Update on PET training demonstrator at INFN

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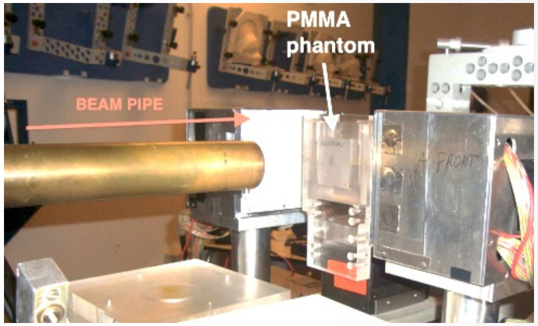
The "dedicated" DAQ approach

- A system is "dedicated" when it is designed with a **specific application in mind**
- Technically, it is a system designed against an **unconventional set of constraints**

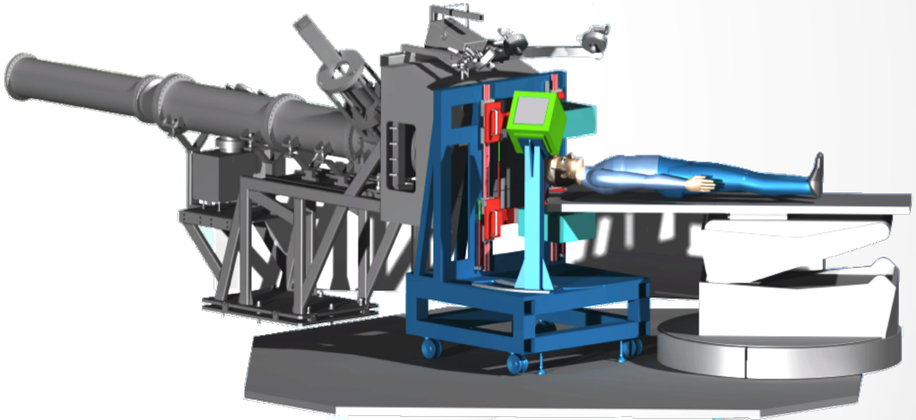
Examples of constraints		
Full angular coverage		Free space
Wide field of view		Synchronization
Good coincidence resolution		High counting capabilities
Good energy resolution		Multiple energy thresholds
LOF resolution		Multiple coincidence detection
Sensitivity		E.M. compatibility

Dedicated PET systems at INFN Pisa

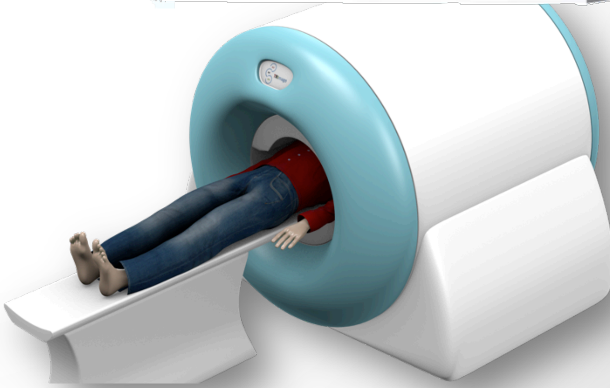
- Range monitoring in hadron therapy with PSPMT (TPS/RDH/DoPET)



- Range monitoring in hadron therapy with SiPMs (INSIDE)



- PET/MRI/EEG brain imaging with SiPMs (TRIMAGE)



Modularization as the key for specialization

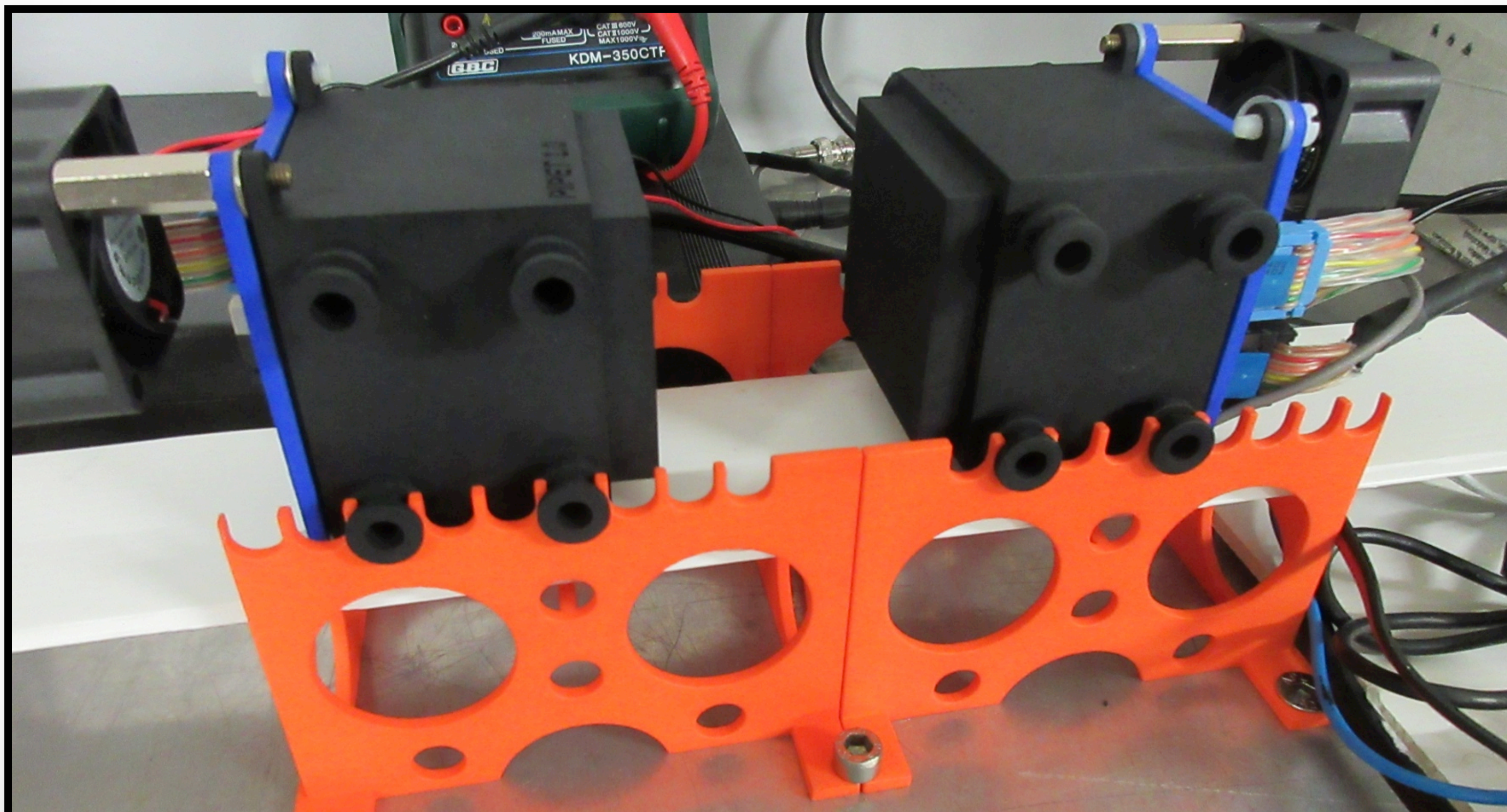
- Developing a DAQ system is a **time consuming** task in developing a PET system
- Developing a dedicated DAQ for every application would be **inefficient**
- **Modularization** has been our strategy to access different applications
    - It allows to intrinsically **parallelize** parts of the system
    - It allows for easier **adaptation or upgrade**

The training problem

- As systems become more specialized, they start to become **unsuitable for students training**
- Dedicated systems can present design choices that can be **hard to understand** without proper scientific and technological background
- Dedicated systems have often **less coverage in the literature** than conventional ones

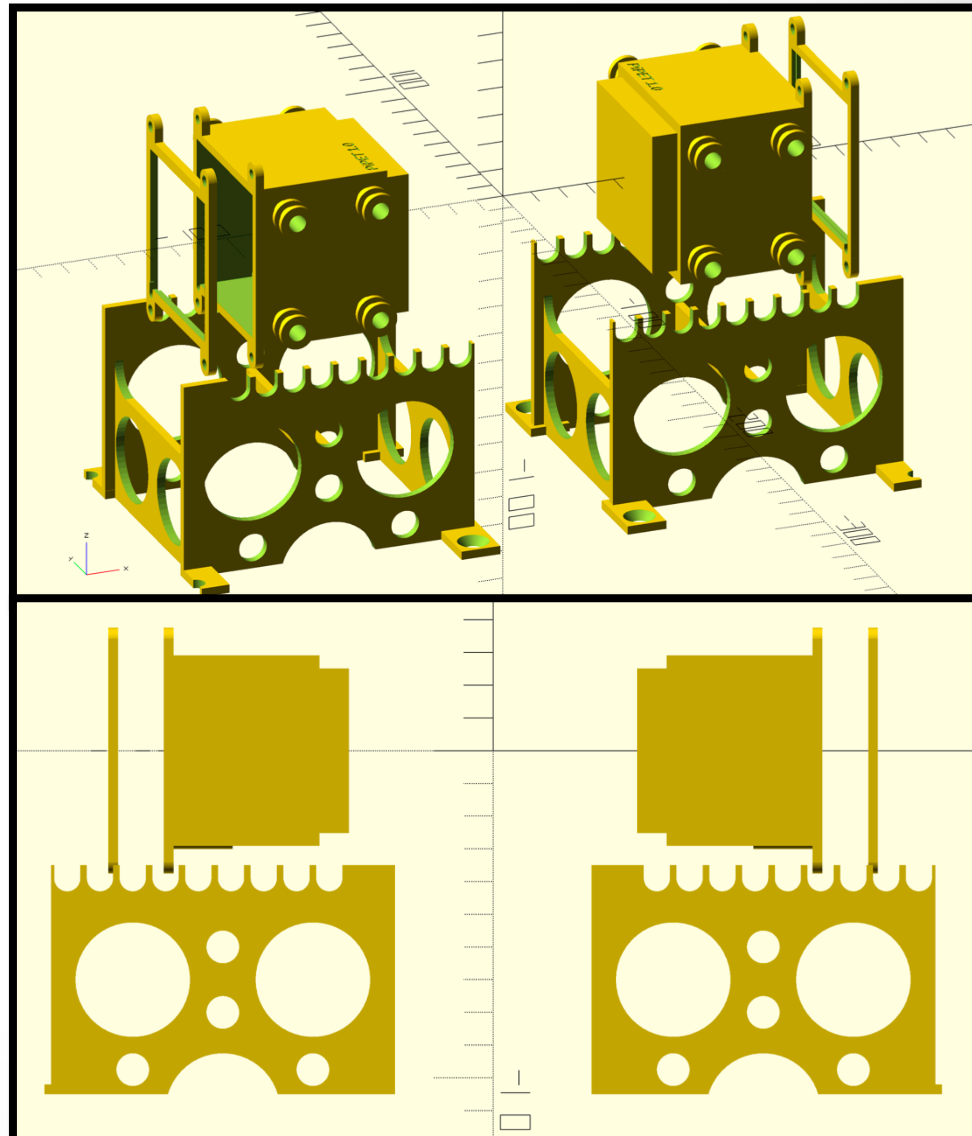
A PET training demonstrator

- *pipet*

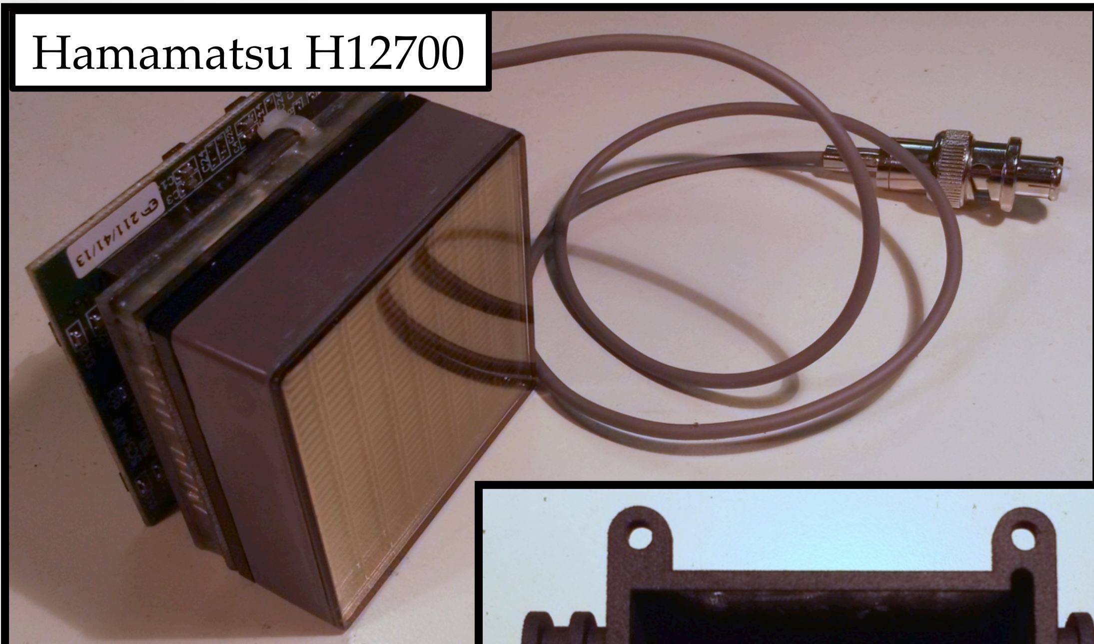


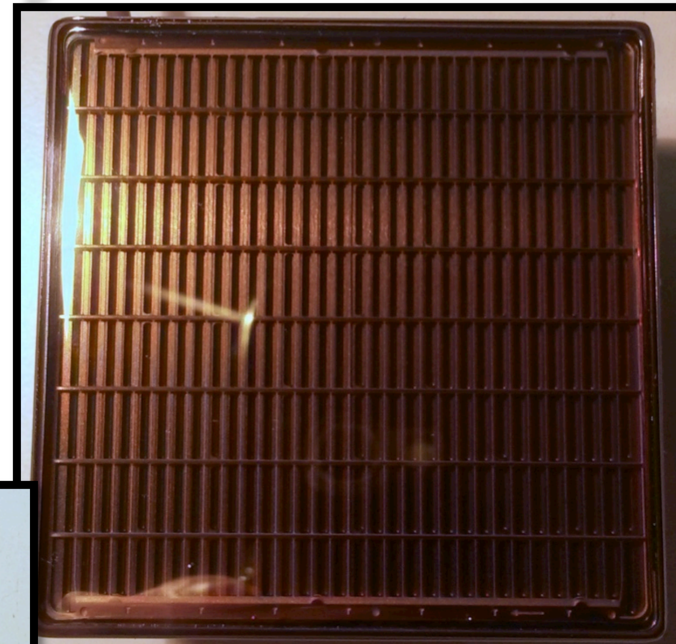
3D printed PET mechanics

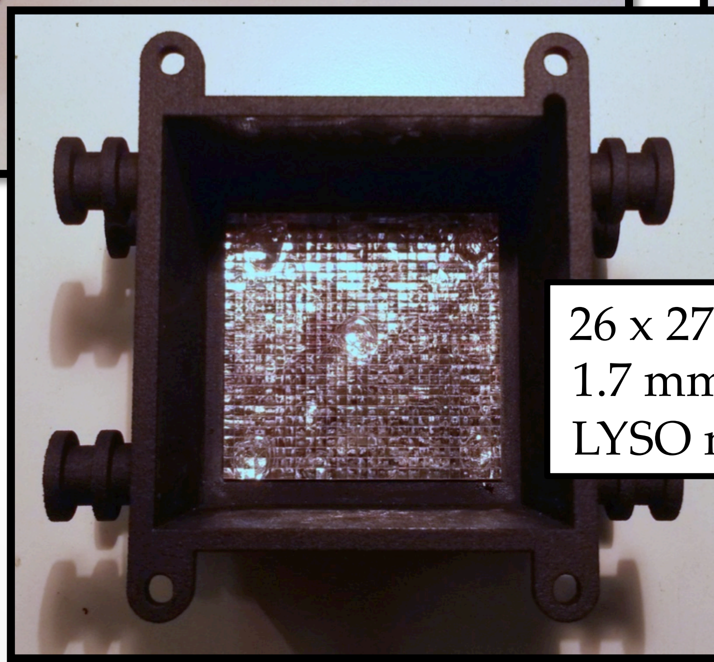
- The two detectors are mounted on a 3D printed precision holder
- The holder is made of a polyamide based plastic material (PA2200)
- Mechanical precision is ± 0.15 mm
- Heatproof up to 80 °C



MAPMT + LYSO detector assembly

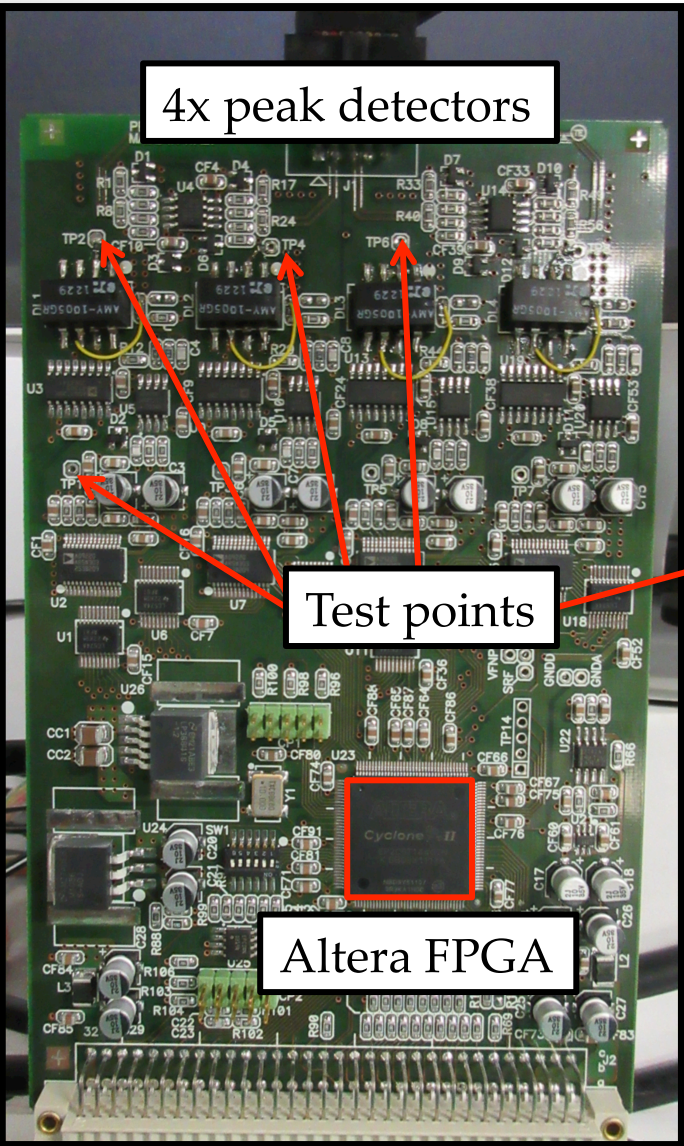


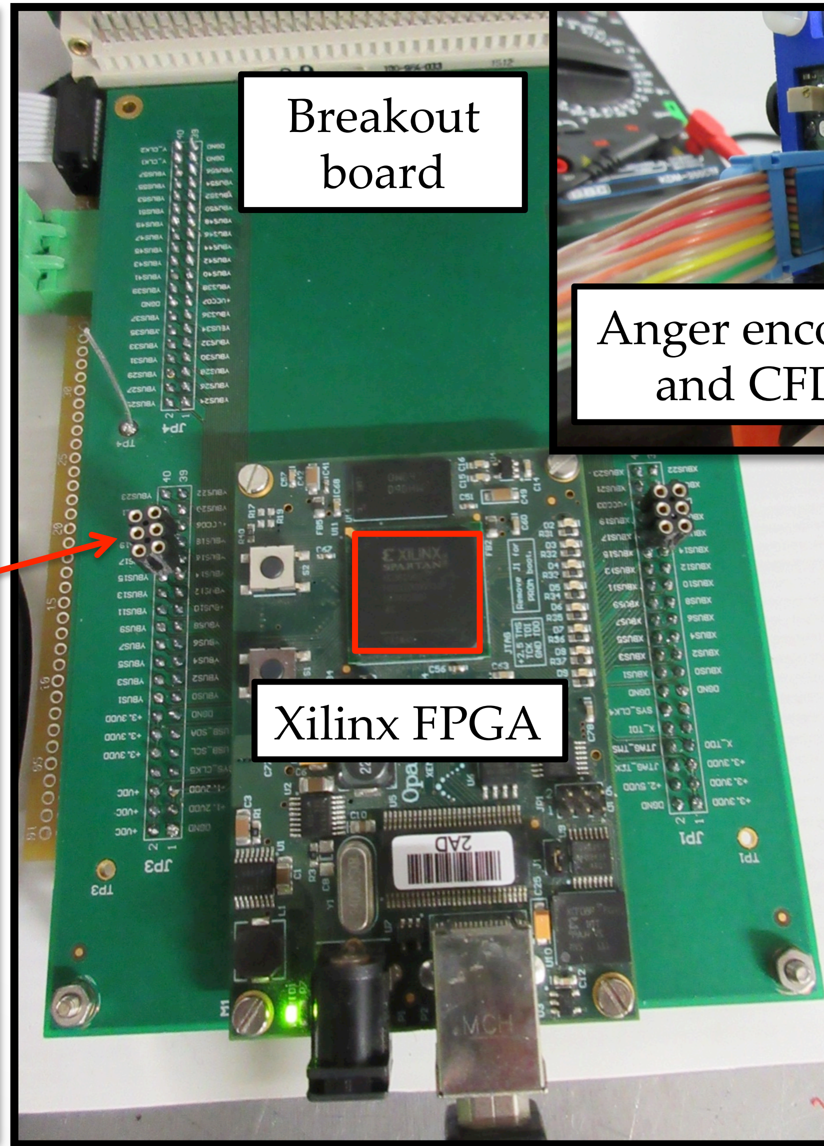


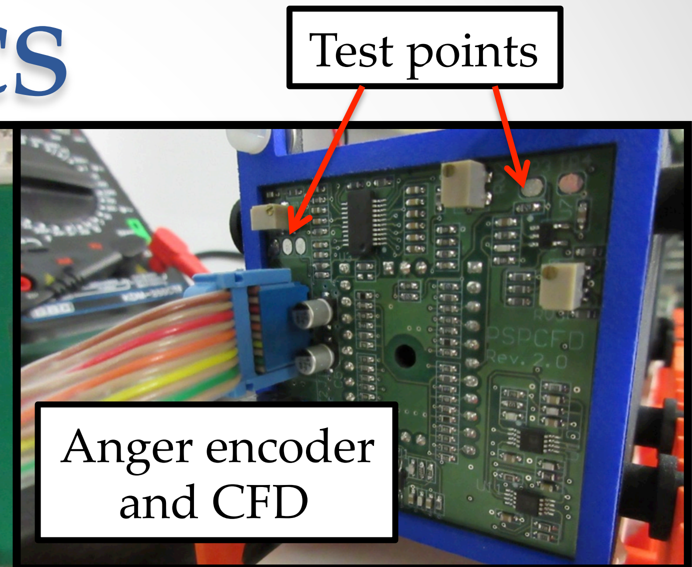


26 x 27 pixels
1.7 mm pitch
LYSO matrix

Accessible FPGA-based electronics

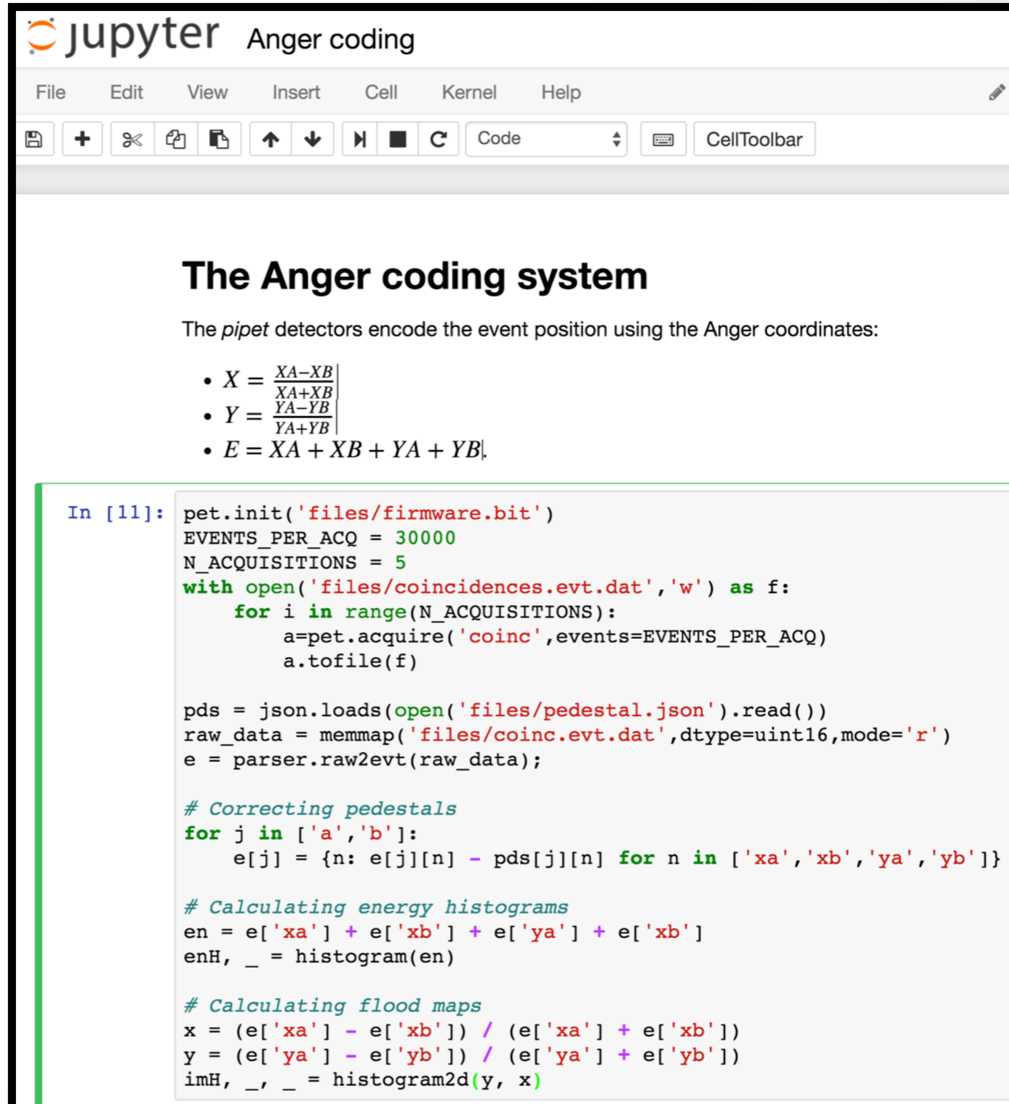






Python-based high level development framework

- Students can connect remotely with their own laptop
- They start learning calibration techniques
- Then they measure the key characteristics of the PET system
- Eventually they customize the firmware and software to improve the system performances



jupyter Anger coding

File Edit View Insert Cell Kernel Help

Code CellToolbar

The Anger coding system

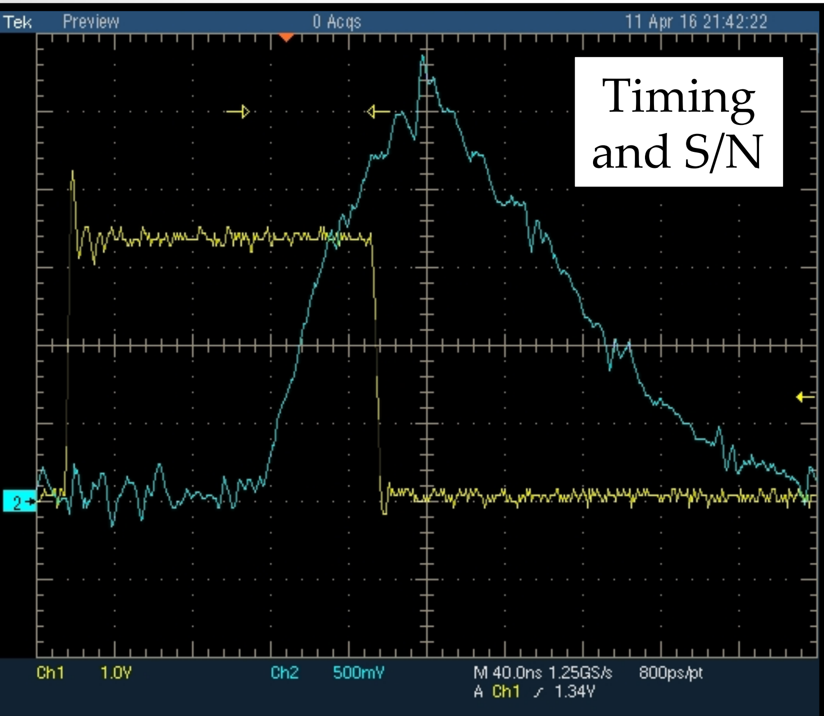
The *pipet* detectors encode the event position using the Anger coordinates:

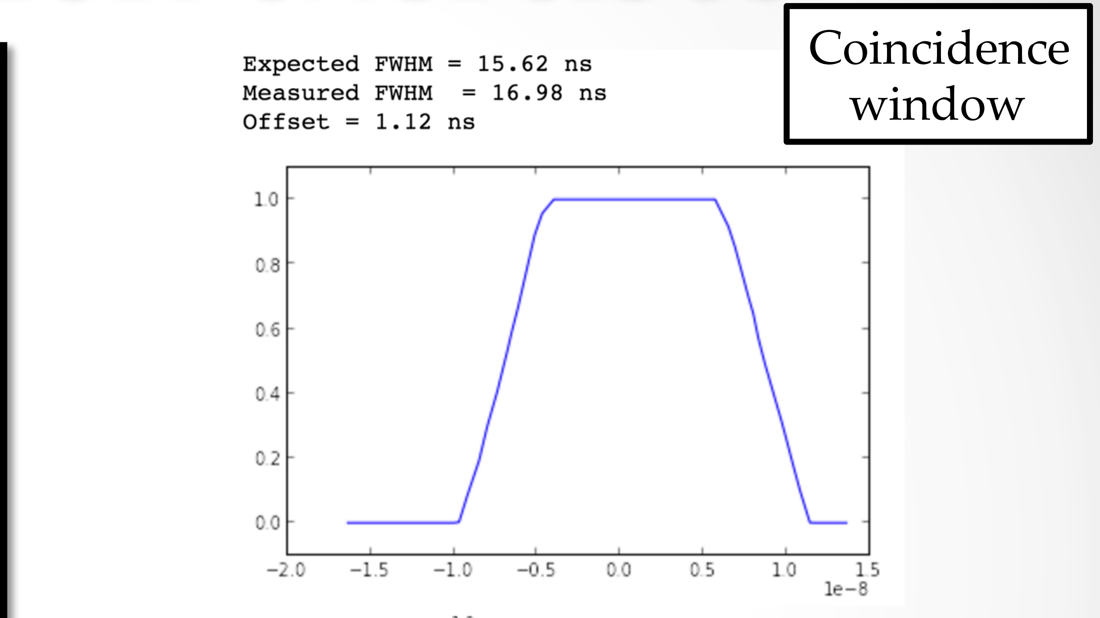
- $X = \frac{XA-XB}{XA+XB}$
- $Y = \frac{YA-YB}{YA+YB}$
- $E = XA + XB + YA + YB$.

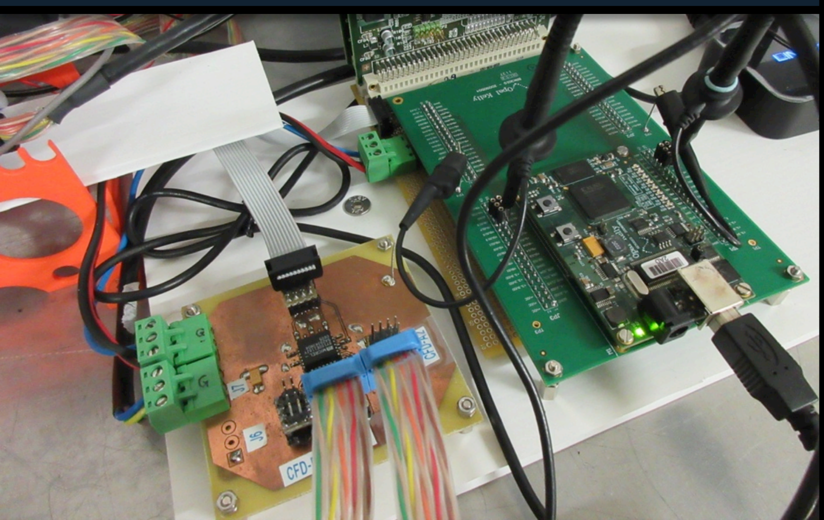
In [11]:

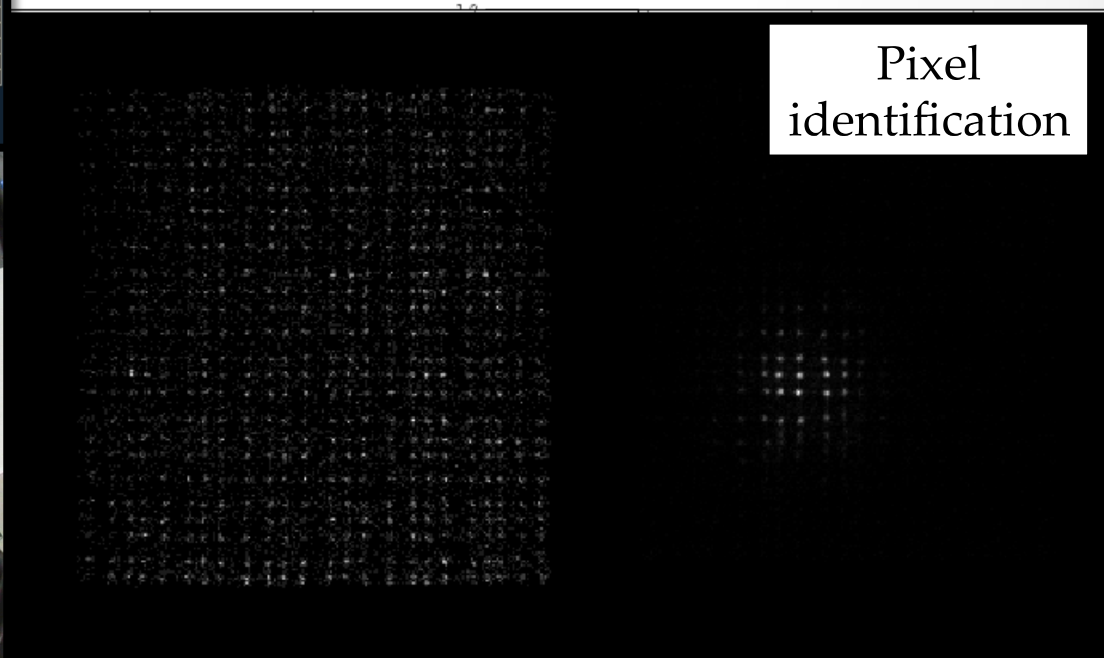
```
pet.init('files/firmware.bit')
EVENTS_PER_ACQ = 30000
N_ACQUISITIONS = 5
with open('files/coincidences.evt.dat','w') as f:
    for i in range(N_ACQUISITIONS):
        a=pet.acquire('coinc',events=EVENTS_PER_ACQ)
        a.tofile(f)

pds = json.loads(open('files/pedestal.json').read())
raw_data = memmap('files/coinc.evt.dat',dtype=uint16,mode='r')
e = parser.raw2evt(raw_data);

# Correcting pedestals
for j in ['a','b']:
    e[j] = {n: e[j][n] - pds[j][n] for n in ['xa','xb','ya','yb']}

# Calculating energy histograms
en = e['xa'] + e['xb'] + e['ya'] + e['xb']
enH, _ = histogram(en)

# Calculating flood maps
x = (e['xa'] - e['xb']) / (e['xa'] + e['xb'])
y = (e['ya'] - e['yb']) / (e['ya'] + e['yb'])
imH, _, _ = histogram2d(y, x)
```

Calibration exercises

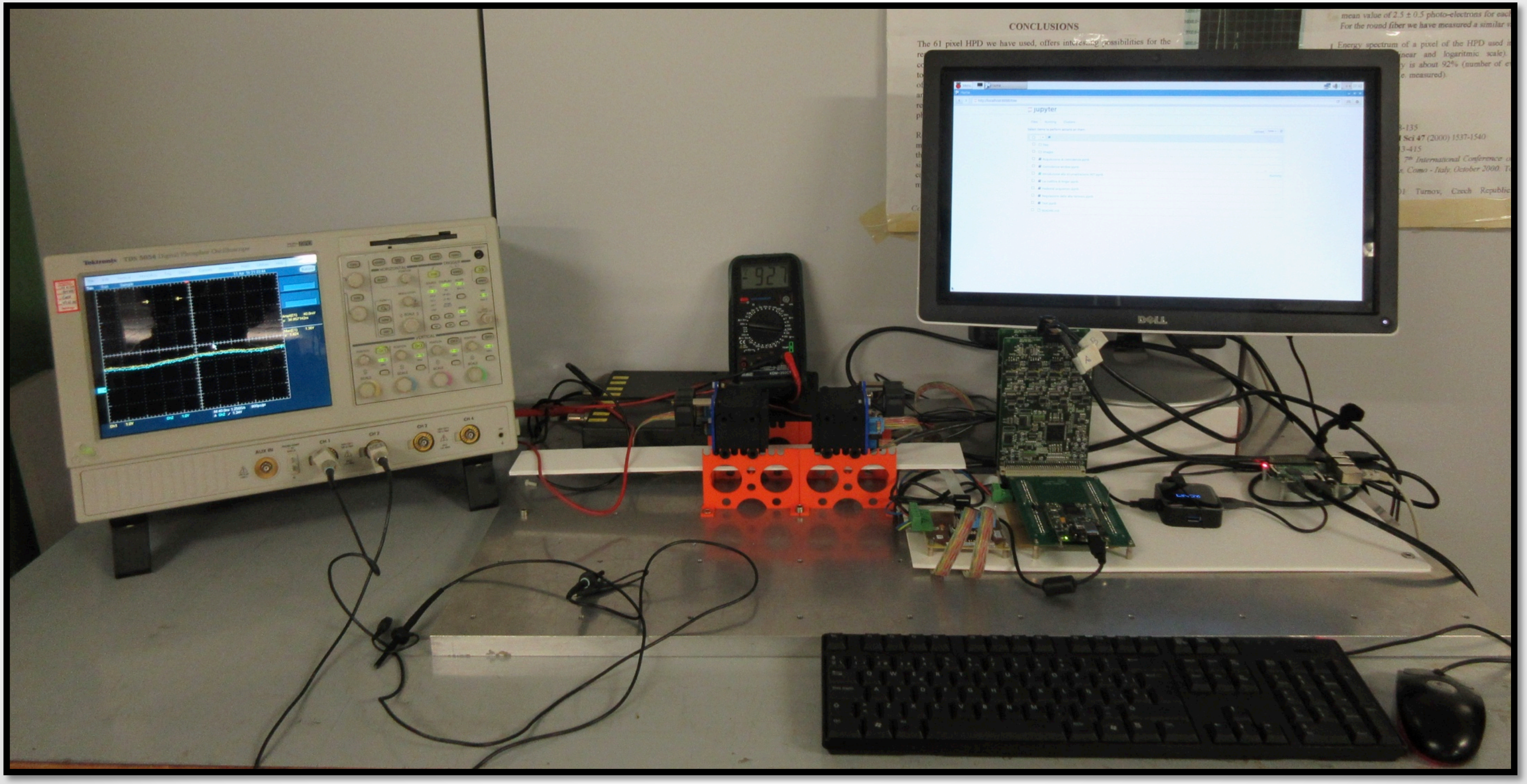






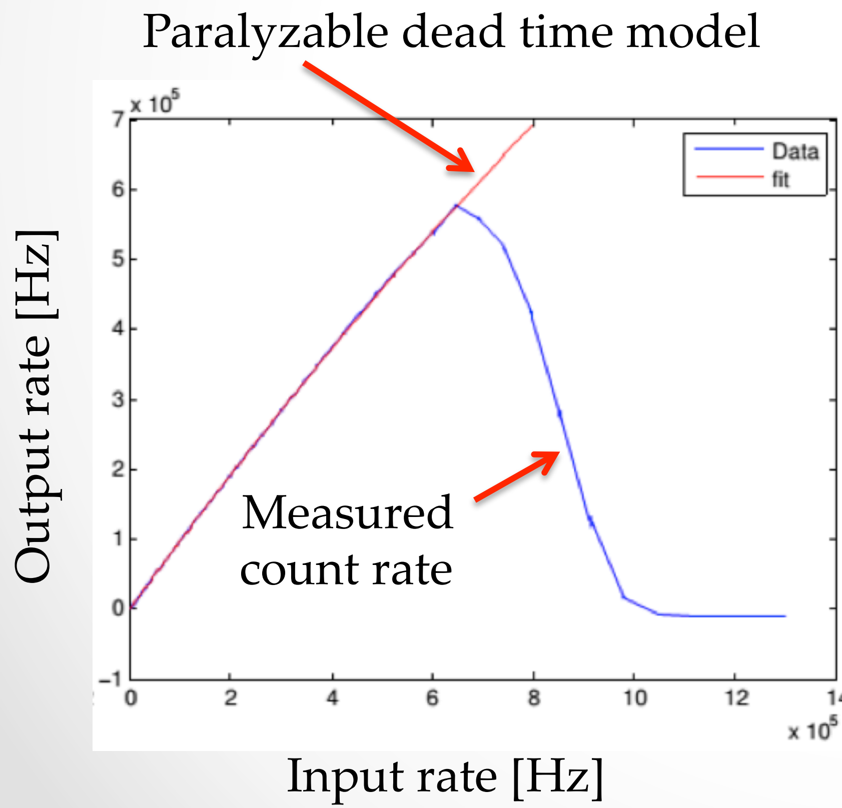


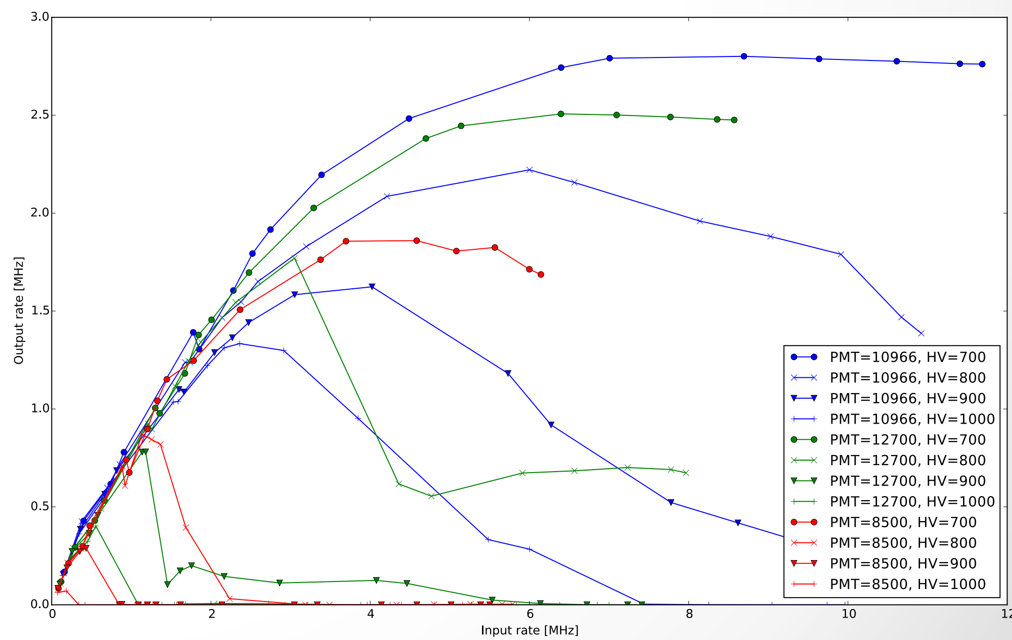
The pipet workbench



A simple problem that can be studied with pipet

- DoPET MA-PMTs show steep loss in count rates at high input rates
- The problem was the PMT itself!





Future works

- Detectors rotation
- SiPM based front-end
- TDC based coincidence processing
- Single-mode data acquisition
- Similar framework for tomographic reconstruction

Conclusions

- We have developed a PET demonstrator that is simple but still compatible with our latest technologies
- The demonstrator can be used either for training or testing specific DAQ characteristics