Barrel EMC Support Design — Technical Decision

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Summary and Conclusions:

Two alternatives for supporting the Barrel EM Calorimeter (EMC) Modules have been proposed. Though it is unlikely that these EMC Modules will be installed until after the Baseline STAR Detector is completed in 1999, the installation of these supports must occur during or soon after Magnet Coil installation. Also, because the EMC Supports interface directly with the Magnet backleg steel bars, they have some impact on the design of these bars. To allow completion of the Magnet steel design, a decision is required on which of these two alternatives will be used.

The two alternative concepts are the 12° segment and the bolted ring design. The 12° segment concept has 270 individual structures, or segments, 30 in azimuth (one per backleg) and 9 in Z. The bolted ring has six approximately 60° elements which bolt together to form a complete ring. The bolted ring design utilizes 8 of these complete rings with a set of 30 of the 12° segments at the center of the detector (at Z=0).

This note describes the reasons for choosing the 12° segment design over the bolted ring design. The primary reasons are simplicity of design, the potential problems associated with mixing the 2 designs (as is necessary in the bolted ring design at Z=0) and minimizing the impact on the nearly complete magnet core design.

Background and Discussion:

Decisions made early in the engineering design process are often made with incomplete information, and therefore must be based on engineering judgment. The design choice between the bolted ring design (developed by ANL engineers) and the 12° segment design (proposed by BNL engineers) is such a case. As stated in a previous memo (Ref 1), the decision was to be based upon a review and impact assessment of the items below. Under each issue is a discussion of how each design measured up.

1) Technical Issues:

a) EMC Load Distribution on Backleg Iron: The non-uniform EMC Module load distribution of the bolted ring design results in a factor of safety (FS) in the magnet backleg bolted joint of 3.5 versus 4.25 for the uniform load distribution of the segmented design. This is not terribly significant given the minimum FS requirement of 3.0 for STAR, but the seismic load case was not assessed for the bolted ring design. This 0.15g load could further reduce the FS to below the minimum required, resulting in the need to resize the elements of the bolted joint.

b) Stresses Due to Thermal Expansion: There are no thermal expansion issues in the 12° segmented design. Each segment is attached to an independent backleg. Even if a 50° F temperature rise is assumed in the bolted ring design, the stresses due to thermal expansion are negligible. This is not an issue by itself (see d below).

c) Alignment Method and Likelihood of Success: Alignment issues associated with either of the designs have not been studied sufficiently to argue which is better. The difficulty of aligning the 270 independent 12° segments is eliminated when fixtures are developed that align, match-drill, and pin all nine segments on a backleg prior to installation.

d) Mixing Bolted Ring and 12° Designs at Center (differences in deflections and therefore load carrying ability): If we look at thermal expansion issues resulting from mixing bolted rings with 12° segments (as is necessary at Z=0 in the bolted ring design case) we find significant differences in radial displacement. Conservative estimates of these radial location differences are on the order of 0.06 inches (see response to Ref. 2). The resulting stresses in the relatively compliant calorimeter rails are on the order of 7Ksi. The stresses in the calorimeter modules themselves (strongback and other elements), given their relative rigidity, could be significantly higher, making this a big issue.

e) Assembly Fixturing Complexity: It is believed that the assembly fixturing required for the bolted ring design will be minimal compared to the 12° segment design. Two strawman concepts for installation and alignment fixturing for the 12° segment design were developed. While not highly refined, both concepts did address the significant potential cost issues (time is money) associated with installing and aligning 270 individual segments. It is believed that these fixtures could be designed and manufactured at a cost of less than $100K. For the purposes of this report, we will assume that the fixturing cost differential is $100K in favor of the bolted ring design.

f) Technical/Design Unknowns: The overall complexity of the 12° segment design is low. The bolted ring design concept is technically more difficult to understand and analyze. The bolted ring design still has some technical issues and unknowns that make it slightly less desirable at this time.

g) Other (little things):
- cracks between segments in terms of fiber guides - ?
- scaffolding complexity inside magnet - minimal
- number and size of holes in Backleg Iron - not a significant issue
- twist due to EMC loads (affects 12° segment alignment?) - ?
- Expando Bolts or match drilling/reaming inside assembled mag) - not necessarily necessary
- Support Ring assembly space provisions (same time as coil assy) - do-able
- Support Ring Handling Fixture (assmbl'd rings are big & flexible) - do-able (maybe even with the coil handling fixtures?)

2) Cost Issues:

a) Manufacturing costs: If we ignore the cost differences of all items other than the rings/segments, we can make the following comparison (Ref 3):

EMC Support Concept	Total Support Concept Cost (incl. matl's) (avg. all bids/ avg. lowest 3)
Bolted Ring	$571K / $425K
12° Segments	$414K / $312K
Difference	+ $160K / $110K (Bolted Rings)

b) Fixturing costs (how do you move these big rings..., addn'l fixturing to install 12° segments)

EMC Support Concept	Total Fixturing Cost
Bolted Ring	$0K*
12° Segments	$100K
Difference	+ $100K (12° Segments)

*see discussion in 1 e) above.

When these 2 elements (a & b) are summed the cost differential is between $10K-$60K depending on assumptions.

c) Assembly/Installation costs: This is a judgment call at this point. They are probably close on the scale of $10s of K. They both require significant preassembly or preparation effort. With good fixturing, they both will require a few or more weeks of installation time. Call it a draw.

d) Cost Risk: Design effort risk is lower for the 12° segments - risk level is on the order of 1/2 man-year. Fabrication risk is probably equal given the number of bids received on each of the two designs - call it equal, but leaning slightly towards the 12° segments. Assembly and alignment risk should probably be lower for the bolted ring design with an associated cost of several man-weeks of effort. Overall, this probably leans us towards the 12° segment design.

3) Schedule Issues:

a) Critical Path Task Duration: The bolted ring design requires that the rings be installed concurrently with coil installation. The 12° segments can be installed after the magnet coil installation is complete. The time required to install the bolted ring design totals on the order of two weeks, while the time required for the 12° segments is probably on the order of 3 weeks, given fixturing, installation, and handling time plus the large number of parts required. Both of these estimates are based on single shift operation. Given good fixturing, the differences between the two are minor.

b) Non-critical Path Task Duration (ring assembly and alignment vs. match drilling backlegs for 12° segments): Assembly and alignment of the ring will take approximately 3 weeks. Match drilling 270 x 4 holes in the backlegs could take approximately 4-5 weeks (two drill set-ups and good fixturing). There is a slight edge to the bolted ring design.

c) C. P. Task Risk (i.e., risk of non-critical path tasks becoming critical path): There is a slight risk that the assembly/alignment of the bolted ring design could delay coil installation. There is also risk that the match drilling of the first few bottom backlegs (needed first for magnet steel installation) could not go well and slow the steel assembly. It is believed that with sufficient planning and well engineered fixturing, neither of these two options has significant risk of non-critical path tasks becoming critical path. The 12° segment design is required much earlier in the magnet assembly process than the bolted ring design. This should be appropriately planned for.

An independent assessment of some of the above items was made by D Fritz, Integration Lead Engineer (see Ref 4).

References:

Ref. 1: Memo from W.R. Edwards to K. Foley and D. Underwood dated June 1, 1994, outlining the EMC Support Selection Criterion, and e-mail from W.R. Edwards to attendees of July 6th meeting at ANL on same subject.

Ref. 2: E-mail correspondence from V. Guarino to W.R. Edwards dated August 31, 1994 on the subject of "Stress on rails from thermal expansion of rings." W.R. Edwards reply on same day suggested that the "worst case" assumptions made in the calculations probably were not the real worst case and that the stress in the rails was not the biggest concern.

Ref. 3: Attached spreadsheet from G. Koehler to W.R. Edwards on the subject of vendor budgetary fabrication price quotes for the two support concepts with a plate and cast material option for each.

Ref. 4: Memo from D Fritz to W R Edwards titled EMC Supports. Memo summarizes Doug's assessment of the two design alternatives - their features, problems and unknowns.