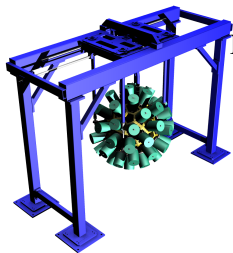


# Gamma-ray and Conversion Electron Spectroscopy at JYFL

Paul Greenlees

Department of Physics  
University of Jyväskylä

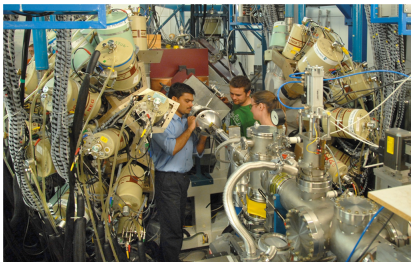


Nuclear Spectroscopy INstrumentation  
Kick-off Workshop  
27.06.-01.07.2016  
San Servolo, Italy

# JYFL Accelerator Laboratory

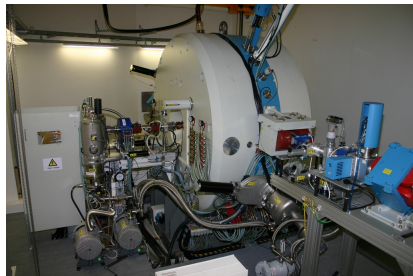


# JYFL Accelerator Laboratory



- University Laboratory - Part of Department of Physics
- Accelerator-Based Physics (Nuclear, Material) and Related Applications
- Academy of Finland Centre of Excellence (2000-present)
- EU Access Facility since FP4, currently ENSAR2 H2020
- National Status as Centre of Expertise (Ministry of Education and Culture)
- Only Operational Research Infrastructure on Ministry of Education Roadmap in "Natural Sciences and Technology"
- Recognised Test Facility of European Space Agency (one of three in Europe)
- Around 200 International Users / year

# Accelerator Facilities

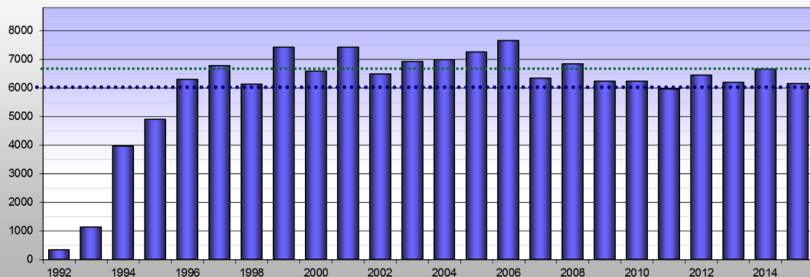


- 6.4, 14 GHz ECR Ion Sources, New 18 GHz source under construction

# Use of the K130 Cyclotron



## Operation of the Jyväskylä Cyclotron

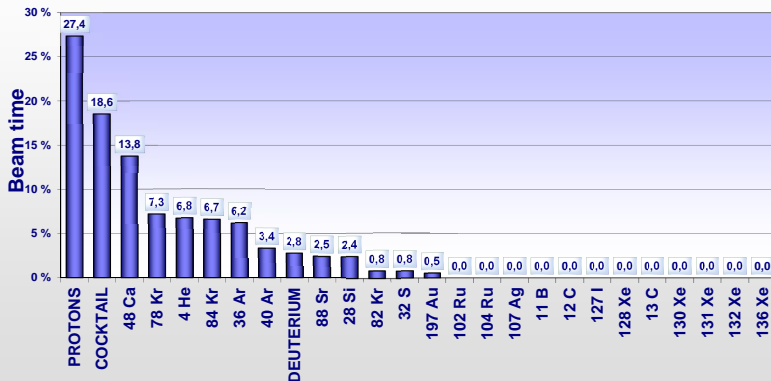


Run time as of 31.12.2015 at 23:59 is 143 112 hours. The average per year (after 1.1.1996) is 6 640 hours.

# K130 Cyclotron Facility



## *Accelerated Ions in 2015 (All)*

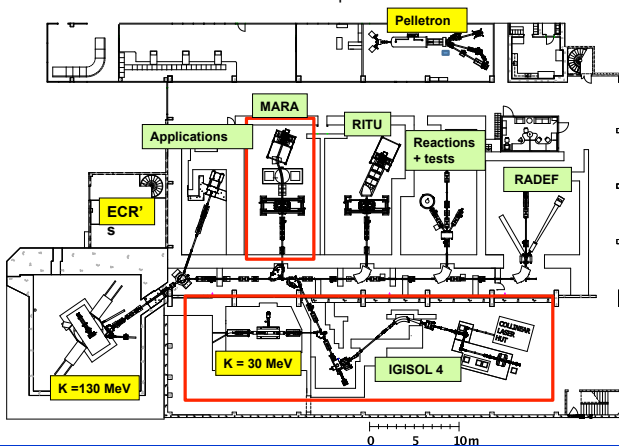


Charts

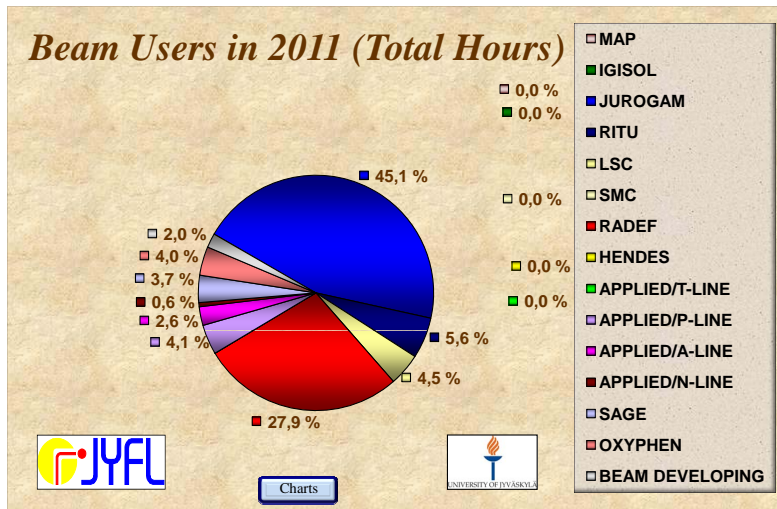
# Laboratory Expansion

## Upgrade of the JYFL-ACCLAB

New K = 30 MeV light-ion cyclotron  
New IGISOL 4  
New MARA recoil separator

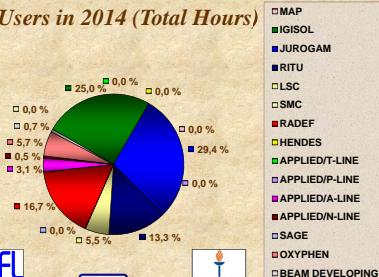


# Consequences: Use of the K130 Cyclotron 2011

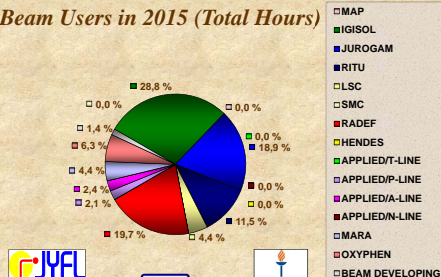


# Use of the K130 Cyclotron 2014/2015

*Beam Users in 2014 (Total Hours)*



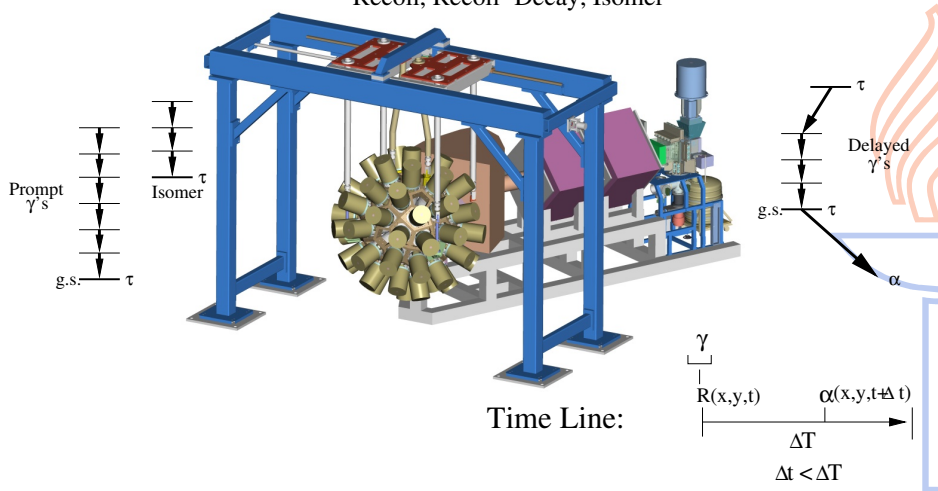
*Beam Users in 2015 (Total Hours)*



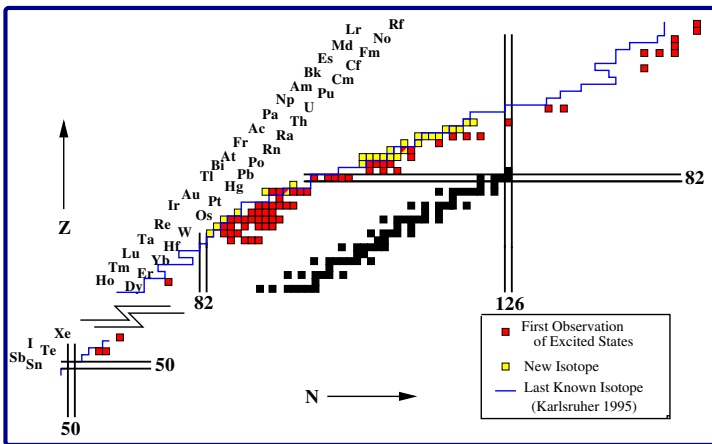
# Principles of RDT

## Tagging Techniques

Recoil, Recoil–Decay, Isomer

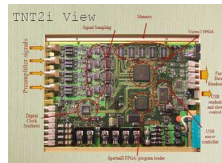
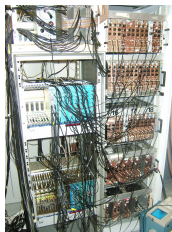
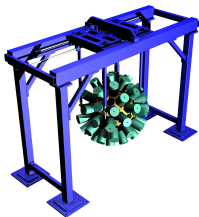


# Regions of Study at RITU



- Shell-stabilized transactinoid nuclei
- Shape co-existence in light Pb and Po region
- Proton dripline nuclei
- K-isomerism in the A=140 region
- Collectivity close to  $^{100}\text{Sn}$
- N=Z nuclei in A=70-80 region

# History of JUROGAM at JYFL



- Fifth and final campaign ended May 2008
- 2003 - 2008: 67 experiments, 11000 hours beam on target
- 2008: Fully instrumented with TNT2 digital electronics
- TNT2 cards in collaboration with CNRS/IN2P3 GABRIELA
- Superseded by JUROGAM II

PRL 102, 212501 (2009)

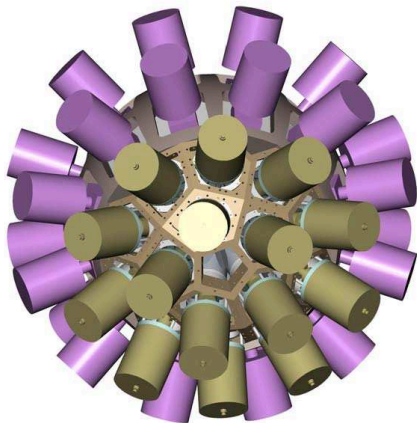
PHYSICAL REVIEW LETTERS

week ending  
29 MAY 2009

## $\gamma$ -Ray Spectroscopy at the Limits: First Observation of Rotational Bands in $^{255}\text{Lu}$

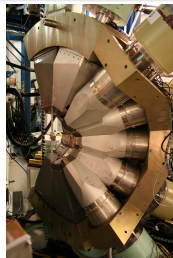
S. Ketelhut,<sup>1,\*</sup> P. T. Greenlees,<sup>2</sup> D. Ackermann,<sup>2</sup> S. Antalic,<sup>3</sup> E. Clément,<sup>4</sup> I. G. Darby,<sup>5,†</sup> O. Dorvaux,<sup>6</sup> A. Drouart,<sup>4</sup> S. Eeckhaudt,<sup>1</sup> B. J. P. Gall,<sup>6</sup> A. Görgen,<sup>4</sup> T. Grahn,<sup>1,‡</sup> C. Gray-Jones,<sup>5</sup> K. Hauschild,<sup>7</sup> R.-D. Herzberg,<sup>5</sup> F. P. Heßberger,<sup>2</sup> U. Jakobsson,<sup>1</sup> G. D. Jones,<sup>2</sup> P. Jones,<sup>1</sup> R. Julin,<sup>1</sup> S. Juutinen,<sup>1</sup> T.-L. Khoo,<sup>8</sup> W. Kortén,<sup>9</sup> M. Leino,<sup>1</sup> A.-P. Leppänen,<sup>1,§</sup> J. Ljungvall,<sup>1</sup> S. Moon,<sup>2</sup> M. Nyman,<sup>4</sup> A. Obertelli,<sup>4</sup> J. Pakarinen,<sup>1,‡</sup> E. Parr,<sup>1</sup> P. Papadakis,<sup>5</sup> P. Peura,<sup>1</sup> J. Piot,<sup>6</sup> A. Pritchard,<sup>5</sup> P. Rähkila,<sup>1</sup> D. Rostrom,<sup>2</sup> P. Ruotsalainen,<sup>1</sup> M. Sandzelius,<sup>9</sup> J. Sarén,<sup>1</sup> C. Scholey,<sup>1</sup> J. Sorri,<sup>1</sup> A. Steer,<sup>10</sup> B. Sulignano,<sup>4</sup> Ch. Theisen,<sup>4</sup> J. Uusitalo,<sup>1</sup> M. Venhart,<sup>3,†</sup> M. Zielinska,<sup>11</sup> M. Bender,<sup>12,13</sup> and P.-H. Heenen<sup>14</sup>

# The JUROGAM II Germanium Array

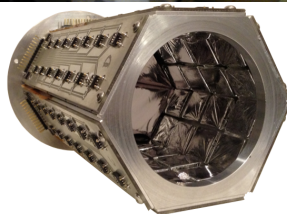
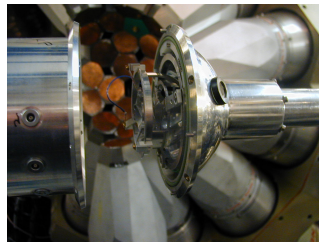
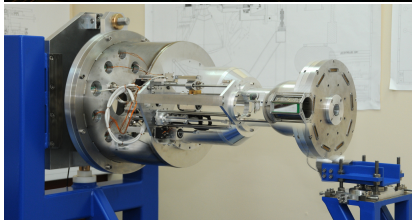
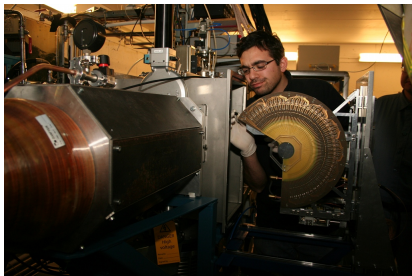


- 2003-present: 178 experiments, over 31200 hours
- 120+ refereed journal articles, 50+ conference proceedings, 60 PhD theses

- 24 Clover and 15 Tapered Ge detectors - GAMMAPOOL resources
- Total Photopeak Efficiency 5.2% @ 1.3 MeV
- Excellent  $\gamma$ - $\gamma$  efficiency
- Autofill system built by University of York, part of GREAT
- Instrumented with Lyrtech digital electronics
- Higher counting rates, higher beam intensities



# Range of Ancillary Devices



UoY Tube THE UNIVERSITY of York

# Conversion-Electron Spectroscopy of $^{254}\text{No}$

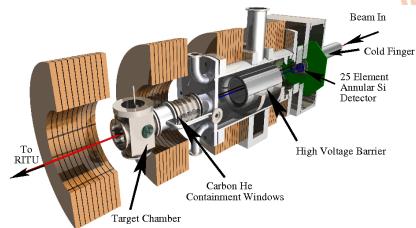
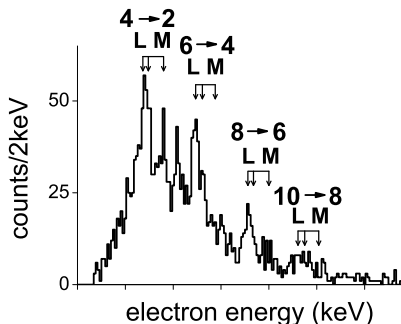
VOLUME 89, NUMBER 20

PHYSICAL REVIEW LETTERS

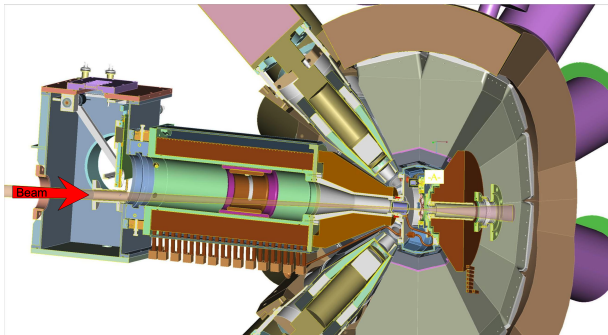
11 NOVEMBER 2002

## Conversion Electron Cascades in $^{254}\text{No}$

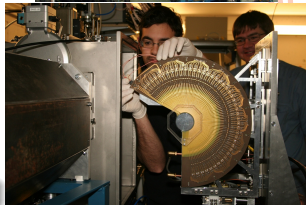
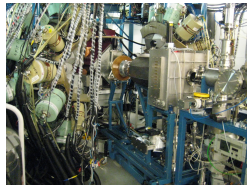
P. A. Butler,<sup>1</sup> R. D. Humphreys,<sup>1</sup> P. T. Greenlees,<sup>2</sup> R.-D. Herzberg,<sup>1</sup> D. G. Jenkins,<sup>1</sup> G. D. Jones,<sup>1</sup> H. Kankaanpää,<sup>2</sup> H. Kettunen,<sup>2</sup> P. Rauhila,<sup>2</sup> C. Scholey,<sup>1,2</sup> J. Uusitalo,<sup>2</sup> N. Amzal,<sup>1</sup> J. E. Bastin,<sup>1</sup> P. M. T. Brew,<sup>1</sup> K. Eskola,<sup>3</sup> J. Gerl,<sup>4</sup> N. J. Hammond,<sup>1</sup> K. Hauschild,<sup>5</sup> K. Helariutta,<sup>4</sup> F.-P. Heßberger,<sup>4</sup> A. Hürstel,<sup>5</sup> P. M. Jones,<sup>2</sup> R. Julin,<sup>2</sup> S. Juutinen,<sup>2</sup> A. Keenan,<sup>2</sup> T.-L. Khoo,<sup>6</sup> W. Korten,<sup>5</sup> P. Kuusiniemi,<sup>2</sup> Y. Le Coz,<sup>5</sup> M. Leino,<sup>2</sup> A.-P. Leppänen,<sup>2</sup> M. Muikku,<sup>2</sup> P. Nieminen,<sup>2</sup> S. W. Ødegård,<sup>7</sup> T. Page,<sup>1</sup> J. Pakarinen,<sup>2</sup> P. Reiter,<sup>8</sup> G. Sletten,<sup>9</sup> Ch. Theisen,<sup>5</sup> and H.-J. Wollersheim<sup>4</sup>



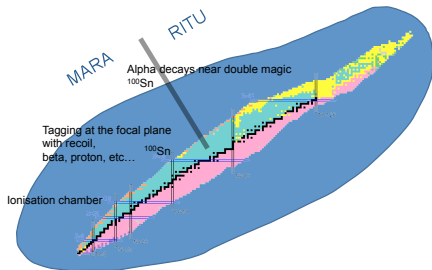
# The SAGE Spectrometer



P. Papadakis et al., AIP Conf. Proc. **1090**, 14 (2009)

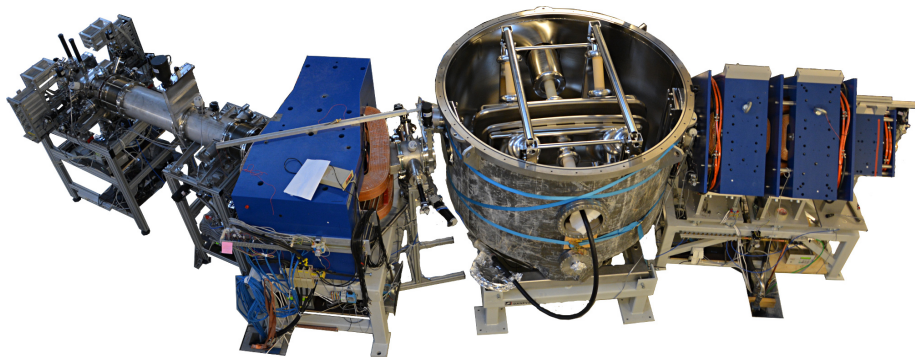


# Future studies of light nuclei - MARA



- Decay spectroscopy (proton and  $\alpha$  emitters)
- In-beam spectroscopy at proton drip line
- Nuclear structure related to astrophysical processes (isomers, etc)
- Studies of  $N \simeq Z$  nuclei
- Super- and hyper-deformation ( $N \simeq Z \simeq 40$ )
- Mirror nuclei
- Combination with existing/new devices (LISA/SAGE/DPUNS/UoYTube...)

# Future studies of light nuclei - MARA



## Commissioning Runs

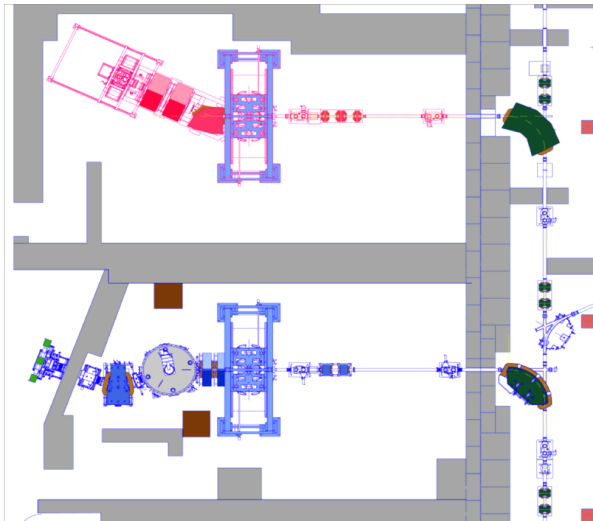
- $^{78}\text{Kr} + ^{98}\text{Mo} \rightarrow ^{176}\text{Pt}^*$
- $^{78}\text{Kr} + ^{58}\text{Ni} \rightarrow ^{136}\text{Gd}^*$

- $^{40}\text{Ca} + ^{45}\text{Sc} \rightarrow ^{85}\text{Nb}^*$
- $^{40}\text{Ca} + \textit{nat}\text{Ca} \rightarrow ^{80}\text{Zr}^*$
- $^{40}\text{Ar} + ^{124}\text{Sn} \rightarrow ^{164}\text{Er}^*$

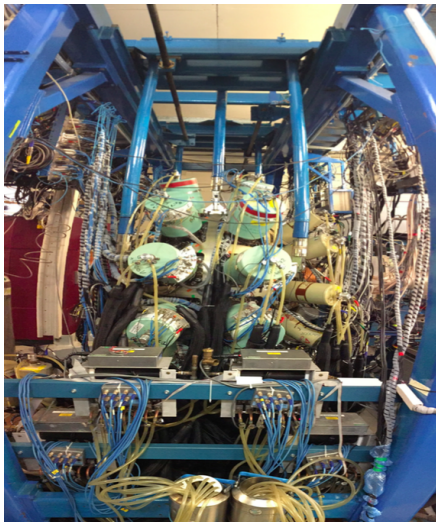
# In-beam studies at MARA

## Common Infra:

- Electronics and DAQ
- High Voltage
- LN2 and Autofill

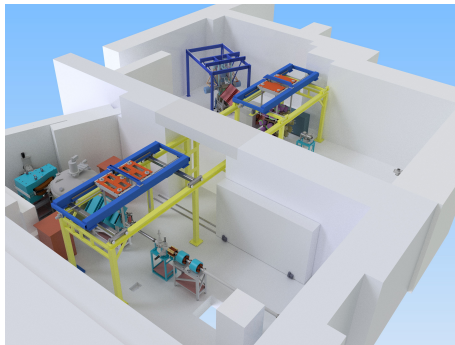


# In-beam studies at MARA

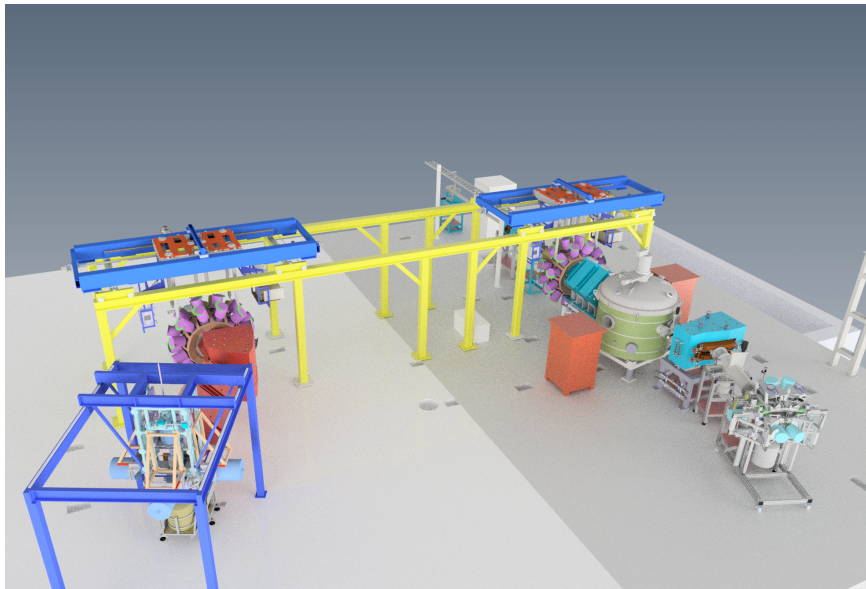


- Infrastructure funding from Finnish Academy
- Support structure 150 k€
- LN2 vacuum feedline extension 50 k€
- BGO HV cards / crates 110 k€
- Total: 310 k€

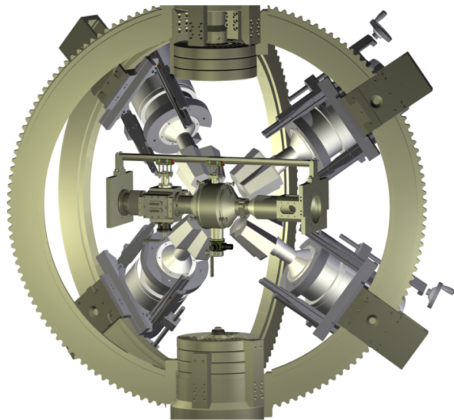
# In-beam studies at MARA / RITU - JUROGAM III



# In-beam studies at MARA / RITU - JUROGAM III

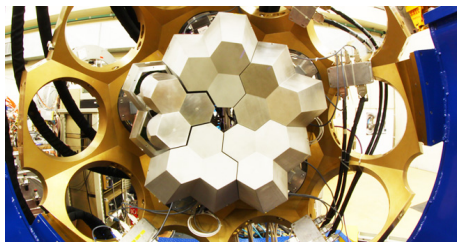


# Activities outside JYFL



## ISOLDE

- SPEDE installed at MINIBALL
- Isolde Decay Station - DAQ and analysis
- MINIBALL DAQ upgrade



## AGATA

- Limited involvement so far
- Signatory of MoU 2016-2021
- Bid for AGATA capsule and infrastructure
- Finnish Academy 359 k€ 2018-2019
- Decision end 2016?
- Relation to FAIR / DEGAS, support from community?

# Summary and Outlook

- Very successful campaigns with JUROGAM and RITU
- Range of ancillary devices: SAGE, DPUNS plunger, UoYTube, LISA
- Laboratory expansion / New Cyclotron - more opportunities for nuclear spectroscopy
- MARA separator - commissioned, focal plane physics 2016-2017
- MARA separator - cave reconstruction and in-beam physics 2017-2018
- Involvement in MINIBALL, AGATA
- Expect a broad and competitive physics program in the future!