Spectroscopy and Indentification of Rare Ions Using S^3

Performances of SIRIUS

&

Status of S^3

VII th Topical Workshop on Modern aspects in nuclear structure

J. PIOT

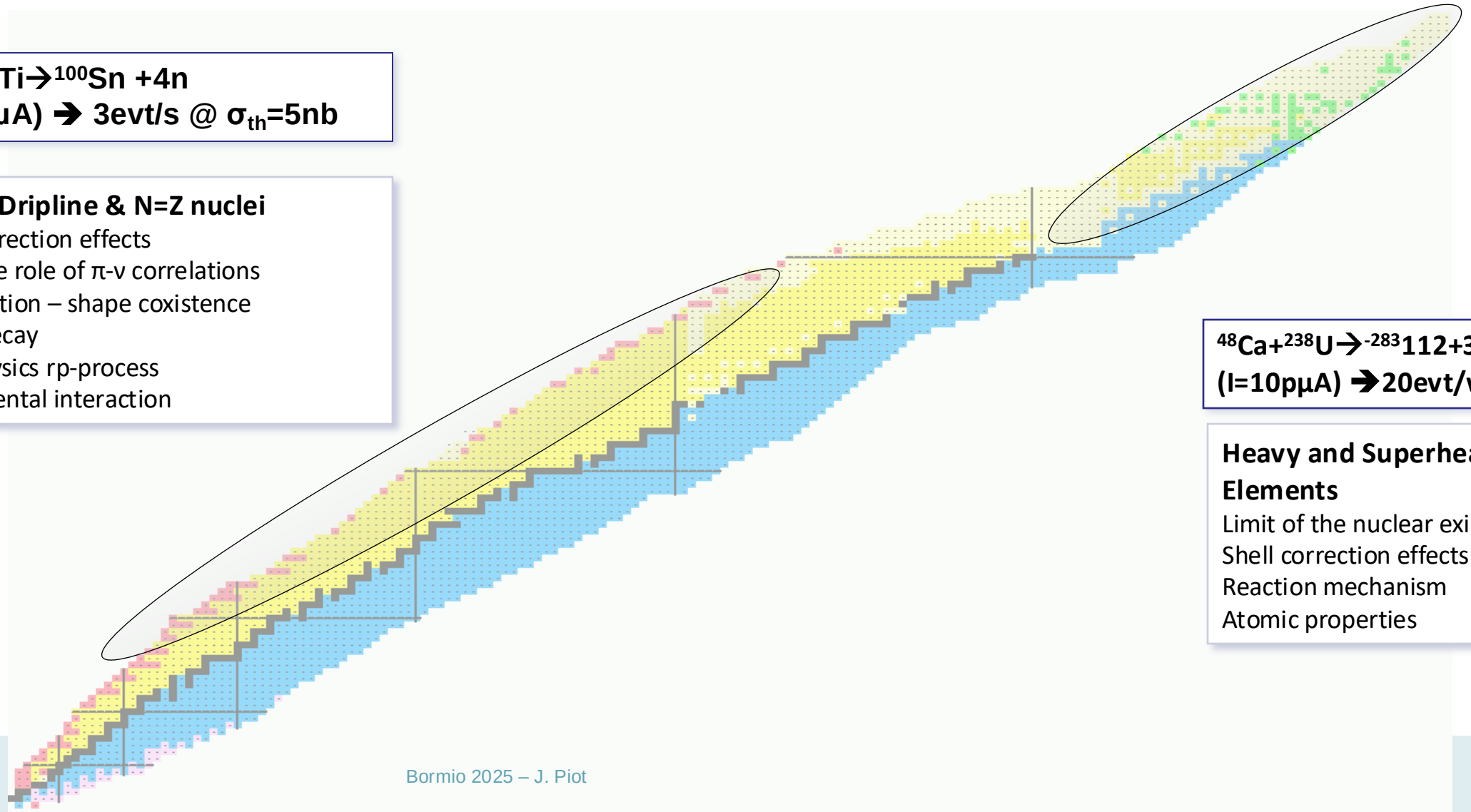
S^3 at SPIRAL2

- Study rare isotopes down to picobarns
- Use high beam currents from SPIRAL 2 and NEWGAIN
- Commissioning ongoing

Super Separator Spectrometer

$^{58}Ni+^{46}Ti \rightarrow ^{100}Sn +4n$
(I=10pμA) ➔ 3evt/s @ σ_{th}=5nb

Proton Dripline & N=Z nuclei
Shell correction effects
Study the role of π-ν correlations
Deformation – shape coxistence
Exotic decay
Astrophysics rp-process
Fundamental interaction

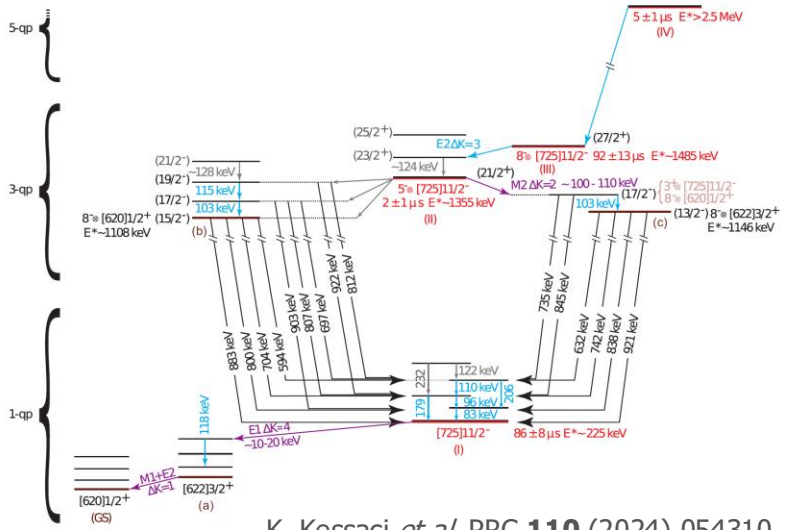


$^{48}Ca+^{238}U \rightarrow ^{-283}112+3,4n$
(I=10pμA) ➔20evt/week/pb

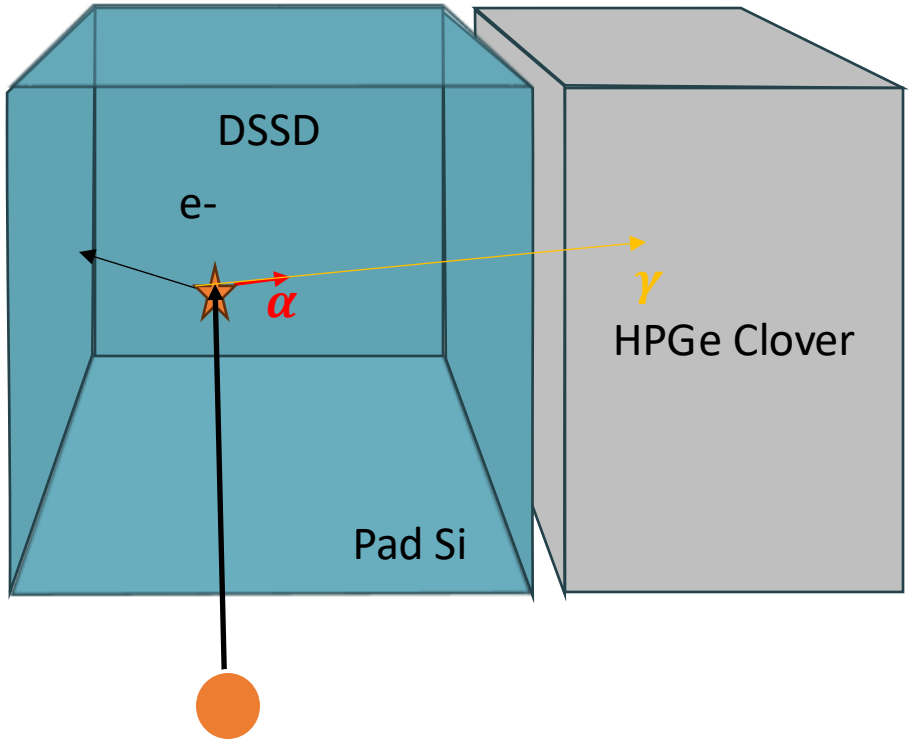
Heavy and Superheavy Elements
Limit of the nuclear existence
Shell correction effects
Reaction mechanism
Atomic properties

Decay Spectroscopy

- α-decay measurement for indentification and spectroscopy
- Conversion electron spectroscopy
- γ-ray and X-ray spectroscopy
- TKE for fission fragments

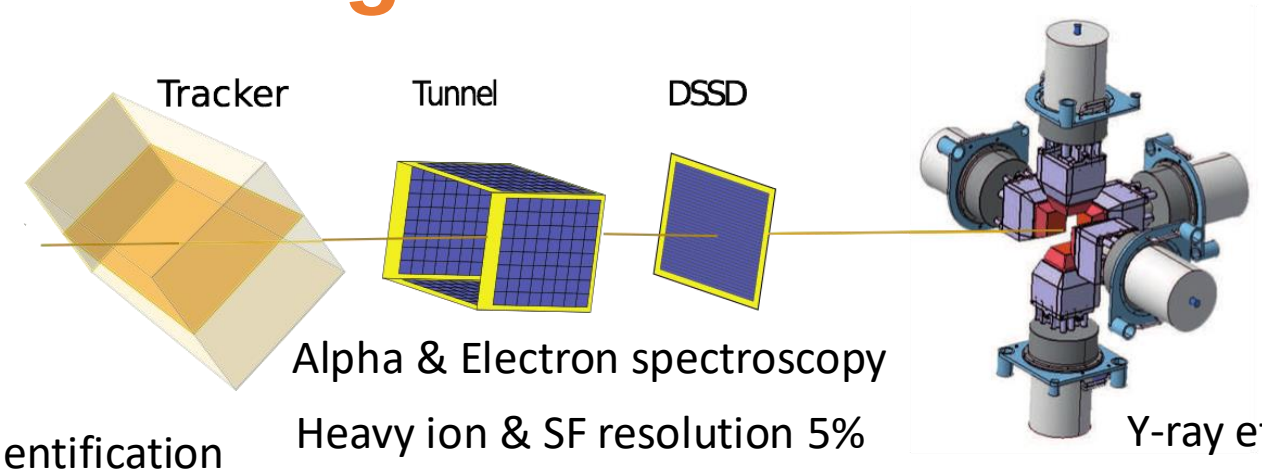


K. Kessaci *et al.* PRC **110** (2024) 054310



Improved energy resolution
Large range detection : from conversion electrons to Fission fragments
Optimized Efficiency

Spectroscopy and Identification of Rare Ions Using S³

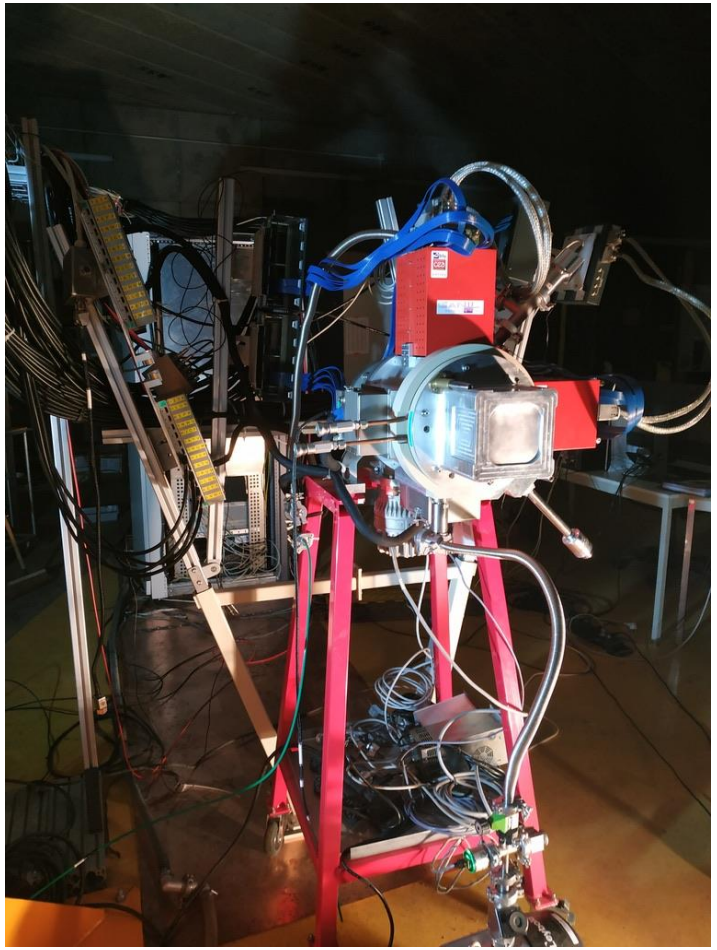


Alpha & Electron spectroscopy

Heavy ion & SF resolution 5%

Mass Identification
A/ΔA ~500
Time of flight

Y-ray efficiency of
40% at 121 keV

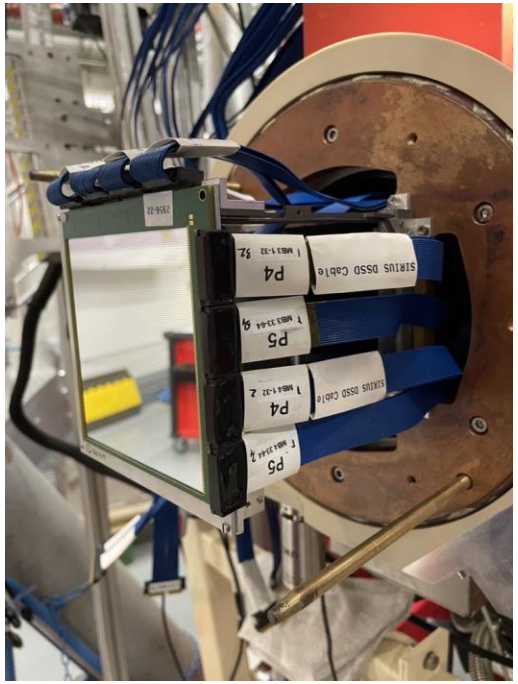


Digital Electronics with PSA & Absence of deadtime
Dual-gain preamplifiers

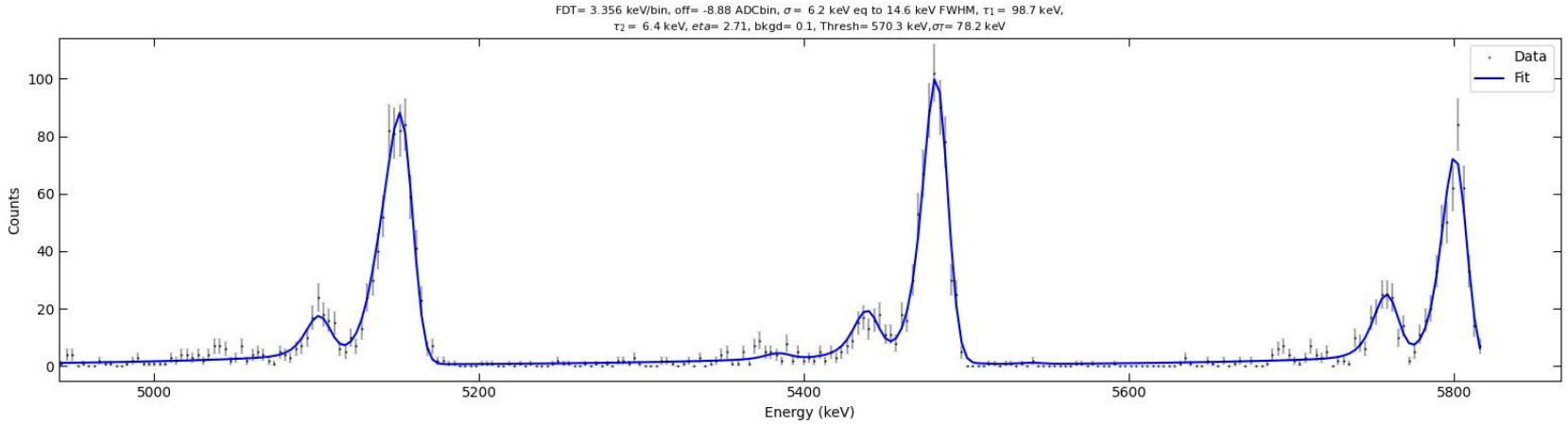
Access to short decay times

Silicon Detectors

DSSD

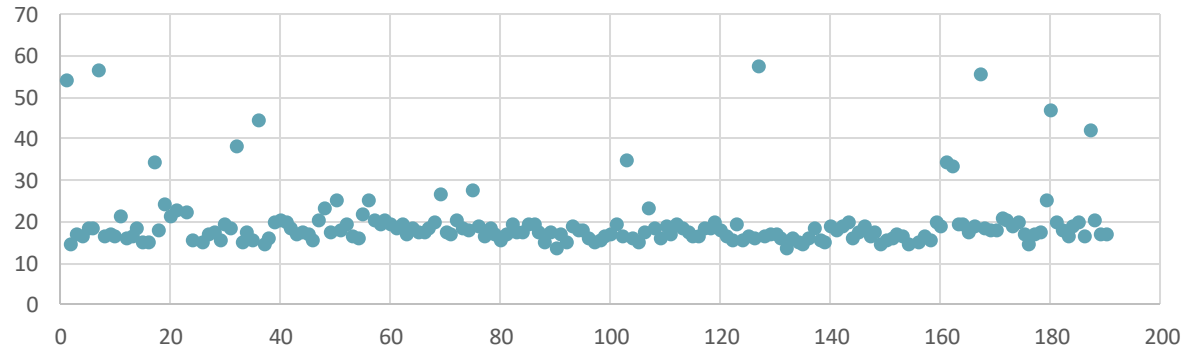


128x128 strips – 10x10 cm^2 active area
Full pulse digitization



High gain (alpha, electrons)
Best resolution : 13,6 keV
Average : 19,6 keV

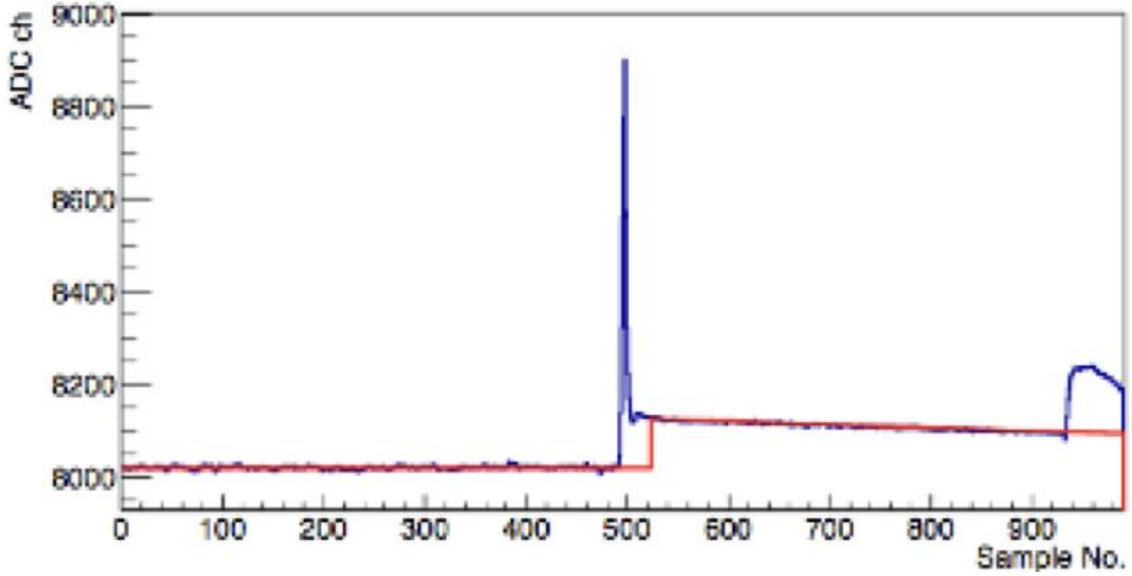
Energy resolutions at 5,8 MeV



DSSD

Large energy range with gain switching capability using Floating Point Charge Sensitive preamplifiers

High gain for Conversion electrons & alpha particles
Low gain for Recoiling nuclei implantation & Fission fragments

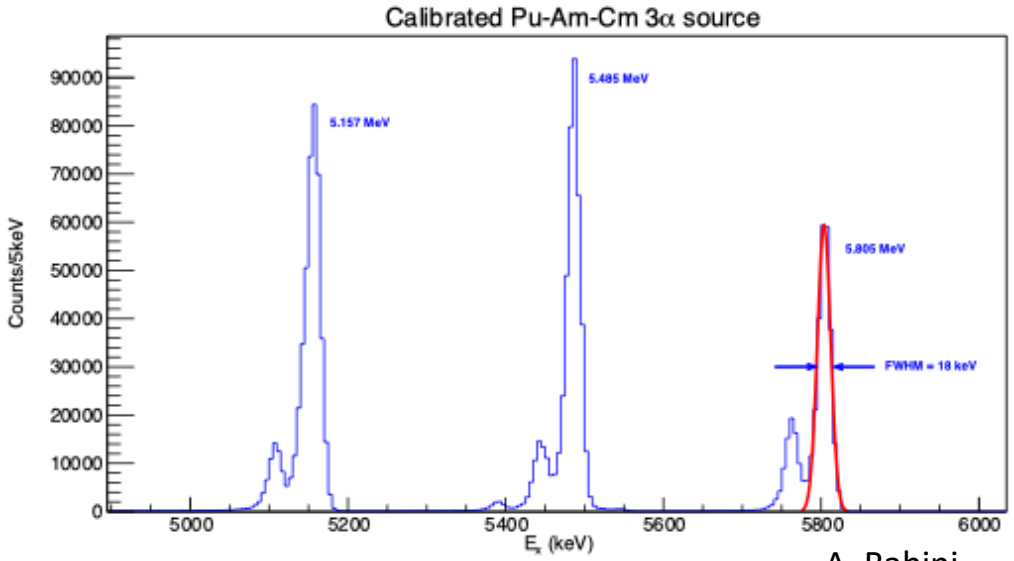


Automatic gain switch - Low gain :
Energy resolution ~ 1 % FWHM

Tunnel detectors

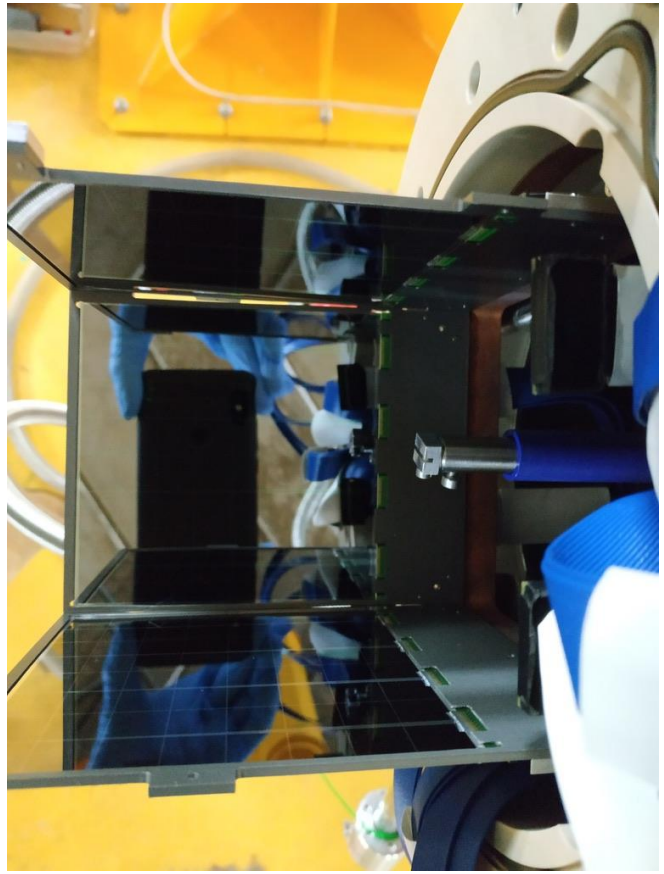
Detectors for alpha and conversion electron spectroscopy

Measurement of particles escaping the DSSD.



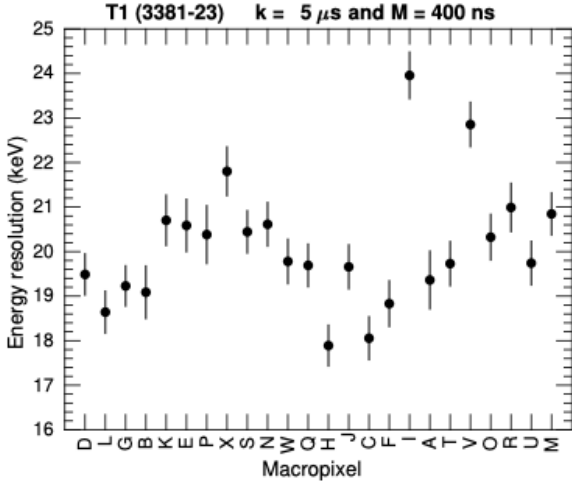
A. Bahini

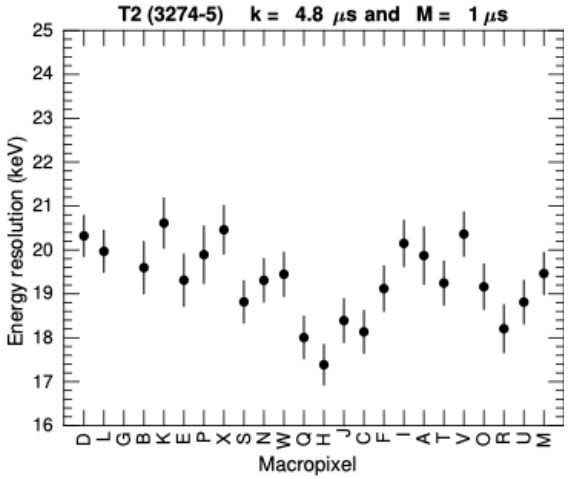
Avergage Energy resolution
21.2 to 18 keV FWHM

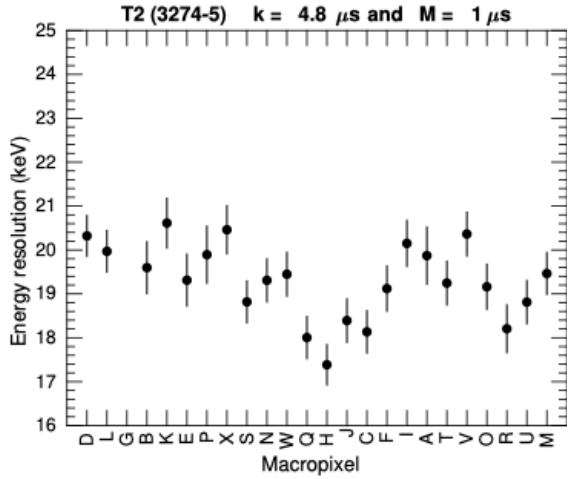


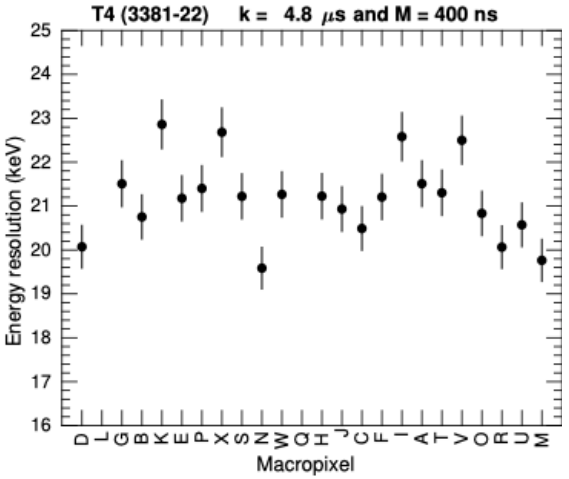
Tunnel detectors

Pictures courtesy of A. Bahini



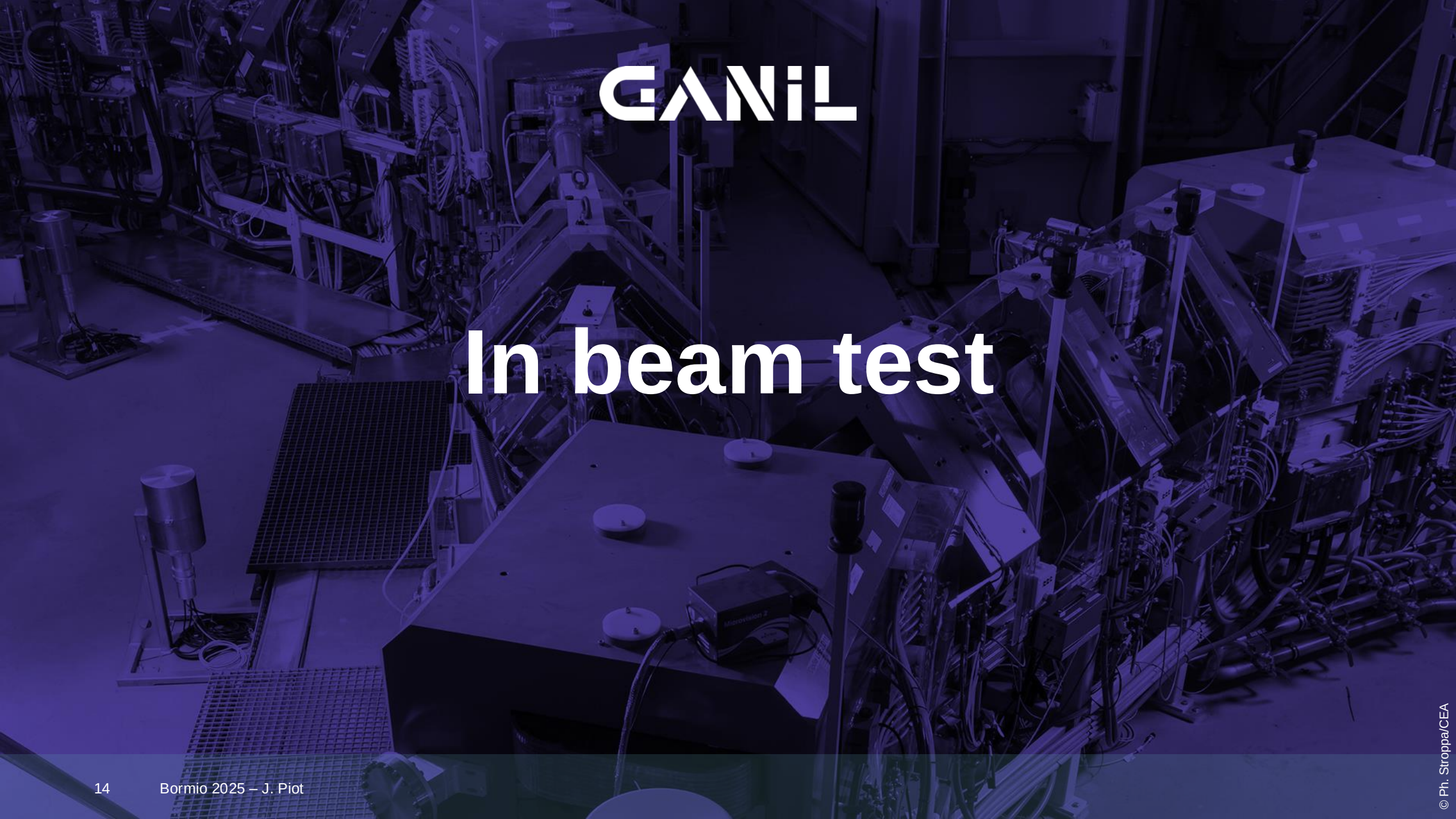






Energy Resolutions close to specifications for alpha particles (< 20 keV FWHM)

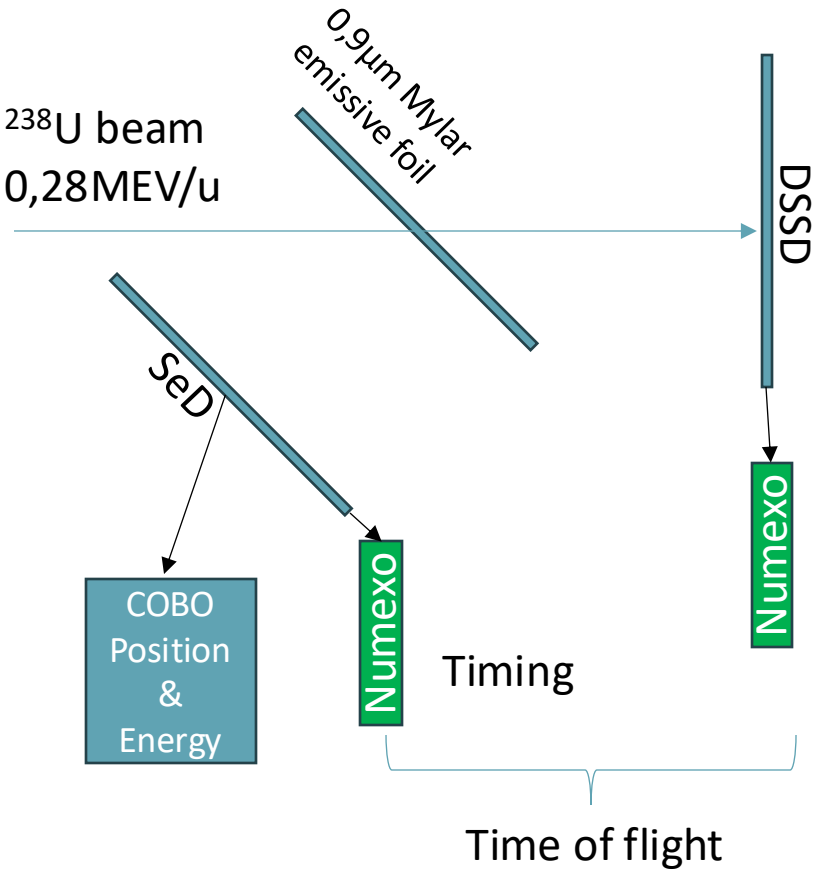
	K		L		W		X
	I		J		U		V
E	F	G	H	Q	R	S	T
A	B	C	D	M	N	O	P

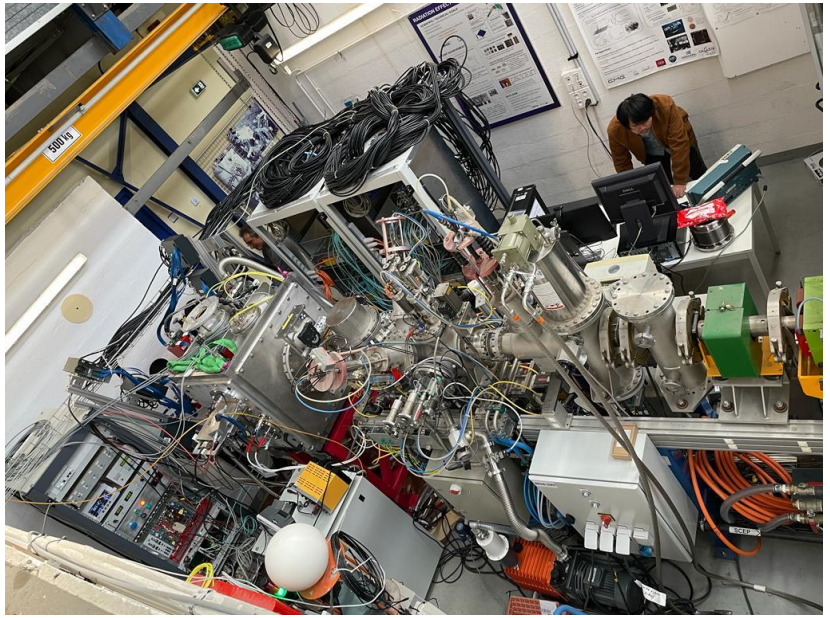


In beam test

Time of Flight & tracking

In-beam test performed at IRRSUD in june 2023



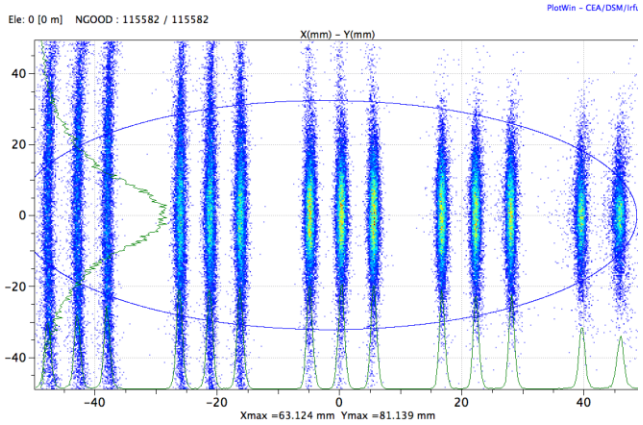


- Tracking between position in SeD and Pixel in DSSD → sub millimeter
- ToF between digitized SeD timing signal & DSSD signal

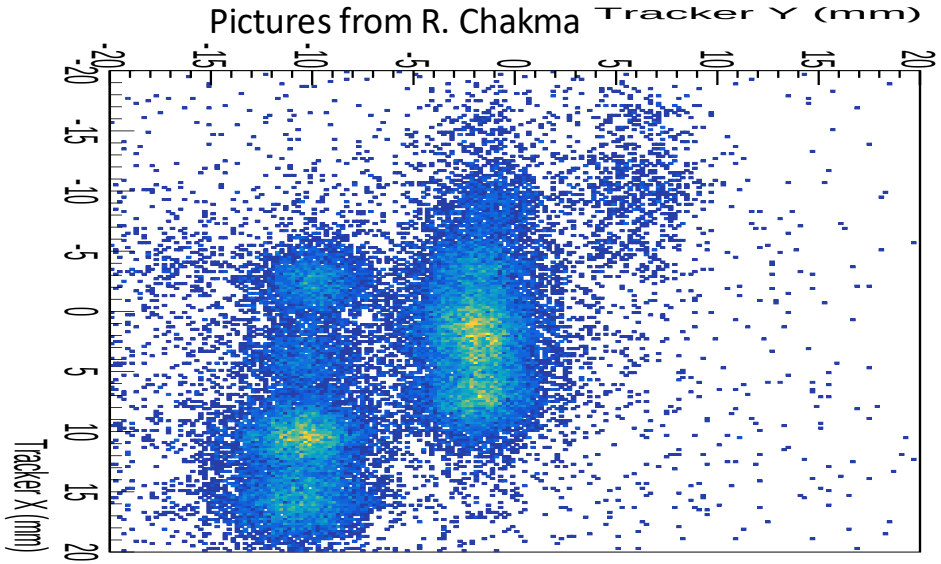
Tracking

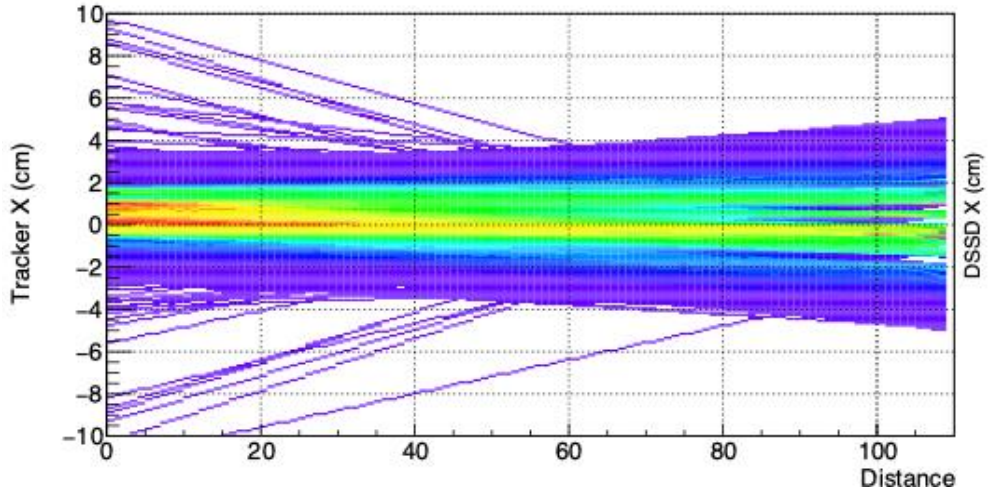
- Position in the Tracker with position resolution 1,1 mm FWHM
- DSSD Strip pitch =700 µm

Ion by ion trajectory reconstruction
→ Selection of events

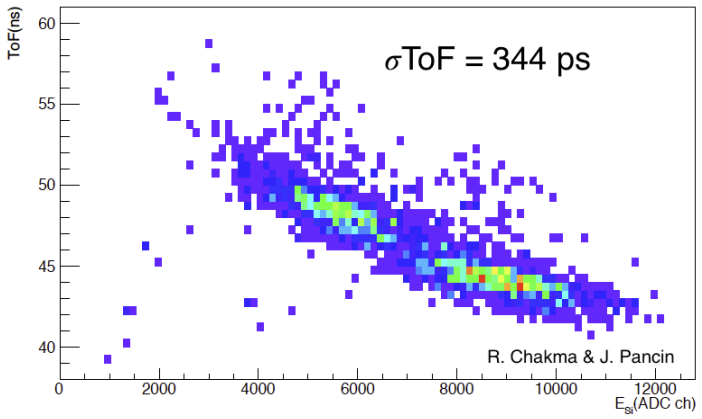


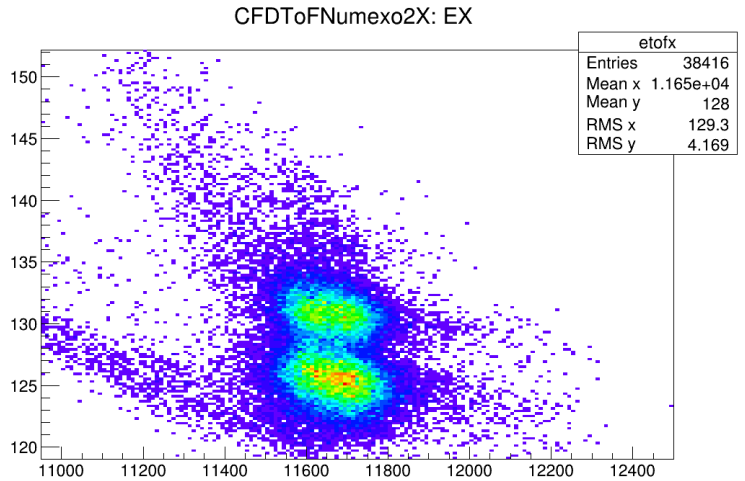
Pictures from R. Chakma

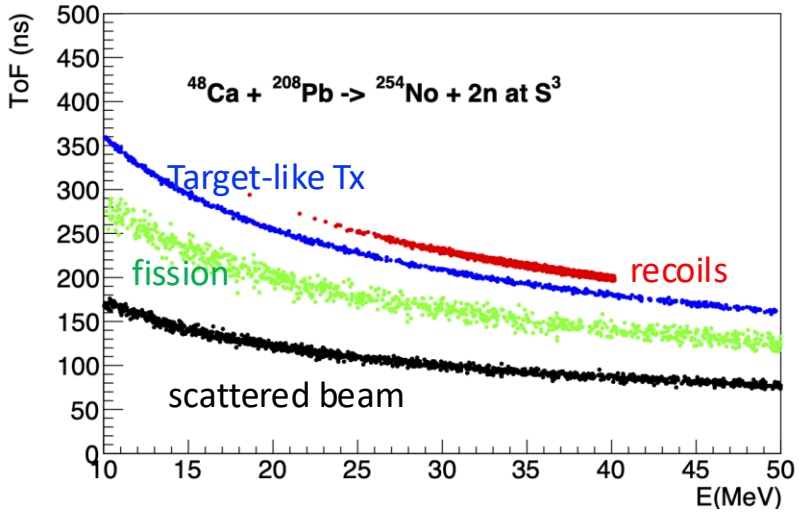




Time of Flight





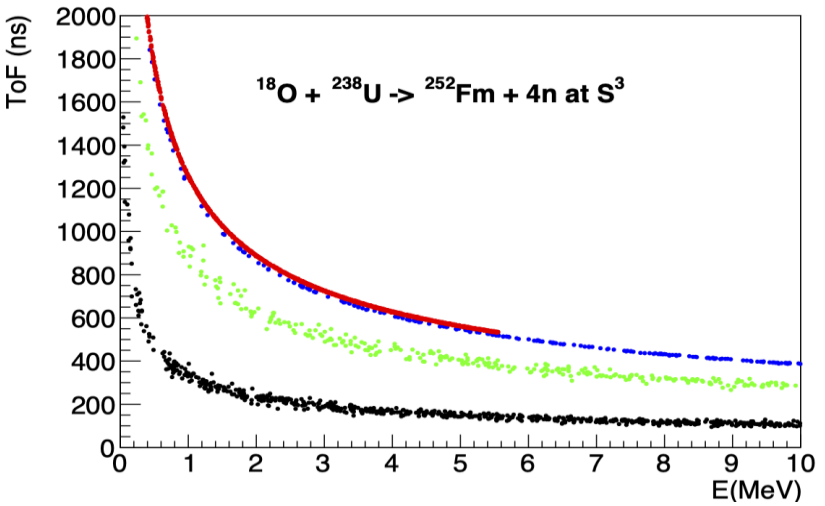


- 238U beam test :

Time of flight resolution FWHM 2.07 ns

→ 1.2 ns FWHM is needed to separate Evaporation residues

→ 800 ps FWHM would be desirable for Mass Resolution



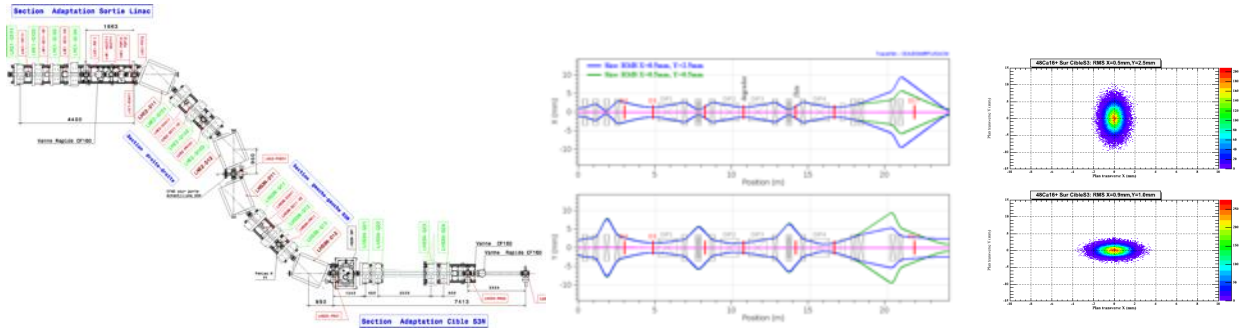
R. Chakma & K. Hauschild

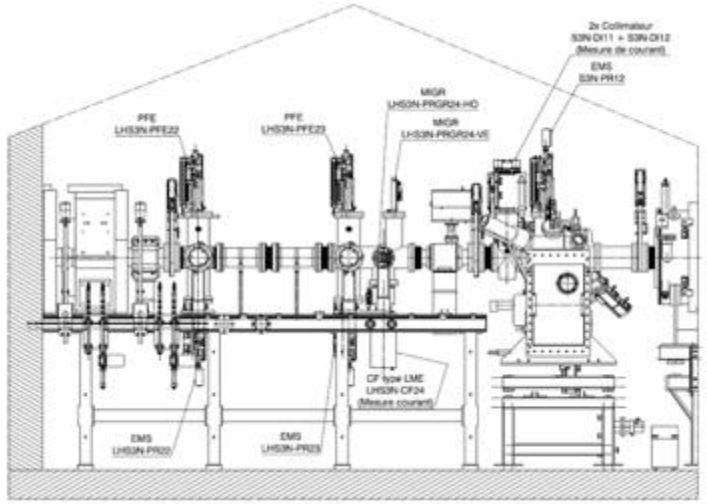
Work ongoing on the DSSD timing (software) to improve

Super Separator Spectrometer

First beam injection in S³

- Direct ^{40}Ar beam ; E = 0.73 - 5 MeV/u (100-140 μAe !!!)
- Injection beam line tuning
- Beam spot optimisation at the target position
- LINAC beam synchronisation / target wheel





NOVEMBER 2024

Slide courtesy to H. Savajols

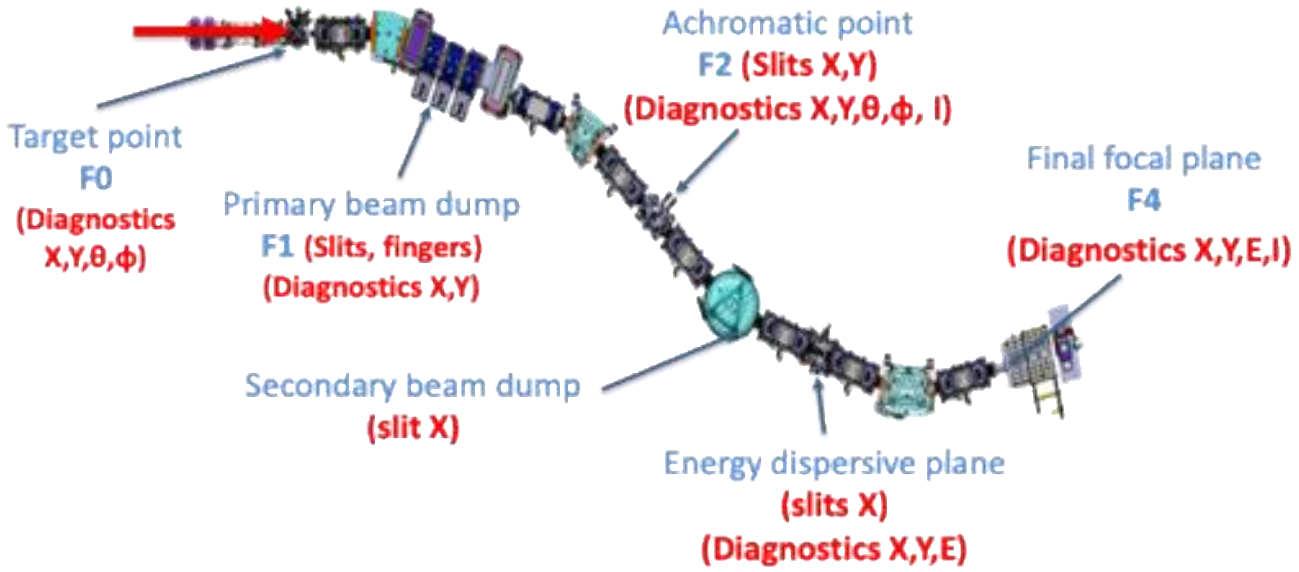
All 223 actions have been cleared out, huge involvement of GANIL staff (more than 30 people from various groups)

Next step: Spectrometer optical commissioning

- Direct and stripped beam up to the focal plane
- Progressive tuning of the elements (MA+ MS)
- Tools : diagnostics along the spectrometer + additional diagnostics at the focal plane (SIRIUS & LEB not used)

➔ E = 0.73-5 MeV/u and intensity of 10 pnA

➔ High intensity 3 alpha source (Bρ= 0.337 Tm and Eρ = 5.49 MV) for the mass separator if required



Order 0 : Optical Alignment

Order 1 : Measure of matrix elements in F1 and F2 (R12, R11, R33, R34, R16)
- Check : dispersion in F1 (R16=1.15cm/%) and achromatism in F2 (R16=R26=0, R12=R34=0, R11=1 …)

Higher orders :
- Measure and optimisation of matrix elements in F1 and F2 (T126 at F1, T122 and U1222: need a tracker)
- Thin degrader foil at the target position

Autumn 2025

Slide courtesy to H. Savajols

Thank you for your attention

S3 has been funded by the French Research Ministry, National Research Agency (ANR), through the EQUIPEX (EQUIPment of EXcellence) reference ANR-10EQPX- 46, the FEDER (Fonds Européen de Développement Economique et Régional), the CPER (Contrat Plan Etat Région), and supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357 and by the E.C.FP7-INFRASTRUCTURES 2007, SPIRAL2 Preparatory Phase, Grant agreement No.: 212692.

SIRIUS has been funded by the CPIER (Contrat Plan Etat Inter Régional) and the Région Normandie & the European Union through the RIN-Tremplin Grant SoSIRIUS.