Marco Rocchini

Università degli Studi di Firenze and INFN Sezione di Firenze

Low-energy Coulomb excitation at LNL with the GALILEO-SPIDER setup: the first case, 66Zn

M. Rocchini[1,2], **K. Hadyńska-Klęk**[3], A. Nannini[2], J. J. Valiente-Dobón[3], A. Goasduff[4,5], D. Testov[4,5], P. R. John[4,5], D. Mengoni[4,5], M. Zielińska[6], D. Bazzacco[4,5], G. Benzoni[7], A. Boso[4,5], P. Cocconi[3], M. Chiari[1,2], D. T. Doherty[8], F. Galtarossa[3], G. Jaworski[3], M. Komorowska[6,9], M. Matejska-Minda[9], B. Melon[2], R. Menegazzo[4,5], P. Napiorkowski[9], D. R. Napoli[3], M. Ottanelli[2], A. Perego[1,2], L. Ramina[5], M. Rampazzo[5], F. Recchia[4,5], S. Riccetto[10,11], D. Rosso[3], M. Siciliano[3,4] and P. Sona[1]

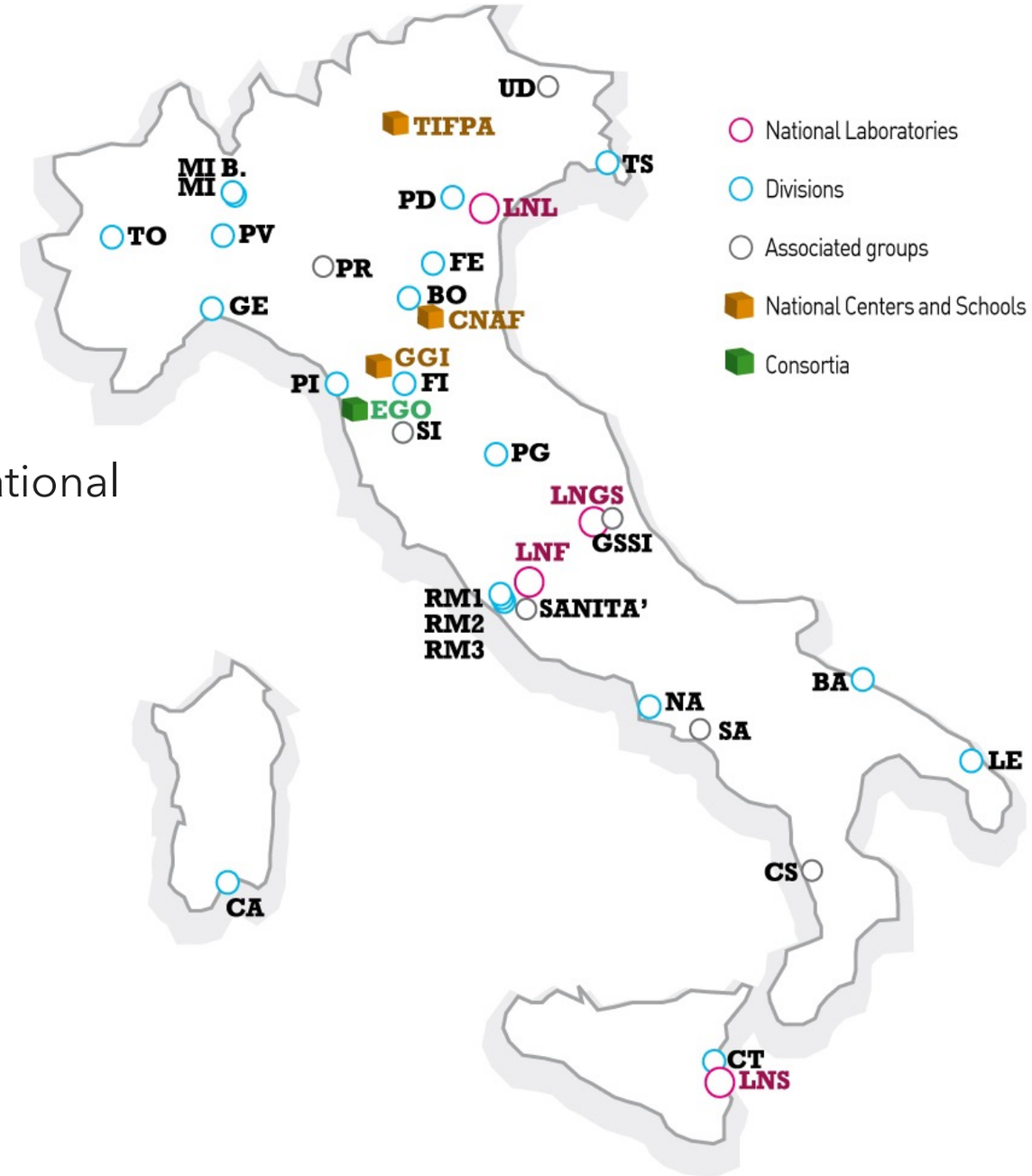
[1] Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Firenze, Italy, [2] INFN, Sezione di Firenze, Firenze, Italy, [3] INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy, [4] Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Padova, Italy, [5] INFN, Sezione di Padova, Padova, Italy, [6] CEA Saclay, IRFU/SPhN, France, [7] INFN, Sezione di Milano, Milano, Italy, [8] University of Surrey, Guildford, United Kingdom, [9] Heavy Ion Laboratory, University of Warsaw, Poland, [10] Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, Perugia, Italy, [11] INFN, Sezione di Perugia, Perugia, Italy

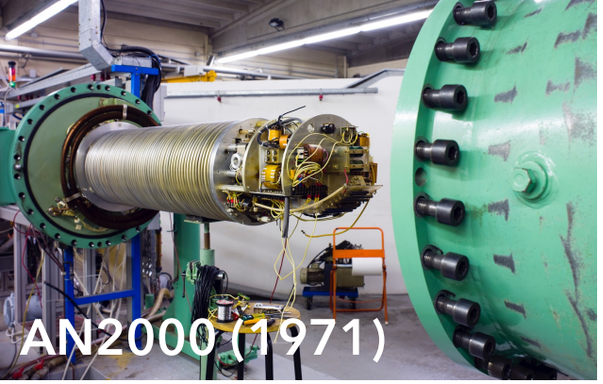
- INFN-LNL
- Coulex @LNL
- First Experiment: ^{66}Zn
- Results
- Second Experiment: ^{94}Zr
- Future Perspectives

Istitito Nazionale di Fisica Nucleare

National Institute for Nuclear Physics

- **4** National Laboratories
- **20** Divisions
- **6** Associated Groups
- **3** National Centers and Schools
- **1** Consortia (EGO, European Gravitational Observatory)
- **5** Lines of Research:
  - CSN1: Particle Physics
  - CSN2: Astroparticle Physics
  - **CSN3: Nuclear Physics**
  - CSN4: Theoretical Physics
  - CSN5: Technological Physics





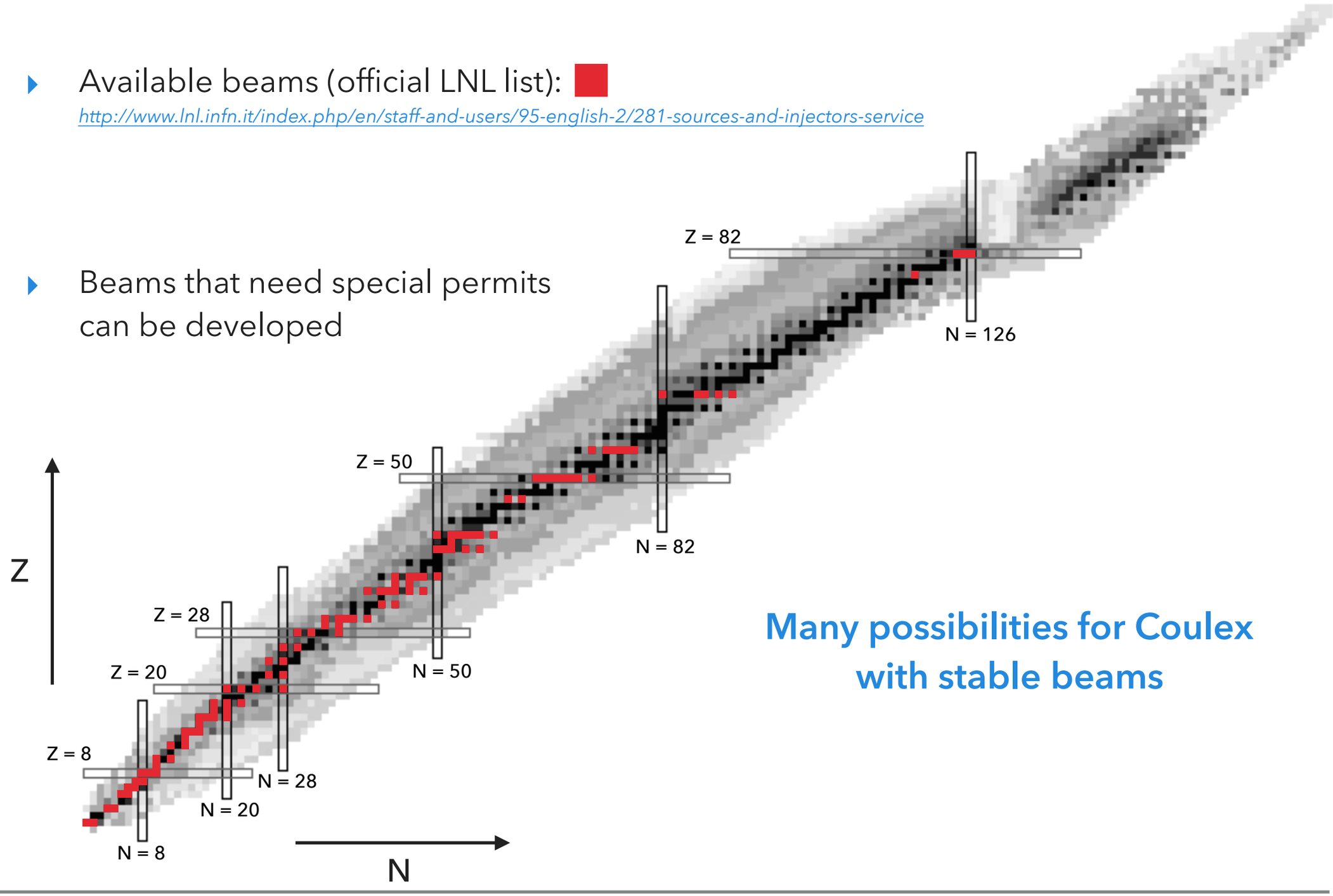
LNL Accelerators

INFN

3rd GOSIA Workshop – Marco Rocchini

Stable Beams @LNL

- Available beams (official LNL list): ■
  http://www.lnl.infn.it/index.php/en/staff-and-users/95-english-2/281-sources-and-injectors-service
- Beams that need special permits can be developed



Many possibilities for Coulex with stable beams

Radioactive Beams @LNL (2021)

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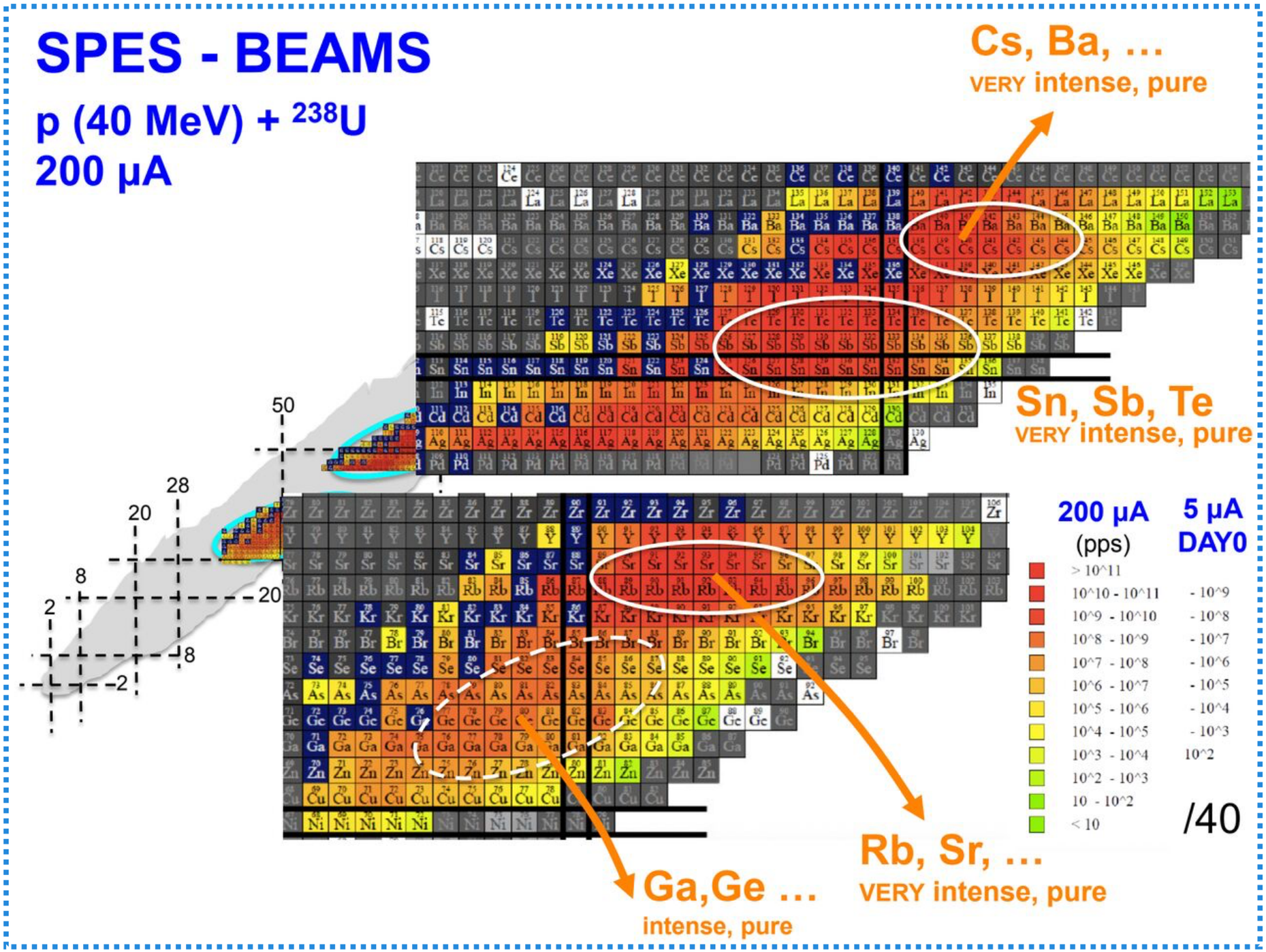
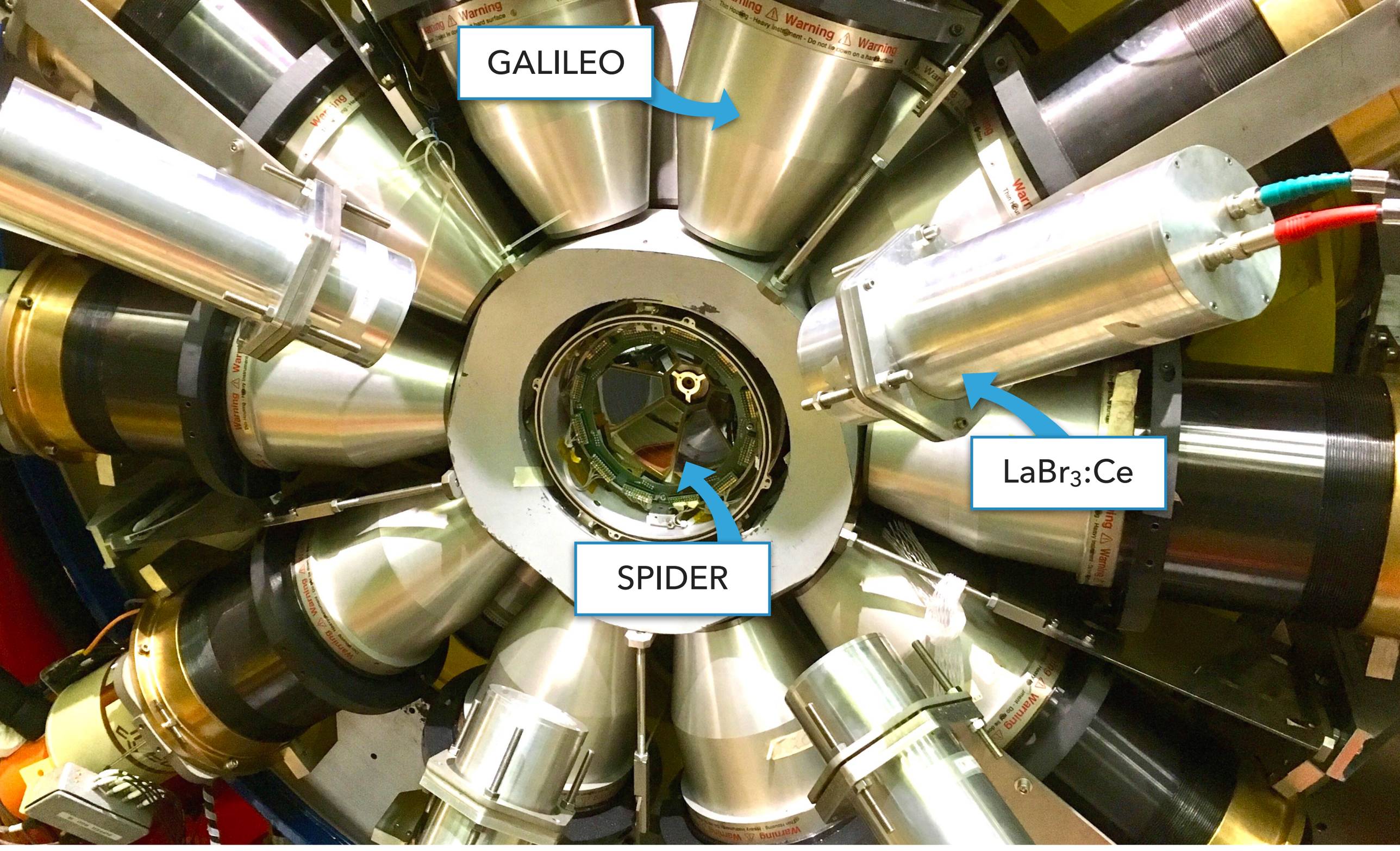




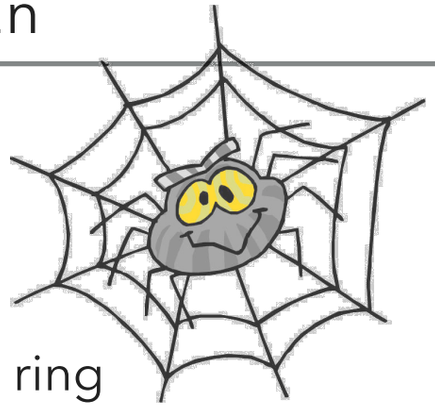
Coulomb Excitation @LNL

Coulex @LNL

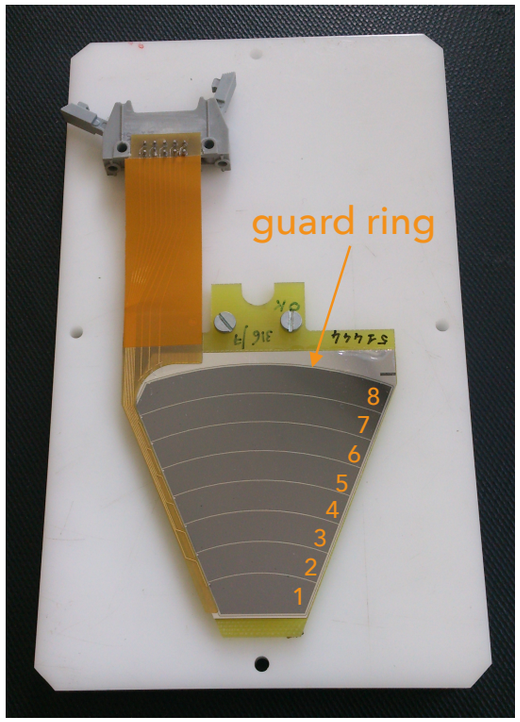
- 25 **HPGe** Compton-suppressed detectors (GASP type)
- **FWHM** (@1332.5 keV) < 2.4 keV
- **Efficiency** (@1332.5 keV) = 2.1%
- Complete **digital DAQ** (takes advantage of the developments made for AGATA):
  - Trigger-less mode
  - Typical operational rate ~ 20 kHz/det
  - Common clock synchronization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

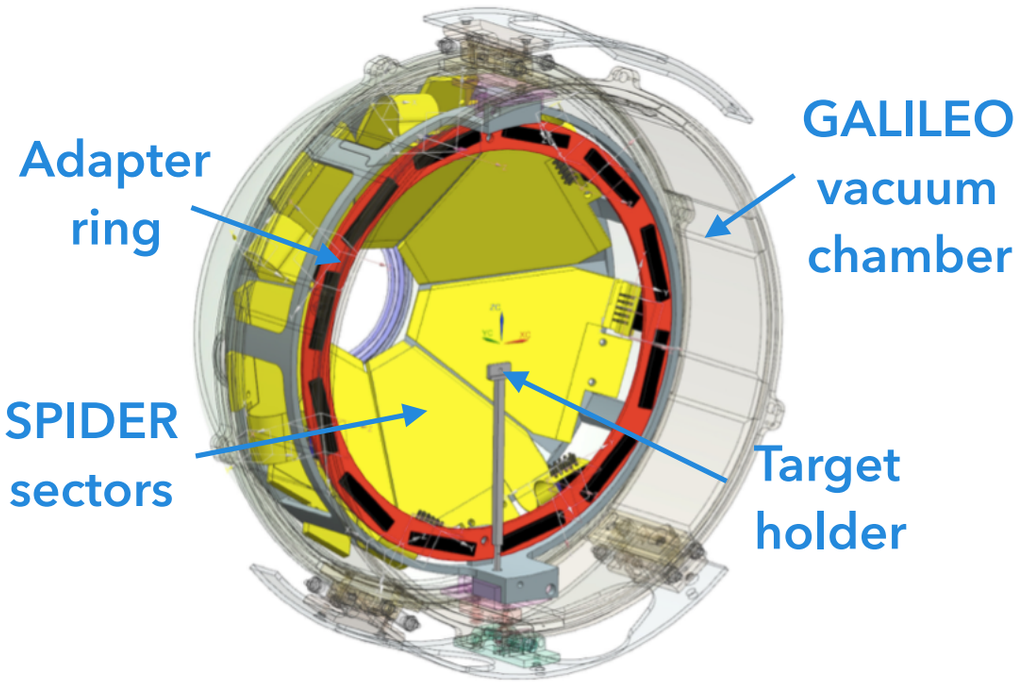
GALILEO 1st Phase (on going)

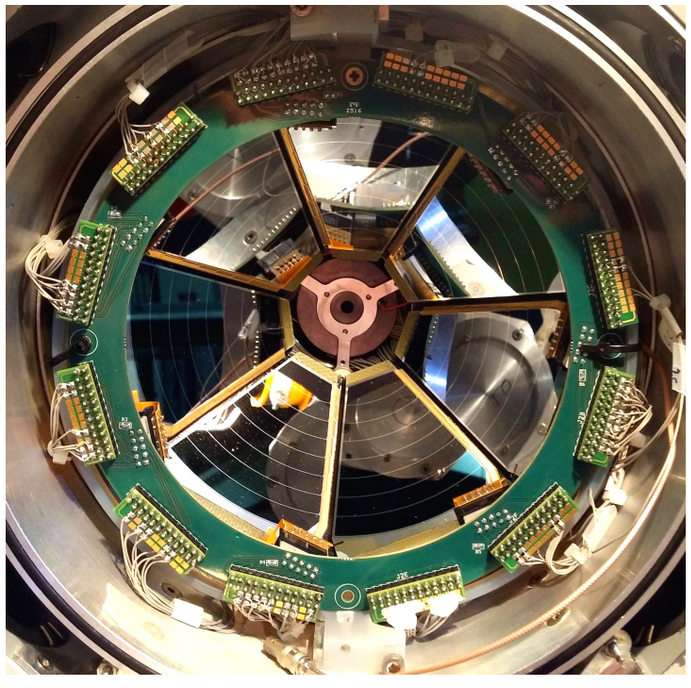
Silicon PIe DEtectoR



- Independent **sectors**, 8 **strips** + guard ring
- Detector **thickness** ~ 300 μm, dead layers ~ 50 nm in the junction (front) side and ~ 350 nm in the ohmic (rear) side
- **Cone configuration** (7 sectors) at **backward angles**: 8.5 cm from the target ⟹ ΔΘ = 37.4°, Ω/4π = 17.3%



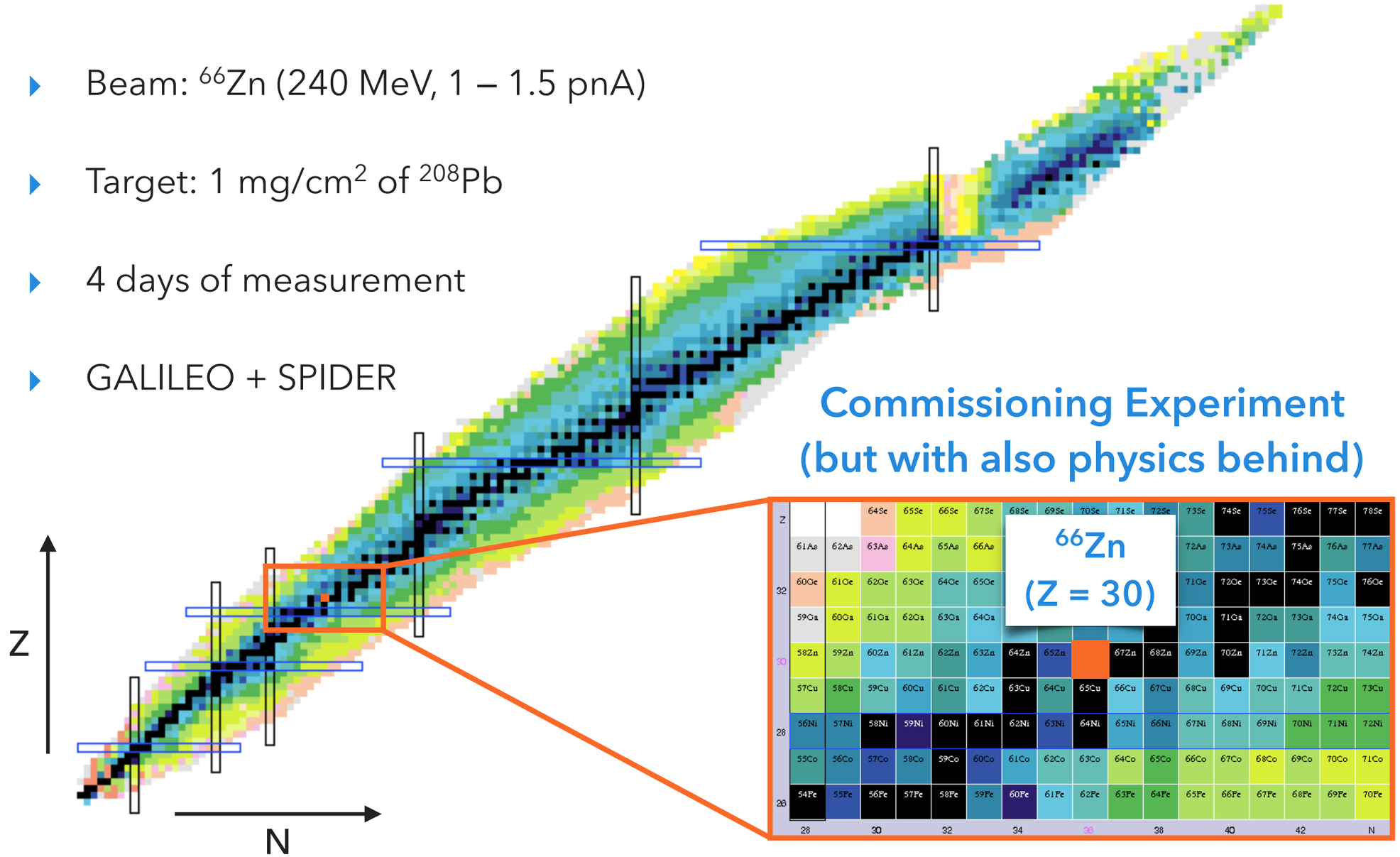




First Experiment: ^{66}Zn

Spokespersons: M. Rocchini, K. Hadynska-Klek

- Coulomb excitation of ^{66}Zn
  - Beam: ^{66}Zn (240 MeV, 1 – 1.5 pnA)
  - Target: 1 mg/cm^2 of ^{208}Pb
  - 4 days of measurement
  - GALILEO + SPIDER



Commissioning Experiment
(but with also physics behind)

Why ^{66}Zn?

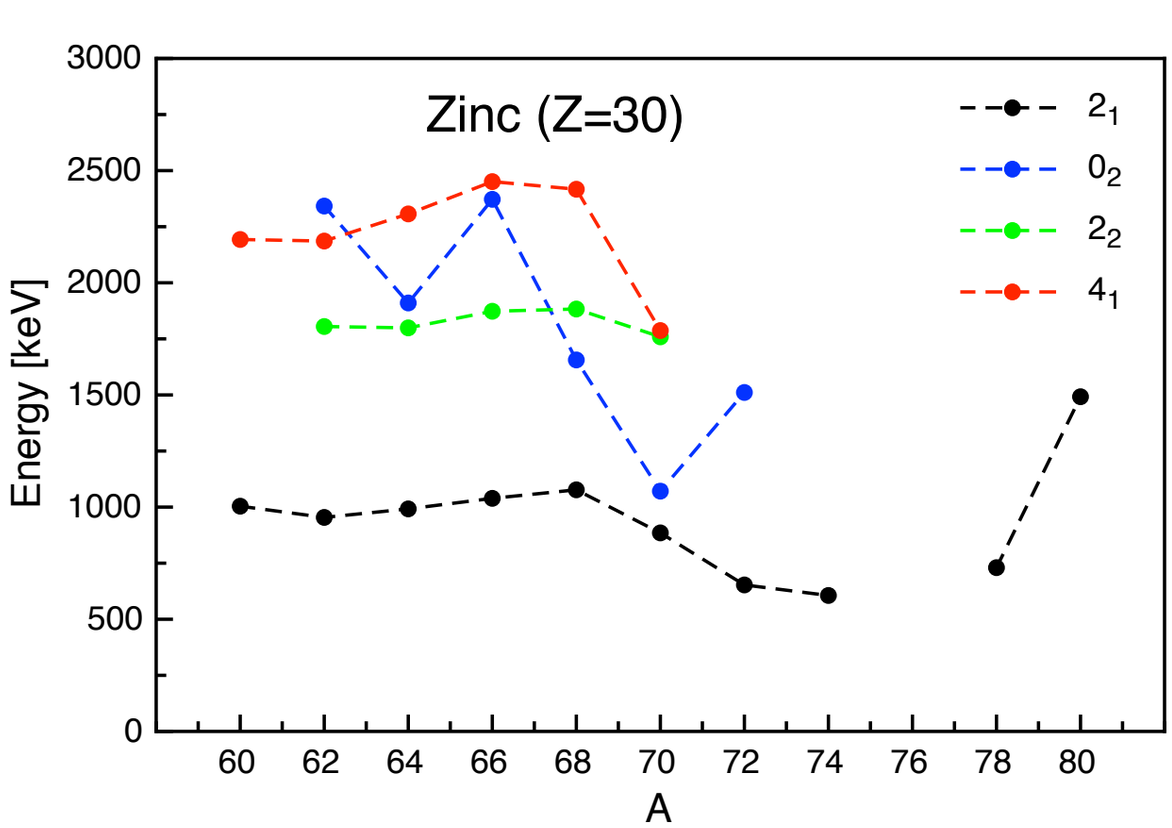
- **$B(E2; 2_1^+ \longrightarrow 0_1^+)$** and **$Q_s(2_1^+)$** known with high precision $\Longrightarrow$ **Commissioning**
- Low-lying structure of stable and nearly stable Zn isotopes:
  - Several interpretations (**vibrational** nuclei, **quasi-rotational** bands, **γ-soft** nuclei)
  - No firm conclusions, many **discrepant results** regarding key observables, the case of ^{66}Zn

	NDS	M. Koizumi *et al.*, 2003	K. Moschner *et al.*, 2010
$B(E2; 4_1^+ \longrightarrow 2_1^+)$ [W.u.]	18(3)	17.5(7)	8.4(15)
$B(E2; 2_2^+ \longrightarrow 2_1^+)$ [W.u.]	330(130)	41(14)	

M. Koizumi et al., Eur. Phys. J. A 18, 87 (2003) 87
K. Moschner et al., Phys. Rev. C 82, (2010) 014301

Why ^{66}Zn?

- **Shape coexistence** and **triaxiality** already observed in Ge and Se isotopes
- **0_2^+ state** in Zn isotopes:
  - B(E2) known only for the $0_2^+ \longrightarrow 2_1^+$ transition for A = 64, 68, 70
  - Energy vs mass $\Longrightarrow$ **Unusual trend**



Final γ-ray Spectrum

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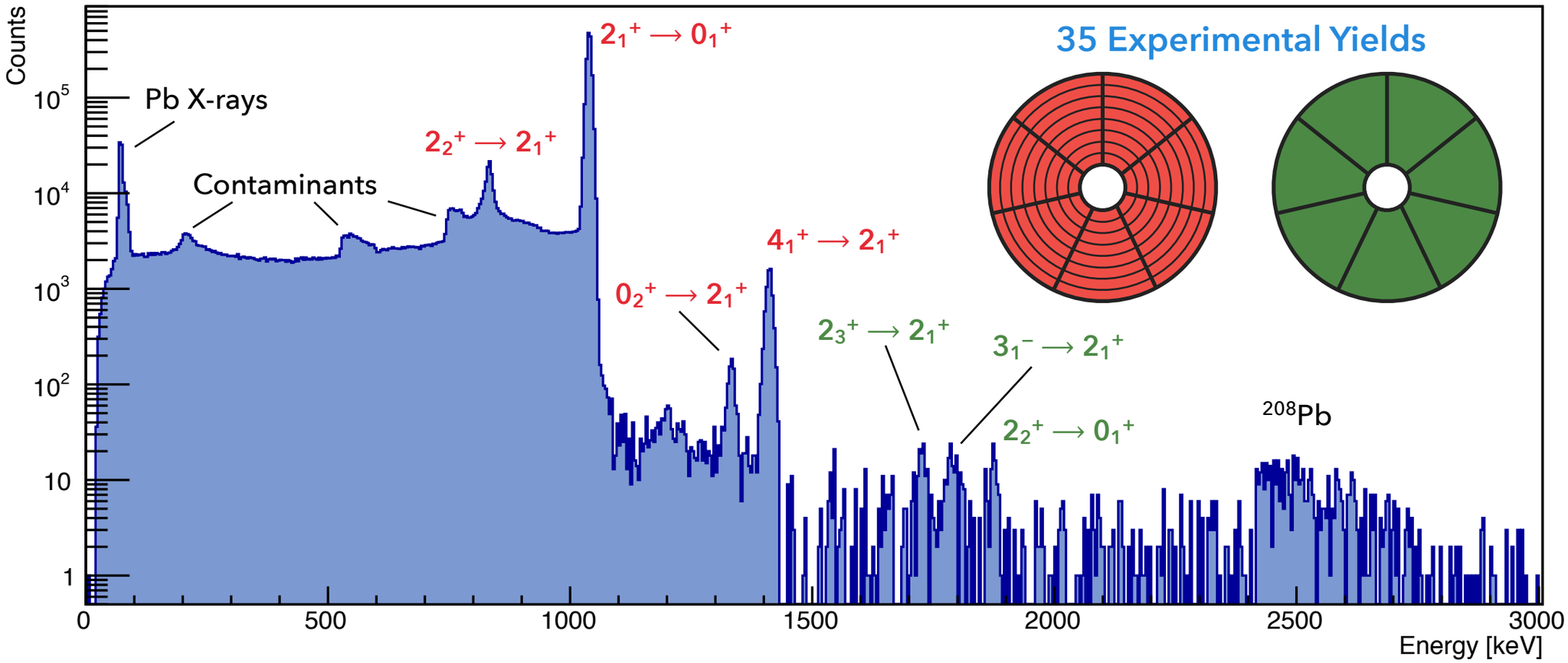
- Coincidences between GALILEO and SPIDER, **full statistics**



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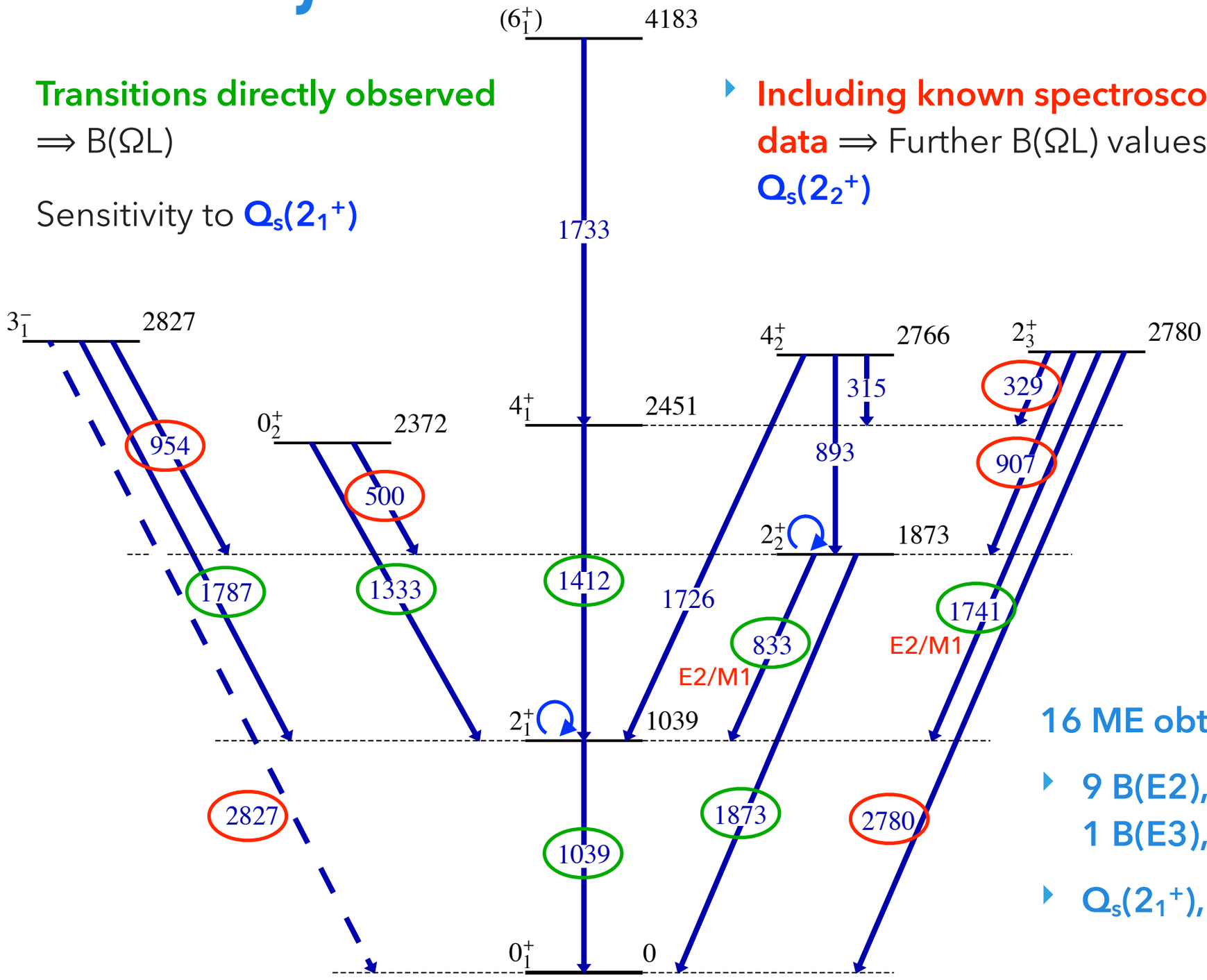
GOSIA Analysis

- **Transitions directly observed** ⟹ B(ΩL)
- Sensitivity to **$Q_s(2_1^+)$**



- **Including known spectroscopic data** ⟹ Further B(ΩL) values, **$Q_s(2_2^+)$**

16 ME obtained:

- **9 B(E2), 2 B(E1), 1 B(E3), 2 B(M1)**
- **$Q_s(2_1^+)$, $Q_s(2_2^+)$**

Results

- Data already available in the literature confirmed, sufficient precision to distinguish between discrepant values achieved
- First measurement of B(E2) values from 0_2^+: B(E2; $0_2^+ \longrightarrow 2_1^+$), B(E2; $0_2^+ \longrightarrow 2_2^+$)
- First measurement of B(E3; $3_1^- \longrightarrow 0_1^+$) in ^{66}Zn using Coulomb excitation

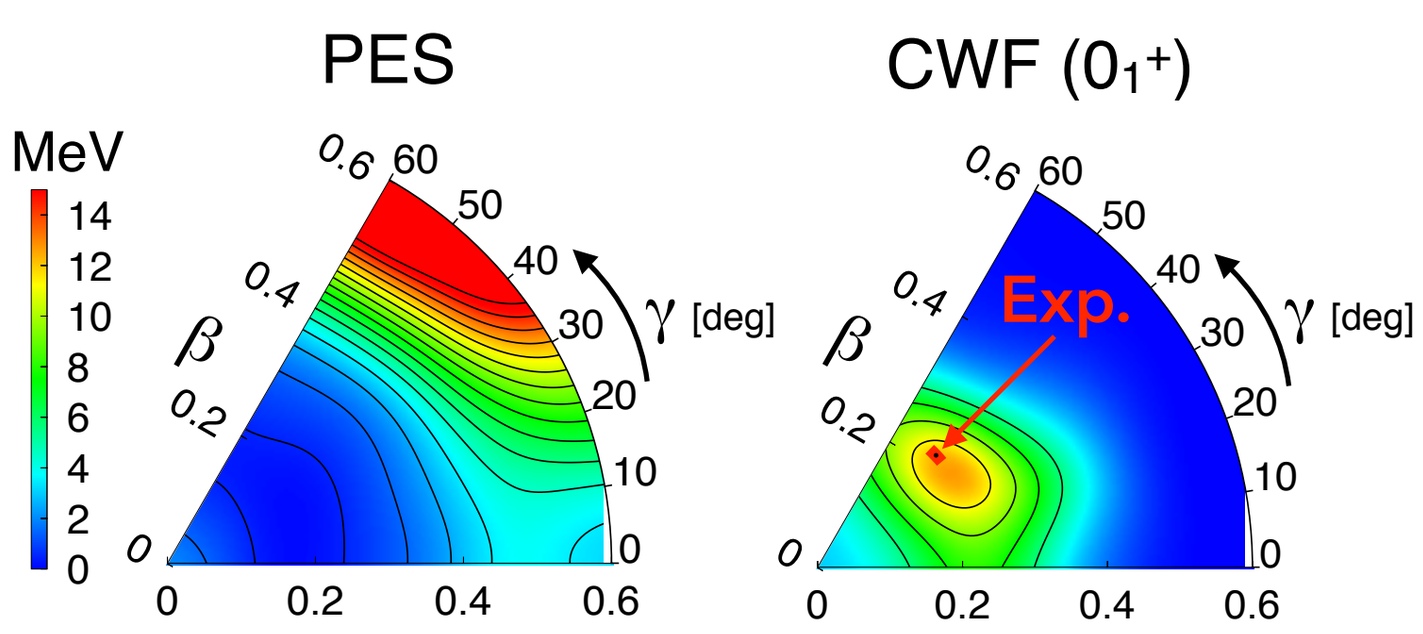
Deformation of 0^+ states (preliminary)

- **Quadrupole sum rule**

Error estimation still on going

  - 0_1^+: $\langle\beta\rangle = 0.225(8)$, $\langle\gamma\rangle = 43°(3°)$
  - 0_2^+: $\langle\beta\rangle = 0.055(5)$

- Comparison with **BMF calculations** (*T. Rodriguez, private communication*)



- **Shell Model calculations** in different model spaces and using different interactions under progress (*H. Naidja, F. Nowacki and A. Gargano*)

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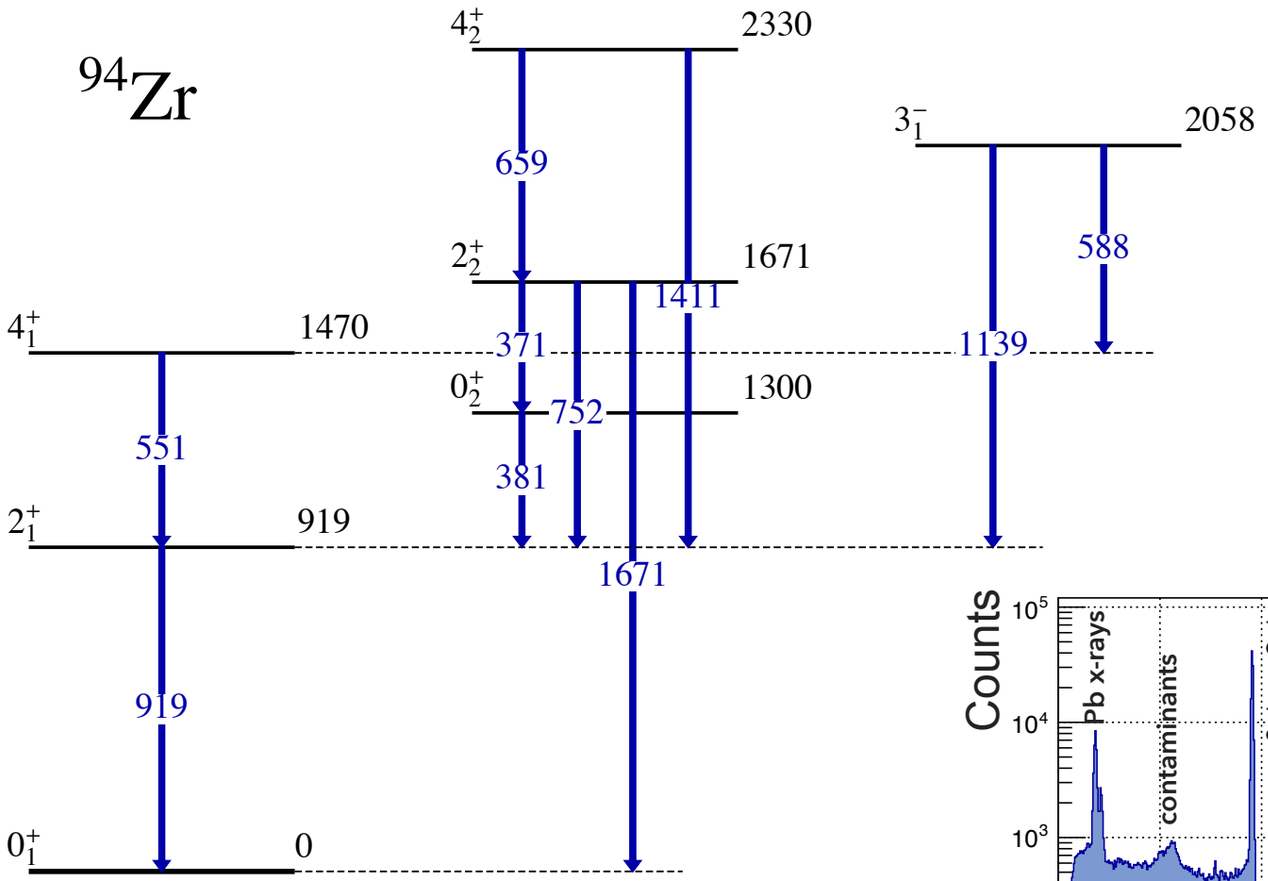
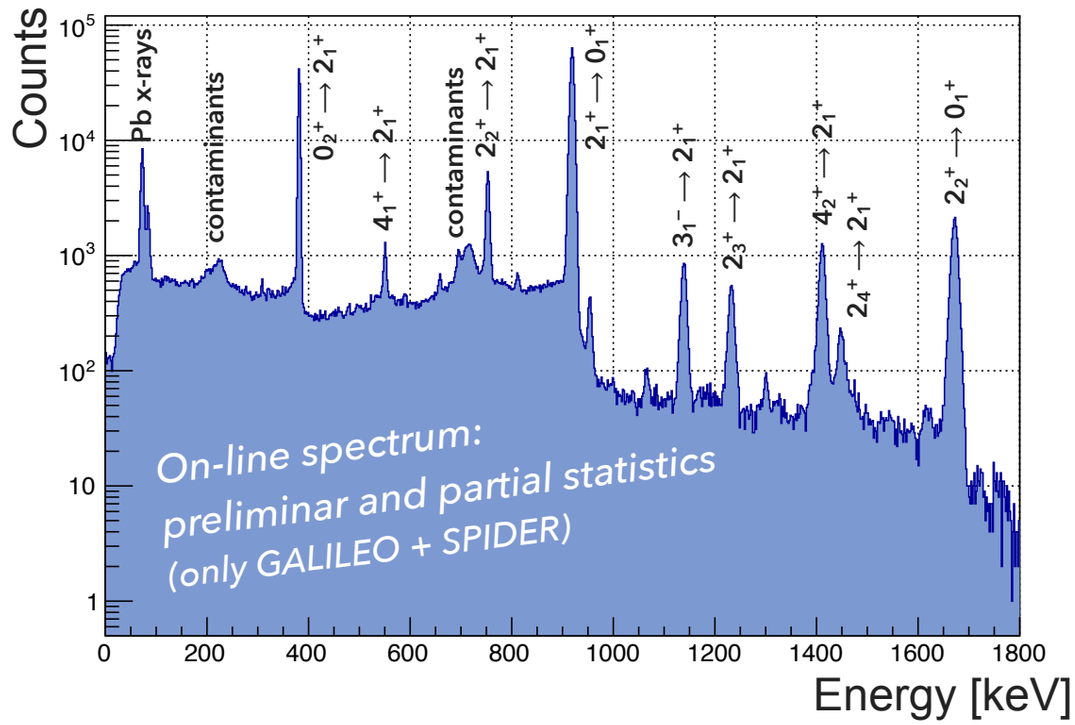
Second Experiment: ^{94}Zr

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



Main goal: deformation of 2_1^+, 2_2^+, 0_1^+, 0_2^+

- *"Probing collectivity and configuration coexistence in ^{94}Zr with low-energy Coulomb excitation"*
- $LaBr_3$:Ce used for the first time in Coulex @LNL



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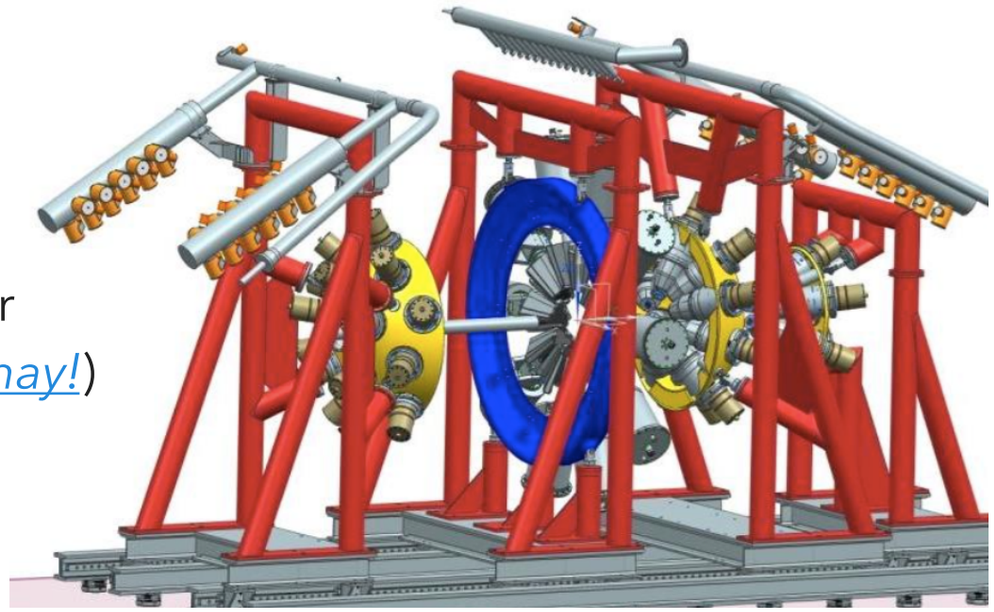
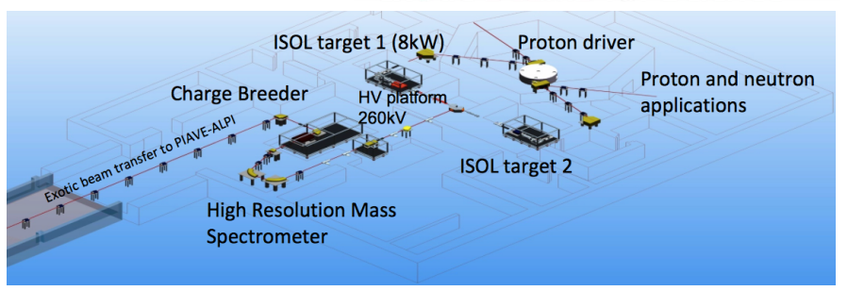
Future of Coulex @LNL



- Near future (**next months**):
  - **Next PAC**: about 4 – 5 new projects under discussion (*submission deadline: end of may!*)
- Middle future (**1 – 3 years**):
  - **GALILEO 2nd phase**: 30 GASP detectors + 10 triple cluster
  - Coupling with **forward particle detector**, **plunger**, **LaBr$_3$:Ce**, **electron conversion detector**
- "Far" future (**3 – 5 years**):
  - **SPES** (7 LoI presented)
  - **AGATA** @SPES



To Take Home

- Coulex @LNL with stable beams on-going, in strong collaboration with experts in this field

- Next LNL proposals submission ⟹ **End of May!**

- Coulex @LNL with radioactive beams in 3 years (from 2021)

THANK YOU FOR THE ATTENTION

M. Rocchini[1,2], **K. Hadyńska-Klęk**[3], A. Nannini[2], J. J. Valiente-Dobón[3], A. Goasduff[4,5], D. Testov[4,5], P. R. John[4,5], D. Mengoni[4,5], M. Zielińska[6], D. Bazzacco[4,5], G. Benzoni[7], A. Boso[4,5], P. Cocconi[3], M. Chiari[1,2], D. T. Doherty[8], F. Galtarossa[3], G. Jaworski[3], M. Komorowska[6,9], M. Matejska-Minda[9], B. Melon[2], R. Menegazzo[4,5], P. Napiorkowski[9], D. R. Napoli[3], M. Ottanelli[2], A. Perego[1,2], L. Ramina[5], M. Rampazzo[5], F. Recchia[4,5], S. Riccetto[10,11], D. Rosso[3], M. Siciliano[3,4] and P. Sona[1]

[1] Dipartimento di Fisica e Astronomia, Università degli Studi di Firenze, Firenze, Italy, [2] INFN, Sezione di Firenze, Firenze, Italy, [3] INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy, [4] Dipartimento di Fisica e Astronomia, Università degli Studi di Padova, Padova, Italy, [5] INFN, Sezione di Padova, Padova, Italy, [6] CEA Saclay, IRFU/SPhN, France, [7] INFN, Sezione di Milano, Milano, Italy, [8] University of Surrey, Guildford, United Kingdom, [9] Heavy Ion Laboratory, University of Warsaw, Poland, [10] Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, Perugia, Italy, [11] INFN, Sezione di Perugia, Perugia, Italy