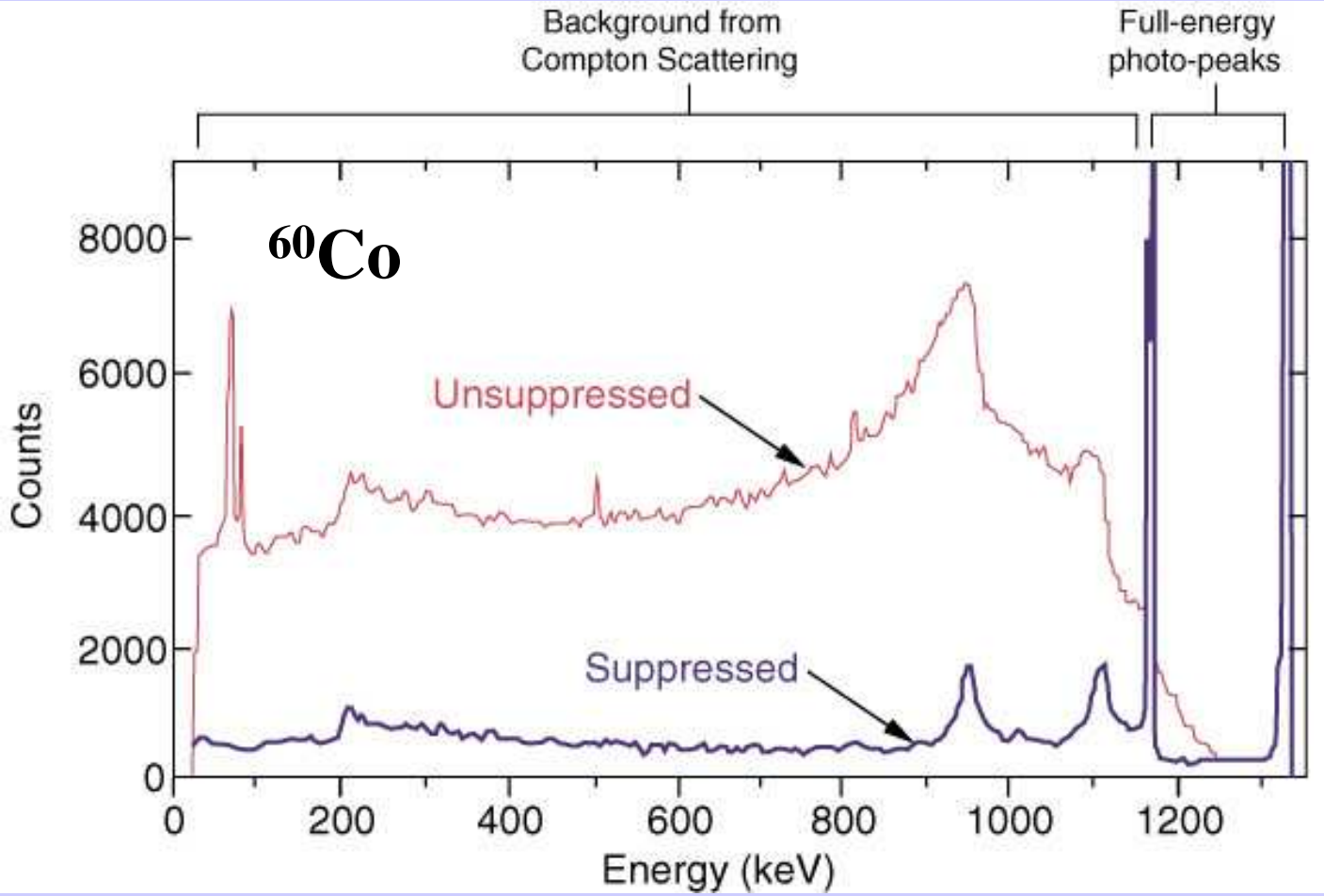
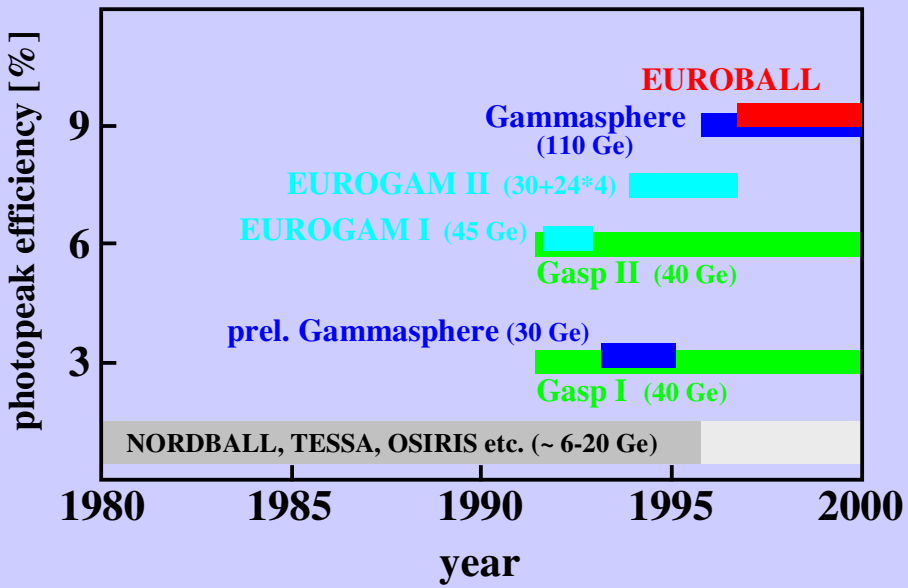
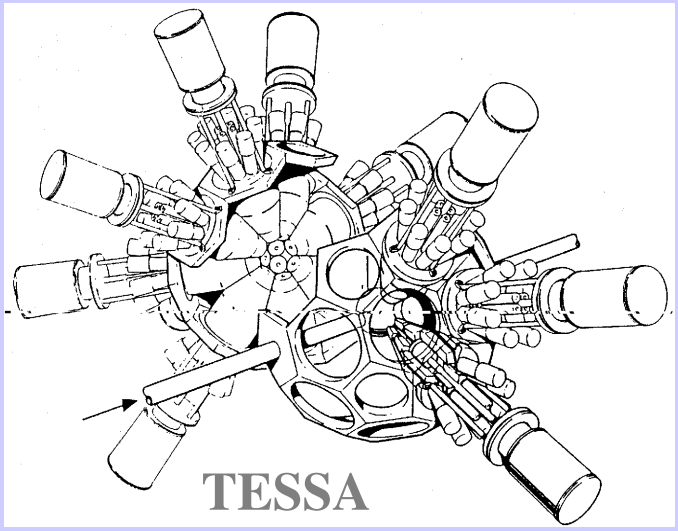
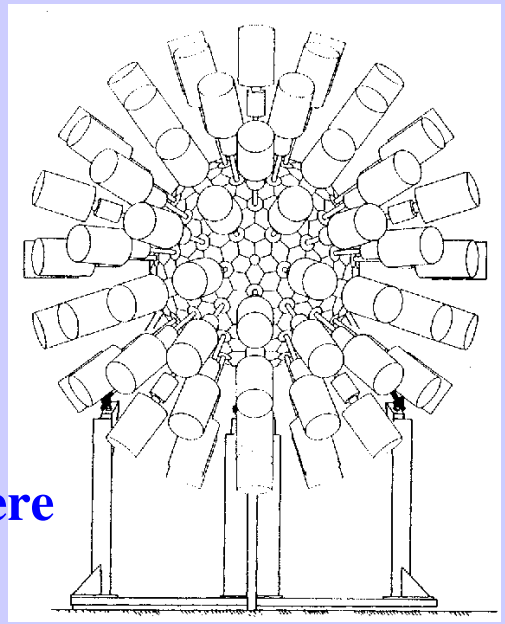
Compton-supressed Ge spectrum



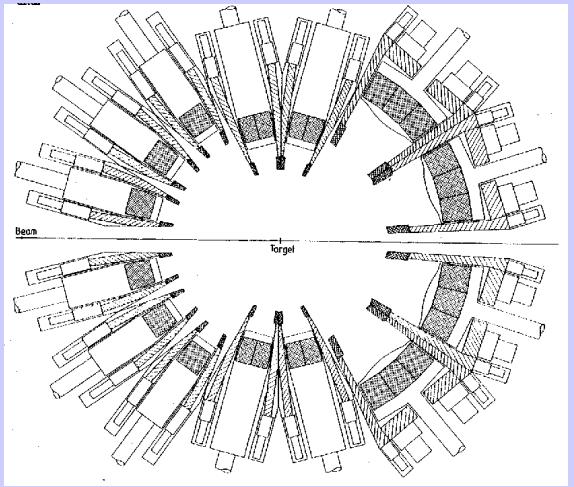
4π γ-ray spectrometer





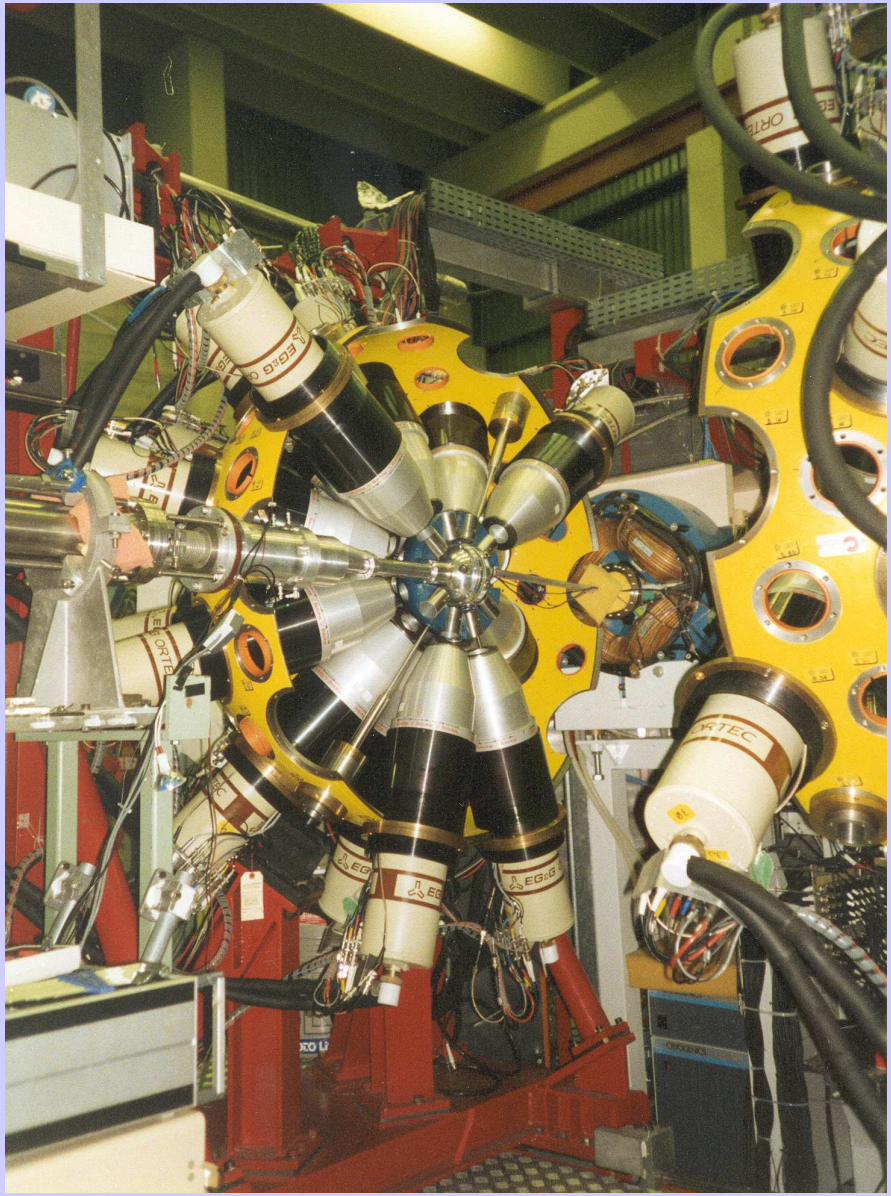


Gammasphere



EUROBALL

The GASP spectrometer in Legnaro

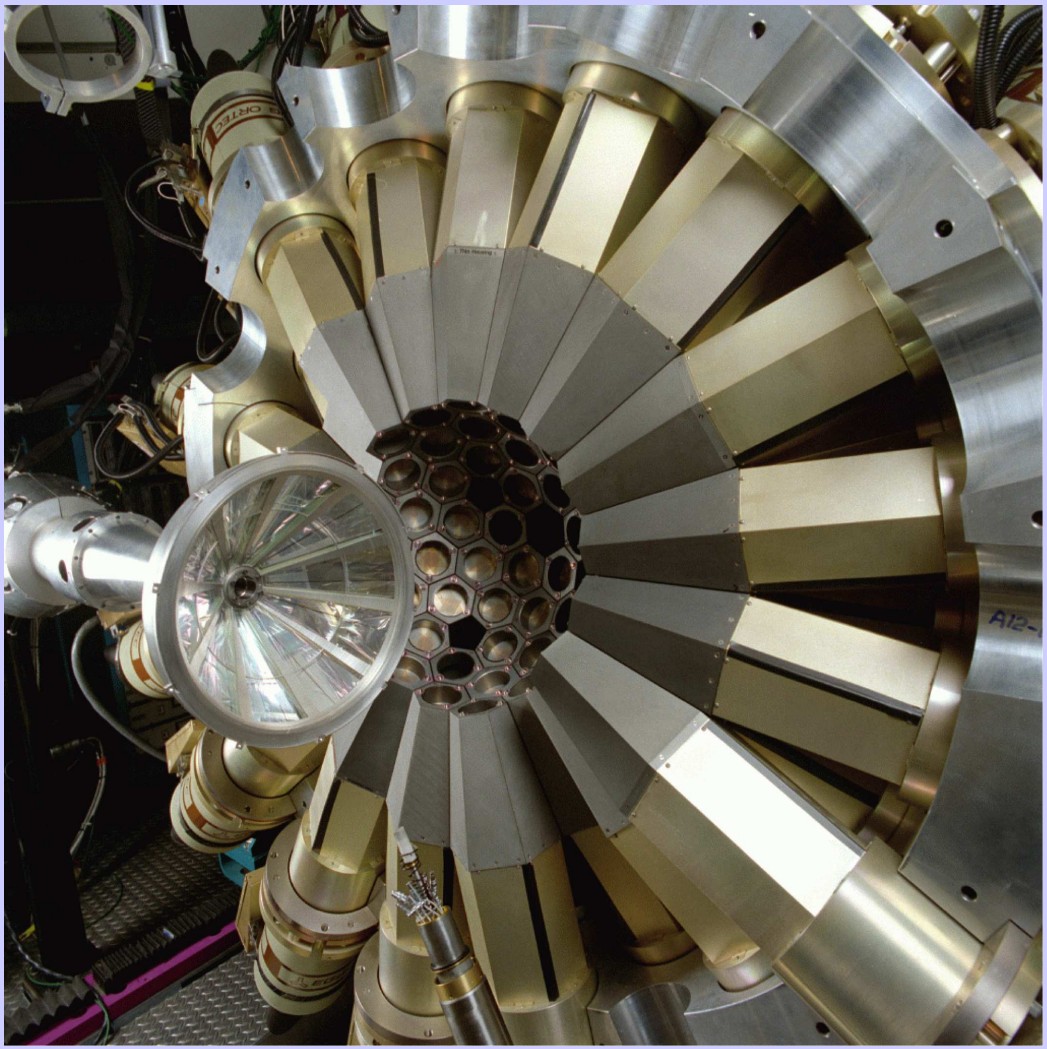


since 1992 in the Laboratori Nazionali di Legnaro, Padova

40 individual Compton-suppressed Ge detectors in 7 rings,

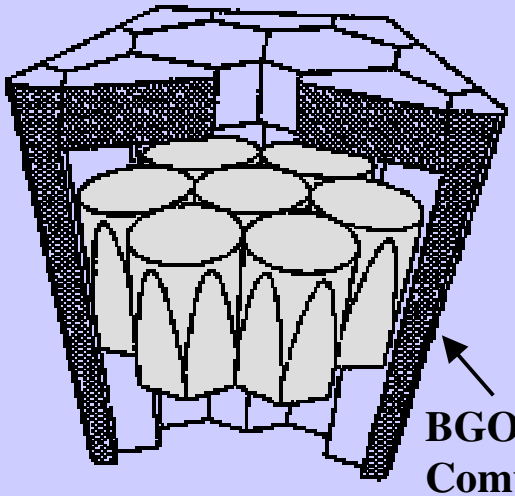
P_{ph} ~ 3 bzw. 6 %

The Gammasphere spectrometer (USA)

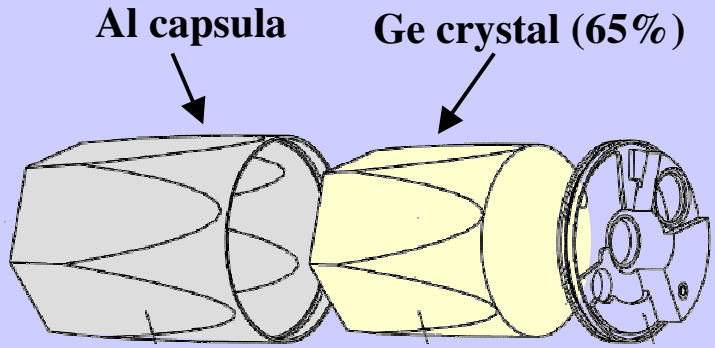


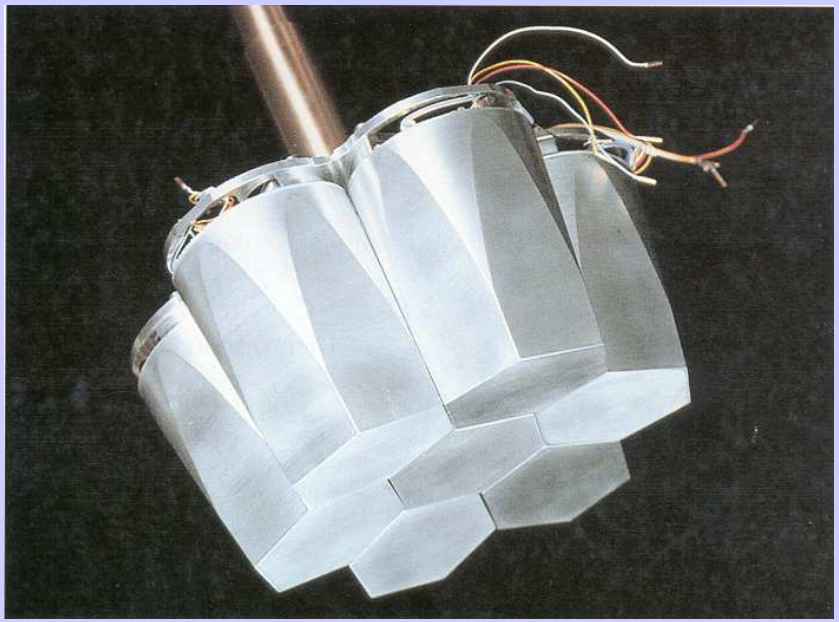
1993-1995 :
preliminary (30 + ... Ge)
since 1996:
Endstufe (110 individual Ge)
Berkeley - Argonne - Berkeley

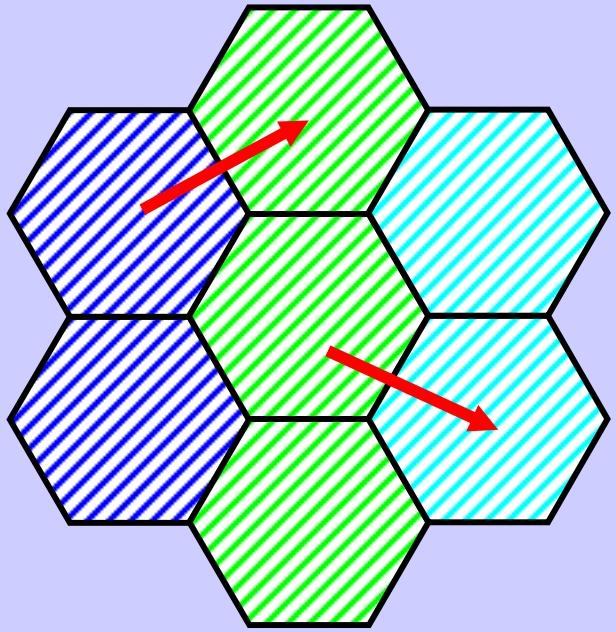
The composite CLUSTER detector of EUROBALL

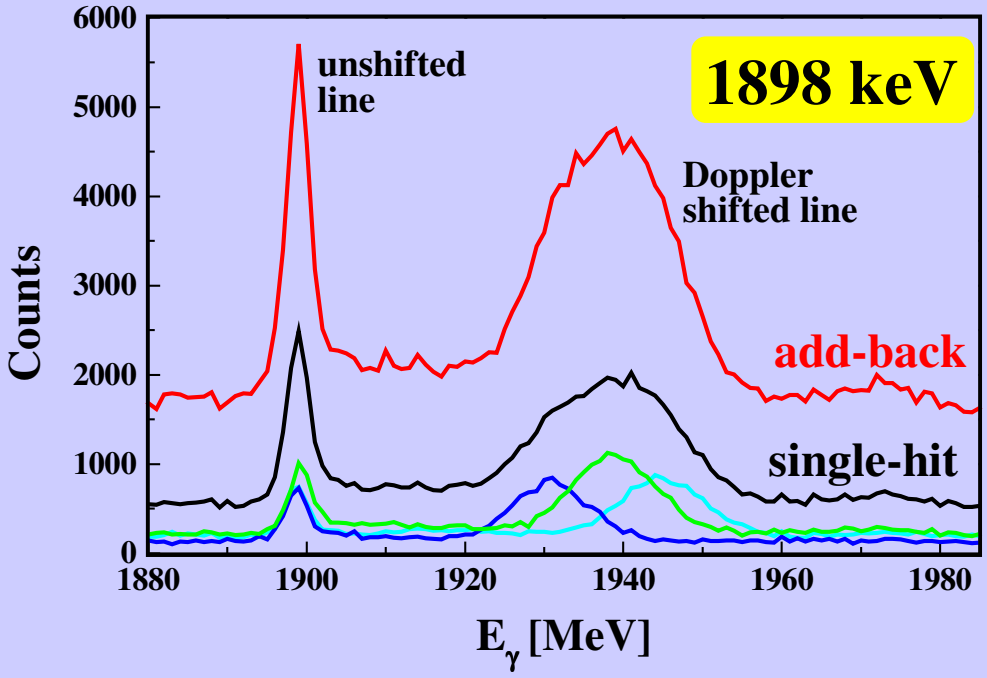


BGO crystals as
Compton suppression shield







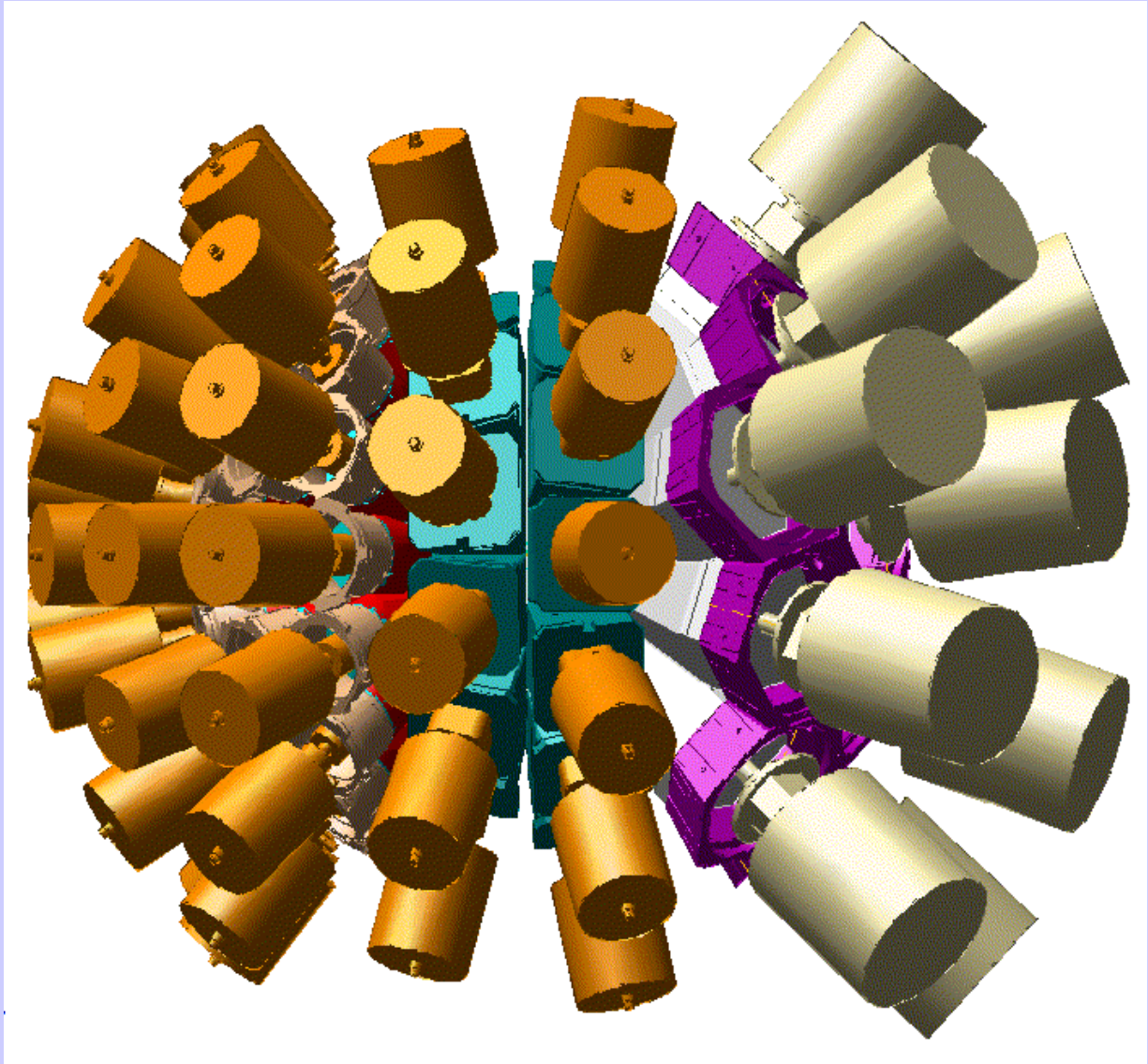


Single hit:
γ only accepted, if no γ has been detected "at the same time" in the neighbouring crystals.

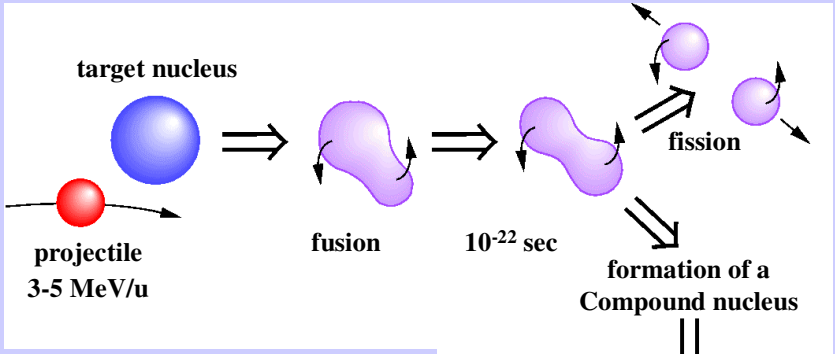
Add-back:
The energies of two γ-rays detected in coincidence (at the same time) in two neighbouring Ge crystals are summed up.

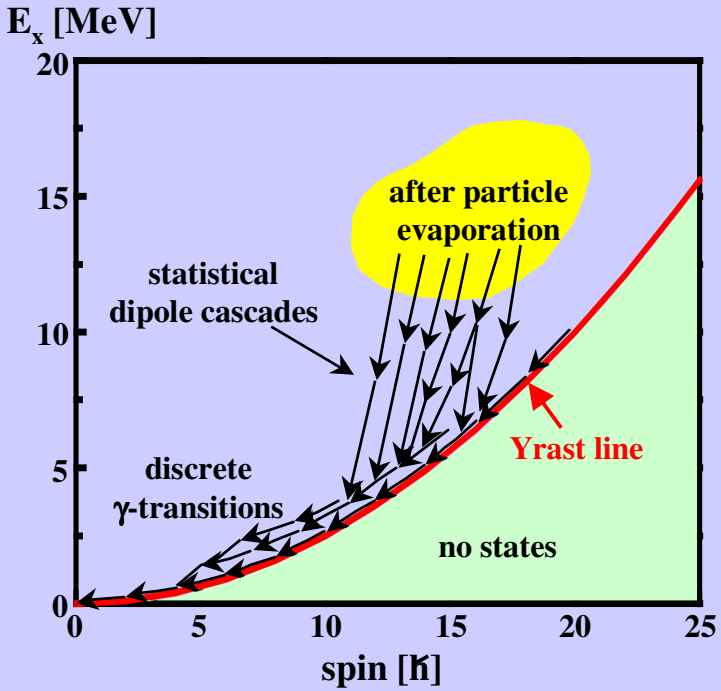
Gain in efficiency at 1898 keV γ-ray energy: 2.08(3) !

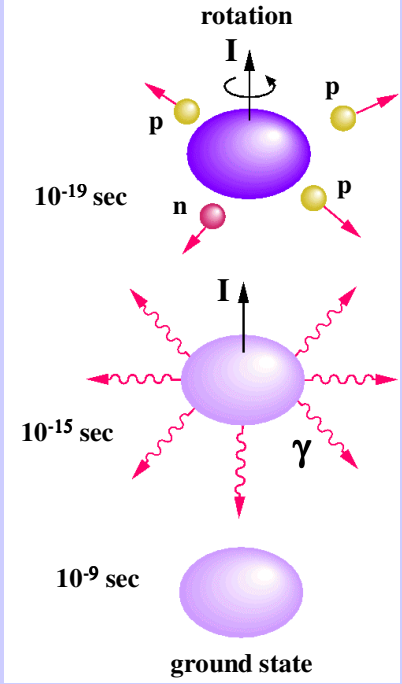
The EUROBALL spectrometer



The heavy-ion induced fusion-evaporation reaction

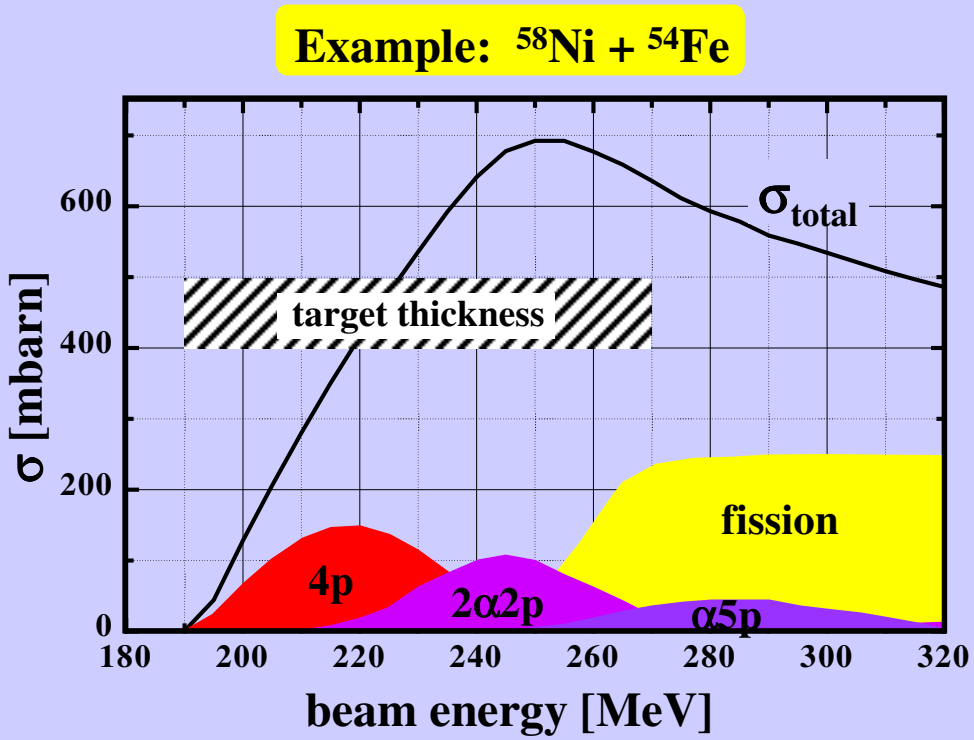


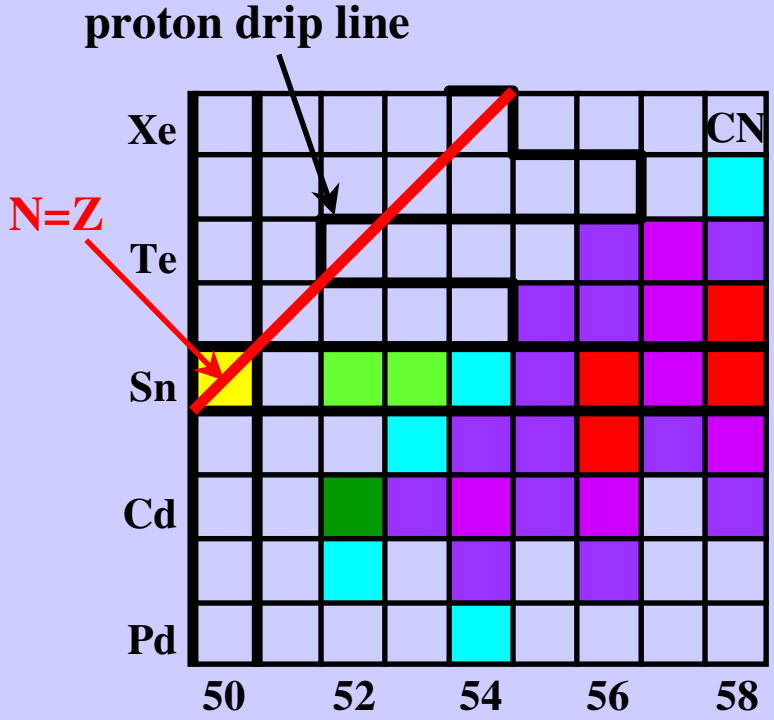




- neutron-deficient nuclei
- high spin and exc. energy
- needs an accelerator
- many different reaction products
- large range of cross sections
- recoil velocity of reaction products v/c ≈ 1-5%

Channel identification:
Which γ-ray belongs to which reaction product ?





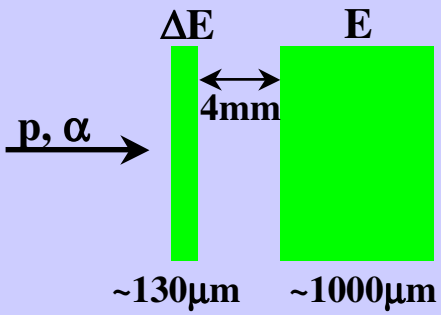
- many different reaction products
- large dynamical range

relative cross section in (%)

>1.0	0.001- 0.01
0.1- 1.0	0.0001- 0.001
0.01- 0.1	<0.0001

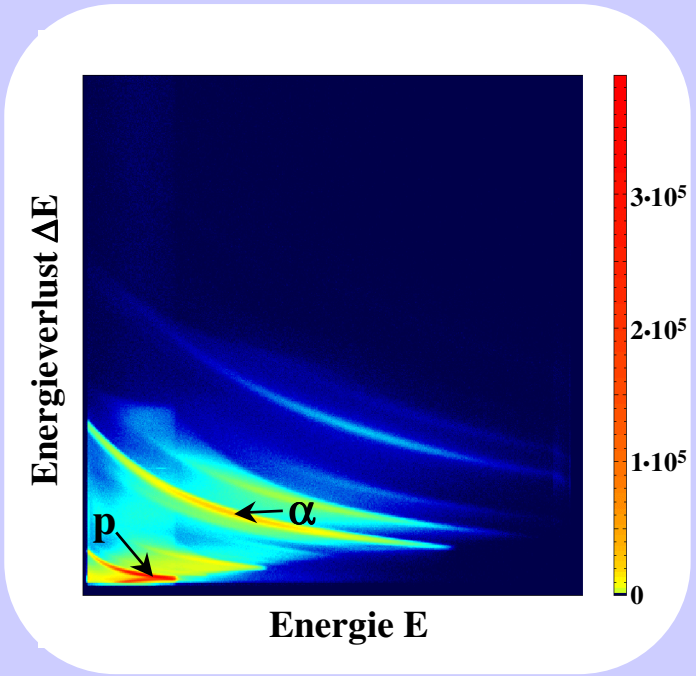
Detection of charged particles

Si telescope



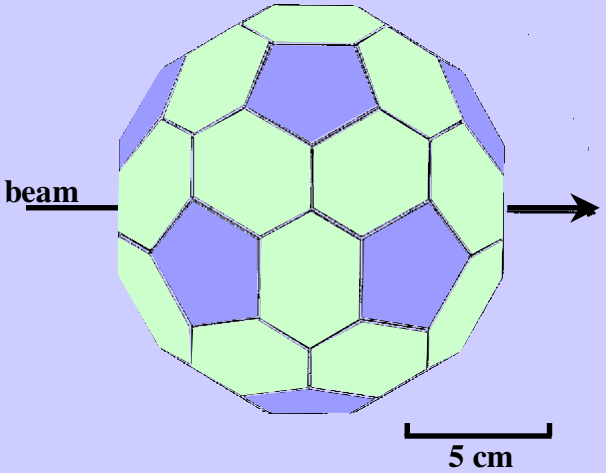
stopping power:

$$\frac{dE}{dx} \sim \frac{m \cdot Z^2}{E}$$



Protons and α clearly separated !

ISIS (Italian SIlicon Sphere)

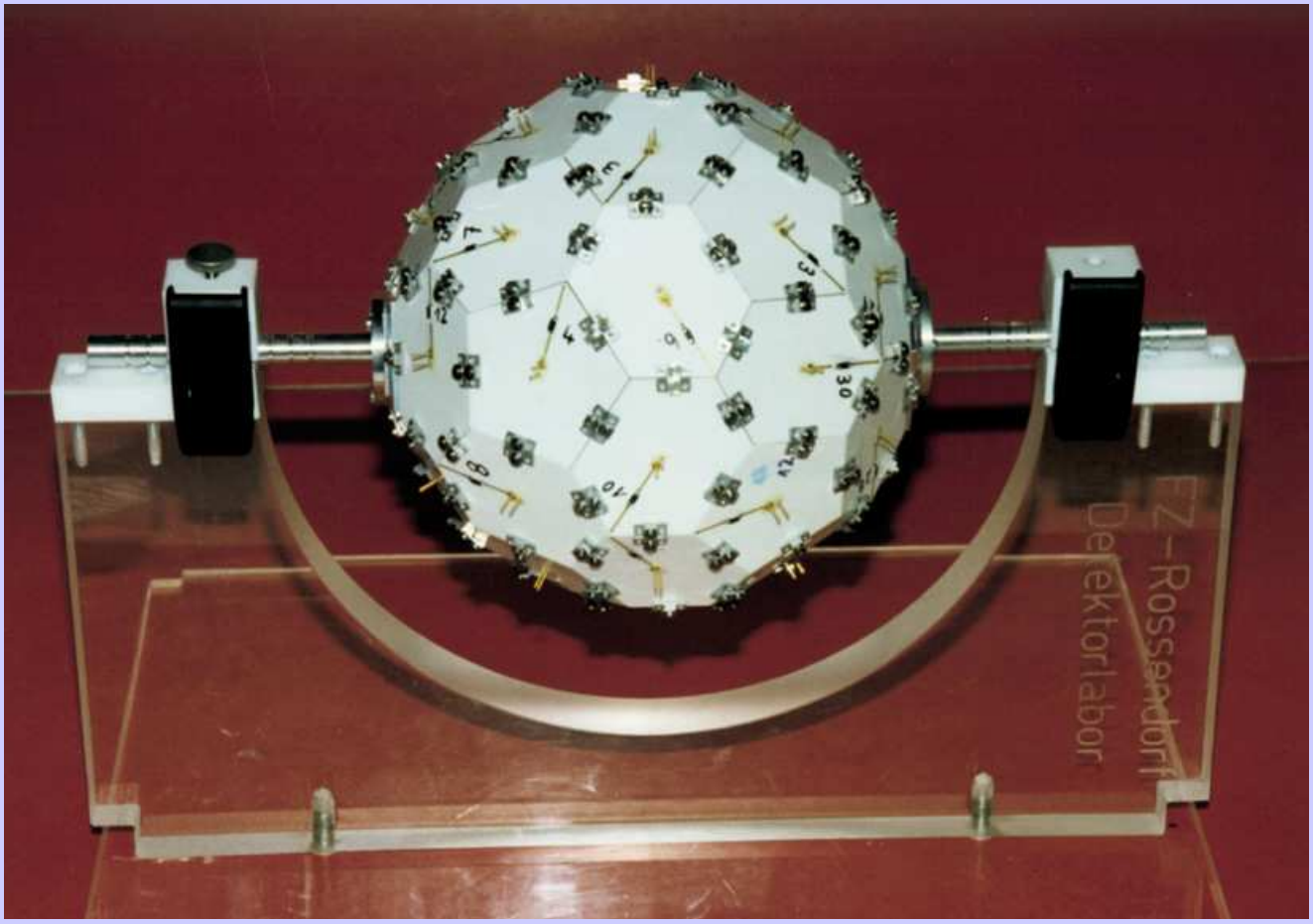


solid angle: 72% of 4π

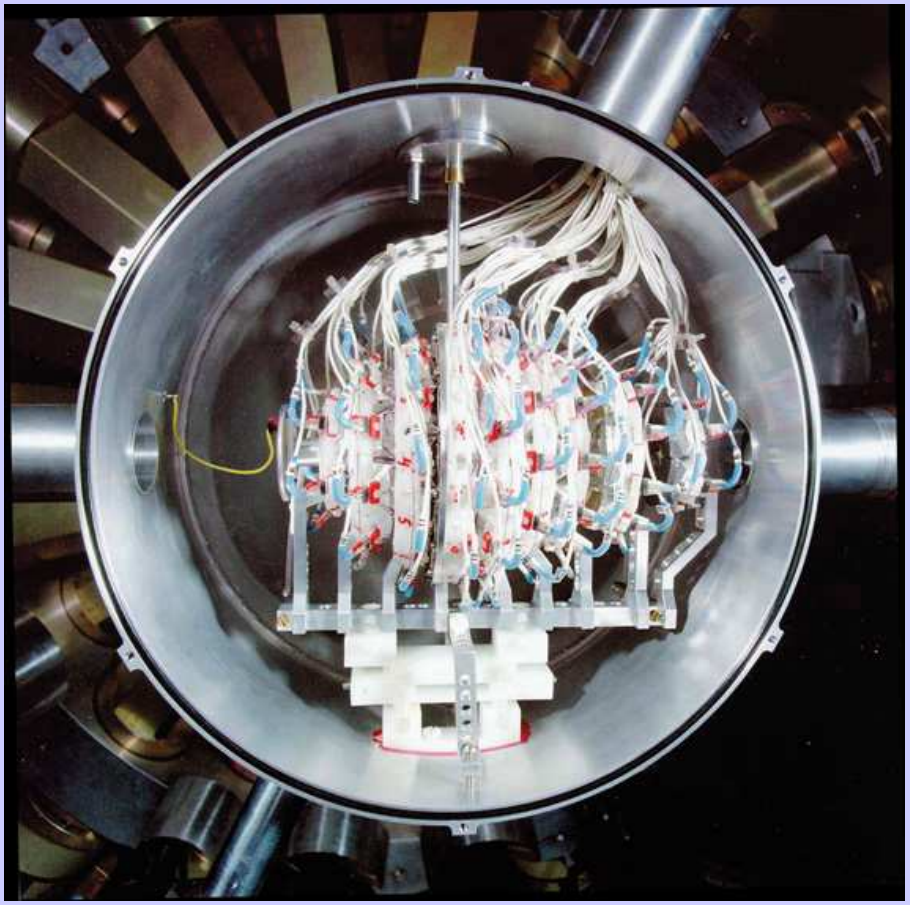
efficiency: 55% for protons
40% for α-particles

12 regular pentagons
30 irregular hexagons

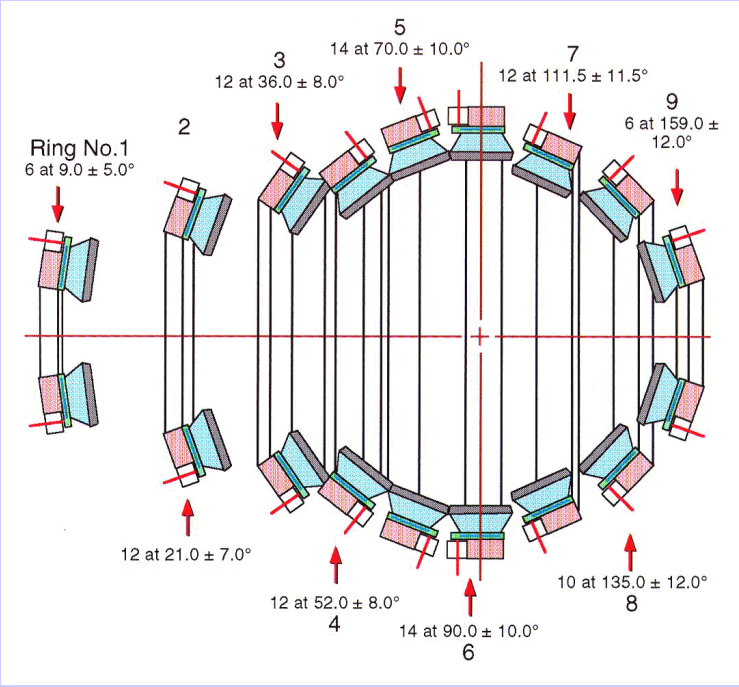
The EUROSiB 4π Si ball for EUROBALL



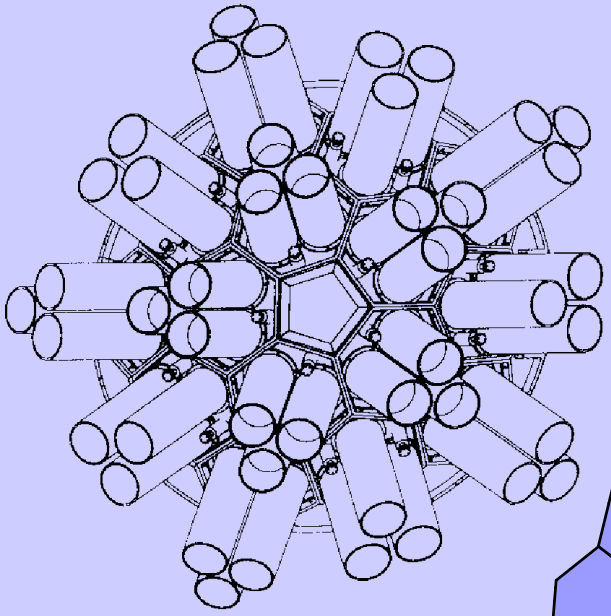
MICROBALL for the detection of light charged particles

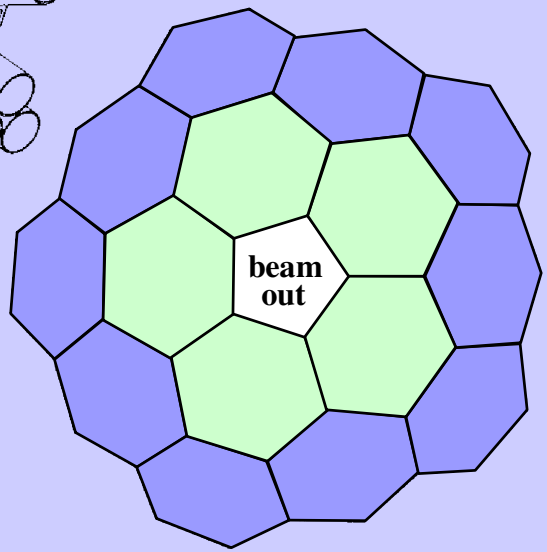


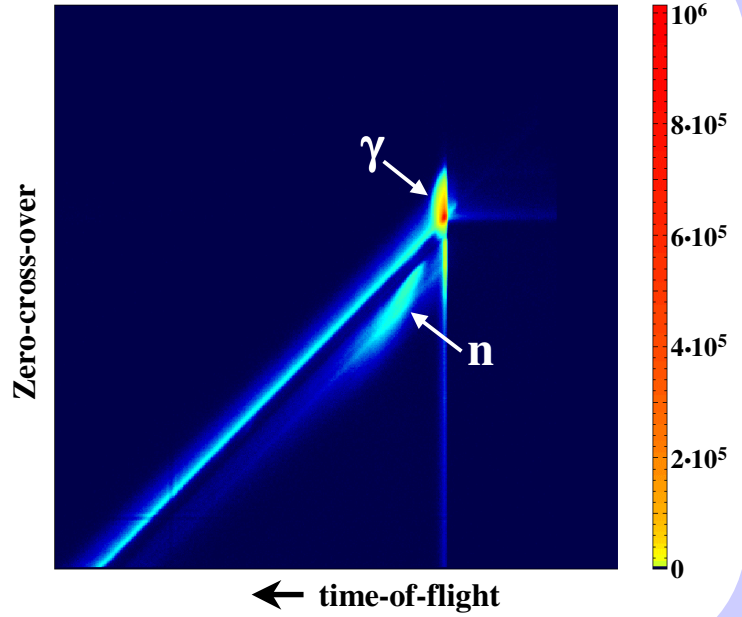
- 95 CsI(Tl) scintillators, arranged in 9 rings around the beam axis
- 97% of 4π



Detection of evaporated neutrons







15 pseudohexoconical
liquid scintillators BC501A

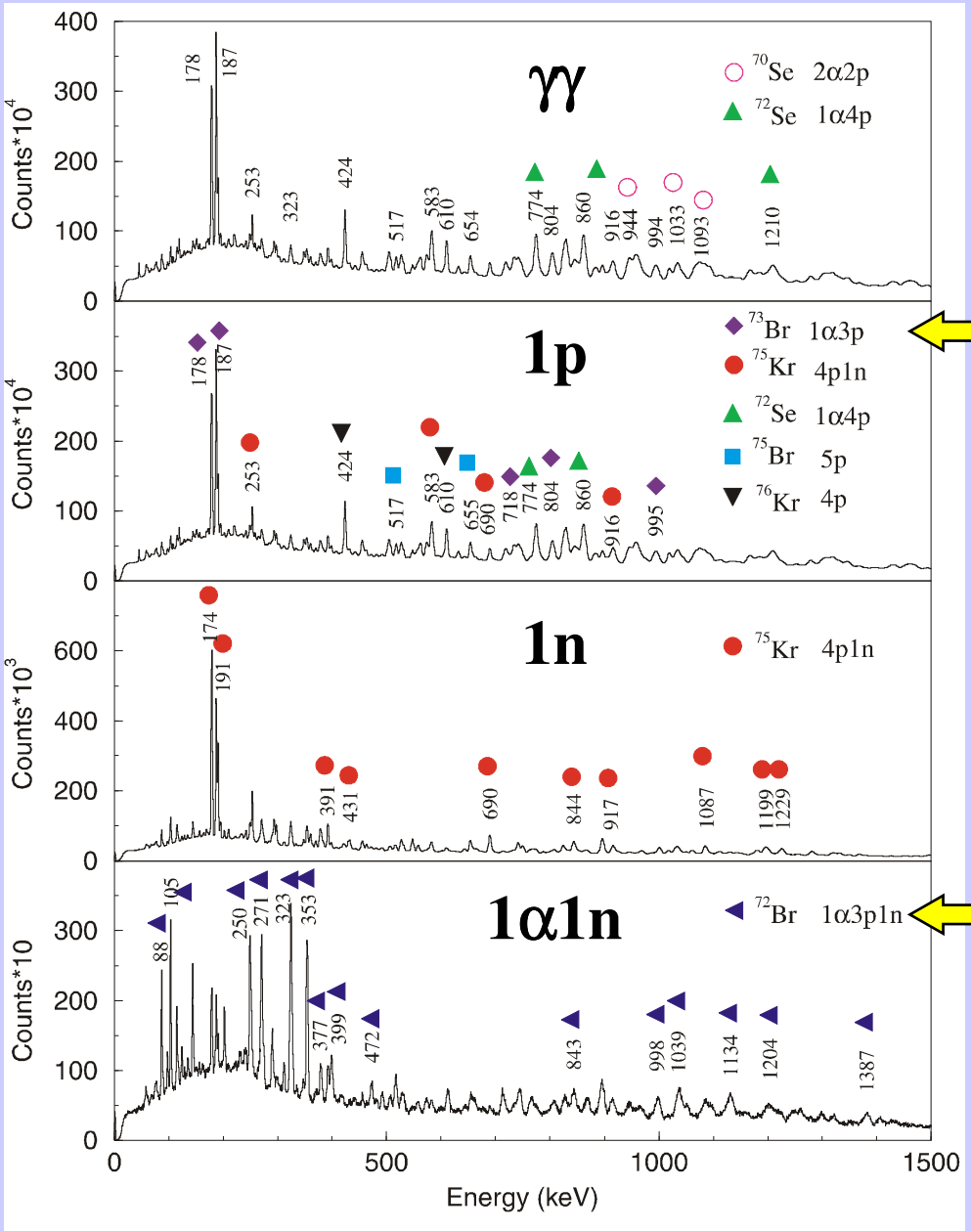
solid angle: 1π
efficiency: 25-30%

n-γ discrimination:

- puls shape – different decay times for protons and electrons
- time of flight - different time-of-flight for n and γ

$^{40}Ca + ^{40}Ca$ @ 185 MeV

EUROBALL
+
ISIS
+
neutron wall



Some recent examples …

- Prompt particle decay from deformed excited states
- Superdeformed bands all over the chart of nuclides
- Spectroscopy of transfermium nuclei: Towards the SHE's …
- Ground state proton decay: spectroscopy beyond the dripline

Funny things around doubly-magic $^{56}Ni_{28}$

Experiment at Berkeley Nat. Lab.:
Gammasphere (82 Ge)
+ MICROBALL
+ 15 neutron detectors

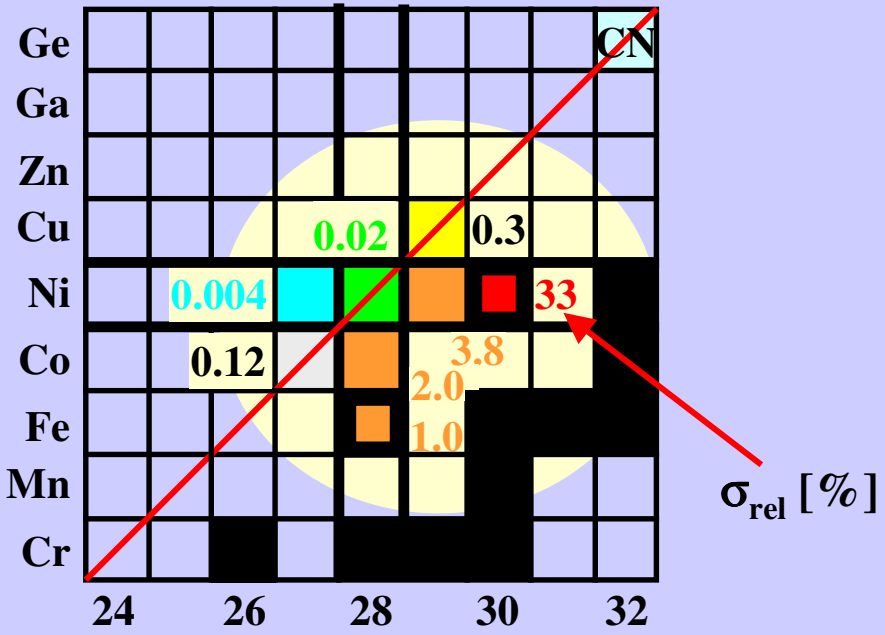
Efficiency: protons 80%
α-particles 65%

2 x 10^9 events (trigger: γγγ or γγn)

for example:

^{58}Cu	αpn	0.30(7)%
^{56}Ni	2α	0.020(3)%
^{55}Ni	2αn	~0.004%

^{36}Ar on ^{28}Si @ 136 MeV

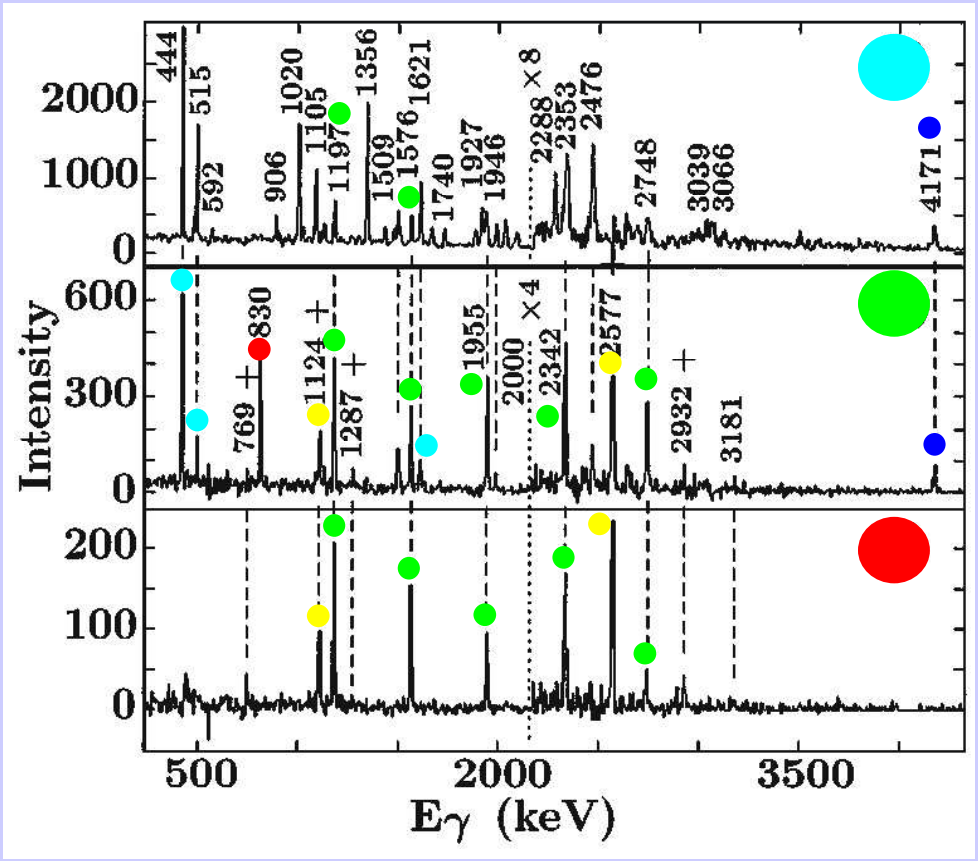


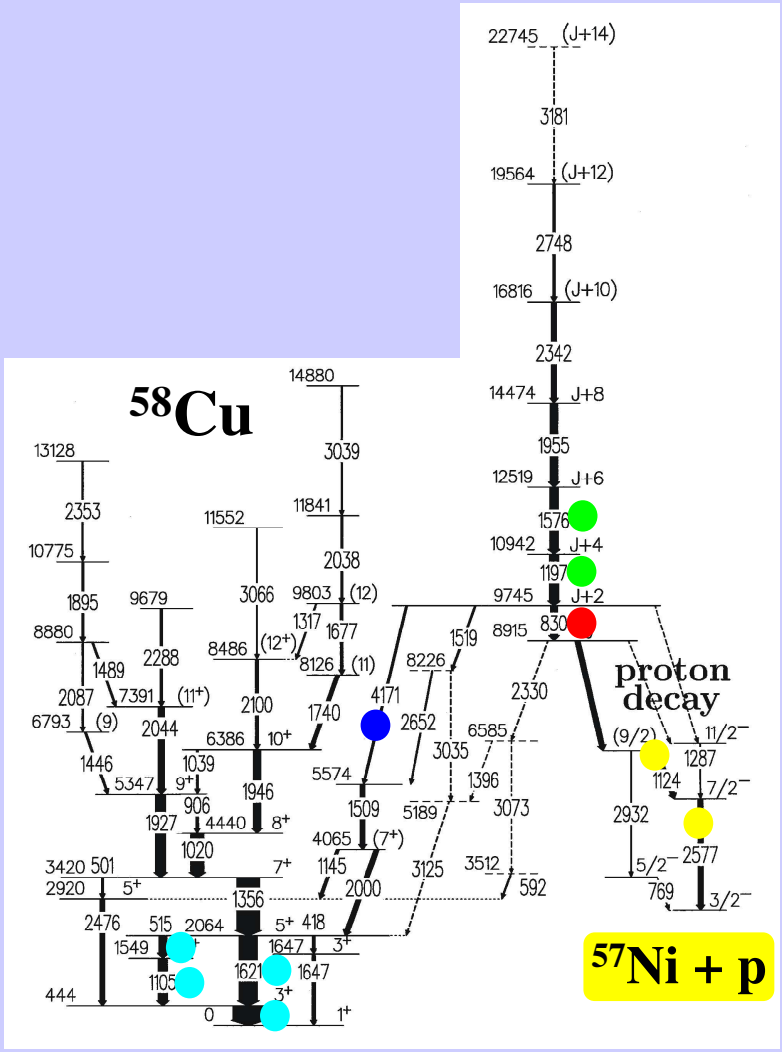
Alltogether 25 reaction channels observed with
σ = 0.004 - 33 % (4 orders of magnitude !)

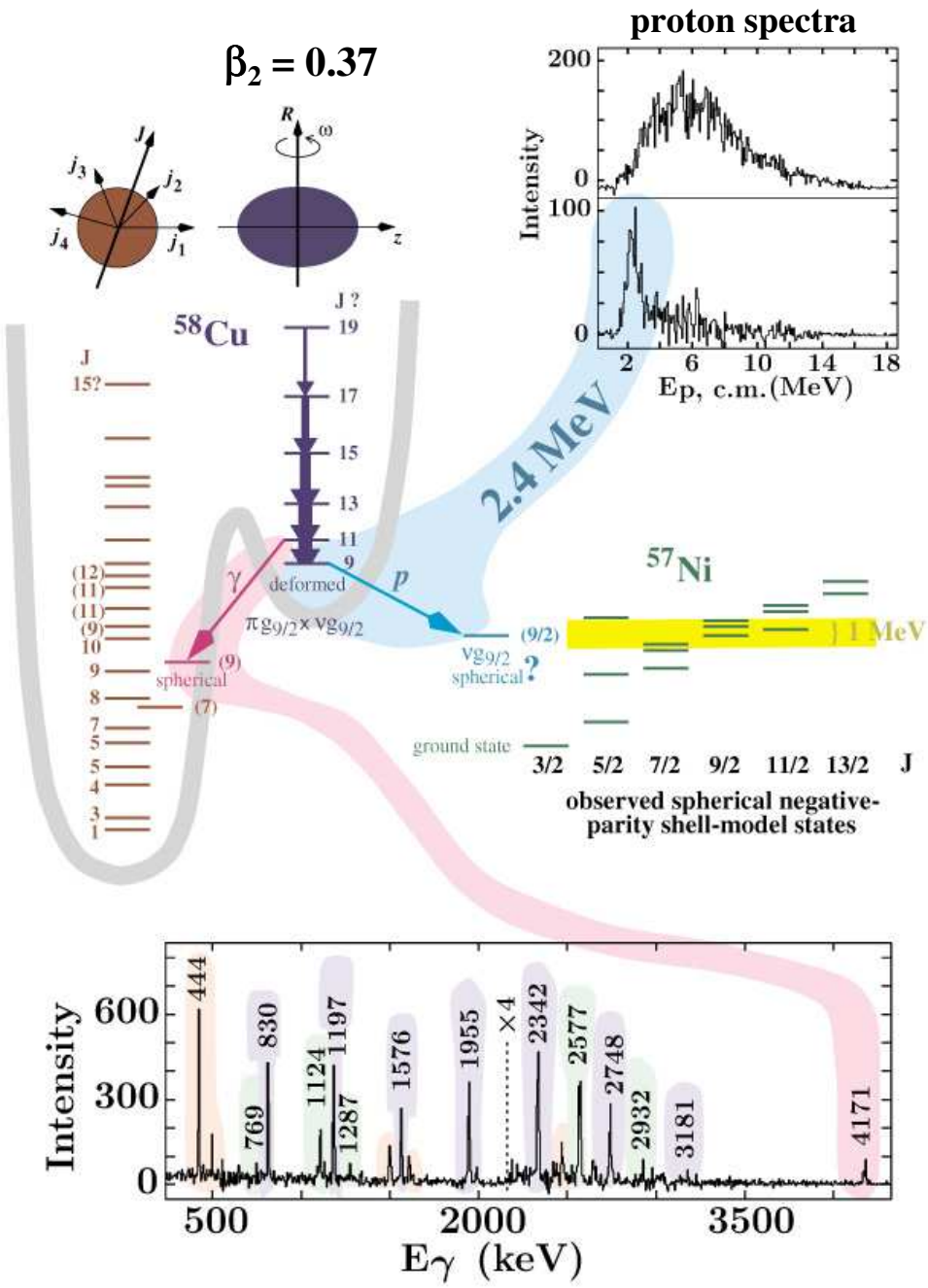
Prompt proton decay of N=Z ^{58}Cu

^{28}Si (^{36}Ar, αpn) ^{58}Cu σ ~ 0.30(7)%

γ-spectra with gate on 1α + 0/1 p + 1n






proton spectra
$\beta_2 = 0.37$
Intensity
200
0
100
0
2
6
10
14
18
Ep, c.m.(MeV)
2.4 MeV
^{58}Cu
J ?
19
17
15
13
11
9
J
15?
(12)
(11)
(11)
(9)
10
9
8
7
5
5
4
3
1
γ
deformed
p
$\pi g_{9/2} \times \nu g_{9/2}$
(9)
spherical
(7)
^{57}Ni
(9/2)
$\nu g_{9/2}$
spherical ?
1 MeV
ground state
3/2
5/2
7/2
9/2
11/2
13/2
J
observed spherical negative-parity shell-model states
Intensity
600
300
0
444
769
830
1124
1197
1287
1576
1955
×4
2342
2577
2748
2932
3181
4171
500
2000
3500
Eγ (keV)

Funny things around doubly-magic $^{56}Ni_{28}$

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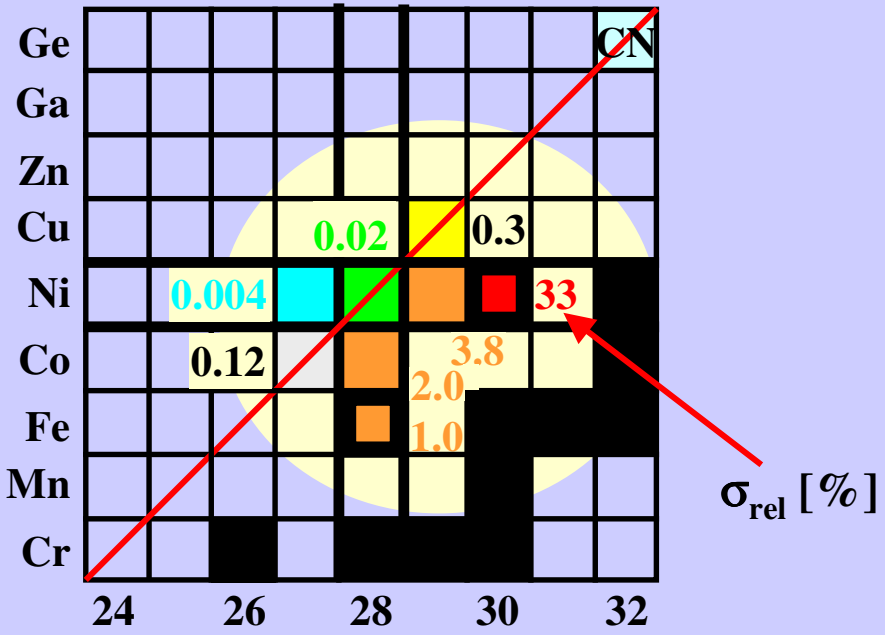

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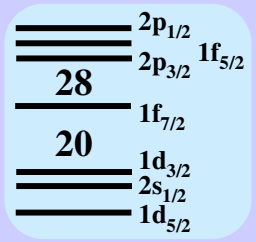
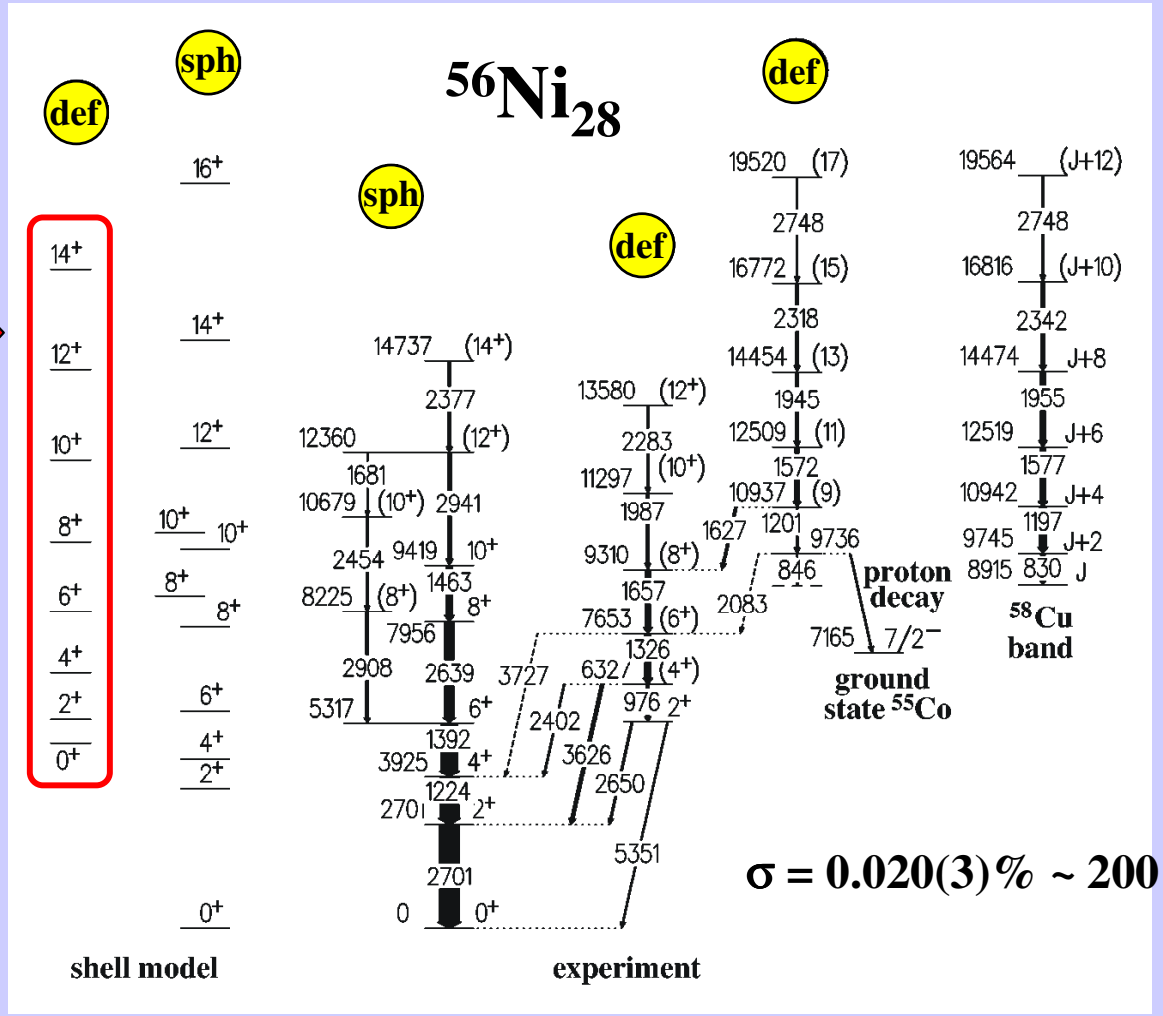
Rotational bands in doubly-magic $^{56}Ni_{28}$

4p-4h



SM with excitation of up to 6 nucleons from $f_{7/2}$ to remaining pf-shell



$\sigma = 0.020(3)\% \sim 200\ \mu b$

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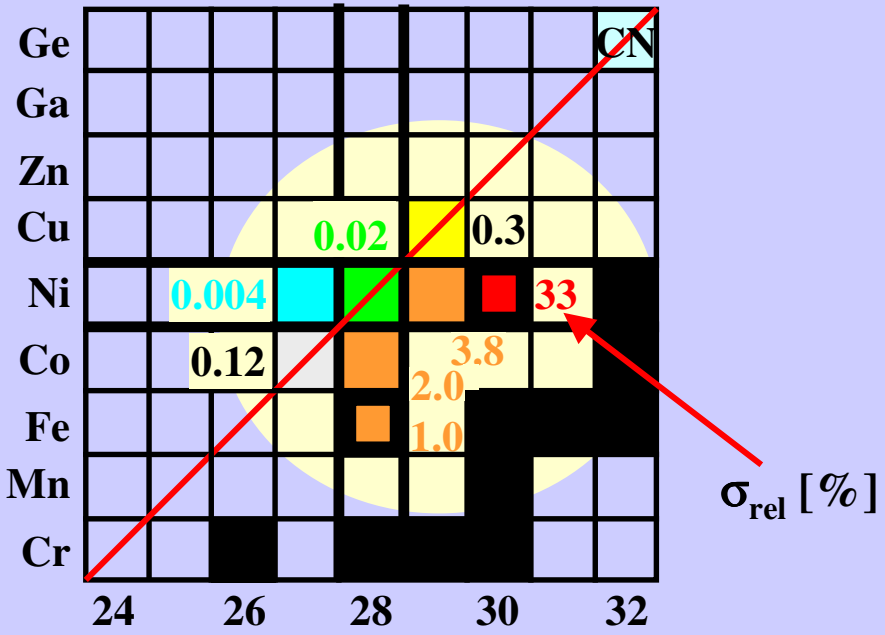

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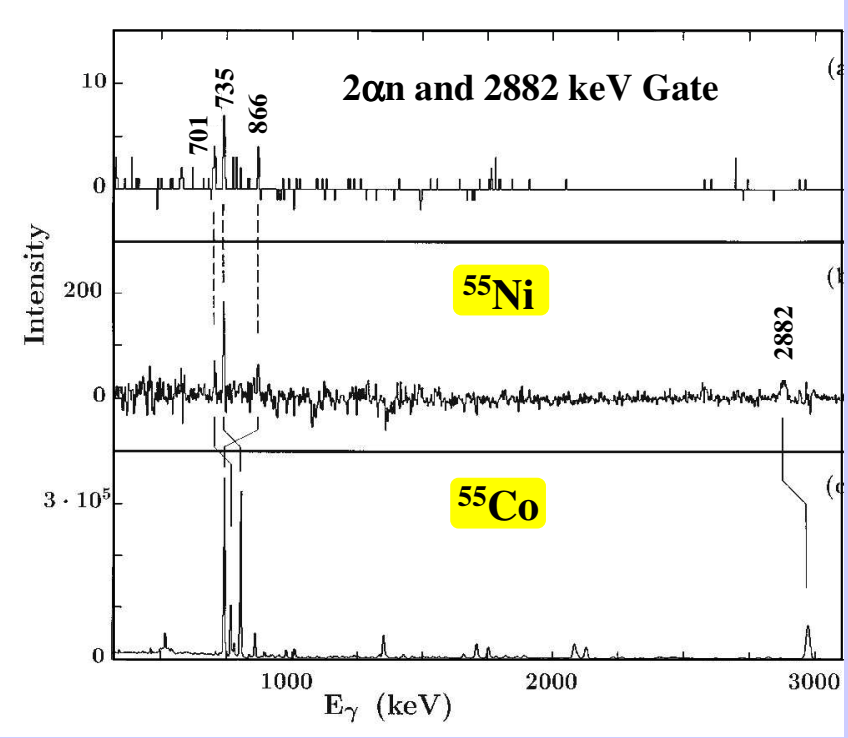
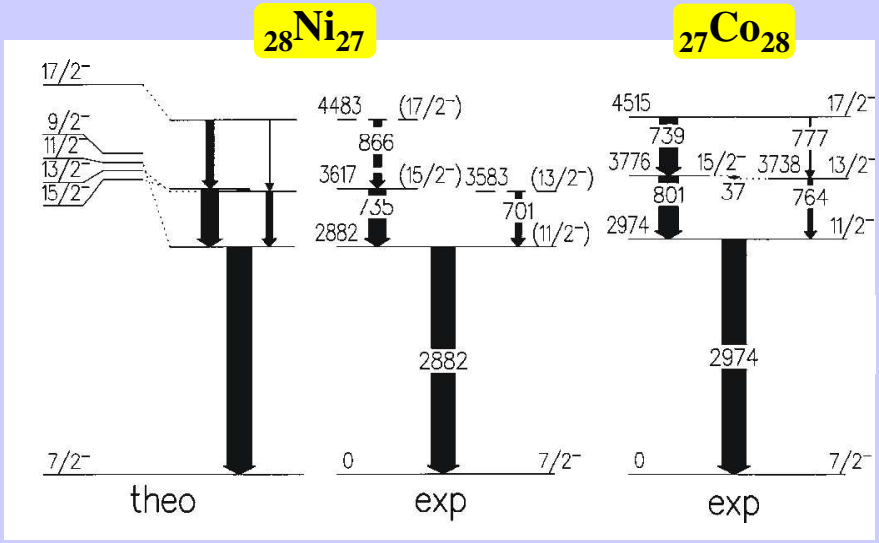
At the limit: ^{55}Ni with σ ~ 0.004 % ≅ 40 μb





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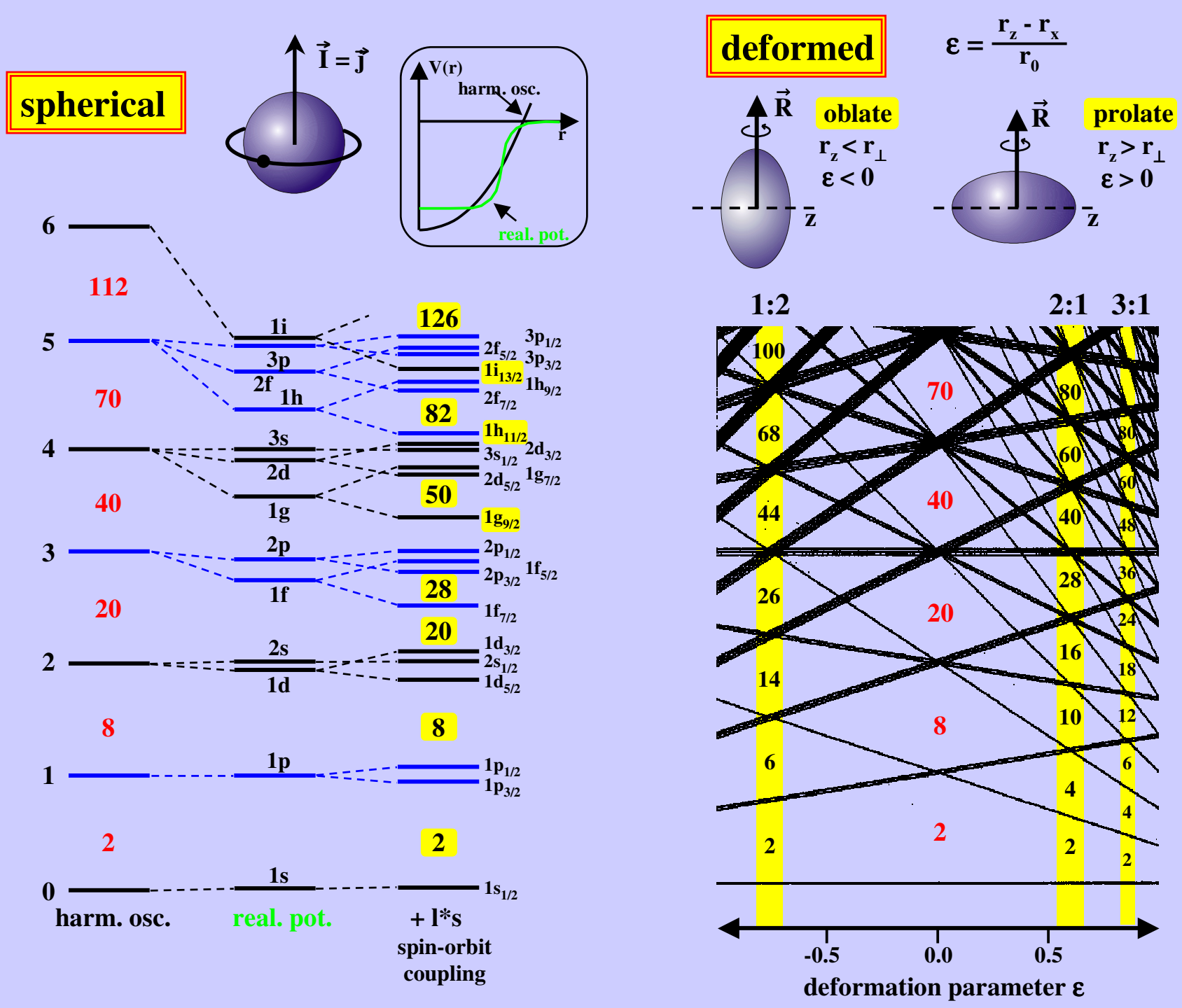
spherical
$\vec{l} = \vec{j}$
V(r)
harm. osc.
r
real. pot.
6
112
5
70
4
40
3
20
2
8
1
2
0
1i
3p
2f
1h
3s
2d
1g
2p
1f
2s
1d
1p
1s
126
82
50
28
20
8
2
$3p_{1/2}$
$2f_{5/2}$
$3p_{3/2}$
$1i_{13/2}$
$1h_{9/2}$
$2f_{7/2}$
$1h_{11/2}$
$3s_{1/2}$
$2d_{3/2}$
$2d_{5/2}$
$1g_{7/2}$
$1g_{9/2}$
$2p_{1/2}$
$2p_{3/2}$
$1f_{5/2}$
$1f_{7/2}$
$1d_{3/2}$
$2s_{1/2}$
$1d_{5/2}$
$1p_{1/2}$
$1p_{3/2}$
$1s_{1/2}$
harm. osc.
real. pot.
+ l*s
spin-orbit
coupling
deformed
$\varepsilon = \frac{r_z - r_x}{r_0}$
$\vec{R}$
oblate
$r_z < r_\perp$
$\varepsilon < 0$
z
$\vec{R}$
prolate
$r_z > r_\perp$
$\varepsilon > 0$
z
1:2
2:1
3:1
100
68
44
26
14
6
2
70
40
20
8
2
80
60
40
28
16
10
6
4
2
80
60
48
36
24
18
12
6
4
2
-0.5
0.0
0.5
deformation parameter ε