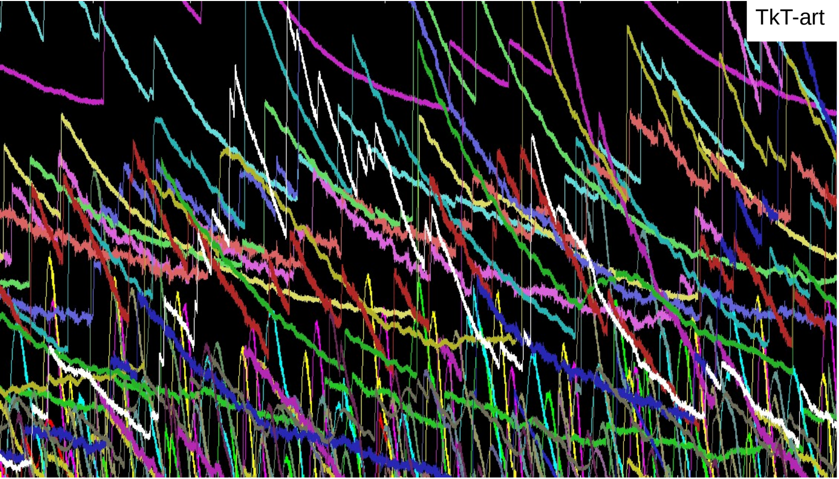
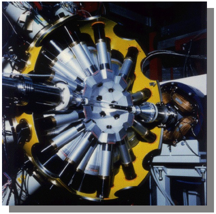


4π light-charged-particle detector EUCLIDES

Andres Gadea *Daniele* Mengoni *Alain* Goasduff
Paolo Cocconi *Roberto* Isocrate ...

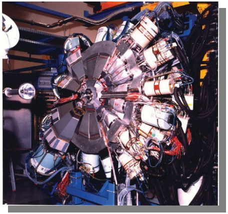
ENSAR2 has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654002.

Large GammaRay Arrays at LNL



GASP
1992

ε_{ph} ~ 3% (@ 27 cm)
~ 6% (@ 22 cm)
P/T ~ 60%

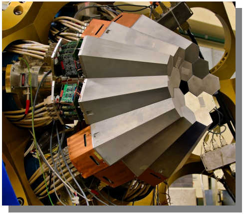


EUROBALL
1998

ε_{ph} ~ 9%
P/T ~ 50%

CLARA
2004

ε_{ph} ~ 3%
P/T ~ 50%

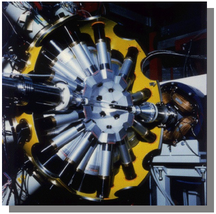


AGATA
2010

ε_{ph} ~ 6%
P/T ~ 50%

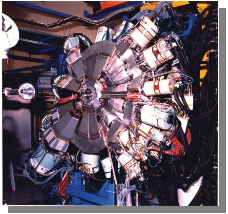
- How does the nuclear force depend on varying proton-to-neutron ratios?
- How are complex nuclei built from their basic constituents?
- What is the effective nucleon-nucleon interaction
- Provide nuclear structure input to other fields like nuclear astrophysics
- Collectivity and shell model
- Isospin symmetries
- Isospin mixing in N=Z nuclei
- How does shell structure change far away from stability ... ...

Large GammaRay Arrays at LNL



GASP
1992

ε_{ph} ~ 3% (@ 27 cm)
~ 6% (@ 22 cm)
P/T ~ 60%



EUROBALL
1998

ε_{ph} ~ 9%
P/T ~ 50%

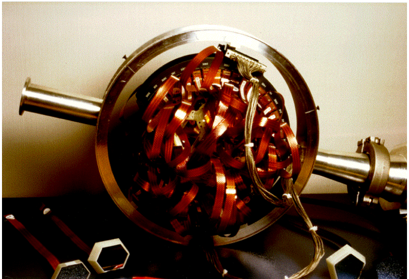
CLARA
2004

ε_{ph} ~ 3%
P/T ~ 50%

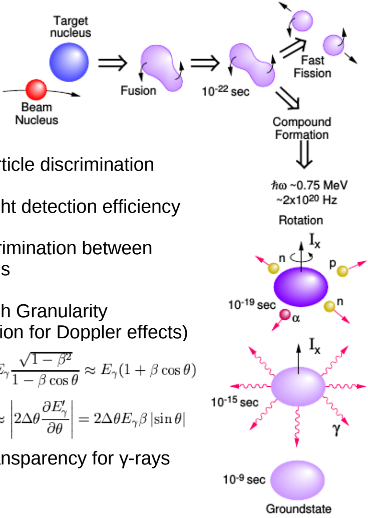
AGATA
2010

ε_{ph} ~ 6%
P/T ~ 50%

- How does the nuclear force depend on varying proton-to-neutron ratios?
- How are complex nuclei built from their basic constituents?
- What is the effective nucleon-nucleon interaction
- Provide nuclear structure input to other fields like nuclear astrophysics
- Collectivity and shell model
- Isospin symmetries
- Isospin mixing in N=Z nuclei
- How does shell structure change far away from stability ... ...



GASP
ISIS Si-array
(Italian Silicon Sphere)



- Particle discrimination
- Hight detection efficiency
- Discrimination between channels
- High Granularity (correction for Doppler effects)

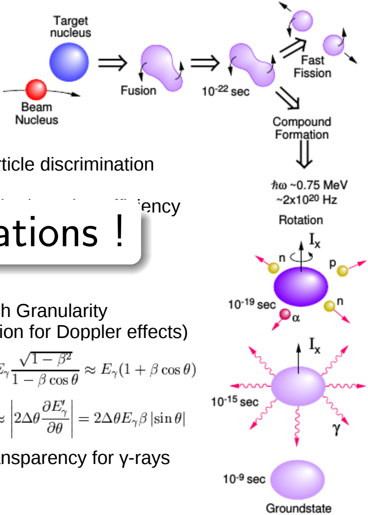
$$E'_\gamma = E_\gamma \frac{\sqrt{1-\beta^2}}{1-\beta\cos\theta} \approx E_\gamma(1+\beta\cos\theta)$$

$$|\Delta E_\gamma| \approx \left|2\Delta\theta \frac{\partial E'_\gamma}{\partial\theta}\right| = 2\Delta\theta E_\gamma \beta\,|\sin\theta|$$

- Transparency for γ-rays

E Farnea, G. de Angelis, M. De Poli et al., Nucl. Inst.&Meth. A 400, 87 (1997)

GASP
ISIS Si-array
(Italian Silicon Sphere)



- Particle discrimination

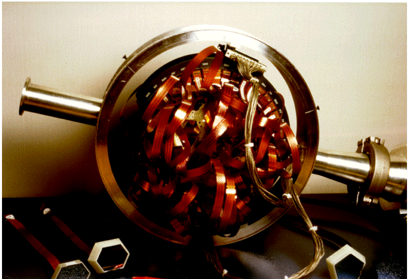
More than 100 publications !

- High Granularity (correction for Doppler effects)

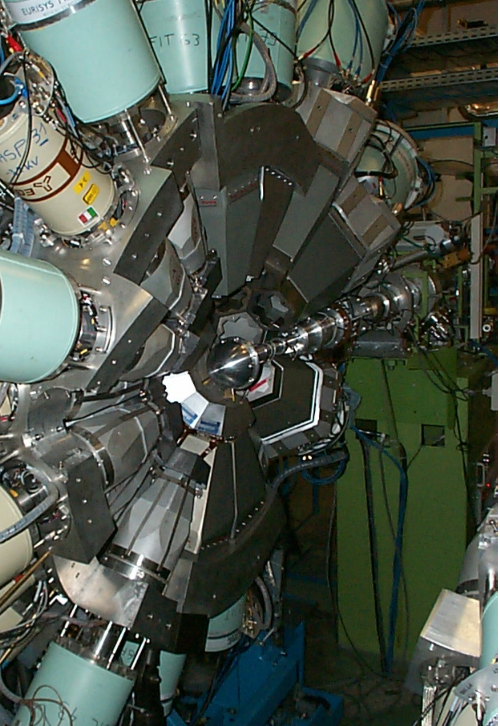
$$E'_\gamma = E_\gamma \frac{\sqrt{1-\beta^2}}{1-\beta\cos\theta} \approx E_\gamma(1+\beta\cos\theta)$$

$$|\Delta E_\gamma| \approx \left|2\Delta\theta \frac{\partial E'_\gamma}{\partial\theta}\right| = 2\Delta\theta E_\gamma \beta\,|\sin\theta|$$

- Transparency for γ-rays

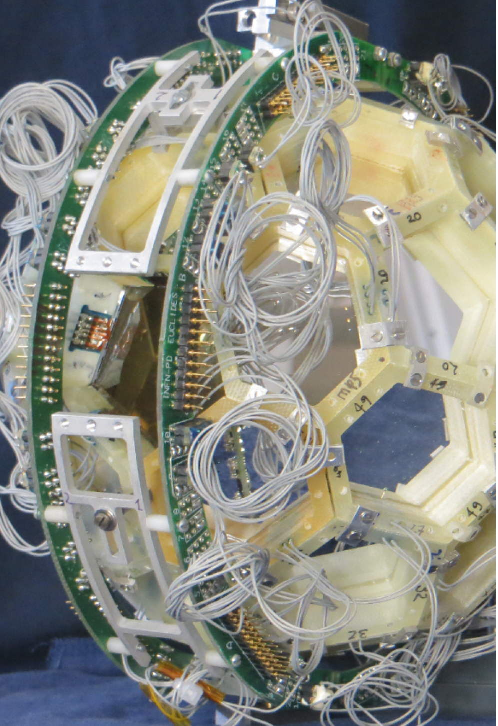


E Farnea, G. de Angelis, M. De Poli et al., Nucl. Inst.&Meth. A 400, 87 (1997)



EUROBALL
new constrains

- Chamber: $\varnothing$32 cm$\rightarrow$20 cm
- New mini-coaxial cables $\varnothing$ 0.5 mm
- Self-supported:
  $\Omega \sim$72%$\rightarrow$82% (for ΔE)

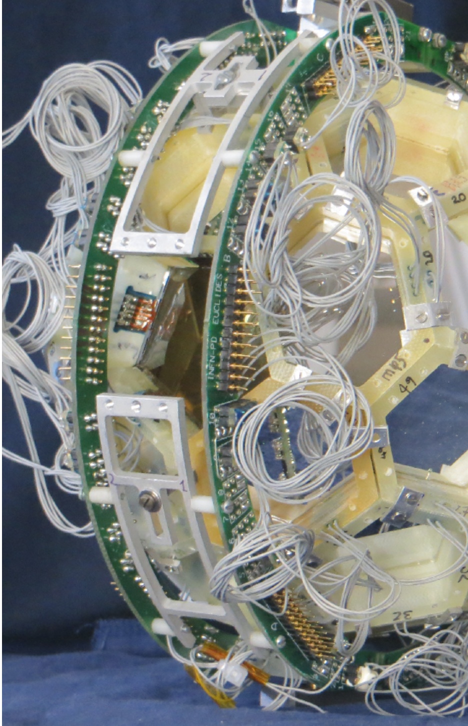


EUROBALL
new constrains

- Chamber: $\varnothing$32 cm$\rightarrow$20 cm
- New mini-coaxial cables $\varnothing$ 0.5 mm
- Self-supported:
  $\Omega \sim$72%$\rightarrow$82% (for ΔE)

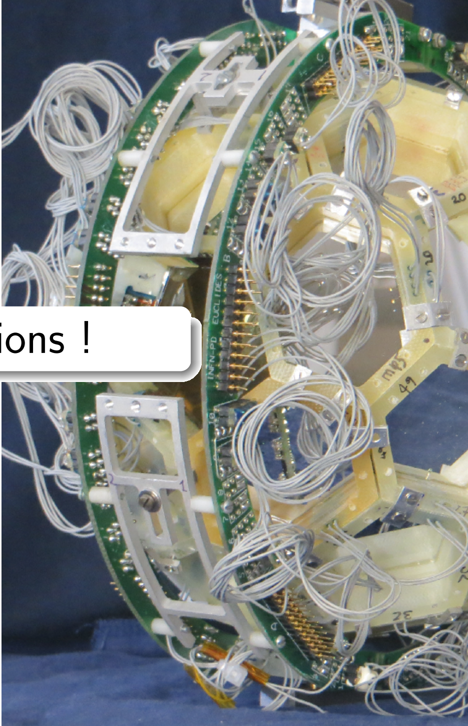
Light Charger particle Si-ball array

- Channel selection
- Enhanced resolving power of EUROBALL
- Correction for Doppler Effect
- 80% of angular coverage
- $\epsilon(\alpha)\sim 40\%^{*}$; $\epsilon(\mathrm{p})\sim 60\%^{*}$
- Plunger configuration
- 3 out of 4 experimet rely on EUCLIDES

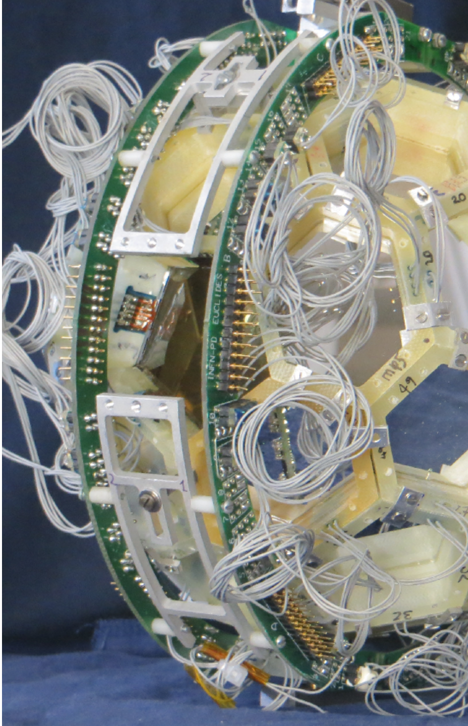


* reaction-dependent

D. Testov, D. Mengoni, A. Goasduff et al., Eur. Phys. J. A (2019) 55 47



Many publications !

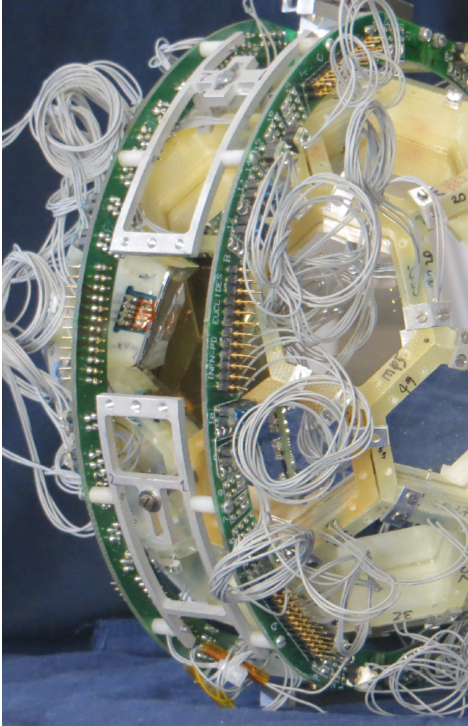


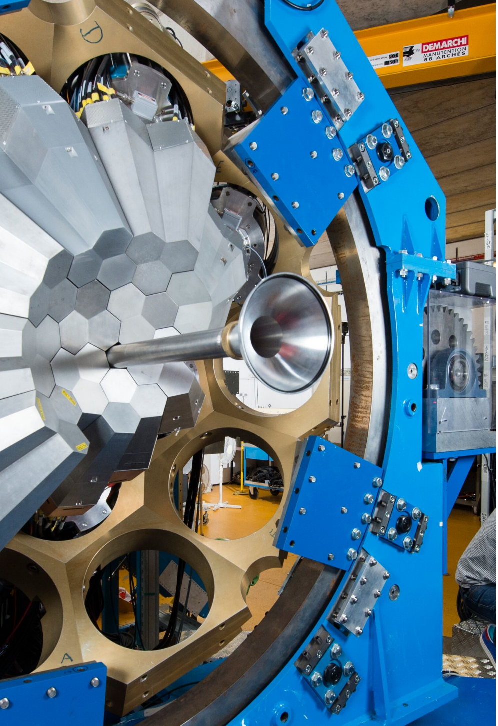
INFN
Istituto Nazionale
di Fisica Nucleare

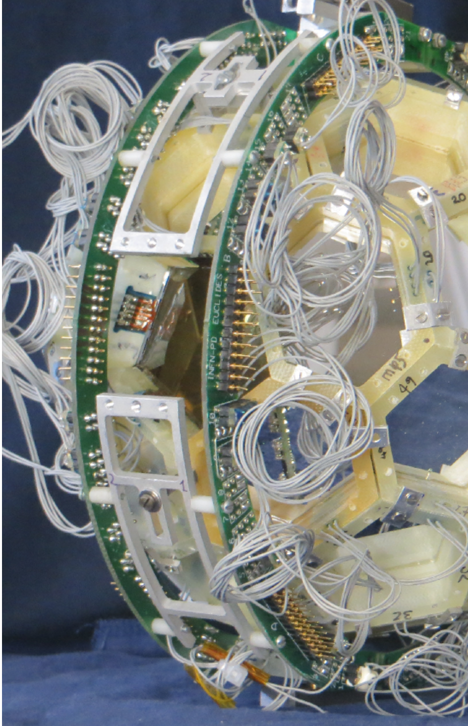
Current array: GALILEO

- 25 HPGe CS detectors
- Angles: 90°/60°, 152°, 129°, 119°
- at 22.5cm; $\epsilon \sim$2.4% at 1332.5 keV
- FWHM at 1332.5 keV $<$ 2.4 keV
- Trigger-less mode
- Typical operational rate $\sim$20 kHz/det
- Common clock synchronization
- Local data processing

INFN
Istituto Nazionale
di Fisica Nucleare




DEMARCHI
MANUTENTION
88 ARCHES


INFN-PD EUCLIDES

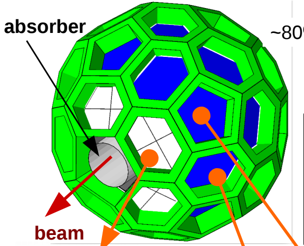
ΔE-E telescopes

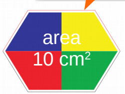
Self-supported structure
55 dE-E telescopes

$$\frac{dE}{dx} \propto \frac{mZ^2}{E}$$

Bethe-Bloch

~80% of 4π



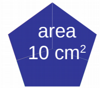


Segmented x5
v/c≈5%
- higher count rate
- correction for Doppler effects

HEXAGON

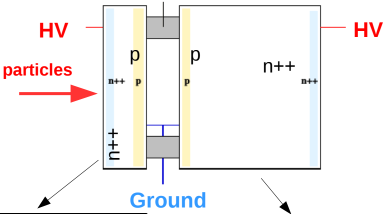
single plate x15

PENTAGON



single plate
x20

Kapton Spacer 100 um

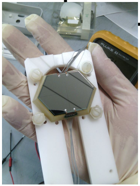


ΔE

Thickness: 150 μm
Bias :~40-50 V
Leakage Current: ~100 nA
Lab resolution: ~50 keV
Capacitance: 850pF

E

Thickness: 1000 μm
Bias :~140-180 V
Leakage Current: ~500 nA
Lab resolution: ~25 keV
Capacitance: 130pF



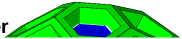
ΔE-E telescopes

Self-supported structure
55 dE-E telescopes

$$\frac{dE}{dx} \propto \frac{mZ^2}{E}$$

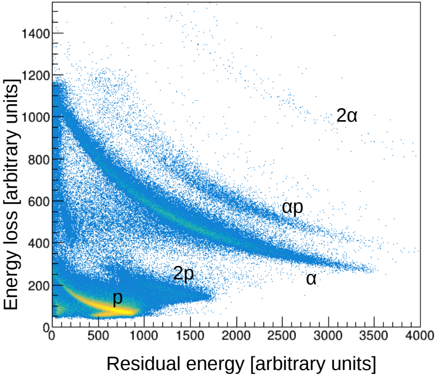
Bethe-Bloch

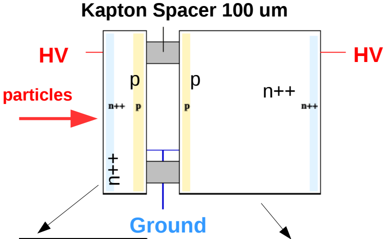
absorber



~80% of 4π

dE-E matrix from a forward segment

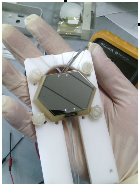




µm ΔE
nt: ~100 nA
~50 keV
50pF

E
Thickness: 1000 µm
Bias :~140-180 V
Leakage Current: ~500 nA
Lab resolution: ~25 keV
Capacitance: 130pF

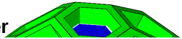
ON
a
m²
plate
0



ΔE-E telescopes

Self-supported structure
55 dE-E telescopes

absorber

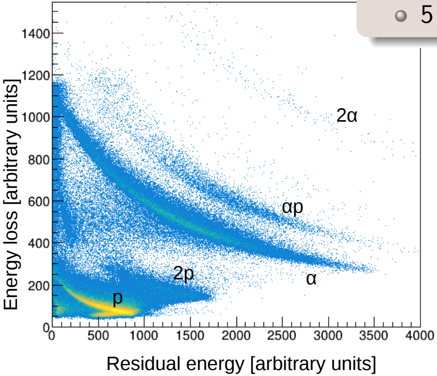


$\frac{dE}{dx} \propto \frac{mZ}{E}$

Bethe-Bl

~80% of 4

dE-E matrix from a forward segmen



Existing Quantity:

- 25 HEX and 10 PENT units
- 5 seg. HEX (2 new)
- 1 seg. HEX (being repeared)

New Orders:

- 2 PENT units (deliverd)
- 2 PENT units (being deliverd)
- 5 seg. HEX order placed

μm ΔE

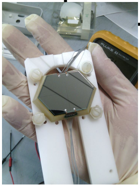
nt: ~100 nA
~50 keV
50pF

E

Thickness: 1000 μm
Bias :~140-180 V
Leakage Current: ~500 nA
Lab resolution: ~25 keV
Capacitance: 130pF

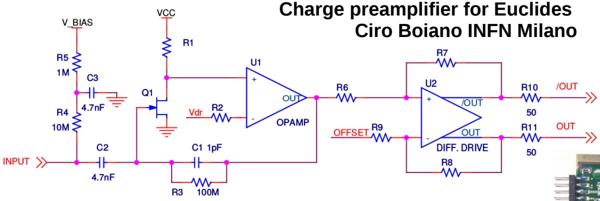
ON

plate
0

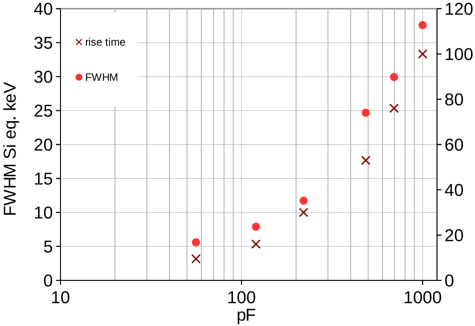


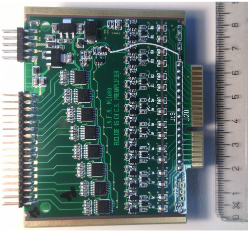
Charge-Sensitive preamplifier

Charge preamplifier for Euclides
Ciro Boiano INFN Milano



differential output

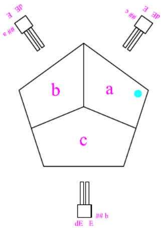


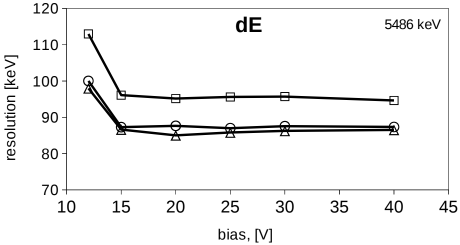


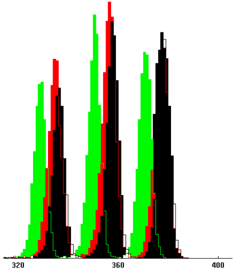
- → 16-channel preamplifier
- → 112 channels total
- → rise time <50 ns
- → fall time <50 μs
- → sensitivity 45mV/MeV
- → dynamic range 100 MeV
- → ~ 980 mW
- → also for

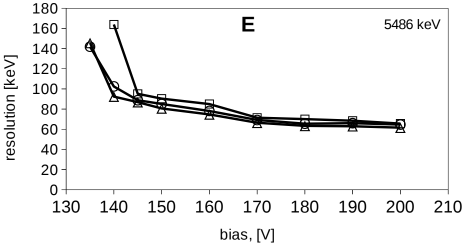
Talk of Andriana

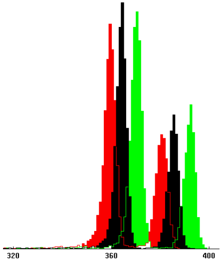
Source test in GALILEO chamber:





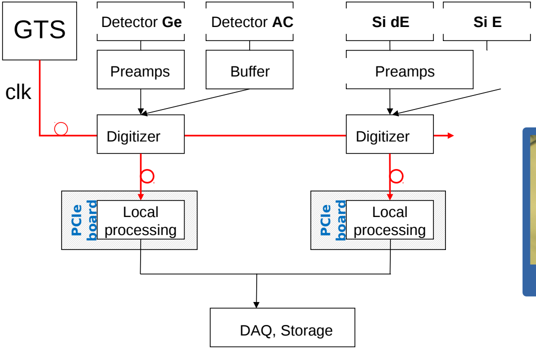






Digital Data Acquisition

Talks of Alain / Andres



- → **HPGe, AC, Ancillary digitized**
- → **Branches are sync by GTS**
- → **Trigger-less operation**
- → **<u>110 channel for EUCLIDES (55 domains)</u>**
- → **Typical rate ~ 20 kHz/det**
- → **Max rate ~ 50 kHz/det**

Same electronics for SPIDER

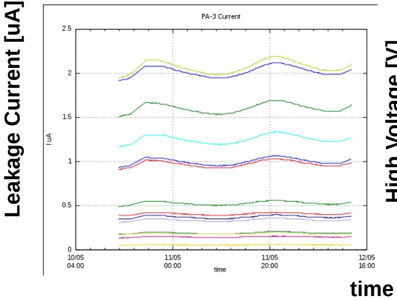
High-Voltage Control

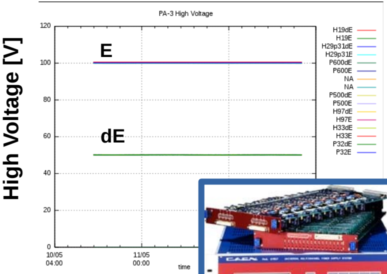
Euclides HV STATUS

14 May 2018, Mon 11:05:29

Last update

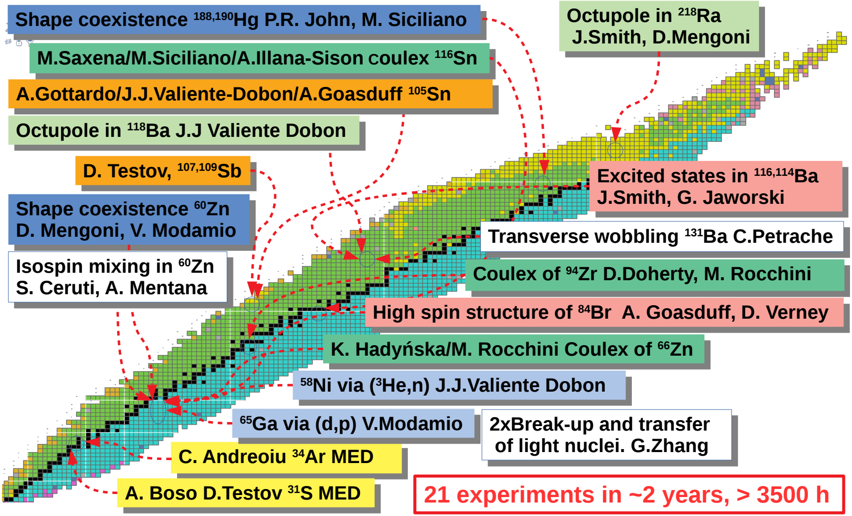
14-05-2018 11:00:45





Caen SY527 rack
A519 modules

Spectroscopy studies using fusion evaporation reactions induced by stable beam/target nuclei at LNL Legnaro

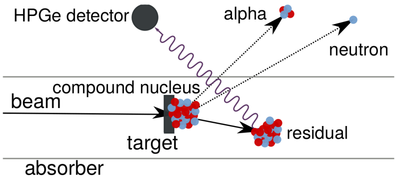


21 experiments in ~2 years, > 3500 h

Full kinematic reconstruction

Credits to P.R. John

^{12}C(at 45 MeV)+^{24}Mg$\rightarrow$^{36}Ag* $\rightarrow$^{31}P [1α1p]



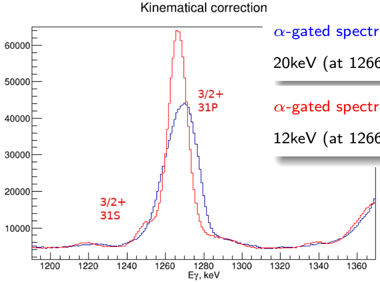
$$p_{residual} = p_{compound} + \sum_{particles} p_{particle}$$

Mean velocity

Euclides Energy Calibration

Energy-loss for each particle in the absorber

Angles of Euclides telescopes

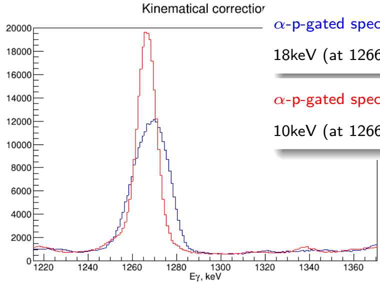


α-gated spectrum

20keV (at 1266 keV)

α-gated spectrum

12keV (at 1266 keV)



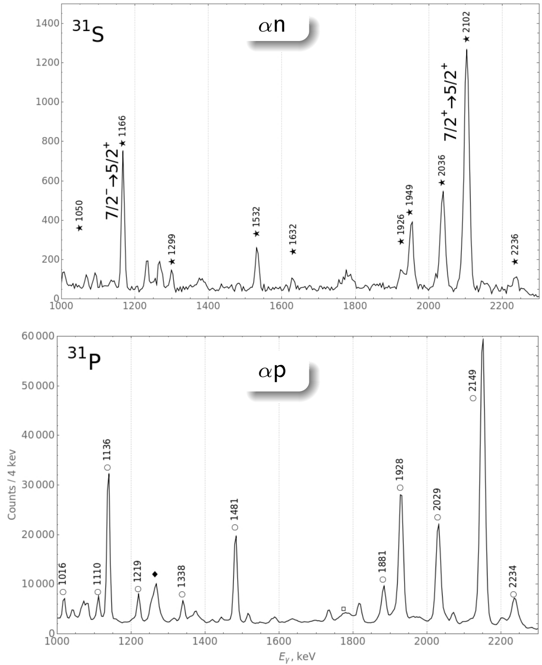
α-p-gated spectrum

18keV (at 1266 keV)

α-p-gated spectrum

10keV (at 1266 keV)

Mirror symmetry at work: A=31



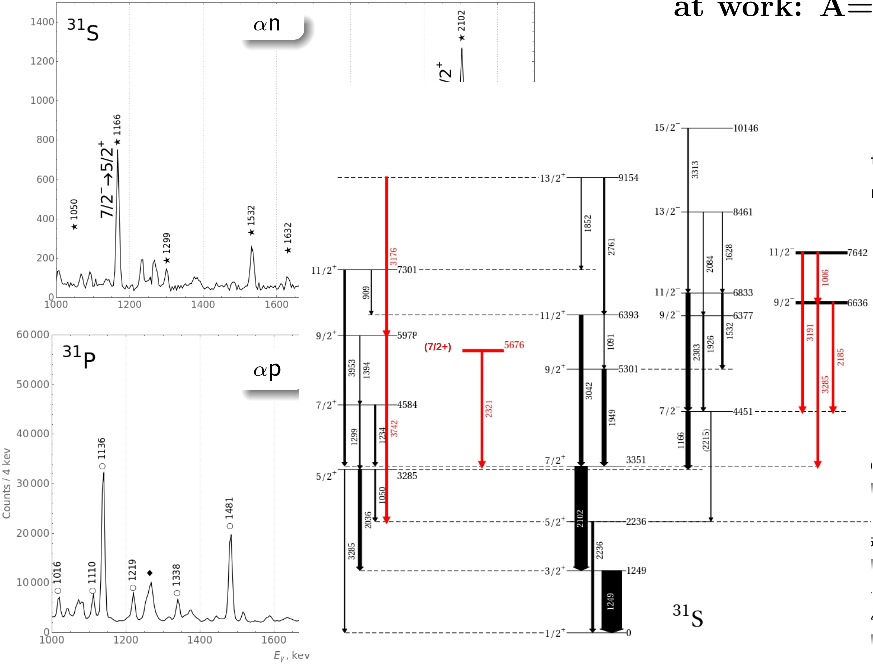
Projection on $\frac{3}{2}^+ \rightarrow \frac{1}{2}^+$ transition in $\gamma - \gamma$ matrix recorded in coincidence with: 1α and 1 neutron; with 1 proton and 1 neutron

M. Ionescu-Bujor et al., Phys. Rev. C 73, 024310 (2006)

D. Jenkins et al., Phys.Rev.C 72 031303(R) (2005)

D. T. Doherty, P. J. Woods, G. Lotay et al., Phys. Rev. C 89, 045804 (2014).

Mirror symmetry at work: A=31



tion

nci-

with

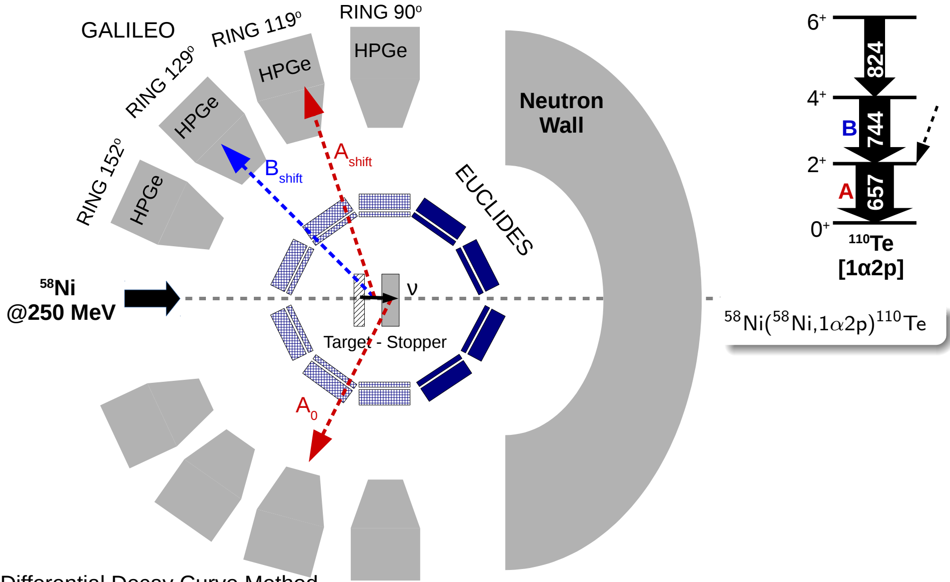
06)

5)

et al.,

4).

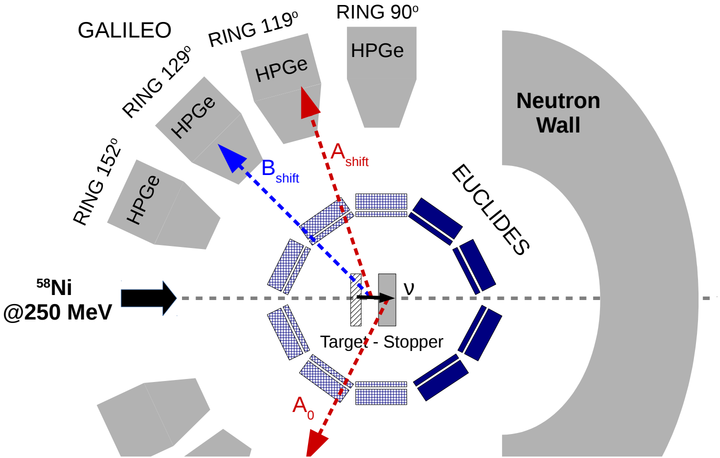
„Advanced" RDDS method for the lifetime measurements

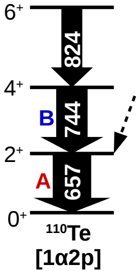


Differential Decay Curve Method

A.Dewald et al., Prog. Part. & Nucl. Phys. 67 (2012) 786

„Advanced" RDDS method for the lifetime measurements





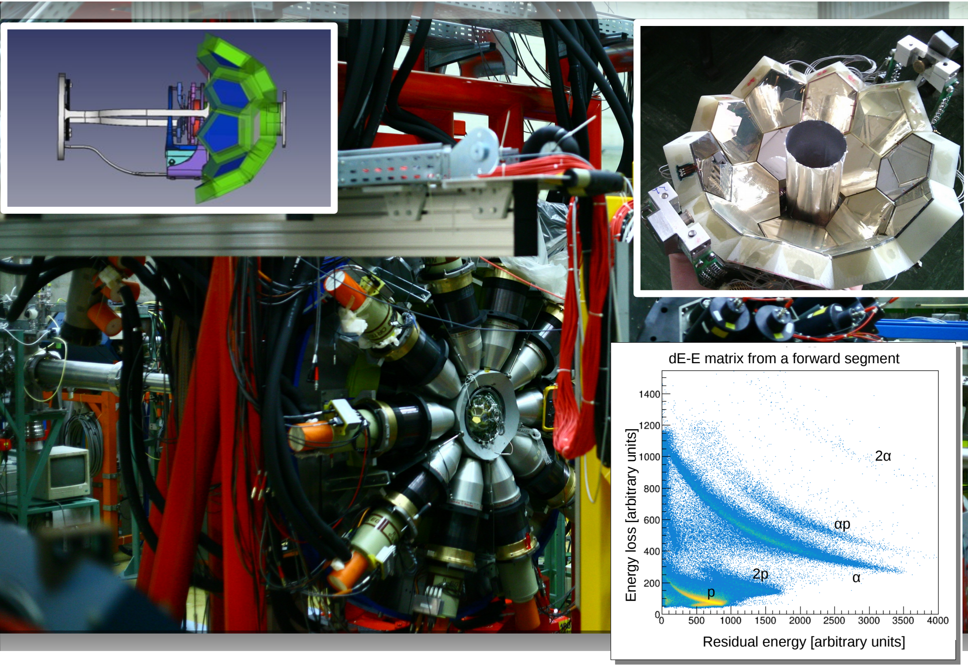
^{58}Ni(^{58}Ni,1α2p)^{110}Te

D. Testov, D. Mengoni, A. Goasduff et al., Eur. Phys. J. A (2019) 55 47;

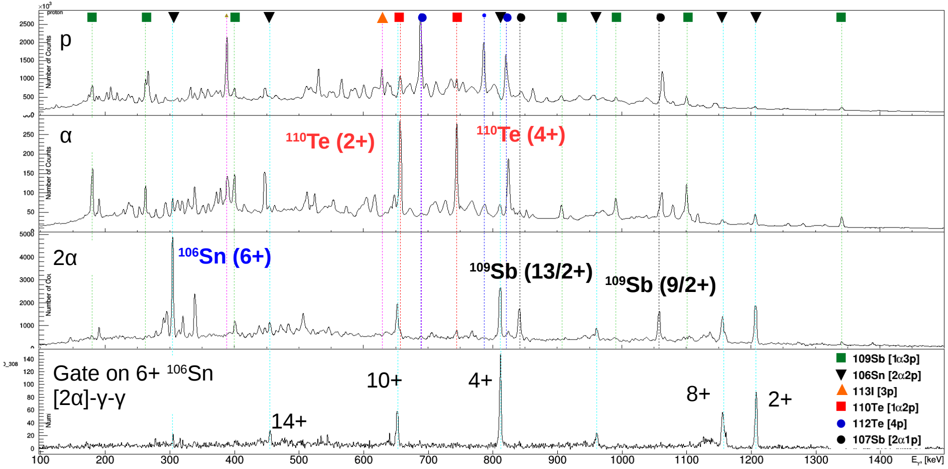
C. Müller-Gatermann, F. von Spee, A. Goasduff at al., Nucl. Inst.&Meth. A 920 95 (2019);

Differential Decay Curve Method

A.Dewald et al., Prog. Part. & Nucl. Phys. 67 (2012) 786

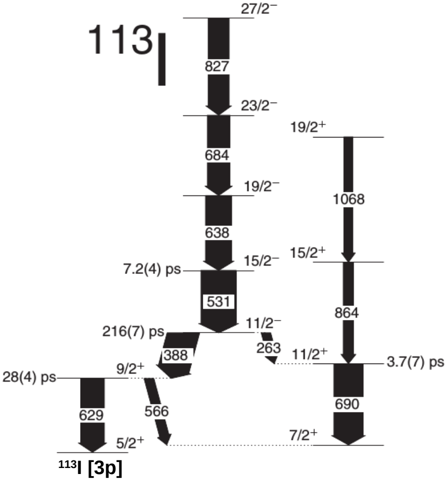

dE-E matrix from a forward segment
Energy loss [arbitrary units]
Residual energy [arbitrary units]
0
200
400
600
800
1000
1200
1400
500
1000
1500
2000
2500
3000
3500
4000
2α
αp
2p
α
p

Selectivity of Euclides



γ-γ (90deg vs 90deg) full projection

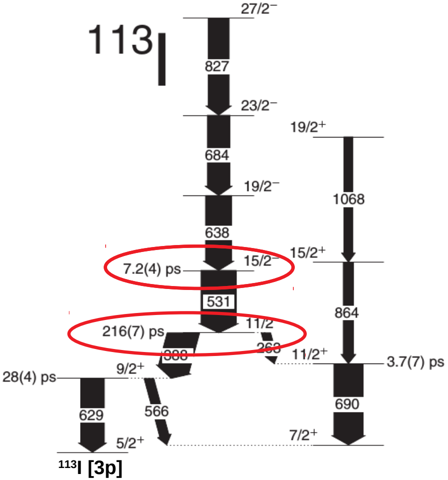
coincidence RDDS method at work



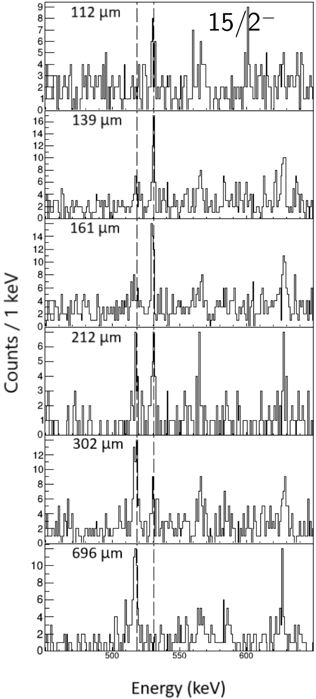
M. J. Taylor et al., Phys. Rev. C 88, 054307 (2013)

Jack Bradbury, Samuel Bakes

coincidence RDDS method at work

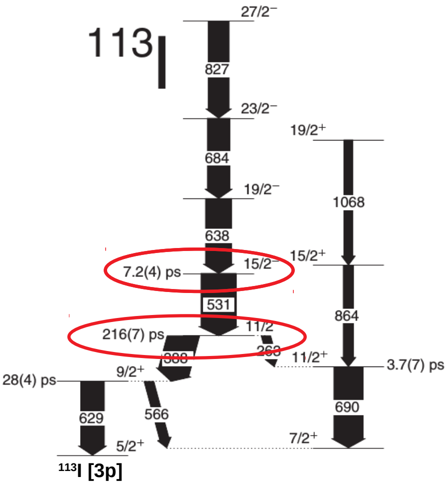


M. J. Taylor et al., Phys. Rev. C 88, 054307 (2013)

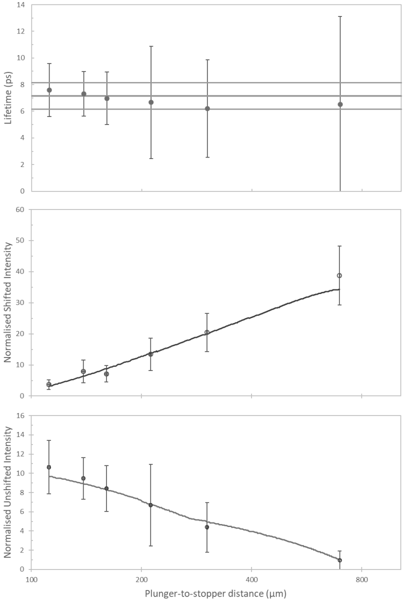


Jack Bradbury, Samuel Bakes

coincidence RDDS method at work

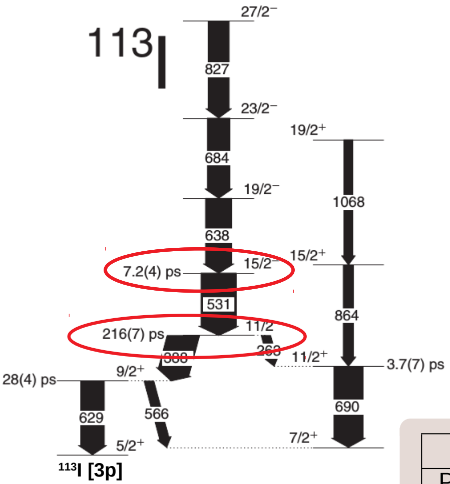


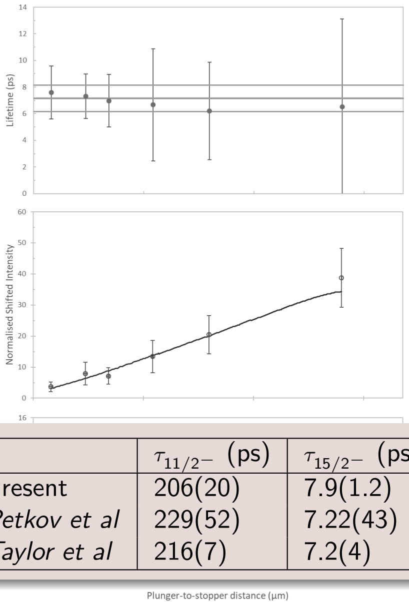
M. J. Taylor et al., Phys. Rev. C 88, 054307 (2013)



Jack Bradbury, Samuel Bakes

coincidence RDDS method at work



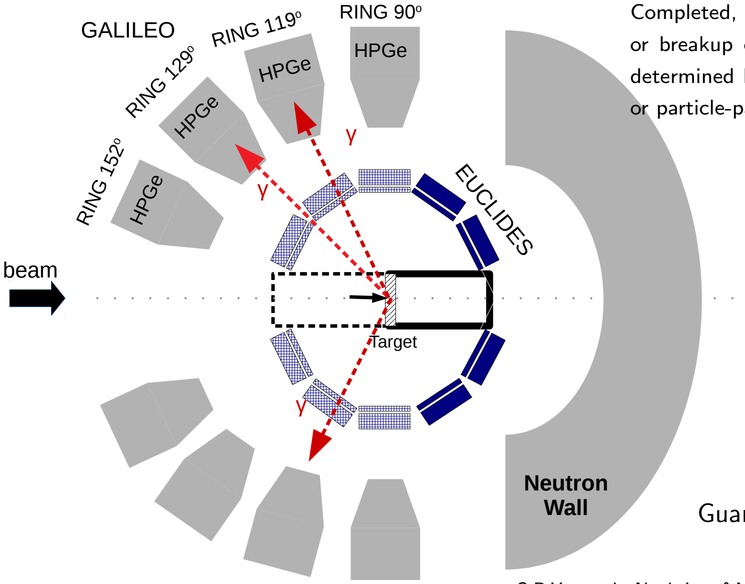


	$\tau_{11/2^-}$ (ps)	$\tau_{15/2^-}$ (ps)
Present	206(20)	7.9(1.2)
Petkov et al	229(52)	7.22(43)
Taylor et al	216(7)	7.2(4)

M. J. Taylor et al., Phys. Rev. C 88, 054307 (201

Jack Bradbury, Samuel Bakes

Breakup of weakly bound nucleus ^{6}Li on ^{89}Y

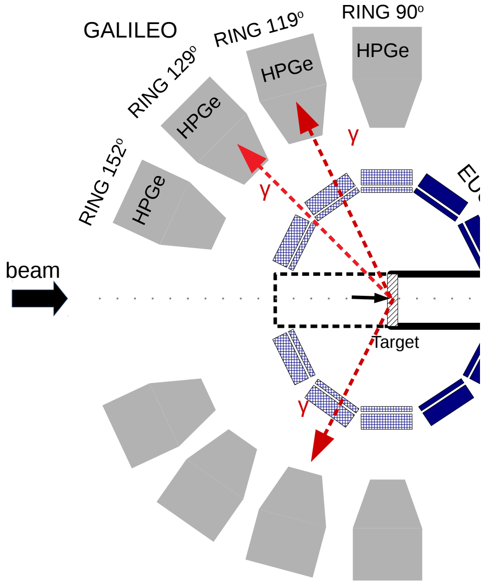


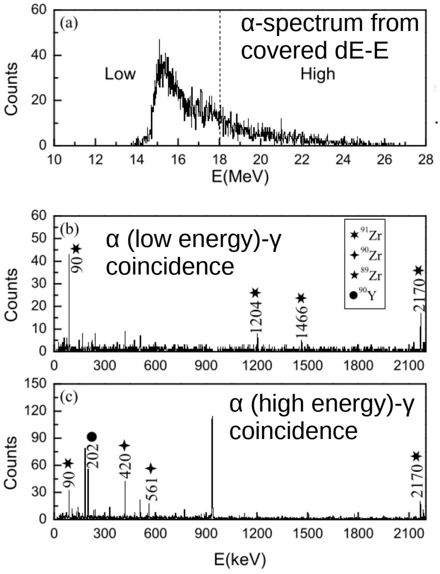
Completed, incomplete fusion or breakup channel can be determined by gamma-particle or particle-particle coincidence.

Guangxin Zang

S.P.Hu et al., Nucl. Inst.&Meth. A 914 64 (2019)

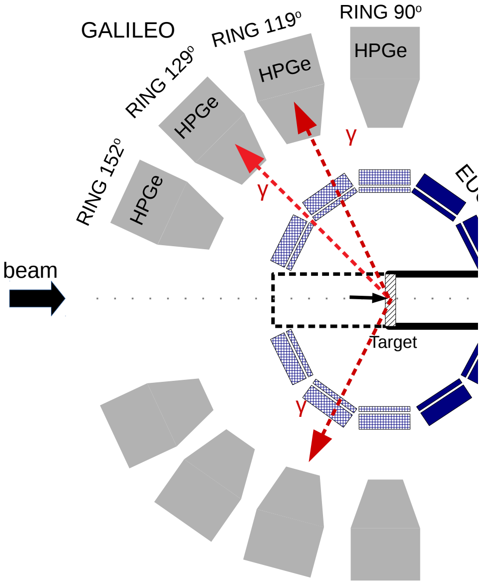
Breakup of weakly bound nucleus ^{6}Li on ^{89}Y

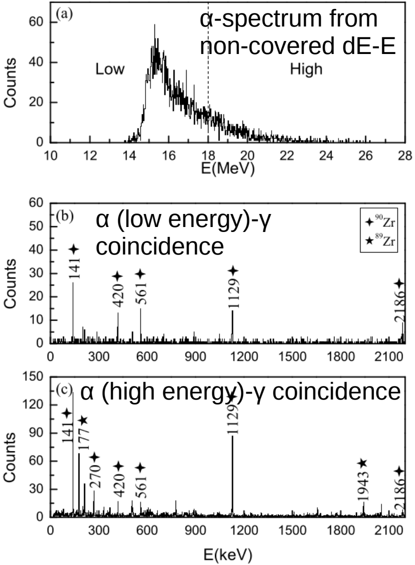




S.P.Hu et al., Nucl. Inst.&Meth. A 914 64 (2019)

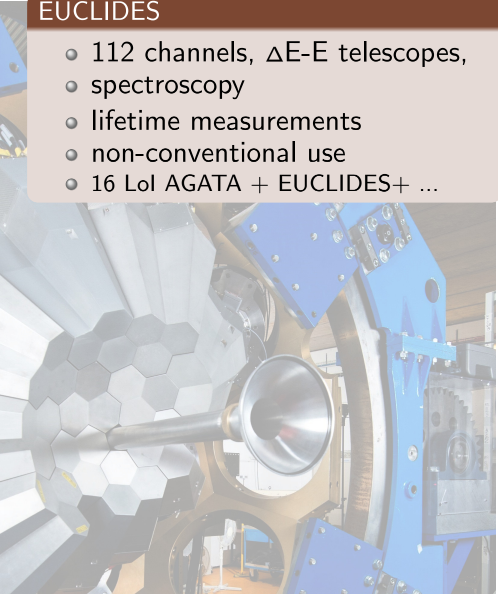
Breakup of weakly bound nucleus ^{6}Li on ^{89}Y

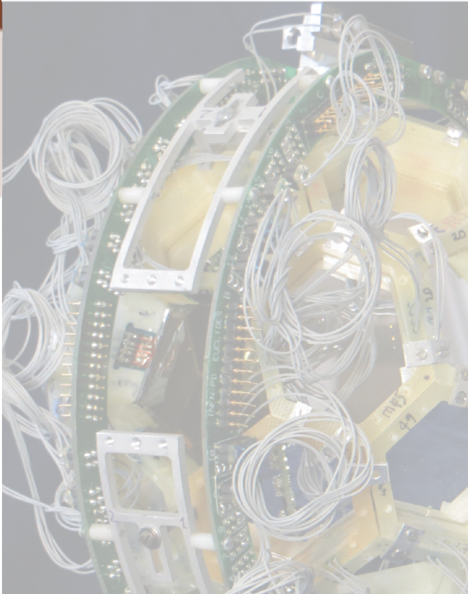




S.P.Hu et al., Nucl. Inst.&Meth. A 914 64 (2019)

EUCLIDES is fully working „plug-and-play” device to AGATA tracking array





EUCLIDES

- 112 channels, ΔE-E telescopes,
- spectroscopy
- lifetime measurements
- non-conventional use
- 16 LoI AGATA + EUCLIDES+ ...

EUCLIDES is fully working „plug-and-play” device to AGATA tracking array

EUCLIDES

- 112 channels, ΔE-E telescopes,
- spectroscopy
- lifetime measurements
- non-conventional use
- 16 LoI AGATA + EUCLIDES+ ...

Setups

+ 0 $\rightarrow$1
+ RFD $\rightarrow$1
+ NEDA $\rightarrow$ 7
+ NEDA + PARIS $\rightarrow$1
+ NEDA + SUGAR $\rightarrow$1
+ NEDA + FATIMA $\rightarrow$1
+ NEDA + plunger $\rightarrow$ 3
+ PARIS $\rightarrow$1

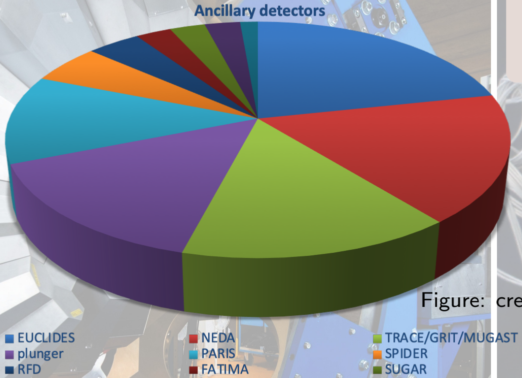


Figure: credits to J.J. Valiente-Dobón

EUCLIDES is fully working „plug-and-play” device to AGATA tracking array

EUCLIDES

- 112 channels, ΔE-E telescopes,
- spectroscopy
- lifetime measurements
- non-conventional use
- 16 LoI AGATA + EUCLIDES+ ...

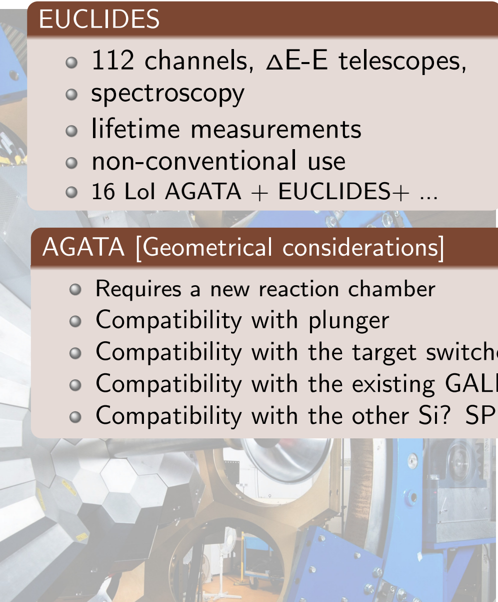
Setups

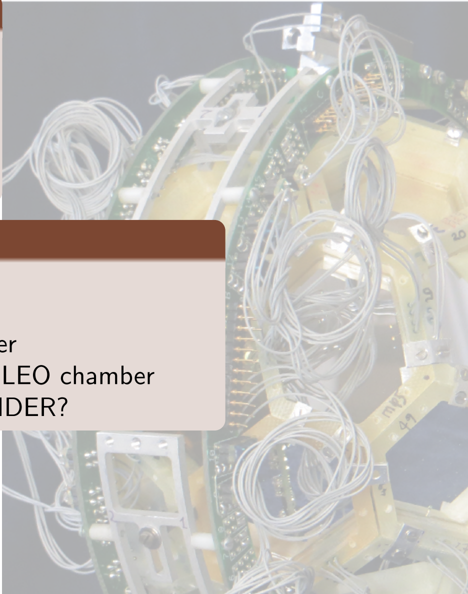
+ 0 $\rightarrow$1
+ RFD $\rightarrow$1
+ NEDA $\rightarrow$ 7
+ NEDA + PARIS $\rightarrow$1
+ NEDA + SUGAR $\rightarrow$1
+ NEDA + FATIMA $\rightarrow$1
+ NEDA + plunger $\rightarrow$ 3
+ PARIS $\rightarrow$1

Distribution per topic:

- High-spin: 5
- Astrophysics: 1
- N=Z: 6
- Nuclear shapes: 3
- Shell structure: 1

EUCLIDES is fully working „plug-and-play” device to AGATA tracking array





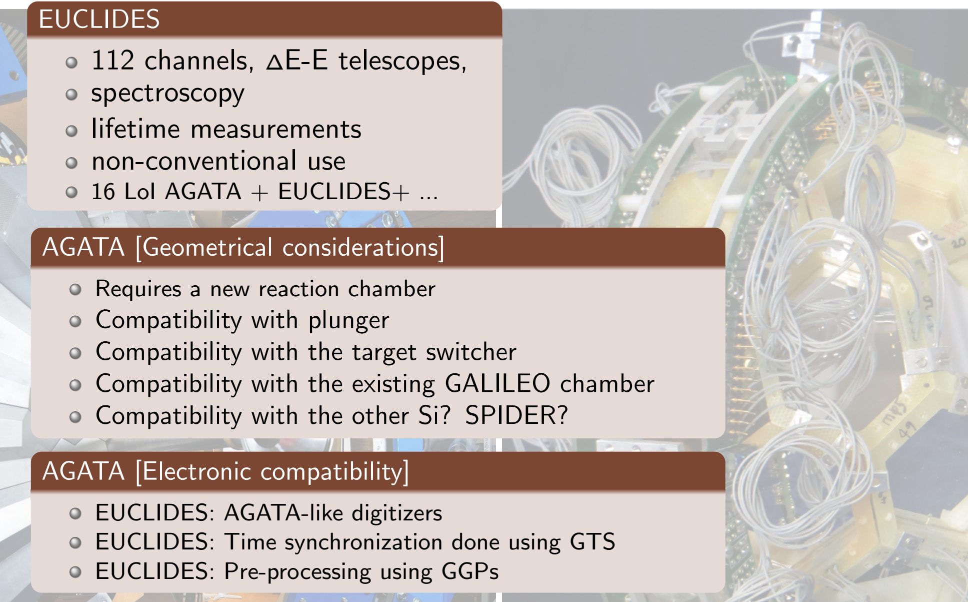
EUCLIDES

- 112 channels, ΔE-E telescopes,
- spectroscopy
- lifetime measurements
- non-conventional use
- 16 LoI AGATA + EUCLIDES+ ...

AGATA [Geometrical considerations]

- Requires a new reaction chamber
- Compatibility with plunger
- Compatibility with the target switcher
- Compatibility with the existing GALILEO chamber
- Compatibility with the other Si? SPIDER?

EUCLIDES is fully working „plug-and-play” device to AGATA tracking array



EUCLIDES

- 112 channels, ΔE-E telescopes,
- spectroscopy
- lifetime measurements
- non-conventional use
- 16 LoI AGATA + EUCLIDES+ ...

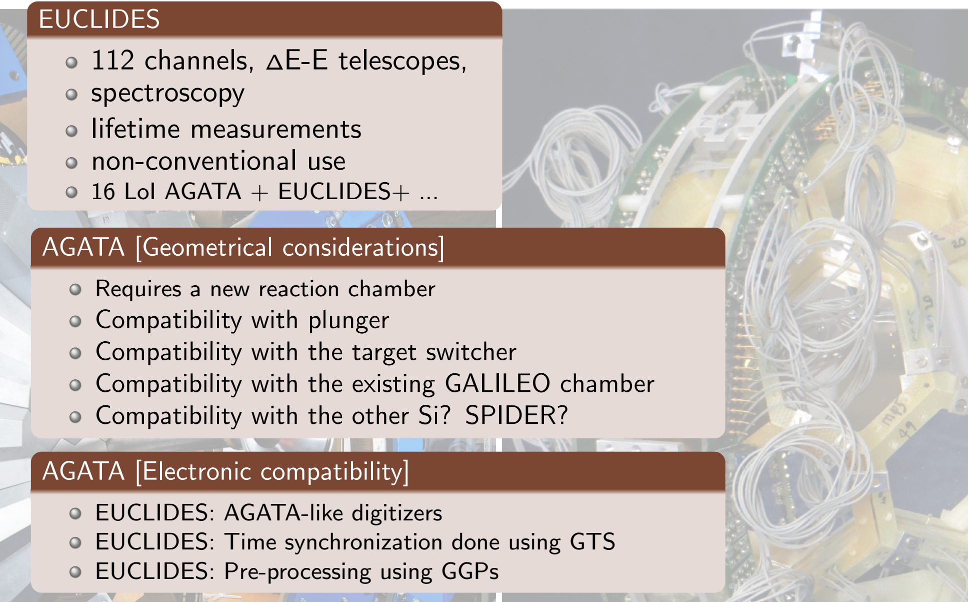
AGATA [Geometrical considerations]

- Requires a new reaction chamber
- Compatibility with plunger
- Compatibility with the target switcher
- Compatibility with the existing GALILEO chamber
- Compatibility with the other Si? SPIDER?

AGATA [Electronic compatibility]

- EUCLIDES: AGATA-like digitizers
- EUCLIDES: Time synchronization done using GTS
- EUCLIDES: Pre-processing using GGPs

Thank you to have contributed fruitfully to the discussions



EUCLIDES

- 112 channels, ΔE-E telescopes,
- spectroscopy
- lifetime measurements
- non-conventional use
- 16 LoI AGATA + EUCLIDES+ ...

AGATA [Geometrical considerations]

- Requires a new reaction chamber
- Compatibility with plunger
- Compatibility with the target switcher
- Compatibility with the existing GALILEO chamber
- Compatibility with the other Si? SPIDER?

AGATA [Electronic compatibility]

- EUCLIDES: AGATA-like digitizers
- EUCLIDES: Time synchronization done using GTS
- EUCLIDES: Pre-processing using GGPs