Gamma decay of ISGQR excited in ^{208}Pb by proton inelastic scattering

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IFJ PAN Kraków

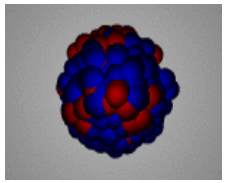
The 7th International Conference on Collective Motion in Nuclei under Extreme Conditions (COMEX7)

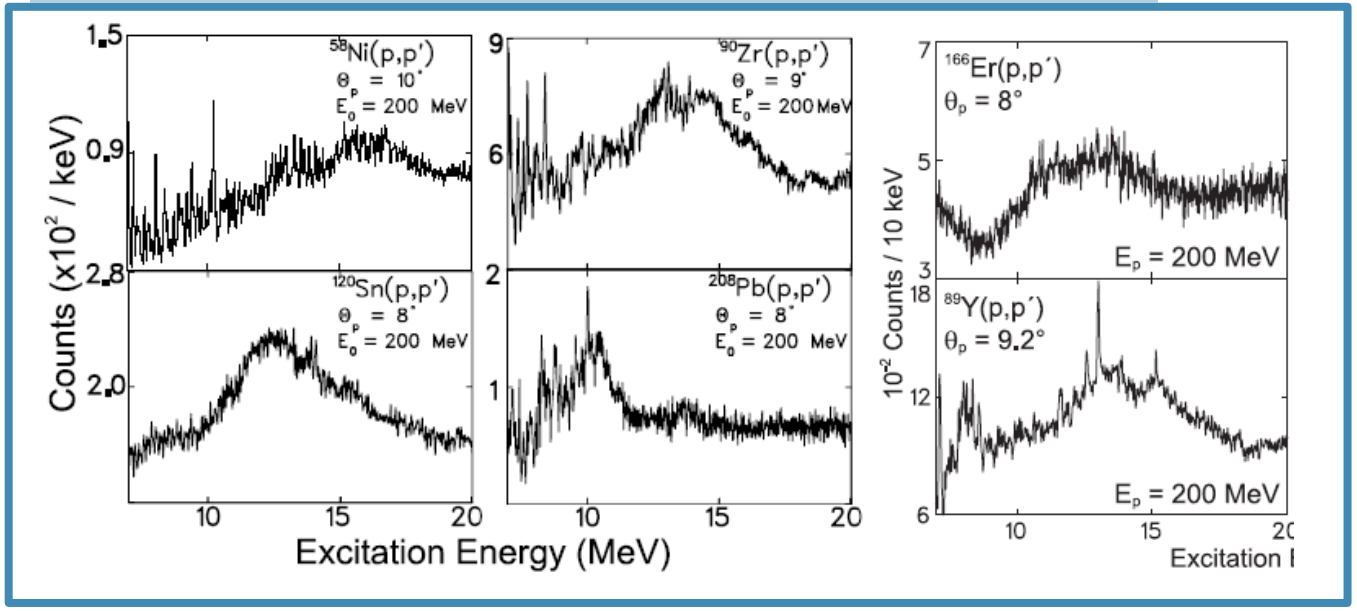
Outline

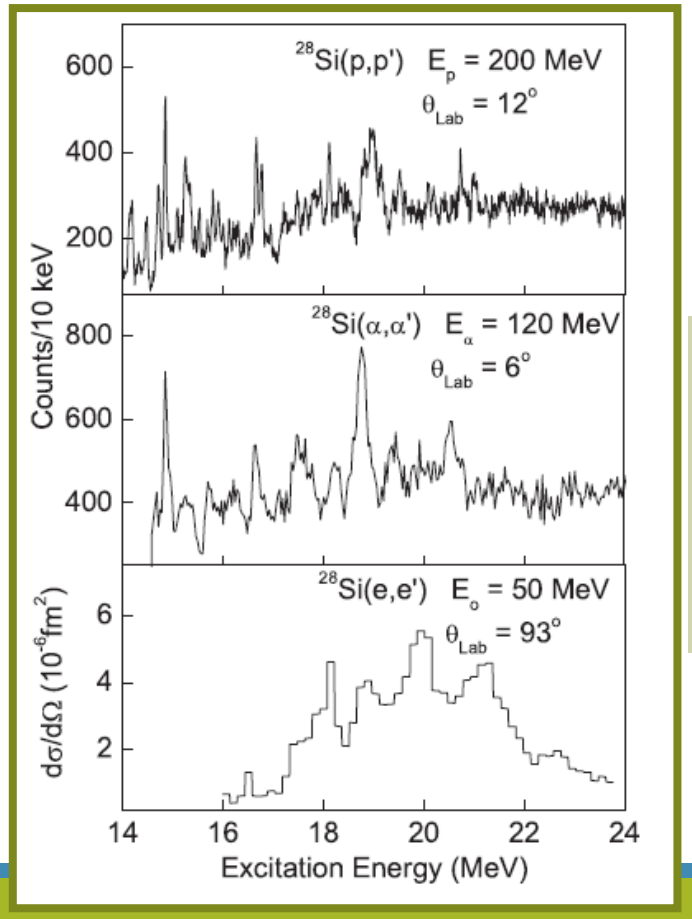
- Motivation
- Idea of the experiment
- The experimental setup
- Results
- Summary and outline

ISGQR

A. Shevchenko et al., Phys. Rev. Lett. 93 (2004) 122501-1
A. Shevchenko et al., Phys. Rev. C79, 044305 (2009)







I.T. Usman et al.,
Phys. Rev. C94, 024308 (2016)

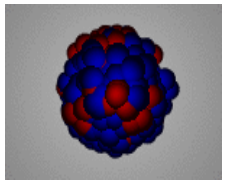
K. van der Borg et al.,
Nucl. Phys. A341, 219 (1980)

A. Richter, Prog. Part.Nucl. Phys. 13, 1 (1985)

γ strength
and γ-decay to gs and excited states
needed to be investigated

W.L. Lv, Y.F. Niu and G. Colo,
Phys. Rev. C 103, 064321(2021)

GQR γ decay



GQR γ–decay observed previously only once, in 1980s

difficult to measure
very small probability ~10^{-4}

J.Beene et al., PRC39(1989)1307

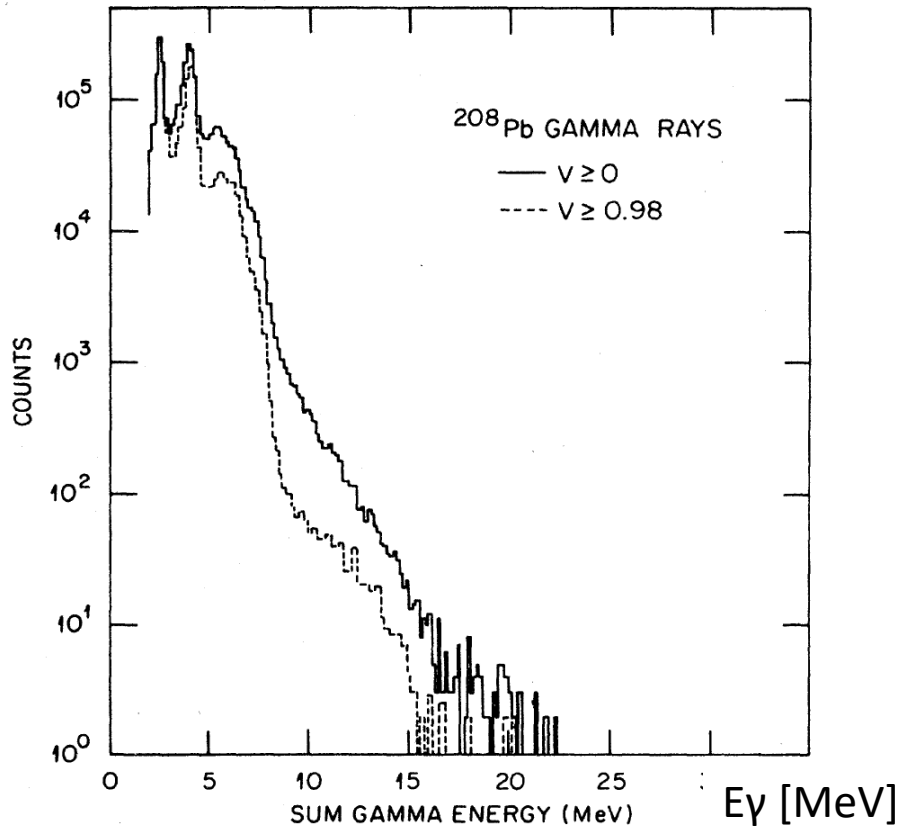


FIG. 5. Gamma-ray spectra from ^{208}Pb for $V \geq 0.98$ (only ground-state gamma rays), and $V \geq 0$ (all gamma rays).

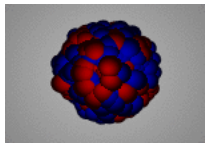
Inelastic scattering
of 381 MeV ^{17}O on ^{208}Pb

coincidence measurement
of gamma rays and scattered ions

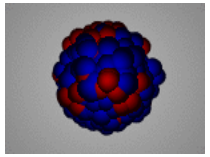
Idea of the experiment

nuclear excitations induced by **proton inelastic scattering**

IVGDR

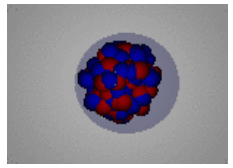


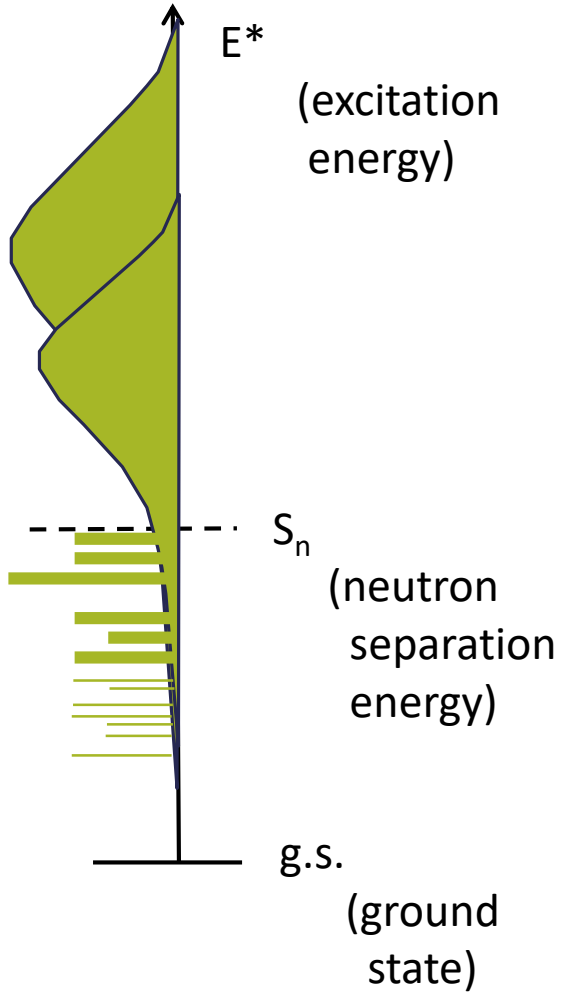
ISGQR



main aim – GQR γ decay

PDR



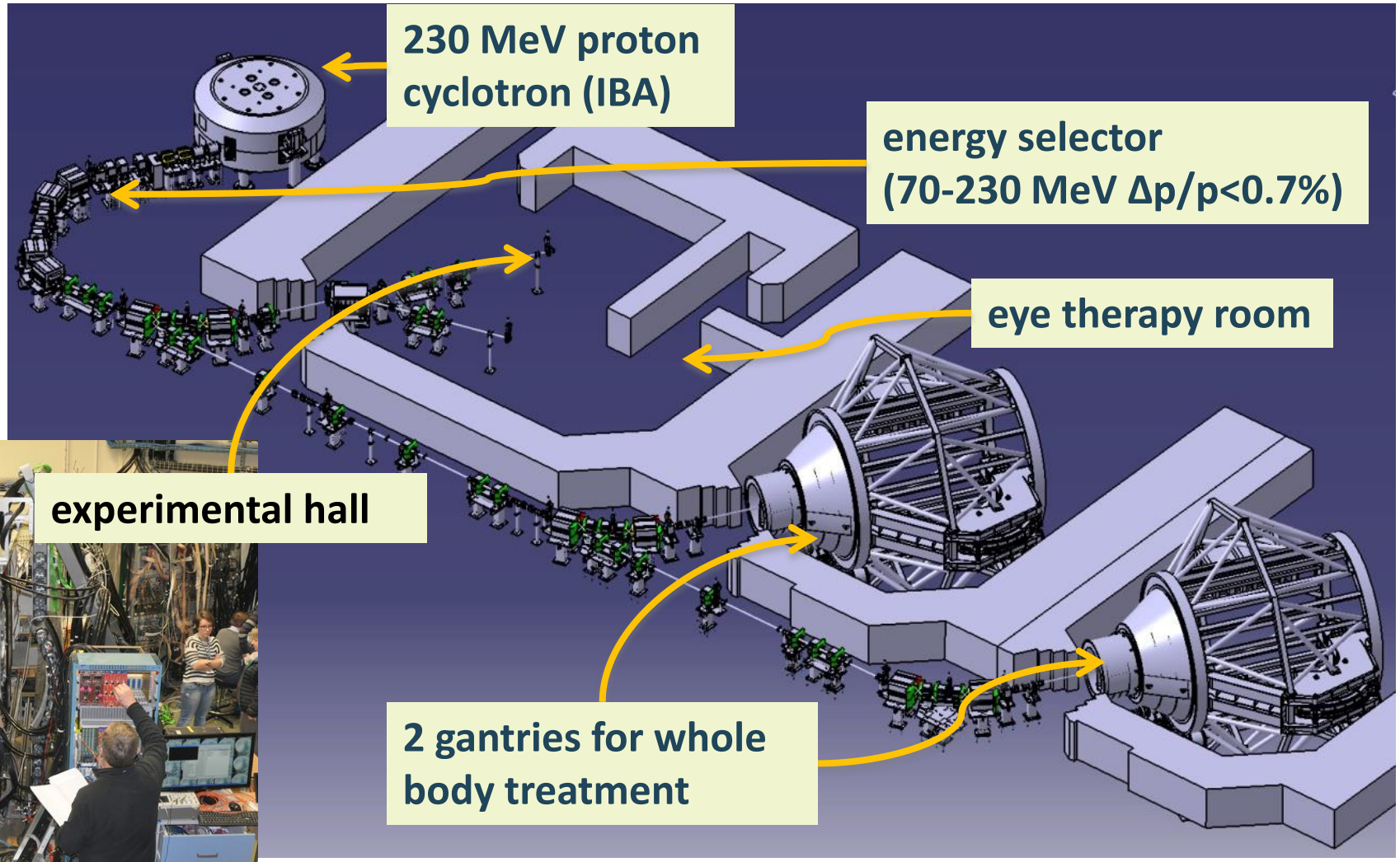


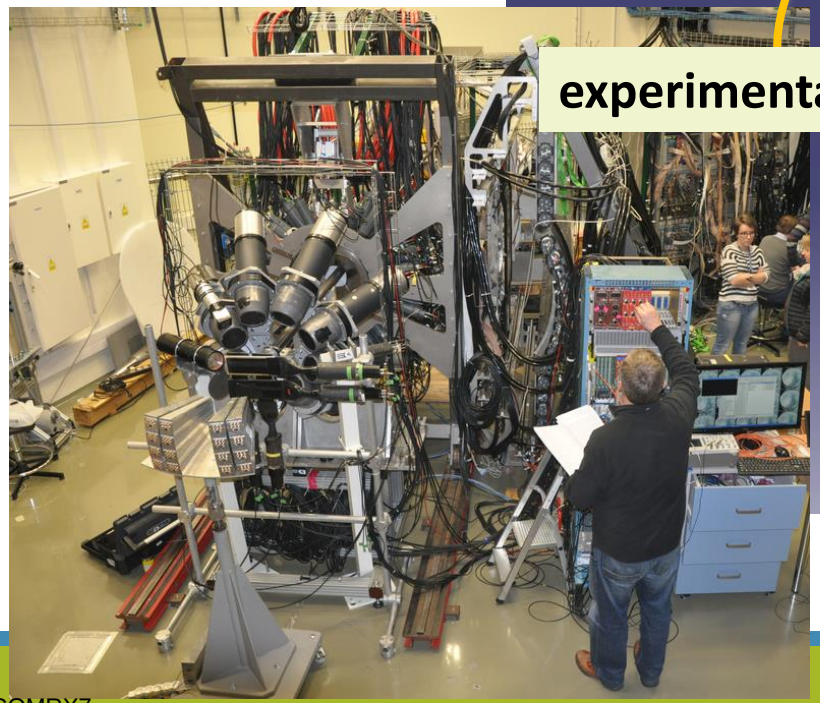
measurement of γ-rays emitted from the decay
(above neutron threshold hindered by neutron emission)

Cyclotron Center Bronowice (CCB) of IFJ PAN Kraków

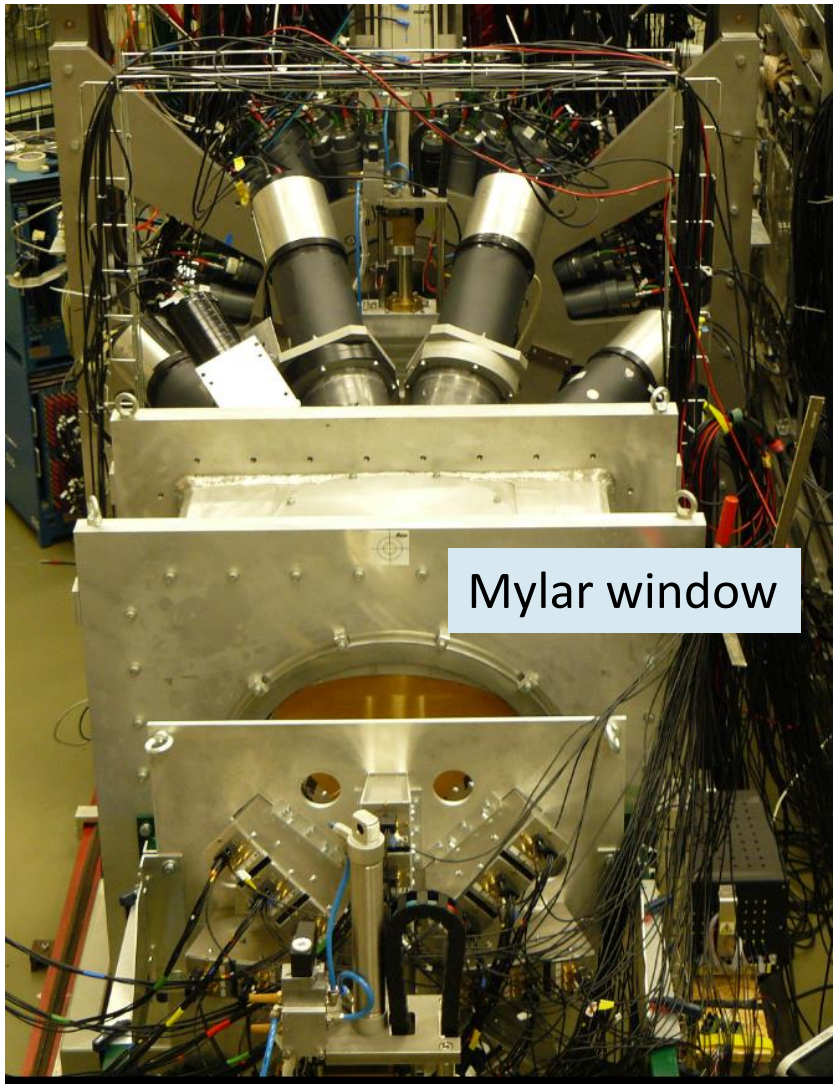
proton cancer therapy
and additionally
research program on:

- nuclear physics,
- radiobiology
- dosimetry
- and medical physics

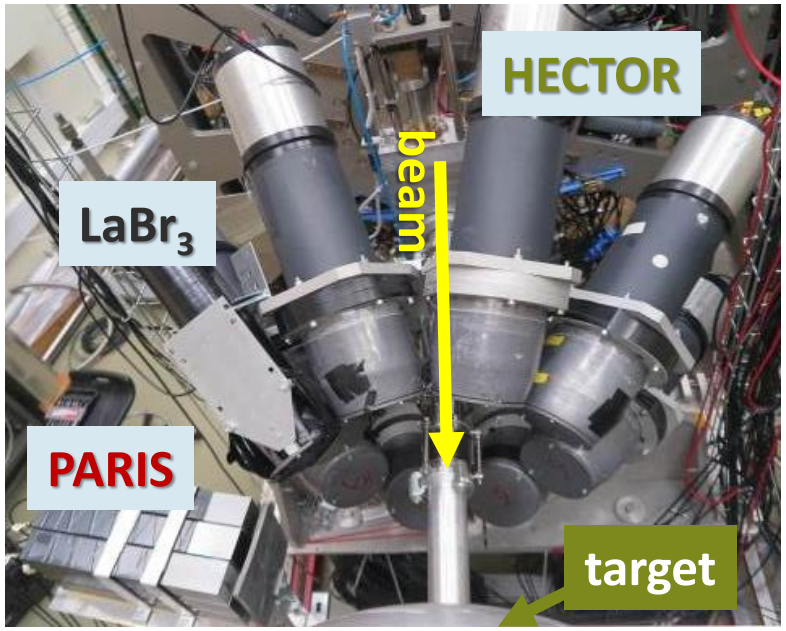


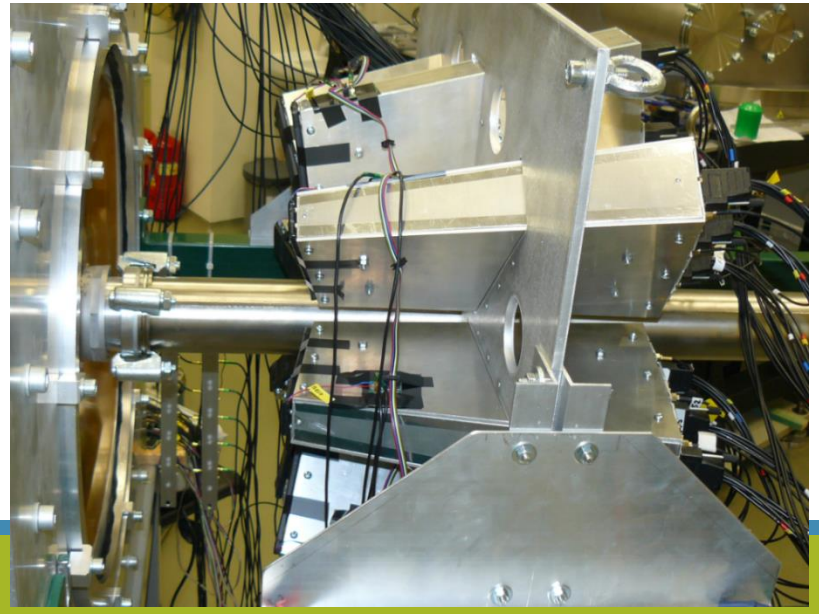


Scattering chamber and detectors



small BINA chamber





HECTOR - 8 BaF_2
(14.5 cm (ϕ) x 17.5 cm)

$LaBr_3$ (large volume 3.5”x8”)

PARIS (cluster of 9 „phoswiches”
$LaBr_3/CeBr_3$ + NaI
2”x2”x2” + 2”x2”x6”)

KRATTA at angles 8.9° - 14.3°
with resolution 1.8°

plastic detectors
in the front
of every 3 KRATTA modules

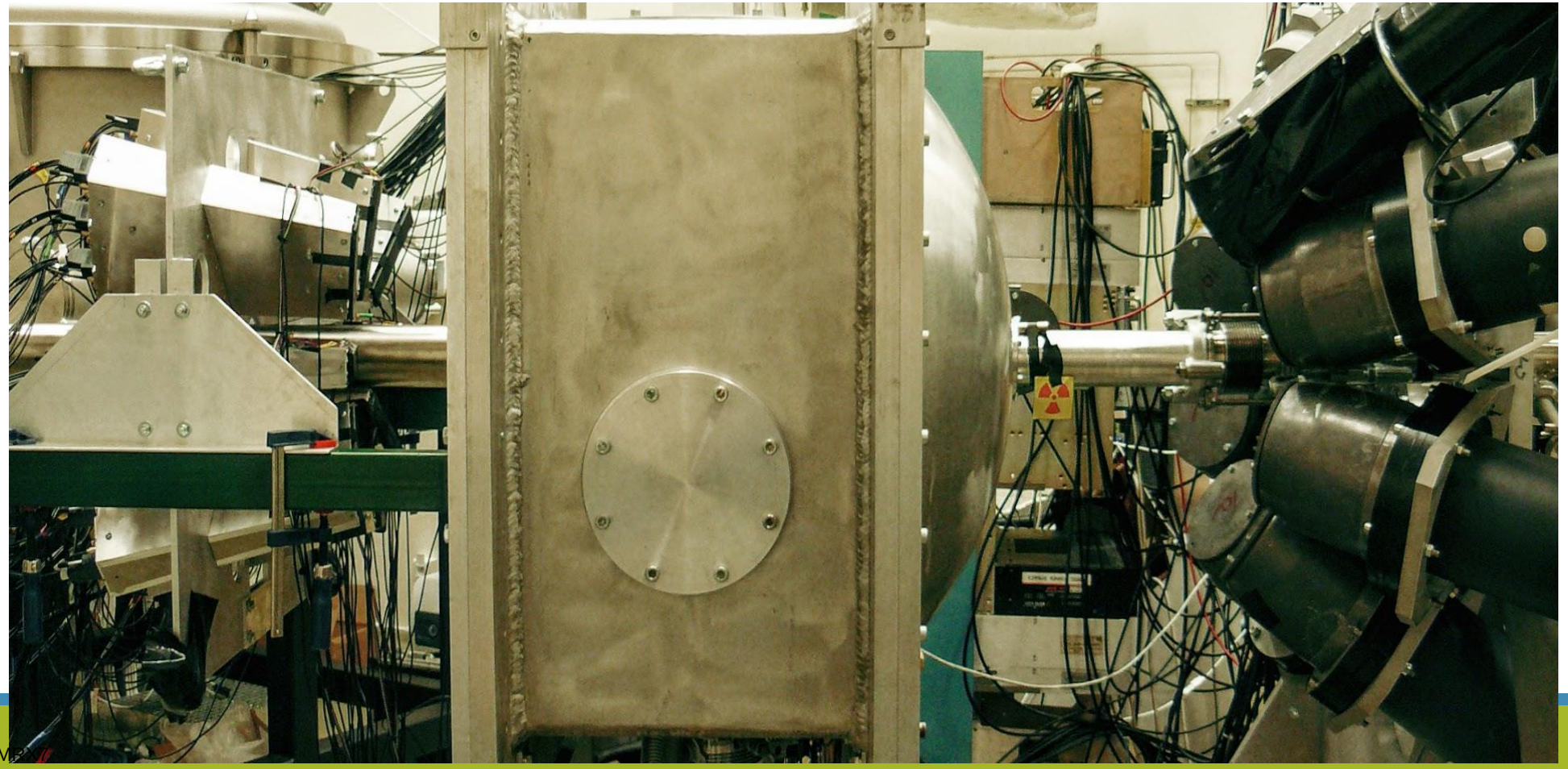
Experiment and setup

p @ 85 MeV on ^{208}Pb target 48 mm (54.5 mg/cm^2) thick

KRATTA (protons)

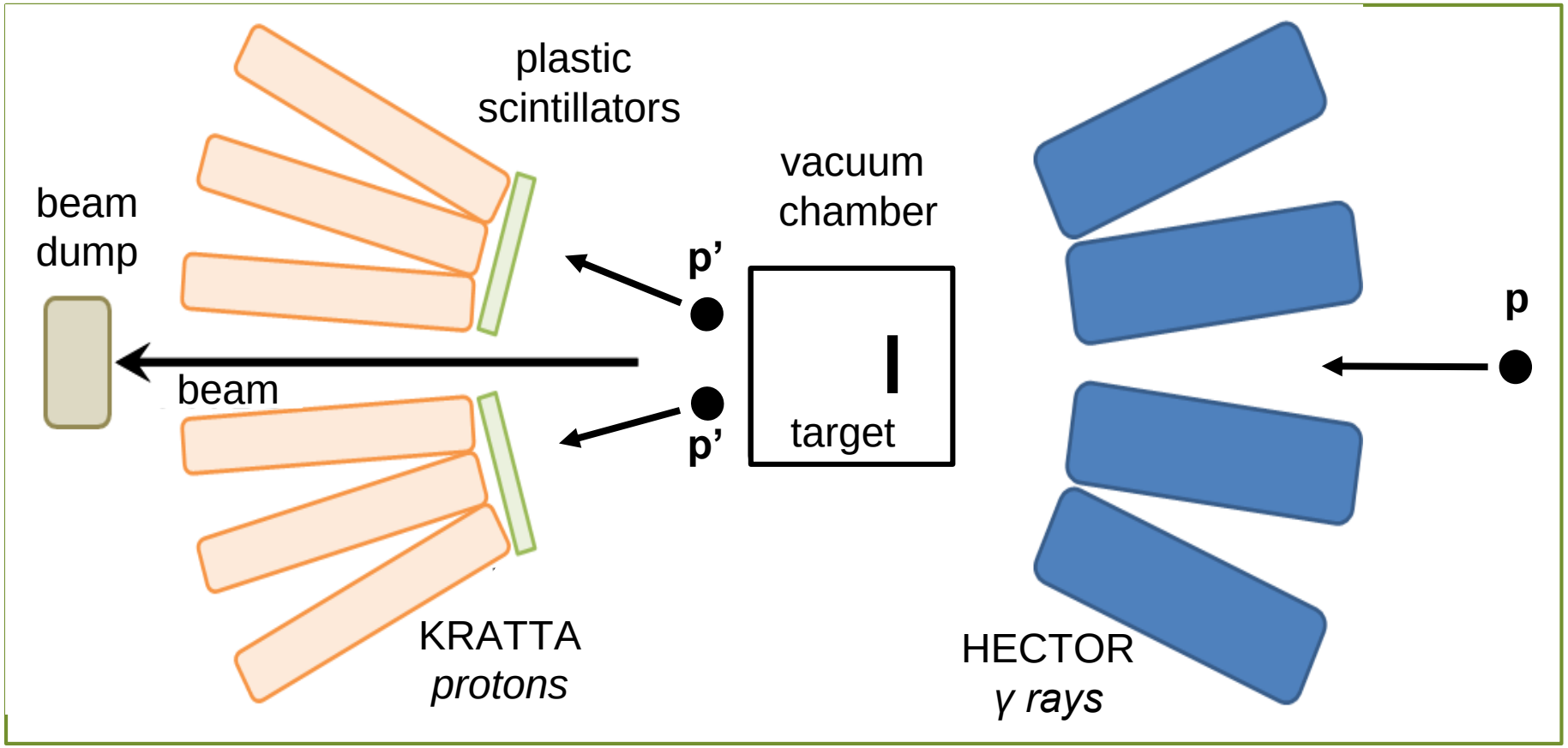
vacuum
scattering chamber

HECTOR + $LaBr_3$ + PARIS
(γ-rays)

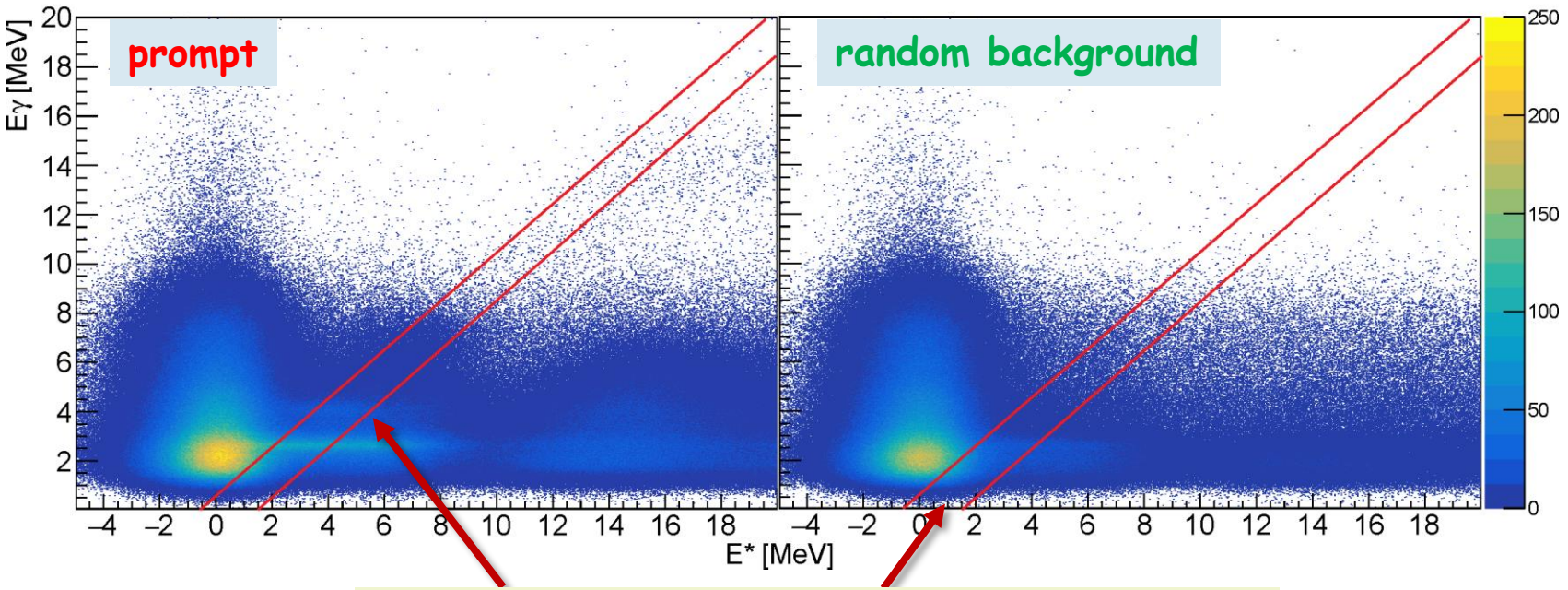


The experimental method

coincidence measurement of gamma rays and scattered protons

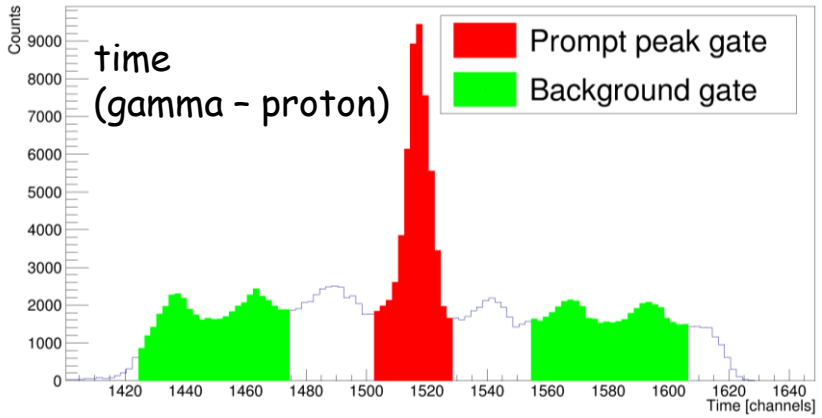


Analysis

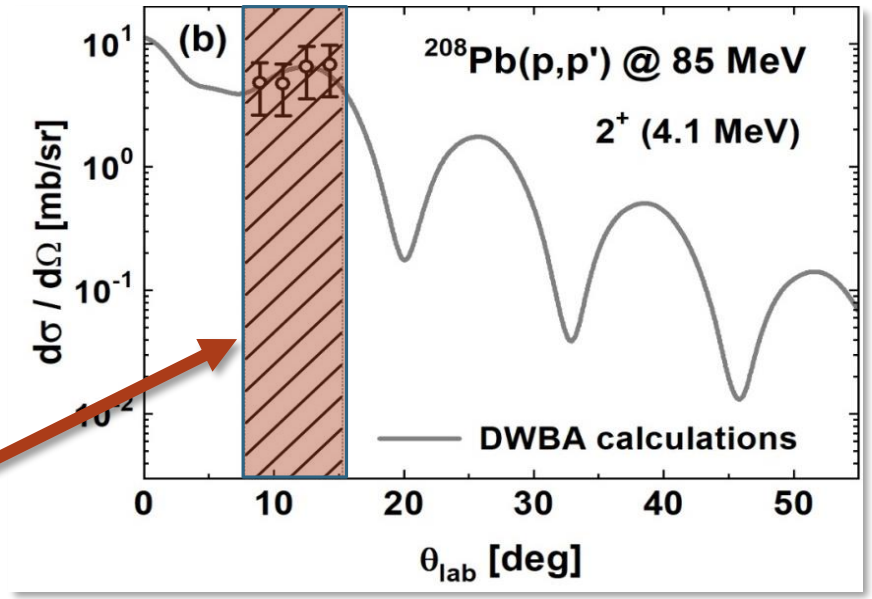


decay to the ground state ([Eγ+0.5-E*] ≤ 1 MeV)

$E^* = E_{beam} - E_{scattered\ proton}$

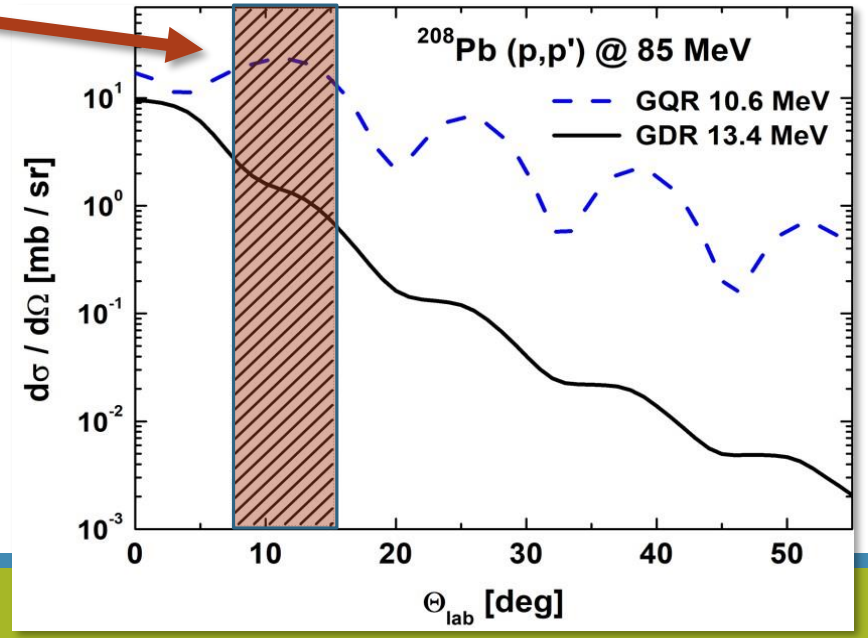


Cross sections for excitations in ^{208}Pb



2^+ state

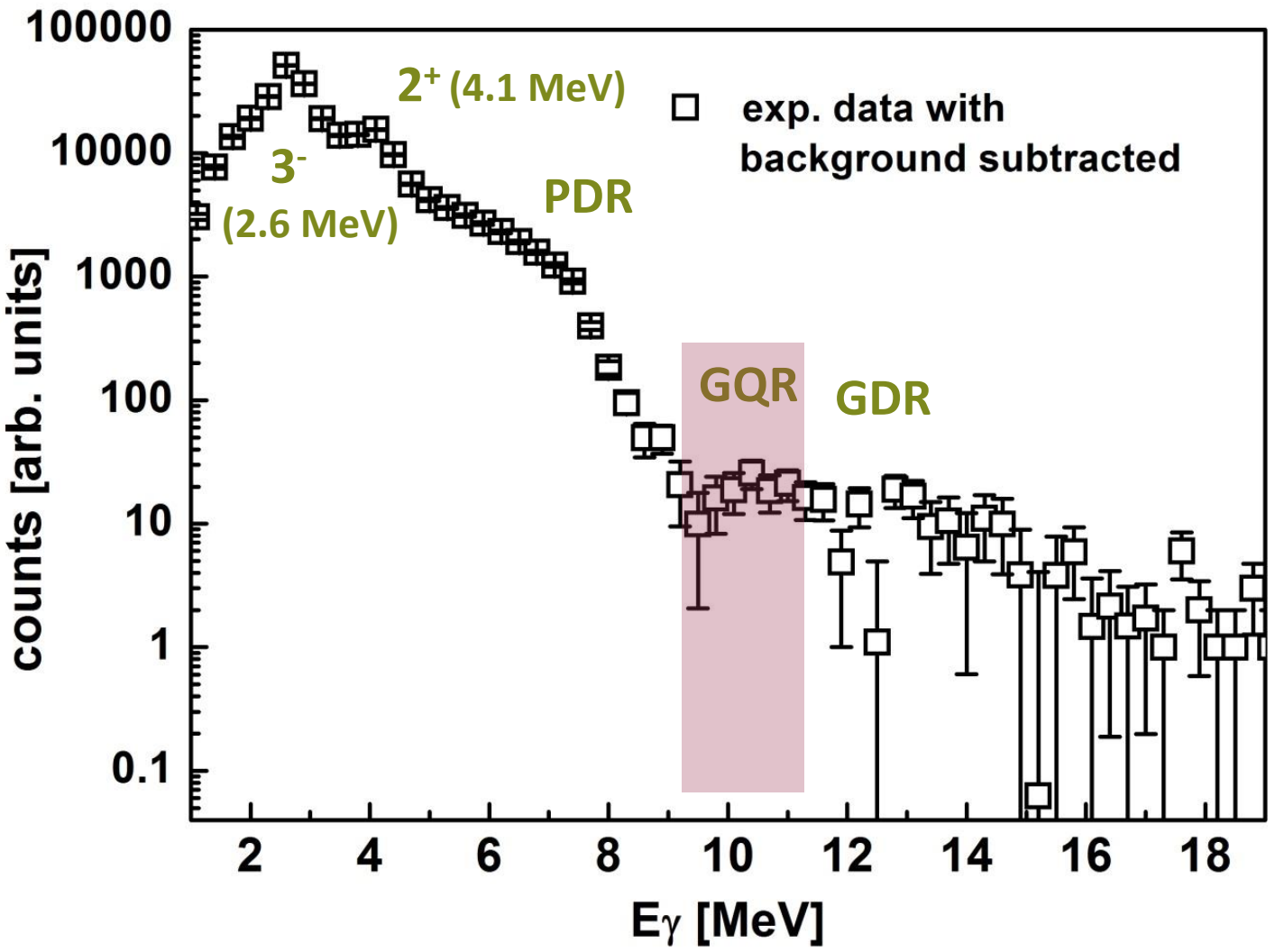
the angles covered by the experimental setup



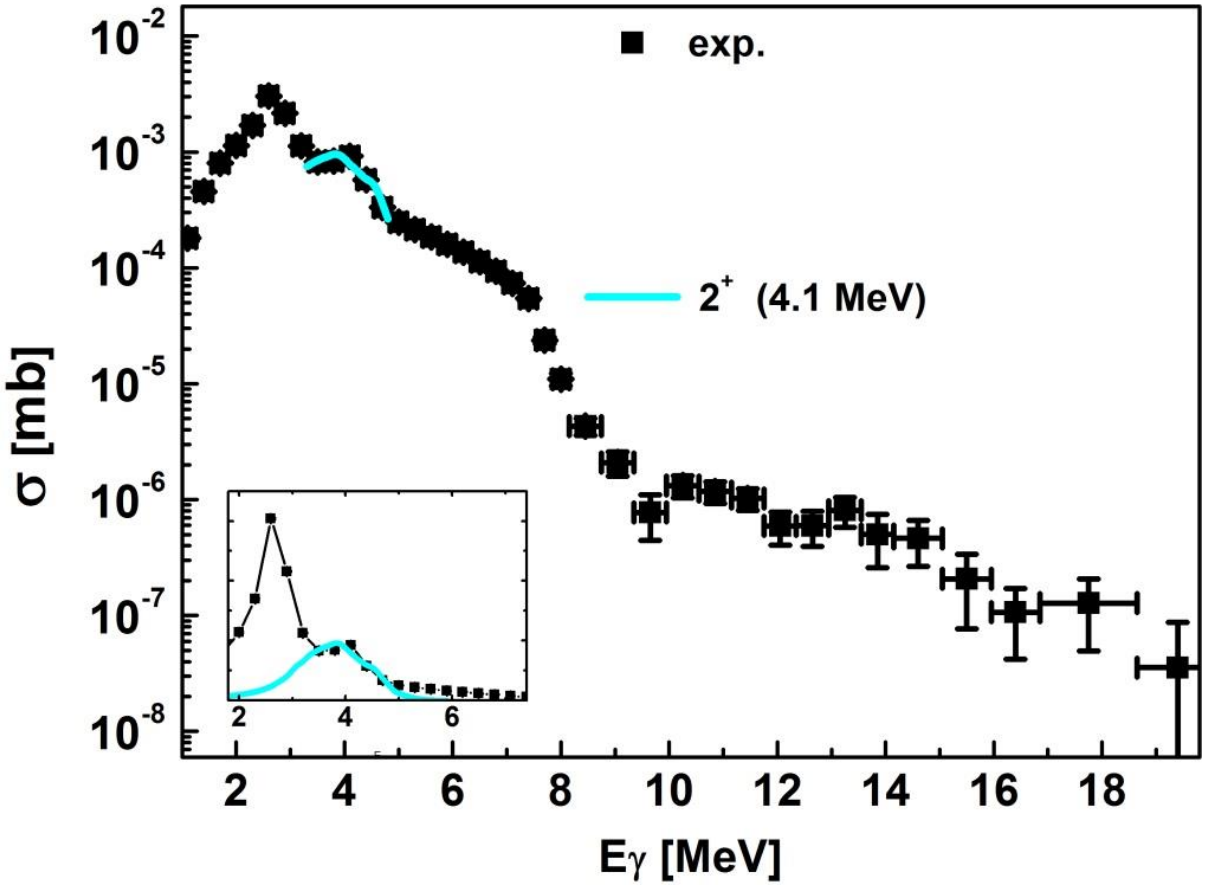
GQR

GDR

Background subtracted γ-ray spectrum



gamma decay cross section



for 2^+ ^{208}Pb

$$\sigma_{p,p\prime} \approx \sigma_{p,p\prime\gamma}$$

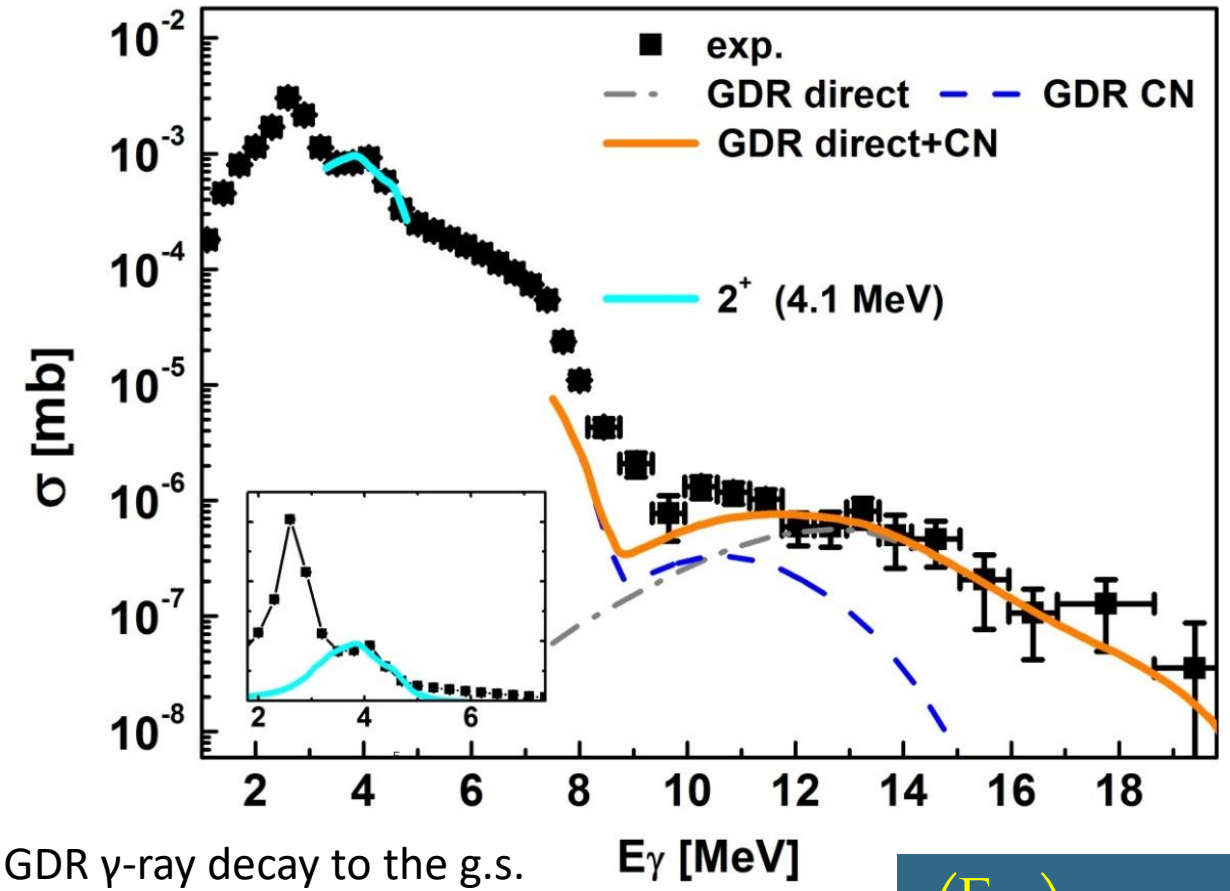
calculated cross section
folded with HECTOR response function

Normalization factor
(taking into account
the HECTOR and KRATTA efficiency)

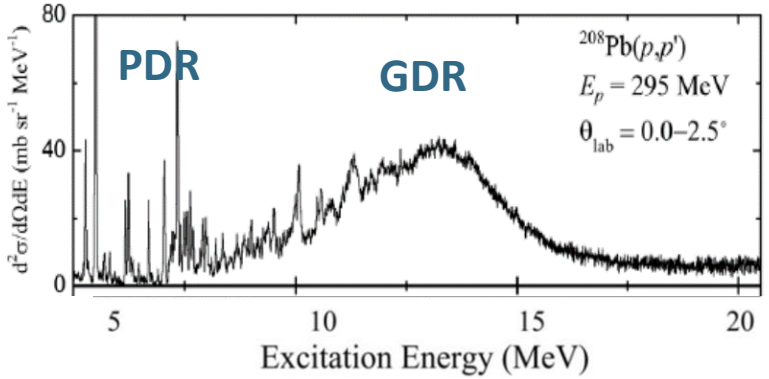
GDR analysis

$$\sigma_{p,p'\gamma 0}(E) = \sigma_{p,p'}(E; B(E1) = 1) b_{E1}(E) \left[\frac{\Gamma_{\gamma 0}}{\Gamma} + \frac{\Gamma\downarrow}{\Gamma} B_{CN}(E) \right] = \underline{\boldsymbol{\sigma_{direct}}} + \underline{\boldsymbol{\sigma_{CN}}}$$

direct decay — statistical (CN) decay



calculated for:
B(E1) for 111% EWSR;
E_{GDR} = 13.4 MeV;
Γ_{GDR} = 3.9 MeV



A. Tamii et al., Phys. Rev. Lett. 107, 062502 (2011)

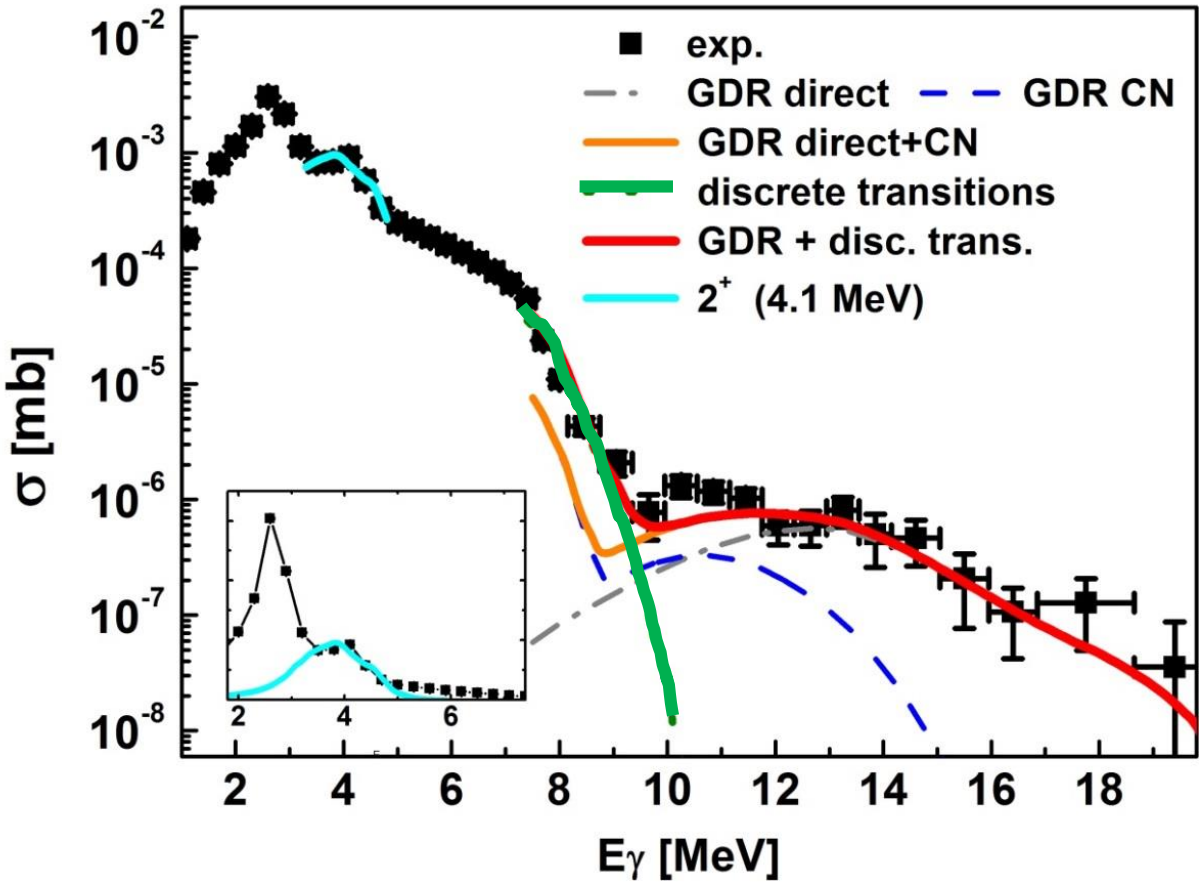
GDR γ-ray decay to the g.s. branching ratio:

$$\left(\frac{\Gamma_{\gamma 0}}{\Gamma}\right)_{GDR} = \sum_E \frac{\sigma_{p,p'\gamma 0}(E)}{\sigma_{p,p'}(E)}$$

$$\left(\frac{\Gamma_{\gamma 0}}{\Gamma}\right)_{GDR} = 1.7 \times 10^{-2} \pm 0.5 \times 10^{-2}$$

In agreement with published value

GDR + discrete transitions



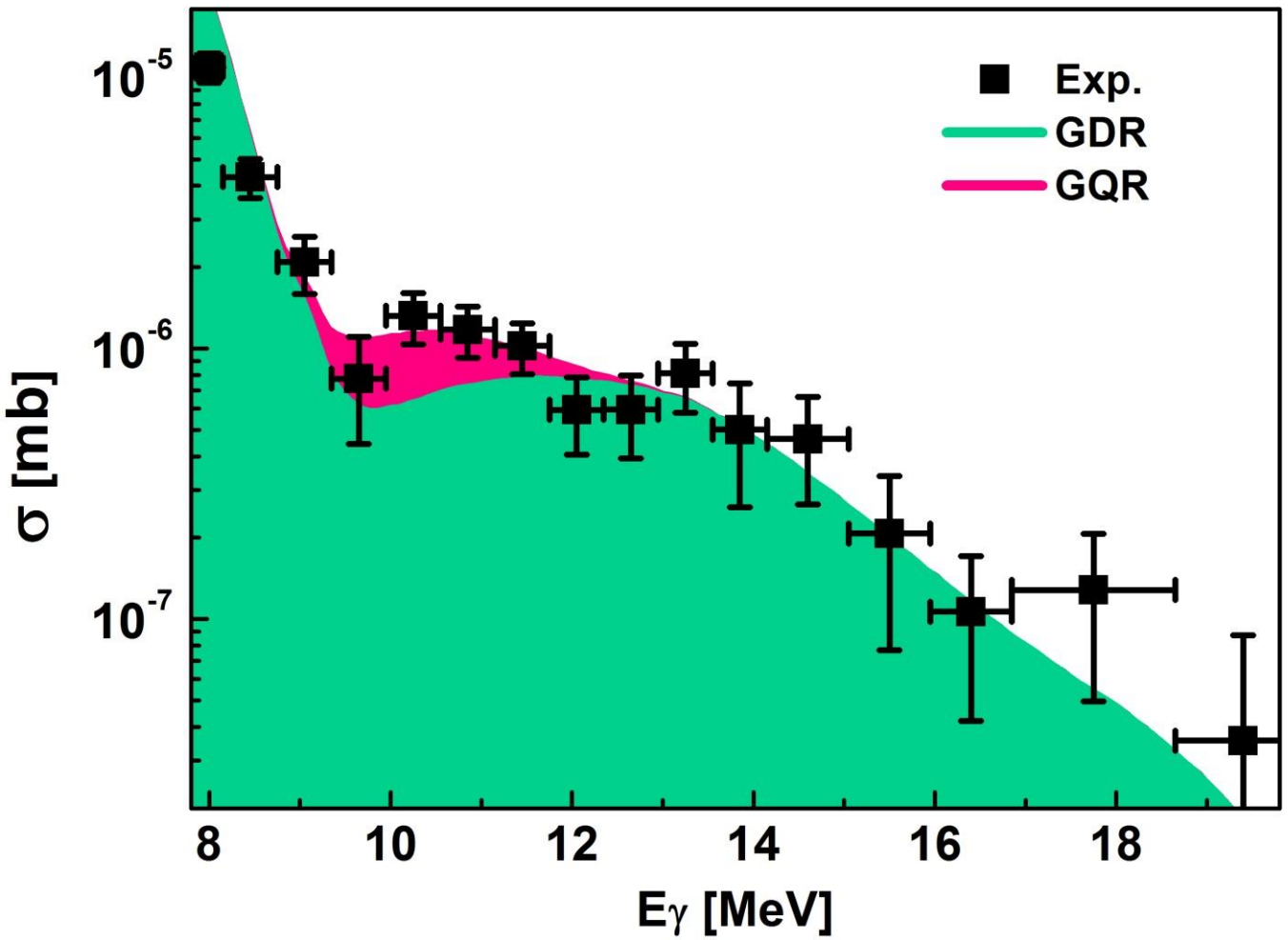
6.26 MeV; 8.37 MeV (1^-)

H. P. Morsch, P. Decowski, and W. Benenson,
Nucl. Phys. A 297, 317 (1978)

7.36; 8.86; 9.34 (2^+)

F. E. Bertrand, et al.,
Phys. Rev. C 34, 45 (1986)

GQR region



excess in the GQR region

Observation, for the 2nd time after 50 years, of the gamma decay of the ISGQR

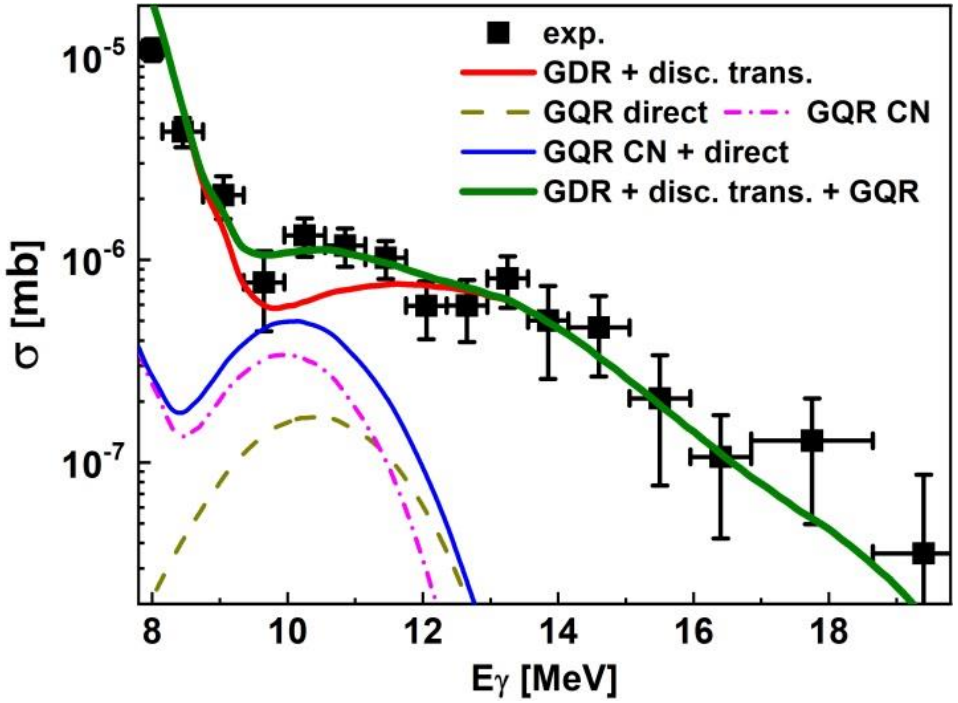
excited in proton scattering reaction

in the experiment by J. Beene
more isoscalar probe: ^{17}O was used

GQR γ-decay to g.s. in ^{208}Pb

85 MeV p inelastic scattering

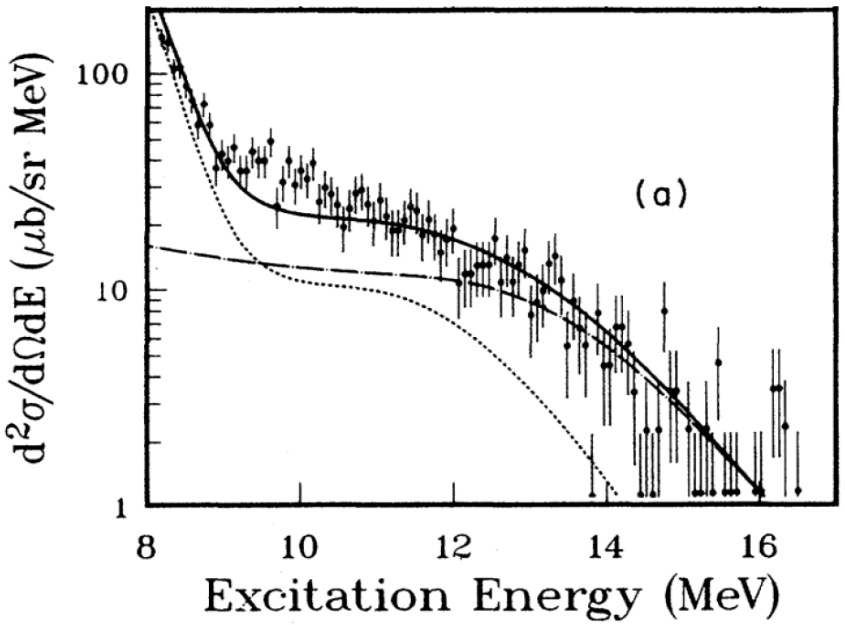
B.Wasilewska et al., PRC105(2022)014310



$$\left(\frac{\Gamma_{\gamma 0}}{\Gamma}\right)_{GQR} = 3 \times 10^{-4} \pm 1 \times 10^{-4}$$

381 MeV ^{17}O inelastic scattering

J.Beene et al., PRC39(1989)1307



in coincidence with γ-rays

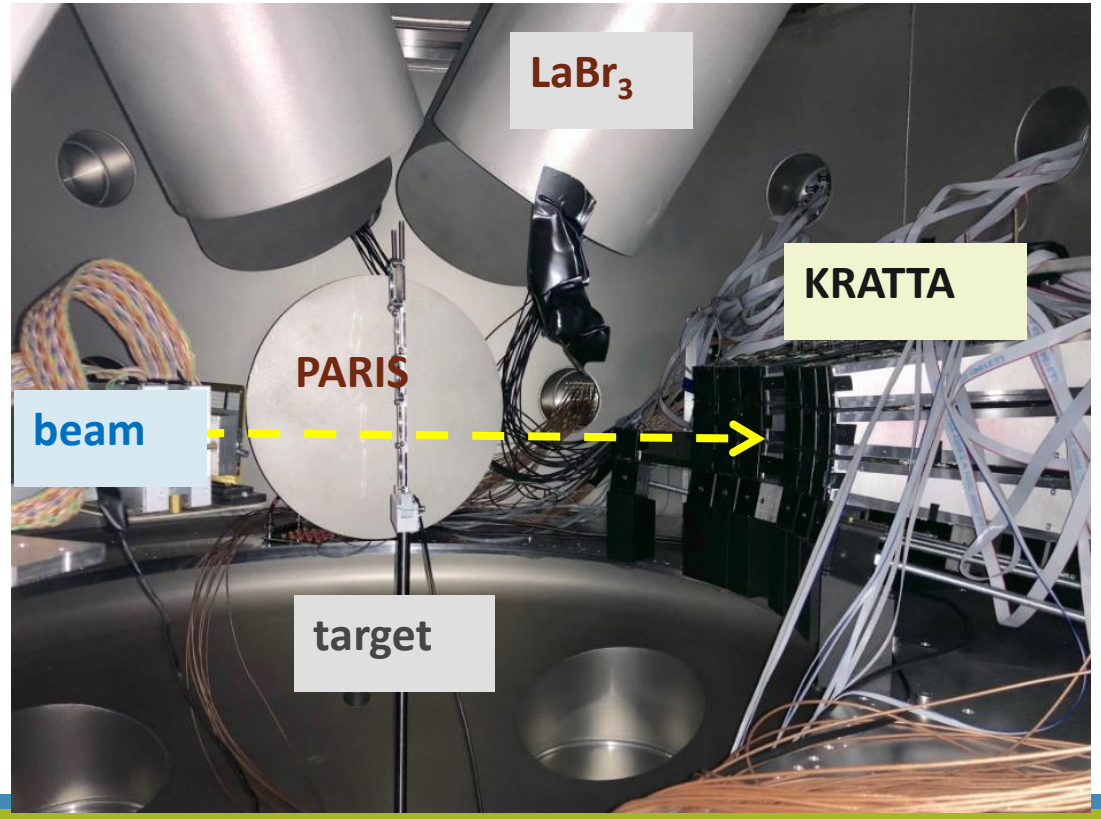
$$\left(\frac{\Gamma_{\gamma 0}}{\Gamma}\right)_{GQR} = 4 \times 10^{-4} \pm 1 \times 10^{-4}$$

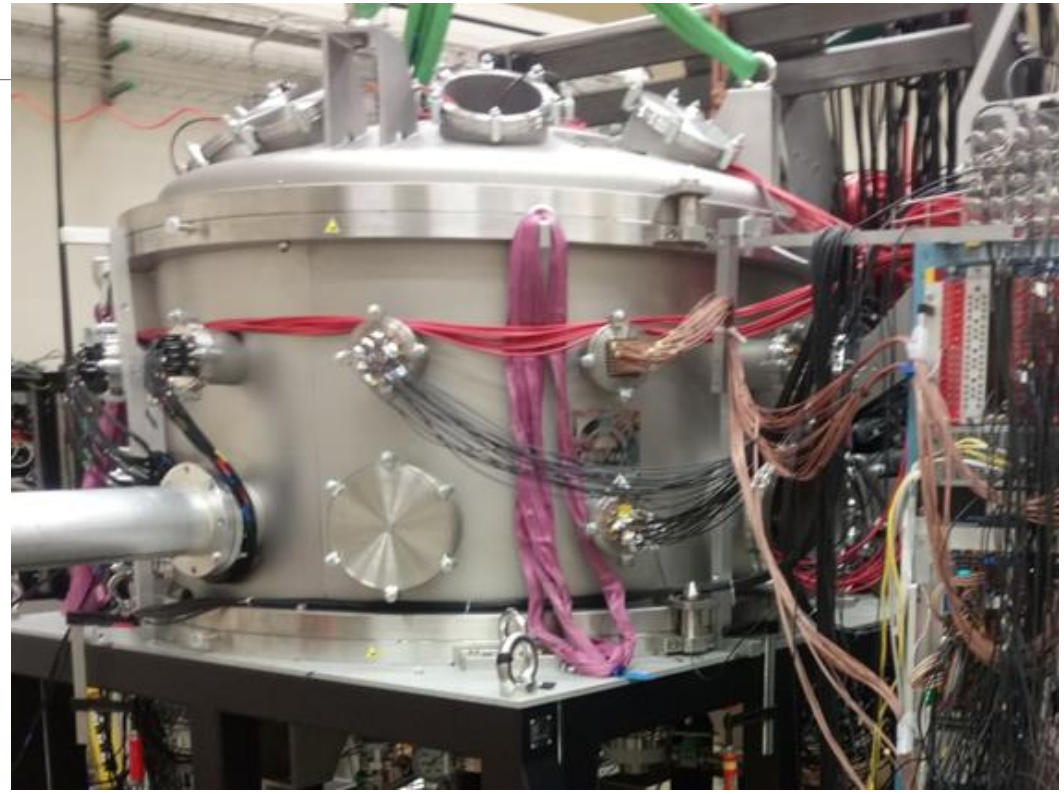
branching ratio for the GQR gamma decay to the ground state
obtained with the use of proton beam - in agreement to previous value measured with heavy ions

Continuation

upgraded setup

KRATTA inside the chamber – in the vacuum
gamma detectors outside
mounted using holders / cylindrical pockets



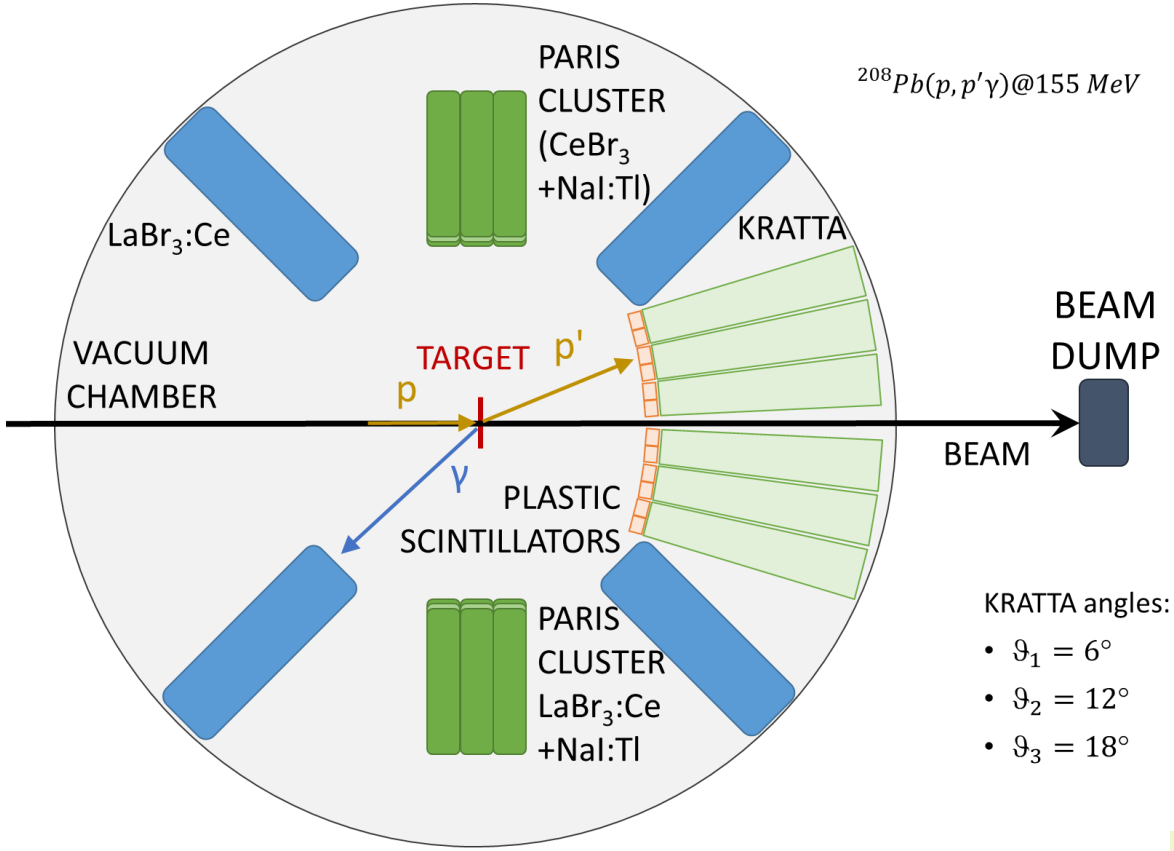


big scattering chamber

New experiments performed

(p,p'γ) on ^{208}Pb @ ~155 MeV

(p,p'γ) on ^{120}Sn @ ~200 MeV

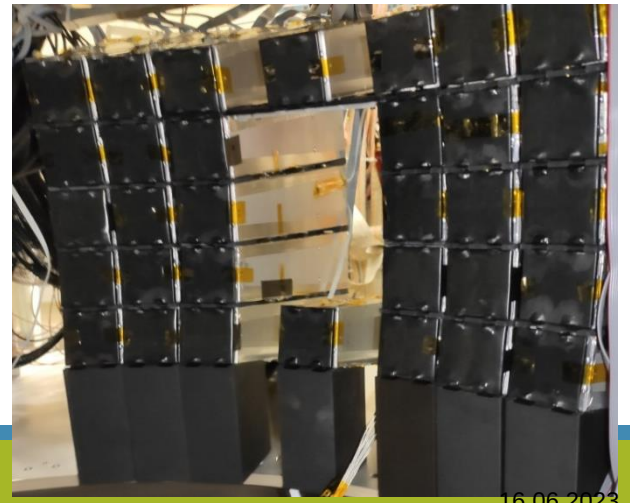


$^{208}Pb(p,p'\gamma)@155\ MeV$

KRATTA angles:

- $\vartheta_1 = 6°$
- $\vartheta_2 = 12°$
- $\vartheta_3 = 18°$

- 4 large volume LaBr3 (3.5"x8") at top
- 2 PARIS clusters: (9 $LaBr_3$+NaI and 9 $CeBr_3$+NaI) at 90°
- KRATTA covering angles from ~8° to ~24°



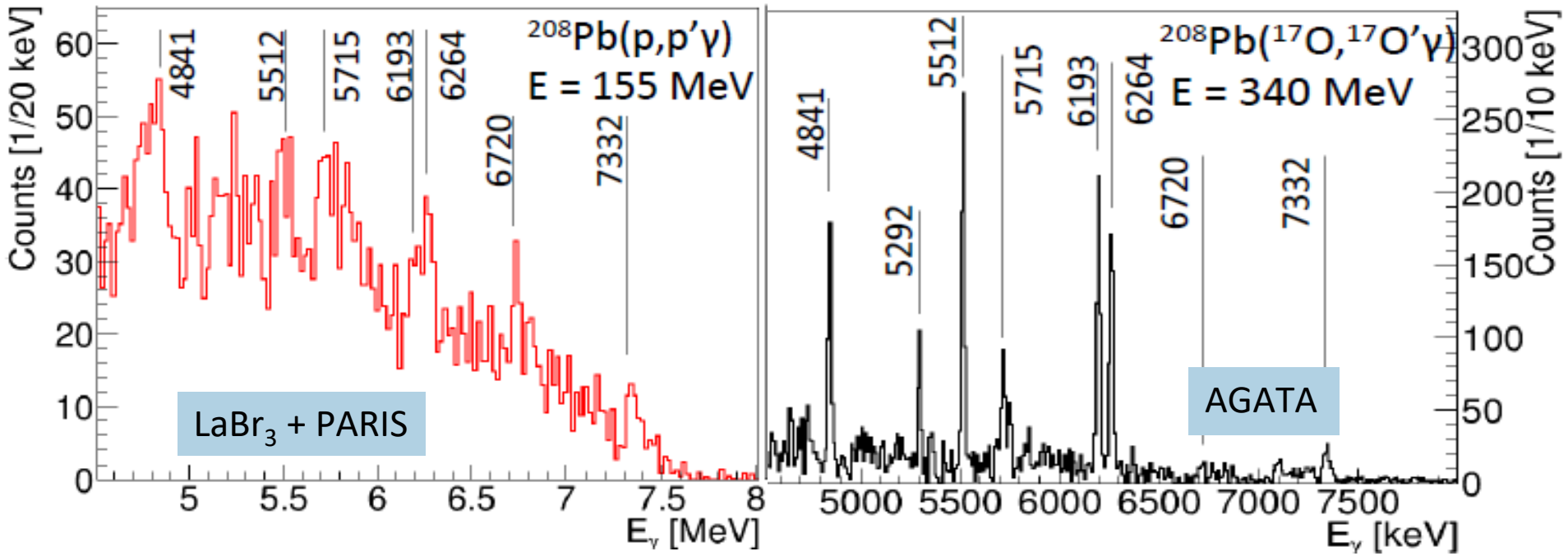
Data are being analysed

PDR region

good energy resolution
of PARIS and $LaBr_3$ detectors

B. Wasilewska et al., Acta Phys. Pol. B (2020) 677

F.C.L. Crespi et al., PRL113 (2014) 012501



- similar transitions
- more detailed studies needed

PDR excited in $^{56\text{-}62}$Ni using proton scattering planned to be measured at CCB IFJ PAN (by O. Wieland et al.) – accepted by IAC

Possible study of GQR γ-decay to excited states

Conclusions

- experimental campaign to study γ-decay from states excited using proton beam has been performed at Cyclotron Center Bronowice IFJ PAN in Krakow
- gamma decay of giant quadrupole resonance (GQR) have been observed for ^{208}Pb in inelastic proton scattering (p,p'γ),
- GQR gamma branching ratio to the g.s. has been measured confirming the only one result published previously
- recently measurements have been done for ^{208}Pb with higher energy proton beam (155 MeV) and for ^{120}Sn with the better energy resolution – attempt to study GQR γ-decay to excited states

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CCB staff

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