TRACE telescopes: the coupling with the AD at LNL

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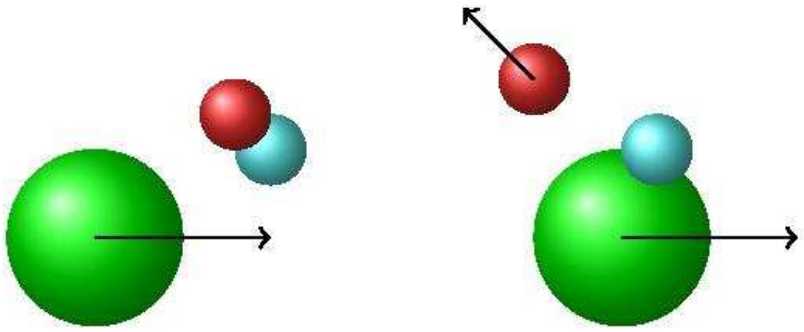
Outline

Introduction

Direct reaction (Transfer,Coulex, ...) as spectroscopic tool



- **Positions of levels** (Q-value)
- **Spin and parities** (Angular distributions)
- **Spectroscopic factor** (Cross sections)

Transfer with RIBs

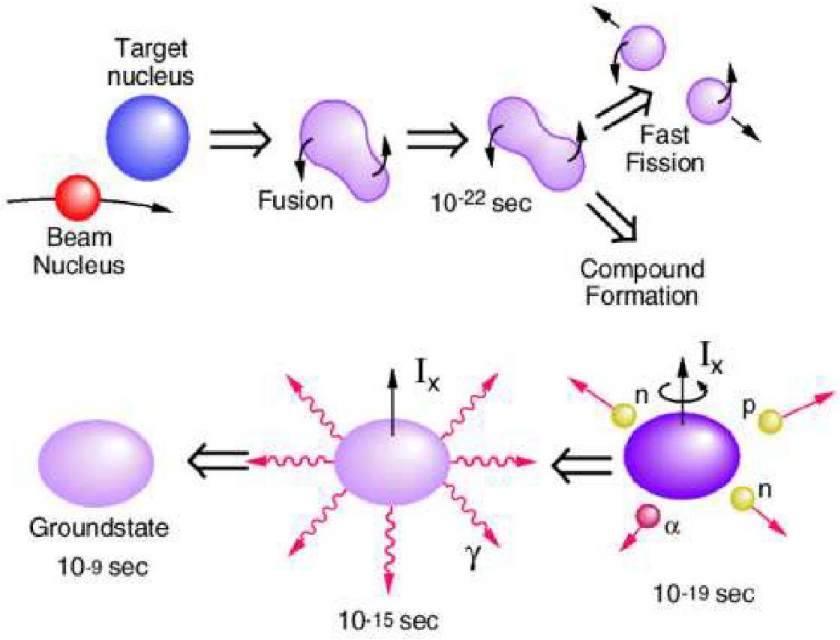
- Inverse kinematics
- Low intensity beams
- Detection: beam-like ejectile (spectrometer), target-like ejectile (Si det.)

Problems

- Energy (angular resolution)
- Efficiency
- Background
- target, beam tracker

Introduction

FE as spectroscopic tool



- **Channel Selection**
- **Doppler Correction**

FE with Intense beam

- Direct kinematics
- High intensity beams
- Detection: light charged particles

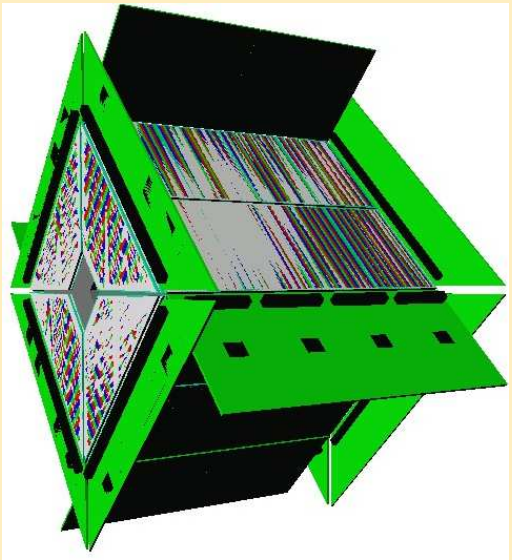
Problems

- Angular resolution
- Particel discrim. Efficiency
- Chilled target

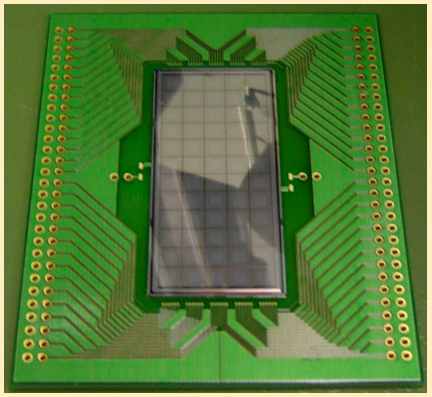
TRACE Design

TRacking Array for light Charged particle Ejectiles

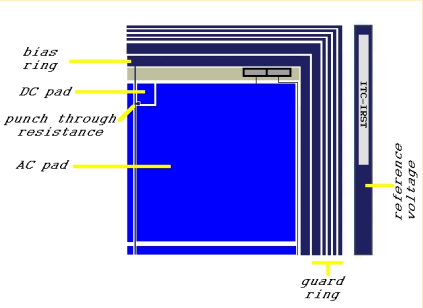
TRACE4,6,8



module



pad layout



- ΔE-E telescope array: 150μm and 1.5mm;
- PSA&ToF, $\sim$1E4 ch, 1$\div$2° 4x4 mm^2 at 10 cm;
- TRACE design: barrel, end-caps.

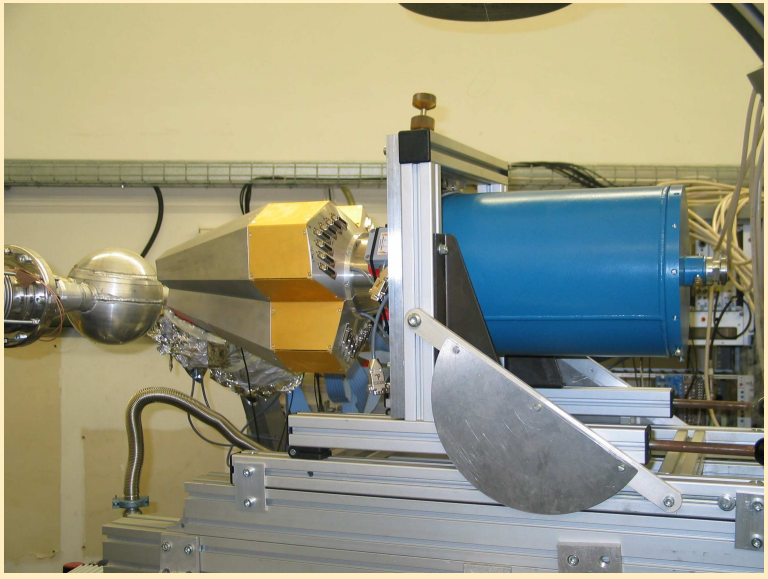
▸ simul

Ancillary impact

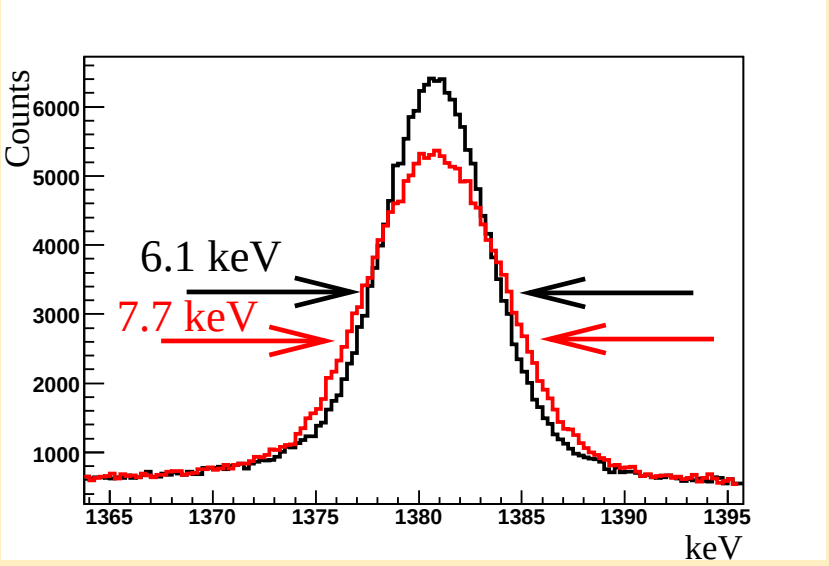
Experimental proof of principle

- Silicon center, PSA on Ge detector
- Full information on the DSSSD, PSA on Ge detector

AGATA cluster + ancillary

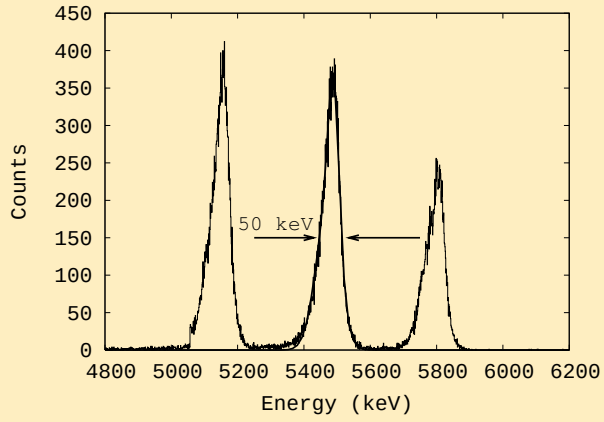


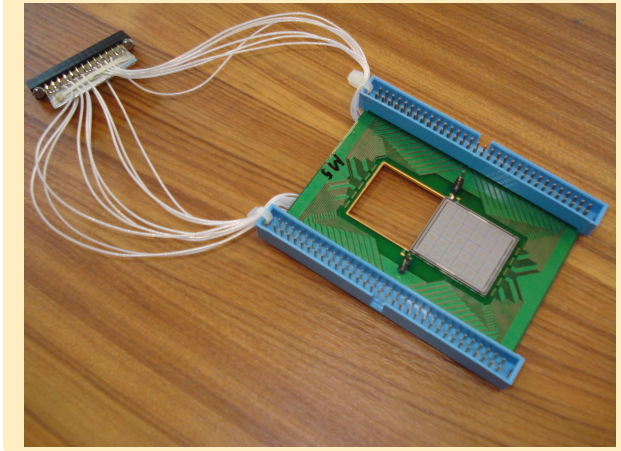
^{49}Ti Energy resolution

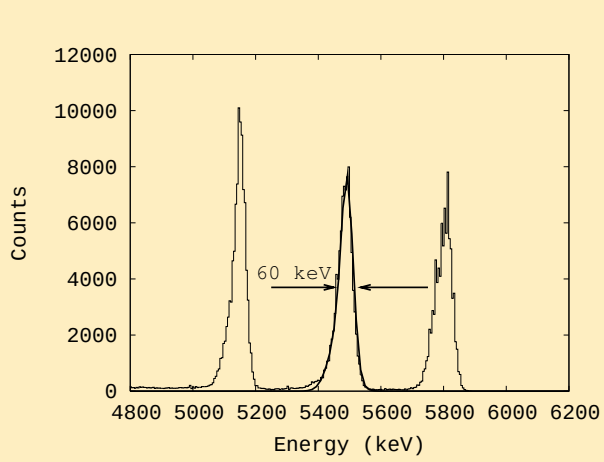


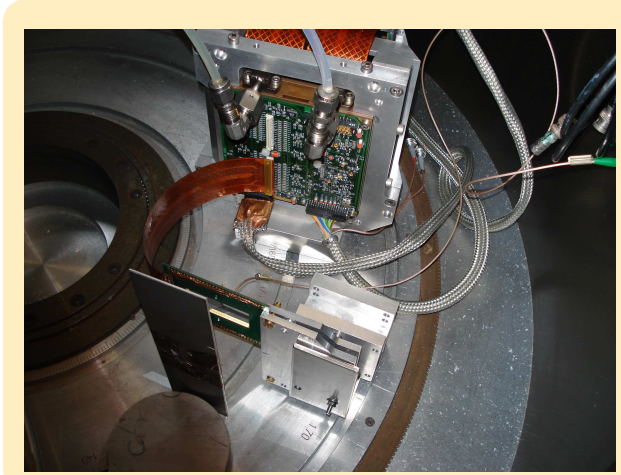
Tests on ITC-IRST detectors

300 μm,1 mm, 1.5 mm thickness, 1x1, 2x2, 4x4 mm^2, low resistivity, AC coupling.







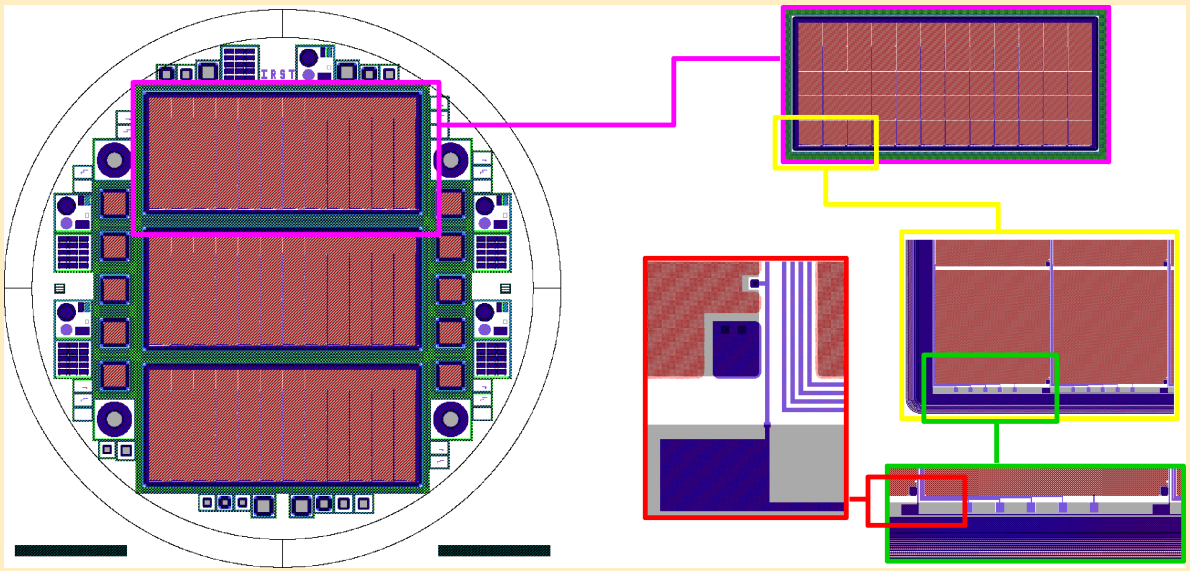


PAD sensor

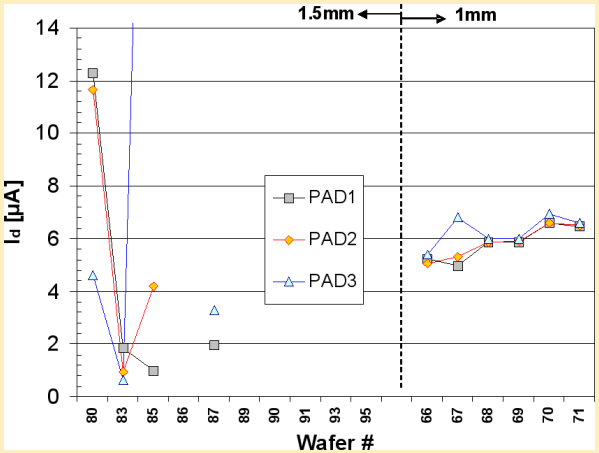
FBK-IRST

1÷1.5 mm thick detector with small dead layer

New detector batch



PAD sensor current



Digital electronics

Detector&Pre

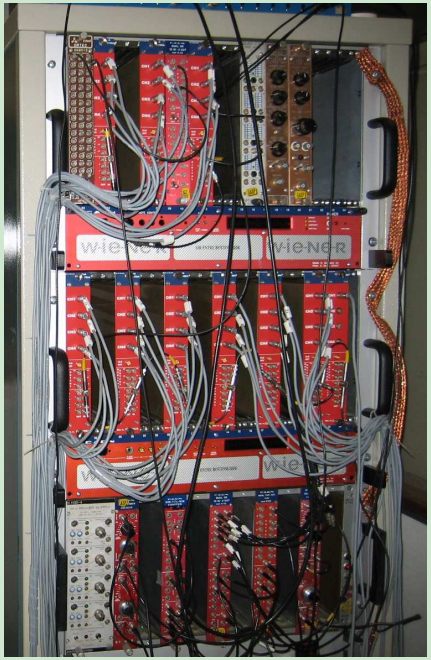
- TRACE, EUCLIDES
- Mesytec, Cologne, Mi, Pd

Preamplifier

- Noise Charac. (FFT)
- Energy Resolution
- Segmentation
- PSA

▸ psa

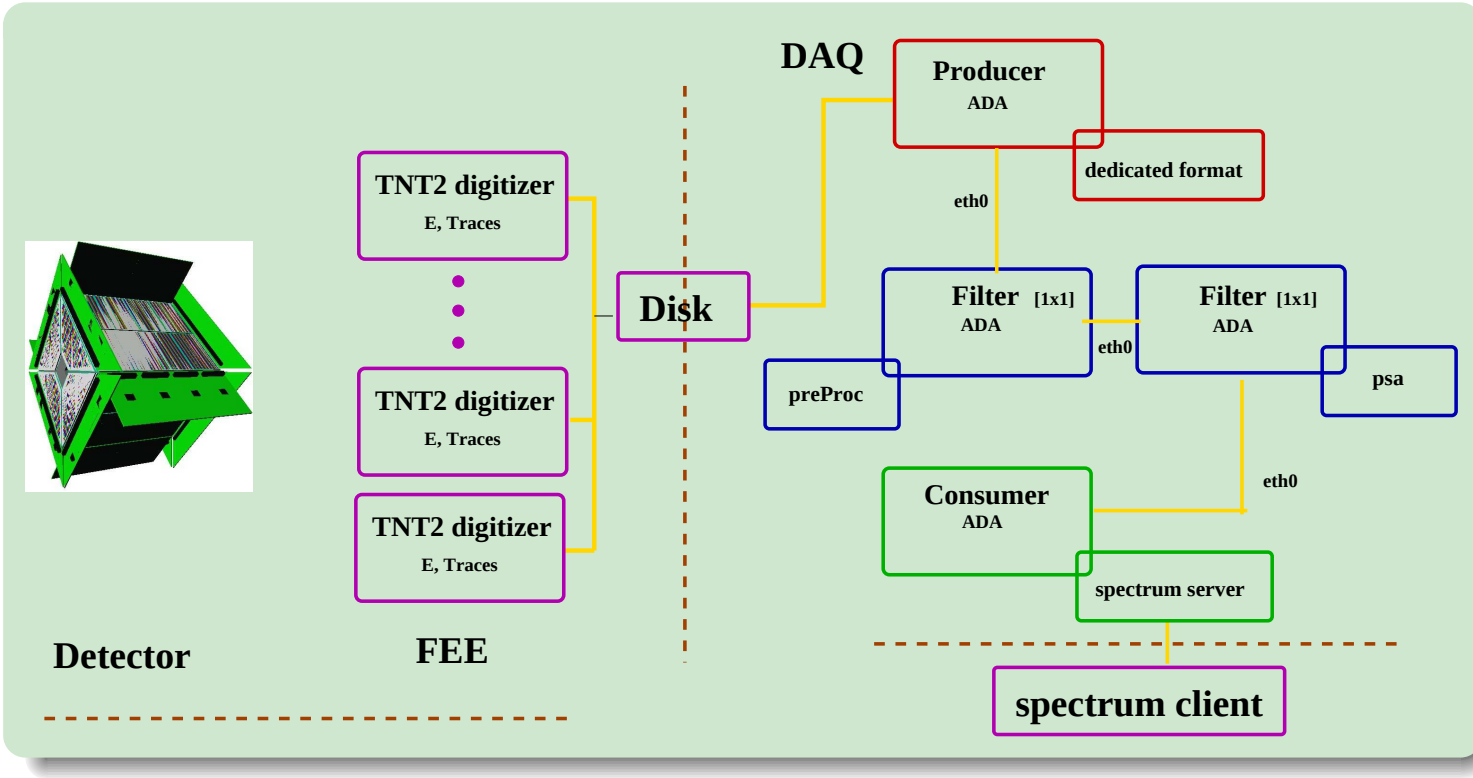
Digitizers



- 100 MHz
- 14 bit
- TUC SW

Trace OFF-LINE DAQ

- sync: self accomplished (1 card), ext built trigger (multiple cards)
- distributed processes

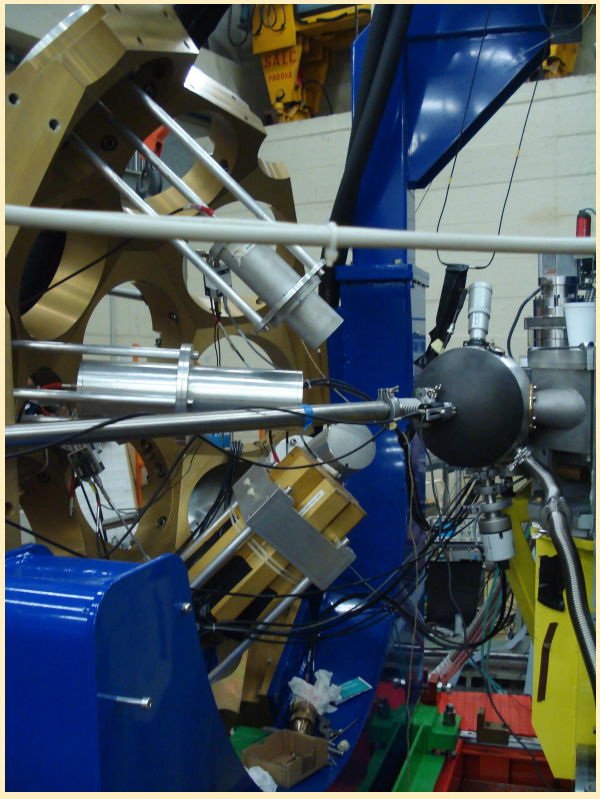


TRACE first in-beam experiment

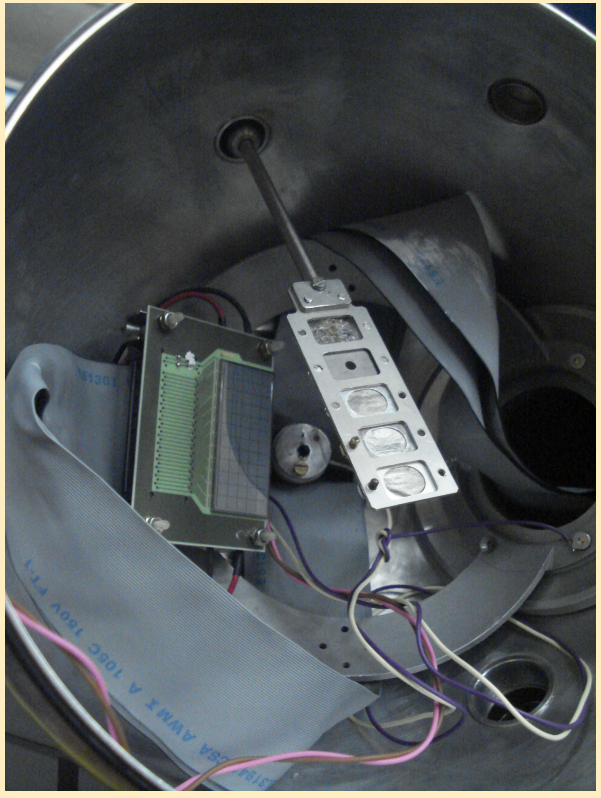
^{17}O(350 MeV)+^{208}Pb

2x120ch (high density con.), 2.5° ang res, 2x12.5° ang range.

TRACE+HELENA



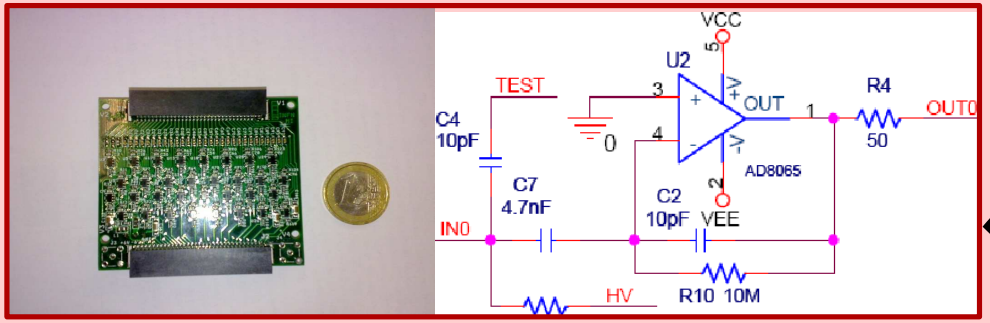
TRACE telescope

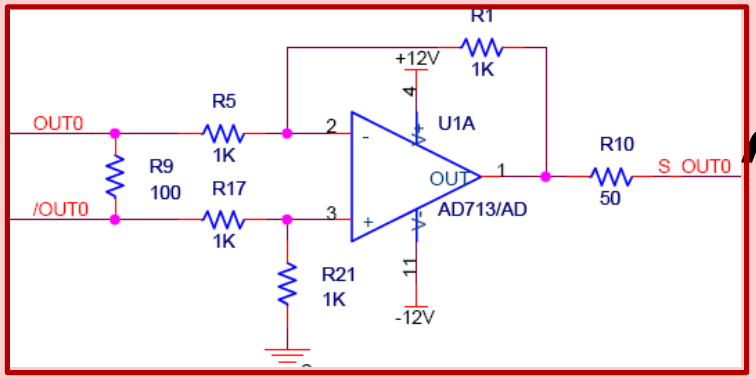


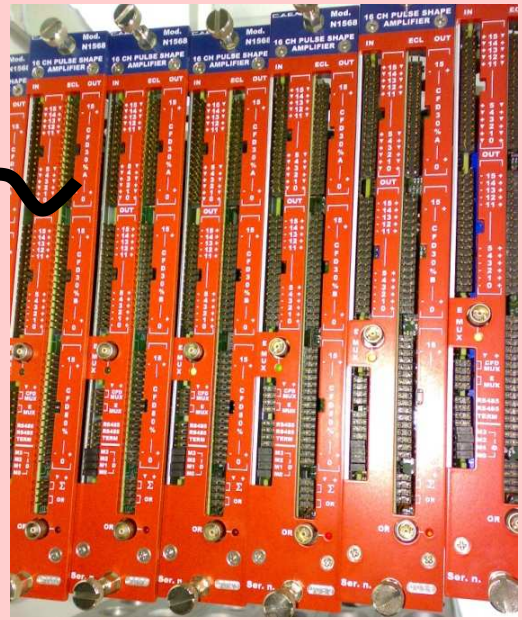
FEE&DAQ

Electronics coupling

FEE

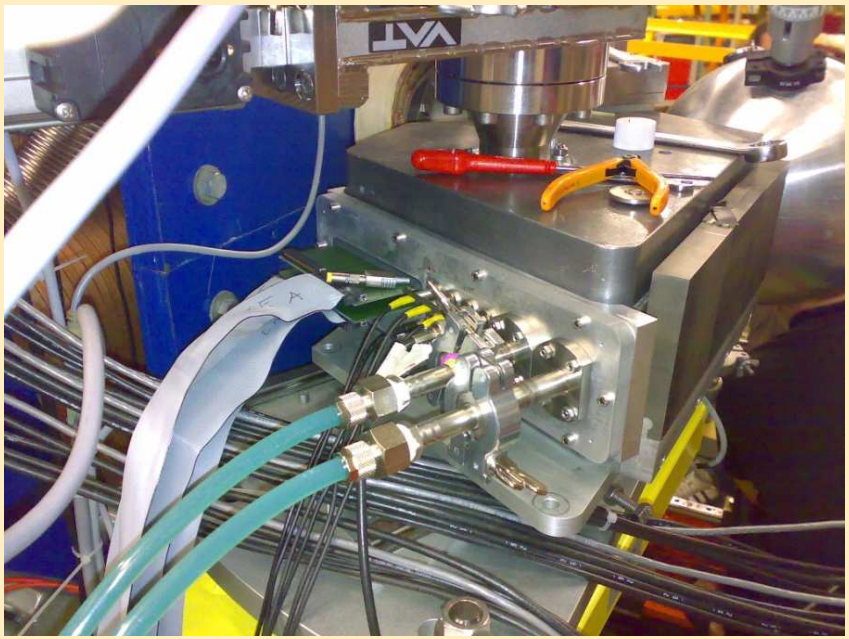




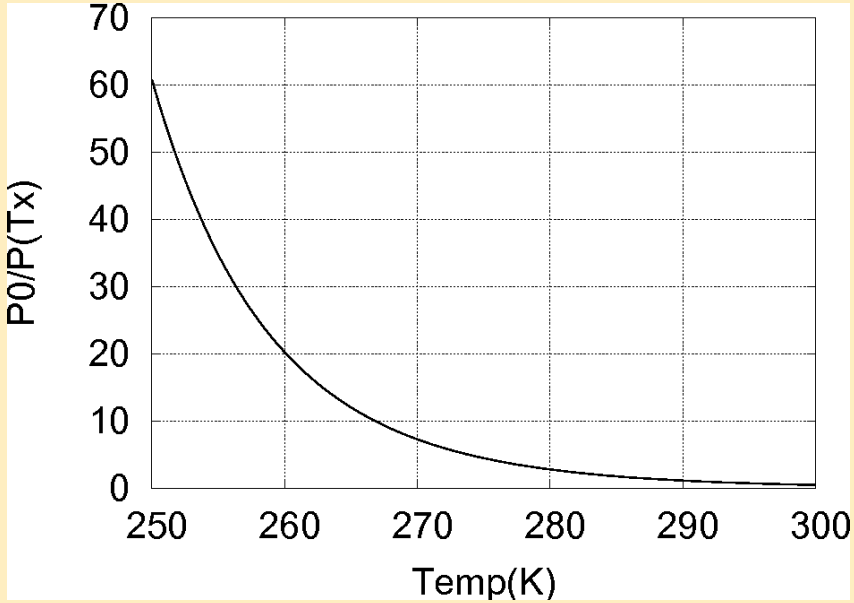


Cooling system
Noise reduction

- Ceramic PCB
- 2 Peltier cell(2x18W)
- water chiller(300 W,18 bar)

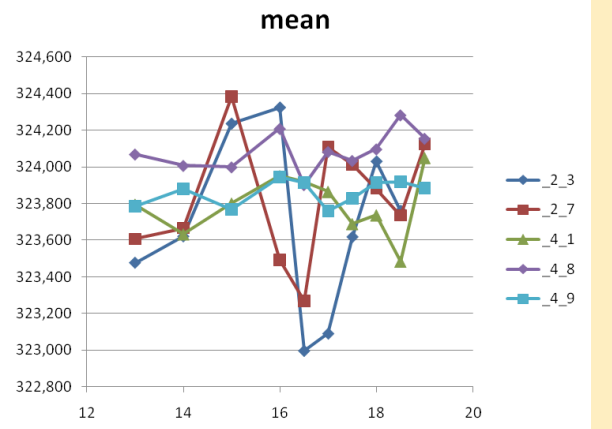


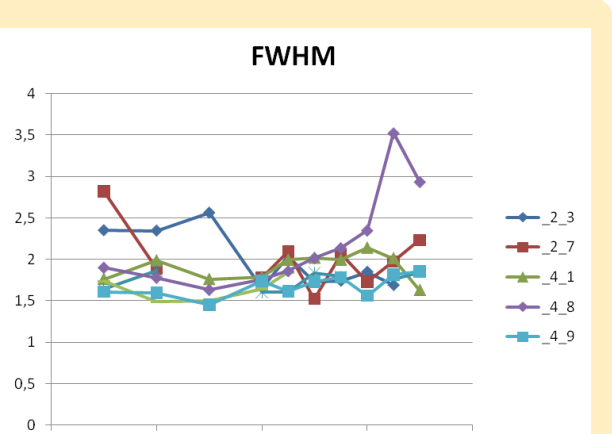
Thermal noise generation



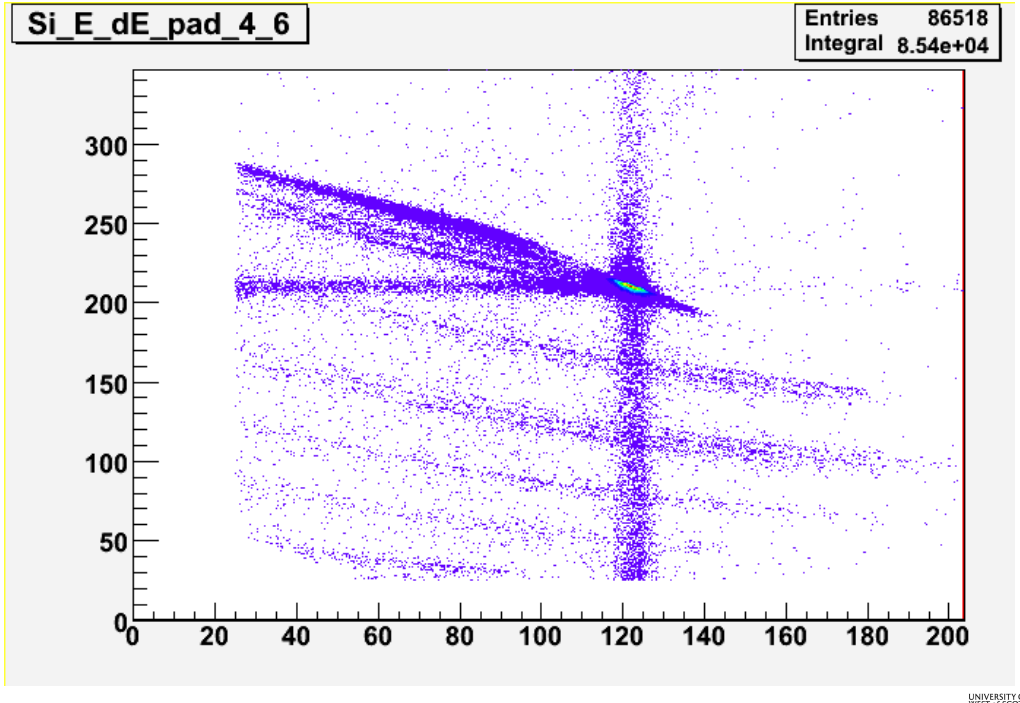
Results

Mass&Energy resolution



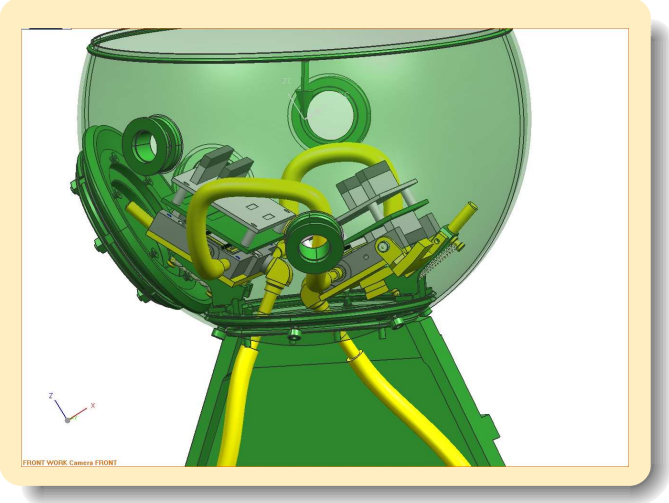


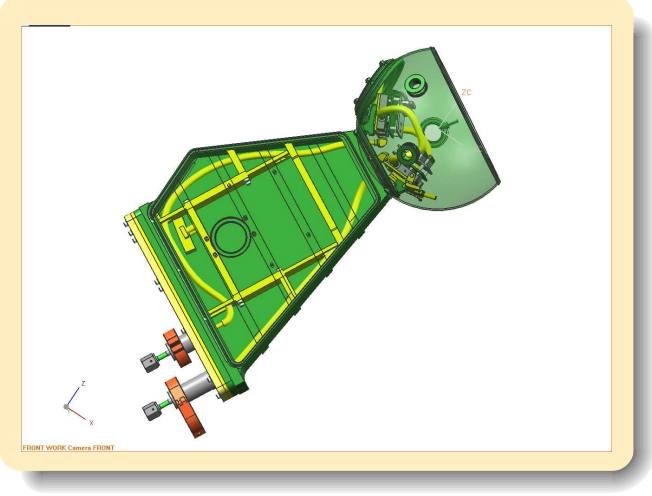
- Isotopic separation: O,N,C, etc
- Si Energy resolution ∼0.45%

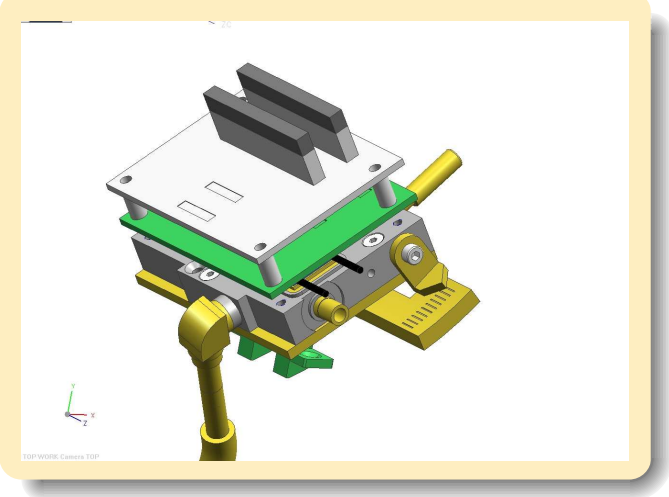


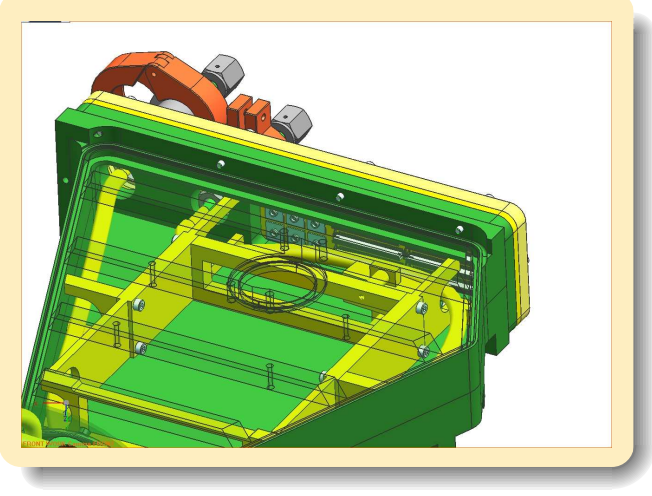
AD exp campaign

TRACE set-up for light ions

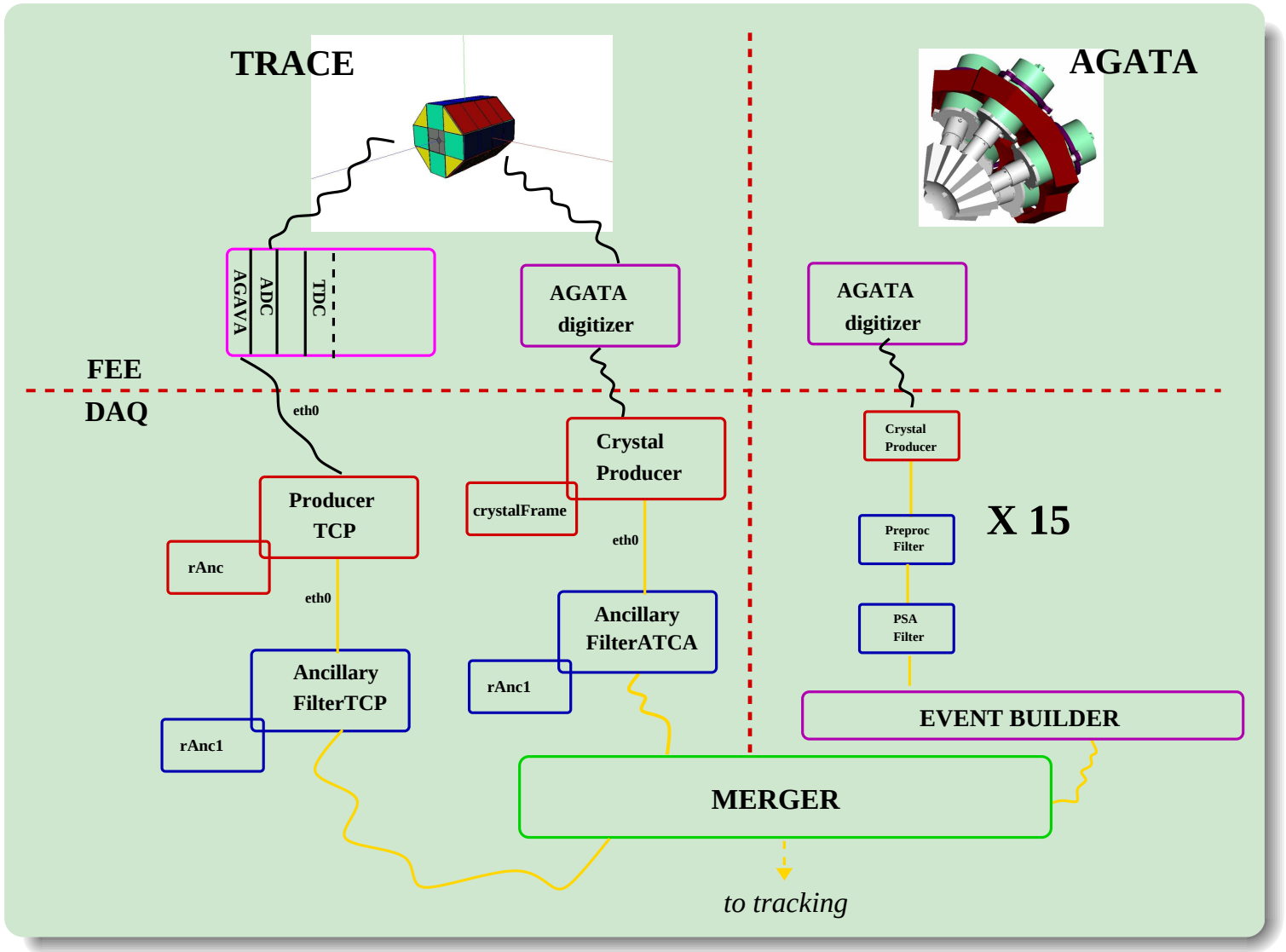






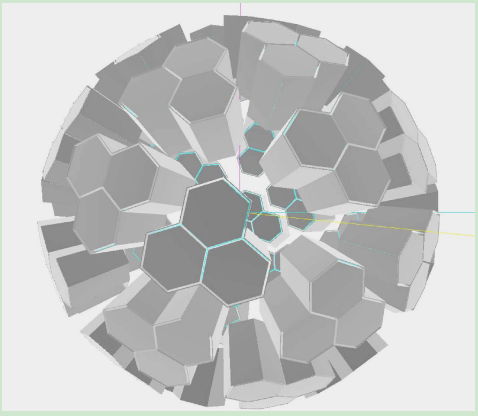


Trace ON-LINE DAQ

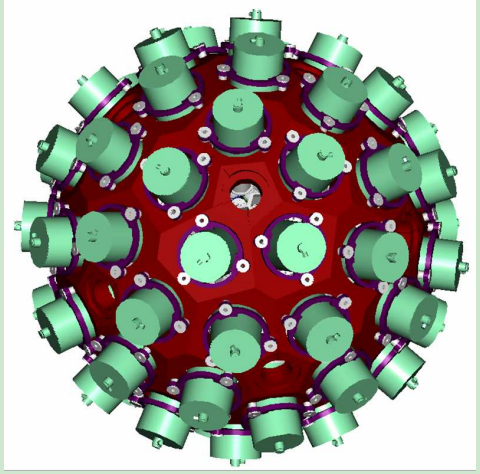


Perspectives

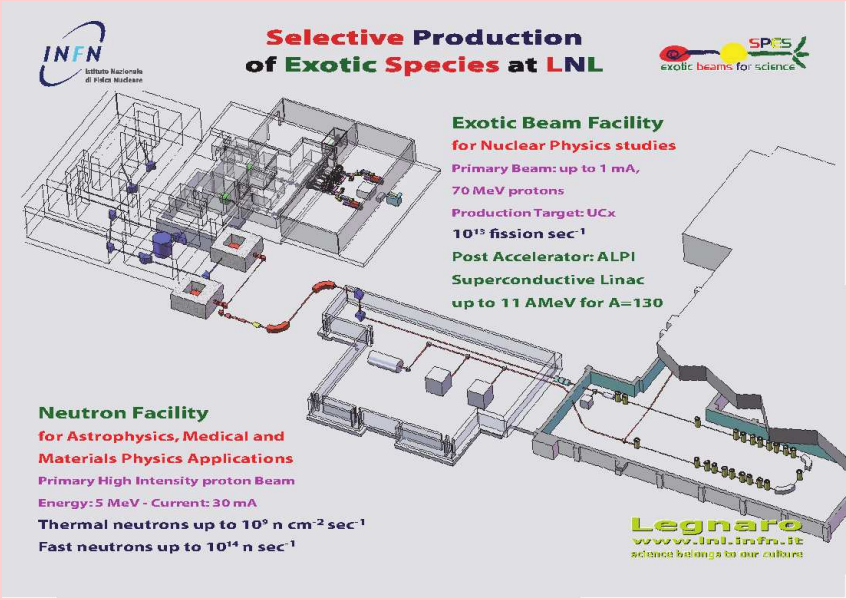
GALILEO



AGATA



SPES



Synergies

- GASPARD (SPIRAL2-GANIL)
- HYDE (FAIR-GSI)

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Summary and conclusions

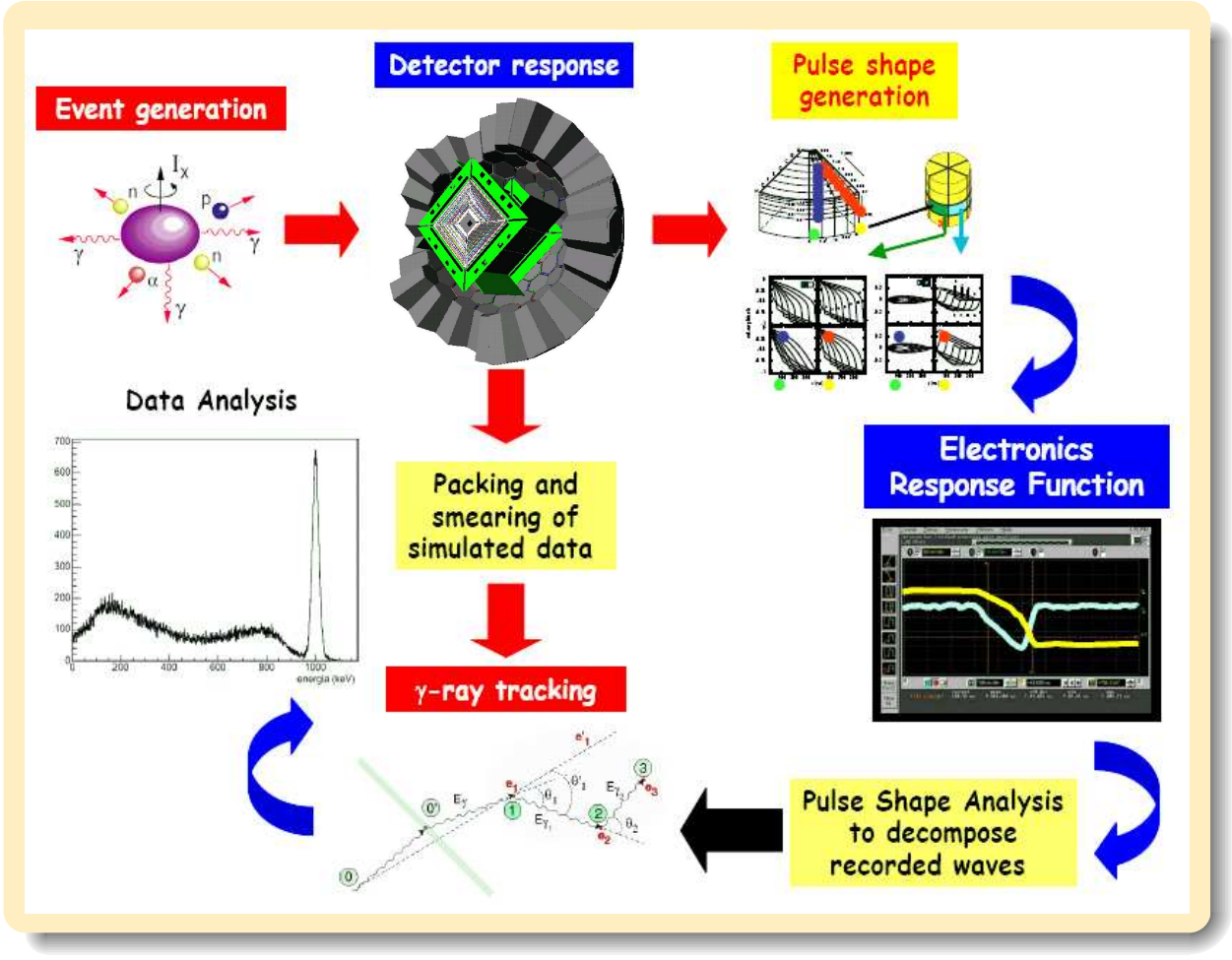
- TRACE telescopes are working;
- Coupling with AD achieved;
- Distributed OFF-LINE DAQ.

ON GOING

- GQR ^{208}Pb, ^{90}Zr: TRACE+AD+HELENA;
- ON-LINE distributed DAQ;
- PSA on light ions and particles.
- Development of new 1.5 mm thick detector;

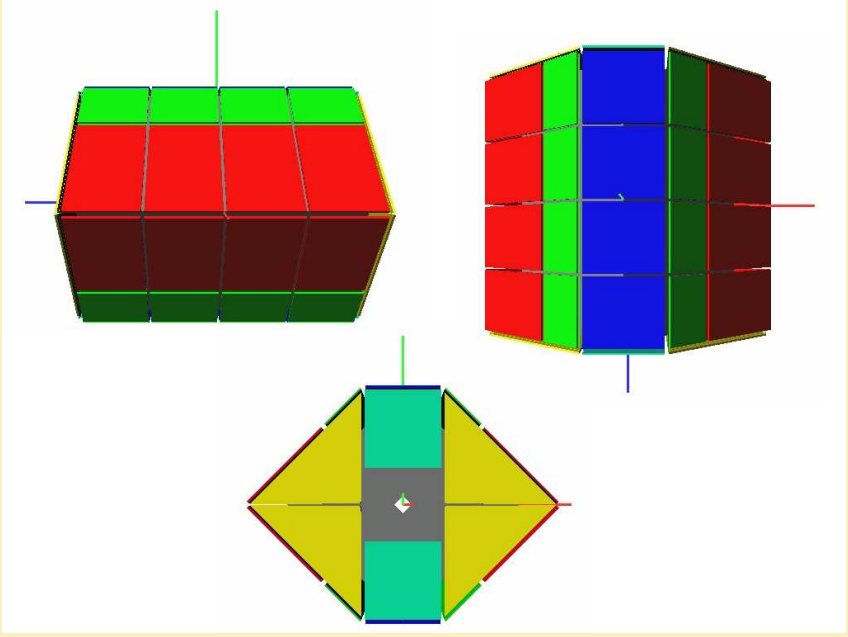
Simulation: framework

Event generator, radiation interaction, filter (PSA, tracking), data collection (matrices and spectra)

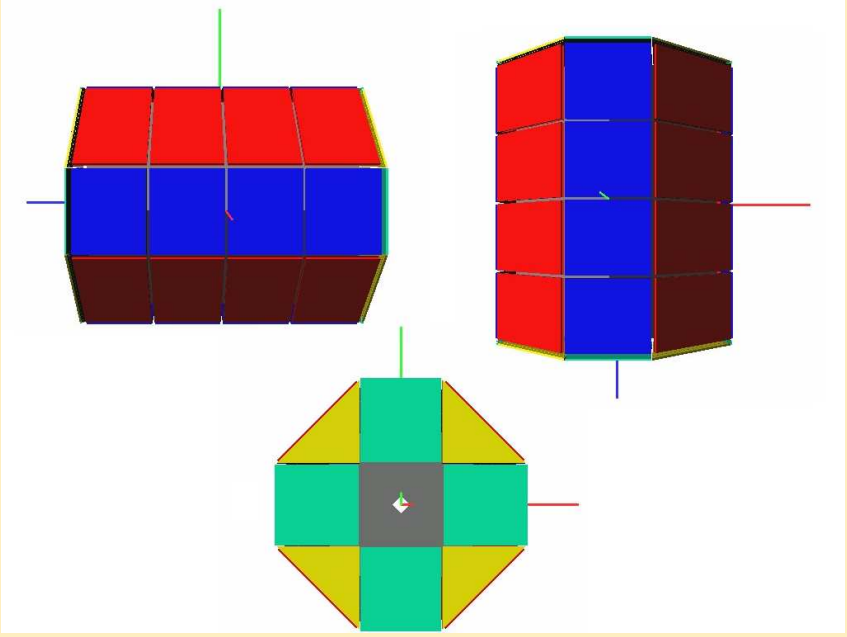


Simulation: framework
other configuration

TRACE6



TRACE8

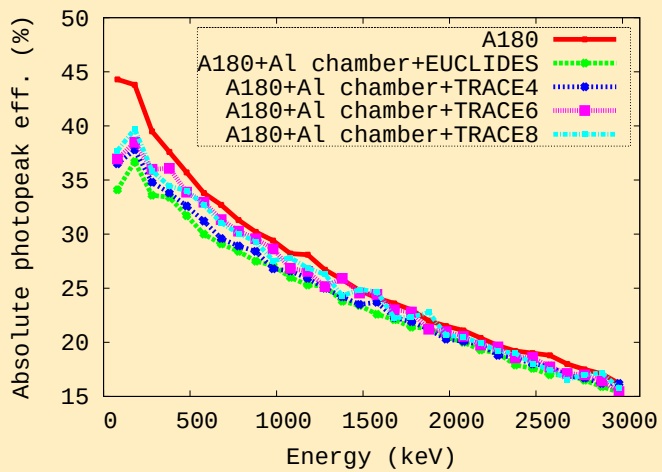


Transparency

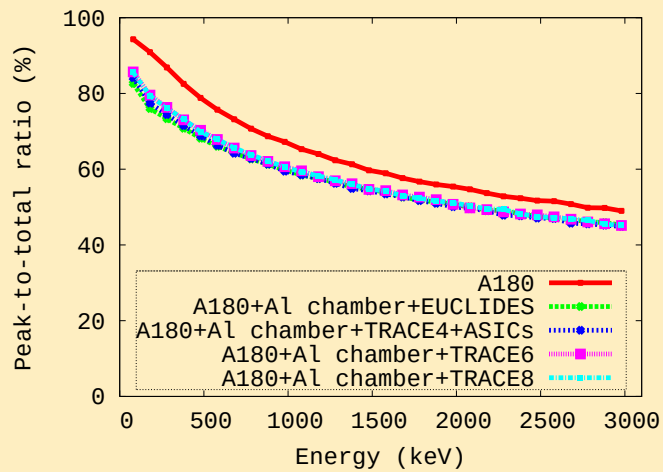
Rotational cascade (M_γ=30, $\frac{v}{c}$=0)

- **Full-energy eff.**:probability to detect the total energy of any emitted photon individually
- **Peak-to-total ratio**: the ratio of full energy efficiency to the total interaction efficiency.

Absolute photopeak eff. (%)



Peak-to-total ratio (%)

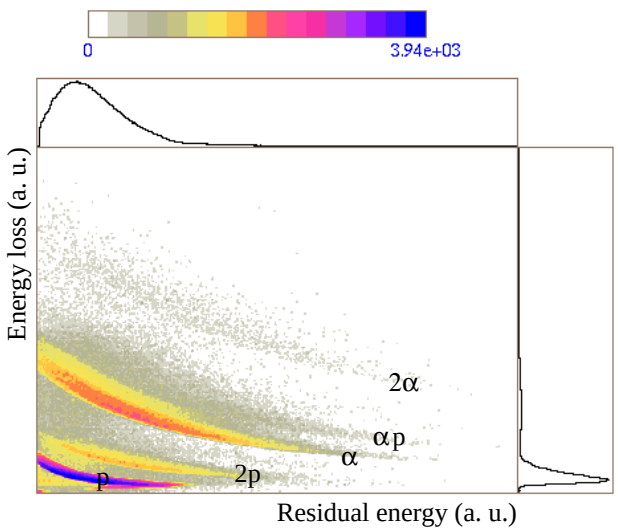


Particle discrimination

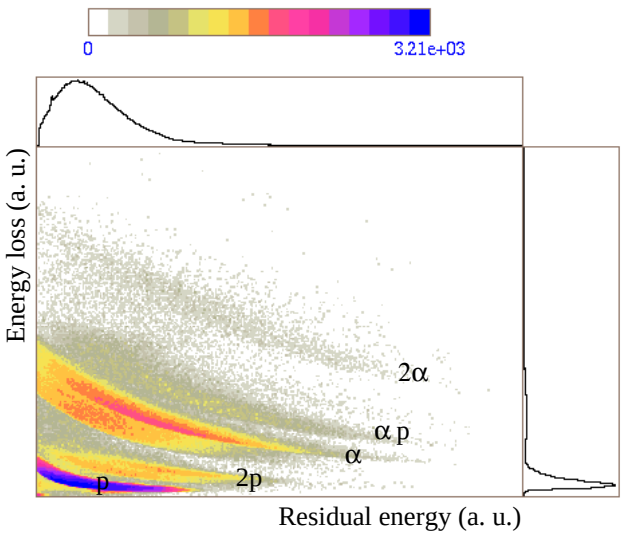
TRACE $E - \Delta E$ matrices, $^{32}S\,(125\,MeV) + ^{40}Ca$

- Bethe-Block expression: $-\frac{dE}{dx} \propto \frac{MZ^2z}{E}$
- $E\frac{dE}{dx}$ is a characteristic of the impinging particle.

TRACE8



TRACE4



Multiple hit probability and efficiency

TRACE8

Multiple hit event: more than one particle hits simultaneously the same segment

Probability *P(M,k)* to detect k particles over M emitted

Assumed isotropic fusion-evaporation (M=6), 1000 pads with 8x8 mm^2 dim.

$P(M,0) + P(M,1) \simeq 99\%$

Efficiency: broadening of the measured fold

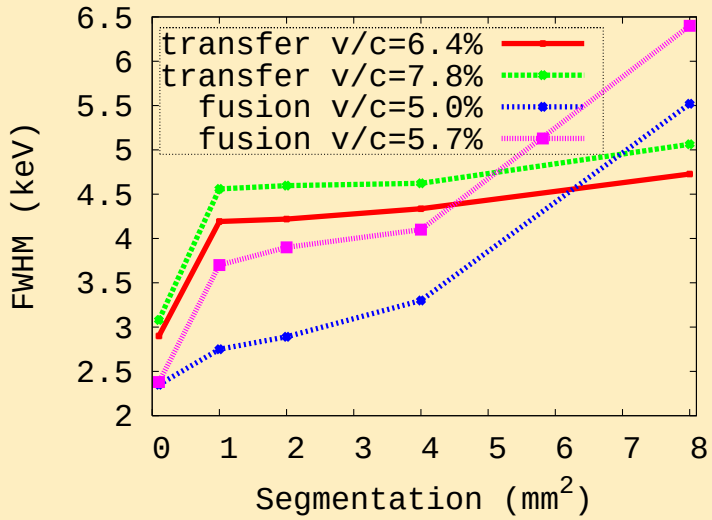
$$\frac{P(M,k)}{P(M,k-1)} \Longrightarrow \varepsilon_\alpha = 40\%,\ \varepsilon_p = 50\%$$

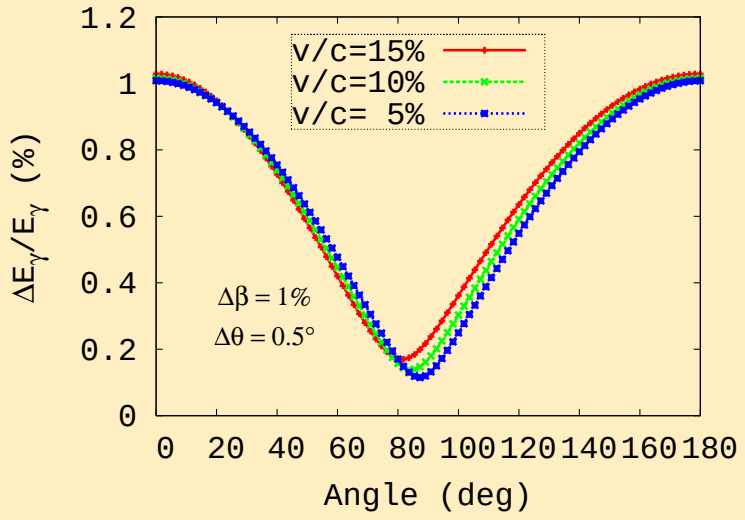
for $^{32}S\,(125\,MeV) + ^{40}Ca$, $\gamma_{2^+\rightarrow 0^+}$ $^{64}Ge(2\alpha)$, $\gamma_{2^+\rightarrow 0^+}$ $^{70}Se(2p)$

Doppler correction
TRACE8

Doppler broadening

- uncertainty in the photon emission angle
- uncertainty in the recoil energy
- intrinsic detector resolution





Ancillary comparison

TRACEx, EUCLIDES

	TRACE4	TRACE6	TRACE8	EUCLIDES
Telesc	40	52	48	40
Crys shap (E)	3	5	4	3
Channels(EΔE)	2856$\div$183E3	2435$\div$156E3	2304$\div$148E3	110
Rate (kHz)	1$\div$80	1$\div$80	1$\div$80	200
Chan selec	EΔE	EΔE	EΔE	EΔE
Abs.ph.eff. (%)	26.6	26.84	27.82	26.0
P/T (%)	58.49	59.57	59.26	58.46
FWHM (keV)	-	-	2.5$\div$5.5	7$\div$8
Solid angle (%)	90	$<$90	$<$90	$\sim$80(exp)
Eff (%)	55,42(sim)	52,38(sim)	53,40(sim)	50,40(exp)
Mass (EΔE, g)	705.5	601.6	569	107.4
Vol (EΔE, cm^3)	302.8	258.2	244.3	46.1

Conclusion

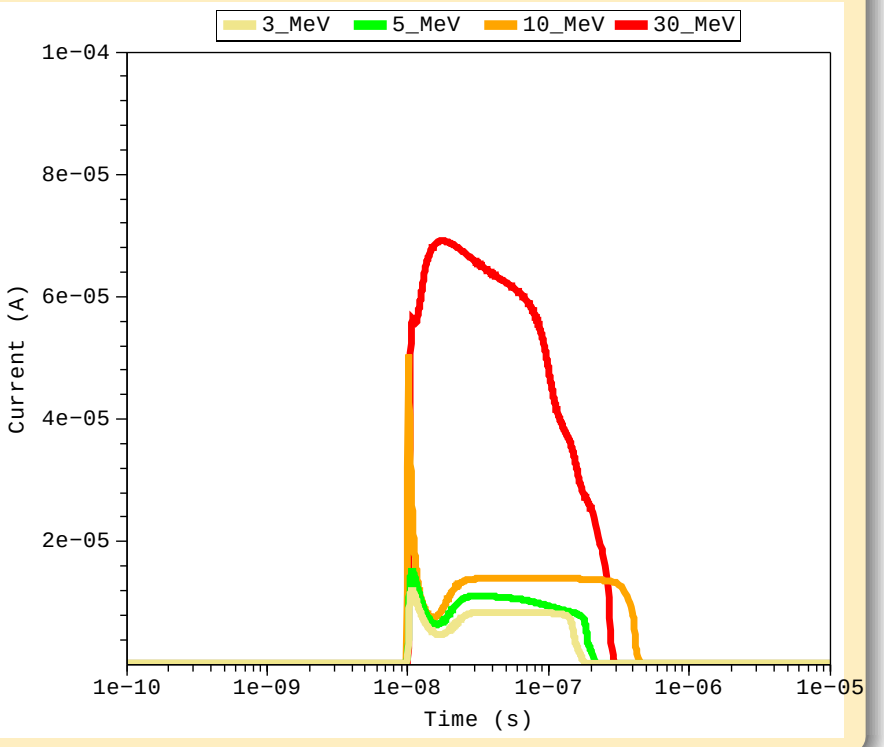
Telescope specifications

- ***D**etector:* Silicon.
- ***G**eometry* & dimensions: *solid angle coverage* $\approx$ 90%; *counting rate:* 20 kHz; *module dimensions* $\simeq$ 40 x 80 mm^2; ΔE: Si-pad det. $\simeq$ 150 μm thick, pad 4x4 mm^2; *E:* Si-pad det. 1.5 mm thick, pad 4x4 mm^2.
- ***A**ngular resolution:* $1 \div 2^\circ$ 4x4 mm^2 at 10 cm.
- ***E**nergy resolution:* <50 keV for 5.5 MeV α-particles.
- ***W**ide energy range:* 200 keV$\div$15 MeV for p, 60 MeV for α-particles.
- ***P**ulse shape analysis*

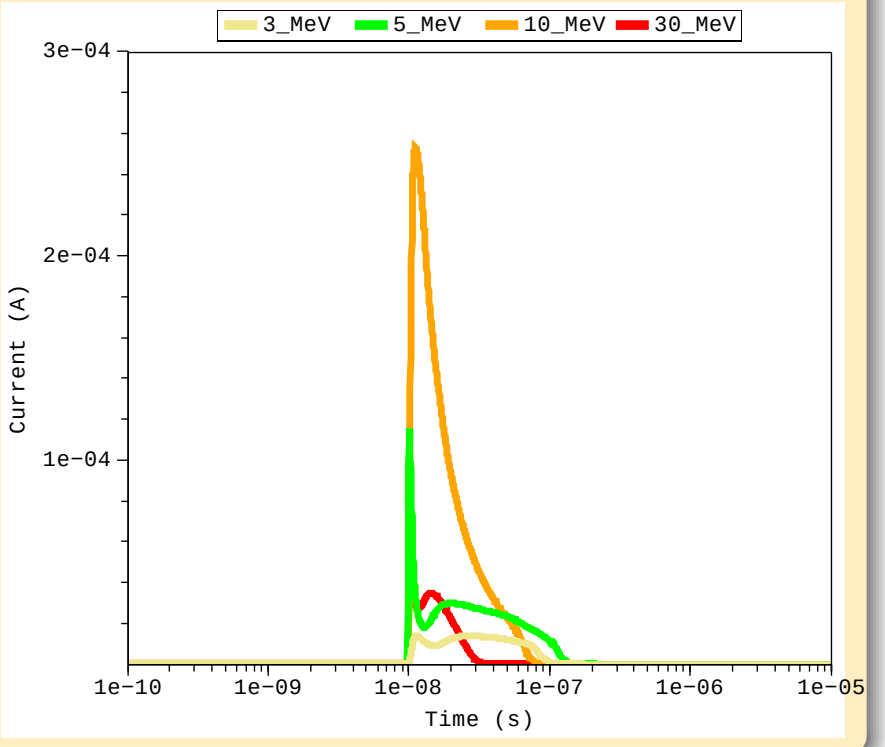
simul

Collecting electrodes

α family

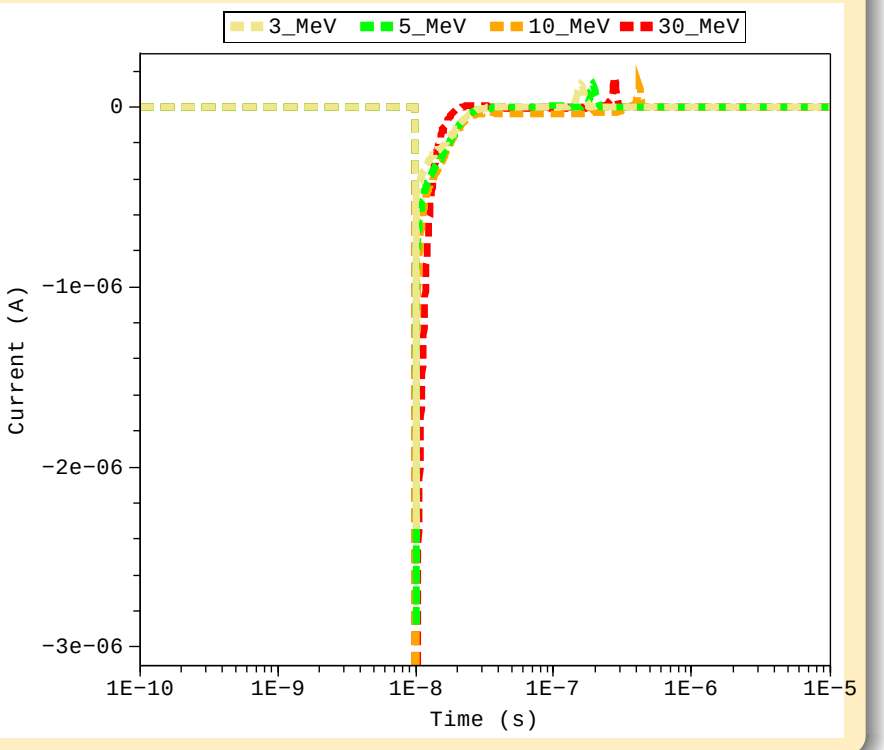


proton family

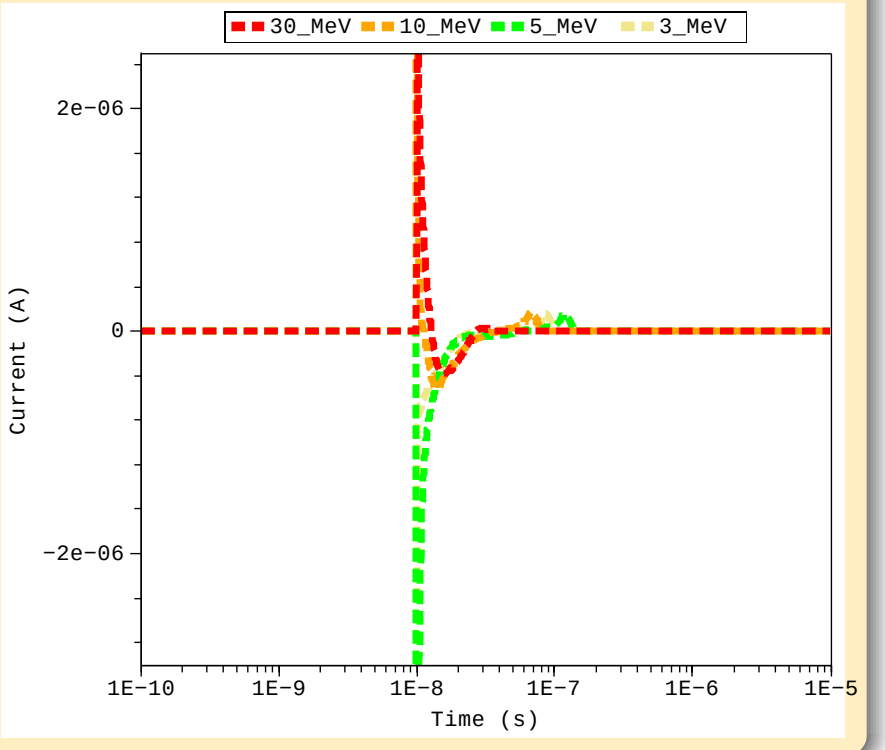


Neighbour electrodes

α family



proton family



▸ psa