An investigation into quasifree scattering of nuclei around N=14

R^{3}B collaboration

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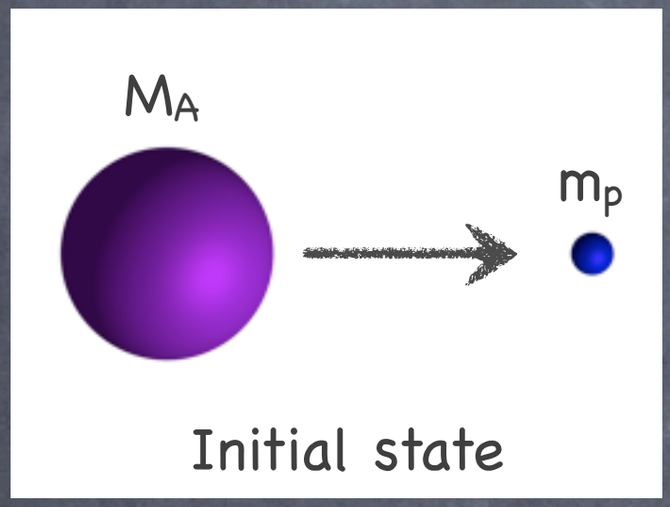
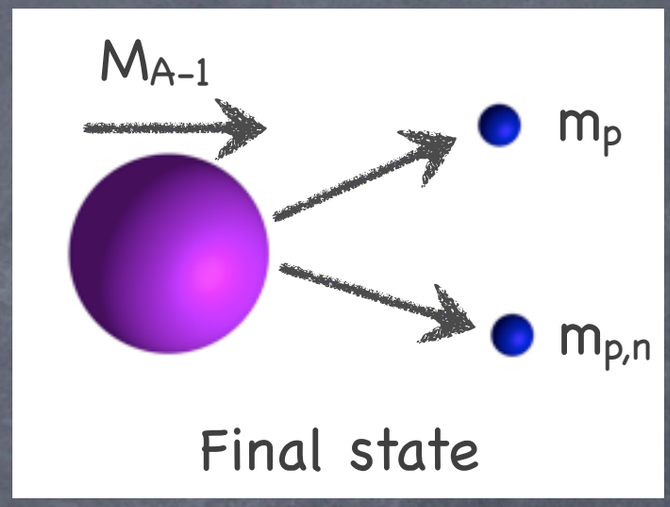
ASY-EOS 2012 International Workshop on Nuclear Symmetry Energy and Reaction Mechanisms

Quasi-free scattering in light neutron-rich nuclei Motivation

Quasi-Free scattering reactions → Evolution of **shell structure** for **valence** and **deeply bound nucleons**

→ **Spectroscopic factors**





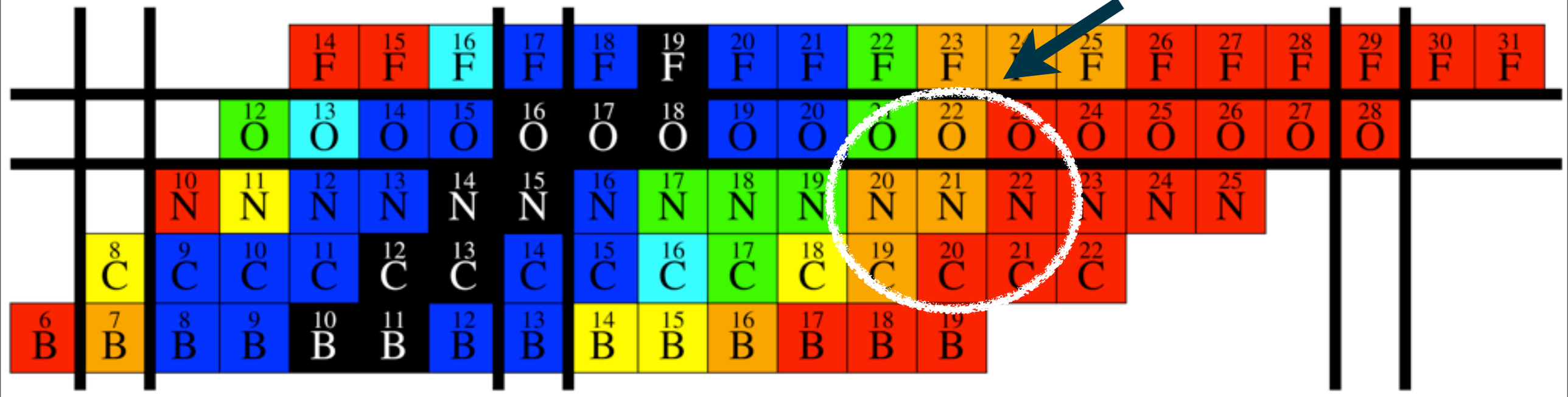
- Kinematical complete measurements of (p,pn), (p,2p), (p,pd), (p,pα), ... reactions
- Redundant information: kinematical reconstruction from proton momenta plus gamma rays, invariant mass, recoil momentum
- Not only sensitive to the surface (knockout from valence and deeply bound states)

Quasi-free scattering in light neutron-rich nuclei

- (p,pn) → n-shell closure N=14
- (p,2p) → bound, unbound states

→ carbon, nitrogen, oxygen

N=14



Selection of the reaction channel:

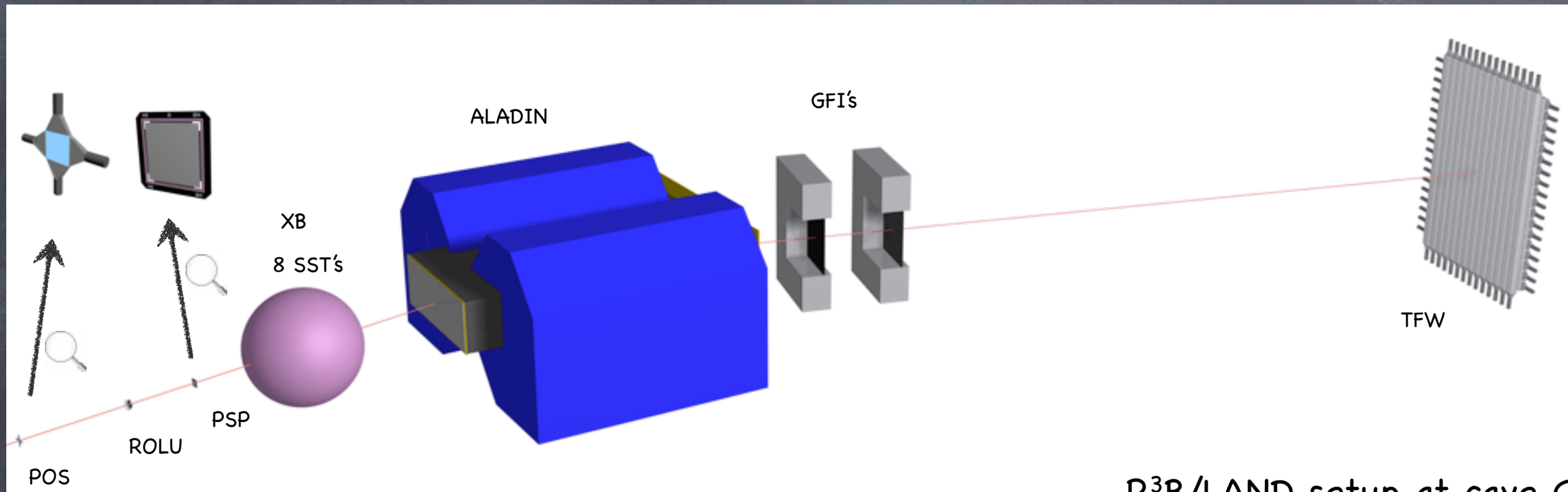
- identification and tracking incoming/outgoing
- level scheme
- angular correlations in (p,2p), (p,pn)

Observables:

- excitation energy
- momentum distributions
- spectroscopic factors

Quasi-free scattering in light neutron-rich nuclei

Setup



R³B/LAND setup at cave C

- POS: used as start (stop) detector for the ToF measurements. It's a quadratic plastic scintillator (2.5 cm x 2.5 cm)
- ROLU: Four movable plastic scintillators, used to define the accepted beam spot size
- PSP: Position Sensitive silicon Pin diode, used for beam tracking and energy loss (Z)
- XB: 4pi gamma-spectrometer, 162 NaI crystals
- SSD's: 8 Silicon Strip Detectors, 4 in-beam and 4 surrounding the target. Used for tracking and energy loss (Z)
- ALADIN: A Large Area Dipole magNet
- GFI's: Grosse Fiber Detector, tracking (horizontal position)
- TFW: Time Flight Wall, time of flight and energy loss measurements

Quasi-free scattering in light neutron-rich nuclei Incoming

Primary beam ^{40}Ar

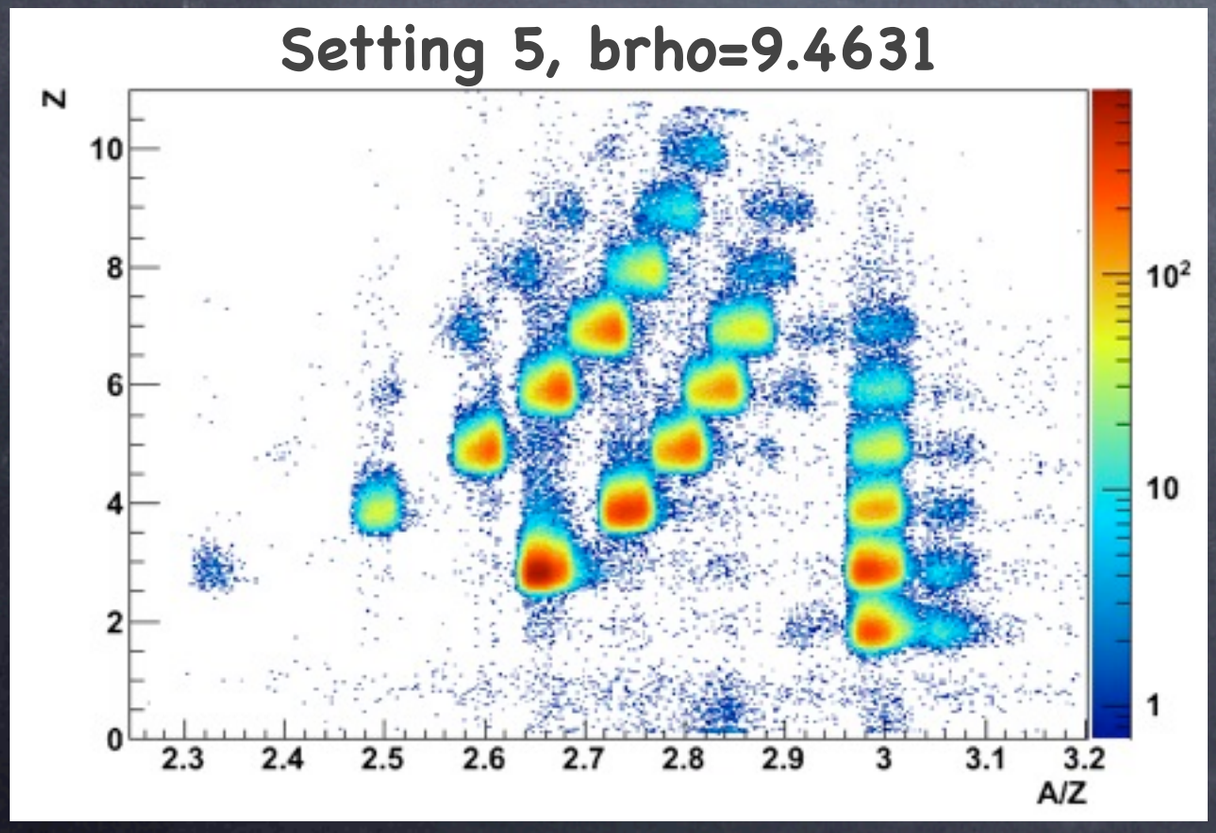
Cocktail Secondary Beam: ~500 AMeV

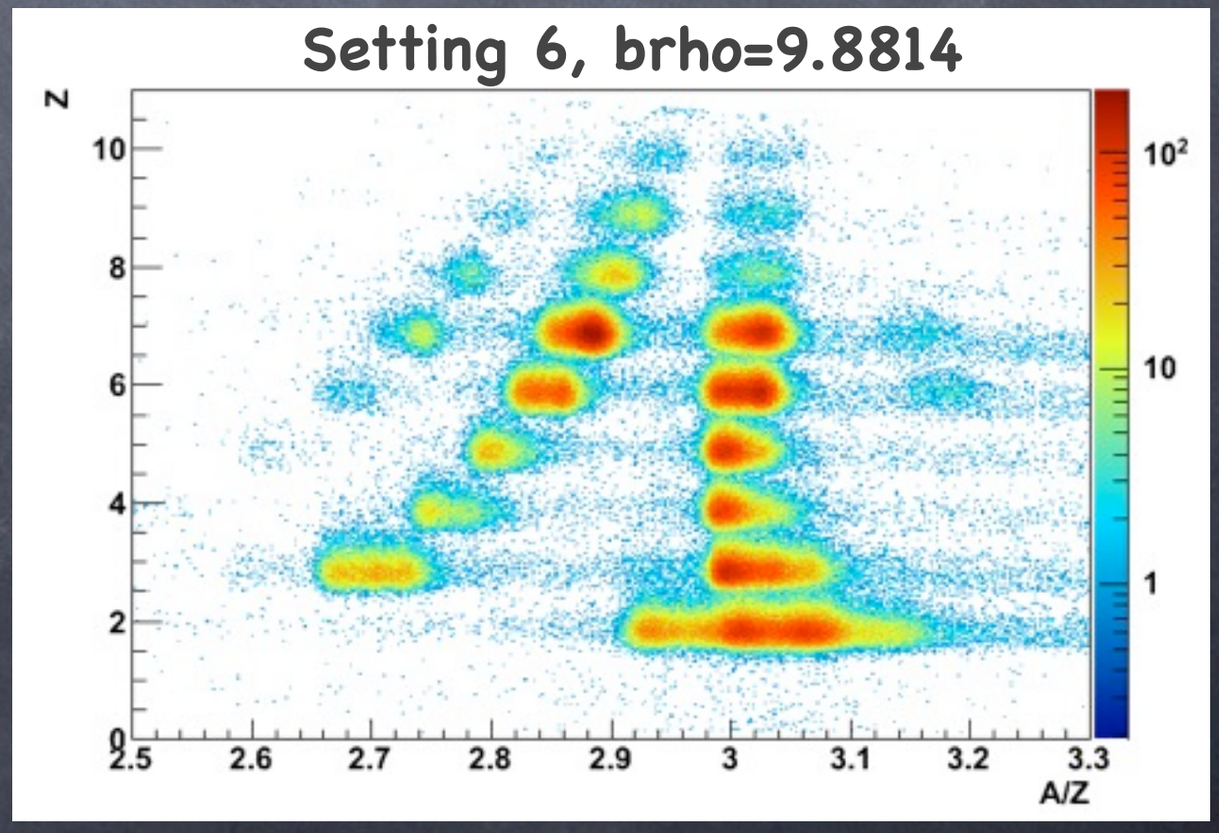
targets → CH_2 922 mg/cm^2 (9.81 mm)

C 935 mg/cm2 (5 mm)

- Time of Flight between S8 and POS => β
- From the FRS => Bρ
- Energy loss in PSP => Z

→ A , Z

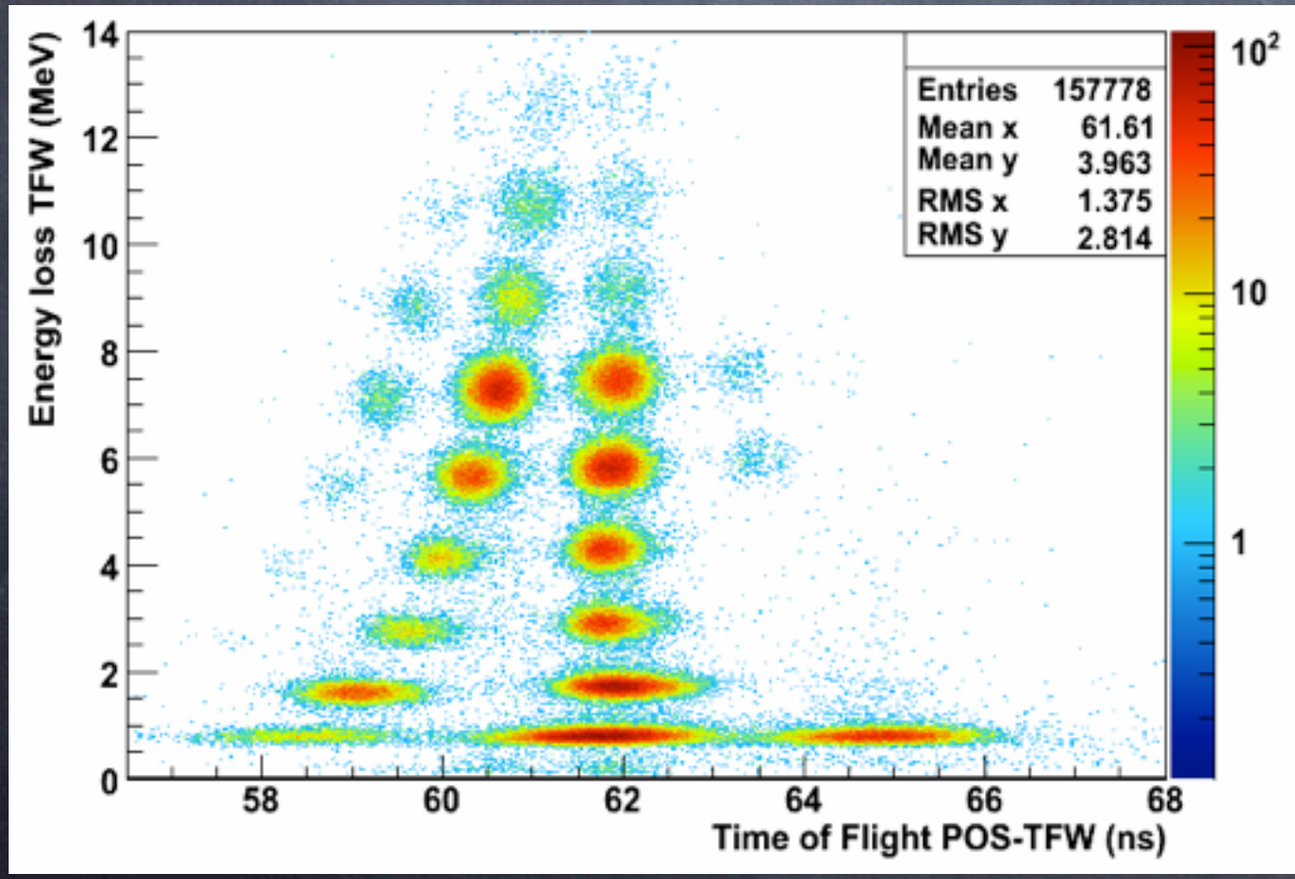


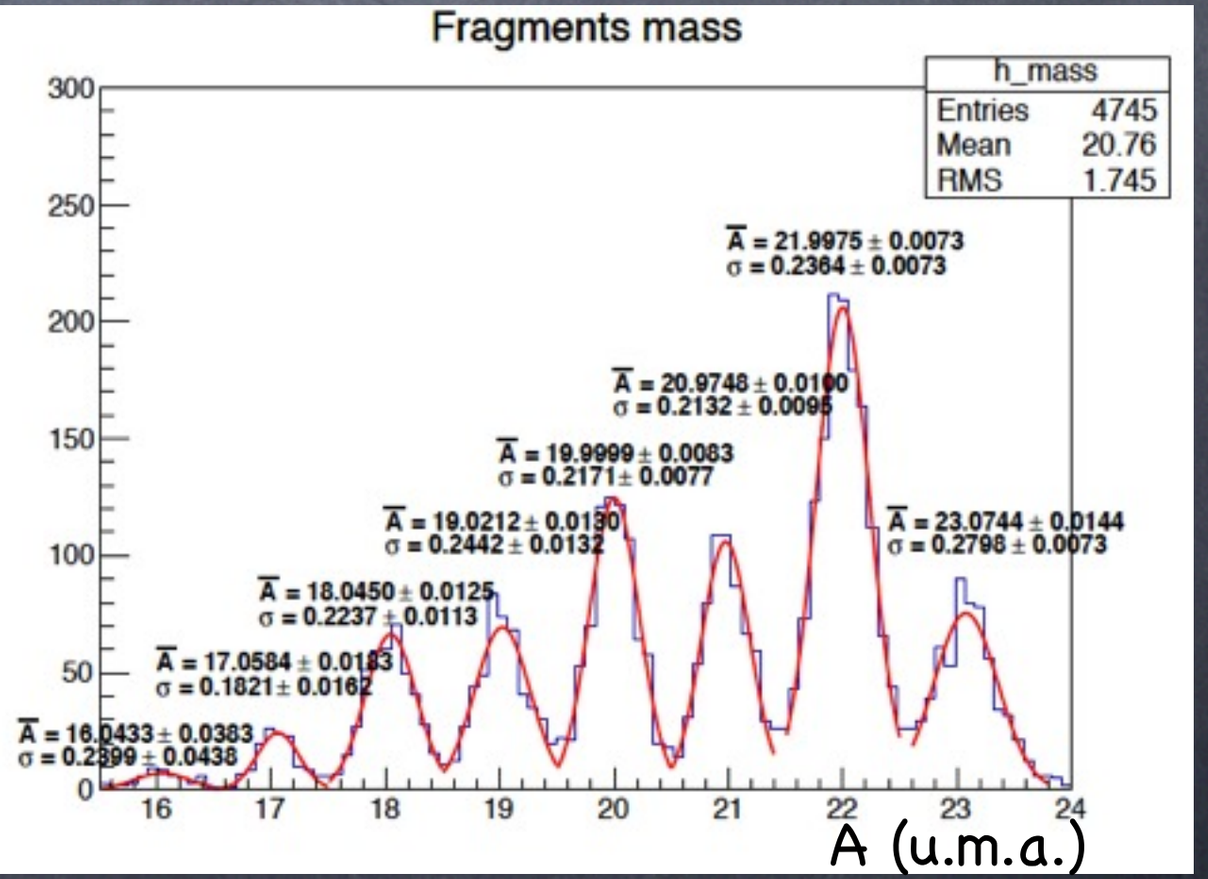


Quasi-free scattering in light neutron-rich nuclei Outgoing

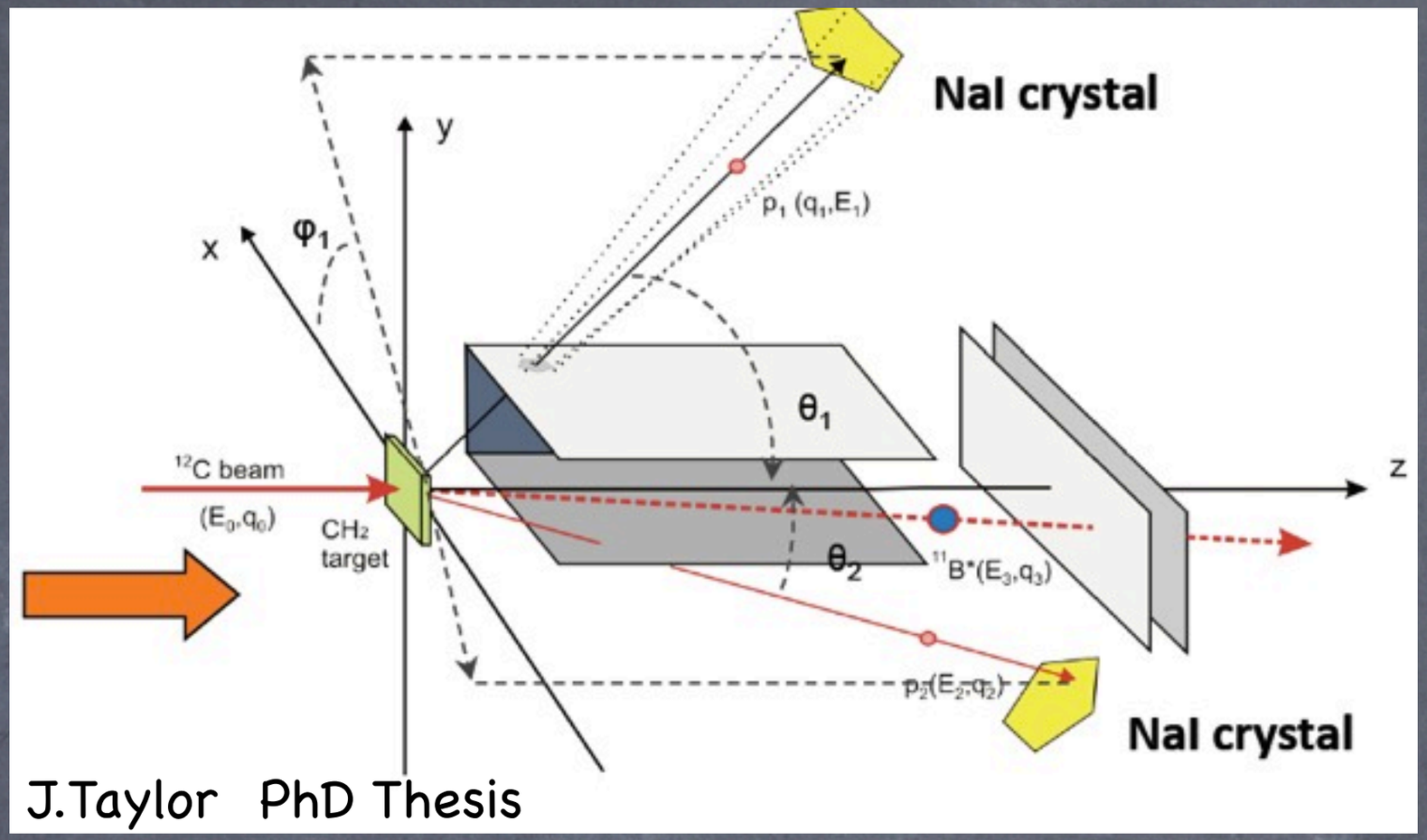
- Time of Flight between target and TFW => β
- Deflection in a magnetic field **(ALADIN + GFI) => Bρ => A/Z**
- Energy loss in TFW and in SSD's => Z

$B\rho \sim \beta\, A/Z$



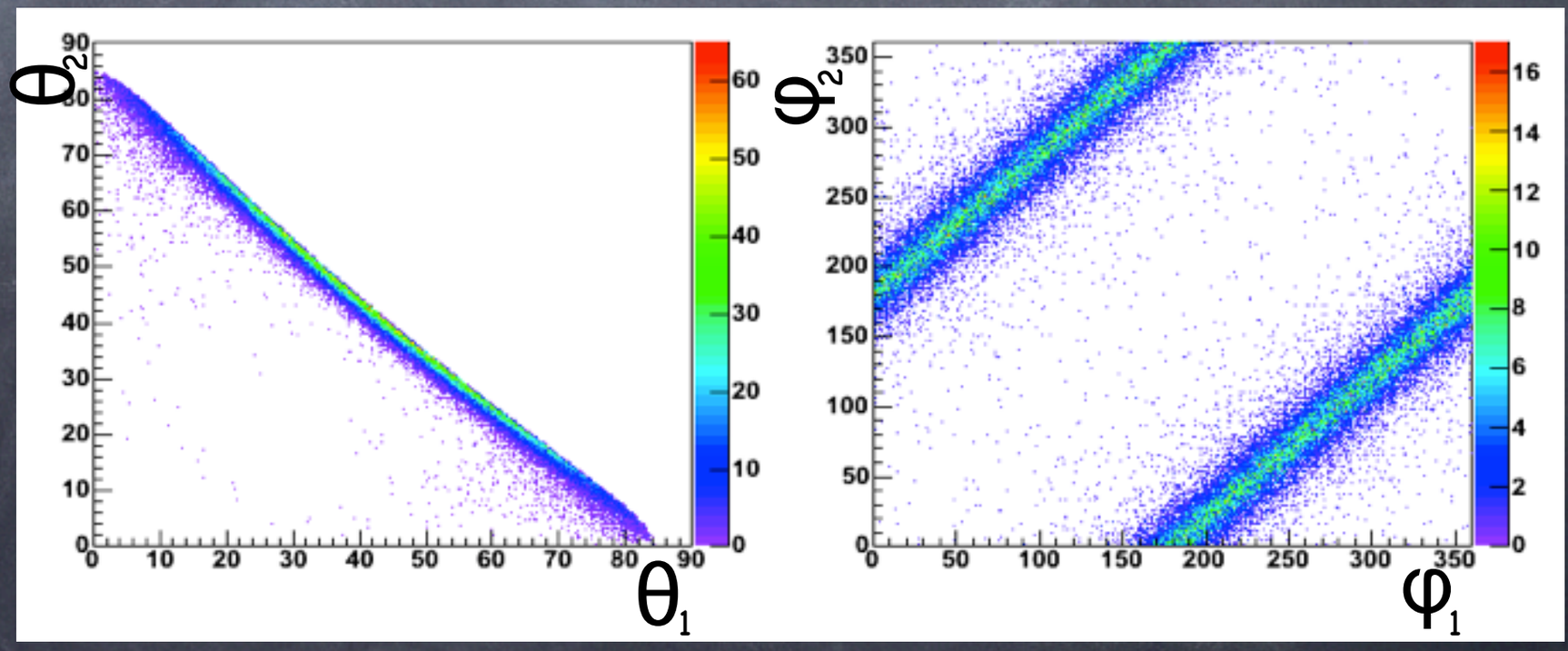


Quasi-free scattering in light neutron-rich nuclei Signature



J.Taylor PhD Thesis

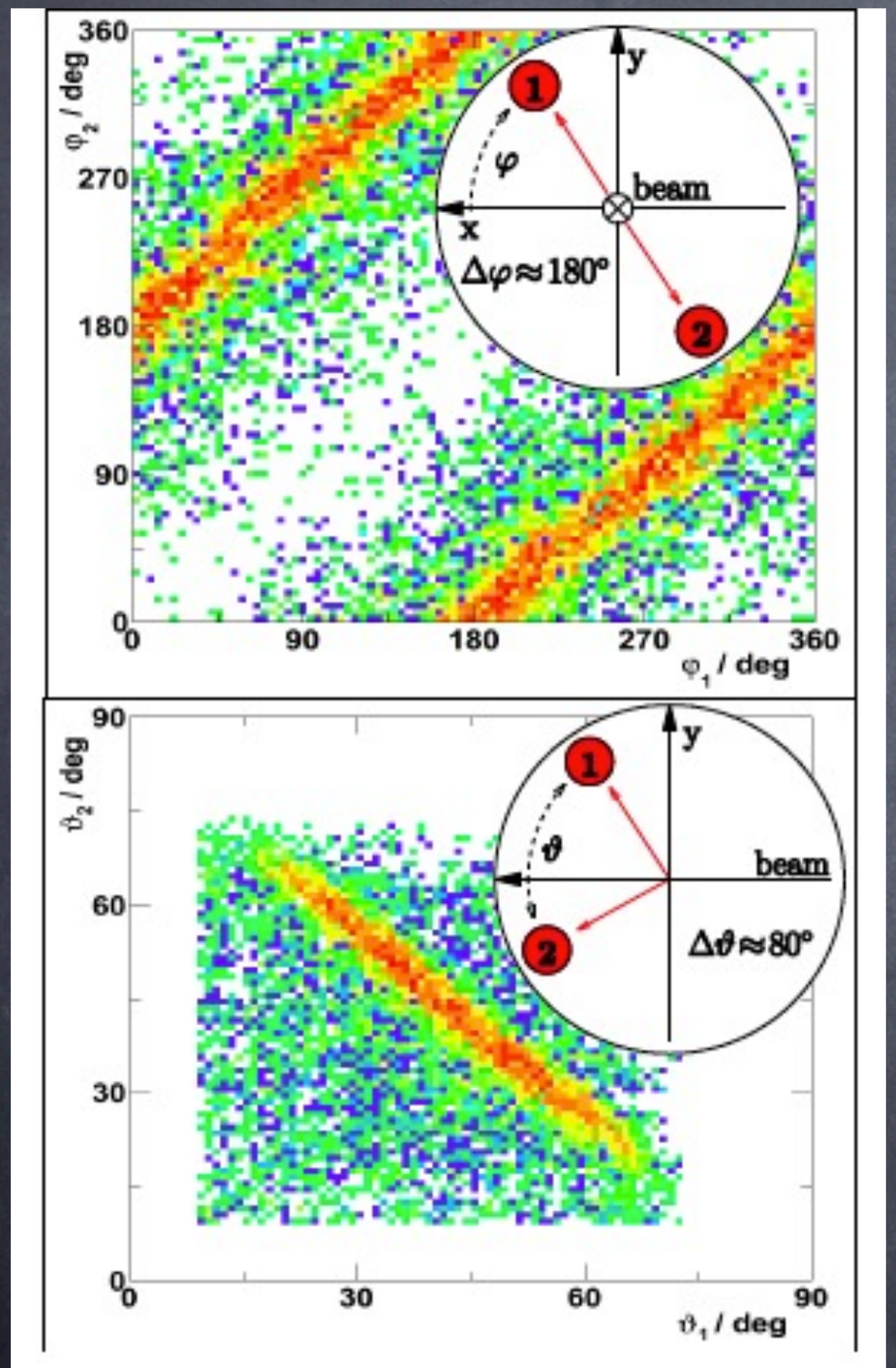
Angular distributions calculated in simulation using L.Chulkov code



Quasi-free scattering in light neutron-rich nuclei

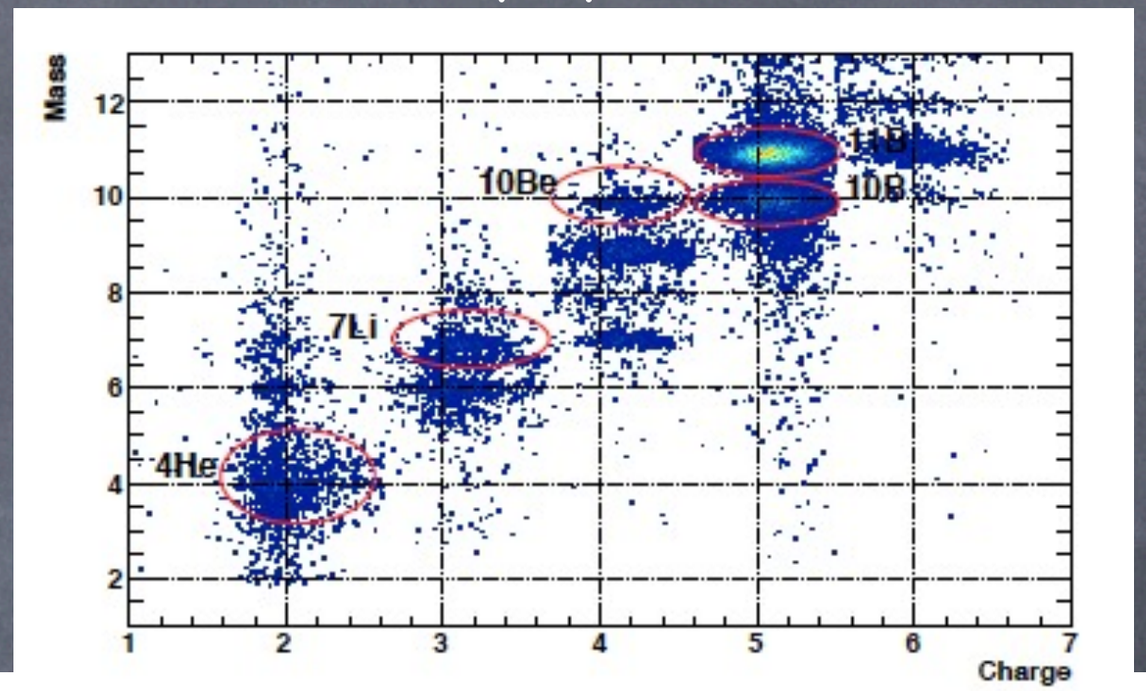
Some previous results of the R3B collaboration using the LAND/R3B setup

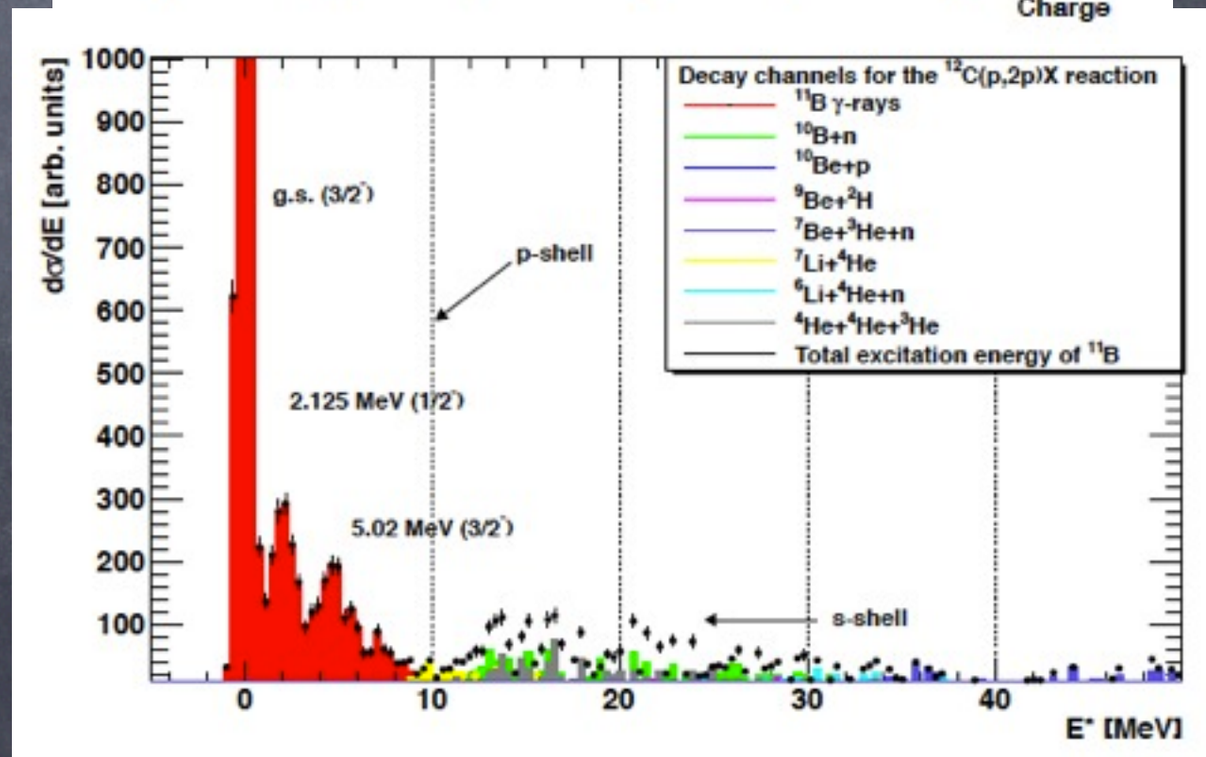
$^{17}Ne(p,2p)^{15}O+p$



F. Wamers PhD thesis

$^{12}C(p,2p)X$





J.Taylor PhD thesis V.Panin PhD thesis

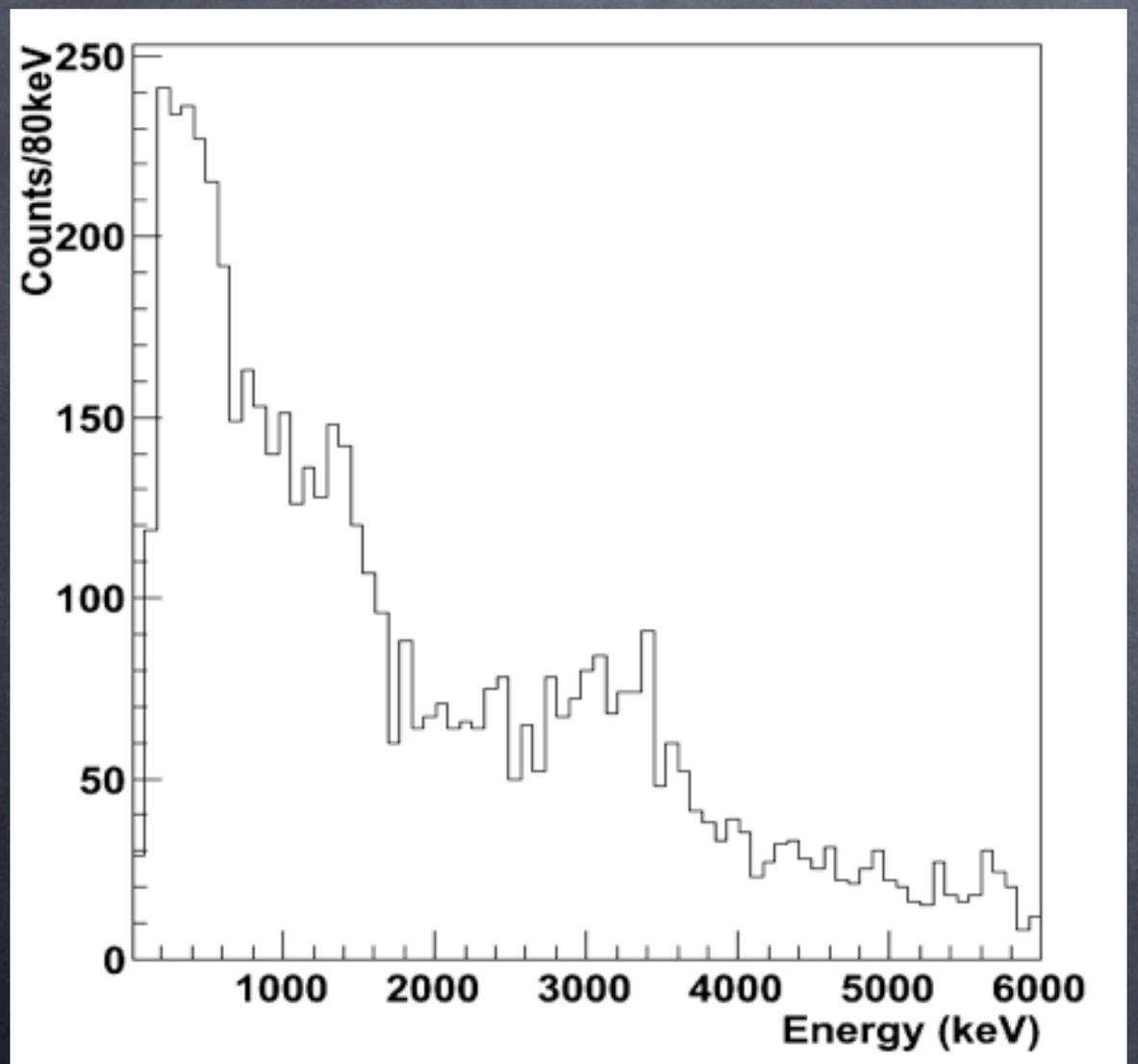
Preliminary results

Gamma rays

Preliminary results: $^{23}O(p,pn)^{22}O$

Gamma rays

Our results



Previous results

VOLUME 93, NUMBER 6 PHYSICAL REVIEW LETTERS week ending 6 AUGUST 2004

Shell Structure of the Near-Dripline Nucleus ^{23}O

D. Cortina-Gil,[1,2] J. Fernandez-Vazquez,[1] T. Aumann,[2] T. Baumann,[3] J. Benlliure,[1] M. J. G. Borge,[4] L. V. Chulkov,[2,5] U. Datta Pramanik,[2] C. Forssén,[6] L. M. Fraile,[4] H. Geissel,[2] J. Gerl,[2] F. Hammache,[2] K. Itahashi,[7] R. Janik,[8] B. Jonson,[6] S. Mandal,[2] K. Markenroth,[6] M. Meister,[6] M. Mocko,[8] G. Münzenberg,[2] T. Ohtsubo,[2] A. Ozawa,[9] Y. Prezado,[4] V. Pribora,[2,5] K. Riisager,[10] H. Scheit,[11] R. Schneider,[12] G. Schrieder,[13] H. Simon,[13] B. Sitar,[8] A. Stolz,[12]

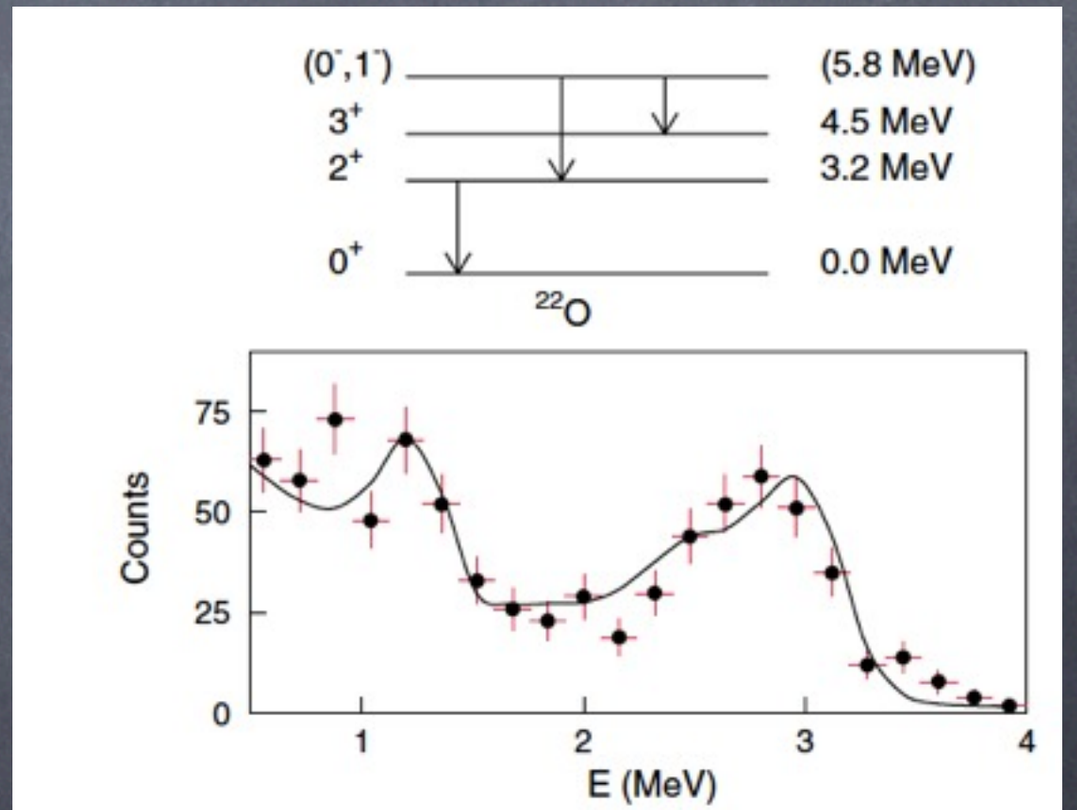


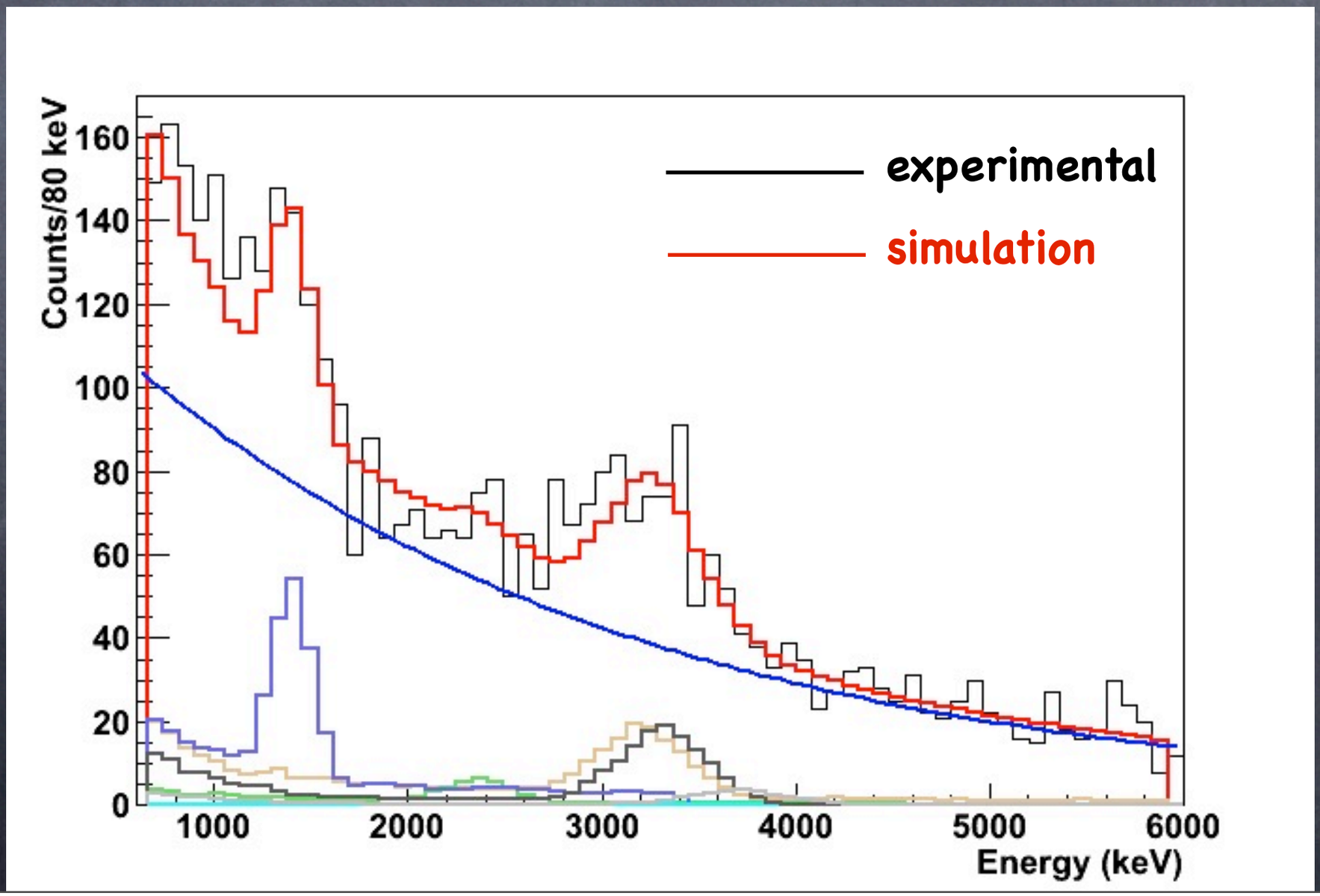
FIG. 2 (color online). Spectrum of γ rays in coincidence with ^{22}O fragments after one-neutron removal from ^{23}O in a carbon target. The spectrum shown has been obtained from the measured γ-ray spectrum (see text). The experimental spectrum is compared with the result of a GEANT simulation adopting the level scheme shown above.

Preliminary results: $^{23}O(p,pn)^{22}O$ Gamma rays

Reproducing the real data with r3broot

experimental gamma ray spectra + simulated peaks: 3199, 1383, 1710, 2354, 3310, 3710

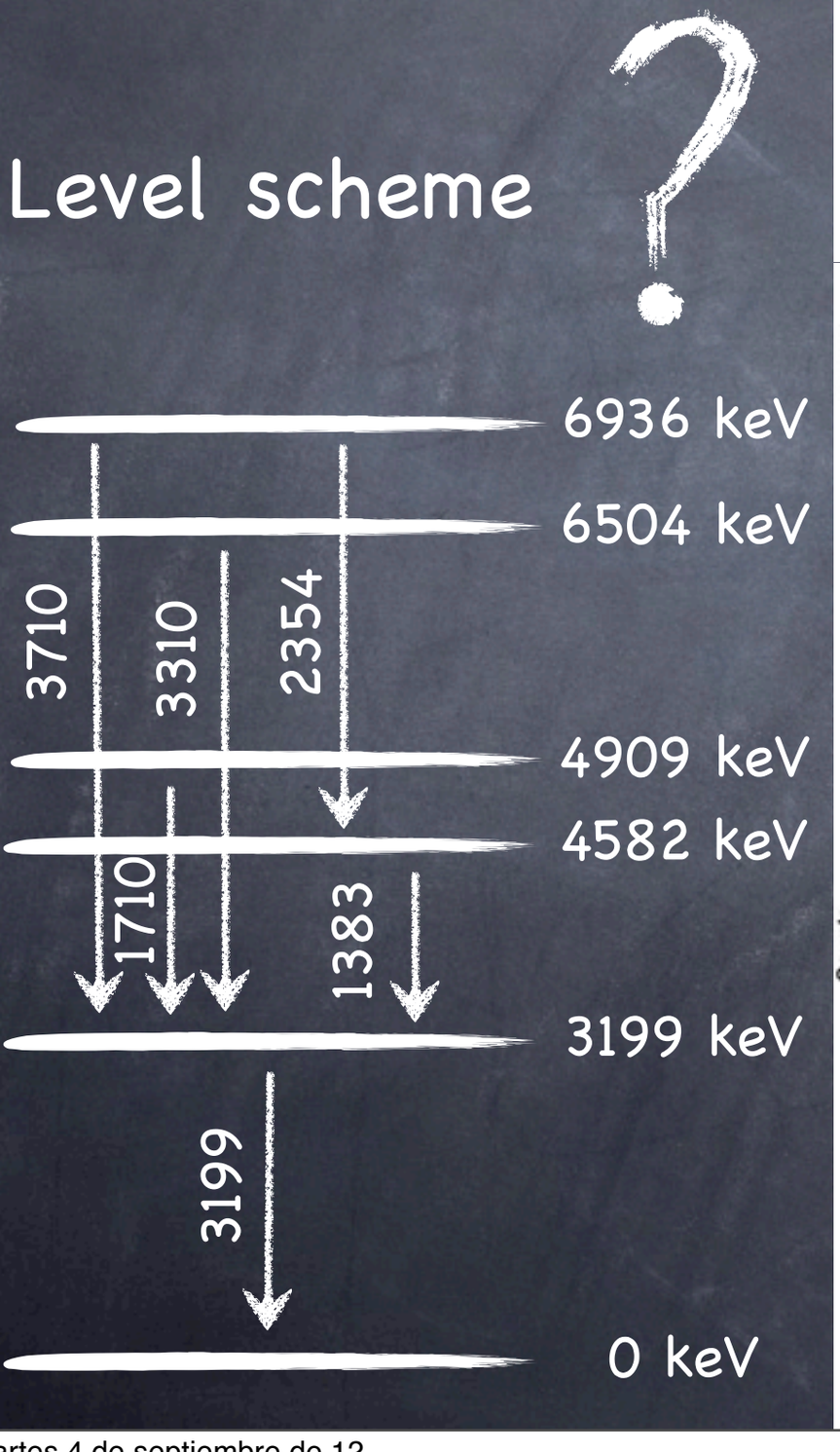
MINIMISATION

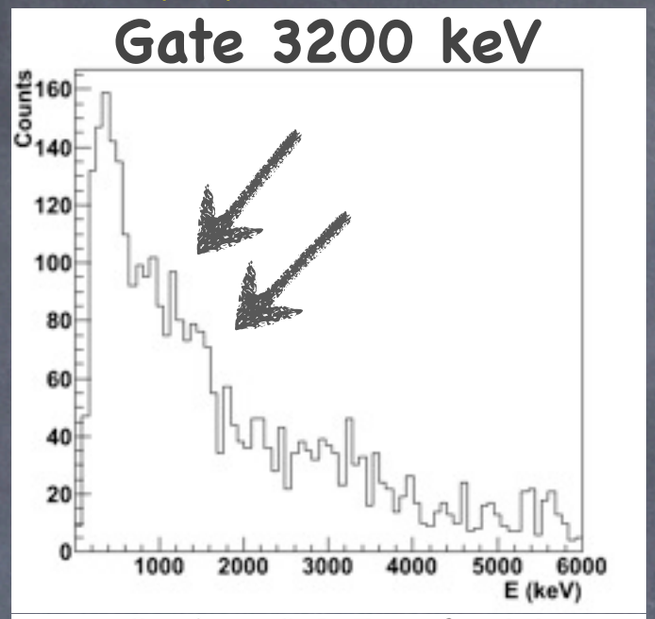


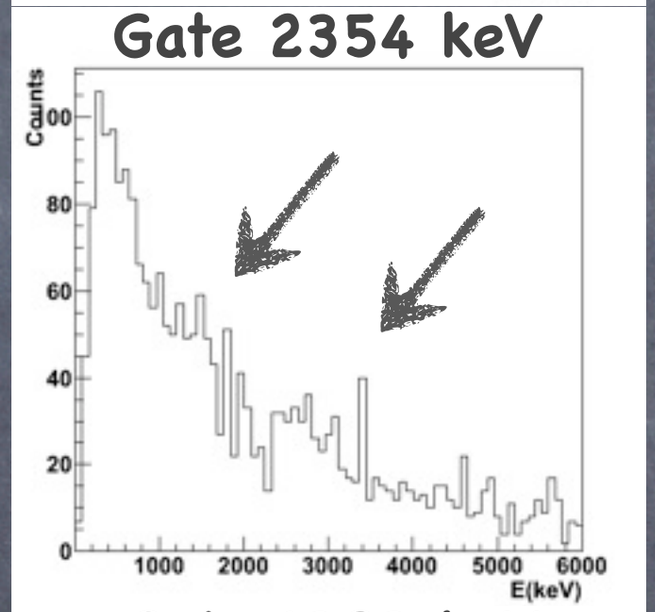
Preliminary results: $^{23}O(p,pn)^{22}O$

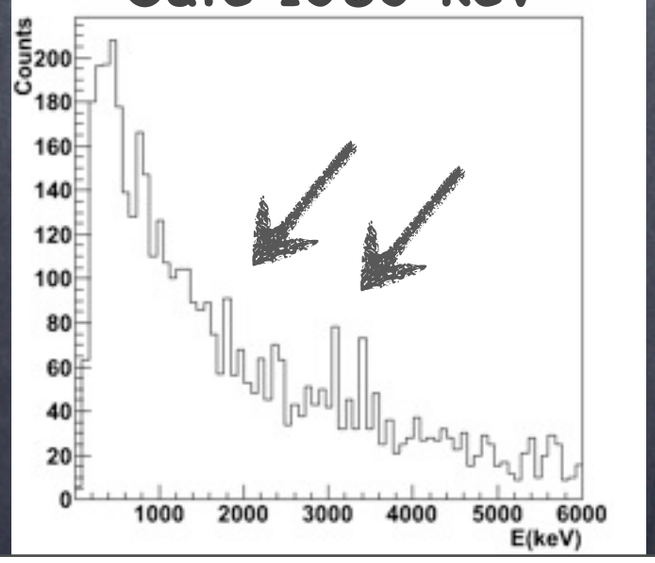
Gamma rays

Level scheme









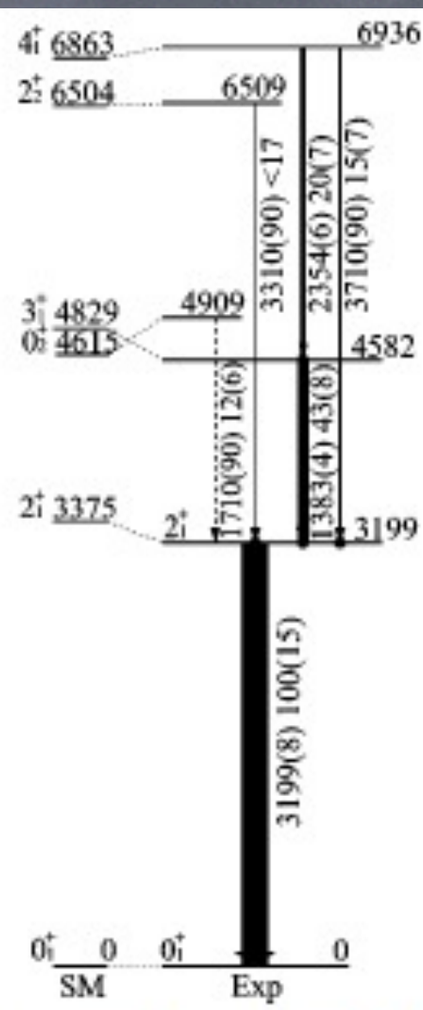


FIG. 10. The measured level scheme of ^{22}O together with the *sd*-shell-model calculations. Transition energies and relative intensities are indicated together with their uncertainties for γ lines.

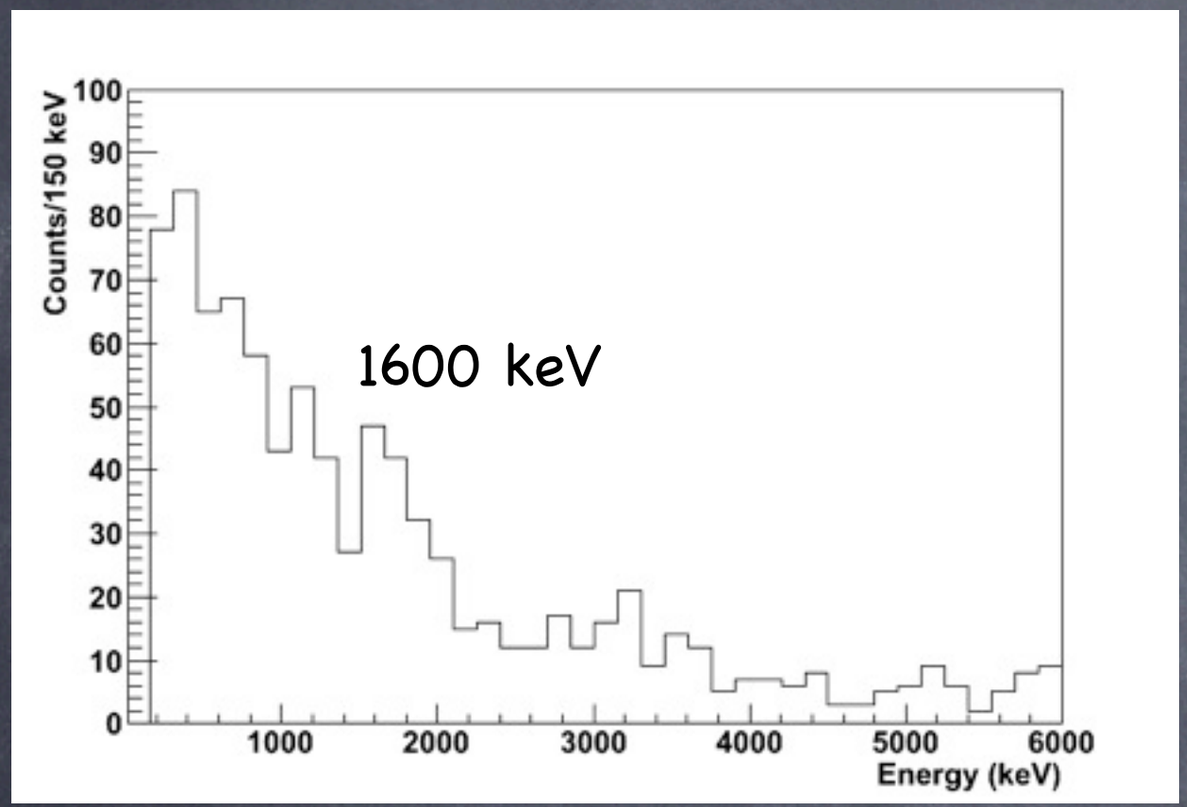
N=14 and 16 shell gaps in neutron-rich oxygen isotopes

M. Stanoiu,[1,2] F. Azaiez,[2] Zs. Dombrádi,[3] O. Sorlin,[2] B. A. Brown,[4] M. Belleguic,[2] D. Sohler,[3] M. G. Saint Laurent,[1] M. J. Lopez-Jimenez,[1] Y. E. Penionzhkevich,[5] G. Sletten,[14] N. L. Achouri,[6] J. C. Angélique,[6] F. Becker,[1] C. Borcea,[7] C. Bourgeois,[2] A. Bracco,[8] J. M. Daugas,[1] Z. Dlouhý,[9] C. Donzaud,[2] J. Duprat,[2] Zs. Fülöp,[3] D. Guillemaud-Mueller,[2] S. Grévy,[6] F. Ibrahim,[2] A. Kerek,[10] A. Krasznahorkay,[3] M. Lewitowicz,[1] S. Leenhardt,[2] S. Lukyanov,[5] P. Mayet,[11] S. Mandal,[11] H. van der Marel,[10] W. Mittig,[1] J. Mrázek,[12] F. Negoita,[7] F. De Oliveira-Santos,[1] Zs. Podolyák,[12] F. Pougheon,[2] M. G. Porquet,[13] P. Roussel-Chomaz,[1] H. Savajols,[1] Y. Sobolev,[5] C. Stodel,[1] J. Timár,[3] and A. Yamamoto[12]

Preliminary results: $^{21}N(p,2p)^{20}C$

Gamma rays

S393

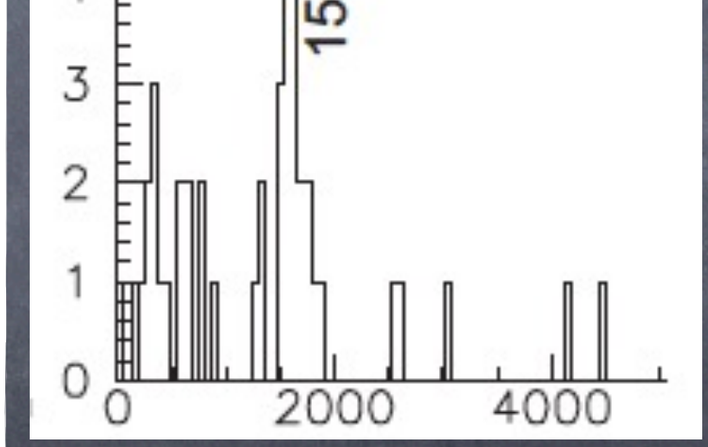


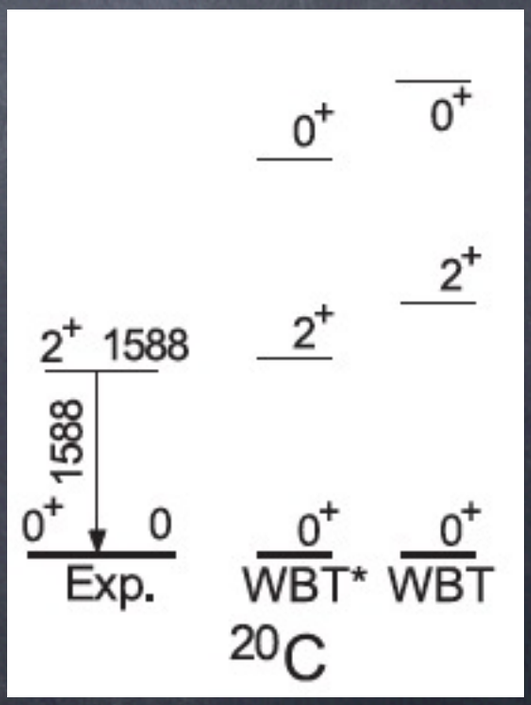
Previous results

PHYSICAL REVIEW C 78, 034315 (2008)

Disappearance of the $N = 14$ shell gap in the carbon isotopic chain

M. Stanoiu,[1,2,3] D. Sohler,[4] O. Sorlin,[2] F. Azaiez,[1] Zs. Dombrádi,[4] B. A. Brown,[5] M. Belleguic,[1] C. Borcea,[3] C. Bourgeois,[1] Z. Dlouhy,[6] Z. Elekes,[4] Zs. Fülöp,[4] S. Grévy,[2] D. Guillemaud-Mueller,[1] F. Ibrahim,[1] A. Kerek,[7] A. Krasznahorkay,[4] M. Lewitowicz,[2] S. M. Lukyanov,[8] S. Mandal,[9] J. Mrázek,[6] F. Negoita,[3] Yu.-E. Penionzhkevich,[8] Zs. Podolyák,[10] P. Roussel-Chomaz,[11] M. G. Saint-Laurent,[2] H. Savajols,[2] G. Sletten,[12] J. Timár,[4] C. Timis,[3] and A. Yamamoto[10]

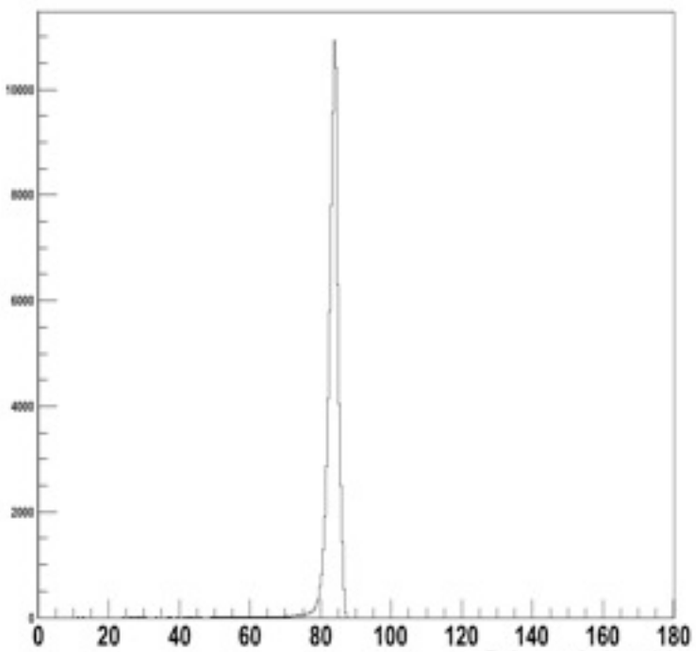




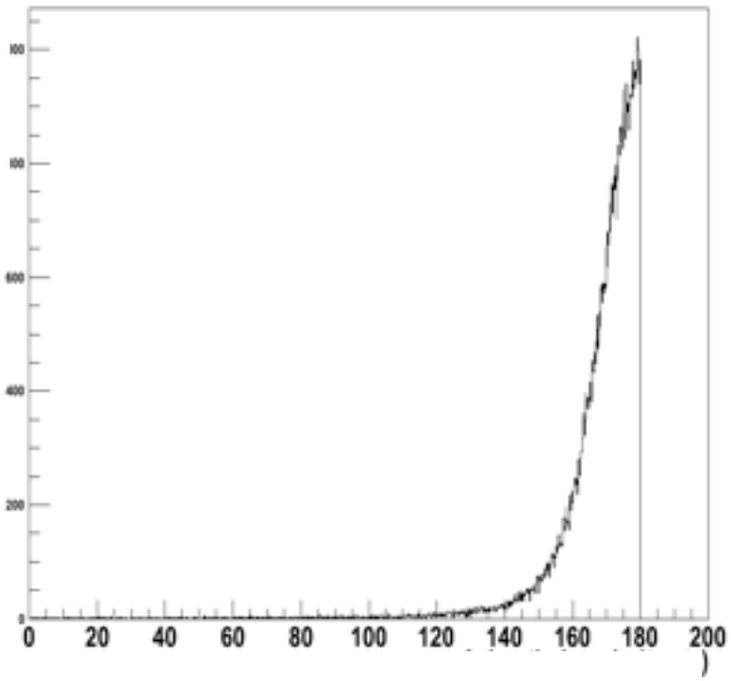
Angular distributions

$^{23}O(p,pn)^{22}O$ Angular Distributions CH2 target

SIMULATION (code by L.Chulkov)

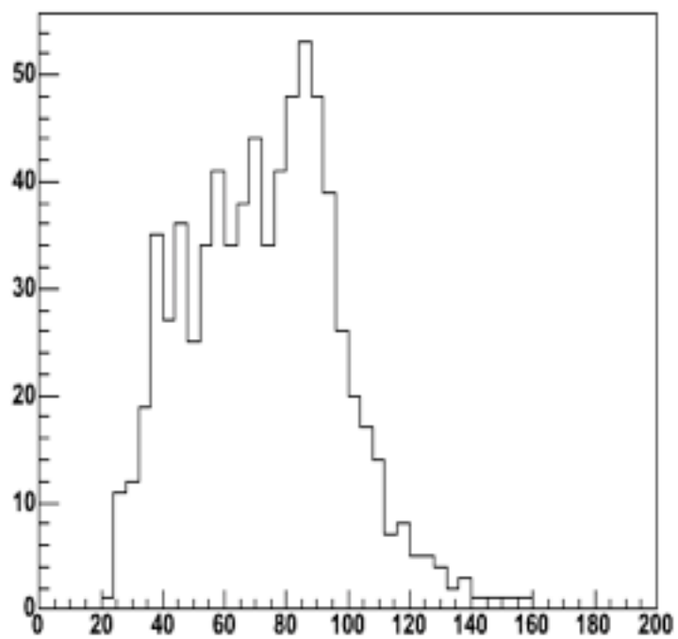


Polar angle ($\vartheta_1+\vartheta_2$)

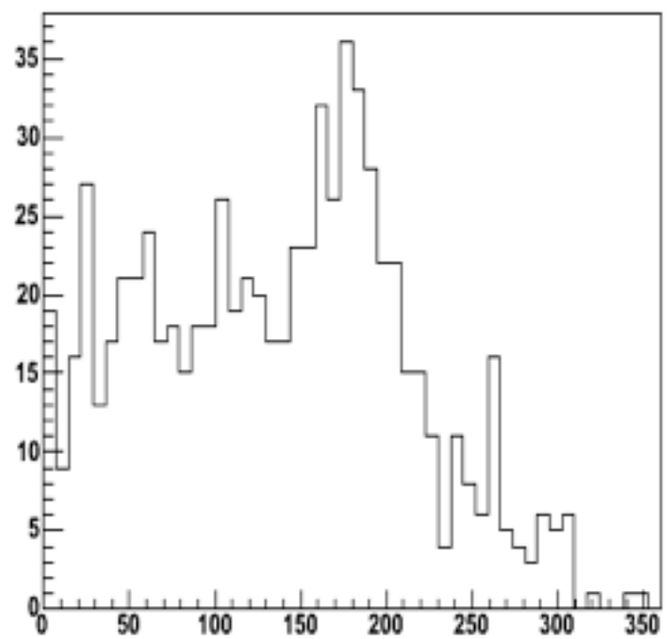


Azimuthal angle ($\varphi_1-\varphi_2$)

EXPERIMENTAL

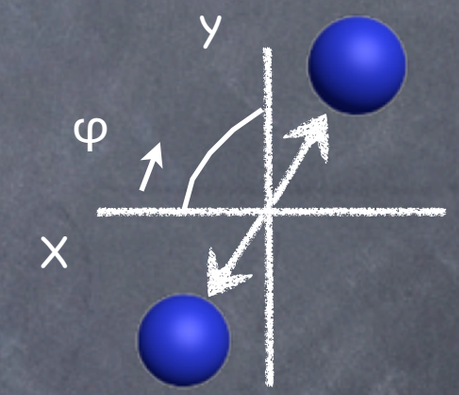


Polar angle ($\vartheta_1+\vartheta_2$)

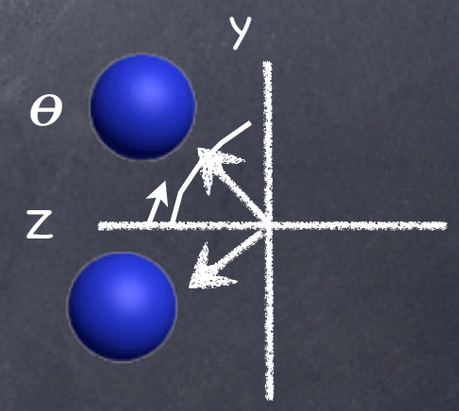


Azimuthal angle ($\varphi_1-\varphi_2$)

Correlation in φ

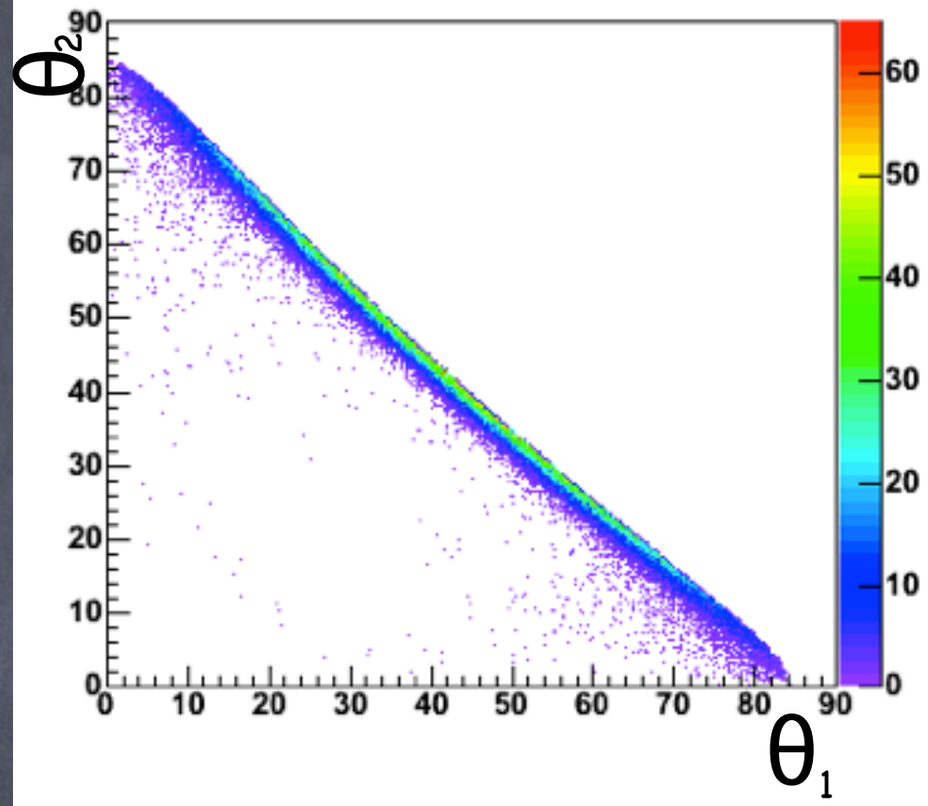


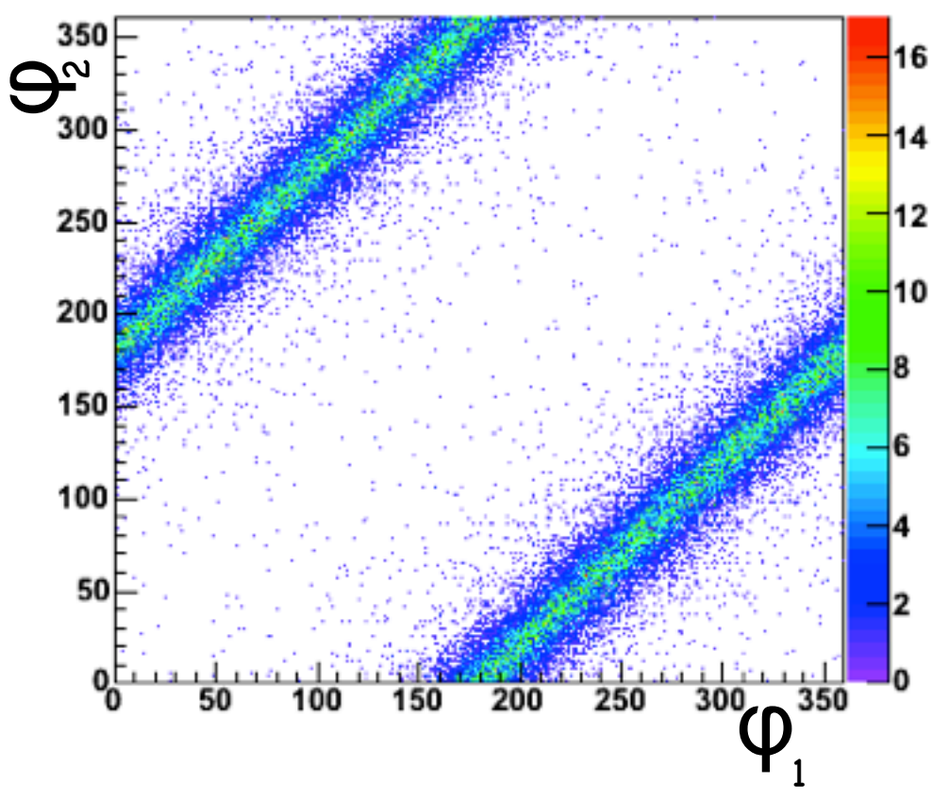
Anticorrelation in θ



$^{23}O(p,pn)^{22}O$ Angular Distributions CH2 target

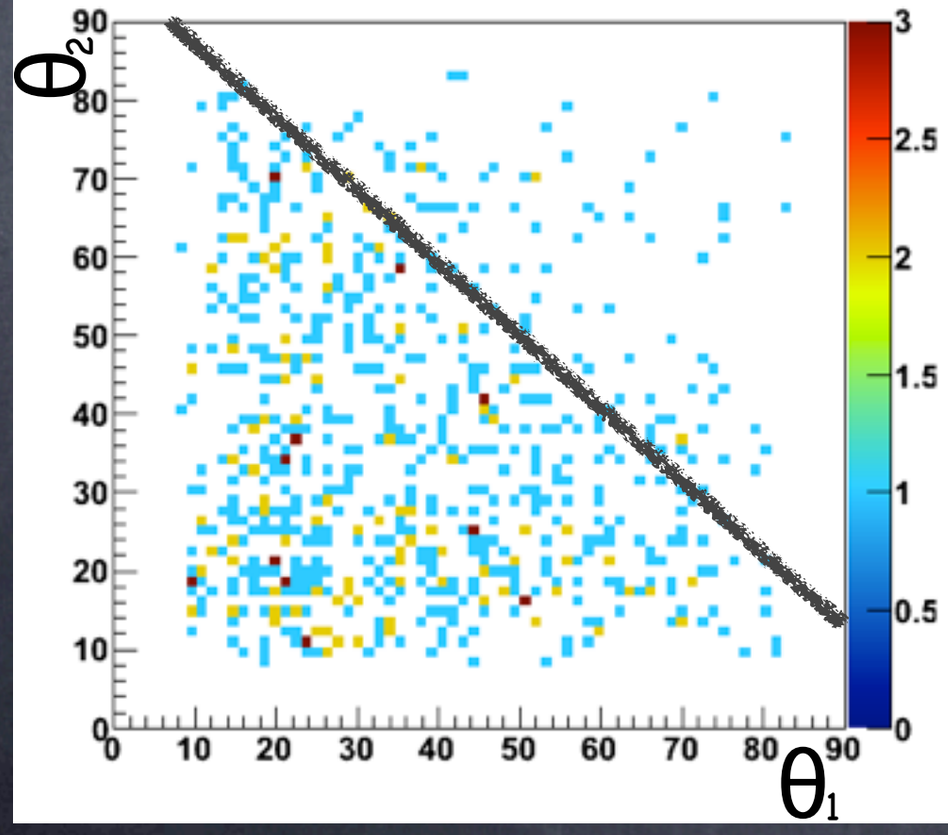
SIMULATION

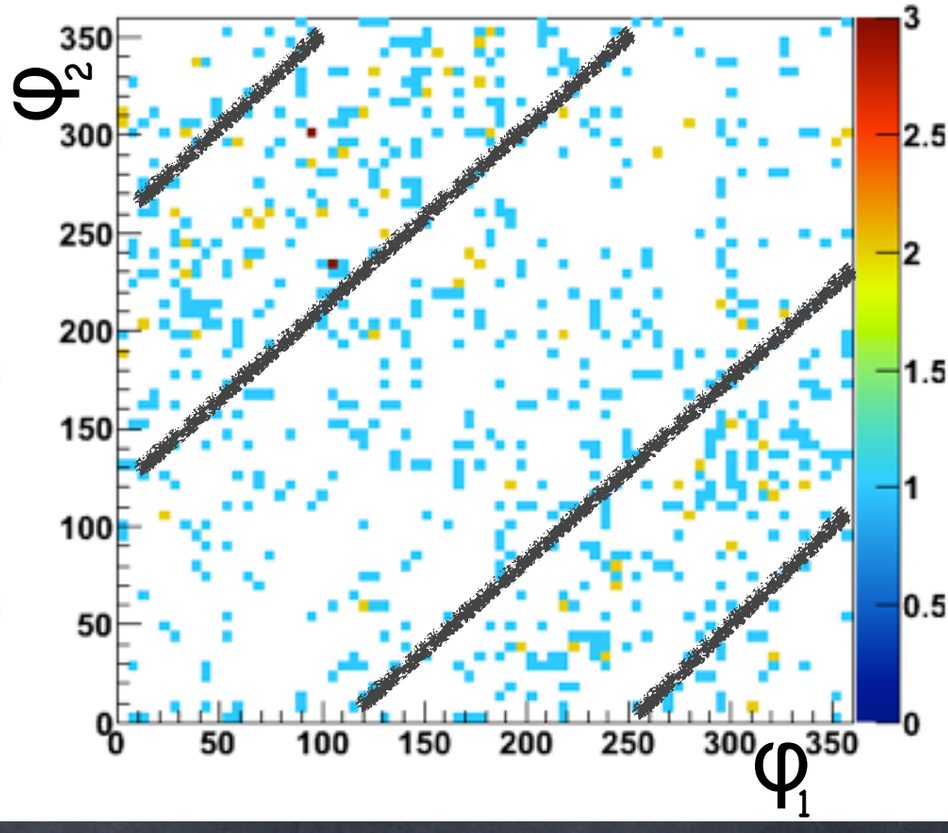




Simulation code by L.Chulkov

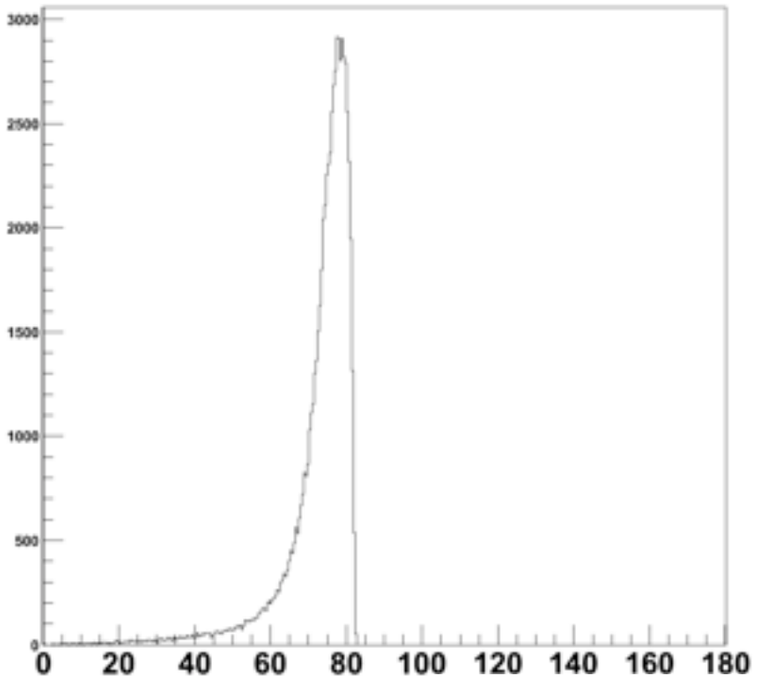
EXPERIMENTAL



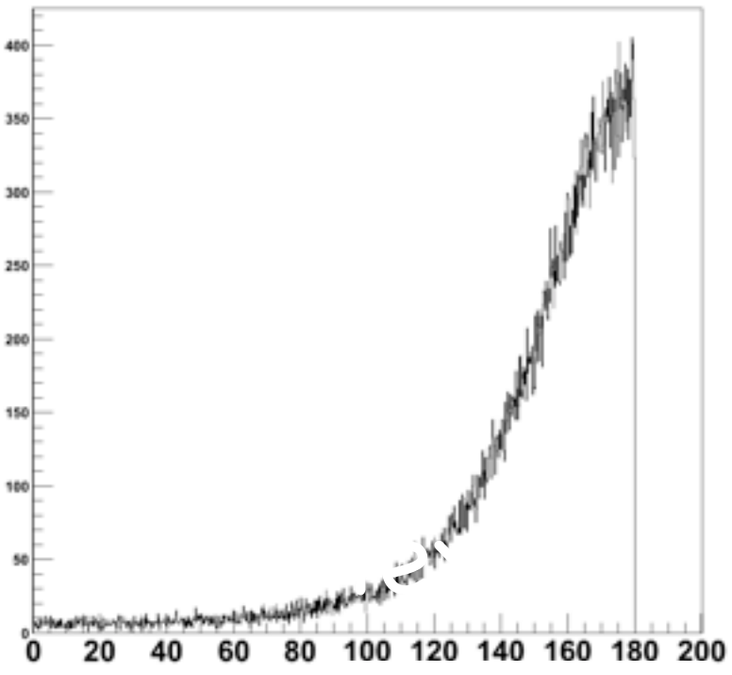


Results: $^{21}N(p,2p)^{20}C$ Angular Distributions CH2 target

SIMULATION (code by L.Chulkov)

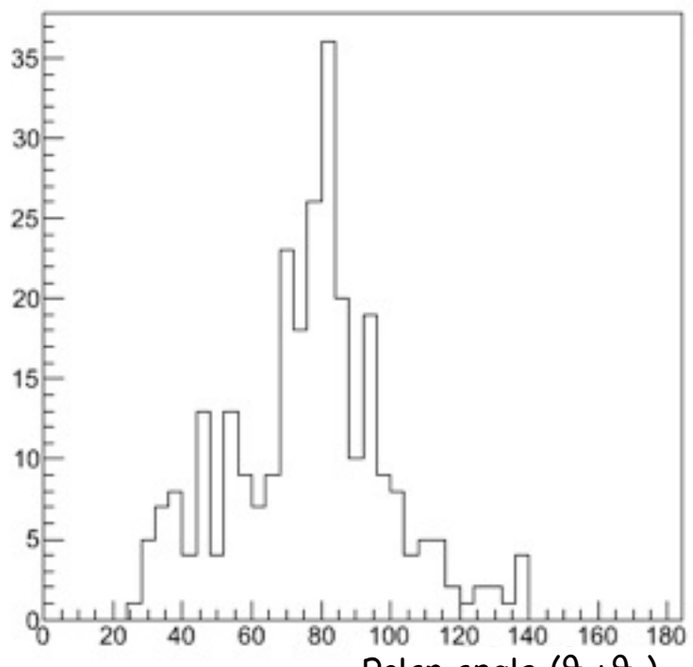


Polar angle ($\vartheta_1+\vartheta_2$)

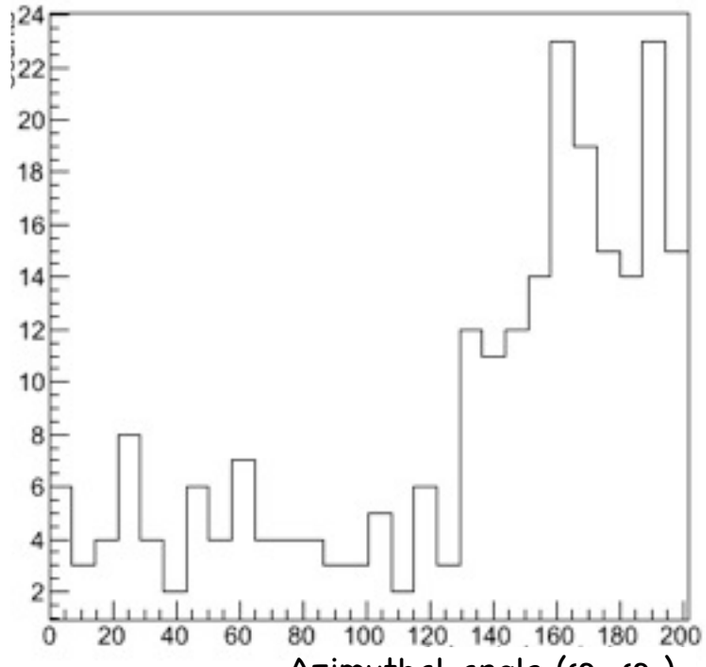


Azimuthal angle ($\varphi_1-\varphi_2$)

EXPERIMENTAL

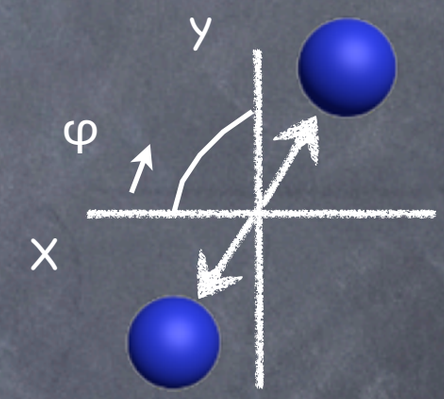


Polar angle ($\vartheta_1+\vartheta_2$)

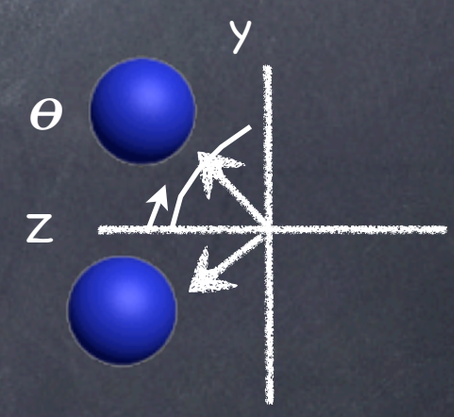


Azimuthal angle ($\varphi_1-\varphi_2$)

Correlation in φ

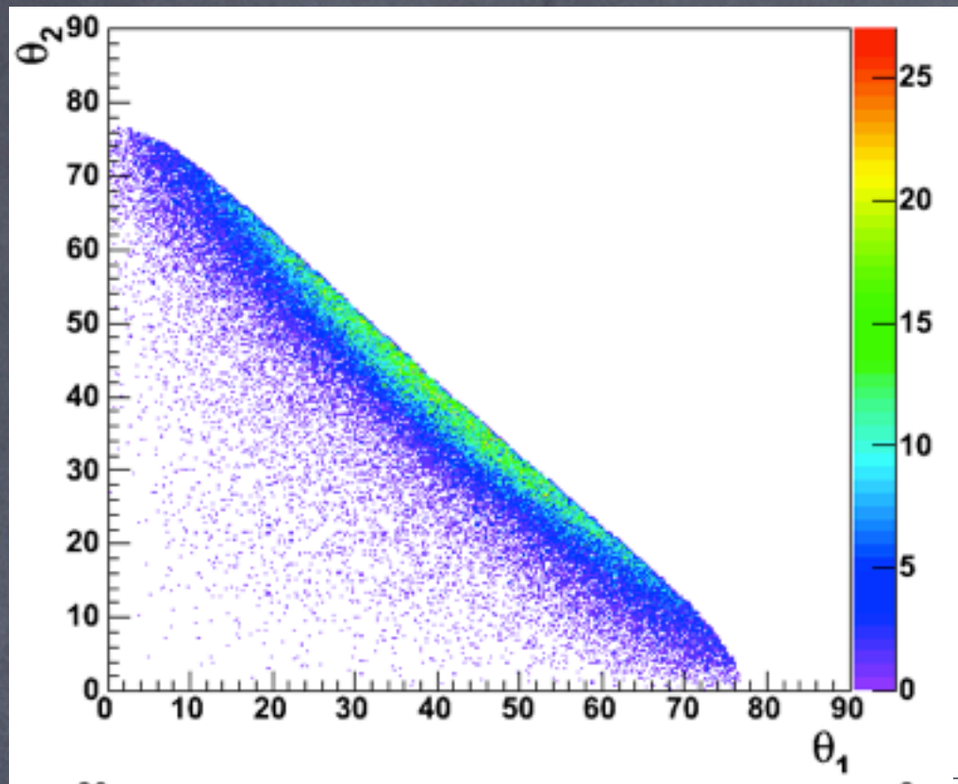


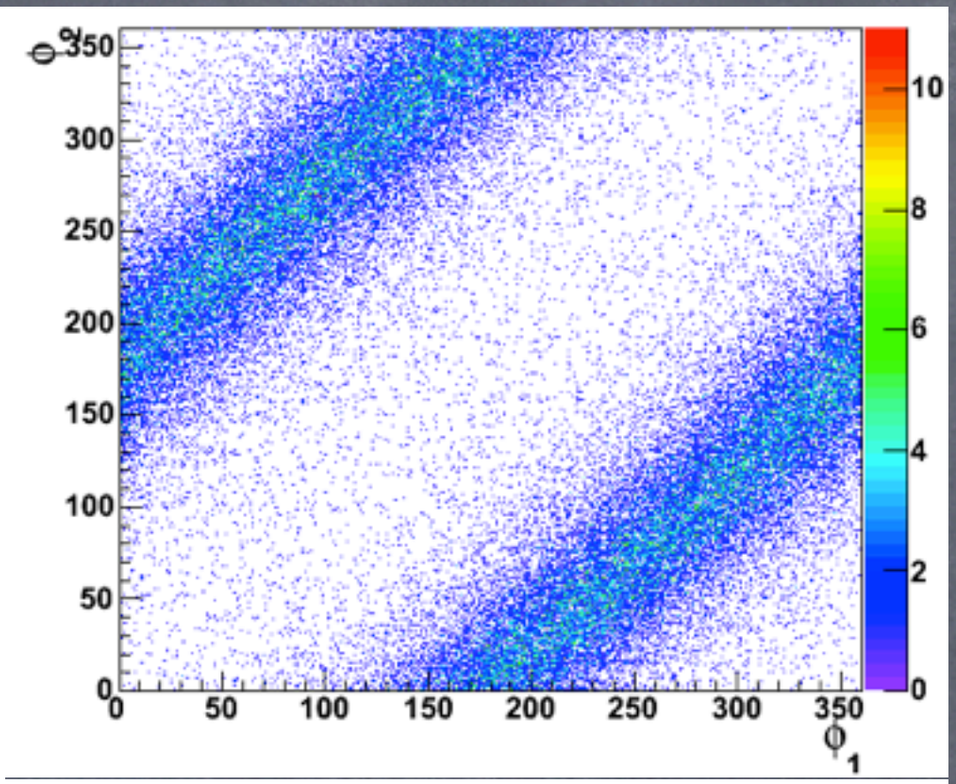
Anticorrelation in θ



Results: $^{21}N(p,2p)^{20}C$ Angular Distributions CH2 target

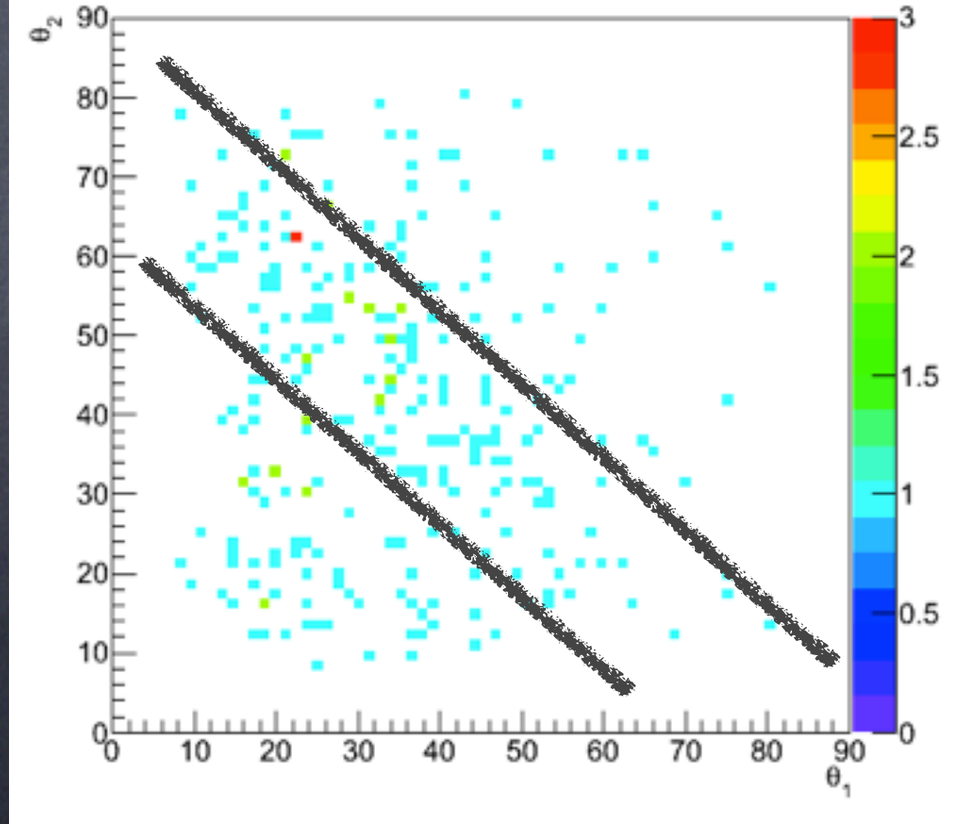
SIMULATION

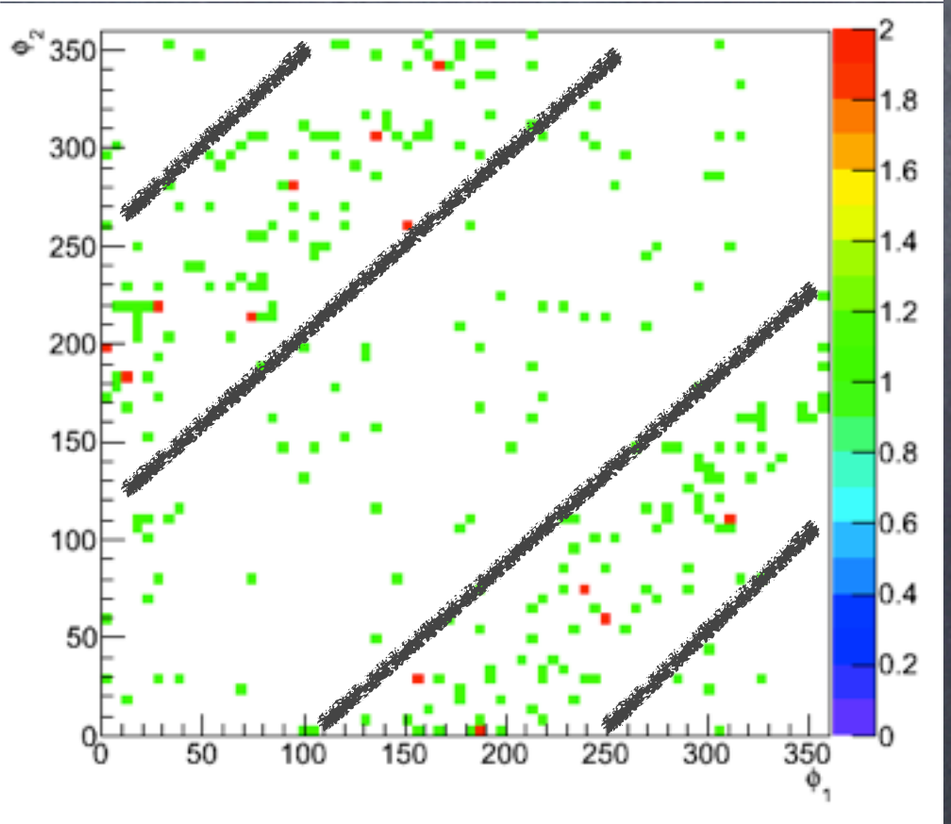




Simulation code by L.Chulkov

EXPERIMENTAL

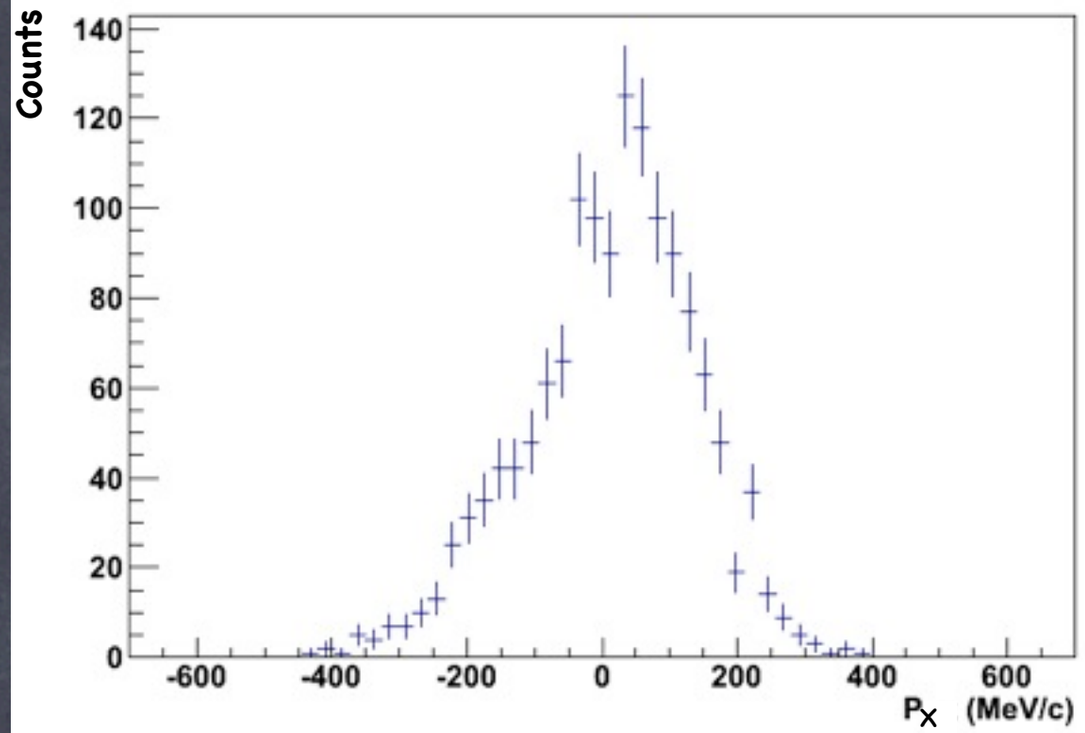


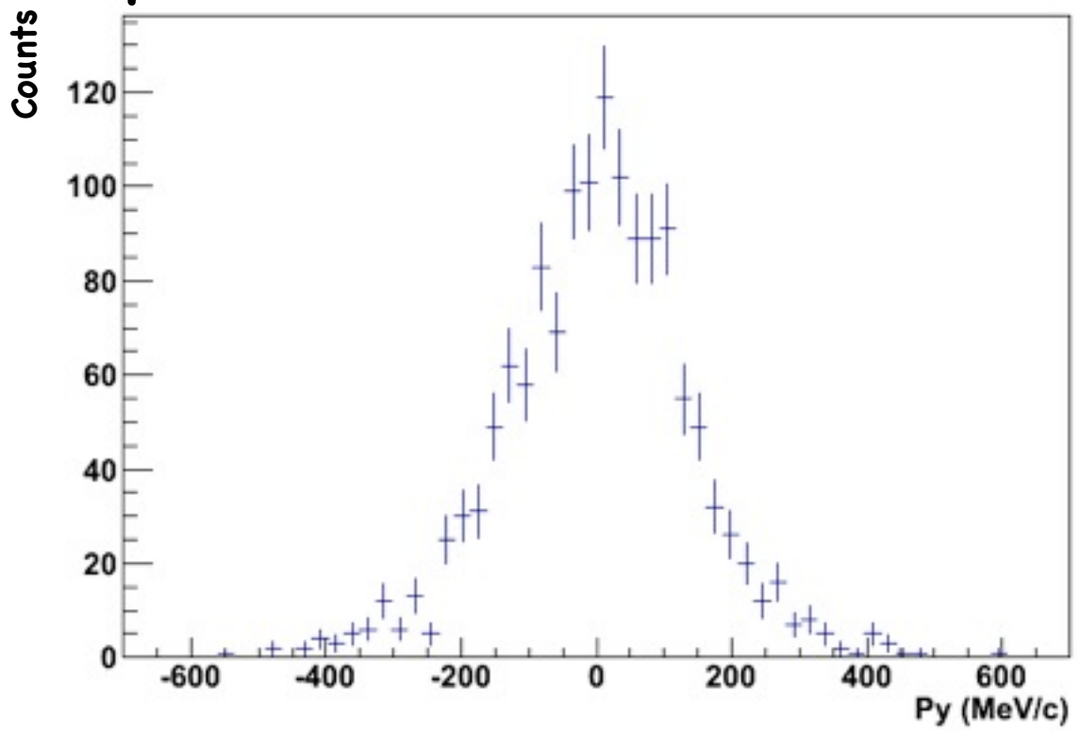


Momentum distributions

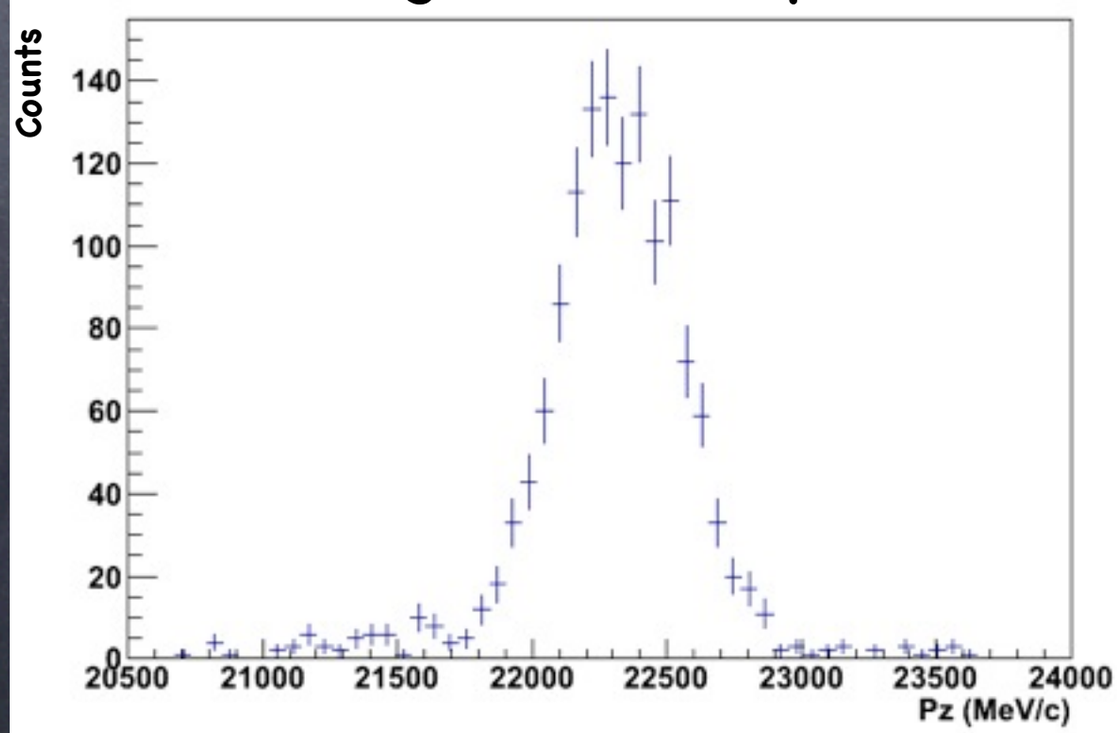
Preliminary results: $^{23}O(p,pn)^{22}O$ Momentum Distributions

Transversal components





Longitudinal component



Summary and Outlook

RESULTS

- Complete tracking of the fragments before and after the reaction
- Momentum distributions for all the reaction products
- QFS: (p,pn) and (p,2p) on ^{23}O and ^{21}N were identified via angular distributions
- Gamma rays spectra for the ^{22}O and ^{20}C in good agreement with previous experiments

OUTLOOK

- Analyse the selected cases => QFS to bound states of interest
- Compare the information obtained for the same nuclei using (p,pn) and (p,2p)
- Extract single-particle strengths from the momentum and the cross sections
- Complete the excitation energy in (p,2p) reactions

Thank you for your attention!