

## Status of the TRACE array

**D. Mengoni**

University of the West of Scotland, Paisley - U.K.  
INFN - Sezione di Padova, Padova - Italy

*SPES workshop, LNL - Italy*  
*Nov 15<sup>th</sup> ÷ 17<sup>th</sup>, 2010*

# Outline

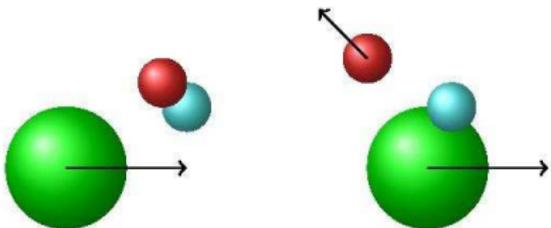
- 1 Introduction
  - TRACE Principle
- 2 Ancillary detector
  - AGATA Campaign
- 3 Plan&Fundings
- 4 Conclusion





# 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

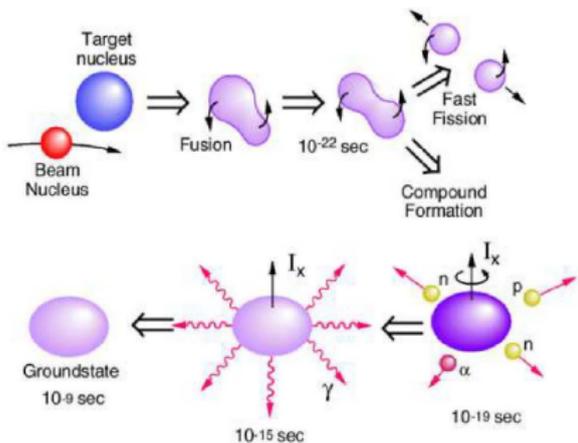
- Inverse kinematics
- Low intensity beams
- Detection: beam-like ejectile (spectrometer), target-like ejectile (Si det.)

## Constraints

- 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

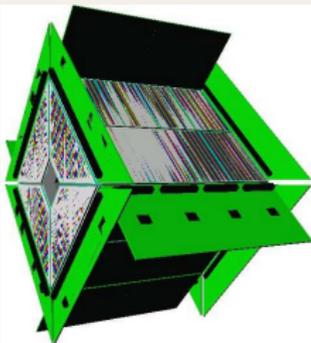
### Constraints

- Angular resolution
- Particle discrim. Efficiency
- Chilled target

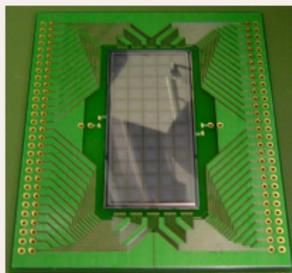
# TRACE Design

TRacking Array for light Charged particle Ejectiles

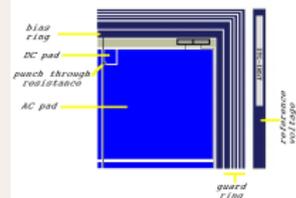
## TRACE4,6,8



## module



## pad layout

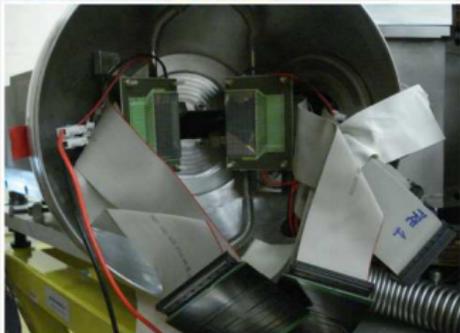
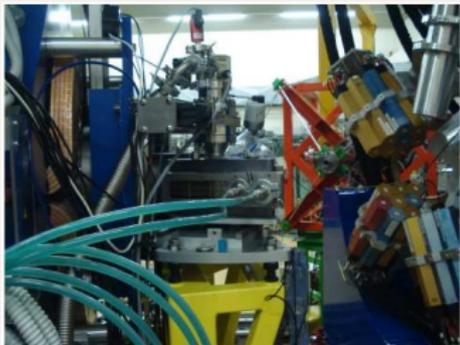


- $\Delta E$ -E telescope array:  $150\mu\text{m}$  and  $1.5\text{mm}$ ;
- **high segmentation** and high-count rate;
- **digital PSA**,  $\sim 1\text{E}4$  ch,  $1\div 2^\circ$   $4\times 4\text{ mm}^2$  at  $10\text{ cm}$ ;
- TRACE design: barrel, end-caps.

▶ simul

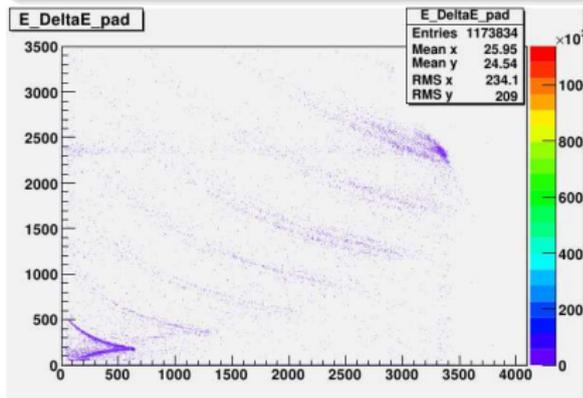
# Deep Inelastic: $^{17}\text{O}(340\text{MeV})+^{208}\text{Pb}$

Spokesperson: R. Nicolini & D. Mengoni - GQR in  $^{207,208}\text{Pb}, ^{90}\text{Zr}$



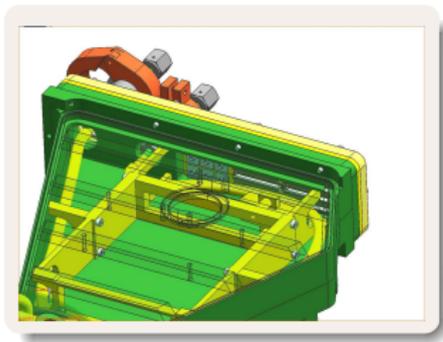
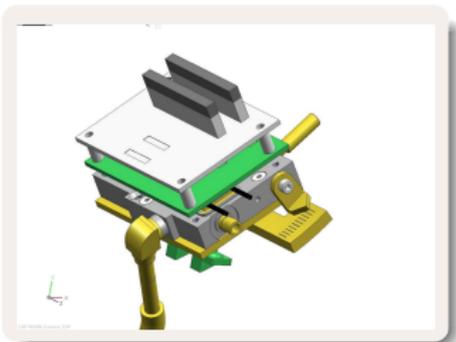
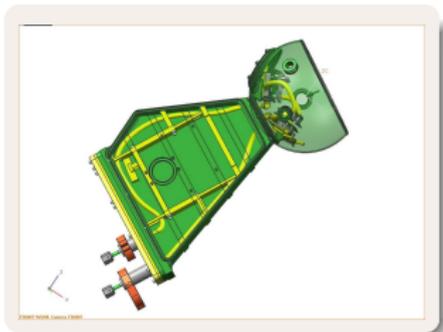
Energy resolution (chilled) 0.4 %

GQR (pigmy and fine structure)  
AD+TRACE+HELENA



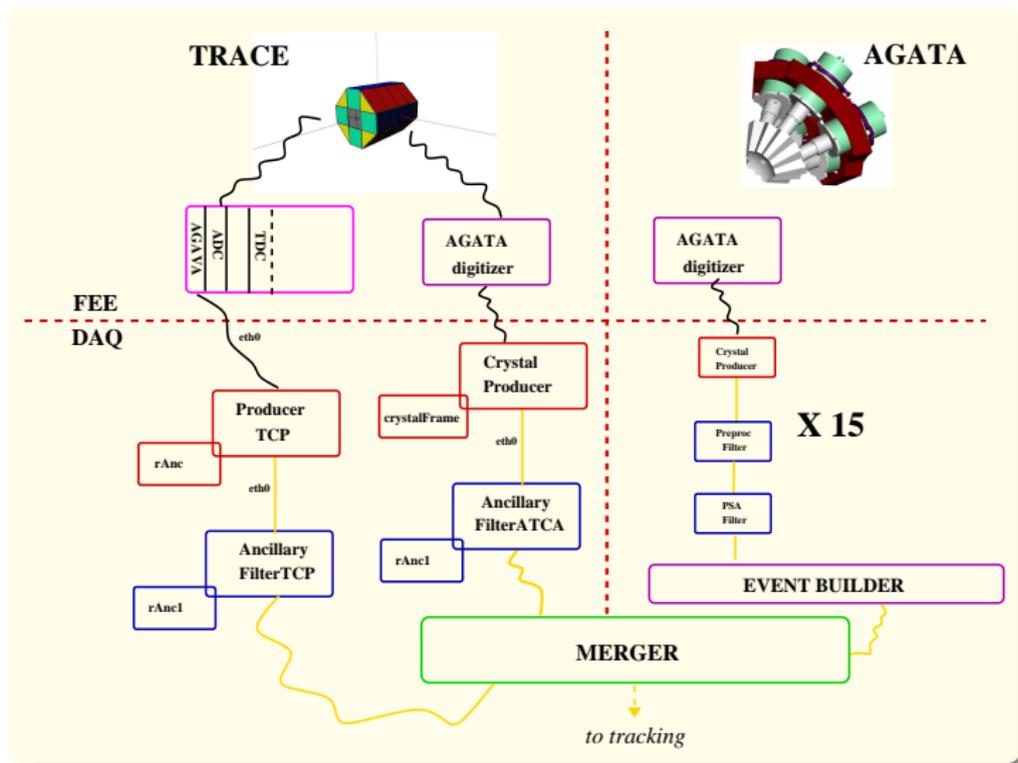
# TRACE MECHANICS

cooling, angular range



# TRACE ON-LINE DAQ

modular electronics



# Ministry fundings & organization

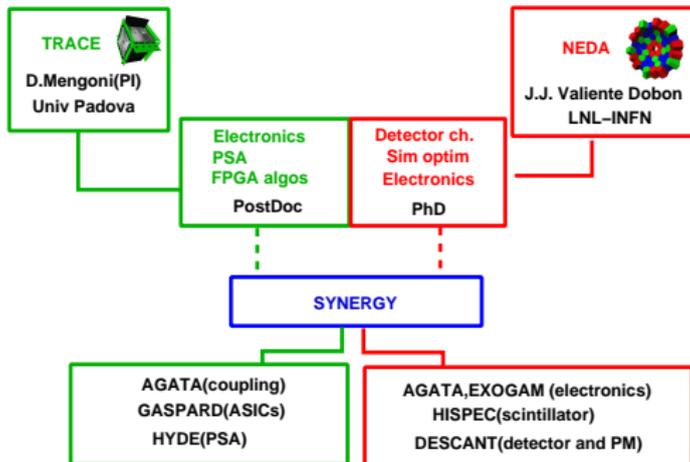
2 research units: D. Mengoni(PI), J. J. Valiente Dobón

## Research units

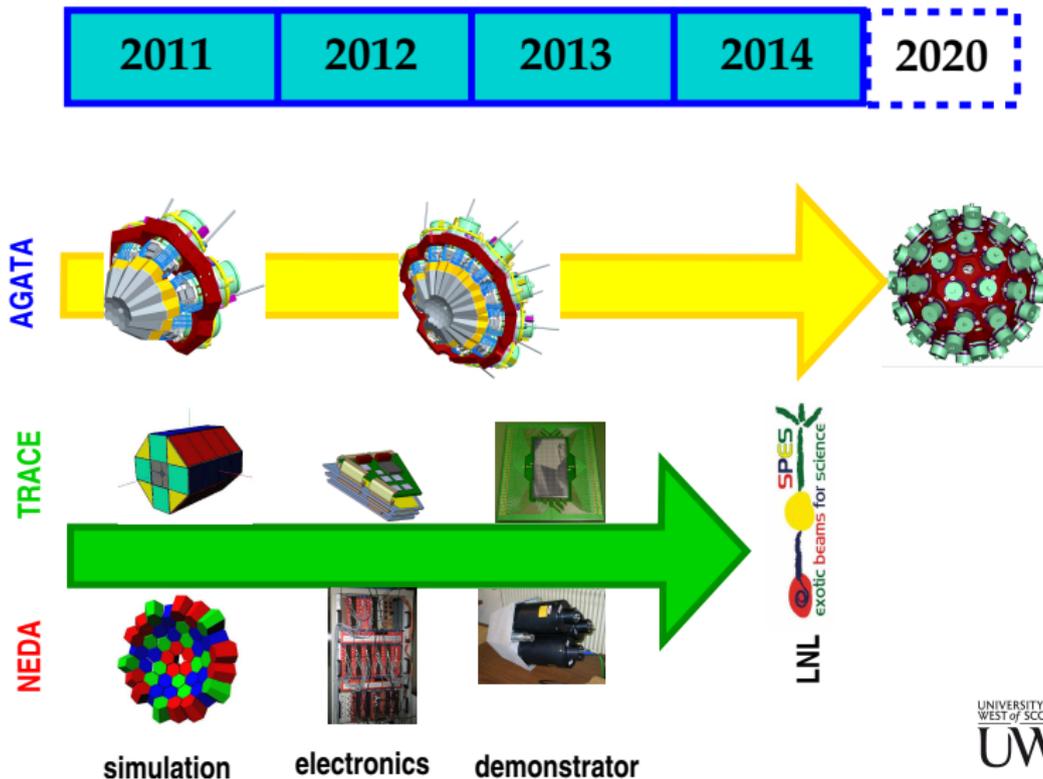
- **Università di Padova:**  
300 k€-TRACE
- **INFN-LNL:** 300 k€-NEDA  
(FP7-Infrastructure:Task5.8)

## Collaboration

- **Università di Padova**
- **INFN: LNL,Pd,Mi,Pg ...**

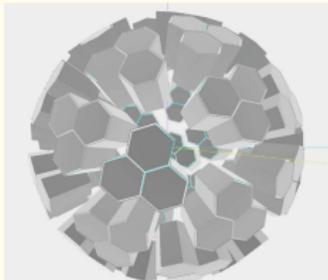


# Timescale

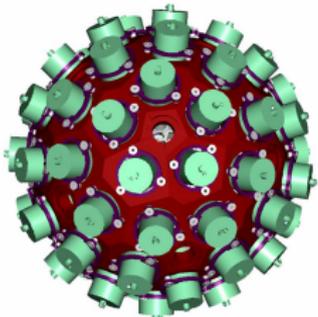


# Perspectives

## GALILEO



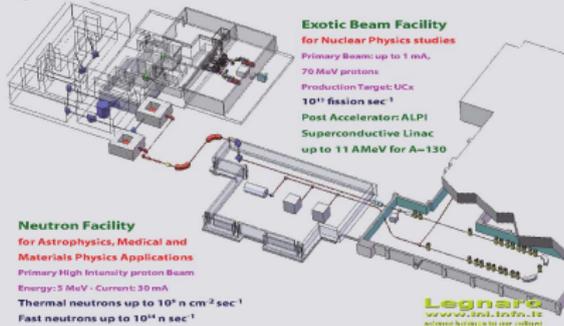
## AGATA



## SPES



### Selective Production of Exotic Species at LNL



## Synergies

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

# Summary and conclusions

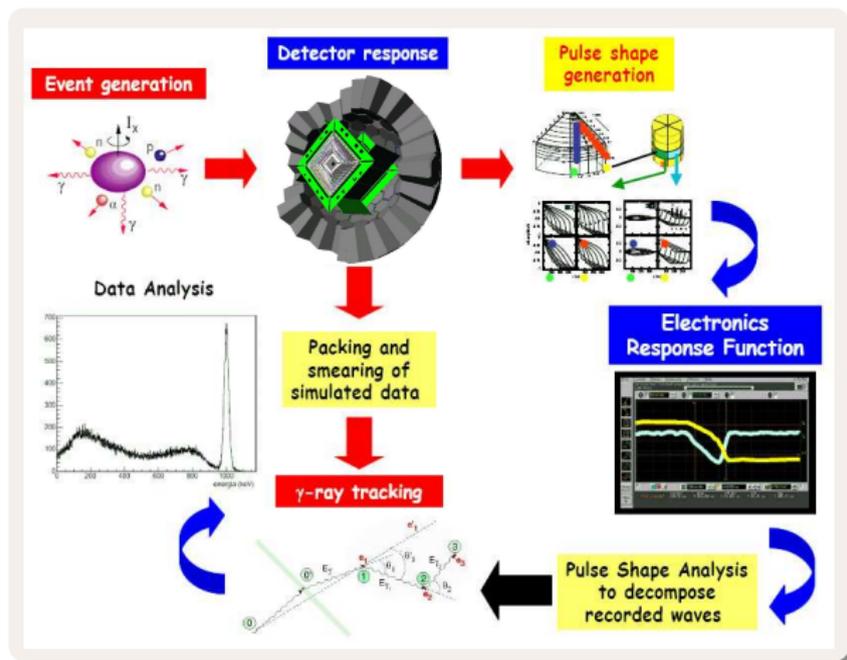
- Si array for DR and FE reactions;
- Coupling with gamma spectrometer (AD);
- GQR  $^{208}\text{Pb}$ ,  $^{90}\text{Zr}$ : TRACE+AD+HELENA;

## final remarks

- Versatile set-up
- PSA on light ions and particles.
- **integrated FEE**
- TRACE Demo ready for SPES

# Simulation: framework

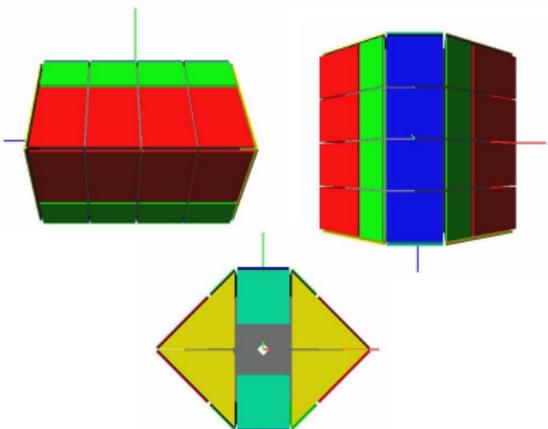
Event generator, radiation interaction, filter (PSA, tracking), data collection (matrices and spectra)



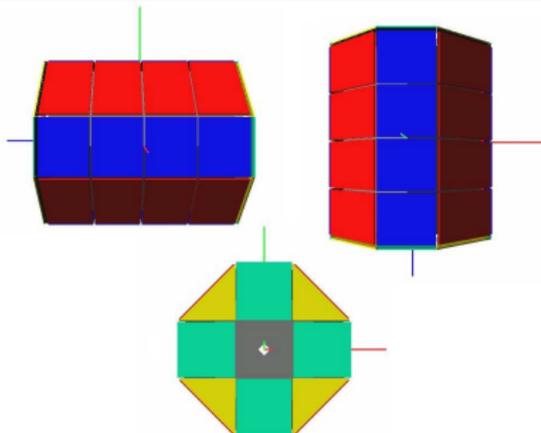
# Simulation: framework

other configuration

## TRACE6



## TRACE8

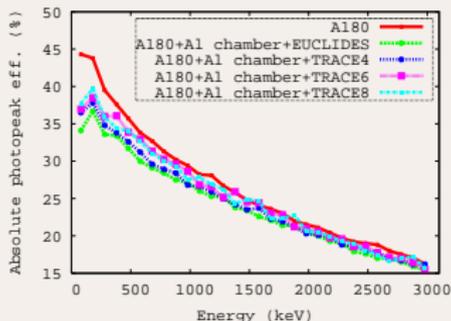


# Transparency

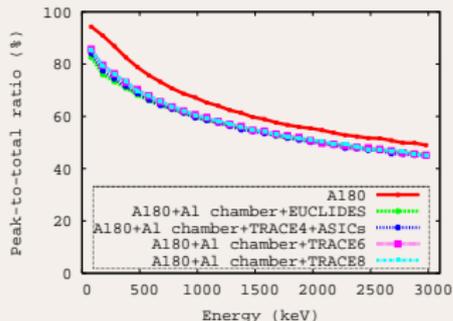
Rotational cascade ( $M_\gamma=30$ ,  $\frac{v}{c}=0$ )

- **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 (%)

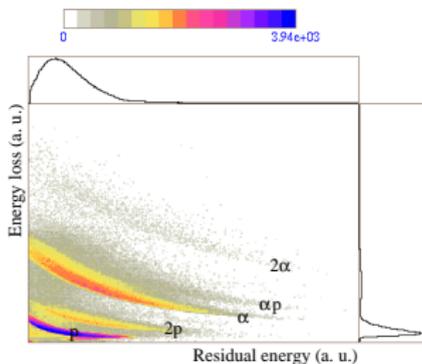


# Particle discrimination

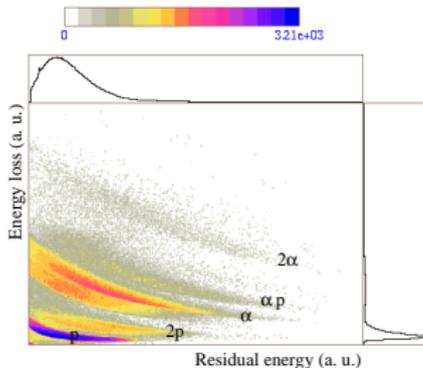
TRACE  $E - \Delta E$  matrices,  $^{32}\text{S}$  (125 MeV) +  $^{40}\text{Ca}$

- 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  $8 \times 8$  mm<sup>2</sup> dim.

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

**Efficiency:** broadening of the measured fold

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

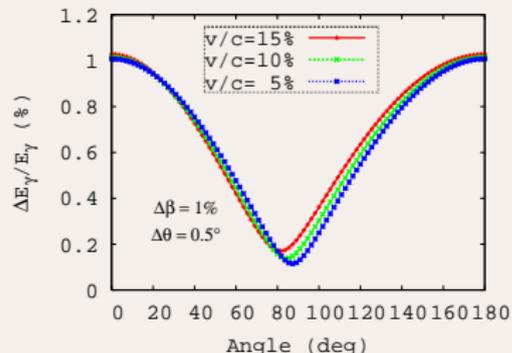
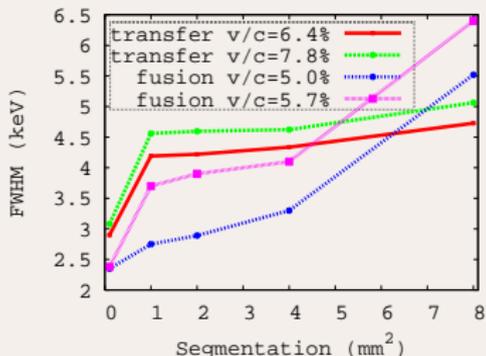
for  $^{32}\text{S}(125\text{ MeV}) + ^{40}\text{Ca}$ ,  $\gamma_{2+ \rightarrow 0+} ^{64}\text{Ge}(2\alpha)$ ,  $\gamma_{2+ \rightarrow 0+} ^{70}\text{Se}(2p)$

# 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(E $\Delta$ E)	2856 $\div$ 183E3	2435 $\div$ 156E3	2304 $\div$ 148E3	110
Rate (kHz)	1 $\div$ 80	1 $\div$ 80	1 $\div$ 80	200
Chan selec	E $\Delta$ E	E $\Delta$ E	E $\Delta$ E	E $\Delta$ E
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 (E $\Delta$ E, g)	705.5	601.6	569	107.4
Vol (E $\Delta$ E, cm <sup>3</sup> )	302.8	258.2	244.3	46.1

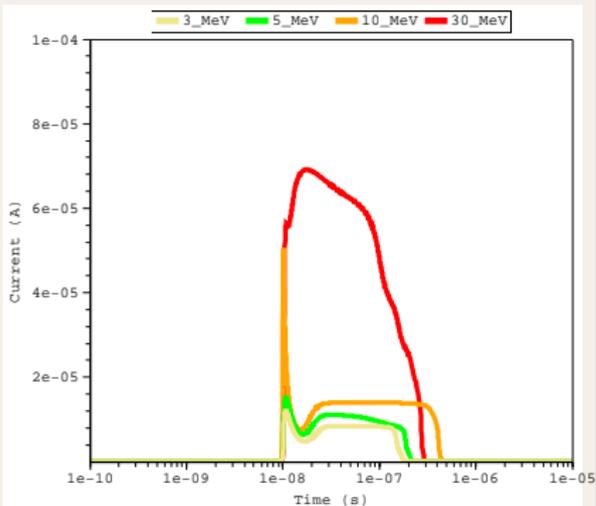
# Conclusion

## Telescope specifications

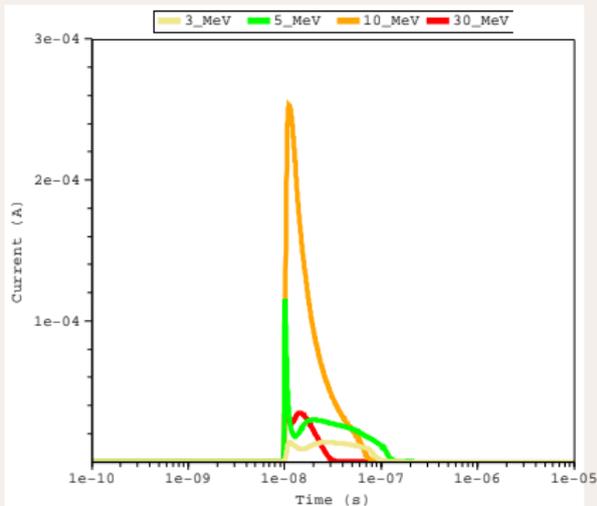
- **Detector:** Silicon.
- **Geometry & dimensions:** *solid angle coverage*  $\approx 90\%$ ; *counting rate:* 20 kHz; *module dimensions*  $\simeq 40 \times 80 \text{ mm}^2$ ;  $\Delta E$ : Si-pad det.  $\simeq 150 \mu\text{m}$  thick, pad  $4 \times 4 \text{ mm}^2$ ;  $E$ : Si-pad det. 1.5 mm thick, pad  $4 \times 4 \text{ mm}^2$ .
- **Angular resolution:**  $1 \div 2^\circ$   $4 \times 4 \text{ mm}^2$  at 10 cm.
- **Energy resolution:**  $< 50 \text{ keV}$  for 5.5 MeV  $\alpha$ -particles.
- **Wide energy range:** 200 keV  $\div$  15 MeV for p, 60 MeV for  $\alpha$ -particles.
- **Pulse shape analysis**

# Collecting electrodes

## $\alpha$ family

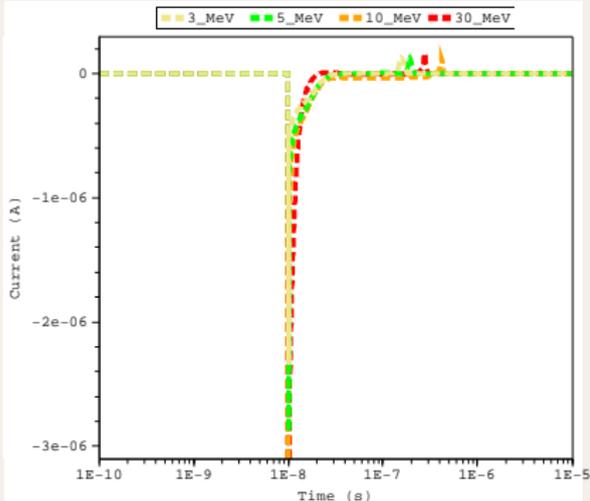


## proton family

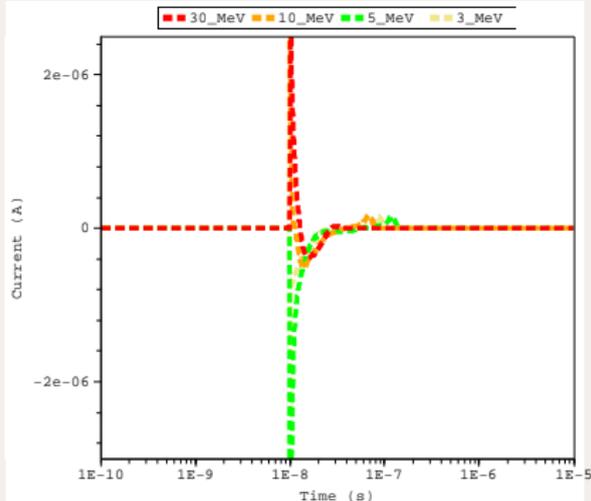


# Neighbour electrodes

## $\alpha$ family



## proton family

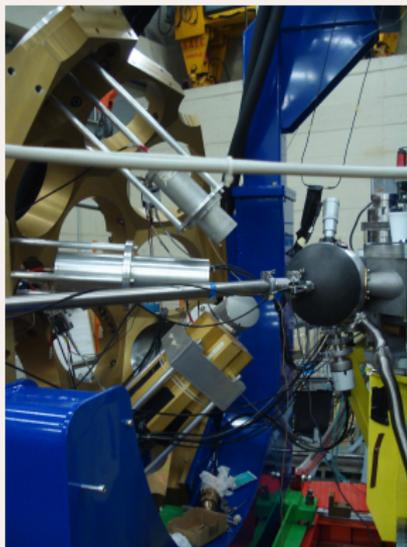


# TRACE first in-beam experiment

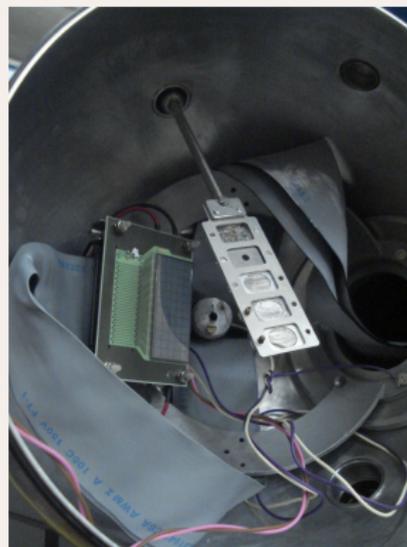
$^{17}\text{O}(350\text{ MeV})+^{208}\text{Pb}$

2x120ch (high density con.),  $2.5^\circ$  ang res,  $2\times 12.5^\circ$  ang range.

## TRACE+HELENA



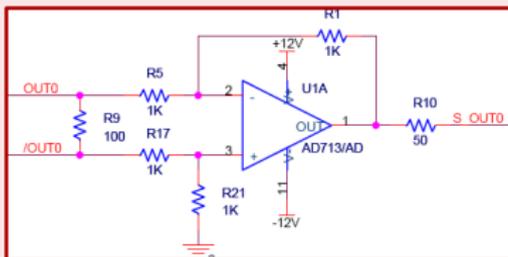
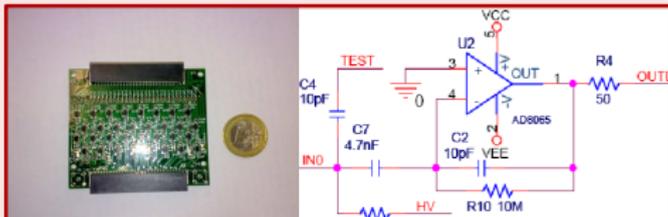
## TRACE telescope



# FEE&DAQ

## Electronics coupling

### FEE



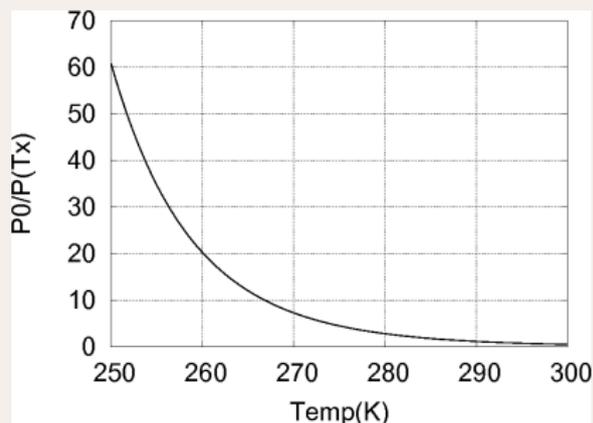
# Cooling system

## Noise reduction

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

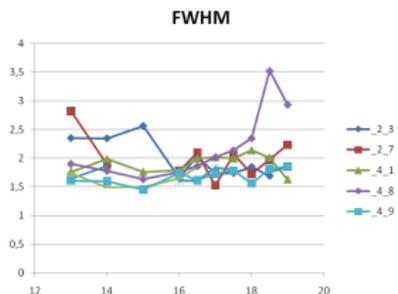
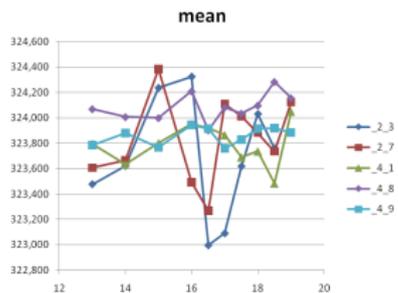


## Thermal noise generation



# Results

## Mass&Energy resolution



- Isotopic separation: O,N,C, etc
- Si Energy resolution  $\sim 0.45\%$

