Purpose/Objective: To investigate the combination of photons, protons and carbons for an optimal study design for the treatment of meningioma. Meningioma lesions frequently show an aggressive local growth and a high incidence of tumor recurrences after neurosurgical resection. The rapid dose fall-off of particles and the increased RBE of carbons could be of potential benefit leading to increased local tumour control and decreased toxicity.

Materials and Methods: Based on the gross tumor volume (GTV) two different planning tumor volumes (PTV) were constructed for 4 meningioma patients: The initial PTV (PTVinitial) treated with 25x2 GyE and the boost PTV (PTVboost) with 3x6 GyE. For the initial clinical target volume (CTVinit) a margin of 1 cm was added to the GTV adapted to the surrounding tissue. CTVinit plus 3 mm formed PTVinitial and for PTVboost the GTV was enlarged by an isotropic margin of 3 mm. Different organs at risk (OARs), delineated using pre- and post operative MRI information adapted to the planning CT, were considered: eyes, optical nerves, chiasm and brainstem.

Intensity modulated photon plans (IMXT) were created with Monaco (V.3.0, Elekta) and intensity modulated proton and carbon ion plans (IMPT and 12C) using the treatment planning system TRIPMB, respectively. For IMXT 6 beams were used for PTVinitial plans and 4 beams for PTVboost plans. IMPT and 12C treatment plans were created assuming fixed beams. Two beams separated by a couch angle of 20-30° from ipsilateral side were used for PTVinit and two beams from cranio-caudal direction for PTVboost. Using the software CERR (Version 4.1, May 2012) dose matrices for the following combinations were generated: IMXT + IMXT or IMPT or 12C; IMXT + IMPT or 12C; IMPT + IMPT or 12C. Plan quality was analyzed by evaluating conformity and homogeneity index (CI, HI) according to ICRU53, V20, D5% and D95%; D5, D95 and V6 values were investigated for OARs.

Results: VGy was higher than 95% for all plans but best for 12C. CI was worst for IMXT with 0.57±0.03 and higher than 0.72 for IMPT and 12C. HI for 12C was 0.04±0.01 and thus 3 times better than for IMXT, for both PTVs. OAR sparing for particle therapy was highly cough angle and tumor size dependent. No remarkable difference in dose was observed for the ipsilateral optical nerve and the chiasm. 12C as single technique could reduce DV5 to the contralateral optical nerve by 10 GyE. The mean dose to the contralateral eye was reduced from 5.0±3.7 GyE for IMXT+IMXT to 3.2±1.9 GyE for IMXT+IMPT/12C. Moreover, IMPT and 12C as sole treatment modality reduced the dose to 0 GyE. V20 of the brainstem was higher than 90% using IMXT as initial technique and less than 50% when using IMPT and 12C (figure 1).

Conclusions: Highly conformal IMPT and 12C plans could be generated with a non-gantry scenario. Improved OAR sparing favors sole 12C and proton plans, which is should be included in future trial design for meningioma patients.