The PEP-N IP Magnet

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A vertical magnetic field is required at the PEP-N Interaction Point (IP) for both separating the LER and VLER bunches before and after collision and to provide at the same time tools for momentum tracking for the Detector equipping the Interaction Region (IR). Design considerations and simulation results are reported in this contribution which reflect the results of studies performed with the aim of matching the often competing requirements from the Accelerator as well as from the Detector side.

1. THE PEP-N INTERACTION REGION

The low energy electron ring VLER is suppose to be installed in the PEP-II long straight IR 12. Three rings will then create the PEP-N environment:

- HER - 8.97 GeV — PEP-II $\mathbf{e}^-$ ring
- LER - 3.12 GeV — PEP-II $\mathbf{e}^+$ ring
- VLER - $0.20 \div 0.50$ (0.80) GeV — New $\mathbf{e}^-$ ring

Given the fixed $\mathbf{e}^+$ energy of the LER and the large energy range desired for the VLER, the PEP-N complex will constitute a very Asymmetric Collider with a CM energy

$$E_{\mathrm{CM}} = 1.58 \div 2.50\,(3.16)\ \mathrm{GeV} \tag{1}$$

and a wide energy ratio

$$r_{\mathrm{E}} = \frac{E_{\mathrm{LER}}}{E_{\mathrm{VLER}}} = 15.6 \div 6.2\,(3.9). \tag{2}$$

The relation (2) suggested the concept, already adopted at PEP-II, of a magnetic separation of the colliding bunches. A vertical magnetic field at the PEP-N IP was then sought as the best solution to eliminate unwanted bunch encounters and to strongly reduce long-range beam-beam effects.

A large central magnetic field with good spacial uniformity is, at the same time, an indispensable ingredient to improve the capabilities of the PEP-N detector.

Obvious difficulties exist to have the small dipole required for beam separation coexisting with the central detector TPC inside a solenoidal field. The solution was then retained of making use of a large IP dipole to contemporarily satisfy both the collider and the detector requirements.

2. REQUIREMENTS AND DESIGN CONCEPTS

The design of the magnetic structure of the PEP-N IP dipole aims at providing high field uniformity in the gap region occupied by the TPC, together with a considerable vertical aperture in the forward direction and a large gap capable of hosting a complex multi-task detector. A uniformity factor along (x) and transversely (y) to the beam direction

$$\eta_{\mathrm{x,y}} = \frac{B_z(\mathrm{x,y})}{B_z(0,0)} \tag{3}$$

is used to compare the performance of different geometries.

Shims on the pole pieces are usually adopted to improve the field uniformity. In our case this would have reduced the gap height available to the detector components. A sort of "anti-shims" approach has been modeled with excavations in the poles [1] which proved successful in considerably improving the uniformity (see Figures 1, 2).

To better exploit the CM boost in providing a longer field region in the forward direction, the dipole magnetic center is located 25 cm downstream the IP in the LER beam direction. A wider gap is then foreseen to maintain the desired forward vertical aperture.

An important ingredient in the design is represented by the operation costs of the magnet. For a given induction $B_{\mathrm{o}} \equiv B_z(0,0)$ and magnet gap g the DC power consumption scales linearly with the current density δ in the coils:

$$P_{\mathrm{DC}} \propto g\, B_{\mathrm{o}} \cdot \delta. \tag{4}$$

The excitation coils of the IP dipole are designed to carry low current densities over the full operation range to contain the exploitation costs within acceptable limits.

3. THE MODELED VERSIONS

Several dipole versions have been conceived and modeled using the TOSCA code [2] to evaluate the field strengths and estimate the uniformity factor (3). Their main characteristics are collected in Table I where the gap, the pole geometry and the forward vertical aperture Φ_{fw} are given.

Field uniformity plots along the beam direction are shown for the region occupied by the TPC (x = ± 0.6 m) in Figures 1 and 2 for the DV.03 and the DV.06 dipoles.

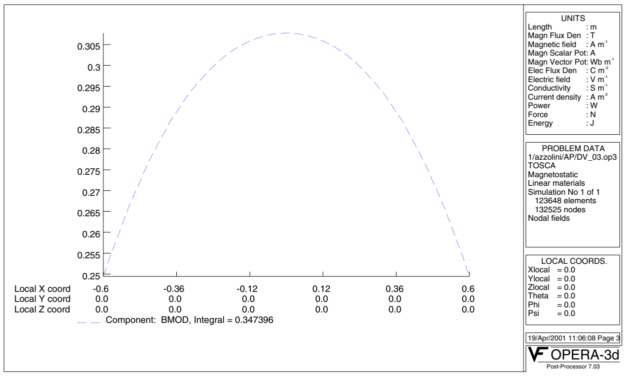

Figure 1: Dipole DV.03: field integral for $x = \pm 0.6$ m at $B_z(0,0) = 0.30$ T. Field uniformity: $\eta_x(\pm 0.6\,\text{m}) = 81.1\%$.

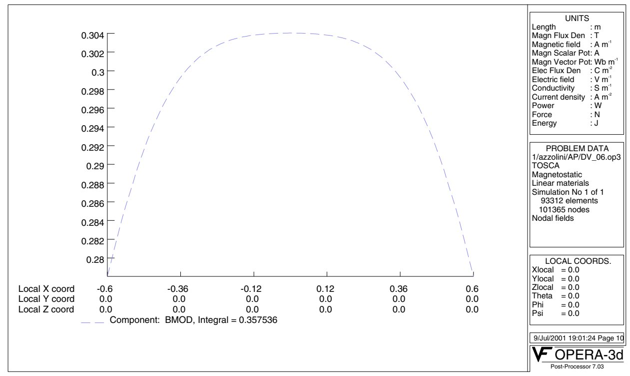

Figure 2: Dipole DV.06: field integral for $x = \pm 0.6$ m at $B_z(0,0) = 0.30$ T. Field uniformity: $\eta_x(\pm 0.6\,\text{m}) = 91.4\%$.

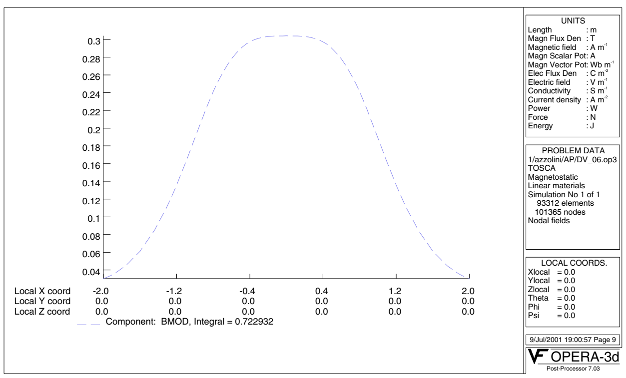

Figure 3: Dipole DV.06: field integral along the beam pipe at $B_z(0,0) = 0.30$ T.

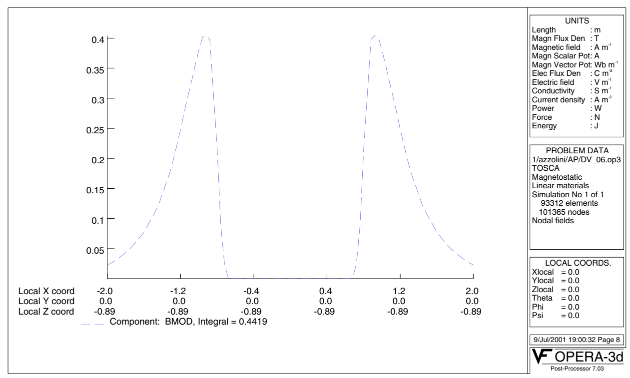

Figure 4: Dipole DV.06: field integral along the HER beam pipe at $B_z(0,0) = 0.30$ T.

3.1. The DV.06 version

The dipole version DV.06 represents at present the best solution to the multiple requirements outlined in Section 2.

The total field strength along the beam axis is shown in Figure 3 and a 3D view in Figure 5.

The physical length of the magnet is 1.60 m. The 1.30 m maximum gap value is limited by the ~ 3 m overall vertical dimension of the iron, imposed by the 0.70 m height of the HER beam w.r.t. the existing floor in IR 12.

Tapered pole pieces improve the vertical forward aperture compared to previous versions and pole excavations provide a 91.4% field uniformity.

The lower pole-piece incorporates the HER vacuum pipe for adequate shielding of the high energy electron beam. The integrated field strength across the HER beam pipe is shown in Figure 4. Although the residual dipolar field in the HER pipe inside the pole-piece is negligible, the contribution to the field integral seen by the HER beam from the lower coils will require additional shielding.

4. OPERATIONAL SCENARIOS

In the **scaling** scenario, the IP magnetic field is suppose to vary with the VLER energy. In this case the incoming and outgoing trajectories of the VLER beam are frozen and the IR layout is uniquely defined. This option presents several disadvantages. Orbit kicks induced on the LER beam depend on the VLER energy and their compensation will be difficult. The accurate mapping of the magnetic field is also required to be performed at several field levels.

Alternatively, a **fixed field** scenario is envisaged where the IP dipole is operated at two field levels. The integrated strengths needed to provide the right IR layout at the different VLER beam energies are obtained by shielding. This solution offers the considerable advantage of reducing the number of magnetic configurations in the IR and simplifies the field mapping task. Two different IR layouts are probably to be envisaged to cope with the large energy range of the VLER. The main parameters associated to the two scenarios are collected in Table II.

5. OUTLOOK

A dipole magnet complying with multiple competing requirements has been designed for the PEP-N Interaction Region. The present solution, retained among the several conceived and modeled with the TOSCA code, is optimized to satisfy the goals and is cost effective in terms of long term operation.

REFERENCES

[1] E. Solodov, private communication.
[2] J. Simkin and C.W. Trowbridge, “Three Dimensional Non-Linear Electromagnetic Field Computations using Scalar Potentials.”
IEEE Proc., Vol 127 (Part B) No 6, 1980, November 1980.

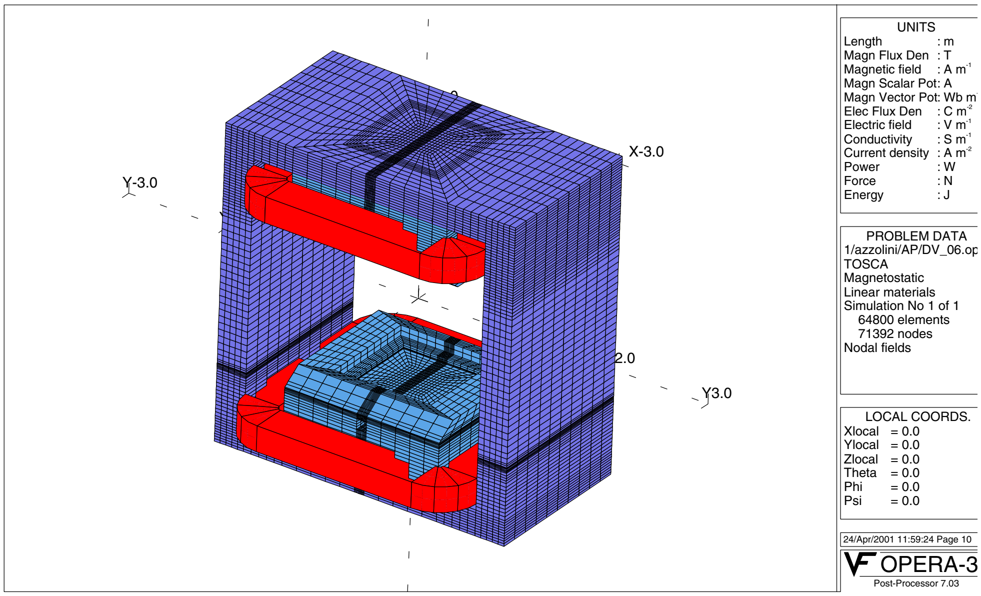

Figure 5: 3D view of the DV.06 dipole. The magnet is about 3 × 3 m (H × W) and 1.60 m long.

Table I Main characteristics of the modeled IP dipole versions. All magnets are conceived in **H-type** geometry. Φ_{fw} is the forward vertical aperture measured from the IP (not the magnet centerline). The DV.07 version is currently being finalized.

VERSION	**GAP**	**POLE GEOMETRY**		Φ_{fw}
DV.02	**1.2 m**	Cyl. ϕ 1.6 m	Flat	$\pm$ **30°**
DV.03	**1.2 m**	Cyl. ϕ 1.6 m	Tapered / Flat	$\pm$ **35.2°**
DV.04	**(1.2 + 0.4) m**	Cyl. ϕ 1.6 m	Tapered / Shims	$\pm$ **35.2°**
DV.05	**(1.2 + 0.4) m**	Square 1.6 m	Tapered / Shims	$\pm$ **35.2°**
DV.06	**(1.3 + 0.3) m**	Square 1.6 m	Tapered / Shims	$\pm$ **37.4°**
DV.07	**(1.3 + 0.3) m**	Square / Circ.	Tapered / Shims	$\pm$ **37.4°**

Table II Main parameters for the **scaling** and the **fixed field** scenarios.

ENERGY		**FIELD**	**DV.03**		**DV.06**		**DV.07**	
E_{CM} (GeV)	E_{VLER} (GeV)	B_o (T)	I (A)	P_{DC} (kW)	I (A)	P_{DC} (kW)	I (A)	P_{DC} (kW)
1.935	**0.300**	**0.180**	**478**	**35.0**	**478**	**56.0**	**521**	**72.0**
2.498	**0.500**	**0.300**	**796**	**96.0**	**796**	**155.0**	**868**	**200.0**
2.922	**0.667**	**0.400**	**1061**	**171.0**	**1061**	**276.0**	**1157**	**356.0**
3.159	**0.800**	**0.480**	**1274**	**246.0**	**1274**	**400.0**	**1390**	**512.0**
Coils: Cu / 20 x 20 mm^2 Φ 8mm			N_c = **180** turns / coil		N_c = **240** turns / coil		N_c = **220** turns / coil	