

# Gamma MRI

Towards high resolution single photon imaging  
using highly-aligned gamma-emitting nuclei

Karolina Kulesz

on behalf of gamma-MRI collaboration

*Faculté des sciences, Université de Genève*

*ISOLDE, CERN*



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Western Switzerland

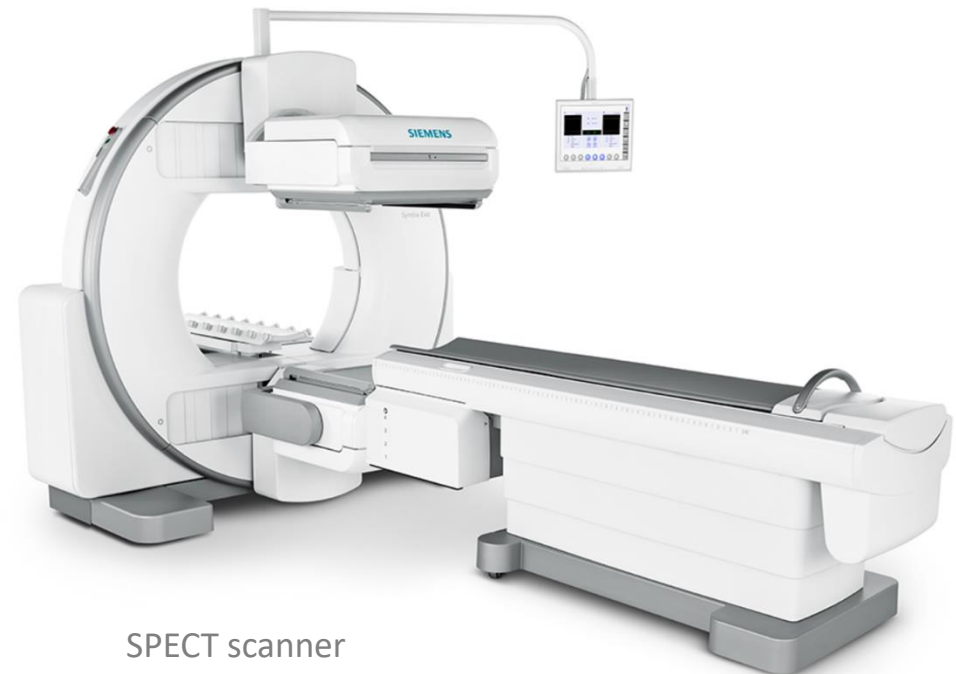


# New medical imaging modality

Increased MRI sensitivity + Improved SPECT resolution



MRI scanner



SPECT scanner

# gammaMRI at a glance

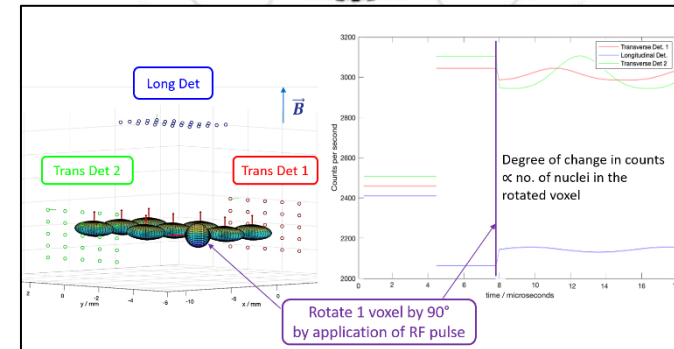
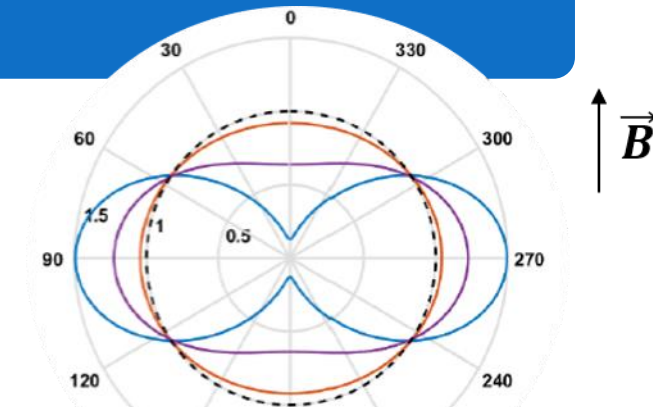
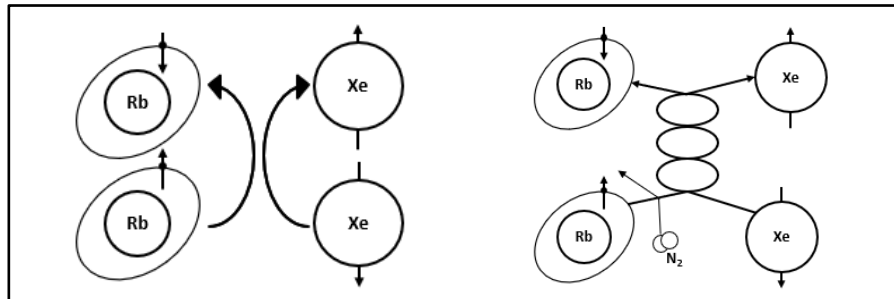
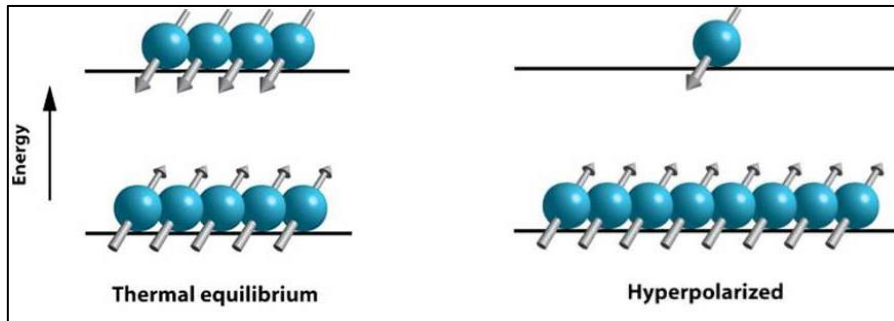
Increased MRI sensitivity + Improved SPECT resolution

detecting **gamma** asymmetries  
from **aligned**  
**radioactive** nuclei  
in weak **magnetic fields**

several orders of magnitude larger signal

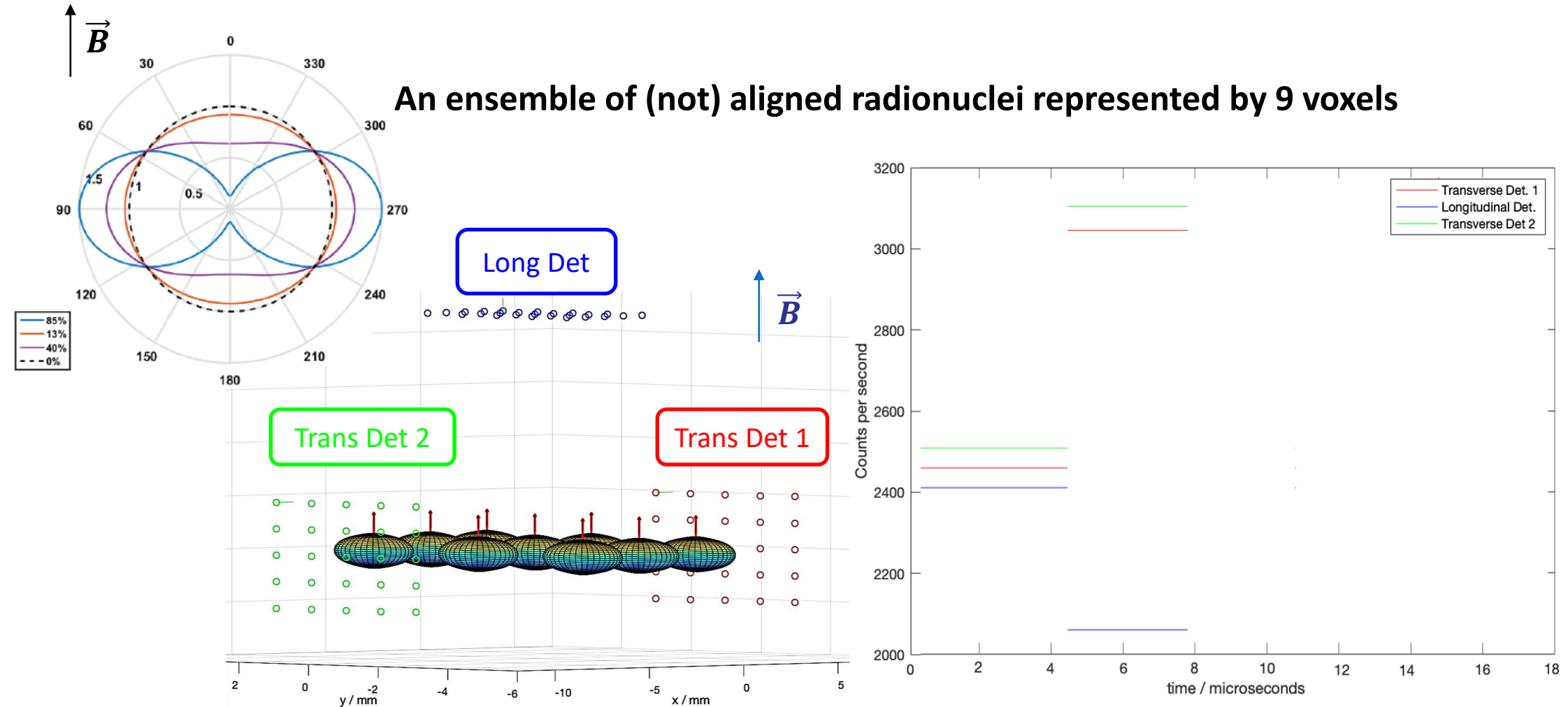
# gammaMRI at a glance

Increased MRI sensitivity + Improved SPECT resolution



several orders of magnitude larger signal

## An ensemble of (not) aligned radionuclei represented by 9 voxels

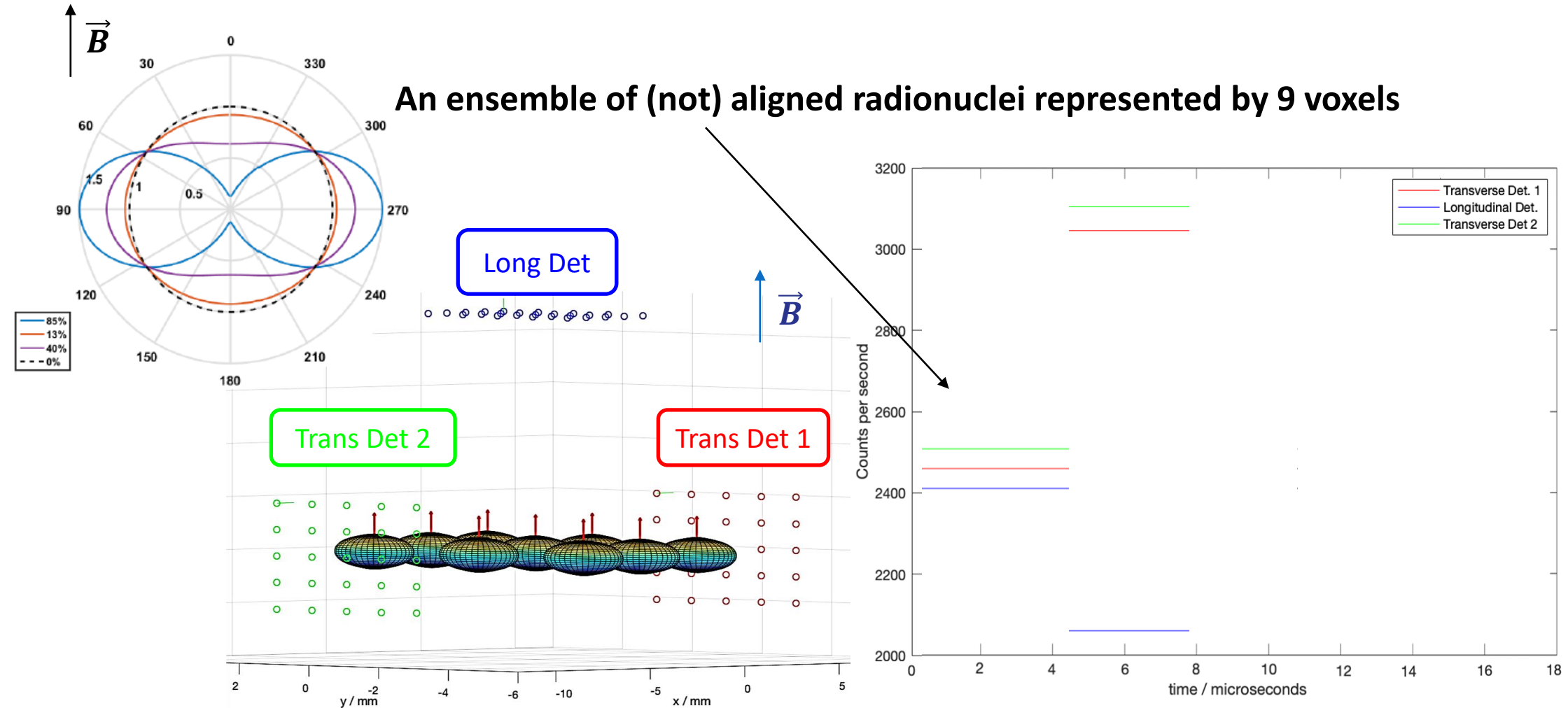


Simulation software for  
anisotropic gamma decay  
by R. Engel and E.L. Wistrom

Proof-of-principle:

Zheng et al. *A method for imaging and spectroscopy using  $\gamma$ -rays and magnetic resonance*. Nature 537, 2016

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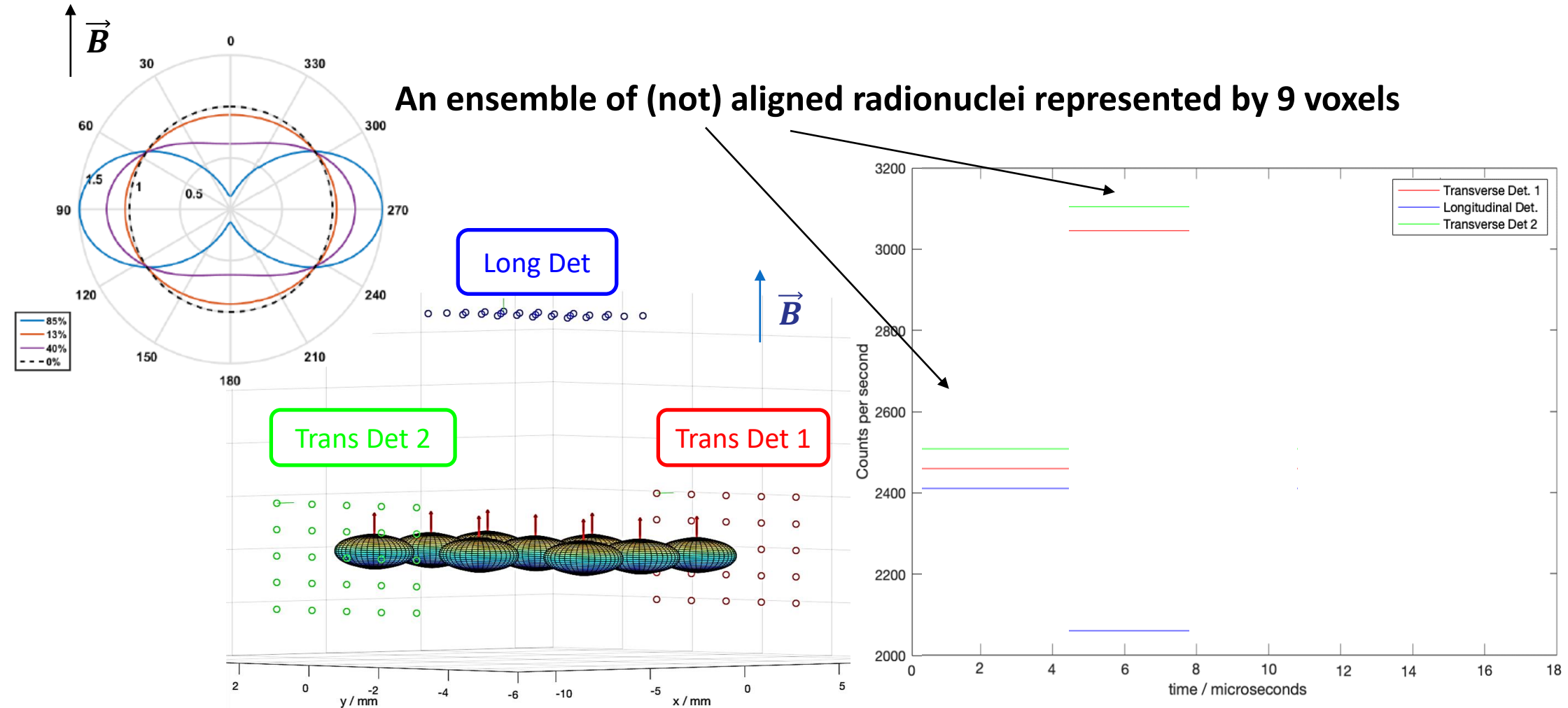


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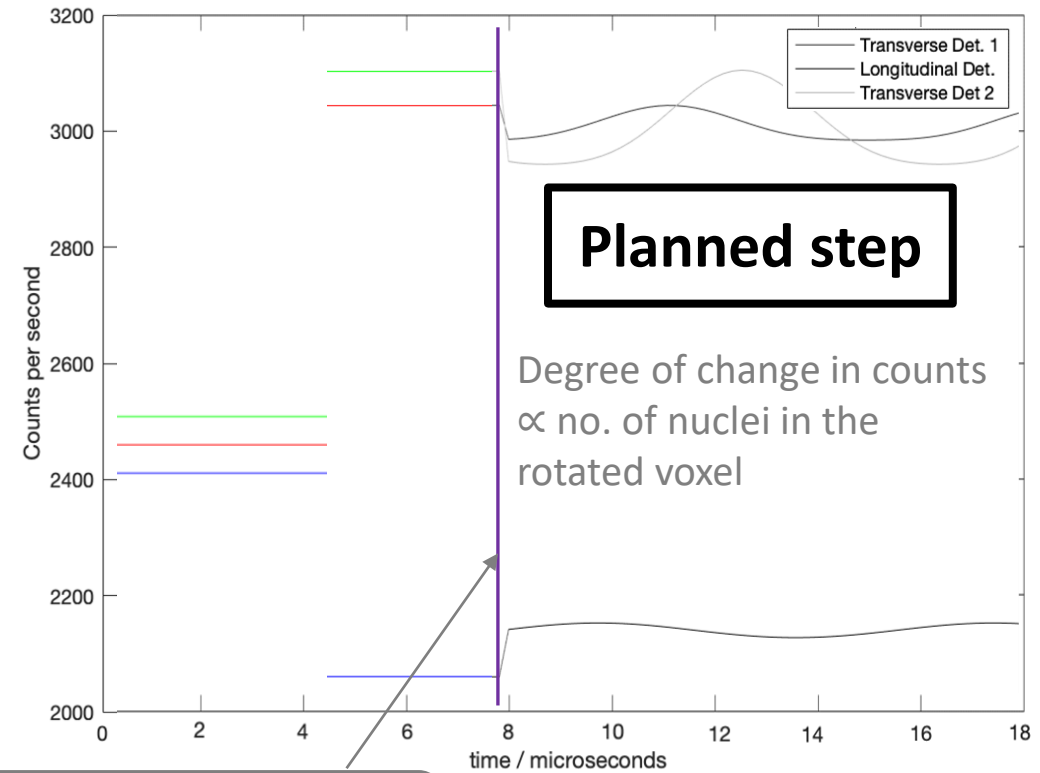
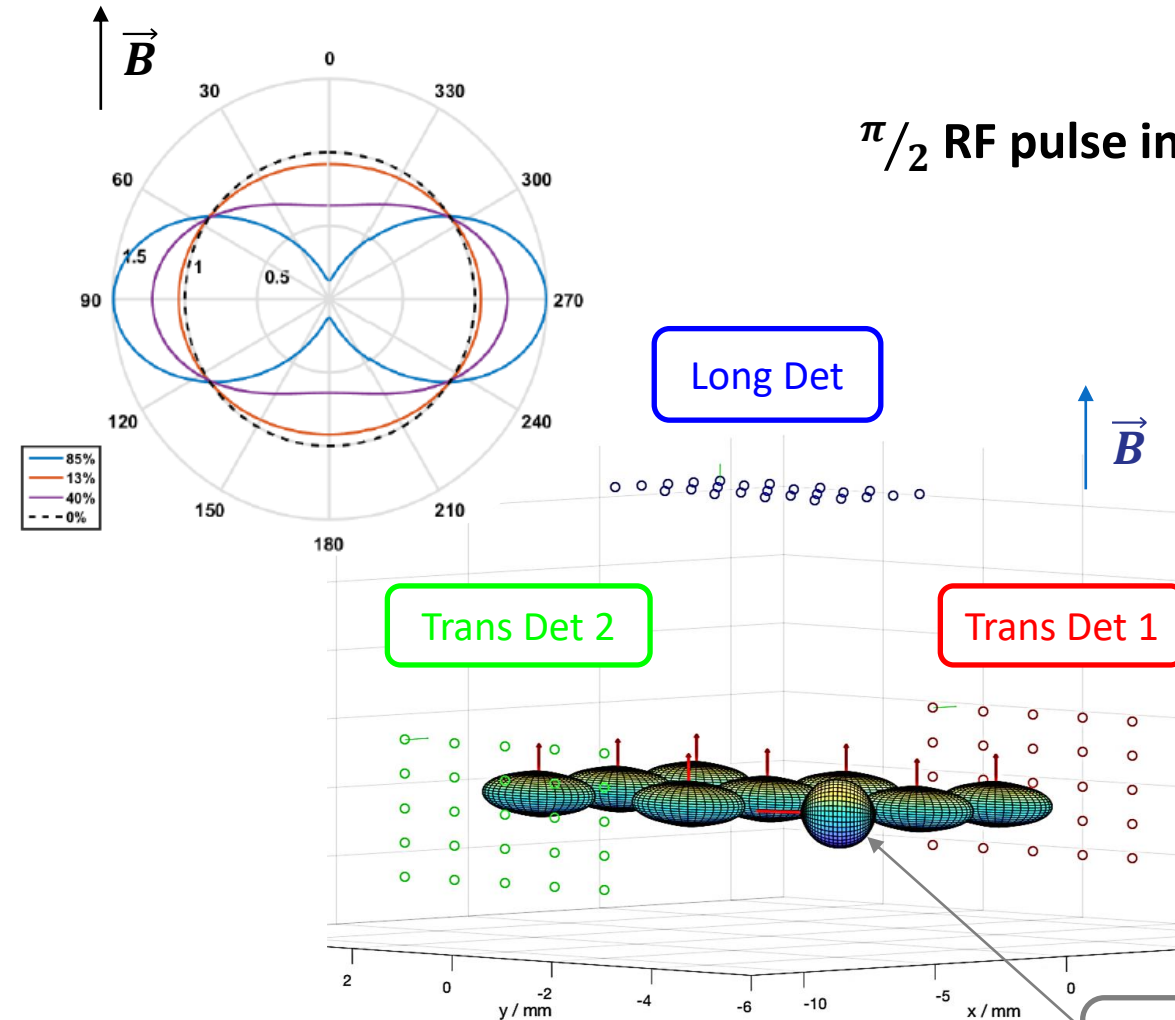


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## $\pi/2$ RF pulse in resonance with 1 voxel



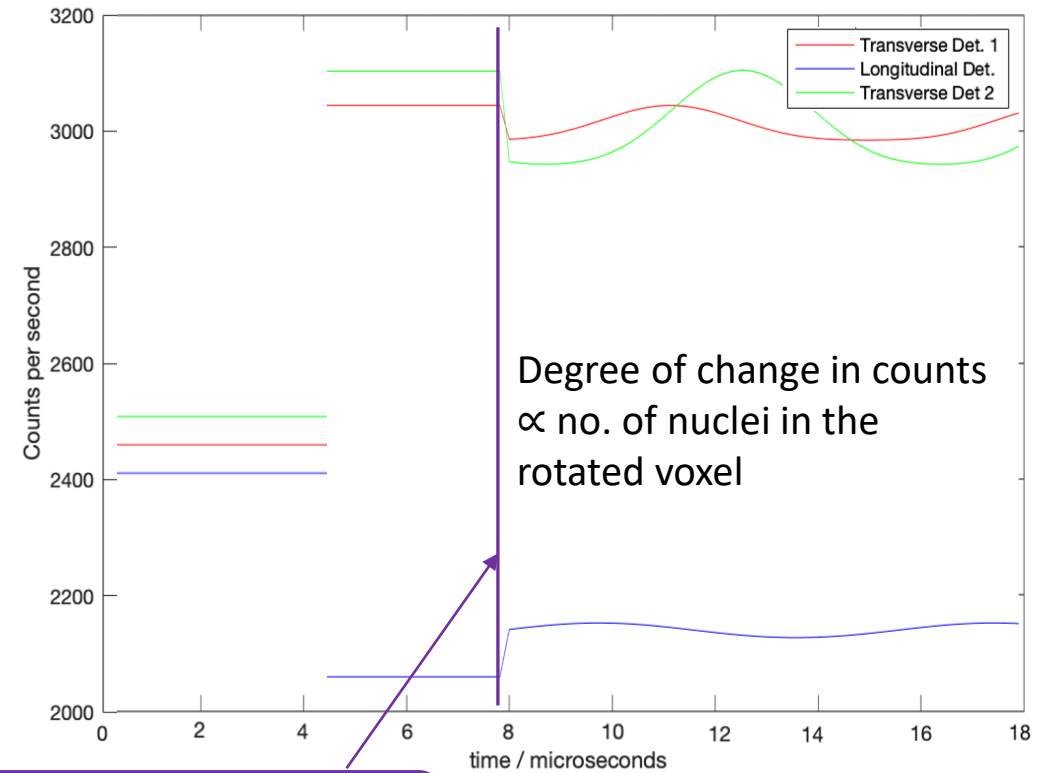
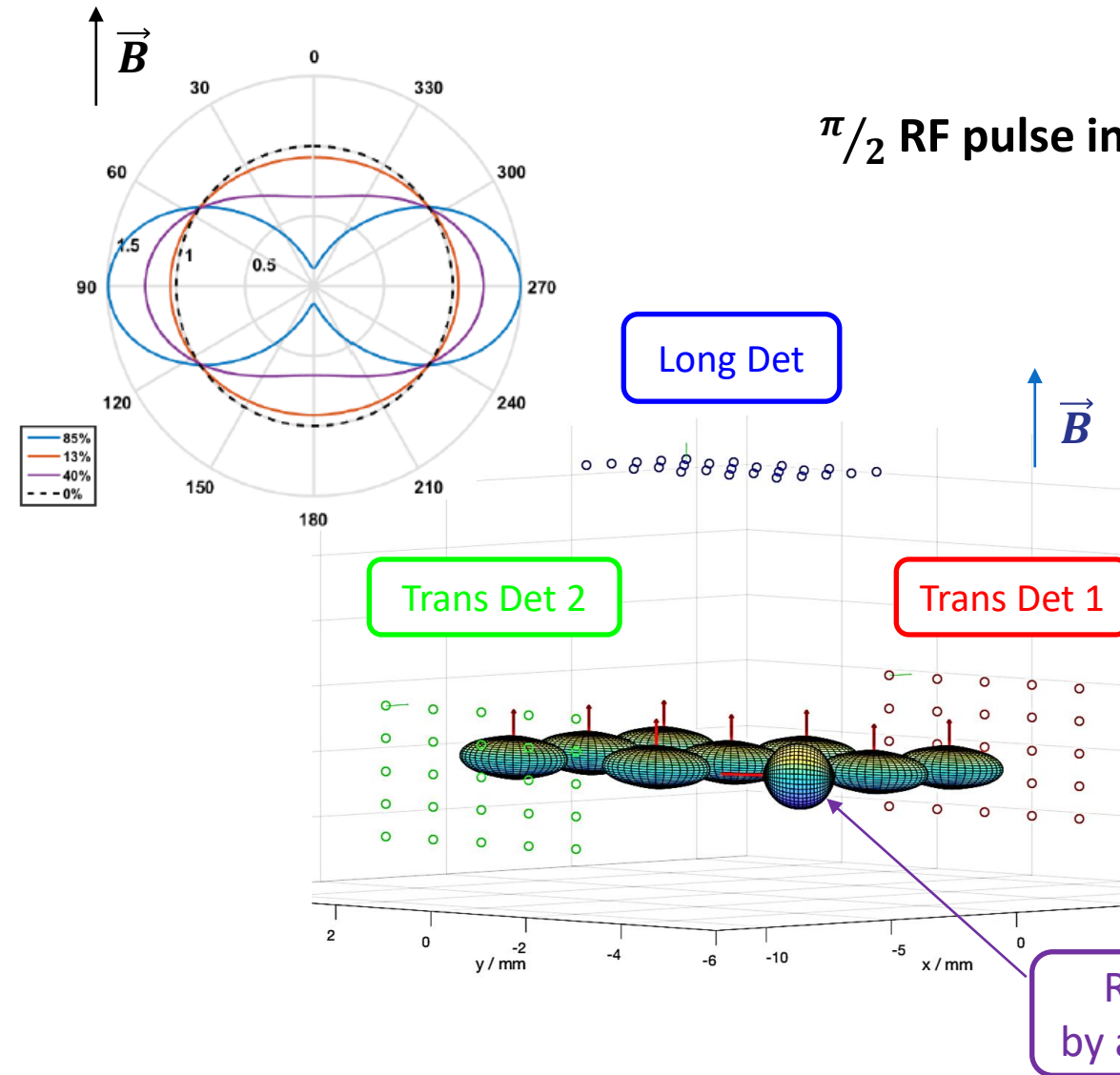
Rotate 1 voxel by  $90^\circ$   
by application of RF pulse

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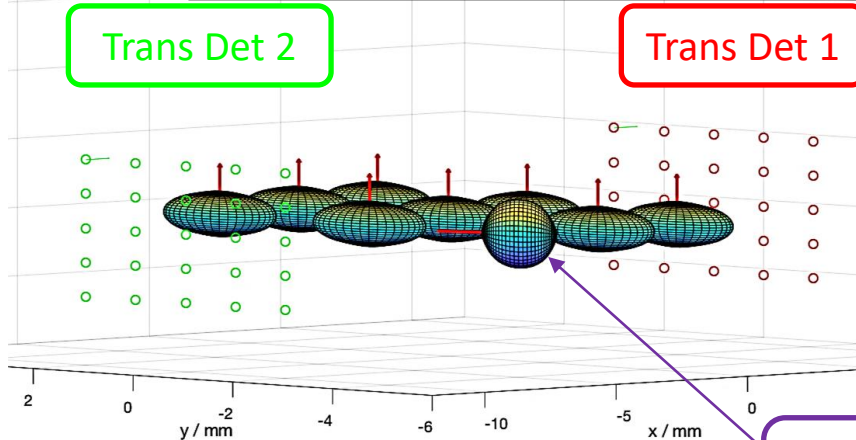
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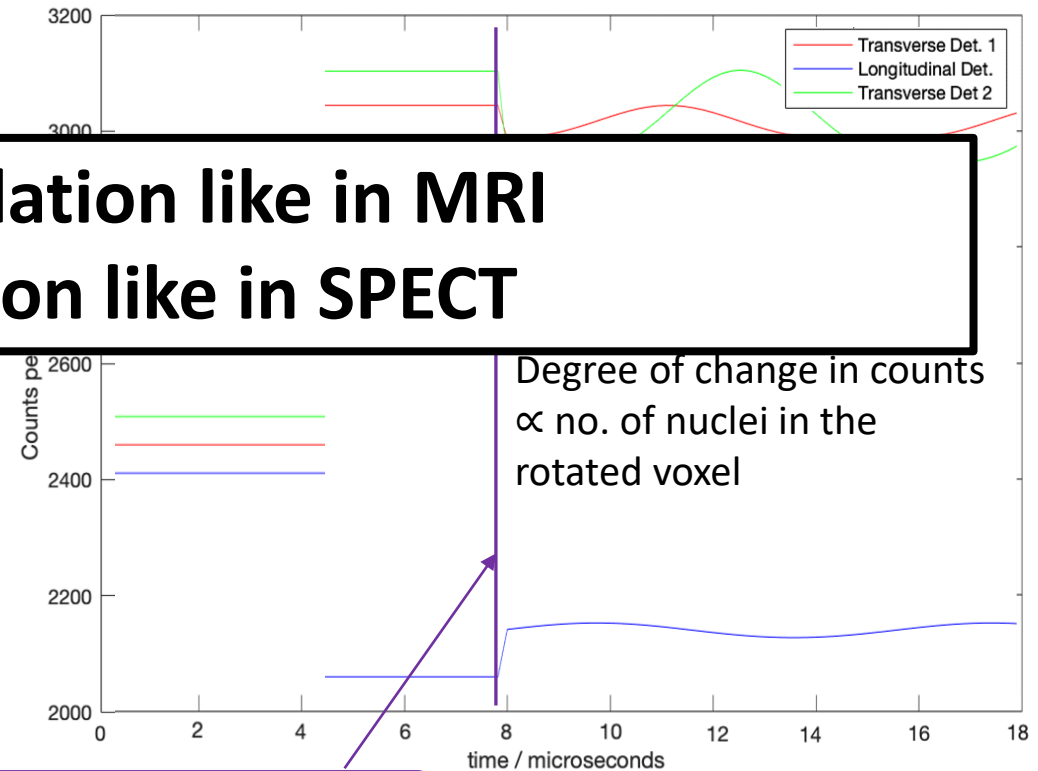
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$\pi/2$  RF pulse in resonance with 1 voxel

## Manipulation like in MRI Detection like in SPECT



Rotate 1 voxel by 90°  
by application of RF pulse

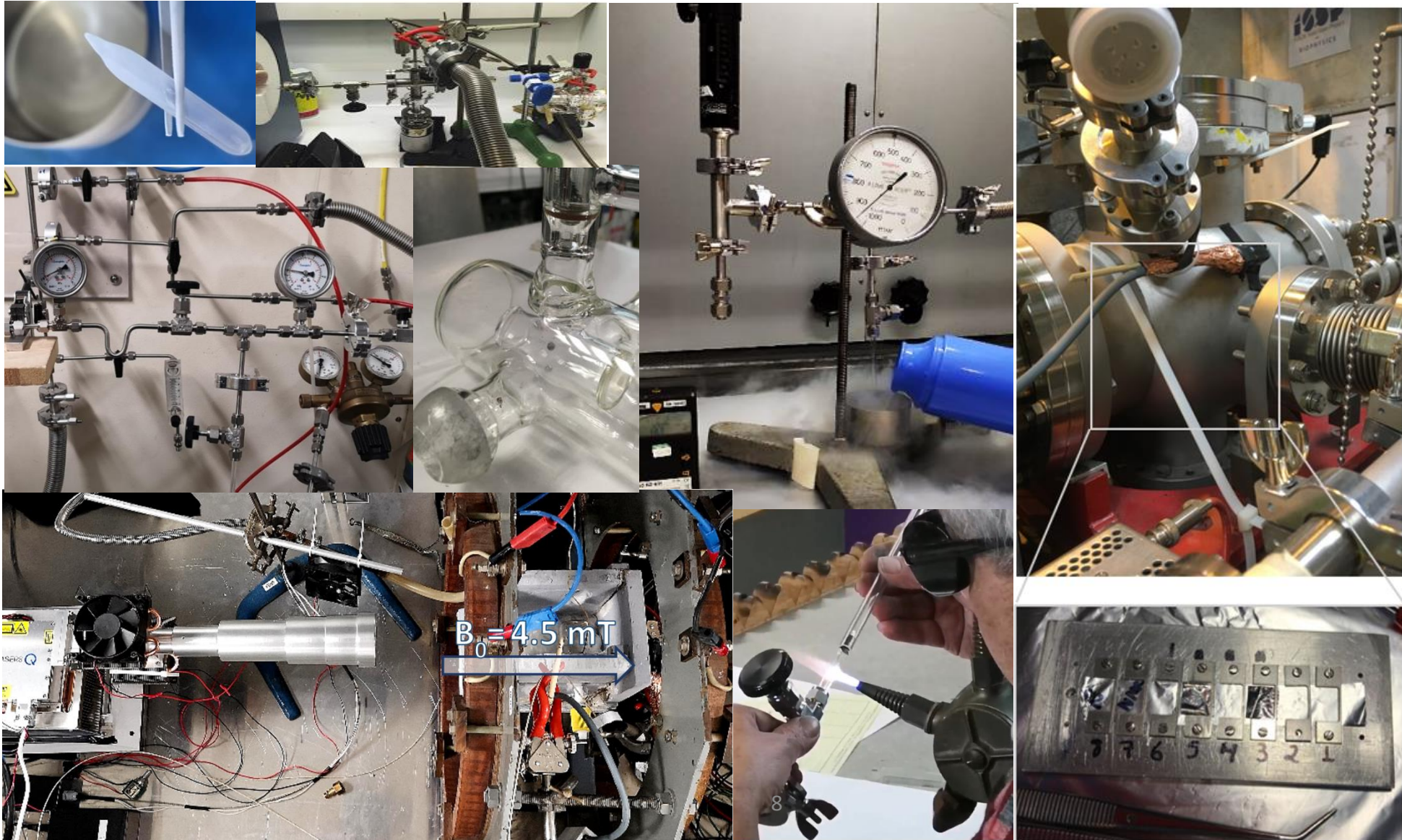


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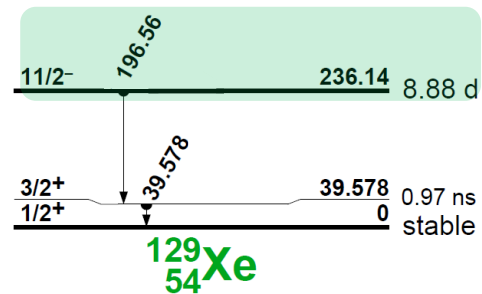
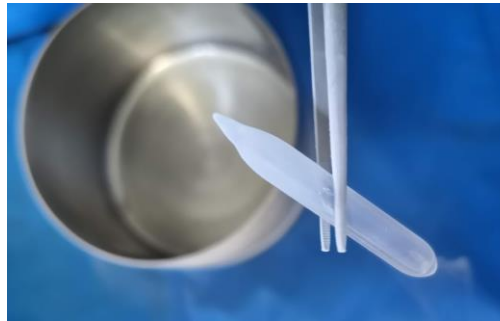
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# Experimental preparations and setups

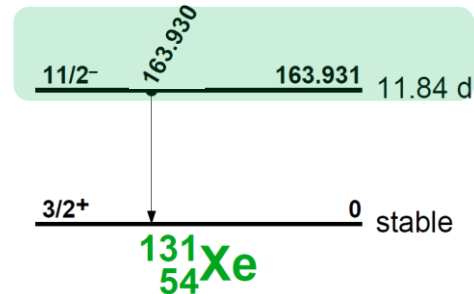


# Xenon production

- ◆ Years of clinical use of  $^{133}\text{Xe}^*$  and stable  $^{129}\text{Xe}^{**}$  in medical imaging
- ◆ **Production:**

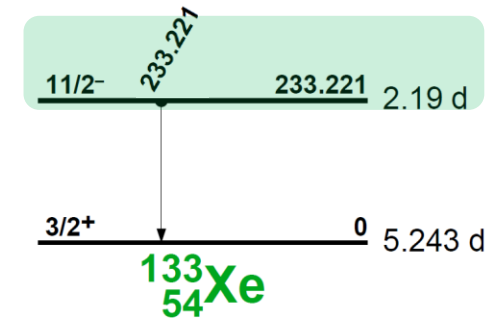


300 MBq



200 MBq

Transfer rate: 69%

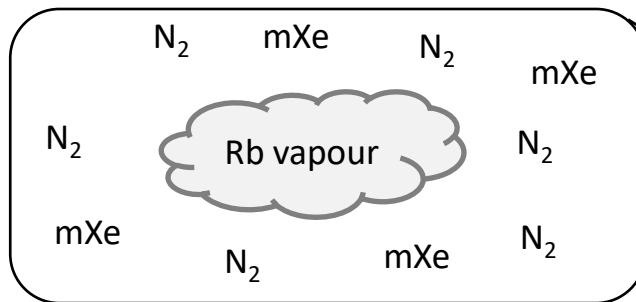


80 – 270 MBq

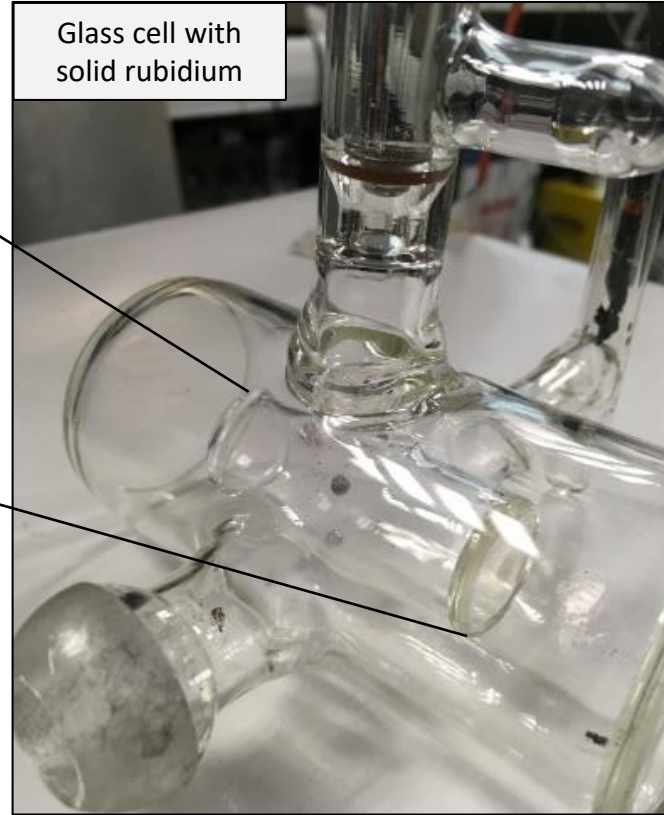
Extraction rate: 21%

# Setup

- Pyrex glass cell.  
Rb + mXe + N<sub>2</sub> inside

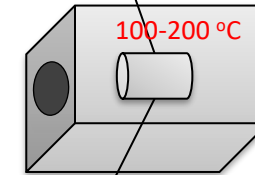
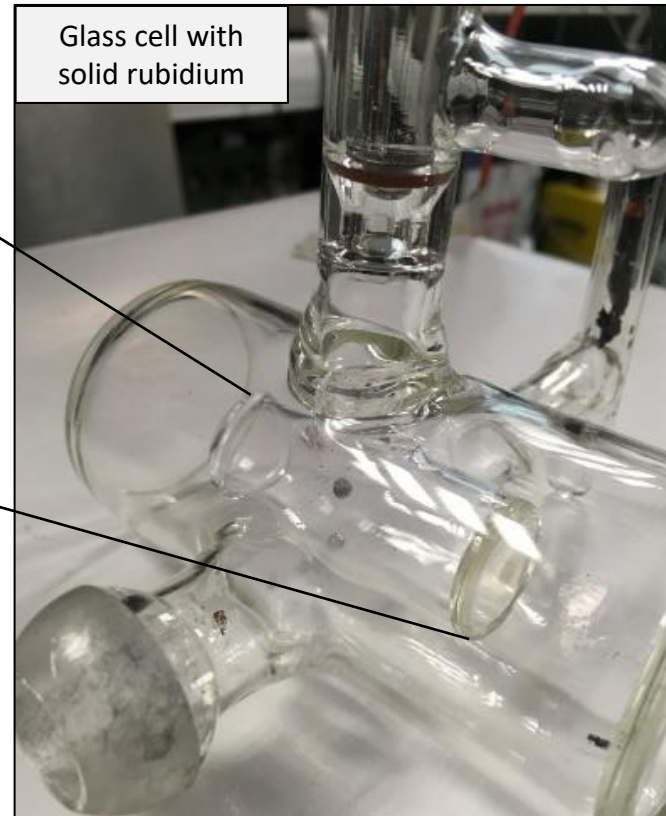
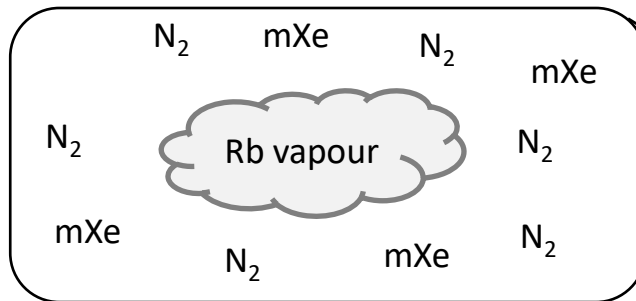


Glass cell with  
solid rubidium



# Setup

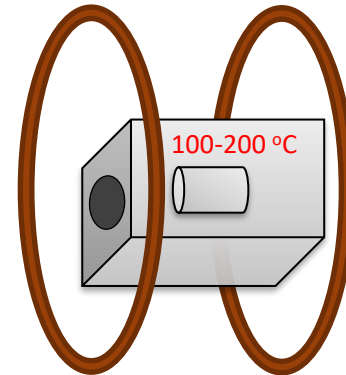
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\*Drawings not in scale.

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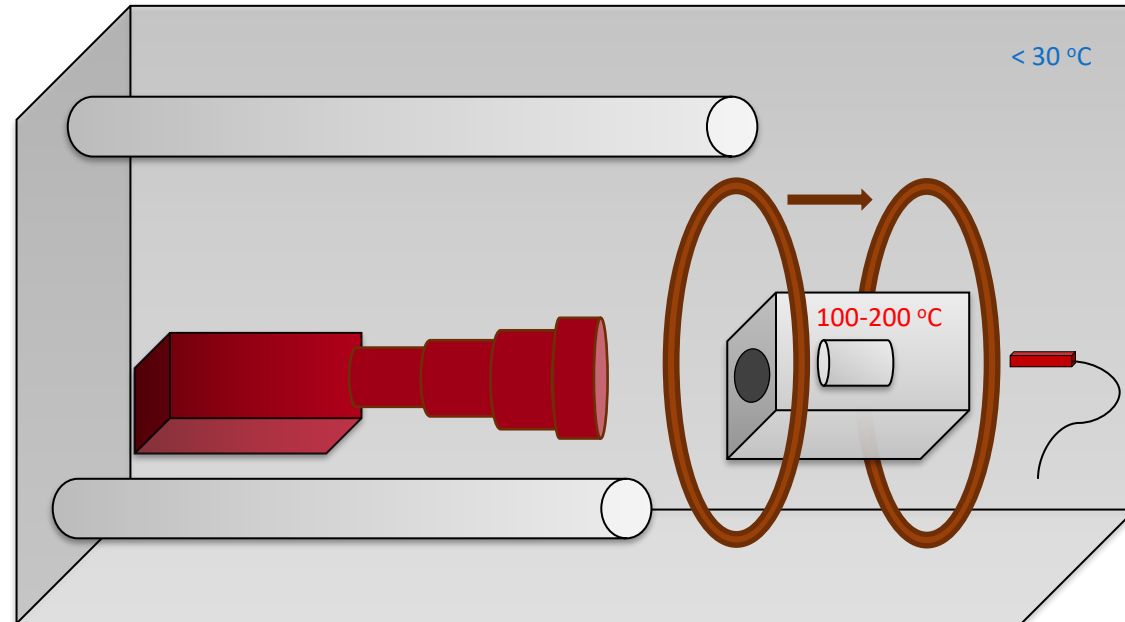
- Pyrex glass cell.  
Rb + mXe + N<sub>2</sub> inside
- Insulating oven  
Temp. inside: 100-200 °C
- Helmholtz coils (4.5 mT)



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# Setup

- Pyrex glass cell.  
Rb + mXe + N<sub>2</sub> inside
  - Insulating oven  
Temp. inside: 100-200 °C
  - Helmholtz coils (4.5 mT)
  - Laser diode array providing  
circularly polarized infrared  
light  $\sigma^+$  (794.7 nm, 50 W)  
Spectrometer
- Temp. requirement: < 30 °C
- Mobile rig with ventilation slots

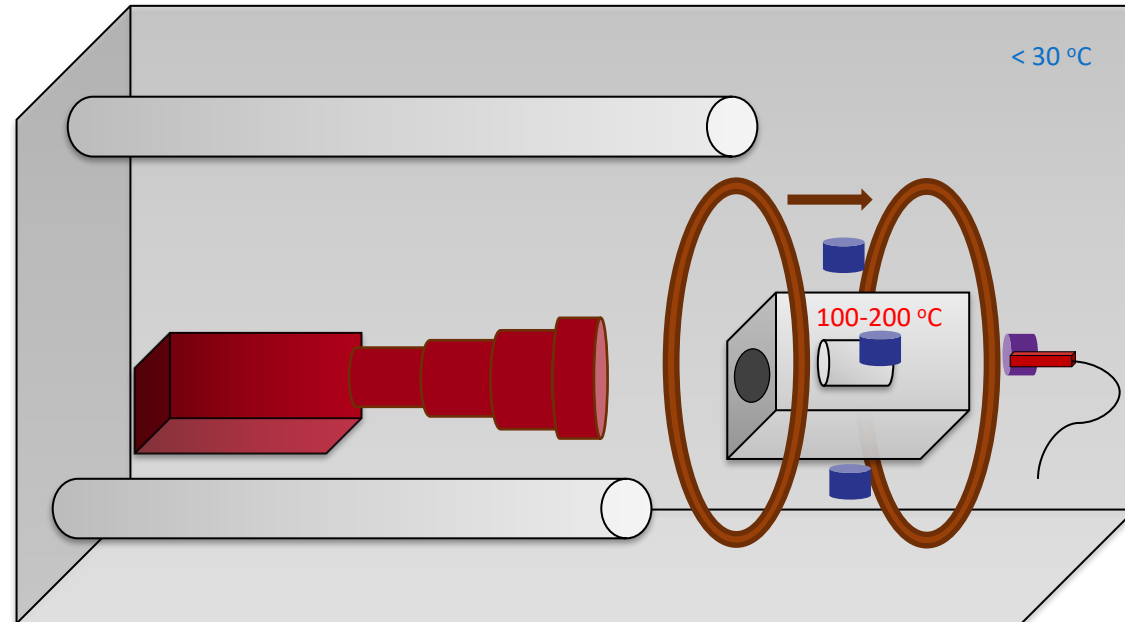


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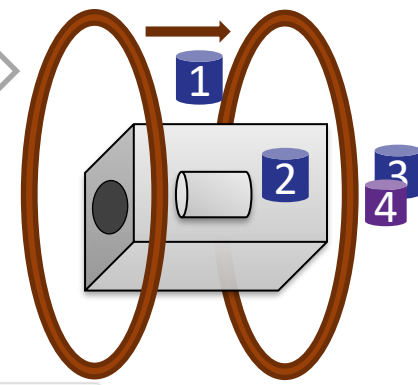
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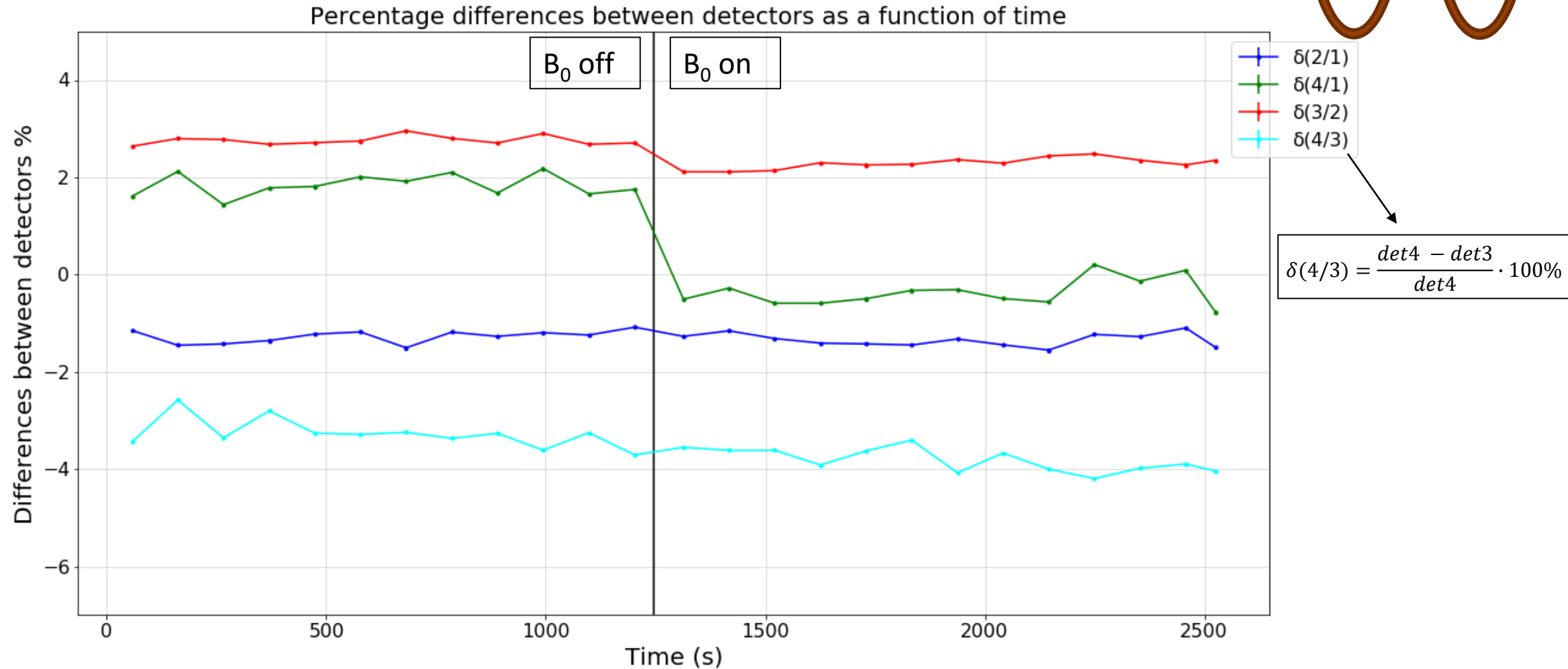


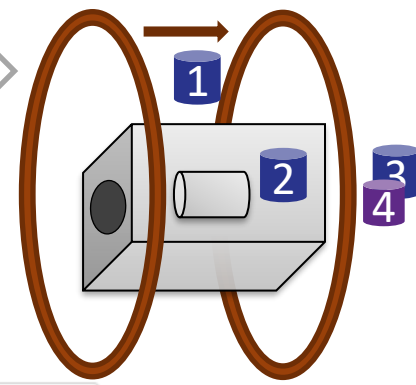
- Mobile rig with ventilation slots
- $\gamma$  detectors coupled with Si PMT:  
3xCeGAGG, 1xLaBr

\*Drawings not in scale.

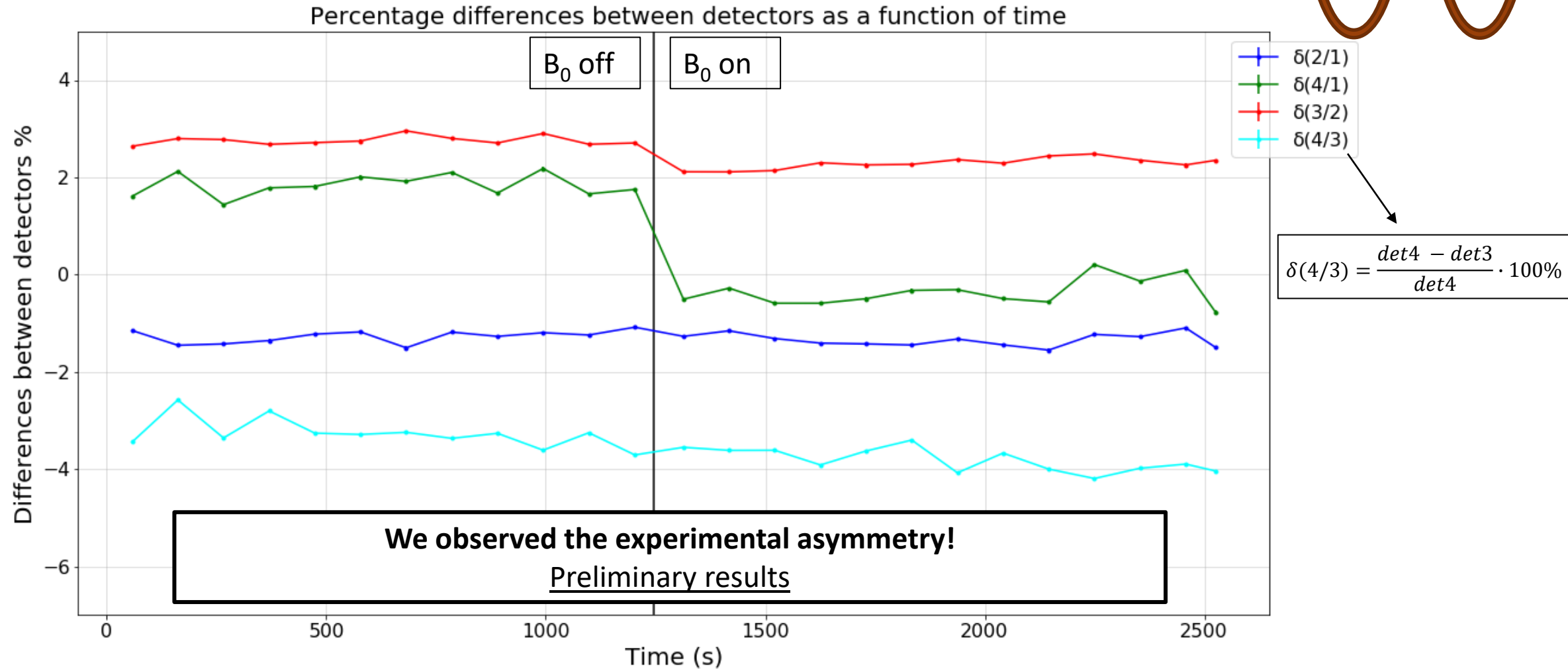


# Systematic investigation of the data





# Systematic investigation of the data



# Where we are now...

- First isotopes -  $^{129}\text{mXe}$ ,  $^{131}\text{mXe}$ ,  $^{133}\text{mXe}$  - produced successfully at different nuclear facilities and extracted efficiently from the native containers
- Experimental setups built from start and optimized to conduct the data acquisition with stable experimental conditions
- Fully operational SEOP setup capable of polarizing Rb well and hinting Xe hyperpolarization
- First proofs of the experimental asymmetry!



# Plans for 2021

- Preparation of mXe (with one or more methods) for next experimental runs (CERN)
  - In order to compare, optimize and standardize mXe production
- Use of gamma detectors with temperature stabilization (UCM)
- Dedicated laboratory space for SEOP & spectra acquisition setup (HESSO)



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**RS<sup>2</sup>D**



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<sup>1</sup> CERN, Meyrin, Switzerland, <sup>2</sup> University of Geneva, Geneva, Switzerland <sup>3</sup> Haute école de santé de Genève, Switzerland,  
<sup>4</sup> Universidad Complutense de Madrid, Spain, <sup>5</sup> KU Leuven, Leuven, Belgium, <sup>6</sup> Institut Laue–Langevin, Grenoble, France,  
<sup>7</sup> University of Oslo, Norway

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# Thank you for your attention!

# Literature

- R. Engel, Master thesis 2018, <http://oops.uni-oldenburg.de/3617/>, <https://cds.cern.ch/record/2638538>
- M. Kowalska et al., Letter of Intent, CERN-INTC-2017-092 / INTC-I-205 (2017)

## Proof-of-principle:

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## Xenon:

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- Xe133-radiospirometry for evaluation of congenital malformations of pulmonary arteries, Arborelius M Jr, Pediatrics. 1971 Mar;47(3):529-36
- Hyperpolarized  $^3\text{He}$  and  $^{129}\text{Xe}$  MR Imaging in Healthy Volunteers and Patients with Chronic Obstructive Pulmonary Disease, M. Kirby, Radiology 2012: Volume 265:600-610.
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