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PREPARATORY WORK ON INSTALLATION OF THE RECOIL FILTER DETECTOR AT GANIL

IFJ PAN, Kraków

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*student PhD

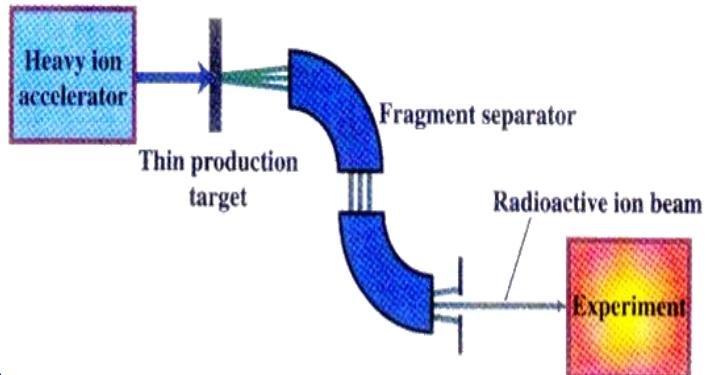
GANIL, Caen

Christelle Schmitt,

Navin Alahari, Maurycy Rejmund, Jean-Pierre Wieleczko

Radioactive Ion Beams (reminder)

Projectile Fragmentation

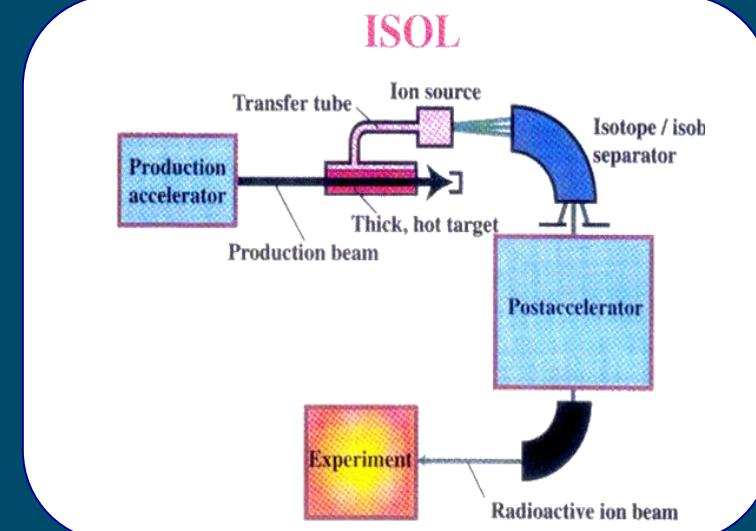


ISOL :
CERN, TRIUMF, GANIL-SPIRAL2

- Energy around the Coulomb barrier
- Possible use of fusion evaporation reactions

In flight:
GANIL, GSI, RIKEN, MSU

- High energies of projectiles
(~100MeV/u),
- Relativistic Coulomb excitation
 - Fragmentation



RIB application in studies of extreme high spins

Spiral2 Day1-Phase2 LoI, A.Maj (Kraków), A.Leoni (Milano) et al.

Study of collective modes of excitations in neutron rich Ba isotopes via fusion-evaporation reactions

- Reaction:

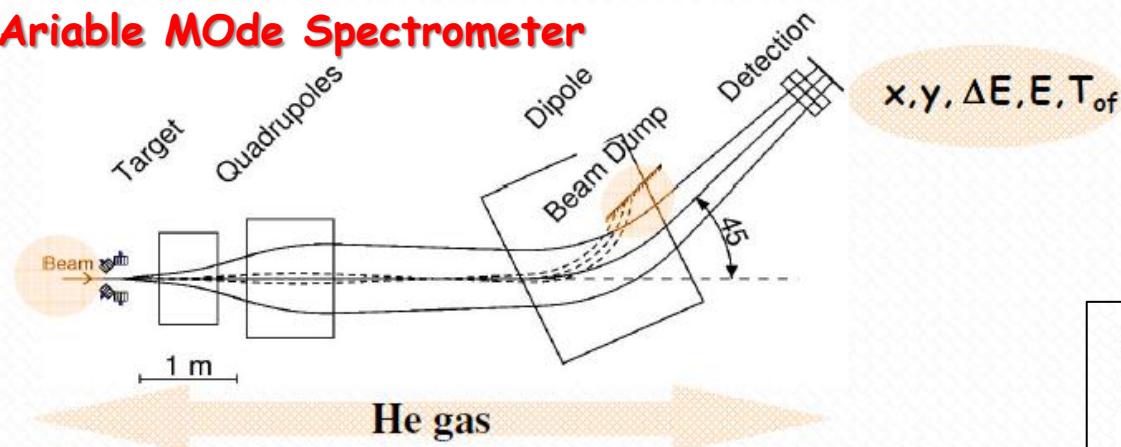


- Setup:

- γ -ray detectors PARIS (2π), EXOGAM2/AGATA
- ER detector for projectiles and fission fragments rejection

Evaporation Residues separation technique with VAMOS at 0°

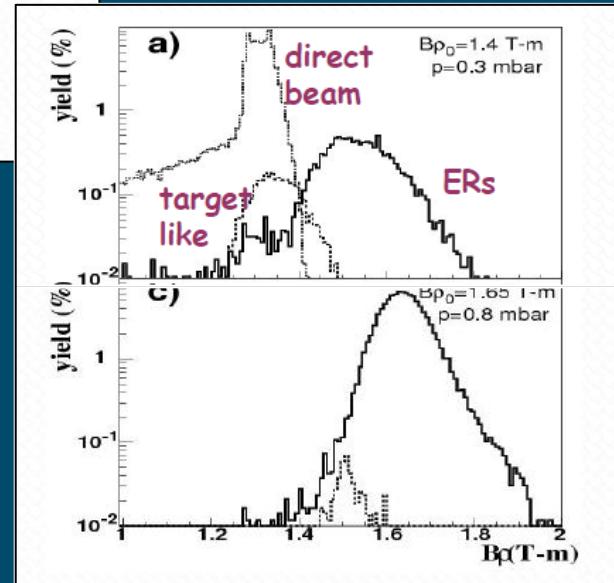
VAriable MOde Spectrometer



$$B\beta \propto A/Q \cdot v$$



C.Schmitt et al., NIM A621 (2010) 558

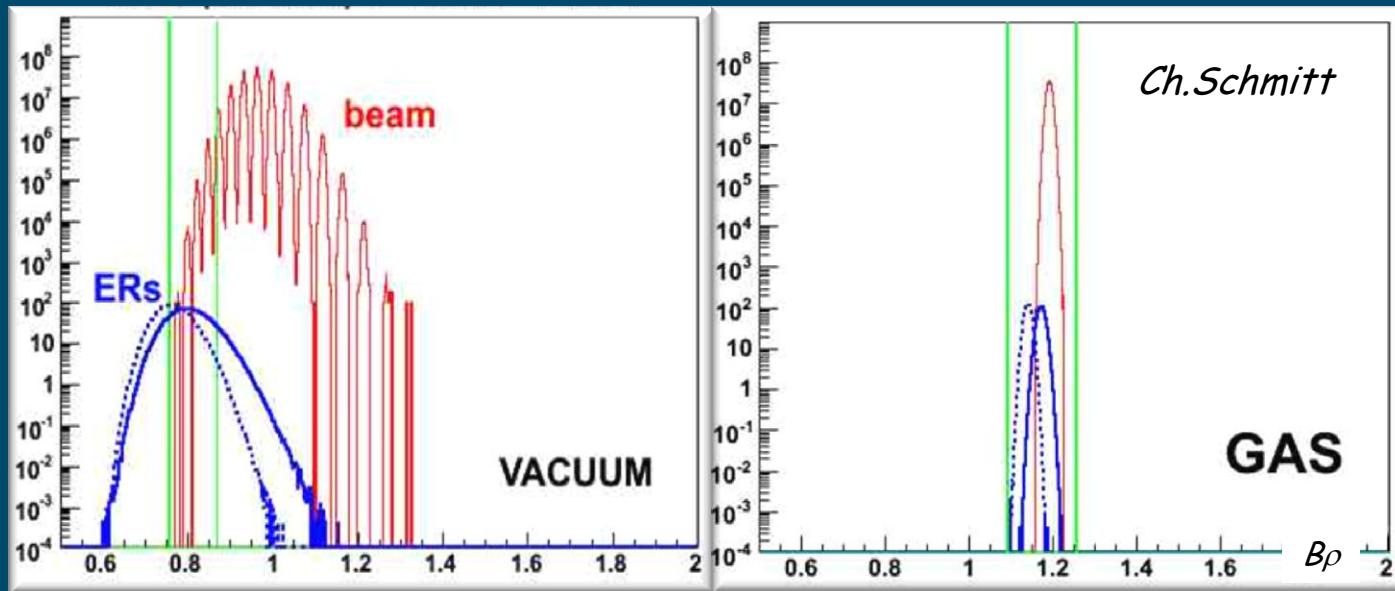


Unfavorable case of inverse kinematics reactions

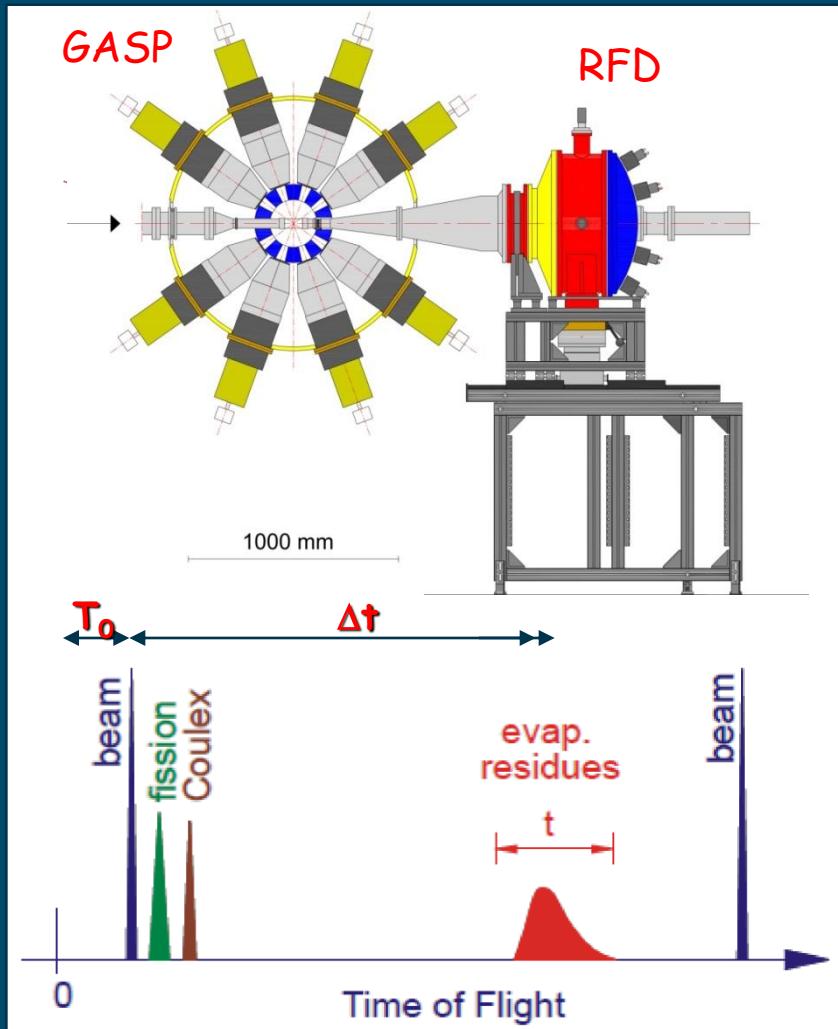


v/c (rec) ~ 7%

v/c (proj) ~ 10%

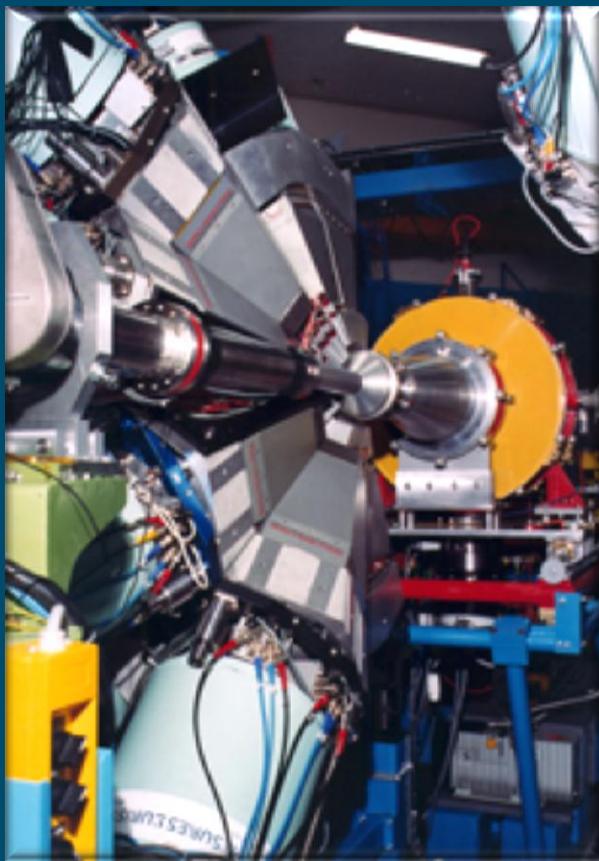


Recoil Filter Detector - an alternative solution

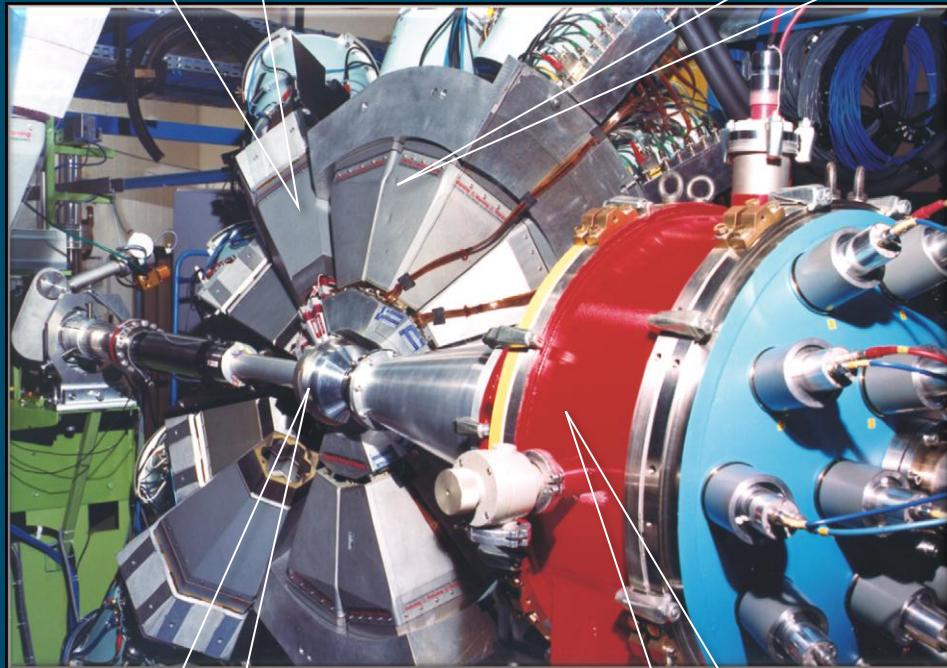


- RFD is a HI detector that measures evaporation residues in coincidence with γ -rays detected in a Ge array
- Time-of-Flight technique is applied to select evaporation residues in event-by-event mode

EUROBALL and RFD (Strasbourg 1999-2003)



Cluster

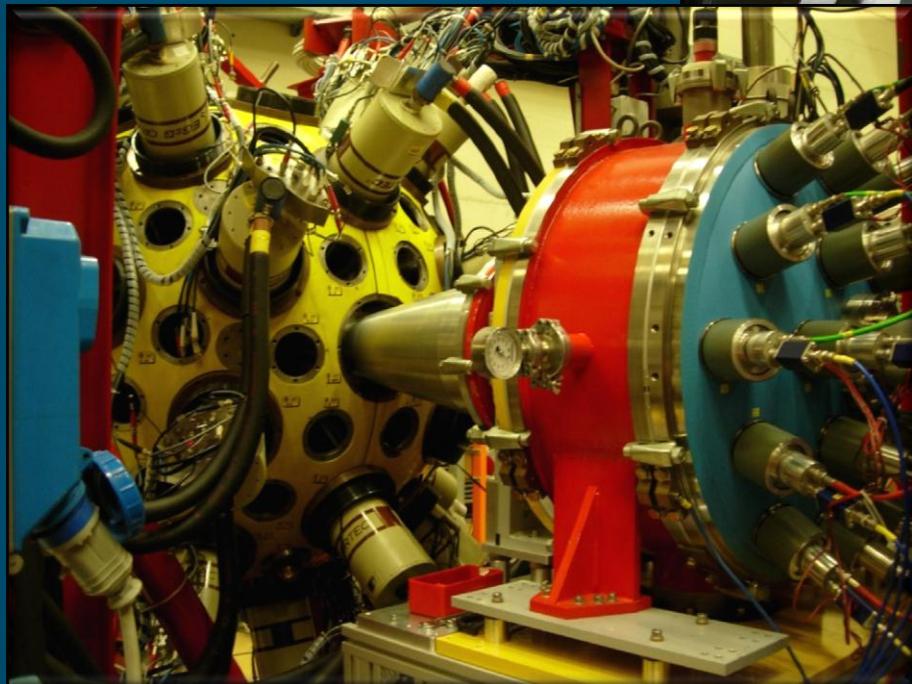
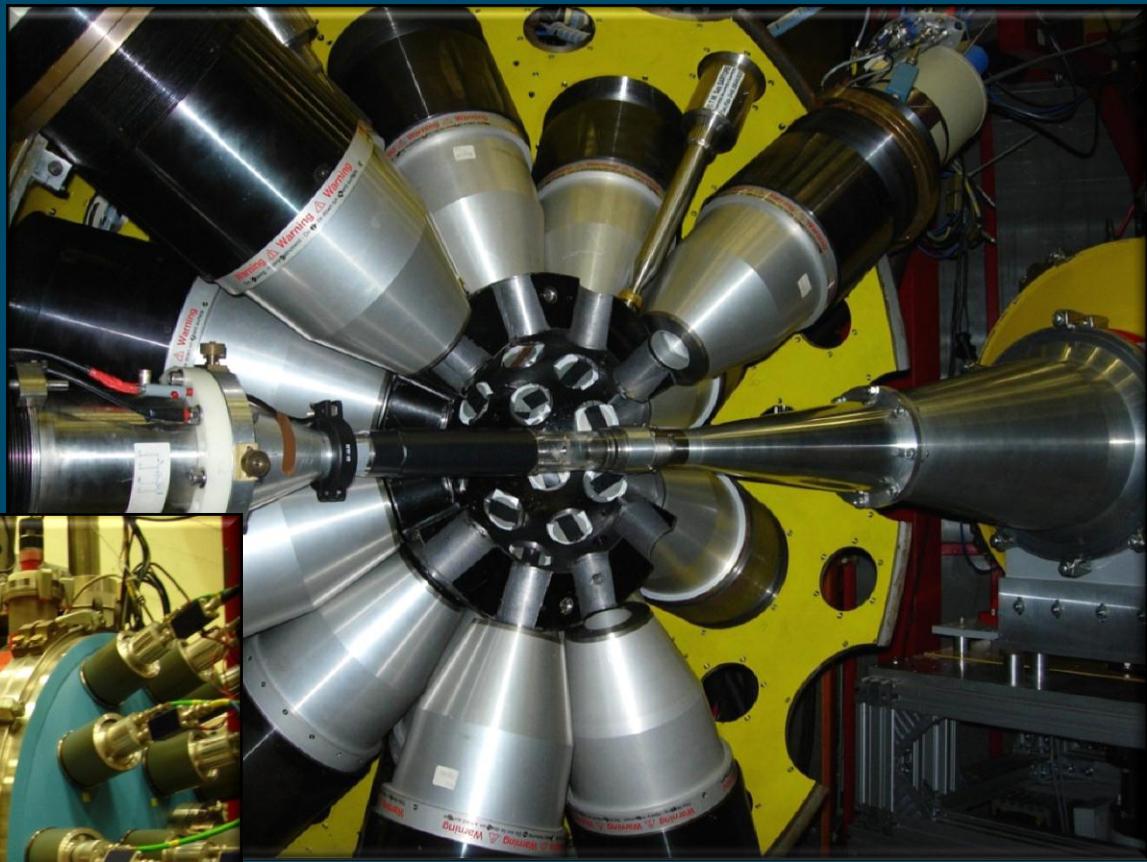


Target chamber

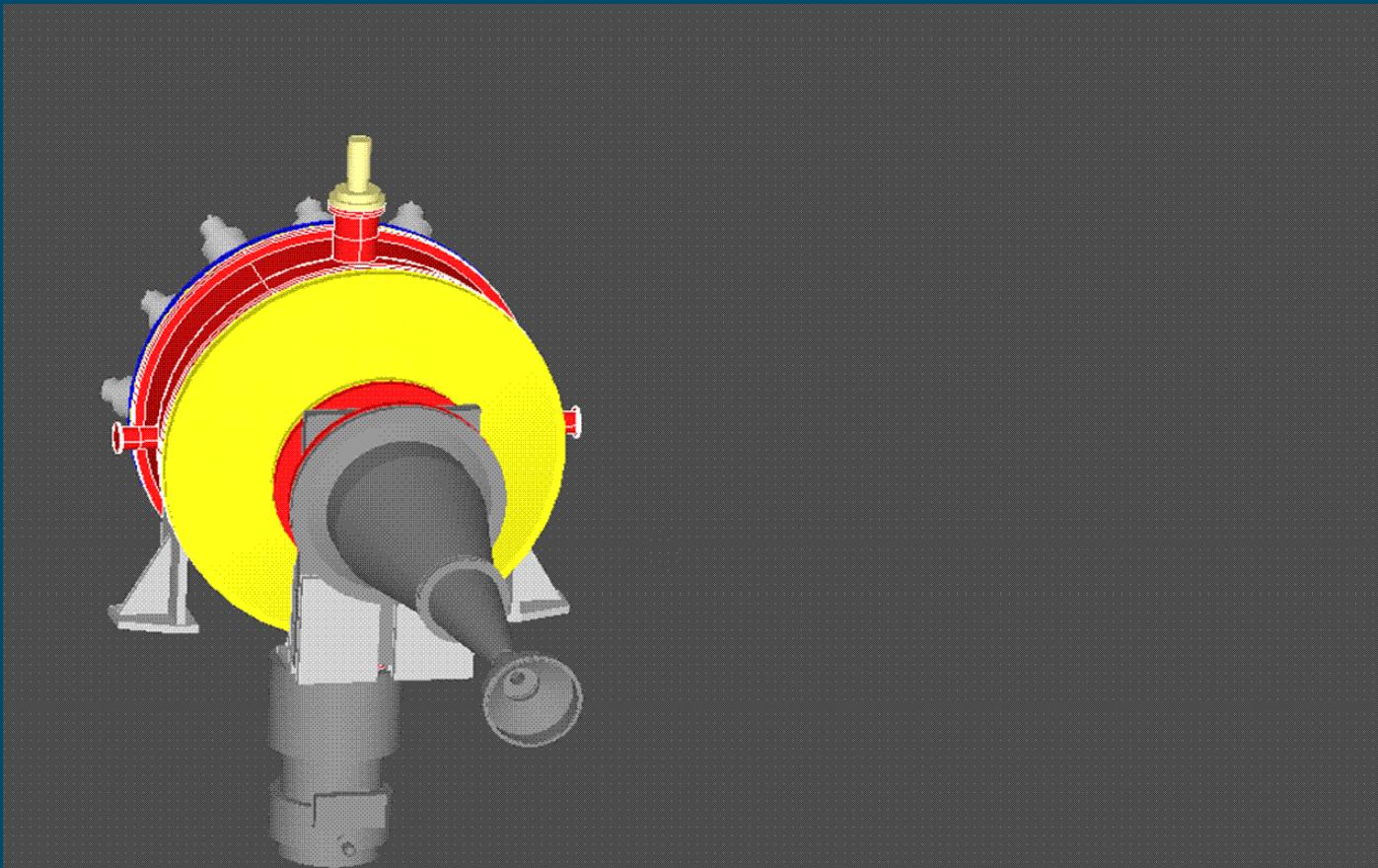
RFD

GASP and RFD (Legnaro 2009-2012)

- All (40) Ge-ACS detectors remained in place

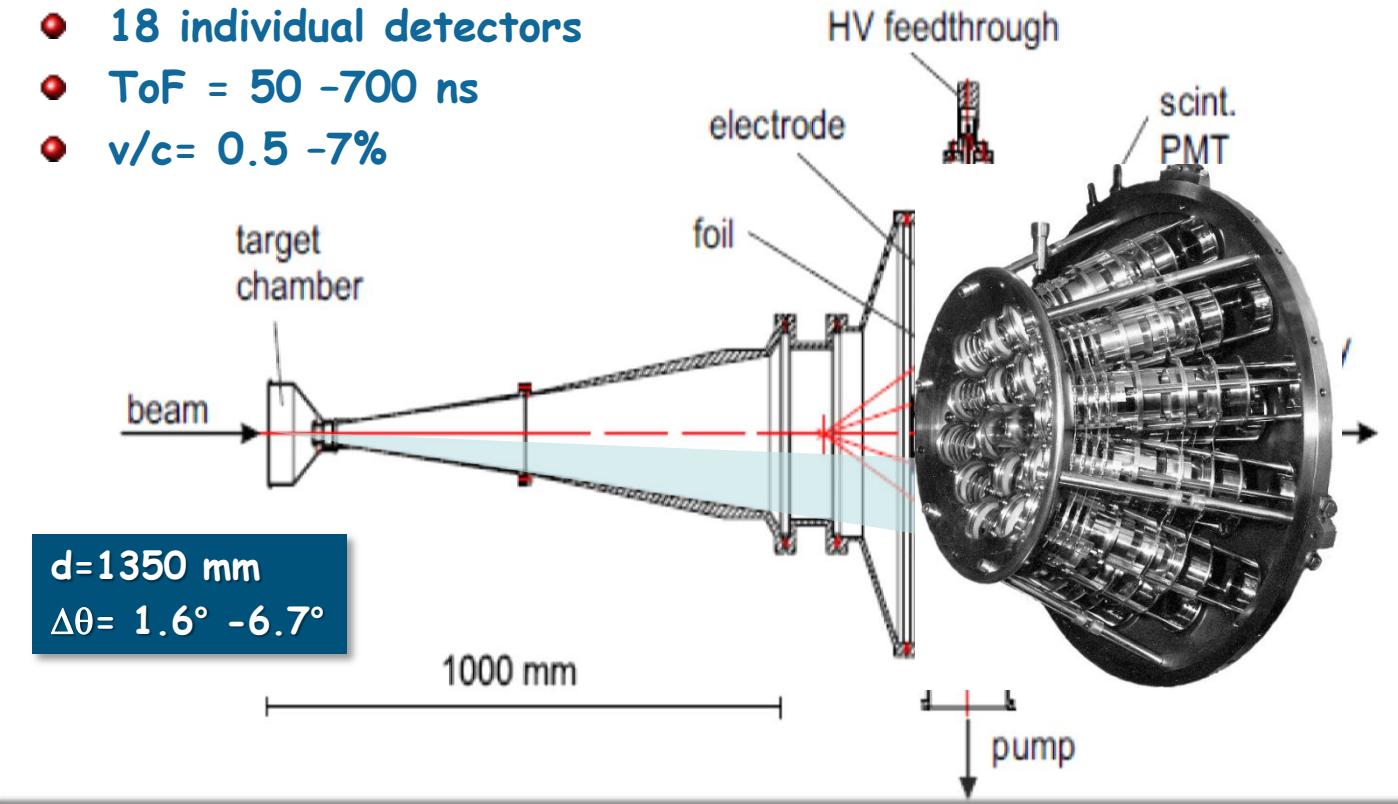


RFD 3D view

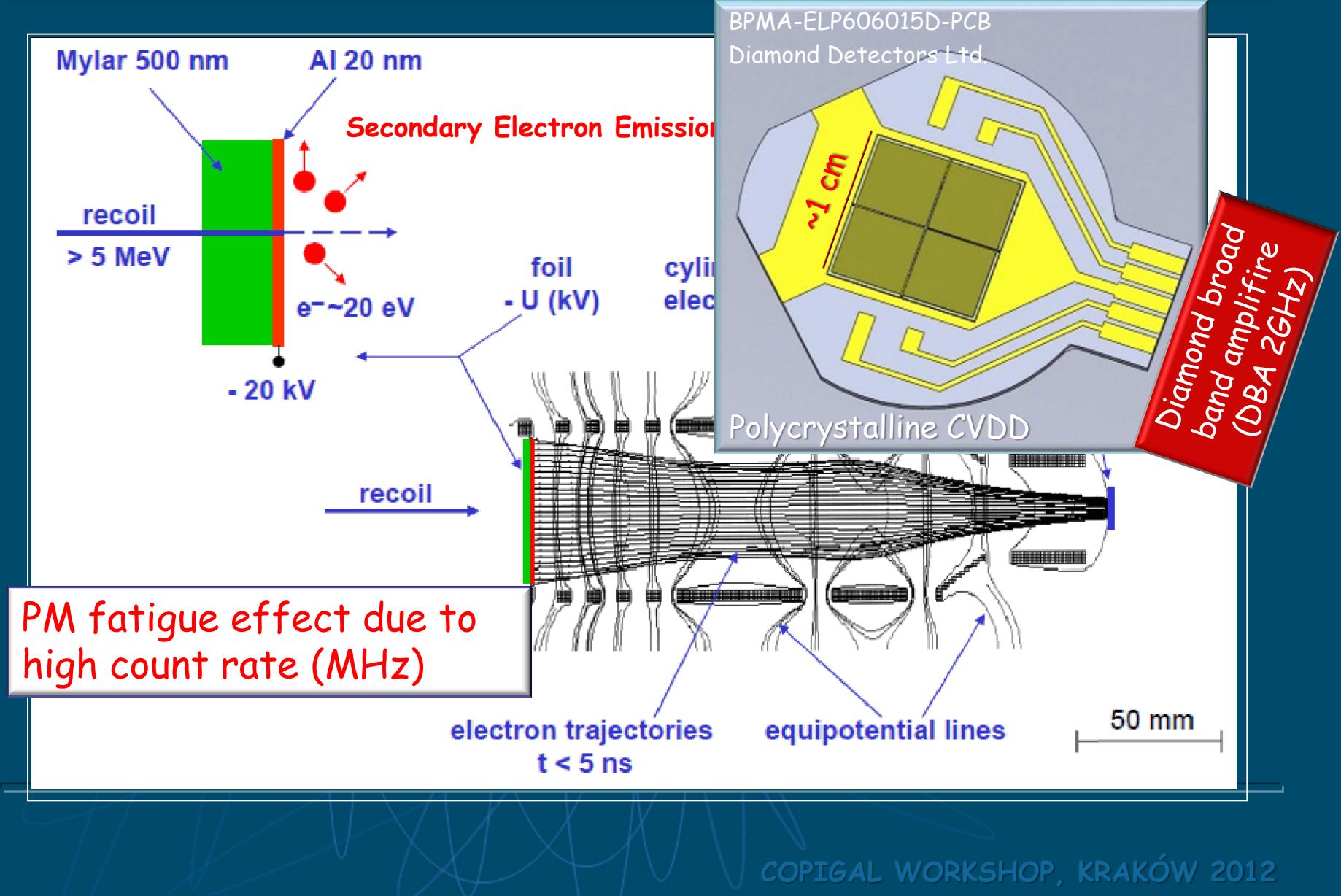


HI Detection Technique

- 18 individual detectors
- ToF = 50 -700 ns
- $v/c = 0.5 -7\%$

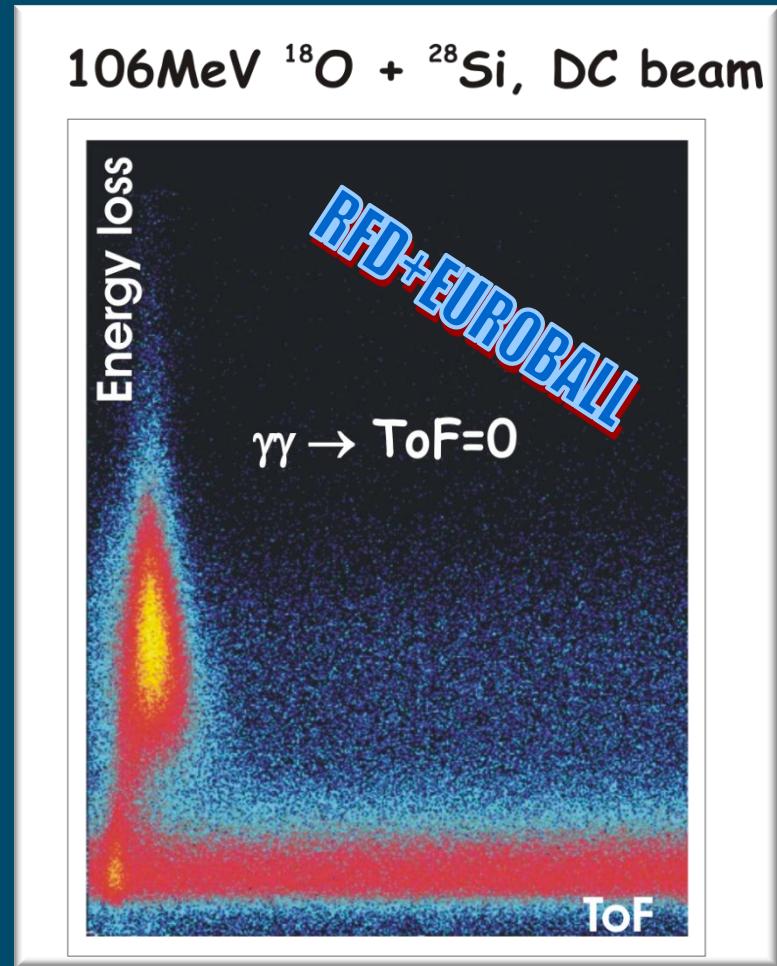


HI Detection Technique



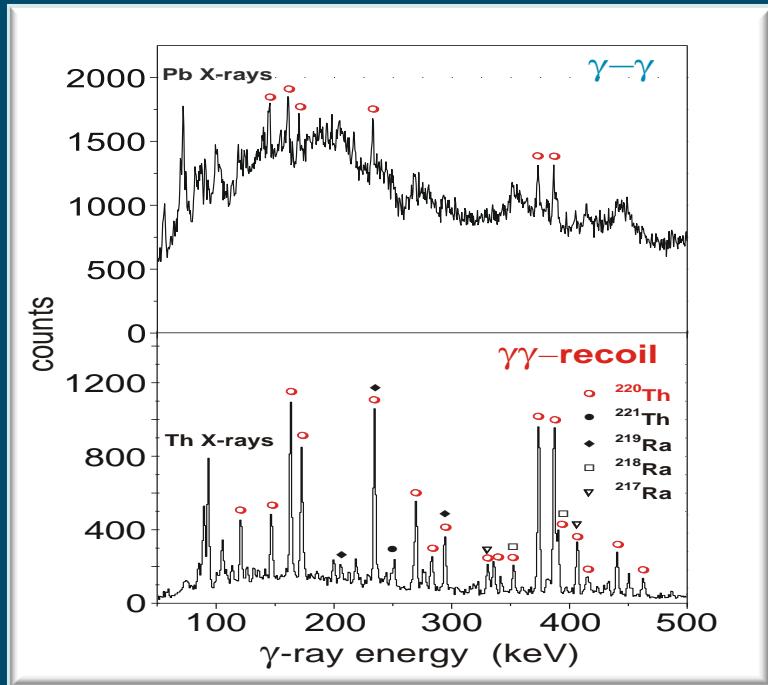
Measurement with a continuous beam

- possible if the recoil and the projectile deposit different energies in a foil
- feasible only at low intensity beams ($I \ll 1\text{pnA}$)
- may not work with a polycrystalline CVDD

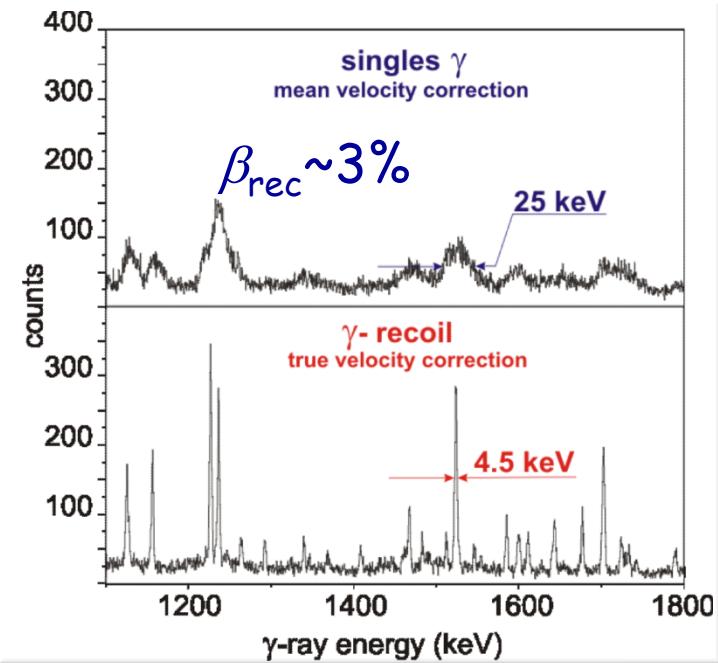


Improvement of γ -spectra by a coincident recoil detection

92 MeV ^{16}O + 0.4 mg/cm² ^{208}Pb



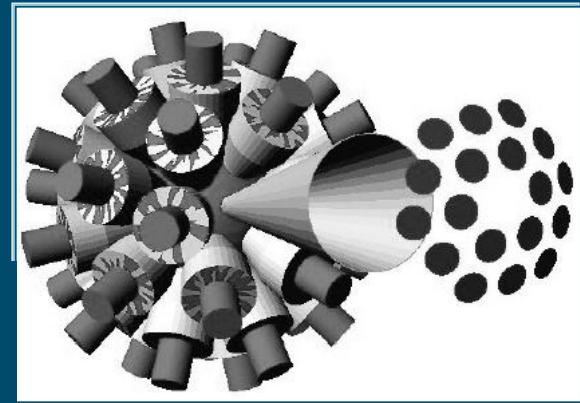
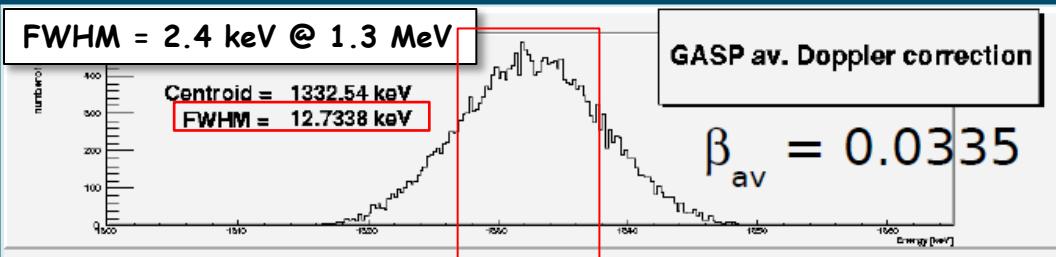
68 MeV ^{18}O + 0.8 mg/cm² ^{30}Si



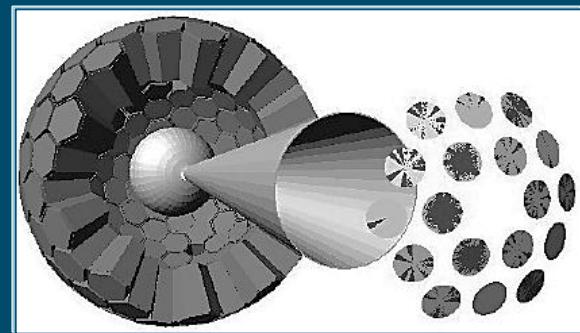
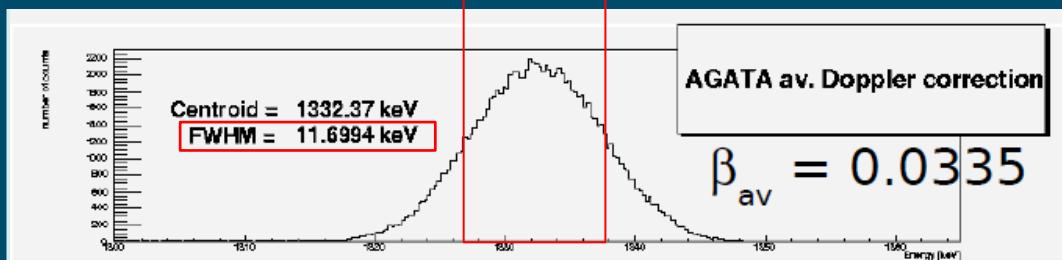
- Heavy systems:
 - ✓ fission background reduction
 - ✓ low ER cross sections $\sigma \sim 0.1$ mbarn

- Large recoil velocity:
 - ✓ reduction of the Doppler broadening

Gamma-ray energy resolution



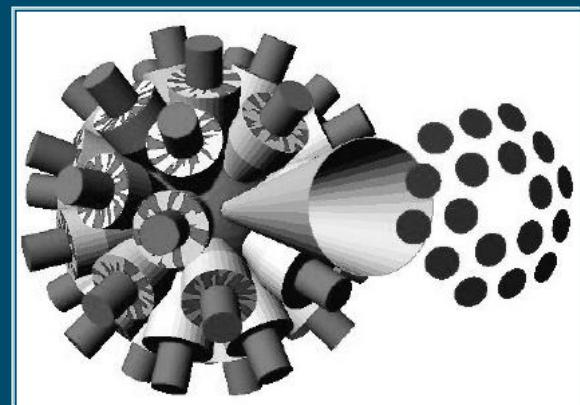
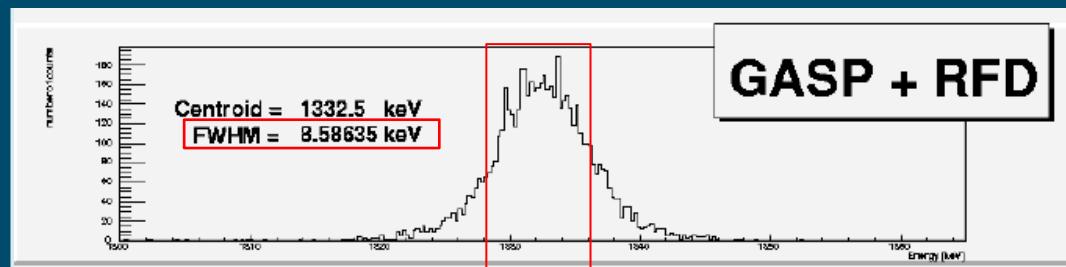
GASP:
 $\varepsilon=5.0\%$
 $\Delta\theta \sim 10^\circ$



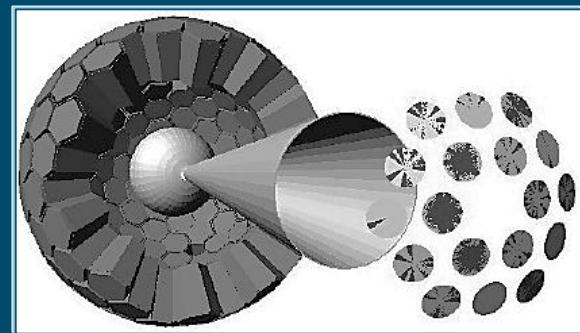
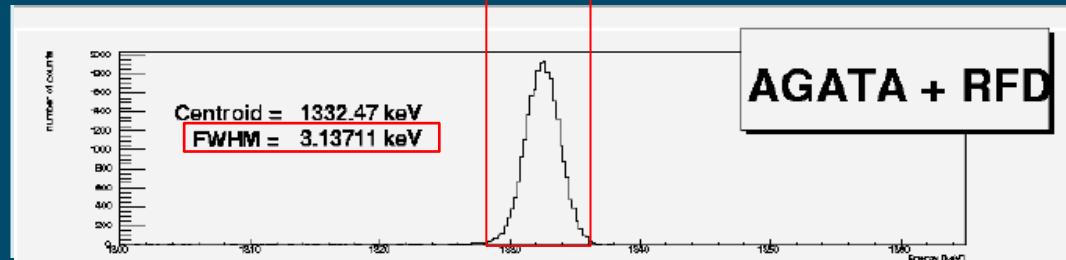
AGATA 3Π:
 $\varepsilon=22\%$
 $\Delta\theta \sim 1^\circ$

Gamma-ray energy resolution

FWHM = 2.4 keV @ 1.3 MeV



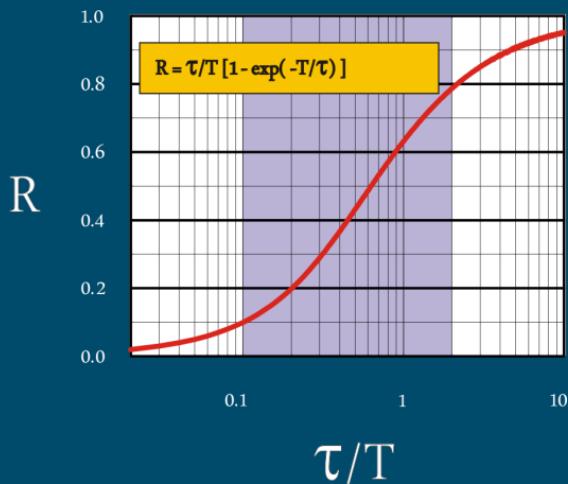
GASP:
 $\varepsilon=5.0\%$
 $\Delta\theta \sim 10^\circ$



AGATA 3Π:
 $\varepsilon=22\%$
 $\Delta\theta \sim 1^\circ$

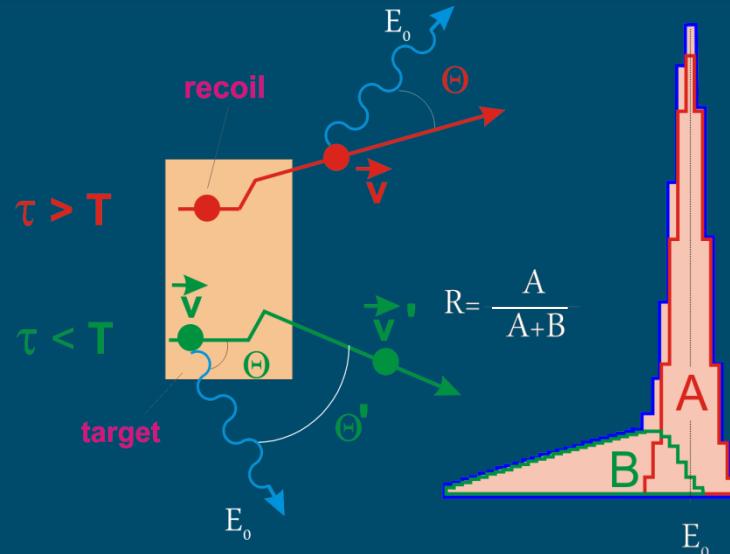
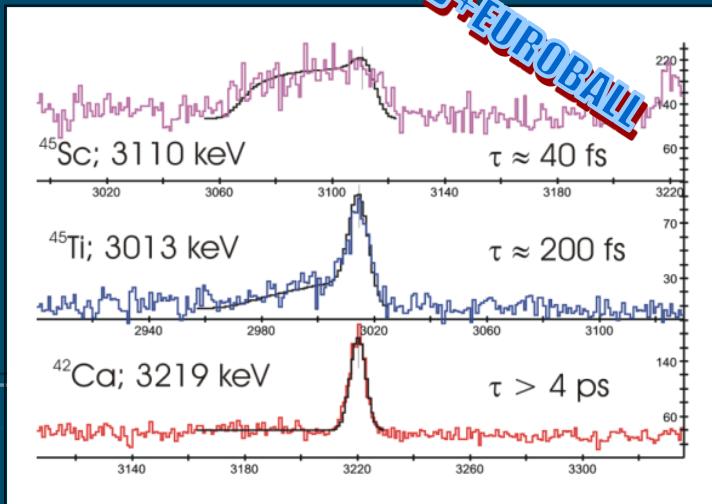
Simulations: G. Jaworski

Estimation of a short lifetime



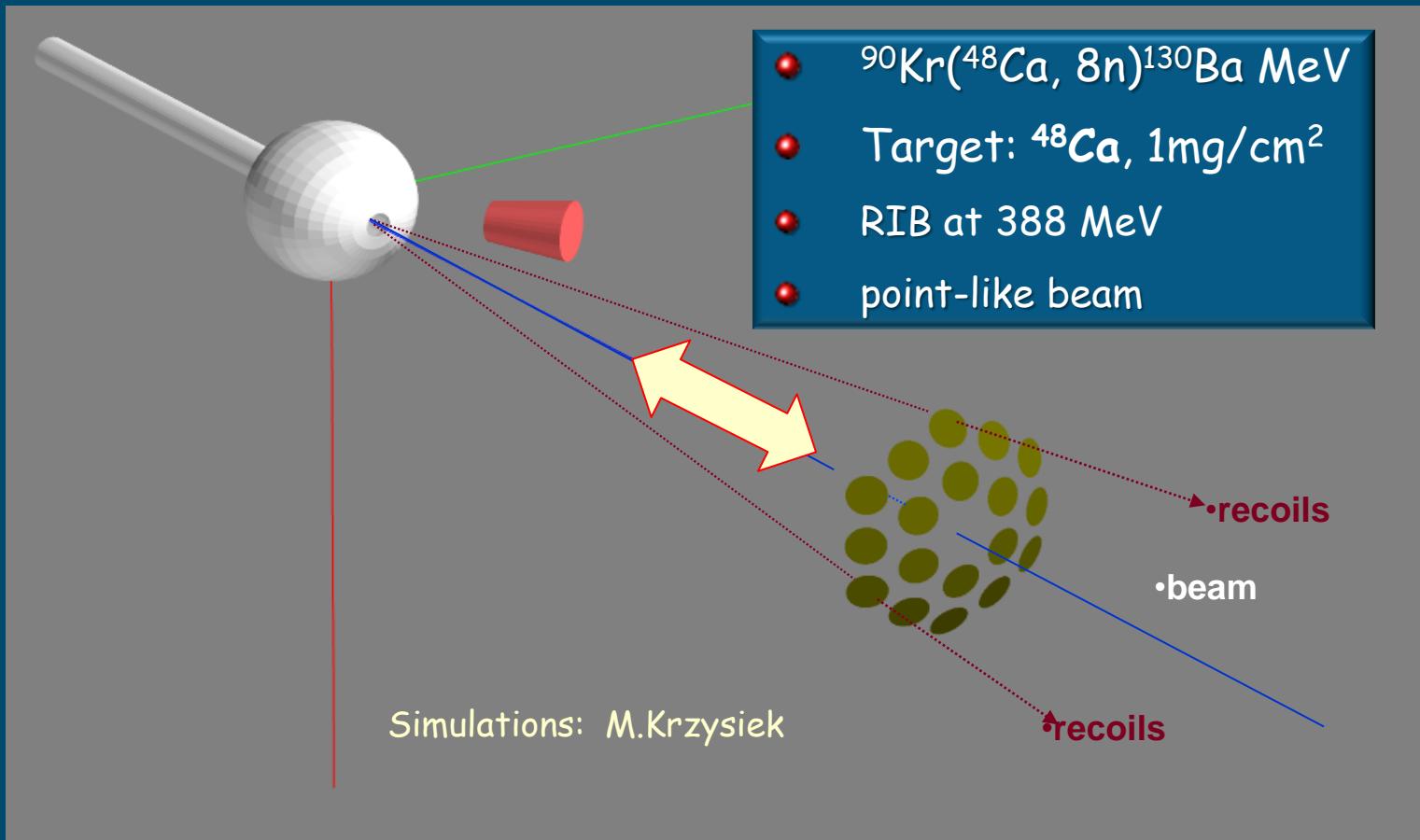
68MeV ^{18}O + 0.8mg/cm² ^{30}Si ;
Recoil transit time ≈ 0.4 ps

RFD+EUROBALL

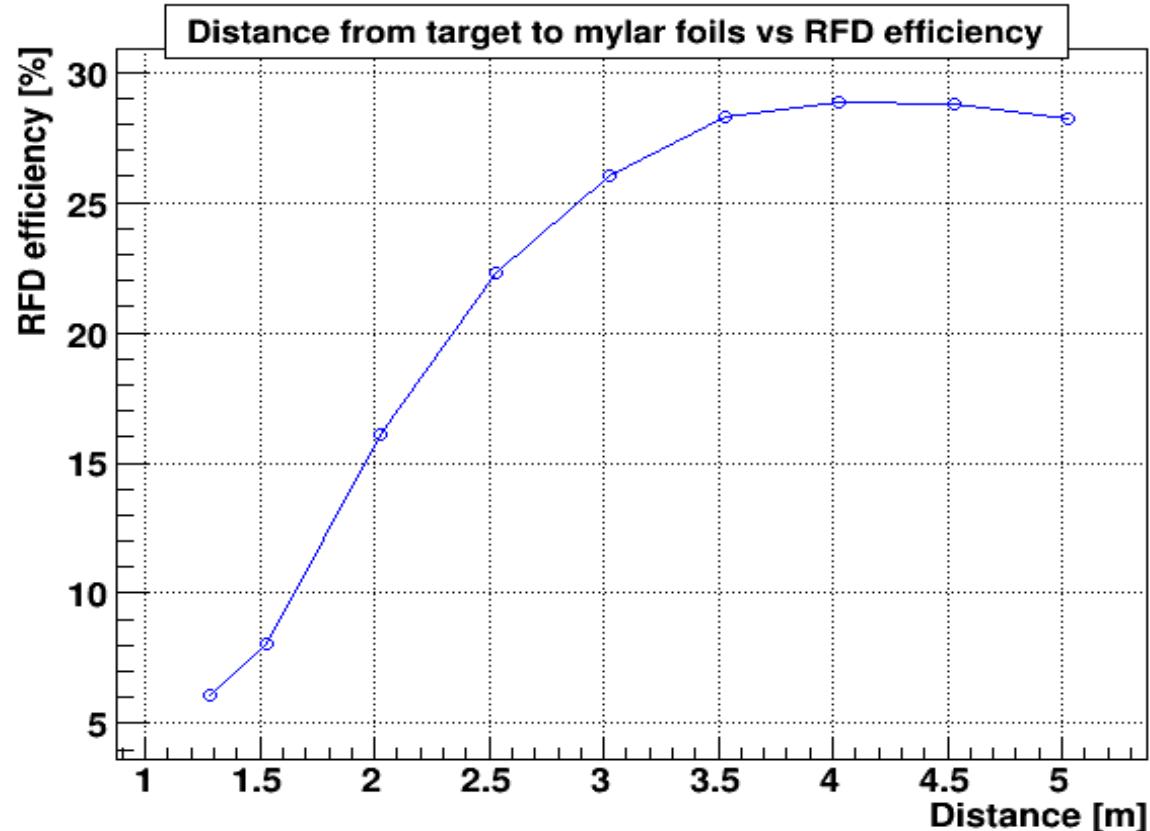


- Energy of a γ -ray emitted in a target (B) is not sufficiently Doppler corrected
- A level lifetime can be expressed by number of decays in vacuum (A) relative to a total γ -line intensity (A+B)
- τ range : <50 fs, 1ps>

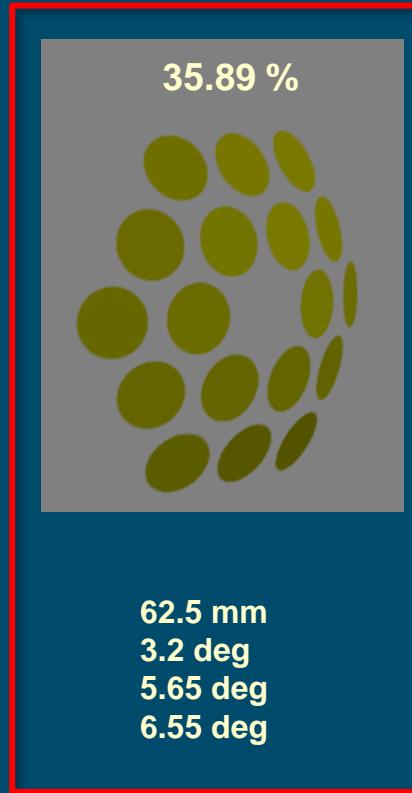
RFD G4 simulations for the Spiral2 D1P2 experiment



Efficiency



Individual element size and position



foil diameter = 50 mm
inner ring theta = 2.9 deg
middle ring theta = 5.1 deg
outer ring theta = 5.69 deg

55 mm
2.9 deg
5.1 deg
5.9 deg

62.5 mm
3.2 deg
5.65 deg
6.55 deg

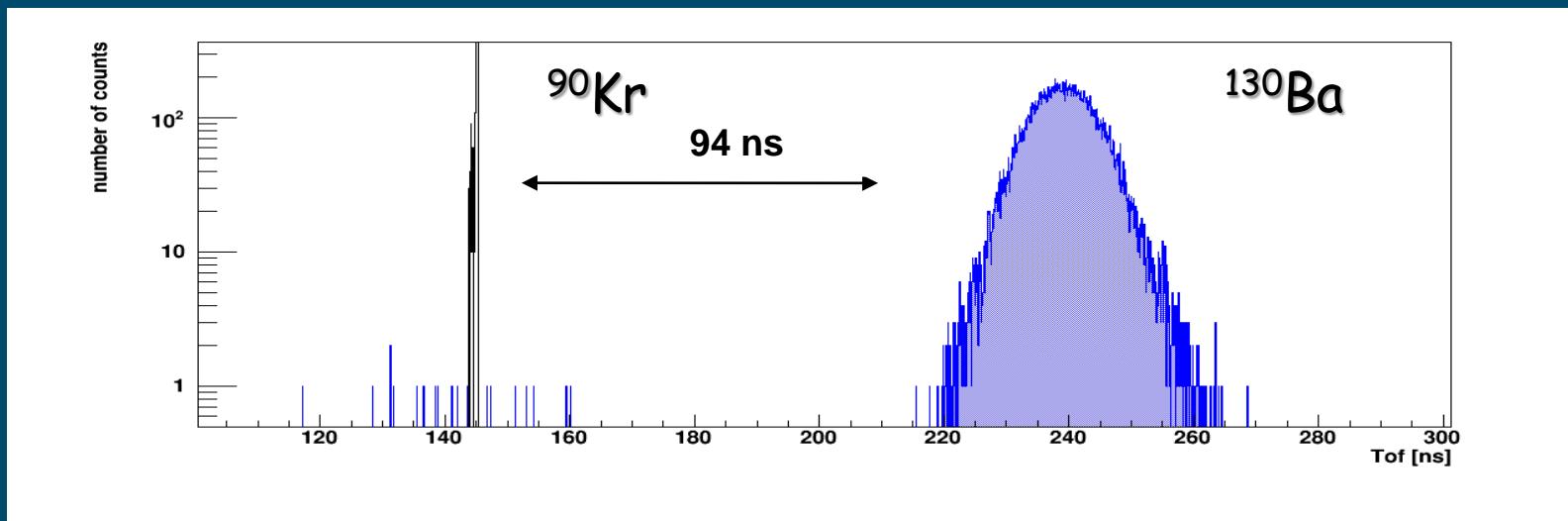
67.5 mm
3.45 deg
6.0 deg
7.0 deg

$$D = 4m$$

Possible projectile-ER separation by ToF at 4m

$Tof_{av} = 145.11 \text{ ns}$
 $\sigma = 0.28 \text{ ns}$

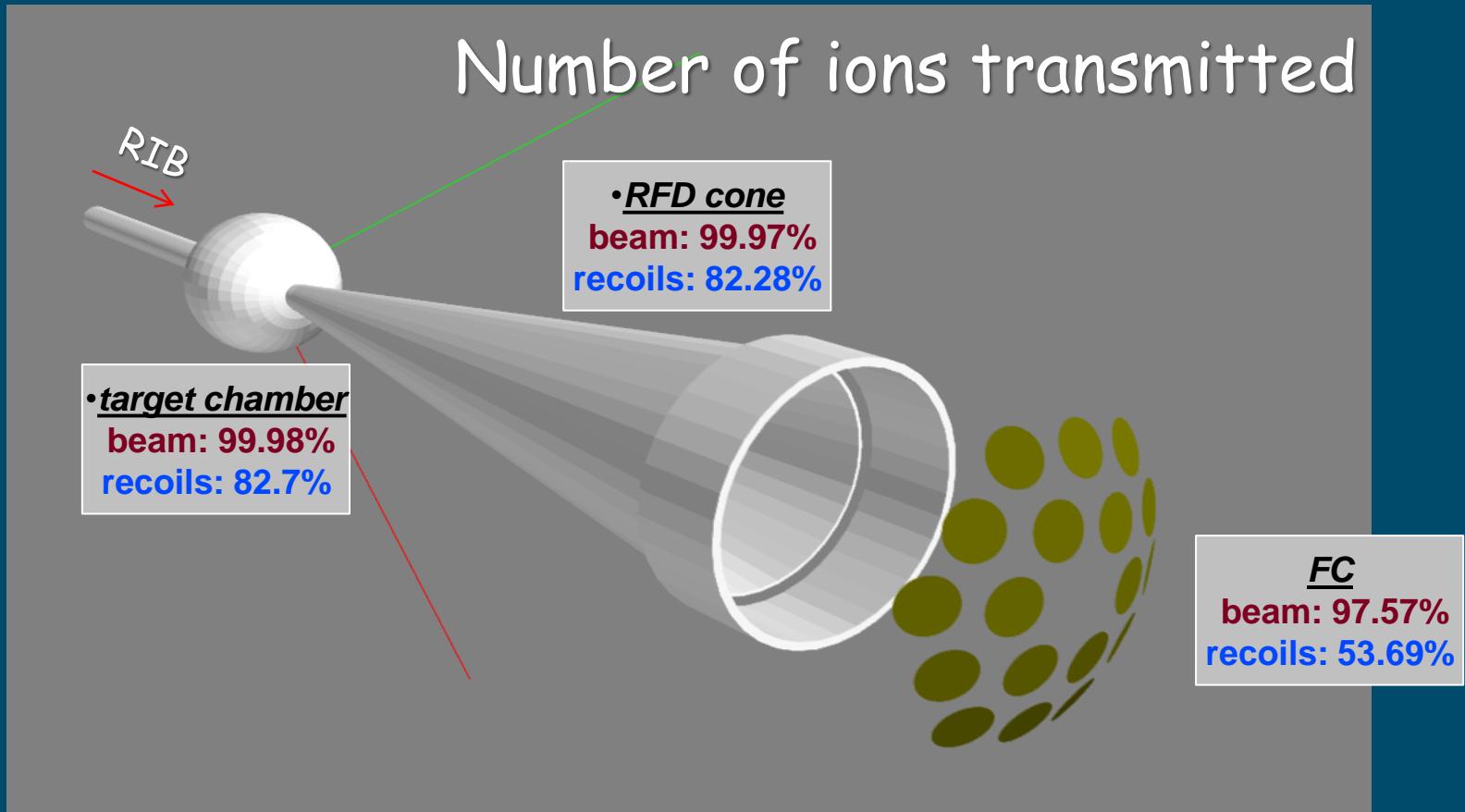
$Tof_{av} = 239.23 \text{ ns}$
 $\sigma = 5.42 \text{ ns}$



$v/c \sim 9 \%$

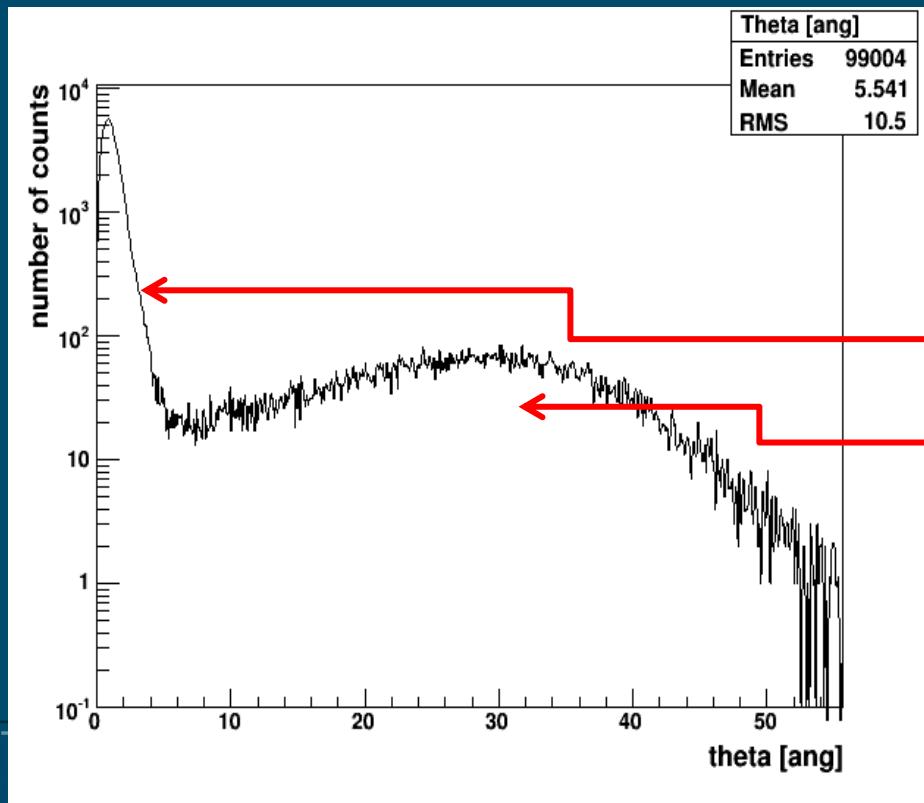
$v/c \sim 6 \%$

Estimation of radioactivity deposition



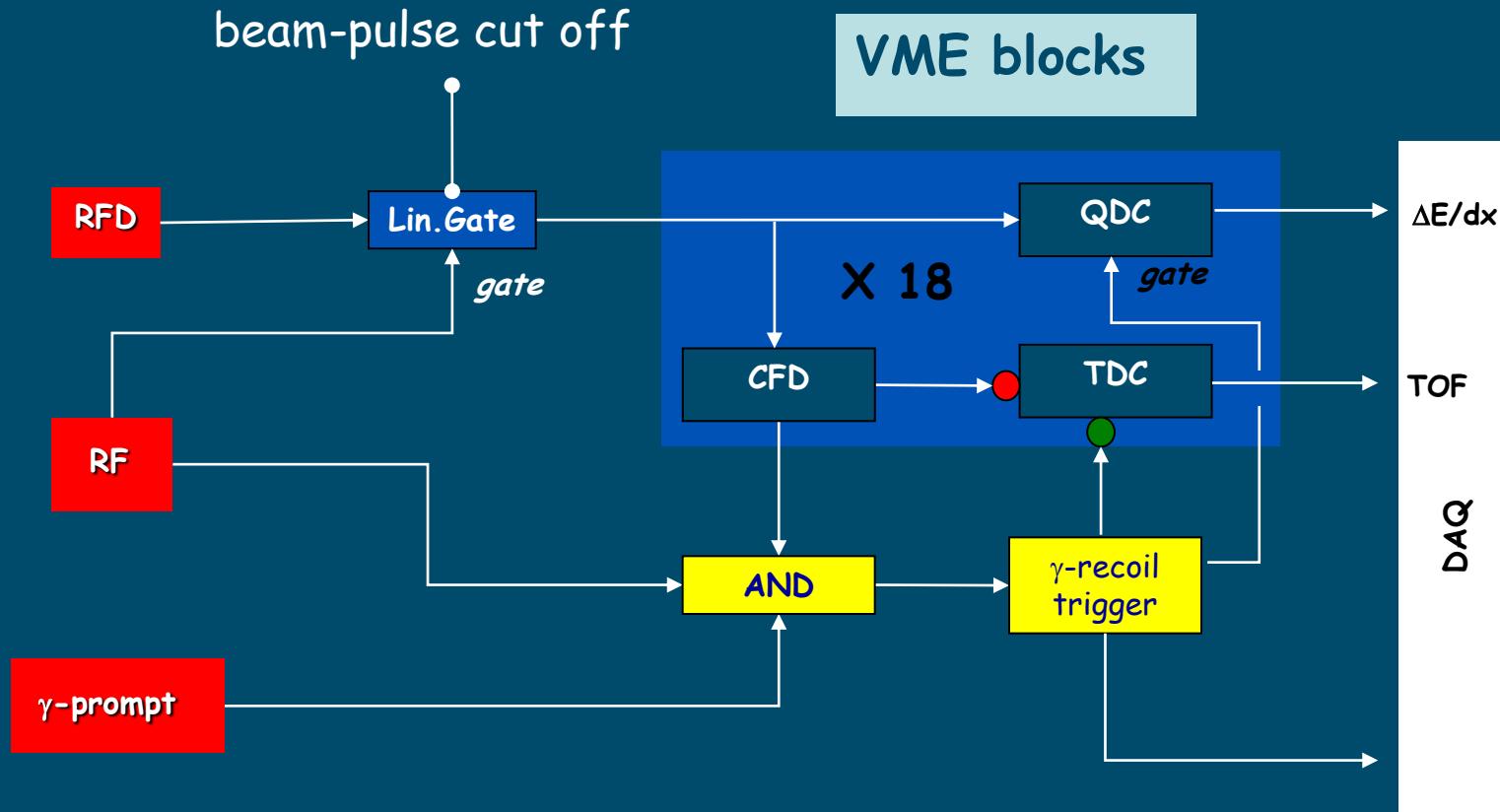
Further improvements

- Realistic RIB profile
- True detector geometry
- Inclusion of competing reaction channels



CASCADE-GEMINI
fusion-evaporation
fission

Simple logics of the RFD Trigger & the DAQ system



Connection to a digital triggerless DAQ (AGATA, EXOGAM, PARIS)

AGATA Demonstrator



AGATA

RecoilFilterDetector



GTS
Time stamp

pulse



Analogu



Data
Synch.

Tracking

Doppler
correction

Conclusion

- Recoil Filter Detector - a good solution for inverse kinematics reactions with RIB
- Projectile, fission rejection
- High efficiency for ER
- Doppler broadening minimization
- Negligible radioactivity deposition