SIRF-CIL Training School
Positron Emission Tomography

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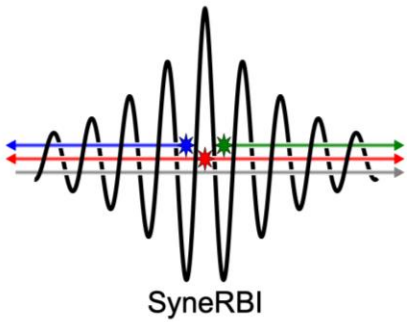
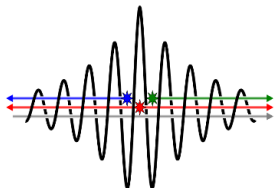
on behalf of the
Collaborative Computational Projects on Synergistic Reconstruction for Biomedical Imaging (CCP SyneRBI)

http://www.ccpsynerbi.ac.uk



PET applications in medicine

- Which areas ?
  - Oncology (e.g. tumour detection)
  - Neurology (e.g. which part of the brain is involved when you talk)
  - Psychiatry (e.g. schizophrenia)
  - Cardiology (e.g. infarct size)
- What for?
  - Diagnosis
  - Measuring therapy effectiveness
  - Drug development
- Sensitive for picomolar concentrations, 1μg tracer in total



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Clinical practice: CT + FDG-PET

- FDG-PET/CT of 42-year-old man with unsuspected testicular cancer.

  "Arrows indicate metastatic lesions. The arrows to the right indicate spleen lesions not visualized by CT."

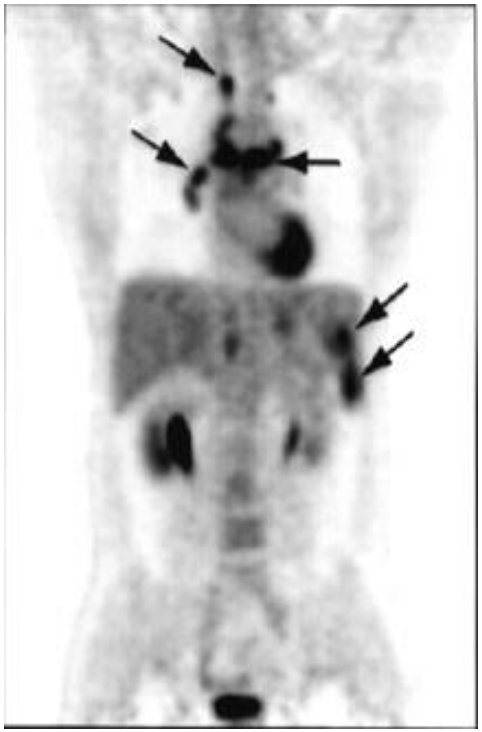
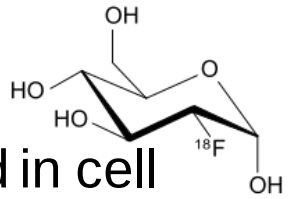


Image and text from www.cpspet.com

Common clinical PET radiotracers

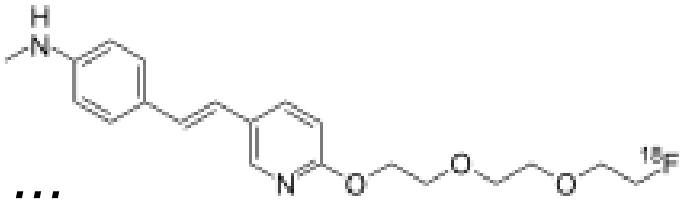
- *^{18}F-FDG*

  fluoro-deoxy-glucose
  glucose analogue
  metabolises as glucose but no glycolysis → trapped in cell
  ⇒ FDG accumulates in cells with high glucose metabolism



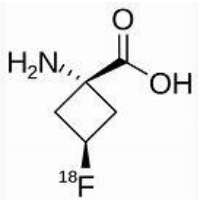
- *^{18}F-flutemetamol, ^{18}F-florbetapir, ^{18}F-florbetaben*

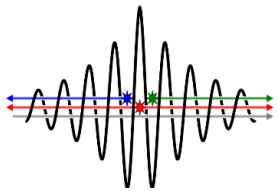
  bind to beta-amyloid
  ⇒ used for Alzheimer diagnosis



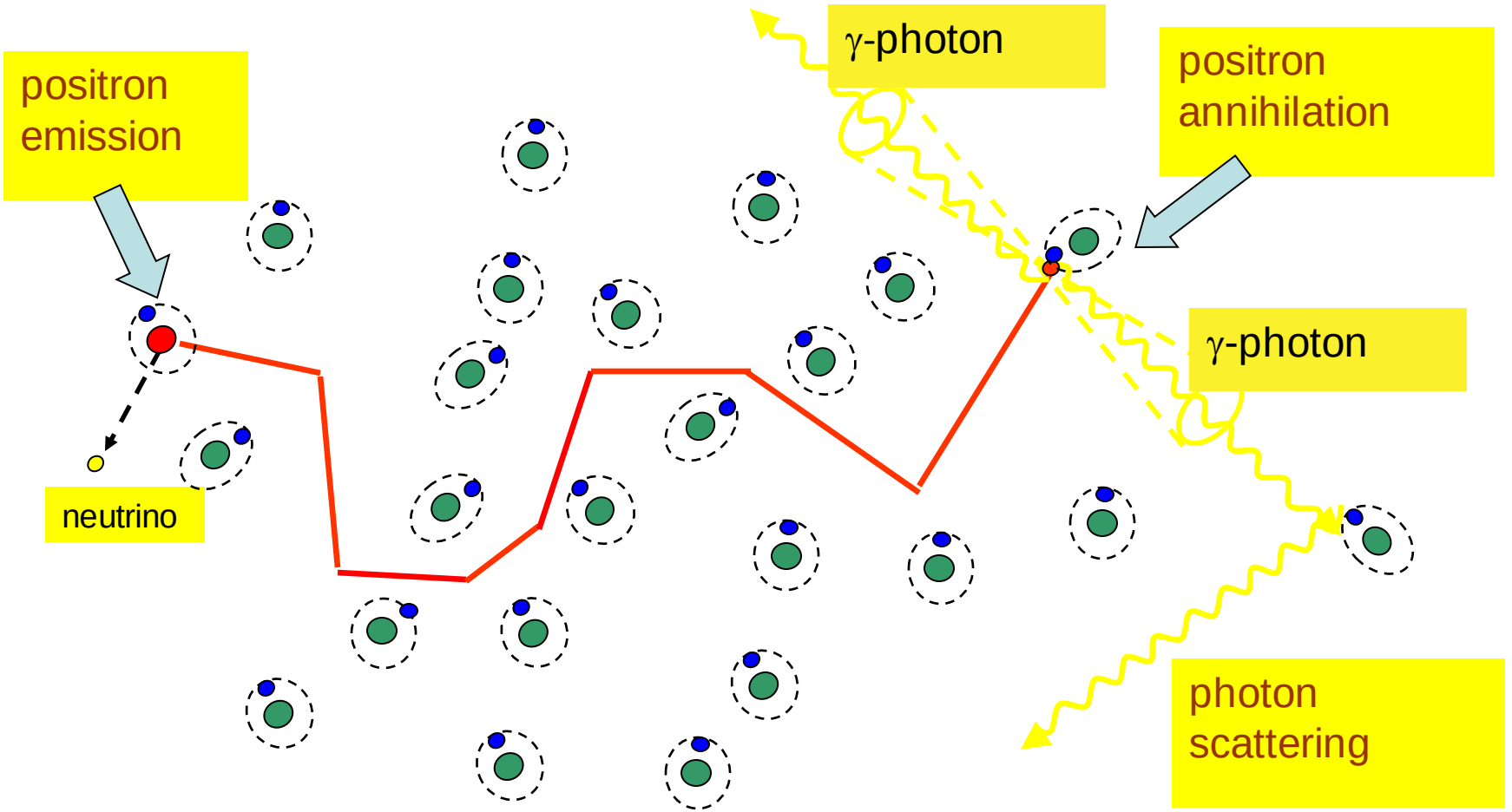
- *^{68}Ga-PSMA-11, 18F-Flucoclovine, ...*

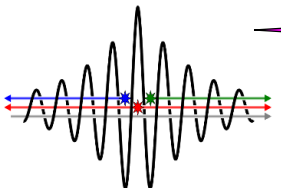
  bind to prostate-specific membrane antigen (which is overexpressed in prostate cancer cells)





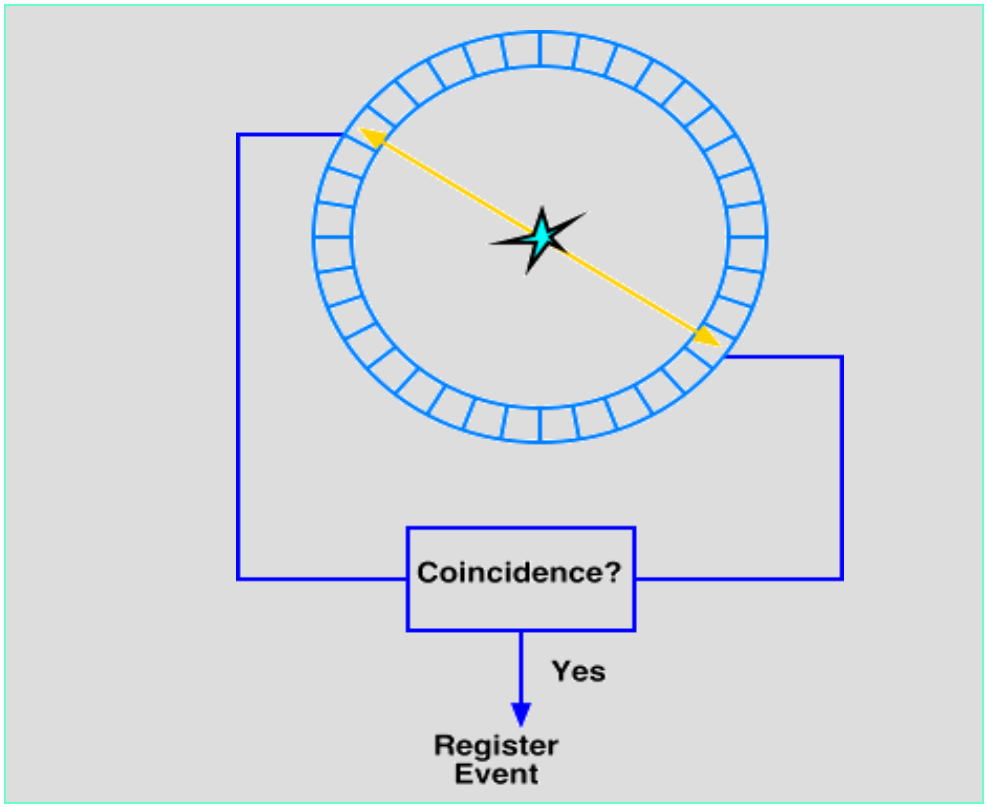
PET physics in a nutshell

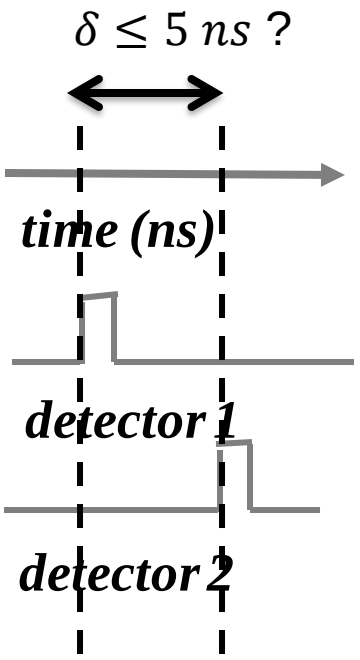




~ 1 mm (depends on isotope and medium)

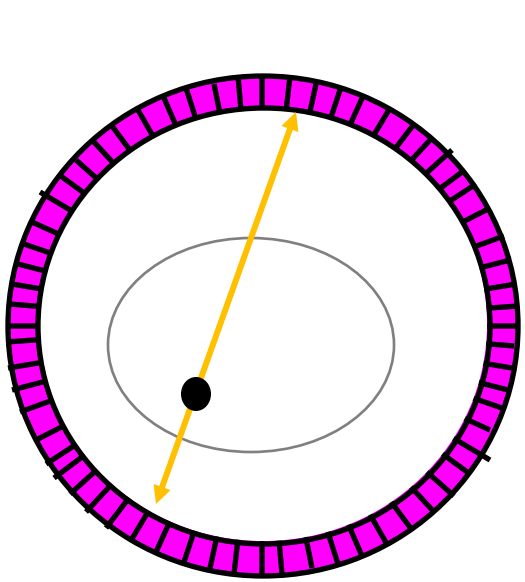
Coincidence Detection



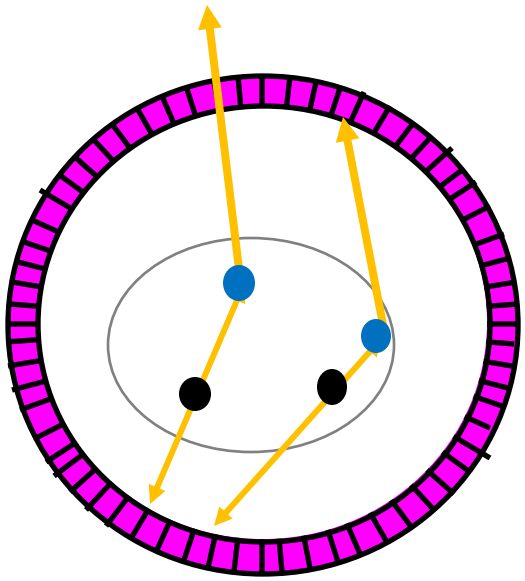


"prompt" coincidence event if two gammas detected within short time (~5 ns)

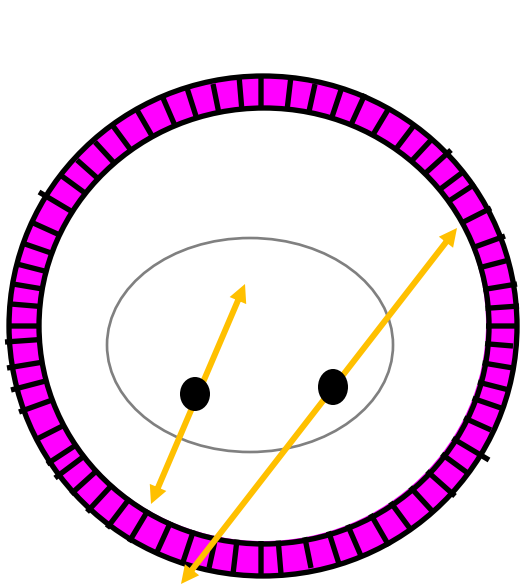
Types of PET coincidences



True (unscattered)



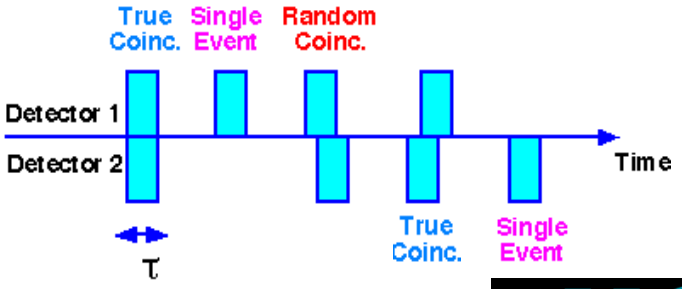
Scattered

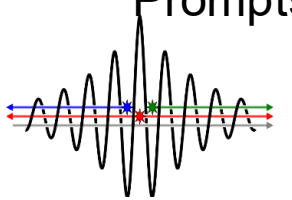


Accidental
or “random”

Measured data:

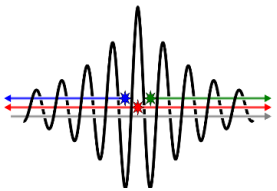
“Prompts” = Trues + Scatters + Randoms

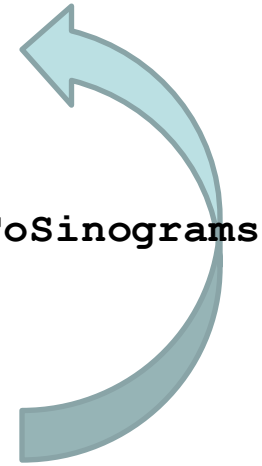




Data storage

- Histogrammed
  - counts detected in a certain time frame
  - often called “sinograms” or “projections”
    - 4D: TOF, (2D) sinogram, view, radial
    - sinogram-index runs over “axial positions” and “ring-differences” (*aka* segments)
- List mode data
  - A list of all coincidences
  - Currently no listmode reconstruction in SIRF
- Attenuation image
- “Normalisation” (or “calibration”) files



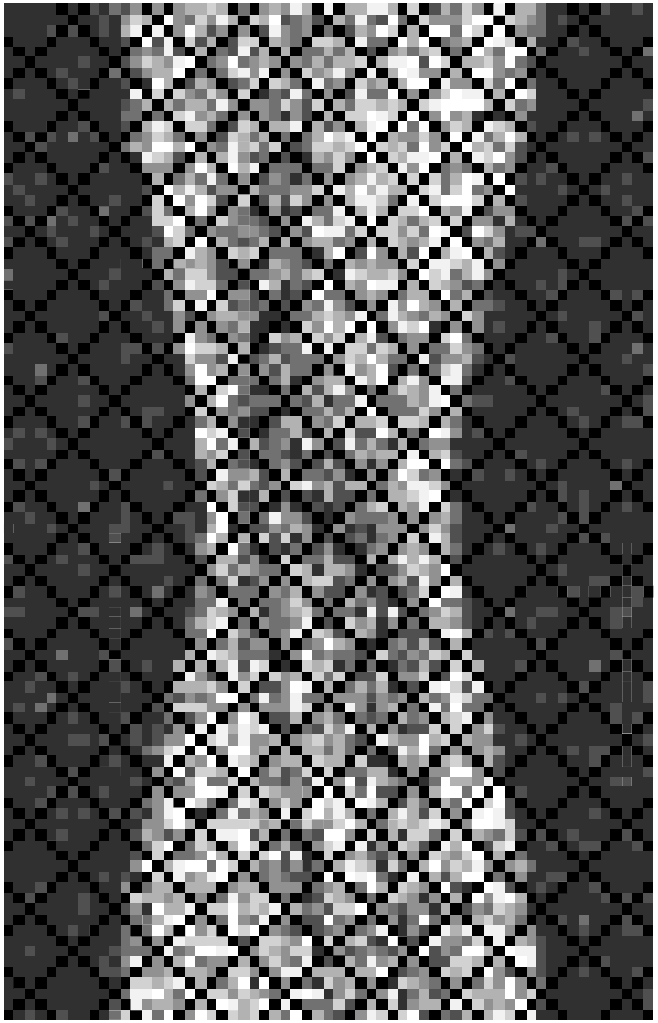


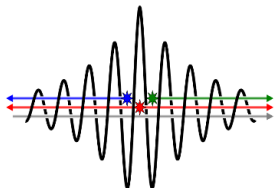
What are the data?

- **Projections**
  (basis for derivation of FBP
- **Add Attenuation, scatter, randoms**
- **Detection efficiencies**

(e.g. defective detector block)

- **Gaps between blocks**
- **Noise!**



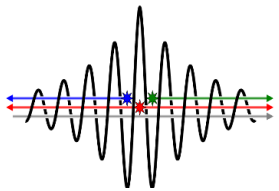


PET data model

- Measured data y (**`AcquisitionData`**) is Poisson distributed
- Given an image x (**`ImageData`**), the **`AcquisitionModel`** can be used to compute the "mean" of the data

$$\bar{y} = A\,x + b$$

  - A : "line integrals", attenuation, detection efficiencies
  - b : mean "randoms" and "scatter"



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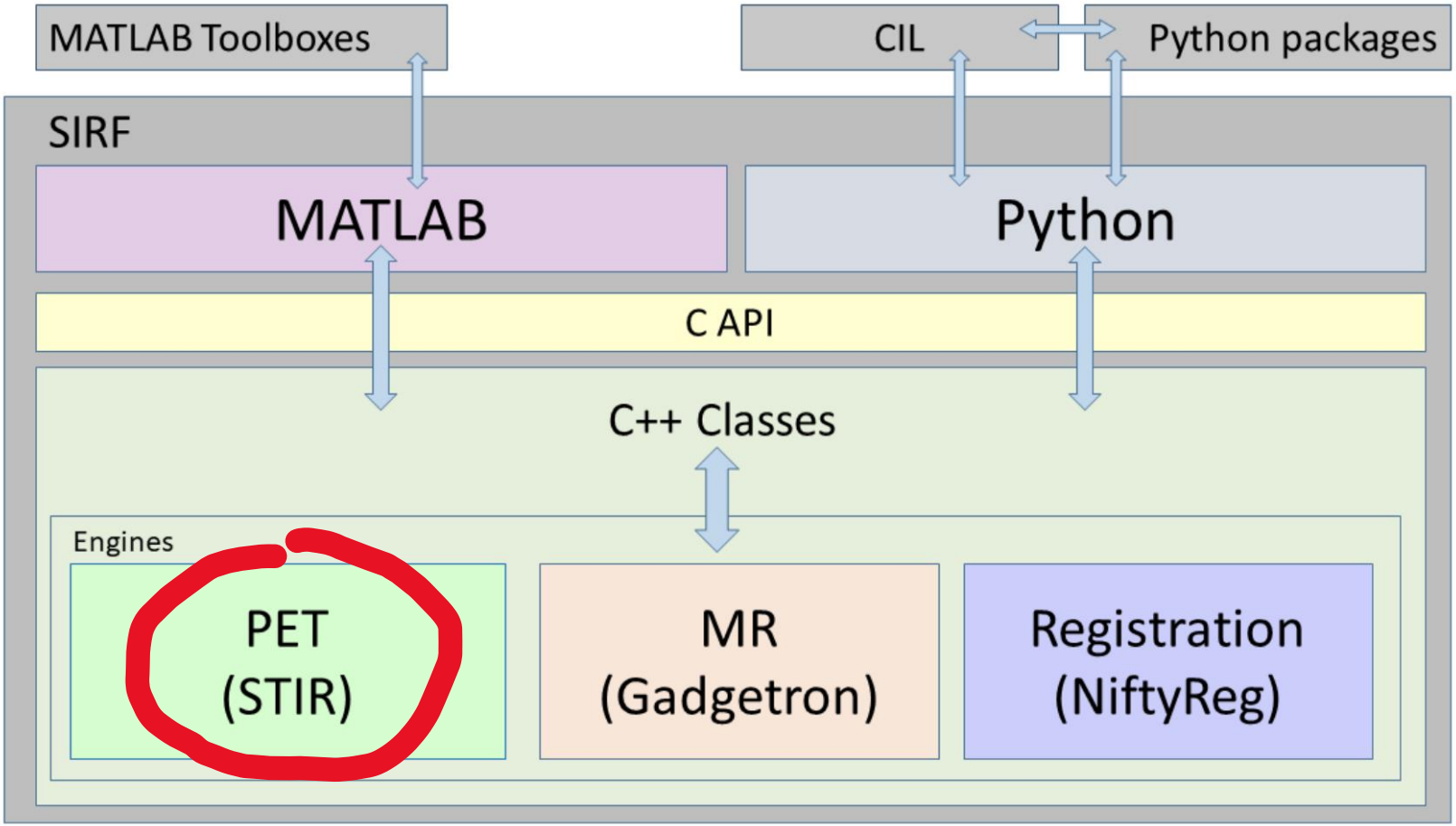
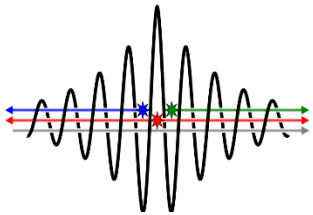
SIRF Software Architecture





STIR

Gadgetron

NiftyReg

STIR

Software for Tomographic Image Reconstruction

http://stir.sourceforge.net
https://github.com/UCL/STIR

Main publication:
Thielemans, Tsoumpas, *et al* (2012) STIR: Software for Tomographic Image Reconstruction Release 2, *Physics in Medicine and Biology*, 57(4):867-83.

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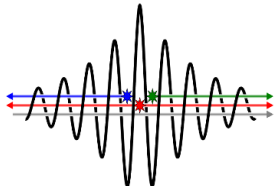
ASC

STIR 1-slide overview

- Development started in 1997, open source from 2000, Apache 2.0 since STIR 4.1.0.
- Covers PET and SPECT
- Aims to provide start-to-end quantitative image reconstruction
- Capabilities
  - Estimation of parts of the acquisition model
  - Image reconstruction
  - Motion-compensated reconstruction
  - Parametric imaging (for dynamic data)



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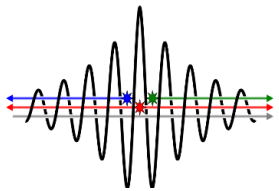
Current PET scanner support (STIR 4.1)

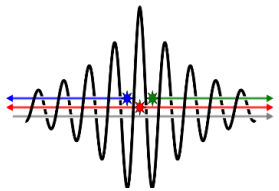
- Siemens mMR and older Siemens scanners
  PET raw data · SyneRBI/SIRF Wiki (github.com)
- GE Signa PET/MR and any GE PET/CT that uses RDF 9
  (SIRF supported is preliminary)

Warning: Time-of-Flight branch of STIR should work via SIRF but has not been tested very well yet.



Some sirf.STIR pecularities

- To do simulations, you need to start from "template" AcquisitionData
  - Read one from file
  - Construct one based on a particular scanner (together with some extra parameters)
- Note that the sinogram-data in this "template" will not be used for the simulation (or even not exist!)



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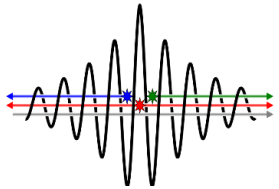
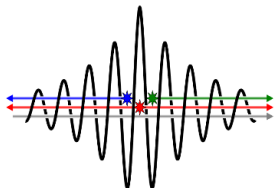
- sirf.STIR image dimensions are restricted for a scanner:
  - axial spacing and number of slices is fixed
  - "in-place" spacing and number of pixels is arbitrary
- Exercises are set-up such that images and acquisition data are compatible.
- You can create an ImageData from an AcquisitionData that works.



- STIR writes diagnostic output by default to the terminal. If you are stuck, you can redirect it to files (as illustrated in some notebooks)

```
msg_red = pet.MessageRedirector('info.txt',
'warnings.txt', 'errors.txt')
```



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https://github.com/SyneRBI/SIRF-Exercises/tree/master/notebooks/PET#readme

reconstruct_measured_data.ipynb minor fixes for MAPEM and reconstruct_measured_data (#140) 2 hours ago

README.md

Contents

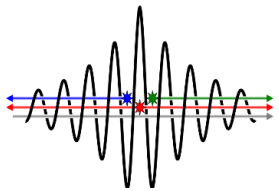
Jupyter notebooks for the PET exercises. Recommended order:

Week 1

1. First look at the Introductory/ notebooks.
2. display_and_projection repeats some of that material but goes in a bit more detail on `PETAcquisitionData`.
3. image_creation_and_simulation shows how to create some images with geometric shapes, and explains attenuation modelling etc.
4. OSEM_reconstruction shows how to run a `sirf.STIR` class for OSEM reconstruction.
5. reconstruct_measured_data goes into detail on how to reconstruct data from the Siemens mMR.

Week 2

1. ML_reconstruction illustrates Maximum Likelihood Estimation via OSEM and gradient ascent.
2. DIY_OSEM invites you to write MLEM and OSEM yourself using SIRF functionality (optional).
3. MAPEM is an exercise to implement the MAP-EM algorithm for the regularised objective function where a quadratic prior is added to the Poisson log-likelihood.



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