The versatile detectors used for research at ISOLDE

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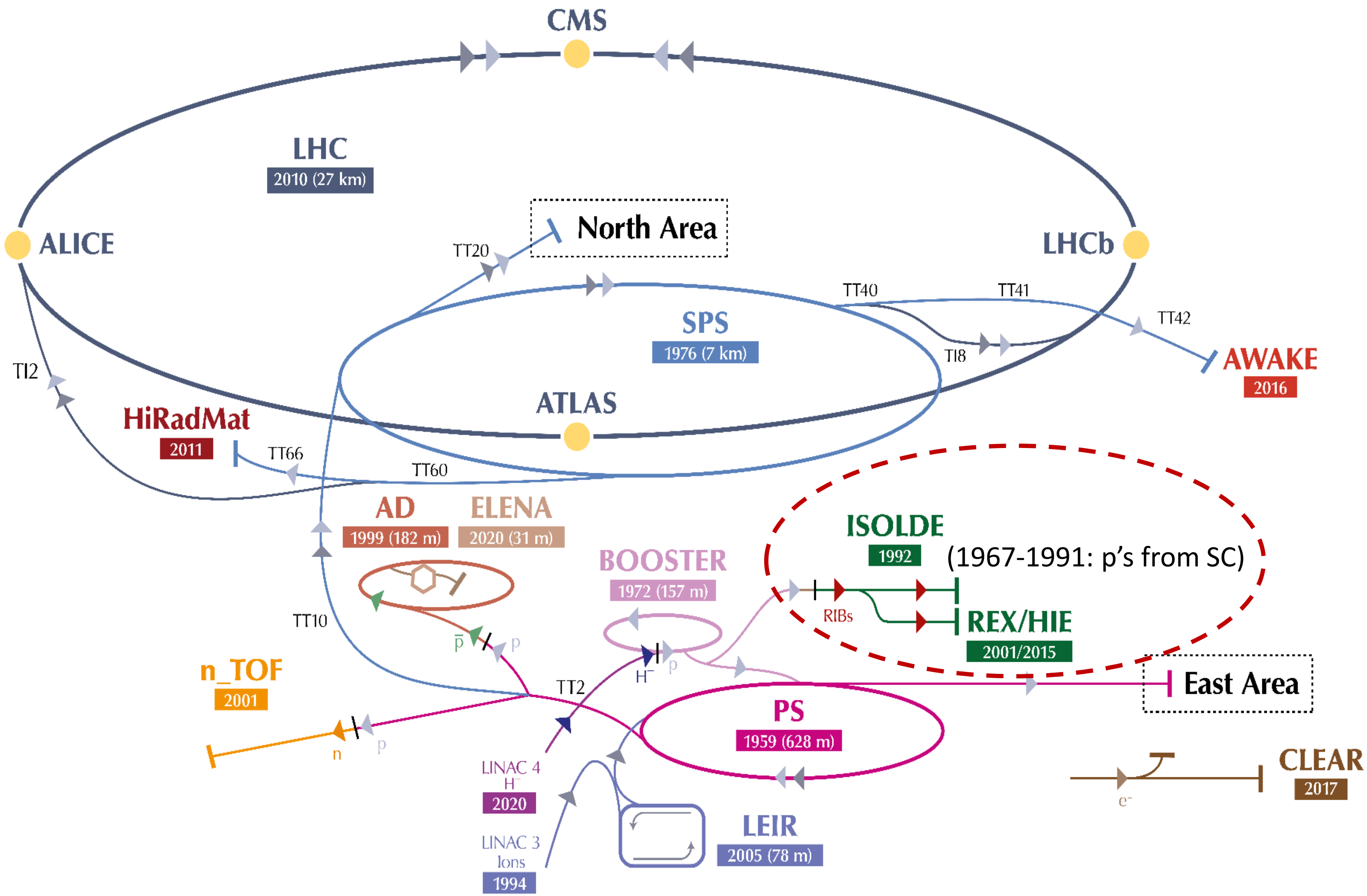
on behalf of the ISOLDE physics team

With input from L. Fraile, R. Garcia Ruiz, R. Lica, S. Malbrunot-Ettenauer, M. Pfutzner, M. Mougeout, S. Sels, P. Van Duppen, U. Wahl

Outline

- **ISOLDE facility at CERN**
- **ISOLDE wide range of particle and photon detectors**
- **Selected examples**
- **Outlook and summary**

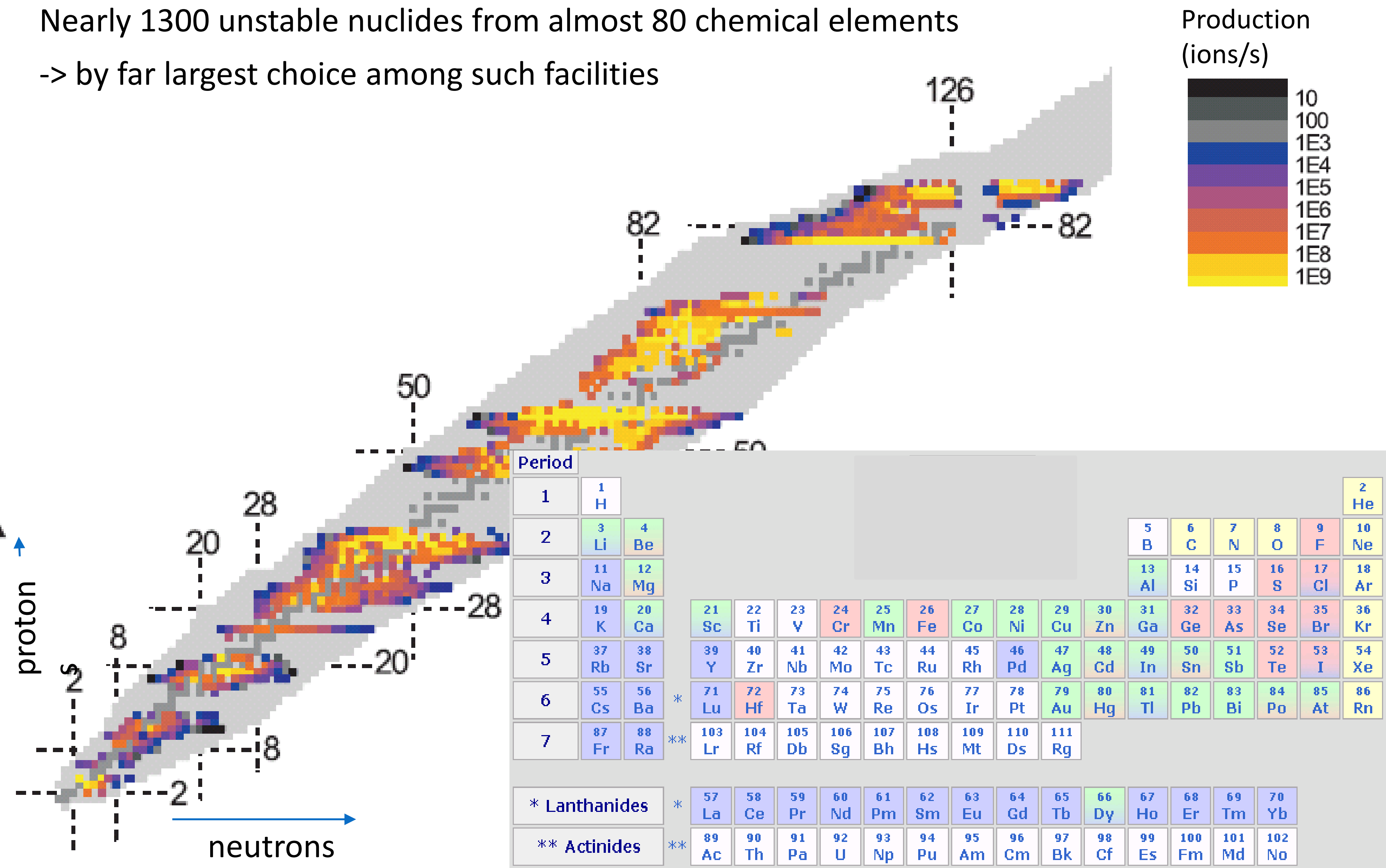
ISOLDE at CERN



ISOLDE radio-nuclei

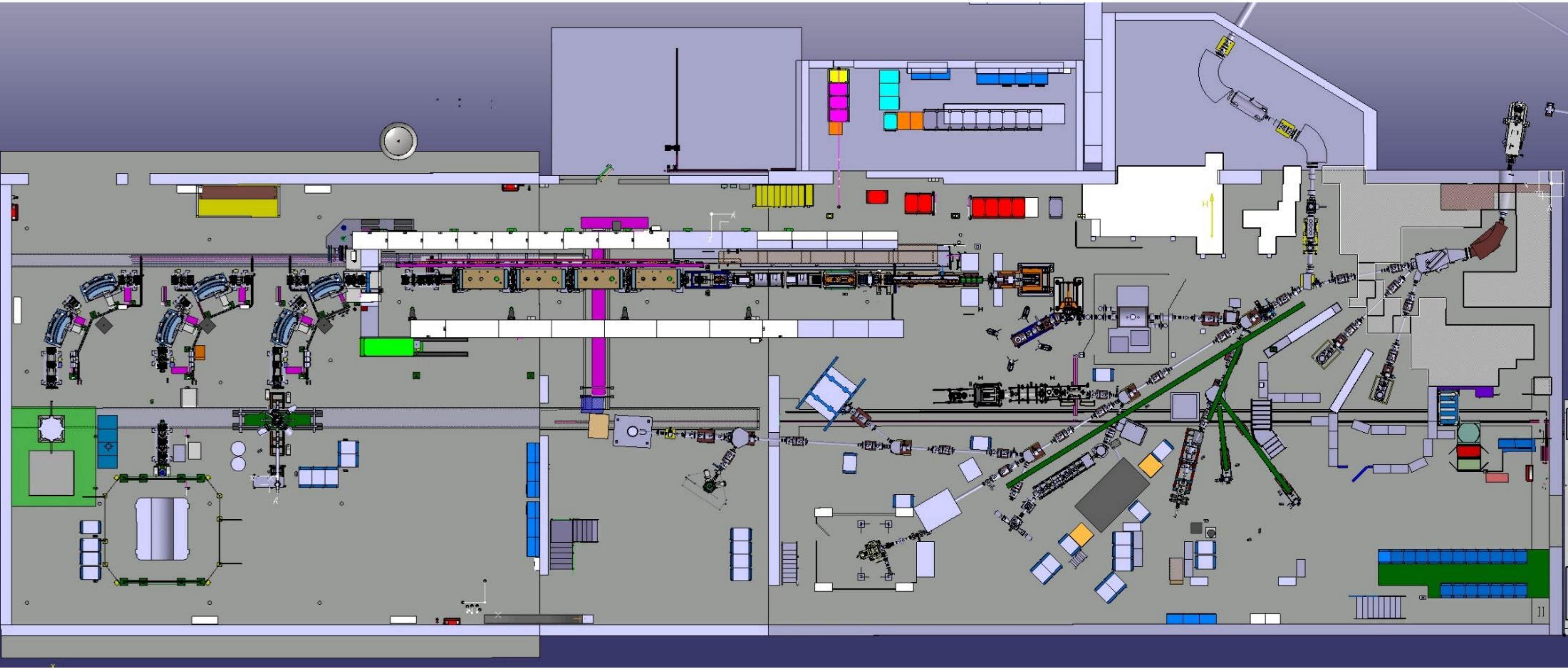
Nearly 1300 unstable nuclides from almost 80 chemical elements

-> by far largest choice among such facilities



ISOLDE experiments

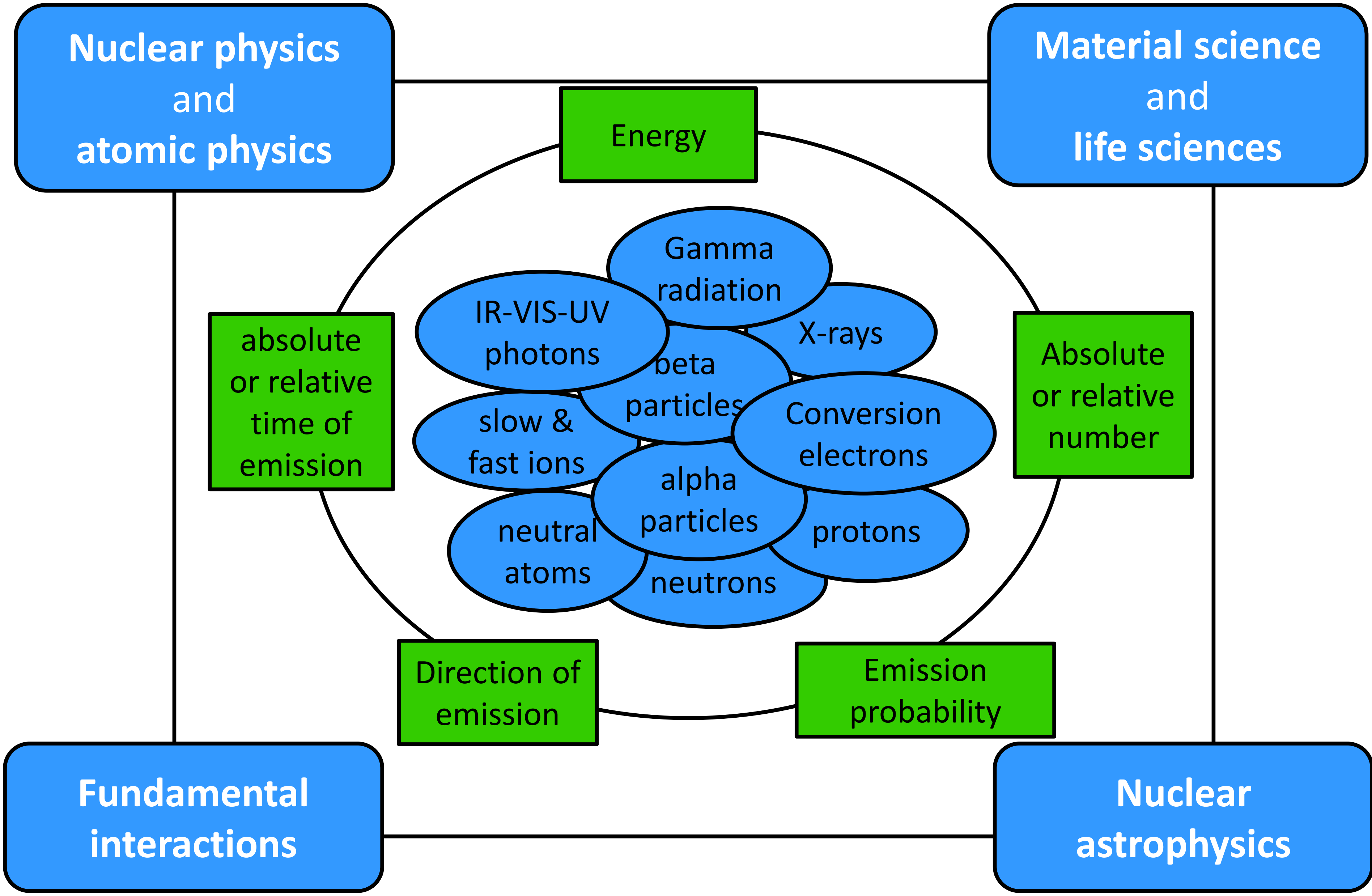
A dozen permanent and travelling experimental setups
100 scientific proposal approved by INTC committee
500 – 900 researchers from around the world



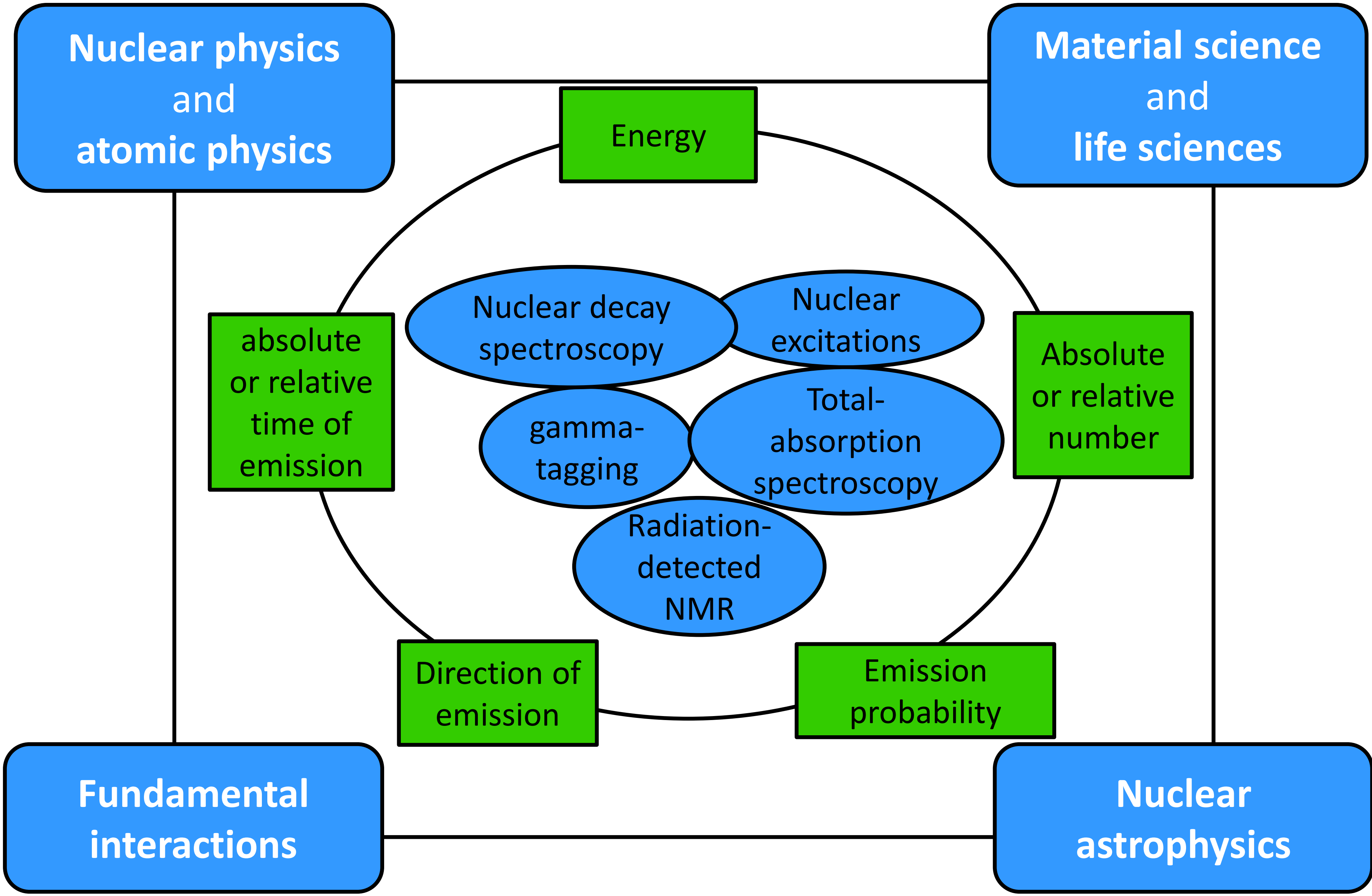
Post-accelerated RIBs, up to 10 MeV/u

Low-energy RIBs, up up to 60 keV energy

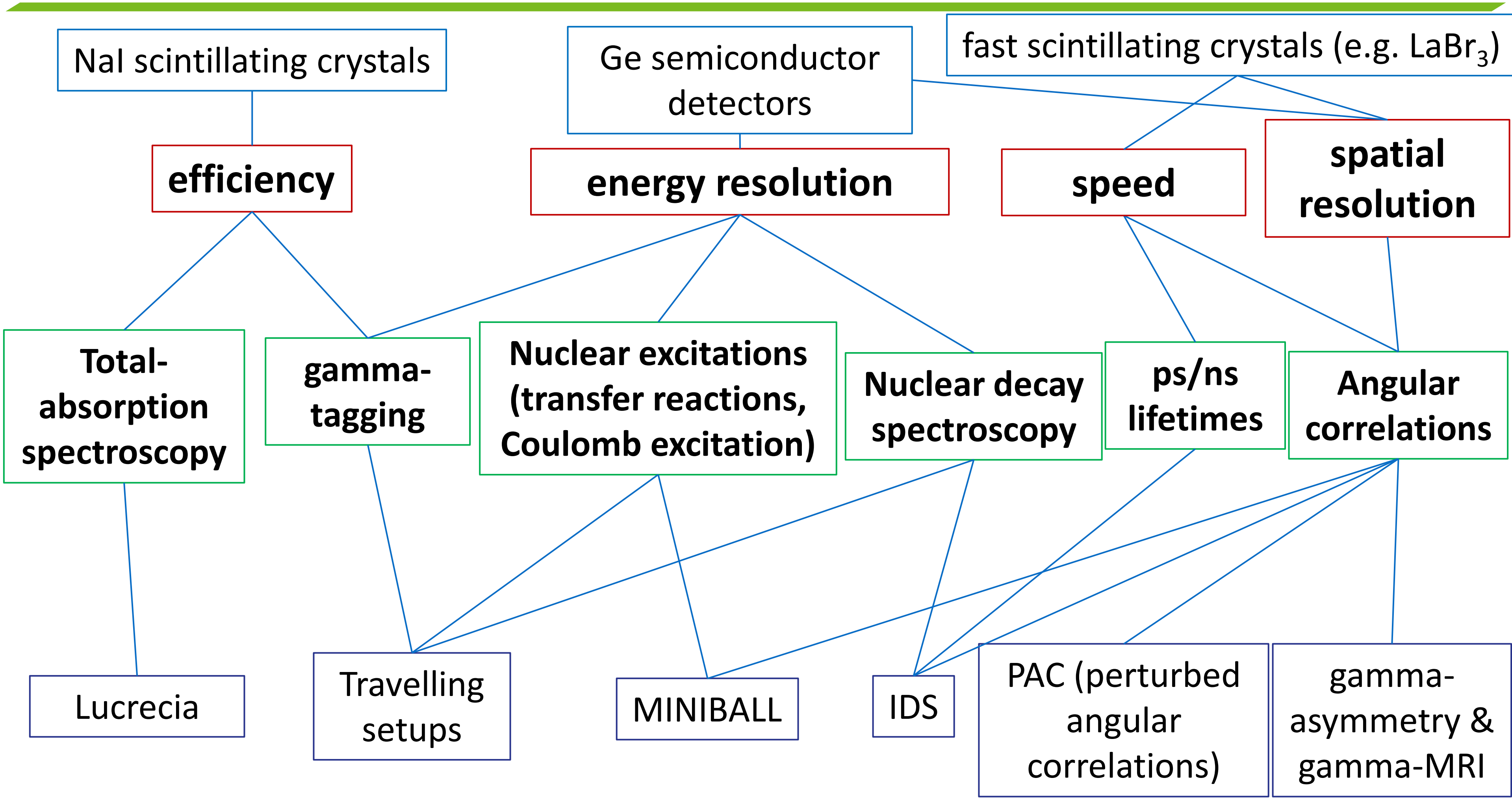
ISOLDE detectors and research topics



Gamma-ray detectors at ISOLDE



ISOLDE gamma-ray detectors



ISOLDE particle detectors

- **To detect particles emitted in decays or reactions of unstable nuclei:**
- Alphas
- Betas
- Protons
- Neutrons
- Other emitted (light particles), e.g. deuterons

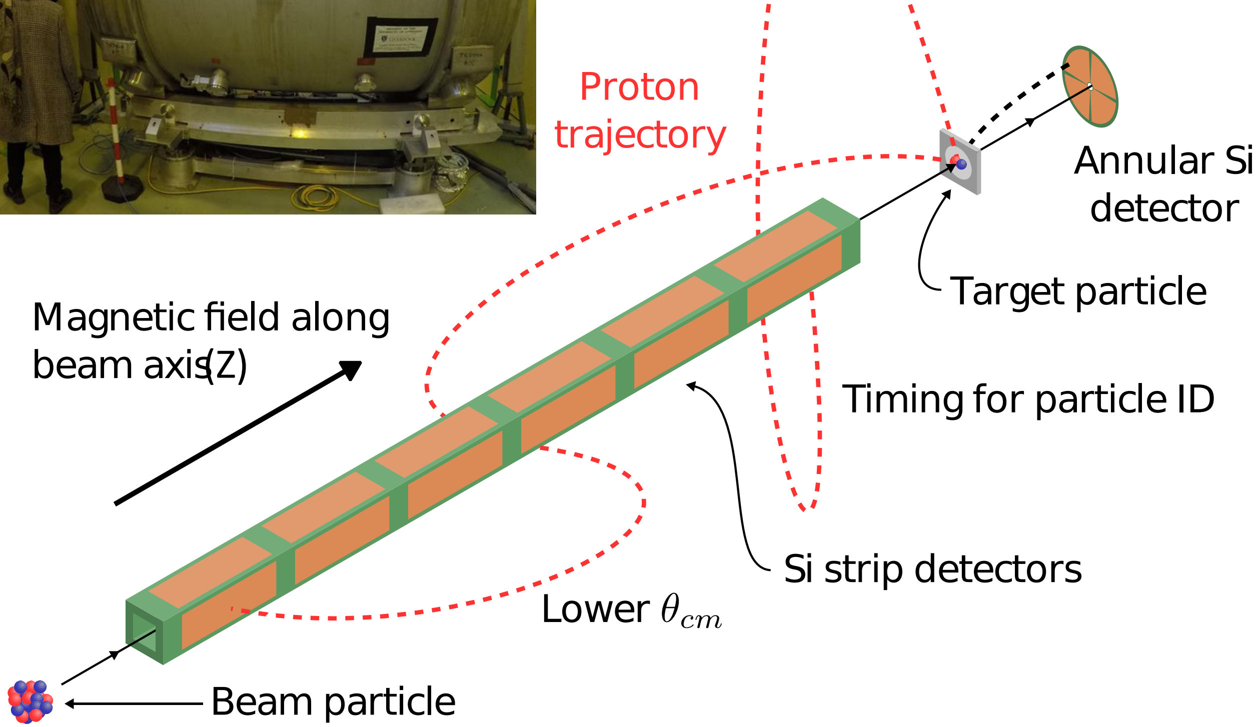
- **What is required:**
- Energy
- Time of emission
- Emission direction

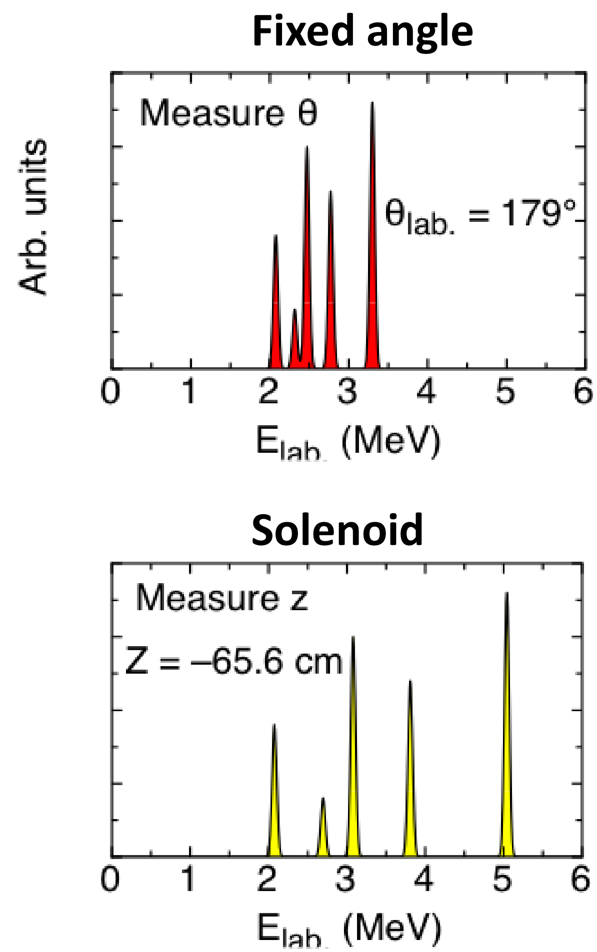
- **Used and tested types of detectors:**
- Si strip detector
- Time projection chamber
- TIMEPIX

ISS: charged particle detection

ISOLDE Solenoidal Spectrometer

direct reactions at HIE-ISOLDE



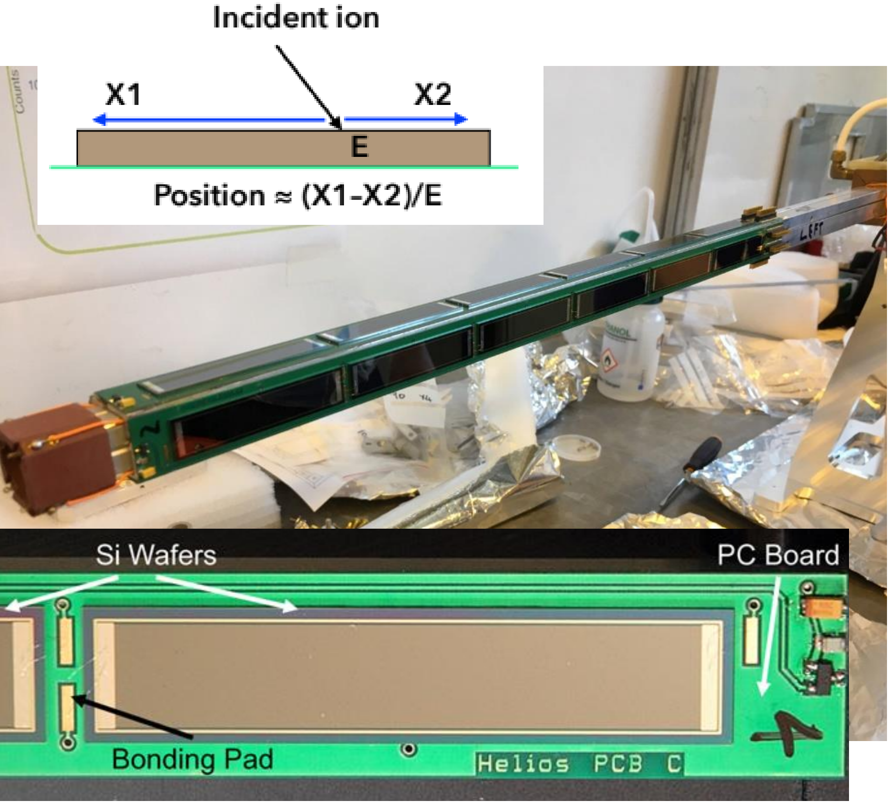


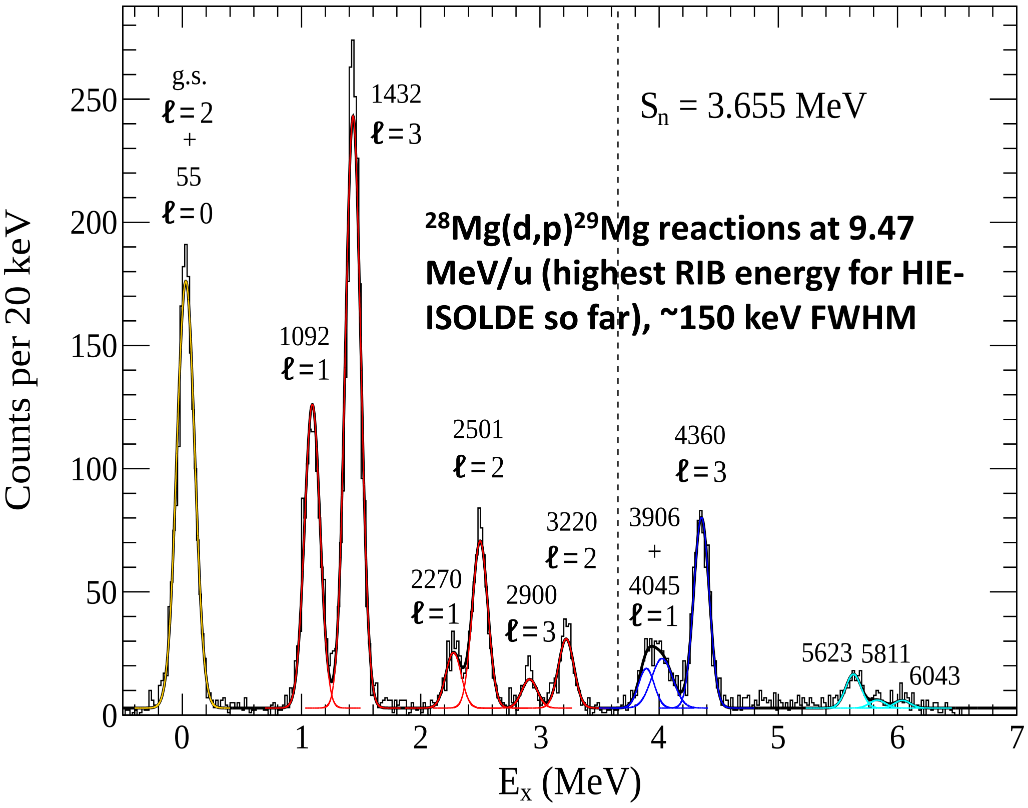
MEASURED: position z where light ejectile returns to axis, cyclotron period T_{cyc}, lab particle energy E_p

no kinematic compression of energy spectrum (unlike at fixed angles)
Linear relationship between E_{cm} and $E_{lab.}$

1^{st} ISS detectors in 2018

- Used HELIOS solenoid (Argonne) 24 resistive strip detectors (PSD) + electronics and DAQ
- Position determined though comparison of signals from each side of detectors



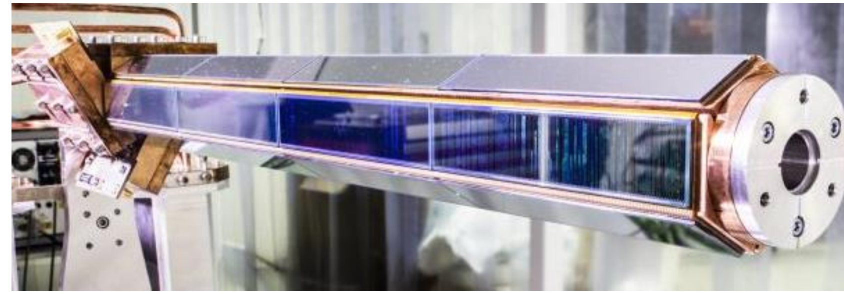


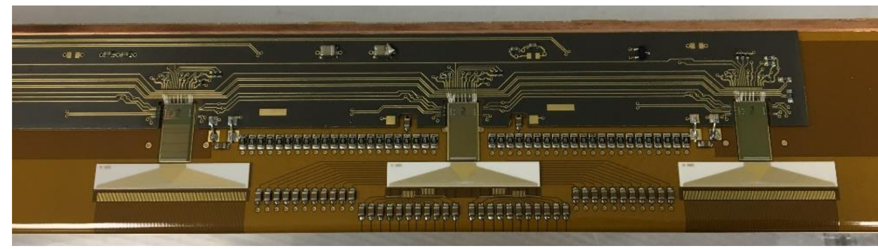
Contact: D. Sharp, U Manchester; L. Gaffney, U Liverpool, et al.

T.L. Tang et al., Phys. Rev. Lett. 124, 062502 (2020)

ISS detectors in 2021

6-sided Si array: 4 double-sided silicon-strip (DSSS) detectors + ASICs readout on each side





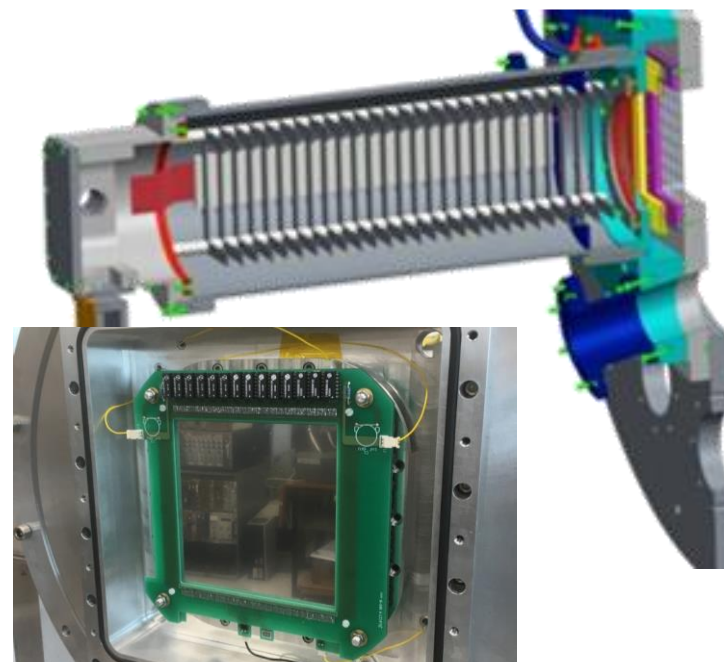
Each detector:

- 128 x 0.95mm strips along detector length
- 11 x 2mm along width
- 3336 channels

Total Si length: 510.4mm (486.4mm active)

- ~70% coverage in azimuthal angle
- Total coverage ~66% (2018: HELIOS PSD ~42%)

New gas-filled recoil detector for recoil identification:



- Position-sensitive multi-wire proportional counter
- Followed by segmented gas-filled ion chamber
- Digitized signals – sample full dE/dx.
- Count rate up to 100kHz

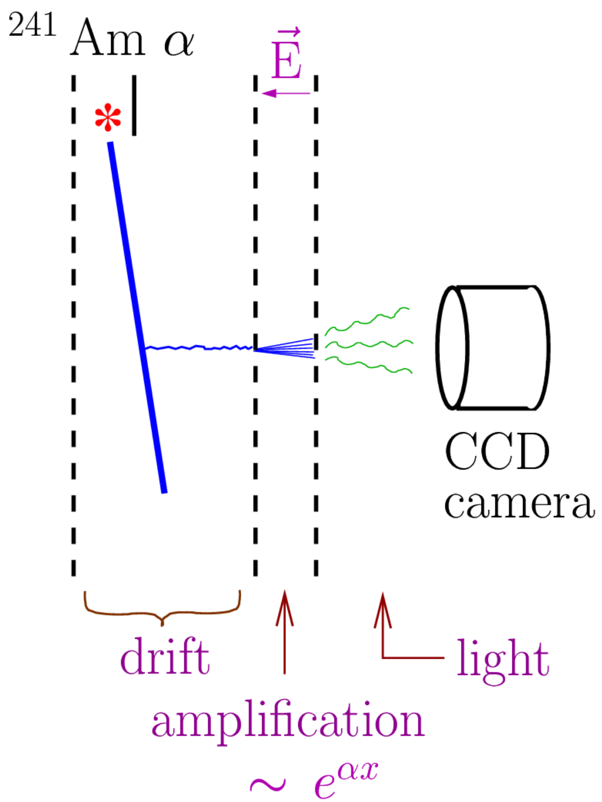
Contact: D. Sharp, U Manchester; L. Gaffney, U Liverpool

Optical TPC: charged-particle imaging

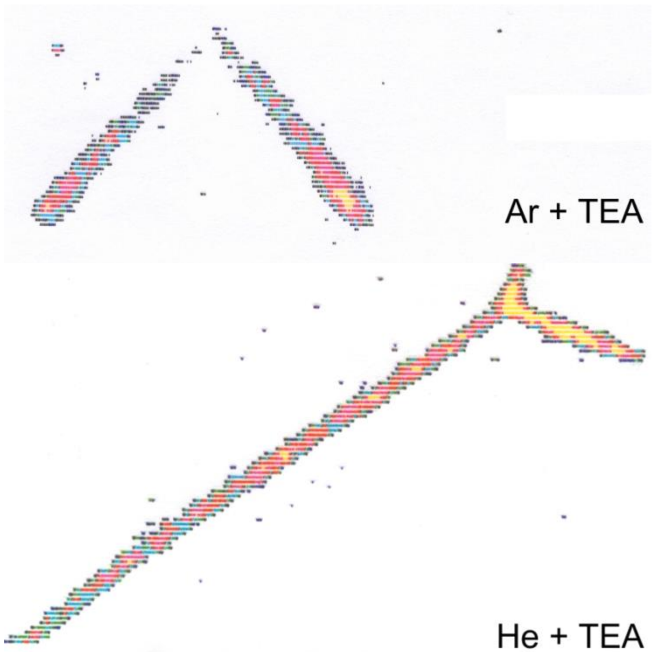
G. Charpak, W. Dominik, J. P. Farbe, J. Gaudaen, F. Sauli, and M. Suzuki,

"Studies of light emission by continuously sensitive avalanche chambers,"

NIM A269 (1988) 142



Example images of α-particle tracks



TEA = Tri-ethyl-amine $N(C_2H_5)_3$

Contact: M. Pfutzner, Warsaw University

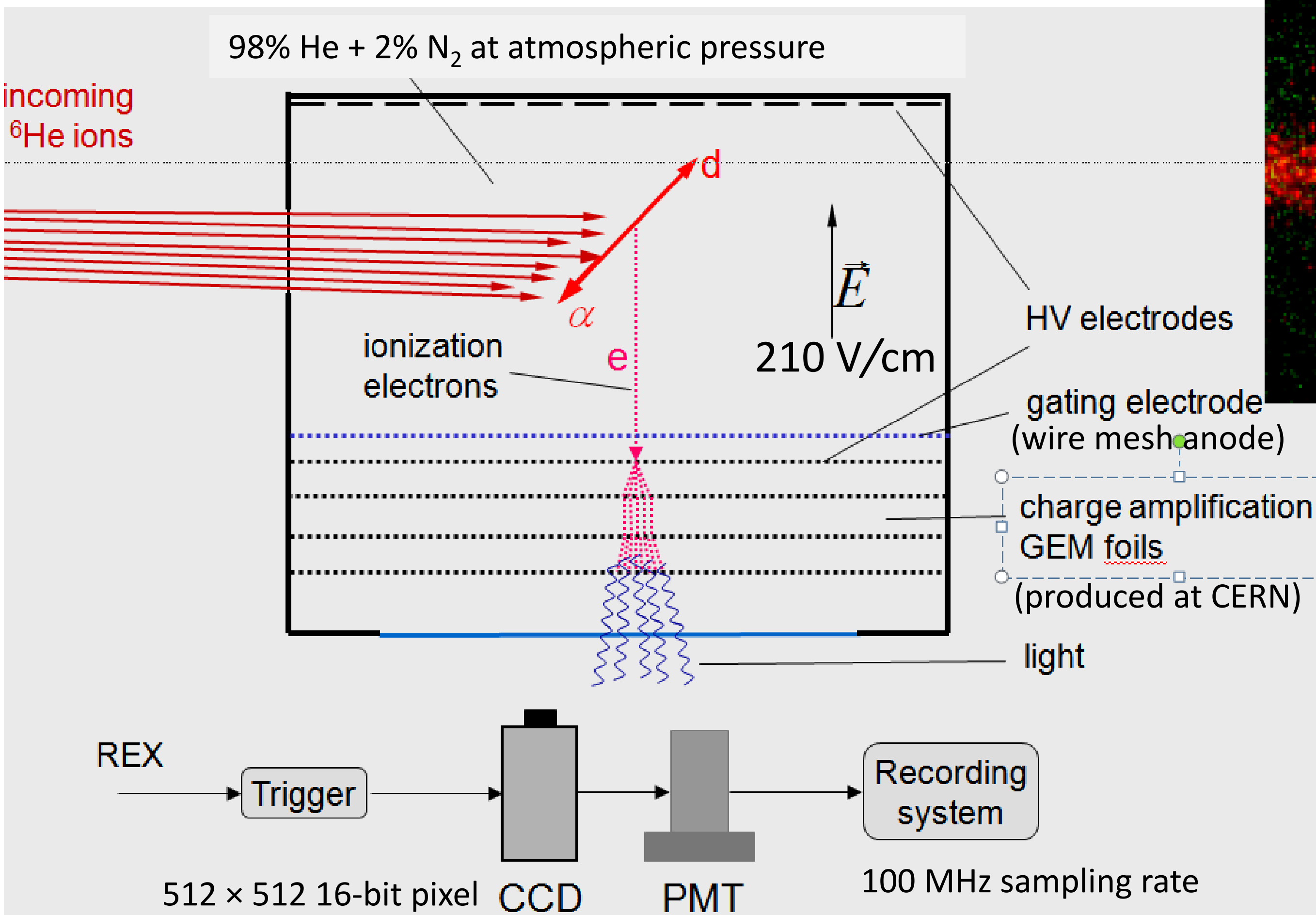
Warsaw OTPC at ISOLDE

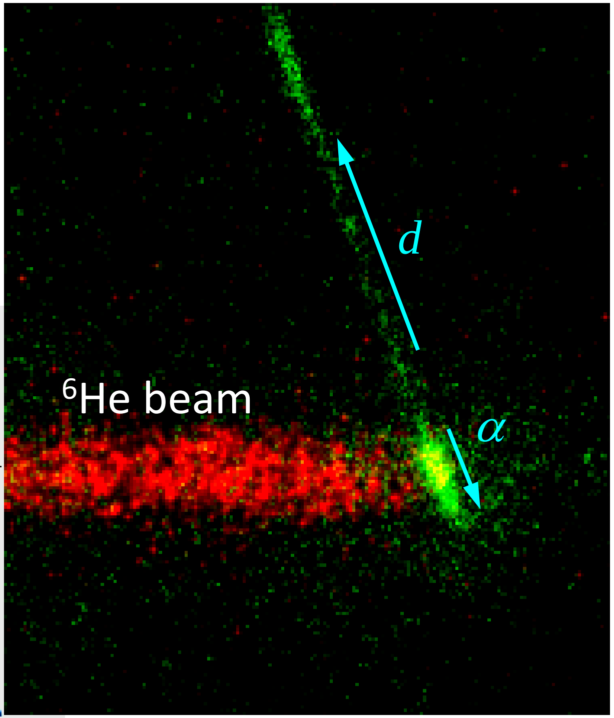
Studying rare decays with particle emission

Rare decay (branching ≈10^{-6}): ^{6}He ➜ α + *deuteron*

-3 MeV/u bunches of about 10^4 ^{6}He ions

- Implantation into OTCP, 650 ms exposure => decays visible



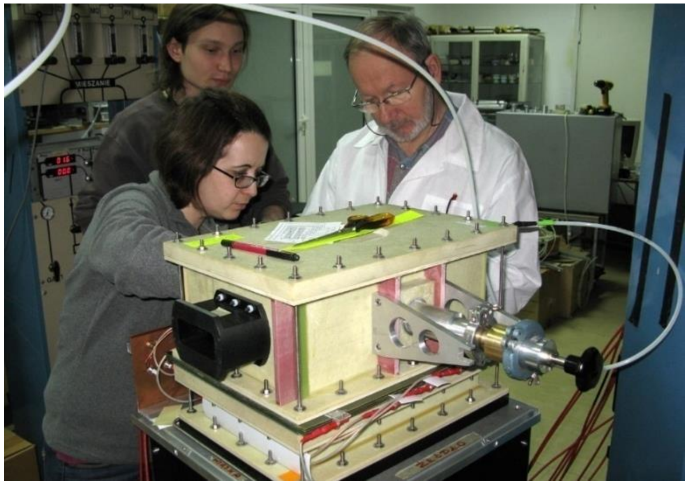


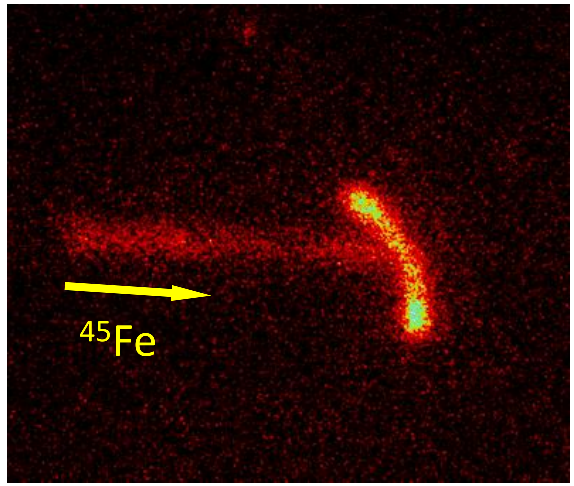
M.Pfutzner et al., Phys. Rev. C 92, 014316 (2015)

Warsaw OTPC at other facilities

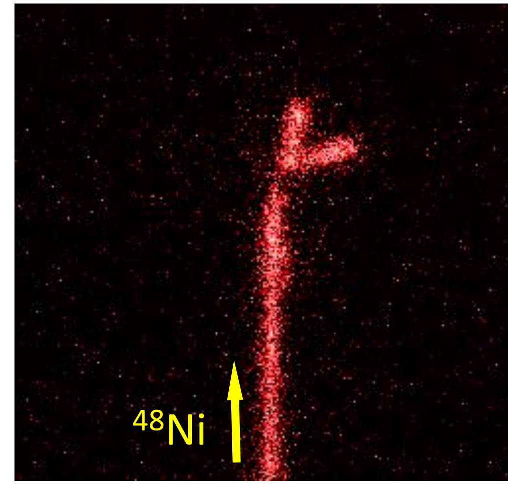
Evidence of 2-proton radioactivity

NSCL, USA: ^{58}Ni @ 161 MeV/u + Ni → ^{45}Fe, ^{48}Ni





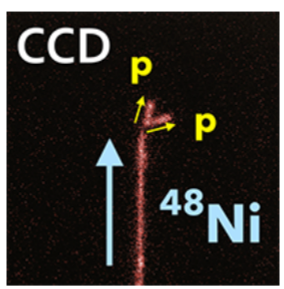
Miernik et al., Phys. Rev. Lett. 99 (2007) 192501



Pomorski et al., Phys. Rev. C 83 (2011) 061303(R)

Physical Review C 50th Anniversary Milestones

50 YEARS PHYSICAL REVIEW C



First observation of two-proton radioactivity in ^{48}Ni

A rare form of radioactivity, in which a proton-laden nucleus decays toward stability via the simultaneous emission of two protons, was observed for ^{48}Ni. Using an optical time-projection chamber, the two-proton emission of four ^{48}Ni nuclei produced at the National Superconducting Cyclotron Laboratory was captured for the first time on CCD camera, marking a new era of optical detection of sub-atomic charged-particle processes in nuclear physics.

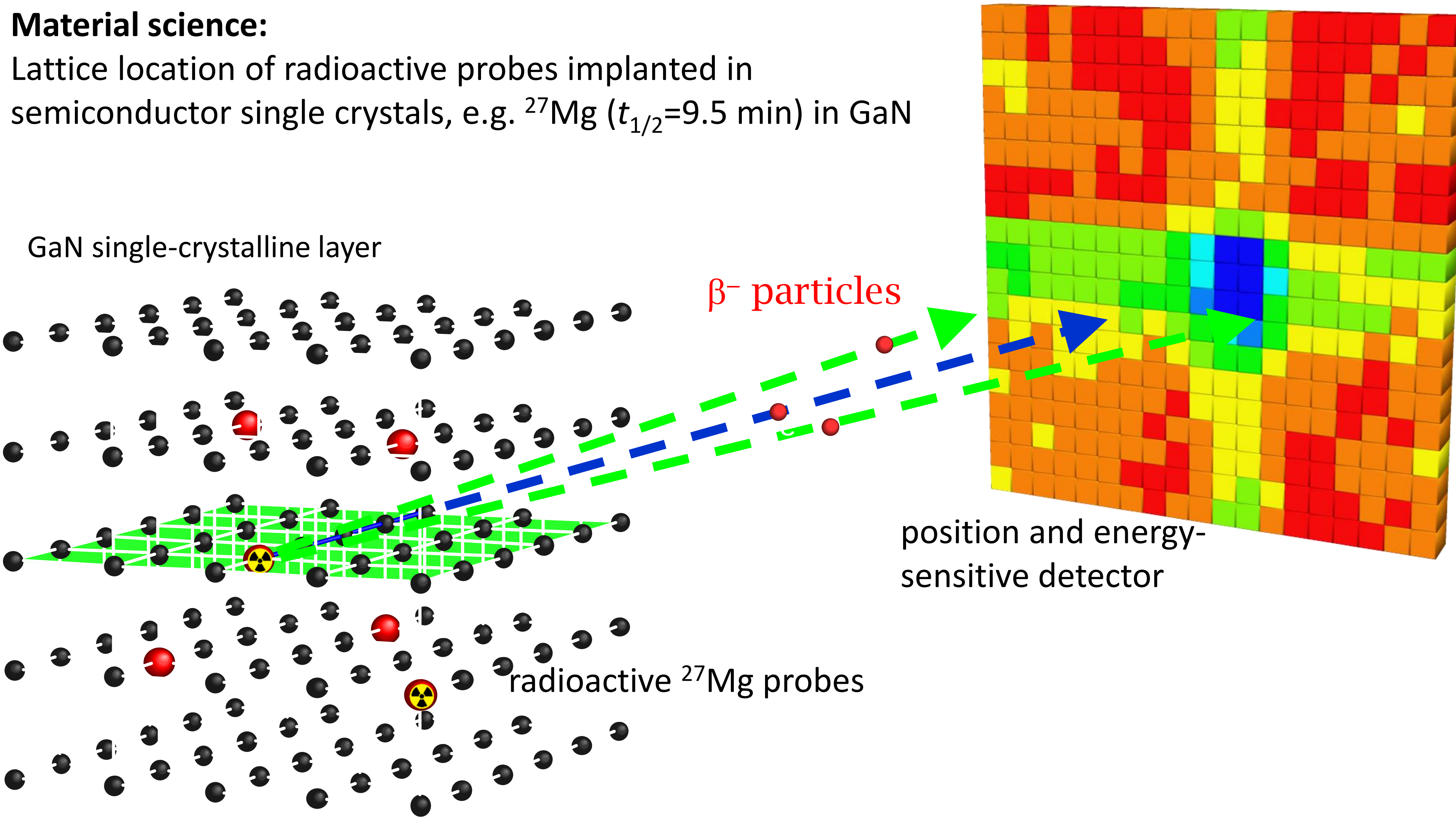
First observation of two-proton radioactivity in ^{48}Ni

M. Pomorski, M. Pfützner, W. Dominik, R. Grzywacz, T. Baumann, J. S. Berryman, H. Czyrkowski, R. Dąbrowski, T. Ginter, J. Johnson, G. Kamiński, A. Kuźniak, N. Larson, S. N. Liddick, M. Madurga, C. Mazzocchi, S. Mianowski, K. Miernik, D. Miller, S. Paulauskas, J. Pereira, K. P. Rykaczewski, A. Stolz, and S. Suchyta

EC-SLI: (beta) emission channeling

Material science:

Lattice location of radioactive probes implanted in semiconductor single crystals, e.g. ^{27}Mg ($t_{1/2}$=9.5 min) in GaN

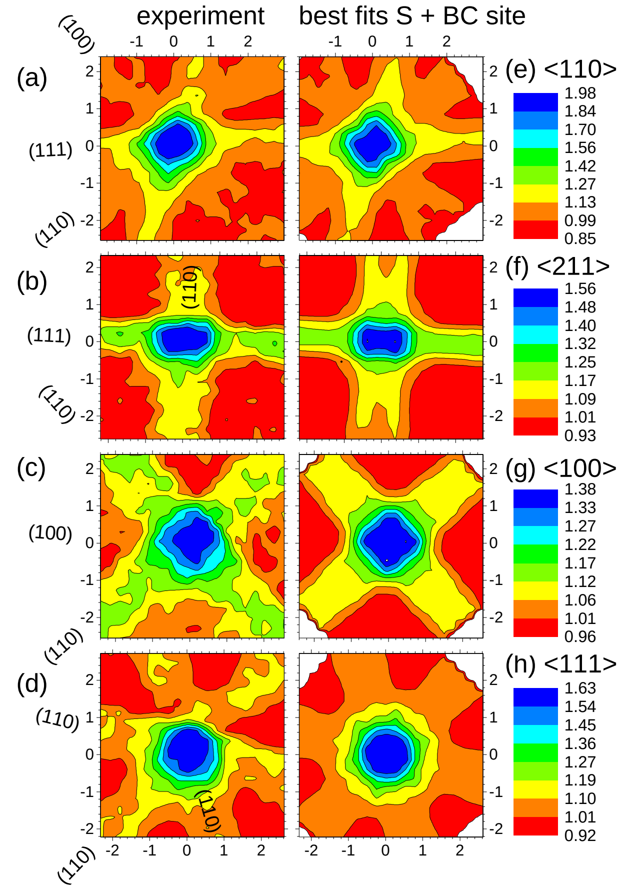


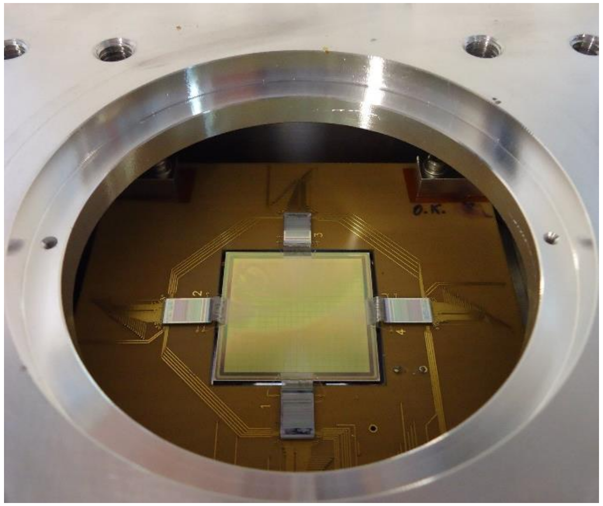
Depending on lattice site of probe atoms =>
emitted β^- particles are channeled or blocked on their way out of crystal

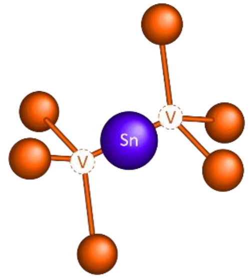
EC-SLI with Si pad detectors

- 3x3 cm^2, 22x22 pixel (1.3x1.3 mm^2) detectors developed at CERN (Peter Weilhammer *et al*) in 1990s as X-ray detectors for PET demonstrators
- Self-triggered readout (VATA-GP3 chips): count rate 3.5 kHz with negligible dead time, saturation at 5 kHz, for on-line measurements
- EC-SLI "Workhorse" detectors since 20 years: a successful spin-off case of CERN detector development

experiment simulation







^{121}Sn (27 h) in diamond

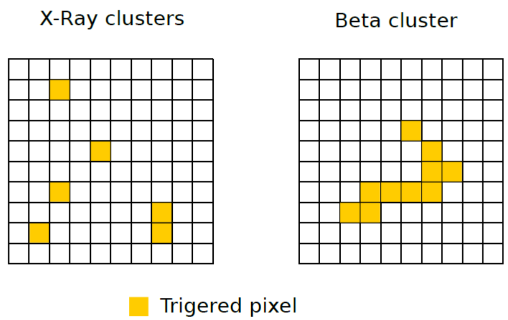
Contact: U. Wahl, Lisbon

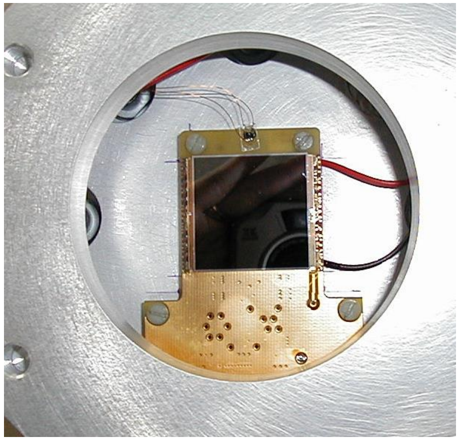
U. Wahl *et al*., NIMA 524 (2004) 245
U. Wahl *et al*., PRL 125 (2020) 045301

EC-SLI with Si Timepix quad detectors

- 3x3 cm2, 512x512 pixel (55´55 mm2) detectors developed by Medipix@CERN collaboration (Michael Campbell et al)
- Needs clustering algorithm

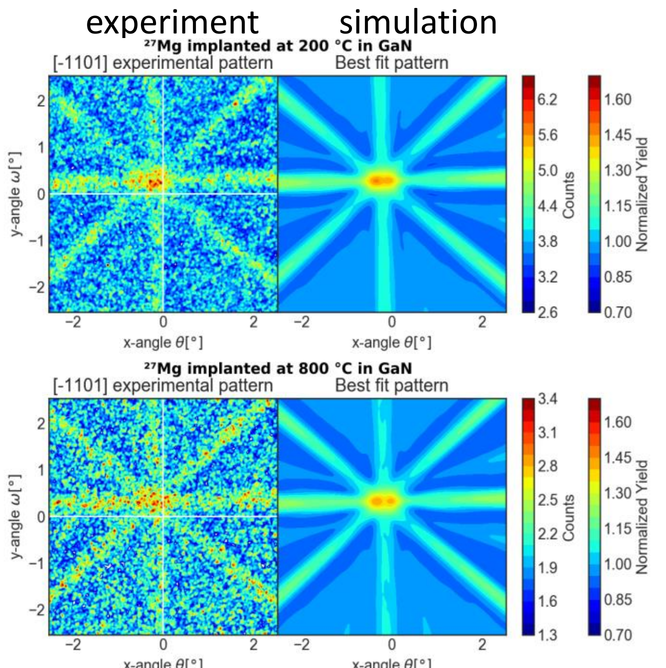
to identify β- tracks





- Tests successful, but frame-based readout of Timepix 2 (e.g. 4 kHz count rate requires 10 frames/s => 50% dead time) proved too slow for EC-SLI routine applications
- Timepix 3 detectors (with faster, data-driven readout in the Mcounts/s range) envisaged to replace the aging pad detectors in the near future

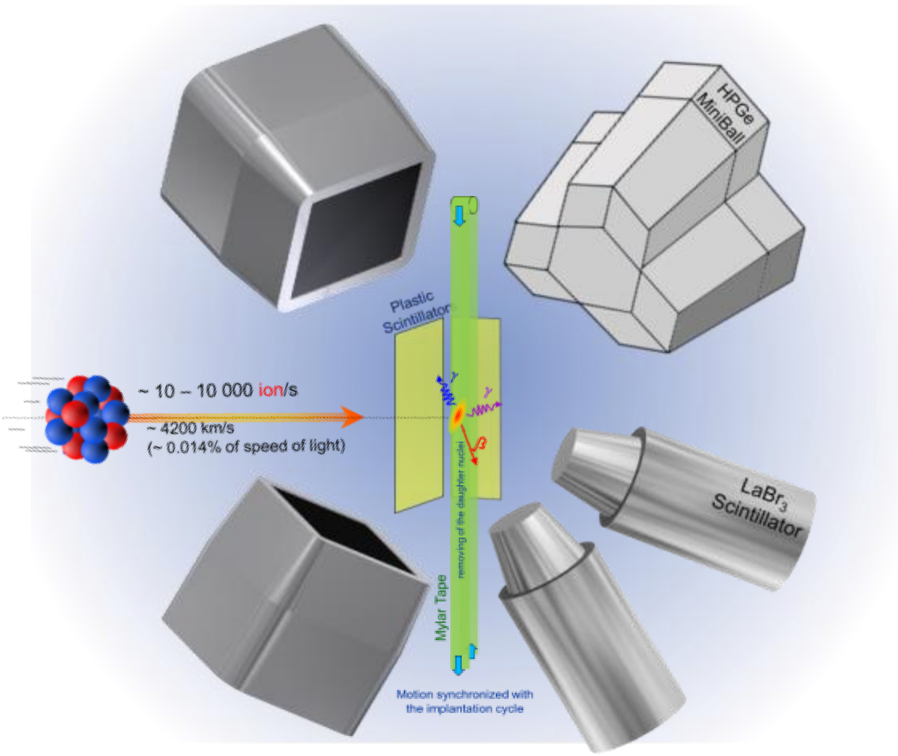
^{27}Mg (9.5 min) *p*-type dopant in GaN (material used in white LEDs)

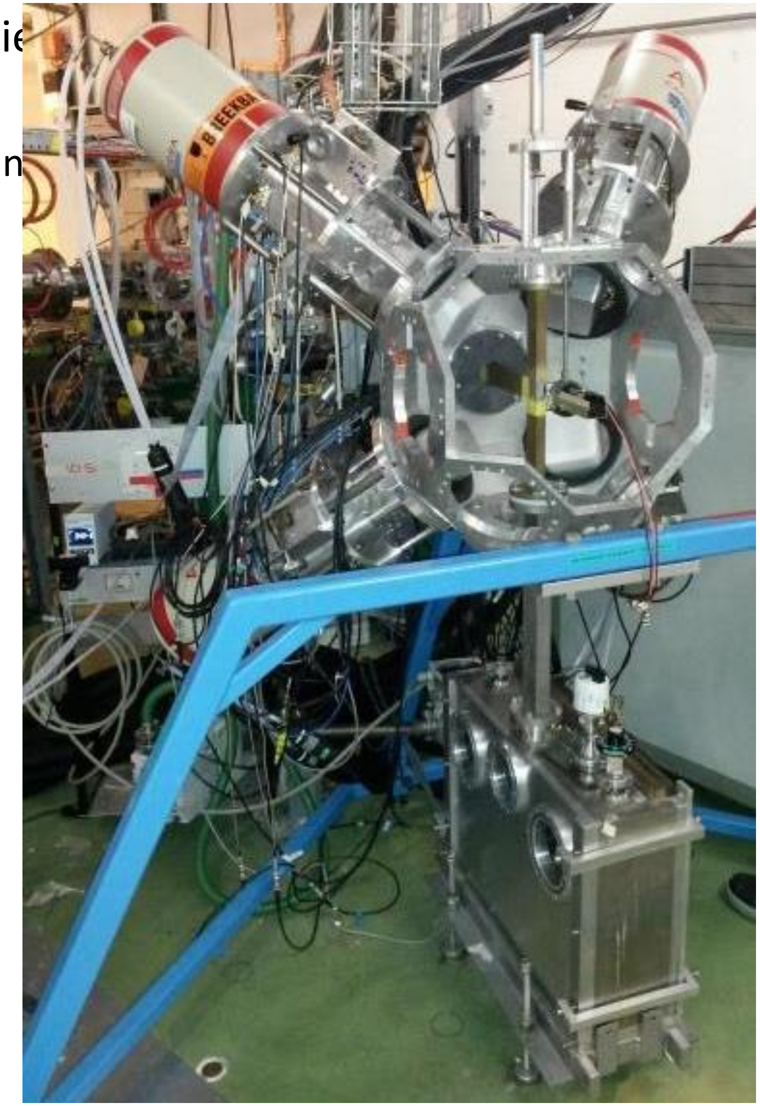


E. Bosne, Emission Channeling Lattice Location Studies in Semiconductors using Highly Pixellated Timepix Detectors, CERN Thesis 2020-239

IDS

- Flexible approach (for several decay types and studie
  - HPGe detectors (4 permanent Clovers + extra)
  - Ancillary detectors (LaBr3, plastic scintillator, silicon, n
  - Tape station
  - In-Source Laser Spectroscopy Studies

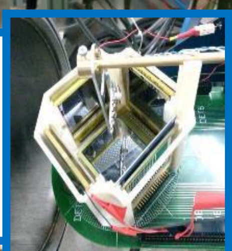




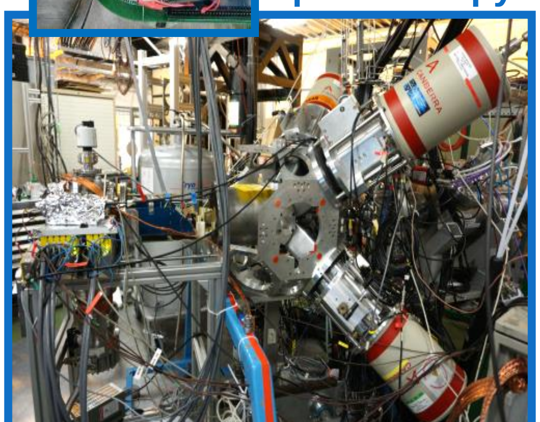
Contact: Razvan LICA, ***IFIN-HH, Romania***

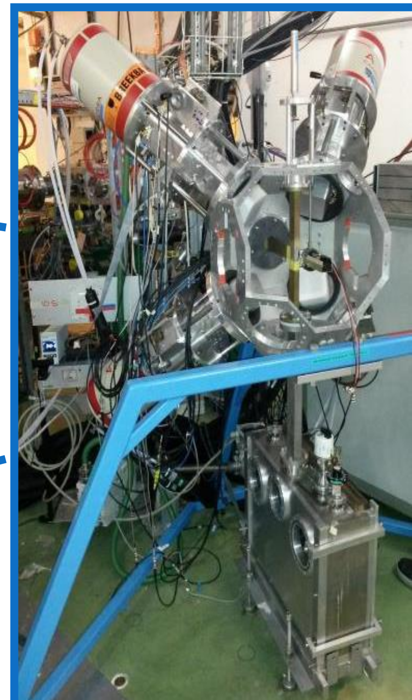
IDS

Neutron Spectroscopy

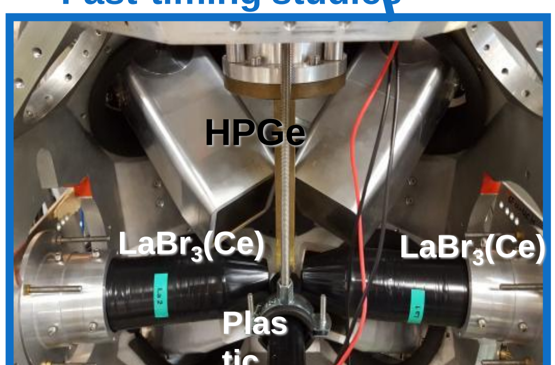


Particle Spectroscopy

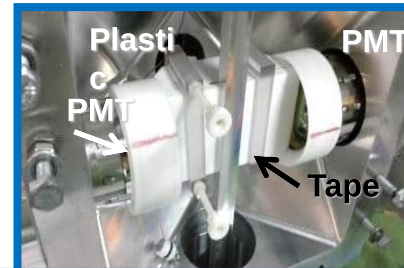


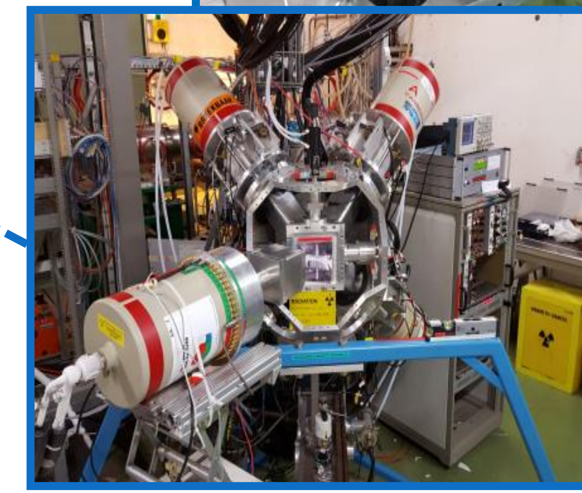


Fast-timing studies

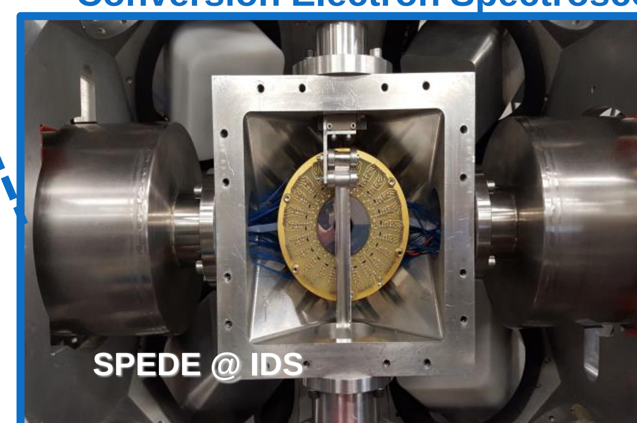


High beta-gamma efficiency



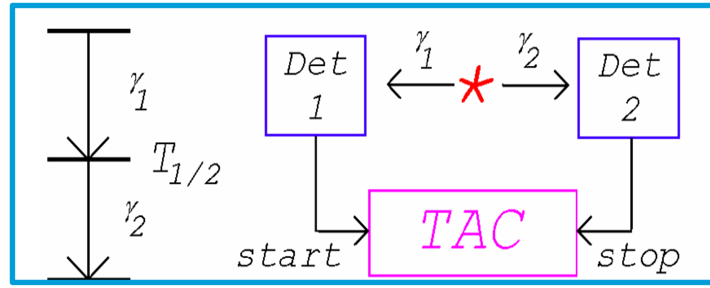


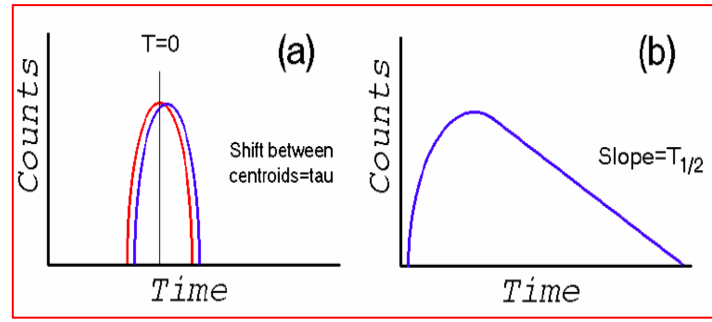
Conversion Electron Spectroscopy

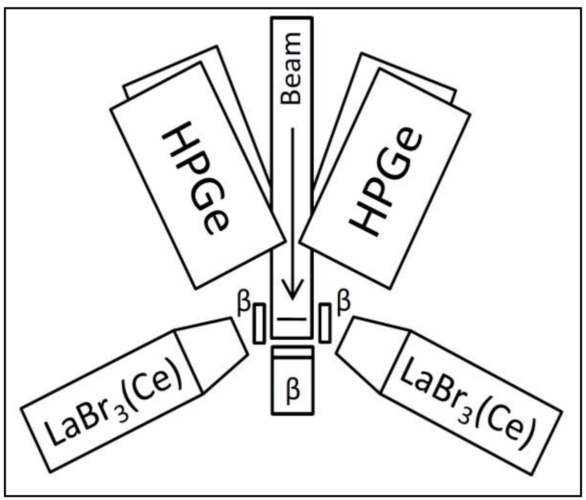


IDS + fast timing

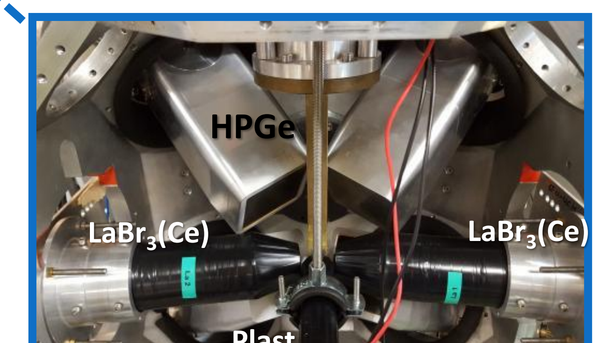
- Well established technique at IDS since 2014
- Detection system:
  - 4 Clover HPGe - 7% abs. eff. at 500keV
  - 2 $LaBr_3(Ce)$ - 3% abs. eff. at 500keV
  - 1 Plastic Scintillator - 20% abs. eff.







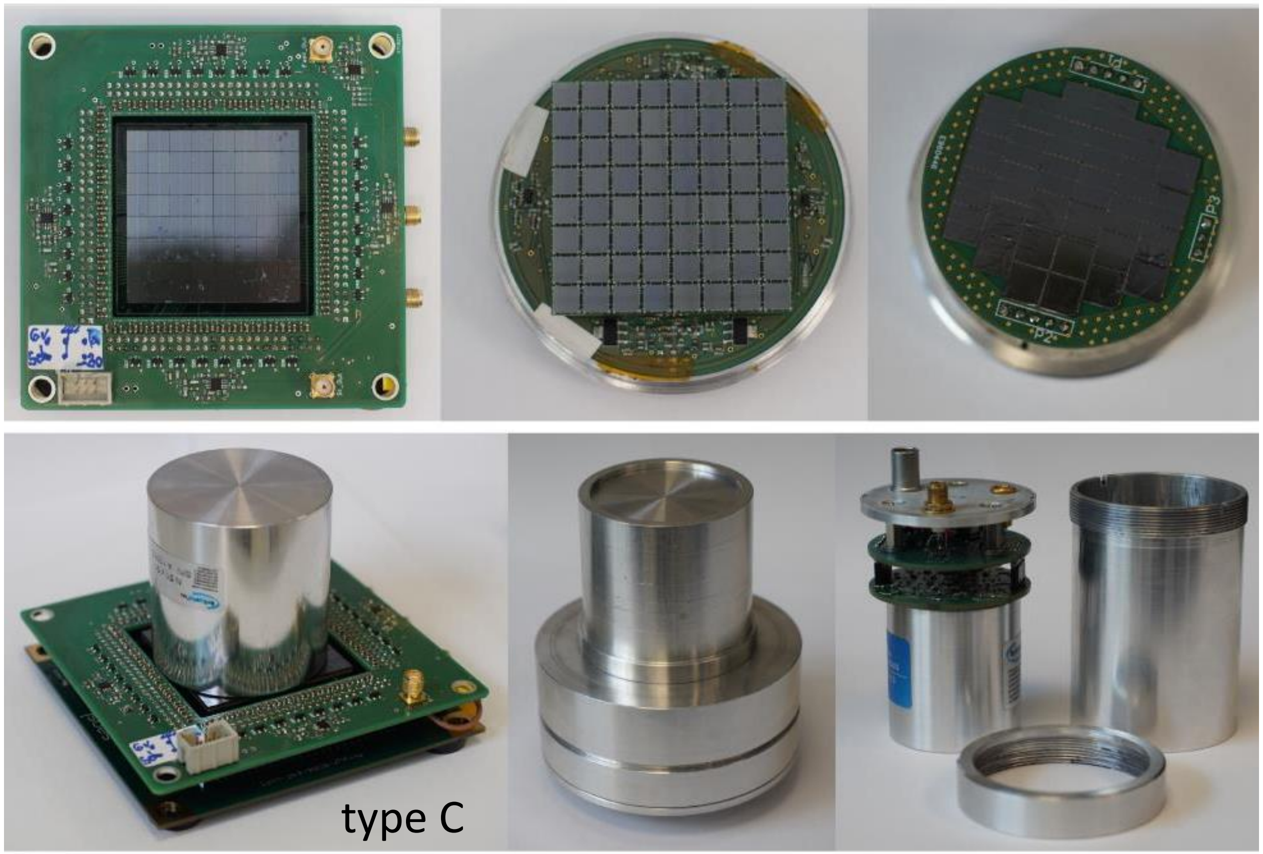
Ranges:
Centroid shift method: - **10 ps - 100 ps**
Slope method - **50 ps - 50 ns** (or longer)
[H. Mach et al. NIM A 280, 49 (1989)]



R. Lica et al., Phys. Rev. C 93, 044303 (2016).
R. Lica et al., J. Phys. G 44, 054002 (2017).
L.M. Fraile, J. Phys. G 44, 094004 (2017).
R. Lica et al., Phys. Rev. C 97, 024305 (2018).

IDS + fast timing

SiPMs developed in-house at IFIN-HH coupled to LaBr3(Ce)



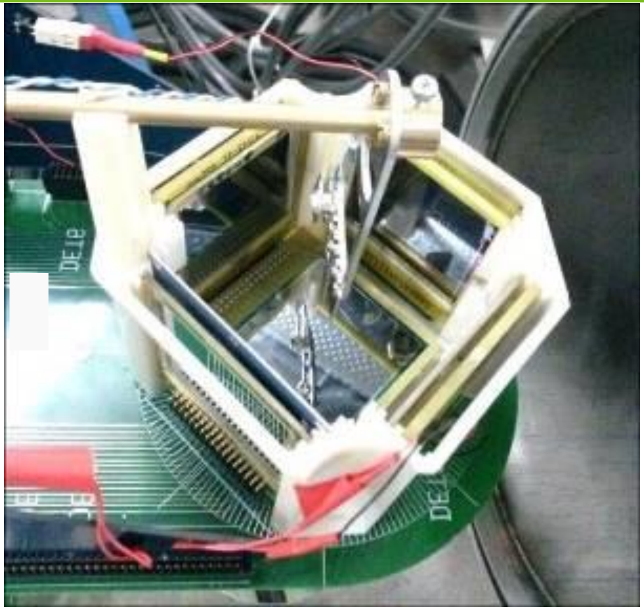
3” crystals with SiPM

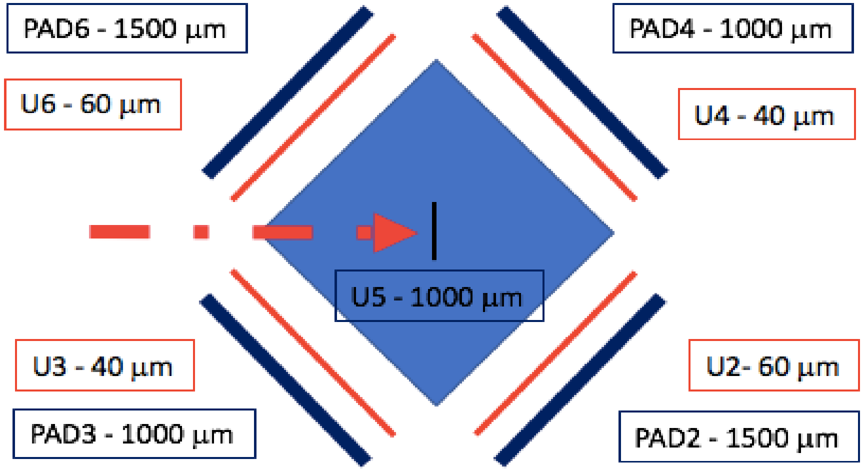
New plastic scintillators

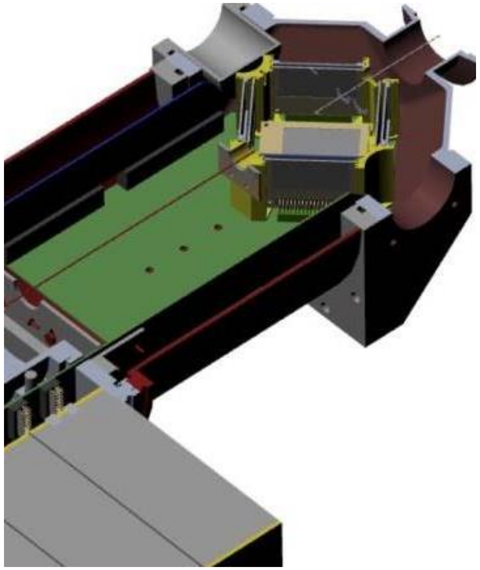
Contact: R. Lica, IFIN-HH, Romania, L. Fraile, Madrid

IDS particle detection

MAGISOL







- 4 HPGe Clover-shape detectors at forward angles
  + Si box: 5 Double-Sided Si Strip Detectors (DSSSD), 4 Pads
- **DAQ: ISOLDE MBS** and IDS Nutaq use in parallel (synchronized)
- Beam implanted on ^{12}C foil or tape

MAGISOL detectors, electronics and DAQ:

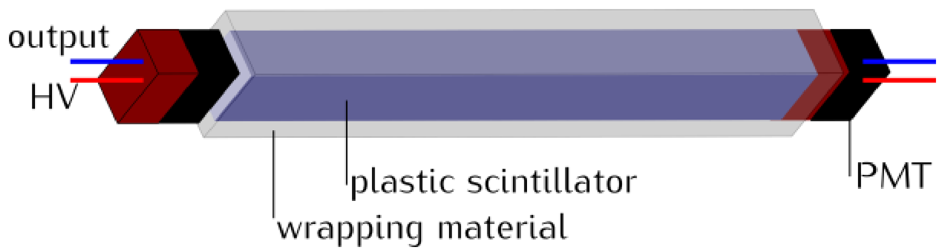
- 165 ch: **Mesytec** preamplifiers (2xMPR64, 2xMPR32)
- Mesytec STM16+ shapers

Contact: H. Fynbo, K. Riisager, U Copenhagen

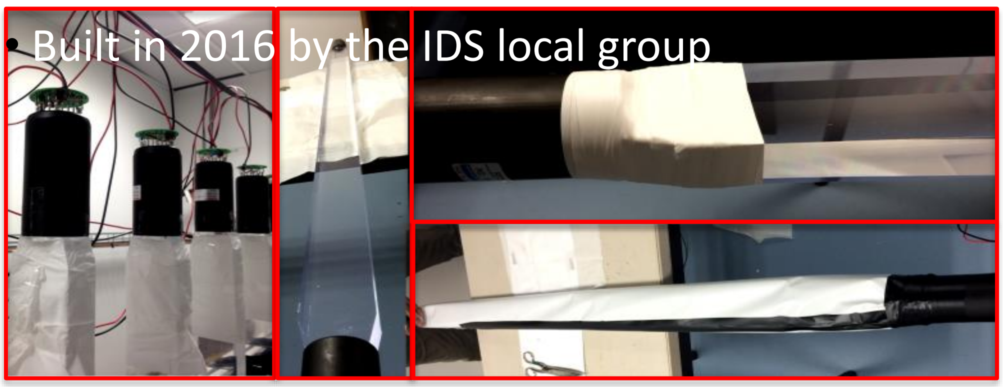
H. Fynbo, O. Tengblad, O. Kirsebom, J. Phys. G 44 (2017), 044005
O. Kisebom et al., Phys. Rev. Lett. 121, 142701 (2018)

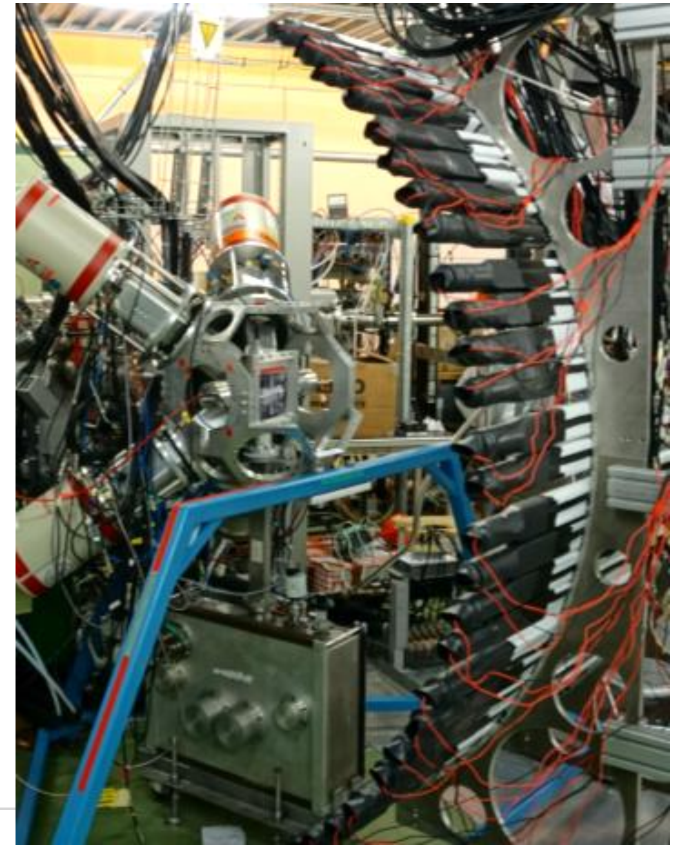
Neutron spectroscopy (INDiE)

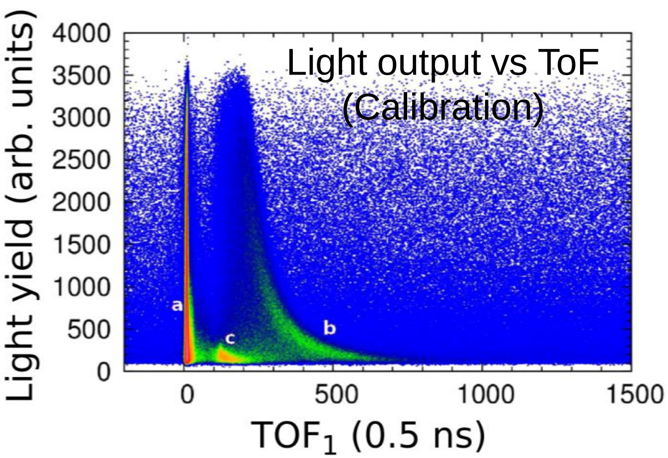
- TOF detector, inspired by VANDLE detector (UTK, USA)

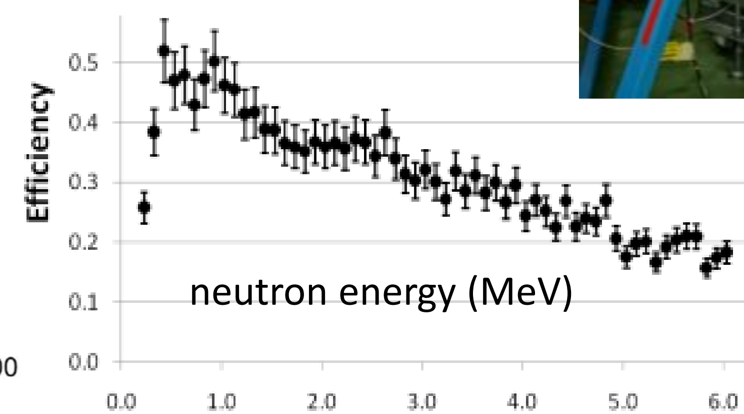


- Built in 2016 by the IDS local group









neutrons @ 1 MeV:

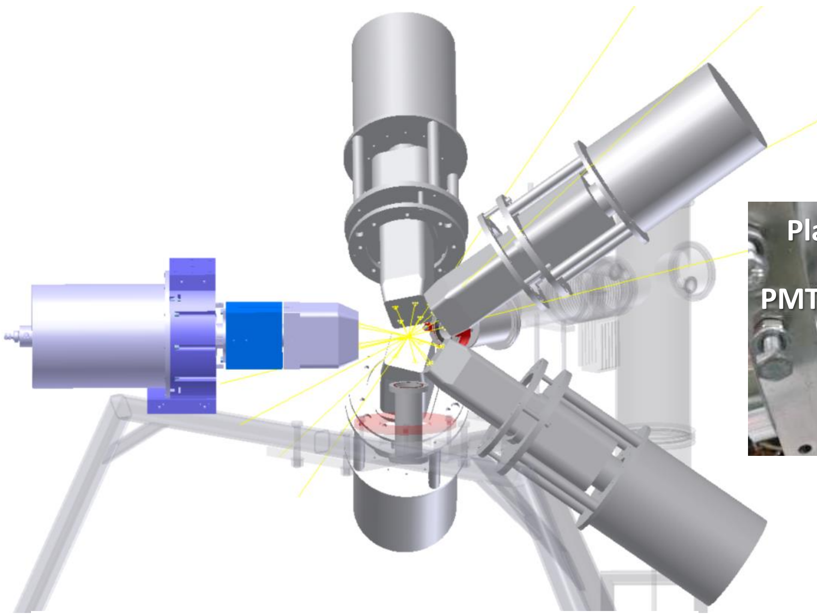
- 45% efficiency/bar
- 80 keV resolution
- Ω = 21.7% of 4π
- 90% β-trigger efficiency
  → 9 % total efficiency

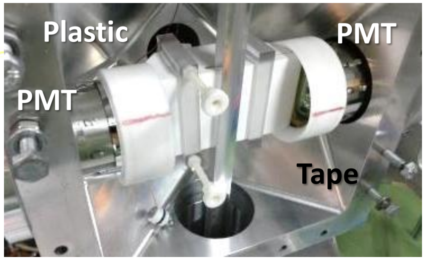
Contact: M. Madurga, U Tennessee - Knoxville

IDS high beta-gamma efficiency

Detection setup

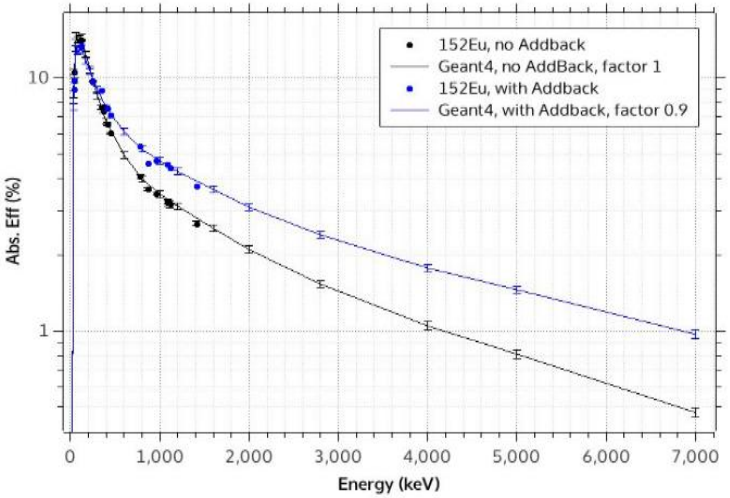
- 5 Clover-shape Ge detectors
- 4π plastic scintillator around implantation point
- 5th Clover detector can be placed at a specific angle to perform **angular correlation studies**.

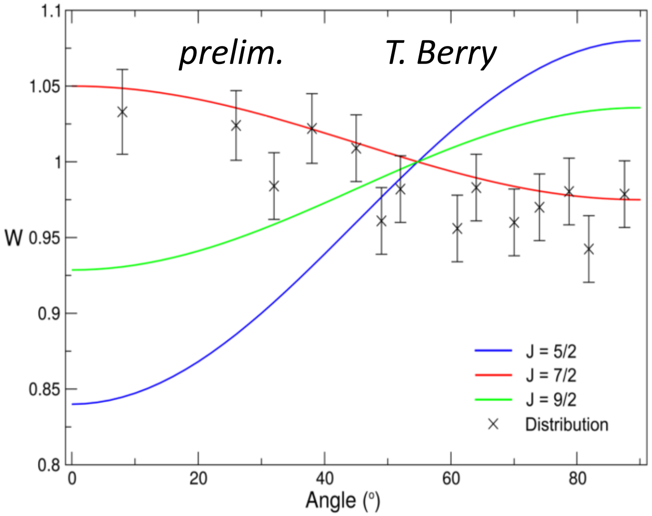


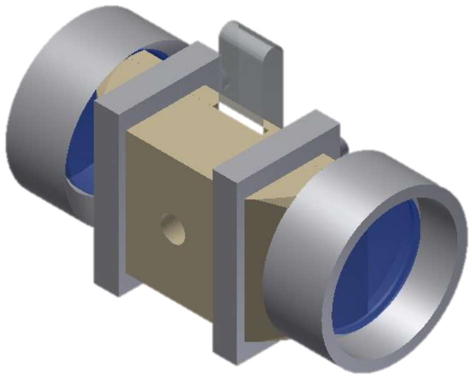


- **Absolute β efficiency - 90(5) %** (single/beta gated ratios)
- **Absolute γ efficiency - 4% @1MeV**

Using GEANT4 to extrapolate



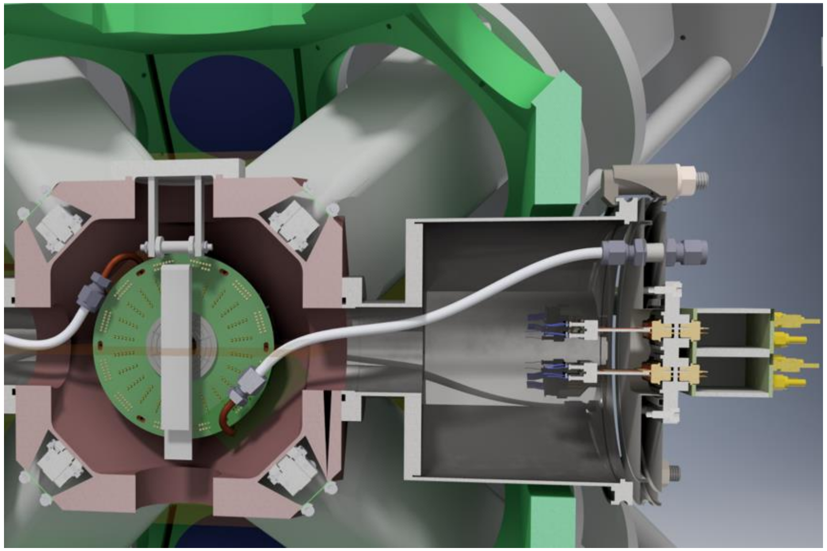




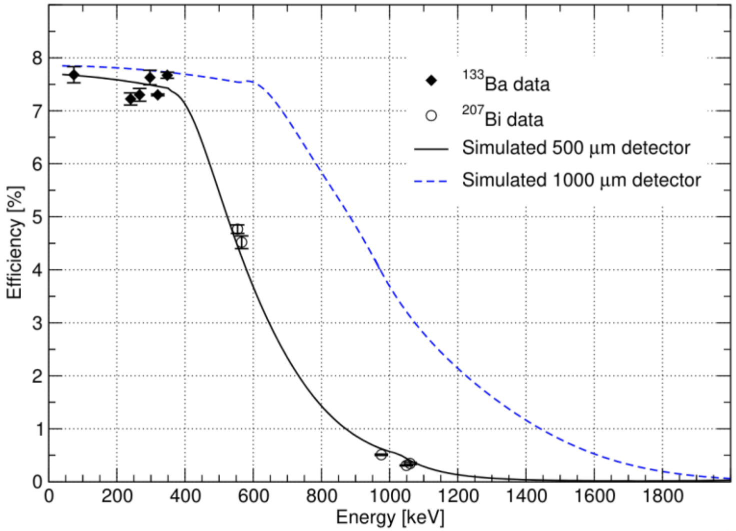
Contact: R. Lica

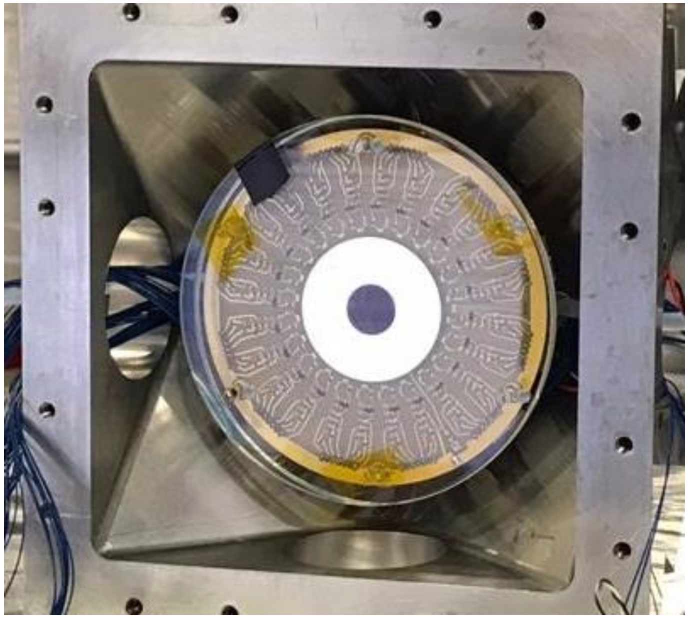
R. Lica et al., Phys. Rev. C 100, 034306 (2019)

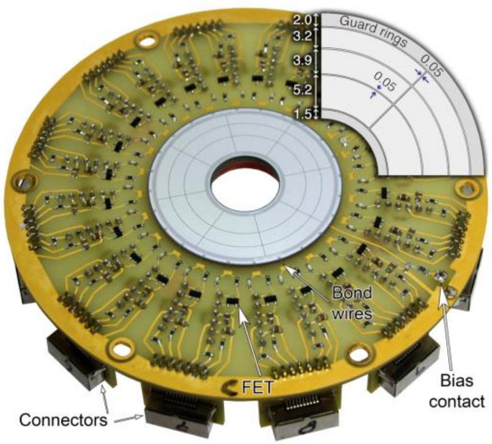
Conversion electron spectroscopy

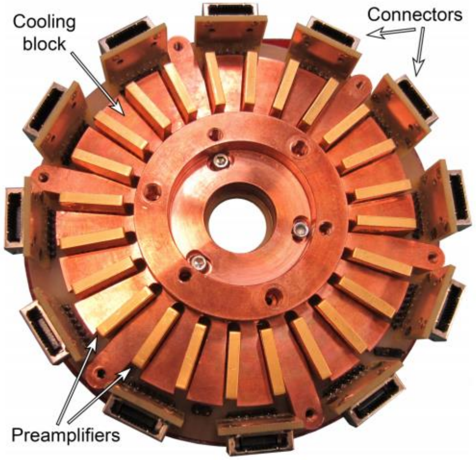


- Annular Si detector with 24 segments
- Ethanol cooled to -20°C
- FWHM at 320 keV around 6-8 keV energy









Contact: J. Pakarinen, Jyvaskyla

P. Papadakis et al., Eur. Phys. J. A. 54:42, 2018

IDS DAQ

Digital DAQ able to run all the different configurations

IDS Configuration	Detectors	Total Channels	OLD DAQ
Particle spectroscopy	4 Clovers + 5 DSSSDs (5 x 32 ch) + 4 PAD (4 x 2 ch) + Logic (6 ch)	**190**	NUTAQ + MBS
Neutron Spectr. (INDiE)	4 Clovers + 26 bars (26 x 2 ch, **traces**) + Beta (2 ch, **traces**) + Logic	**76**	PIXIE
Conversion Electron Spectroscopy	5 Clovers + SPEDE (24 ch) + Beta (1 ch) + Logic	**51**	NUTAQ
High beta-gamma efficiency	5-6 Clovers + Beta (2 ch) + Logic	**32**	NUTAQ
Fast-timing	4 Clovers (4 x 4 ch) + 2 LaBr + Beta (1 ch) + 3 TAC + Logic	**28**	NUTAQ

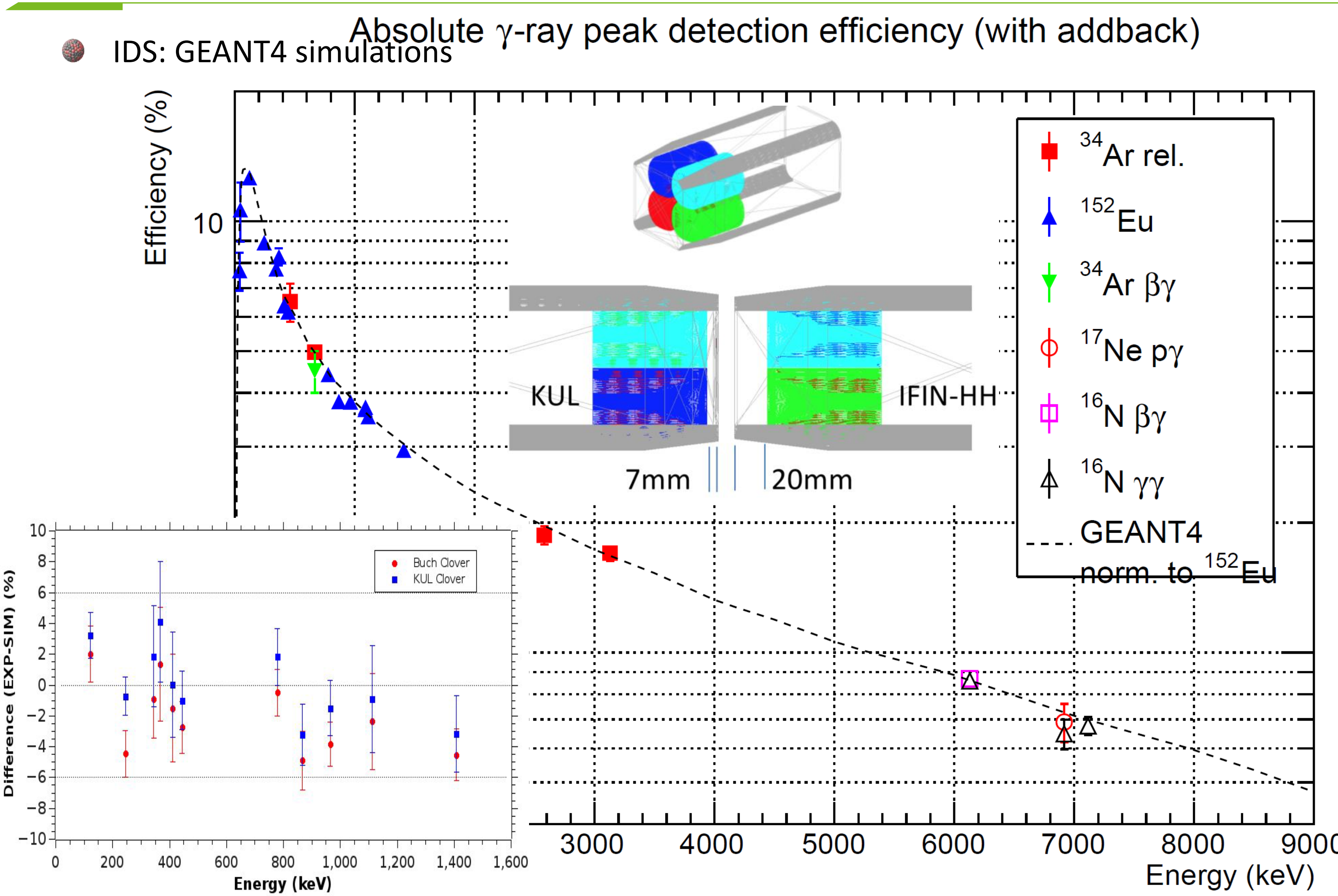
NUTAQ: 100 MHz, 14 bit ADC, **max. 80 ch (5 x 16)**

PIXIE: 250 MHz, 16 bit ADC, **max. 208 ch (13 x 16 / crate) ->** tested and installed in 2020

FEBEX: 100 MHz, 14 bit ADC, 16 ch / module. (v4)

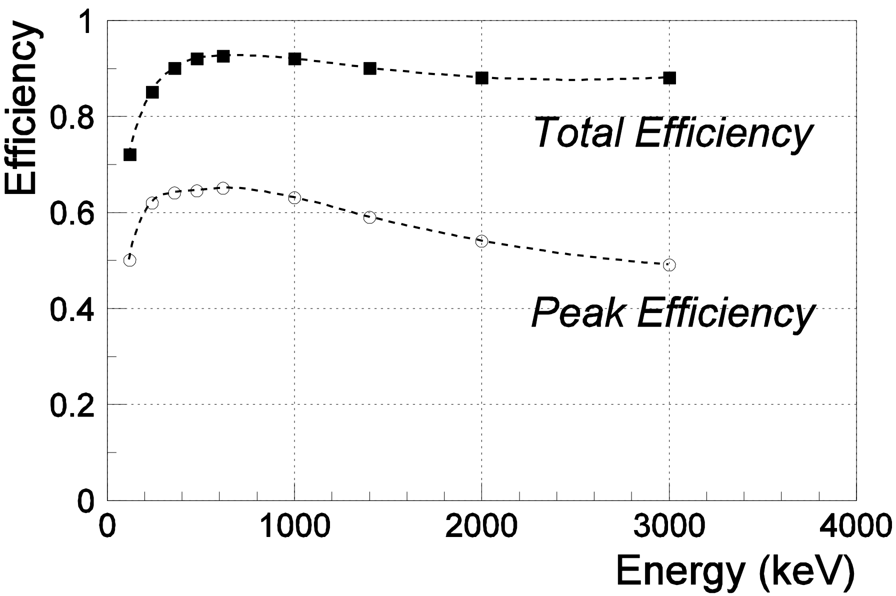
High-purity germanium gamma detectors

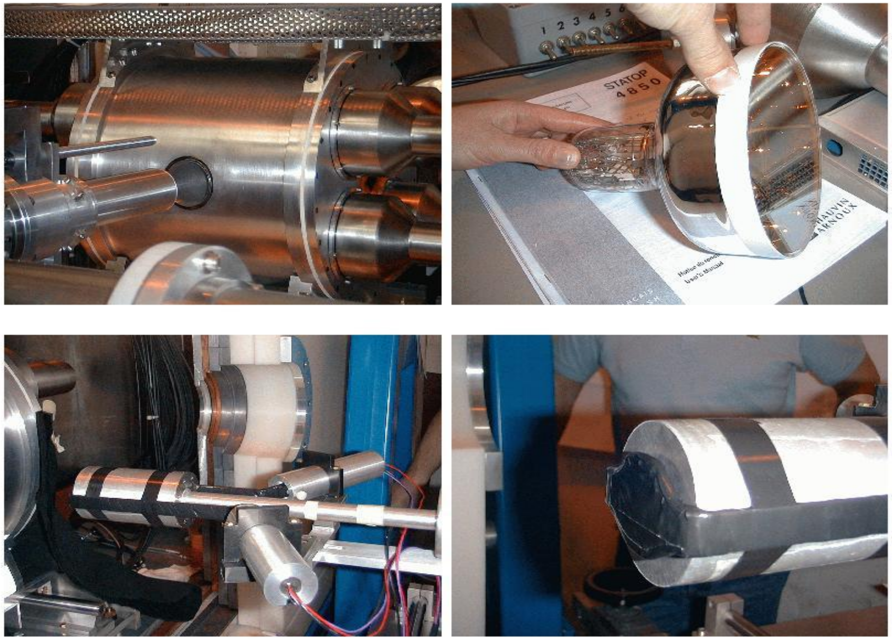
- IDS: GEANT4 simulations



LUCRECIA

- Permanent TAS setup at “Lucrecia”





- Main crystal: NaI(Tl) cilinder of big dimensions (∅38 cm x 38 cm);

- Ancillary detectors:
  - plastic scintillator
  - Ge telescope (planar/coaxial)

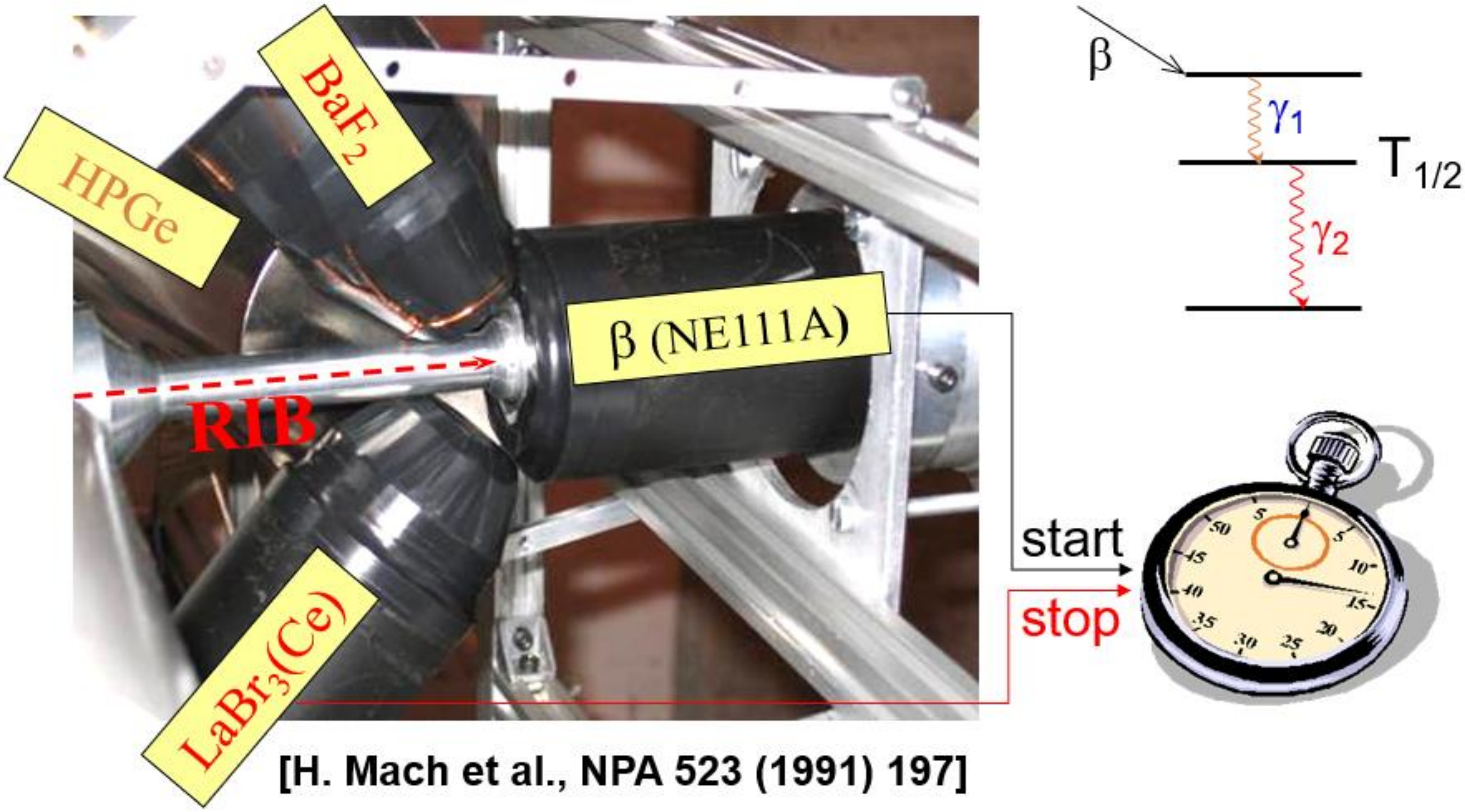
Summary and oulook

- Number and versatility of ISOLDE detectors matches that of the unstable nuclei it produces
- This talk: examples of detectors for gamma-rays, charged particles, neutrons
- Not covered in this talk: ion and atom detectors
- Aim: give an overview of ISOLDE detectors and trigger discussions, collaborations with the respective groups

Fast timing

Contact: L. Fraile, UCM, Madrid

The Advanced Time-Delayed ßγγ(t) method



Time difference

[H. Mach et al., NPA 523 (1991) 197]

HPGe: BRANCH SELECTION
High energy resolution
Poor time response

Plastic β scintillator: TIMING
Fast response
Efficient start detector

$LaBr_3$(Ce)/BaF_2: TIMING
Fast response γ-detectors
Stop detectors

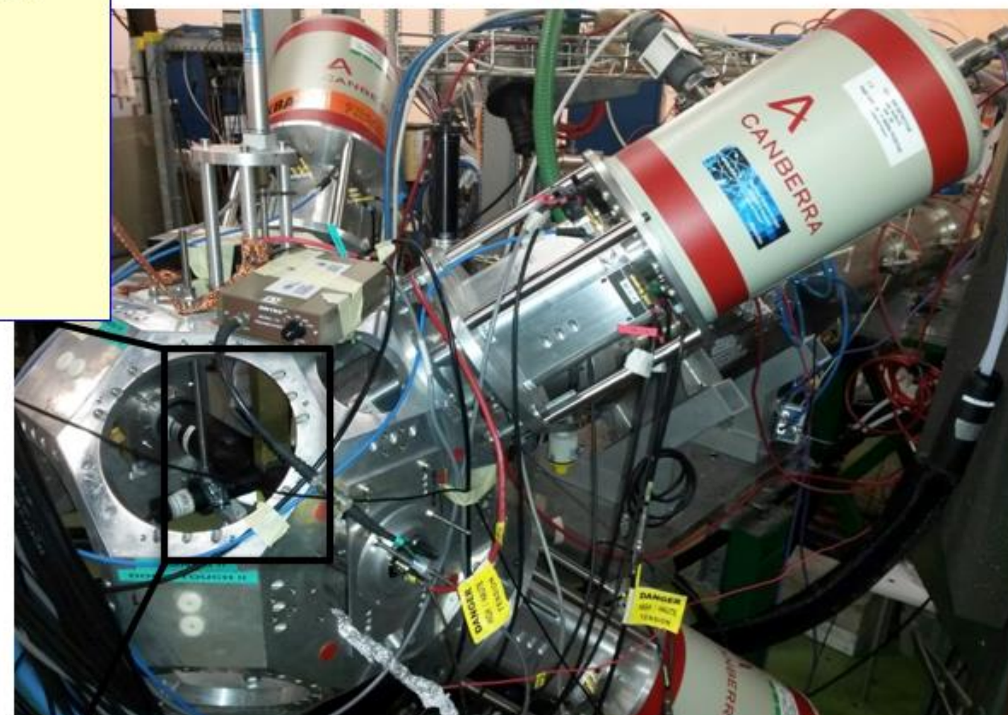
→ **Double coincidences: βγ: beta-Ge and beta-$LaBr_3$**

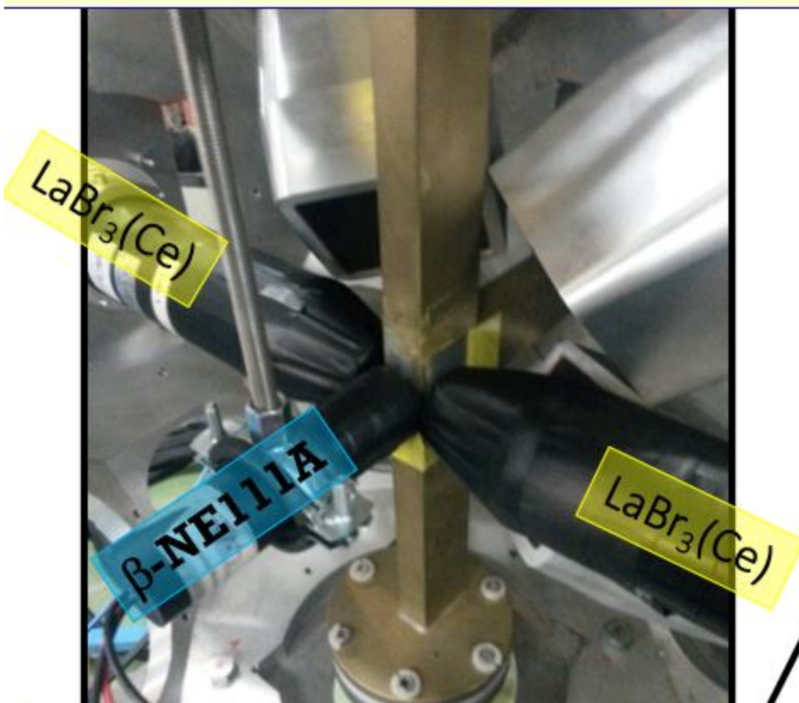
→ **Triple coincidences βγγ: beta-Ge-Ge and beta-Ge-$LaBr_3$**

ISOLDE Decay Station

Fast-timing, GFN-UCM

- 4 Clover HPGe ~ 3.7% **eff**. @600keV
- 2 $LaBr_3$(Ce) ~ 4% (2% each) @600keV (or up to 6 detectors)
- 1 Plastic Scintillator ~ 20% eff.
- DAQ – Digital system
- Analog TACs

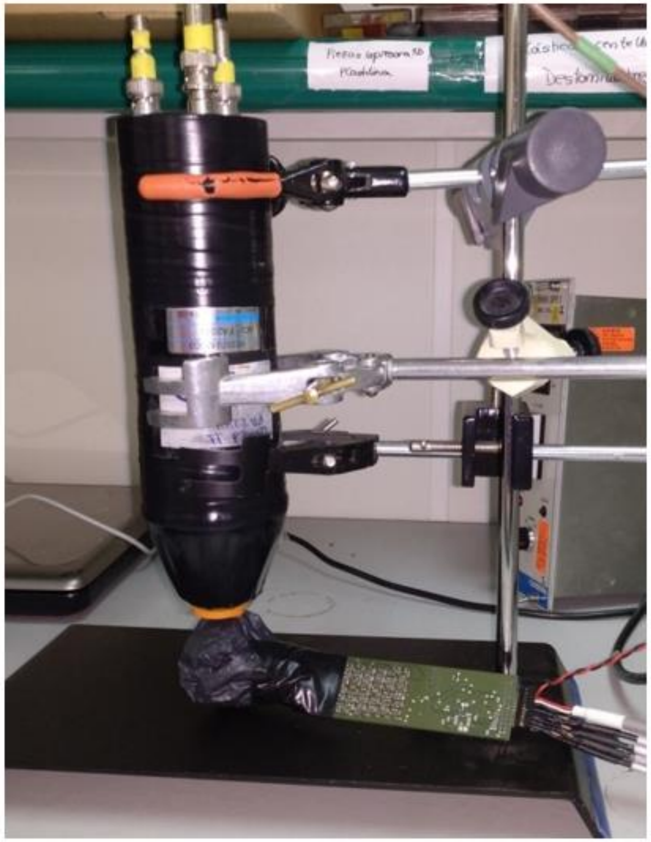




- Analog timing processing: ORTEC CFD and 3 TAC for fast-timing
- Digital DAQ **Nutaq / XIA Pixie**

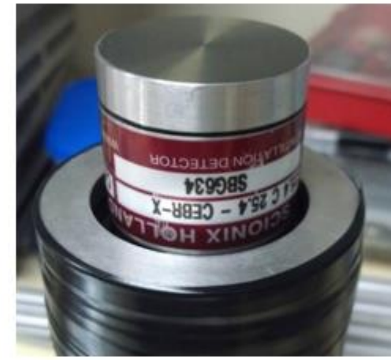
- Movable tape system to remove activity

Detectors



CLYC Pr:LuAG

SrI_2



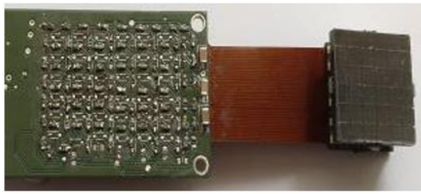
$LaBr_3(Ce)$

Tipo	Estructura	Cantidad
Alcalinos	$LaBr_3(Ce)$	1
	NaI(Tl)	3
	CsI(Tl)	2
	KI(Tl)	1
No Alcalinos	BaF_2	1
	GSO	1
	LYSO	1
	BGO	1
	LFS	2
	MLS	64

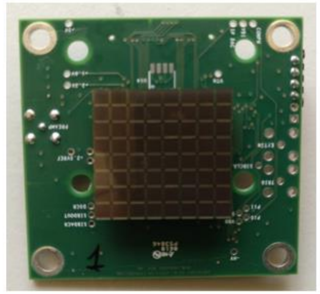
Instituto de Física de Partículas y del Cosmos

Si PMs and boards

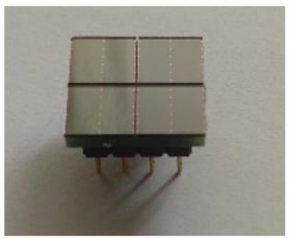
Grupo de Física Nuclear



Array 6x6 MicroFJ-30035 (SensL)

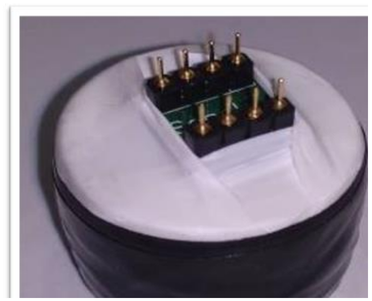


Array 8x8
PA3325-WB
(Ketek)

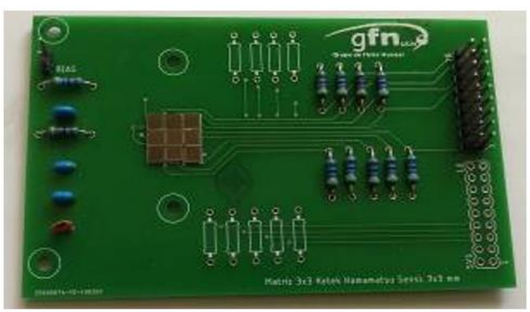


Array 2x2 MicroFJ-60035 (SensL)

Lanthanum bromide 2x2 cm + Array 2x2 SiPM 3x3 mm



Grupo de Física Nuclear



Array 3x3 PM3325-WB (Ketek)
Array 3x3 MicroFJ-30035 (SensL)

Cross Array 2x2 MicroFJ-60035 (SensL)

LaBr3

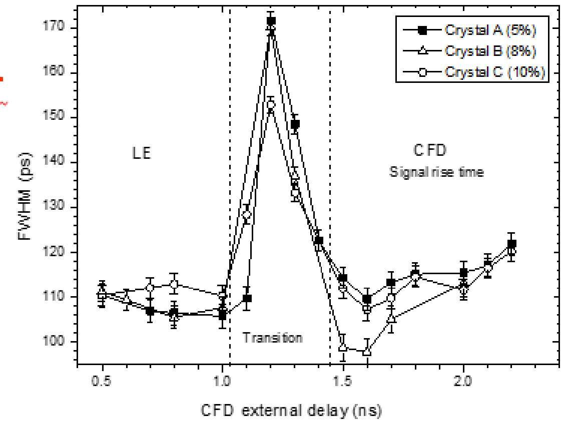
1-inch cylindrical $LaBr_3(Ce)$ crystal

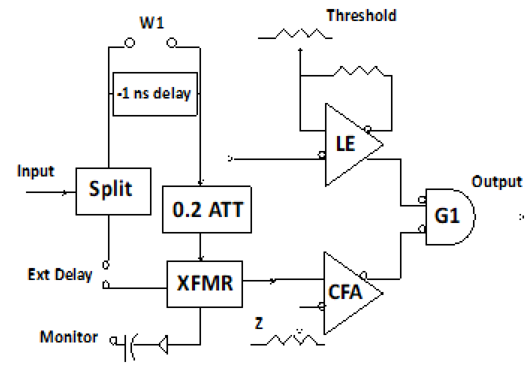
✓ Optimization procedure: PARAMETERS

→ HV applied to PMT

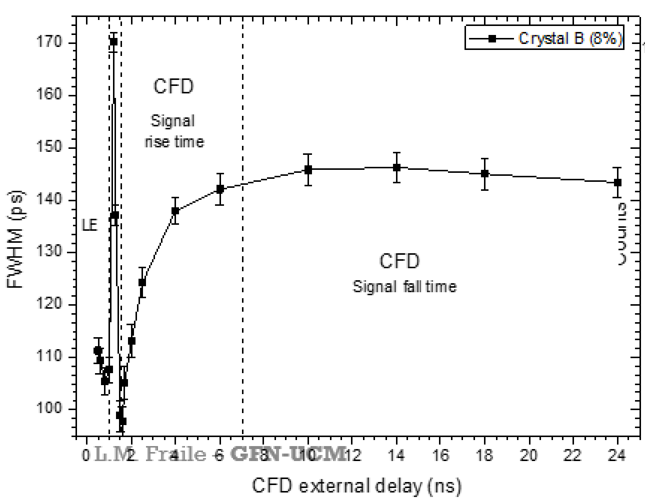
→ "External CFD delay

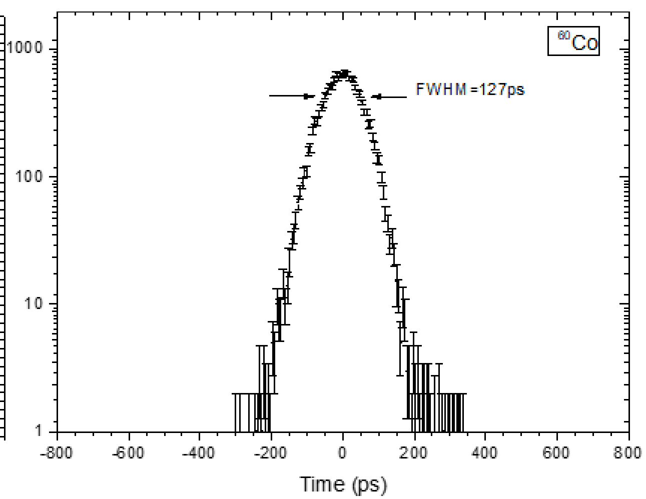
→ Zero crossing





V. Vedia et al.,
Nucl. Instrum. Methods A 795 (2015) 144–150





$LaBr_3(Ce)$ detector FWHM time resolution:

148(2) ps ^{22}Na 511 keV
98(2) ps ^{60}Co source.

LaBr3

Nuclear Instruments and Methods in Physics Research A 867 (2017) 98–106

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

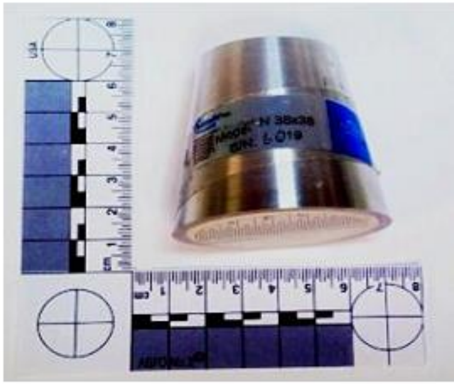
journal homepage: www.elsevier.com/locate/nima

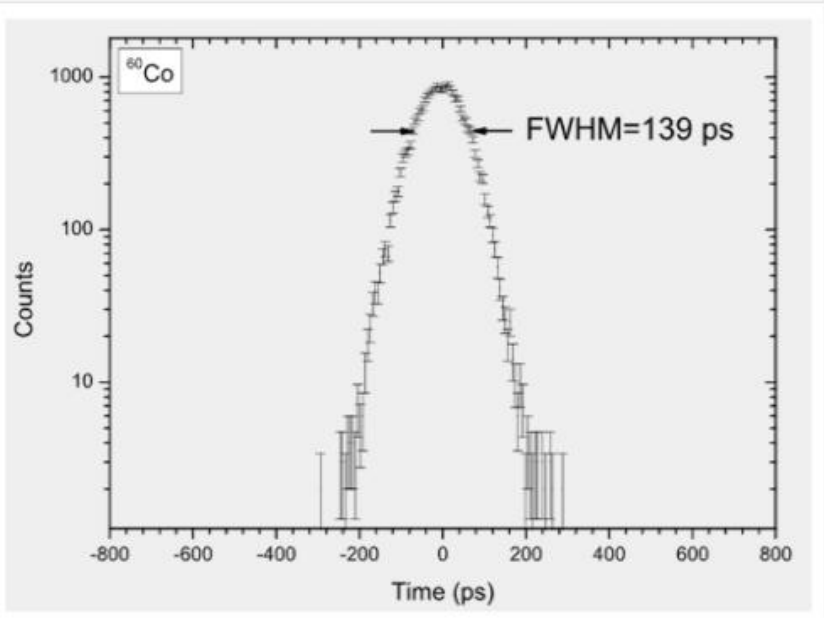
Performance evaluation of novel $LaBr_3(Ce)$ scintillator geometries for fast-timing applications

V. Vedia[a,*], M. Carmona-Gallardo[a], L.M. Fraile[a], H. Mach[a,b,1], J.M. Udías[a]

[a] Grupo de Física Nuclear, Facultad de CC. Físicas, Universidad Complutense, CEI Moncloa, 28040 Madrid, Spain

[b] National Centre for Nuclear Research, Division for Nuclear Physics, BP1, Warsaw, Poland





- Design of scintillator shapes and geometries for fast timing applications
- Optimization of parameters of readout using fast PMTs and analog electronics
- Best time resolution to-date obatined

> FWHM time resolution:
> 110±3 ps @ ^{60}Co
> 158±3 ps @ ^{22}Na 511 keV

- Fully-digital readout for time and energy
- Coupling to SiPM and readout

CeBr3

Alternative:

Price

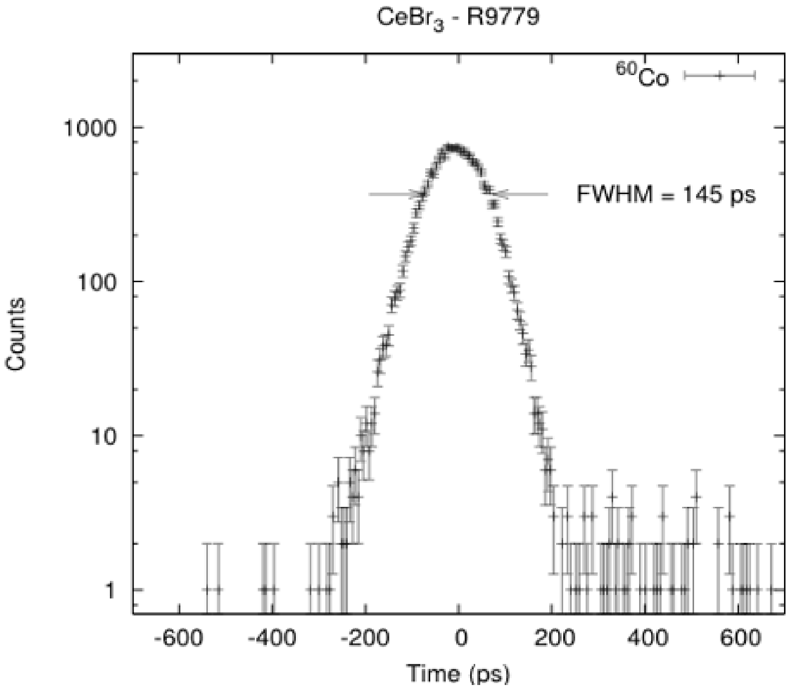
E resolution

Timing

Geometries…

FWHM

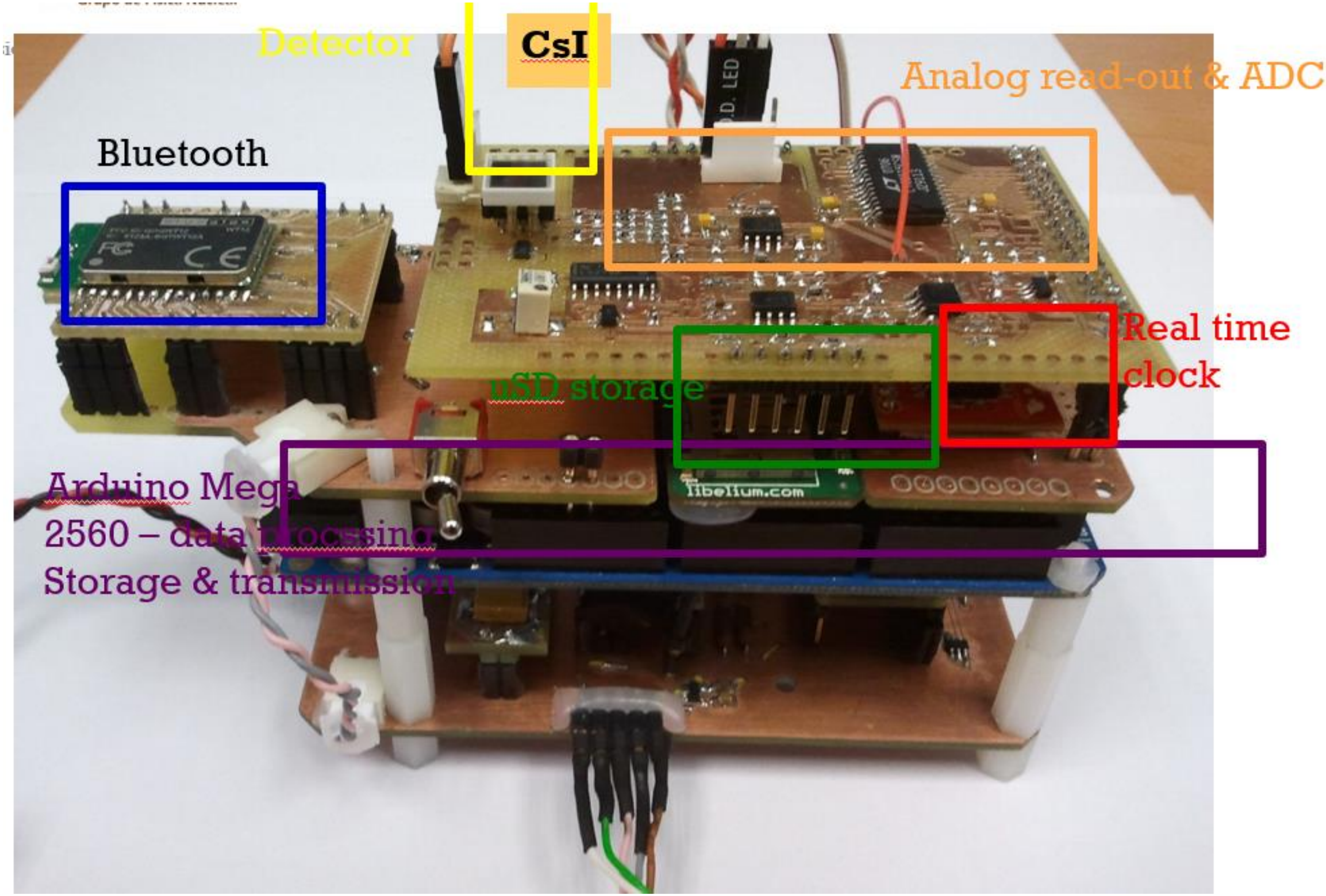
119 ± 2 ps at ^{60}Co



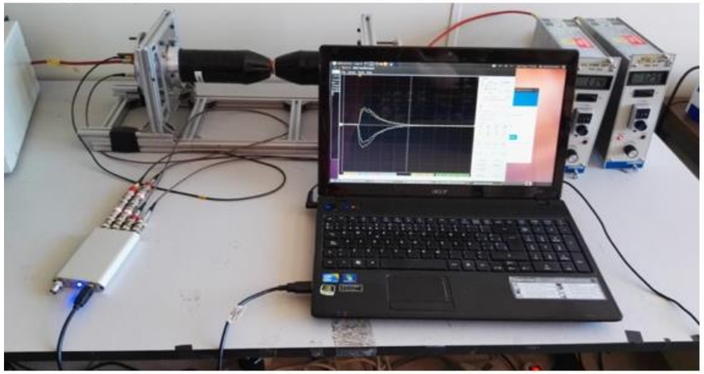
NIM A701 (2013) 235

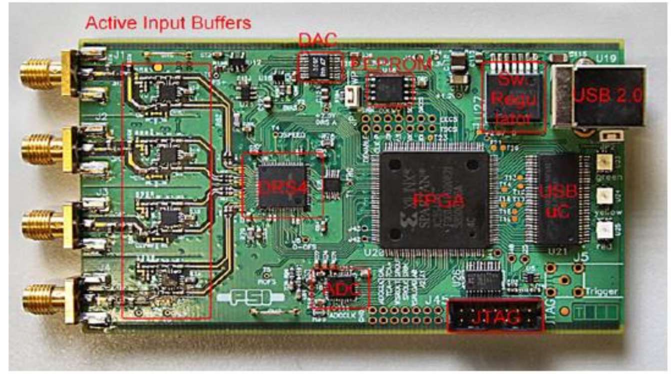
Time resolution FWHM (ps) per detector					
PMT	^{60}Co	^{22}Na	Delay (ns)	HV (V)	Z (mV)
XP20D0	145 ±2	210 ± 2	6.0	1200	-2.2
R9779	119 ±2	164 ±2	1.5	1330	2.0

Integrated system



DAQs





- 4 channels, 1024 samples per channel in a pulse
- 1 to 5 GS/s
- 12 bit
- USB power
- 500 pulses / s in the PC, full 4 channels, 12 bits at 5 GS/s

DRS4 @ PSI
http://drs.web.psi.ch
S. Ritt

- Series 2000
- 1 GS (Maximum) Sampling speed
- 50 MHz bandwidth
- Vertical resolution 8 bits

VME-based data acquisition
XIA digital data acquistion system + …

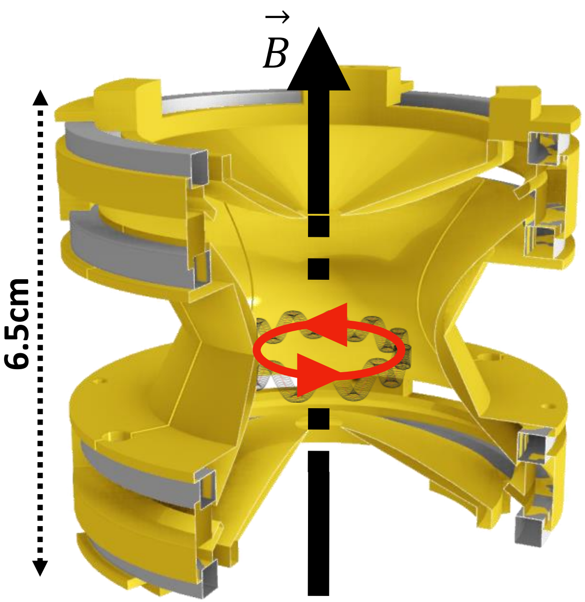
- Continuous digitizing capabilities not really required
- Simple: the same board can acquire and digitize data for energy and time coincidences. Preserve pulse properties
- Flexibe. Any kind of processing and filter is possible, median filter, recursive filters, FFT and frequency based filters.
- Stable and noiseless

Mass spectrometry with ISOLTRAP

Contact: M. Mougeout, K. Blaum, D. Lunney, L. Schweikhard

Penning-trap mass spectrometry at ISOLTRAP

- The Penning trap :

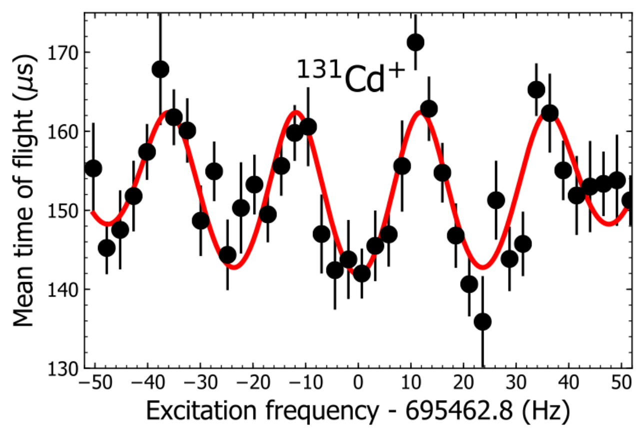


High precision determination of :

$$\nu_c = \frac{qB}{2\pi m_{ion}}$$

- ToF-ICR:

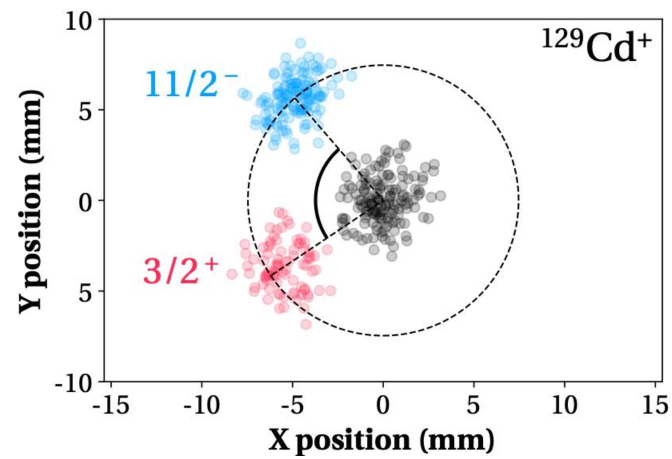
- Scanning
- t_{meas} ~ 50 - 2000 ms
- $\delta m/m$ ~ 10^{-7} - 10^{-9}
- $m/\Delta m$ ~ 10^4 - 10^6



- PI-ICR :

- **Non**-scanning
- t_{meas} ~ 50 - 2000 ms
- $\delta m/m$ ~ 10^{-7} - < 10^{-9}
- $m/\Delta m$ ~ 10^6 - > 10^7

$$\nu = \frac{\phi + 2\pi n}{2\pi t_{meas}}$$

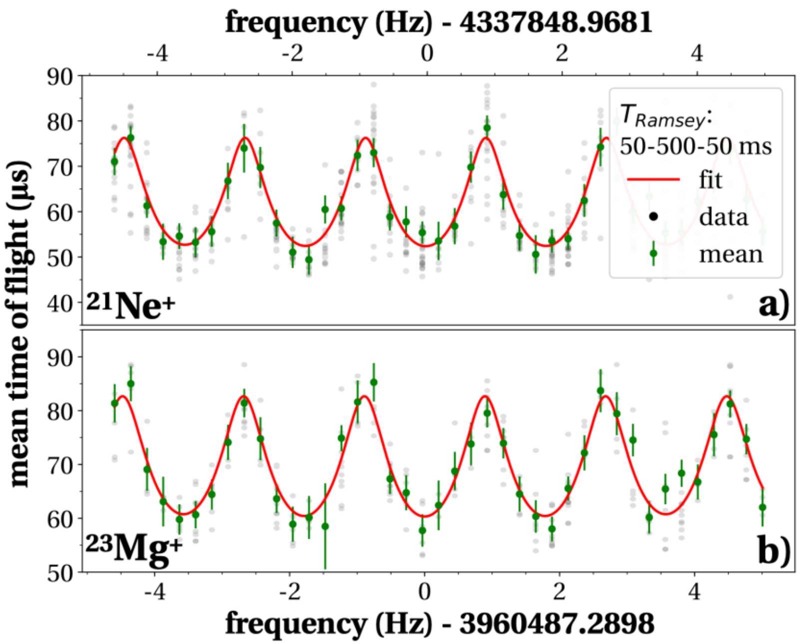


V. Manea, J. Karthein *et al.*, Phys. Rev. Lett. 124, 092502 (2020)

High-precision Q_{EC}-values of mirror nuclei

- ^{21}Na —> ^{21}Ne and ^{23}Mg —> ^{23}Na:

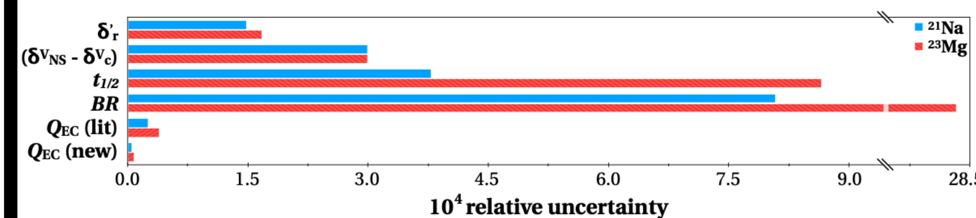
$$Q_{EC} = (M_p - M_d)c^2$$



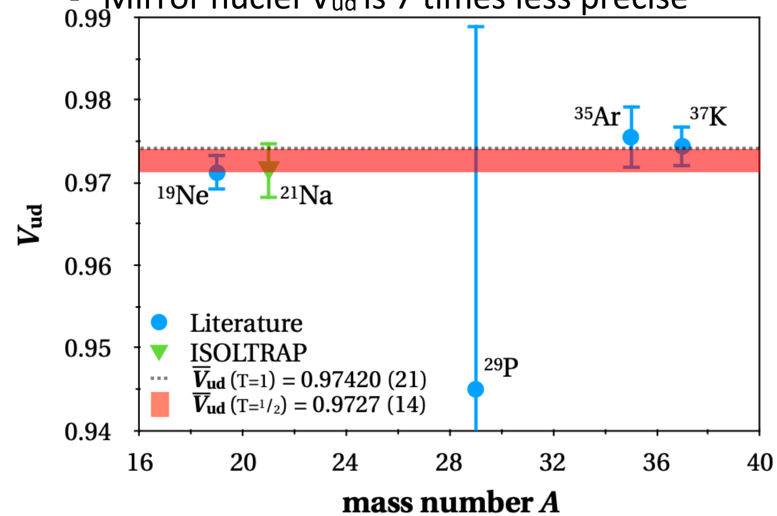
- 30 spectra of ^{21}Na, ^{21}Ne and 18 of ^{23}Mg, ^{23}Na
- ^{21}Na —> ^{21}Ne: $\delta m/m = 9*10^{-10}$
- ^{23}Mg —> ^{23}Na: $\delta m/m = 1.5*10^{-9}$
- Both Q_{EC}-values uncertainty improved by a factor of 5

J. Karthein *et al.*, Phys. Rev. C 100, 015502 (2019)

- V_{ud} element extracted from mirror nuclei:
  - Q_{EC}-values have the smallest contribution to the error budget



  - Cannot extract V_{ud} for ^{23}Mg (missing $\beta\nu$ correlation coefficient)
  - Mirror nuclei V_{ud} value agrees well with the one extracted from super allowed decays
  - Mirror nuclei V_{ud} is 7 times less precise



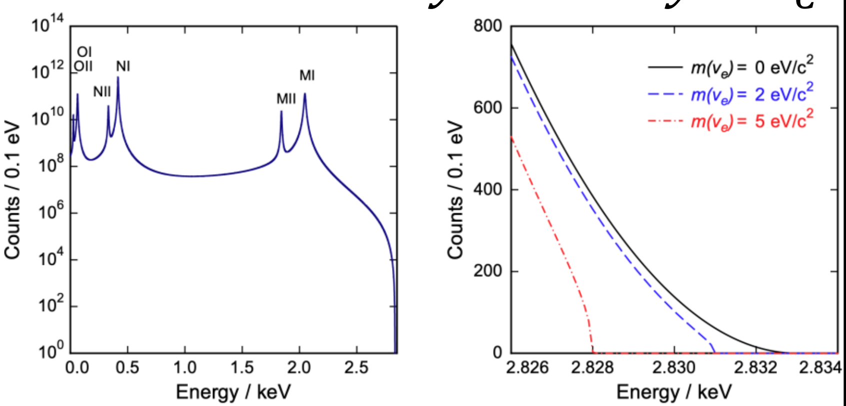
High-precision Q_{EC}-values for neutrino physics

- Primary goal:
  - Contribute to direct determination of neutrino mass
  - Precise knowledge of the QEC-value of EC required by micro-calorimeters

$$Q_{EC} = (M_p - M_d)c^2$$

- Ex: $^{163}Ho + e^- \rightarrow ^{163}Dy^* + \nu_e$

$$^{163}Dy^* \rightarrow ^{163}Dy + E_C$$

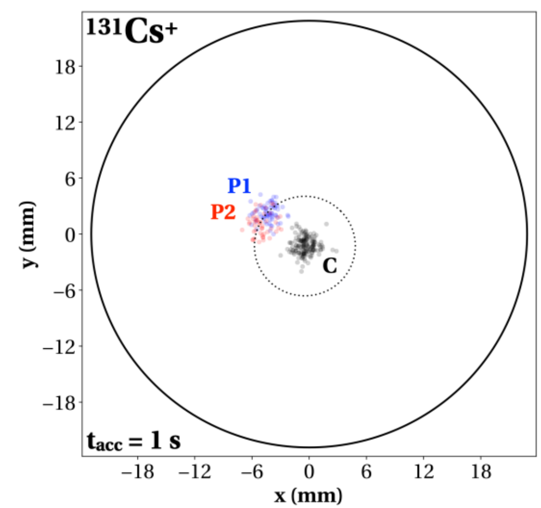


- But also:
  - Test functioning of microcalorimeters
  - Test theoretical description of EC-spectrum
  - Search for new candidate EC-transitions

L. Gastaldo *et al.*, Eur. Phys. J. Special Topics 226, 1623–1694 (2017)

- The ^{131}Cs —> ^{131}Xe candidate pair:
  - Improve Q_{EC} uncertainty by a factor of 25
  - Precludes 131 CS as possible candidate for the ν_e-mass determination
  - Successful PI-ICR online test (1st ISOLTRAP publication on PI-ICR)

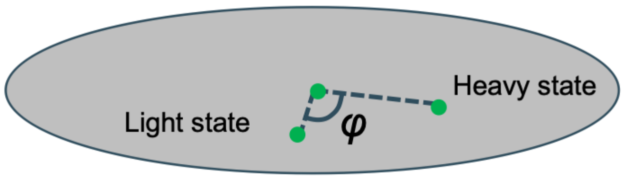
Mother	$T_{1/2}$	Daugh.	Q_{ge} / keV	δQ_{ge} / keV	Decay
^{131}Cs	9.7 d	^{131}Xe	-15 -11	5 5	EC_L EC_M
^{131}Cs	9.7 d	^{131}Xe	-11.5 -7.2	0.2 0.2	EC_L EC_M



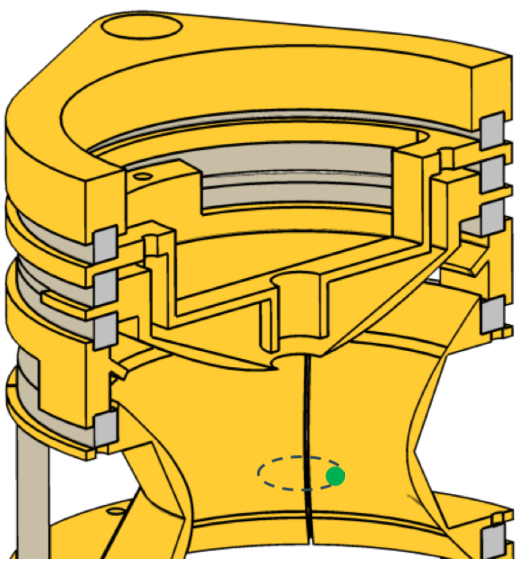
J. Karthein *et al.*, Hyperfine Interact (2019) 240:61

Phase-Imaging Ion Cyclotron Resonance

- The technique:

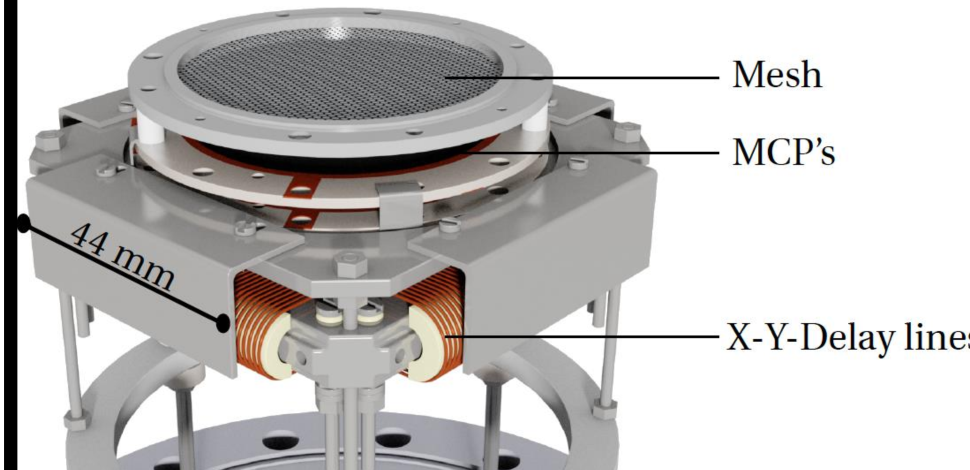


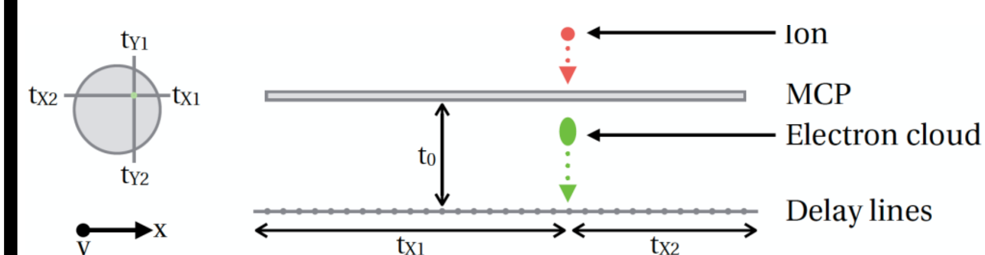
$$\nu = \frac{\phi + 2\pi n}{2\pi t_{meas}}$$



- The delay-line detector:

- Single pitch propagation time (1mm) ~ 0.75ns
- $X = t_{x1} - t_{x2}$ (same for Y)
- Single ion sensitivity :)
- Poor dynamic range (~3ions/bunch) :(



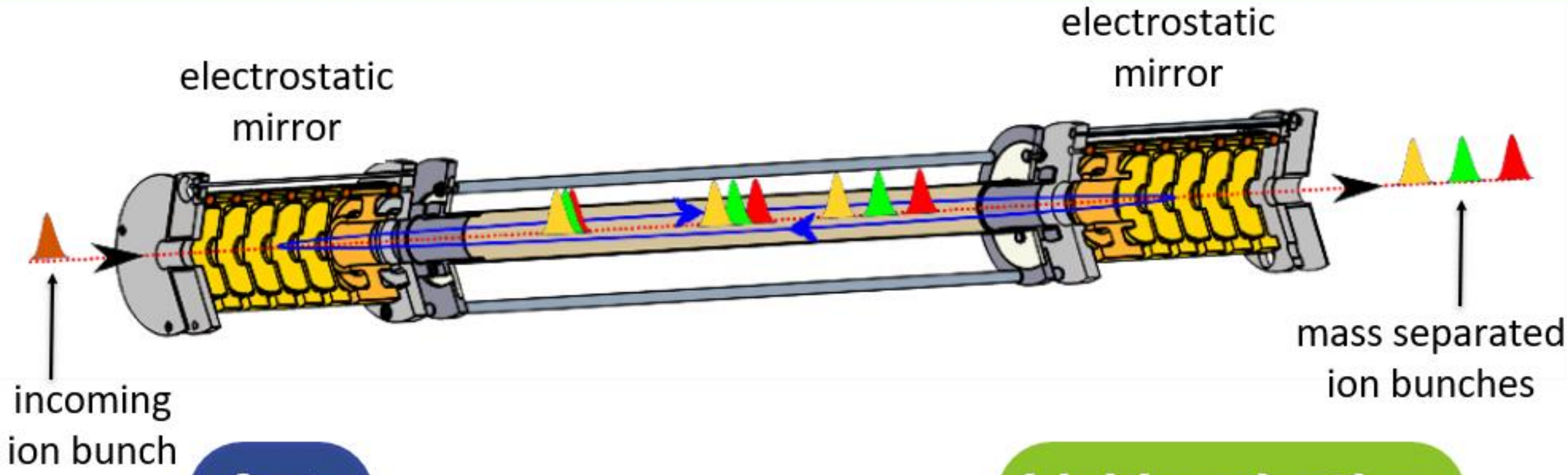


J. Karthein, Master Thesis *CERN-THESIS-2017-281*

MIRACLS: MR-TOF, Multi-Reflection-Time of Flight spectrometer

Contact: S. Malbrunot, CERN

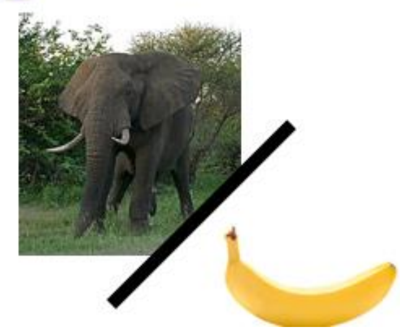
MR-TOF devices



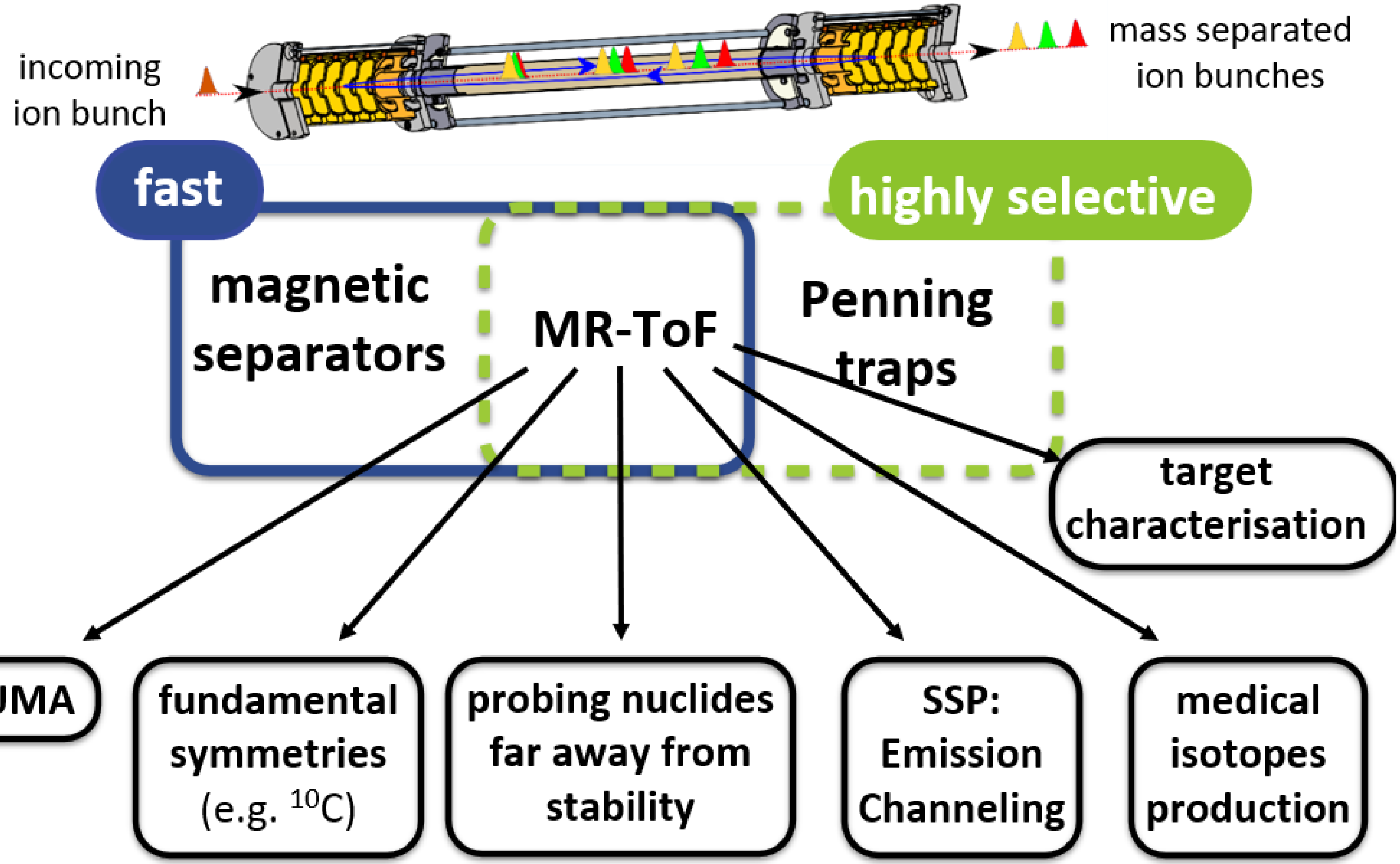
Characteristics:

- $m/\Delta m > 10^5$ achieved in a few milliseconds
- ion capacity to $\approx 10^6$ ions/s (limitation due to space-charge effects limit)

$m / \Delta m$ □

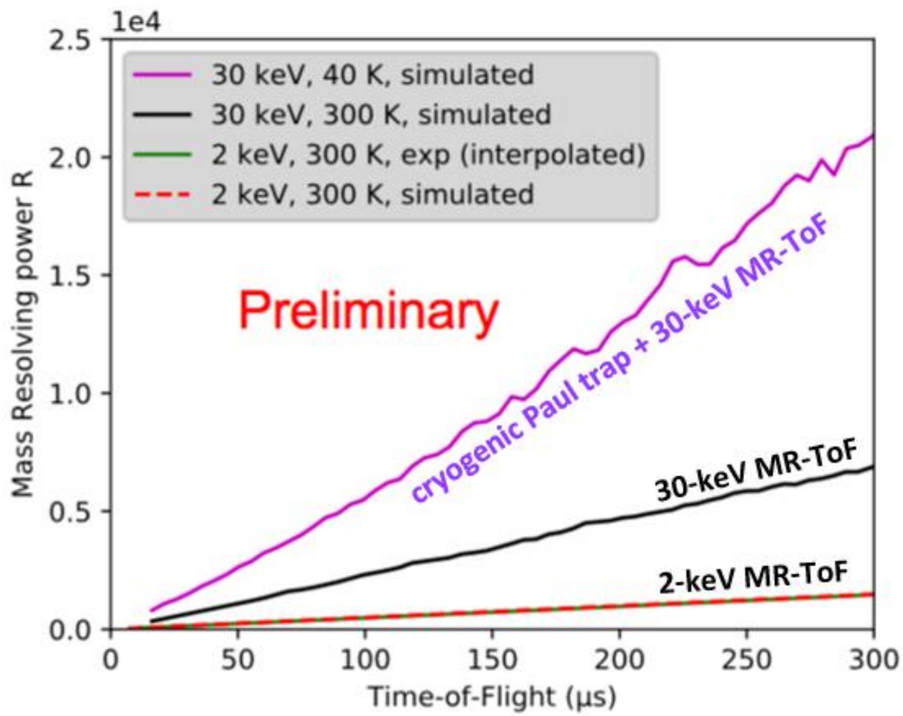


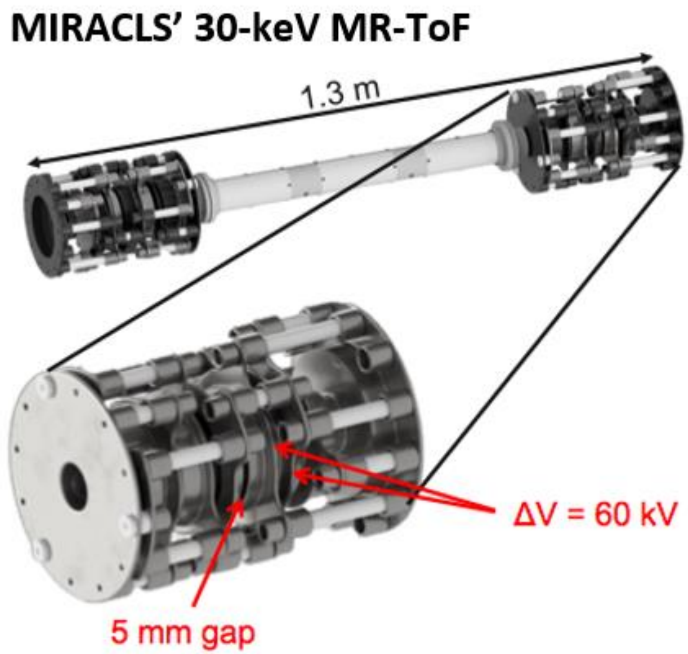
applications for high-flux MR-ToF



⇒highly beneficial for entire ISOLDE community

30-keV MR-ToF: new opportunities for purified ISOLDE beams





faster isobaric separation in MR-ToF while keeping high mass resolving power

- higher ion flux through MR-ToF device ('bypass' space-charge limits)
- initial goal: a few pA (ultimate goal: >100 pA)

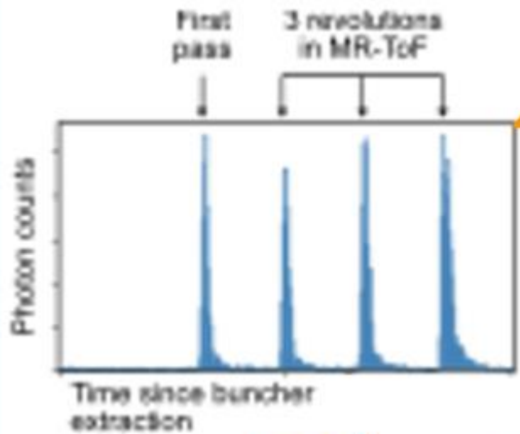
MIRACLS erc ISOLDE

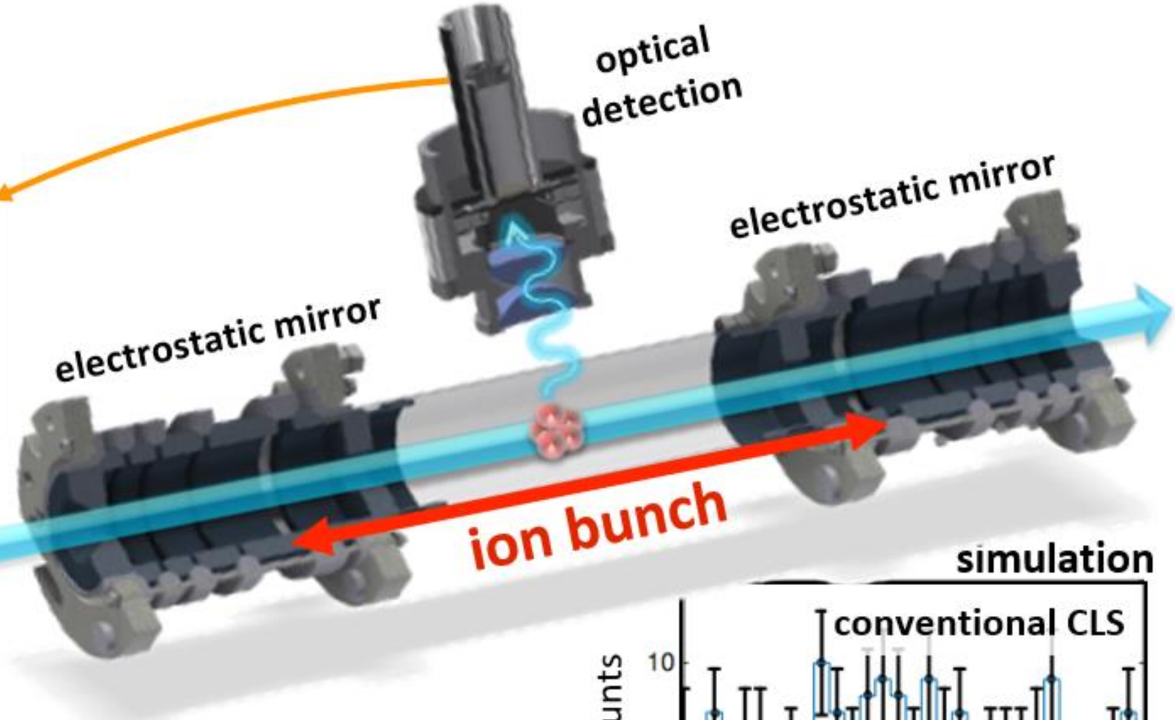
the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

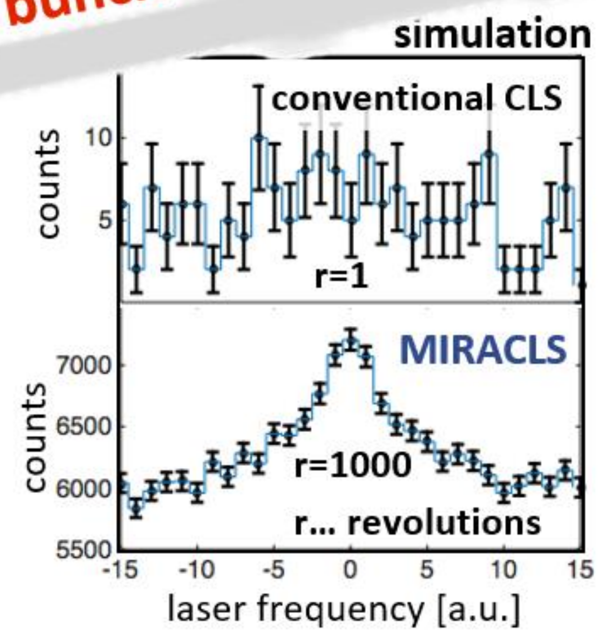
European Research Council

trap ⇒ long observation time ⇒ higher sensitivity ⇒ more exotic nuclides accessible

MR-ToF devices:







MIRACLS

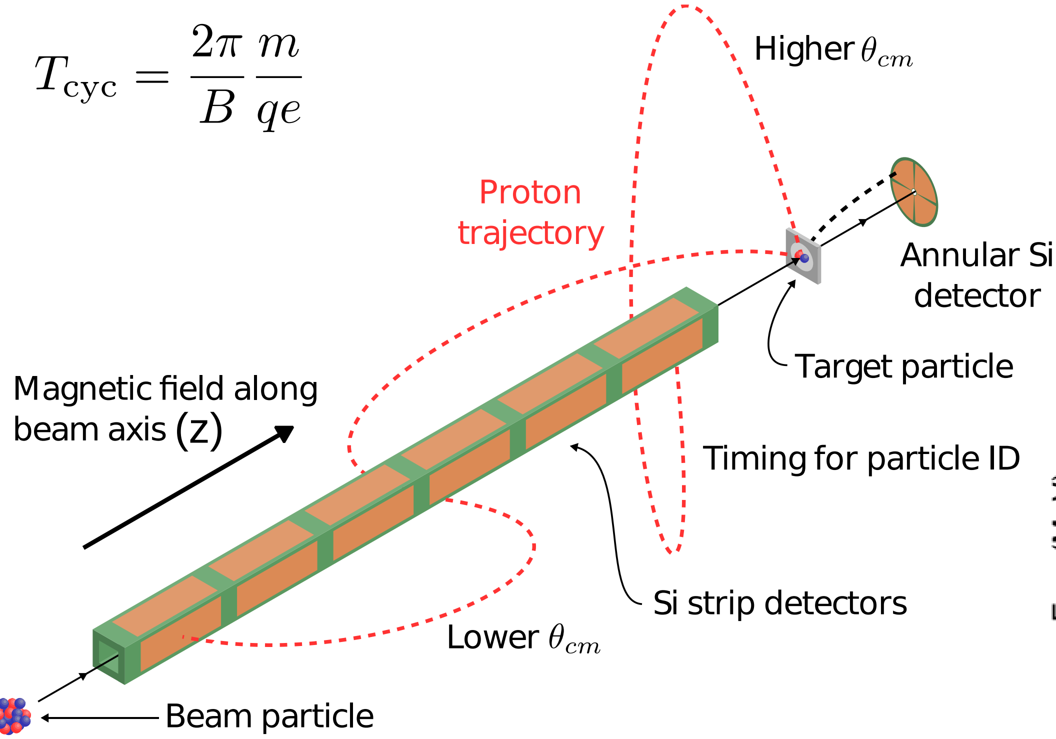
novel approach for collinear laser spectroscopy:

- ion trap ⇒ long observation time
- 30 keV beam ⇒ high resolution

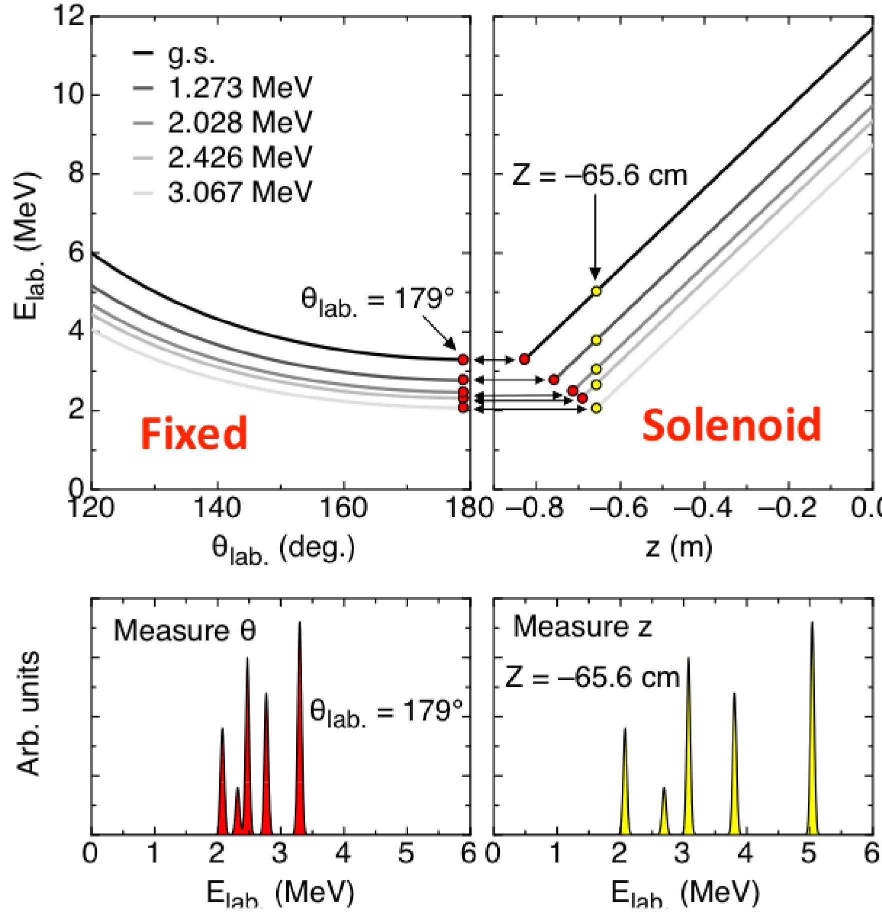
ISS

ISS: direct reactions

$$T_{\rm cyc} = \frac{2\pi}{B}\frac{m}{qe}$$



$$E_{\rm cm} = E_{\rm lab} + \frac{mV_{\rm cm}^2}{2} - \frac{mzV_{\rm cm}}{T_{\rm cyc}}$$



MEASURED: position z that light ejectile returns to axis, cyclotron period T_{cyc} and lab particle energy $E_{p.}$

no kinematic compression of Q-value spectrum (unlike measurements at fixed angles)

Linear relationship between E_{cm} and $E_{lab.}$

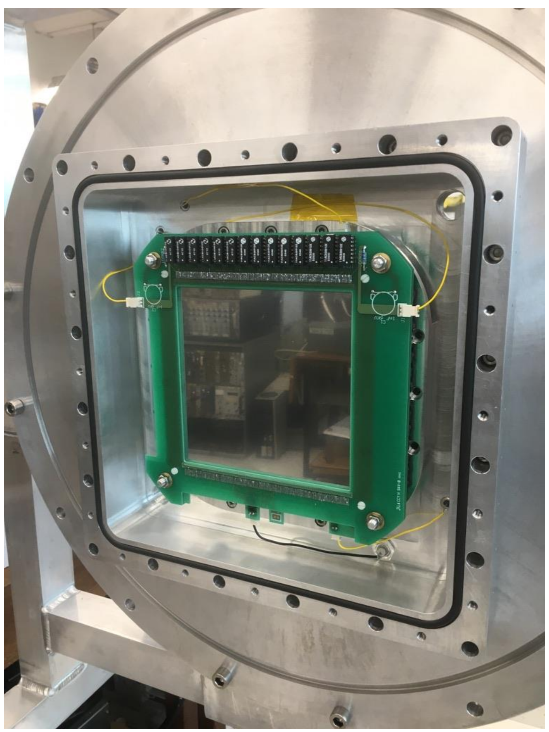
Upgraded recoil detection

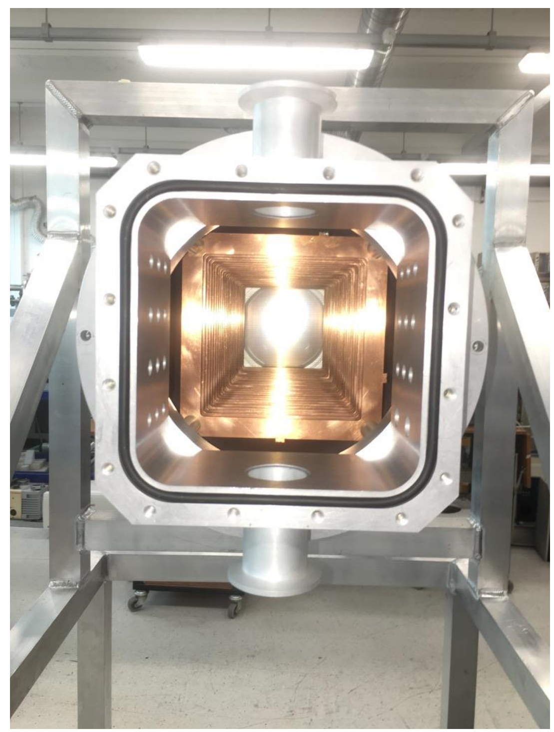
New gas-filled recoil detector for recoil identification

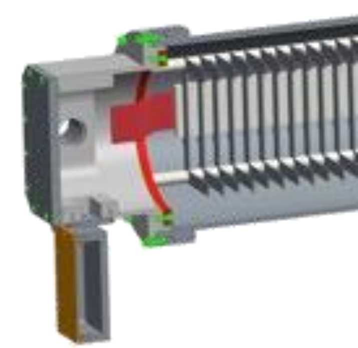
Position-sensitive (delay lines) multi-wire proportional counter. Followed by segmented gas-filled ion chamber.

Digitized signals – sample full dE/dx.

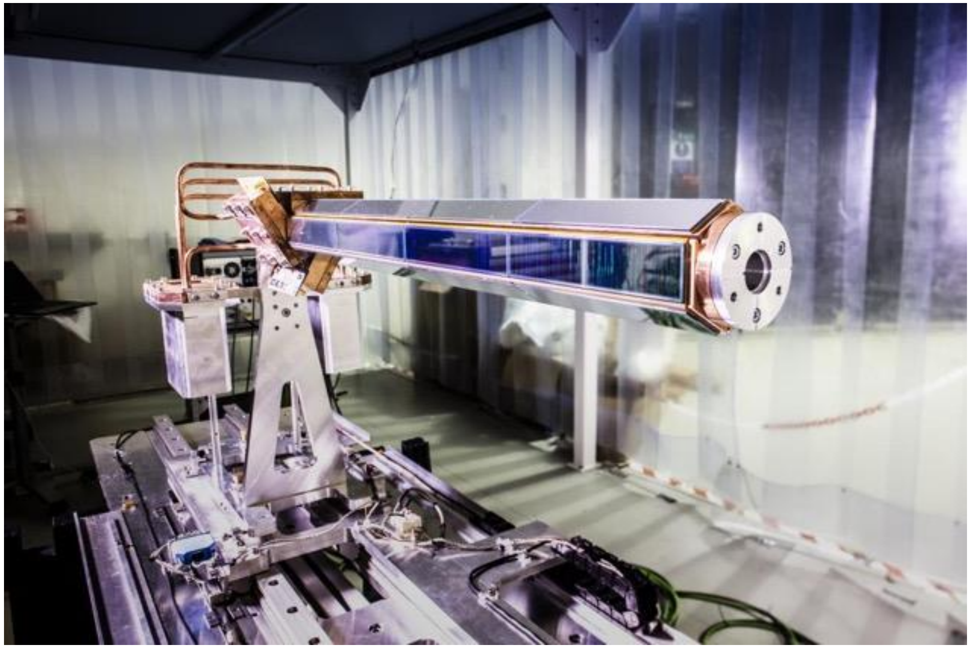
Count rate up to 100kHz.

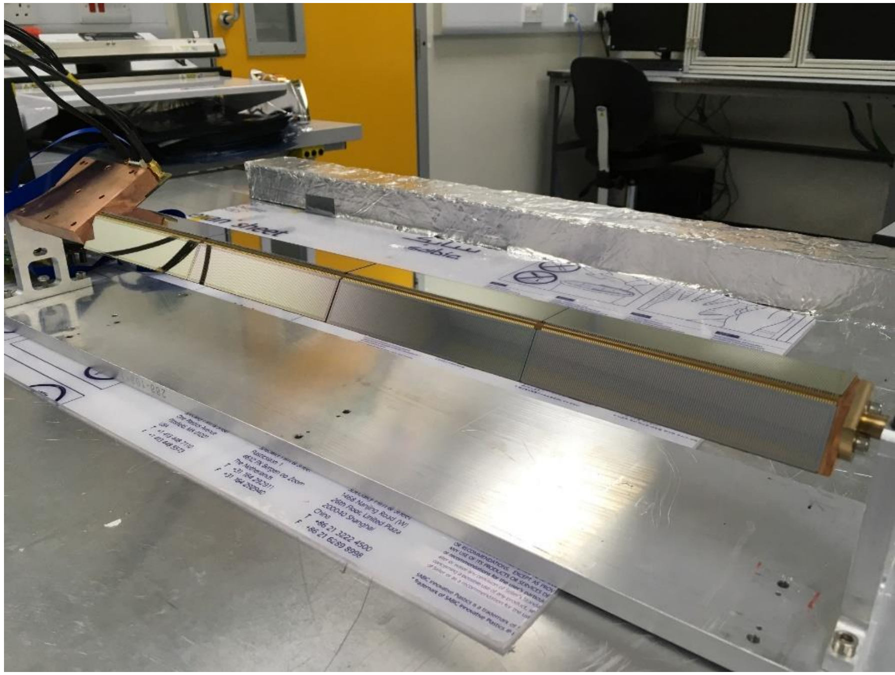






Completed detector of 3 modules



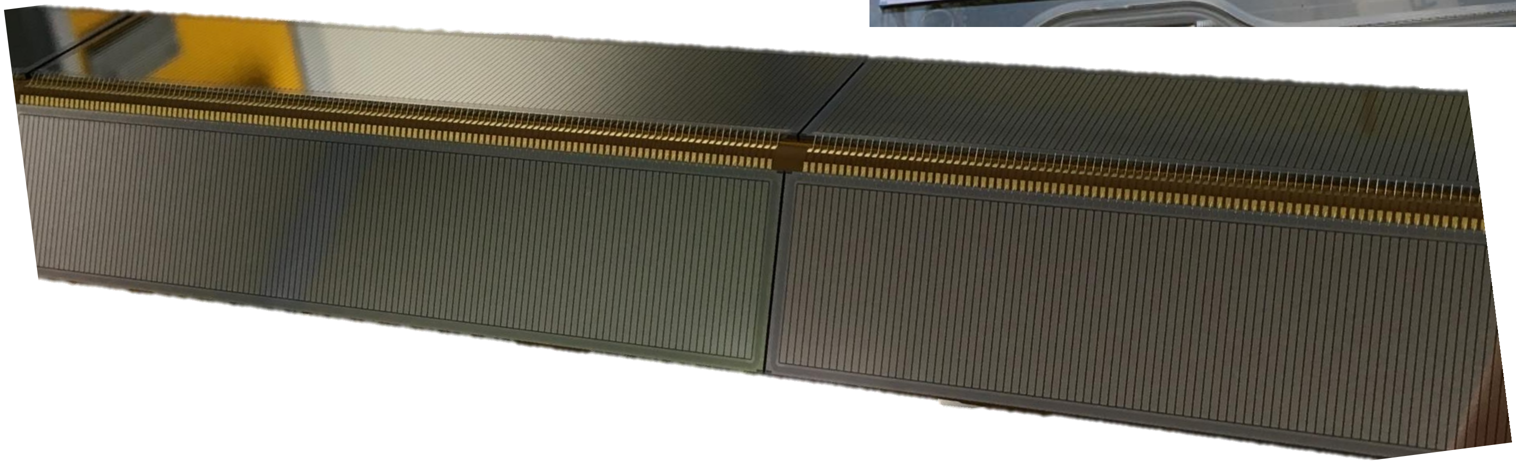


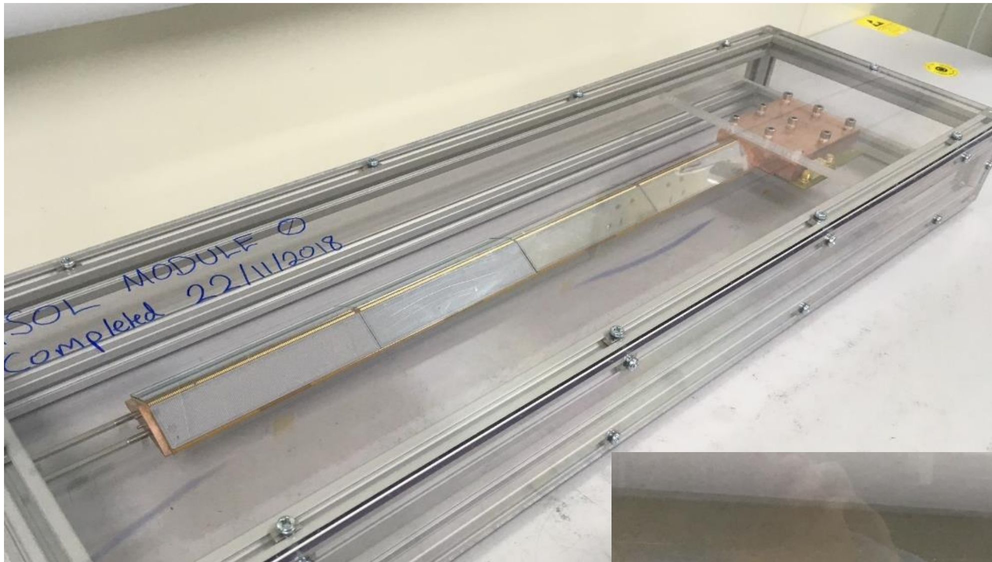
1 module with 2 sides
4xDSSSD wafers per side

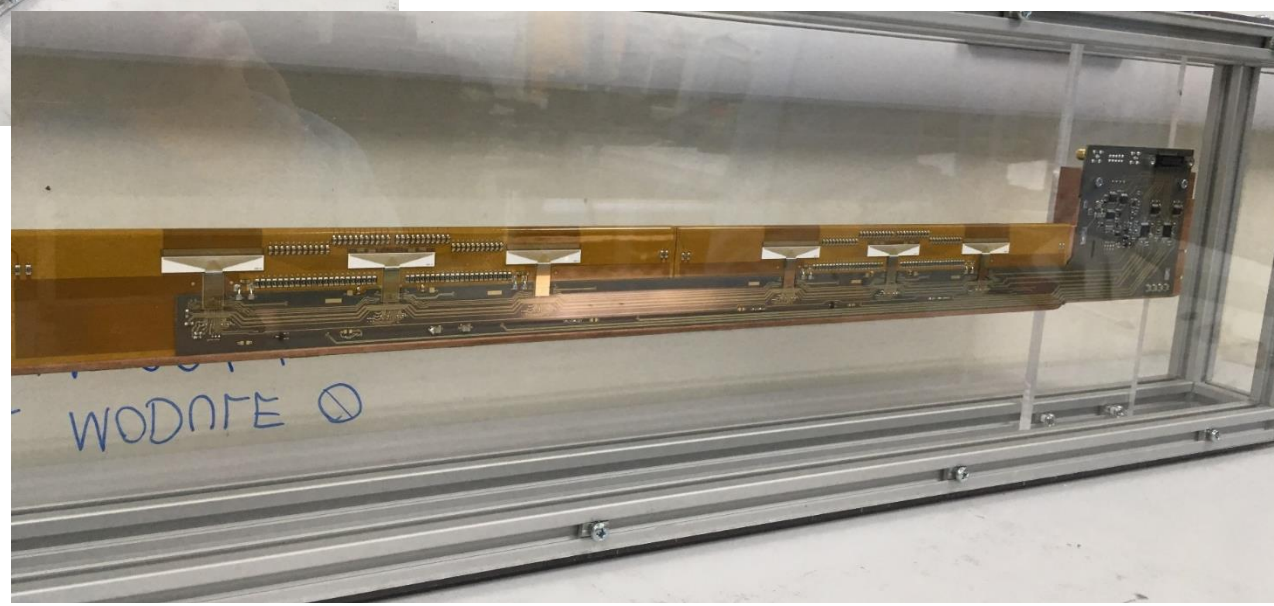
DSSSD wafers

Ohmic (n)
[glue bonded]
back

Junction (p)
[wire bonded]
front



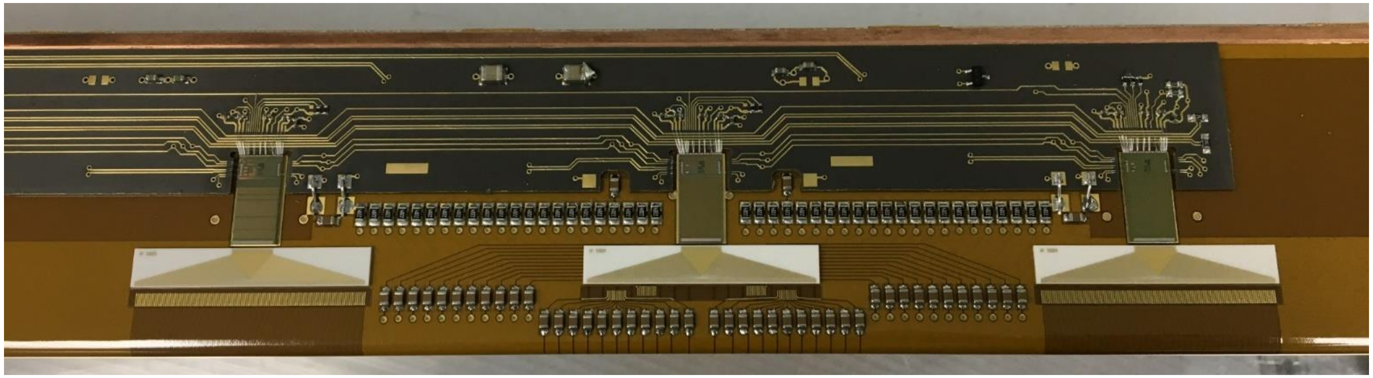




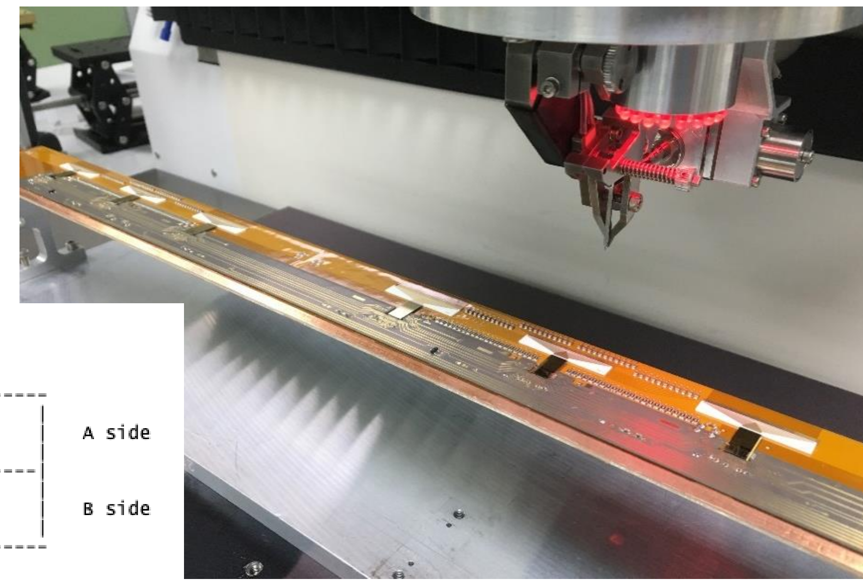
Completed module

3 → Array (CERN)

1 → Spare (CERN)



6 ASICs per module
3 forward end
3 rear end

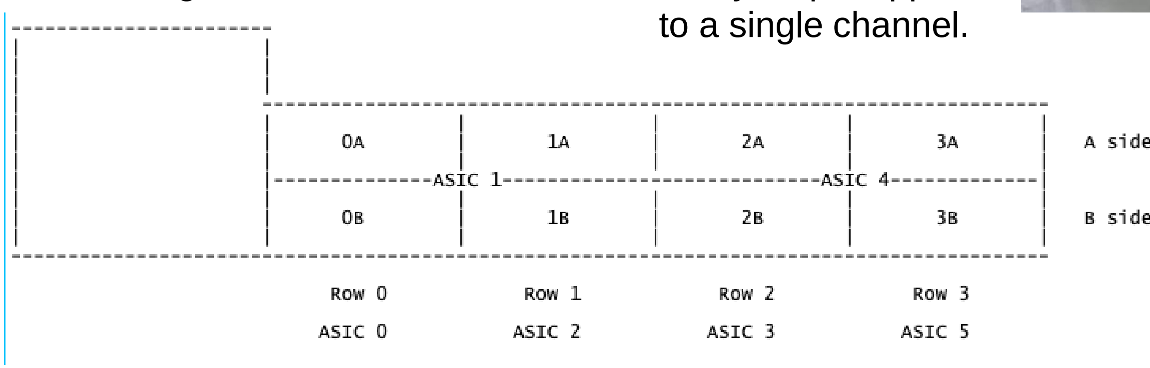


ASIC 0, 2, 3, 5 - p-side strips

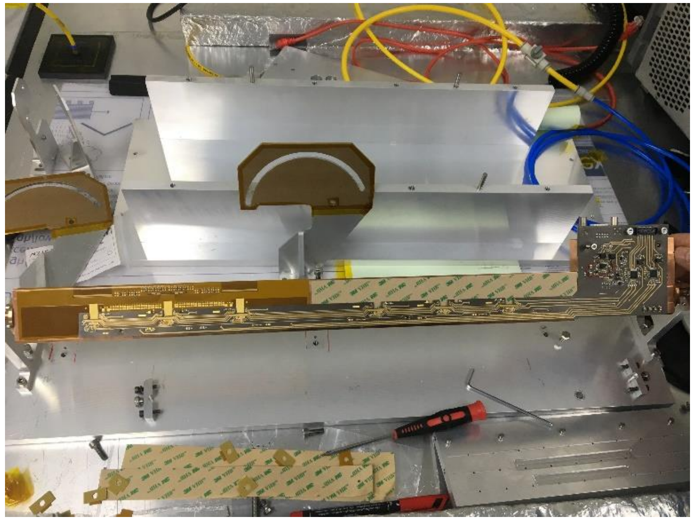
- 128 channels per ASIC.
- Strips “paired” by wire bonding from A side to B side

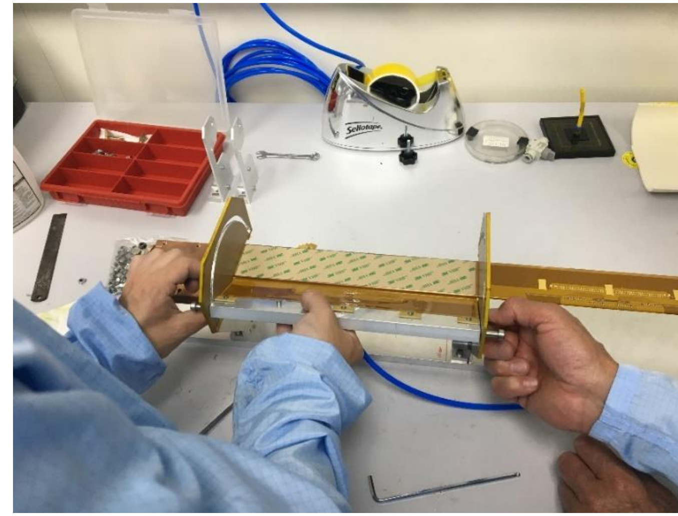
ASIC 1, 4 - n-side

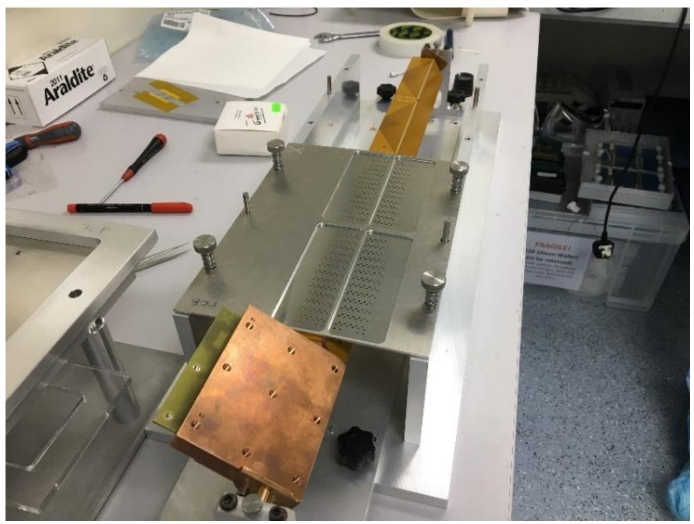
- 44 channels per ASIC.
- Every strip mapped to a single channel.

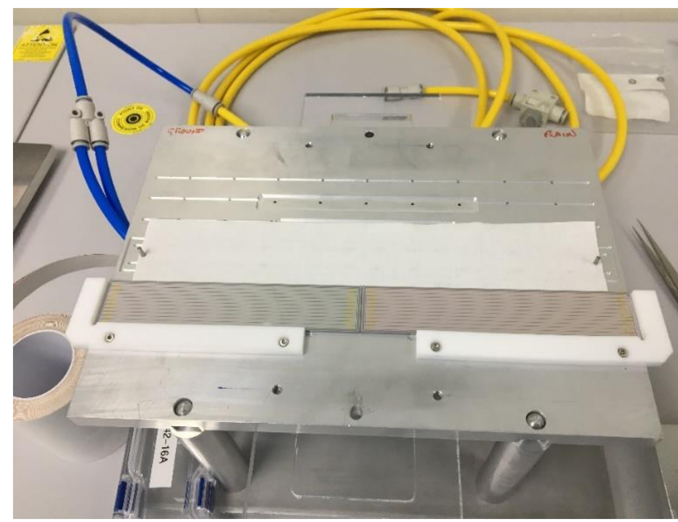


Module Assembly



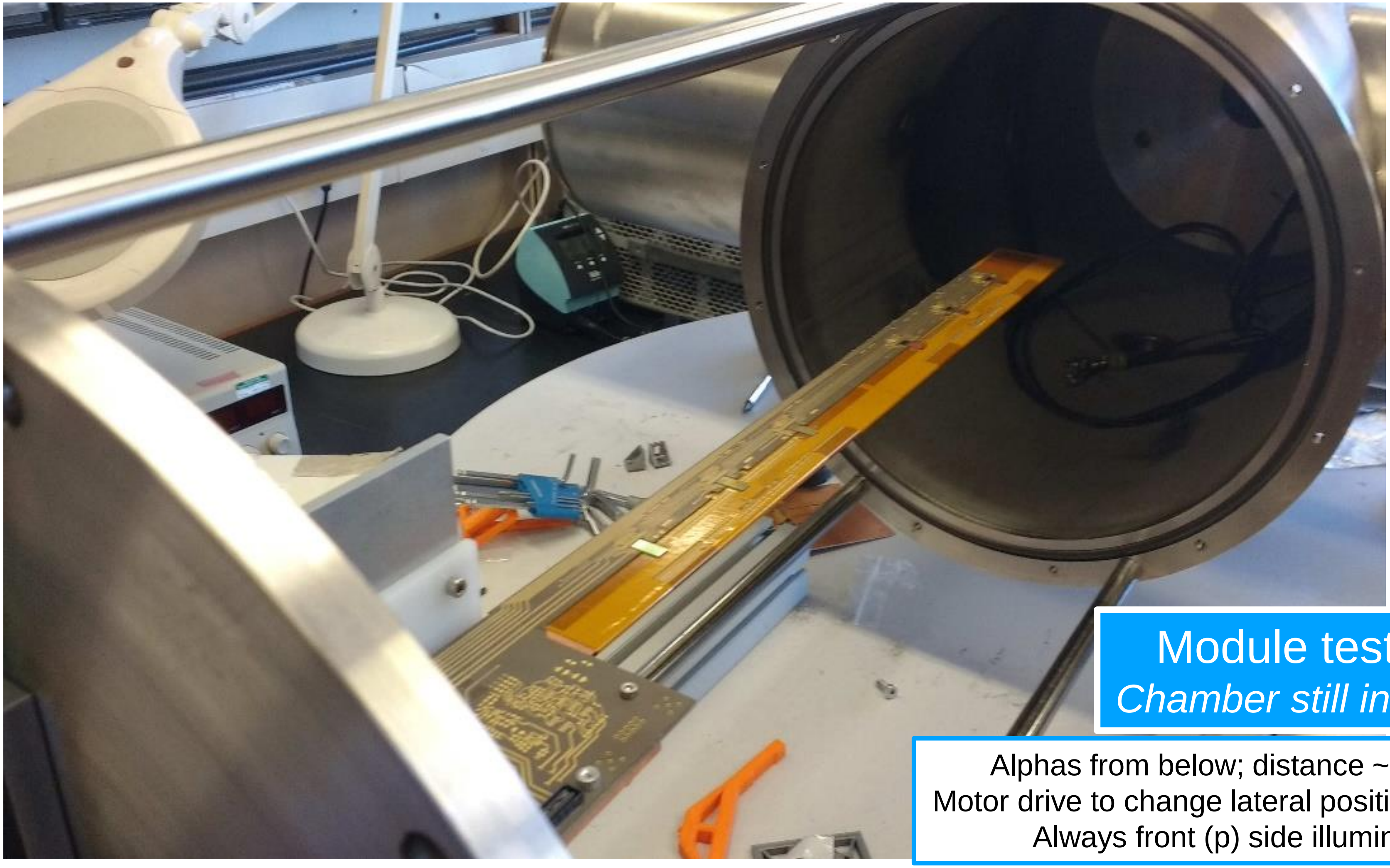






Module test setup

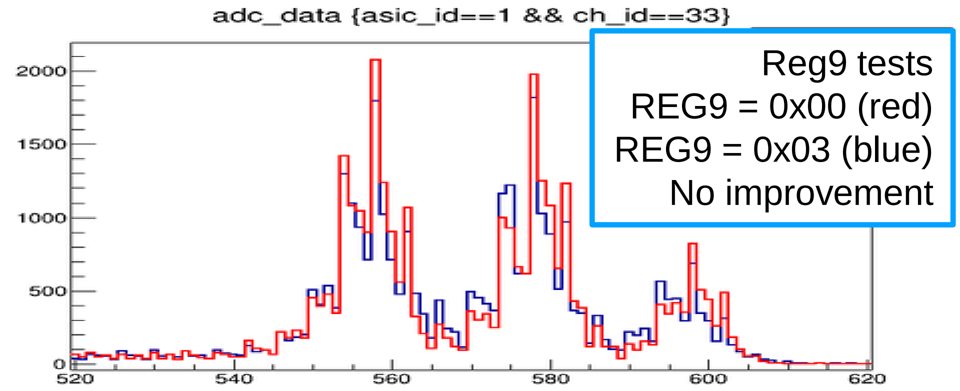
Chamber still in Liverpool

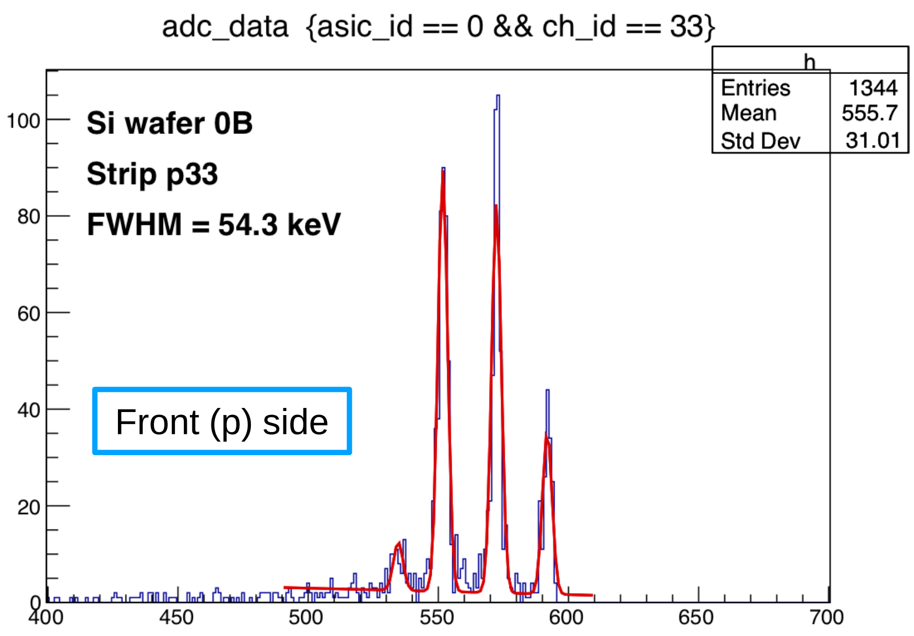


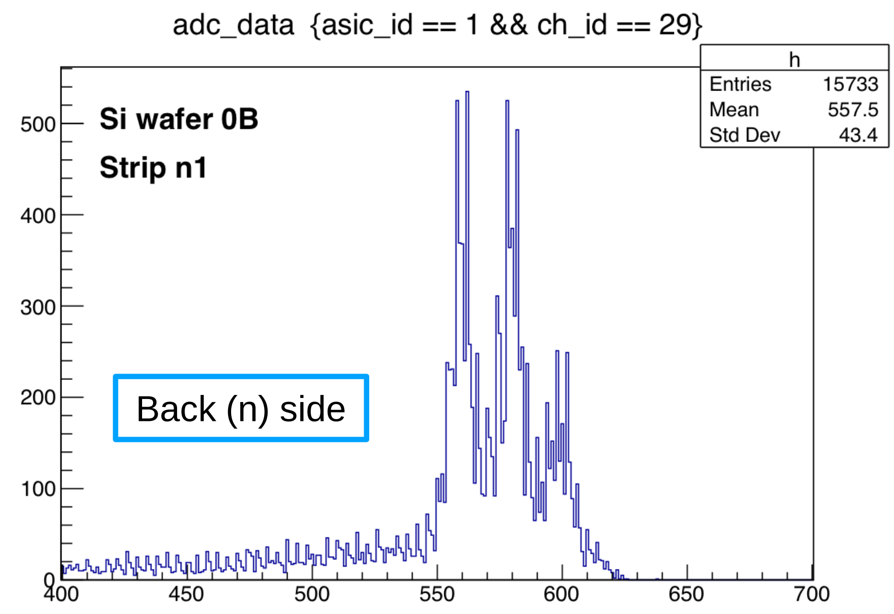
Alphas from below; distance ~250 mm.
Motor drive to change lateral position of source.
Always front (p) side illuminated.

Alpha spectra

- No fine structure included in the fits.
- Edge effects observed (small peak).
- Coincidences not yet tested.







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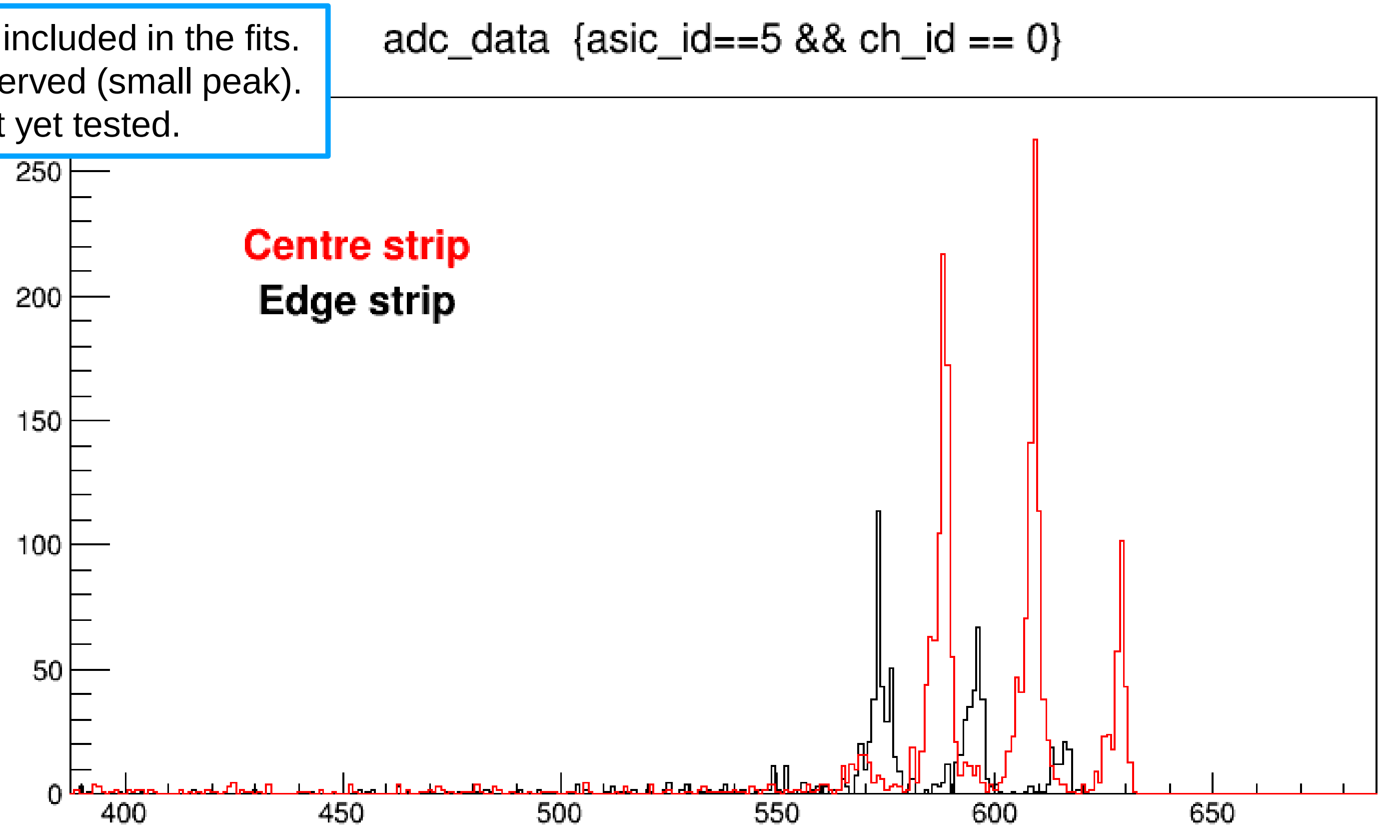


Calibrated Ge detector

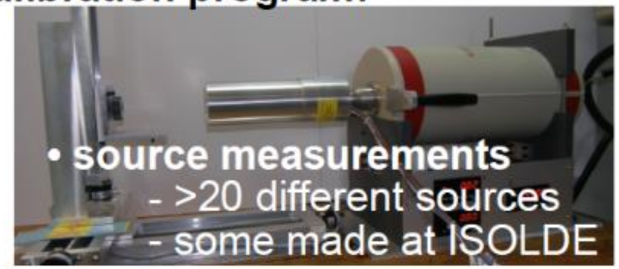
Contact: B. Blank, Bordeaux

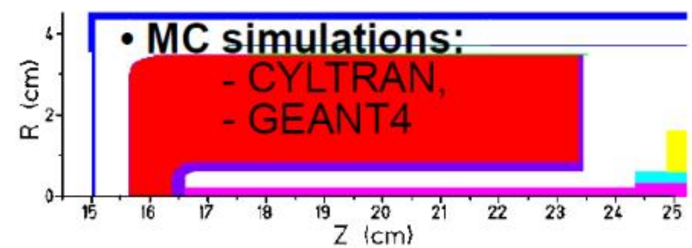
Lifetime t1/2 and branching ratio BR

- Decay studies with high-purity Ge detector (Bordeaux)
  - Very well known efficiency

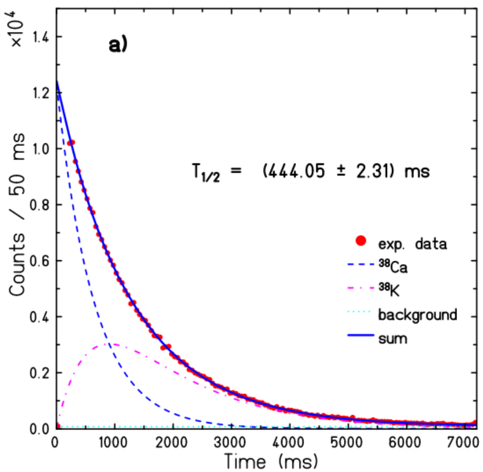
B. Blank et al., NIM A 776, 34 (2015)

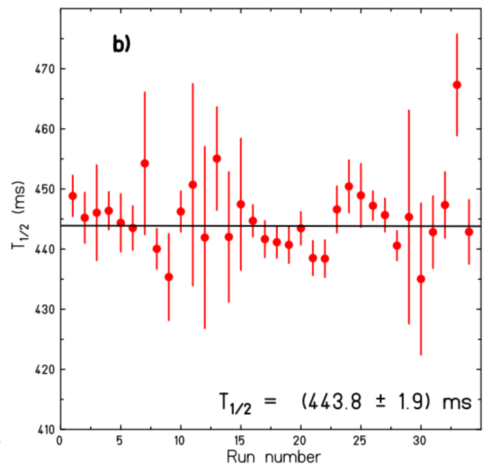
calibration program:



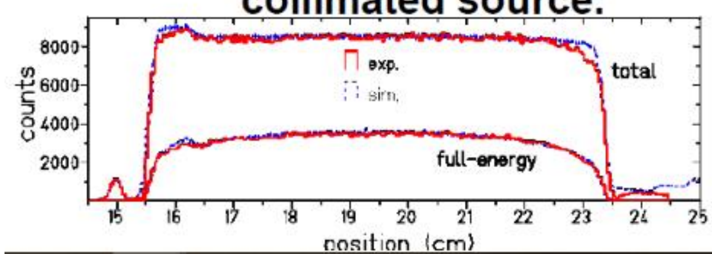


- Recent examples 38,39Ca, 37K





• scan of the crystal with collimated source:



Contact: B. Blank, Bordeaux

229Th nuclear clock

Contact: P. Van Duppen, KU Leuven

Nuclear clock based on 229mTh

Nucleus is more separated from environment:

- Expected to outperform present-day best clocks
- World-wide effort to created nuclear clock

BUT : Nuclear properties not know with high enough precision!

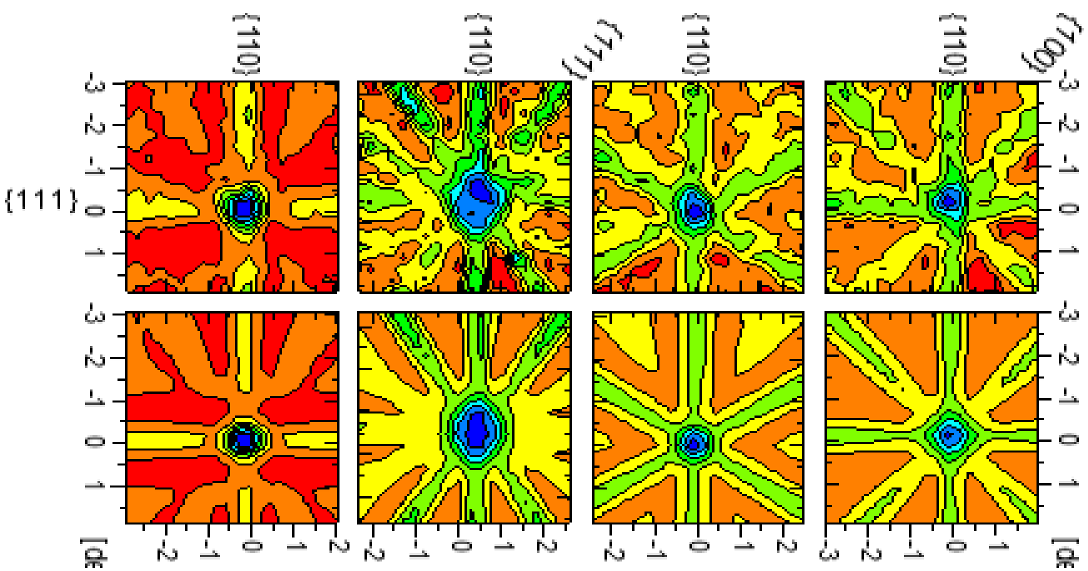
^{229}Th ← β^- ← ^{229}Ac

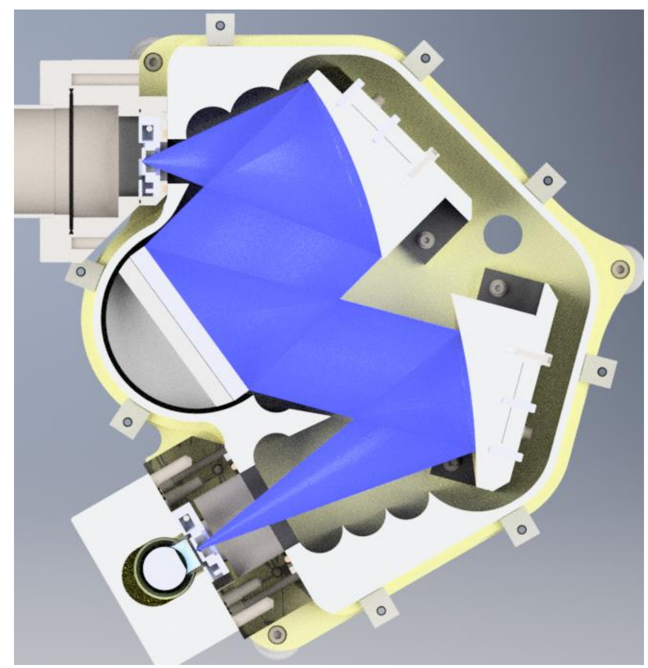
Goal:

- Create ^{229}Ac at ISOLDE, implant it in wide-bandgap CaF crystal at correct site (emission channeling measurement)
- Measure direct photon emission from ^{229m}Th → ^{229}Th with high-resolution VUV photon spectrometer with $\Delta \mathrm{E} < 0.1\ \mathrm{nm}$
- prerequisite for direct laser excitation

$$\Delta E = 1\ \mathrm{nm} = 0.05\ eV$$

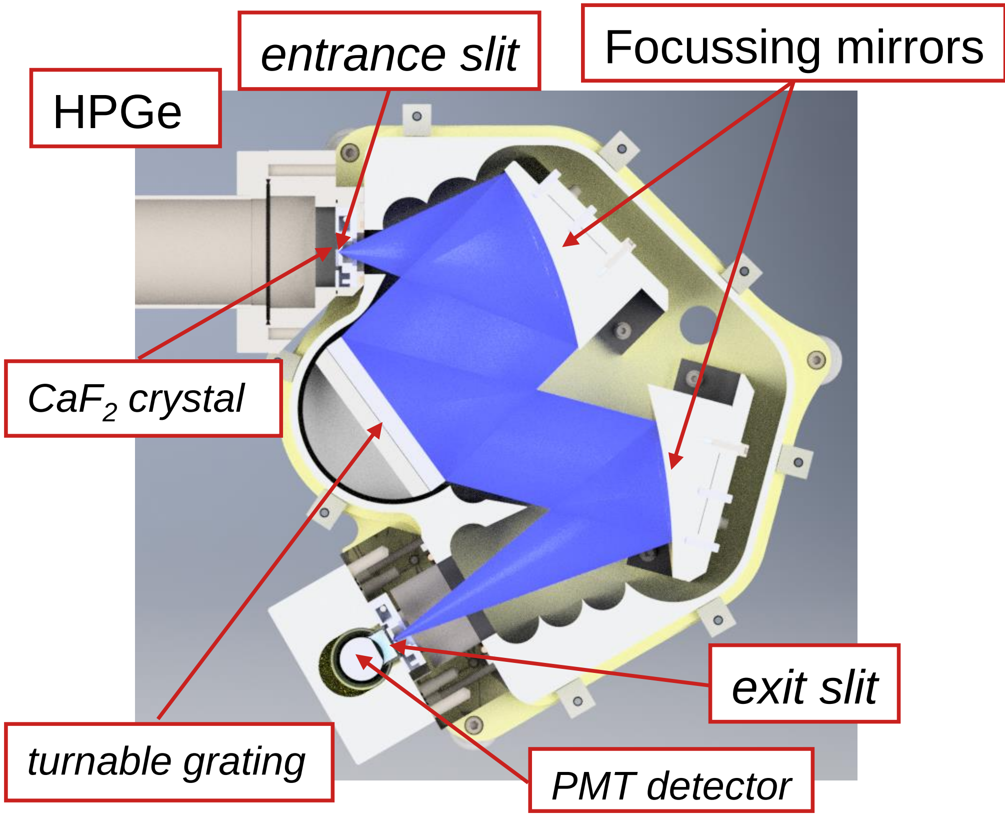
P. Van Duppen, S. Sels, KU Leuven





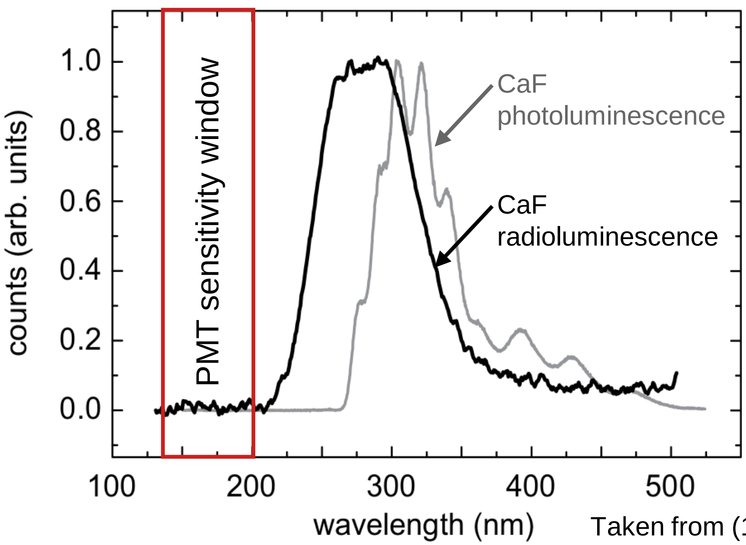
II. Spectroscopy of the Radiative Decay: Methodology

- Implantation into thin (50nm) CaF_2 crystal on Si backing (characterization at KU Leuven)
- Implantation time: 2 half-lives
- Transfer of crystal under vacuum to spectrometer
- Crystal positioned close to entrance slit of VUV spectrometer (design based on Resonance Ltd customized VM180)
- Activity monitoring using a Ge detector
- Simulation of signal strength and worst-case background contributions (see next slide)



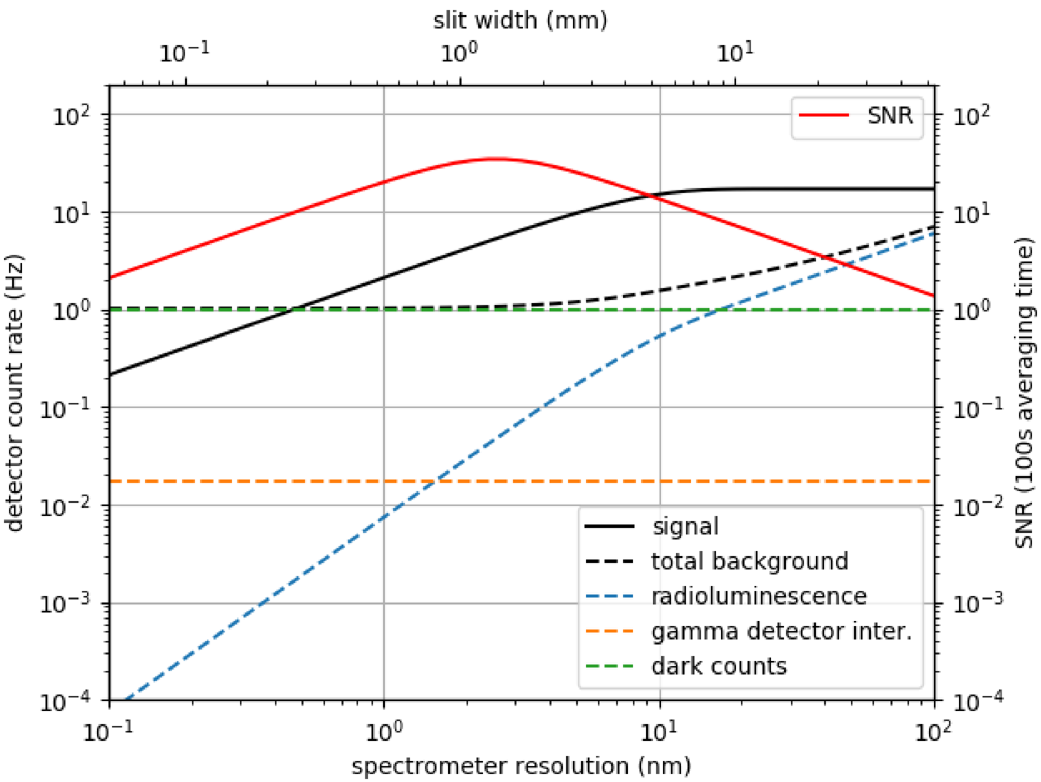
II. Spectroscopy of the Radiative Decay: Background

- Implantation of a 4 mm FWHM ion beam
- Scintillation properties in CaF_2
  α,β: from literature $\sim 1\%$ conversion
  γ: 100% conversion
- PMT sensitivity window
- Conservative estimates of
  - photon coll.+ det. efficiency: $> 0.01\%$
  - substitutional lattice position: 50%
  - isomer feeding: 14%



Taken from (11)

Signal (counts/sec.) and background contributions for $3h$ measurement at $10^6 pps$ implantation (2 h) and $2h$ isomer half-life:

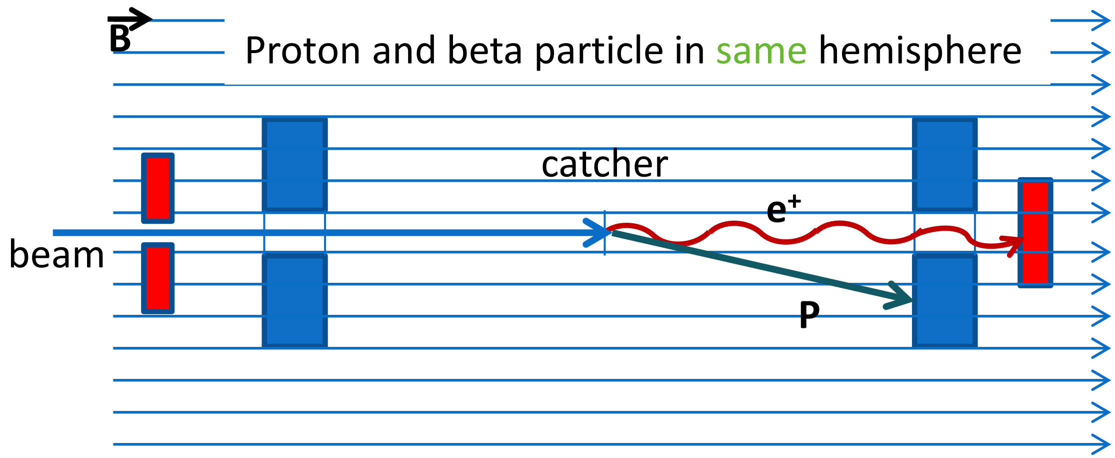


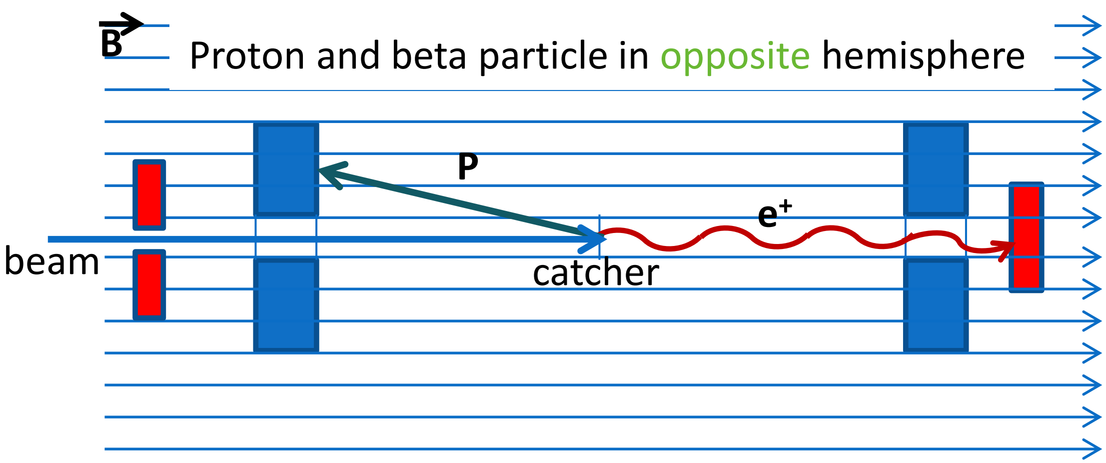
WISARD

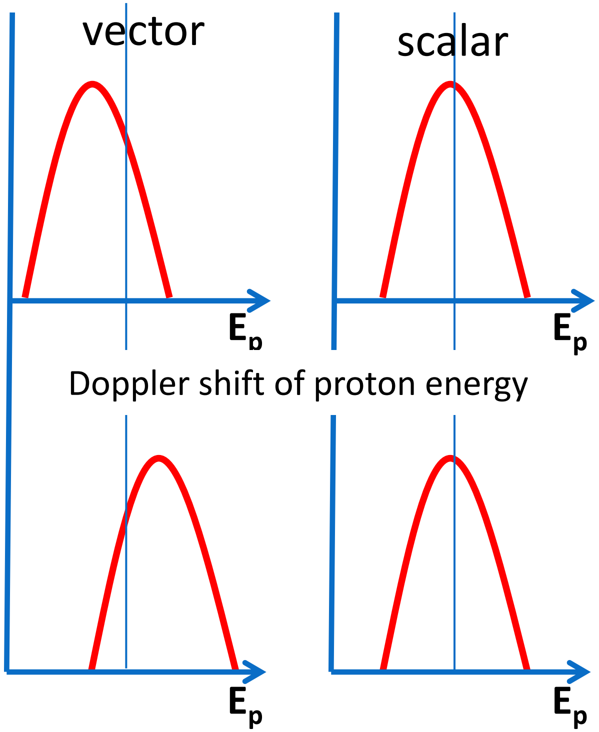
Contact: B. Blank, Bordeaux

32Ar at WISARD

Weak Interaction Studies with ^{32}AR Decay:
e+-p coincidence in B field







WISARD

Proof of Principle Detection Setup

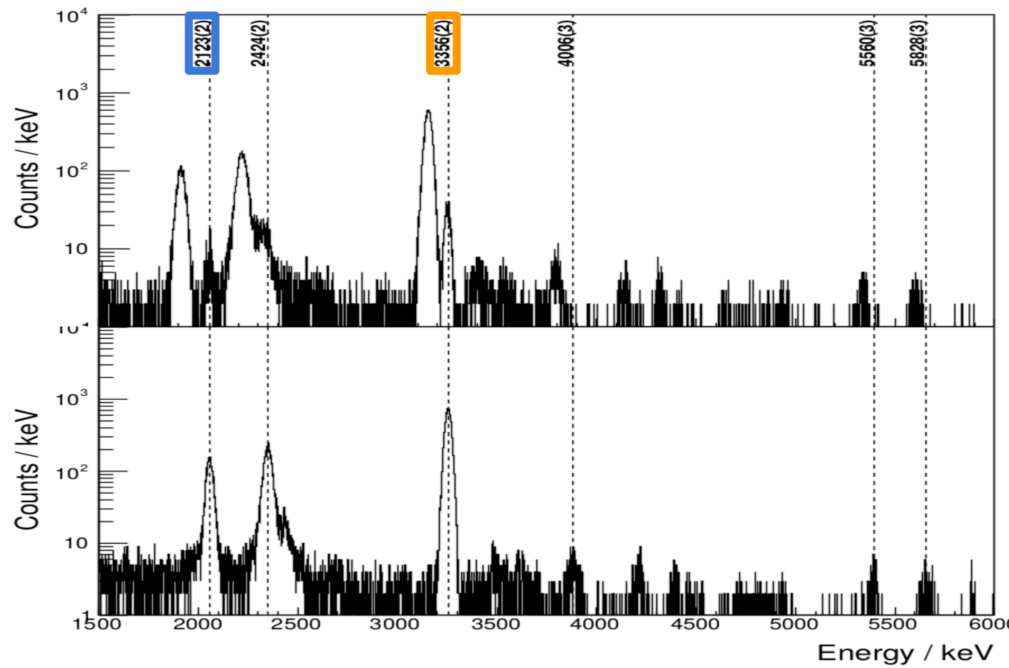
Beta detector* + SiPM

proton detectors planes**

Catcher***

Upper detectors

Lower detectors



- Proton energies shifted due to Catcher thickness
- Energy shifts observed in all detectors due to the dead layer

* Plastic scintillator;
** Silicon surface-barrier (thickness = 300 μm);
*** Aluminized Mylar (thickness = 6.7 μm)

V. Araujo-Escalona et al. Phys. Rev. C101, 055501 (2020)

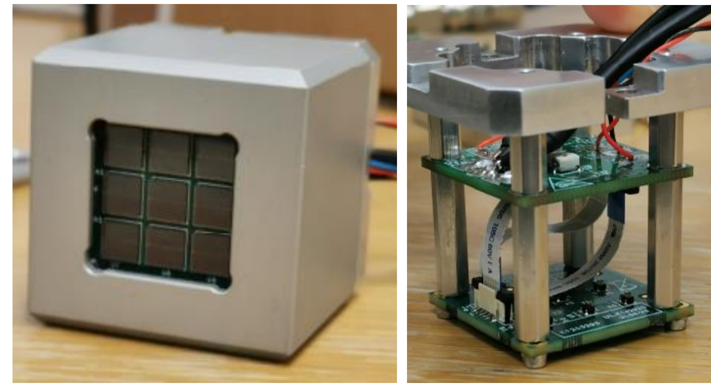
ISOLDE tape station

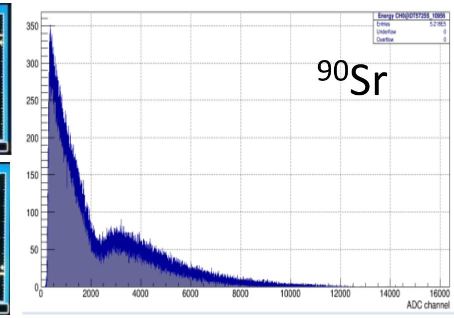
Detectors at ISOLDE tape-station

- **Beam instrumentation and low level control:**
  - Tape control and counter readout tested (on FESA level)
  - Beam scanner to be installed by BE-BI
- **Beta detectors**:
  - 2 prototypes (3x3 SiPM array) tested at CERN, noise at tapestation position is absent, ready for production. Same design can be used for all the positions.
  - Updating drawings and producing new parts, collaboration with SY-STI-TCD.
- **HPGe detector:**
  - Preliminary tests at GSI show a fully recovered resolution, however noise from cooling system was identified and currently addressed.
- **Data acquisition:**
  - CAEN DT5725 purchased, all-in-one solution
- **Top level Controls (GUI)**
  - Basic version by BE-OP (Java)
  - Expert interface via STI-RBS (tbd)
- **Future**
  - Final tests to be performed by March with all detectors in place
  - Once TS1 ready launching TS2 installation

Contact: R. Lica, S. Rothe

IFIN-HH 3x3 SiPM array



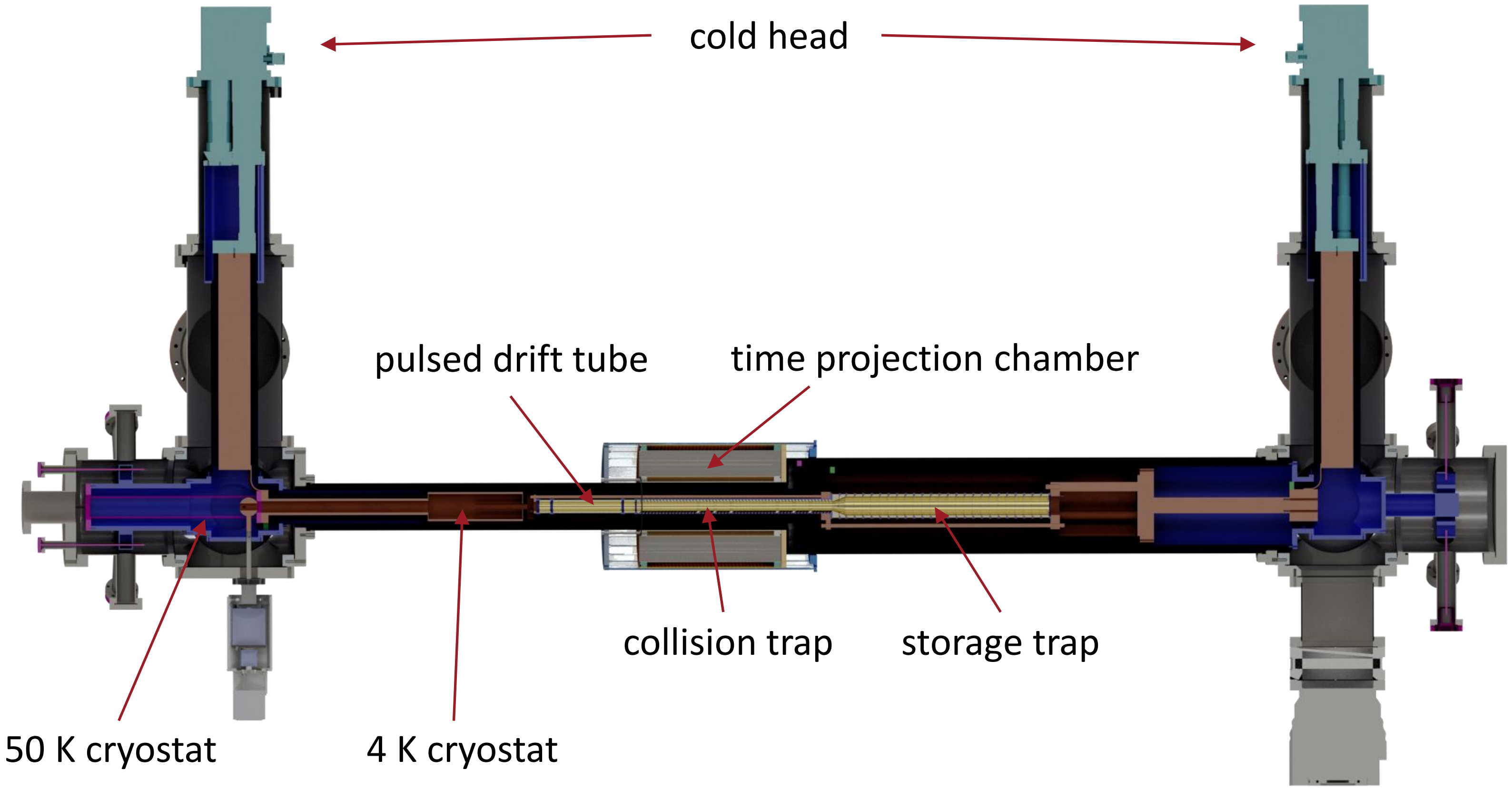


Old Tapestation HPGe detector

PUMA

Contact: A. Obertelli

PUMA cyostat



PUMA traps and detectors