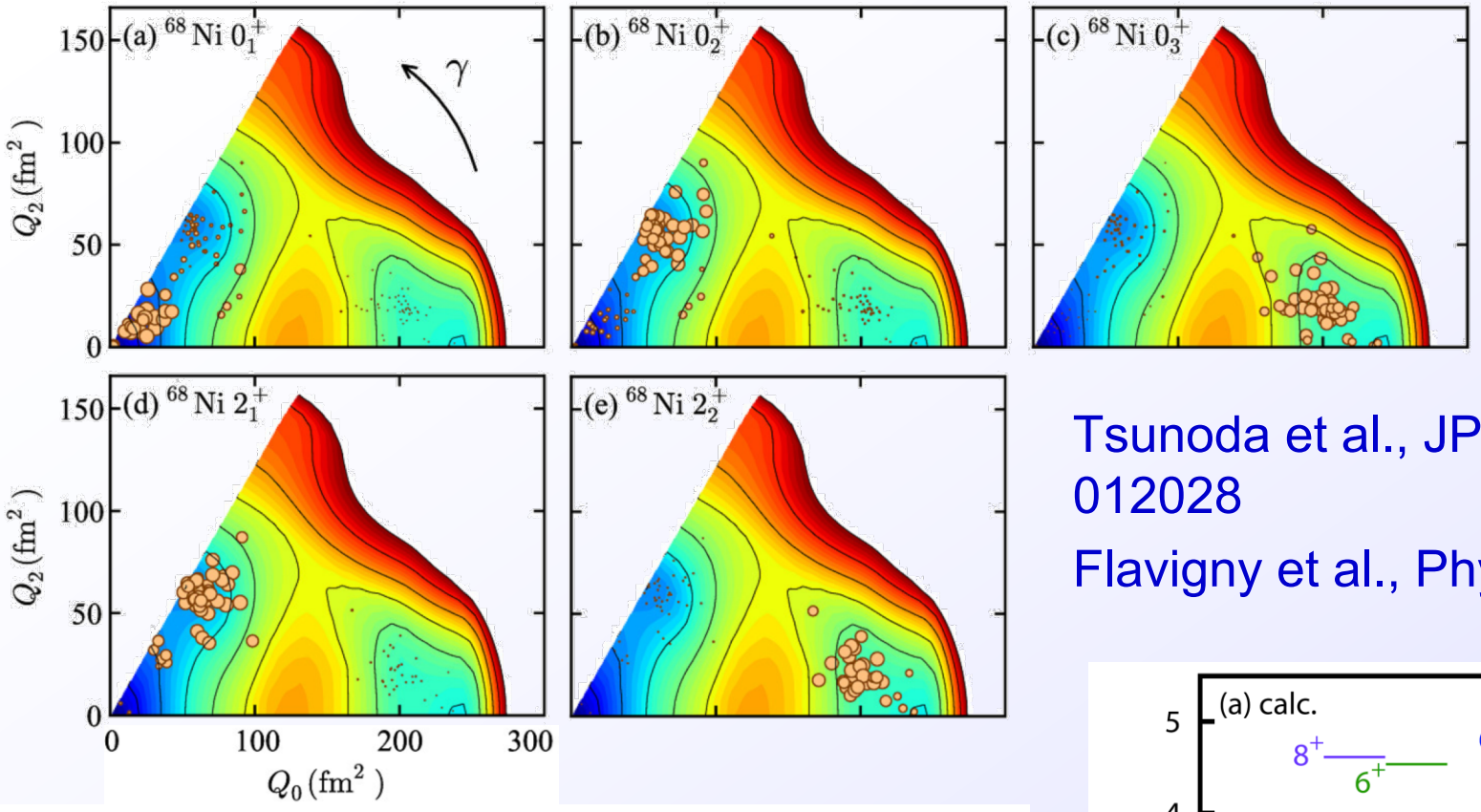
IS590 Characterization of the low-lying 0^+ and 2^+ states of ^{68}Ni

Ch. Sotty (KU Leuven, IFIN-HH Bucharest)
L.M. Fraile (U Complutense Madrid)

Motivation: ^{68}Ni (Z=28, N=40)



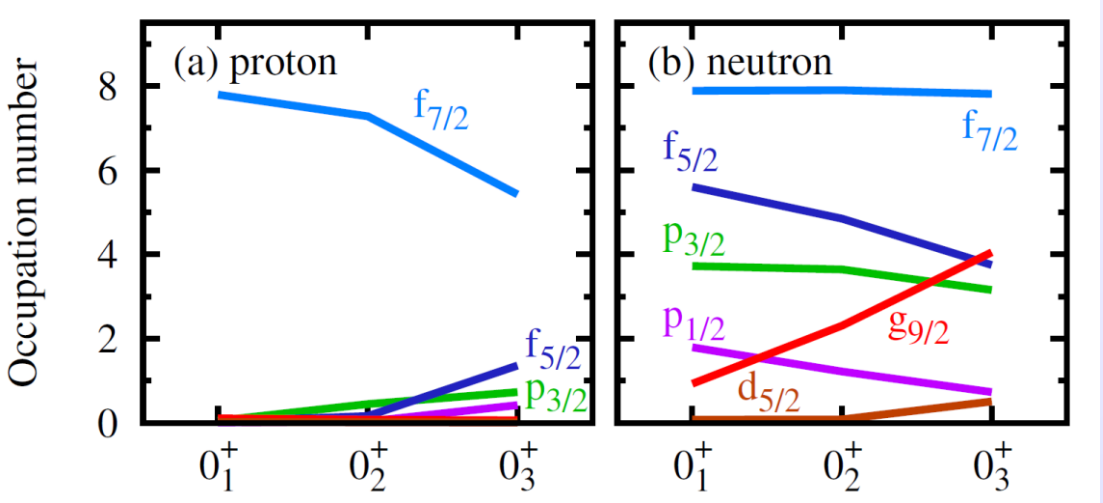
Monte Carlo Shell Model

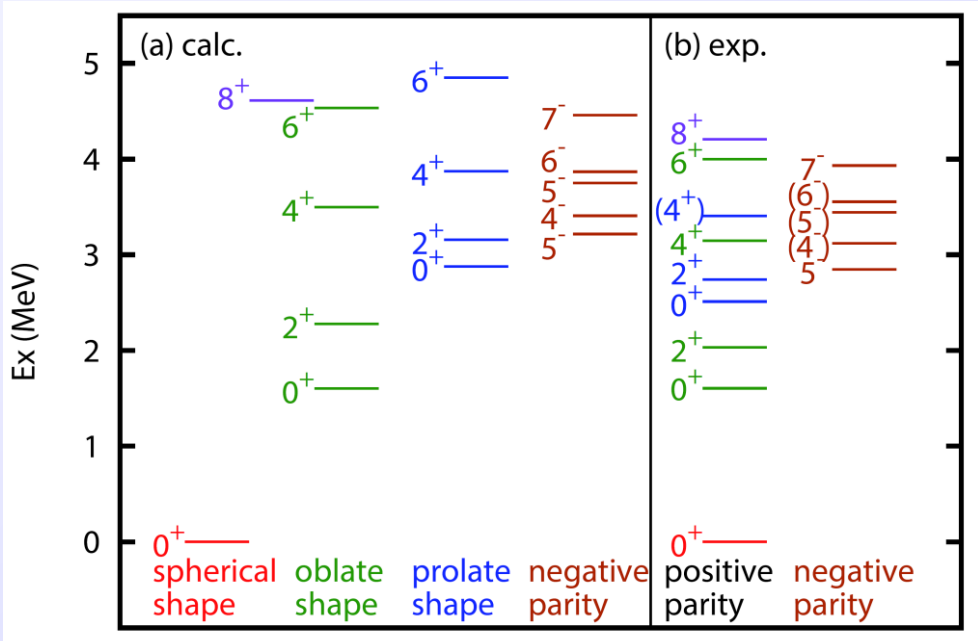
A3DA modified

pf $g_{9/2}$ $d_{5/2}$ shell

Tsunoda et al., JPhys Conf Ser **445** (2013) 012028

Flavigny et al., Phys Rev C **91** (2015) 034310





Prior to IS590 proposal

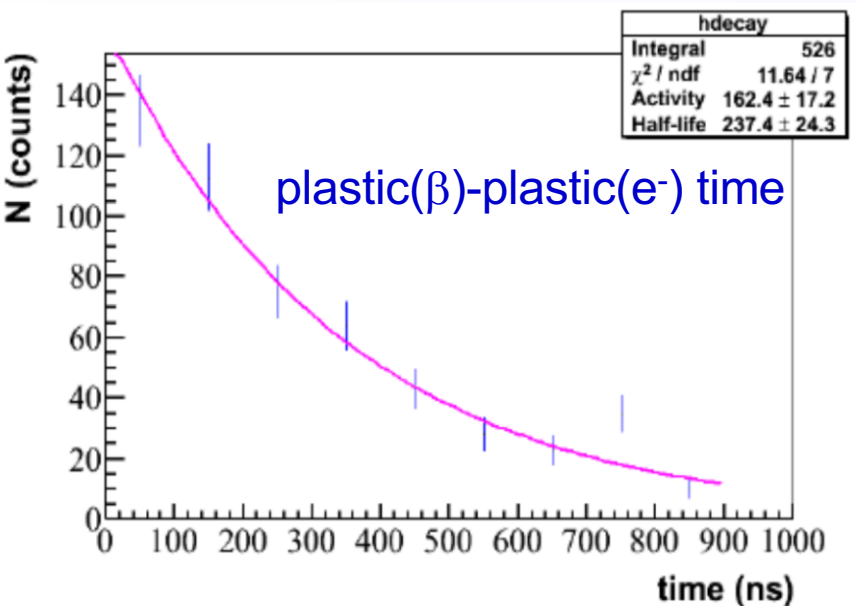
- ✓ Identified 0^+ and 2^+ states
  - → R. Broda *et al.*, Phys. Rev. C **86**, 064312 (2012).
  - → W.F. Mueller *et al.*, Phys. Rev. C **61**, 054308 (2000).
- ✓ Position of the 0^+_2 state in ^{68}Ni fixed: 1604 keV
  - → F. Recchia et al., Phys. Rev. C **88**, 041302(R) (2013).
  - → S. Suchyta et al., Phys. Rev. C **89**, 021301(R) (2014).
  - → F. Flavigny et al., IS467, Phys. Rev. C 91 034310 (2015).
- ✓ Investigation of 0^+ states via 2n transfer reaction
  - → ^{66}Ni(t,p)^{68}Ni in inverse kinematics (2013)
    - Now published: F. Flavigny, J. Elseviers et al., Phys. Rev. C **99**, 054322 (2019)
- ✓ Approach to via ^{68}Ni multiple experimental tools

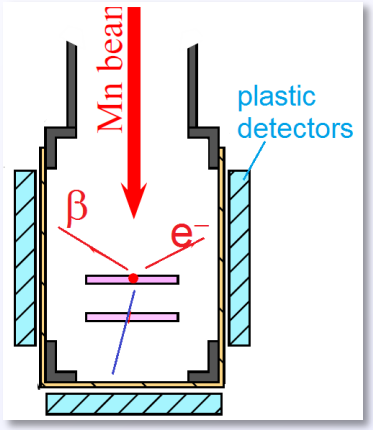
β-γ -E0 delayed coincidences

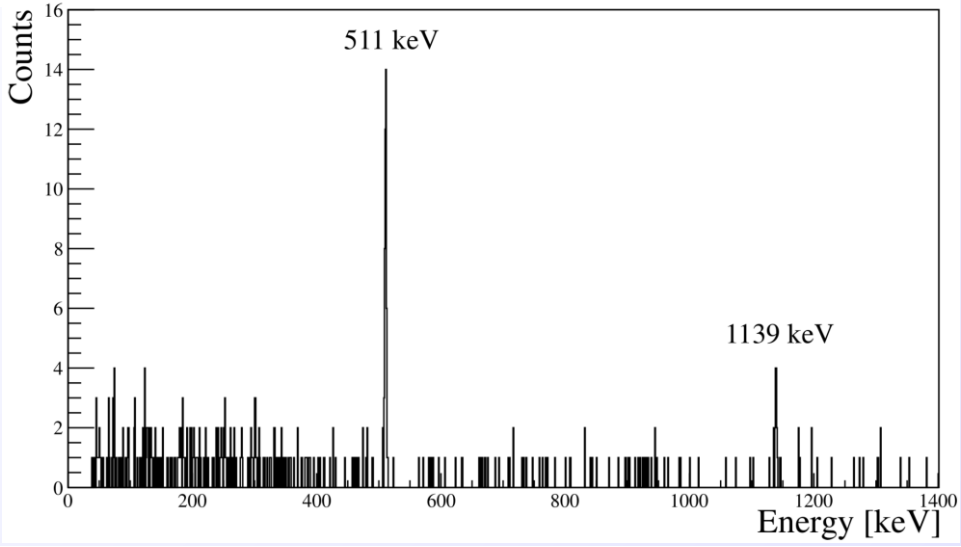
(3^+) 1.6 s

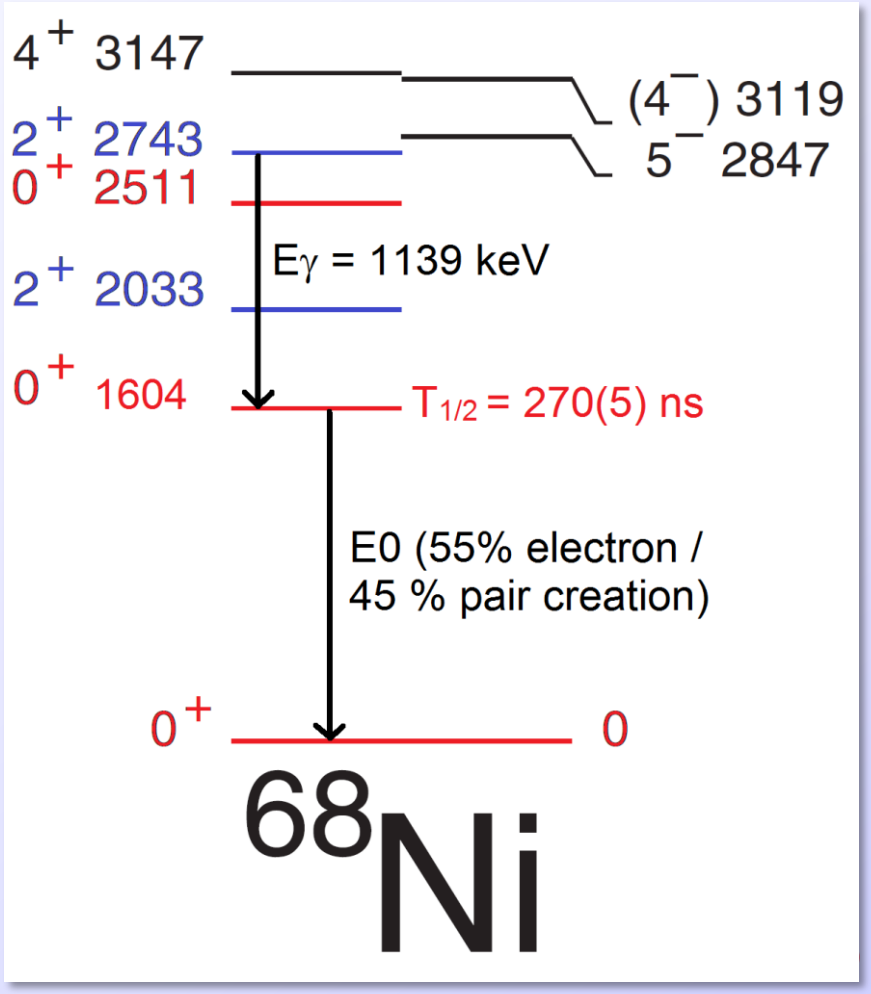
^{68m}Co

F. Flavigny et al., Phys. Rev. C 91 034310 (2015).

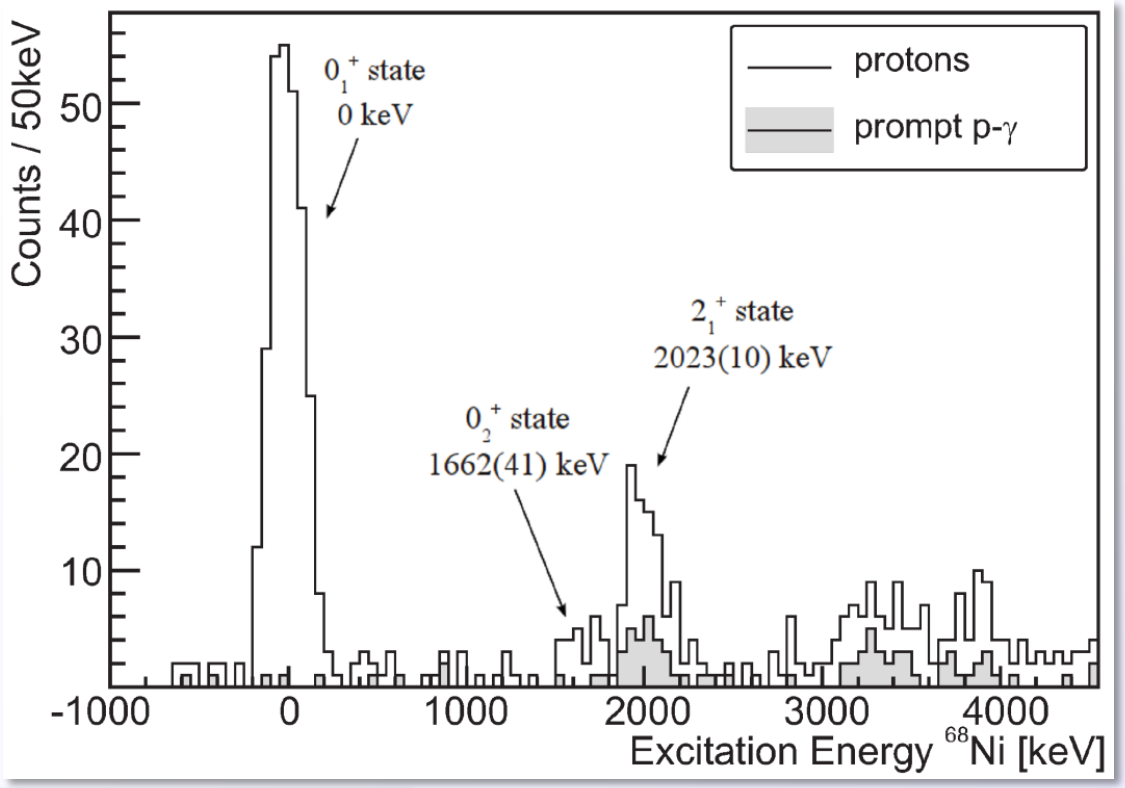


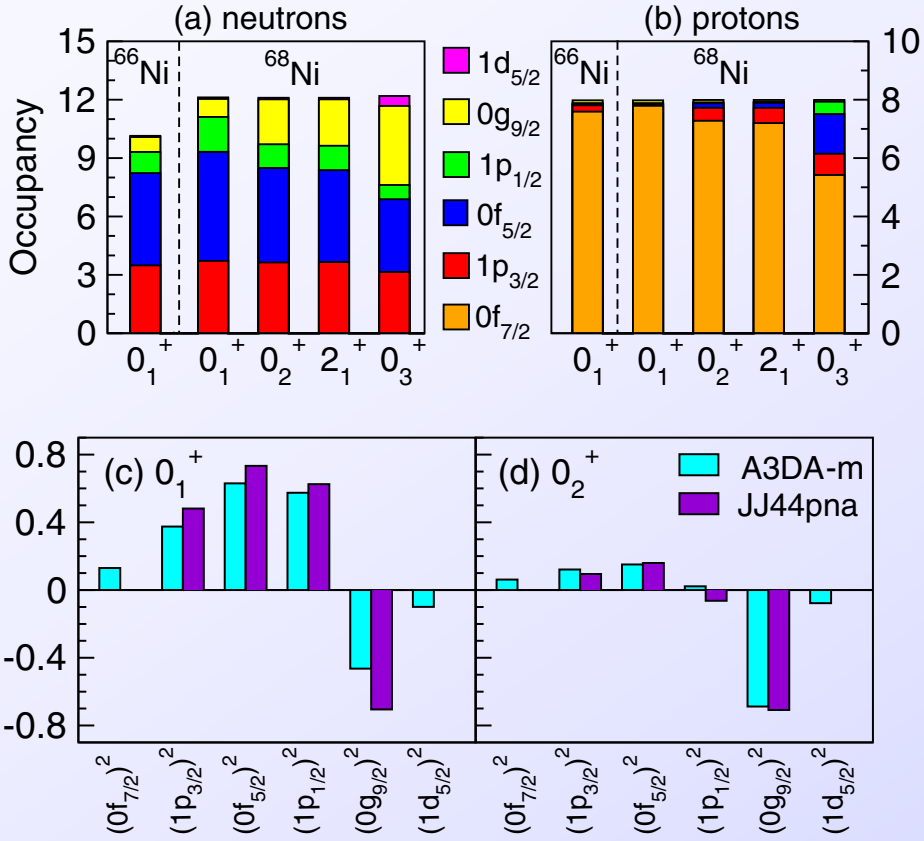


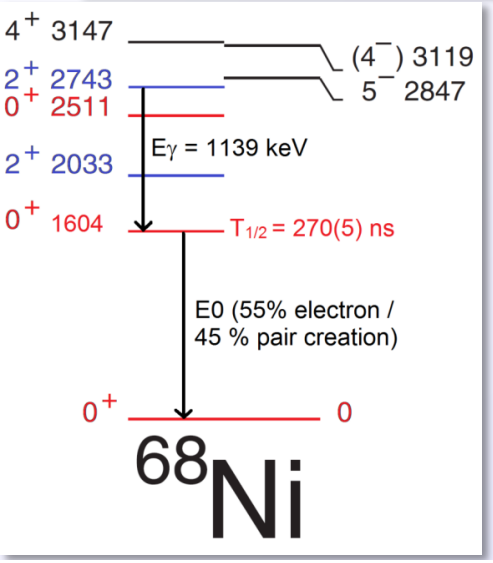




^{66}Ni(t,p)^{68}Ni (IS504 - Elseviers 2013)

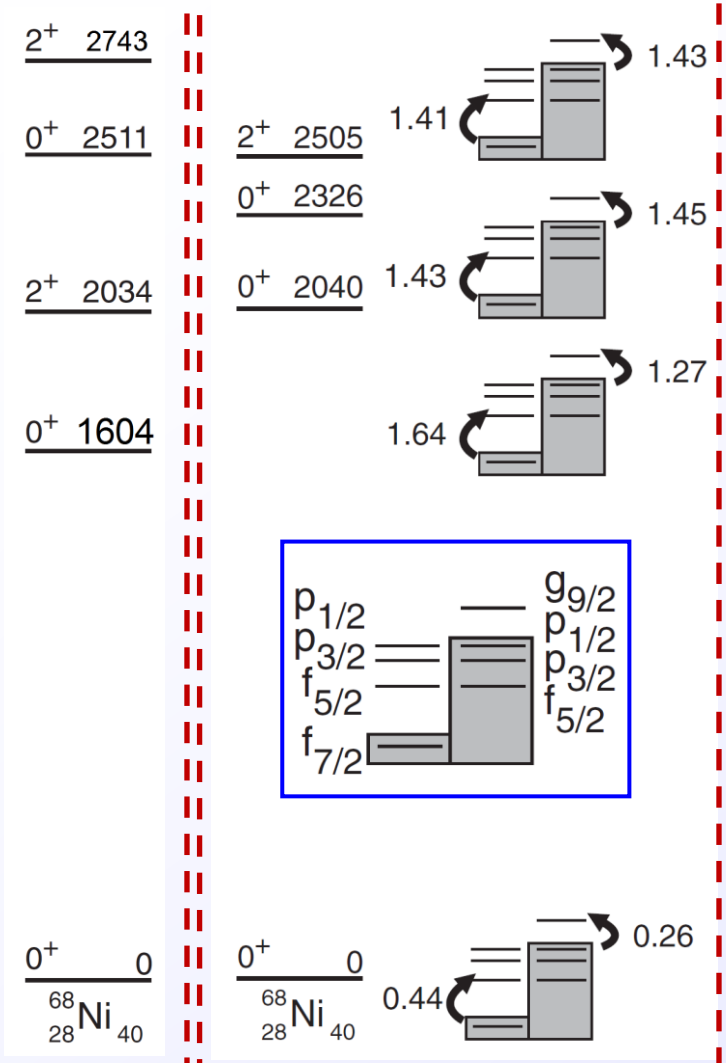






F. Flavigny, J. Elseviers et al.,
Phys. Rev. C **99**, 054322 (2019)

Calculations



Liddick PRC87 (2013)

"dominant proton configuration has exactly two $f_{7/2}$ protons less than the ground state"

0^+ 2400

0^+ 1140

"The 0^+_1 and 0^+_2 states "are characterized by "similar proton occupancies with leading 0p-0h (neutron) configuration for the 0^+_1 ground state and 2p-2h (neutron) configurations for the 0^+_2."

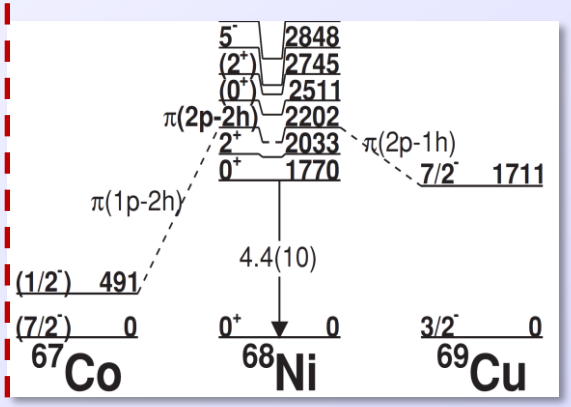
0^+ 0

$^{68}Ni_{40}$

Lenzi PRC82 (2010)

0^+ 2202

π(2p-2h)



0^+ 0

$^{68}Ni_{40}$

Pauwels PRC82 (2010)

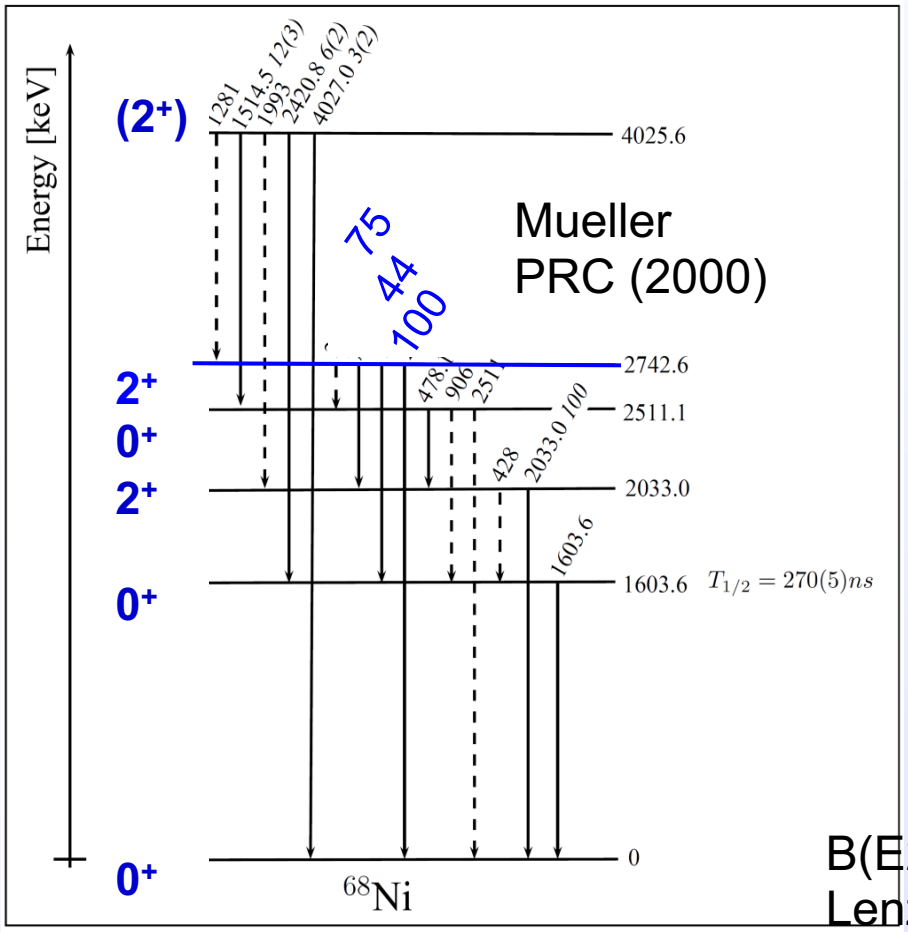
π pf - ν $pfg_{9/2}$ (^{48}Ca core)

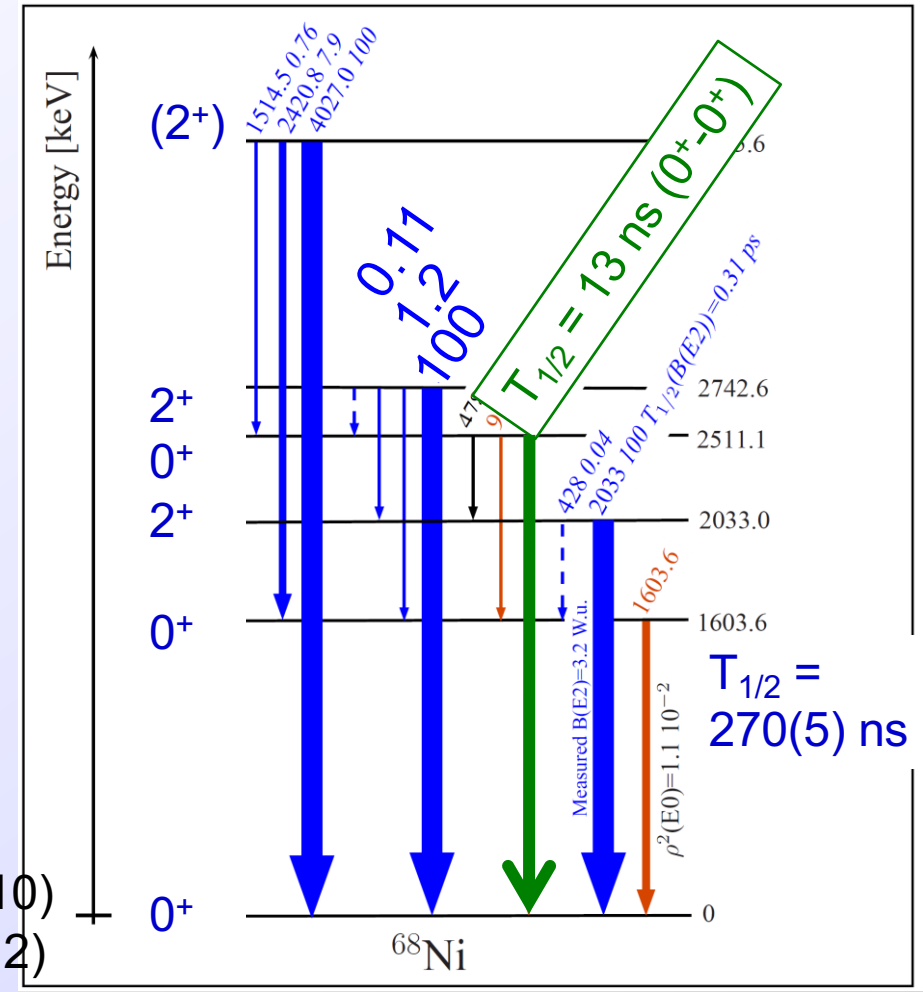
π pf - ν $pfg_{9/2}d_{5/2}$ (^{48}Ca core)

Aim of the experiment

- ✓ "Obtain precise gamma- and electron transition intensities between the 0^+ and 2^+ states"
- ✓ Lifetime measurement of the 0^+ at 2511 keV

$T_{1/2}$ = 1.5 ns

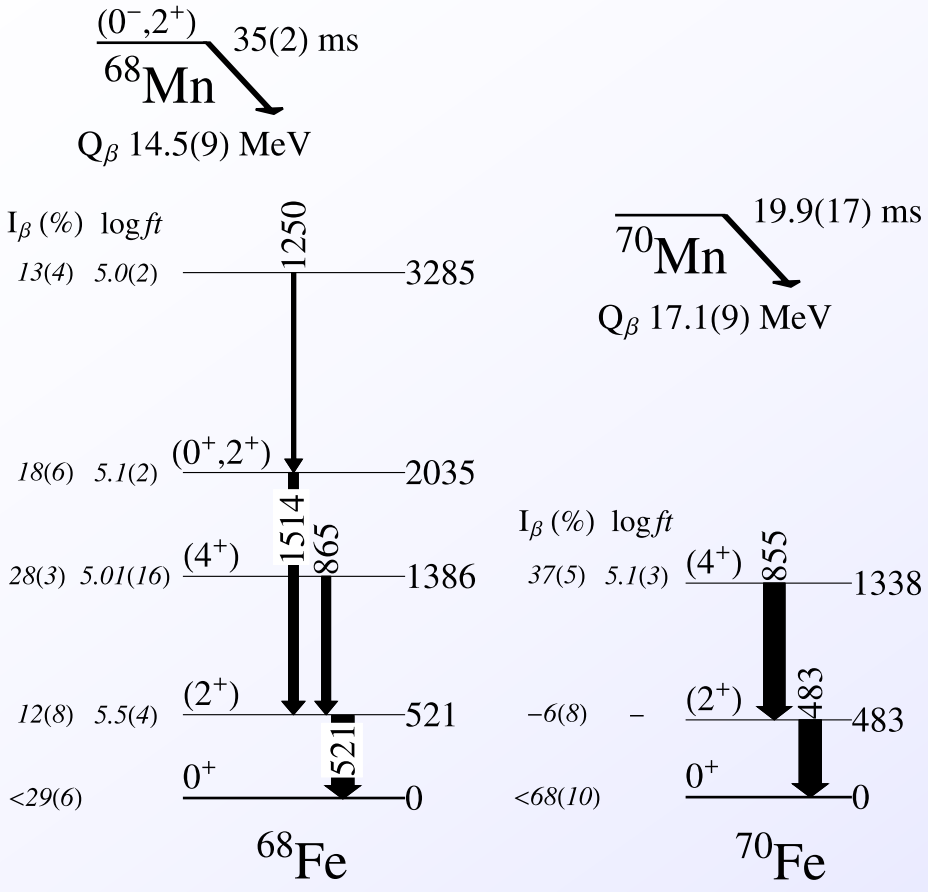




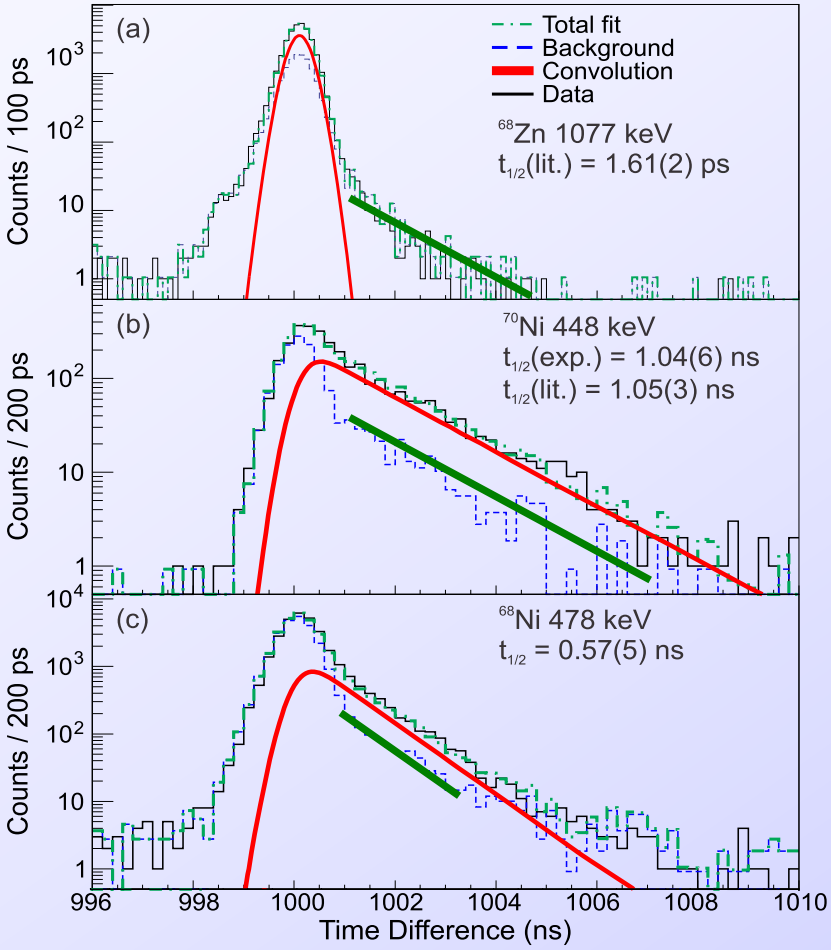
B(E2) from LNSP
Lenzi PRC82 (2010)
A. Dijon PhD (2012)

After the proposal

✓ β-decay to ^{68}Fe (RIKEN), ^{68}Ni level lifetime (NSCL)

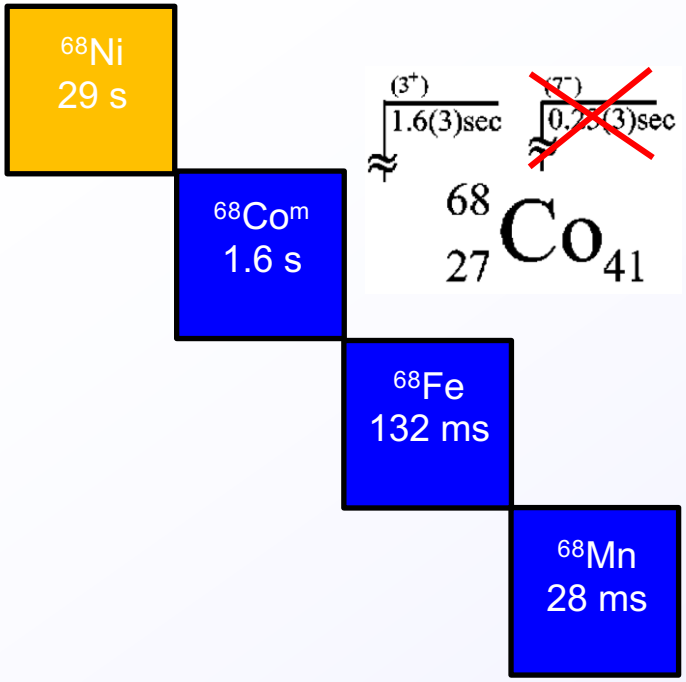


G. Benzoni et al.,
Physics Letters B 751 (2015) 107–112

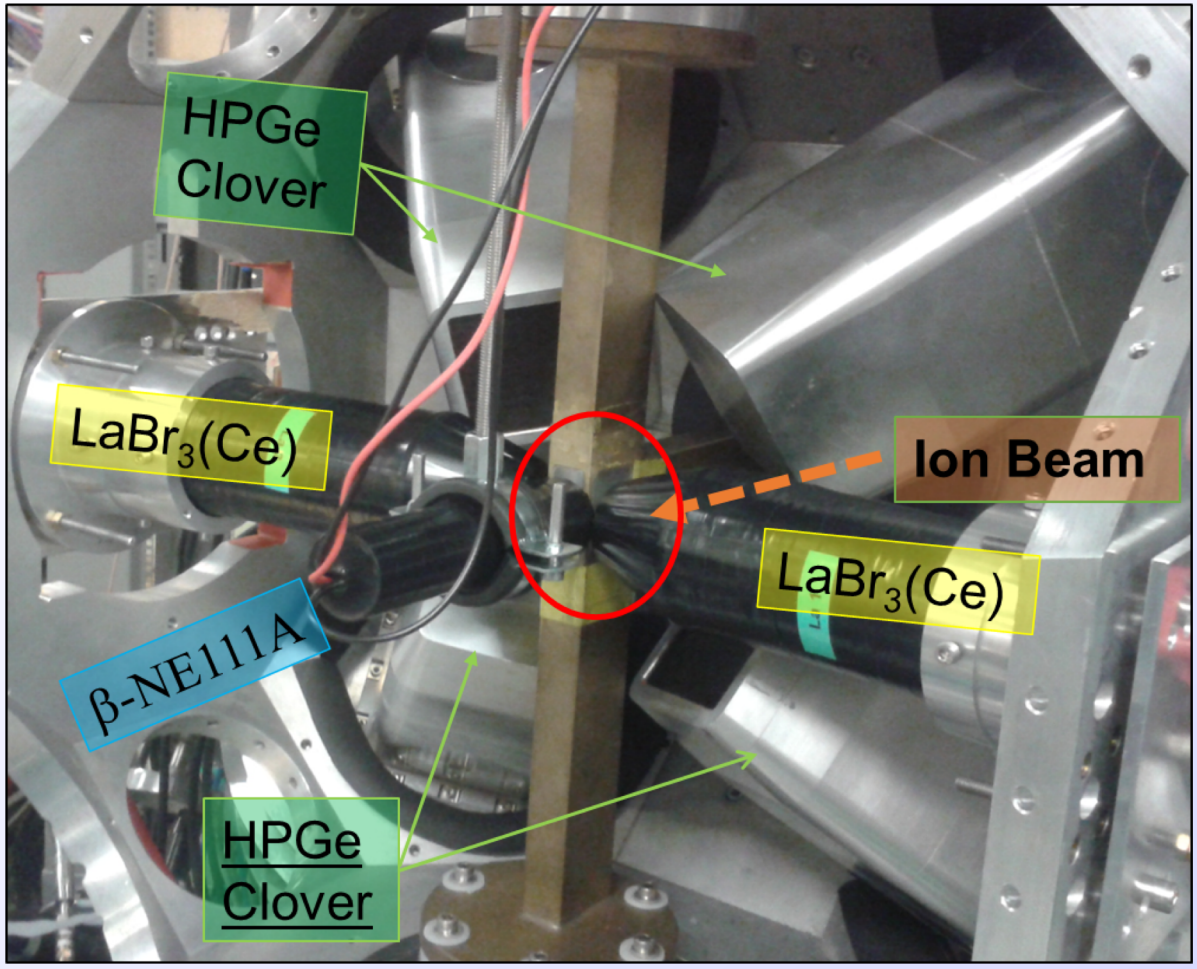


B. Crider et al.,
Physics Letters B 763 (2016) 108–113

Experiment, part 1



ISOLDE Decay Station



Life timing measurement of the 0^{+}_{3} state

Estimates:

β–γ(LaBr$_3$(Ce)): 2663 counts/14 shifts

β–γ(Ge)-γ(LaBr$_3$(Ce)): 40 counts/14 shifts

γ(LaBr$_3$(Ce)) - γ(LaBr$_3$(Ce))

12 shifts granted by INTC

Experiment, part 2

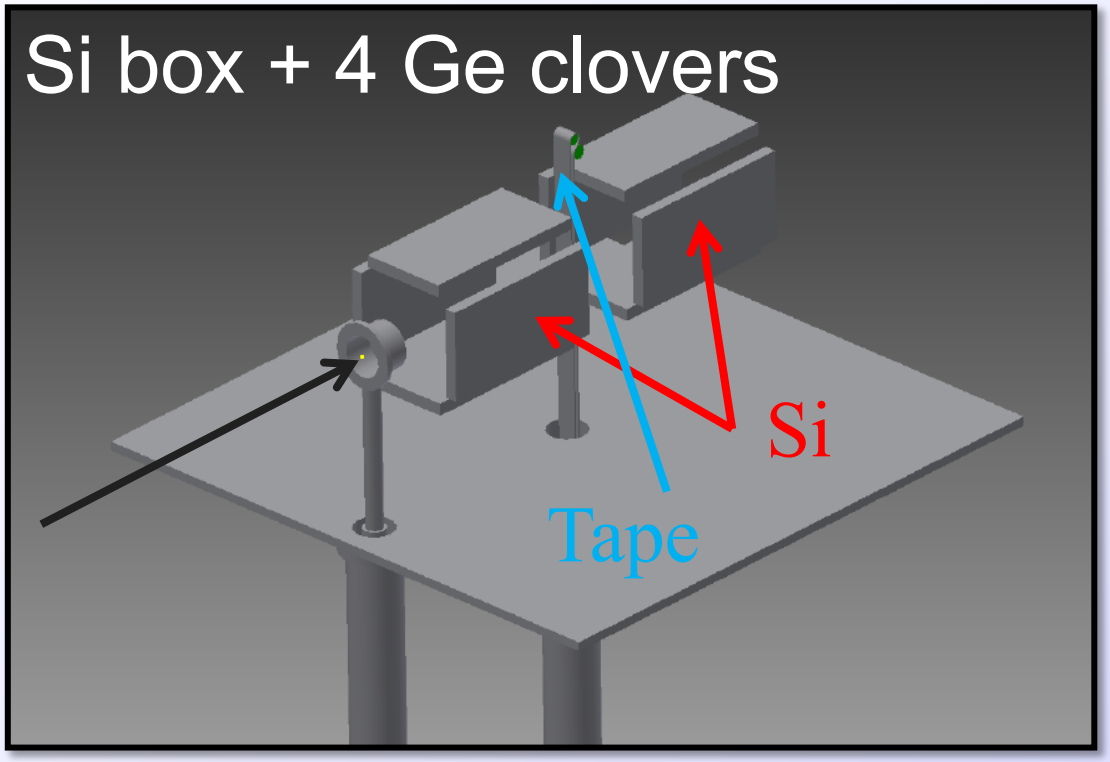
Gamma- and electron spectroscopy (Si box - Ge clover array)

- Ge eff. for 2033 keV detection: 3.4 %
- β/electron efficiency: 60%

β – γ(2033): 26600 counts/experiment

→ Iγ (limit) < 0.1%

β – (e+-e-2.5 MeV pair) – γ(511): 43 counts



14 shifts requested

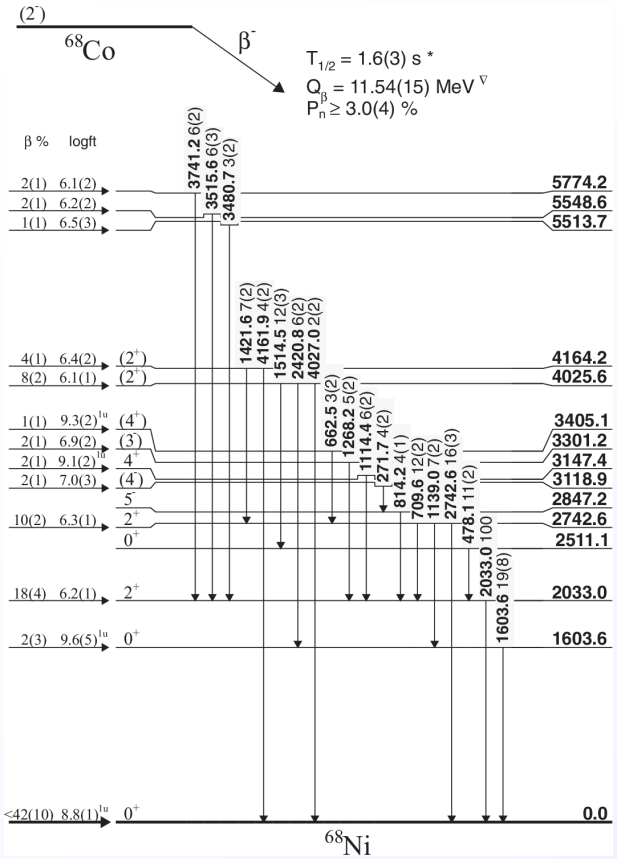
12 shifts granted by INTC

Beamtime details (for part 1)

- ✓ A beam test + 2 (3) unsuccessful beamtimes (2014, 2015)
- ✓ Experiment done in September 2015
  - → 10 shifts of effective beam time, 2 shifts several problems
  - → about 1.5 shifts on beam optimization, Ga to Mn ratio
  - → Total of ~8.5 **^{68}Mn** shifts with real data
- ✓ Yields and ^{68}Mn activity
  - → Database (updated): 4.0 / μC
  - → Proposal: 5.5 /s assuming ~1.9 uA and 70% transmission
  - → Average yield down by a factor of ~ 4-5 (1.51 /s)
  - → Peak yields: 7.5 /s, 3.8 /s for data

- Transmission not optimal ~75%
- Beta detector efficiency

Analysis



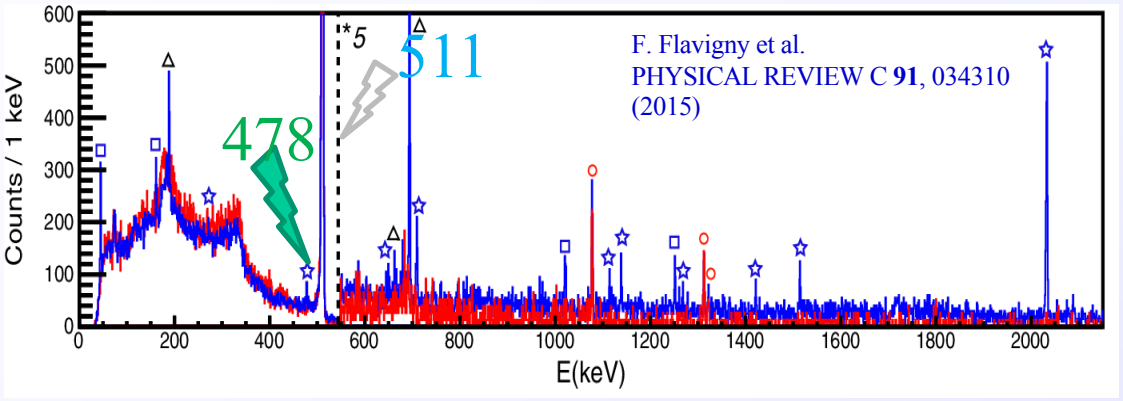


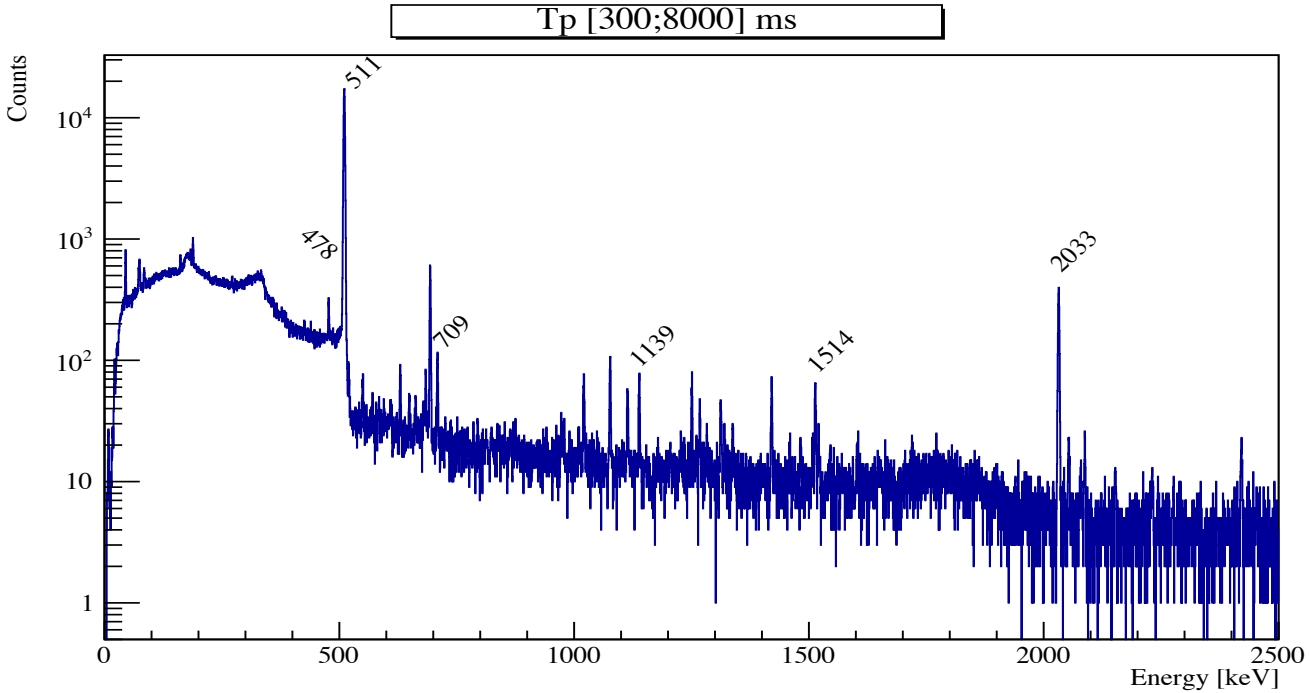
FIG. 3. (Color online) β-gated γ -ray spectrum in the time window [350, 2200] ms after the proton pulse impinged on the target when (blue) lasers are tuned to resonantly ionize Mn and (red) lasers are off. The laser-off spectrum was scaled to the laser-on one using the 1313-keV peak from 136I for comparison. Symbols indicate lines associated with: 68Co decay (stars), 68Fe decay (squares), 67Fe and 67Co decay after β-delayed neutron emission (triangles), laser off 68Ga and 136I contaminants decay (circles).

Amount of counts in the 1514-keV – 478-keV (Clover): 41(7)

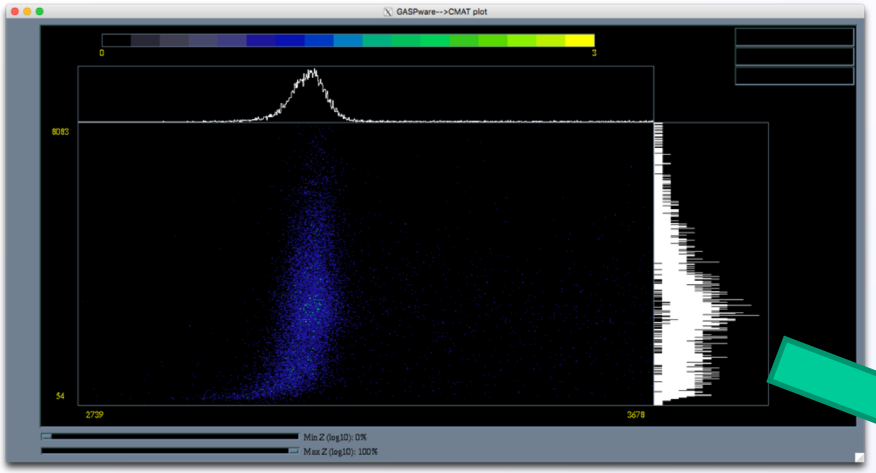
Efficiency corrected ~ 47k

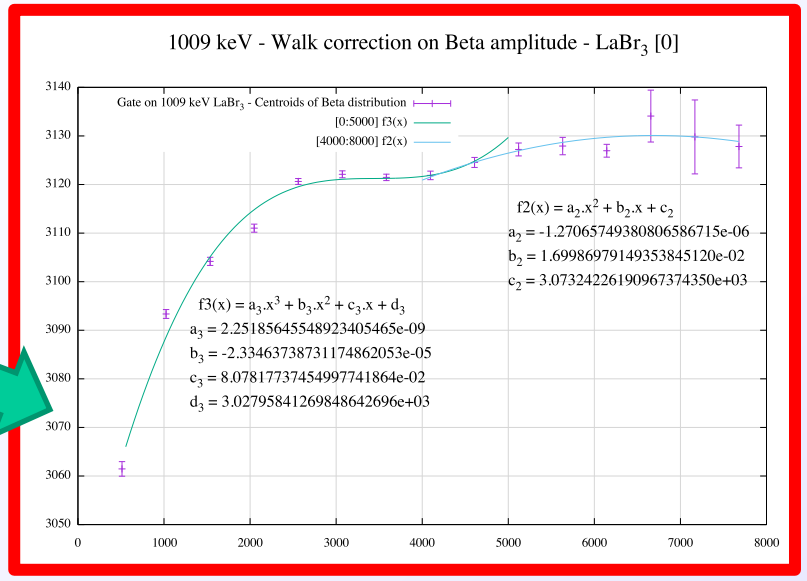
Amount of counts in the 2033-keV – 478-keV (Clover): 62(8)

Efficiency corrected ~ 84k



Fast timing calibrations

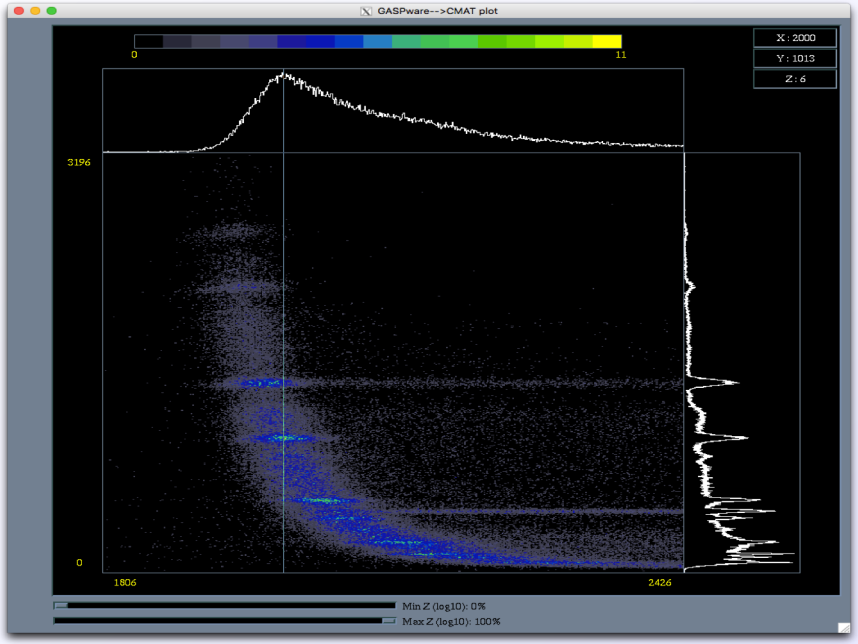


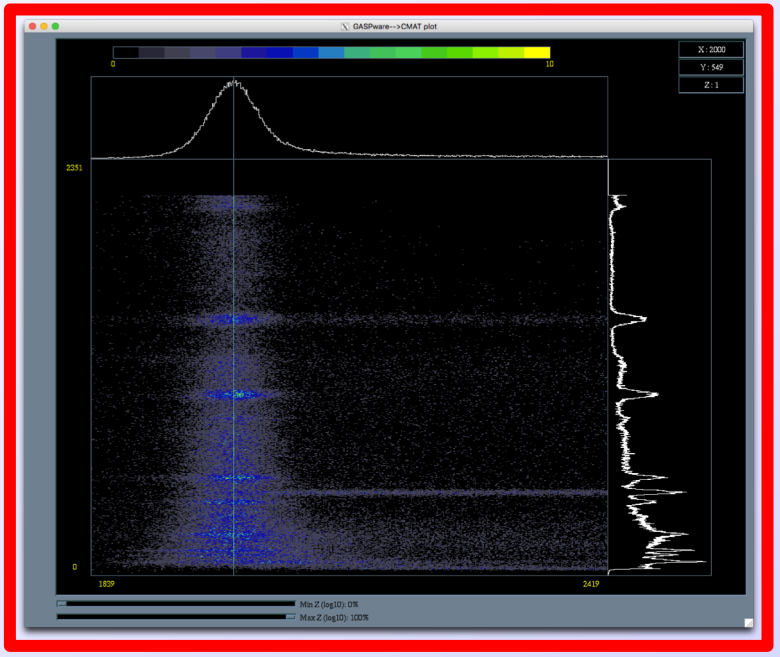


^{138}Cs source

Gate on ”high” energy gamma at 1009 keV

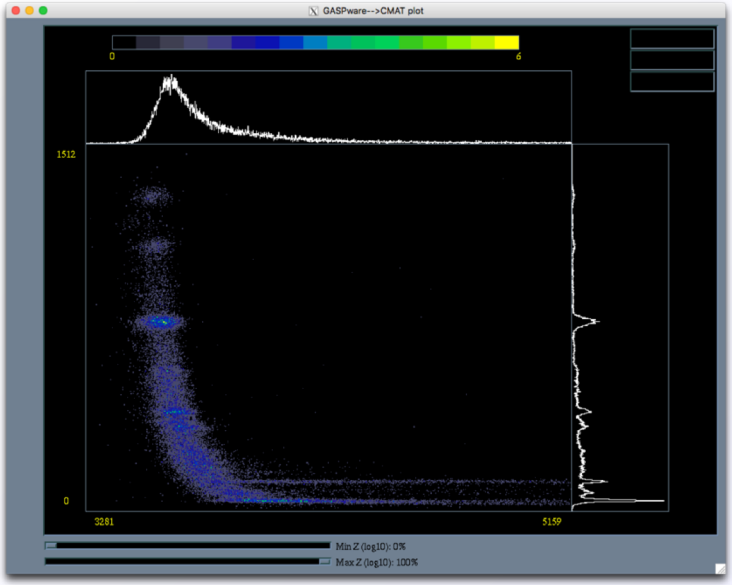
Walk corrections β response

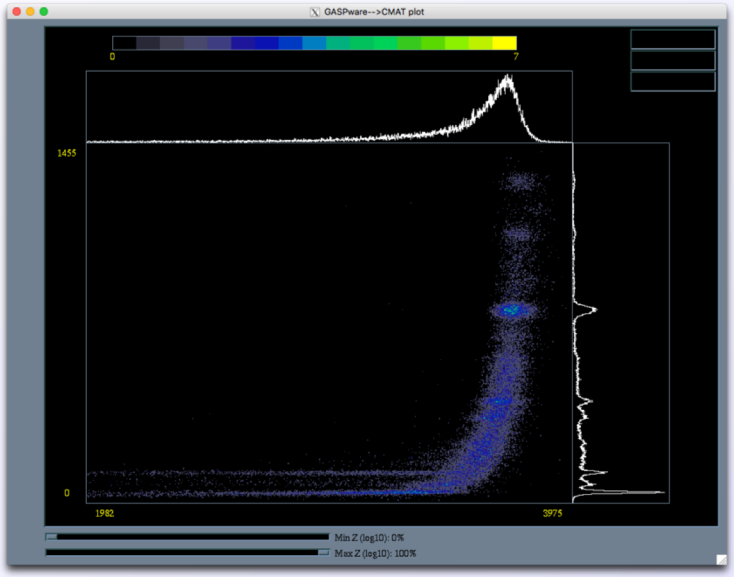


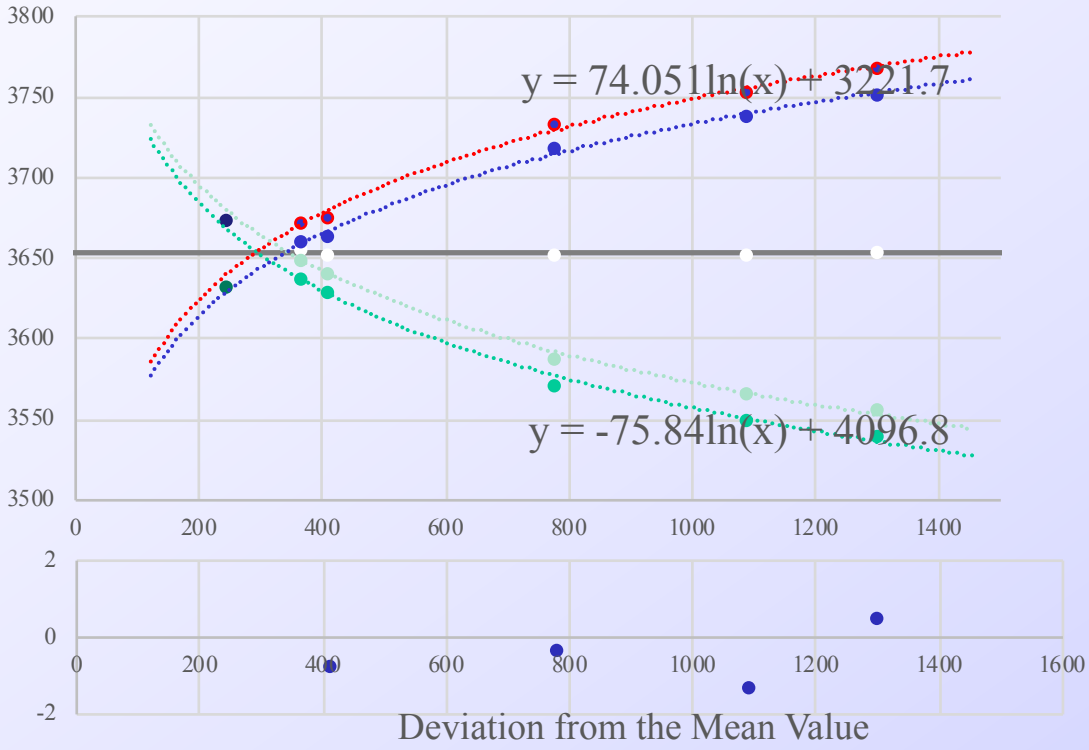


Walk corrections FEPs for $LaBr_3(Ce)$

Fast timing calibrations

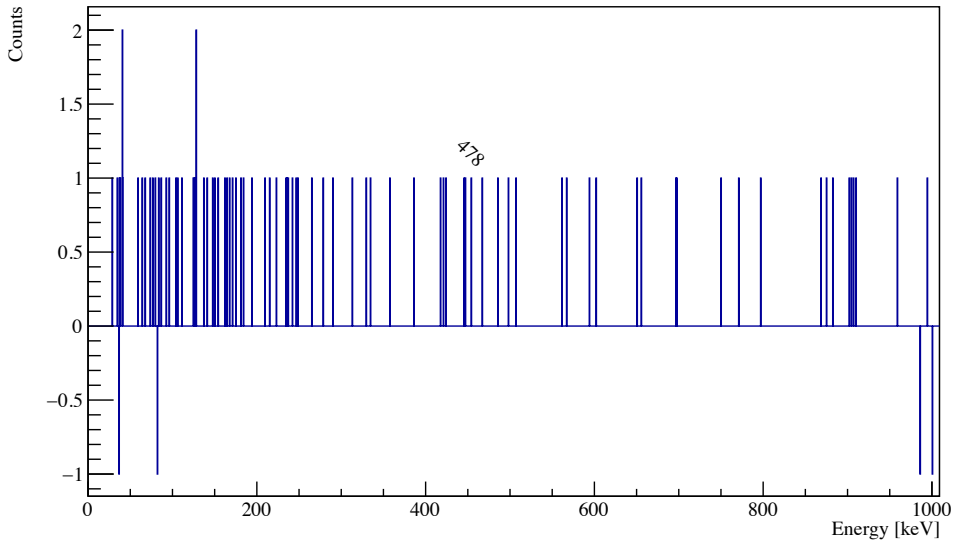


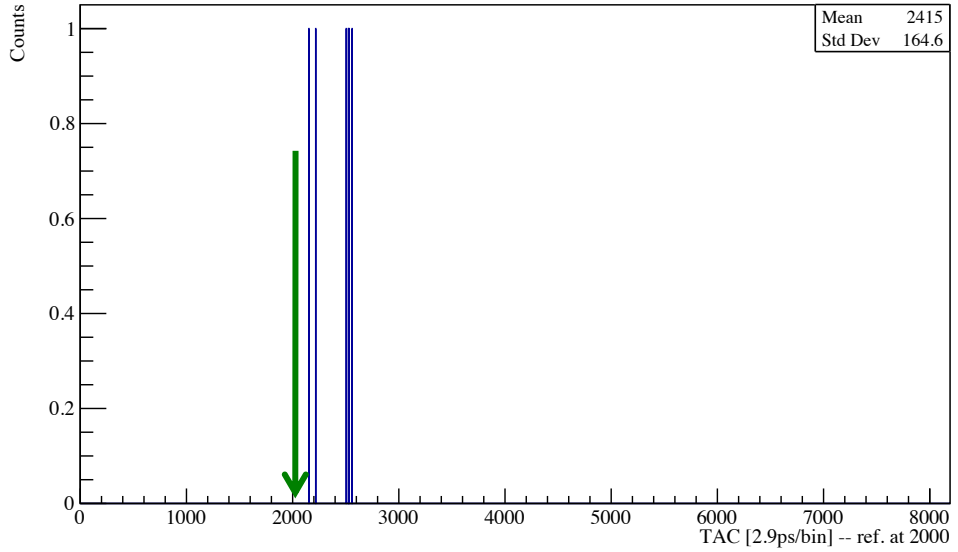




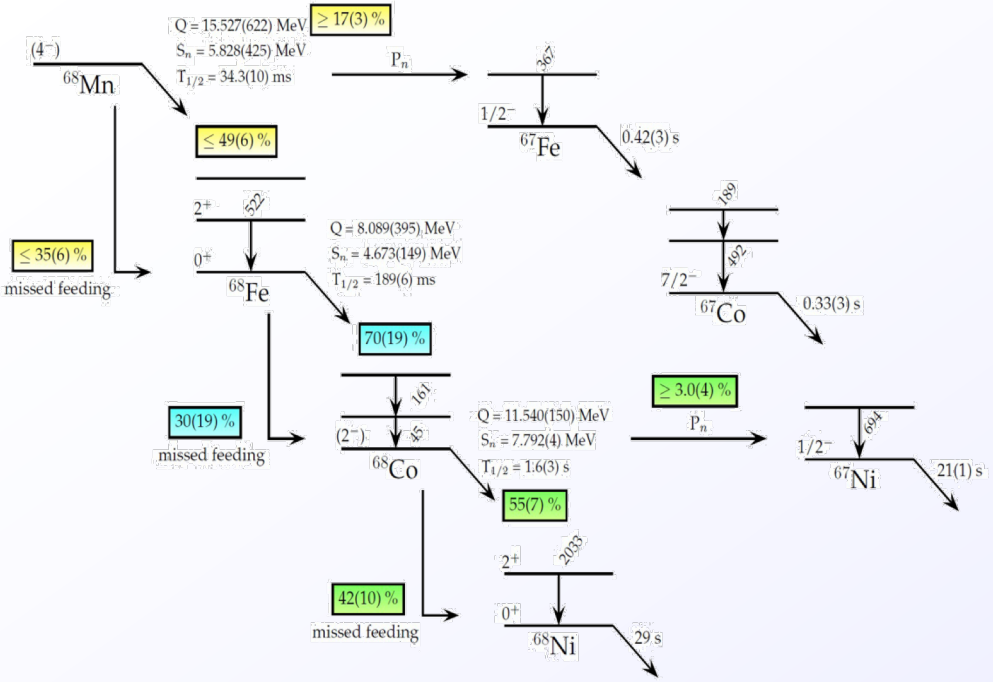
Analysis

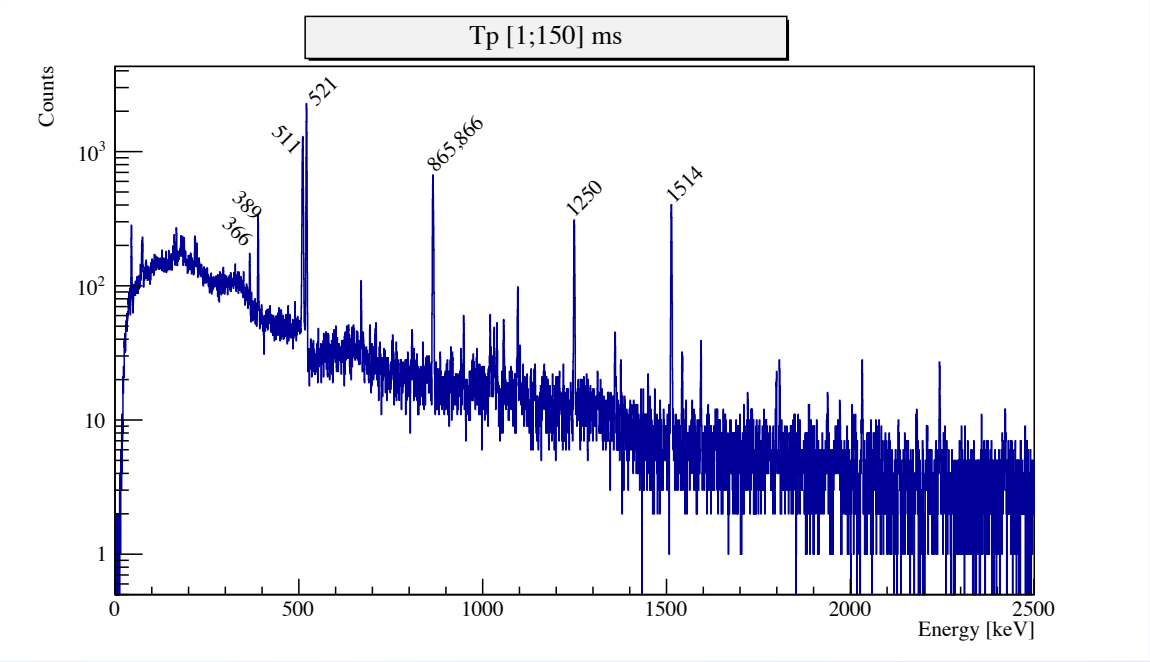
- ✓ Background subtraction (^{68}Ga)
- ✓ Timing calibrations
- ✓ Gate selection
  - → Beta-gamma-gamma(t)
    - Optimized beta, clean Ge-bckg, $LaBr_3(Ce)$ selection…
  - → Gamma-gamma(t) 2033 – 478 keV $LaBr_3(Ce)$
    - One start – stop combination
    - Order of 10 counts in both





Analysis: ^{68}Fe





- ✓ Analysis ongoing for ^{68}Fe
  - → G.s. lifetime
  - → Relative intensities
  - → Level scheme
  - → P_n value + g.s. feeding
  - → Level lifetimes