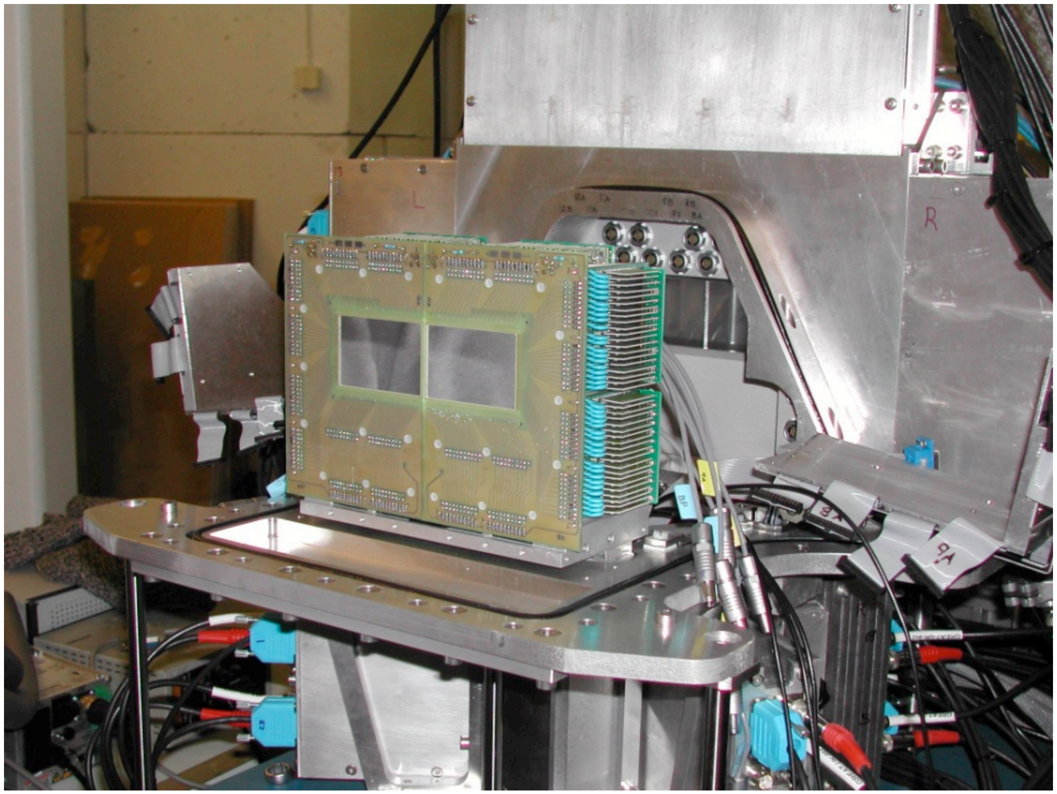
Focal plane systems

Juha Uusitalo
University of Jyväskylä



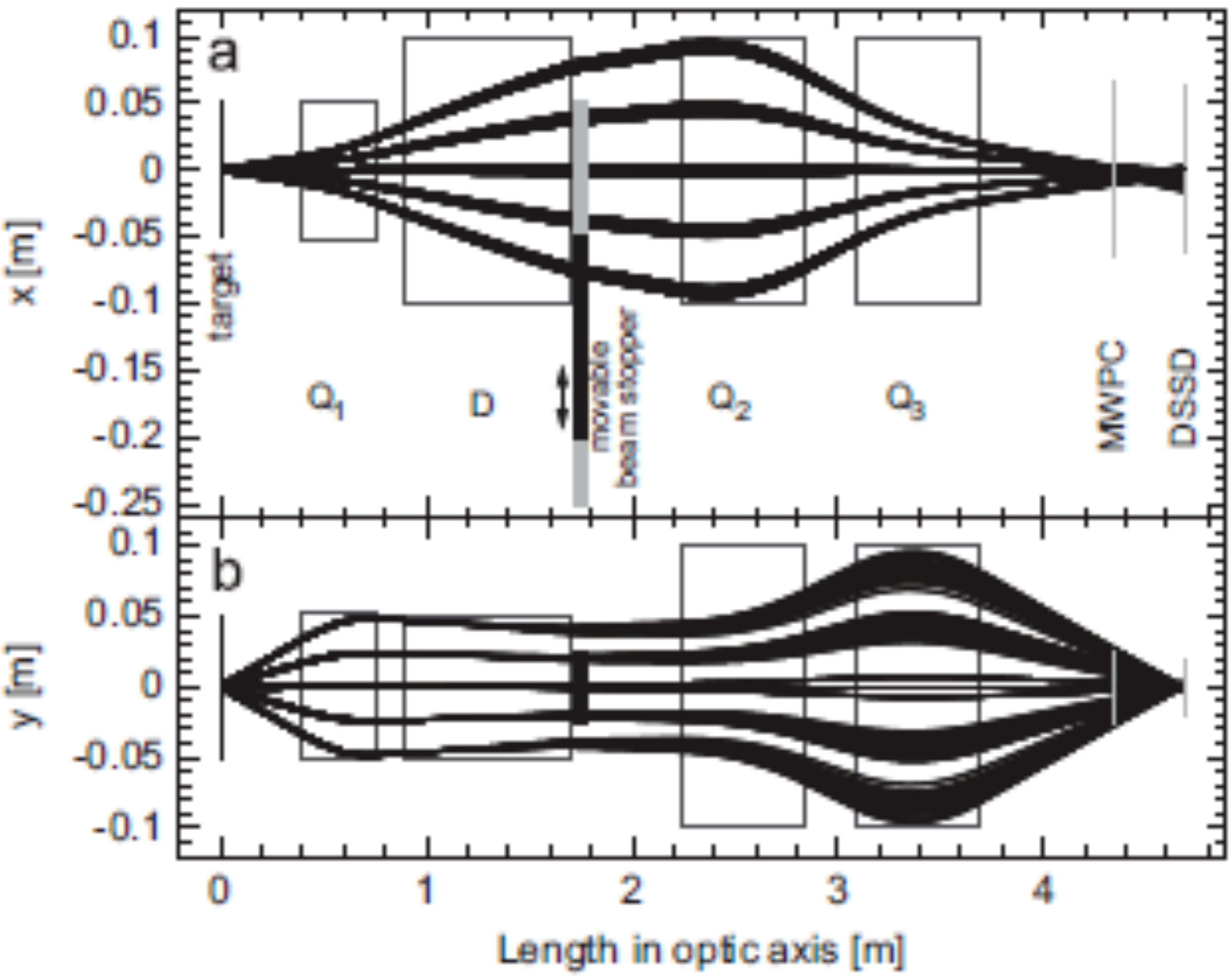
EGAN 25-28.07.2012

European Gamma and Ancillary detectors Network

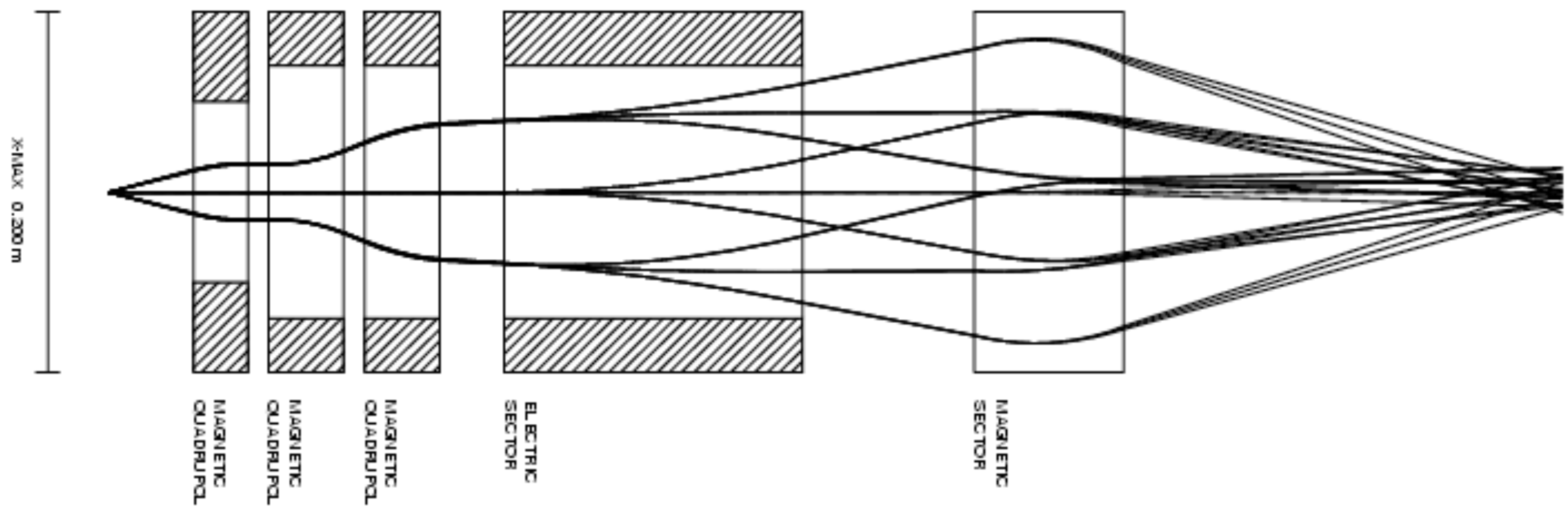
In-flight Recoil Separators (@ barrier energies)

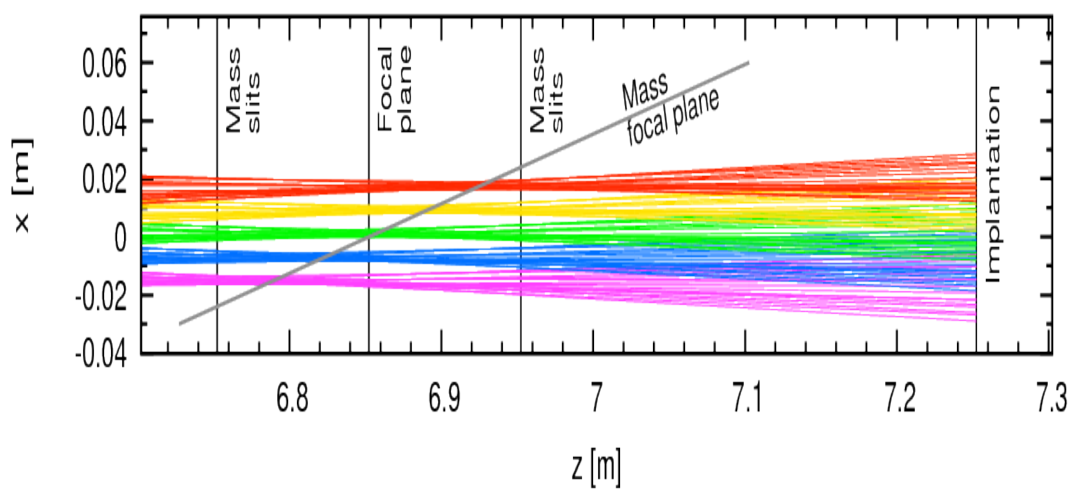
- Gas-filled recoil separators
  - TASCA, GARIS, DGRS, RITU, BGS
  - GARISII, AGFA, VAMOS (gas-filled mode), SHANS
  - helium cooling, beam spot size~ 100 mm Ø
- Vacuum-mode separators
  - Velocity filters
    - SHIP
    - VASSILISSA (upgraded)
    - beam spot size~ 100 mm Ø
  - Mass separators
    - FMA, EMMA, JAERI-RMS
    - S3, MARA
    - beam spot size ~ 2mm dispersive plane
  - Non-zero angle magnetic separators
    - multi-nucleon transfer, deep-inelastic….
    - VAMOS, PRISMA
    - IRiS

Gas-filled separator RITU



Vacuum-mode mass separator MARA





$^{208}Pb(^{48}Ca,2n)^{254}No$

- Only 2n channel, 2 μb, very strong fission competition
- Total rate ~ 1Hz/10 pnA

$^{169}Tm(^{40}Ar,6n)^{203}Fr$

- Total rate 100-300 Hz/ 10 pnA, strong fission competition

$^{96}Ru(^{78}Kr,p3n)^{170}Au$

- Total rate 2-3 kHz/ 10 pnA

$^{58}Ni(^{54}Fe,2n)^{110}Xe$

- Total rate > 1 kHz/ 1 pnA

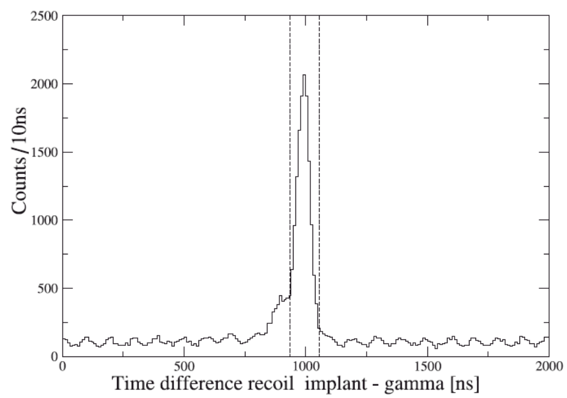
$^{40}Ca(^{28}Si,pn)^{66}As$

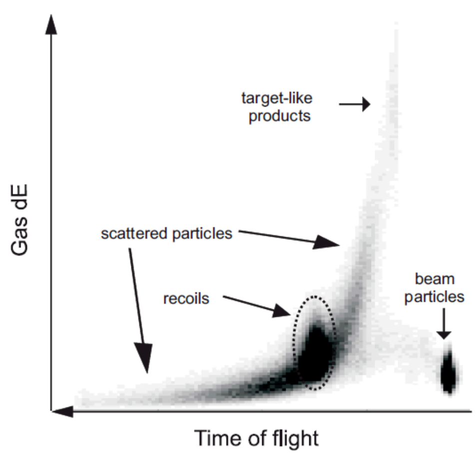
-Total rate > 1 kHz/ 1pnA

-Target position Ge detectors 5-10 kHz/crystal/ 10 pnA

$^{208}Pb(^{48}Ca,2n)^{254}No$

- Only 2n channel, 2 μb, very strong fission competition
- $\sigma_{2n} \approx \sigma_{ER} << \sigma_f$
- Total focal plane rate ~ 1Hz/10 pnA
- at the target position single detector Ge rate 5-10 kHz / 10 pnA
- with digital electronics Ge-detectors could be used at 50 kHz
- Recoil gating





Sarah Eeckhaudt et al.,

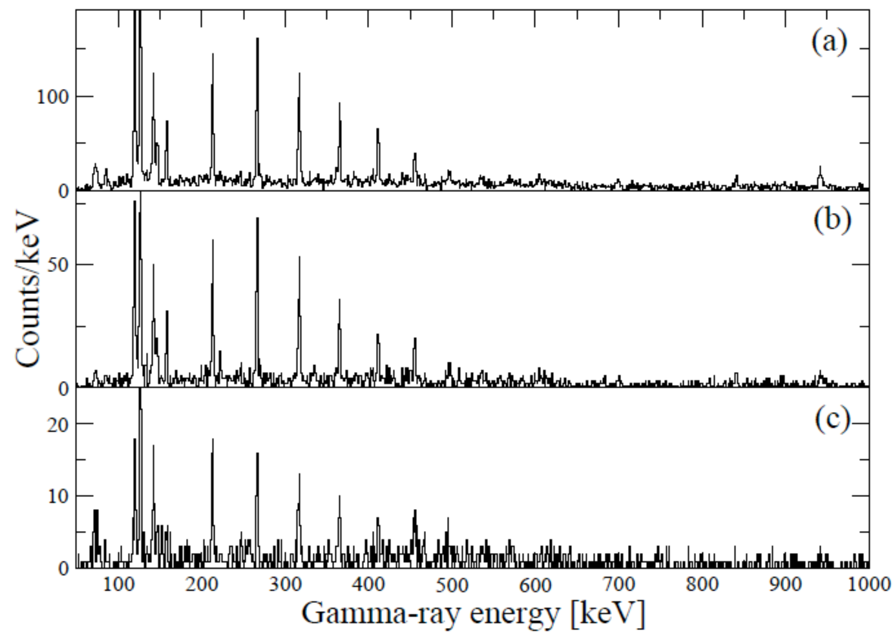


Figure 4.10: Gamma-ray singles spectra of ^{254}No with data of both beam energies combined: (a) Recoil-gated γ-ray singles spectrum (b) No-α tagged γ-ray singles spectrum (c) The recoil-gated γ-ray singles spectrum for higher beam energy only.

$^{96}Ru(^{78}Kr,p3n)^{170}Au$

-Total rate 2-3 kHz/ 10 pnA

- Recoil gating and α (or proton tagging)

- maximum beam intensity limited by random correlations

Heikki Kettunen et. al.,

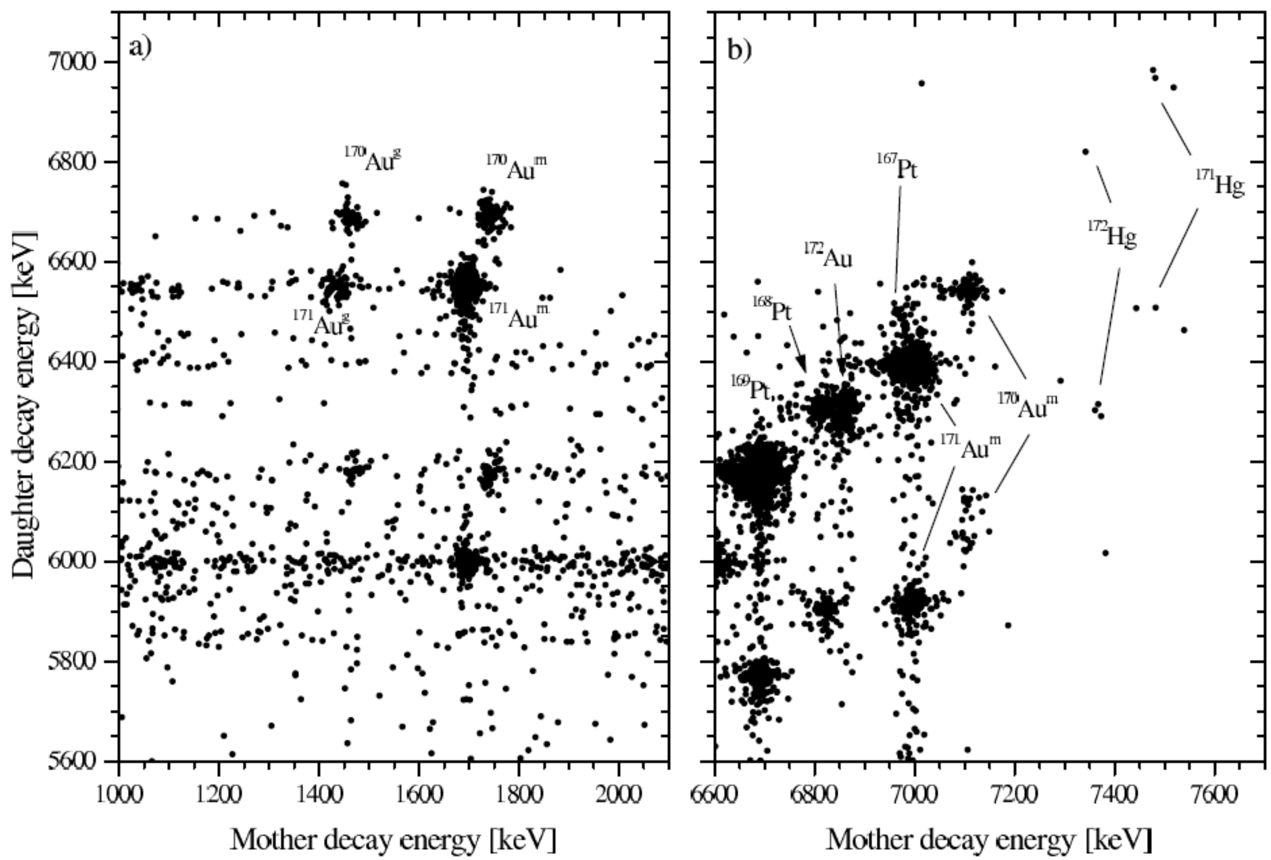


FIG. 2: Two-dimensional plot of the mother and daughter decay energies of correlated decay chains of the type $ER - p_m/\alpha_m - \alpha_d$ observed in the $^{78}Kr + ^{96}Ru$ reaction. (a) Correlations where the proton decay of mother nucleus is followed by an α decay of the daughter nucleus ($ER - p_m - \alpha_d$). (b) Correlated decay chains for α decays ($ER - \alpha_m - \alpha_d$). Maximum search times for the mother and daughter decays were 10 ms and 200 ms, respectively.

σ_{3n} ~ 2 nb

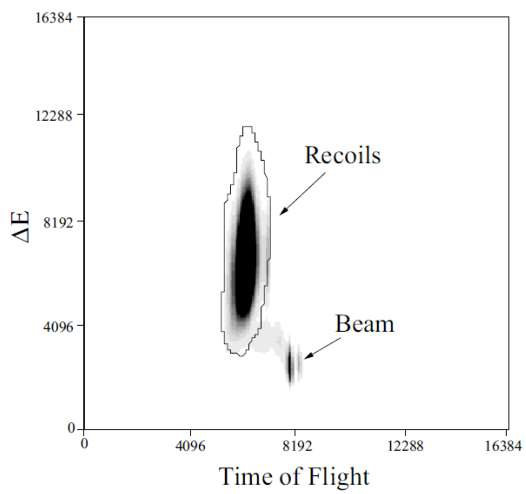
σ_{p3n} ~ 90 nb

σ_f ~ 100 mb

$^{58}Ni(^{54}Fe,2n)^{110}Xe$

- Total rate 1 kHz/ 1 pnA
- σ_{2n} ~ 20 nb << σ_f = n x 100 mb
- Recoil gating and α-α tagging

Mikael Sandzelius et. al.,



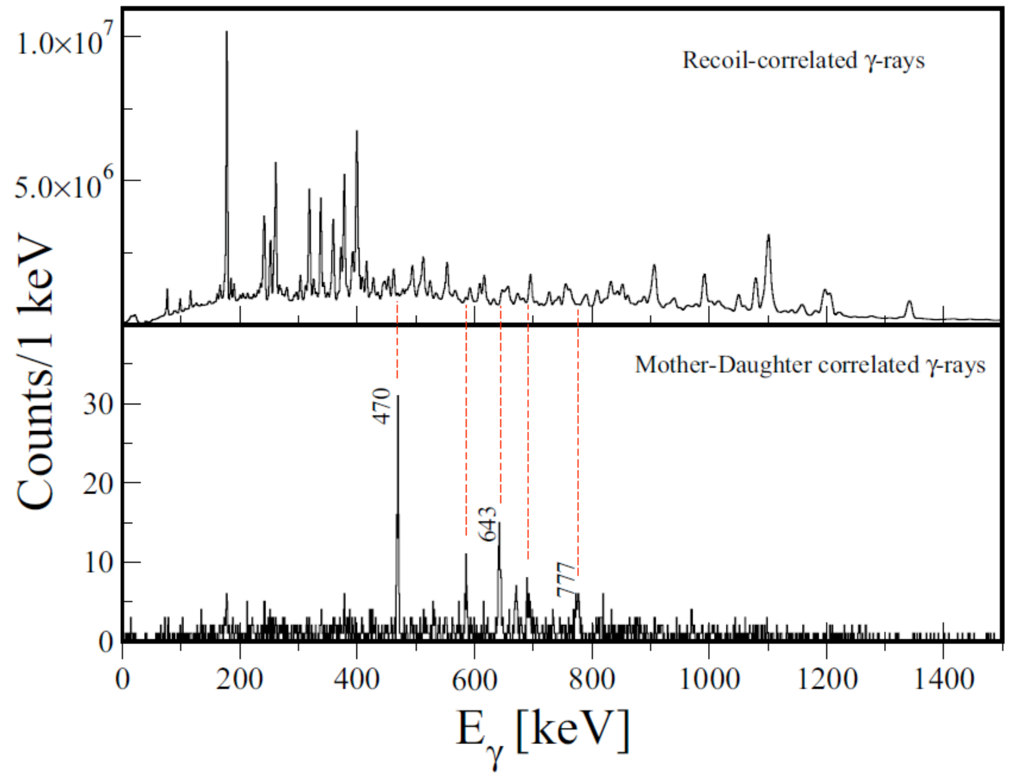
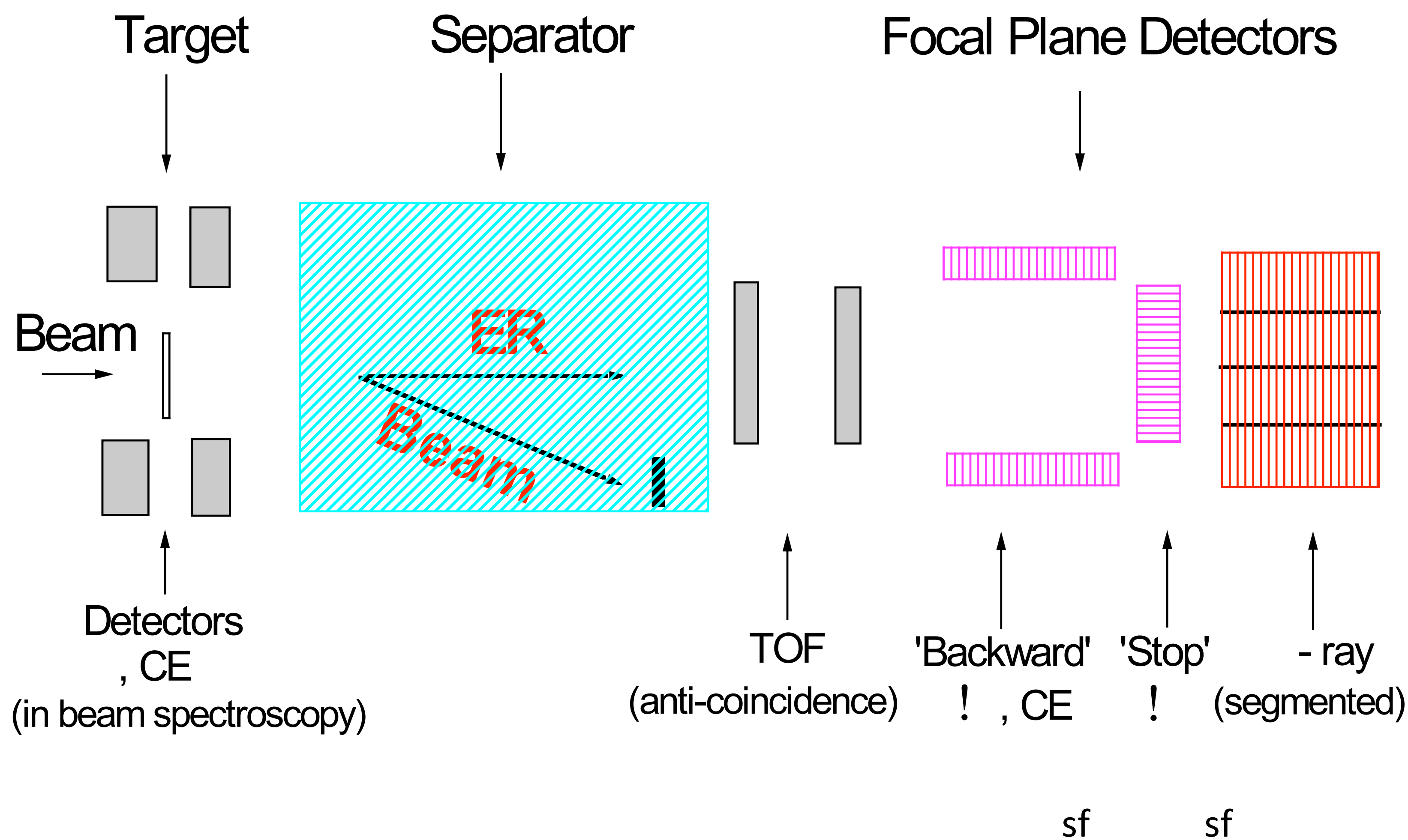
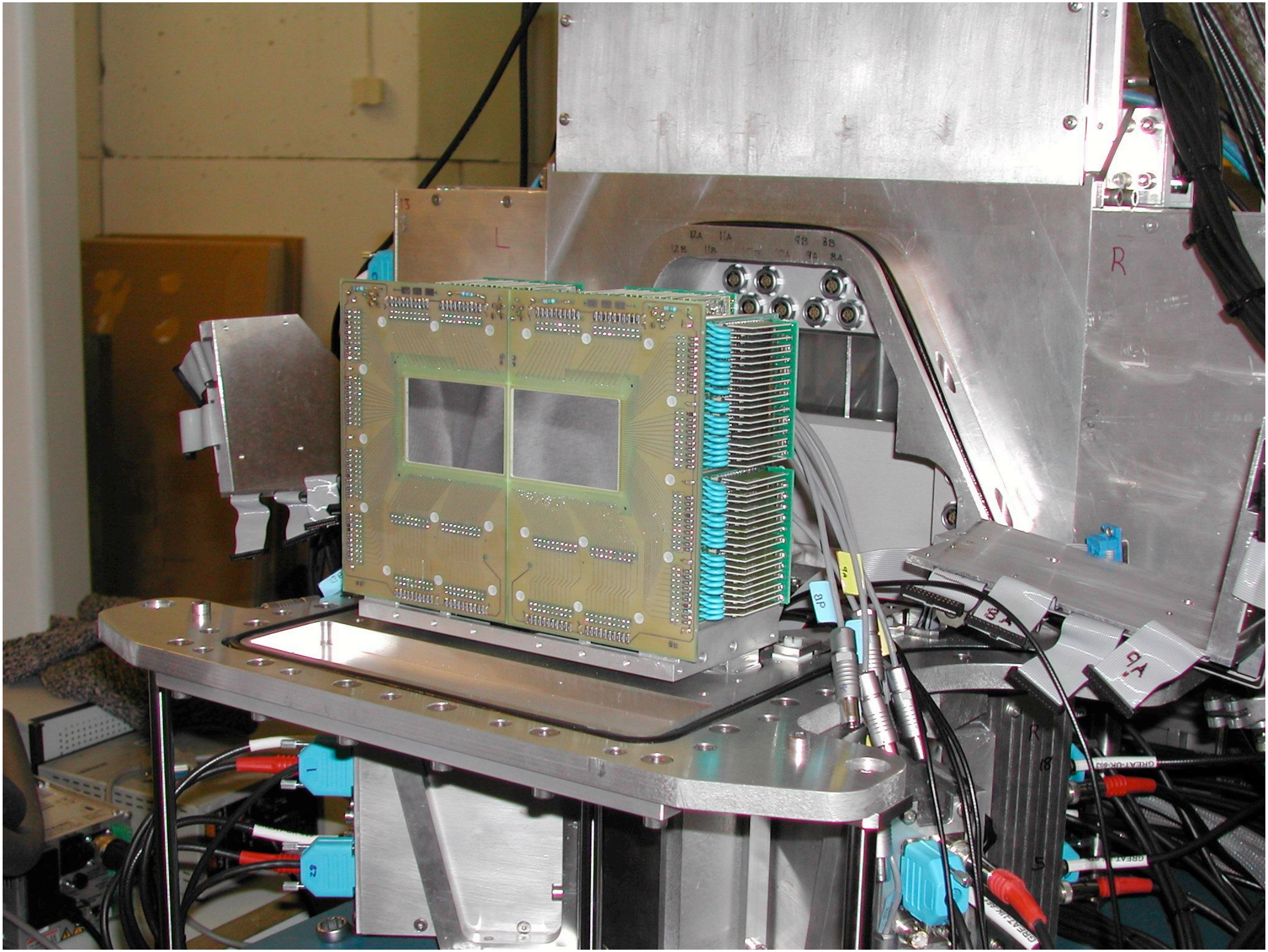
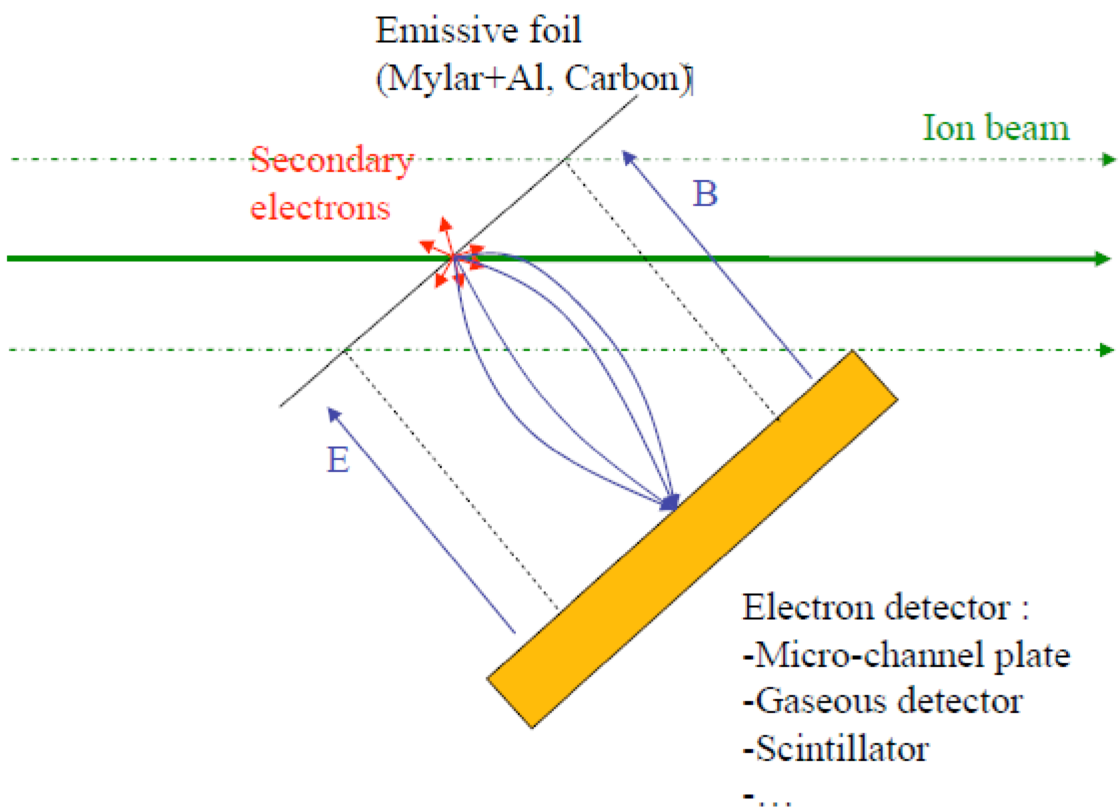


Figure 3.2: Gamma-ray spectra showing prompt γ rays at the target position. The spectrum in the top panel is recoil-gated only, showing all the γ rays detected in the experiment from every fusion-evaporation residue giving a signal in the DSSD. The spectrum in the bottom panel is recoil-decay tagged. The prompt γ rays are correlated by requiring both the subsequent mother ^{110}Xe and daughter ^{106}Te α decays in the same pixel in the DSSD as the recoil implantation. The three strongest transitions assigned to ^{110}Xe are indicated, which cannot be resolved in the total recoil-gated spectrum. The selectivity is greater than 10^{-6}.


Target
Separator
Focal Plane Detectors
Beam
ER
Beam
Detectors
, CE
(in beam spectroscopy)
TOF
(anti-coincidence)
'Backward'
! , CE
'Stop'
!
- ray
(segmented)
sf
sf

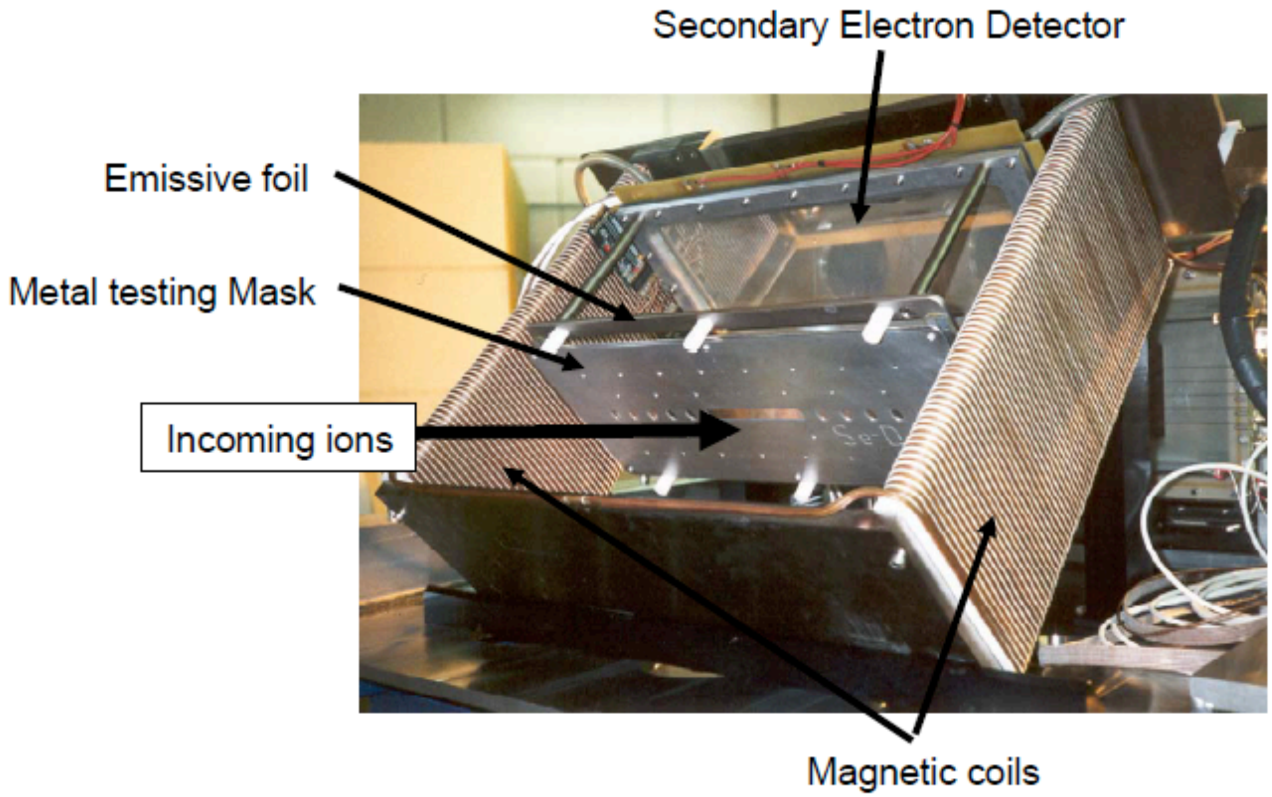

L
R

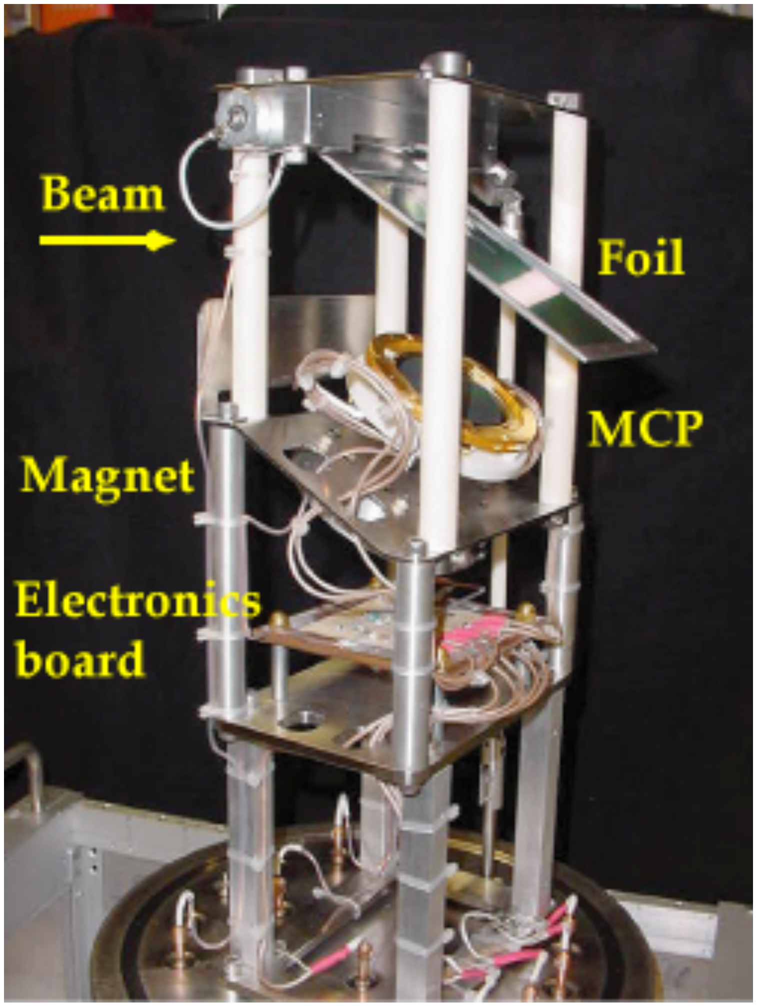
Example 1. Emissive foil detectors (SeD)



Antoine Drouart DSM/DAPNIA/SPhN

Se-D active area 10x40 cm^2





Availability of largea area position sensitive MCPs ?

+ little space needed

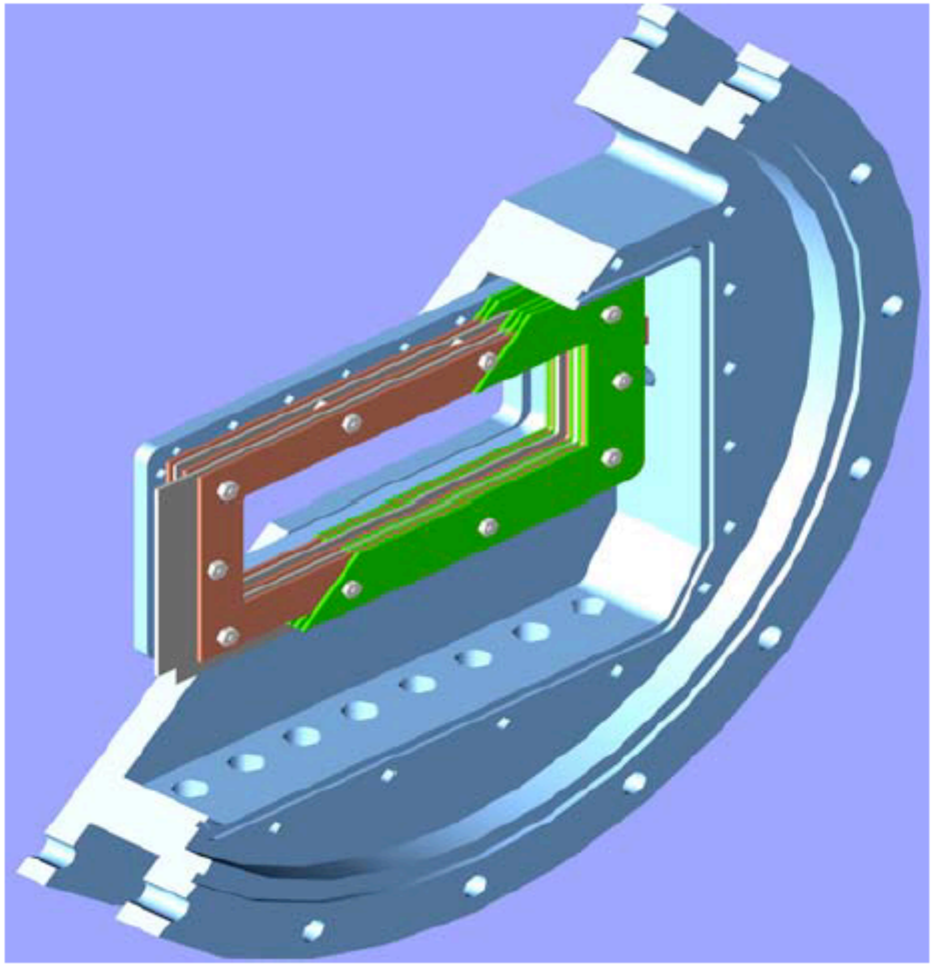
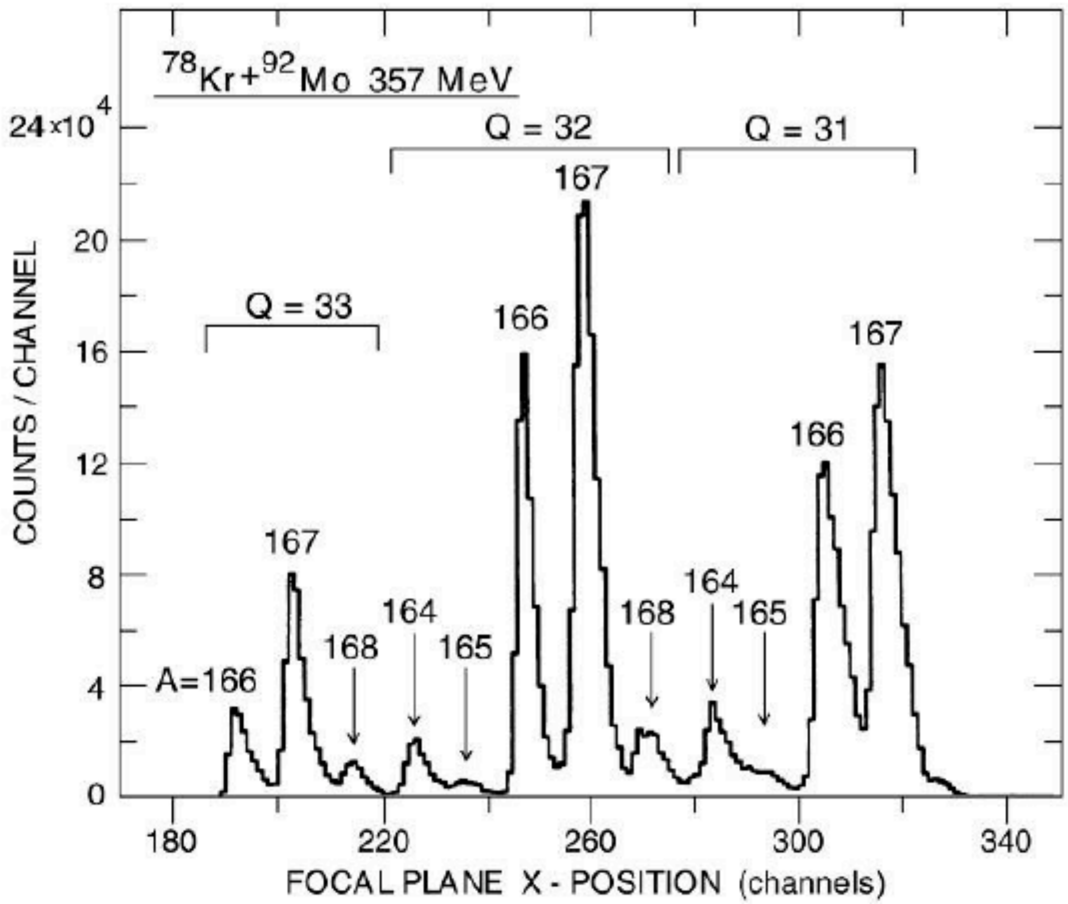


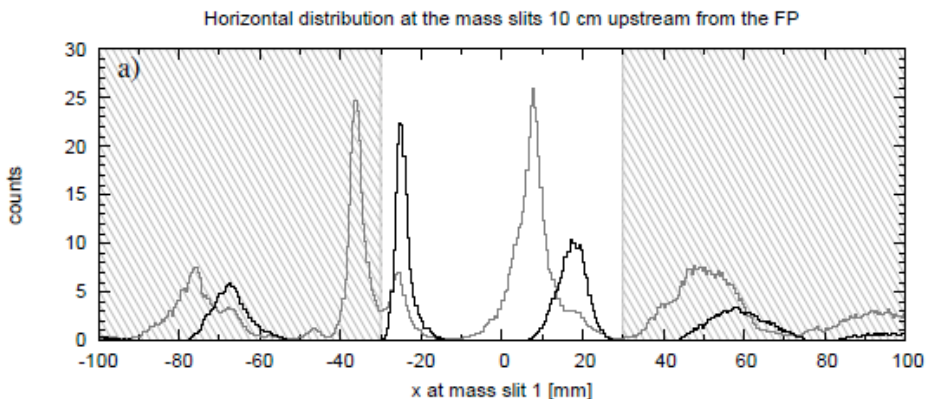
Fig. I-73. Cutaway view of the MWPC with the new anode and cathodes.

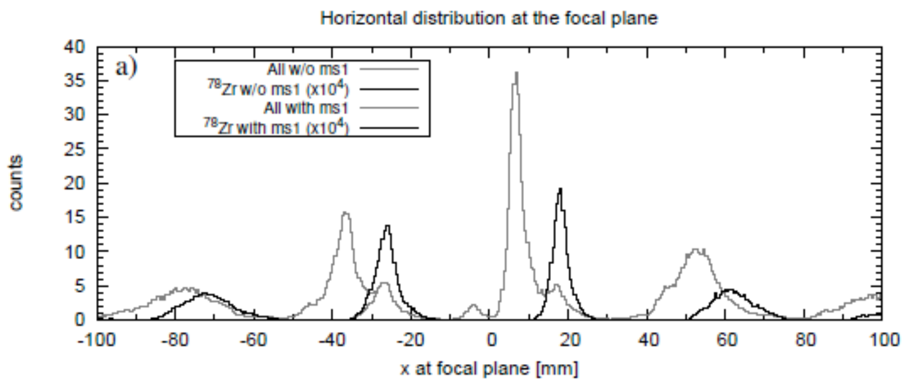
-Two mylar foils needed

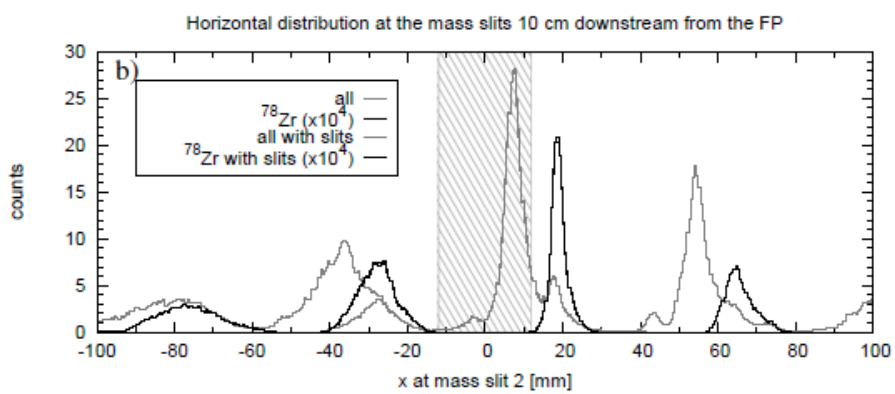
-Transmission losses due to wires

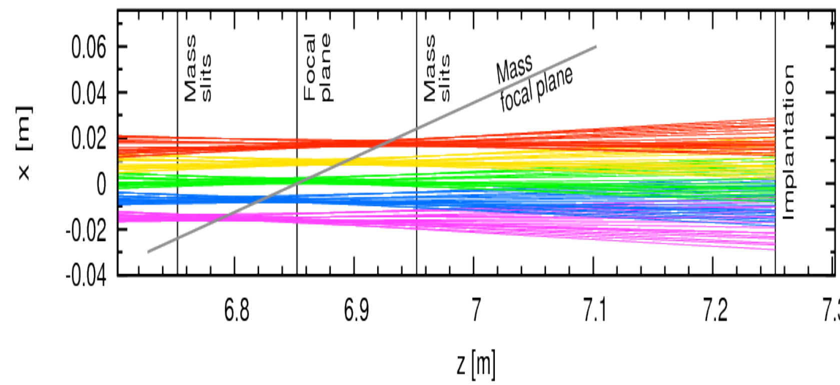
FMA Focal Plane M/Q Spectrum

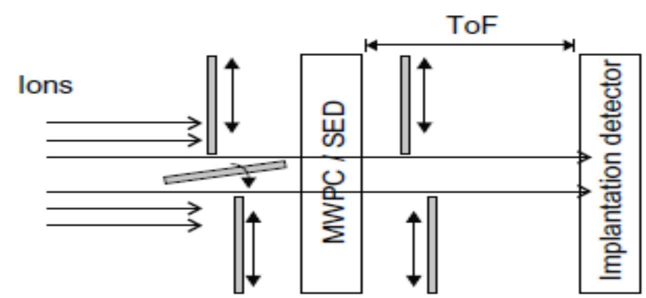


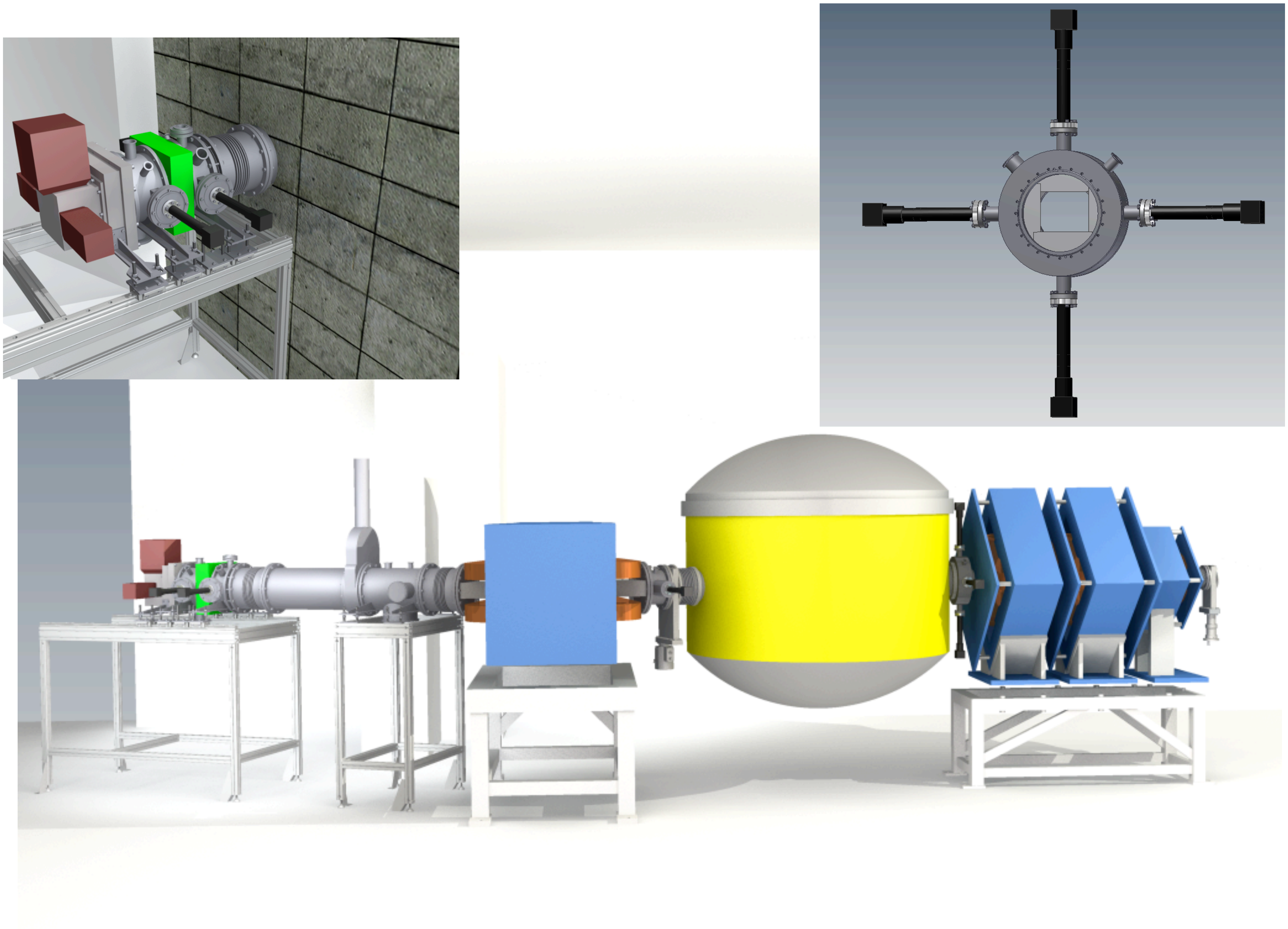

Horizontal distribution at the mass slits 10 cm upstream from the FP
a)
counts
x at mass slit 1 [mm]

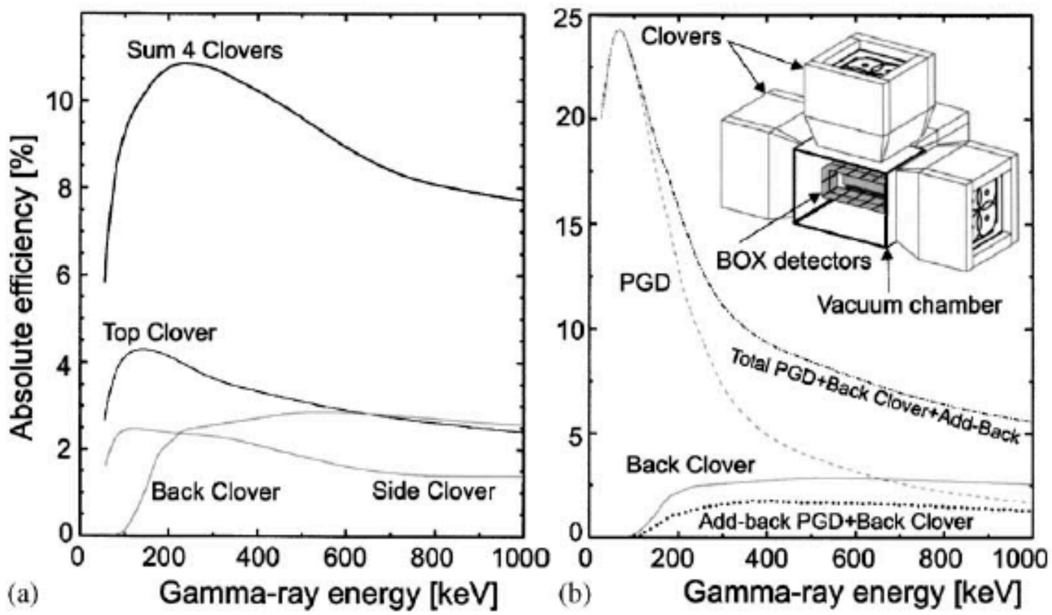

Horizontal distribution at the focal plane
a)
All w/o ms1
78Zr w/o ms1 (x10^4)
All with ms1
78Zr with ms1 (x10^4)
counts
x at focal plane [mm]


Horizontal distribution at the mass slits 10 cm downstream from the FP
b)
all
78Zr (x10^4)
all with slits
78Zr with slits (x10^4)
counts
x at mass slit 2 [mm]

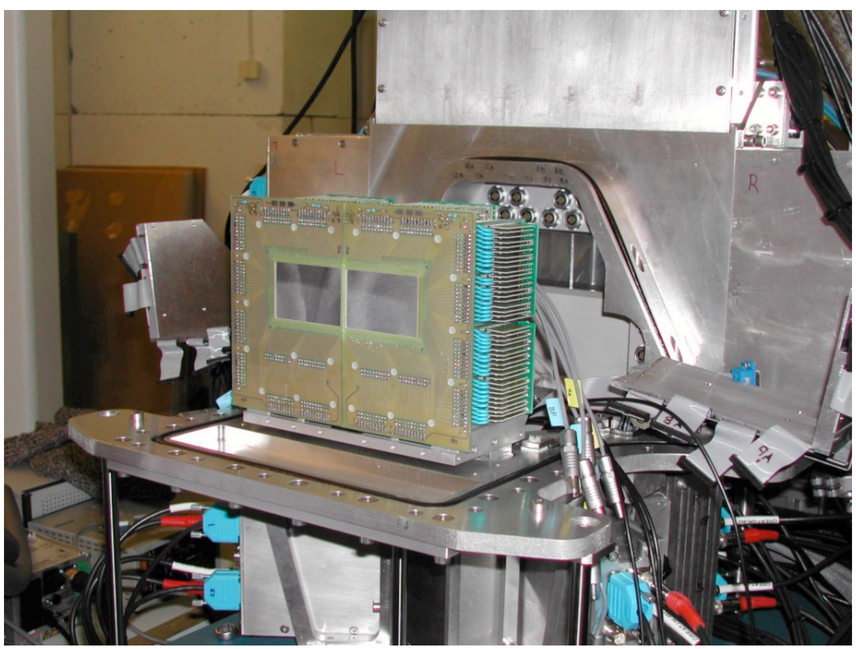

Mass slits
Focal plane
Mass slits
Mass focal plane
Implantation
x [m]
z [m]


Ions
ToF
MWPC / SED
Implantation detector



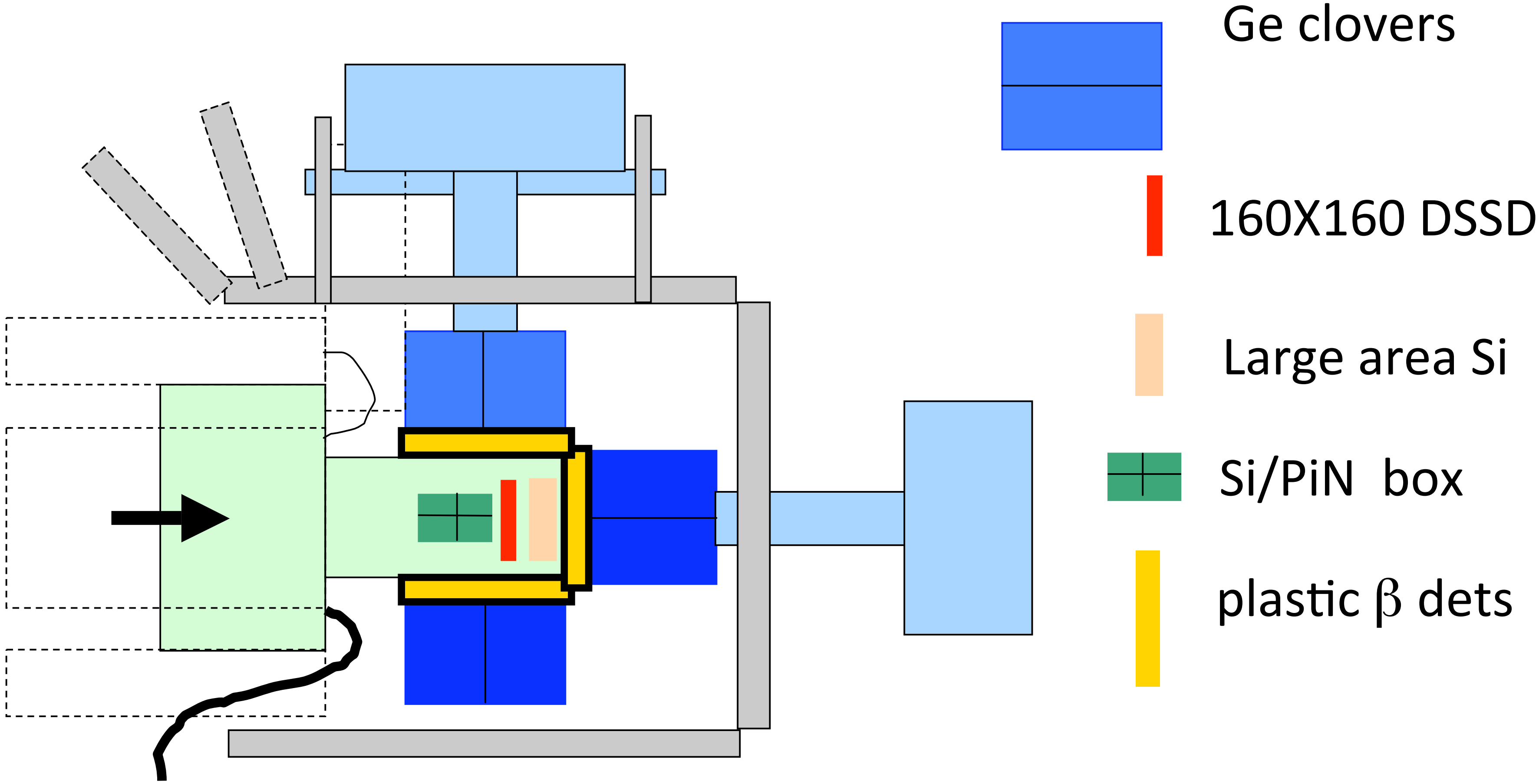


Sum 4 Clovers
Top Clover
Back Clover
Side Clover
Absolute efficiency [%]
Gamma-ray energy [keV]
(a)
Clovers
BOX detectors
Vacuum chamber
PGD
Total PGD+Back Clover+Add-Back
Back Clover
Add-back PGD+Back Clover
Gamma-ray energy [keV]
(b)



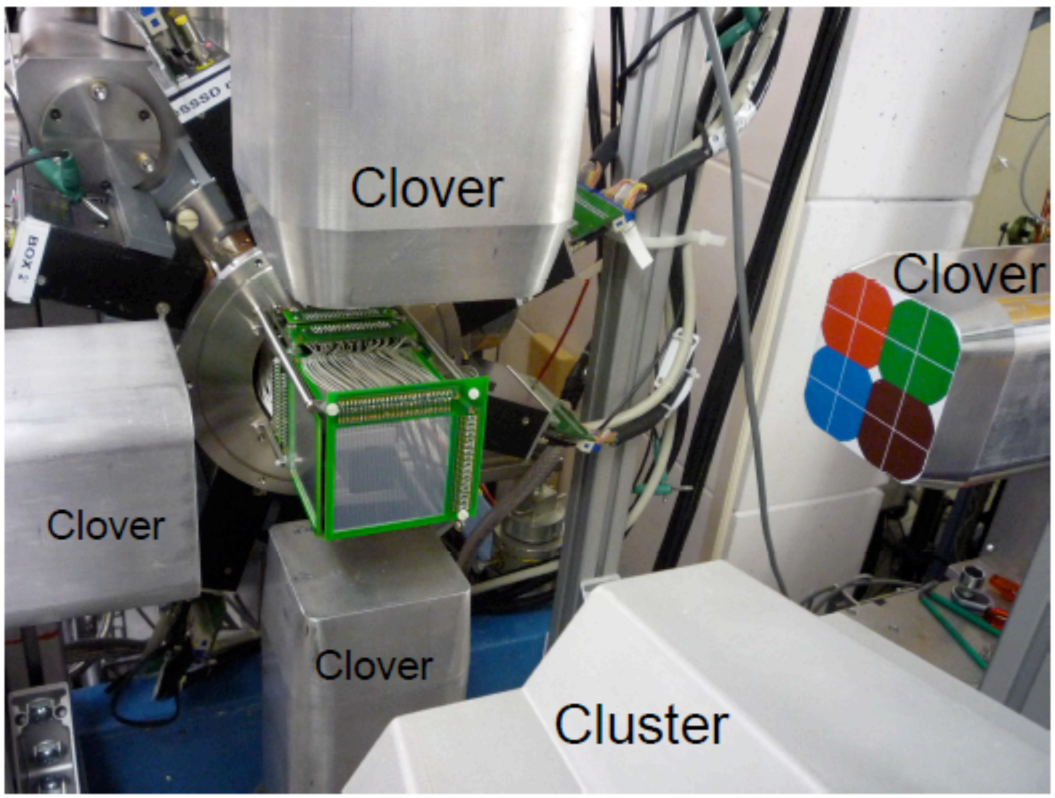
ORTEC

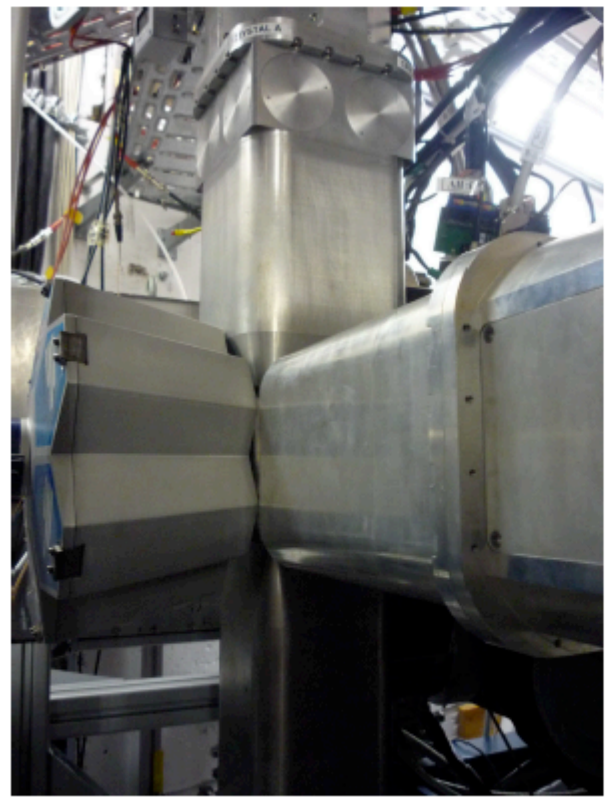
FMA implantation station



The TASISpec Detector Set-up

Details of the construction





Eur. Phys. J. A **17**, 537–558 (2003)
DOI 10.1140/epja/i2002-10162-1

THE EUROPEAN
PHYSICAL JOURNAL A

Alpha-decay studies of the new isotopes ^{191}At and ^{193}At

H. Kettunen[a], T. Enqvist, T. Grahn, P.T. Greenlees, P. Jones, R. Julin, S. Juutinen, A. Keenan, P. Kuusiniemi, M. Leino, A.-P. Leppänen, P. Nieminen, J. Pakarinen, P. Rahkila, and J. Uusitalo

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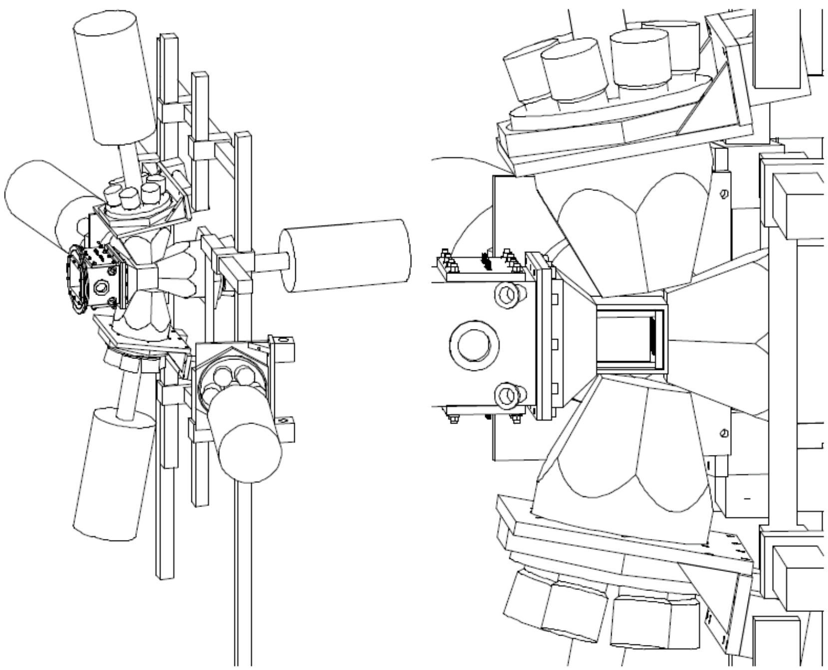
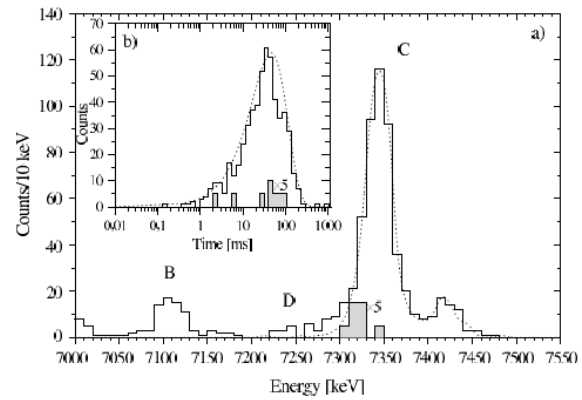




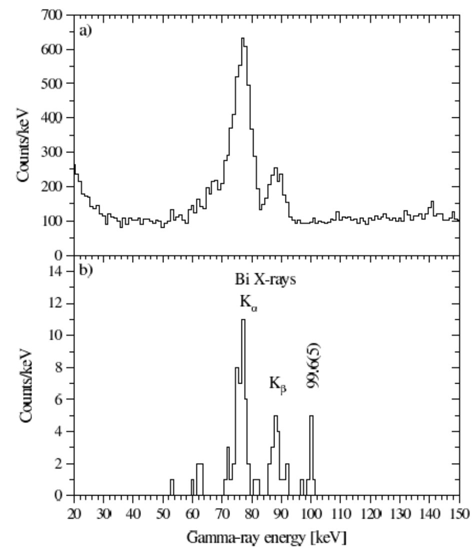
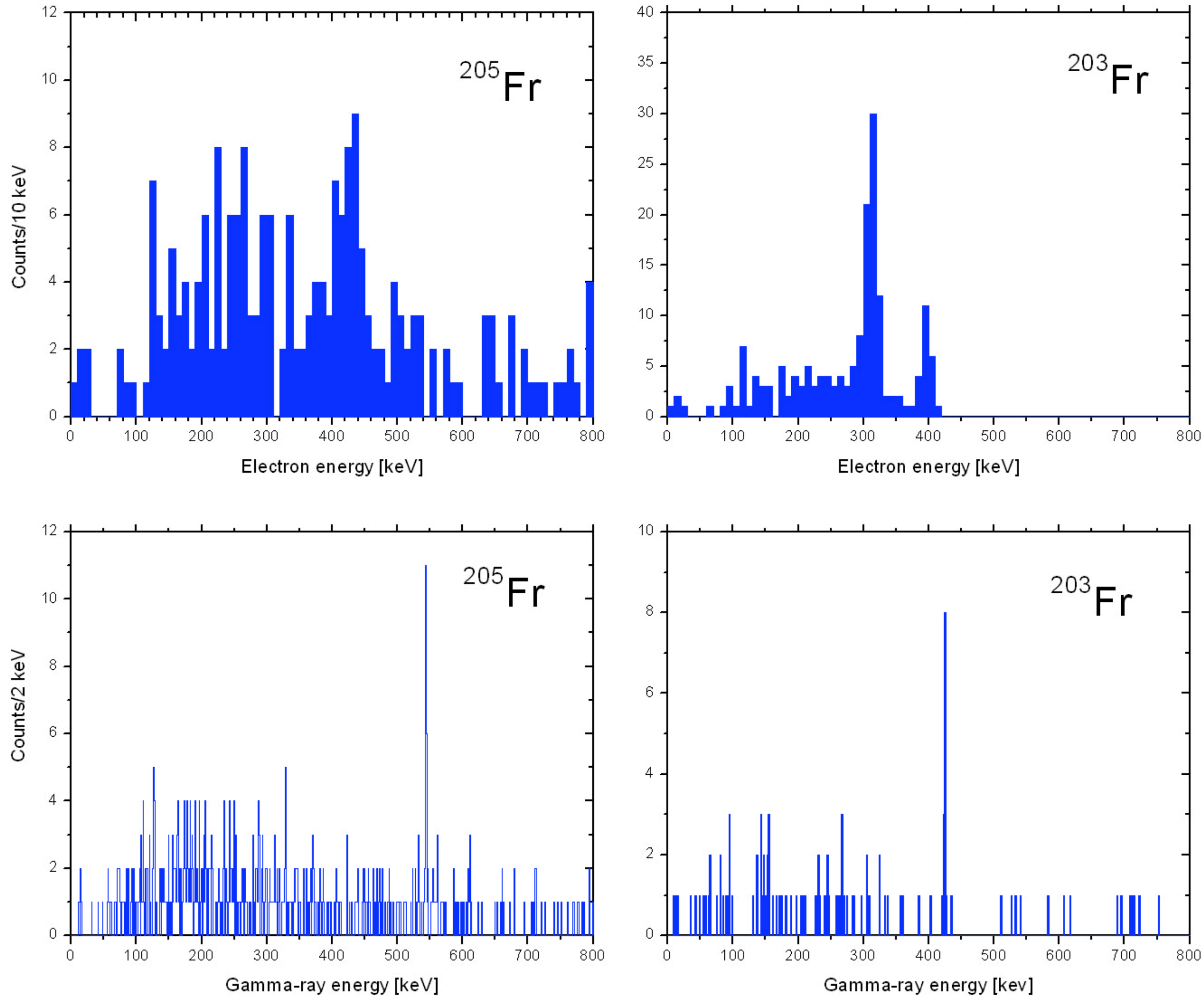


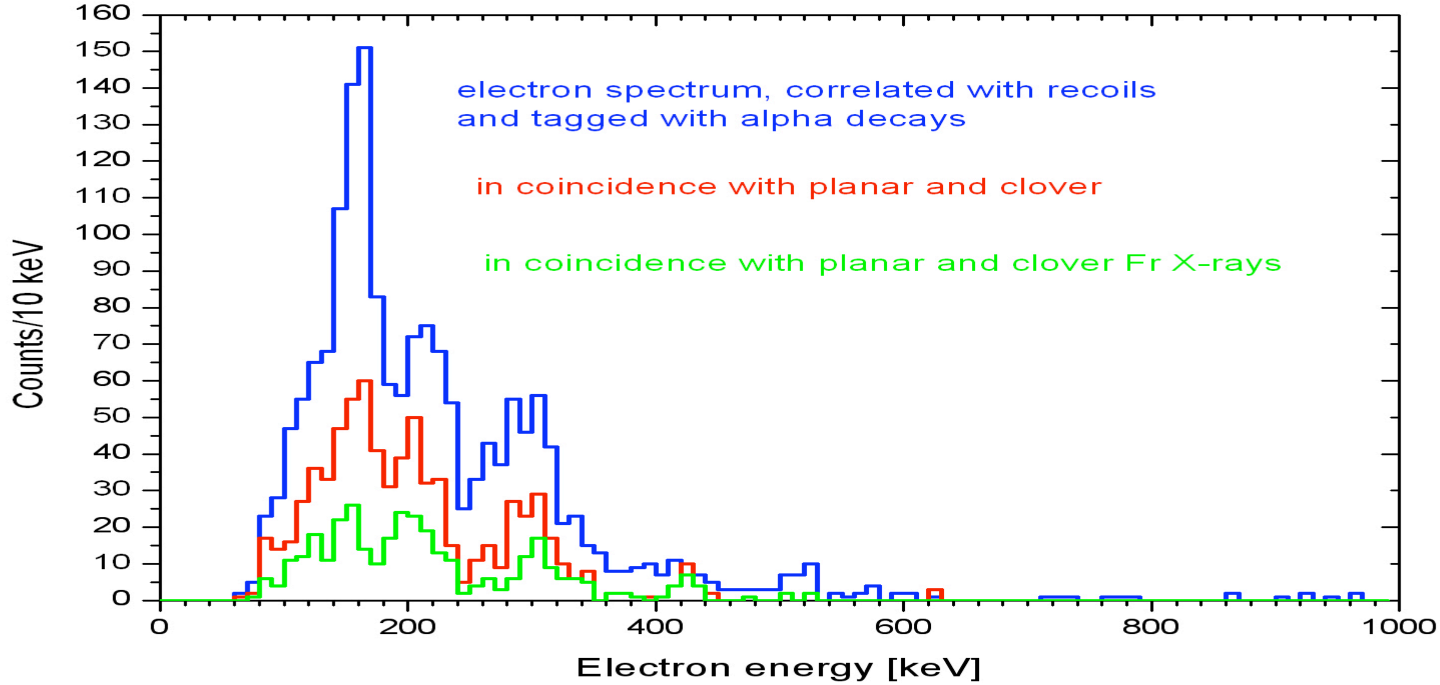
Fig. 5. a) A part of the energy spectrum for gamma-ray events observed in coincidence with any event within a 8 μs time interval in the silicon detector. b) Gamma-ray energy spectrum of group C in fig. 3.

~ 80 ns ~ 200 ns

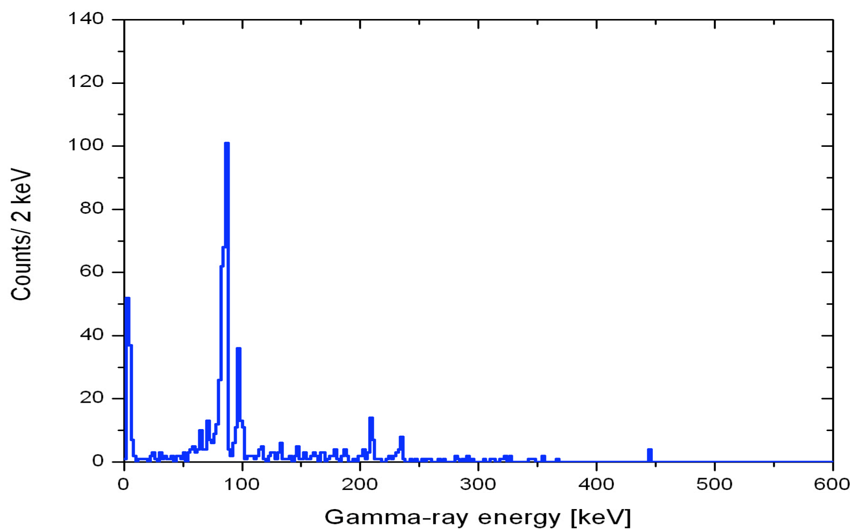


$\alpha_{tot} = 0.36, \alpha_k = 0.27$ $\alpha_{tot} = 0.74, \alpha_k = 0.56$

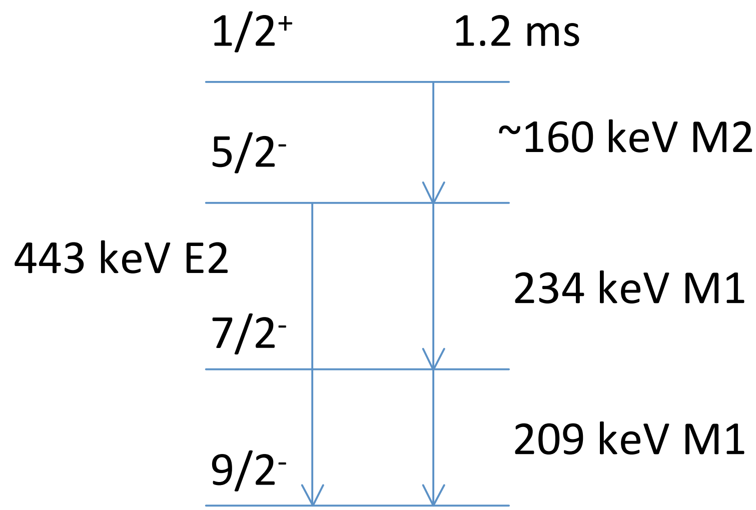
^{205}Fr



electron spectrum, correlated with recoils
and tagged with alpha decays
in coincidence with planar and clover
in coincidence with planar and clover Fr X-rays
Counts/10 keV
Electron energy [keV]
0
200
400
600
800
1000
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0



Counts/ 2 keV
Gamma-ray energy [keV]
0
100
200
300
400
500
600
140
120
100
80
60
40
20
0

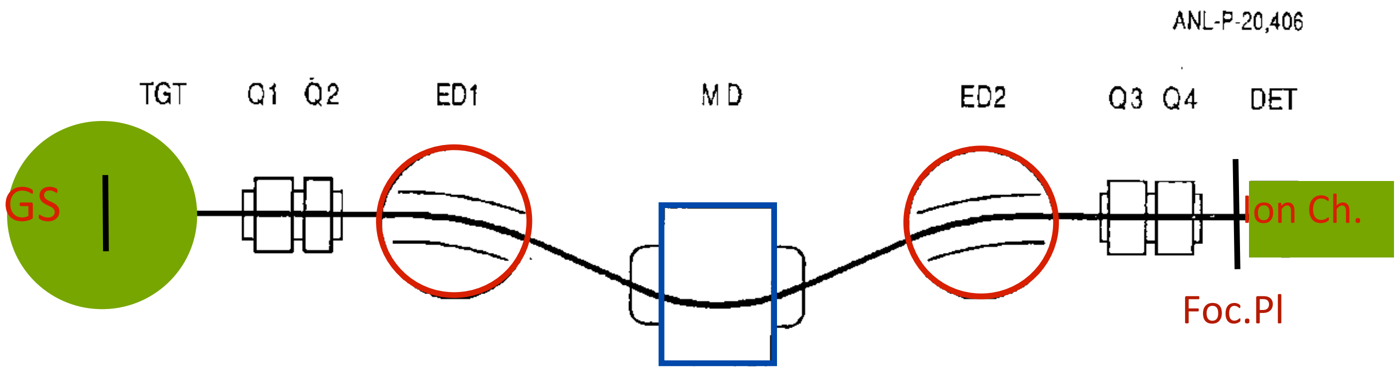


1/2+
1.2 ms
5/2-
~160 keV M2
443 keV E2
7/2-
234 keV M1
9/2-
209 keV M1

THE UNIVERSITY *of York*

Odd-odd T=1 IAS - ^{44}V new data

- **N=Z-2 (T_z=-1) nucleus ^{48}Mn: Z=23, N=21**
- Mirror of ^{44}Sc: Z=21, N=23
- Gammasphere + Fragment Mass Analyser (Argonne N.L.)

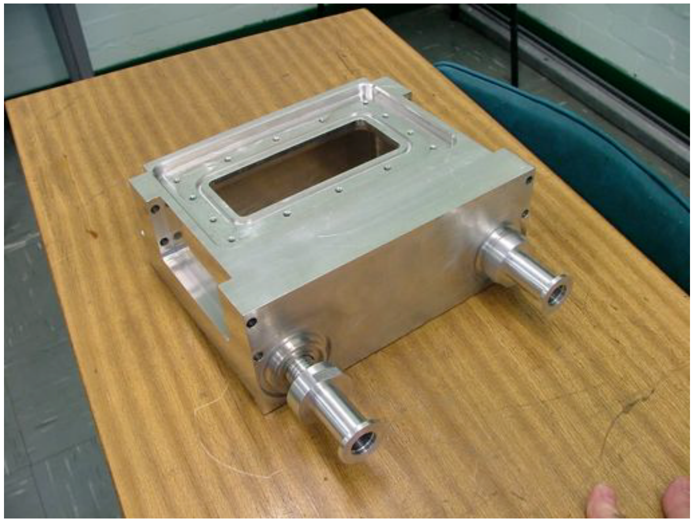


- ^{40}Ca + ^{10}B, 105 MeV, v/c ~ 6 %, E_{rec} ~ 70 MeV
- A/Q from dispersion, Z from Ion Chamber
- Z-selection essential….

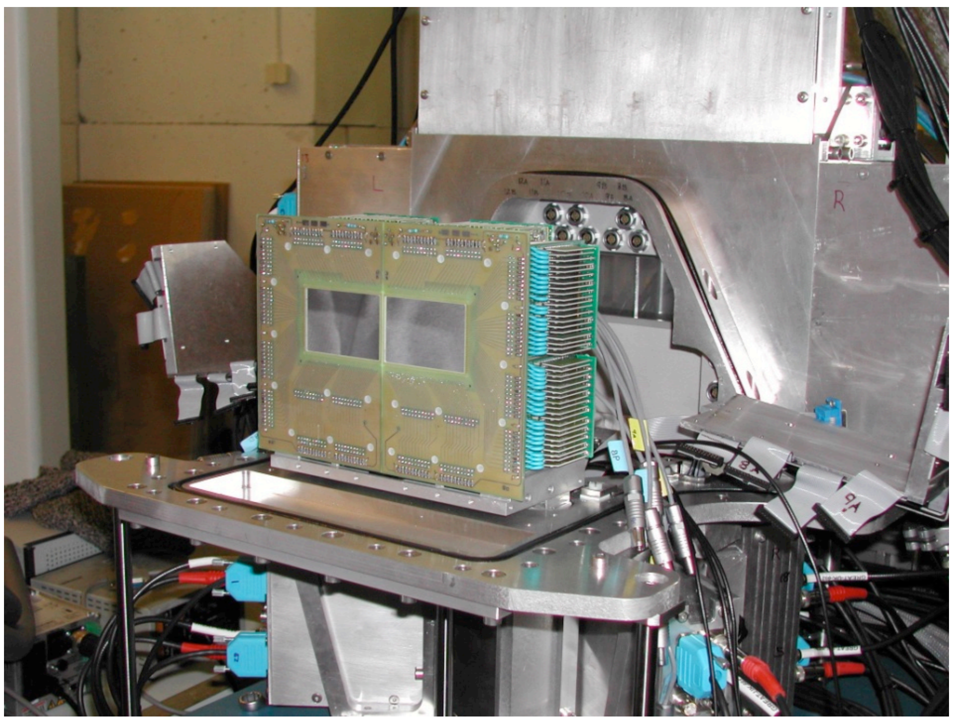
$$^{36}_{18}Ar_{18} + ^{10}_{5}B_{5} \rightarrow ^{46}_{23}V^{*}_{23}$$

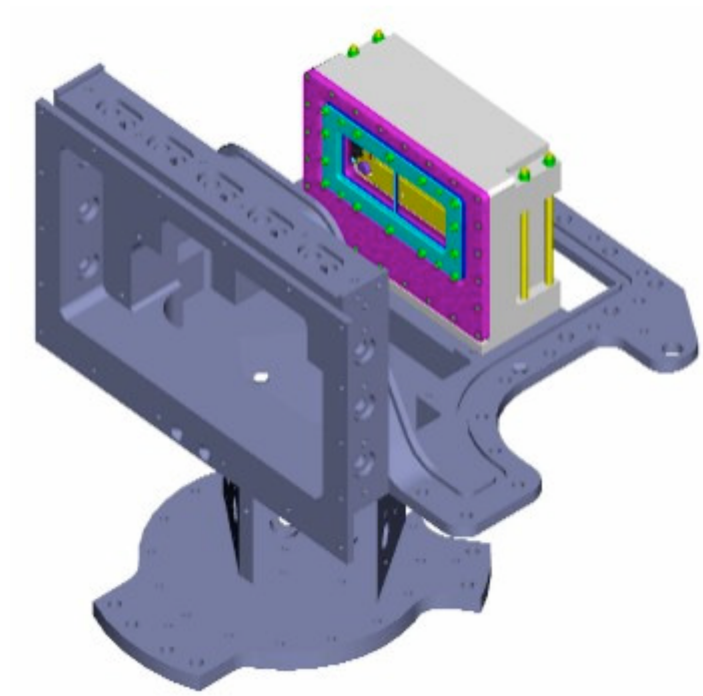
$$\rightarrow ^{44}_{21}Sc_{23} + 2p \qquad \sigma_{fus} \sim 100mb$$

$$\rightarrow ^{44}_{23}V_{21} + 2n \qquad \sigma_{fus} \sim 100\mu b$$

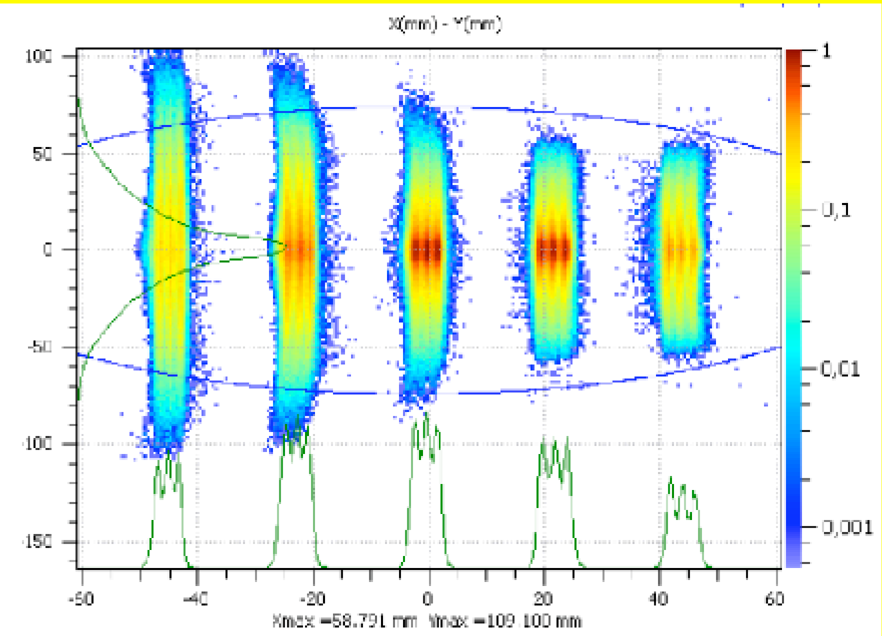


Two MWPC:s and catcher foil
TOF and Isomer tagging
University of Manchester





Mass determination



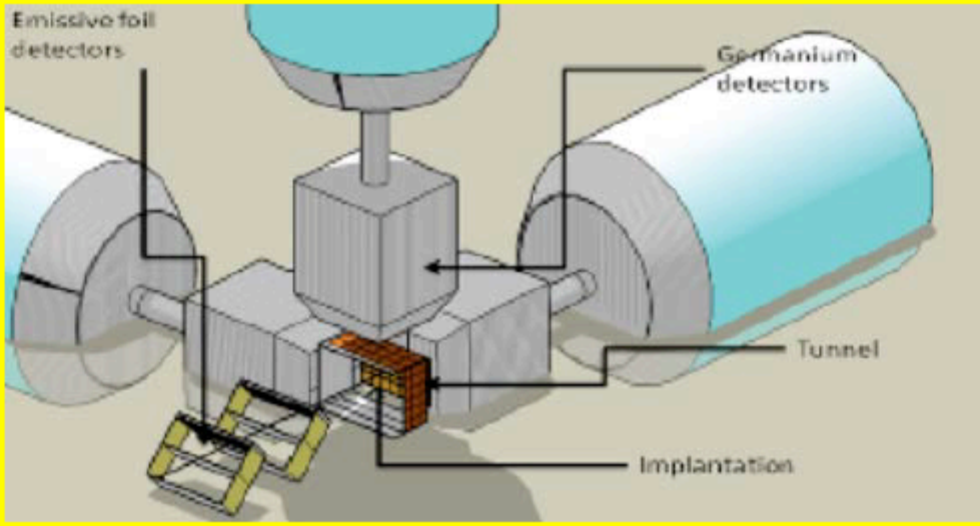
S^3 simulation; $^{48}Ca + ^{248}Cm \rightarrow ^{291,292,293}116$ with q = 22+…26+ M/ΔM ≈ 300

Focal plane detectors

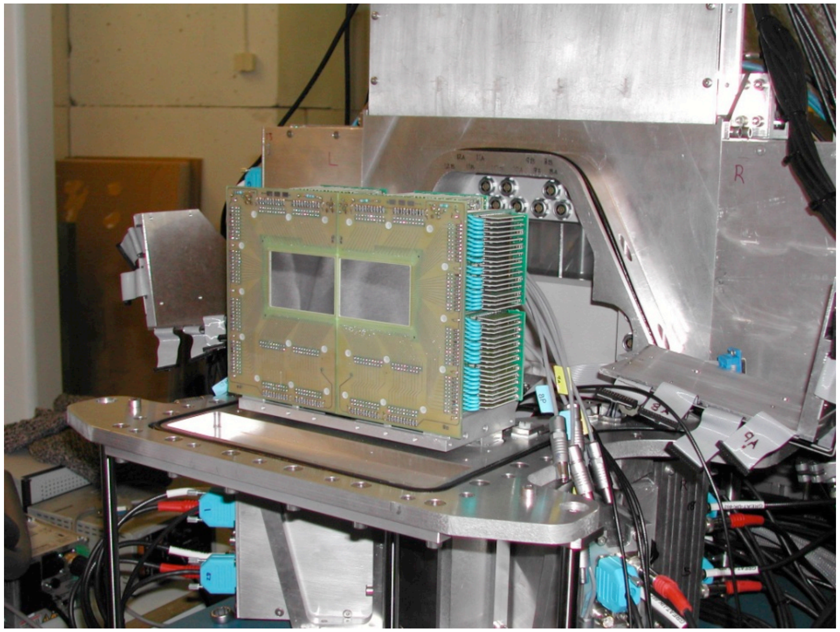
Size is an interesting question

Si is cheap
Electronics is not that cheap? (large size $\rightarrow$ large number of channels)
Many pixels $\rightarrow$ low accidental count rate
But: Need a reasonably high γ detection efficiency

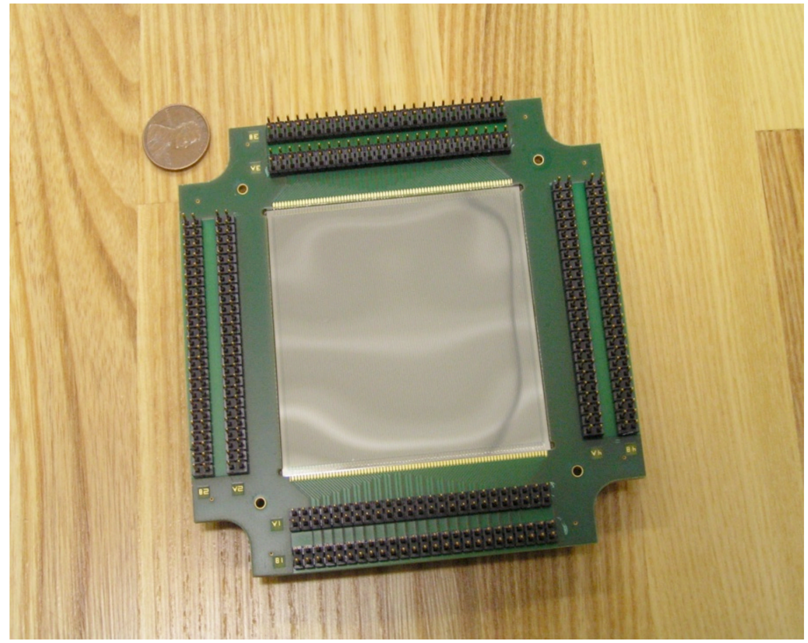
An example: S^3 $< 10 \times 20\ cm^2$

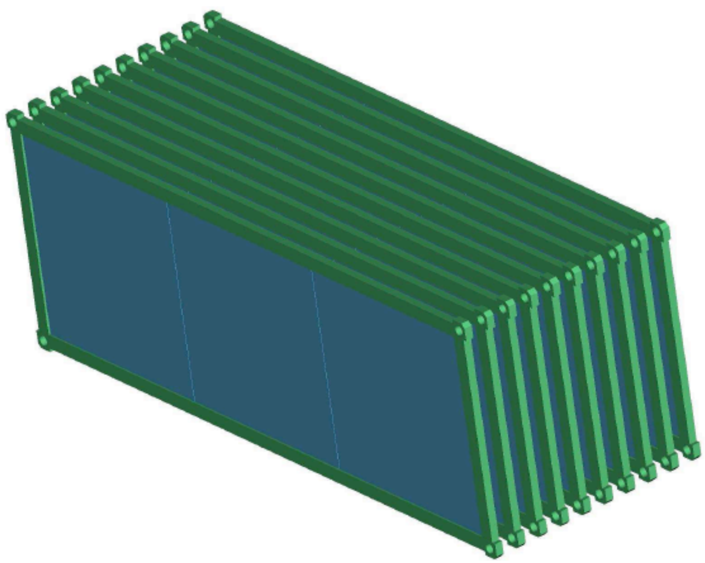


GREAT 2 x 60 mm x 40 mm 60X40 DSSD
strip pitch = 1000 µm



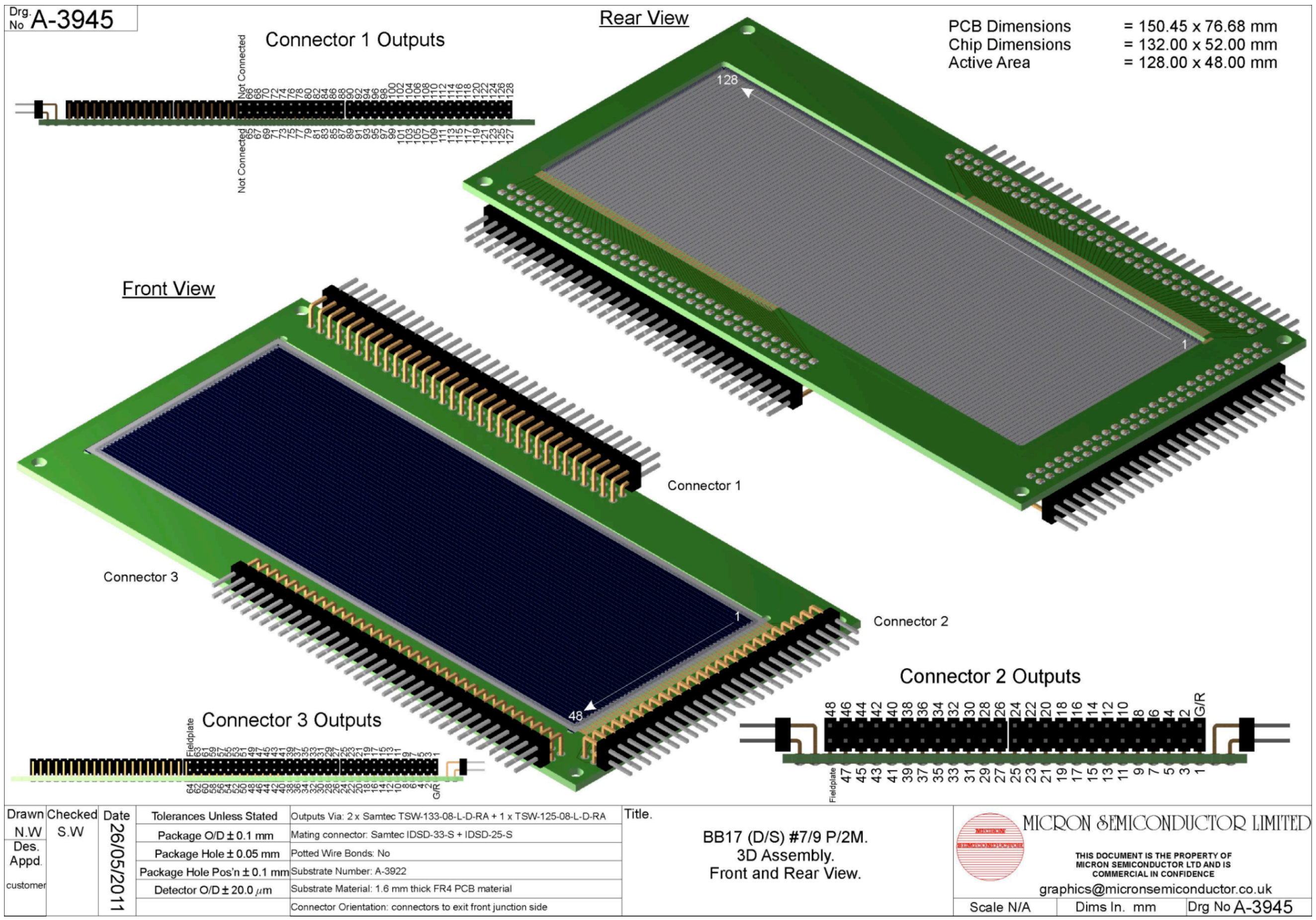
160X160 DSSD 64 mm * 64 mm
FMA ANL, strip pitch = 400 µm





AIDA Design
“standard” configuration “compact” configuration
24 cm x 8 cm (or 3 x 8 cm x 8 cm)
Si thickness = 1 mm, strip pitch = 625 µm,
3 x 128 x 128
>5000 channels

www2.ph.ed.ac.uk/~td/AIDA



DSSD for MARA

128 mm x 48 mm

1 mm strip pitch

In total 176 channels

GREAT @ RITU

DSSD 120 mm x 40 mm

2 x 40 x 60 = 200 channels

University of York

Talk by Panu Ruotsalainen

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 565 (2006) 630–636
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Recoil-beta tagging: A novel technique for studying proton-drip-line nuclei

A.N. Steer[a,*], D.G. Jenkins[a], R. Glover[a], B.S. Nara Singh[a], N.S. Pattabiraman[a], R. Wadsworth[a], S. Eeckhaudt[b], T. Grahn[b], P.T. Greenlees[b], P. Jones[b], R. Julin[b], S. Juutinen[b], M. Leino[b], M. Nyman[b], J. Pakarinen[b,1], P. Rahkila[b], J. Sarén[b], C. Scholey[b], J. Sorri[b], J. Uusitalo[b], P.A. Butler[c], I.G. Darby[c], R.-D. Herzberg[c], D.T. Joss[c], R.D. Page[c], J. Thomson[c], R. Lemmon[d], J. Simpson[d], B. Blank[e]

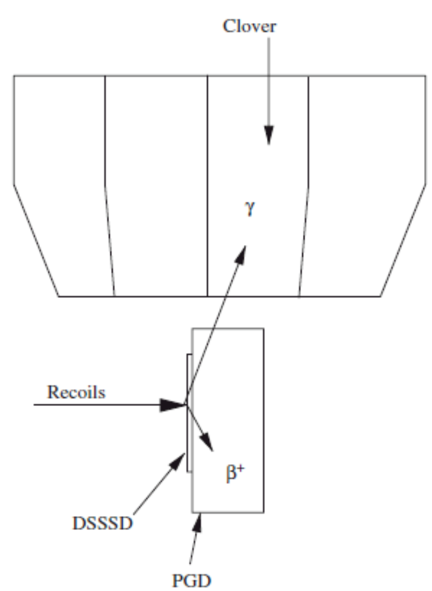


Fig. 2. A schematic side view drawing of GREAT showing recoiling nuclei implanting in the DSSSD, subsequent β-decay products are then detected in the PGD and Clover detectors.

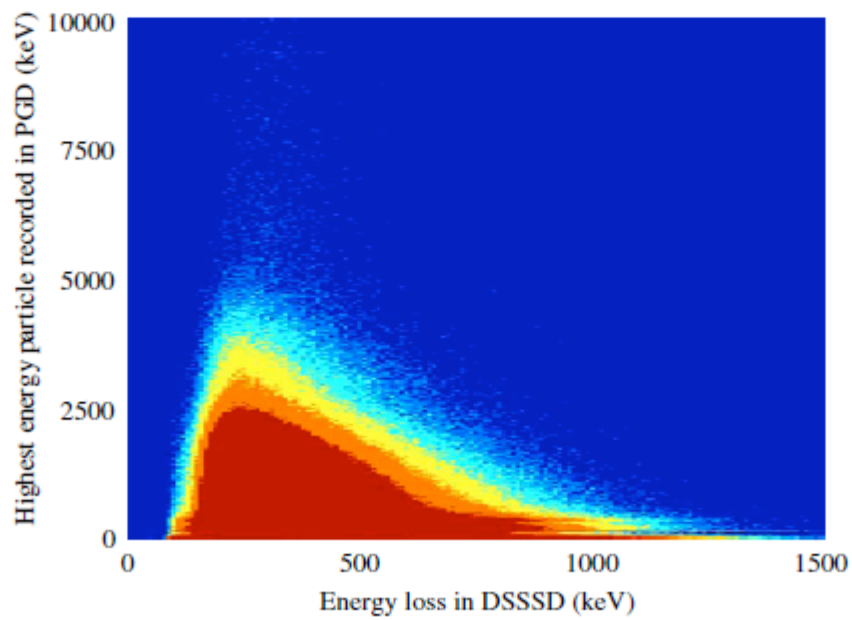


Fig. 5. (Colour online). Highest energy of ionising particle recorded in the PGD vs. energy loss in the DSSSD.

Table 1
Beta decay properties of nuclei produced in the $^{36}Ar+^{40}Ca$ reaction at E_{beam} = 103 MeV, including the reaction channel, half-life, and Q(EC) value, where known

Nucleus	Channel	Half-life	Q(EC) (MeV)	σ (mb)
^{74}Rb	pn	65 ms	10.4	0.260
^{74}Kr	2p	11 min	3.14	3.01
^{74}Sr	2n	> 1.2 μs	–	0.014
^{73}Kr	2pn	12 s	6.67	5.62
^{73}Br	3p	3.4 min	4.66	41.8
^{72}Kr	α	17.2 s	5.04	0.044
^{72}Br	3pn	78.6 s	8.7	0.439
^{72}Se	4p	8.4 d	0.355	6.28
^{71}Br	αp	21.4 s	6.5	2.20

Cross-sections were estimated using the fusion evaporation code, ALICE. This code overestimates the cross-section by a factor of ~20, however, the relative yields are in accordance with the observed experimental information.

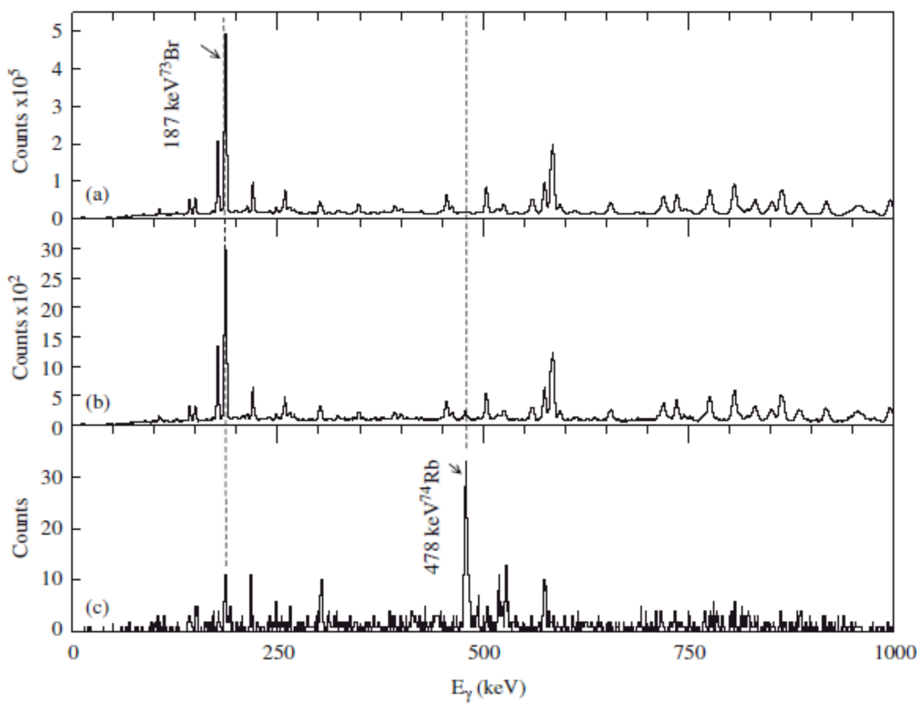
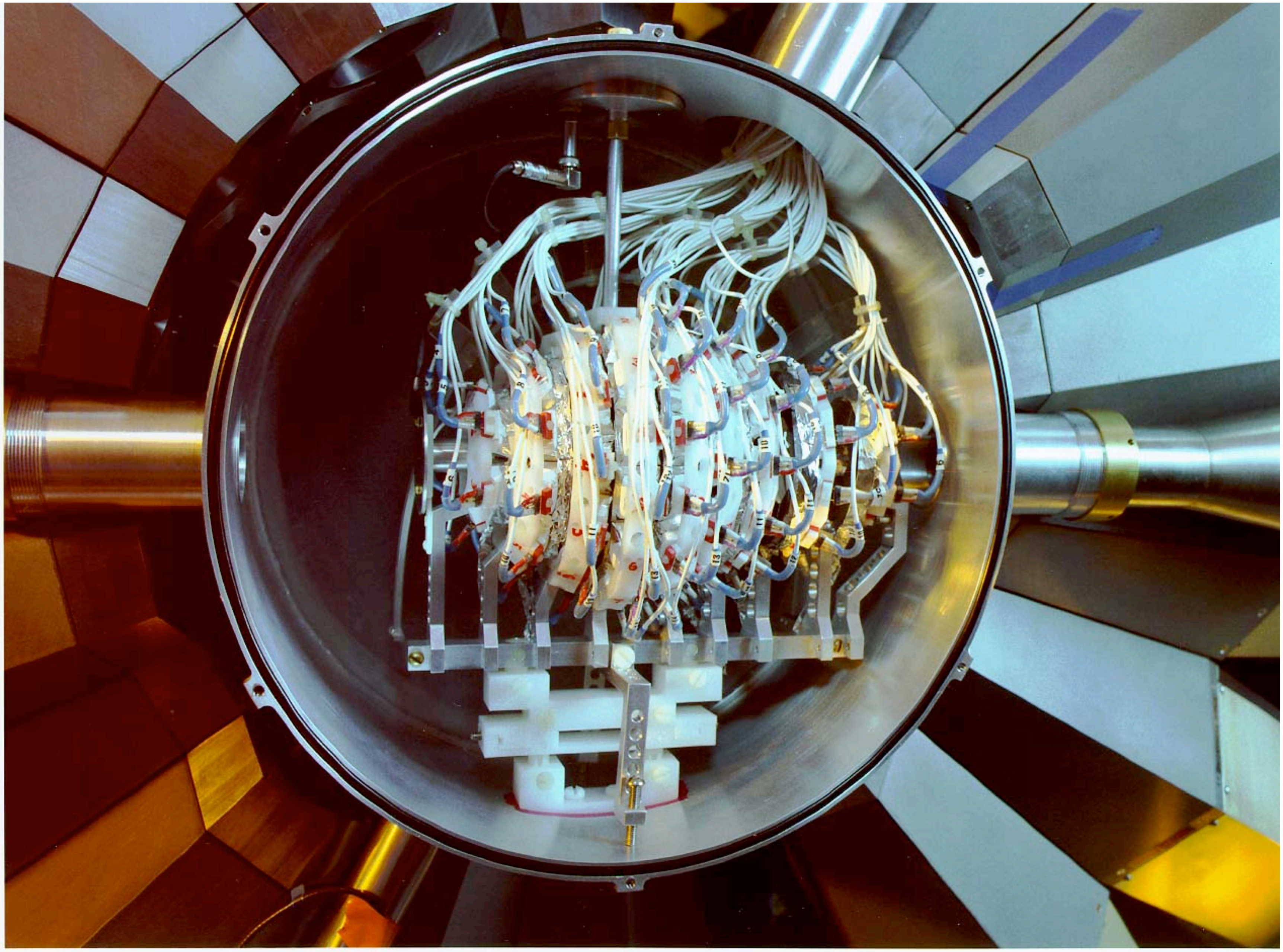
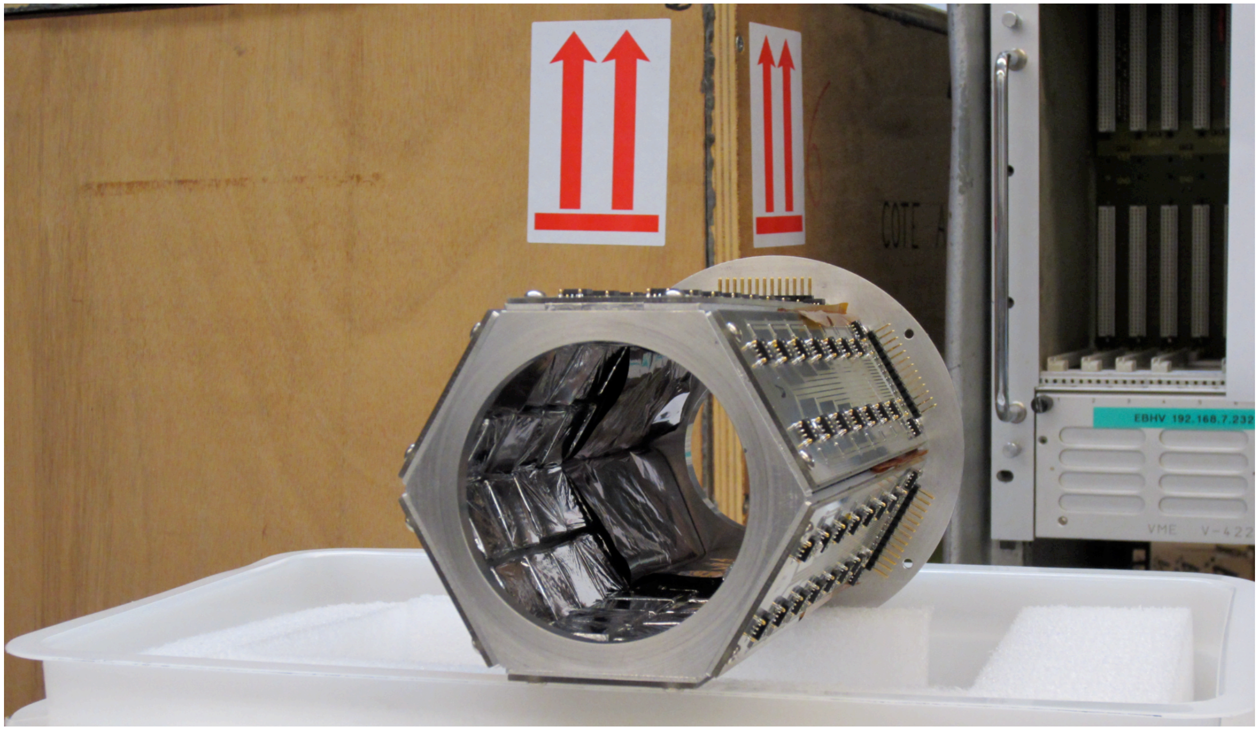


Fig. 4. Spectra showing the enhancement of the ^{74}Rb reaction channel under successive gating conditions at I_{beam} = 4 pnA: (a) recoil-gated, (b) recoil-gated with a time coincidence window of 100 ms between the recoil and β-decay, and (c) β-particle energy between 3 and 10 MeV measured in the PGD, in addition to the 100 ms time gate.



UoYTube, University of York



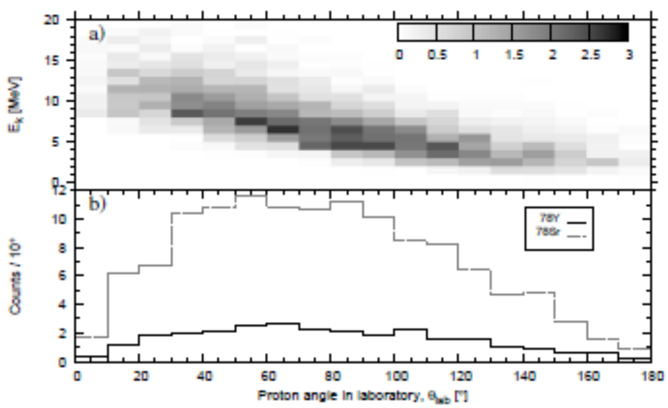


Figure 2.52: Distribution of evaporated protons from reactions ending in the production of ^{78}Y or ^{78}Sr. Only those protons belonging to recoils transmitted to the implantation detector (without slits) are taken into account. Counts correspond to $1 \cdot 10^{10}$ beam particles.

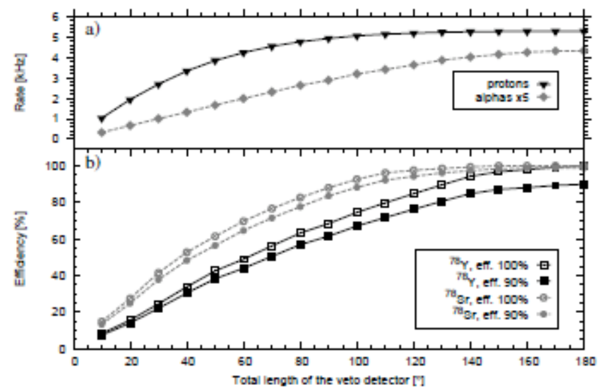
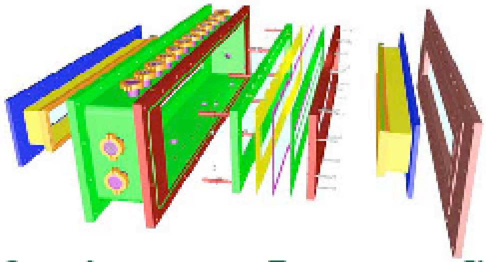


Figure 2.53: a) Proton and alpha particle rates in the reaction ^{40}Ca(^{40}Ca,2n)^{78}Zr and b) veto efficiency of the veto detector as a function of its length for two channels. The length of the detector is here the angle in which the detector is seen from the target. The center of the detector is at the position of the target. Rates correspond to a ^{40}Ca current of $1 \cdot 10^{10}$ 1/s.

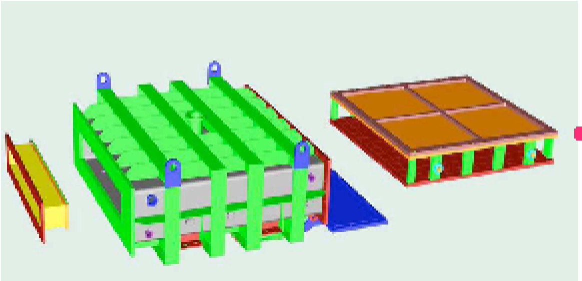
The PRISMA Spectrometer

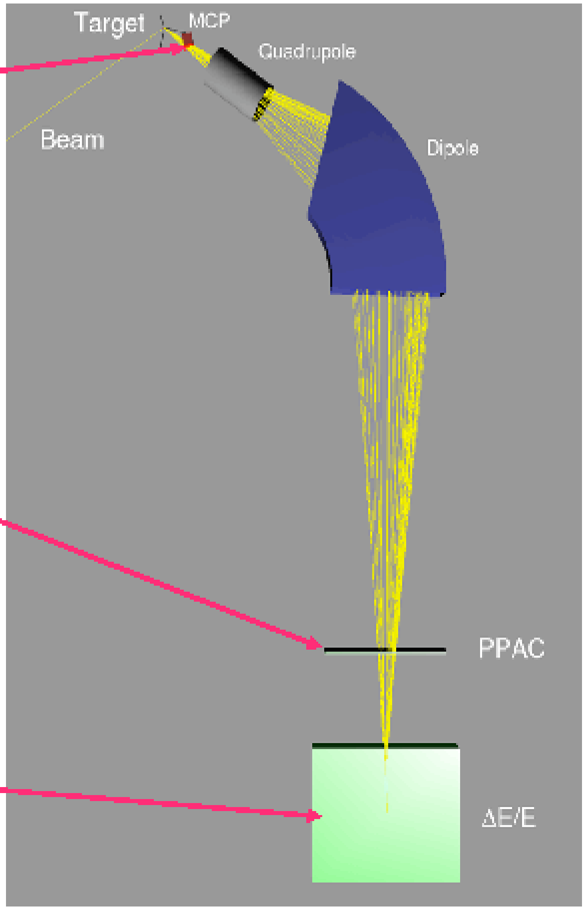
Position sensitive MCP
8 x 10 cm²

10 sections Multiwire PPAC
Active Area: 100 x 13 cm²



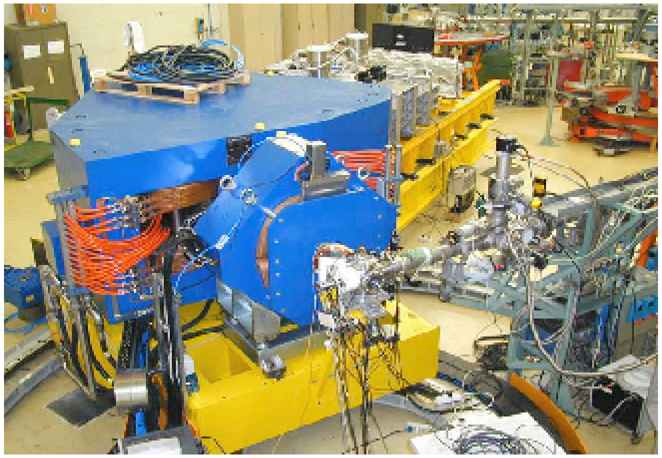
10 x 4 sections Ionization Chamber
Each Section: 10 x 25 cm²





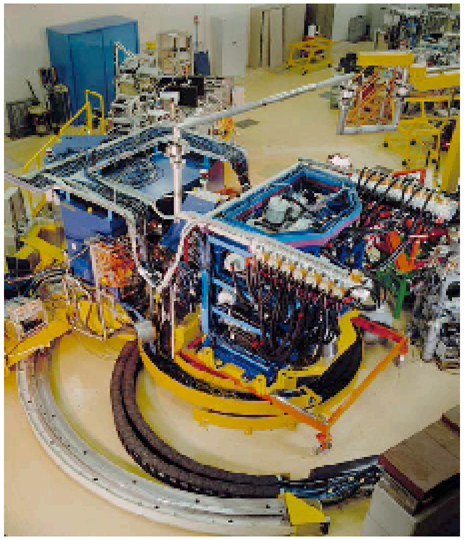
PRISMA – CLARA Setup

PRISMA



Angular acceptances	$\Delta\theta \approx \pm 6^{o}$ $\Delta\varphi \approx \pm 11^{o}$
Solid angle	≈ 80 msr
Distance target – FPD	7 m
Energy acceptance	± 20%
Resolving power	$p/\Delta p \approx 2000$
Mass resolution	1/200 (measured)
Energy resolution	1/1000 (via ToF)
Z resolution	≤ 1/60 (measured)
Count rate capability	up to 2×10^{5} sec^{-1}

CLARA

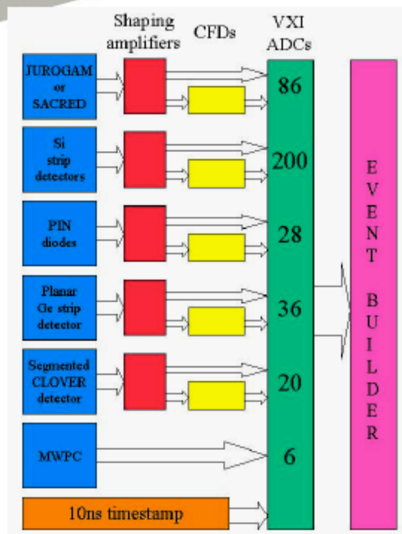


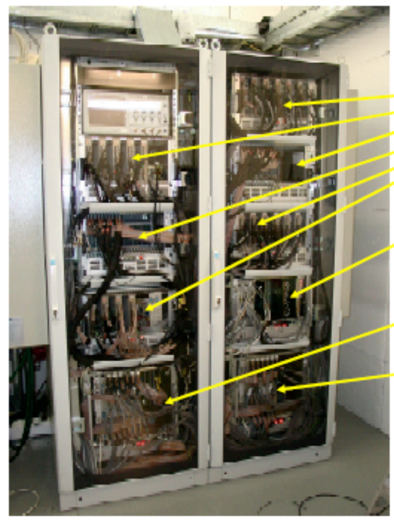
24 to 25 Clovers setup
Efficiency ~ 3 % @ 1.3 MeV
Peak/Total ~ 45 %
Position θ = 103^{o}–180^{o}
FWHM ~ 10 keV
for E_{γ}= 1.3 MeV @ v/c = 10%

Ian Lazarus
(STFC Daresbury)

Science & Technology Facilities Council

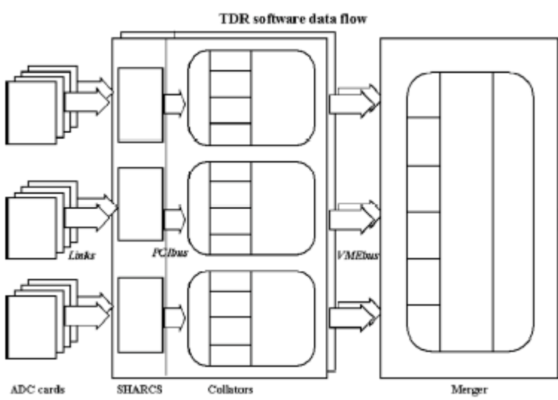
GREAT TDR



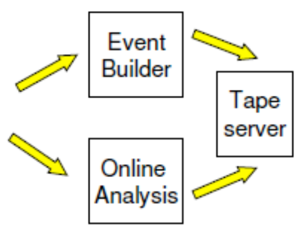


Rack includes

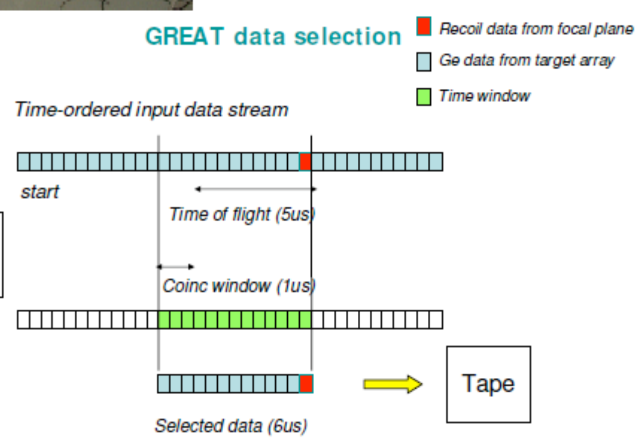
- 4 NIM and 2 CAMAC for front end Amps, CFDs.
- A VME crate (data merger, metronome and pattern unit)
- 2 VXI crates containing between 12 and 15 32 channel cards (up to 480 channels).



Single stream of time ordered data to event builder.



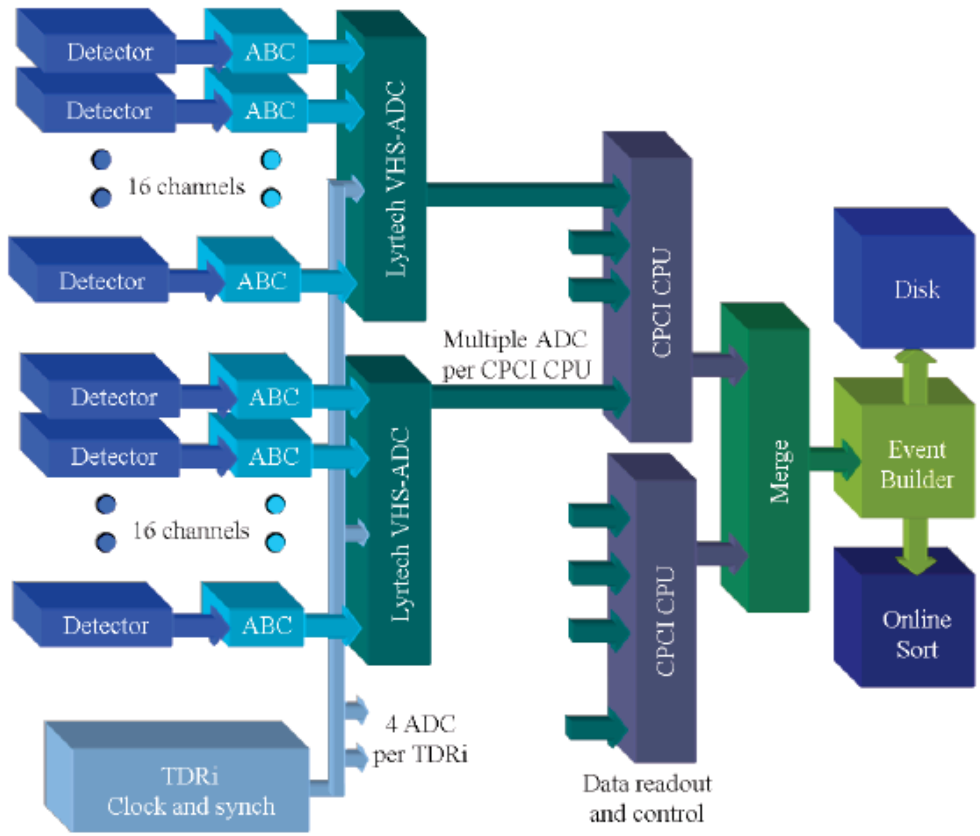
GREAT data selection



201 Fully digital channels

- 90 Si channels
- 111 Ge channels

Lyrtech VHS-ADC



$^{48}Ca + ^{175}Lu \rightarrow ^{223}Pa^* \rightarrow ^{220}Pa + 3n$