Innovative Instrumentation (not only) for reaction studies at EURISOL

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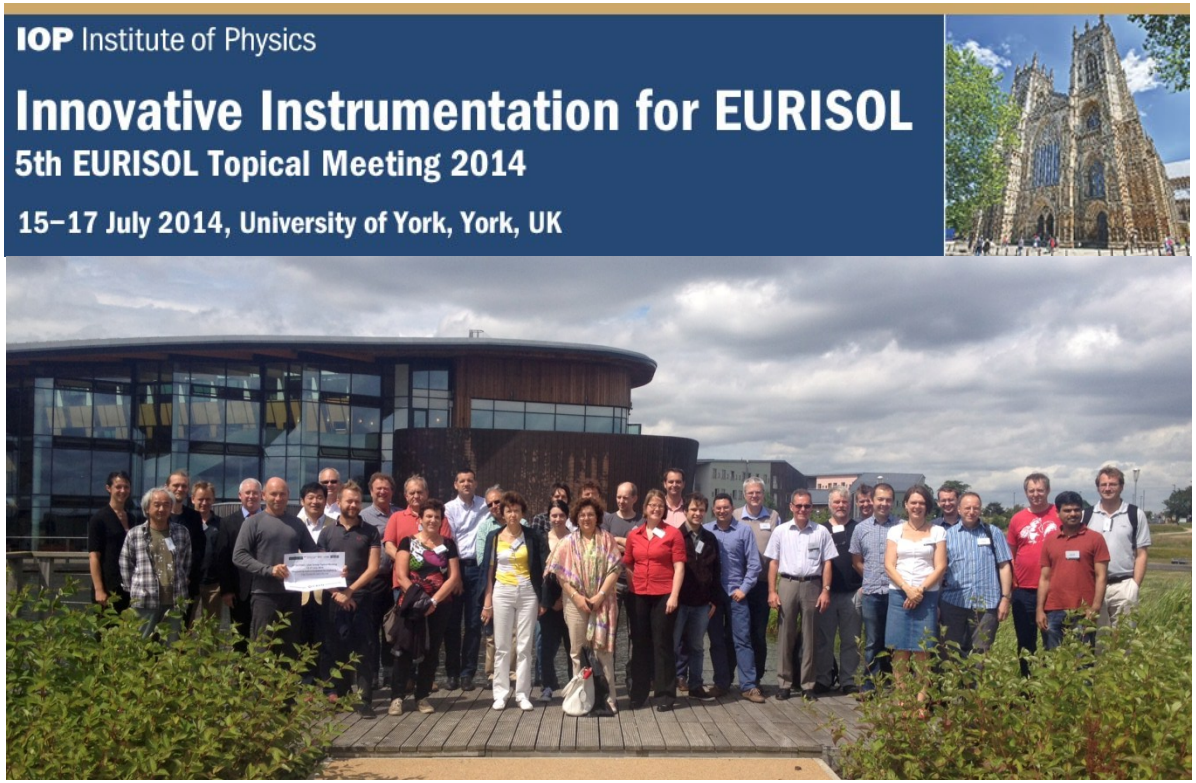
KU Leuven, Instituut voor Kern- en Stralingsfysica

Introduction

- EURISOL Topical Meeting, York, July 2014
- Review the instrumentation and techniques presently used at the ISOL facilities and discuss the possible future ideas and developments for the EURISOL facility



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NUCLEAR AND RADIATION PHYSICS

Introduction

Topics presented at York

- Current status of the main upgrade projects and projects for new facilities
- Instrumentation for beam handling: storage rings, separators, ion traps
- Instrumentation for radiation detection: charged particles, γ-rays, neutrons, electrons
- Spectroscopic techniques: electron scattering, fast timing, recoil decay tagging, measurement of ground-state properties

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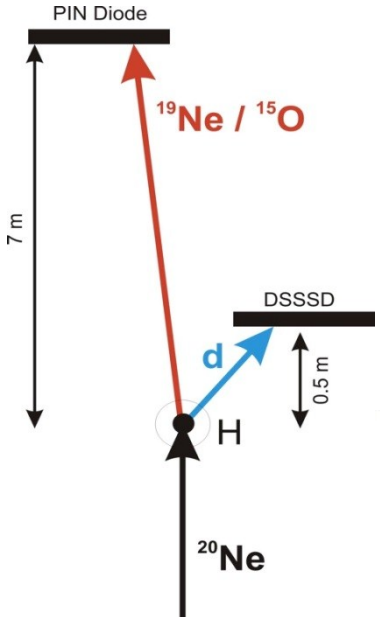
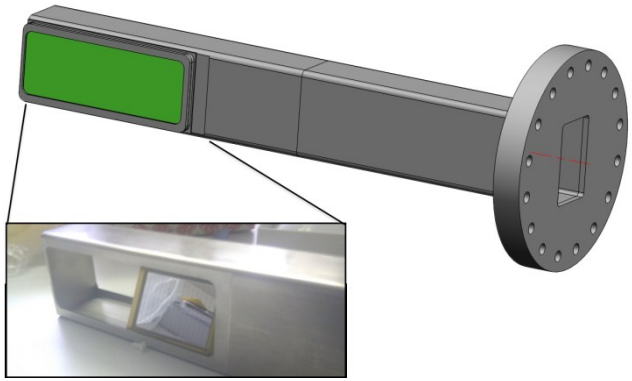
Beam handling

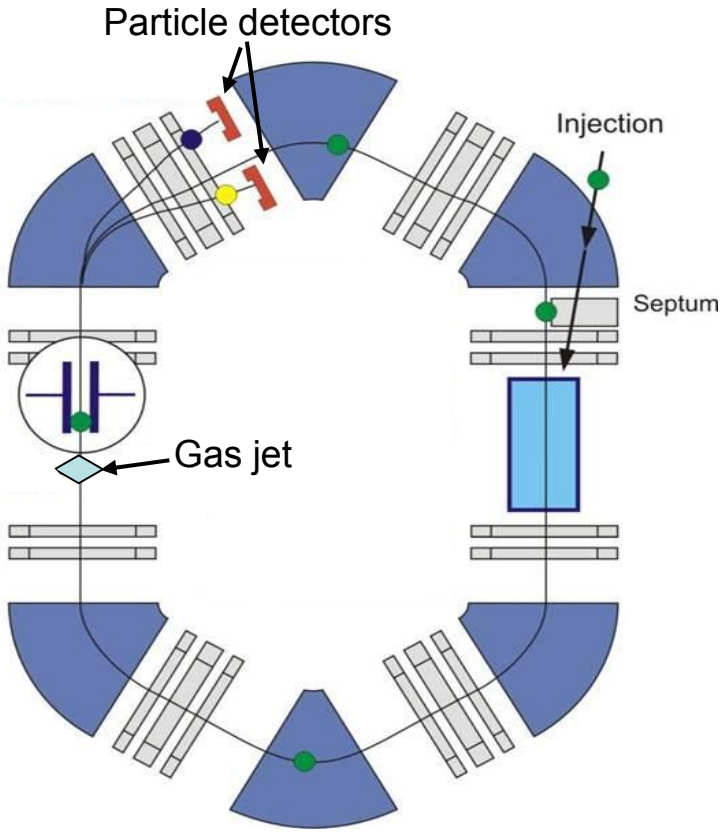
Figures: P. J. Woods

Measurement in rings: ESR

- $^{96}Ru(p,\gamma)^{97}Rh$
  $^{20}Ne(p,d)^{19}Ne$
  $^{56}Ni(p,p')$
- Gas target (10^{13} H_2/cm^2)
  Decelerated beam
- Detectors in pockets separated from UHV







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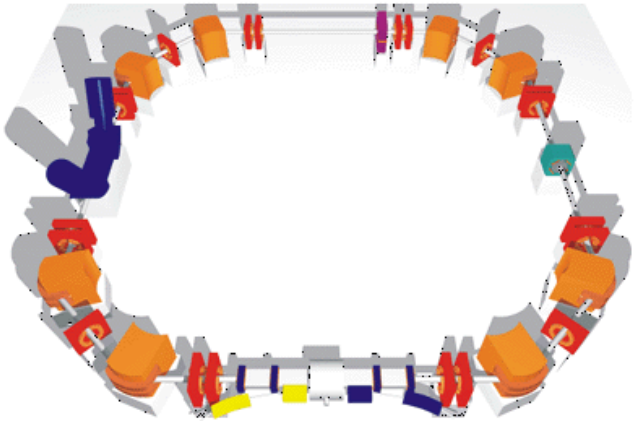
Beam handling

Measurement in rings: TSR@HIE-ISOLDE

K. Blaum and many others

Physics programme

- Astrophysics
  Capture, transfer reactions
  ^{7}Be half life
- Atomic physics
  Effects on half lives
  Di-electronic recombination
- Nuclear physics
  Reaction studies
  Isomeric states
  Decay of halo states
  Laser spectroscopy
- Neutrino physics



Beam handling

Figures: EXL

Measurement in rings: TSR@HIE-ISOLDE

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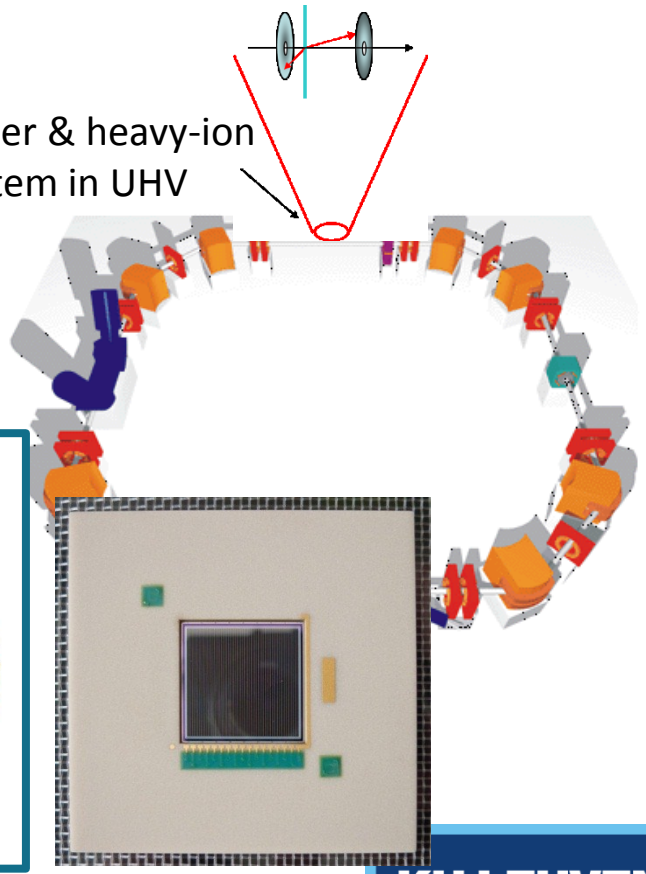
TSR@ISOLDE

^{26}Al^{m}(^{3}He,d)^{27}Al
In-ring target chamber & heavy-ion recoil detection system in UHV



EXL setup @FAIR

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Beam handling

Figures: P. J. Woods

Measurement in rings: TSR@HIE-ISOLDE

K. Blaum and many others

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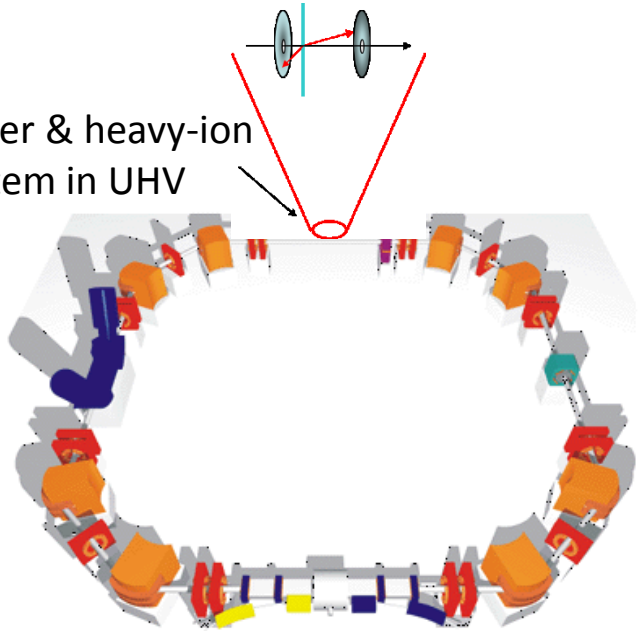
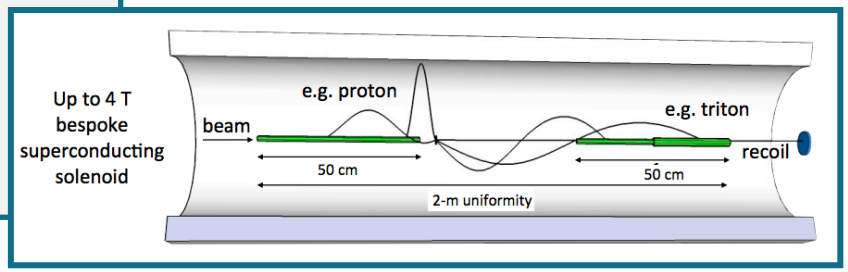


External solenoidal spectrometer



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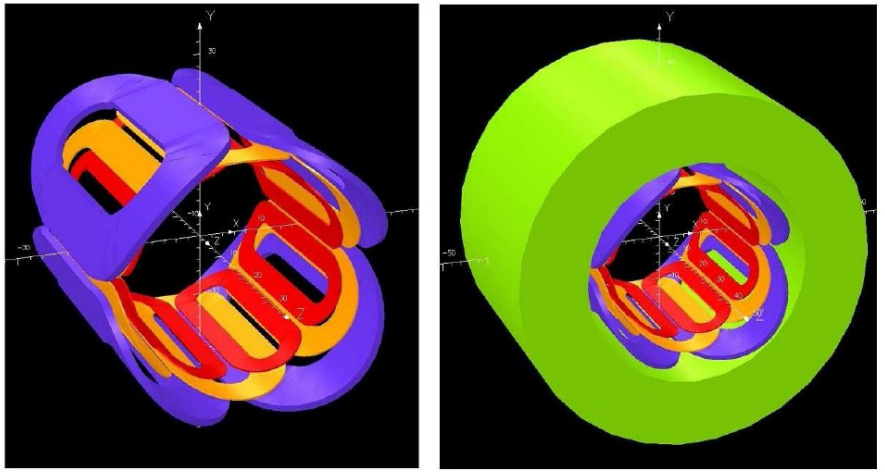
Beam handling

Figures: J. Nolen

Separators: multi-poles

- Current spectrometer/separators: either good physical separation but small acceptance or large acceptance and software reconstruction
- Solution: (SC) multi-pole elements S^3 at SPIRAL2 (CEA Saclay, GANIL, Argonne): corrections directly in the hardware



Coils | Coils with Iron Shell

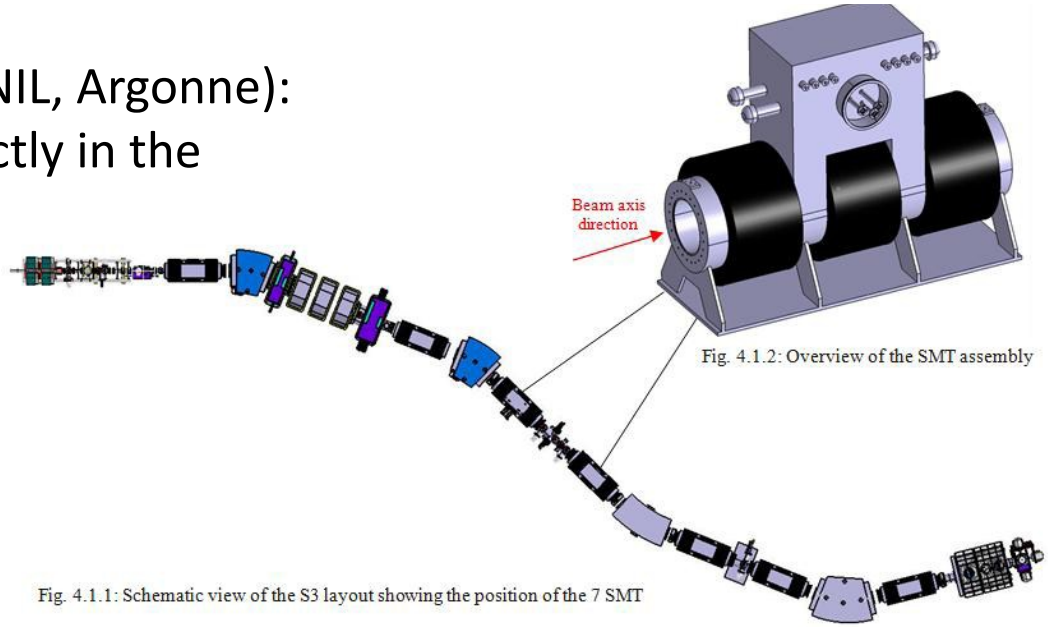


Fig. 4.1.2: Overview of the SMT assembly

Fig. 4.1.1: Schematic view of the S3 layout showing the position of the 7 SMT

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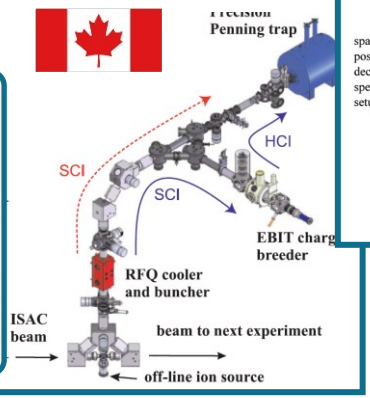
Beam handling

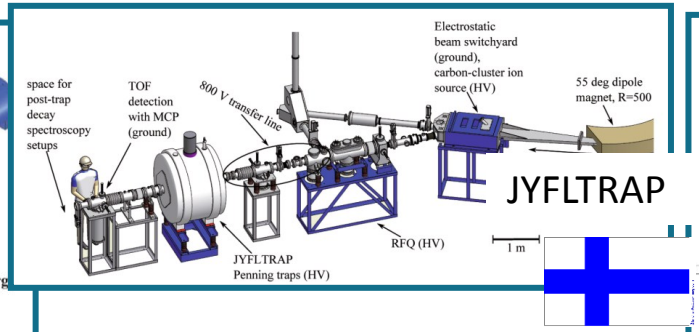
Figures: S. Kreim

Penning traps

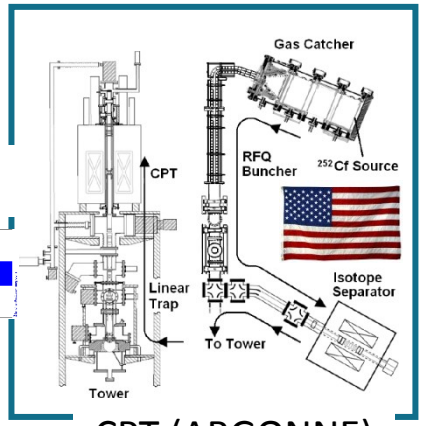
Beyond TOF-ICR for rare isotopes: shorter times, beam preparation

TITAN (TRIUMF)

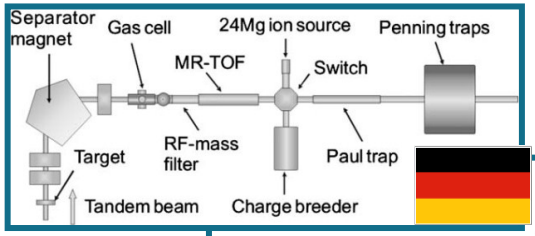




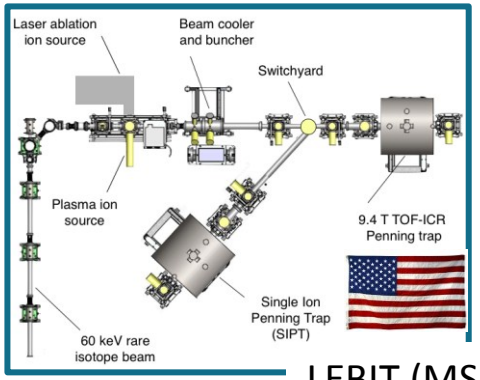
JYFLTRAP



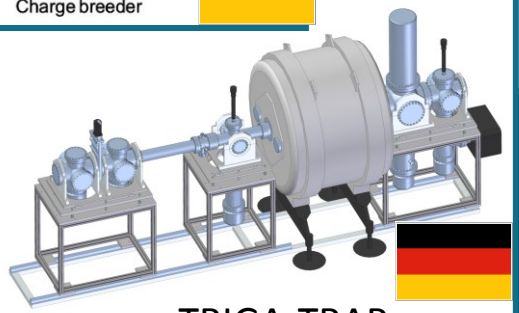
CPT (ARGONNE)



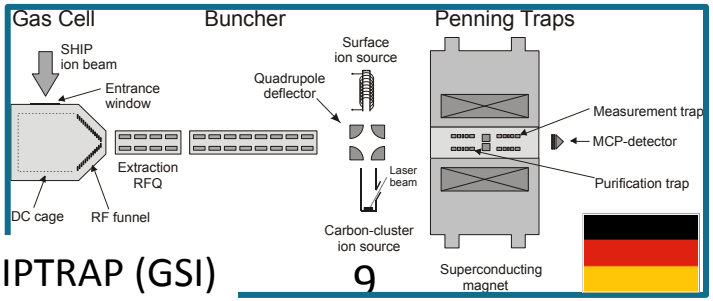
MLLTRAP



LEBIT (MSU)



TRIGA-TRAP



SHIPTRAP (GSI)

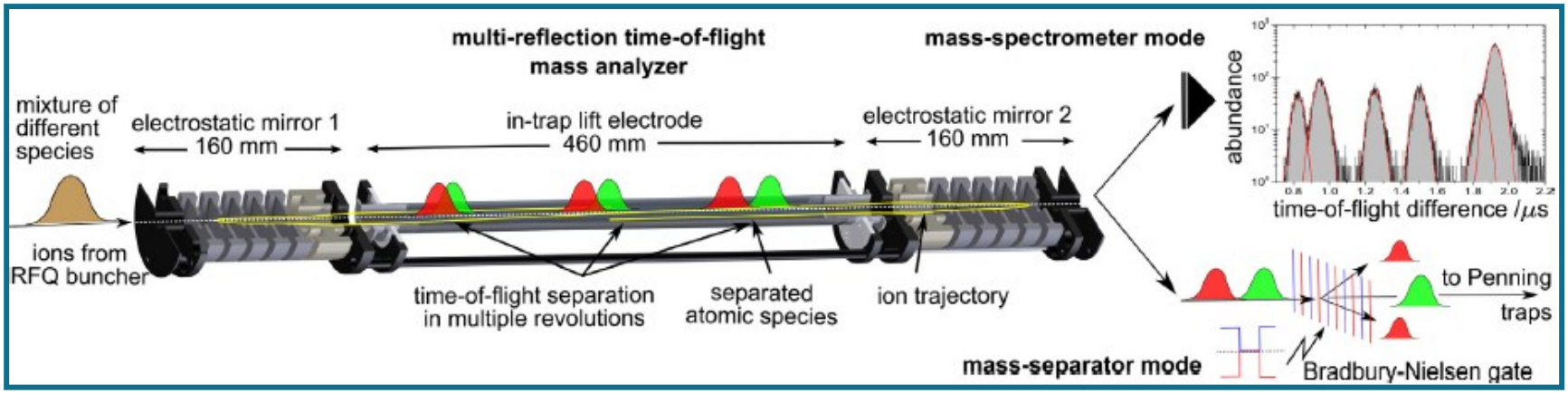
ISOLTRAP(CERN)

Beam handling

Figures: S. Kreim

Multi-Reflection Time-of-Flight Mass Separator

- Beam preparation for **trap** measurements (purified sample, shorter measurement)
- Spectrometer for mass measurements
- Spectrometer for ion-beam yield analysis
- Very high mass resolving power $m/\Delta m \approx 10^5$
- Transmission ≈ 50% at 30 ms, 10^3 ion/cycle



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Beam handling

Figure: J. Gerl

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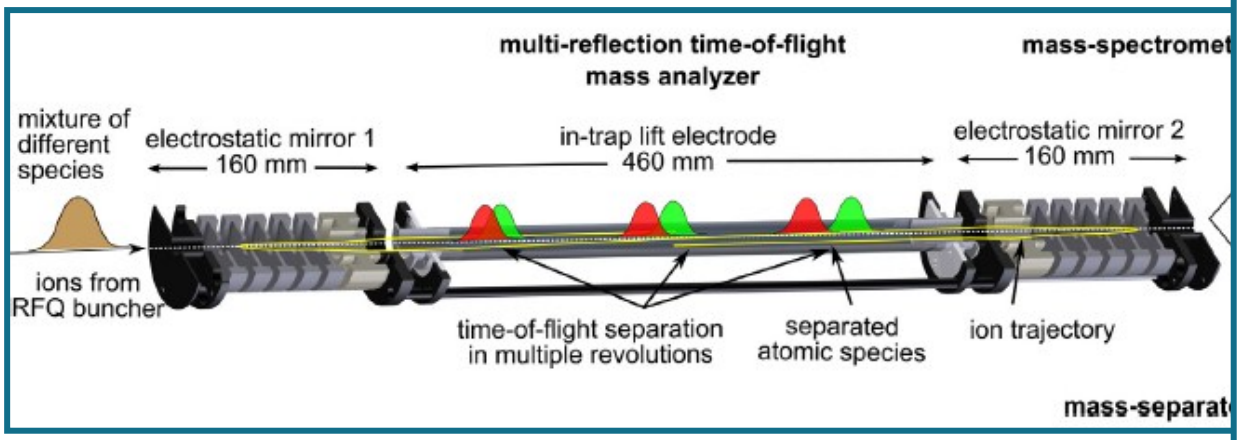

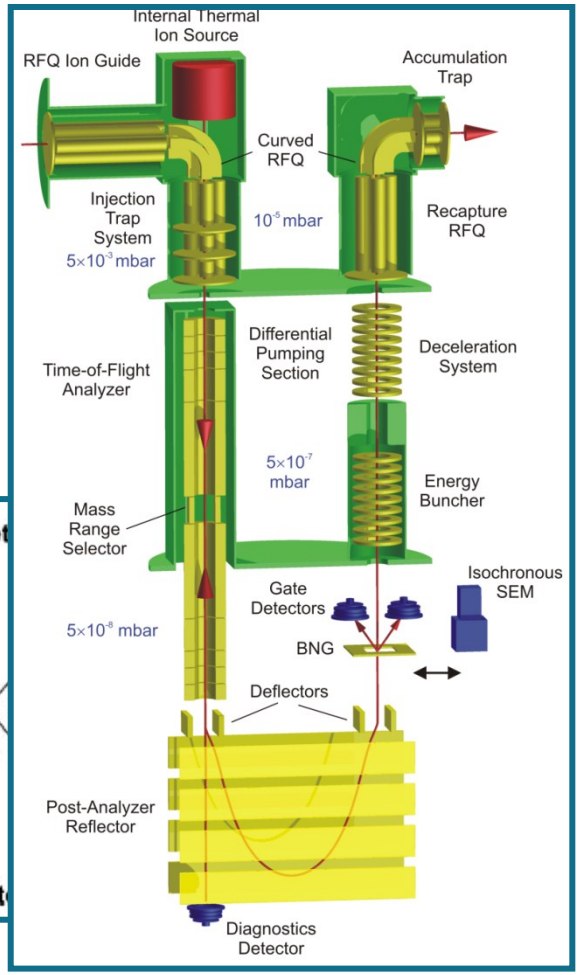

W.R. Plaß et al., NIM B 266 (2008) 4560
W.R. Plaß et al., Int. J. Mass Spectrom. 394 (2013) 134

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Ion handling

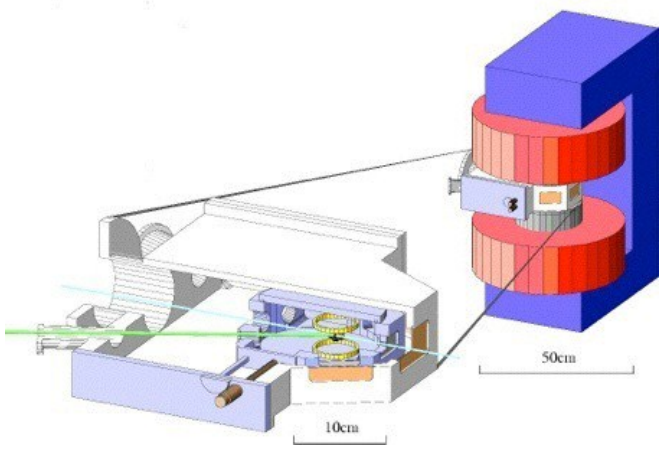
Figures: T. Uesaka

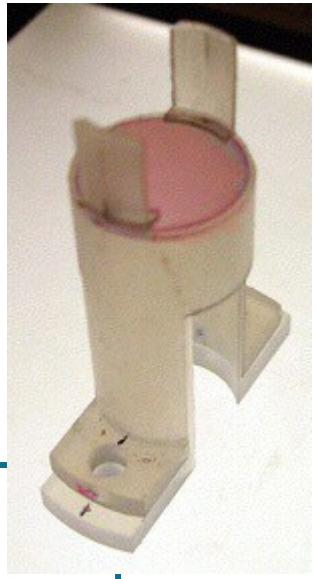
Polarised proton target

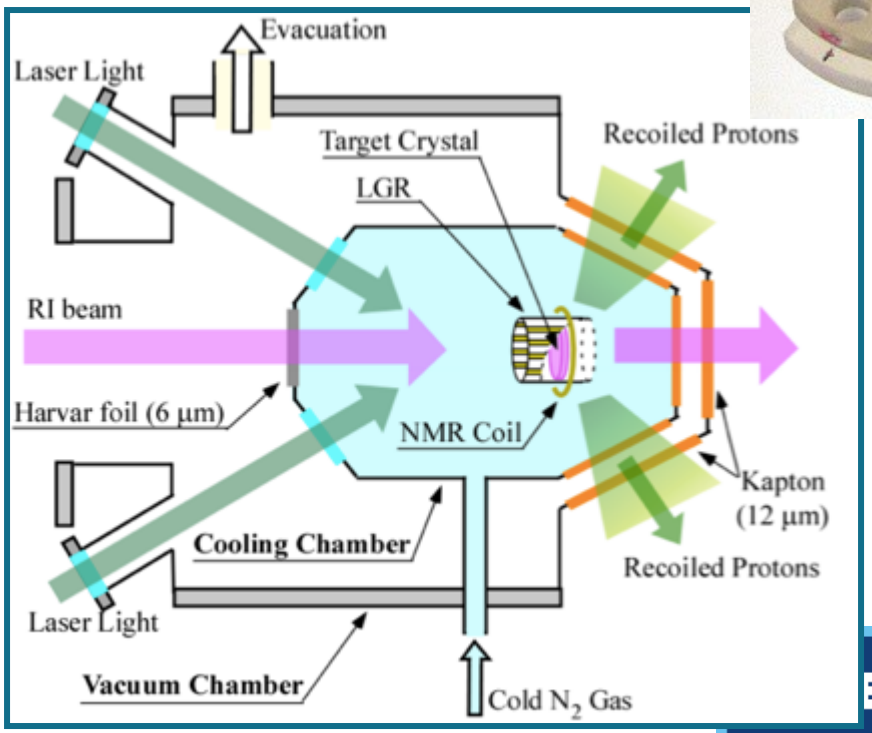
- "Magic" pentacene molecule electron polarisation (lasers) transferred through microwave radiation
- Limits: polarisation power, relaxation time
- Improved lasers new host for pentacene

40% polarisation at room temperature!

- Extremely interesting application in imaging





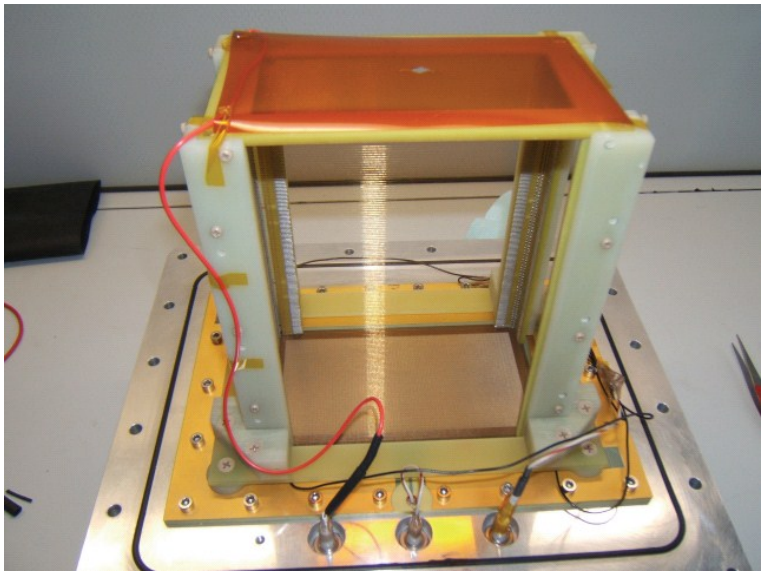


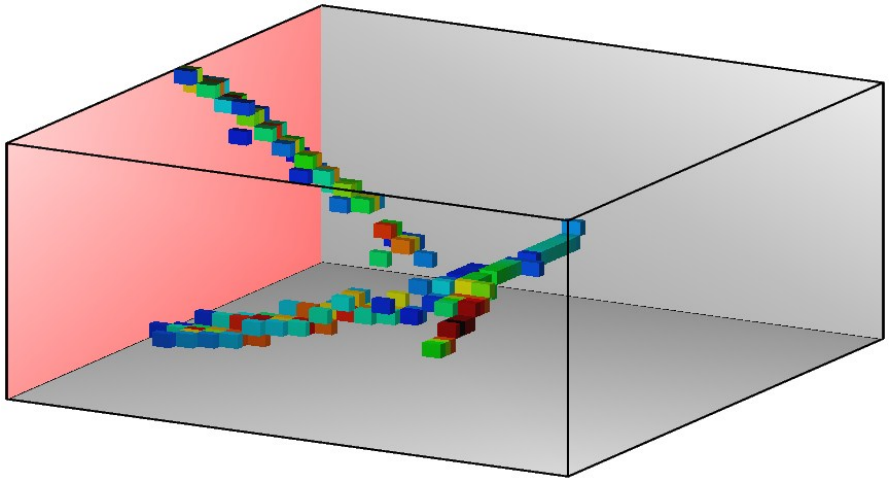
Radiation detection

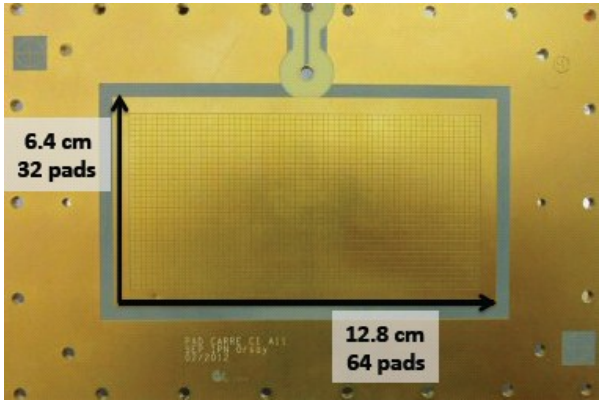
Figures: T. Roger

(light) Charged particles: active target

- Tracking of particles
- High luminosity
  preserving resolution
- Versatile, portable
- ACTAR TPC (here Demonstrator):
  16000 channels
  ERC grant G. Grinyer







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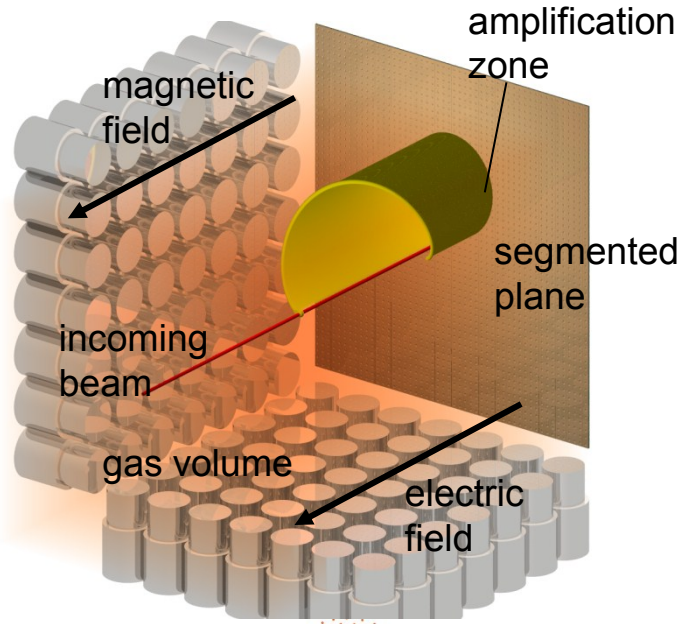
  ERC grant G. Grinyer
- SpecMAT: scintillator array
  ERC grant RR



erc
European Research Council
Established by the European Commission

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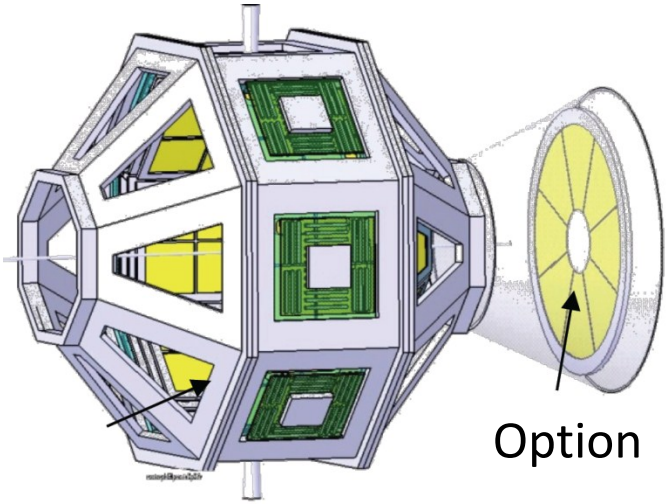
Radiation detection

Figures: M. Assié

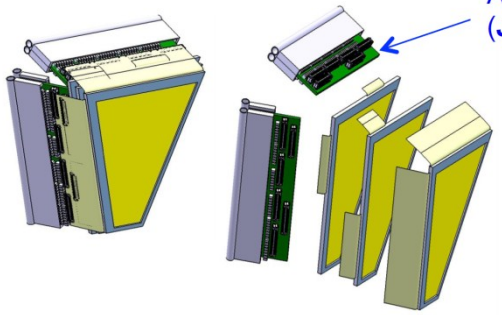
(light) Charged particles: silicon

- GASPARD:
  Integration with AGATA, PARIS, CHyMENE
- Particle identification
  through pulse shape analysis:
  GASPARD, FAZIA



Option

To technical design :



ASIC preamps iPACI
(**J-J. Dormard, E. Rauly**, IPNO)

iPACI gives current & charge signals

1st version =9 channels

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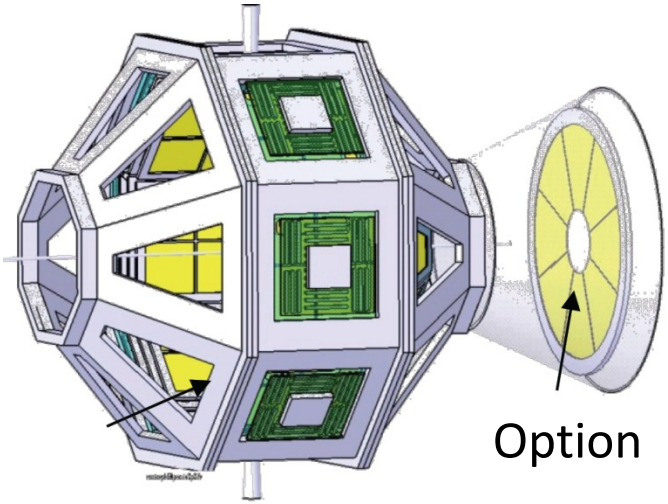
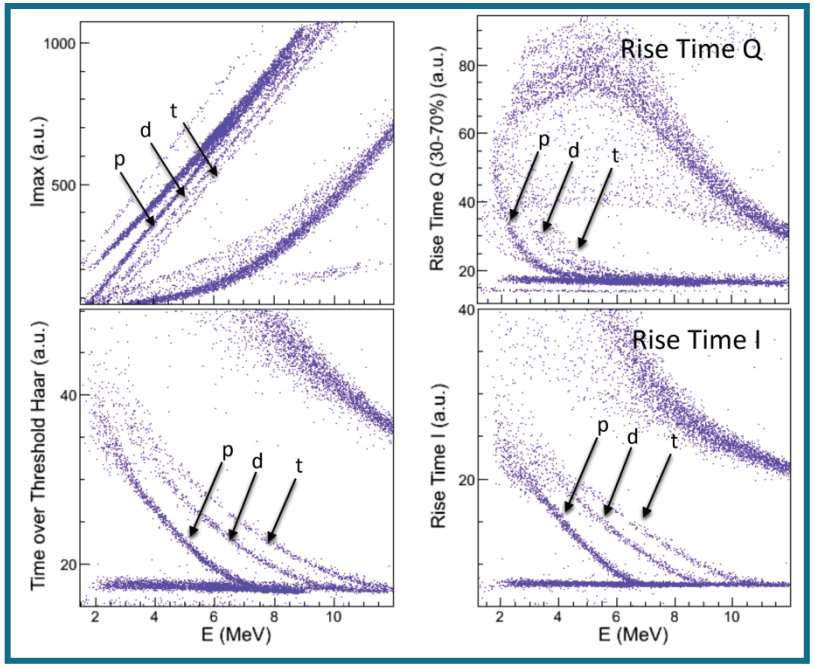
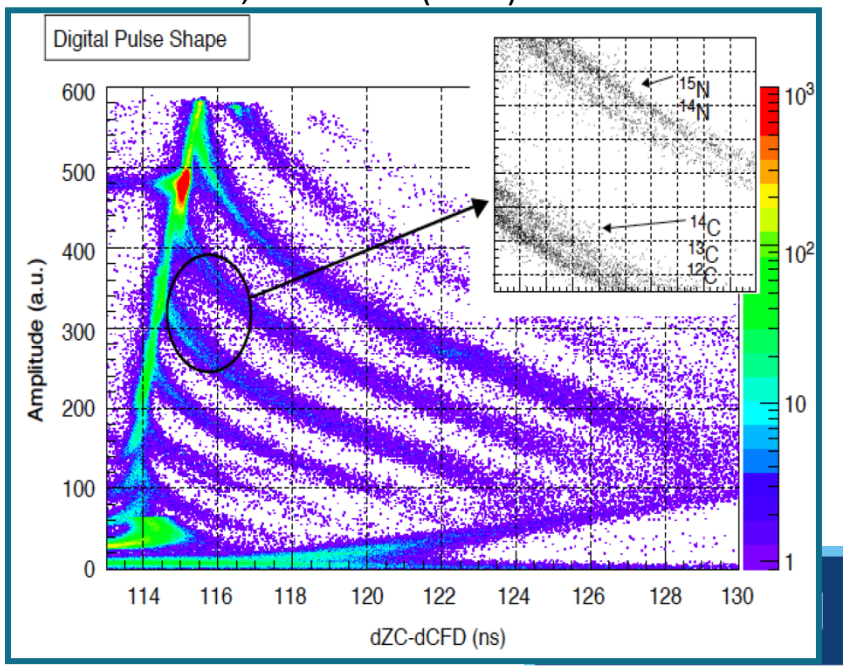


Option

L. Bardelli et al, NIMA 521 (2004) 480





Radiation detection

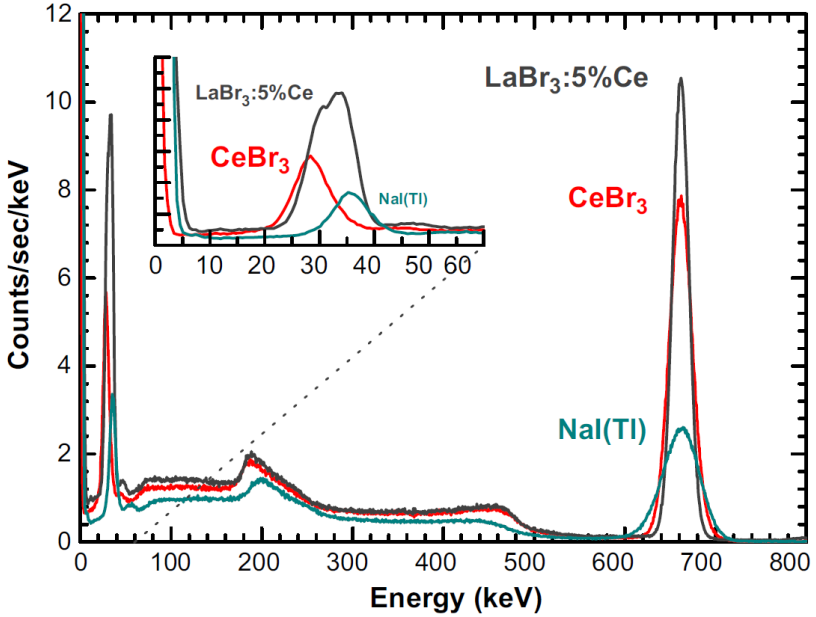
Figures: D. Jenkins

Scintillators: new materials

- $LaBr_3$(Ce): good resolution, but expensive and high internal radioactivity
- New materials:
  $CeBr_3$: res < 5%, fast, available; co-doping?
  SrI_2(Eu): res < 3-4%, slow, available
  GYGAG (ceramic): Z≈48, res < 5%, rare
- Elpasolites (CLYC, CLLC and CLLB):
  good for gammas and neutrons
  high linearity, high efficiency, res < 4%

CLYCs enriched with 7Li, 6Li to emphasize fast and slow neutron detection

F.G.A. Quarati et al., NIMA 729 (2013) 596



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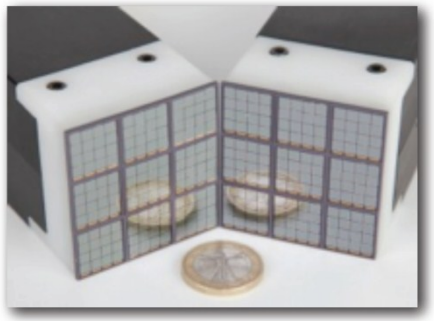
Radiation detection

Figures: D. Jenkins, T. Kroell

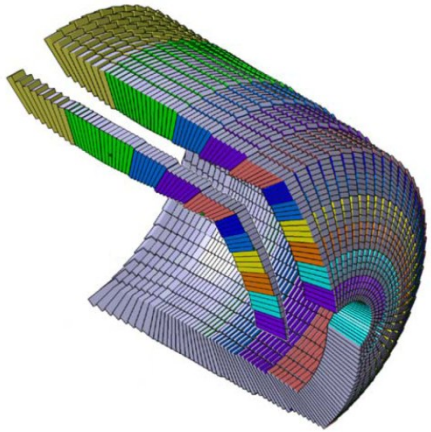
Scintillators: light collection

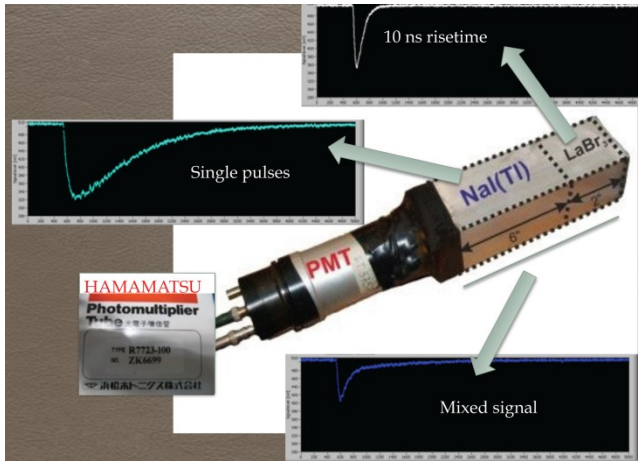


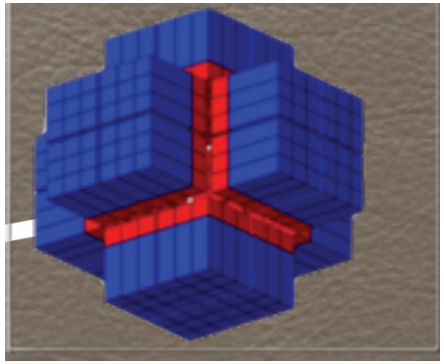
- Avalanche Photodiodes and Si photomultipliers
  Work in magnetic field, low HV, possible good timing steadily improving
- Combinations: Phoswich

CALIFA: $LaBr_3$+$LaCl_3$, CsI(Tl) gammas and protons

PARIS: $LaBr_3$+NaI(Tl)







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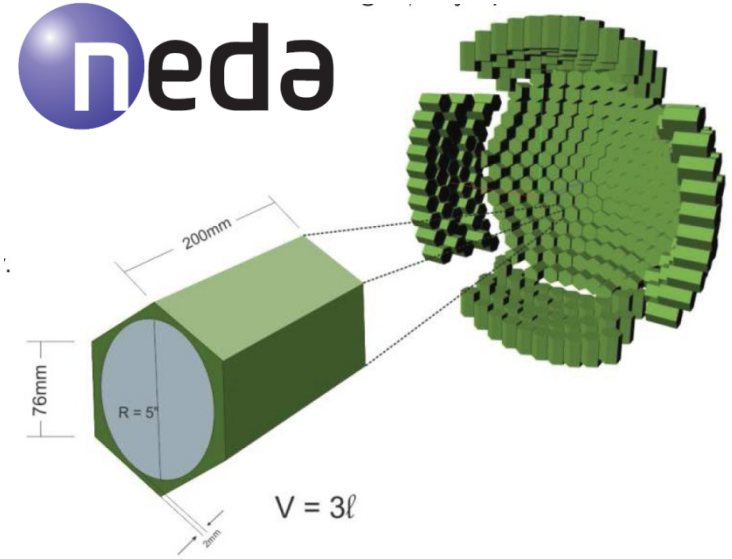
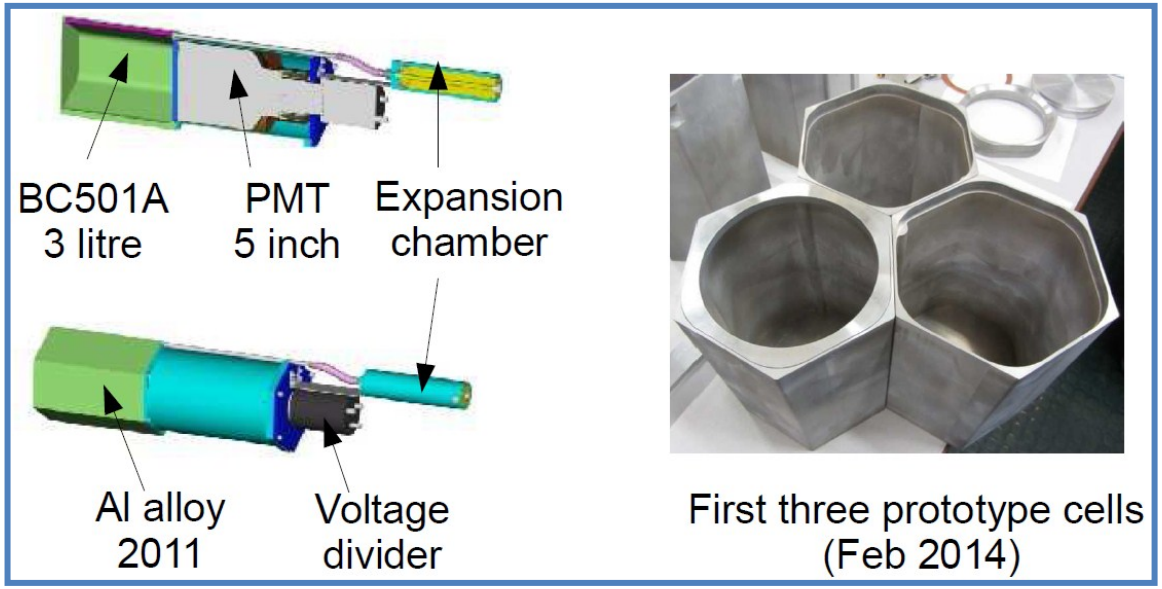
Radiation detection

Figures: J. Nyberg

Neutrons

- NEDA array:
  - Compact, modular, portable
  - Coupled with large γ-ray arrays
  - Excellent n- γ and cross-talk discrimination and count-rate capabilities
- Looking into new materials





First three prototype cells (Feb 2014)

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Radiation detection

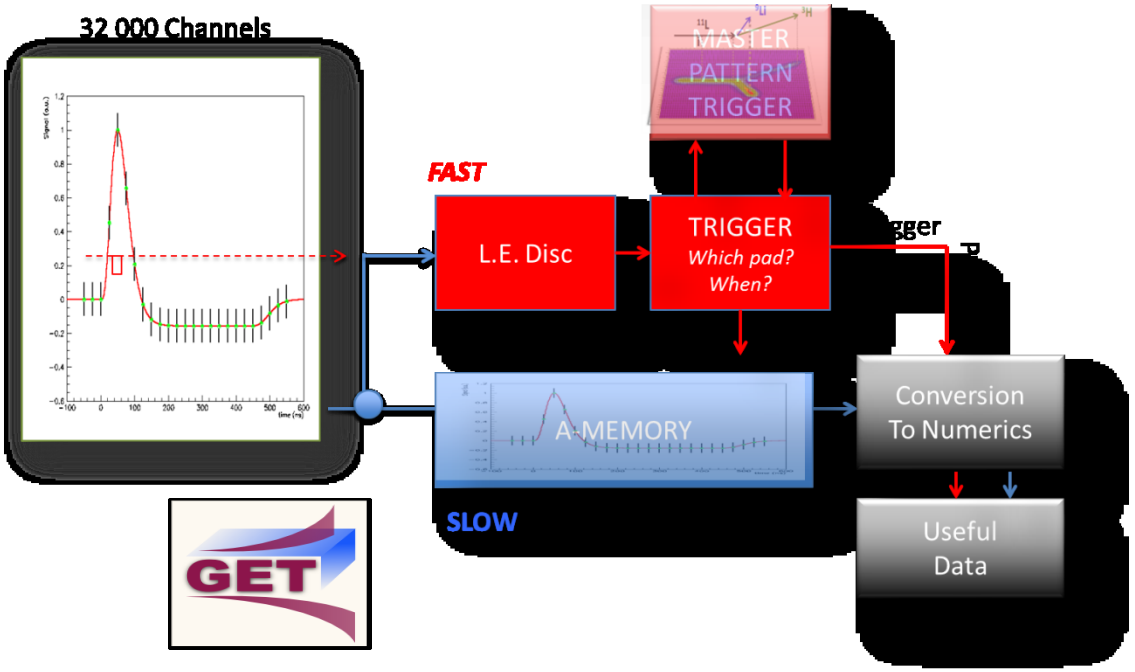
Figures: E. Pollacco

Electronics

- General trends:
  - Digitisation
  - Large number of channels
  - ASICs, on-board software
- But: developing a dedicated electronics take several years!

  → Look around!
  Use standards/solutions from industry and other communities

  → Towards "generic" solutions?
  i.e. same ASIC, followed by ADCs, rapid data transmission and FPGA
  Customisation: preamps and FPGA



Future: coordinated efforts will be mandatory!

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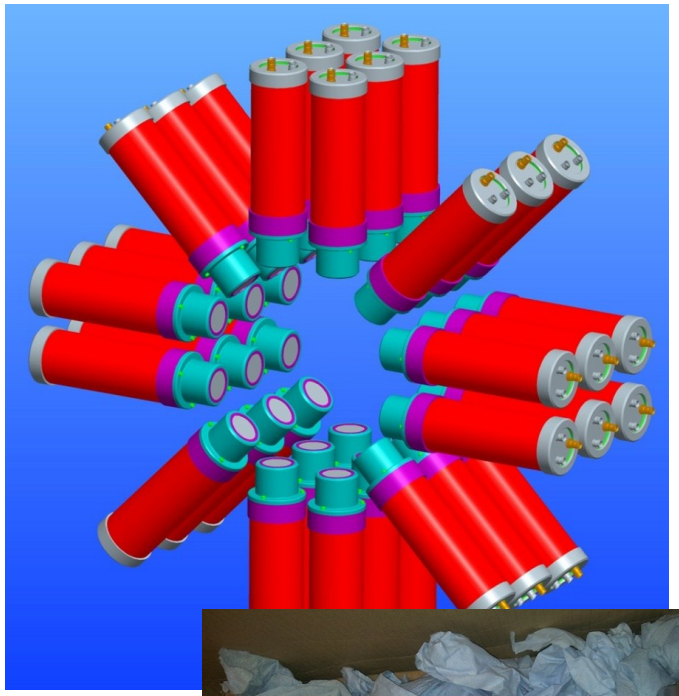
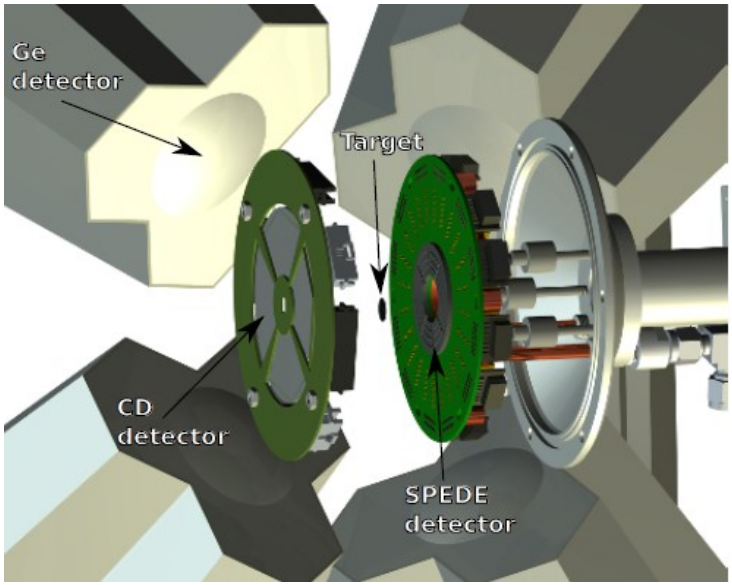
Spectroscopic techniques

Figures: G. Simpson, O. Roberts

Implementation of technologies (today already)

- RDT: electronics, segmented detector…
- Fast timing: new crystals
  FATIMA: modular, 50ps - 10ns half lives
- Conversion electrons
  SC coils, segmented arrays





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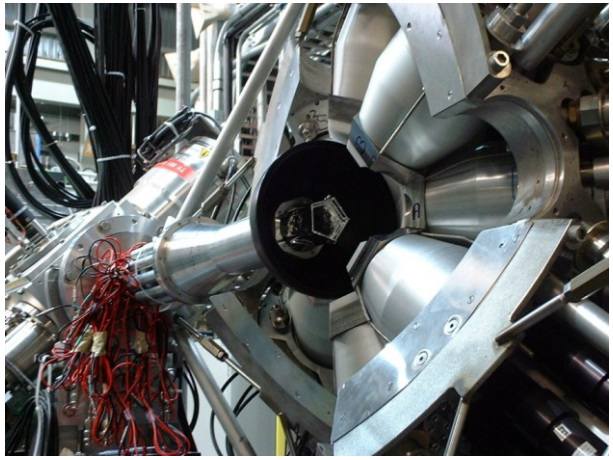
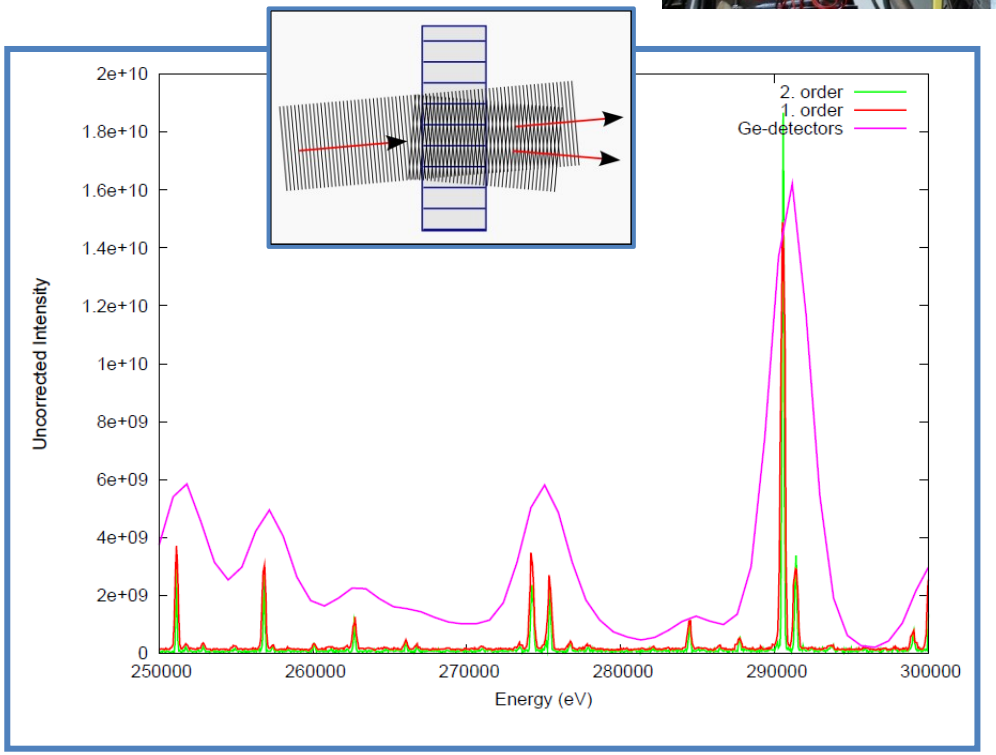
Spectroscopic techniques

Figures: P. Garrett, M. Jentschel

Detailed spectroscopy

- Complete information:
  electrons (β and EC), γ , timing
  moments
  TAS
- Ultra-high-resolution γ spectroscopy





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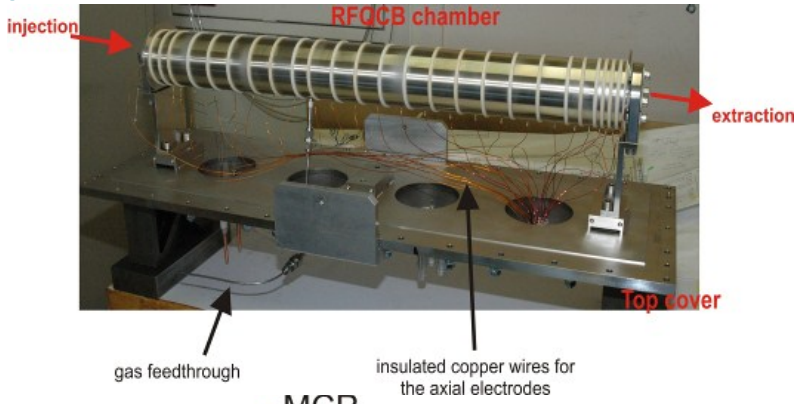
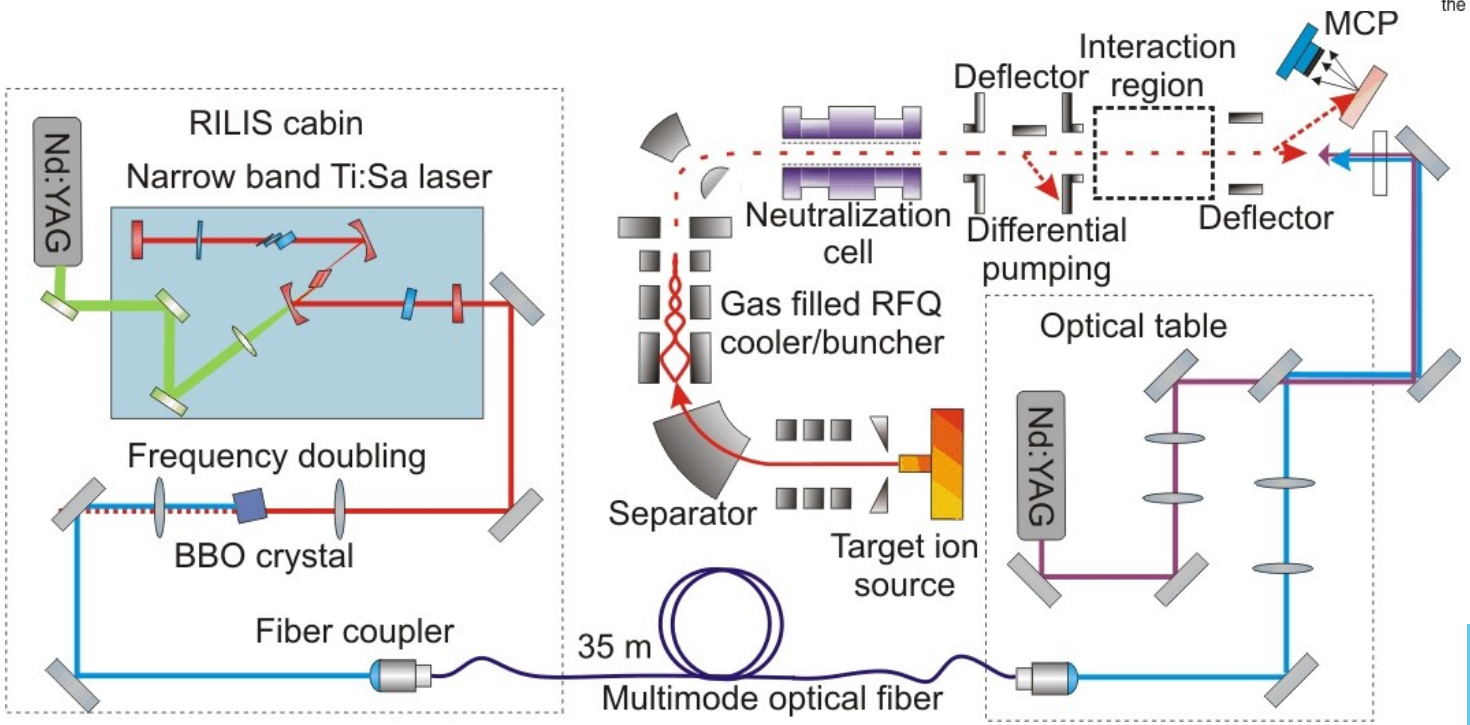
Spectroscopic techniques

Figures: K. Flanagan

Lasers spectroscopy: spins, moments, radii

- Regimes: high sensitivity or high precision
  New physics in both!
- Contributing to / relying on ion handling:
  ISCOOL for CRIS at ISOLDE





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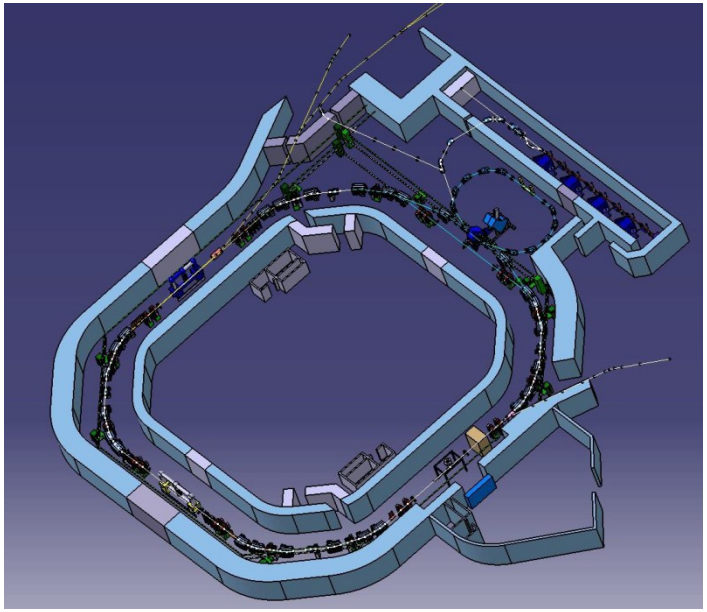
Spectroscopic techniques

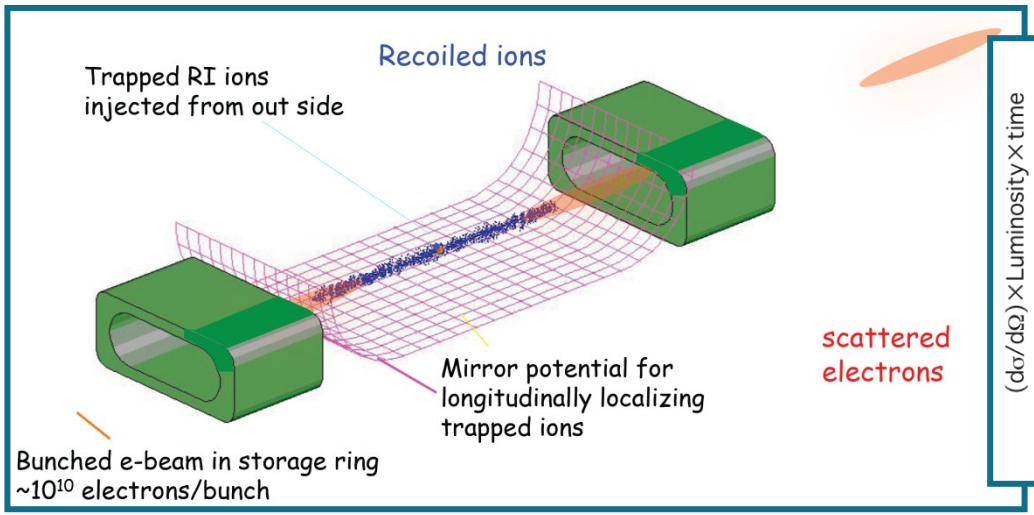
Figures: H. Simon, M. Wakasugi

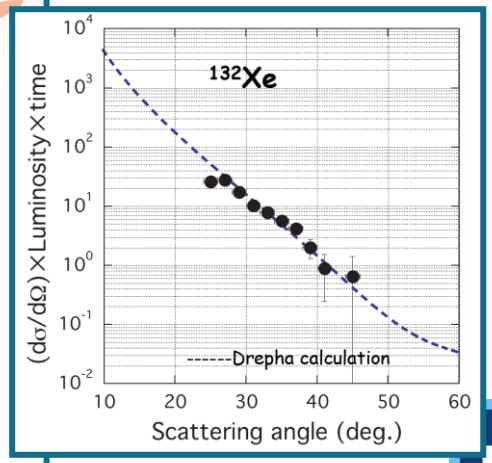
Electron scattering brought to exotic nuclei



- ELISe at GSI:
  Colliding beams in rings
  proposed placement at a modified ESR

- SCRIT at RIKEN:
  ion target in electron ring
  …it works!





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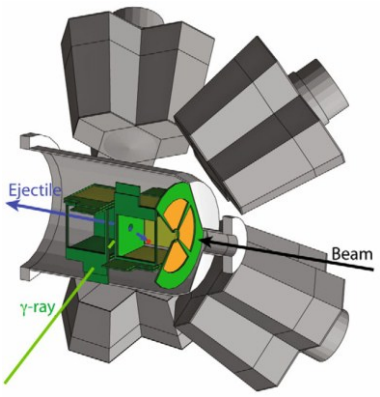
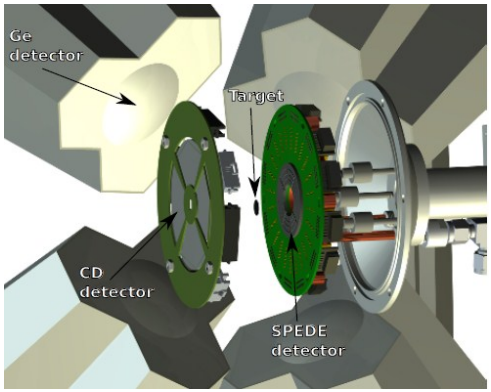
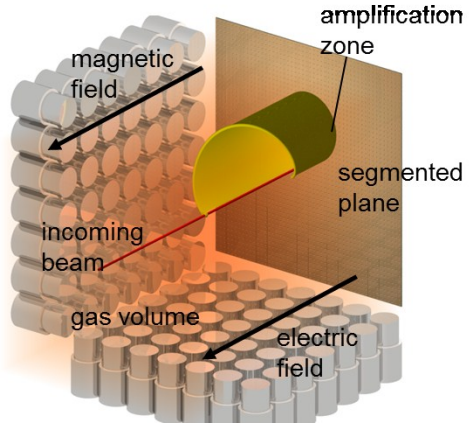
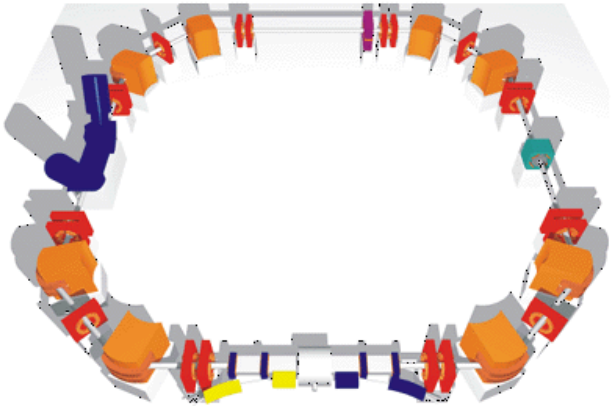
Facilities

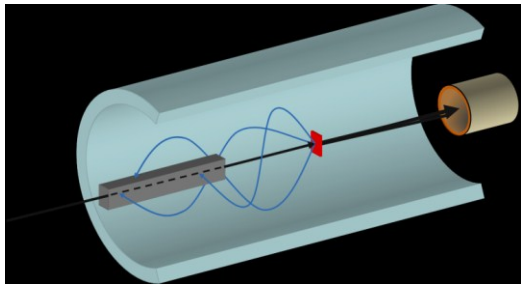
- Presentations on HIE-ISOLDE, ALTO, SPES, ISOL@MYRRHA, SPIRAL2, NUSTAR











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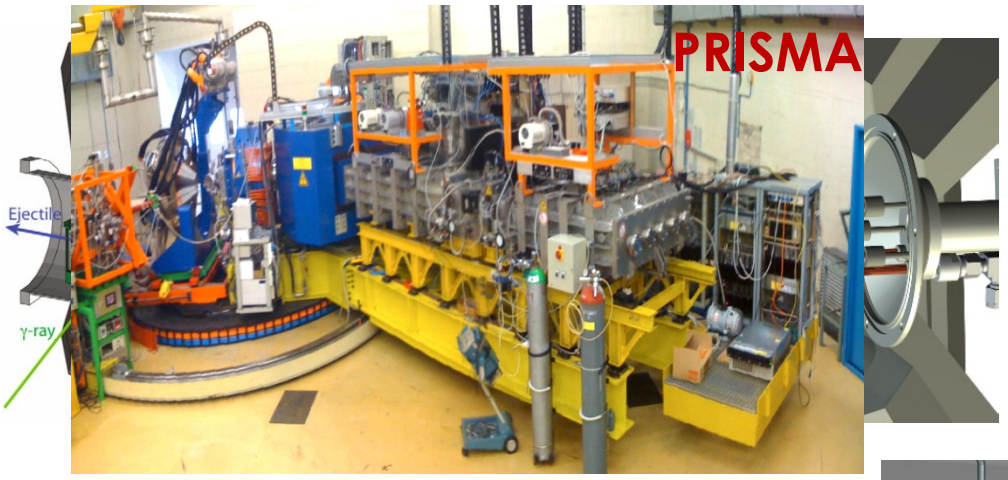

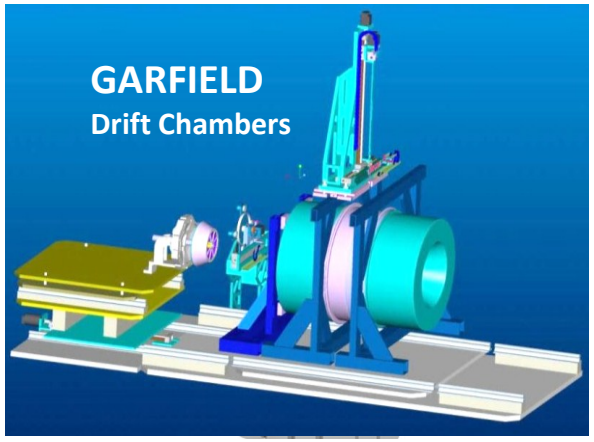

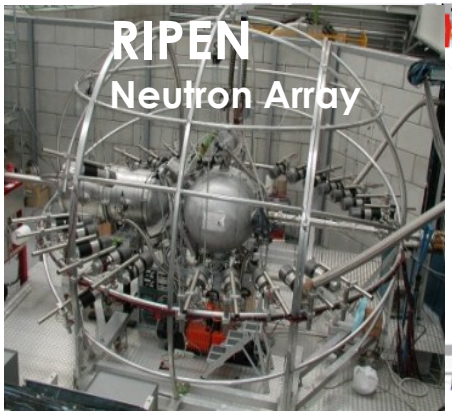

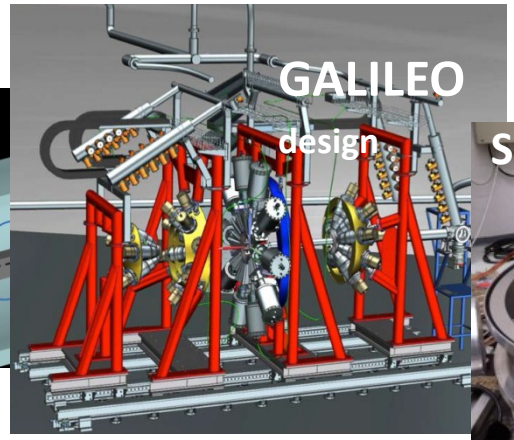

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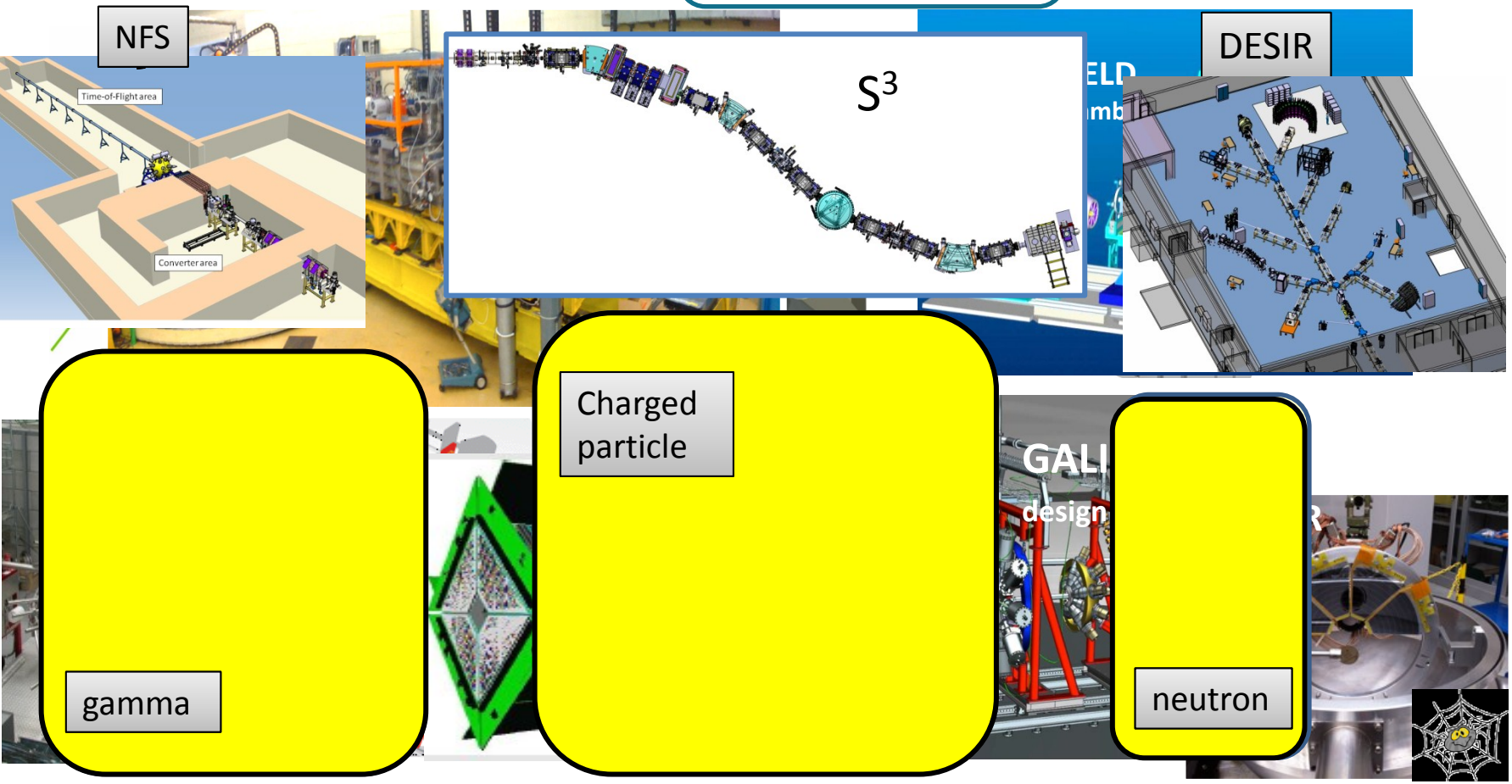

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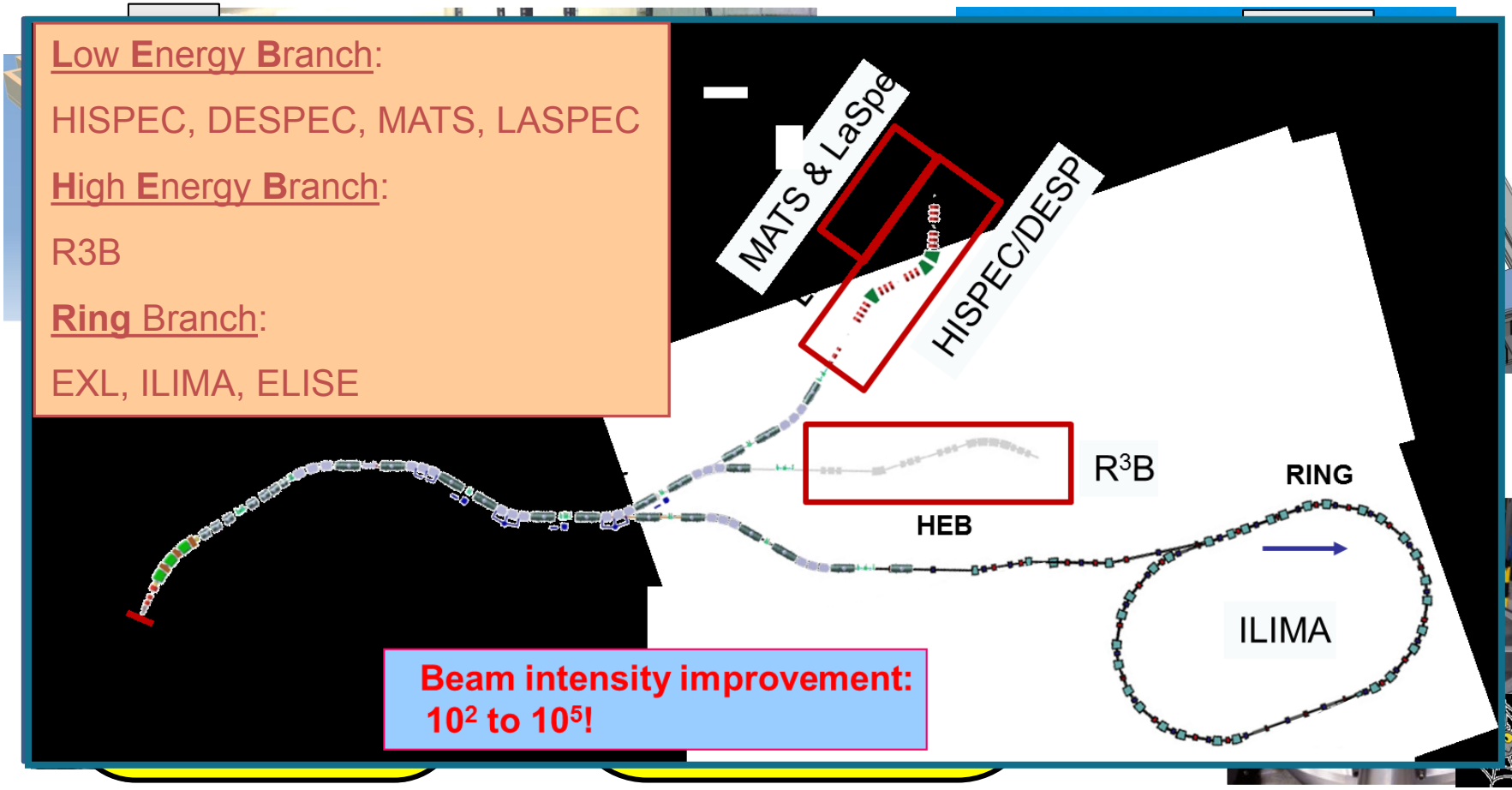

Conclusions

- Diversity is a resource:
  Spectroscopic techniques that probe different aspects
  Source of new approaches (there is time before EURISOL…)
- But some aspects need to be coordinated
  Data acquisition
  Development efforts on materials, technologies…
- Look for existing needs and solutions in other fields
- Final facility: run in multi-user mode
  with dedicated lines for time-consuming techniques

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