ANPC

African Nuclear Physics Conference

Kruger National Park
South Africa
1 - 5 July 2019
www.anpc2019.tlabs.ac.za

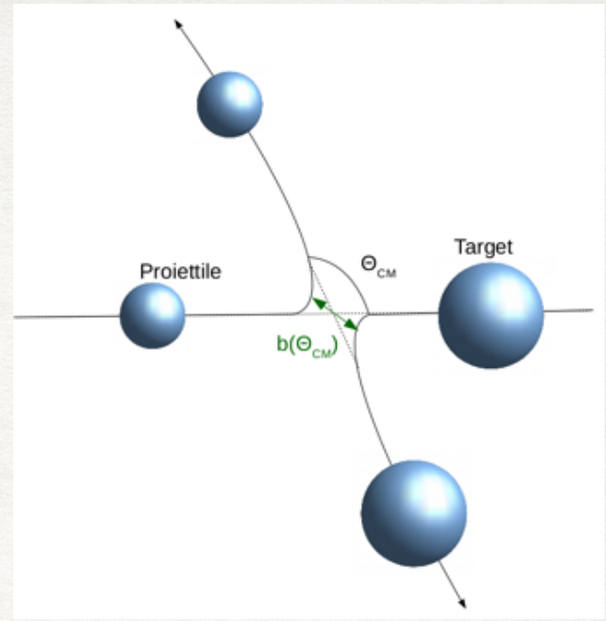
COULOMB EXCITATION AT LNL WITH SPIDER-GALILEO SETUP

INFN

Istituto Nazionale di Fisica Nucleare

ADRIANA NANNINI
INFN — FIRENZE

WHY COULOMB EXCITATION?



Low-energy Coulomb excitation is a powerful and direct experimental tool to study nuclear collectivity and shapes.

- the excitation process is purely electromagnetic

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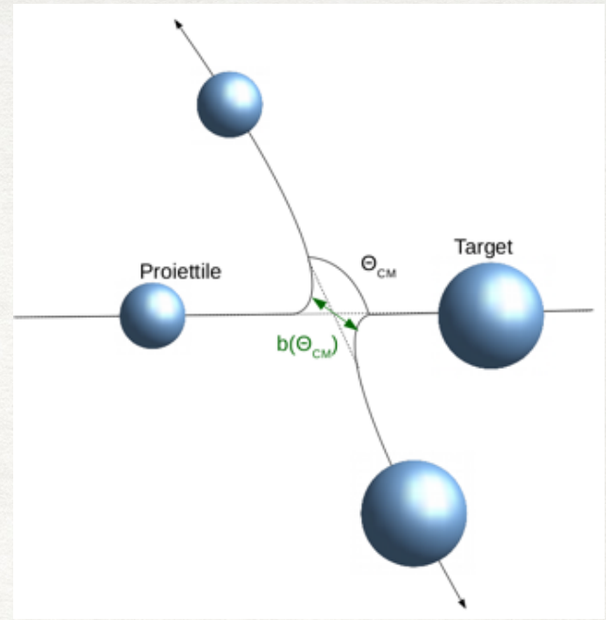
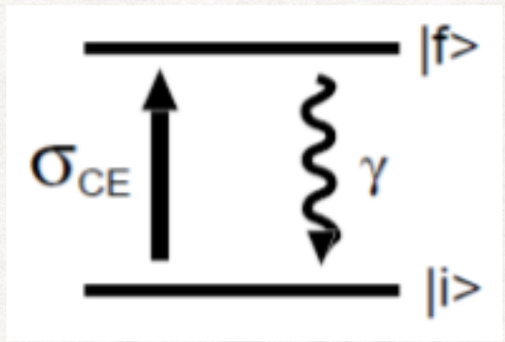


Low-energy Coulomb excitation is a powerful and direct experimental tool to study nuclear collectivity and shapes.

- the excitation process is purely electromagnetic
- cross-sections give a measure of the matrix elements of the e.m. operators

$$B\left(\Omega L; J_i \longrightarrow J_f\right) = \frac{1}{2J_i + 1} \left|\langle J_f || M(\Omega L) || J_i \rangle\right|^2$$



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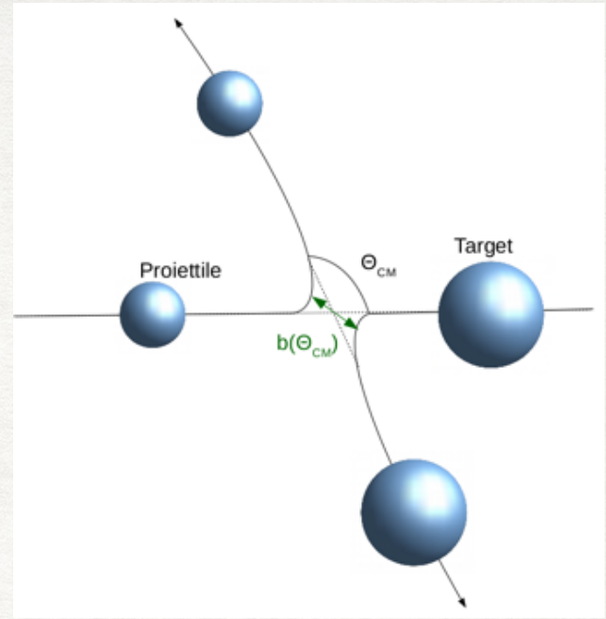

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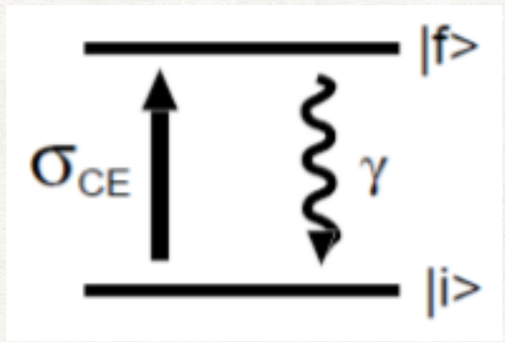

- diagonal matrix elements (spectroscopic quadrupole moments) give a measure of charge distribution

$$Q_s\left(J\right) = \sqrt{\frac{16\pi}{5}}\frac{\langle JJ20|JJ\rangle}{\sqrt{2J+1}}\langle J\,||E2||\,J\rangle$$

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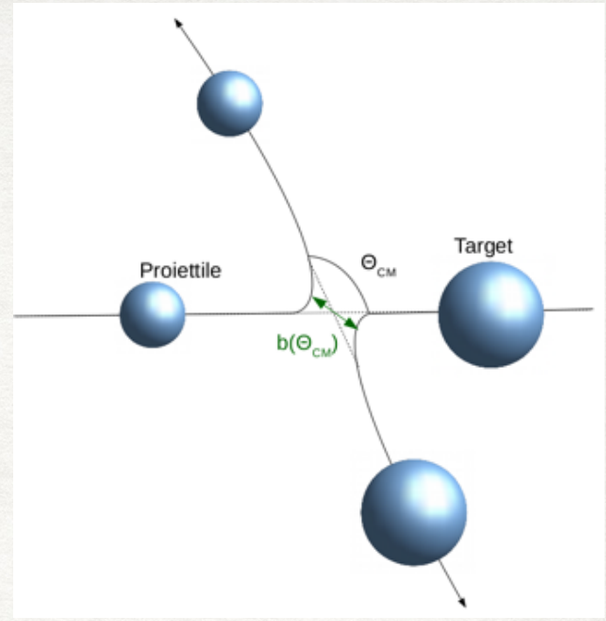

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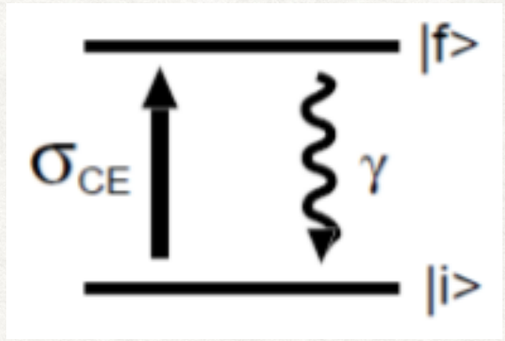

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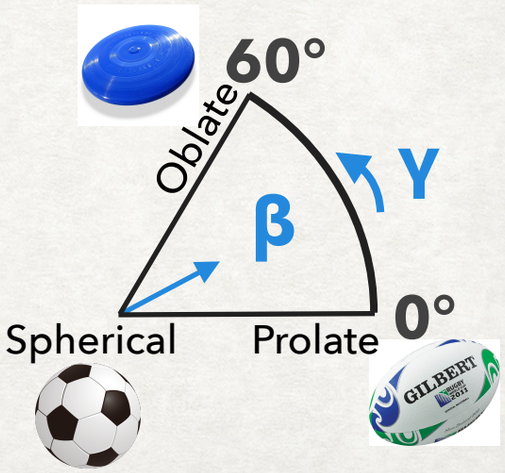
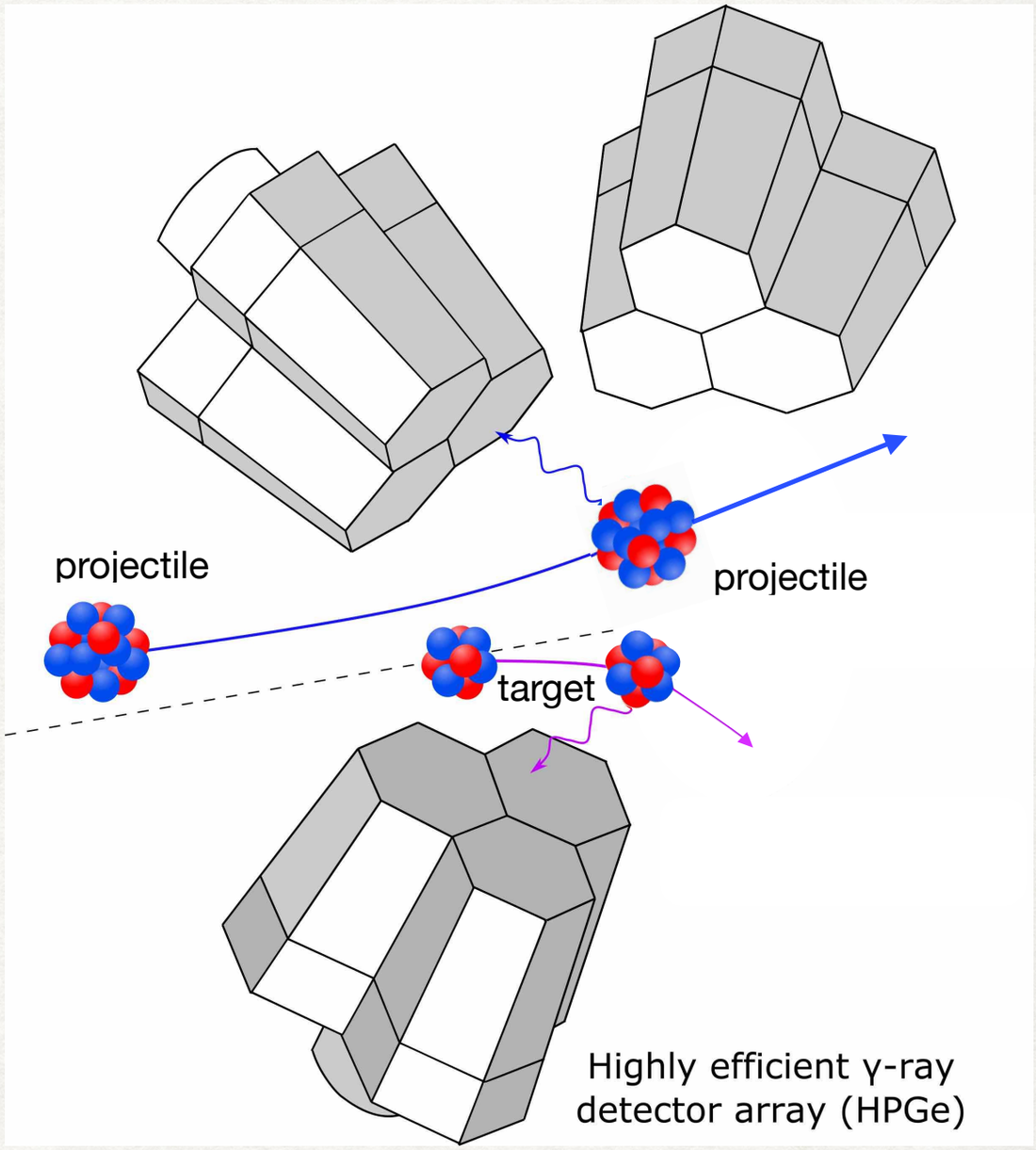
$$Q_s\left(J\right) = \sqrt{\frac{16\pi}{5}}\frac{\langle JJ20|JJ\rangle}{\sqrt{2J+1}}\langle J\,||E2||\,J\rangle$$

- complete set of E2 matrix elements brings information on shape parameters via the quadrupole sum rules



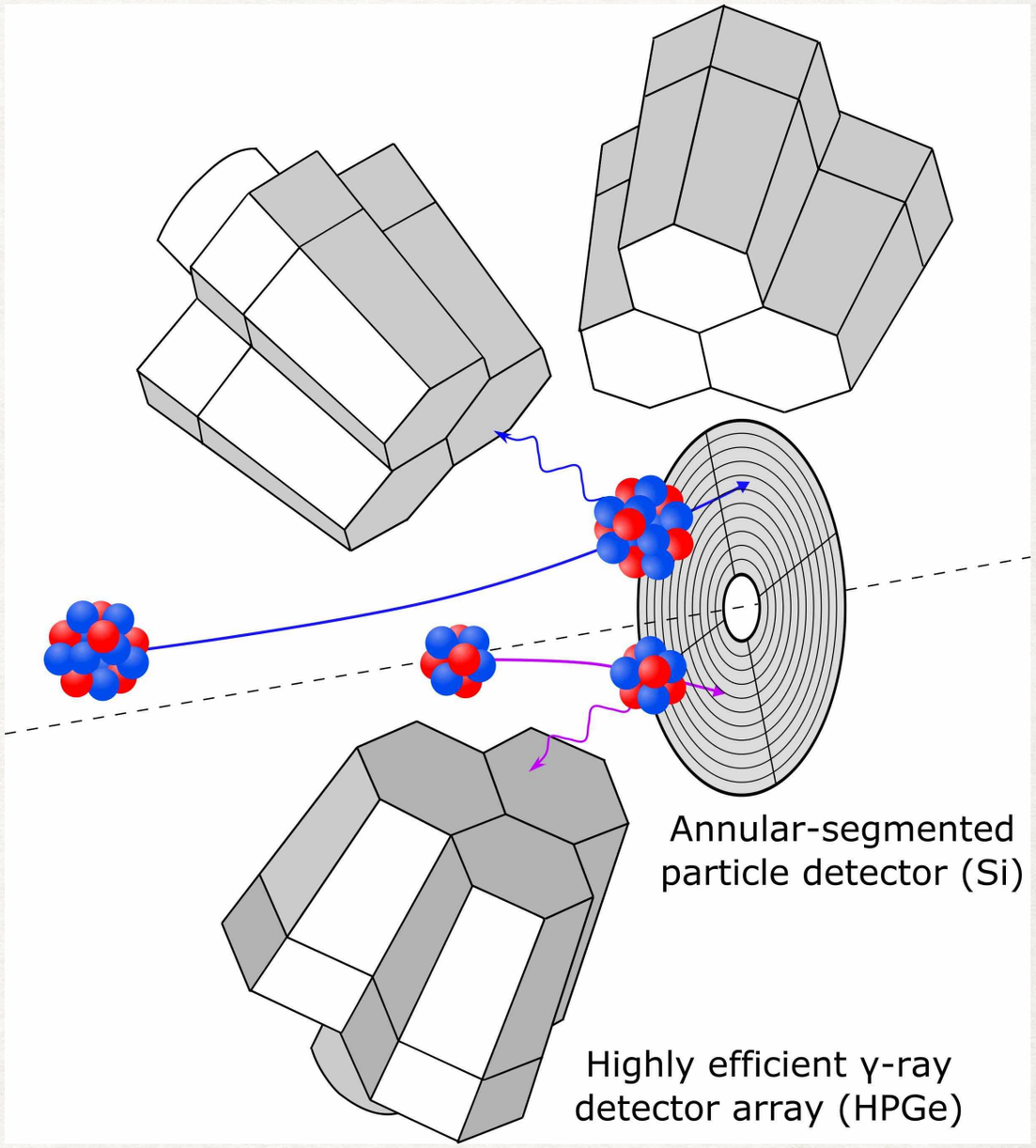
COULOMB EXCITATION MEASUREMENTS

- germanium detectors to detect γ-rays
  - Doppler correction of γ-ray spectra



COULOMB EXCITATION MEASUREMENTS

- germanium detectors to detect γ-rays
- segmented particle detector to detect the scattered projectiles and/or recoiling target nuclei
  - to select Coulomb Excitation events
  - to determine scattering angle and reconstruct the kinematics of the reaction
  - to perform Doppler correction



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WHY COULOMB EXCITATION @ LNL?

- The SPES ISOL facility for radioactive beams under construction
- Coulomb excitation ideal first day experiment

- ❑ New High power compact CYCLOTRON 70 MeV 750 microA (BEST company)
- ❑ New configuration of High power ISOL System (8 kW Target ion source)
- ❑ ALPI superconductive linac (up-graded) for RIB's reacceleration

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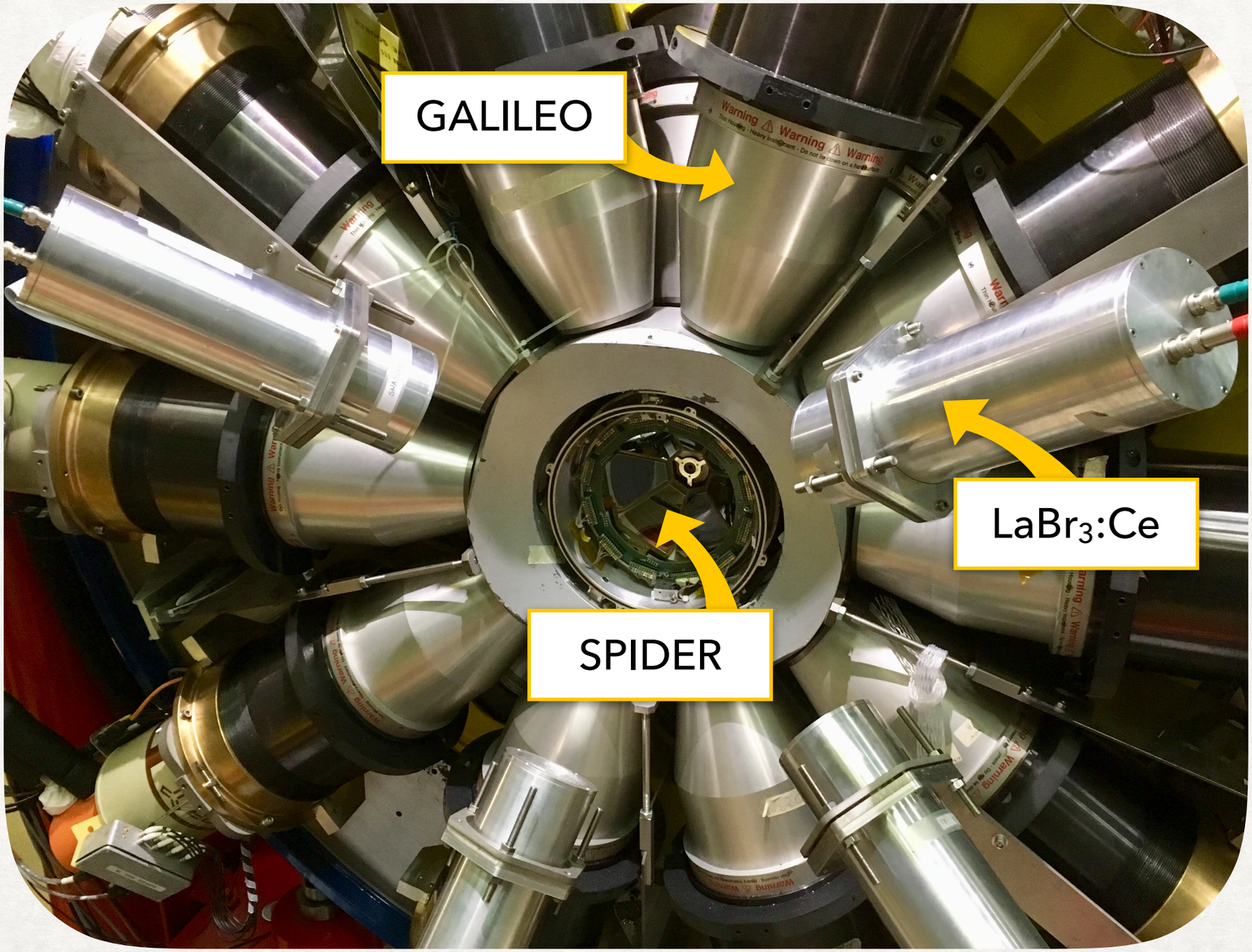
THE SPIDER - GALILEO SETUP



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THE SPIDER - GALILEO SETUP

GALILEO 1st Phase

- 25 **HPGe** Compton-suppressed detectors (GASP type)
- **FWHM** (@1332.5 keV) < 2.4 keV
- **Efficiency** (@1332.5 keV) = 2.1%
- Complete **digital DAQ** (takes advantage of the developments made for AGATA):
  - Trigger-less mode
  - Typical operational rate ~ 20 kHz/det
  - Common clock synchronization

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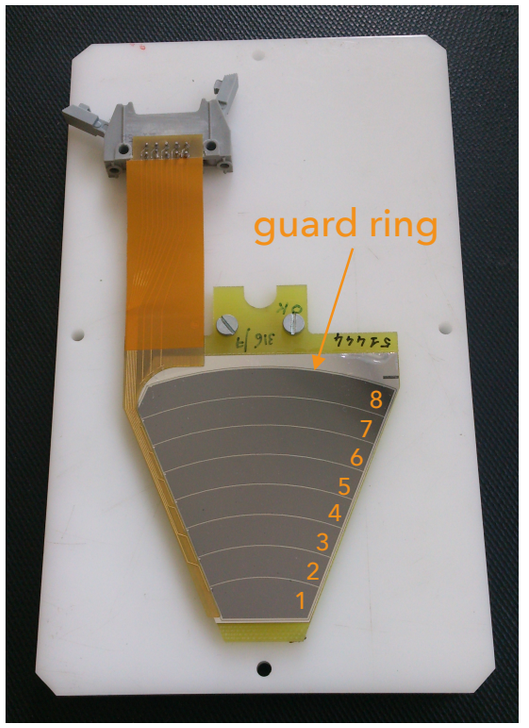
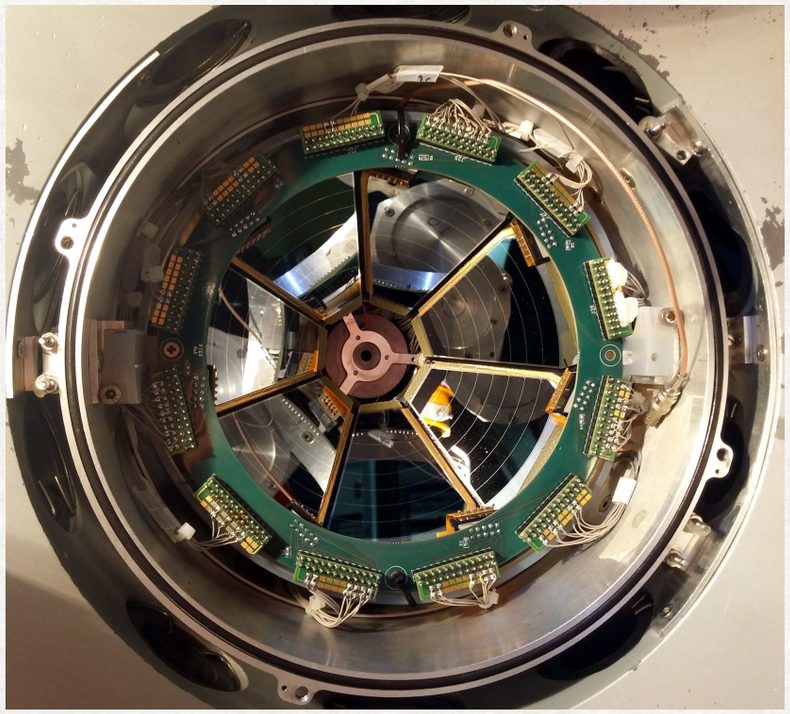
THE SPIDER - GALILEO SETUP

SPIDER Silicon Ple DEtectoR

- 8 independent **sectors**, 8 **strips** + guard ring
- Detector **thickness** ~ 300 μm
- **FWHM** ~21 keV for **α**-particles @ ~5.5 MeV
- modularity: with GALILEO **cone configuration** (7 sectors) at **backward angles** $\Longrightarrow \Delta\Theta = 37.4°$, $\Omega/4\pi = 17.3\%$



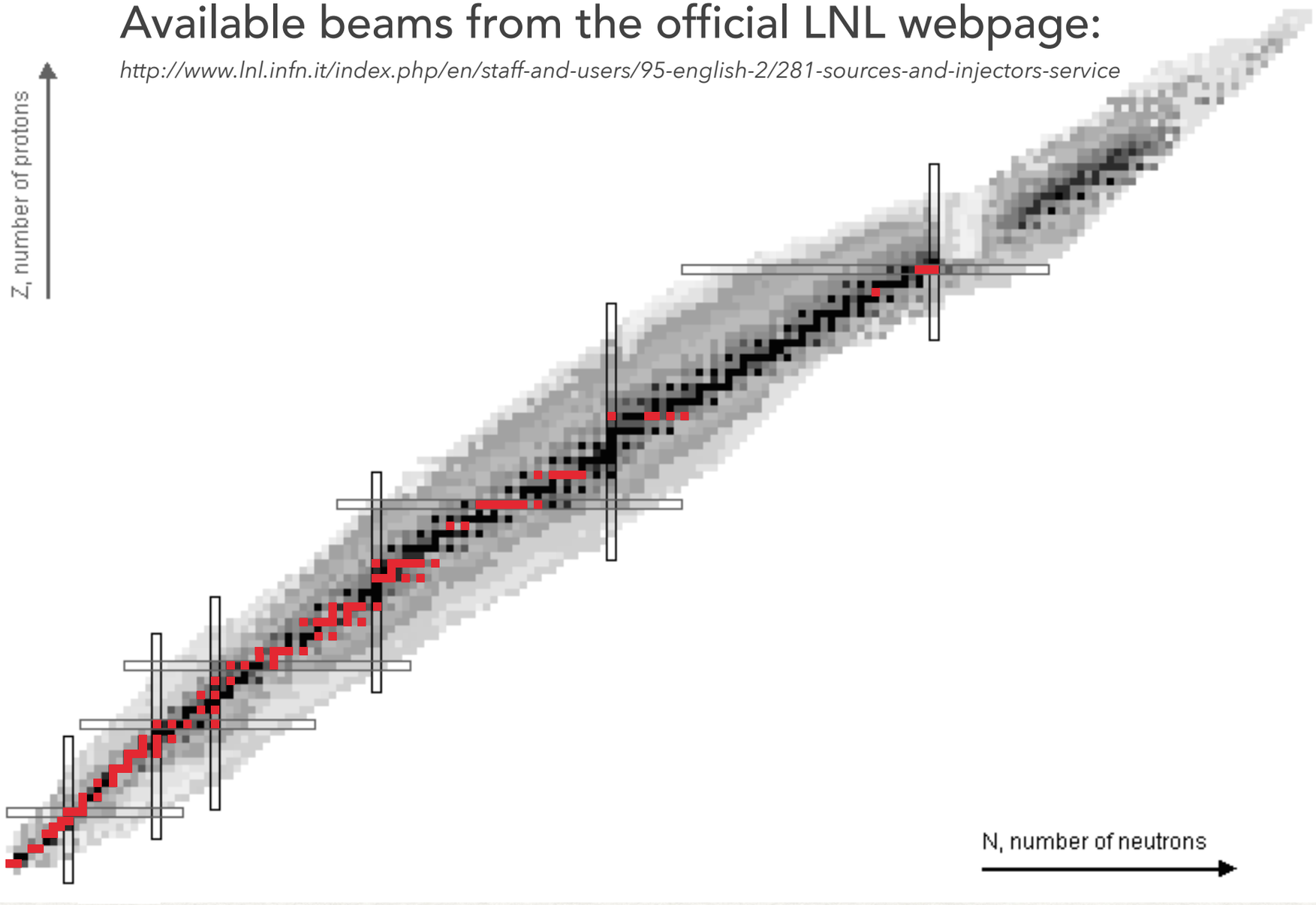


COULEX @ LNL SPIDER&GALILEO

- **Any possibilities for Coulex with stable beams?**

Available beams from the official LNL webpage:

http://www.lnl.infn.it/index.php/en/staff-and-users/95-english-2/281-sources-and-injectors-service



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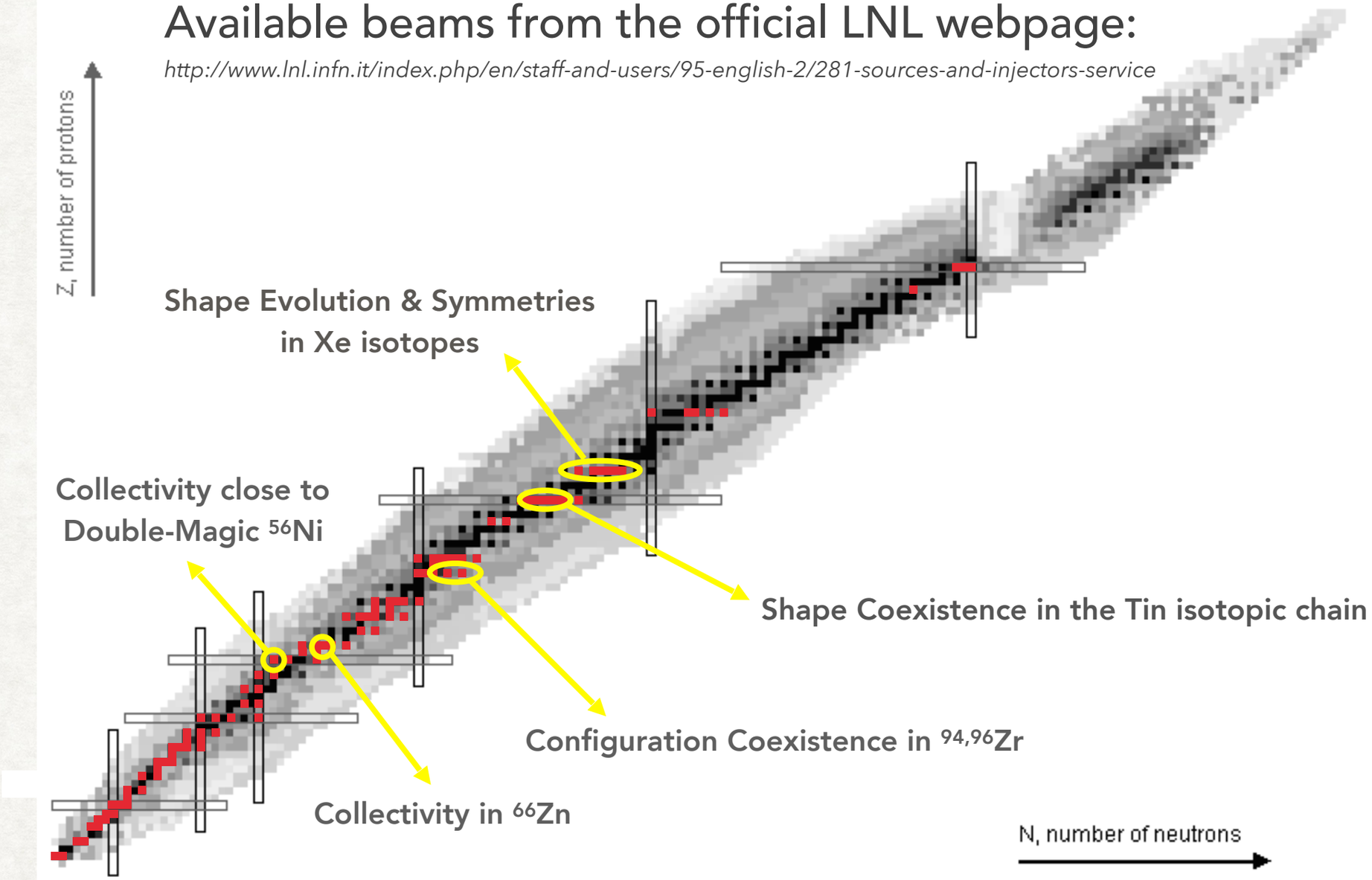
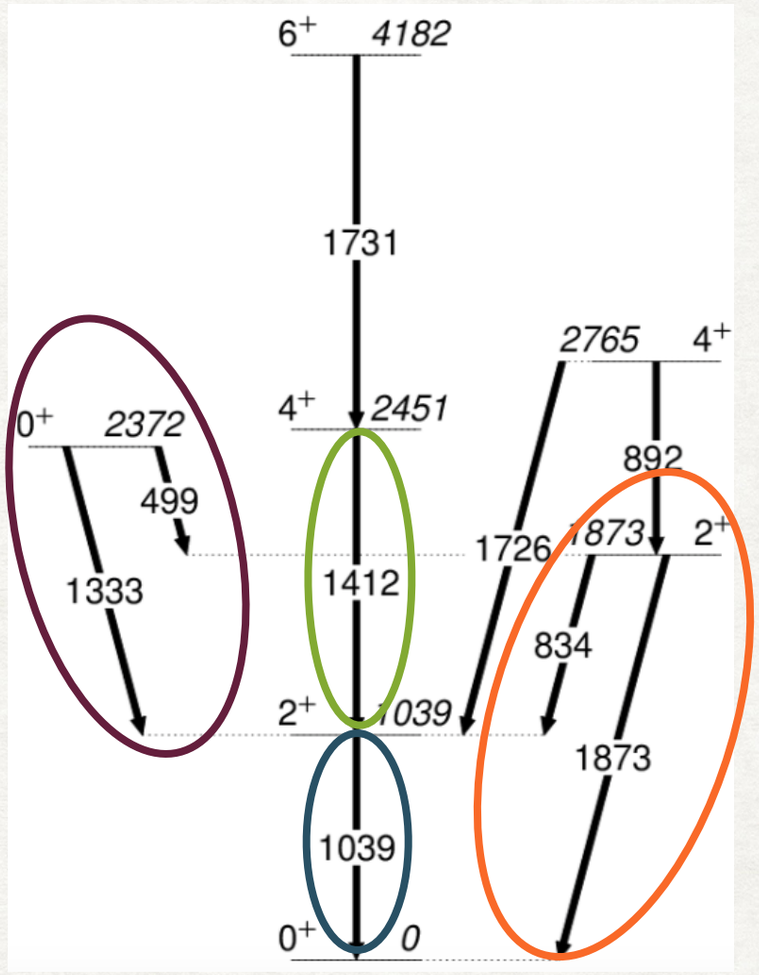


COULEX @ LNL SPIDER&GALILEO

First Experiment: Collectivity of low-lying states in ^{66}Zn

Spokespersons: M. Rocchini, K. Hadynska-Klek

- Commissioning of the apparatus: $Q(2_1^+)$ known with high precision.
- New physics:
  - Shape of 0_2^+ ? B(E2) value unknown
  - Is the 2_2^+ high-collective or not? Discrepant values for its lifetime
  - Is the 4_1^+ collective or not? Discrepant values for the B(E2; $4_1^+ \longrightarrow 2_1^+$)
- Beam: ^{66}Zn (240 MeV, 1 — 1.5 pnA)
- Target: 1 mg/cm^2 of ^{208}Pb



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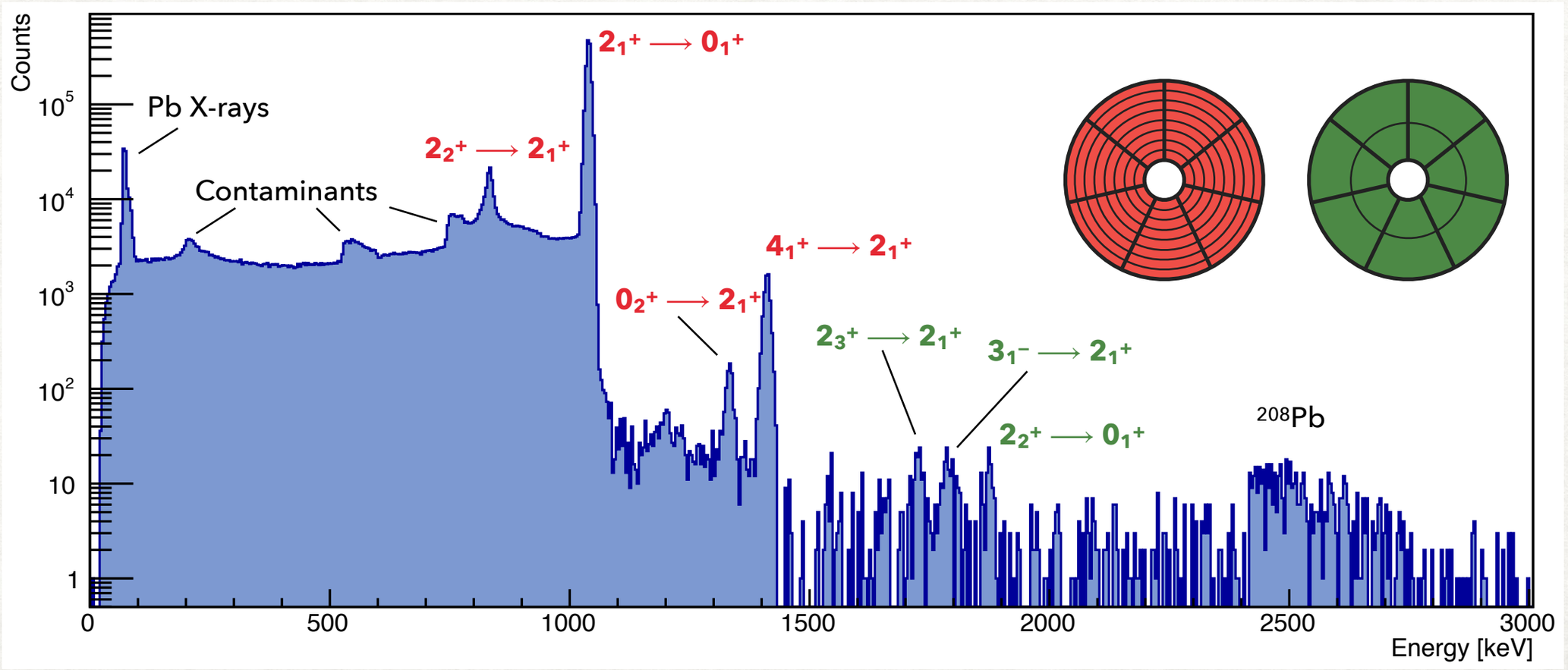
- Coincidences between GALILEO and SPIDER
- 38 experimental yields
- Analysis with the GOSIA code (T. Czosnyka, D. Cline, C. Wu, Bull. Amer. Phys. Soc. 28 (1983) 745)



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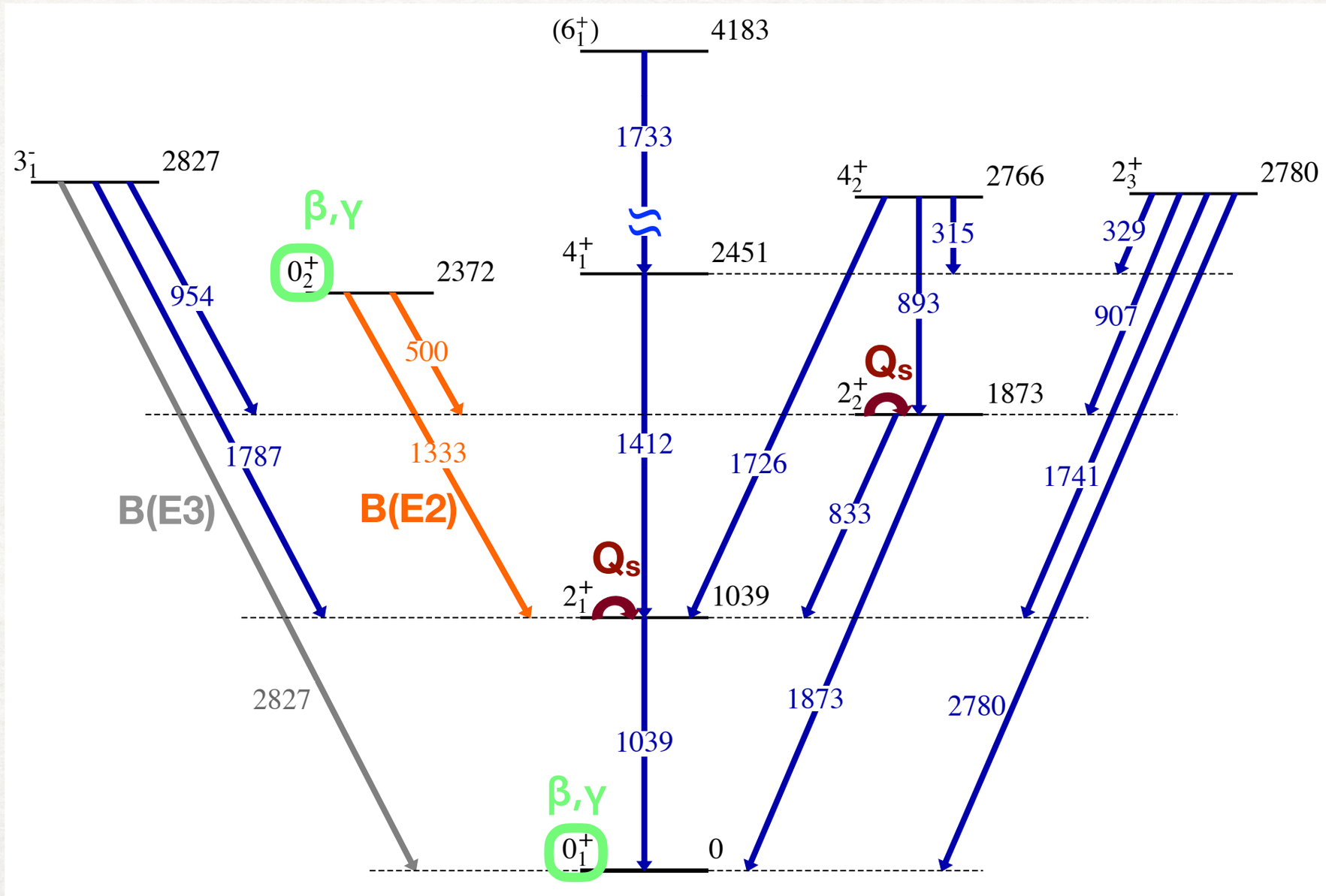
- validation of the setup performances: $Q_s(2_1^+)$=+24(9) [$Q_s(2_1^+)$=+24(8)] efm^2
- **new physics**



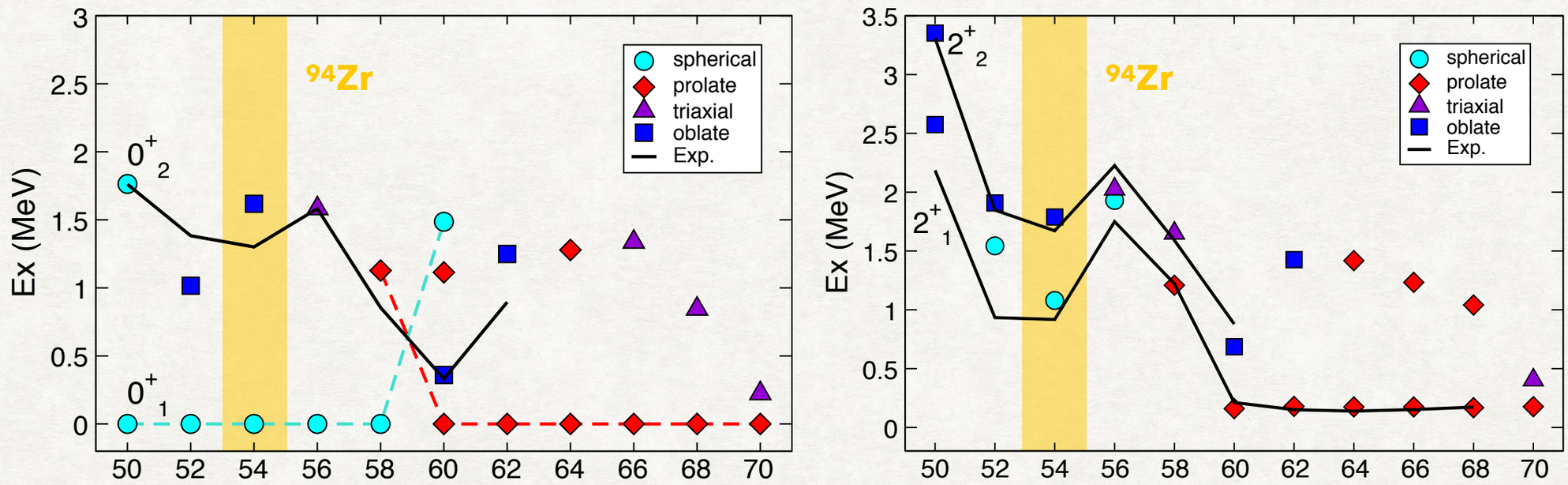
COULEX @ LNL SPIDER&GALILEO

Probing collectivity and configuration coexistence in ^{94}Zr

Spokespersons: D. Doherty, M. Rocchini, M. Zielinska

- Recent state-of-the-art Monte Carlo shell model calculations predict shape coexistence in Zr isotopes.

T. Togashi, Y. Tsunoda, T. Otsuka e N. Shimizu, Phys. Rev. Lett. ***117****, 172502 (2016)*



- Observation* of a strong $2^+_2 \rightarrow 0^+_2$ transition (19 W.u.) suggests a deformed band built on 0^+_2

* *A. Chakraborty et al., PRL 110, 022504 (2013).*

COULEX @ LNL SPIDER&GALILEO

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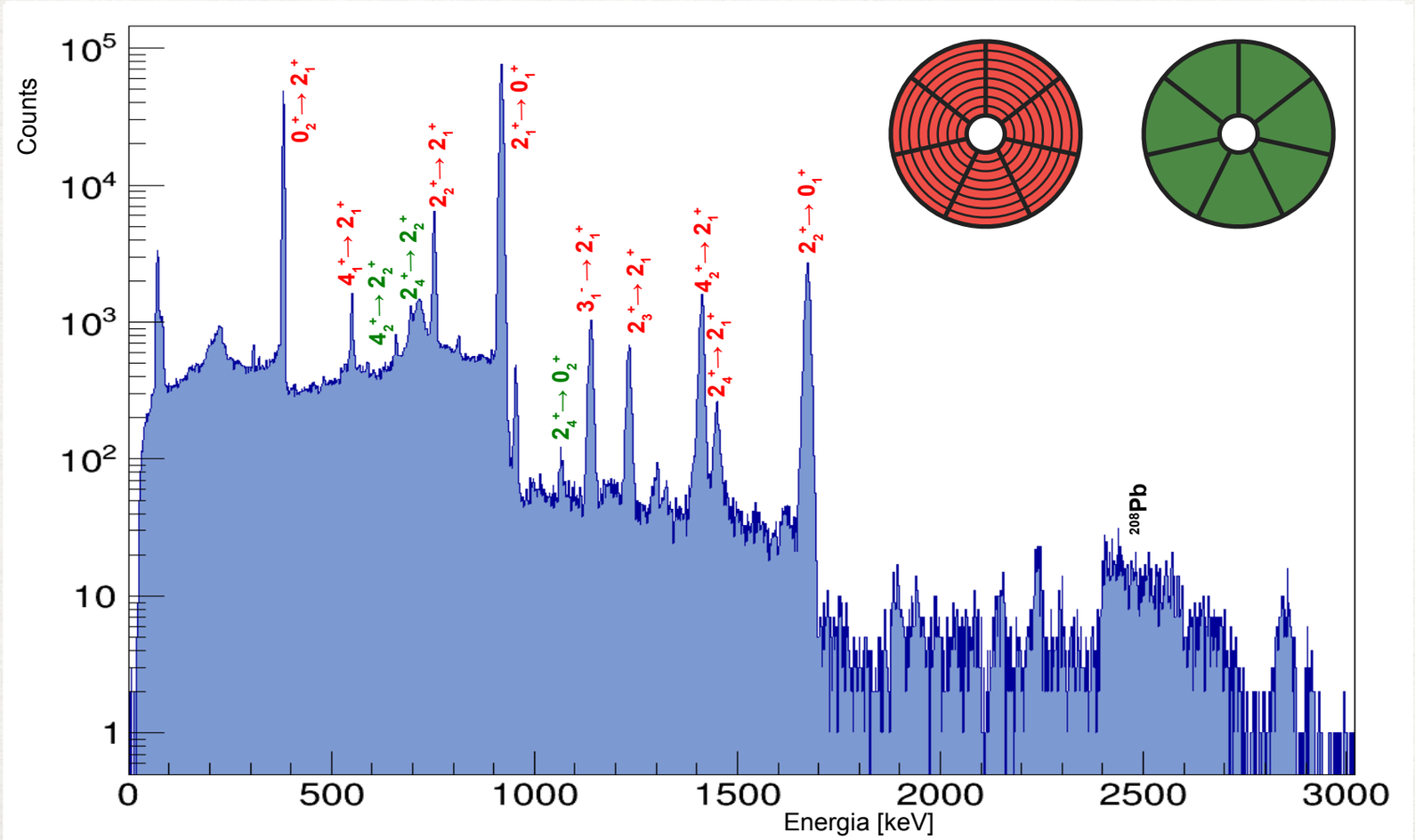
- Beam: ^{94}Zr (370 MeV, 1 — 1.5 pnA)
- Target: 1 mg/cm^2 of ^{208}Pb
- Six 3"X3" $LaBr_3$:Ce used for the first time in COULEX @LNL



- Coincidences between GALILEO and SPIDER
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- Random-background-subtracted γ-γ coincidence spectrum gated on the 382 keV

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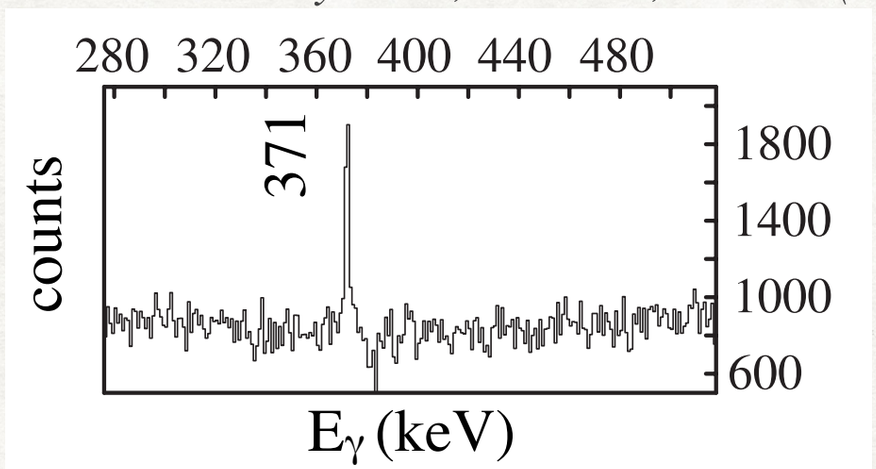
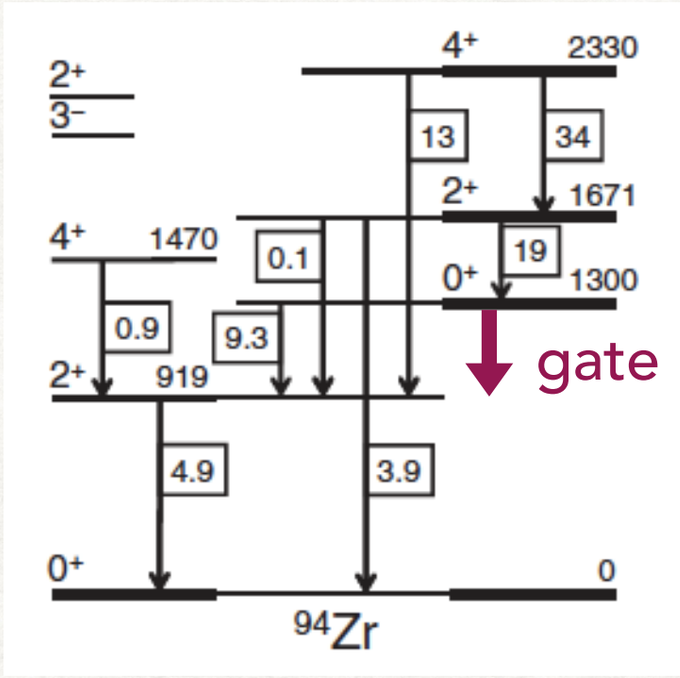
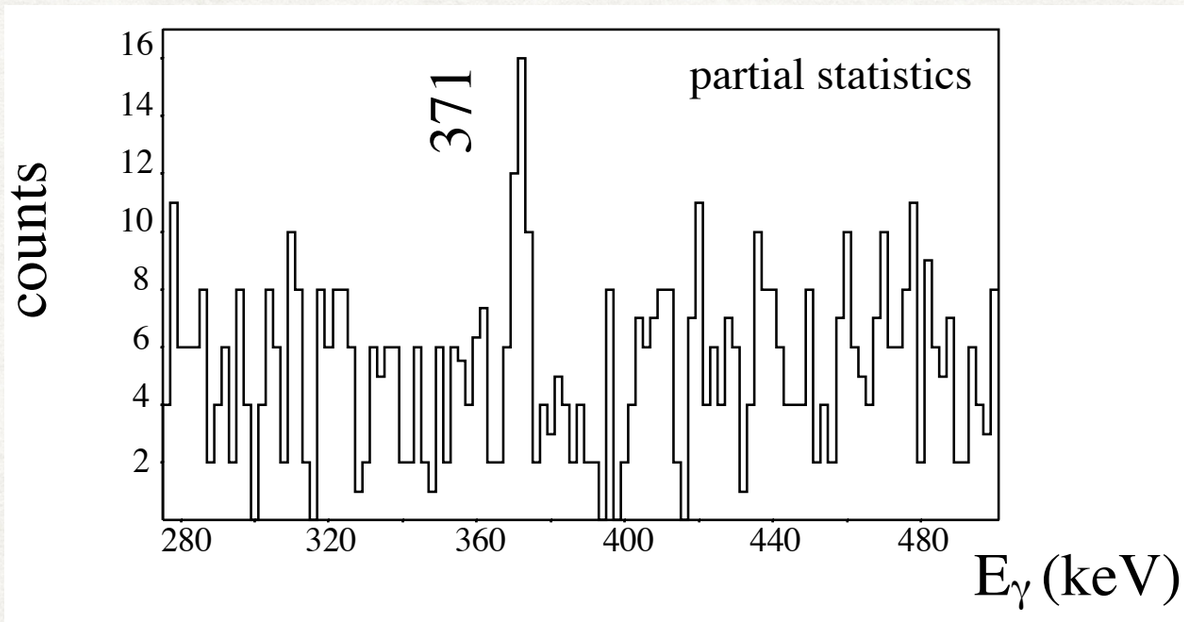




- Random-background-subtracted γ-γ-particle coincidence spectrum gated on the 382 keV



COULEX @ LNL SPIDER&GALILEO

Probing collectivity and configuration coexistence in ^{94}Zr

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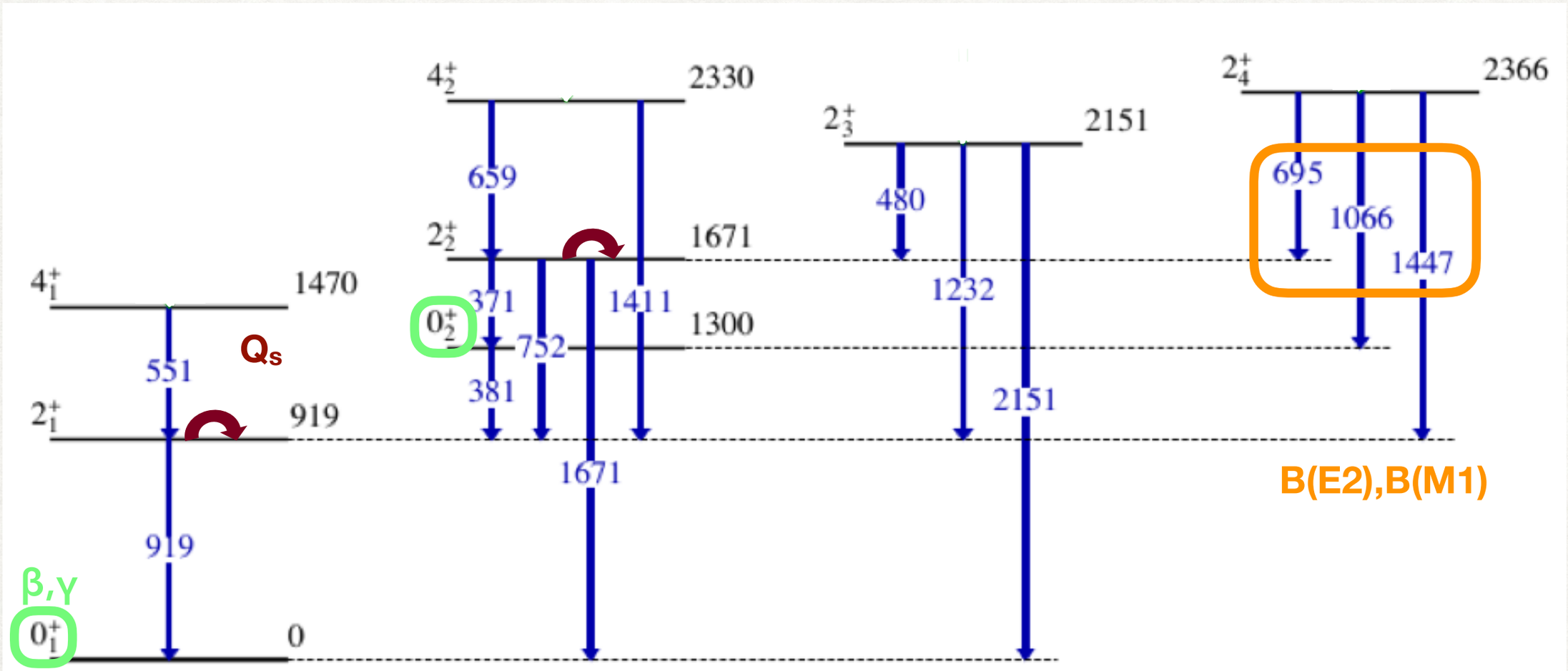
- GOSIA analysis on-going
- new B(E2) values from single step COULEX

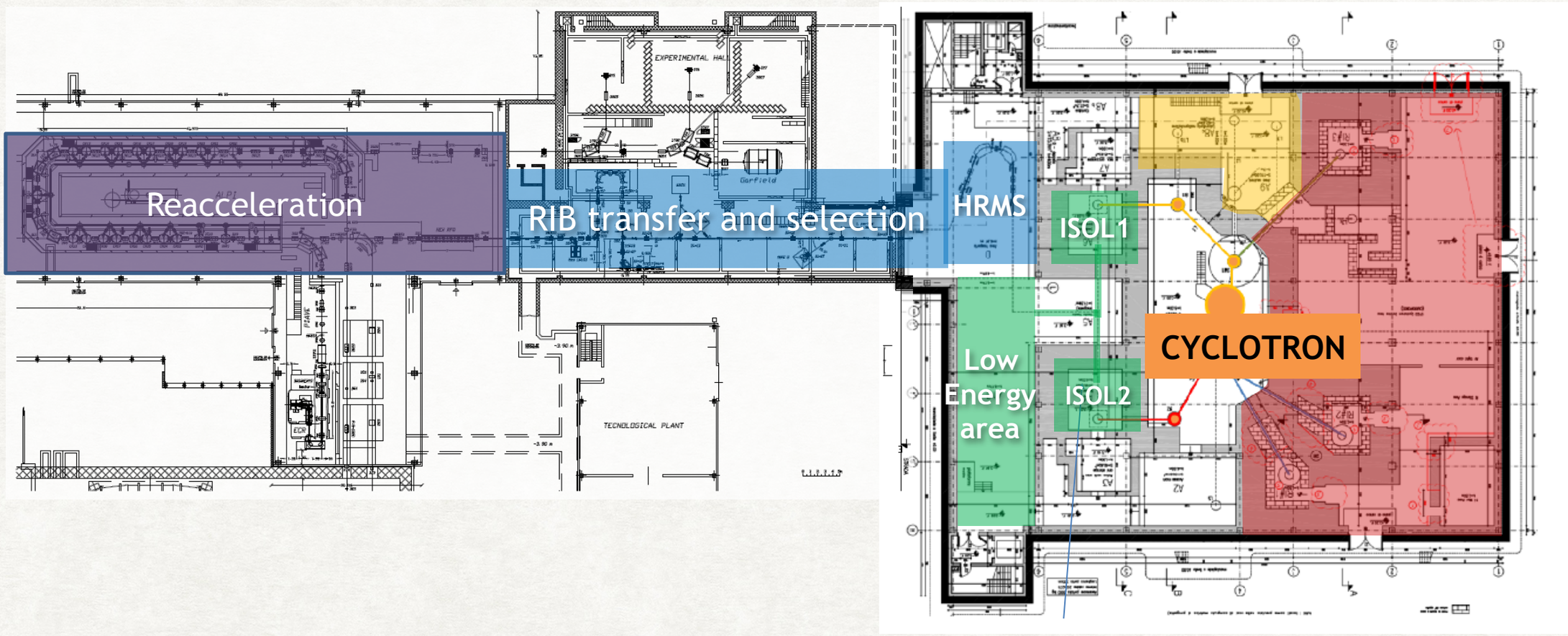
preliminary B(E2; $2_1^+ \longrightarrow 0_1^+$) : 5.05 Wu (15 stat) (25 syst)* [NNDC: 4.9 (11) Wu)]

** M. Zielinska, Private Communication*



PERSPECTIVE WITH SPES

SPES layout



RIB reacceleration:

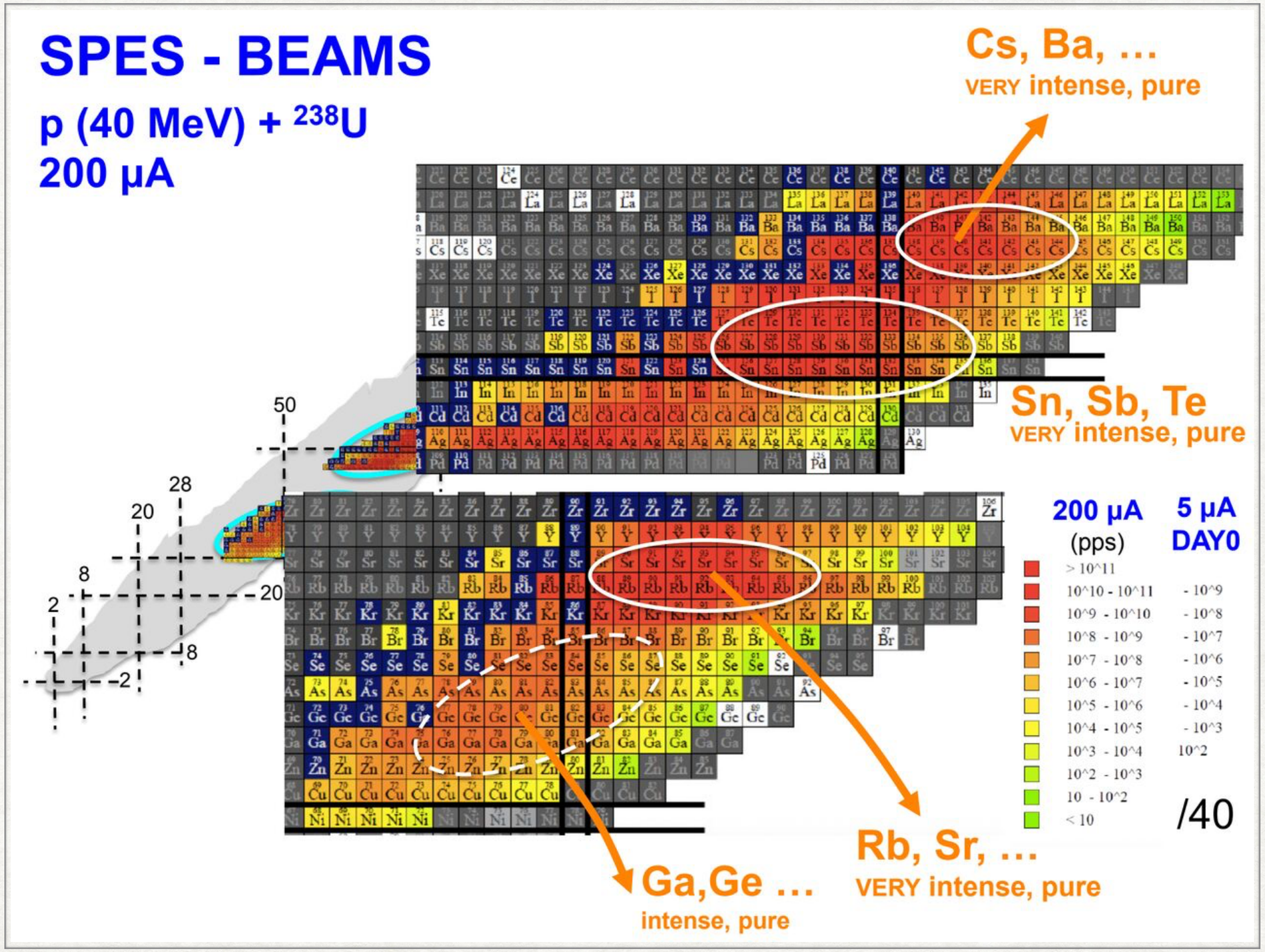
- new RFQ
- ALPI

1/20.000 Mass separator (Beam Cooler + HRMS)
Electrostatic beam transport
Charge Breeder (n+)
1/1000 mass separator

ISOL bunkers
1/200 mass separator
low energy experimental area

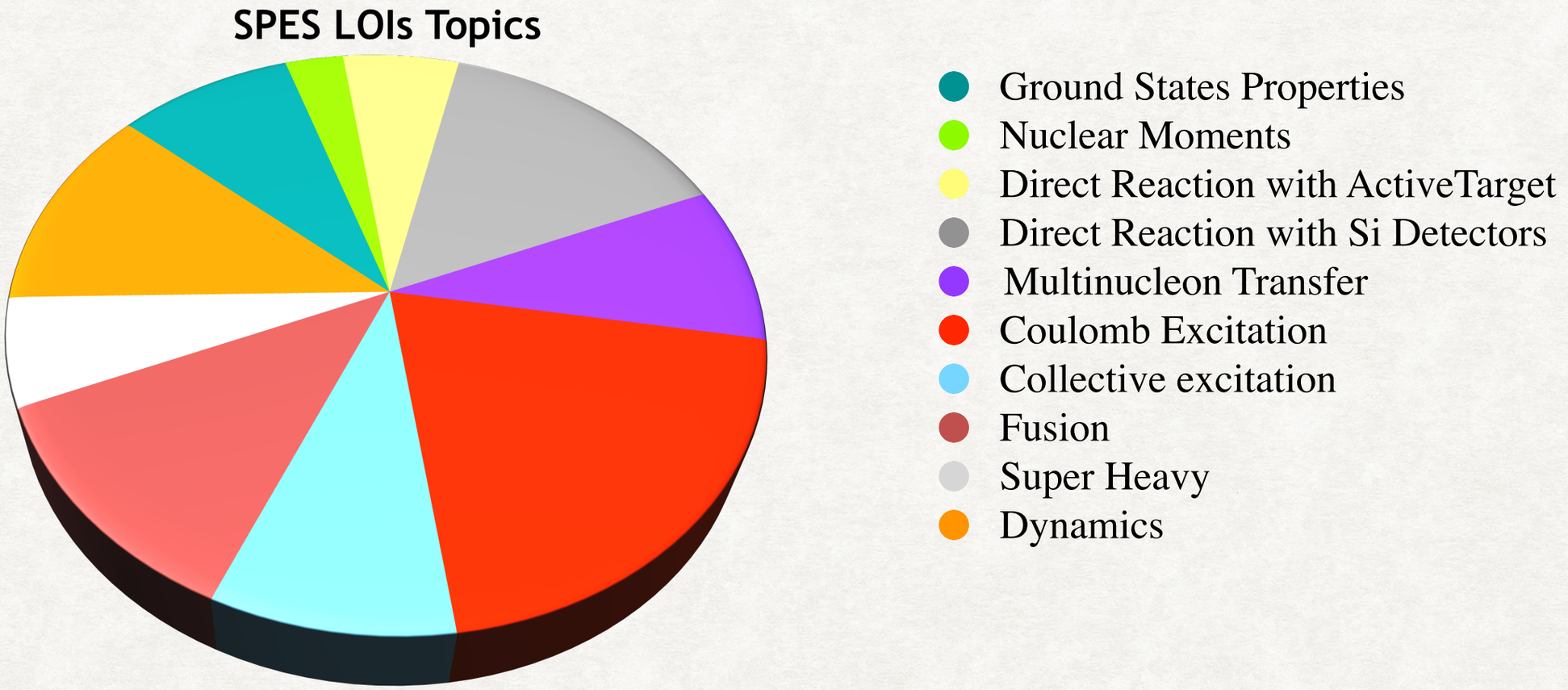
Radioisotopes production area

PERSPECTIVE WITH SPES



PERSPECTIVE WITH SPES

SPES International Workshop: 47 Letter of Intents



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SUMMARY AND OUTLOOK

- Coulomb Excitation @LNL with stable beams is on-going
- New experiments already approved (one in two weeks)
- Near future: 2nd phase GALILEO 30 GASP detectors + 10 triple cluster
- Far future: Coulex @LNL with SPES radioactive beams

THANK YOU FOR THE ATTENTION

A. N[1], M. Rocchini[1], N. Marchini[1,2], K. Hadyńska-Klęk[3],J. J. Valiente-Dobón[3], A. Goasduff[4,5], D. Testov[4,5], D. Mengoni[4,5], M. Zielińska[6], D. T. Doherty[8], D. Bazzacco[4,5], G. Benzoni[9], F. Camera[10] M. Chiari[1,2], M. Komorowska[6,9], M. Matejska-Minda[9],B. Melon[2], P. Napiorkowski[9], M. Ottanelli[2], A. Perego[1,2], L. Ramina[5],M. Rampazzo[5], F. Recchia[4,5], D. Rosso[3], M. Siciliano[3,4] and P. Sona[1]

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DOPPLER CORRECTION OF GAMMA SPECTRA