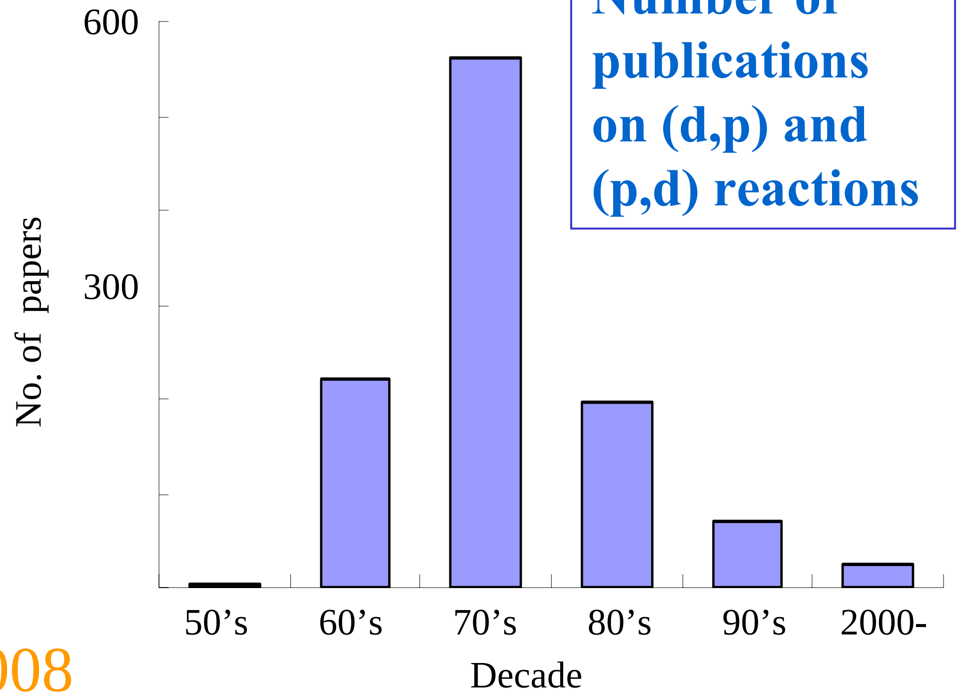
Neutron Spectroscopic Factors from Transfer Reactions



Number of publications on (d,p) and (p,d) reactions

What have we learned in the past?

What can we learn in the future?

Kernz08
Dec 1-5, 2008

Betty Tsang
The National Superconducting Cyclotron Laboratory
@Michigan State University

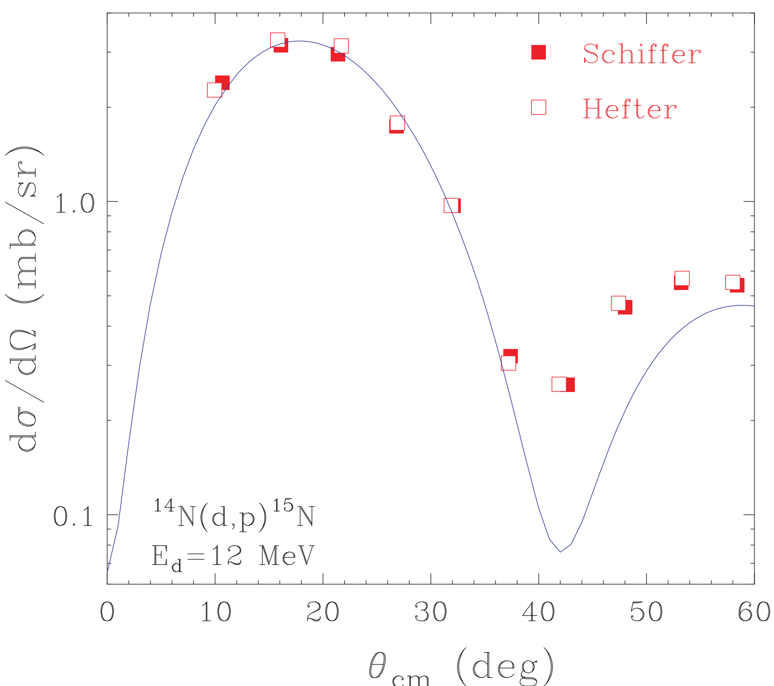
Outline

1. Review of n-spectroscopic factors of nuclei A=B+n extracted from A(p,d)B and B(d,p)A reactions.
2. Comparison to large-basis shell model calculations – Horoi
3. Comparison to quenching of the SF strengths observed in knockout & (e,e'p) reactions.
4. Can we resolve the observed discrepancies?
5. Preliminary results from ^{34,36,46}Ar(p,d) analysis.
6. Summary

Properties of valence nucleons

Experimental SF :

$$S_{exp} = \frac{(\frac{d\sigma}{d\Omega})_{EX}}{(\frac{d\sigma}{d\Omega})_{RM}}$$



⇒ **Spectroscopic factor (SF)**

measures the orbital configuration of the valence nucleons.

Independent Particle Model (IPM), SF represents how good we can describe the nucleus as a single particle plus a core.

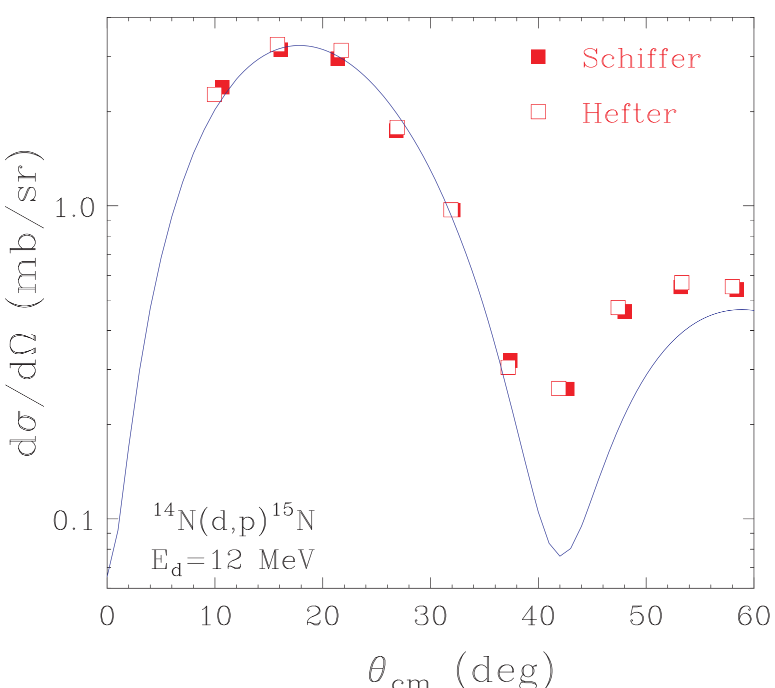
$S_{exp}/S_{IPM} = 1$ pure single-particle state

$S_{exp}/S_{IPM} < 1$ IPM needs refinement →LBSM.

Properties of valence nucleons

Experimental SF :

$$S_{exp} = \frac{\left(\frac{d\sigma}{d\Omega}\right)_{EX}}{\left(\frac{d\sigma}{d\Omega}\right)_{RM}}$$



⇒ Spectroscopic factor (SF)

measures the orbital configuration of the valence nucleons.

Large Basis Shell Model (LB-SM), SF can be used to test the interactions used in SM.

$$S_{exp} / S_{IPM} = 1$$

SM orbital description is accurate

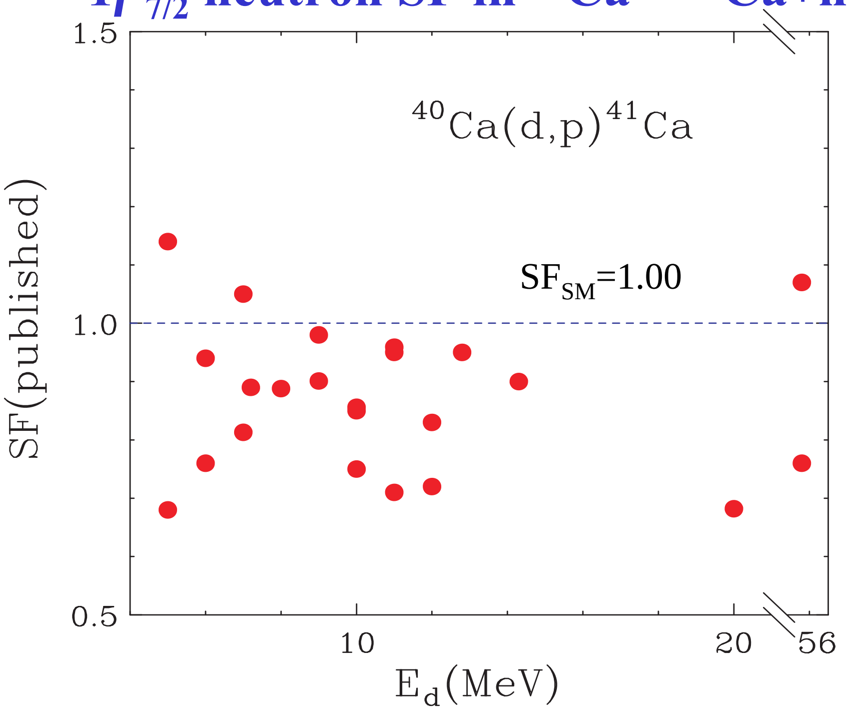
$S_{SM/}$

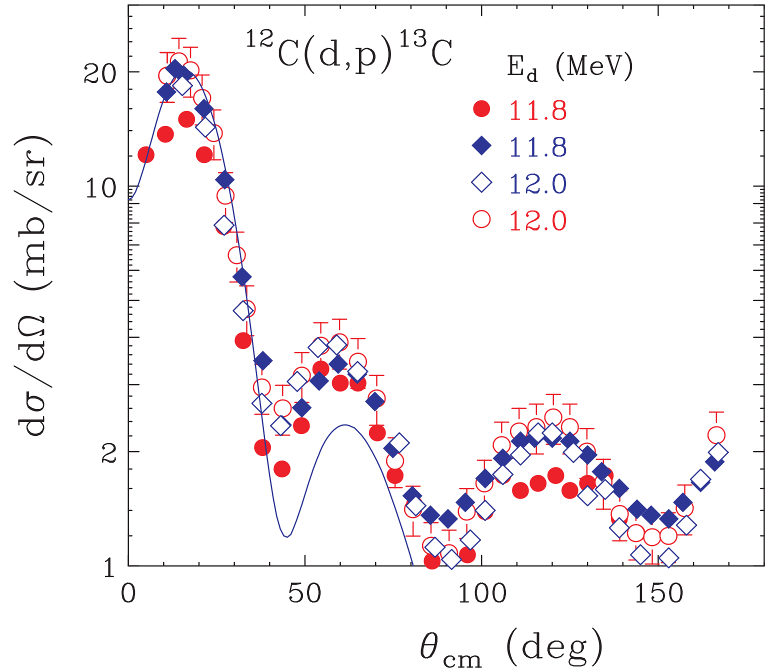
$$S_{exp} / S_{IPM} < 1$$

Improvement in interactions?.

Why review past SF’s

1*f* $_{7/2}$ neutron SF in ^{41}Ca = ^{40}Ca+n





Large fluctuations : due to different optical model potentials and reaction model input parameters

Realistic experimental uncertainties and need for evaluation of data

Systematic & consistent approach to extract SF

Systematic approach to extract spectroscopic factors

$$\left(\frac{d\sigma}{d\Omega}\right)_{EXP} = SF_{EXP}\left(\frac{d\sigma}{d\Omega}\right)_{Theo}$$

ADWA

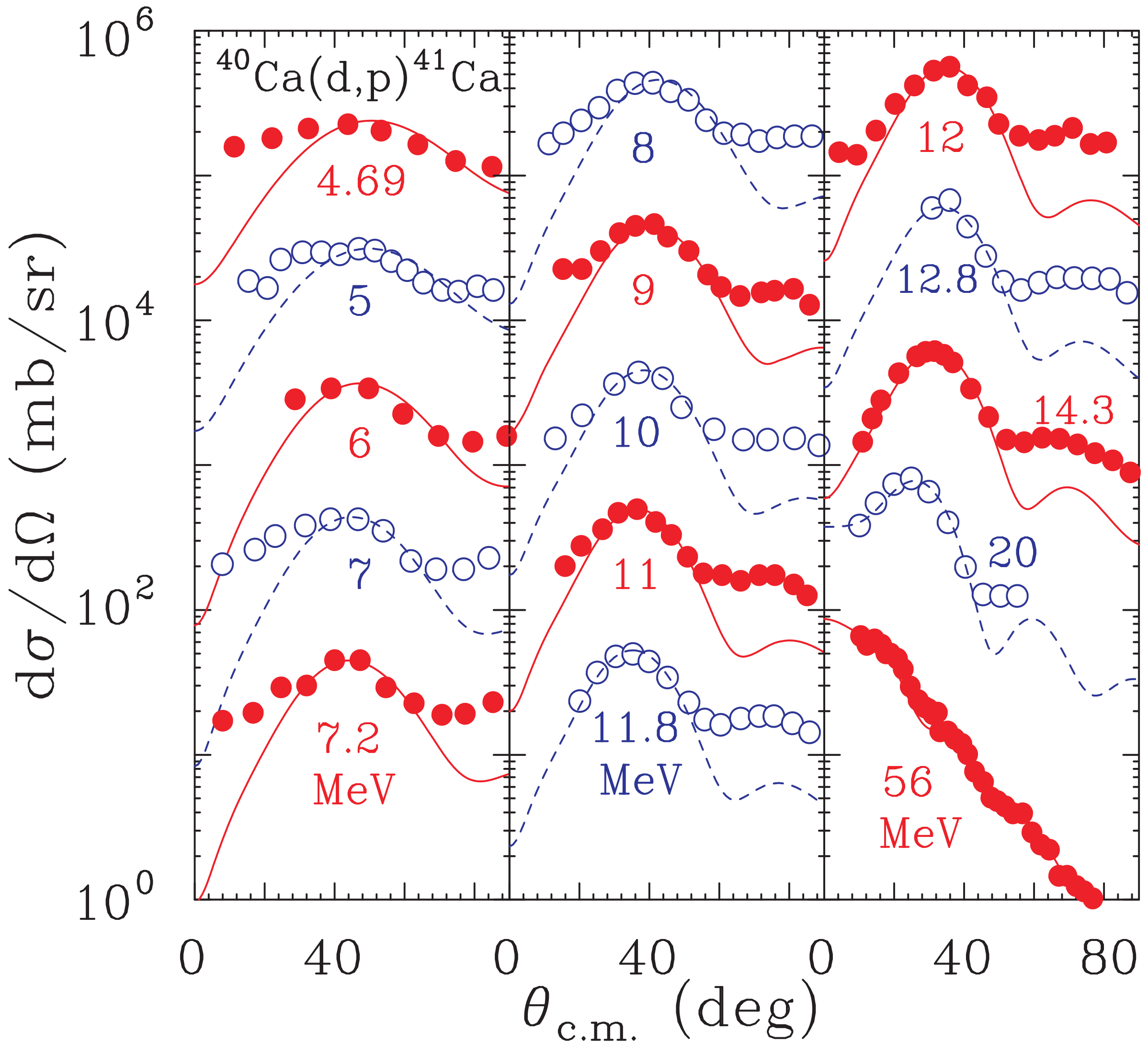
✓ *Johnson-Soper (JS) Adiabatic Approximation takes care of d-break-up effects*

✓ *Use global p and n optical potential with standardized parameters (CH89)*

✓ *Include finite range & non-locality corrections*

✓ *n-potential : Woods-Saxon shape r_o=1.25 & a_o=0.65 fm; depth adjusted to reproduce experimental binding energy.*

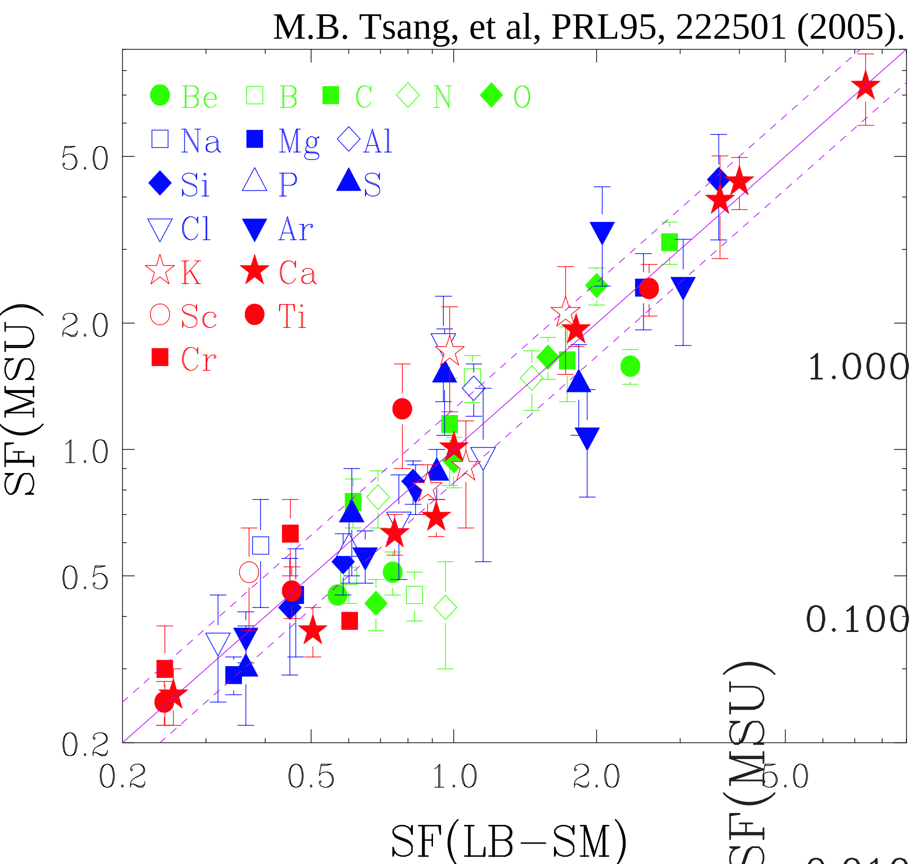
→ *TWOFNR code from Jeff Tostevin (U of Surrey)*



SF=1.01±0.06; SF(SM) = 1.0

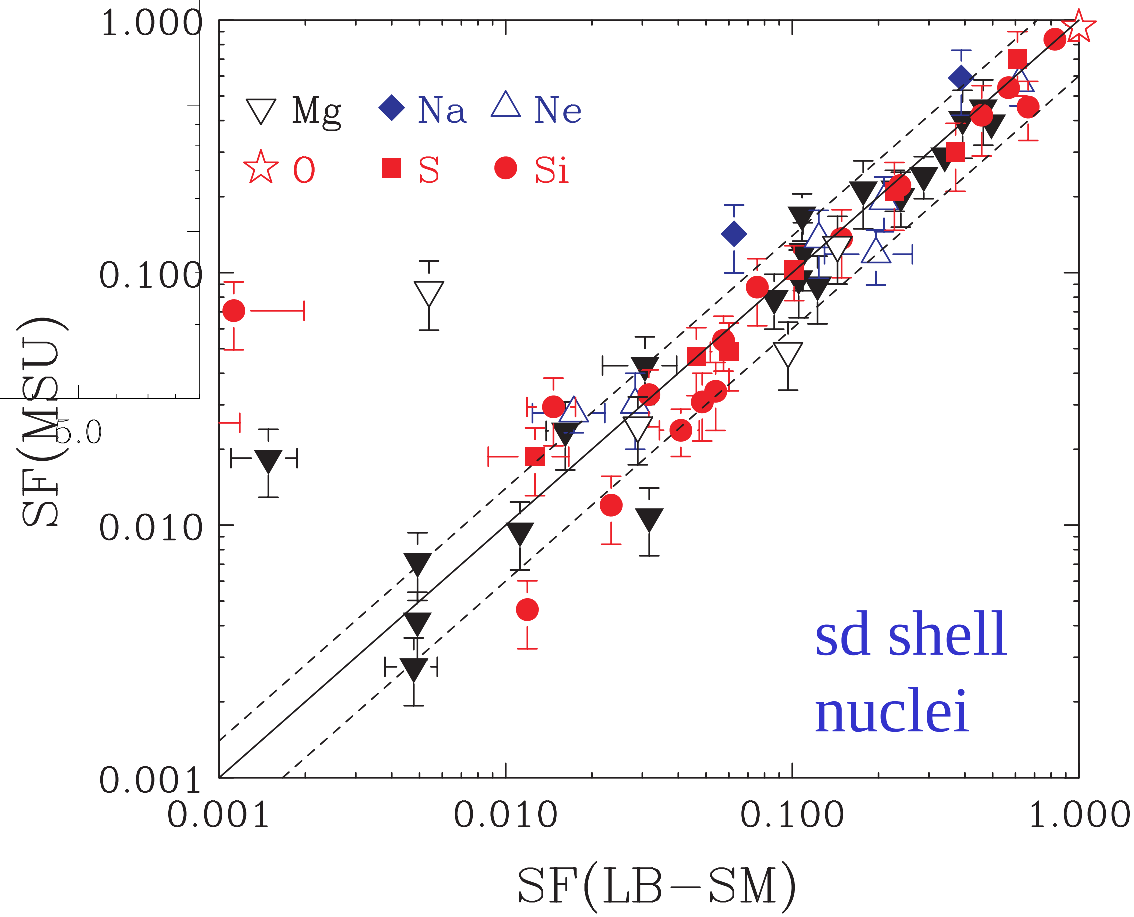
J. Lee et al, Phys. Rev. C75 (2007) 064320

Compare with LB-Shell Model

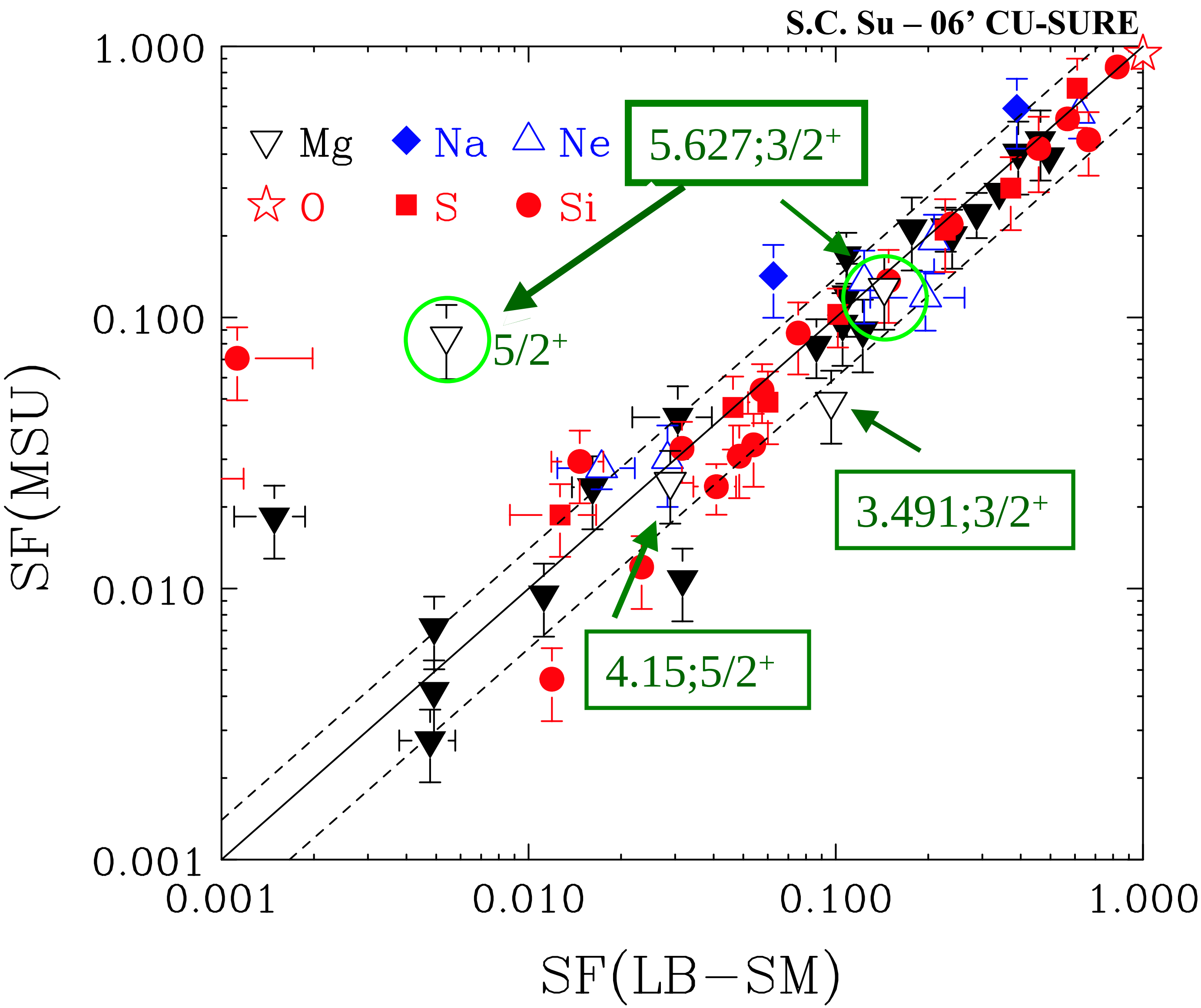


USDA & USDB interactions
Agreement with Shell Model 30% for SF>0.002. For SF<0.002, SM calculations are not accurate.

20% agreement for gs SF

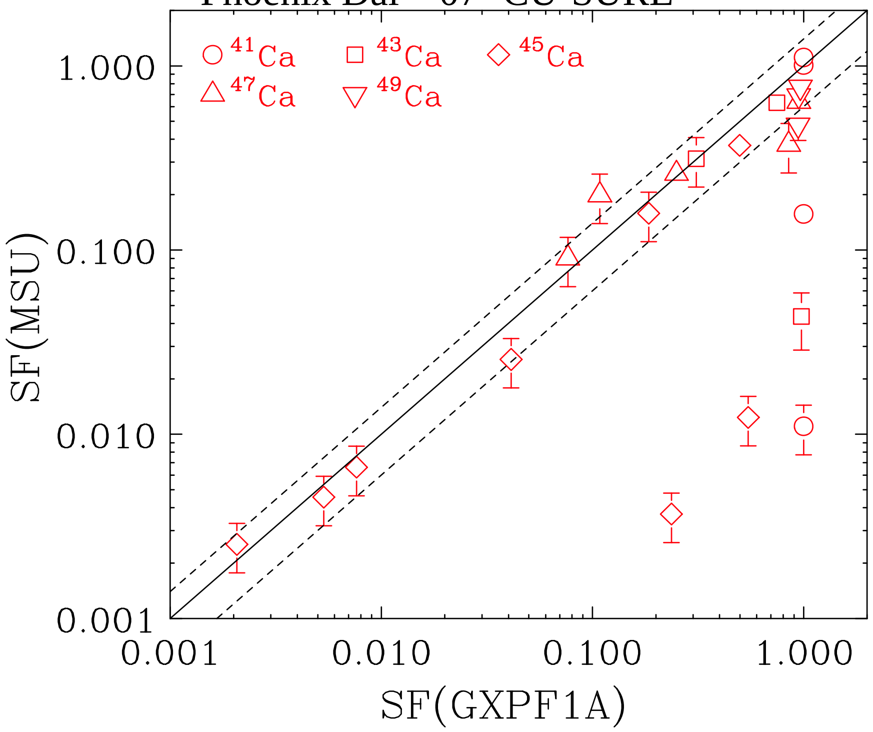


Application: Spin assignments from Systematics

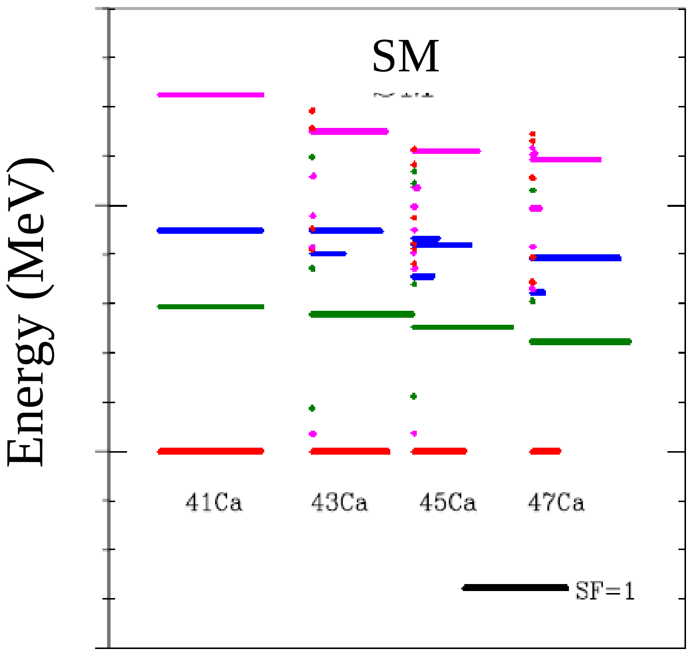


Neutron Spectroscopic Factors for Ca Isotopes

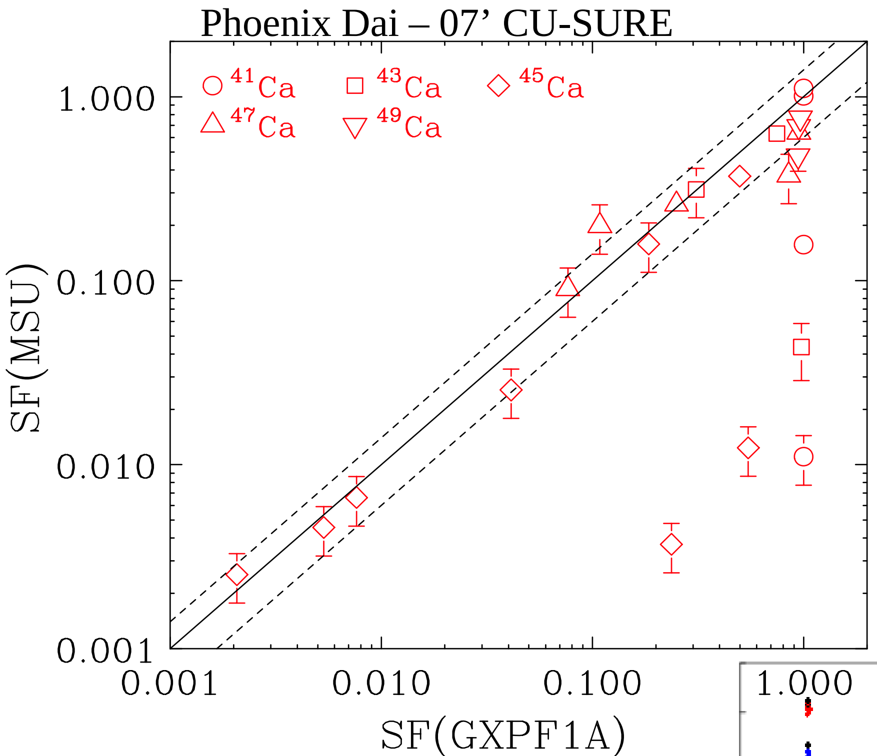
Phoenix Dai – 07' CU-SURE



Shell Model – closed ^{40}Ca core: mainly single particle states



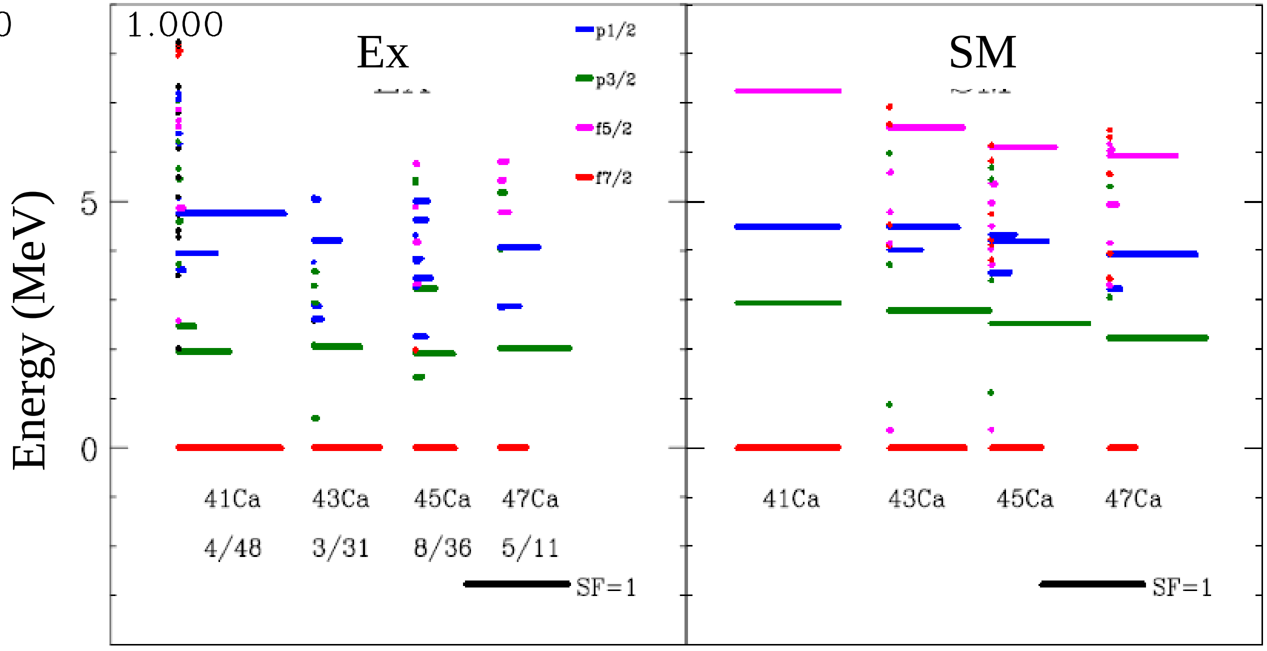
Neutron Spectroscopic Factors for Ca Isotopes



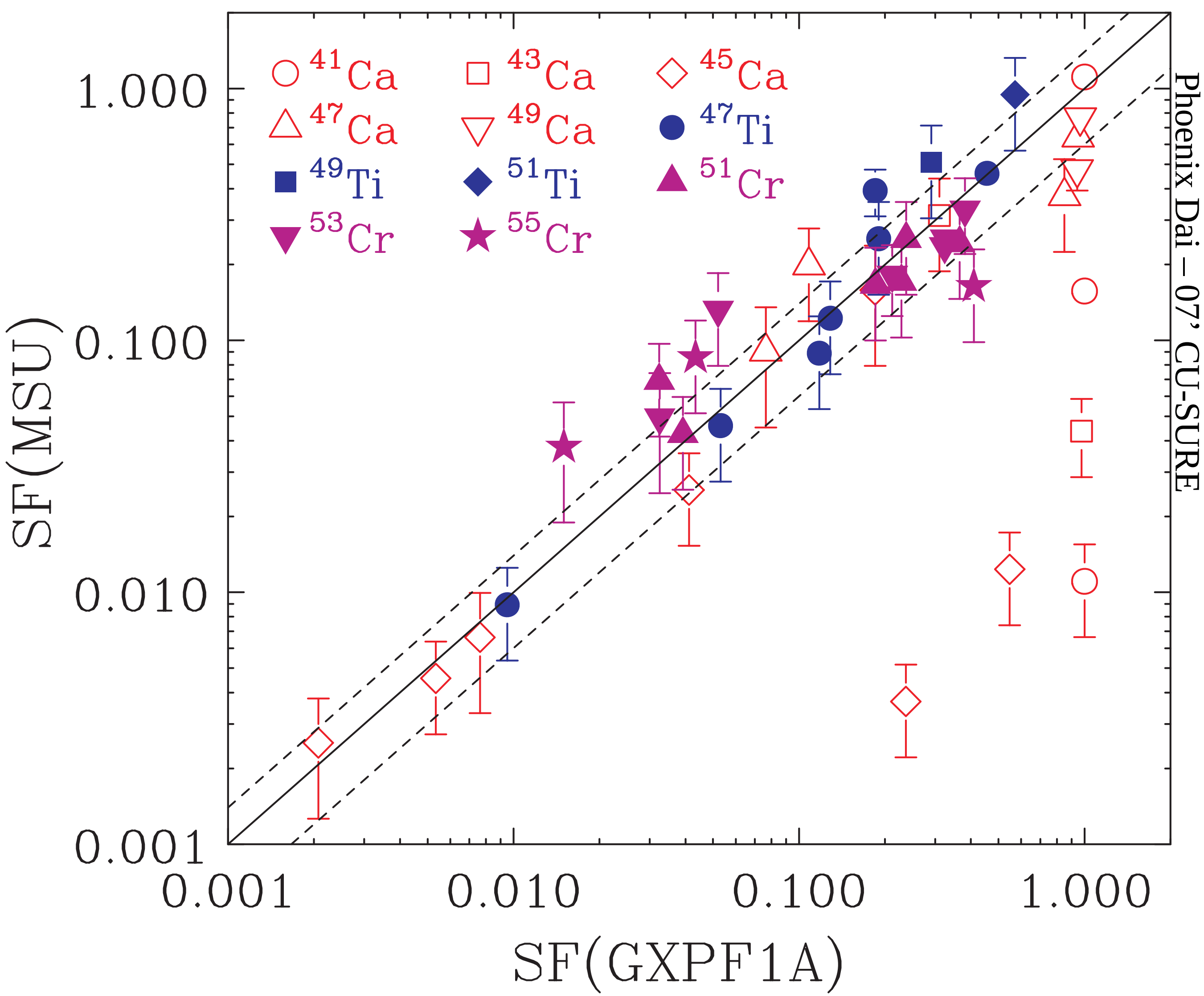
Shell Model – closed ^{40}Ca core: mainly single particle states

Experiment: Large fragmentation even for ^{41}Ca

Horoi's talk



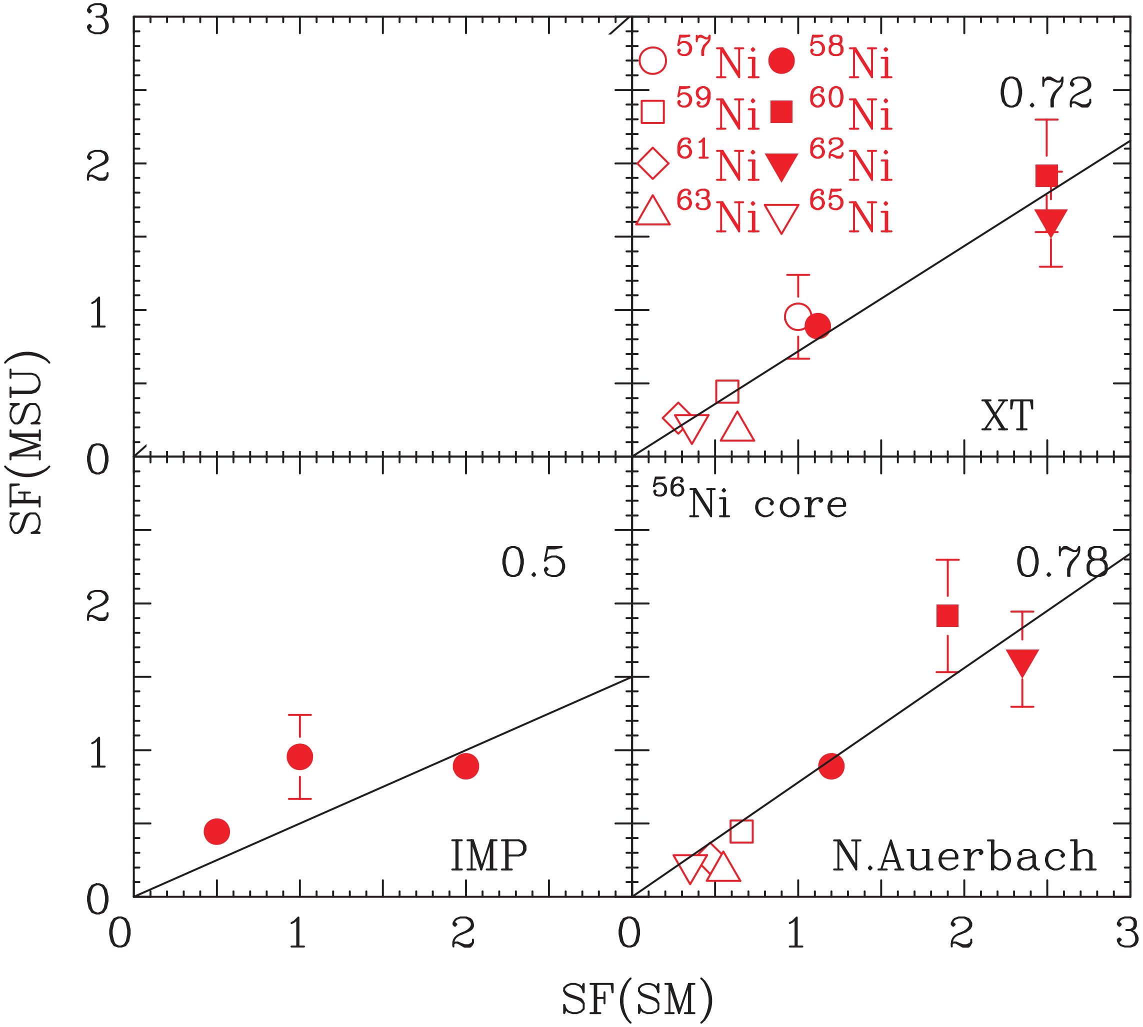
Neutron Spectroscopic Factors for Ca, Ti, Cr isotopes



Shell Model predictions improve away from closed shell

-- Horoi

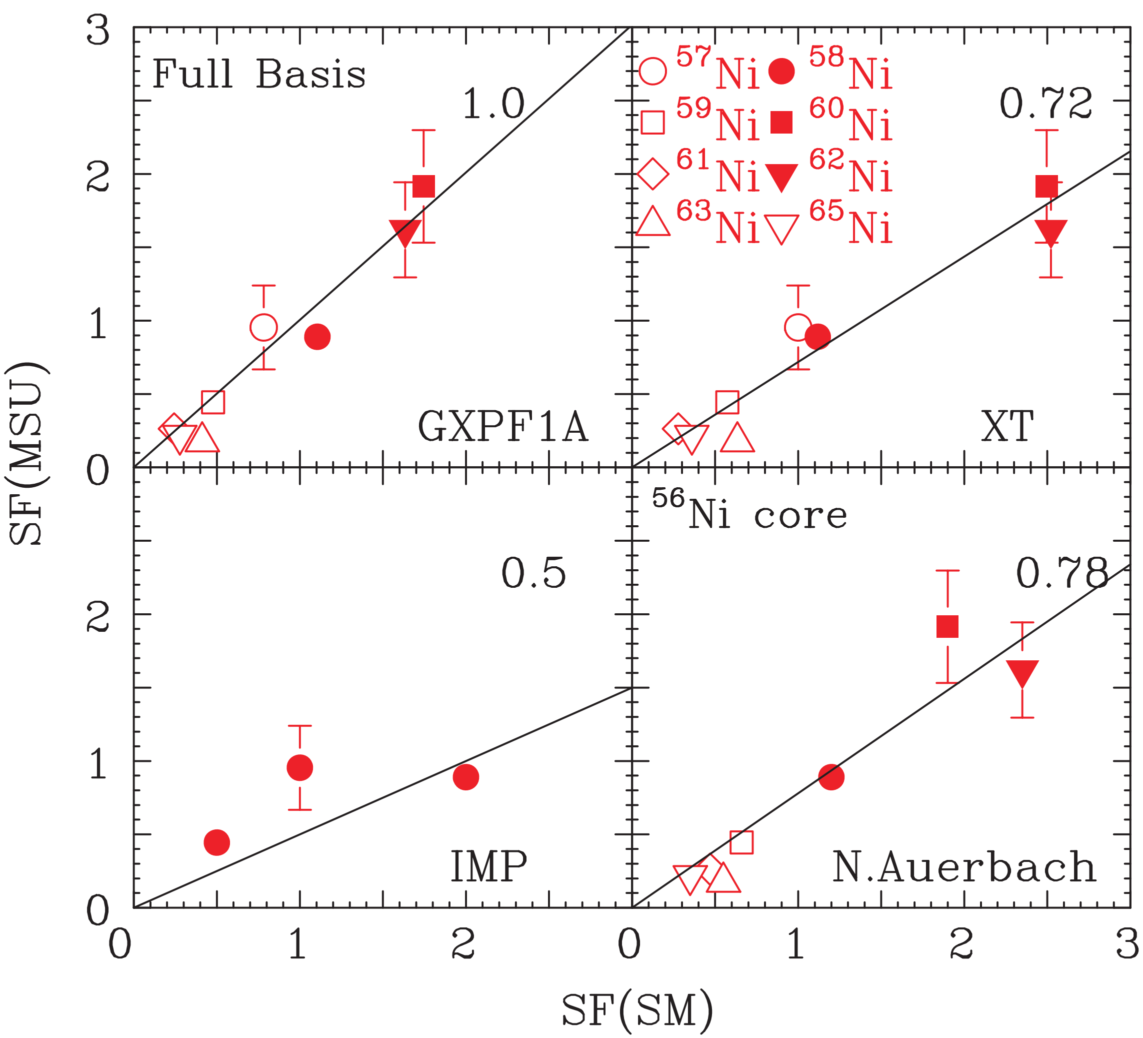
Ground State Neutron Spectroscopic Factors for Ni isotopes



^{56}Ni core

- IPM
- Auerbach interaction ('60)
- XT : T=1 effective interaction (derived for heavy Ni isotopes)

Ground State Neutron Spectroscopic Factors for Ni isotopes



^{56}Ni core

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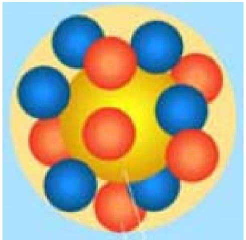


- ^{40}Ca core, in fp model space
- GXPF1A – complete basis
→CPU intensive

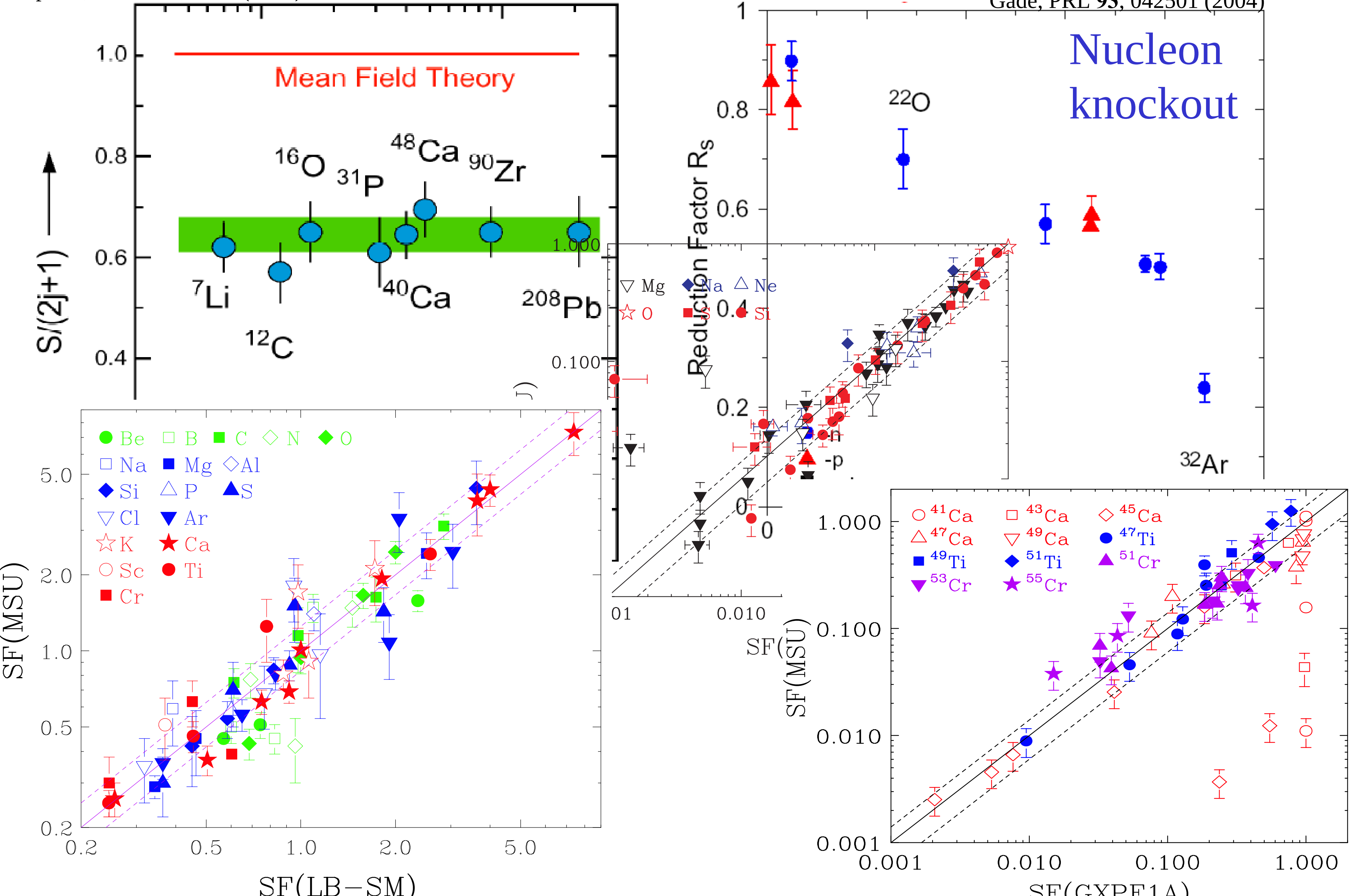
➢ ^{56}Ni is not a good closed core

➢ description of Ni isotopes requires ^{40}Ca core.

Quenching observed from (e,e'p) and knockout reactions

Lapikas, NPA **553**, 297c (1993)

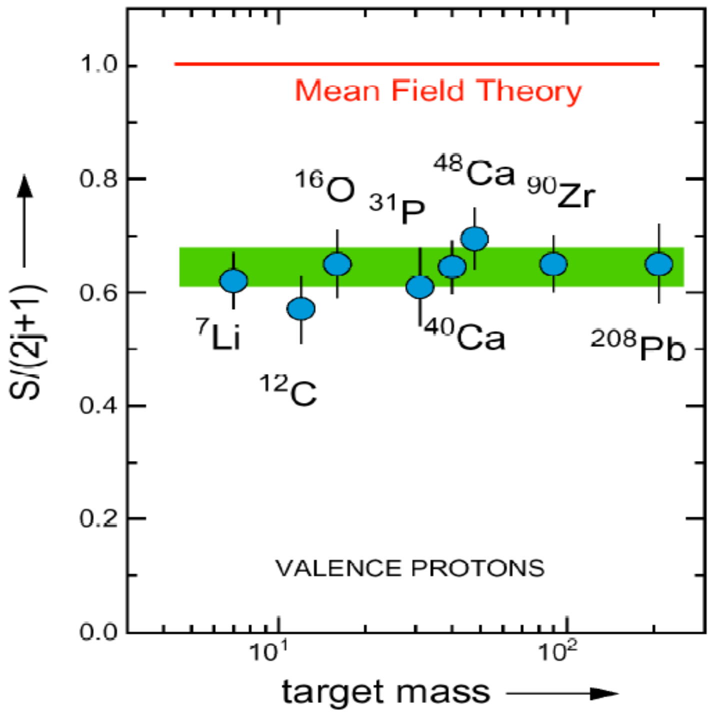
Gade, PRL **93**, 042501 (2004)



Are there inconsistencies between different types of measurements?

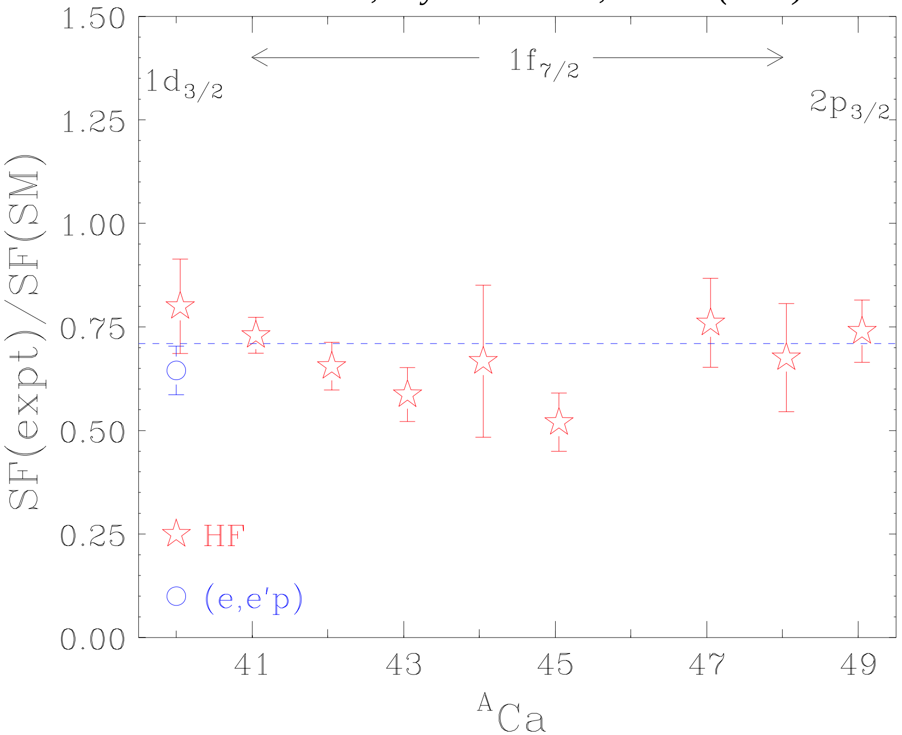
Reduced spectroscopic factors from transfer reactions

G.J.Kramer et al., Nucl. Phys. A 679, 267 (2001)



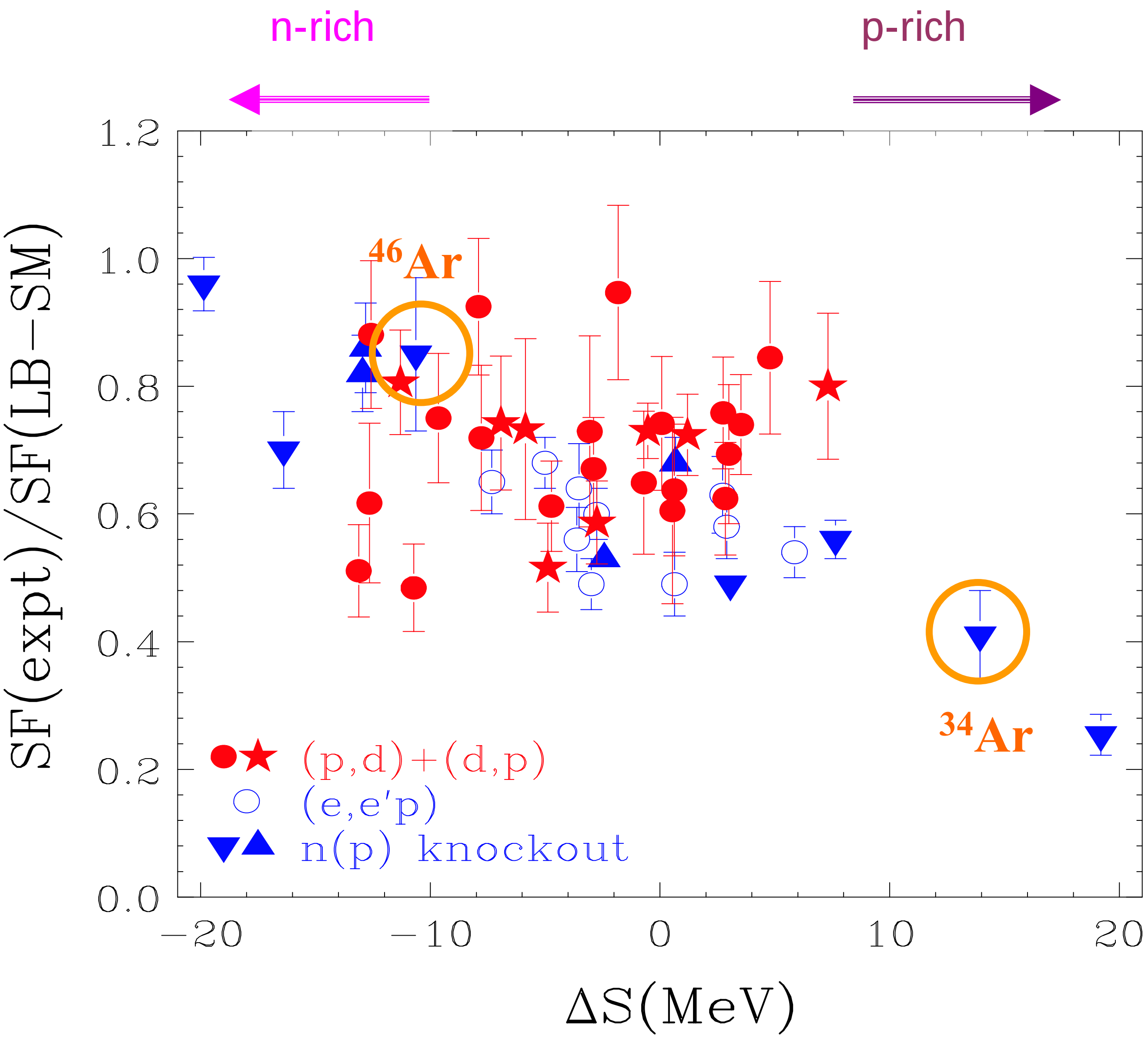
Correlation is beyond the residual interactions employed in the shell model.

J. Lee et al, Phys. Rev. C 73 , 044608 (2006)



JLM optical potential + bound n-radii constrained with HF geometry

Neutron transfer reactions for neutron rich and proton rich Ar isotopes

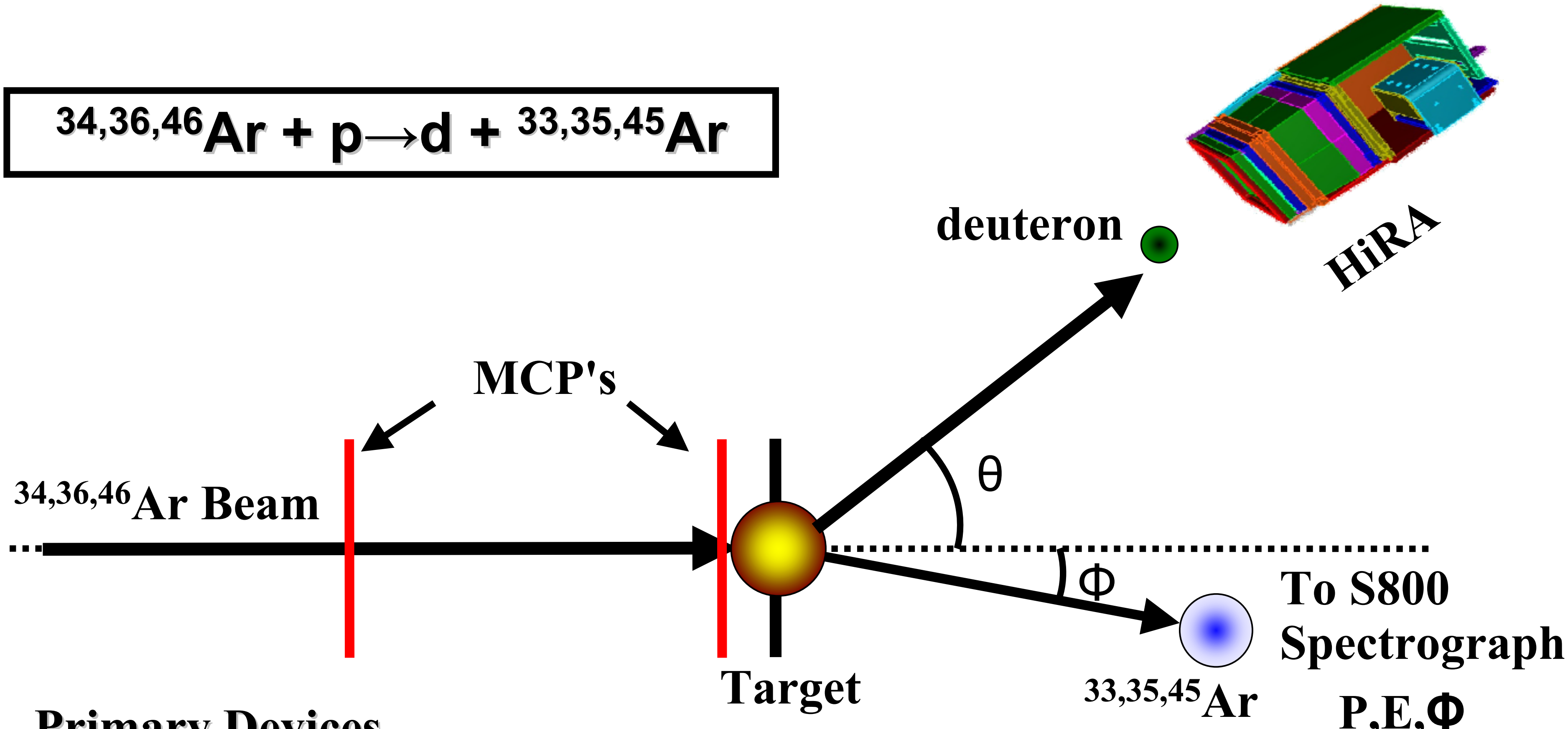


p(^{34}Ar,d)^{33}Ar
p(^{46}Ar,d)^{45}Ar

Inverse kinematics at 33MeV/u

NSCL Expt 05133 (Oct 19-30, 2007)

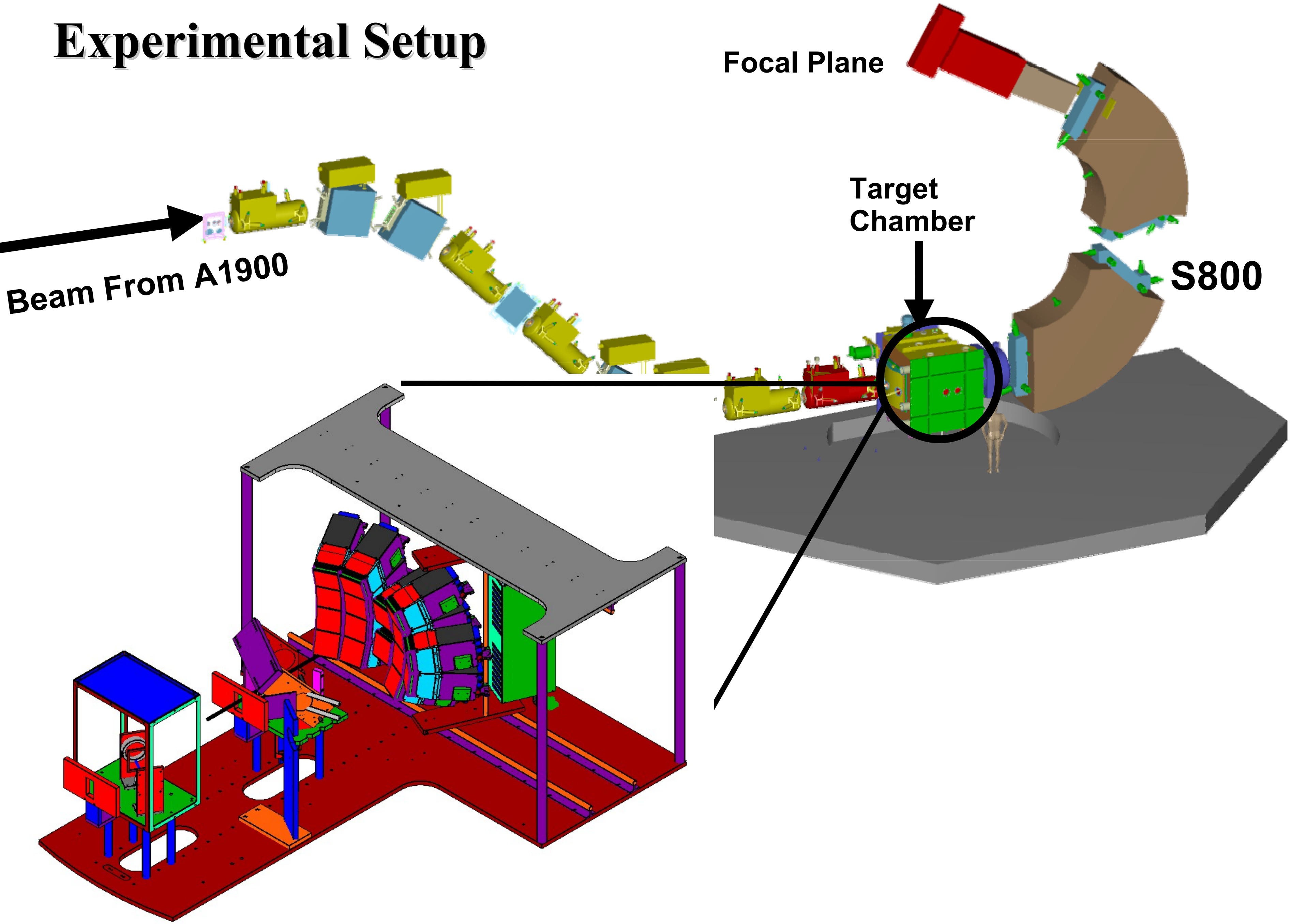
$^{34,36,46}Ar + p \rightarrow d + ^{33,35,45}Ar$



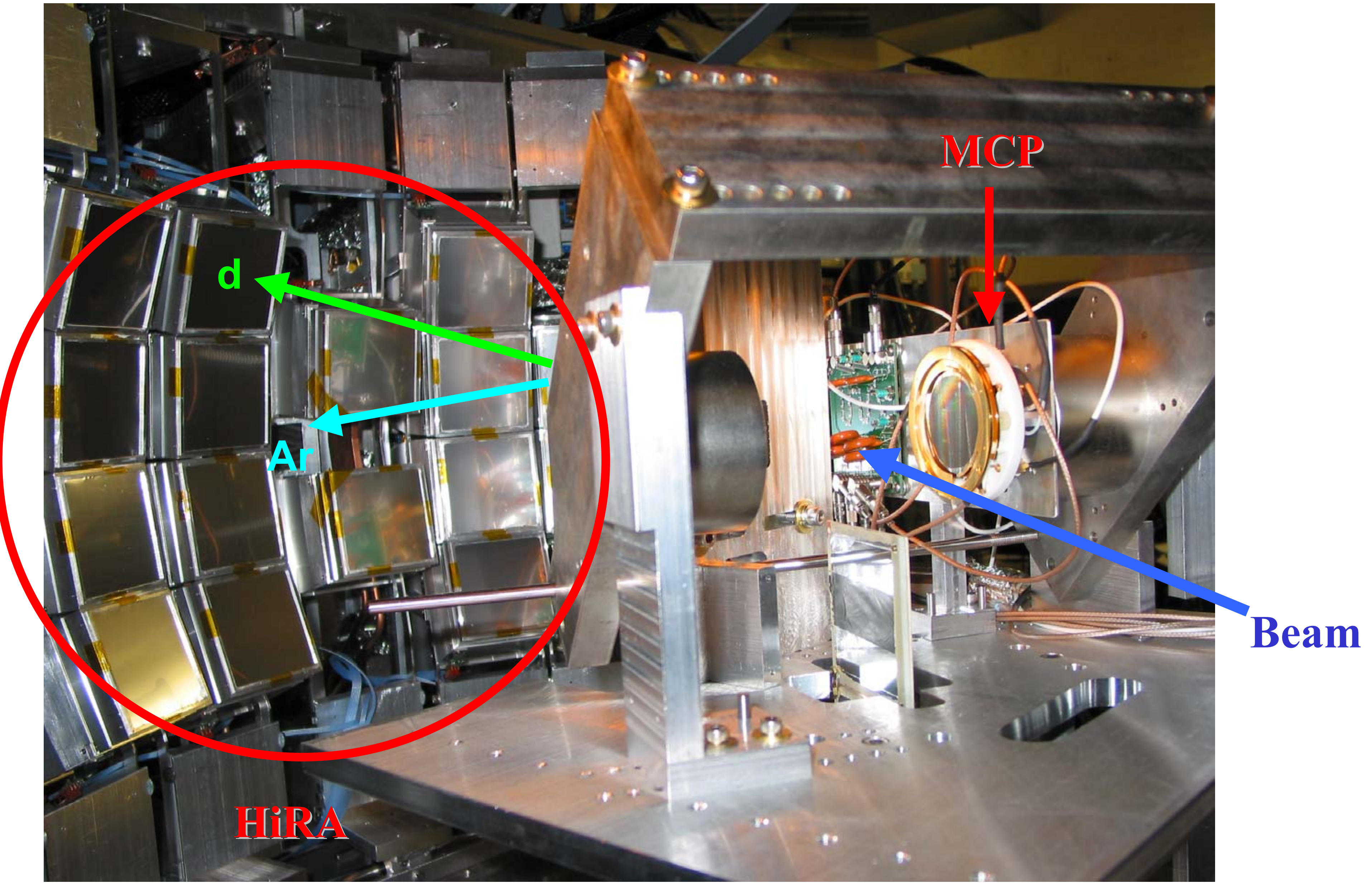
Primary Devices

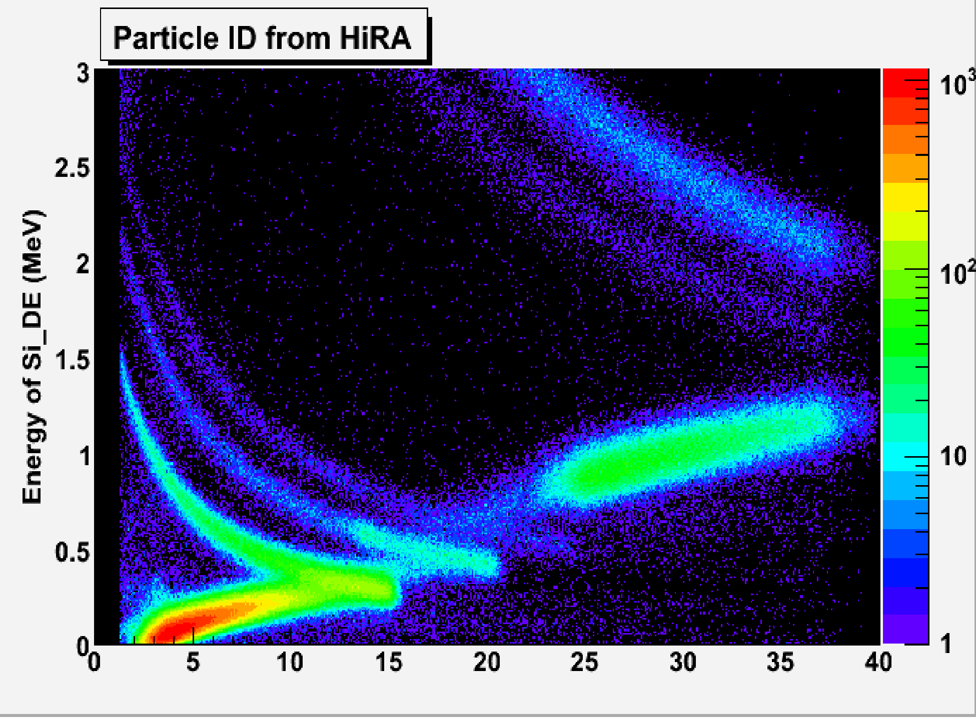
1. High Resolution Array
2. S800 Spectrograph
3. MicroChannel Plates

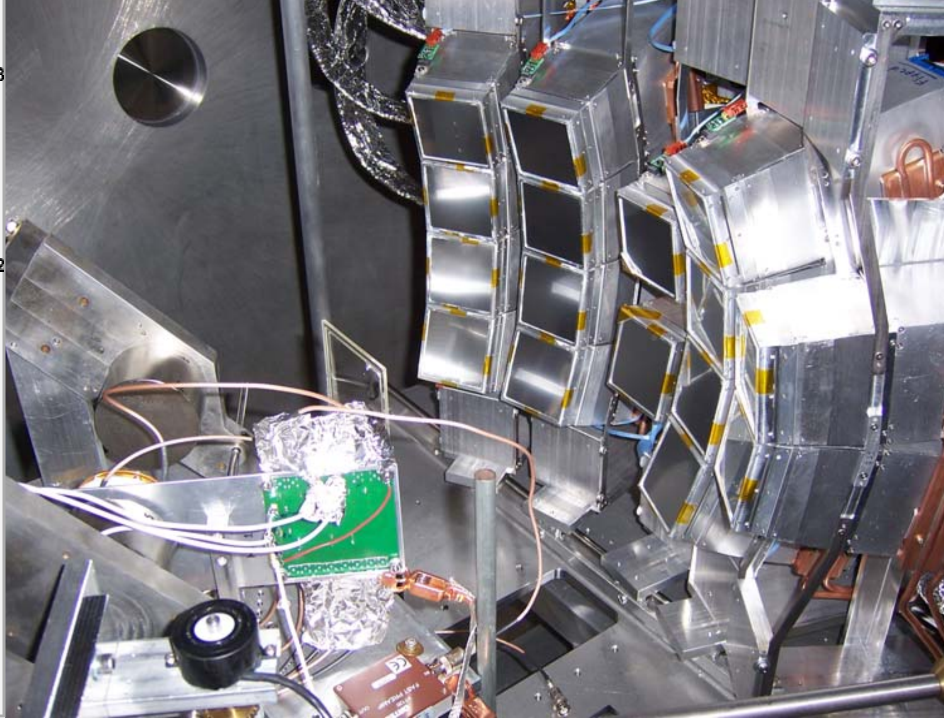
Experimental Setup

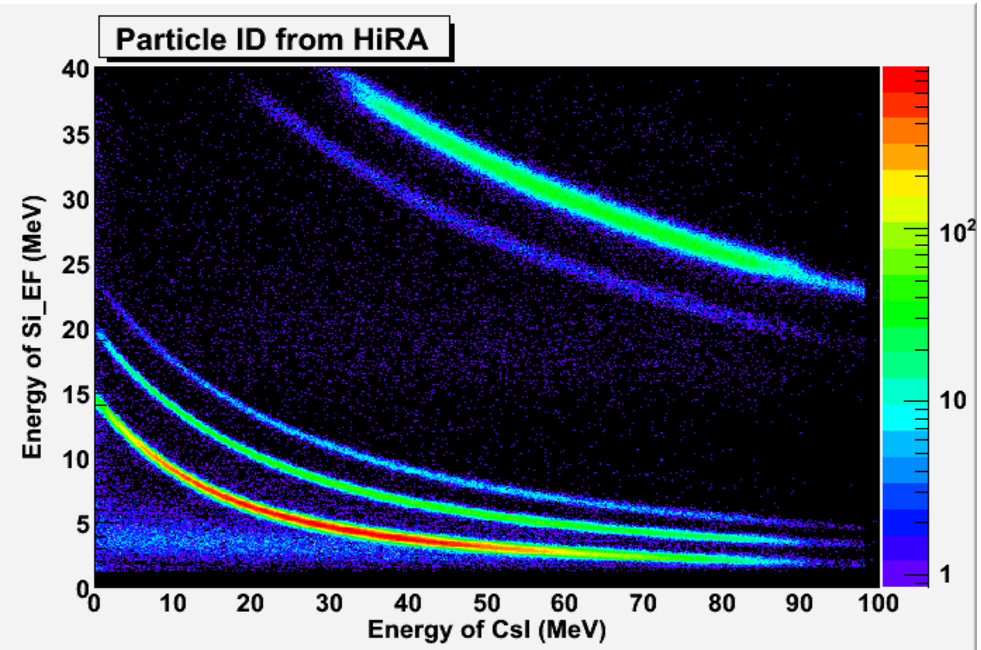


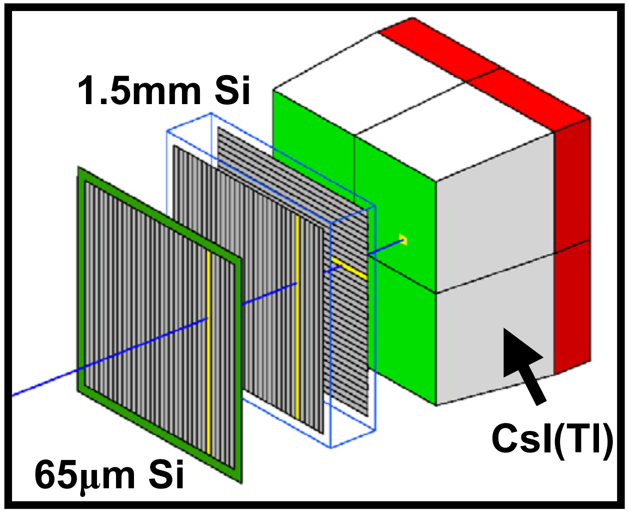
Experimental Setup

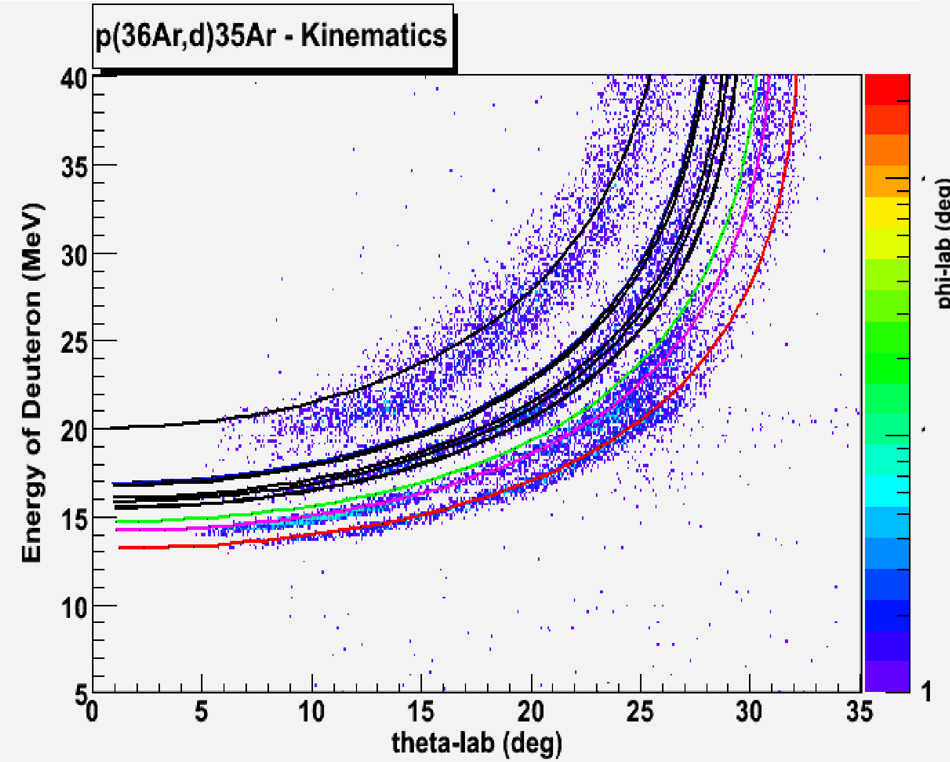


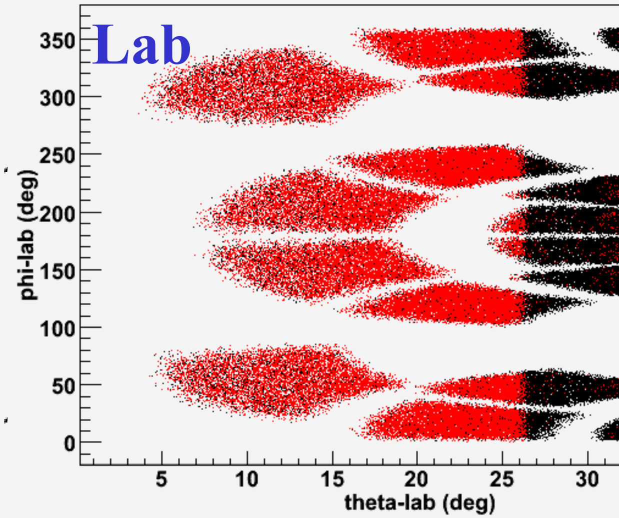

Particle ID from HiRA
Energy of Si_DE (MeV)
0
0.5
1
1.5
2
2.5
3
0
5
10
15
20
25
30
35
40
1
10
10^2
10^3




Particle ID from HiRA
Energy of Si_EF (MeV)
Energy of CsI (MeV)
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
90
100
1
10
10^2


1.5mm Si
65μm Si
CsI(Tl)

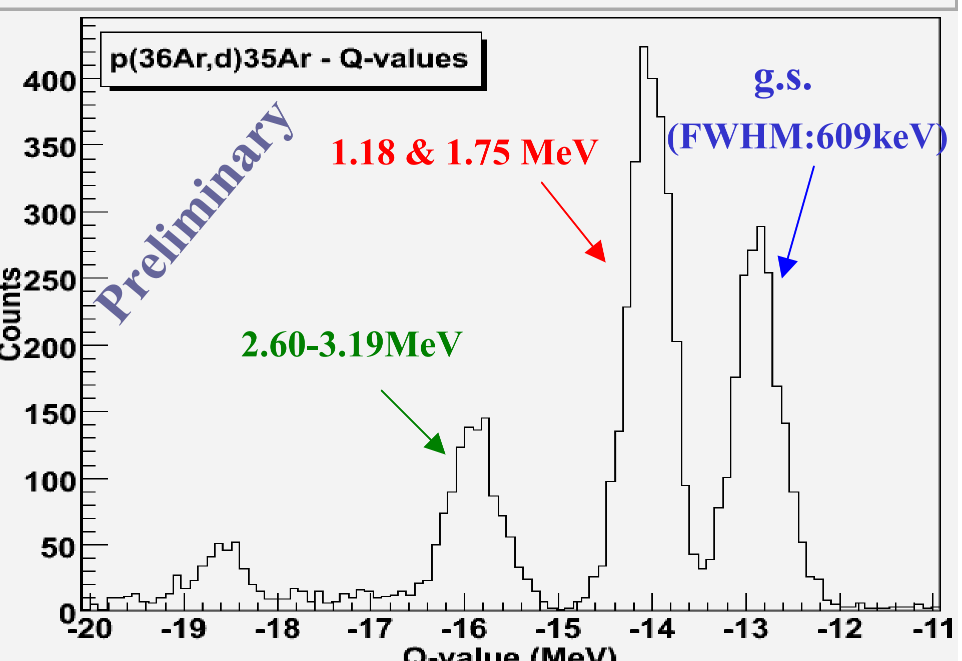




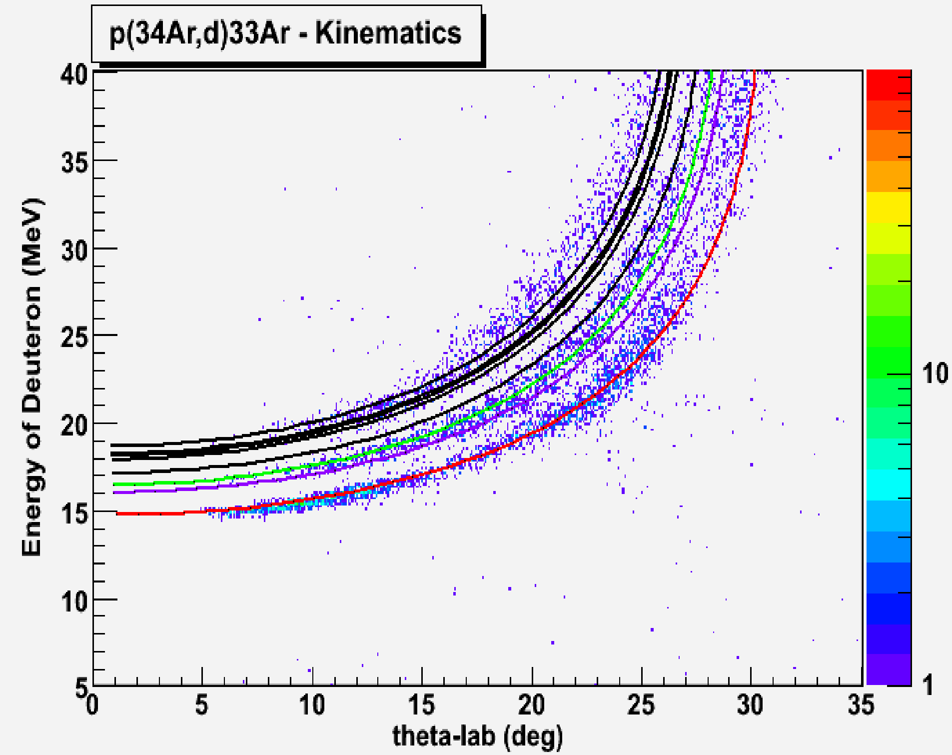
^{2}H punch-through energy in Si=22MeV

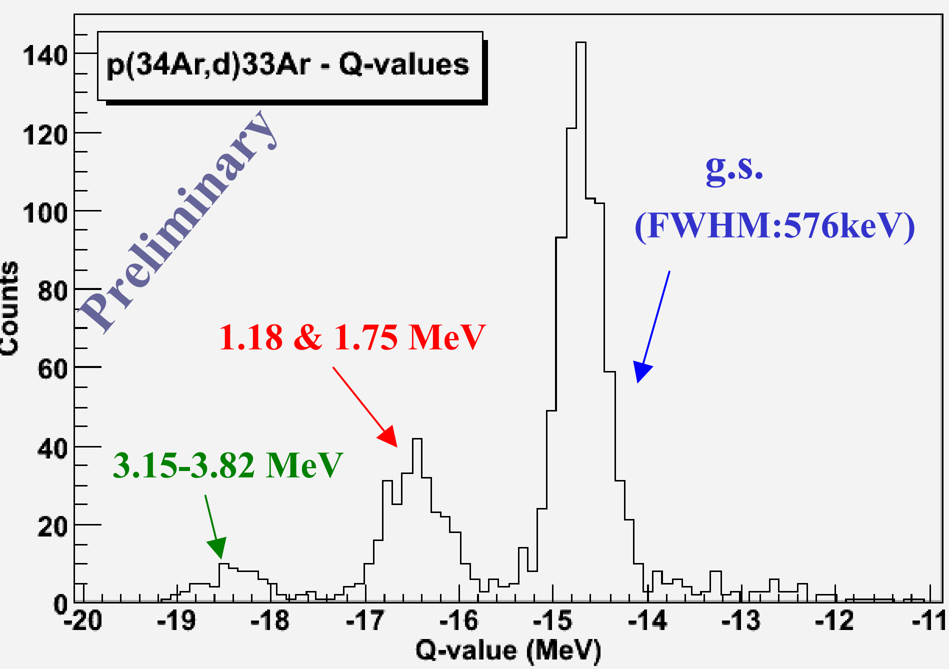
- E_d > 22 MeV
- E_d <= 22 MeV (no CsI)

2982.81 *13*	(3/2,5/2)+
3193 *10*	(5/2,7/2)-
3884 *10*	1/2+
4012 *10*	(1/2,3/2)-
4065.1 *4* ?	(1/2,3/2,5/2)+
4110 *10*	
4142 *10*	(1/2,3/2)-
4350 *10*	
4528.2 *5*	(1/2,3/2,5/2)+
4725.8 *6*	1/2+
4785.8 *6*	(1/2,3/2,5/2)+
5048 *10*	
5116 *10*	(3/2,5/2)+
5205 *10*	
5387 *10*	
5484 *10*	(3/2,5/2)+



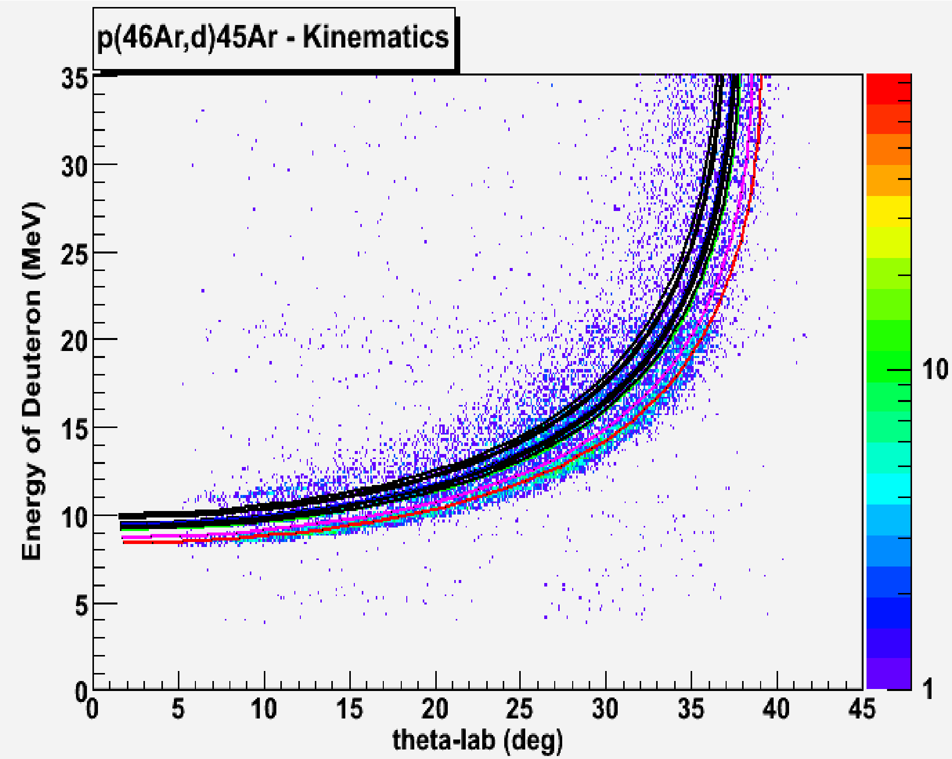
$p(^{34}Ar,d)^{33}Ar$

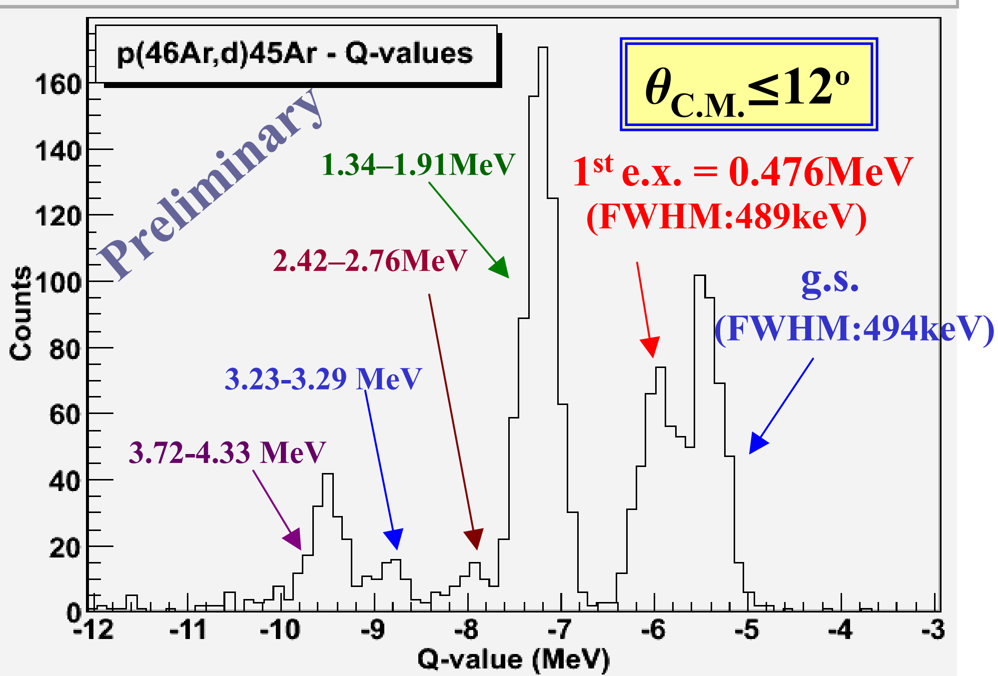




(NNDC)

E_{level} (keV)	Jπ
0	1/2+
1359 2	(3/2+)
1798 2	(5/2+)
2439 3 ?	(3/2+)
3154 9	(3/2+)
3361 5	(5/2+)
3456 6	(7/2+)
3819 3	(5/2+)





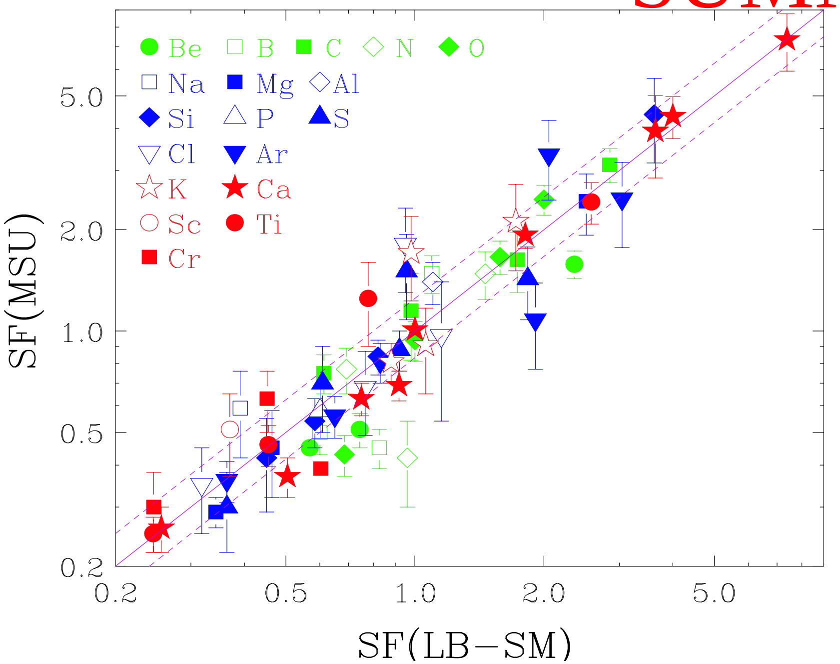
$p(^{46}Ar,d)^{45}Ar$

(NNDC)

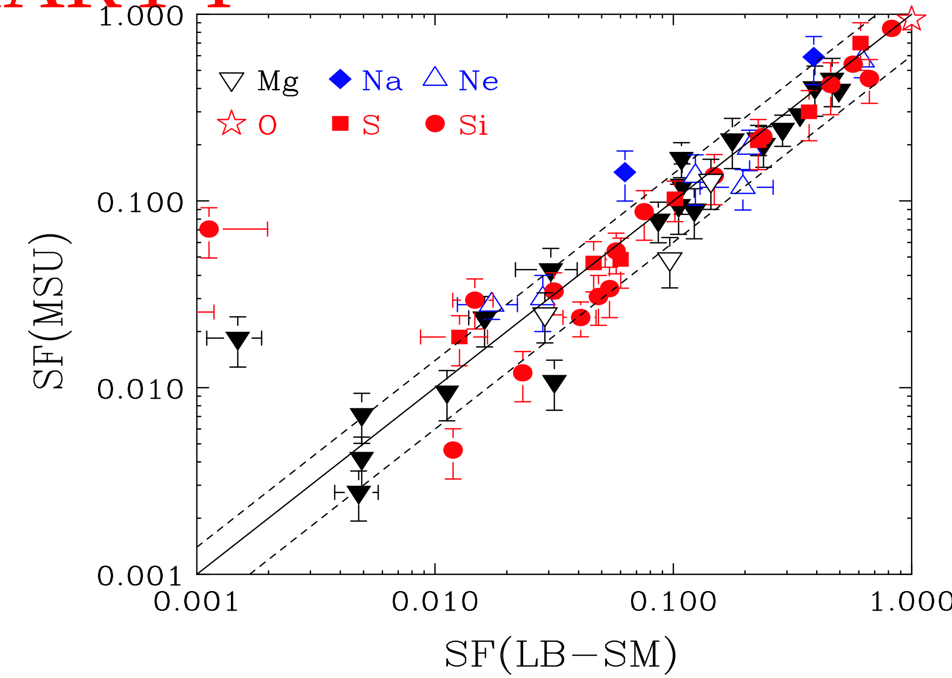
E_{level} (keV)	Jπ
0.0	5/2-,7/2-
542.1 6	1/2-,3/2-
1339.9 8	
1416.1 12	1/2-,3/2-
1660 50 ?	
1734.7 9	
1770.3 8	
1876	1/2-,3/2-
1911 5	
2420 50	
2510	1/2-,3/2-
2757.0 12 ?	
3230	
3294.8 8	
3718	
3949.7 12 ?	
4280	
4326.1 9	
4800	
5773	

To resolve g.s. and 1st excited state at $\theta_{C.M.} > 12^o$ ➔ require MCP's

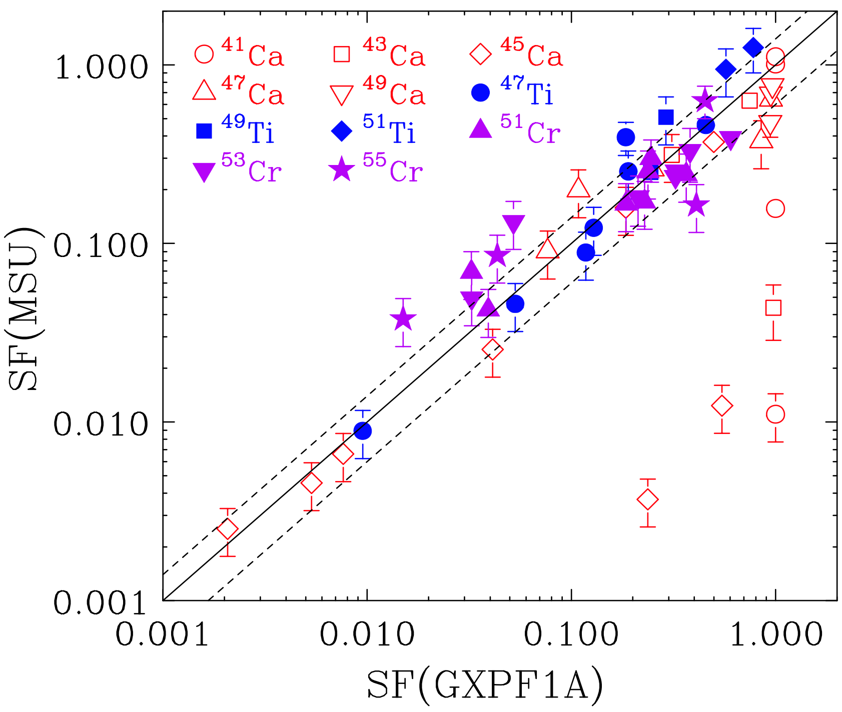
SUMMARY I



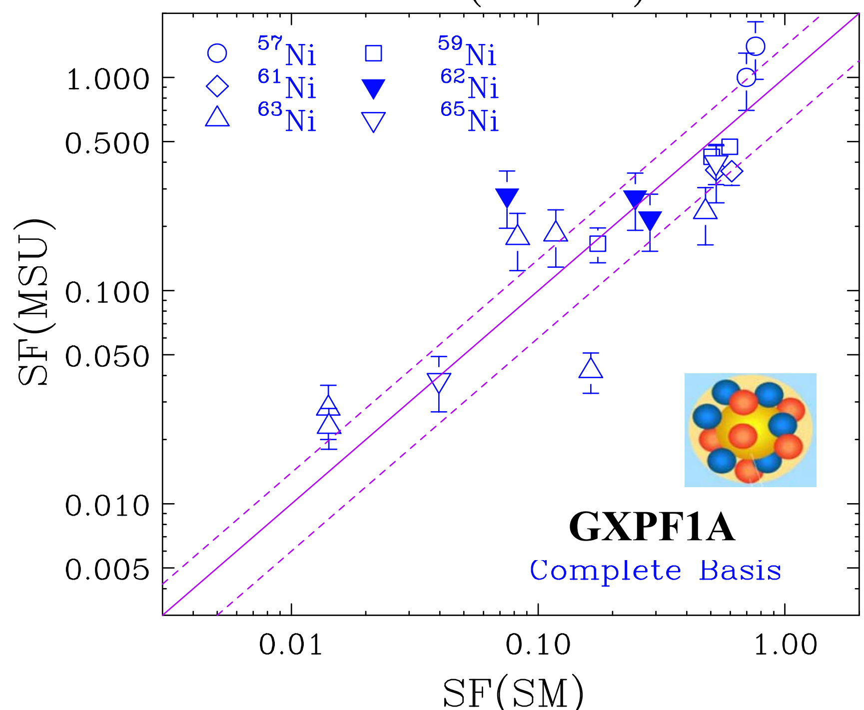
Be B C N O
Na Mg Al
Si P S
Cl Ar
K Ca
Sc Ti
Cr
0.2
0.5
1.0
2.0
5.0
SF(MSU)
SF(LB–SM)



Mg Na Ne
O S Si
0.001
0.010
0.100
1.000
SF(MSU)
SF(LB–SM)

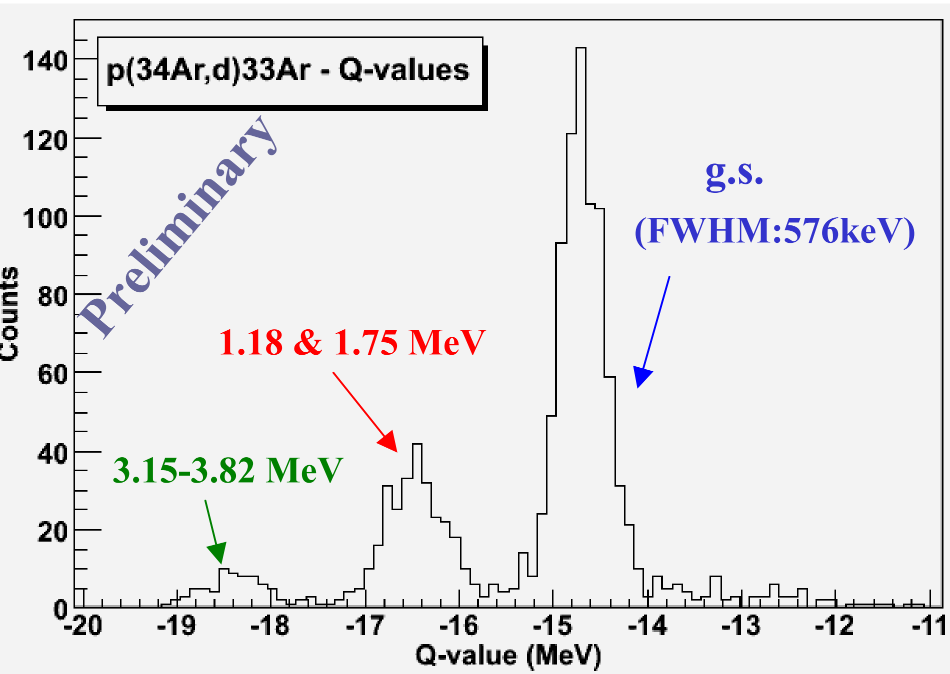


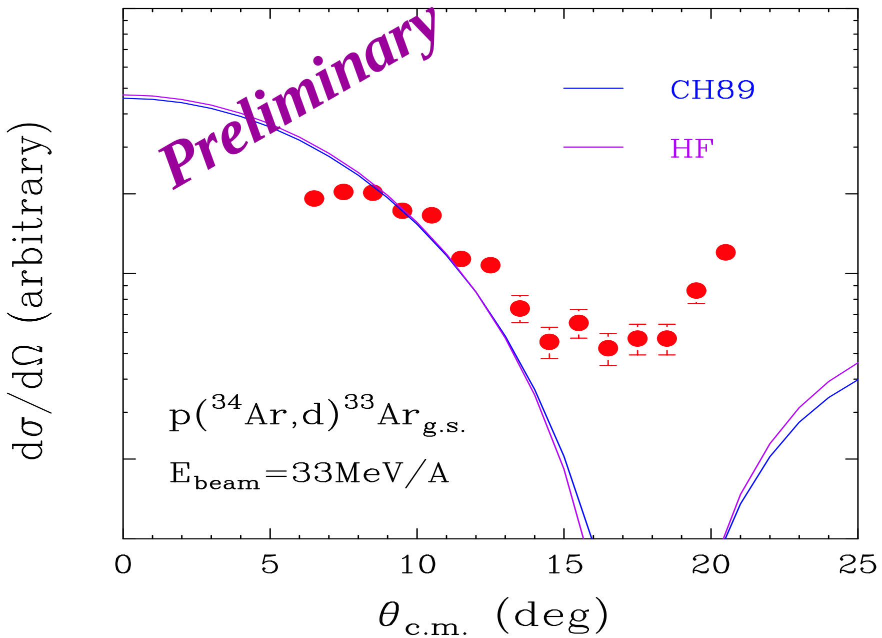
41Ca 43Ca 45Ca
47Ca 49Ca 47Ti
49Ti 51Ti 51Cr
53Cr 55Cr
0.001
0.010
0.100
1.000
SF(MSU)
SF(GXPF1A)

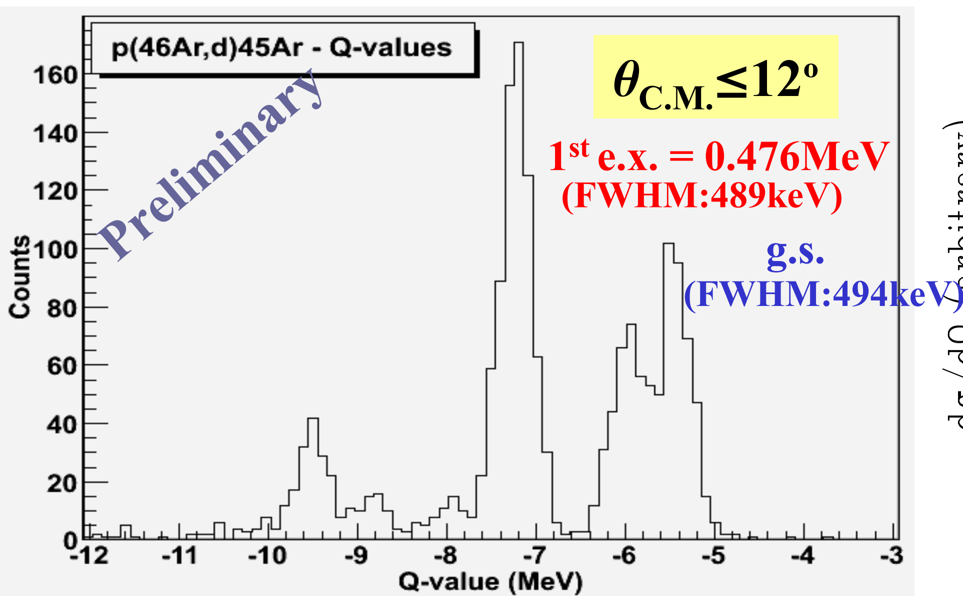


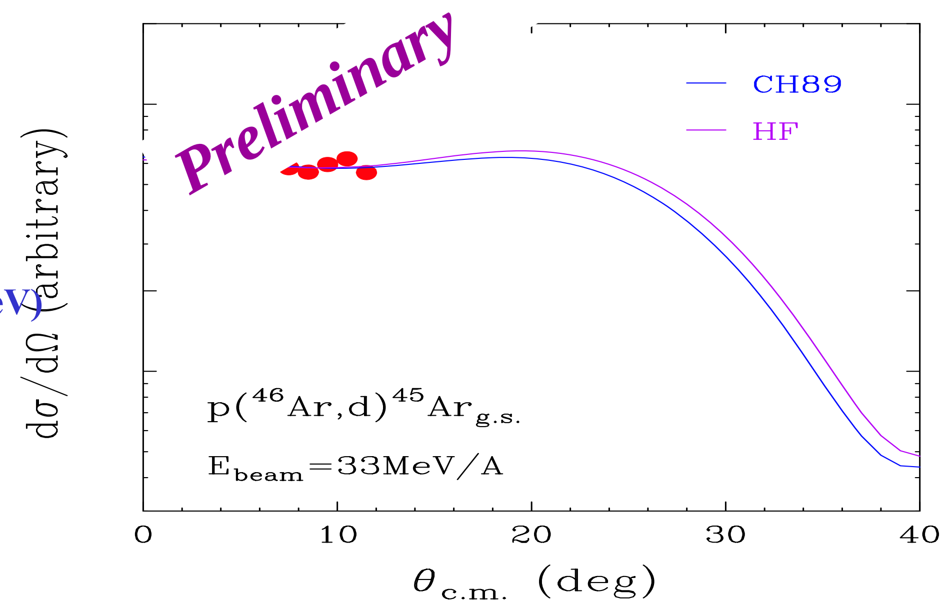
57Ni 59Ni
61Ni 62Ni
63Ni 65Ni
0.005
0.010
0.050
0.100
0.500
1.000
0.01
0.10
1.00
SF(MSU)
SF(SM)
GXPF1A
Complete Basis

SUMMARY II Analysis of p(^{34,46}Ar,d)^{33,45}Ar is in progress









Transfer reactions @NSCL

NSCL
Bill Lynch, Betty Tsang, Vladimir Henzl, Daniela Henzlova, Daniel Coupland, Micha Kilburn, Jenny Lee, Andy Rogers, Alisher Sanetullaev, Sun Zhiyu, Mike Youngs,, Daniel Bazin, Marc Hausmann, Mauricio Portillo, Len Morris, Craig Snow

WU in St. Louis ***Bob Charity, Jon Elson, Lee Sobotka***

Indiana University ***Romualdo Desouza, Sylvie Hudan***

Western Michigan University ***Mike Famiano, Alan Wousma***

LANL ***Mark Wallace***

ORNL ***Dan Shapira***

Rutgers University ***Jolie Cizewski, Patrick O'Malley,Bill Peters***

University of Tennesee ***Andy Chae, Kate Jones, Kyle Schmitt***
INFN, Catania, Italy ***Giuseppe Verde***