Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
Świerk

IFPiLM

POLISH PARTICIPATION TO JET4 PROJECTS

National Centre for Nuclear Research (NCBJ) – Świerk

Institute of Plasma Physics and Laser Microfusion

National Centre for Nuclear Research (NCBJ)

NCBJ pure/applied research profile combines nuclear power-related studies with various fields of sub-atomic physics (elementary particle physics, nuclear physics, hot plasma physics etc.).

Radioactive sources

- standard γ-ray sources
  - ^{137}Cs, ^{22}Na, ^{60}Co and many other
- PuBe with 4.4 MeV γ-ray
- PuC with 6.1 MeV γ-ray

The JET diagnostics dedicated to confined α-particle studies are the KN3 γ-ray camera and the KM6 γ-ray spectrometer.

For lost α-particle studies, a new diagnostics is proposed.

GCU Gamma Ray Camera Upgrade
GSU Gamma Ray Spectrometer Upgrade
LRM Lost Alpha Gamma Rays Monitor

These 3 projects are implemented under the EUROFusion Consortium for the period

1st January 2014 to 31st December 2017

and they are parts of the JET Enhancements Programme WPJET4

Close collaboration with Italian institutes

GCU Gamma Ray Camera Upgrade

- *Marco Tardocchi – Project Leader*
- *Giuseppe Gorini from CNR*

Istituto di Fisica del Plasma „Piero Caldirola" (CNR)

GSU Gamma Ray Spectrometer Upgrade

- *Giuseppe Gorini from CNR*

$D + T \rightarrow \alpha + n$

Measurements of the alpha particles are done via gamma-ray emission spectroscopy of the nuclear reaction

$$^{9}Be + \alpha \rightarrow {}^{13}C \xrightarrow{n} {}^{12}C^{*} \xrightarrow{\gamma(4.44\ MeV)} {}^{12}C_{g.s.}$$

In addition to 4.44 MeV gamma-ray line, gammas with energy of 6.13 MeV are observed in the reaction induced by neutrons on oxygen

$$^{16}O + n \rightarrow {}^{16}N + p, \qquad {}^{16}N \xrightarrow{\beta} {}^{16}O^{*} \xrightarrow{\gamma(6.13\ MeV)} {}^{16}O_{g.s.}$$

Scintillators

- $LaBr_3$, $CeBr_3$, NaI, CsI, GAGG, BGO, …
- dimensions: 10×10×5 mm^3 to 3” ×3”
- cuboid and cyllinder shapes

Photodetectors

- photodiode (PD)
- photomultiplier (PMT)
- avalanche photodiode (APD)
- silicon photomultiplier (SiPM)

Gamma Camera Upgrade (GCU)

Replacement of the CsI detectors in the Gamma Ray Camera

Gamma Camera Upgrade (GCU)

Replacement of the CsI detectors in the Gamma Ray Camera

- The Gamma Ray Camera in JET is equipped with a detector array which comprises 19 CsI:Tl photodiodes with a diameter of 20 mm and a thickness of 15 mm.
- CsI:Tl crystals are characterised by a comparatively long scintillation decay time, around 1000 ns.
- At the expected high counting during D-T campaigns (in MHz range) it is required to replace CsI by detectors with a shorter decay time, e.g., $CeBr_3$ or $LaBr_3$:Ce detectors with a scintillation time around 20 ns.
- New detector material should not contain oxygen to avoid unwanted background due to a reaction on oxygen.

Gamma Camera Upgrade (GCU)
Replacement of the CsI detectors in the Gamma Ray Camera

6. PROJECT SCOPE – ***IPPLM + ENEA main common activities***

- Design, manufacture and installation of two pilot spectrometers adopting two different detector solutions (crystal plus photodetectors)
- Design, manufacture and installation of detectors replacing the existing CsI
- *Design, manufacture and installation of Control and Monitoring System (if possible)*

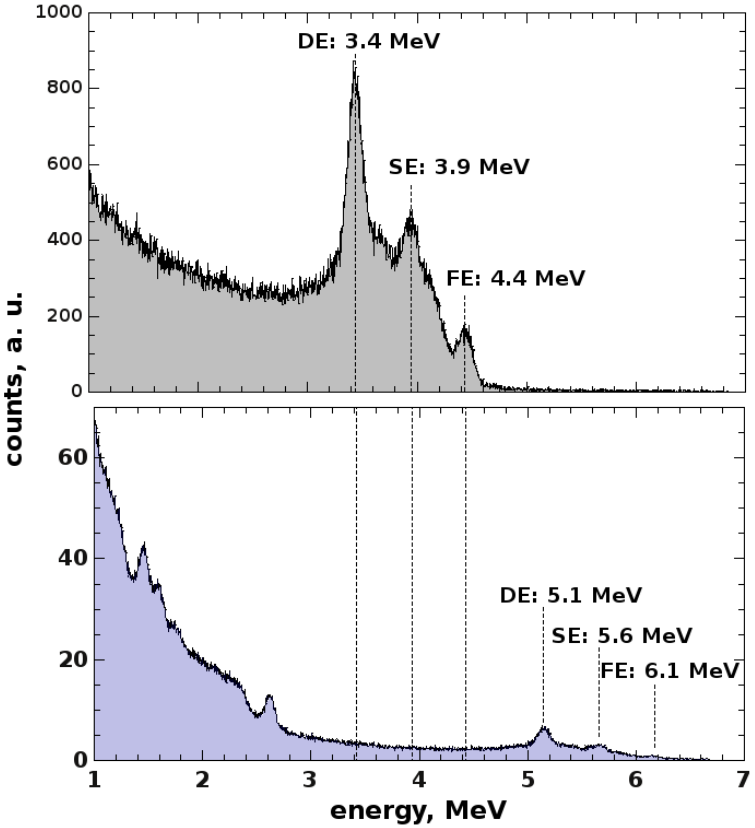
• Simulation and modelling

- detector response function calculations

$CeBr_3$ scintillator

20 mm (diameter) × 20 mm (length)

PiN diode 10x10 mm



PuBe source

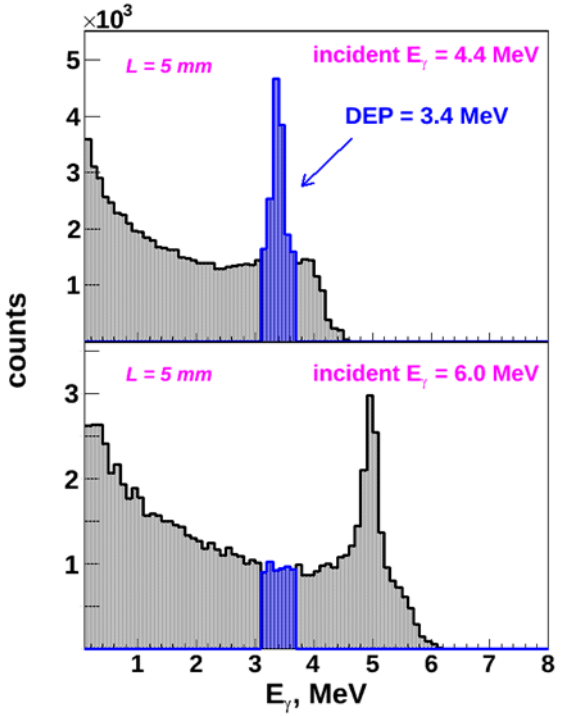
E_γ= 4.4 MeV

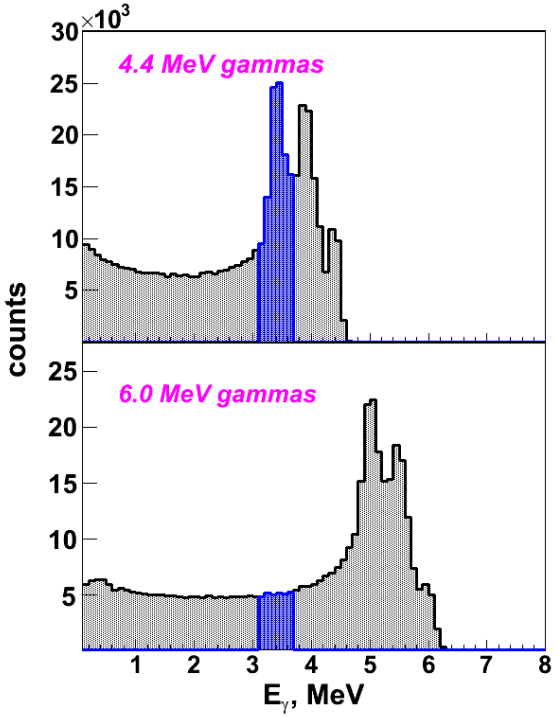
PuC source

(weak source, long measurement time)

E_γ = 6.1 MeV

Monte Carlo Simulations with Geant4





L = 5 mm, ϕ = 20 mm

L = 35 mm, ϕ = 35 mm

scintillator

PMT

detector capsule

photodiode

$CeBr_3$ scintillators from Scionix

20 mm × 20 mm

with outer dimensions of

28 mm × 24 mm

Gamma Spectrometer Upgrade (GSU)

Replacement of the existing BGO detector in the Gamma Spectrometer

- Gamma ray detector must work at high count rates – detector based on the BGO scintillator has a long decay time and old electronics that does not fulfill requirements for high count rate measurements (DT experiments).

- New material should not contain oxygen to avoid unwanted background.

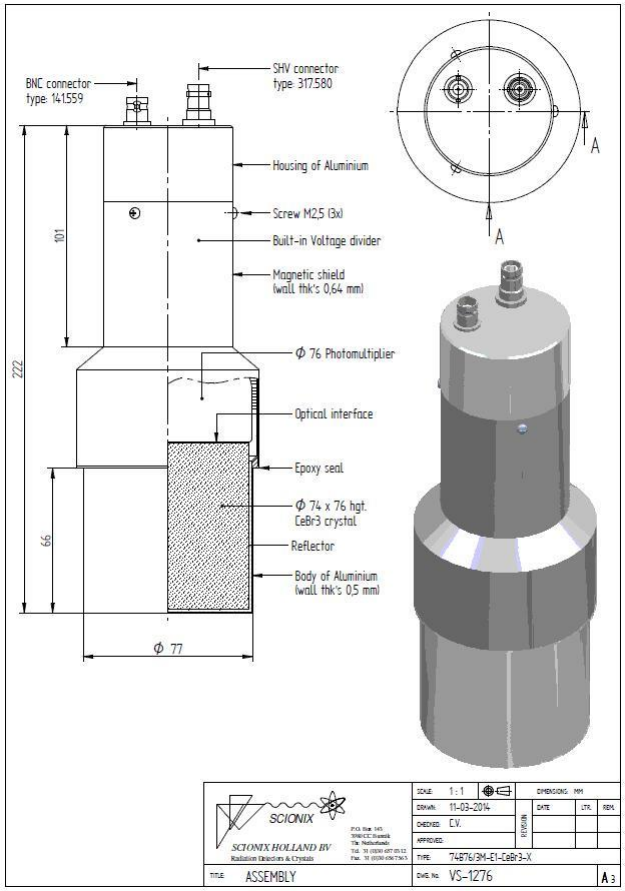
Gamma Spectrometer Upgrade (GSU)

Replacement of the existing BGO detector in the Gamma Spectrometer

Similar tasks for both Italian and Polish teams

- Manufacturing and assembling of two detector modules
  - CNR: based on $LaBr_3$
  - IPPLM: based on $CeBr_3$
- Calculation of detector response functions

3” × 3” $CeBr_3$ (schematic)



voltage divider

PMT

scintillator

Lost Alpha Gamma Rays Monitor (LRM)

- **For lost α-particle studies, a new diagnostics is proposed**
- **No final decisions made**
- **IPPLM contributions**
  - design, manufacture and installation of two KA4 detectors based on $CeBr_3$, similar to GCU detectors
  - calculation of KA4 detector response function

SUMMARY

- JET4 projects in a close collaboration with Italian colleagues in all stages.
- Similar tasks allow us to exchange experience and know-how.
- Already gained experience makes us sure that our projects will be successful.