Large-aperture polarized target design concept

B. Wojtsekhowski,

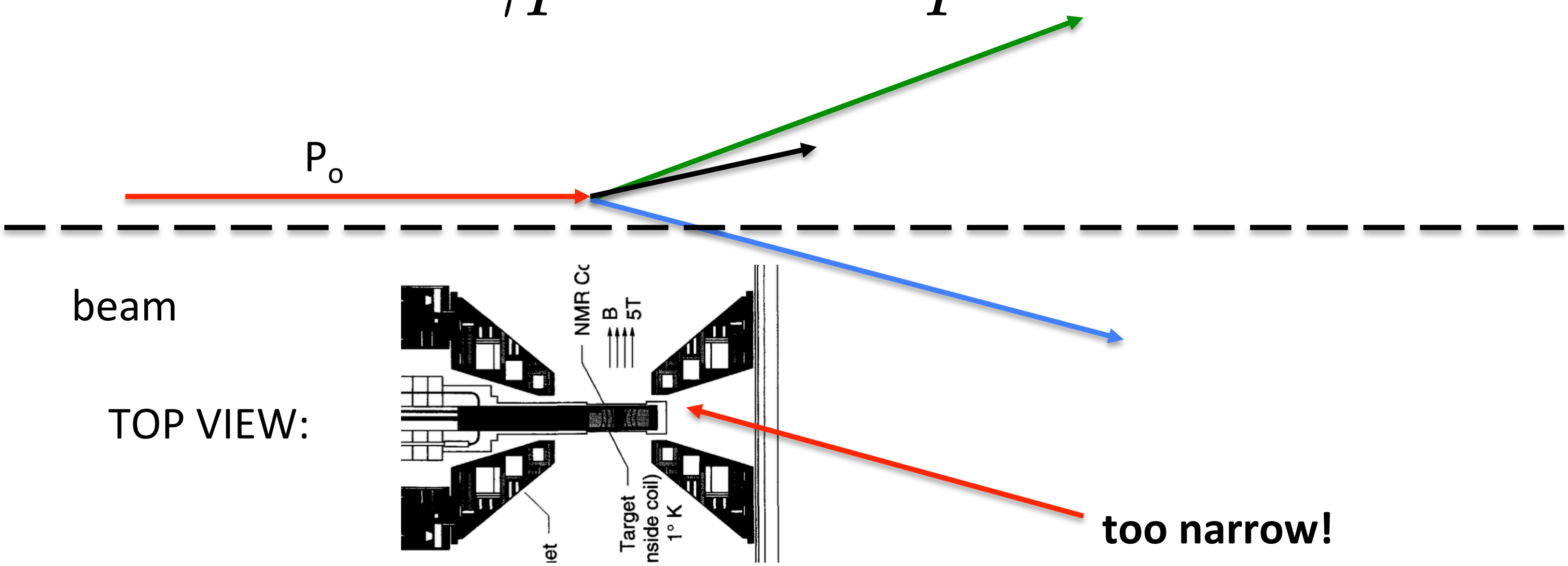
January, 2017

Why does the opening need to be large?

- The current physics interest has moved to Deeply Virtual processes like DVCS and TCS where the products of interest are moving in the forward direction near the beam. At the same time the target needs to be transversely polarized.

- There is also a set of wide angle processes, like D(e,e’d), which also needs a larger acceptance in the direction transverse to the target polarization.

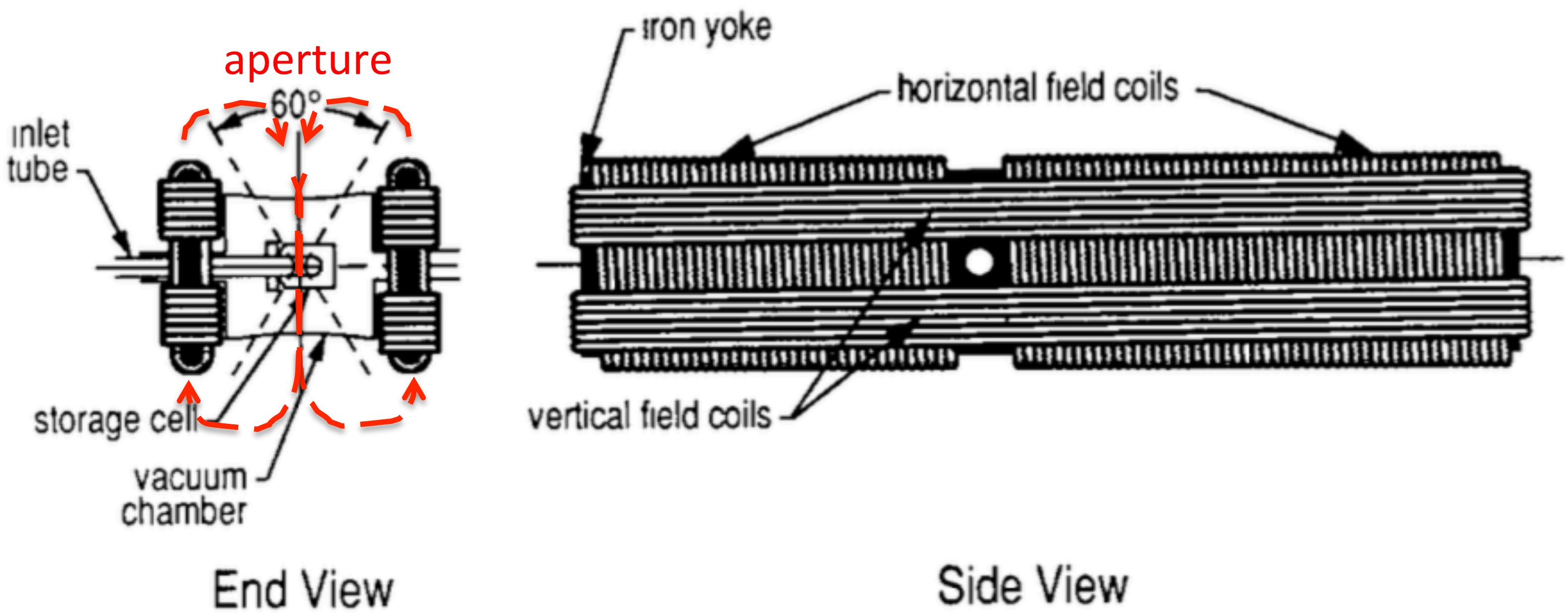
$$\gamma\vec{p} \rightarrow e^{+}e^{-}p$$



Beam induced spin-flip in the atomic target

Polarized targets need a magnetic field whose essential components often block the aperture for produced particles.

A fringe field magnet for a storage cell of a polarized atomic target at electron storage ring VEPP-3, D(e,e'd) or T20 experiment in 1988.



It was used at VEPP-3, AmPS, and SHR/Bates

History of polarized target magnet

Proceedings of the
International Conference on Polarized Targets and Ion Sources
Saclay, France December 5-9, 1966

H.H. ATKINSON,
Rutherford Laboratory,
Chilton
TECHNOLOGY OF HIGH
ENERGY TARGETS

The 12° opening
just
enough for a beam

TECHNOLOGY OF HIGH ENERGY TARGETS

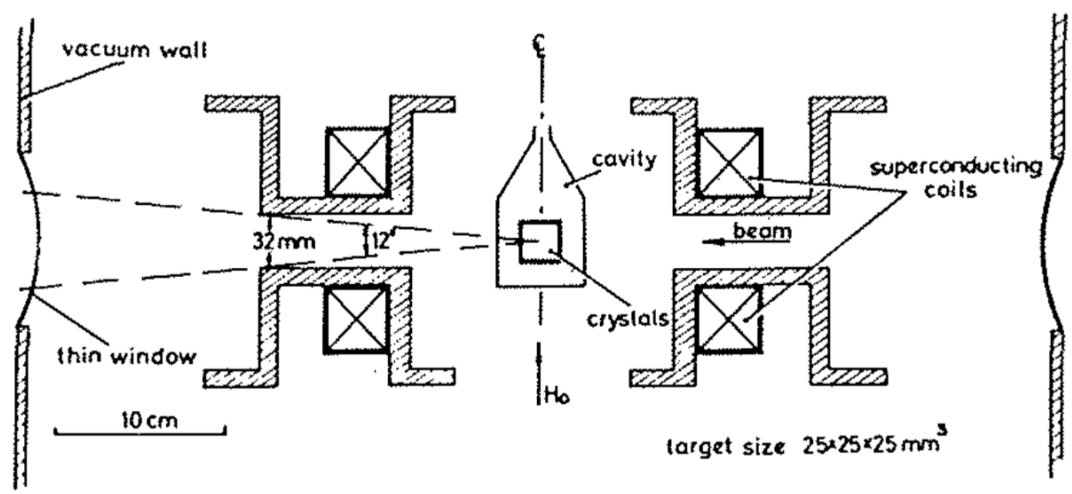


Fig. 9 Superconducting magnet on the Harvard target.

History of polarized target magnet

Proceedings of the
International Conference on Polarized Targets and Ion Sources
Saclay, France December 5-9, 1966

H.H. ATKINSON, Rutherford Laboratory, Chilton
TECHNOLOGY OF HIGH ENERGY TARGETS

"Helmholtz" pair allows
a good opening along
magnetic field but only
a tiny one in
the transverse direction

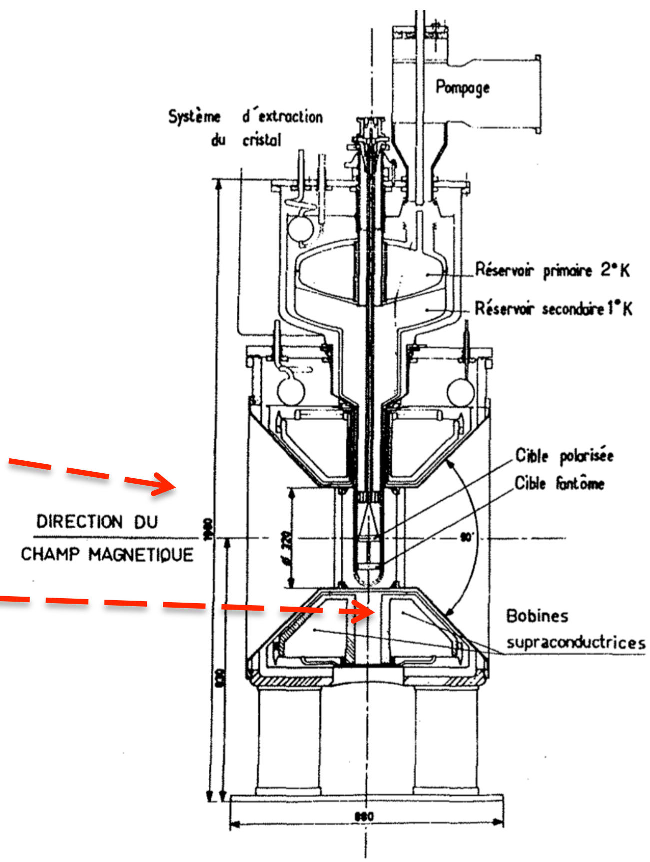


Fig. 10 Superconducting magnet built at Saclay for experiment requiring beam and polarization directions to be parallel.

History of polarized target magnet

HIGH ENERGY PHYSICS WITH POLARIZED BEAMS AND TARGETS
23-27 August 1976, Argonne, IL, USA

POLARIZED TARGET AT ANL by D. Hill

Ten years later after Atkinson
ANL made a very good Helmholtz
pair which allows
a good opening along
magnetic field but only
a small range of +/- 12^{o} in
the transverse direction

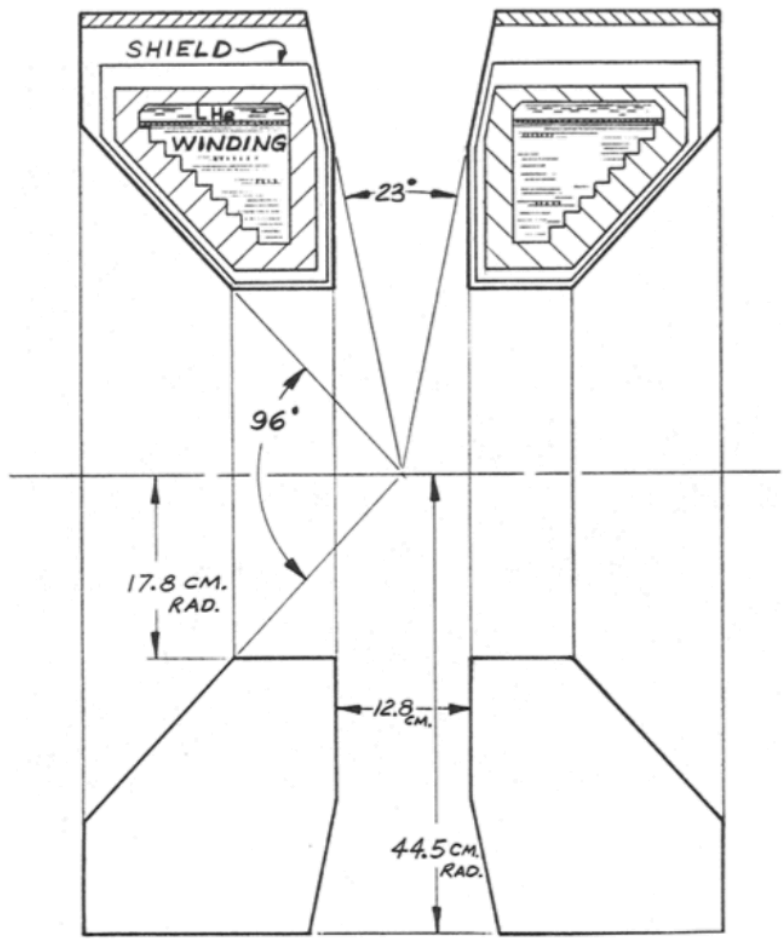


Figure 1

History of polarized target magnet

HIGH ENERGY PHYSICS WITH POLARIZED BEAMS AND TARGETS
23-27 August 1976, Argonne, IL, USA

POLARIZED TARGET AT ANL

D. Figure 18 shows the magnet in side view. The magnet was commissioned in April, 1976, for use in our C_{SS} measurements. Figure 19 shows an overhead view of this set-up. Figure 20 shows the magnet with the horizontal polarized target cryostat. Typically, proton polarization of 85% is achieved in an 8 cm long target. During two month-long running periods the magnet and its power supply have performed very satisfactorily. The measured heat gain to the helium vessel is 2.6 w. Since being welded up, the magnet has not quenched.

I conclude with a brief rundown of the characteristics of the Spin Solenoid. Figure 21 shows this magnet as set up in a beam line. This magnet is a monolithic solenoid with a cold bore of 11.2 cm. The conductor is NbTi. To tip proton spins by 90° at a momentum of 6 GeV/c requires 112.6 kG-m. The operating current is 422 A, the stored energy is 510 kJ, and the central field is 63 kG. The heat gain to the helium vessel is 1.3 w. The Solenoid has been used in several month-long running periods and has never quenched.

History of polarized target magnet

Proceedings of the IInd International Conference on Polarized Targets,
30 August – 2 September, 1971, Berkeley

Super conducting magnets for polarized targets by H. Desportes

60 H. DESPORTES

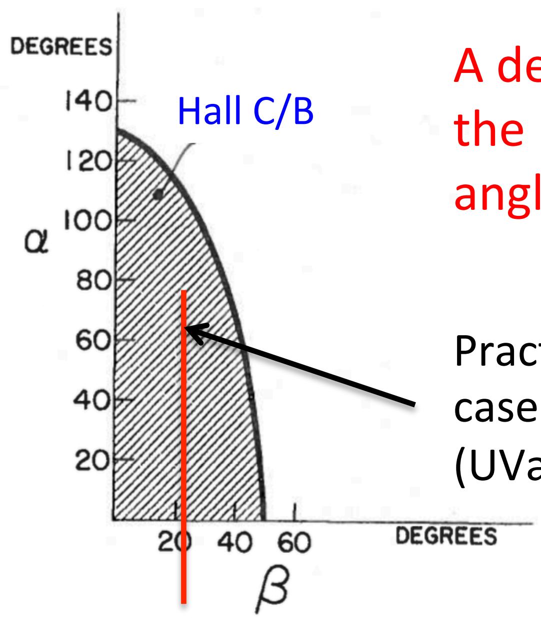
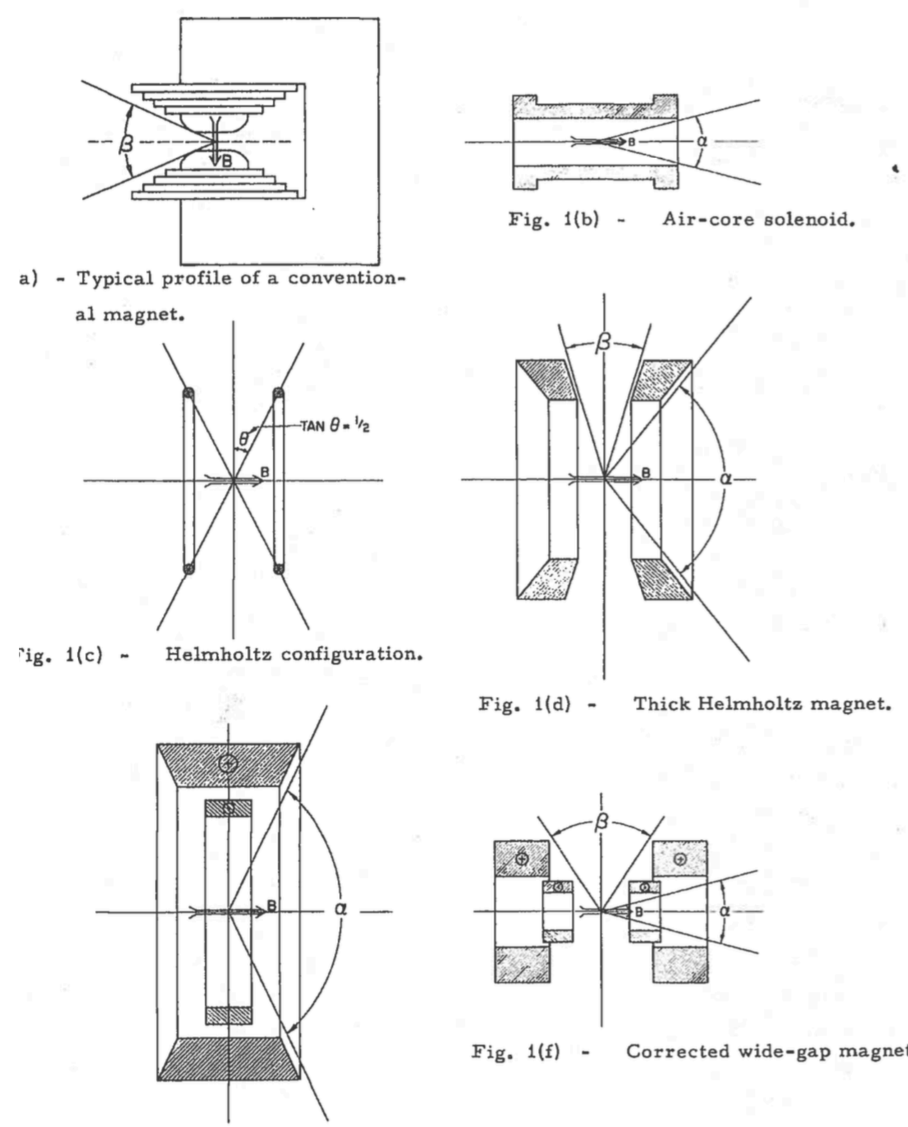


Fig. 2 - Practical feasibility range for α and β.

A detailed analysis of the max possible angles α and β

Practical limit for β in the case of a 5 Tesla field (UVa target)

SUPERCONDUCTING MAGNETS FOR POLARIZED TARGETS



a) - Typical profile of a conventional magnet.

Fig. 1(b) - Air-core solenoid.

Fig. 1(c) - Helmholtz configuration.

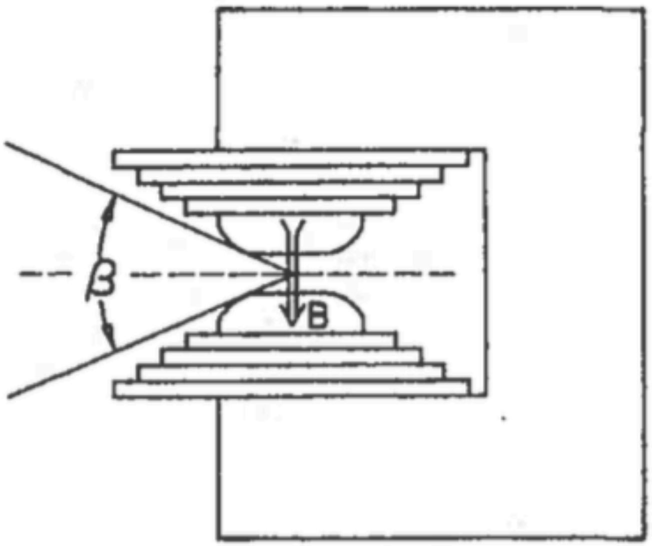
Fig. 1(d) - Thick Helmholtz magnet.

1(e) - Corrected short solenoid.

Fig. 1(f) - Corrected wide-gap magnet

History of polarized target magnet

SUPERCONDUCTING MAGNETS FOR POLARIZED TARGETS



a) - Typical profile of a conventional magnet.

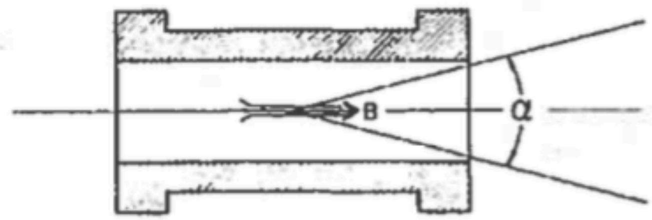
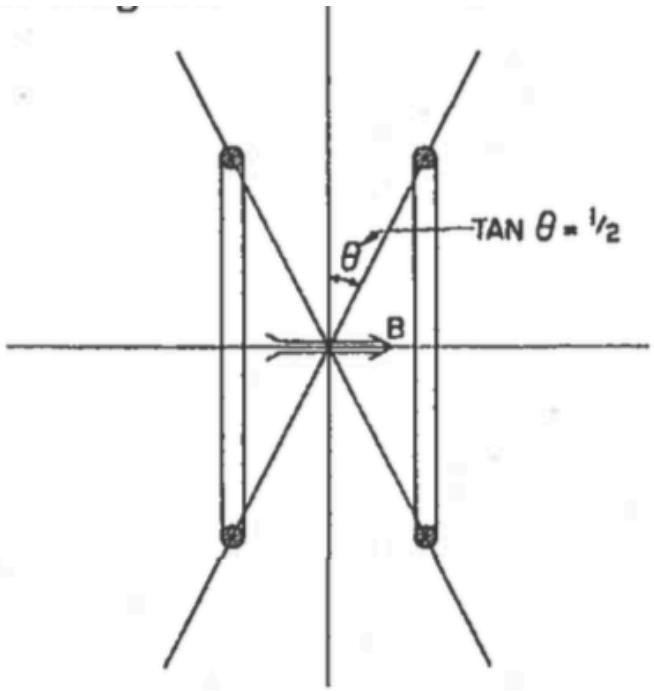


Fig. 1(b) - Air-core solenoid.

History of polarized target magnet



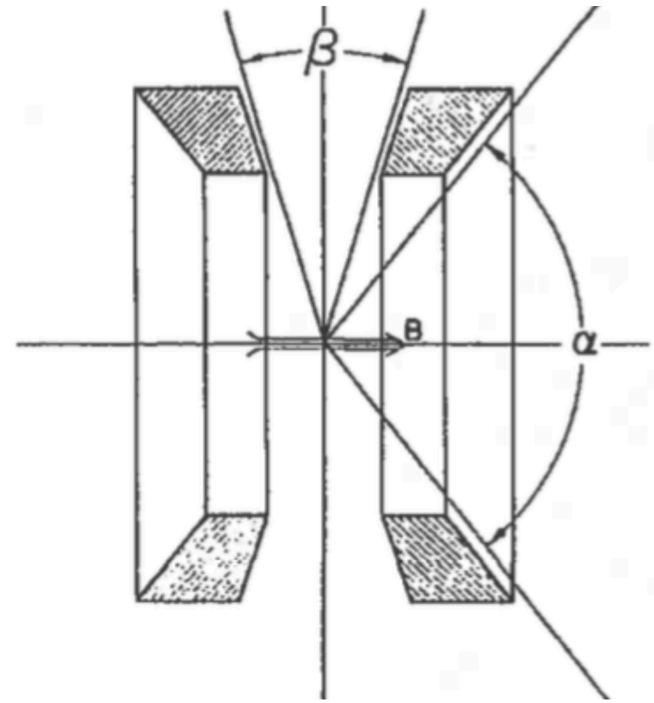
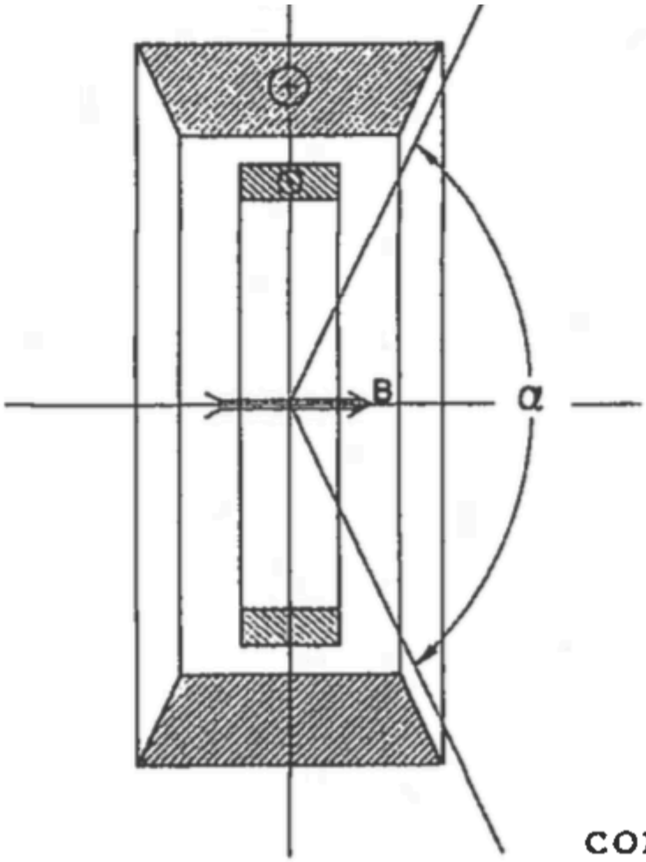


Fig. 1(c) - Helmholtz configura tion coils. The apertures obtained in this case depend on the size and shape of the coils including their mechanical structure, but correspond naturally to a large ratio between α and B, with β practically limited to 25° and α to 100°.

History of polarized target magnet



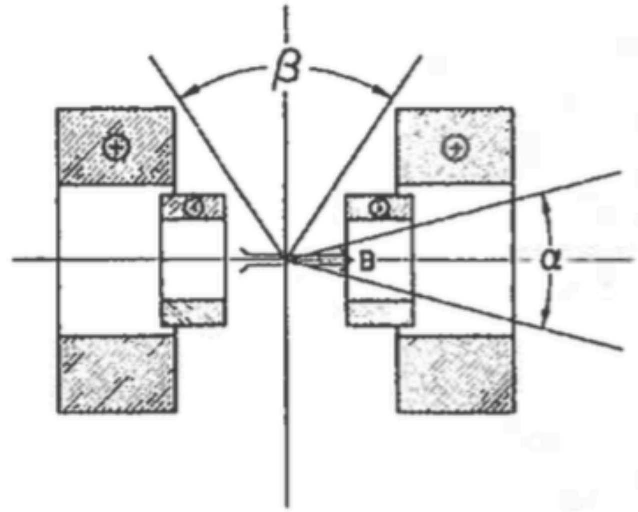


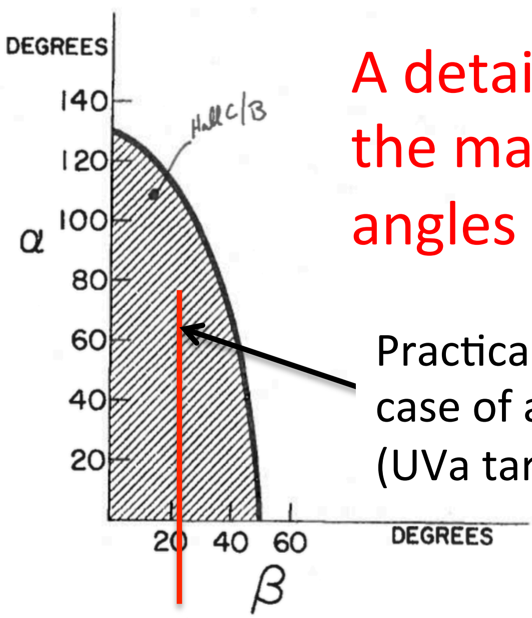
Fig. 1(f) - Corrected wide-gap magnet.

configuration shown on Figure 1(e), while β can be increased by increasing the gap and by using a pair of correction coils as shown on Figure 1(f).

History of polarized target magnet

Proceedings of the IInd International Conference on Polarized Targets, 30 August – 2 September, 1971, Berkeley

H. Desportes, Super conducting magnets for polarized targets



A detailed analysis of the max possible angles α and β

Practical limit for β in the case of a 5 Tesla field (UVa target)

Fig. 2 - Practical feasibility range for α and β.

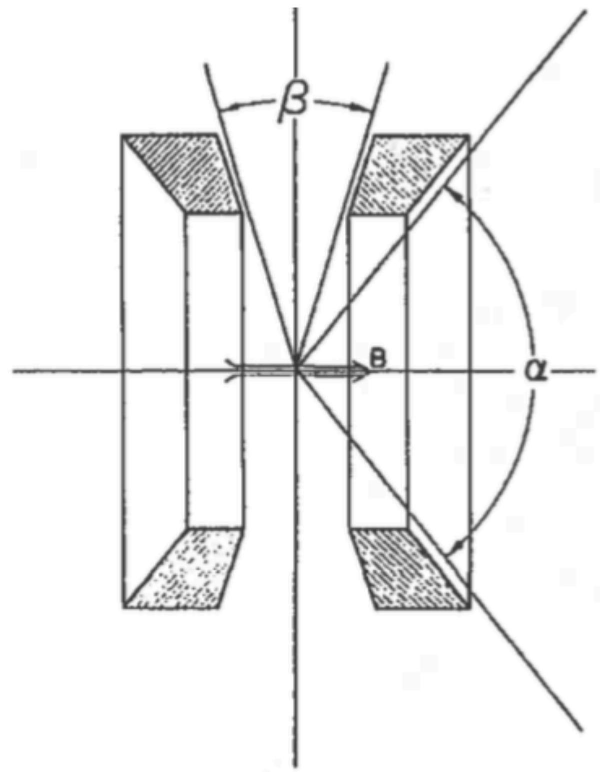


Fig. 1(d) - Thick Helmholtz magnet.

History of polarized target magnet

Proceedings of the IInd International Conference on Polarized Targets, 30 August – 2 September, 1971, Berkeley

H. Desportes, Super conducting magnets for polarized targets

60 H. DESPORTES

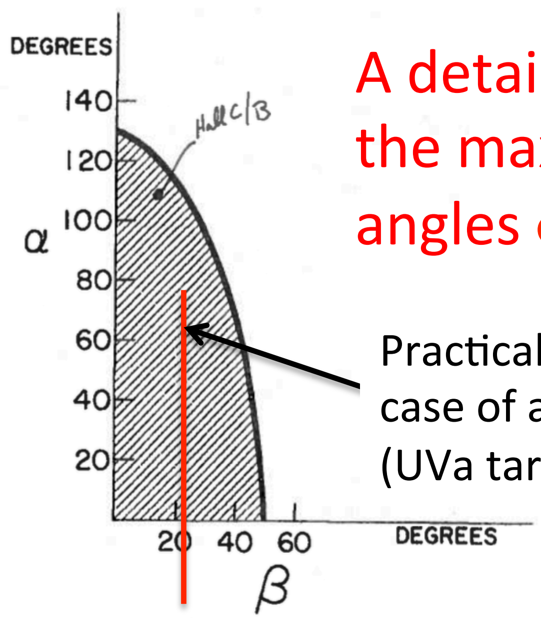


Fig. 2 - Practical feasibility range for α and β.

A detailed analysis of the max possible angles α and β

Practical limit for β in the case of a 5 Tesla field (UVa target)

It can be easily observed that, whilst very large α's are quite easy to obtain with air-core magnets, large β's are the most difficult to achieve and lead to more complex and less efficient systems. A practical upper limit of β for a field of 25 kGauss would be of the order of 45°. The diagram shown on Figure 2 summarizes roughly the range of feasibility of these two angles α and β.

History of polarized target magnet

HIGH ENERGY PHYSICS WITH POLARIZED BEAMS AND TARGETS
23-27 August 1976, Argonne, IL, USA

B. Sandler presented the ANL experiment:

It worked well for the particles detected in the directions close to the field orientation.
However, the forward angle range is very limited.

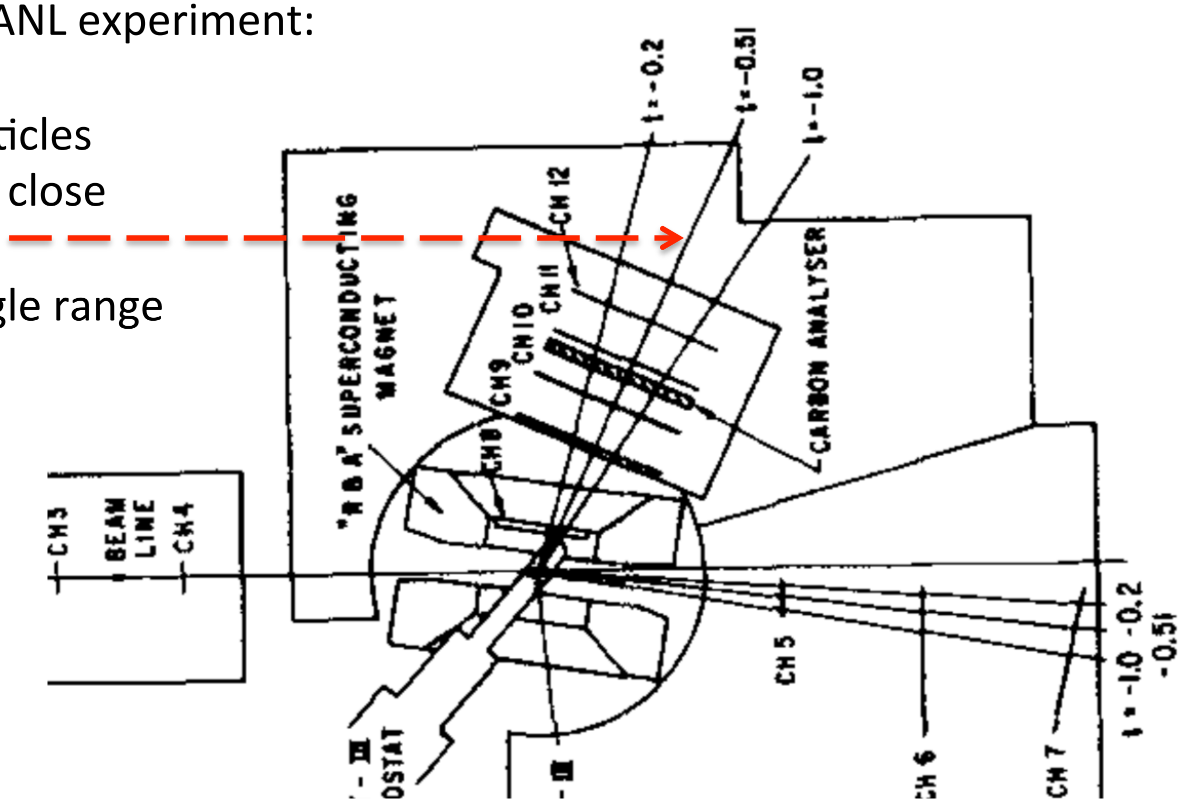


Figure 4

History of polarized target magnet

The Virginia/Basel/SLAC polarized target: operation and performance during experiment El43 at SLAC , by D.G. Crabb *, D.B. Day, NIM A 356 (1995)

Twenty years later

Practically the same geometry of the coils: +/- 13° opening in transverse direction

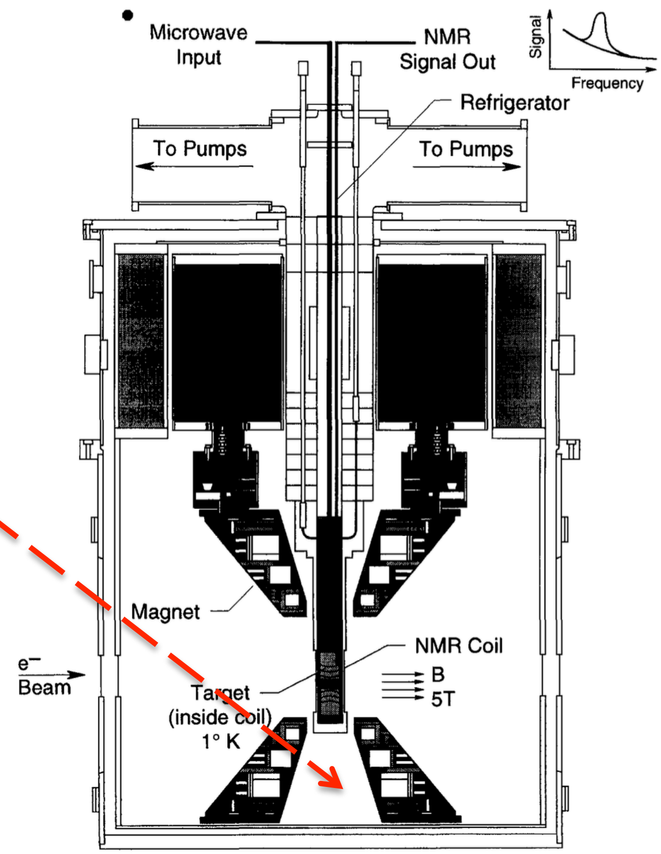


Fig. 1. Schematic of the E143 polarized target.

Why does the opening need to be large?

- The current physics interest has moved to Deeply Virtual processes like DVCS and TCS where the products of interest are moving in the forward direction near the beam. At the same time the polarized target needs to be transversely polarized.

- There is also a set of wide angle processes, like D(e,e’d), which also needs a larger acceptance in the direction transverse to the target polarization.

It is interesting to note that many modifications were made for the “frozen spin” targets where a low value of 0.5 T field is sufficient and luminosity is for a 10^7 gamma/s photon beam.

However, HIGH LUMINOSITY requires a 5 T field. At such a high field a thin correction coil is not easy to realize.

Why is the opening so small?

1. Helmholtz opening is given to be ~53 deg.

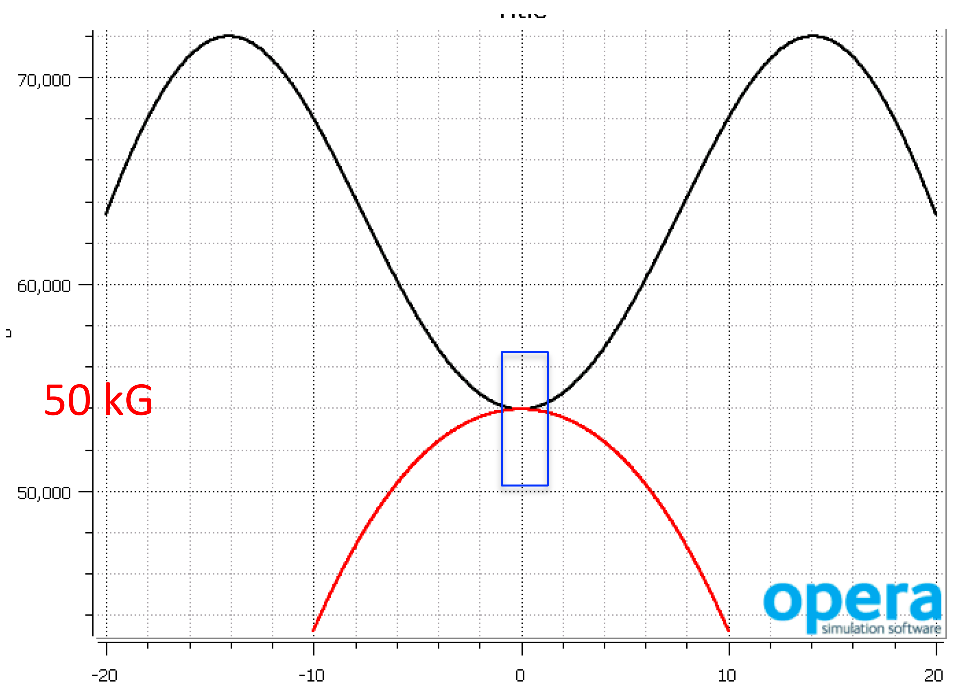
2. Field is 5 Tesla => strong mechanics and SC coils.

3. Resulting opening is just 26 deg.

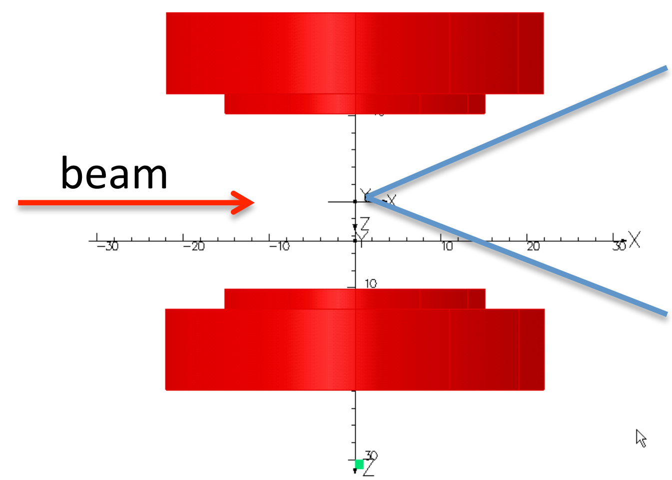
We have to open the gap!

Yes, the field would be bad!
Let us look at it and correct.

What are the field properties?



Double gap (+ 10 cm)!
Opening is 50 deg.
~ 2 * 21*tan((5+4.8)/21)

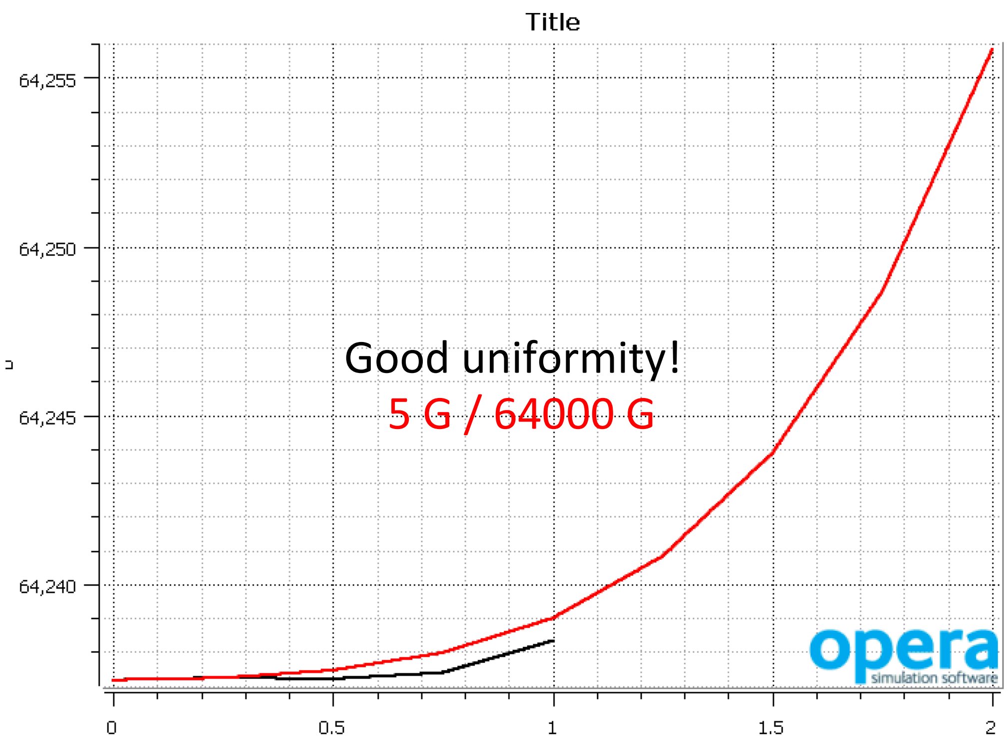


Red is Bz along the beam direction
Black is Bz along the axis of a solenoid

We double the gap and double the coil length

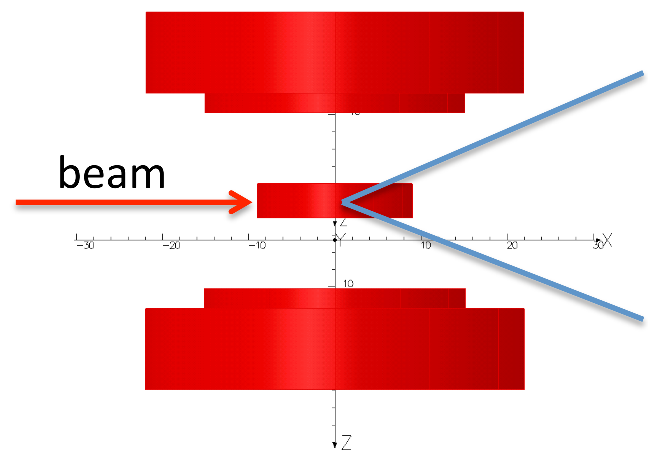
Variations are of 200 G over +/- 1 cm target size
4×10^{-3} non-uniformity

Central correcting coil



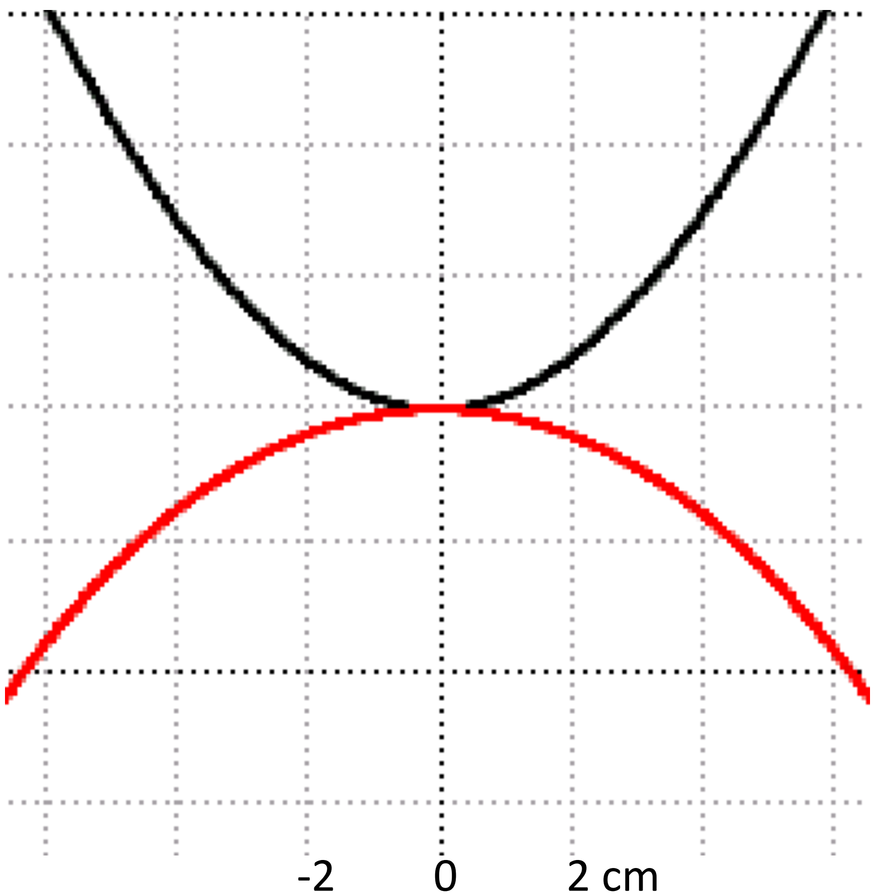
Red is Bz along the beam direction
Black is Bz along the axis of a solenoid

Double gap (+ 10 cm)!
Opening is 50 deg.
~ 2 * 21*tan((5+4.8)/21)



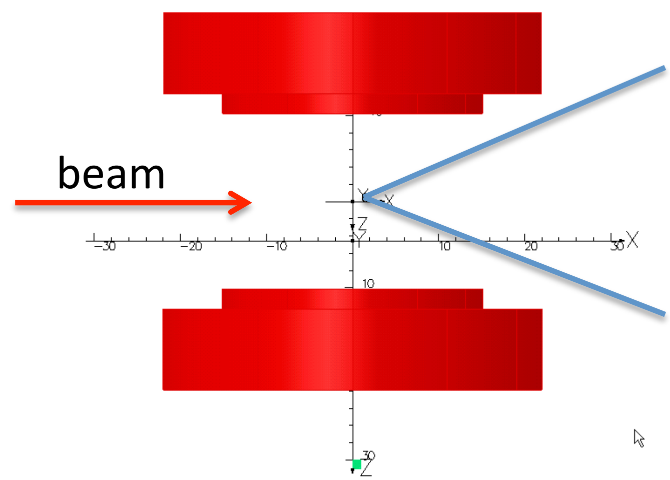
Correction solenoid is in the middle is blocking the aperture!

What are the field properties?



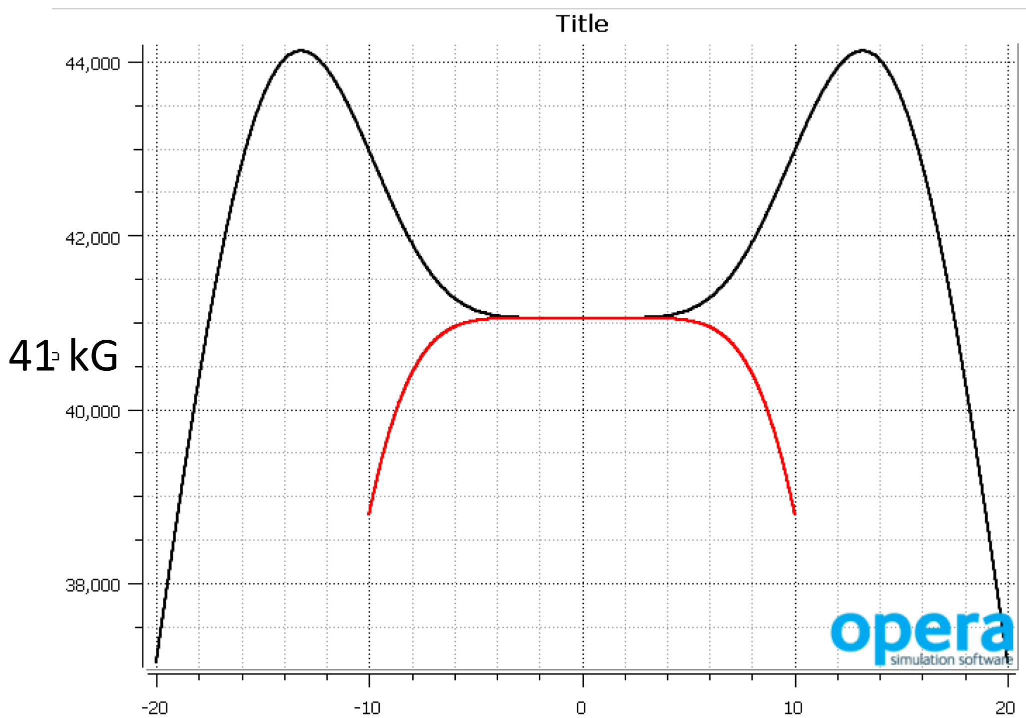
Let us add a correction field in
the opposite direction at z = +/- 2 cm

Double gap (+ 10 cm)!
Opening is 50 deg.
~ 2 * 21*tan((5+4.8)/21)



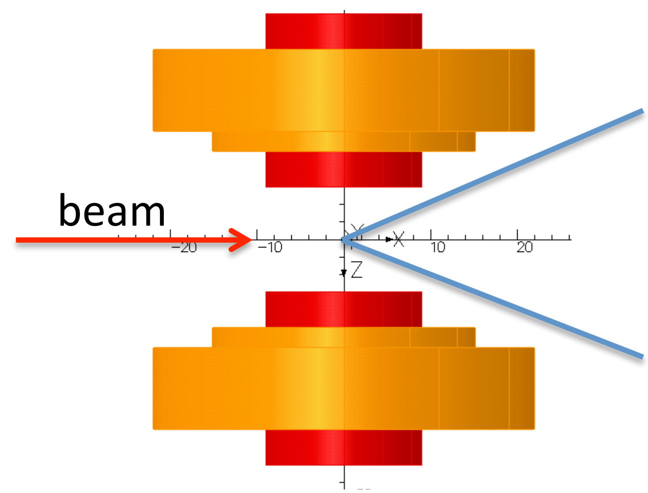
We double the gap and
double the coil length

Obtained solution



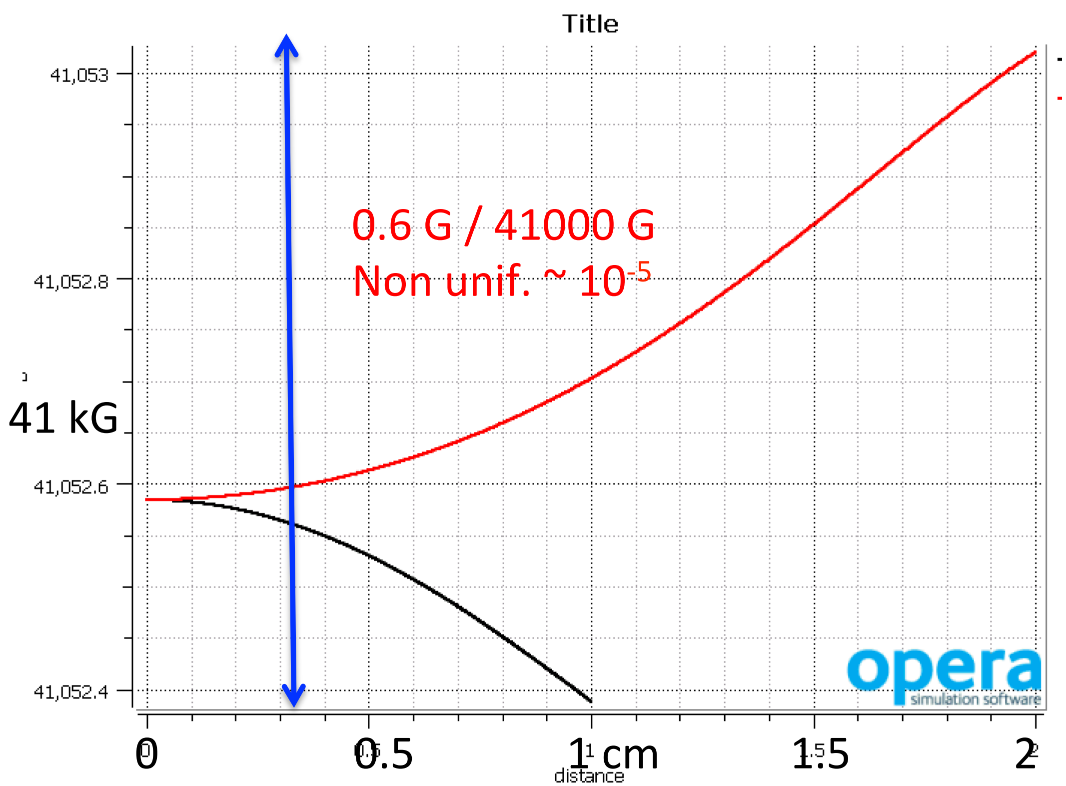
Red is Bz along the beam direction
Black is Bz along the axis of a solenoid

Double gap (+ 10 cm)!
Opening is 50 deg.
~ 2 * 21*tan((5+4.8)/21)



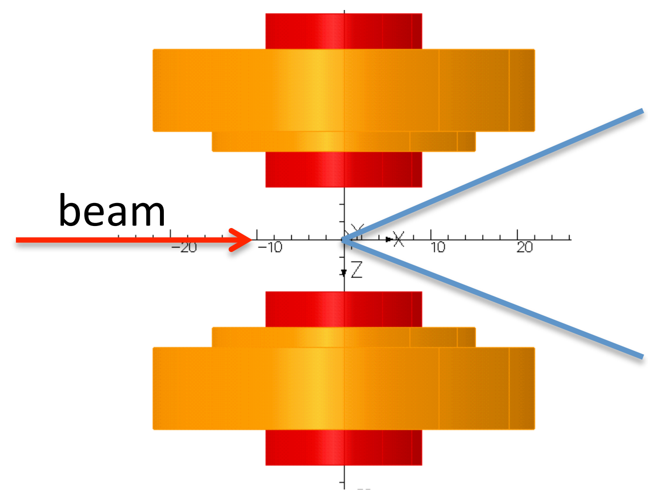
Correction solenoids are outside of the aperture

What are the field properties?



Red is Bz along the beam direction
Black is Bz along the axis of a solenoid

Double gap (+ 10 cm)!
Opening is 50 deg.
~ 2 * 21*tan((5+4.8)/21)



Correction solenoids are outside the aperture

Summary

- The concept of a magnet with a 50 deg. opening (double the existing) is ready for design stage.
- Other options (with even a 60 deg. opening!) are already modeled.