γ-electron coincidence measurements with the BeGam set-up on the $^{70}Zn(p,x)$ reaction products

Proton @ LNL Workshop

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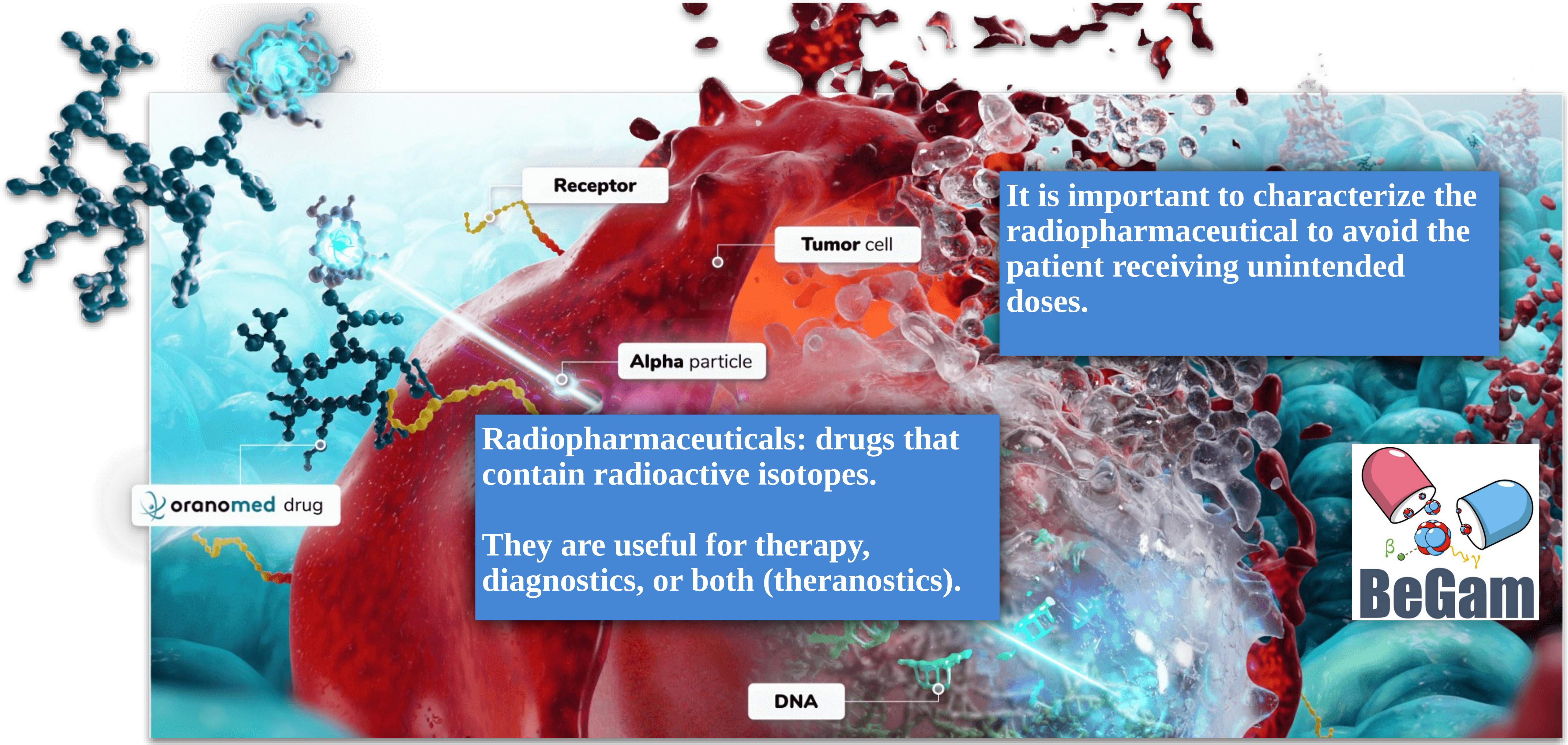
BeGam: β and γ discrimination in radiopharmaceuticals



It is important to characterize the radiopharmaceutical to avoid the patient receiving unintended doses.

Radiopharmaceuticals: drugs that contain radioactive isotopes.

They are useful for therapy, diagnostics, or both (theranostics).

BeGam

Isotope Production

Reaction: ^{70}**Zn(p,x)** @ 35 - 50 MeV

	T1/2	Reaction channel on ^{70}Zn target		Q-value (MeV)	Threshold (MeV)
^{67}Cu	61h	p,α	b- 100%	2.619	0
		p,p+t		−17.195	17.443
		p,n+^{3}He		−17.959	18.218
		p,2d		−21.228	21.534
		p,n+p+d		−23.452	23.790
		p,2n+2p		−25.677	26.047
^{64}Cu	12h	p,3n+α	EC b+ 61.5% b- 38.5%	−23.490	23.829
		p,n+2t		−34.822	35.324
^{61}Cu	3h	p,4n+2t	EC b+ 100%	−62.477	63.377
^{67}Ga	3 d	p,4n	EC 100%	−27.682	28.081
^{66}Ga	9 h	p,5n	EC b+ 100%	−38.909	39.469
^{69m}Zn	13h	p,d	IT + b- 100%	−6.994	7.094
		p,n+p		−9.218	9.351
^{65}Zn	243 d	p,3n+t	EC b+ 100%	−35.528	36.039

^{67}**Cu** has **theranostics** applications in nuclear medicine.

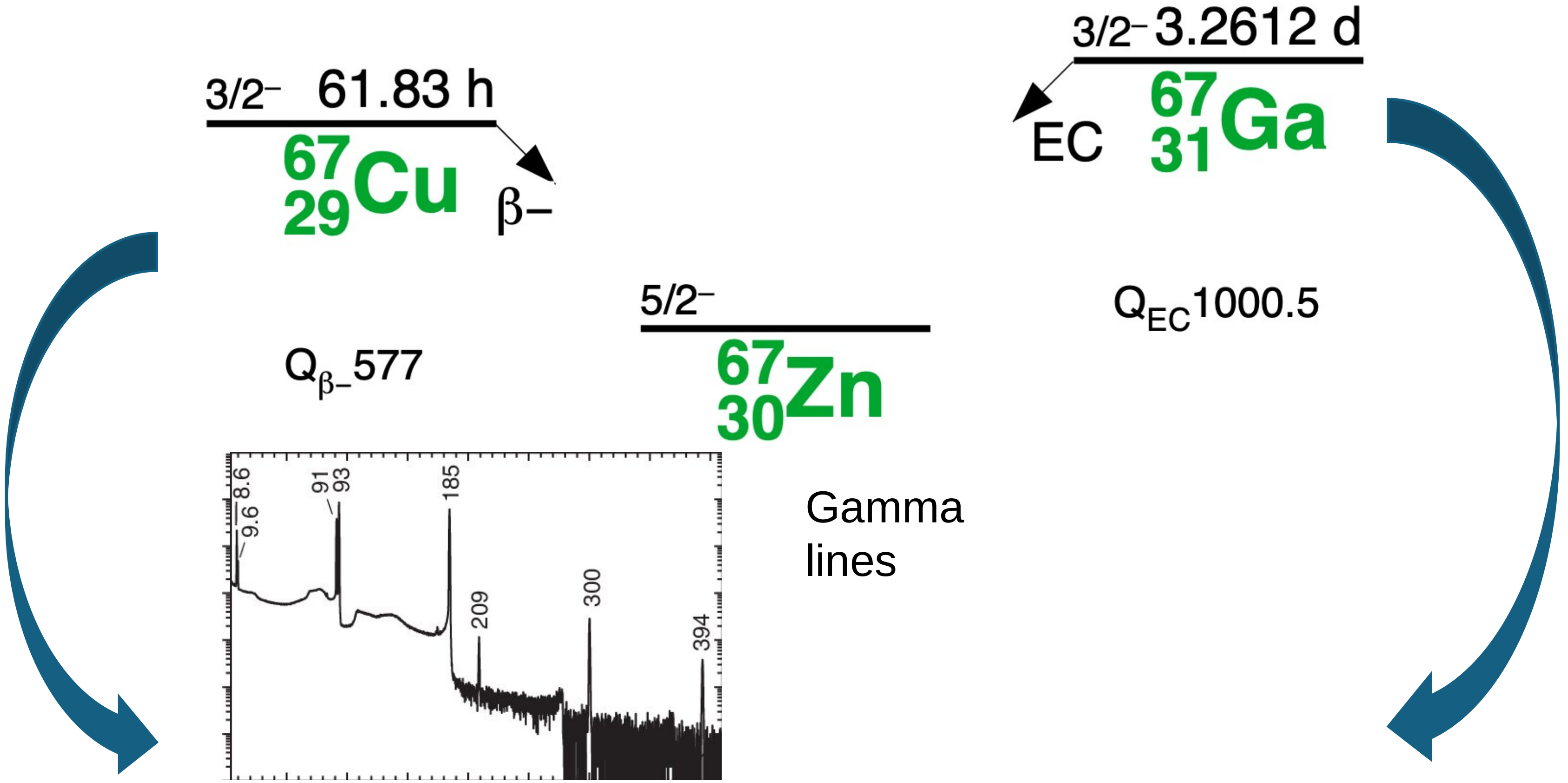
It combine **therapy** and **diagnostics** applications

Isotope Production

Major concern

Desired isotope: ^{67}**Cu**

Contaminant isotope: ^{67}**Ga** – similar half-life (**3.2** d vs **2.6** d) and **same daughter nucleus**



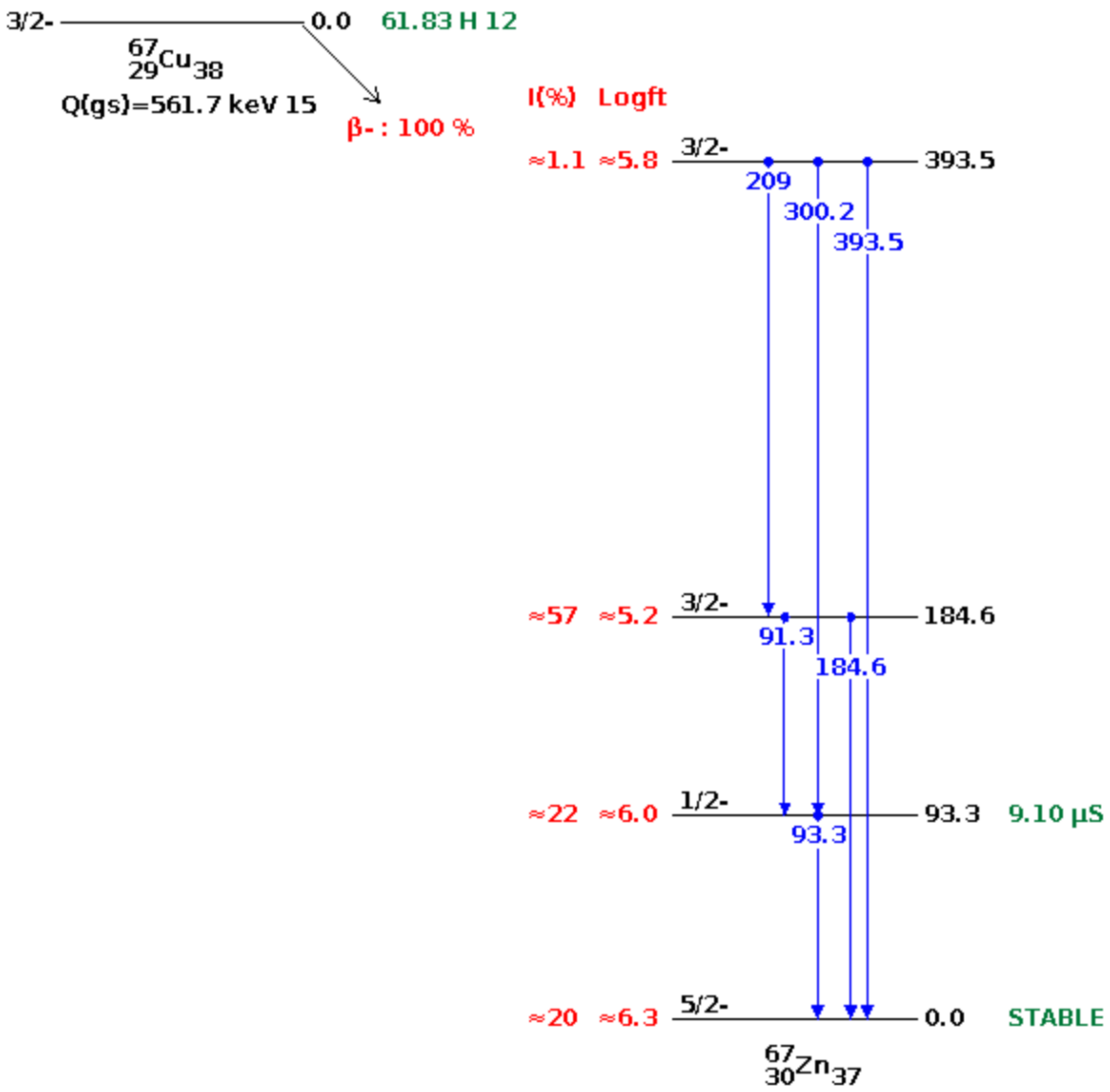
Coincidences with BeGam

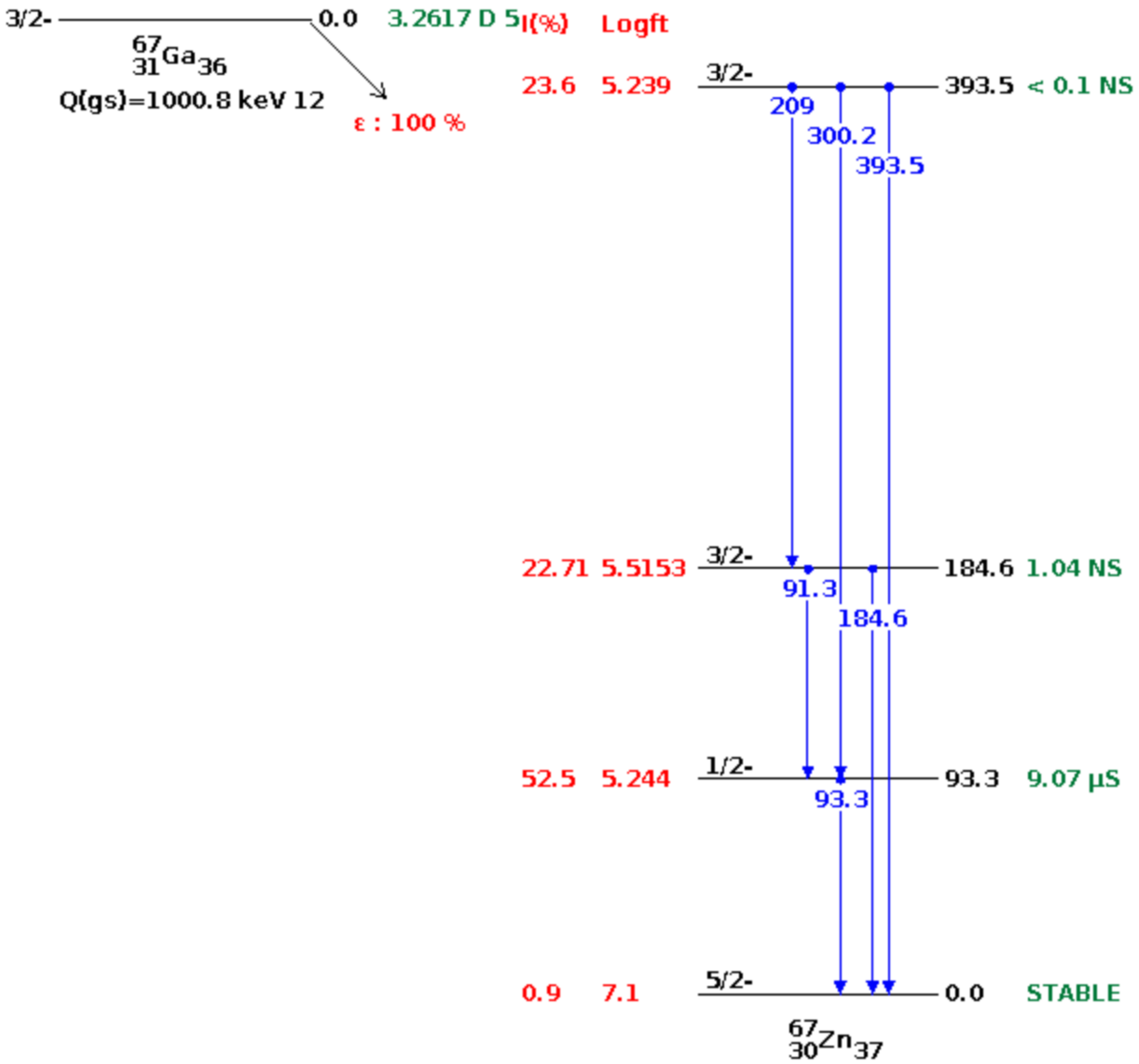
Anticoincidences with BeGam

Begam employs **coincidence** and **anticoicidence** techniques to estimate the activity of contaminants in radiopharmaceuticals

Isotope Production

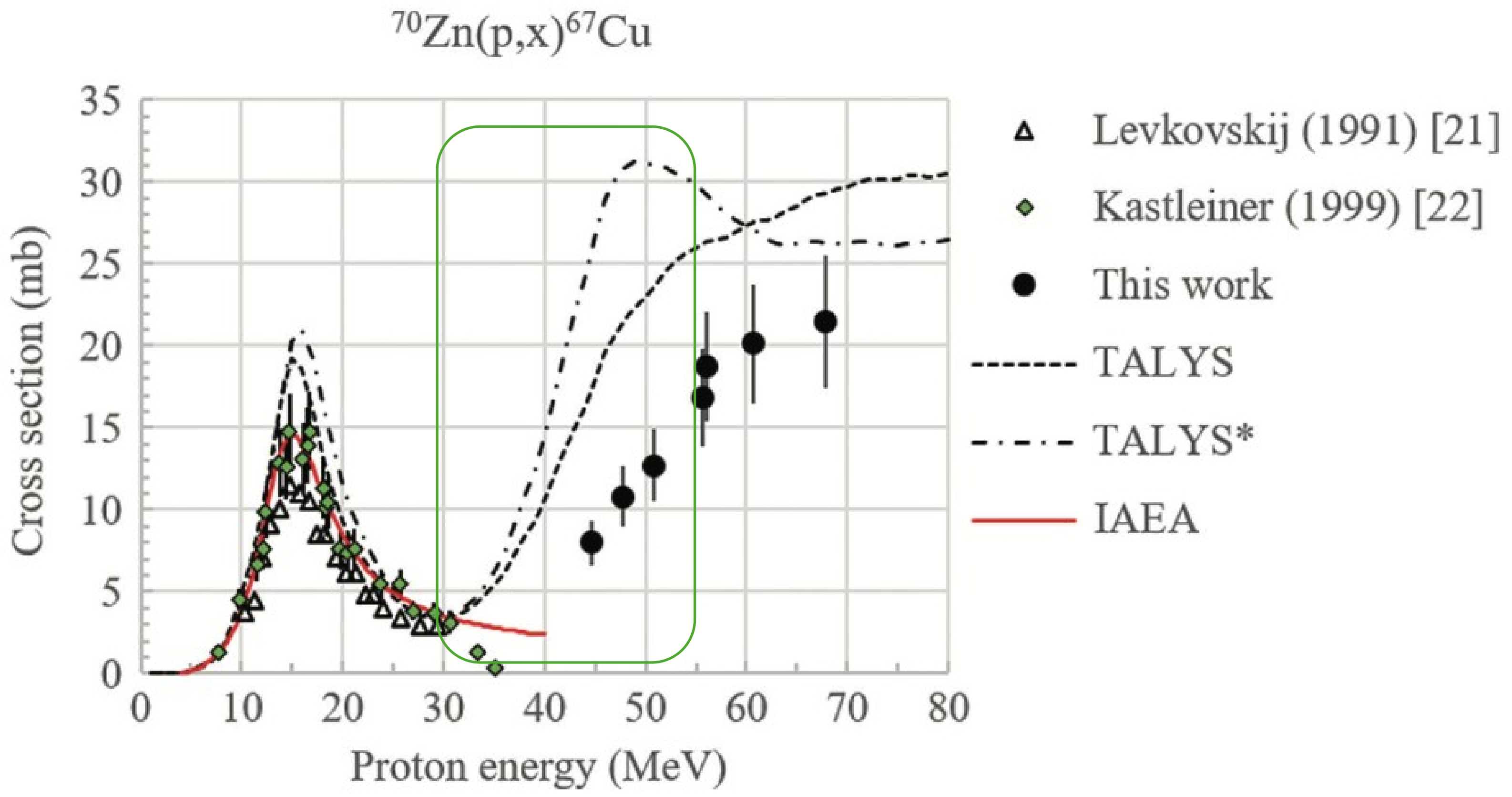
Reaction: ^{70}**Zn(p,x)** @ 30 - 50 MeV





Isotope Production: Cross Section

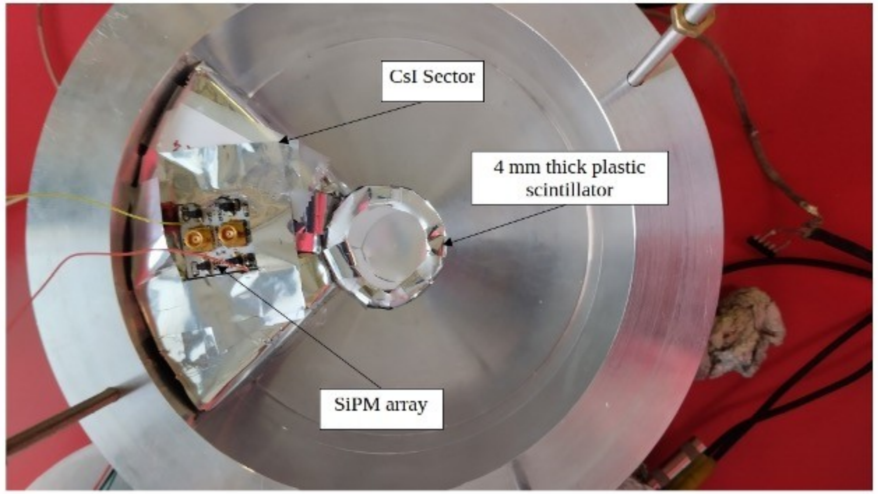
Results of the **^{70}Zn(p,x)^{67}Cu** nuclear **cross section** measured by Pupillo et al. Radiochim. Acta 2020; 108(8) 593



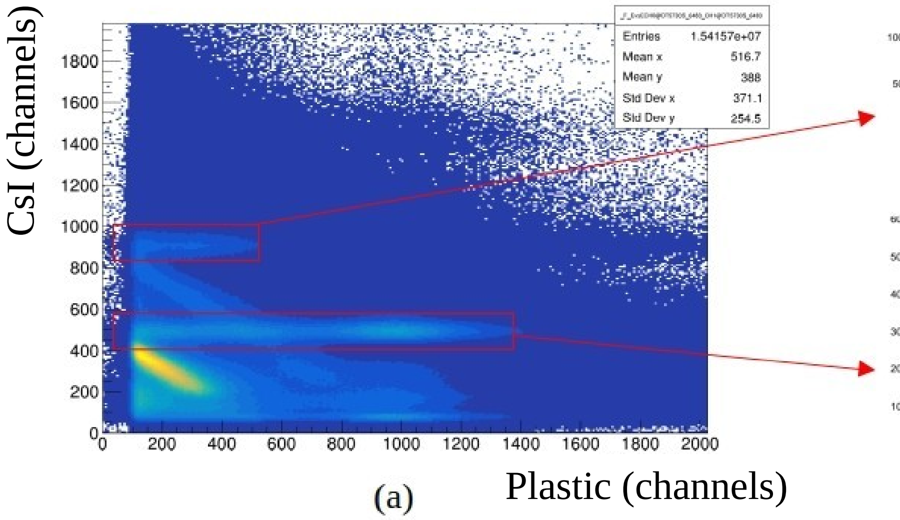
Gap between **30 and 45 MeV**

BeGam, a new apparatus for the identification of β−contaminants in radiopharmaceuticals

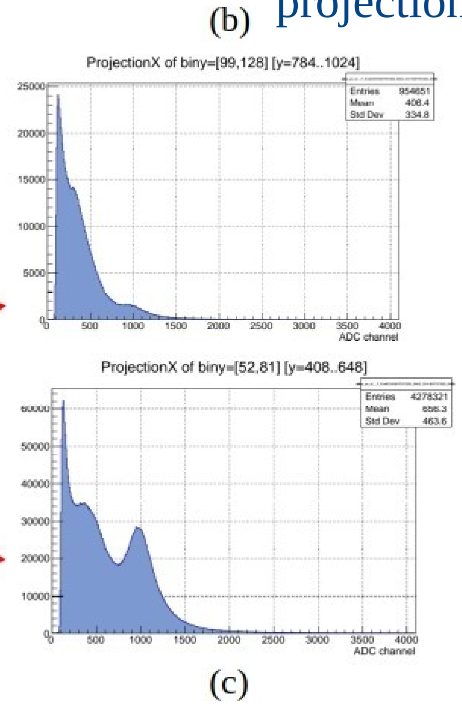
The prototype



Test with ^{207}Bi source



Plastic scintillator projections



Goal:

Perform **coincidence/anticoincidence** measuraments between the **plastic** scintillator and the **GaGG/CsI** to estimate the activity of **contaminats**

First measurements @AOUC (^{99m}Tc from ^{99}Mo generator): a lot of pile up!

To be done:

- new preamplifier with shorter decay time
- GaGG scintillator as an alternative of CsI
- thinner plastic scintillator (to minimize the Compton coincidences)

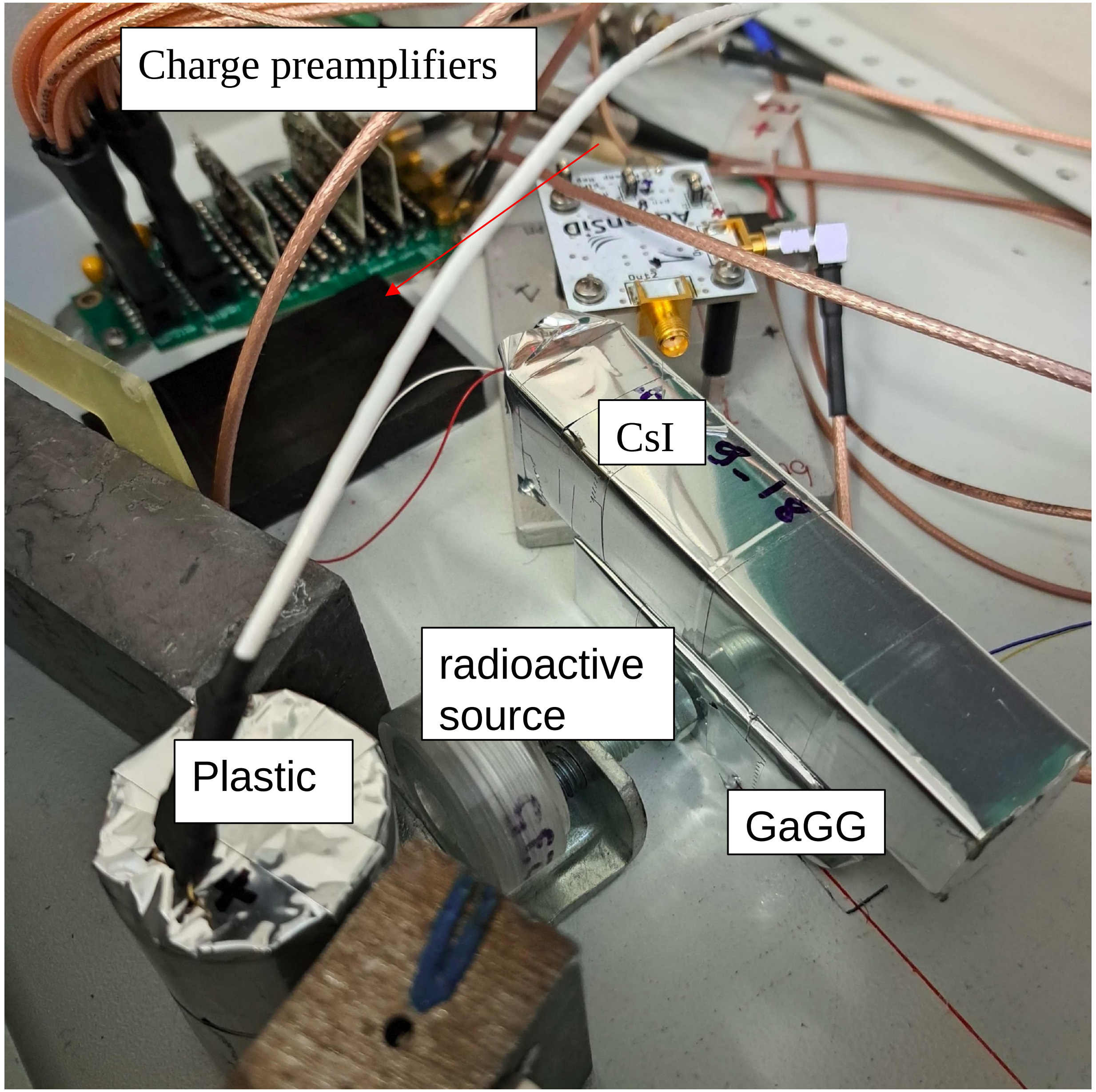
Experimental Set-Up

Scintillators:

- **CsI**: slow scintillator
- **GaGG**: fast comparable with Plastic scintillator
- **Plastic**

CsI, GaGG: **γ - spectroscopy**

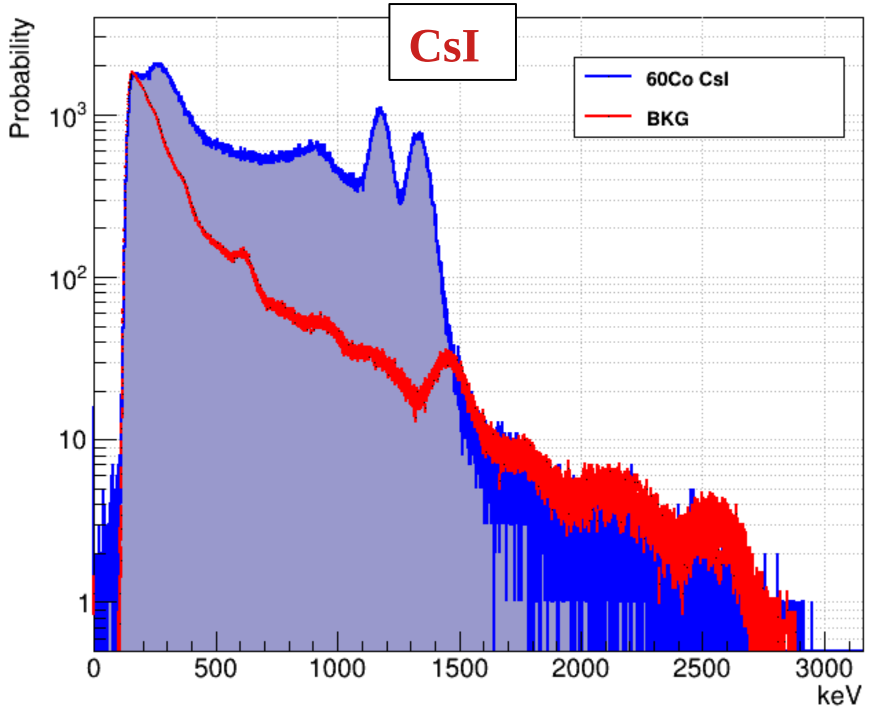
Plastic: **β - spectroscopy**

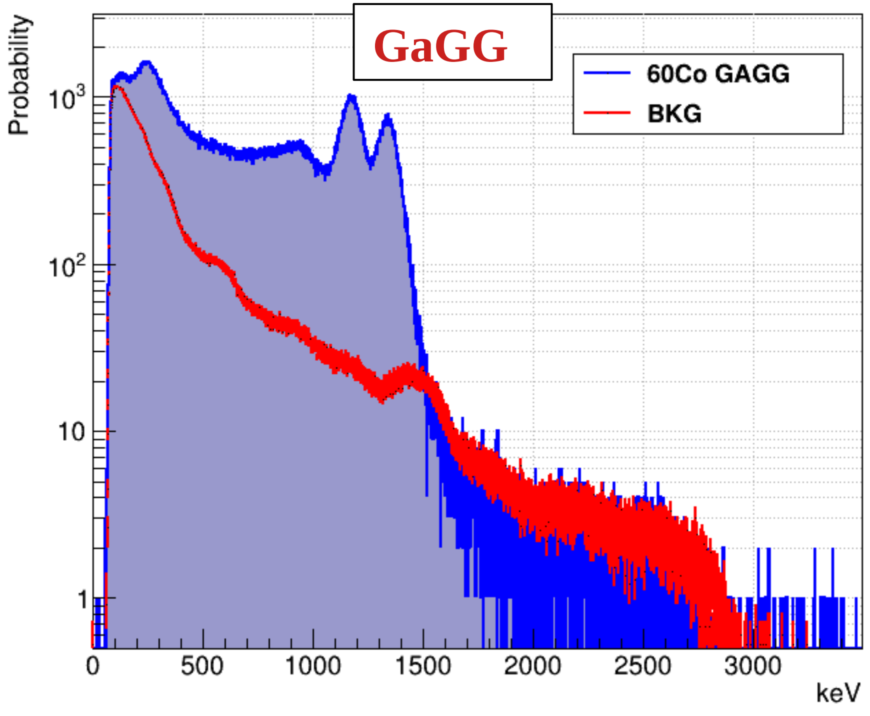


Test in Lab - 60Co (GaGG vs CsI)

Crystals dimensions - 20x20x(80/100) mm3
SiPM readout - custom **matrix** of 2x2 Broadcom 6x6mm2 SiPM tiles
Charge preamplifier - modified NeT preamplier, standard in use for the **GARFIELD** apparatus at **LNL**
Acquisition - DT5730 Caen digitizer

Blue = ^{60}Co at around 10cm from the crystal center, side irradiation
Red = Bkg with normalized run duration (no source)





Resolutions
(1332 keV)

GaGG: **8.7%**

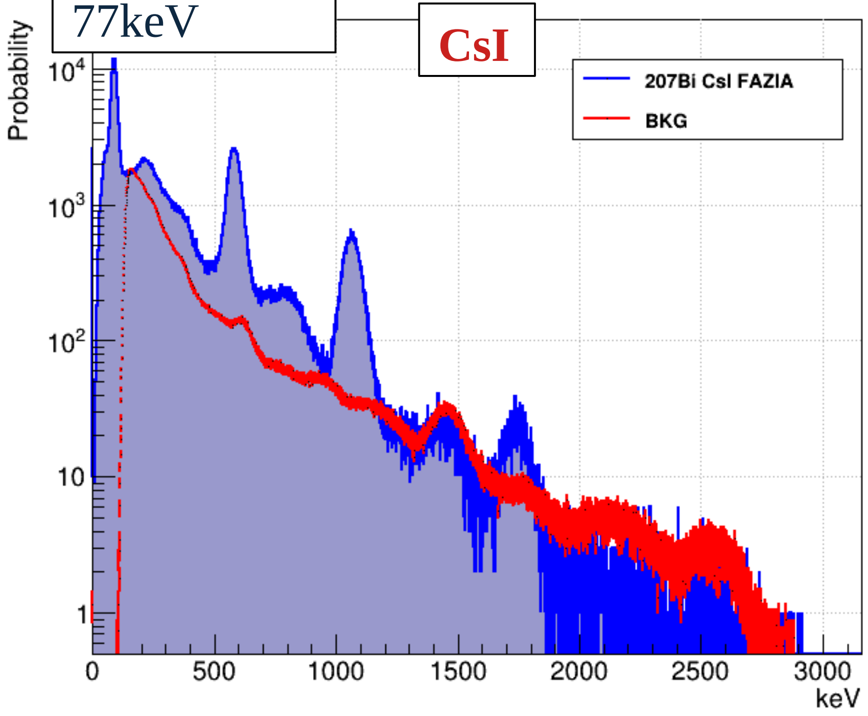
CsI: **7.5%**

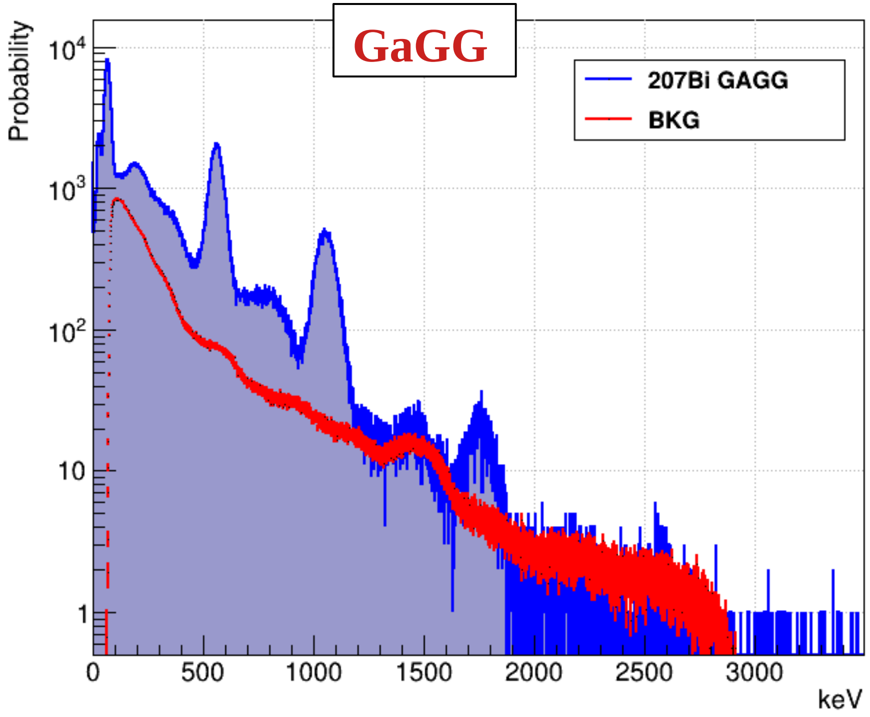
Test in Lab - 207Bi (GaGG vs CsI)

Crystals dimensions - 20x20x(80/100) mm3
SiPM readout - custom **matrix** of 2x2 Broadcom 6x6mm2 SiPM tiles
Charge preamplifier - modified NeT preamplier, standard in use for the **GARFIELD** apparatus at **LNL**
Acquisition - DT5730 Caen digitizer

Blue = ^{207}Bi at around 10cm from the crystal center, side irradiation
Red = normalized BKG (no source)

X-ray arond 77keV



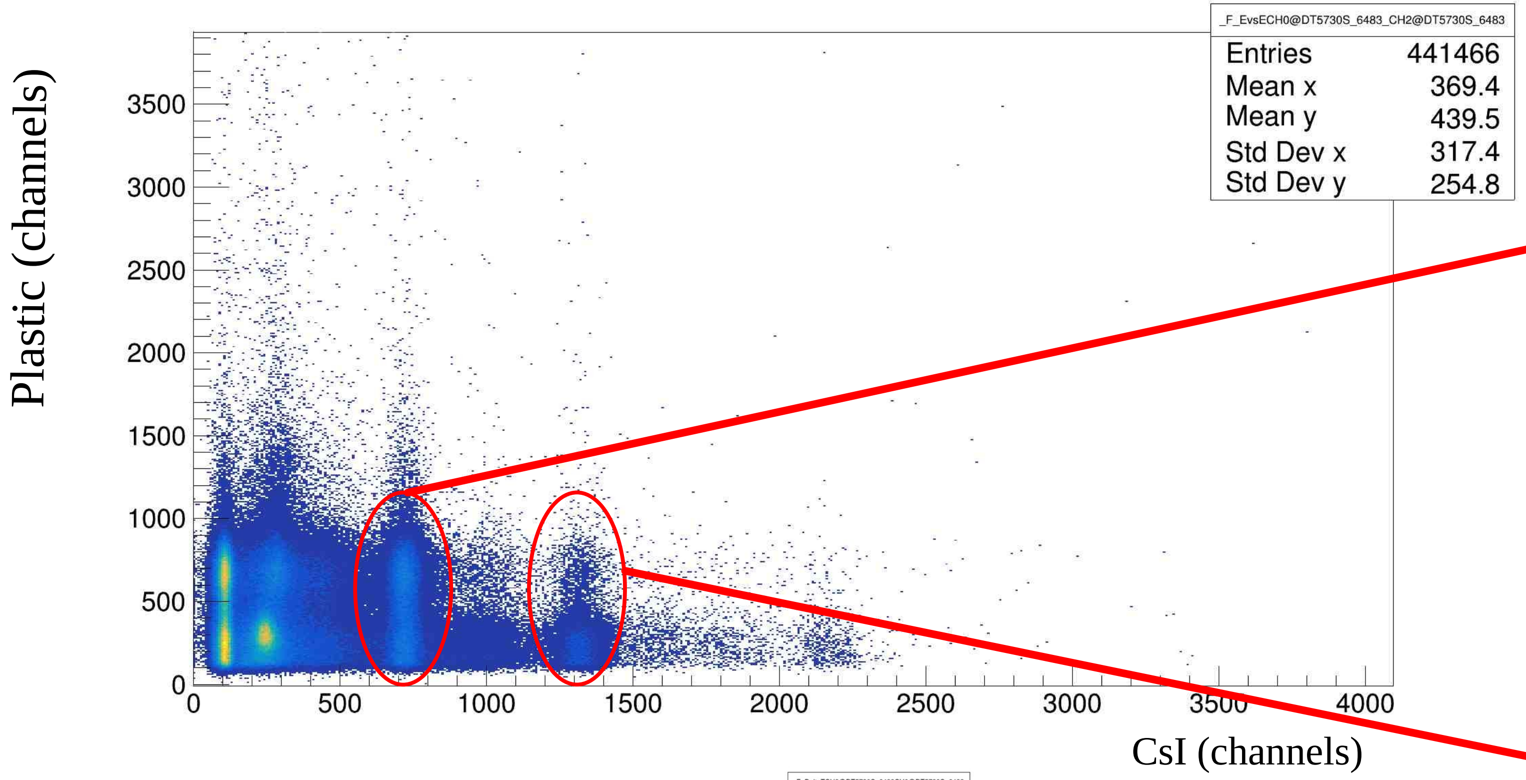


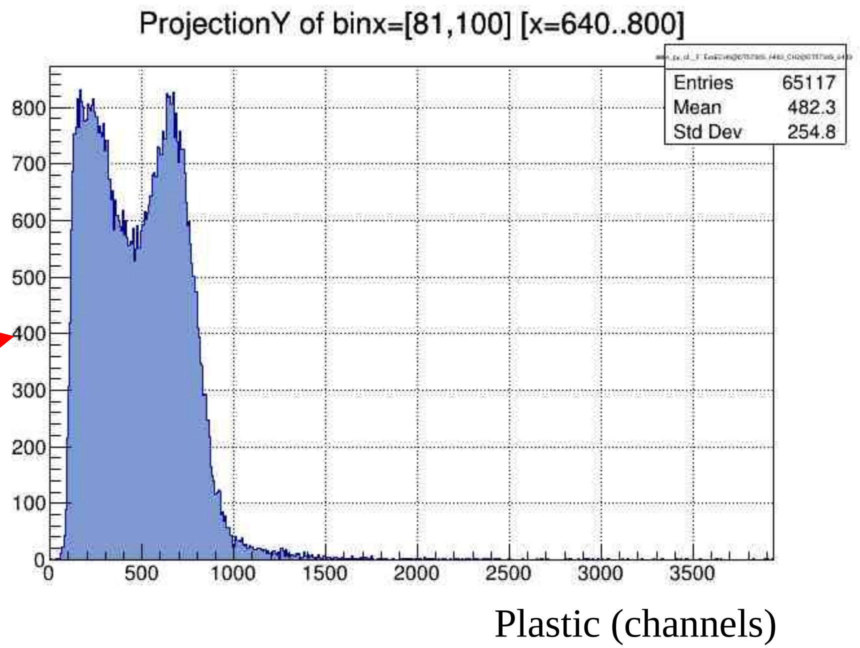
Resolutions (**560 keV**)

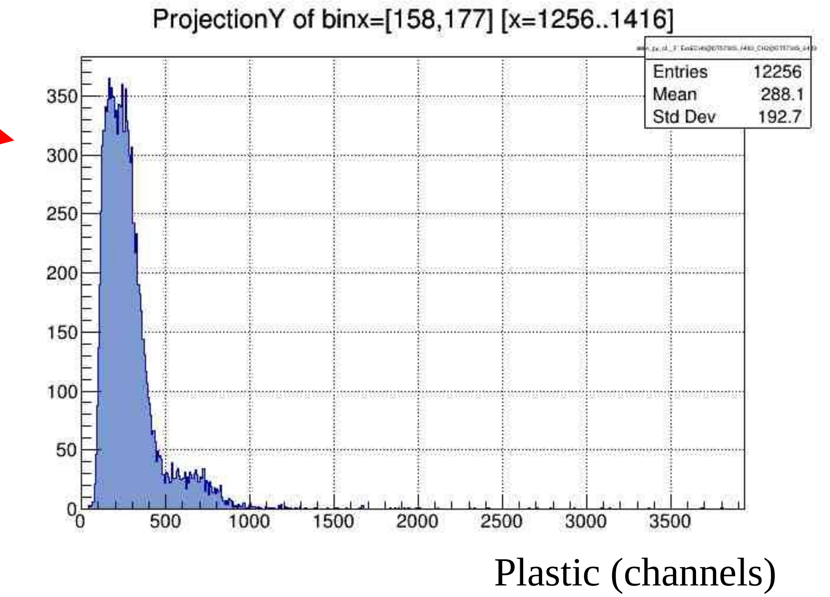
GaGG: **14.2%**

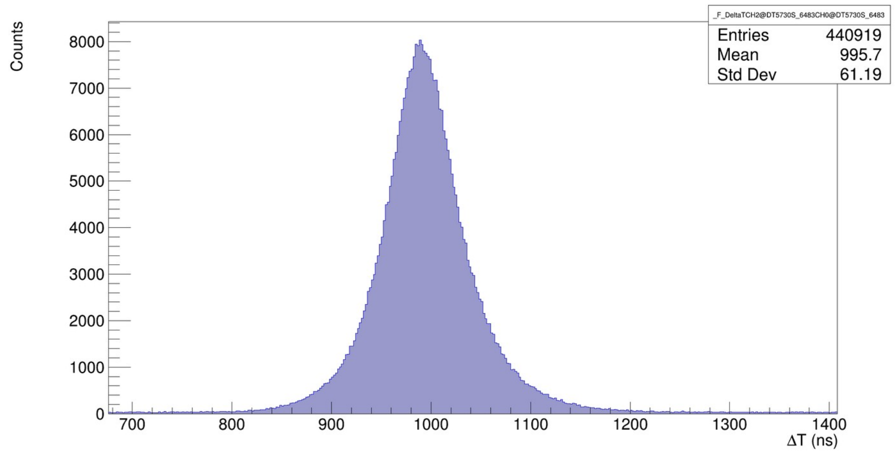
CsI: **11.8%**

CsI – Plastic coincidence







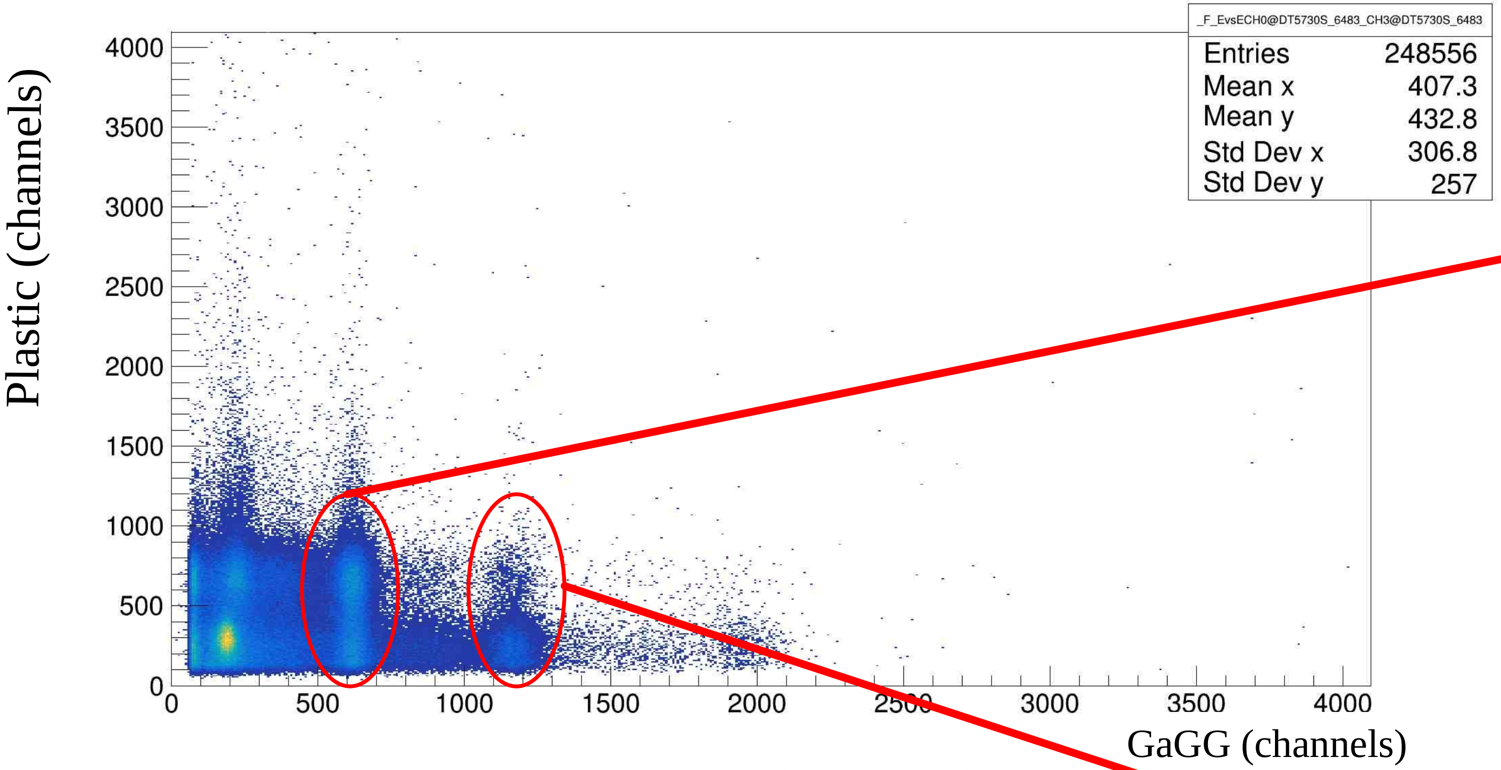


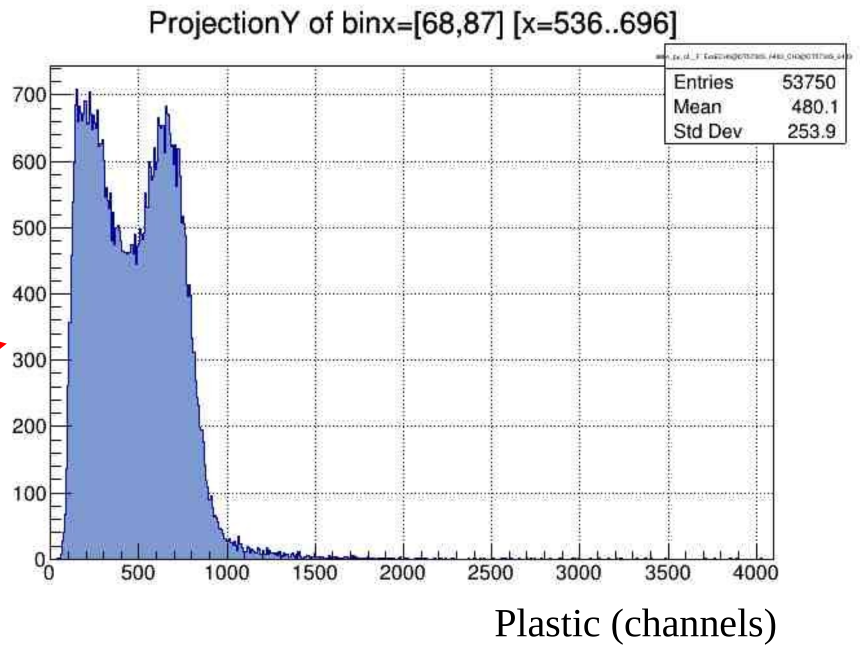
ΔT - plot

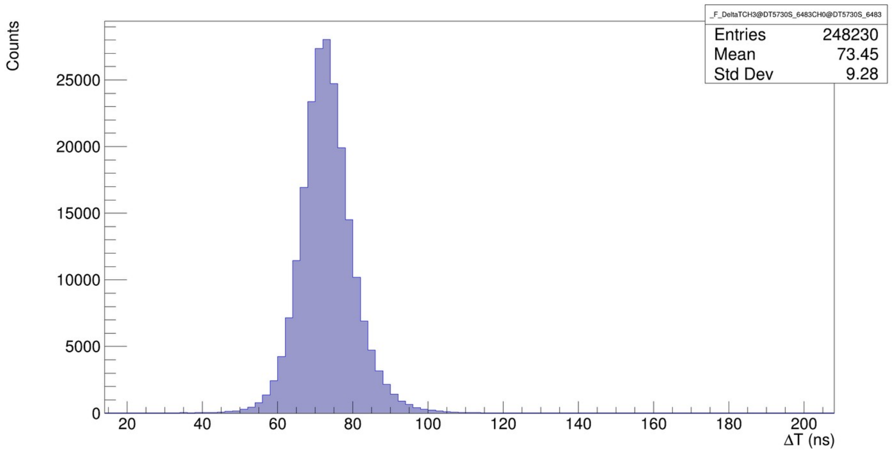
Mean 992.5 ns

FWHM 97 ns

GAGG – Plastic coincidence



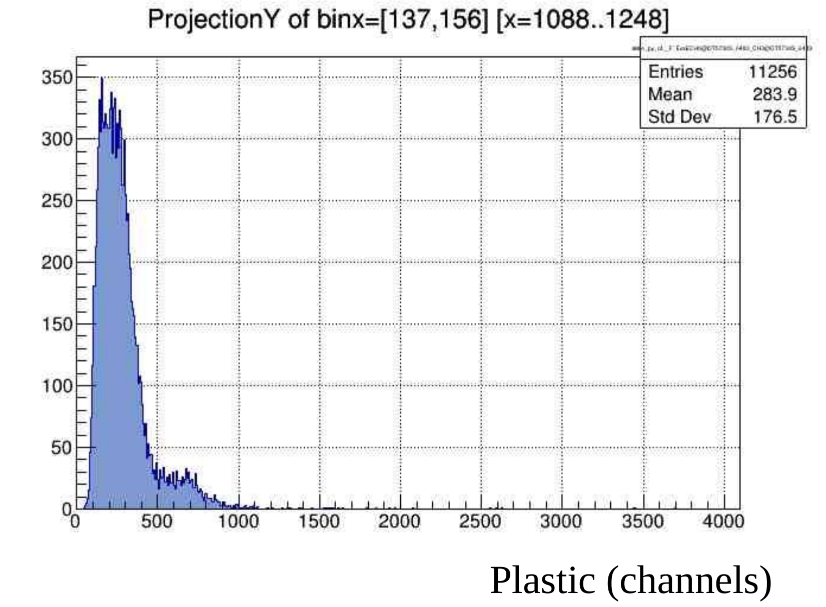




ΔT - plot

Mean 73 ns

FWHM 15.4 ns



First comments about performance of the crystals

- As expected we can have a **smaller coincidence window** with the **GaGG** scintillator

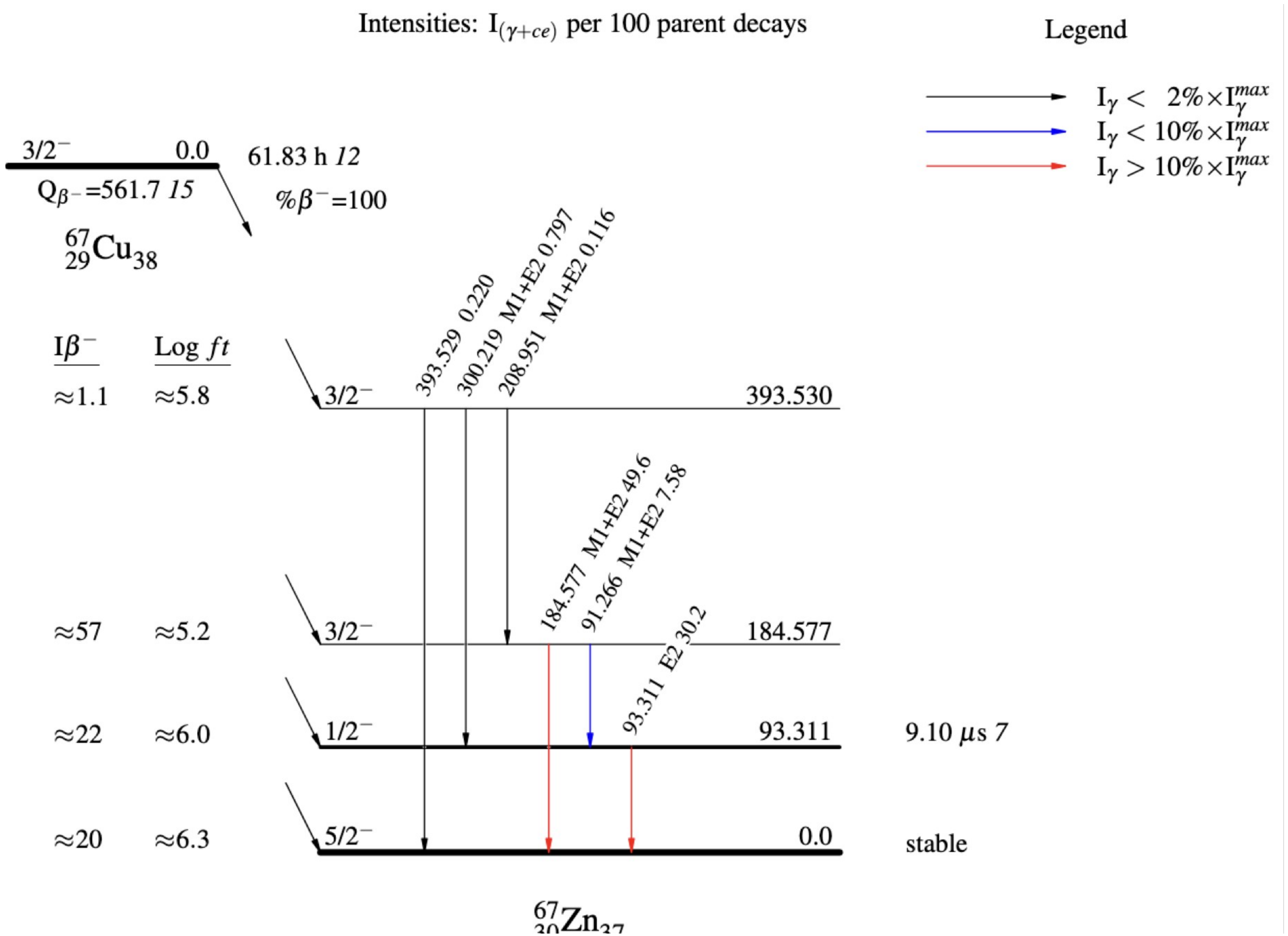
- Both crystals allow a relatively good spectroscopy from below **80keV up about 2 MeV** at least (covering in practice the range for several interesting radiopharma)

- The E-resolution for 1331keV 60Co line is **7.5% for CsI** and is **8.7% for GAGG**

Possible tests with BeGam at LNL after SPES proton irradiation

- Previous measurements: irradiation time **1.5 h for each energy -** beam current around **100 nA**
- Possible measurements - beam current **1 μA**, irradiation time **30 m**
- **5 proton energies** (30 - 35 – 40 – 45 – 50 MeV)
- Multiple target holder (?)
- After the irradiation the target will be moved to the **BeGam** apparatus for the **measurements**
- Space needed to place BeGAM in the expermintal hall: around 1m x 2m

Isotope Production: ^{67}Cu



Isotope Production: ^{67}Ga