# A setup to measure the quenching factor in spherical TPCs at LPSC Grenoble: Electron calibrations

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for NEWS-G

[1]LPSC Grenoble, [2]Queen's University

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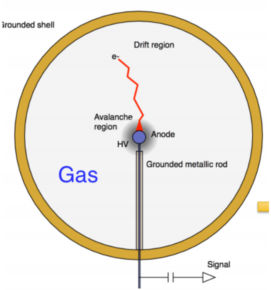
# collaboration

- **Queen's University Kingston** – G Gerbier, P di Stefano, R Martin, T Noble, D Dunrford A Brossard, A Kamaha, P Vasquez dS, Q Arnaud, K Dering, J Mc Donald, M Clark, M Chapellier
  - Copper vessel and gas set-up specifications, calibration, project management
  - Gas characterization, laser calibration, on smaller scale prototype
  - Simulations/Data analysis
- **IRFU** (Institut de Recherches sur les Lois fondamentales de l'Univers)**/CEA Saclay** -I Giomataris, M Gros, C Nones, I Katsioulas, T Papaevangelou, JP Bard, JP Mols, XF Navick,
  - Sensor/rod (low activity, optimization with 2 electrodes)
  - Electronics (low noise preamps, digitization, stream mode)
  - DAQ/soft
- **LSM** (Laboratoire Souterrain de **Modane**), IN2P3, U of Chambéry - F Piquemal, M Zampaolo, A DastgheibiFard
  - Low activity archeological lead
  - Coordination for lead/PE shielding and copper sphere
- **Thessaloniki University** - I Savvidis, A Leisos, S Tzamarias, C Elefteriadis, L Anastasios
  - Simulations, neutron calibration
  - Studies on sensor
- **LPSC** (Laboratoire de Physique Subatomique et Cosmologie) **Grenoble** - D Santos, JF Muraz, O Guillaudin
  - Quenching factor measurements at low energy with ion beams
- **Technical University Munich** – A Ulrich, T Dandl
  - Gas properties, ionization and scintillation process in gaz
- **Pacific National Northwest Lab** - E Hoppe, D Asner
  - Low activity measurements, Copper electroforming
- **RMCC (Royal Military College Canada) Kingston** – D Kelly, E Corcoran
  - 37 Ar source production, sample analysis
- **SNOLAB –Sudbury** – P Gorel
  - Calibration system/slow control
- **University of Birmingham**– Kostas Nicolopoulos
  - Simulations, analysis, R&D
- **Associated lab : TRIUMF** - F Retiere
  - Future R&D on light detection, sensor

*April 2017*

# Context (cf Arnaud (M3-3), Brossard, Durnford (M4-3), Gerbier (R3-3))

- Astrophysical observations imply most of matter in universe is exotic Weakly Interacting Massive Particles (WIMPs)
- The NEWS-G collaboration is searching for WIMPs using spherical TPCs:



- Assets of these detectors include low-threshold, choice of gas and pressure (0.1 – 10 bar)
- Spherical detectors calibrated using electron recoils (usually from X-ray sources), but WIMPs scatter off nuclei (ionize less for same energy deposit)
- Need to know conversion between electron recoil scale and nuclear recoil scale: quenching (Q).

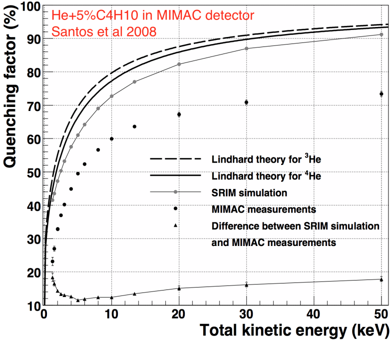
# How to determine quenching?

$$\text{Quenching: } Q(E) \equiv \frac{\text{Signal created by nuclear recoil of energy } E}{\text{Signal created by electron recoil of energy } E}$$

## Simulations: SRIM

Doesn't take pressure into account.

Discrepancies observed with data in other types of detectors [1].



## Neutron scattering experiment

Preferably with mono-energetic neutron source.

Need to measure scattering angle.

Simulations to account for multiple scatters.

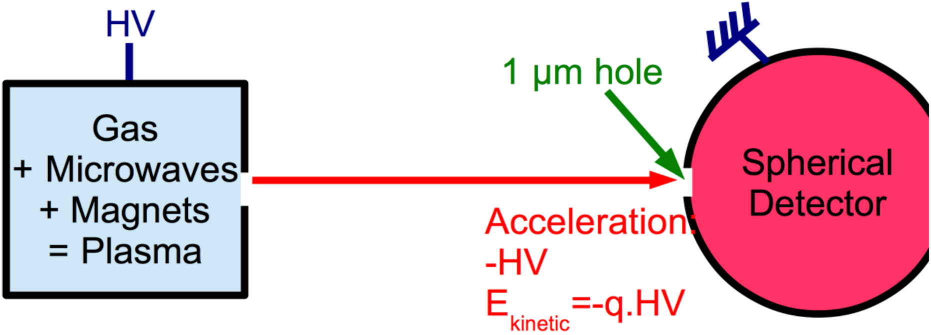
## COMIMAC line @ LPSC [2]

Send ions and electrons of precisely known energy.

Ions are equivalent to recoiling nuclei of same element [3] → direct measurement of $Q(E)$.

# Simplified Principle of COMIMAC Line

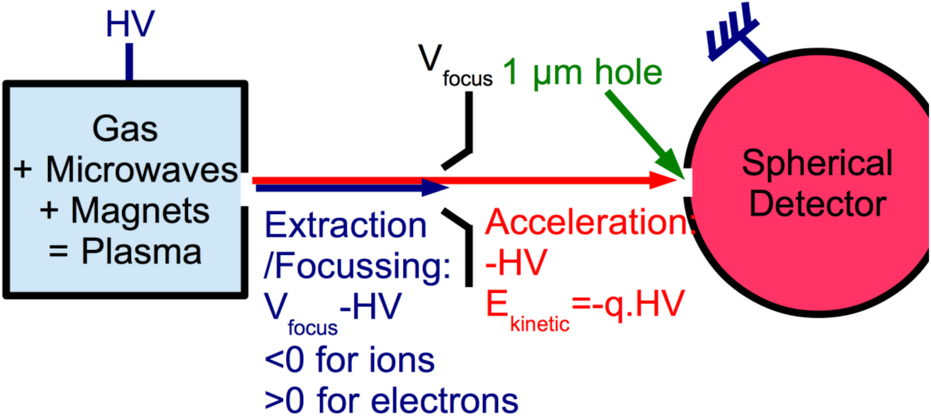
*(Guillaudin, Lamy, Muraz, Santos, Sortais: LPSC)*



Acceleration:
-HV
$E_{kinetic}$=-q.HV

# Simplified Principle of COMIMAC Line

*(Guillaudin, Lamy, Muraz, Santos, Sortais: LPSC)*



HV

Gas
+ Microwaves
+ Magnets
= Plasma

$V_{focus}$ 1 µm hole

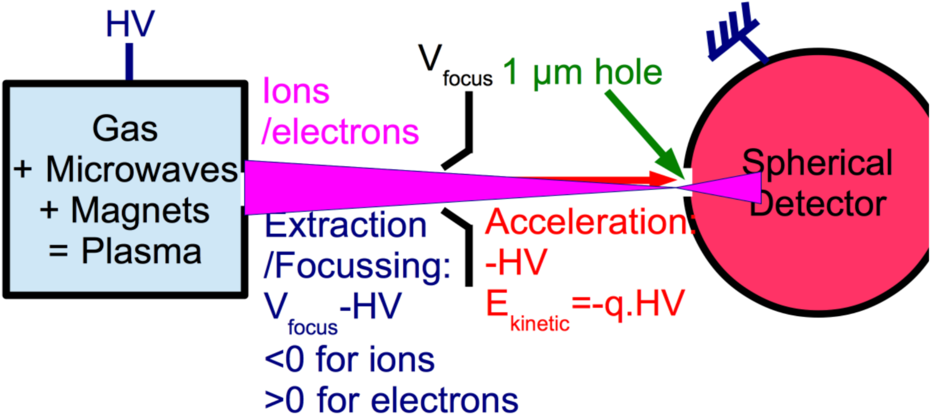
Spherical Detector

Extraction
/Focussing:
$V_{focus}$-HV
<0 for ions
>0 for electrons

Acceleration:
-HV
$E_{kinetic}$=-q.HV

# Simplified Principle of COMIMAC Line

*(Guillaudin, Lamy, Muraz, Santos, Sortais: LPSC)*



HV

Gas
+ Microwaves
+ Magnets
= Plasma

Ions
/electrons

$V_{focus}$

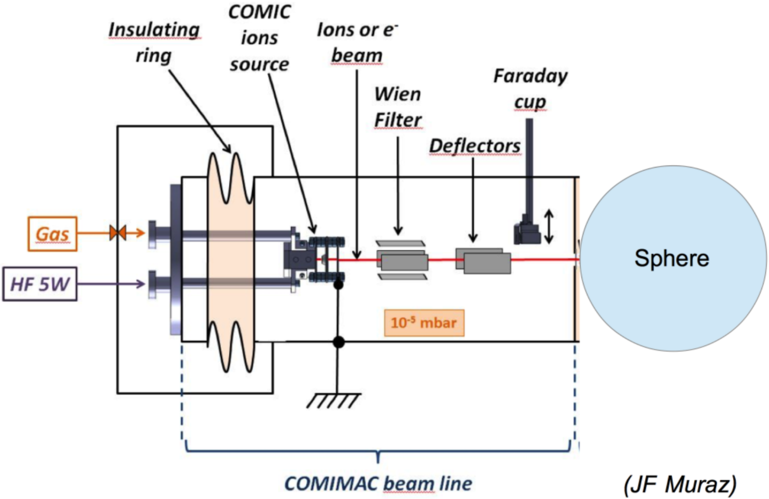
1 µm hole

Spherical
Detector

Extraction
/Focussing:
$V_{focus}$-HV
<0 for ions
>0 for electrons

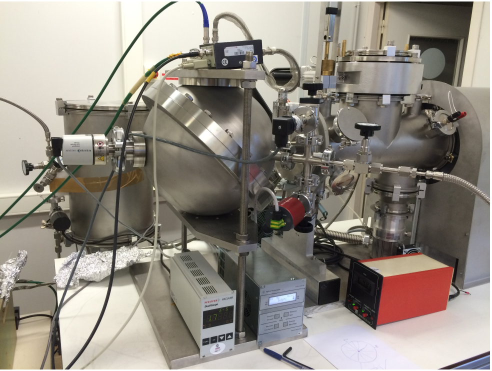
Acceleration:
-HV
$E_{kinetic}$=-q.HV

(Deflection, Wien filter not shown)


Insulating ring
COMIC ions source
Ions or e$^-$ beam
Wien Filter
Faraday cup
Deflectors
Gas
HF 5W
10$^{-5}$ mbar
Sphere
COMIMAC beam line

(JF Muraz)

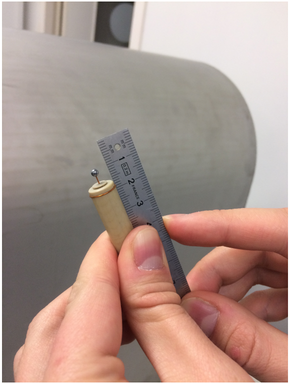
# S30 and COMIMAC to measure quenching



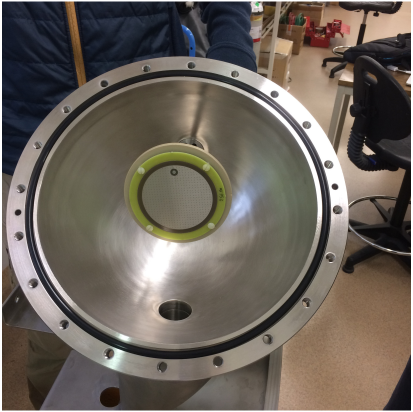
- S30: 30 cm sphere designed at LPSC Grenoble
  - Stainless steel
  - Opens at hemispheres
  - Modular
    - direction of sensor
    - choice of sensor
  - Rated up to 10 bar
- Fits on a table-top
- Gases used so far:
  - $He+5\%C_4H_{10}$
  - $Ne+0.7\%CH_4$
  - $0.2$ bar $< P < 3$ bar
- COMIMAC can send electrons or ions into sphere

# Sensors used

Example of ball sensor for NEWS-G (3 mm Si):

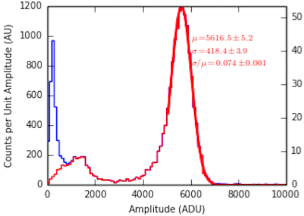


Micromegas sensor (250 $\mu$m)



# An electron result (He+5%C4H10, 200 mbar, 1249 V)

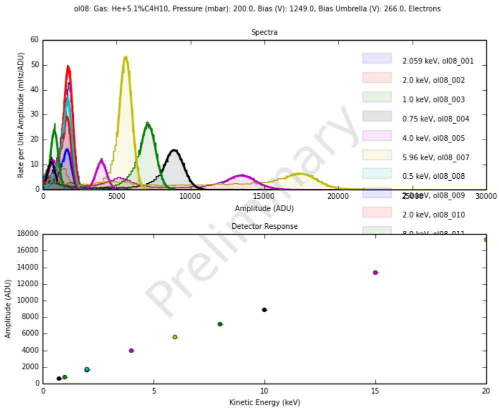
## Example: 5.96 keV $\beta^-$s



$\frac{\sigma}{\mu} = 7\%$

At this pressure, can calibrate with $\beta^-$s this way, whereas standard calibration with $^{55}Fe$ X-rays is impossible

## Response to 0.75–20 keV $\beta^-$s

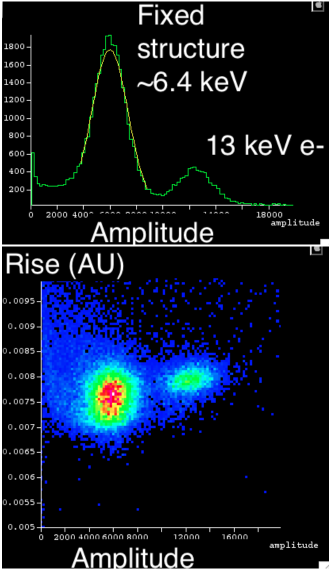


/Users/distefano/Documents/Code_Svn/Samba_Tango/sambaUtilities.py eRuns

Nice linearity.

Can work at rates of the order of 100 Hz.

# Identifying fluorescence using rise time

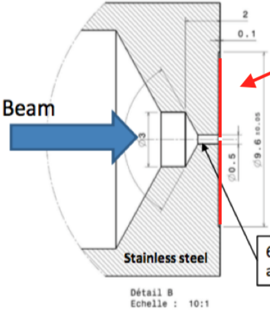


Ne+0.7%CH4 at 1 bar.

8 keV electrons localized interactions at edge of sphere → long rise times, small spread

6.4 keV fluoresence X-rays interact in larger volume → larger spread in rise times

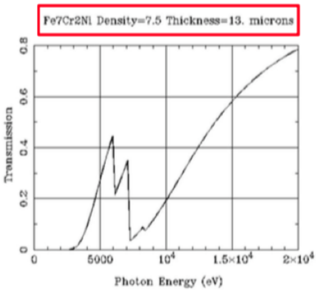
# Interface and Fluorescence



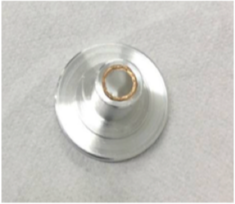
Stainless steel
13 µm thick disk

6 keV X rays are produced along the surface

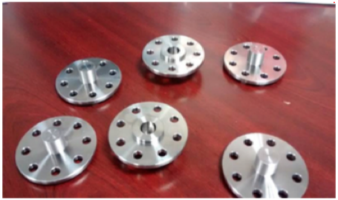
**Filter Transmission**



S15 holders were in **aluminium**



S30 holders are in **stainless steel**



# Presence of fluorescence

- Electrons (and ions?) of $E > 6.4$ keV can stimulate fluorescence of Fe X-rays (6.4 keV) from stainless steel around interface.
- X-rays are visible when gas molecules are Z-enough and pressure is high enough
- X-rays can be identified by energy and by rise time which is broader than that of locally-interacting electrons and ions.
- Energy of X-rays is fixed, and in no way depends on charge build-up anywhere, that could, potentially, affect energy of ions and electrons
- Provides absolute energy reference for electrons and ions that have enough energy to create fluorescence

# Conclusions and outlook

- Measuring the quenching factor in various gases will be of interest to NEWS-G and other collaborations
- Versatile, table-top, set-up in place at LPSC Grenoble using ions and electrons with a modular spherical detector
- Response to electrons mature; able to calibrate at low pressures not accessible to external X-ray sources
- Work under way to characterize response to ions

# References I

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*arXiv:0810.1137 [astro-ph]*, October 2008.

J.F. Muraz, J. Médard, C. Couturier, C. Fourrel, O. Guillaudin, T. Lamy, M. Marton, Q. Riffard, P. Sortais, D. Santos, and N. Sauzet.
A table-top ion and electron beam facility for ionization quenching measurement and gas detector calibration.
*Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 832:214–218, October 2016.

Jelena Ninković, Peter Christ, Godehard Angloher, Dieter Hauff, Partick Huff, Emilija Pantić, Federica Petricca, Franz Pröbst, and Wolfgang Seidel.
New technique for the measurement of the scintillation efficiency of nuclear recoils.
*Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 564(1):567–578, August 2006.

# Examples of particle ranges in gas

In 0.1 bar He+5%C4H10:

- X, 1 keV: 53 cm
- $\beta^-$, 10 keV: 8 cm
- $\alpha$, 1 keV: 0.08 cm