Coulomb excitation of ^{45}Sc

thick target experiment

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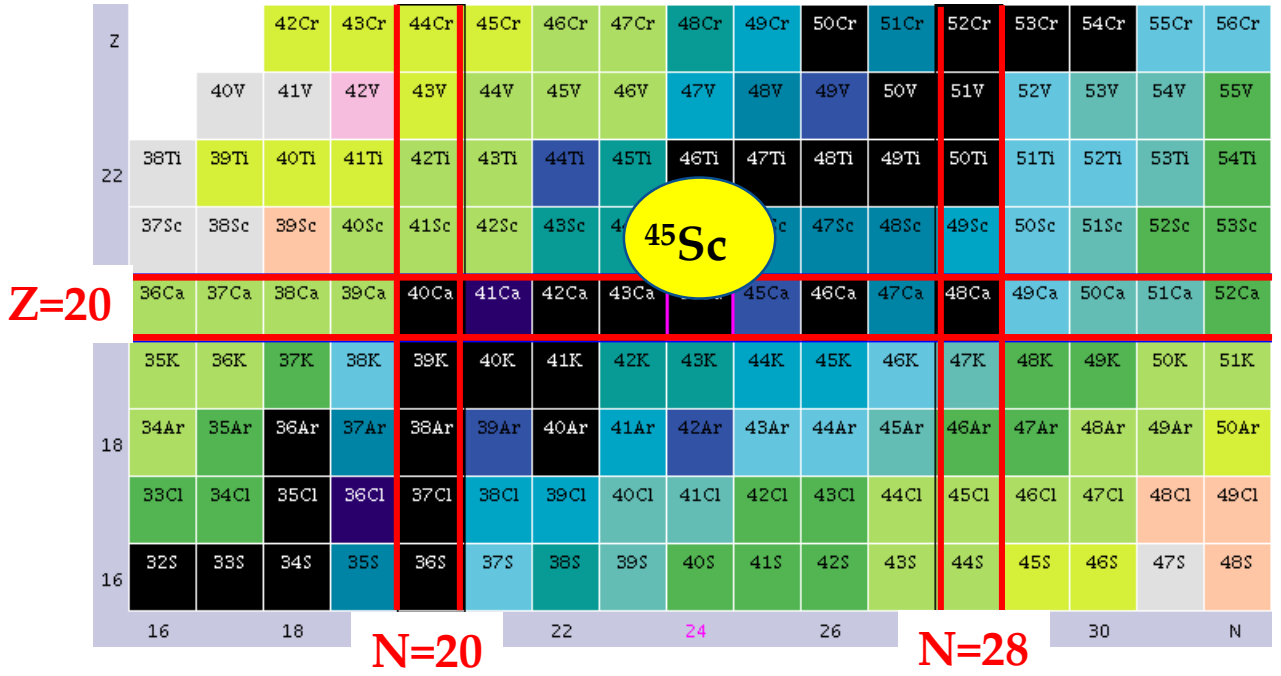
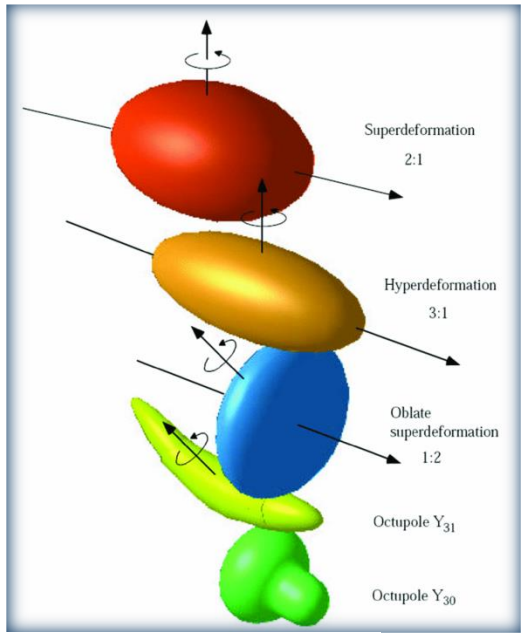
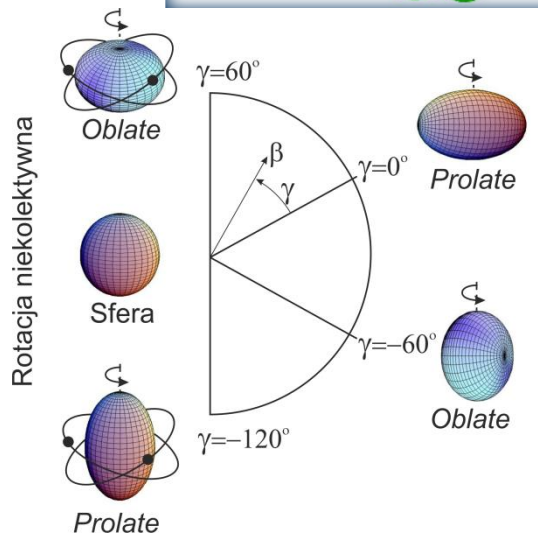
AGENDA

- Why ^{45}Sc? Overview
- Experimental setup @ HIL UW
- Gosia analysis
- Difficulties due to the thick target measurement
- New measurement @ IUAC New Delhi

Why ^{45}Sc?





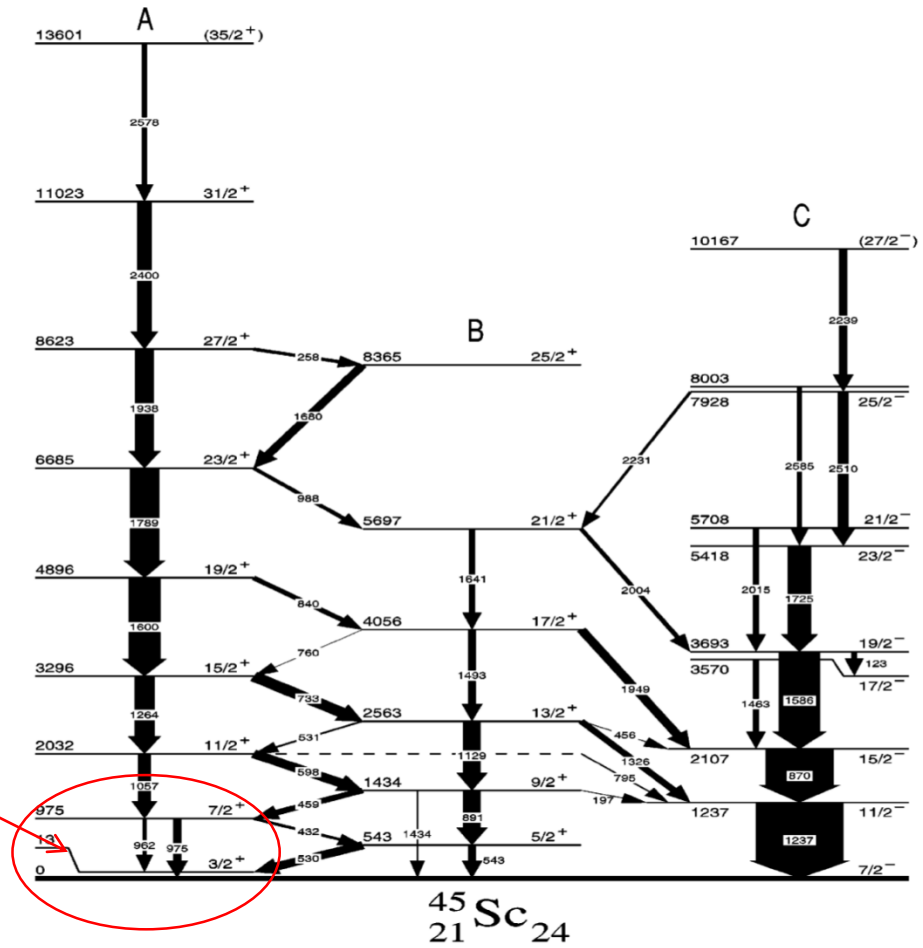


^{45}Sc: odd-even nucleus, 1p4n beyond N=Z=20
GS structure – spherical SM
p-h excitations results in SD

^{45}Sc - overview

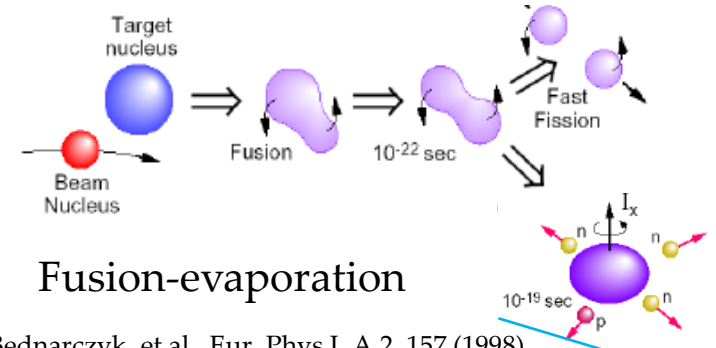
- Negative parity g.s. spherical
- Positive parity well deformed rotational-like band is formed upon the isomer
- Low-lying positive parity states: promotion of an s-d shell particle to the $f_{7/2}$ shell
- proton 2p1h excitation

Izomeric 3/2+ state, 12.4 keV, $T_{1/2}$=318 ms



^{45}Sc level scheme, taken from P. Bednarczyk, et al., Eur. Phys. J. A 2, 157 (1998).

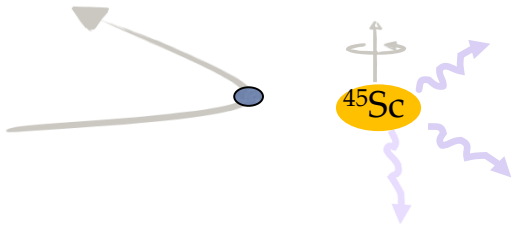
Experimental data on ^{45}Sc



Fusion-evaporation

P. Bednarczyk, et al., Eur. Phys.J. A 2, 157 (1998).

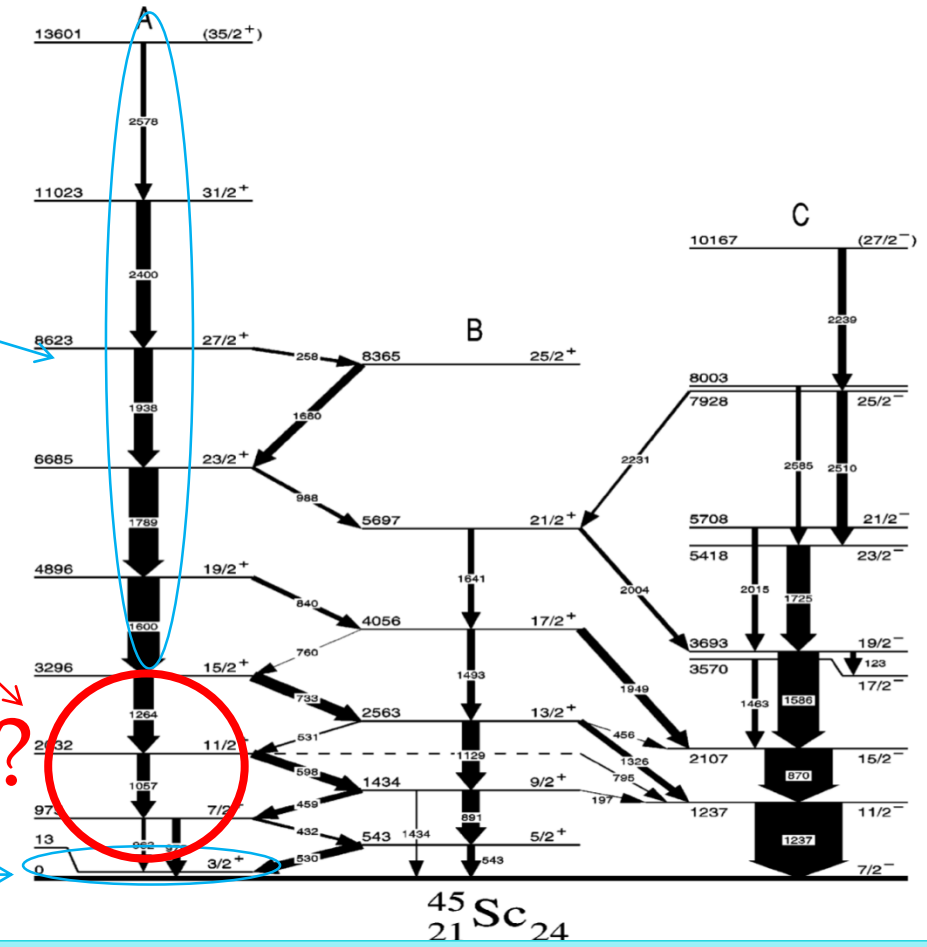
Coulomb excitation



Izomeric 3/2+ state, 12.4 keV, $T_{1/2}$=318 ms,
Laser spectroscopy measurement

Qs=0.28(5) b, prolate def. β~0.3

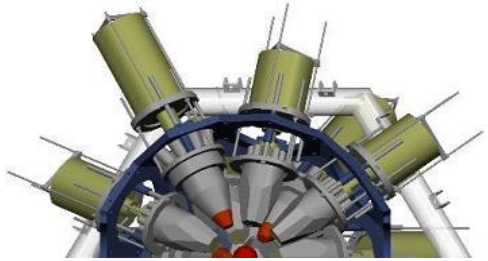
M. Avgoulea, et al., J. Phys. G: Nucl. Part. Phys. 38, 025104 (2011)



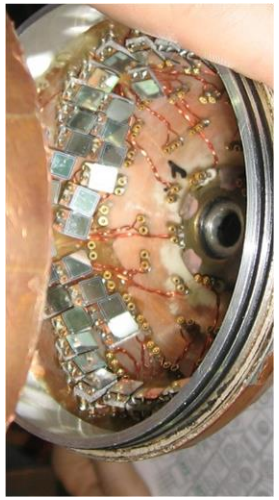
Unique case – to compare results obtained in two model independent techniques

Experimental setup @HIL UW

70 MeV ^{32}S + 1mg/cm^2 ^{45}Sc



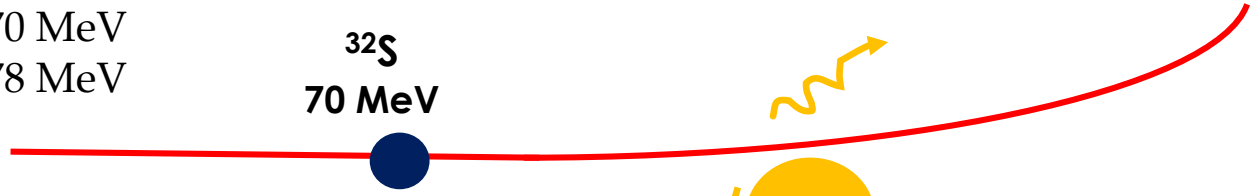
Particle detector



48 PiN-Diode HI Detectors

θ_{LAB}: 49÷69 deg
θ_{CM}: 38÷111 deg

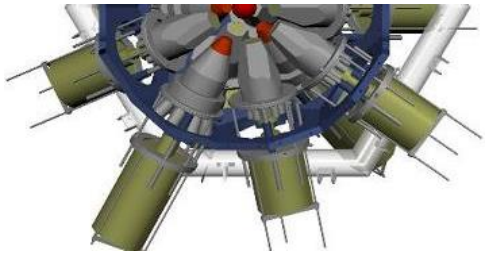
Emax(69°) = 70 MeV
Emax(49°) = 78 MeV



EAGLE γ-ray spectrometer

16 HPGe & ACS
Efficiency@1112 keV: 0.9%

γ-rays in coincidence
with scattered ions



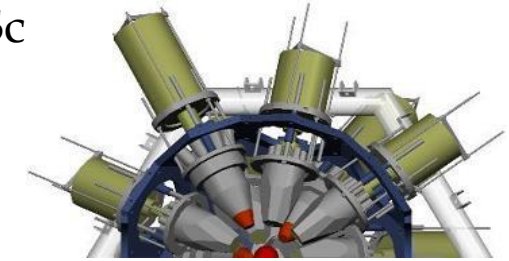
PD set at forward angles for the very first time!
Energy of back-scattered ions is too small to be detected in PIN diodes.

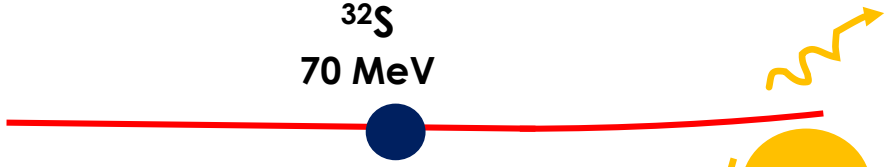
PiN diode problem

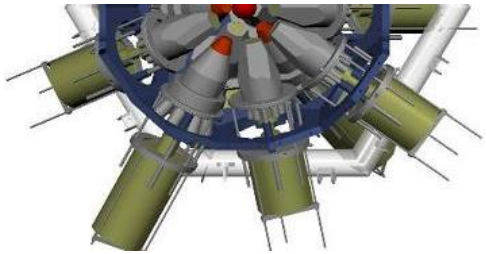
- PIN OR starts continuously lowering, detectors were less and less efficient
- Sunday 20 November
  - 04:40 -> 1.2 kHz (starting it was ~ 20 kHz)
  - 05:35 -> 800 Hz,
  - 07:56 -> 400 Hz
- We increase beam intensity and bias (to 150 V)
- In next few hours PIN OR went down to few counts……
- Radiation damage appeared - only 16h was possible – change the concept

Experimental setup @HIL UW part2

70 MeV ^{32}S + **15** mg/cm^2 ^{45}Sc







EAGLE γ-ray spectrometer

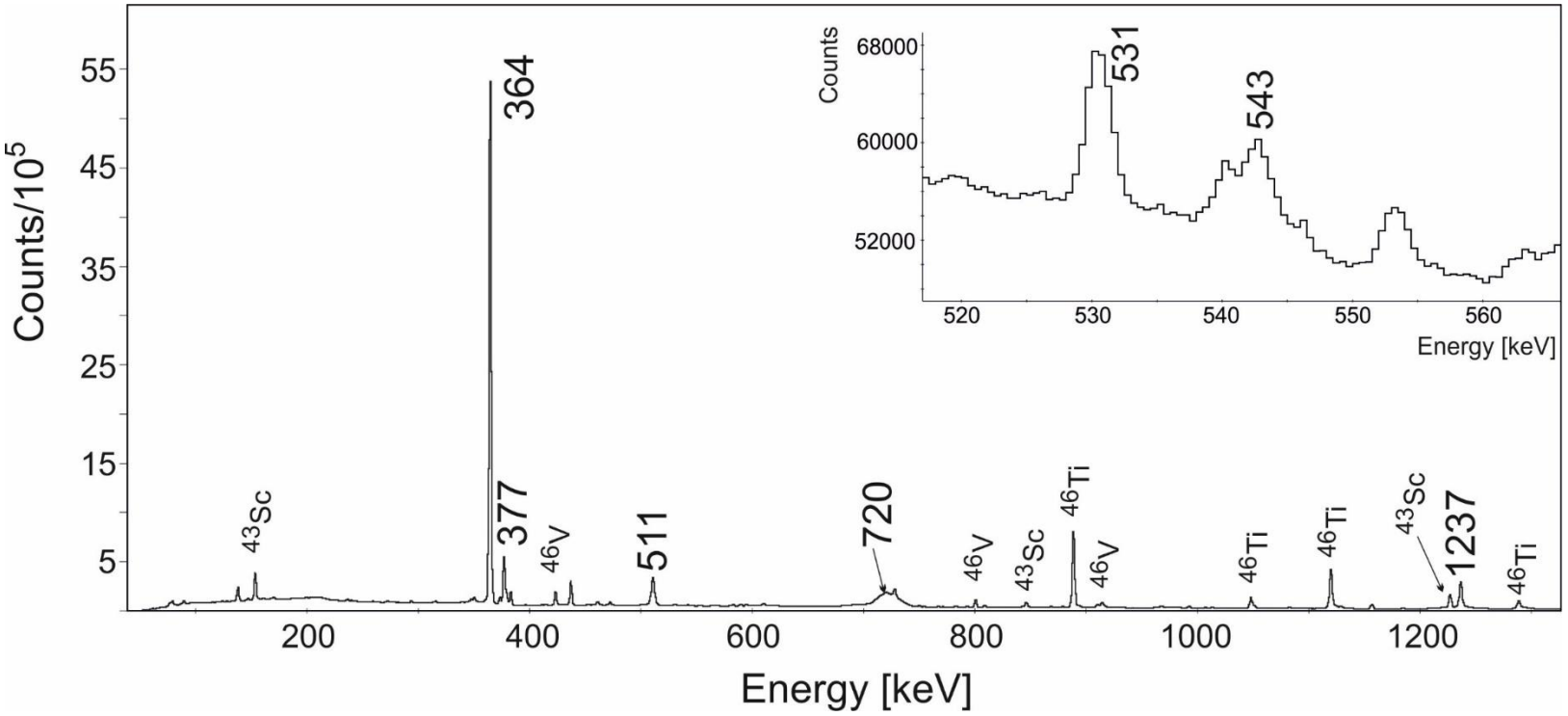
16 HPGe & ACS
Efficiency@1112 keV: 0.9%

Integral measurement:

θ_{CM}: 0÷180 deg

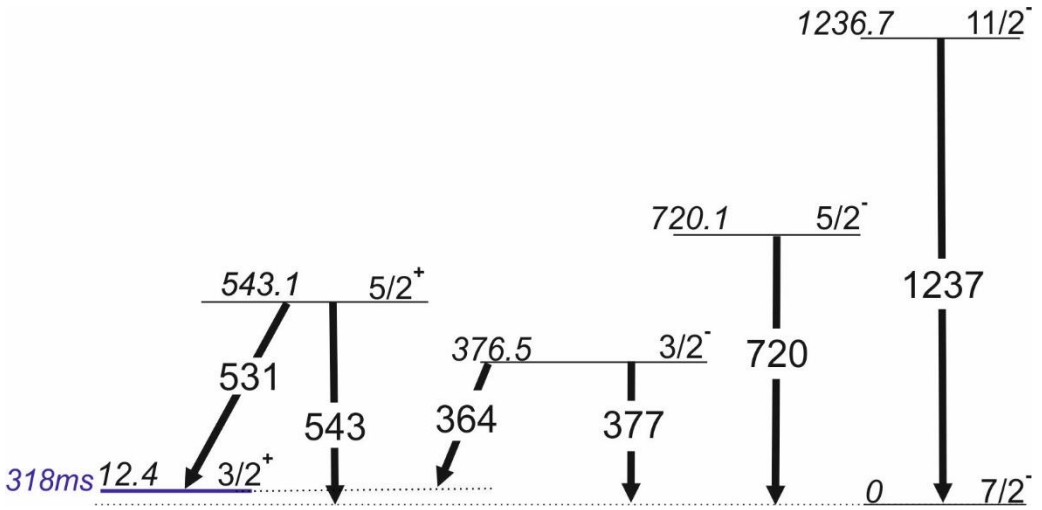
While previously:
θ_{LAB}: 49÷69 deg
θ_{CM}: 38÷111 deg

Collected γ-ray energy spectrum



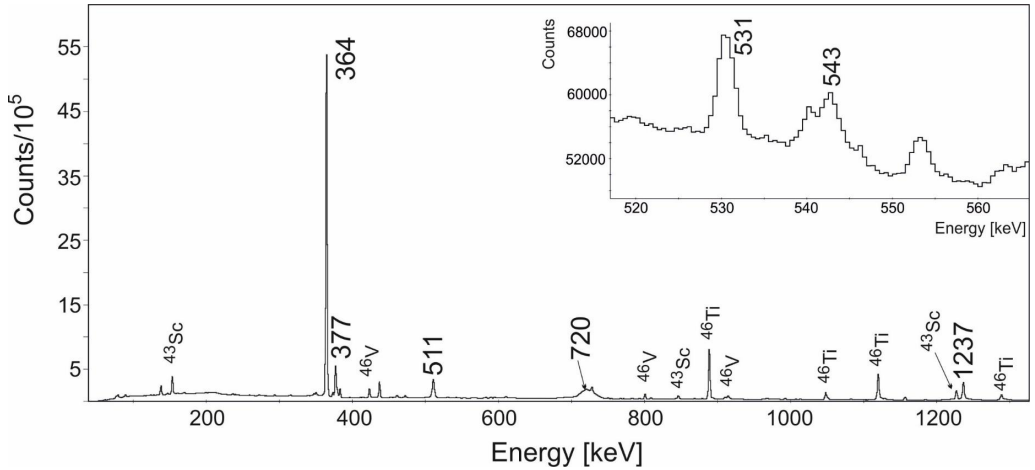
- 70 MeV ^{32}S beam + thick 15 mg/cm2 ^{45}Sc target
- Sum over 16 detectors
- Lines originating from the reaction products on the target oxidation are marked; i.e. ^{46}Ti, ^{46}V, ^{43}Sc

^{45}Sc level scheme



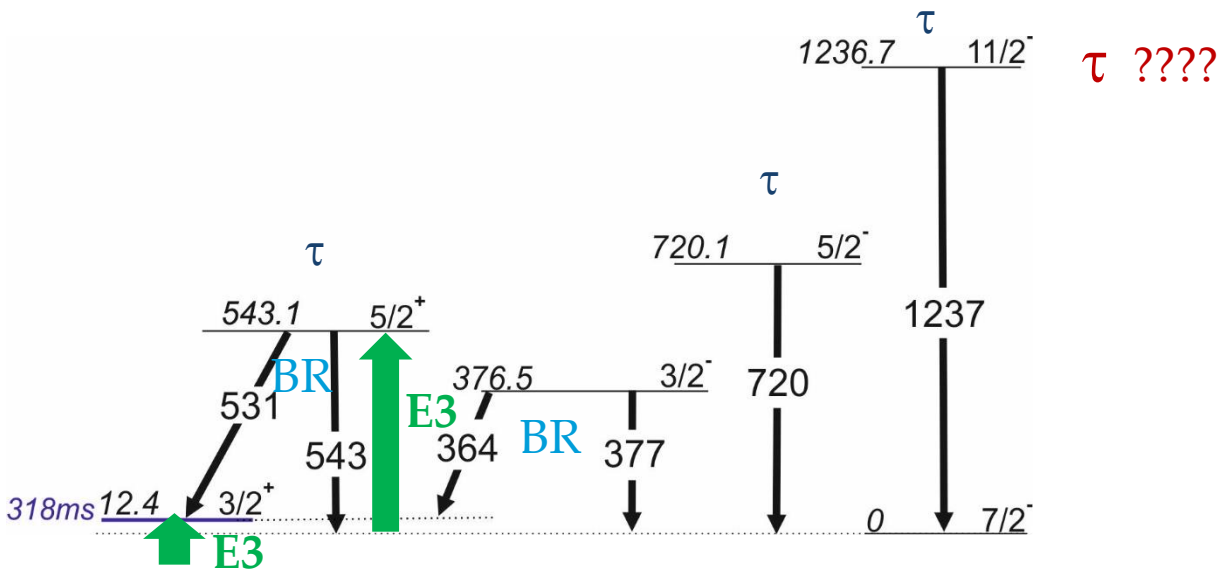
- Observation of the 531 and 543 keV confirmed that the positive parity band was populated, and BR confirms identification

Uncertainity estimation

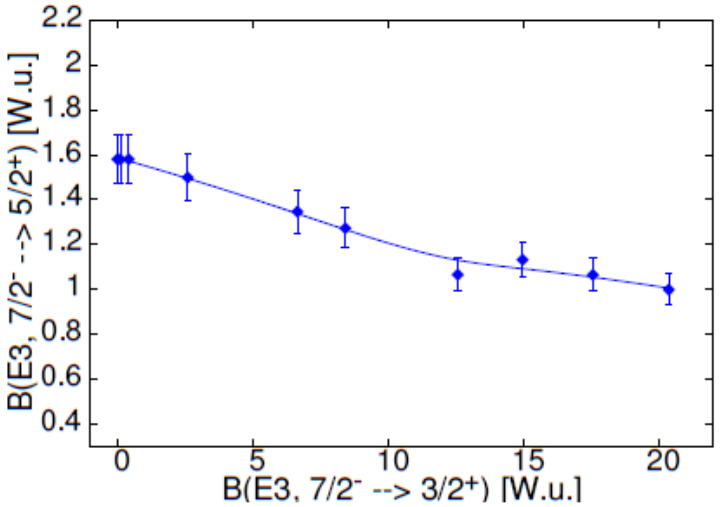


- Thick target – oxidized – PACE4
- ^{45}Sc is one of the weakest fusion-evaporation channel
- The cross-section for the ^{46}Ti is 10^3 times larger than the one for ^{45}Sc
- We took the number of counts in the strongest yrast ^{46}Ti line, and we assume the worst scenario, that all decay goes through isomeric band
- 0,001 of ^{46}Ti – it is 5% of the intensity in the 531 and 543 keV lines
- 5% it is maximal addition to our counts
- we increase our experimental uncertainty

GOSIA calculations



Different than the value in the NNDC



In the NNDC data base:

$B(E3, 7/2^-_{g.s.} \rightarrow 3/2^+) \leq 105\ e^2fm^6 = 0.87$ W.u.

$B(E3, 7/2^-_{g.s.} \rightarrow 5/2^+)$ was unknown

Result:

$B(E3, 7/2^-_{g.s.} \rightarrow 5/2^+) \leq 1.7$ W.u.

„Safe" energy calculations

E_b = 70 MeV was calculated for PiN diodes set in angles: θ_{LAB}: 49÷69 deg

For the thick target experiment E_b = 70 MeV is correct for angles:

- for 5 fm: 0 to 70 deg. – above the critical angle is 4% (for 543 keV) – in the limit of experimental uncertainties
- for 6 fm: 0 to 50 deg. – 11 %
- for 7 fm: 0 to 45 deg. – 14%

What value should be used for light nuclei (like ^{45}Sc)? 5, 6, 7 fm ???

With thick target – easy experiment - difficult analysis……..

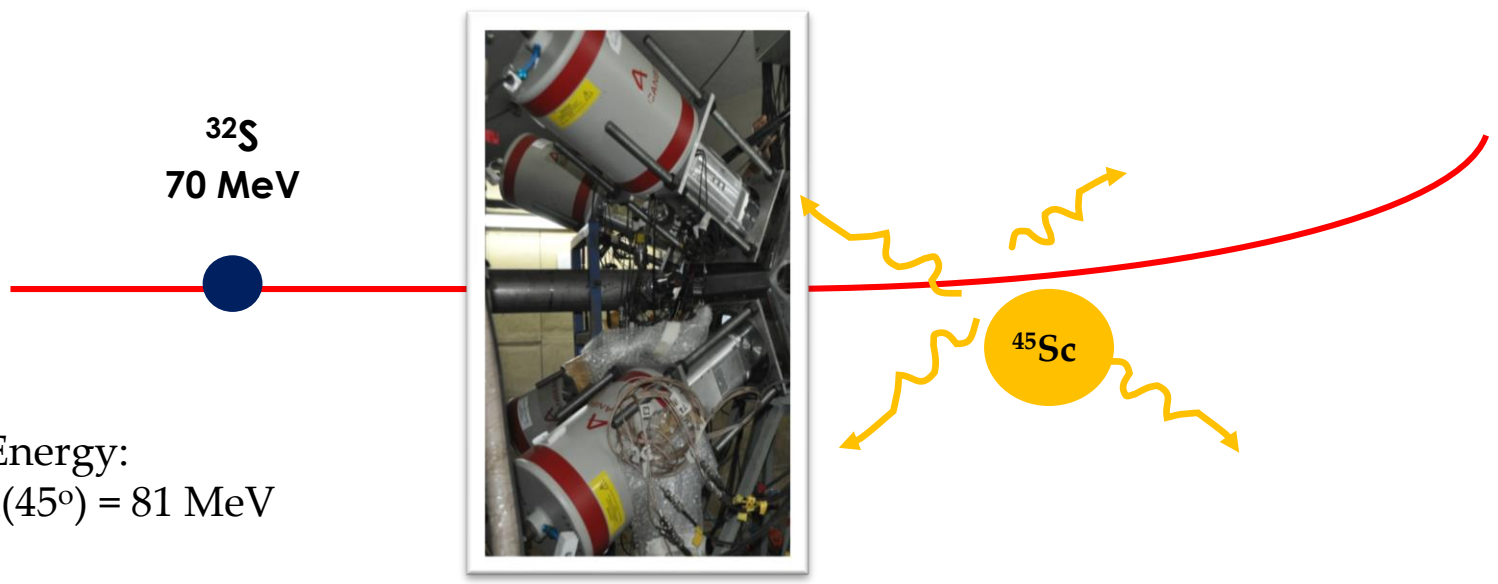
- Integrate over wide range of scattering angles
- Integrate over wide range of bombarding energies (energy loss in thick target)
- Could not determine both B(E3) excitation probabilities

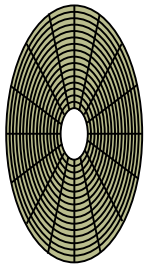
- Projectile and target combination we were able to populate isomeric band
- Spectrum with particle-gamma coincidences we get at the beginning was very promising, number of counts was similar to the simulated one

Experimental setup @IUAC, New Delhi

70 MeV ^{32}S + 1mg/cm^2 ^{45}Sc

Particle detector
PPAC





PPAC @ forward angle

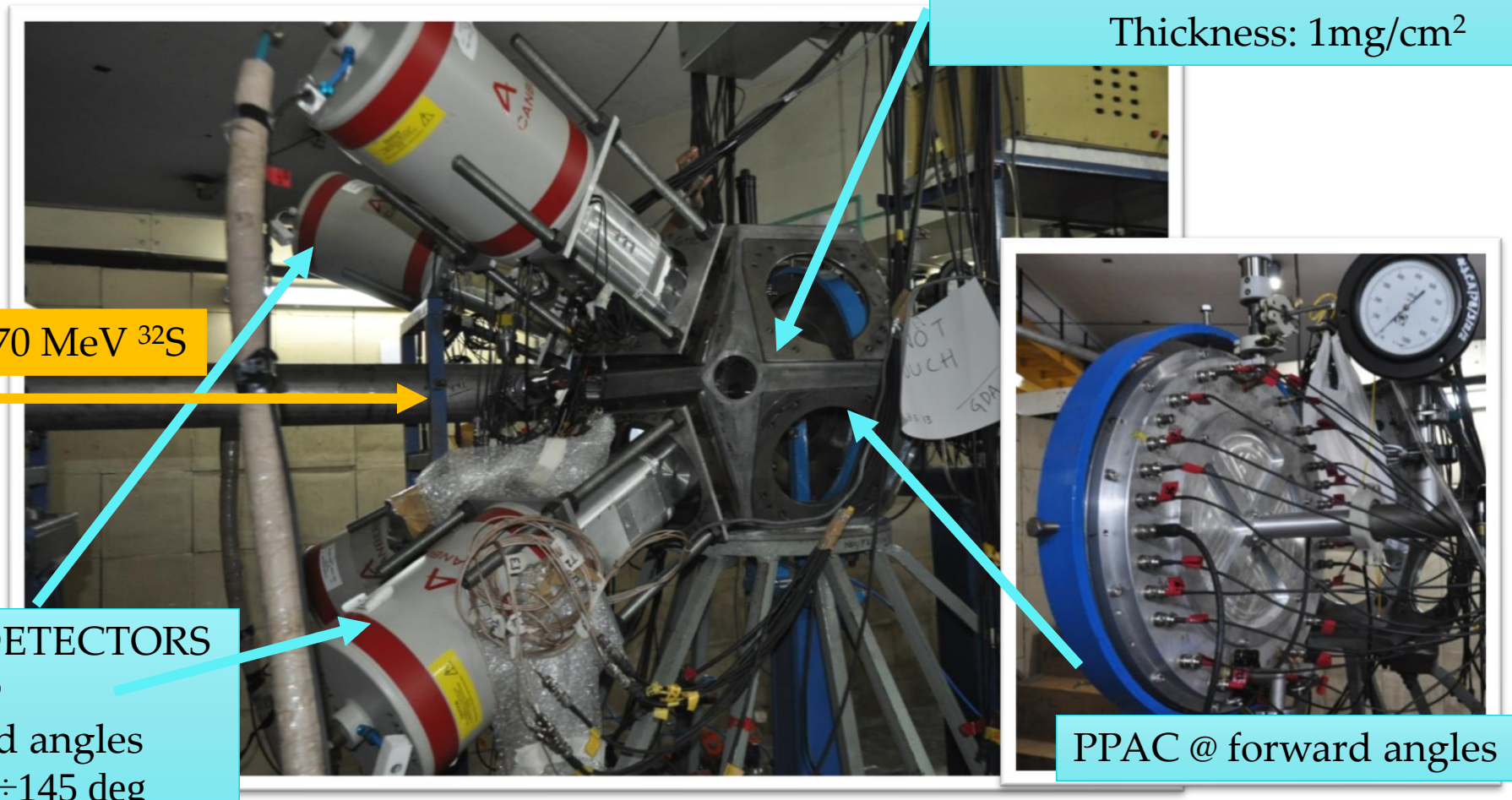
Safe Energy:
Emax(45°) = 81 MeV

θ_{LAB}: 15÷45 deg
ϕ_{LAB}: 0÷360 deg

4 CLOVER DETECTORS
@ backward angles
θ_{LAB}: 130÷145 deg
Efficiency@1.3MeV: 0.5%

Experimental setup @November 2017

^{45}Sc TARGETS were made in HIL UW
Thickness: 1mg/cm^2

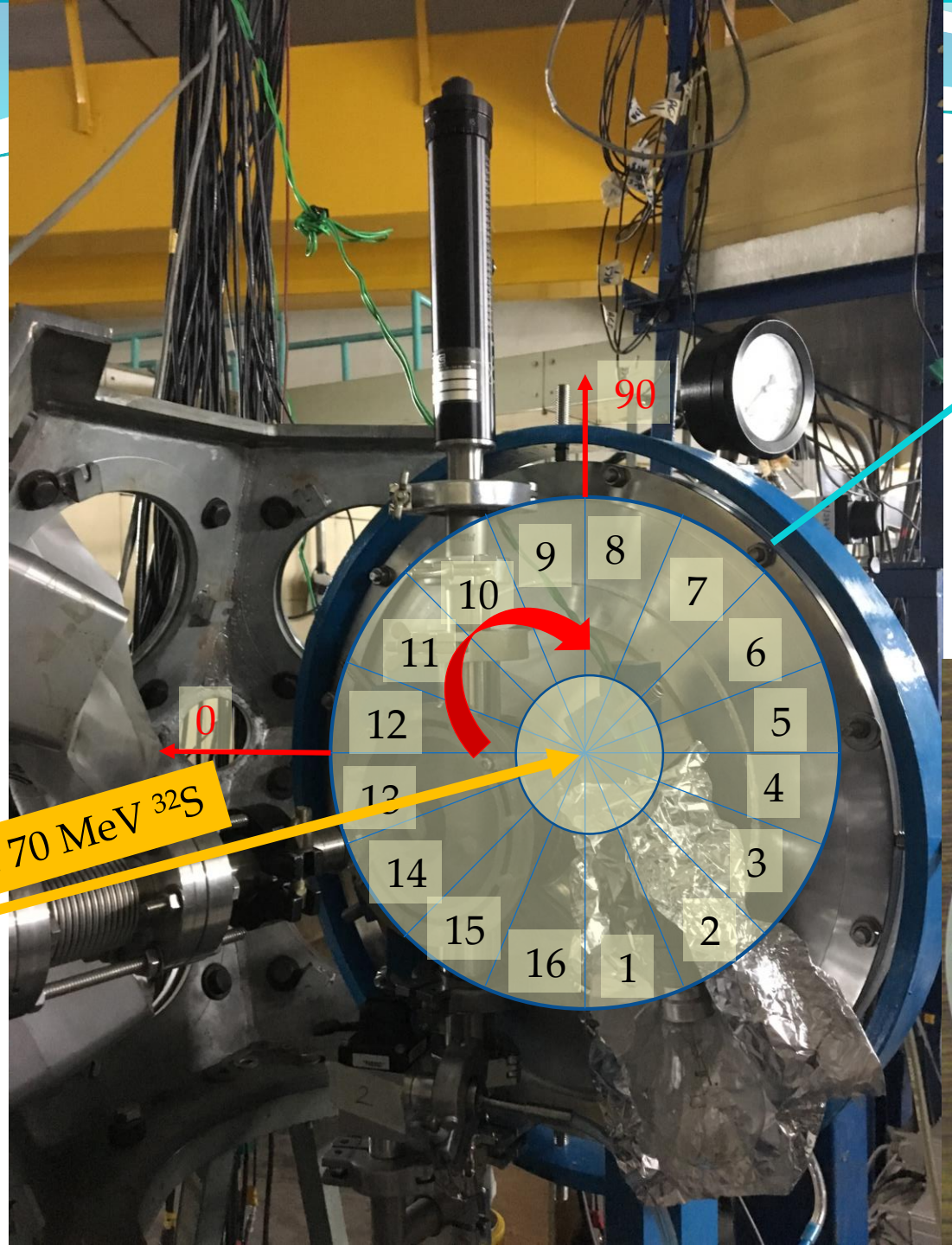


Beam: 70 MeV ^{32}S

4 CLOVER DETECTORS
@
backward angles
θ_{LAB}: 130÷145 deg

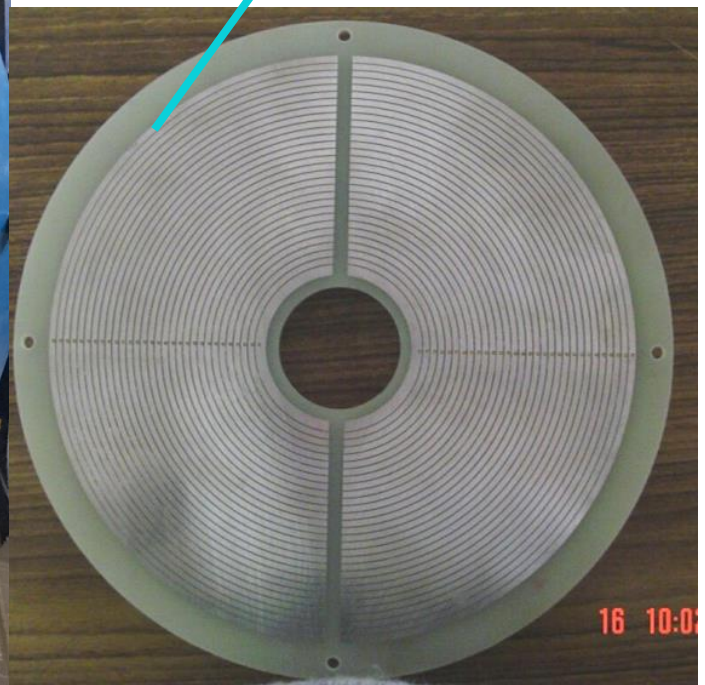
PPAC @ forward angles

Particle detector

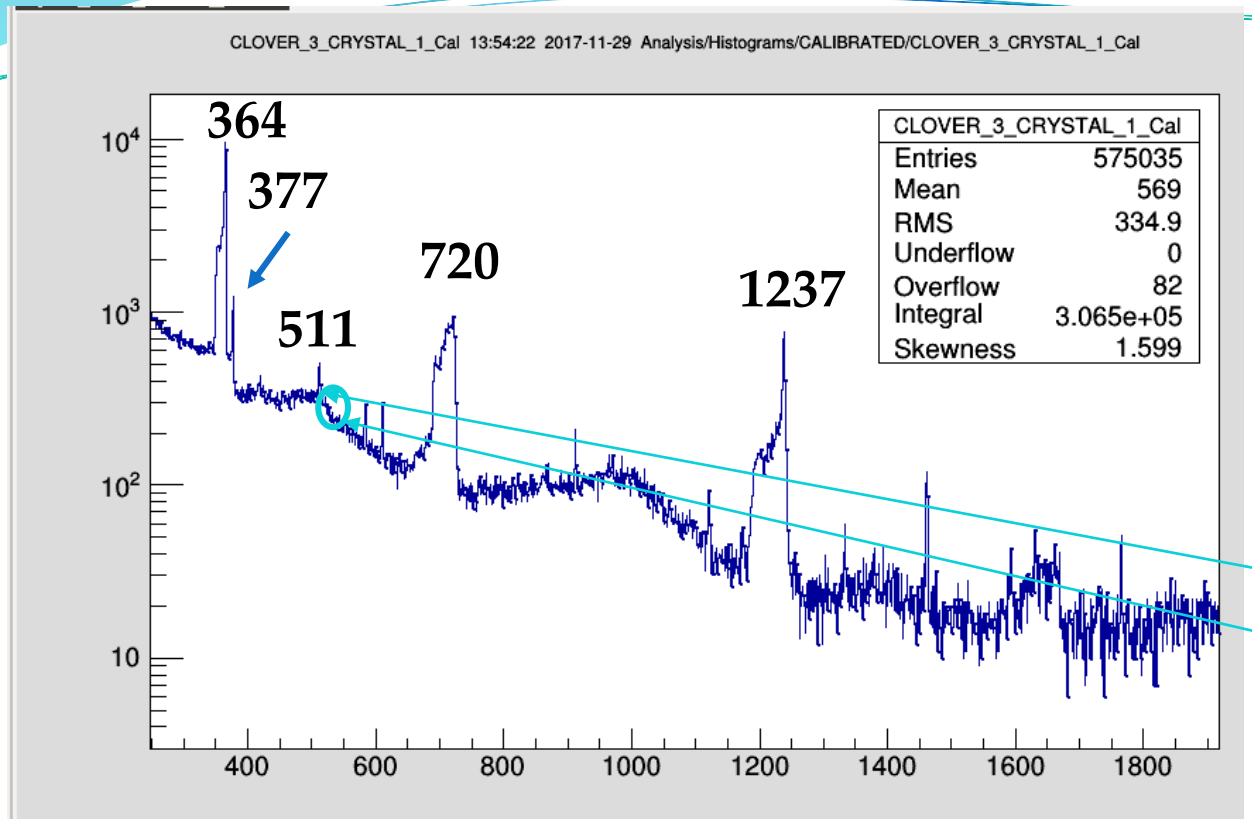


Front (Sectors) → Phi angle

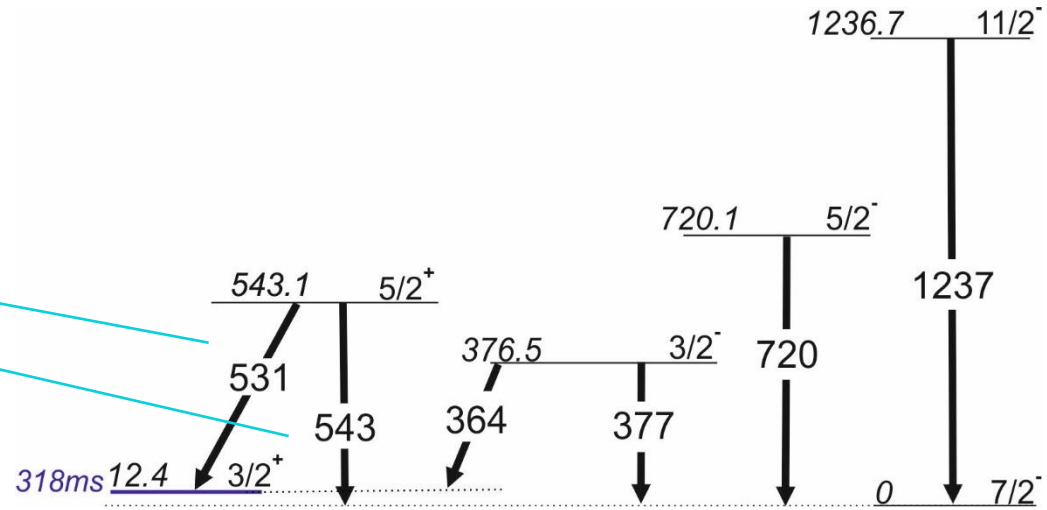
Back (Delay lines) → Theta angle



One Crystal and all PPAC segments – no DC



Lines seen @ HIL UW



Measurement performed in November 2017
Analysis is ongoing …….

- With full statistic (14 crystals)
- Doppler correction for both kinematics
- Gating ….. Etc. …….we hope to see more lines

COLLABORATION

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SUMMARY

- Performed 2 COULEX of ^{45}Sc
- Analysis of thick target measurement gives us some hints about BE3 and lifetimes of the $11/2^-$ state
- More lines will come up from new data
- Common analysis of both sets -- get some of the proposal goals
- Disentangle contributions from the BE3 transition probabilities and more …

THANK YOU FOR YOUR ATTENTION