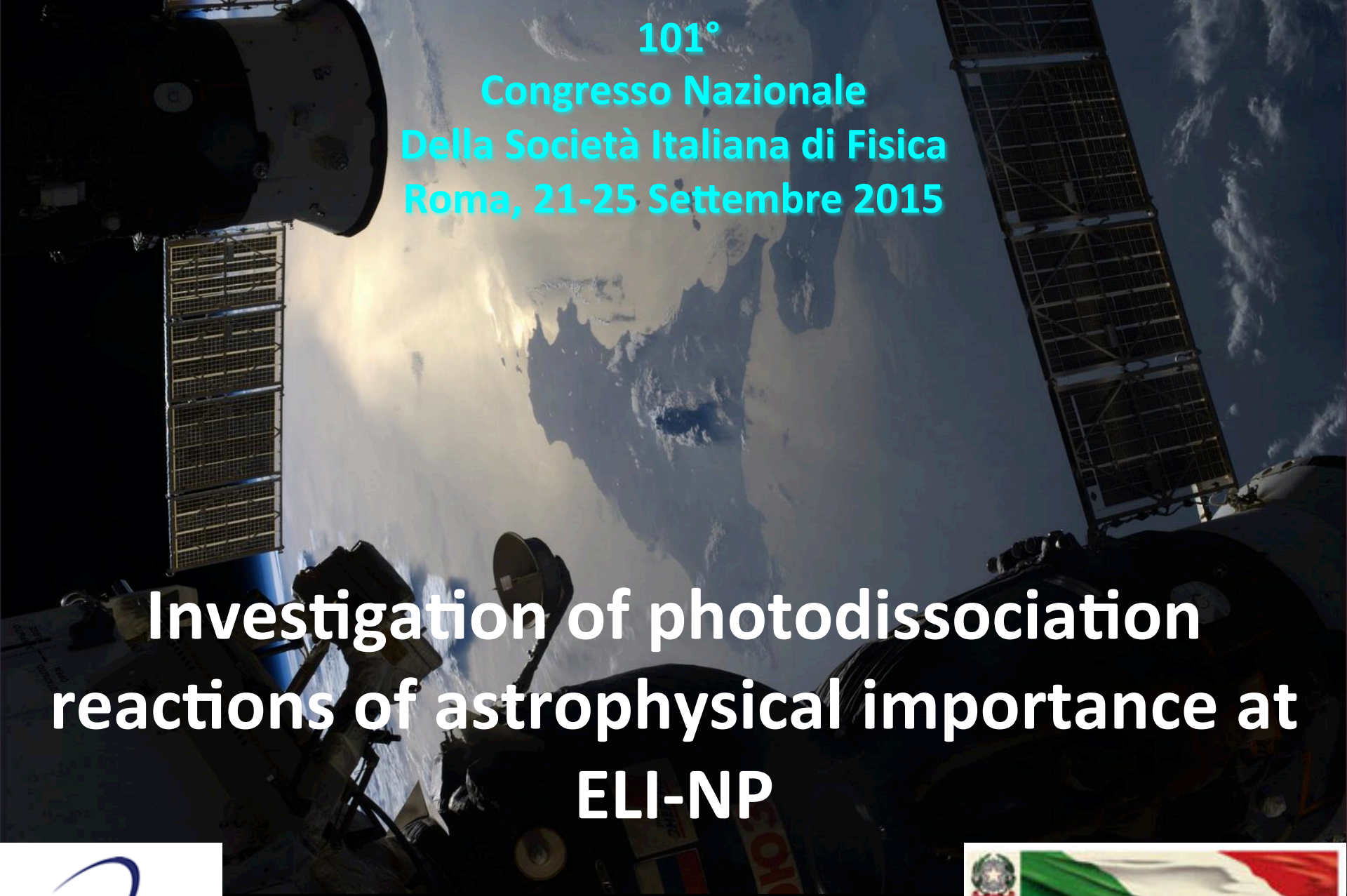

101°
Congresso Nazionale
Della Società Italiana di Fisica
Roma, 21-25 Settembre 2015

Investigation of photodissociation reactions of astrophysical importance at ELI-NP

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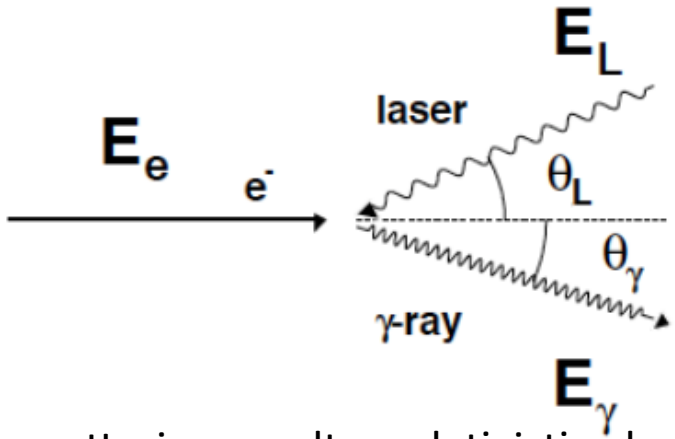
Ministero dell'Istruzione
dell'Università e della Ricerca

Extreme Light Infrastructure

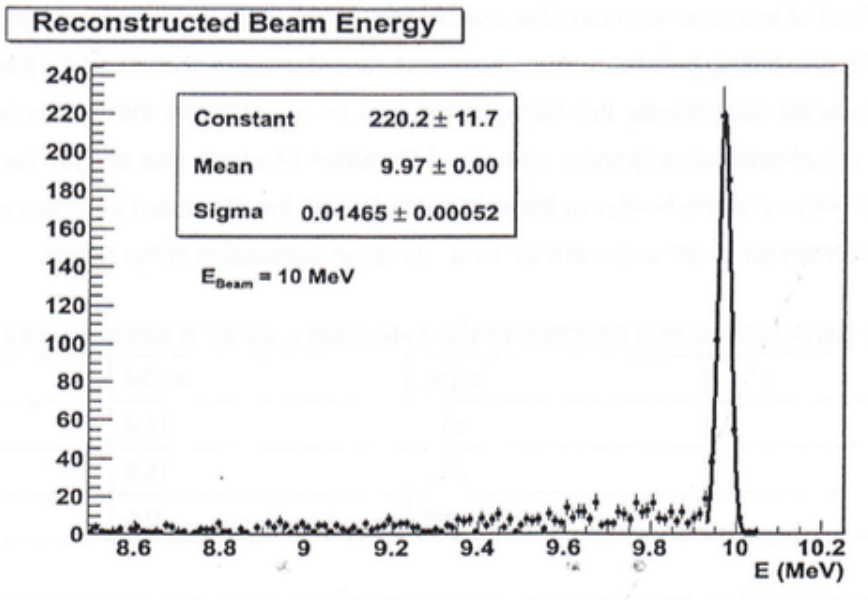
- High power laser system, 2 x 10PW maximum power

- Gamma radiation beam, high intensity, tunable energy up to 20MeV, relative bandwidth 10^{-3}, produced by Compton scattering of a laser beam on a 700 MeV electron beam produced by a warm LINAC



Photon scattering on ultra relativistic electrons

$$E_\gamma = 2\gamma_e^2 \cdot \frac{1+\cos\theta_L}{1+(\gamma_e\theta_\gamma)^2 + a_0^2 + \frac{4\gamma_e E_L}{mc^2}} \cdot E_L$$



Nuclear Astrophysics @ ELI-NP

Nuclear physics with high power lasers:
- Fission & Fusion
- Production of exotic nuclei
- Nuclear reactions in plasmas & electron screening
- Nuclear excitations in plasma
- …

Photo dissociation reactions
- Nuclear spectroscopy and cluster studies
- Photofission
- Investigation of GDR and Pigmy Dipole Resonance
- **Nuclear astrophysics**
  - **Direct measurements: reactions in explosive environments**
  - **Indirect measurements: investigation of radiative capture reactions**

Industrial & medical applications, material science…

Nuclear Astrophysics @ ELI-NP

For the first time high intensity (>10^7 γ/s) high resolution (<10^{-3}) will be available, making it possible to measure photodissociation reactions of astrophysics importance.

A few physical cases to be addressed @ ELI-NP

He-burning in stars

- $^{12}C(\alpha,\gamma)^{16}O$ through the $^{16}O(\gamma,\alpha)^{12}C$ reaction [indirect measurement]
- $3\alpha \rightarrow {}^{12}C+\gamma$ through the $^{12}C(\gamma,3\alpha)$ reaction [indirect measurement]

Si-burning in stars and presupernova phase

- $^{24}Mg(\gamma,\alpha)^{20}Ne$

p-process (production of proton rich nuclei along the stability valley)

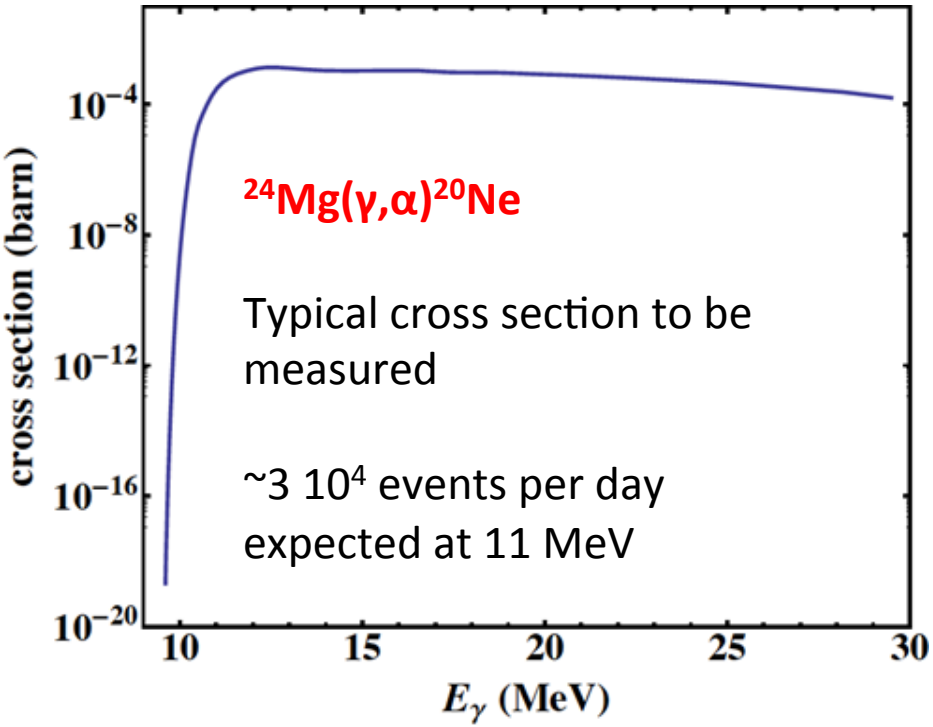
- $^{96}Ru(\gamma,\alpha)^{92}Mo$
- $^{74}Se(\gamma,p)^{73}As$

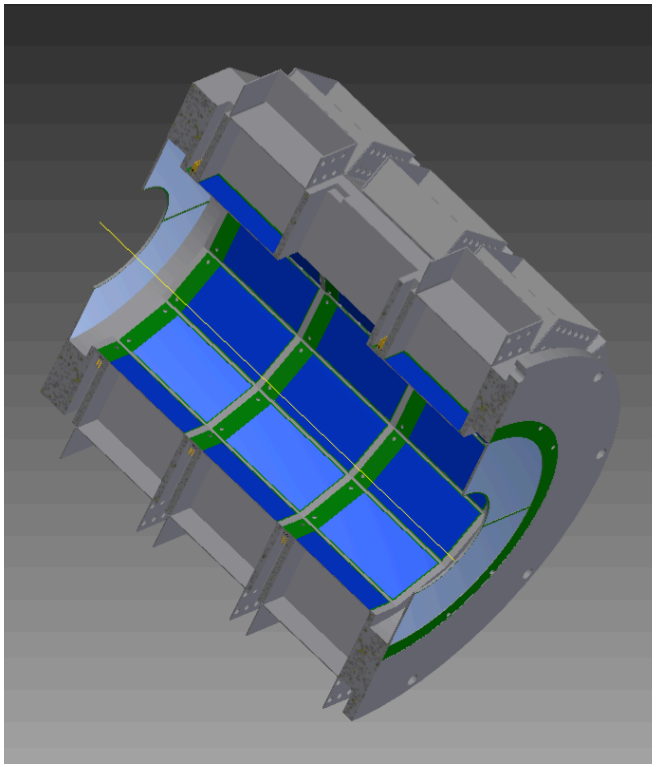
Indirect measurements: the detailed balance principle is used to deduce the cross section of interest from the one of the time-reversed process.

The ELI-NP SSD array

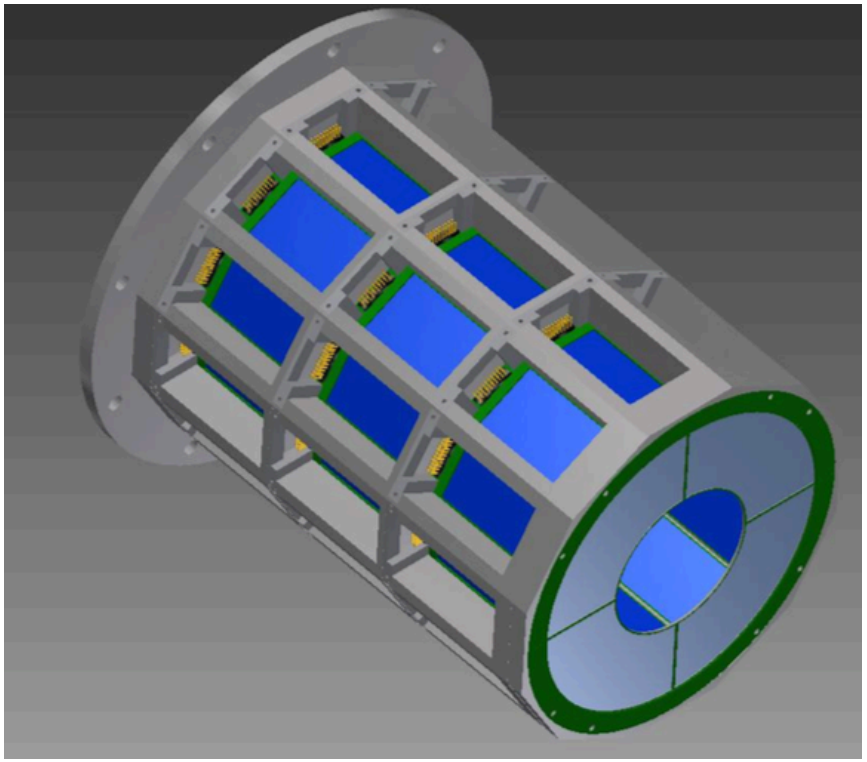
Requirements:

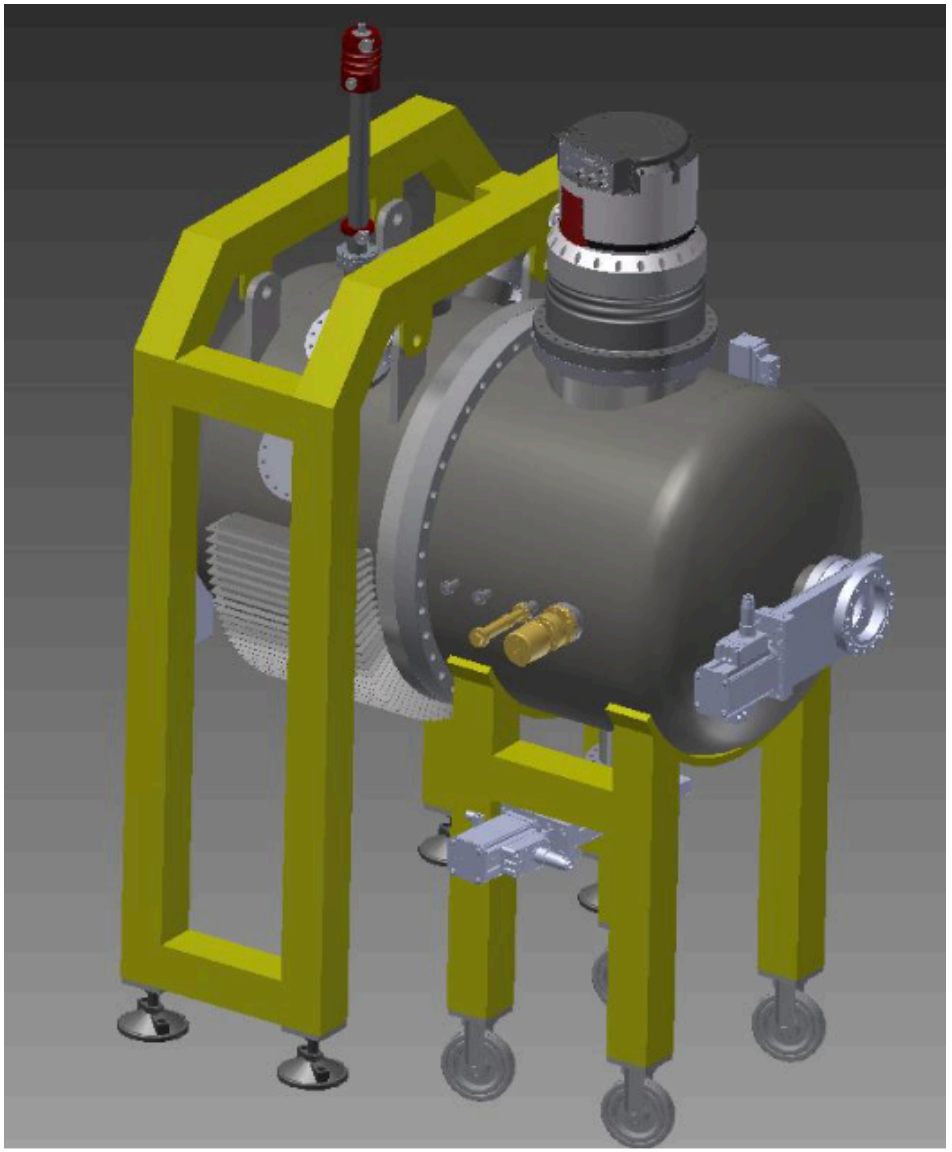
- Low detection threshold
  - Low energy particles (< few MeV) → no ΔE detector, ToF, PSD
- High energy and angular resolution for kinematic particle ID





Pictures of the detector





The SSD array covers about 80% of 4π

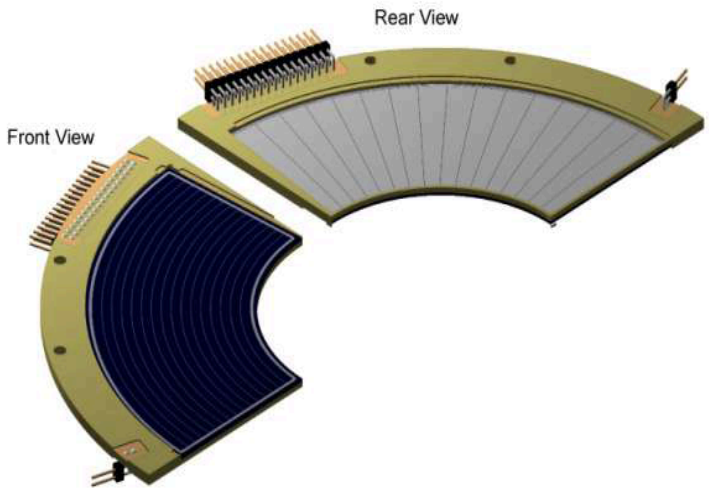
Thanks to the use of charge-partition position sensitive detectors the number of electronic channel is ~300

The ELI-NP SSD array

#35 X3 position sensitive detectors in barrel configuration

Energy resolution (FWHM) ~ 0.3%

Angular resolution 1 mm or ~ 0.4 deg

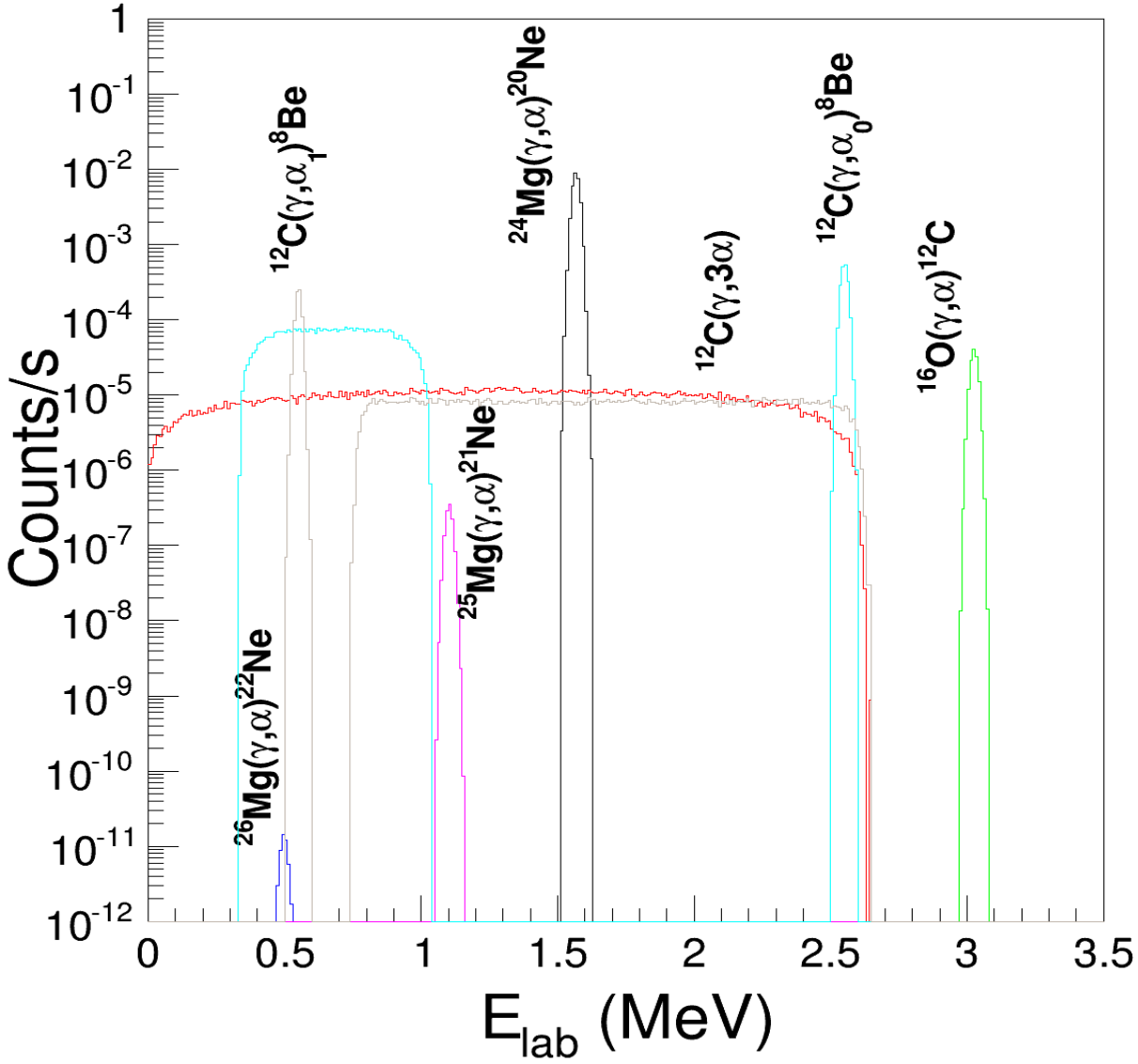


8 QQQ3 DSSSD as end cap detectors

Energy resolution (FWHM) ~ 0.3%

Angular resolution 3 mm or ~ 0.8 deg

Simulated spectra



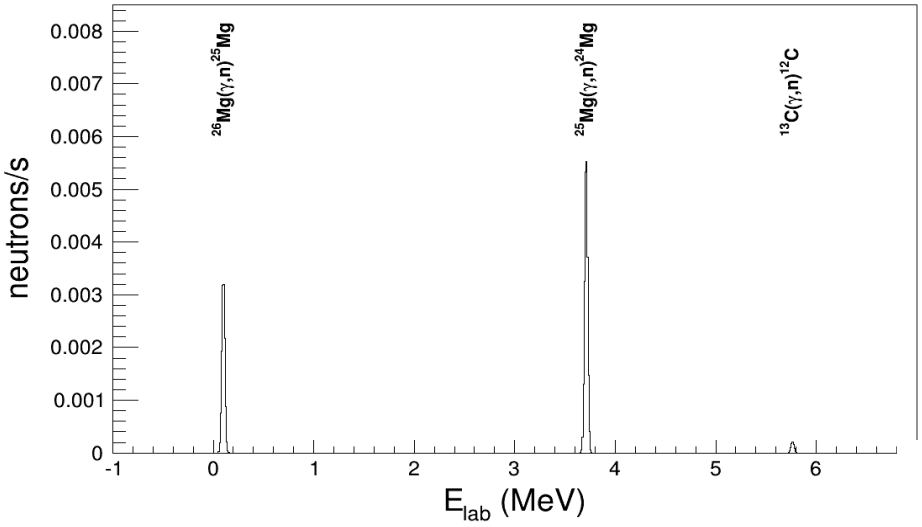
Particle yield for a 11 MeV gamma beam impinging on a ^{24}Mg target with C backing

Energy and angular resolution of detectors, gamma beam energy spread and emittance, straggling into dead layers were accounted for

Signal is much stronger than background (3 orders of magnitude)

Kinematic separation viable

Background (GEANT4)



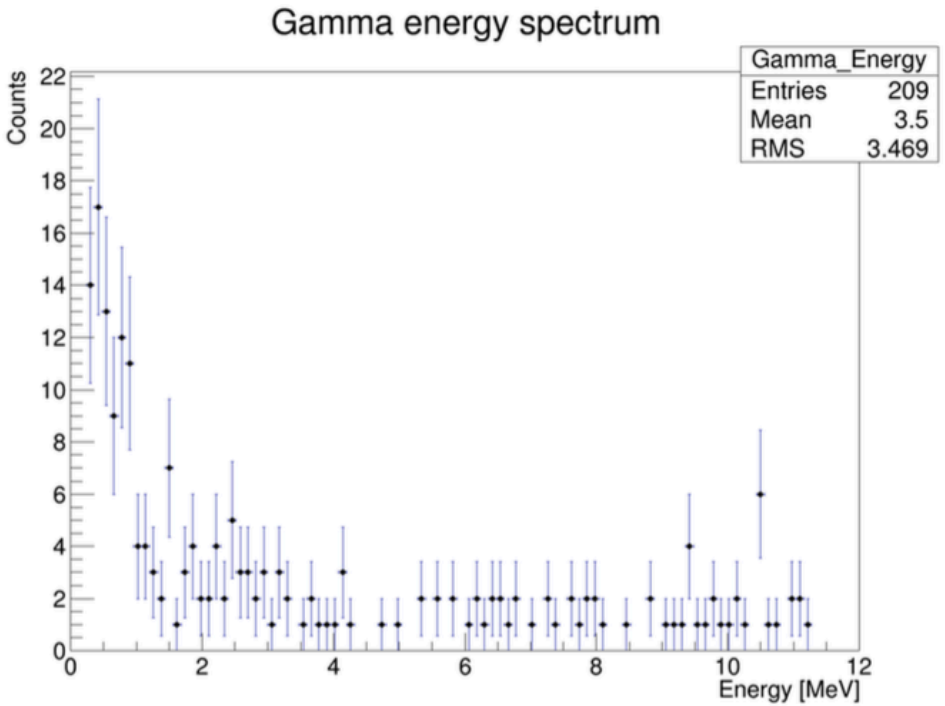
Neutron background includes:

- Neutrons emitted in photodissociation reactions off target nuclei (see picture on the left)
- Neutrons emitted in reaction triggered by scattered photons (negligible)

Electromagnetic background includes:

- Electrons and gammas from Compton scattering
- Electron-positron pairs
- Photons from nuclear or atomic deexcitation

The picture on the right shows the gamma per second hitting whole detector → negligible rate & damage



Conclusions

- The advent high-intensity & high resolution gamma-ray beam facilities is a great opportunity for nuclear physics and astrophysics, as a number of reaction of key astrophysical importance can be measured for the first time

- ELI-NP cutting-edge features must couple with high-performance detectors

- For nuclear astrophysics, particles of energies as low as few hundreds keV are emitted, making it necessary a careful detector implementation

- GEANT4 simulations have been performed, implementing the detector configurations are updating the physics wherever necessary (especially in the case of photodissociation reactions)

- A SSD array in barrel configuration (plus end cap detectors) turns out to be a very suited tool for nuclear astrophysics studies

THANKS FOR YOUR ATTENTION