A study of the ^{85g}Kr(d,pγ) reaction to constrain a key s-process branching point

Sara Carollo
University and INFN Padova

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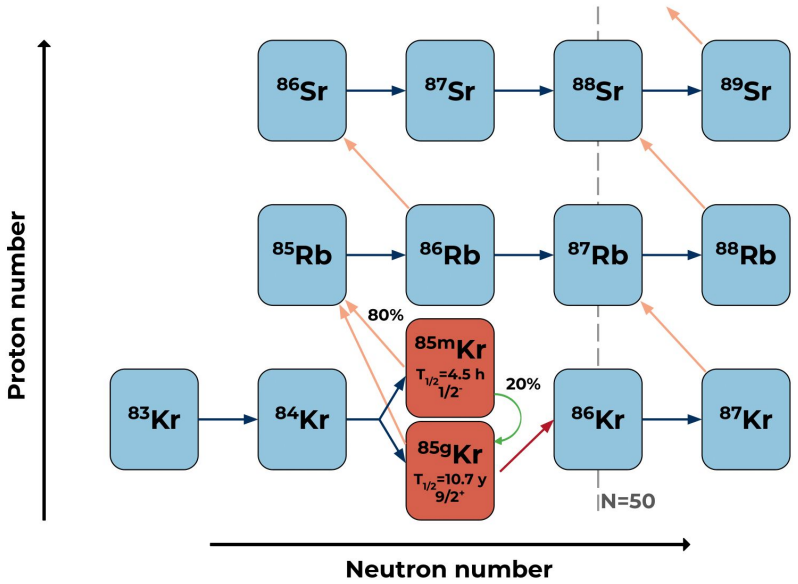
Motivation

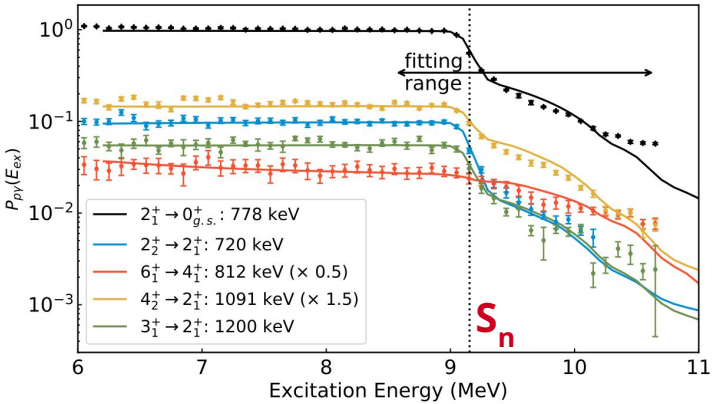
- 50% of elements heavier than Fe are produced by the s-process: $\tau_\beta \lesssim \tau_n$
- Great uncertainty derives from the competition between n-capture and β-decay in some isotopes called **branching points**
- **^{85}Kr** is an important branching point of the s-process, that influences:
  - ^{86}Kr/^{82}Kr ratio in **presolar grains**
  - Abundances of heavy **Sr isotopes** that are produced also by r-process (lines in kilonova)

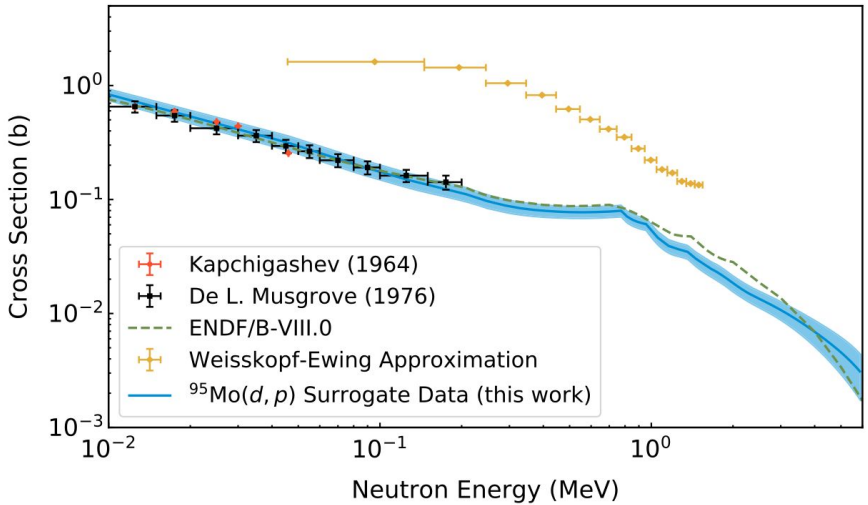


Surrogate reaction method: (n,γ) from (d,pγ)

^{85}Kr activity is too high to perform activation or ToF measurement → Surrogate reaction method (d,pγ) can be performed in inverse kinematics → ^{85}Kr as beam → ≳99% purity!

$$P_{p\gamma}(E_{ex}) = N_{p\gamma}(E_{ex})/[N_p(E_{ex})\epsilon_\gamma].$$





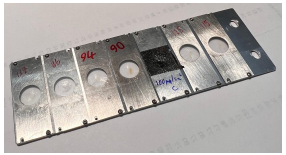
J. E. Escher et al., Phys. Rev. Lett. 121, 052501 (2018)
A. Ratkiewicz et al. Phys. Rev. Lett. 122, 052502 (2019)

Experimental set-up

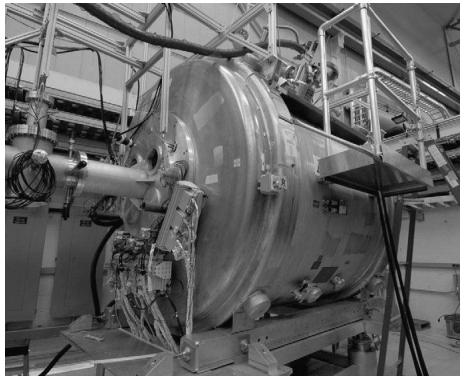
Reaction: ^{85}Kr(d,py)

Beam: ^{85}Kr 10 MeV/u, 10^7 pps

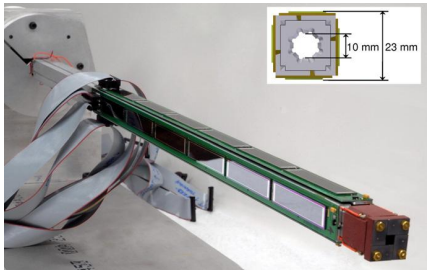
Targets: CD_2



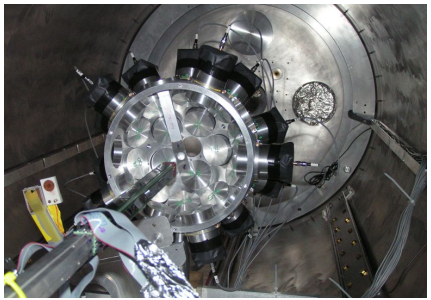
HELIOS: Solenoidal magnetic spectrometer with B=2.0 T



For **protons**: position sensitive Si array

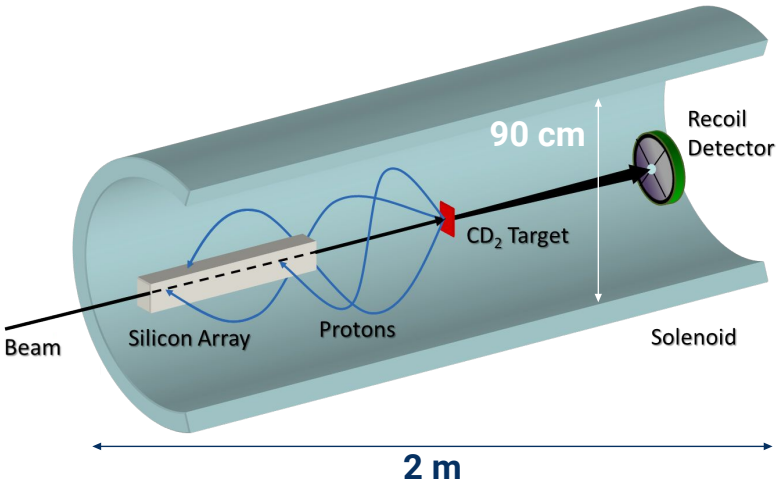


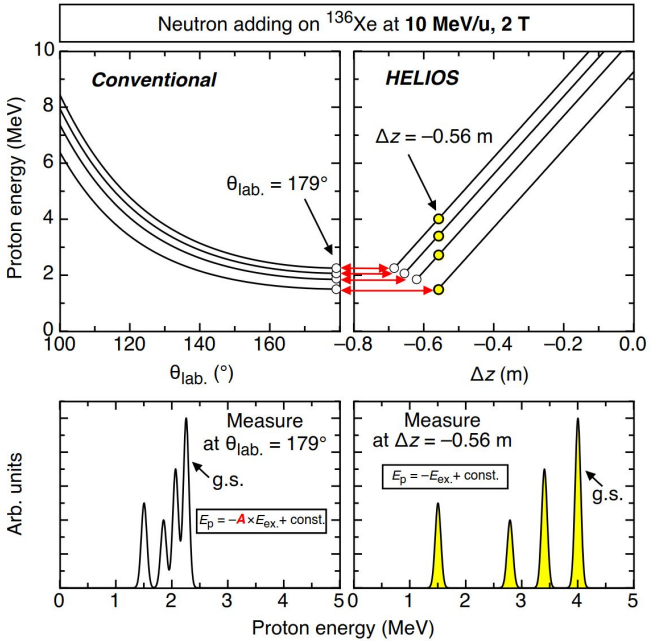
For **y-rays**: Apollo scintillator array, 5 LaBr + 15 CsI



HELIOS: Helical Orbit Spectrometer

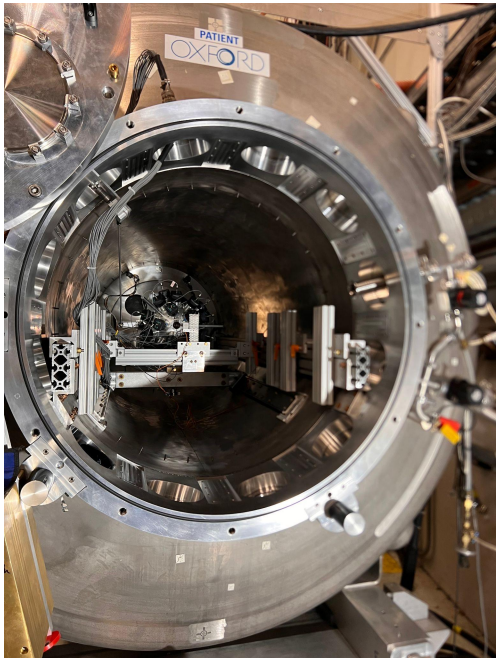
Solves the problem of **kinematic compression!**

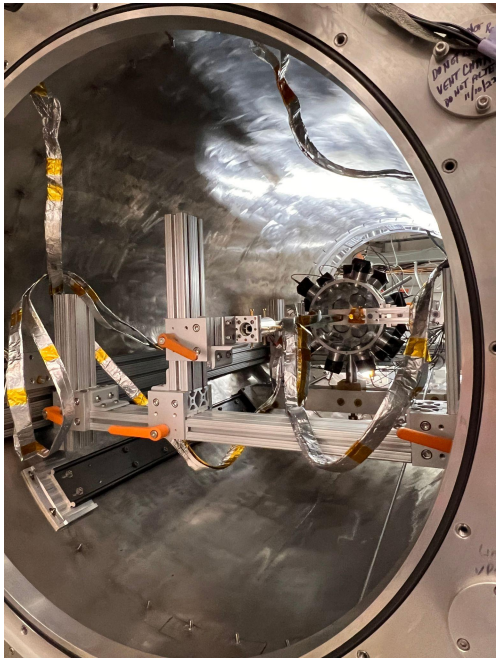




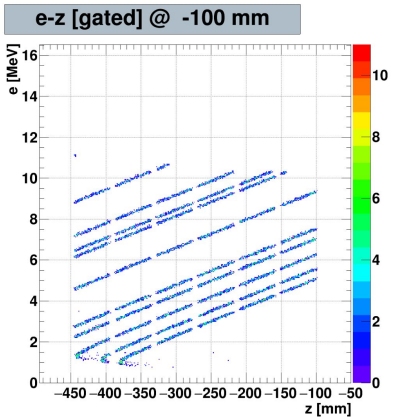
B. P. Kay et al. 2012 J. Phys.: Conf. Ser. 381 012095

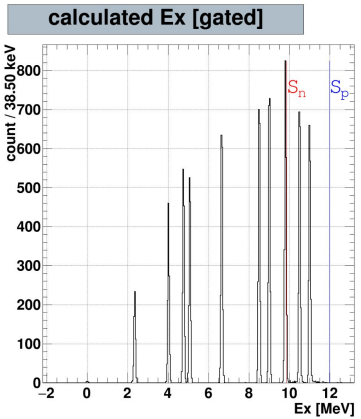
Experimental set-up





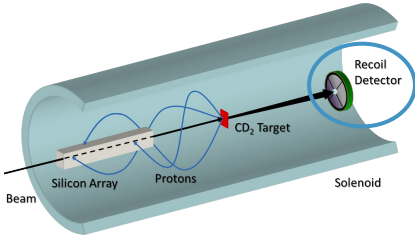
Target-array (1st) distance = 100 mm



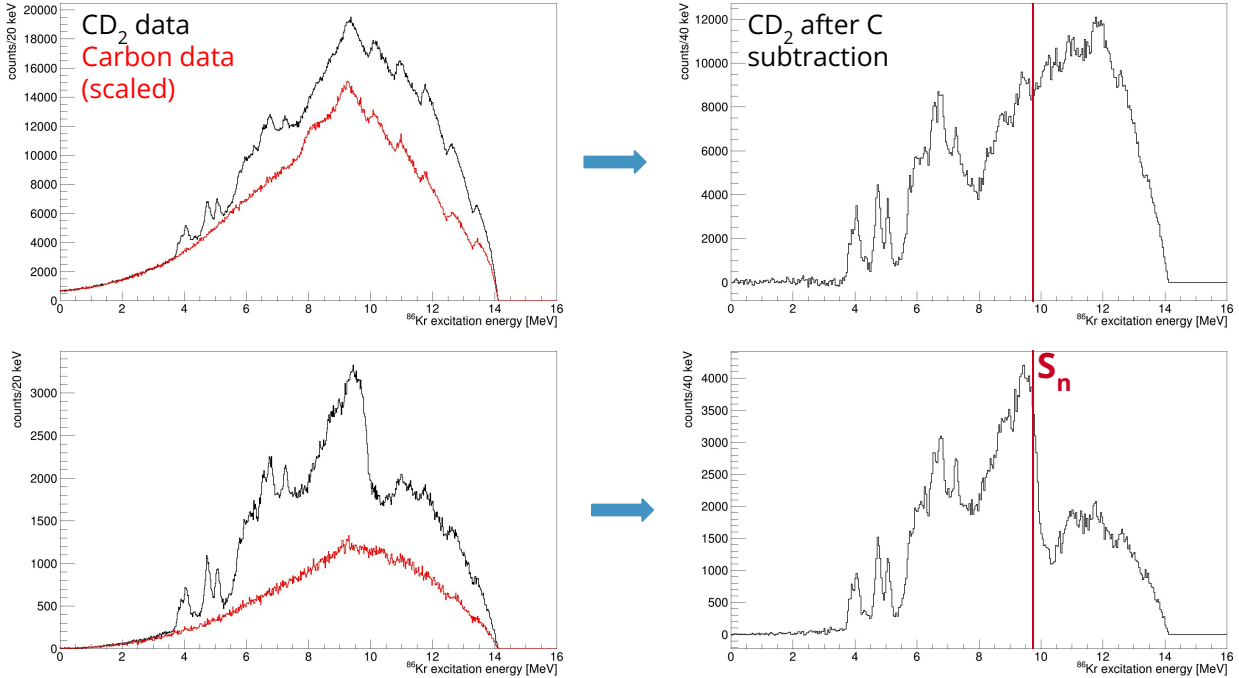


Q-value=7.63 MeV

Analysis: C subtraction



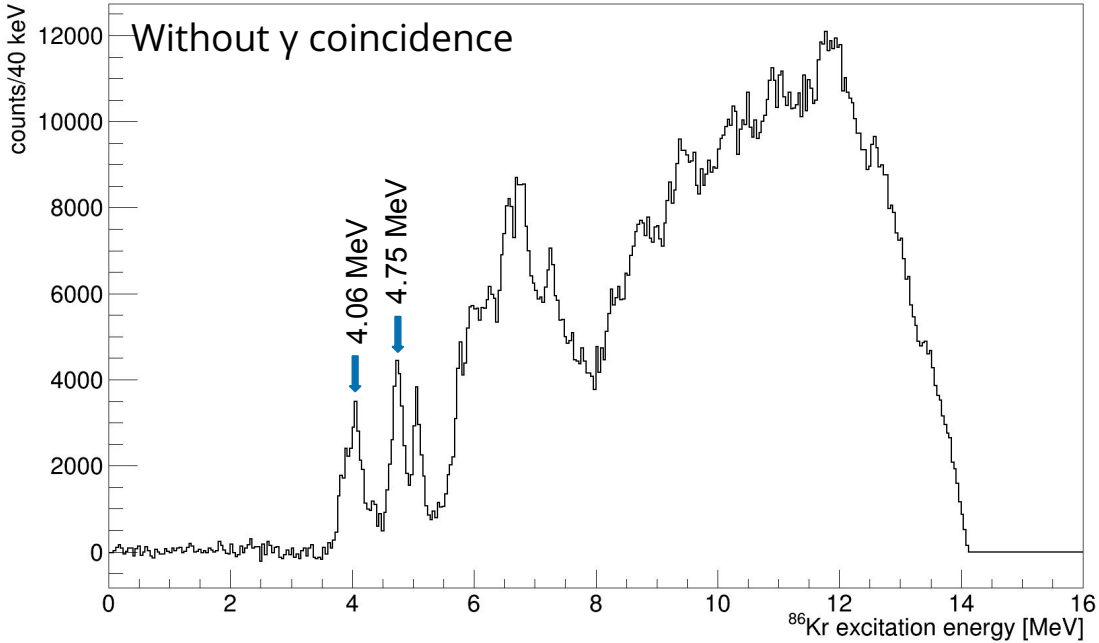
Heavy recoils → can't use recoil detector → Need a run with C target to subtract
2 factors: for p only and for p-γ coincidences



Only protons

p-γ coincidences

Analysis: ^{86}Kr excitation energy spectrum

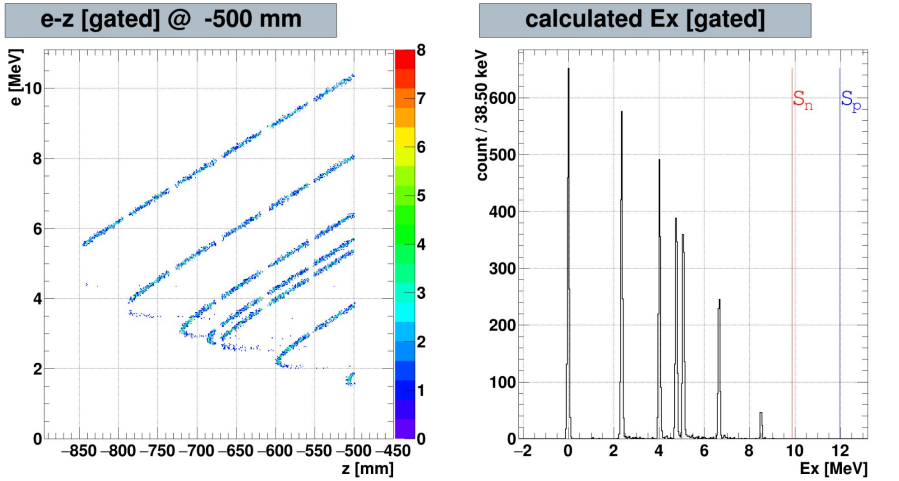


Q-value FWHM ~ 150 keV

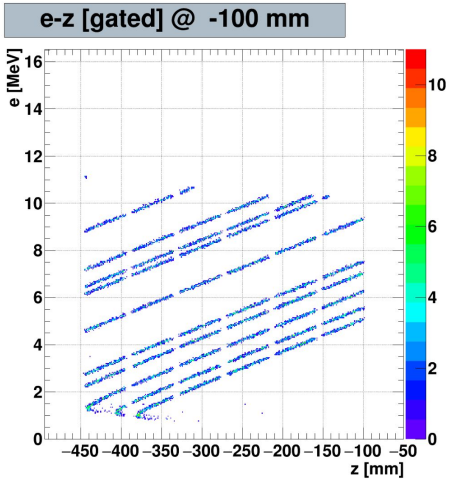
Only a few states already known

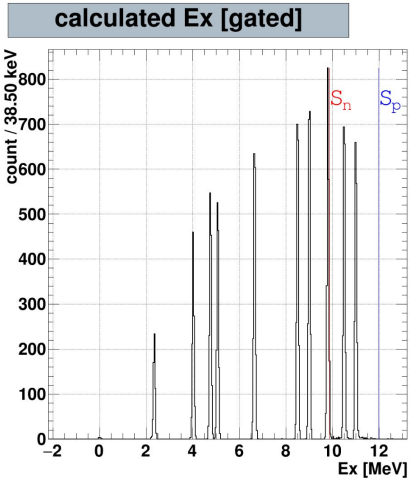
Analysis: 2nd array position

Target-array distance = 500 mm

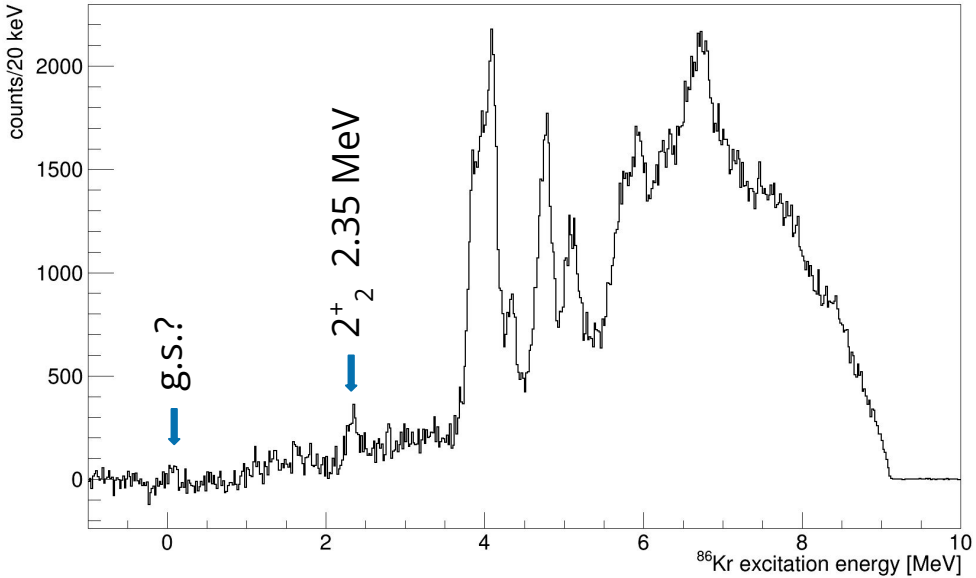


Target-array distance = 100 mm

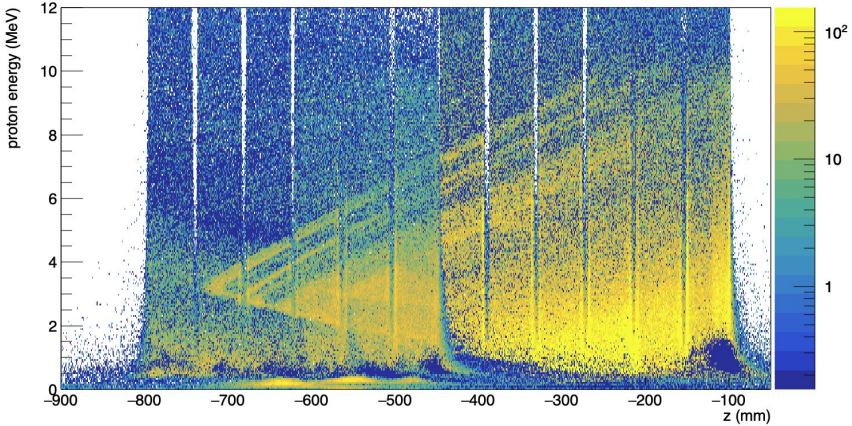




Analysis: 2nd array position



Full kinematics lines!



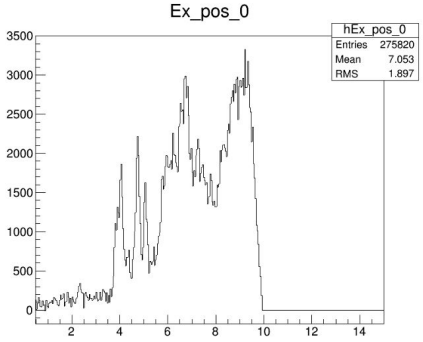
Without γ coincidence

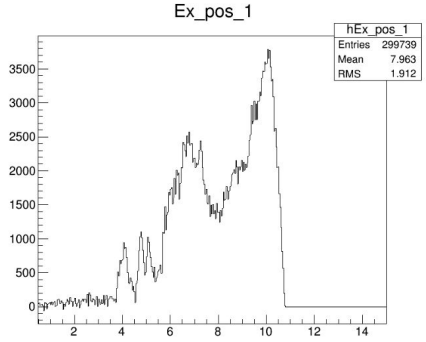
Analysis: angular distributions

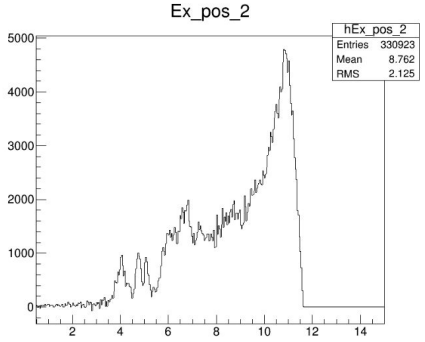
Possible to get angular distributions:

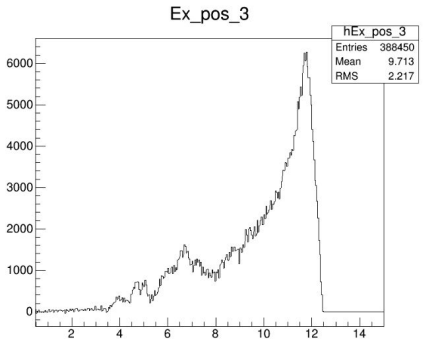
Position in silicon array

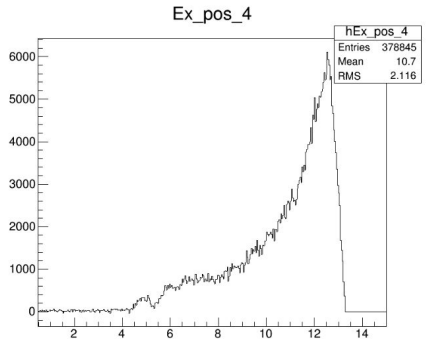
Angle of emission in CM (and geometrical acceptance)

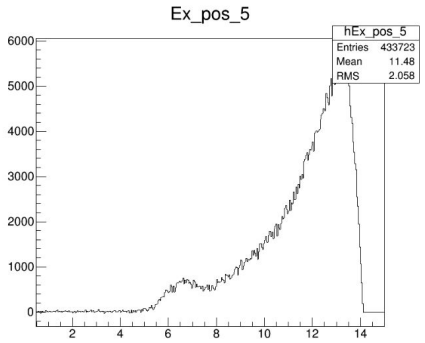








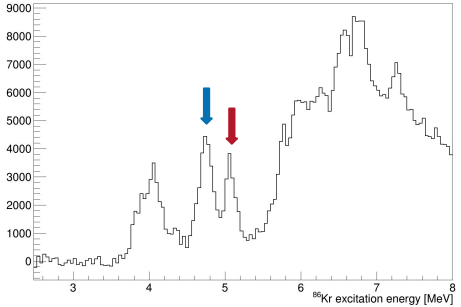


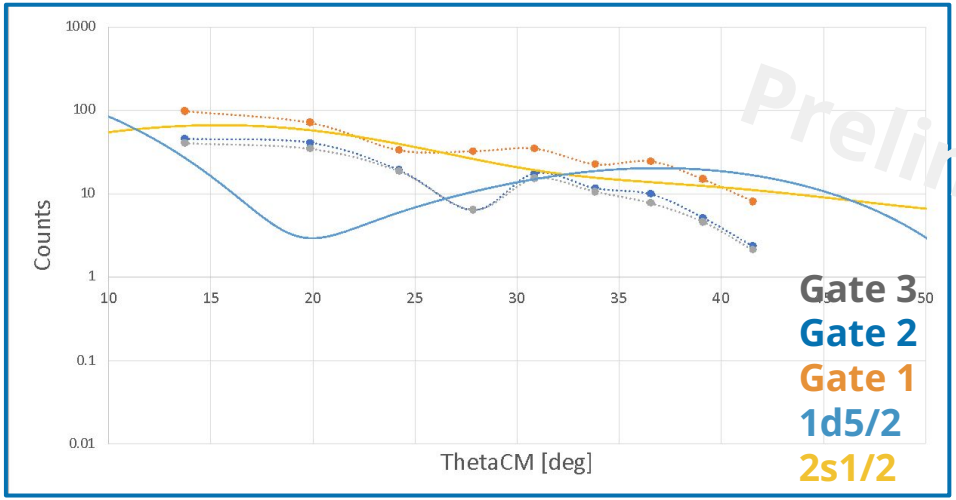


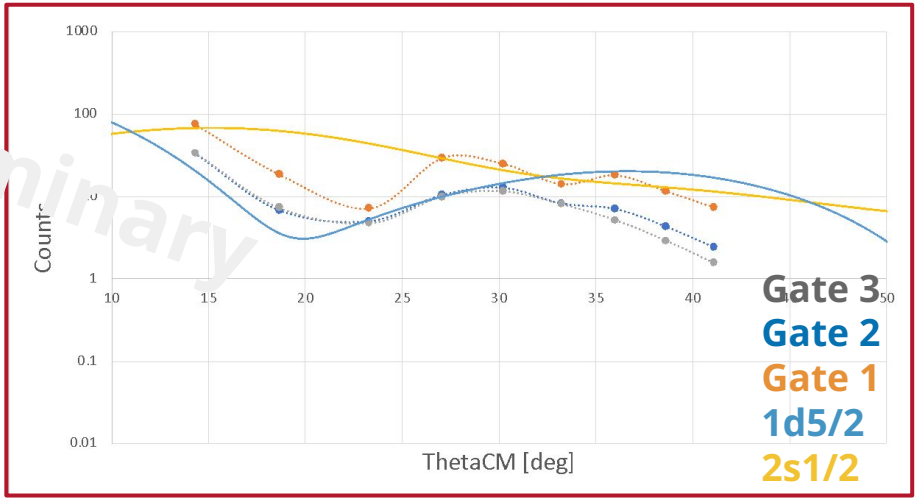
Without γ coincidence

Courtesy of N. Watwood

Analysis: angular distributions

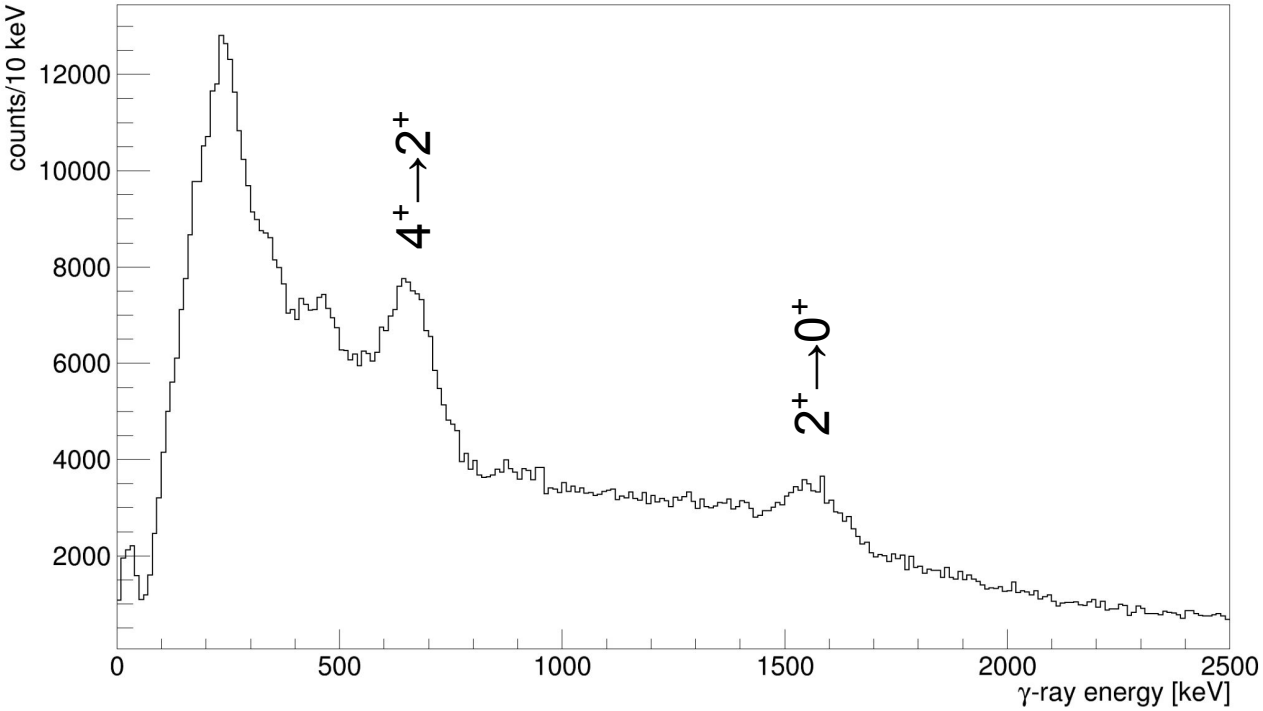






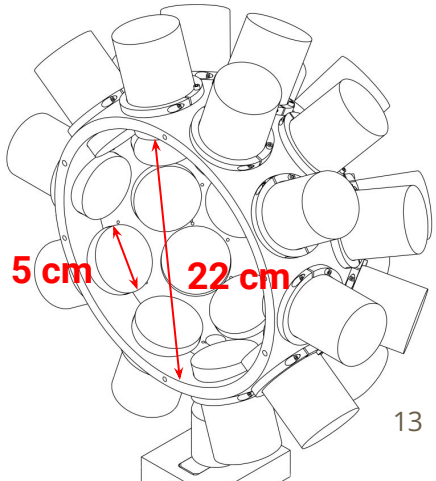
With γ coincidence

Analysis: γ spectrum

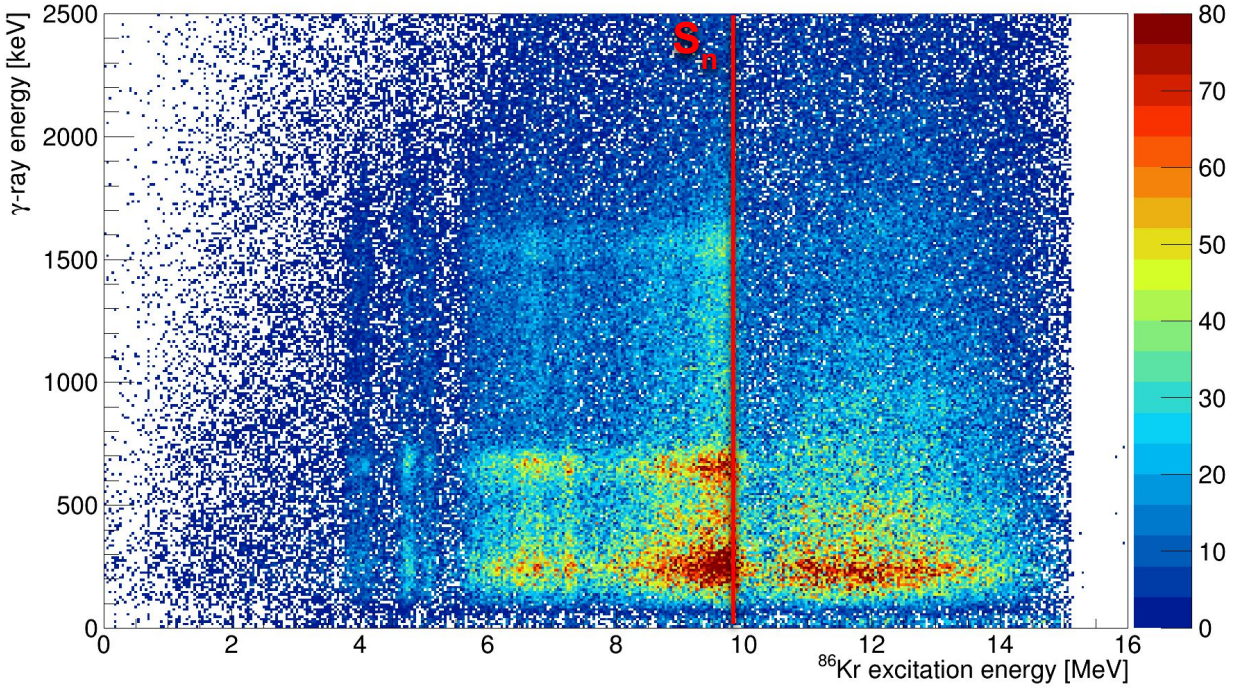


Full statistics

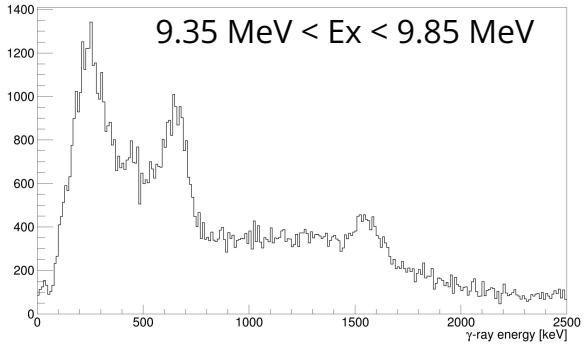
→ Large Doppler broadening

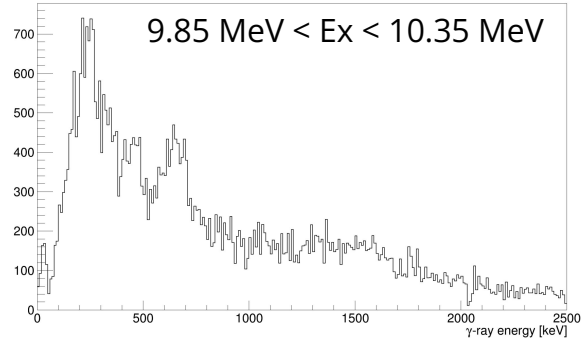


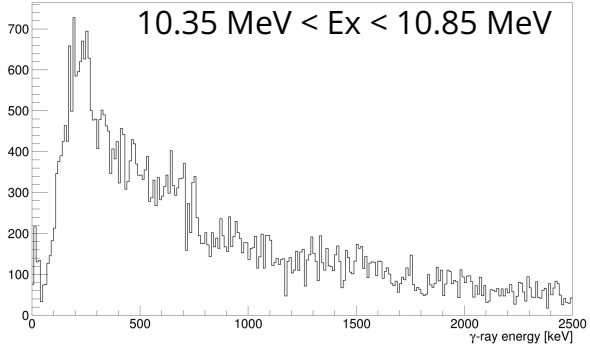
Analysis: γ vs excitation energy



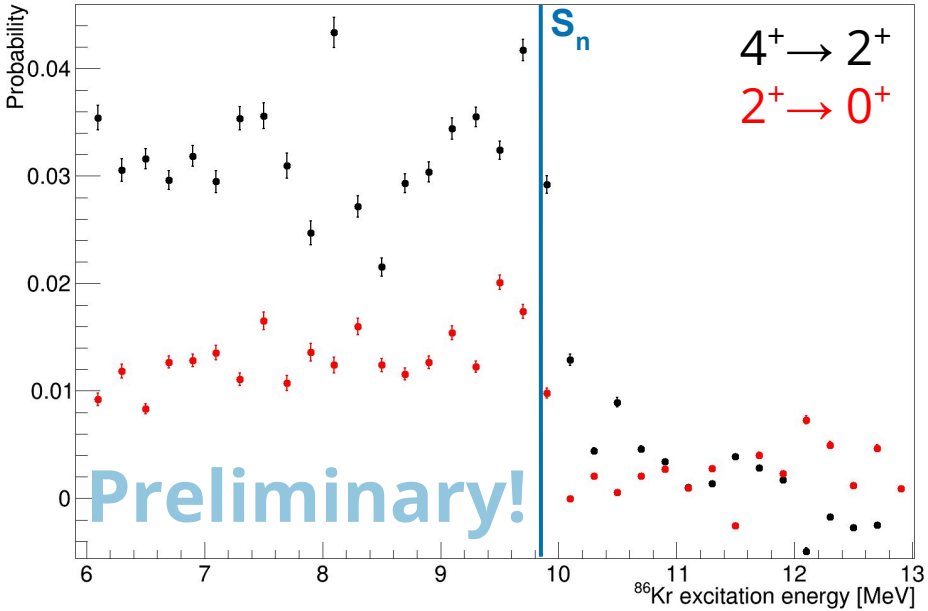
S_n=9.85 MeV

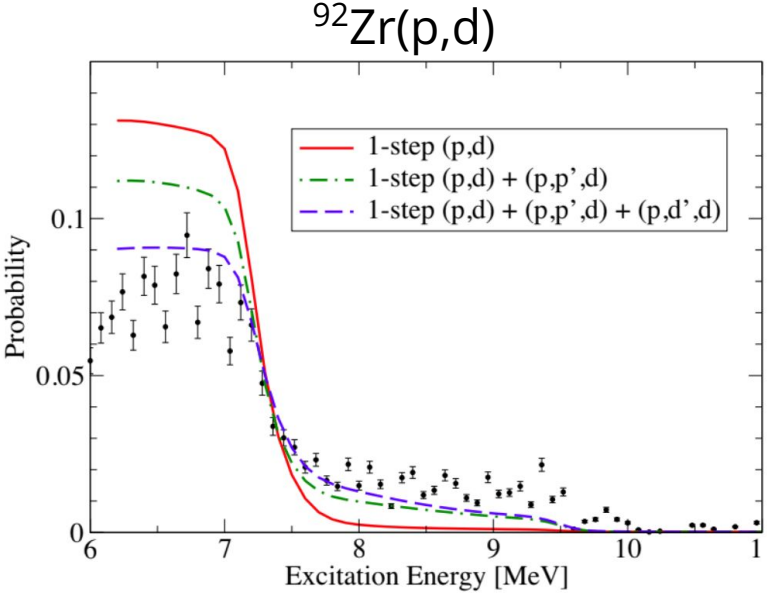






Coincidence probability estimation





J. Escher et al. EPJ Web of Conferences 122, 12001 (2016)

Conclusion

- Coincidence between protons and ys observed ✔
- C subtraction ✔
- First estimation of coincidence probability ✔

Next steps:

- 4^+ is an isomer ($T_{1/2}$=3.1 ns) → need a simulation
- (n,γ) conversion

New possibilities: ^{59}Fe(d,pγ) and ^{134}Cs(d,pγ) proposals accepted!

Thank you for your attention!

A study of the (d,pγ) reaction on radioisotope ^{85g}Kr to constrain a key s-process branching point

S. Carollo[1,2], N. Watwood[3], B. P. Kay[3], F. Recchia[1,2], G. de Angelis[4], P. Aguilera[1,2], M. L. Avila[3], J. Benito Garcia[2], K. Bhatt[3], D. Brugnara[4], K. A. Chipps[5], A. Couture[6], S. Dutta[7], A. Ertoprak[4], R. Escudeiro[1,2], S. J. Freeman[8,9], F. Galtarossa[2], B. Gongora Servin[4,10], A. Gottardo[4], A. Hall-Smith[3,11], J. Henderson[12], C. Hoffman[3], R. O. Hughes[13], H. Jayatissa[6], S. M. Lenzi[1,2], D. Mengoni[1,2], M. R. Mumpower[6], W. J. Ong[13], M. Paul[14], J. Pellumaj[4,10], R. M. Perez Vidal[4,15], S. Pigliapoco[1,2], A. Ratkiewicz[13], K. Rezynkina[2], D. K. Sharp[9], Y. Sun[7], T. L. Tang[16], I. A. Tolstukhin[3], M. Williams[13].