Innovative developments for **proton therapy at PSI**: **beam delivery with SC magnets**

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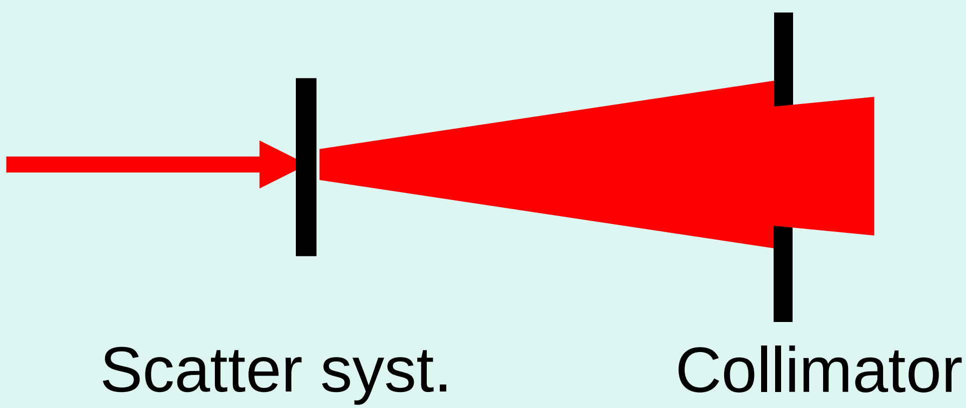
Contents

- Dose spreading in proton therapy
- Gantries
- PSI's Gantry-2 with SC magnets
- Conclusions & WHAT DO WE NEED ?

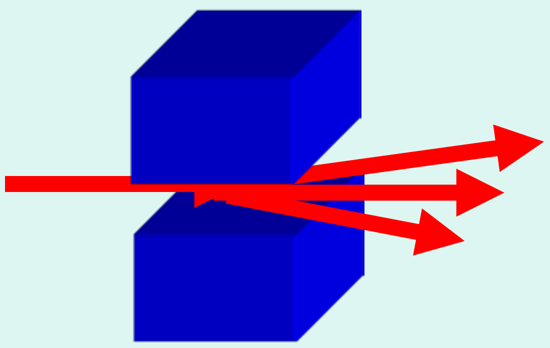
Dose delivery techniques: **Width**

transversal spread:

scattering



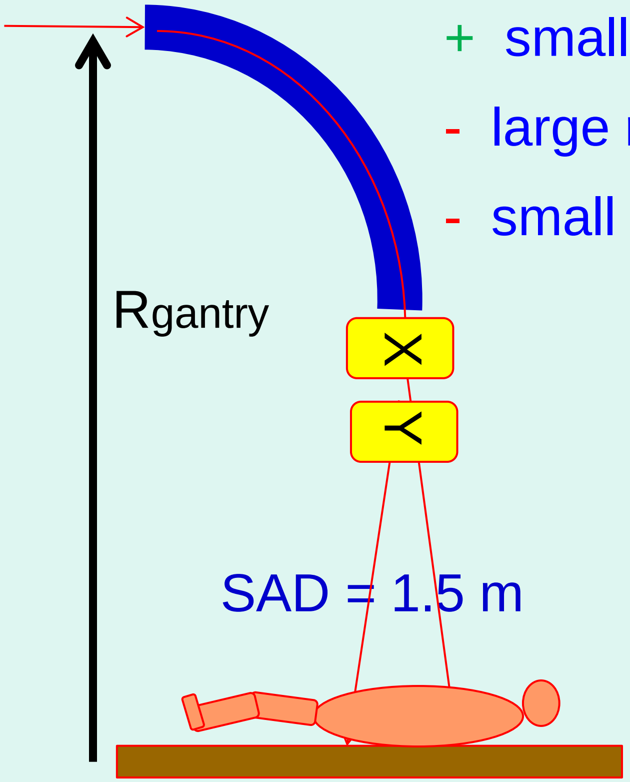
scanning



scanning

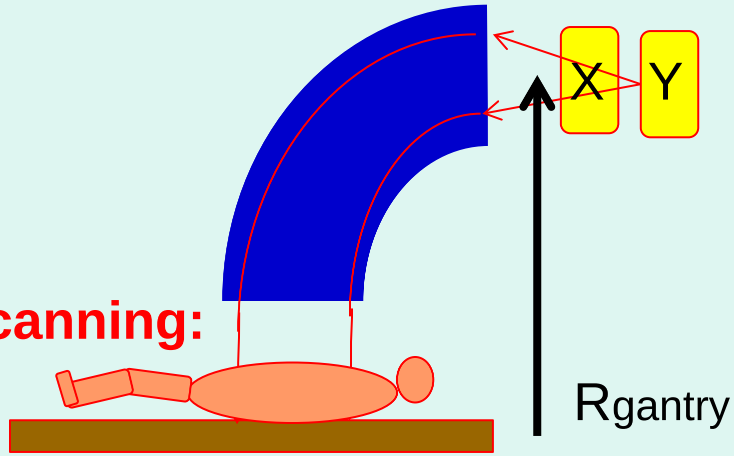
Down-stream scanning:

+ small aperture,
- large radius because of SAD
- small spots difficult

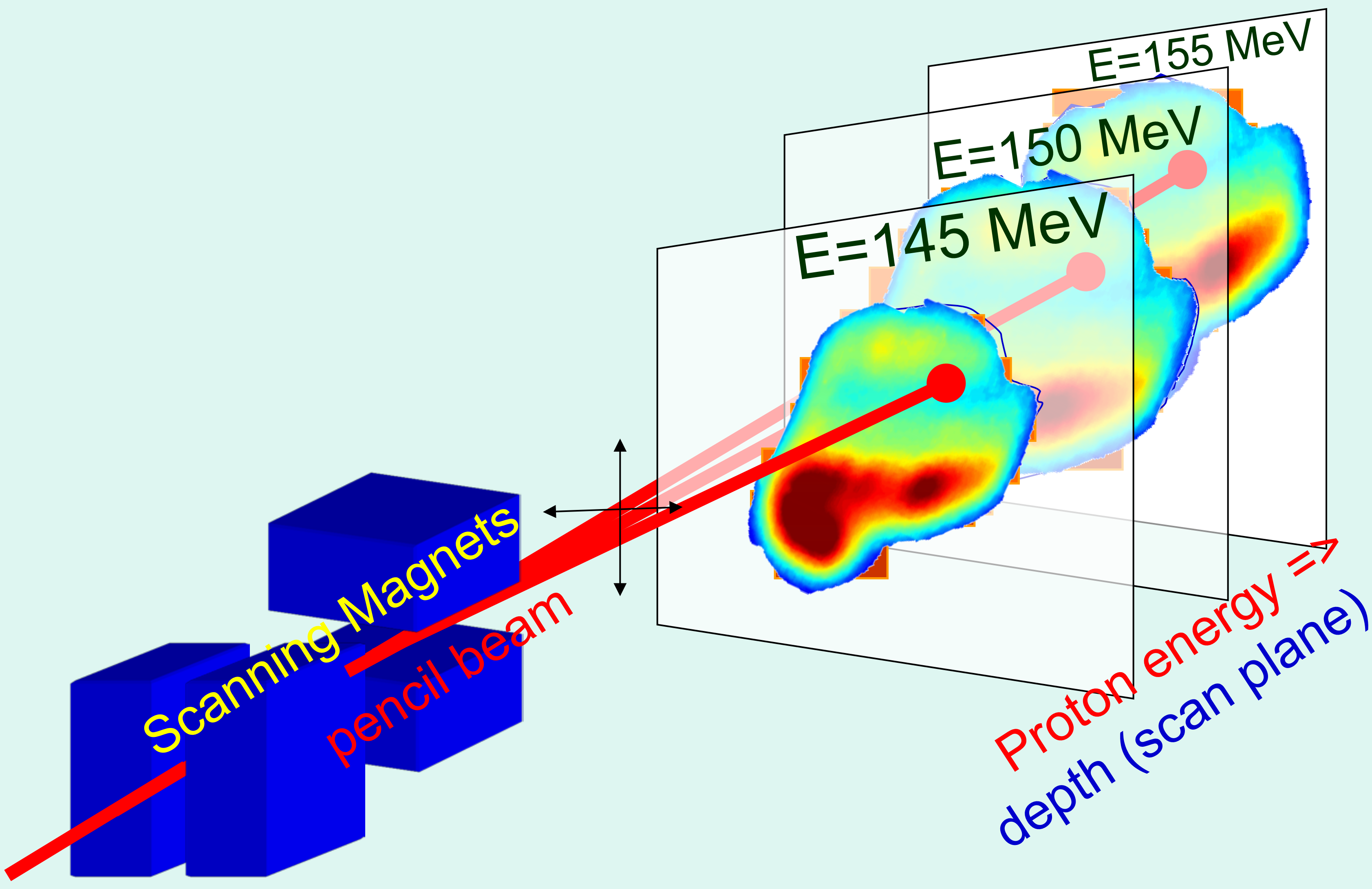


Up-stream scanning:

+ parallel
+ small gantry radius
+ small spots possible
- wide aperture SC magnet

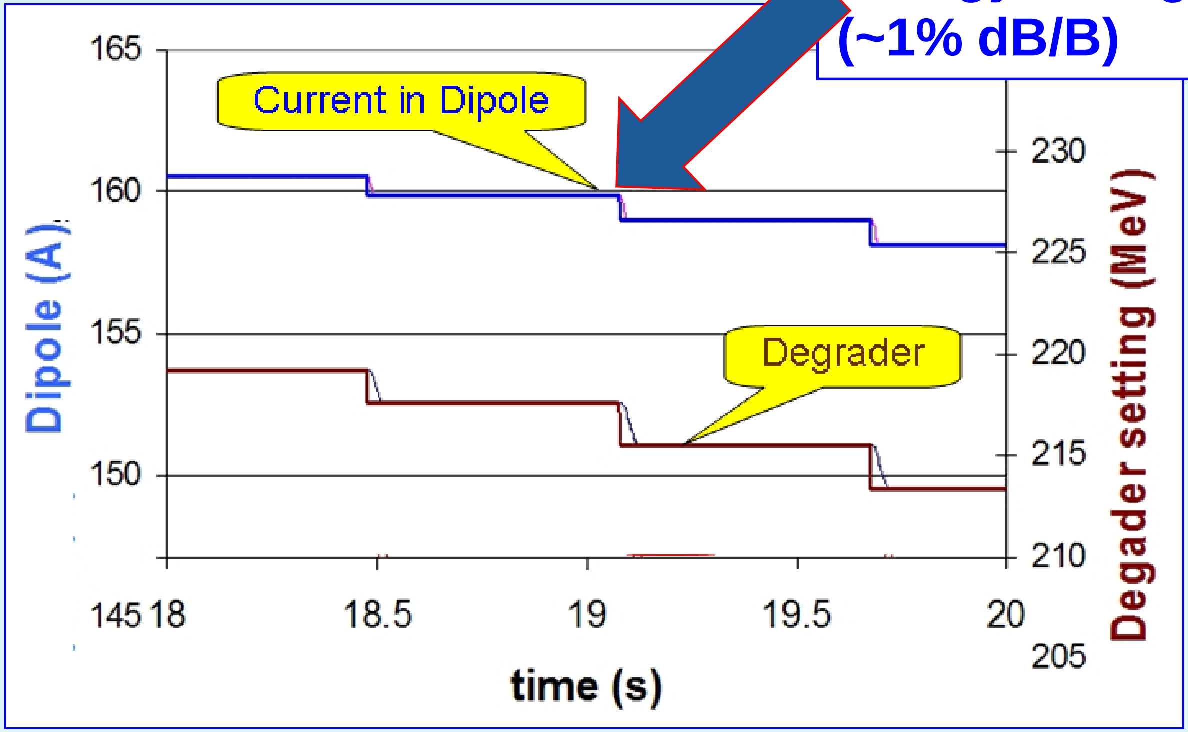


3D Pencil beam scanning: **DEPTH**

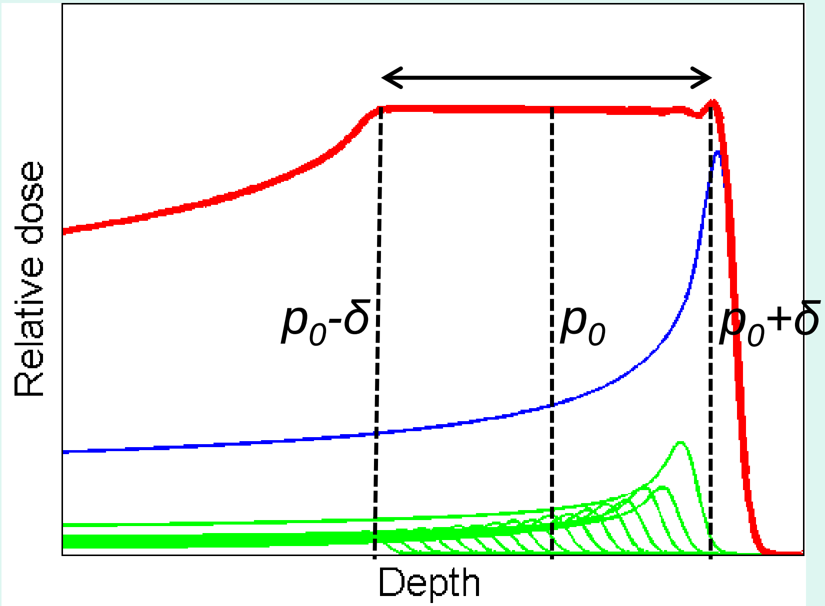


3D Pencil beam scanning: **DEPTH**

After each layer:
Energy change in 100 ms
(~1% dB/B)



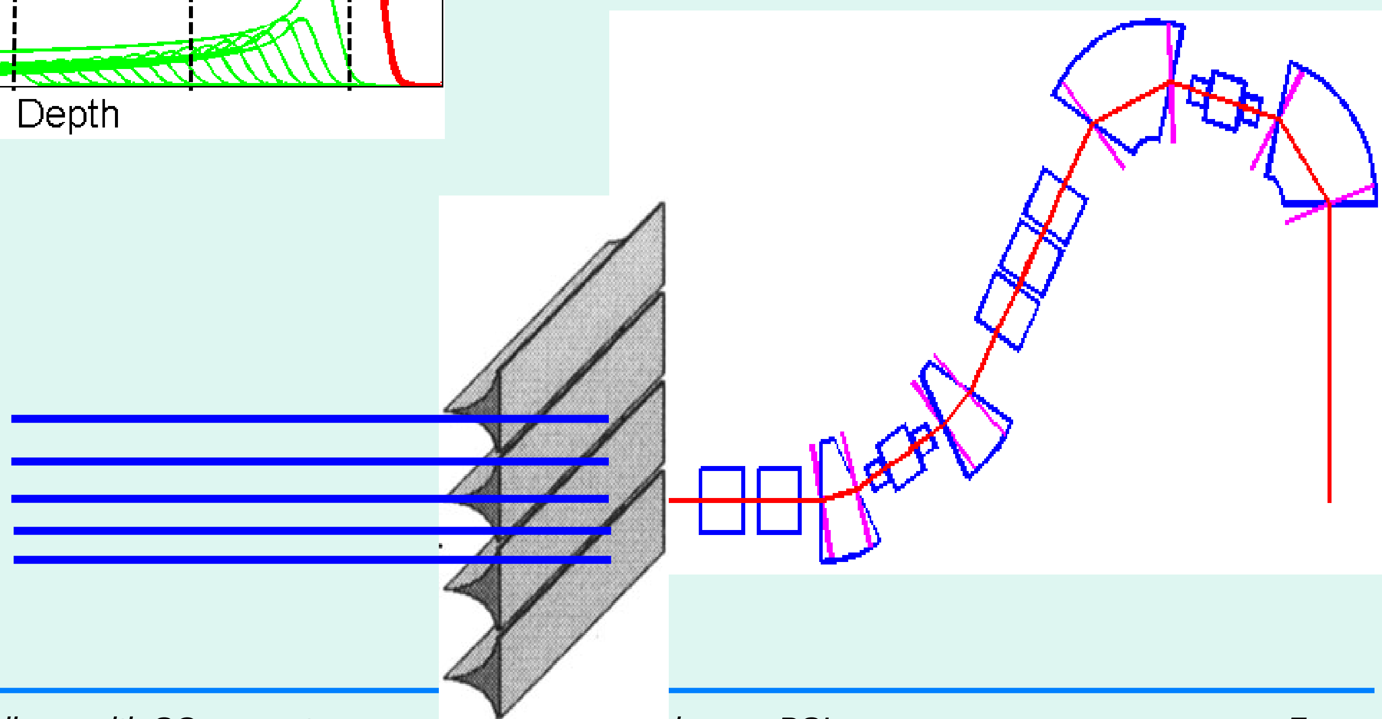
Using large momentum acceptance:



Static Delivery of

Spr.Out Bragg Peak

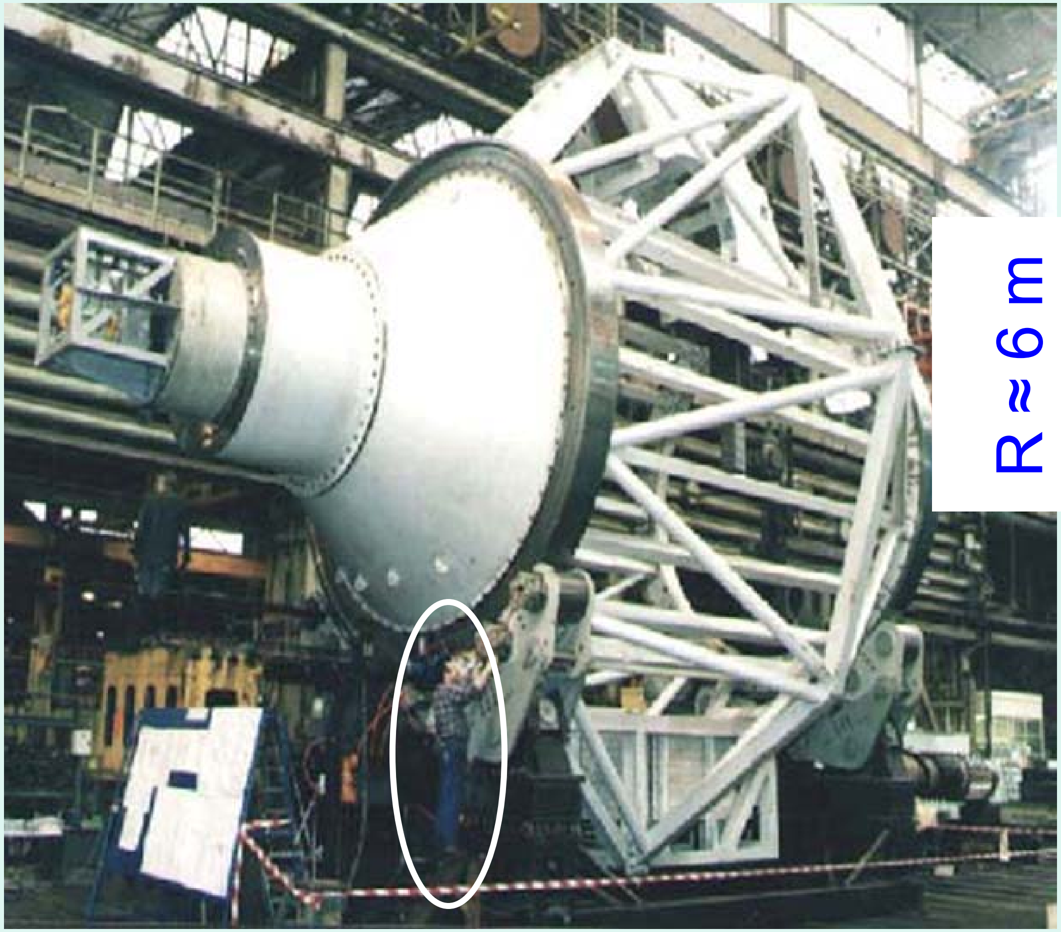
- SOBP can be delivered **without magnetic field changes**



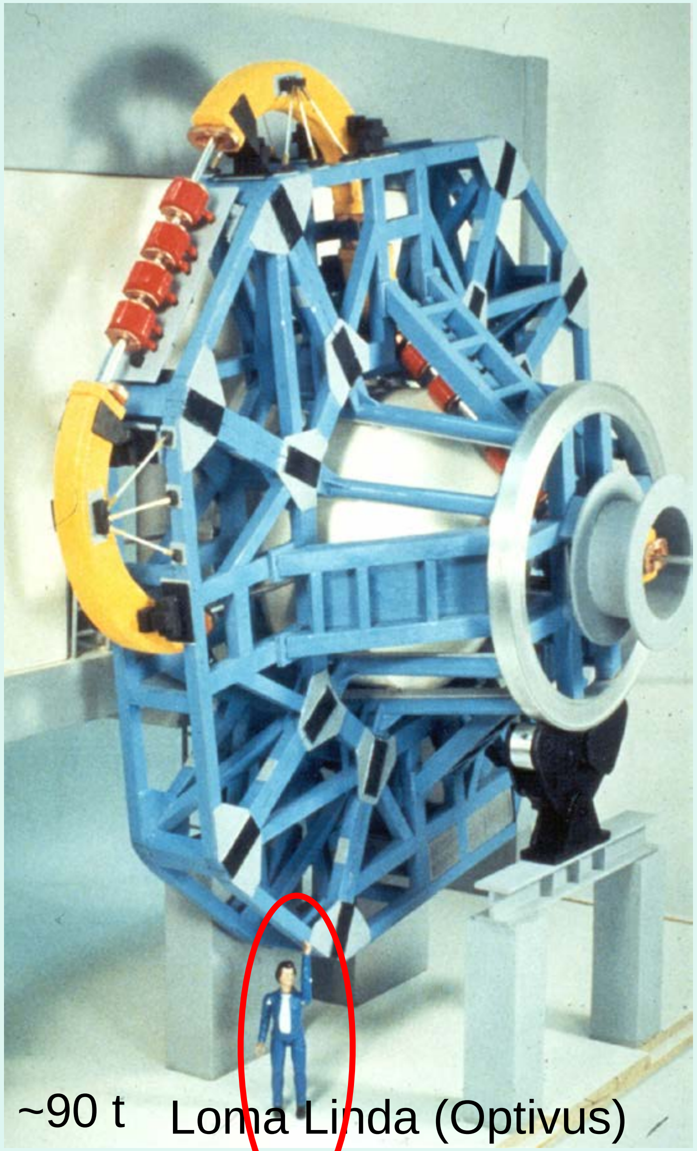
Gantry design

Some typical gantries…..

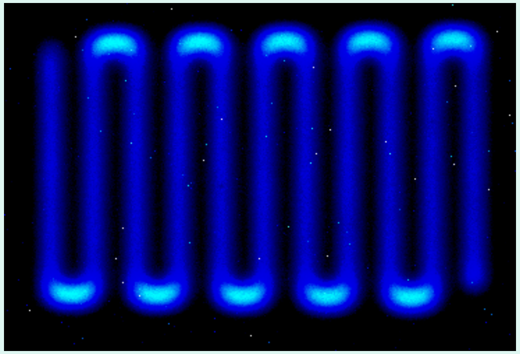
IBA & Optivus Gantry for protons

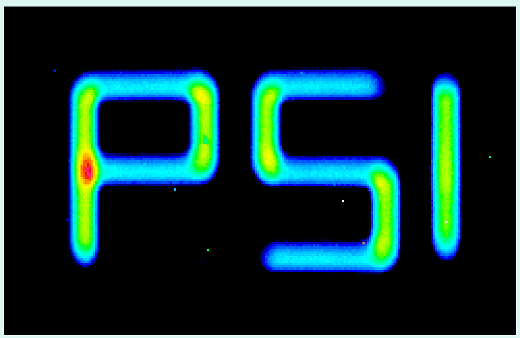


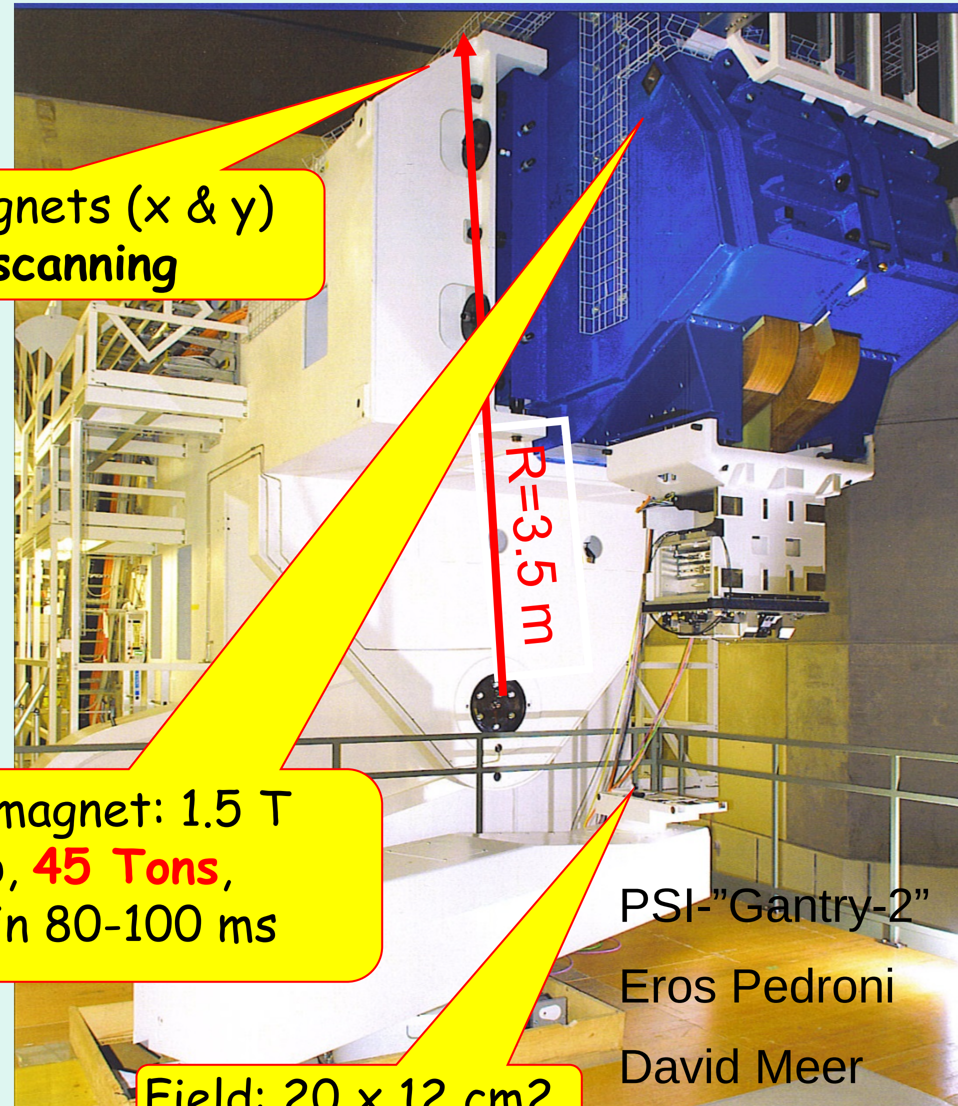
R ≈ 6 m



PSI Gantry-2: fast 3D scanning







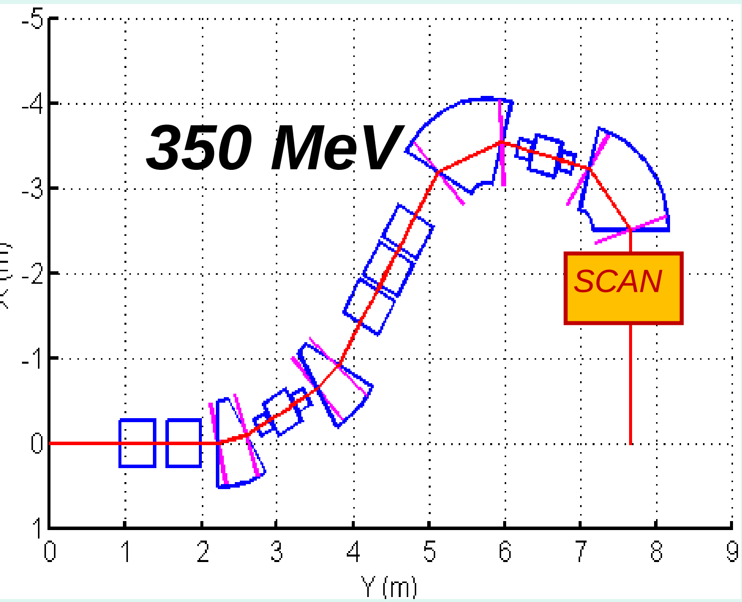
scanning magnets (x & y)
for **2D // scanning**

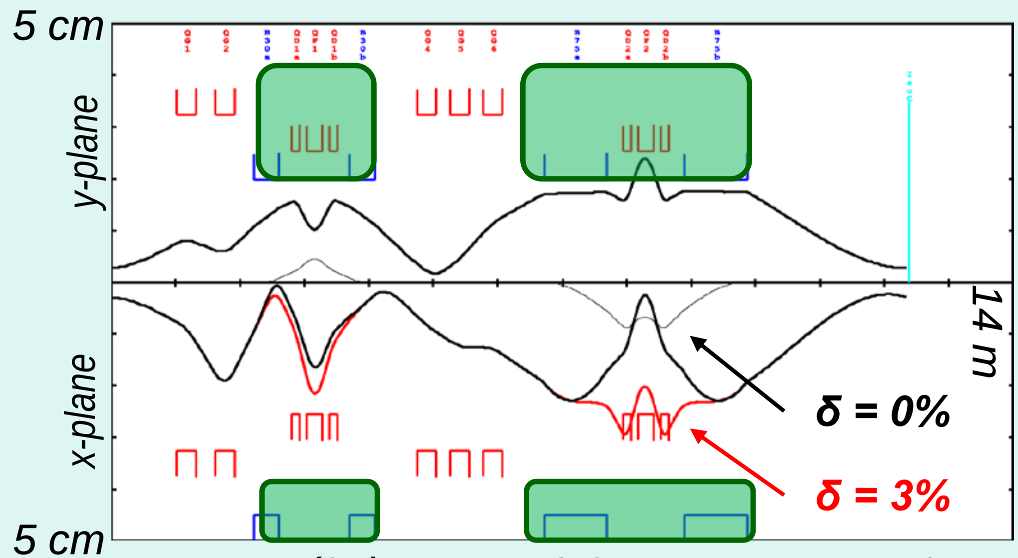
90 degr. magnet: 1.5 T
15 cm gap, **45 Tons**,
dB/B 1% in 80-100 ms

Field: 20 x 12 cm2

PSI-Optics for 350 MeV

originaly from: PRONOVA ***235 MeV***





IN-Beam (2σ): x = y = 3.0 mm , x' = y' = 7.0 mr

PSI optics:

- Point-to-point imaging
- Positive pole face rotations

→ **Large** emittance <u>and</u> momentum **acceptance:**

ε = 21π mm.mrad <u>and</u> **δ = ± 3%**

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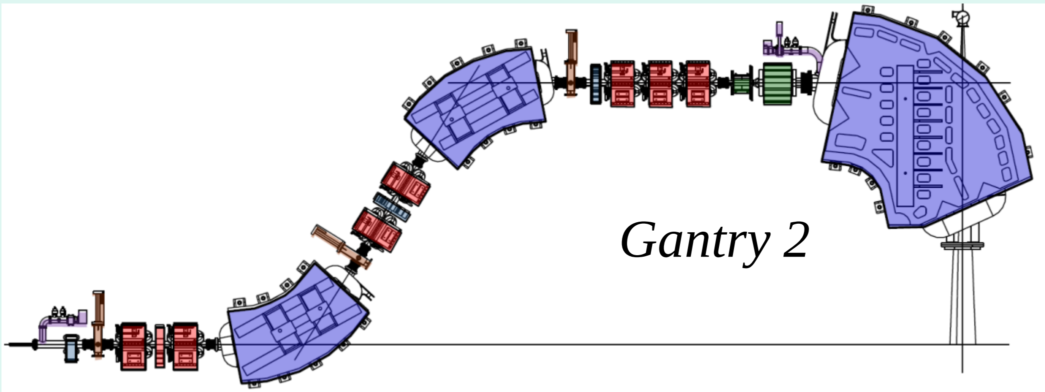
Gantry 2 Layout

Three dipoles with -60°, 60° and 90° bending

Scanning magnets upstream from the 90° bending section: parallel scanning

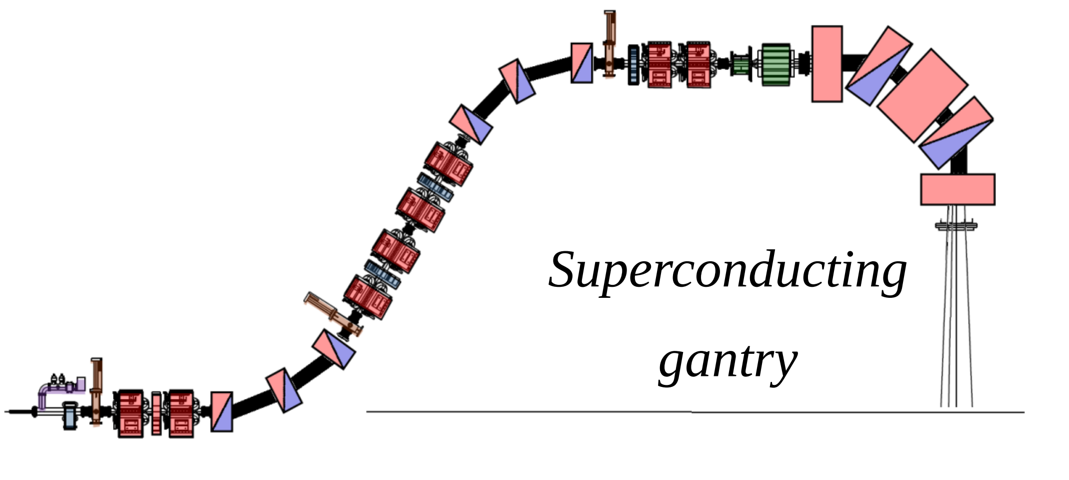


Radius = 3.2 m

Length = 8.9 m

Weight = 200 t

Scanning field: 12 x 20 cm2



Radius = 4.5 m (can be reduced for upstream scanning version)

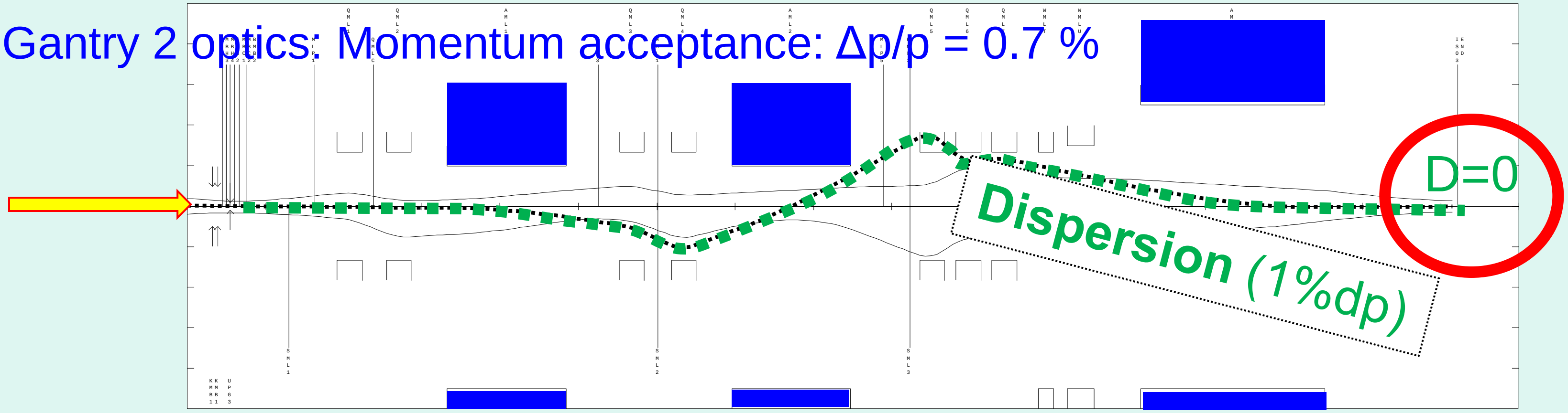
Length = 8.4 m

Weight < 50 t

Scanning field: 20 x 25 cm2

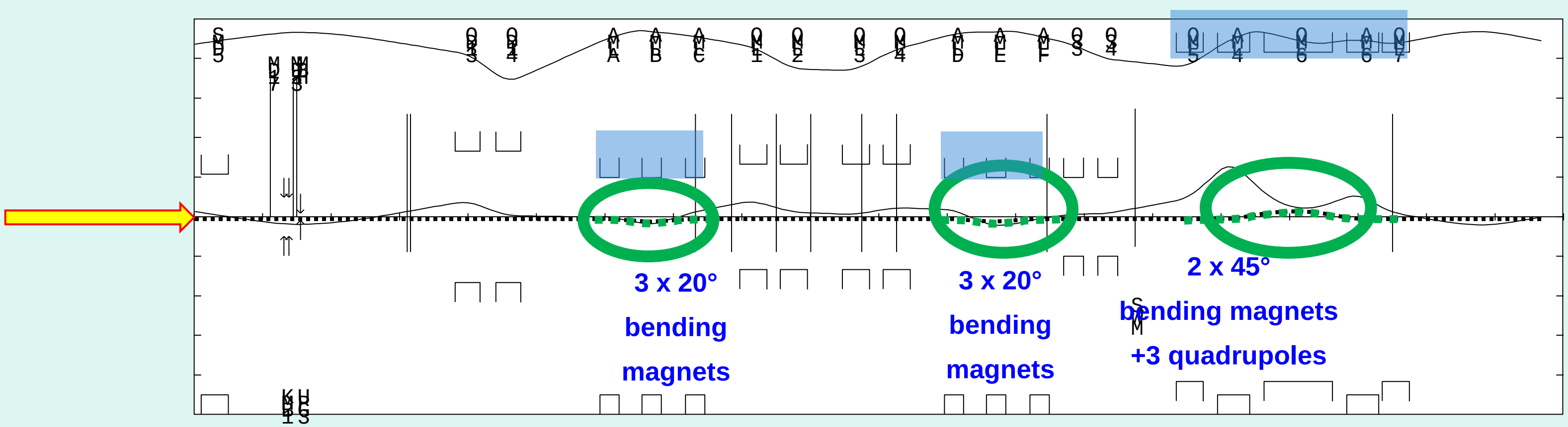
Beam Optic Gantry-2 & SC version

Gantry 2 optics: Momentum acceptance: Δp/p = 0.7 %



SC Bending sections: dipole +combined Q+D : dispersion suppression

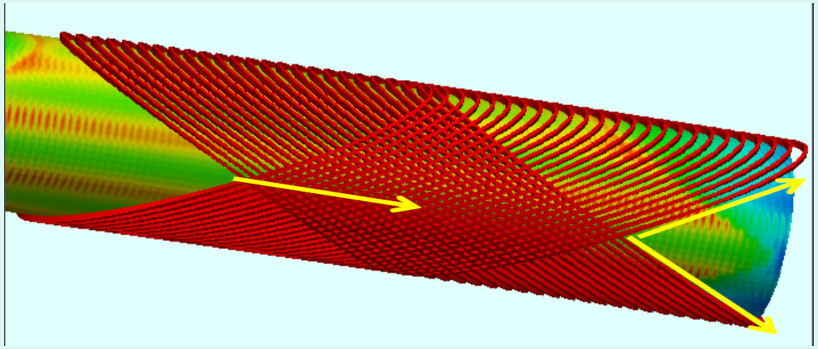
=> Very large momentum acceptance: **Δp/p** > 10 %



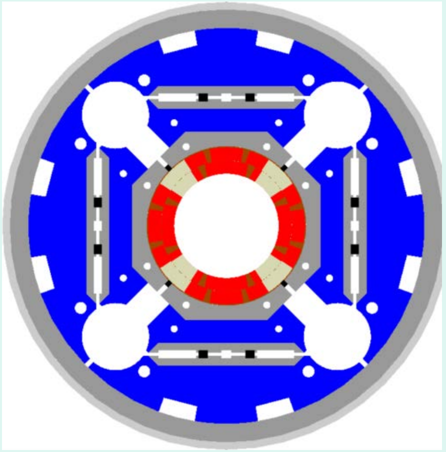
Required magnet properties

Types of used magnets	B-Field (T)	Maximal gradient (T/m)	Aperture radius (mm)
Normal conducting quadrupoles	0	31.7	30
Superconducting combined function magnets for the **first two bending sections**	3	23	30
Superconducting combined function magnet for the **last bending secton**	4	14	125
Superconducting quadrupoles	0	9.8	125

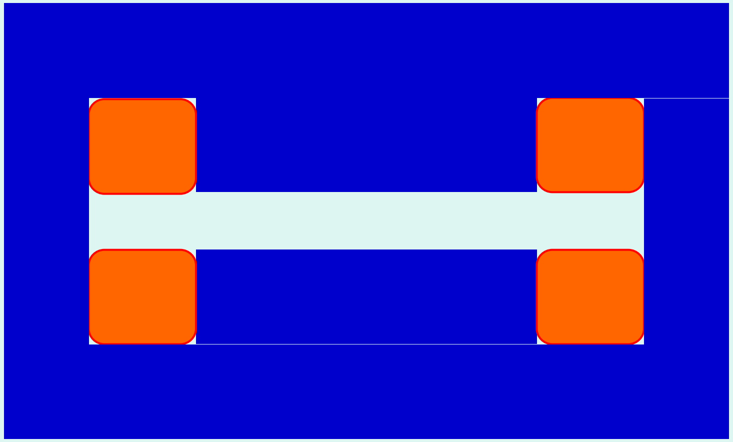
Magnets in consideration



Canted Coil Solenoid



Cosine Theta



Race rack with much less iron

Conclusions on SC-Gantry

SC GANTRY:

Not much smaller in diameter.

Much **less weight**

New beam optics possible → large **energy acceptance**

What do we need ?

Faster: dB/dt > 10%/s (≈ 0.8 T/s)

Lighter: 20 tons

Stronger fields: 4 T + 30 T/m

But „no“ stray fields: <0.5 T but at patient < 0.5 mT

SC: no LHe AND no quenching

Radiation resistant


The End
Thank you
Bild: Luftwaffe Schweiz