HIB@LNS: CONCLUDING REMARKS

F. Gramegna (LNL)
Laboratori Nazionali del Sud
14-15 December 2015
The evolutionary character of the main reaction mechanism in HI above Coulomb energy ($E/A > 10$ MeV/nucleon)

Time scale of nuclear detection

**Upgrading of the Cyclotron → introduction by A. Pagano**

**DETECTION**

- Auxiliary Correlators detectors
  - ARGOS
  - LASSA
  - HiRA
  - MUST2
  - HODO
  - FAZIA

- Heavy-Ions

- Properties of Nuclear matter away from equilibrium
  - Light-ion
    - ISIS, FASA
  - Projectile decay fragmentation
    - EOS, ALADIN, FAUST, MULTICS, FIRST

- n detection
  - ORION
  - Superball
  - NIMROD
  - LAND
  - EDEN
  - DEMON n-walls

- 4π detectors
  - Nautilus
  - Miniball
  - INDIRA
  - CHIMERA
  - FOPI
  - HERACLES
  - GARFIELD
  - MEDEA
  - CHIM-FARCOS

**Time**

$10^{-23}$ s ($\approx$ fm/c)  

$10^{-20}$ s ($\approx$ fm/c)
NUCLEAR PHYSICS: STABLE & EXOTIC BEAMS

LNS & LNL: an italian working consortium for NUCLEAR PHYSICS

STABLE BEAMS:

• **LNS**
  ✓ the Superconducting Cyclotron (Intermediate energies ➔ Reaction Dynamics)
  ✓ the TANDEM (Astrophysics)

• **LNL**
  ✓ The SC LINAC ALPI & PIAVE (low & medium energies ➔ Reaction and Structure)
  ✓ The TANDEM (Nuclear Structure)
LNS & LNL: a working consortium for NUCLEAR PHYSICS

RADIOACTIVE BEAMS:
→ our BET on future

ISOL & FRAGMENTATION
LOW ENERGY & INTERMEDIATE ENERGY

SPES: Selective Production of Exotic Species
- European framework
- Physics with SPES (mainly UCx fission but also SiC, B4C etc.)
- Instrumentation

FRIBS: Radioactive Ion Beams at Intermediate Energy produced by the In-Flight method at LNS
- European framework
- Physics with FRIBS (intermediate energy, light ions)
- Instrumentation
Atomic nuclei are one of the richest and most challenging quantum systems with a finite number of strongly interacting fermions of two kinds: protons and neutrons.

Still crucial and long-standing questions remain:

- What are the limits for the existence of nuclei?
- Which is the shell evolution (magic numbers, proton-neutron interaction, shell gap creation and disappearance)?
- How does the nuclear force depend on the proton-to-neutron ratio?
- How can collective phenomena be explained from individual motion?
- Is it possible to explain complex nuclei on the basis of simple building blocks?
LNS & LNL: a working consortium for NUCLEAR PHYSICS

The mainframe in which the two Laboratories are working is at European level:

ECOS (talk by F. Azaiez)

The Science with high intensity stable ion beams, Beam intensity limitations and technical developments for various types of research lines!
- \( N=Z \) nuclei (in-beam spectroscopy and decay studies)
- SHE search (Super heavy nuclei (in-beam spectroscopy and decay studies)
- Neutron-deficient nuclei (in-beam spectroscopy and decay studies)
- Nuclear astrophysics

not only RIBs but intense stable beams needed

Science Key Questions

What are the limits of the heaviest elements?

SCIENCE Magazine- Top 125 Questions:
Are there stable high-atomic-number elements?

What are the limits of stability?

How the elements are made in the Universe?
LNS & LNL: a working consortium for NUCLEAR PHYSICS

The mainframe in which the two Laboratories are working is at **European level**:

ECOS (talk by F. Azaiez)

**Did we progress?**

**FP8 ENSAR2**

### Partners of

- **7 ⇒ 10 TNA Facilities**
- **30 ⇒ 30 beneficiaries**
  - **15 countries**

**Community:** 2700-3000 scientists and highly qualified engineers

Close collaboration with infrastructures outside Europe:
- Canada: TRIUMF
- China: IMP Lanzhou
- Japan: RIKEN & RCNP
- Russia: Dubna/JINR
- South Africa: iThemba
- United States: NSCL & ANL

**ENSAR2**

**LIA CollAGAIN**

**LIA POLITA**

**LIA COPIGAL**

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F.G. - Concluding Remarks - HIB@LNS 14-15 December 2015
LNS → high intensity Superconducting Cyclotron for NUCLEAR PHYSICS

**NUMEN:** → HI-DCE a method to have access to the neutrino mass → talk by F. Cappuzzello

New physics for the next decades
but requires

Nuclear Matrix Element (NME)!

\[ |M_{\alpha\beta}^{\rho\sigma vo}|^2 = \langle \Psi_f | \hat{O}_{\alpha\beta}^{\rho\sigma vo} | \Psi_i \rangle^2 \]

Data from Magnex give first evidence of getting quantitative results about nuclear matter elements from experiments:
The \( ^{40}\text{Ca}(^{18}\text{O},^{18}\text{Ne})^{40}\text{Ar} \) reaction.

**Challenging some hot cases in Phase 2**

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Energy (MeV/n)</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
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<tr>
<td>(^{115}\text{Sn}(^{18}\text{O},^{18}\text{Ne})^{115}\text{Cd} )</td>
<td>15-30</td>
<td></td>
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<tr>
<td>(^{115}\text{Cd}(^{18}\text{Ne},^{18}\text{O})^{115}\text{Sn} )</td>
<td>15-25</td>
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<tr>
<td>(^{130}\text{Te}(^{20}\text{Ne},^{20}\text{O})^{130}\text{Xe} )</td>
<td>15-25</td>
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<td></td>
</tr>
<tr>
<td>(^{76}\text{Ge}(^{28}\text{Ne},^{28}\text{O})^{76}\text{Se} )</td>
<td>15-25</td>
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<tr>
<td>(^{76}\text{Se}(^{40}\text{O},^{40}\text{Ne})^{76}\text{Ge} )</td>
<td>15-30</td>
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<tr>
<td>(^{150}\text{Cd}(^{40}\text{O},^{40}\text{Ne})^{150}\text{Pd} )</td>
<td>15-30</td>
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</tbody>
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**Major upgrade of LNS facilities: the MAGNEX spectrometer**

- The MAGNEX focal plane detector rate (from 2 kHz to several MHz)
  - R&D key issue: GEM-based tracker at low pressure and wide dynamic range
  - INFN-LNS (M. Cavallaro), collaboration with INFN-LNF, CERN, INFN-BA

From multi-wire tracker
To micro-pattern tracker

From wall of 60 Si pad
To wall of 2500 SiC-SiC pad telescopes

A big challenge!
0.9 M€ call approved by INFN CSNS (SICILIA)
P.I. S. Tomaso, collaboration with CNR, STMS, FBK
NUMEN: Upgrading of electronics needed → talk by D. Bonanno
Upgrade of the MAGNEX detector → upgrade of Front End & Read Out electronics for the FOCAL PLANE

Front-end and read-out electronics

ELECTRONICS PROTOTYPES (D. LoPresti)

1) ASIC front-end chip:
   for FPD chip VMM2(3) in collaboration with Brookhaven National Laboratory (8x10^4 transistor/channle for 64 channels)
   for PM and PM-like signal chip DRS4 commercial chip delivered by PSI

2) Read-out: new generation of FPGA and System On Module (SOM)

Number of channels

- Gas tracker ~ 30000 ch
- SiC-SiC ~ 7500 ch
- Gamma array ~ 2500 ch

Tot ~ 40000 ch
LNS → high intensity Superconducting Cyclotron for NUCLEAR PHYSICS

Upgrading of the Cyclotron needed → talk by A. Galan, D. Rifugiaiato

Major upgrade of LNS facilities: The CS accelerator

The CS accelerator current (from 100 W to 5-10 kW);

To enhance the extraction efficiency

Extraction by stripping

New channel needed to optimize extraction
New extraction line
New Switching magnet

- The beam transport line transmission efficiency to nearly 100%

Project submitted to INFN MAC

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**Physics cases:**

**Isospin Physics** with FAZIA: physics at intermediate energy → talk by S. Piantelli

- $<N>/Z$ of QP phase space products systematically higher when the target is nrich
- $<N>/Z$ of neck emitted fragments higher than $<N>/Z$ of QP evaporated fragments
- No dependence on lab velocity for QP fission fragments

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S. Barlini et al., PRC87(2013)054607
Physics cases

FAZIA present and future → talk by N. Le Neindre

Excellent resolutions in terms of A,Z, Energy

$^{80}\text{Kr}+^{40-48}\text{Ca} @ 35 \text{ A MeV IsoFazia experiment, June 2015, LNS Catania}$

Good resolution, excellent results but low intensity for detectors and electronics → only the upgraded FRIBS program can be considered.

Severl campaign:
FAZIA@LNS
FAZIA+INDRA @GANIL
FAZIA @SPES
FAZIA @HIB-CS? → with FRIBS?
LNS → high intensity Superconducting Cyclotron for NUCLEAR PHYSICS

**Transfer-like reactions** from Coulomb to Fermi energy → talk by Diaz-Torres

**Low-Energy Nuclear Reaction Dynamics**

- Relative Motion
- Nuclear Structure

Strong interplay of **nuclear structure** and **reaction dynamics** determines reaction outcomes (cross sections)

**Summary**

- The **diabatic picture** supports the dinuclear model for heavy-ion complete fusion in competition with quasi-fission at energies near the Coulomb barrier.

- **Elasto-plastic effects** on the mass & charge distributions of the reaction products should be important as energy increases from Coulomb to Fermi energies.

- How does elasto-plasticity impact on observables?

**Location of toroidal events on the θ_{plane} vs θ_{flow} plane**

**Talk by R. Planeta**
LNS → high intensity Superconducting Cyclotron for NUCLEAR PHYSICS

Development of new instrumentation/electronics:
Instrumenting a Nuclear Physics Program → talk by E. Pollacco

- Instrumentation for intense beams at LNS is a significant challenge.
- Path towards success is **time** for development.
  - Apply new detection media (*experimentalist*).
  - New electronics (*engineering support*).
  - New structure in the labs to analyse & extract the physics from data (*physicists*).

Develop SPECIFIC/NOUVELLE physics program → SPECIFIC instrument.
LNS $\rightarrow$ high intensity Superconducting Cyclotron for NUCLEAR PHYSICS

**FRIBS:** The exotic beams by fragmentation $\rightarrow$ talk by G. Cardella

The cyclotron intensity upgrade and the installation of a new fragment separator open very interesting perspectives for the use of fragmentation beams at LNS.

- Intensity upgrade $\rightarrow$ good for lighter masses
- New spectrometer $\rightarrow$ larger efficiency for higher masses
- Improvement in the tagging
- Improvement in the detector system

Tagging system

Position sensitive PPAC to measure trajectory

With 68Ni fragmentation beam last week
Study of **new FRIBs facility line** → talk by A. Russo

The new FRIBs solution consists in:
- 2 - triplets
- 2 - doublets
- 2 - 45° dipoles
- 1 - 90° dipole

- The new system guarantees very good optic performances.
  The beam can be easily delivered to different experimental rooms.

**Degrader inside the 90° dipole**

**Magnex could use it as energy spread selector**
FRIBS: the common problem of beam diagnostics → talk by E. Pagano

Fig. 2. Beam particle counter, based on a plastic scintillator coupled to a photomultiplier.

Fig. 3. PSSD mounted in a pneumatic actuator. The mask made by brass is 2mm thick.

Fig. 4. Corrected beam profiles of a EXCYT (a) and a FRIB (b) beam, acquired by means of the PSSD and using two different masks.
The Super-FRS itself takes well established detection system, like the FRS one, to its operation limit → preserve high resolution at the highest rate.

To obtain a clean PID:

- $B_p$ reconstruction needs high-precision tracking detectors,
- higher efficiency: FRS TPCs → Super-FRS Twin GEM-TPC
- ToF detector with timing resolution $\sigma t < 50$ ps
- $\Delta E$ detector with pile-up correction, stripper between MUSIC sections helps to disentangle charge states.

PID for in-flight radioactive separator → talk by C. Nociforo

Time Projection Chamber (TPC)
- ‘Twin´ Gas Electron Multiplication (GEM)-TPC
- Plastic scintillator readout by PMTs pcCVD-DD (0.3mm) and scCVD-DD (0.09mm)
MAGNEX: exotic nuclei & isospin with RIB and stable beams → talk by C. Agodi

Outlook

- MAGNEX: a magnetic spectrometer with a large acceptance and high energy, mass and angular resolution, allowing $0^\circ$ measurements
- NUMEN
- HIB @ LNS
- MAGNEX + CS Upgrade
- FRIBS @ LNS for ISGMR in exotic nuclei
- Drip line: spectroscopy studies with tiny cross sections

High Intensities CS Beams @ LNS: New challenging series of experimental studies!
LNS → high intensity Superconducting Cyclotron for NUCLEAR PHYSICS

Study of Neutron proton pairing through transfer reactions → talk by M. Assie

Pairing in the T=0 or 1 np channel: GANIL experiment

Theory: Form Factors- Beyond the MF

Experiment: analysis of $^{56}\text{Ni}(p,3\text{He})$, $^{56}\text{Ni}(d,\text{alpha})$

analysis of $^{56}\text{Ni}(p,3\text{He})$, $^{52}\text{Fe}(d,\text{alpha})$

No T selection in p,3He only T=0 in d, alpha

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Transfers proportional to the number of pairs $\sigma(0+)/\sigma(1+)$ --< strength of the np coupling

Strong coupling

[particle diagrams]
Decays (in beam)

Shell structure
Colloettive modes-shape
vs N/Z
Symmetries

Heavy-ions 50 MeV/u

Reactions

peripheral
Nuclear structure
Termodynamics
Viscosity-high spin
Equation of state

Multi-framm

GAMMA- PRISMA- EXOTIC- NUCLEX
MAGNEX- LNS_STREAM - FRIBS - EXOCHIM

5-10 MeV/u

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Personnel & Structures in the Laboratories

National & International Laboratories needs a structure:
- Divisions – Services - Technologies - Experimental groups

Support to National & International Users

LNS & LNL can have common problems and should find common solutions

No antagonism but cooperation and collaboration to be a unique stronger Community
In the next future for EPR (Public research Institutions):
60% of Turn over for researcher & engineers
20% or 60% for technicians? → this is a big issue for Laboratories!!!
20% for administration people

We may have a certain number of new positions for researchers → how many for INFN? How many for Nuclear Structure & Dynamics? Will it be discussed a scientific plane as an united national community in order to reinforce all the NP future Community?
Thank you