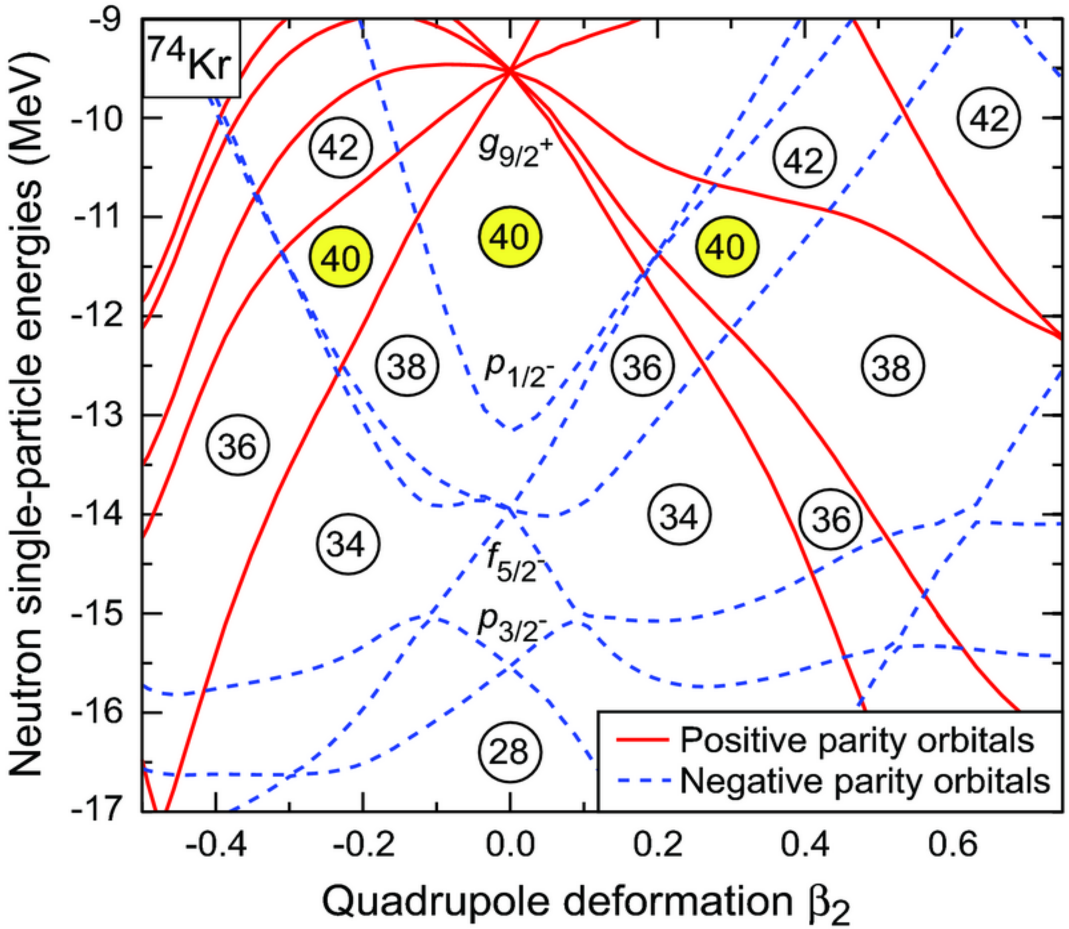
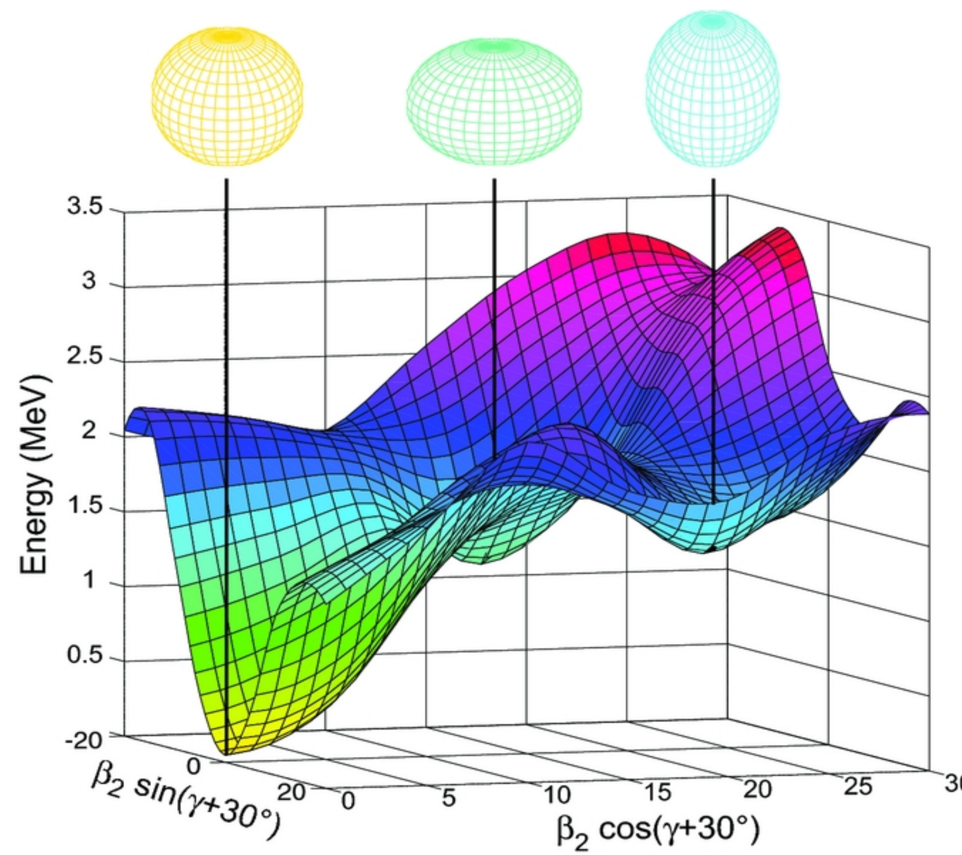
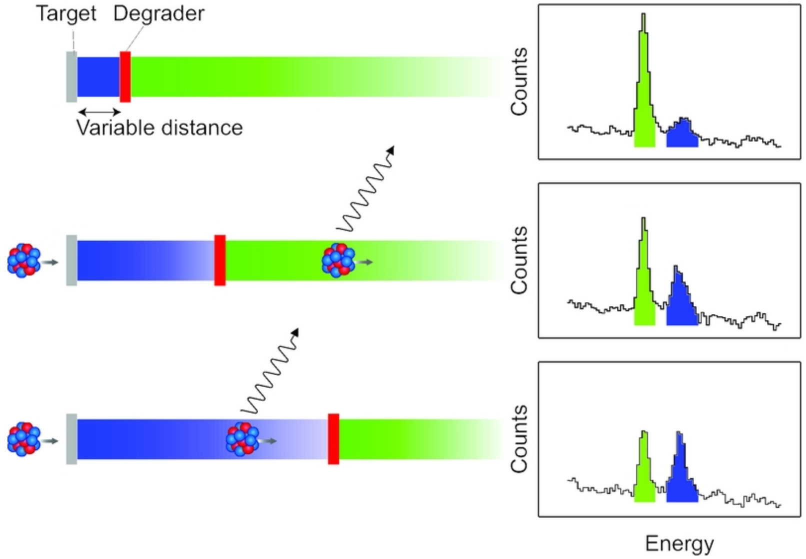
Shape coexistence along the N=Z line



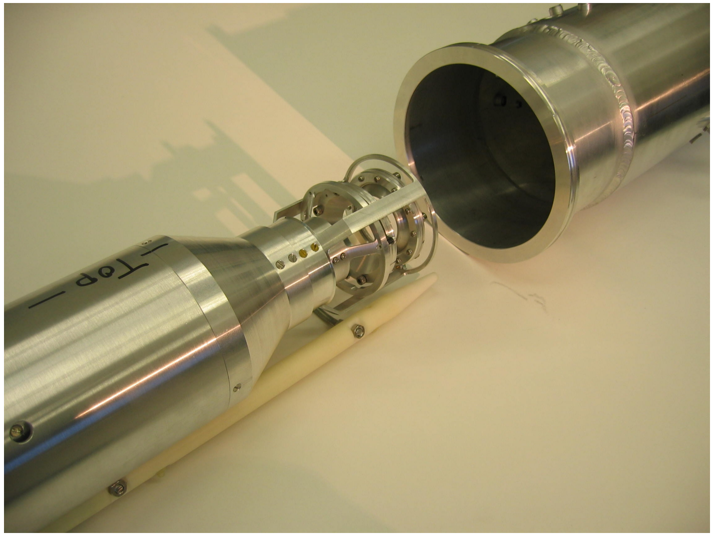


Recoil Distance Method for knock-out reactions.

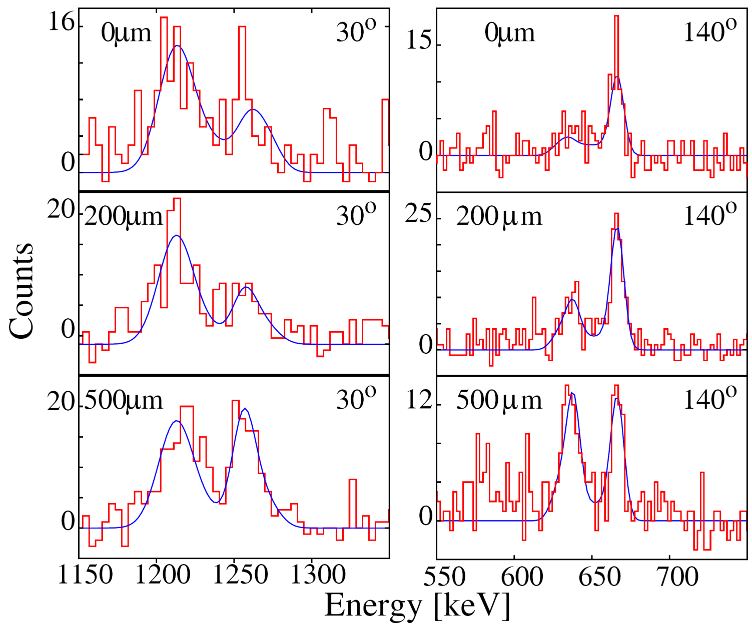
The method

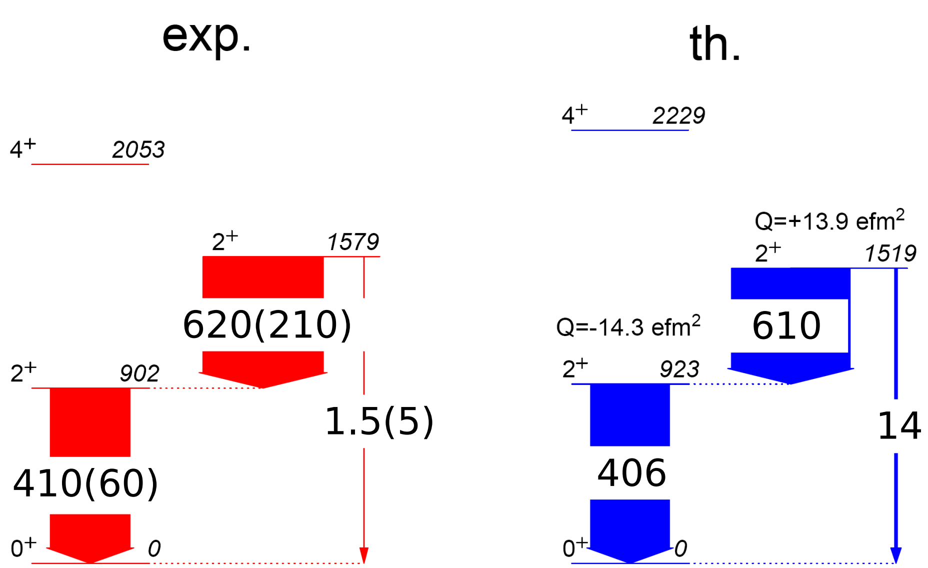


NSCL/Köln plunger device



Transition rates in N=Z ^{64}Ge





NSCL: K. Starosta, IKP Köln: A.Dewald et al. PRL 99, 042503 (2007)

CMU: M. Horoi

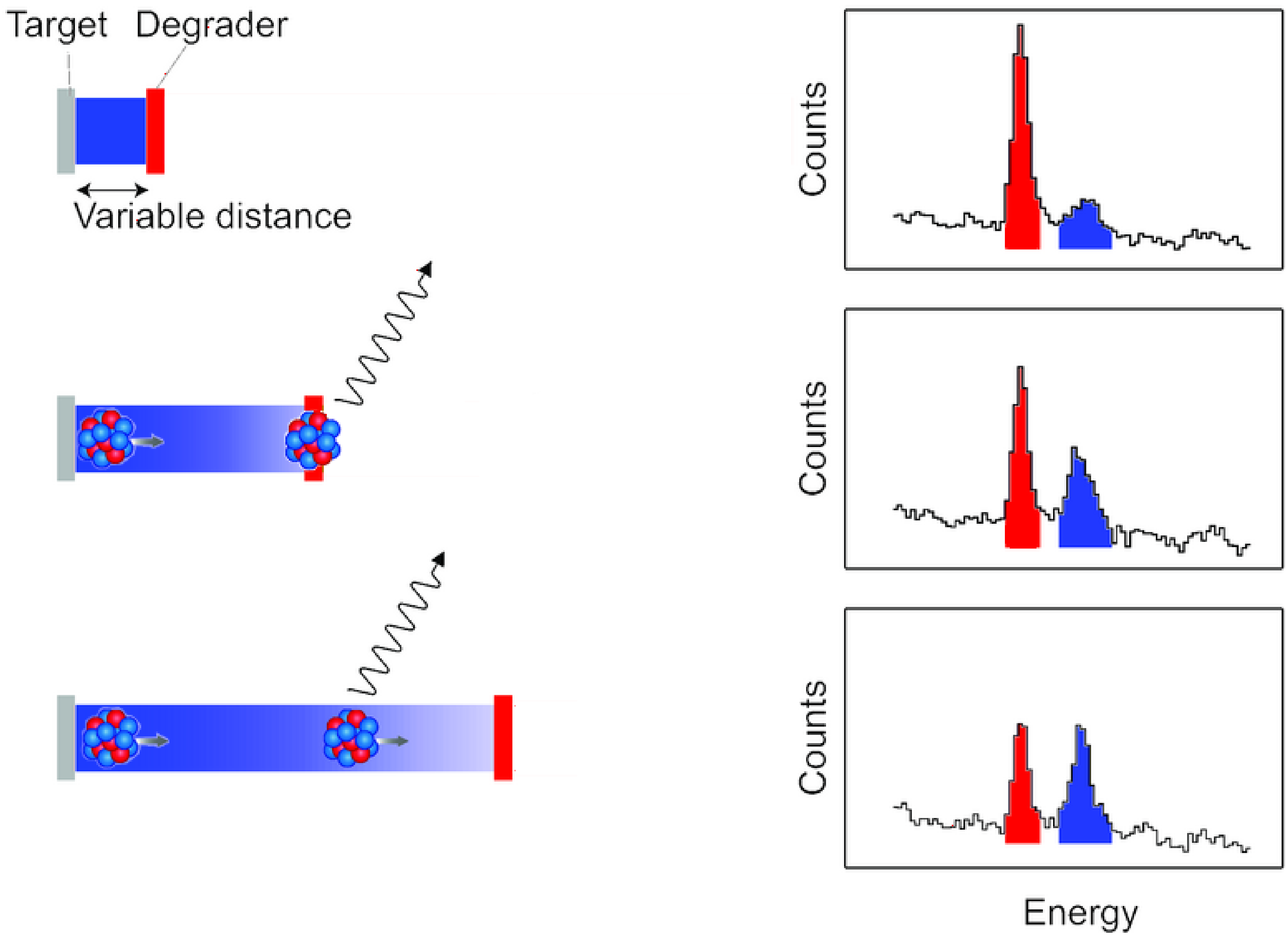
^{68}Se transition rate predictions

Table 1: Comparison between the predictions for the B($E2$,$2_1^+ \rightarrow 0_1^+$) according to the models discussed in Refs. [8—12].

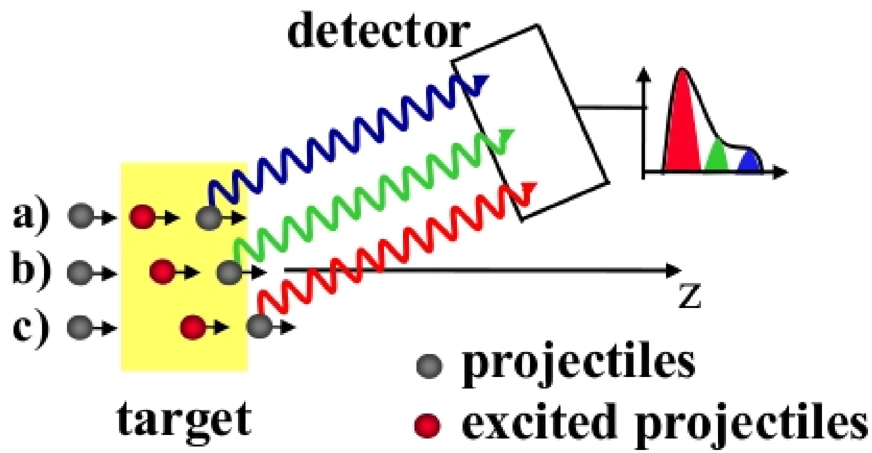
Model	Shell Model	Interacting Boson Model	Hartree-Bogoliubov	Self-consistent Collective Coordinate		Vampire
Reference	[10]	[9]	[11]	[8](a)	[8](b)	[12]
B($E2$,$2_1^+ \rightarrow 0_1^+$) [e^2fm^4]	100	280	500	725	834	1048

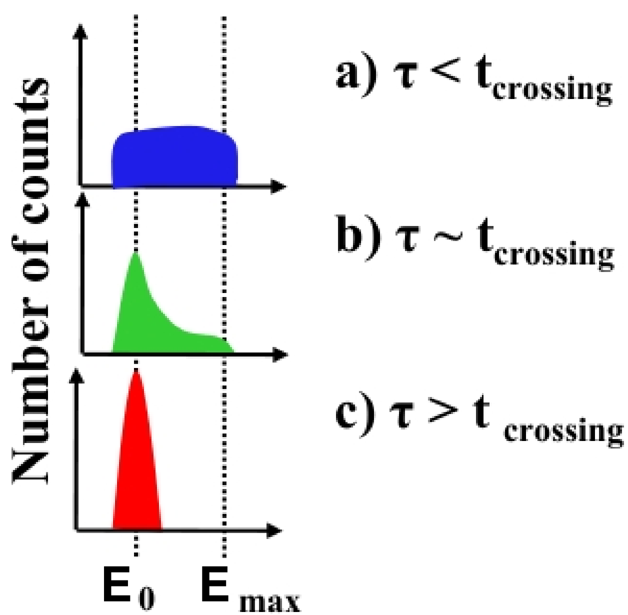
8. N. Hinohara *et al.*, Prog.Theor.Phys.(Kyoto) 119, 59 (2008) .
9. F.H.Al-Khudair, Y.S.Li, G.L.Long, Phys.Rev.**C** 75, 054316 (2007).
10. M.Hasegawa *et al.*, Phys.Lett.**B** 656, 51 (2007).
11. T.A.War *et al.*, Eur.Phys.J.**A** 22, 13 (2004).
12. A.Petrovici *et al.*, Nucl.Phys.**A**710, 246 (2002).

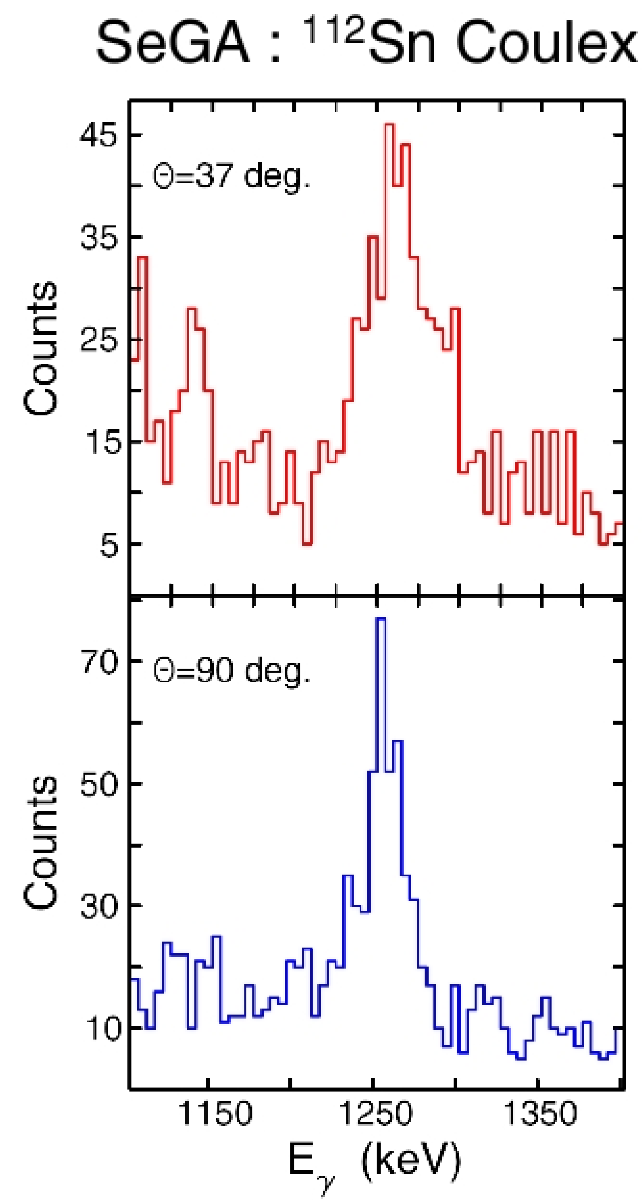
Recoil Distance Method



Doppler-Shift Attenuation Method







Reactions for accessing nuclei along the 28<N=Z<50 line

REACTIONS	stable beams	TRIUMF unstable beams
witout neutron detection	$^{40}Ca(^{24}Mg,2\alpha)^{56}Ni$ $^{40}Ca(^{28}Si,2\alpha)^{60}Zn$ $^{40}Ca(^{32}S,2\alpha)^{64}Ge$ $^{40}Ca(^{36}Ar,2\alpha)^{68}Se$ $^{40}Ca(^{40}Ca,2\alpha)^{72}Kr$	$^{40}Ca(^{38}K,2p)^{76}Sr$ $^{28}Si(^{38}K,2\alpha)^{58}Cu$ $^{32}S(^{38}K,2\alpha)^{62}Ga$ $^{40}Ca(^{38}K,2\alpha)^{70}Br$
with neutron detection	$^{40}Ca(^{40}Ca,2p2n)^{76}Sr$ $^{46}Ti(^{40}Ca,\alpha 2n)^{80}Zr$ $^{50}Cr(^{40}Ca,\alpha 2n)^{84}Mo$ $^{54}Fe(^{40}Ca,\alpha 2n)^{88}Ru$ $^{58}Ni(^{40}Ca,\alpha 2n)^{92}Pd$	$^{46}Ti(^{38}K,\alpha 2n)^{78}Y$ $^{50}Cr(^{38}K,\alpha 2n)^{82}Nb$ $^{54}Fe(^{38}K,\alpha 2n)^{86}Tc$ $^{58}Ni(^{38}K,\alpha 2n)^{90}Rh$

channel identification is the key

comments on rates and cross sections are coming

Reactions for accessing nuclei beyond the 28<N=Z<50 line

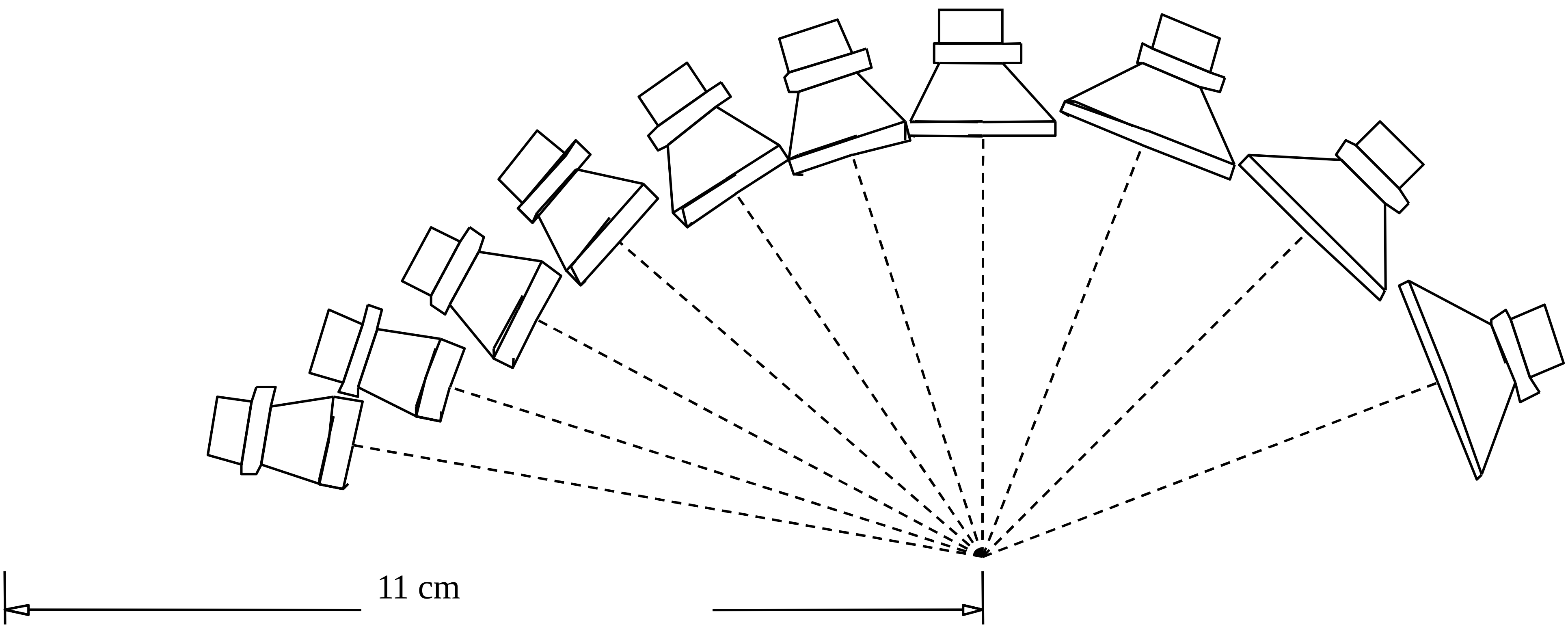
REACTIONS	stable beams	TRIUMF unstable beams
witout neutron detection		
with neutron detection		^{40}Ca(^{19}Ne,αn)^{54}Ni ^{40}Ca(^{23}Mg,αn)^{58}Zn

channel identification is the key

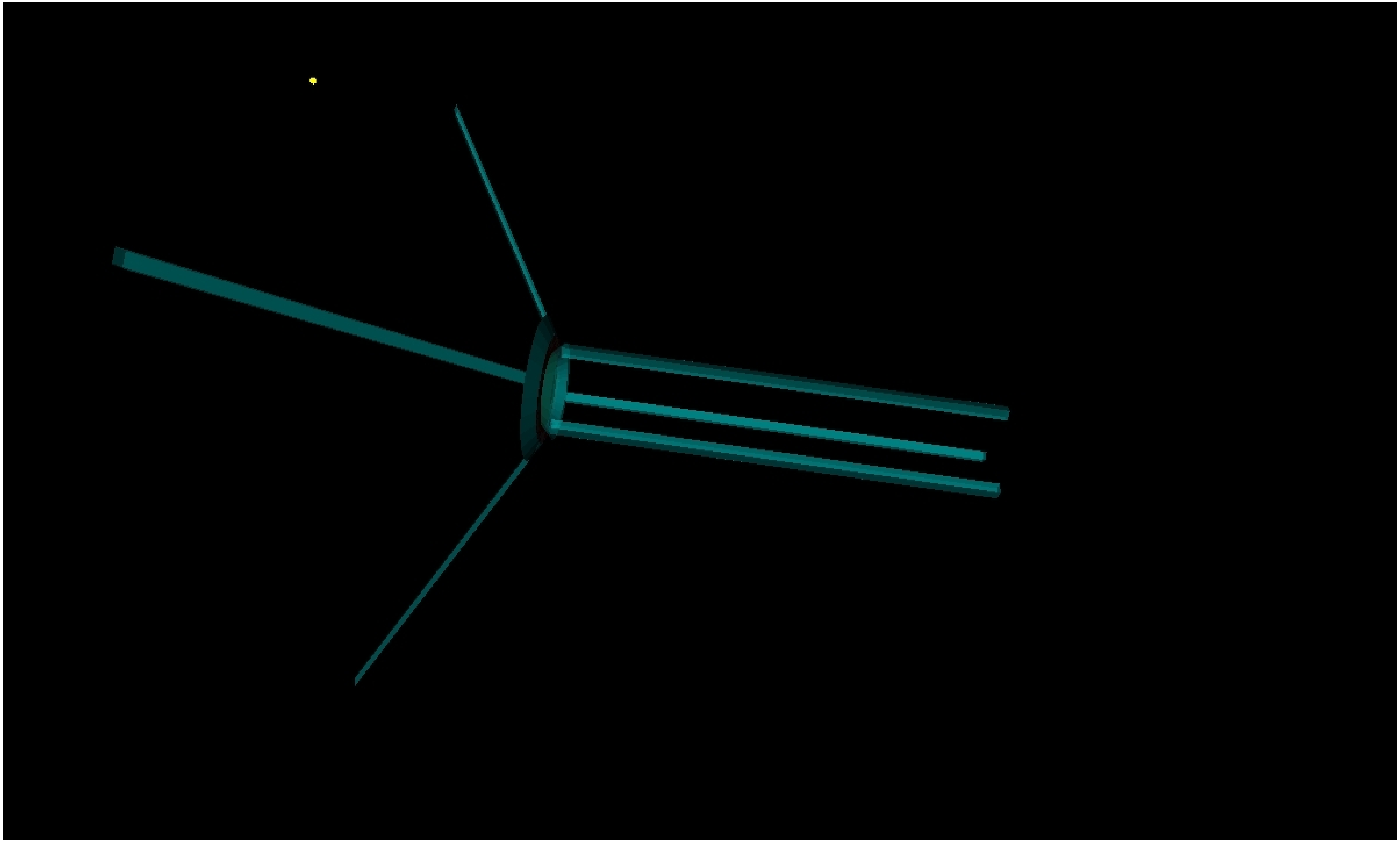
comments on rates and cross sections are coming

TIGRESS integrated plunger (TIP)

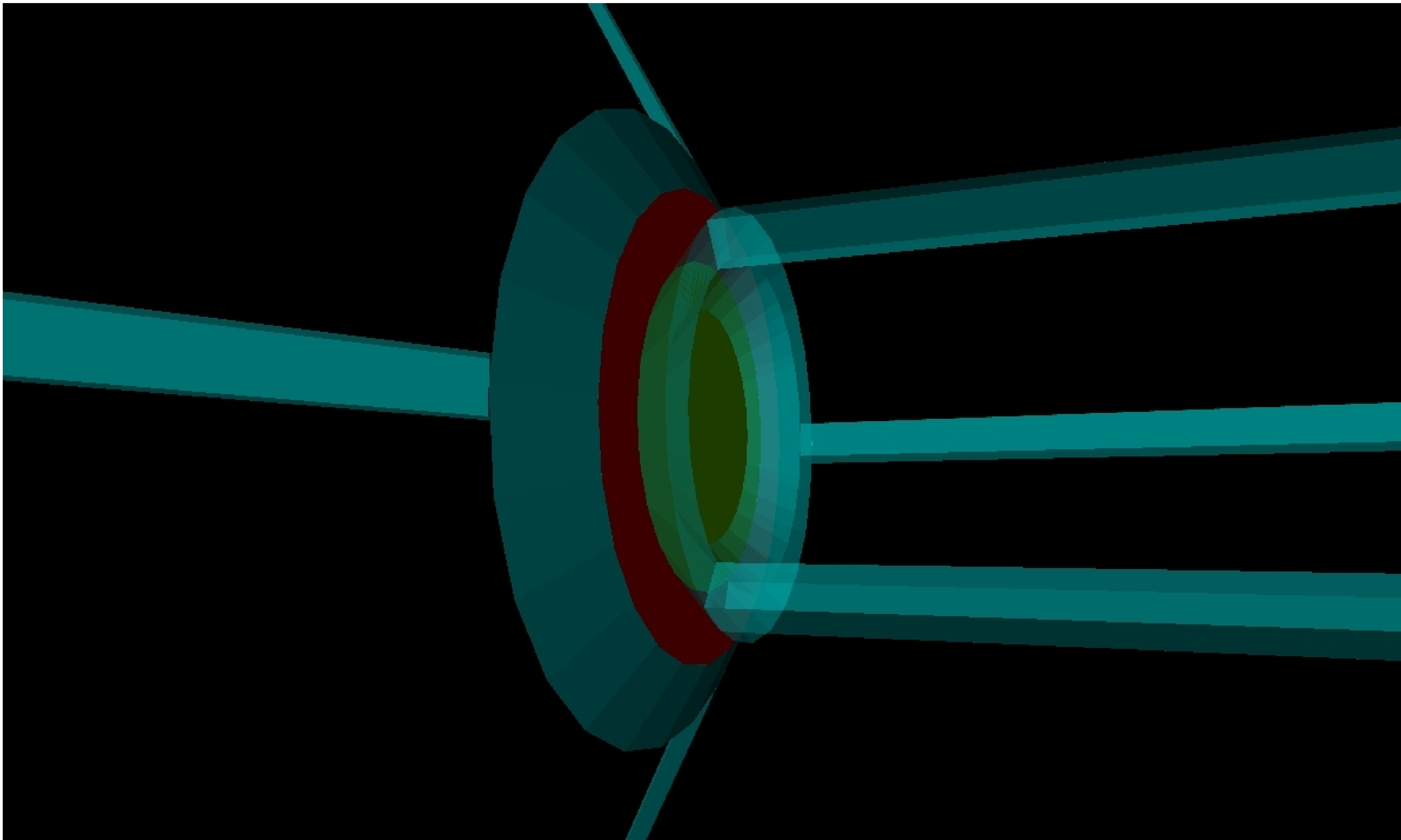
plunger capable of working in conjunction with the TIGRESS CsI array



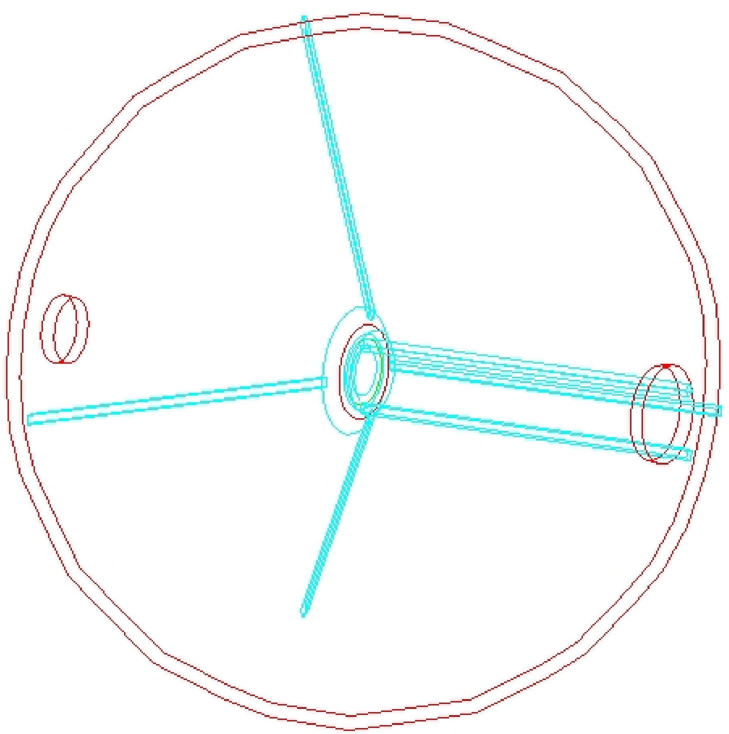
TIGRESS integrated plunger (TIP)

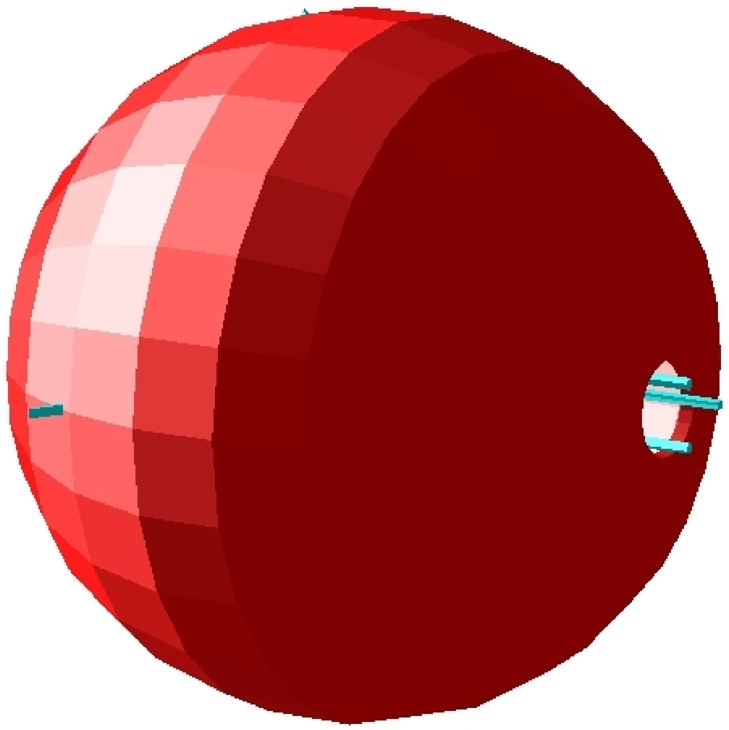


TIGRESS integrated plunger (TIP)



TIGRESS integrated plunger (TIP)



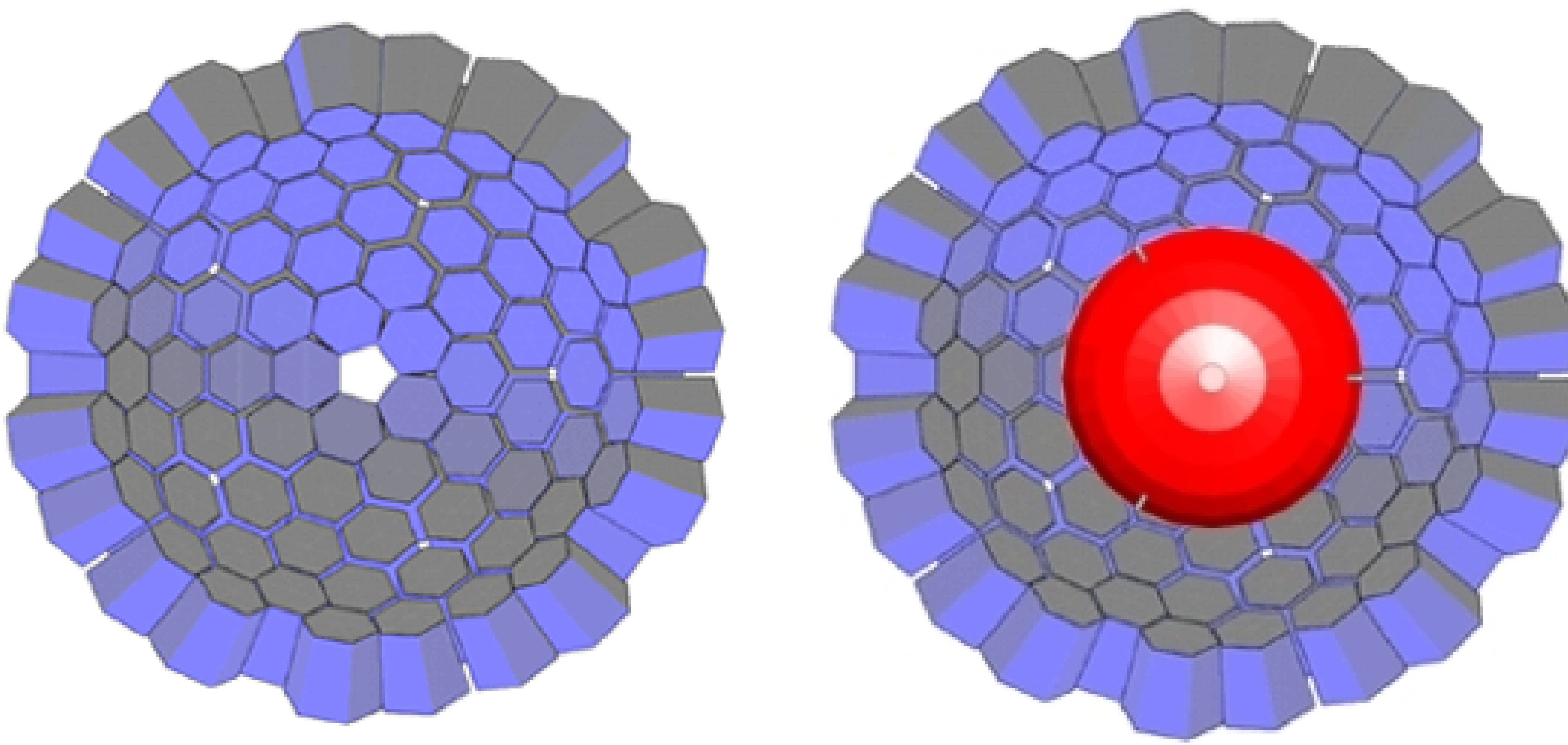


TIGRESS integrated plunger (TIP)

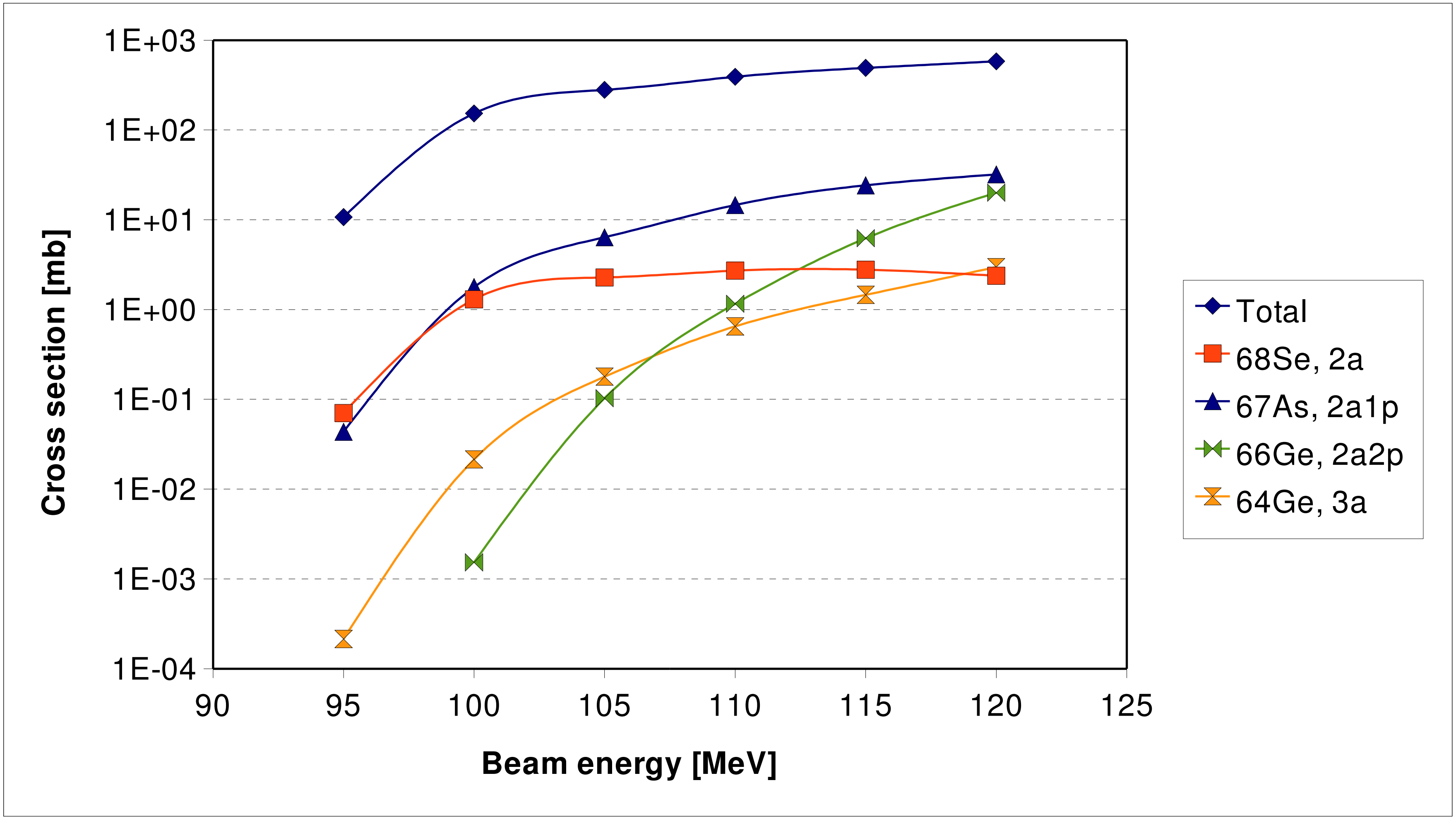
Clover center	Crystal center	Doppler shift [%]	Doppler broadening [%]	Fraction of efficiency	Efficiency at 1 MeV [%]
45	35	2.87	0.70	0.125	1.25
45	55	2.01	1.00	0.125	1.25
90	80	0.61	1.20	0.250	2.50
90	110	-0.61	1.20	0.250	2.50
135	125	-2.01	1.00	0.125	1.25
135	145	2.87	0.70	0.125	1.25

TIGRESS integrated plunger (TIP)

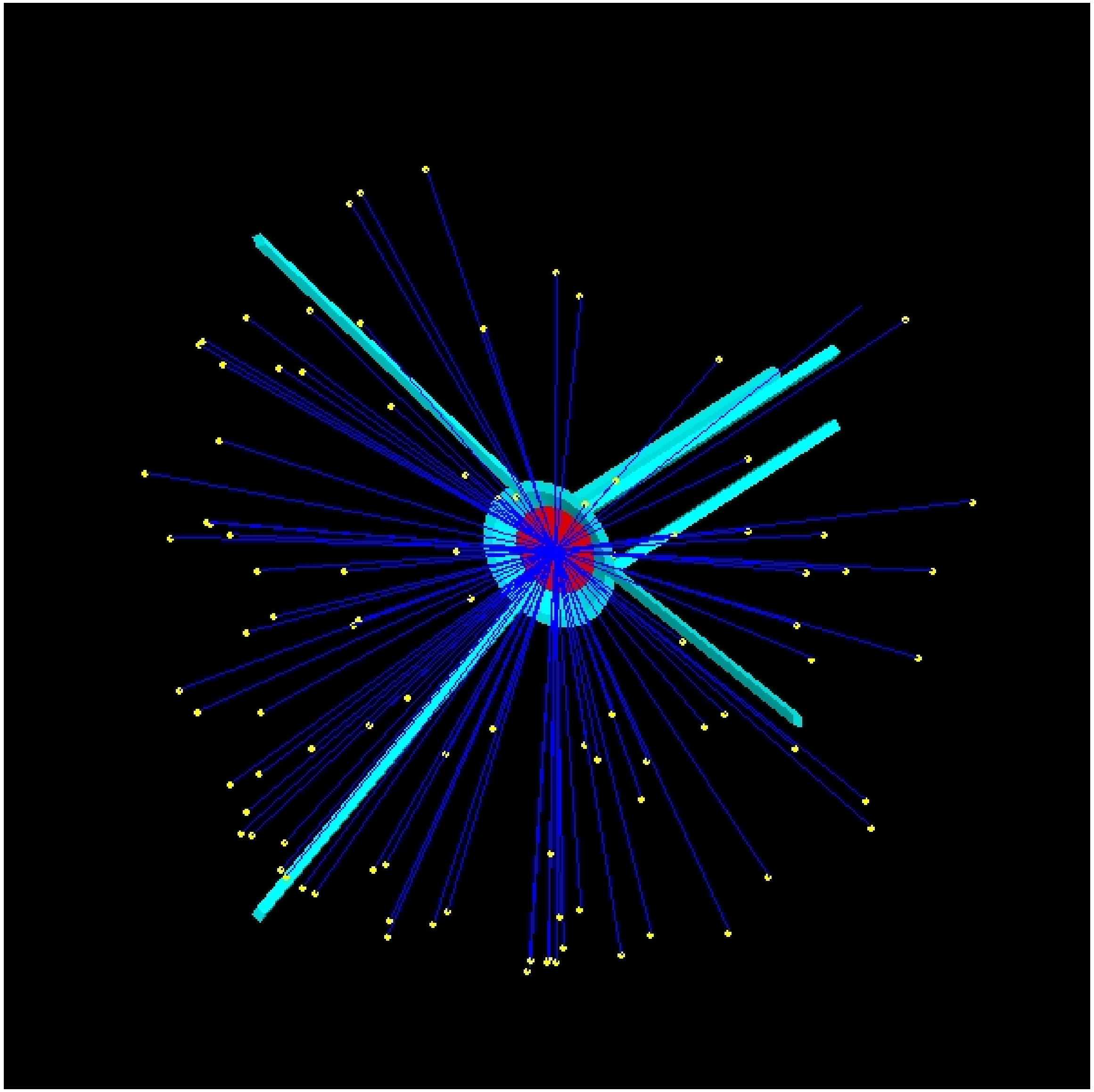
in conjunction with DESCANT



The start: ^{68}Se via ^{40}Ca(^{36}Ar,2α) reaction



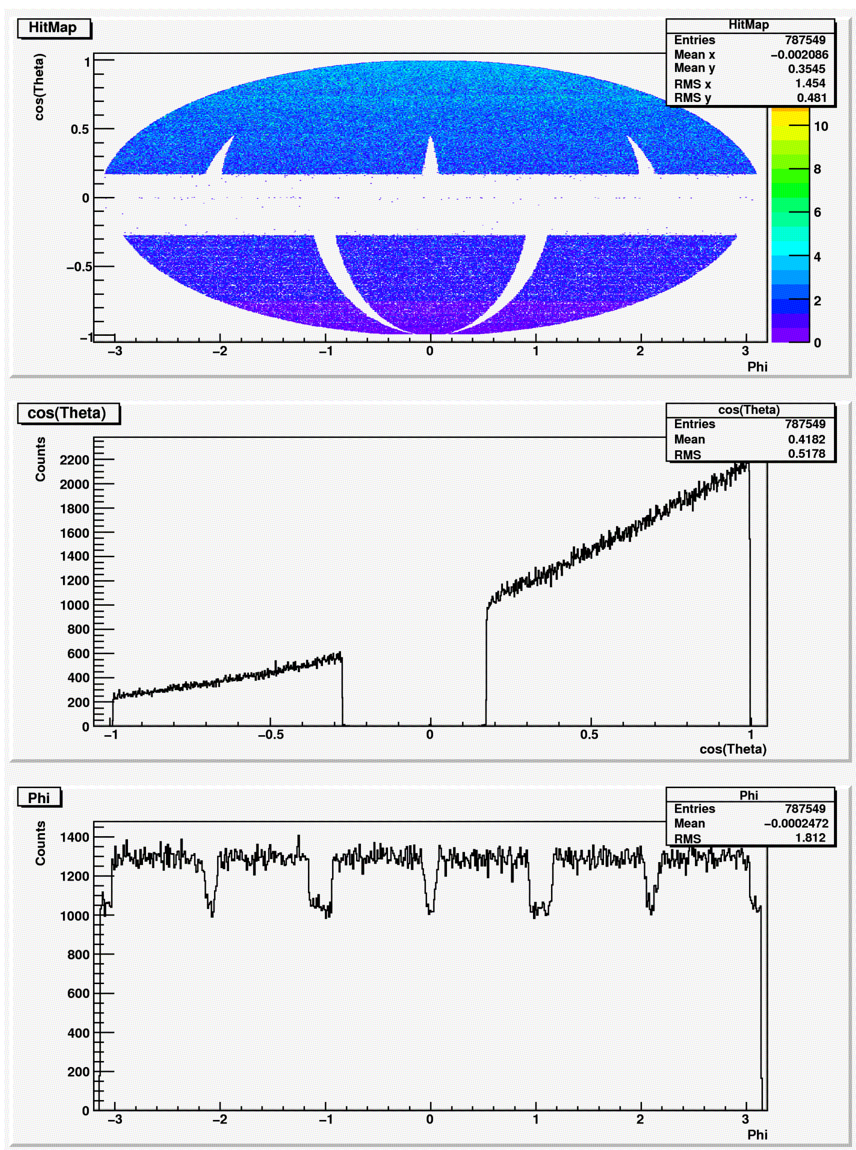
GEANT4 simulation for TIP's efficiency
^{36}Ar on ^{40}Ca at 97.5 MeV



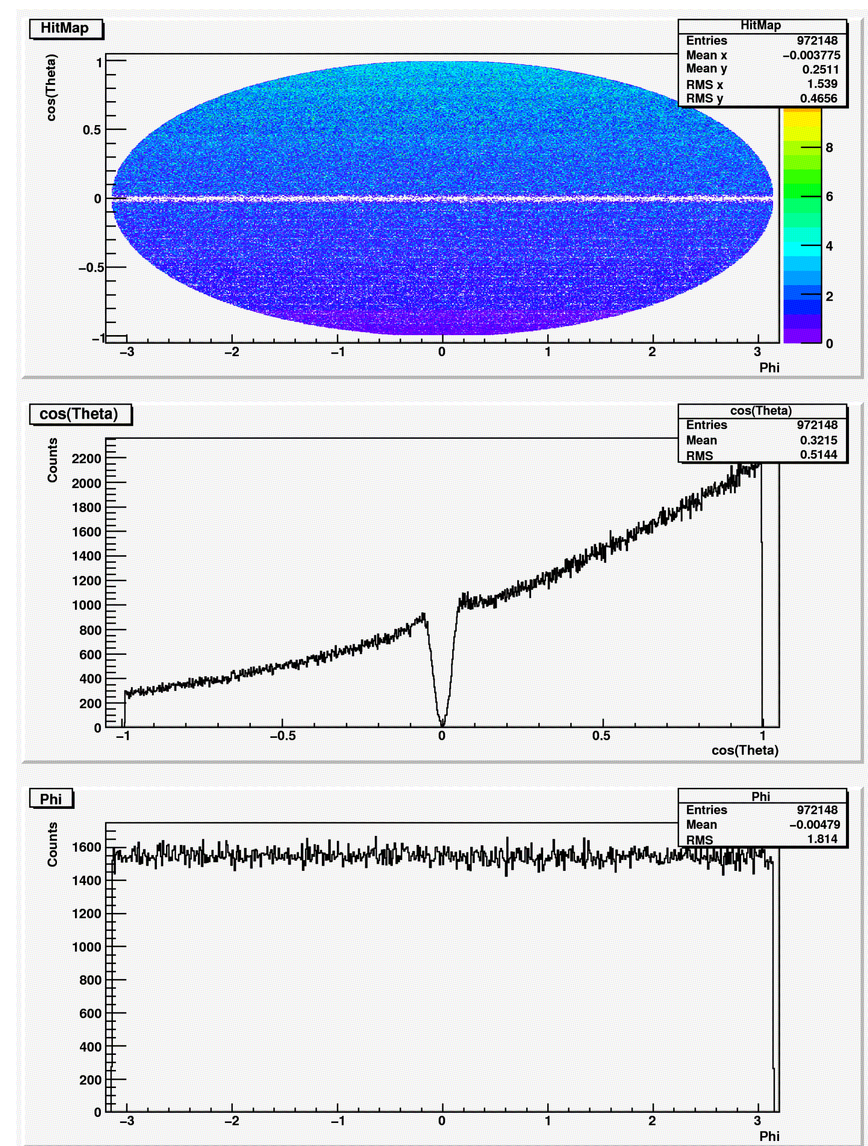
GEANT4 simulation for α efficiency

^{36}Ar on ^{40}Ca at 97.5 MeV

TIP: 75% solid angle covered

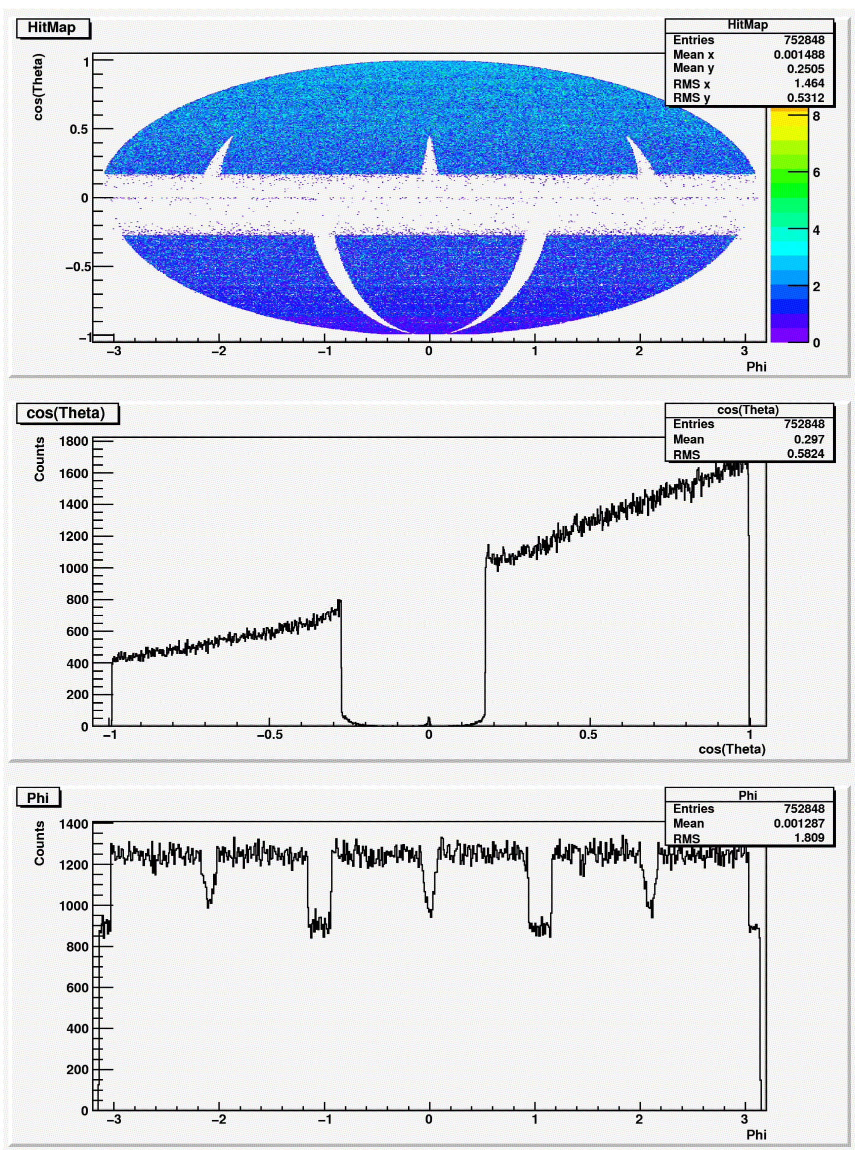


Target only: 97% solid angle covered

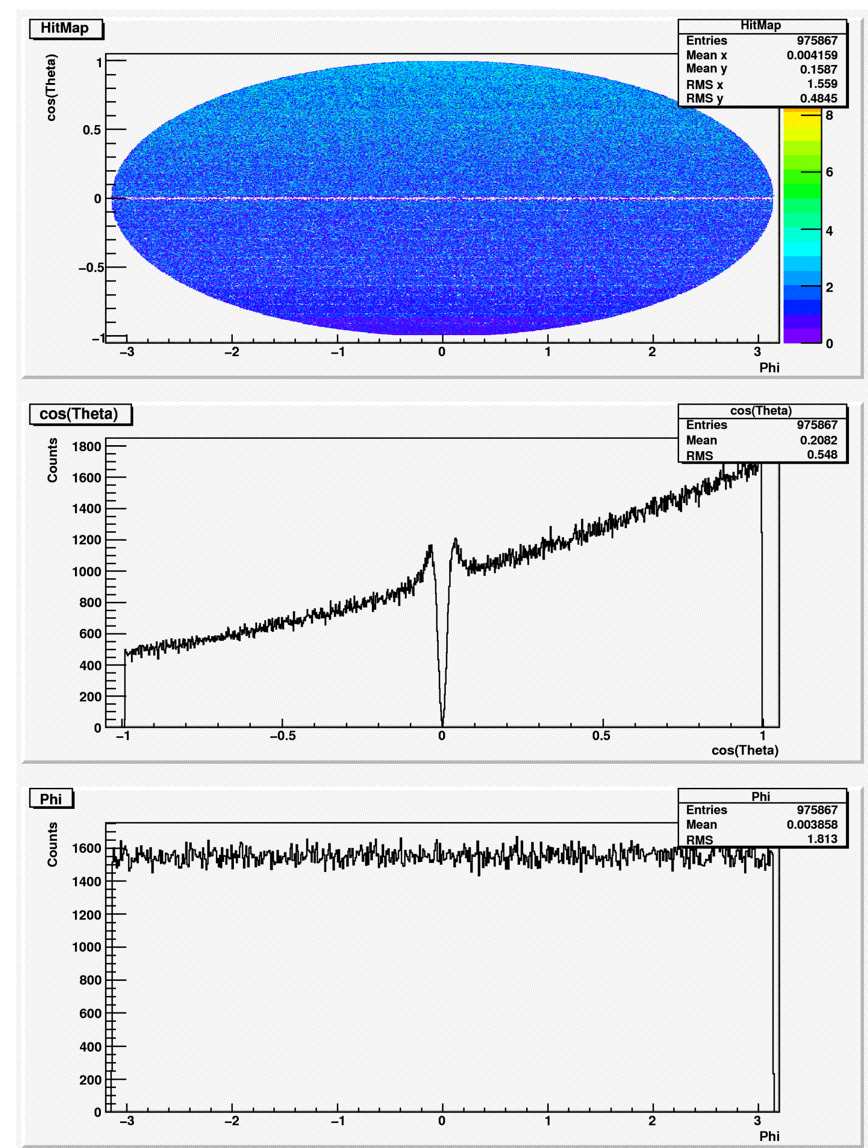


GEANT4 simulation for proton efficiency
^{36}Ar on ^{40}Ca at 97.5 MeV

TIP: 75% solid angle covered



Target only: 97% solid angle covered



Comments on rates and cross sections

•Cross sections:

- are predictable, well described by fusion-evaporation statistical codes,
- have strong dependence on the projectile energy,
- for 2α channel are on the order of a few millibarns at the max. of the excitation function, for N~Z nuclei are decreased at least by an order of magnitude for each evaporated neutron.

•Beam rates:

- stable beams are limited to a few particle nano-ampers (10^{10}) by plunger targets,
- unstable beam of interest have already good intensities:
  - 2.2×10^8 for ^{38}K
  - 7.2×10^7 for ^{23}Mg
  - 1.0×10^7 for ^{19}Ne
- intensities can be expected to increase with time,
- other beams may be developed.

Comments on the balance between sensitivity and statistics for accessing N=Z nuclei

- One better find the right one.

- Need to be optimized for each case individually based on availability of beams, targets and detectors for channel selection.

- Charged-particle evaporation channels have higher cross sections and detection efficiency, the program should take advantage of that at the start.

- Neutron-evaporation channels provide a cleaner tag at the cost of reduced overall efficiency of the setup.

- A large number N=Z of nuclei can be accessed using stable beams, the program should take advantage of that at the start.

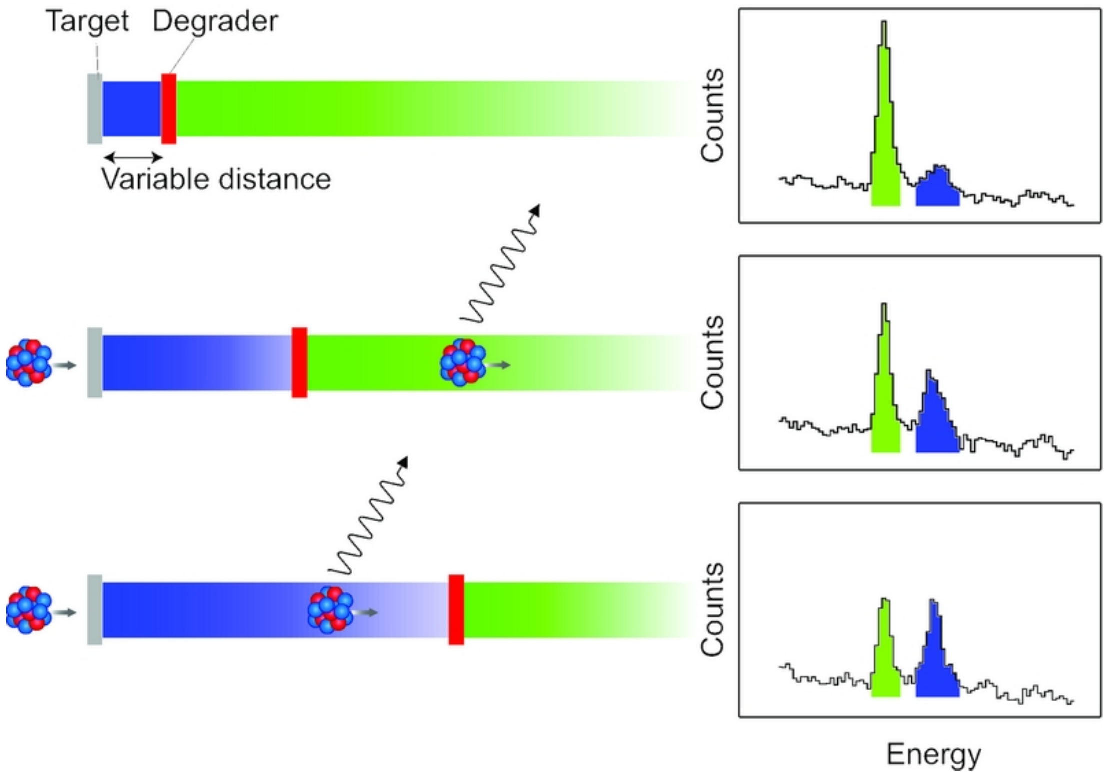
- Unstable beams critical to go beyond the N=Z line and towards ^{100}Sn.

- For clean particle identified spectra, lifetimes can be measured using γ-ray singles which is critical for low statistics experiments at the extreme.

Outlook

•RDM/DSAM can be used in any other region beyond the N=Z line.

•RDM/DSAM can be extended to inverse kinematics reactions using EMMA for channel selection.



➢ RDM for short lived, picosecond γ-ray emitting excited states.

➢ RDM for short lived, picosecond proton-emitting ground states.

The TIP collaboration:

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