CAESAR

A high-efficiency scintillator array for gamma-ray spectroscopy with fast beams of rare isotopes

NIM A624 (2010) 615-623

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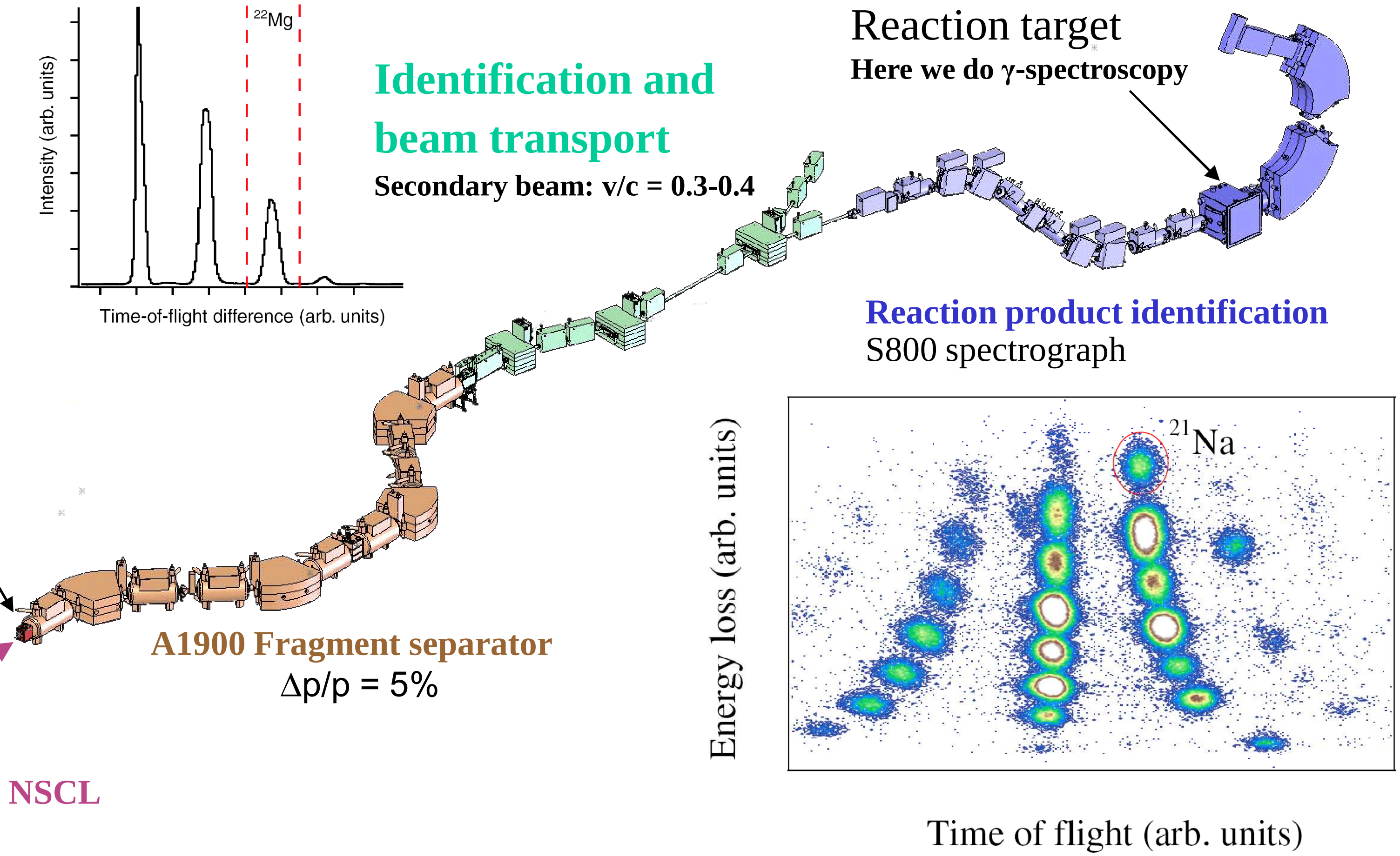
Supported by US National Science Foundation under contracts PHY-0722822 and PHY-0606007

Exotic beams for γ spectroscopy at NSCL



Identification and beam transport

Secondary beam: v/c = 0.3-0.4

Reaction target

Here we do γ-spectroscopy

Reaction product identification

S800 spectrograph

Momentum: ± 2.5%

Angle: ±3.5° (vertical)

±5° (horizontal)

Production target

(usually Be)

A1900 Fragment separator

Δp/p = 5%

Primary beam from NSCL Coupled Cyclotrons

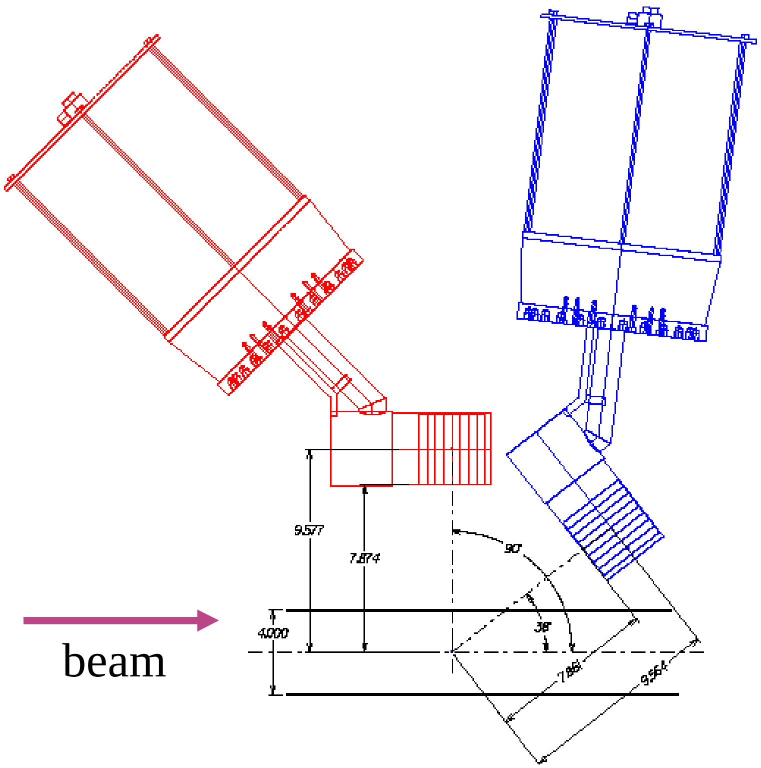
e.g.

^{36}Ar 150 MeV/u 50 pnA

^{48}Ca 140 MeV/u 80 pnA

^{76}Ge 130 MeV/u 20 pnA

Workhorse for γ rays: SeGA



SeGA in 'classic' configuration
- o 32-fold segmented HPGe detectors
  (8 slices and 1cm each, 4 sectors)
- o Spatial resolution $d\theta \approx 2.5^{o}$
- o 10 detectors at 90^{o}, 8 at 37^{o}
- o In-beam FWHM resolution 2-3%
- o In-beam ε=2.5% at 1 MeV

For (much) more efficiency we have to increase solid angle coverage (a lot).

Scintillators for γ Spectroscopy

Gamma spectroscopy with fast beams using **Ge-detectors** (like SeGA)
Fact 1: Energy resolution is dominated by Doppler broadening → FWHM ~ 3%
Fact 2: Efficiency is quite low → ε~2-3% (SeGA)
Fact 3: VERY expensive to upgrade

Gamma spectroscopy with fast beams using **scintillators**
Fact 1: Energy resolution is dominated by intrinsic detector resolution
Fact 2: Comparably cheap detection systems with high detection efficiency

Question (for a scintillator array like CAESAR):

Is it worthwhile to sacrifice energy resolution (factor 3) for gaining efficiency (order of magnitude)?

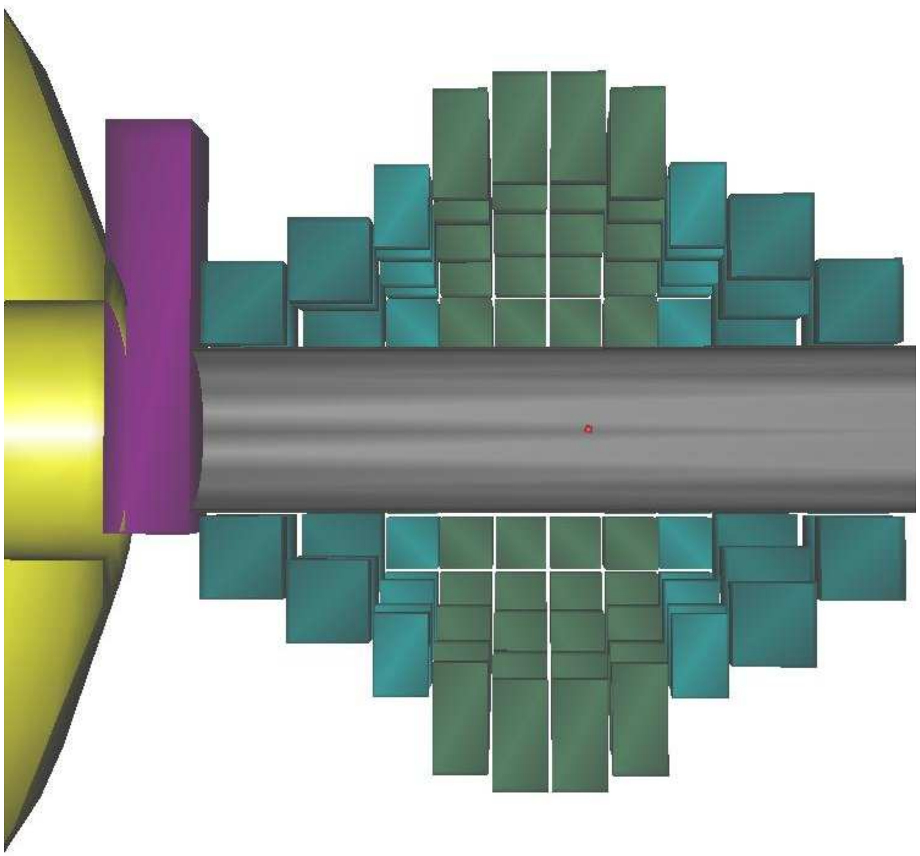
Examples (40% γ-ray detection efficiency):

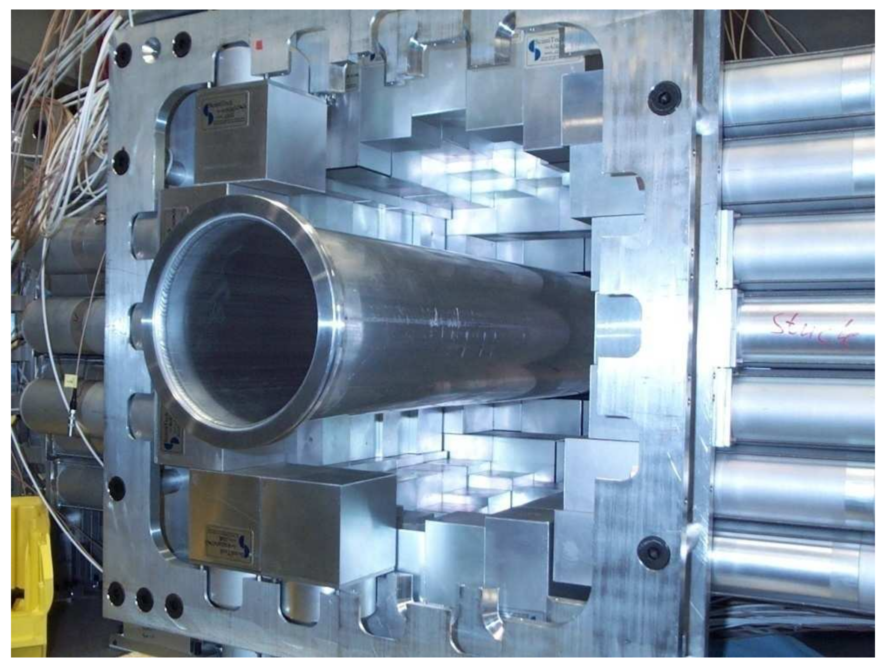
Coulex	2 pps, 300 mg Au, 500 mb: 132 detected gamma rays
Knockout	2 pps, 300 mg Be, 25 mb: 144 detected gamma rays
2p-KO or **exchange**	100 pps, 500 mg Be, 0.1 mb: 48 detected gamma rays

….but can we resolve those in a real-life spectrum with background?

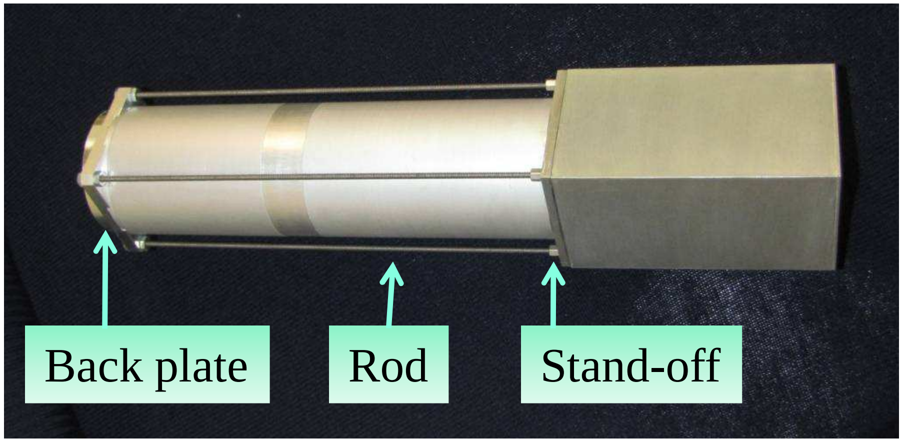
The CAESium iodide ARray

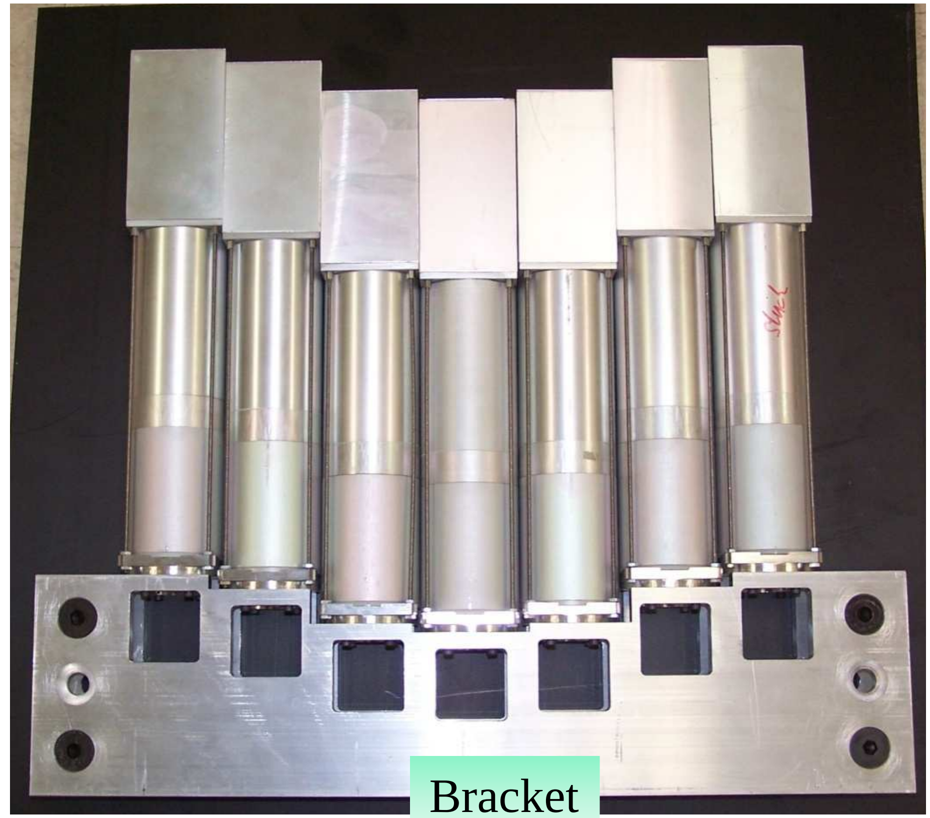
- CsI(Na)
- 48 3”x 3”x 3” crystals
- 144 2”x 2”x 4” crystals
- Solid angle coverage 95%
- In-beam FWHM: 9.2% (@1 MeV)
- Full-energy-peak efficiency 35% at 1MeV





A detail: Mechanics



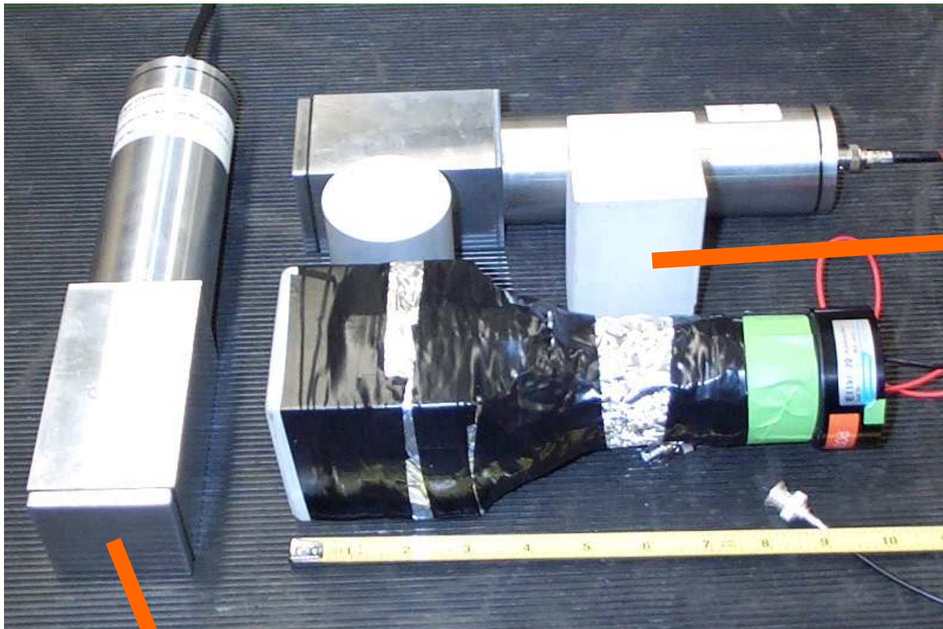


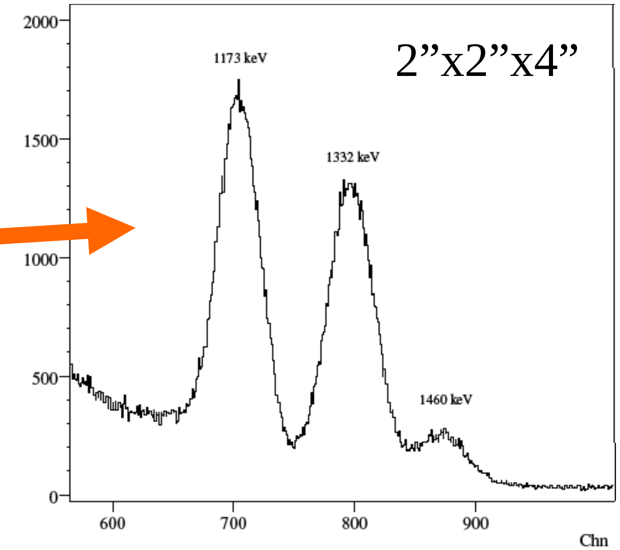
- Detector housing offers stand-offs.
- Support and alignment done by threaded rods
- Back plate bolted in bracket

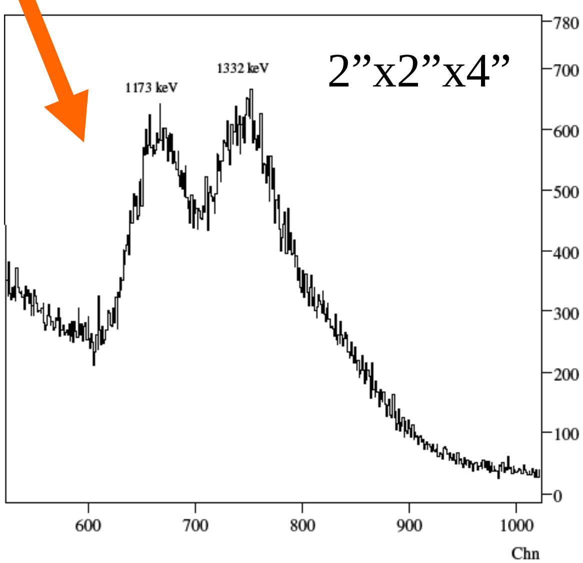
Advantage

- ➢Mech. tolerances of detector mustn't be tight
- ➢Once aligned, a bracket can be handled easily

Light collection and peak shape



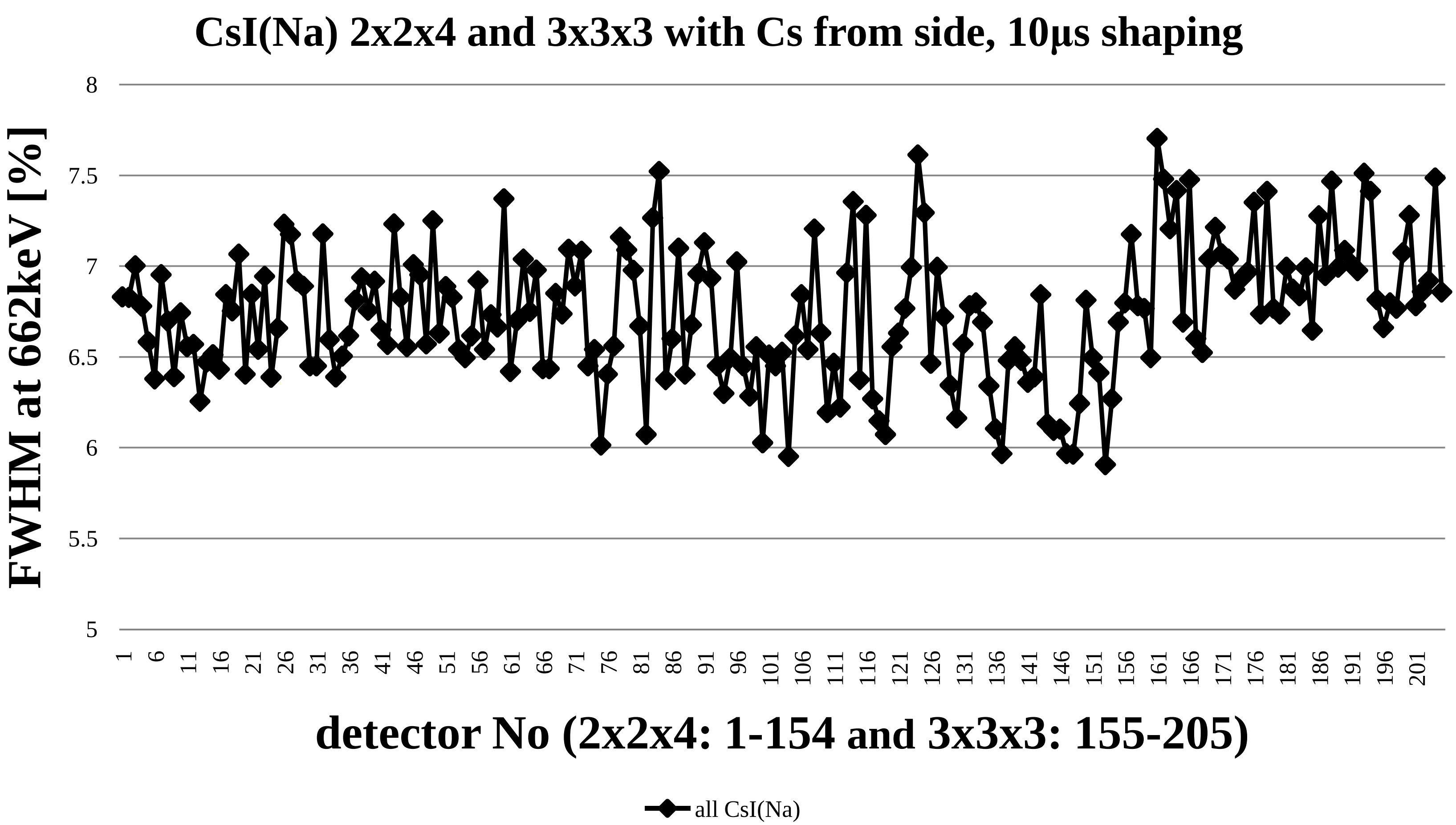




One major question during planning phase:
“Can we get good spectral response from rectangular crystal geometry?”

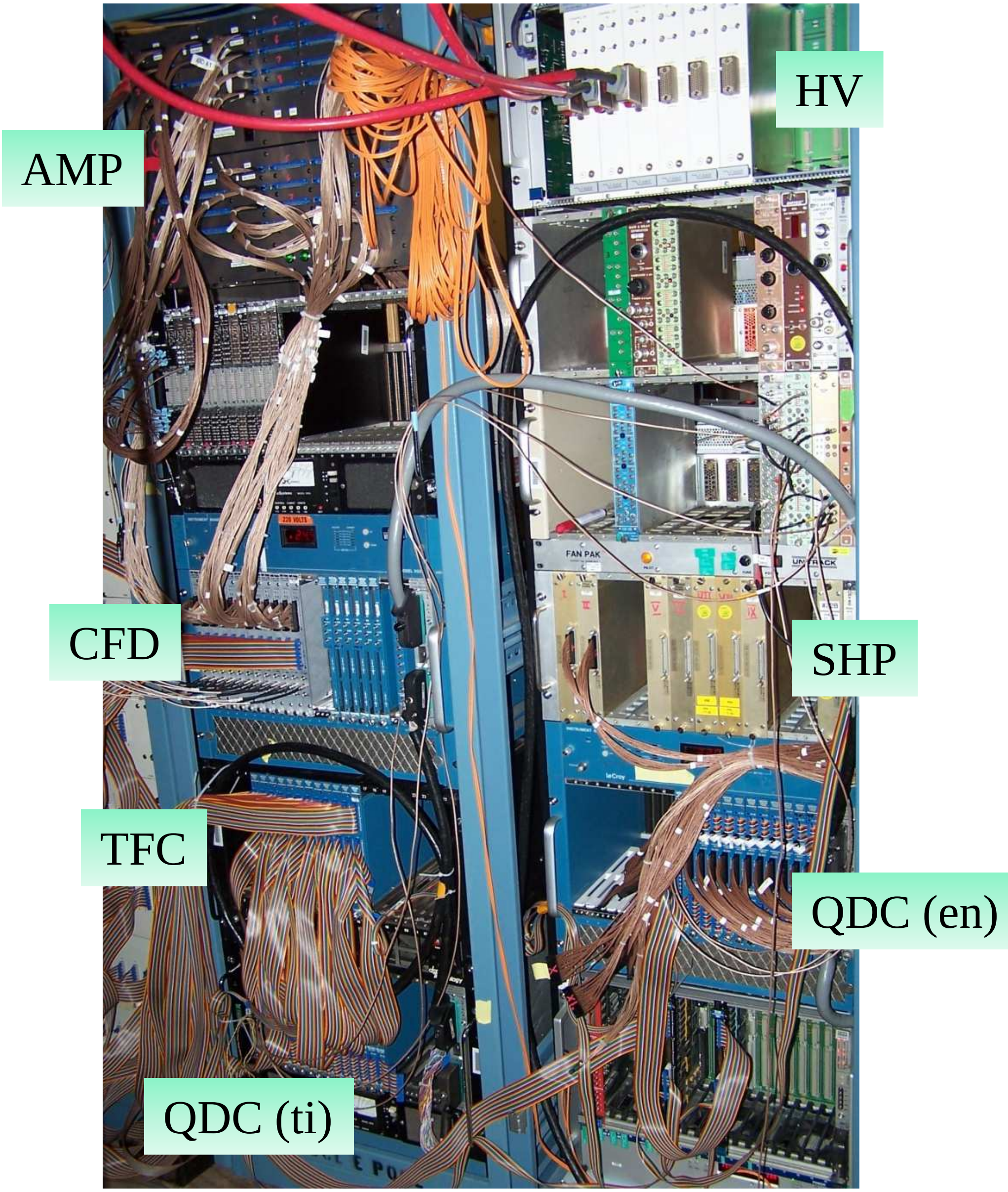
Results shown for samples from different vendors. ^{60}Co source irradiated from side.

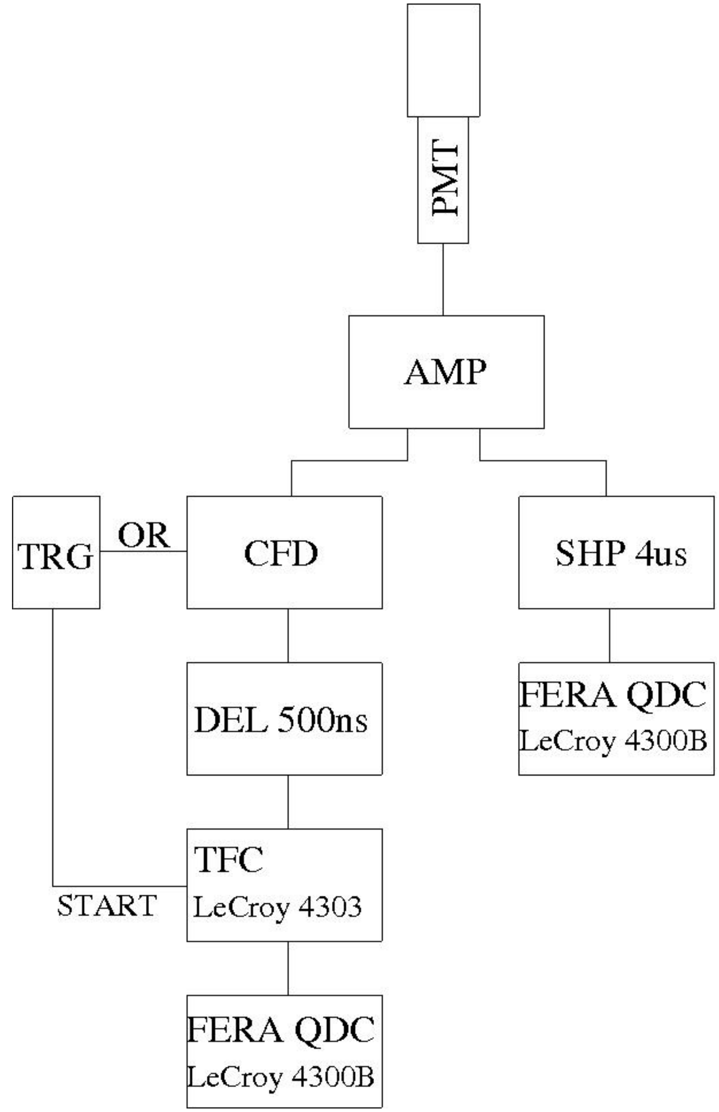
FWHM for ^{137}Cs



(Vendor guaranteed better than 7.7%)

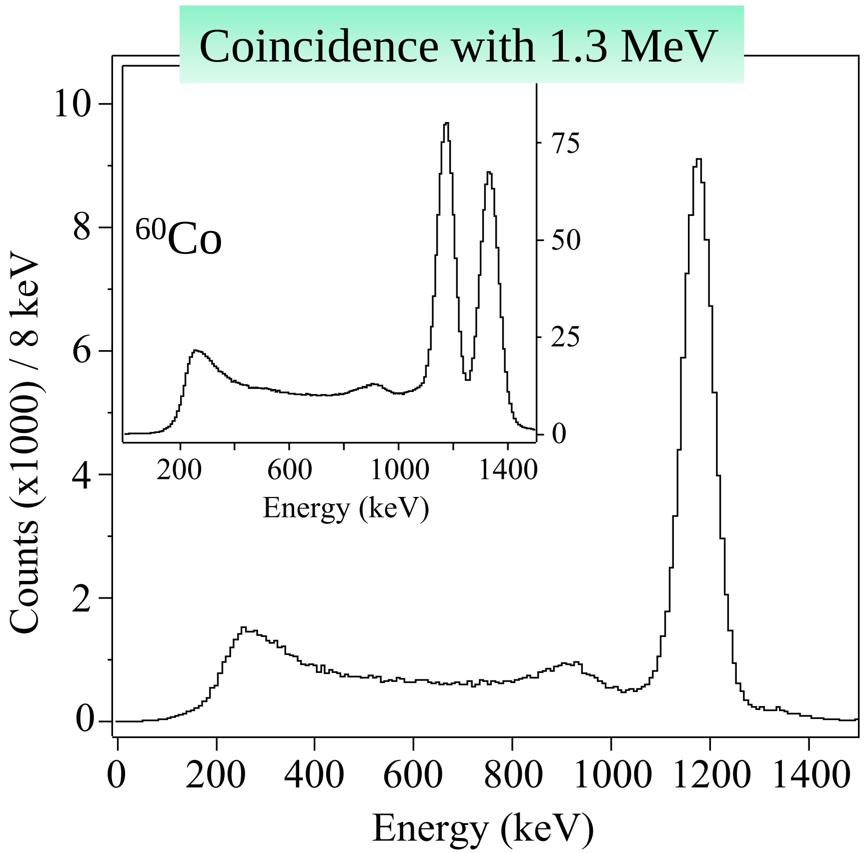
CAESAR electronics

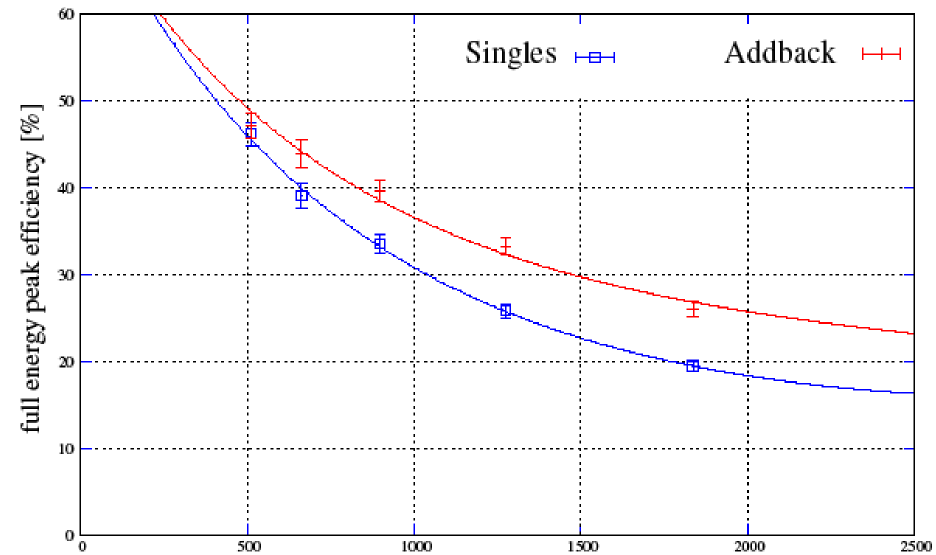


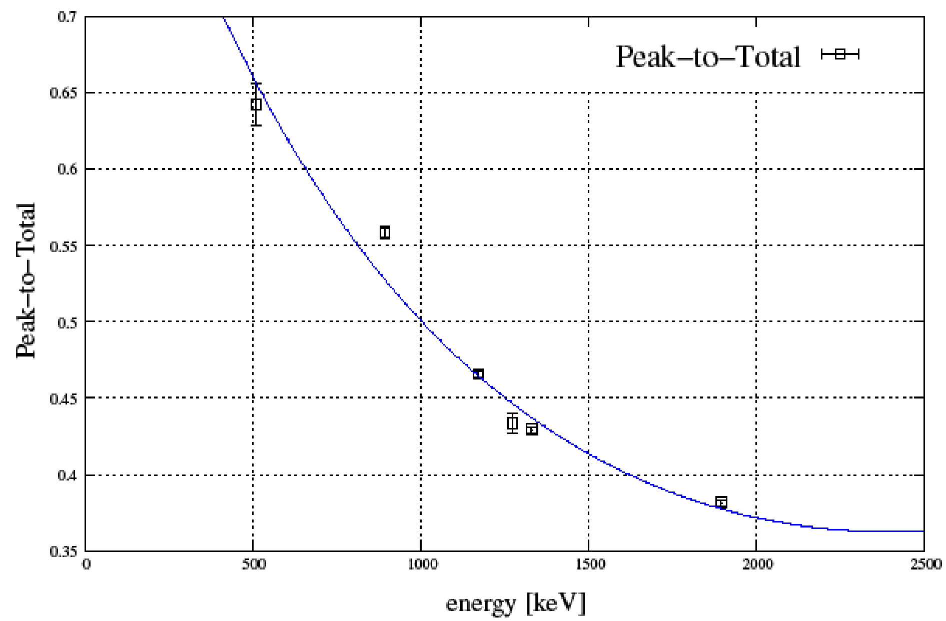


First implementation worked with DISCRIMINATORS, not CFD

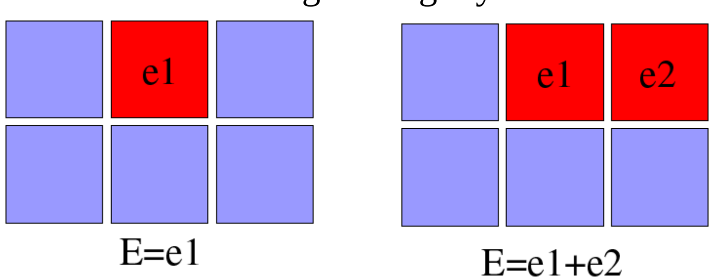
Source performance of CAESAR



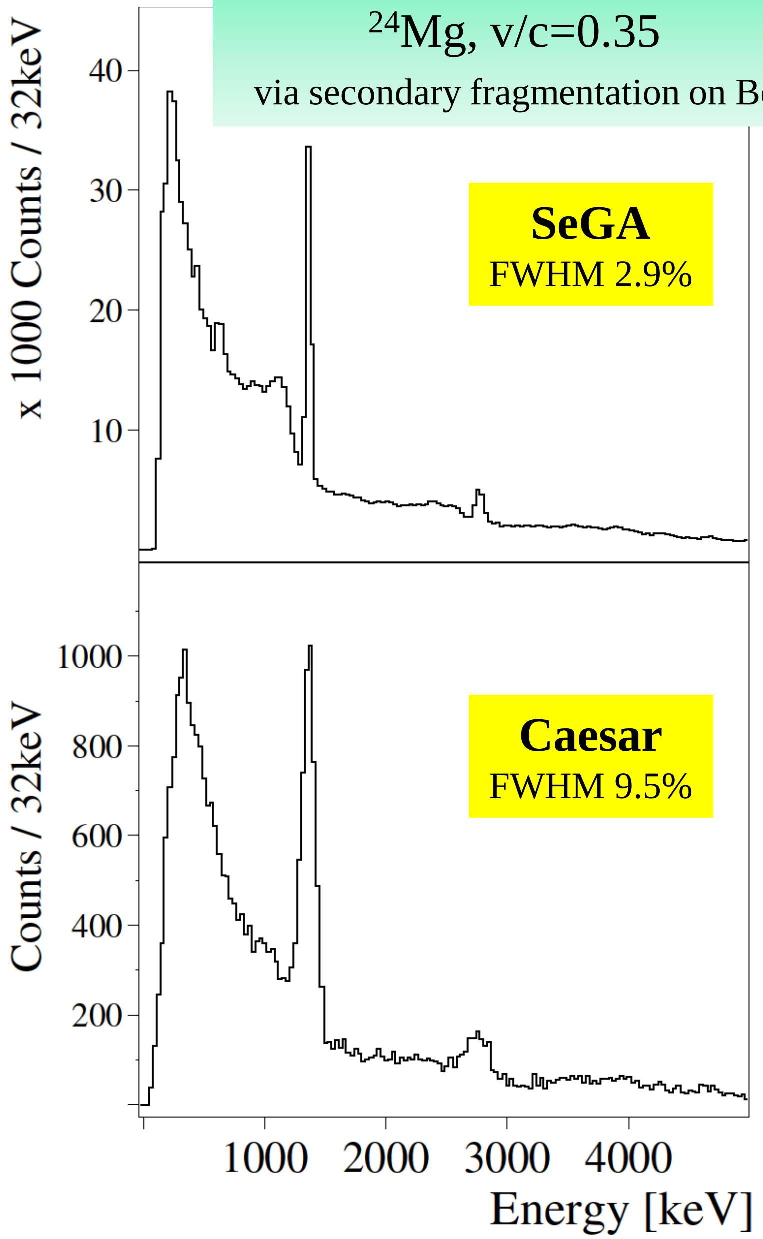




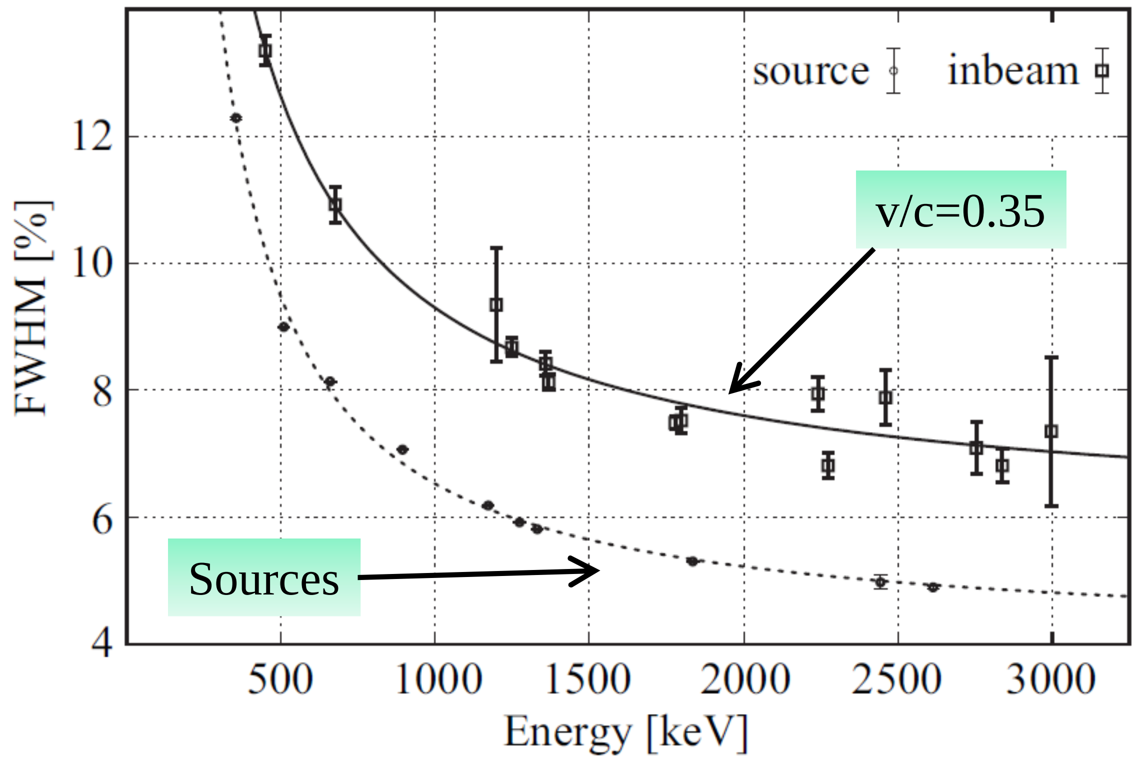
Addback: Recover energy of γ scattered between two neighboring crystals



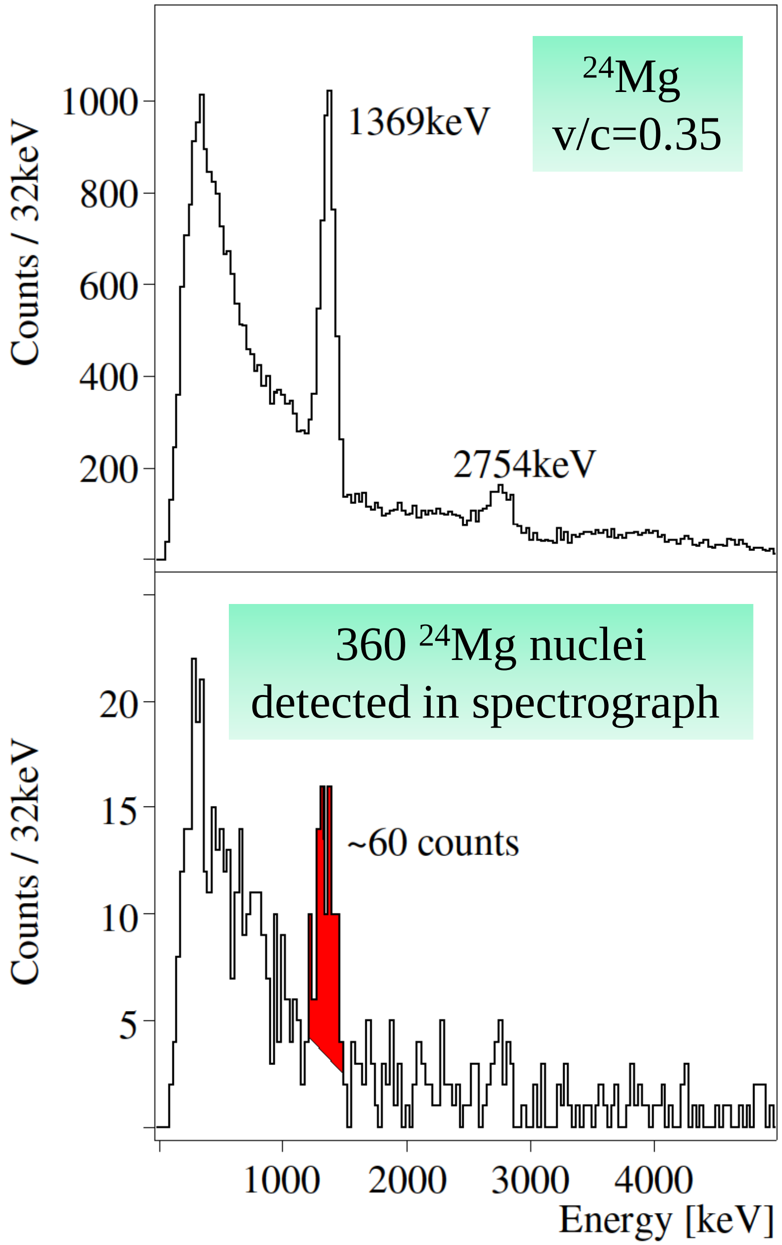
In-beam performance



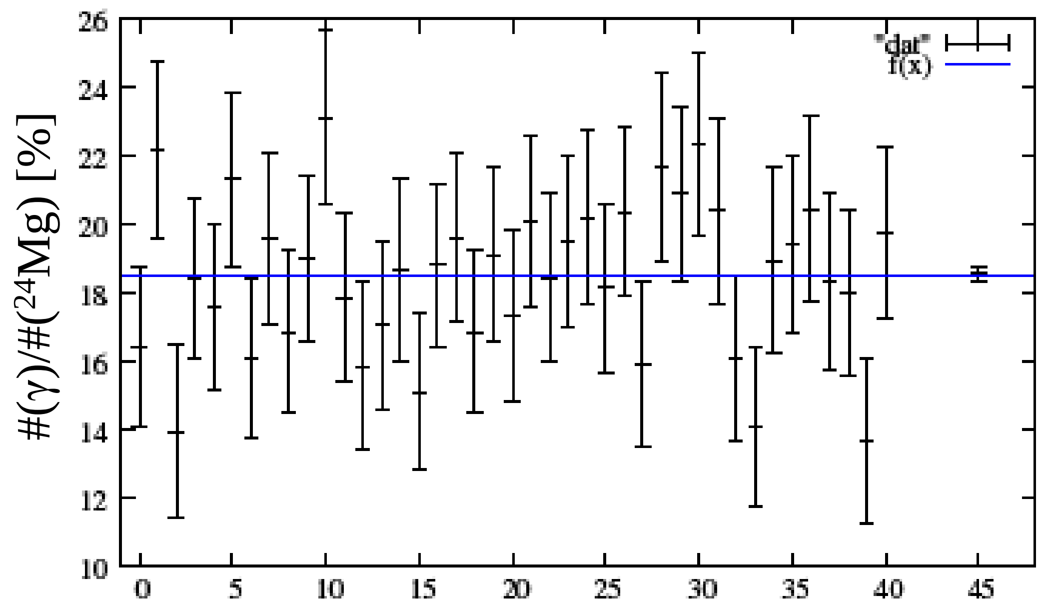
Energy resolution (FWHM [%]) of CAESAR **in-beam** (from Doppler-reconstructed spectra) and **intrinsic** (from calibration sources)



Secondary fragmentation reaction



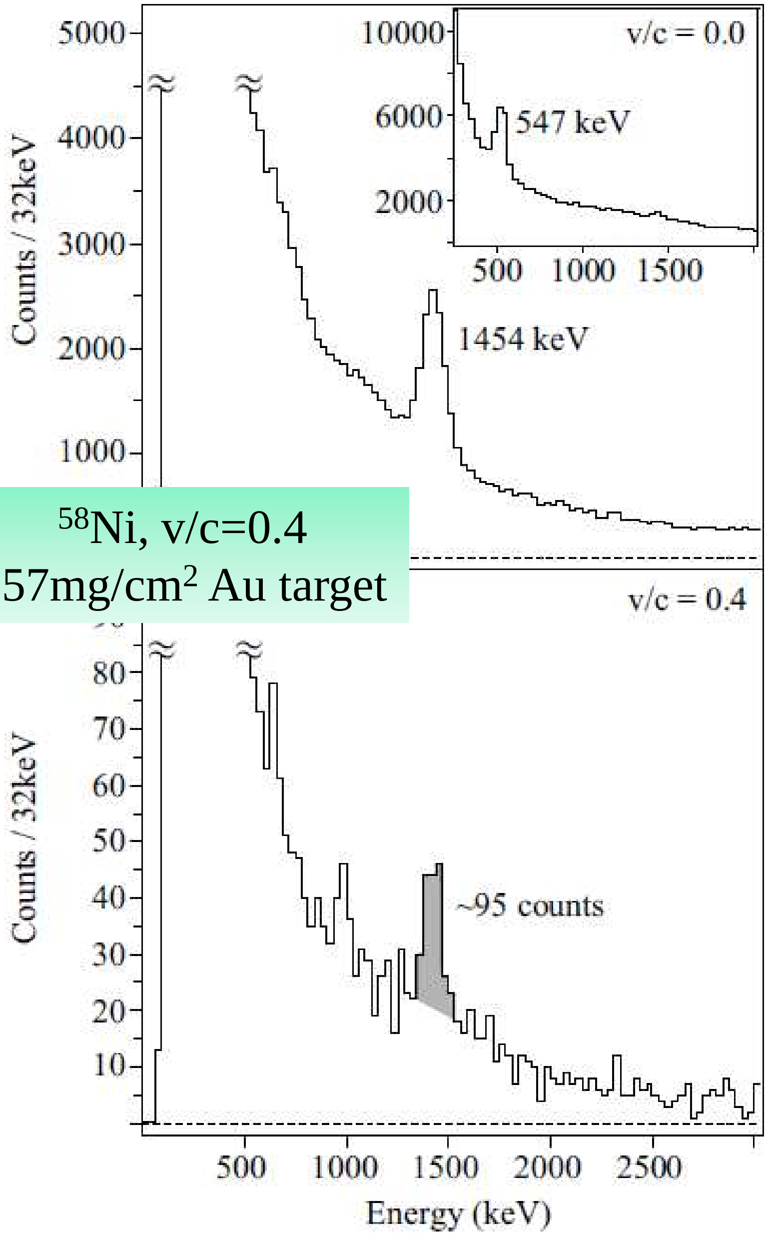
^{9}Be(^{33}Cl,^{24}Mg)X at 65 MeV/u



Gamma yield #gamma/#(^{24}Mg in S800)
for various chunks of data with ~100 γ's and ~500 ^{24}Mg in S800 (points 0-40)

Point 45 from using full statistics.

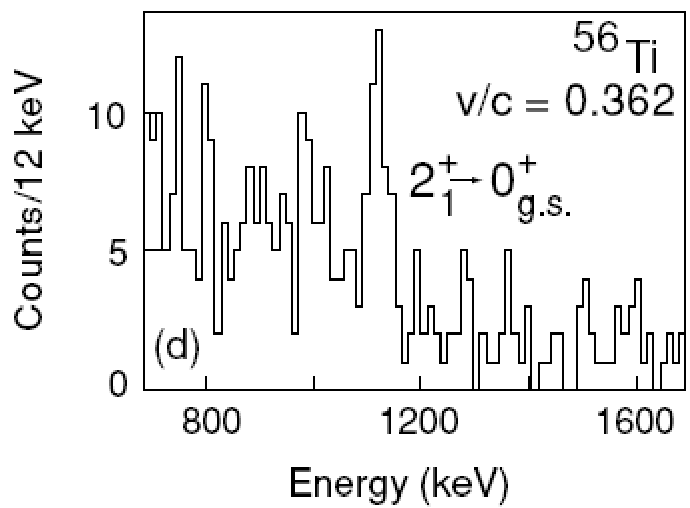
Coulomb excitation experiment



^{58}Ni, v/c=0.4
257mg/cm^2 Au target

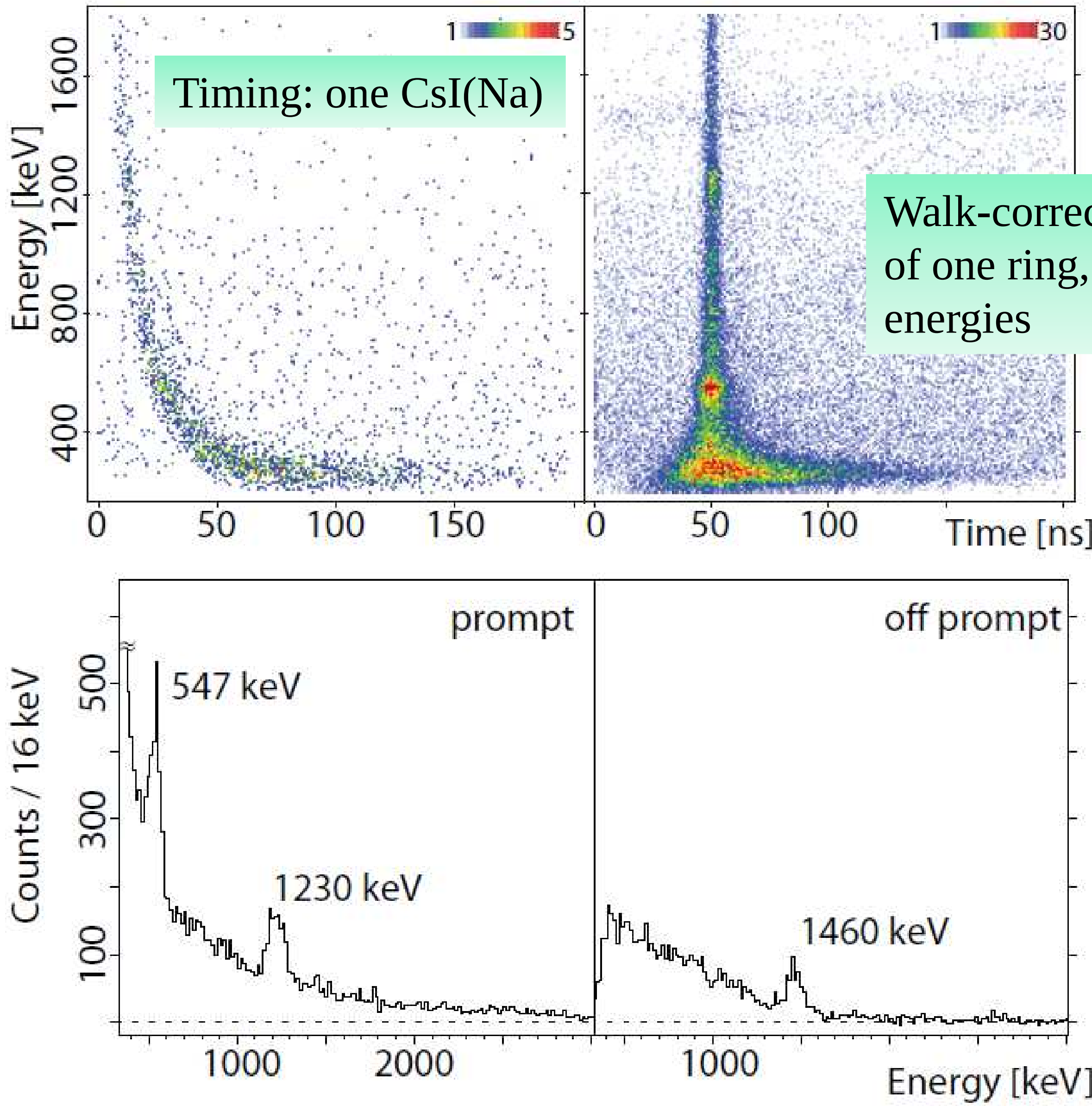
Challenge:
Background from Bremsstrahlung, atomic processes, and random particle-gamma coincidences
(as unreacted beam enters and triggers focal plane detectors)

Low statistics case
in SeGA



PRC 71,041302 (2005)

Randoms in inelastic scattering exp.



^{58}Ni on 260mg Au target
→1-2 excitation to 1st 2^{+} per 10.000 ^{58}Ni projectiles

But: 10^4 Hz background gives 10^4 x 10^4 x 10^{-7} = 10Hz random coincidences…
and timing near threshold is bad (addback!)

→ We switched to CFDs

Lessons learned

For inelastic scattering experiments random coincidences are an issue
→Replacement of discriminators (walk, bad timing near threshold) with CFD

Many experiments need high(er) threshold, but addback mode suffers from that
→Two level discrimination (i.e. CFD at low threshold gated by disc. for gamma OR)

Light collection
→ z-dependence with interaction. Strong variation between vendors.

Magnetic shielding
→Individual shielding of PMT with μ-metal (keeps PMT 'alive' in up to 30G)
→¼" thick iron shield plate between CAESAR and spectrograph entrance quad
→energy calibration still needs to be done at spectrograph's field setting

Quality control
→10% of delivered detectors went back as they didn't met specs

Customized solutions for electronics
→ Having 'geeks' in electronics was most valuable. Example: Amplifier box

Our experience with LaBr

As you well know:
LaBr provides energy resolution comparable to FWHM measured in-beam with Ge-based arrays in fast-beam experiments

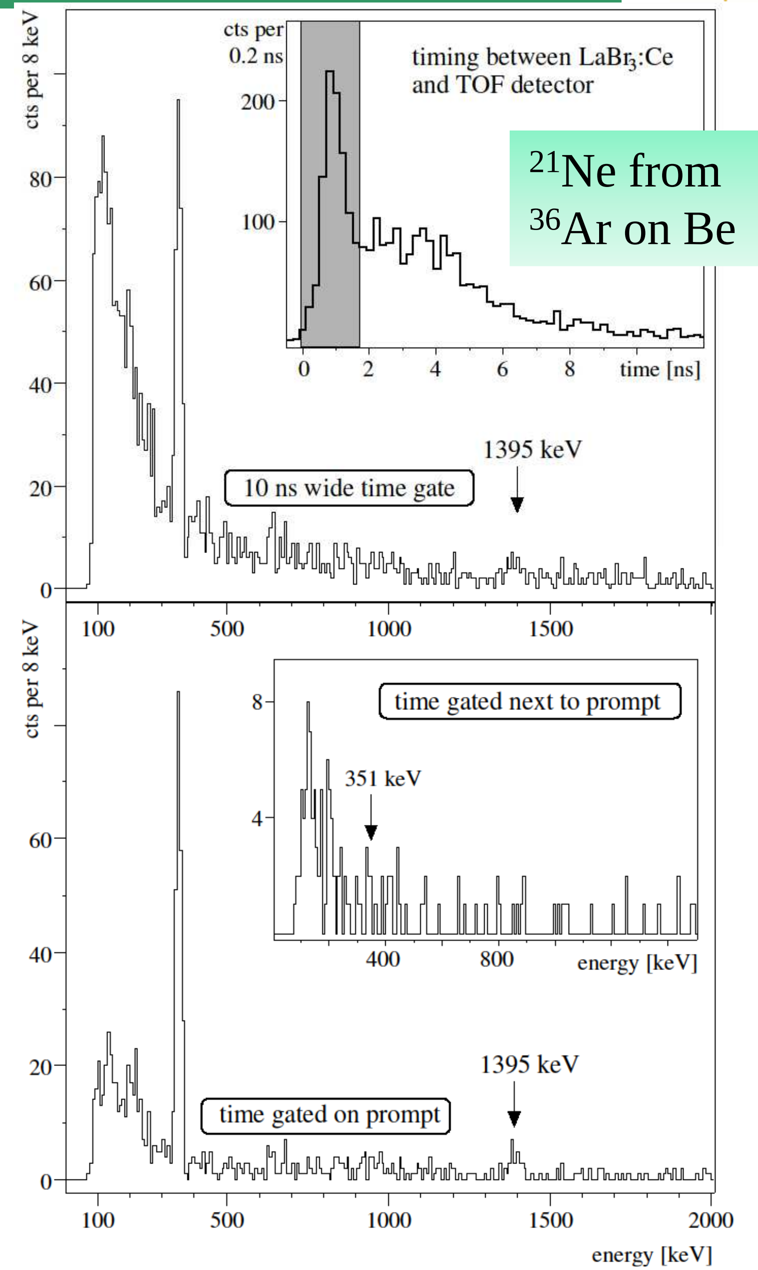
LaBr provides excellent timing (<300ps)

Conclusion from an in-beam test:

- ➢Resolution as good as with SeGA (almost)
- ➢Time gate removes **beam-correlated** background.
- ➢Intrinsic bg no issue.

(see NIM A594 (2008) 56-60)

But SHOGUN has ~50.000 cm^3
→ ~150kHz rate from intrinsic contamination
Issue?



Summary

The scintillator array CAESAR provides high efficiency (35% at 1MeV) and moderate in-beam energy resolution (10% FWHM) for γ-ray spectroscopy with fast beams .

In experiments with low contribution to γ-ray background (e.g. knockout, pickup, or secondary fragmentation) around 20 counts in the γ-ray peak are sufficient to identify γ-ray transitions.

For Coulomb excitation experiments, the background contribution in CAESAR from bremsstrahlung and atomic processes is significant. The example of ^{58}Ni demonstrates that experiments with cross sections above 100 mb and 100 counts in the γ-ray peak are feasible.

Last but not least: Money!

Thank you!