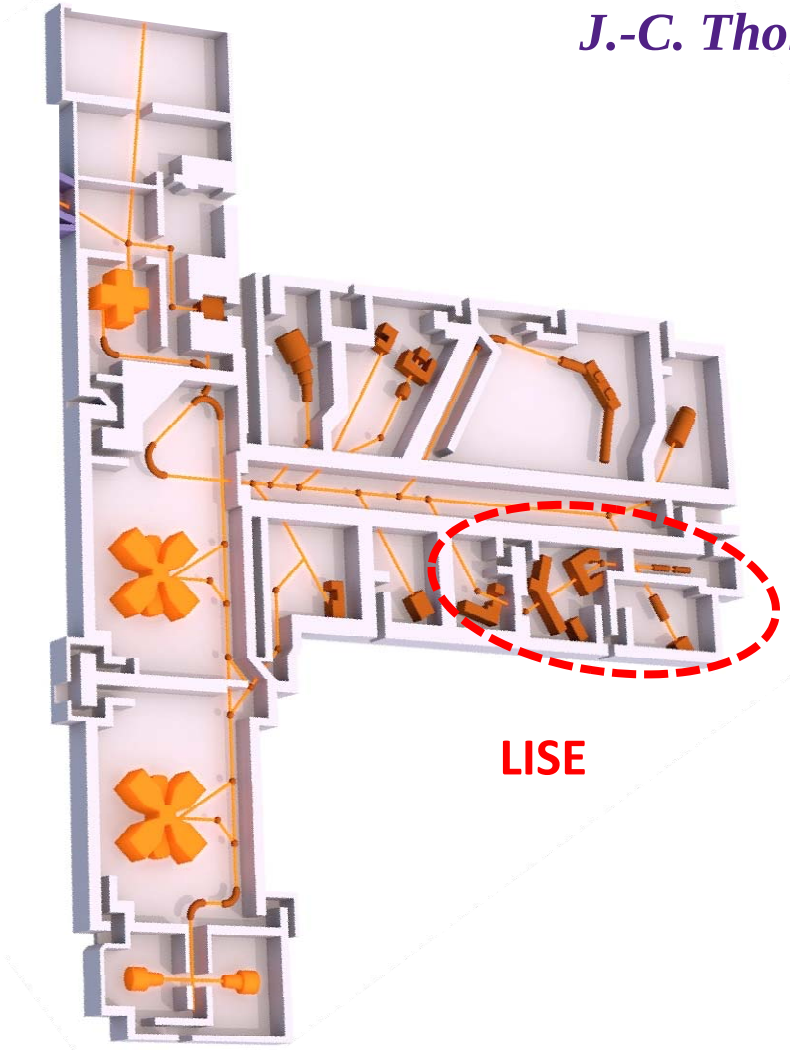
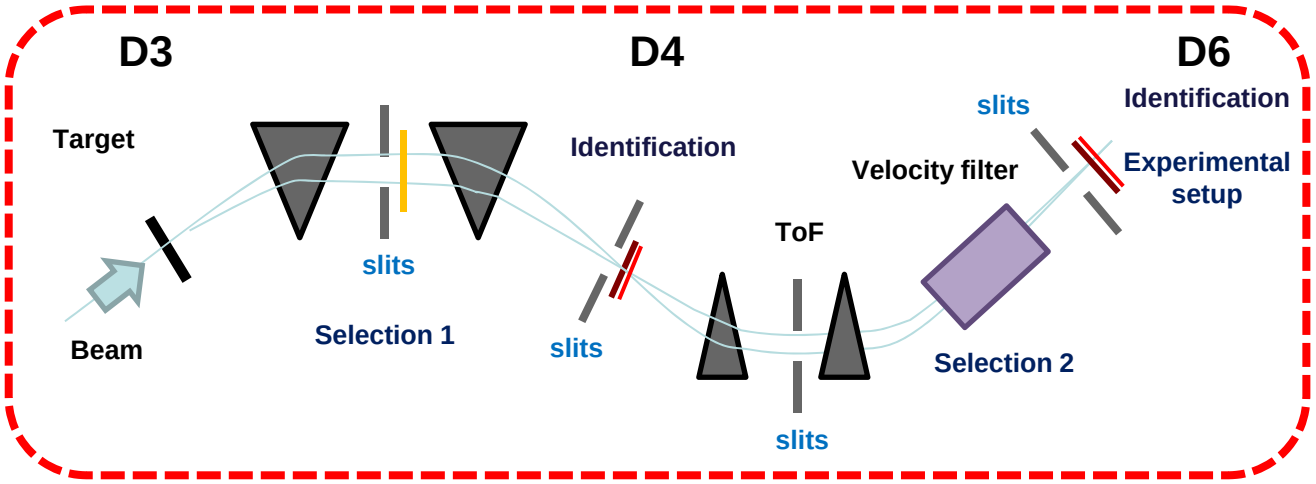
The LISE spectrometer at GANIL
present and near future

J.-C. Thomas, for the LISE collaboration



- **LISE operation 2011-2017**
  - Overview
  - Recent experiments (2016-2017)
- **LISE future**
  - Organization
  - Roadmap

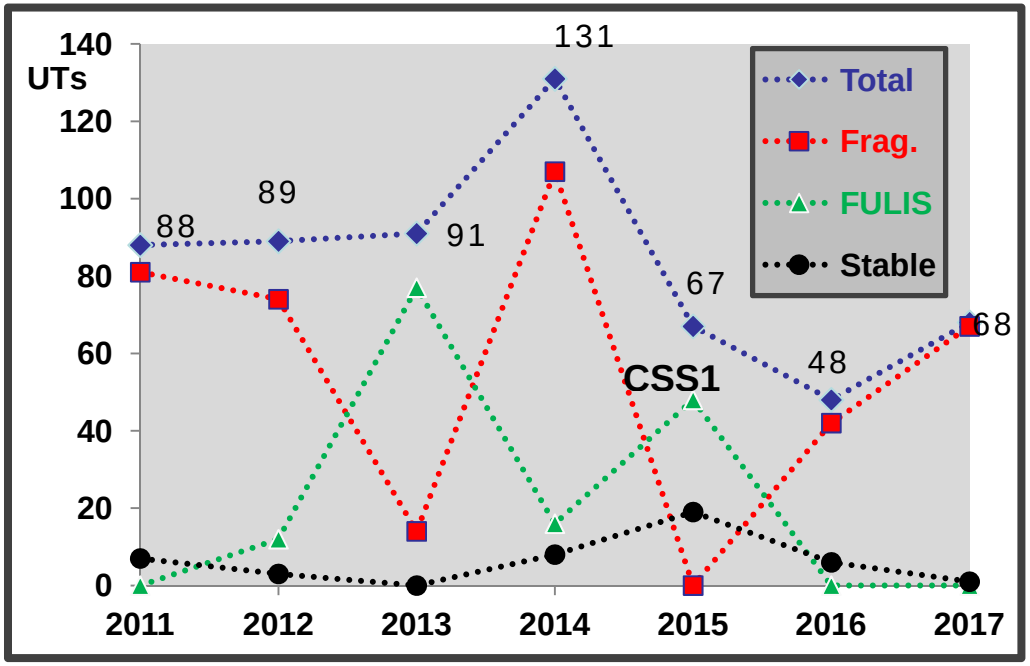
The GANIL/LISE spectrometer

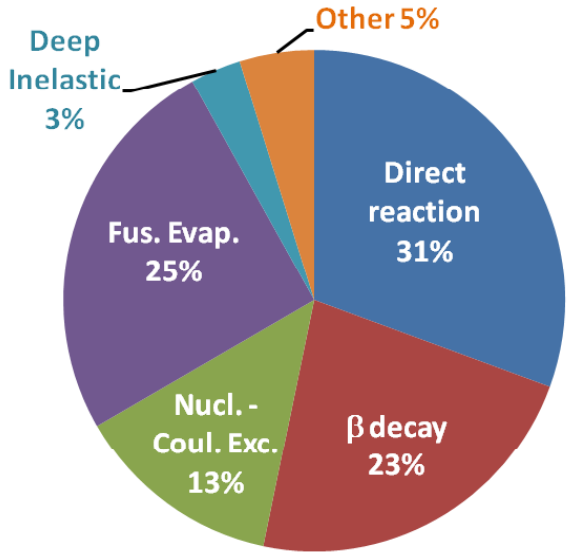


- **Beams**
  - ✓ Stable (CSS1+CSS2): ~5 to 95 MeV/u
    - -> Projectile fragmentation (15 to 50 MeV/u); polarized
    - -> Fusion-evaporation reaction (FULIS mode)
  - ✓ (New) SPIRAL1 beam; purification
- **Selection** B_ρ + degrader + B_ρ + Velocity filter
- **Identification** ΔE, ToF + tracking
- **Experimental areas** D4, D6 + LISE2000

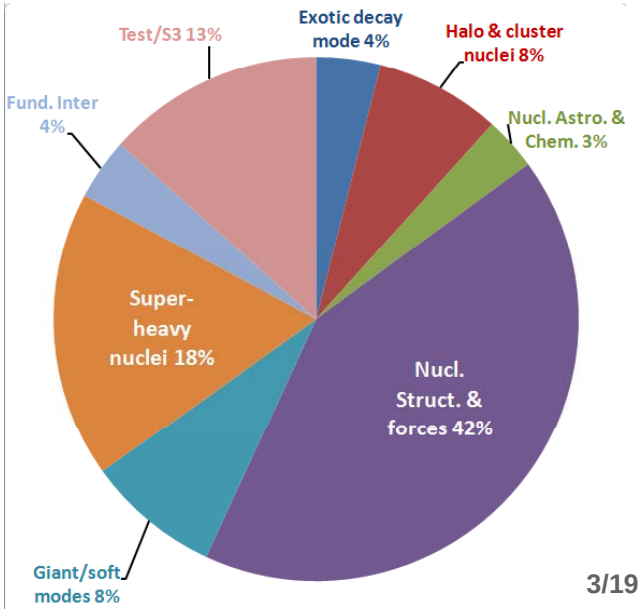
LISE operation 2011-2017

- 576 UT (20 exp + 14 tests (14%))
  - ✓ Fragmentation : 66%
  - ✓ Fusion-evaporation : 26%
  - ✓ Stable beams: 8%
- Tests
  - ✓ LISE (detection)
  - ✓ Beam Prod S^3 / Astrophysics
  - ✓ S^3 (targets)
- Experimental technique



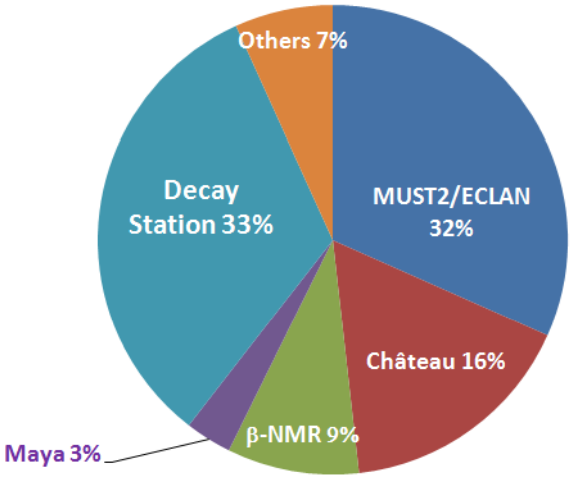


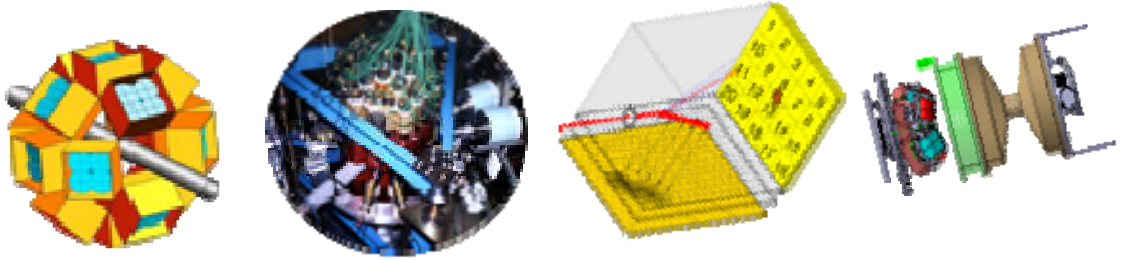
- Scientific cases
  - ✓ 68 % = Nucl. Struc.
  - ✓ 21 % = S^3 related



LISE operation 2011-2017

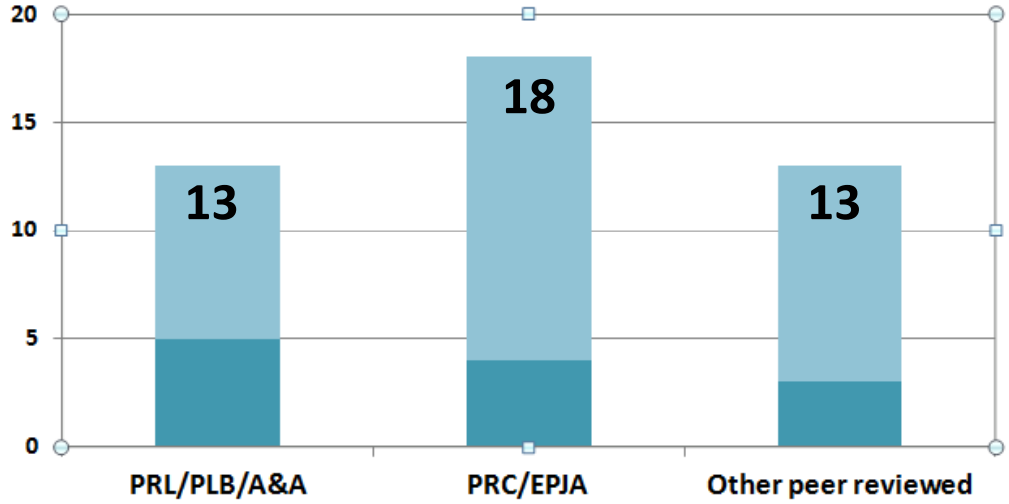
- Experimental setups





- EXOGAM -> *EXOGAM2*
- Château de cristal -> *PARIS*
- MUST2/TiaRa -> *GASPARD*
- MAYA -> *ACTAR TPC*
- Decay (tape) station, β-N(Q)R, …

- Publication record



Average time: Δt(Pub. - Exp.)
- ✓ Letters = 3 years
- ✓ PRC/EPJA = 5 years

LISE experiments 2016-2017

β-decay (stopped beams)

- **Nuclear structure and deformation at N=20**
  -> $^{34}Al^{m}$ g-factor and quadrupole moment, *E650 – G. Neyens et al., IKS Leuven*

  Talk by H. Heylen
- **Weak interaction**
  -> 0+ -> 0+ super-allowed β decay of ^{30}S, *E691, B. Blank et al., CENBG*

  Talk by B. Blank
- **Isospin mixing in the fp shell**
  -> BR_p/BR_γ in the decay of n-deficient nuclei, *E666 – B. Blank et al., CENBG*

Reaction (2nd RIB)

- **Nucleon-nucleon forces at the drip-line**
  -> $^{10,12}Be(d,^{3}He)\ ^{10,12}Li$, *E748 - A. Matta et al., LPC Caen*
- **Clusters**
  -> $^{10,11,12}Be + {}^{4}He \rightarrow {}^{14,15,16}C^{*}$, *E692 – C. Wheldon et al., Univ. Birmingham*

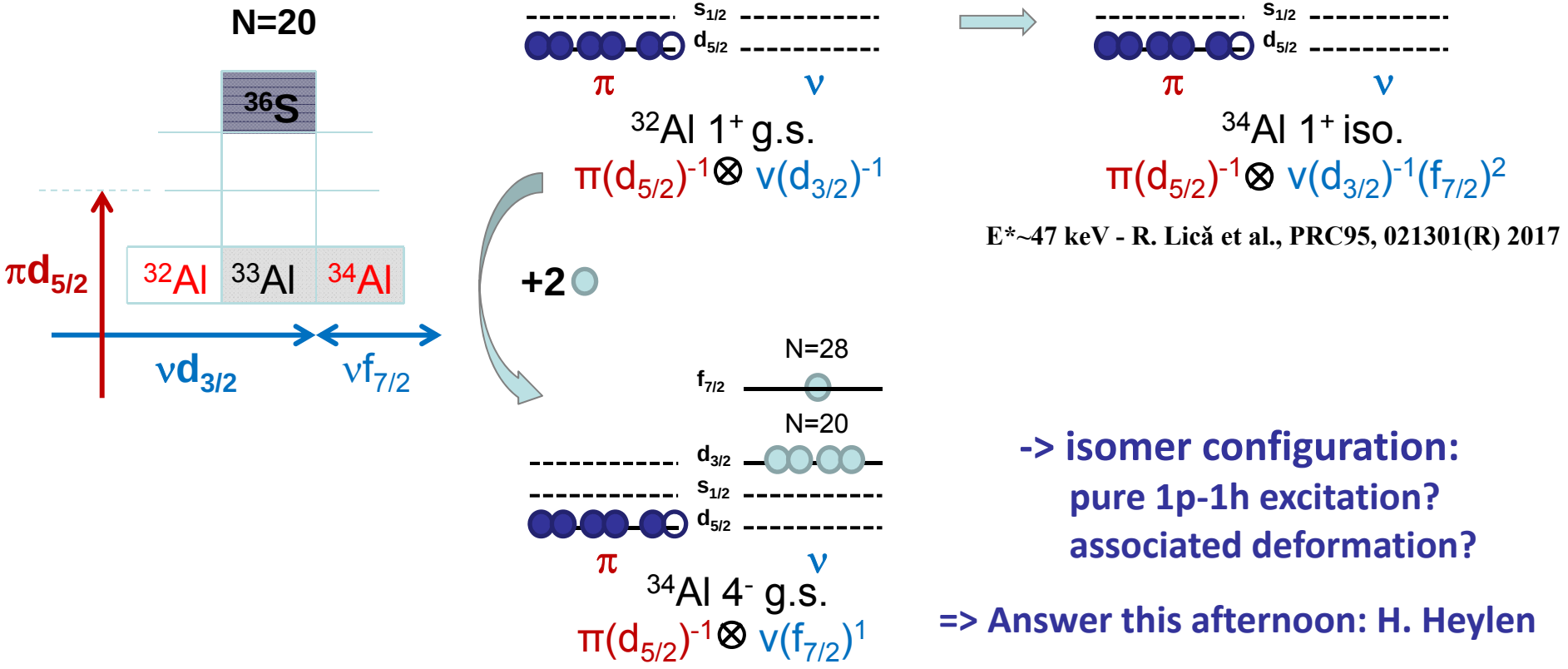
Run3 - 2017

LISE experiments 2016-2017

E650 - G. Neyens, H. Heylen, Z. Xu et al.

Nuclear structure and deformation at N=20 (island of inversion)

-> g-factor and quadrupole moment of ^{32}Al and ^{34}Al^{m}



-> isomer configuration:

pure 1p-1h excitation?

associated deformation?

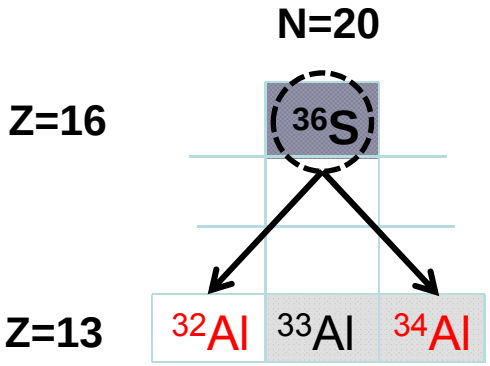
=> Answer this afternoon: H. Heylen

LISE experiments 2016-2017

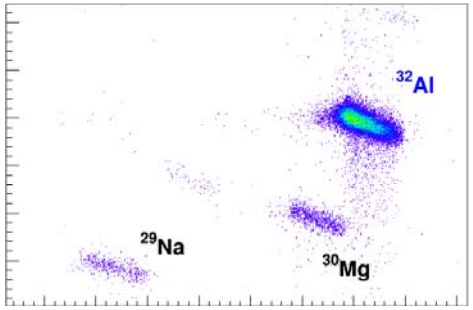
E650: Nuclear structure and deformation at N=20 (island of inversion)
-> g-factor and quadrupole moment of ^{32}Al and ^{34}Al^{m}

Production
^{36}S@77.5 MeV/u, 1.4 10^{12} pps

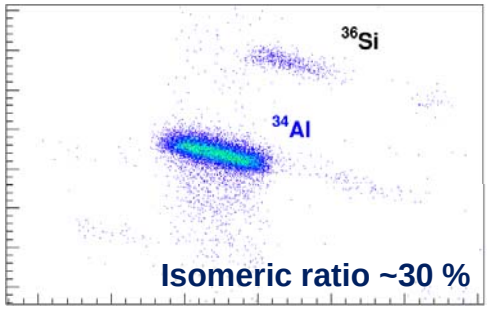
frag./pick-up
+ spin polarization



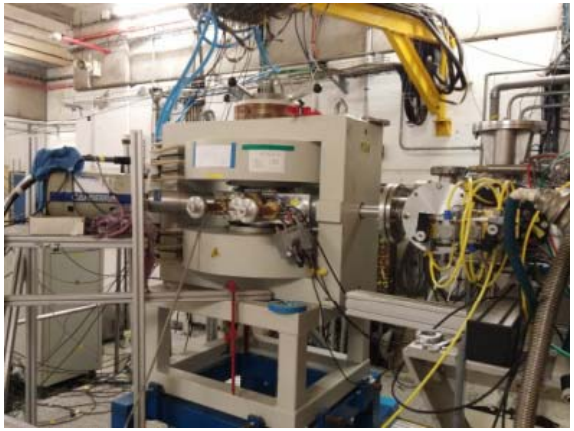
^{32}Al
~15000 pps, 90 % purity



$^{34(m)}$Al
~600 pps, 90 % purity



Measurement: β-NMR and β-NQR



LISE experiments 2016-2017

E691 – B. Blank, J. Giovinazzo, J.-C. Thomas et al.

Weak interaction study

-> 0+ -> 0+ super-allowed β decay of The T_z = -1 nucleus ^{30}S

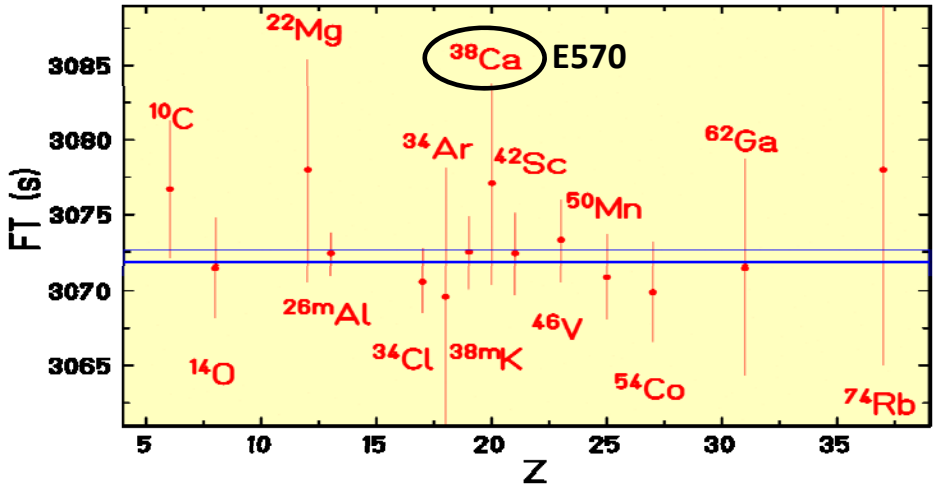
CVC hypothesis

$$Ft = ft\,(1 + \delta_R')\,(1 - \delta_c + \delta_{NS}) = \frac{K}{g_V^2\,(1 + \Delta_R)\,\langle M_F \rangle^2} = Cst$$

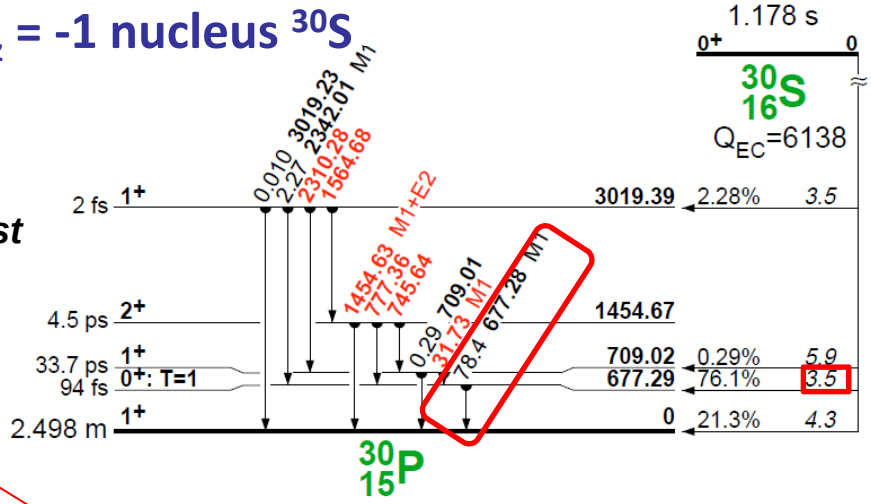
Isospin symetry breaking correction

$V_{ud} = g_V/g_\mu$ -> ***CKM matrix unitarity test***

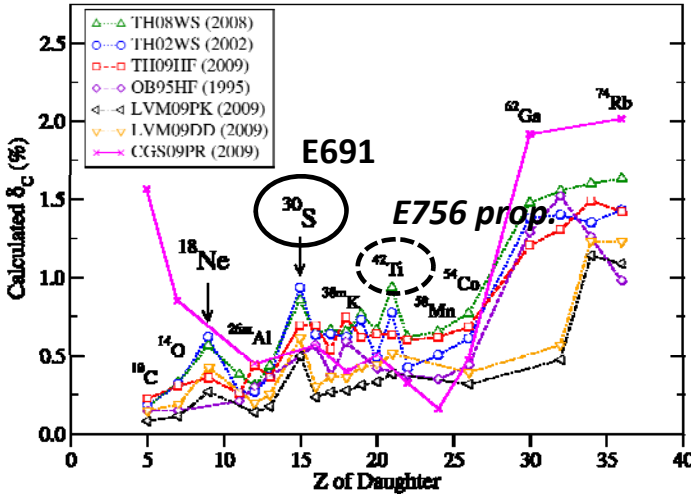
(V_{ud} = 0.97417 ± 0.00021, Σ V_{ux} = 0.99978 ± 0.00055)



B. Blank et al., EPJA 51 (2015) 8: ^{38}Ca $T_{1/2}$ & BR (0.5% precision)



G. F. Grinyer et al., NIM A 622, 236 (2010)



LISE experiments 2016-2017

E691: 0+ -> 0+ super-allowed β decay of The T_z = -1 nucleus ^{30}S

Aim: $\Delta T_{1/2}/T_{1/2}$ ~0.1 % *(0.14 % today)*

$\Delta BR/BR$ ~0.2% *(1.3% today)*

Production

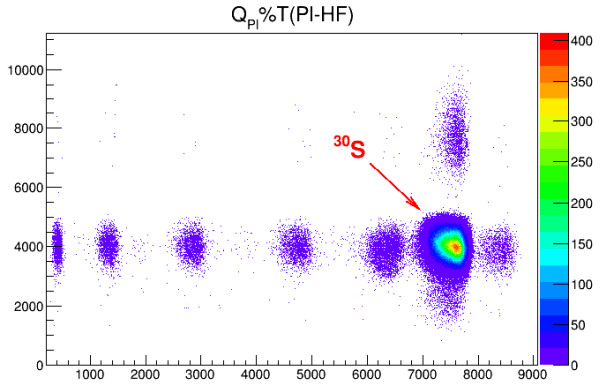
^{32}S@50 MeV/u, 10^{12} pps

fragmentation

^{30}S

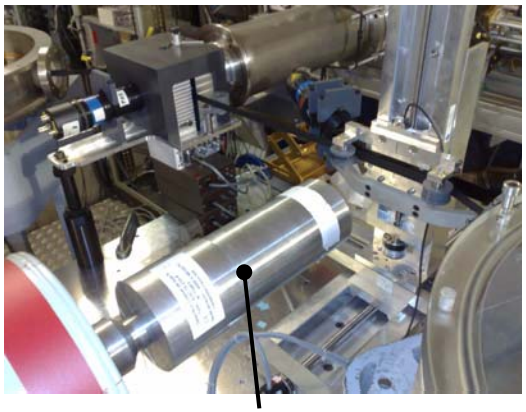
~few 10^4 pps, typically 97% purity

NB: beam pipe cooling

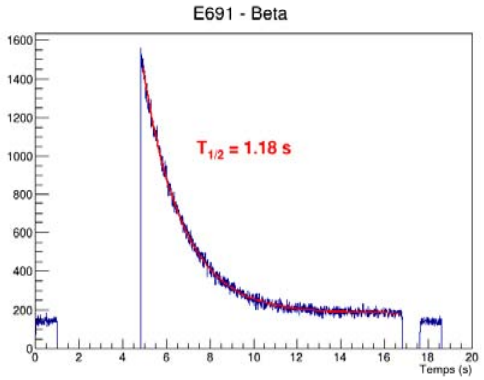


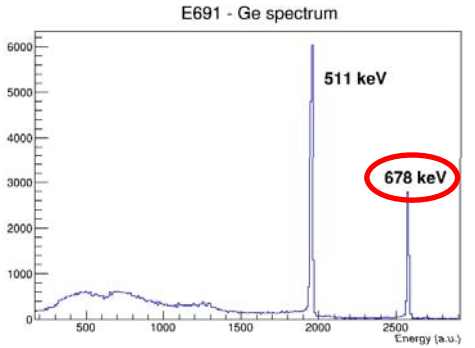
Measurement: β-γ coïncidences, tape station

High precision HPGe



B. Blank et al., NIM A 776, 34 (2014)





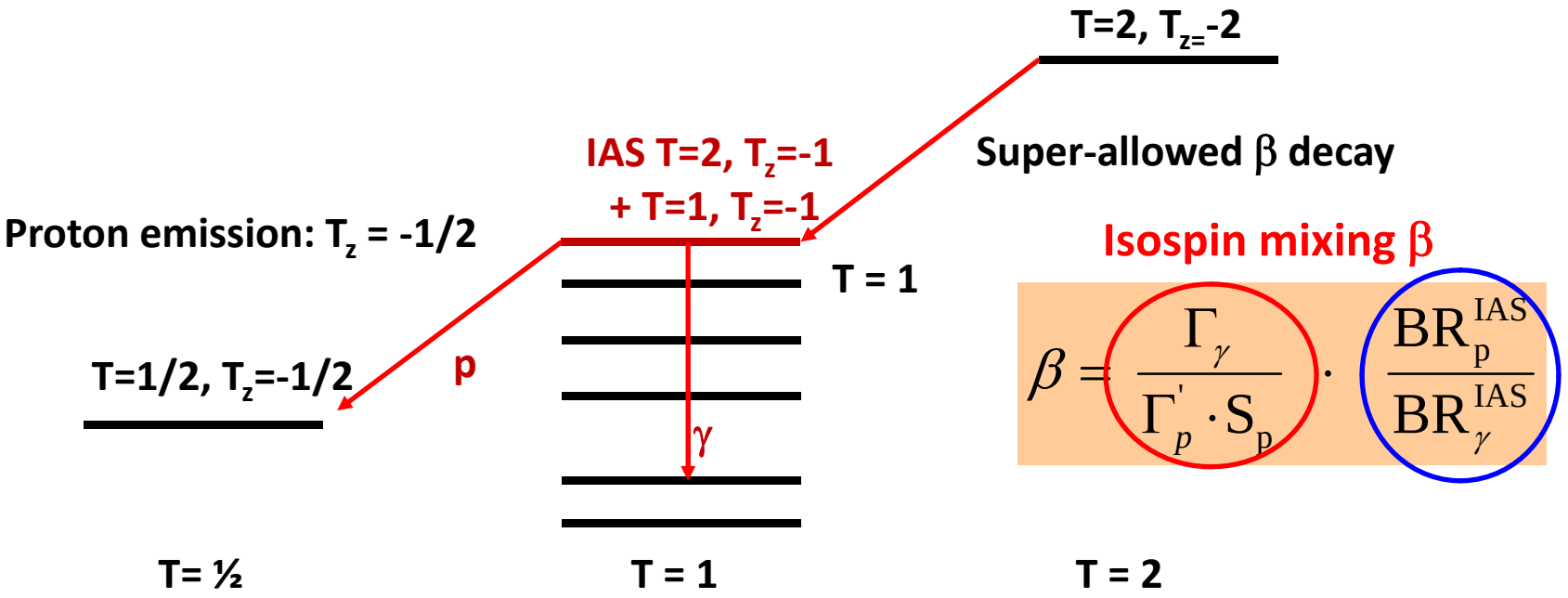
Issue: remaining statistics after cleaning (Wien filter)?

LISE experiments 2016-2017

E666 – B. Blank , J. Giovinazzo, P. Ascher, A. M. Sánchez Benítez et al.

Isospin mixing in the fp shell (T_z=-2 case)

-> BR_p/BR_γ in the decay of IAStates



Isospin mixing β

$$\beta = \frac{\Gamma_\gamma}{\Gamma_p' \cdot S_p} \cdot \frac{BR_p^{IAS}}{BR_\gamma^{IAS}}$$

Theoretical framework: N.A. Smirnova et al., PRC 95, 054301

-> β ~1 % in the case of ^{44}Cr, ^{48}Fe – Precise spectroscopic data needed

LISE experiments 2016-2017

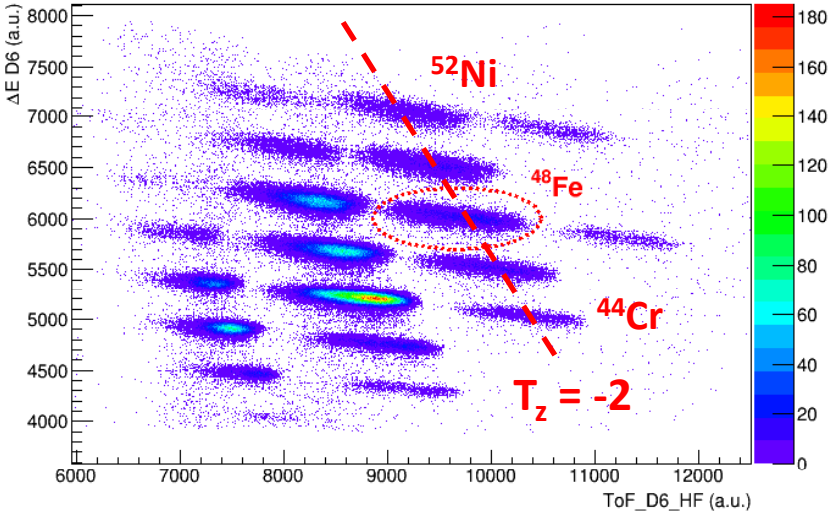
E666: Isospin mixing from BR_p/BR_γ in the decay of T_z=-2 nuclei

Production

^{58}Ni@75 MeV/u, 7 10^{11} pps

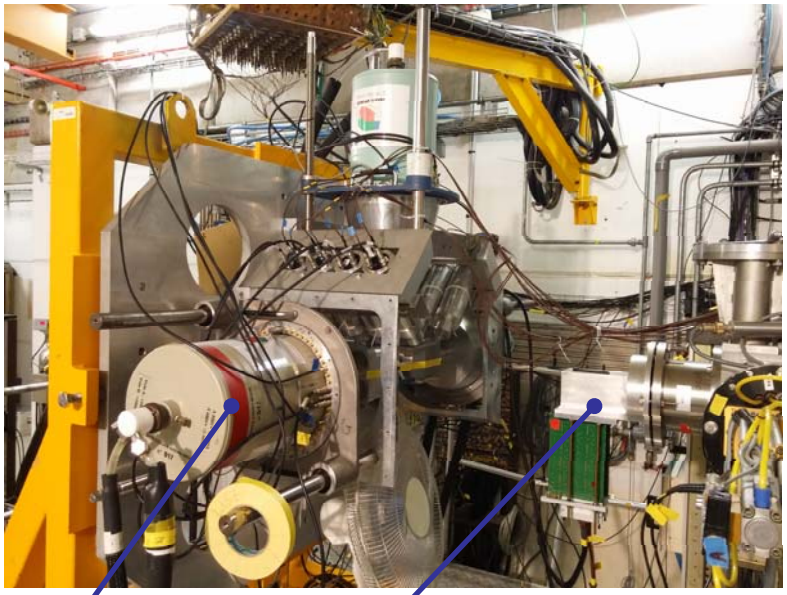
fragmentation

^{48}Fe ~ 3 pps



Measurement

Impl.-βpγ spatial and time correlations

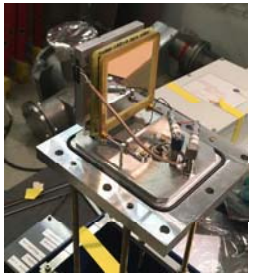


✓ EXOGAM clovers

✓ ΔE-E-Veto telescope

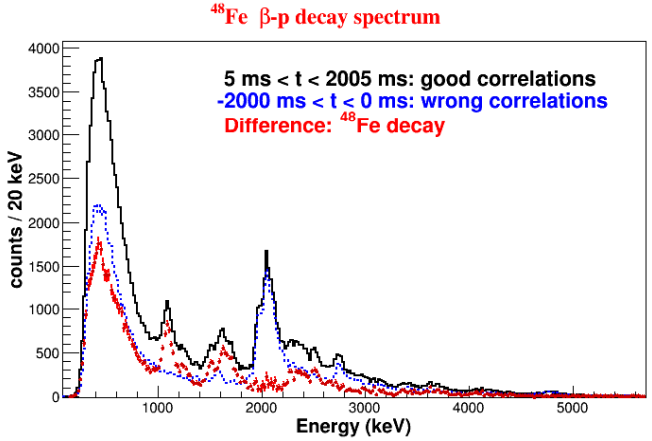
↳ DSSSD2*16*3 mm: XY

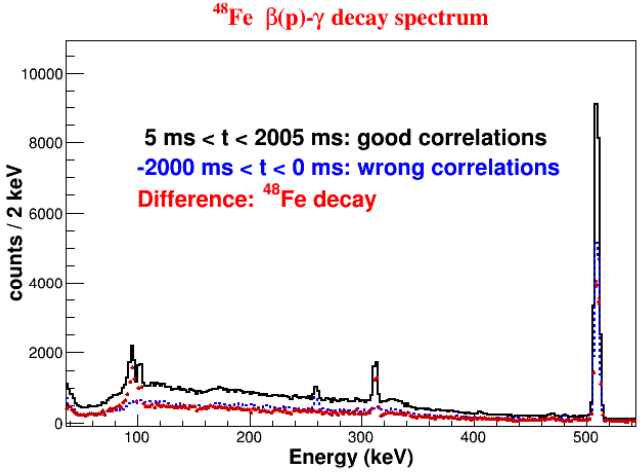
✓ ToF: CAVIAR-HF, D6-HF



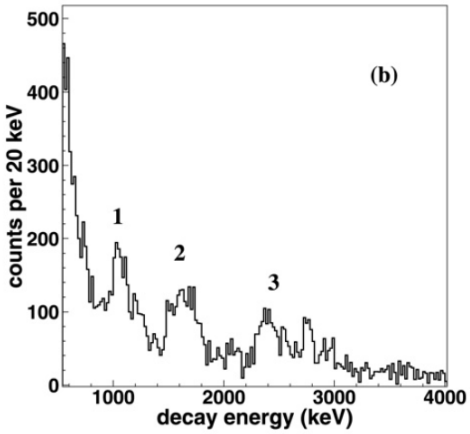
LISE experiments 2016-2017

E666 Preliminary (J. Giovinazzo): ^{48}Fe case

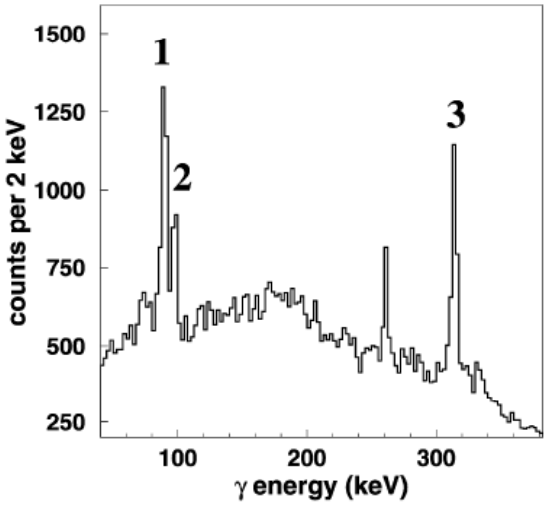




-> Higher statistics than in all previous campaigns at LISE
Further cleaning work required (gating)



C. Dossat et al., NPA792 (2007) 18



LISE experiments 2016-2017

E748 – A. Matta, S. Koyama et al. – 1st exp. of the MUST2 campaign

Direct reaction modeling and nucleon-nucleon forces at the drip-line

-> ^{10,12}Be(d,^{3}He) ^{9,11}Li

✓ **n-rich Be : halo structure**

↕ **Geometrical w.f. mismatch**
-> very low cross section

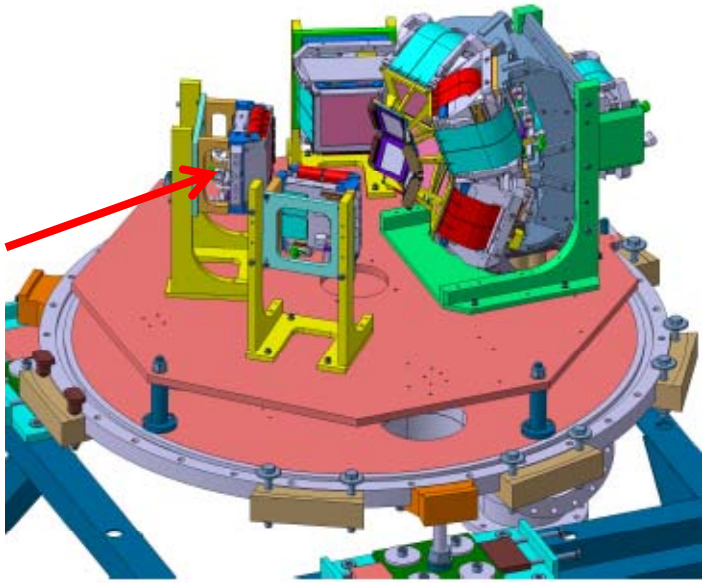
n-rich Li: core excitations

✓ **^{10}Be(d,^{3}He) vs. ^{12}Be(d,^{3}He)**
-> π strength evolution in n-rich Be isotopes

✓ **Other channels: (d,p), (d,d), (d,t), (d,α), (d,^{6}Li)**
-> optical models, pn pairing, clustering, …

Measurement

"Standard" MUST2 setup with 8 telescopes



✓ **ToF & Tracking: CAVIAR, 2*CATS**
✓ **0° detection: CHIO + NUMEXO2**

LISE experiments 2016-2017

E748: ^{10,12}Be(d,^{3}He) ^{10,12}Li

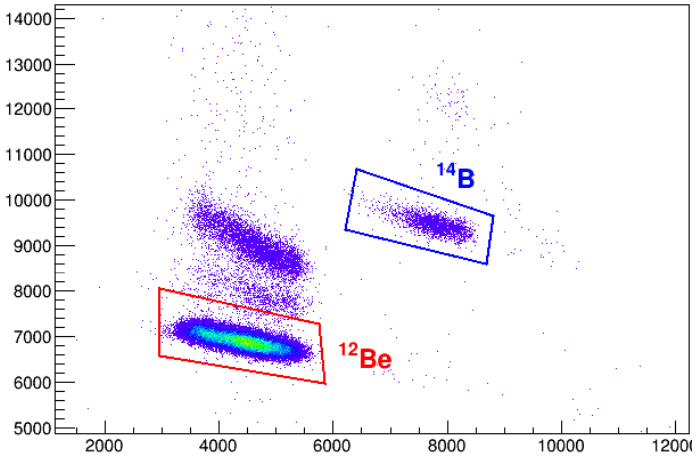
Production

^{18}O@50 MeV/u, 2 to 6 10^{12} pps

fragmentation

^{10}Be ~ 10^{5} pps; ^{12}Be ~5 10^{4} pps

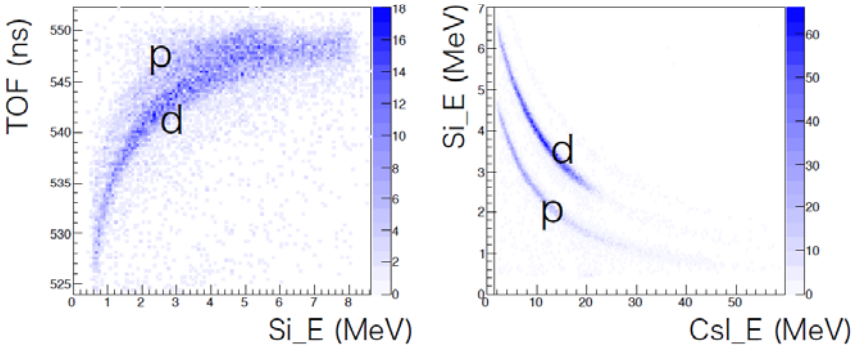
~95% purity

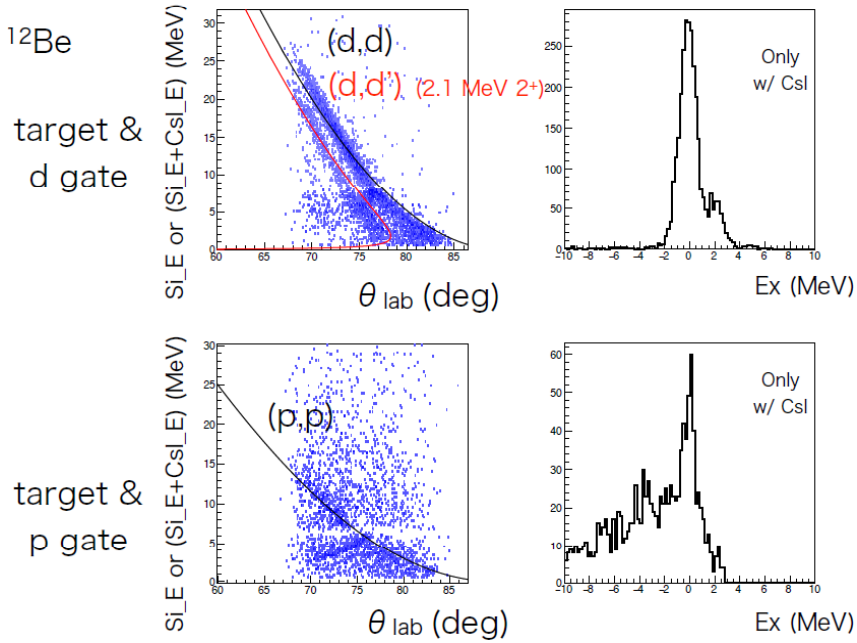


Looks promising!

E748 Preliminary (S. Koyama)

Particle Id.





LISE experiments 2016-2017

E692 – C. Whedlon et al., to be performed in November

Resonant elastic scattering to probe cluster structures in n-rich C isotopes

-> ^{10,11,12}Be(α,α') => ^{14,15,16}C(E*, Γ, J$^{\pi}$)

Production

^{18}O@50 MeV/u, few 10^{12} pps

Fragmentation -> ^{10,11,12}Be, few 10^{4} pps

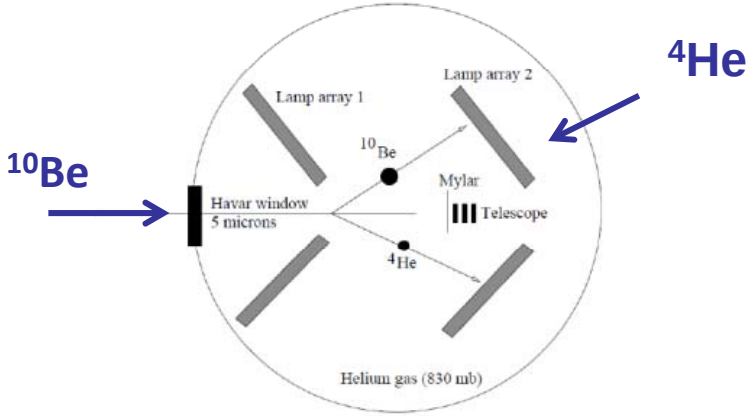
Energy reduction down to 4-5 MeV/u

Measurement

ECLAN chamber in D4 room

+ LAMP detectors

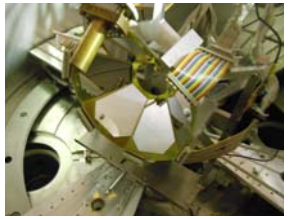
+ DSSSD telescope (16x16 strips)



Exit channels to be investigated

^{10}Be + ^{4}He -> ^{14}C* = ^{10}Be + ^{4}He; ^{8}Be + ^{4}He;
^{9}Be + ^{5}He ;…

^{12}Be + ^{4}He -> ^{16}C* = ^{12}Be + ^{4}He; ^{10}Be + ^{6}He;…



LISE Future: organization

Organization based upon:

- **Regular discussions with users: 3 LISE-ICC workshops in 2015-2016***

-> Physics program: 15 proposals
  - nuclear structure and nuclear forces
  - exotic decay modes
  - nuclear astrophysics
  - collective excitation modes

-> Definition of experimental campaigns:
  - using existing (MUST2) and new detectors (ACTAR TPC, PARIS, MUGAST,...)
  - using new beams (SPIRAL1-U)

-> Keeping the possibility to run standalone experiments

- **Technical upgrade of the LISE spectrometer**

-> Beam pipe cooling after the 1st dipole	✓2017
-> Improved detection capabilities: CAVIAR, CHIO+NUMEXO2	✓2017
-> LISE QD6: optical/purity improvement for 2nd reactions	2017-2019

LISE roadmap: scientific program

2017 -> 2018

- 1st campaign: transfer with MUST 2
  - E748 performed – A. Matta et al.
  - Two remaining, dealing with exotic structures at the proton drip line
  - PAC 2017: 3 more proposals, nucl. struc./forces at the drip line; 1 astro.

-> Prog. in 2018: PAC res. & cryogenic target & SPIRAL1 beams

2019-2020

- 2nd campaign: 2p and (β)p decays + reactions with ACTAR TPC
  - Two accepted experiments: exotic decays
  - PAC 2017: 2 more proposals, 1 astrophysics, 1 nuclear structure

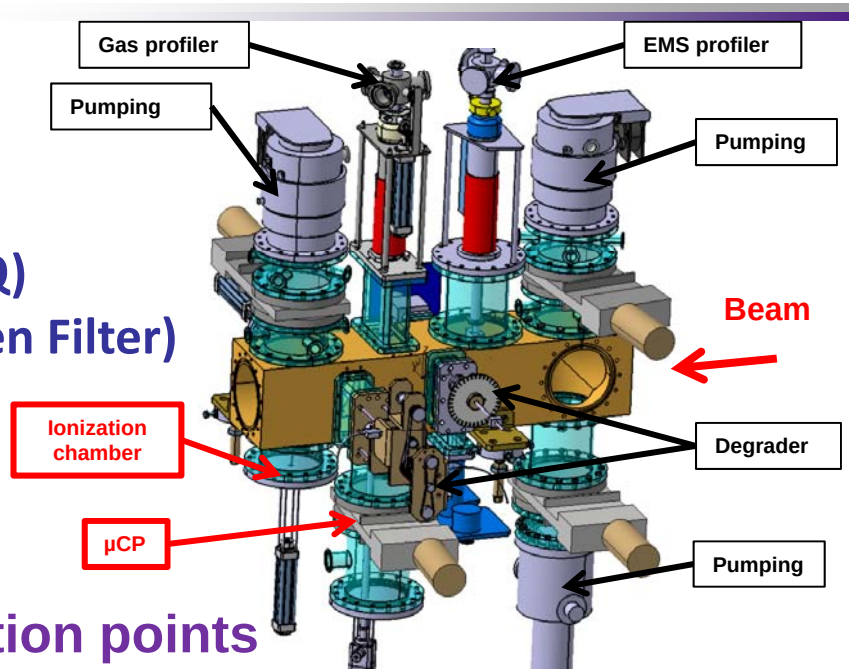
-> Prog. in 2019: to be defined in view of the other exp. In G3

- 3nd campaign: collective excitation modes
  - Proposal to the GANIL PAC: Ni isotopic chain
  - Part of the ACTAR TPC campaign if the LISE QD6 project is completed

LISE roadmap: technical developments

2017 -> 2018

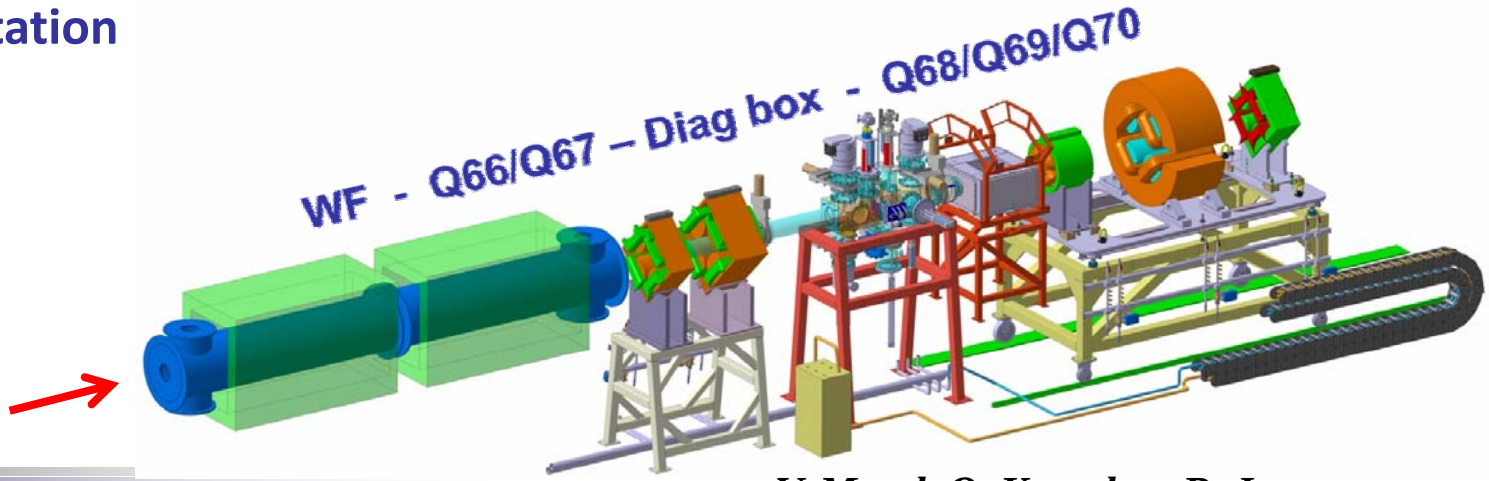
- Removal of the D6 platform
- Removal of the last quadrupole (3Q -> 2Q)
- New diagnostic box (set closer to the Wien Filter)



2018->2019

Optics between the 1st and 2nd focalization points

- Technical solution to be defined (3Q, 4Q?)
  -> constraints = setup size, compatibility with slowed-down beams
- Implementation



V. Morel, O. Kamalou, B. Jacquot

Conclusion

- **2011-2017**
  - ✓ In average: ~1 month of beam time, 3 exp./year + tests

  2016-2017:
  - ✓ Complementary investigation techniques/physics cases
  - ✓ Rather successful experiments
  - ✓ New MUST2 campaign initiated

- **2018 -> 2020**
  - ✓ MUST2 campaign completion with new proposals (?): requires a cryogenic target, SPIRAL1 beams -> organization
  - ✓ ACTAR TPC campaign (2 + x) -> scheduling vs G3 exp.

- **Risks/Opportunities**
  - ✓ Available/Required beam time
  - ✓ LISE QD6 scheduling

-> timeline of the campaigns

Reminder: LISE-ICC Workshop, 6-8 December 2017 at GANIL

Thank you for your attention!

and to the contributors and reviewers

B. Blank, J. Giovinazzo, O. Kamalou, A. Matta, V. Morel, O. Sorlin, C. Stodel