traces using tracking, while dropping below 50% when the tracking system was deactivated.

Table 1. Gamma passing rates of films (lying on the sagittal plane) acquired in different dynamic conditions using films irradiated in stationary conditions as reference.

| path | TT amplitude in CC [mm] | Chest wall amplitude in UD [mm] | Breathing frequency [bpm] | $GI_{2\%/1mm}$ | $GI_{3\%/1mm}$ |
|---|---|---|---|---|---|
| Linear | 10 | 10 | 11.2 | 96% | 97% |
| Linear no sync | 10 | 10 | 11.2 | 90% | 97% |
| Elliptical | 10 (5 AP) | 10 | 10.4 | 96% | 99% |
| Linear patient | 10 (max) | 10 (max) | 11 (max) | 94% | 97% |
| Linear patient no tracking | 10 (max) | 10 (max) | 11 (max) | 30% | 45% |

TT tracking tool, CC cranio-caudal, AP anterior-posterior, UD up and down

**Conclusion**

The new ADAM's tool demonstrates suitable performances to test, in realistic patient-like conditions, tracking systems based on soft tissue detection.

**PV-0479 Development of an anthropomorphic multimodality pelvis phantom for PET/MRI- and CT-based RT planning**

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**Purpose or Objective**

The aim of the study is the further development of an anthropomorphic multimodality pelvis phantom (ADAM, [1]) for the integration of PSMA-PET/MRI-based treatment planning of prostate cancer patients.

**Material and Methods**

CT and 3T-MRI characteristics of different tissue types are mimicked using agarose gels (Agarose NEEO Ultra-Qualität Carl Roth GmbH + Co. KG, Germany) mixed with different concentrations of Gadolinium (Gd, MultiHance® 0.5 M, Bracco Imaging Deutschland GmbH) and sodium fluoride (NaF, Carl Roth GmbH + Co. KG). Gels were scanned using a 3T PET/MRI (Biograph mMR, Siemens Healthineers, Erlangen, Germany) using a saturation recovery sequence with multiple inversion times and a spin-echo sequence with multiple echo times. Based on the resulting images, T1- and T2-relaxation times were determined using in-house written software. CT scans of the agarose mixtures were performed on a stand-alone CT scanner (Somatom Definition Flash, Siemens Healthineers) at 120 kV and 390 mAs.

Agarose mixtures that agreed best with reference values derived from literature data [2-4] were subsequently doped with patient-specific activity concentrations of $^{18}F$ and $^{68}Ga$ (e.g. 3 kBq/ml $^{68}Ga$ and 11 kBq/ml $^{18}F$ for the primary tumor). Organ shells (prostate with two intraprostatic lesions, lymph nodes and bone metastases) were printed using a 3D printer (Stratasys Objet 300 Connex 3, print material: VeroClear). The doped, liquid agarose gels were filled into the organ shells where they solidified within seconds. Organ shells were scanned at the 3T PET/MRI scanner (PET acquisition time: 10 min, MRI: T2-weighted morphological sequence).

**Results**

The final compositions of agarose gels are the following (given as mass fractions of agarose/NaF/Gd): Prostate (1.35%/3.2%/0.011%), lesions (2.25%/3.2%/0.0085%) and lymph nodes (3.2%/1.4%/0.025%).

T1- and T2-relaxation times and CT numbers of the developed agarose gels fit well to reference values (Figure 1). Exemplary PET- and MR-images of a prostate with two intraprostatic lesions doped with 11 kBq/mL $^{18}F$ are shown in Figure 2. The PET signal can be detected and the tumors appear hypointense on T2-weighted MRI.

**Conclusion**

Agarose gel mixtures with organ-specific MR-relaxation times at 3T and CT numbers have been developed and doped with radioactive tracers. The gels will be used in the pelvis phantom which will be central to simulate and optimize the technical workflow for the integration of PSMA-PET/MRI-based RT planning of prostate cancer patients.

**References**

**[1]** Niebuhr et al, DOI: 10.1118/1.4939874
**[2]** de Bazelaire CM et al, DOI: 10.1148/radiol.2303021331
**[3]** C. Wagner-Manslau et al, DOI: 10.1007/BF00599063
**[4]** W. Schneider et al, DOI: 10.1088/0031-9155/45/2/314

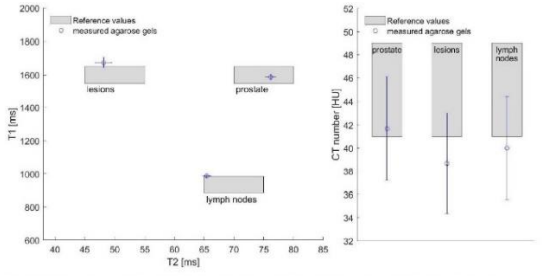
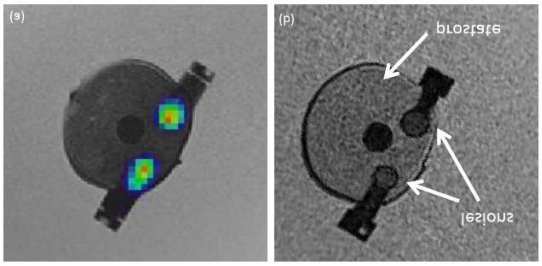



Figure 1: Comparison of T1- and T2-relaxation times (left) and CT numbers (right) of optimized agarose gels with reference values. Reference values were derived based on literature data [1-3].




**PV-0480 Plastic-scintillator based PET detector for proton beam therapy range monitoring: preliminary study**

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**Purpose or Objective**

Proton beam therapy (PBT) range monitoring is required to fully exploit the advantages of a proton beam in the clinic. In PBT the distribution of beta+ emitters induced

by a proton beam in a patient can be detected by PET scanners, the emission distribution can be reconstructed and used for monitoring of the beam range. A prototype of a diagnostic strip-based whole-body PET scanner (J-PET) has been developed and tested at the Jagiellonian University in Krakow (Moskal et al. Phys. Med. Biol. 61 (2016) 2025-2047). The advantages of the system over commercial PET scanners is that it increases the geometrical acceptance and facilitates integration in the treatment room, off-line or in the treatment position. The aim of this work is to study a feasibility of the J-PET technology for range verification in PBT.

**Material and Methods**

A single detection module of the strip-PET scanner is constructed out of thirteen 50-cm long organic scintillator strips. The light pulses produced in a strip by gamma quanta are propagated to its edges and converted into electrical signals by silicon photomultipliers (see Fig. 1). They are read-out by fast on-board front-end electronics allowing excellent overall coincidence resolving time (CRT) of about 300 ps, which shows a significant improvement compared to the standard LSO-based PET scanners. Three different configurations of the modular system were investigated: (i) a single layer consisting of 24 modules, (ii) a two-layer consisting of 20 and 24 modules, and (iii) three-layer consisting of 20, 24 and 28 modules. GATE Monte Carlo (MC) toolkit has been used to investigate the modular JPET system efficiency for detection of beta+ annihilation back to back photons induced in PMMA target by a proton beam (see Fig. 2). A MC based comparison of a J-PET based dual head system consisting of 2x5 modules configured as two opposing heads with the clinically operated inter-spill dual-head PET system installed at CNAO (V. Ferrero et al. Sci. Rep. 8:4100 2018) has been performed.

Fig. 1.

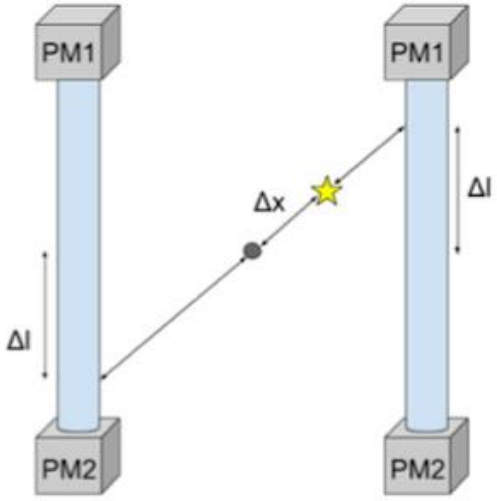
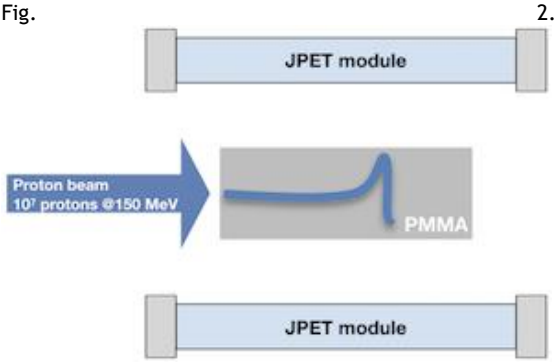



Fig. 2.




**Results**

The efficiency of the system in the proton beam simulation increases quadratically with the number of detector layers. It ranges from 0.12% for single layer setup to 0.75% for three-layer setup. Detected coincidences per primary proton for the single layer, two and three layer modular JPET configurations is 4.0*10^(-5), 1.3*10^(-4) and 2.5*10^(-4), respectively. The comparison of the dual head JPET and PET system installed at CNAO reveals comparable results.

**Conclusion**

Performed simulations suggest the signal obtained with the J-PET detector technology during proton beam therapy is sufficient for range monitoring. The results revealed that inter-spill beam range monitoring is achievable with both, dual-head and multi-layer JPET configurations. Experimental verification of the performed simulations is planned.

**PV-0481 IMRT/VMAT QA in heterogeneous media: first experience with a 2D solid-state detector prototype**

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**Purpose or Objective**

Under-sampling dose distributions in IMRT/VMAT QA may potentially lead to incorrect gamma index analysis. At the present time, the spatial resolution of commercially available phantom-based array detectors is generally larger than 3 mm.

These devices are also not designed for measurements in heterogeneous media.

In this context, the present study aimed at introducing the use of a high-resolution (2 mm) 2D solid-state detector prototype 'MP512' embedded into a customized (in terms of density, dimensions, shape and location of inhomogeneities with respect to the active area of the detector) heterogeneous phantom.

**Material and Methods**

The MP512 has diode-sensitive volumes with a square area of 0.5 m side each.

They are uniformly distributed with a pitch of 2mm over a square area of 52 mm side.

The MP512 and Gafchromic™ EBT3 films were lodged into a phantom (cedar wood, ρ=0.38 g/cm$^3$, to simulate lung tissue) of total thickness 5 cm with a small solid water insertion (0.5 cm radius, ρ=1 g/cm$^3$ , to simulate the tumour target).