Compact and not expensive compromise transport system for proton and ion beams.

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The best transport equipment is GANTRY.
It is very large equipment with very high cost.

MY Purpose:
design of **compact and not expensive realistic compromise** transport system for proton and ion beams **with suitable properties and high productivity**.

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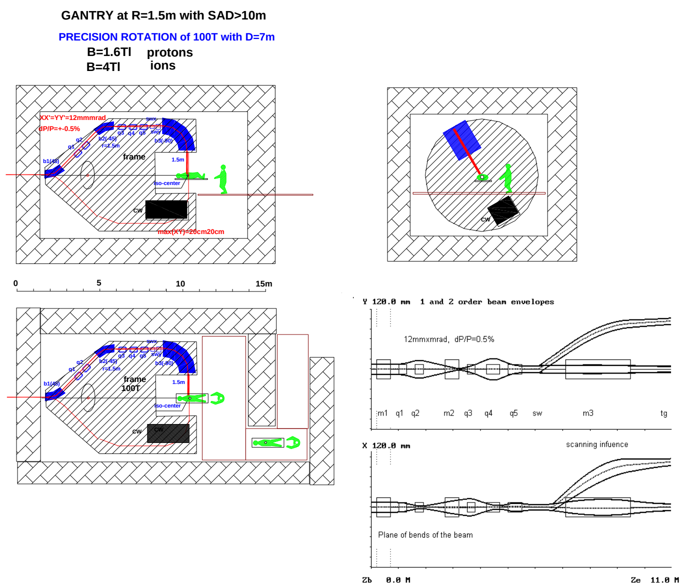
- **Compromises :**
- Spread of possible direction can be limited in one room.
- Spread of possible direction can be different in each room.
- Treatment table with horizontal placed patient can be displaced according of beam direction.

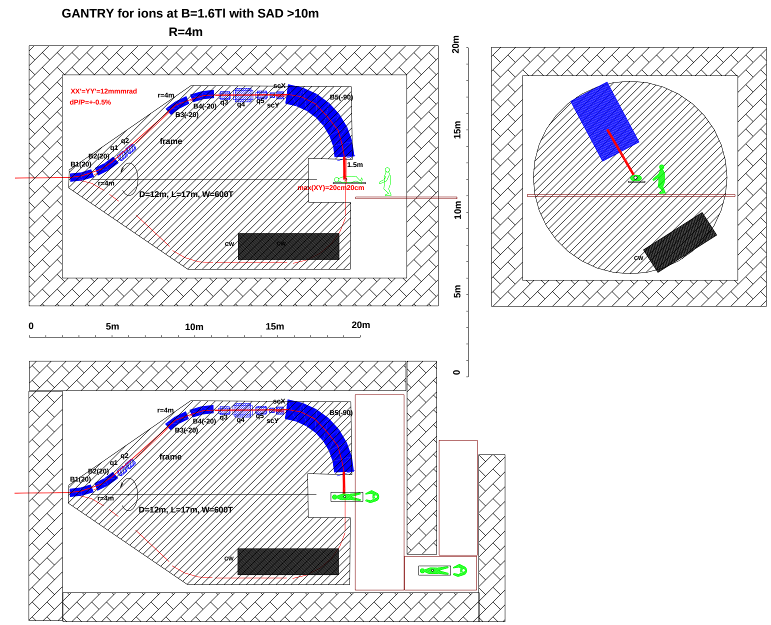
GANRTY schemes with parallel scanning(1998)

Its sizes and cost MUST be decreased according of opinion insurance companies

R=1.5m



R=4m



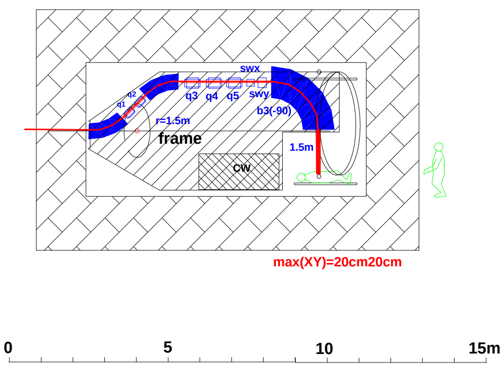
At R=0.5m (protons at B=4Tl) I see difficulties with scanning.

It were many attempts for design compact GANTRY.

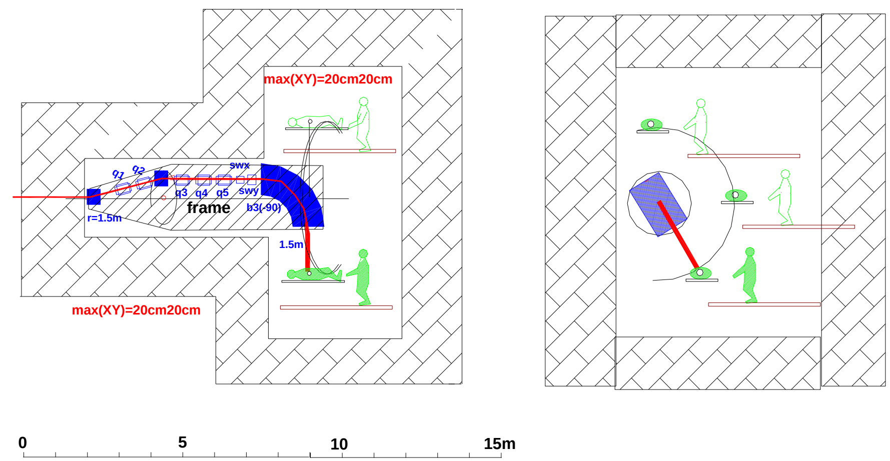
Eccentric GANTRY [PSI-1, PIMMS (2000), Kats (2002)]

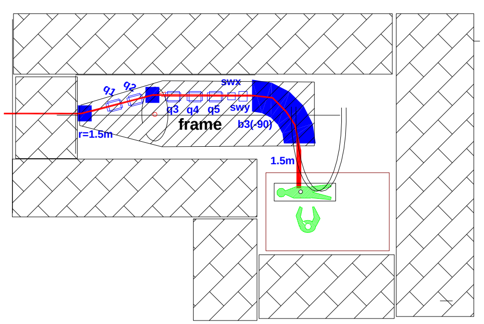
bends of treatment table with horizontal placed patient

around of heavy magnets which bends on the same angle



D(frame)= D(patient)= 2x(R+H/2)
No acces

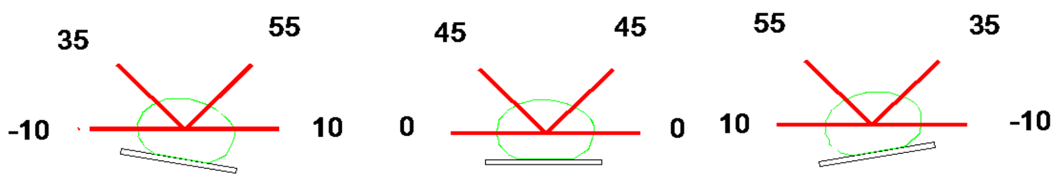




D(frame)=R(bend)/2+H/2(magnet)
NO CW
ACCES
D(patient)= R(bend)/2+1.5m

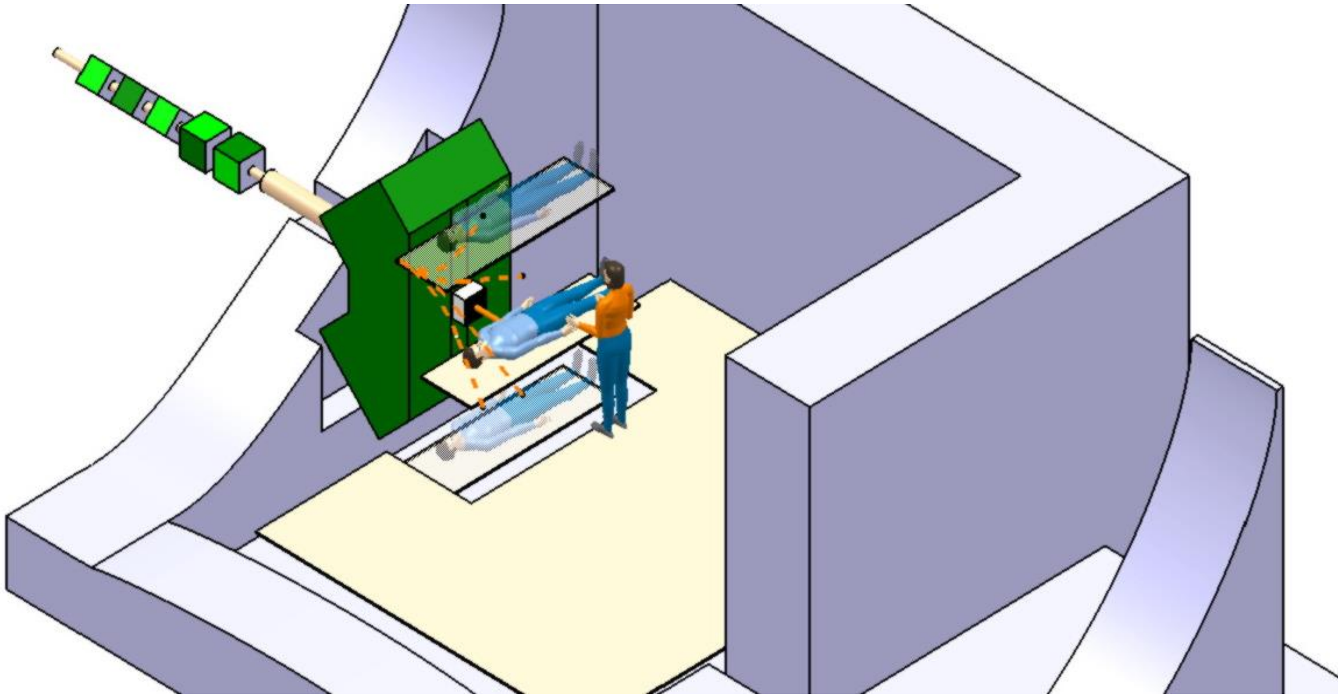
Bends of a patient in vertical position around of vertical axis (V.Balakin)
It is suitable for some targets.

Bends of a treatment table with patient around of horizontal axis with limits in angles and with additional tomography, additional un useful dozes, and additional plan of irradiation after each bend.



http://www.p-cure.com/

Scheme of Planar System M.Kats 2002

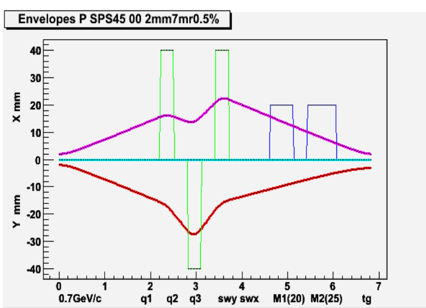


A patient is fixed horizontally. Changing irradiation direction requires the beam to be turned off in vertical plane and the treatment table to be moved up or down. The redirection of the beam in the vertical plane is done by immovable magnet with increased gap placed in front of a patient. Quick access to a patient remains possible at all times. Floor in treatment room to be moved up and down like table. This floor is joined with permanent floor by stair in safety corridor.

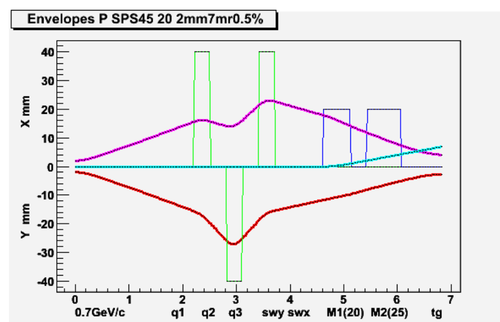
Advantages of Planar System.

- Heavy magnets are immovable.
- Beam’s optic is simple. Beam’s optic depends on direction.

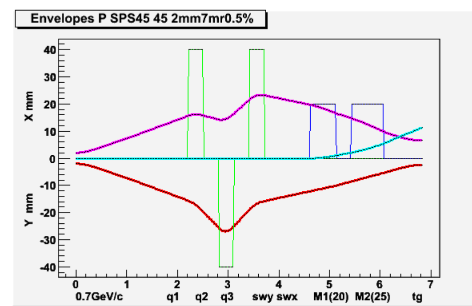
(2mm×7mr, dP/P=±0.5%)



f= 0



f= 20



F= 45

Required size of the treatment room is minimum
(like 6m*7m*7m for protons at B<1.6Tl
and the same for ion beam at B<4Tl).

- Required electric power is minimum
(middle power for SPS45 10 times less then for GANTRY).

- Cost of equipment per treatment room is minimum.
(like 0.3GANTRY cost).

- Medics have quick access to patient at any position of treatment table.
- SAD is more 3m, it will be bigger as bigger angle f.

- Planar System can be used for significant extend possibility of any treatment rooms with horizontal direction of the beam even at small magnet.

- Planar systems can work with any accelerators in many versions and with scanning systems, .

- Planar systems are especially useful for ion beam transport.

Disadvantages of planar system.

- There are limits in irradiation directions.
- There is uncompensated linear dispersion on the target in vertical plane (like 15mm/% for 45 degrees)
- There is displacement of the table with patient and all devices. There is displacement of floor in treatment room according of table position.

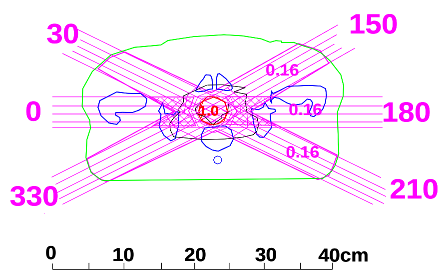
Ways to overcome disadvantages:

At compromise directions interval of (-45≤ f ≤+45) + (-135≤ f ≤+225) degrees to the horizontal plane, it is possible to choose a few (3 for example) suitable or optimal directions in any fraction (almost as in usual GANTRY).

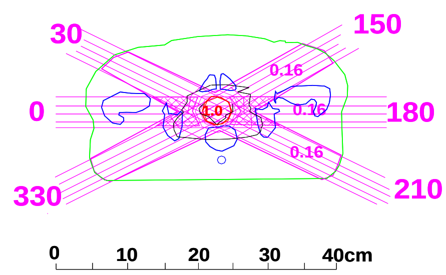
How many targets (from 100) can't be irradiated with suitable properties by SPS45? I suppose like 20. Show me them.

At prostata treatment optimal beam directions at using SPS(45) or GANTRY are the same! (directions near to vertical are closed by bladder and rectum).

SPS(45)



GANTRY



Influence of linear dispersion is small enough (at using beam after extraction from synchrotron (dP/P =0.1%), at small bends of the beam in main magnet, at large or deep targets...). If the target is small and dP/P=0.5% (after ESS) dP/P can be decreased by gap of collimator.

Displacement of treatment table with a patient together with all devices (less 1t) in the vertical plane in the interval of ±1.5m with precision ±0.3mm is not difficult to achieve.

Displacement of floor in treatment room (less 1t) together with its stair in safety corridor in the same interval of ±1.5m with precision ±1sm is more simple task.

Unmovable position of patient on treatment table can be controlled by optic devices (like on GANTRY).

- **For increasing productivity of accelerator and for possibility of using for irradiation any spatial directions** it is suggested to use 3 independent treatment rooms at 3 levels with SPS45 into each room (around of direction of beam at it enter in this room). Treatment of any patient can be made with using all rooms in different fractions.

- **System of three treatment rooms placed on three levels with planar systems SPS45 into each room** can work with very compact and simple transport system to rooms based on one magnet with bend of the beam in vertical plane. Such compact and simple system seems me as very perspective. **Any directions** at treatment are possible, 3 independent rooms have **year productivity like 900 patients.**

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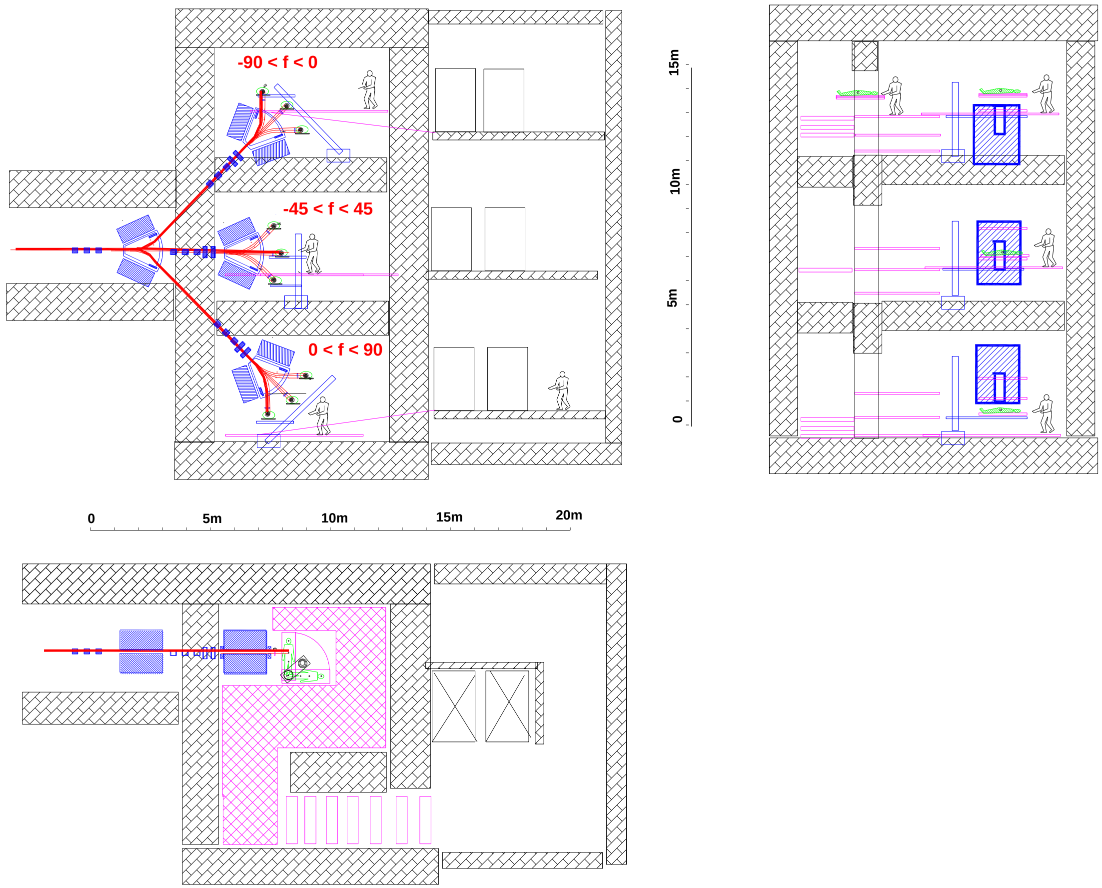
Scheme of 3 rooms with planar systems SPS45 into each room (7m*7m*6m)

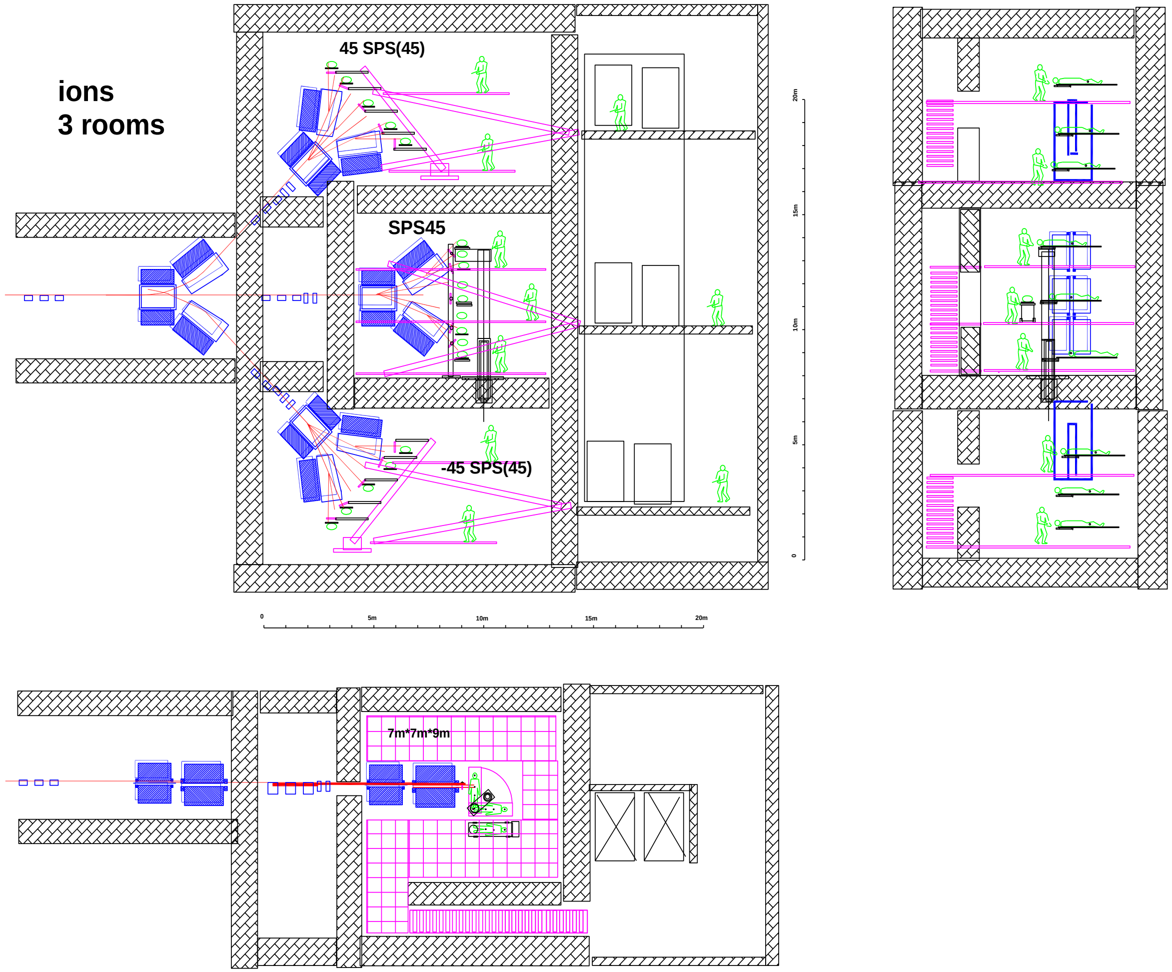


It can be useful for proton beam at magnets with fields up to 1.6Tl.

The same rooms are need for ion beam at magnets with fields up to 4Tl. It is realistic system!

Scheme of 3 rooms with planar systems SPS45 into each room

for ion beam at B<1.6Tl



It is realistic system!

Example of magnet for protons SPS(60)
was designed in Dubna by N.Morozov in 2010.

Requirements for its field are not so hard, as for GANTRY (bend f < 90degrees, distance to the target is smaller)
Magnet for SPS(45) will be smaller and simple.

Расчет магнита SPS-60

Н.А.Морозов
Дубна, октябрь 2010г.

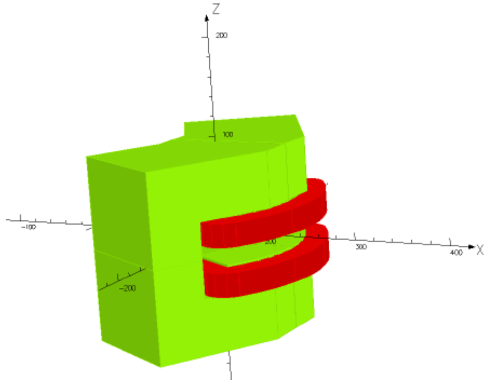
Общий вид расчетной модели показан на Рис.1. В использованной системе координат начало полюса X=100 см (прямая), конец полюса X=230 см (радиус R=140 cm, Xc=90 см). Угловой размер полюса - 60 град.

Распределение магнитного поля для уровня поля в зазоре B=1.6 Тл приведено на Рис.2-3.

Рис.2 - поле вдоль оси X (края полюса X=100-230 см).

Рис.3 поле вдоль оси У (X=105 см).

Рис.4 – поле в поперечном направлении по дугам R=60, 110, 135 см (центр Xc= 90 см).



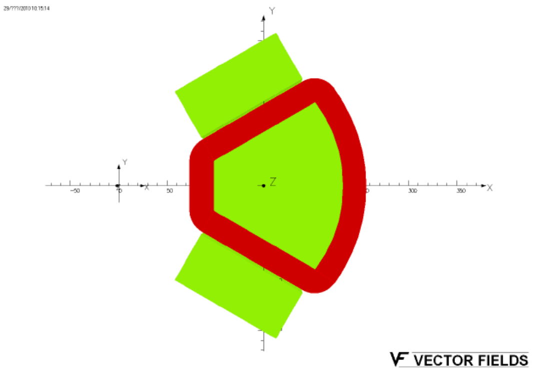
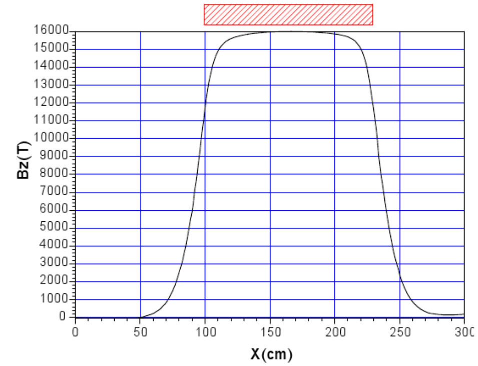
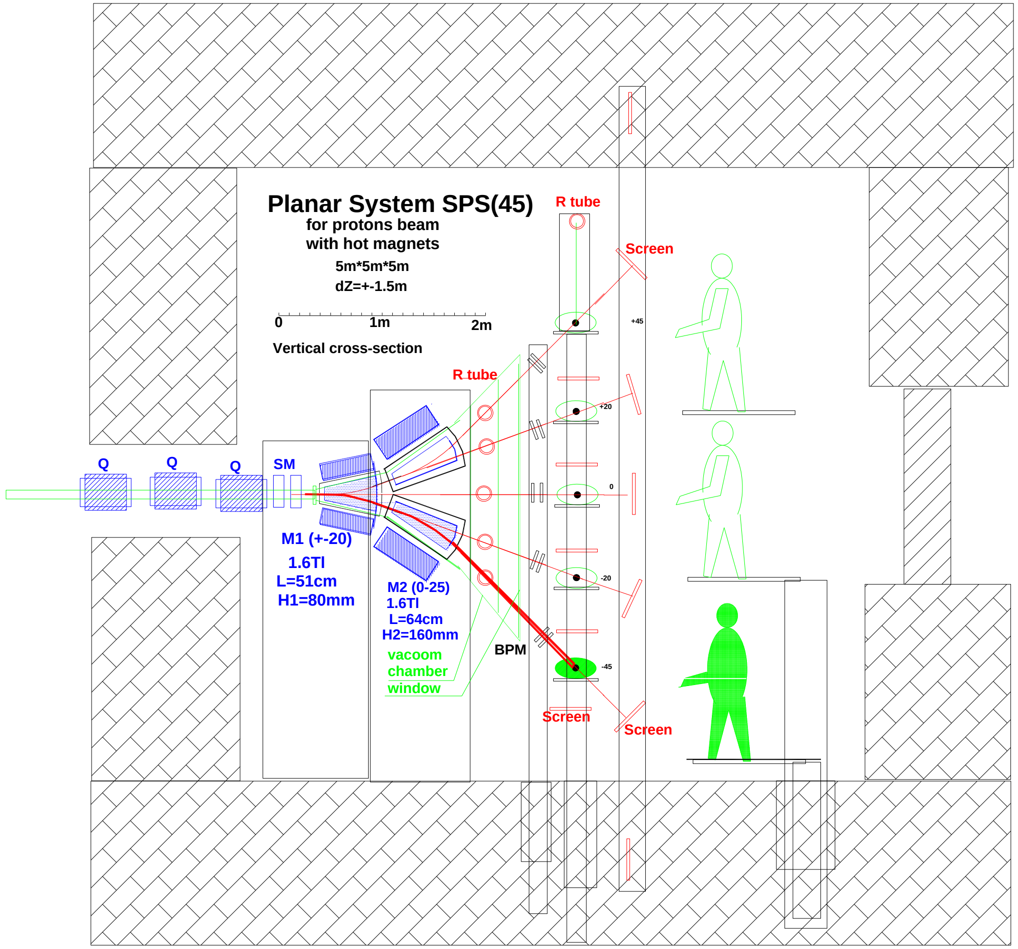


Рис.1. Виды модели магнита SPS-60

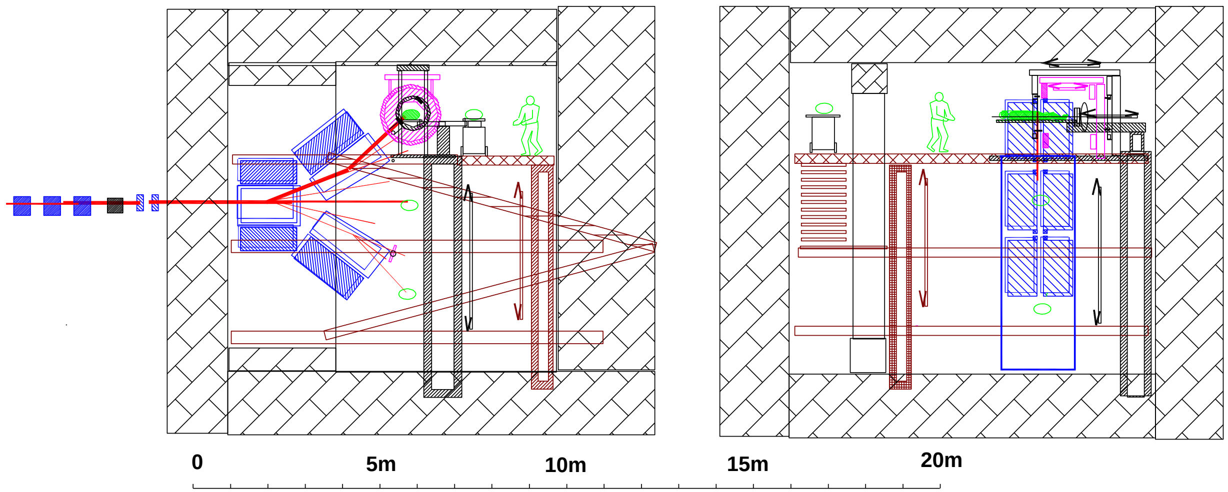


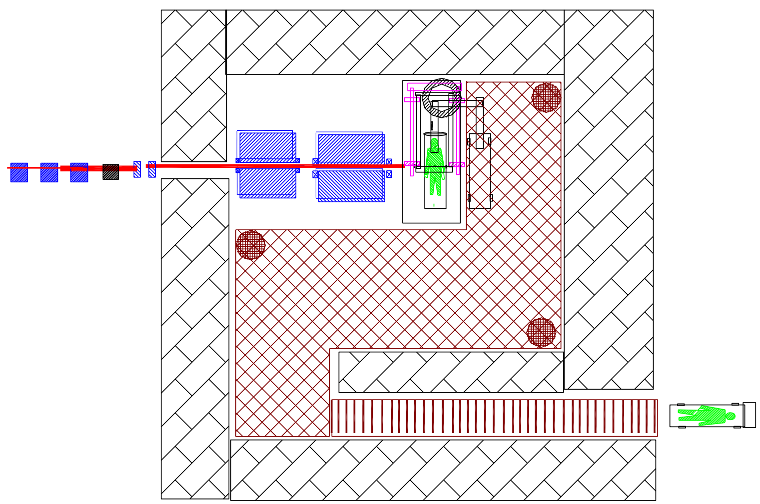
A few schemes of SPS(45) were sketched and calculated.



Treatment room with SPS(45) for ion beam at B<1.6Tl

with displayed tomograph and small bends of treatment table.



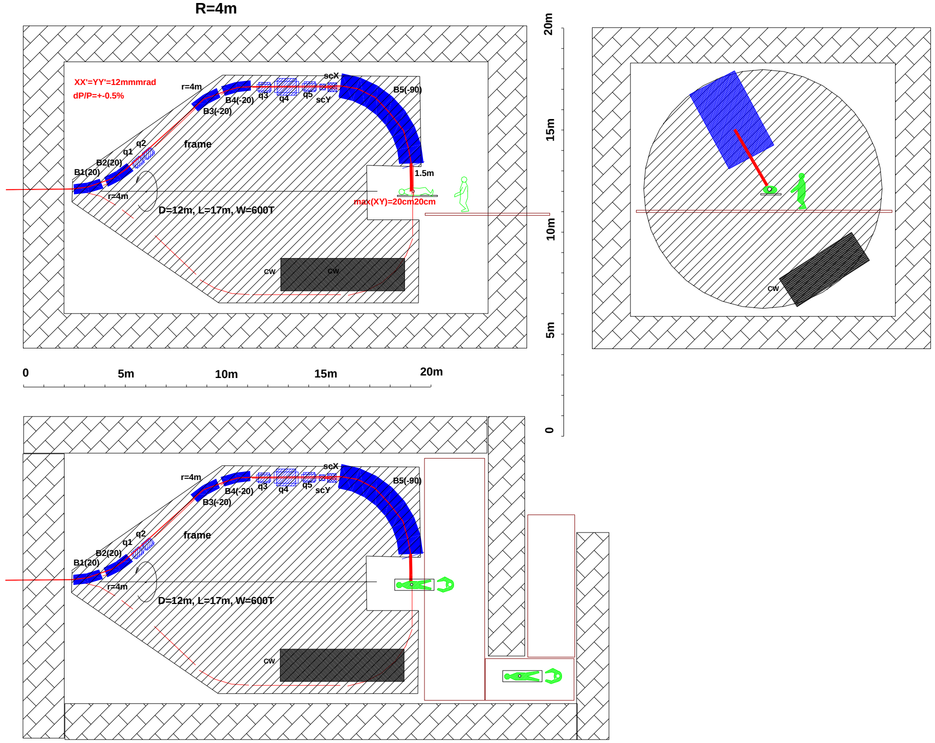


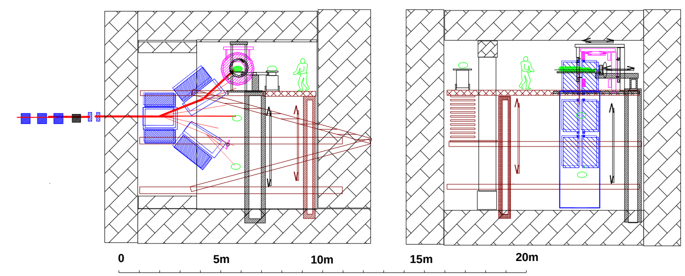
Ions C
P/q < 1.9GeV/c
B < 1.8Tl
-45 < f < 45
135 < f < 225
df=15
9m*7m*8m
dY(max) = +_ 2.5m

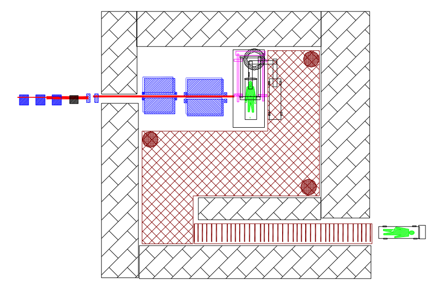
Spatial schemes of treatment rooms for ion beam at B<1.8Tl with usual GANTRY and SPS(45)

GANTRY for ions at B=1.6Tl with SAD >10m

R=4m







Ions C
P/q < 1.9GeV/c
B < 1.8Tl
-45 < f < 45
135 < f < 225
df=15
9m*7m*8m
dY(max) = +_ 2.5m

It is possible to use industrial robots for precision displacements table with patient and devices.

For example

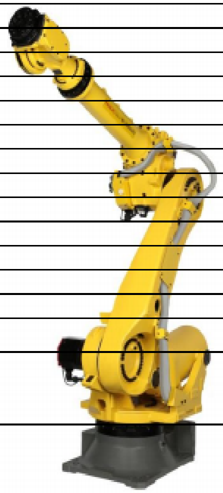
ООО FANUC
Nauchniy Proezd, 19
117246 Moscow
RUSSIA
Tel.: +7 49 56 65 00 58
www.fanuc.ru

FANUC

ООО ФАНУК
Научный проезд, 19
117246 Москва
РОССИЯ
тел: +7 49 56 65 00 58
www.fanuc.ru

Основные Технические Характеристики
Промышленный робот FANUC R-2000iC/210F

Модель		**R-2000iC/210F**
Тип		Шарнирно-Сочленённый
Количество контролируемых осей		6 осей (J1, J2, J3, J4, J5, J6)
Количество сочленений		6
Установка		Напольная
Радиус досягаемости		2655 мм
Угол поворота, град	J1-axis	360°
	J2-axis	136°
	J3-axis	316°
	J4-axis	720°
	J5-axis	250°
	J6-axis	720°
Макс. скорости по осям	J1-axis	95°/c
	J2-axis	90°/c
	J3-axis	95°/c
	J4-axis	120°/c
	J5-axis	120°/c
	J6-axis	190°/c
Макс. Нагрузка - грузоподъемность		210 кг
Допустимый момент	J4-axis	1333 Н/м
	J5-axis	1333 Н/м
	J6-axis	706 Н/м
Допустимый момент инерции	J4-axis	141.1 кг/м^2
	J5-axis	141.1 кг/м^2
	J6-axis	78.4 кг/м^2
Тип приводов		Сервопривода переменного тока, находящиеся внутри корпуса робота
Повторяемость		±0.3 мм
Масса		1 240 кг
Среднее энергопотребление		~3,0 кВт
Температурный диапазон, град°		0-45°



Conclusion:

Using of Planar Systems is a realistic way to decrease sizes and cost of suitable compromise transport equipment.

Using a few treatment rooms at different level with Planar Systems is a way for increasing productivity of future centers for treatment by proton and ion beams.

Literature

1. M.M.Кац Простая плоская система ПТЭ 2002, 2, 136-141, (Rus)

2. M.Kats Simple Planar System PARTICLES n30 07.2002 p.17.

3. M.M. Kats New schemes of multidirectional patient irradiation systems for cancer treatment with heavy charged particle beams. Preprint TERA 01.2002 .

4. M.M.Кац Новая Плоская Система (NPS) транспортировки пучков протонов и ионов для терапии. Медицинская физика 2007, 1, стр.37-41 (Rus).

5. M.Kats Compact and non expensive transport systems for medical facilities using proton and ion beams PAC2009, 05.2009 Vancouver

6. M.Kats Planar Systems and its Comparison with GANTRY and Fixated Beams. PTCOG50, Philadelfia, May 2011.

Thank you for attention!