295.6
4642	A2 B3 C3	0.22	2156.0
46415	A3 B3 C3	0.05	9400.0

- **GIF++ Community: Projects foreseen for LHC Upgrades**

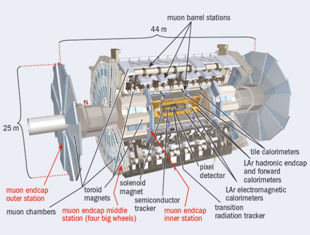
2017 - Week 19

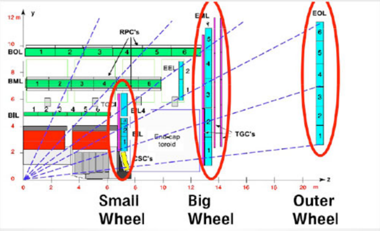


- The high source activity produces a **very intense background gamma field** allowing to accumulate doses equivalent to **High Luminosity LHC** experimental conditions in a reasonable time

High Luminosity LHC (HL-LHC)

- **Resistive MicroMegas** is a well established technology to be used with many applications
  - For example in ATLAS for the New Small Wheel (NSW) project
- ATLAS will replace the current two small wheels (CSC, MDT, TGC)



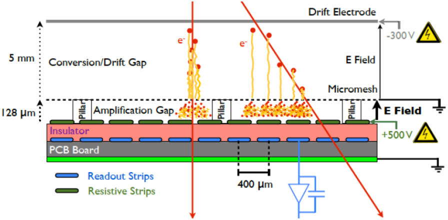


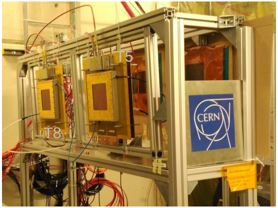
- Very high rate (15 kHz/cm^2) at high luminosity (5x10^{34} cm^{-2}s^{-1})
- Some irradiation tests in resistive MM were done in the past
- **New studies:**
  - Long-term irradiation
  - Measurements of the detector performance under high irradiation

*For more details about the NSW project, see Paolo Iengo's talk:
https://indico.cern.ch/event/466934/contributions/2590420/

Description of the MicroMegas used in GIF++

- Two resistive bulk-micromegas chambers (T5&T8) built @ CERN
  - Active area of **10x10 cm^2**
  - Single readout plane with strip pitch 400 μm and strip width 300 μm
  - Readout strips covered with a 50μm thick Kapton foil carrying high resistivity ($\sim$1MΩ/sq) carbon strips $\rightarrow$ *spark protection*
  - The gas volume is divided in two by a **metallic micro-mesh**
  - **Mesh** consisting of 18 μm diameter wires with 64 μm pitch
  - Amplification gap of 128 μm, drift gap of 5 mm





- These are gaseous particle detectors detecting particles by amplifying the charges that have been created by **ionisation** in the gas volume

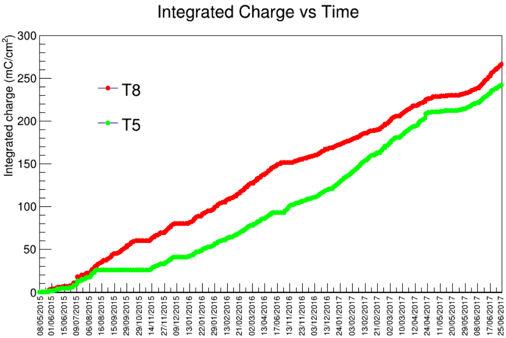
Data-taking and Working Conditions

- Data acquired with **APV-25** front-end ASICs and RD51 Scalable Readout System (**SRS**)
- **Data-taking** varying attenuation filters and amplification voltages
  - **Att. Factors:** 1, 2.2, 4.6, 10, ..., 100
  - **Amplification Voltage Scan:** 420-540 V
  - **Drift Field:** 600 V/cm
  - Source **ON/OFF** + Muon Beam
- **Working conditions:**
  - **Gas:** $ArCO_2$ 93%, 7%, **Gas Flow:** 5 l/h
  - **Operating Gain:** $\sim 5x10^3$

RESULTS

Integrated Charge

- **Goal:** to accumulate the equivalent integrated charge expected after 10 years of **HL-LHC** operation
- After $\sim$**2 years** of exposure to an intense γ irradiation the desired accumulated charge of more than **0.2 C/cm^2** has been reached

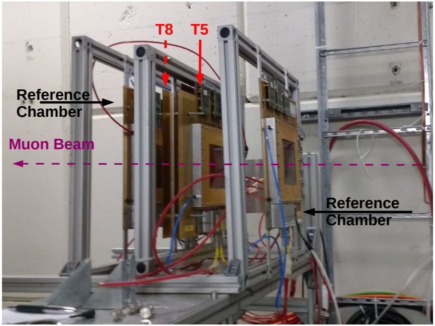


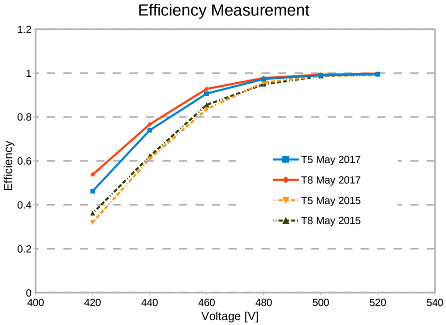
Chambers exposed at GIF++ from May 2015 to June 2017

Detection Efficiency Measurements

Efficiency measured w.r.t reference detectors using **muon tracks**

- **May 2015:** muons from cosmic rays at the CERN *RD51 GDD lab*
- **May 2017:** GIF++ muon beam





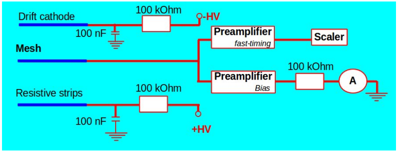
- Both datasets reach **full efficiency** around **500 V**
- **Voltage** was not corrected by *T, P and H*

No degradation of the **efficiency** observed due to irradiation

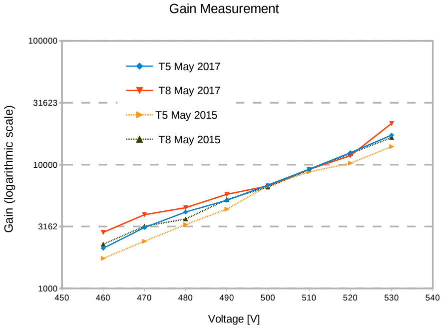
Gain Measurements

Gain measurements were conducted on **T5** and **T8** chambers using an ^{55}Fe source in the *RD51 GDD lab* in **May 2015 and 2017**

Experimental set-up



$$\textbf{Gain} = \frac{\textit{Current from the mesh}}{\gamma \ \textit{conversion Rate x } q_{e^-} \textit{ x } N_{e \ per \ \gamma}}$$

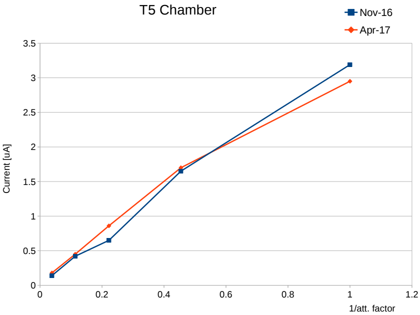


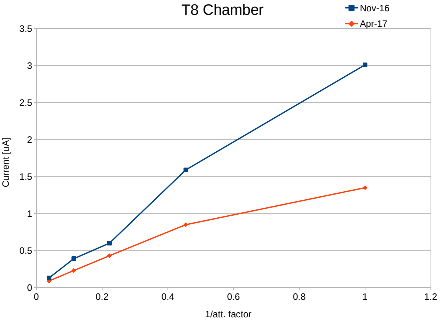
- No significant changes on the gain are observed for any of the two chambers

No degradation of the gain observed due to irradiation

Current vs Voltage and Attenuation Factor

- Study the current as a function of the amplification voltage and attenuation factor
- Slight difference due to atmospheric conditions: T, P and H





- **In April 2017**, **T8** was moved further from the source from **1 m** to about **1.35 m**
- The current difference follows:

$$I_1 * d_1^2 = I_2 * d_2^2, \text{ if } d_2 > d_1 \rightarrow I_2 < I_1$$

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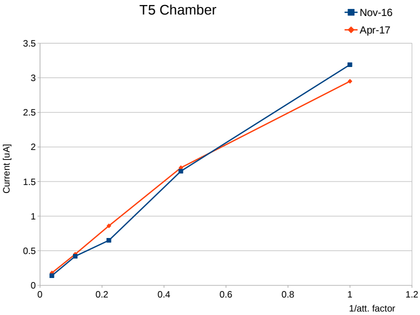

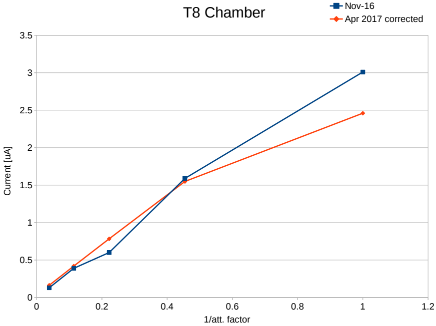

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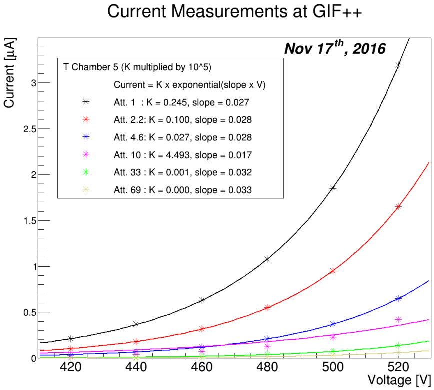
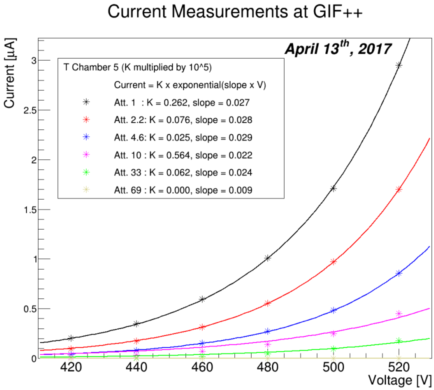
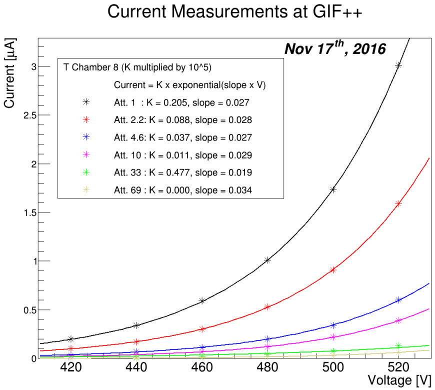
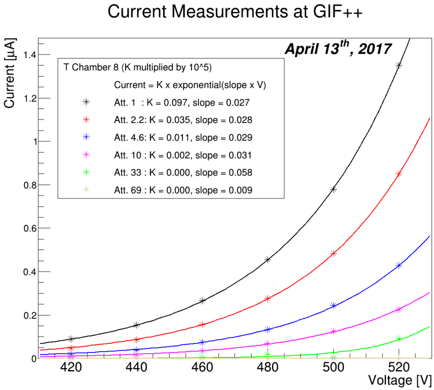
Current vs Voltage and Attenuation Factor – T5





Current vs Voltage and Attenuation Factor – T8

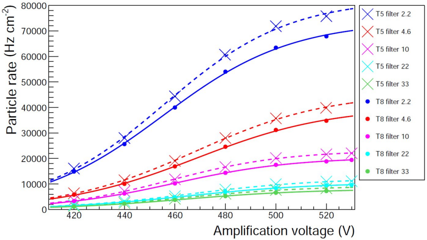




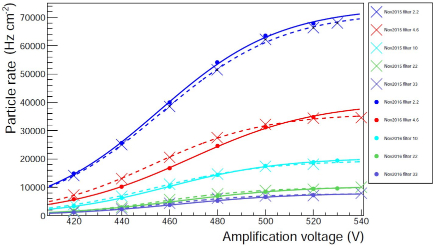
Particle Rate and Detector Sensitivity

Particle rate as a function of the **amplification voltage** per att. factor

Nov 2016 data-taking, T5 and T8



Nov 2015 and 2016 data-takings, T8

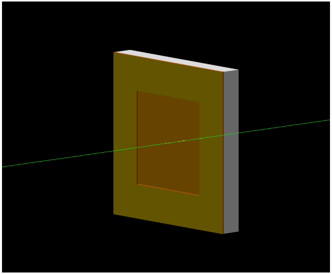


Att. Factor	Measured Particle Rate [x10^3]		Observed Rate [x10^6]	Sensitivity [x10^{-3}]	
	T5	T8		T5	T8
2.2	7.6	6.8	20.0	3.8	3.4
4.6	4.0	3.5	9.8	4.0	3.6
10	2.2	1.9	5.0	4.3	3.8

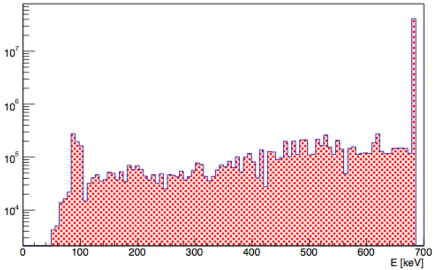
- The **detector sensitivity** of ∼**3.8 x10^{-3}** extracted from the measured particle rate from the fully efficient region **@ 520 V** and the photon observed rate at **U1**
- This agrees with the Geant4 simulations which include the resistive bulk-micromegas chambers

Geant4 Simulation

- Simulation including the bulk-micromegas detector design and the GIF++ source spectrum



Spectrum simulated for att. factor 10

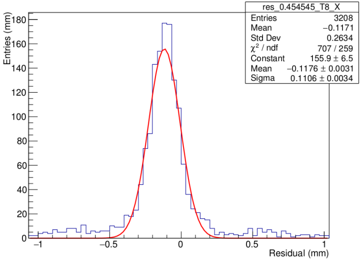


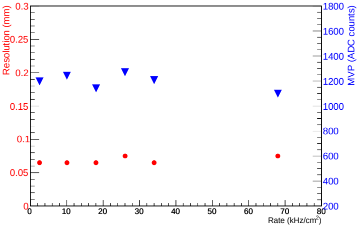
- As result the **detector sensitivity**, estimated as the number of γ depositing an energy more than 26 eV in the gas gap over the total number of generated γ, is about $\sim$**3.8 x10^{-3}**

Tracking with muon beam

Reminder: GIF++ $\rightarrow$ γ source + muon beam

- Muon tracks distinguished from photons using the *Hough transform*
- **Cluster position difference** between T5 and T8 fitted with a Gaussian:





- Tracking resolution stable up to **68 kHz/cm^2** *(4 times more than the expected rate during the* **HL-LHC)**
- The **most probable value (MPV)** of the cluster charge is also shown and is constant up to this very high photon flux

Conclusions

- The *efficiency, gain, particle rate and tracking resolution* measurements for two **bulk-micromegas chambers** have been presented
- After two years of irradiation at GIF++ with an accumulated charge of more than **0.2 C/cm^2** **no aging effects** have been observed in either of the two chambers
- Studies on the **tracking resolution** performed in *November 2015* have been also shown, stable up to **68 kHz/cm^2**
  - These studies will be repeated for the full accumulated charge
- **Activities at GIF++ continue:**
  - Irradiation of T5 and T8 chambers
  - Irradiation and muon test beams for other MicroMegas prototypes
- **Acknowlogements:**
  - CERM GIF++ Community
  - CERN *RD51 GDD lab*
  - Nicholas Karastathis for the Geant Simulation

https://espace.cern.ch/test-RD51/RD51%20internal%20notes/RD51-NOTE-2015-011.pdf

THANK YOU

BACK-UP SLIDES

References

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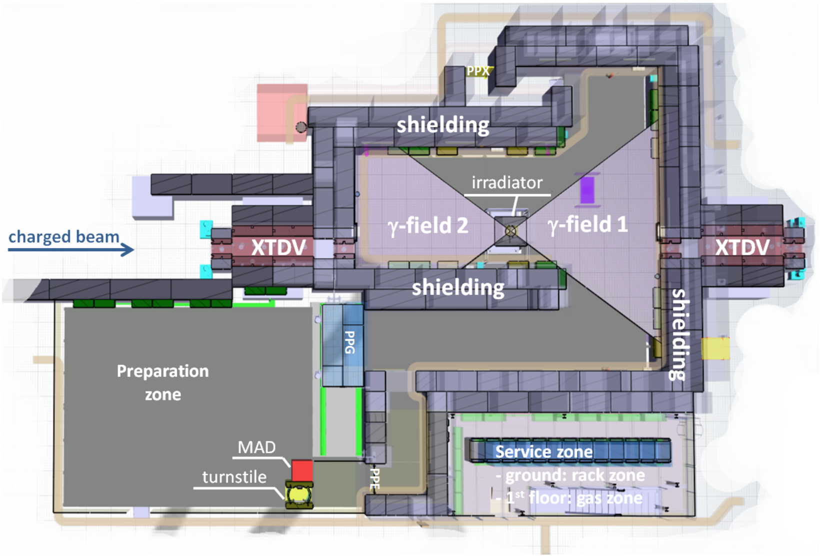
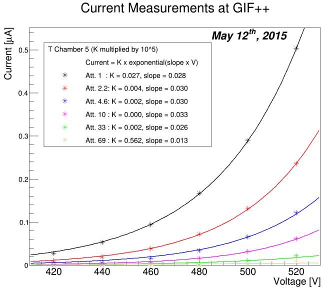
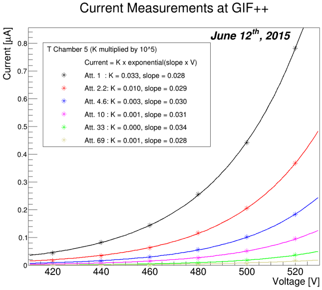
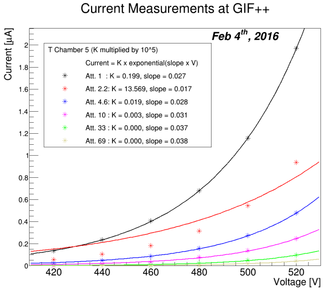
CERN Gamma Irradiation Facility (GIF++)

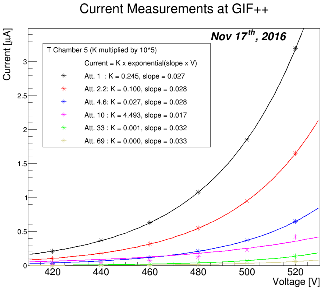


Current vs Voltage — T5









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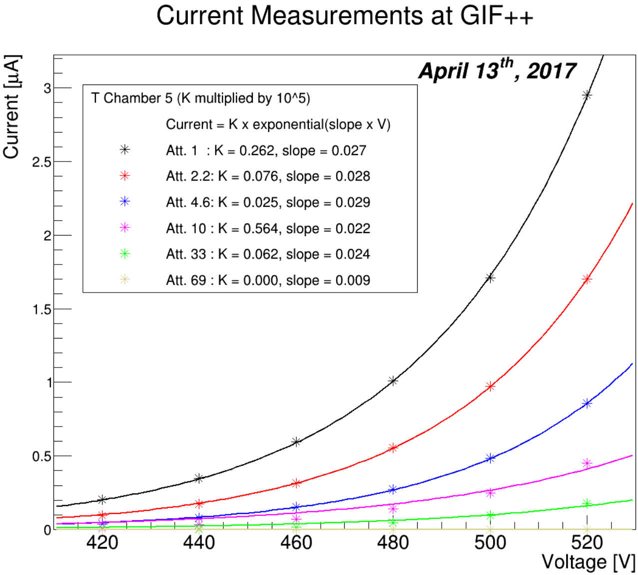
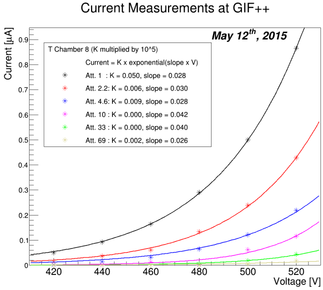
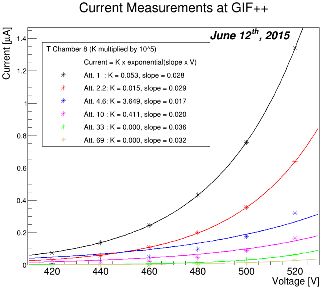
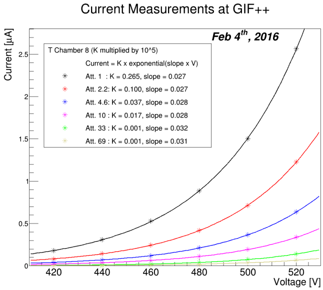
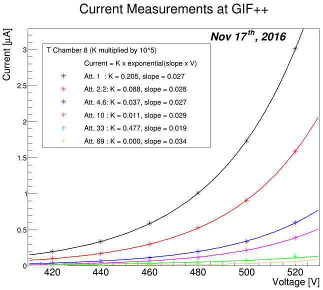


Current vs Voltage — T8









Current vs Voltage — T8