Two proton decay of ^{48}Ni with ACTAR TPC.

Aurora Ortega Moral

CENBG (CENTRE D'ETUDES NUCLEAIRES BORDEAUX-GRADIGNAN)

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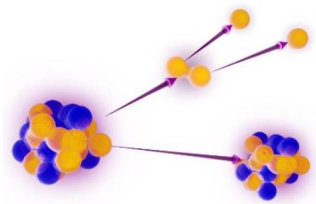
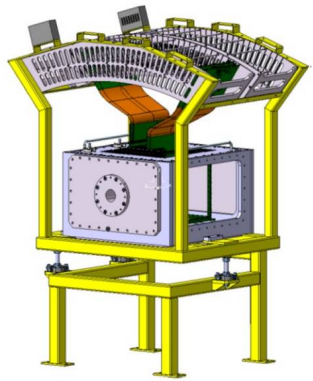
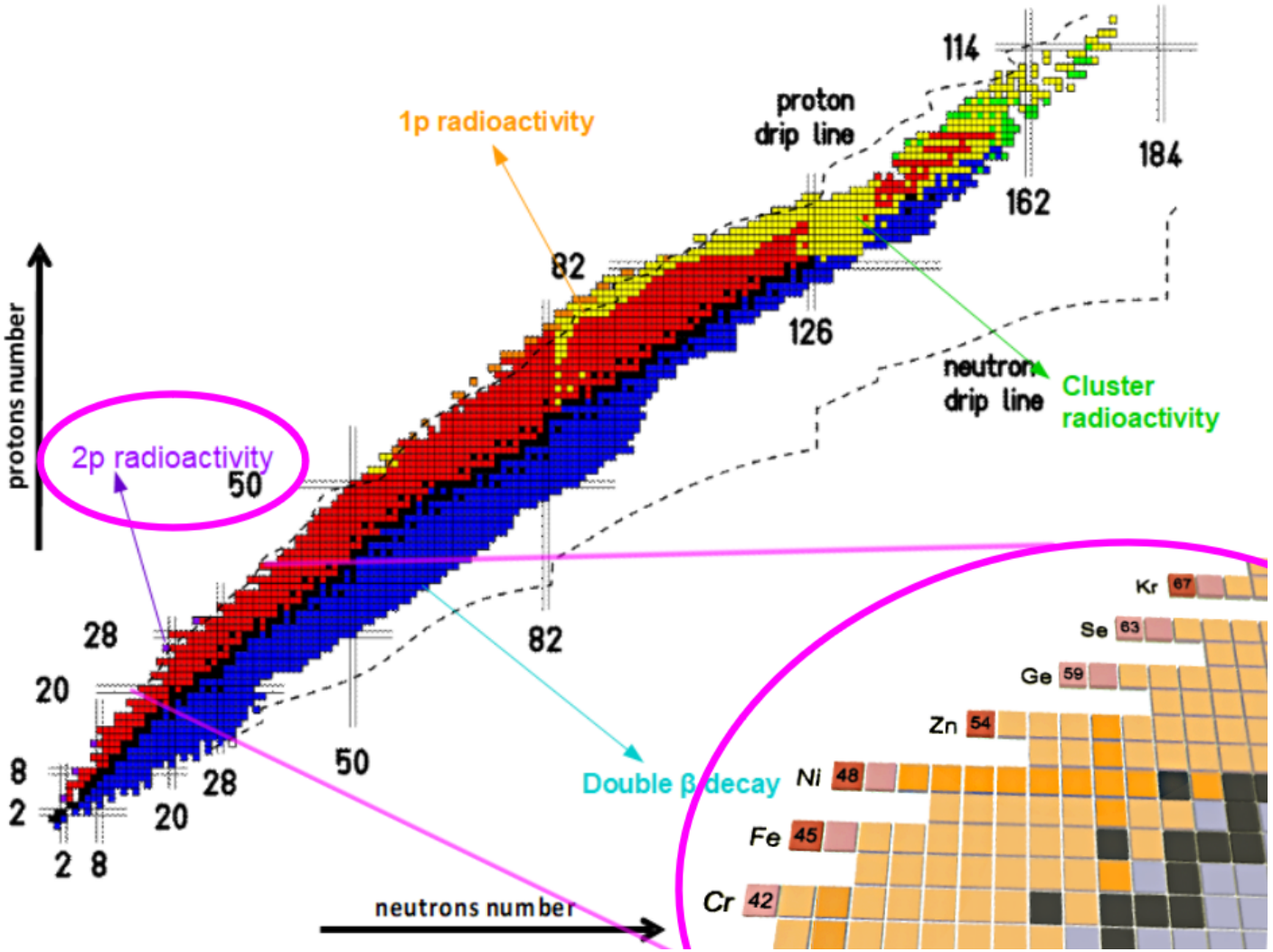


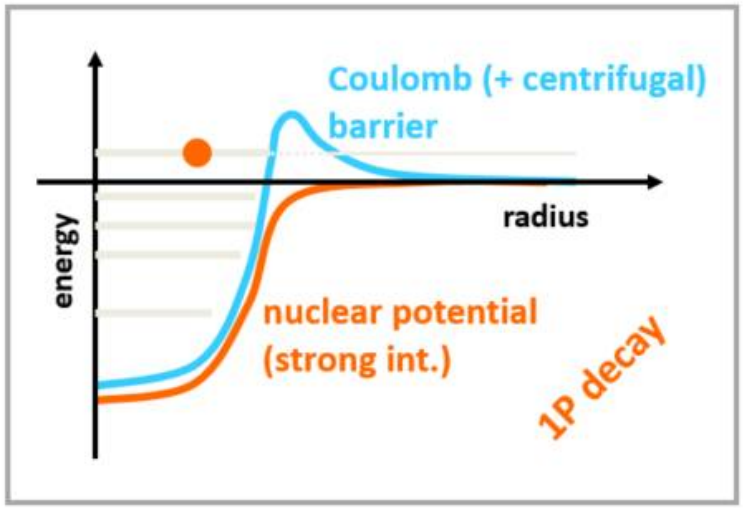
- Introduction
- Proton radioactivity
- ACTAR TPC
- Preliminary results
- Further results



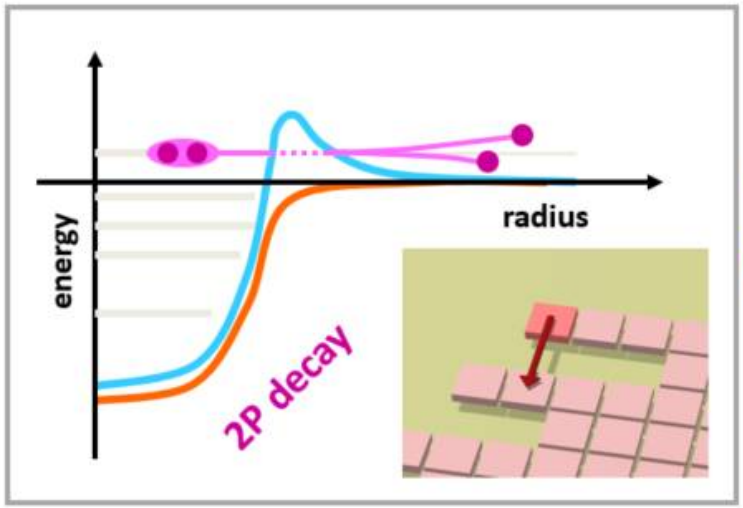
Exotic decays



Proton(s) radioactivity



odd -Z isotope



even-Z isotope

- Pairing energy : There is an extra binding energy if the number of protons are even.
- The system is strongly correlated inside and completely unbound outside (Interesting information about nuclear structure)

Theoretical models

- ***3 body model*** $\longrightarrow$ Dynamical description of the process. Angular distribution, Half life
  Agreements with (^{45}Fe) experiments
- ***Hybrid model*** $\longrightarrow$ Mixes both dynamics (3-body model) and structure (shell-model amplitudes) descriptions. Half life
  Agreements for (^{45}Fe, ^{54}Zn, ^{48}Ni)

Disagreements (^{67}Kr) $\longrightarrow$ Two new hypothesis:

- ***Semi-analytical R-matrix calculation*** $\longrightarrow$ ^{67}Kr is in an intermediate situation between 2p emission and a sequential decay process depending on the position of the intermediate state. Proton energies
  (L.V. Grigorenko, PRC 2017)
- ***Gamow Coupled Channels*** $\longrightarrow$ takes into account the ^{67}Kr deformation. Angular distribution, Half life
  (S.M. Wang & W. Nazarewicz, PRL 2018)

Theoretical models

Availability of the models

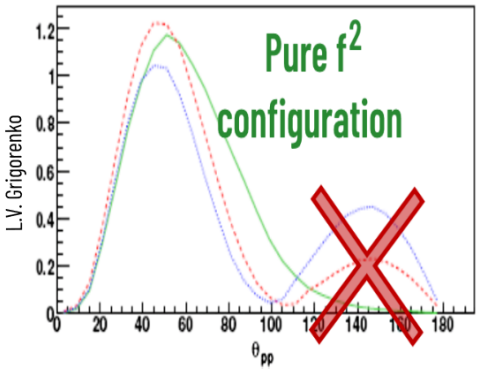
Model	Observable	^{48}Ni	^{67}Kr
3 body	$T_{1/2}$, θ_{pp}	extrapolation	-
Hybrid	$T_{1/2}$	yes	Doesn't work
R-Matrix	Ep1/Q2p	-	yes
GCC	$T_{1/2}$ & θ_{pp}	yes	yes

Why ^{48}Ni ?

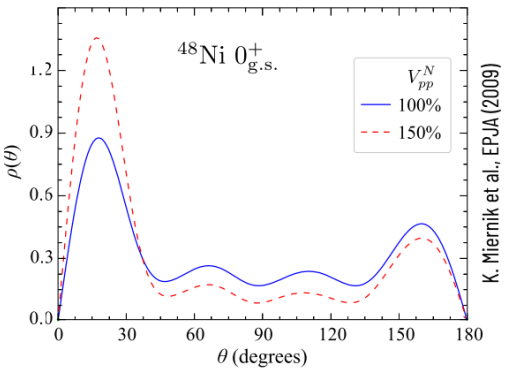
- Accesible today (GANIL)
- Different theory models available
- Spherical (benchmark for GCC model)
- Double magic nuclei (more stable)

3-body model

(extrapolation from ^{45}Fe and ^{54}Zn)

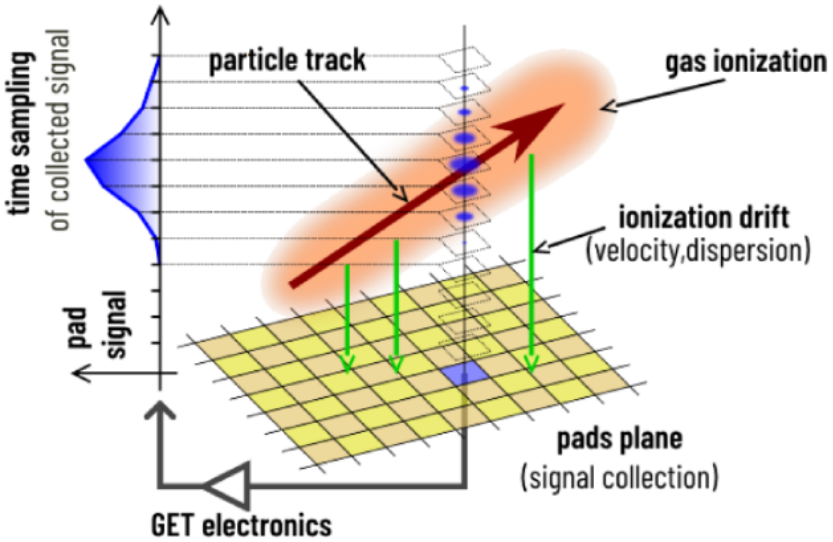


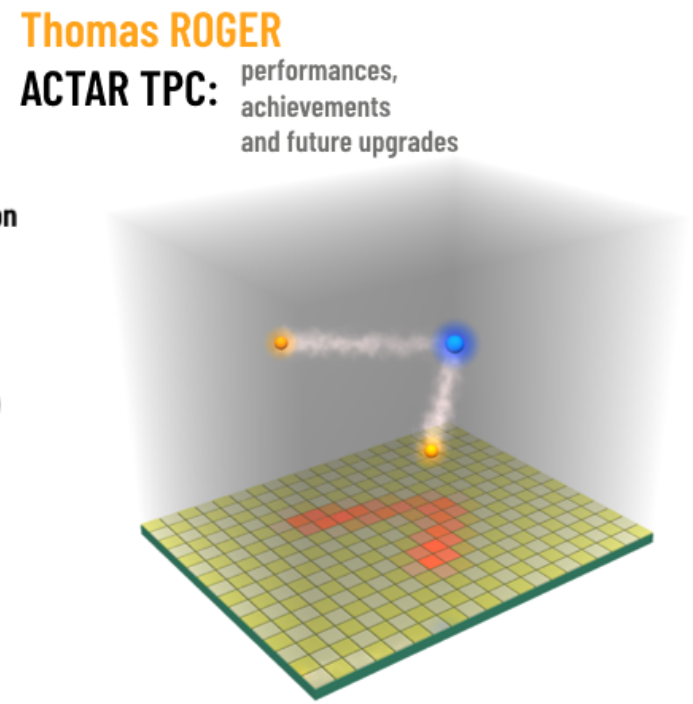
Gamow Coupled Channels (GCC) model



—> Measurement of 2p angular distribution for ^{48}Ni

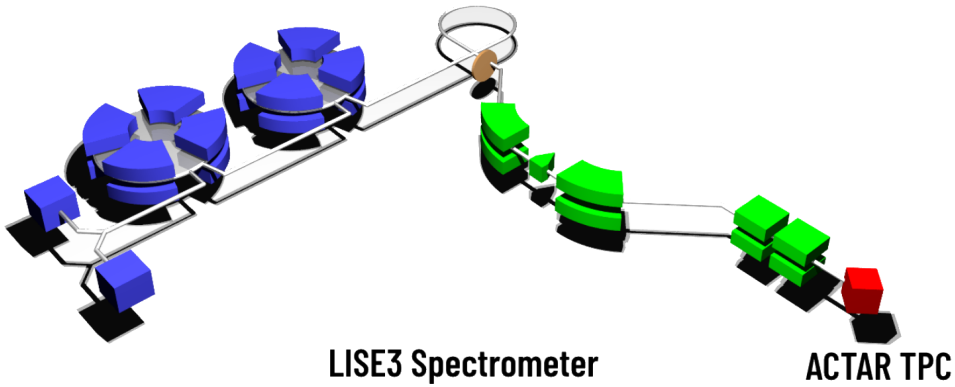
ACtive TARget Time Projection Chamber



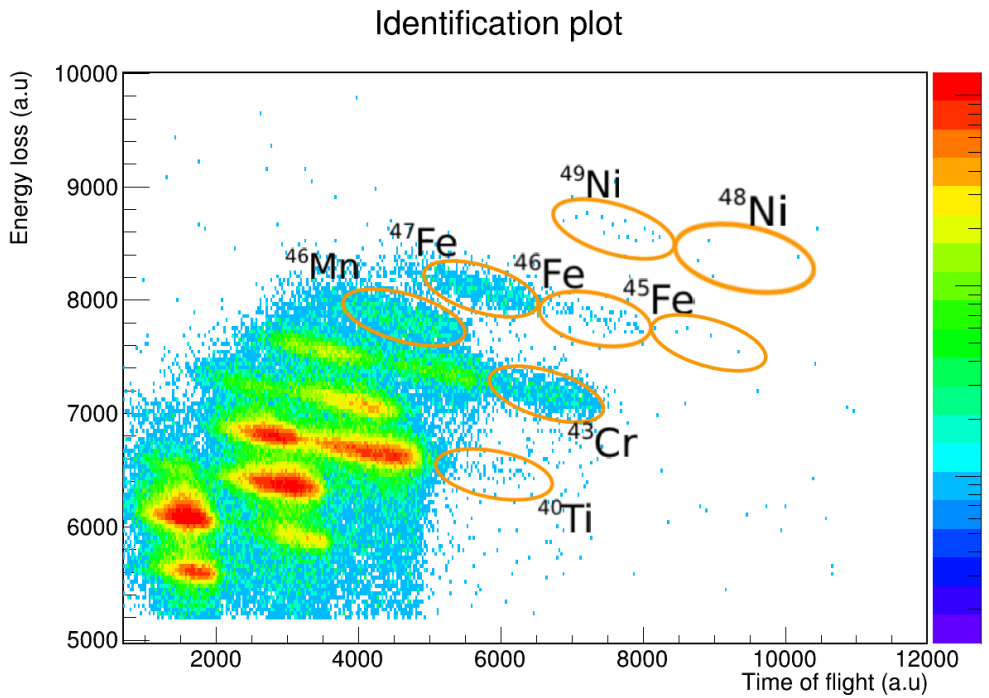


- ACtive TARget: Gas=target and detector
- Time Projection Chamber: The signal on each pad is sampled in time for full 3D reconstruction
- 16384 channels (128 x 128 pads)

Preliminary results E791 experiment (GANIL-May 2021)



Production

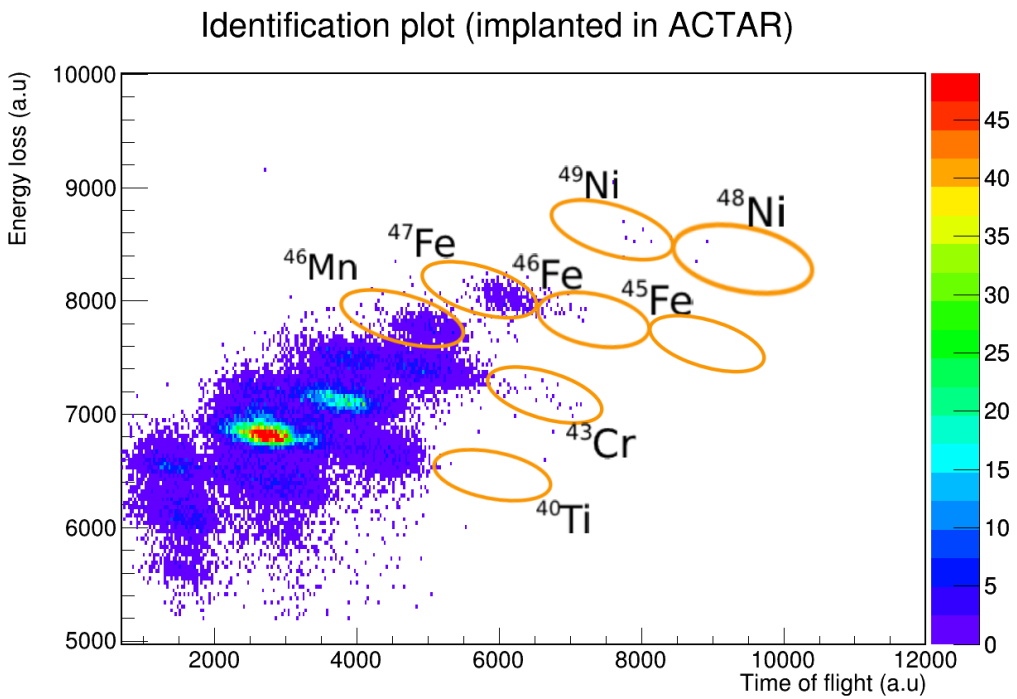


	Production	
^{40}Ti	6119	32/h
^{43}Cr	20750	
^{46}Mn	41258	
^{47}Fe	12108	
^{45}Fe	82	10/day
^{46}Fe	962	
^{49}Ni	178	1/h
^{48}Ni	11	1/day

PRELIMINARY

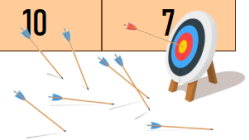
- Produced by fragmentation by a $^{58}Ni^{26+}$ beam with an intensity of about 5μ A on a 210 μm thick ^{nat}Ni target.
- Exotic fragments selected using the LISE3 spectrometer.

Implantation



	Production	Seen in ACTAR	Correctly implanted in ACTAR
^{40}Ti	6119	5707	362
^{43}Cr	20750	19132	4330
^{46}Mn	41258	4913	4773
^{47}Fe	12108	2312	2264
^{45}Fe	82	75	13
^{46}Fe	962	794	553
^{49}Ni	178	72	68
^{48}Ni	11	10	7

PRELIMINARY

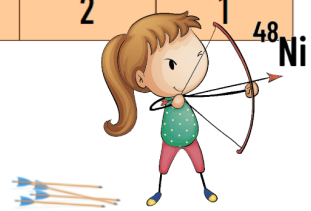


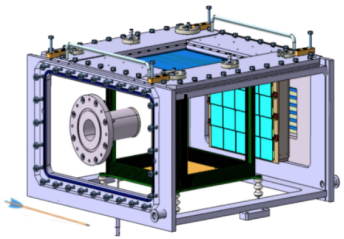
- Optimized for ^{48}Ni.
- Long tuning time due to a low production rate of exotic nuclei .

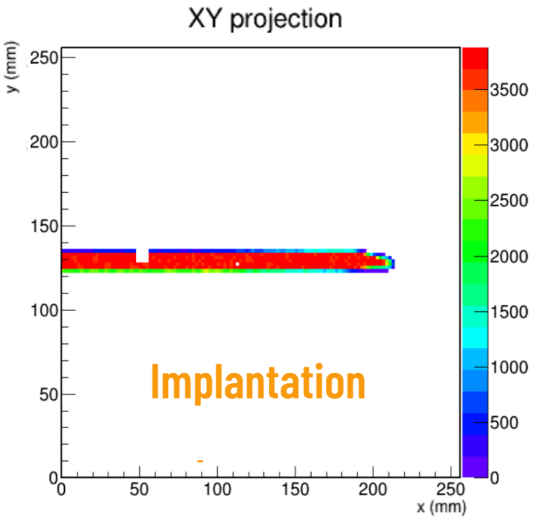
^{48}Ni events

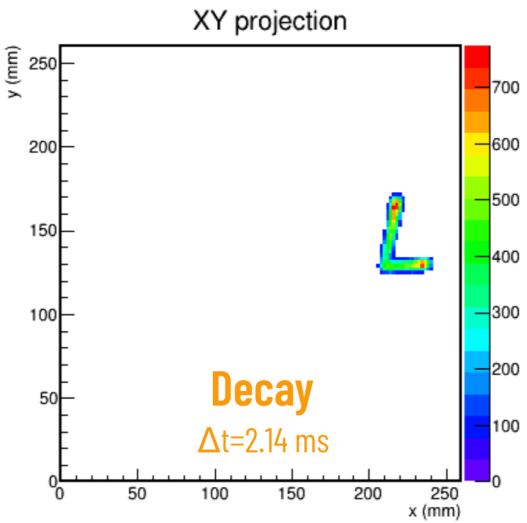
	Production	Seen in ACTAR	Correctly implanted in ACTAR	Decay seen in ACTAR	2-proton decay	β-1p decay	β-3p decay
^{48}Ni	11	10	7	5	2	2	1

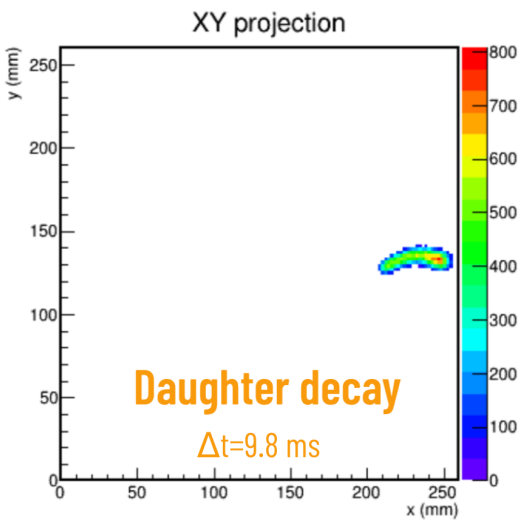
- $T_{1/2}$(average)=3.2 ms
- $T_{1/2}$(literature)=2.1 ms





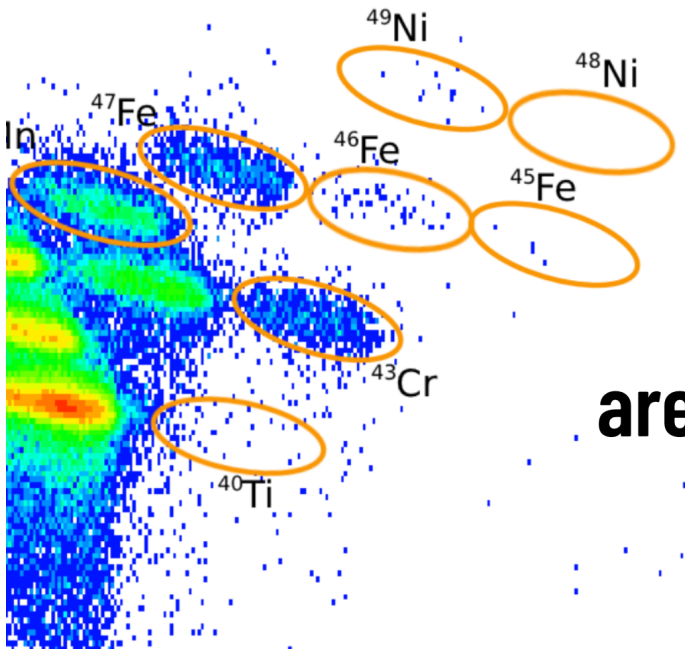






$^{48}Ni \xrightarrow[2p]{} {}^{46}Fe \xrightarrow[\beta\text{-}p]{} {}^{45}Cr$

Not enough stadistic to build an angular distribution



But other data in this exotic neighborhood are REALLY interesting

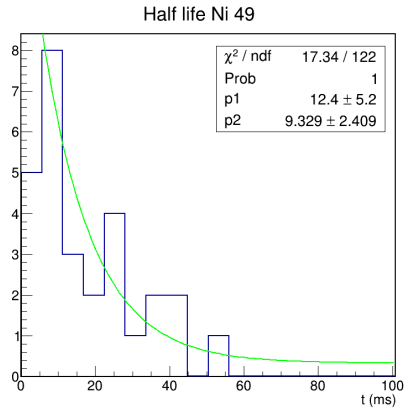
^{49}Ni events

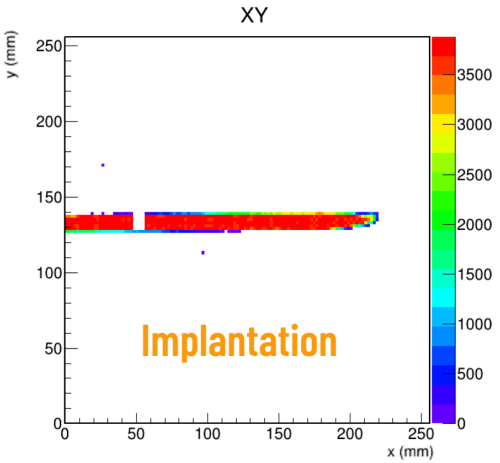
	Production	Seen in ACTAR	Correctly implanted in ACTAR	Decay seen in ACTAR	β-1p decay	β-2p decay	β-3p decay
^{49}Ni	178	72	68	60	38	18	1

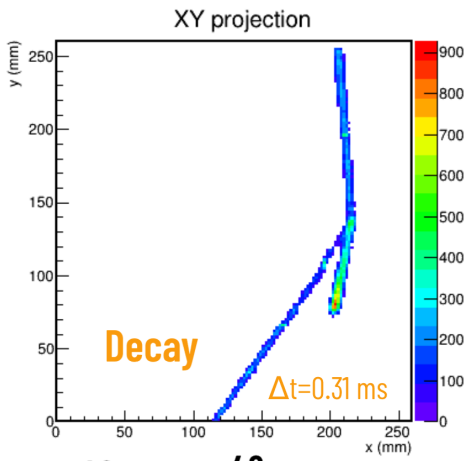
- 2 events potential 2-p candidates from 48Ni
- 1 event not well identified

PRELIMINARY

- $T_{1/2}$(exp)=9.3±2 ms
- $T_{1/2}$(literature)=7.5 ±1 ms

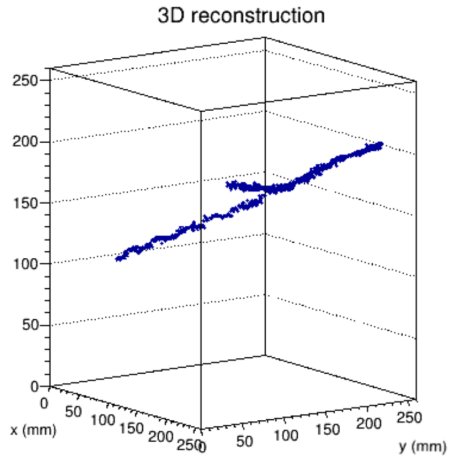






$^{49}Ni \rightarrow {}^{46}Cr$

β-3p



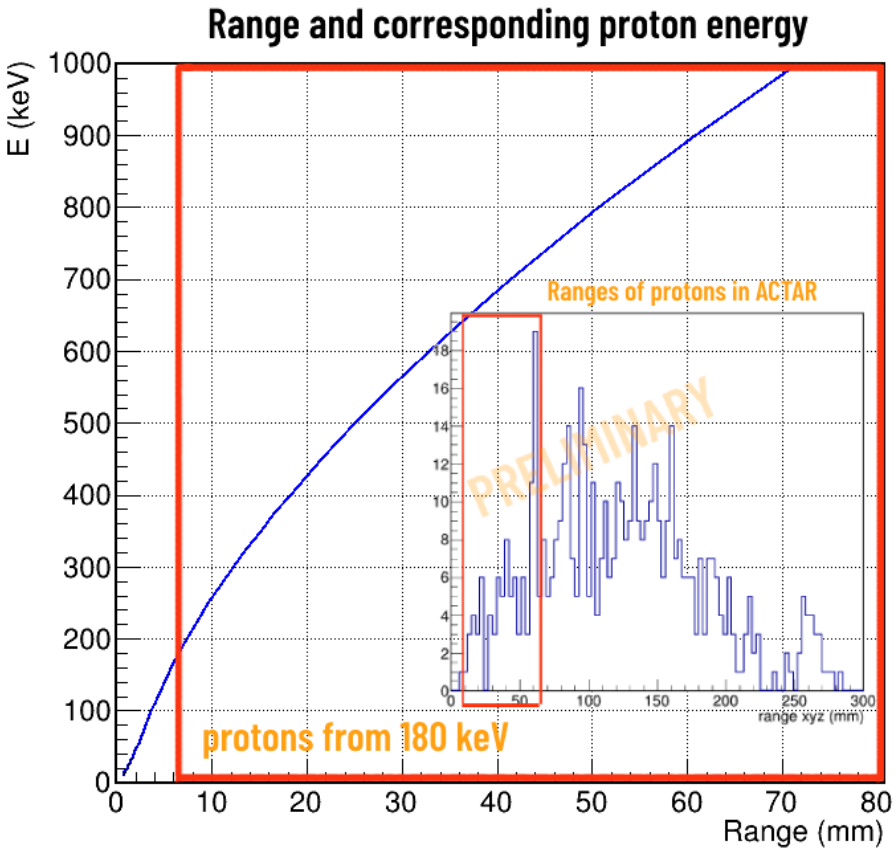
Branching ratios

66 % β-p
32 % β-2p
2% β-3p

FIRST OBSERVATION!

^{46}Mn , ^{47}Fe events

- $\beta - 2p$ decays for both ^{46}Mn , ^{47}Fe found ***for the first time***
- Low energy protons (bellow 1 MeV) from $\beta - p$ emissions of ^{46}Mn measured ***for the first time***



- Give information about unreachable excited states of ^{46}Cr , that enable the study of the inverse reaction

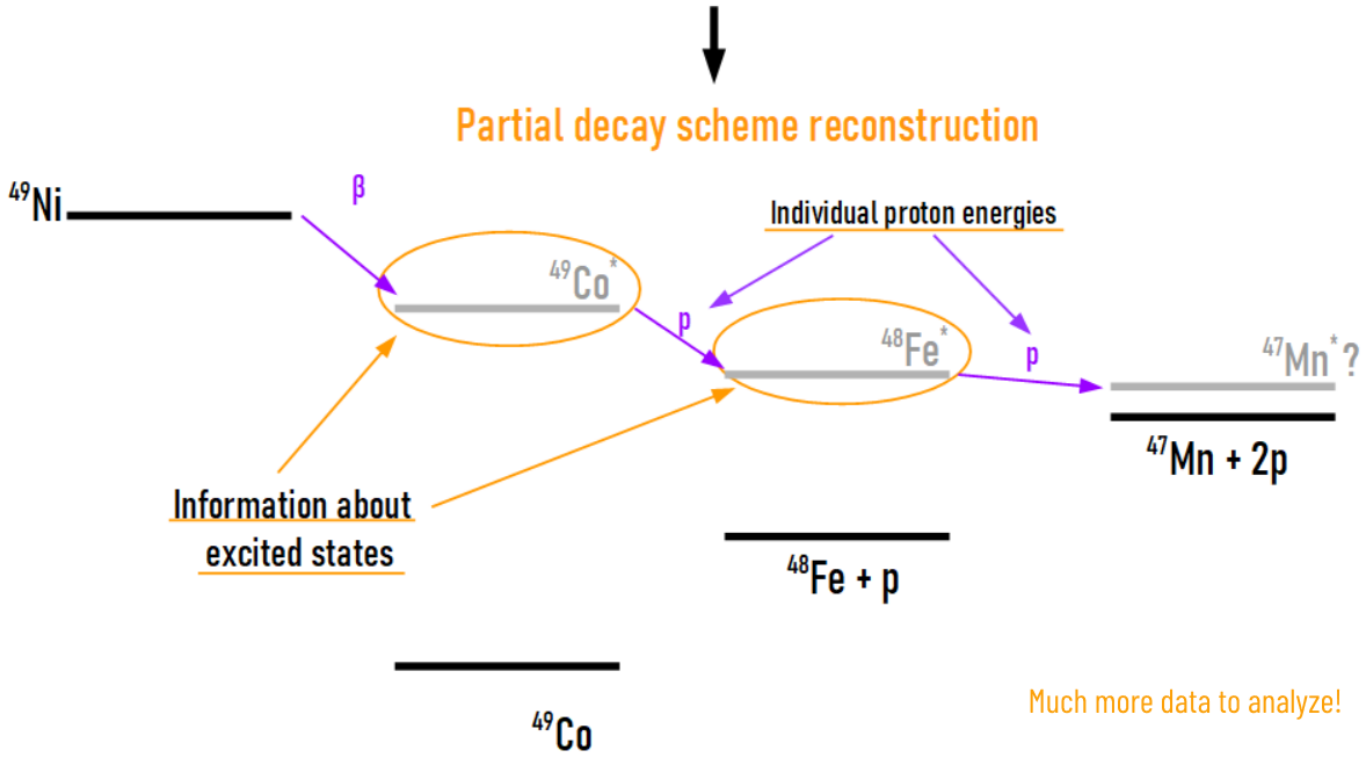
$$^{46}Cr^{*} \longleftarrow ^{45}V + p \ ,$$

an important missing ingredient for Supernova of type II models.

(Proposal A.M.Sánchez-Benítez)

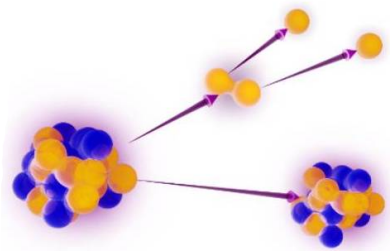
Expected further results

- Study of individual proton's energies (1p emission, 2p emission, 3p emission) for the nuclei of interest.
- Branching ratios $\beta - p$, $\beta - 2p$, $\beta - 3p$ for the different nuclei $^{43}Cr, ^{46}Mn, ^{47}Fe, ^{46}Fe, ^{45}Fe, ^{40}Ti$



Do not forget: these results are PRELIMINARY

- Idea of production and implantation events during the experiment
- Some ^{48}Ni events with $2-p$ emission (but too few), also for ^{45}Fe
- ^{49}Ni half life and branching ratio β-1p, β-2p, β-3p
- Ovserved for the first time:
  $^{49}Ni \rightarrow \beta$-3p, $^{47}Fe \rightarrow \beta$-2p, $^{46}Mn \rightarrow \beta$-2p, low energy protons



Thanks for your attention

Special thanks to GANIL, ACTAR TPC collaboration, LISE3 collaboration and all e791 experiment participants