Contribution of Small Facilities to the study of Nuclear Reactions

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Summary

- Role of small facilities in ENSAR:

ENSAF network.

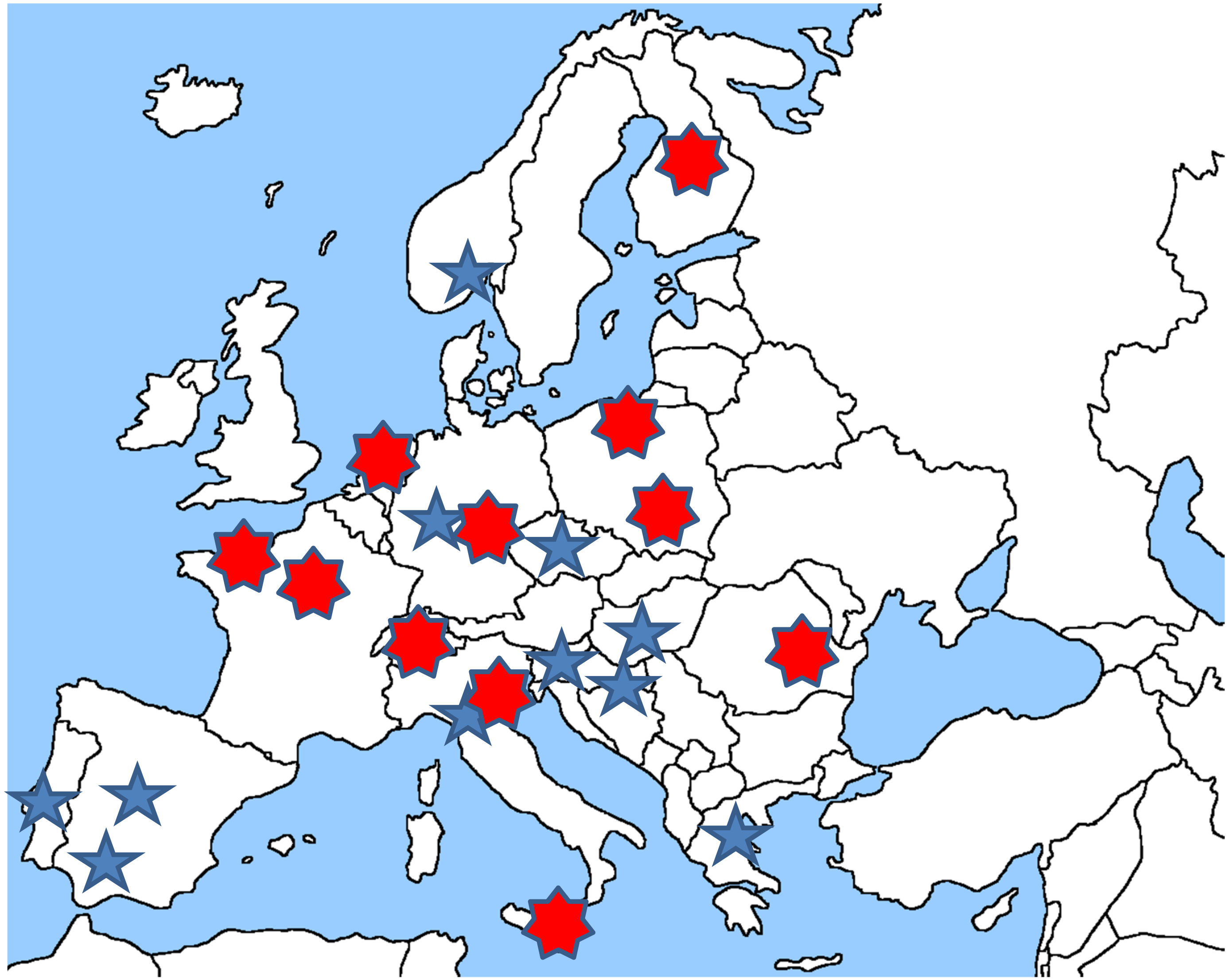
- Contribution to beam tracking at FAIR:

Instrumentation development in Small scale facilities.

- Solid He Targets for exotic beams:

Applications vs basic science in Small Scale facilities.

ENSAF ★ vs TNA ✶



ENSAF facilities

- RBI, Zagreb, Croacia.
- NPI, Rez, Czechia.
- ATOMKI, Debrecen, Hungary.
- IST, Lisboa, Portugal.
- JSI, Ljubljana, Eslovenia.
- CMAM, Madrid, Spain.
- RUBION, Bochum, Germany.
- Fysisk Inst, Oslo, Norway.
- CRSD, Athens, Greece. (Coordinator: S. Harissopouloss)
- INFN, Legnaro, Italy.
- CNA, Sevilla, Spain. (Dep. Coordinator: JGC)

Ensaf workshop, Sevilla, October 2016

http://indico.ific.uv.es/indico/conferenceDisplay.py?ovw=True&confId=2824

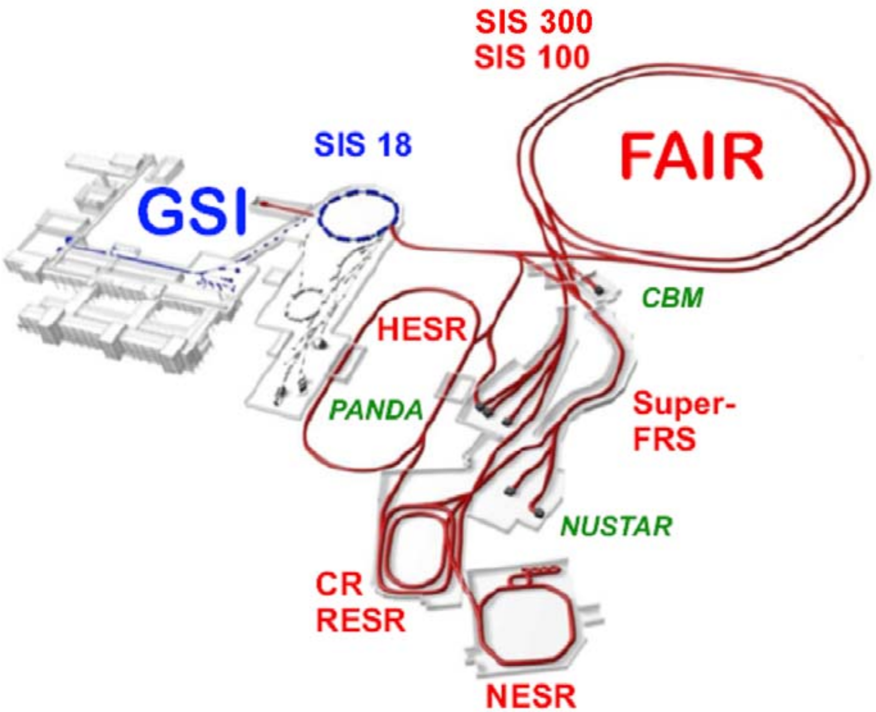
ENSAF Topics

- Detector tests and development (All)
- Role in large facilities planning (NPI, CMAM, Lisboa, Oslo ..)
- Nuclear astrophysics & fundamental research (CMAM, NPI, Oslo ..)
- Neutron production (NPI, CNA …)
- Research for fusion (Atomki, Lisboa, CNA …)
- Accelerator research (Atomki)
- Ion beam techniques (All)
- Medical applications (CNA …)

- Radiation hardness tests in detectors: Several facilities had a relevant contribution to radiation tests in different detectors. In particular, the IBIC (Ion Beam Induced Charge), was found very interesting for the future of small facilities. The participation of Zagreb in AIDA2020, as well as the participation of Sevilla and Zagreb in IAEA projects was found very positive, although the funding was very limited. Neutron production, both in reactors and in accelerators was also discussed as a niche for the participation of small accelerators.
- Participation in the testing of detector arrays of large facilities. The Madrid and Lisbon facilities contributed to the testing of the CALIFA detector array, which will be installed in FAIR. Synergies between the Rez facility and the Czech contributions to SPIRAL and FAIR were outlined. Debrecen contributed to improvement of beam production in large Japanese facilities.

Contribution to large scale facilities: Tracking for FAIR

New facilities will provide radioactive ion beams at low energy (<10 MeV/n) and high current ($\approx 10^6$pps)

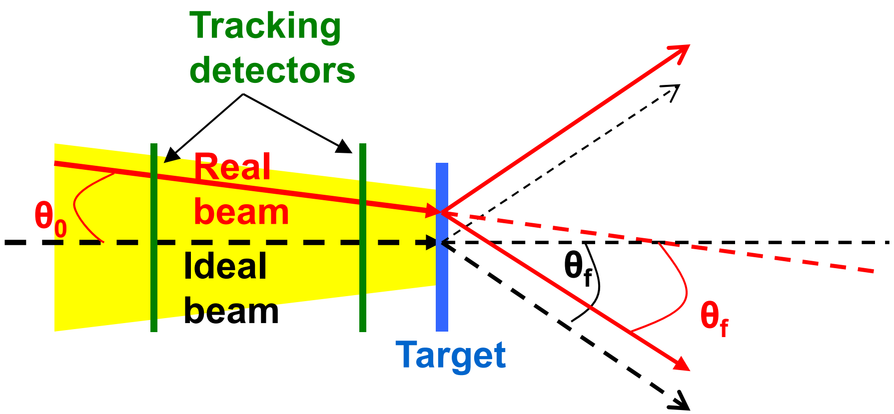


FAIR (GSI):

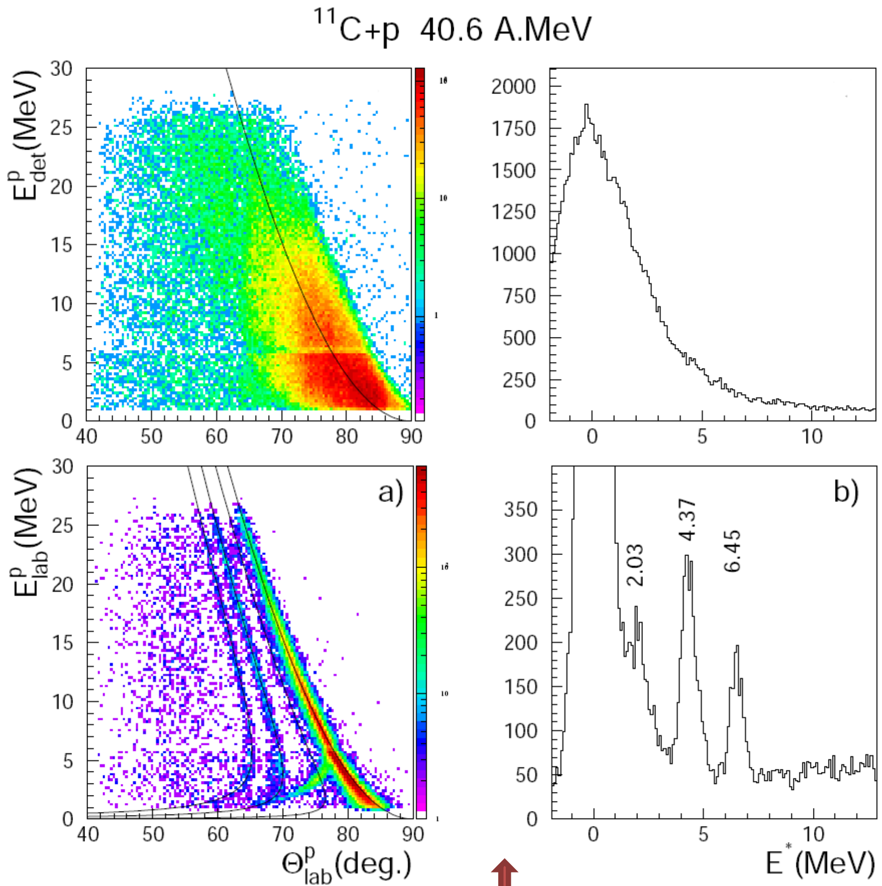
- Collaboration NUSTAR: HISPEC/DESPEC
- Low energy branch: exotic nuclei studies
- Beams with large energy and angular straggling

Why tracking in very exotic beams:

Beams with large energy and angular straggling



Without tracking
detectors information



With tracking
detectors information

Tracking detectors: time and spatial information, event by event, to reconstruct the reaction kinematics with minimal disturbance of the beam.

C. Jouanne et al. Phys. Rev. C, 72:014308 (2005)

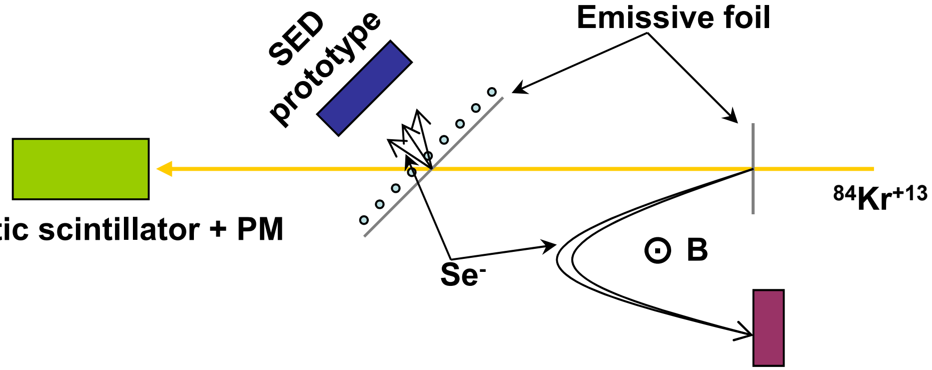
Beam Test at GANIL STP-226

Characterization of SED mini-prototypes at the exit of cyclotron CIME-GANIL.
Beam: $^{84}Kr^{+13}$ @ 1.7 MeV/n. n_{SE} ~ 107 emitted from the emissive foil.

Goals of the experiment:

- Higher precision on time resolution measurements
- Study the counting rate influence on the gain, time resolution and sparking limit

Experimental Set-up



Miniprototypes tested:

1. miniSED-1D: gap 0.8+2x1.6 mm
2. miniSED-2D1: gap 0.8+1.6 mm
3. miniSED-2D2: gap 2x1.6 mm
4. Micromegas: 2.3 mm drift+128 µm amplification gap

Beam Test at GANIL: Results

Time Resolution Comparison

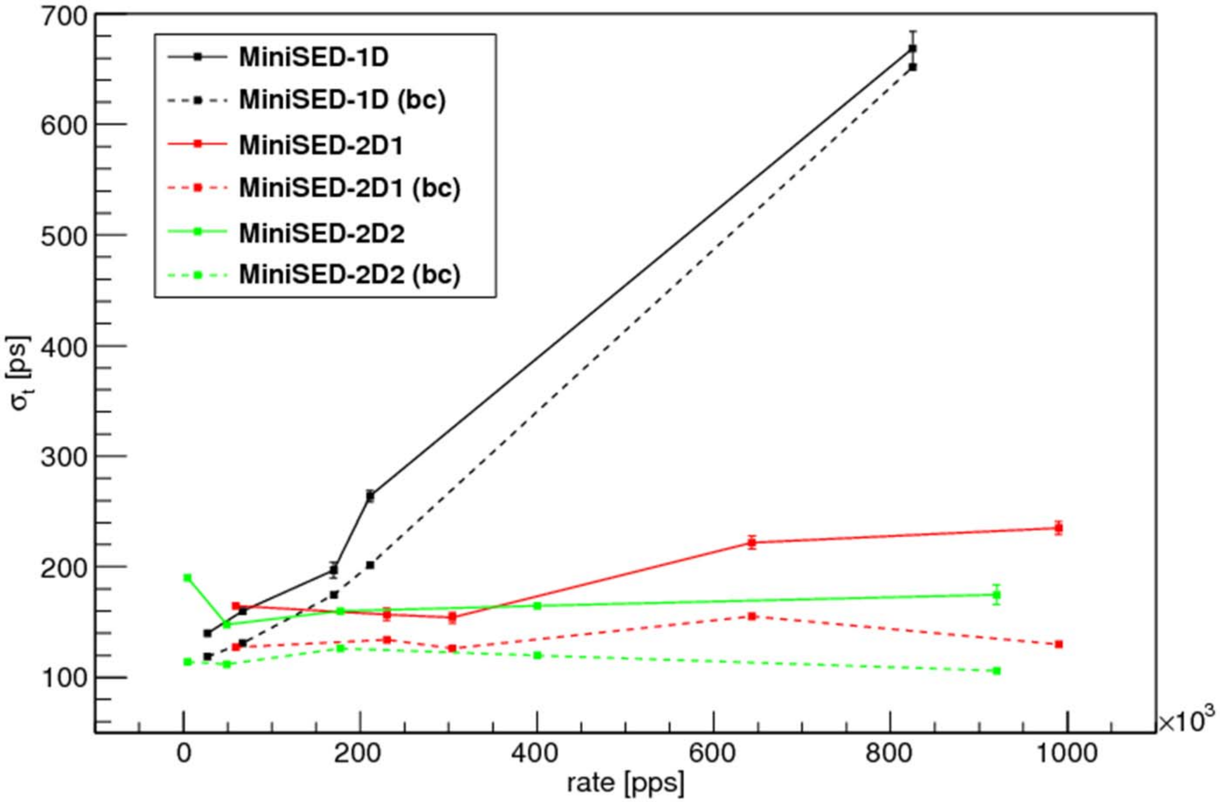
- ✓ Best time resolution results with the counting rate for each detector

- ✓ **MiniSED-1D**: Time resolution is highly degraded at high counting rates due to the reduction of the polarization voltage: **σ_t≈700 ps** for 9x10^5 pps

- ✓ **MiniSED-2D**: time resolution is more stable than 1D with the counting rates: **σ_t≈150 ps** (miniSED-2D2)

- ✓ **Micromegas**: Good behavior with counting rates

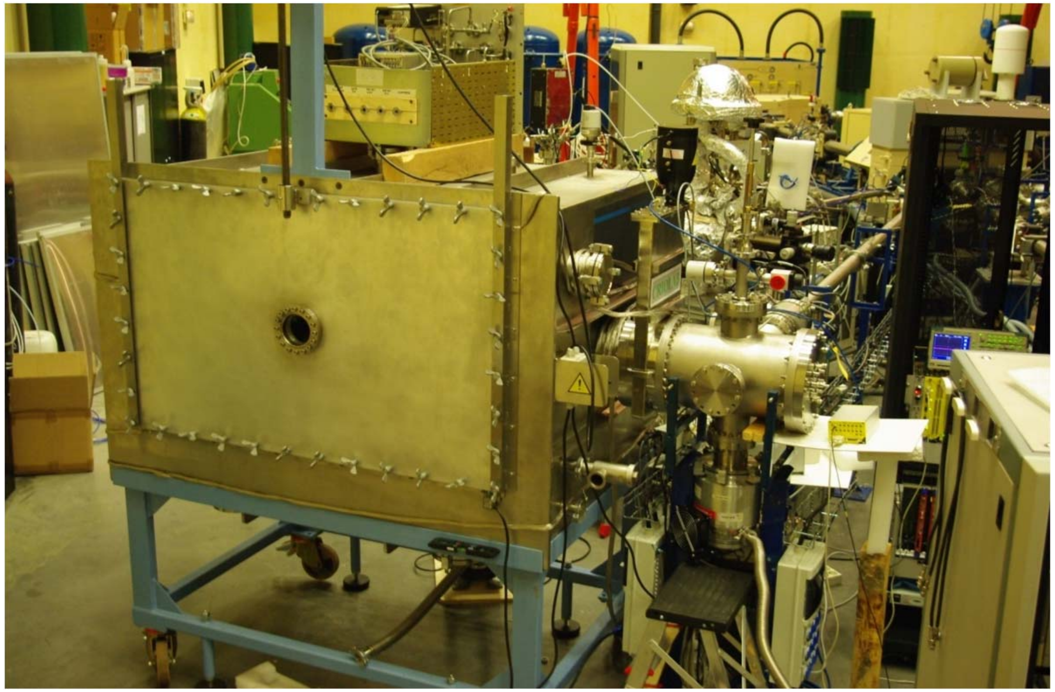
- ✓ Time resolution improves when beam correction (bc) is applied: **σ_t≈100 ps** (miniSED-2D2)



M Voštinar, B Fernández et al. JINST 8 C12023 *(2013)*

FNB Line at the CNA

Motivation: Use stable ion beams, from the 3 MV Tandem accelerator, for testing SED prototypes (and nuclear instrumentation in general), at CNA-Seville

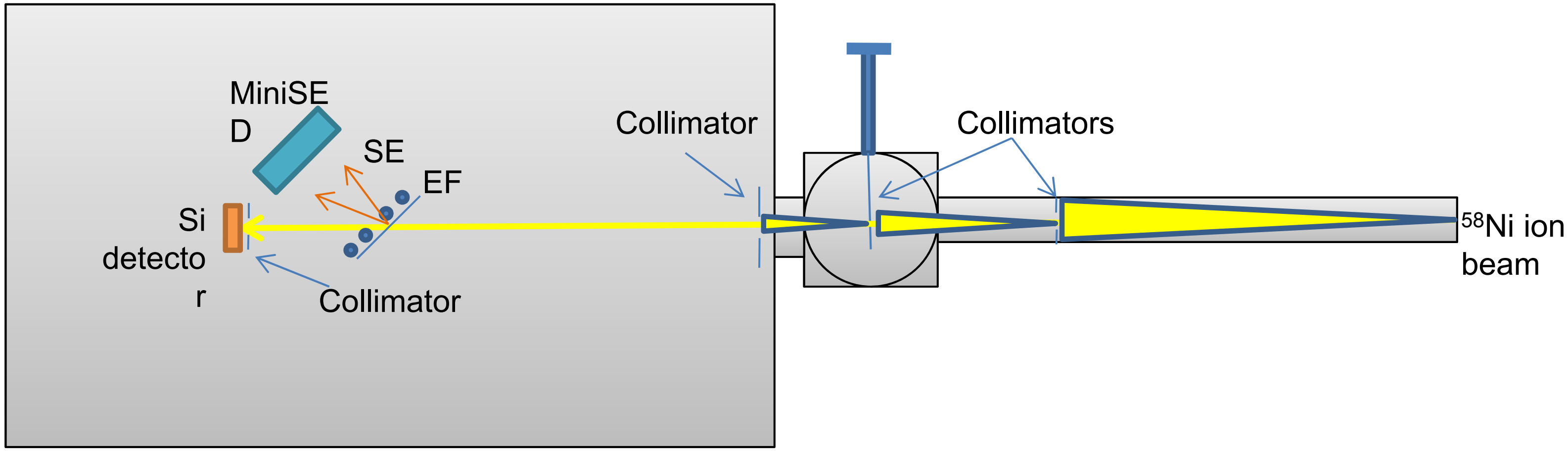


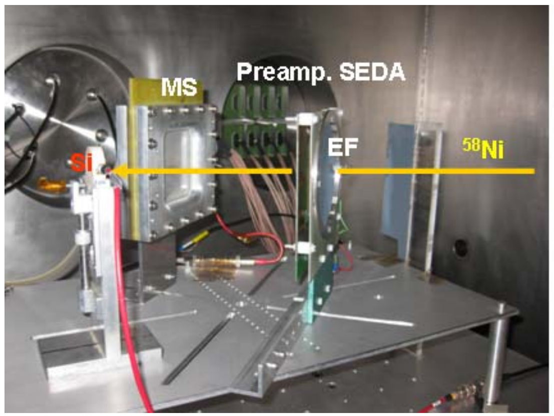
- **+30° line of the 3 MV Tandem at CNA**
- **2 vacuum chambers: reaction chamber and tracking chamber**
- **Vacuum: $2x10^{-6}$ mbar**
- **Flanges with electrical connections**
- **Gas regulation system at very low pressure**

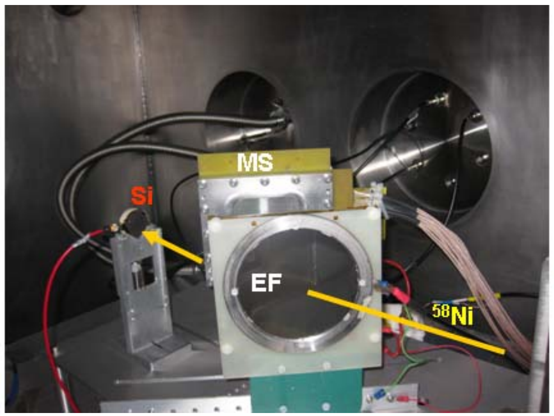
Beam Test at CNA: Measurements

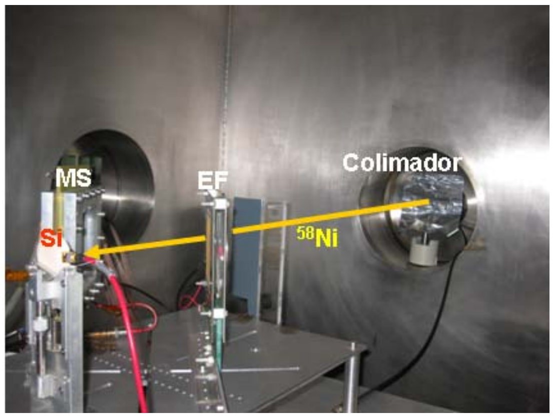
Viability study: Set-up

- Beam: ^{58}Ni @ 36 MeV and 200 pA
- Trigger: coincidence between Si and MiniSED



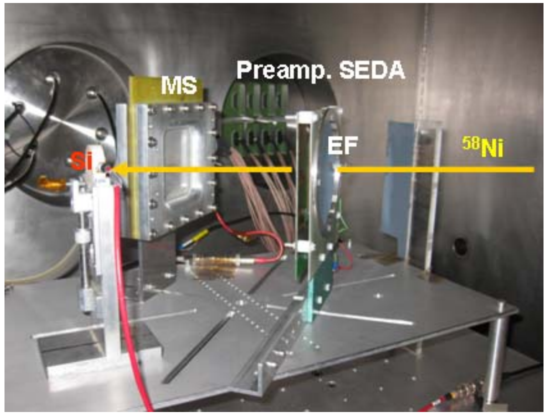




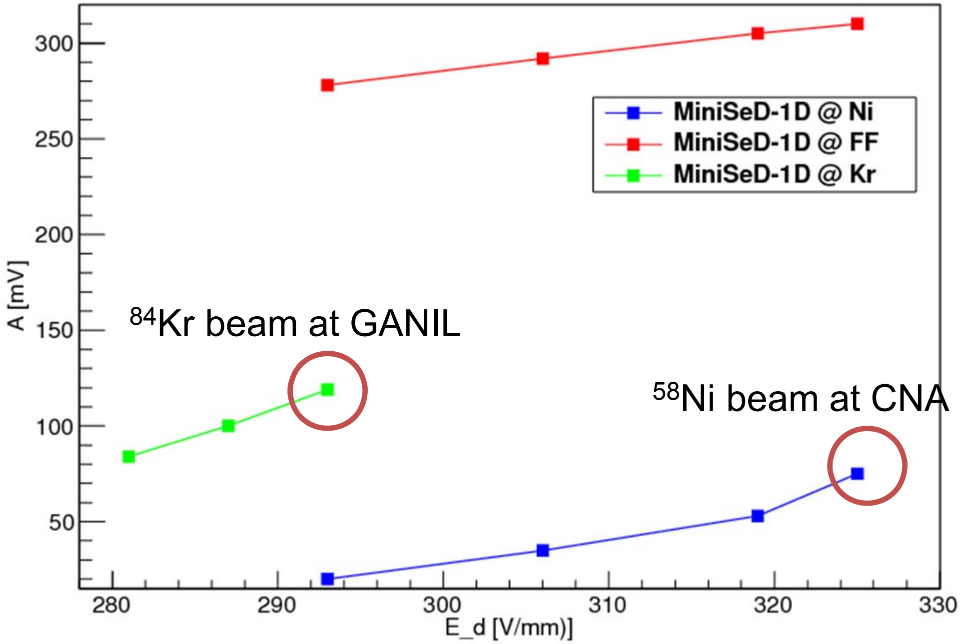


Beam Test at CNA: Viability study

- Beam: ^{58}Ni @ 36 MeV and 200 pA
- Trigger: coincidence between Si and MiniSED



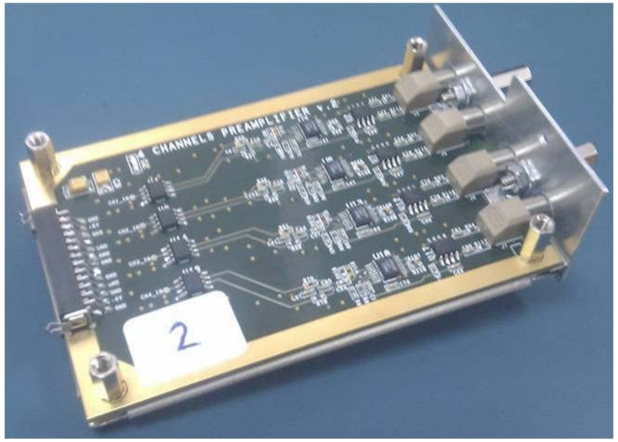
Amplitude comparison between beam and FF source



- Difference in amplitude due to the SE emitted by the EF
- Amplitude signal obtained at CNA comparable to the GANIL one (75 mV vs 85 mV)

Consistence with the idea of testing SED detectors with stable beams at CNA

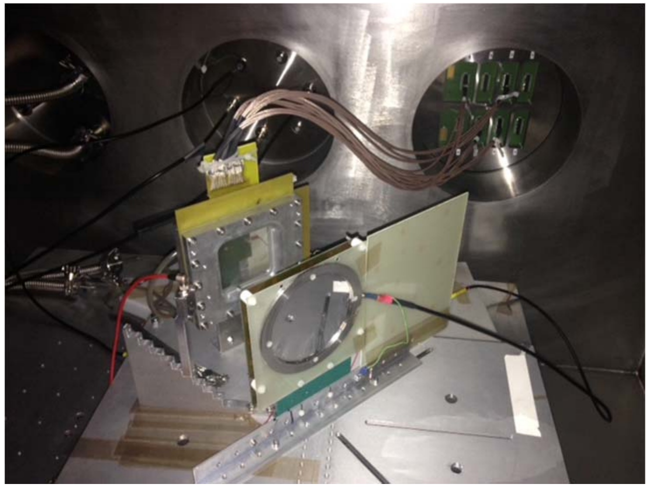
SPATIAL CHARACTERIZATION OF MINISED COUPLED TO SEDA PREAMPLIFIER AT CNA



SEDA is a Trans-impedance Pre-Amplifier developed by CNA & IMSE (Seville) for secondary electron detectors (PhD Alejandro Garzón):

- 4 channels per SEDA card
- shaping time between 140 and 170 ns
- External control of gain by a line receiver module (G=1,2,4,8)
- Good signal to noise ratio relation: 100/10

Experimental Set up



Measurements conditions:
- Beam ^{58}Ni @37.5 MeV
- Study performed changing detector polarization and isobutane pressure

Spatial resolution without magnetic field

σ = 1.2 mm

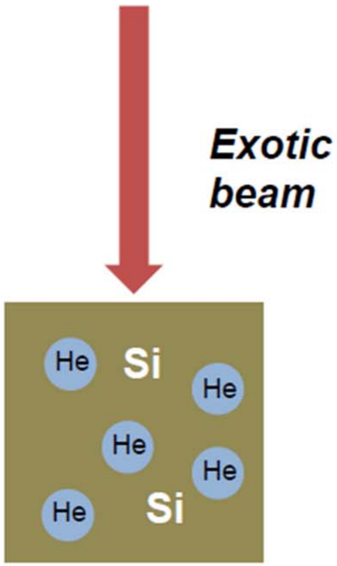
“Solid” He targets for exotic beam experiments

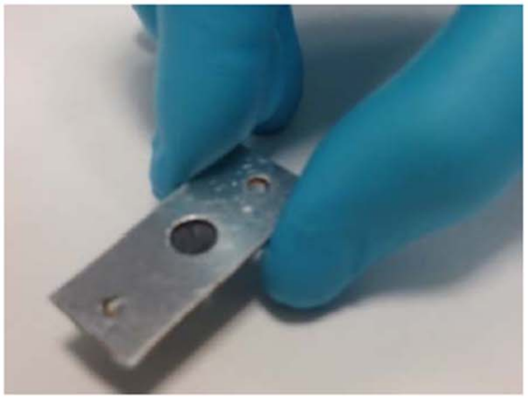
- In material science, magnetron sputtering is an effective procedure to produce thin films of Si and other metals.
- The films contain a large fraction of the inert gas (4He).
- ENSAF facilities (i.e. CNA) routinely analyze thin films by IBA techniques (PIXE, RBS)
- 4He is an ideal probe to investigate other nuclei by scattering.
- For exotic nuclei, 4He would make an ideal target (Inert, spin 0, Isospin 0).
- However, 4He is a gas and does not form solid molecules.

- Can we use thin films, rich in 4He, as targets for exotic nuclei?

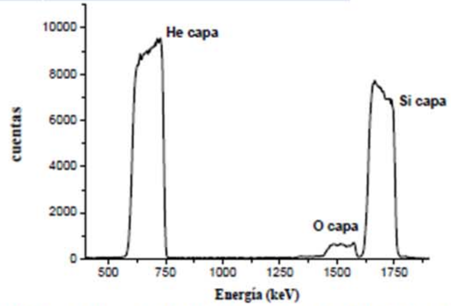
Development of He solid targets for nuclear reaction experiments

	GODINHO et al. (MS)	Vanderbist et al. (Ionic Implant.)	Raabe et al. (Ionic Implant.)	Ujic et al. (Ionic Implant.)
Metal (10^{15} at/cm^2)	**9250 (Si)**	1200 (Al)	4200 (Al)	1200 (Al)
He (10^{15} at/cm^2)	**4060**	275	270	130
O (10^{15} at/cm^2)	**700**	60	100	??

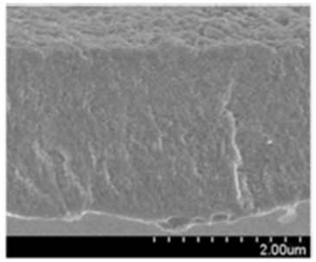




Self-supported Si:He target



RBS spectrum of Si:He target using 2,0 MeV protons and 165° scattering angle

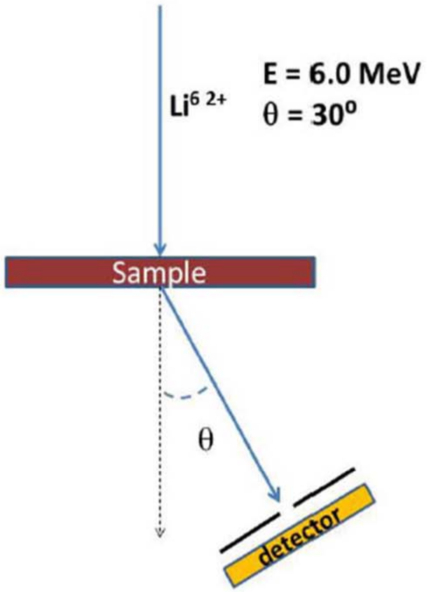


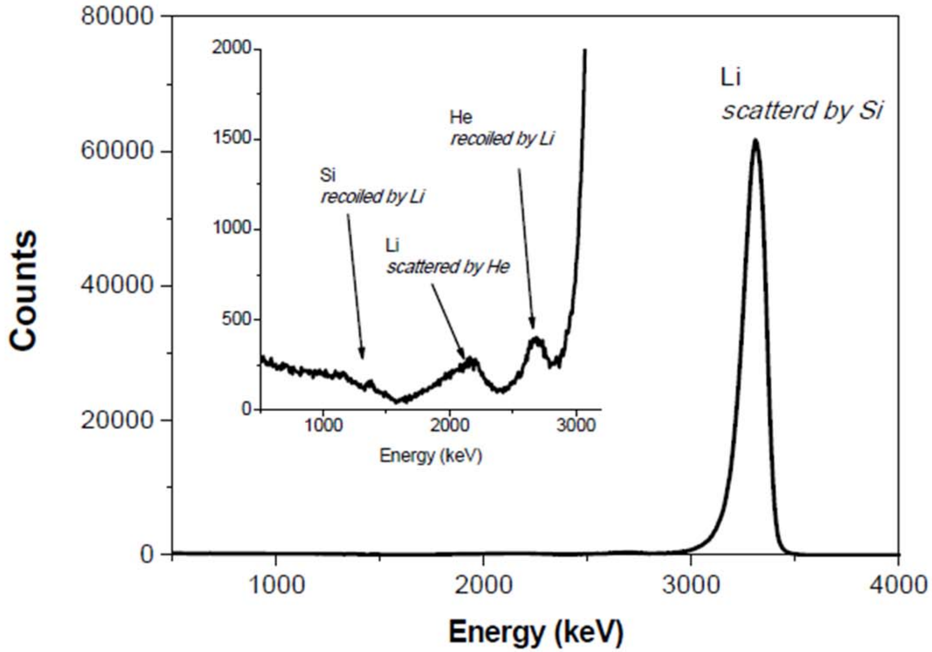
SEM corss section of the Si:He target

Development of He solid targets for nuclear reaction experiments

Si: 9250 $\times 10^{15}$ at/cm^2 = 430 µg/cm^2
He: 4060 $\times 10^{15}$ at/cm^2 = 27 µg/cm^2
O: 700 $\times 10^{15}$ at/cm^2 = 19 µg/cm^2

- $^4He(^6Li, ^6Li)^4He$ Elastic scattering



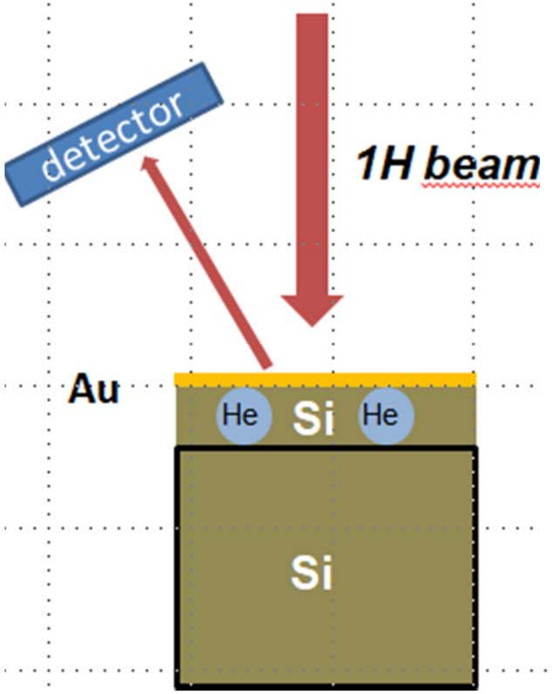


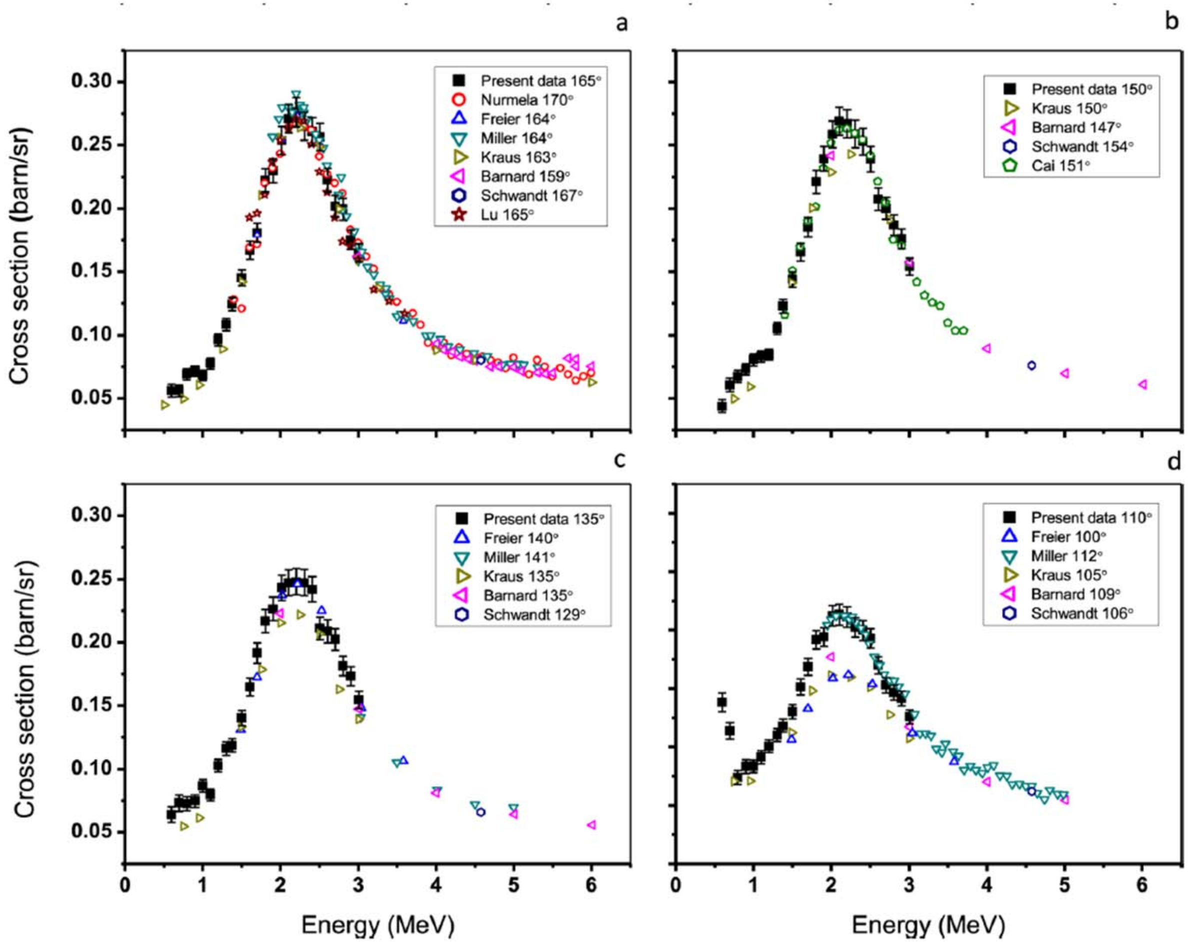
Development of He solid targets for nuclear reaction experiments

$^4He(^1H,^1H)\,^4He$ Elastic scattering

Backscattering (θ> 90°)

Si: 1000 x10^{15} at/cm^2
He: 550 x10^{15} at/cm^2



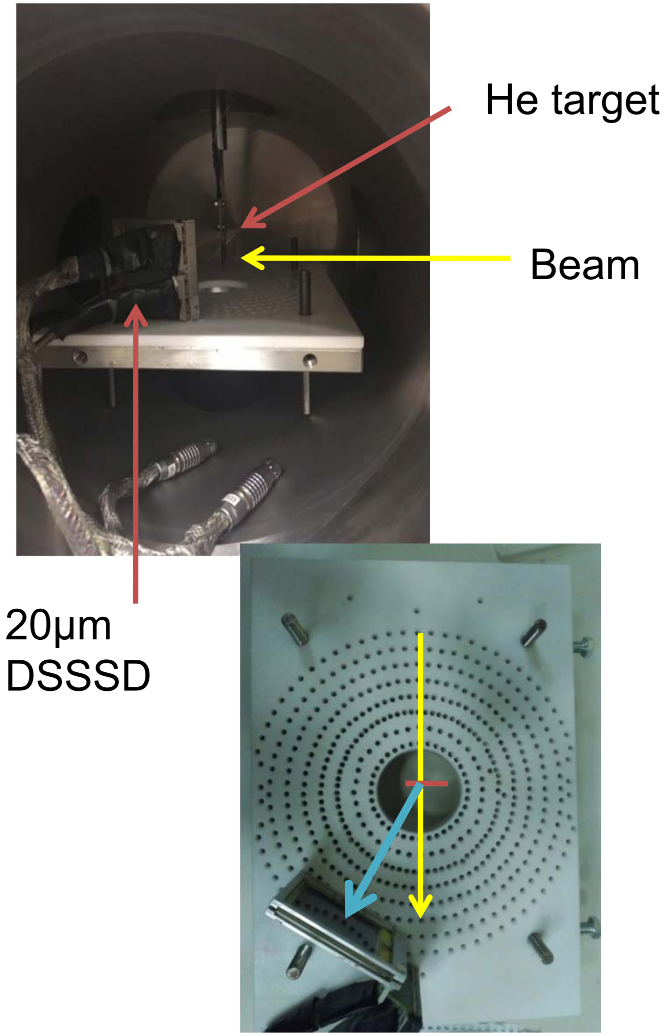


Obtained He(p,p)He elastic scattering cross-section at scattering angles of 165° (a), 150° (b), 135° (c), and 110° (d) as a function of proton energy at our laboratory (with the Au/a-Si:He/Si sample) in comparison to earlier data published at similar angles.

V Godinho, F. Ferrer, B. Fernández, J. Caballero-Hernandez, J. Gómez-Camacho, A. Fernández, ACS Omega, 1 (2016)

He Solid Target Beam test at CNA

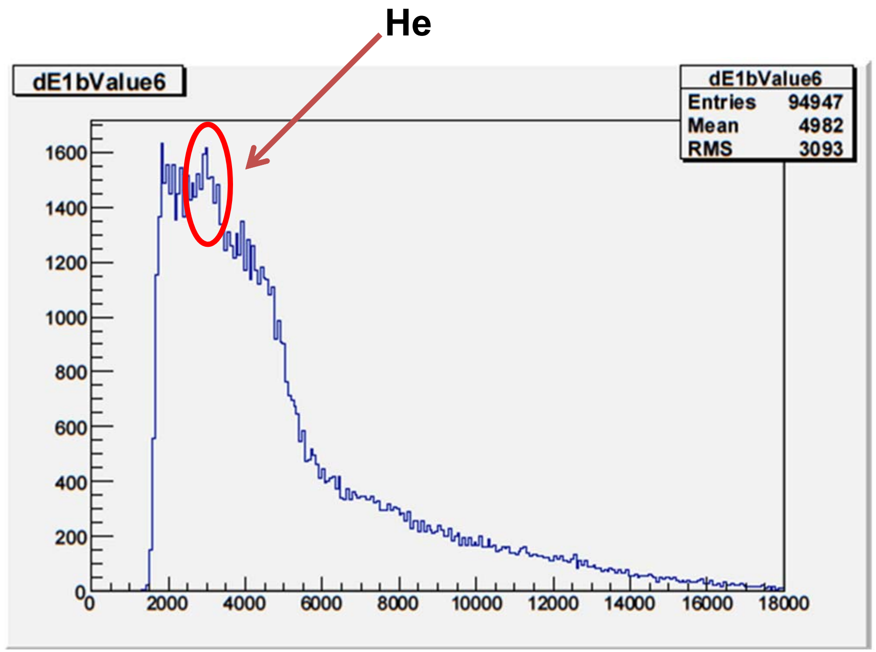
Experimental Set up



Ion beam: ^{28}Si @ 20MeV
Detector place at forward direction (40º-70º)

Target composition:

- Si: 9100 x10^{15} at/cm^2
- He: 4200 x10^{15} at/cm^2
- O:860 x10^{15} at/cm^2
- C:50 x10^{15} at/cm^2



Conclusions

- ENSAF as a network of small accelerators within ENSAR2, with links to TNA that should be promoted, facilitated and funded.
- CNA, in collaboration with GANIL, GSI, Koln is contributing to the development of Beam Tracking solutions for the LEB of FAIR.
- A collaboration led by ICMSE (NanoMatMicro) and CNA is contributing to the development of solid He targets for exotic beam experiments at ISOLDE.

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- ENSAF network