



UNIVERSITÉ
DE GENÈVE



Update on MRI and medical applications

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UNIGE, CERN

Outline

- **Our medical project at/and CERN**
- **Decay of spin-polarized nuclei**
- **Limitations of NMR and MRI**
- **Towards gamma-detected MRI in medicine**
- **Summary and outlook**



Background

Our medical project at/and CERN

Some background:

- My ERC grant at ISOLDE on beta-detected NMR in biology
- Renaud Jolivet's medical-physics joint CERN/UNIGE appointment
 - link to IdeaSquare, MAPF, Marzio, ATTRACT
- Article in 2016 in Nature on gamma-detected MRI
- Very motivated PhD candidate willing to work with us on gamma-MRI

Our medical project at/and CERN

Resulting in:

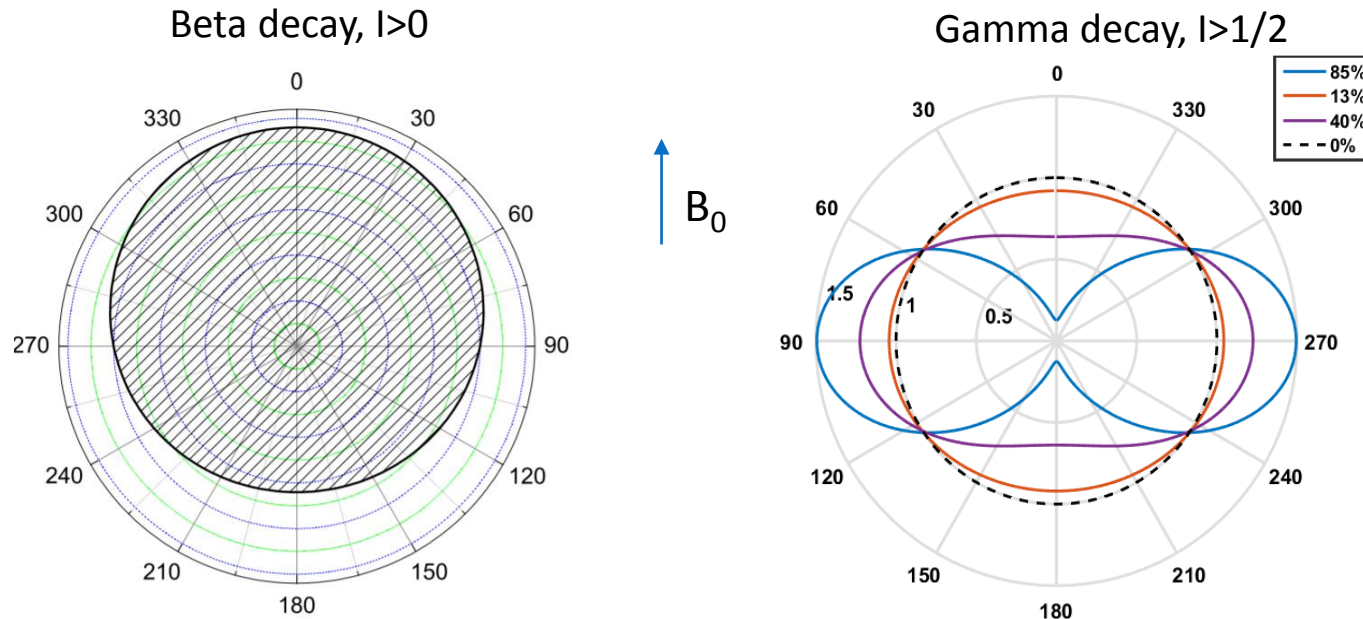
- Active collaboration with Haute Ecole de Santé in Geneva
- Discussions at CERN with Thierry Stora, Etienne Auffray and Paul Lecoq
- Approved CERN Medical Applications Funding – student and equipment
- The student: Swiss funding with Renaud and top-up from CERN
- Application to ATTRACT
- Application to FET_OPEN
- First contacts with industry
- More ideas for applications



Project

Decay of spin-polarized nuclei

Beta and gamma decay of spin-polarized nuclei anisotropic in space



Degree of asymmetry:

depends on degree and order of spin polarization and transition details (initial spin, change of spin)

Observed decay asymmetry can be used to:

- Probe underlying decay mechanism -> fundamental physics
- Determine properties of involved nuclear states -> nuclear physics
- Derive differences in nuclear energy levels -> this talk

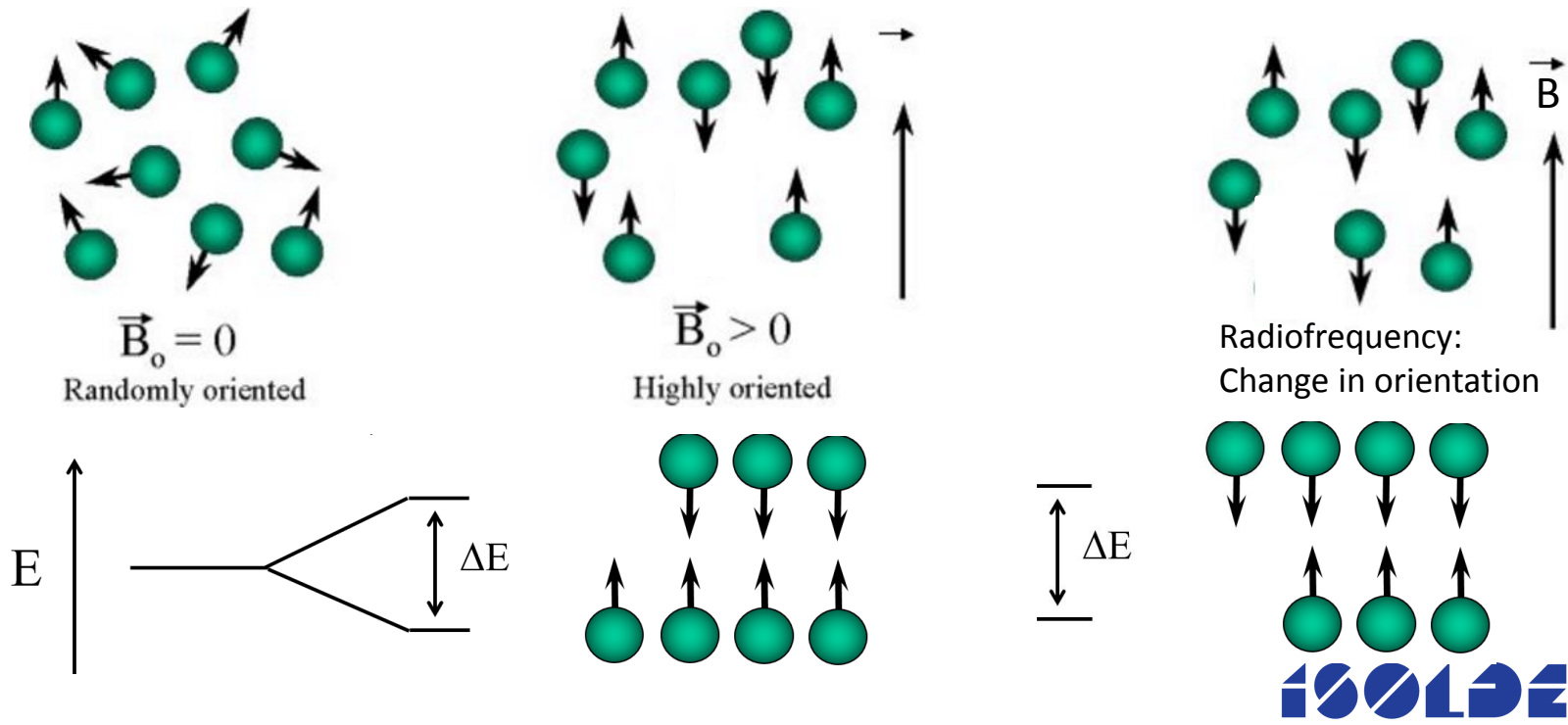
NMR principles

Participants:

- Probe nuclei with spin different from 0
- Sample/ environment

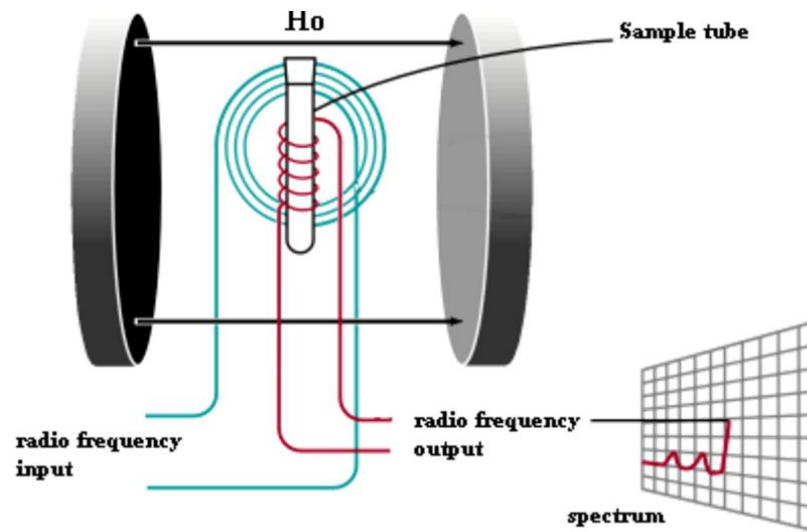
Magnetic field

- Strong static field (B_0) -> when different at different positions -> **MRI (Magnetic Resonance Imaging)**
- Weaker field (B_1) oscillating at radio-frequency (MHz)



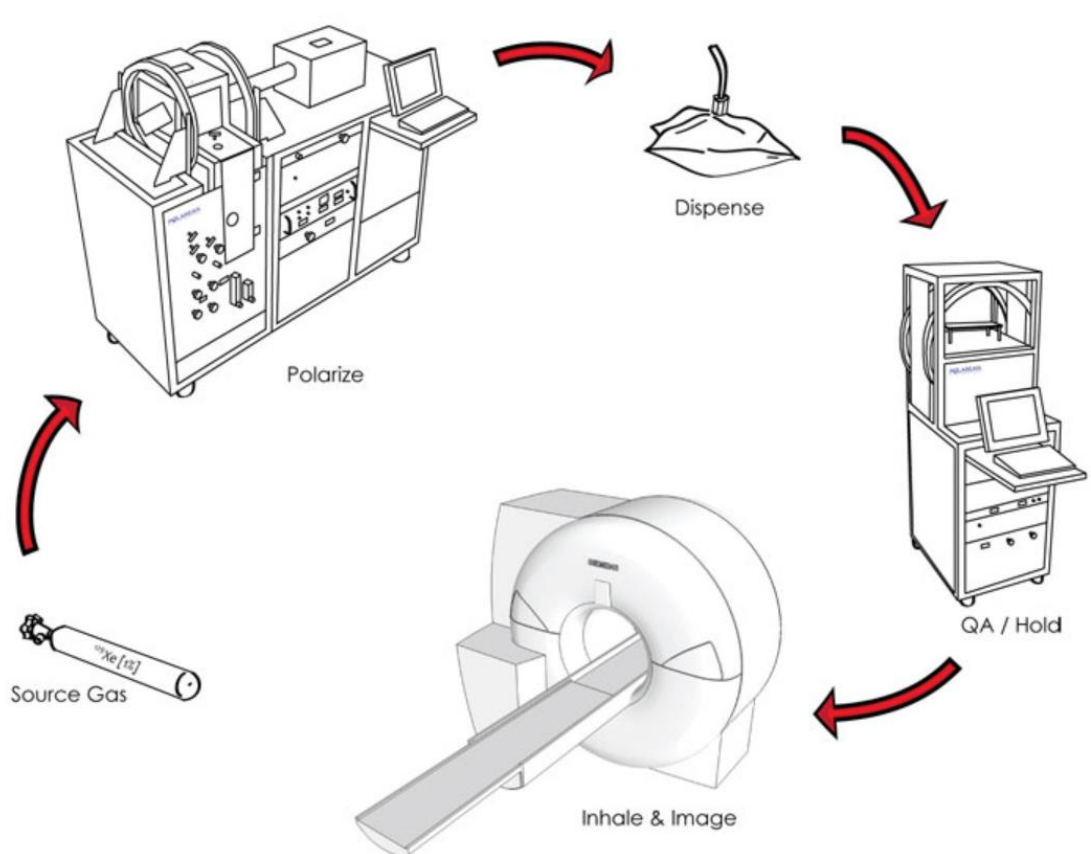
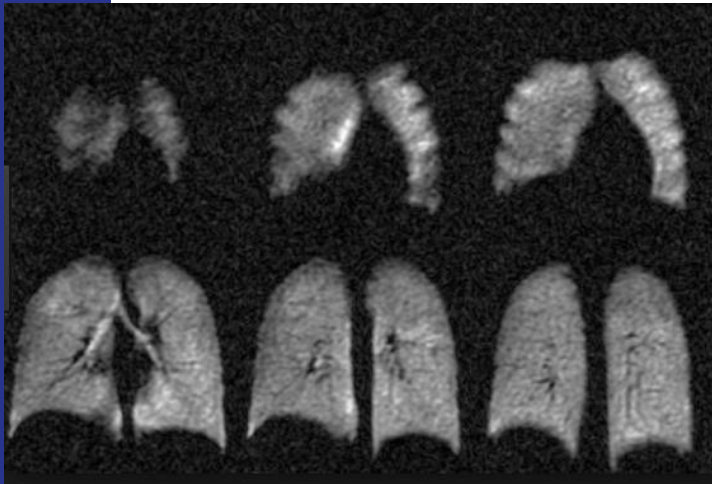
NMR limitation: sensitivity

- NMR is powerful but not sensitive
 - Small degree of polarization
 - Inefficient detection
- Our combined paths to increase sensitivity: beta-NMR and gamma-NMR/MRI
 - Hyperpolarization
 - Detection of asymmetry in beta or gamma decay



MRI with hyperpolarized stable nuclei

- Best example: ^{129}Xe :
 - Polarized via spin-exchange with laser-polarized Rb
 - Applications: lung and brain MRI, encapsulation and use in body liquids



1st medical applications of ^3He :
W. Heil et al, Mainz, Nature 1996



New modality: gamma-MRI

PET/SPECT and MRI have complementary features:

	Detection efficiency	Spatial resolution
PET and SPECT	high	Low (e.g. >5mm for ^{82}Rb)
MRI	low	High

Solution: **gamma-MRI (or simultaneous SPECT-MRI):**

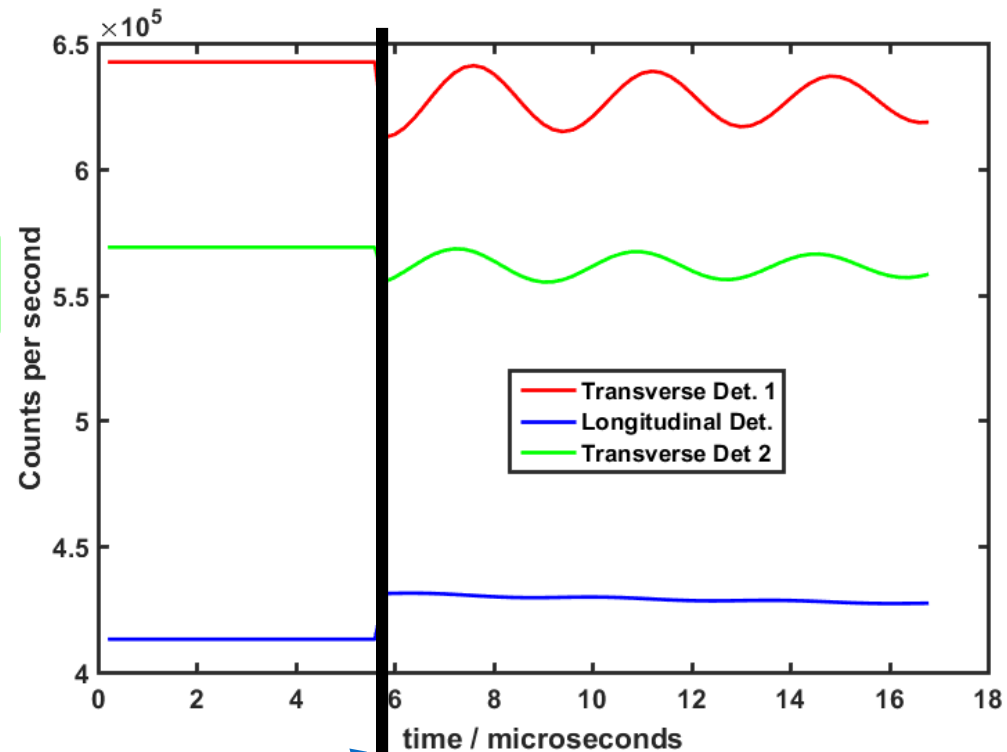
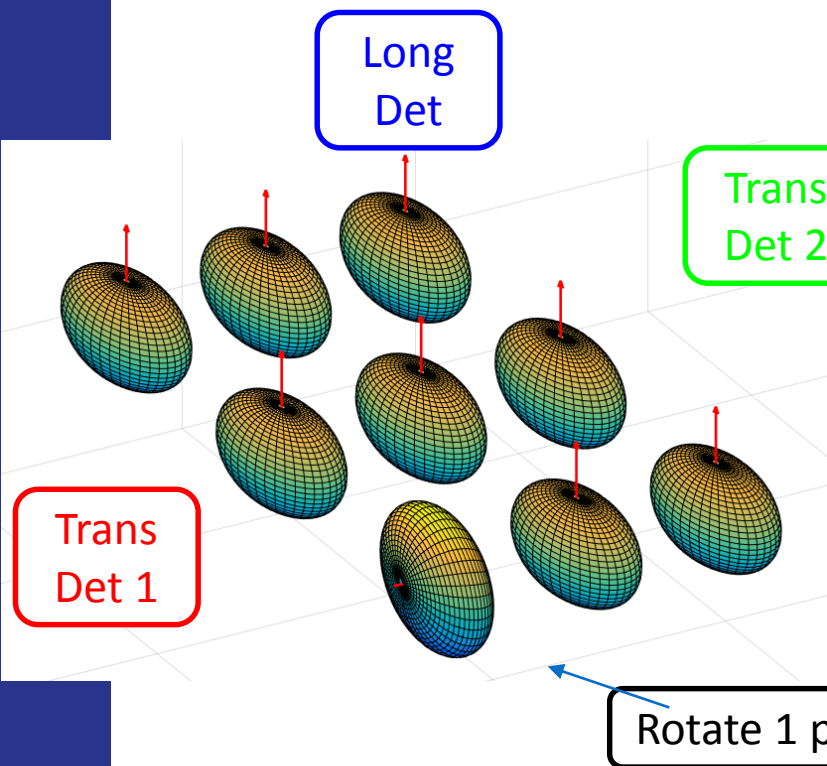
- What - Record MRI signals from PET/SPECT-type nuclei
- How - Hyperpolarize spins and observe asymmetry of gamma decay
- Result - **high efficiency (gamma detection) and high resolution (MRI)**
- Status: method shown to work: Y. Zheng, et al., Nature 537, 652 (2016)

● Gamma-MRI Equipment:

- $I > 1/2$ gamma-emitting nuclei
- Spin-polarizer
- MRI magnet
- **Gamma detectors inside B field: SiPMs**

Gamma MRI – spatial resolution

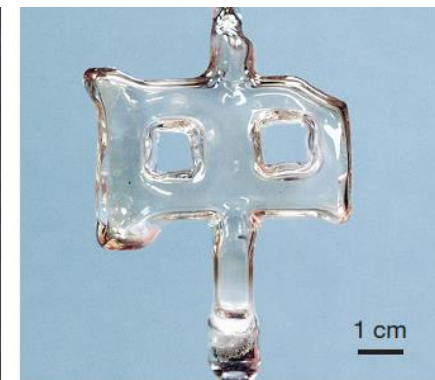
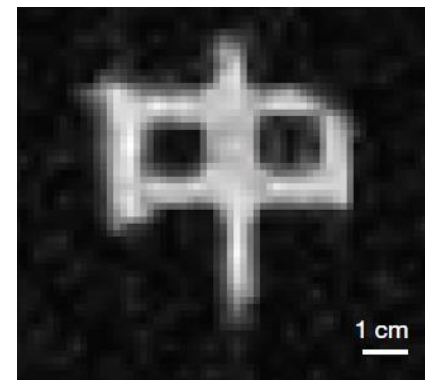
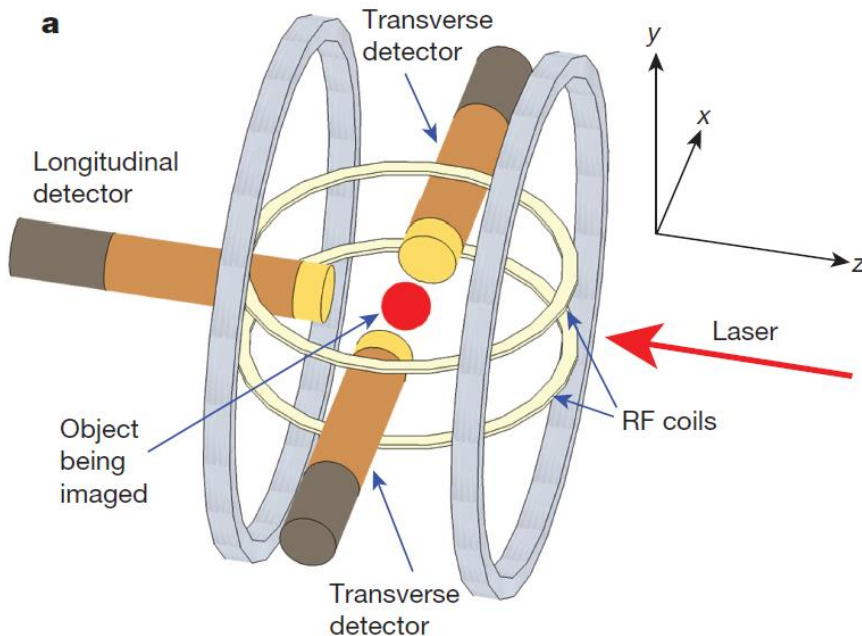
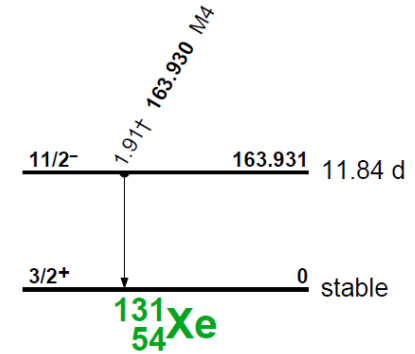
- **Voxel size**
 - defined by slope of B-field gradients and spectral width of rf pulse
 - more nuclei -> smaller pixels possible up to B gradient and rf limit
- **1 pixel in resonance:**
 - change in total gamma counts visible in each detector
 - Degree of change proportional to number of nuclei in addressed pixel



First gamma-MRI

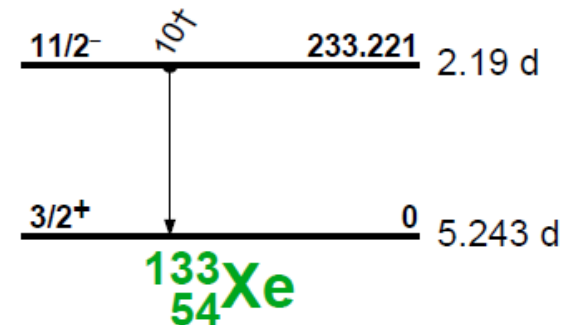
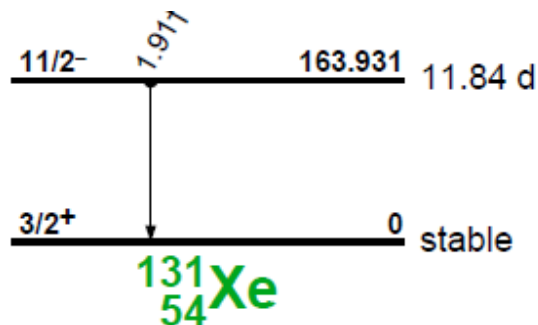
Y. Zheng, G.W. Miller, W.A. Tobias, G.D. Cates, Nature 537, 652 (2016)

- **$^{131\text{m}}\text{Xe}$** : $t_{1/2} = 12$ days
- **Setup**: low B-field
- **Results**: space-resolved signal (recorded pixel after pixel) with $1e13$ nuclei vs $1e24$ normally



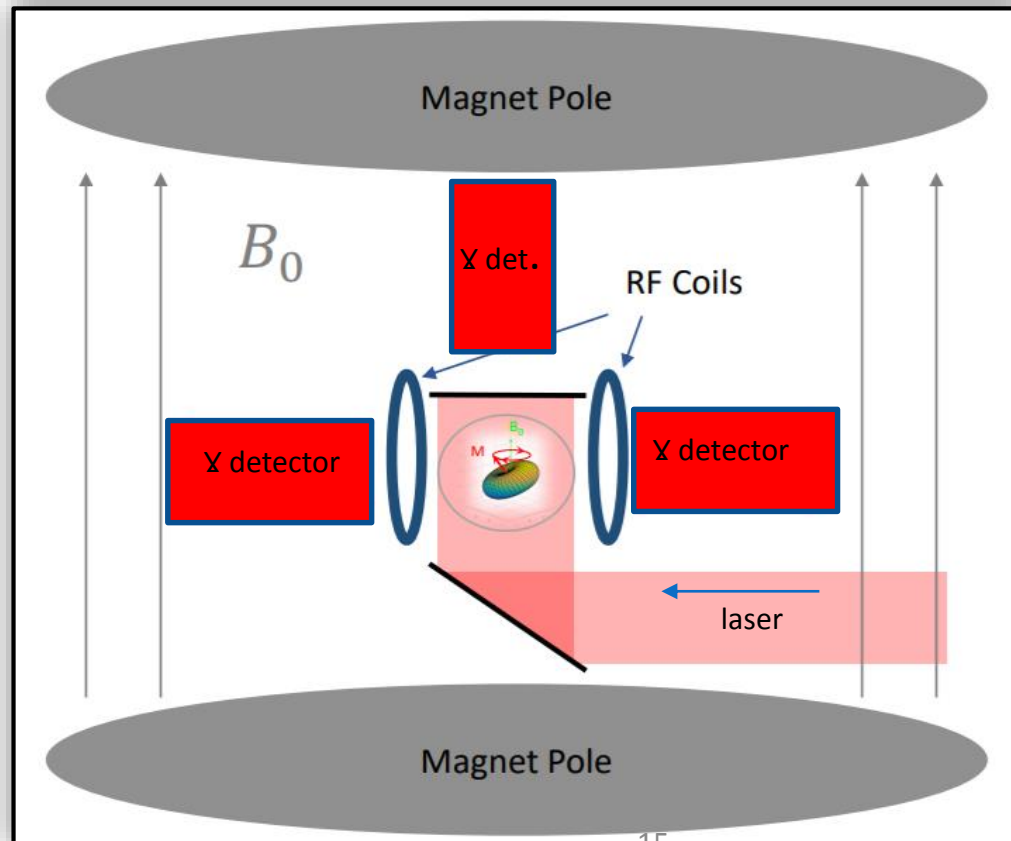
Our gamma-MRI project

- Work on feasibility of the technique:
 - Use long-lived Xe isomeric states
 - Optimise rf pulses
 - Maintain polarization
 - First detectors
- => lower dose required to record signals
- Work on proof-of-principle experiment with commercial MRI scanner
- Explore other chemical elements

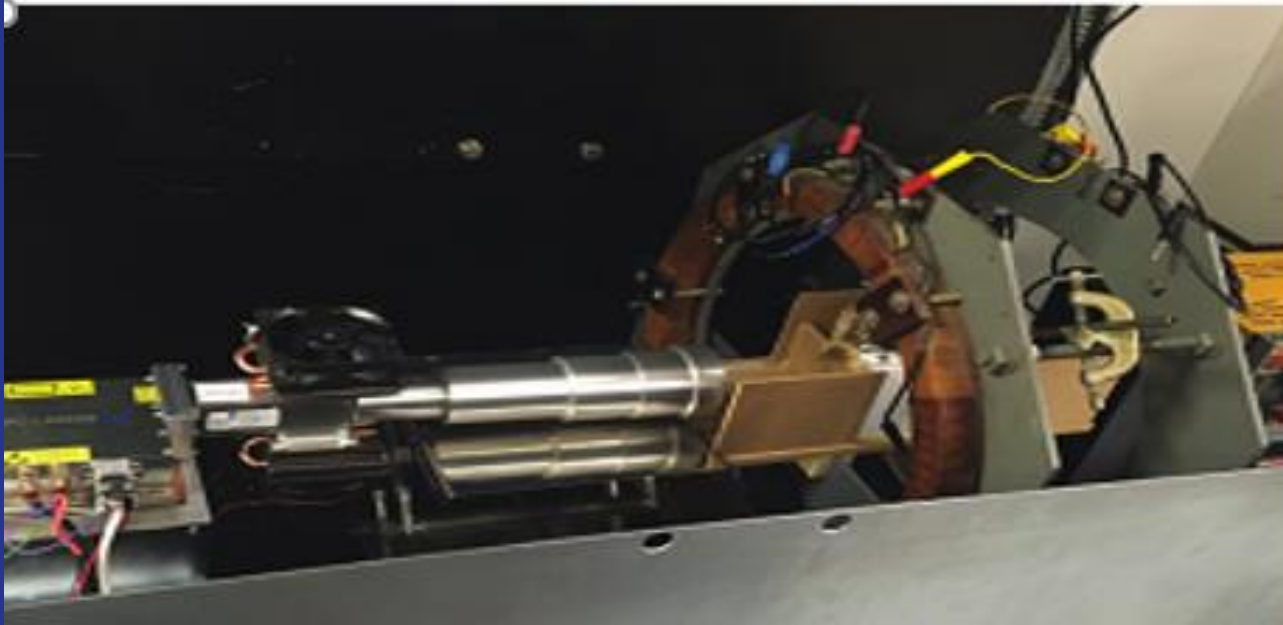
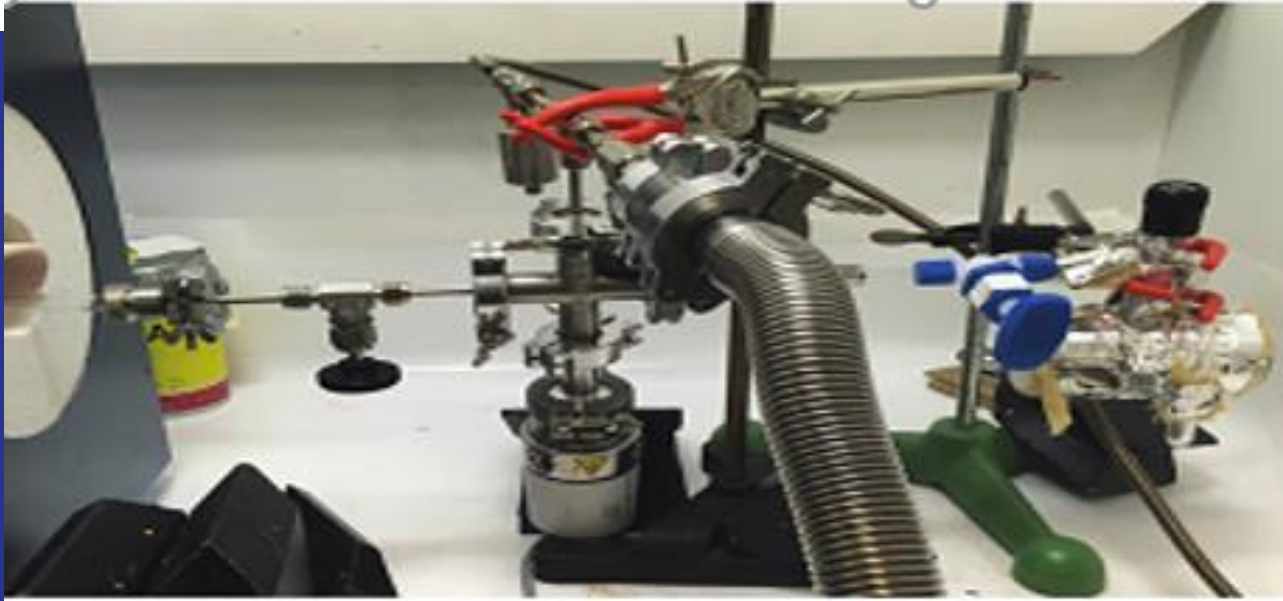


gamma-MRI test setup

- Project:
 - Proof-of-principle gamma-MRI study
- Status:
 - Compact setup to polarize and detect asymmetry tested



gamma-MRI tests in 2018



Summary and outlook

- Medical project born around IdeaSquare
- Gamma-MRI idea:
 - Can increase sensitivity of MRI and increase spatial resolution of PET and SPECT
 - Collaboration started to perform proof of principle experiments
- 2019: 1st studies on ^{131}mXe and ^{133}mXe and on other isotopes
- Status of funding applications:
 - Funding granted for PhD student and small equipment from CERN Medical Applications
 - Waiting for results from ATTRACT and FET-OPEN
 - Planning to apply to other funding schemes
- How can we use IdeaSquare in the future?

Acknowledgements

Young researchers: K. Kulesz, S. Pallada, J. Croese, R. Engel

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