The GALILEO Array at LNL and its first physics campaign

NUSPIN 2016

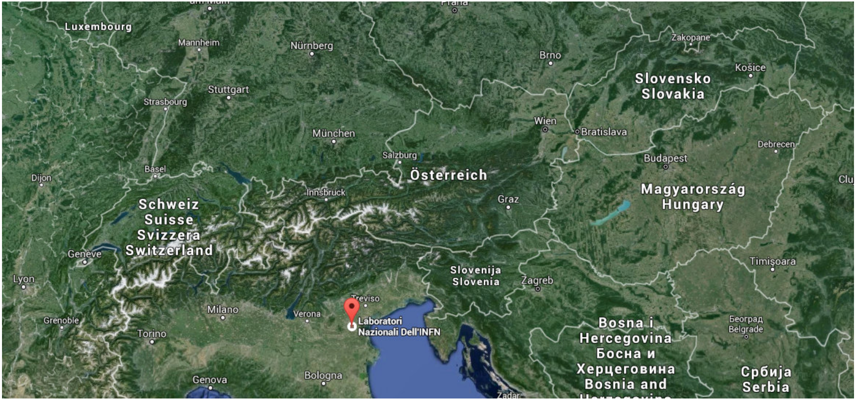
P.R. John (philipp.john@pd.infn.it)
On behalf of the GALILEO collaboration

June 30, 2016

Outline

Legnaro National Laboratories (LNL)

- Where is Legnaro?



Legnaro National Laboratories (LNL)

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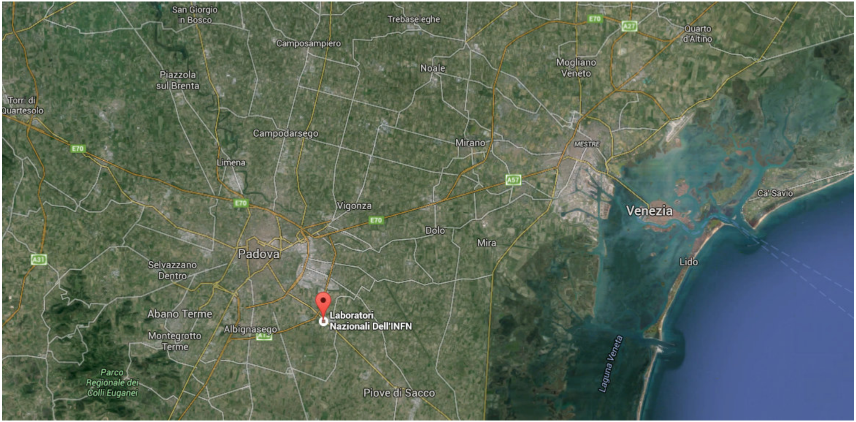


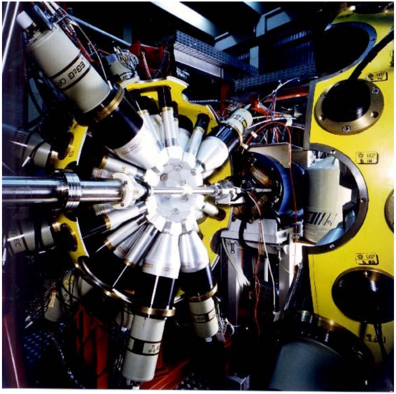
Legnaro National Laboratories (LNL)

- Where is Legnaro?

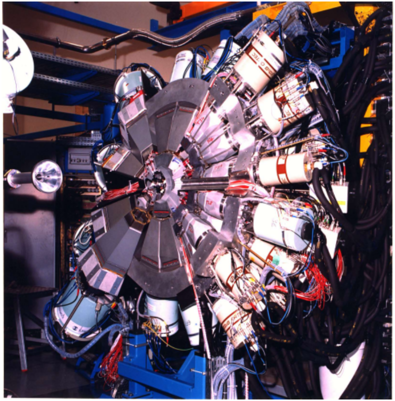
Tradition of γ-ray spectrometers in LNL

- Study of (mostly) proton-rich nuclei

GASP (1992)



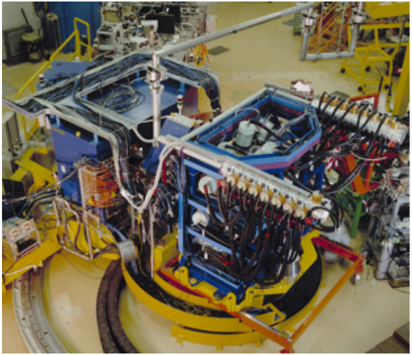
EUROBALL (1998)



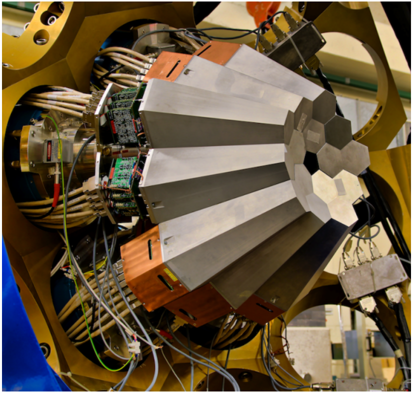
Tradition of γ-ray spectrometers in LNL

- Study of (mostly) neutron-rich nuclei

Clara (2004)

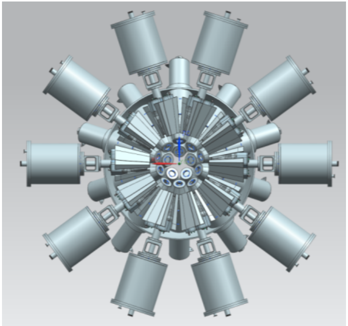


AGATA (2006)



GALILEO a new 4π γray 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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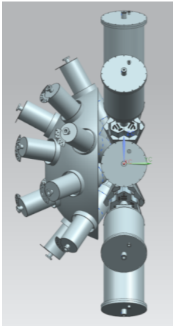

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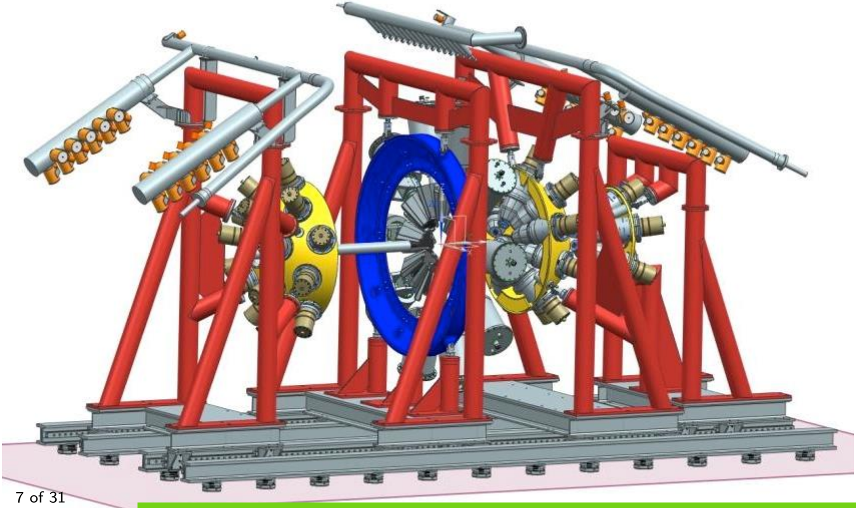

GALILEO current status

GALILEO NeutronWall campaign

- γ-array
  - 25 HPGe Compton-suppressed GASP detectors
  - 4 angular groups
- Light charged particles EUCLIDES
  - 4π DE-E Si ball (110 detectors)
  - Segmented with segmented detectors
  - Position and energy
- Neutron Wall
  - 50 liquid scintillator detectors
  - n-γ discrimination via TOF and ZCO
  - Analog electronics

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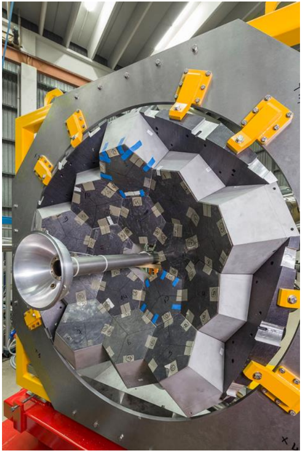
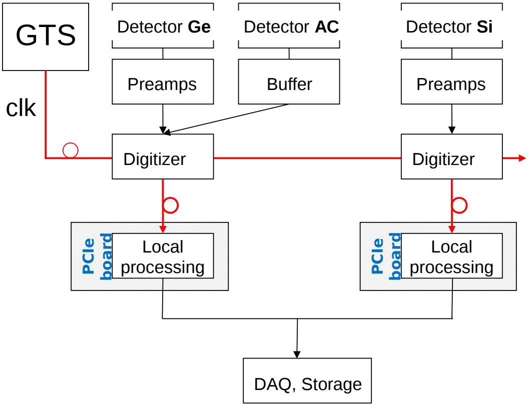
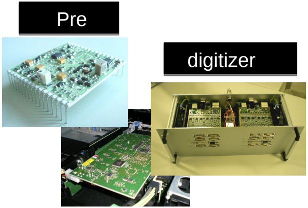


GALILEO electronics

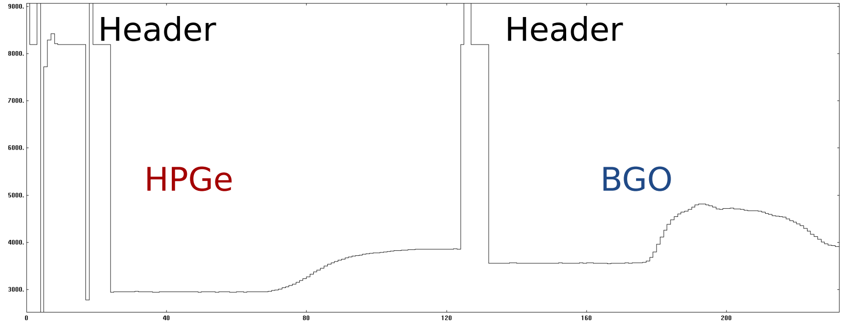




- **HPGe,AC, Anc. digitized**
- **Branches are sync by GTS.**
- **Trigger-less operation**
- **240 channels available**
- **Typical rate ~ 20 kHz/det**
- **Max rate ~ 50 kHz/det**

GALILEO electronics

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



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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 μs rise time, 1μs 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

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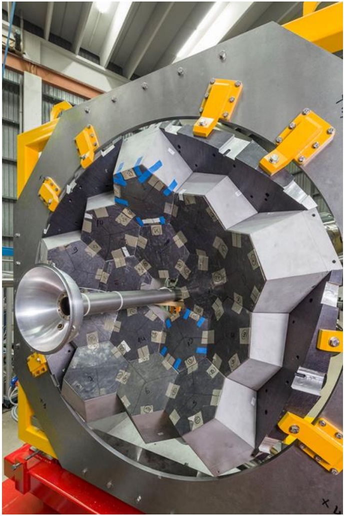
Neutron Wall

- 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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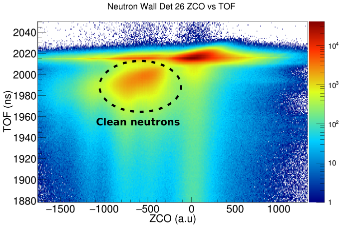
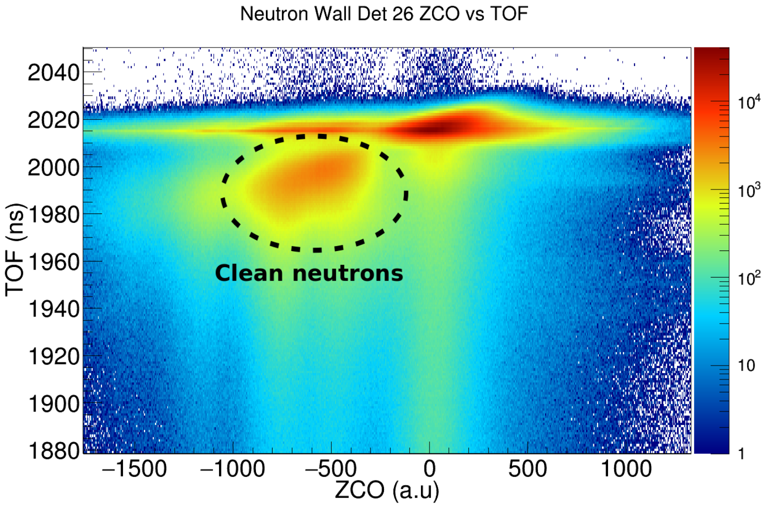


G. Jaworski

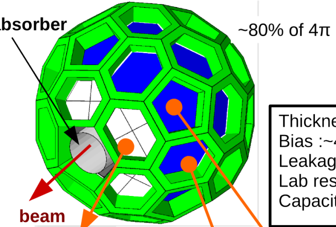
Neutron Wall



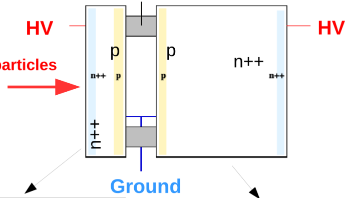
G. Jaworski

Euclides π light charged detector

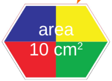
Self-supported structure
55 dE-E telescopes



Kapton Spacer 100 um



ΔE	E
Thickness: 150 µm	Thickness: 1000 µm
Bias :~40-50 V	Bias :~140-180 V
Leakage Current: ~100 nA	Leakage Current: ~500 nA
Lab resolution: ~50 keV	Lab resolution: ~25 keV
Capacitance: 850pF	Capacitance: 130pF



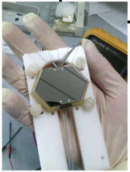
Segmented x5
v/c≈5%
- higher count rate
- correction for Doppler effects

HEXAGON

single plate x15

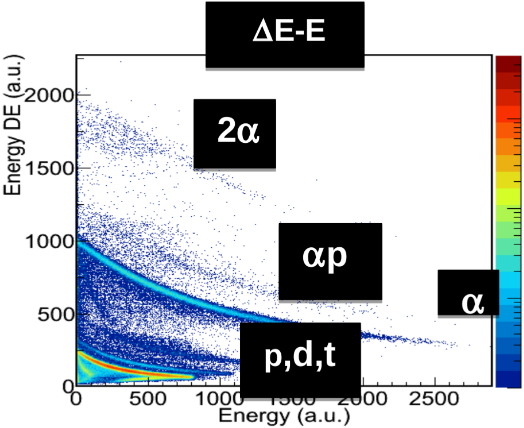
PENTAGON

single plate
x20



Euclides Channel selection

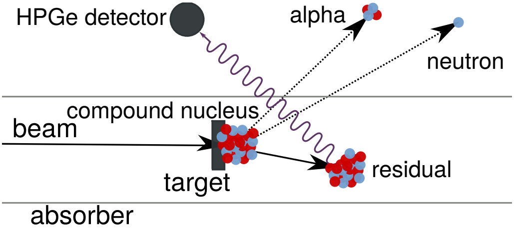
- 110 Silicon detectors ($80\%4\pi$)
- New compact electronics
- Trigger less operation
- Efficiency highly depends on experiment

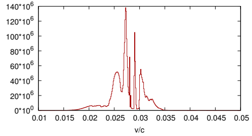


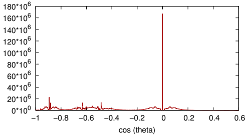
D. Testov

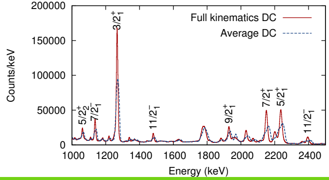
Doppler Correction

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







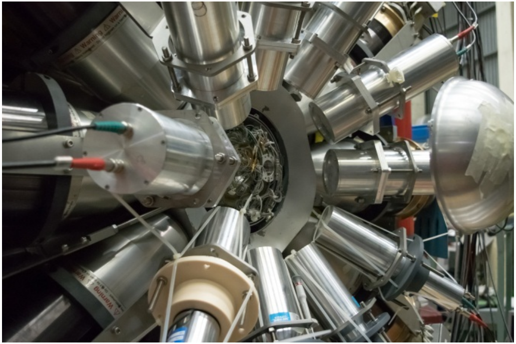


GALILEO complementary detectors

- 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 $LaBr_3$ detectors

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



S. Ceruti

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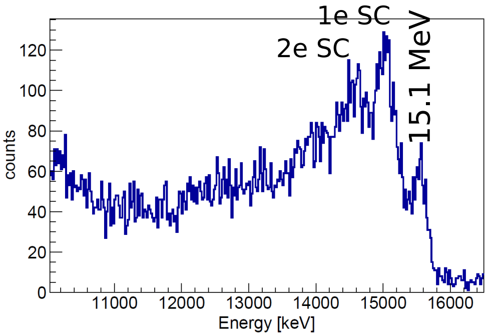
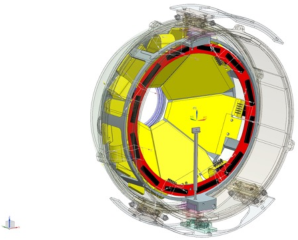
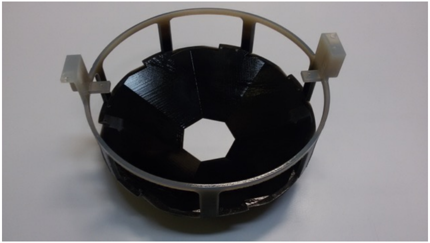


Silicon Pi Detector (SPIDER): For Coulex Experiments

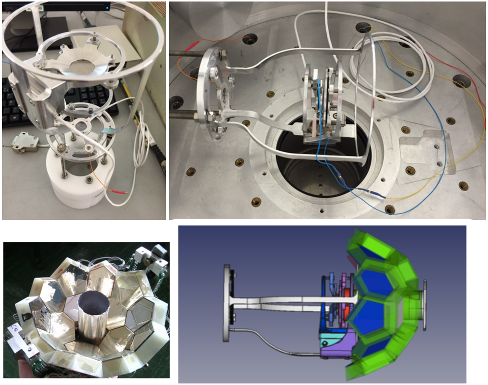
- Cone configuration to fit the GALILEO vacuum chamber
- Same acquisition system as EUCLIDES: 56 electronic channels can be used as trigger signals ⇒ 56 needed for SPIDER (8 strips for 7 sectors)
- New mechanical frame and electronic adapter to connect SPIDER
- Commissioning: Coulex of ^{66}Zn: 11.07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





Compact Plunger

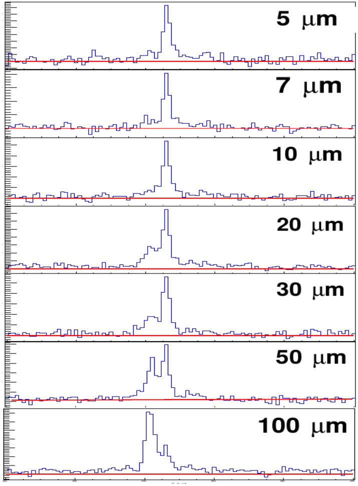
- Compact plunger
- Constraints Ancillary detectors
- Possibility to couple with part of Euclides



A. Goasduf, Ch. Fransen

Compact Plunger

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



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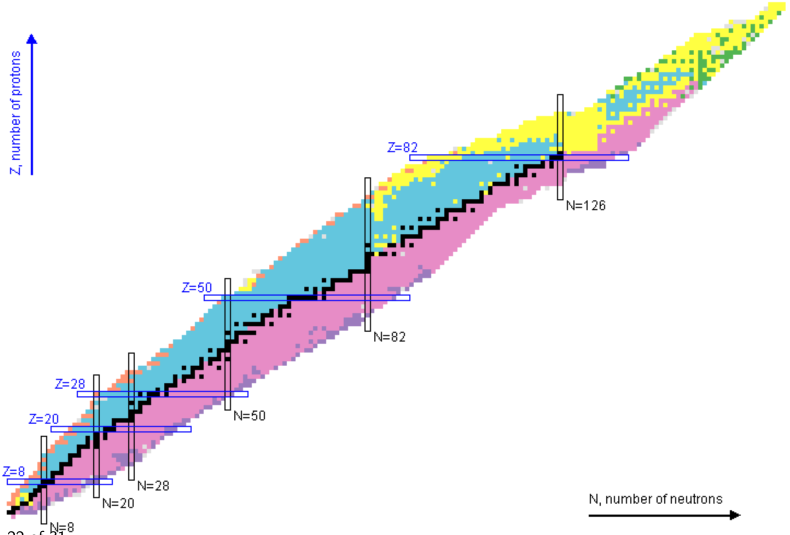
GALILEO Experiments



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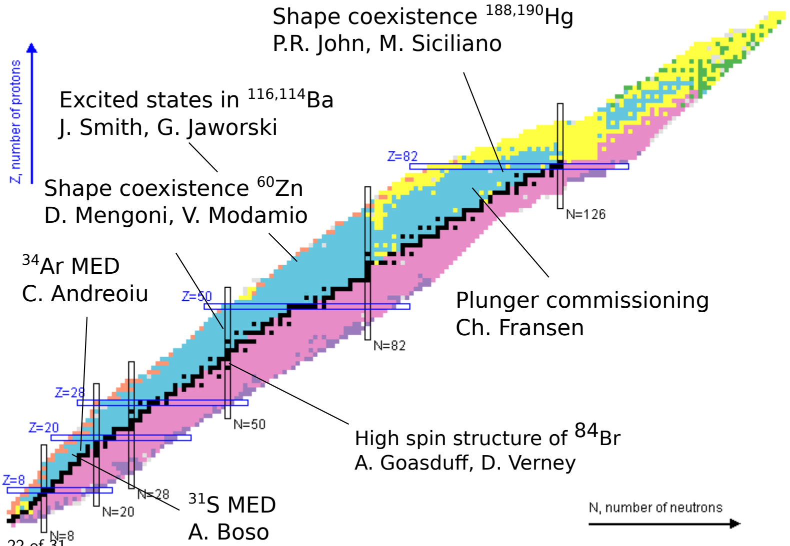

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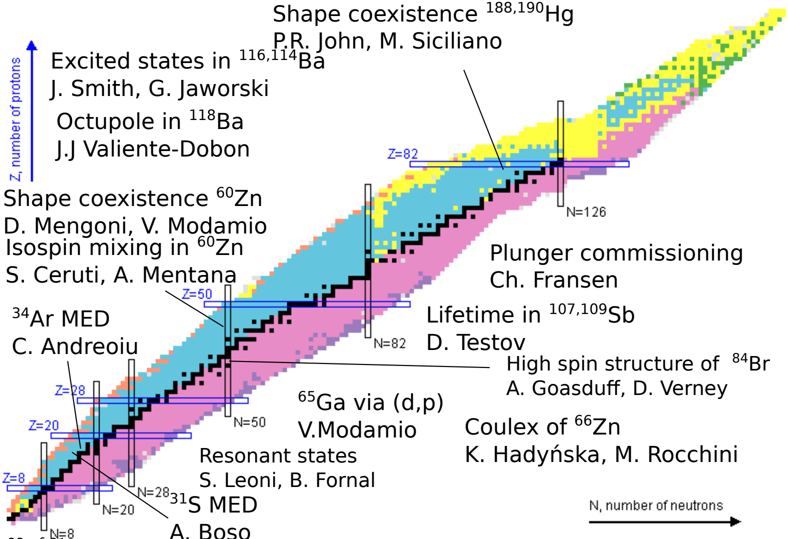


Shape coexistence ^{188,190}Hg
P.R. John, M. Siciliano

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

^{34}Ar MED
C. Andreoiu

Plunger commissioning
Ch. Fransen

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

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

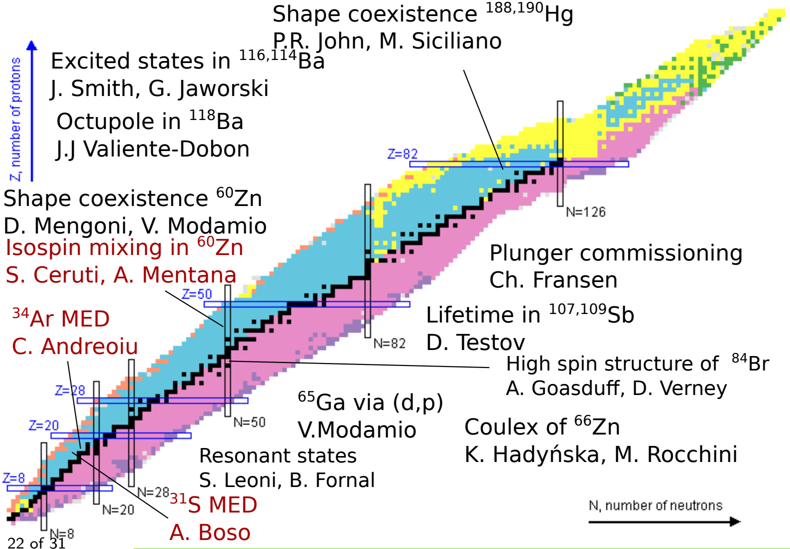
^{65}Ga via (d,p)
V.Modamio

Coulex of ^{66}Zn
K. Hadyńska, M. Rocchini

Resonant states
S. Leoni, B. Fornal

^{31}S MED
A. Boso

GALILEO Experiments



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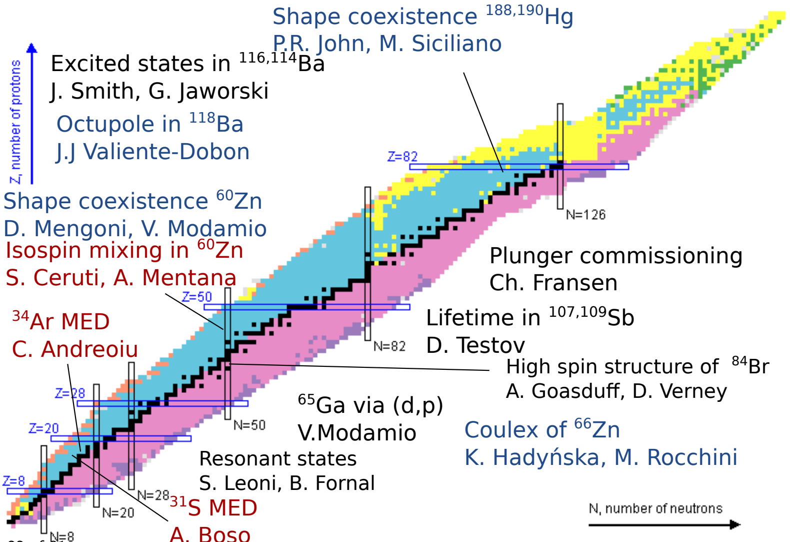

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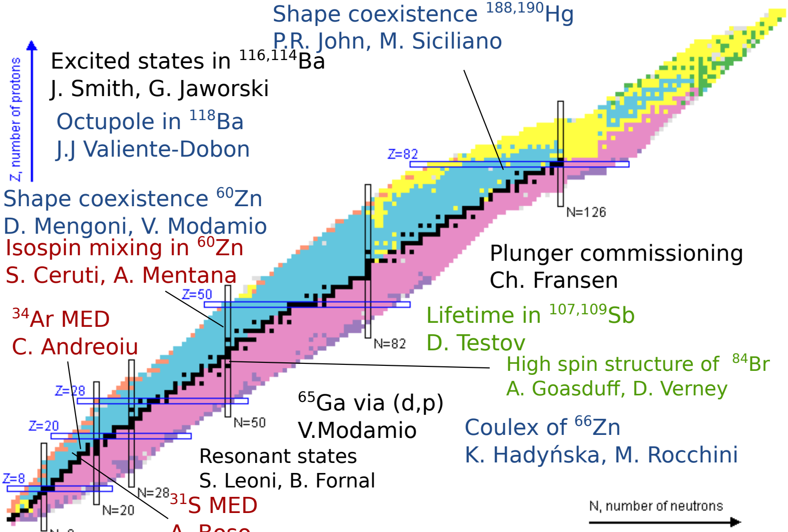

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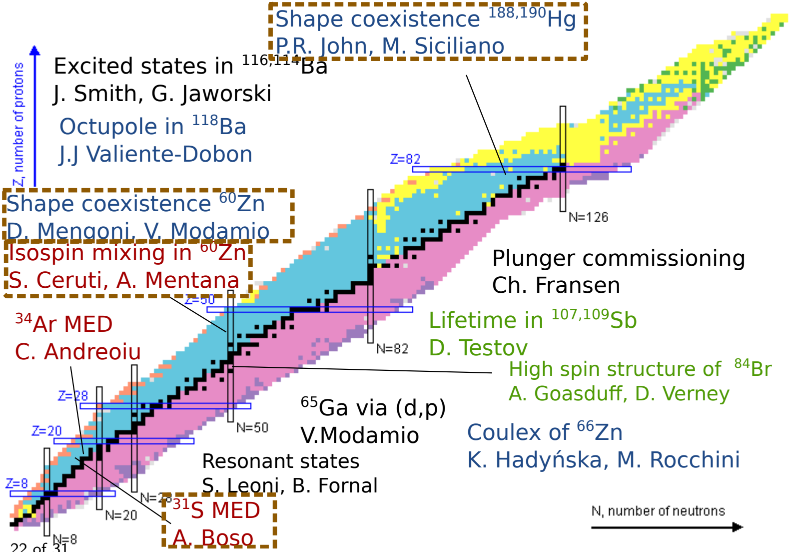
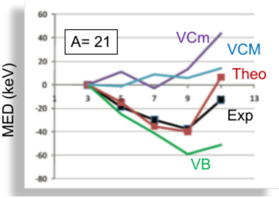
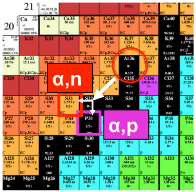
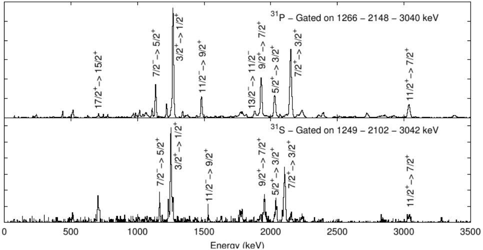


Mirror Energy Difference in mirror nuclei A=31

- 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





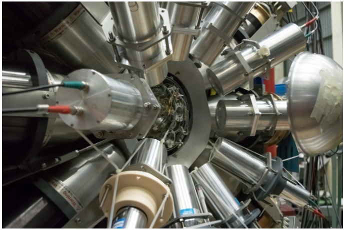


A. Boso, S.M. Lenzi., F. Recchia

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

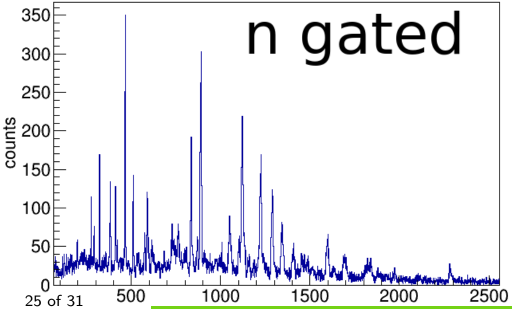
Reaction	CN	E_{beam} [MeV]	σ_{fusion} [mb]	E^* [MeV]
$^{32}S + ^{28}Si$	$^{60}Zn^*$	86	480	47
$^{32}S + ^{30}Si$	$^{62}Zn^*$	75	300	47
$^{32}S + ^{28}Si$	$^{60}Zn^*$	110	880	58
$^{32}S + ^{30}Si$	$^{62}Zn^*$	98	800	58

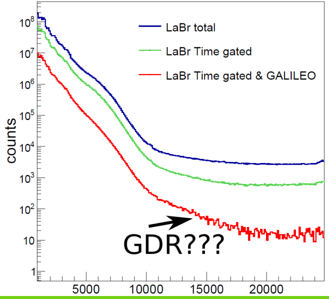


S. Ceruti, A. Mentana., C. Michael

Study of Isospin symmetry in ^{60}Zn

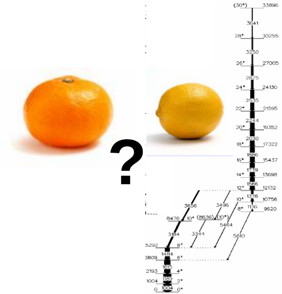
- $LaBr_3$:Ce Detection high-energy γ rays Good Efficiency ($\epsilon \approx$1%@E=16MeV)
- GALILEO Detection low-energy γ rays and identification of reaction channels
- The coincidence between GALILEO & $LaBr_3$:Ce detectors allow to have a clean selection of the fusion reaction channel

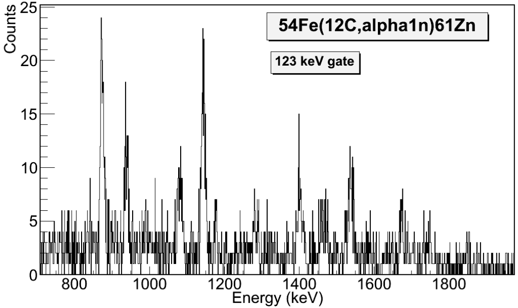




Shape Coexistence in ^{60}Zn

- Study of side band of ^{60}Zn
- Experiment performed in May 2016
- Nearline analysis: spectrum of ^{61}Zn

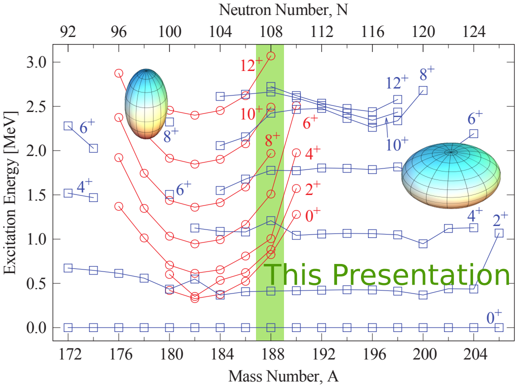




D.

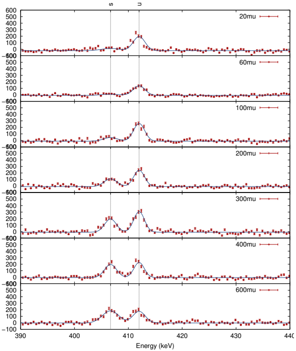
Shape coexistence in the neutron-deficient Hg isotopes

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



Shape coexistence in the neutron-deficient Hg isotopes

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



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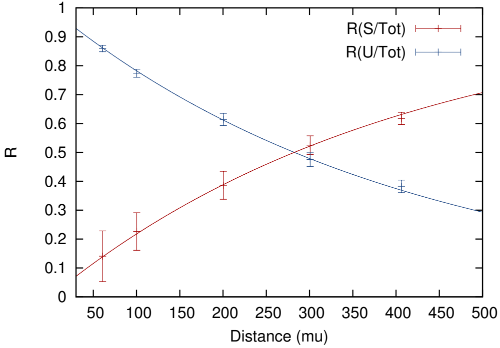
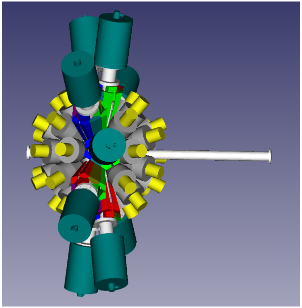
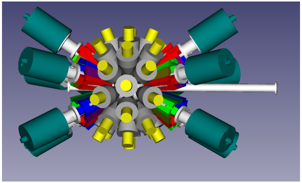
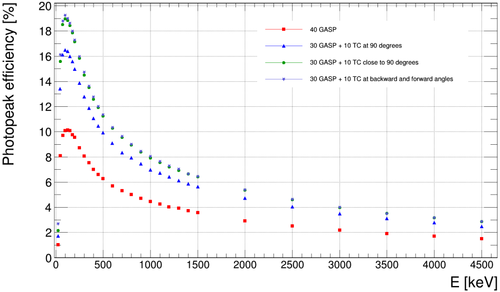


Future of Galileo





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 γ-ray spectrometer, in combination with AGATA, with the advent of RIBs at SPES.
- Prototype of the tripple cluster expected soon

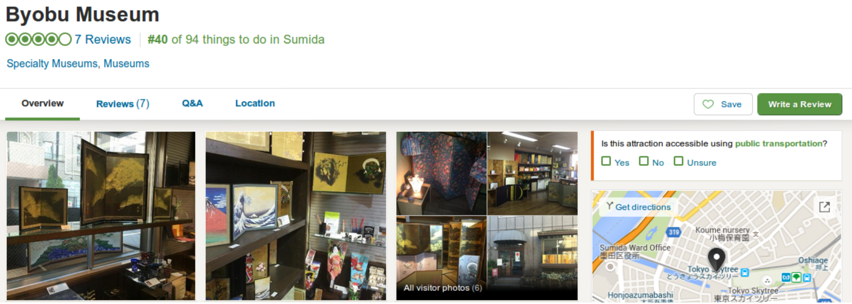
Thank you for your attention

Thank you for your attention

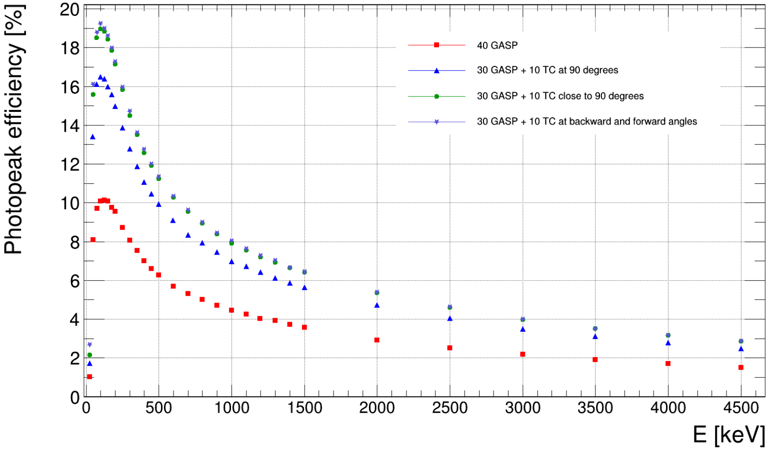
Thank you for your attention

Thank you for your attention

- If you like Galileo, you will also like

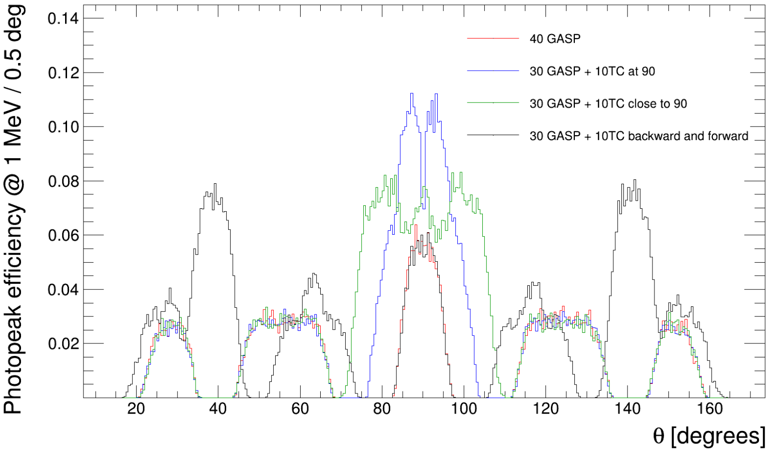


Outlook



Photopeak efficiency [%]
E [keV]
40 GASP
30 GASP + 10 TC at 90 degrees
30 GASP + 10 TC close to 90 degrees
30 GASP + 10 TC at backward and forward angles
0
2
4
6
8
10
12
14
16
18
20
0
500
1000
1500
2000
2500
3000
3500
4000
4500

Outlook



Photopeak efficiency @ 1 MeV / 0.5 deg
0.14
0.12
0.10
0.08
0.06
0.04
0.02
20
40
60
80
100
120
140
160
θ [degrees]
40 GASP
30 GASP + 10TC at 90
30 GASP + 10TC close to 90
30 GASP + 10TC backward and forward