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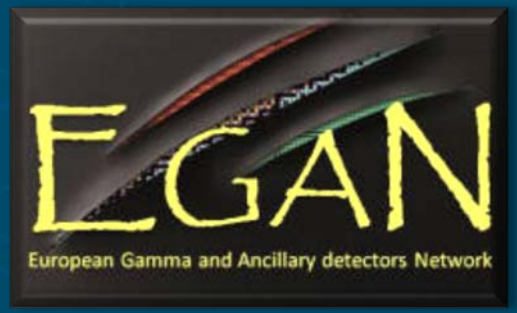
γ-Ray and Recoil Coincident Measurements;

Application in Lifetime Determination of a Short-lived Nuclear State



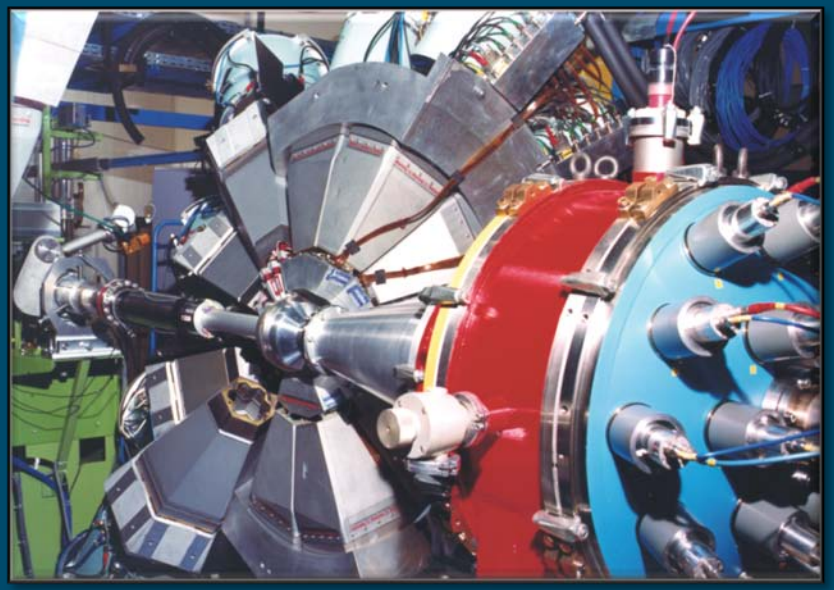
Outline

- Present status of the Recoil Filter Detector
  - -Principle of opertion
  - -Heavy Ion detection technique
  - -In beam performance
  - -Examples of lifetime measurements (A~40, A~70)

- Perspectives
  - -AGATA
  - -RIB facilities

RFD Historical Outlook

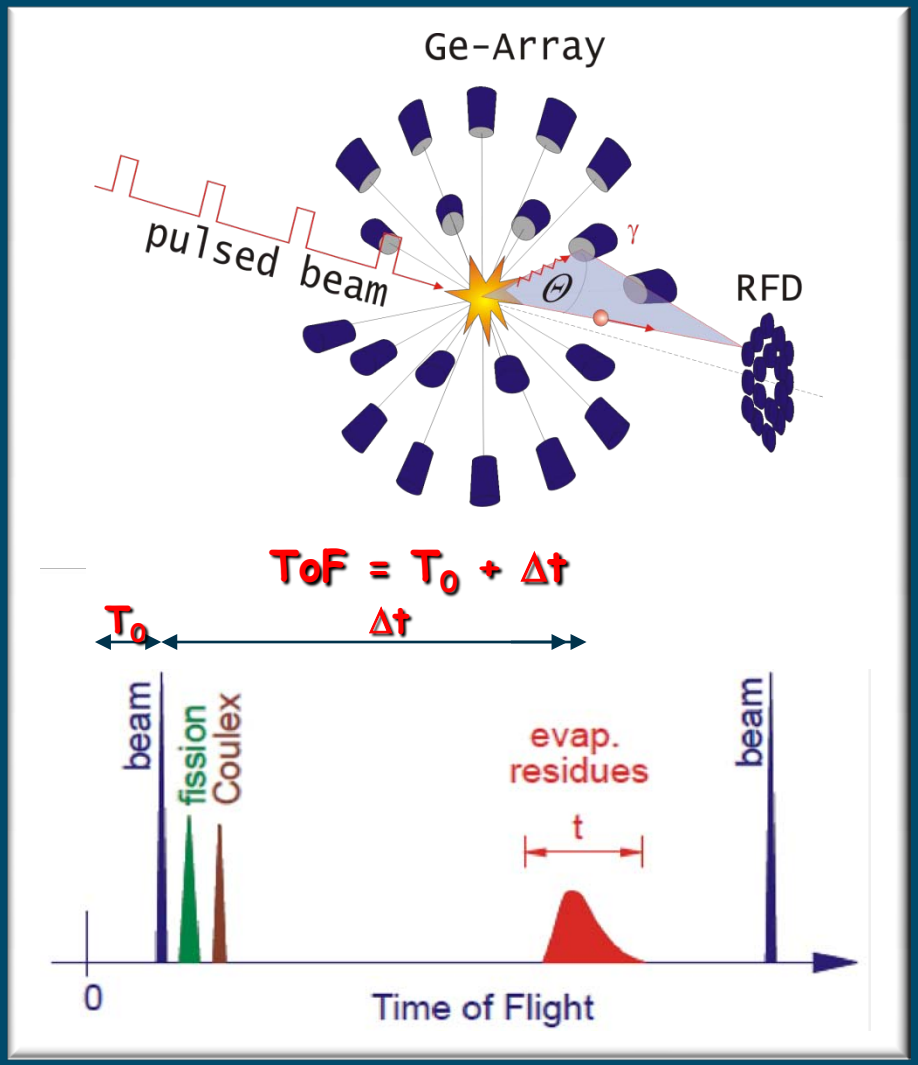
- **OSIRIS**, Berlin
  J. Heese et al., ,
  Phys. Lett. B 302, 390 (1993)
- **GAREL+**, Strasbourg
  W. Męczyński, et al.,
  Eur. Phys. J. A 3, 311 (1998)
- **EUROBALL IV**, Strasbourg
  P.Bednarczyk, et al.,
  Acta Phys. Pol. B 32 , 747 (2001)



- **GASP**, LNL (2009)

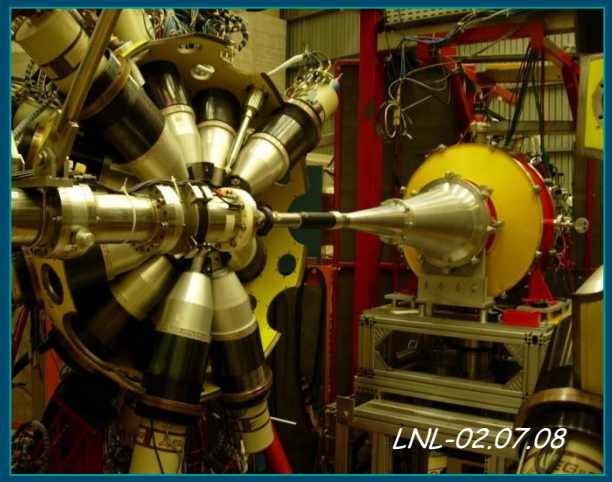
Long Write-up:
W. Męczyński, et al., Nucl. Instr. and Meth.. A 580 (2007) 1310

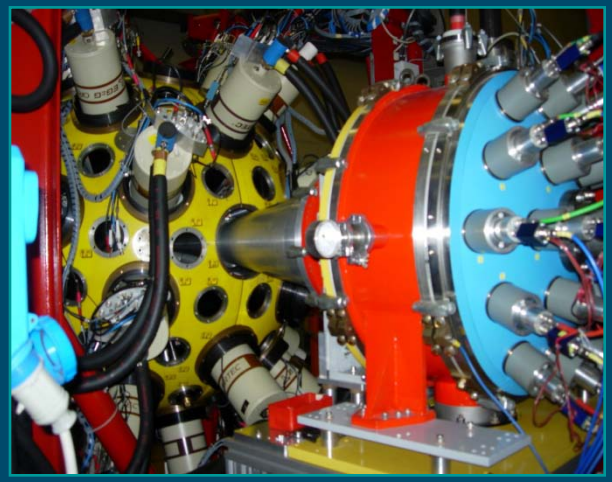
Recoil Filter Detector - Principle of Operation



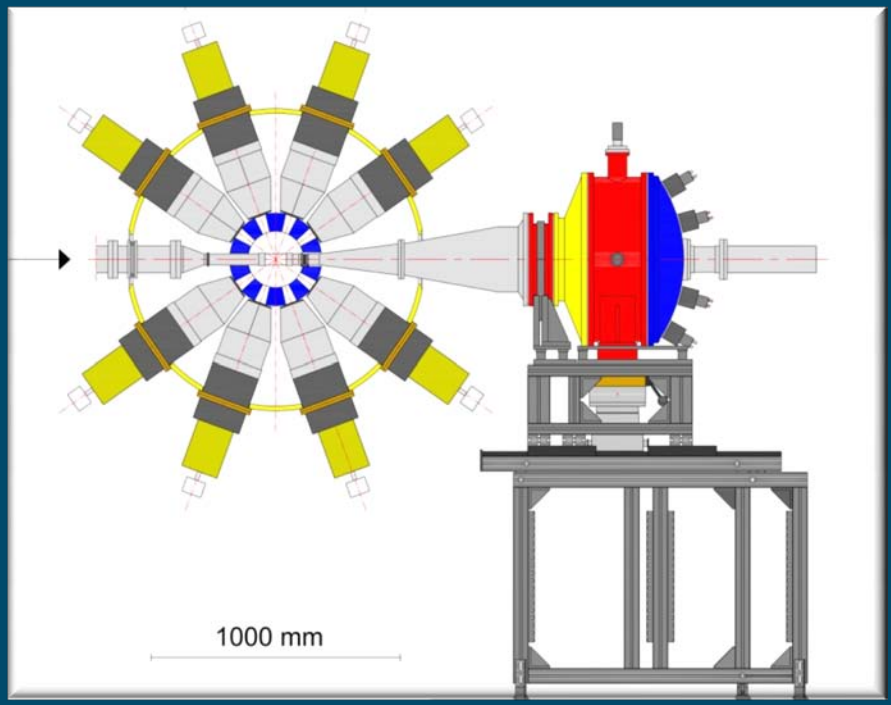
- RFD is a HI detector that measures evaporation residues in coincidence with γ-rays detected in a Ge array
- Time-of-Flight technique is applied to select evaporation residues in event-by-event mode

GASP & RFD at LNL

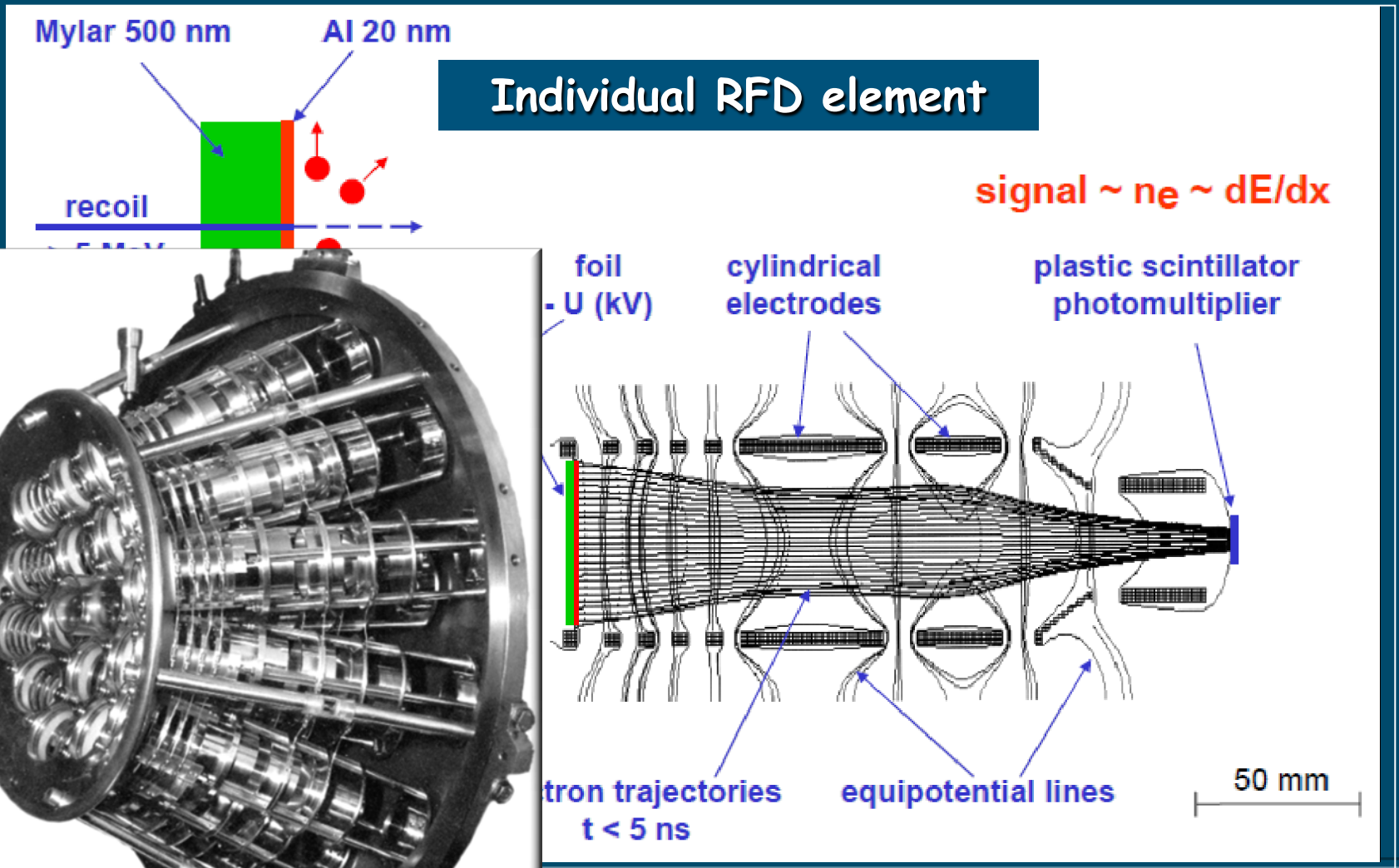




- Installation 2008
- Experiments 2009

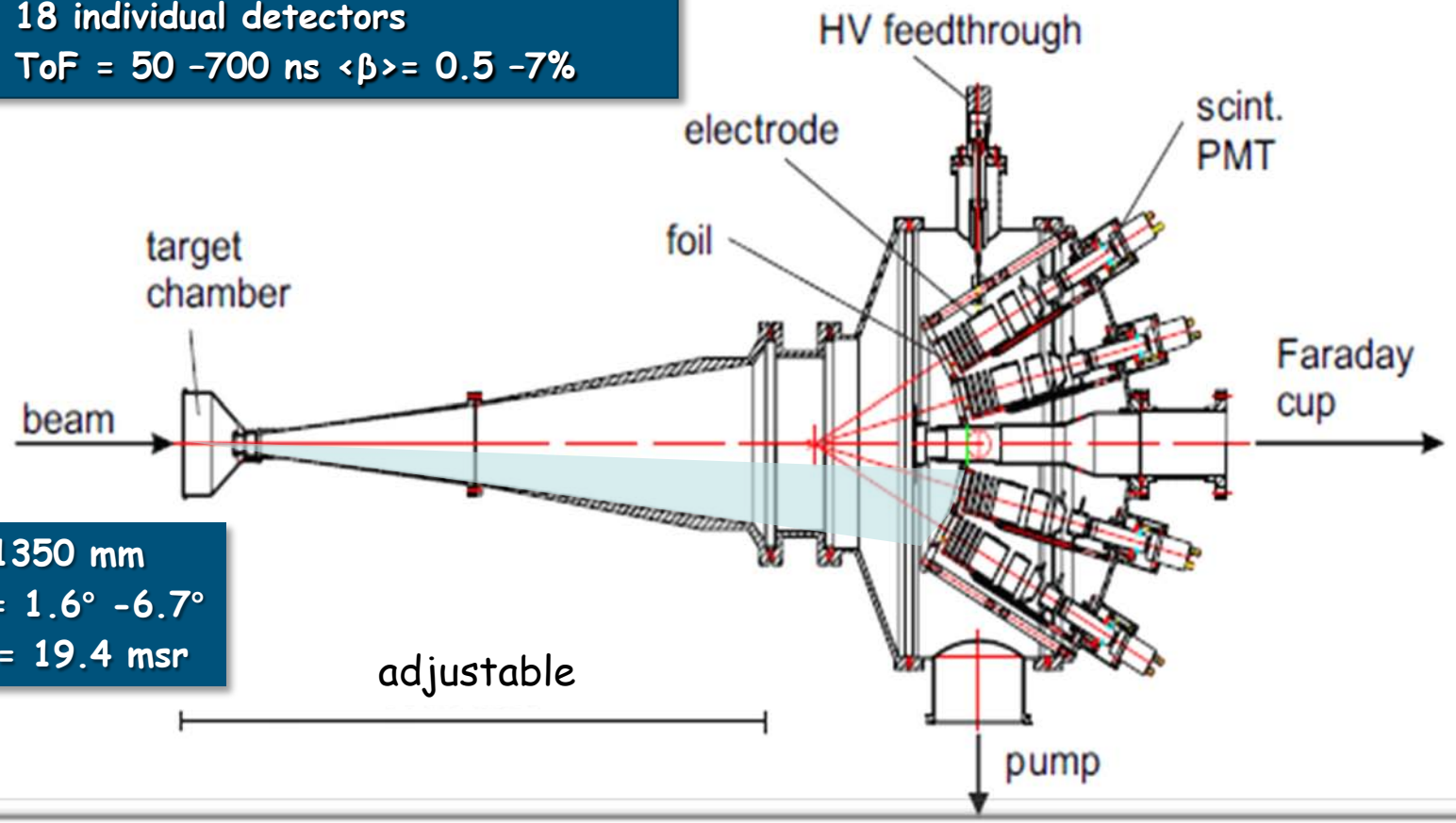


HI Detection Technique



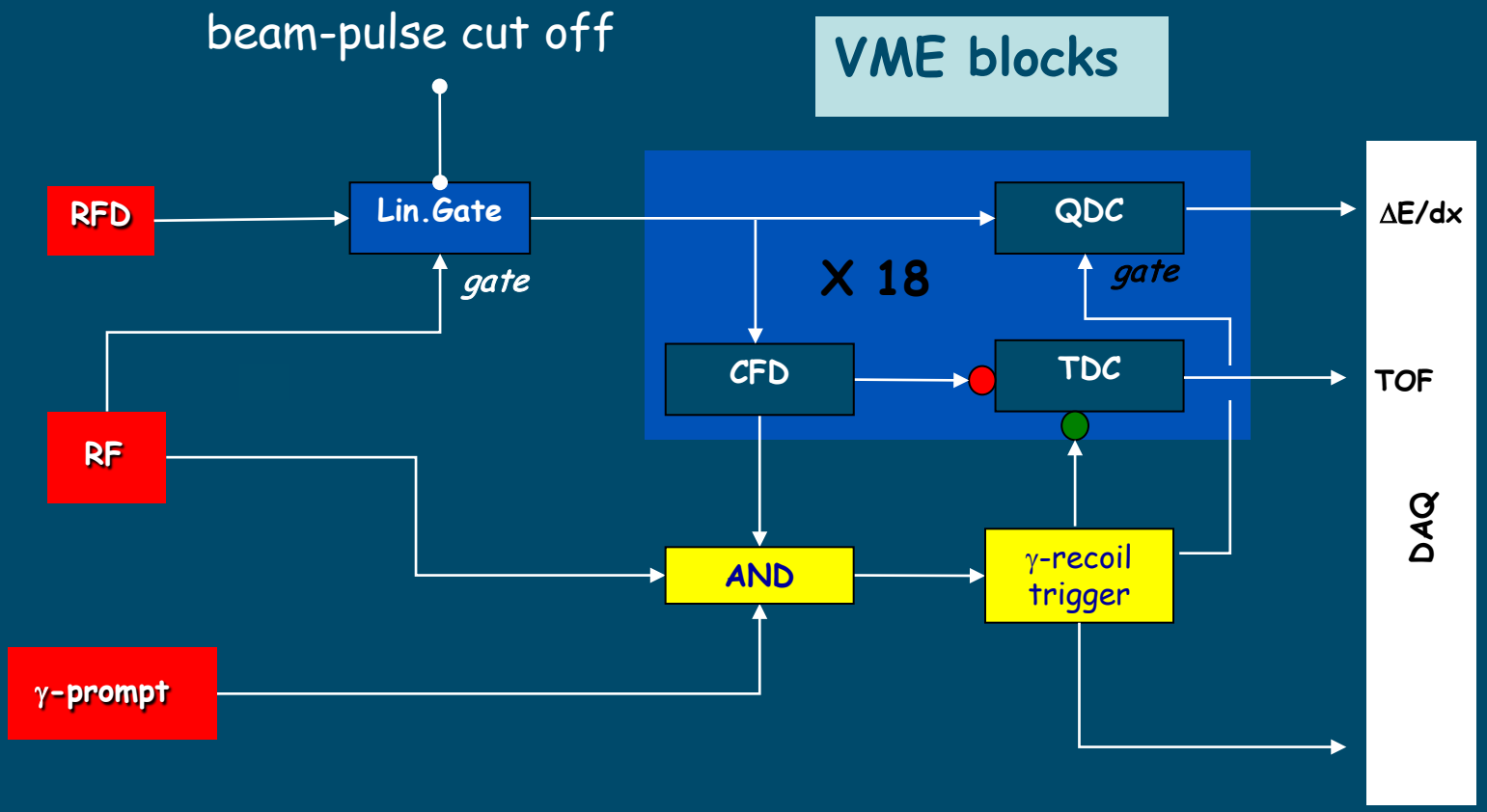
HI Detection Technique

- 18 individual detectors
- ToF = 50 –700 ns <β>= 0.5 –7%



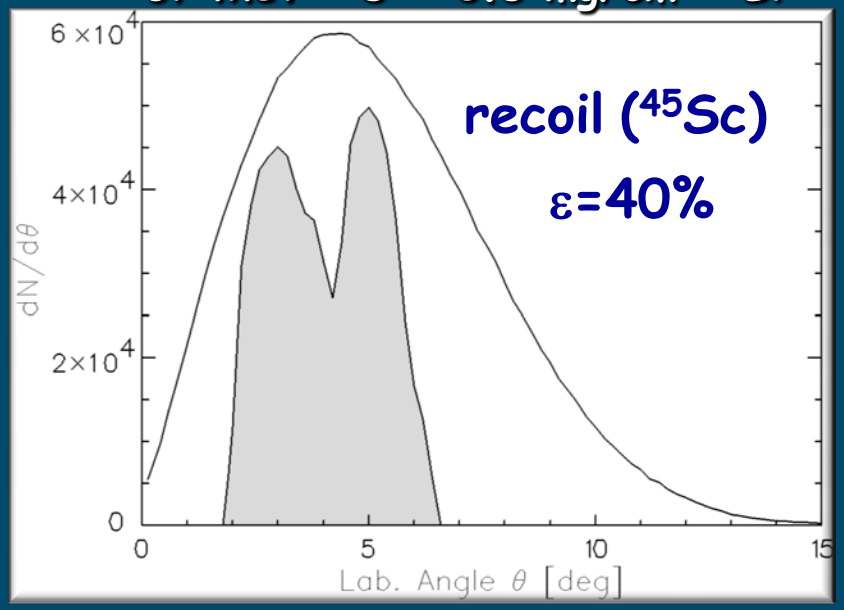
- Detectors don't look directly at the target
- Scintillators are far from the beam line

Simple logics of the RFD Trigger & the DAQ system

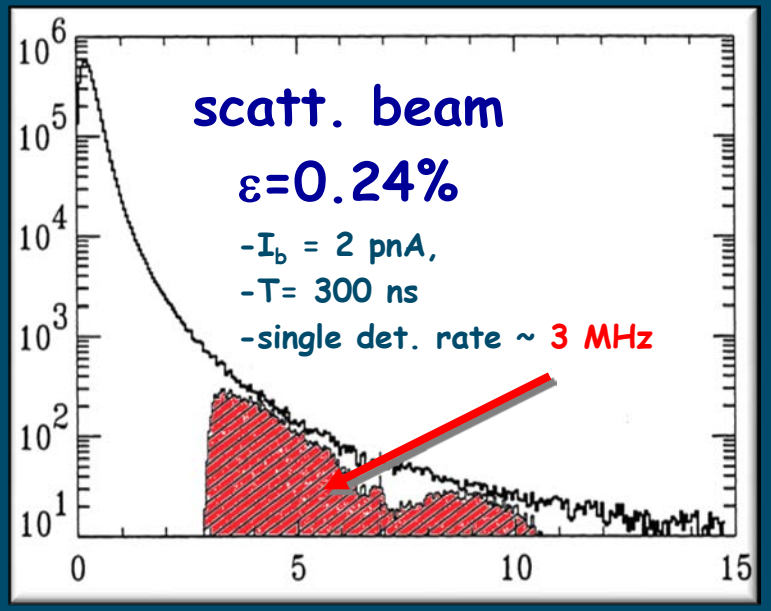


Efficiencies: Recoil-Detection, Beam-Rejection

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



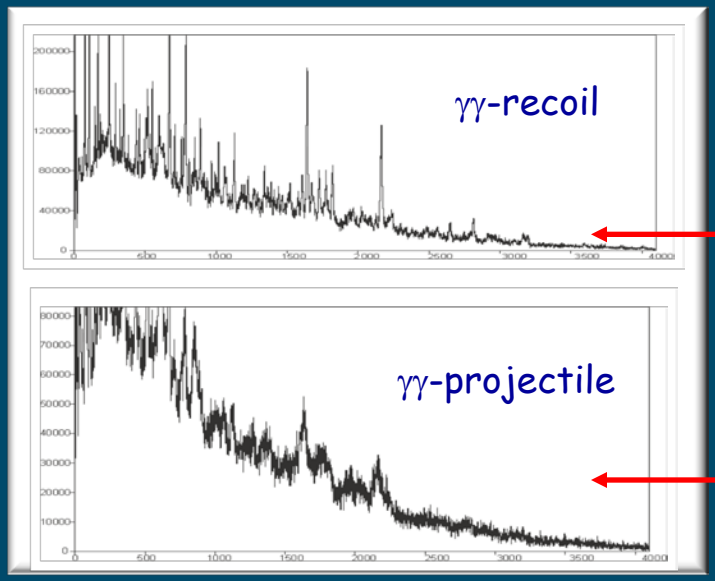
141 MeV ^{28}Si + 1.0 mg/cm^2 ^{175}Lu

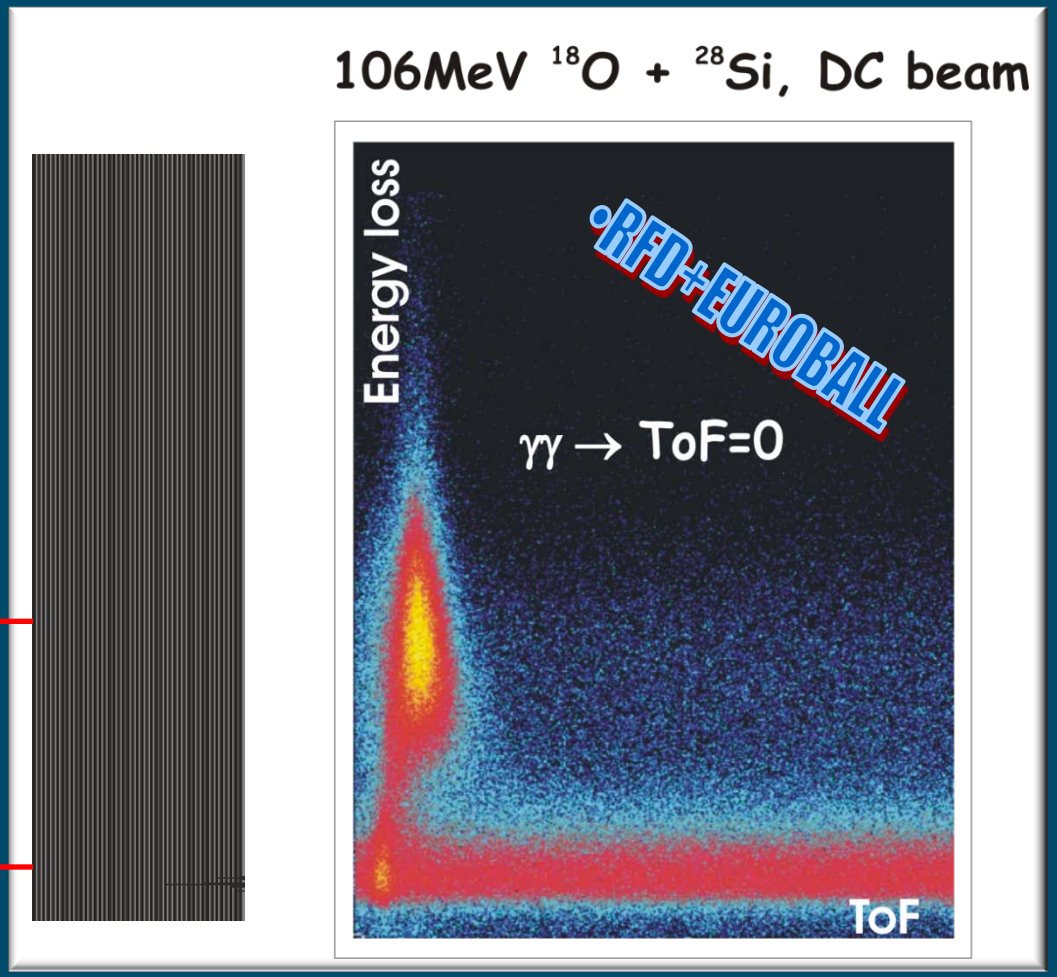


- Most of projectiles go to FC
- The tail of a beam pulse is cut off electronically in order to avoid a DAQ related dead-time

Measurement with a continuous beam

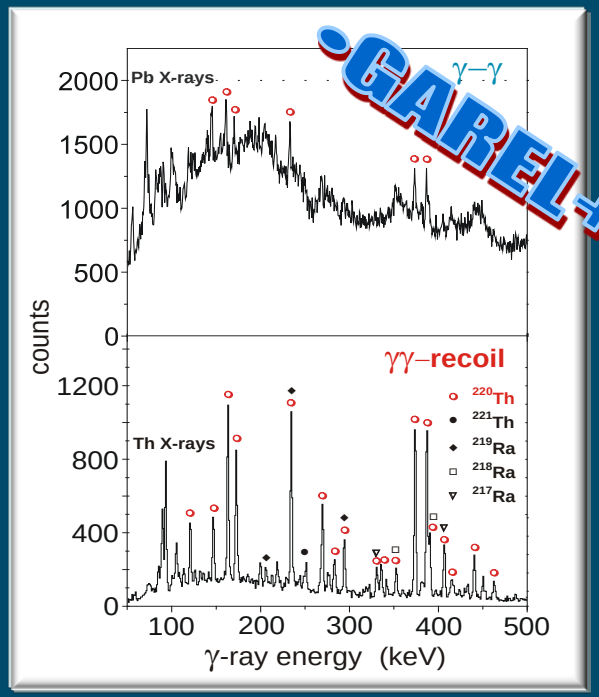
- possible if the recoil and the projectile deposit different energies in a foil
- feasible only at low intensity beams



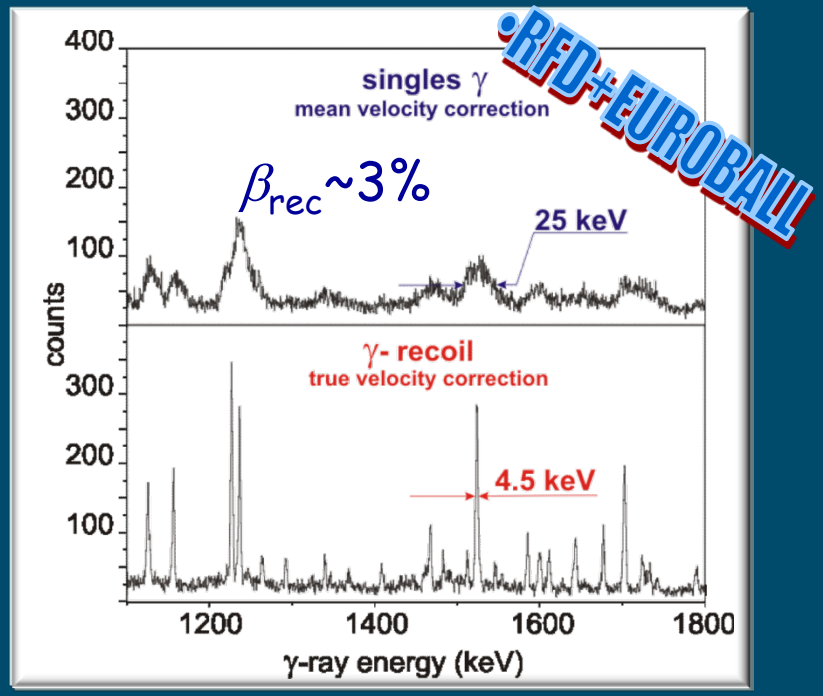


Improvement of γ-spectra by a coincident recoil detection

92 MeV ^{16}O + 0.4 mg/cm^2 ^{208}Pb

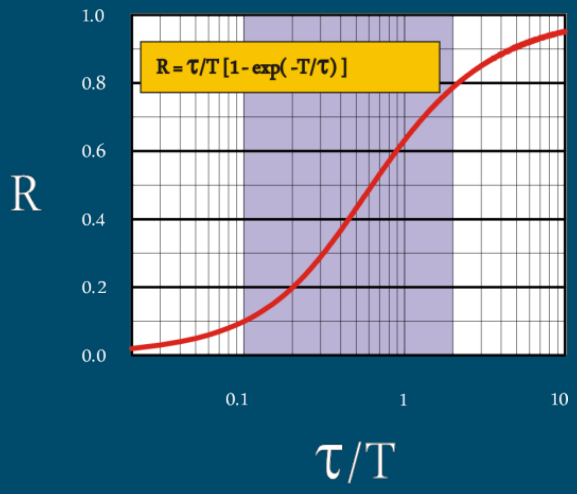


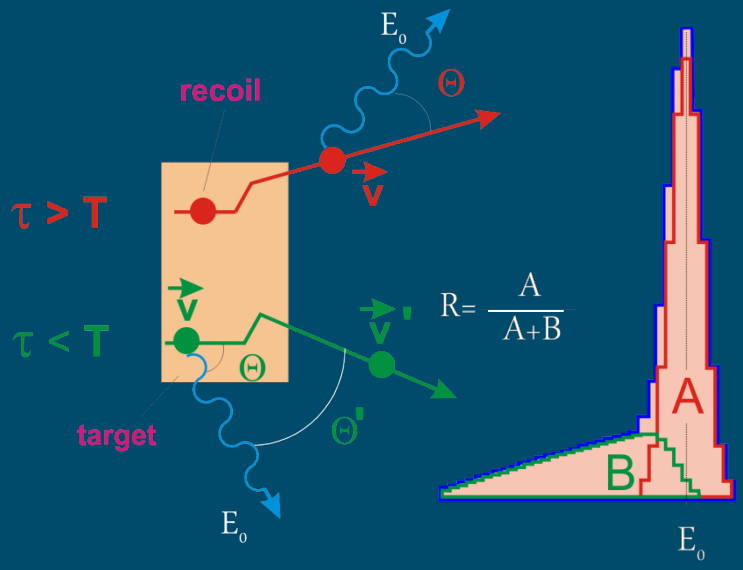
68 MeV ^{18}O + 0.8 mg/cm^2 ^{30}Si



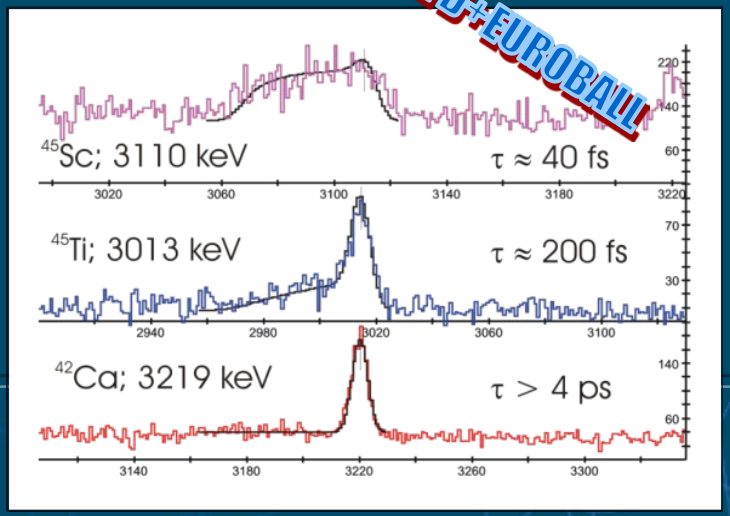
- Heavy systems:
  - ✓ fission background reduction
  - ✓ low cross sections σ ~ 0.1 mbarn
- Large recoil velocity:
  - ✓ reduction of the Doppler broadening

Estimation of a short lifetime



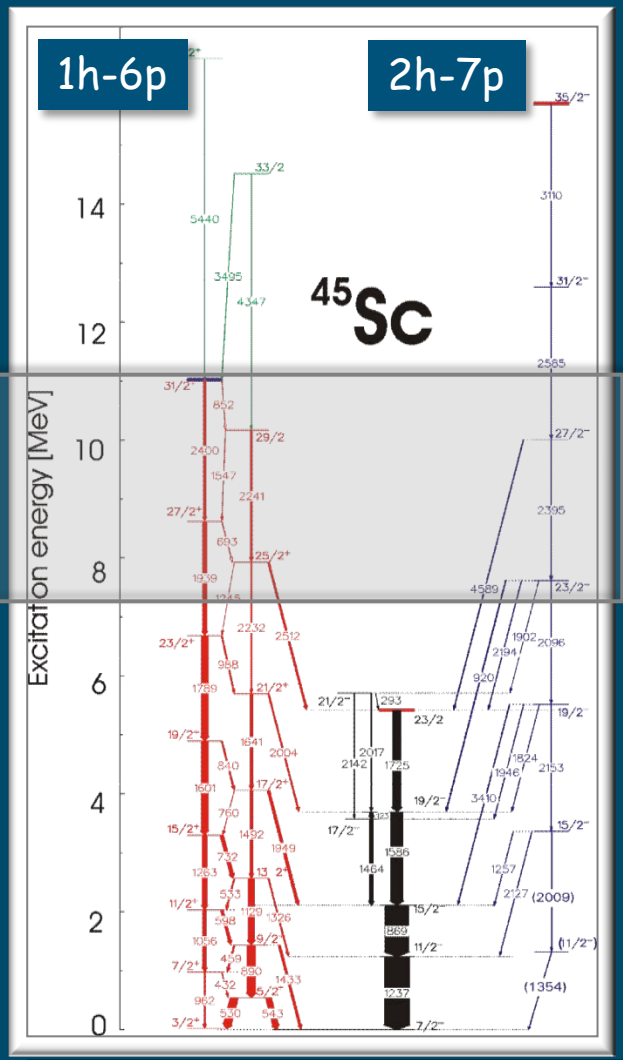


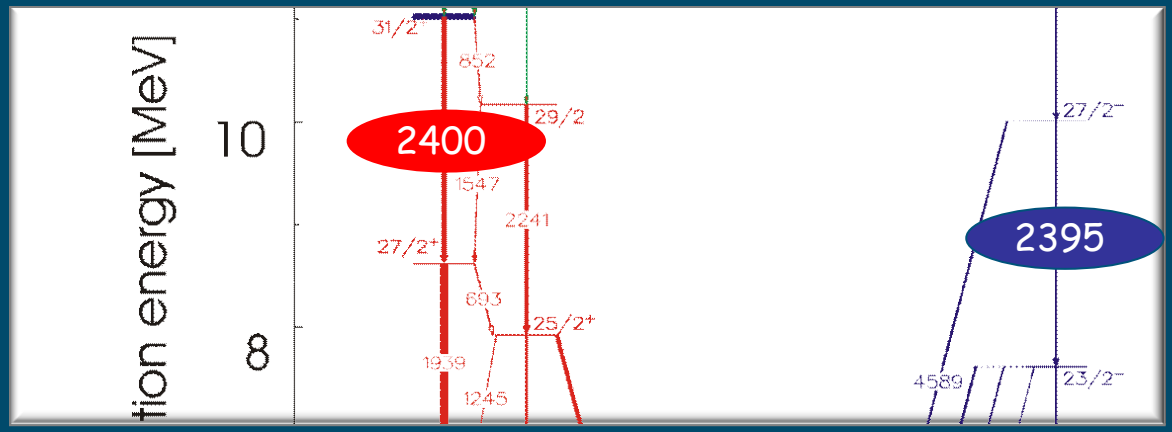
68MeV ^{18}O + 0.8mg/cm^2 ^{30}Si;
Recoil transit time ≈ 0.4 ps

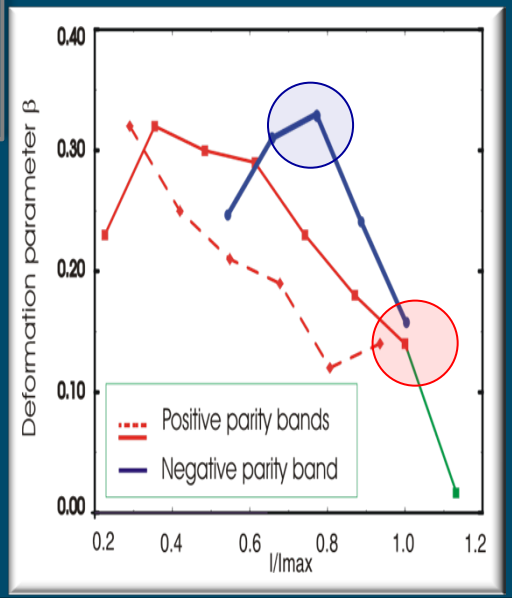


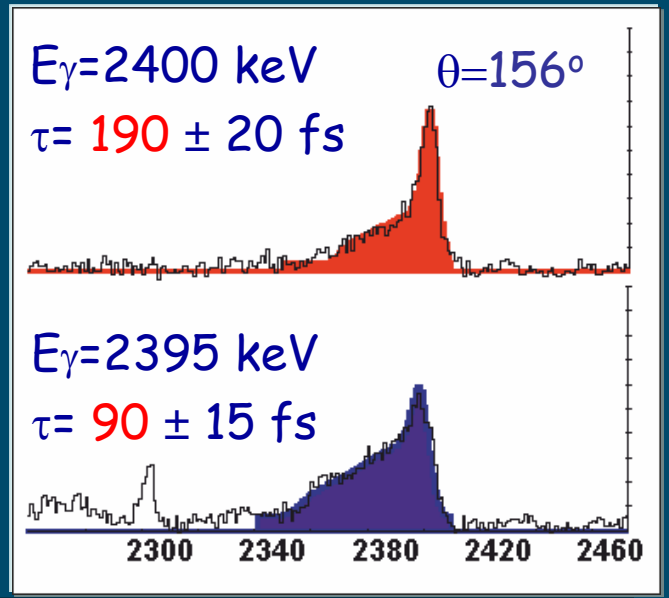
- Energy of a γ-ray emitted in a target (B) is not sufficiently Doppler corrected
- A level lifetime can be expressed by number of decays in vacuum (A) relative to a total γ-line intensity (A+B)
- τ range : <50 fs, 1ps>

Lifetimes along terminating bands in ^{45}Sc



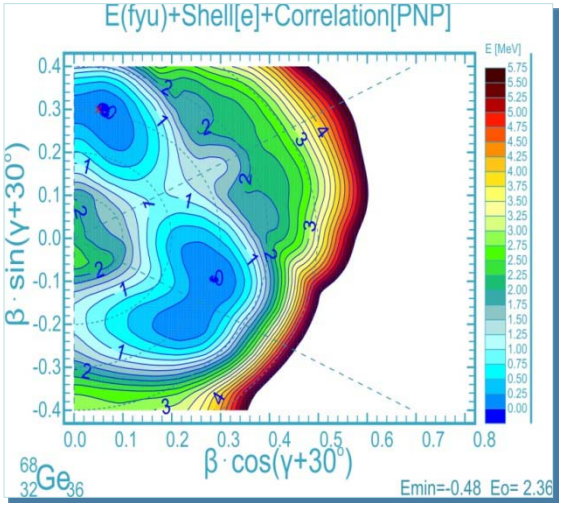


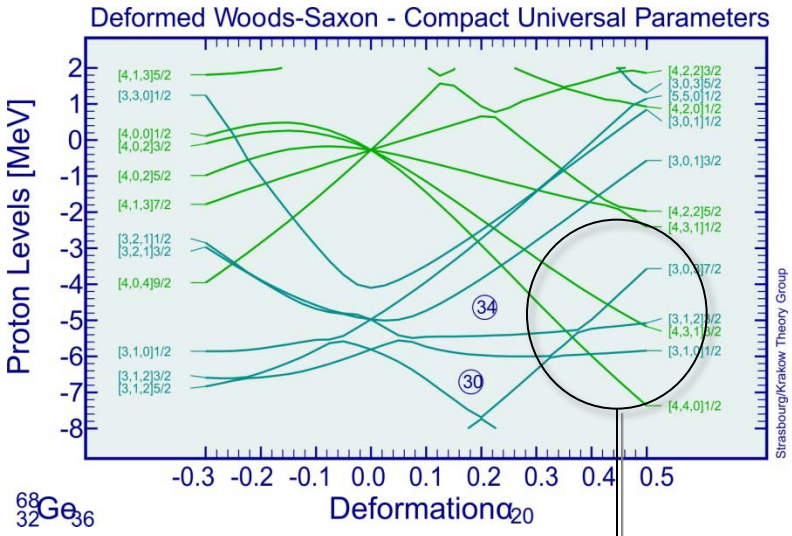




P. Bednarczyk, et al.,Eur. Phys. J. A 20 , 45 (2004).

Spectroscopy close to the $N=Z=32$ line





Variety of shapes and shape coexistence:

- Oblate at GS
- γ-soft
- Breaking of the ^{56}Ni core results in SD bands

$g_{9/2}$ intruders

GASP + RFD measurement at LNL: ^{69}As

- GS oblate β~0.3
- Low spin prolate triaxial, β~0.3
- At HS (I~20) expected a prolate SD band (β=0.45, π=+)

  A.Bruce et al,. PRC 62 027303 (2000)

- Complete spectroscopy at EUROBALL

  I.Stefanescu et al,. PRC 70 044304 (2004)

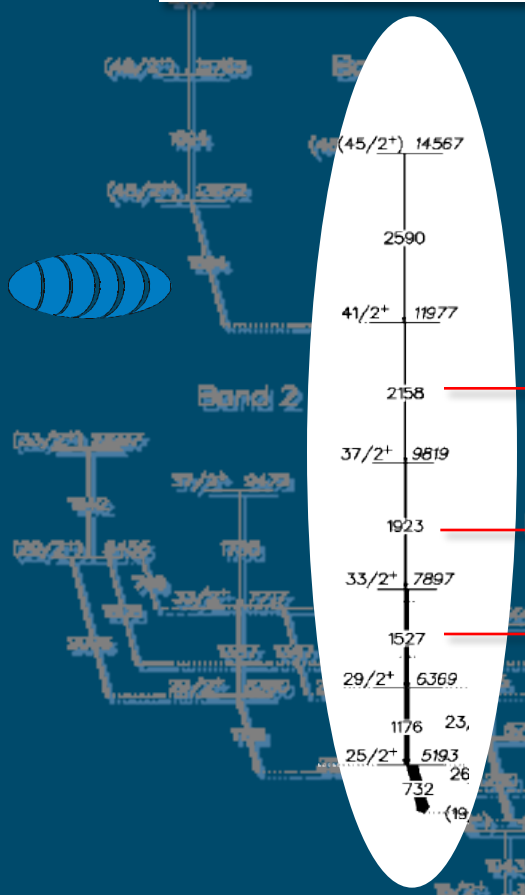
- Shell model description of the T=0 p-n alignment at HS (untypical for an odd-even system)

  M.Hasegawa et al,. PRC 72 064320 (2005)

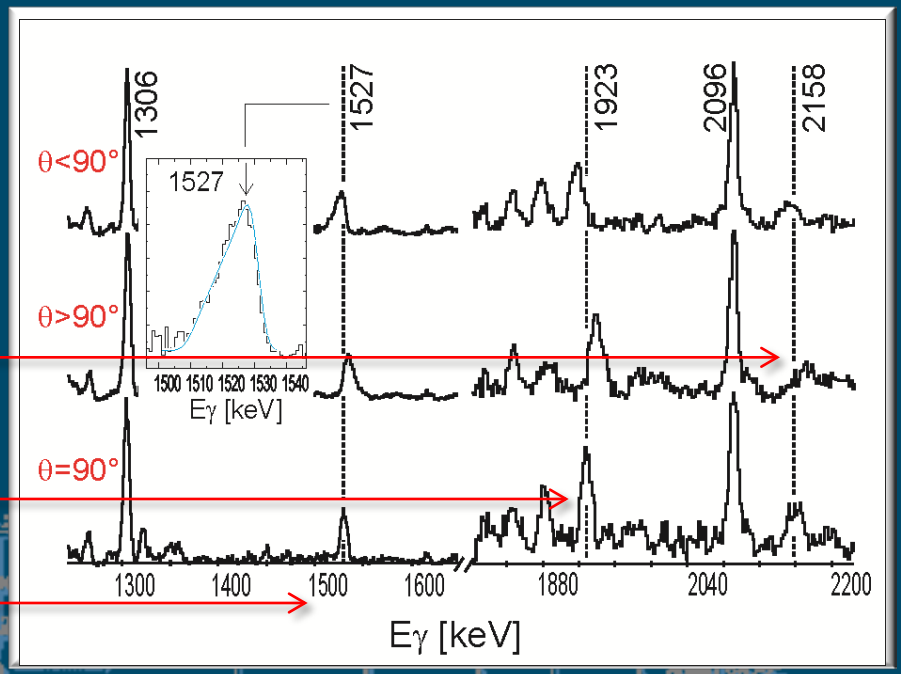
GASP + RFD @ LNL: $^{40}Ca(^{32}S,3p)^{69}As$ at 95 MeV

$\pi(g_{9/2})^1\ \nu(g_{9/2})^2$, I_{max}=49/2

$\tau \sim 40$ fs $\rightarrow \beta \sim 0.5$



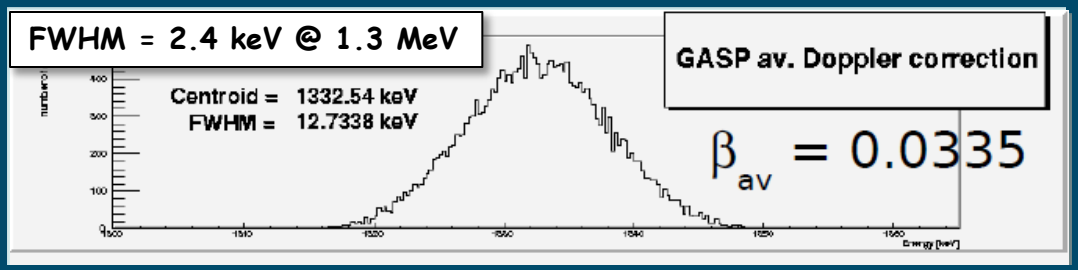
^{69}As

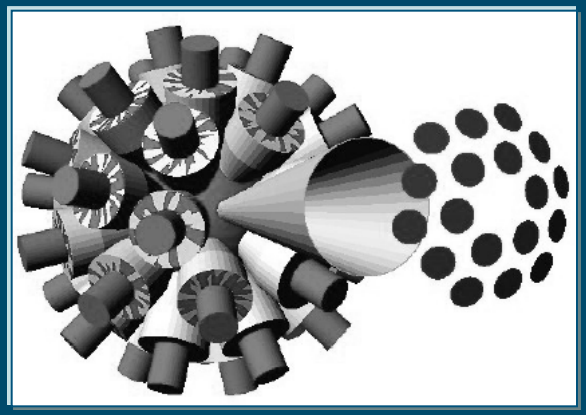


EUROBALL + EUCLIDES

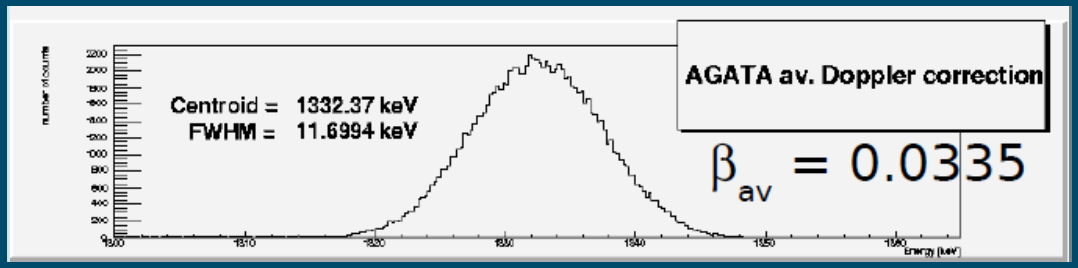
I.Stefanescu et al,. PRC 70 044304 (2004)

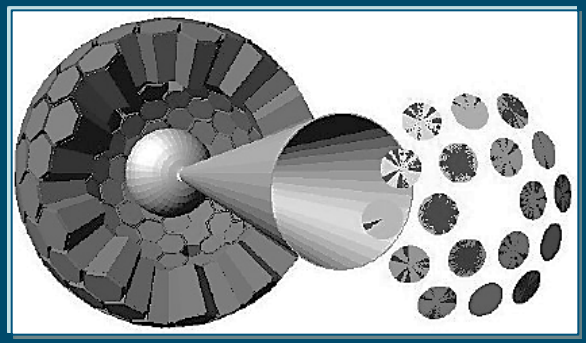
Resolution contest: GASP vs AGATA





GASP: ε=5.0%





AGATA 3Π: ε=22%

GIV Simulations by G. Jaworski , M.Palacz

Connection to a digital triggerless (AGATA) DAQ

AGATA Demonstrator

pulse sampling

PSA

GTS
Time stamp

AGAVA
interface

Data
Synch.

Ancillary event

Tracking

Analogue VME

Doppler
correction

RFD

FUTURE: RFD at RIB

- **RFD may be a good solution for measurements with intense radioactive beams in a broad energy range**
  - ✓ projectiles do not irradiate any part of the setup, can be transported to a FC distant from the experimental area.
  - ✓ detectors are far from the beam-line
  - ✓ distance target-RFD can be adjusted to a particular experiment in order to optimize the projectile/recoil separation and the efficiency

- **Compatible with Ge-arrays:**

  AGATA, EXOGAM, GALILEO, PARIS

  @ GANIL(SPIRAL2), LNL(SPES)

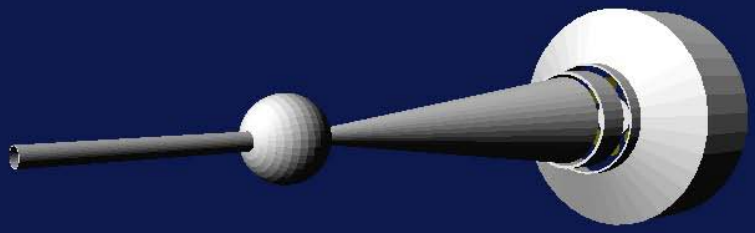
- **Possible future modifications**
  - ✓ replacement of scintillators by ultra fast diamond detectors or Si diods
  - ✓ use of digital FEE

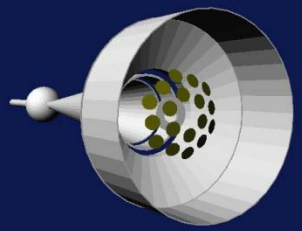
GEANT4 simulations of RFD @RIB facilities (SPIRAL, SPES)

Goal:

-Estimate radiactivity accumulated in the detector

-Evaluate the influence on a gamma detection system





G.Jaworski , M.Palacz, M.Ciemała

Thanks to:

- **Set-up:**

  A.Czermak, M.Ciemała, B.Fornal, J. Grębosz, M.Kmiecik, K.H. Maier, A.Maj, M.Matejska-Minda, W.Męczyński B.Sowicki J.Styczeń, M.Zięblíński, PB, IFJ-PAN Krakow

  S.Brambilla,S.Leoni, et al., INFN, Milano

- **Simulations:**

  M.Palacz,G.Jaworski, HIL, Warszawa

- **Host Laboratories:**

  IRES (EBIV) D.Curien, J.C Merdinger et al.

  LNL (GASP) E.Farnea, R.Menegazzo, D.Napoli, C.Ur et al.

  GANIL(EXOGAM) Ch. Schmitt et al.

THE END