The GALILEO Array at LNL and its first physics campaign

NUSPIN 2016

P.R. John (philipp.john@pd.infn.it)
On behalf of the GALILEO collaboration

June 30, 2016
Outline

Gamma-ray spectroscopy in Legnaro

The GALILEO project

The Galileo Euclides NeutronWall campaign

Complementary detectors

The first experimental campaign
Legnaro National Laboratories (LNL)

- Where is Legnaro?
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- Where is Legnaro?
Tradition of $\gamma$-ray spectrometers in LNL

- Study of (mostly) proton-rich nuclei

GASP (1992)  
EUROBALL (1998)
Tradition of $\gamma$-ray spectrometers in LNL

- Study of (mostly) neutron-rich nuclei

Clara (2004)  
AGATA (2006)
GALILEO  a new $4\pi \gamma$-ray spectrometer

- takes advantage of the developments made for AGATA
  - preamplifiers
  - digital sampling
  - preprocessing
  - DAQ
- uses the EUROBALL cluster detectors capsules
  - improved efficiency
  - development of a new cluster detector with 3 capsules

- 30 GASP detectors
- 10 triple cluster detectors
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GALILEO  a new $4\pi$ $\gamma$-ray spectrometer
GALILEO current status
GALILEO NeutronWall campaign

- **\( \gamma \)-array**
  - 25 HPGe Compton-suppressed GASP detectors
  - 4 angular groups

- **Light charged particles EUCLIDES**
  - \( 4\pi \) DE-E Si ball (110 detectors)
  - Segmented with segmented detectors
  - Position and energy

- **Neutron Wall**
  - 50 liquid scintillator detectors
  - n-\( \gamma \) discrimination via TOF and ZCO
  - Analog electronics
GALILEO NeutronWall campaign

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GALILEO electronics

- Detector Ge
  - Preamps
  - Buffer
  - Digitizer
  - Local processing
  - PCIe board
- Detector AC
  - Preamps
  - Buffer
  - Digitizer
  - Local processing
  - PCIe board
- Detector Si
  - Preamps
  - Buffer
  - Digitizer
  - Local processing
  - PCIe board

- Pre
- Digitizer

- HPGe, AC, Anc. digitized
- Branches are sync by GTS.
- Trigger-less operation
- 240 channels available
- Typical rate ~ 20 kHz/det
- Max rate ~ 50 kHz/det
GALILEO electronics

- Local processing of the data recorded
- Online Pulse Shape Analysis
- Agata style Local processing
GALILEO electronics

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GALILEO HpGe detectors – today

- 25 HPGe detectors Gasp Type
- FWHM@1332.5 keV < 2.4 keV with experimental shaping: 17 mounted
- Completely digital DAQ
  - 4 $\mu$s rise time, 1 $\mu$s flat top energy stored
  - initial part of the signal taken
  - BGO slave of HPGe
  - very low noise
  - recover time information from the signal
- Efficiency@1332.5 keV 2.4%

March 2016
GALILEO HpGe detectors – today

- 25 HPGe detectors Gasp Type
- FWHM@1332.5 keV < 2.4 keV with experimental shaping: 17 mounted
- Completely digital DAQ
  - 4\(\mu s\) rise time, 1\(\mu s\) flat top energy stored
  - initial part of the signal taken
  - BGO slave of HPGe
  - very low noise
  - recover time information from the signal
- Efficiency@1332.5 keV 2.4%

March 2016
Neutron Wall

- 50 (45) detectors, organic scintillators [BC501A]
- Three types of signals for each of them: QVC, TOF, ZCO
- Preselected neutron condition provided to the trigger
- $\epsilon(1n) = 23\text{-}27\%$; advantageous for identification of 2n channel
- VME electronics ... going to digital?
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G. Jaworski
Neutron Wall

Neutron Wall Det 26 ZCO vs TOF

Clean neutrons
Euclides $\pi$ light charged detector

Self-supported structure
55 dE-E telescopes

absorber

~80% of 4\pi

beam

Kapton Spacer 100 \mu m

HV

particles

Ground

\begin{align*}
\Delta E \\
\text{Thickness: 150 \mu m} \\
\text{Bias: \sim 40-50 V} \\
\text{Leakage Current: \sim 100 nA} \\
\text{Lab resolution: \sim 50 keV} \\
\text{Capacitance: 850 pF}
\end{align*}

E

\begin{align*}
\text{Thickness: 1000 \mu m} \\
\text{Bias: \sim 140-180 V} \\
\text{Leakage Current: \sim 500 nA} \\
\text{Lab resolution: \sim 25 keV} \\
\text{Capacitance: 130 pF}
\end{align*}

Segmented x5
v/c=5% 
- higher count rate
- correction for Doppler effects

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D. Testov
Euclides Channel selection

- 110 Silicon detectors (80%4π)
- New compact electronics
- Trigger less operation
- Efficiency highly depends on experiment

D. Testov
Doppler Correction

- Identification of evaporated particles
- Event-by-event calculation
- Estimate energy of them, correct for energy loss
- Kinematical Correction
- Mass difference by AME2012 database
GALILEO complementary detectors

- Study weak reaction channels using stable beams ⇒
  - High efficiency
  - High resolving power
- Light charged particle detectors
  - EUCLIDES (Presentation by D. Testov)
  - Trace (to be commissioned in July)
  - Spider (to be commissioned in July, Presentation by M. Rocchini)
- Neutron detectors
  - NeutronWall
- Recoil detectors
  - Recoil Filter Detector (to be commissioned, Presentation by P. Bednarcyk)
- Fast timing Highenergy γray detector
  - Array of 10 LaBr$_3$ detectors
- Plunger
  - Build in collaboration with Cologne (Presentation by Ch. Fransen)
Array of LaBr₃ detectors

- Cylindrical LaBr₃:Ce crystal 3 x 3
- Good Energy Resolution: \( \approx 3\% @ 661 \text{ keV} \)
- Excellent Time Resolution: \(< 1 \text{ ns}\)
- Placed at 20 cm from the target position
- Good Efficiency: \( \approx 1\% @ 16 \text{ MeV} \) (10 crystals)

S. Ceruti
Array of LaBr$_3$ detectors

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S. Ceruti
Silicon Pi Detector (SPIDER): For Coulex Experiments

- Cone configuration to fit the GALILEO vacuum chamber
- Same acquisition system as EUCLIDES: 56 electronic channels can be used as trigger signals ⇒ 56 needed for SPIDER (8 strips for 7 sectors)
- New mechanical frame and electronic adapter to connect SPIDER
- Commissioning: Coulex of $^{66}$Zn: 11.07 - 17.07

M. Rocchini
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Compact Plunger

- Compact plunger
- Constraints Ancillary detectors
- Possibility to couple with part of Euclides

A. Goasduf, Ch. Fransen
Compact Plunger

- Compact plunger
- Constraints Ancillary detectors
- Possibility to couple with part of Euclides
- Commissioned February 2016
- $^{32}\text{S} @ 172\text{ MeV} + ^{154}\text{Sm} \rightarrow ^{180}\text{Pt} + 6\ \text{n}$
GALILEO Experiments
GALILEO Experiments

High spin structure of $^{84}$Br
A. Goasduff, D. Verney

$^{34}$Ar MED
C. Andreoiu

$^{31}$S MED
A. Boso

Shape coexistence $^{188,190}$Hg
P.R. John, M. Siciliano

Excited states in $^{116,114}$Ba
J. Smith, G. Jaworski

Octupole in $^{118}$Ba
J.J Valiente-Dobon

Shape coexistence $^{60}$Zn
D. Mengoni, V. Modamio

Isospin mixing in $^{60}$Zn
S. Ceruti, A. Mentana

$^{65}$Ga via (d,p)
V. Modamio

Resonant states
S. Leoni, B. Fornal

Lifetime in $^{107,109}$Sb
D. Testov

Plunger commissioning
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N, number of neutrons
### GALILEO Experiments

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$^{126}\text{Zn}$
N.= 126

$^{82}\text{Zn}$
Z. = 82

$^{50}\text{Zn}$
Z. = 50

$^{20}\text{Zn}$
Z. = 20

$^{8}\text{Zn}$
Z. = 8

N. = 8

N. = 20

N. = 50

N. = 82

N, number of neutrons
Mirror Energy Difference in mirror nuclei A=31

- High-spin states in mirror $^{31}$P and $^{31}$S
- $J > 13/2$ states not yet observed in $^{31}$S
- $^{12}$C@50 MeV + $^{24}$Mg
- Experiment in March 2016
- Analysis in early stage, but already higher spin states visible

A. Boso, S.M. Lenzi., F. Recchia
Study of Isospin symmetry in $^{60}$Zn

- Coulomb interaction breaks the isospin symmetry $\Rightarrow$ Isospin Mixing
- E1 transitions (as Giant Dipole Resonance decay) in N=Z nuclei are sensitive to the degree of mixing
- Isospin mixing decreases as the excitation energy increases
- Comparison of yield of GDR in a N=Z nucleus to the one of N$\neq$Z allow to extract the isospin-mixing probability

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<tr>
<th>Reaction</th>
<th>CN</th>
<th>$E_{beam}$ [MeV]</th>
<th>$\sigma_{fusion}$ [mb]</th>
<th>$E^*$ [MeV]</th>
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<td>$^{60}$Zn*</td>
<td>86</td>
<td>480</td>
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S. Ceruti, A. Mentana., C. Michael
Study of Isospin symmetry in $^{60}$Zn

- LaBr$_3$:Ce Detection high-energy $\gamma$ rays Good Efficiency ($\epsilon \approx 1\% @ E = 16\text{MeV}$)
- GALILEO Detection low-energy $\gamma$ rays and identification of reaction channels
- The coincidence between GALILEO & LaBr$_3$:Ce detectors allow to have a clean selection of the fusion reaction channel

![Graphs showing n gated and GDR]**
Shape Coexistence in $^{60}$Zn

- Study of side band of $^{60}$Zn
- Experiment performed in May 2016
- Nearline analysis: spectrum of $^{61}$Zn
Shape coexistence in the neutron-deficient Hg isotopes

- Shape coexistence in $^{188}$Hg
- Experiment performed in March 2016
- Early stage analysis

![Diagram showing excitation energy and mass number for Hg isotopes.](This Presentation)
Shape coexistence in the neutron-deficient Hg isotopes

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Future of Galileo

Upgrade of Galileo with 10 tripple clusters

A. Goasduf
Summary

- GALILEO is a permanent spectrometer available at LNL
- Its first implementation, Phase-1, is now operational with 25 detectors
- GALILEO will make use of various ancillary detectors managed by national and international collaborations.
- First campaign GALILEO Phase-1 in 2015-2017 NW + Euclides + plunger + ...
- It is expected to represent the resident $\gamma$-ray spectrometer, in combination with AGATA, with the advent of RIBs at SPES.
- Prototype of the tripple cluster expected soon
Thank you for your attention

Thank you for your attention
Thank you for your attention

- If you like Galileo, you will also like

Byobu Museum
[Review Rating: 7 Reviews] #40 of 94 things to do in Sumida
Specialty Museums, Museums
Outlook
Outlook

![Graph showing photopeak efficiency at 1 MeV / 0.5 deg](image)

- 40 GASP
- 30 GASP + 10TC at 90
- 30 GASP + 10TC close to 90
- 30 GASP + 10TC backward and forward