Photon induced γ-γ coincidence experiments at the γ³-setup at HIγS

22.02.2014

Bastian Löher
b.loeher@gsi.de

ExtreMe Matter Institute EMMI and Research Division
GSI Helmholtzzentrum für Schwerionenforschung

Frankfurt Institute for Advanced Studies FIAS

B. Löher[1,2], T.Aumann[5], N.Cooper[6], V.Derya[3], J.Endres[3], E.Fiori[1,2], J.Kelley[4], N.Pietralla[5], R.Raut[4], G.Rusev[4], D.Savran[1,2], A.Tonchev[4], W.Tornow[4], V.Werner[6] and A.Zilges[3]

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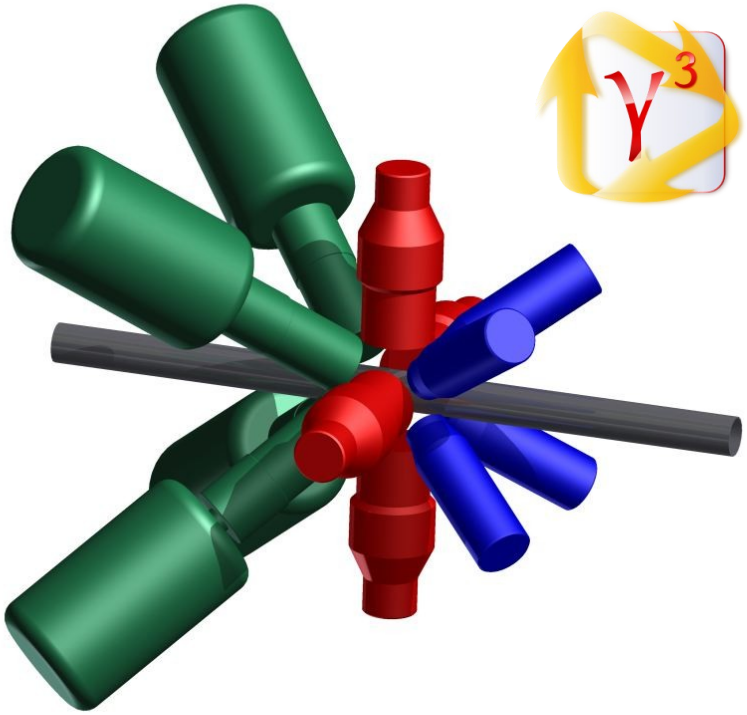
[2]Frankfurt Institute for Advanced Studies FIAS, Frankfurt
[3]Institut für Kernphysik, Universität zu Köln, Köln
[4]Department of Physics, Duke University, Durham, USA
[5]Institut für Kernphysik, Technische Universität Darmstadt
[6]WNSL, Yale University, USA



Decay of the PDR in ^{140}Ce. First results from the γ^3 coincidence setup at HIγS

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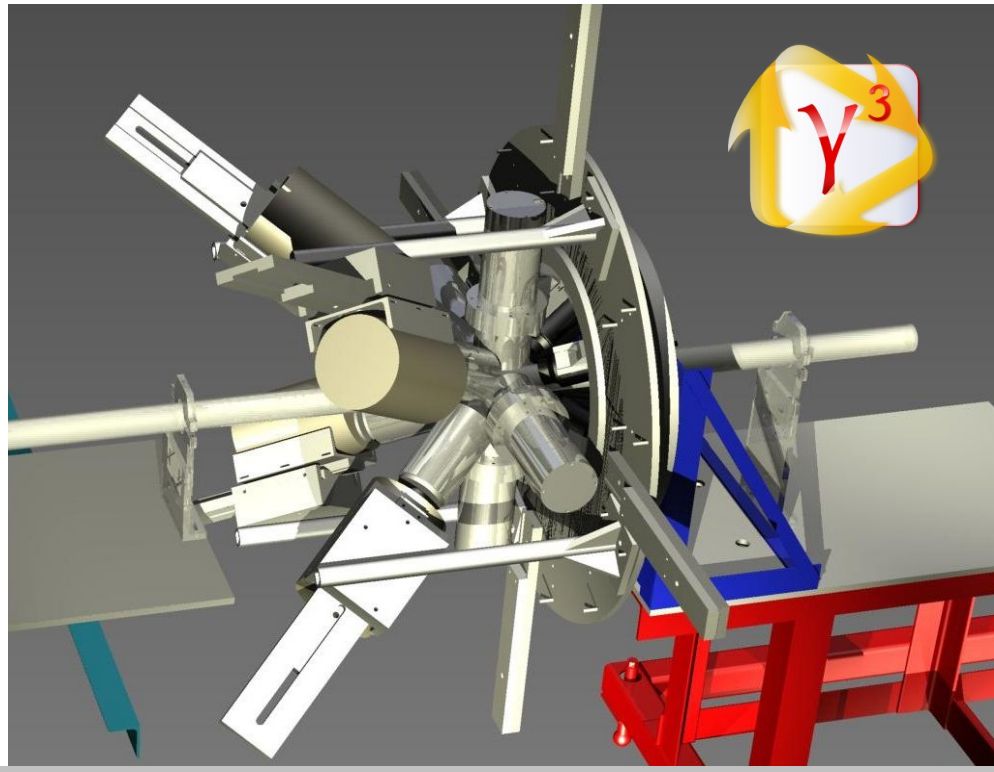


HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

FIAS Frankfurt Institute for Advanced Studies

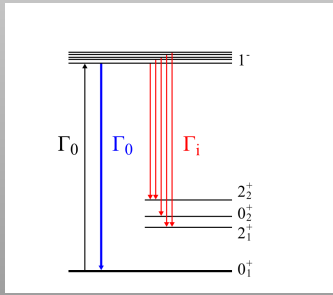
Motivation

New experimental possibilities at γ^3 to study decay patterns

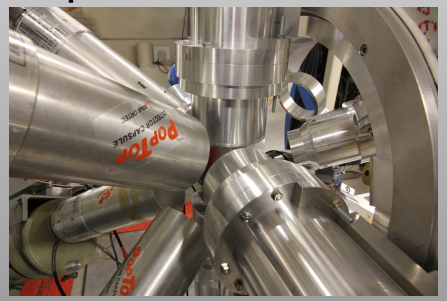
- Study of the Pygmy Dipole Resonance
- Deeper Investigation of the Scissors Mode
- Two phonon excitations in light and heavy nuclei

Motivation

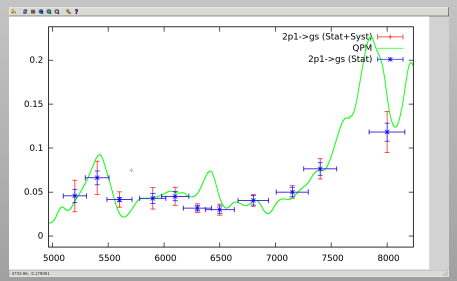
Introduction



Experiment



Results



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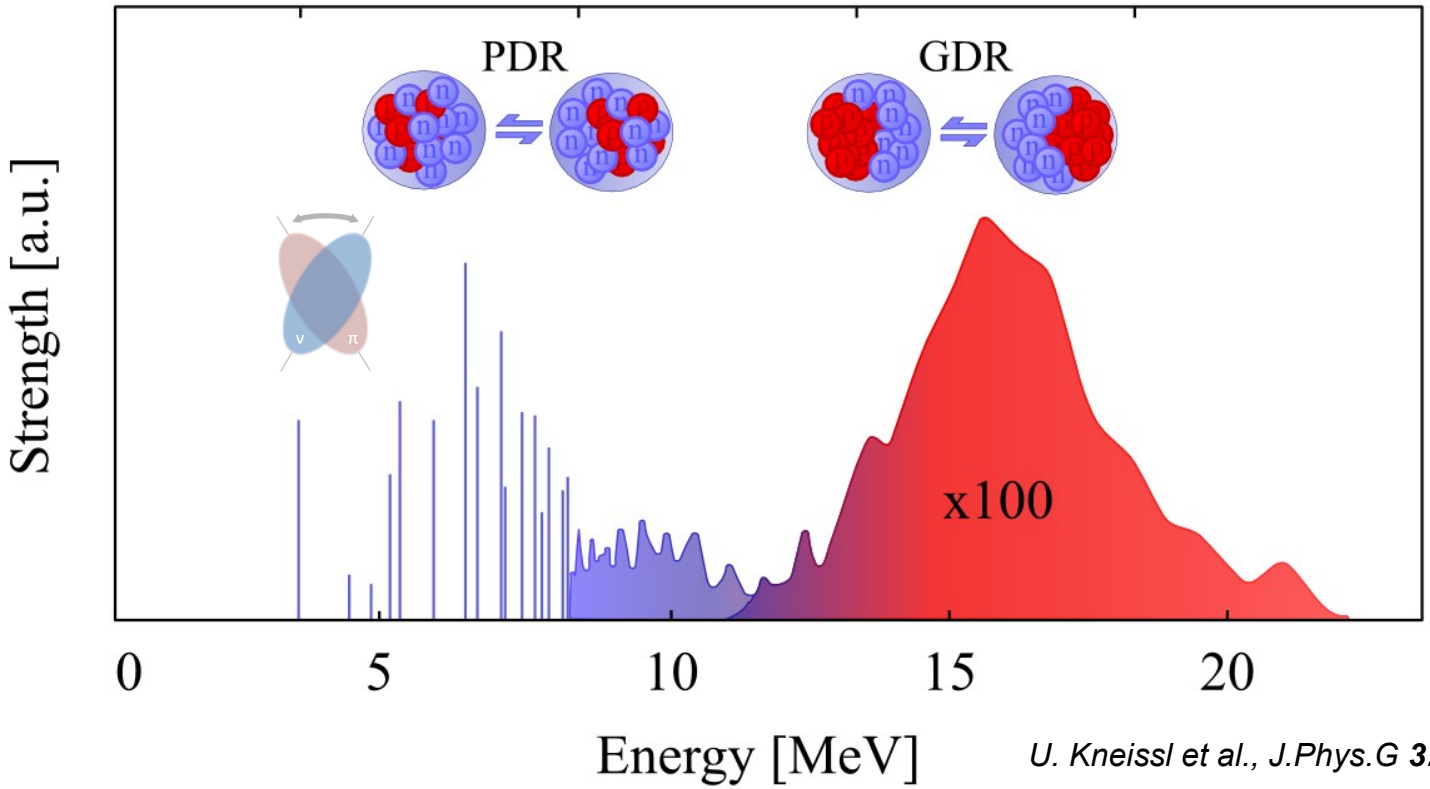
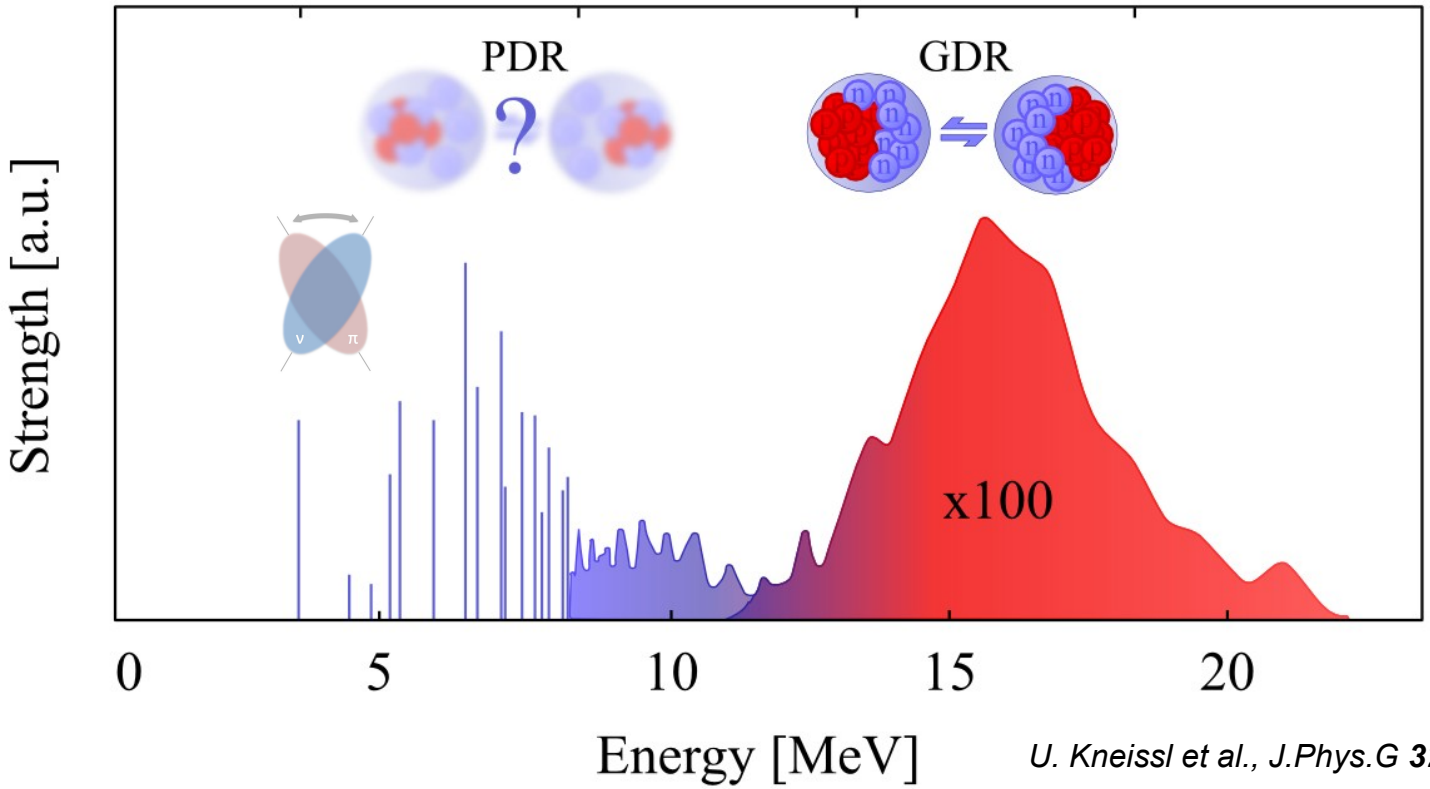


*U. Kneissl et al., J.Phys.G **32**, R217 (2006)*

Dipole Photoresponse of (spherical) nuclei

- M1 Scissor's Mode
- GDR: Oscillation of Neutrons vs. Protons
- PDR: Oscillation of Neutron skin vs. Core

Motivation



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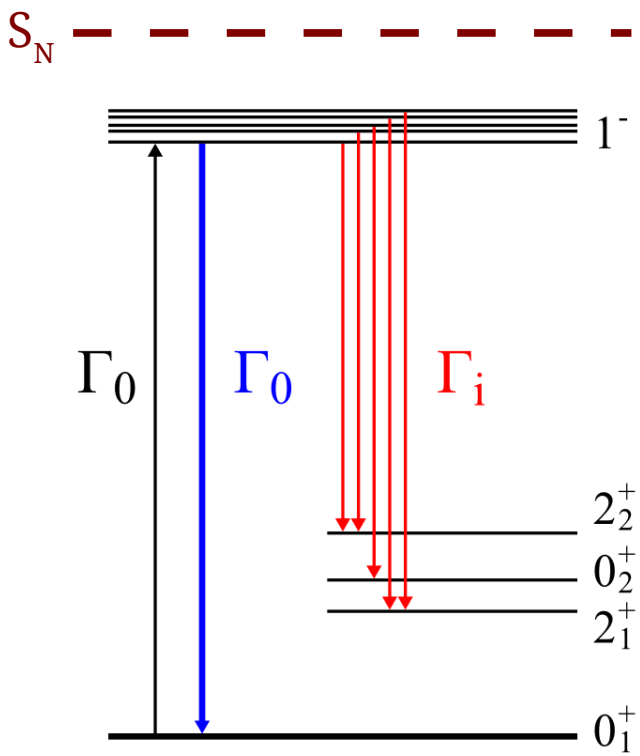
Experimental Method

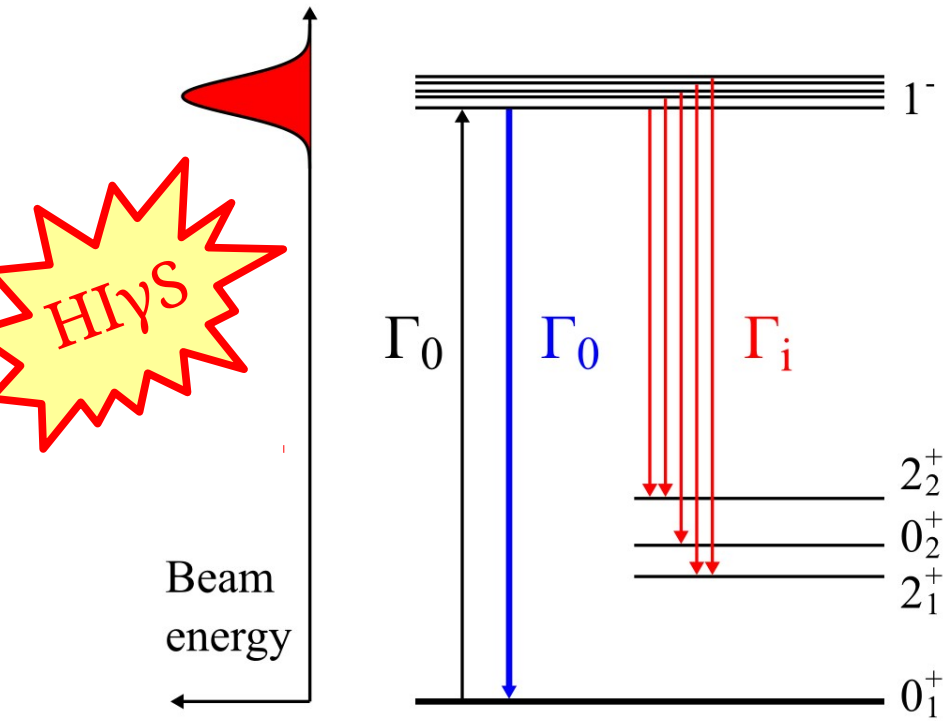


- Decay „elastic“ (Γ_0) or „inelastic“ (Γ_i)
- Elastic channel dominant: ($\Gamma_0 \gg \Gamma_i$)

Nuclear Resonance Fluorescence (NRF)

X(γ,γ')X

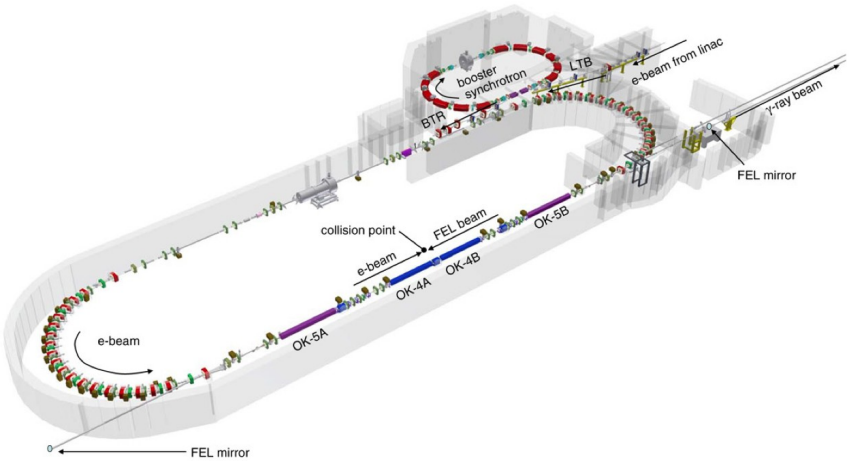
Experimental Method



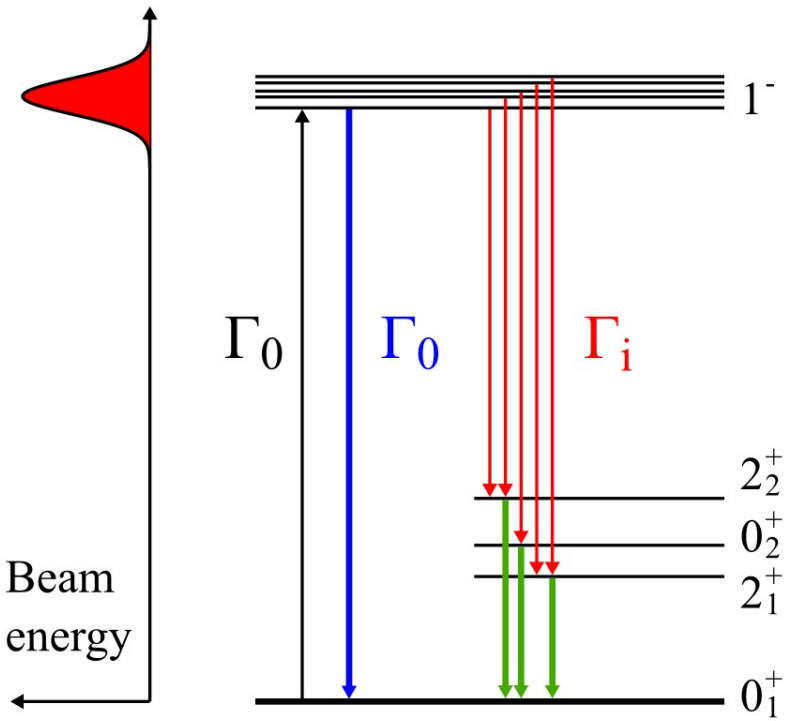
Weller *et al.*, Prog. Part. Nucl. Phys. 62 (2009) 257

Use:

- Selectivity of NRF reaction and mono-energetic beam
  → Prepare nucleus in well-defined excitation mode



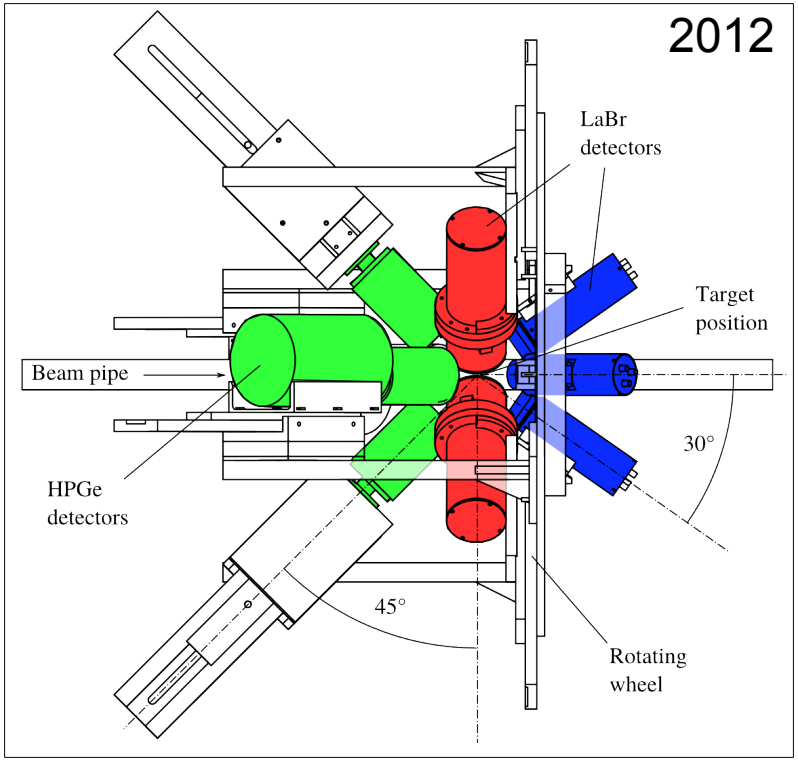
Experimental Method

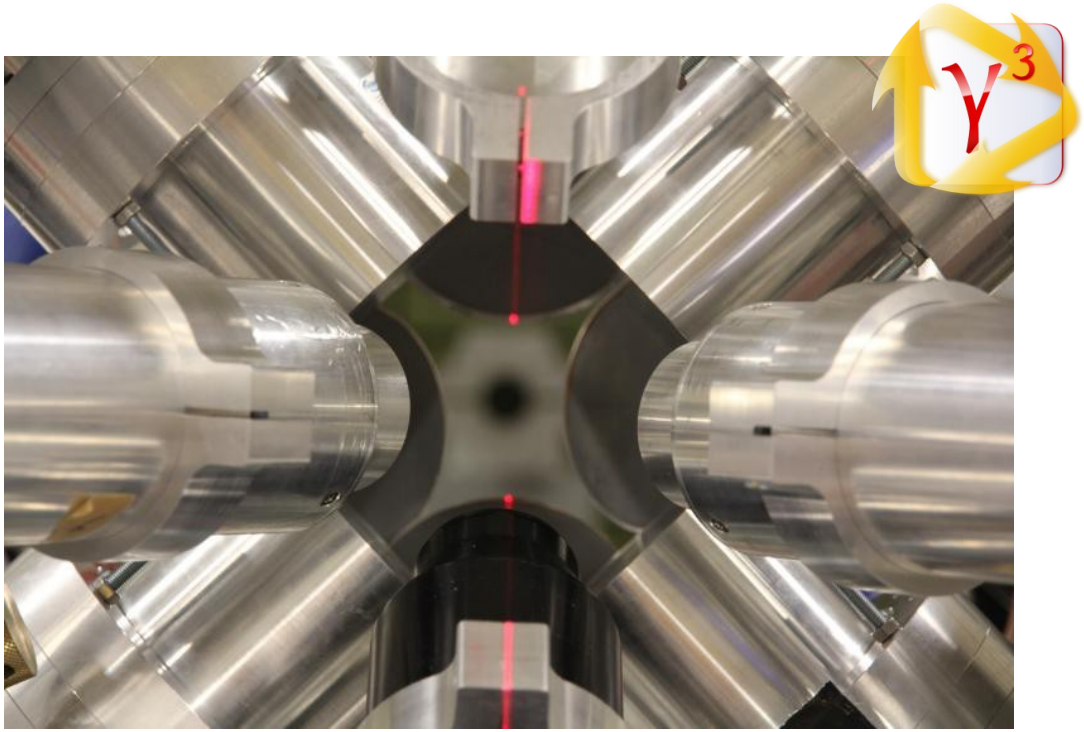


Combine:

- Selectivity of NRF reaction and mono-energetic beam
- Sensitivity of γ-γ coincidence method
- Select low energy decay

The γ^3 setup





B. Löher et al., Nucl. Instruments Methods Phys. Res. Sect. A **723**, 136–142 (2013).

New detector array at **HIγS**

- 4 high resolution HPGe detectors
- 7 high efficiency LaBr detectors

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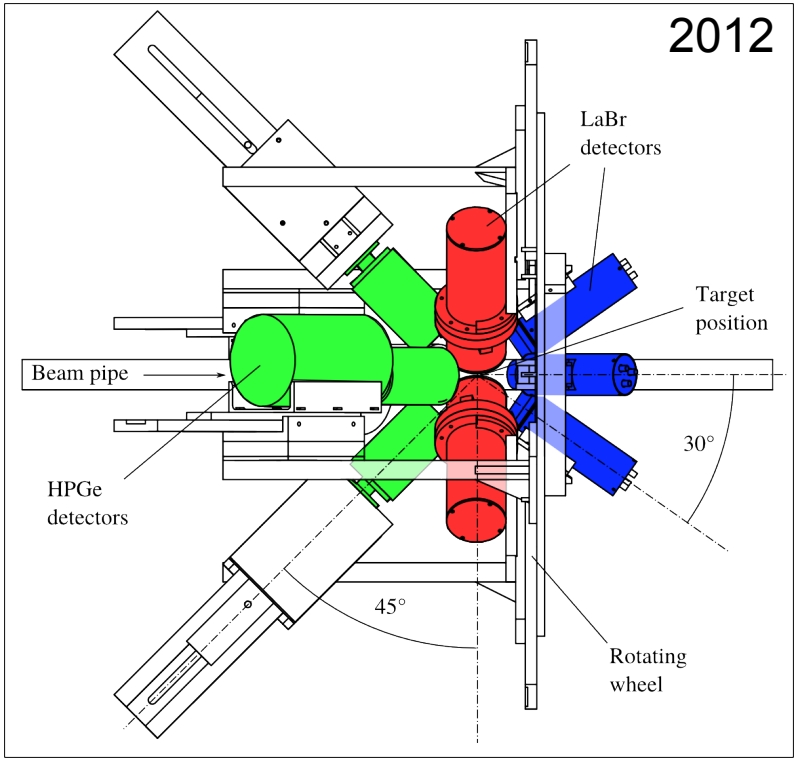

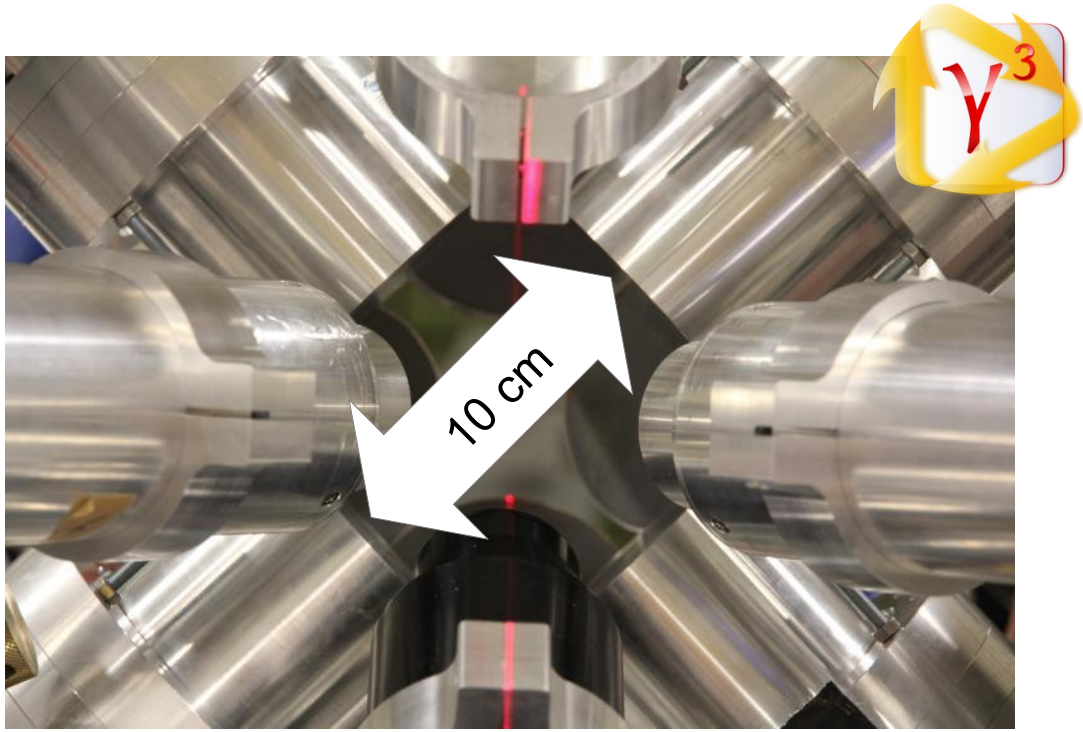

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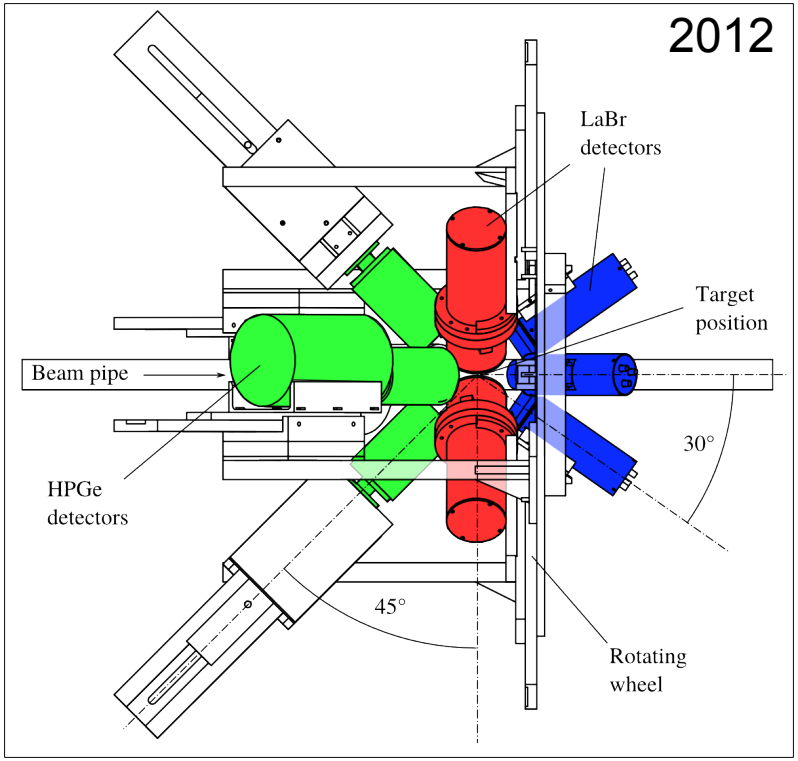

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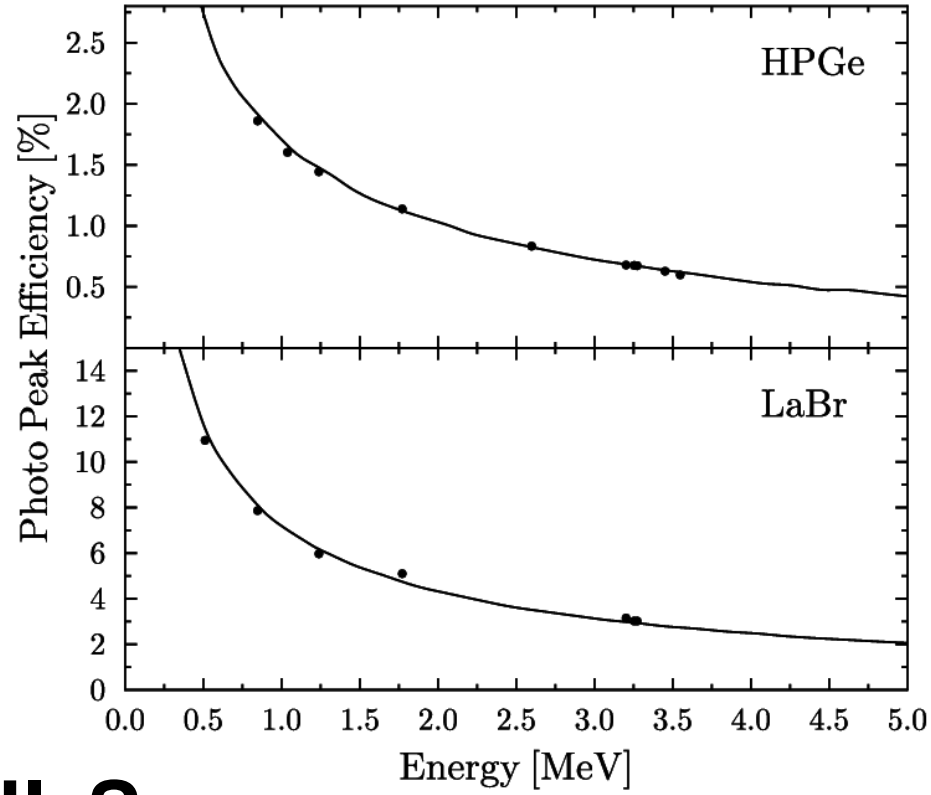
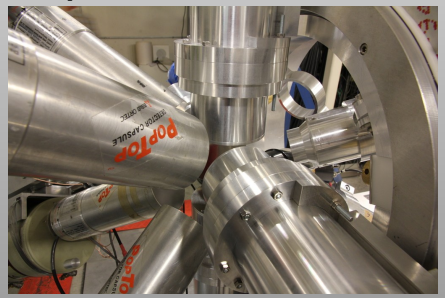


New detector array at **HIγS**

- Total efficiency: >7% @ 1.3 MeV (LaBr+HPGe)

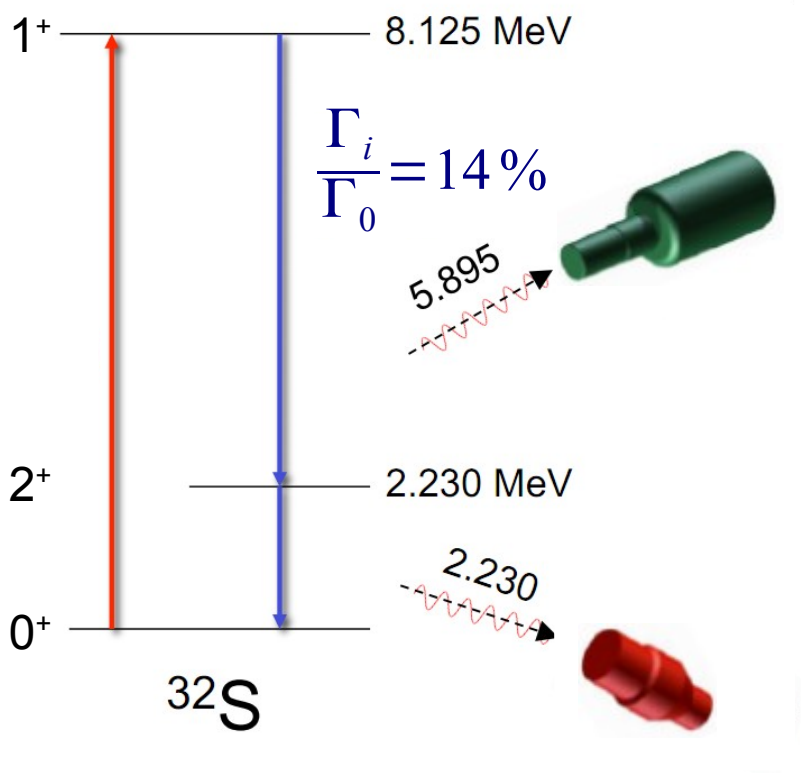
Experiments

Experiment



- Commissioning phase 2012 (^{32}S)
- Experimental Campaign 2012
- Experimental Campaign 2013

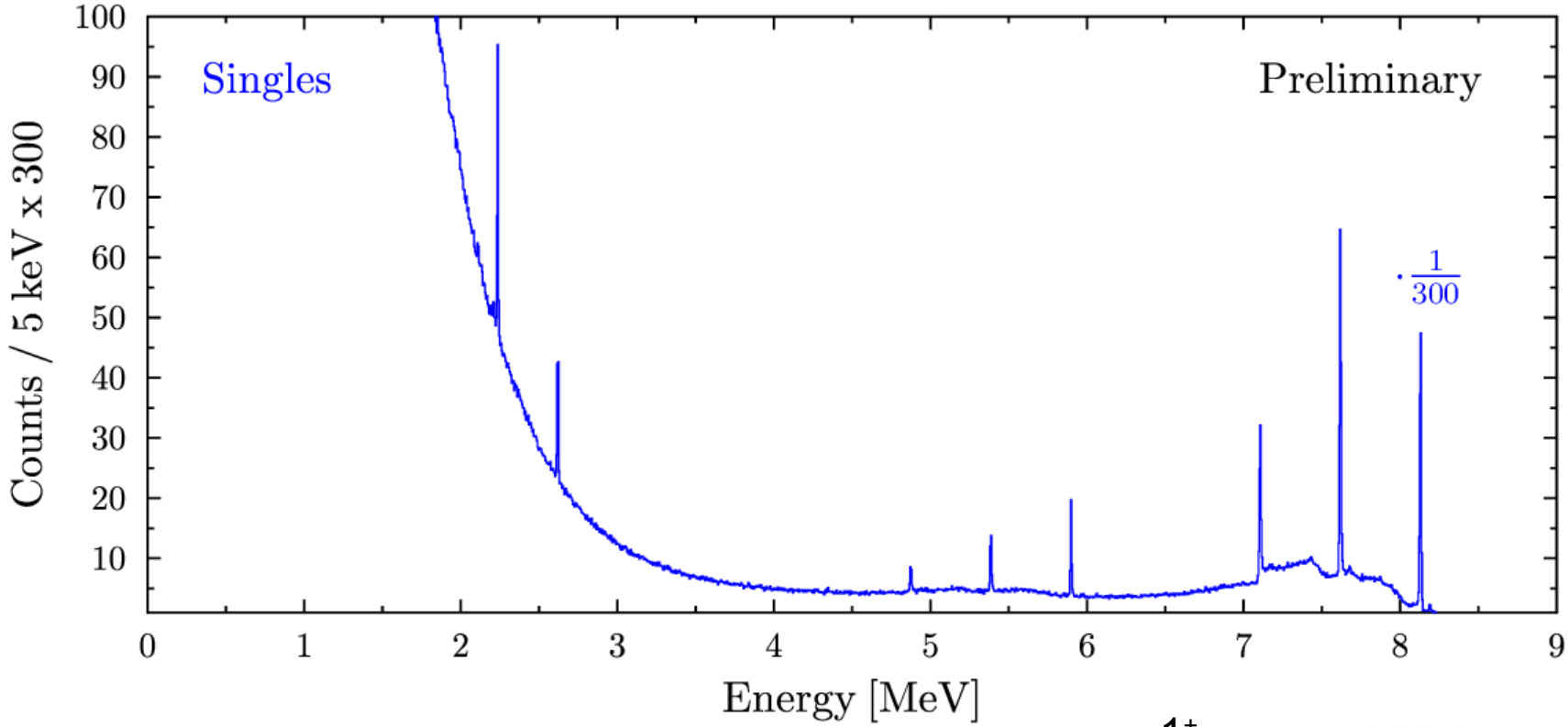
Setup Commissioning

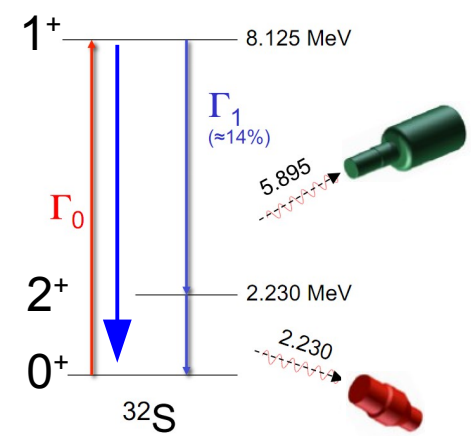


Detectors:
4x HPGe (60%)
+ 4x 3“x3“ LaBr

- Target: ^{32}S @ 8.125 MeV beam energy
- Beam on Target: 4 h

Setup Commissioning





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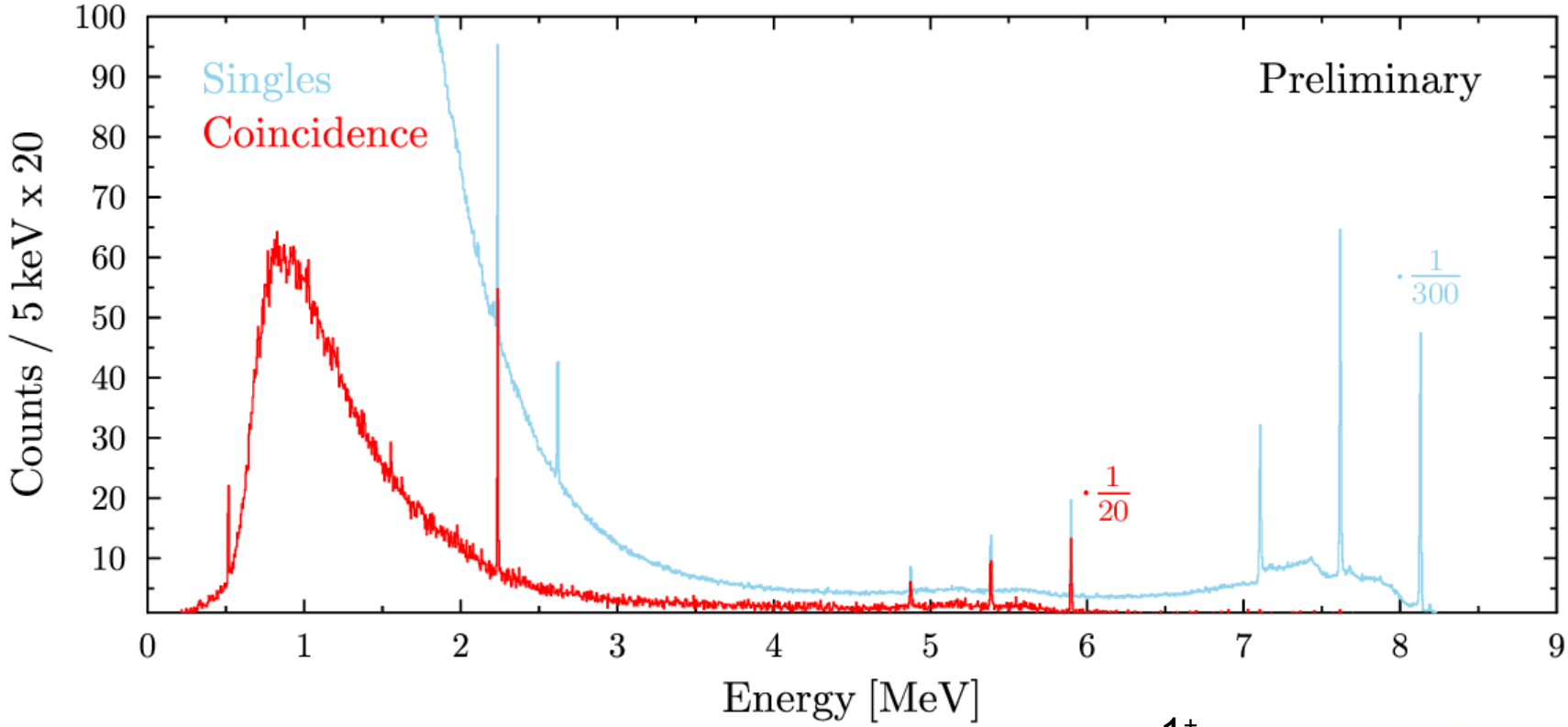

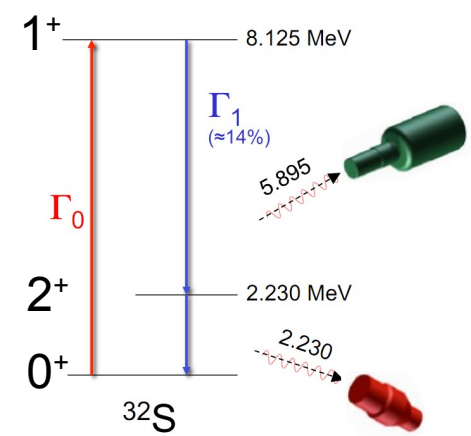

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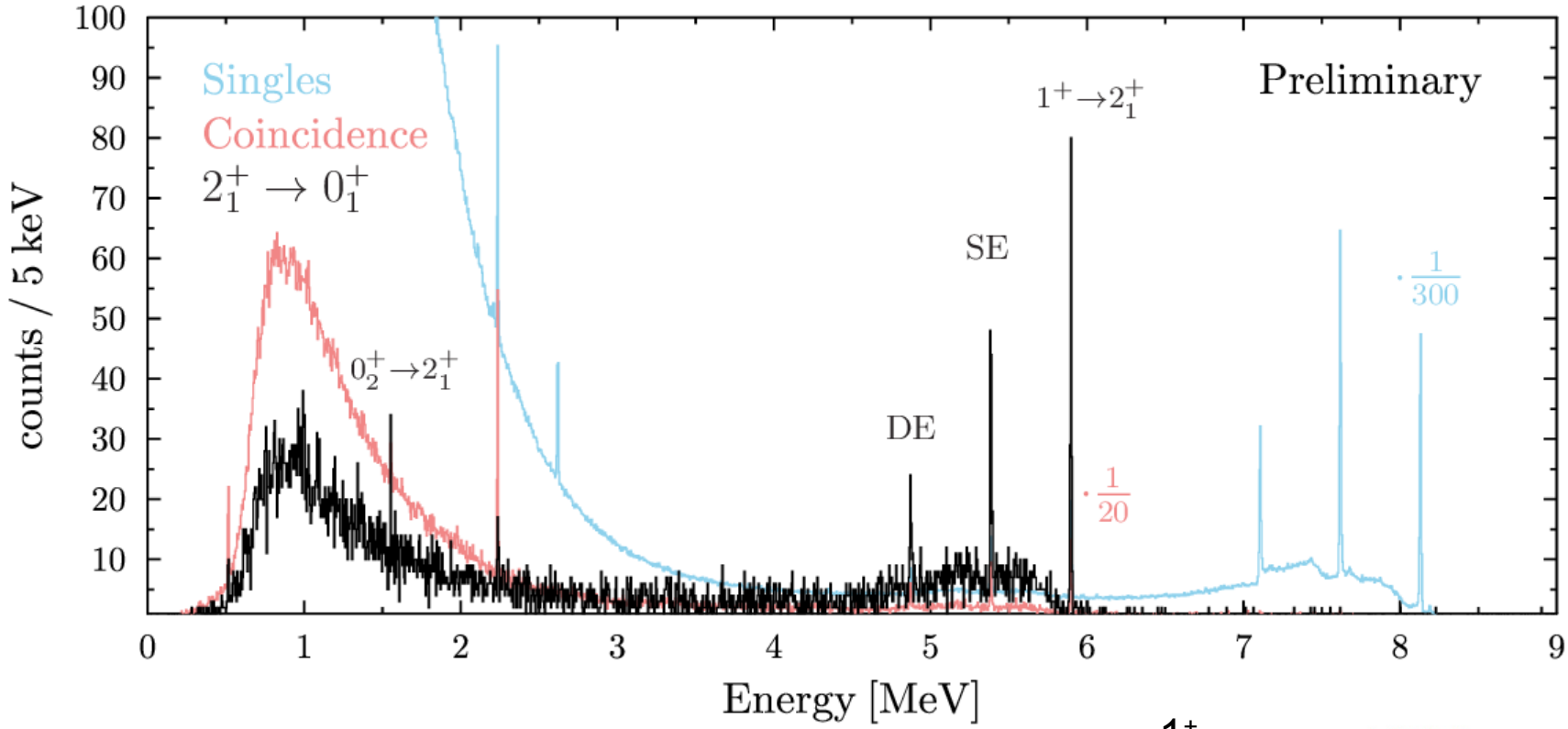
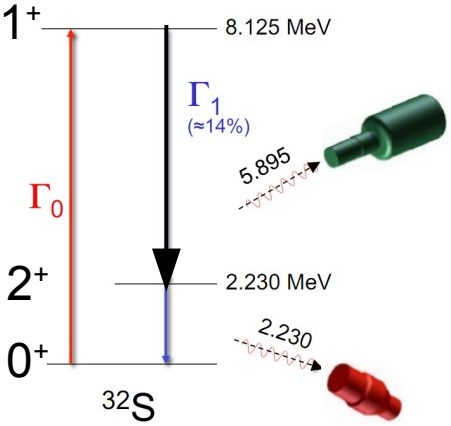


Peak to Background:

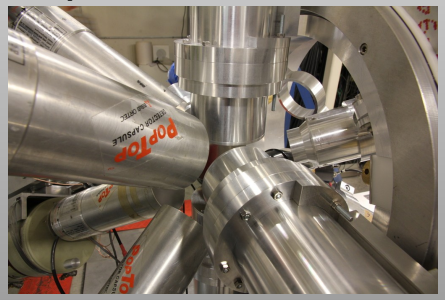
2230 keV
- Singles: 0.197(3)
- Energy Cut: 9.6(15)

5894 keV
- Singles: 1.03(2)
- Energy Cut: 11.7(13)



Experiments

Experiment



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Experiments

Beam time 2012:

- 700 h of beam time in 5+1 weeks
- Investigated 7+3 nuclei:
- ^{124}Sn, ^{140}Ce, ^{76}Ge, ^{40}Ca, ^{156}Gd + ^{240}Pu, ^{233}U, ^{32}S

Beam time 2013:

- >700 h of beam time in 8 weeks
- Investigated 9+2 nuclei:
  - ^{128}Te, ^{152,156}Gd, ^{140}Ce, ^{92,94}Zr, ^{206}Pb, ^{162,164}Dy + ^{11}B, ^{32}S

Goals:

- Parities, Decay of Scissors Mode and PDR, Measurement of the PSF, 2 phonon state

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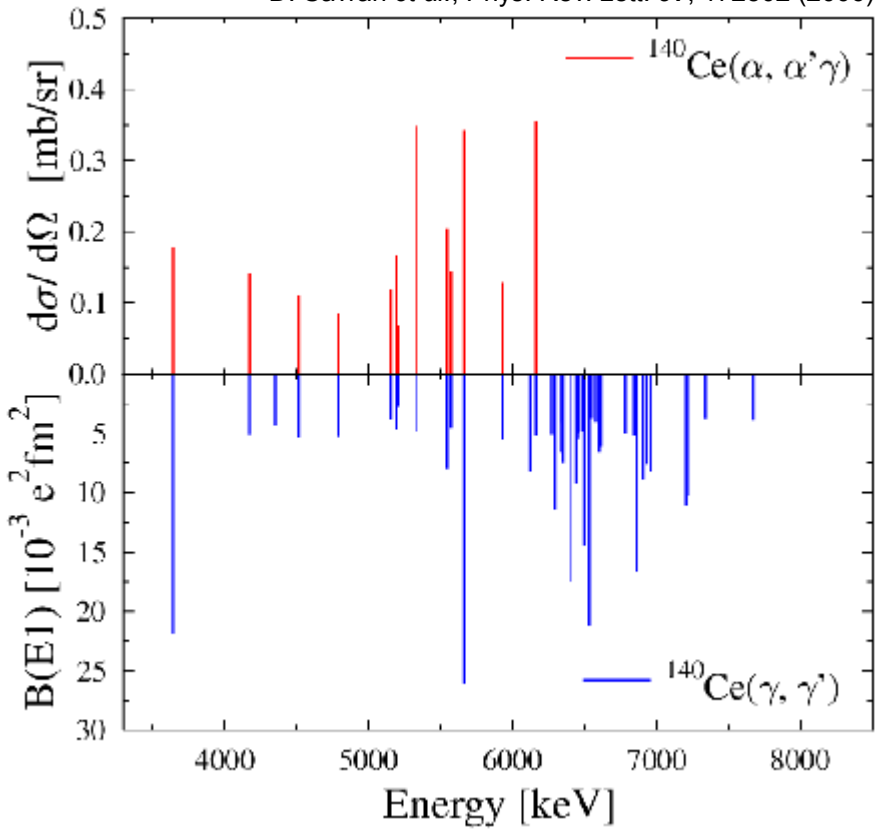
^{140}Ce (γ,γ')

D. Savran *et al.*, Phys. Rev. Lett. **97**, 172502 (2006)



Experiment at HIγS:

- 5 days of beamtime
- 11 Beam energies (+2 in 2013)
- ~100 h beam on target
- Target: 2.35 g enriched $^{140}CeO_2$

Splitting of PDR observed with different probes
→ Decay pattern may yield additional information

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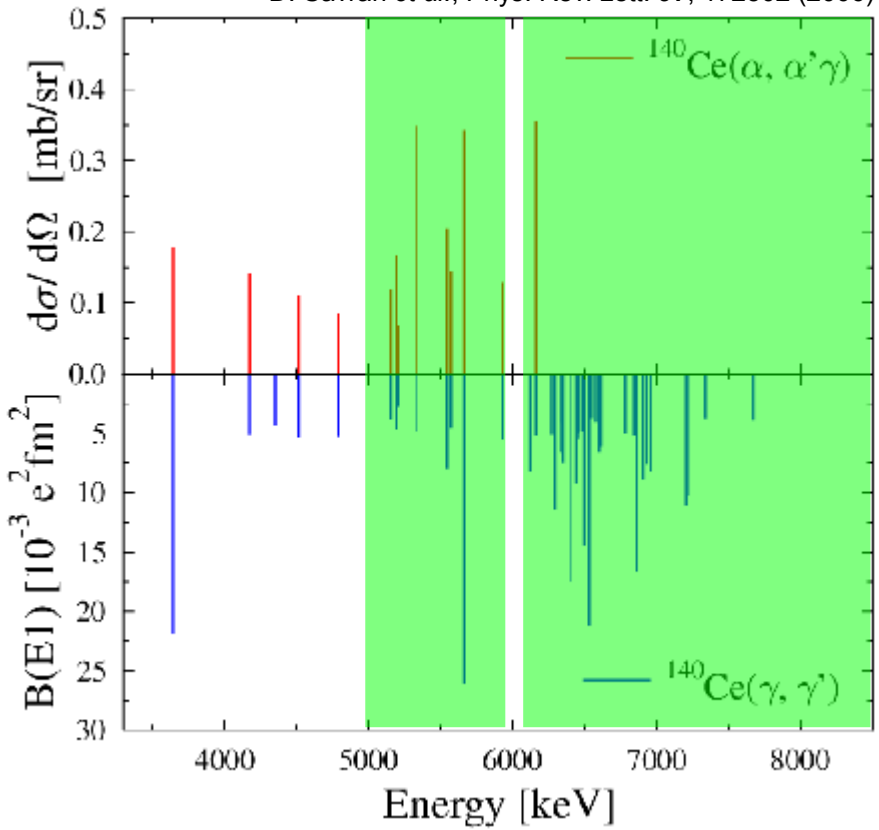

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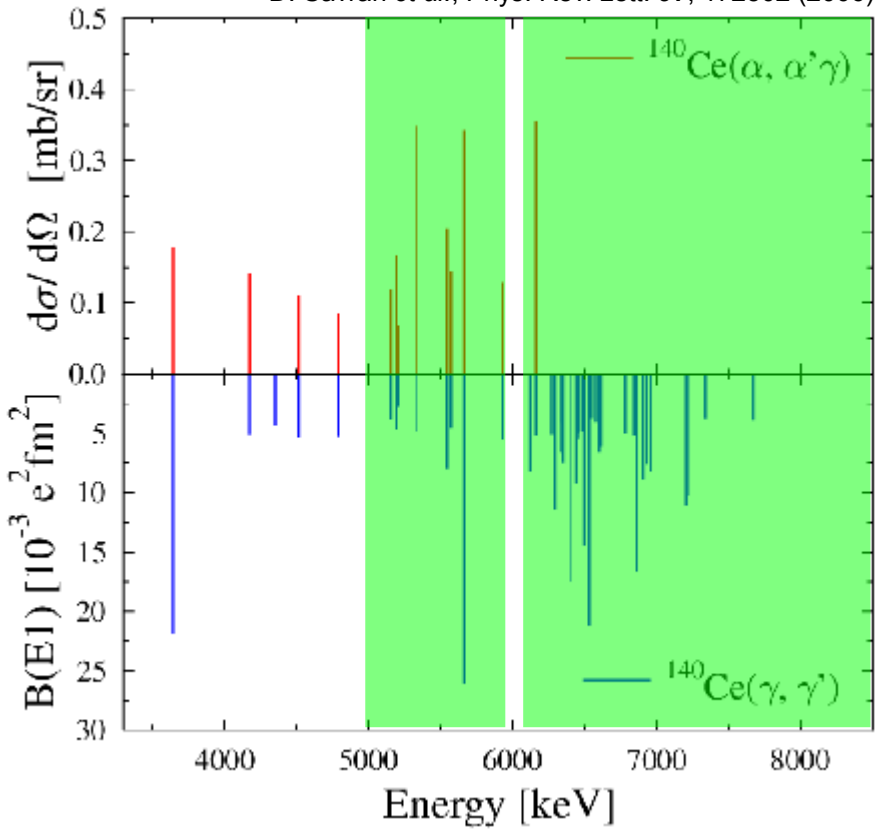

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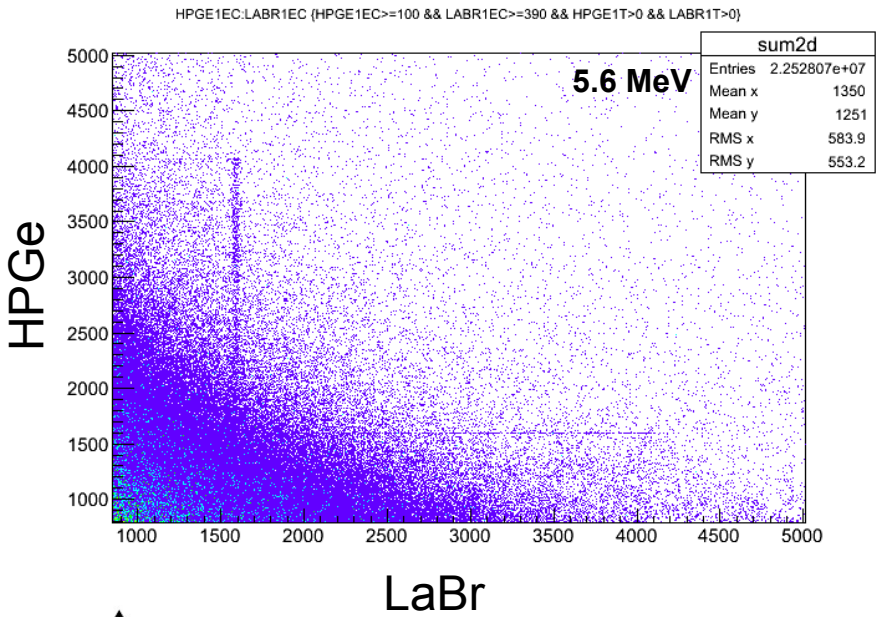
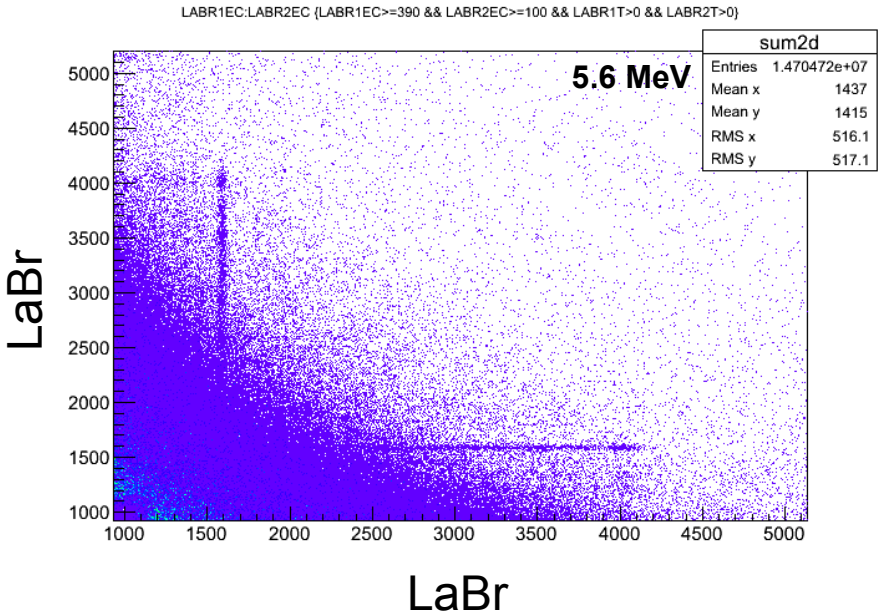
Analysis:

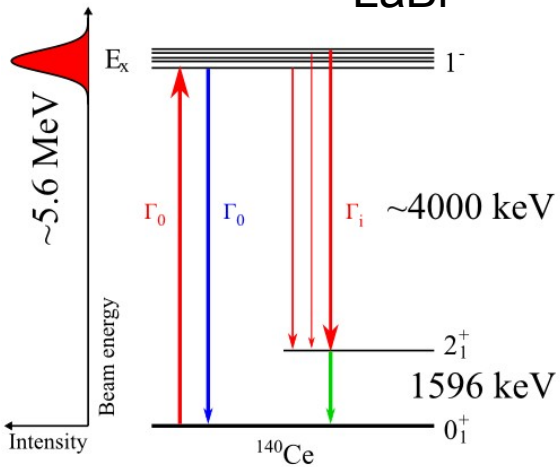
- Singles → Cross-Sections, Parities
- Coincidences → Branching Ratios

^{140}Ce (γ,γ')

Experimental data yields two matrices:







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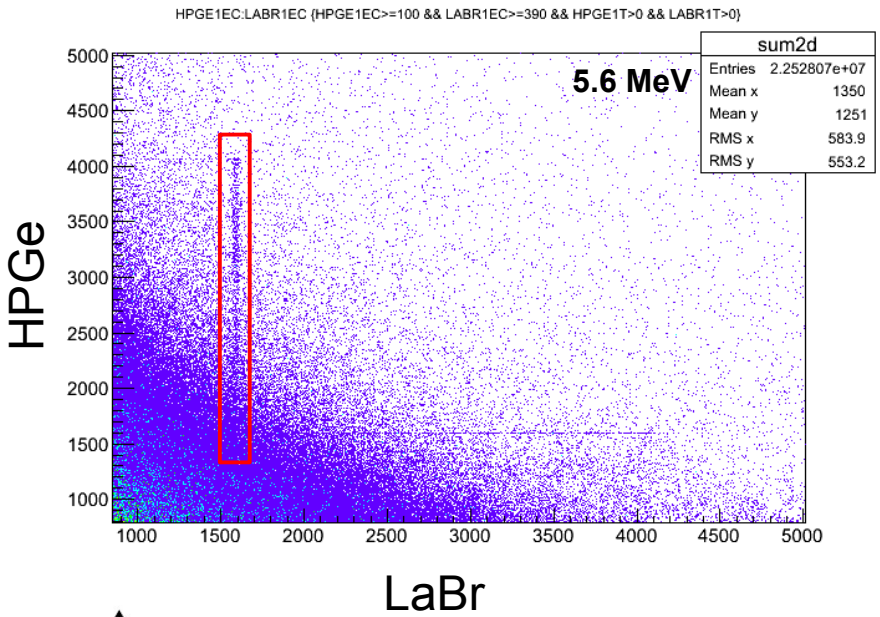

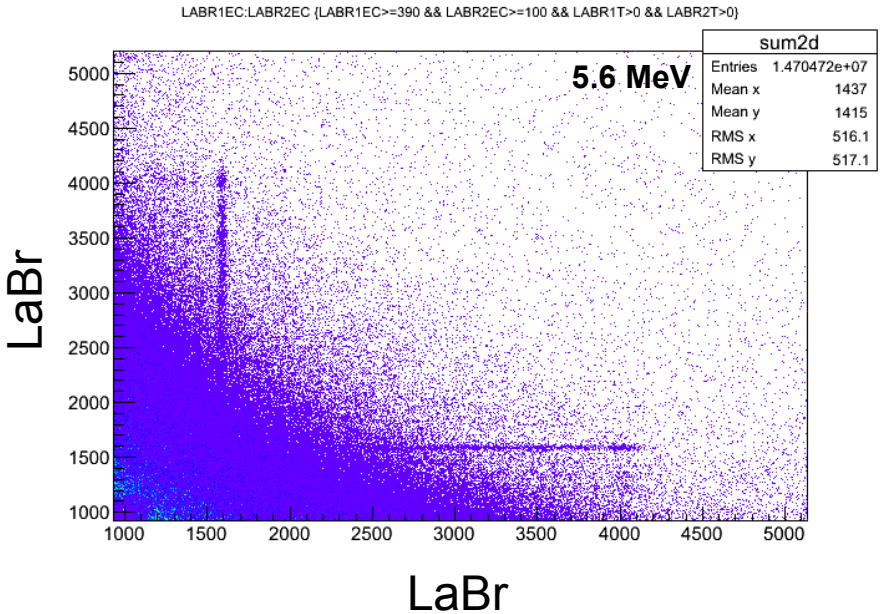

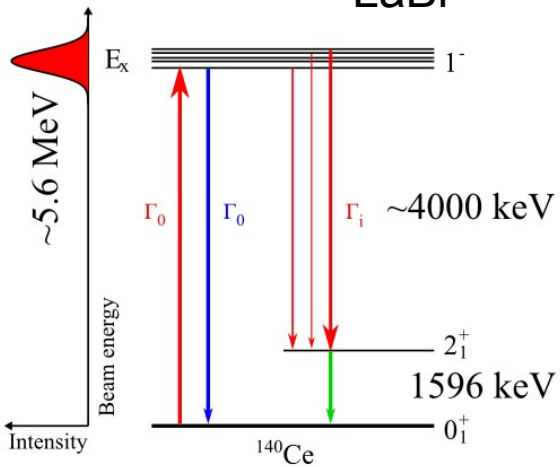

Possible analyses:

- Gate on $2^+_1 \rightarrow 0^+$ in LaBr:
  1) HPGe spectra (high resolution → single states)

^{140}Ce (γ,γ')

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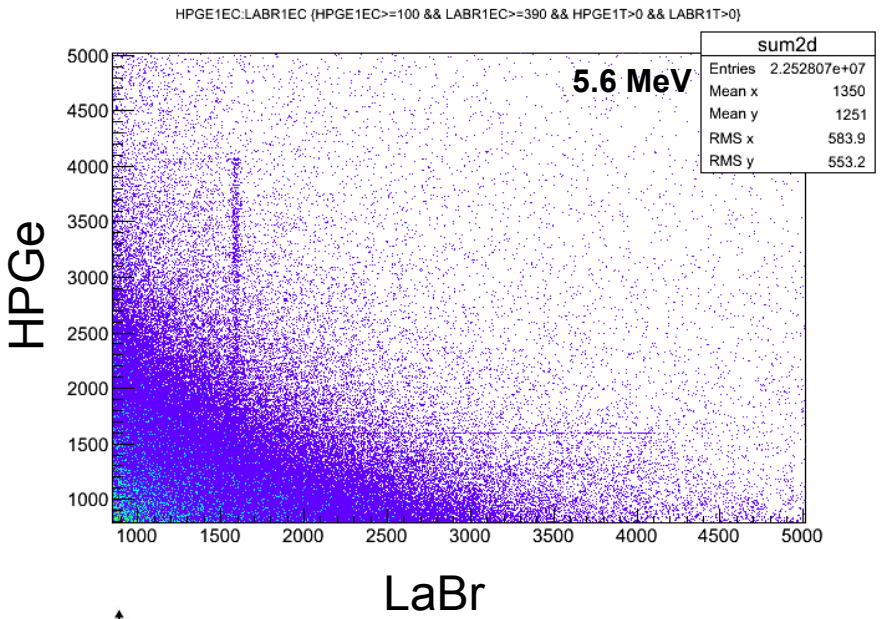

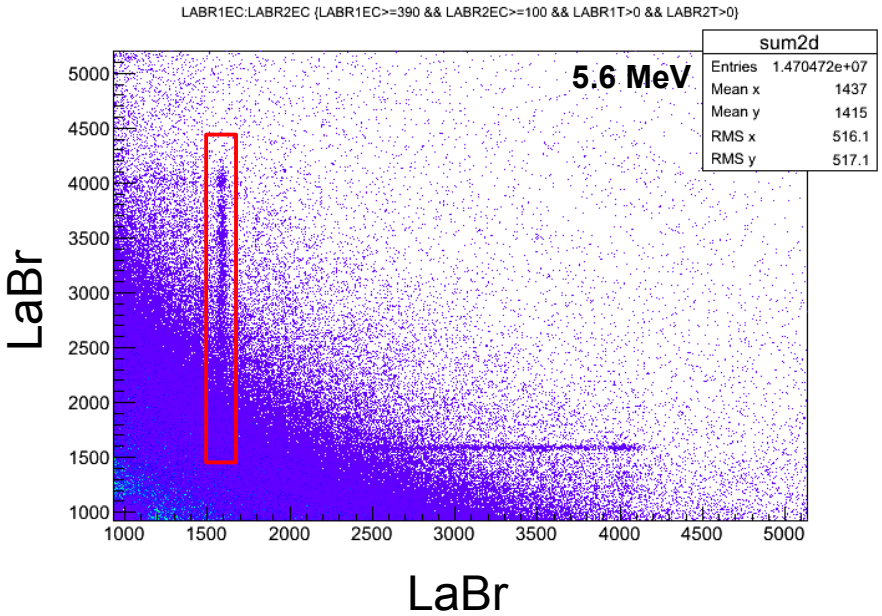

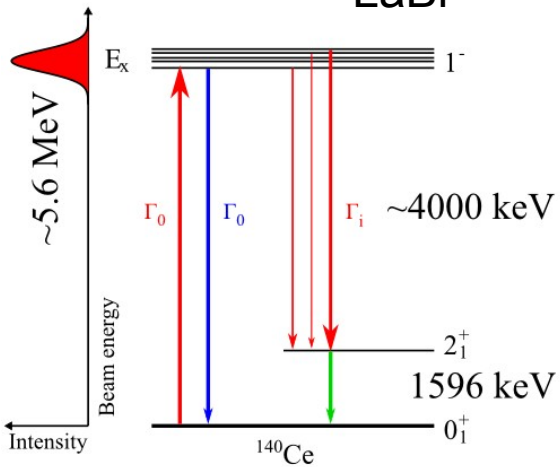

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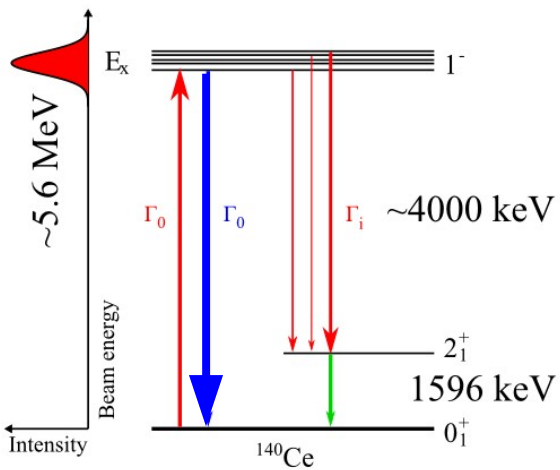
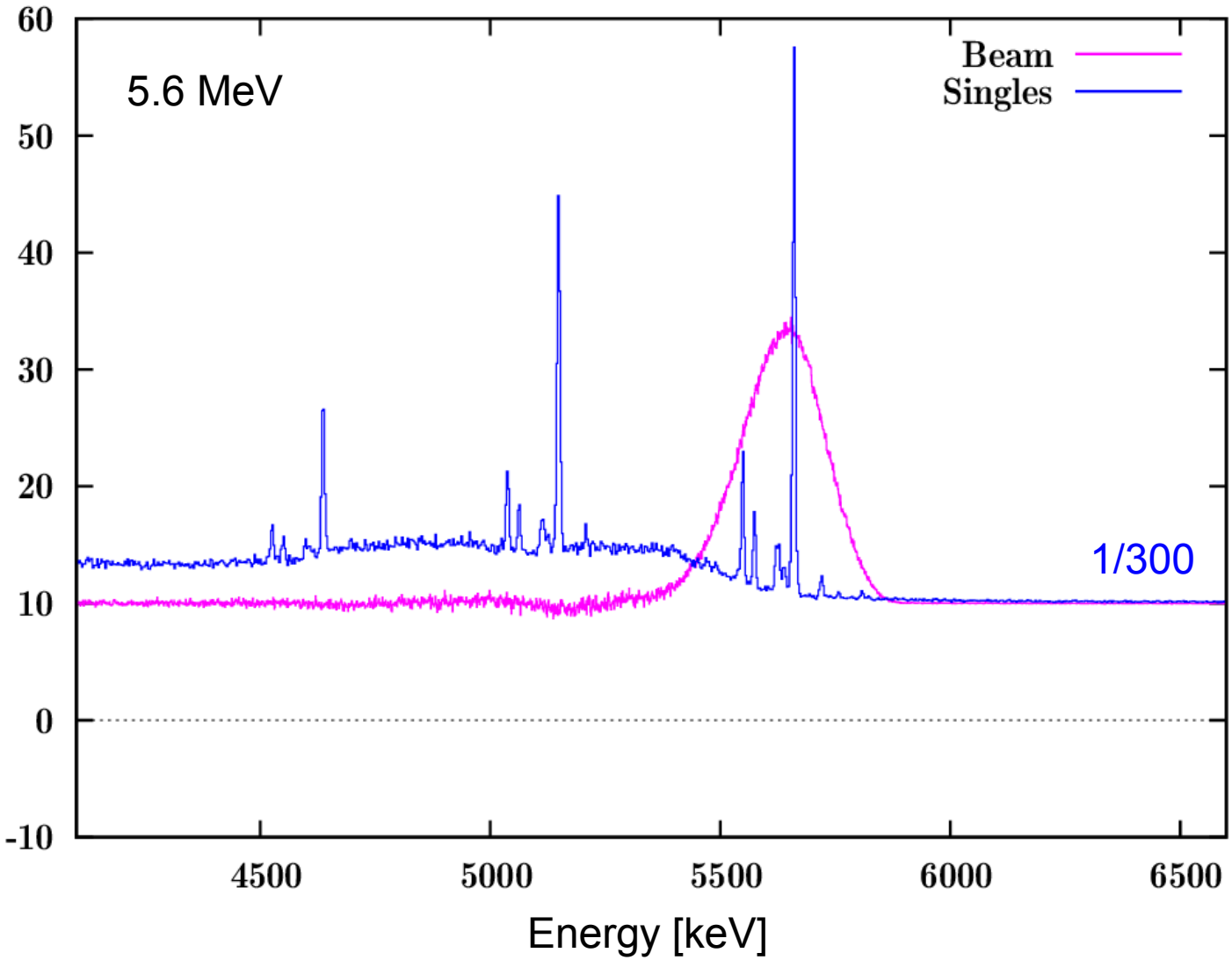
  2) LaBr spectra (better efficiency → averaged)

^{140}Ce (γ,γ')

Gate on LaBr → HPGe spectra



$E(2^+_1)$ = 1596 keV



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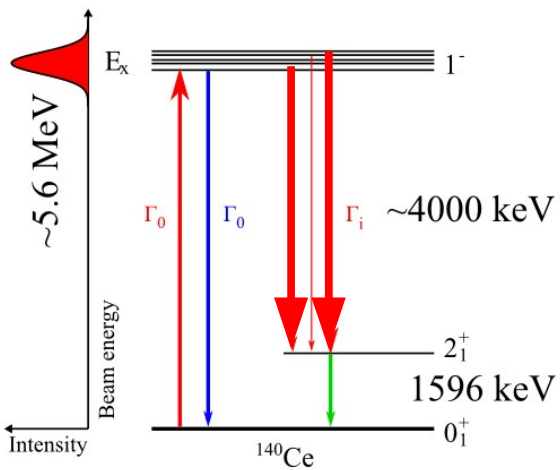

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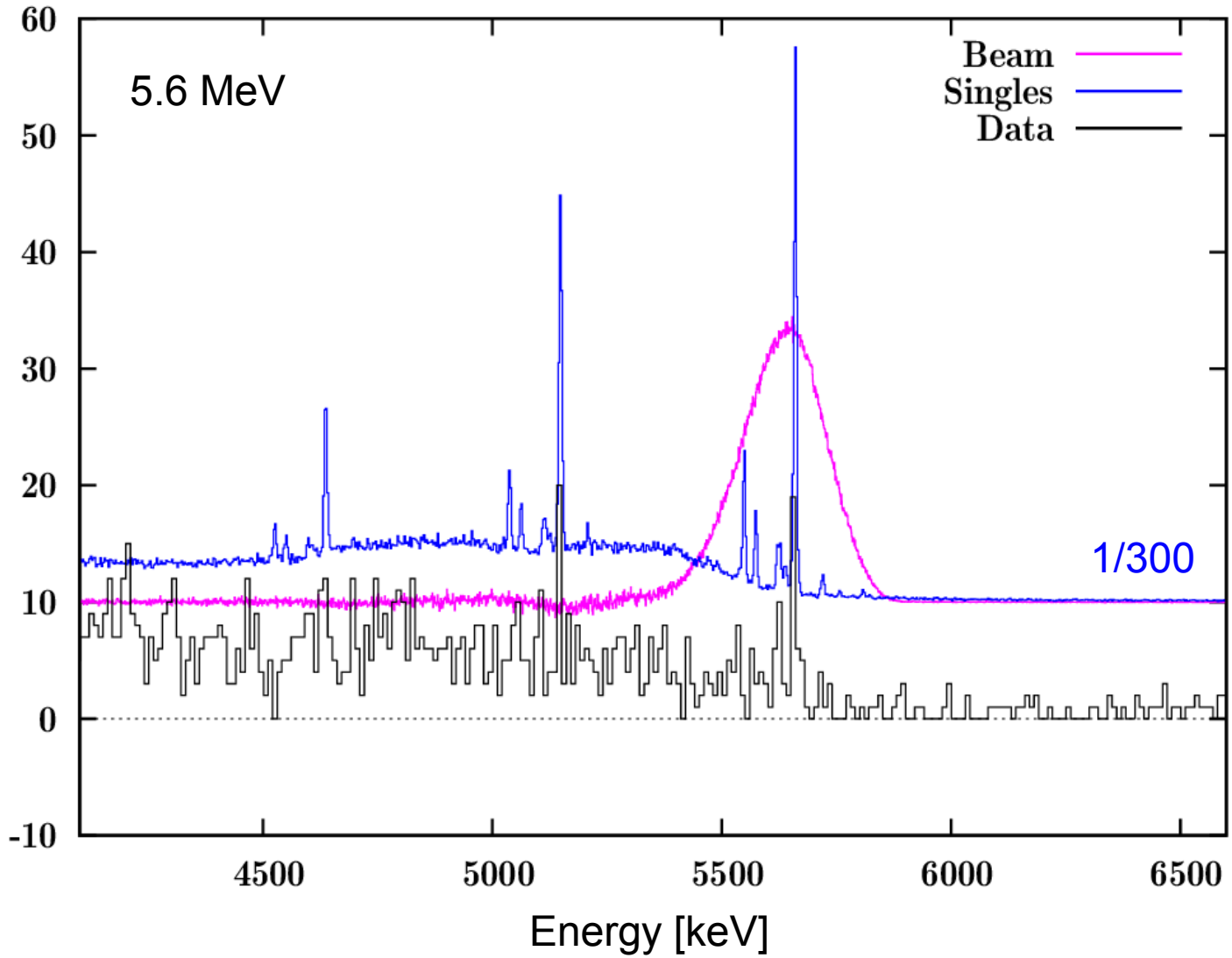

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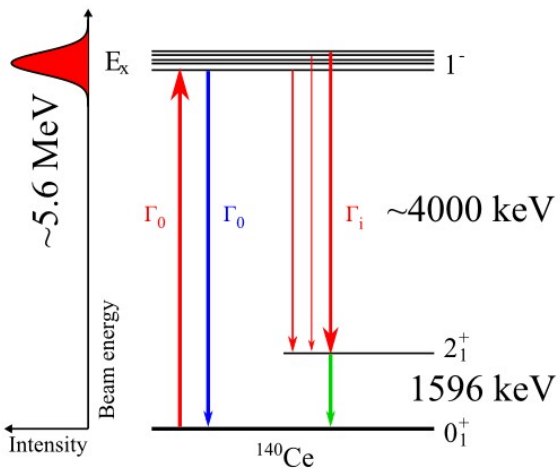

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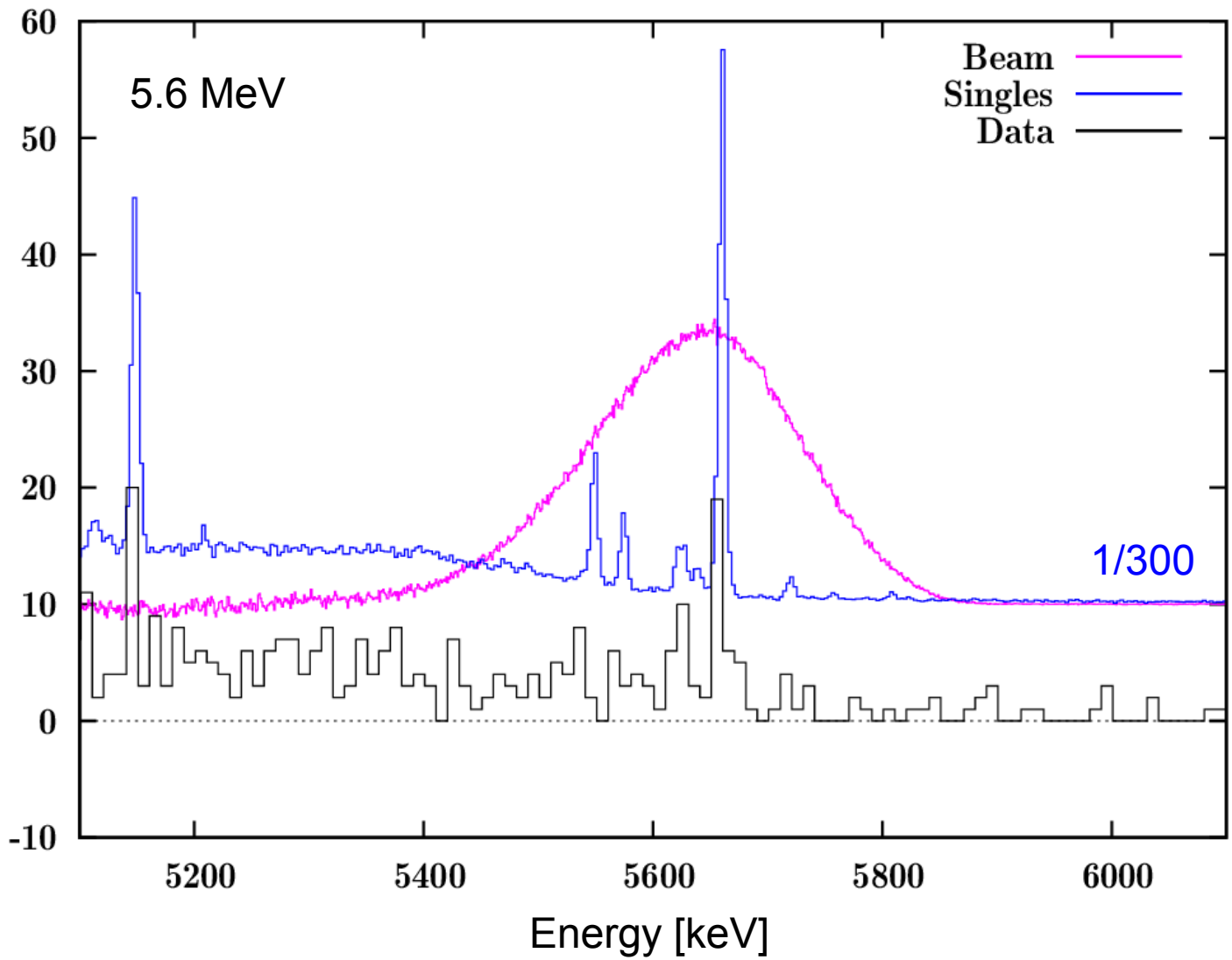
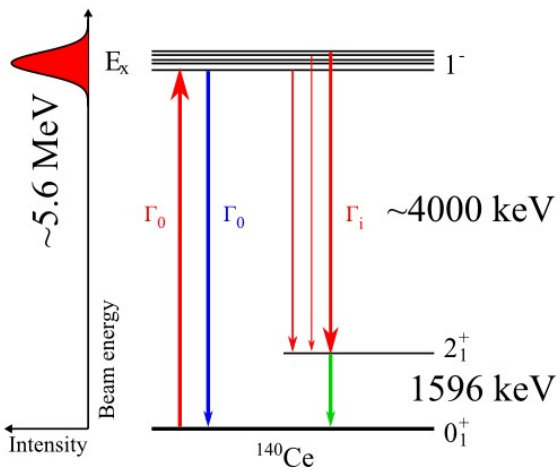
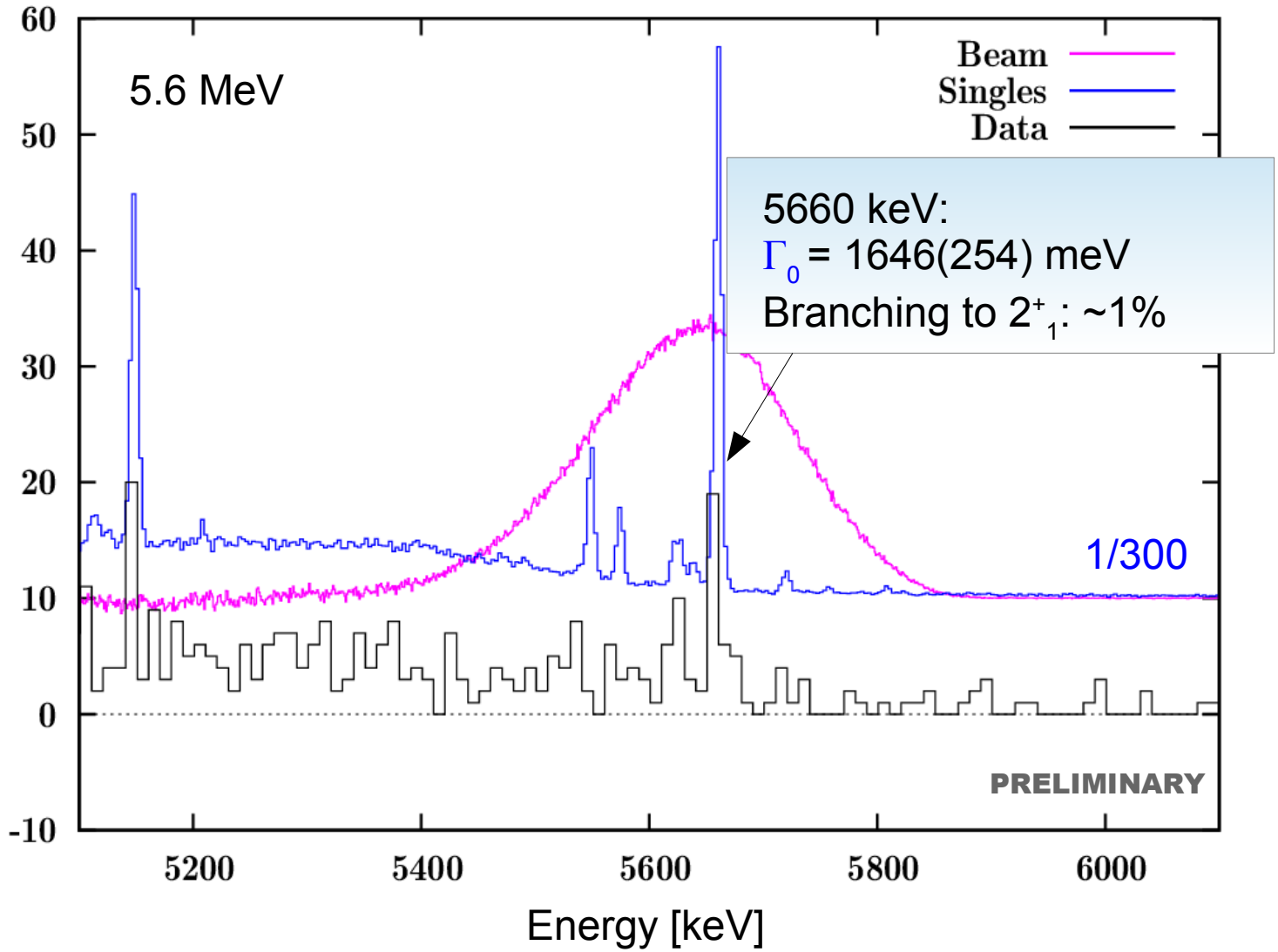


^{140}Ce (γ,γ')

Gate on LaBr → HPGe spectra

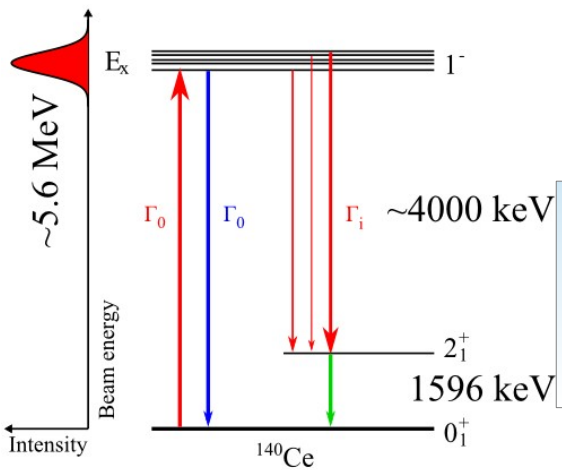


$E(2^+_1)$ = 1596 keV

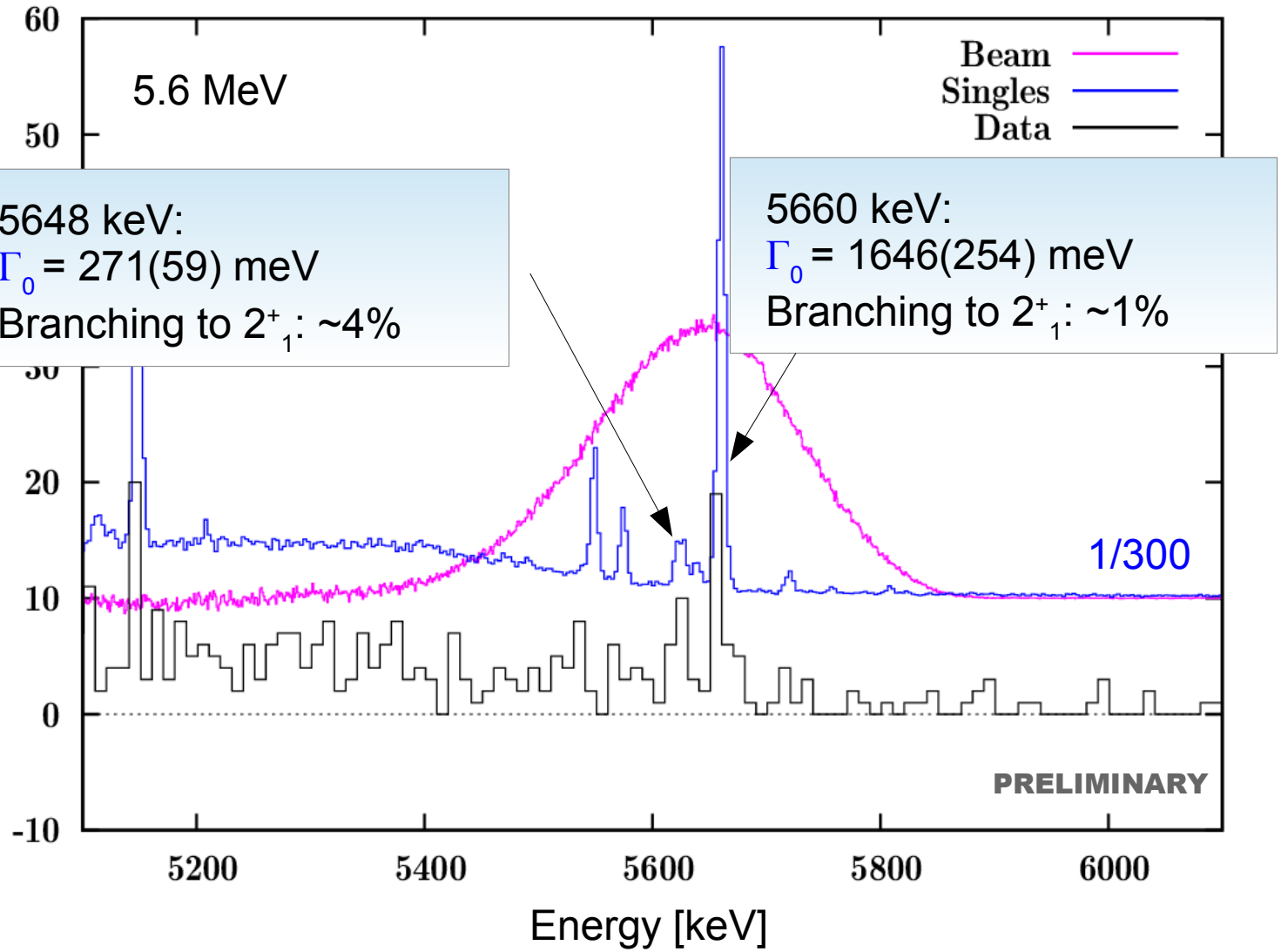


^{140}Ce (γ,γ')

Gate on LaBr → HPGe spectra



$E(2^+_1)$ = 1596 keV

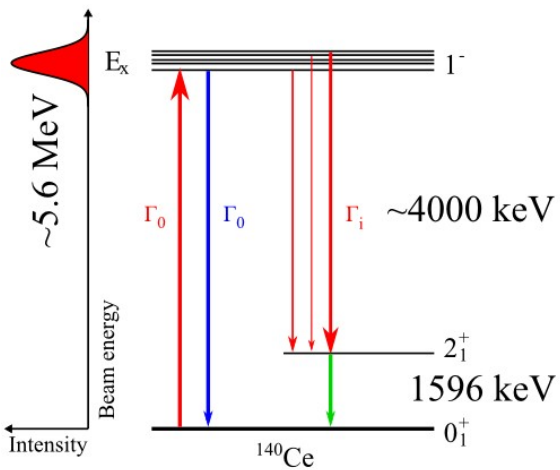


5648 keV:
Γ_0 = 271(59) meV
Branching to 2^+_1: ~4%

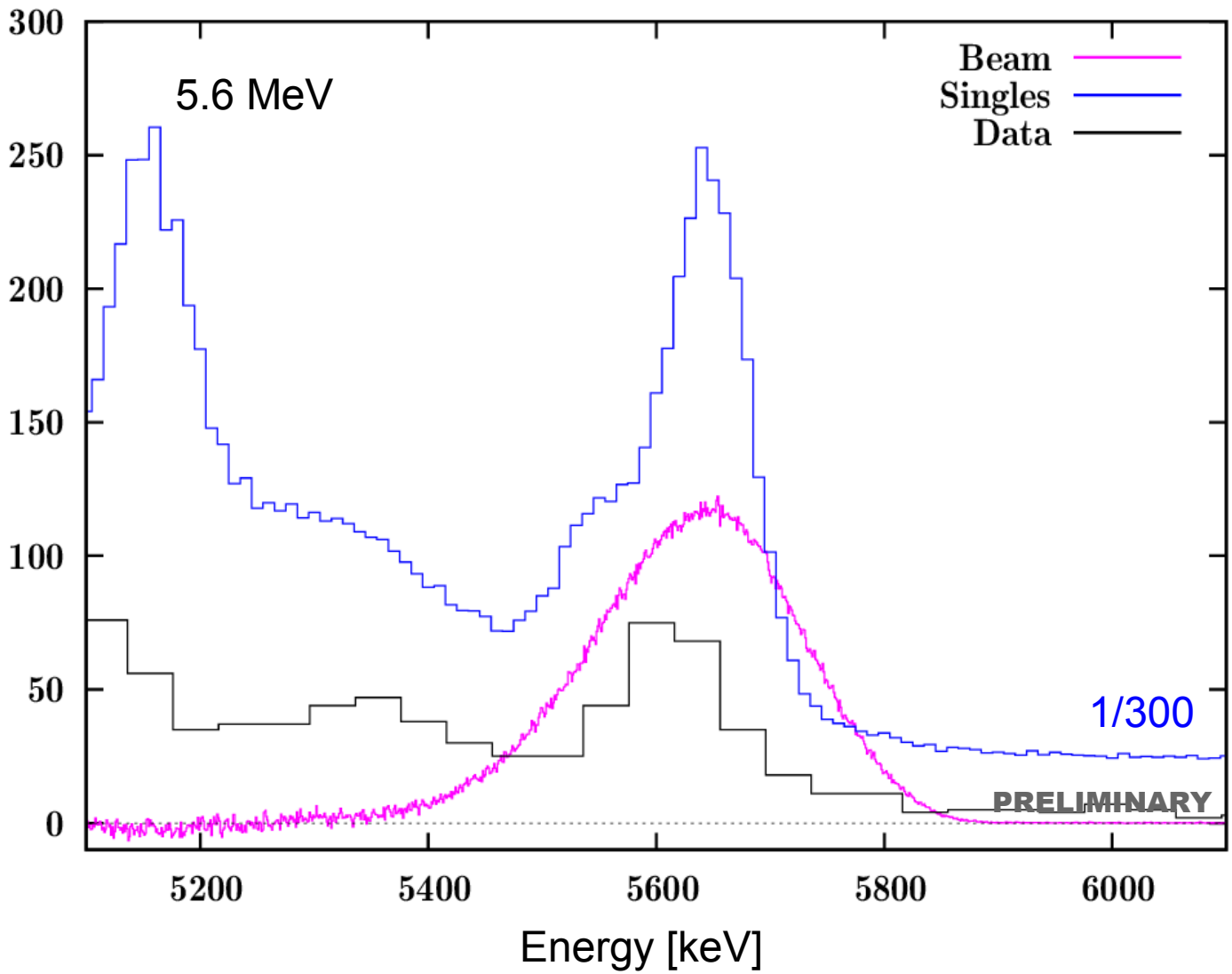
5660 keV:
Γ_0 = 1646(254) meV
Branching to 2^+_1: ~1%

^{140}Ce (γ,γ')

Gate on LaBr → LaBr spectra

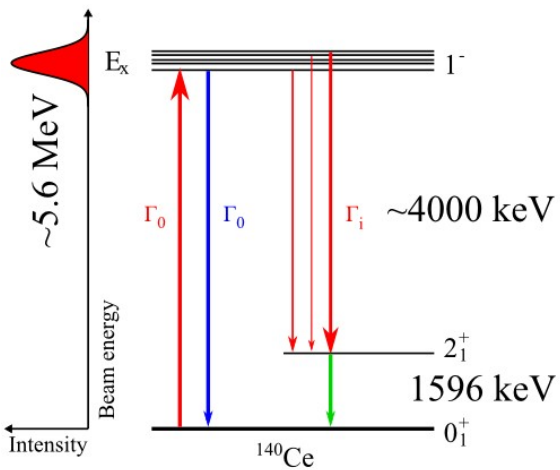


$E(2^+_1)$ = 1596 keV

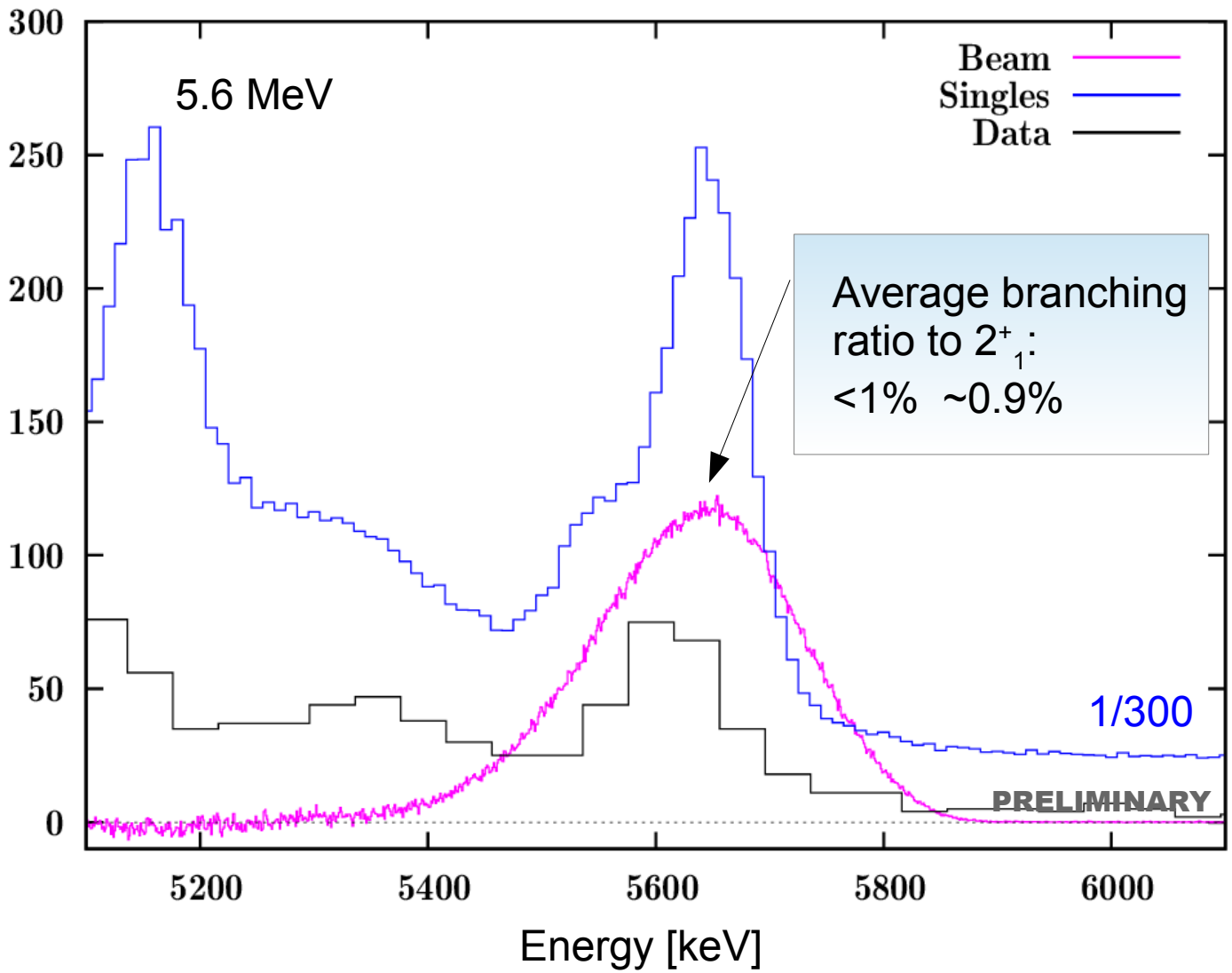


^{140}Ce (γ,γ')

Gate on LaBr → LaBr spectra

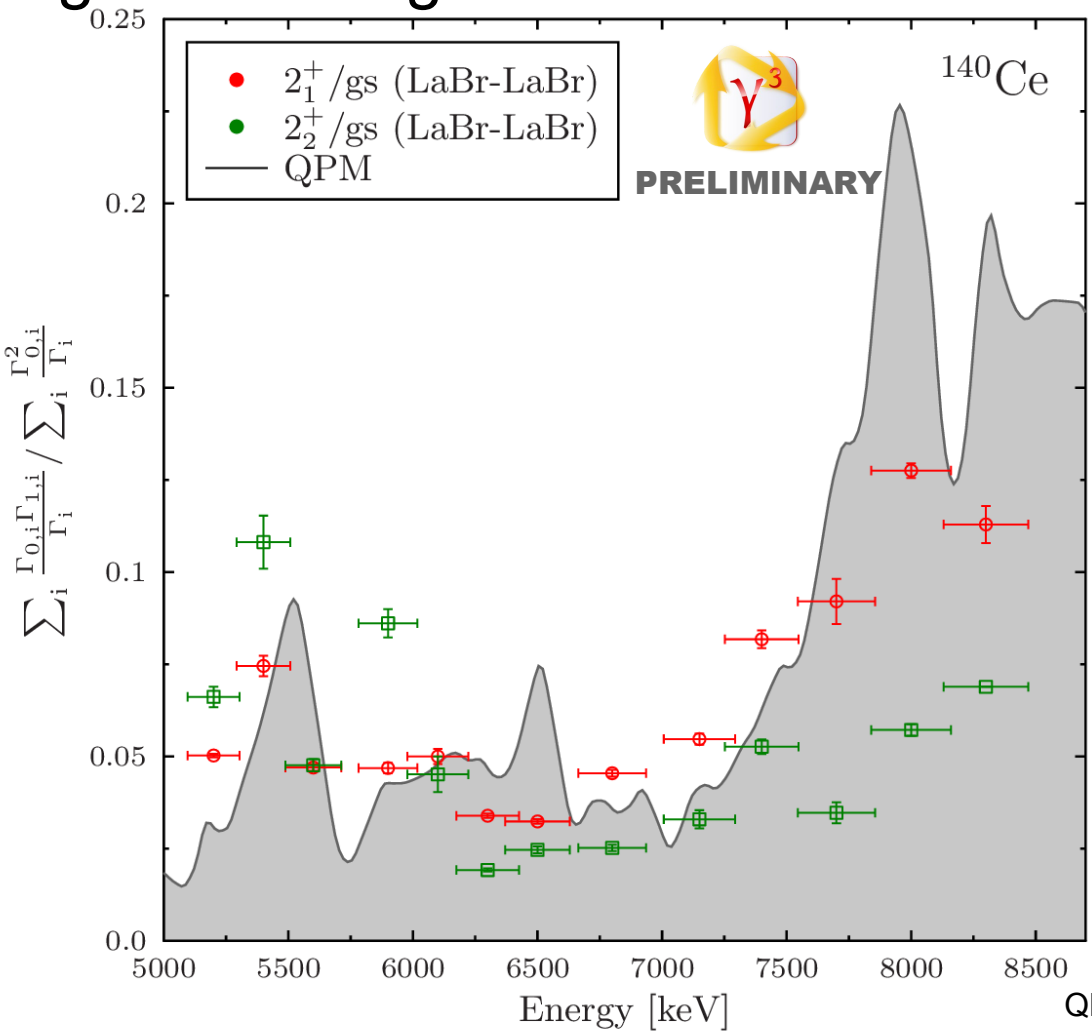


$E(2^+_1)$ = 1596 keV



^{140}Ce (γ,γ')

Average branching ratio to first excited states



Only statistical errors

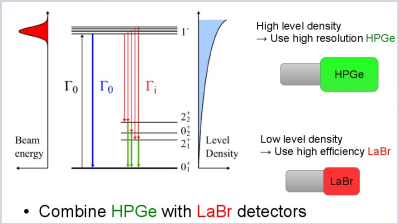
QPM: V.Yu. Ponomarev, priv. comm.

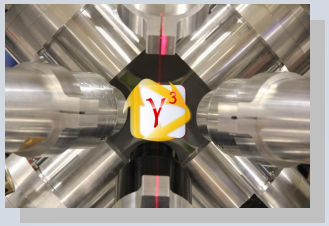
^{140}Ce (γ,γ')

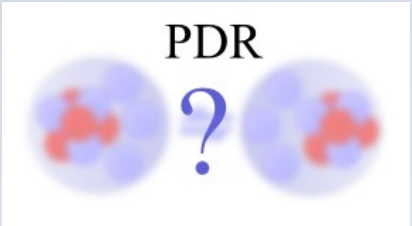
- Determine branching ratios of single states (Sensitivity 1-5%)
- Average branching ratios (Sensitivity ~1%)

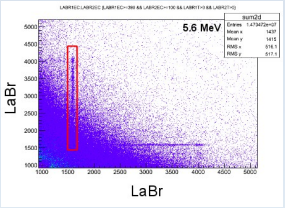
Summary

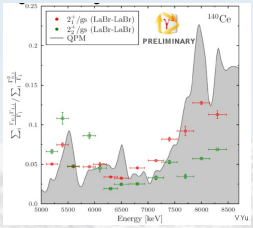
- γ-γ coincidence method to increase sensitivity for weak transitions
- The new γ^3 setup at HIγS
- Commissioning with ^{32}S
- PDR in ^{140}Ce
- Analysis of coincidences
- Now possible to measure Single and Average branching ratios,
  → Good agreement with QPM



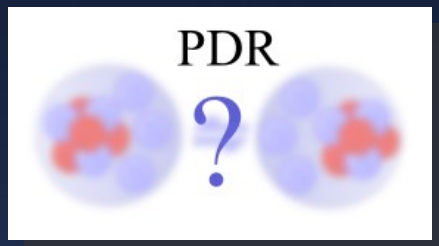


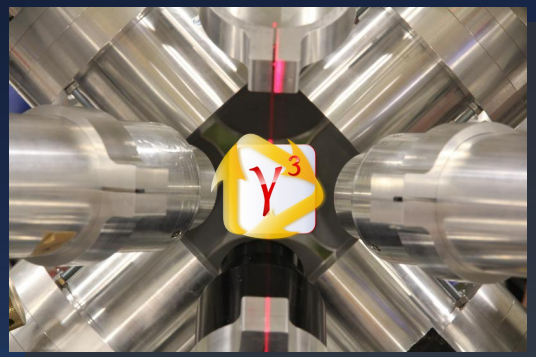


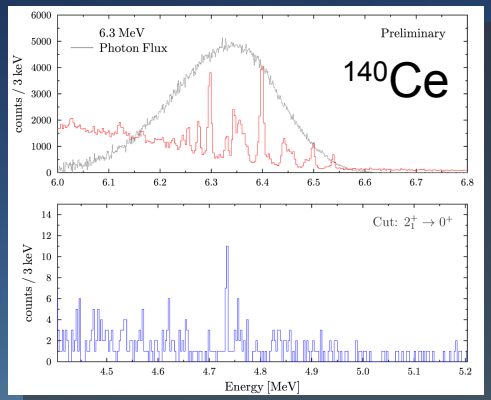




γ³ Collaboration

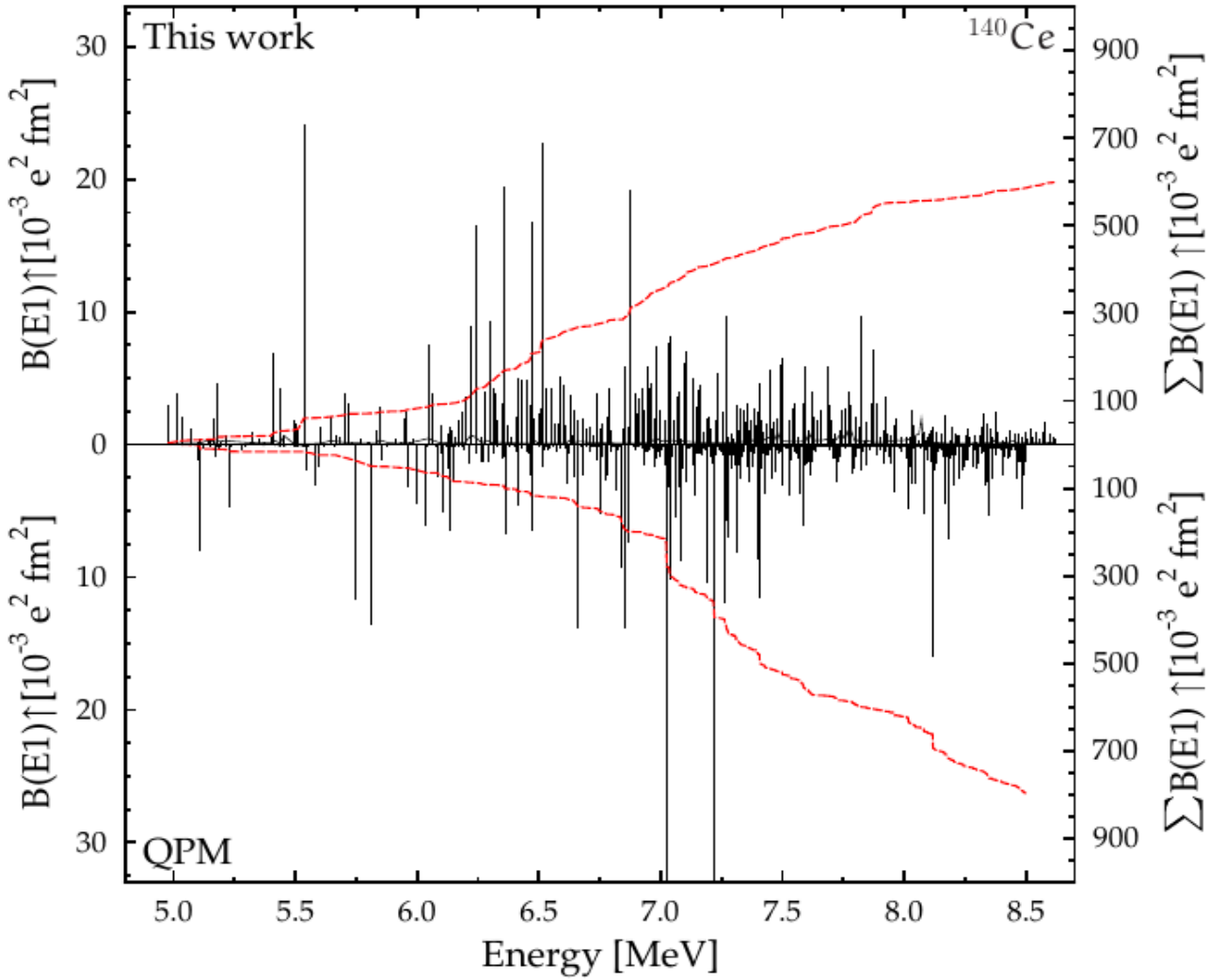


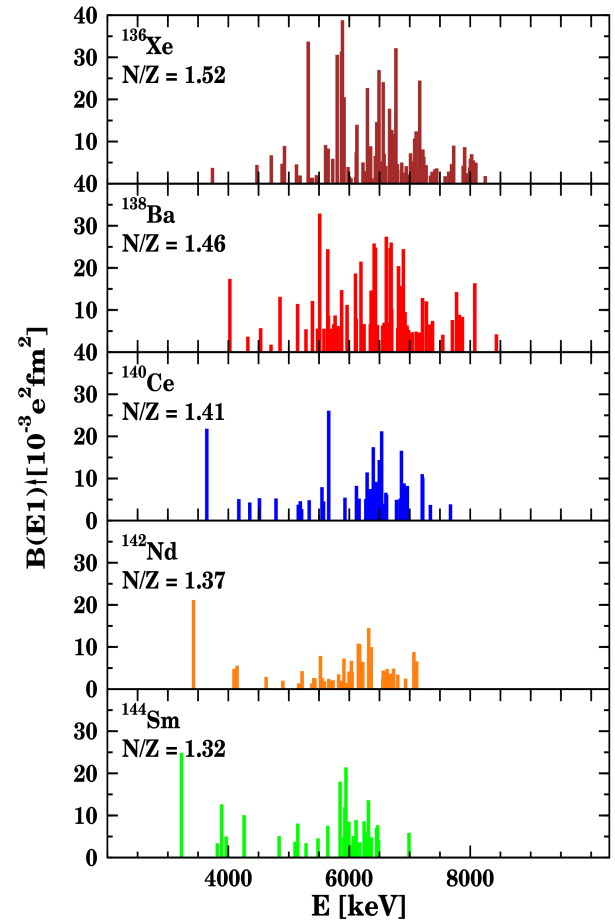




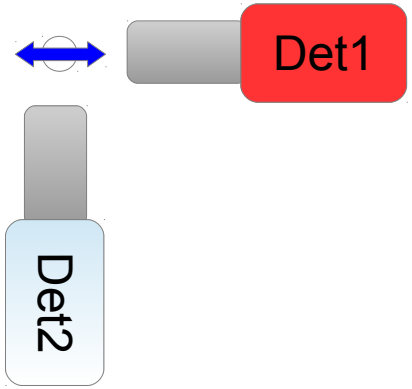
- **EMMI/GSI**
  - B.Löher, E.Fiori, J.Isaak, D.Savran, J.Silva
- **TU Darmstadt**
  - T.Aumann, J.Beller, M.Duchêne, M.Knörzer, N.Pietralla, M.Scheck, H.Scheit
- **Universität zu Köln (Cologne)**
  - V.Derya, J.Endres, A.Zilges
- **HIγS (Duke University)**
  - M.Bhike, M.Gooden, J.Kelley, A.Tonchev, W.Tornow, H.Weller
- **Yale University**
  - N.Cooper, P.Humby, V.Werner

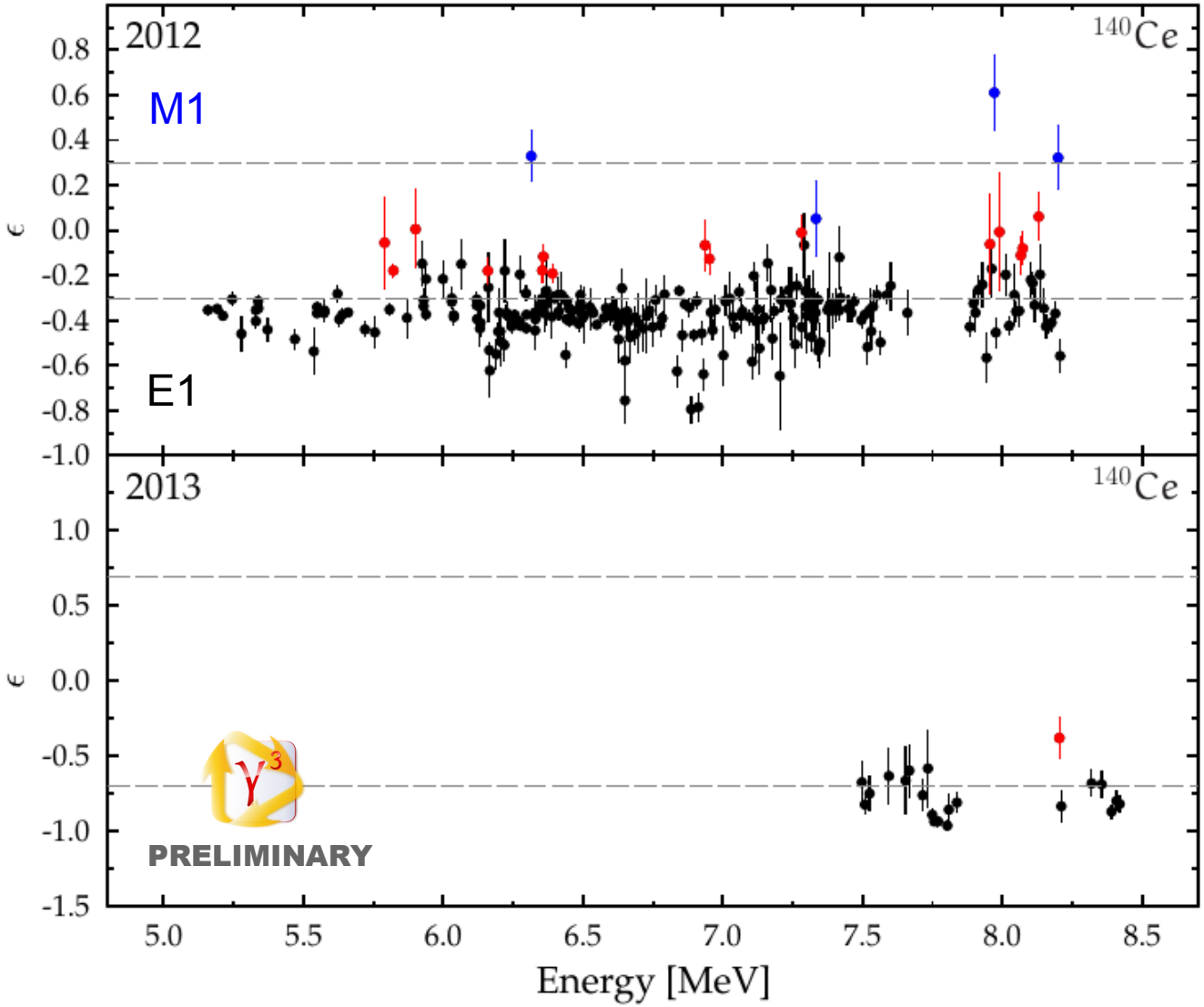
^{140}Ce B(E1)


This work
^{140}Ce
QPM
B(E1)↑[10^{-3} e^2 fm^2]
∑B(E1)↑[10^{-3} e^2 fm^2]
Energy [MeV]

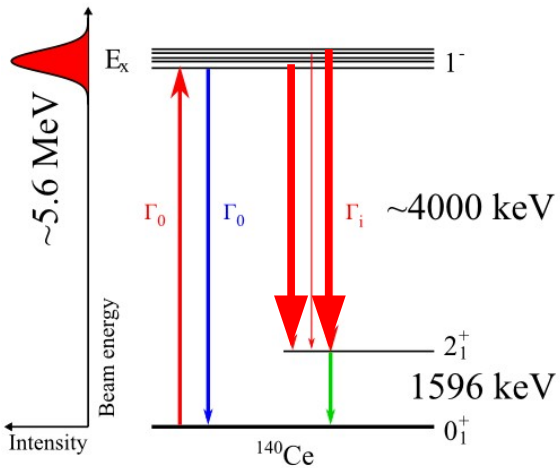

^{136}Xe
N/Z = 1.52
^{138}Ba
N/Z = 1.46
^{140}Ce
N/Z = 1.41
^{142}Nd
N/Z = 1.37
^{144}Sm
N/Z = 1.32
B(E1)↑[10^{-3} e^{2}fm^2]
E [keV]

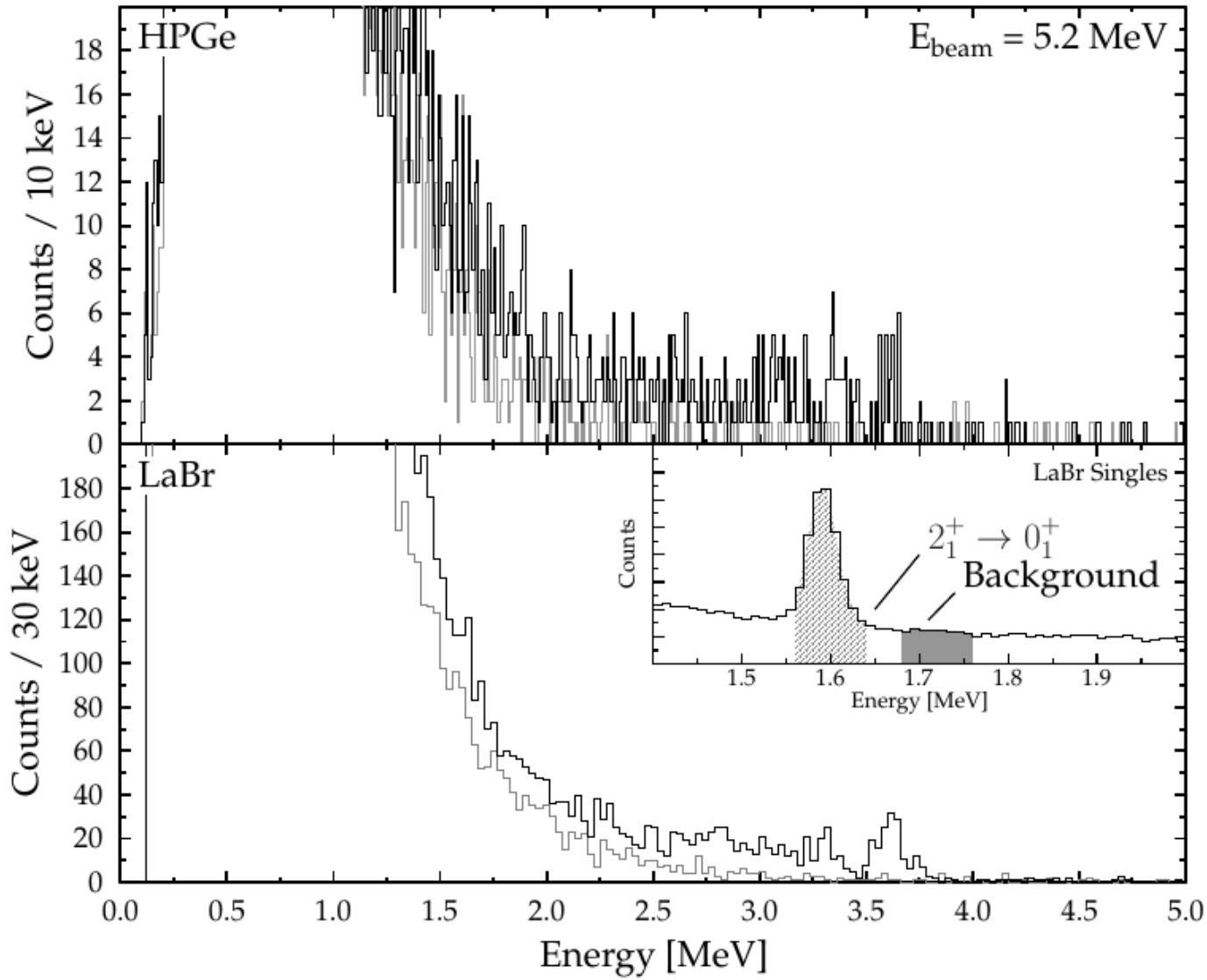
^{140}Ce Parities





^{140}Ce Energy Gate





^{140}Ce LaBr Unfolded