Measurements, simulations and analysis tools for the PIGE technique

IDPASC/LIP PhD Students Workshop, Braga 2019

Elisabet Galiana

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- Motivation
- PIGE technique
- PIGE: experimental analysis of Chlorine
- EnsarRoot framework
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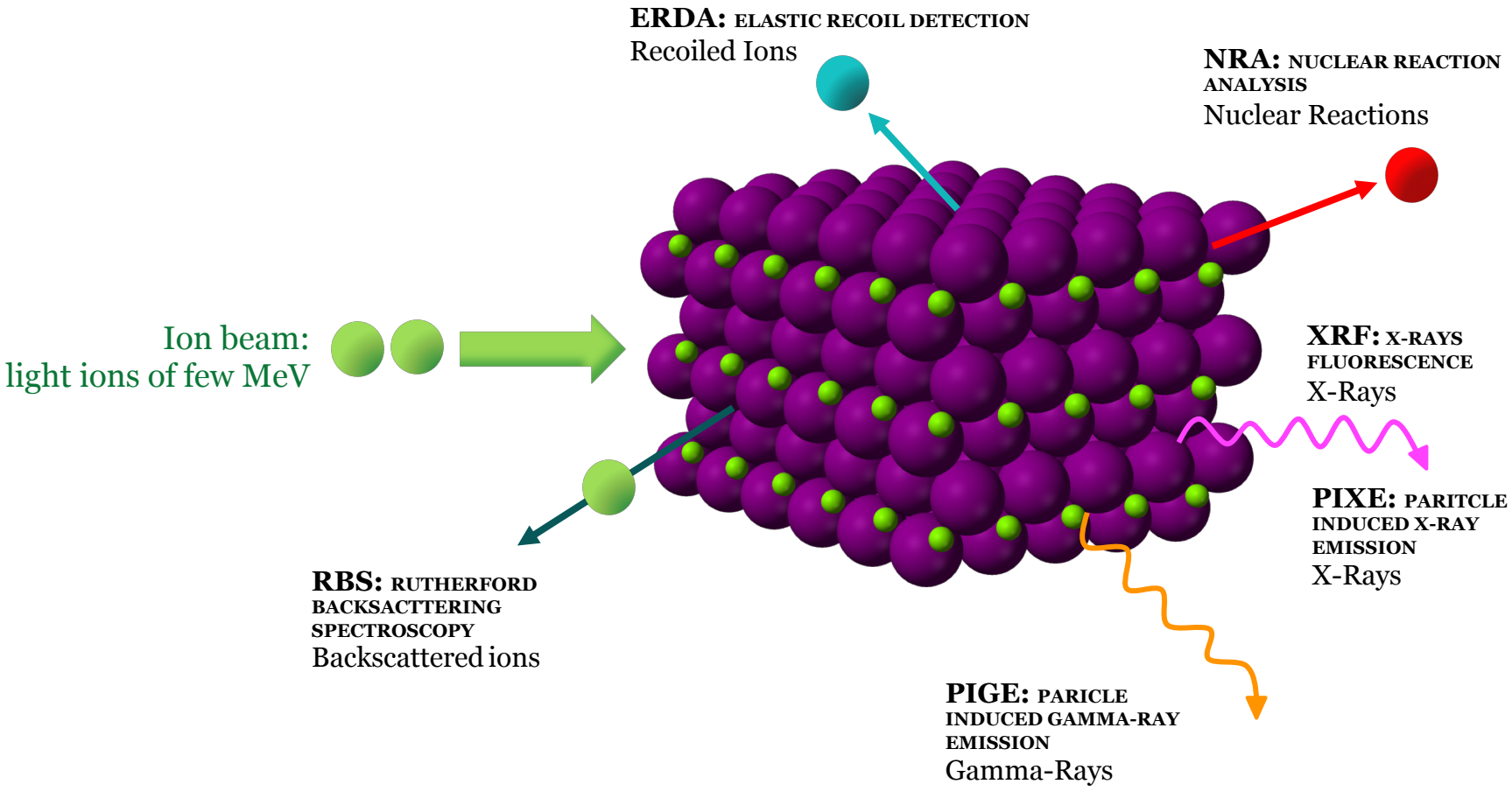
MOTIVATION: What type of interactions occurs when an ion beam hits a target?

Ion Beam Analisys techniques



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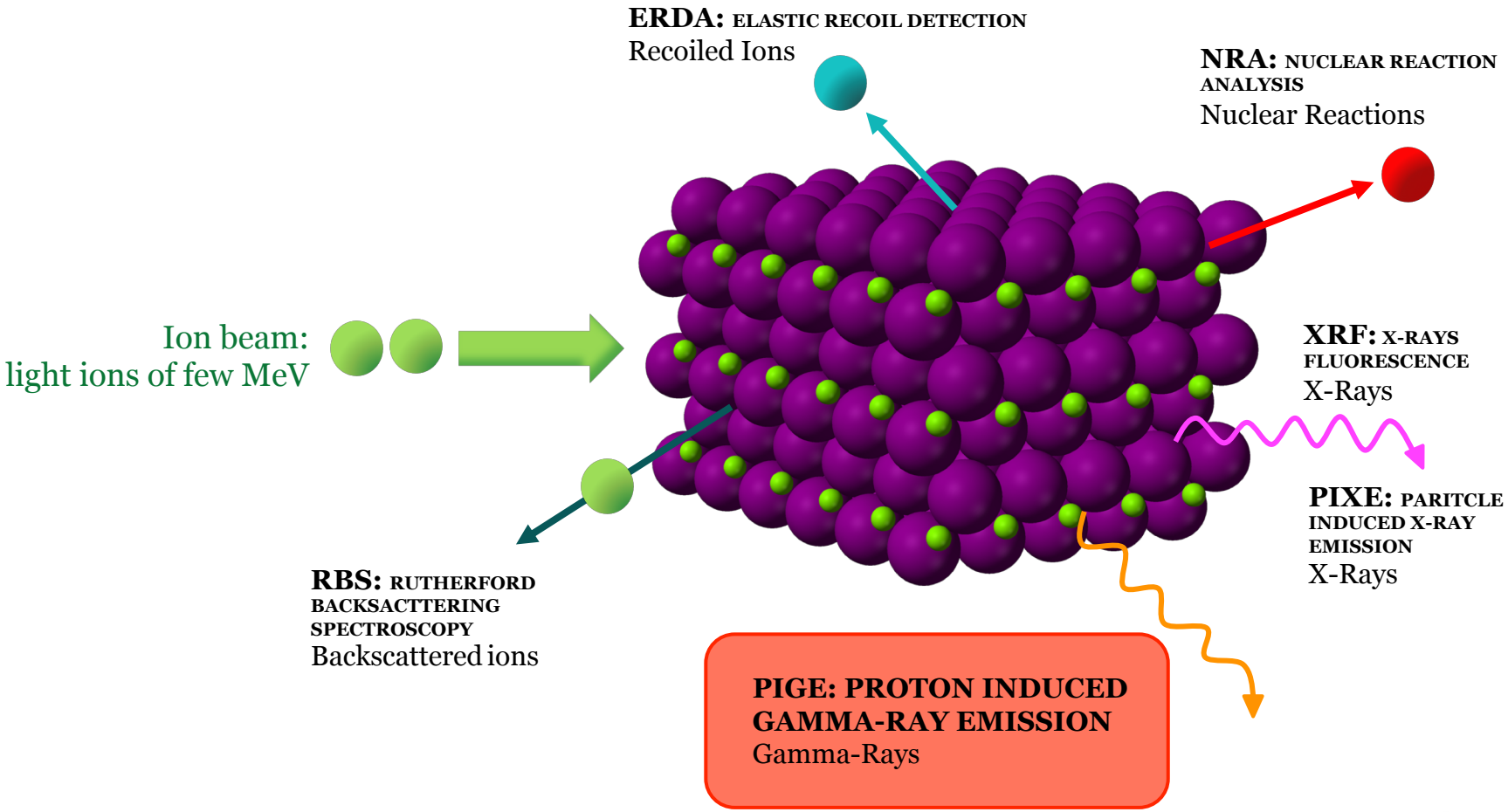

PIGE TECHNIQUE (PROTON INDUCED GAMMA-RAY EMISSION)

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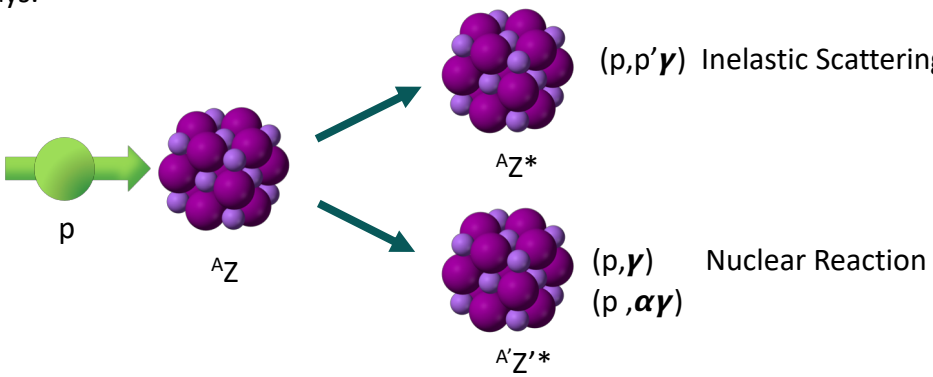
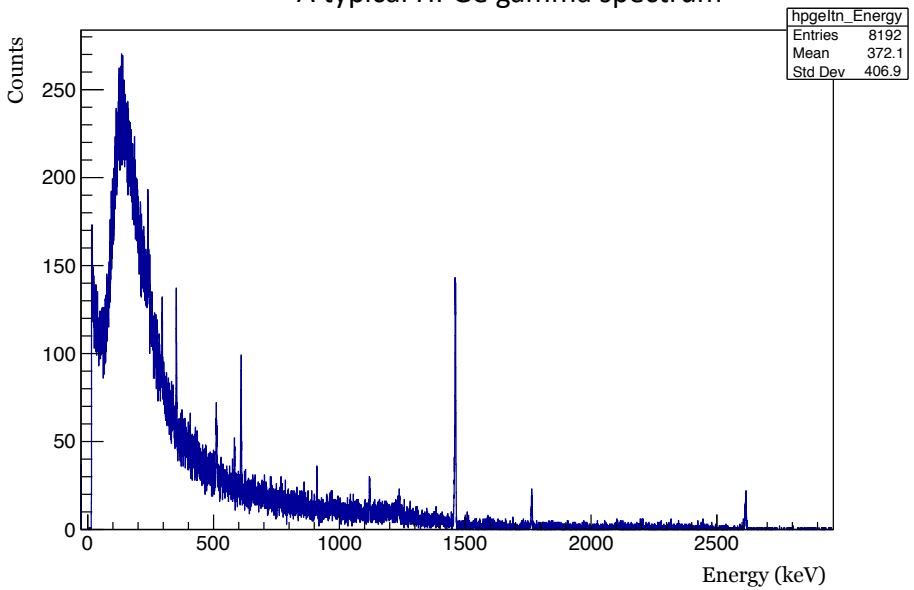


Therefore, it consists on the detection of gamma-rays emitted in these reactions.

A typical HPGe gamma spectrum



— Advantages —

- Non-destructive
- Quantitative technique, determination of absolute concentration
- Permits multielemental analysis
- Allows isotopical differentiation
- Light element differentiation (Z<20)
- Complementary to PIXE (Z>20)

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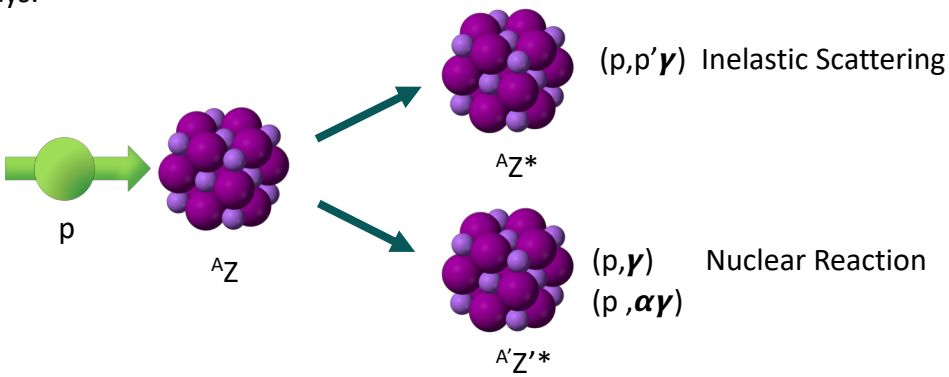

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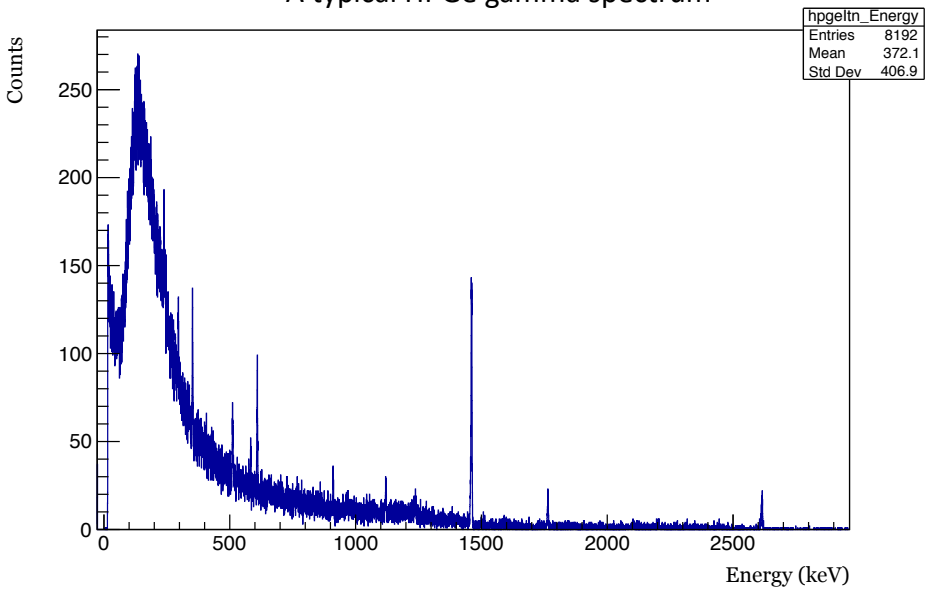

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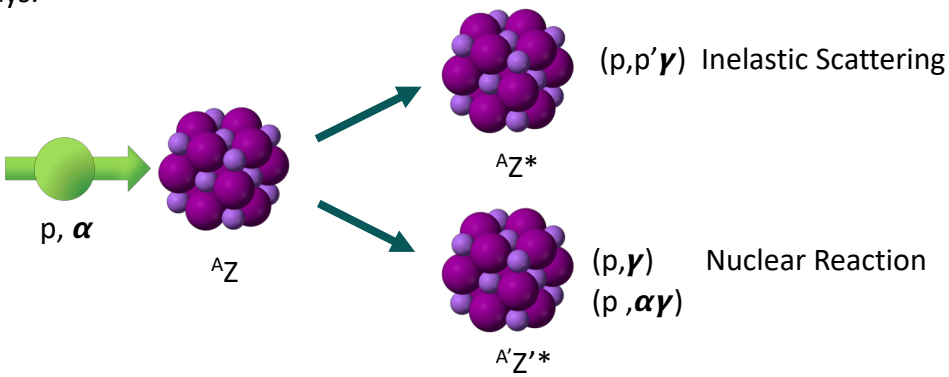

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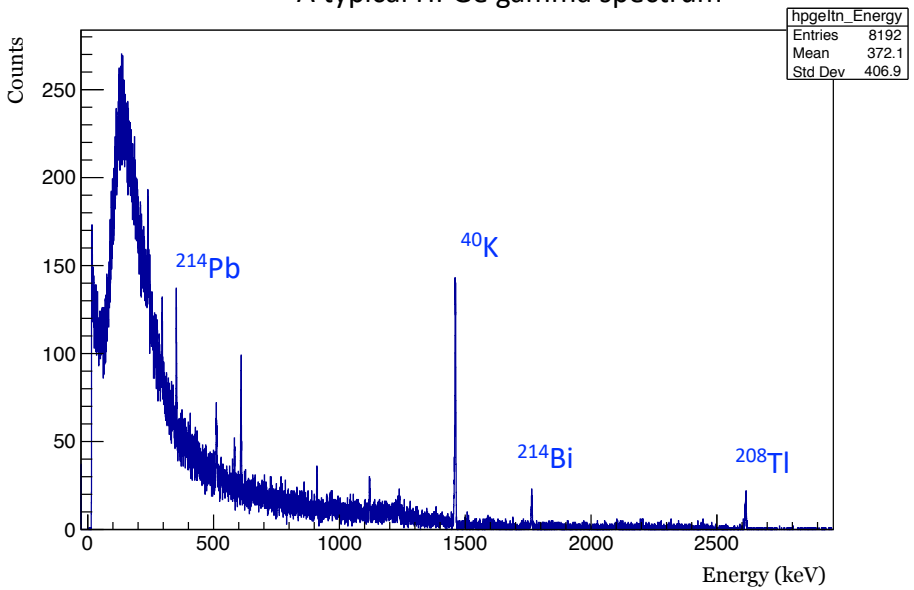

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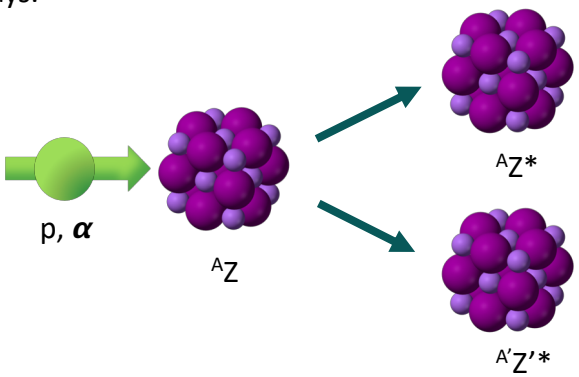
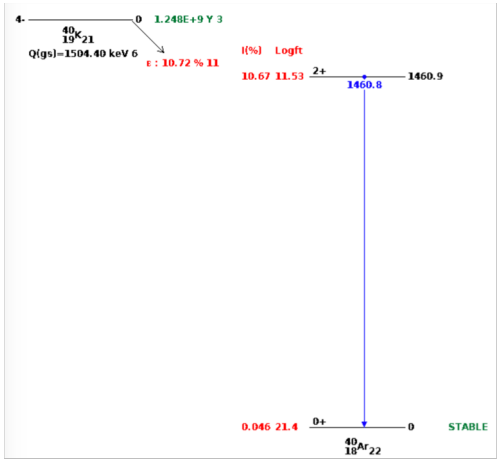


(p,p'***γ***) Inelastic Scattering

(p,***γ***) Nuclear Reaction

(p ,***αγ***)

40K



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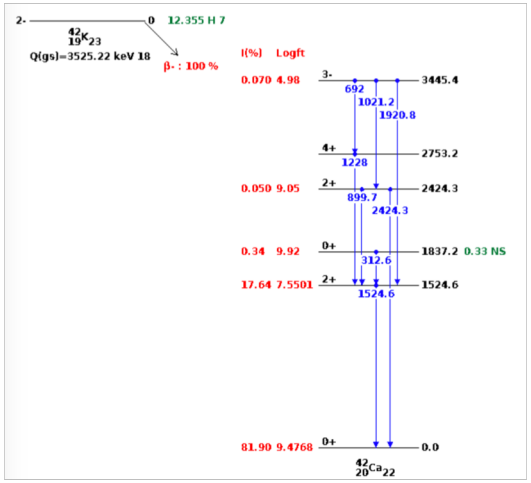
42K



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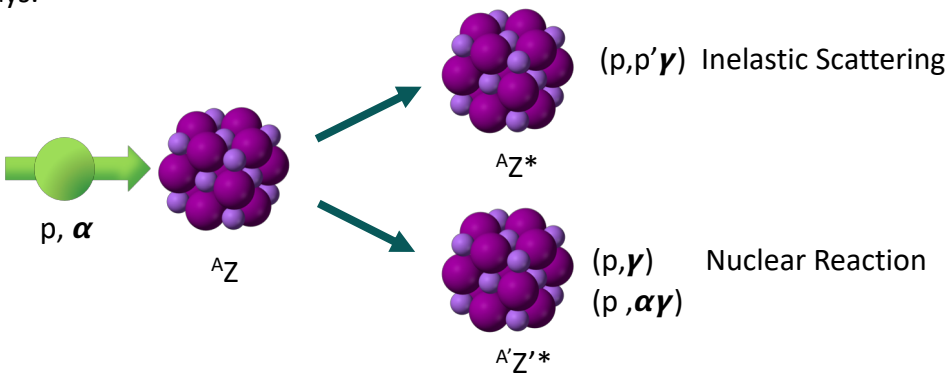

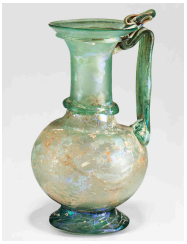

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- Quantitative technique, determination of absolute concentration
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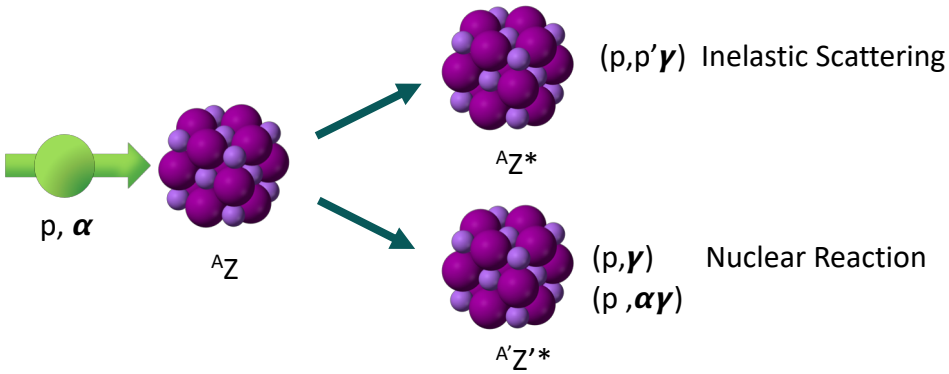
- Allows isotopical differentiation
- **Light element differentiation (Z<20)!!!**
- Complementary to PIXE (Z>20)

The Z<16 correspond to 95% of the Earth crust.

Department of Physics&Astronomy of the University and Istituto Nazionale di Fisica NucleareFlorence, Italy

PIGE TECHNIQUE (PROTON INDUCED GAMMA-RAY EMISSION)

The PIGE technique uses **proton**, deuteron or , ***α***-beam at **low energies**, traditionally up to 3 MeV where only **nuclear forces** are involved. The basic mechanism is the formation of a compound nucleus in a highly excited state which de-excites by the emission of gamma-rays.



— Technique Limitations —

1. The fact that the repulsive **Coulomb barrier** has to be **surpassed** results in a limitation of this method. For low energy beams the only accessible elements are the **light elements with Z<20**.

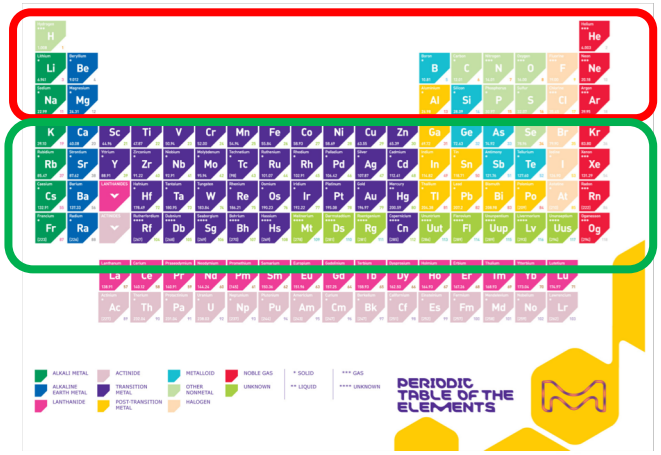
2. A setback which could appear is the **overlap of gamma-rays** in the spectrum making an element determination a challenge.

— Advantages —

- Non-destructive
- Quantitative technique, determination of absolute concentration
- Permits multielemental analysis
- Allows isotopical differentiation
- **Light element differentiation!!!**
- **Complementary to PIXE. The X-ray of Z>20 are more energetic.**

PIGE

PIXE



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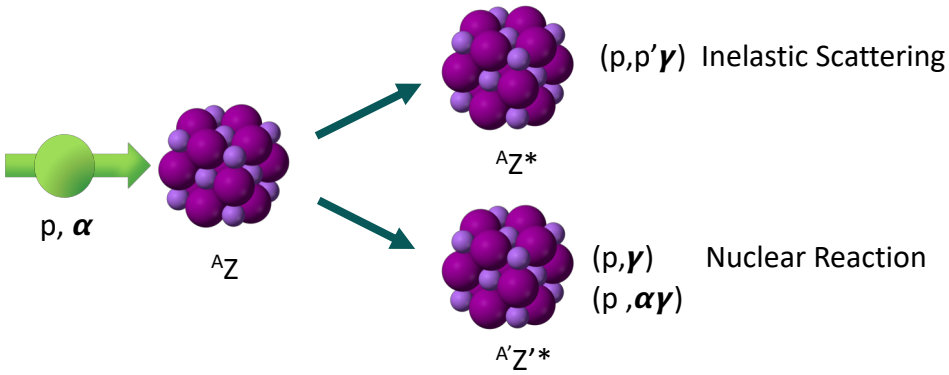

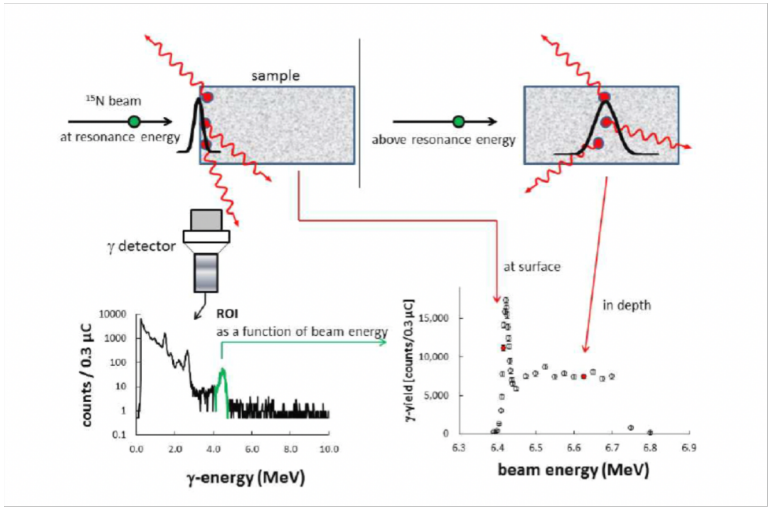

Depth Profiling SchemeIAEA, TEC-DOC Series

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— Depth Profiling —

The profile information can be obtained using **(p,γ) reactions** within cross sections that present **a strong resonance**.

The principle of it is to compensate the intrinsic lack of depth resolution in PIGE bulk analysis by performing measurements at **increasing beam energy** in order to probe the sample composition **at increasing depths** (increasing ranges)

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PIGE: EXPERIMENTAL ANALYSIS OF CHLORINE *from Ancient Greek χλωρός, 'pale green'*

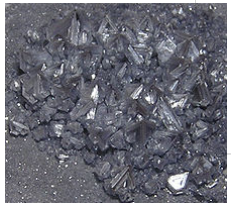
It is the **twenty-first most abundant chemical element in Earth's crust**, mainly forming **ionic sales** (eg: NaCl) and also it is present with the majority of **metals** (eg: AgCl).
We can find **great quantities** of it in **salt mines** and dissolved in **sea water**, but also **humans use it industrially** as a catalyst, cleaning products, bleaching, water disinfectant, even as a chemical weapon (toxic gas). Moreover, it is an essential nutrient for metabolism (eg. hydrochloric acid in the stomach).


salt

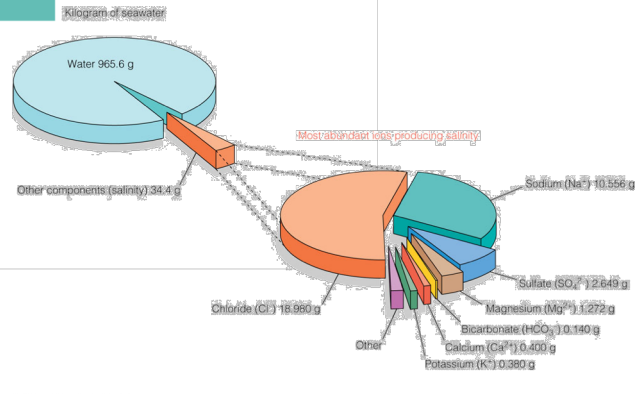
Bleaching


Carl Wilhelm, discoverer of chlorine (1774)


Cl_2 gas


AgCl

Chloroform



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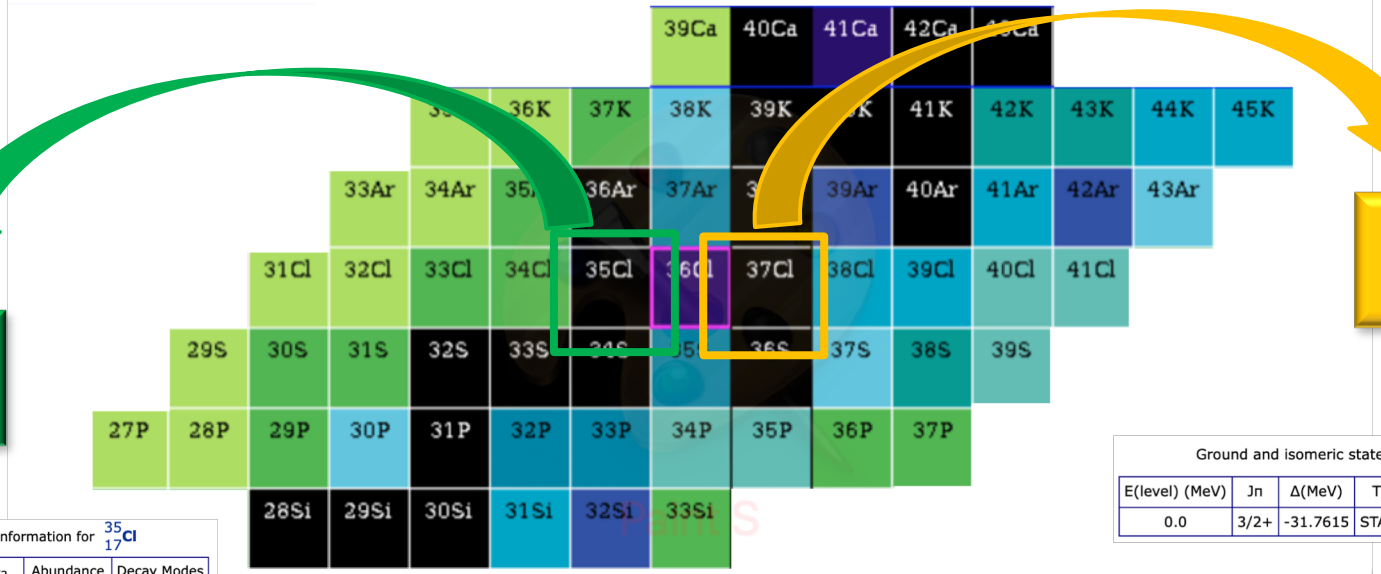

Ground and isomeric state information for $^{35}_{17}Cl$

E(level) (MeV)	Jπ	Δ(MeV)	$T_{1/2}$	Abundance	Decay Modes
0.0	3/2+	-29.0135	STABLE	75.76% *10*	

Ground and isomeric state information for $^{37}_{17}Cl$

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PIGE: EXPERIMENTAL ANALYSIS OF CHLORINE

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Regarding PIGE literature, there is a lack of information in both stable isotopes.
Cross sections and yields are not well defined.

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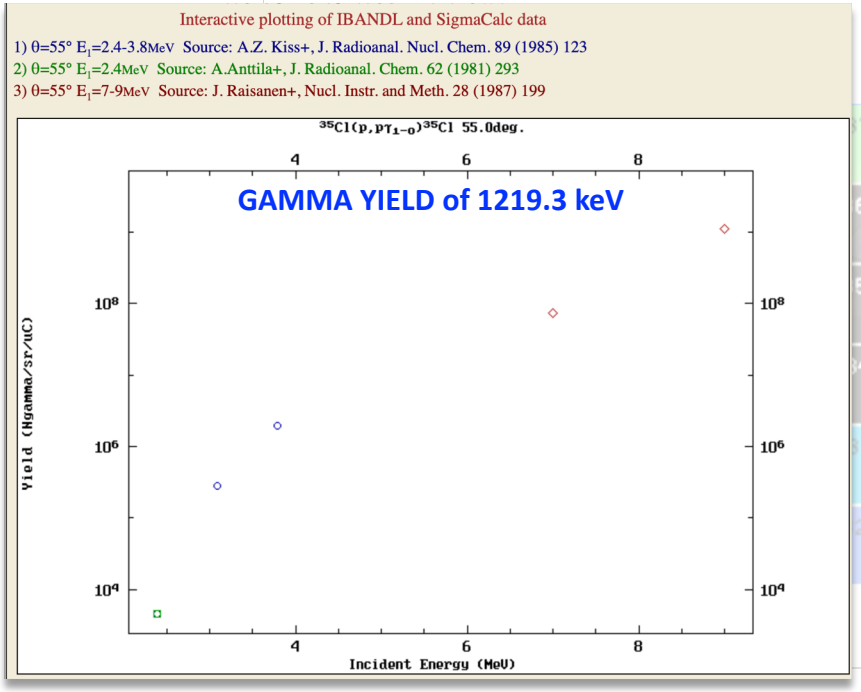

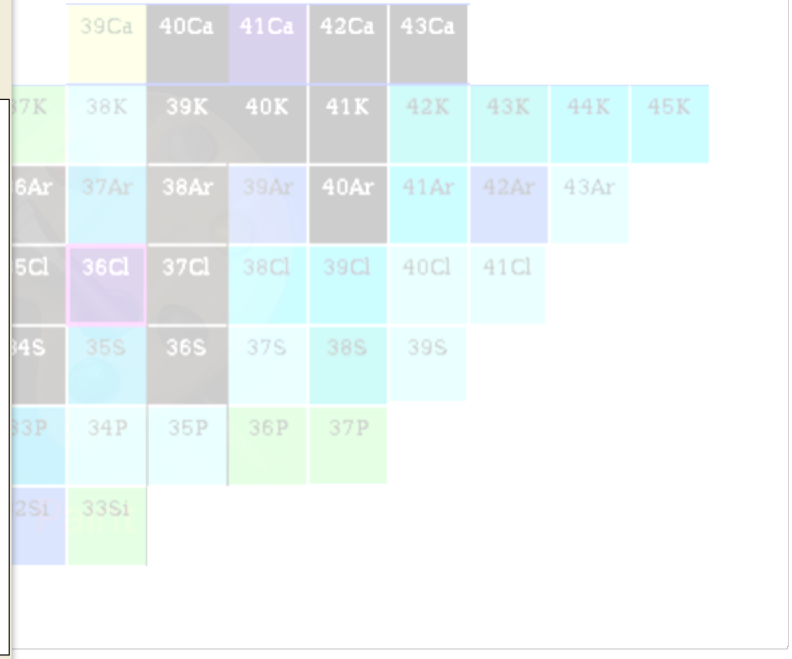

^{35}Cl(p,p'$\gamma_{1\text{-}0}$)^{35}Cl

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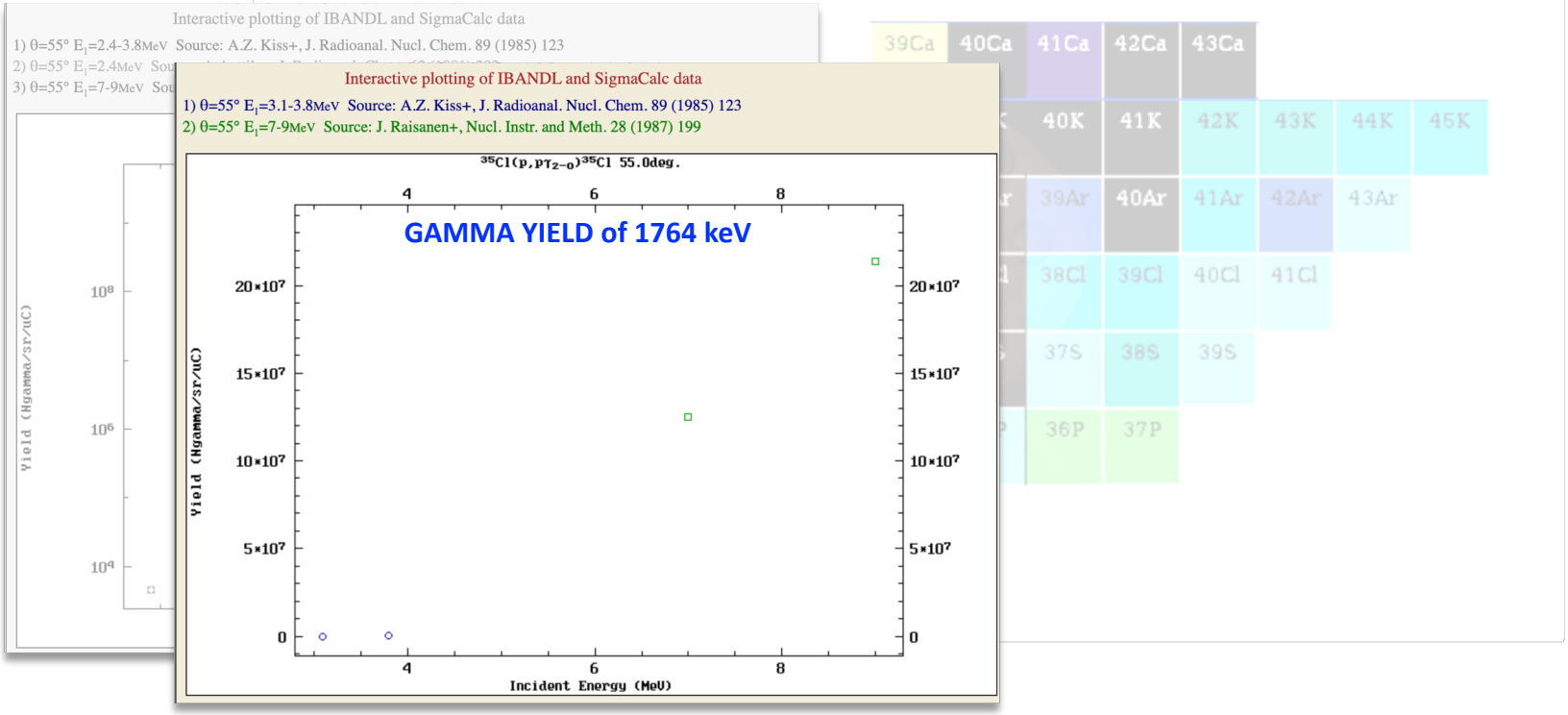

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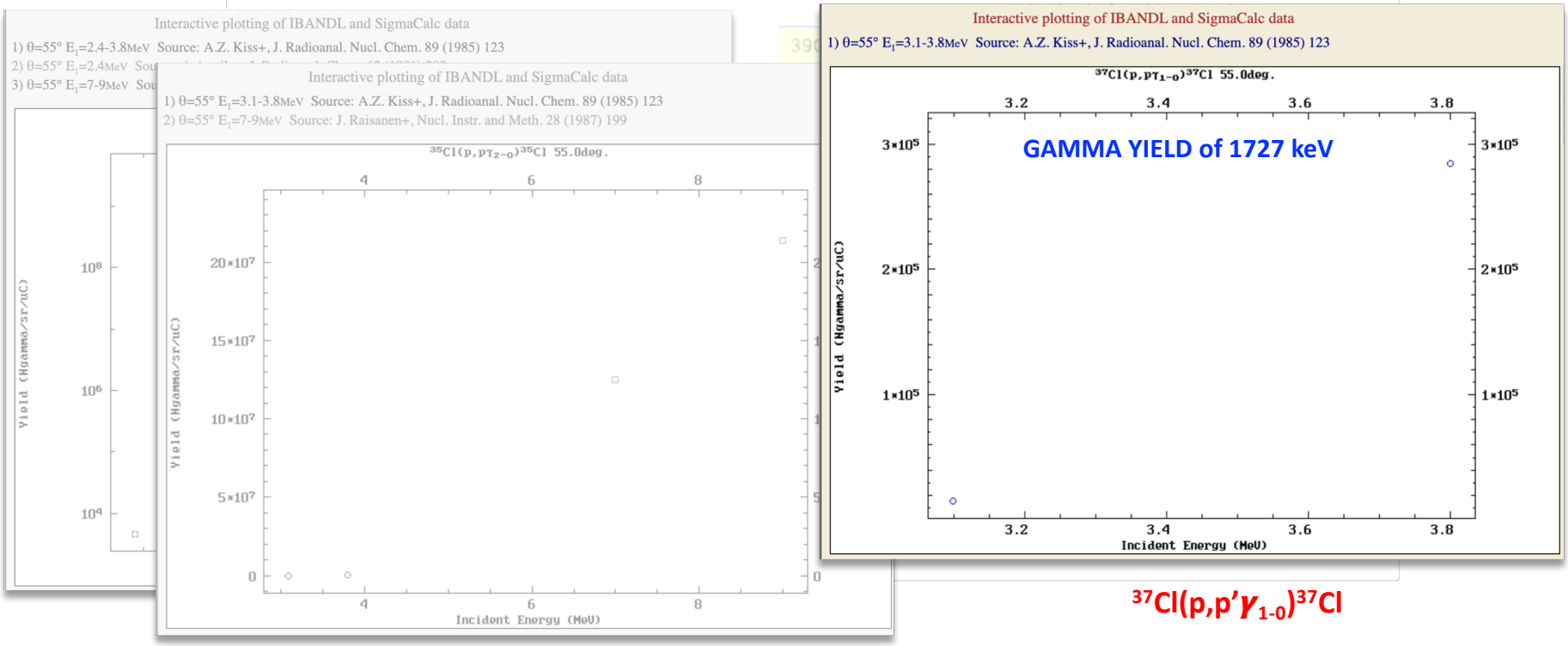

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GOAL:

The purpose is to provide ^{35}Cl and ^{37}Cl cross section data at low energies completing, and adding to the available data sets. The experimental campaign will take place at the CTN/IST Laboratory (Sacavém) using an HPGe detector.

TÉCNICO LISBOA

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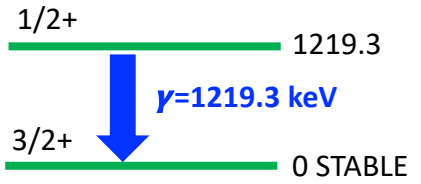
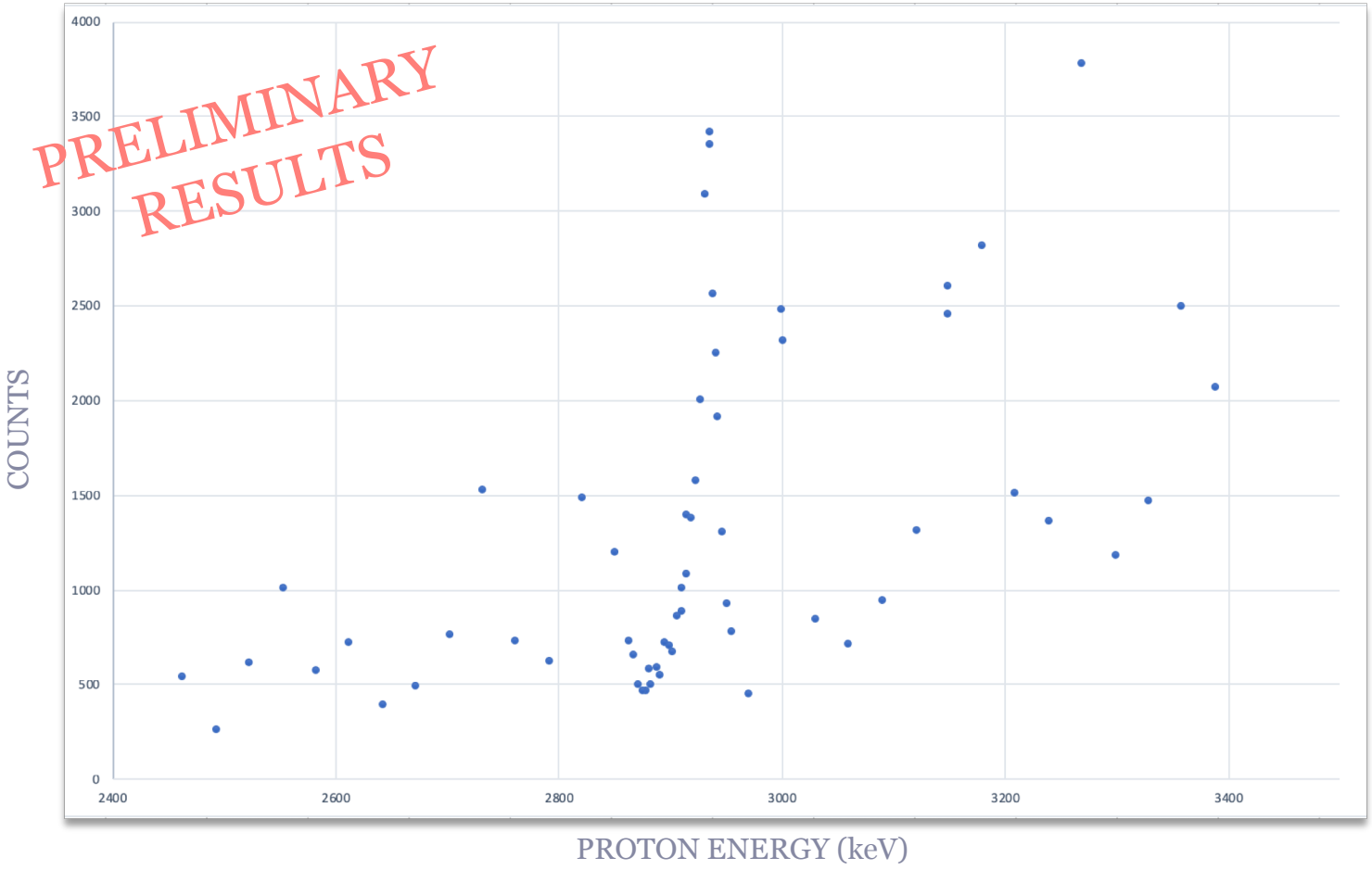
PIGE: EXPERIMENTAL ANALYSIS OF CLHORINE

TARGET: AgCl

$^{35}Cl(p,p'\gamma_{1-0})^{35}Cl$



GAMMA YIELD of 1219.3 keV



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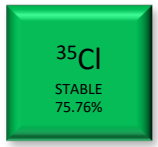

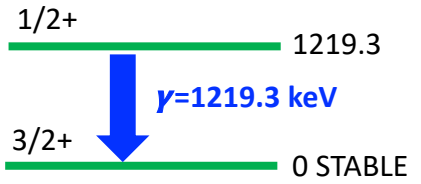

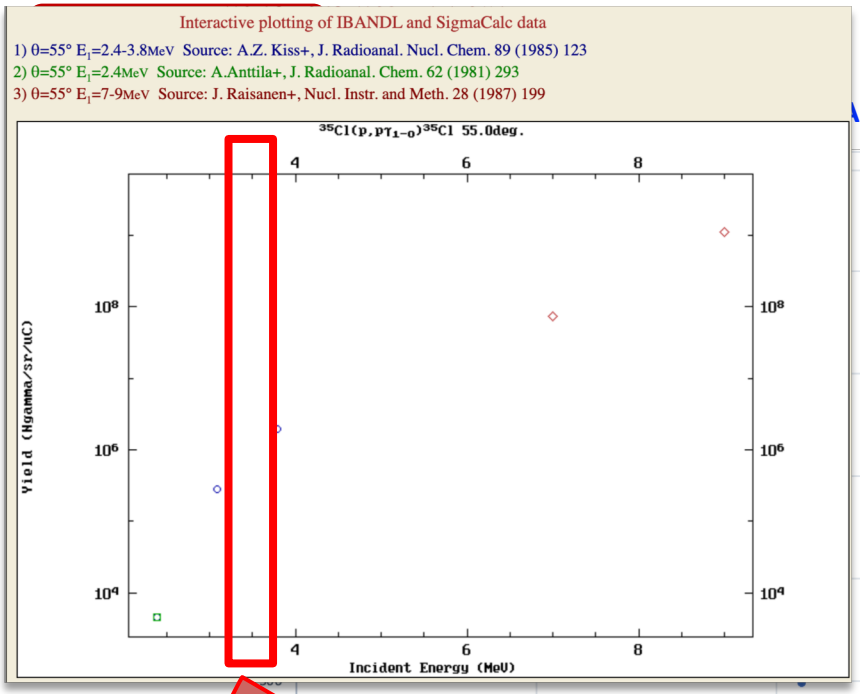

YIELD of 1219.3 keV

$^{35}Cl(p,p'\gamma_{1\text{-}0})^{35}Cl$

PROTON ENERGY (keV)

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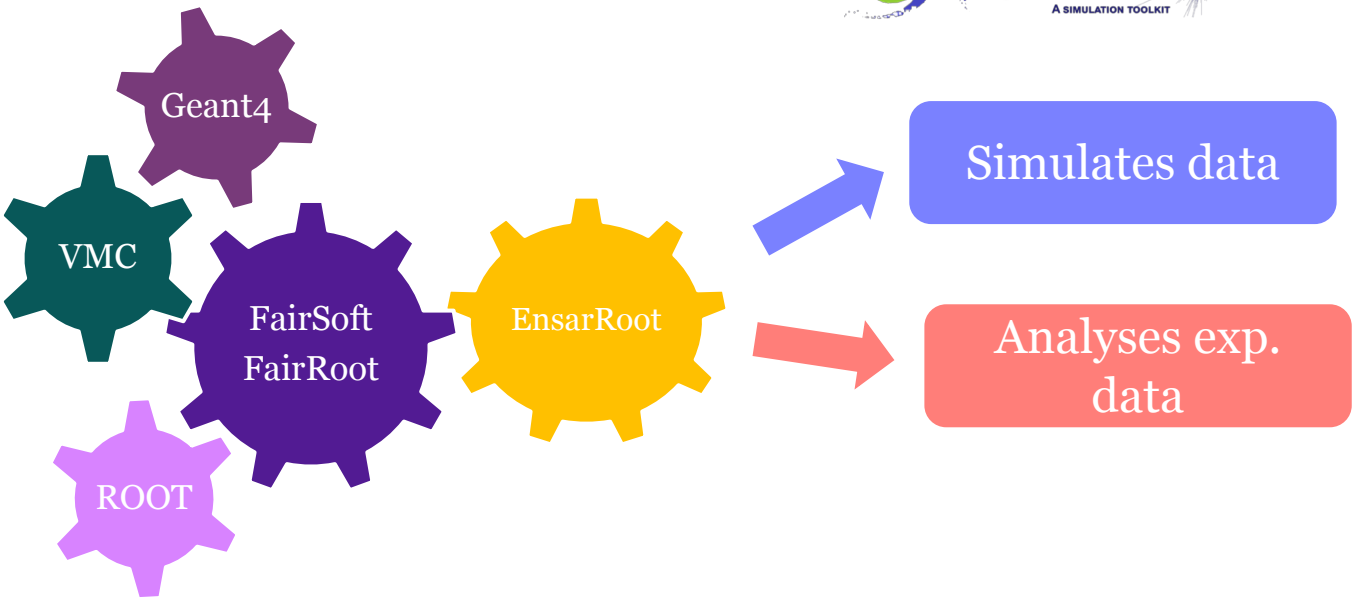
ENSARROOT FRAMEWORK

EnsarRoot consist on a VMC framework for the analysis and simulation of different moderate size setups and tools.

https://github.com/EnsarRootGroup/EnsarRoot
http://igfae.usc.es/satnurse/ensarroot.html
Pablo Cabanelas et al J. Phys.: Conf. Ser. 1024 012038 (2018)

It is based on

- **FairSoft** and **FairRoot** which are fully based on the **ROOT** code
- **Virtual Monte Carlo** platform
- Supports different transport engines, such as Geant3 and **Geant4**.



It is possible to **simulate data** and perform the **data analysis** within the same framework. Moreover, **experimental data can be analysed** on equal footing.

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SUMMARY

- **PIGE** technique is a widely used IBA method which **analyses gamma yields** of excited **low Z elements** present in organic samples, archaeological remains, paintings, etc.

- The aim is to provide the **missing PIGE information** regarding these two essential stable isotops: ^{35}Cl and ^{37}Cl

- An **experimental campaing** has been initiated to be carried out at **CTN/IST Laboratory** to measure the **gamma yields** and the **cross sections** of these two isotopes

- The data (simulated and experimental) will be analysed using the **EnsarRoot framework,** it will be **further developed to include PIGE** analysing tools

Cofinanciado por:

Thanks to my supervisors & collaborators:

Daniel Galaviz[3,4], Héctor Alvarez-Pol[1,2], Pablo Cabanelas[1,2], Pamela Teubig[3,4]
Eduardo Alves[5], Rui C. da Silva [5], Luís Peralta [3,4], Sandra Soares [4,6]

[1]Universidad Santiago de Compostela, [2]IGFAE
[3]Faculdade de Ciências da ULisboa, [4]LIP, [5]CTN/IST,
[6]Universidade da Beira Interior

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Thanks for your attention!

Questions?

Suggestions?

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APENDIX

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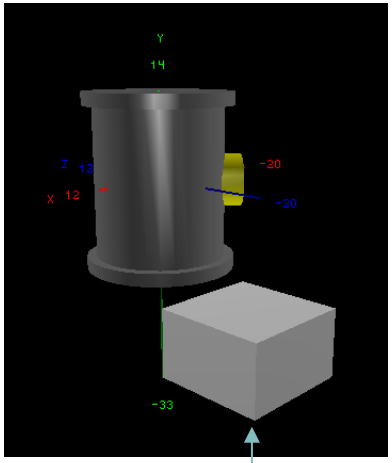
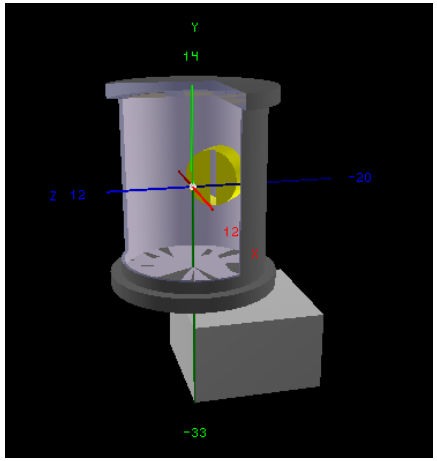
ENSARROOT DEVELOPMENTS

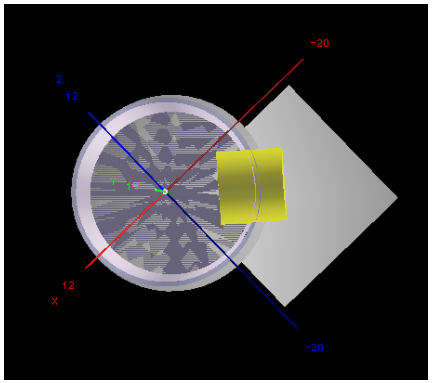
Setup Simulation

The purpose of this part was to **simulate** the detailed experimental **setup of CTN/ITN (Lisbon),** including a high resolution **HPGe detector** and a **reaction chamber** within the air media,





Silicon layer of 12.20 cm The earth is made by an outer silicate solid crust.



Uranium & Thorium & Actinium chains: the parent nuclei are located in rocks, walls and other building materials, for this reason, the simulated setup should be modified including a **Silicon layer** under the HPGe detector. Otherwise, we will lose the **energy lost effect** produced when **gammas travel through matter**.

*The thickness of this layer has been calculated using the fundamental **Law of Gamma Attenuation** for the 265 keV 212Pb peak (Thorium chain).*