# Effect of magnetic field on PMT

• All photomultiplier tubes (PMTs) are sensitive to external magnetic field and their characteristics change under the influence of magnetic fields. So creation of effective magnetic shields for their protection is very important.

• The effect of magnetic field (whose strength > 0.1 Gauss) on the performance of a PMT is twofold:

- The trajectories of photoelectrons are effected such that the collection efficiency at the first dynode is a function of the orientation of the PMT relative to the magnetic field
- The trajectories of secondary electrons in the dynode chain are effected such as to increase fluctuation in the PMT gain

• Note, even the Earth's relatively weak magnetic field, which typical value ~0.5 Gauss, has a notable effect and for the good performance required shielding.

• The impact on the performance depends on the PMT diameter, its internal dynode structure, and on the PMT orientation in the field:

- The effect of the field on the PMT performance increases with the PMT diameter
- The axial component of the field (field along the PMT axis) have highest impact

# PMT magnetic shield

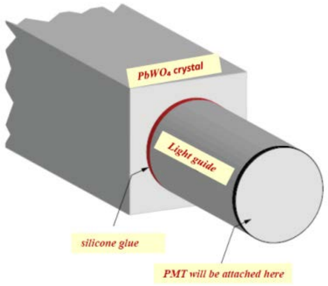
• For the weak magnetic fields (with strength below 10-20 Gauss) these effects are not large, so the classic technique of shielding a PMT with a cylinder made from μ-metal

• For the fields above ~30-50 Gauss in addition to μ-metal, soft iron shield must be used. (As an example, μ-metal and an additional ~2mm thick soft iron shield are used in Gluex Forward Electromagnetic Calorimeter to neutralize up to 200 Gauss fringe field).

• For better effect, this shielding needs to extend beyond the photocathode by at least the diameter of PMT or more (or ~3cm for the phototubes R4125 proposed in NPS).

• Therefore, if field strength is too high the PMT with diameter 2 cm can not be coupled directly to the block 2cm × 2cm, and an additional light guide is required:

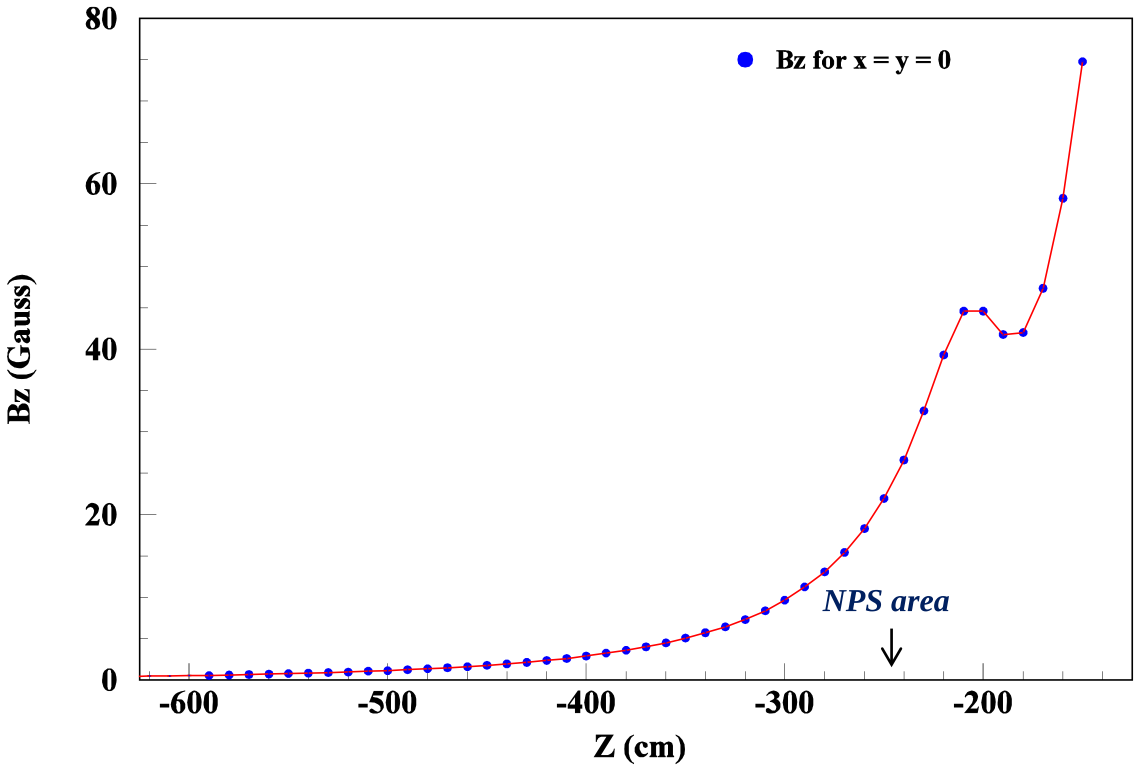
- for the NPS we will need light guide (Ø=2 cm) between the R4125 PMT and $PbWO_4$
- we will need crystals with dimensions ~$2.5\times2.5$ $cm^2$.
- the light guide will be glued to a crystal, and
- the PMT will be glued (or coupled with grease) to light guide
- need more manpower and finances, make worse resolution




• Other solutions for the PMTs operating at high magnetic field  (without light guide):

- use μ-metal shield around PMT and surround the entire detector with soft iron
- use the compensating (backing) coils around the detector to cancel field effect.

# Bz component of magnetic field in the NPS area




*Data taken from Bogdan's field map*

- The coordinate system is aligned to the sweep magnet center (157 cm from the target)
- Target at +157 cm upstream from the magnet center
- NPS detector will be at ~400 cm from the target or at -250 cm from the magnet center
- Strength of the fringe field in the area of NPS is expected ~20-25 Gauss for the 0.3 Tm regime (or ~50 Gauss for the 0.6 Tm)

# NPS magnetic shield and proposed tests

• Cost effective and more simple solution for NPS would be to couple $PbWO_4$ module directly to the PMT without light guide. Use only a cylinder made from a few layers of μ-metal to shield the PMT (1 mm thick μ-metal shield must be sufficient up to ~50 Gauss)

• Since in the area of NPS strength of fringe field can exceed 50 Gauss (at highest setting of sweep magnet), prior the calorimeter design take into account possibility for surrounding the entire detector or its back side (area of PMTs location) with soft iron .

• To finalize design of individual modules and entire NPS detector, to estimate effects of expected fringe field and efficiency of magnetic shield need to perform following works:

- Assembling of the prototype (from 3×3 crystals) and its LED based gain monitoring system. Activation all electronics and necessary items for tests
- If possible, try to localize SEP for each PMT and optimize their operation HV. (Newer exceed high voltages above 1.3 kV, you may damage PMT or bases).
- Take series of runs to optimize the LED regime for the light intensity ~100 or more (preferable ~200-500) photo-electrons. Check short-term (1-2 hours) and long-term (1-2 days) stability and reproducibility of the data (LED).
- Set Helmholtz coil current for the fields in the range 0.0 – 20 Gauss (if possible, up to 50 Gauss). Define the field direction and field strength (B) versus coil current (I)

• Install prototype in magnetic field. Take data at B=0-20 Gauss (or higher) with step 2-3 Gauss. Do measurements at different orientation of PMTs relative to the field direction