# Experimental studies of low-spin states with SONIC@HORUS

**S.G. PICKSTONE***,
V. DERYA, A. HENNIG, J. MAYER, L. NETTERDON, S. PASCU,
P. SCHOLZ, M. SPIEKER*, M. WEINERT, J. WILHELMY, AND A. ZILGES

INSTITUTE FOR NUCLEAR PHYSICS
UNIVERSITY OF COLOGNE


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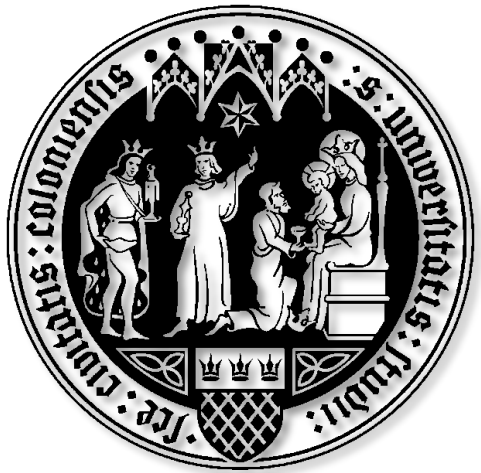
* Member of the Bonn-Cologne Graduate School Honours Class




**EGAN Workshop 2014, GSI**

# Outline

- Experimental technique
  - Particle-γ coincidences
  - SONIC@HORUS

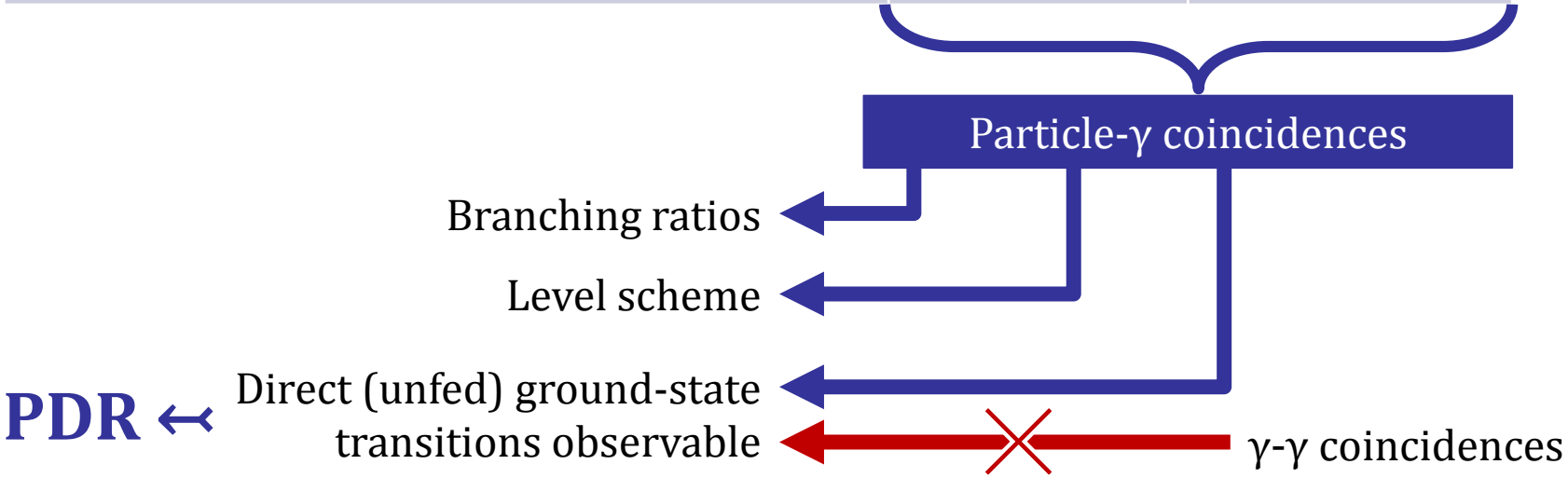
- $^{92}$Mo(p,p'γ)
  - Physics: Decay of Pygmy Dipole Resonance (PDR)
  - Determination of branching ratios

- $^{96}$Ru(p,p'γ)
  - Physics: mixed-symmetry states
  - Determination of lifetimes with DSAM

- $^{119}$Sn(d,pγ)$^{120}$Sn
  - Physics: Excitation of the PDR
  - One-neutron transfer

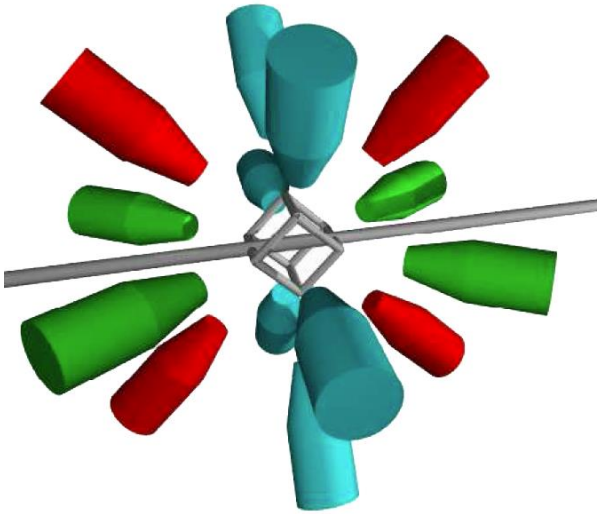
# Particle-γ coincidences

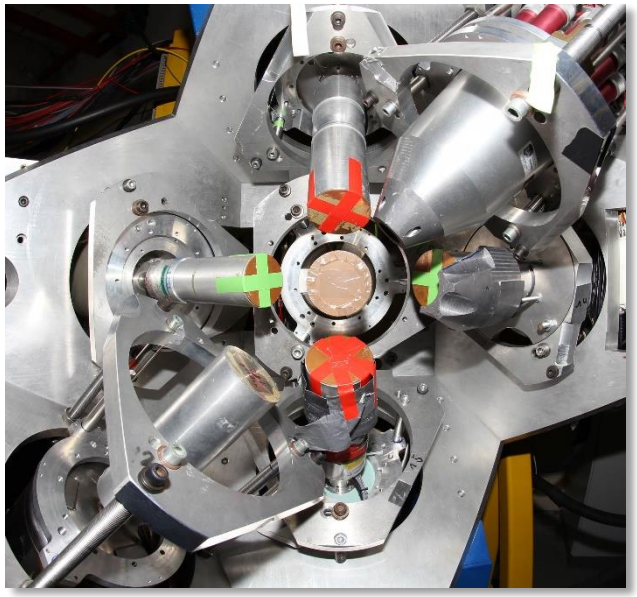
| Spectroscopy Detector | γ HPGe | Particle (Ion) Silicon |
|---|---|---|
| Excitation | × | ✓ |
| Deexcitation | ✓ | × |
| Energy resolution of detector | ++ (2 keV @ 1.3 MeV) | + (15 keV @ 5.5 MeV) |
| Energy resolution in-beam | ++ | o |
| Information | spectra | gate |



# γ-spectrometer: HORUS

- 14 HPGe detectors
  - 6 BGO shields
  - 2 Clover detectors optional
- 5 angles relative to beam axis
- Photopeak efficiency
  - ~2% @ 1332 keV
- Energy resolution
  - Digital Signal Processing (XIA):
    ≤2.5 keV@ 1332 keV, 6 kcps



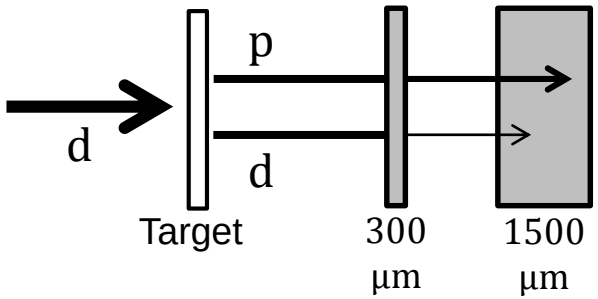


Wed, $12^{\underline{00}}$
M. Weinert

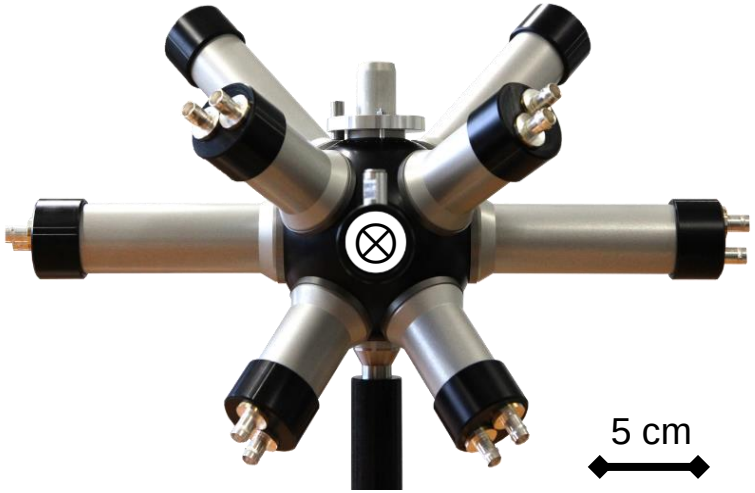
# Particle Spectrometer: SONIC

**Silicon Identification Chamber**

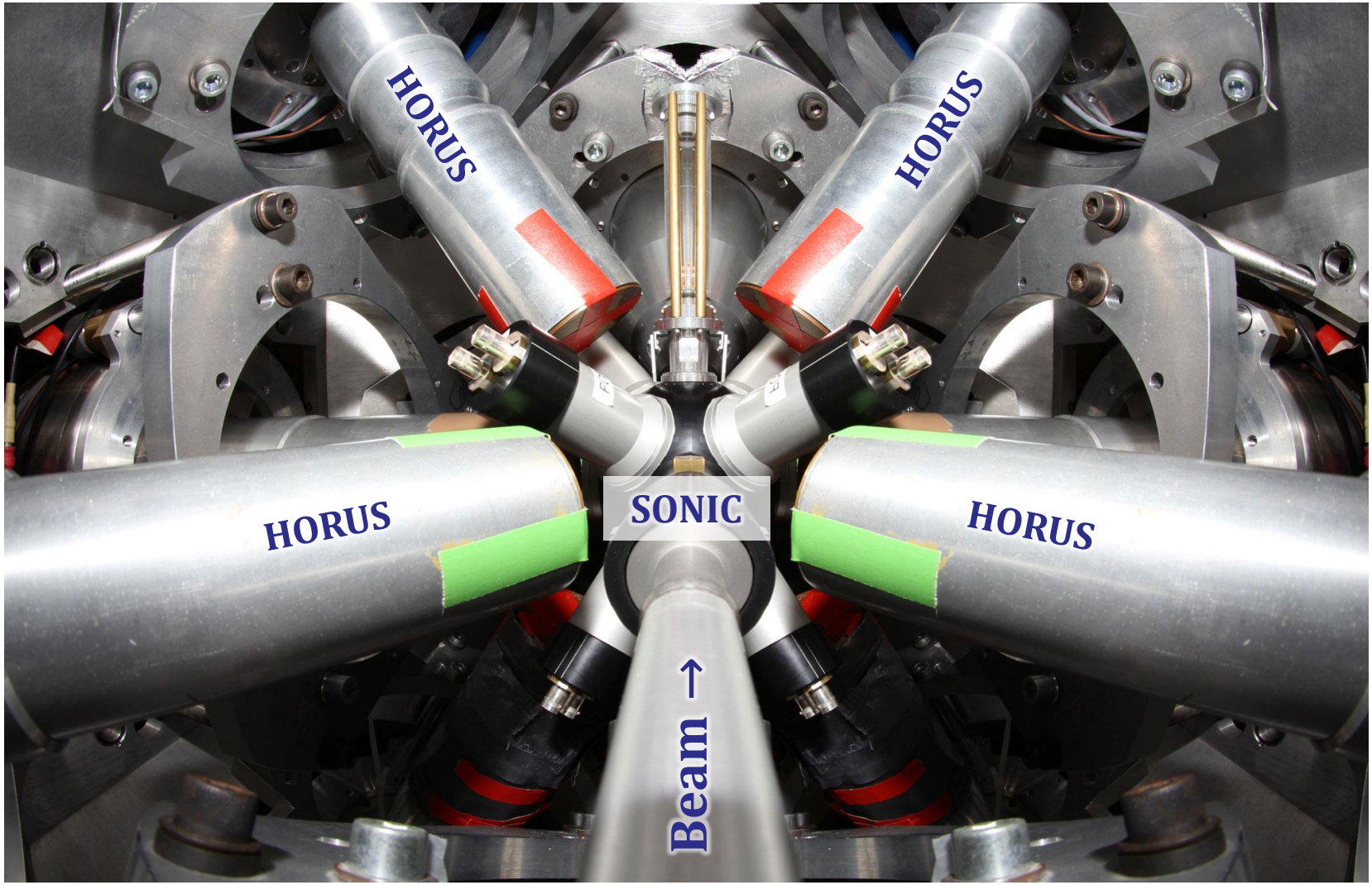
- Reaction channel from particle identification by ΔE-E
- Excitation energy from ejectile energy measurement



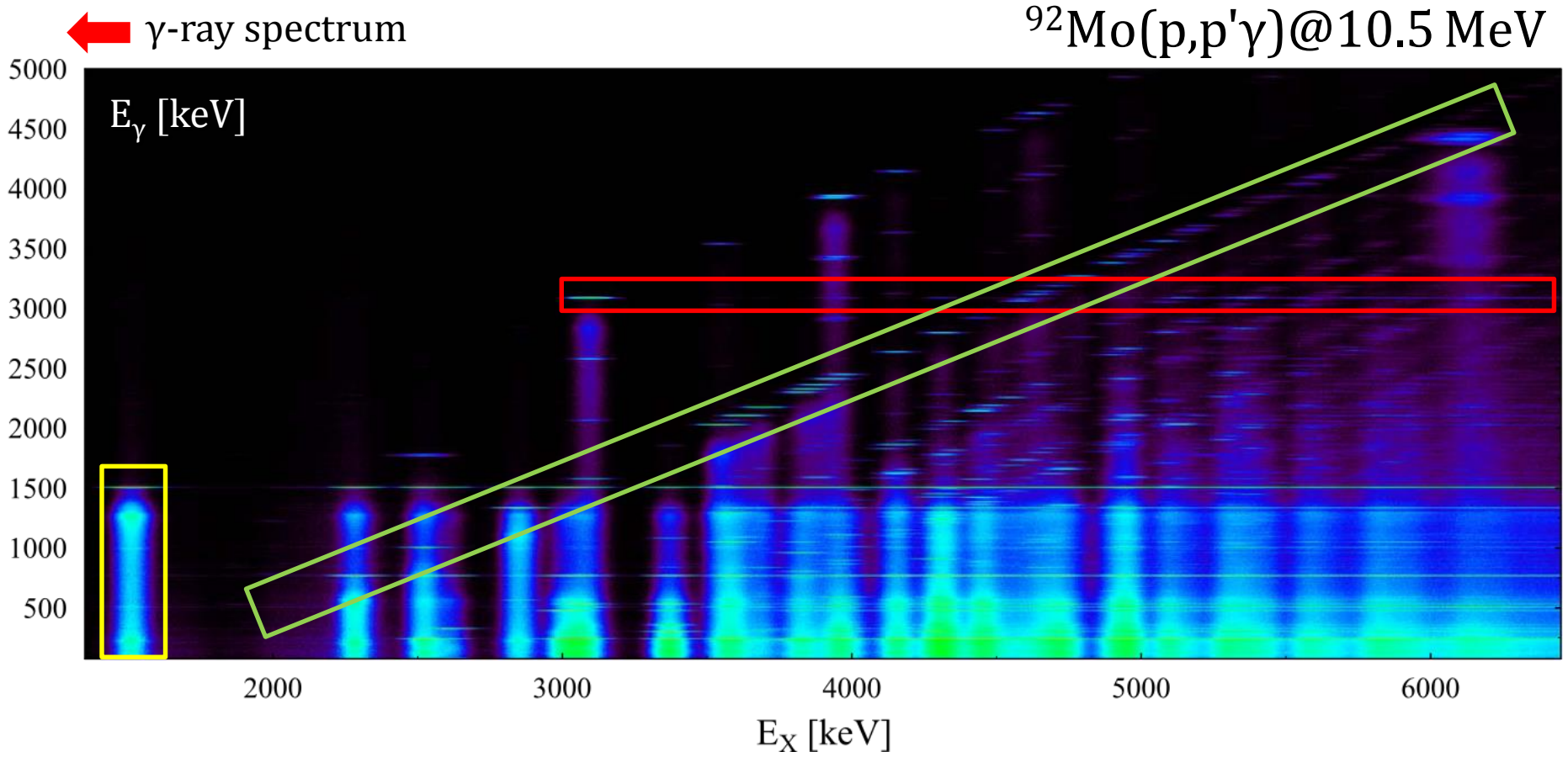

- 8 detector tubes
  - In gaps between HPGe detectors
  - Variable detector-target distance to customise count rate
- Solid angle coverage
  - ~4 % in total
- Positions
  - θ=60°, 90°, 120°, 130°(x2)



# Combined Setup

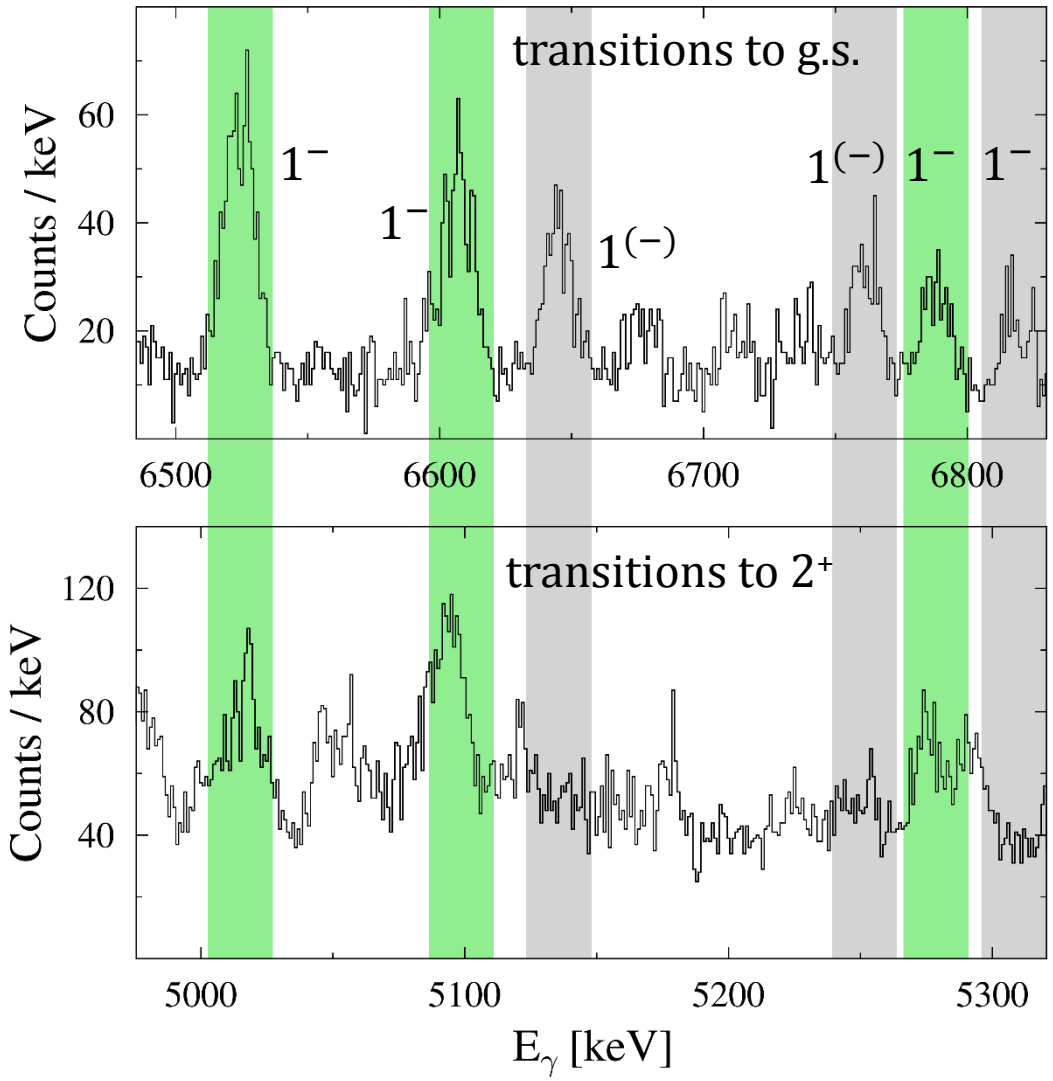


# Coincidence Matrix: ($E_X$,$E_\gamma$)




| | | |
|---|---|---|
| **Row** ($E_\gamma$): | De-excitation *via* specific level | $E_\gamma = 3091$ keV |
| **Column** ($E_X$): | Excitation *of* specific level | $E_X = 1510$ keV |
| **Diagonal**: | De-excitation *to* specific level | $E_\gamma - E_X = 1510$ keV |

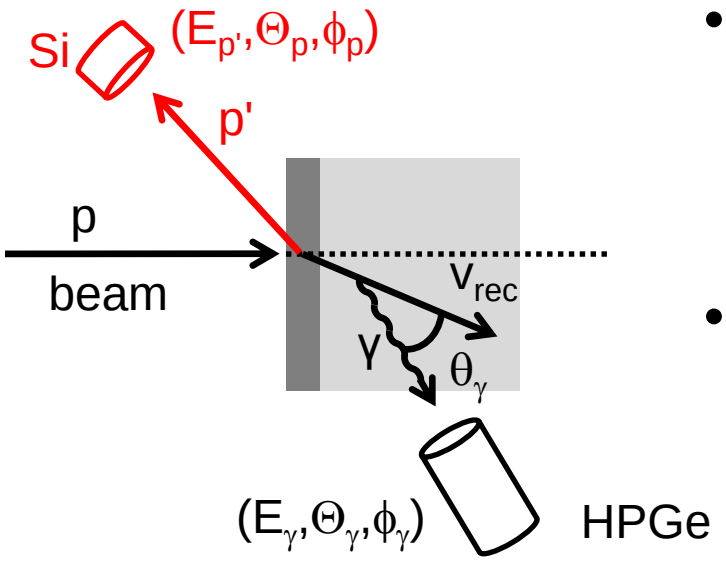
# Decay properties of PDR states in $^{92}$Mo



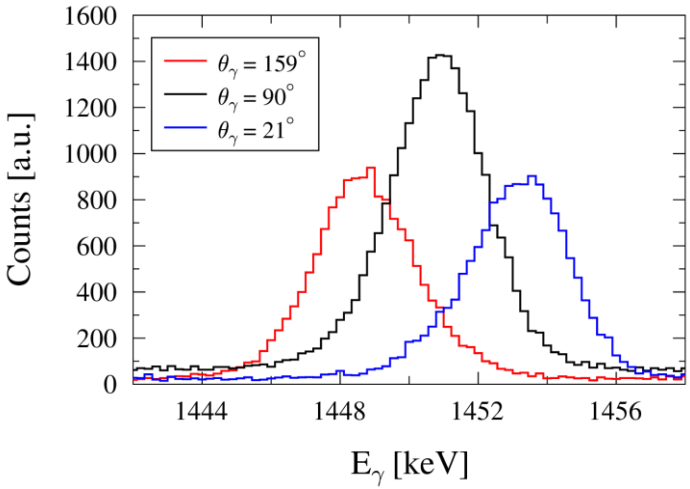

| $E_x$ [keV] | $\gamma \rightarrow 0_1^+$ | $\gamma \rightarrow 2_1^+$ | $\gamma \rightarrow 2_2^+$ | $\gamma \rightarrow 0_2^+$ |
|---|---|---|---|---|
| 5401 | ✓ | ✓ | | |
| 5533 | ✓ | ✓ | ✓ | |
| 5555 | ✓ | ✓ | ✓ | ✓ |
| 5703 | ✓ | | | ✓ |
| 5789 | ✓ | ✓ | | ✓ |
| 5842 | ✓ | | | ✓ |
| 5981 | ✓ | | | |
| 6126 | ✓ | | ✓ | |
| 6139 | ✓ | ✓ | | |
| 6192 | ✓ | ✓ | | |
| 6300 | ✓ | | | |
| 6378 | ✓ | ✓ | ✓ | |
| 6525 | ✓ | ✓ | | |
| 6606 | ✓ | ✓ | ✓ | |
| 6645 | ✓ | | (✓) | |
| 6761 | ✓ | | ✓ | |
| 6787 | ✓ | ✓ | | |
| 6818 | ✓ | | | |
| 6883 | ✓ | ✓ | ✓ | |
| 6996 | ✓ | | | |
| 7031 | ✓ | | | |
| 7070 | ✓ | | | |
| 7077 | ✓ | | | |

Theoretical branching ratios calculated by N. Tsoneva - Tue, 10[15]

# Advantages of p-γ-coincidence DSAM

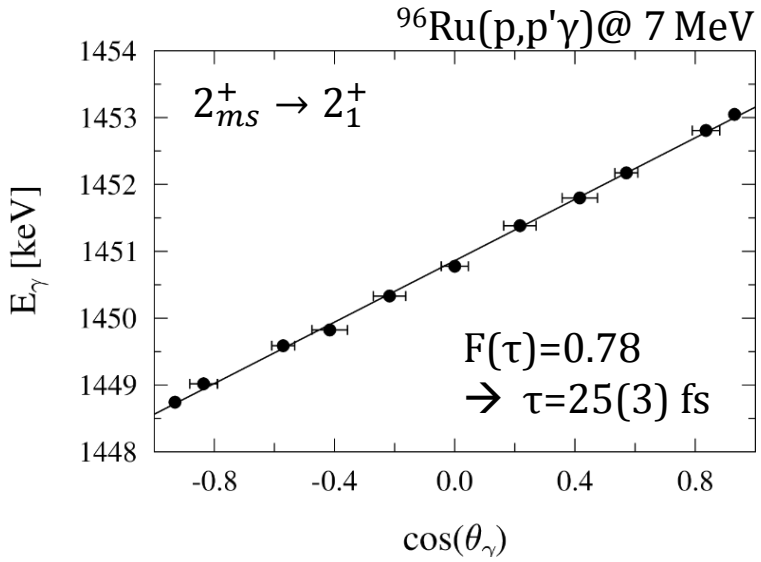


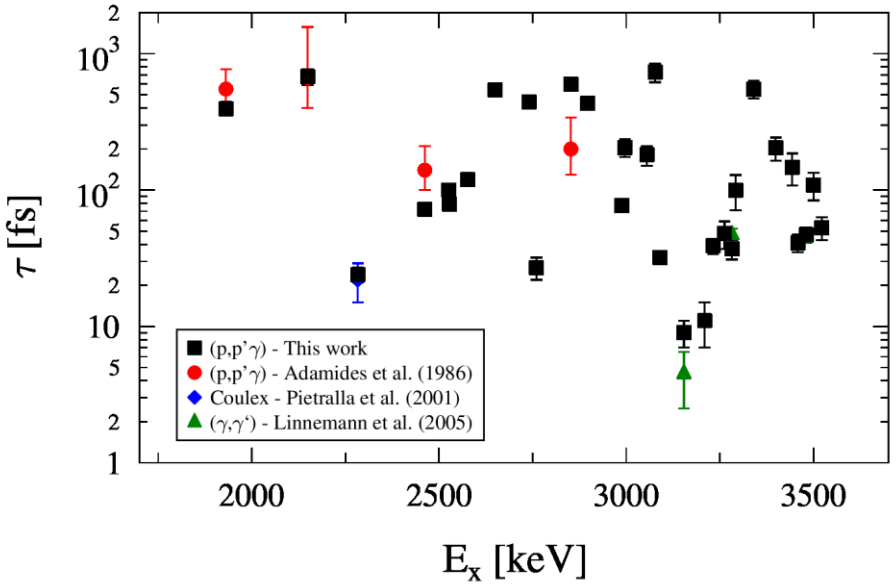

- Complete Kinematics:
  - Knowledge of $\vec{v}_{rec}$, thus $\theta_\gamma$
    - No averaging over different $\theta_\gamma$
- Centroid shift from gated spectra
  - Analysis of weak transitions
  - No feeding
    - "Real" instead of effective lifetimes




- Particle detectors at backward angles
  - Larger momentum transfer
    - Larger shifts
    - Higher sensitivity

# DSAM Results




- Lifetime extracted from shift:

$$\Delta E(\theta_\gamma) = F(\tau) E_0 \frac{v_0}{c} \cos\theta_\gamma$$

- Slowing-down process has to be simulated for lifetime extraction (Monte Carlo)
- 8 lifetimes confirmed
  - Excellent agreement with (γ,γ') and Coulex data
- **22 determined for first time**

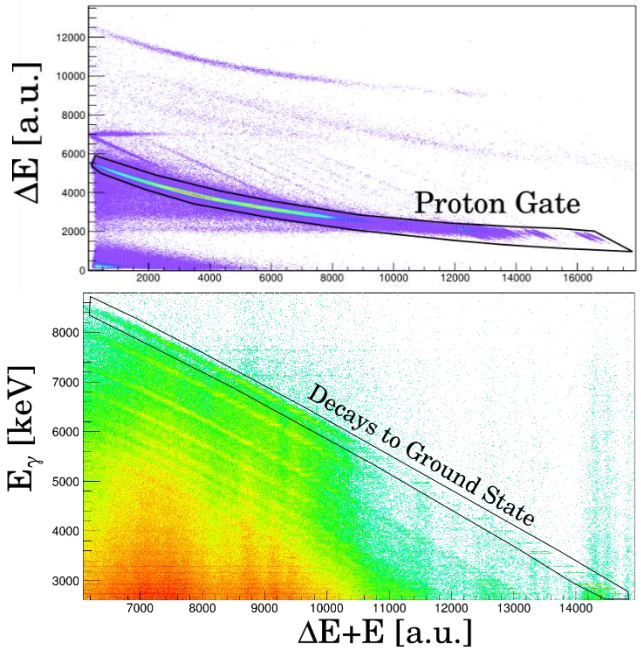
# $^{119}$Sn(d,pγ)$^{120}$Sn to test PDR

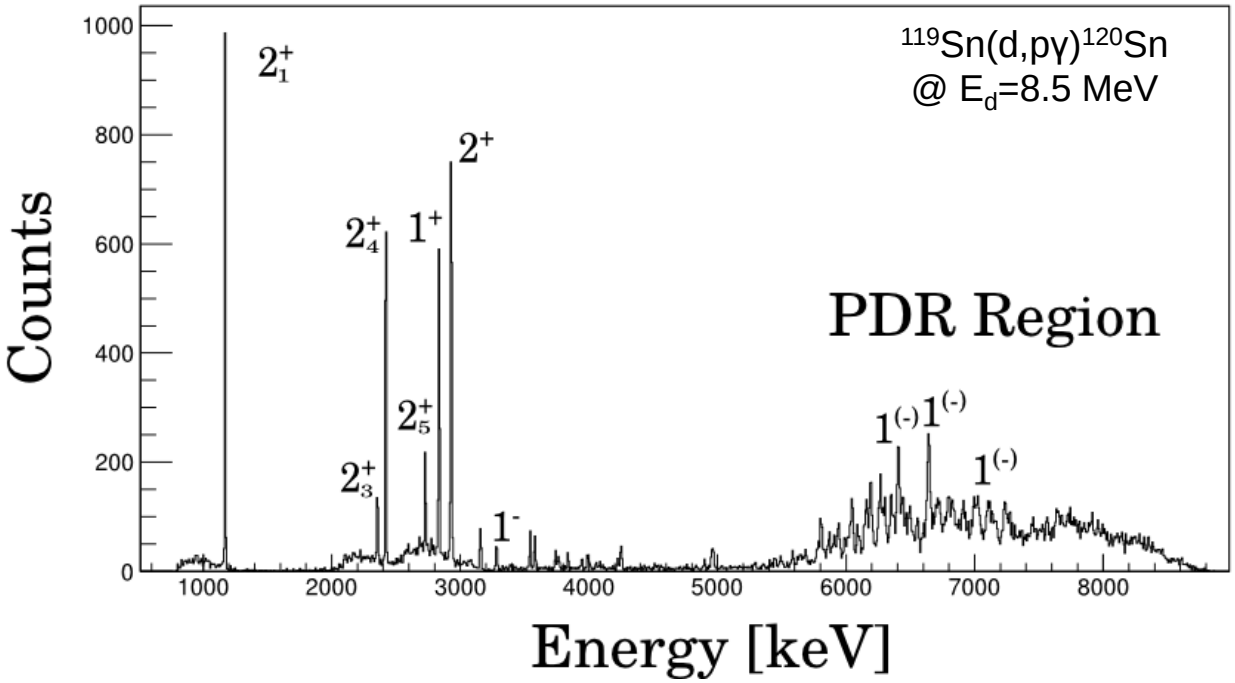
**(d,p):** neutron transfer tests neutron particle-hole character

**Pioneering experiment:** $^{119}$Sn(d,pγ)$^{120}$Sn

- PDR strongly excited: Branching ratios can be determined

**Next experiment:** $^{137}$Ba(d,pγ)$^{138}$Ba



# Summary & Outlook

- Complete analysis of $^{92}$Mo(p,p'γ), $^{96}$Ru(p,p'γ), $^{94}$Zr(p,p'γ),$^{119}$Sn(d,pγ)$^{120}$Sn

- SONIC@HORUS established for:
  - (p,p'γ) decay studies of the PDR
  - (p,p'γ) DSAM measurements
  - (d,pγ) measurements to excite the PDR

- Future experiments:
  - e.g. $^{120}$Sn(p,p'γ) for investigation of PDR
  - e.g. $^{96}$Mo(p,p'γ) for DSAM and mixed-symmetry
  - e.g. $^{137}$Ba(d,pγ)$^{138}$Ba for investigation of PDR