New Developments for GaSp

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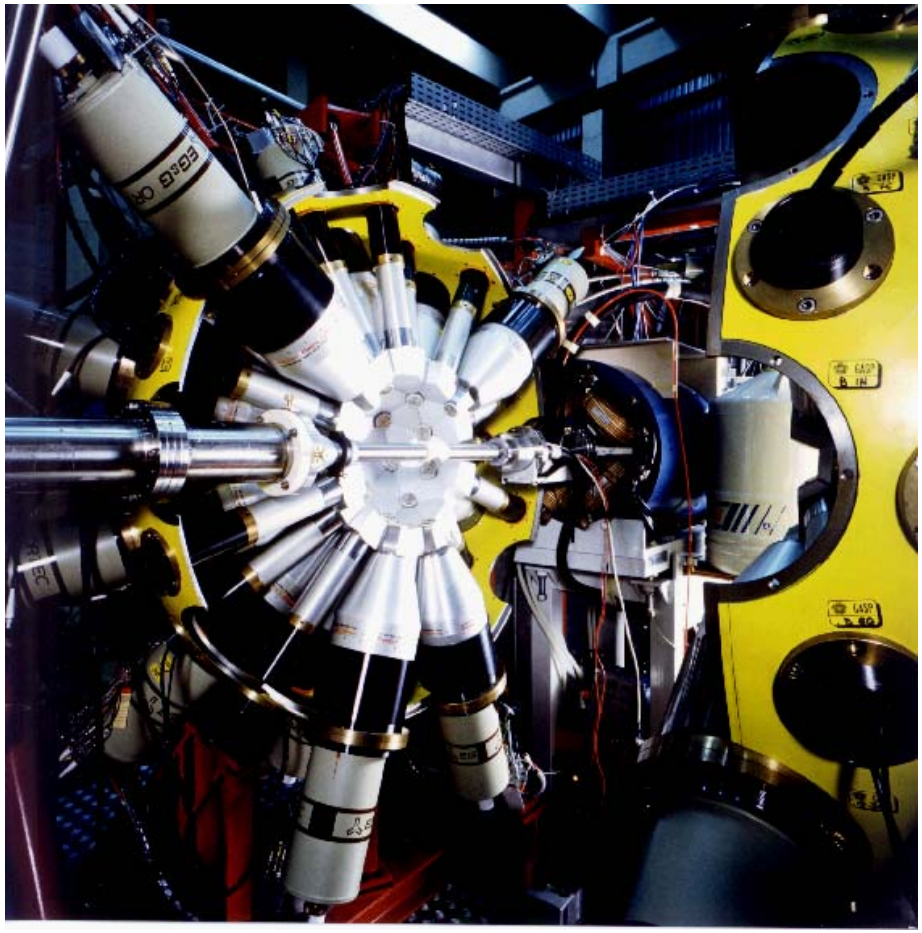
Layout of the Presentation

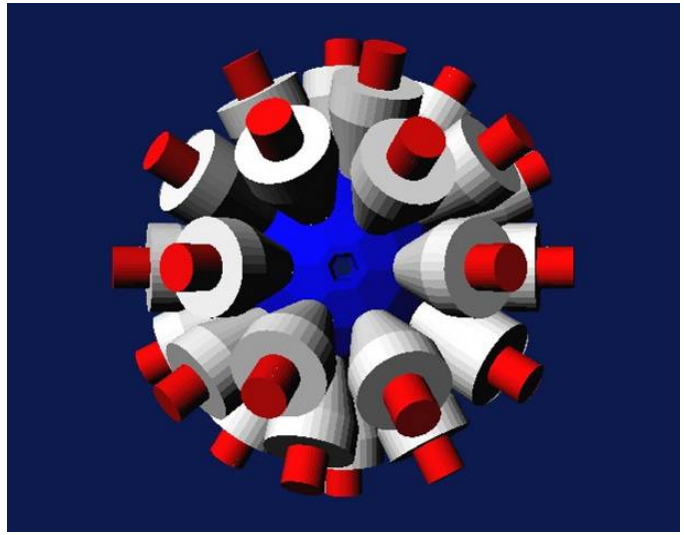
- General presentation of GaSp
  - Configuration I
  - Configuration II
- Ancillary detectors
  - Overview and perspectives
- Concluding remarks

The GaSp Array – The Ge Detectors

- 40 n-type HPGe detectors
  - FWHM < 2.4 keV @ 1332.5 keV
  - ε_{int} ~80% @ 1332.5 keV
  - P/T ratio ~25% with ^{60}Co source
  - symmetrically placed on 7 rings at 35°, 60°, 72°, 90°, 108°, 120°, 145°
- 40 anti-Compton shields
  - hardware anticoincidence
  - P/T ratio ~60% with ^{60}Co source

The GaSp Array – Configuration I

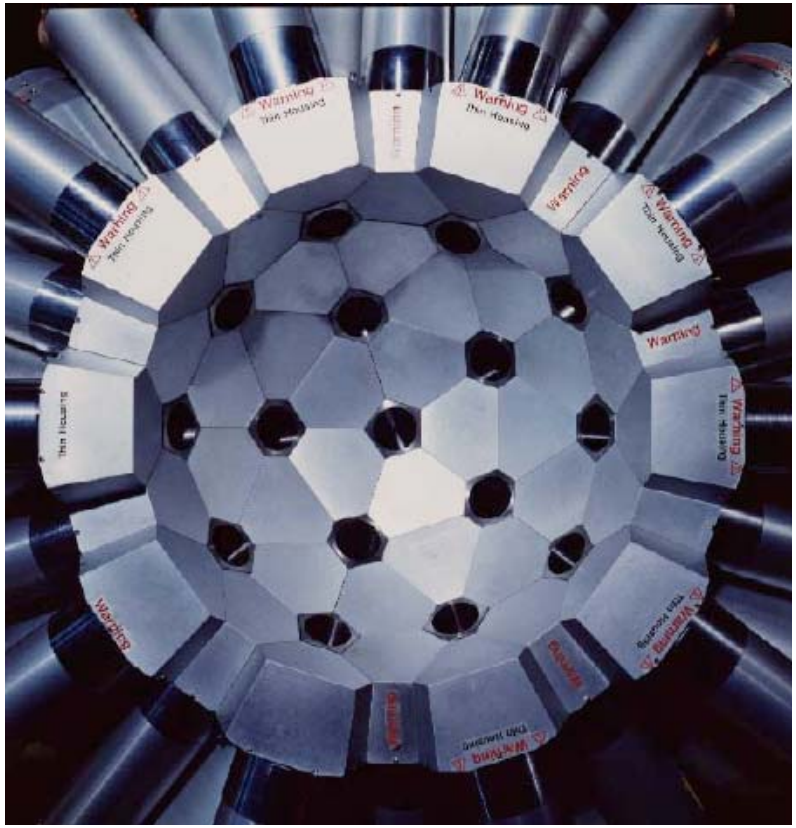




- 40 HPGe + AC
  - $d_{target\text{-}det.}$ = 27 cm
  - Ω_{Ge} ~ 10%
  - ε_{ph} ~ 3% @ 1332.5 keV
- BGO inner ball

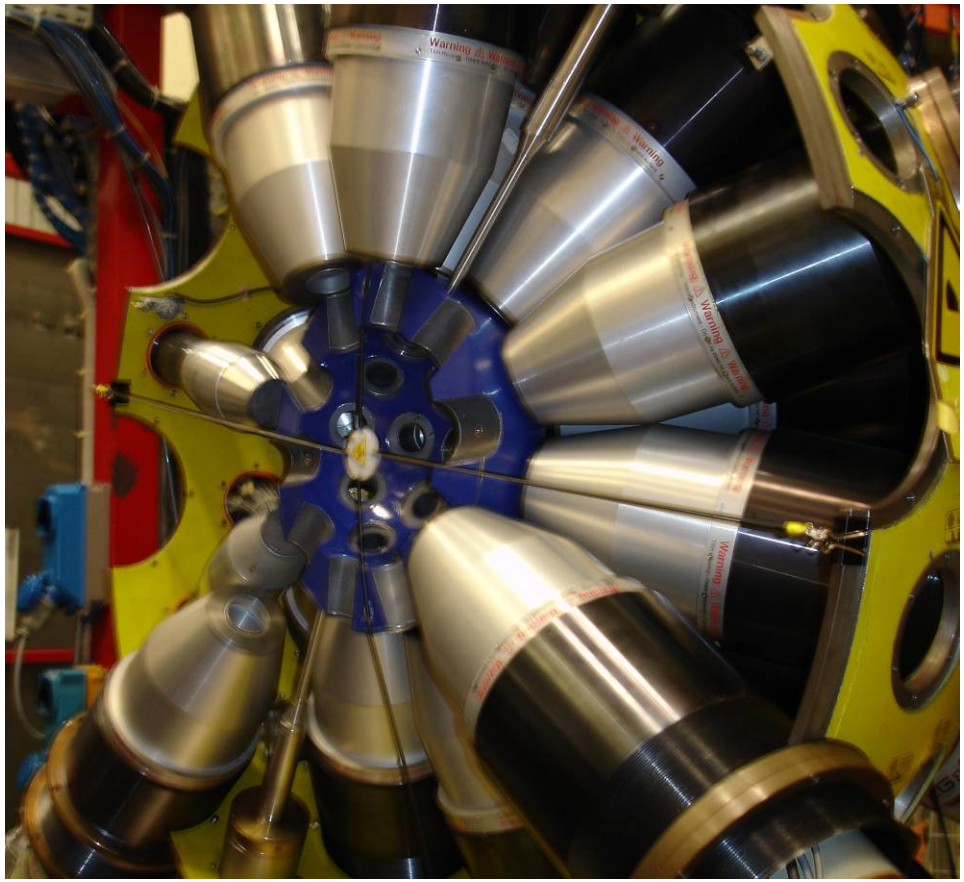
High spin gamma–ray spectroscopy

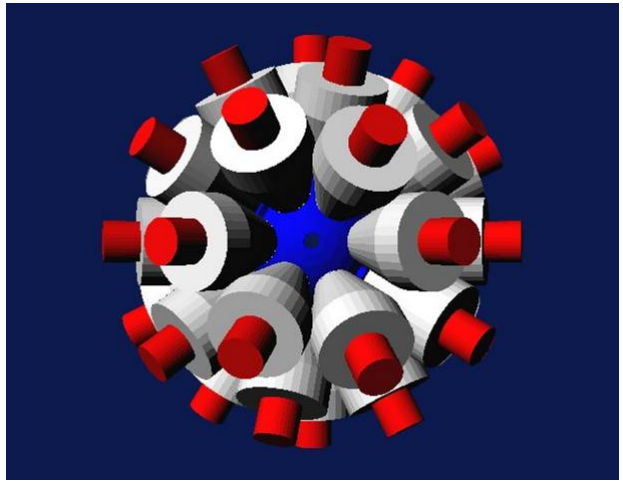
The GaSp Array – The BGO Inner Ball



- 80 BGO elements
  - thick = 6.5 cm
  - Ω_{BGO} ~ 80%
  - ε ~ 95% @ 1000.0 keV
  - ε_{tot} ~ 70% @ 1000.0 keV
  - R_0 ~ 2 – 4
- Multiplicity and sum energy
- Collimator for the Ge det.
- Inner space: R_{int} = 17 cm

The GaSp Array – Configuration //





- 40 HPGe + AC
  - $d_{target\text{-}det.}$ = 22 cm
  - ε_{ph}~ 5.8% @ 1332.5 keV
- Pb collimator (6 cm thick)
  - inner space R_{int} = 15 cm

Lifetime measurements

7 rings @	35°,	60°,	72°,	90°,	108°,	120°,	145°
	6	6	4	8	4	6	6

The GaSp Array – Figure of Merit

$P_F = \alpha N_o \varepsilon_o (k\varepsilon_{Ph})^F$ Area of F-fold peak

- α Population intensity
- N_o Number of reactions
- k Fraction of peak area in gate
- ε_{Ph} Total photopeak efficiency of the array
- ε_o Efficiency of ancillary detectors

$PB_F = \alpha R_o (kR)^F$ Peak to Background

$R = \frac{SE_\gamma}{\Delta E_\gamma} PT$ **Resolving power**

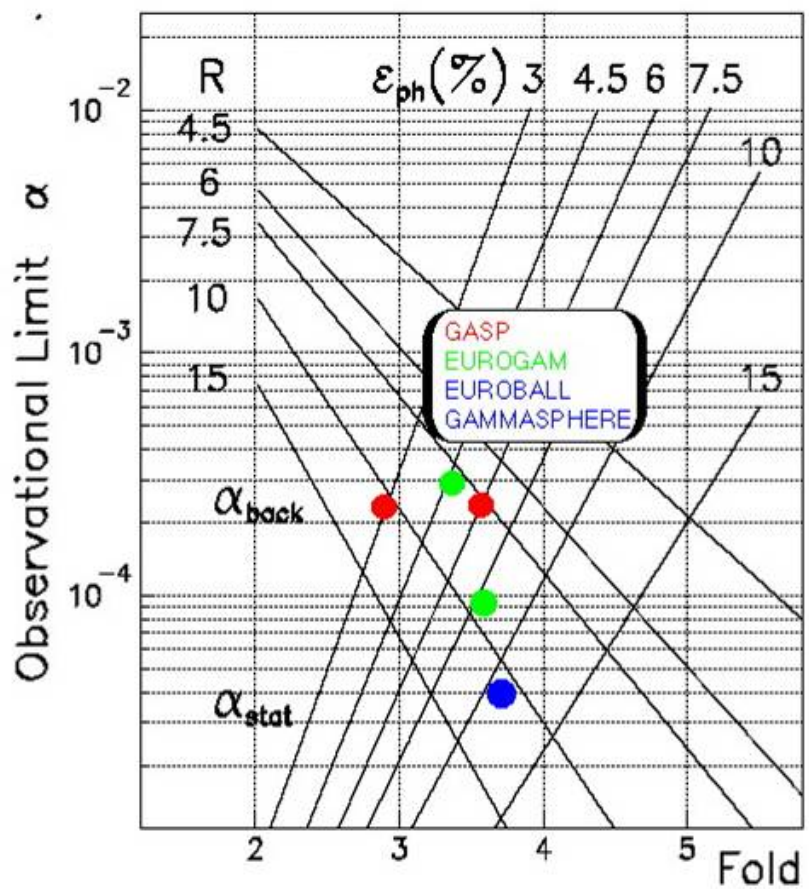
- SE_γ Energy separation
- ΔE_γ Energy resolution
- PT Peak to Total ratio
- R_o Resolving power of ancillary detectors

$\alpha_{stat} = P_F / N_o \varepsilon_o (k\varepsilon_{Ph})^F$ Statistical limit

$\alpha_{back} = PB_F / R_o (kR)^F$ Background limit

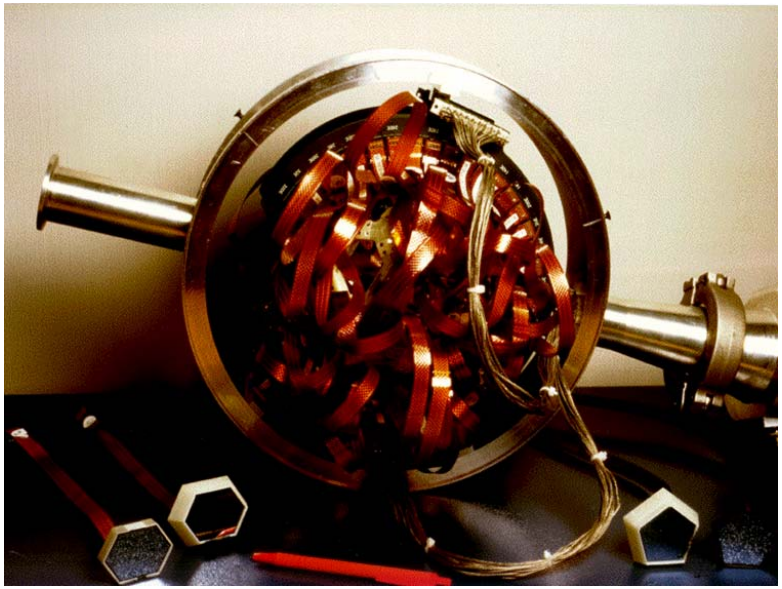
$\alpha_{limit} = \min(\alpha_{stat}, \alpha_{back})$ ← Figure of merit

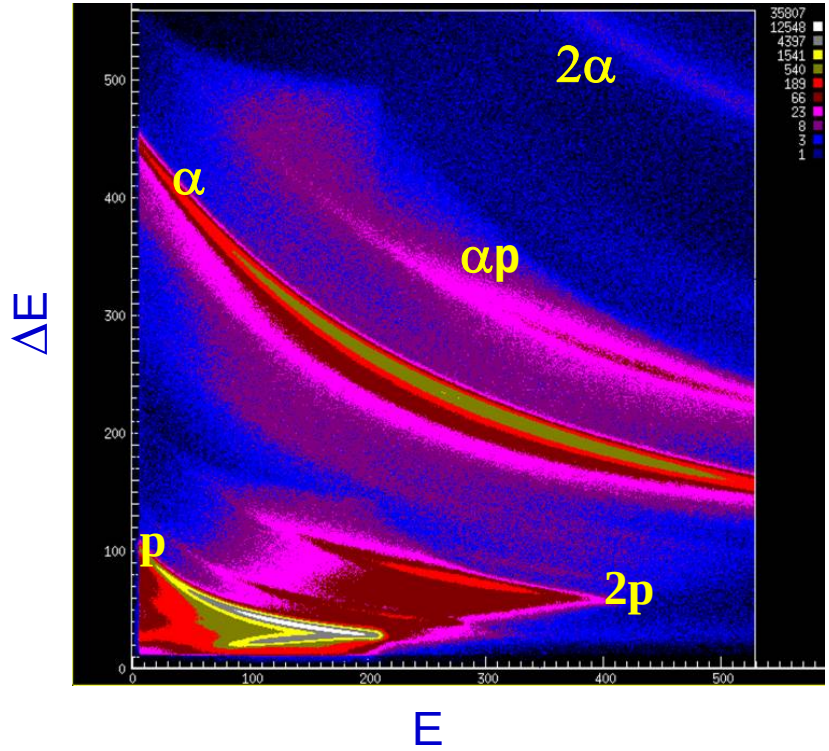
Observational limit



Ancillary Detectors – ISIS

40 Si E-ΔE telescopes





- 40 E–ΔE Si telescopes
  - ΔE ~ 130 μm ~ 71%
  - E ~ 1000 μm ~ 65%
- Only Configuration I

- Total efficiency
  - ε_{proton} ~ 60%
  - ε_{alpha} ~ 35%

E. Farnea

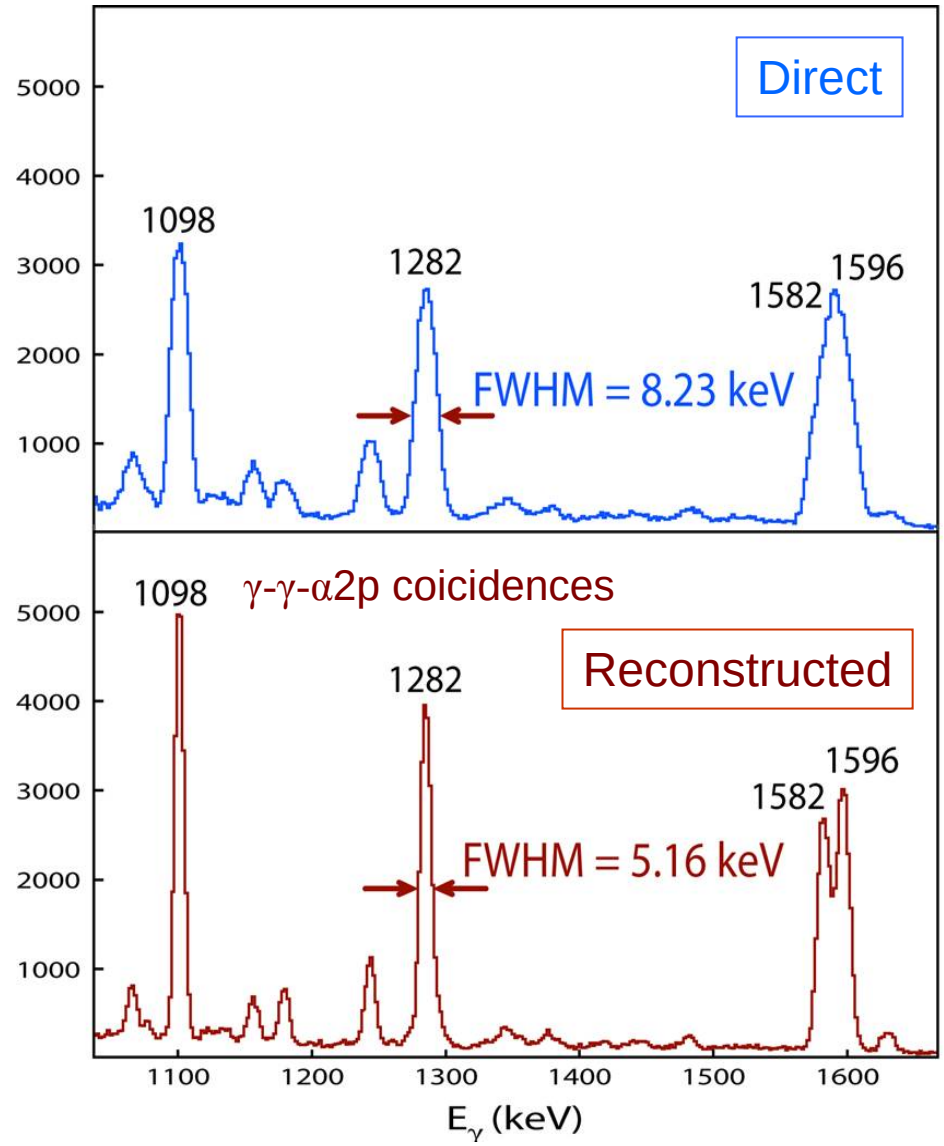
Ancillary Detectors – ISIS

-channel selection

-kinematical reconstruction

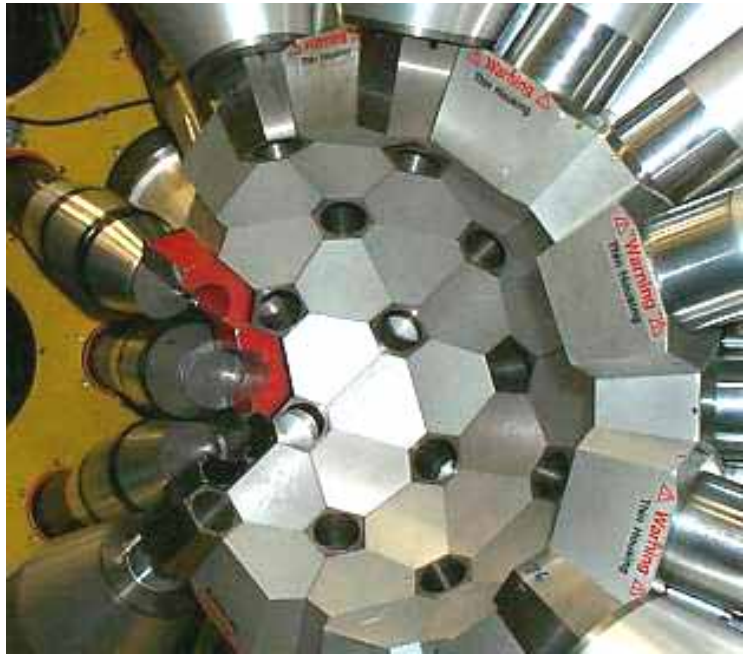
^{32}S (@132MeV) + $^{24}Mg \Rightarrow$
$^{50}Cr + \alpha 2p$
v/c~5%

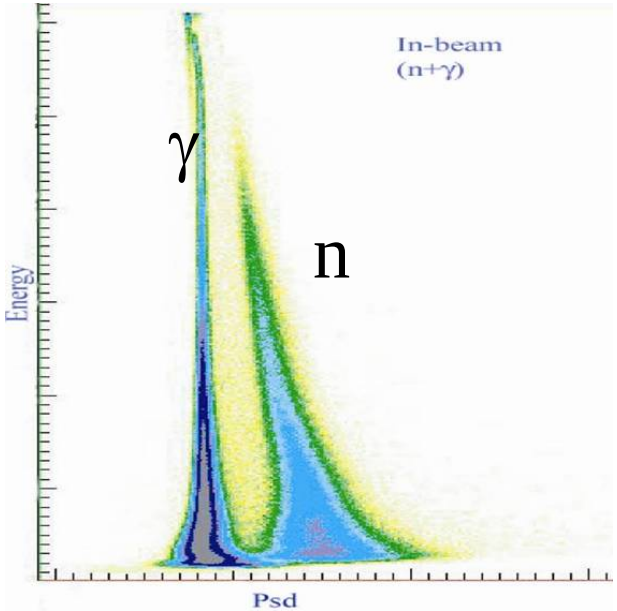
GASP I + ISIS



S.M.Lenzi et al, Phys. Rev. C 56, 1313 (1997)

Ancillary Detectors – nRing





- Configuration I and II
  - 6 HPGe det. → 31 cm
  - Ω_{tot} = 6% @ 20°
  - ε_{rel} = 3–5%
  - R_0 = 6–7 RJ=10^{-5}
    → $\alpha \sim 10^{-5}$

- Configuration I
  - ε_{ph}~ 2.8% @ 1332.5 keV
- Configuration II
  - ε_{ph}~ 5.2% @ 1332.5 keV

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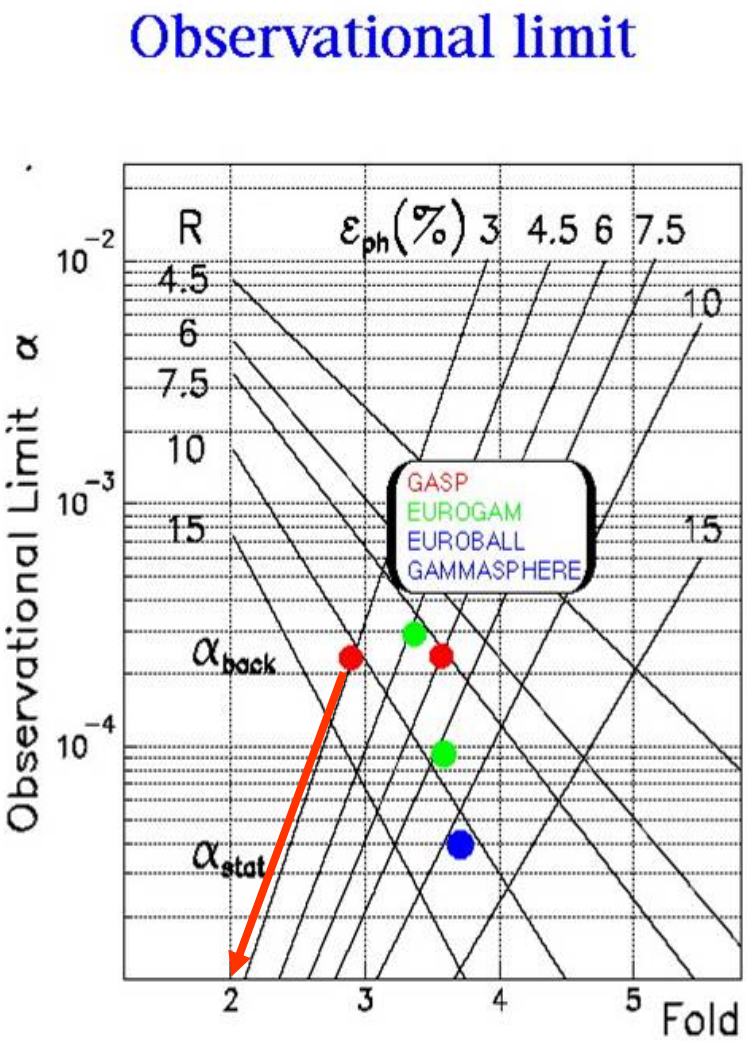
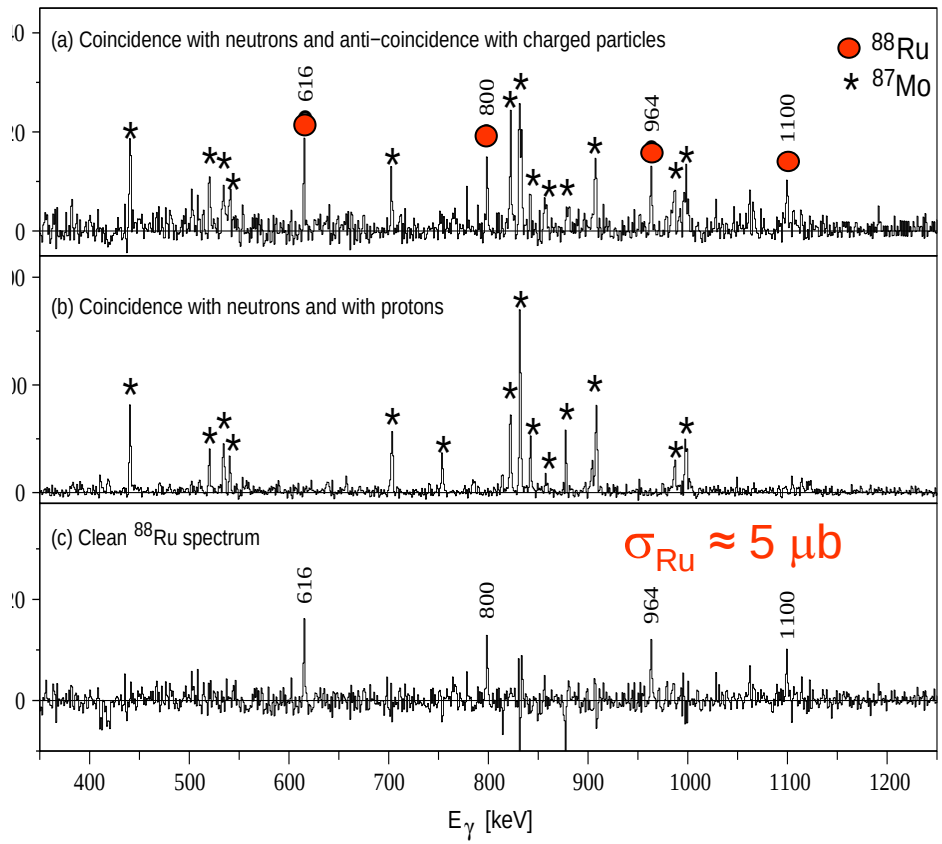
Ancillary Detectors – nRing



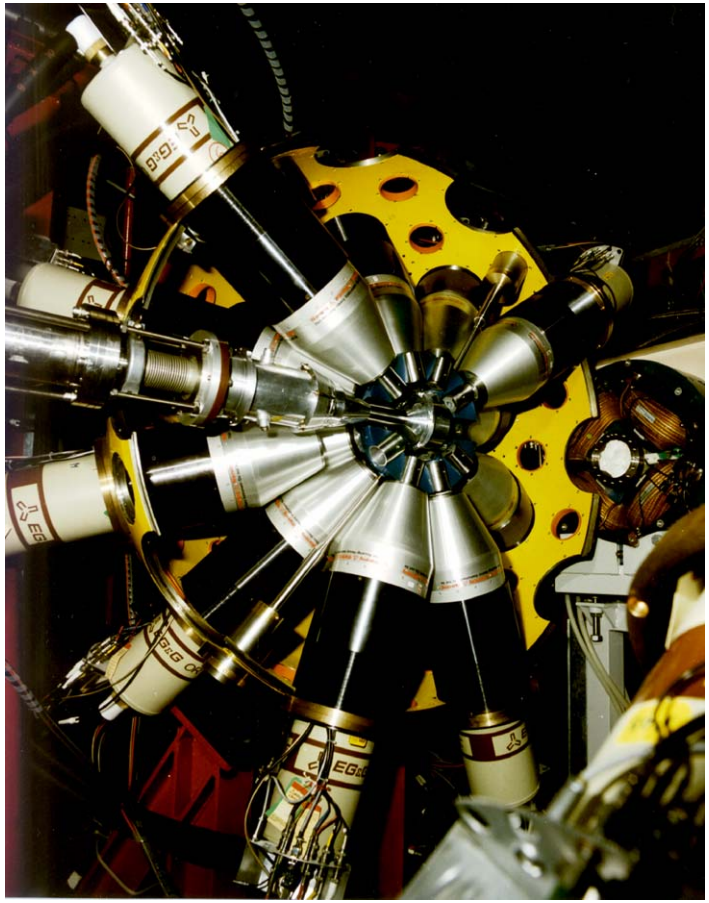
^{32}S (@105MeV) + $^{58}Ni \Rightarrow {}^{88}Ru$ + 2n

GaSp I + ISIS + nRing



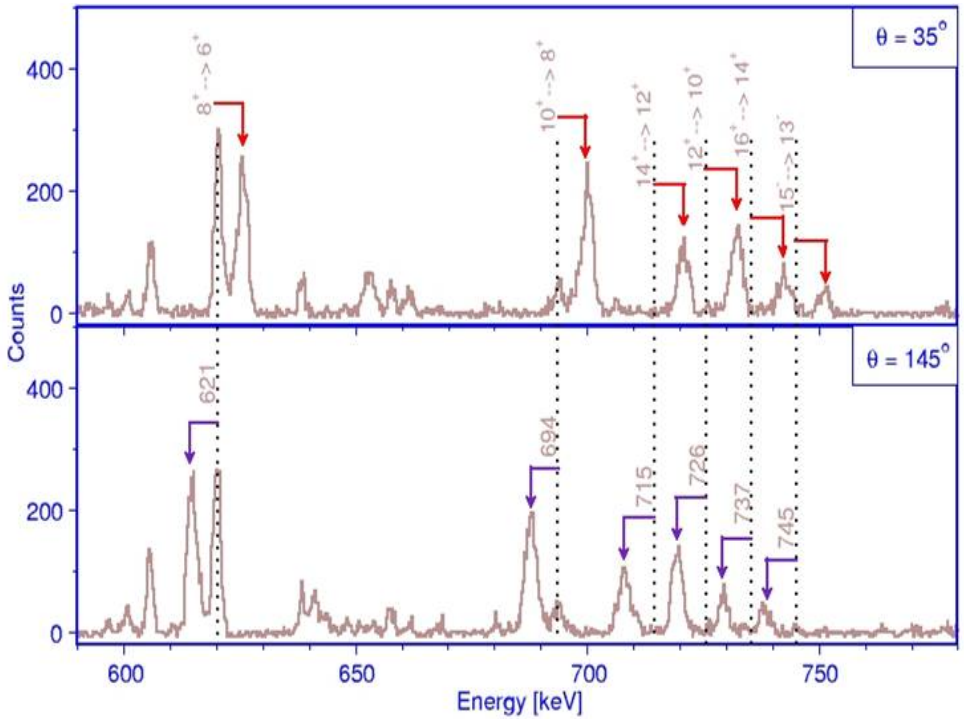
N.Marginean et al., Phys.Rev. C 63, 031393 (2001)

Ancillary Detectors – Koeln Plunger



^{16}O (@69MeV) + $^{108}Cd \Rightarrow {}^{122}Ba$ + 2n

GASP II + Plunger

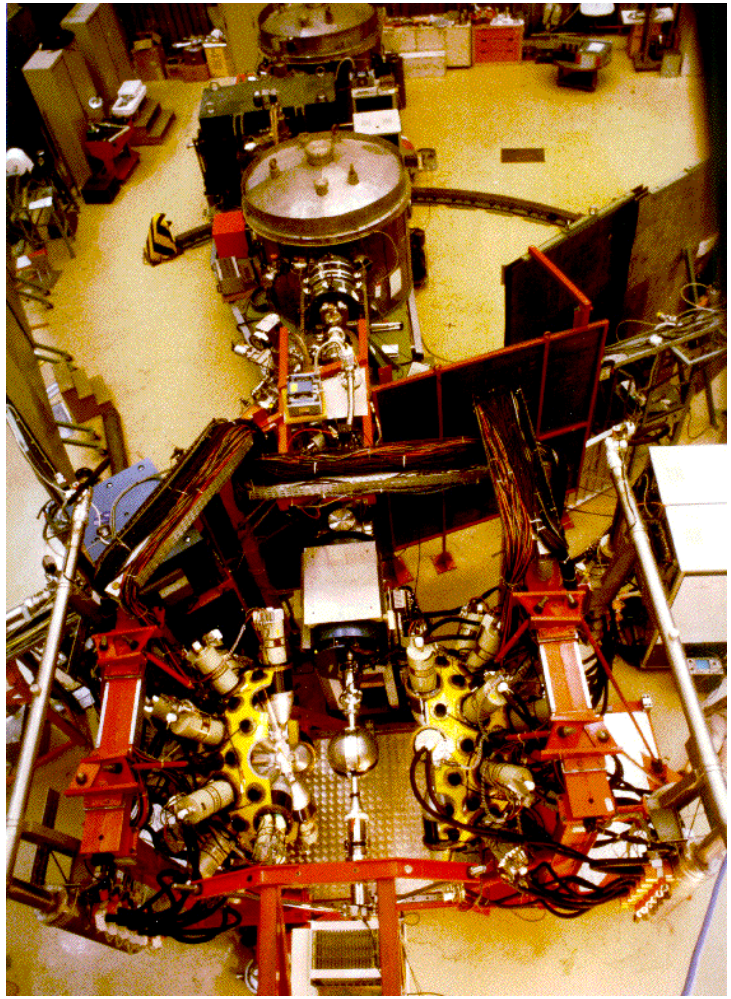


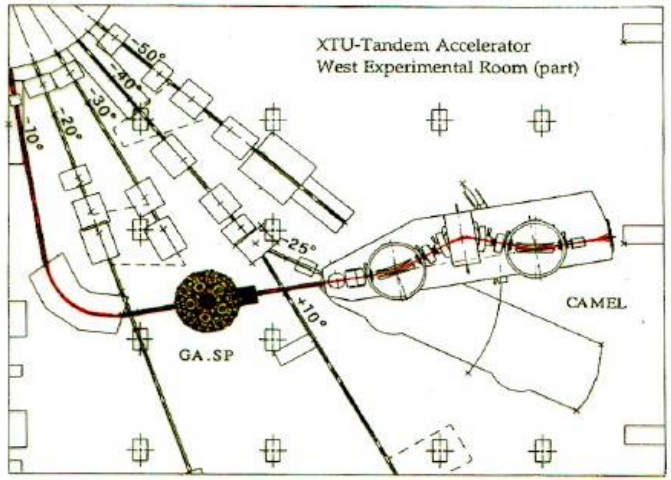
P.G. Bizzetti et al., LNL Annual Report 2005

- Configuration I and II

A. Dewald

Ancillary Detectors – CAMEL-RMS





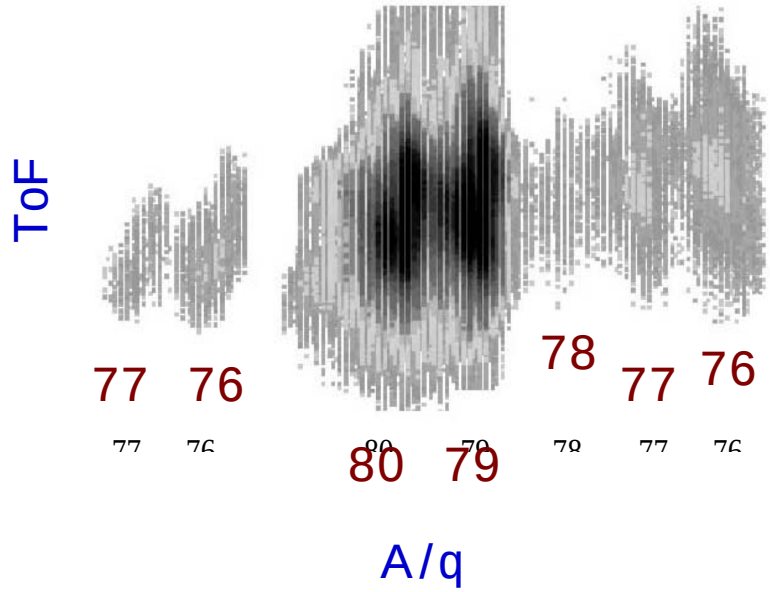
- Q–ED–BM–ED
- FP–MWPPAC (120x80 mm^2)
- ToF (GaSp trigger – PPAC)
  - ε~ 5–15%
  - $\Delta A/A$ ~ 1/300
  - R_0 ~ 2–6

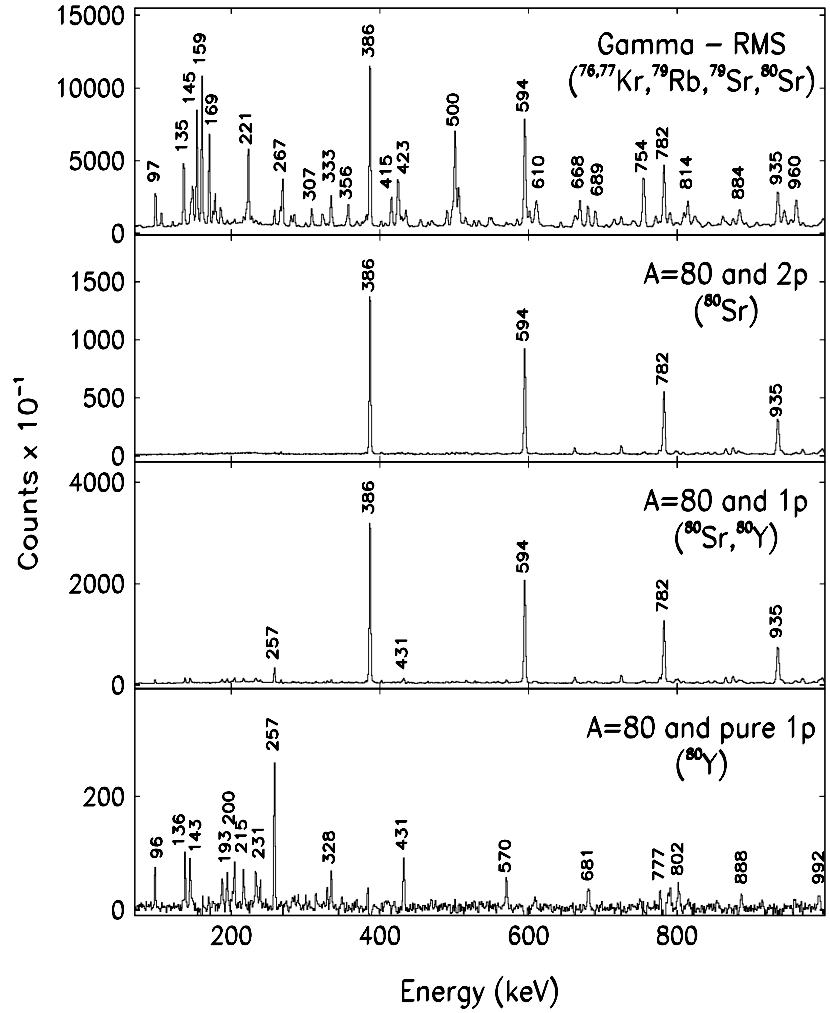
- Configuration I and II

P. Spolaore

Ancillary Detectors – CAMEL-RMS

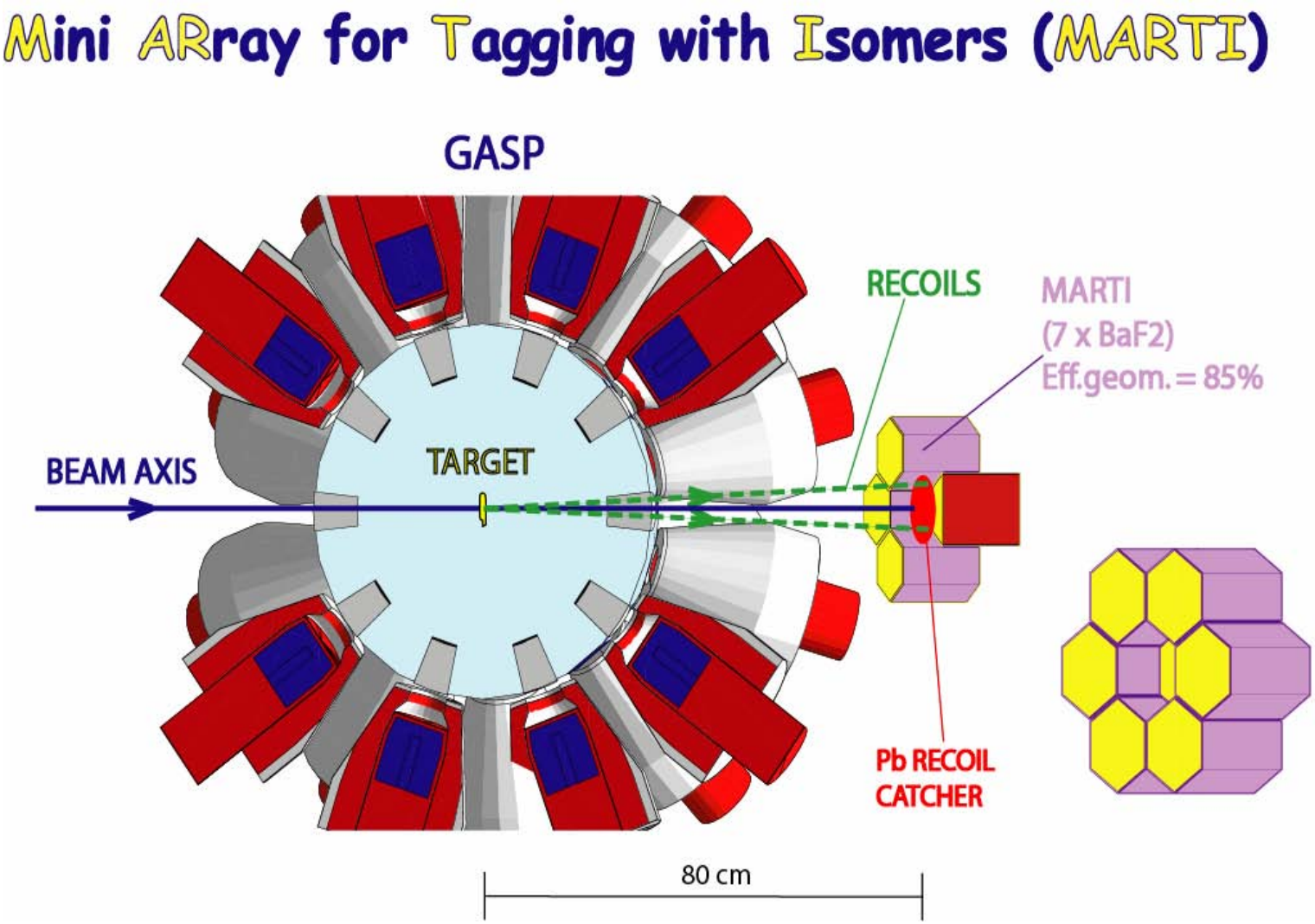
^{24}Mg (@77MeV) + $^{58}Ni \Rightarrow {}^{80}Y$ + pn





D. Bucurescu et al., Nucl. Phys. A 705, 3 (2001)

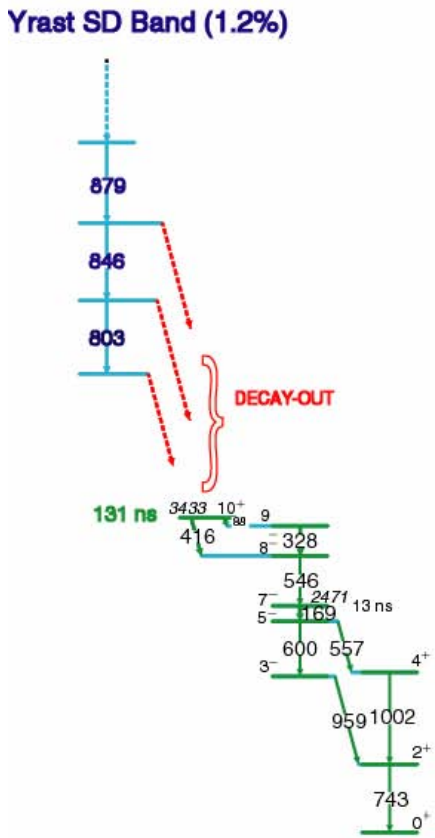
Ancillary Detectors – MARTI

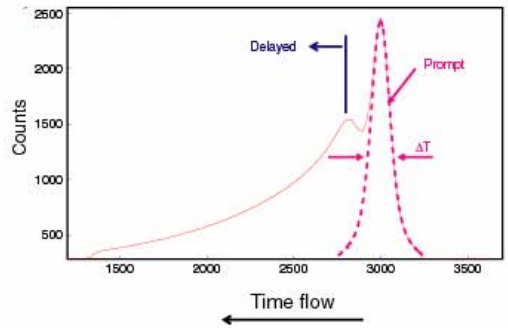


C.A. Ur

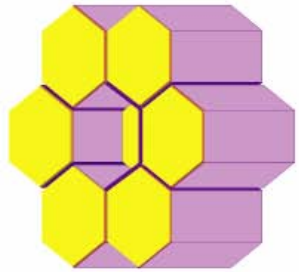
Ancillary Detectors – MARTI

Mini ARray for Tagging with Isomers (MARTI)



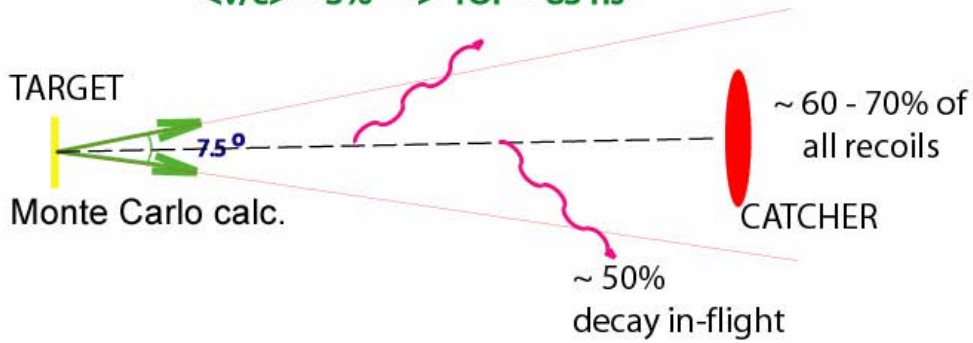


GEANT4
70 - 80%



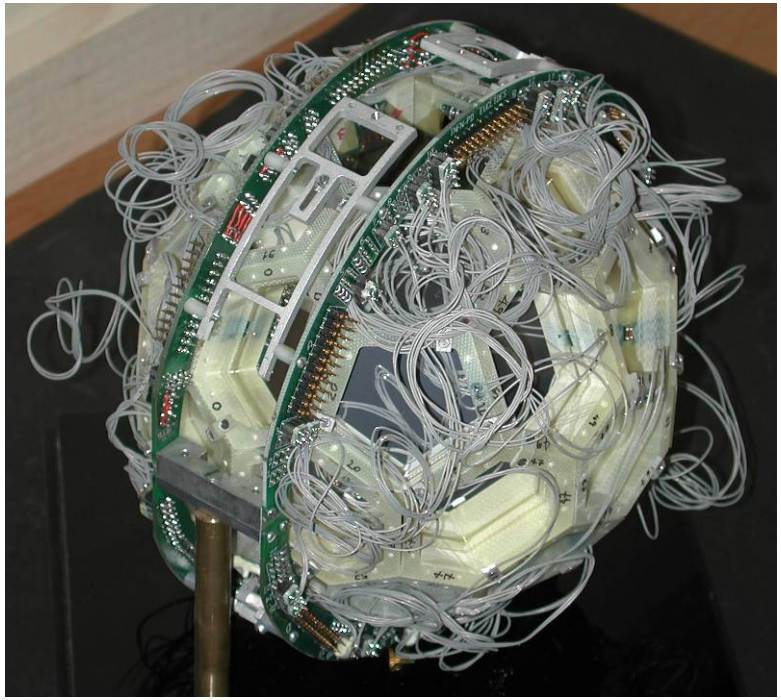
48Ti + 100Mo @ 215 MeV –> 144Gd + 4n

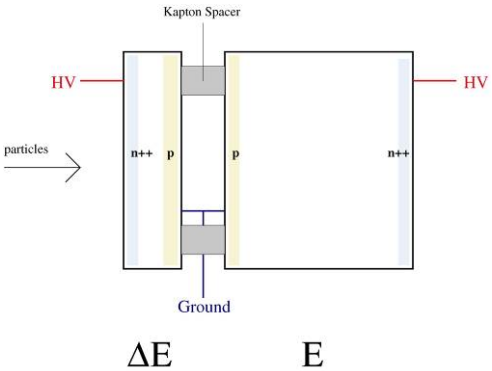
<v/c> ~ 3% –> TOF ~ 85 ns

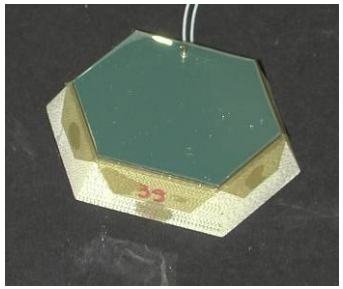


TOTAL EFFICIENCY ~ 20 - 30 %

Ancillary Detectors – EUCLIDES







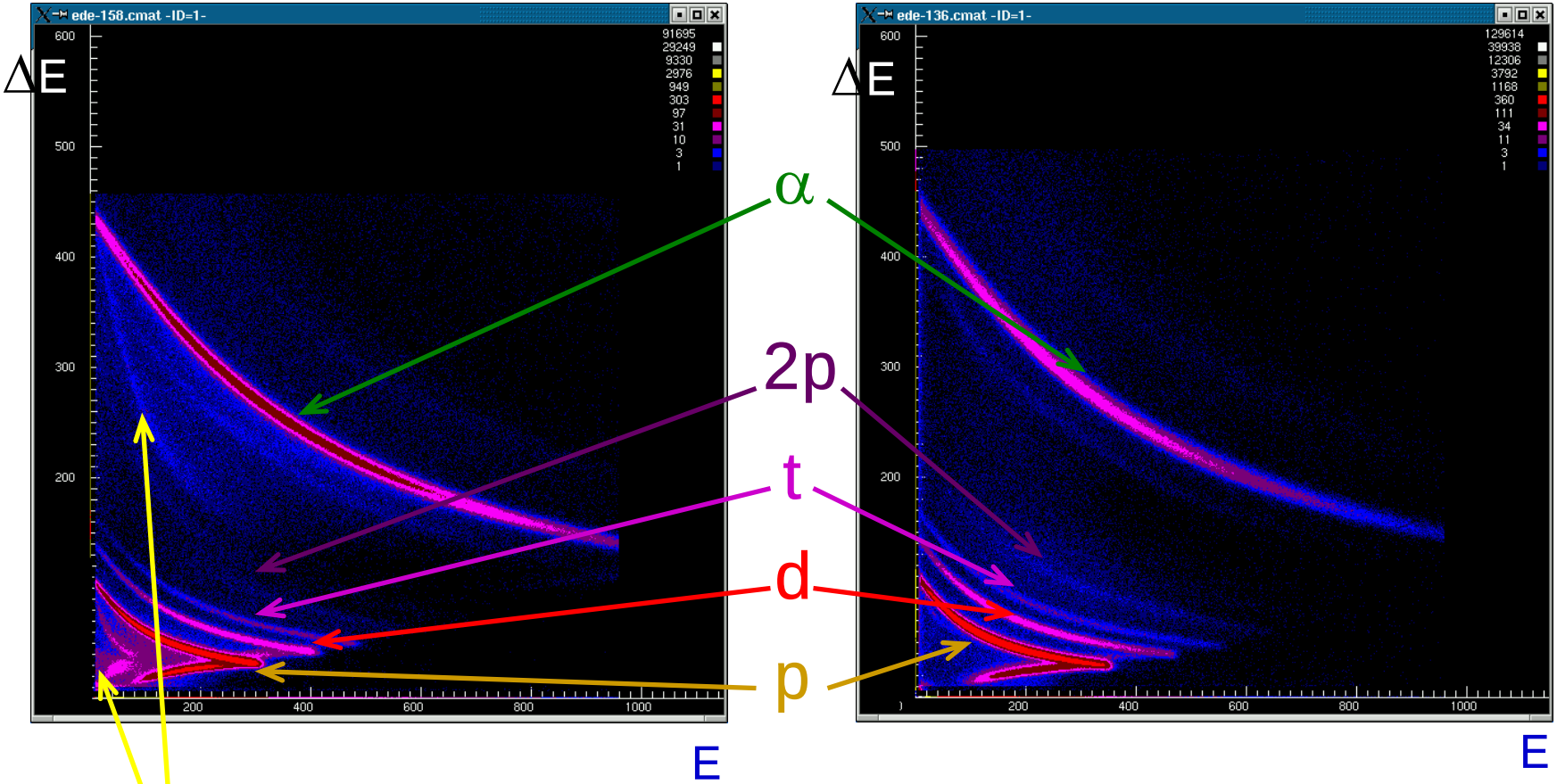
- 40 ΔE-E telescopes
  - ΔE ~ 130 μm ~ 81%
  - E ~ 1000 μm ~ 80%
- Segmented forward telescopes
- Total efficiency
  - ε_{proton} ~ 60%
  - ε_{alpha} ~ 35%
- Good transparency to γ–rays
- Specially design CAMAC electronics (Silicon Shaper Analyzer)
- Configuration I and II

E. Farnea

Ancillary Detectors – EUCLIDES

Segmented

Non segmented

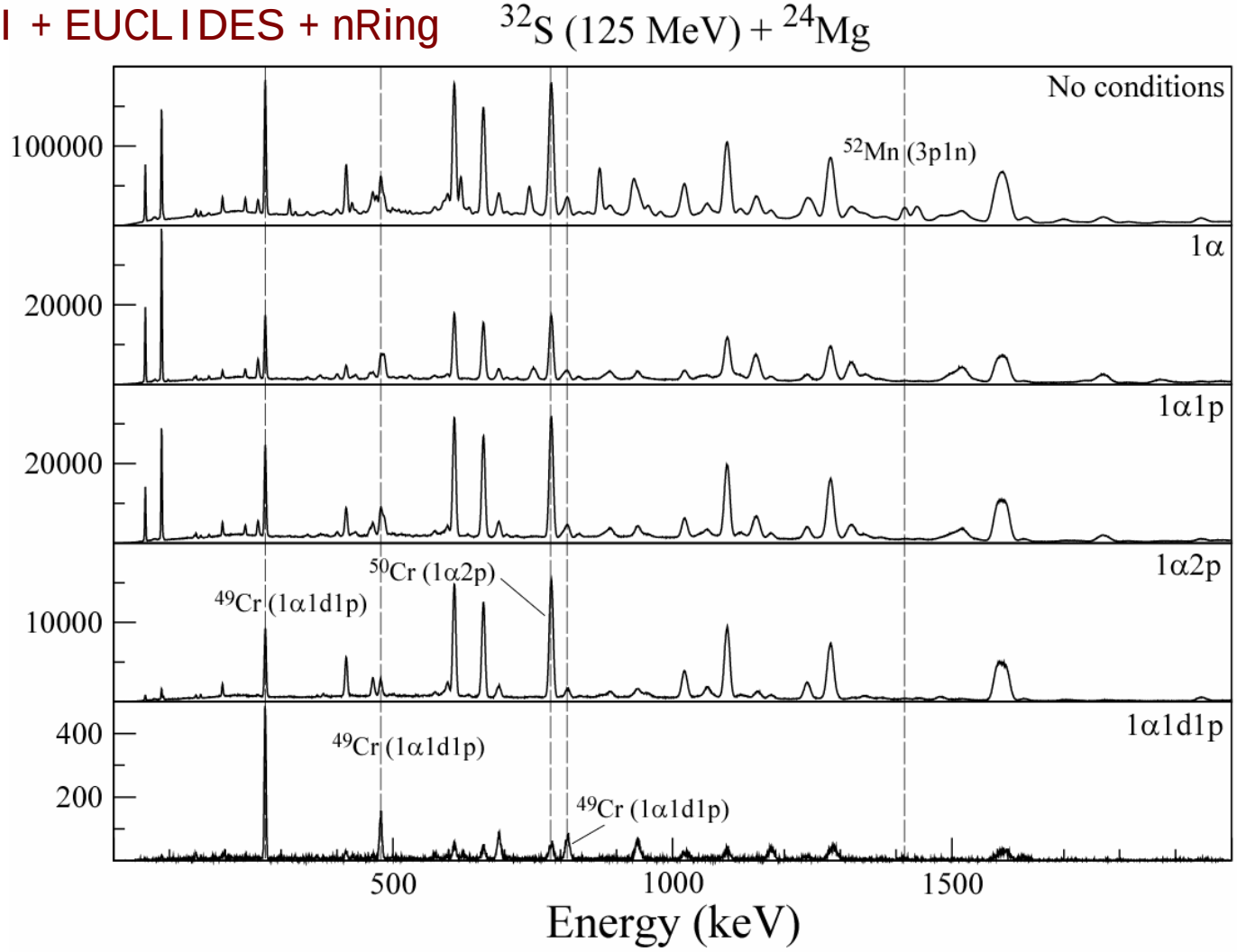


Incomplete charge collection

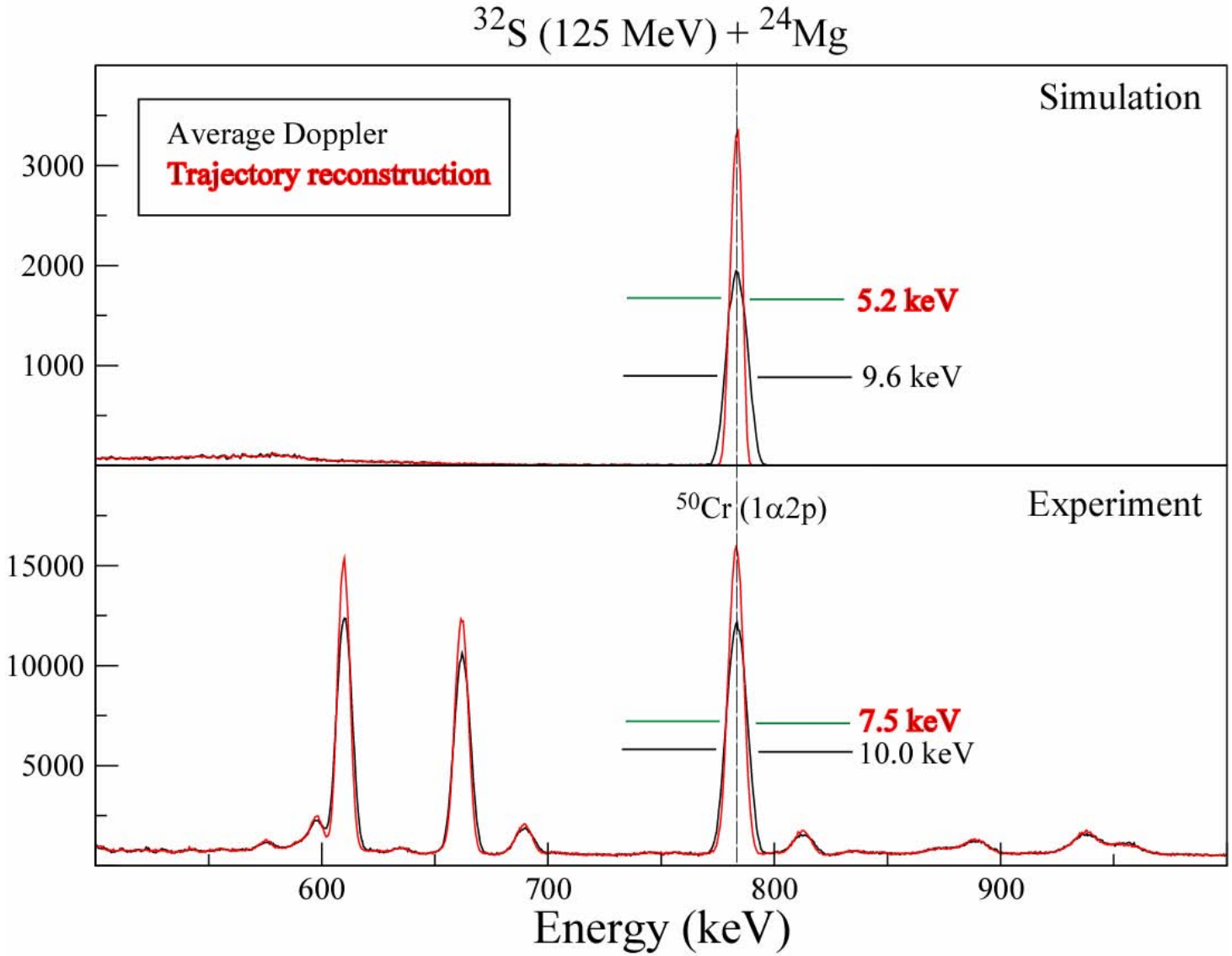
Ancillary Detectors – EUCLIDES

GaSp II + EUCLIDES + nRing

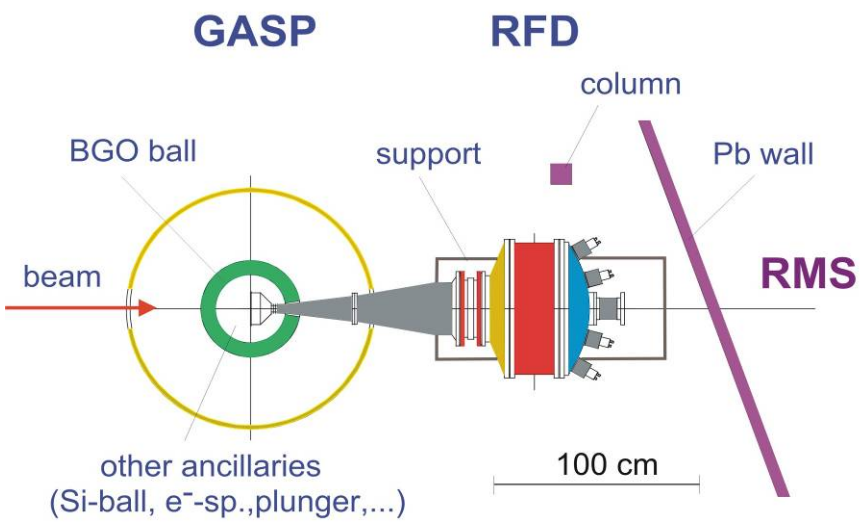
In–beam commissioning with GaSp (March 2006)

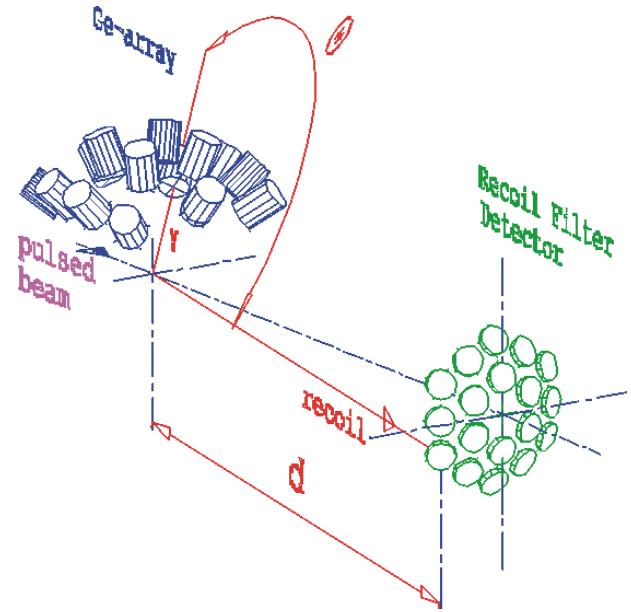


Ancillary Detectors – EUCLIDES

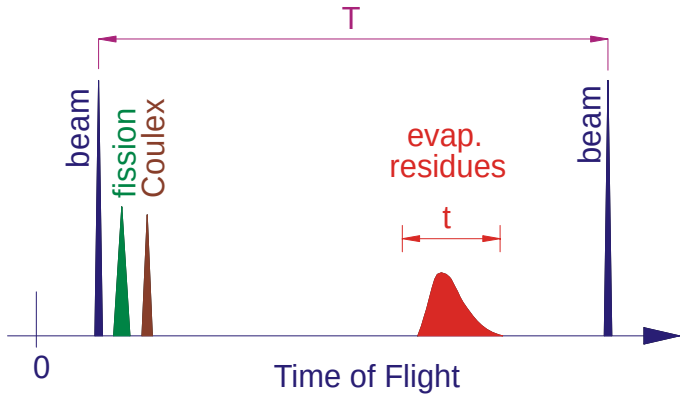


Ancillary Detectors – RFD





- RFD measures evap. residues (recoils) in coincidence with γ-rays detected in Ge-array
  - selection of the recoil of interest by ToF technique
  - determination of the recoil velocity vector event–by–event
- Configuration I and II

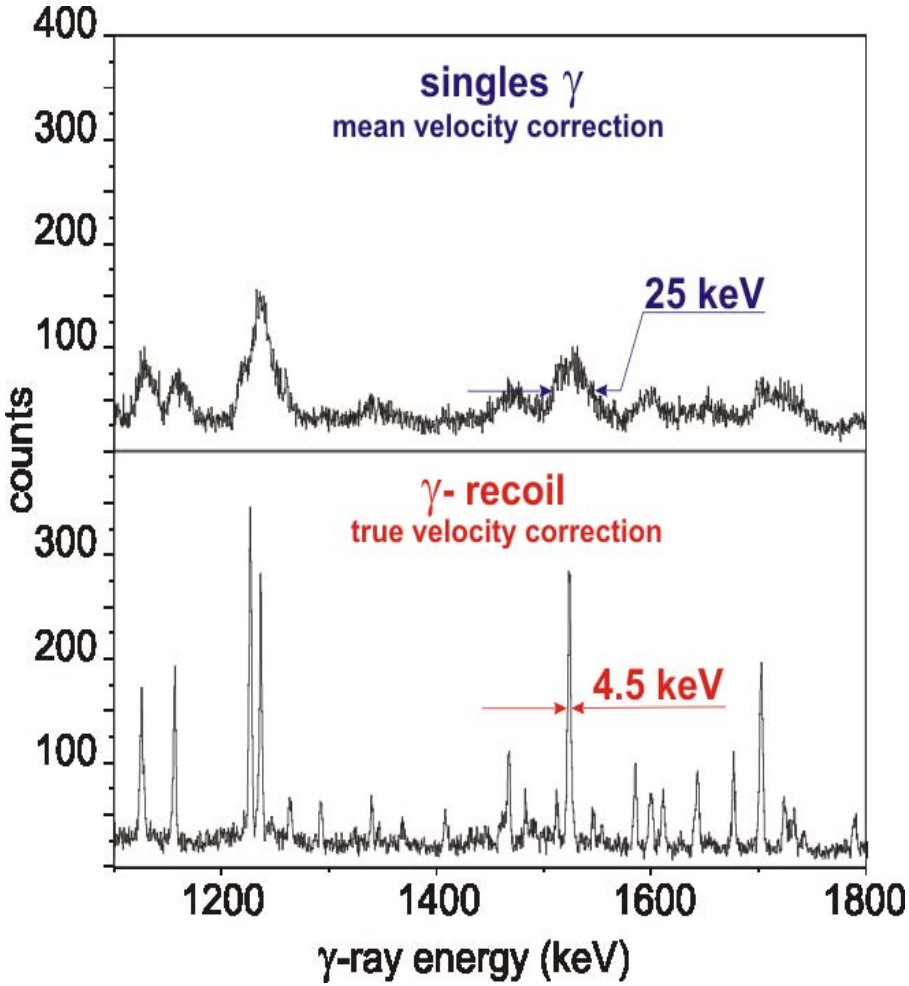


W. Męczyński

Ancillary Detectors – RFD

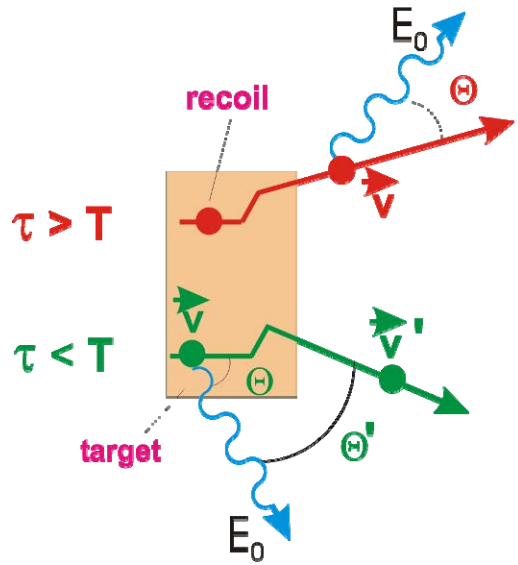
- Features & requirements
  - efficiency of γ-recoil coincidences: 20–50%
  - R_0 ~ 2–5
  - precise Doppler broadening correction for recoil velocity up to ~7%
  - detection angle 1.8° – 6.7°
  - a pulsed beam with a time interval from 100 ns up to 1000 ns with $\Delta\tau$ ~ 1 ns
  - σ_{fus} > 50 μb
  - counting rate of the individual recoil detector not higher than 3 MHz
  - kinetic energy of a recoil greater than 4 MeV

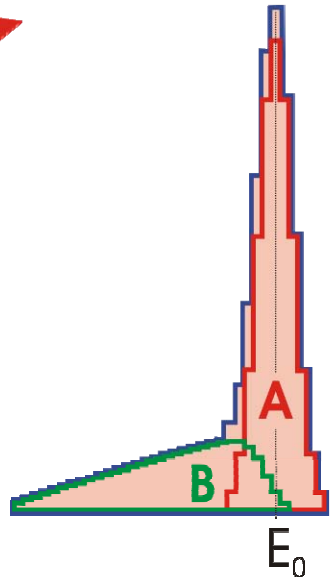
^{18}O(@67 MeV) + 0.8 mg/cm^2 ^{30}Si

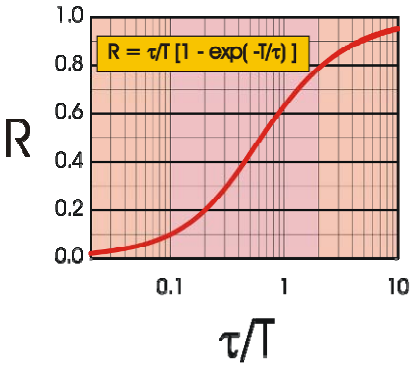


P.Bednarczyk et al., Acta Phys. Polon. ***B32****, 747 (2001)*

Ancillary Detectors – RFD & lifetimes



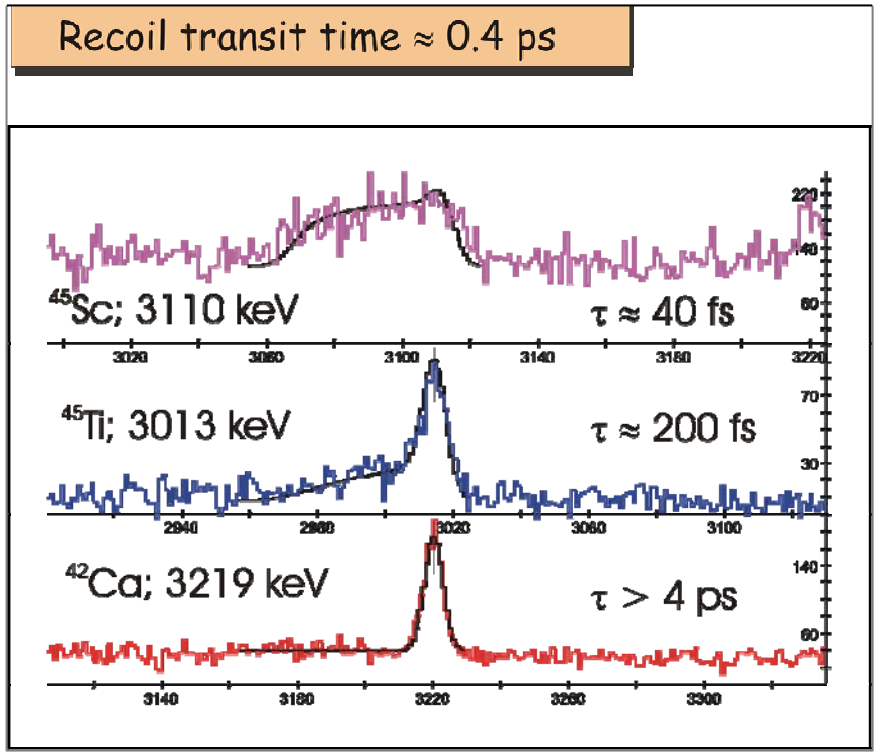




$$R = \frac{A}{A+B} \longrightarrow \tau$$

^{18}O(@67 MeV) + 0.8 mg/cm^2 ^{30}Si

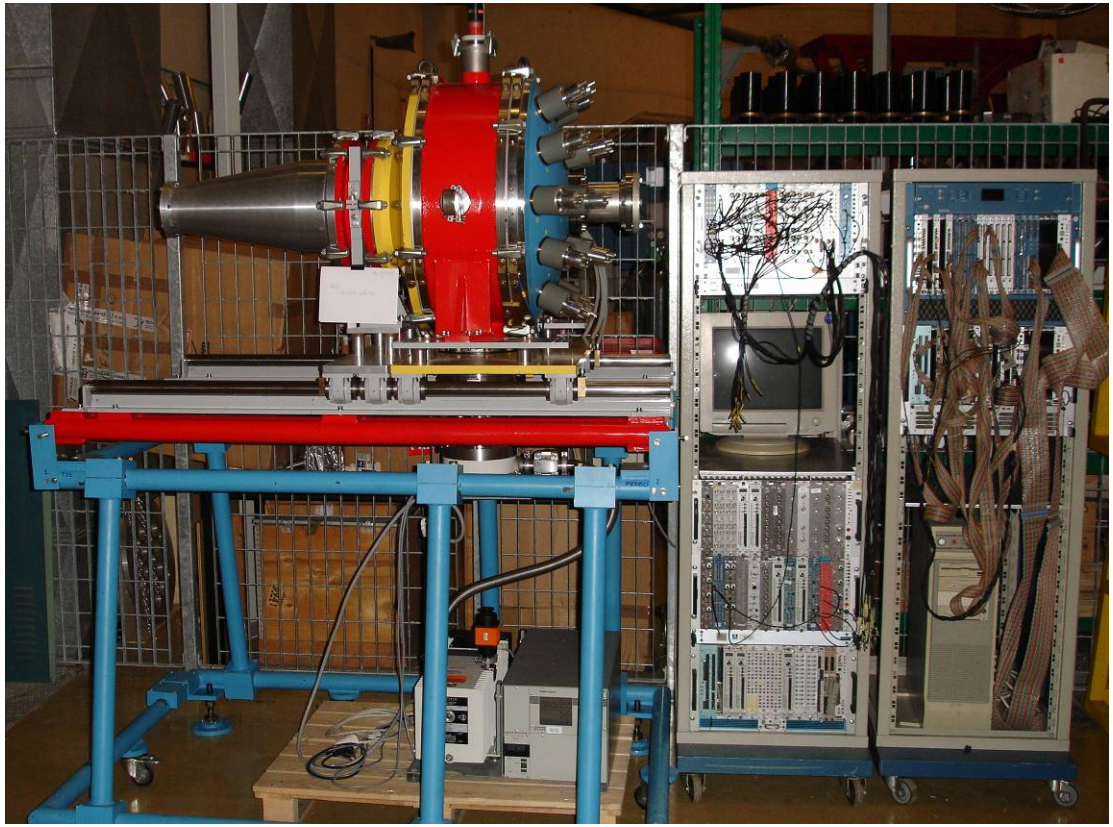
$\langle \beta \rangle = 2.8\%$



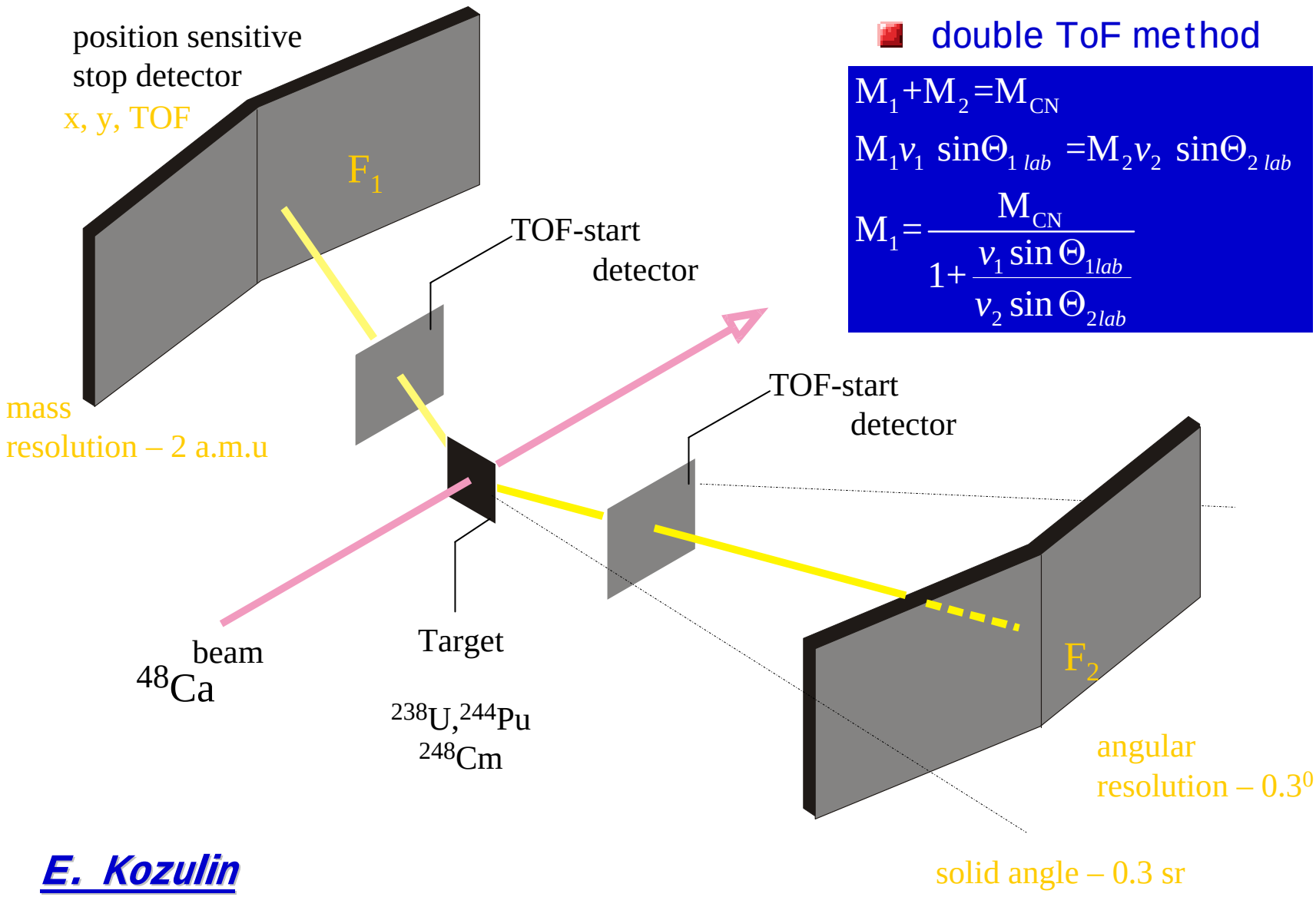
target thickness (recoil transit time T) defines a range of measured lifetimes (τ = 40 – 800 fs)

P. Bednarczyk et al., to be published

Ancillary Detectors – RFD @ Legnaro



Ancillary Detectors – CORSET



- double ToF method

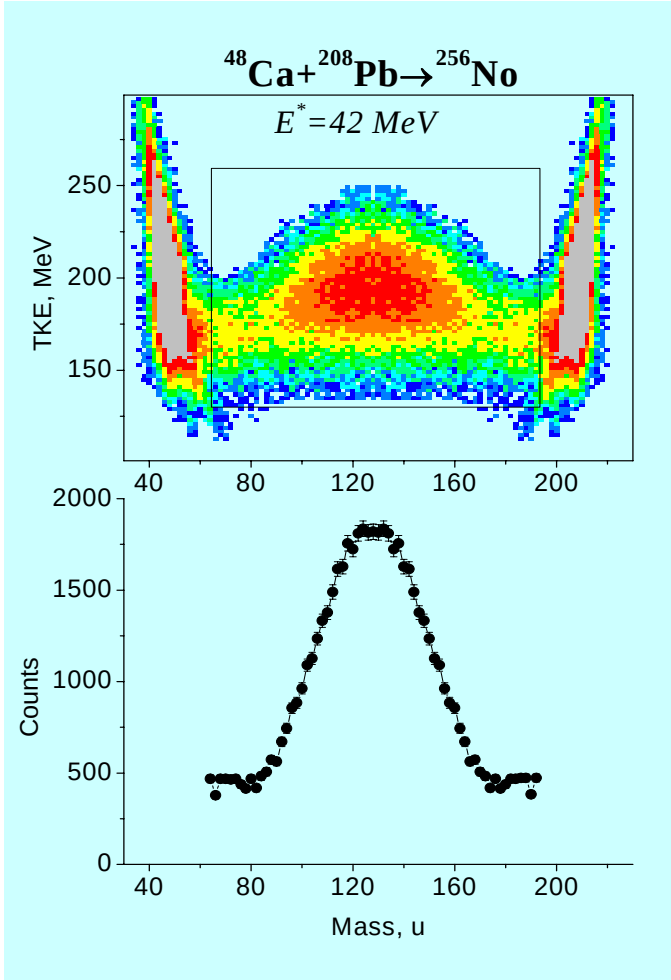
$$M_1 + M_2 = M_{CN}$$

$$M_1 v_1 \sin\Theta_{1\,lab} = M_2 v_2 \sin\Theta_{2\,lab}$$

$$M_1 = \frac{M_{CN}}{1 + \frac{v_1 \sin\Theta_{1lab}}{v_2 \sin\Theta_{2lab}}}$$

Ancillary Detectors – CORSET

- study of low- and intermediate-energy fission process: combined prompt gamma-ray spectroscopy with mass and energy distribution of fission fragments measurement
  - structure of neutron-rich fragments covering a wide range with A ≈ 60–190 and Z ≈ 24–68
  - direct information on the excitation energy of fission fragment partners and its distribution between collective and internal degrees of freedom



Dubna, July 2005

Ancillary Detectors – CORSET

- Characteristics
  - Time resolution Δt~120–180 ps
  - Mass resolution ΔA ~ 1.5 amu
  - TKE resolution ΔE ~ 1 MeV
  - Start–Stop distance ~ 10 cm
  - Angular resolution

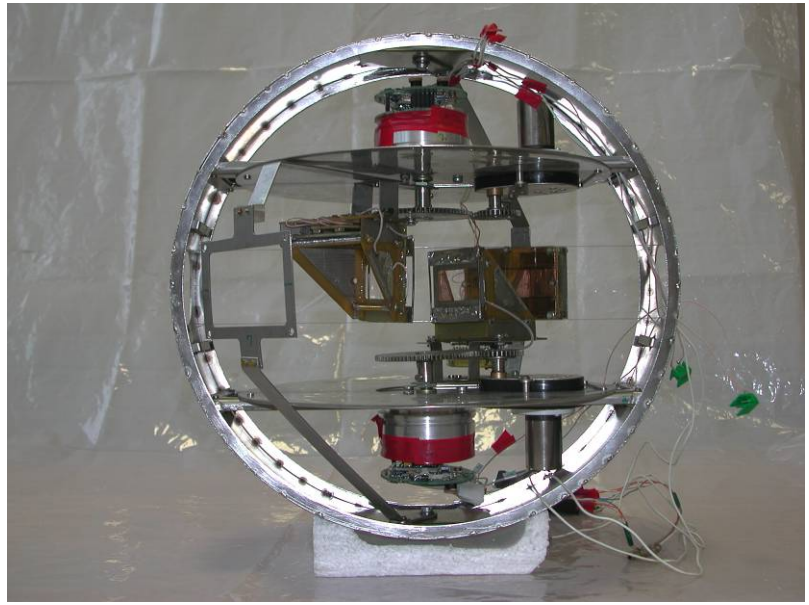
    $\Delta\theta \sim 0.3^{o}$

    $\Delta\varphi \sim 0.3^{o}$
  - Solid angle of each arm

    $\Omega \sim 150$ msr
  - Angle in the reaction plane

    $\theta=65°\pm13°$
  - Angle out of the reaction plane

    $\varphi=\pm10°$
- Configuration I



Concluding Remarks

- GaSp in 2 Configurations (I and II) campaigns
- Improve sensitivity → use ancillary detectors
  - EUCLIDES
  - nRing
  - RFD
  - CORSET
  - RMS
  - LuSiA
- Ancillary detectors can be operated independently or coupled together

- GaSp goes digital !?