The $^{33}S(p,\gamma)^{34}Cl$ reaction in classical nova explosions

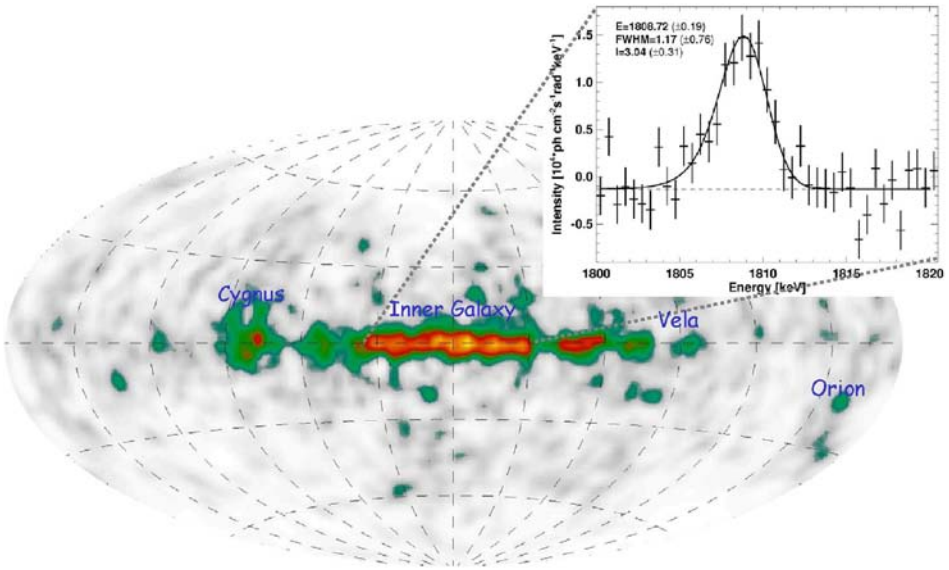
Anuj Parikh

Physik Department E12

TU-München

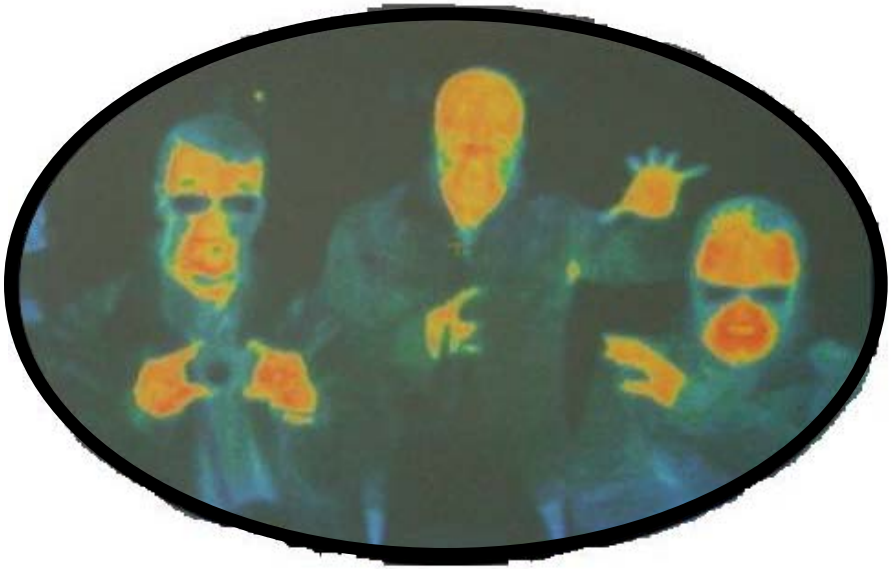
Excellence Cluster Universe

Galactic ^{26g}Al ($t_{1/2}$ = 717 000 y)



(R. Diehl / MPE Garching)
Talk 333, R. Diehl

Galactic ^{34m}Cl ($t_{1/2}$ = 32 min)



N. Machiavelli et al.
RIP Proc. (2010)

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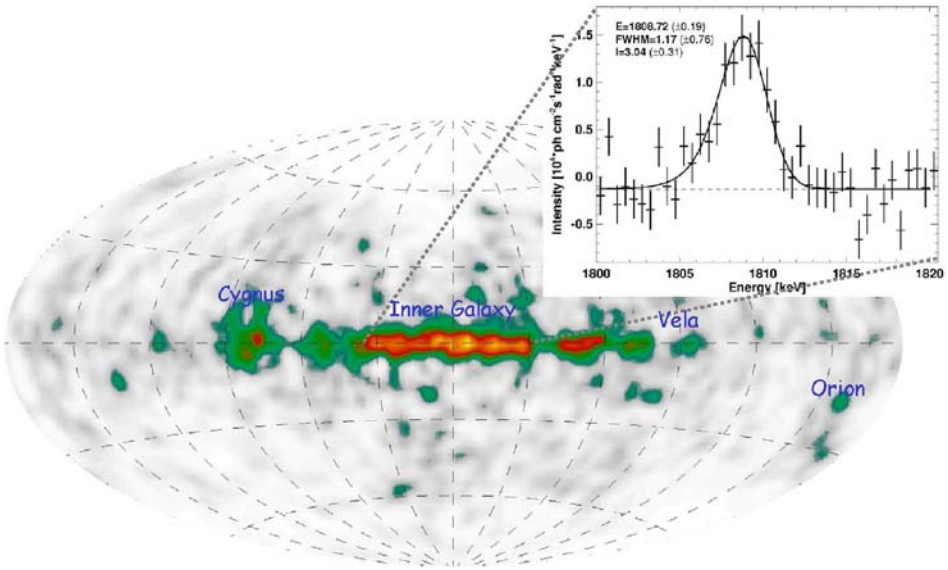
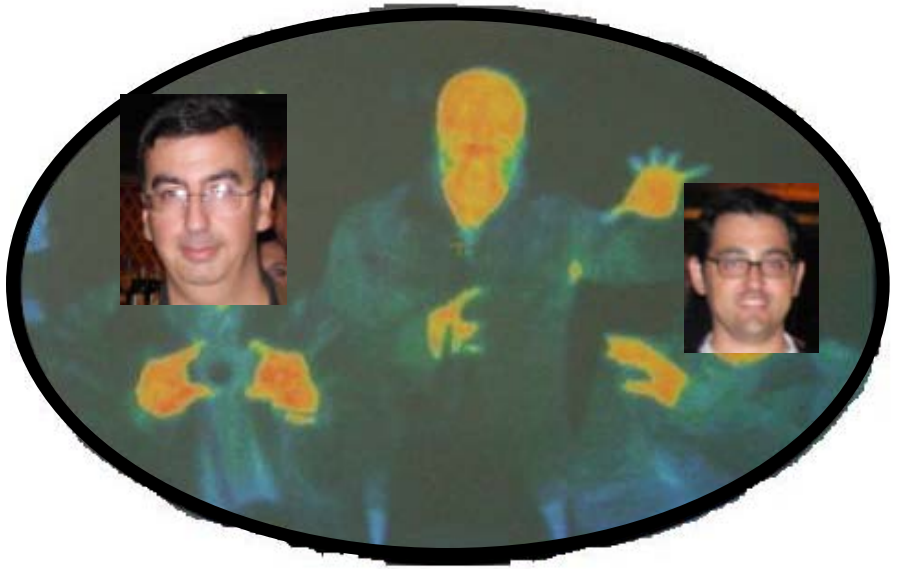


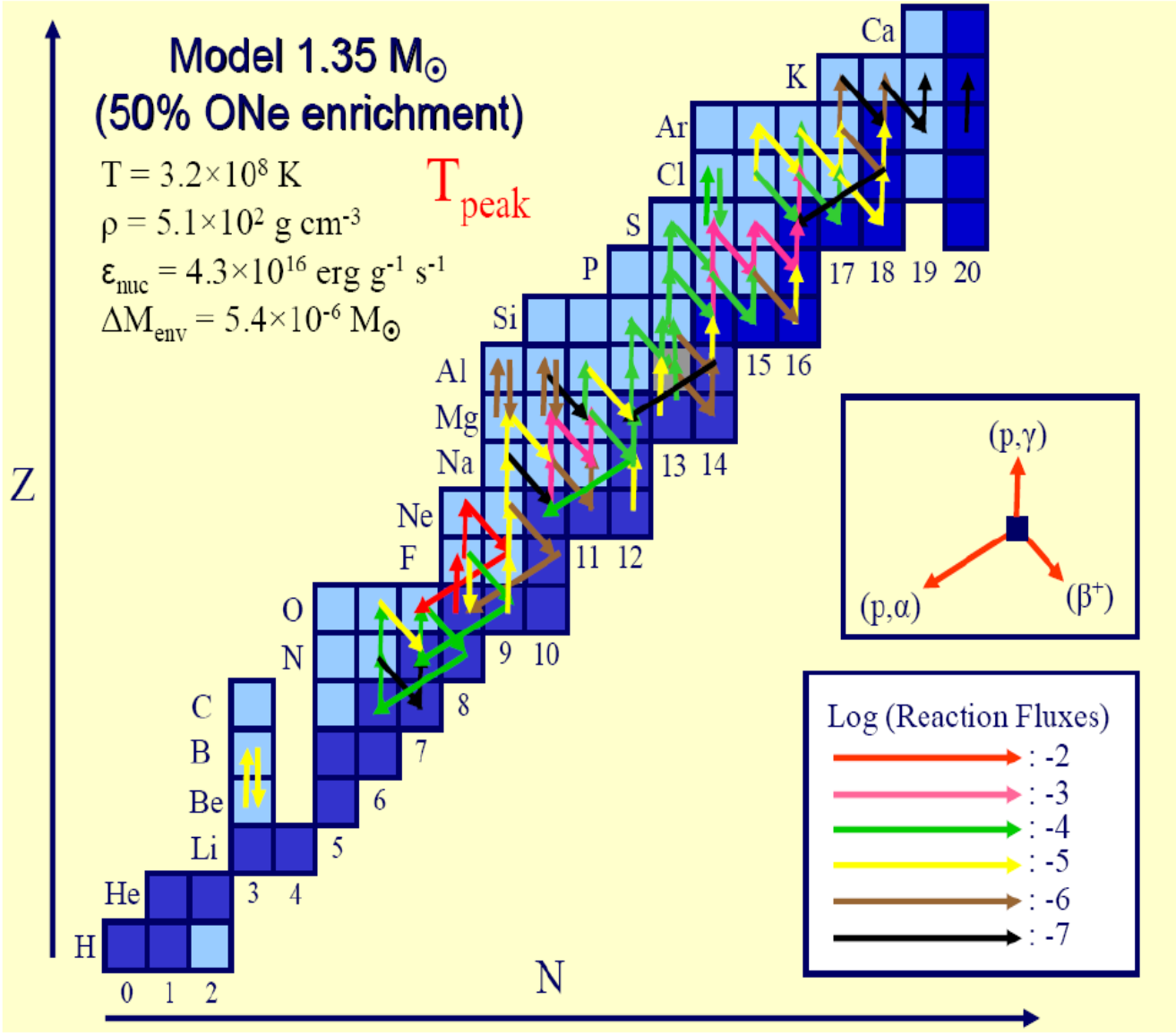
(R. Diehl / MPE Garching)
Talk 333, R. Diehl

Infrared camera (T = 16 C)



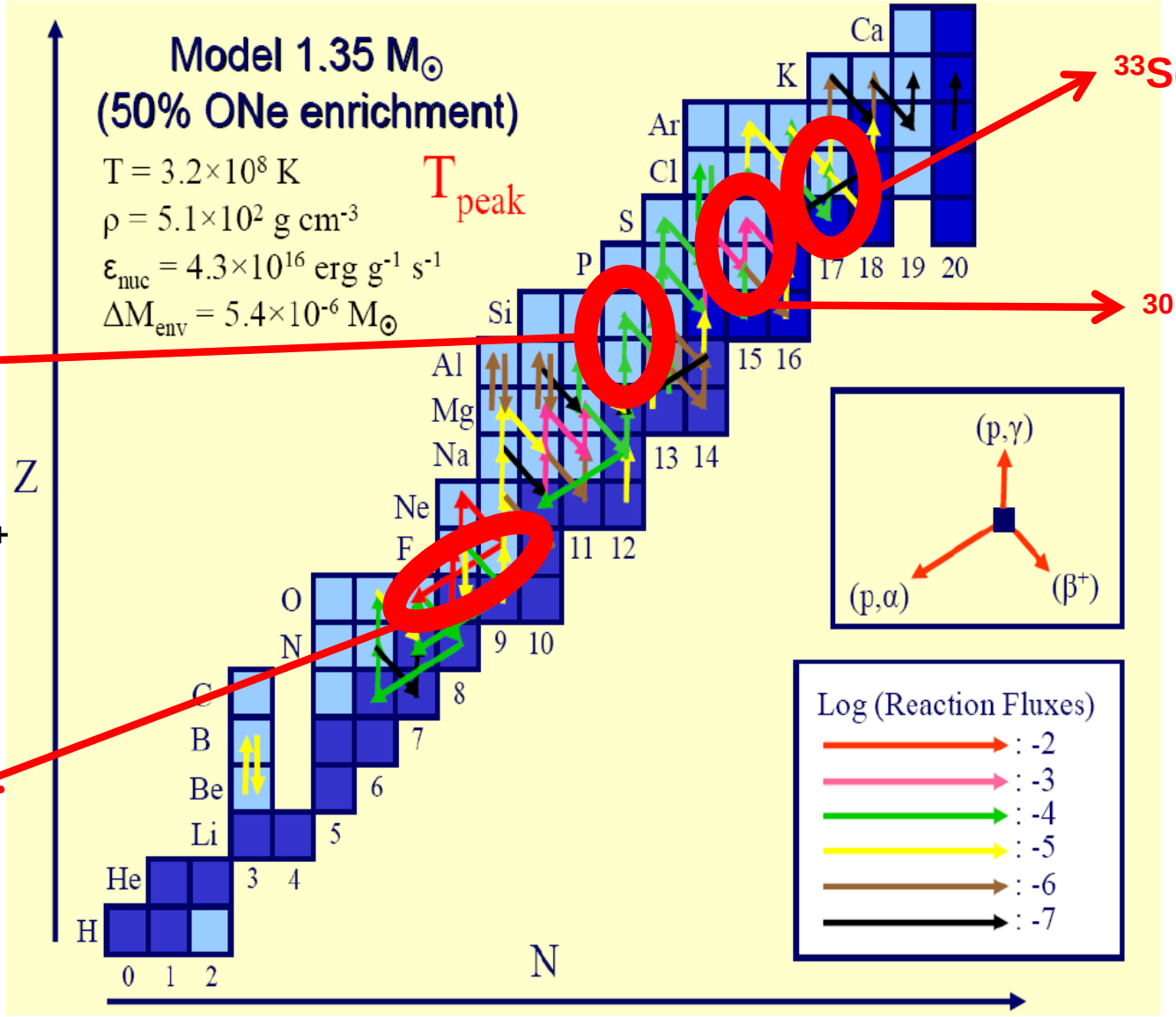
Air and Space Museum, Washington, DC

Classical nova explosions: *reaction fluxes at T_{peak}* (1.35 M_{sol} ONe WD, M_{acc} = 2x10^{-10} M_{sol} / yr)



José, Casanova, Moreno, García-Berro, AP, and Iliadis (2010)

Classical nova explosions: *reaction fluxes at T_{peak}* (1.35 M_{sol} ONe WD, M_{acc} = 2x10^{-10} M_{sol} / yr)



$^{33}S(p,\gamma)^{34}Cl$

$^{30}P(p,\gamma)^{31}S$

$^{25}Al(p,\gamma)^{26}Si$

Poster 149, K. Chipps+

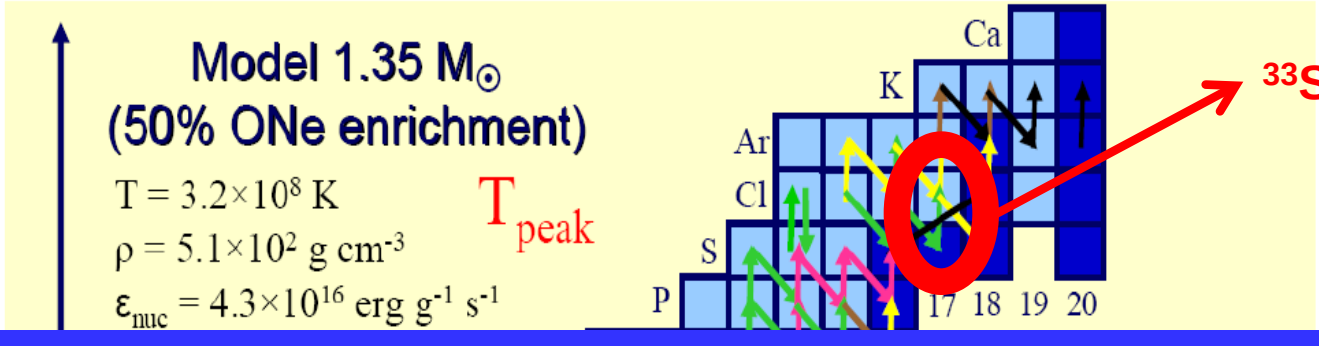
Poster 390, N. de Séréville+

$^{18}F(p,a)^{15}O$

Poster 344, A. Laird+

José, Casanova, Moreno, García-Berro, AP, and Iliadis (2010)

Classical nova explosions: reaction fluxes at T_{peak} (1.35 M_{sol} ONe WD, M_{acc} = 2x10^{-10} M_{sol} / yr)



^{33}S(p,γ)^{34}Cl:

- Iliadis et al. (2002): Δ(rate) → affects production of A = 33 – 37
  → firm nucleosynthetic endpoint in classical nova events (Ca?)

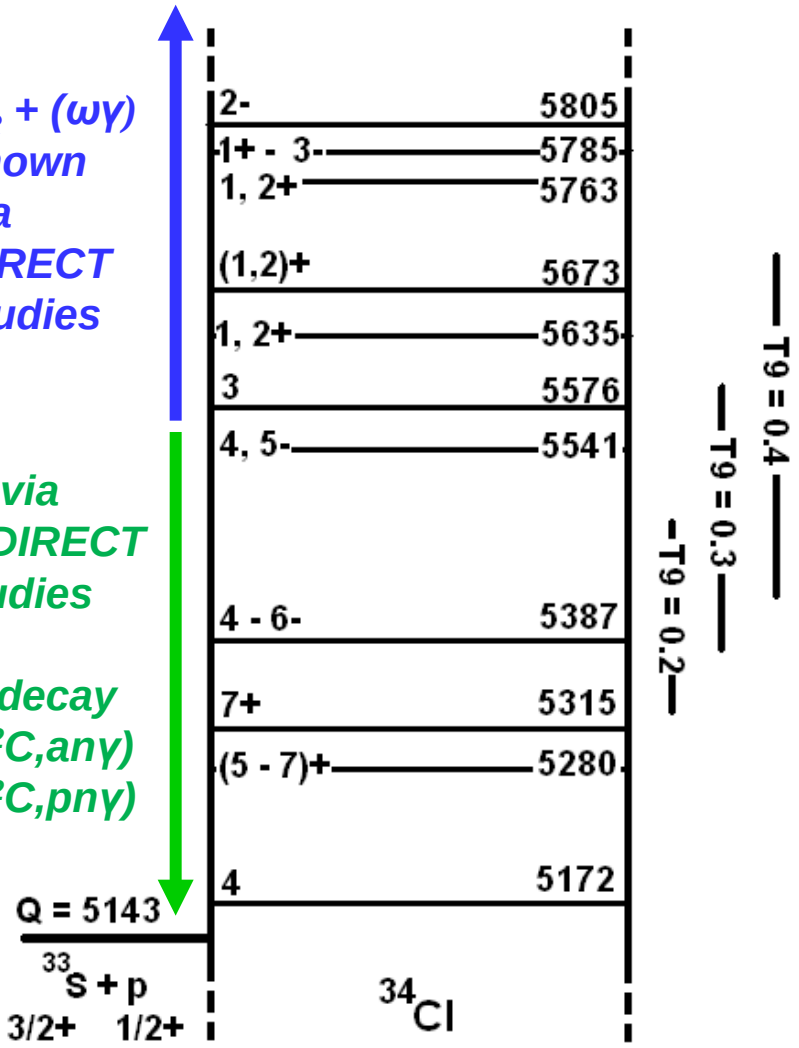
- José et al. (2001): ^{33}S / $^{33}S_{sol}$ ~ 150; δ ~ 309
  "the predicted ^{33}S excess may provide a **remarkable signature** of a classical nova event"
  → meteoritic grains…^{13}C, ^{15}N, ^{30}Si (δ = 40 – 1110) excesses for nova paternity
  (Amari et al. (2001); Nittler and Hoppe (2005); Gyngard and Zinner (2009))
  → ***Poster 239, F. Gyngard+***

- confirm / rule out ^{34m}Cl ($t_{1/2}$ = 32 min) γ-rays as possible nova observables
  (E_γ = 3.3, 2.1, 1.2 MeV; first suggested by Leising and Clayton (1987))
  → ***Poster 100, C. Herlitzius+***

The $^{33}S(p,\gamma)^{34}Cl$ reaction rate

$$< \sigma\upsilon >= \left(\frac{2\pi}{\mu kT}\right)^{3/2} \hbar^2 \sum_i (\omega\gamma)_i \exp\left(\frac{-(E_{R,i}^{CM})}{kT}\right)$$

[reactions / s / density]



Measure directly or indirectly

E_R^{CM} and (ωγ)

(masses, spins, partial widths, lifetimes)

DIRECT

$p(^{33}S,\gamma)^{34}Cl$

TRIUMF

$^{33}S(p,\gamma)^{34}Cl$

CENPA
Center for Experimental Nuclear Physics and Astrophysics

INDIRECT

$^{33}S(^3He,d)^{34}Cl$

$^{34}S(^3He,t)^{34}Cl$

LMU MLL

LMU Excellence Cluster Universe

Endt (1990)
Waanders et al. (1983)
Dassie et al. (1977)

INDIRECT studies of $^{33}S(p,\gamma)^{34}Cl$

Maier-Leibnitz-Laboratorium (Garching)

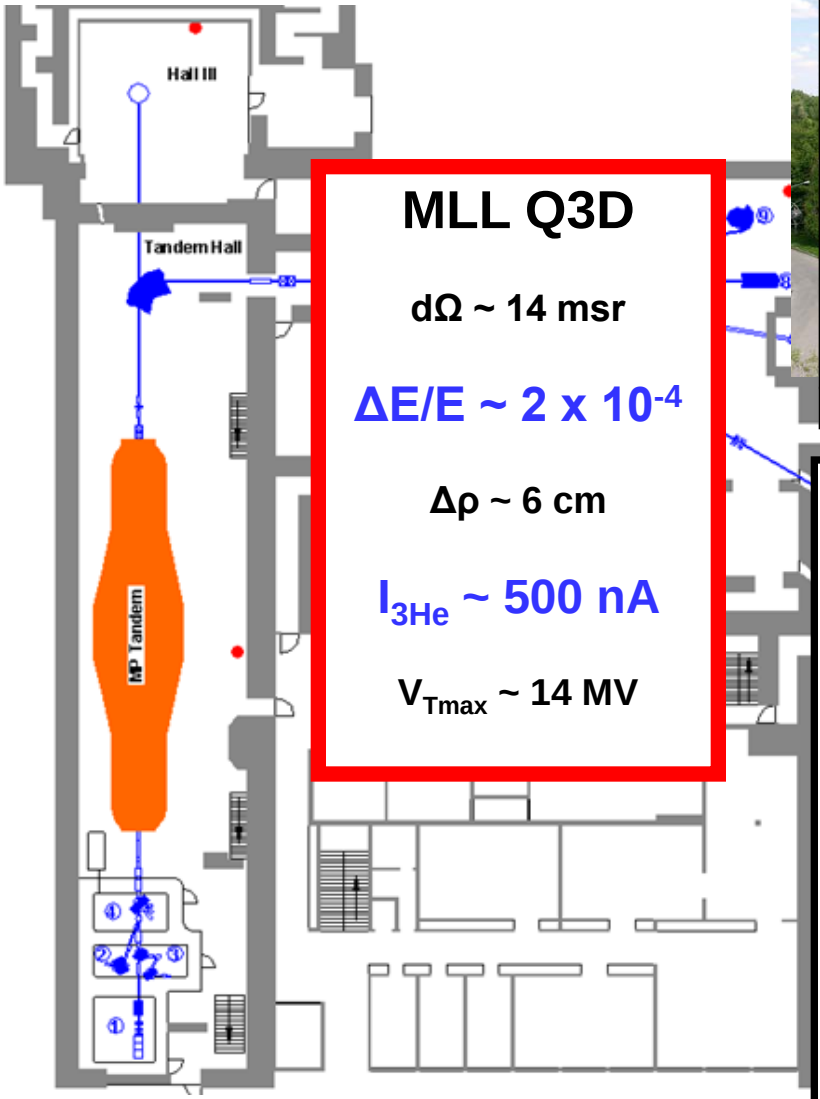
Also: Talk 198, C. Wrede

LMU MLL TUM

INDIRECT studies of $^{33}S(p,\gamma)^{34}Cl$

Maier-Leibnitz-Laboratorium **(Garching)**

Also: Talk 198, C. Wrede



MLL Q3D

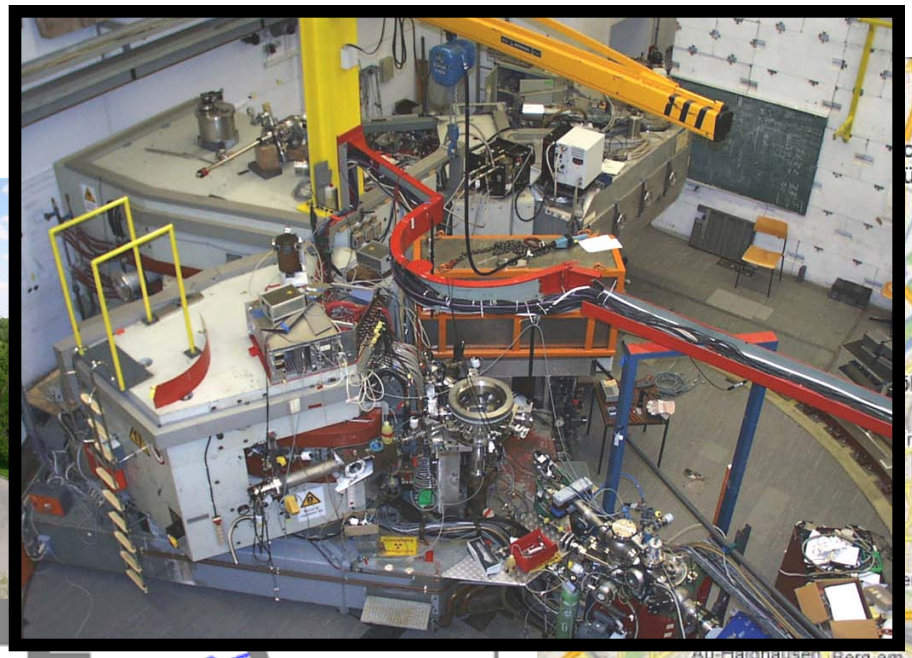
dΩ ~ 14 msr

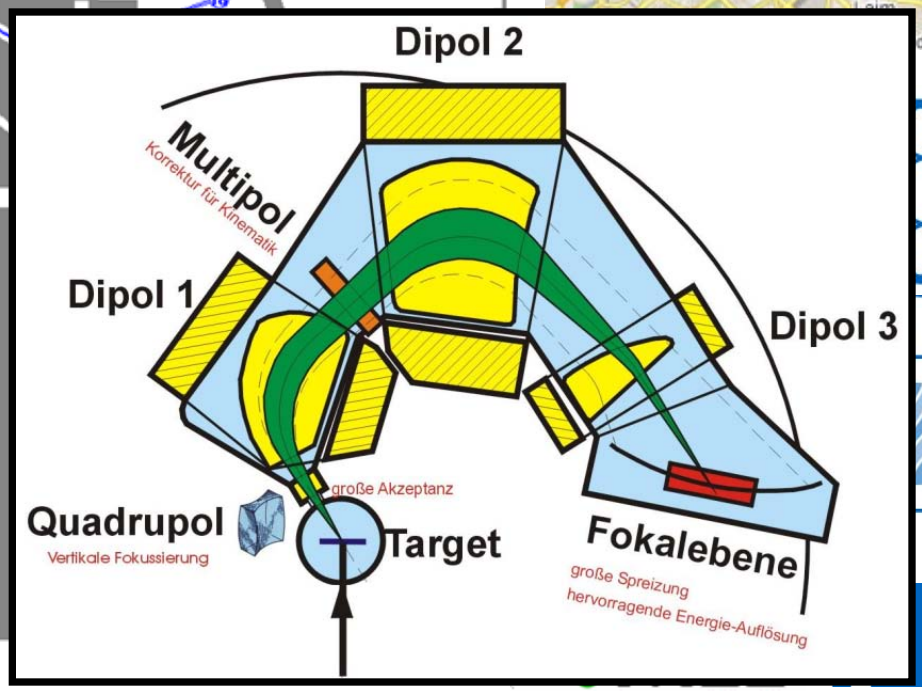
$\Delta E/E \sim 2 \times 10^{-4}$

Δρ ~ 6 cm

$I_{3He} \sim 500$ nA

$V_{Tmax} \sim 14$ MV

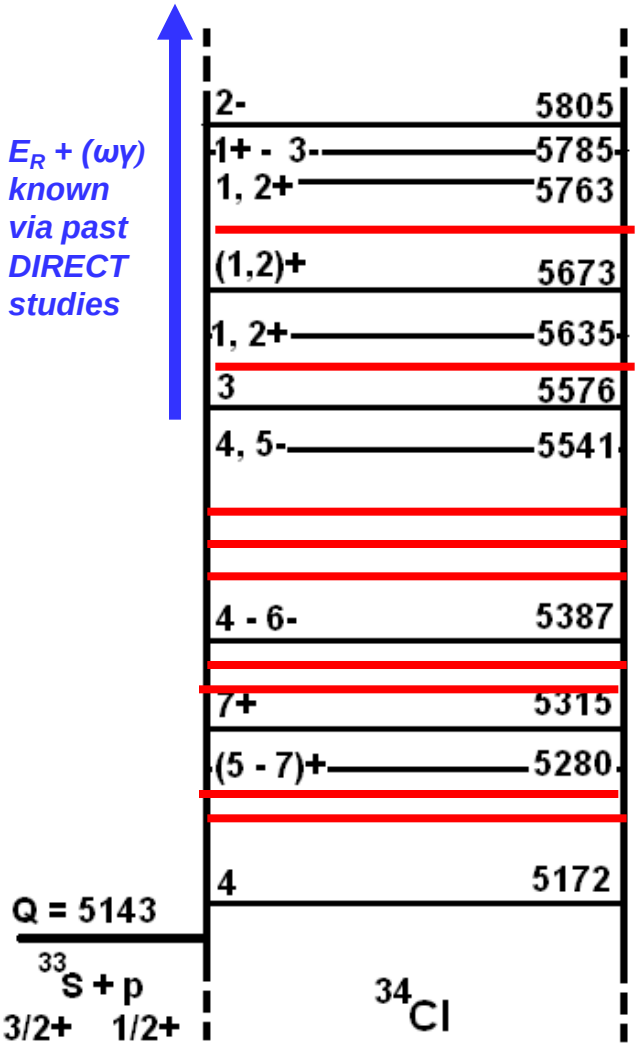




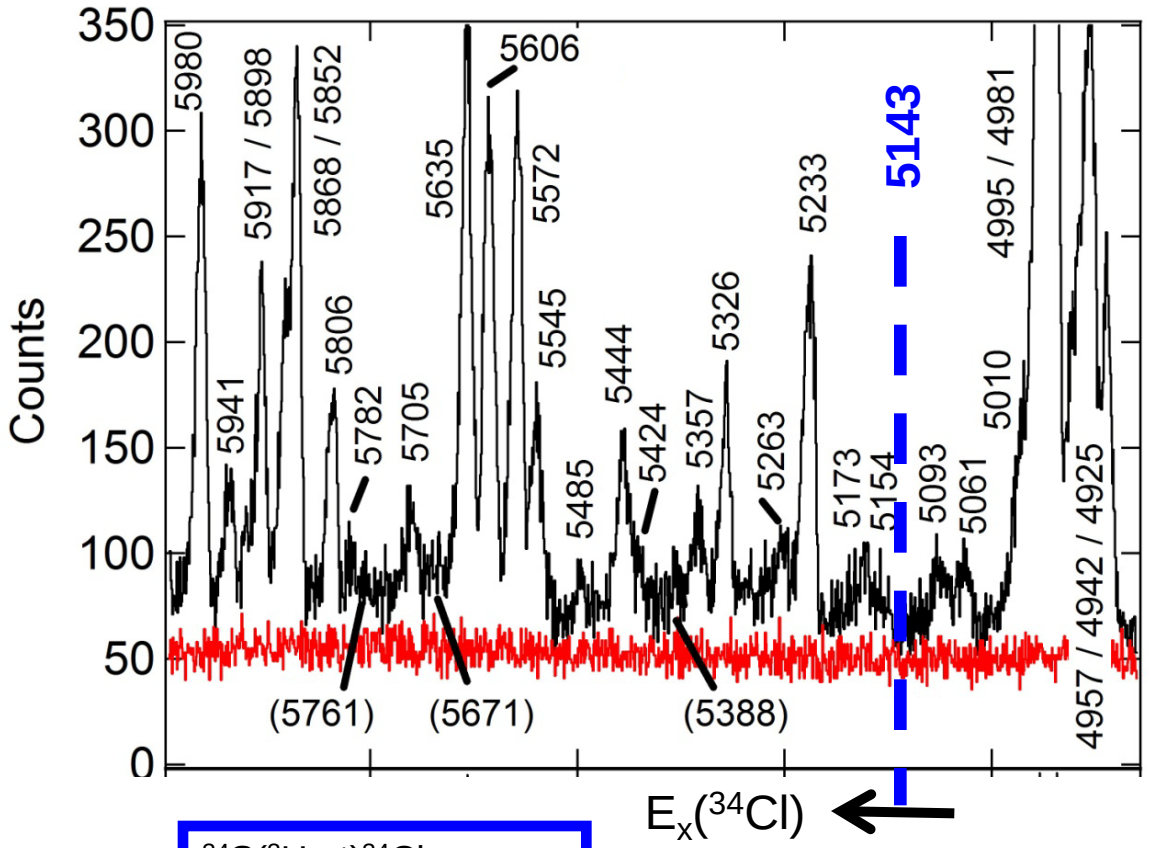
INDIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (1) $^{34}S(^3He,t)^{34}Cl$

FIRST search for ^{34}Cl p-threshold states with $^{34}S(^3He,t)^{34}Cl$

→ 9 new states within 600 keV of $S_p(^{34}Cl)$



Endt (1990)
$^{34}S(^3He,t)^{34}Cl$



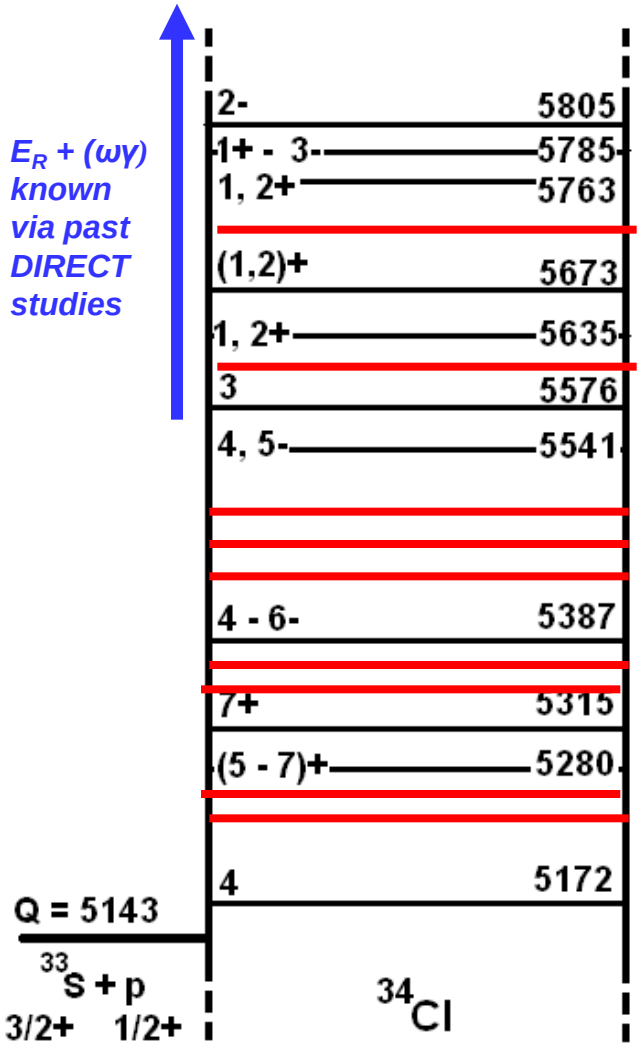
$^{34}S(^3He,t)^{34}Cl$
E_{3He} = 25 MeV; 15°
MLL Q3D
ΔE = 10 keV
24 h @ 500 nA

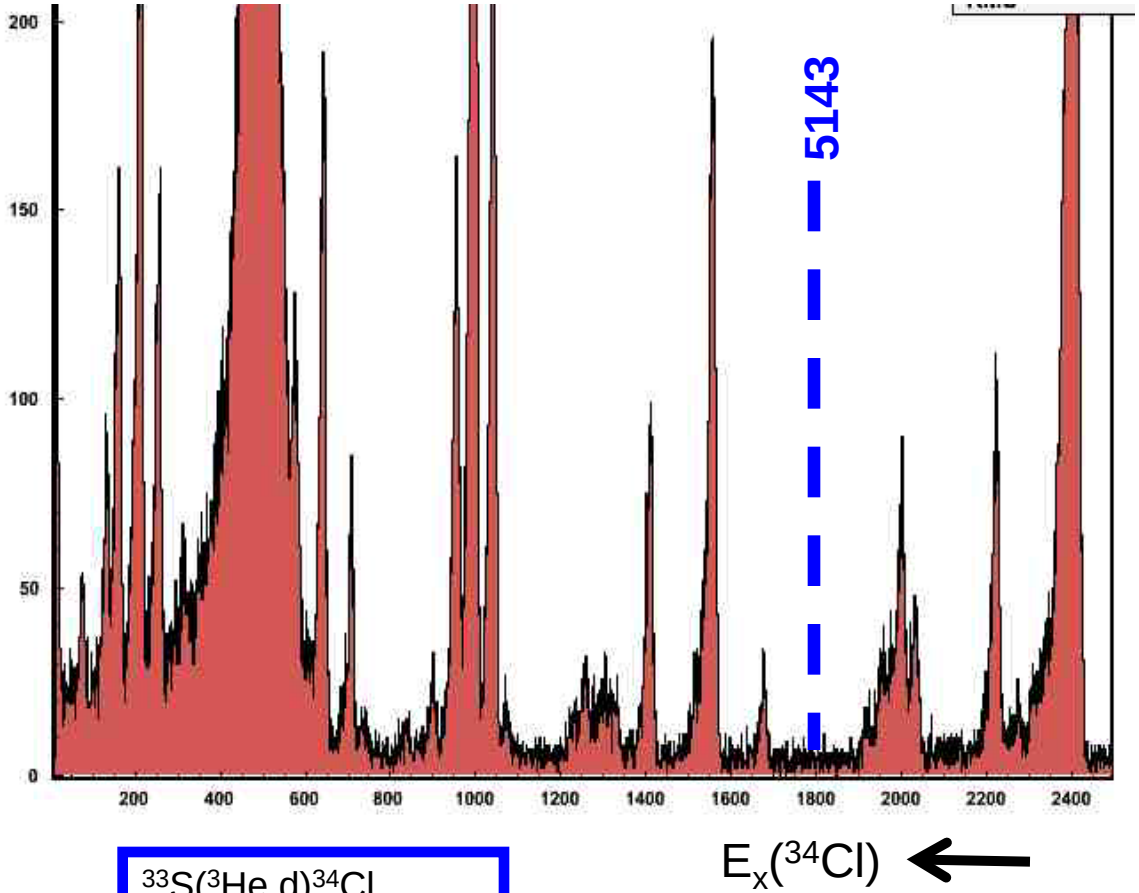
AP et al. (2009)

INDIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (2) $^{33}S(^3He,d)^{34}Cl$

FIRST search for ^{34}Cl p-threshold states with $^{33}S(^3He,d)^{34}Cl$

→ estimating (ωγ) via proton C^2S…PRELIMINARY!





$^{33}S(^3He,d)^{34}Cl$
E_{3He} = 25 MeV; 10°
MLL Q3D
ΔE ~ 10 keV
1 h @ 500 nA

Endt (1990)
$^{34}S(^3He,t)^{34}Cl$ + $^{33}S(^3He,d)^{34}Cl$

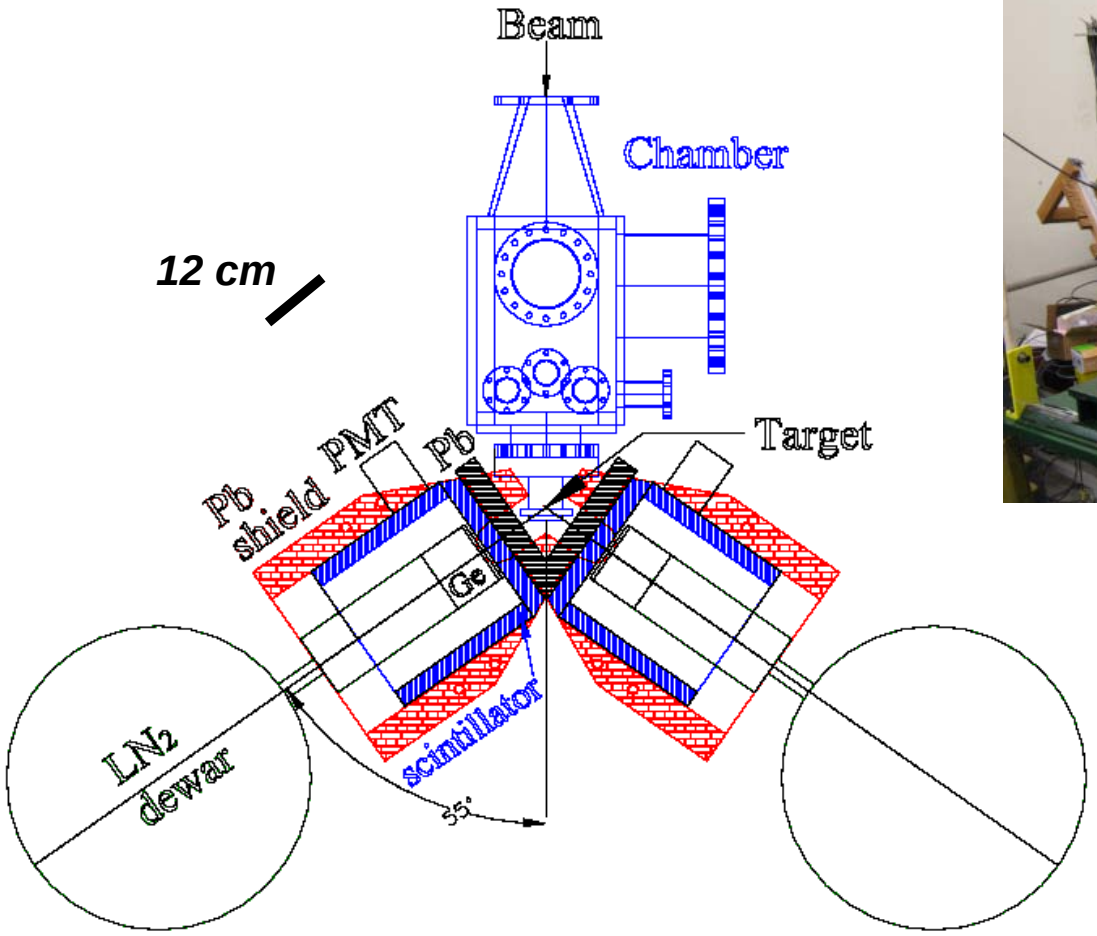
AP et al. ("soon")

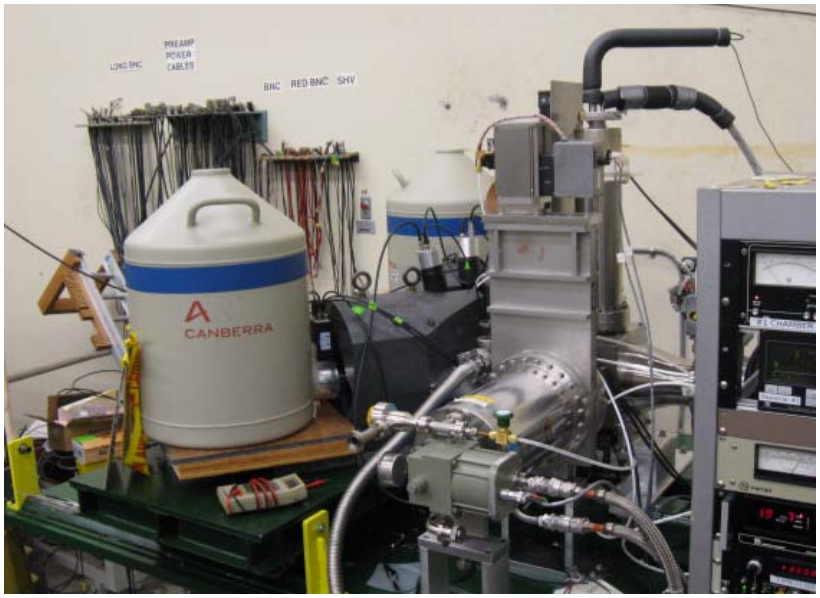
DIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (1) $^{33}S(p,\gamma)^{34}Cl$

CENPA
Center for Experimental Nuclear Physics and Astrophysics

***Center for Experimental Nuclear Physics and Astrophysics* (Seattle)**

Also: Talk 122, A. Sallaska





~45 μA protons over 121 h (total)

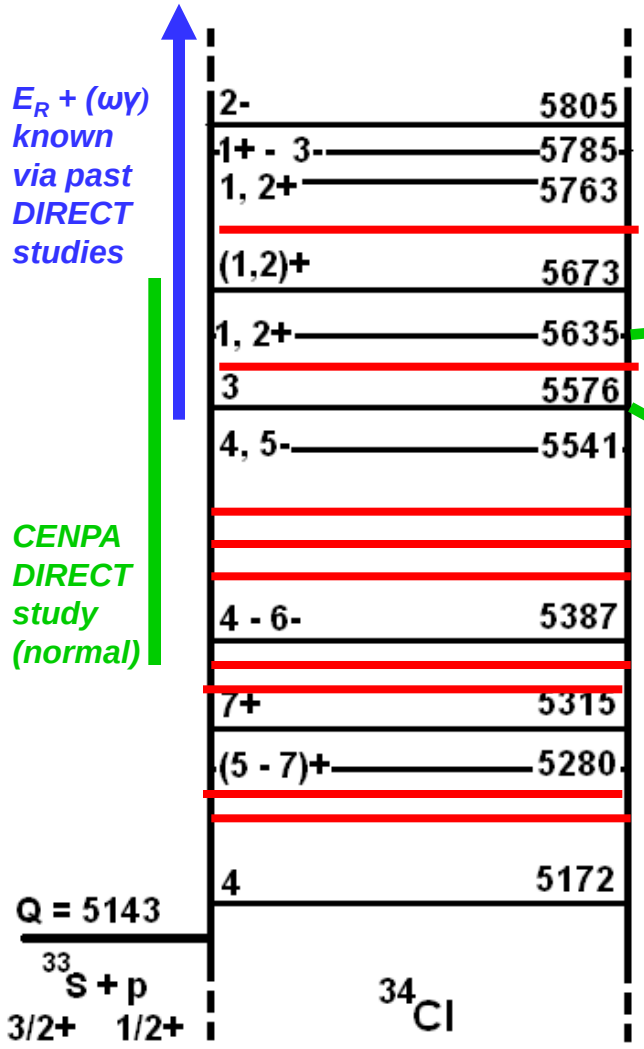
~3 μg/cm^2 ^{33}S implanted into a [OFHC] Cu plate (@ CENPA)

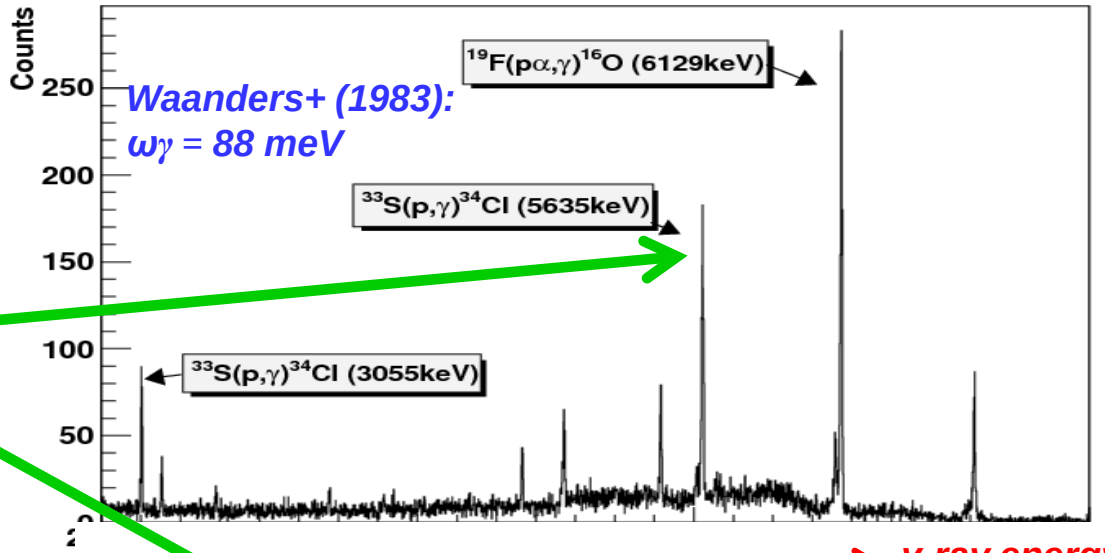
Thanks to A. Sallaska (UW)

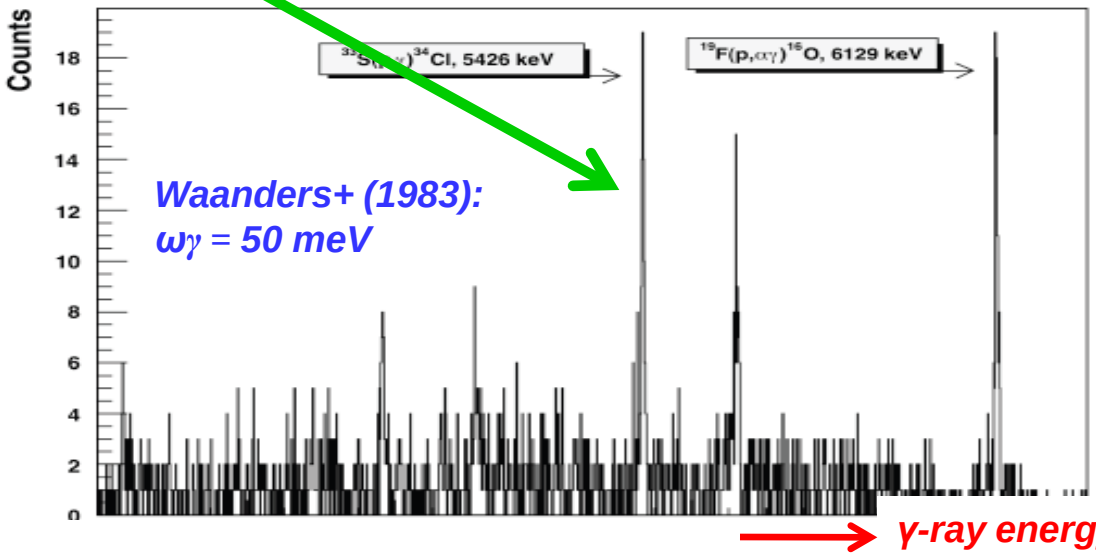
DIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (1) $^{33}S(p,\gamma)^{34}Cl$

CENPA Center for Experimental Nuclear Physics and Astrophysics

Center for Experimental Nuclear Physics and Astrophysics (Seattle)







Endt (1990)

$^{34}S(^3He,t)^{34}Cl + ^{33}S(^3He,d)^{34}Cl$

Thanks to B. Freeman (UW)

DIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (2) $p(^{33}S,\gamma)^{34}Cl$

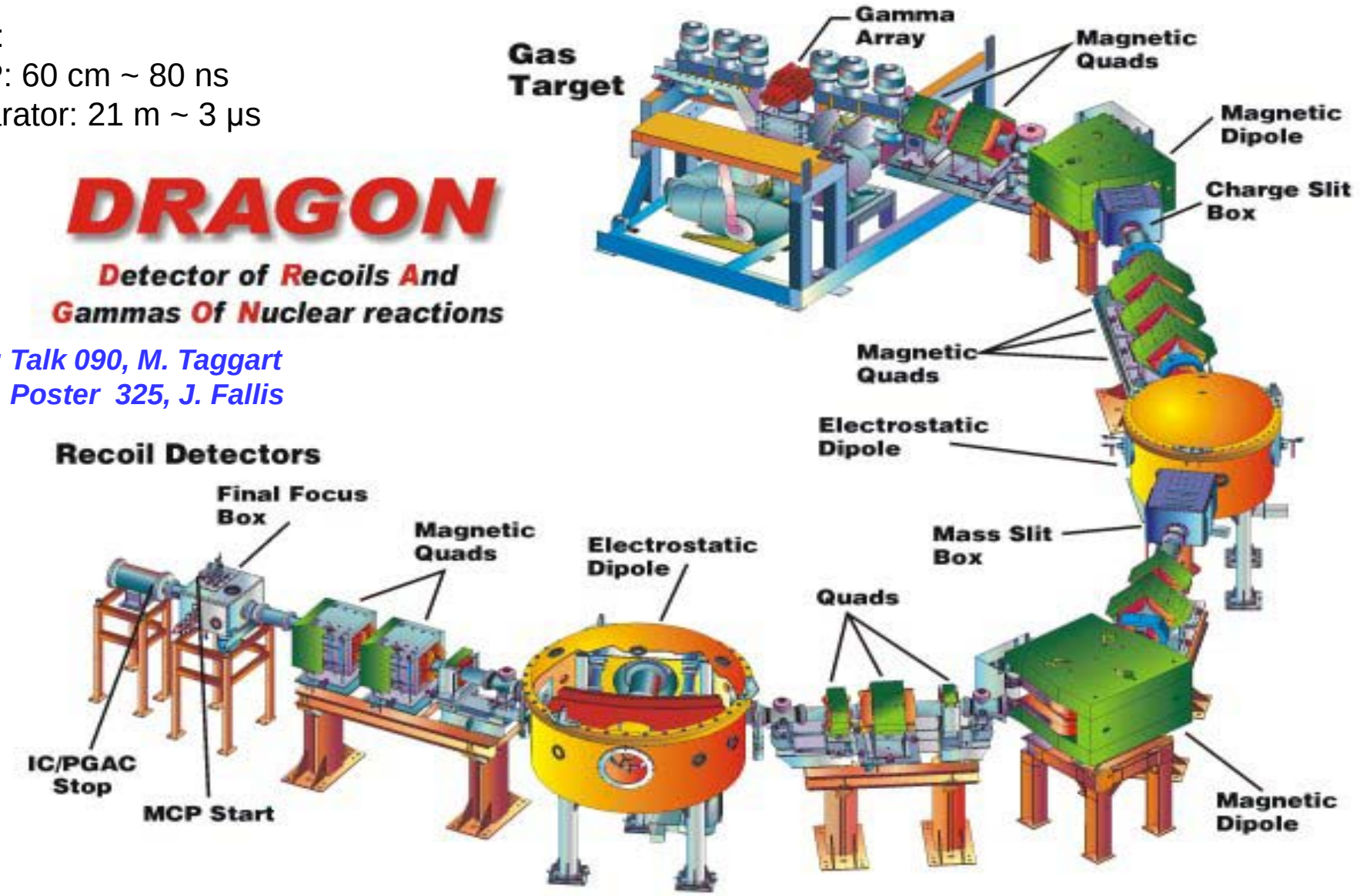
***DRAGON @ TRIUMF* (Vancouver)**

~10^{10} ions ^{33}S / s over 130 h (total)

TOF:
MCP: 60 cm ~ 80 ns
separator: 21 m ~ 3 µs

DRAGON

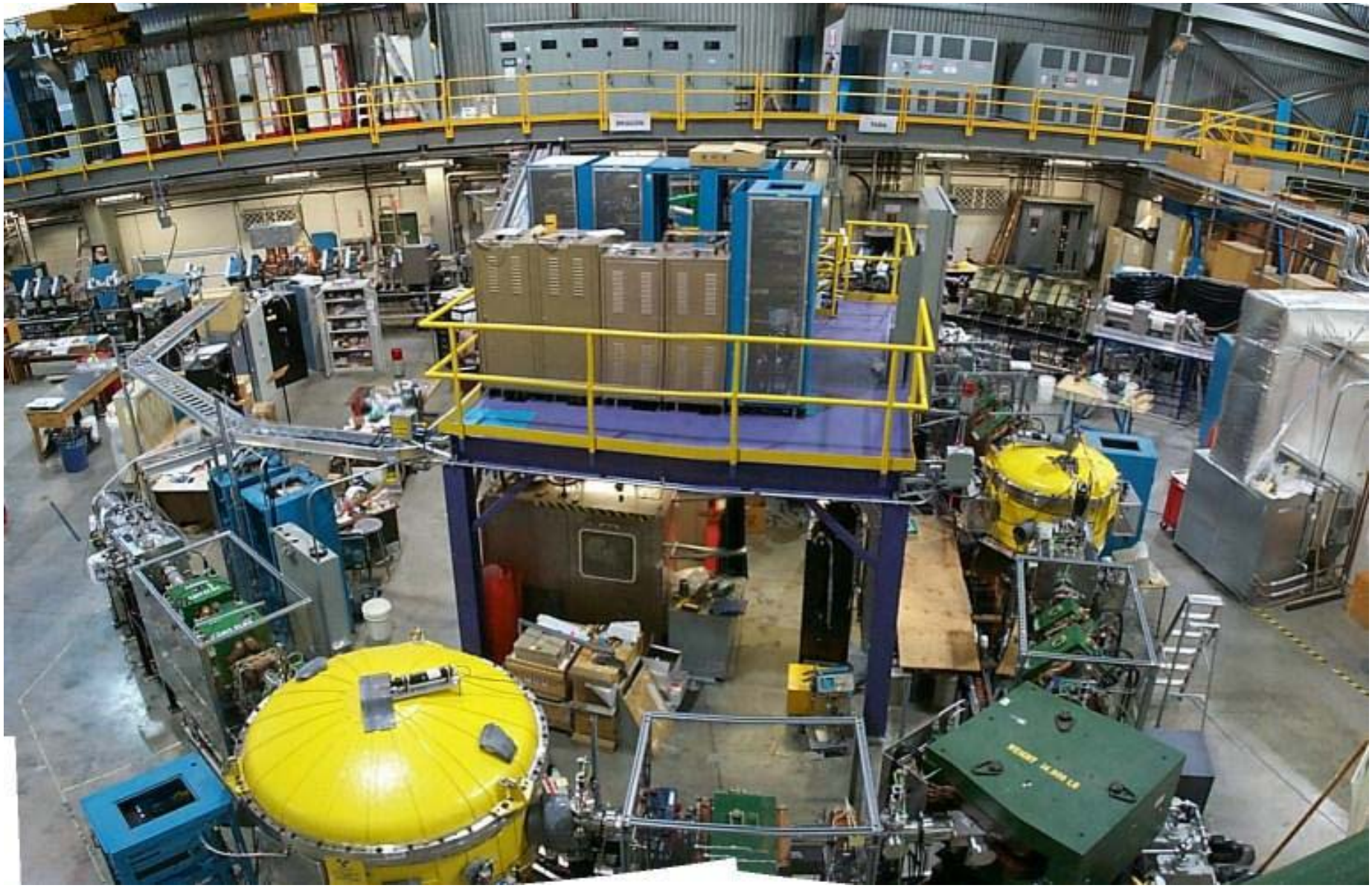
Detector of Recoils And Gammas Of Nuclear reactions



Also: Talk 090, M. Taggart
Poster 325, J. Fallis

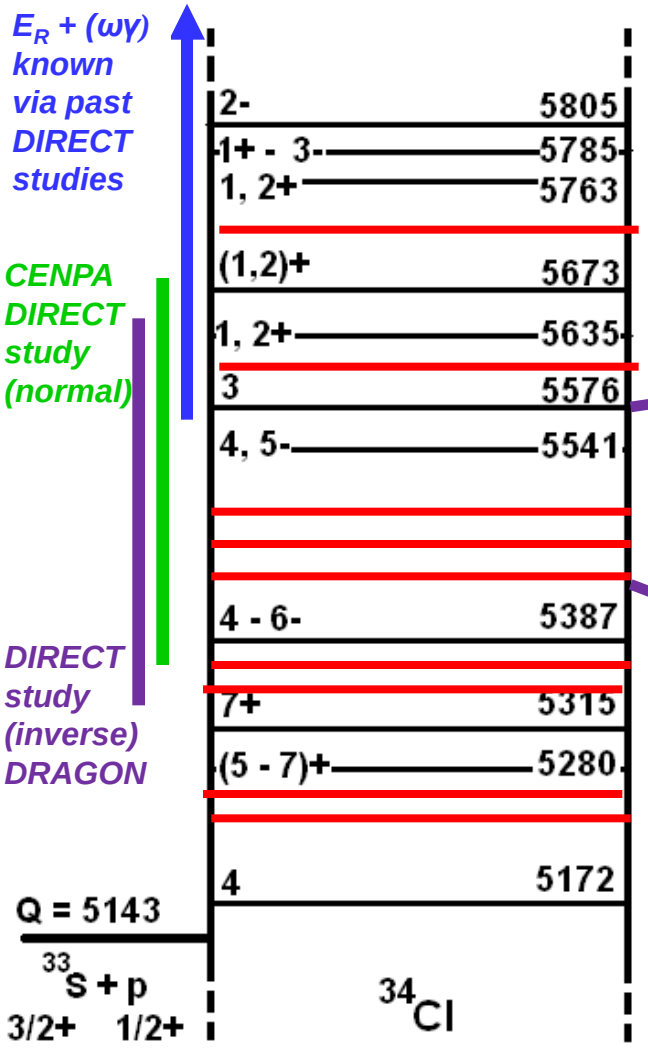
DIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (2) $p(^{33}S,\gamma)^{34}Cl$

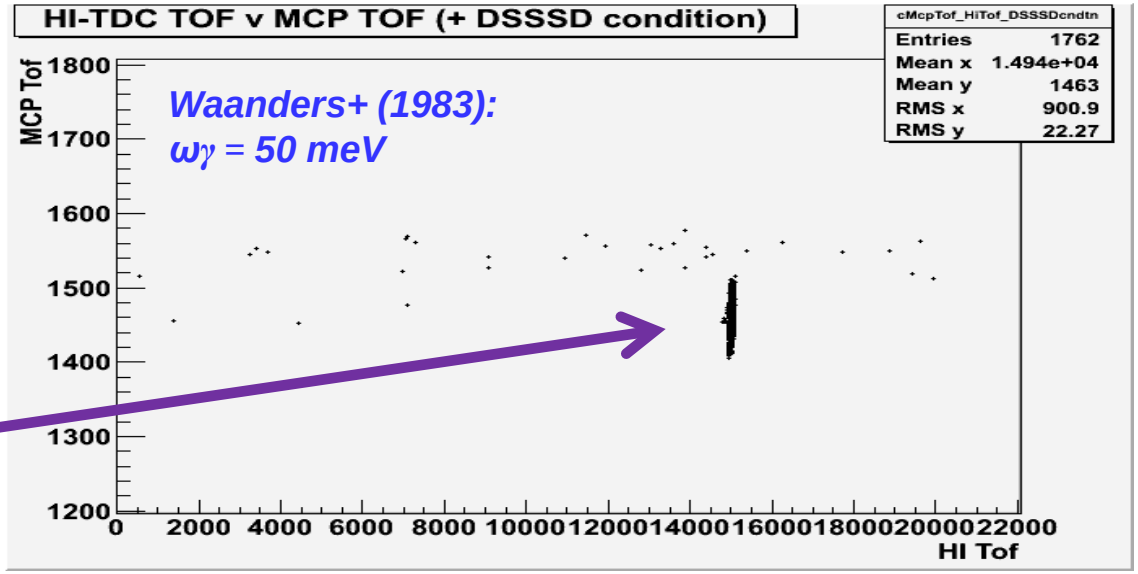
DRAGON @ TRIUMF **(Vancouver)**

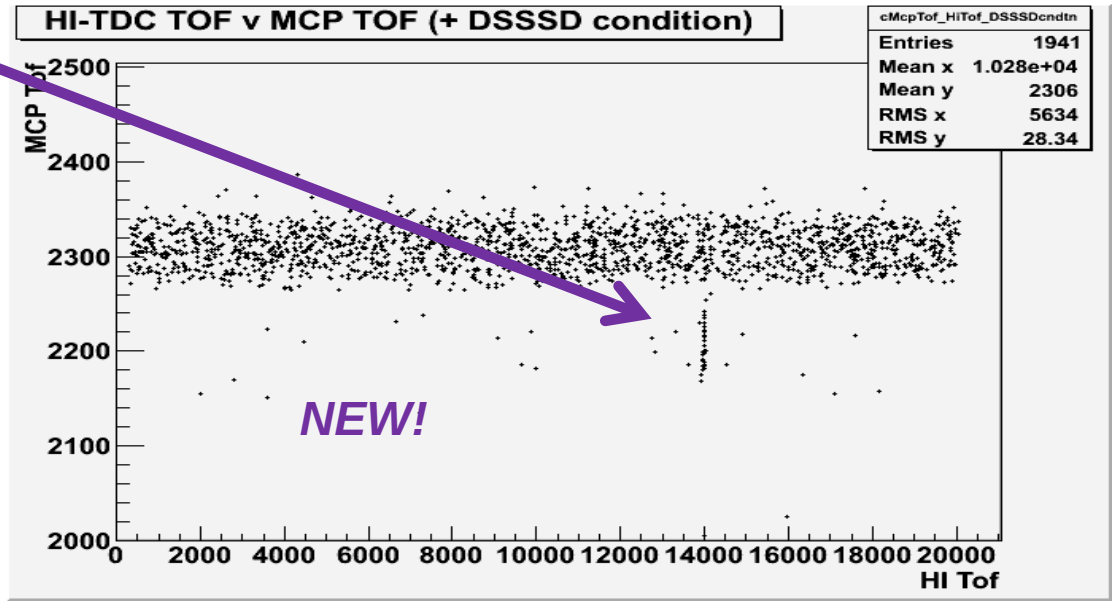


DIRECT studies of $^{33}S(p,\gamma)^{34}Cl$: (2) $p(^{33}S,\gamma)^{34}Cl$

DRAGON @ TRIUMF (Vancouver)





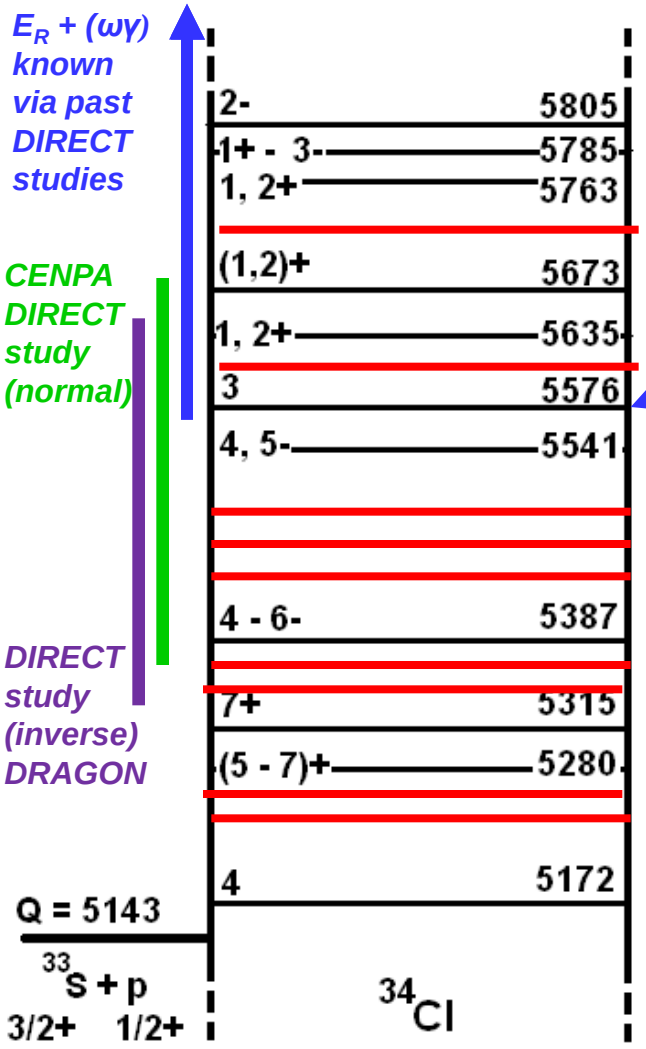


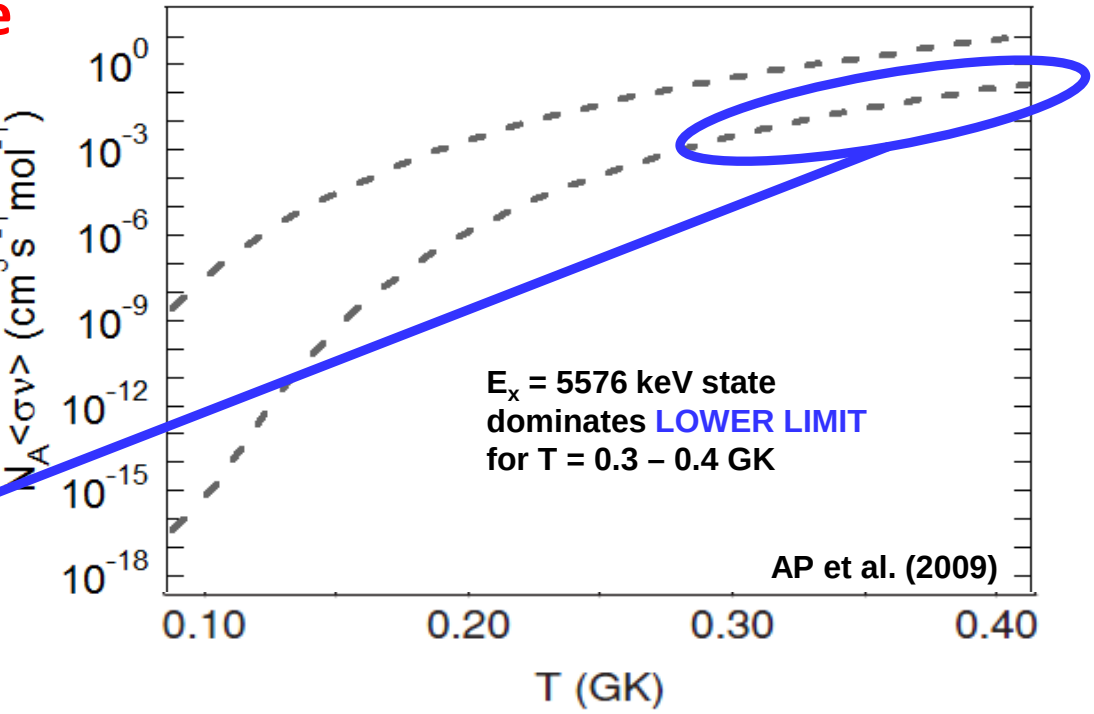
Endt (1990)

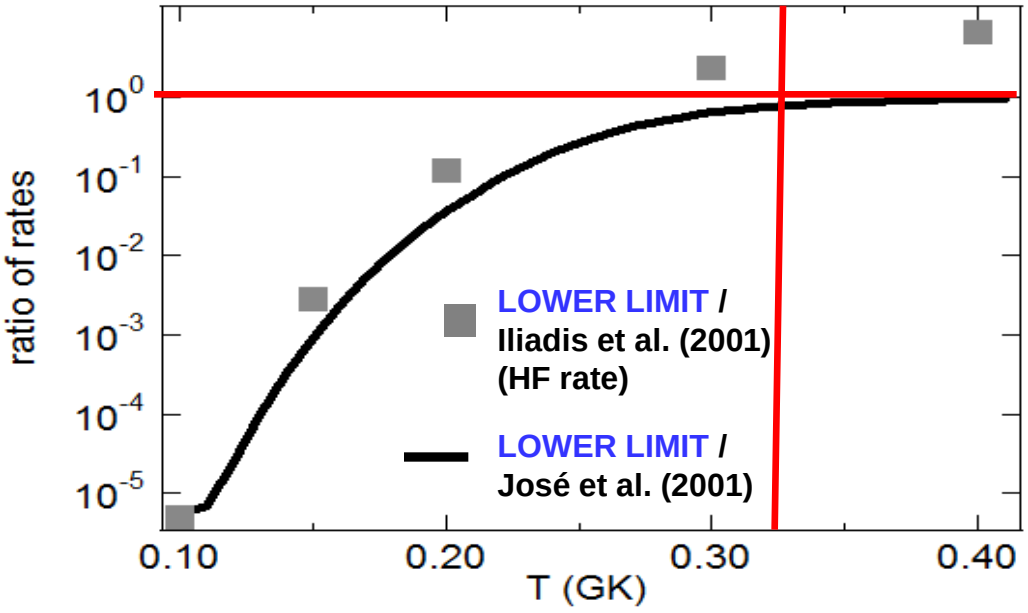
$^{34}S(^3He,t)^{34}Cl + ^{33}S(^3He,d)^{34}Cl$

Thanks to J. Fallis (TRIUMF)

The $^{33}S(p,\gamma)^{34}Cl$ reaction rate







Endt (1990)

$^{34}S(^3He,t)^{34}Cl$ + $^{33}S(^3He,d)^{34}Cl$

SULPHUROUS COLLABORATORS

T. Faestermann, R. Krücken, T. Behrens, V. Bildstein, S. Bishop, K. Eppinger, C. Herlitzius, C. Hinke, O. Lepyoshkina, P. Maierbeck, G. Rugel, M. Schlarb, D. Seiler, K. Wimmer

J. Fallis, C. Ruiz, D. A. Hutcheon, U. Hager, D. Ottewell

B. Freeman, C. Wrede, A. García, B. Delbridge, A. Knecht, A. Sallaska

R. Hertenberger, H.-F. Wirth

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P. D. Parker

B. Fulton, A. Laird

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B. Guo, Z. Li, E. Li, G. Lian, Y. Wang