Study of new physics cases and preparation of SPIRAL2 experiments using the PARIS array

Project acronym: PARISNPC
Project ID: C2-09

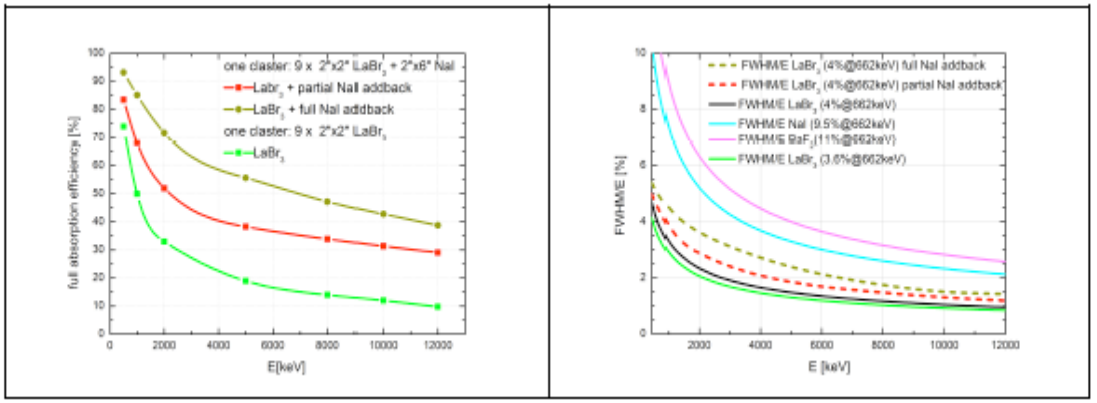
Participating laboratories:

GANIL, IRFU **CEA Team coordinator: Geoff GRINYER**
IFIN-HH **RO Team coordinator: Florin NEGOITA**

PARIS

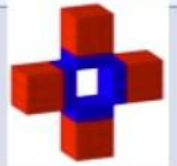
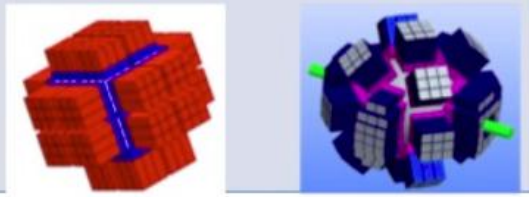
- Photon Array for Studies with Radioactive Ion and Stable Beams -

High efficiency at high energy and very good timing (< 1 ns) make it competitive with existing/proposed HPGe balls.



PARIS phoswich (scintillation detector):

2"x2"x2" LaBr3:Ce + 2"x2"x6" NaI + photomultiplier

Phase 1 **2011/2012** **PARIS Prototype**	1 cluster: 9 phoswiches		200 k€	Decided Funds: SP2PP, ANR, Orsay, Strasbourg, Kraków, Mumbai Tests in-beam and with sources
Phase 2 **2014** **PARIS Demonstrator**	4 clusters: 36 phoswiches		800 k€	**Only if Phase1 validated** **FR, PL, IN, IT, TR, RO**
Phase 3 **2017** **PARIS 2π**	12 clusters: 108 phoswiches		≈ 2 M€	**Only if Phase2 validated** Funds: MoU, PARIS consortium Ph2Day1 exp. with AGATA and GASPARD Other exp.
Phase 4 **≈2019** **PARIS 4π**	≥24 clusters: ≥216 phoswiches		≈ 4 M€	**Only if Phase3 validated** Funds: PARIS consortium Regular experiments in various labs

Objectives of PARISNPC project

The main objective of the project:

- Prepare several experiments of interest for both Romanian and French teams in the field of fundamental and applied research in nuclear physics using PARIS multidetector.

Project aims:

- Propose and perform simulation for new experiments using PARIS:
  - PARIS at Neutron for Science(NFS) facility at SPIRAL2@GANIL
  - PARIS at ELI-NP
  - PARIS coupled to ACTAR TPC (Time Projection Chamber)

- Contribute to PARIS development:
  - Tests of phoswhich detectors
  - Pulse shape analysis: treatment of events occurring in rapid succession
    (pairs/burst of pulses induced in phoswhich detector)

PARISNPC work plan / contributions

The project is organized in 4 tasks:

T1: Definition of new experiments with PARIS and simulation start-up (report end 2012) [**CEA,IFIN-HH**]

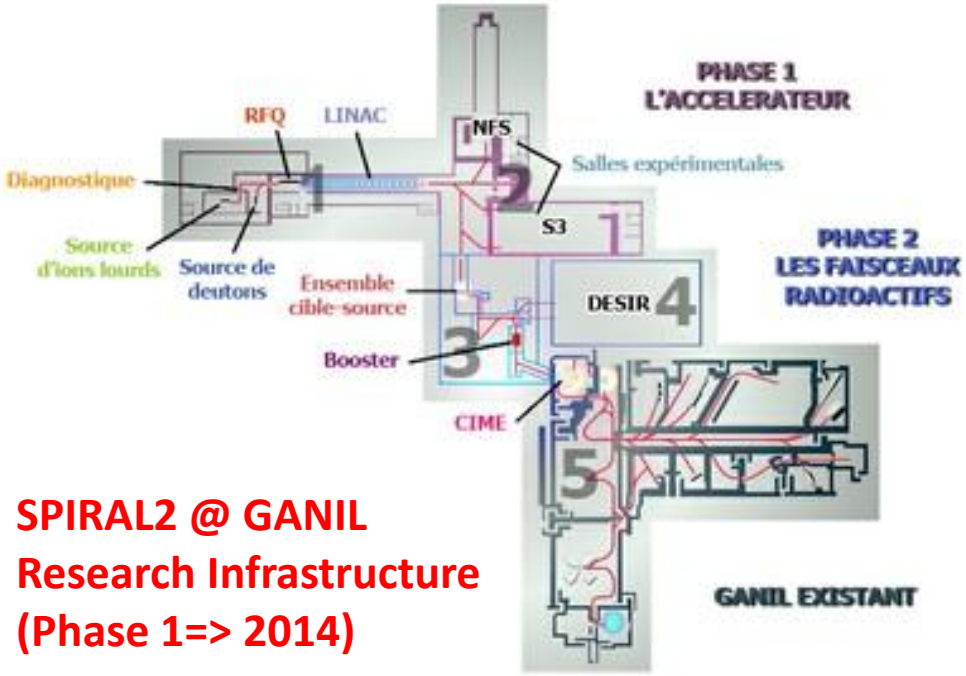
T2: Simulation of new physics cases with PARIS (report end 2013)

- PARIS at NFS **[CEA, IFIN-HH]**
- PARIS at ELI-NP [**IFIN-HH**, CEA]
- PARIS + ACTAR TCP [**CEA**, IFIN-HH]

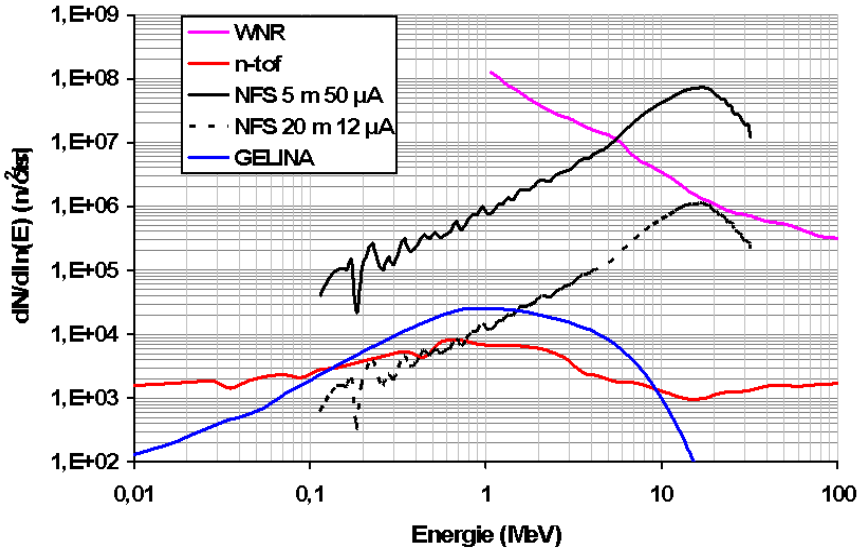
T3: Pulse-shape analysis (report end 2014) [**IFIN-HH**, CEA]

T4: Experiments with the PARIS prototypes (report 2015) [**IFIN-HH**,CEA]

PARIS at NFS



SPIRAL2 @ GANIL
Research Infrastructure
(Phase 1=> 2014)



Expected neutron flux at NFS from deuteron break-up

(+ mono-energetic flux from (p,n) reactions)

Objective of studied experiments:

understanding the prompt γ emission from fission-fragments (neutron induced fission of actinide targets)

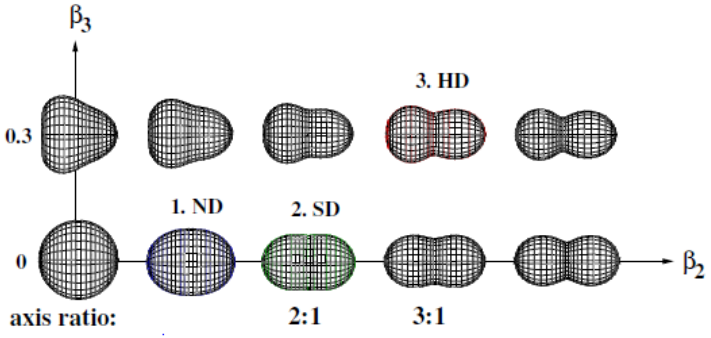
Simulation objectives:

- expected counting rates
- phoswich detector answer to neutrons
- coupling with a fission fragments detectors such as FALSTAFF (developed by IRFU/CEA)
- effects of neutron and gamma background

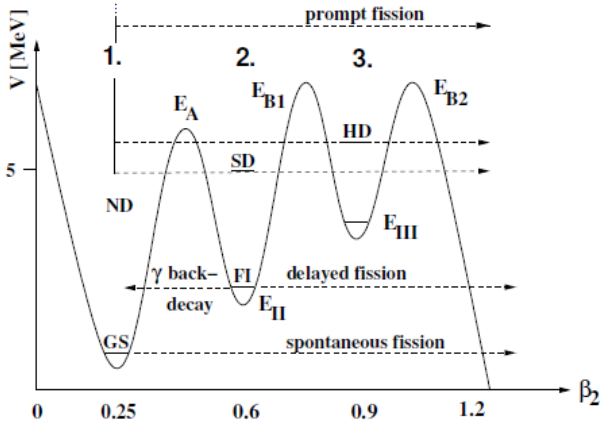
PARIS at ELI-NP

One of the proposed experiments at ELI-NP:

study of double/tripple humped fission barrier in actinides. [P. Thirolf and D. Habs, Prog. Part.Nucl.Phys. 49, 325 (2002).]



The narrow bandwidth (0.1%) of ELI-NP γ - beam will allow to populate selectively the states in second and third minima, defining in more details the shape of fission barrier and better understanding of fission process.

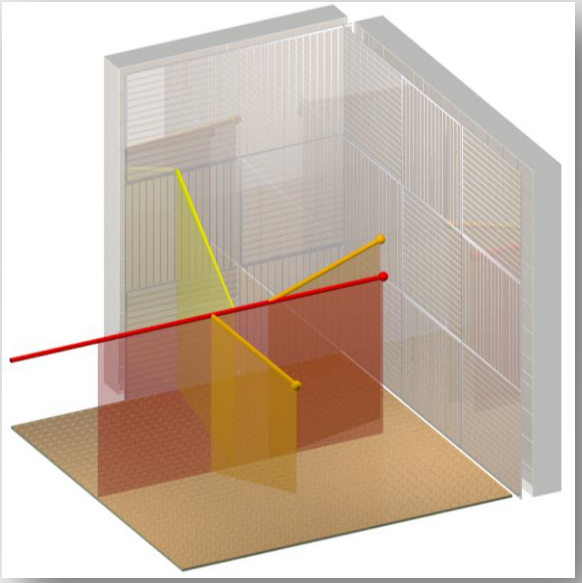


Simulation objective:

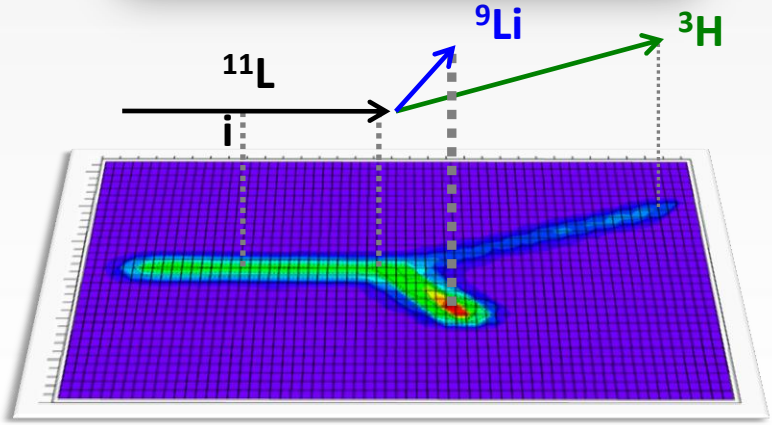
- estimate beam induced background (due to Compton and pairs creation processes)
- estimate counts rates and limits of measurable (integrated) cross-section
- optimise detection geometry

ACTAR TPC

- Active Target and Time Projection Chamber
  - High efficiency and low thresholds
  - Thick targets and good resolution
  - Event-by-event reconstruction in 3 dimensions
  - Unambiguous particle identification
  - Require relatively low beam intensities
  - *A versatile detector for the most exotic nuclei*

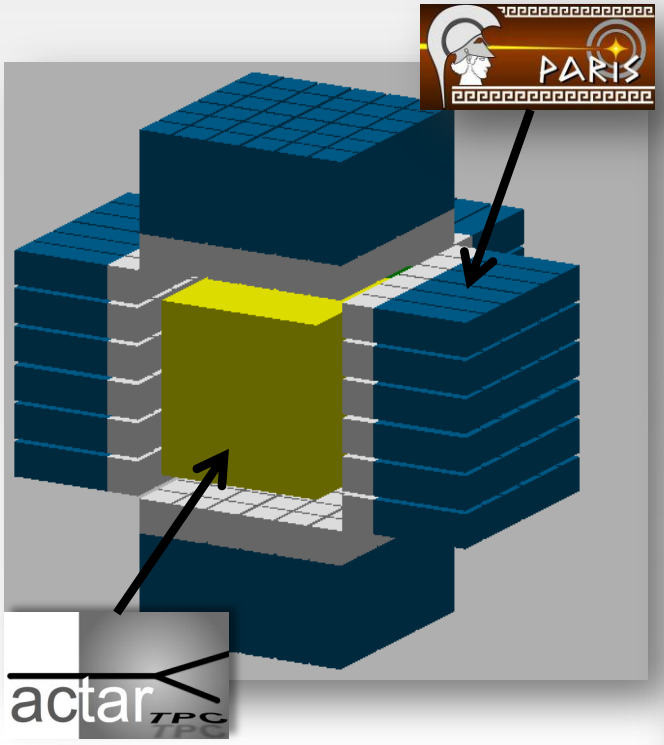


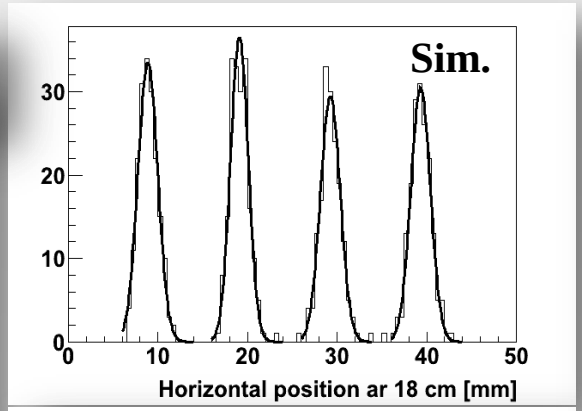
- Physics Opportunities
  - One and two nucleon transfer reactions
  - Resonant elastic scattering
  - Inelastic scattering and giant resonances
  - Nuclear astrophysics
  - Exotic nuclear decay (2p, β3p, βαp, …)

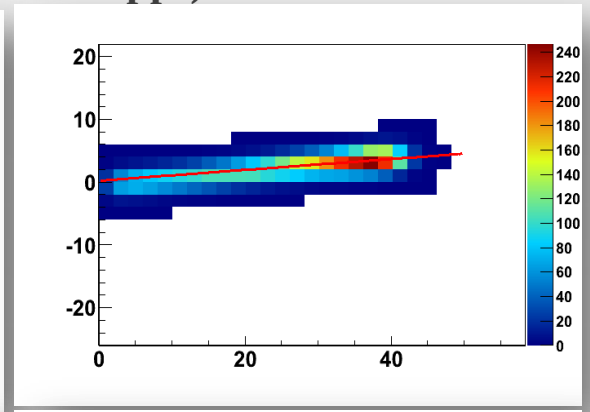


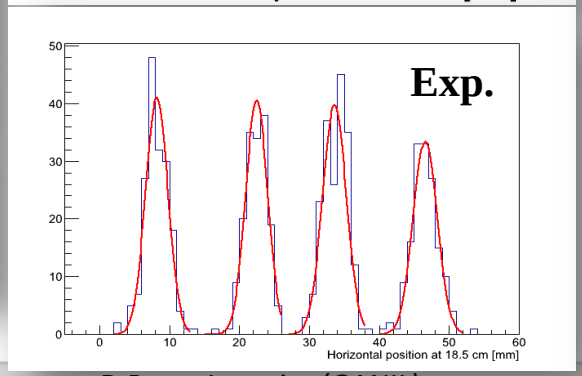
ACTARsim

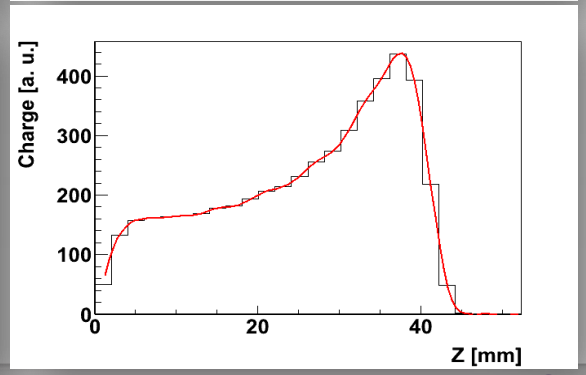
- Complete GEANT4/ROOT simulation and analysis software for gas filled target
  - Simulations of ACTAR TPC physics cases for day 1 experiments at SPIRAL2
  - Have successfully compiled the PARIS geometry files into ACTARsim
    - ACTAR TPC + PARIS simulations work (Sept. 2012 – Aug. 2013)
    - Test case: (d,p) reaction with radioactive beams (down to 1000 pps)











Pulse shape analysis

- **The time structure of ELI-NP γ-beam:**
  - 120 Hz macro bunches
  - Up to 100 micro bunches of ~2 ps separated by ~10 ns

  => **make pile-up (overlapped) events very probable !**

- Timing characteristics of pulses from phoswiches (LaBr3: $\tau \sim 16$ ns and NaI: $\tau \sim 200$ ns) required special signal treatment to recover information from overlapped events (not to reject them)

- The objective is to develop adequate algorithm and check performances after FPGA implementation

- Preparative work:
  - development of acquisition programme for a 2 GSamples/second digitizer
  - tests in beam in an experiment at CERN to determine the population in beta-decay of an $T_{1/2}$=16 ns isomeric E0 transition generating a pair of pulses in a plastic scintillator ($\tau \sim 2$ ns)

1st year results

- **Identification of the main types of experiments and simulation conditions.**

- **Start-up of simulation work:**
  - **installation of simulation framework developed by PARIS collaboration**
  - **coupling with other existing simulation code (ACTAR)**
  - **adapting/adjusting geometry and physics process**

- **Preparatory work on pulse shape analysis**

- **Romanian team signed the PARIS MoU and**
  started discussion on contribution of PARIS demonstrator construction (+ other funding sources)

Perspective of collaboration

- **The present project develops a new direction of collaboration between IFIN-HH and GANIL & IRFU/CEA**

- **The result of the project will be new experiment proposals at major (and world-class) French and Romanian facilities currently under construction**

- **It is expected that the collaboration strengthen and continue long after the end of present project (2015)**

Thank you for attention !