# Revised Radial Build Data; Breeding and Streaming Concerns


L. El-Guebaly

Fusion Technology Institute

UW - Madison

**With input from:**

L-P. Ku (PPPL),

R. Raffray, S. Malang, X. Wang (UCSD)



**ARIES-CS Project Meeting**

January 23, 2006

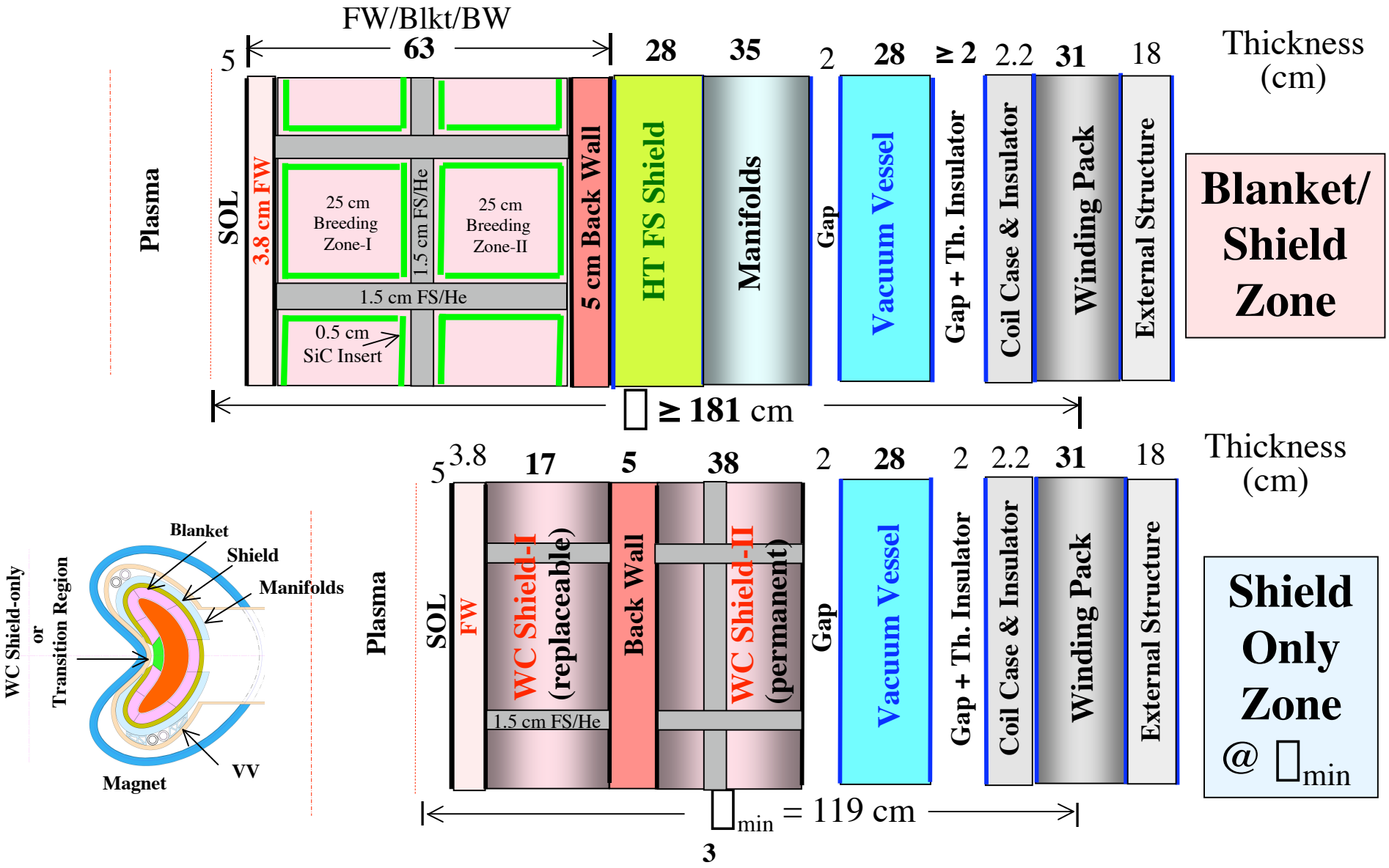
UCSD

# Contents

- Plasma - midcoil separation contours for R = 7 m baseline case.
- Breeding concern due to less blanket coverage.
- Shielding requirement for He access tubes.
- Recommended design changes to solve breeding and streaming problems.

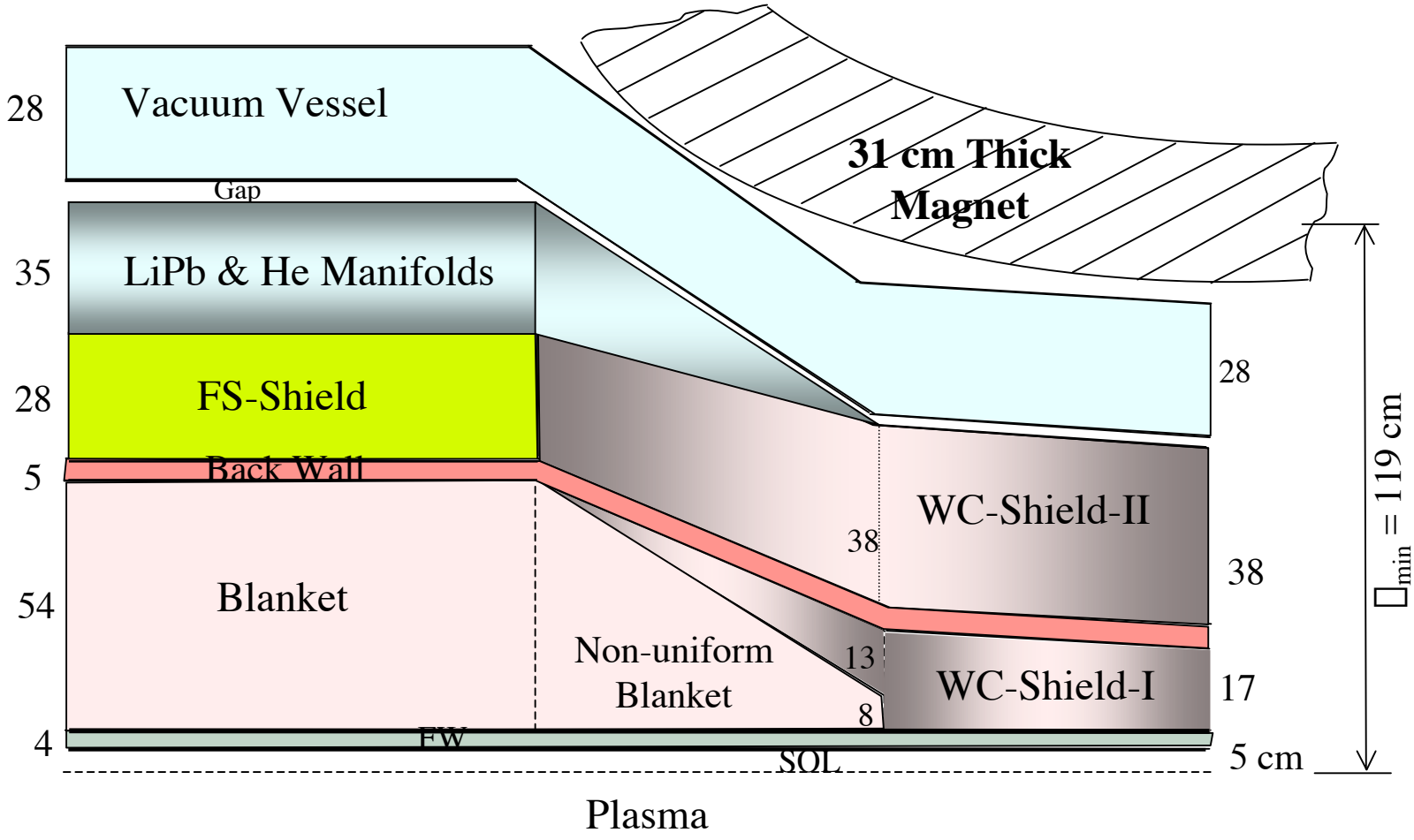
# Previous Radial Build - R = 8.25 m

(3 FP Configuration; LiPb/FS/He System; 3 MW/m$^2$ peak □)



# Previous Case - R = 8.25 m

(peak □ = 3 MW/m²)



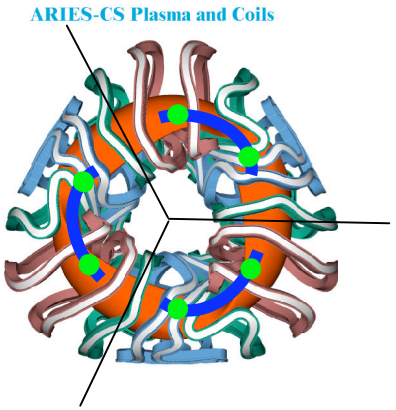

**Nominal Blanket/shield Zone** (80-85%)

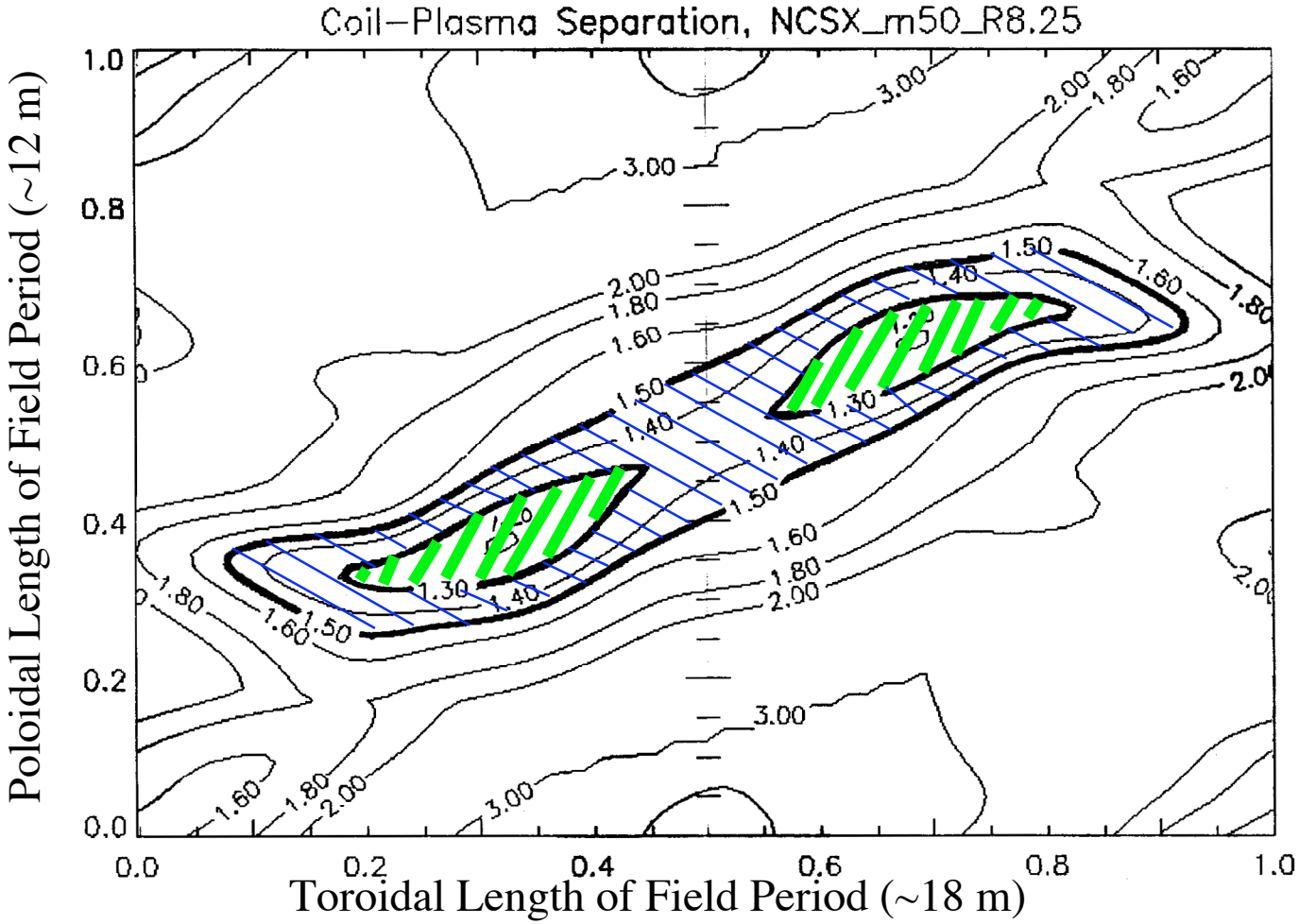
**Transition Region** (10-13.5%)

**WC-Shield only Zone** (5-6.5%)

# Previous Design - 2 $\Delta_{min}$ per Field Period

(R= 8.25 m)



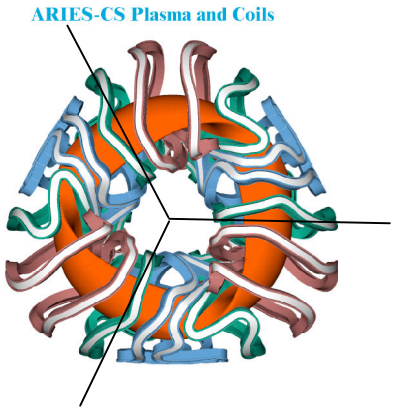

Shield-only zone (**green**), transition region (**blue**), and nominal blanket zone cover **>5%, >10% and <85%** of FW area, respectively

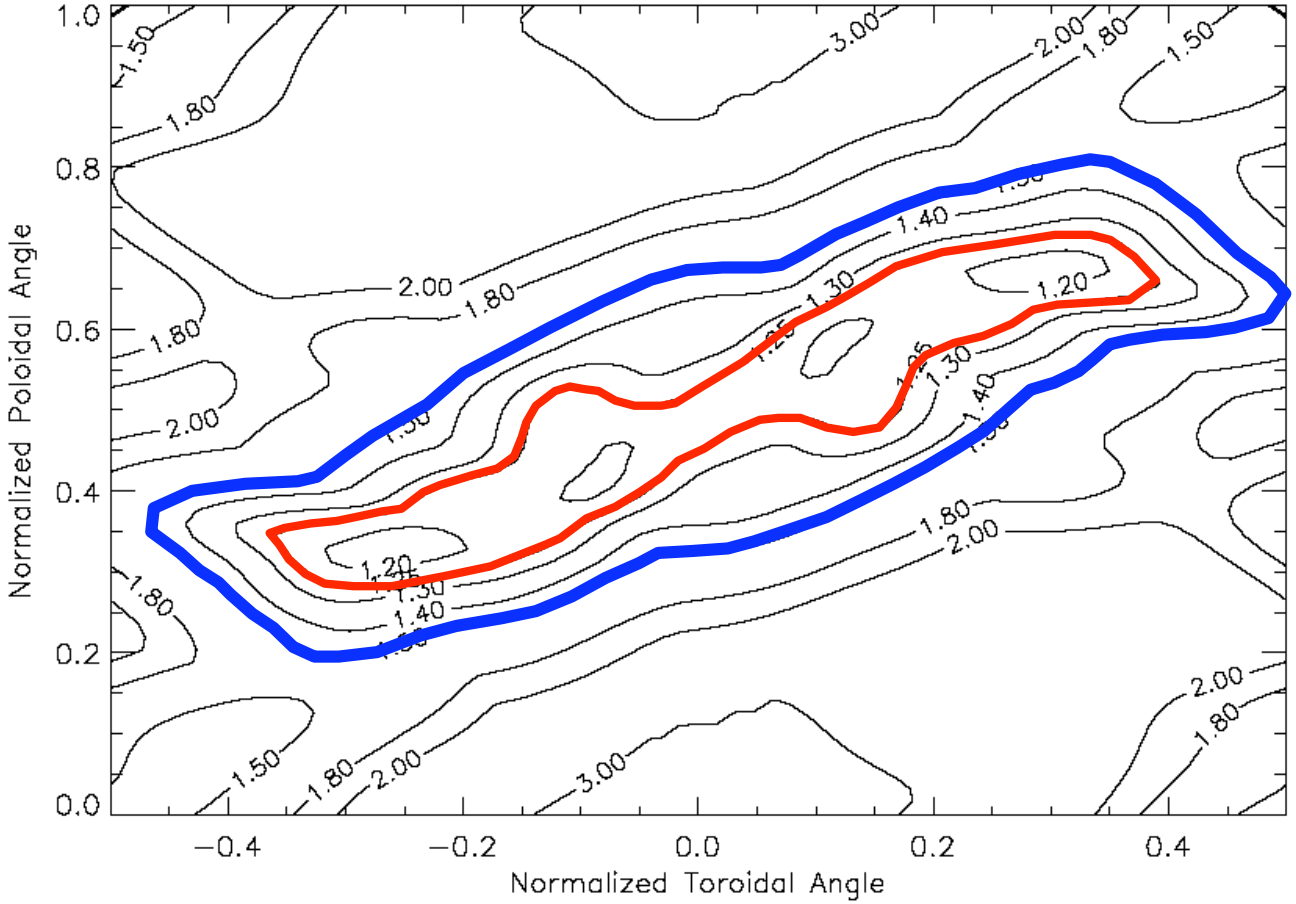
# New Baseline Design (R = 7 m)

- 4 $\square_{min}$ per field period $\square$ Less blanket coverage $\square$ less breeding.
- ~ 5 MW/m$^2$ peak neutron wall loading $\square$ more shielding
- 18 cm thick magnet, not 31 cm $\square$ 6 cm free space at $\square_{min}$
- $\square_{min}$ = 118 cm, not 119 cm
- Per Siegfried:
  - No He/LiPb manifolds at $\square_{min}$
  - He/LiPb access tubes placed at least 1 m away from $\square_{min}$

    $\square$ streaming problem
  - No cut/reweld of VV sections near $\square_{min}$.

# New Baseline Design - R= 7 m
# 4 $\iota_{min}$ per Field Period




- Shield-only zone (red) **and** transition zone (blue) cover large area (~35%).
- Nominal blanket covers only **~ 65%** of area, raising **breeding concern**.

# FW Coverage Fraction (%)

| | UW Estimate | CAD | UW Estimate | CAD |
|---|---|---|---|---|
| R (m) | 8.25 | 8.25 | 7 | 7 |
| Shield-only zone | ~ 5 | 6.5 | ~ 10 | ? |
| Transition zone | ~ 10 | 13.5 | ~ 25 | ? |
| Full blanket | ~ 85 | 80 | ~ 65 | ? |

**Need coverage fraction from UCSD to check TBR for R= 7 m.**

# Overall TBR

- 1-D and 3-D TBR comparison indicated good agreement for **full** blanket coverage (no blanket variation, no divertor system, no penetrations) - refer to June 05 presentation.

- Overall TBR is based on 1-D results combined with blanket coverage.

- **Assumptions**:
  - Divertor/baffle system covers 10% of FW area:
    - 12.5 cm thick divertor/baffle system covers 8% of FW area followed by 42 cm thick blanket.
    - Divertor He manifolds cover 2% of FW area without blanket behind manifolds.
  - Penetrations occupy 1% of FW area.

# Baseline Design

(R = 7 m, peak □ = 5 MW/m$^2$)

- Limited blanket coverage

  □ unacceptable overall TBR

- 6 cm free space available @ □$_{min}$

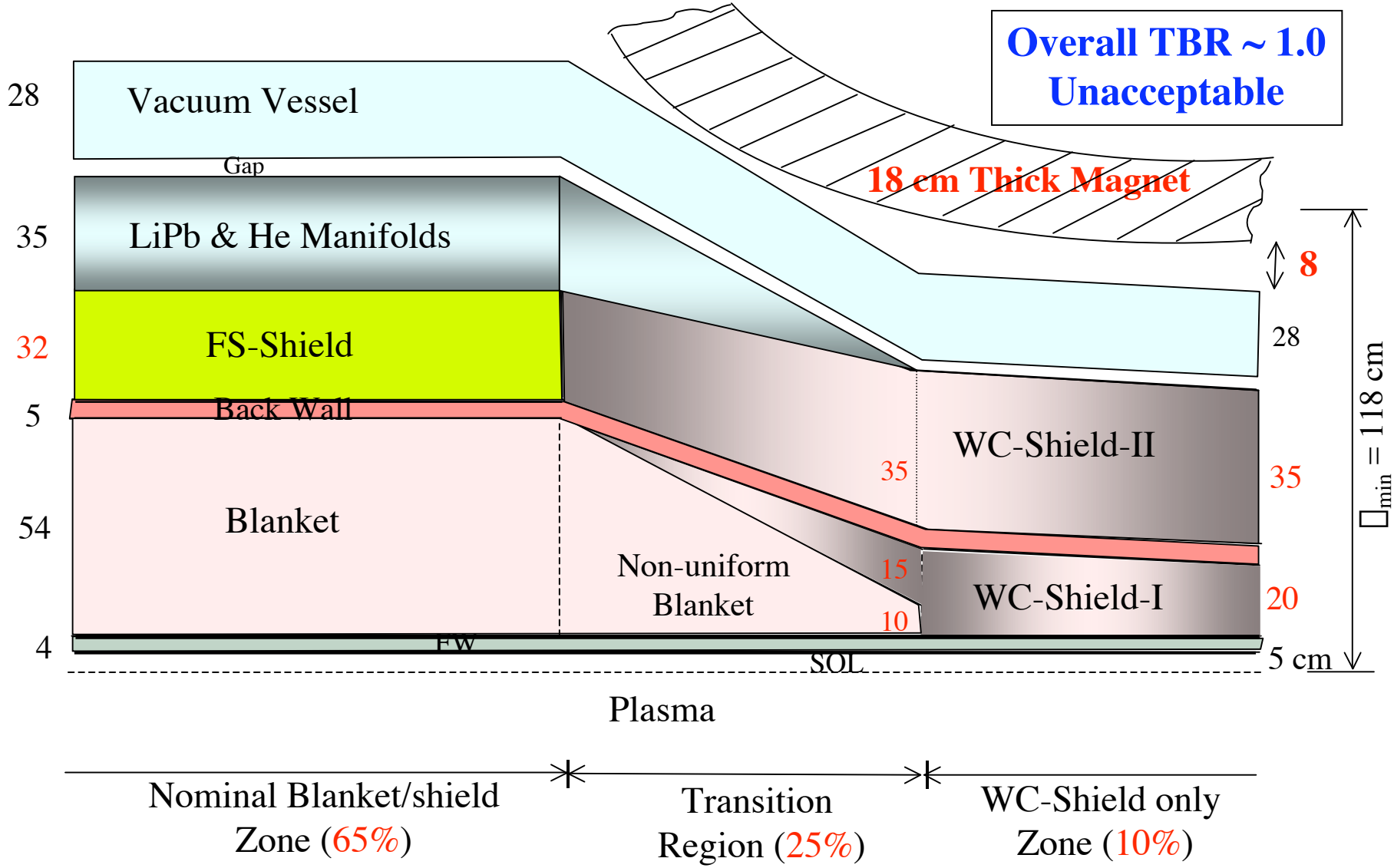
  □ install thin blanket at □$_{min}$

- **Two Options:**

| | **I** | **II** |
|---|---|---|
| Shield-only zone | √ | --- |
| Transition zone | √ | √ |
| Full blanket | √ | √ |

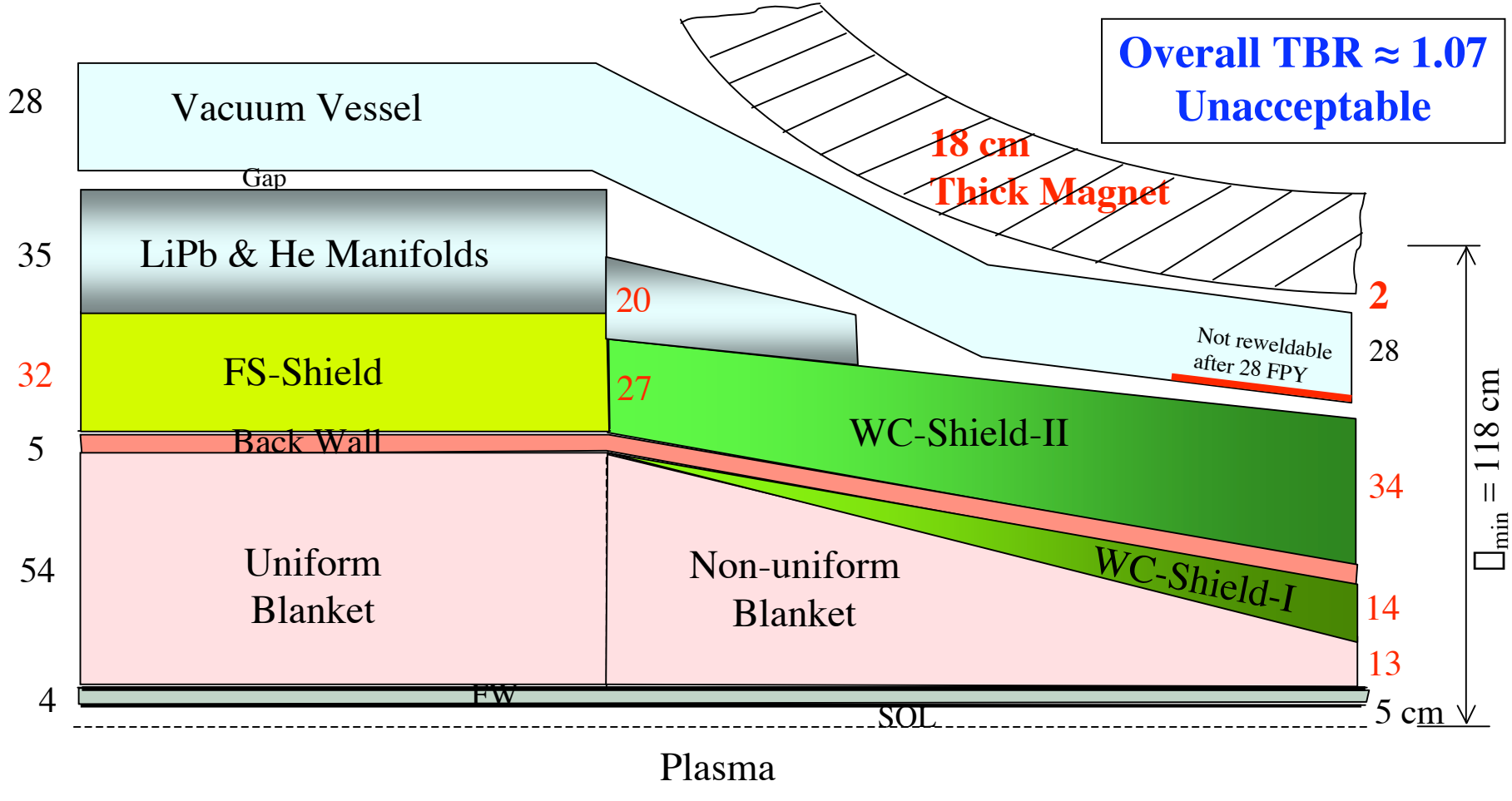
# Baseline Design - Option I

(R = 7 m, peak □ = 5 MW/m²)



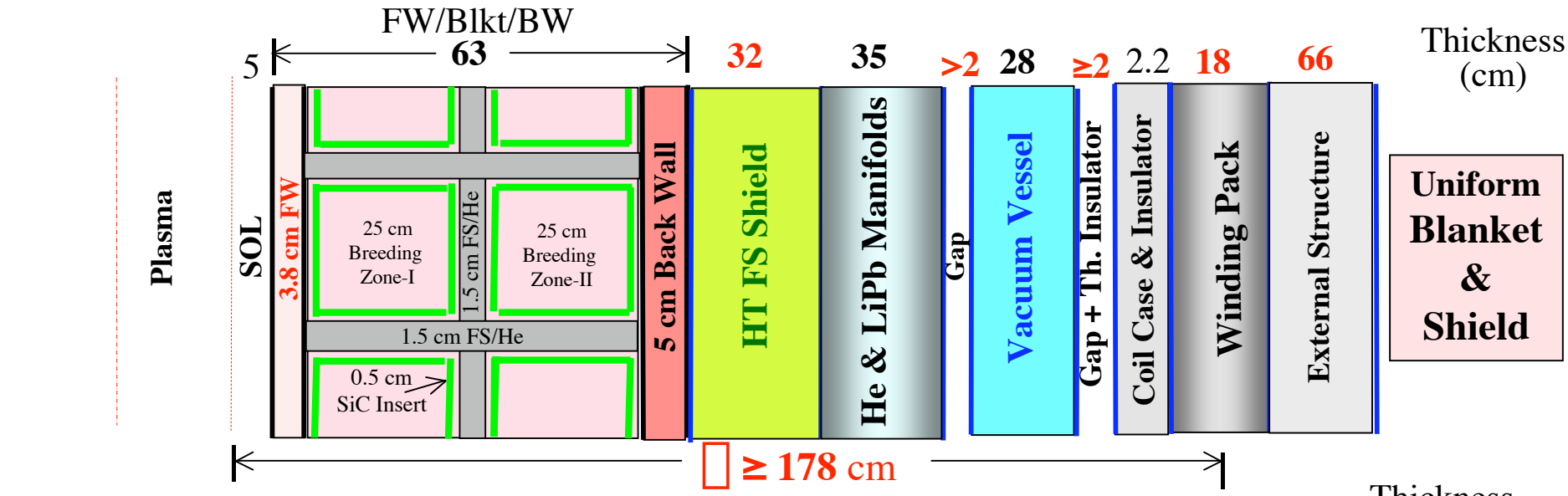
# Baseline Design - Option II

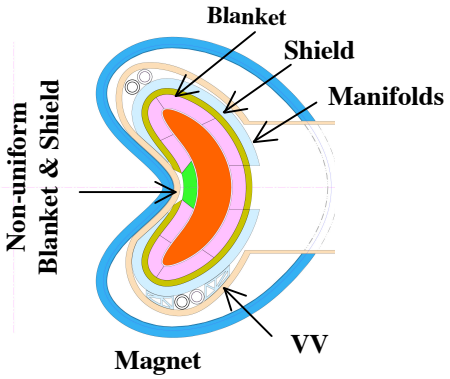
(R = 7 m, peak □ = 5 MW/m$^2$)

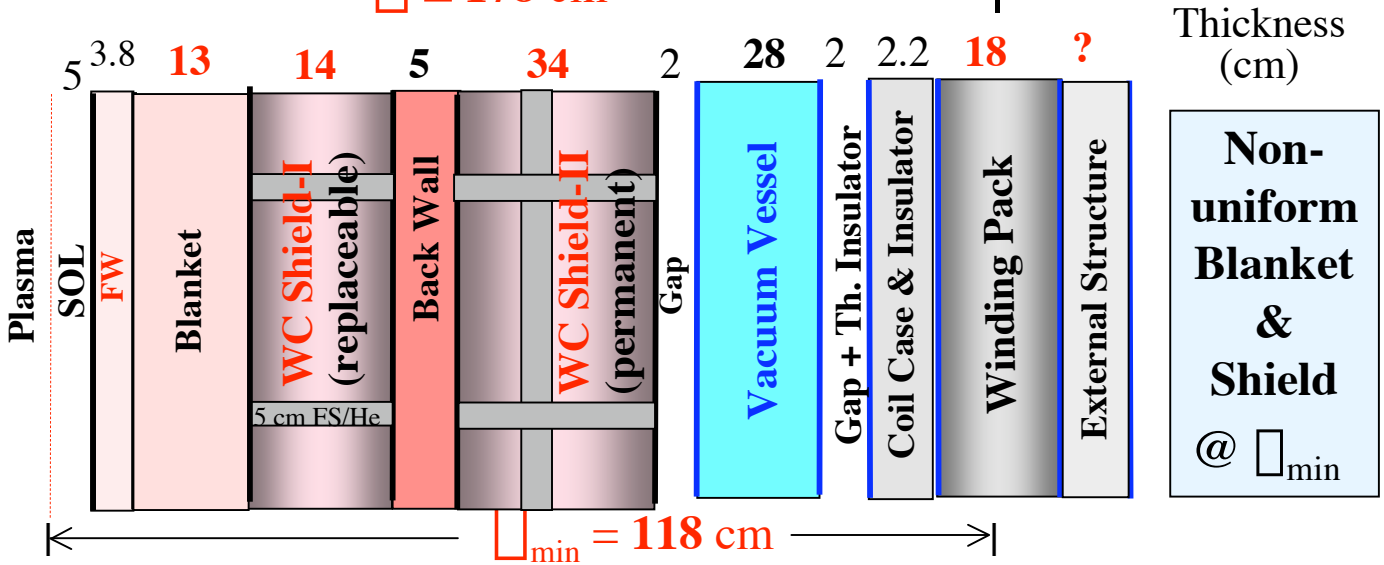


# Radial Build – Option II

(5 MW/m$^2$ peak □; changes marked in red)

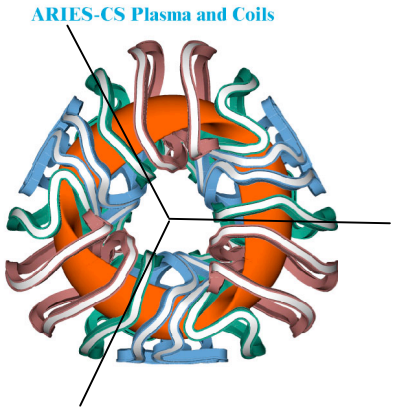


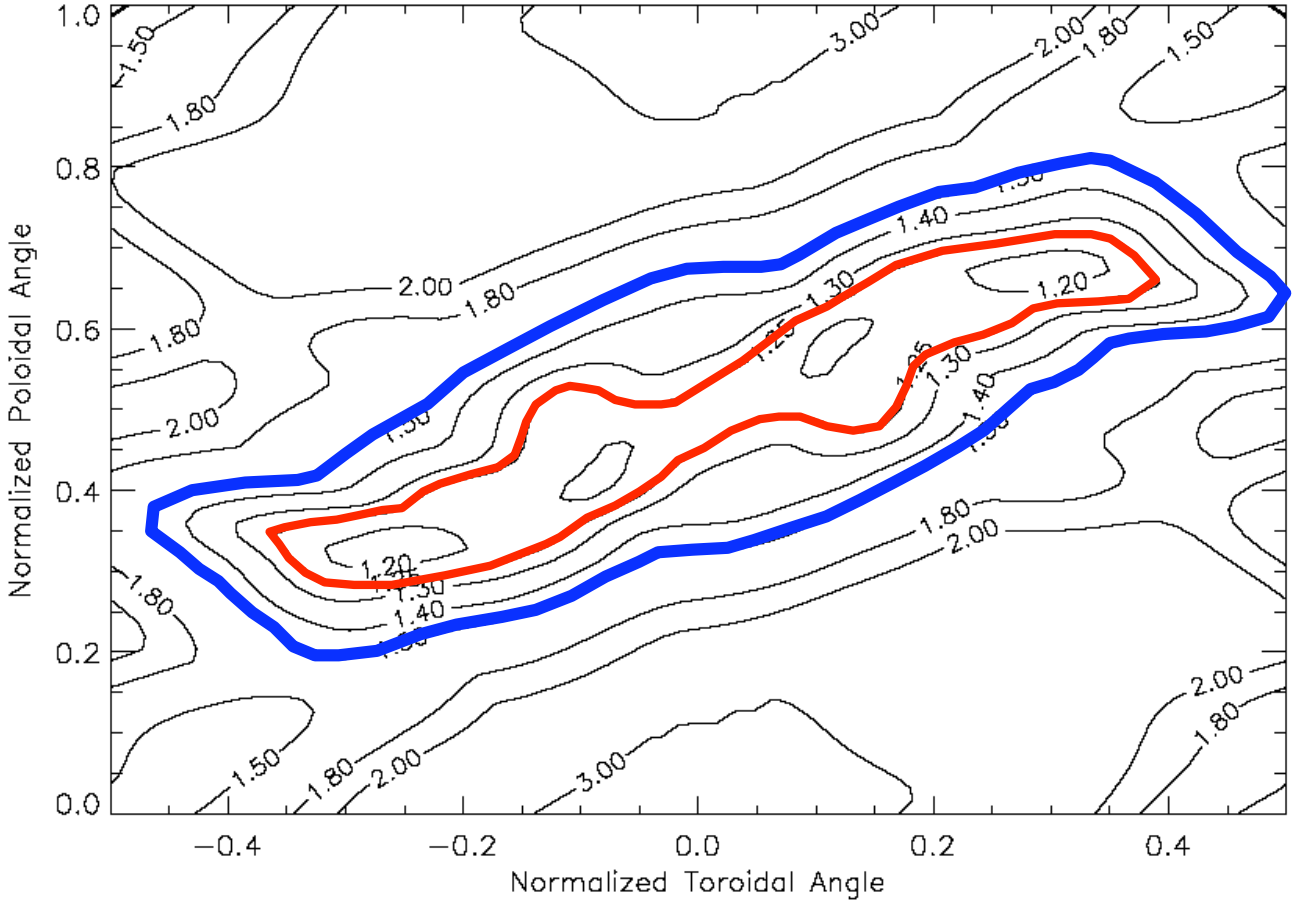



# Red Contour Designates 10% of VV near $\Box_{min}$ (not reweldable after 28 FPY)

Option-II

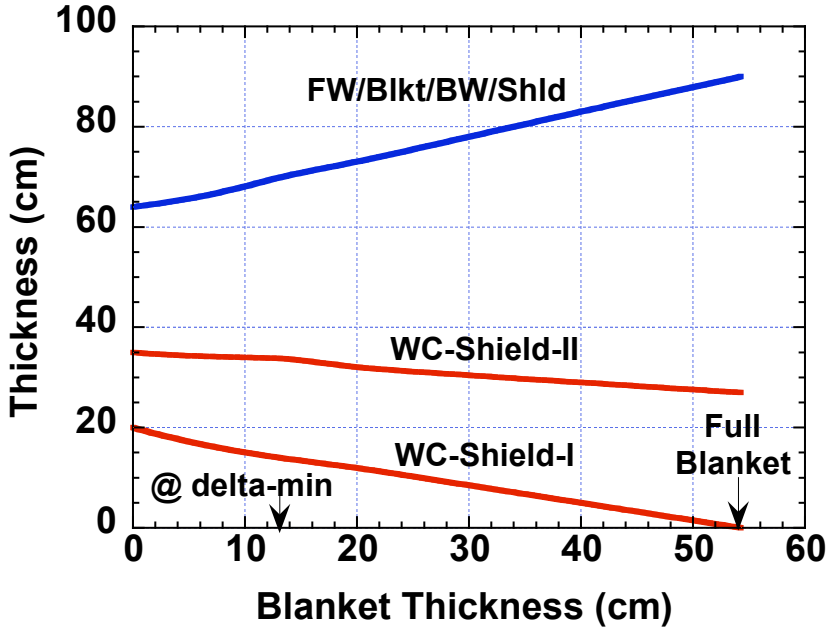



Reweldable VV everywhere requires additional 3 cm WC-shield

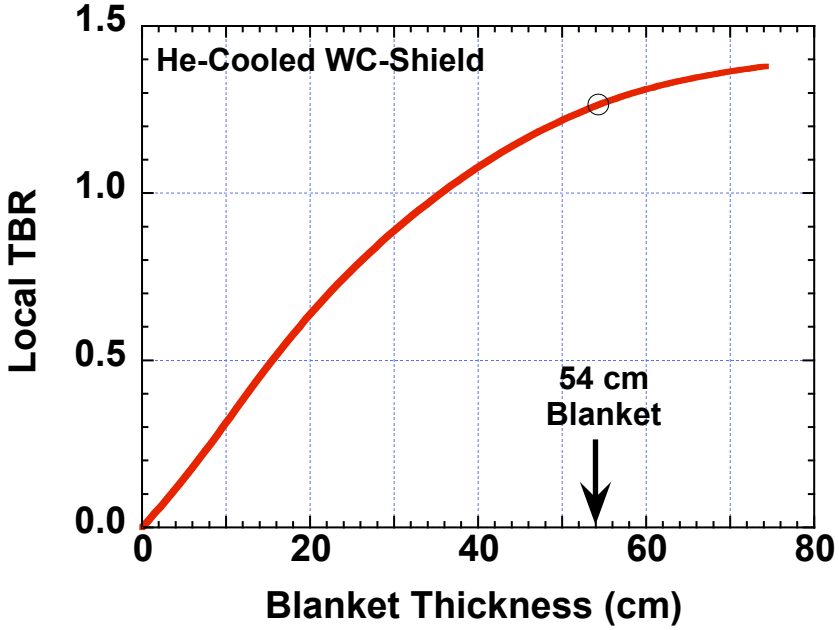
$\Box$ 121 cm $\Box_{min}$ , not 118 cm.

# Blanket / WC-Shield Tradeoff
## (Non-uniform Blanket/Shield Region - Option-II)




- Replaceable components: FW/blanket, WC-shield-I, back wall.
- WC-shield-II and magnet protected for plant life.
- VV near $\delta_{min}$ is **not** reweldable after 28 FPY.

# Insufficient Tritium Breeding Calls for Design Change




Option-II

**Overall TBR ~ 1.07**

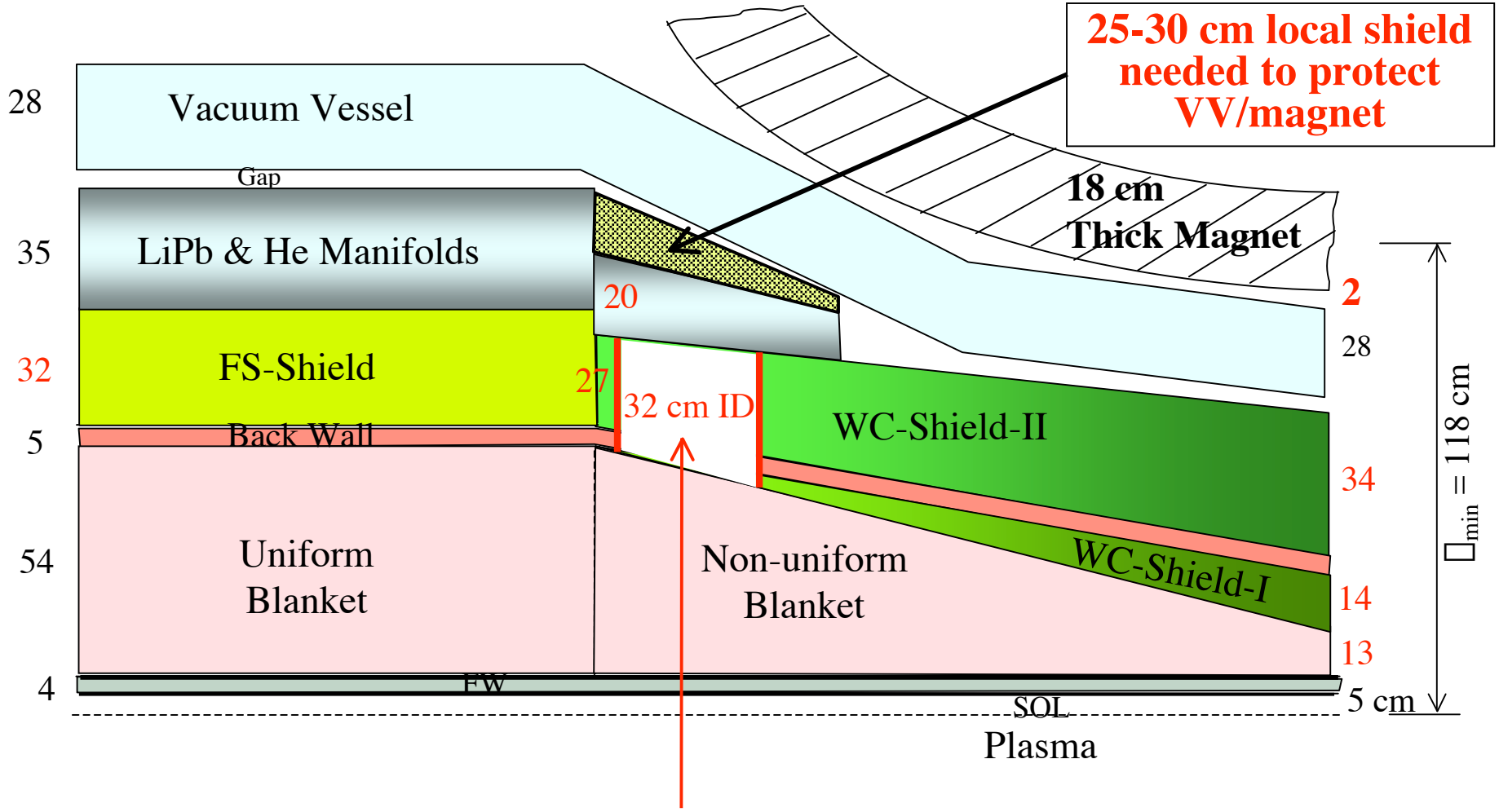
- **Potential solutions to meet breeding requirement (overall TBR = 1.1):**
  - Increase "full blanket" thickness by 10 cm (from 54 cm to 64 cm).
  - Increase major radius (R > 7 m) to allow more "full blanket" coverage (> 65%) (preferred option).

# Streaming Through He/LiPb Access Tubes (Non-uniform Blanket Region)

- Each LiPb/He access tube replaces 32-40 cm of WC-shield and back wall.
- Neutrons streaming through He tube increase magnet damage by 1-2 orders of magnitude.
- 25-30 cm thick local shield needed between manifolds and VV to protect VV and magnet. To be confirmed by 3-D analysis.
- Tilted tube away from $\theta_{min}$ helps reduce size of local shield and relocate it in area of more free space.
- **Q to UCSD**: does radial space allow 25-30 cm of local shield? If not, larger machine with R > 7 m is needed.

# Xn Through He Access Tube

(R = 7 m, peak □ = 5 MW/m²)




**Most critical shielding space (not at □min )**

# Conclusions

- Thin magnet (18 cm thick) permits installing thin blanket at $\rho_{min}$.
- Baseline design with R= 7 m offers low "uniform blanket" coverage, causing breeding problem (TBR < 1.1).
- Blanket consists of two main regions: uniform (≥ 54 cm thick) and non-uniform (13-54 cm). **Need** coverage fractions from UCSD to confirm TBR estimate.
- To fix streaming problem, 25-30 cm local shield is needed behind He access tubes.
- Breeding and streaming problems call for larger machine with R > 7 m. **Need** from L-P Ku: plasma-midcoil separation contours for R=7.5 and 8 m with $\rho_{min}$~1.2 m.
- New design could be driven by radial standoff at He access tube, not at $\rho_{min}$.
- Designs employing no He coolant (such as advanced LiPb/SiC system) could be more suitable for compact stellarators.

  No streaming problem and higher $\eta_{th}$

  $\Rightarrow$ smaller machine and lower COE (~ 20 mills/kWh saving).

# Future Plan

- Get plasma-midcoil separation contours from PPPL for R > 7 m and solve breeding and streaming problems.

- Optimize dimensions of local shield behind He access tubes and confirm VV/magnet protection with 3-D analysis.

- Perform 3-D breeding calculation. Need CAD input files from UCSD for baseline design with blanket variation, divertor system, and penetrations.

- Update radial build for LiPb/SiC system.