Status of the facility
a hybrid facility

Radioactive beams

ISOL
Beta-decay, laser spectroscopy...
Tape system; close geometry

OSCAR
(Orsay Segmented Clover Array)

stable beams

ligne 320
BACCHUS
ORGAM phase2

ligne 410

ligne 420
ORGAM phase1

Cluster beams

stable beams

Stable beam without spectrometer

Stable beam with spectrometer

Radioactive beam lines

SPLIT POLE

TRIUMF June 2008
Production of fission fragments by photo-fission

- Target: W (d = 2 mm)
- \( E_\gamma = 45 \text{ MeV} \)
- \( E_\gamma = 25 \text{ MeV} \)
- \( E_\gamma = 10 \text{ MeV} \)

Graphs showing:
- \( N_\gamma \text{ per MeV} \cdot \text{sr} \cdot \text{electron} \)
- Fission cross section (mb)
- Yield (fission per electron)

Electron energy (MeV)
Comparison between cold and hot fission
$^{132}$Sn region

A=132
Energy: 50 MeV
Average current: \( \leq 10 \, \mu A \)
Beam frequency: 100 Hz max
RF frequency: 3 GHz
Impulse: 0.2-2\,\mu s
Emittance: 0,6 \( \pi \) mm.mrad @ 50 MeV
Diameter of beam on target: 10 mm
Beam structure

- Modulateur 3GHz
- Gun
- Beam

10 ms to 40 ms (100 Hz to 25 Hz)

10 ms to 3 µs

< 70 mA

≤ 10 µA

333 ps

15 ps
Linac tests

December 2005:

ALTO first beam

10 µA@50 MeV after the section section

2006:

Optimization of the injected RF power
Energy dispersion measurements
Beam transmission measurements
Target ion source
Shielding
Production of fission fragments with various targets

Good release properties:
⇒ T1/2 ≈ some 100ms

High density:
⇒ higher production for long T1/2
Uranium carbide target

UCx target:
Ø = 14 mm, L = 140 mm
Density = 3.2 g/cm³
Tests of target ion sources for SPIRAL2 and EURISOL at ALTO
Some ion sources currently used at ALTO

**Febiad**

- High temperature (1900 °C)
- Compact: the target is part of the source high efficiency
- Well adapted for a large number of elements
- **No selectivity**

**Surface ionization**

- Very high efficiency for alkaline
- Dedicated to alkaline and Ga In

**Laser source**

- Very selective ion source
- High efficiency depending on the rate frequency of the laser
- Large number of elements could be ionized
- **Contamination with surface ionization**
On line laser ion source

Laser room

Tests at CEA Saclay
The IRENA source

Temperature of use 2500 °C

Cylindrical cathode

Can work much longer than a classical Febiad (3 months?)

First prototype tested but not in optimal conditions

\[ 1900°C < T_{\text{cathode}} < 2200°C \]

Optimization of the geometrical parameters with Lorentz code
Shielding of the target ion source

Simulations with FLUKA code

- Concrete Bunker:
  - 1 m thick for walls
  - 1.2 m for the roof

- Wrapped in a structure:
  - Pb, steel and polyethylene (PE)
  - 0.70 m total thickness
Separator and new lines
Deflection of the beam and new lines

- deflector 45° & 60°
- Electrostatic QP
- Kicker bender
ALTO tests carried out in accordance with the procedure notified by ASN

Check the agreement between the measurements and the Fluka calculations

Irradiations in steps between 0.1 and 10µA

For each test, a report is submitted to the ASN for validation and authorization of the following test
Radioprotection measurements

Program:

2006

$\rightarrow 100 \, \text{nA}$

verify the Fluka code in the PARRNe configuration

2007

$\rightarrow 500 \, \text{nA}$

bunker configuration with only the concrete shielding

$\rightarrow 1 \, \mu\text{A}$

Bunker with the complete structure for the roof and concrete on the front

2008

$\rightarrow 5 \, \mu\text{A}$ and $10 \, \mu\text{A}$ (extraction with Febiad and surface IS)

final configuration of the bunker
Zone 1: inside TIS cave
Zone 2: roof of the cave
Zone 3: Corridor
Mesurements @ 1 μA

Double deviation of the electrons

Bunker TIS

887nA electrons 50 MeV
pulsation 0.25μs 100Hz
Yields of Xe, Sn, In and I beams

Comparaison of the yields by photofission and by neutrons (100 nA electrons@50 MeV = 1 µA deutons@26 MeV-PARRNe)
Extrapolation of the yields @10 μA

Gain ALTO/PARRNe ~100

$^{132}\text{Sn} : 3 \times 10^7 \text{ pps}$
$^{78}\text{Zn} : 1 \times 10^5 \text{ pps}$
Possible Physics program at a low energy

Some examples

Study of neutron rich nuclei around N=50 (or any closed shell)

Laser spectroscopy

$\beta$ strength functions

$\beta n$ $\beta 2n$ decay measuring

$g$ factor measurements

Fast timing measurements

Nuclear astrophysics
Some examples

Study of neutron rich nuclei around N=50

Laser spectroscopy at ALTO

$\beta$ strength functions

$\beta n$ $\beta 2n$ measurements

Need for a high efficiency Ge set-up and complementary detectors (neutrons, electrons)

Need for pure beams
\[ I = \Phi \cdot \sigma \cdot N \cdot \varepsilon \]

**Neutron detector**

**Conversion electron detector**

**OSCAR**: Orsay Segmented Clover Array

\( \gamma \)-Ring: 4 segmented clovers @ 6cm

\(~ 10\% \) efficiency
\( I = \Phi \cdot \sigma \cdot N \cdot \varepsilon \)

**β-decay** studies of fission fragments as a powerful tool for
the exploration of the nuclear structure close to \( N=50 \)

Typical Experimental Setup
First experiments study of N=50 towards $^{78}$Ni

Filling of the neutron $1g_{9/2}^+$ subshell

Radioactive beam: REX
Deep inelastic Legnaro
Radioactive beam: REX ISOLDE (Leuven group)
Isomer decay: LISE-GANIL

β-decay: PARRNe Orsay

β-decay: Orsay

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**Experiment 1: the $^{83}\text{Ga}_{52} \rightarrow ^{83}\text{Ge}_{51}$ decay study**

\[ ^{83}\text{Se} \rightarrow ^{83}\text{Br} \quad 356 \text{ keV} \]

\[ ^{83}\text{Br} \rightarrow ^{83}\text{Kr} \quad 529 \text{ keV} \]

\[ ^{83}\text{Ge} \rightarrow ^{82}\text{As} \quad 1092 \text{ keV} \]

\[ ^{83}\text{Ga} : T_{1/2} = 325.4 \pm 57.8 \text{ ms} \]

\[ ^{83}\text{Ge} : T_{1/2} = 282.9 \pm 34.0 \text{ ms} \]

\[ ^{83}\text{Ga} : T_{1/2} = 300 \pm 10 \text{ ms} \]
Proposed spin assignment for the observed levels in $^{83}$Ge$_{51}$

$2^+ \otimes \nu d_{5/2}$

Evidence of a weak coupling structure in $^{83}$Ge$_{51}$

Persistance of N=50
HFB calculations

O Perru & J. Libert private communication
HFB calculation using the Gogny interaction
GCM $\rightarrow$ Bohr dynamics

E (keV) Ge

$\begin{array}{cccc}
4^+_1$ & $4^+_1$ & $2^+_1$ & $2^+_1$
\end{array}$

N=50

triaxial static shape predicted!
Experiment 2: the $^{81}\text{Zn}_{51} \rightarrow ^{81}\text{Ga}_{50}$ decay study
Results from the $^{81}\text{Zn}_{51} \rightarrow ^{81}\text{Ga}_{50}$ $\beta$-decay study

- $^{81}\text{Ga}_{51} \rightarrow ^{81}\text{Ge}_{50}$ ($37.4\%$)
  - Energy spectrum gated by the 351.1 keV line
- $^{81}\text{Ge}_{51} \rightarrow ^{81}\text{As}_{50}$ ($11.5\%$)
- Energy spectrum gated by the 216.47 keV line
- Energy spectrum gated by the 451.7 keV line

Unknown!

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Proposed level scheme for $^{81}$Ga: persistence of N=50 shell closure

observed in β-decay at Orsay
D. Verney et al.

observed in DIC experiments at Legnaro
G. De Angelis et al.

$^{81}$Zn

$^{81}$Ga

$\ell_{5/2}^3$

$J=3/2, \nu=3$

$\ell_{5/2}^3$

$J=5/2, \nu=1$

$\ell_{5/2}^2$

$\ell_{3/2}$

$J=3/2$
First experiment with electron beam
April 2008
$T_{1/2} = 71 \pm 31\text{ms}$

Equation: $y = A_1 \exp(-x/t_1) + y_0$

- $\chi^2/\text{DoF} = 2.03956$
- $R^2 = 0.3118$
- $y_0 = 1.78507 \pm 0.46805$
- $A_1 = 200.11121 \pm 276.28588$
- $t_1 = 0.07067 \pm 0.03128$
First results at ALTO : d5/2 and s1/2 very close beyond N=50

\[ \gamma f_{5/2} \otimes \nu d_{5/2} \]

\[ \pi f_{5/2} \otimes \nu s_{1/2} \]

\[ \gamma s_{1/2} \otimes \nu d_{5/2} \]

\[ {^{84}}\text{Ga} \]

\[ {^{85}}\text{Ge} \]

\[ {^{83}}\text{Ga} \]

\[ N=53 \]

\[ E^2 (\text{keV}) \]

\[ N \]

Isolde and ALTO
Gate 100 keV

Gate 42.7 keV

42.7 keV

100 keV

386 keV
\[ ^{84}\text{Ga} \quad \pi f_{5/2} \otimes \nu s_{1/2} \]

\[ ^{84}\text{Ge} \quad 99\% \]

\[ ^{84}\text{Ge} \quad \pi f_{5/2} \otimes \nu d_{5/2} \]

\[ ^{84}\text{As} \]

\[ (1^-) \quad 242.7(2) \]

\[ (2^-) \quad 243 \]

\[ (4^-) \quad 42.7(7) \]

\[ > 2500 \]

\[ 386(5) \]

\[ 529 \]

\[ 100(8) \]

\[ 143 \]

\[ 0 \]
Present limits for the experimentally known structure towards $^{78}\text{Ni}$
Next step for $\beta$ decay experiments at ALTO towards $^{78}\text{Ni}$
2000: exploratory experiment at CERN
2001: arrival of the cavity
2002: construction of the LINAC bunker
2003: First e-beam extracted
2004: RF system
2005: electron-beam on the target ion source ensemble
2006: building of the low energy beam lines
2007: commissioning
2008: exploitation
2009: EXPLOITATION
2010:

2006: fission fragment yields measured after mass separation

2000-2010: TRIUMF June 2008

TRIUMF June 2008

F. Ibrahim
Thank you for your attention
Interprétation for $^{83}$Ga→$^{83}$Ge


Ground state $\frac{5}{2}^+$

2d$_{3/2}$ 1g$_{7/2}$ 3s$_{1/2}$ 2d$_{5/2}$

Neutron orbital

91Y $\rightarrow$ 89Rb $\rightarrow$ 87Br $\rightarrow$ 85As $\rightarrow$ 83Ga

Proton orbital

$\nu_d^{5/2} \otimes 2^+$

$\frac{1}{2}^+$

$\frac{1}{2}$

$\frac{3}{2}$ $\frac{5}{2}$ $\frac{7}{2}$ $\frac{9}{2}$

$\nu_s^{1/2} \otimes 0^+$

$\frac{1}{2}$

$\frac{3}{2}$ $\frac{5}{2}$ $\frac{7}{2}$ $\frac{9}{2}$

1238

867

91$\mbox{Zr}_{51}$ 89$\mbox{Sr}_{51}$ 87$\mbox{Kr}_{51}$ 85$\mbox{Se}_{51}$ 83$\mbox{Ge}_{51}$

TRIUMF June 2008

F. Ibrahim
Interpretation for $^{83}\text{Ga}ightarrow^{83}\text{Ge}$
Manutention de l’ECS

Le cycle d’irradiation est le suivant:

- < 1 semaine de préparation de l’ECS
- 3 semaines d’irradiation pour délivrer le faisceau
- 1 semaine de refroidissement avant démontage

Dose rate at 50 cm from the target (extrapolation from PARRNe measurements)