SANDA WP2

New nuclear data measurements for energy and non-energy applications

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Generic goals of WP2

**New measurements** will be carried out to significantly **improve the accuracy of nuclear data** needed in **energy and non-energy modelling applications**, mainly in the field of **fission**, radiation protection, safety, sustainability and enhancement of nuclear technologies.

At the end of the project a number of **new high precision nuclear data sets will be available for the major actinides present in advanced reactor fuels**, to reduce uncertainties in new isotopes in closed cycles with waste minimization, to better assess the uncertainties and correlations in their evaluation.

The measurements to be carried out will **use extensively the instrumentation** (detectors, data acquisition systems), methodologies, new techniques and new facilities (n_TOF EAR2 and NFS) **developed during the project and also for the CHANDA Project**.

**Strong links to WP1!**
WP2 Tasks

Task 2.1: Neutron induced fission and charged particle production cross sections
Task coordinator: **UMANCH**, partners: **CNRS/CENBG, CNRS/LPCC, CVREZ, NPI-CAS, NTUA, UOI, UU**

2.1.1: Neutron induced fission cross sections
2.1.2: Neutron induced charged particle production cross sections

Task 2.2: Neutron capture cross sections
Task coordinator: **ENEA**, partners: **CIEMAT, JRC, ULODZ, IRSN**

2.2.1. Capture measurements of fissile isotopes.
2.2.2. Capture measurement of stable isotopes.

Task 2.3: Neutron elastic and inelastic scattering and neutron multiplication cross sections
Task coordinator: **IFIN-HH**, partners: **CNRS/IPHC, JRC**
Task 2.4: Decay data measurements
Task coordinator: CSIC, partners: CEA/LNHB, CNRS/Subatech, CSIC, JRC, SCK, UPC

2.4.1. Beta decay measurements with TAGs.
2.4.2. Beta delayed neutron measurements.
2.4.3. Measurement of half-live and gamma-ray emission probabilities of beta emitters.

Task 2.5: Fission yields measurements
Task coordinator: UU, partners: CEA/IRFU, CNRS/LPSC, UJY, USC

2.5.1. Fission yield studies in (n,f) reactions.
2.5.2. Fission yield studies in inverse kinematics.

Task 2.6: New measurements for non-energy applications
Task coordinator: USE, partners: IST, NPL, PTB

2.6.1. Spectrum averaged cross sections for dosimetry.
2.6.2. Measurement of cross sections relevant for hadron therapy.
2.6.3. Measurement of beta+ emitters.
CEA/LNHB (Laboratoire Nationale Henri Becquerel) – M. Kellet

- Task 2.4.3 CEA/LNHB will undertake half-life measurements of $^{106}$Ru, $^{153}$Sm, $^{166}$Ho, $^{186}$Re, $^{212}$Pb, $^{225}$Ac and $^{223}$Ra using the existing and calibrated gamma spectroscopy facility at LNE-LNHB.

- MS26 “Completion of the measurements at the CEA-LNHB” M36

- Preparation of the D.2.15 Report on the of half-life and gamma-ray emission probabilities of beta emitters measurement (CEA) M40

CEA/IRFU (Institut de recherche sur les lois fondamentales de l'Univers) – D. Doré

- Task 2.5.1 CEA/IRFU will perform an innovative experiment on $^{235}$U at the research reactor of the ILL by coupling the first arm of FALSTAFF to the brand new FIPPS gamma-ray spectrometer. FALSTAFF will measure the fragment kinetic energy and will identify the fragment mass after evaporation. FIPPS will measure the cascade of gamma-rays emitted by the fragments.

- MS12 “Completion of the measurements with FALSTAFF at ILL” M36

- Preparation of D.2.13 Report on fission yield studies with FALSTAFF at ILL (CEA) M48

CEA effort in WP2: 7.1 PM
Planning for the end of the first arm tests

- Energy loss measurement (Si detector) at Lohengrin in Fall 2019
- Analysis of 2019 data taking into account Lohengrin measurements
- Modifications of electronics, adding target support, monitoring (slow control).

FALSTAFF at FIPPS (ILL)

✓ Direct comparisons with fission and de-excitation models
✓ Prompt gamma-ray spectra with a good identification of the atomic number and mass of the fragments
✓ Information on the angular momentum of the fission fragments

TECHNIQUE

- One fragment stopped in the target, the other one free to leave it
- Identification (A,Z,E) of the flying fragments in FALSTAFF arm
- Detection of 2 gamma-rays in coincidence in FIPPS array

- ILL long shutdown in 2020 or 2021 - not yet settled
- At some stage, FIPPS should move to another neutron guide to accommodate a gas filled magnet but planning is not yet fixed
- Falstaff experiment at NFS difficult to plan and have to be taken into account for FALSTAFF@FIPPS planning

Expected rates: $^{235}\text{U} - 200 \mu\text{g/cm}^2 : 5 \cdot 10^4 \text{ fissions/s}$
CIEMAT (Centro de Investigaciones Energéticas, MedioAmbientales y Tecnológicas) – 14.3 PM, D. Cano-Ott

- Coordination of WP2
- Reporting and compilation of Task leader reports for the different reporting periods
- Task 2.2.1 CIEMAT will perform various cross section measurements in collaboration with, ULODZ and JRC at GELINA and n_TOF on the high priority reactions $^{239}\text{Pu}(n,g)$ and $^{239}\text{Pu}(n,f)$. Collaboration with ULODZ (fission) and JRC (production of the $^{239}\text{Pu}$ targets)
- MS21 “Measurement of the $^{239}\text{Pu}(n,g)$ at n_TOF” M36
- Contribution to D.2.3 M40

![Total Absorption Calorimeter](image)

Combined fission (ULODZ) and capture cross section measurements: technique developed within CHANDA
CNRS/CENBG (Centre d’Etudes Nucleaires Bordeaux Gradignan) – B. Jurado

- Task 2.1.1 CNRS/CENBG will apply the surrogate reaction analysis technique for providing new excitation functions and cross sections for the $^{239}\text{Pu}(n,f)$, $^{241}\text{Pu}(n,g)$ and $^{241}\text{Pu}(n,f)$ reactions.
- Contribution to D.2.1 M48

$$\text{He}^4 + ^{240}\text{Pu} \rightarrow \text{He}'^4 + ^{240}\text{Pu}^*$$

$J^\pi$ Distributions $^{240}\text{Pu}^*$
Calculated by M. Dupuis with JLM folding model + QRPA

Decay Probabilities of $^{240}\text{Pu}$
$P(E^*, J, \pi)$
With parameters tuned with neutron-induced data
CNRS/IPHC (Institut de PHysique Corpusculaire) – M. Kerveno

- Task 2.3 CNRS/IPCH will perform (in collaboration with IFIN-HH and JRC) neutron inelastic cross section measurements on several isotopes of interest for development of nuclear facilities: $^{239}\text{Pu}$, $^{233}\text{U}$, $^{14}\text{N}$ and $^{35,37}\text{Cl}$.
- Contribution to D.2.4 M48

CNRS/LPCC (Laboratoire de Physique Corpusculaire Caen) – F. Lecolley

- Task 2.1.2 CNRS/LPCC will perform a new measurement on the $^{16}\text{O}(n,\alpha)$ reaction in the energy range from the threshold up to 20 MeV.
- MS18 “Measurement of the $^{16}\text{O}(n,\alpha)$ cross section at NFS, GENESIS and AMANDE” M36
- Preparation of D.2.2 Report on the (n,chg) cross section measurements (CNRS) M48

SCALP:
- Scintillating ionization Chamber for ALpha particle Production in neutron induced reaction

(n, alpha) cross section on $^{16}\text{O}$, $^{19}\text{F}$, $^{12}\text{C}$
- at GELINA (Geel, Belgium) – 2019/2020
- at GENESIS (LPSC, Grenoble, France) – 2020
- at NFS (SPIRAL2 GANIL, Caen, France) – 2020/2021/2022

SANDA kick off meeting, 9th – 10th of September
CNRS/LPSC (Laboratoire de Physique Subatomique & Cosmologie) – G. Kessedjan

- Task 2.5.1 CNRS/LPSC will develop new program with the LOHENGRIN spectrometer at the Laue Langevin Institute (ILL) allowing to test deeply the assumption of the models used in the fission yield evaluations. The program will be the measurement of kinetic energy dependency of yields, isomeric ratios or isotopic distributions. The Gas Filled Magnetic spectrometer developed within will be used in the measurements coupled to the LOHENGRIN spectrometer for purification of the extracted beam.
- Preparation of D.2.12 Report on the fission yield studies with the LOHENGRIN spectrometer at ILL (CNRS) M36.

Targets expected: $^{235}\text{U}$, $^{239,241}\text{Pu}$, $^{241}\text{Am}$ and $^{245}\text{Cm}$
CNRS/Subatech – M. Fallot

- Task 2.4.1 CNRS/Subatech (in collaboration with CSIC) will measure high precision decay data for fission products from major and minor actinides present in working and future advanced reactor fuels. A proven combination of the total absorption gamma spectroscopy technique (TAGS) and high-resolution radioactive beam purification schemes techniques will be applied. The DTAS detector and the GASIFIC data acquisition system will be used in the measurements.

- Contribution to D.2.6 M42

Combined effort of CNRS: 21 PM
CSIC (Consejo Superior de Investigaciones Científicas) – 14.4 PM, A. Algora

- Coordination of Task 2.4
- Preparation of Task reports for the different reporting periods.
- Task 2.4.1 CSIC (in collaboration with CNRS/Subatech) will measure **high precision decay data for fission products** from major and minor actinides present in working and future advanced reactor fuels. A proven combination of the total absorption gamma spectroscopy technique (TAGS) and high-resolution radioactive beam purification schemes techniques will be applied. The DTAS detector and the GASIFIC data acquisition system will be used in the measurements.
- Task 2.4.2 CSIC and UPC will perform **new measurements with the BELEN detector and the GASIFIC data acquisition.**
- MS25 “Completion of the measurements with TAGS and BELEN” M40
- Preparation of the D.2.6 Report of the decay data measurements performed with DTAS and BELEN (CSIC) M42
Isotopes of interest: As, Br, G, Y, In, Sn, and Nb.
CVREZ (Centrum Vyzkumu REZ S.R.O.) – 11.7 PM, M. Kostal

- Task 2.1.2 CVREZ will obtain information on **the prompt fission neutron spectra** above 10 MeV by performing activation measurement with well-known threshold reactions at a nuclear reactor.
- MS11 “Activation measurements for the extraction of prompt fission neutron spectra above 10 MeV” M24

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<th>SACS [mb] (\textsuperscript{235}UFNS)</th>
<th>Unc. [%]</th>
<th>CIELO PFNS [mb]</th>
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<td>\textsuperscript{89}Y(n,2n)</td>
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<td>\textsuperscript{23}Na(n,2n)</td>
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<td>4.9</td>
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Coordination of Task 2.2
Preparation of Task reports for the different reporting periods.
Task 2.2.1 ENEA will measure the $^{92,94,95}\text{Mo}(n,g)$ cross sections at GELINA and at the n_TOF facility with the high performance total energy detectors. The data will be part of an evaluation done in WP4 by IRSN.

MS22 "Measurement of the Mo isotopes at GELINA and n_TOF"

Preparation of the D.2.3 Report on the $^{239}\text{Pu}(n,g)$, $^{92,94,95}\text{Mo}(n,g)$ cross measurements at n_TOF and GELINA (ENEA)
IFIN-HH (Institutul national de cercetare–dezvoltare pentru Fizica si Inginerie nucleara Horia Hulubei) – 11.2 PM, A. Negret

- Coordination of Task 2.3
- Preparation of Task reports for the different reporting periods.
- Task 2.3 IFIN-HH will perform (in collaboration with CNRS/IPCH and JRC) neutron inelastic cross section measurements on several isotopes of interest for development of nuclear facilities: $^{239}\text{Pu}$, $^{233}\text{U}$, $^{14}\text{N}$ and $^{35,37}\text{Cl}$. 
- MS23 “Completion of the $^{239}\text{Pu}$, $^{233}\text{U}$, $^{14}\text{N}$ and $^{35,37}\text{Cl}$ (n,2n) inelastic and (n,2n) cross section measurements at GELINA” M40
- Preparation of the D.2.4 Report on the $^{239}\text{Pu}$, $^{233}\text{U}$, 14N and $^{35,37}\text{Cl}$ inelastic cross section measurements at GELINA (IFIN-HH) M48

**GAINS:** $^{14}\text{N}$, $^{35,37}\text{Cl}$.
- 12 large volume HPGe detectors
- Flight Path: 100 m

**GRAPhEME:** $^{233}\text{U}$, $^{239}\text{Pu}$.
- 5 HPGe planar + 1 segmented detectors
- Flight Path: 30 m
IRSN (Institut de Radioprotection et de Surete Nucleaire) – 1.5 PM, I. Duhamel
• Task 2.2.1 Collaboration with ENEA in the $^{92,94,95}$Mo(n,g) cross section measurements at GELINA and at the n_TOF facility.
• Contribution to D.2.3 M40

IST-ID (Instituto Superior Técnico) – 4 PM, P. Vaz
• Task 2.6.3 IST will carry out (in collaboration with PTB) the measurement of double-differential charged-particle emission cross sections will be carried out at the CERN n_TOF facility in the neutron energy range from 20 MeV to 200 MeV. Part of the necessary equipment will be developed by HZDR within WP1.
• Contribution to D.2.10 M48
JRC (Joint Research Centre Geel) – 17.2 PM, P. Schillebeeckx

- Task 2.2.1 JRC will prepare and deliver the $^{239}$Pu samples necessary for the measurement of the $^{239}$Pu(n,g) and $^{239}$Pu(n,f) cross sections, to be carried out in collaboration with CIEMAT and ULODZ at GELINA (fission) and n_TOF (fission and capture) in combination with the Total Absorption Calorimeter.
- Task 2.3 JRC will perform (in collaboration with IFIN-HH and CNRS/IPCH) neutron inelastic cross section measurements on several isotopes of interest for development of nuclear facilities: $^{239}$Pu, $^{233}$U, $^{14}$N and $^{35,37}$Cl.
- Task 2.3 JRC will perform high accuracy measurements of the branching ratio for $^{209}$Bi, $^{208}$Pb(n,tot) and $^{238}$U(n,inel) cross sections at GELINA.
- Task 2.4.3 JRC will perform (in collaboration with SCK) new decay measurements on high priority isotopes defined in NFRP-2018-6. Data for $^{244}$Cm production and neutron emission rates. Decay data for decay heat prediction.

- MS12 “Measurement of the energy dependence of the nubar with the MONET setup” M24
- MS24 “Completion of the branching ratio for $^{209}$Bi, $^{208}$Pb(n,tot) and $^{238}$U(n,inel) cross section measurements at GELINA” M40
- Contribution to D.2.3 M40
- Contribution to D.2.4 M48
- Preparation of the D.2.5 Report on the measurements of the branching ratio for $^{209}$Bi, $^{208}$Pb(n,tot) and $^{238}$U(n,inel) cross sections at GELINA. (JRC) M48
JYU (University of Jyväskylä) – 5 PM, H. Pentillä

- Task 2.5.1 JYU has begun to apply a pioneering technique called Phas-Imagin Ion-Cyclotron-Resonance (PI-ICRS) for **determining isomeric yield ratios (IYR) in fission**. In a CHANDA-supported experiment isomeric ratios of neutron rich indium and cadmium isotopes in proton-induced fission were measured. JYU will develop a method based on the PI-ICR technique for general fission product yield studies.

- Preparation of the D.2.8 Report on the method based on the PI-ICR technique for general fission product yield studies at JYFL (JYU) M36

The necessary resolution can be reached with the second trap (**precision trap**) and PI-ICR (Phase-Imaging Ion-Cyclotron Resonance) technique

*PRL 110, 082501 (2013)*
*EPJA 54, 154 (2018)*

Technique has already applied to resolve isomers to deduce isomeric yield ratios

*PRC 99, 014617 (2019)*

\[ ^{119}\text{Cd}^+, t_{\text{acc}} = 416 \text{ ms} \]
NPI-CAS (Ustav Jaderne Fyziky av cr) – 17.3 PM, M. Majerle

- Task 2.1.2 NPI CAS will provide new (n,chp) cross section data with a powerful array of hyper pure germanium detectors - dE-E telescopes (Si) on a rotating table constructed recently.
- MS19 “Completion of the (n,chp) cross section measurements at NPI CAS with germanium Si detectors” M36
NPL (National Physics Laboratory) – 2.3 PM, N. Hawkes

- Task 2.6.1 NPL will perform spectrum-averaged benchmark measurements of the activity induced in foils by neutrons from a $^{252}\text{Cf}$ source via the $^{117}\text{Sn}(n,\text{inl})^{117m}\text{Sn}$ and $^{60}\text{Ni}(n,p)$ reactions.
- Preparation of D.2.9, Report on the spectrum averaged cross sections for dosimetry (NPL) **M44**

$^{252}\text{Cf}$ spectrum-averaged cross sections: at least one of $^{117}\text{Sn}(n,\text{inl})^{117m}\text{Sn}$ and $^{60}\text{Ni}(n,p)$. Both are in the NEA High Priority Request List.
NTUA (National Technical University of Athens) – 6 PM, R. Vlastou

- Task 2.1.1 The NTUA will perform a new measurement of the poorly known $^{230}\text{Th}(n,f)$ cross section at the n_TOF EAR2 facility
- MS15 “Measurement of the $^{230}\text{Th}(n,f)$ cross section at n_TOF” M36
- Contribution to D.2.1 M48

Highly enriched samples of $^{230}\text{Th}$ have been provided for the measurements by JRC-Geel.

- Detectors: A Micromegas (Micro-MEsh GAseous Structure) will be used.
- Reference Reactions $^{235}\text{U}(n,f)$ and $^{238}\text{U}(n,f)$

SANDA kick off meeting, 9th–10th of September.
PTB (Physikalische Technische Bundesanstalt) – 4PM, R. Nolte

- Task 2.6.3 PTB will carry out (in collaboration with IST-ID) the measurement of **double-differential charged-particle emission cross sections** will be carried out at the CERN n_TOF facility in the neutron energy range from 20 MeV to 200 MeV. Part of the necessary equipment will be developed by HZDR within WP1.
- Preparation of the D.2.10 Report on the measurement of double-differential charged-particle emission cross sections at the CERN n_TOF facility in the neutron energy range from 20 MeV to 200 MeV. (PTB) M48

High-Energy DDX for $^{12}\text{C}(n, l\text{cp } x)$ at n_TOF EAF

- n_TOF area 1 (183 m station)
- $3\times10^{18}$ protons on spallation target (~30 days)
- Sample: 225 mg/cm2 C
- Development of DE-DE-E telescopes in WP1

Δ$E_1$: 50 μm Si diode
Δ$E_2$: 1 mm Si diode
E: inorganic scintillator

SANDA kick off meeting, 9th – 10th of September
SCK (Belgian Nuclear Research Centre) – 2.2 PM, A. Stankovskiy
• Task 2.4.3 SCK will perform (in collaboration with JRC) new decay measurements on high priority isotopes defined in NFRP-2018-6.

ULODZ (University of Lodz) – 12 PM, J. Andrzejewski
• Task 2.2.1 ULODZ will develop a new ionization chamber and test it in a $^{239}$Pu(n,f) measurement at JRC in collaboration with CIEMAT and JRC.
• Contribution to D.2.3 M40

UMANCH (University of Manchester) – 10 PM, G. Smith
• Coordination of Task 2.1
• Preparation of Task reports for the different reporting periods.
• Task 2.1.1 The UMANCH will perform a new measurement of the high priority $^{239}$Pu(n,f) cross section. The measurement will be carried out with the STEFF spectrometer at the n_TOF EAR2 facility.
• MS17 "Measurement of the $^{239}$Pu(n,f) cross section at n_TOF" M36
• Preparation of D.2.1 Report on the (n,f) cross section measurements (UMANCH) M48
UOI (University of Ioannina) – 6 PM, N. Patronis

- Task 2.1.1 The UOI will carry out a new measurement on the $^{241}$Am(n,f) cross section at the n_TOF EAR2 facility.
- MS16 “Measurement of the $^{241}$Am(n,f) cross section at n_TOF” M36
- Contribution to D.2.1 M48

UPC (Universidad Politécnica de Cataluña) – 1.8 PM, F. Calviño

- Task 2.4.2 UPC and CSIC will perform new measurements with the BELEN detector and the GASIFIC data acquisition and develop a new technique for extracting low resolution energy spectra with long counters following the Bonner sphere principle.
- Preparation of the D.2.7 Report on the development of a new technique for obtaining low resolution information on the beta delayed neutron energies with BELEN-like detectors. (UPC) M30
- Contribution to D.2.6 M42
USC (Universidad de Santiago de Compostela) – 10 PM, J. Benlliure

- Task 2.5.2 USC will perform an experiment to demonstrate the use of \((p,2p)\) as surrogate reactions for fission experiments and identify key nuclei accessible by the new FAIR facility for fission experiments induced by \((p,2p)\) reactions. The experiment will allow investigating the fission of \(^{233}\text{Pa}\), determining the resolution achieved in excitation energy of the fissioning compound nucleus and the possibility to determine fission barriers.

- MS14 “Completion of the measurement on the \((p,2p)\) fission induced reactions at FAIR” M30

- Preparation of the D.2.14 Report on fission yield studies in inverse kinematics at FAIR (USC) M34

SOFIA@R3B

Characterization of the fissioning nucleus \((A, Z, E^*) \to (p,2p)\) with CALIFA+tracker

Characterization of both fission fragments \((A, Z, TKE,) \to \text{SOFIA}\)

Neutrons, gammas and light-charged particles \(\to\) NeuLAND + CALIFA

Beam time granted: 21 shifts main, 15 shifts parasitic in spring 2020

SANDA kick off meeting, 9\(^{th}\) – 10\(^{th}\) of September
USE (Universidad de Sevilla) – 10 PM, C. Guerrero

- Coordination of Task 2.6
- Preparation of Task reports for the different reporting periods.
- Task 2.6.1 USE will perform measurements of production cross sections of beta+ emitters used for range verification in proton therapy. The list of isotopes covers the high priorities of IAEA: $^{11}\text{C}$, $^{13}\text{N}$, $^{15}\text{O}$, $^{30}\text{P}$ produced by protons with energies up to 250 MeV. The gamma-ray detection set-up will consist of a medical PET scanner, or equivalent, and successful preliminary tests have been carried out already at CNA. Other recently proposed isotopes for range verification, with shorter half-lives such as $^{10}\text{C}$, $^{12}\text{N}$, $^{38}\text{mK}$ and $^{29}\text{P}$ will be considered along the project.

- Preparation of D.2.11 Report on the production cross sections of beta+ emitters used for range verification in proton therapy. (USE) M30

Production below 18 MeV
@CNA (+PET)

Production of short-lived ($^{12}\text{N}$, $^{29}\text{P}$ and $^{38}\text{mK}$) up to 230 MeV
@KVI-AGOR (+ array of LaBr$_3$)

Production of long-lived ($^{11}\text{C}$ and $^{13}\text{N}$) up to 230 MeV
@ICP Orsay (+ PET)

Proposal submitted

9th – 10th of September
UU (Uppsala Universitet) – 9 PM, S. Pomp

- Coordination of Task 2.5
- Preparation of Task reports for the different reporting periods.
- Task 2.1.1 UU will perform a high accuracy measurement of the energy dependence of the nubar for the \( \text{^{235}U(n,f)} \) cross section at JRC-Geel.
- Task 2.1.2 UU will perform a new measurement on the \( \text{natC(n,lchp)} \) reaction at NFS facility and provide high quality data for improving cross section standards.
- Task 2.5.1 The UU will perform fission yield measurements as a follow up of the developments achieved with CHANDA. Independent fission yields in neutron induced fission will be performed using the IGISOL/JYFLTRAP facilities at JYU.
- MS19 “Measurement of the \( \text{natC(n,lchp)} \) at NFS” M42
- Contribution to D.2.1 M48

\( \text{^{235}U(n,f)} \) at 5 MeV in 2020

SANDA kick off meeting, 9\textsuperscript{th} – 10\textsuperscript{th} of September
Long term goal: Study DDX for $^{nat}\text{C}(n,\text{lcp})$ in the 10 to 30 MeV range;
Facility: **NFS**; approved experiment
Instrument: **Medley** chamber
When: Initially we will run at QMN (30 MeV), depending on NFS commissioning;

Evacuated chamber
DE-DE-E technique + angles $\Rightarrow$ double differential $\times$s (DDX)

Example of exp. data from previous measurement at high energy:

### List of participants

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<th>Work package number</th>
<th>WP2</th>
<th>Lead beneficiary</th>
<th>CIEMAT</th>
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<tr>
<td><strong>Short name of participant</strong></td>
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<td>Person-months per participant</td>
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<td>9</td>
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<tr>
<td>Start month</td>
<td>1</td>
<td><strong>End month</strong></td>
<td>48</td>
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23 institutions / 213 PMs